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Preface

This volume contains the abstracts of all the contributions presented at the International Conference in ΣΤΑΤΙΣΤΙΚΗ ΦΥΣΙΚΗ held in Kolympari at the Orthodox Academy of Crete, Greece, from July 14 to 18, 2008.

The oral and the poster presentations are more than 300, among them more than 80 are Invited talks.

The conference covers the following topics:

A) Foundations, theoretical aspects and mathematical formalism of statistical physics.

B) Connection with information theory and mathematical statistics.

C) Applications (classical and quantum physical systems, dynamical systems, transport theory etc).

D) Application of statistical methods beyond physics (biophysics, econophysics, social systems, networks, traffic flow, etc).

Format of the conference:

The conference is organized in sessions dealing with general aspects and fundamental problems of statistical physics.

A special session is organized under the auspices of the EPS-SNP (European Physical Society - Statistical and Nonlinear Physics Division).

A further special session is devoted to the 60-th birthday of Prof. Giorgio Parisi.

Moreover 2 workshops (Socio-Econo-Physics, Networks) and 7 symposia (Fisher Information and Geometry, Nonextensive Statistical Mechanics, Nonlinear Kinetics, Quantum Computation and Statistical Mechanics, Statistical Physics Methods in Geosciences and Enviroment Sciences, Superstatistics, Transport in gases of Cold atoms) cluster several talks dedicated to special topics.

The conference includes also two poster sessions devoted to general and special topics of statistical physics.

G. Kaniadakis and A.M. Scarfone
(Editors of the Abstract Booklet)

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Bosonic correlations in weighted networks.
D. Garlaschelli and M.I. Loffredo (Talk)

Towards a rigorous derivation of quantum kinetic equations.
V.I. Gerasimenko (Talk)

Evolution of correlations of quantum many-particle systems.
V.I. Gerasimenko and V.O. Shtyk (Poster)

Scaling behavior of earthquakes' inter-events time series.
F. Ghanbarnejad, Sh. Shadkhoo, G. Afshar, G. Reza Jafari, M. Reza Rahimi Tabar (Poster)

On the statistics of a few body Hamiltonian system at the edge of chaos.
A. Giansanti (Invited Talk)

The phase diagram of a bilayer Ising model.
M. Gitterman and E. Sloutskin (Talk)

The Lévy sections theorem applied to econophysics.
I. Gleria, A. Figueiredo, R. Matsushita and S. da Silva (Talk)

Quantum computation of populations dynamics of the resonant levels for atomic and nuclear ensembles in a laser pulse: optical bi-stability effect and nuclear quantum optics.
A.V. Glushkov, O.Yu. Khetselius, A.P. Fedchuk, E.P. Gurnitskaya and A.V. Loboda (Talk)

Non-linear prediction statistical method in forecast of atmospheric pollutants.
A.V. Glushkov, N.S. Loboda, V.N. Khokhlov, A.A. Svinarenko and Yu.Ya. Bunyakova (Poster)

Cold-atom realizations of a generalized Kicked-Harper model and accelerating quantum Ratchet transport without a bichromatic optical lattice.
J. Gong (Talk)

Stochastic modeling of trading activity and volatility in financial markets.
V. Gontis, J. Ruseckas and A. Kononovičius (Talk)

Shock waves in reactive mixtures.
M. Groppi (Invited Talk)

Statistical characterisers of transport in a communication network.
N.M. Gupte and S. Mukherjee (Talk)

Could a persistent power be observed?
V.L. Gurtovoi, A.V. Nikulov and V.A.Tulin (Poster)

Instability transition and ensemble equivalence in diffusive flow.
M. Ha (Talk)

Time evolution of long-range correlation in the Turkish language using non-corpus parametrization.
A. Hacinhyan, G. Şahin, Ö. Aybar (Talk)

Physics of evolution.
R. Hanel, S. Thurner (Talk)

Quantum Brownian motion, entropy and the third law of thermodynamics.
P. Hänggi, G.-L. Ingold and P. Talkner (Invited Talk)

Statistical physics of steady-state two-phase flow in porous media.
A. Hansen (Invited Talk)

Novel percolation approaches in complex networks.
S. Havlin (Invited Talk)

Boundary-induced nonequilibrium phase transitions into absorbing states.
H. Hinrichsen (Invited Talk)

Extending minimum curvature estimators using spartan spatial random fields.
D.T. Hristopulos (Talk)

A complex network approach to human mobility modeling.
P. Hui, P. Lio, J. Crowcroft and M. Musolesi (Poster)

Confirmation of the additivity principle for current fluctuations in a model of heat conduction.
P. Hurtado and P.L. Garrido (Talk)

Quantum mean-field decoding algorithm for error-correcting codes.
J. Inoue, Y. Saika and M. Okada (Talk)

Matrix-product states and double-shock structures in a branching-coalescing system.
F.H. Jafarpour (Talk)

Nonextensivity and the power-law distributions for the systems with self-gravitating long-range interactions.
Du Jiulin (Invited Talk)

On rôle of information theoretic uncertainty relations in quantum theory.
P. Jizba and P. Harremös (Talk)

Superpositions of probability distributions.
P. Jizba and H. Kleinert (Talk)

Dynamics of finite and infinite self-gravitating systems.
M. Joyce (Invited Talk)

On completeness of the description of an equilibrium canonical ensemble by an s-particle distribution function.
M.I. Kalinin (Talk)

The simplified Fermi-Ulam accelerator revisited.
A.K. Karlis, F.K. Diakonos, V. Constantoudis and P. Schmelcher (Poster)

Energy landscapes and their relation to thermodynamic phase transitions.
M. Kastner (Talk)

Modeling scaled processes by the nonlinear stochastic differential equations.
B. Kaulakys and M. Alaburda (Talk)

Distribution of eigenvalues and scattering data for the NLSE Zakharov-Shabat problem with random Gaussian input.
P. Kazakopoulos and A.L. Moustakas (Talk)

Smoother quantum walks.
V. Kendon (Invited Talk)

Novel exponents control the quasi-deterministic limit of the extinction transition.
D.A. Kessler and N.M. Shnerb (Talk)

Highly localized nonlinear excitations in crystalline charged-particle configurations.
P. Kevrekidis, V. Koukouloyannis, I. Kourakis and D. Frantzeskakis (Poster)

Stationary noise sustained structures in systems with chemical reactions.
D.O. Kharchenko and A.V. Dvornichenko (Talk)

Exact solutions for the generalized Fokker-Planck equation modeling magnetic field diffusion in magnetohydrodynamics including Hall current.
A.H. Khater, D.K. Callebaut, K.El. Rashidy and T.N. Abdelhameed (Talk)

Solutions for the generalized (2+1) dimensions Fokker-Planck equation.
A.H. Khater, D.K. Callebaut, K.El. Rashidy and T.N. Abdelhameed (Poster)

Quantum stochastic computation of energy transfer and effect of the rotational and V-T relaxation on multi-photon excitation and dissociation in molecules.
O.Yu. Khetselius, A.V. Loboda, S.V. Malinovskaya, Yu.V. Dubrovskaya and A.A. Svinarenko (Poster)

Dynamics of multi-layers neural networks on basis of photon echo: Effects of chaos and stochastic resonance.
O.Yu. Khetselius, A.V. Glushkov, N.G. Serbov, A.A. Svinarenko and V.V. Buyadzhi (Talk)

Synchronization and Laplacian spectra on weighted random networks.
D. Kim and B. Kahng (Invited Talk)

Restricted curvature model and restrited-solid-on-solid model with conserved noise.
J.M. Kim (Poster)

An explanation for the emergence of commonly observed stylized facts using data from experimental financial markets.
M. Kirchler and J. Huber (Talk)

Probability of large movements in multivariate intermittent time-series.
R. Kitt, M. Säkki and J. Kalda (Talk)

Parkinson's law revisited: Socio-physical investigations on 3 essays.
P. Klimek, R. Hanel and S. Thurner (Talk)

Statistics of competing lattice instabilities and structural transitions in complex oxides.
E. Klotins and A. Kuznetsov (Talk)

Spreading of innovations in socio-economic systems.
G. Kocsis and F. Kun (Poster)

Conductivity with cold atoms.
A.R. Kolovsky (Talk)

Correlations in complex systems.
I. Kondor (Invited Talk)

Subnetworks in genetic networks.
M. Krawczyk (Poster)

The norm game - how a norm fails.
K. Kułakowski (Talk)

Coupling via threshold-induced switching in a heterogeneous agent financial model.
H. Lamba (Talk)

Detecting the overlapping and hierarchical community structure of complex networks.
A. Lancichinetti, S. Fortunato and J. Kertész (Invited Talk)

Relaxation of relativistic plasmas under the effect of wave-particle interactions.
G. Lapenta, S. Markidis and G. Kaniadakis (Invited Talk)

Two dimensional gas of Bosons or Fermions in the context of q-deformed algebra.
A. Lavagno and P. Narayana Swamy (Poster)

Continuous electrodynamics and collective dynamics of vortices in nanostructured superconductors.
F. Laviano, R. Gerbaldo, G. Ghigo, L. Gozzelino, G. Lopardo, B. Minetti, and E. Mezzetti (Poster)

Analysis of packet traffic in a data network model under normal traffic conditions & under distributed denial-of-service attack.
A.T. Lawniczak, S. Xie, H. Wu and B. Di Stefano (Talk)

Beyond the PB equation: developments in the field theoretic formulation of the statistical mechanics of a macro-ion surrounded by electrolyte solution.
D. Lee (Poster)

Dynamics of human communication network.
D.-S. Lee and A.-L. Barabási (Talk)

Birkhoff's theorem and Ergometer: Meeting of two cultures.
M. Howard Lee (Invited Talk)

Entropy duality in nonextensive statistics.
M.P. Leubner (Invited Talk)

Collisionless relaxation in non-neutral plasmas and gravitational systems.
Y. Levin, R Pakter, F.B. Rizzato and T.N. Telles (Talk)

Power-law scaling in human balance control.
J.-S. Lih, C.-Y. Liu, C.-H. Lin and I-M. Jiang (Poster)

Dynamical structure of a financial cross-correlation matrix under attacks.
G. Lim, S. Kim, J. Kim, P. Kim , Y. Kang, S. Park, K. Kim and D.-In Lee (Poster)

Experimental evidence of phase synchronization between two coupled Chua circuits.
C.-H. Lin, H.-T. Jan, I-M. Jiang, M.-C. Ho and J.-S. Lih (Poster)

Wavelet-domain statistics of packet switching networks near traffic congestion.
P. Lio, A.T. Lawniczak, S. Xie and J. Xu (Poster)

Intermittent search strategies.
C. Loverdo, O. Bénichou, M. Moreau and R. Voituriez (Talk)

Hydrodynamic cavitation: from theory towards a new experimental approach.
U. Lucia and G. Gervino (Poster)

Magnetic hysteresis loops of Ising spin systems with long-range interaction.
K. Malarz (Poster)

Dynamic localization and transport of a quantum particle in an optical lattice.
P. Maniadis and G.P. Tsironis (Poster)

International Trade network, structure and properties.
S.S. Manna (Invited Talk)

Analysis of dynamical networks by Granger causality.
D. Marinazzo, M. Pellicoro and S. Stramaglia (Talk)

Pondering over protein-protein interactions.
E. Marras and E. Capobianco (Poster)

Designer patterns: Encoding information into precipitation structures.
K. Martens, I. Bena, M. Droz, I. Lagzi, Z. Rácz and A. Volford (Talk)

Bayesian updating as basis for opinion dynamics models.
A.C.R. Martins (Talk)

Emergence of feedforward networks and entrainment in oscillator networks via a biological synaptic plasticity rule.
N. Masuda and H. Kori (Invited Talk)

Jamming transitions induced by a slow vehicle in two-lane traffic flow.
S. Masukura, T. Nagatani and K. Tanaka (Poster)

Colony formation in bacteria - Experiments and modeling.
M. Matsushita (Invited Talk)

Bridging structure and function via network spectral properties.
P. McGraw and M. Menzinger (Talk)

Contact line stability of ridges and drops.
S. Mechkov (Poster)

Structural properties of complex networks.
J.F.F. Mendes, S.N. Dorogovtsev, A.V. Goltsev (Invited Talk)

Role of DNA configuration in stochastic gene control.
R. Metzler (Invited Talk)

Global positioning of central traveler destinations.
J.I.L. Miguéns and J.F.F. Mendes (Talk)

Glass transition in a monoatomic simple liquid.
T. Mizuguchi, T. Koumyou and T. Odagaki (Poster)

Analysis of high-resolution product prices in an online shopping mall.
T. Mizuno and T. Watanabe (Talk)

Predator-prey model for stock market fluctuations.
M. Montero (Talk)

Lyapunov modes for nonequilibrium systems.
G. Morriss (Invited Talk)

Quanum Onsager-type equations for Bohm's potential.
D. Mostacci, V. Molinari and F. Pizzio (Talk)

A transport theory approach to percolation of liquids through porous media.
D. Mostacci, V. Molinari and M. Premud (Poster)

Vector precoding for wireless multi-antenna systems.
R. Muller, D. Gou, B. Saidel and A.L. Moustakas (Talk)

On the cooling and freezing processes.
G. Murariu and A. Dinescu (Talk)

On the analysis of the climatic factors influences.
G. Murariu and M. Praisler (Poster)

Solvable multi-species reaction-diffusion processes with particle-dependent hopping rates.
Y. Naimi (Poster)

Weakly interacting Bose-gas in disordered environment.
T. Nattermann and V. Pokrovsky (Talk)

Fisher's information metric in the context of generalised entropies.
J. Naudts (Invited Talk)

Why the persistent current observed at a non-zero resistance is challenge to the second law of thermodynamics.
A.V. Nikulov (Talk)

Networks of optimal synchronizability.
T. Nishikawa and A.E. Motter (Talk)

Combinatorial entropies and statistics for particles in indistinguishable states.
R.K. Niven (Talk)

Exchange bias in spin glasses and nanoparticle systems.
P. Nordblad (Invited Talk)

Self organization of hierarchy and villages in timid and challenging societies.
T. Odagaki, R. Fujie and T. Okubo (Invited Talk)

A closer look at linear response theory via an exactly solvable model of classical spins in a time-dependent rotating magnetic field.
S.K. Oh, S.-C. Yu, T. T. Tham and K. Tarigan (Poster)

Geometric aspects and the Legendre structure of generalized entropies.
A. Ohara (Invited Talk)

Derivation of the Tsallis, Rényi and Nonextensive Gaussian entropy from deformed multinomial coefficients.
T. Oikonomou (Poster)

Non-extensivity parameter of self-similar statistical system.
A.I. Olemskoi, A.S. Vaylenko and I.A. Shuda (Poster)

Nonextensive/dissipative correspondence in relativistic hydrodynamics.
T. Osada and G. Wilk (Invited Talk)

Social group dynamics in networks.
G. Palla, A.-L. Barabási and T. Vicsek (Invited Talk)

Superstatistics and renewal critical events.
P. Paradisi and P. Grigolini (Talk)

Replica approach to glass transition and jammed states of hard spheres.
G. Parisi (Invited Talk)

Scale invariance and self-averaging in disordered systems.
G. Parisi, M. Picco and N. Sourlas (Invited Talk)

Phase space embedding method. The hydrided ZY-4 SEM micrographs evaluation by time series technique.
V.-P. Păun (Poster)

Two-dimensional diffusion model for the biopolymers dynamics at nanometer scale.
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Tuning the correlation decay of resistance fluctuations in multi-species networks: From power-law to exponential decay of correlations.
C. Pennetta and E. Alfinito (Invited Talk)

A model of subjective supply-demand: the maximum Boltzmann/Shannon entropy solution.
E.W. Piotrowski and J. Sładkowski (Poster)

A model of subjective supply-demand: the minimum Fisher information solution.
E.W. Piotrowski, J. Sładkowski and J. Syska (Talk)

Mechanism of polarization freezing in disordered polar dielectrics.
R. Pirc (Talk)

Maximal exponential models on Gaussian spaces.
G. Pistone (Talk)

Stochastic modeling of imatinib-treated leukemic cell dynamics.
N. Pizzolato, D. Valenti, D. Persano Adorno, B. Spagnolo (Poster)

The manifold facets of entropic nonadditivity.
A. Plastino and C. Vignat (Invited Talk)

Brachistochrone evolution, entanglement and quantum statistics.
A.R. Plastino (Invited Talk)

Modules recognition in complex networks by dynamical clustering algorithms based on different oscillators systems.
A. Pluchino, V. Latora and A. Rapisarda (Talk)

Generalized central limit theorem behavior and nonergodic anomalous dynamics in quasi-stationary states of long-range interacting systems.
A. Pluchino, G. Miritello and A. Rapisarda (Invited Talk)

Topology properties of written human language.
T.B. Progulova and B.R. Gadjiev (Talk)

Nonlinear kinetics on lattice with long-range diffusion.
A. Provata (Talk)

Multifractal and non-extensive analysis of magnetic confined plasma turbulence.
M. Rajković and M. Škorić (Talk)

Simplicial complexes from networks: static and dynamic aspects.
M. Rajković, S. Maletić and D. Vasiljević (Poster)

Systems with negative specific heat in thermal contact: violation of the zeroth law.
A. Ramírez-Hernández, H. Larralde and F. Leyvraz (Poster)

Composite CDMA - A statistical mechanics analysis.
J. Raymond and D. Saad (Talk)

Non Equilibrium thermodynamics and entropy generation of ferrites and ferrite-polymer composite materials under electromagnetic field applied.
A.C. Razzitte, S. Boggi and W.G. Fano (Talk)

Plasmonic noise in nanometric semiconductor layers.
L. Reggiani and J.-F. Millithaler (Invited Talk)

Thermodynamics of alternating spin chains.
G.A.P. Ribeiro and A. Klümper (Talk)

Directed abelian algebras and their applications to stochastic models.
V. Rittenberg (Invited Talk)

Definitive answer on the occurrence of a q-deformed statistical-mechanical structure for the dynamics at the Feigenbaum attractor.
A. Robledo and L.G. Moyano (Invited Talk)

Distribution functions for charged particles interacting, elastically and/or inelastically, with medium and subjected to an electric field.
A. Rossani (Talk)

Nonextensivity at the edge of chaos of a new universality class of one-dimensional unimodal dissipative maps.
G. Ruiz and C. Tsallis (Poster)

Effects of quantum dot characteristics on the electronic spin-subbands states entanglement.
R. Safaiee, N. Foroozani, M. M. Golshan (Poster)

Bayes inference to the problem of inverse-halftoning based on statistical mechanics of the Q-Ising model.
Y. Saika, J. Inoue, M. Okada and H. Tanaka (Talk)

A statistical mechanical study of evolution of robustness under noisy environment.
A. Sakata, K. Hukushima and K. Kaneko (Poster)

Statistical properties of number fluctuations observed in Internet blog keywords.
Y. Sano, K. Yamada, K. Watanabe, T. Mizuno, H. Takayasu, M. Takayasu (Poster)

Emergence of communities in social networks.
J. Saramäki, J.M. Kumpula, J.-P. Onnela, K. Kaski and J. Kertész (Invited Talk)

Gauss' law of error revisited in the framework of Sharma-Taneja-Mittal information measure.
A.M. Scarfone, H. Suyari and T. Wada (Poster)

Interacting ensemble of particles in the context of q-deformed algebra.
A.M. Scarfone and P. Narayana Swamy (Talk)

Asymptotic solutions of a nonlinear diffusive equation in the framework of κ-generalized statistical mechanics.
A.M. Scarfone and T. Wada (Talk)

Criticality and corresponding states in ionic systems.
W. Schröer (Invited Talk)

Dynamical analyses of normal and anomalous diffusion in nonlinear Fokker-Planck equations.
V. Schwämmle, E.M.F. Curado and F.D. Nobre (Talk)

Time evolution of q-Gaussians in the linear and nonlinear diffusion equations.
V. Schwämmle, F.D. Nobre, and C. Tsallis (Talk)

Stochastic thermodynamics: Theory and experiments.
U. Seifert (Invited Talk)

Dynamic frustration and persistence in spin systems.
P. Sen (Talk)

Self-similarity of complex networks and hidden metric spaces.
M.A. Serrano (Invited Talk)

On creation of an exact microscopic heat theory on the basis of local distribution functions.
S.R. Sharov (Poster)

Localization length of waves in disordered media and the red-shift of the spectral density.
A. Sheikhan, N. Abedpour, R. Sepehrinia, M.D. Niry, M. Reza Rahimi Tabar and M. Sahimi (Poster)

Noise induced Hopf bifurcation.
I.A. Shuda, S.S. Borisov and A.I. Olemskoi (Poster)

Non-Markovian stochastic Liouville equation and its Markovian representation. Extensions of the continuous-time random walk approach.
A.I. Shushin (Talk)

Correlations in commodity markets.
P. Sieczka and J.A. Hołyst (Talk)

Scaling of clusters in a one-dimensional system.
J. Sienkiewicz and J.A. Hołyst (Talk)

An exactly solvable of $p + ip$ wave superconductivity.
G. Sierra (Invited Talk)

Physics and banking.
S.S Smyrnaki and T. Smyrnakis (Talk)

The therapy of shock therapy.
S. Solomon (Invited Talk)

Anomalous scaling behavior in polymer thin film growth.
S.-W. Son, M. Ha and H. Jeong (Poster)

Spontaneous symmetry breaking and criticality during animal development: hydra axis definition.
J. Soriano and A. Ott (Invited Talk)

How scaling and market efficiency determine the irreversible evolution of financial indices.
A.L. Stella (Invited Talk)

Generalized dimension D_q and Tsallis entropy S_q derived from the nonlinear differential equation $dy/dx = y^q$.
H. Suyari (Talk)

100-years of long term dependence in the Dow Jones index.
P.G. Szilagyi and J.A. Batten (Poster)

On efficient searching of hidden targets.
M. Tachiya (Invited Talk)

Collective charge fluctuations in single-electron processes on nano-networks.
B. Tadić and M. Suvakov (Invited Talk)

Renormalization of random multiplicative processes: An application to the universal statistics of company growth.
H. Takayasu, H. Watanabe and M. Takayasu (Talk)

Basic statistical properties of random walks in moving potential forces: the PUCK model for market prices.
M. Takayasu, T. Mizuno, K. Watanabe and H. Takayasu (Talk)

Quantum fluctuation theorems.
P. Talkner and P. Hänggi (Invited Talk)

Trajectory decomposition for unsupervised learning neural models.
V. Tereshko (Talk)

q-Gaussian approximants mimic non-extensive-statistical-mechanical expectation for many-body probabilistic model with long-range correlations.
W. Thistleton (Invited Talk)

Generalized-generalized entropies and central limit distributions.
S. Thurner and R. Hanel (Invited Talk)

Central limit behavior of one-dimensional discrete dynamical systems.
U. Tirnakli (Invited Talk)

Symbolic dynamics at the threshold of chaos.
R. Tonelli and M. Lissia (Talk)

Pesin identity at the edge of chaos: Averaging on single trajectories vs ensemble averages.
R. Tonelli, G. Mezzorani, F. Melloni and M. Lissia (Talk)

Interaction as the key to non-extensive statistical physics.
F. Topsøe (Talk)

Classifying superstatistics.
H. Touchette (Invited Talk)

On the foundations of statistical mechanics. Additive and nonadditive entropies, central limit theorems, and related matters.
C. Tsallis (Invited Talk)

Inhomogeneous coupling in two-channel asymmetric simple exclusion processes.
K. Tsekouras and A.B. Kolomeisky (Talk)

Nonlinear theory of quantum Brownian motion.
R. Tsekov (Talk)

Information geometrical study of Trp-cage folding dynamics.
C.-Y. Tseng, C.-P. Yu and H.C. Lee (Talk)

Kinesin motor protein as an electrostatic machine.
G.P. Tsironis, A. Ciudad and J.M. Sancho (Talk)

Fractional differential equation for subrecoil laser cooling.
V.V. Uchaikin and R.T. Sibatov (Talk)

Dynamic behaviors in directed networks: Synchronization and opinion dynamics.
J. Um, S.-G. Han and B.J. Kim (Invited Talk)

Topological phases in the Kitaev honeycomb lattice model on tours.
J. Vala, G. Kells, A.T. Bolukbasi and N. Moran (Invited Talk)

Dynamics of three interacting species in single compartment and in spatially extended system by moment equations
D. Valenti, L. Schimansky-Geier, B. Spagnolo (Talk)

Fracture and earthquake physics in a non extensive view.
F. Vallianatos (Poster)

Thermodynamics of relativistic fluids.
P. Ván (Talk)

Seismic electric signals and natural time.
P. Varotsos, N. Sarlis, E. Skordas and M. Lazaridou (Invited Talk)

Generalized fractional Fokker-Planck equation for anomalous diffusion: The Gaussian statistics recovered.
F. Vazquez (Talk)

Generalized fractional Fokker-Planck equation for anomalous diffusion: The Gaussian statistics recovered.
A. Veksler and R. Granek (Talk)

Generating function approach to thermodynamics based on time averages.
J. Velázquez and A. Robledo (Poster)

Superstatistical distributions from maximum entropy principle.
E. Van der Straeten and C. Beck (Poster)

Tsallis statistics framework for the information bottleneck method in unsupervised learning applications.
R.C. Venkatesan (Poster)

Collective dynamics of interacting neural networks in competition.
R. Vicente, A.C.R. Martins, F. Ribeiro and N. Caticha (Talk)

First-passage times in complex scale invariant media.
R. Voituriez, O. Bénichou, S. Condamin, V. Tejedor and J. Klafter (Talk)

The future poverty hiding in cities.
D. Volchenkov (Invited Talk)

Generalized log-likelihood functions and Bregman divergences.
T. Wada (Poster)

Variational principles in physics: from regular to irregular statistical dynamics.
Q.A. Wang (Invited Talk)

Generalized simulated annealing on complex networks for modelling memory in psychology.
R.S. Wedemann, R. Donangelo and L.A. V. de Carvalho (Talk)

Quantum transport of atoms in optical lattices of variable inversion symmetry.
M. Weitz (Invited Talk)

Uncertainty relations in terms of Tsallis entropy.
G. Wilk and Z. Włodarczyk (Talk)

Interplay between chaos and external noise in an extended system: intrinsic stochastic resonant phenomena.
H.S. Wio, J.A. Revelli and M.A. Rodriguez (Invited Talk)

PCA and wavelet PCA analyse of packet switching network traffic.
S. Xie, A.T. Lawniczak and P. Lio (Poster)

Complex duffing system driven by Gaussian colored noise.
Y. Xu and H.Q. Zhang (Talk)

Evaluation of pedodiversity in terms of generalized entropy.
T. Yabuki, Y. Matsumura, and Y. Nakatani (Poster)

q-Gaussian analysis of the transient current through Al-PMMA-Al thin films.
G. Yalçın, Y. Skarlatos and K. Gediz Akdeniz (Talk)

Analysis of chaotic dynamical system by extended ensemble Monte Carlo.
T. Yanagita and Y. Iba (Talk)

Thermal conductivity of a classical one dimensional spin-phonon system.
X. Zotos, A.V. Savin and G.P. Tsironis (Talk)

Simulations of environmental spatial data using Ising and potts models.
M. Zukovi and D.T. Hristopulos (Talk)

Why square root? Statistical physics and voting in European Union.
K. Zyczkowski and W. Słomczyński (Invited Talk)

Conditional approach to superstatistics and generalized thermodynamics.

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Nonequilibrium complex systems often exhibit dynamics that can be decomposed into several different time scales. Superstatistics [1] is a generalized statistical-mechanical theory, which allows one to treat in a consistent way a stationary state of such a complex system having temperature fluctuations. This theory is indeed based on the assumption that two time scales, fast local relaxation and slow temperature fluctuations, are largely separated. It has been formulated after some preliminary considerations [2] about nonextensive statistical mechanics [3].
Here, superstatistics is reformulated by taking advantage of the conditional quantities regarding local equilibria [4]. A kep point is to notice that each Boltzmann-Gibbs local equilibrium state maximizes the conditional entropy in each spatial cell set in the system, which is small but contains an enough number of particles and has a local value of the temperature. The temperature fluctuations are treated as the quenched disorder. In this way, conditional generalizations of thermodynamic relations are established. Then, the superstatistical correction to Boltzmann-Gibbs thermostatistics is systematically evaluated, and the ordinary thermodynamic results are recovered in a special case when the temperature fluctuations are absent. An important outcome of the present conditional approach is that the distribution of the temperature fluctuations can be derived from the maximum entropy method based on the conditional entropy. The resulting distribution is found to be a generalization of Einstein's 1910 theory of fluctuations around equilibrium [5]. A simple example of a classical gas is examined, and it is shown that such a model gives rise to the distribution of the temperature fluctuations that obeys a power law.

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Random-matrix theory within superstatistics.

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In analogy to Beck and Cohen's superstatistics [1], we connect the canonical Gaussian ensembles of the random-matrix theory (RMT) to their superstatistical generalizations through the fluctuation of an intensive parameter, the local density of states [2]. On one hand, the superstatistical RMT, seen from the present perspective, may bear interest per se because of the additional nontrivial fluctuations introduced in a simple model. On the other hand, it may constitute a useful statistical paradigm for the analysis of the spectral fluctuations of systems with mixed regular-chaotic dynamics. In contrast to other proposals for applying RMT to mixed dynamics, the superstatistical approach yields ensemble of matrices, which are invariant with respect to base transformation. The formalism has been checked by the analysis of experimental resonance spectra of mixed microwave billiards [3]. The spectra for each billiard are represented as time series in which the level order plays the role of time. Each series is shown to have two relaxation times as required by superstatistics, which involves the folding of two distribution functions. Analysis of the time series suggests that the superstatistical parameter has an inverse-chi-square distribution. The experimental distribution nearest-neighbor level spacings and strength functions agree with the corresponding predicted distributions.

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$GF(q)$ sparse random matrices: Some properties via statistical physics.

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The present work is concerned with two key properties of sparse random $M \times N$ matrices with entries in $GF(q)$, the Galois field of order q: the average dimension of their null space and the number of matrices for a given distribution of entries. These properties will be analysed in the thermodynamic limit of *large matrices*, with $N \to \infty$ and M/N constant.
Generalising the usual transformation of $x \to (-1)^x$ from $GF(2)$ into $\{\pm 1\}$ using the group homeomorphism between $GF(q)$ under addition mod q and the complex q-th roots of unity, we map the problem into a system of interacting "spins", what allows the use of methods developed for disordered spin lattices in statistical physics to obtain the required properties. A replica symmetric approach is then used to calculate the average dimension of the null space. Using general arguments based on the analogy with thermodynamical quantities corresponding to free energy, internal energy and Hamiltonian and the gauge invariance of the later, we show that there is no replica symmetry breaking in this problem. The calculations are similar to the ones used in the study of Low-Density Parity-Check (LDPC) error correcting codes. However, we introduce a more general technique for taking the average over the matrices which in addition to being conceptually clearer, allows for the use of general constraints.
These new introduced techniques lead to a factorization of the interactions for general distributions and produce saddle-point equations that were solved numerically using a population dynamics algorithm for different matrices distributions. We found that the average dimension of the null space is equal to $1 - M/N$ in all cases studied and conjecture that this result is always valid. Using the same techniques, we also found the total and average number of matrices for given relevant distributions and used numerical calculations to obtain plots and analyse the results.
Our results have practical relevance in several areas. For LDPC codes, the ANSD result implies that randomly generated codes typically have a rate of exactly $1 - M/N$, an assumption generally made but which lacks rigorous derivations. Also, as sparse matrices can represent connectivity profiles of

graphs, the average number of matrices provide a principled approach to determine the average number of graphs with general connectivity distributions.
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Agent based models for economics: Stylized facts and their self-organization.

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Economic and financial time series show well defined deviations from the simple Random Walk. These Stylized Facts (SF) consist mainly in the Fat Tails, Volatility Clustering and Arbitrage properties (1). Agent Based Models (ABM) have been introduced to reproduce them but it is difficult to identify the specific origin of the SF and, in particular, why the system self-organizes in this quasi-critical state. In the Lux-Marchesi model (2) the strategies of the agents are categorized in two basic classes. The fundamentalists consider the distance of the price from a fundamental reference price defined by economic criteria. The chartists are basically trend followers and define their strategy on the basis of the price time series. These two classes lead to a competition between stabilization and destabilization effects which characterizes price dynamics. A basic point is the possibility for the agents to change their strategy from fundamentalist to chartist and vice versa depemnding on herding and on the price properties. The model has several parameters and, only for certain specific values, it reproduces the stylized facts. In addition these properties depend critically on the number of agents N and are reproduced only for an intermediate value (N=500). We introduce a new ABM model (3) with the objective of the maximum seimplification (and reduction) of the parameters. For example the description of the chartists is in terms of the effective potential model (3) which focuses only of the strenght of the destabilization. We analyze in detail the oscillations between the two classes of agents and it results that a punctuated equilibrium is achieved only fora an intermediate number of agents. In this perspective the stylized facts correspond to finite size effects and not to asymptotic critical exponents. The specific origin of these properties can now be traced in detail and this permit to pose the key question of the self-organization in the quasi-critical state. A basic point is the fact that agents can decide to enter or not in the market depending on the signal they detect. This is a crucial element for the nonstationarity of the dynamics. The variation of the number of agents N (usually assumed to be fixed) is shown to be naturally linked to the phenomenon of self-organization.

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Correlations between political party size and voter memory: A statistical analysis of opinion poll.

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This work describes the novel [1-3] application of standard statistical methods from physics to political polling data in order to look for correlations and memory effects. We propose measures for quantifying these effects by using the correlation function and scaling analysis. These methods reveal time correlations and self-affine scaling properties respectively. The methods have been applied to polling data from Norway taken monthly over the last 30 years. The data is not strictly statistically stationary, and is also sparse compared to data sets normally considered for statistical analysis in physics. The choice of methods and measures are influenced by this, and a discussion of the impact is given.
The Auto Correlation Function (ACF) analysis indicates that there is a power-law correspondence with a positive exponent between party size and both the integrated correlation time τ and the time where the ACF first turns negative. This suggests that the polling data for a party are auto-correlated for a longer time for larger parties, and hence that larger parties have a longer memory than smaller parties.
The scaling analysis is based on the Average Wavelet Coefficient (AWC) and the Detrended Fluctuation Analysis (DFA) methods. Both the AWC and DFA results indicates a self-affine behaviour of the polling data, and a difference in behaviour between large and small parties. This possible crossover is compared to the time scales found in the ACF analysis. A discussion of the impact of polling uncertainties in the data is also included.
The larger parties are shown to have a Hurst exponent (H) smaller than 0.5, and therefore an anti-persistent behaviour over all the time scales considered. For the smaller parties there are indications in both the AWC and DFA methods of a crossover from $H < 0.5$ for small time scales to $H > 0.5$ for larger time scales. This may originate form a shift in behaviour for the smaller parties from anti-persistent on small scales to persistent on larger scales.

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Critical scaling in standard biased random walks.

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Random walk theory has allowed to deal with a diversity of problems in a number of areas of physics, as well as in many other theoretical and applied fields.
In any phenomenon where random walks are relevant, a fundamental quantity is the number of distinct sites visited, since

it furnishes the extent of the active territory. Indeed, it is crucial in processes ranging from reaction kinetics to population dynamics, and also in technical applications such as in search strategies. The vast literature on coverage mainly deals with two dimensions, although there are also many works about the standard symmetric onedimensional random walk. Meanwhile, as far as we know, little or no attention has been paid to the asymmetric onedimensional case, despite of its importance in biased or anisotropic processes such as electrophoresis, polymer translocation through pores, and Brownian ratchets. However, as we will show, the asymmetric onedimensional problem presents its own peculiar features and nontrivial scaling properties.

In this work, we scrutinize the spatial coverage produced by a single discrete-time random walk, with an asymmetric jump probability $p \neq 1/2$ and nonuniform steps (different step lengths, l^+ and l^-, occur in opposite directions), moving on an infinite one-dimensional lattice. Mutually prime l^+, l^- are considered. Analytical calculations are complemented with Monte Carlo simulations.

We will show that, for appropriate step sizes, the model displays a critical phenomenon, at $p = p_c$. In fact, the two anisotropic ingredients play competing roles and a nontrivial changeover between different coverage regimes, dependent on p, may take place. The scaling properties as well as the main features of the fragmented coverage occurring in the vicinity of the critical point will be exhibited. In particular, in the limit $p \to p_c$, the distribution of fragment lengths is scale-free, with nontrivial exponents. Moreover, a box counting procedure allows to reveal that the spatial distribution of cracks (unvisited sites) defines a fractal set over the spanned interval. Thus, from the perspective of the covered territory, a very rich critical phenomenology is revealed in a simple onedimensional standard model.

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Electric power grids as complex networks.

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Complex networks have been one of the most actively studied branches of statistical physics in recent years, due both to their theoretical-mathematical interest and to their wide range of applications (in physics, engineering, biology, sociology, etc.) [1].

Electric power systems are interconnected networks whose smooth functioning is crucial to modern society. A power system is a continent wide physical system composed by hundreds or thousands of nodes and lines, characterized by time-varying power flows. Not always a detailed analytical model, especially under dynamic conditions, can be feasible or computationally possible.

In this context it is quite natural to try to apply general concepts and ideas developed in complex networks also to electrical power grids and some application have already been published [2]. However, power systems are characterized by some features, very specific of this context, that cannot be found in other telecommunication or information networks. Therefore some of the traditional complex networks concepts need to be updated or adapted in order to be suited to power systems. Some of the main specific features of power systems are the following:

- transmission line flow limits;
- power flows obeying physical laws;
- need for a feasible operative profile in terms of voltage and line flow limits;
- timely power production and supply.

In this talk we give an overview of some main concepts and relevant quantities in complex networks, such as average path length, clustering coefficient, degree distribution, betweenness, efficiency and discuss their meaning in the framework of power systems. We show, with reference to some examples, how the traditional approach for studying complex networks can be adapted and usefully applied to power systems providing meaningful indications.

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Molecular motors interacting with their own tracks.

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Dynamics of molecular motors that move along linear lattices and interact with them via reversible destruction of specific lattice bonds is investigated theoretically by analyzing exactly solvable discrete-state "burnt-bridge" models [1,2,3]. Molecular motors are viewed as diffusing particles that can asymmetrically break or rebuild periodically distributed weak links when passing over them. Our explicit calculations of dynamic properties show that coupling the transport of the unbiased molecular motor with the bridge-burning mechanism leads to a directed motion that lowers fluctuations and produces a dynamic transition in the limit of low concentration of weak links. Interaction between the backward biased molecular motor and the bridge-burning mechanism yields a complex dynamic behavior. For the reversible dissociation the backward motion of the molecular motor is slowed down. There is a change in the direction of the molecular motor's motion for large concentration of bridges. The molecular motor also experiences non-monotonic fluctuations due to the action of two opposing mechanisms: the reduced activity after the burned sites and locking of large fluctuations. Large spatial fluctuations are observed when two mechanisms are comparable. The properties of the molecular motor are different for the irreversible burning of bridges where the velocity and fluctuations are suppressed for some concentration range, and the dynamic transition is also observed. Dynamics of the system is discussed in terms of the effective driving forces and transitions between different diffusional regimes.

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Non-self averaging of a two-person game only with positive spillover: A new formulation of Avatamsaka dilemma process.

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We have the Avatamsaka game Aruka [1] as a two-person game only with positive spillovers. In this game, selfishness would not be determined even if the agent selfishly adopted the strategy of defection. Individual selfishness could only be realized if the other agent cooperated. Any same-sized gain can be generated by either defection or cooperation. The sanction by defection as a reaction of the rival agent never then implies the selfishness of the rival. This game can be classified into a dependent game (Akiyama and Aruka [3]).
Aruka [2] gave an idea to formulate an Avatamsaka game process in terms of Polya urn process. If we regarded an evolution of gain-ratio of each agent as a nonlinear function, the dynamics of gain addition could eventually give a limiting expected value. Here, agents shall then initially be motivated by the behaviors of the other agents, and in the event, agentsf behavior could be independent from the others.
Now we introduce different spillovers, i.e., indifferent pay-off matrices. Each agent may then be faced with a different pay-off matrix. A ball in the urn is interpreted with reference to an agent's gain ratio, while a box a pay-off type. We apply Ewensf sampling formula to our urn process under this environment. In this case, we will have a similar result as in the classical case, because we have the averaging on variances of gain-ratios. We then apply Pitmanfs sampling formula to our urn process. Here the invariance of the random partition vectors under the properties of exchangeability and size-biased permutation does not hold in general. Incidentally, Pitmanfs sampling formula depends on the two parameter Poisson-Dirichlet distribution whose special case is just Ewens formula. In Ewens setting, it matters only one probability α on a new entry, on one hand. On the other hand, we can refer to an additional probability θ on an unknown type entry will be argued in the Pitman formula.
More concretely, we will investigate the effects of differing pay-off sizes of playing a series of different games coming out newly. As Aoki and Yoshikawa [4] dealt with a product innovation and a process innovation, they criticized Lucasf representative method that Microsoft and small grocery store on the street face micro shocks drawn from the same unchanged probability distribution. In the light of Aoki and Yoshikawa [4], we may show the same argument in our Avatamsaka game with different pay-offs.

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Nonlinear time series analysis of the current through PEG-Si thin films under varying relative humidity.

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Polyethylene Glycol is known to have an irregular current characteristic under constant voltage and slowly varying relative humidity. In this study the current through a thin film of Gamma-isocyanatopropyltriethoxysilane added Polyethylene glycol (PEG-Si) as a function of increasing relative humidity at equal time steps is analyzed for chaoticity. PEG-Si thin films were prepared either by dip coating, or by dropping the polymer on the glass substrate. Aluminum electrodes were coated in coplanar structure on the polymer by vacuum evaporation. The relative humidity was increased and the current was measured at uniform time intervals. Time series analysis and detrended fluctuation analysis thus became feasible. In previous studies it has been suggested that, after reaching a certain relative humidity level, a phase transition occurs from a semi crystalline state to a gel state. Fluctuations in the elastic force relaxations and in the number of Hydrogen bonds cause the irregularities observed in the time varying current.
We suggest that the irregular behavior of current through PEG-Si thin films as a function of increasing relative humidity could best be analyzed for chaoticity using both above mentioned methods where the relative humidity is kept as a slowly varying parameter and the data is split into 1% relative humidity bins. The delay times were investigated using the average mutual information and the embedding vectors were constructed using embedding dimension values from the method of false nearest neighbors. The presence of more then one regime was suggested by the calculation of the maximal Lyapunov exponents. Furthermore, the maximal Lyapunov exponent in each of the regimes was positive, thus confirming the presence of low dimensional chaos. The regime change signalled by the changing values of the maximal Lyapunov exponent occurred around a relative humidity of 70%. This is consistent with the phase transition from semi crystalline state to gel state. The behavior of the system was also analyzed using detrended fluctuation analysis to confirm the presence of at least two different regimes. Results of this analysis are consistent with the behavior of the maximal Lyapunov exponent in the time series analysis.

Kinetic effects on the transport properties of nanostructured devices investigated by deterministic solutions of the Boltzmann-Poisson system.

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In highly integrated semiconductor devices, the scale length of individual components is comparable with the distance between successive scattering events of the carriers. An accu-

rate description of the charge transport in such regimes requires the treatment on a kinetic level. Sophisticated kinetic transport models are based on semiconductor Boltzmann equations (BE) coupled with the Poisson equation determining the phase-space distribution of electrons and the electric field in a self-consistent way. The high-field electron transport in polar semiconductors, such as gallium arsenide or indium phosphide, as well as in graphene is essentially influenced by the non-equilibrium behavior of optical phonons [1,2]. Therefore, we consider a transport model consisting of a coupled set of Boltzmann equations for electrons and optical phonons to take into account the hot-phonon effects dynamically. To solve this set of kinetic equations, we developed efficient deterministic solution methods. The methods are based on a full discretization of the phase space. Conservative finite-difference schemes with shock-capturing reconstructions of the numerical fluxes are applied to approximate the distribution functions accurately even at the junctions of sharp doping profiles [3]. Hence, the developed numerical techniques allow us to perform detailed studies of the transport properties of submicron semiconductor devices in far-from-equilibrium situations. The deterministic approach offers the possibility to directly obtain the distribution functions without statistical noise at computational effort comparable with that of Monte Carlo methods [4]. We present kinetic effects on the electron transport in a silicon npn-structure, which are studied by comparing the solution of the Boltzmann equation with corresponding maximum entropy distributions. An indium phosphide diode is considered to investigate the impact of non-equilibrium polar optical phonons on the electron transport. Further, we demonstrate the applicability of the developed scheme on graphene by fully accounting for the special properties of this novel material. The main distinction to common semiconductor materials lies in the reduced dimensionality, the zero-energy-gap, and the constant velocity dispersion relation, often referred to as Dirac-cone. We present how these characteristics, together with the influence of optical phonons, affects the electronic transport in graphene.

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Noise-induced phenomena in transient dynamics of short and long Josephson junctions.

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The investigation of nonlinear properties of Josephson junctions (JJs) is very important due to their broad applications in logic devices. Currently, all Josephson junctions are manufactured with the use of optical and electronic lithography, and they can always be considered as distributed. Moreover great interest recently has attracted, from theoretical and experimentally point of view, the investigation of the influence of thermal fluctuations in macroscopic quantum phenomena of short and long Josephson junctions. Particularly the role of the noise on the life time of the superconductive state has been subject of many investigations. In fact for some devices, as the rapid single flux quantum devices (RSFQ), based on Josephson junctions, minimization of the switching time is required for better performance. In the frame of the resistive McCumber-Stewart model we analyze the transient dynamics of short and long overdamped Josephson junctions, in the presence both of a periodic driving force and a Gaussian autocorrelated noise. We use the archetypal source for colored noise, i. e. an exponentially correlated Ornstein-Uhlenbeck process. We focus our study on the behavior of the mean switching time (MST), and its standard deviation, from superconductive to resistive regime as a function of the colored noise parameters, i.e. noise intensity σ and correlation time τ_c. The resonant activation (RA) and the noise enhanced stability (NES) phenomena have been investigated with different noise parameters and bias current. In a short Josephson junction we find that fluctuations may both decrease and increase the mean switching time and that the positions both of the minimum of RA and the maximum of NES depend on the value of the noise correlation time τ_c. Moreover in the frequency range where RA is observed, the mean switching time exhibits a non-monotonic behavior as a function of τ_c. In order to take into account the spatial effects, we consider the phase values depending also on the space and, therefore, the stochastic dynamics of a long Josephson junction is investigated, in the frame of the sine-Gordon model. The influence of the length of the JJ on the mean switching time and on the above-mentioned noise induced phenomena (RA and NES), in the presence of colored noise, is analyzed. The influence of different bias currents on the MST is also investigated. Our results are discussed and compared with those obtained in the presence of white noise.

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Statistical dynamics of religion evolutions.

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Wealth, language, age, sex, ... religion can be considered as degrees of freedom of any agent on the human genre network. In fact, religiosity is one of the most important sociological aspects of human populations. Like languages and wealth, religions evolve and adapt to the society developments.
Several questions can be raised and have been considered from statistical physics points of view
(i) from a macroscopic one: How many religions exist at a

given time?
(ii) from a microscopic one : How many adherents belong to one religion?
(iii) and does the number of adherents increase or not, and how?
(iv) and why ???
Quantitative answers and mathematical laws are found or guessed about religious adherence; agent based models can be imagined to describe such non-equilibrium processes. It is found [1,2] that empirical laws can be deduced and related to preferential attachment processes, like on an evolving network; different algorithmic models reproduce well the data. A Lotka-Volterra growth-death equation is shown to be a plausible one for the growing evolution dynamics in a continuous time framework. The case of decaying religions is a little bit more complicated. Sometimes the data is also very unreliable. The importance of a so called "external field influence" is stressed in several cases. This indicates a more "complete" cluster-like expansion, and the greater interest/possibility of a Hamiltonian or Langevinian description in the case of religions than in language studies.
If time permits preliminary results about the competition between two "religious networks" (creationism and darwinism) will be described and commented upon.

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Study of the $\beta \to \beta'$ transformation for a generalized hydrogen atom in Tsallis statistics.

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In this article the $\beta \to \beta'$ transformation method proposed in Tsallis statistics is applied and studied for a hydrogen atom in different space dimensions (the generalized hydrogen atom [1]) in contact with a heat reservoir. For the difficulties with Boltzman-Gibbs (BG) statistics in describing systems with the long range interactions [2], the Tsallis statistics has been applied to study the specific heat of a hydrogen atom in contact with a heat reservoir using the un-normalized q expectation value formalism [3]. In our recent paper [4], we extended the method presented by Tsallis et al [3] on the behavior of the specific heat of a hydrogen atom in contact with a heat reservoir in different space dimensions (D). In the next study on the $\beta \to \beta'$ transformation method proposed by Tsallis et al [6], we showed that [5] the re-normalized temperature T for a hydrogen atom in contact with a heat reservoir, which is a function of intermediate temperatures $T\prime$, does not behave as a monotonically increasing function for the accepted range of q. Therefore the $\beta \to \beta'$ transformation is not applicable for $3D$-hydrogen atom. In this article, our previous work [5] is extended and applied to the hydrogen atom in different space dimensions. The results indicate that the general behavior of T as a function of $T\prime$, is almost independent of the space dimensions. It linearly increases with slope of one, passing through the origin for $0 < T\prime < (1-q)\frac{16D}{(D^2-1)^2}$. Then it decreases for $(1-q)\frac{16D}{(D^2-1)^2} < T\prime < (1-q)\frac{4}{(D-1)^2}$ and approaches zero as $T\prime \to (1-q)\frac{4}{(D-1)^2}$. The rate of approach depends on the space dimensions and it increases as the dimension increases especially for larger values of q ($\frac{1}{2} < q < \frac{7}{9}$). There also exist several local maxima in the decreasing range. The number of these maxima increases as the dimension increases. The behavior is more pronounced for small values of q ($0 < q \leq \frac{1}{2}$) and for lower intermediate temperatures. It is easy to show that the local maxima correspond to the anomalous behavior of the specific heat [4] calculated in the un-normalized q expectation value formalism.

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Rate equations and scaling in pulsed deposition.

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We study a simplified model for pulsed deposition (PD) [1] by rate equations. We consider several variants of these equations. First a simple set of rate equations, where the islands are treated as point-like objects. The equations are solved exactly in the limit of strong and temporally separate pulses (the so-called PD limit as opposed to the MBE limit of continuous deposition), reproducing some features of the model for very small values of the coverage. Since this approximation does not take the dimension of the islands into account it is not possible to faithfully reproduce the crossover from MBE to PD. This problem is overcome with a second improved set of rate equations that takes the dimension of the islands into account. As in the case of MBE, we show that these improved equations lead to results which are in excellent agreement with simulations for pulsed deposition.
As an alternative suggestion, to a previously observed logarithmic scaling of the nucleation density, we propose that the nucleation density, for a fixed value of the coverage, as a function of I follows a power law and that the exponent varies with the coverage. This suggestion is supported by numerical simulations and leads to data collapses which are more accurate than those obtained by using logarithmic scaling. This is a hint that logarithmic scaling has to be replaced by a different type of scaling theory.
We point out another new feature of the model in the PD limit, namely, the probability distribution p_s that a site belongs to a cluster of size s is not scale invariant when considering different values of the pulse intensity. This non-universal behavior may lead to the conclusion that for different pulse intensities the fractal dimension of the islands is different. However, studying the one-dimensional model, where islands have no fractal properties, the same effect is observed, indicating that this is not the case.

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Weak ergodicity breaking.

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In nature the noisy signal representing a physical observable is in many cases unpredictable, though the long time average of the signal is identical to the ensemble average (ergodicity). For this reason Boltzmann-Gibbs ergodic statistical mechanics is a powerful tool which gives predictions on time averages. Certain processes characterized by power law sojourn times, in such a way that the average waiting time in a state of the system is infinite are known to exhibit weak ergodicity breaking. For such scale free (in time) processes, time averages remain random even in the limit of long measurement time. The fundamental question is what statistical theory replaces standard ergodic statistical mechanics?

Recent examples of systems and models which exhibit weak ergodicity breaking include blinking quantum dots [1], anomalous diffusion of mRNA in the cell, non-linear maps which generate sub-diffusion deterministically [2], the sub-diffusive continuous time random walk model [3], and the quenched trap model [4]. In these diverse systems the distribution of waiting times in a micro-state of the system decays like a power law, with a diverging average sojourn time. For example blinking quantum dots have an on state in which many photons are emitted and an off state where the dot is in a dark state. The probability density function $\psi(t)$ of on and off times follows power law statistics with an average on and off time which is infinite $\psi(t) \sim t^{-(1+\alpha)}$ and $0 < \alpha < 1$. Hence if we perform a time average it can never be made for long enough time to obtain ergodicity since the average on and off times diverge. At the same time the quantum dot explores its phase space of state on and off many times during the experiment, thus naturally leading to the concept of weak ergodicity breaking introduced by Bouchaud.

A general theory of weak ergodicity breaking [5], based on Lévy's generalized central limit theorem, gives the distribution of the time averages of physical observables for these systems. Let $\mathcal{O}$ be a physical observable, in a system with $x = 1, \cdots, L$ states. When the system is in state x the physical observable attains the value $\mathcal{O}_x$. Let α describe the power law waiting times, specifically in the well known continuous time random walk model $\langle x^2 \rangle \sim t^\alpha$ so α is the anomalous sub-diffusion exponent. The probability density function of the time average $\overline{\mathcal{O}}$ is

$$f_\alpha\left(\overline{\mathcal{O}}\right) = -\frac{1}{\pi} \lim_{\epsilon \to 0} \mathrm{Im} \frac{\sum_{x=1}^{L} P_x^{\mathrm{eq}} \left(\overline{\mathcal{O}} - \mathcal{O}_x + i\,\epsilon\right)^{\alpha-1}}{\sum_{x=1}^{L} P_x^{\mathrm{eq}} \left(\overline{\mathcal{O}} - \mathcal{O}_x + i\,\epsilon\right)^{\alpha}} \ ,$$

where P_x^{eq} is the probability in ensemble sense to occupy state x. Validity of this equation is discussed in the talk. For models with thermal detailed balance P_x^{eq} is Boltzmann's canonical law.

Dynamical processes with zero Lyaponov exponent, exhibiting Pomeau Manneville type of intermittency, are shown to exhibit weak ergodicity breaking. A generalized q exponential Lyaponov exponent is found to describe the separation of nearby trajectories in these models. Simple Physical mechanism for ergodicity breaking of blinking quantum dots is also presented.

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A statistical description of the human a-wave ERG component.

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The precise form of the response of the retinal photoreceptors to light has not yet been established with certainty. The registration of the retinal response to a luminous stimulus (electroretinogram-ERG) provides an accurate estimate of the photoreceptoral behavior in vertebrates including the living human eye. The ERG records a composite signal consisting of a sequence of time-delayed potentials (i.e., early response, a-, b-, c-wave, late potentials, etc) originated in different retinal layers. The study of the a-wave of the ERG signal is one of the main fields of research in ocular electrophysiology, since it strictly reflects the functional integrity of the photoreceptors. Several models concerning the contributions of the early photoreceptoral response are available in current literature [1,2,3,4,5], but a fully comprehensive theory is still missing. In fact, since the response it is a combination of millions of individual photoreceptoral contributions, it is of fundamental importance to individuate possible correlations among the centers. These correlations, if present, affect the line shape of the overall response that is a gaussian only in the case statistically independent contributions are present.

We here investigate the kinetics of the light response by adopting a statistical approach about the analysis of the a-wave shape in healthy human subjects. The physiological behavior at various levels of luminance has been explored by modeling the corresponding a-waves with a set of appropriate statistical functions, representing possible mechanisms governing the interactions in the early stages of phototransduction. The results indicate that correlations between photoreceptoral populations are present, as a consequence of direct cell-to-cell interactions among rods and/or cones. It turns out that the response is a combination of a gaussian with a different function that accounts for the correlations.

A further step regards the extension of this study to the analysis of ERGs recorded in human subjects affected by specific visual pathologies involving the activation upon illumination of only one population of photoreceptors.

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Formation and evolution of urban road patterns.

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More than 50% of the world population now lives in cities and this number is bound to increase [1]. It became thus urgent and important to understand the basic mechanisms governing the growth of urban areas in order to help urban planners in their task. In particular, transportation networks which convey energy, matter, or individuals from one point to the other are crucial in our large cities and their evolution needs to be understood.
In this talk, I will focus on the road network which can be considered as a planar network where segment of roads are the edges and intersections represent the nodes. Using previous empirical measures [2,3,4] I will first show that these networks display surprising regularities across many cities in different parts of the world [5], even in the absence of a global design. These regularities suggest the existence of a simple mechanism governing the growth of the urban network of roads. In this talk I will present such a process, based on a local optimization and which allows to reproduce most of the observed empirical facts and in a more qualitative way explains the tendency to have bent roads-even in the absence of geographical obstacles-and perpendicular intersections [5]. The rationale to invoke a local optimality principle in this context is that every new road is built to connect a new location to the existing road network in the most efficient (less costly) way.
This model also leads to the conclusion that the road pattern results from the coupling between a local optimization and the spatial distribution of centers (homes, offices, etc), and suggests a modeling of the urban road network in terms of co-evolution between land use and transportation networks. Within this framework, we explicitely introduce the topology of the road network and analyze how it evolves and interact with the evolution of population density [6]. We show that accessibility issues -pushing individuals to get closer to high centrality nodes- lead to high density regions and the appearance of densely populated centers. In particular, this model reproduces the empirical fact that the density profile decreases exponentially from a core district. In this simplified model, the size of the core district depends on the relative importance of transportation and rent costs.

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Structure in gold and silver spread fluctuations.

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The price dynamics of precious metals, generally, and gold and silver in particular, has long been a matter of popular concern and fascination. Recently, a number of authors have successfully modelled the stochastic nature of precious metal returns [1] while the new tools of econometrics have demonstrated important insights in the long term price relationships between bivariate combinations of precious metal prices [2].
The objective of this study is to report the dynamics of the bivariate relationship between gold and silver prices. First, we investigate the spread, measured as the price difference between gold and silver trading as a futures contract, then the presence of long-term dependence in the spread returns (ΔP_t) between gold and silver is measured using statistical techniques based on rescaled range analysis [3] after accommodating short-term autocorrelated innovations in the return process [4,5]. Collectively this filtering process usually via Autoregressive Moving Average Models (ARMA) models is the basis for rescaled range analysis. Of specific interest is the residual ψ_t after applying various filters (AR(1) $\rightarrow$ ARMA (2,1)) to ΔP_t .
An ARMA(2,1) model of the form $\Delta P_t = \alpha_0 + \beta_1 \Delta P_{t-1} + \beta_2 \Delta P_{t-2} + X_1 \lambda \psi_{t-1} + \psi_t$ provides the best fit to the data with $\beta_1 = 0.4802$ ($p = 0.06$), $\beta_2 = 0.1109$ ($p = 0.000$) and $X_1 = 0.5780$ ($p = 0.024$). For each ψ_t the classical rescaled adjusted range $(R/\sigma)_n$ is calculated where $\overline{X}_t$ is the sample mean and σ_n is the standard deviation of ψ_t over a particular series n and h_n (termed the local Hurst coefficient) = $\log(r/\sigma)_n / \log n$. In this study n is set to either 22 days or 66 days, which is equivalent to a standard one and three month period. This procedure in effect creates a time-series of exponent values, the change in whose value can be measured over time. The local Hurst exponent reveals episodes of both positive and negative dependence, though the positive dependent relationship appears to be dominant. This last finding is of importance for spread traders and portfolio managers since trading strategies based upon mean reversion in the spread offers limited profit opportunities

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Superstatistics: An overview on theoretical approaches and recent applications.

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A review of the superstatistics concept is given. Many complex driven nonequilibrium systems are effectively described by a superposition of several statistics on different time scales, in short a "superstatistics" [1-5]. A simple example is a Brownian particle moving in a spatially inhomogeneous medium with temperature fluctuations on a large scale, but the concept is much more general. Superstatistical systems typically have marginal distributions that exhibit fat tails, for example power law tails or stretched exponentials. Tsallis statistics is obtained for special cases. In most appliactions one finds three relevant universaliy classes: Lognormal superstatistics, chi-square superstatistics and inverse chi-square superstatistics. In recent years superstatistical techniques have been applied to a variety of complex systems, for example turbulence (Lagrangian, Eulerian, environmental), hydroclimatic fluctuations, pattern formation, mathematical finance, traffic delay statistics, random matrix theory, networks, systems described by path integrals, as well as medical and biological applications. In this talk I will concentrate on some recent applications for Lagrangian turbulence [1] as well as on a new application in medicine: a superstatistical model of metastasis and cancer survival [5].

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A stochastic approach to quantum statistics distributions: Theoretical derivation and Monte Carlo modelling.

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This contribution describes a method devoted to the statistical evaluation of the thermal equilibrium distribution of an ideal gas consisting of interacting/non interacting classical and quantum particles (or quasi particles) in thermal contact with a heat bath (canonical ensemble). The method is alternative to standard procedures since it makes use of a strategy based on the stochastic evolution of the microstates constituting the system. It allows the formulation of microscopic models of the systems of interest, compatible with their macroscopic behavior. Equilibrium is reached via a convergent Markov chain. The condition of detailed balance yields the appropriate distribution function for each particle species. A theoretical derivation of Bose-Einstein and Fermi-Dirac distributions constitutes a good starting point for the development of a variant of the Monte Carlo Metropolis algorithm, it takes into account the indistinguishability of identical quantum particles. The results of the simulations concern the evaluation, without the approximations typical of current statistical methods, of the principal distribution laws and thermodynamic properties of two- and three-dimensional systems, they reproduce the theoretical behavior of systems of particles characterized by different microscopic properties and, hence subjected to different statistical properties. They apply to situations of low degeneracy as well to those of in which the system is highly degenerate. In the first case, the results yield small differences between the three distribution functions since the average occupation number is much smaller than one, only in the limit case $\epsilon/k_{\rm B}\,T \to 0$ small differences appear. The bosons, in particular tend to occupy states of lower energy, whereas the fermions do not. In the second case (high degeneracy), appreciable differences among the three distributions are evident. The classical distribution is little affected, the quantum distributions, on the other hand, suffer drastic changes: bosons evidence an appreciable tendency to condense into states of lower energy (Bose-Einstein condensation), fermions tend to occupy all energy states below the Fermi level.

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Fluctuation-dissipation dispersion relation for systems with slowly varying parameters.

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Fluctuations play an important role in the constitution of dissipative structures [1], in the sensitivity of the devices; find applications in diagnostic procedures. In thermodynamic equilibrium, the fluctuations are determined by the system temperature and the dissipation [2]. The matter becomes more delicate even in the local-equilibrium case. In the general case parameters of the systems can be change in both time and space. Inhomogeneities in space and time of these quantities will certainly also contribute to the fluctuations. In the context of plasma physics, using the Langevin approach and the time-space multiscale technique, it has been shown that the amplitude and the width of the spectral lines of the electrostatic field fluctuations and the electron form factor are determined not only by the imaginary (dissipative) part of the dielectric susceptibility but also by the derivatives of its real (dispersive) part [3]. As a result of the inhomogeneity, these properties become asymmetric with respect to the inversion of the sign of the frequency. In the kinetic regime, the form factor is more sensitive to space gradients than the spectral function of the electrostatic field fluctuations. This asymmetry of lines can be used as a diagnostic tool to measure local gradients in the plasma. The fluctuation-dissipation relation has been generalized to the non-equilibrium systems with slowly varying parameters [4]. The important conclusion of this analysis is to reveal that the spectral function of the fluctuations is determined not only by dissipation but also by the deriva-

tives of the dispersion. The non-Joule dispersion contribution is characterized by a new non-local effect originating from an additional phase shift between the force and the response of the system. That phase shift results from the parametric control to the system. The example of an electrical oscillation circuit shows the dispersive contributions strongly affect the quality factor. These results are applicable to other systems and are important for the understanding of various behaviors observed in different field of physics, communication, chemistry, biophysics and econo-physics.

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Long-range interactions: An econometric approach based on stock market indexes.

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It is widely recognized that long-range interactions can be understood in a variety of ways. Hurst [1], when studying the flow of the river Nile was the first author to detect and model the presence of the so-called long memory phenomenon which can be viewed has an example of this kind of interactions. Interestingly, after his seminal work, many other researchers found the same pattern in other domains of science such as biology, physics, economy or even finance, just to cite a few. One question that arises when analyzing this phenomenon is the adequacy of tests developed to detect this property. Actually, empirical evidence has shown that many of them rely precisely on the estimation of the Hurst exponent, for which several techniques are known. One of the most popularized in literature is the rescaled range statistics (**R/S** henceforth) that, however, has shown some drawbacks since it lacks robustness in the presence of short memory and heteroscedasticity, as [2], *inter alia*, pointed out. Regarding this, it became obvious among investigators, the need for alternative approaches. So, other methods started to emerge. One of them, that constitute the main focus of this study, consists in studying this same property by looking on the characteristics of the time series. In this regard, it is usual to distinguish between two criteria: the time domain or the frequency domain. In the time domain, long memory manifests itself as hyperbolically decaying autocorrelation functions. On the other hand, in the frequency domain, we get the same information in a form of a spectrum which has the advantage of showing all information within the interval $[0, \pi]$.
In this paper we go a little further and present an approach based on econometric formulations derived from the original ARCH - Autoregressive Conditionally Heteroscedastic Model such as the GARCH - Generalized ARCH, IGARCH - Integrated GARCH and FIGARCH - Fractionally IGARCH models, *inter alia*, in order to detect the presence of short/long memory in four stock indexes: PSI 20 (Portugal), STOXX 50 (EU), SP 500 (USA) and NASDAQ 100 (USA). The empirical evidence so obtained shows the presence of long memory in all indexes, exception made for the PSI 20 index which evidences short memory. Overall, we may say that our purpose with this study was two-fold: i) investigate the presence of long-range interactions in finance and ii) discuss alternative methods to detect it based on econometric models.

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Stock market volatility: an approach based on Tsallis entropy.

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One of the major issues actually studied in finance that had always intrigued, both scholars and practitioners, and to which there weren't yet discovered a unified theory, is the reasons why price moves over time and the underlying volatility inherent to those movements, which actually seems to affect markets as a whole. Since there are several well known traditional techniques in literature to measure stock market volatility, a central point in this debate that constitutes the actual scope of this paper, is to put together this common approach in which we discuss popular techniques like the variance and/or standard deviation, from which depart all the Autoregressive Conditionally Heteroscedastic Models - ARCH type models, and an innovative methodology called the Econophysics approach which applies concepts of physics to explain economic/financial phenomena. This new branch of knowledge has some defendants (e.g. [1]), and emerged when some regularities between such areas were found in a consistent way. In our particular study, we use the concept of Tsallis entropy, S_T to capture the nature of volatility. To shed some light in this discussion we shall clarify that the concept of entropy was originally introduced in 1865 by Clausius in the context of thermodynamics and, since then, several formulations have been constructed. Although the debate generated over its meaning, it is generally understood as measure of disorder, uncertainty, ignorance, dispersion or even lack of information. More precisely, what we want to know in our study is if Tsallis entropy is able to detect volatility in stock market indexes and to compare its values with the ones obtained from the variance and/or standard deviation analysis. Also, we shall refer that one of the advantages of this new methodology when compared with the traditional one is its ability to capture nonlinear dynamics, which does not happen with the common variance and/or standard deviation of the traditional approach. This is especially relevant as it has been widely recognized by several authors ([2], *inter alia*) that economic and financial relationships are typically nonlinear. For our purpose, we shall basically focus on the behaviour of stock market indexes and considered the FTSE 100 (UK), SP 500 (USA), CAC 40 (France), MIB 30 (Italy), Nikkei 225 (Japan), IBEX 35 (Spain) and PSI 20 (Portugal) for a comparative analysis between the approaches mentioned above.

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The nonequilibrium Ehrenfest gas: A chaotic model with flat obstacles?

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The tools of statistical mechanics and billiards theory are essential to study transport phenomena in models of physical systems at or away from equilibrium [1,2].
Dispersing Sinai billiards are chaotic systems with singularity [3], but is unknown whether billiards at non-equilibrium with focusing and/or flat obstacles are chaotic and the current analytical techniques seem not suitable to answer this question since they uses the fact that obstacles are dispersing [4]. The Ehrenfest gas with electric field and Gaussian isokinetic thermostat is a model where the obstacles are rhombi, hence flat, [5]. The presence of flat boundaries and the external field may suggest that nearby trajectories are always focused, so that the overall dynamics should be not chaotic. However, it is not obvious that this is the case for all values of the electric field. Numerical investigations, starting with random initial conditions and considering the electric field in different ranges, show that the asymptotic behaviour of the system is either chaotic, periodic or quasi periodic orbit. In the latter case, after a large number of collisions, we observe a striking decrease of the largest Lyapunov exponent towards negative values, as time grows. The exponent looks to have converged for a large number of collisions, but after a longer time it starts to decrease. This suggests the presence of a small stable region that is situated around the vertex of the rhombi. A periodic orbit of period four was oserved, which is embedded in the chaotic attractor and has one positive Lyapunov exponent, strongly suggesting the presence of chaos. Furthermore, we show how the attractor changes by increasing the magnitude of electric field or by changing the parameters of the geometry. The chaotic regions and the stable regions interchange each other with strong discontinuities and it is necessary to hone the range of the parameters to smaller and smaller cipher.
This unexpected behaviour has an impact on the global transport properties, whose study is of both theoretical and nanotechnological interest.

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Equilibration of relativistic matter with non-extensive composition rules.

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The non-extensive approach to thermodynamics has been debated by Nauenberg based on the treatment of the thermal equilibration process. The main objection was that while in the classical thermodynamics the equilibration of the temperature is unique, in the two (or more) parameter approach it is not straightforward how and whether both parameters would equilibrate and whether this process would be unique. If this were so, then one may not consider power-law spectra of particles as ones stemming from a statistically stationary state.
We address this controversy in the framework of a particular simulation of collisions between relativistic (in fact massless) particles: Our approach is, however, not based on using a non-extensive entropy formula. Instead we consider non-extensive energy composition rules as a basic dynamical ingredient to our model.
Since due to a mathematical theorem the function equations describing a general, associative but not necessarily additive composition rule, can always be mapped to the addition (this is the so called formal logarithm of the composition group), an additive quasi-energy, $X(E)$, arises in terms of which the stationary distribution is exponential, $f(E) \sim \exp(-X(E)/T)$. It is extremely interesting that to leading second order in the low-energy expansion of an associative composition formula the emerging rule is given by the Tsallisian one: $h(x,y) = x+y+a\,x\,y$. In this case one obtains $X(E) = 1/a\,\log(1+aE)$ and the stationary distribution becomes a power-law $f(E) \sim (1+a\,E)^{-v}$ with $v = 1/a\,T$.
We have studied lately the equilibration between two subsystems of massless particles prepared with stationary power-law tailed distributions of the one-particle kinetic energy in the framework of a particular parton cascade model solving numerically the Boltzmann equation with the above energy composition rules in micro-events. We have found that even subsystems with different non-extensivity parameters achieve a common equilibrium. In the particular cases of the same $a = (q-1)/T$ value, the two systems with an equal number of particles thermalize to the arithmetic mean in T and q and keep the power-law form of the distribution.

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Univariate and multivariate properties of wind velocity time series.

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It is well known that wind can help the the ecosystem to reabsorbs pollutants and can be used for energy generation also. The statistical approach to wind study has a long story [1] but its definitive modeling is still a challenge. As atmospheric wind is a highly non-stationarity process, simple models fails to catch some of its statistical properties. For instance, the

scaling of the probability density function (PDF) of wind velocity differences diverge from that of isotropic turbulence [2,3]. Moreover the wind velocity recorded in a particular station is correlated in space and time with the wind velocity recorded in neighboring stations, therefore a multivariate analysis can be used to extract relevant statistical information.
Among the different existing wind models some of them take into account different regimes of mean and/or variance to explain the presence of extreme values in wind differences PDF [2,3]. Moreover seasonality and autocorrelation of wind velocity as well as spatial correlations require appropriate statistical treatments [1].
In this work we present results concerning the study of the individual as a well as the collective dynamics in the wind velocity time series. The analysis has been carried out using wind velocity time series recorded in 29 different recording station of the SIAS [4] located in Sicily. The velocities have been recorded during the 4-year period 2003-2006.
The results concerning the individual dynamics are aimed to illustrate the statistical properties of wind velocity differences. Specifically, we compare PDF and calm time intervals with those obtained from models showing the extent to which such models are applicable.
The collective dynamics investigation has been performed by associating a metric distance $d_{ij} = \sqrt{2(1-\rho_{ij})}$, based on the cross-correlation ρ_{ij} of the wind velocity time series, to each couple of stations. Using this distance it is possible to obtain a dendrogram and a network - Minimum Spanning Tree (MST) - that are able to reveal the taxonomy of correlations in the analyzed time series reproducing the geographic distribution of the stations of observation. Moreover, the MST provides informations not available in the dendrogram such as the connections and lagged correlations.

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Navigability of complex networks.

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Networks are ubiquitous in all domains of science and technology, and permeate many aspects of daily human life, especially upon the rise of the information technology society. Our growing dependence on them has inspired a burst of activity in the new field of network science, keeping researchers motivated to solve the difficult challenges that networks offer. Among these, the relation between network structure and function is perhaps the most important and fundamental. Transport is one of the most common functions of networked systems. Examples can be found in many domains: transport of energy in metabolic networks, of mass in food webs, of people in transportation systems, of information in cell signaling processes, or of bytes across the Internet.
In many of these examples, routing or signaling of information propagation paths through a complex network maze plays a determinant role in the transport properties of the system. The observed efficiency of this routing process in real networks poses an intriguing question: how is this efficiency achieved? When each element of the system has a full view of the global network topology, finding efficient routes to target destinations is a well-understood computational process. However, in many networks observed in nature, including those in society and biology (signaling pathways, neural networks, etc.), nodes efficiently find intended communication targets even though they do not possess any global view of the system. For example, neural networks would not function so well if they could not route specific signals to appropriate organs or muscles in the body, although no neuron has a full view of global inter-neuron connectivity in the brain.
In this work, we identify a general mechanism that explains routing conductivity, or navigability of real networks based on the concept of similarity between nodes [1]. Specifically, intrinsic characteristics of nodes define a measure of similarity between them, which we abstract as a hidden distance. Taken together, hidden distances define a hidden metric space for a given network. Our recent work shows that these spaces explain the observed structural peculiarities of several real networks, in particular social and technological ones [2]. Here we show that this underlying metric structure can be used to guide the routing process, leading to efficient communication without global information in arbitrarily large networks. Our analysis reveals that, remarkably, real networks satisfy the topological conditions that maximize their navigability within this framework. Therefore, hidden metric spaces offer explanations of two open problems in complex networks science: the communication efficiency networks so often exhibit, and their unique structural characteristics. Our results have enormous consequences for network science and engineering, opening the possibility, for example, to design efficient routing and searching strategies for the Internet and other technological or social networks.

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Assessment of structural vulnerability of power grids by network performance based on complex networks.

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Complex networks (CN) have received considerable attention recently since the investigation of small-world and the characterization of scale-free have been discovered in many real networks. Power grids have been widely acknowledged as a typical type of CN. Many works have applied concepts and measurements of CN to analyze the structural vulnerabilities or the mechanism of cascading failure in power grids. However, the theory of CN has developed most from the generic physical perspective which focuses on the common features of all interested networks including internet, WWW, social network, and transportation networks etc. Therefore, the initial research works on CN developed many common concepts and measurements which are supposed to be efficient to any kind of complex networks. Whereas, the common features of CN mostly

refer to their non-trivial topological characteristics which do not occur in simple networks. In contrast, the functions and objectives of different networks would be totally different and take many specific characteristics that can not be dealt with by general methodologies. When the theory of CN is gradually applied to some fields involving the specific functions and objectives of networks, such as the protection of networked infrastructures, it is unavoidable to adapt the common concepts and measurements according to the considered scenarios.
Specially, when we focus on power grids, we would find that their basic functions and final objectives are very different from many other well-known complex networks which are often the references in traditional research. The basic function of power grids is to satisfy the power supply required by load nodes efficiently and flexibly. Different kinds of vertices, such as generation buses, transmission buses and distribution buses, have different positions and influences to the achievements of the objectives of the networks. The general assumption about the shortest path as the distance between two nodes is no meaningful for power grids where all paths between them should be involved in energy transmission. Furthermore, most of works on CN are based on unweighted and undirected graphs where the obvious physical constraints in power system operation can not be effectively taken into account. The load in cascading failure model of general theory of CN has been defined equally to betweenness. This is far from the real physical loads in power grids and the related capacities of components can not be taken into account.
In this paper, based on reconsidering several well-known assumptions of general theory of CN with reference to the specific features and objectives of power grids, several impact factors which are crucial for research of power grids in CN will be proposed. Furthermore, the specific concept of global network performance of power grids will be defined based on global network efficiency proposed in general theory of CN by adapting to these impact factors. Power Transmission Distribution Factors (PTDF) and impedance will be resorted to redefine the distance between two nodes in power grids. The conception of load will be defined as the real physical energy transmitted in the networks. Then the capacities of transmission lines will be taken into account to evaluate the network ability to achieve its essential function from statistical perspective. It will be applied to security analysis of power systems in contrast to results from former common methods of CN to prove its effectiveness.

Generalized diffusion: A microscopic approach.

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The random walk is a classical paradigm for the microscopic mechanism underlying diffusive processes as demonstrated by Einstein in one of his famous 1905 papers. There are many systems observed in nature where it seems logical to use the language of diffusion, but where non-classical (non-Gaussian) distributions are observed. Now Einstein's master equation for the random walk can be generalized when the probability $P_j(r)$ that the particle at position r at time t performs a displacement of j lattice sites, is a functional of the particle distribution function $f(r,t)$. One then obtains a generalized diffusion equation (GDE) which can admit of q-exponential solutions.
An important result is that exact self-similar solutions of the GDE (without drift) are only possible if the jump probabilities scale as power laws, and thereby gives an answer to the question : what underlying dynamics can give rise to the observed q-Gaussian statistics.
The GDE bears some resemblance with the porous media equation (PME) but contains new terms (absent in the PME). An interesting question is whether these new terms play any role, or whether they could be neglected giving a result close to the porous media equation with drift. Numerical solution of these equations compared to microscopic simulation results show that the full GDE is necessary to provide a correct description of the system for all values of q.
In the presence of either drift (non-symmetric jump probabilities) or an external field, the generalized diffusion equation is more complex than the equivalent extension of the porous media equation, and no simple scaling solution is evident. In the case of an external field but no drift, a scaling solution is possible, but only with a trivial external field. This suggests that exact scaling is only possible in the GDE in the case of no field and no drift. It leaves open the possibility of approximate scaling in the long-time limit or of more complex assumptions for the dependence of the jump-probabilities which might give completely different scaling properties.

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Mean first passage times for stochastic models of eco-hydrological systems.

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Level crossing properties and mean first passage times (MFPT, i.e. the times at which a stochastic process first reaches a critical value) in systems driven by external noise have been frequently utilized to characterize stochastic dynamics in different fields, including chemistry, physics, and statistics [4]. MFTP can also have useful applications to the study of environmental parameters, like soil moisture and water stress. For example, their analysis is important to investigate the linkage between climate, soil, and vegetation through soil moisture dynamics. In fact, plants begin to suffer water stress when soil moisture is below a threshold value [3]. The mean first passage time of this threshold has been shown to be an important indicator of plant conditions (water stress), but the study of MFPT through numerical analysis can be computationally demanding. Recent studies have determined relatively simple analytical expressions for MFPT of process driven by uncorrelated noise, i.e. white shot noise and gaussian white noise (*e.g.*, [1]), while more complicated expressions are needed when dealing with processes forced by correlated noise, such as the dichotomous Markov noise [2]. Moreover, earlier studies have also shown that ecosystem dynamics can be well-described through a dichotomic Markov process, i.e., as an alternation between two different states, corresponding to stressed and unstressed conditions for vegetation: in each state the dynamics are described by a different equation, and the long term behavior of the system can be investigated using

the framework of the dichotomous Markov process. Here this framework is adopted to analyze the water stress dynamics in dryland ecosystems. In particular, we use analytical MFPT expressions to investigate the role of climate, soil, and vegetation (i.e., rainfall occurrences, soil porosity) in arid and semi-arid ecosystems.

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Out of equilibrium phase transitions of two dimensional flows and other systems with long range interactions.

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I) Random switches between large scale flows with different topologies.
We study the two dimensional Navier Stokes equation with stochastic forces (SNS Eq.). This is an example of out of equilibrium system, without detailed balance. The most striking physical result is the existence of out of equilibrium phase transitions : one observes random bifurcations from one topology of large scale flow (dipoles) to another (unidirectional flows) (similarly to a bistable system).
After the theoretical study of a bifurcation diagram for the microcanonical statistical equilibria of the 2D Euler equation, we have conjectured the existence of these out of equilibrium phase transitions. Similar considerations leads to the predictions of out of equilibrium phase transitions in a large class of other geometries, and also for geostrophic, large rotation or 2D magnetic flows.
The system roughly behaves as a bistable one. However this analogy is extremely limited. Indeed, in our case no potential landscape exists, that would explain the phenomena. Moreover the turbulent nature of the flow (infinite number of degrees of freedom) makes the phenomena much richer than in the classical two well problem. Analogies with the Earth magnetic field reversal, and with similar phenomena in experiment of two dimensional and geophysical flows will be discussed.

II) Stochastic Landau damping.
From a theoretical point of view, the 2D Navier Stokes equation with stochastic forces belongs to the class of out of equilibrium systems with long range interactions. It shares for instance deep analogies with out of equilibrium plasma. We consider the kinetic theory for such systems.
At leading order, fluctuations around equilibria are described by the linearization close to statistical equilibria, of the SNS Eq. or of the Vlasov equation with stochastic forces.
We thus study theoretically these linearized equations. In the limit of zero dissipation, as expected no stationary distribution exist for the Gaussian vorticity field. By contrast, the Gaussian stream function or velocity fields strikingly converge toward a stationary Gaussian process. The velocity field thus acts similarly to a dissipative system, when dissipation is no more present. An explanation of this seemingly anomalous behavior and its relation to the deterministic Landau damping of plasma physics and Orr mechanism for 2D vortices will be given.

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Quantization methods and quantum simulations of random walks and of Lie walks.

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Rules for quantizing the walker+coin parts of a classical random walk are provided by treating them as interacting quantum systems, forming a quantum statistical model of a particle (walker) immersed in a bath of other particles (coins). Quantum walks following the so called U- and ε- quantization rules are presented. The former rule involves unitary transformation of the quantum coin system, while the latter one involves a completely positive trace preserving map. This last map acts on the quantum coin system, and is motivated and justified by the fact that it allows to consider coin systems as quantum systems interacting with external agents. Asymptotic statistics of walker's position exhibiting enhanced diffusion rates, as compared to classical ones, are analytically treated. The setting of these walks is further shown to provide the framework for implementing the mechanism of quantum simulation among quantum systems. Lie group theoretical extensions of these walks are provided. The case of U(n) valued coin systems, is detailed by using techniques of the root and weight systems from the theory of Lie group classification and representations. The resulting polypodic quantum walks have dimensionality of walker space determined by the rank of the group, and walker "footprint size" (polipodicity), determined by the dimensionality of the irreducible representation chosen. Furthermore

directional and boundary aspects of the accelerated diffusion rate of the walker, are also reported, and their associations with problems of quantum computing are also discussed.

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Adaptive networks in a simple model of economy.

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We introduce and analyze a simple model of interacting agents. The agents are represented as nodes of a network and the possible exchanges between them via links. The network is dynamical, with links adapting to the flow of money between the agents. The exchange of money is driven by a dynamic process that is local on the network and depends on the wealth of the concerned agents. The two levels of dynamics interact: the wealth distribution influences the network topology and the network topology shapes the circulation of wealth amongst the agents. Connections between agents are established according to a wealth-preferential rule and are dis-established in a random fashion. The money flow follows the local dynamics defined in the paper [1]: the corresponding equations combine incoming and outgoing wealth flows for each node with stochastic interactions associated with external, exogenous factors modeled via a multiplicative white noise.
Given the interactions between the network links and the wealth of agents, the system as a whole is driven to a steady state. The properties of this state depend on the parameters of the model, and in particular on the ratio of traders' activity and the strength of the multiplicative noise. When the ratio is small, the steady state of the model is characterized by a very heterogeneous network with a scale-free degree distribution, and a heterogeneous distribution of wealth $p(w)$; there is then a scale free tail $p(w) \sim w^{-1-\mu}$ with exponent $\mu < 1$. On the contrary when the ratio is large, the network becomes dense and the tail of the distribution becomes less fat. The order parameter for this transition is the inverse participation ratio for the wealth distribution. For the phase with $\mu < 1$, the inverse participation ratio is positive, while in the other phase it is zero. This means that in the first phase there is wealth-condensation and in the second wealth is rather uniformly distributed. We observe a strong correlation between the density of links and the inverse participation ratio. If one looks at the time evolution, one sees that in periods of increasing link density the inverse participation ratio decreases, while when the network becomes sparse and more heterogeneous the wealth inverse partipation ratio increases.

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Wetting transitions in polydisperse fluids.

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In a polydisperse fluid, the particles are not all identical, but instead exhibit variation with respect to some attribute such as their size, shape or charge. As is becoming increasingly clear, the bulk and surface phase behavior of such fluids is considerably richer - in both variety and form - than that of their monodisperse counterparts. The source of this richness is traceable to "fractionation" effects, whereby the distribution of the polydisperse attribute differs from one coexisting phase to another, even when the form of the overall (parent) distribution is fixed. As a consequence, the compositions of the coexisting phases depend not only on the prevailing temperature, but also on the scale of the parent distribution, i.e. on the overall density of the system [1]. In this talk we begin by briefly outlining principal aspects of the phenomenology of bulk phase coexistence in polydisperse system. We then describe an investigation of the influence of particle size polydispersity on the wetting behaviour of a polydisperse Lennard-Jones fluid in contact with a planar, structureless wall [2]. We propose that the dependence of the bulk compositions of the phases on the overall density engenders density-driven wetting transition inside the coexistence region. A likely topology for the wetting phase diagram is suggested, and tested using Monte Carlo simulations of a model polydisperse fluid, tracing the wetting line inside the cloud curve and identifying the relationship to prewetting. We argue that the phenomenon of tricritical wetting should be more readily observable in polydisperse fluids than in monodisperse ones.

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Evolution and clustering in the World Trade Web.

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World Trade Web:
The results of the present work are based on the empirical analysis of a large data set reporting the annual values of the population size $p_i(t)$ and of the GDP *per capita* $z_i(t)$ of each world country i for each year t from 1948 to 2000, together with the annual amount of money $f_{ij}(t)$ flowing from each country i to each country j due to exports from j to i between 1950 and 2000. The use of a standard reference money unit such as $\$_{1996}$ factors out the effects of inflation and allows a comparison between figures corresponding to different years. This problem can be mapped onto the so-called *fitness model* [1] where it is assumed that the probability p_{ij} for a link from i to j is a function $p(x_i, x_j)$ of the values of a *fitness* variable x

assigned to each vertex and drawn from a given distribution. The importance of this model relies in the possibility to write all the expected topological properties of the network (whose specification requires in principle the knowledge of the N^2 entries of its adjacency matrix) in terms of only N fitness values.

Rich club coefficient:
Amongst the various quantities used to characterize the WTW we discuss here the *rich-club coefficient*. This quantity indicated as $\phi(k)$ is a measure of the connections between nodes with a degree larger than a given k value. In particular, given the number $E_{>k}$ of edges between the $n_{>k}$ vertices whose degree is larger than k we define $\phi(k) = (2E_{>k})/(n_{>k}(n_{>k}-1))$. For this quantity a comparison with a null case is crucial in order to determine if the properties of a real instance of a graph are particular or characteristic of a whole class [2]. The standard approach works by selecting two edges randomly and by exchanging them. To overcome the problems arising when the graph is dense, we explicitly transforming the graphs analysed into weighted graphs. This procedure allows also to define a rich-club coefficient in the weighted case as $\phi^w(s) = (2E_{>s})/(n_{>s}(n_{>s}-1))$. where now $E_{>s}$ is the number of edges (topological) between vertices whose *strength* is larger than s and $n_{>s}$ is the number of vertices whose *strength* is larger than s.

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Spontaneous reversal of irreversible processes in a many-body Hamiltonian evolution.

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In earlier work [1], we had shown how several Hamiltonians could be modified through the introduction of an arbitrary real parameter Ω in such a way that all initial conditions have period $2\pi/\Omega$ so that the system becomes *isochronous*. Based on this work, we then showed [2] how a largely arbitrary N-particle Hamiltonian system can be extended by one single degree of freedom, in such a way that all the orbits of the extended system become periodic with the period $T = 2\pi/\Omega$. The extended system is, of course, still Hamiltonian. Furthermore, it is seen that, over times $\tau \ll T$, the evolution of the extended system remains close to that of the original up to a constant time rescaling. This has interesting consequences from the point of view of statistical mechanics if we choose T much larger than the relaxation times of the original system, and put the latter in a non-equilibrium initial condition. In this case, the normally irreversible relaxation process is repeated four times in every period, twice in the forward and twice in the backward time direction. This example shows first that an integrable system can display exponential sensitivity to initial conditions over a broad range of times. It also shows that the second law can be strongly violated in a system, the short-time dynamics of which can be made to resemble arbitrarily closely that of an "ordinary" N-particle system. All this suggests that any proof of the second law from a purely mechanical foundation will require hypotheses that may be difficult to justify on an empirical basis.

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The Hurst exponent of high-dimensional fractals.

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The application of fractal concepts, through the estimate of the Hurst exponent H, has been proven useful in a variety of fields. In $d = 1$, heartbeat intervals of healthy and sick hearts are discriminated on the basis of the value of H; the stage of financial market development is related to the correlation degree of return and volatility series; climate models are validated by analyzing long-term correlation in atmospheric and oceanographic series. In $d = 2$ fractal measures are used to model and quantify stress induced morphological transformation; isotropic and anisotropic fracture surfaces; static friction between materials dominated by hard core interactions; diffusion and transport in porous and composite materials; mass fractal features in wet or dried gels and in physiological organs. A number of fractal quantification methods such as rescaled range analysis (R/S), detrended fluctuation analysis. (DFA), detrending moving average analysis (DMA), and spectral analysis, have been thus proposed to accomplish accurate and fast estimates of H in order to investigate correlations at different scales in d=1. A comparatively small number of methods able to capture spatial correlations, operating in $d = 2$, have been proposed so far. We have developed an algorithm to estimate the Hurst exponent of high-dimensional fractals and thus is intended to capture scaling and correlation properties over space. The proposed method is based on a generalized highdimensional variance of the fractional Brownian function around a moving average. We will discuss the relationships holding for fractals with arbitrary dimension. It is argued that the implementation can be carried out in directed or isotropic mode. We show that the detrending moving average (DMA) method is recovered for $d = 1$. The feasibility of the technique is proven by implementing the algorithm on rough surfaceswith different size and Hurst exponent Hgenerated by the random midpoint displacement (RMD) and by the Cholesky-Levinson factorization (CLF) methods. The generalized variance is estimated over subarrays with different size "scales" and then averaged over the whole fractal domain. This feature reduces the bias effects due to nonstationarity with an overall increase of accuracycompared to the two-point correlation function, whose average is calculated over all the fractal. Furthermorecompared to the twopoint correlation function, whose implementation is carried out along one-dimensional lines e.g., for the fracture problem, the two-point correlation functions are measured along the crack propagation direction and the perpendicular one, The Hurst exponent of high-dimensional fractals is estimated by generalization of the Detrending Moving Average algorithm. We apply the method in rough surfaces generated by the random midpoint displacement and by the Cholesky-Levinson factorization algorithms. The surrogate surfaces have Hurst exponents ranging from 0.1 to 0.9 with step 0.1, and different sizes. The computational efficiency and the accuracy of

the algorithm are also discussed.

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Fat tails and long memory in the behaviour of traders and programmers.

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The time between consecutive events observed in many human activities is neither Poissonian nor Markovian, but exhibits bursts of rapidly occurring events separated by long periods of inactivity. The distribution of interevent times follows heavy-tailed distributions (see e.g. [1,2]).
Although activity patterns resulting from an aggregated behaviour, such as financial markets, have been studied for a long time, recent work focused on the individual behaviour. It has been shown that in some cases non-Poissonian behaviour is not only a by-product of human interaction, but can be traced back to individuals. Some remarkable examples are web surfing and e-mail communication [1,2].
An important issue is the relationship between individual behaviour and aggregate activity in very large systems. This talk addresses this issue for traders in financial markets and programmers contributing to open source software. Whereas data is difficult to obtain from brokers, data on open source software is freely available: for instance CVS logs keep track of who did what when and sometimes why.
We report activity data analysis on real traders [3] and several open source software projects [4]. Their typical activity patterns are compared, focusing on their activity level, the time between two actions and the size of their actions. Fat-tailed distributions and long-term memory are found in both cases, suggesting that quiet periods are followed by cascading modifications. The differences between the two dynamics are discussed and explained in part by software structure.

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Kinetic theory of 2D point vortices from a BBGKY-like hierarchy.

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Starting from the Liouville equation, we derive the exact hierarchy of equations satisfied by the reduced distribution functions of the single species point vortex gas in two dimensions. Considering an expansion of the solutions in powers of $1/N$ (where N is the number of point vortices) in a proper thermodynamic limit $N \to +\infty$, and neglecting some collective effects, we derive a kinetic equation satisfied by the smooth vorticity field which is valid at order $O(1/N)$. For axisymmetric flows, this equation takes a simple form that can be studied in detail. We discuss the properties of this kinetic equation in regard to the H-theorem and the convergence (or not) towards the statistical equilibrium state (Boltzmann distribution). Specific attention is given to the peculiar properties resulting from the long-range nature of the interaction and the non-extensivity of the system. In particular, the point vortex gas can remain trapped in long-lived quasistationary states (QSS) whose distribution is neither given by the Boltzmann nor by the Lynden-Bell statistics (because of incomplete relaxation). We also consider the relaxation of a test vortex in a bath of field vortices and obtain a Fokker-Planck equation incorporating a term of diffusion and a term of drift. The drift coefficient is related to the diffusion coefficient by an Einstein relation. The diffusion coefficient is inversely proportional to the local shear and decreases very rapidly with the distance. This implies that the relaxation of the test vortex has a peculiar behaviour. The tail of the distribution function of the test vortex develops a front structure which evolves very slowly (logarithmically) with time. On the other hand, the temporal correlation function of the position of the test vortex decreases algebraically rapidly instead of exponentially.

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Node-voltage-based and branch-current-based hybrid electric power network equations and research of reactive power optimization problem.

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The networks are widely existed in nature and human society. There are a large number of theories and approaches proposed to study the flow in networks, which is especially aimed to the traffic network. The network flow arithmetic is also used in power system calculation with the dc power flow formulation being the most common representation for the transmission system. The dc power flow formulation is only a simple model for power system analysis, so it is essentially different between electric power network flow and the conventional traffic network flow. There is no damp for the traffic network flow, but the active power flow of electric power network is decreasing because of the branch impedance.
The line current may be adopted to replace the active power as electric power network flow due to it is not damped, therefore the successful theories and approaches in network flow can be used for power system calculation.
The electric power network is traditionally described by node-voltage-based equations if the line current is not regarded. In the last century, the loop current model is developed by Goswami[1 4] etc for load flow calculation of distribution sys-

tems with better convergence and meshed modeling while the grounding admittance is ignored and the constant impedance model of load is used, but it is improper and limited in the transmission network with such assumptions.
The reactive power optimization problem is described by an optimal power flow model with the objective function as network losses minimization, and various approaches are proposed such as interior point methods, evolutionary algorithms and others, which are summarized in literature[5]. It is discommodious for the network losses that are generally represented by the sum of injective active powers at slack nodes or all nodes, and it is necessary to improve the computational efficiency of present reactive power optimization approaches.
In this paper, the enlarged electric power network equations are established by regarding the grounding branch as a current source with node voltage and branch current variables, so the objective function can be wrote as the product of line current and resistance, and the reactive power optimization problem can be decomposed into two sub-problems with a minimum cost flow model and a linear equations. It is solved to the minimum cost flow model by a quadric programming approach, therefore the computational efficiency is improved and the found optimal solution is closed to global. The case study is made at the IEEE-30 system and the better results are obtained.
The assumptions are introduced in this paper as following: 1) The reactive power optimization is aimed to the injective reactive power at all nodes; 2) The transformer's tap ratio optimization is ignored because it is not obvious to reduce the network losses; 3) The active power is considered as constant, and the reactive power and node voltage at all nodes are regarded as variables.

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A physical-statistical model for snow avalanche release.

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Firstly, the paper proposes a fractal model to analyse the density and the porosity of the snowpack, based on the statistical generalisation of the Menger sponge. We show the fractal character of the snow at all scales and the dependence of its density from the scale. On the basis on fractal evidence for snow and avalanches, we put forward a general physical-statistical model for spontaneous snow avalanche release. By defining triggering of snow avalanches as a critical phenomenon (e.g., as a phase transition characterized by scale invariance) and considering the variability of the shear strength inside the snowpack, the Renormalisation Group Theory is applied (Smalley et al., 1985; Carpinteri, 1994; Chiaia, 2002). Under the hypothesis of a Weilbull distribution of the shear strength and modelling at each scale the snow cover as a hierarchical bi-dimensional vector of n cells divided in n/4 at the lower scale we are able to analyse the evolution of the weak layer into the snow cover starting from the local failure condition of a single cell. The energy transfer between broken clusters and unbroken neighbour ones represents the physical peculiarity of the model. The model provides the definition of a Probability Stability Index, showing how a very compact snow continuum, e.g. characterised by less cohesionless zones, although requiring larger rupture stresses is more brittle and definitely more sensitive to catastrophic large avalanches. The model justifies also retarded triggering (no sudden collapse after a snowfall) and the release of the slab avalanche under applied nominal stresses lower than the strength of the weak zones. In conclusion, the RG model represents the probabilistic link between interacting events at the microscopic scale (Mode II fracture propagation in the weak layer) and the events at the macroscopic scale (global release of the snow avalanche).

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VBL: Virtual Biophysics Lab.

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The speed and the versatility of today's computers open up new opportunities to analyze complex biological systems, and suggest that in the future we shall be able to simulate the behavior of large cell populations *ab initio*, starting from individual molecular reactions in single cells and climbing the ladder of complexity up to the behavior of whole multicellular organisms [1].

Because of the extreme complexity of the problem most existing numerical studies are limited to rather small subnets of molecular circuits within a single cell. In the last few years we have taken a different path that ensures the feasability of the numerical approach by giving up, at least temporarily, the detailed description of many biochemical and biophysical processes. We proceed in a partly phenomenological way that leads to simple parameterizations: in exchange, we achieve a huge reduction in computational complexity and a considerable reduction of the space-time scale problems that affect simulations aimed at calculating the properties of macroscopic objects starting from microscopic models. We are developing a program that simulates cell metabolism, growth and proliferation and the extracellular environment. We can now simulate large populations of dispersed cells, like those in the culture wells used for *in vitro* growth, and we have produced numerical estimates that are in excellent qualitative agreement, and in good quantitative agreement, with experimental data [2,3]. Although the actual simulation of a living organism is still a faraway goal, with our program we can perform virtual experiments in settings that are difficult to realize or to control *in vitro*, and thus the program is a true *in silico* laboratory.
Here we focus on methods implemented in the simulation program and borrowed from computational statistical physics, like the solution of the various simultaneous diffusion problems on discrete structures, and the simulation of the dynamics of ensembles of soft spheres.

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Scaling of human behaviour in the World Wide Web.

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The cyberspace can be understood as a complex system of human actions,with one very popular kind of this activity corresponding to the information search in this virtual world. The set of web pages we choose, the browsing art, and the time we spend reading the contents reflects our pastime habits and interests in the real world.
To study this issue we used the data from Polish portals, and considered the behavior of a user on a Web page. Our analysis is based on cookie statistic provided by Gemius company. For example the portal www.onet.pl consists of 515 sub pages which are visited by 4 milions cookie users during one day. We constructed a weighted network of sub pages defining link weights as the number of users moving from one sub page to another. The weights distribution is a power law with characteristic exponents $\gamma = 1.45 - 1.65$. We observed the traffic at the portal and we learnt about habits and patterns of behaviour of internauts by the analysis of network properties.
Our data contains also the information about the time spent by a user on various sub pages. We investigated the distribution of total time a user spent on the portal, and the distribution of times spent on one sub page. This distribution is a power law $p(t) \sim t^{-\gamma}$ ($\gamma = 1.19$ for the www.gazeta.pl and $\gamma = 1.31$ for the www.onet.pl) over two decades. We also examined also properties of partial time distribution. A partial time is the time the user stayed on one sub page normalized by the total time spent on the portal for this user. The distribution of partial times is a power law with $\gamma = 1.10$ for the www.gazeta.pl and $\gamma = 1.13$ for the www.onet.pl). On the other hand we observed an exponential distribution of numbers of different pages visited by a single user. We constructed a model explaining some of features observed at sub pages networks.

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Classification of Darboux polynomials for three dimensional Lotka-Volterra systems.

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We consider a general three-dimensional Lotka-Volterra system defined by a skew-symmetric matrix. The most general form of the equations is

$$\dot{x}_i = \varepsilon_i x_i + \sum_{j=1}^{n} a_{ij} x_i \, x_j, \quad i = 1, 2, \ldots, n \ ,$$

We would like to understand the behavior of a Hamiltonian system based on the algebraic properties of its Darboux polynomials. As a first step we would like to examine the set of Darboux polynomials of the low dimensional cases of Lotka-Volterra equations without linear terms ($\varepsilon_i = 0$) and where the matrix $A = (a_{ij})$ is skew-symmetric.
Special cases include the open and periodic KM-system, and several other well-known integrable Hamiltonian systems. We classify the Darboux polynomials (also known as second integrals) for such system for various values of the parameters, and give the explicit form of the corresponding cofactors. More precisely, we show that a Darboux polynomial of degree greater than one is reducible. In fact, it is a product of linear Darboux polynomials and first integrals. Darboux polynomials are important since they give rise to many first integral search techniques, such as the Prelle-Singer procedure. In the special case that two relatively prime Darboux polynomials exist with the same cofactor, their ratio is a rational first integral. The Lotka-Volterra dynamical system was introduced by Lotka in order to model a chemical reaction, and independently by Volterra to model competition among species, in 1925. It has been widely used in applied mathematics and in a large variety of physical topics such as laser physics, plasma physics, neural networks, etc. The integrability of various forms (for arbitrary values of ε_i and a_{ij}) of the three-dimensional Lotka-Volterra system has been examined extensively.

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Extension of recommendation model to dynamic population.

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Recommendation Model [1] is a model that is used to investigate the effects of memory size with respect to the population size where an agent learns a new agent by recommendation.
In recommendation model, there are n agents where each of them has the same memory size, m. The memory M_i of an agent a_i is a subset of the agents in the population. An agent a_i knows a_j if a_j is an element of M_i. The knownness k_i of an agent a_i is the number of agents that know a_i. If $k_i = 0$, then the agent a_i is called completely forgotten. The fame f_i of an agent a_i is k_i/n. The memory ratio ρ is m/n.
Initially, an agent knows its m-neighbors. At each simulation cycle, a giver agent a_G selects the recommended agent a_R from its memory and recommends a_R to a taker agent a_T. If a_T already knows a_R, it does not do anything. Otherwise, a_T learns a_R by forgetting an agent a_F from its memory (learning an agent means getting it into the memory and forgetting an agent means removing it from the memory). The a_G, a_T, a_R and a_F are selected randomly. The simulation ends when the average recommendation per agent is 10^6.
Minimum fame in the population, maximum fame in the population, cumulative (average) fame of the top 5 percent of the agents from the population that are selected by ordering the agents according to their fame values in decreasing order and percentage of forgotten agents in the population vs. ρ graphs are investigated at the end of simulations for different combinations of n and ρ.
Why not try to extend the Recommendation Model to simulate the fame in a world where agents born and die, agents can communicate with a limited number of agents, memory size of agents is not static and agents don't forget an agent that they know randomly.
The features of Recommendation Model that will be extended are dynamic population size, dynamic memory size, dynamic selection of a_F and dynamic selection of a_T. Simulation result of each possible combination of these features is going to be investigated one by one to see the effect of each feature.

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The κ-generalized model of income distribution.

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Fitting a parametric model to income data can be a valuable and informative tool of distributional analysis. Not only can one summarize the information contained in thousands of observations, but also useful information can be drawn directly from the estimated parameters. For example one could be interested in measuring income inequality, comparing different distributions or elaborating income redistribution policy: these concepts may sometimes be directly derived from parameters of a fitted distribution.
The symmetric bell-shaped curve that describes the Gaussian distribution is inappropriate for describing most income distributions because they tend to be skewed with a peak in the lower-middle income range and to have a long right-hand tail. To capture these features, a large number of functional forms other than the Gaussian distribution have been suggested (see *e.g.* the comprehensive monograph by [1]).
In the present study we propose a three-parameter distribution that is a generalization of the Pareto and the Weibull distribution using a new approach recently advanced by one of us to describe both physical [3] and non-physical [4] systems. This approach characterizes the distribution as solution of a maximum entropy model based on the κ-deformed exponential and logarithmic functions

$$\exp_\kappa(x) = \left(\sqrt{1+\kappa^2x^2}+\kappa x\right)^{1/\kappa}, \quad x \in \mathbf{R}, \qquad (1)$$

$$\log_\kappa(x) = \frac{x^\kappa - x^{-\kappa}}{2\kappa}, \quad x \in \mathbf{R}^+. \qquad (2)$$

These κ-deformed functions satisfy most properties of the standard exponential and logarithm, which are recovered as the real deformation parameter κ approaches zero; for applications to statistical analysis of income distribution, the most interesting property is their power-law asymptotic behavior, and thus their ability to satisfy the Weak Pareto Law [2].
Starting from the definitions in Eqs. (1) and (2), we derive the basic statistical properties of the proposed new distribution along with some tools for the description of income distribution, including the Lorenz curve and various indices widely used to assess inequality trends and differences, such as the Gini coefficient and the Generalized Entropy (GE) and Atkinson indices. The distribution provides a very good description of actual data on personal income from five countries, and the inequality analysis expressed in terms of its parameters reveals very powerful compared to other models for the size distribution of income.

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Dynamical heterogeneities in glasses, gels and granular media.

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One of the challenge in condensed matter over the last years is understanding the phenomenon of the glass and jamming transitions. One of the recent advances in the field is the idea of the dynamical heterogeneities (DH), which play the role of the critical fluctuations in ordinary critical phenomena[1]. Dynamical heterogeneities are group of particles which move in a dynamical correlated way to allow the decay of density fluctuations. The quantity which describe the dynamical heterogeneities is the non linear susceptibility which is the integral of a four point correlation function. Interestingly, recently, it has been shown that DH can be obtained within the Mode Coupling Approximation[2] with precise quantitative prediction. In this talk I will review some of the properties of the DH in various systems such as glasses, irreversible gels, colloidal gels and granular media. The behaviour of glasses and granular materials are closely related. As function of the time in bo! th cases the dynamical susceptibility exhibits a peak at a characteristic time which scales with the long relaxation time of the system. In the case of irreversible gelation the dynamical susceptibility reaches asymptotically a plateau, whose value coincide with the mean cluster size[3]. In colloidal gelation, a more complex dynamic is found with a slowing down with gellike features, due to the formation of persistent structures. By means of Molecular Dynamics simulations of a model colloidal suspension, it is shown that, at low volume fractions, the dynamical heterogeneities are in fact dominated by the clusters of long living bonds. The dynamical susceptibility at intermediate time reaches a plateau and then eventually decays to zero. This feature for intermediate time is rather similar to the one observed in irreversible gelation, where the presence of dynamical heterogeneities can be explicitly related to the mean cluster size. At longer time instead due to the finite lifetime of the bonds the clusters decay and consequently the dynamical susceptibility goes to zero. At higher volume fraction, instead, where crowding of the particles starts to be relevant, dynamical heterogeneities show the typical pattern observed in glassy systems.

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Material-induced anomalous scaling in the surface roughness of etched films.

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The formation and evolution of surface roughness during the processing of a film is a non-equilibrium process with many implications on micro- and nanotechnology due to the increasing impact of roughness on device operations as dimensions shrink down. A great impetus to the theoretical understanding of roughness evolution was given by the assumption that local and global surface width scale in a similar fashion. This allowed the development of a scaling theory akin to that of equilibrium critical phenomena which led to the definition of new dynamic critical exponents and new classification schemes for roughness evolution processes [1]. However, soon it was realized that the surfaces produced by most experiments and models do not obey the above assumption and normal scaling behavior. On the contrary, they exhibit local fluctuations enhancing with time in an anomalous way and leading to a scaling behavior of the local surface width different than that of global width [2]. Although a lot of works reported the presence of anomalous scaling, the identification of the physical origins for that is still an open question. The aim of the present work is to investigate the contribution of the inhomogeneities of processed material to the occurrence of anomalous scaling behavior in roughness evolution. In particular, we focus on the kinetic roughening of plasma etched films motivated by the principal role of plasma etching in micro- and nanopatterning and the concomitant demand for a better control of its formation and evolution. The investigation is made through a two-dimensional kinetic Monte Carlo simulation of the etching process and a lattice representation of the film. Two kinds of inhomogeneous films are investigated modeling composite and porous materials respectively. The first includes films with lattice cells being etched much slower than the bulk material and modeling the filler of the composite [3]. The second employs films with voids modeling the pores of the material. Both isotropic (chemical) and anisotropic (ion sputtering) etching modes are considered and the evolution of vertical (surface width) and spatial (correlation function) roughness are reported. The crucial role of the vertical correlations between filler or pore positions is exemplified and it is shown that roughness evolution and its scaling behavior during the etching of a film can be used as a diagnostic tool of correlations in filler or pore distributions in film material.

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Nonlinear statistical analysis of natural language written texts.

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In this work, natural language written texts in English and Greek are investigated by using methods of nonlinear statistical analysis. Both aim and methodological approach are twofold. The first aim is to reveal fundamental structures in written language texts, compare various natural languages and seek for possible universal features. The second is to address the question whether simple representations of a written text capturing fundamental features of it, such as word lengths, can reflect text semantics. The latter is apparently related to the problem of the automatic classification of texts with respect to their content. The methodology for the achievement of the

above goals consists of two branches. The first uses symbolic dynamics and the second nonlinear time series analysis methods. In the first approach, symbolic sequences are obtained using a primitive coarse-grained description where every character is mapped to "1" and all other characters, belonging to the space class, are mapped to "0". A linear scaling of the corresponding block entropies of symbolic dynamics is observed, characteristic for a mixing system with a positive Kolmogorov-Sinai (KS) entropy. We calculate the KS entropy for various English and Greek texts ranging from politics and economics to literature and sports. The obtained values lie in the interval [0.38-0.42] for the Greek and in [0.41-0.45] for the english texts. Universality and classification issues in this context, posed by the aforementioned aims, are also discussed. In the second approach, time-series are generated from natural language written texts in English and Greek by mapping the length of the words in a text to the order of their appearance ("length time series" see [1]) . Then the obtained length time-series are analyzed using the turning point distribution method [2]) and it is found that the word-length 3 in the Greek texts possesses the characteristics of a fixed point in the considered dynamics. Long range dynamical correlations with a critical profile in the time-series are also investigated using the method of critical fluctuations introduced in [3]. Our results show that the correlations in the considered text dynamics are limited to short ranges. Finally, the length time series of the English texts are analyzed by similar methods and the results of the analysis are compared with those of Greek texts.

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Anomalous enhancement in low energy fusion rates: The role of ion statistical distribution.

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Significant divergence from theoretical predictions of non-resonant fusion cross-section has recently been observed in low-energy experiments with deuterated matrix target. Different ideas have been proposed to explain the observed enhancement in fusion rate: the most interesting models include thermal effects, anomalous electron screening, or quantum-effect dispersion relations. All these models give some enhancement, but none of them can completely explain the experimental results. We compare and develop previous proposals, including the possibility that more than one effect may act at the same time. In addition, we consider the effect of electron redistribution from host metallic matrix to the adsorbed atoms and address the very important experimental issue of which stopping power should be used at the energies of few KeV, where data are not available.
Since the velocity distribution of the ions adsorbed in the matrix has an important role for the reaction rate when the energy of the beam is low, we consider the possibility that alternative distributions. In particular, we study how the distribution is affected by the uncertainties in the energy-momentum relation, due to the Galitskii-Yakimets quantum effect. In fact, this effect leads to a power law behavior in the high energy tail distribution. We estimate that this effect can contribute to the observed reaction rate enhancement at the few KeV beam energies. We also discuss the effective energy at which fusion reactions happen and the dependence of the effect from the plasma state and the adopted collisional cross section.

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Multifractal regime transition in a modified minority game model.

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In the last years several agents based models for asset returns have been proposed in the literature, in particular the called Minority Game Model [1] . One of the reasons for this interest is that the traditional models derived from the geometrical Brownian motion do not explain adequately many properties of real markets. The Minority Game (MG) and its variants constitute one of the most promising models due to their capability of explaining a wider range of properties found in price and index signals. It is usual to characterize economic time series from their empirical properties called stylized, which includes multifractal long range correlations. There are several ways to characterize the long-range correlations from the real time series and from its models. Some of these methods are the autocorrelation functions, power spectral densities (either from Fourier or wavelets transforms) and probability distribution functions [2-4]. In addition, the fractal and the multifractal analysis provide more insights, respectively, on the self-similar and self-affine scaling exponents. In this work we focus on the multifractal properties found in price and index signals. Although the usual Minority Game models do not exhibit multifractality, we study here one of its variants that does. We show that the nonsynchronous MG models in the nonergodic phase is multifractal and in this sense, together with other stylized facts, constitute a better modeling tool. Using the Structure Function (SF) approach we detected the stationary and the scaling range of the time series generated by the MG model and, from the linear (nonlinear) behavior of the SF we identified the fractal (multifractal) regimes. Finally, using the Wavelet Transform Modulus Maxima technique [5] we obtained its multifractal spectrum width for different dynamical regimes. We showed that the MG model presents a very rich dynamics with anomalous fluctuations that arise due to strong correlation similar to the one observed in systems driven out of equilibrium. One of the more difficult stylized fact to obtain from models for financial systems are the long range correlations that generate the fractal and multifractal properties present in real time series. The synchronous MG model does not present multifractality. However, only one ingredient added to the model generates multifractal region on

the space control parameter α. This ingredient was the broken of synchronicity. As the statistical properties of the MG are preserved, the observed multifractal regime belongs to the non-ergodic phase, where the market is informationally efficient.

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Persistence and critical behavior in non-Markovian random walkers.

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The effect of memory losses is studied for the limiting case of unbounded memory in non-Markovian random walks for which the decisions are based on the prior random walk step directions. The walker can retain memory of its entire or partial history and the current step direction, at time t, is chosen first by randomly selecting a previous time t' with equal *a priori* probabilities. The decision taken at t' can then be accepted with probability p. The dependence of the Hurst exponent α on the fraction f of the total time t remembered by the random walkers is studied. The dynamics can range from sub-diffusion ($\alpha < 1/2$), through normal diffusion ($\alpha = 1/2$), to superdiffusion ($\alpha > 1/2$). Persistence (i.e., long-range correlations) is characterized by the latter, and cause the random walker to repeat past behavior. It is shown that otherwise nonpersistent random walkers switch to persistent behavior when inflicted with significant memory loss with only the distant past being remembered. This is contrary to the common belief that loss of memory of the past cannot cause persistence but rather can only diminish it, since persistence is interpreted as a tendency to repeat past behavior. Such amnestically induced persistence suggests a causal relationship between repetitive behavior and memory loss for systems with negative feedback. It is also shown that memory losses induce the probability density function of the walker's position to undergo a transition from Gaussian to non-Gaussian. These findings are interpreted in terms of a breakdown of self-regulation mechanisms. The possible relevance of these results to some of the burdensome behavioral and psychological symptoms of Alzheimer's disease and other dementias are also discussed. The random walker with anterograde amnesia is also shown to display phase transitions. The phase diagram of the system is fully characterised along with a complete description of the phase transitions. These studies are carried out both numerically and analytically. Part of this work has recently been published in [1,2].

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Universal non-equilibrium phenomena at submicrometric surfaces and interfaces.

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The recent widespread interest in processes that take place at micro and nanometric scales has increased the physical relevance of the surfaces and interfaces that constitute system boundaries. At equilibrium, this is merely the result of an increased surface to volume ratio. In the case of far-from-equilibrium systems, such as for instance growing systems, the dynamical relevance of the surface is clear, since growth events often take place at the surface itself. Moreover, these considerations hold both for inorganic and for biological systems, submicrometric scales providing a common playground for both type of systems. Focusing in the case of non-equilibrium surfaces and interfaces, frequently universal phenomena occur, in the sense of properties and/or behaviors for which some notion of universality applies. Examples are scale invariance (surface kinetic roughening), surface pattern formation, or domain coarsening. However, theoretical descriptions of these systems feature limited predictive power when merely based on universality principles. We will review examples from Condensed Matter Physics and Materials Science at nano and submicrometric scales, that underlie the importance of describing growing surfaces and interfaces by means of (phenomenological) constitutive laws, in order to correctly describe the rich behaviors experimentally found across many different contexts. These laws need be established from detailed experimental/computational studies of specific systems. Fortunately, the ever increasing precision of current experimental and computational tools provide us with high quality data on which such studies can be based. Moreover, many times the (new) theoretical models that are thus elaborated feature in turn universal or generic properties that make them of interest in the wider contexts of Statistical Physics and Non-Linear Science.
This talk will be based to a large extent on work done in collaboration with Mario Castro, Javier Muñoz-García, Raúl Gago, Matteo Nicoli, and Luis Vázquez. For a partial overview with references, see [1].

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Renormalizing the chaotic dynamics of motile particles in fractal porous media.

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Natural porous media often display a fractal character which is manifest through a fractal Eulerian velocity or conductivity field. By assuming the fractal Eulerian velocity gives rise to a fractal Lagrangian drift velocity, we may model the motile particle paths in the spirit of a nested hierarchy of stochastic ordinary differential equations (SODEs) with stochastic drift. If we further assume that the motile particles have a preferred direction of travel (e.g., chemotaxis) and/or that the porous media is anisotropic, it is possible to represent both the drift and diffusion as operator stable processes. Further, if the hydraulic conductivity is statistically homogeneous, then it is not unreasonable to assume it imparts on a particle a Lagrangian drift velocity with stationary increments. With these assumptions at hand, we develop a rigorous renormalization procedure and derive the renormalized Fokker-Planck equations for particle trajectories over the hierarchy. As an illustrative example of the general procedure we employ Levy motions to model both the motility at the microscale and drift at the mesoscale. On the microscale (pore scale) the motile particle is modeled as an operator stable Levy process with stationary, ergodic Markov drift velocity. The micro to meso and meso to macro scale homogenization is handled with generalized central limit theorems which can be shown equivalent to a renormalization group approach. On the mesoscale, to account for the fractal medium, the Lagrangian drift is modeled as an operator stable Levy process, however, on this scale the diffusion is the asymptotic limit of the total microscale process. At the macroscale the process is the asymptotic limit of the total mesoscale process. The Fokker-Plank equations at each scale possess fractional spatial derivatives, the order of which can be obtained via particle tracking experiments and the finite-size Lyapunov exponent (FSLE). The FSLE is the exponential rate at which two particles separate from a distance r to ar $(a > 1)$ and provides a measure of the dispersive mixing in chaotic systems. We can show analytically that for alpha-stable Levy processes, the FSLE is proportional to the diffusion coefficient and its log is proportional to the negative of the stability constant.

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Studying the mechanical properties of Nickel (Ni) in nano-scale.

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We studied the elastic constants and the youngs module of the Ni in nano scale. We used the molecular dynamic simulation method (MD) and the Morse potential as the interaction potential between atoms. We use a system of identical particles of Ni that are arranged in the f.c.c lattice in the ground canonical ensemble. The initial velocities of particles are randomly distributed corresponding to the initial temperature in the simulation so that the center of mass of the system remains fixed. The equations of motion are solved with the Verlet algorithm. The order of simulation time step is femtosecond. The temperature increases 10 degree after each equilibrium stage and during the simulation the pressure is remained fixed. Also the Nose-Hoover thermostat is used to keep temperature fixed. After each equilibrium stage, 1000 final data of total energy, pressure and volume are averaged and the results are reported as average in terms of instantaneous temperature. The number of particles is 500, 864, 1372, 2048, 2916, 4000, 5324, 6912, 8788, 10976. The initial temperature is 20K and the pressure is zero. We show that the elastic constants and the youngs module of Ni decreases as temperature increases. Also we show that the mechanical properties of Ni depend on the size of the sample so that C_{11} is decreases and C_{12}, C_{44} increase as the size increases. The Young's module has its minimum values in the 2nm to 5nm of size. The MD simulation results show that whatever the sample is smaller, it has the better resistance against the tension strain but lower resistance against shear stress. Also we find that the Morse potential function calculates C_{12}, C_{44} so near each other and this point is a weak point of this binary potential. Despite this deficiency in the Morse potential, the changes of C_{12}, C_{44} in terms of temperature show a good agreement with the experimental results.
Outlook: We are going to show that the dependence of the mechanical properties of Ni on the size of the sample reach the macroscopic values. Also we are going to calculate these properties for the $Cu - Ni$ alloy in nano scale.

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Rapidly-converging methods for the location of quantum critical points from finite-size data.

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We analyze in detail, beyond the usual scaling hypothesis, the finite-size convergence of thermodynamic observables toward the infinite-size limit. After the identification and cancellation of the terms that are responsible for the leading power-law scaling, we are able to obtain sequences of pseudo-critical points governed by next-to-leading terms which display larger shift exponents as compared to currently used methods, in particular the so-called Phenomenological Renormalization Group [1] that is still the common choice for the location of quantum critical points. Similarly, we are also able to improve our recent Finite-Size Crossing Method [2].
Our new approach [3] is valid in any spatial dimension and for any value of the dynamic exponent. We demonstrate the effectiveness of our methods both analytically on the basis of the one-dimensional XY model in transverse field, and numerically considering $c = 1$ transitions occurring in non integrable spin models, which are also relevant in the context of quantum information theory due to their entanglement features. In particular, we show how the Homogeneity Condition Method is able to locate the onset of the Berezinskii-Kosterlitz-Thouless transition making only use of ground-state properties on relatively small systems.

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The Sl(2) loop algebra symmetry of the XXZ spin chains at toots of unity, higher-spin XXZ correlation functions, and their applications to the superintegrable chiral Potts model.

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We show rigorously in some sectors that integrable higher-spin XXZ chains have the sl(2) loop algebra symmetry if parameter q is given by a root of unity satisfying $q^{2N} = 1$ for an integer N. In particular, we discuss the spin-$N/2$ case of the higher-spin XXZ chain, whose twisted transfer matrix commutes with the transfer matrix of the superintegrable chiral Potts model (SCP model). We review a conjecture between the degenerate eigenspectra of the spin-$N/2$ XXZ chain and those of the SCP model that every irreducible representation of the sl(2) loop algebra of the spin-$N/2$ XXZ spin chain should correspond to an irreducible representation of the Onsager algebra which commutes with the transfer matrix of the SCP model [1]. We also review another conjecture that the twisted transfer matrix of the six-vertex model at roots of unity with some discrete twist angles should have the sl(2) loop algebra symmetry [2]. Assuming the two conjectures, we derive the Ising-like spectrum of the SCP model, or more specifically, that of the Z_N symmetric Hamiltonian which commutes with the transfer matrix of the SCP model. We then discuss eigenvectors of the Z_N symmetric Hamiltonian in terms of the evaluation parameters of the sl(2) loop algebra. Motivated by the application of the spin-$N/2$ XXZ chain, we derive form factors and correlation functions for the higher-spin XXZ chains, making an explicit use of the algebraic Bethe ansatz techniques, in particular, the so-called F-basis introduced by the Lyon group. However, we extend the derivation of the Lyon group in the following sense that we take full advantage of the quantum group invariance of the XXZ monodromy matrix, which is not manifest in the standard R-matrix of the XXZ spin chain. Thanks to the quantum-group invariance, we can evaluate explicitly scalar products and then derive expressions for the correlation functions of the higher-spin XXZ chains. Finally, combinig the results of the sl(2) loop algebra and higher-spin XXZ chains, we discuss an algorithm for deriving the norms of eigenvectors of the SCP model or the Z_N symmetric Hamiltonian. (Several parts of the present work are obtained in collaboration with Akinori Nishino, and Chihiro Matsui.

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Multivariate statistical data analysis of analog signals applied to electromagnetic object identification.

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Objects identification by electromagnetic pattern recognition is one of the most studied topics in present technology researches. Electromagnetic waves of proper frequencies could allow not only the object identification but also non destructive analysis [1]. Non destructive analysis has increasing request in modern technological processes. We study the possibility of object identification by irradiation with electromagnetic waves of four different frequencies. The irradiating antenna is also the detector of the scattered electromagnetic power. The electromagnetic object response is analysed in frequency, phase and amplitude [2]. The collected data are matched with proper multivariate data analysis. From the stored multivariate data, after the application of proper feature extraction, pre-processing and normalisation, we aim at studying the intrinsic characteristics of the data in order to disclose all of the eventual internal information.
We apply for this purpose the Principal Component Analysis (PCA) in a proper representation space [3]. Mathematically PCA is a linear transformation that we describe as $S = W \cdot X$. Here X is the experimental data set, W is the transformation matrix and S are the data in the representation space. PCA peculiarity is a data set representation onto a dimensionally reduced subspace where the statistical properties of the original data set are preserved.
PCA usually assumes the multivariate data are described by Gaussian distribution and then PCA is calculated considering only the second moment of the probability distribution of the data (covariance matrix). We present some interesting and encouraging results obtained in studying the electromagnetic object "fingerprints" in the frequency range 300 MHz −

1200 MHz. We apply to multivariate data for the first time a non-extensive statistical distribution with q within $1.01 - 1.1$. The information noise has been supposed to have a Maxwell-Boltzmann structure with T = virtual temperature free parameter: with this assumption we notice a great improvement in hampering the data background. We present a very wide set of experimental data where it is shown that, within 20 cm distance, the multivariate statistical analysis of analog signals detected by antenna allows an efficiency of around 90% right object electromagnetic "fingerprint" identification.

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Emergence of fame in ethnicially diverse populations.

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In today's modern Industrial cities we see that many people having different cultures share the same settlement and form a typical social complex system. People come from other cities or even foreign countries and form an ethno-culturally diverse population. Newcomers bring their cultural values such as clothings, meals, likes and dislikes. As a result of interacting with other people some cultural values change, some completely forgotten while others become popular and known by the majority of people. There should be a mechanism helping some cultural values and choices being more popular and causing other people being assimilated by majorities. This mechanism may not be as simple as because of their population sizes, instead, there may be other factors such as groups choice of interactions with other groups. Different cultures interactions with each other and consequences of their interactions will be investigated by the principle rules of Simple Recommendation Model (SRM) which is proposed by Bingol in 2006. We will try to make predictions about the result of interactions of different ethno-national cultures by composing the SRM and work of Wimmer that gives emrical data for our work. We will propose a model in which agents interact with each other according to their choice of interactions and impose their choices to others. We will extend the recommendation model based on Wimmers work on a Swiss society with Italian and Turkish immigrants [2]. The agents will be grouped according to their national origin and remember and forget the choices instead of agents. Also selections of interacted agents will be made according to peoples choices.

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Cellular metabolism as a constrained optimization problem.

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Understanding the organization of reaction fluxes in metabolic networks from the underlying stoichiometry is a central issue in systems biology, especially for elucidating the networks response to a gene knock-out and for metabolic engineering purposes. Methods based on mass-balance conditions coupled with local optimization rules are only able to reproduce experimental findings for relatively simple organisms in specific conditions. We define and study a constraint-based model of metabolic networks where neither mass balance nor flux stationarity are postulated [1]. The basic assumption is that the relevant flux configurations maximize the global growth of the system. The problem of computing flux distributions can then be re-cast as that of solving a graphical version of Von Neumanns expanding model [2, 3], the underlying topology being given by the real metabolic network. Solutions can be calculated numerically with a modified MinOver algorithm. It turns out that configurations corresponding to maximal metabolic growth provide the correct statistics of fluxes for the bacterium E. coli in different environments. Furthermore, comparing E. coli with the behavior of an ensemble of random metabolic networks (where a full analytic solution is achievable via the cavity method) it is possible to clarify the role of conserved pools of metabolites in determining growth rates and flux variability in natural networks. Finally, a connection is established between phenomenologically essential genes (i.e. genes necessary for the cell to live and highly conserved across different species) and fluxes with smaller allowed variability, corresponding to "frozen" variables in the optimization problem. In particular, essential genes turn out to be highly correlated with frozen fluxes.

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Prediction of viscosity of liquid mixtures.

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There is a need for reliable and internally consistent methods for prediction of viscosity of a wide range of fluid mixtures. Methods based purely on theoretical approaches are not accurate enough for industrial applications. It is therefore desirable to make use of the large body of accurate experimental work already completed on pure fluids. The VW method[1] makes use of Enskog rigid-sphere theory in a self-consistent manner to interpolate between the viscosities of the pure components. It has been used to successfully predict the viscosity of supercritical fluid mixtures and liquid mixtures of similar sized molecules. Nevertheless, the VW scheme fails for highly asymmetric mixtures.
In this work, we extend Enskog theory to include effects of molecular shape on the viscosity and incorporate this into the VW method. Molecules are described as chains of equal-sized, tangentially-joined rigid spheres. Correlation between spheres is included through the excluded volume and through the screening effects between neighbouring segments of the chains.
We show that the results from our Enskog theory for chains of rigid spheres are consistent with statistical associating fluid theory for equilibrium thermophysical properties of pure systems. We compare the viscosity results of the extended VW method to experimental viscosities for a range of highly asymmetric mixtures of long molecules, such as n-octane + n-dodecane and methane + n-decane. We show that the extended VW method predicts experimental viscosities of liquid mixtures with good accuracy (typically about 5%) and is limited by the information available on the viscosities of the pure liquids.

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Fluctuation theorems from nonequilibrium OnsagerMachlup theory for a Brownian particle in a time-dependent anharmonic potential.

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Statistical physics regards instantaneous values of macroscopic (or mesoscopic) quantities as *fluctuations* around the ensemble averages dealt with by thermodynamics. The interest in their study has steadily increased over time for reasons like e.g. being serious hindrances to accurate measurements in very sensitive experiments, being a prime source of information about the system's dynamics (a known example is the fluctuation–dissipation theorem established in linear response theory near equilibrium, linking transport coefficients to the autocorrelation functions of fluctuations, and evolved from Einstein's relation, Nyquist's theorem, Onsager's reciprocal relations, etc.) and since they can induce nonequilibrium phase transitions, lead to the appearance of spatiotemporal patterns, and assist, enhance, or sustain a host of mesoscopic phenomena impossible in their absence.
The natural framework to describe their temporal behavior is the theory of stochastic processes. A milestone was *Onsager–Machlup's fluctuation theory* around equilibrium, using a functional integral approach for stochastic linear relaxation processes, and leading to a variational principle (Onsager's principle of minimum energy dissipation). Another milestone has been set by recent *fluctuation theorems*, asymmetric relations for the distribution functions of work, heat, etc. Several laboratory experiments have verified their validity even far from equilibrium or from the thermodynamic limit.
Recently, Taniguchi and Cohen [1] have considered a dragged harmonically bound Brownian particle, and generalized to nonequilibrium steady states the Onsager–Machlup theory. They have thus derived nonequilibrium analogs of the laws of thermodynamics and steady-state detailed balance relations from which (among others) a fluctuation theorem for work valid in the long-time limit can be derived. Their approach has been recently extended to nonsteady states [2], by submitting a free Brownian particle to an external oscillating field. In this work we explore the consequences of driving a harmonically bound Brownian particle *multiplicatively*, namely regarding it as bound by $(V(x,t) = \frac{1}{2}a(t)x^2)$ [3] and controlling $(a(t))$ externally. A possible extension is to consider $(V_b(x,t) = \frac{1}{2}a(t)x^2 + b\ln x)$ (defined for $(x > 0)$) which for $(b < 0)$ and $(a(t) > 0)$ describes a monostable time-dependent anharmonic oscillator.

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Analysis of the statistical distributions of the frequency components of stable sinusoidal signals sampled with a digital oscilloscope.

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A large number of papers, a few of which appear as references [1,2], has been devoted to the analysis of any kind of noise affecting time domain signals collected with digital oscilloscopes. In this paper we memorized the signals coming from a very stable (the atomic clock used is a HP 5071A, high performance cesium standard) sinusoidal signal generator (100 kHz and 1 MHz) and applied both the FFT routine built into the oscilloscope and the one of a mathematical program. Due to the finite length T of the signals, we used the so called "Hanning window", to avoid the distortions in the spectral analysis when a "rectangular window", i.e. no temporal window, is employed [3]. Since the so called atomic clock time and frequency signals are stable within few units in 10^{14}, even in large ambient tem-

perature variations, the expected frequency spectrum would be a δ shaped function, if the time base of the oscilloscope were stable within the same order of magnitude. Systematic errors in the oscilloscope time base, time (frequency) uncertainty (jitter) of the clock in the oscilloscope, and the electronic noise of the input amplifiers, make the power spectrum peak become a Gaussian function distribution added to a more or less flat background. The experimental power spectra present a Gaussian trend only near the top of the distribution, with larger and wider "tails" near the background, the Gaussian function is clearly unable to fit.

In the last few years two new one parameter distribution functions have been discovered, able to well represent statistical functions showing power law tails, for values far from the maximum ones. These functions are named q-Gaussian [4] and a κ-Gaussian [5] respectively, from the symbol used for the characterizing parameters. The deformed Gaussian curves recover the usual Gaussian distribution for $q = 1$ and $\kappa = 0$ respectively. When applied to our power spectra, there are no differences between the deformed or true Gaussian curves near the top of the peaks, while both deformed Gaussians are in good agreement with the experimental points in the lower parts of the curves. The obtained best fit values for 1 MHz signal are: $q = 1.23$ and $\kappa = 0.116$ respectively.

The good agreement between the deformed Gaussians and the experimental points can be attribute to the fact that the casual drifts in the time base of the oscilloscope determine, with a kind of domino effect, drifts in the sampling times of the input signals, that become this way no more independent each other. This gives rise to the deformed Gaussian distributions, as shown in the last recalled papers.

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Nonextensive model for varibles with longlasting correlations in magnitude.

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Many of the so-called complex systems are characterised for having times series with a peculiar feature: although the quantity measured presents an autocorrelationfunction which is basically at noise level for all time lags, when we appraise the autocorrelation of the magnitudes a slow and asymptotic power-law decay is found. This behavour can be observed in a widespread of systems like temperature fluctuations, neuromuscular activation signals, financial markets or even fluctuations in presidential approval ratings. Moreover, these time series are also characterised by probability density functions with asymptotic power-law decay and a profile suggestive of intermittency identified by regions of quasi-laminarity alternating with spiky regions. Hence, this type of time series might be seen as a succession of measurements with a time-dependent standard deviation. Mathematically, such kind of stochastic process is named heteroskedastic in opposition to a process with constant standard deviation which defined as homoskedastic [1,2,3]. In this talk a new dynamical model is presented [4]. It uses a q_m-exponential memory kernel, $\mathcal{K}(t') \propto \left[1 + (1-q_m)\frac{t'}{T}\right]_+^{\frac{1}{1-q_m}}$ $(t' \leq 0, T > 0, q_m < 2)$, whose outcome are uncorrelated random variables which, inspite of that, are leptokurtic with a longlasting correlation between their magnitudes as well. From analytical and numerical considerations we show that the autocorrelation function of magnitudes is described by a q_c-exponential funcion and that the distribution is accurately described by a q-Gaussian probability density function maximising non-additive entropy S_q. Specifically, relations between the triplet $\{q_m, q, q_c\}$ are presented for the first time in this talk. Moreover, we introduce results regarding the multi-scaling and non-linear nature of this particular stochastic process. In the former case we apply the non-additive generalisation of the Kullback-Leibler measure. Last of all, we introduce an asymmetrical generalisation (in the standard deviation) to this model and some applications.

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Superstatistical multiplicative-noise processes.

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The physical description of driven non-equilibrium complex systems has frequently been made considering their dynamical behaviour characterised by spatio-temporal fluctuations of some parameter, $\tilde{\beta}$. Usually, this parameter has been taken as the (inverse) temperature, the dissipation of energy in turbulent flows [1], the amplitude of Gaussian white noise, the *local* mean-reverting value [2] or the *local* variance. As an example, we mention the standard case of a Brownian particle diffusing along an inhomogeneous medium in which temperature (hence diffusion "constant") fluctuates in both space and time. In this approach, as it can be understood, there are two important time scales: the scale in which the dynamics is able to reach a stationary state (assuming a fixed value for parameter $\tilde{\beta}$), and the scale at which the fluctuating parameter evolves. A particular case to consider is when these two time scales are clearly separated, specifically, when the time needed for the system to reach stationarity (considering a predetermined $\tilde{\beta}$) is much smaller than the scale at which that parameter changes. In the long-term, the non-equilibrium system is described by the superposition of different local dynamics at different time intervals that was coined as *superstatistics* or "statistics of statistics" [3]. Frequently, systems labelled as "superstatistical" exhibit non-Gaussian distributions with kurtosis excess, or distributions with non-exponential decay. In addition, superstatistical systems present a parameter, $\tilde{\beta}$, that fluctuates on a large scale, T, and follows a time-independent distribution, $p(\tilde{\beta})$.

In this talk we discuss a superstatistical approach of a dynamical system which belongs to the Feller class of stochastic processes and whose (local) stationary probability density function is reminiscent of a Weibull distribution. Such a proposal is driven on two ways [4]. The first one in which the power of multiplicative noise term is time-dependent, and another one that is equivalent to the evolution of the noise width in the stochastic term of the corresponding differential equation. The main advantage of the former is the possibility of mimicking systems that hold a rather complex dynamics going through a (random) sequence of dynamical regimes [5,6] in which the functional form of the second-order Kramers-Moyal moment evolves as well. We determine either analytically or numerically the long-term probability density function which can assume all types of kurtosis.

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Partial structure factors of the binary liquid metal alloys within the square-well model.

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Let us consider an arbitrary model fluid with particles interacting via the potential having the hard-core repulsive part. For such a fluid we assume that the direct correlation function inside the hard core can be expressed as an expansion in polynomial series. This expression leads to obtaining the Fourier transform of the direct correlation function in the framework of any closure relation of the theory of liquids. In conjunction with the numerical fulfilling of the condition that the pair distribution function is equal to zero inside the hard core the suggested approach can be used instead of the Ornstein-Zernike integral equation to obtain the structure and thermodynamics of the fluid under consideration.
Recently, we used named above method for the quantitative description of the square-well (SW) fluid in the framework of the mean-spherical approximation (MSA) [1]. The results obtained are reproduced the available numerical integral-equation MSA solution for the pure SW fluid [2]. The square-well model pair interatomic potential is rather realistic since it possesses the main feature of a real pair interaction, containing both the repulsive and attractive forces. In limiting cases, the SW potential coincides with the hard-sphere (HS) or sticky HS potential. At the same time, the SW potential allows one to describe the vapour-liquid transition, which is impossible for the HS fluid. Thus, the SW model is a good approximation for the study of a wide class of real fluids: non-polar molecular fluids, colloidal fluids, liquid metals, etc.
Here, we generalize our SW-MSA procedure to binary SW mixtures and apply it to calculate the Ashcroft-Langreth [3] and Bhatia-Thornton [4] partial structure factors of two-component alkali-metal liquid alloys. An agreement with the available experimental data is quite satisfactory.
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Persistence and survival in reactive-wetting interfaces.

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In the last decade there has been a lot of interest in determining the nontrivial persistence exponent θ , which describes a power law decay of the probability of a fluctuating variable to stay above or below a certain reference level, $P(t) \sim t^{-\theta}$. The persistence exponent has been calculated for a wide range of theoretical, numerical and experimental systems [1].
In this work we study the persistence and survival probabilities in propagating reactive-wetting interfaces of a mercury droplet ($\sim 150\mu m$) spreading on a thin ($4000\dot{A}$) flat silver substrate in room temperature [2]. We calculate the persistence exponent in our experimental system, and study its relation to well known exponents such as the growth exponent β , which describes the dynamic growth of the reactive-wetting interface width. We also study the survival probability, which differs from the persistence probability in the definition of the reference level, hence decays exponentially in time [3]. From the survival probability we determine the survival time scale τ_s in the experimental system. Finally we present simulation results of an interface which grows according to QKPZ equation. Persistence and survival of this system are compared to the results obtained in the non-linear experimental system.
Our results show that there are three kinetic regimes in our system. In the first one, while the interface width itself is not yet growing, the persistence exponent is $\theta = 0.55 \pm 0.05$, which is typical for random walk behavior. In the second time regime, there is an effective growth of the interface width, with growth exponent $\beta = 0.68 \pm 0.07$, and the value of θ is $\theta = 0.37 \pm 0.05$. In this time regime, the well known relation, $\theta + \beta = 1$ [4], seems to hold for our experimental system. The third time regime is where the interface width saturates, and the roughness exponent α is measured. In this regime, the persistence exponent value is $\theta = 0.47 \pm 0.01$, which again reflects a random walker behavior. The survival time scale turns out to strongly depend on the total experimental duration, and occupies about 35% of the total experiment time, and 63% of the growth duration.
Finally, we compare these results with QKPZ simulation results. The persistence exponents of the QKPZ simulation in the transient and the growth regimes turn out to be almost the same, $\theta = 0.8 \pm 0.01$ and $\theta = 0.76 \pm 0.006$, respectively, which means that the same mechanism is responsible for both of them, unlike the experimental system, in which different mechanisms control each of the two regimes. The difference

between the exponent values in the experimental and the simulation systems suggests that the microscopic mechanism in the experimental one is rather different than the QKPZ, even though its macroscopic behavior seems to obey the QKPZ equation, based on the results for the scaling exponents α and β.

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Local relaxation in non-equilibrium quantum many-body dynamics.

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A reasonable physical intuition in the study of interacting quantum systems says that, independent of the initial state, the system will tend to equilibrate. In this talk we will consider a setting where relaxation to a steady state is exact, namely for the Bose-Hubbard model where the system is quenched from a Mott quantum phase to the strong superfluid regime. We find that the evolving state locally relaxes to a steady state with maximum entropy constrained by second moments, maximizing the entanglement, to a state which is different from the thermal state of the new Hamiltonian. Remarkably, in the infinite system limit this relaxation is true for all large times, and no time average is necessary. For large but finite system size we give a time interval for which the system locally "looks relaxed" up to a prescribed error. Our argument includes a central limit theorem for harmonic systems and exploits the finite speed of sound. We generalize these findings to the case of having correlated inital states. We also discuss implications on entropy scaling in such quenched systems and the difficulty of simulating them using matrix-product states.
The final part of the talk will be concerned with numerical work on the strongly interacting case, using t-DMRG, as well as experimental implications. The idea of local relaxation has led to a joint project with an experimental group which aims at observing local relaxation using cold atoms in optical lattices. Here, the key idea is that optical superlattices allow for a period two read out of densities and correlations, such that relaxation phenomena can be studied without the need of locally addressing individual sites.

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A mathematical structure for the generalization of the conventional algebra.

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An abstract mathematical framework is presented in this paper as a unification of several deformed or generalized algebra [1,2] proposed recently in the context of generalized statistical theories [3] intended to treat certain complex thermodynamic or statistical systems. It is shown that, from mathematical point of view, any bijective function can be used in principle to formulate an algebra in which the conventional algebraic rules are generalized. We proceed as follows:
Let X and Y be two nonempty sets, and let $*$ and $\perp$ be two binary operations on X and Y respectively, and let $\bullet$ be an external law on Y. We denoted by 1_X and 1_Y the neutral element (when this exists) of $(X, *)$ and $(Y, \perp)$ respectively, and by x^{-1} the inverse of x if x is invertible in $(x, *)$ or in $(Y, \perp)$. We mean by ϕ a bijection of X in Y and by ψ the inverse function of ϕ. We have the following properties
a) The functions $+_{(\phi,\perp)}$ and $-_{(\phi,\perp)}$ defined on $X \times X$ by

$$\forall(x,\, x') \in X \times X\ , \quad x +_{(\phi,\perp)} x' = \psi(\phi(x) \perp \phi(x'))\ ,$$
$$\forall(x,\, x') \in X \times X\ , \quad x -_{(\phi,\perp)} x' = \psi(\phi(x) \perp (\phi(x'))^{-1})\ ,$$

(when this exists)

are binary operations (laws) on X.
b) The functions $\times_{(\phi,*)}$ and $\div_{(\phi,*)}$ defined on $Y \times Y$ by

$$\forall(y,\, y') \in Y \times Y\ , \quad y \times_{(\phi,*)} y' = \phi(\psi(y) * \psi(y'))\ ,$$
$$\forall(y,\, y') \in Y \times Y\ , \quad y \div_{(\phi,*)} y' = \phi(\psi(x) * (\psi(x'))^{-1})\ ,$$

(when this exists)

are binary operations (laws) on Y.
c) The function $\bullet_{(\phi,\bullet)}$ defined on $K \times X$ by

$$\forall(\lambda,\, x) \in R \times X\ , \quad \bullet_{(\phi,\bullet)}(\lambda,\, x) = \psi(\lambda \bullet \phi(x))\ ,$$

is an external law on X.
d) $(Y, \perp)$ is an abelian group if and only if $(X, +_{(\phi,\perp)})$ is an abelian group.
e) $(X, *)$ is an abelian group if and only if $(Y, \times_{(\phi,*)})$ is an abelian group.
f) If $(Y, \perp, \bullet)$ is a vector space on K, then $(X, +_{(\phi,\perp)}, \bullet_{(\phi,\bullet)})$ is a vector space on K.

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Evidence of common peculiarities of critical phenomena in quantum optics and condensed matter in case of multiquantum interaction processes.

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Quantum phase transition and quantum criticality are well-known as phenomena which occur in many-body quantum systems, usually associated to field of condensed matter [1]. In the last time a great interest appears to these phenomena considered for quantum optical systems, for example in problems of light-atoms interaction, which explain us the mechanism of transition of system from normal radiation to collective radiation (super-radiance, coherent emission) [2, 3, 4].
Some methods successfully used in laser physics, for example the control of quantum coherence superposition or processes of strong interaction of atoms with cavity photons, can be applied for studying of effects in artificial solid structures as quantum wires or dots [2]. On the other hand, some concepts of solid state physics are well adapted for realization and explanation of quantum phase transition of atoms in optical lattices. The recent investigations in the field of strong correlated electronic systems are oriented basically to the profound studying of phase transitions or critical phenomena [1]. The main idea is that many systems of different physical nature can emphasize similar behavior in the critical regime, hence amplifying the concept of universality of effects. In order to enlarge the class of universality, considering here the systems of diverse complexity characters, it is important to do a step forward to perspective of unifying our knowledge in physics, where the complex phenomena (classical or quantum) are studied.
In this paper we propose to study the pictures of phase transitions for different systems where two-quantum exchange interactions between the small and large subsystems are possible. We will emphasize the particularities of phase transitions in cases of two-photon super-radiant emission and two-phonon superconductivity. As example the phase transition of an extended ensemble with N identical two-level atoms interacting with a bimodal cavity field by scattering processes is studied. It is shown that for this system in the thermodynamic limit the two-photon exchange integral between the radiators strongly depends on the temperature via the average number of quanta in the thermostat, so that unusual picture of phase transition of atomic system is obtained. Consequently the process of nonlinear exchange between the quasi-spins leads to the increasing of critical temperature as compared to traditional second order phase transition of quasi-spin system.

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Statistical properties of information flow in financial time series.

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Studies on the information flow between financial assets are very interesting because they help us to understand the complex interactions between assets and the pricing process of financial markets. In the financial literature, there are many studies to quantitatively measure the information flow between stocks or markets. However studies on the possible factors that can affect significantly the information flow was insufficient. In this study, we have investigated empirical evidence of the possible factors that can affect information flow between stocks. In order to sufficiently observe the information flow between stocks, we considered the number of whole links between N stocks; that is, $N(N-1)/2$. In addition, we suggest the stock network by the minimal spaning tree (MST) method to investigate the information flow effectively, This method is choosing $N-1$ most important links among the whole ones consisting of individual stock price in the financial market. Through these efforts, we discovered characteristics of information flow in viewpoint of the whole market. We used the individual stocks traded in various countries, such as Korea, Japan, Taiwan, Canada, and the USA.
According to the observing results, we find that the information flow between stocks observed by the causality model get the influence significantly from the changes of time scales of return. That is, the relationship between the time scale of return and the frequency of significant information flow is negative. Furthermore, using the time series removed the temporal time correlation, we cannot find the significant information flow of the previous results. In addition to these, the empirical evidences on the properties of time-dependency of information flow using the MST is not different. Next, we investigate the possible factors that can affect the information flow based on the observed results of the time-dependency in information flow. We find that the frequency of significant information flow decrease as we eliminates the properties of market from the individual stocks by the market index. We also find that the information flow between stocks have the properties of time-varying according to the market status, especially around the market crisis. And, we also discover that the difference in degree of relative efficiency between stocks play a crucial role to determine the direction of information flow between stocks.

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Metal-insulator transition in random superlattices with long-range correlated disorder.

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It is known that all electron states in uncorrelated disordered one dimensional systems are exponentially localized [1]. In recent years, a number of models [2,3,4] have predicted the existence of extended states for disordered one-dimensional systems with *short* and *long range* correlations. In this paper, we study the electronic properties of disordered GaAs-$Al_xGa_{1-x}As$ semiconductor superlattices with structural long-range correlations. The system consists of quantum barriers and wells with different thicknesses and heights which fluctuate around their mean values randomly, following a long-range correlated pattern with a power spectrum of the type $S(k) \propto 1/k^{(2\alpha-1)}$, where the exponent α quantifies the strength of the long-range correlations [5]. A single quantum well in this structure consists of a layer with thickness d_W of a semiconductor (GaAs) embedded in a semiconductor ($Al_xGa_{1-x}As$) with thickness d_b. We consider the situations in which the values of d_W and d_b (also the height of the barriers) fluctuate around their mean values. The energy of incoming electrons is assumed to be less than the barrier heights. A sequence of long range correlated values with Gaussian distribution is produced by the Fourier filtering method. The exponent α is called correlation exponent, and quantifies the degree of correlations imposed in the system. For a given system size L, we find a critical value of the exponent α (α_c) for which a metal-insulator transition appears: for $\alpha < \alpha_c$ all the states are localized, and for $\alpha > \alpha_c$, we find a continuous band of extended states. In order to distinguishing extended state from Localized one and determining metal-insulator transition, we calculate Localization length of the wave function in SSl using transfer matrix method. The wave function of the SSL ends can be related together by calculating a product of transfer matrices. The transfer matrix connects the wave functions of sites n and $n-1$. Using the components of transfer matrix, we calculate localization length λ of SSL. When the localization length starts to be greater than the system size ($\lambda \geq L$), we say that a transition from localized states (insulator) to extended states (metal) is observed *for finite system size*. Also, the knowledge of localization length λ enables us to obtain the transmission coefficient at a given energy. Using Landuer formula, we calculate Dc conductance of the system and show that the existence of extended states causes a strong enhancement of the DC conductance of the SSl at finite temperature, which increases in many orders of magnitude when crossing from the localized to the extended regime. Finally, we perform finite size scaling and we obtain the value of the critical exponent α_c in the thermodynamic limit, showing that the transition is not a finite-size effect.

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Glass as a time independent non-dissipative nonequilibrium nonergodic state.

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We examine the question of whether the formal expressions of equilibrium statistical mechanics can be applied to time independent non-dissipative systems that are not in true thermodynamic equilibrium and are nonergodic. By assuming the phase space may be divided into time independent, locally ergodic domains, we argue that within such domains the relative probabilities of microstates are given by the standard Boltzmann weights. In contrast to previous energy landscape treatments, that have been developed specifically for the glass transition, we do not impose an a priori knowledge of the inter-domain population distribution. Assuming that these domains are robust with respect to small changes in thermodynamic state variables we derive a variety of fluctuation formulae for these systems. We verify our theoretical results using molecular dynamics simulations on a model glass forming system. Non-equilibrium Transient Fluctuation Relations are derived for the fluctuations resulting from a sudden finite change to the system's temperature or pressure and these are shown to be consistent with the simulation results. The necessary and sufficient conditions for these relations to be valid are that the domains are internally populated by Boltzmann statistics and that the domains are robust. The Transient Fluctuation Relations thus provide an independent quantitative justification for the assumptions used in our statistical mechanical treatment of these systems.

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Dominant reaction pathways in high dimensional systems.

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Rare thermally activated transitions in high dimensional systems cannot be efficiently studied by means of Molecular Dy-

namics (MD) simulations. This is because all the computational time is invested for describing the motion of the system, when it is exploring the portion of configuration space associated to the stable and meta-stable states. On the other hand, one is often mostly interested in the information encoded in the reaction pathways joining different states and in the transition state ensemble.
In this talk, we present a recently developed theoretical/computational framework denominated Dominant Reaction Pathways Ensemble (DoRPE), which allows to rigorously identify the ensemble of statistically significant transition pathways, avoiding investing CPU time in simulating the local thermal motion in the meta-stable configurations and without relying on any choice of reaction coordinates.
The method is based on the analogy between the Fokker-Planck conditional probability for a transition from a given initial to a given final configuration and the "quantum" propagation in imaginary time. In this language, the most probable thermally activated transitions (or Dominant Reaction Pathways, DRPs) correspond to tunneling trajectories, i.e. instantons. The idea is therefore to apply the saddle-point approximation to the stochastic path integral representation of the conditional probability, to derive the (time independent) equation for the DRPs and to include the leading thermal fluctuations around them by Monte Carlo sampling.
In this talk we present the formalism, and the first applications to the study of conformational transitions of alaninde dipeptide in a all-atom molecular model and to the folding of a 16-residue beta hairpin. We validate the DoRPE results against MD simulations and show that the computational advantage of the former approach is impressive and makes it possible for the first time to study entire protein folding reaction on available computers. We In addition, we discuss how DoRPE can be used to efficiently compute rates in high-dimensional systems.

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Quasi stationary states and out of equilibrium phase transitions in mean field dynamics.

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Statistical mechanics allows us to investigate the behaviour of systems composed by a large number of interacting elements. Powerful mathematical tools make it possible to accurately describe the so called equilibrium state, namely the asymptotic stage of the evolution which is eventually reached for very long times. However, many interesting properties take place out-of equilibrium and deserve to be carefully addressed. This is particularly true for system subject to long-range forces, where a global network of connections is driving the dynamics of every constituting element. Surprisingly, long-range system may be trapped in intermediate states which last virtually forever and which substantially differ from the corresponding equilibrium configuration [1]. The galaxies that we observe nowadays represent the most spectacular example of such far-from-equilibrium processes, but analogous phenomena are also being reported in fundamental problems of magnetic fusion and planetary environment plasma. These mestastable states are often termed in the literature Quasi-Stationary States, hereafter QSS, and bear an extraordinary conceptual important as they potentially corresponds to the solely experimentally accessible regimes.
With reference to the Hamiltonian Mean Field (HMF) model, I shall review the QSS phenomenology and discuss in particular the presence of out of equilibrium phase transitions separating homogeneous (zero magnetisation) and in-homogeneous (magnetised) phases [2]. The latter are here identified by means of a statistical mechanics treatment of the underlying continuous Vlasov picture [3]. Phase space structures are inspected and shown to correspond to invariant tori of reduced, integrable, Hamiltonian systems [4]. Within this picture, the aforementioned transition is understood as a bifurcation corresponding to a switch in the associated low dimensional model. Interestingly, a trend to local integrability is observed as the system size is increased. This fact reflects the counterintuitive tendency for the HMF system to become more and more regular when the number of elementary constituents get larger.

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Hydrodynamic interactions between two swimming nano-machines.

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We propose a two dimensional microscopic swimmer consisting of spheres linked by thin elastic rods with capability of stretching and bending. The three spheres in the head of swimmer linked by thin rigid rods whose lengths can change between two values due to a small motor is inserted in the second sphere. This model device can swims at low Reynolds number because of performing a periodic motion in a nonreciprocal fashion which breaks the time-reversal symmetry as well as translational symmetry. The out of phase oscillations of the first and second arms and also propagation of a longitudinal wave in the tail propel the swimmer. Because of low Reynolds number condition (small size of spheres, small values of velocities, and high viscosity of fluid) the Oseens tensor is used to construct the equations of motion of each bead. It means that in this situation the force does not create the acceleration but it creates the velocity. However there is a linear relation between force and velocity.
In the simulation the average velocity is calculated and the dependence of it to the stretching constant is studied. Then we place two of these swimmers in a highly viscous fluid like water and let them swim and interact with each other via the

ambient medium. Three different situations are studied:
(a) Two swimmers are parallel and move toward each other.
(b) Two swimmers are parallel and swimmer (2) moves behind swimmer (1) in the same direction.
(c) Swimmer (2) moves perpendicular to the swimmer (1) and toward it.
The average velocity of swimmer (1) is calculated in each situation and is compared with the velocity of single swimmer. In situation (a) the velocity is decreased and swimmers absorb each other, in situation (b) the velocity is increased and two swimmers repel each other, and in situation (c) the velocity is increased. Also the effect of height difference on the velocities is studied. In each situation the average velocity tends to the velocity of single swimmer as the height difference increases.
Outlook: We are going to calculate the hydrodynamic interactions between large numbers of such swimmers and obtain the collective behaviors such as pattern recognition and self organization and etc. also we want to obtain the hydrodynamic equation for a complex fluid consists of such swimmers.

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First-order transition behaviour in presence of dilution in $3D$.

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Most of phase transitions in Nature are of first order: energy, pressure, magnetic field, etc. change abruptly at the transition point. On the other hand, most of natural systems are diluted to some degree. An obvious question is: what happens to a system undergoing a first-order phase transition on a perfectly pure sample if one increasingly deteriorates the quality of the sample introducing impurities? This is a problem with important implications in fields such as highly correlated electron systems (as high temperature superconductors or colossal magnetoresistance oxides). It is known that in two dimensions the smallest amount of impurities is enough to change a first order phase transition to be a second order one but this was not clear at all in three dimensional systems. Theoretical studies pointed out the existence of a tricritical point separating the two behaviours with a non null value of the impurities density [1]. Nevertheless, up to now, numerical studies have been hardly achievable due to the existence of interphases which make the autocorrelation times growth exponentially with the size of the system.
In this work, whose preliminary results have already been published [2], we have been able to confirm the theoretical result by using a recently proposed powerful microcanonical method [3]. Using this method we have been able to widely outperform all the previous investigations [4,5]: we simulate lattices larger by a factor of 10. With this method, the system entropy as a function of the energy is directly computed , from which one can directly measure the latent heat or the surface tension. We have obtained very precise measures of these quantities as a function of the dilution degree obtaining that both latent heat and surface tension reduce quickly when increasing dilution up to a point where they become zero, being the apparent critical dilution strongly dependent of the lattice size. We have used Finite Size Scaling techniques in order to obtain size independent quantities. We also found that the latent heat is a self-averaging quantity for random first-order transitions while the surface tension is not. The tricritical point dilution obtained at the thermodynamic limit from the crossing points of ξ/L is definitively smaller than one and as a result we can conclude that random first-order transitions do exist in $D=3$ although their phase space is really small.

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The entropic analysis of electoral results: the case of European countries.

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Entropy is a measure of information and uncertainty which has been used recently in different areas, besides of its original utilization in physics. Finance, microeconomics, macroeconomics, utility functions or even psychology are approached areas, using analogies between the areas physics and nature, creating a new research area: Econophysics (see, for example, [1,2]).
This paper intends to explore the utilization of entropy through politics and election results, an area just slightly explored [3]. It generalizes interpretation of entropy, considering it a measure of dissatisfaction and disillusion of populations in relation to politics.
Some phenomena like the increase of abstention in a country, consequence of the dissatisfaction of population and of their alienation in relation to politics could be detected and analysed. This discontentment could result, for example, in the appearance of new political parties, with more division of votes and increasing entropy (result of the discontentment and uncertainty by electors). Absolute majorities, while imply less dispersion of votes, are synonym of more confidence in a given party, making a reduction of entropy.
Electoral results could also be influenced by particular phenomena, like those terrorist attacks made in vespers of the two last elections in Spain, with consequences on the affluence to the polls by electors, and influencing levels of entropy. Elections' dates could also influence results: for example, elections on summer season suffer from more abstention. Elections' results could also be connected with aspects like safety feeling of citizens, with unpopular socio-economic policies taken by

government or even with the economic performance of a country. One of the purposes of this paper is to find these types of phenomena and try to relate them with the concept of entropy. Another objective is to analyse the reality in different European countries.

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Growth and pattern formation in the Kardar-Parisi-Zhang equation.

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The large majority of natural phenomena are characterized by being out of equilibrium. This class includes turbulence in fluids, interface and growth problems, chemical reactions, processes in glasses and amorphous systems, biological processes, and even aspects of economical and sociological structures. As a consequence much of the focus of modern statistical physics, soft condensed matter, and biophysics has shifted towards such systems. Drawing on the case of static and dynamic critical phenomena in and close to equilibrium, where scaling and the concept of universality have successfully served to organize our understanding and to provide a variety of calculational tools, a similar strategy has been advanced towards the much larger class of nonequilibrium phenomena with the purpose of elucidating scaling properties and more generally the morphology or pattern formation in driven nonequilibrium system. There is a particular interest in the scaling properties and general morphology of nonequilibrium models. Here the Kardar-Parisi-Zhang (KPZ) equation has played a prominent and paradigmatic role. The KPZ equation describes aspects of the nonequilibrium kinetic growth of a noise-driven interface and provides a simple continuum model of an open driven nonlinear system exhibiting scaling and pattern formation. Here we address the KPZ equation for a growing interface in arbitrary dimensions. Applying an extended form of the canonical weak noise approach in order to incorporate multiplicative noise and drawing from the insight gained by the analysis of the 1D case, we identify the localized growth modes for the KPZ equation. The growth modes are spherically symmetric and are equivalent to the domain walls or solitons identified in the 1D case. The growth modes propagate and a dilute gas of modes constitute a dynamical network accounting for the kinetic growth of the interface.
We also consider the issue of an upper critical dimension for the KPZ equation. The KPZ equation lives at a critical point, conforms to the dynamical scaling hypothesis and is characterized by the scaling exponents. Dynamic renormalization group calculations yield d=2 as lower critical dimension. In addition to the scaling properties in the rough phase, characterized by a strong coupling fixed point, a major open problem concerns the existence of an upper critical dimension. In the present context we interpret the upper critical dimension as the dimension beyond which the growth modes cease to exist. On the basis of a numerical analysis and an exact argument based on Derrick's theorem we propose d=4 as the upper critical dimension for the KPZ equation.

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DNA bubble dynamics as a quantum Coulomb problem.

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Under physiological conditions the Watson-Crick double-helix of DNA constitutes the equilibrium structure, its stability ensured by hydrogen-bonding of paired bases and base stacking between nearest neighbor pairs of base pairs. By variation of temperature or pH-value double-stranded DNA progressively denatures, yielding regions of single-stranded DNA, until the double-strand is fully molten - the helix-coil transition at temperature Tm. However, already at room temperature thermal fluctuations cause rare opening events of small denaturation zones in the double-helix. These DNA bubbles consist of flexible single-stranded DNA, and their size fluctuates in size by step-wise zipping and unzipping of the base pairs at the two zipper forks where the bubble connects to the intact double-strand. The multistate DNA breathing can be monitored in real time on the single DNA level. Biologically, the existence of intermittent (though infrequent) bubble domains is important, as the opening of the Watson-Crick base pairs by breaking of the hydrogen bonds between complementary bases disrupts the helical stack. The size of the bubble domains varies from a few broken base pairs well below Tm, up to some two hundred closer to Tm. Above Tm, individual bubbles continuously increase in size, and merge with vicinal bubbles, until complete denaturation. DNA breathing has been investigated in the Dauxois-Peyrard-Bishop model that describes the motion of coupled oscillators representing the base pairs. On the basis of the Poland-Scheraga model, DNA breathing has been studied in terms of continuous Fokker-Planck approaches, and in terms of the discrete master equation and the stochastic Gillespie scheme.
Here we study the Langevin and Fokker-Planck nonequilibrium extension of the Poland-Scheraga model in terms of a mapping to a quantum Coulomb problem. This allows us to investigate in more detail the finite time singularity underlying the breathing dynamics, as well as the survival of individual bubbles. In particular, we demonstrate that the associated Fokker-Planck equation is equivalent to a Coulomb problem. Below the melting temperature the bubble lifetime is associated with the continuum of scattering states of the repulsive Coulomb potential, at the melting temperature the Coulomb potential vanishes and the underlying first exit dynamics exhibits a long time power law tail, above the melting temperature, corresponding to an attractive Coulomb potential, the long time dynamics is controlled by the lowest bound state. Correlations and finite size effects are discussed.

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An analysis of diffusion and juxtacrine signalling for embryonic pattern formation.

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Cells can interact through the binding of proteins at their membranes and signal, accordingly, to neighbouring cells [1]. This type of cell-to-cell communication, the so-called juxtacrine signalling, has been shown to enable the formation of fine grained patterns of differentiated cells. An interesting case to study is the Notch signalling pathway related to the neurogenetic network in *Drosophila* [4]. In this case, a minimal model of two coupled ordinary differential equations per cell has been proposed in which the activities of the receptor Notch (n) and its ligand Delta (d) characterize the cell fate cells differentiate into [2]. Notch inhibits Delta, which in turn activates Notch in neighbouring cells. For this model, it has been shown that the homogeneous state can become linearly unstable and a chess board-like pattern with two types of cells can arise [2]. One cell type has high and low levels of Notch and Delta activities, respectively, and the other cell type has the opposite: low Notch and high Delta activities. However, recent experiments have shown that full-length Delta can diffuse into the extracellular matrix [3], raising the question of how the pattern is modified by such a transport. Accordingly, herein we analyse the effect of diffusive transport on juxtacrine signalling. To this end, we modify the above mentioned minimal model into :

$$\dot{n}_P = f(\bar{d}_P) - n_P$$
$$\dot{d}_P = v\{g(n_P) + s\nabla_P^2 d_P - d_P\}$$

where dynamics for Notch (n) and Delta (d) activities of cell P are detailed. f and g are continuous increasing and decreasing Hill functions, respectively, and $\bar{d}_P$ denotes the mean of the levels of ligand activity in cells adjacent to cell P; thus this term is responsible for the intercellular nearest-neighbor coupling [2]. By means of linear stability analysis and computer simulations of the overall dynamics we show that diffusion does not change the wavelength of the pattern and reduces the parameter space region where the pattern arises. In addition, we provide a generic anlysis through a linear stability analysis of how the wavelength of patterns can be modified. Notice that juxtacrine signaling involves short-range inhibition (mediated by Notch) and long-range activation (mediated by Delta), reminding of Turing-like mechanisms [5,6]. Thus, our results show that despite the activator Delta increases its spatial range, the pattern is not altered. By analysing this and more detailed and complex models, herein we discuss the analogies and differences of such juxtacrine interaction with Turing-like dynamics, as well as the effect of coupling diffusive transport with juxtacrine signalling.

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The photon-atom entanglement dynamics of the Λ-type atoms in photonic crystal nano-cavities.

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It is well known that quantum entangled states plays an important role in the field of quantum information theory, particularly, quantum teleportation, quantum computation, etc. [1]. The research on the entanglement normally focuses on two subjects: How the entanglement is implemented and how it may be quantified. One approach to realize entanglement for quantum information processing, is cavity quantum electrodynamics [2]. In this approach, the interaction of material qubits (atomic or electronic quantum states) with a high finesse optical resonator is used for atom-atom, atom-photon [2] or photon-photon entanglements [3]. The main challenge in this approach is to avoid de-coherence induced by the cavity modes that leak to the environment. An attractive architecture to overcome this obstacle is formed by high-Q, coupled nano-cavities in a photonic crystal [4]. Photonic crystals are periodic dielectric structures having photonic band gaps. It is well known that, because of the complicated dispersions inside the photonic crystals and the consequent interferences, the structure, under specific conditions, does not allow the electromagnetic field to propagate [5]. The field energy is, therefore, mostly trapped inside the crystal.
In the present work, we investigate the dynamics of entanglement for Λ-atoms in a nano-cavity, surrounded by a photonic crystal. By calculating the time dependent probability amplitudes [5] and using Von Neumann entropy as a measure of entanglement, we show that, when the upper level lies below the photonic gap, the atom-photon entanglement reaches a steady value which is expected to be much higher than that in the V-type models. The reason for such behavior is the fact that under the aforementioned condition the population of the upper atomic level, after a short period of oscillations, becomes steady [5]. We further present the effect of the photonic band gap frequency and the detuning on this steady value, showing how they may be used to control the degree of entanglement.

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Vehicular traffic flow at a non-signalised intersection.

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Modelling the dynamics of vehicular traffic flow has constituted the subject of intensive research by statistical physics and applied mathematics communities during the past years [1,2]. While the existing results in the context of highway traffic seem to need further manipulations in order to find direct applications, researches on *city traffic* have more feasibility in practical applications [3,4,5]. Recently, physicists have paid notable attention to controlling traffic flow at intersections and other traffic designations such as roundabouts [6,7]. In this respect, our objective is to study some generic features of vehicular traffic flow at a single intersection. Our study includes first some aspects of conflicting traffic flows at an intersection without a traffic light. In this case, approaching cars to the intersection yield to traffic at the perpendicular direction by adjusting its velocity to a safe value to avoid collision. The yielding dynamics in the vicinity of the intersection is implemented by introducing a safety distance D_s. The approaching cars (nearest cars to the crossing point) should yield to each other if their distances to the crossing point, denoted by d_1 and d_2 for the first and second street respectively, are both less than the safety distance D_s. In this case, the movement priority is given to the car which is closer to the crossing point. This car adjust its velocity as usual with its leading car. On the contrary, the further car, which is the one that should yield, brakes irrespective of its direct gap. Figure one illustrates the situation. Closed boundary condition is applied to the streets. Extensive Monte Carlo simulations is taken into account to find the model characteristics. Our results suggest that yielding mechanism gives rise to a high total flow throughout the intersection especially in the low density regime. In some ranges of densities, yielding mechanism even improves and regulates the flow in comparison to the absence of perpendicular flow. It is observed that for small densities in the west-bound street up to 0.05, the current of north-bound street rises to its maximum value, then it undergoes a short rapid decrease after which a lengthy plateau region, where the current is independent of global density, is formed. Intersection of two chains makes the intersection point appear as a site-wise dynamical defective site. It is a well-known fact that a local defect can affect the low dimensional non-equilibrium systems on a global scale [8,9,10]. This has been confirmed not only for simple exclusion process but also for cellular automata models describing vehicular traffic flow. Next, we consider a signalised intersection which is controlled under a fixed time scheme. There is cycle time T which is divided into two parts: T_g and $T - T_g$. The light remains green for road A for T_g seconds (red for the perpendicular road B). Then the light turns into red for road A (green for road B) for the remaining time of the cycle i.e.; $T - T_g$ seconds. We show the simulation results for this signalised intersection and will compare them to the results of the unsignalised scheme. By this comparison, we will able to quantify the conditions at which the signalised scheme operates in a more efficient manner.

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Markov processes of nonlinear kinetics.

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Many studies in nonlinear physics make extensive use of nonlinear evolution equations for concentration fields and particular densities. The underlying stochastic processes in these cases can often be represented by means of nonlinear kinetic equations such as Vlasov equations, nonlinear drift diffusion equations, and nonlinear Fokker-Planck equations. Fundamental examples in this regard are the Desai-Zwanzig model [1], the Kuramoto model [2] and the nonlinear Fokker-Planck equation introduced by Plastino and Plastino [3] in the context of Tsallis statistics [4]. However only very little studies attempt to go beyond first-order statistics. The reason for this seems to be that in physics a key concept is not well-known: the theory of nonlinear Markov processes. In contrast, in the mathematical literature this concept has been studied for several decades. In the talk we will clarify the difference between linear and nonlinear Markov processes. To this end we review some previous work on nonlinear Fokker-Planck equations [5] and discuss it in the context of nonlinear Markov processes. We will construct Green functions that represent conditional probability densities and admit to built up the complete hierarchy of joint probability densities. This hierarchy in turn is needed to characterize a stochastic process. In the case of nonlinear Markov processes these Green functions can be used to write nonlinear kinetic equations in terms of nonlinear integral equations. That is, these Green functions give rise to integral equations that are equivalent to nonlinear partial differential equations given in terms of Vlasov equations, nonlinear drift diffusion equations, and nonlinear Fokker-Planck equations. Finally, we will argue that nonlinear Markov processes are at the heart of nonlinear physics and self-organization.

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Self organization of social hierarchy and village in a democratic challenging society.

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Social structure such as emergence of winners and losers in human beings and animals originates from non-linear interaction among individuals who have their own assets. We modify the model introduced by Bonabeau *et al.* [1] to incorporate the trend of societies, and investigate emergence of hierarchies and villages.
In their model, each individual is assumed to have its own power as an internal state. The basic processes are random walk, fighting when two individuals meet in which the winner (loser) gets (loses) its power and the winning probability depends on the difference in their power, and relaxation of power. We study a democratic challenging society, where warlike individuals challenge the strongest among their neighbors and perform random walk in random order. We show that the transition occurs in two steps as the population is increased and that two different hierarchical societies exist. The transition from egalitarian state to first hierarchical state is continuous, and the society can be characterized with widespread winning probability. The second hierarchical state emerges discontinuously and consists of a small number of extreme winners and many intermidiates and losers. In the second hierarchical society, a giant village which has a layered structure is formed and some losers stray around the village. Moreover, when the relaxation rate of power is large, we observe only one transition from egalitarian to the second hierarchical state.
We also show that there are clear differences between our results and the features of the feudal challenging society [2] where warlike individuals perform random walk in a preassigned sequence. In the feudal system, the hierarchical society and some villages emerge as a single discontinuous transition, and the villages have the intricate structure consisting of winners and losers. These discrepancies are caused by only the difference in the diffusion rule.

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Large-scale structure of production network and Chain of bankruptcy in Japan.

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Production network in economics refers to a line of economic activities in which firms buy intermediate goods from "upstream" firms, put added-values on them, and sell the goods to "downstream" firms. Net sum of added values in the whole network is basically the net total production in a nation, that is, gross domestic product (GDP). The entire line of these processes of putting added-values in turn, therefore, forms a giant web of production ranging from upstream to downstream, finally down to consumers.
Although there are insightful models of production network including inventory dynamics [1], suppliers/customers dynamics [2], and credit-chain model [3]. These works are, unfortunately, not based on any empirical study on the structure of production network. It is highly desirable to investigate the structure on a nation-wide scale to develop these insightful models, but such a study has been considered only a formidable task so far. We study a nation-wide production network comprising a million of firms and millions of supplier-customer links by using recent statistical methods developed in physics. We show in the empirical analysis scale-free degree distribution, disassortativity, correlation to firm-size, and community structure having sectoral and regional modules. We also examine firms' growth and temporal change of the network. Since suppliers usually provide credit to their customers, who supply to theirs in turn, each link is actually a creditor-debtor relation. We also study chains of failures or bankruptcies that take place along those relations in the network as a dynamics of avalanches.
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A comparative study of the effects of quenched bond randomness in 2D spin models.

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We investigate, by means of extensive Monte Carlo simulations, the effects of quenched bond randomness in the self-averaging properties and the scaling behavior of the specific heat of 2D square Ising models. In particular, we perform a comparative study between the well-known, but still controversial, case of the random bond Ising model and the random bond Ising model with nearest- (J_{nn}) and next-nearest-neighbor (J_{nnn}) antiferromagnetic interactions. For the latter model we consider the case $R = J_{nn}/J_{nnn} = 1$, for which the competitive nature of interactions produces a sublattice ordering known as superantiferromagnetism (SAF) [1]. For this value of R the pure system undergoes a clear second-order phase transition (from the SAF state to the paramagnetic state) with a positive specific heat exponent [1]. Therefore, the disorder version of this model, called hereafter as random bond SAF model, is a desirable case to study bond randomness effects, since according to the Harris criterion, it is expected, at least for $R = 1$, to reach a new critical behavior. The numerical scheme we implement closely follows our recent Wang-Landau [2] implementations of an energy restricted sampling, appropriately adapted to the study of systems with complicated free-energy landscapes [3]. We impose periodic boundary conditions on square lattices with linear sizes L in the range $L = 20 - 120$ and repeatedly simulate large ensembles or disorder realizations. Using various finite-size measures, such as the scaling behavior of the width of the distribution of the sample dependent pseudocritical temperatures and properly defined noise to signal ratios [4], we address the issue of self-averaging of the models in terms of characteristic thermodynamic quantities, such as the specific heat and the magnetic

susceptibility. Subsequently, we inspect the scaling behavior of the specific heat maxima. For the marginal case of the random bond Ising model we discuss possible crossover effects, whereas for the random bond SAF model, strong disorder effects are manifested in a clear saturation of the specific heat, reflecting the sensitivity of the microscopic interactions, responsible for the SAF ordering, to bond randomness. These latter effects are much more dramatic than those already observed in other 2D random bond spin models, such as the 2D random bond three-state Potts ferromagnet [5].

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Invasion percolation and the time scaling behavior of a queueing model of human dynamics.

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In this talk we present our results about a recently proposed model of queueing theory for human dynamics by A. L. Barabasi and collaborators [1,2]. The model deals with the dynamics of a list of tasks with random priority indeces in which the execution protocol of the tasks is priority driven, the execution is instantaneous, and such that once a task is executed, it is removed and replaced in the list by one or more other tasks again with random priorities. The most important quantity to study is the waiting time probability distribution (WTPD) for a generic task in the list before being executed. The main feature of the WTPD for this model consists in a decaying power law behavior when at any time-step only the task with the highest priority at that time is executed. However the large time scaling behavior of this quantity at the stationary state differs in the two cases of task lists with fixed or variable length. In the first case, in fact, the stationary WTPD looks to be characterized by a fat tail with exponent -1 when at each time-step the highest priority task is executed with probability p approaching to 1. In the second case instead the exponent is $-3/2$. For both cases we show that arguments from both diffusion and percolation theory allow to describe accurately the list dynamics in and out of stationarity and to determine the scaling behavior of the WTPD. In particular an exact mapping of the task list dynamics to Invasion Percolation (IP), respectively in one dimension and on a Caley tree, permits to associate the list dynamics to the evolution through critical avalanches of IP whose size distribution and hierarchical structure permits to derive the aforementioned exponents [3,4].

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Disorder and critical phenomena.

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In the present paper we are discussing the influence of the fractal distribution of defects on the critical behavior of the system. Investigation of defect influence on the physical properties of crystals near phase transitions is a present-day problem of statistical physics. Theoretical approaches mainly consider single-domain crystals with a homogeneous distribution of defects in the structure. However the conditions of crystal growth generate an inhomogeneous distribution of defects [1]. For the latter case, we are able to extend the Landau-Khalatnikov equation for the order parameter and represent it in the form of a differential equation of the fractional order. With this equation solved, it is possible to define the temperature dependence of the imaginary part dielectric susceptibility and the temperature dependence of this curve's maxima, i.e. modes that accompany phase transition. We also obtain the energy spectrum and derive the corresponding renormalization group equation, and define from its analysis the system critical indexes near the phase transition. In our analysis renormalization group equation it is possible to use as a small parameter a module of difference between the fractal dimension of the structure and the nearest integer. We have obtained explicit dependences of critical indexes on the fractal dimension of structure. We consider a case when the equation of motion for the order parameter contain at the same time influences of defects of type a random field and a random temperature and we show, that it can leads to change of distribution function from Gibbs distribution to Tsallis distribution or more the general statistics q-type [2]. We deduce and solve corresponding renormalization group equation and calculate the critical indexes of corresponding system. We show that our result allows understanding the reason of the change of temperature dependences of thermodynamic functions induced by the change of concentration of the defects widely observed in the magnetic crystals with a variable composition.

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Phase ordering in eukaryotic directional sensing.

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The cells of multicellular organisms are endowed with a chemical compass of amazing sensitivity, formed as a result of billions of years of evolution. Concentration differences of the order of a few percent in the extracellular soluble attractant chemicals from side to side are sufficient to induce a chemical polarization of the membrane leading to cell migration towards the signal source. This way, a sensible amplifier of slight gradients in the distribution of chemicals in the surrounding environment is realized. Its relevance is easily understood if one recognizes that no multicellular organism could exist without the constituent cells being able to organize themselves following chemical cues.

The directional sensing process is initiated by the early chemical polarization of the cell membrane into two sharply defined domains, populated by different phospholipid molecules and oriented along the signal anisotropy. It has been realized recently that this early polarization process is the result of a phase-separation instability in a well-characterized network of diffusion-controlled chemical reactions [1]. A universal description of this early symmetry breaking process can be given, resorting to the theory of domain coarsening in first-order phase transitions [2]. This description implies the existence of two clearly separated polarization regimes depending on the presence or absence of a gradient in the activation pattern produced by the extracellular attractant factor, and the existence of a sensitivity threshold for the anisotropic component. Simple scaling laws are found, linking the polarization time to the amplitude of the applied gradient: the polarization time t_ϵ in the presence of an anisotropic extracellular signal depends on the anisotropy degree ϵ of the signal through the power law $t_\epsilon \propto \epsilon^{-2}$. Moreover, in a cell of radius R there should exist a threshold value $\epsilon_{\rm th} \propto R^{-1}$ for the smallest detectable anisotropy, a fact which may explain why spatial directional sensing developed in eukaryotic cells and not in bacteria, which are in average one order of magnitude smaller.

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Genus distributions for extended matrix models of RNA.

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RNA (Ribose Nucleic Acid) is the only known biomolecule which plays the dual role of being a carrier of genetic information and an enzyme in important biological reactions. The folding-unfolding dynamics, kinetics, types of structures of RNA etc under varying conditions have kept scientists busy for quite some time. Inside a cell, RNA's are subject to structural changes due to various processes like transcription and translation. A random matrix model of RNA folding counts the total number of possible structures and gives the classification for a given length of the polymer [1,2]. However, the number of structures that have been discovered are a very small subset of these vast number of structures.
We construct and study an extended random matrix model of RNA (polymer) folding based on the model in [1,2]. A perturbation which acts on all the nucleotides in the chain is added to the action of the RNA partition function. A parameter α (α is the ratio of the strengths of the original and perturbed term in the action) is found explicitly in the extended matrix model (RNA-EMM). The effect of the perturbation (in terms of variation of α) on the partition function and the genus distributions is studied. For $\alpha = 0$, the extended matrix model (RNA-EMM) reduces to the model in [1]. We find for $\alpha = 1$, the partition functions for odd lengths of the polymer chain vanish completely. This brings significant changes in the genus distributions in terms of the number of structures and the shape of the distribution as compared with the results of the model in [1].
This perturbation is able to distinguish between the paired and the unpaired bases. In the Feynmann diagrams corresponding to the extended matrix model, each unpaired base in the polymer chain is associated with a factor of $(1 - \alpha)$. For $\alpha = 1$, the partition function and genus distribution for odd lengths vanish and the partition function is non-zero for even lengths where only those structures remain which have fully paired bases. We refer to the transition at $\alpha = 1$ as a "structural transition" from an "unpaired base phase" to a "completely paired base phase". The perturbation has thus created a phase where RNA structures with a limited biological activity (as only structures with paired bases are possible) are separated out from the otherwise possible vast number of structures (where structures with both paired and unpaired bases are possible).

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Bosonic correlations in weighted networks.

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All the empirical results indentifying complex patterns in real networks rely on underlying assumptions on the correct null hypotheses. As our understanding of the correct null models improves, our picture of network structure evolves [1]. Correlations are detected by comparing an observed property with the behaviour expected in the uncorrelated or null case. Therefore, the choice of the correct null model is of fundamental importance.
In unweighted networks, many properties which were first interpreted as nontrivial were later shown to be merely due to a lower–level structure of the graph [2,3]. For instance, even under the null hypothesis of statistically independent links, unavoidable structural correlations were shown to arise in unweighted networks. In particular, it was shown that even maximally random networks with specified degree sequence are unavoidably biased towards disassortativity (the average nearest–neighbors degree k_i^{nn} decreases with the degree k_i) and hierarchy (the clustering coefficient c_i decreases with k_i) [2,3]. This is due to an effective repulsion between vertices with large degree, which can be connected by at most one link, and this is in some sense 'less' than expected by randomly matching them. Thus the local properties alone determine higher–order structural correlations, and purely uncorrelated unweighted networks do not exist.
Since structural correlations are due to the 'Fermionic' constraint that at most one link exists between two vertices [3] in unweighted networks, they are unexpected for weighted graphs, where large weights (equivalent to multiple edges) are allowed. However, here we show that significant structural constraints (stronger than previously believed [4]) are present in weighted networks as well, as a result of their 'Bosonic' or more generally 'mixed' nature. We show that all the null models that have been proposed for weighted networks can be fully characterized at a microscopic level. This allows us to obtain analytically the correct null hypotheses for topological and weighted properties. Remarkably, we find that these Bosonic

correlations correspond to a type of weighted structural constraints biasing many properties in a direction opposite to what happens in the unweighted case.
Our results show that the correct null behaviour of weighted quantities is different from what previously believed [4,5]. This clearly indicates that the definition of new unbiased measures is necessary for weighted networks.

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Towards a rigorous derivation of quantum kinetic equations.

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We discuss possible approaches to the problem of a rigorous derivation of quantum kinetic equations from underlying quantum many-particle dynamics. The current hypothesis on this problem consists in the following. Since the evolution of states of infinitely many particles is generally described by sequences of n-particle density operators (marginal density matrices), which are a solution of the initial-value problem to the quantum BBGKY hierarchy [1], then the evolution can be effectively described by the one-particle density operator, which satisfies the kinetic equation, only in a suitable scaling limit (for instance, in the mean field limit). We demonstrate that in fact, if the initial data are completely defined by the one-particle density operator, then all possible states of infinitely many particles at arbitrary instant of time can be described within the framework of the one-particle density operator without any approximations.
For that we construct a new representation of a solution of the initial-value problem to the quantum BBGKY hierarchy as an expansion in terms of particle clusters whose evolution are governed by the corresponding order cumulant (semi-invariant) of evolution operators of finitely many particles [2,3]. For the initial data from the space of trace class operators satisfying the "chaos" property in the case of the Maxwell-Boltzmann statistics we prove that the Cauchy problem to the quantum BBGKY hierarchy is equivalent to the corresponding initial-value problem for certain generalized quantum kinetic equation and an infinite sequence of explicitly defined functionals depending from a solution of this generalized quantum kinetic equation. The specific quantum kinetic equations such as the quantum Boltzmann equation and other ones, can be derived from the constructed kinetic equation in the appropriate scaling limits.

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Evolution of correlations of quantum many-particle systems.

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We discuss the origin of the microscopic description of correlations in quantum systems. It is well known that there are various possibilities to describe the evolution of states of quantum many-particle systems. The sequence of the von Neumann equations for density operators, the BBGKY hierarchy for marginal density operators and the BBGKY hierarchy for marginal correlation operators give the equivalent approaches for the description of the evolution of finitely many particles. For correlation operators that give the alternative description of the quantum state evolution of many-particle systems, we deduce the von Neumann hierarchy of nonlinear equations for the general type of an interaction potential. The von Neumann hierarchy for correlation operators can be a foundation for the description of the quantum dynamics instead of the von Neumann equations for density operators.
A solution of the von Neumann hierarchy is constructed in the form of an expansion over particle clusters whose evolution is described by the corresponding order cumulant (semi-invariant) of evolution operators of the von Neumann equations for the density operators. We prove that constructed solution generates a group of nonlinear operators of the class C_0 on the space of trace class operators. We establish typical properties of cumulants. The concept of cumulants of evolution operators forms the basis for the solution expansions of various evolution equations of quantum systems of particles, in particular, the BBGKY hierarchy for infinitely many particles. For the initial data from the space of sequences of trace class operators the existence of a strong and a weak solution of the Cauchy problem to the von Neumann hierarchy is proved.
We also discuss the relationships of the von Neumann hierarchy solution both with the solution of the BBGKY hierarchy and with the marginal correlation operators, i.e. with the solutions of the hierarchies of evolution equations of infinitely many quantum particles.

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Scaling behavior of earthquakes' inter-events time series.

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In recent years, considerable research has been devoted to the study of seismic data that carry information about the complex events that lead to earthquakes. Several important characteristics of earthquakes have been discovered. Recently, Saichev and Sornette demonstrated that the earthquakes inter-events times have a universal distribution. By analyzing theoretically the earthquakes recurrence times using a formulation based on the probability generating functions, and assuming that all earthquakes are similar (making no distinction between the foreshocks, main shocks, and aftershocks), Saichev and Sornette derived analytically specific predictions for the probability density function (PDF) of the recurrence time between earthquakes in a single homogeneous region, as well as for multiple regions. In particular, they showed that, the scaling laws of the inter-event times do not reveal more information than what is already provided by the well-known laws of seismicity, namely, the Gutenberg-Richter and the (modified) Omori laws. Their theory accounts quantitatively for the empirical power laws suggested by Bak et al. and Corral. Saichev and Sornette also showed that the empirical statistics of the inter-events times result from subtle crossovers, rather than being genuine asymptotic scaling laws, and that universality does not strictly hold for such power laws. The existence of power laws and scaleinvariant properties in the spatial-temporal data series of earthquakes indicate the presence of a fractal-like behavior. Thus, studies of fractal properties of the data for earthquakes have been quite common in recent years. In this note, we study the statistical and scaling properties of the California earthquakes' inter-events over a period of recent 40 years. To detect long-term correlations behavior, we apply detrended fluctuation analysis (DFA), which can systematically detect and overcome nonstationarities in the data set at all time scale. We calculate for various earthquakes with magnitudes larger than a given M. The results indicated that the Hurst exponent decreases with increasing M; characterized by a Hurst exponent, which is given by, $H = 0.55 + 0.68/M$, indicating that for events with very large magnitudes, M have a Hurst exponent asymptotically approaching 0.50, which is for independent events.

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On the statistics of a few body Hamiltonian system at the edge of chaos.

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We reconsider here the stochastic properties of a class of gauge theories having remarkable geometric features, namely the so called topologically massive gauge theories introduced by Schonfeld, Deser, Jackiw and Templeton[1,2]. In these (2+1) theories it is possible to give a mass to a vector field without spontaneously breaking the symmetry. The topological mass term, in the form of a Chern-Simons density, is in fact quantized by gauge invariance in relevant cases. We revisit a work we did years ago, devoted to the study of chaos in Yang-Mills theories [3,4]. The field theoretic model is not considered here for its relevance in the mathematical study of fundamental interactions, but as a model of hamiltonian microcanonical dynamics where mixing is controlled by two integrals of motions and by a specific nonlinearity. Our initial motivation has been the search for peculiar ergodic properties induced by the geometric constraints of the theory. Under a classic assumption of spatial homogeneity of the fields and in a particular gauge, the dynamics of the fields is represented, in the case we consider, by the classical motion of three particles, confined in a plane perpendicular to a background magnetic field. The three particles are nonlinearly coupled by a quartic potential. The microcanonical dynamics of the model is controlled by two conserved quantities, total energy and angular momentum. The dynamics is very rich and it displays a transition regime, between order and chaos, which suggests a complex structure of the phase space of the system with an interwoven coexistence of regular and irregular motions. The aim of this presentation is to further investigate the dynamics of the model and its statistics in the transition regime, where a peculiar production of entropy is revealed. A characterization of the regularity and irregularity of the motion will be done through the evaluation of the Lyapounov exponents, of power spectra and singularity distribution functions.

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The phase diagram of a bilayer Ising model.

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The rapid progress of surface-specific experimental techniques in the last decade resulted in the discovery of numerous new phenomena which occur at interfaces. In addition to the well-known "surface freezing" phenomenon, the surface-induced ordering phenomena, forming, in some cases bilayers, were observed in liquid metals, liquid crystals, molten salts, membranes of biological cells, etc. Therefore, the theoretical study

of the phase diagram and dynamic behavior of the bilayers is of great importance. For the analysis of the phase diagram of a bilayer, we use the two-dimensional Ising model with different in-plane and inter-layer interactions [1]. The simple method of an estimate of the critical temperature of the Ising model [2] has been used. The critical behavior is discussed and the problem is shown to belong to the two-dimensional Ising universality class for any given values of the inter-layer interaction. Indeed, the addition of the second layer changes the local environment of a spin in the first layer, and thus the critical temperature will be altered. On the other hand, the critical exponents, which determine the asymptotic behavior of the thermodynamic quantities, cannot be influenced by the changes at distances shorter than the correlation length. Far from criticality, the correlation length can be of order of the thickness of the n-layer system or smaller, and thus the behavior of the system may differ from that of the two-dimensional Ising lattice. However, upon approaching criticality the correlation length diverges to values much larger than the thickness of the n-layer system. The system's finite thickness ceases to matter, and the universal two-dimensional Ising behavior is recovered.

We study also the phase diagrams of bond-diluted bilayers. In the absence of short-range spatial correlations between the diluted bonds, the phase diagram is the same as that of the non-diluted model, while in presence of these correlations the critical temperature is obtained by means of Bethe approximation.

Results are compared with those obtained by mean-field and renormalization group approaches, and verified by comparison to earlier results obtained by computer simulations, perturbation series expansion, Bethe-tree approximations and other methods. The model describes a "surface phase" produced by a crystalline monolayer at the free surface of alkane [3] and some other surface-induced ordering phenomena. The possible applications include a molecular junction.

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The Levy sections theorem applied to econohysics.

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Recently the study of complex systems has attracted the attention of a growing number of physicists. Scaling laws, self-organized criticality, self-similarity, and fractals, just to name a few, have been found in fields as diverse as biology and economics. These phenomena have created the need for a general theoretical framework to explain them coherently through a physics of complex systems.

A branch known as econophysics attempted to explain the self-similarity and fat tails observed in financial distributions that can be responsible for a variety of behaviors [1]. Here one major contribution was Mantegna and Stanley's truncated Levy flight, which takes into account both the departures from the classical central limit theorem and the presence of scaling laws. In this work we suggest an alternative approach based on the Levy sections theorem [2]. The classical central limit theorem does not take chains of random variables that are dependent into account. Yet the Levy sections theorem is stated under Levy's generalization of the classical central limit theorem to encompass dependent variables. The Levy sections theorem is not to be confused with his stable distribution of infinite variance. Levy also employed his notion of sections to outline a proof for the generalization of the classical central limit theorem in order to consider the sums of dependent random variables [3].

Taking Levy sections amounts basically to using the inverse of the predictable quadratic variation as a random time change to transform a given process into a Gaussian one. And every continuous martingale is a time-changed Wiener process, where the time change is the quadratic variation. This is known as the Dambis-Dubins-Schwarz theorem. Also every semimartingale is a time-changed Wiener process. At first, the last result can be employed for discrete time processes (time series). And in particular, asset prices can be considered as time-changed Wiener processes. This work thus extends the Levy sections theorem's approach to time series. And we take historical daily returns of selected dollar exchange rates from both developed and emerging markets to illustrate our case. By using the Levy sections to account for local volatilities we find universal patterns in the random behavior of actual financial series. Indeed we explain their stylized fact of elevated kurtosis by the volatilities. And the extra elevated kurtosis of emerging markets is explained by the duration of exchange rate pegs. The longer foreign exchange intervention is, the greater the kurtosis. One can then build a gauge of exchange rate peg duration based on the kurtosis. In the end, our extension of the Levy sections theorem provides an approach that is simpler than the more common explicit modeling of fat tails and dependence.

The main purpose of this paper is to build up a technique based on the sections that allows one to artificially remove the fat tails and dependence present in a data set, and then compare this set with a Gaussian one, only to realize that both data sets become very similar if analyzed through the lenses of the Levy sections theorem.

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Quantum computation of populations dynamics of the resonant levels for atomic and nuclear ensembles in a laser pulse: optical bi-stability effect and nuclear quantum optics.

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Present paper has for an object (i) to carry out numerical quantum computation of a temporal dynamics of populations' differences at the resonant levels of atoms and nuclei in a large-density medium in a non-rectangular form laser pulse and (ii) to determine possibilities that features of the effect of internal optical bi-stability at the adiabatically slow modification

of effective filed intensity appear in the sought dynamics. It is known that the dipole-dipole interaction of atoms in dense resonant mediums causes the internal optical bi-stability at the adiabatically slow modification of radiation intensity. The experimental discovery of bistable co-operative luminescence in some matters, in crystal of $Cs_3Y_2Br_9Yb_3$ particularly, showed that an ensemble of resonant atoms with high density can manifest the effect of optical bi-stability in the field of strong laser emission. The Z-shaped effect is actually caused by the first-type phase transfer. On basis of the modified Bloch equations, we simulate numerically a temporal dynamics of populations differences at the resonant levels of atoms in the field of pulse with the non-rectangular cosh form. Furthermore, we compare our outcomes with the similar results, where there are considered the interaction between the ensemble of high-density atoms and the rectangularly- and sinusoidally-shaped pulses. The modified Bloch equations describe the interaction of resonance radiation with the ensemble of two-level atoms taking into account the dipole-dipole interaction of atoms [1,2]. A fundamental aspect lies in the advanced possibility that features of the effect of internal optical bi-stability at the adiabatically slow modification of effective filed intensity for pulse of cosh form, in contrast to the pulses of rectangular form, appear in the temporal dynamics of populations differences at the resonant levels of atoms. Modelling nuclear ensembles in a super strong laser field provides opening the field of nuclear quantum optics [3].

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Non-linear prediction statistical method in forecast of atmospheric pollutants.

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During the last two decades, many studies treated chaos theory with respect to various dynamical systems. It is naturally that an attention of ecologists was attracted the new methodology. Nevertheless, the studies of chaos that was applied to time series of atmospheric pollutants are few in number, and their outcomes are ambiguous. For example, Lanfredi and Machhiato (1997) not concluded the presence of low-dimensional chaos in the time series of some air constituents; Palu et al. (2001) showed that the forecast skill improves if the non-linear methods are used to predict the ozone concentrations; the PM10 concentrations that were predicted by Chelani (2005) are quite successful. In other words, the use of chaos theory and non-linear short-range forecast of atmospheric pollutants are in principle possible, but time series of air constituents are by no means always chaotic. Therefore, the present study is two-aimed: (1) to identify the chaos in the hourly time series of nitrogen dioxide (NO2) and sulfurous anhydride (SO2) at two sites in Gdansk (Poland) during the 2003, and (2) to forecast the concentrations of these pollutants using the non-linear prediction method. The length of series is 8760. To identify the chaos in the time series, the following methods are applied. (1) To determine time delays, the concept of mutual information is used; (2) To determine attractor dimensions, we apply both the correlation integral method and the false nearest neighbours algorithm; (3) To refine the obtained results, we use surrogate data sets; (4) We evaluate Lyapunov exponents as the dynamic invariants of chaotic system. In spite of the fact that the correlation integral method provides the relatively small attractor dimensions, both the surrogate data method and the false nearest neighbours algorithm assert that the more reliable dE for all datasets is 6. Such a value for the embedding dimension is comparatively large, but still indicates the presence of low-dimensional chaos in the studied time series. Also, two positive Lyapunov exponents validate the previous outcome. The sum of positive Laypunov exponents is the Kolmogorov entropy which is in turn inversely proportional to the predictability limits. In our case, these limits vary from about three to four days. Using the results of previous analysis, we apply the non-linear prediction method and compare the predicted values with both last one hundred data and nine hundred random data in the series. As an example, the real and predicted concentrations of NO2 , SO2 etc in Gdansk and Odessa regions are presented. Our results can be considered as an example of quite satisfactory short-range forecast for the air pollutants in the industrial city. Let us note that the predicted values using the non-linear method are close to the real data in the case of abrupt changes of concentrations; at least, all tendencies to the increase or decrease are uncovered.

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Cold-atom realizations of a generalized Kicked-Harper model and accelerating quantum ratchet transport without a bichromatic optical lattice.

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Hofstadter's butterfly spectrum [1,2] are of fundamental interest to many research areas, including studies of quantum Hall effect, quantum phase transition, high-temperature superconductivity, and quantum chaos, etc. Systems with a butterfly spectrum are also of interest to studies of quantum phase transition insofar as they can display an infinite number of phases when some external parameters are scanned.
Hofstadter's butterfly can also emerge in the quasi-energy spectrum of periodically driven systems. One important model is the so-called kicked Harper model, adapted from the well-known Harper model [2] by considering a delta-kicking po-

tential. The kicked Harper model has been a paradigm in understanding (i) how a fractal quasi-energy spectrum affects the quantum dynamics and (ii) how the underlying classical nonlinear dynamics affects the butterfly. Despite this significant role in understanding quantum nonlinear dynamics and despite couple of previous experimental proposals, the kicked Harper model has not been realized experimentally.

Using a dilute Bose-Einstein condensate periodically kicked by a certain sequence of pulsed optical lattice potentials, we show how a variant of the kicked Harper model with Hofstadter's butterfly quasi-energy spectrum can be realized in a rather straightforward manner [3]. Our proposal only requires slight modifications of existing cold-atom experiments on a different paradigm of nonlinear mapping systems, namely, the kicked-rotor model. Theoretically, upon a canonical transformation the classical limit of the variant of the kicked Harper model we obtain is identical with the standard classical kicked Harper model. Indeed, the butterfly spectrum associated with our realization is almost indistinguishable from the standard result previously calculated for the kicked Harper model. As such, a direct connection between two paradigms of quantum and classical chaos, i.e., the kicked rotor model and the kicked Harper model, is hence established for the first time. The results are expected to open up a new generation of cold-atom experiments on quantum nonlinear dynamics and motivate more theoretical interests in periodically driven systems with Hofstadter's butterfly quasi-energy spectrum.

Our approach can be extended to realize an entire class of generalized kicked Harper models. Based on such extensions we further propose an intriguing cold-atom realization of a quantum ratchet accelerator [4]. Unlike previous scenarios for the generation of quantum ratchet transport, here we show that quantum ratchet current can increase linearly with time without the use of a bichromatic optical lattice. The results are of immediate experimental interest [5].

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Stochastic modeling of trading activity and volatility in financial markets.

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We present generalization of the point process models for the Poissonian-like processes with slowly diffusing mean interevent time [1] and adjust the parameters of the model to the empirical data of trading activity and volatility in the financial markets [2,3], reproducing the probability density function (PDF) and the power spectral density (PSD). Such point process is stochastic and defined by the stochastic interevent time $\tau_k = t_{k+1} - t_k$, with t_k being the occurrence times of the events. We model the flow of trades in the financial markets as Poissonian-like process driven by the multiplicative stochastic equation, i.e., define the rate $n = 1/\tau$ of this process by the continuous stochastic differential equation

$$dn = \sigma^2 \left[(1-\gamma_\sigma) + \frac{m}{2}\left(\frac{n_0}{n}\right)^m\right] \frac{n^4}{(n\epsilon+1)^2}dt + \frac{\sigma n^{5/2}}{(n\epsilon+1)}dW \ . \quad (1)$$

This SDE with the Wiener noise W describes the diffusion of the stochastic rate n restricted in some area: from the side of the low values by the term $m(n_0/n)^m/2$ and from the side of high values by the relaxation γ_σ. The general relaxation factor $\sigma^2 n^4/(n\epsilon+1)^2 \mathrm{d}t$ is keyed with multiplicative noise $\sigma n^{5/2}/(n\epsilon+1)\mathrm{d}W$ to ensure the power-law distribution of n. The multiplicative noise is combined of two powers to ensure the spectral density of n with two power law exponents. A parameter ϵ defines the crossover between two areas of n diffusion. For more details see [2,3]. Equation (1) models stochastic rate n with two power-law statistics, i.e., PDF and PSD, reproducing the empirical data of the trading activity in the financial markets. In this contribution we generalize the stochastic model to reproduce statistical properties of the return volatility observed in NYSE.

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Shock waves in reactive mixtures.

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The shock structure problem for a chemically reacting gas mixture may be investigated at kinetic level as well as at fluid-dynamic level. We consider a four component mixture of species A^i, $i = 1, \ldots, 4$, colliding among themselves and undergoing the reversible reaction $A^1 + A^2 \rightleftharpoons A^3 + A^4$, that may be described at the kinetic level, according to the model proposed in [1] and [2], by a set of nonlinear integrodifferential Boltzmann-like equations. The collision term may be split into its mechanical and chemical parts, provided by suitable integral operators accounting for, together with the usual conservation laws, also exchange of mass and of energy of chemical bond in a chemical reaction. Existence of an H-functional has been proven, yielding also collision equilibria as a seven-parameter family of Gaussian distributions, with number densities related by the well known mass action law. A proper hydrodynamic closure at Euler level can be deduced from the kinetic model, with reference to situations close to thermal equilibrium in case of slow chemical reaction. Such simplification retains the most important features of the kinetic level, in particular exact conservation equations and mass action law at equilibrium. The shock structure for the four component gas mixture is investigated in one space dimension with reference to the Rankine-Hugoniot conditions linking the upstream ($-$) and downstream ($+$) asymptotic equilibria, and to the second principle of thermodynamics. The shock wave solutions can be determined for the kinetic equations in their relaxation time approximation, by resorting to a consistent BGK model for the reactive collision operator proposed in [3]. Results should be compared with the corresponding phenomenology observed for the reactive Euler equations for different upstream Mach numbers.

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Statistical characterisers of transport in a communication network.

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We discuss a $2-d$ communication network of regular nodes and randomly distributed hubs. Average travel times for single messages on this network show stretched exponential behaviour as a function of hub density. The travel times cross over to q-exponential behaviour if short cuts are set up between the hubs via random assortative connections, or via gradient connections, where the gradient is set up by assigning random message handling capacities to hubs, and connecting hubs of low capacity to the nearest hub with the highest value of capacity [1]. Since the $q-$exponential distributions have a power-law tail, it is seen that the average travel time falls rapidly with hub density. This power law tail can be explained by analysing the distribution of travel times. The distribution of travel times shows log-normal behaviour for the gradient connections and log-normal with power-law tails for the random assortative connections. Finite size scaling is observed for all the statistical characterisers.
In the case of multiple message transfer, we study the relaxation behavior of the network when a large number of messages are created simultaneously at random locations, and travel on the network towards their designated destinations [2]. For this case, both the base network, and the network with random assortative or gradient short-cuts can show a congestion to decongestion transition due to the formation of transport traps. The waiting time distributions in the congested phase show signatures of the congestion to decongestion transition, being normal in the congested phase and log-normal in the decongested phase. Phase synchronisation is seen between the queues formed at the hubs in the congested phase. If the hubs are ranked by the coefficient of betweenness centrality, it is seen the that the highest ranked hub drives the synchronisation of the others.
We compare the behaviour of the model network with airport traffic data for U.S. airports. We observe two classes for the distribution of travel times, log normal and log-normal with power law tails. We speculate on the reasons for the existence of these two classes.

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Could a persistent power be observed?

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It is well known that a potential difference $V = (R_{ls} - R_l l_s/l)I = R_{an}I$ is observed on a segment l_s (with a resistance R_{ls}) of an asymmetric conventional metal loop l (with a resistance R_l) when a circular current $I = \oint_l dlE/R_l$ is induced by the Faraday's voltage $\oint_l dlE = -d\Phi/dt$ in this loop. On the other hand the magnetization measurements give evidence of a circular direct current observed in semiconductor [1], normal metal [2] and normal state of superconductor [3] nanostructures under equilibrium. The observed periodical change of the magnetization with magnetic field at the period corresponding to the flux quantum for single electron $\Phi_0 = 2\pi\hbar/e$ or pair $\Phi_0 = \pi\hbar/e$ gives unambiguous evidence that this equilibrium quantum phenomenon is a consequence of the persistent current $I_p(\Phi/\Phi_0)$, i.e. the equilibrium circular direct current which can be observed how any long time at constant magnetic flux $\Phi \neq n\Phi_0$, i.e. without the Faraday's voltage $d\Phi/dt = 0$. The observations [4] of the quantum oscillation of the dc voltage $V_p(\Phi/\Phi_0)$ on a system of aluminium loops near its superconducting resistive transition, i.e. at $R_l > 0$, demonstrate that the persistent current $I_p(\Phi/\Phi_0)$, just as the conventional circular current, can induce the potential difference $V_p(\Phi/\Phi_0) = R_{an}I_p(\Phi/\Phi_0)$ on a ring with non-homogeneous dissipation $R_{an} \neq 0$. But the experimental results [4] raise a question about a source of the power V_p^2/R_{ls} observed in the $V_p(\Phi/\Phi_0)$ phenomena since the persistent current, in contrast to the conventional current, is observed without the Faraday's voltage. It is enough obvious that the dc voltage $V_p(\Phi/\Phi_0)$ observed in [4] is induced by a noise, non-equilibrium or equilibrium. In the second case the V_p^2/R_{ls} is a persistent power, i.e. the dc power observed under equilibrium, any observation of which violates the second law of thermodynamic. Therefore the problem on the source of the V_p^2/R_{ls} power investigated in our experimental work may have fundamental importance for statistical physics.

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Instability transition and ensemble equivalence in diffusive flow.

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The role of boundary and bias is tested in one-dimensional stochastic flow with competing nonlocal and local hopping events, where we use the totally asymmetric simple exclusion process (TASEP) [1] and the symmetric simple exclusion process (SSEP) [2], respectively. With open boundaries, both systems undergo dynamic instability transitions from a populated

finite density phase to an empty road (ER) phase as the nonlocal hopping rate increases [3,4]. Nonlocal skids in principle promote strong clustering, but such clusters are stable only at the transition for the unbiased case, while they are stable in the whole populated phase for the biased case. Using such a cluster stability analysis, we determine the location of nonequilibrium phase transitions, their nature, and scaling properties, which agrees well with numerical results. Our cluster analysis provides a physical insight into the mechanism behind such transitions. For the biased case with open boundaries, we numerically establish that the instability transition into the ER phase is second order in the regime where the entry point reservoir controls the current and first order in the regime where the bulk controls is in control. For the unbiased case with open boundaries, the transition is always abrupt, i.e., first order as long as there is the left-right symmetry. The first-order transition originates from a turnabout of the cluster drift velocity for the biased case where the current remains analytic, the road density vanishes linearly, and fluctuations scale as uncorrelated noise at the critical line, while such an abrupt transition is attributed to the cluster stability for the unbiased case, which is in contrast to the same unbiased case with periodic boundary conditions where the continuous one has been observed [5]. Finally, we discuss the equivalence of ensembles in the generalized TASEP as well as the generalized SSEP with the thermodynamic limiting states. In particular to the biased case with periodic boundary conditions, we argue that there is some signature of the instability threshold even though the condensation transition does not occurs, which can also determine the location of the transitions in its open system [3].

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Time evolution of long-range correlation in the Turkish language using non-corpus parametrization.

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The existence of long-range correlation in (twelve) natural languages by means of detrended fluctuation analysis had been reported by Hacinliyan [1] et al where each language shows two distinct scaling regimes. The study was made possible by using a corpus that does not depend on corpus and is not affected by its existence or quality. This work extends this line of research to demonstrate that the historical development of a language such as Turkish can easily be traced out using the proposed corpus independent parametrization. It would be virtually impossible to collect sufficiently large corpora from different time periods (and use Zipf's law) for a rapidly developing language under different cultural influences.
The first issue involved in an attempt to analyze a natural language as a time series is the mapping of texts onto a time series. The usual choice is using a time series derived form a corpus (see [2,3,4]). Our proposed variable in this work is inspired by DNA random walks and is derived by assigning values to the letters constituting a given word. The resultant time series for texts in the Turkish language from different time periods are analyzed via detrended fluctuation analysis (DFA) [5].
The texts analyzed in this work include one of the oldest known Turkish texts dated from 732 CE, a religious poem from 1409 CE, a poem from around 1540 CE and two modern Turkish texts. All texts show two different regimes under DFA, the short range regime is virtually parallel within errors in all cases, while the long range correlations for the two poems belonging to the same literary tradition and time period are markedly different from the other three texts. The ancient text shows a more moderate departure from the two modern texts as compared to the poems. These results imply that the time evolution in a language can be detected by means of DFA based on the proposed parametrization.
This supports results of our previous work [1] where the same analysis was applied to different languages and correlation properties that characterize each language were observed.

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Physics of evolution.

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Since Darwin's "The origin of species" the concept of evolution has fanned heated debates. Biological evolution is not a continuous process, as indicated by the discontinuities in the fossil record with its persistent absence of transitory species. Rather, evolution is characterized by typical large-scale catastrophes as well as times of explosive increase in diversity. In order to understand such erratic behavior we address this problem from a purely mathematical view and solve a set of equations which have been long proposed for a formal understanding of biological evolution and technological innovation, .e.g. [1,2]. Though well studied for specific cases the equations remained unsolved in the general form. By mapping these equations onto a random-network framework it is possible to proof the existence of two sharply separated phases in evolutionary systems [3]. One phase is characterized by its non-increasing low diversity, the other one by an ever increasing diversity. The transition from one phase to the other happens sharply. This way creative bursts in evolution - such as the Cambrian explosion in biology - can be understood as simple phase transition phenomena, well known in physics. Along the same lines the stability of evolutionary systems such as ecosystems

or economic systems with respect to external shocks can be addressed, too. Evolutionary systems will radically die out without remarkable precursors in the system dynamics once a critical number species gets removed. We have originally shown these results in a setting slightly too simple to understand selection and extinction processes or self-organized criticality as intrinsic properties of the system. These questions can be addressed by extending the setting to include suppressive interactions between species, without compromising the fundamental results above. We discuss first results in these matters. It is interesting to note that the proposed formalism can also be applied to study problems of opinion formation in societies.

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Quantum Brownian motion, entropy and the third law of thermodynamics.

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While some physical disciplines such as classical mechanics and electrodynamics underwent profound changes with the birth of quantum mechanics and relativity theory the Laws of thermodynamics and statistical mechanics per se proved impressively robust over the last century. The main reason being that the formulation of statistical mechanics rests on few pillars only, such as ergodic theory, ensemble theory, the scale of interactions, an entropic concept of temperature, and alike. The grandness of Thermodynamics is that these concepts hold independent of the details of the corresponding total system dynamics. Nevertheless, the field of statistical mechanics entails some subtle issues when going from a closed description of all degrees of freedom, including those of large environments, to a reduced description of an *open* systems where bath degrees of freedom are traced over. The latter situation is the one typically discussed in the majority of textbooks. But even here, pitfalls can arise in the quantum case already, as recently elucidated in Ref. [1].
Here we study the quantum thermodynamic behavior of small systems in presence of *finite quantum dissipation* [1]. We consider the archetype cases of a quantum damped harmonic oscillator and a quantum free quantum Brownian particle [2]. A main first finding is that quantum dissipation helps to ensure the validity of the Third Law. For the quantum oscillator, finite damping replaces the zero-coupling result of an exponential suppression of the specific heat at low temperatures by a power-law behavior.
Rather intriguing is, however, the behavior of the free quantum Brownian particle. In this case, quantum dissipation is able to restore the Third Law, which knowingly is violated classically: Instead of being constant down to zero temperature, the specific heat now vanishes proportional to temperature with an amplitude that is inversely proportional to the ohmic dissipation strength.
A distinct subtlety of finite quantum dissipation is the result that the various thermodynamic functions, – such as the entropy –, of the sub-system do not only depend on the dissipation strength but these depend as well on the prescription employed in their definition. Some subtleties relating to the Second Law and the measure of information in dissipative nanosystems are elucidated [3].

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Statistical physics of steady-state two-phase flow in porous media.

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Steady-state two-phase flow in porous media has received very little attention compared to the instabilities that occur in connection with flooding, i.e., when the porous medium is initially saturated with one of the fluids whereafter the other fluid is injected into it displacing the first, leading to e.g. viscous fingering. Steady-state flow, on the other hand, occurs e.g. in a representative volume element (RVE) of a porous medium when statistically the flow leaving the RVE is the same as that entering it. At low flow rates, steady state flow essentially consists of one fluid being held in place by capillary forces whereas the other fluid moves. However, at higher flow rates, both fluids will move and there will be a incessant breakup and merging of fluid clusters. In this regime, the flow settles into a state which is independent of the initial conditions and determined only by the flow parameters.
This opens for a statistical description of the flow which is closely related to that of statistical mechanics and thermodynamics [1]. We discuss this approach, based on a numerical model where we follow the motion of interfaces at the pore level [2]. Steady-state conditions are implemented by invoking periodic boundary conditions in the flow direction.
We argue that the probability $W\{x_i\}$ that the interfaces between the two fluids in the porous medium form the configuration $\{x_i\}$ follow a Boltzmann statistics where the hydrodynamic dissipation plays the role of a "hamiltonian" [1]. We discuss thermodynamic implications of this approach, in particular the relation between fractional flow, saturation and pressure drop across the system, showing that there is a simple relation between these [3]. We will also discuss the phase diagram of steady-state two-phase flow, where both first and second order phase transitions are found [4].
From a numerical point of view, the existence of a probability $W\{x_i\}$ opens for replacing the extremely costly time integration of the flow equations in the numerical model by a Monte Carlo method.
Lastly, we will discuss the stability of the interface between two immiscible fluids flowing in parallel in a porous medium [5]. Contrary to common belief, there is no Kelvin-Helmholtz instability. Rather, viscous fingers forming at the interface creates a foam zone that moves with constant speed and thickness in the direction of the more wetting fluid.

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Novel percolation approaches in complex networks.

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Statistical physics is one of the main approaches applied successfully recently to understand the topology, robustness and function of complex networks. We will show how ideas and tools from percolation theory lead to novel results on the robustness, immunization strategies, optimal paths and minimum spanning trees which are relevant to many real world networks including the Internet. It will be also shown how one can generalize percolation theory to include path length restrictions which are relevant for transport. A novel percolation process which is characterized by fragmenting the network by removing the minimal number of nodes will be also discussed. This result is usefull for efficient immunization strategies.

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Boundary-induced nonequilibrium phase transitions into absorbing states.

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Nonequilibrium phase transitions differ significantly from ordinary transitions at thermal equilibrium. For instance, under non-equilibrium conditions continuous phase transitions may occur even in one-dimensional systems. A well-known example is the contact process, where diffusing particles multiply and self-annihilate. Depending on the rate for offspring production, the contact process is either able to sustain a positive stationary density of particles or it approaches a so-called absorbing state without particles from where it cannot escape. The active and the absorbing phase are separated by a continuous transition belonging to the universality class of directed percolation. This type of critical behavior is obtained by tuning the rate for offspring production at all sites, meaning that the transition is bulk-induced.
The talk discusses a class of one-dimensional models with a boundary-induced absorbing phase transition. It is defined on a one-dimensional lattice, where the leftmost site evolves in the same way as in the contact process while particles in the bulk diffuse according to a symmetric exclusion process. Each particle created at the leftmost site performs a one-dimensional random walk in the bulk, which in one dimension is bound to return to the origin after finite time. The returning particles may either disappear or release another bunch of particles. Varying the rate for offspring production at the leftmost site the model exhibits a non-equilibrium phase transition from a fluctuating active phase into an absorbing state with a non-trivial critical behavior. This is probably the simplest non-trivial absorbing phase transition, much simpler than ordinary directed percolation, but nevertheless exhibiting properties which cannot be explained within mean field theory.
It turns out that particles are not created continuously but rather in form of intermittent bursts. It is argued that these irregular bursts are responsible for the observed nontrivial scaling properties. These scaling properties can be explained by a reduced toy model and by means of a non-Markovian Langevin equation.

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Extending minimum curvature estimators using spartan spatial random fields.

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Spatial interpolation is useful for the analysis and visualization of geophysical processes that are sampled irregularly in space. The principle of minimum curvature has been used to derive a non-parametric spatial interpolator for scattered data [1]. A different view assumes that the measurements form a sample from a spatial random field. Spatial interpolation is then formulated in a stochastic framework, in which one can derive estimates of the process at non-sampled points as well as characterize their uncertainty. This procedure is typically implemented in the form of the Best Linear Unbiased Estimator (BLUE), also known as Wiener filter and kriging. Recently, a family of Spartan spatial random fields [2, 3] has been proposed with a joint probability density function that is based on a Ginzburg-Landau-like (GL) energy functional. The main idea in this approach comes from statistical physics, and it is that spatial correlations are enforced by means of geometrically identifiable interactions, in contrast with the data driven covariance matrix typically used in geostatistics. The energy functional of these random fields incorporates both the gradient and the curvature of the random field. The spatial correlations involve four parameters (scale and shape coeffi-

cients, characteristic length and spectral cutoff) that should be determined from the data. We develop a parametric spatial interpolator in d dimensions that extends the minimum curvature principle by means of the GL functional. This work aims to provide a spatial predictor that incorporates contributions from the gradient, as well as the curvature term of the spatial random field. The proposed predictor offers more flexibility than the minimum curvature counterpart, in exchange for an increase in numerical complexity. This involves the computational cost for estimating the model parameters, and for the numerical calculation of the Spartan covariance function.
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A complex network approach to human mobility modeling.

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In this paper, we seek to use statistical inferences of human network topologies and contact patterns from current available mobility traces to model human interaction and bootstrap large-scale human mobility trace. We model human mobility as temporal graphs with community structures on the network topology and power-law inter-contact time on the temporal attachment of the edges. Empirical mobility traces are very important for the mobile network community to evaluate their routing algorithms, systems, applications, and study social interaction. Currently, the most fine-grained human mobility traces are collected and provided by the Haggle Project [1], but the scale of these traces is not large enough (up to 100 nodes) for a city-wide evaluation, and the duration is limited to several weeks due to battery duty-cycle. It is important to generate large-scale realistic mobility traces for city-scale applications and protocol evaluations. Our model is based on two empirical observation from 5 real human mobility traces [5]. These two observations are community structure [5] and varying power-law coefficients for inter-contact time [2] for members within same community and between two communities. Based on these two observations, we model contact-based human mobility as a temporal graphs [3] with community structures as the underlying human network topology, and different inter-contact time distributions for intra-community node pairs and inter-community node pairs. We use two ways of generating the synthetic mobility traces, the first one to to use static topology with dynamic temporal attachment. In this method, we use several well know community generation models and also topology data from a crawling of a real online social network (Orkut) with 3 million nodes and 0.2 billion edges to generate the community structures. The second method approach is to use dynamic evolution model by Kumpula et al [4] but using power-law contact duration as the increment of the weight of the network. To the best of our knowledge, this is the first contact-based human mobility model solely based on empirical observations.

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Confirmation of the additivity principle for current fluctuations in a model of heat conduction.

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Using numerical simulations, we study the large deviation function of the energy current in the one-dimensional Kipnis-Marchioro-Presutti model of heat conduction [1]. For that purpose, we use a recently introduced algorithm [2,3] which allows the direct evaluation of large deviation functions. We compare our results with a novel theoretical approach to current large deviations in one-dimensional diffusive systems, which is based on a current additivity principle [4]. We find a very good agreement between theory and simulations for the large deviation function in a wide interval of current fluctuations, confirming the general validity of the additivity principle. Moreover, the Gallavotti-Cohen symmetry is satisfied in this range.
The predictions derived from the additivity principle involve the minimization of a functional with respect to a temperature profile. We find that this optimal profile is indeed a physical observable, corresponding to the average temperature profile measured *within* the time interval during which the large deviation is observed. In particular, we confirm the theoretical prediction that this temperature profile is independent of the current sign, i.e. $T(x,q) = T(x,-q)$. On the other hand, typical temperature profiles *at the end* of the large deviation event are significantlly different from the optimal profiles, and depend on the detailed definition of energy current. These results confirm the validity of the current additivity principle as a general and powerfull tool to compute large deviation functions in one-dimensional diffusive systems.

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Quantum mean-field decoding algorithm for error-correcting codes.

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We investigate statistical properties of the mean-field decoding algorithm for Sourlas error-correcting codes [1] to obtain the Bayes optimal solution [2][3] that minimizes the bit-error rate (BER). In the Sourlas codes, in order to transmit the original message $\{\xi\} \equiv (\xi_1, \cdots, \xi_N), \xi_i \in \{-1, 1\}$ through the noisy channel, we send all possible combinations of the products of p-components in the N-dimensional vector $\{\xi\}$ such as $J^0_{i1,\cdots,ip} = \xi_{i1}\xi_{i2}\cdots\xi_{ip}$. As well-known, the channel coding theorem tells us that zero-error transmission is achieved if the condition $R \leq C$ is satisfied, where R denotes the rate of the transmission and C is the channel capacity, respectively. For the Sourlas codes in which the zero-error transmission is achieved asymptotically in the limit $C, R \to 0, R/C = \mathcal{O}(1) \leq 1$, the Bayes optimal solution is obtained for each bit as a simple majority vote: $\overline{\xi}_i = P(\sigma_i = +1|\{J\}) - P(\sigma_i = -1|\{J\}) = \mathrm{sgn}(\langle\sigma_i\rangle)$, where $P(\sigma_i|\{J\})$ is a posterior marginal defined by $P(\sigma_i|\{J\}) = \mathrm{tr}_{\{\sigma\}} P(\{\sigma\}|\{J\})$. The posterior $P(\{\sigma\}|\{J\})$ is given by $P(\{\sigma\}|\{J\}) = \mathrm{e}^{-H(\{\sigma\}|\{J\})}/\mathrm{tr}_{\{\sigma\}}\mathrm{e}^{-H(\{\sigma\}|\{J\})}$ with $H(\{\sigma\}|\{J\}) = -\beta_J \sum_{i1,\cdots,ip} J_{i1\cdots ip}\sigma_{i1}\cdots\sigma_{ip}$ for a uniform prior distribution. It should be noted that we defined $\{\sigma\}$ as the estimate of the original message and observable $\{J\}$ denotes the configuration of the parity bit $J_{i1,\cdots,ip}$ (the output of the channel). In classical system specified by a given finite temperature, the Bayes optimal solution $\mathrm{sgn}(\langle\sigma_i\rangle)$ minimizes the BER $p_\mathrm{b} = (1/2)(1-(1/N)\sum_i \xi_i\overline{\xi}_i) = (1/2)(1-[\xi\overline{\xi}]_{\{\xi\}})$ on the Nishimori line [3]. However, in the corresponding quantum system, the condition is not yet clarified. In our preliminary study [4], we considered the quantum version of the posterior. To decode the original message practically, we use the mean-field algorithm. In this paper, we first attempt to apply the modified mean-field equations for $p = 2$ [5], and then, we extend the equations up to the case of $p = \mathcal{O}(N)$ and discuss the relation between the convergence of the algorithm and the Almeida-Thouless instability, which was investigated for the case of the LDPC (Low Density Parity Check) codes [6].

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Matrix-product states and double-shock structures in a branching-coalescing system.

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We introduce a generalized branching-coalescing system on a discrete lattice of length L with reflecting boundaries. The particles in this system have nearest-neighbors interactions. At two consecutive sites the particles interact with each other according to the following reaction rules

$$\begin{array}{ll} \emptyset + A \to A + \emptyset & \text{with rate } w_{32} \\ A + \emptyset \to \emptyset + A & \text{with rate } w_{23} \\ A + A \to A + \emptyset & \text{with rate } w_{34} \\ A + A \to \emptyset + A & \text{with rate } w_{24} \\ \emptyset + A \to A + A & \text{with rate } w_{42} \\ A + \emptyset \to A + A & \text{with rate } w_{43} \end{array} \qquad (2)$$

where A and $\emptyset$ stand for the presence of a particle and a hole respectively. In [1] the authors have studied the same system in the following special case

$$\omega_{24} = \omega_{23} = q^{-1}\ ,\ \omega_{34} = \omega_{32} = q\ ,\ \omega_{42} = \Delta q\ ,\ \omega_{43} = \Delta q^{-1}.$$

However, here we first calculate the steady state weights for this generalized system using the matrix-product approach [2]. It turns out that the quadratic algebra of this system has a four-dimensional matrix representation provided that the following constraints on the reaction rates in (2) are held

$$\frac{\omega_{24} + \omega_{34}}{\omega_{42} + \omega_{43}} = \frac{\omega_{23}}{\omega_{43}} = \frac{\omega_{32}}{\omega_{42}}.$$

On the other hand, we study the dynamics of a product shock measure with two shock fronts in this system. It turns out that these two shock fronts have simple random walk dynamics under some constraints. Surprisingly these constraints are exactly the necessary conditions for the quadratic algebra to have a four-dimensional representation. Now we can construct the steady state of the system as a linear superposition of such measures and find the same weights obtained from the matrix product approach. Our calculations show that it seems there is direct relation between the existence of a finite-dimensional representation for the quadratic algebra of a driven-diffusive system and the fact the the steady state of the system can be written in terms of a linear superposition of product shock measures.

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Nonextensivity and the power-law distributions for the systems with self-gravitating long-range interactions.

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We study the nonextensivity and the power-law distributions for the many-body systems with the self-gravitating long-range interactions. We assume that the entropy and the energy are both nonextensive for such many-body systems. Namely, the entropy is Tsallis entropy and the energy takes the form [1]

$$\epsilon_q^{K+P}(q) = \frac{1}{(1-q)\beta}\left\{1 - \left[1 - (1-q)\frac{1}{2}mv^2\right]\left[1 + \beta(1-q)m\psi\right]\right\}.$$

The nonextensive form of total energy represents the long-range inter-particle interactions and the non-local correlations

within the systems. By making a natural nonextensive generalization of the conservation of energy in the q-kinetic theory, we show that the power-law distributions can be determined by the q-equilibrium in the generalized Boltzmann equation, which describe the long-range nature of the interactions and the non-local correlations within the self-gravitating system with the inhomogeneous velocity dispersion. Correspondingly, the nonextensive parameter q can be uniquely derived from the microscopic dynamical equation and thus the physical interpretation of q different from unity can be clearly presented for the system. The relation is obtained between the nonextensive parameter $q \neq 1$ and the measurable quantities of the self-gravitating system [2]: the velocity dispersion σ and the mass density ρ

$$1 - q = -2\,\sigma\,\frac{d\,\sigma}{d\,r}\Big/\frac{d\,\varphi}{d\,r} = -2\,\sigma\,\frac{d\,\sigma}{d\,r}\Big/\frac{G\,M(r)}{r^2}\ ,$$

or

$$1 - q = -\frac{\sigma\,\nabla^2\sigma + (\nabla\sigma)^2}{2\,\pi\,G\,\rho}\ .$$

Furthermore, we can derive a nonlinear differential equation for the radial density dependence of the self-gravitating system with the inhomogeneous velocity dispersion, which generalizes the form of M.P. Leubner [3] and correctly describes the density distribution for the dark matter in the above physical situation. We use this q-kinetic approach to analyze the nonextensivity of self-gravitating collisionless systems and self-gravitating gaseous dynamical systems, giving the power-law distributions the clear physical meanings. We also can prove that the so-called stellar polytropes is actually not the polytropic distribution but the *Tsallis isothermal* spheres.

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On rôle of information theoretic uncertainty relations in quantum theory.

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The essence of quantum-mechanical uncertainty relations is to put an upper bound to the degree of concentration of two (or more) probability distributions, or equivalently, impose a lower bound to the associated uncertainties. In the usual Heisenberg's uncertainty relations (HUR) the measure of uncertainty/concentration is a variance. While the variance is often a good measure of the concentration of a given distribution, there are many situations where this is not the case. Heavy tail distributions may serve as an example.
It might be thus desirable to quantify the inherent quantum unpredictability also in a different, and often more expedient, way. A particularly distinct class of such non-variance-based uncertainty relations are the uncertainty relations based on information theory. There the uncertainty is quantified in terms of various information measures — entropies, which often provide more stringent (and intuitive) bound on concentrations of involved probability distributions.
In this talk I first briefly review existent information-theoretic uncertainty relations. This will be done both for discrete and continuous distribution functions. As a next step I extend these results to account for Rényi's entropy and related differential entropy [1]. The concept of Rényi's entropy power will be axiomatically introduced and the ensuing entropy power inequalities will be derived. In the usual Shannonian information theory the entropy power inequalities are tightly connected with Fischer-information (or Cramér-Rao) inequality which yields the usual (variance-based) HUR. In the present case the Fischer-information inequality boils down to 2-parametric class of inequalities which reduce to the Cramér-Rao case only for a particular choice of parameters.
Another way how to generate the information-theoretic uncertainty relations is to use Deutsch's entropic uncertainty principle [2]. With the help of the Riesz-Thorin inequality I will derived the corresponding generalization for Rényi's entropy. I will also show a geometric illustration of this inequality in terms of Bhattacharyya's distance [3]. This will in turn reveal a close connection with a geodesic rule in the information geometry based on Fischer-Rao metric [4]. This concept of estimation of inaccuracy fits well into a general geometric approach to statistical inference which is based on the Fischer-Rao information metric. For this reason these uncertainty relations can be called information-geometric uncertainty relations (IGUR). The potency of above two types of uncertainty relations will be illustrated on a simple two-level system. There the generalized Fischer-information inequalities substantially improve upon the usual HUR. Improvement is also achieved on the level of IGUR which improve upon Deutsch's entropic uncertainty relation. The obtained restrictions on quantum distributions are of relevance, e.g, in the Jaynes-Cummings model.

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Superpositions of probability distributions.

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Probability distributions which can be obtained from superpositions of Gaussian distributions of different variances $v = \sigma^2$ play presently a favored role in quantum mechanics and in theory financial markets [1]. In general, such superpositions do not necessarily obey the Chapman-Kolmogorov semigroup relation for Markovian processes because they often introduce memory effects. In this talk we derive the general form of the smearing distributions in v which do not destroy the semigroup property. The presented smearing technique has two immediate applications which we wisch to discuss [2,3].
Firstly, our approach permits simplifying the system of Kramers-Moyal (and Fokker-Planck) equations for smeared and unsmeared conditional probabilities. In the latter case the dynamics of the smearing distribution is explicitly separated from the dynamics of the transitional amplitude which a desirable starting point, for instance, in quantum optics or in superstatistics.
Secondly, our smearing technique can be conveniently implemented in the path integral calculus. This is because in many cases, the superposition of path integrals can be evaluated

much easier than the initial path integral. To put some flesh on the bar bones we will present three simple examples [2,3]; "microcanonical" smearing, Heston's stochastic volatility model and relativistic scalar particle. We will also briefly comment on the possibility of extension of the presented technique to quantum mechanics and quantum field theory. Finally, some comments will be also added on a natural appearance of the Tsallis distribution in the scheme.

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Dynamics of finite and infinite self-gravitating systems.

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We explain the motivation, mainly from cosmology, for studying the out of equilibrium dynamics of both finite and infinite systems of particles interacting only by their mutual Newtonian self-gravity, from certain classes of simple initial conditions. We discuss in particular the precise definition and meaning of the infinite system limit in this context, and its relation to other infinite particle number limits which may be studied for such systems. We then describe and analyse the results of numerical simulations starting from infinite perturbed lattices, explaining the essential qualitative features ("hierarchical" clustering and "self-similar" temporal evolution) which are characteristic of analogous simulations of "dark matter" in cosmology. The development of the correlations at small scales at early times can be well understood as the result of evolution in two phases a first phase in which the dynamics is described by a perturbative treatment analogous to harmonic theory for classical phonons in crystals, and a second phase in which particles interact only with their nearest neighbours. The dynamics at longer times, and increasingly large scales, is, on the other hand, poorly understood. This is the regime primarily of relevance in the context of cosmology, as the corresponding structures are the "haloes" of dark matter which are believed to be the basic building blocks for the large scale structure of the universe. We discuss in more detail some specific questions about this "non-linear regime" of the evolution of such systems specifically the question of the adequacy of the Vlasov-Poisson limit to describe the evolution of the infinite discrete system, and then also basic issues about the nature and physics of the "haloes" used by cosmologists to describe the evolving system. We consider finally what light be may thrown on these systems using as a toy model the analogous problem in one dimension (i.e. the so-called "sheet" model).

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On completeness of the description of an equilibrium canonical ensemble by an s-particle distribution function.

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An equilibrium system of N molecules in a volume V are described by Gibbs distribution. For a system with an additive interaction, reduced partial distribution functions are used. It is assumed that partial distribution functions contain less information about the system than the full Gibbs distribution [1]. In [2] it has been proved that the Gibbs distribution of an equilibrium system with pair interaction can be uniquely expressed via the two-particle distribution function. In this work the result of [2] is generalized on an equilibrium system with s-particle interaction between molecules, where s is fixed number: $2 < s < N$.
For that system a whole potential energy is equal to sum of interaction potentials of all particles: $u_i(q_1, \ldots, q_i)$, $i = 1, 2, \ldots, s$. The Gibbs distribution function of this system depends on s different independent functions $u_i(q_1, \ldots, q_i)$. It can be shown that the potential energy is expressed as a sum

$$U_N(q_1, \ldots, q_N) = \sum_{1 \le i_1 < \cdots < i_s \le N} \phi_s(q_{i_1}, \ldots, q_{i_s}) \ ,$$

of a single function $\phi_s(q_1, \ldots, q_s)$ which is a definite composition of potentials $u_i(q_1, \ldots, q_i)$. This implies that the Gibbs distribution function depends really on a single function $v_s(q_1, \ldots, q_s) = exp\{-\beta\phi_s(q_1, \ldots, q_s)\}$. Therefore an s-particle distribution function $F_s(q_1, \ldots, q_s)$ can be represented as a result of nonlinear operator action on this single function: $F_s = \mathcal{F}(v_s)$. We consider this expression as a nonlinear operator equation relative to v_s. If all potentials $u_i(q_1, \ldots, q_i)$ are bounded below this equation satisfies the existence and uniqueness of solution conditions. Therefore there exists an inverse operator $\mathcal{F}^{-1}$ and the function v_s is expressed uniquely via F_s: $v_s = \mathcal{F}^{-1}(F_s)$. This implies that the full Gibbs distribution is expressed uniquely via the s-particle distribution function. Therefore if we know the F_s, we know D_N too. For $i < s$ partial distribution functions F_i are expressed via v_s too, that is there exist a transformation from v_s to F_i. But doesn't exist inverse transformation from F_i to v_s if $i < s$. This implies that these partial distribution functions F_i define a contracted description of system if $i < s$. The s-particle distribution function F_s define full description of system and contain the same information about considered system as the full Gibbs distribution function.

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The simplified Fermi-Ulam accelerator revisited.

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Fermi-Ulam model [1], originally proposed for testing the feasibility of gaining energy through scattering off moving targets, i.e. Fermi acceleration [2], consists of one harmonically oscillating and one fixed infinitely heavy hard wall and an ensemble of non-interacting particles bouncing between them. The equations defining the dynamics of the FUM are of implicit form with respect to the collision time, which complicates numerical simulations and hinders an analytical treatment. A simplification (known as the *static wall approximation* (SWA)) [3,4], which treats the oscillating wall as fixed in space, yet transfer of momentum is allowed as if the wall were oscillating, has become over the time the standard approximation for studying the FUM. The SWA speeds-up numerical simulations and facilitates the analytical treatment of the problem, while it has been generalized to higher-dimensional billiards with time-dependent boundaries, such as the time-dependent Lorentz Gas [3].
However, the application of the SWA in the FUM suffers from two drawbacks. The first is that it leads to a considerable underestimation of the particle acceleration. It has been shown [3,4] that the underestimation is caused by small additional fluctuations of the time of free flight due to the displacement of the oscillating wall occurring in the exact model, which are neglected within the SWA. The second has to do with the possibility of multiple consecutive collisions between the oscillating wall and the particles that the SWA also does not take into account. This deficiency in the SWA gives rise to a fundamental inconsistency: the ensemble mean of the absolute velocity obtained analytically does not change through collisions with the "*moving*" wall, despite the well-established numerical result that Fermi acceleration does take place in the phase-randomized FUM.
The aim of this work is twofold. Utilizing the hopping approximation introduced in Ref. [4] the transport coefficients of the Fokker-Planck equation, describing the diffusion in velocity space, are calculated and the asymptotic time-evolving probability density function of particle velocities is derived. Moreover, a consistent semi-analytical treatment for the calculation of the first moment of the absolute particle velocities directly via the dynamical equations is presented resolving the above contradiction [5]. In a more general context, this work exemplifies the effect of low-probability events on the transport properties of a time-dependent billiard.

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Energy landscapes and their relation to thermodynamic phase transitions.

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A phase transition is an abrupt change of the macroscopic properties of a many-particle system under variation of a control parameter. An approach commonly used for the theoretical description of phase transitions is the investigation of the analyticity properties of thermodynamic functions like the canonical free energy of enthalpy. It is long known that nonanalytic behavior in a canonical or grandcanonical thermodynamic function can occur only in the thermodynamic limit in which the number of degrees of freedom N of the system goes to infinity. Recently, however, it was observed that the microcanonical entropy, or Boltzmann entropy, of a finite system is not necessarily real-analytic, i. e., not necessarily infinitely many times differentiable [1].
In order to better understand the occurrence of nonanalyticities of thermodynamic functions, we adopt an approach based on the study of *energy landscapes*: The relation between saddle points of the potential energy landscape of a classical many-particle system and the analyticity properties of its thermodynamic functions is studied for finite as well as infinite systems. For finite systems, each saddle point is found to cause a nonanalyticity in the microcanonical entropy, and the functional form of this nonanalytic term can be derived explicitly [2]. With increasing system size, the order of the nonanalytic term grows unboundedly, leading to an increasing differentiability of the entropy. Nonetheless, in the thermodynamic limit, asymptotically flat saddle points may cause a phase transition to take place [3]. For several spin models, the absence or presence of a phase transition is predicted from saddle points and their local curvatures in microscopic(!) configuration space.
These results establish a relationship between properties of energy landscapes and the occurrence of phase transitions. Such an approach appears particularly promising for the simultaneous study of dynamical and thermodynamical properties, as is of interest for example when for protein folding or the glass transition.

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Modeling scaled processes by the nonlinear stochastic differential equations.

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The inverse power-law spectra and distributions of the signals, as well as scaling behavior are ubiquitous both inside and outside the physics and has become a welcome careful description of complexity in many fields including natural phenomena, human heart rhythm in biology, spatial repartition of faults in

geology, as well as human activities such as traffic in computer networks and financial markets. The multifractal formalism has received much attention as one of the most popular frameworks to describe and analyse signals and processes that exhibit scaling properties, covering and connecting both the local scaling and the global one in terms of sample moments. Multiplicative processes and multifractals have earned increased popularity in applications ranging from hydrodynamic turbulence to computer network traffic, from image processing to economics. Here we will consider analytically and numerically the scaling properties and multifractality [1] of the signals generated by the stochastic nonlinear and linear with fluctuating relaxation rate differential equations [2, 3], as well as of the multiplicative point processes models [4]. The proposed models relate the power-law spectral density with the power-law distribution of the signal intensity into the consistent theoretical approach and may model processes in different systems with the inverse power-law distributions and long-range memory [5, 6].

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Distribution of eigenvalues and scattering data for the NLSE Zakharov-Shabat problem with random Gaussian input.

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One defining development in telecommunications technology during the last two decades has been the widespread use of optical fibers for transmitting enormous quantities of data across large-even transoceanic-distances. For such increasingly large distances, one cannot neglect the non-linearities in the fiber, which tend to distort transmitted pulses. This is an important problem, since it makes it difficult to find ways to modulate the signal. For fibers with negative group velocity dispersion (GVD), it is possible to compensate these effects, creating stable solitonic pulses [1]. As a first approximation, these solitary waves are solutions of the non-linear Schrödinger equation (NLSE).
The problem of determining the spatial evolution of an incoming pulse $u(t) \equiv u(t,0)$ is solved via the inverse scattering transform (IST), where $u(t)$ enters as the "potential" in a linear eigenvalue problem. For the NLSE this is the non-Hermitian Zakharov-Shabat (ZS) eigenvalue problem [2], comprising of the a 2×2 system of coupled first order differential equations

$$\begin{pmatrix} i\partial_t & u^*(t) \\ -u(t) & -i\partial_t \end{pmatrix} \mathbf{\Psi}_z(t) \equiv \mathbf{U}(t)\mathbf{\Psi}_z(t) = z\mathbf{\Psi}_z(t),$$

where $\mathbf{\Psi}_z(t) = [\psi_1(t)\ \psi_2(t)]^T$, and appropriate asymptotic conditions on the eigenstates.
We analyze the distribution of the scattering data, *i.e.* the average density of states (DOS) of $\mathbf{U}$ and the average distribution of a set of complex numbers $\{b_k\}$ that determine the asymptotics of the eigenstates, when $u(t)$ is drawn from a zero-mean, δ-correlated Gaussian distribution, describing the distribution of transmitted codewords. Gaussian input signals are often used in information theory, and in linear transmission problems they often reach the Shannon capacity. In addition, when the characteristic signal amplitude u_0 is much smaller than its bandwidth τ^{-1} (but with $D \equiv u_0^2\tau$ arbitrary), it is reasonable to approximate [3] the input distribution with a δ-correlated Gaussian for eigenvalues z small in the scale of τ^{-1}. We first calculate the Lyapunov exponent in closed form taking advantage of its self-averaging properties. Combining this with a generalization of the Thouless formula for non-Hermitian operators [4], that relates the Lyapunov exponent with the DOS, we arrive at an explicit expression for the latter. Since the Lyapunov exponent is simply related to the localization length, it also provides information for the eigenfuctions of the potential. We discuss the implications in the context of information transmission through non-linear optical fibers.

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Smoother quantum walks.

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Quantum versions of random walks have been used to produce several new quantum algorithms with a speed up over the best known classical algorithms. On the line and the cycle, quantum walks show a quadratic improvement over classical random walks in their spreading rates and mixing times respectively. Non-unitary quantum walks can provide a useful optimisation of these properties, producing a more uniform distribution on the line, and faster mixing times on the cycle. This talk will examine the interplay between quantum and random resources. The entanglement between the coin and the position of the quantum walker can be used to indicate the quantum character of the process. It is found that the entanglement reduces to zero by the chosen end of the optimal quantum walk, as would be expected for a nearly uniform distribution. The randomness required to obtain this optimal outcome is logarithmic in the number of steps and can be provided as part of the non-unitary process: an external source of randomness is not required. Although the long time behaviour of non-unitary quantum walks is classical (with a Gaussian limiting distribution), the spreading or mixing rate of the optimal non-unitary quantum walk occurs with the full quantum speed up over the chosen (finite) number of steps. It is also necessary to apply the non-unitary evolution to the position of the quantum walk, and not just to the coin. Non-unitary evolution applied to the coin only does not produce faster mixing or significantly smoother distributions on the line. Instead, classical correlations build up before the quantum correlations (entanglement) has all been removed, leading to a cusp-shaped distribution.

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Novel exponents control the quasi-deterministic limit of the extinction transition.

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The quasi-deterministic limit of the generic extinction transition is considered within the framework of standard epidemiological models. The susceptible-infected-susceptible (SIS) model [1] is known to exhibit a transition from extinction to spreading, as the infectivity is increased, described by the directed percolation transition class [2]. We consider the SIS model with N individuals per lattice site. We find that the distance of the directed percolation transition from the classical transition point, and the prefactor controlling the divergence of the perpendicular correlation length, both scale with the local population size with two novel universal exponents. We prove that the total number of infections at the classical transition point scales as the square of the perpendicular correlation length, and thus grows faster than in the zero dimension (well-mixed) case. Since classically, the model exhibits a transition to a propagating wave of Fisher-type [3], for large N at a finite distance above the classical threshold, the velocity is that of the Fisher wave with Brunet-Derrida corrections [4]. Thus, there is generically a new scaling regime with N in the immediate vicinity of the classical threshold. Different exponents characterize the large N behavior of the susceptible-infected-recovered (SIR) model [5], where recovered individuals are immune from further infection, and which belongs to the dynamic percolation class and so does not exhibit a transition in one dimension. We demonstrate numerically that these new exponents are indeed universal, and are independent of the details of the model, such as strength and nature (contact vs. diffusive) of the spatial interaction. The same exponents as the SIS model are found in a model of diffusive branching and annihilating particles. We conjecture that these characteristics are generic and may be used in order to classify the high density limit of any stochastic process on the edge of extinction.

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Highly localized nonlinear excitations in crystalline charged-particle configurations.

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We consider the existence and stability of multipole, vortex and soliton type localized modes in hexagonal and honeycomb lattices, with an aim to model strongly nonlinear transverse oscillations of charged dust grains in dusty plasma lattices (DPLs). The theory is essentially formulated in terms of the coupling (discreteness) parameter $\epsilon = \omega_T^2/\omega_0^2$ (here ω_T is the eigenfrequency of the tranverse DPL mode, and ω_0 is related to electrostatic inter-grain interactions [1]), thus allowing for a direct interpretation in terms of experimentally measurable plasma quantities. Two approaches, relying on the discrete nonlinear Schrödinger [2] and the Klein-Gordon [3] paradigms, are employed and found to agree to a satisfactory extent.
The first approach, based on the discrete nonlinear Schrödinger paradigm [2], has been associated to beam propagation in optical waveguide arrays [2]. Among the principal findings of the work is the fact that in contours involving three lattice sites, the vortex configuration of topological charge S=1 is the most stable one. For 6-site configurations, we obtain the surprising feature that vortices of lower topological charge (S=1) may be unstable, while those of higher topological charge (e.g., S=2) may be stable. The analysis is complemented by numerical simulations and bifurcation studies.
The second analytical approach relies on a nonlinear Klein-Gordon model [3]. Extending previous work on breather excitations in 1D crystals [3], the anticontinuum-limit method is employed, to investigate single- and multi-site excitations. Instability occurs beyond a threshold value of ϵ, which is lower for multi-breathers than for single-site ones. For the multi-site excitations we have to take under consideration the phase difference between the oscillators. Only particular realizations are continued as stable multibreathers until the critical value of ϵ where destabilization occurs.
These results complement earlier investigations of quasi-continuum 2D envelope dust-lattice modes [4].

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Stationary noise sustained structures in systems with chemical reactions.

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Self-organization processes induced by internal multiplicative noise in spatially extended systems with reactions and diffusion are considered by means of variational principle. A prototype model of the system is constructed with a help of continuity equation for the relative scalar field $x = x(\mathbf{r}, t)$ with a diffusion flux $J = -D(x)\nabla\mu(x, \nabla^2 x)$ and chemical reactions $R(x)$ [1]. Taking into account these two forces, a corresponding deterministic evolution equation for the field x can be represented through an effective Lyapunov functional $\mathcal{U}$ as follows: $\partial_t x = [D(x)]^{-1}\delta\mathcal{U}/\delta x$. Considering the system in a bath, we introduce an internal fluctuations in an *ad hoc* from, assuming the fluctuation-dissipation relation holds [2]. It yields the Langevin equation in the form $\partial_t x = [D(x)]^{-1}\delta\mathcal{U}/\delta x + \sqrt{[D(x)]^{-1}}\xi(\mathbf{r}, t)$, where Gaussian white noise ξ with intensity σ^2 is introduced. The corresponding probability density function can be found explicitly, $\mathcal{P}_{st} \propto \exp(-\mathcal{U}_{ef}[x]/\sigma^2)$, where $\mathcal{U}_{ef}[x] = \mathcal{U}(x) - \sigma^2/2 \int \mathbf{dr} \ln D(x)$ [3].
To investigate a possibility of noise sustained stationary structures $x(\mathbf{r})$ formation, we use variational principles and solve a problem of minimization of the effective functional $\mathcal{U}_{ef}$. It was found that with an increase in the noise intensity a symmetry of the distribution function is changed. To study inhomogeneous solutions we consider Fickian and nonFickian diffusion, separately. It was found that in the former case noise induces formation of a single-period spatial structures, where the field x oscillates between positions of two minima of the effective potential. In the case of nonFickian diffusion a situation is changed crucially: (i) homogeneous solutions are centers of one-dimensional limit cycles (single-period spatial structure) or two-dimensional tori (two-period spatial structures) in four-dimensional phase space. Analysis of motion on tori is performed in details. We have set that with an increase in the internal noise intensity following picture of self-organization is observed: at small noise intensity the system is unstable; with an increase in the noise two set of concentrated tori are realized; with further increase in the noise intensity existing set of tori is changed by another set of concentrated tori; continuing increase the noise the set of tori is destroyed and the system becomes unstable. Therefore, with the noise intensity ranging, a reentrant self-organization picture is observed. Analytic results are verified by computer simulations.

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Exact solutions for the generalized Fokker-Planck equation modeling magnetic field diffusion in magnetohydrodynamics including Hall current.

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The need for a Fokker-Planck (FP) description of a beam-driven plasma was recognized in the 1950s. A nonlinear two-dimensional multi-species FP model was developed for the mirror programme in 1973. Pucci and Saccomandi [3] obtained necessary conditions in conservation form for the FP equation to admit potential symmetries. This yielded invariant solutions for the FP equation, the wave equation in non-homogeneous form and the quasi-linear wave equation. Further developments followed (algorithms, classification of FP-type equations according to the maximal symmetry groups, etc.). Khater and coworkers (see references in [1, 2]) studied the generalized FP equation modelling the magnetic field diffusion in magnetohydrodynamics (MHD). More recently Khater et al. [1, 2], using the potential symmetries, studied a further generalized FP equation modelling the magnetic field diffusion MHD including even the Hall current. The inclusion of the Hall current is a typical feature in recent MHD literature while some other effects which are slightly smaller are still neglected. Here we continue this work with a different approach. Starting from the basic equations for MHD, introducing dimensionless quantities and making suitable choices, we obtain several classes of exact solutions for the corresponding generalized FP equation in (1 + 1) dimension. We have now used the extended eigenfunction method introduced by van Kampen [4] and further improved by Malfliet [5]. Through their transformation an equation is generated which can be solved although containing an integral of a function depending on the magnetic field and velocity field. Substituting a function which allows the integration thus generates new exact solutions which involve the effects of time-dependent flow using physically realizable forms of the velocity and magnetic field. Solutions are first obtained in Cartesian coordinates (easier case), then in cylindrical coordinates (oriented toward applications). Several graphs illustrate the results. Some comparison with the previous work [1, 2] is made.

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Solutions for the generalized (2+1) dimensions Fokker-Planck equation.

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Malfliet [1] solved the Fokker-Planck (FP) equation in (1 + 1) dimensions by using the van Kampen eigenfunction method [2] to obtain a (linear) Schrödinger equation in 1 dimension. Malfliet [1] thus obtained the solution of the Burgers' and the damped Burgers' equation in a systematic way. Khater et al. further analysed in a series of papers ([3] and references therein) the (1 + 1) dimensional FP equation and the inhomogeneous non-linear diffusion equation. Here we extend the method to the FP equation in (2 + 1) dimensions, moreover generalizing it by two arbitrary constants α and β

$$\partial_t P = \alpha\,(\nabla^2 U)\,P + \beta\,\nabla U\cdot\nabla P + \nu\,\nabla^2 P\ ,$$

where $P = P(x,\,y,\,t)$ and $U = U(x,\,y)$, while ν is a constant. Using the transformation

$$P = e^{-\lambda\,t - U/2\,\nu}\,\Phi(x,\,y)\ ,$$

we obtain the 2 D Schrödinger equation

$$\nabla^2\Phi + (E - V(x,\,y))\,\Phi = 0\ ,$$

Several interesting solutions are considered. The link with a generalized Burgers' equation is made and a class of solutions for the latter equation is obtained. Corresponding graphs are provided.
The approach is an alternative to some of our previous investigations concerning the FP equation and its generalizations [4, 5] where a conservation law admitting potential symmetries for the FP equation was used to obtain solutions. The present approach differs from the one in an accompanying paper too although it uses the transformation of Malfliet and van Kampen too, but it is in (1 + 1) dimensions and does not use the Schrödinger equation to obtain solutions.

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Dynamics of multi-layers neural networks on basis of photon echo: Effects of chaos and stochastic resonance.

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In this work we carry out new quantum models for dynamics of the optical neural networks on the basis of the photon echo and study the features of the optical bi-stability manifestation, resonance-stochastic effects in two-level atomic ensembles [1] and provide the PC computer realization of the models with the aim of computer modelling the neural networks dynamics [2]. We proposed a new quantum model of optical photon echo neural networks, provided by hyperfine structure of states of the two-level atomic ensembles. The results of the computer experiments on dynamics of neural networks with input rectangular pulse are presented. On the basis of the object oriented programming we carried out the numerical realization of the new model and fulfilled the computer simulation experiments in order to study the optimal information possibilities of photon echo neural network in tasks of the images and complex signals detection and estimate a possibility of the resonance stochastic effects manifestation. In particular, the input signal is modelled by the sin, cos , soliton-like, rectangular pulses. Besides, it has been considered a case of the noise input signal sequence. It is shown that for definite value of the additive noise intensity D ($D = 0.000 - 0.004$) a tutoring process of the neural network is very effective and the signal reproduction is an optimal (the optimal value $D = 0.0017$). A coherence of input and output is optimal under definite level of noise. So, it is shown firstly that it's possible a realization of the stochastic resonance regime in a system.

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Quantum stochastic computation of energy transfer and effect of the rotational and V-T relaxation on multi-photon excitation and dissociation in molecules.

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Phenomenological approach to description uncollisional excitation of number of molecules (CF3I, SF6, OsO4 etc.) has been realized in papers of Letokhov, Stown etal [1]. At the same time a problem of correct quantum computation of dynamics of multi-photon processes, a role of collisions, selectivity of dissociation, absorption and energy transfer etc. requires a further studying. In this paper within new stochastic, quantum kinetics model we carried out the quantum computation of energy transfer and effect of the rotational and V-T relaxation on multi-photon excitation and dissociation in molecules.

It is studied a link between the integral characteristics of the multi-photon excitation and dissociation with parameters of relaxation in a medium of the buffer gas (N2). It is calculated the output of multi-photon dissociation and absorbed energy for the following molecules UF_6, SF_6, CF_3Br and others.
We describe a process of excitation into continuum within generalized kinetical equations model [2]. A key moment is connected with account of the stochastic diffusion mechanism in quasi-continuum. To describe an excitation on the lowest discrete levels it is used a modified Letokhov model where the lowest levels system is described by two velocities: radiative velocity of excitation of some separated levels, which is proportional to pressure, and the rotational relaxation velocity. We calculate a dependence of the absorbed energy and dissociation output upon the summarized pressure (for example $p = p(N_2) + p(CF_3Br)$) for a number of the CO_2 laser lines as follows $1048.66, 1043.16, 1035.47\ cm^{-1}$. It is carried out an analysis of absorption by molecules in the quasi continuum, molecules on the lowest levels, contribution of the V-T relaxation. Stochastic model block is manifested in more correct description of the excitation quantum dynamics in the quasi continuum.

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Synchronization and Laplacian spectra on weighted random networks.

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Spectral properties of Laplacian matrix defined on weighted complex networks are of interest in connection with the synchronization problem. The spectral density, or the density of states, of various matrices defined on the static model of scale–free networks can be obtained from nonlinear integral equations [1]. When the mean degree of the network is large, the nonlinear integral equations admit simple solutions. The formalism has been applied first to the adjacency matrix [2] and subsequently to the Laplacian, normalised Laplacian (or random walk), weighted Laplacian and weighted adjacency matrices in Ref[1].
However it can be applied to the Laplacian of weighted network only when one approximates the diagonal elements by their ensemble averaged values. We find the approximation is good in the large eigenvalue tails and explore its consequences. With this proviso, the eigenratios which determine the stability of synchronized states of coupled nonlinear oscillators are derived analytically for several cases of link weights. When comparable, our results confirm the universal behavior found in Zhou et al. [3] Also when the coupling strengths on scale-free networks are normalized by k^β, k being the degree of a node and β a constant, the eigenratio scales with the system size N as $|1-\beta|\log N$ in agreement with numerical data of Motter et al. [4].

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Restricted curvature model and restrited-solid-on-solid model with conserved noise.

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The activation of adatoms through the surface diffusion creates some randomness, and the surface diffusion itself generates a conservative noise [1]. Actually different exponents and universality classes are expected for the equation with a conservative noise [2,3,4]. We introduce a conserved noise restricted curvature (CNRC) model, which has volume conservation in the restricted curvature model. One particle on the $x+1$ site is moved to the x site with probability 1/2 producing $h(x) \longrightarrow h(x)+1$ and $h(x+1) \longrightarrow h(x+1)-1$, or *vice versa* $h(x) \longrightarrow h(x)-1$ and $h(x+1) \longrightarrow h(x+1)+1$. If the restriction on the local curvature $|\nabla^2 h| = |h(x+1)+h(x-1)-2h(x)| \leq N$ on both the pair sites and the nearest neighbor sites is not satisfied, the corresponding local movement of the particle is forbidden, where N is a preassigned integer. There is no deposition or evaporation of particles except local diffusions of surface particles so that the sum of the heights $\sum_x h(x)$ is conserved. In the CNRC model, the surface width W of the model grows as t^β at the beginning with $\beta \approx 0.25$ and becomes saturated at L^α for $t \gg L^z$ with $\alpha \approx 1.5$ in one substrate dimensions, where L is the system size. They are consistent with $\beta = \frac{1}{4}$, $\alpha = \frac{3}{2}$ and $z = 6$. In the restrited-solid-on-solid (RSOS) model with conservation of total number of particles, we obtain $\beta \approx 0.12$ and $\alpha \approx 0.49$ being consistent with $\beta = \frac{1}{8}$, $\alpha = \frac{1}{2}$ and $z = 4$ within the error bar. The conservation law leads to different universality classes following sixth-order (RC) and fourth-order (RSOS) linear equation with the conservative noise. The relations between our models and the equations are discussed.

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An explanation for the emergence of commonly observed stylized facts using data from experimental financial markets.

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In this paper we present data from market experiments conducted with students at the University of Innsbruck. In our laboratory markets we find almost identical stylized facts com-

pared to real market data. The cumulative distribution function of absolute log returns exhibits fat tails with Hill Estimators ranging from 1.8 to 3.6. All experimental treatments also show the typical pattern of increasing Hill estimators with decreasing tail size. Regarding the volatility clustering property we observe a fast decay of the ACF of log-returns, while the autocorrelation function of absolute log-returns decays slowly towards zero. Another stylized fact is reported in Scalas et al. (2006) and Kaizoji and Kaizoji (2004). They find that the survival function of waiting times between trades is non-exponential, but exhibits fat tails. In real financial markets the probability of large waiting times is much higher than can be expected by an exponential function with the same parameters. In our laboratory markets, the survival function of normalized waiting times does not coincide with the exponential fit, but shows large outliers in the tail of the distribution. In a next step, we analyze the data with pooled linear regression models to explain the emergence of fat tails and volatility clustering. The latter is mainly caused by the time effects of decreasing uncertainty and increasing homogeneity in traders' expectations within the experiment and within each period. Thus, the probability of large price deviations is highest at the beginning of the experiment and at the beginning of each period due to traders' heterogeneity in expectations. When we relate this finding to the suggestion of Campbell et al. (1997), that fat tails are caused by variations in volatility, our results show that volatility is highest after the arrival of new information, and decreases as information is reflected in prices. Traders' opinions seem to converge towards an endogenously evolving equilibrium in the course of the experiment. Besides these time effects, the actions of uninformed traders contribute significantly more to fat tails than do informed traders. Additionally, the percentage of the use of a fundamental strategy within each trade has no clear influence on our volatility measure.

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Probability of large movements in multivariate intermittent time-series.

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Mankind has tried to predict the future since early ages. Similarly to the attempt to invent *perpetum mobile*, the future telling has failed. However, there is causality between the events, or sequences of the events, in the nature (and social systems), i.e., the events can be correlated. The attempts to reveal the correlations or causality have proven to be more successful in the scientific world.
In our recent work we have studied multivariate intermittent time-series and introduced a method of time series analysis based on properties of periods of low-variability [1-4]. The latter refers to the technically simple, but surprisingly powerful method that can be viewed as a complementary tool to the standard multifractal analysis. Low-variability period is referred to the consequent values of realizations, where the change in some signal remains below given threshold. In [2], we have devised a relationship that offers the probability of observing larger-than-threshold movement in input signal after having observed the "silent" period. We have already empirically tested the probability of the "silence breaking" in financial time-series [4].
In this paper we elaborate the concept of the probability of large variations to the biological signal, such as human heart rate dynamics. Previously [3], we have shown that the distribution of low-variability periods in human heart rate follows power law for meaningfully broad inertial range of scales. Such scaling properties lead to the same result for the probability of "silence breaking" in case of heart rate as it was for financial time-series. This paper highlights super-universal nature of that empirical relationship. Finally, we propose a new characteristic – the range of scales where the probability of "silence breaking" is inversely proportional to the length of low-variability period. This measure adequately describes short-time heart rate variability and therefore can be diagnostically useful tool.

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Parkinson's law revisited: Socio-physical investigations on 3 essays.

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Despite the rampantly growing body of management literature, there are only few of these works that have received the honour to become scientifically underpinned seminal knowledge. Parkinson's Law [1] is one such example. Notwithstanding the original humorous formulation, the main conclusions drawn by him (e.g. the famous sentence that 'work expands so as to fill the time available for its completion') find their validity in diverse fields like sociology, human resource management and information technology. The present paper aims at revitalizing three results from C. Northcote Parkinson by means of a socio-physical analysis. We begin with a review of his studies on directors and councils, where he conjectures that a decision-making body is rendered inefficient after its membership passes a certain size (the 'Coefficient of Inefficiency'). We reported evidence for the existence of such a critical group size by empirically relating the cabinet size of a country to indicators for governance quality and human development [2,3]. We extended an opinion formation model [4] to small groups which gives quantitative insights into the mechanisms constituting this critical size. Secondly, we analytically develop a framework for bureaucratic growth as proposed by Parkinson from his studies on the British naval history. We show that the forces he conjectured to govern this growth, namely that (i) officials try to maximize their subordinates and (ii) officials make work for each other, indeed provide an explanation for the swelling of bureaucratic institutions. We thus derive an explicit formula for "Parkinson's Law". Finally we turn to a

third essay where we tackle the question at which age an official should retire in order to ensure an optimal functioning of the administrative body he is working for. Here we find that this 'Pension Point' does not solely depend on the capabilities of the official whose retirement we are considering, instead we have to look at his possible successors and prevent them from becoming frustrated by a lack of opportunities to get promoted (also known as suffering from the Prince Charles Syndrome).

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Statistics of competing lattice instabilities and structural transitions in complex oxides.

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Structural phase transitions are important ingredient in any description of complex oxides with electric polarization as the defining property. Despite its primary role in phenomenological theories, the microscopic understanding of structural transitions is an objective of extensive research, especially in the context of modern applications, where spatial inhomogeneity and deviation from thermodynamic limit becomes significant. Unlike canonical Ising-type models, the standard picture of what happens inside a metastable complex oxide is almost invariable based on empiric (Landau) and first-principles effective Hamiltonians [1]. A framework, unifying both types of Hamiltonians, is the unavoidable interaction of the system with thermal environment resulting in the statistics capturing both the anharmonic Hamiltonian and stochastic dynamics.
Here we present advancements in the mathematical tools effective for modeling and identification of lattice instabilities. The regular behavior is modeled both for Landau [2] and effective lattice dynamical (phonon) [3] Hamiltonians whereas the stochastic dynamics emerges from thermal environment. Fokker-Planck approach for these model Hamiltonians yields multivariate probability density of lattice instabilities as a competing effect of long-range Coulomb, elastic and electroelastic interactions in presence of thermal environment. Special attention is paid to the solution of time dependent Fokker-Planck equation mapped to imaginary time Schrödinger equation as a complementary alternative to Monte Carlo simulations.
Representative examples [4] include time and temperature development of the intrinsic (domain) structure triggered by a source of ergodicity breaking and affected by electrical and mechanical boundary conditions. Structural transitions in dots and thin films are modeled for $BaTiO_3$ as the prototype complex oxide.
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Spreading of innovations in socio-economic systems.

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Technological evolution of socio-economic systems has two major components [1]: (*i*) *Innovation* New products, ideas, paradigms emerge as a result of innovations which are then tested by the market. (*ii*) *Spreading* Successful technologies spread over the system resulting in an overall technological progress. Recently, we have introduced an agent-based model for the spreading of technologies in socio-economic systems where the technology is mainly used for the communication/interaction of agents [2]. In the model, the agents use products of different technologies to communicate with each other which induce costs proportional to the difference of technological levels. Additional costs arise when technologies of different providers are used. Agents can adopt technologies and providers of their interacting partners in order to reduce their costs leading to microscopic rearrangements of the system. Analytical calculations and computer simulations performed on a square lattice have revealed that starting from a random configuration of different technological levels a complex time evolution emerges where the spreading of advanced technologies and the overall technological progress of the system are determined by the amount of advantages more advanced technologies provide, and by the structure of the social environment of agents [2].
In the present project we study the effect of network topologies of agents' social contacts on the competition of products of different technological levels and on the spreading of new innovations. To make the model more realistic we considered networks of agents with small-world and scale-free properties. Analytic calculations and computer simulations revealed a broad spectrum of novel behaviors when the topology of social contacts is varied. We show that the degree polydispersity and long range connections of agents can facilitate, but it can also hinder the spreading of new innovations, depending on the amount of advantages provided by the innovation. We determine the critical fraction of innovative agents required to initiate spreading and to obtain a significant technological progress. As the fraction of innovative agents reaches the critical value, the spreading process slows down analogous to the critical slowing down of continuous phase transitions. The relaxation time proved to have a power law divergence when increasing the system size with a critical exponent 5/4. The model captures some relevant features of the spreading of innovations in telecommunication technologies.

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Conductivity with cold atoms.

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The ordinary theory of conductivity in metallic crystal relies on two assumptions: (i) a finite conductivity is mainly due to the electron scattering on impurities or lattice defects; (ii) absolute value of the electron velocity, given by the Fermi velocity, is affected neither by electric field nor collisions with impurities. It is easy to show that in the classical approach these two assumptions lead to diffusive current proportional to the electric field. In the quantum theory of ordinary conductivity, also known as the Kubo-Greenwood approach, one additionally takes into account interference between different electron paths, which was found to suppress the diffusion in the 3D geometry (the so-called phenomenon of weak localization), and completely eliminates it in the 1D geometry (Anderson localization).
In the present work we critically review the ordinary theory of conductivity, having in mind its application to cold atoms in an optical lattice. Obviously this quantum-optics system models the solid state system, where neutral atoms and optical lattice play roles of electrons and crystal lattice, respectively. However, there are two essential differences. First, unlike the Fermi electron velocity, the atom velocity is close to zero and even a weak static force considerably changes its absolute value, thus invalidating assumption (ii). The second difference concerns the nature of scattering centers. Because optical lattices are perfect, one introduces impurities by adding different species of atoms. Clearly these are not stationary impurities, although their mobility can be decreased towards zero by increasing the lattice depth. Thus one meets both the cases of "static" and "dynamic" impurities.
The first part of the talk is devoted to diffusion of cold atoms due to elastic scattering on static or dynamic impurities in the presence of a static force. We show that even in the case of static impurities the effect of forcing may overcome the effect of Anderson localization, which leads to diffusive dynamics already in the 2D geometry. In the second part of the talk we focus on drift atomic current in the presence of inelastic collisions, where we employ the master equation approach to obtain the current-voltage characteristic of the system.

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Correlations in complex systems.

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One of the fundamental properties of complex systems is their irreducibility: they depend on a huge number of details that all can become important. We argue that this is tantamount to saying that correlations in a complex system must be long ranged in the sense that any component of the system must be strongly correlated with a large number of other components, though not necessarily with its geometrically close neighbours. If we arrange the correlations between any given component with the others in descending order according to their absolute values, then we will not find a characteristic value beyond which the correlations would become negligible. This means that the correlations must fall off as a power law. This has far reaching consequences for the description of complex systems, and also for their numerical simulations. These ideas are illustrated on the example of a random Kaufman automaton where we find extremely slowly, perhaps even logarithmically decaying correlations. Preliminary results for a spin glass modell are also presented.

Subnetworks in genetic networks.

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Computational analysis of genetic networks grapples with two sources of noise: one resulting from the individual fluctuations of the gene expression and another resulting from the biological measurement. Analysis of the experimental data in this case is possible via an application of the clustering algorithms, which enable for the division of the whole set of analysed genes into groups. The characteristic feature of the clustering algorithms is that some division is achieved regardless of the possible random structure of the network. Because of that, the relevance of the obtained results is the most difficult problem in the problem. Another important question is if the applied algorithm enables to obtain the proper division of noisy data.
In our work we analyse three different clustering algorithms in terms of their ability to reproduce the initial structure of a noisy network. Networks used in computer experiment are constructed as follows: the starting point is a set of separated clusters (nodes belonging to given cluster are not connected with nodes in other clusters). Subsequently all values of the connectivity matrix are disturbed by random numbers selected from the uniform distribution $(0, \varepsilon)$, where ε is the amplitude of the noise. Next we apply the well-known Newman algorithm [1], where at the beginning the number of clusters in equal to the number of nodes of the network, and the connection of clusters is based on the maximisation of the modularity. The second analysed algorithm is based on the evolution of the connectivity matrix elements according to the set of differential equations [2]. The last algorithm is based on the synchronisation of the a of oscillators placed at the vertices of the network. There, the dynamics of the system depends on the strength of the interactions between the oscillators [3].

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The norm game – how a norm fails.

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The norm game described by Axelrod [1,2] was recently treated within the master equation formalism [3]. The strategies are: to obey the norm or to defect and to punish those who break it or not. Our aim is to control the space of parameters and to construct a phase diagram of the game. The punishment, the temptation, the punishment cost and the relaxation of vengeance are modeled by four parameters; for the fixed points and their stability, only two ratios of these parameters are relevant. Here [4] we discuss the case, when *i)* those who break the norm cannot punish and the opposite, *ii)* the tendency to punish is suppressed if the majority breaks the norm. For some values of the parameters the solution displays the saddle-node bifurcation. The stable branch describes the case when the amounts of defectors and punishers depend on the model parameters. Another solution is that everybody breaks the norm. This branch is always stable. The results indicate, that the amount of defectors can sharply increase when the punishment cost exceeds some critical value.
The model is supplemented by new Monte-Carlo simulations on the Erdős–Rényi directed network. The node degree is equivalent to the number of those who can punish. The dynamic parameters are the punishment are the punishment cost. For some values of the parameters we observe a bistable solution; the stationary state depends on the initial distribution of the boldness and the vengeance of the agents. In two different states either most of agents defects, or most of them punish. As the punishment cost increases, the latter solution is less stable and finally disappears. If the node degree is less than two, the bistability is lost; instead, we observe a continuous rise of the number of defectors with the punishment cost. More details can be found in [4].

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Coupling via threshold-induced switching in a heterogeneous agent financial model.

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We consider a class of financial heterogeneous agent models that allow for the sytematic study of deviations from the standard efficient market assumptions. An important component of these efficient market theories is the hypothesis (known as rational expectations) that even though agents differ in their future expectations of market performance, on average their forecasts are 'correct' and so the aggregate behaviour is also 'correct' with asset prices efficiently incorporating all available information. A necessary condition for the rational expectations condition to hold is that no coupling occurs between agents, resulting in the valid reduction to rational expectations via a mean-field limit.
We propose a class of models within a highly simplified trading environment in which each agent can only be long or short one unit of stock, and where an agent's 'strategy' is represented by a pair of moving thresholds straddling the current asset price. When either of the thresholds is breached by the asset price the agent switches trading position and a new pair of thresholds for that agent is generated. Such a modeling approach plausibly represents the decision-making process of irrational investors, purely mechanical buy/sell automated trading programs and all points inbetween. The thresholds for each agent evolve in time and different threshold dynamics can be interpreted as mimicking differing investor motivations ranging from pure information-processing, through rational-but-perverse behaviour induced by moral hazards or perverse incentives, to purely psychological effects.
Assuming a continuum of agents, the entire system can be modeled as a Preisach weight function that itself evolves in time, unlike the weight functions used to model magnets that are constant. This approach highlights strong similarities to other systems displaying self-organized criticality and may help shed light on the existence of power-law exponents that have been observed in many real-world financial markets

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Detecting the overlapping and hierarchical community structure of complex networks.

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Many networks in nature, society and technology are characterized by a mesoscopic level of organization, with groups of nodes forming tightly connected units, called communities or modules, that are only weakly linked to each other. Uncovering this community structure is one of the most important problems in the field of complex networks and has countless applications in different disciplines like biology, computer and social sciences. The solution is hampered by the fact that the organization of networks at the "mesoscopic", modular level is usually highly non-trivial, for at least two reasons. First, there is often a whole hierarchy of modules, with communities embedded within other communities. Second, nodes often belong to more than one module, resulting in overlapping communities. Here we present the first algorithm that finds both overlapping communities and the hierarchical structure. The method performs a local exploration of the network, searching for the natural community of each node. During the procedure, nodes can be visited more times, no matter whether they have been assigned to a community or not. In this way, overlapping communities are naturally recovered. The variation of a resolution parameter, determining the average size of the communities of a modular structure, allows to explore all hierarchical levels of the network. The method is very fast and makes pos-

sible the analysis of systems with millions of nodes. Tests on real and artificial networks give excellent results. The method is also capable to reveal the absence, not only the presence, of community structure, as shown by applications on random graphs.

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Relaxation of relativistic plasmas under the effect of wave-particle interactions.

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We simulate the acceleration of electrons to relativistic energies due to the interaction of electrons with waves generated by longitudinal (i.e., electrostatic) streaming instabilities in plasmas. Two equal systems undergoing a streaming instability evolve, one according to the classical Newtons law and one according to the special relativity dynamics equation. The system that obeys Newtons law relaxes to a Maxwellian equilibrium distribution. In the case of the relativistic dynamics, the equilibrium distribution exhibits peaks in the phase space at high momenta and a larger number of particles at high energies. This steady electron population at higher energies could explain power-law energy distribution in many plasma physics and astrophysical systems.
The present work provides a physical mechanism to substantiate the statistical mechanics approach recently proposed by Kaniadakis [1,2]. Based solely on the metric of the Minkowski spacetime, a new class of particle distributions can be derived: a hybrid distribution similar to a Maxwell-Jüttner at low energy and to power laws at high energy.
The converging conclusion of the previous theory by Kaniadakis and of the present simulation study is that extreme electron energization in streaming instabilities and the subsequent onset of high-energy power-law tails is a reflection of the nature of the Minkowski spacetime and not of any specific plasma physics phenomenon. On account of this possibility, the mechanism outlined above can have a larger scope than just the specific configuration considered.

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Two dimensional gas of Bosons or Fermions in the context of q-deformed algebra.

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It is well-known from the early work of R. May in 1960's that Bosons do not exhibit condensation phenomenon in two dimensions i.e., a two dimensional gas does not exhibit Bose condensation [1]. On the other hand it is also well-known that the thermostatistics arising from q-deformed oscillator algebra has no connection with the spatial dimensions of the system and hence exhibit q-Bose condensation in any space dimension [2,3]. Our recent work [2,3] was devoted to the study of generalized thermodynamics of q-deformed Bosons and Fermions, in particular the important thermodynamic functions such as the entropy, occupation number,internal energy and the specific heat in ordinary three spatial dimensions. We had shown that such a thermostatistics is described in a consistent manner using the Jackson Derivative in q-deformed thermodynamics. While two dimensional ensembles obey anyon statistics, as a continuous variation from Bose to Fermi, with special properties and peculiarities due to invariance under the braid group [4], it turns out that the statistics is either Bosonic or Fermionic in the q-deformed algebra formulation without any intermediate statistics, and furthermore the q-deformation of the algebra of oscillators has the same form in all spatial dimensions. It is thus unclear as to how to describe the thermostatistics of an ensemble in two dimensions. This question is therefore unresolved and we now investigate this problem. We show that the absence of Bose condensation persists also in the q-deformed case.
It is not clear whether there is any connection between the thermostatistics and q-deformed algebras in two dimensions. Many recent attempts have been made to investigate deformed algebras in two dimensions [5]. The crucial first step is thus the investigation of thermostatistics of ensembles described by q-deformed algebras in two dimensions. Furthermore it is also well-known [1] that an ensemble in two spatial dimensions has some unusual behavior e.g., there is no discontinuity in the specific heat, the specific heat at constant volume is the same for Bosons and Fermions; although the Bosons do not condense, they do crowd into the lowest few states, giving a sharply peaked distribution; the Fermi distribution is similar to the three-dimensional case with uniform occupation of all states up to the Fermi energy. We investigate the behavior of specific heat at constant volume for Bosons and Fermions and other features in two spatial dimensions in the context of q-deformed algebra.

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Continuous electrodynamics and collective dynamics of vortices in nanostructured superconductors.

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High temperature superconducting films electrodynamics can be controlled by tailored nanostructuring into microsize regions. We created local pinning modulations in YBCO films by means of confined high energy heavy ion irradiation. The high energy of the ions allows us to introduce nanometric size defects with a well defined anisotropy [1]. The dose was chosen in such a way to reduce the local critical current of the irradiated area. The nanostructured pattern consists of micrometer scale channels embedded into the as-grown superconductor. The basic geometry of a rectangular region inside strip-shaped samples was considered in order to investigate in detail the effect of the orientation of planar boundaries with respect to the super current flow direction. Here we present the two complementary orientations of the modulated region: perpendicular and parallel to the main supercurrent flow. We used a quantitative magneto-optical analysis to measure the magnetic field vector and the supercurrent for each point of the whole sample surface [2]. From a general point of view for a transversal geometry the enhanced magnetic flux diffusion at defect interfaces is well described by taking into account the electric field focusing at such planar boundaries [3]. The quantitative measurement of both magnetic field and current density distributions allows indeed comparison with continuum models of superconducting electrodynamics in thin films [4]. However in the case of micropatterned regions parallel to the main current flow, vortex bundle jumps and a Meissner volume compression are clearly observed after the vortices enter the irradiated region. The discrete nature of vortex matter in this system becomes evident from peculiar local magnetic field distribution inside the nanostructured channel and the whole scenario presents some new patterns that could be better accounted for in a framework of self organising phenomena in complex systems.

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Analysis of packet traffic in a data network model under normal traffic conditions & under distributed denial-of-service attack.

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The Packet Switching Network (PSN) is a dominant technology of data communication networks. Many factors, e.g. routing algorithms, traffic load and type, network connection topology type, influence performance of PSNs. To achieve the desired network performance, one needs to study quantitatively which of these factors and which of their interactions have more significant effect on various network performance metrics measuring service delivery of packets.
A denial of service (DoS) attack is an attempt to make a computer resource normally available in a PSN unavailable to its intended users. In a distributed DoS (DDoS) attack, the attacker carries on his/her actions by means of multiple computers, called "zombies", located at various network nodes, almost always controlled in a covert and surreptitious way, without any knowledge of their legitimate owners. For example, by issuing a huge number of ping, 'echo requests', from a very large number of zombies spread all over the network, it is possible to cripple the target victim rendering it so overloaded that it will eventually come to a standstill.
We present a modification of our existing PSN model of the Network Layer of the 7-Layer OSI Reference Model and its C++ simulator, Netzwerk [1,2,3] to study DDoS attack [4,5]. This modification allows modeling a PSN containing one victim computer and a user defined number of zombies located at either specified nodes or located at random. Start and end of attack time can be specified separately for each zombie. As in most real life cases, zombies continue to carry on their normal jobs during the attack, i.e., they act also as source, destinations, and routers of legitimate data transfers. However, each zombie also sends a packet to the victim at each time step of the simulation.
Using statistical techniques of design of experiment (DoE) and functional fixed effect models based on ANOVA (Analysis of Variance) we study how the factors routing cost metric and source load, considered at various levels, and their interactions affect response metric network performance indicator "number of packets in transit" NPT. For normal type of traffic our focus is on the study near phase transition point from free flow to congested states of our PSN model where the transmission efficiency is the highest. The aggregate measure of network performance indicator NPT provides important information about the packet traffic level and if the network is congested or not. We study the effects of DDoS attacks on NPT. Additionally, we use information entropy to detect the presence of a DDoS attack [4,5]. We consider different dynamic routing cost metrics and static routing cost metric. We present selected simulation results and outline our future work.

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Beyond the PB equation: developments in the field theoretic formulation of the statistical mechanics of a macro-ion surrounded by electrolyte solution.

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I consider a model of a macro-ion surrounded by small ions of an electrolyte solution. It is possible to transform the statistical mechanical formulation of such a system into the statistical field theory of a fluctuating electrostatic potential [1]. My field theoretical formulation goes further than [1] in three ways. Firstly, the macro-ion core is modeled as a region of low dielectric constant. Secondly, the effects of finite size charge distributions of the small ions are considered. Lastly, it is also possible to consider chemi-adsorption, in the formulation, which can be modeled by a short range interaction potential between the ions and the surface of the macro- ion. Including such considerations, I extend the Hartree approximation considered in [1]. In such a framework, it is possible to derive a modified P-B equation, which describes the mean electrostatic potential, coupled to an equation that describes the correlation function of the fluctuating field. These equations include ion correlation, finite size and image charge effects. These are neglected in the standard Poisson- Boltzmann equation, which is simply the Gaussian or saddle point approximation of this field theory for point like ions. So far, I have estimated the mean electrostatic potential, number distributions of ions and the charge density (all, at the moment, without chemi-adsorption), for a uniformly charged macro-ion, using a WKB like approximation for second of these two Hartree equations. Such an estimate illustrates qualitative physics arising from the interplay between finite size, image charge repulsion and correlation effects. Fur- thermore, it is possible to derive an integral equation for the full difference between this approximation and full Hartree solution using Greens function techniques, as well as an integral for the leading order correction. The former may work better in obtaining an exact solution than working with the the original equation. The later may be used to estimate the quantitative accuracy of this WKB like approximation to the Hartree result.

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Dynamics of human communication network.

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Human behaviors, often exhibiting irregularity characterized by a wide range of intensities and frequencies [1], are not fully driven by themselves but also motivated by others' activities. Communication including phone conversations and e-mail exchanges, etc enables such interpersonal influence and is also an important activity of humans, creating and maintaining social networks at various levels. While the topological features of large-scale human communication networks have been investigated, providing insights into the structure of social networks on global scales [2,3], little is known about the temporal evolution and collective dynamics of human communication patterns in a society. As a first step here we propose a stochastic equation describing the time evolution of individual communications that have heterogeneous volumes and influence one another, and to test the proposed theory, we analyze the calling patterns for 6 months of hundreds of thousands of mobile phone users. One of the most remarkable features identified in these large-scale human communication records is the existence of correlations in the cumulated phone calls at distant links. These correlations appear due to the local interactions of the communication activities over the connected links and we use the proposed theory to describe quantitatively this phenomenon. The activity of phone communication diffuses differently from link to link and this heterogeneity should be taken into account for mapping the information transfer pathways in the communication network. We apply the multivariate analysis to derive the diffusion matrix of the communication network and analyze its eigenvalue spectra. Based on the proposed theory, we show that there exists instability in the communication dynamics so that the phone communication patterns may be driven far from normal even by certain small perturbations. We identify such small but dangerous perturbations and investigate the resultant disturbance of the communication dynamics on a global scale.

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Birkhoff's theorem and ergometer: Meeting of two cultures.

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Statistical mechanics considers Boltzmann's ergodic hypothesis (EH) one of its foundations. Since its introduction over a hundred years ago, EH has given raison d'etre for statistical mechanics. One does not calculate time averages of what are being measured. One calculates ensembles and uses them to compare with the measurement. Is this practice correct and justified? In other words is EH really valid? If so, how widely? Is there a way one could determine it? This fundamental physics question needs a physics answer. But over the years it has drawn attention more from mathematicians than physicists. The latter seem content to accept the hypothesis despite lack of proof probably because it seems to work well, which is a powerful argument in itself. The proof has been largely left to the hands of the mathematicians. By its own nature it should be no surprise that such proof would suit the goals of the mathematicians, which need not be the same as what is needed by the practicing physicists as discussed below very briefly.
In 1931 G.D. Birkhoff [1], a noted mathematician, gave a theorem which is said to prove EH under certain conditions. They are however very abstract. It is difficult for most physicists to

discern what has really been proved. It is not unreasonable to even question [2].
whether his proof is of physical value. As an illustration consider the most famous of all math theorems, the one due to Pythagoras: The length of one side of a triangle is not independent of the other two lengths. Its condition? The triangle must be a right one. But what if we had no means of measuring angles? The condition would be abstract. Right triangles are a small subset of triangles, only to which the Pythagorean theorem relates. A reflection of Birkhoff's theorem in this light is telling. To make Birkhoff's theorem relevant to physics would require some device or devices to measure its own "angles". For the sake of physics the subset of "right triangles" is not small. Birkhoff never addresses these issues for such are not the concerns of the mathematicians but of the physicists.
In 2001 I developed a physical theory, which gives an ergodic condition, now dubbed an ergometer, for it acts like a measurer. It can tell whether a system is ergodic and why so. With this ergometer at hand one can begin to determine how widely is RH valid. This testing brings the two approaches together and the convergence of the two processes is much like meeting of two different cultures. In this talk this meeting is illustrated through solvable many-body models of physical interest [3].

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Entropy duality in nonextensive statistics.

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Nature appears non-local and nonlinear on all observable levels resulting in a large variety of complex phenomena in different scientific fields. In this situation the classical Boltzmann-Gibbs extensive thermo-statistics, applicable whenever microscopic interactions and memory are short ranged and the environment is a continuous and differentiable manifold, fails. We are dealing with systems generally subject to spatial or temporal non-local interactions, evolving in a non-Euclidean/multifractal space-time, making their behavior nonextensive. An appropriate generalization of the entropy functional [3] is intrinsically nonlinear, leading upon entropy maximization naturally to power-law distributions as manifestation of long-range interactions and correlations in the system. Moreover, the nonextensive context is per se subject to entropy bifurcation, generating a tandem character of structures, where higher order stationary states of reduced entropy reside besides lower order stationary states of increased entropy. Dynamical changes in a system are available without changing the global entropy and are controlled by a single and physically interpretable parameter, accounting for non-local and cross-scale correlations [2]. This leading entropic index is shown to be related also to the heat capacity of the system where positive values represent thermodynamic states and negative values are associated with self-interacting systems. The limiting Boltzmann-Gibbs state, subject to infinite entropic parameter, is characterized by self-duality [1]. Along with the discussion of the fundamental theoretical concepts, significant consequences of nonextensive entropy bifurcation, apparent in astrophysical environments, are illuminated by comparing the distribution characteristics arising from electromagnetically and gravitationally induced long-range interactions with those available within standard Boltzmann-Gibbs statistics.

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Collisionless relaxation in non-neutral plasmas and gravitational systems.

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Since the pioneering works of Boltzmann and Gibbs, systems with long range interactions have been a major stumbling block to the development of statistical mechanics. The difficulty was already well appreciated by Gibbs, who has noted that the equivalence between statistical ensembles breaks down when the interparticle potentials decays with exponents smaller than the dimensionality of the embedding space. When this happens, systems exhibit some very unusual properties which appear to violate the second law of thermodynamics. In this talk a theoretical framework will be presented which allows us to quantitatively predict the final stationary state achieved by two paradigmal long range interacting systems during the process of collisionless relaxation: the confined non-neutral plasmas [1] and self-gravitating gases.
It will be shown that when the initial one particle distribution function satisfies the virial condition, the non-neutral plasmas and the gravitational systems quickly relax to a metastable state described *quantitatively* by the Lynden-Bell distribution. On the other hand, if the initial distribution function does not meet the virial requirement, systems undergo violent oscillations. The theory presented allows us to quantitatively predict the density and the velocity distributions in the final stationary state. For gravitational systems it also allows us to calculate the amount of mass lost to evaporation. All the results are in excellent agreement with the dynamics simulations.

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Power-law scaling in human balance control.

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Effect of time-delayed feedback on dynamical systems has been studied extensively in recent years. One important observation is that an unstable system can be controlled by introducing time-delayed feedback. For example, the sensory-motor system of humans is controlled by neural systems which have an inevitable delay. There have been many studies on the dy-

namics of the sensory-motor system, including hand tracking [1], postural control [2], and stick balancing [3], etc. In the experiment of stick balancing at the fingertip, Cabrera and Milton found that the fluctuations in the vertical displacement angle of a stick balanced at the fingertip obey a scaling law with two scaling regions: one with slope -0.5 in the regime of low frequency and another with slope -2.5 in the regime of high frequency. To go a step further to investigate the origin of power-law scaling in the stick balancing experiment, we design a virtual experiment to study the dynamic of a balancing task in the computer screen. Subjects participated in the experiment were asked to balance a visual target moving in horizontal direction in the screen as stable as possible. The motion of the visual target is controlled by the relative horizontal distance between the visual target and a cursor in the screen produced by hand motion through a computer mouse. Performing such a virtual experiment allows us to investigate the dynamics of balance task corresponding to different system parameters, such as delayed-time effect of human sensory-motor system, boundary effect of the visual target motion, etc.

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Dynamical structure of a financial cross-correlation matrix under attacks.

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A financial market has been referred to as an example of an adaptive complex system consisting of many interacting components [1,2]. One of the salient features of these complex systems is inter-dependence between components, spatially and temporally. Accordingly, an abrupt change or variant on a certain component can be spatially dispersed over other components and affect itself temporally. The well known stylized features in security price fluctuations, namely, a fat-tailed distribution and volatility clustering, are recognized as the results of herding behaviors, which form in a complicated manner among market participants. As financial markets become increasingly larger, various investment strategies have been developed, covering a variety of financial goods. As a result, various stocks comprising a stock market are interrelated via portfolios sold by stockbrokerage firms and investment banks. Furthermore, investors positioned at various levels of information make orders in the market. Together, these behaviors make the market more complex and unpredictable.
In this work, we mainly study 492 stocks of the KOSPI (Korea Composite Stock Price Index) considered during 2000-2007 and introduce the tick data of each 1950 record, which are all quoted daily. Using this database, we investigate how the whole market, i.e., the KOSPI, responds to small perturbations exerted on specific stocks, which are top-ranked in terms of correlation coefficients. The distribution of correlation coefficients of a newly constructed correlation matrix is presented and comparison with predictions of the random matrix theory is performed [3,4], wherein the distribution of eigenvalues and the inverse participation ratio should be examined. Finally, a correlation-based network is constructed from a filtered correlation matrix, which is generated from the original correlation matrix by filtering out the market effect in terms of a multi-factors model. As is well known, the largest eigenvalue and its eigenvector are responsible for the market effect. The structure of the network is analyzed against two attack conditions, strong correlation and weak correlation attacks.

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Experimental evidence of phase synchronization between two coupled Chua circuits.

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Phase synchronization of dynamical systems has been a very active research topic in recent years. There are many applications in the fields of the plasma, laser, fluid, and biological systems. Murilo S. Baptista, et al. [1], had confirmed that the chaotic Chua circuit can be phase synchronized with a periodic signal. The chaotic attractor of the Chua circuit is the phase coherent attractors. However, most attractors do not satisfy the requirements of phase coherence. Romulus Breban [2] had proposed that the periodic driver, within the dense periodic windows of the phase incoherent chaotic attractor, can phase synchronize the chaotic attractor. Until now, phase synchronization is not observed in a chaotic attractor, with ill-defined phase, in experiment. We show numerical and experimental results of phase synchronization between a chaotic Chua circuit, with ill-defined phase, and the other quasi-periodic Chua circuit. We extract the output signal of the quasi-periodic Chua circuit to the chaotic Chua circuit by using unidirectional coupling. The real-time observation of the phase synchronization process can be detected by using stroboscopic sampling of the output voltages of the chaotic attractor. Peaks of the input signal are employed as the specific sampling time marker on the phase space. So, we can detect the phase synchronism on the real-time computer screen frames. If the two chaotic attractors are lack of phase synchronism, the stroboscopic map will spread all over the attractor in phase space. When the stroboscopic map remains constrict within a limited region of the attractor, a clear indication of phase synchronism. In this work, we will show that it is possible for an ill-defined-phase chaotic Chua circuit to be phase synchronized with a quasi-periodic Chua circuit. And, we will study the phase relations, between the two different Chua circuits, as a function of coupling modulation by the stroboscopic aspect. Numerical results also show

good agreement with the experimental observations.

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Wavelet-domain statistics of packet switching networks near traffic congestion.

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The identification of the conditions of traffic congestion in the Internet and other types of communication networks, such as wide area networks (WANs), local area networks (LANs), wireless communication systems, ad-hoc networks, and sensors networks, is an important area for data analysis and modeling. A general paradigm of these networks is represented by the Packet Switching Network technology (PSN) which can be exemplified by a data communication network consisting of a number of nodes (i.e., routers and hosts) that are interconnected by communication links. Here, after transforming the data into wavelet domain, we have applied a broad variety of advanced statistical technique (e.g., to study packet traffic in a packet switching network model, focusing on the spectral properties of packet traffic near phase transition (critical point) from free flow to congestion, and considered different dynamic & static routing metrics [1,2]. Many standard statistical techniques are effective on data that are normally distributed with constant variance. Data obtained from PSN typically violate these assumptions since they come from non-Gaussian distributions with a non-trivial mean variance relationship. Several methods have been proposed that transform data to stabilize variance and draw its distribution towards the Gaussian. Some methods, such as log or generalized log, rely on an underlying model for the data. Others, such as the spread-versus-level plot, do not. We have applied data-driven wavelet approach, called the Data-Driven HaarFisz which is distribution-free in the sense that no parametric model for the underlying PSN data is required to be specified or estimated. We show that wavelet power spectra and variance are important estimators of the changes occurring with source load increasing from subcritical, through critical, to super-critical and it depends on the routing algorithm. We apply these methodologies (e.g., [1,2,3,4,5]) to the analysis of the number of packets in transit (NPT) from their sources to their destinations in our PSN model for various routing algorithms and network connection topologies when source loads are close to the critical ones, i.e., the phase transition points from free flow to congestion. We characterize the critical point by the level of packets production at sources in the PSN model and estimate the in.uence of long-range dependence (LRD). Tackling these problems will lead to improved understanding of the effects of network connection topology, routing and cost parameters on packet traffic dynamics.

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Intermittent search strategies.

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Search strategies are crucial in various domains, ranging from chemistry, biology, to rescue operations. In lot of cases, the target is difficult to detect. In some cases, there is the choice between two search phases, one of slow motion but enabling detection, and another phase of faster motion, but non-reactive. For example, the perception of animals searching for a hidden prey can be degraded by speed [1]. Another example is transport within biological cells, where reactants can either freely diffuse or bind to motors which perform ballistic motion on the cytoskeleton [2].
I will present a model taking into account this intermittency [3,4]: diffusive reactive phases alternate with ballistic non-reactive phases. We wonder whether "losing" time in the fast non-reactive phase makes reaction faster. And if so, we wonder if there is an optimal way to share time between the two phases. To answer these questions, we calculate explicitly mean first passage time on the target. We conclude that intermittency minimizes the mean first passage time on the target under some conditions, and that there are optimal durations of the two phases: there is an optimal strategy. We studied this model in one, two and three dimensions. All these cases are relevant for example to reactant transport within biological cells. Indeed, structures like dendrites can be considered as one-dimensional, membranes are two-dimensional, cytoplasmic bulk is three-dimensional. The dependence with the target density is important in the one-dimensional case, low in the two-dimensional case, but disappears in the three-dimensional case. Our results are robust, as the optimal duration to spend in the ballistic phase is quite independent from the description of the reactive phase.

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Hydrodynamic cavitation: from theory towards a new experimental approach.

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Cavitation consists of the generation and the subsequent collapse of cavities in a liquid as a consequence of the flow of bulk liquid. This process is very important in technology and science because the collapse of the bubbles may cause the rise of local temperature and pressure. In order to understand the growth of cavities in homogeneous liquids, Harumi demonstrated that the cavitation probability can be expressed in terms of the fluctuations probabilities, but this result can not be directly used for a computational theory because some experimental data can not be measured, as the authors themselves have underlined [1]. Here the thermodynamic results, obtained in the analysis of the open systems [2], will be applied to obtained a computational thermo-physical model for hydrodynamic cavitation. The thermodynamic system considered consists of a finite volume element in which pressure variations cause the bubbles. From the experimental results [1], it can be argued that the pressure variations in the volume cause the phase transition and the consequent variations of the local temperature T, while the mean global temperature T_m of the system is constant. The bubbles cause a variation in quality $x = \frac{m_{vap}}{m_{vap}+m_{liq}}$. Moreover the system can be supposed adiabatic with respect to external environment and no chemical reactions can occur in it. Considering an horizontal pipe without external work with the mass flow through the volume considered $\dot{m}$, the fluid velocity w, the pressure P, the time during which the fluid element crosses the volume considered $\Delta\tau = \Delta y \langle w \rangle$ and the length of the pipe Δy, at the mean velocity $\langle w \rangle = (\Delta y)^{-1} \int_0^{\Delta y} w(y)\, dy$, and a two-phase flow which goes into the control volume with temperature T_{in}, pressure P_{in}, constant because of the Stevin principle, and quality x_{in}, and using the principle of maximum for the irreversible entropy variation [2], the global ratio $\frac{\Delta T}{T_{in}}$, generated by cavitation and related to quality x. This result consists of a phenomenological method of investigation, by which the global physical conditions for the stability of the cavitation can be obtained. As a consequence, by a comparison between the quality in the pipe designed and the threshold value of cavitation, it is possible to predict if the flow will be cavitating. Consequently, it represents both a physical approach to cavitation and an economical saving in planning because the theoretical analysis allows engineers to reduce the experimental tests and the consequent costs in the design process.

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Magnetic hysteresis loops of Ising spin systems with long-range interaction.

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The system of magnetic nanoparticles may exhibit many interesting properties [1]. When such nanoparticles interact magnetostatically, the system display all features of logical circuits with logical states described by a single-domain magnetization and magnetic solitons carrying the information through the circuit [2]. Slowly changed external magnetic field $\vec{B}$ may drive the system from one fully saturated state (all domains "up") to another (all domains "down") through subsequent Barkhausen-like jumps. The avalanches of domains flips show some signs of self-organized criticallity (SOC) for the scale-free or exponential topology of the circuits and antiferromagnetic coupling among domains [3,4]. These signs vanish for the magnetic domains located at the vertexes of regular grid [5].
In this paper we check and report the shape of hysteresis loops for magnetic domains located in the nodes of square lattice and interacting in long-range fashion each with other. A domain with magnetization $\vec{\mu}$ at distance $\vec{r}$ enriches the external field $\vec{B}_{\rm ext}$ by a supplementary local magnetic field $\vec{B} = 3\vec{r}(\vec{r} \circ \vec{\mu})/r^5 - \vec{\mu}/r^3$. We check the spin flips avalanches size distribution [3,4] during a system scanning with the external field $\vec{B}_{\rm ext}$ as well.
The results may influence the concept of the magnetic cellular automaton which may be used as the future version of the RAM or the ultra-high integration systems [1,2].

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Dynamic localization and transport of a quantum particle in an optical lattice.

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We study quantum mechanical evolution in an optical lattice under the influence of combined external constant and time dependent fields [1]. It is known that in the purely linear case of a tight binding Hamiltonian, the presence of a constant field induces localization of the particles due to the energy mismatch between adjacent lattices sites introduced by the field. On the other hand, when a pure ac electric field is present in the lattice, generally the particles become delocalized except in some special cases. When both dc and ac fields are present the Stark localization is generally winning except in the special case of resonant tunneling. The latter occurs when the multiphonon ac-terms match the site energy non-degeneracy introduced by

the constant field. We analyze the linear case and obtain exact solutions for the modified tunneling rates as well as the mean square displacement of the initially localized Bose gas population. We compare the exact results with simulations and find perfect agreement. Subsequently we introduce nonlinearity in the form of the Bose-Hubbard Hamiltonian that leads to the Discrete Nonlinear Schrödinger (DNLS) equation driven by combined dc and ac fields. We search numerically for the modification of the resonant tunneling condition and calculate numerically the modified tunneling rate. We compare our numerical results with approximate expressions for the tunneling rates and explore the regimes where there is agreement [2]. We also address the problem from the point of view of the integrable Ablowitz-Ladik equation where nonlinearity modifies the transfer rates directly rather than the on-site Hubbard term[3]. We compare our theoretical and numerical analysis with recent experimental findings on resonant tunneling [4] and also comment on multiband extensions of this problem [5].

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International trade network, structure and properties.

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Over last decade tremendous interests have been seen from multi-disciplinary scientific community to study different real-world and man made complex networks. Mainly these efforts were devoted to study the structure, function of networks as well as processes on these networks. Main question is if it is possible to find the key underlying features which are responsible for similar properties of the different networks of vastly different origins. It has now been argued that the concepts of the theory of critical phenomena, namely the scaling analysis and universality may be applicable to the large complex networks. In last few years different groups in the world have studied the International Trade Network (ITN) as one of the most interesting example of weighted networks where the volume of trade between a pair of countries is regarded as the link weight. In our recent studies of the ITN we have shown that the weighted International Trade Network can be looked upon as an excellent example of a complex network obeying scale-invariance and universality features. The scaled distributions of annual world trade volumes between countries collapse well to a log-normal distribution and it remains unchanged over a span of 53 years implying robustness or universality. Secondly, the nodal strength measuring the total trade volume of annual trade associated with a country grows non-linearly with its GDP with an exponent which varied from country to country but its distribution is peaked around a non-trivial value. It is also observed that a club of few rich countries trade among themselves a large fraction of the global trade and interestingly it is observed that the size of the club shrinks its size as time goes on. This observation is quantified using the "rich-club" coefficient measure of the weighted networks and it has been shown that the size of the rich-club controlling half of the worlds trade is systematically shrinking within the period of observation within 1948-2000. Finally, the main features of the real-world ITN have been reproduced by using a simple non-conservative dynamical model starting from the well-known gravity model of social and economic sciences.

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Analysis of dynamical networks by Granger causality.

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Dynamical networks [1] model physical and biological behavior in many applications; examples range from networks of neurons, Josephson junctions arrays to genetic networks , protein interaction nets and metabolic networks. Synchronization in dynamical network is influenced by the topology of the network. A great need exists for the development of effective methods of inferring network structure from time series data. Recent approaches dealt with the case of low number of samples and proposed methods rooted on L1 minimization.
Granger causality has become the method of choice to determine whether and how two time series exert causal influences on each other [2]. This approach is based on prediction: if the prediction error of the first time series is reduced by including measurements from the second one in the linear regression model, then the second time series is said to have a causal influence on the first one. This frame has been used in many fields of science, including neural systems and reo-chaos. The estimation of linear Granger causality from Fourier and wavelet transforms of time series data has also been recently addressed. Kernel algorithms work by embedding data into a Hilbert space, and searching for linear relations in that space. The embedding is performed implicitly, by specifying the inner product between pairs of points. We have recently exploited the properties of kernels to provide nonlinear measures of bivariate Granger causality [3,4]. We reformulated linear Granger causality and introduced a new statistical procedure to handle over-fitting in the linear case. Our new formulation was then generalized to the nonlinear case by means of the kernel trick, thus obtaining a method with the following two main features: (i) the nonlinearity of the regression model can be controlled by choosing the kernel function; (ii) the problem of false-causalities, which arises as the complexity of the model increases, is addressed by a selection strategy of the eigenvectors of a reduced Gram matrix whose range represents the additional features due to the second time series.
Here we address the use of Granger causality to estimate,

from multivariate time series data, the topology and the drive-response relationships of a dynamical network. To this aim, we generalize our method to the case of multivariate data. The effectiveness of the method is tested on a network of chaotic maps and on a simulated genetic regulatory networks.

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Pondering over protein-protein interactions.

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The integration of several multiomic sources (data, DB, etc.) is becoming key to advance in the protein interactomics field. At the same time it is imperative to reduce the impact of false positives and negatives which are generated by various kinds of measurements. Then, since proteomes are dynamically changing systems (due for instance to development, response to external stimuli, etc.), complementary information is needed from additional biological sources. Many in silico methods and computational techniques exist and are implemented in ordet to mine the current literature or public data repositories, and then merge the heterogeneous retrieved information to predict functional associations among proteins. In order to correct the experimental data from the influence of spurious effects, several features are examined, such as gene expression, knockout phenotype, subcellular localization, genetic interaction, phylogenetic profiling, etc., and they all need to be integrated to the original raw interaction data for improving the overall accuracy. Interaction data are of two types: binary for protein pairs, and groups of interacting partners when protein complexes are considered. The quality of the interactions is measures, usually, by coverage and accuracy. While the former refers to false negatives (the missing part of interactome information), the latter refers to false positives (i.e. bad measurements). In order to control the false detection rate, the strongest limitation to deal with is the fact that reference datasets, or gold standards, are also incomplete and biased, for instance towards proteins of high abundance, or highly connected, or with a certain cellular localization. As more methods should be used to improve accuracy, the question is how to normalize their difference, or weight their contributiuons with confidence. Some of them will detect physical binding between proteins, other methods will be designed to handle genetic interactions, others will deal with cross-links from shared pathways. It is thus required a good definition of positive gold standards, based on the degree with which interacting proteins are annotated with the same functional category, the known protein complexes, 3D structures and other biological characterization. As a result, one might find an ideal high-confidence interaction map to work with. Consequently, the issue of reliability of the detected interactions becomes very relevant, and statistical methods can offer solutions to interpret the goodness of fit of certain distributional laws in the presence of more or less error or uncertainty cover in the available interaction data.

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Designer patterns: Encoding information into precipitation structures.

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Understanding and controlling precipitation patterns formed in reaction-diffusion processes is of fundamental importance with high potential for technical applications [1,2,3]. In the field of material design the search for pattern control methods is an important challenge [4], since this new approach figures as possible competitor of the traditional *top-down* techniques, where material is removed in order to create structures. We propose a new *bottom-up* control tool for bulk-pattern creation by direct regulation of reaction-diffusion processes [5]. The flexible control of precipitation, resulting from reactions between charged agents, is realized by imposing a time-dependent electric current on the system. Our theoretical model describes the underlying dynamics for the charged agents in terms of reaction-diffusion equations obeying local electroneutrality [3]. The second stage of the process is the phase separation of the reaction product, modeled by a Cahn-Hilliard equation with an additional source term accounting for the presence of a moving reaction front [1]. Simulations show how the spacing and widths of a band-like precipitation pattern can be tuned by an appropriately designed current. We describe examples of current dynamics, yielding periodic bands of a prescribed wavelength, as well as more complicated patterns. The experimental demonstration of the feasibility of the proposed pattern control is carried out for the reaction $2AgNO_3 + K_2Cr_2O_7 \rightarrow \underline{Ag_2Cr_2O_7} + 2KNO_3$ taking place in a gel with initially separated reagents. By combining the electric field based control with various geometries and initial conditions of the setup, one can achieve a vast variety of possible patterns that allow to encode information into bulk patterns. The applicability is demonstrated in several simulations realizing the inscription of Morse codes and musical rhythms into precipitation structures.

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Bayesian updating as basis for opinion dynamics models.

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Opinion Dynamics modeling has been based, so far, in models that seem reasonable descriptions of the way people interact and change their opinions. However, while it is true that the area has observed a few first successes in describing systems as elections, it still lacks a theoretical basis. No unifying principles have been suggested and the models, while ingenious, are typically proposed in an ad hoc basis. In this article, I propose to use a decision theoretic framework as a tool for describing the interaction between the agents in Opinion Dynamics problems.
This idea of using Bayesian updating rules was presented before in the context of binary expression of choices, with a continuous underlying probability associated to each choice, the Continuous Opinions and Discrete Actions (CODA) [1] model. The CODA model allowed the observation of emergence of extremism, even when no extremist agents were observed initially. It will be briefly reviewed here as an example of the application of Bayesian update rules.
In order to study Bayesian updating rules as a basis for modeling the agents, those rules will be applied to agents who exchange continuous opinions about the value of a variable x [2]. The likelihood each agent assigns to hearing from another agent a specific value of x will be defined by a Gaussian term centered in his current opinion and a probability associated to an uniform distribution, representing the idea the other agent might have no idea about what he is talking about. This model will allow us to understand better what approximations to rational behavior are involved behind the rules of some of the standard current continuous models.
The effect of updating only a few moments of the distribution will be studied. A simple agent who updates only its average opinion will be shown to be produce results similar to those of the Bounded Confidence model. By also updating the uncertainty associated with that average value, the consequence will be the survival of several different opinions in the long run. These surviving opinions will be closer or more distant to each other, depending on the probability of error and initial uncertainty. Finally, the effect of the probability of error in the emergence of a network of agents who are able to influence each other will be discussed.

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Emergence of feedforward networks and entrainment in oscillator networks via a biological synaptic plasticity rule.

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Neurons connected by chemical synapses form asymmetric networks whose synaptic strengths, that is, weights of edges, are generally plastic. A common plasticity rule (Spike-Timing-Dependent Plasticity) dictates that synaptic weights are strengthened most when a presynaptic spike time precedes a postsynaptic spike time by a small amount of time, namely, of the order of 10 milliseconds or less. If a postsynaptic spike slightly precedes a presynaptic spike, the corresponding synaptic weight is depressed. Because of the asymmetric learning window, STDP does not enhance mutual coupling. In other words, even if two neurons are connected bidirectionally, increases in the synaptic weight in one direction imply decreases in the opposite direction. For stability, the amount of the depression is usually set larger than that of the potentiation. Accordingly, STDP may not promote synchrony, which often stems from strong mutual coupling.
We analyze STDP-based dynamical evolution of neural networks driven by a pacemaker. Pacemaker neurons are those unaffected by rhythms of others and found in, for example, the basal ganglia and respiratory networks in the pre-Botzinger complex. We model neural dynamics by the standard phase oscillators and connected them via a standard sinusoidal coupling function. The pacemaker is equipped with a prescribed natural firing rate. The other neurons are equipped with the identical natural firing rate that is smaller than that of the pacemaker. We assume that 100 neurons are initially placed in an asymmetric random network with mean degree 10. We pick a value of the initial coupling strength common to all the synapses and examine what kind of networks and dynamics result in the course of sufficiently slow evolution of networks based on STDP. We also establish a theory to explain behavior of two-neuron networks (i.e. one pacemaker and one follower oscillator).
We show that STDP promotes formation of a feedforward network. In this situation, the pacemaker is eventually located at the root of the feedforward network, and the other oscillators are entrained by the pacemaker with small delay. The initial synaptic weights necessary for the entrainment to occur are much smaller with STDP than without STDP.

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Jamming transitions induced by a slow vehicle in two-lane traffic flow.

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Traffic flow is a kind of self-driven many-particle system of strongly interacting vehicles [1,2]. We study the vehicular traffic on a two-lane highway. The vehicular traffic changes highly by introducing a slow vehicle. The dynamical behavior varies with density. The dynamical phase transitions occur with increasing density. We study the dynamical phase transitions induced by a slow vehicle in a two-lane vehicular traffic. We extend the conventional optimal velocity model to the two-lane traffic by taking into account the lane changing [3]. We apply the extended model to the two-lane traffic flow including a slow vehicle under the periodic boundary condition. The fundamental (flow-density) diagram is derived. The fundamental diagram changes highly by introducing a slow vehicle on a two-lane highway. It is found that there are the four distinct states for the two-lane traffic flow including a slow vehicle. The spatio-temporal patterns are shown for the distinct traffic states. The dynamical state of traffic changes with increasing density. The traffic flow shows (1) the free traffic at a low density, (2) the jammed traffic at an intermediate density, (3) the homogeneous traffic with headways different from lanes with increasing density furthermore, and (4) the homogeneous congested traffic with the same headway on 1 and 2 lanes at a high density. It is shown that the dynamical transitions among the distinct states occur at three values of density. At the first transition point, the free traffic changes to the jammed state. The jammed state changes to the homogeneous traffic with headways different from lanes at the second transition point. At the third transition point, the homogeneous traffic changes to the homogeneous congested traffic with the same headway on 1 and 2 lanes. The dependence of traffic current on the velocity of slow vehicle is derived from numerically and analytically. The jamming transitions are analyzed theoretically. The transition points and fundamental diagram derived from the theory agree with the simulation result.

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Colony formation in bacteria - Experiments and modeling.

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We first present experimental results of colony formation in bacteria. We then discuss modeling attempts for them.
If one wants to argue about the behavior of biological organisms from the viewpoint of population, the main characteristics of individual organisms may be reproduction and active motion. They reproduce themselves and move actively in an appropriate environment. Since these characteristics of reproduction and active motion are so common to almost all biological organisms, patterns produced by the population such as colonies and even cities may exhibit some universal features. Here we would like to address this problem, especially focussing on the colony formation of bacteria.
Common bacterial species Bacillus subtilis is known to exhibit several distinct colony patterns, depending on the environmental conditions, namely, substrate softness and nutrient concentration [1]. Distinct types of colony patterns include DLA, Eden, densely branched with smooth circular envelope called DBM, concentric-ring and simple disk ones [2]. Some of them are known to be seen in inorganic systems such as dendritic crystals and viscous fingers in fluid dynamics. But macroscopic growth behavior of some colonies really reminds us of the formation of human colonies such as villages, towns and cities. Only differences seem to be characteristic time and length scales. We have established the morphological diagram of colony patterns, and then examined and characterized both macroscopically and submacroscopically how they grow. For instance, DLA-type colonies were found to grow under the diffusion-limited condition of nutrient, and various experimental results on simple disk colonies were found to be consistent with the solution behavior of two-dimensional Fisher's equation. The most impressive growth is the formation of concentric-ring colonies [3]. By repeating migration (moving) and consolidation (resting) periods alternately, bacteria produce well-organized concentric-ring colonies. Our experimental results suggest that macroscopically the most important factor for its growth is the cell population density, i.e., that there seem to be higher threshold of the cell population density to start migrating and lower one to stop migrating. Bacterial cells may have cell-density sensing mechanism and start-stop switching mechanism through cell-density threshold. Very recently we found that several other common bacterial species such as Serratia marcescens and Eschelichia coli also exhibit repetitive growth of colonies under appropriate conditions. This fact suggests that this type of periodic growth is common in the bacterial world. All these results imply that although bacteria are mostly regarded as single cell organisms, they never make their colony individually and randomly but somehow collaborate multicellularly. Microbiological and/or genetic reasoning is clearly needed.
There have been quite a few phenomenological models to explain or reproduce observed macroscopic patterns of bacterial colonies [4]. They are all based on the nonlinear reaction-diffusion-type PDEs. The reason is the following: The reproduction of bacterial cells can be regarded as a kind of chemical reaction associated with a few factors such as nutrient, which is clearly nonlinear. The active motion of cells can be roughly approximated as diffusion, which may also be nonlinear under some environmental conditions. Several of models proposed so far are reviewed systematically and critically, based on our experimental results.

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Bridging structure and function via network spectral properties.

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Some of the most important questions regarding networks have to do with their collective dynamics. For example, brain networks, and the biological networks of protein interaction and gene regulation are important precisely because of their capacity for complex, adaptable behavior. The dynamics of networks is influenced by the properties of the individual nodes and by their connections, but even in relatively simplified mathematical models of idealized coupled oscillators, let alone in systems like the brain,the collective behavior of the network can be quite difficult to infer from that of the component parts. We discuss ongoing efforts to understand the connections between network structure and dynamical function.
By explicitly separating the contributions of network structure and individual node behavior, the master stability funtion (MSF) [1] technique provides a powerful approach to a very limited structure-function question (namely, the linear stability of a perfectly synchronized state of identical units). The MSF uses network Laplacian spectra as a bridge between structure and dynamics. We demonstrate an approach to diagnosing dynamics by identifying collective degrees of freedom derived from the network spectra, which is partly inspired by the MSF but uses more spectral information [2].
As one application, we show that in a system of partially synchronized oscillators, variables derived from the network Laplacian eigenvectors behave quasi-independently even well away from the linear regime where we would expect them to be most relevant. Eigenvectors with higher eigenvalues are effectively frozen out of the dynamics at weaker coupling strengths than those with lower eigenvalues. Therefore many features of the path to synchronization (and not only linear stability of a synchronized state) can be explained in terms of spectral properties. In particular, we use these spectral variables to study the effects of clustering [3] and coupling asymmetry[4] on the path from incoherence to partial and complete synchronization. Spectral variables, among other uses, are well-suited to examining the role of modularity (community structure) versus other network properties in collective dynamics.
The outlook for approaches to the structure-function relationship based on natural collective variables of the network is examined.

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Contact line stability of ridges and drops.

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Contact line (CL) stability of liquid drops or ridges on solid surfaces has been under a debate within last years. The point is that for sufficiently small drops the negative CL tension may overcompensate the ensuing gain of surface free energy and cause different types of instabilities. This question has been long considered as a purely academic one, since the critical drop size is typically in the nanometric range. Recently, however, when the nanoscale has become directly accessible to experimental observation, it received a renewed interest in view of possible implications.
The question of the CL stability has been addressed, among others, by Brinkmann et al [1] for axisymmetric drops or long liquid filaments (ridges). Within the framework of a macroscopic capillary theory the authors have obtained complete phase diagrams as a function of the contact angle, line tension, and the perturbation wavelength, showing both stable and unstable regimes. In particular, it was shown that a negative CL tension destabilizes a liquid filament with respect to contact line deformations of any wavelength for sufficiently small contact angles, which queries the standard view that the spontaneous break-up of a filament into a chain of droplets (known as varicose or Rayleigh-Plateau instability) occurs only for wavelengths large compared with the lateral size of the filament.
However, this analysis treats the interfacial tension, contact angle, and the CL tension as independent parameters, whereas for an actual system they are linked on the microscopic level. This prompted us to revisit the problem of CL stability in order to determine what kind of instabilities can be encountered in realistic systems and hence, which parts of the phase diagrams deduced by Brinkmann et al are physically plausible.
Within the framework of a semi-microscopic interface displacement model we analyzed the linear stability of sessile ridges and drops of a non-volatile liquid on a homogeneous, partially wet substrate, for both signs and arbitrary amplitudes of the three-phase contact line tension [2]. Focusing on perturbations which correspond to deformations of the three-phase contact line, we found that drops are generally stable while ridges are subject only to the long-wavelength Rayleigh-Plateau instability leading to a breakup into droplets, in contrast to the predictions of the capillary model by Brinmann et al. Therefore, we demonstrated that the short-wavelength instabilities predicted within the framework of the latter macroscopic capillary theory occur outside its range of validity and thus are spurious.
We plan to extend the developed approach to the analysis of CL stability of nanodroplets on fibers.

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Structural properties of complex networks.

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The k-core decomposition was recently applied to a number of real-world networks (the Internet, the WWW, cellular networks, etc. and was turned out to be an important tool for visualization of complex networks and interpretation of cooperative processes in them [1-4]. Rich k-core architectures of real networks were revealed. The k-core is the largest subgraph where vertices have at least k interconnections. We find the structure of k-cores, their sizes, and their birth points the

bootstrap percolation thresholds. I will show a derivation of exact equations describing the k-core organization of a randomly damaged uncorrelated network with an arbitrary degree distribution. This allows us to obtain the sizes and other structural characteristics of kcores in a variety of damaged and undamaged random networks and find the nature of the k-core percolation in complex networks.
We have found that the unique properties of the k-core percolation transition are essentially determined by the corona subset of the k-core, that is, by vertices with exactly k connections to the k-core. These are the weakest vertices in the k-core. The critical correlations in the k-core are due to the correlations in the system of the corona clusters. In the "k-core phase", the corona clusters are finite, but their sizes and longrange correlations grow as the network approaches the k-core percolation threshold. The mean size of a corona cluster to which a randomly chosen corona vertex belong diverges at the k-core percolation threshold. This quantity plays the role of a critical susceptibility in this problem. So, the k-core percolation threshold coincides with the percolation threshold for corona clusters, and the k-core phase is the normal phase for the corona. The dramatic difference from the ordinary percolation is that the corona disappears on the other side of the threshold, and so critical fluctuations in the phase without the k-core are absent. For understanding the nature of this transition, we have studied the process of the destruction of the k-core due to the random deletion of vertices. The deletion of a vertex in the k-core results in the clipping out the entire adjacent corona clusters from the k-core due to the domino principle. This effect is enormously increased when corona clusters become large near the k-core percolation threshold. In the threshold, the removal of a tiny fraction of vertices results in the complete collapse of the corona and the k-core. In this respect, the k-core percolation problem can be mapped to a model of cooperative relaxation, which undergoes critical relaxation with a divergent rate at some critical moment.

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Role of DNA configuration in stochastic gene control.

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Simple chemical reactands search for each other by three-dimensional diffusion until encounter, as originally described by Smoluchowski. At low concentrations of reactands, pure 3D search is quite inefficient. Nature has therefore come up with various active and passive solutions to speed up search. I will discuss the example of facilitated diffusion as observed in gene regulation on a molecular scale. A gene is regulated through binding of specific, passive regulatory proteins.
Facilitated diffusion of regulatory proteins for a specific binding site on a DNA molecule consisting of megabases of basepairs combines 3D volume diffusion with 1D motion along the DNA. The latter is mediated by so-called non-specific binding, a finite binding affinity to DNA also at segments that are not the specific binding site. The combination of these two mechanisms significantly speeds up the search. In addition intersegmental transfers that occur at contact points of chemically remote segments of the DNA due to looping give rise to Lévy flights along the DNA to further optimise the search. I will discuss in detail the influence of the DNA configuration on the search dynamics of binding proteins. The theoretical claims are supported by recent single DNA molecule experiments. While most of these investigations are performed in dilute in vitro conditions, an increasing body of information is revealed on the differences of gene regulation in living cells. In the cell larger biomolecules occur at very dense concentrations, apparently causing the subdiffusion of regulatory proteins and longer nucleotides. I will introduce a simple model to account for the subdiffusional exchange of regulatory proteins with DNA in the cell.

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Global positioning of central traveler destinations.

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Worldwide tourist arrivals and departures, on the year of 2004, is partially a complex human system embedding sociologic and economic ties that emerge from local ties [1]. The arrivals (weighted edges) over 206 countries and territories (nodes) around the World are analyzed over in strength and out strength shows, resulting on a highly directed and heterogenetic network. The random network of connectivity is reflects a power-law network of intensities [2].
Interdisciplinary the cohesiveness on tourist arrivals is analyzed, showing the particularity of each method to detect social subgroups, dyads, triads, k-core and clustering coefficients. All the methods are performed on topological and weighted network, and the flows are considered directed. These considerations highlight the importance of weighed and directed networks for depicting certain patterns.
The local interactions define global patterns of networks. On a dyad analysis, the regional density and reciprocity of connections increases with tourist arrivals, as expected. Clustering was also studied on the local level, where topological and weighted networks bring different perspectives, claiming the essence of weights on networks measurements [3]. Local patterns have interesting differences on triad pattern, which may affect modelling constraints. Along with clustering is also the network dynamic, as the growth rate of global clustering coefficient follows the total number of international tourist arrivals and departures.
Local and global interactions interaction measurements were analyzed, and on the global level k-core approach, the subgraph in which every node is a neighbour to at least k nodes,

reveals a strong concentration of information flow on hubs [4]. The betweeness of links, measuring information flow of connection, has a decrease over weights, which brings question on which are the main connections of spectrum nodes and how important are the weak ties [5]. By other hand k-core measures over global subgroups structure, where the most connected subgraph has almost the whole information flow centrality, and aggregates almost all the connections weight. The importance of location on network structure is challenge by comparing centrality with k-core measurements, questioning better location for better connections in addition to the number of connections, degree.

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Glass transition in a monoatomic simple liquid.

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We present a molecular dynamics study of a monatomic simple liquid in two dimensions, where atoms interact with other atoms through the Lennard-Jones-Gauss (LJG) potential [1]

$$V(r) = \epsilon_0 \left\{ \left(\frac{r_0}{r}\right)^{12} - 2\left(\frac{r_0}{r}\right)^{6} - \epsilon \exp\left[-\frac{(r-r_{\rm G})^2}{2\,\sigma^2}\right] \right\} ,$$

with $r_{\rm G} = 1.47\,r_0$, $\epsilon = 1.5$, $\sigma^2 = 0.02\,r_0^2$. It is known that the ground state of this system with these parameters is a complex phase consisting of pentagonal and triangular tiles. We first prepare a well-equilibrated liquid state at a temperature far above the melting temperature ($\approx 0.44\,\epsilon_0/k_{\rm B}$). Then we quench the system at a constant rate to the specified temperature below the melting temperature. Although the super cooled state at intermediate temperatures is crystallized when it is kept at the temperature, the crystallization time at lower temperatures become longer, and below a certain temperature, the system is turned into a glassy state. When the glassy state is heated again at a constant rate, the temperature dependence of the energy deviates from the Dulong-Petit law at a certain temperature, signifying the glass transition. We find that the glass transition temperature is lower for slower cooling rate of the quenching process, which is in line with experiments for glass formers. We investigate static and dynamic properties of the glassy state by the structure factor, the dynamical structure factor and the intermediate scattering function. We show that phason-like dynamics exists in the glassy state and that the super cooled LJG liquid shares the same characteristics in dynamics with other glass forming systems. This fact indicates that the topological ordering, not the chemical ordering, is important in determining the dynamical characteristics of the glass forming process.

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Analysis of high-resolution product prices in an online shopping mall.

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Recently, huge point-of-sale (POS) databases containing detailed records of all customer purchases in many stores have been attracted the attention of both physicists and economists [1,2]. In this conference, we will show statistical laws of high-resolution product prices in an online shopping mall.
"Kakaku.com" is the famous online shopping mall in Japan. There are about 1,500 electronics retail stores. About 12 million persons come to the shopping mall in one month. Kakaku.com always ranks the stores from the best price to the worst price for each product. As a result, many stores are engaged in a price war.
We investigate a time series graph of average prices of a LCD television in all stores. We can observe a fractal property of the prices in the time axis. The Hurst exponent of the price is 0.5, and the auto-correlation function for the price change decays very quickly. Therefore, the statistics of product price changes is close to random walk. However, volatility of the product price has a long memory. These statistical laws can be also observed in financial markets [3,4]. In this conference, we show statistical similarities between a product price in competitive online markets and a stock price in financial markets.

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Predator-prey model for stock market fluctuations.

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We present a dynamical model that describes the evolution of offer and demand in a financial market. The model considers a nonspatial set of interacting agents that may be willing to operate in the market, either by selling the stock or by buying it, or that are not interested in operating at that moment. The agents change their mind only through self (they may decide to leave the stock exchange by their own) or mutual influence, and the decision is adopted on a random basis. The model is thus is inspired in a predator-prey model for population dynamics [1].

One of the most appealing characteristics of such a systems is the reported presence of large oscillations in the value of the density of any two competing species. This finite-size effect is self-instigated by a noise-induced resonant magnification. The values around which both densities fluctuate can be obtained after imposing the "thermodynamic" limit: in this situation the system is described by a coupled set of Volterra equations, with a sole stable solution. In fact, the resonant frequency of the fluctuation in the species population can be approximately expressed in terms of the coefficients of the linear mean field system in the surroundings of the stable fixed point.
This set-up can be used in the modelling of the order book, but in our case, the difference in population of the two sets of active agents, sellers and buyers, will be directly translated into the evolution of the stock through a simple model of excess of demand, that will rise the price when there are more buyers than sellers in the market, and fall it in the opposite case. The random nature of the fraction of each operating agents is responsible for the stochastic evolution in the asset value, whereas the oscillating behaviour promoted the presence of bullish and bearish periods in the data series in a natural way, with no external interference needed.
We will simulate the time evolution of the system under different market conditions, analyse the most relevant traits, and compare them afterwards with empirically obtained properties.

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Lyapunov modes for nonequilibrium systems.

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We present the numerical observation of Lyapunov modes (the mode structure of Lyapunov vectors) in a system maintained in a nonequilibrium steady state [1]. The system is a two-dimensional particle model for heat conduction with a hot reservoir on the left and a cold reservoir on the right. The model is similar to others studied recently where boundary conditions couple the system to the reservoir, [2,3]. These models also exhibit anomalous thermal conductivities which is studied both numerically and analytically using simplified stochastic models which reflect the underlying Hamiltonian structure.
The modes show some similarities and some differences when compared with the results for equilibrium systems. The Lyapunov exponents in the step region show positive and negative pairs of equal magnitude for the transverse modes, whereas the longitudinal and momentum proportional modes have negative exponents of larger magnitude than the positive ones. This effect is proportional to the external temperature gradient.
The breaking of energy conservation removes a zero exponent and introduces a new mode. The transverse modes are only weakly altered but there are systematic changes to the longitudinal and momentum dependent modes. This is the first systematic study of Lyapunov modes of a nonequilibrium system as a function of system size and external temperature gradient. The possible connections between stability properties, such as Lyapunov exponents and modes, and measurable thermodynamic properties is explored.

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Quanum Onsager-type equations for Bohm's potential.

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When investigating the transport of fermions or bosons, Sommerfeld's parameter gives a rule of thumb on whether a classical approach can be taken or a quantum treatment is needed: if the parameter is much smaller than one, then degeneracy is negligible and a classical treatment is adequate; otherwise, degeneracy and quantum effects are important and a quantum approach must be taken. In this work, interest is focused on particle current and heat flux when quantum effects cannot be neglected. From Bohm's interpretation of Quantum Mechanics, a quantum kinetic equation (QKE) has been derived in a previous work by the present authors [1]: a kinetic equation taking into account quantum effects can be applied to a wide variety of problems, as a number of approximate equations can be derived from the QKE - just to name a few, macroscopic conservation equations [2] and Onsager-type equations. The present work investigates how the presence of Bohm's potential affects both particle current and heat flux, leading to a set of "Onsager" equations relating these two quantities to density and temperature gradients. To this aim, starting from the QKE obtained in [1], with an expansion in Legendre polynomials, Onsager-type equations are derived: it must be stressed though that, since Bohm's force is proportional to the third derivative (in space) of the density, the expansion must be carried at least to the terms of third order, i.e., a P3 rather than the usual P1 approximation. A further point is that, since in the derivation of the QKE a collision term has to be specified: in deriving the aforementioned QKE the Boltzmann, Uehling and Uhlenbeck (BUU) collision term was adopted [1,3]. In the present work the coefficients appearing in the Onsager-type equations are defined in terms of the density and temperature, with the use of the appropriate equilibrium distribution function: Fermi-Dirac or Bose-Einstein. The differences between the behaviour of fermions and that of bosons will be demonstrated.

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A transport theory approach to percolation of liquids through porous media.

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The motion of fluids through porous media is a subject of interest in many fields of engineering and medicine. It is often tackled in the framework of diffusion approximation: however, this approach can only take into account density gradients, whereas temperature distribution also plays an important role in transport phenomena. The interplay of density and temperature gradients is best analyzed with the help of Onsager-type equations [1]. In the present work, a method is presented that is based on an Onsager equations approach to the problem of a liquid diffusing through a porous medium.
Onsager equations are, originally, a phenomenological description of non-equilibrium thermodynamics: but once they are written down in terms of gradients and coefficients, these latter still need to be determined for the equations to be useful. This can perhaps be done experimentally, or by yet other means: however, it is possible to derive them from kinetic theory, making suitable approximations on the distribution function and then making use of Boltzmann's equation [2]. In this sense, they become a rigorous result of kinetic theory, and a useful tool in those physical instances in which legitimate use can be made of them, allowance being made for the assumptions and limitations introduced in their derivation [3].
The first problem presenting itself is how to incorporate the effect of liquid state into the Boltzmann-Vlasov equation that will be the starting point of the present work: this entails calculating the self consistent Vlasov field due to the intermolecular forces. Once this field calculated, from expanding Boltzmann-Vlasov equation in series of spherical harmonics and truncating to the first two terms, Onsager-type equations are derived for a liquid diffusing in a slab of porous medium subjected to temperature and pressure gradients. The coefficients of these equations are calculated considering van der Waals type interactions.
The situation considered in the present work is as follows: a slab of porous material, having breadth and length large enough compared to thickness that the problem may be viewed as one-dimensional, is in contact with a liquid having known temperature T_0 and pressure p_0 on one side, andT_L and p_L on the other side. The liquid diffuses through the porous material under the effect of density and temperature gradients.
Onsager equations are then solved to obtain temperature, density and pressure profiles inside the slab, and from these latter the distribution function for the liquid molecules.

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Vector precoding for wireless multi-antenna systems.

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Current wireless communications technology schemes usually involve base stations with several antennas to transmit to users with terminals (e.g. mobile phones or laptops), also employing several antennas. This multiple-input-multiple-output (MIMO) channel is represented by a matrix, with its elements corresponding to the complex propagation amplitudes from each transmitting to each receiving antenna. Due to battery and size limitations it is desirable for user terminals to minimize the complexity of their algorithms. For this to happen, it is often the case that the algorithmic complexity has to be shifted to the base station. A simple yet promising suggestion was recently proposed by Peel *et al.* [1] and involves premultiplying (*precoding*) the transmitted signal with the inverse of the channel matrix, so that simple symbol-by-symbol detection can be used in lieu of sophisticated multiuser detection at the receiver. As a result however, one has to pay the price of considerably increased transmitting power when some eigenmodes of the channel matrix become vanishingly small.
This paper studies a nonlinear vector precoding scheme based on [2,3] which minimizes the transmit energy by relaxing the transmitted symbols to a larger alphabet for precoding, while preserving the minimum signaling distance. Essentially the minimization procedure tries to find the transmit vector within the alphabet space closest to the highest energy eigenvectors of the channel matrix. The replica method is used to analyze the average energy savings with random MIMO channels in the large-system limit.
It is found that significant gains can be achieved with complex-valued alphabets. The analysis applies to a very general class of MIMO channels, where the statistics of the channel matrix enter the result via the R-transform of the asymptotic empirical distribution of its eigenvalues, which has been used extensively in free probability theory. When the transmit antennas are less than the receive antennas, it is shown that the minimum transmit energy is in fact finite. The results are also analyzed within the one-step broken replica symmetry assumption.

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On the cooling and freezing processes.

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In the last period, the mass and heat transfer processes are important subjects in the cooling and freezing food product domain [1]. The past years literature' study reveals an increasing interest for controlling and freezing front propagation in these kind practices [1,2,3]. A series of analytical or numerical approaching were developed [3,4,5].
The present paper exposes a comparative investigation for such specific processes, in order to succeed in finding out a representation. In this means, using experimental data sets for strawberry cooling and freezing process, it was researched a model to succeed in evaluating the temperature' dynamics and the heat transfer' magnitude. In the first step were considered different identification system methods in order to find out the mathematical models. For restricted temperature domains, could be developed a series of linear mathematical models, in good correspondence with the experimental data sets [5]. Basing on them, it is considered a merged general mathematical model.
On the second stage, considering specific experimental circumstances, it was derived a finite difference model in order to succeed in reaching the same problem of the prediction for the temperature evolution.
In the last step, is proposed a physical model in order to describe the transfer process and to cover the experimental data results. For the transfer coefficients evaluations, were built up a specific algorithm and a related software program in order to obtain a polynomial approximation. Considering the previous results from the specific literature, our methods offer a comparative precision and could be extended to other cooling and freezing food product processes.

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On the analysis of the climatic factors influences.

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In our days, theoretical investigations are involved and used in a huge class of research domains [1]. An important aim in the most such works is to obtain the mathematical model for the considered system or process [2, 3]. The common approach is therefore to start from measurements of the behavior of the system and the external influences (inputs) and try to determine a mathematical relation between them without going into the details of what is actually happening inside the system [4]. Accepting this way, could be investigated the climatic phenomena in a very sensible area of the Lower Danube zone where, in the past years, a series of climatic disasters had been happening and the ambiance risk factors ' management is a necessity. Using a huge historical evidence data warehouse, in this way, could be considered and designed a nonlinear model for analysis of these climatic factors. In a first step, it was considered mathematical model building' procedures, employing a series of system identification methods in order to succeed in reaching the correlation between the recorded water rains' amounts and the rivers' flood levels evidences [2, 3]. For restricted data domain, could be developed a series of linear mathematical models, and, basing on them, it could be built a merged covering model. This approach is an initial phase toward a DSS - Decision Support System aiming the climatic risk management. The equivalent correlation is analyzed in the same time, using statistical methods, in order to find out the parameters' domain.
In the second step, is was intended a physics model which includes the land shape representation and watercourse sections' drawing, in order to obtain a good correlation between the rivers flood levels' evolution and the water rains' flux amounts [5]. For this stage, was used a particular GIS system in correlations with a specific computer software package which included a series of numerical evaluation methods.

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Solvable multi-species reaction-diffusion processes with particle-dependent hopping rates.

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By considering the master equation of the totally asymmetric exclusion process with particle-dependent hopping rates on a one-dimensional lattice, we obtain two types of boundary conditions i.e. type 1 and type 2 boundary condition, for p-species exclusion processes, in the terms of two $p^2 \times p^2$ matrices c and b respectively. By using the conservation of particles, we obtain a constraint on the sum of the elements of each column of matrix c and b. Each boundary condition introduces the different interactions, so we have two new families of the multi-species reaction-diffusion processes with particle-dependent hopping rates. The first family (i.e. reaction-diffusion models) has the

following reactions

$$\begin{array}{rcll} A_\alpha\emptyset & \rightarrow & \emptyset A_\alpha & \text{with rate } v_\alpha, \\ A_\alpha A_\beta & \rightarrow & A_\gamma A_\delta & \text{with rate } c_{\gamma\delta}^{\alpha\beta}. \end{array}$$

In this model, we have the case of distinct particles where each particle A_α drifting to the right with its own intrinsic hopping rate v_α if the right site is empty, and the particles interact with each other if two of them are adjacent. The second family (i.e. drop-push models), describes the following processes

$$\begin{array}{rcll} A_\alpha\emptyset & \rightarrow & \emptyset A_\alpha & \text{with rate } v_\alpha, \\ A_\alpha A_\beta\emptyset & \rightarrow & \emptyset A_\gamma A_\delta & \text{with rate } b_{\gamma\delta}^{\alpha\beta}. \end{array}$$

In this system, any particle can hope to right site with rate depends on type of particle, if that site is empty. If the right site is occupied, the left particle can still hope to that site by pushing the right one, but in the mean time there is a probability that the type of the particles change. It is also shown that, there is a drop-push reaction between a block of $n+1$ adjacent particles with rate that is specified by a specific combinations of $b_{\gamma\delta}^{\alpha\beta}$'s. These families are the generalization of TASEP models have been studied in [1] and [2], respectively, in which all particles have the equal hopping rate.

Another reactions are annihilation processes that they are diffusion-limited reaction-diffusion processes. In these interactions, particles annihilate pairwise or coagulate to the right and left whenever they meet each other. These processes are

$$\begin{array}{rcll} A_\alpha A_\beta & \rightarrow & \emptyset A_\beta & \text{with rate } \delta_{\alpha\beta}, \\ A_\alpha A_\beta & \rightarrow & A_\alpha\emptyset & \text{with rate } \gamma_{\alpha\beta}, \\ A_\alpha A_\beta & \rightarrow & \emptyset\ \emptyset & \text{with rate } \eta_{\alpha\beta}. \end{array}$$

It is important that, if we consider the initial state with n particles, no annihilation processes can lead to a n-particle state at any later time. So we don't have the conservation of particles and therefore the constraint on the sum of the elements of each column of matrices can be changed to modified constraint, and by imposing this modified constraint to the matrices c and b, the rates of annihilation processes enter the matrices c and b.

Now we add above annihilation-diffusion processes to the previous reactions of both families. We obtain two distinct new models. It is shown that these models are exactly solvable in the sense of the Bethe anstaz, provided some conditions are satisfied. The two-particle conditional probabilities and large-time behavior of such systems are also calculated.

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Weakly interacting Bose-gas in disordered environment.

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We consider zero-temperature phase diagram of a weakly interacting Bose-gas in a static random potential $U(\mathbf{r})$ with pair correlation function $\langle U(\mathbf{r})\,U(\mathbf{r}')\rangle = \kappa^2\delta(\mathbf{r}-\mathbf{r}')$. We first analyze the structure of single-particle states extending the Zittartz-Langer-Lifshitz-Halperin-Lax theory. A characteristic length scale of quantum states is the so-called Larkin length $\mathcal{L} = \hbar^4/(m^2\kappa^2)$, where m is the particle mass. The characteristic energy is $E_{\mathcal{L}} = \hbar^2/(2m\mathcal{L}^2)$. States with energy $E \geq E_{\mathcal{L}}$ are delocalized, other states are localized. The states with the negative energy E such that $|E| \gg E_{\mathcal{L}}$ or, equivalently with the radius $R \ll \mathcal{L}$, are strongly localized. They have an exponentially small density $R^{-3}\exp\left(-\frac{\mathcal{L}}{R}\right)$. The tunneling amplitude between them is $t \sim \exp\left[-\exp\left(\frac{\mathcal{L}}{3R}\right)\right]$. The ground state of the ideal Bose gas in such a potential is not ergodic: it depends on a specific realization of the random potential or on the details of cooling process. The interaction makes the gas ergodic. We assume disorder weak enough: $\mathcal{L} \gg a$, where a is the s-scattering length. At small average concentration $n \ll n_c \sim (\mathcal{L}^2 a)^{-1}$, the Bose particle occupy deep bound states with the radius $R \leq R(n) = \mathcal{L}/\ln\left(\frac{n_c}{n}\right)$. Each deep state is occupied by a well defined number of particles and has maximally uncertain phase. The tunneling amplitude is $t \sim \exp\left[-\left(\frac{n_c}{n}\right)^{1/3}\right]$. This is a disordered singlet state with no superfluidity. At n approaching n_c the phase correlation between different wells grows and a transition to a coherent, but inhomogeneous superfluid state proceeds.

We applied the same ideas to the weakly interacting Bose gas in a harmonic trap. At very small disorder $\mathcal{L} > \ell$, where ℓ is the oscillator length, the crossover from a condensate in the ground oscillator state to the Thomas-Fermi spherical cloud takes place at increasing number of particles. At a stronger disorder $\ell < \mathcal{L} < 3Na$, the cloud is single connected and spherical. It becomes divided into fragments of the linear size $\mathcal{L}$ at $N > \mathcal{L}/(3a)$. The phase of the condensate inside a fragment is uncertain, the superfluidity is absent. The total linear size of the fragmented cloud grows as $R_F \sim (Na)^{1/3}\mathcal{L}^{2/3}$. When N reaches the value $N_c \sim \ell^6/(\mathcal{L}^5 a)$, the trap energy exceeds the disorder. The cloud again becomes single connected, but its size exceeds the Larkin length. The phase coherence is established in the cloud and it becomes superfluid. The size of such cloud is determined by the Thomas-Fermi approximation $R \sim (aN)^{1/5}\ell^{4/5}$.

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Fisher's information metric in the context of generalised entropies.

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A main topic of statistical physics is the study of statistical models which depend on a few parameters $\theta_1, \theta_2, \cdots, \theta_n$, such as inverse temperature β, and chemical potential μ. The goal is then to derive thermodynamic relations between these parameters θ_j and the corresponding extensive quantities U_j. With each set of θ there corresponds an equilibrium probability distribution p_θ, or a density matrix ρ_θ. The extensive quantities U_j are then the expectation values with respect to these p_θ of some variables, denoted H_j.

Together, the p_θ form the statistical manifold, the geometry of which is determined by Fisher's information metric. This metric can be derived from a potential, which is the Massieu function $\Phi(\theta)$. Usually, this potential is the logarithm of the partition sum. Its Fenchel dual is the thermodynamic entropy S(U). The well-known thermodynamic relations

$$\frac{\partial\Phi}{\partial\theta^k} = -U_k\ , \quad \text{and} \quad \frac{\partial S}{\partial U_k} = -\theta^k\ ,$$

follow from this duality.

The information-theoretic interpretation of Fisher's metric is based on the inequality of Cramér and Rao. This inequality is optimal when the model belongs to the exponential family. This means that the equilibrium states satisfy the variational principle with respect to the Boltzmann-Gibbs-Shannon entropy / the von Neumann entropy. However, some models of statistical physics do not belong to the exponential family – see for instance [1]. For such models a generalised notion of exponential family is appropriate.

A particular feature of the generalised formalism is the appearance of escort probability distributions [2], denoted P_θ. The pair (p_θ, P_θ) satisfies a generalisation of the inequality of Cramér and Rao. It becomes optimal when the model belongs to the generalised exponential family and the escort P_θ is chosen in a suitable manner [3,4]. The generalised Fisher metric involves both p_θ and P_θ. The Massieu function $\Phi(\theta)$ still is a potential for the Fisher metric. The duality relation between $S(U)$ and $\Phi(\theta)$ is still valid. One can conclude that equilibrium thermodynamics is valid to a much wider extent than has been derived in standard statistical mechanics based on the Boltzmann-Gibbs-Shannon / von Neumann entropy functions.

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Why the persistent current observed at a non-zero resistance is challenge to the second law of thermodynamics.

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The second law of thermodynamics holds the supreme position among the laws of Nature. Nevertheless some challenges [1] force us to feel a doubt about this universality. It is written in the end of the section "Nikulov Inhomogeneous Loop" of the book [1] that the experimental results revealing evidence of a direct equilibrium motion represent a cogent challenge to the second law but conclusive violation cannot be claimed. I am agree. But I should note that only a miracle can rescue the second law against the experimental evidence of the persistent current I_p observed at a non-zero resistance $R > 0$. The equilibrium persistent current is a periodical function $I_p(\Phi/\Phi_0)$ of magnetic flux Φ inside thin-wall superconductor ring with the period equals the flux quantum $\Phi_0 = \pi\hbar/e$. This periodicity becomes apparent in the observations [2] of the quantum oscillations of the ring resistance $R(\Phi/\Phi_0)$ and the dc voltage $V_{dc}(\Phi/\Phi_0)$ measured on semi-ring of asymmetric rings in the temperature region corresponding to the fluctuation region of superconducting transition where $R > 0$. The observations of the dc voltage $V_{dc}(\Phi/\Phi_0)$ and the persistent current $I_p(\Phi/\Phi_0)$ at $R > 0$ without any external dc power source [2] testify an intrinsic dc power source RI_p^2 since any current must disappear at $R > 0$ without a power source because of the power dissipation RI_p^2. The equilibrium persistent current $I_p \neq 0$ is observed at $R > 0$ only in the fluctuation region. Therefore it is enough obvious that RI_p^2 is the power of thermal fluctuations, i.e. equilibrium dc power, any observation of which contradicts to the second law. This challenge to the second law evident experimentally has profound cause in symmetry breaking between opposite directions because of the Bohr's quantization on the macroscopic level [3]. The Bohr's quantization can not break the symmetry at the atomic level and has broken it at the macroscopic level because of the fundamental difference between the essence of the quantum phenomena on these levels [4]. I would like to consider consequences of the symmetry breaking for foundations of statistical physics and destiny of the second law.

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Networks of optimal synchronizability.

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In a network of dynamical elements, one of the most fundamental issues is the relationship between the network structure and the collective dynamics of the system. The study of complete synchronization, a simplest form of collective dynamics in a network in which all oscillators behave in precisely the same way, provides an excellent starting point for understanding how collective network behavior arises. The stability of complete synchronization in a weighted directed network of oscillators can be formulated using the well known master stability function and the eigenvalues of the Laplacian matrix encoding the topological structure of the network. A measure of synchronizability, defined as the relative range of overall coupling strength for which synchronization is stable, can be computed as the ratio of the largest and the smallest nonzero eigenvalues of the Laplacian matrix. Thus, a network property and a collective dynamical property are simply and elegantly related to each other through the eigenvalues. In this talk, I will use this measure of synchronizability to address an interesting optimization problem [1,2]: which network topology has the highest synchronizability? After formulating the problem, I will establish that the optimality condition can be expressed as a simple condition that all nonzero eigenvalues of the Laplacian matrix are equal. This condition, therefore, defines a class of networks with optimal synchronizability. To see which types of networks have the optimal synchronizability, I will first look at a large subclass of optimal networks which has well-defined directionality. This subclass contains all directed trees with appropriate connection weights. The optimal networks of this type are easy to construct explicitly and its optimality can be intuitively understood to arise from the hierarchical ordering

among the oscillators. However, many of them suffers from a long transient before the exponential stability sets in. In exploring other types of networks with optimal synchronizability, I will discuss certain symmetry of the entire class. I will also discuss the robustness against the structural perturbation, i.e., how does a optimal network lose the optimality as the network connection weights are perturbed?

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Combinatorial entropies and statistics for particles in indistinguishable states.

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In the combinatorial basis of entropy ("Boltzmann principle" [1]), the entropy function is defined as $H = N^{-1} \ln \mathbb{W}$, where N denotes the number of entities within the system and $\mathbb{W}$ is the number of ways in which a specified realization of the system can occur (the "statistical weight"). By maximizing this entropy (MaxEnt), subject to the constraints on a system, one selects its "most probable" (MaxProb) realization, which can be used to represent the system [2,3]. Examining systems of particles within states, four scenarios can be considered: (i) distinguishable entities and states, for which H converges to the Shannon entropy as $N \to \infty$; (ii) indistinguishable entities and distinguishable states, for which H converges to the Bose-Einstein entropy (or, if a maximum of one entity per state, to the Fermi-Dirac entropy) [4]; (iii) distinguishable entities and indistinguishable states, which give a new statistic [5]; and (iv) indistinguishable entities and states. The last two cases are examined here, for both non-degenerate and equally degenerate levels, leading to new entropy measures which incorporate factorial terms, coding parameters and Stirling numbers of the first or second kind; their asymptotic convergence as $N \to \infty$ is markedly different to Maxwell-Boltzmann (multinomial) statistics. In the non-asymptotic case ($N \ll \infty$), it is necessary to represent such systems using a "superpositional" most-probable distribution, involving an average of all possible distributions weighted by their probabilities of occurrence [3]. The analysis has important implications for the analysis of a variety of network, transport, biological, economic and social systems.

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Exchange bias in spin glasses and nanoparticle systems.

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The low temperature hysteresis curves of archetypal Cu(Mn) and Ag(Mn) spin glasses exhibit exchange bias and abrupt magnetization jumps. This was discovered and investigated in detail several decades ago [1,2]. The behaviour has similarities with the Meiklejohn and Bean [3] discovery of exchange bias in systems with Co nanoparticles in cobalt oxide shells. Recently it was found that multilayers of spin glass films and thin ferromagnetic layers show exchange bias [4], in similarity with layers of antiferromagnetic-ferromagnetic materials. The origin of exchange bias is still an unsolved problem.
The zero field (in experiments low field) dynamics of spin glasses is governed by the collective spin glass phase, which however is strongly affected (destroyed) by a (higher) magnetic field. Cooling the spin glass in a high magnetic field as is done in an exchange bias experiment and entering into a region of in-field slow dynamics (crossing the dynamic AT-line) introduces a field induced unidirectional anisotropy (and excess moment) that at lower temperature becomes frozen in up to higher reversal fields than the cooling field; i.e. introduces exchange bias. Does this excess moment also cause the observed collective jumps in the magnetization curves? This phenomenology gives a verbal understanding and questions, but how does the behaviour come to pass from spin glass theory and models? In similarity, the uncompensated antiferromagnetic moments at the interface between a ferromagnetic and an antiferromagnetic layer is locked in the direction of the ferromagnetic magnetization direction when cooled through the antiferromagnetic transition temperature in a magnetic field. The weak excess moment of the AF layer becomes locked in its cooling direction at lower temperatures and causes exchange bias? Is a similar interface effect the cause of the exchange bias in spin glass-ferromagnetic multilayers [4], or is it the intrinsic exchange bias of Cu(Mn) that causes the phenomenon? These and related questions and problems regarding spin glass and nanoparticle magnetic hysteresis will be discussed.

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Self organization of hierarchy and villages in timid and challenging societies.

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Emergence of social hierarchy and villages in various societies is studied on the basis of the agent-based model proposed by Bonabeau et al. [1]. The trait of societies is incorporated in the model by modifying the diffusion rule. We introduce two

different societies, a timid society where all individuals are peace-loving and timid [2], and a challenging society where all individuals are warlike and brave [3]. In the timid society, the self-organization of hierarchy is shown to occur in two steps as the population is increased, i.e. there are three states, one egalitarian and two hierarchical states. Within the mean field approximation, we show that the transition from the egalitarian to the first hierarchical state is continuous and the transition from the first hierarchical state to the second one is discontinuous [4]. In the challenging society [3], the self organization of hierarchy as the population is increased accompanies formation of villages and the structure of the transition depends on the sequence of random walk of individuals. When the order of the walk is pre-assigned to individuals, the hierarchical society consists of villages in each of which there exist a few winners with many middle class and losers and the distribution of winning probability is widespread. When the order of the walk is random, then the transition occurs in two steps; while the first transition is continuous to a society with widespread winning-probability, the second transition is discontinuous to a society which consists of a small number of extreme winners and many middle class and losers [5]. In the latter case, a giant village is formed and some people stray around the village. Our results indicate that among controlling processes of diffusion and fighting of individuals and relaxation of wealth, the trend of action which individuals take plays the pivotal role in the self-organization of hierarchy and villages.

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A closer look at linear response theory via an exactly solvable model of classical spins in a time-dependent rotating magnetic field.

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In the absence of any generally accepted method to investigate nonequilibrium statistical mechanics problems and formidable difficulty in solving equations of motion for a system with a given Hamiltonian, linear response theory (LRT) [1,2] has been widely used. However, rather unfortunately, there are no means provided by the theory to delimit its range of validity. Most people think that LRT is valid for very small fields and for some limited time after the onset of the perturbation.
Past works examining the validity of linear response theory [3,4] had been either mathematically rigorous but sophisticated or physically plausible but qualitative, and there were few direct comparison of the consequences of LRT with those of exact calculation. Hence, in this work, we would like to examine explicitly the valid region of LRT via an exactly solvable model of noninteracting classical spin in a time-dependent rotating field described by the Hamiltonian

$$H = -h_z S_z - h_0\{S_x \cos(\omega t) - S_y \sin(\omega t)\} \ ,$$

where S_α $(\alpha = x, y, z)$ denotes the total spin components, and this Hamiltonian originated from nuclear magnetic resonance studies of magnetic materials.
In order to carry out a calculation within LRT, we write the previously described Hamiltonian in the form $H \equiv H_0 + H_1(t)$ where H_0 denotes the unperturbed Hamiltonian in the form $H_0 = -h_z S_z - h_0 S_x$ and $H_1(t)$ denotes the perturbed Hamiltonian in the form

$$H_1(t) = h_0[S_x\{1 - \cos(\omega t)\} + S_y \sin(\omega t)] \ .$$

By making use of the formula

$$< S_\alpha(t) >_{ne} = \ < S_\alpha(t) >_{eq} + \frac{1}{i\hbar}\int_0^t dt' < [S^I_\alpha(t), H_1(t')] > \ ,$$

and by taking the classical limit of the result obtained from this, we find the nonequilibrium total spin components within LRT. Then we compared the LRT results with those of exact calculation. Thereby, we found that the nonequilibrium magnetization components of the classical noninteracting spins in a rotating field obtained via linear response theory have the value close to that of exact calculation for very small fields and small angular frequencies far away from the resonance frequency. However, it is invalid at or near the resonance angular frequencies, irrespective of the magnitude of the rotating magnetic field. Thereby, it cannot be used to quantitatively interpret the results of magnetic resonance experiments.

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Geometric aspects and the Legendre structure of generalized entropies.

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In recent decades *information geometry* [1,2], which is geometry based on the Legendre structure, has been successfully applied mainly to the fields of statistics, information theory, learning theory and so on. The purpose of this talk is to demonstrate that information geometric viewpoints give new insights and interesting ways of understanding for the framework of statistical physics with generalized entropies.
Let $p_\theta(x)$ be a probability distribution parametrized by θ. Consider a function $\psi(p_\theta)$ convex with respect to θ, or so-called *divergence* functions $D(p_{\theta_1}, p_{\theta_2})$ satisfying certain conditions. Using derivatives of ψ or D, the corresponding information geometric structure such as *Riemannian metric* and a pair of *dual affine connections* is induced to the space of distributions p_θ. The typical and familiar examples for ψ or D in statistical physics would be the generalized Massieu potentials or the minus of generalized entropies, or generalized relative entropies. In this first part we briefly introduce some useful general results of such geometries making much of the relation with the Legendre structure.
In the second part we discuss properties of the space of distributions and Tsallis relative entropy minimization using information geometry induced from the Tsallis relative entropy. We prove that the space has constant curvature with respect to the

geometry, and from which, the nonextensive relation of Tsallis (relative) entropy is derived. In this sense, the nonflatness is geometrically interpreted as a source of the nonextensivity. Further, by showing that the special geometric property called *α-autoparallelism* holds for the *normalized q-expectation constraints*, we establish uniqueness and global minimality of the equilibrium distribution for the Tsallis relative entropy minimization problem. The relation with the escort probability is also slightly discussed. The results of this part are mainly in [3].
Finally in the third part, we discuss geometric aspects of a certain type of nonlinear Fokker-Plank equation. The behavior of the solution is characterized in terms of geometry induced from a so-called *Bregman divergence*.
Using the fact that the corresponding generalized exponential family is flat, we establish the Pythagorean relation of the divergence. Further, we show that the trajectory of the solution on the family coincides with the geodesic curve with respect to the one of the dual affine connections. The physical implication of this fact is also discussed.

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Derivation of the Tsallis, Rényi and nonextensive Gaussian entropy from deformed multinomial coefficients.

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We define for an arbitrary generalized logarithmic function $\ln_{\mathcal{Q}}(x)$, where $\mathcal{Q} = \{Q_i\}_{i=1,\cdots,m}$, is a set of parameters and $x \in \mathbf{R}_+$, the respective deformed multiplication and division, in such a way that the relation $\ln_{\mathcal{Q}}(x \otimes_{\mathcal{Q}} y) = \ln_{\mathcal{Q}}(x) + \ln_{\mathcal{Q}}(y)$ holds. Based on the above deformed operations we present two deformed factorial operators and construct then the respective deformed Multinomial Coefficients (dMC) [1]. For this construction we have introduced two different parameter sets, $\mathcal{Q}$, as given above, and $\mathcal{R} = \{\mathcal{R}_\rangle\}_{\rangle=\infty,\ldots,\setminus}$, whose distinction is of central importance. By replacing the generalized logarithm $\ln_{\mathcal{Q}}(x)$ in the two dMC-definitions with the one-parametric logarithmic-like functions $\ln_q(x) := (x^{1-q} - 1)/(1 - q)$ and $\ln_{2-q}(x) := (x^{q-1} - 1)/(q - 1)$ respectively, using each time the appropriate parameter set, we can derive the Tsallis, Rényi and Nonextensive Gaussian entropy (S_q^{T}, S_r^{R}, S_q^{G}), shedding light on the relation between the three above entropy definitions in the respective validity range of their parameters. Considering the two dMC's, it can be proved that the entropy S_q^{T} is defined in the ranges $q \in [0, 1]$ and $q \in [1, \infty)$, respectively. Accordingly, the Tsallis entropy describes different statistics in the above q-ranges, since the different structures of the dMC's is not a matter of a q-transformation. Analogous results we obtain for the entropy S_q^{G} under the extension of the $q_{\leq 1}$-branche to $q \in (-\infty, 1]$. In the case of Rényi entropy S_r^{R} both dMC's lead to the same r-range, namely $r \in [0, 1]$. Another important point within the dMC-approach is the determination of the maximum configuration function. For the entropy S_q^{T} we obtain a q-exponential and a $2 - q$-exponential function in the ranges $q \in [0, 1]$ and $q \in [1, \infty)$, respectively. This result is the same for the entropy S_q^{G} in the respective q-ranges, while in the case of S_r^{R} the maximum configuration function is an ordinary exponential function. The two latter results are in contradiction with the ones obtained from the Jaynes's Max-Ent Principle [2,3] and indicate that the application of this formalism does not lead generally to correct results.

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Non-extensivity parameter of self-similar statistical system.

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We consider a self-similar statistical system being inherent in the homogeneous function $f(x) \sim x^q$ characterized with the non-extensivity parameter q. This system possesses a discrete symmetry with respect to multiple action of the Jackson derivative

$$D_\lambda f(x) \equiv \frac{f(\lambda x) - f(x)}{(\lambda - 1)x} = \frac{[q]_\lambda}{x} f(x) \ ,$$

reduced to the q-basic number $[q]_\lambda \equiv (\lambda^q - 1)/(\lambda - 1)$ with dilatation parameter λ. Action of the Lee group operator $T_\lambda(t) \equiv \exp(tD_\lambda)$ with transformation parameter t is shown to give

$$T_\lambda(t) f(x) = \mathrm{e}^{t/x} f(x) \tag{1}$$

at condition

$$[q]_\lambda [q-1]_\lambda \cdots [q-(n-1)]_\lambda = 1 \tag{2}$$

where $n - 1 < q < n$, $n = 1, 2, \ldots$ Physically, the transformation (1) means the dilatation strengthens exponentially the homogeneous function within the domain of small values x due to the self-similarity condition.
In slightly dilated system ($\lambda \to 1$) the condition (2) takes the simple form $\prod_{m=0}^{n-1}(q - m) = 1$. In the case of one-fold dilatation ($n = 1$) the homogeneity exponent $q = 1$ relates to the linear function $f(x) \sim x$. At two-fold dilatation ($n = 2$) the homogeneity exponent is reduced to the gold mean $q = (1 + \sqrt{5})/2 \simeq 1.618$. For dilatation orders $n \gg 1$, one obtains $q \simeq (n - 1) + 1/(n - 1)!$. In general case of the λ-dilated system, one has

$$q \simeq (n - 1) + \frac{\ln\{1 + (\lambda - 1)/[n - 1]_\lambda!\}}{\ln \lambda} \ .$$

At $n = 1$ the homogeneity exponent does not depend on the dilatation parameter λ, whereas with increasing $n > 1$ the q value decays monotonically to the magnitude $q = n - 1$ the faster the more order n of dilatation.

Obviously, the value $n = 1$ related to non-dilated system corresponds to usual case of the Boltzmann-Gibbs statistics with $q = 1$. The case $n = 2$ relates to the Tsallis statistics, for which the non-extensivity parameter equals to the gold mean $q \simeq 1.618$ at $\lambda = 1$ and decays to the lower limit $q = 1$ with $\lambda \to \infty$. What about the dilatation orders $n > 2$, the physical nature of related statistics has not been discussed before.

Nonextensive/dissipative correspondence in relativistic hydrodynamics.

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We present nonextensive version of hydrodynamical model for multiparticle production processes proposed by us recently [1]. It is based on nonextensive statistics assumed in the form proposed by Tsallis and characterized by nonextensivity parameter q which characterizes some specific form of local equilibrium, which in the case of nonextensive thermodynamics replaces the local thermal equilibrium assumption of the usual hydrodynamical models. It accounts therefore, in a natural way, for some intrinsic fluctuations possibly existing in the hadronizing system and/or for all possible long range correlations and memory effects present in the hadronization system and not accounted for when using the usual formulation. In its new form our model resembles, in its ideal fluid version, a nonextensive perfect fluid, described by the following equation

$$\mathcal{T}^{\mu\nu}_{q;\mu} = \left[\varepsilon_q(T_q)u^\mu_q u^\nu_q - P_q\Delta^{\mu\nu}_q\right]_{;\mu} = 0, \qquad (1)$$

with ε_q, P_q and u^μ_q being the respective q-modified energy density, pressure and flow vector, whereas $\Delta u^\mu_q \equiv u^\mu_q - u^\mu$ with flow field u^μ corresponding to $q = 1$. However, using now relations $\varepsilon(T) = \varepsilon_q(T_q) + 3\Pi$ and $P(T) = P_q(T_q)$ (T and T_q are, respectively, temperature and its q equivalent) and denoting $\Pi \equiv \frac{1}{3}(\varepsilon_q + P_q)[x^2 + x]$, where $x \equiv u^\mu_q u_\mu$, one gets the standard form of dissipative hydrodynamic equation for *viscous fluid* (here $W^\mu = (g^{\mu\alpha} - u^\mu u^\alpha)\,\mathcal{T}_{q\ \alpha\beta}u^\beta$)

$$\left[\varepsilon(T)u^\mu u^\nu - (P(T) + \Pi)\Delta^{\mu\nu} + W^\mu u^\nu + W^\nu u^\mu + \pi^{\mu\nu}\right]_{;\mu} = 0. \qquad (2)$$

Therefore solving Eq. (1) for *ideal q-fluid* is equivalent to solving Eq. (2) for *viscous fluid* and the corresponding nonextensive entropy current includes automatically higher order terms in dissipative entropy current. The possibility of such *nonextensive/dissipative correspondence* is then further investigated and elucidated with connection between the perfect nonextensive hydrodynamical model and dissipative phenomena being stressed and discussed in more detail.

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Social group dynamics in networks.

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The rich set of interactions between individuals in the society results in complex community structure, capturing highly connected circles of friends, families, or professional cliques in a social network. Due to the frequent changes in the activity and communication patterns of individuals, the associated social and communication network is subject to constant evolution. The cohesive groups of people in such networks corresponding to families, friendship circles, work groups, etc., are under permanent change as well. These groups can grow by recruiting new members, or contract by loosing members; two (or more) groups may merge into a single community, while a large enough social group can split into several smaller ones; new communities are born and old ones may disappear. Our knowledge of the mechanisms governing this community dynamics is limited, but is essential for a deeper understanding of the development and self-optimisation of the society as a whole. Here we discuss a new algorithm based on a clique percolation technique [1], that allows to investigate in detail the time dependence of communities on a large scale and as such, to uncover basic relationships of the statistical features of community evolution. Our focus is on two networks of major interest, capturing the collaboration between scientists and the calls between mobile phone users. According to the results, the behavior of smaller collaborative or friendship circles and larger communities, eg. institutions show significant differences [2]. Social groups containing only a few members persist longer on average when the fluctuations of the members is small. In contrast, we find that the condition for stability for large communities is continuous changes in their membership, allowing for the possibility that after some time practically all members are exchanged. We also show that the knowledge of the time commitment of the members to a given community can be used for predicting the communitys lifetime. These findings offer a new view on the fundamental differences between the dynamics of small groups and large institutions.

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Superstatistics and renewal critical events.

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Superstatistics [1] offers a general framework to describe nonequilibrium stationary states of complex systems (e.g., a Brownian particle in a inhomogeneous fluid environment). The statistical distribution associated with the stationary state is

described as a superposition of Boltzmann-like factors, each one generated by a local and fast dynamical component of the system. The central idea of superstatistics is that these Boltzmann-like factors are weighted by the probability density of an intensive parameter fluctuating on a large spatio-temporal scale (e.g., temperature in a thermal bath, energy dissipation rate in a turbulent flow, etc...).
Following this approach, the authors of Ref. [2] introduced a methodology to derive a superstatistical description from a given experimental time series. An equivalent superstatistical model is found by estimating the probability distribution of the intensive parameter and the model is tested by checking the separation of the time scales, which is a crucial condition for the validity of superstatistics.
In addition to the superstatistical features, it should be convenient to consider also the aspects related to *renewal theory* [3] and, in particular, to the presence of *critical events*, i.e., *Renewal non-Poisson* events [4] , characterized by genuine randomness and often by power-law or stretched-exponential decay. In fact, different models can be in agreement with the same distribution density of the intensive fluctuating parameter, and the renewal features could give some effort in the choice of the most suitable model.
In recent years a statistical techinque, based on the concept of *Renewal Aging*, was developed [4,5]. This technique can detect the presence of critical events in a time series, thus evaluating the renewal features of the time series itself.
In this talk we will show the application of Renewal Aging analysis to some simple models with different renewal properties and we will make a brief discussion about the possible connections between superstatistics and renewal theory.

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Replica approach to glass transition and jammed states of hard spheres.

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Hard spheres are ubiquitous in condensed matter: they have been used as models for liquids, crystals, colloidal systems, granular, and powders. Packings of hard spheres are of even wider interest, as they are related to important problems in information theory, such as digitalization of signals, error correcting codes, and optimization problems. In particular, amorphous packings have attracted a lot of interest as theoretical models for glasses, because for polydisperse colloids and granular materials the crystalline state is not obtained in experiments for kinetic reasons. I will review here a theory of amorphous packings, and more generally glassy states, of hard spheres that is based on the replica method: this theory gives predictions on the structure and thermodynamics of these states. In dimensions between two and six these predictions can be successfully compared with numerical simulations. I will also discuss the limit of large dimension where an exact solution seem to be possible.
The aim of this talk is then to identify a class of amorphous packings that might be described using of equilibrium statistical mechanics, that is, in a static framework. These packings will be defined as the infinite pressure limit of glassy states of hard spheres: such glassy states, if dense enough, are well defined metastable states with very long life times, and should be then correctly described by equilibrium statistical mechanics.
I will also to clarify the main assumptions that are beyond this theory and in particular the relation between our static computation and the dynamical procedures used to construct amorphous packings.

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Scale invariance and self-averaging in disordered systems.

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We study by large scale numerical simulations the long distance behaviour of correlation functions in the random field Ising model (RFIM) in three dimensions and in the random ferromagnetic Potts models in two dimensions in the disordered phase.
In both cases we find that the correlation length is not self-averaging near the critical temperature T_c while it is self-averaging far away from T_c. We find in particular that at long distances $|x-y| >> 1$

$$\overline{< \sigma(x)\sigma(y) >^2} \sim \overline{< \sigma(x)\sigma(y) >}^2 .$$

We discuss the implications of this finding.
In field theory, this behaviour can be explained only by the formation of bound states. It is well known that in most cases interactions between replicas are attractive and that in two dimensions even a small attraction produces bound states. In three dimensions the formation of bound states is not generic but depends on the strength of the attraction.
We argue that these non perturbative phenomena are at the origin of the breaking of the perturbative renormalization group and dimensional reduction for the randon field Ising model in two and three dimensions.
We expect also the possibility that these non perturbative phenomena invalidate other predictions of perturbative renormal-

ization group most notably the classifications into universality classes. According to perturbative renormalization group, many different distributions of the random fields and several diluted antiferromagnets in a magnetic field should be in the same universality class. If this is not correct, it would explain the strong disagreement between different experiments on the critical behaviour of those systems.

Phase space embedding method. The hydrided ZY-4 SEM micrographs evaluation by time series technique.

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This paper aims to quantitatively characterize the fractal properties of the "physical objects" surfaces analyzing images obtained from scanning electron microscopy (SEM). Therefore, we introduce some efficient algorithms and develop a computer application most of them based on the time-series method [1]. Then we use the phase space embedding technique to reconstruct the attractor and to compute the autocorrelation dimension. The procedure to analyze a SEM micrograph starts by loading a bitmap version of the image in our software application [2]. The first step in our analysis is to generate the Weighted Fractal Dimensions Map (WFDM) which reveals the possible modified structures, according to previous papers [1], [2] and [3]. The second step is to generate a time (in fact a spatial) series for a selected area of the image as follows: we cut the original image in pieces of about 12-16 pixels height; by putting together all these pieces we obtain a strip. The time (spatial) series is obtained by computing the average value of the gray level for each of the columns of pixels within the strip. The nonlinear analysis of these data series starts with the reconstruction of the attractor by embedding the series in a higher dimensional phase space. The Zircaloy-4 tubes occlude hydrogen during operational service in the presence of the high-temperature water, used to extract heat from the CANDU nuclear reactor [4]. The SEM micrographs of the hydrided Zircaloy-4 samples surface have been analyzed. The present study was done on 30 SEM micrographs with modified areas (with the precipitated hydride). The average value of the autocorrelation dimension for the modified areas (highly hydrided zones) is 0.1032.

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Two-dimensional diffusion model for the biopolymers dynamics at nanometer scale.

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In this paper the biopolymer transport dynamics in a 2D lattice model is investigated. The polymers translocation through a nanometer sized pore, namely nanopore, plays a critical role in many biological processes. For example the motion of DNA and RNA molecules across nuclear pores, gene swapping and protein transport through membrane channels involve the motion of biopolymers across membranes [1]. Brownian dynamics simulation is the most used molecular method for the biopolymers transport quantitative evaluation. The movements of particles which follow Brownian motion are described by Langevin equation. The problem of polymer translocation through a nanopore in the presence of an external electric force has been investigated. The polymer chains are modeled as bead-spring chains of Lennard-Jones (LJ) particles with the Finite Extension Nonlinear Elastic (FENE) potential. The bead-to-bead Van der Walls interactions are modeled by a repulsive LJ potential between all bead pairs. The general dynamics of each monomer results from the random bombardment of solvent molecules [2]. The polymer transport dynamics in a 2D lattice model (by focusing on the time of polymer translocation through a nanometer pore) has been investigated. Obviously the polymer escaping time is function of the monomers number. Due to the existence of an external electric field, the first monomer of polymers is pulled through the nanopore from cis to trans zone. In the absence of the external field, the translocation is extremely slow, even impossible. The bigger the external force resulted from the electric field action, the highest the probability such that the polymer to translocate the pore. In particular, we were interested in the effect of superimposed electric field on the polymer translocation time [3]. The dependence of the diffusion process on the stiffness and the monomers number of the polymer is also considered.

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Tuning the correlation decay of resistance fluctuations in multi-species networks: From power-law to exponential decay of correlations.

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A new network model is proposed to describe the $1/f^{\alpha}$ resistance noise of a resistor in non-equilibrium stationary states for a wide range of α values ($0 < \alpha < 2$). The network is made by different species of resistors, distinguished by their resistances and by their energies associated with thermally activated processes of breaking and recovery. The correlation

behavior of the resistance fluctuations is analyzed as a function of temperature and applied current, in both the frequency and time domains. For the noise exponent, the model provides $0 < \alpha < 1$ at low currents, in the Ohmic regime at a given temperature, with α decreasing at higher temperatures, and $1 < \alpha < 2$ at high currents in the non-Ohmic regime. Since the threshold current associated with the onset of nonlinearity depends also on temperature, the proposed model qualitatively accounts for the complicate behavior of α versus temperature and current observed in many experiments [1]. Correspondingly, in the time domain, the auto-correlation function of the resistance fluctuations displays a variety of behaviors (from a power-law up to an exponential decay) which are then finely tuned by the external conditions.

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A model of subjective supply-demand: the maximum Boltzmann/Shannon entropy solution.

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The present authors have put forward a projective invariant model of rational trading (Information Theory Model of Markets [1]). The expected (mean) value of the time that is necessary to strike a deal and the profit strongly depend on the adopted strategy. A frequent trader often prefers maximal profit intensity to the maximization of profit resulting from a separate transaction because the gross profit/income is the correct benchmark. To investigate activities that have different periods of duration we define, following the queuing theory, the profit intensity as a measure of this economic category. In the above mentioned model, the profit intensity in a repeated trading has a unique property of of attaining its maximum at a fixed point regardless of the shape of demand curves [2] for a wide class of probability distributions of random reverse transaction (ie closing of the position). These conclusions remain valid in the analogous model based on supply analysis. This type of market games was considered in the research aiming at finding an algorithm that maximizes trader's profit who negotiates prices with the Rest of the World (collective opponent) that posses a definite and objective supply profile. Such idealization neglects the sometimes important influence of an individual trader on the demand/supply profile of the Rest of the World and in extreme cases questions the very idea of demand/supply profile. Therefore we put forward a trading model that in which the demand/supply profile of the Rest of the World induces the (rational) trader to (subjectively) presume that he/she lacks all knowledge concerning the market but his/hers average frequency of trade. This point of view introduces maximum entropy principles into the model and broadens the range of economics phenomena that can be perceived as a sort of thermodynamical system [3,4]. The profit intensity has a fixed point with a astonishing connection with Fibonacci classical works and looking for the quickest algorithm for extremum of a convex function: this function reaches its maximum when the probability of transaction is given by the Golden Ratio rule $\frac{\sqrt{5}-1}{2}$. This condition sets a sharp criterion of validity of the model.

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A model of subjective supply-demand: The minimum Fisher information solution.

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The present authors have put forward a projective invariant model of rational trading (Information Theory Model of Markets [1]) that implies a model for subjective demand/supply profiles if one considers the closing of a position as a random process. Such models, although simple and elegant, have several drawback from the theoretical point of view. As games, they do not have any natural "quantum" version. ("Quantization" often suggests ways of avoiding paradoxes in game theory due to absence of limitations of the classical theory of probability. This approach has interesting consequences in decision sciences, cf for example papers by E. Haven and A. Yu. Khrennikov.) Such a possibility would be welcome because non-gaussian shape of the of the demand (supply) curve suggests the existence of Giffen goods [2]. Obstacles in quantization of such models can be overcome by replacing the maximum Boltzmann/Shannon entropy principle with the requirement that the Fisher information gets its minimum (a discussion on the connection between the principle of minimum of Fisher information and equations of quantum theory can be found in [3]). In this way a simple method of quantum-like reformulation game theory models that stem from statistical considerations. We would like to present the analysis of a subjective variant of rational repeated trading model [4]. In this model, the trader gets the maximal profit intensity when the probability of transaction is ≈ 0.5853. There is also an interesting phase transition if this probability falls to $\frac{2}{\pi+4} \approx 0.28$. We will present a comparison with the model based on the Maximum of Entropy Principle. To the best of our knowledge, this is a analysis that shows concrete situation in which trader profit optimal value is in the class of price-negotiating algorithms (strategies) resulting in non-monotonous demand(supply) curves of the Rest of the World (collective opponent). Our model suggests that there might be a new class of rational trader strategies that neglect the supply-demand profile of the market. This class emerges when one (tries to) minimize the information that strategies reveal.

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Mechanism of polarization freezing in disordered polar dielectrics.

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Compositionally disordered polar perovskites such as lead magnesium niobate (PMN) are commonly termed relaxor ferroelectrics. In contrast to normal ferroelectrics, where long range polar order exists below the Curie temperature, relaxor ferroelectrics are characterized by a broad temperature peak in the quasistatic dielectric constant and by strong frequency dispersion of the complex dielectric permittivity. The characteristic relaxation time is found to diverge according to the well-known Vogel-Fulcher (VF) relation $\tau = \tau_0 \exp[U/k(T - T_0)]$, where T_0 is the VF or freezing temperature ($T_0 \sim 215$ K in PMN). It is now well established that the physical properties of relaxors are associated with the appearance of polar nanoregions (PNRs) below the so-called Burns temperature ($T_B \sim 700$ K in PMN). Neutron scattering experiments indicate that as the temperature is lowered, PNRs increase in size and reach a volume fraction of $\sim 30\%$ near T_0. Here we present a simple model for the growth of PNRs, assuming a power-law radial dependence of the polarization cloud associated with each PNR. The corresponding correlation radius r_c is determined by the thermal fluctuations of the polarizable medium near the PNR boundary. As the temperature decreases, r_c increases and clusters of PNRs are formed. In analogy to disordered magnets, the barrier height governing cluster orientation is taken as being proportional to the cluster volume, which increases until the percolation limit is reached and an infinite cluster is created. Thus the relaxation time τ is found to diverge at the percolation threshold [1]. In the framework of mean field theory of percolation we thus derive an expression for the temperature dependence of τ, which readily reproduces the VF relation. A similar mechanism is expected to describe the relaxation in random magnets, spin glasses, supercooled organic liquids, and structural glasses.

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Maximal exponential models on Gaussian spaces.

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The structure described by [1] has been extended to the non parametric case, see e.g [3]. Given any sample space $(X, \mathcal{X}, \mu)$, if $\mathcal{M}_>$ denotes the set of positive densities and $\mathcal{M}^1$ denotes the set of (signed) functions f such that $\int f \, d\mu = 1$, we can construct Banach manifolds on both $\mathcal{M}_>$ and $\mathcal{M}^1$, modeled respectively on the Orlicz spaces for the Jung functions $\Phi(x) = \cosh(x) - 1$ and is conjugate Ψ. The affine atlases

$$q \mapsto u = \log\left(\frac{q}{p}\right) + D(p\|q) \quad \text{and} \quad q \mapsto u^* = \frac{q}{p} - 1 \ ,$$

$p \in \mathcal{M}_>$, are used. The functional $K_p(u) = \log\left[\mathbb{E}_p\left(\mathrm{e}^u\right)\right]$ is analytic and its Hessian at 0 is the Fisher metric at p. The first atlas defines the *exponential manifold*; a maximal chart co-domain is the *maximal exponential model* at p, namely

$$\mathcal{E}(p) = \left\{ \mathrm{e}^{u - K_p(u)} \cdot p : u \in \mathcal{S}_p \right\},$$

where $\mathcal{S}_p$ is the interior of the proper domain of K_p.
The finite state space case does not require any special functional framework but has interesting algebraic features, see e.g. [3]. The case of an underlying gaussian space prompts for the use of the relevant Malliavin calculus, see e.g. [2], for the study and the approximation of the maximal exponential model. The gaussian Sobolev spaces and the variational computations that seem to be of interest are discussed.

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Stochastic modeling of imatinib-treated leukemic cell dynamics.

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Chronic Myeloid Leukemia (CML) is a slowly progressing cancer that makes the body produce too many cancerous myeloid white blood cells. The molecular characteristics of CML is the presence of the Philadelphia (Ph) chromosome, created by the reciprocal translocation of the ABL gene on chromosome 9 with the BCR gene on chromosome 22. The fused oncogene BCR-ABL influences the activity of large protein complexes that regulate the blood cell growth, producing an increasing number of immature white cells. All transforming activities of BCR-ABL mutant depend on its elevated tyrosine kinase activity. The introduction of the ABL tyrosine kinase inhibitor *imatinib* (Gleevec) for the treatment of CML represents the first example of a successful targeted therapy. Despite its striking efficacy, however, the development of resistance to imatinib is observed in a proportion of patients, especially those with advanced-stage CML.
Numerous studies on cancer genetics have confirmed the basic idea that cancer arises when a single cell experiences multiple mutations, inactivating the tumor suppressor genes (TSGs) in both alleles [1,2,3]. In the present work, the dynamics of the cancer progression is studied by modeling the stochastic evolution of a finite population of replicating cells. In our model, we consider three types of cells, denoted by 0, 1 and 2, because they contain 0, 1, and 2 mutations, respectively. Healthy cells (type 0) can experience a genetic mutation and

transform to first-mutant cells (type 1). This population represents an intermediate phenotype, in which the first allele of the TSGs has been inactivated. A second genetic alteration is simulated to confer the malignant form to the cell and to generate cancerous clones (type 2). The evolutionary dynamics of this system of cells is described by a Moran process [4], in which cells reproduce asynchronously and each elementary step of the stochastic process consists of a birth and a death event. In this framework, mutations cause an increase of the net reproductive rate, providing a selective advantage for mutated cells.
Several scenarios of the evolutionary dynamics of imatinib-treated leukemic cells are described as a consequence of the efficacy of the different modeled therapies. Under specific conditions, an intrinsic periodicity of the evolutionary dynamics of malignant cells has been observed. The development of resistance is also investigated, as an induced effect of enhancement of the mutation rates caused by the therapy itself.

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The manifold facets of entropic nonadditivity.

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Non-additivity, or non-extensivity, recognizes a multiplicity of origins and manifold interpretations. The concomitant viewpoints arise from quite different perspectives. We can mention, for instance, statistical, geometric, and physical origins. In this presentation we will survey some of them, with emphasis on mathematical aspects. One possible viewpoint refers to a quite frequent experimental scenario, that in which data are gathered using a set-up that performs a normalization-pre-processing. One can show, by means of a suitable reinterpretation of recent mathematical results, that the ensuing normalized input, as recorded by the measurement device, will always be q-Gaussian distributed if the incoming data exhibit elliptical symmetry, a rather usual circumstance. This entails a physical origin, detector-caused, for a non-extensivity feature, associated to q-Gaussian behaviour. As an example, Gaussian data (the most common situation) will appear, after normalizing, in the guise of q-Gaussian records. Moreover, one may show that the value of the associated parameter q can be deduced from the normalization technique that characterizes the device. On a different angle, Beck and Cohens have shown that Superstatistics can be seen to be "statistics" of "canonical-ensemble statistics", where the pertinent mixing parameter is the temperature. In analogy, one can derive similar arguments based upon the micro-canonical ensemble. The mixing parameter is then not the temperature but the non-extensivity index q associated with the non-additive Tsallis' entropy. In still another vein, interesting geometric properties of the maximum entropy Tsallis-distributions under energy constraint can be mentioned. For instance, in the case $q > 1$, these distributions can be proved to be marginals of uniform distributions on the sphere. In the case $q < 1$, they can be constructed by projecting uniform distributions on the sphere in cylinder-type shapes. As such, these distributions reveal the relevance of using Tsallis distributions for at the micro-canonical level.

Brachistochrone evolution, entanglement and quantum statistics.

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The quantum evolution $|\psi(t)\rangle$ of a physical system between initial and final (pure) states $|\psi_i\rangle = |\psi(t=0)\rangle$ and $|\psi_f\rangle = |\psi(t=\tau)\rangle$ such that $\langle\psi_i|\psi_f\rangle = 0$ and $\langle\psi_i|\psi(t)\rangle \neq 0$ for $0 \leq t < \tau$ is of particular interest. Such a quantum evolution, connecting a final state perfectly distinguishable from the initial one, can be construed as an elementary information processing step. The associated time τ measures, basically, how long one has to wait to "see something happening". It constitutes a natural indicator of the "speed" of quantum evolution and provides a valuable tool for estimating the fundamental limits that basic physical laws impose on how fast information can be processed or transmitted. It has been recently pointed out that there is an interesting connection between quantum entanglement an the aforementioned way of measuring how fast quantum evolution proceeds [1]. This connection can be studied from two complementary points of view. On the one hand, one can consider the minimum time required for a system governed by a given Hamiltonian to reach a state orthogonal to a prescribed initial state. On the other hand, we can consider the quantum brachistochrone evolution (that is, the quantum evolution requiring the minimum time under an appropriate energy constraint) connecting two prescribed orthogonal states, the Hamiltonian being (partially) determined by the optimization problem itself. In the case of composite quantum systems with distinguishable sub-systems quantum brachistochrone evolutions cannot be implemented without entanglement, excepting trivial cases in which only one of the subsystems evolves [2]. In the present contribution we explore the connection between entanglement and time-optimal quantum evolution for systems of identical particles, elucidating its dependence on the type of statistics obeyed by the particles. We show that, both for bosons and for fermions, typical brachistochrone evolutions involve a considerable amount of entanglement.

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Generalized central limit theorem behavior and nonergodic anomalous dynamics in quasi-stationary states of long-range interacting systems.

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Recently there has been an increasing interest in generaliza-

tions of the Central Limit Theorem (CLT) [1] and on their possible (strict or numerically approximate) application to systems with long-range correlations [2] or systems at the edge-of-chaos [3], that is nonlinear dynamical systems whose maximal Lyapunov exponent tends to vanish in the thermodynamic limit (increasingly large systems) or is exactly zero, hindering in this way mixing and consequently the application of standard statistical mechanics. Furthermore a possible application of nonextensive statistical mechanics has been advocated in these cases. Along this line we will discuss in the present paper a detailed study of a paradigmatic toy model for long-range interacting Hamiltonian systems, i.e. the Hamiltonian Mean Field (HMF) model which has been intensively studied in the last years. We will discuss molecular dynamics numerical results for the HMF model showing three kinds of quasi-stationary states (QSS), starting from the same water-bag initial condition with unitary magnetization. The CLT behavior is influenced by the different microscopic dynamics observed in the three classes of QSS. In general, averaging over the three classes can be misleading. Indeed, the frequency of appearance of each of these classes depends on the size of the system under investigation, and there is no clear evidence that a predominant class exists. Finally we will also address the similarities between the anomalous and nonergodic dynamics of the Hamiltonian Mean Field and that of the Kuramoto model [4], a dissipative model of fully coupled rotators which has been intensively investigated with regards to synchronization. Also in this case we will particularly focus our attention on the generalized CLT and nonextensive statistical mechanics applications [5].

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Modules recognition in complex networks by dynamical clustering algorithms based on different oscillators systems.

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We recently introduced an efficient method for detection and identification of modules in complex networks. For practical purposes, modules can be roughly defined as subsets of network nodes *within* which the connections are dense, but *between* which they are sparse. In the last years many efficient heuristic methods have been proposed to investigate the presence of these structures in complex networks, and their performances have been tested on both real and computer generated networks with a known subdivision in different communities.
We present a *dynamical clustering* (DC) algorithm for modules identification based on the de-synchronization properties of a given dynamical system associated to the network. The dynamics of a network of N coupled oscillators can be described by

$$\dot{\mathbf{x}}_i = \mathbf{F}(\mathbf{x}_i) - \frac{\sigma}{\sum_{j\in K_i} l_{ij}^{\alpha}} \sum_{j\in K_i} l_{ij}^{\alpha}\mathbf{H}[\mathbf{x}_i - \mathbf{x}_j] \quad i = 1, \ldots, N,$$

where $\mathbf{F}(\mathbf{x})$ governs the dynamics of each individual oscillator, $\mathbf{H}(\mathbf{x})$ is a vectorial function, σ is the overall coupling strength and α is a real tunable parameter. K_i is the set of neighbors of node i^{th}.
The main ingredient of our algorithm is the load l_{ij} of the link connecting nodes i and j, which is quantified by the so called *edge betweenness*, i.e. the number of shortest paths that are making use of that link. The key idea is that, if the system starts in a perfectly synchronized state at $\alpha = 0$ (for a given value of the coupling σ) and α is let to slowly decrease in time from 0 to $-\infty$, the links with the higher load will be weighted less and less with respect to the other links, thus inducing a progressive desynchronization (dynamical clustering) of the system in a hierarchy of clusters of oscillators corresponding to different configurations of modules for the network considered. In order to select which one of these configurations is the best one as a function of $\alpha(t)$, we look to local or global maxima of the *modularity* Q, a quantity that simply compares the fraction of edges within n_c arbitrary communities (intra-community links) of a given network with the expected fraction of such edges in a random network, which does not exhibits community structures.
We implement our dynamical clustering algorithm on several dynamical systems $\mathbf{F}(\mathbf{x}_i)$, such as Rössler, Kuramoto and the so called Opinion Changing Rate model, and we perform tests on both computer generated networks and real networks, whose modular structure were already known. The algorithm attains a high level of precision, which strictly depends on the choice of the oscillators system adopted. The results indicate that the global performance and the computational effort of the algorithm - $O(KN)$ on a generic graph with N nodes and K links - is very competitive if compared with the best methods existing on the market.

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Topology properties of written human language.

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Written human language is one of the most important examples of self-organization systems. Fundamental distributions of statistical mechanics for complex systems are derived from general principles; therefore, based on their grounds, the topology description of the word network is of considerable interest. We use extended model Barabasi [1] when rewired process is absent and show that degree distribution for corresponding networks is Tsallis distribution in the form $P(k) = \frac{1}{Z}(1-(1-q)\beta k)^{\frac{1}{1-q}}$, where $Z = \sum_k (1-(1-q)\beta k)^{\frac{1}{1-q}}$ [2]. We offer an analysis of the novel "The Sound and the Fury" by W. Faulkner in English and in Russian, and show that the degree distributions of the relevant word networks are described with the Tsallis distribution.
Finite chains in the graph terms correspond to separate sentences in our representation of the word network. At the network evolution, these finite chains intersect in the vertices that correspond to general words. As a result, a network is formed that is a multigraph.
Our special interest in the novel "The Sound and the Fury" by W. Faulkner was the fact that its four parts correspond to four types of perception; however, they are induced by the same events. Therefore, we have analyzed the corresponding parts of the novel and substantively constructed word networks that correspond to various types of perception. The first network (B) corresponds to the infant, pre-logic, sensuous perception of Benjamin, the second network (Q) corresponds to the adolescent broken perception of Quentin, the third one (J) – to the adult, pragmatic, unimaginative perception of Jason and the fourth network (A) corresponds to the wider and more independent perception of the author-observer. Besides, we have analyzed the word network (W) that corresponds to the novel on the whole.
We have constructed degree distributions for each of the relevant word networks and defined the value of the nonextensivity parameter q with the maximum likelihood method. For the novel text in English $q_B = 1.57$; $q_Q = 1.49$; $q_J = 1.53$; $q_A = 1.47$; $q_W = 1.54$, and for the translation into Russian $q_B = 1.50$; $q_Q = 1.42$; $q_J = 1.46$; $q_A = 1.40$; $q_W = 1.47$. Therefore if the translation of the novel is regarded as mapping, the nonextensivity parameters ordering $q_B > q_W > q_J > q_Q > q_A$ is an invariant of this mapping. We result examples of word networks for which the accelerated growth is not characteristic.

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Nonlinear kinetics on lattice with long-range diffusion.

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In the current study we explore the influence of long (but finite) range diffusion on the kinetics of non-linear systems realised on low dimensional lattice supports. In particular we choose to study minimalistic reactive schemes which are lattice compatible and which correspond to conservative dynamical systems, demonstrating "center" behavior at the mean field level. The realisation of these conservative dynamical systems on low dimensional supports is performed using Kinetic Monte Carlo (KMC) simulations on square lattices. Each lattice site can be found in different states corresponding to the occupying species participating in the reactive scheme, while the lattice also contains empty sites.
The restriction of the dynamics on the support has revealed a number of unexpected features. In the absence of diffusion these systems exhibit only local oscillations, which vanish in the limit of large system sizes. In other terms, the system divides itself into local oscillators, each of which demonstrates its own phase. The phases of the different oscillators have a random distribution and thus for large systems the oscillations are averaged out.
When diffusion is added to these KMC systems the above picture changes drastically. Diffusion is introduced as state exchange between two distant, randomly selected lattice sites and takes place with a probability p relative to reaction. When the range of the diffusion l is small (the particles diffuse in their immediate neibhourhood) still local oscillators persist while global oscillations vanish. When the range of diffusion l increases then synchronization of the local oscillators takes place. Namely, above a critical (reaction/diffusion) rate p_c a Hopf-like bifurcation appears and the system synchronises into a global periodic attractor of limit cycle type. Below p_c the system follows the $p = 0$ behavior and presents only local oscillations, which vanish when the system size tends to infinity. The critical point p_c is shown to depend on the kinetic parameters.
In the absence of diffusion clustering of the various species takes place on lattice due to the cooperative nature of the reactions. When diffusion is introduced with distant sites then the clusters brake and a global regime is established. For $p < p_c$ the clusters are disturbed only locally by the diffusiong particles, while for $p > p_c$ the clusters are totally destroyed giving rise to a statistically homogeneous state. The same is true for all other local phenomena on the lattice, such as the fractal morphology of the clusters, and the spiral patterns and stripes which appear depending on the initial conditions.

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Multifractal and non-extensive analysis of magnetic confined plasma turbulence.

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Plasma edge turbulence, known for a long time to be intermittent in the scrape-off layer , is in focus of intense current research efforts aimed to understanding plasma confinement and dynamics of turbulent transport in magnetic fusion devices which represent important issues related to the control of confined plasma. Turbulence studies of the scrape-off layer (SOL) have revealed that intermittency in this region is caused by large-scale coherent structures with high radial velocity designated as blobs (or avaloids). A natural route for understanding turbulence and intermittency in the edge region of confinement devices and related transport properties is to search for universal properties and differences between dynamics of different systems and regimes. Existence of long-range correlations, noticed in several magnetic confinement devices, suggested that scaling models with a single parameter are appropriate at large temporal scales but at small scales, characteristic for intermittency, more parameters are needed. As a consequence, a need for multifractal analysis was recognized recently. We present a multifractal analysis based on the local wavelet analysis and the use of Large Deviation spectra.
In plasma turbulence due to specific nature of nonlinearities, turbulence is created and damped at the same spatial position where measurements are taken so that spatial and temporal informations are interwoven and it is very difficult to quantify energy dissipation in contrast to the neutral fluid turbulence. Using experimental data consisting of the ion saturation current fluctuations (essentially density fluctuations) we construct the quantity corresponding to the surrogate dissipation used in neutral fluid turbulence. The criterion we implement is that the scaling of two-point correlation function of L-mode (low confinement mode) fluctuations would yield an intermittency exponent as close to the value for neutral fluid turbulence, as possible. As shown in [1] L-mode intermittent fluctuations are very similar in their fractal and multifractal aspects to the neutral fluid intermittency. The following measure

$$\epsilon = c \cdot \frac{\left(\left|n\frac{dn}{dt}\right| - \left\langle\left|n\frac{dn}{dt}\right|\right\rangle\right)^2}{\left\langle\left(\left|n\frac{dn}{dt}\right| - \left\langle\left|n\frac{dn}{dt}\right|\right\rangle\right)^2\right\rangle},$$

was chosen for multifractal analysis. Based on the above expression we define a stochastic variable measuring the energy transfer rate ($\epsilon_n/\epsilon_{n-1}$) between coherent structures. The obtained stochastic variable follows the Tsallis-type distribution with the entropy index q. The model of Arimitsu and Arimitsu [2], utilizing two distinct Tsallis-type MaxEnt distributions (one for the tail part of the PDF and the other for the center part), is then applied to the analysis of the PDFs of plasma edge turbulence in the Mega Amper Spherical Tokamak (MAST). It is shown that this model is of great accuracy for the edge plasma turbulence and we discuss the implications of the results for the understanding of plasma intermittency and formation of edge localized modes.

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Simplicial complexes from networks: static and dynamic aspects.

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Our approach is to encode a network (nodes and links) into a simplicial complex and in the first part of the exposition we present static properties of these complexes. Simplicial complexes may be constructed from directed graphs (digraphs) in several different ways. Here we only mention the so called neighborhood complex $N(G)$ constructed from the graph G, with vertices $\{v_1, ..., v_n\}$. For each vertex v of G there is a simplex containing the vertex v, along with all vertices w corresponding to directed edges $v \to w$. In such a way we obtain a complex structure which could be considered from three different aspects:

1. a combinatorial model of a topological space
2. a combinatorial object
3. an algebraic model

The versatility of such an approach enables construction of various topological and algebraic invariants whose statistical properties reveal higher levels of connectedness of networks. Consequently, the invariants of simplicial complexes may be defined based on their different aspects and each one of them provides completely different measures of the complex and, by extension, of the graph from which the complex was constructed. In the first case (topological aspect) various topological measures may be associated such as homotopy and homology groups. Some topological properties of networks may be distinct even if they have the same degree distribution and we show examples of such properties. In the second case (combinatorial aspect) several combinatorial invariants may be defined and numerically evaluated. Besides the dimension of the complex, an invariant is the so called Q-vector (first structure vector) whose i-th component is equal to the number of i-connectivity classes. Also, an invariant is the f-vector (second structure vector) whose i-th component is equal to the number of i-dimensional simplices in the complex. Additional useful measures such as eccentricity, vertex significance and others are constructed in order to extract information from various aspects of connected structures. In the third case (algebraic aspect) an important invariants are the Betti numbers which, in a simplified description, allow measurement either of the number of holes (simplices representing holes) of various dimensions present in a simplicial complex, or equivalently, the number of times the simplex loops back upon itself.
We study the invariants corresponding to all three aspects for the well known types of networks such as random, scale-free, small world etc [1]. In the case of scale-free networks we show that invariants including the Betti numbers follow the q-exponential distribution and we discuss how interplay of topological, combinatorial and algebraic factors leads to such distribution.
In the second part of the exposition, the construction of simplicial complexes from graphs is extended to include dynamical changes the network (simplicial complex) may experience. We present new topological methods and a branch of topology called persistence homology [2], which enables updating (instead of complete calculation) of various invariant measures due to dynamical changes of the network.
Finally we show some applications to social networks and gene-regulatory networks.

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Systems with negative specific heat in thermal contact: violation of the zeroth law.

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In recent years, the study of *Small* systems and systems with long range interactions has suggested that these kind of systems can show inequivalence between the canonical and microcanonical ensembles. In particular, it is possible that the specific heat can be negative in the microcanonical ensemble, which is always positive in the canonical ensemble. In spite of this, the behaviour of systems with negative specific heat in thermal contact has not been extensively studied.
We show that systems with negative specific heat in thermal contact can violate the zeroth law of thermodynamics, which is among the most fundamental assumptions concerning macroscopic systems in equilibrium. Since systems with negative specific heat are thermodynamically unstable when they are thermally coupled to the surrounding medium, anomalous behaviour is surely to be expected when such systems interact. However, it is not obvious that this will cause violations of the zeroth law. The reason is that when we test the zeroth law, heat exchange is always allowed, thus the restriction on fixed energy which characterizes the microcanonical ensemble is lifted and we might think that this leads to a canonical-like case, in which the specific heat is always positive.
By numerical simulations and by using exact expressions for free energy and microcanonical entropy for a modified Hamiltonian Mean Field (HMF) model, we show that when two identical systems with the same intensive parameters but with negative specific heat are thermally coupled, they undergo a process that leads to an irreversible change in the intensive parameters of the subsystems. This indicates that the equality of the intensive variables is not enough to ensure that both systems are in *stable* equilibrium with one another, in violation of the zeroth law. We corroborate our results using two different kinds of couplings between the HMF systems. We confirm that our results hold also for the Ising model with long and short-range interactions, which also has a parameter region with negative specific heat in the microcanonical ensemble. Further, we show that no change is induced via coupling to a sufficiently small system (that will work as a thermometer). Therefore, we show an instance of violation of the zeroth law of thermodynamics.

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Composite CDMA - A statistical mechanics analysis.

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Code Division Multiple Access (CDMA) is a method that facilitates multi-user communication by spreading user transmissions over some bandwidth using robust channel codes; it is currently employed in wireless internet and mobile phones. Methods of statistical physics are useful in the study of CDMA due to the random nature of the interference and channel coding methods [1]. In a dense code ensemble each user transmits on the whole bandwidth, while in a sparse code ensemble each user transmits on only a small part, but at higher power. A random element may be introduced in the modulation sequences and access patterns. The performance of sparse [2] and dense [1] random codes is near optimal, with each having benefits in different channel conditions. This study considers the performance of a composite code ensemble with each user's code being a mixture of sparse and dense modulation sequences. This diversity may be used to hedge bets in terms of channel conditions, hamper malicious interference or optimise decoder performance.
We consider a model with transmission by phase shift keying on a single bit interval, in a channel with additive white Gaussian noise. For a class of Bayes decoders we determine the optimal decoding properties by the replica method under the replica symmetric assumption. This involves simultaneous application of methods developed for sparse and dense random systems [3]. We demonstrate the effect of diversity on the dense and sparse solutions in regimes where solutions are unique, and in the regimes of metastability. The analysis demonstrates that the optimal performance interpolates the results for the two unmixed extremes in such a way that the Bit Error Rate (BER) remains near optimal. In the metastable regime, dynamical effects may allow composite codes to outperform either extreme in terms of decoding BER. We compare results to finite size realisations of the model, implementing composite belief propagation decoding methods [4].

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Non Equilibrium thermodynamics and entropy generation of ferrites and ferrite-polymer composite materials under electromagnetic field applied.

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Macroscopic theory of irreversible processes can deal with a number of problems concerning irreversible processes in sys-

tems of which some components carry electrical charges. In the framework of thermodynamics of irreversible processes the conservation laws of mass, momentum and energy are set up for systems of which the properties are continuous functions of time and space co-ordinates. The analysis is for the entropy of materials that have average polarizations P and M which are subjected to electromagnetic driving. The analysis will develop equations in time and frequency domain. The entropy law and the entropy balance equation is derived which contains a source term, the entropy production, which characterize the irreversibility due to the dielectric and magnetic polarization, because the system is driven by hight frequency fields, so it is not in equilibrium. The net entropy will increase due to the tendency to relax from a non-equilibrium state to an equilibrium state. We consider a system subjected to applied electromagnetic fields E and H at temperature T. For non equilibrium systems, the entropy can change even if it is thermally isolated, due to internal relaxation. In the systems under our analysis the complex part of the magnetic permeability and the complex part of the dielectric permittivity play a fundamental role, because the entropy production are associated to these terms throughout the flow of electromagnetic energy dissipation. In the present paper the numerical treatment of the magnetic and dielectric loss of different ferrites and ferrite-composite materials is investigated and the entropy production is calculated taking into account the magnetic and dielectric response in frequency of the systems under analysis. For the numerical simulation of the behavior of the entropy production due to the magnetic relaxation we use a recent published causality model [1]. For the dielectric relaxation the well known Jonscher model are used [2]. The entropy is related to the energy dissipated by the driving fields and internal relaxation, this change in entropy must be related to the stored energy, electrical impedance, permittivity and permeability. The spectral entropy for a system at constant temperature can be calculated, assuming e^{iwt}time dependence for $\Delta S(\omega)=\Delta S'(\omega)-i\Delta S''(\omega)$ [5]. We discuss the behavior of the entropy plot as a function of frequency Following the development of Landau and Lifshitz [3] and S.R de Groot and P.Mazur [4], we could consider that the entropy production for a system with homogeneous density in which no viscous flows, thermal conduction or diffusion occurs.
Then we correlate the results with the Boltzmann H-theorem for the statistical analysis.

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Plasmonic noise in nanometric semiconductor layers.

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Generation and detection of electromagnetic radiation in the TeraHertz (THz) domain is a subject in fast development because of its potential applications in different branches of advanced technologies, such as broad-band communications, high-resolution spectroscopy etc [1, 2]. As a consequence, the realization of solid-state devices operating in the THz domain at room-temperature and with compact, powerful, and tunable characteristics is a mandatory issue. To this purpose, one of the most promising strategies lies in the plasmonic approach. In this talk we will report a recent theoretical investigation on the plasma frequency associated with voltage fluctuations in an n-type InGaAs layer of nanometric thickness W in the range $1 \div 100\,nm$ and variable length L in the range $0.01 \div 10\,\mu m$ embedded in a dielectric medium operating at room temperature. Theoretical calculations are carried out by using an ensemble Monte Carlo simulation self-consistently coupled with a two dimensional (2D) Poisson solver and in the presence of an external applied voltage. At low applied voltages, the system exhibits an Ohmic behaviour of the current voltage characteristics. Here, for $W \geq 100\,nm$ and carrier concentrations of $10^{16} \div 10^{18}\,cm^{-3}$ the results are in good agreement with the standard three dimensional (3D) expression of the plasma frequency. For $W \leq 10\,nm$ the results exhibit a plasma frequency that depends on the length of the layer, thus implying that the oscillation mode is dispersive. The corresponding frequency values are in good agreement with the 2D expression of the plasma frequency obtained for a collisionless regime within the in-plane approximation for the self-consistent electric field [3]. Furthermore, the simulations evidence a region of crossover between the 2D and 3D behaviors of the plasma frequency for $W > 10\,nm$. At high applied voltages, the system exhibits a saturation behavior of the current. Here, the presence of negative differential mobility conditions leads to a suppression of the plasma oscillations in favour of the onset of current oscillations associated with the electrical instability driven by the presence of a negative differential mobility. Under these conditions the increase of voltage fluctuations plays the role of a precursor for the onset of instability conditions.

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Thermodynamics of alternating spin chains.

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We consider integrable quantum spin chains with alternating spins (S_1, S_2) [1]. We derive a finite set of non-linear integral equations for the thermodynamics of these models by use of the quantum transfer matrix approach. By means of the quantum transfer matrix approach, a finite set of non-linear integral equations can be derived exploiting analyticity properties

of the quantum transfer matrix. These equations have been shown to be successful in the description of thermodynamical properties in the complete temperature range for many important models like Heisenberg model [2] and its spin-S generalization [3], the $t-J$ model [4], Hubbard model [5].
Nevertheless, the standard construction of the quantum transfer matrix assumes models with isomorphic auxiliary and quantum spaces. Here we are concerned with extensions to more general models with non-isomorphic auxiliary and quantum spaces. Important examples of such systems are mixed spin chains.
Using some symmetry properties of our operators, we have been able to formulate the quantum transfer matrix approach to the case of alternating spin chains. Subsequently, we have solved numerically these non-linear integral equations for many different cases and thus provided a description of the thermodynamics of the alternating spin chains. We obtained solutions for quantities like free energy, entropy, specific heat, magnetization and magnetic susceptibility for the complete range of temperature. At low temperatures one class of models ($S_1 < S_2$) shows finite magnetization and the other class ($S_1 \geq S_2$) presents antiferromagnetic behaviour. Quite generally, we observe residual entropy for $S_1 \neq S_2$.
In addition, we have obtained the thermal Drude weight for the case of homogeneous spin chain ($S_1 = S_2 = S$). This quantity describes the thermal conductivity at zero frequency. At low temperature, the thermal Drude weight is linear in temperature. From the low temperature asymptotic behaviour, it has also been obtained that the thermal Drude weight is proportional to the central charge $c = \frac{3S}{S+1}$ of the system.

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Directed abelian algebras and their applications to stochastic models.

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To each directed acyclic graph (this includes some D-dimensional lattices) one can associate some abelian algebras that we call directed abelian algebras (DAA) [1]. On each site of the graph one attaches a generator of the algebra. These algebras depend on several parameters, are semisimple and in general have only one trivial ideal. Using any DAA one can define a family of Hamiltonians which give the continuous time evolution of a stochastic process. The calculation of the spectra and groundstate wave functions (stationary states probability distributions) is an easy algebraic exercise.
If one considers D-dimensional lattices and choose Hamiltonians linear in the generators, in the finite-size scaling the Hamiltonian spectra a gapless with a critical dynamic exponent $z = D$.
One possible application of the DAA is to sandpile models. We present this application in the present paper considering one and two dimensional lattices. In the one dimensional case, when the DAA conserves the number of particles, the avalanches belong to the "random walker" universality class [2]. We study the local density of particles inside large avalanches showing a depletion of particles at the source of the avalanche and an enrichment at its end.

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Definitive answer on the occurrence of a q-deformed statistical-mechanical structure for the dynamics at the Feigenbaum attractor.

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We show that the dynamics towards [1] and within [2-3] the Feigenbaum attractor combine to form a q-deformed statistical-mechanical construction. The rate at which ensemble trajectories converge to the attractor (and to the repellor) is described by a q-entropy obtained from a partition function generated by summing distances between neighboring positions of the attractor [1]. The values of the q-indexes involved are given by the unimodal map universal constants, while the thermodynamic structure is closely related to that formerly developed for multifractals. As an essential component in our demonstration we expose, at a previously unknown level of detail, the features of the dynamics of trajectories that either evolve towards the Feigenbaum attractor or are captured by its matching repellor. The dynamical properties of the family of periodic superstable cycles in unimodal maps are seen to be key ingredients for the comprehension of the discrete scale invariance features present at the period-doubling transition to chaos. Elements in our analysis are the following: i) The preimages of the attractor and repellor of each of the supercycles appear entrenched into a fractal hierarchical structure of increasing complexity as period doubling develops. ii) The limiting form of this rank structure results in an infinite number of families of well-defined phase-space gaps in the positions of the Feigenbaum attractor or in the repellor. iii) The gaps in each of these families can be ordered with decreasing width in accord to power laws and are seen to appear sequentially in the dynamics generated by uniform distributions of initial conditions. iv) The power law with log-periodic modulation associated to the rate of approach of trajectories towards the attractor (and to the repellor) is explained in terms of the progression of gap formation. v) The relationship between the law of rate of convergence to the attractor and the inexhaustible hierarchy feature of the preimage structure is elucidated. vi) A "mean field" evaluation of the atypical partition function, a thermodynamic interpretation of the time evolution process, and a crossover to ordinary exponential statistics is given. We make clear the dynamical origin of the anomalous thermodynamic framework existing at the Feigenbaum attractor.

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Distribution functions for charged particles interacting, elastically and/or inelastically, with medium and subjected to an electric field.

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The linear Boltzmann equation for inelastic scattering is here applied in the study of the distribution functions of charged particles subjected to an external electric field in a host medium of two-level atoms. Connections with the transport of electrons in a crystal are pointed out. After a study of the collision integral we construct its Fokker-Planck approximation. In the presence of both inelastic and elastic collisions we derive the distribution function for both hard sphere and Maxwell interaction laws. Garibotti and Spiga developed a formalism for the introduction of inelastic interactions in the linear Boltzmann equation. Field particles (FP) endowed with two levels of internal energy and test and test particles (TP) are considered. A connection will be shown with the case electrons and phonons of a crystal lattice.
In this paper our aim is
(1) to study the properties of the collision integral of such equation
(2) to point out the connections to transport of electrons interacting with a phonon background
(3) to construct, under suitable assumptions, a Fokker-Planck approximation susceptible of analytic solutions
Through the FP (mass M), TP (mass $m << M$ charge $\mathcal{Q}$) diffuse in the presence of an external electric field $\mathbf{E}$. The TP are supposed to interact with FP according to the following scheme

$$TP + FP_1 \rightleftharpoons TP + FP_2 \ ,$$

where 1 and 2 mean fundamental and excited state, respectively. The number density of TP is considered much lower than the one of FP: $\mathcal{N}$ so that the medium can be modelled as a fixed background in thermodynamical equilibrium at the temperature T. Since M is much larger than m, the distribution function $\mathcal{F}_k$ for TP_k can be approximated as follows

$$\mathcal{F}_k(\mathbf{v}) = \mathcal{N}_k \, \delta(\mathbf{v}) \ .$$

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Nonextensivity at the edge of chaos of a new universality class of one-dimensional unimodal dissipative maps.

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We introduce a new universality class of one-dimensional unimodal dissipative maps. The new family, from now on referred to as the logarithmic map, corresponds to a natural generalization of the z-logistic map [1]. The logarithmic map exhibits the opposite behaviour of the exponential map, as it characterizes a smaller degree of flatness. This characterization minimizes some inherent numerical problems related to the finite precision of the involved parameters. Such problems are ubiquitous in the study of chaos threshold and have been recently understood in the study of the logistic map [2] and the exponential map [3].
It has been recently shown that the time-average attractor at the edge of chaos of the z-logistic map is numerically consistent with a q-Gaussian. The q-Gaussian is the distribution which, under appropriate constraints, optimizes the nonadditive entropy S_q. We are interested in clarifying if the new class of map represents a new class of universality with regard to the q-Gaussian attractor distributions.
We are also interested in understanding the entropy production per unit time on the new unimodal dissipative map, both for strong (Lyapunov exponent $\lambda > 0$) and weak ($\lambda = 0$) chaotic cases. All these results are expected to contribute to the correct interpretation of various experimental results in dissipative dynamical complex systems (e.g., [4]). The q-sensitivity indices should be obtained as well, and we expect them to differ from those of the z-logistic family.

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Effects of quantum dot characteristics on the electronic spin-subbands states entanglement.

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Quantum entanglement, how it is realized and how it is quantified, has been the subject of numerous reports [1]. Among the many proposals for experimental realizations of quantum information processing, heterostructural systems have the advantage of offering the perspective to integrate a large number of quantum gates into a quantum computer once the single gate and qubits are established [2]. One approach to build a solid-state quantum computer is provided by exploiting quantum states of artificial atoms (quantum dots) or other nanostructures [3]. A common realization of heterostructures is composed of two layers of GaAs and InGaAs, with a planar interface. Owing to different band gaps, a steep, asymmetrical potential dip is formed along a direction normal to the interface. The asymmetry of the interface potential leads to the spin dependent effect, the Bychkov-Rashba spin-orbit interaction [4].
In the present work, the entanglement dynamics of spin-subbands states for an electron in a 2D isotropic Rashba quantum dot, with an applied magnetic field of arbitrary strength, is studied. We also explicitly include the confining (gate) effects as a two dimensional isotropic harmonic oscillator. The von Neumann entropy, as a measure of entanglement, is calculated as a function of time, by going to Fock-Darwin representation. Our results indicate that under specific conditions the

entanglement between the spin states and the union of structural subbands undergoes periodic collapse-revivals'. Furthermore, it is shown that the period and amplitude of collapse-revivals' strongly depend upon the confining length and the Rashba coupling. Our results, thereby, provide means of controlling the degree of entanglement through external agents.

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Bayes inference to the problem of inverse-halftoning based on statistical mechanics of the Q-Ising model.

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A Bayesian approach to solve the problem of inverse-halftoning [1] is proposed. The inverse-halftoning is a kind of information processing defined as the inverse problem of the halftoning of grayscale images, that is, as representing each grayscale in terms of black and white binary dots by means of the so-called dither method [2]. In our previous study [3], we formulated the inverse process of the halftoning as a combinatorial optimization to find the original grayscale image as the minimum energy state. Here we consider the problem from the view point of the Bayesian approach. In the Bayesian approach, we need to specify both the likelihood and the prior to obtain the posterior. As the prior, here we choose $P(\{z\}) \propto \exp[-(J/T)\sum_{\rm n.n.}(z_{x,y}-z_{x',y'})^2]$, where $\{z\} \equiv \{z_{x,y} \in 0,\cdots,Q-1|x,y=1,\cdots,L\}$ denotes the estimate of the original grayscale image and J,T are the so-called hyper-parameters. The summation $\sum_{\rm n.n.}(\cdots)$ runs all over the nearest neighboring pixels. In halftoning process, an original image $\{\xi\} \equiv \{\xi_{x,y} \in 0,\cdots,Q-1|x,y=1,\cdots,L\}$ is converted into the halftone binary dots $\{\tau\} \equiv \{\tau_{x,y} \in 0,1|x,y=1,\cdots,L\}$ in terms of the dither method as $\tau_{x,y}=\theta(\xi_{x,y}-M_{x,y})$ for each pixel, where $M_{x,y}$ is a threshold at the site (x,y) and $\theta(\cdots)$ means a step function. To construct the likelihood, we assume that each pixel of the halftone image $\tau_{x,y}$ is fluctuated around the *successfully converted value*: $\theta(z_{x,y}-M_{x,y})$ and the fluctuation is measured by a Gaussian variable $n_{x,y}$ with mean zero and variance T/h. This reads immediately $P(\{\tau\}|\{z\}) \propto \exp[-(h/T)\sum_{(x,y)}\{\theta(z_{x,y}-M_{x,y})-\tau_{x,y}\}^2]$, and then we find that the posterior $P(\{z\}|\{\tau\})$ is identical to the Gibbs distribution of the ferromagnetic Q-Ising model having the random field: $-(h/T)\,\tau_{x,y}^2$, the *clipped state-dependent field*: $-(h/T)\,\theta(z_{x,y}-M_{x,y})$, and the product of these two on each cite at temperature T. For this posterior, we retrieve the original image as $\tilde{z}_{x,y} = \arg\max_{z_{x,y}}\sum_{\{z\}\neq z_{x,y}} P(\{z\}|\{\tau\})$ for each pixel. Using the MCMC simulations for a set of the snapshots from the Gibbs distribution of the ferromagnetic Q-Ising model, we show that our approach is successful in inverse-halftoning. In this paper, we discuss the relationship between our optimal condition and the condition for the Bayes-optimal solution which is well-known as Nishimori line in the research field of spin glasses [4].

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A statistical mechanical study of evolution of robustness under noisy environment.

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The biological functions need to be robust against system's change by noise or mutation. They depend on a specific pattern or structure of phenotype, which is given as a result of the dynamical process governed by genes. The phenotypes with a higher function (i.e., fitness) are more selected, and the genotype to produce such phenotypes is transferred to the next generation. Note, however, that the expression dynamics from the genotype to the phenotype is rather noisy and stochastic. An interesting issue to be addressed is how such stochasticity is related to the evolution of robustness [1].
We introduce an abstract spin model that captures the essential features of the evolution and discuss the above question. The spin variable $\mathbf{S}$ defined on i-th site ($i=1,\cdots,N$) and the interaction $\mathbf{J}$ between the spins represent the phenotype and the genotype, respectively. We assume that the elements of both the spin S_i and the interaction J_{ij} take ±1 and the interaction matrix is symmetric.
We adopt the Glauber dynamics as a dynamical process of $\mathbf{S}$ for a given $\mathbf{J}$ with the energy function $H(\mathbf{S}|\mathbf{J}) = -\frac{1}{2}\sum_{\mathbf{ij}}\mathbf{J_{ij}}\,\mathbf{S_i}\,\mathbf{S_j}$, in which the spins are in contact with a heat bath of the temperature T_S. The transition probability of the spin dynamics satisfies the detailed balance condition, yielding the equilibrium probability distribution of $\mathbf{S}$ that has a variability characterised by T_S.
The genotype $\mathbf{J}$ has also an intrinsic dynamics caused by the mutation and the selection with a fitness. We define the fitness as

$$Fit(\mathbf{J}|\mathbf{T_S}) = \Big\langle \prod_{\mathbf{i<j}\in\mathbf{t}} \delta(\mathbf{S_i}-\mathbf{S_j}) \Big\rangle ,$$

where $\langle\cdots\rangle$ is an average with respect to the probability distribution of $\mathbf{S}$ and $\mathbf{t}$ is a subset of $\mathbf{S}$ [2].
We again the Glauber dynamics as the genotype dynamics with the fitness. Then, an equilibrium probability distribution function of $\mathbf{J}$ is given by

$$P(\mathbf{J},\mathbf{T_S},\mathbf{T_J}) = \frac{\mathbf{e}^{\beta_\mathbf{J}\mathbf{Fit}(\mathbf{J}|\mathbf{T_S})}}{\mathbf{Z_J}(\mathbf{T_S},\mathbf{T_J})} ,$$
$$Z_J(T_S,T_J) = \mathrm{Tr}\mathbf{J} e^{\beta_J Fit(\mathbf{J}|\mathbf{T_S})} ,$$

with an inverse temperature $\beta_J = 1/T_J$.
We have studied the above-mentioned spin model numerically and analytically. The adapted configurations of **J** at an intermediate T_S range are found to be less frustrated, which could be measured by a loop correlation of **J** associated with **t**, and they are robust against the mutation, in contrast to those at very low T_S. We will explain its mechanism [3].

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Statistical properties of number fluctuations observed in internet blog keywords.

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Human activity of word-of-mouth may be very important for our society, however, it was impossible to observe its historical record quantitatively. The Internet has changed the situation drastically. Instead of vocal information exchange, people use textual information in blogs. By using the search-engine technology we can observe appearance of any given keyword in blogs automatically with detail time stamps. It is a new scientific activity [1,2] to explore empirical laws in the number fluctuation of blog keywords and to clarify its impact to the society.
In order to establish empirical statistical laws from time sequential data in general, it is required that the data is stationary. However, in the case of blog keywords there are a few inevitable non-stationary factors which make the analysis difficult. For example, the number of blog sites tends to increase nearly monotonically, so the average number of keywords may grow. Or some blog servers suddenly stop working due to maintenance or hardware replacement, which may cause sudden decrease of word frequency for a while. Moreover, there is always a calendar effect such that keyword numbers increase on holidays. It is important to introduce a procedure of normalization which can evaluate the keyword frequency independent of such non-stationary factors.
To this end we calculate daily summation of frequencies for randomly chosen N sample adverbial words such as "more", and show that the time sequential pattern of summation nearly converges for N larger than 20. Then, by dividing the number of keyword frequency by this summation we get a time sequence of normalized word frequency. It is confirmed that the normalized time sequence successfully removes the above non-stationary factors.
Applying this method we find that any resulting normalized time sequence does not follow an independent Poisson process, instead the keyword frequency shows a long autocorrelation characterized by so-called the $1/f$ noise for those keywords which appear frequently everyday, such as "TOYOTA".
There are keywords which clearly show sharp boom such as "Christmas" which apparently tends to diverge on December 25th. For such a case we can approximate the functional form of increase before the critical day by a power law in terms of the difference of the observing day and the critical day. Also the decay form after the critical day can also be modeled nicely by a power law.

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Emergence of communities in social networks.

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Topology and weights are closely related in complex networks and, e.g., for social networks, this is reflected in their modular structure. I will present a model of social networks [1], which is based on microscopic dynamics of tie formation and reinforcement. The model is motivated by a recent large-scale empirical study [2,3], where we have studied the structure of a society-wide network derived from the calls of over 7 million mobile phone users. In this study, we have shown that weak and strong social ties play different roles: strong ties are associated with dense network neighbourhoods, i.e. communities, which are connected by weaker ties. This is also reflected in the robustness of the network to tie removal - weak ties are more important for global connectivity.
Our social network model starts from a set of plausible microscopic rules governing the formation of ties at the individual level ("cyclic closure" and "focal closure" in the social sciences literature). In cyclic closure, new acquaintances result from local searches along ties within the individual's network neighbourhood. This mechanism is augmented by weight dynamics: frequently used ties are reinforced, and strong ties are preferentially chosen for the searches. The strength of the reinforcement, and thus the sensitivity of the rules to weights, can be tuned by a control parameter. The focal closure rule accounts for random formation of ties, independent of the network topology. A third mechanism, node removal and subsequent insertion of a node with no links, reflects people entering and leaving the network.
These rules are iterated for a fixed-size network until a steady state is reached. It turns out that by tuning the weight sensitivity control parameter, the resulting networks undergo a gradual structural transition from a community-free topology to one with communities. In the community regime, the resulting networks display characteristics similar to the empirical observations: stronger ties are associated with denser network neighbourhoods, and weak ties act as bridges. At the global level, removing weak ties fragments the networks quickly, whereas they are relatively insensitive to strong tie removal.

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Interacting ensemble of particles in the context of q-deformed algebra.

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Having accomplished a great deal of understanding of the q-deformed systems revealed by recent investigations ([1] and references therein), we ask the question whether there are simple physical descriptions of what constitutes a deformation. It has been observed in [2] that an interacting Boson gas can be described by a Hamiltonian containing various powers of the operators a and $a^\dagger$, where the lowest order is given by the non-interacting Hamiltonian with only one pair of these operators. Furthermore, from a study of non-ideal gases we can learn that the state equations of interacting particle systems are well described by means of the virial expansion in terms of powers of the number of particles, where the Van der Walls approximations is given by the first two terms in the series.
Therefore, the power series expansion is a convenient tool to describe interacting systems, with the lowest order representing the system of non-interacting particles in the ensemble. An interesting interpretation of the origin of the q-deformation in an interacting particles system has been developed in [3]. It is shown that many thermodynamic quantities of a q-Boson system can be expressed as a power series in powers of N or in series of the deformed parameter q, implying that the q-deformation arises from the interaction among the particles of the ensemble.
Following this idea, we investigate the q-deformed system of many Bosons described by the q-deformed oscillator algebra. We examine the nature of interaction among the particles of the ensemble, with a view to interpreting the interaction in terms of the general properties of the q-deformation. We show that this can be accomplished by means of the virial expansion of the complex system of a real gas in powers of the deformation parameter q. The lowest order virial coefficient reduces to that of the standard non-interacting Bose gas, while the higher order virial coefficients contain effects arising from interaction. This formulation enables us to examine many interesting features of the thermostatistics of the q-deformed Bosons.

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Gauss' law of error revisited in the framework of Sharma-Taneja-Mittal information measure.

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Gaussian distribution is one of the most known and ubiquitous distributions in nature. Its universality is explained by the central limit theorem, which states that Gauss distribution arises as the limit distribution of a large number of statistically independent and identically distributed events.
Notwithstanding, it is nowadays well recognized that non Gaussian distributions are widely observed in several physical, social and economical systems. From a mathematical point of view, they can be obtained as the limit distributions of a large number of statistically correlated events.
In this work, we explore this possibility by following the original Gauss derivation, as known as Gauss' law of error. We revisit this derivation in the framework of the Sharma-Taneja-Mittal information theory, recently reconsidered from the statistical mechanics point of view in [1,2], and explore the underlying algebraic structure.
Two different Abelian fields, denoted in $\mathcal{A} \equiv (\mathbb{R}^+, \oplus, \otimes)$ and $\tilde{\mathcal{A}} \equiv (\mathbb{R}^+, \tilde{\oplus}, \tilde{\otimes})$, can be constructed starting from the two fundamental relations $\ln_{\{\kappa,\,r\}}(x \otimes y) = \ln_{\{\kappa,\,r\}}(x) + \ln_{\{\kappa,\,r\}}(y)$ and $\exp_{\{\kappa,\,r\}}(x \,\tilde{\oplus}\, y) = \exp_{\{\kappa,\,r\}}(x)\exp_{\{\kappa,\,r\}}(y)$, where $\ln_{\{\kappa,\,r\}}(x)$ and $\exp_{\{\kappa,\,r\}}(x)$ are the two-parameter generalized logarithmic and exponential functions, respectively.
The statistical correlation among events can be taken into account by means of the generalized product $\tilde{\otimes}$, through the introduction of the following likelihood function

$$\mathcal{L}_{\kappa,\,r}(\theta) = f(x_1-\theta) \otimes f(x_2-\theta) \otimes \ldots \otimes f(x_n-\theta) \ ,$$

where $f(x_i-\theta)$ is the distribution function of each single datum x_i centered around to the most probable outcome θ (mean value).
According to the Maximal Likelihood Principle, we show that the distribution function $f(x_i-\theta)$ maximizing the quantity $\mathcal{L}_{\kappa,\,r}(\theta)$ is provided by a $(\kappa,\,r)$-Gaussian which reduces to the standard Gaussian in the $(\kappa,\,r) \to (0,\,0)$ limit.
In the same limit, the likelihood function $\mathcal{L}_{\kappa,\,r}(\theta)$ reduces to the ordinary product of distribution functions so that it describes statistically independent events.
This work extend the cases previously discussed in [3,4] for the one parameter q-distribution and κ-distribution to the whole family of two-parameter $(\kappa,\,r)$-distributions.

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Asymptotic solutions of a nonlinear diffusive equation in the framework of κ-generalized statistical mechanics.

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In the non-equilibrium framework, irreversible processes can be described by means of Fokker-Planck equations, and their time evolutions are characterized by non-increasing Lyapunov functionals. In a recent work [1], we have derived a nonlinear Fokker-Planck equation for non-equilibrium systems in the picture of a generalized statistical mechanics based on the κ-entropy, and discussed its relation with the associate Lyapunov functional or Bregman type divergence.
Since this kinetic equation has a nonlinear diffusive term whose nonlinearity has a binomial dependence in $\rho(x,\, t)$, it makes difficult to obtain explicit solutions.
In this work we classify the group-invariant solutions of the κ-deformed diffusive equation. The only possible group-invariant solutions reduce to the self-similar solutions and to travelling waves whilst this new diffusive equation does not admit a solution corresponding to a kind of κ-deformed Gaussian, a generalization of Gaussian with the standard exponential replaced by its κ-deformed version [2,3].
The self-similar solutions, although non normalizable, can describe the time evolution of an order parameter (like temperature) characterizing the propagation of a physically significant quantity (like heat flux).
We derive the ODE for the self-similar solutions and we obtain, numerically, its solution for several different initial conditions. Although these solutions collapses, in the $\kappa \to 0$ limit, to the well known Erf(x) function, the deformed case exhibits more rich structures compared to the corresponding undeformed case.
In a more general fashion, we explore numerically the evolution of a localized state, whose spreading is governed by the κ-diffusive equation. It is shown that, independently from the initial conditions, the numerical solutions approaches, after a certain time, to a shape which is well fitted by the κ-Gaussian. Corroborated by these results, we conjecture that the κ-Gaussian, even though is not an exact solution for the κ-diffusive equation, can be interpreted as quasi-self-similar solutions, since it well approximates, asymptotically in time, the shape produced by different localized initial profiles.

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Criticality and corresponding states in ionic systems.

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Ionic liquids, which are molten salts with melting points below 100°C, down to −80°C, are a hot research topic at present. Many applications in chemical engineering and preparative chemistry are envisaged for this new fascinating group of compounds [1].
The interplay of Coulomb interaction and with van der Waals interactions provides a challenge for the theoretical understanding of the special properties of the ionic liquids and of their solutions. Some ionic liquids are soluble in non-polar solvents as hydrocarbons others in polar solvents like water. Vice versa some are insoluble in non-polar others insoluble in polar solvents.
Liquid-liquid phase transitions are observable at ambient temperatures enabling investigations of the critical properties (coexistence, critical fluctuations, critical dynamics) with mK accuracy. Such research is of fundamental interest: While in nonionic systems the liquid-gas as well as liquid-liquid phase transitions are driven by short range van der Waals interactions with an r^{-6}-range dependence, the phase transitions in the ionic systems are driven by long-range r^{-1}-Coulomb interactions. The universality hypothesis that liquid-gas as well as liquid-liquid phase transitions all belong to the Ising universality class has been theoretically proven for r^{-n} interactions with $n > 4.97$, while the nature of the critical point in Coulomb systems was unknown [2].
Some experiments reported mean-field behavior for such systems. Meanwhile, experiments [3] as well as simulations support the conclusion that Coulomb systems also belong to the Ising universality class. The simulations concern the so called restricted primitive model (RPM), which considers equal sized charged hard spheres in a dielectric continuum. The critical points of the liquid-liquid phase transitions in ionic solutions in non-polar solvents are in agreement with the prediction of the RPM. Corresponding state analysis based on the reduced variables of the RPM reveals different behavior, when comparing phase separation in aprotic solvents (hydrocarbons) with that in protic solvents (alcohols , water). In terms of the RPM- variables the phase separation in aprotic solvents, which is driven by Coulomb interactions, have an upper critical solution point, while the coexistence curves in protic solvents have a lower critical solution point, typically for phase separation caused by hydrophopic interactions [4].

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Dynamical analyses of normal and anomalous diffusion in nonlinear Fokker-Planck equations.

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A general type of nonlinear Fokker-Planck equation can be derived directly from a master equation, by introducing generalized transition rates. The H-theorem is demonstrated for systems that follow those classes of nonlinear Fokker-Planck equations, in the presence of an external potential. For that, a relation involving terms of Fokker-Planck equations and general entropic forms is discussed. It is possible to show that, at equilibrium, this relation is equivalent to the maximum-entropy principle. Therefore, those classes of nonlinear Fokker-Planck equations may be related to a single type of entropy [1,2]. The stationary distribution of a given entropy, under some constraints, is the same stationary distribution of the whole class of nonlinear Fokker-Planck equations with the same constraints. It is also shown that the Boltzmann-Gibbs entropy, apart from its connection with the standard – linear Fokker-Planck equation – may be also related to a family of nonlinear Fokker-Planck equations. We discuss this relation and, by numerically integrating the nonlinear Fokker-Planck equation, analyze the time evolution of systems which are related to Boltzmann-Gibbs entropy and Tsallis entropy. Curiously, the class of nonlinear Fokker-Planck equations related to the Boltzmann-Gibbs entropy present, in all nonlinear cases, anomalous diffusion in a scale of time much smaller than the time required to reach the stationary distribution (a Gaussian, if we consider a harmonic external potential). Alternatively, it is also possible to find a class of nonlinear Fokker-Planck equations related to Tsallis entropy which present, in a scale of time much smaller than the time needed to reach the stationary distribution (a q-Gaussian), a normal diffusion regime. The relaxation of the system to the stationary state also presents a power-law behavior for some cases within one class, unlikely the behaviors norm ally obtained in the literature.

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Time evolution of q-Gaussians in the linear and nonlinear diffusion equations.

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The linear diffusion equation is one of the most important differential equations of classical physics, being appropriate for a description of many physical phenomena, usually classified as normal diffusion. One of its simplest generalizations comes out to be the porous-medium equation [1]

$$\frac{\partial P(x,t)}{\partial t} = D\frac{\partial^2 P^{2-q}(x,t)}{\partial x^2} \ ,$$

which governs the time evolution of the probability distribution $P(x,t)$ for finding a diffusing particle in the position x at time t, in a medium characterized by a diffusion constant D; the linear diffusion equation comes out as the particular case $q = 1$. In the present work, the stability of q-Gaussian distributions as particular solutions of the linear diffusion equation and its generalized nonlinear form, the porous-medium equation, is investigated through both numerical and analytical approaches [2]. It is shown that by using a q-Gaussian, characterized by an index q_i, as the *initial* distribution, the approach to the *final*, asymptotic solution, characterized by an index q_f, occurs in such a way that the relaxation rule for the kurtosis evolves in time according to a q-exponential, with a relaxation index $q = q(q_f)$ [3]. In some cases, particularly when one attempts to transform an infinite-variance distribution ($q_i \geq 5/3$) into a finite-variance one ($q_f < 5/3$), the relaxation towards the asymptotic solution may occur very slowly in time. This fact might shed some light on the slow relaxation, for some long-range-interacting many-body Hamiltonian systems [4,5], from long-standing quasi-stationary states to the ultimate thermal equilibrium state.

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Stochastic thermodynamics: Theory and experiments.

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Stochastic thermodynamics provides a framework for describing small systems embedded in a heat bath and externally driven to non-equilibrium. Examples are colloidal particles in time-dependent optical traps, single biomolecules manipulated by optical tweezers or AFM tips, and motor proteins driven by ATP excess. A first-law like energy balance allows to identify applied work and dissipated heat on the level of a single stochastic trajectory. Total entropy production includes not only this heat but also changes in entropy associated with the state of the small system. Within such a framework, exact results like an integral fluctuation theorem for total entropy production valid for any initial state, any time-dependent driving and any length of trajectories can be proven [1]. These results hold both for mechanically driven systems modelled by overdamped Langevin equations and chemically driven (biochemical) reaction networks [2]. These theoretical predictions have been illustrated and tested with experiments on a colloidal particle pushed by a periodically modulated laser towards a surface [3]. Key elements of this framework like a stochastic entropy can also be applied to athermal systems as experiments on an optically driven defect center in diamond show [4]. For mechanically driven non-equilibrium steady states, the violation of the fluctuation-dissipation theorem can be quantified as an additive term directly related to broken detailed balance (rather than a multiplicative effective temperature) [5]. Integrated over time, a generalized Einstein relation appears which we have recently verified experimentally [6]. If velocities are measured with respect to the local mean velocity, the usual form of the FDT holds even in non-equilibrium. Finally, op-

timal protocols are derived which minimize the work required to switch from one equilibrium state to another in finite time [7].

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Dynamic frustration and persistence in spin systems.

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Certain spin systems are not able to reach the equilibrium ground state under a zero termperature quench which we term "dynamical frustration". In the Ising model with a competing second neighbour interaction (ANNNI model) several interesting phenomena are associated with the dynamic frustration. In one dimension, the Hamiltonian is given by

$$H = -J_1 \left[\Sigma\, S_i\, S_{i+1} - \kappa\, \Sigma S_i\, S_{i+2}\right] ,$$

with $\kappa > 0$. The persistence probability $P(t)$, that a spin has not flipped till time t, goes to zero in a stretched exponential manner when $\kappa < 1$ when the number of domain walls freeze even though they remain mobile [1]. This dynamics is mapped onto that of a system of interacting random walkers and independently studied [2] and the results are found to be consistent.
In the two dimensional ANNNI model where the competing interaction occurs along one direction only, we again find dynamic frustration for $\kappa < 1$, but quite different in nature. Here the dynamics becomes extremely slow as quasi-frozen structures resembling lattice animals appear in the system.
In order to analyse the results, we also study the dynamics of the domain walls and the distribution of the number of domain walls along both horizontal and vertical directions.
In both one and two dimensions, persistence decays as a power law for $\kappa \geq 1$ but with exponents different from that of the ferromagnetic Ising model [3]. The same is true for the dynamical growth exponent.
The above results are obtained using single spin flip Glauber dynamics. We will also discuss in brief how one can use simulated annealing (both classical and quantum) to overcome the dynamic frustration and enable the system to reach its ground state for $\kappa < 1$.

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Self-similarity of complex networks and hidden metric spaces.

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Self-similarity and scale invariance are traditionally known as characteristics of certain geometric objects, such as fractals, or of field theories describing system dynamics near critical points of phase transitions. In these cases, objects or physical systems are intrinsically embedded in metric spaces and distance scales in these spaces are natural scaling factors. In complex networks, it is difficult to define self-similarity and scale invariance in a proper geometric sense because many networks are not explicitly embedded in any physical space and they lack any metric structure except the topological one given by the collection of lengths of shortest paths between nodes, which is a poor source of length-based scaling factors since it does not have large lengths as it usually exhibits the small-world property. We demonstrate [1] that hidden metric spaces underlying the observed topologies of some complex networks –in particular the Border Gateway Protocol map of the Internet at the Autonomous System level and the Pretty Good Privacy social web of trust– appear to provide a plausible explanation of the observed self-similarity of their main topological characteristics -degree distributions, degree-degree correlations, and clustering– with respect to a simple degree-thresholding renormalization scheme which produces a hierarchy of nested subgraphs. Nodes are assumed to reside in an underlying hidden metric space, meaning that for all pairs there are defined hidden distances satisfying the triangle inequality. Clustering –cycles of length three– in the topology becomes then a natural consequence of the triangle inequality in this metric space underneath. If we take the most generic interpretation of hidden distances as measures of either structural or functional similarity between nodes, and admit that more similar nodes are more likely to be connected, then the hidden and observable forms of transitivity become clearly related. In future work, hidden metric spaces may find far-reaching applications such as the design of efficient routing and searching algorithms for communication and social networks.

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On creation of an exact microscopic heat theory on the basis of local distribution functions.

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There were obtained exact expressions for changing entropy and quantity of the heat given by the environment on the basis of a local approach and subsystem ensemble. Traditionally, design of non-equilibrium statistical mechanics is carried out on the basis of Gibbs ensemble and Liouville equation, which seem to cover all the possible conditions of a macroscopic system and that's why they should also describe the process of transition to equilibrium in a time-dependent system. But a nonstationary system can't be ergodic and that's why this approach is not strict. No one has managed to get an exact nontrivial solution to Liouville equation. Different approximate methods, which rigor can't be proved enough,

are used for getting solutions. The criterion is certain compliance of the result with the second law of thermodynamics. As we know, there is no exact microscopic heat theory, based on laws of motion. But while designing non-equilibrium statistical mechanics it's possible to pass on to a local description of a system, as it's possible in nonequilibrium thermodynamics, regarding physically infinitely small volume elements as quasi-equilibrium. One can construct an ensemble of subsystems, developing in time in accordance with equations of motion in the form of Hamilton equations [1]. In contrast to Gibbs ensemble [2] coordinates and momenta of external objects, i.e. particles, surrounding the considered sub-system, have different values for each of the subsystem. Evolution equations of such systems ensembles have exact solutions with clear physical meaning and describe evolution of subsystems which are not adiabatic, i.e. they exchange not only mechanical work but also heat with the environment. The second obtained equation describes interaction of subsystems with the environment. In quantum mechanics the same equation describes transition of subsystem particles from one power level to another, while the first one describes the change of the levels themselves, i.e. adiabatic interaction with the environment. The local approach can be a single basis for equilibrium and non-equilibrium statistical mechanics and kinetic theory. Though obtained results have a simple form, it's rather difficult to get them because we are beyond the domain of applicability of a number of mathematical theorems while considering subsystems. Gibbs distributions are extreme cases out of local distribution functions.

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Localization length of waves in disordered media and the red-shift of the spectral density.

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We introduce a novel method to calculate the localization length in a disordered medium using the amplitude change and red-shift of the spectral density of an incident pulse propagating in the medium. The method is general and applicable to any disordered medium of any space dimensionality. It is used to study electromagnetic wave propagation through a three-dimensional, statistically homogeneous disordered medium. The frequency dependence of the localization length and the variance of the polarization are computed in terms of the strength σ of the disorder. We also show, using the red-shift of the spectrum of black-body radiation, that due to localization of light in disordered media, measurements of the temperature at a distance Z from the source yield values that are lower than that of the source. The shifts in the frequency of the spectral peak and its corresponding temperature depend also on σ. For weak disorder we find that the temperature shift is given by, $\{T_0 - T(Z)\}/T_0 \sim Z$, where T_0 is the source's temperature.

Noise induced Hopf bifurcation.

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We study the Hopf bifurcation of stochastic system resulted in creation of limit cycle in two-dimensional phase space. We start with Langevin equation [1]

$$\dot{X_\alpha} = F^{(\alpha)} + G_\alpha \zeta(t),$$

where force $F^{(\alpha)} = F^{(\alpha)}(X_1, X_2)$ and noise amplitude $G_\alpha = G_\alpha(X_1, X_2)$ are functions of stochastic variables X_α, $\alpha = 1, 2$. We assume: (i) white noise $\zeta(t)$ is equal for both degree of freedom X_α and (ii) microscopic transfer rates are non-correlated for different X_α. Then, the Fokker-Planck equation related takes on a steady state solution whose explicit form is determined with a non-trivial combination of the noise amplitudes G_α, its derivatives over X_α and generalized forces $\mathcal{F}^{(\alpha)} = F^{(\alpha)} + \lambda \frac{\partial (G_\alpha G_\beta)}{\partial X_\beta}$ being fixed with choice of the calculus parameter $\lambda \in [0, 1]$. As a result, divergence condition of the steady state distribution determines a domain of zero values of stochastic variables X_α being bounded with a closed line of the limit cycle [2].
To verify above scheme we consider modulated regime of spontaneous laser radiation whose behaviour is presented in terms of the radiation strength E, the matter polarization P and the difference of level populations S [3]. It appears noise destroys limit cycle if the first of these values varies most fast. In opposite case, domain where stochastic states are forbidden is shown to extend with growth of noise intensities of P and S.

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Non-Markovian stochastic Liouville equation and its Markovian representation. Extensions of the continuous-time random walk approach.

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Some specific features and extensions of the continuous time random walk (CTRW) approach [1, 2] are analyzed in detail within the Markovian representation (MR) and CTRW-based non-Markovian stochastic Liouville equation (SLE) [3]. In the MR CTRW processes are represented by multidimensional Markovian ones. In this representation the probability density function (PDF) $W(t)$ of fluctuation renewals is associated with that of reoccurrences in a certain jump state of some Markovian controlling process. With the use of the MR the non-Markovian SLE, which describes the effect of CTRW-like noise on relaxation of dynamic and stochastic systems, is generalized to take into account the influence of relaxing systems on statistical properties of noise. Some applications of the generalized non-Markovian SLE are discussed. In particular, it is applied to study two modifications of the CTRW

approach. One of them considers the cascaded CTRWs in which the controlling process is actually CTRW-like one controlled by another CTRW process, controlled in turn by the third one, etc. The simple expression for the PDF $W(t)$ of total controlling process is obtained in terms of Markovian variants of controlling PDFs in the cascade. The expression is shown to be especially simple and instructive in the case of anomalous processes determined by long time tailed $W(t)$. The cascaded CTRWs can model the effect of complexity of a system on relaxation kinetics (in glasses, fractals, branching media, ultrametric structures, etc. [2]). Another CTRW-modification describes the kinetics of processes governed by fluctuating $W(t)$. Within the MR the problem is analyzed in a general form without restrictive assumptions on correlations of PDFs of consecutive renewals. The analysis shows that fluctuations of $W(t)$ can strongly affect the kinetics of the process. Possible manifestations of this effect are discussed.

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Correlations in commodity markets.

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Commodities, traded at free markets, follow the rules of the efficient market hypothesis [1], the same as stocks, currencies, and others. Their prices are, therefore, random and in major part unpredictable. Similarly to stock markets, we can expect that commodity prices are also correlated. Investigating the correlation is interesting, both from theoretical and practical point of view [2,3].
We analyzed cross-correlations for commodities such as: metals, fuels, meat, grains, and other plant products. Using logarithmic price returns of future contracts for commodities, we created the correlation matrix C_{ij}. We observed that a majority of the correlation matrix eigenvalues lie outside the random matrix region, which can be treated as an argument that the matrix C_{ij} contains real information about correlations between studied time series.
In the next step the matrix C_{ij} was used to create a correlation based metric that provides a measure of distances between contracts. Using this metric we constructed a minimal spanning tree of investigated contracts as a way to extract the most important correlations. The tree allowed us to identify basic branch groups formed by the nodes.
We observed that the correlations are non-stationary and we investigated such properties as an average correlation, its variance, a mean graph occupation layer, and changes in network topology. The mean correlation has grown significantly in recent years and the tree has become more compact. We found also changes in betweenness centrality of different nodes. Betweenness of gold and oil increased while betweenness of corn, soybean, and copper decreased.

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Scaling of clusters in a one-dimensional system.

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Most of the well-known works [1,2,3] concerning the spreading of social opinion are based on the models in which some representatives try to convince the others that do not share their opinion. We investigate evolution of a growing system of two-state objects (e.g. spins or representatives of some binary opinions) that are randomly added at empty sites in the course of time. Our numerical and analytical calculations show that even a simple one-dimensional model (a chain of N nodes) provides interesting results. The system's dynamics is described as follows: in each time step a new spin / a new representative of opposite opinions is chosen with the probability of 1/2 and placed at a random, not occupied node in the chain until all sites are filled. It can occur that after adding of a new element a cluster appears that consists of n consecutive group members with the same opinion surrounded by two elements that are opposite to the clusters member elements. In such a case we treat all members of the cluster as inactive (blocked) and those nodes no longer interact with the rest of the chain. We observed a critical density in the investigated system, it is a moment at which the first blocked spin appears. This density vanishes in the thermodynamical limit (N goes to infinity). The number of the blocked nodes Z increases with time as $Z \sim t^{\gamma}$ with γ exponent close to 3. We provide analytical expressions for the time evolution of the number of blocked nodes Z, as well as for the critical density τ_c. Our analytical studies are consistent with the numerical simulations. The character of the growth is universal (it does not depend on the system size).
In the extended version of the model the number of different opinions is equal to m. Each member added to the chain has the opinion drawn from the uniform distribution $\langle 0, m-1 \rangle$. The blocked opinions are formed from the cluster of identical opinions surrounded by two other identical opinions. The time evolution of the number of blocked opinions follows a power-law with the same exponent as in the two-opinion case. We also checked the interplay of number of nodes N and number of opinions m and its impact on the critical density.

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An exactly solvable of $p + ip$ wave superconductivity.

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We shall present the exact solution of a two dimensional BCS model of superconductivity where the order parameter has $p + ip$ wave symmetry. The solution is obtained using the Quantum Inverse Scattering Method and it is similar to the previously known exact solution of the reduced BCS model with s-wave symmetry, due to Richardon in 1964, and which plays an important role in Nuclear Physics and mesoscopic Physics, notably in the study of ultrasmall superconducting

grains. The $p + ip$ wave model in the mean field approximation, gives rise, in a certain regime of the coupling constants, to the Moore and Read wave function proposed to describe the Fractional Quantum Hall effect at filling fraction 5/2 and whose excitations are non abelians anyons, which on the other hand can be relevant for Quantum Computation. It is thus of great interest to have an exact solution of this model in order to analyze in detail the structure of the wave function of the $p + i\,p$ model. We have solved numerically the Bethe ansatz equations for a finite number of Cooper pairs, and the results have been compared, in the limit of large number of pairs, with the electrostatic solution la Gaudin, which in turn reproduces the mean field equations. In this manner we have obtained a very clear physical picture of the phase diagram. The latter contains a weak coupling BCS regime, a strong coupling BEC regime and a crossover region between them, associated to the Moore-Read wave functions. We compute several observables as number occupacions, the fidelity, etc, to characterize the transitions between these three different regions.

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Physics and banking.

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The statistical physicists observed that the behavior of a macroscopic system, which is composed of a great number of microscopic particles, obeys certain laws which concern mostly random exchange energy phenomena and these laws established the field of Quantum Mechanics and Thermodynamics. Quantum atomic models and kinetic theory of gases prove suitable for studying dynamic structures such as a bank's balance-sheet.
The bank is considered to be a complex economical system which is segmented by different units, whereas it interacts with the economic environment and thus, it can be studied according to the complex networks methodology. This means that the macroscopic balance sheet's behavior emerges from the microscopic units interactions. The return which derives from the changes of the bank's economic value is approached through the ideal gas model. The future business and interest rate scenarios comprise the possible states of the system and the return distribution corresponds to the energy distribution of the gas. The entropy increases until the immunization state where economic value tends to remain stable. However, due to duration drift of products, the economic value changes rapidly and the changes occurring in the structure of the balance sheet are offset with various business strategies in ALM, which correspond to the new structures of internal entropy production in the case of the gas.
The application of Fair Value (FV) according to the IAS offers dynamism to the financial states of the bank which depicts its special characteristics, the market conditions and the customers' options. The FV may be compared to the dual nature of light as it provides a dual substance of a financial instrument's value (it includes the return and the undertaking risk in a single number). The FV is produced as the terms return and risk reproduce one another, just like the electromagnetic wave in Maxwell's theory.
The fair value which is produced by the product's transition from one time bucket to another defines the possible position and quantizes the risk, just as a similar process occurs with the wave length λ of the emitted radiation due to Bohr's quantized energy. The electromagnetic spectrum which includes the analysis of radiation may be used for the scaling of each product's risk, in correspondence with the risk rating that is used by rating agents. The idea of risk quantization could be used for the achievement of balance-sheet immunization against the market's fluctuations.

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The therapy of shock therapy.

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We show that a simple model reproduces very closely the evolution of the GDP in constant dollars of many countries during the times of recession and recovery.
We find that quite universally, significant reforms (even the most ultimately successful ones) are followed by a period of decay. Thus, as an important lesson for policy makers, we derive that the success of a reform is to be evaluated by a more sensitive analysis that we describe. Such an analysis discriminates between the negative effect that the reforms have on the "old established economy" and the growth induced by the reforms on the "new leading sectors".
A theoretical analysis illustrates how an optimal dynamical policy reduces both recession duration and severity, and increases the value of GDP at all times. Thus the focus of this policy planning is transfered from the negative aspect related to blocking the economic collapse to the optimization of the recovery process as a whole.
The capability of the government to steer economic recovery encompasses taxation and redistribution, which is a small part of the processes and phenomena taking place. We show however that in fact when used optimally, according to an understanding of the underlying economic processes, even this very limited set of tools can lead to remarkably better results.

Anomalous scaling behavior in polymer thin film growth.

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To understand anomalous kinetic roughening and multifractality in the vapor deposition polymerization (VDP) growth

which have been experimentally observed [1], we study a simple model proposed by Bowie and Zhao [2] for the polymer thin film growth by vapor deposition, where the VDP process is mimicked by monomer diffusion, polymer nucleation as a dimer (oligomer), chain propagation with limited active end bonding, polymer-polymer chain interaction, and shadowing effects originated from cosine flux of incident monomers. Using extensive numerical simulations of the simple model, we investigate various polymer properties as well as growing surface properties as measuring both global and local quantities, e.g., surface width, height distributions, monomer/polymer density, polymer length distributions, polymer end-to-end distance scaling, height-height correlation functions, height-difference q-th moments, structure factor, step size fluctuations and distributions, active end fluctuations, and so on. It is found that the role of monomer diffusion in the VDP growth is quite different from that in the molecular beam expitaxial (MBE) growth. While monomer diffusion in the MBE growth makes surface smooth [3], that in the VDP growth makes surface rough due to the fact that monomers diffuse along polymer bodies. In the steady state, we observe that there is a typical polymer length, which is independent of system sizes and only depends on the ratio of diffusion coefficient to deposition (flux) rate, and that the nearest-neighbor height difference (step size) distribution becomes power-law, which is clear evidence of anomalous scaling and multi-scaling behavior as in the earlier growth studies with the power-law decaying noise distributions instead of the usually assumed Gaussian form [4,5]. We argue that such anomalies in the VDP growth are attributed to the instability induced by the nonlocal shadowing effects in polymerization, and such rare events effectively change the type of noise from Gaussian to power-law decaying form. Our numerical results and critical exponents are quantitatively compared to those in the ballistic deposition growth with power-law decaying noise distributions [5]. Finally, our (2+1)-dimensional results are qualitatively compared with recent VDP experimental data as tuning the ratio of diffusion coefficient to flux rate.

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Spontaneous symmetry breaking and criticality during animal development: Hydra axis definition.

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Hydra, a phylogenetically old organism, has become an attractive model organism in the hope to better understand the evolution of development. Hydra consists of a cylindrical body column framed by foot and head. Adult hydra is in a steady state: cells are continuously multiplying at its center, with age these cells migrate to both ends of the body column, where they become irreversibly differentiated (specialized) before they die. Hydra has astonishing regeneration capabilities - it can even reform from a completely disordered cell cluster, condensed from dissociated, single hydra cells. Contrary to hydra, most other organisms preserve an initial asymmetry during development and translate it to the axis of the animal [1]. Only in very few cases hydrodynamic flow or electric fields as external factors could be shown to be able to direct the developmental symmetry. Here we ask if spontaneous symmetry breaking exists during animal development. Child hypothesized in 1929 that a metabolic rate gradient should dictate the embryonic axis position. Metabolic rates depend strongly on temperature. Although numerous experiments on different model systems in a temperature gradient failed to confirm Childs hypothesis, we show, that a temperature gradient dictates the axis of the developing hydra, if it is applied sufficiently early. Using this finding, we identify the axis locking moment and note that it coincides with organizer formation. We visualize gene expression of the hydra specific gene ks1 [2], which serves a marker for potentially head forming cells. Ks-1 expressing cells form domains with a power-law size distribution. These domains attain a fractal shape at the symmetrybreaking moment. Since the genetic pathways during the regeneration process are identical for all cells, we propose that the cells need to increase their fluctuations in expression profile to create an asymmetry. Hydra locks this asymmetry as the fluctuations appear scale free at system size. Hydra follows a classical path of spontaneous symmetry breaking. We discuss similarities with models such as Ising or forest fire.

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How scaling and market efficiency determine the irreversible evolution of financial indices.

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In setting up a stochastic description of the time evolution of a financial index, the challenge consists in devising a model compatible with all stylized facts emerging from the analysis of financial time series and providing a reliable basis for simulating such series. Based on constraints imposed by market efficiency and on an inhomogeneous-time generalization of standard simple scaling, we propose an analytical model which accounts simultaneously for empirical results like the linear decorrelation of successive returns, the power law dependence on time of the volatility autocorrelation function, and the multiscaling associated to this dependence. In addition, our approach gives a justification and a quantitative assessment of the irreversible character of the index dynamics. This irreversibility enters as a key ingredient in a novel simulation strategy of index evolution which demonstrates the predictive potential of the model. The idea of basing the process construction on scaling, and the construction itself, are closely inspired by the probabilistic renormalization group approach of statistical mechanics and by a recent formulation of the central limit theorem for sums of strongly correlated random variables.

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Generalized dimension D_q and Tsallis entropy S_q derived from the nonlinear differential equation $dy/dx = y^q$.

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The q-exponential function $\exp_q(x)$ was first derived from maximizing Tsallis entropy under some constraints for a generalization of Boltzmann-Gibbs statistics. On the other hand, from a mathematical point of view, the q-exponential function $\exp_q(x)$ is characterized as the solution of the fundamental nonlinear differential equation: $\frac{dy}{dx} = y^q$ [1], which introduces the generalized multiplication called q-product $\otimes_q$ satisfying the generalized exponential law $\exp_q(x_1) \otimes_q \exp_q(x_2) = \exp_q(x_1 + x_2)$ [2,3]. Applying the q-product to the mathematical formulations such as q-Stirling's formula, q-multinomial coefficient, we derive Tsallis entropy as the unique information measure corresponding to the q-exponential function [4]. Recently, as an extension of the above result, we derive Tsallis entropy S_q from the (μ,ν)-multinomial coefficient where $\nu(1-\mu)+1 = q\,(\neq 0)$, which recovers the 4 typical mathematical structures in Tsallis statistics: additive duality "$q \leftrightarrow 2-q$", multiplicative duality "$q \leftrightarrow 1/q$", q-triplet and multifractal triplet [5].
In our presentation, we mathematically show

$$\exp_q(S_q(p_i)) = \exp_{\frac{1}{q}}\left(S_{\frac{1}{q}}(P_j)\right) \simeq \varepsilon^{-D_q} \qquad (1)$$

where P_j is the so-called escort distribution defined by $P_j := p_j^q / \sum_{i=1}^n p_i^q$ and D_q is the so-called generalized dimension in multifractal analysis. The identity (1) reveals that the parameter "q" in Tsallis entropy S_q coincides with "q" in D_q which recovers the 3 typical dimensions: capacity (box-counting) dimension ($q = 0$), information dimension ($q = 1$), correlation dimension ($q = 2$). Moreover, our mathematical study presents the direct relations between three q's in $\frac{dy}{dx} = y^q$, Tsallis entropy S_q and the generalized dimension D_q. Other similar relations as (1) are also shown and discussed.

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100-years of long term dependence in the Dow Jones index.

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We investigate the presence of long-term dependence in over 100-years of daily returns on the Dow Jones Stock Index. We measure the presence of long-term dependence in the price returns (ΔP_t) using statistical techniques based on the rescaled range analysis of Hurst [1]. What is novel about our approach is that we consider different return lags to accommodate short-term autocorrelated innovations in the return process [2] and we estimate the local Hurst exponent over different interval lengths.
We begin with a filtering process using an Autoregressive (AR) model where the residual ψ_t is of interest. Specifically, we apply five levels of filters AR(1)→ AR (5) to ΔP_t. Such lagged effects on prices are generally considered a test of price efficiency. For example, consider an AR(5) model of the form $\Delta P_t = \alpha_0 + \beta_1 \Delta P_{t-1} + \ldots + \beta_5 \Delta P_{t-5} + \psi_t$, where for each ψ_t the classical rescaled adjusted range $(R/\sigma)_n$ is calculated. In this case set $\overline{X}_n$ to the sample mean and σ_n is the standard deviation of ψ_t over a particular series n and h_n (termed the local Hurst coefficient) $= \log(r/\sigma)_n / \log n$. We set the interval length n is set from 22 days (1-month) to 252 days (1-year). This procedure in effect creates a time-series of exponent values, the change in whose value can be measured over time.
The average local Hurst exponent estimated on a monthly and annual basis reveals time-varying and statistically significant positive dependence ($0.9 > h > 0.5$, for $n = 252$), which is consistent with a fractal process and inconsistent with economic notions of market efficiency. A process that exhibits positive dependence is one that is non-mean reverting - a finding of considerable economic significance for market arbitragers. Applying short-term AR filtering does not significantly change this finding, although the filtering slightly lowers the actual exponent.

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On efficient searching of hidden targets.

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We consider how an animal can search for hidden targets efficiently. We assume that the animal moves in n-dimensional space and finds a target if the distance between the animal and the target becomes less than a. We define that the animal has searched a position r if it approaches that position up to distance a. Let $U(r,t)$ denote the probability that an animal which starts from the origin will not search a position r until time t. The probability that the animal will search a position r by time t is given by $1 - U(r,t)$. Accordingly the volume $V_s(t)$ the animal searches by time t is given by

$$V_s(t) = \int [1 - U(r,t)]\, dv$$

If the concentration of targets is c, the average number of targets the animal finds by time t is given by $cV_s(t)$. Therefore, we can use $V_s(t)$ to characterize the efficiency of searching, irrespective of the concentration of targets.
We have calculated the searched volume $V_s(t)$ when an animal performs ballistic motion and Brownian motion in three dimensions, and showed that when the animal performs ballistic motion it can search a larger volume for a given time [1]. However, when the animal performs ballistic motion, it has a greater probability of missing a target ultimately even if it comes close to the target, compared with the case when it performs Brownian motion [2]. This missing effect is more enhanced, especially when the initial position is close to the target [2].
When the animal comes close to a target, it senses odor from the target and know that it is close to a target. If the animal changes its motion from ballistic to Brownian when it senses the odor, the probability that the animal finds the target ultimately will increase significantly, but the time taken to find the target will not increase so much. Therefore, the efficiency of searching will be maximized if the animal performs ballistic motion as long as it does not sense the odor and Brownian motion once it senses the odor. This conclusion is in agreement with the widely observed intermittent behavior of foraging animals.

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Collective charge fluctuations in single-electron processes on nano-networks.

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Functional soft materials composed of many nano-particles often have a complex structure both as 2-dimensional films [1] and 3-dimensional super-crystal structures [2], that emerges from self-assembly processes with appropriately functionalized nano-particles. These assemblies exhibit a wide range of physical properties which are not found in bulk materials and can often be related to their spatial structure. The conduction via single-electron tunnelings in films of metallic nanoparticles is important for nano-electronics. Experimentally a large nonlinearity of the current–voltage curve has been found in self-assembled nanoparticle films on substrates [1,3].
The random structure of these films can be adequately modelled by planar graphs (nano-networks) [5]. We use the model with long-range electrostatic interactions of the capacitively-coupled nanoparticles on substrate [4,5] and simulate numerically single-electron tunnelings driven by the external voltage [6]. We study the collective dynamic behavior which is in the background of the observed $I(V)$ nonlinearity, in particular, the long-range correlations in charge fluctuations monitored at each nanoparticle and inhomogeneous charge flow along the conducting paths through the sample. Various related pdfs appear to be q-Gaussian. We demonstrate how the topological and charge disorder affects the quantitative statistical properties and $I(V)$ dependences.

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Renormalization of random multiplicative processes: An application to the universal statistics of company growth.

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In the first half of this talk we review results of analysis of company's financial data based on a recently accessible huge database which covers about 1 million companies or practically all active companies in Japan. It is shown that clear power laws are confirmed for the distributions of sales, incomes, numbers of employees, and annual growth rates [1]. As a simplest mathematical description of such company data we can introduce the following random multiplicative process for the time evolution of sale of a company, $x_j(t)$

$$x_j(t+1) = b_j(t)\, x_j(t) + f_j(t) \ ,$$

where $b_j(t)$ is the growth rate and $f_j(t)$ is a random noise. The validity of this approximation can be checked directly by the data, and from theoretical viewpoint the power law distribution can be understood as the steady state distribution of this random multiplicative process [2].
Regarding that this random multiplicative process is the most fundamental process of company's activity we assume that this stochastic process holds microscopically in any branch of a company and consider that the whole company can be viewed as an aggregation of this process, $X(t) = \sum_{j=1}^{N} x_j(t)$. Then, this aggregated quantity can also be supposed to satisfy a random multiplicative process with a renormalized growth rate, $B(t)$. This is a renormalization of random multiplicative process and we show that there exists a universal distribution of renormalized growth rate, which is fairly close to the growth rate distribution of real companies. The resulting growth rate distribution is given by a t-distribution (or a q-Gaussian distribution) having power law tails. This result proves that even in the case that microscopic growth rate distribution has no long tail, renormalized macroscopic growth rate distribution has power law tails in general, so that a macroscopic system generally has a risk of extraordinary large fluctuation.

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Basic statistical properties of random walks in moving potential forces: the PUCK model for market prices.

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High frequency data analysis of market price fluctuations has clarified that random walks of prices in markets have several peculiarities which are very different from a simple random walk. We pay attention to the following 5 empirical facts for market prices:

- I: The distribution of price change in a unit time has nearly symmetric long tails approximated roughly by power laws.
- II: The autocorrelation of price changes decay quickly to zero often accompanied by a negative correlation for very short time.
- III: The square of price changes has a long correlation.
- IV: Abnormal diffusion is observed for short time scales.
- V: Many-body distribution of signs of price changes is significantly different from that of independent random walks.

Mathematical models of markets such as the ARCH model can satisfy I to III by tuning parameters, however, IV and V can not be fulfilled by such stochastic models that assumes no correlation in the signs of price differences. In order to overcome such difficulty we have already introduced a random walk model called PUCK in which potential force is moving and deforming in time [1]

$$x(t+1) - x(t) = -\frac{d}{dx} U_M(x,\, t)\Big|_{x=x(t)-x_M(t)} + f(t)\ ,$$

$$U_M(x,\, t) = \frac{b_2(t)}{M-1}\,\frac{x^2}{2} + L\ ,$$

where $x_M(t)$ is the simple moving average of latest M prices. It is shown that when $b_M(t)$ is a constant only IV and V are satisfied, however, by introducing random fluctuations of $b_M(t)$ around 0 all these properties can be retained. Direct estimation of $b_M(t)$ from market price time series also supports the validity of this theoretical approach.

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Quantum fluctuation theorems.

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During the last decade various fluctuation and work theorems have been formulated and discussed. They provide information about the fully nonlinear response of a system under the action of a time-dependent force, in contrast to linear response theories in which the response is expressed in terms of correlation functions of the unperturbed system. In this presentation we will discuss specific quantum aspects of the work performed on a quantum system by an external force. The performed work is a key quantity describing the nonlinear response to an external perturbation of finite strength and finite duration. It is a random quantity due to the intrinsic randomness of quantum mechanics which may additionally be superimposed by the classical randomness of a mixed initial state of the system. The statistics of the work is completely determined by its characteristic function defined as the Fourier transform of the corresponding probability measure. We demonstrate that this characteristic function of work can be expressed in terms of a correlation function of the exponentiated system's Hamiltonians at the two instants of times which mark the beginning and the end of the force protocol [1]. For systems which initially stay in a canonical state the Jarzynski work theorem [1] and the Tasaki-Crooks fluctuation theorem [2] follow immediately from the characteristic function. Also for a microcanonical initial state a fluctuation theorem of the Crooks type holds [3]. It relates the ratio of the probabilities of work for the original process and the time reversed process to the ratio of the densities of states of the system at the beginning and the end of the process, and consequently to the difference of the thermodynamic entropies of the corresponding microcanonical systems. From this relation a novel "entropy-from-work" theorem is derived which allows one to infer the difference of thermodynamic entropy solely from the process running forward in physical time [3]. The influence of the initial conditions is discussed for the example of an externally driven harmonic oscillator [4]. In particular, we compare the probability distributions of work which follow from microcanonical, canonical and coherent initial states for the same force protocol.

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Trajectory decomposition for unsupervised learning neural models.

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In this paper, use the trajectory decomposition technique to rigorously prove the similarity between different neural models. First, we derive the free energy function for an unsupervised net of stochastic neurons with lateral interactions. The temperature incorporated in this function serves as control parameter in the annealing schedule. Then, we consider the incremental and batch modes of learning resulting in corresponding versions of soft topology-preserving mapping. The mapping utilizes only weak lateral interactions that can be, therefore, approximated by the nearest-neighbour ones. Considering the weight vector of a neuron as a "particle" moving in the space-time of imposed patterns, we decompose this particle trajectory over these patterns. Using the decomposition for incremental and batch modes of soft topology-preserving map, we derive the cortical map and the elastic net respectively [1,2]. The temperature of the above maps is transformed into the Gaussian variance of the cortical map and the elastic net. This fact elucidates indirect incorporation of soft competition and deterministic annealing into the cortical map and the elastic net, which makes them to be very powerful neuro-

computational models. We show that the batch version of soft topology-preserving map is rigourously reduced to the corresponding elastic net. Unlike, the incremental version of soft topology-preserving map is reduced to the cortical map only in the low temperature limit. We tested the models on the relevant to them tasks: the travelling salesman problem and the development of visual cortex topology, namely the formation of retinotopy and ocular dominance. The difference in derivation of the latter systems results into the difference in their behaviour: the batch soft topology-preserving map and the elastic net produce similar outputs whereas the incremental soft topology-preserving map and the cortical map behave differently.

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q-Gaussian approximants mimic non-extensive-statistical-mechanical expectation for many-body probabilistic model with long-range correlations.

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q-Gaussian distributions seem to provide a class of distributions which may successfully model a wide variety of natural phenomena [1] and which serve as an attractor for certain correlated systems [2]. However, it is not always obvious what underlying generating mechanism gives rise to these models. Possible mechanisms do exist, however. For example [3] describes Student-t distributions (a special case of q-Gaussians) as a family of scale mixtures of normal laws. In this talk we introduce and study a strictly scale-invariant probabilistic N-body model with symmetric uniform identically distributed random variables. Correlations are induced through a transformation of a multivariate Gaussian distribution with covariance matrix decaying out from the unit diagonal, as $\frac{\rho}{r^\alpha}$, for $r = 2, 3, \ldots N$, where r indicates the displacement from the diagonal; $\alpha \geq 0$ characterizes the range of the correlations; and $0 \leq \rho \leq 1$ characterizes the strength of the correlation. We show numerically that, as N increases towards infinity, the sum of the N random variables quickly approaches a nontrivial limiting distribution which mimics (but is not equivalent to) to a compact support q-Gaussian distribution with $q(\rho, \alpha) \leq 1$. In the particular case of $\alpha = 0$ we obtain $q = \frac{1-(5/3)\rho}{1-\rho}$. This result was analytically derived in a recent paper by Hilhorst and Schehr [4] addressing the present model. Our present results with these q-Gaussian approximants precisely mimic the behavior that was expected in the frame of non-extensive statistical mechanics. The fact that the $N \to \infty$ limiting distributions are not exactly, but only approximately, q-Gaussians reveal that the present random variables are not exactly, but only approximately, q-independent, in the sense of the q-generalized central limit theorem recently proved by Umarov, Steinberg and Tsallis. Short range interaction ($\alpha > 1$) and long range interactions ($\alpha < 1$) are discussed. Other simple mechanisms which lead to the production of q-Gaussians, such as mixing, are discussed as well.

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Generalized-generalized entropies and central limit distributions.

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The importance of non-exponential distributions arising from an impressive number of complex statistical systems is by now beyond any doubt. Clearly, for most of these systems the classical approach of statistical mechanics is highly unjustified and bound to fail. Since many of these systems are statistical in nature it should be possible to keep the maximum entropy principle, however with a modified entropy functional. It is known for 20 years that for variables following asymptotic power-laws the associated maximum entropy principle can be formulated in terms of generalized entropies where the usual logarithm of the Boltzmann entropy gets replaced by the so called q-logarithm [1]. However, in diverse complex systems frequently distributions are observed which do not fit into the framework of the class of generalized entropies. This calls for a more general setting. We showed lately that for every reasonable class of distribution functions it is possible to derive a unique entropy functional (generalized-generalized entropy), which guarantees not only the correct results under the maximum entropy principle [2], but is also fully compatible with the two fundamental thermodynamic requirements, i.e. the first and the second law of thermodynamics [3].
We show how limit theorems for correlated random variables – as recently introduced by Hilhorst and Schehr [4] – pave a road that leads to a further level of generalized entropy functionals, which is able to take into account scaling relations in the distribution functions. Although the level of generalization of entropy – required to incorporate all possible distributions resulting from such limit theorems – is now considerable, this new class of entropies remains fully compatible with the first and the second law of thermodynamics.

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Central limit behavior of one-dimensional discrete dynamical systems.

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One of the cornerstones of statistical mechanics and of probability theory is the central limit theorem. It states that the sum of N independent identically distributed random variables, after appropriate centering and rescaling, exhibits a Gaussian distribution as $N \to \infty$. In general, this concept lies at the very heart of the fact that many stochastic processes in nature which consist of a sum of many independent or nearly independent variables converge to a Gaussian. For deterministic dynamical systems, a central limit theorem is valid only if the system is sufficiently mixing. Recently we analytically calculated the leading-order correction to the central limit theorem for the fully developed logistic map and cubic map and found perfect agreement with numerical results [1]. On the other hand, due to strong temporal correlations, a standard central limit theorem is not valid when the system is at the edge of chaos. In [1] we also showed numerically that the probability distribution of sums of iterates of the logistic map at the edge of chaos can be well approximated with a q-Gaussian, the distribution which, under suitable constraints, maximizes the entropy $S_q \equiv \left(1 - \sum_i p_i^q\right) / (q-1)$, the basis of nonextensive statistical mechanics. A closer look has also been attempted [2] in order to better analyse the entire distribution (both the central part and the tails) to see under what conditions there is convergence to a q-Gaussian. A theoretical argument has been provided on determining the optimum value of N (the number of iterates) in order to achieve the best convergence to a q-Gaussian. These results are consistent with a large number of already available analytical and numerical evedences that the edge of chaos is well described in terms of the entropy S_q and its associated concepts. In this work, after giving a review of these and other recent results, we discuss the interplay between the number of iterates and the precision of the value of the critical map parameter making use of the scaling relation given in [2].

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Symbolic dynamics at the threshold of chaos.

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Symbolic dynamics is a powerful tool for the analysis of dynamical systems and provides a natural environment for the evaluation of entropies. In fact it considers a partition of the phase space in disjoint subsets, assigning to each subset a symbol drawn from an alphabet and coding the evolution of the trajectory of the corresponding dynamical system in the phase space as a sequence of symbols. Thus it provides a direct correspondence among the probabilities of visiting sub-regions of the phase space and the probabilities of occurrence of strings of symbols. For a system in the chaotic state the number of different strings of length N grows exponentially N. We are interested in the behavior of systems at the onset of chaos, where the growth is weaker than exponential. It is then convenient to introduce, when using symbolic dynamics at the onset of chaos, the formalism of non-extensive thermodynamics, which naturally describes the occurrence of power-law growth through the use of deformed logarithms and exponentials. The formalism of symbolic dynamics allows also to analyze sequences of symbols as walks on a graph and to build an adjacency matrix associated to the dynamical system. This in turn provides the system entropy as a function of the eigenvalue spectra. In this work we extend the theory of symbolic dynamics and the associated graph theory to describe and characterize weak sensitivity to initial conditions and power-law behavior in systems at the threshold of chaos. We analyze the sequences of symbols resulting from various partitions of the phase space for the logistic map at the critical border of chaos and describe the rate of growth of the number of strings of fixed length versus increasing length using different deformed logarithms. We look for the associated adjacency matrix and we use again deformed statistics to characterize the properties of the eigenvalue spectra. Finally we compare our results with the ones we already obtained in a previous work using the framework of non-extensive thermodynamics to calculate ensemble properties for the same dynamical system.

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Pesin identity at the edge of chaos: Averaging on single trajectories vs ensemble averages.

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Recently an extension of the Pesin identity for dynamical systems in the chaotic state has been proposes in the case of dynamical systems at the threshold of chaos, using the framework of non-extensive thermodynamics. This identity in the case of chaotic systems is based on the definition of Kolmogorov-Sinai entropy evaluated along a single trajectory in the phase space, assuming this trajectory on the basin of attraction of some attractor onto which the dynamics evolves. The phase space is then partitioned into boxes and the system state is thus observed at discrete intervals of time. This definition requires the evaluation of the joint probability that the trajectory visits a defined sequence of boxes in the limit that such a sequence be infinite. This may be computationally prohibitive and an approach based on the evolution of the divergence among two infinitely close trajectories is usually employed. This is also

true in the case of the less critical divergence at the threshold of chaos, for systems weekly sensitive to initial conditions. In order to extend the Pesin identity, using the formalism of non-extensive thermodynamics, to the threshold of chaos, we have used the more convenient ensemble averages to calculate the non-extensive entropies. This approach leads to an interesting and well-defined extension of the identity, which also appears physically correct. There exist, however, the logical possibility that the ensemble averaged entropy and the entropy calculated using joint probabilities along a single trajectory, in spite of being equal in many instances, might behave differently in specific systems. It is, therefore, very interesting to study whether the two approaches are equivalent at the edge of chaos. We tackle this problem by introducing a new quantity related to the scaling of the correlation integral, which includes the possibility of more general formalisms such as the one used in non-extensive thermodynamics. We evaluate an extension of the correlation integral along a single trajectory in the phase space and use appropriated deformed exponentials/logarithms to analyze power-law behaviors. In the limit of usual exponentials/logarithms we recover the standard form for the KS entropy, which is correctly null at the border of chaos but it is unable to detect the weaker power-law sensitivity. We compare result obtained with this single-trajectory approach with the corresponding results obtained through ensemble averages.

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Interaction as the key to non-extensive statistical physics.

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We present approaches to the generation of entropy-measures, especially to the generation of *Tsallis entropy* [8], and other quantities of interest when studying the exchange of information in a broad sense.
Consider a notion of *interaction between Truth and Belief*, related to the interplay between *System* and *Observer*. The notion may well be related to the process of *measurement* (for a recent discussion see [3]). Taken in a direct physical sense, interaction has often been singled out as an important feature of non-extensive statistical physics, cf. [1], for example. Here, interaction is understood in a mathematical sense.
If x represents Truth and y Belief, both related to some *event*, then the interaction $\pi(x, y)$ represents the *"weight"* of the event as it is conceived by *Observer*. Observer seeks to determine a function $y \curvearrowright \kappa(y)$, the *coder*, which represents, for each y, the *effort* which Observer is willing to (or *has to*) assign to any event in which he has the Belief y. It is understood that κ is taken as small as possible, observing a certain *feasibility constraint* and subject to conditions of normalization, agreed to be $\kappa(1) = 0$ and $\kappa'(1) = -1$.
Classically, $\pi(x, y) = x$ ("no interaction") and this leeds to Shannon-Boltzmann-Gibbs entropy via the coder $\kappa(y) = \ln \frac{1}{y}$.
If the interaction is *consistent* in a suitable sense, resulting in the form $\pi(x, y) = qx+(1-q)y$, you are led to Tsallis q-entropy via the coder

$$\kappa(y) = \frac{1}{1-q}\left(x^{q-1} - 1\right).$$

Regarding possibilities for true coding interpretations, see [5]. The feasibility constraint leading to the above conclusions is related to the "fundamental inequality" of information theory (classically amounting to the "log-sum inequality").
The approach is related to previous game theoretical modelling, [6]. An axiomatic characterization of *complexity, entropy* and *divergence*, is also possible, cf. [7]. Key examples relate to *Bregman divergence*, see also [2,4,6]. This again may leed to Tsallis q-entropy, though in a less convincing manner than for the approach via interaction. Other examples are quite different in nature and related to geometry.

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Classifying superstatistics.

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The notion of superstatistics was introduced by Beck and Cohen (Physica 322, 267, 2003) as way to understand how statistical distributions that are non-canonical (in the sense that they differ from the distribution of the canonical ensemble) may arise as a mixture of distributions that are canonical. The idea is to consider an extended system as being composed of different regions in which equilibrium holds locally, and to average the canonical distribution that characterizes each of these regions in order to obtain a non-canonical distribution, which is thought of to characterize the system as a whole. Beck and Cohen showed that the mixed distribution or superstatistics obtained by this averaging process can have many different forms, depending on the form of mixing distribution used for performing the average. It will have the form of a

q-exponential, in particular, if the mixing distribution is the χ^2 distribution.
I will present in this talk a classification of many different superstatistics based on their asymptotic and central properties, together with a corresponding classification of mixing distributions underlying these superstatistics. I will argue that our efforts at understanding superstatistics from a non-phenomenological point of view should go at building microscopic models of the general mixing distributions that are thus classified. Some models that go in this direction will be presented.

On the foundations of statistical mechanics. Additive and nonadditive entropies, central limit theorems, and related matters.

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The full accomplishment of the ambitious *Boltzmann program* remains elusive still today. However, the following highlights support the success of statistical mechanics based on the (additive) Boltzmann-Gibbs entropy $S_{BG} = -k \sum_i p_i \ln p_i = k \sum_i p_i \ln(1/p_i)$.
(i) S_{BG} is *extensive* ($S_{BG}(N) \sim N$) for say classical short-range-interacting Hamiltonians.
(ii) Consider say the logistic map. If the *Lyapunov exponent* $\lambda_1 > 0$, the *sensitivity to the initial conditions* $\xi = e^{\lambda_1 t}$, and the BG *entropy production* equals λ_1 (Pesin-like equality).
(iii) Consider the Fokker-Planck equation $\frac{\partial p(x,t)}{dt} = \frac{\partial}{\partial x}\left[\frac{\partial U(x)}{\partial x}\, p(x,t)\right] + D\frac{\partial^2 p(x,t)}{dx^2}$ ($U(x)$ is a confining potential). Its stationary solution is given by the BG factor $p(x,\infty) \propto e^{-\beta\, U(x)}$ ($\beta = 1/D$). $U(x) = k_1 x + k_2 x^2$ ($k_2 > 0$) implies $p(x,t) \propto e^{-\beta(t)\, x^2}$; x^2 scales with t (*normal diffusion*) if $k_1 = k_2 = 0$. The H-theorem property mandates S_{BG} as the admissible entropy.
(iv) Maximization of S_{BG} with appropriate constraints yields the celebrated BG weight $p_i = e^{-\beta\, E_i}/Z$. And analogous maximization of S_{BG} (continuous form) yields $p(x) \propto e^{-\beta\, x^2}$.
(v) This latter result, as well as the Gaussian form associated with the above Fokker-Planck equation, are deeply linked to the Central Limit Theorem. Consistently, time-averaged dynamical variables with maximal $\lambda_1 > 0$ approach, after centering and scaling, Gaussian attractors. Finally, the velocity distribution of a classical Hamiltonian is the Maxwellian.
(vi) $dy/dx = a_1\, y$ with $y(0) = 1$ yields $y = e^{a_1\, x}$. This exponential may represent the typical dependence of three paradigmatic quantities within the BG theory, namely the *sensitivity to the initial conditions* $\xi = e^{\lambda_1\, t}$ (λ_1 plays the role of a_1), the *relaxation* of a macroscopic quantity M (e.g., the entropy itself) in the form $\mu \equiv \frac{M(t)-M(\infty)}{M(0)-M(\infty)} = e^{-t/\tau_1}$ ($-1/\tau_1$ plays the role of a_1), and the *canonical thermal equilibrium* weight in (iii) ($-\beta$ plays the role of a_1).
These properties are consistent with probabilistic independence (or quasi-independence). In many complex systems, this hypothesis is heavily violated. Nonextensive statistical mechanics addresses such systems [1,2]. Its grounding entropy is $S_q = k\frac{1-\sum_i p_i^q}{q-1} = k \sum_i p_i \ln_q(1/p_i)$ ($S_1 = S_{BG}$), $\ln_q x \equiv \frac{x^{1-q}-1}{1-q}$. So, if the system is classical and its maximal $\lambda_1 > 0$ (*strongly chaotic*), BG statistical mechanics is justified. If it is *zero*, then a most interesting possibility emerges, namely when $q < 1$ and the maximal q-generalized Lyapunov coefficient $\lambda_q > 0$ (*weakly chaotic*). This is the basic justification of nonextensive statistical mechanics.

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Inhomogeneous coupling in two-channel asymmetric simple exclusion processes.

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Asymmetric exclusion processes for particles moving on two parallel one dimensional channels with inhomogeneous coupling at a single point are investigated theoretically. Particles interact with hard-core exclusion and move in the same direction (to the right) on both lattices, while transitions between the channels are allowed at one specific location in the bulk of the system. Entrance and exit rates are identical for both channels. An approximate mean-field theoretical approach that describes the dynamics in the vertical link and horizontal lattice segments exactly but neglects the correlation between the horizontal and vertical transport is developed. It allows us to calculate stationary phase diagrams, particle currents and densities for symmetric and asymmetric transition rates between the channels. It is shown that in the case of the symmetric coupling there are three stationary phases, similarly to the case of the single-channel totally asymmetric exclusion processes with local inhomogeneity. In contrast to the totally asymmetric exclusion process however, these three phases do not include a maximal current phase. In place of that we find a phase exhibiting a sharp first-order phase transition at the linking point which separates an area of high density before the link and an area of low density after it. The phase diagram is symmetric and although the three phase point location is found to depend on the coupling strength this does not affect the symmetry. Further, asymmetric coupling between the lattices leads to a very complex phase diagram with ten stationary-state regimes. We demonstrate that the large number of phases is due to the asymmetric coupling breaking the symmetry between the lattices enabling the current on each segment to fluctuate with far fewer constraints than is able to do under a symmetric coupling regime. One result of this is that while individual segments do undergo numerous phase transitions there are no more system-wide phase transitions to be found. Also, a small asymmetry becomes evident, ultimately caused by a slight breaking of the particle-hole symmetry at the linking site. Extensive Monte Carlo computer simulations generally support theoretical predictions, although simulated stationery-state properties slightly deviate from calculated in the mean-field approximation, suggesting the importance of correlations in the system.

Dynamic properties and phase diagrams are discussed by analyzing constraints on the particle currents across the channels.

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Nonlinear theory of quantum Brownian motion.

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A nonlinear theory of quantum Brownian motion in classical environment is developed based on a thermodynamically enhanced Schrödinger equation [R. Tsekov, arXiv:0711.1442v2]. Since the included local entropy and action depend on the wave function, it is a nonlinear Schrödinger equation. Therefore, the superposition principle is not valid anymore and the energy levels of the Brownian particle permanently change in time. The entropy represents an original thermodynamic DFT potential and some specific statistical properties of the Brownian particle can be modeled via its dependence on the probability density. For instance, the Boltzmann entropy leads to the logarithmic Schrödinger equation. The action induces frictional decoherence, which is similar to that in the Schrdinger-Langevin equation. This nonlinear Schrödinger equation is transformed via dissipative Bohmian mechanics into a nonlinear quantum Smoluchowski equation, which is proven to reproduce key results from the quantum and classical physics. The application of the theory to a free quantum Brownian particle results in a nonlinear dependence of the position dispersion on time, being quantum generalization of the Einstein law of Brownian motion. At large time the dispersion tends asymptotically to the Einstein law, while at short time a purely quantum expression holds. The characteristic time of decoherence, proportional to the square of the thermal de Broglie wavelength divided by the Einstein diffusion constant, marks the transition from quantum to classical diffusion. For shorter times the classical Einstein law violates the Heisenberg principle due to the equilibrium momentum dispersion. According to the present theory, the non-equilibrium momentum dispersion exhibits non-exponential decay in time. It satisfies the Heisenberg principle at any time and reduces at infinite time to the well-known equilibrium momentum and position dispersions. This non-equilibrium expression describes the spreading of a Gaussian wave packet continuously monitored by the thermal bath. This happens via reversible and irreversible entropy changes, which according to the Shannon theory are equivalent to information exchange. Therefore, the measurements are not a privilege of the human being only. They exist in any open system divided to observable subsystem and non-observable environment.

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Information geometrical study of Trp-cage folding dynamics.

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In protein-folding research, two major areas are studied constantly: 1) predicting a protein's native configuration and 2) discovering its folding dynamics. Because complicated atomic interactions among proteins and between proteins and solvents create a complicated energy landscape, a protein structure may be trapped in a local energy minimum during the molecular dynamic (MD) simulation. The problem can be overcome by using the replica exchange technique (or "parallel tempering"), based on aspects of the Monte Carlo method. Incorporating the MD simulation with parallel tempering thus becomes one of theoretical approaches to resolving the first issue. However, there is a trade-off: the dynamics of the folding process will be concealed under a vast sample space generated by the parallel tempering technique. This sample space consists of an enormous number of various protein configurations obtained from simulations at different temperatures and times. To study the dynamics of protein folding, we explore the use of information geometry advocated by Caticha [1,2] and consider a two-stage approach. First, we cluster proteins with similar configurations ("microstates"), to reduce the degree of freedom in the sample space. The overall cluster is defined as a "mesostate", a collection of the microstates. Next, we parameterize the sample space by specific physical quantities, such as energy or root mean square distance of two structures, and we assign a probability distribution to each microstate and mesostate, according to the method of maximum entropy. Thus, by determining the dynamics of the protein-folding process, we are in fact exploring the evolution of the mesostate. Caticha has shown that information geometry provides a natural way to study the evolution of probability distributions [1]. An entropic folding dynamic is thus proposed. The well-studied, 20-residue Trp-cage peptide designed by Neidigh et al. [3,4] is by far the fastest folding protein known to us, and this process can be simulated within a reasonable computational time. Therefore, in this work, we demonstrate and analyze the entropic folding dynamics of the Trp-cage peptide. We utilize the AMBER simulation package to conduct the MD simulations with the parallel tempering technique, in which we consider 24 different initial temperatures, given a random coil of the Trp-cage peptide as an initial configuration. Each simulation is 140ns long.

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Kinesin motor protein as an electrostatic machine.

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Kinesin and related motor proteins utilize ATP fuel to propel themselves along the external surface of microtubules in a processive and directional fashion [1,2]. Motion proceeds along a single protofilament through sequential detachment of the kinesin head that gets hydrolyzed and attachment of the other head. One important feature of this step-like motion is that it consumes one ATP molecule per step [3,4]. While a large number of mechanical, statistical as well as chemical models exits for analyzing the kinesin dynamics there has not been much interest in understanding the physical basis for the motion. We show here though a simple yet not trivial model that we can obtain all the essential experimentally determined kinesin walk features if we take as a basis for the motion the electrostatic interactions between kinesin and microtubule. Due to the different polarity charges of ATP and ADP the interaction between kinesin and the microtubular surface is fluctuating leading to time varying electrostatic interactions. We show that the observed step-like motion is possible through time varying charge distributions furnished by the ATP hydrolysis circle while the static charge configuration on the microtuble provides the guide for motion [5]. As a result, while the chemical hydrolysis energy induces appropriate local conformational changes, the motor translational energy is fundamentally electrostatic. Numerical simulations of the mechanical equations of motion show that processivity and directionality are direct consequences of the ATP-dependent electrostatic interaction between kinesin and microtubule. Furthermore, electrostatic calculations show that the ATP charge upon entry in kinesin may interact and thus influence ADP expulsion from the tethered head.

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Fractional differential equation for subrecoil laser cooling.

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A new technological process in nanophysics called subrecoil laser cooling has undergone spectacular progress during the last two decades (see [1] and the bibliography therein). The use of resonant exchanges of momentum between atoms and laser light photons allowed to obtain samples of atoms at temperatures in the nanokelvin range corresponding velocities in the mm/s range. The cooling process may be interpreted as a random walk of atoms in momentum space with a jump rate $R(\mathbf{p})$ continuously depending on the atom momentum $\mathbf{p}$ in such a way that $R(0) = 0$. An atom can stay near the origin for a long time θ and then leaves it for diffusion motion over the rest momentum space up to the next hit on the trap after time τ. Both these times are considered to be mutually independent random variables with pdf's $q_0(t)$ and $q_\tau(t)$ respectively. Thus we can restrict ourselves to consideration of a two state jump process (diffusion-rest-diffusion-res-...). So that each realization of the random history of an atom leaving the trap at the moment $t = 0$ can be represented by a sequence of independent $\tau_1, \theta_1, \tau_2, \theta_2, \tau_3, \theta_3, ...$ Trajectories of different atoms are considered to be independent too.
The cooled atoms consideration $N_0(t)$ is proportional to the probability of finding the atom at the origin range, $f_0(t)$. The latter function is expressed through the integral

$$f_0(t) = \int_0^t [F(t') - F'(t')]dt'$$

from the difference of transition rates of return times $F(t)$ and of exit times $F'(t)$ obeying the integral equation system (under condition that the motion starts with leaving the trap):

$$F(t) = q_\tau(t) + \int_0^t F'(t-t')q_\tau(t')dt',$$

$$F'(t) = \int_0^t F(t-t')\ q_0(t')dt'.$$

As shown in [1], $\mathrm{Prob}(\theta > t) \propto t^{-\alpha}$ and $\mathrm{Prob}(\tau > t) \propto t^{-\beta}$, $0 < \alpha, \beta < 1$, $t \to \infty$. Using this assumption, the Laplace transform and the Tauberian theorem we prove in this report that the asymptotical term of the $f_0(t)$ obeys the differential equation with fractional derivatives of the Riemann-Liouville type:

$$[{}_0D_t^\alpha + b_0 D_t^\beta]f_0(t) = \frac{1}{\Gamma(1-\alpha)}t^{-\alpha}.$$

The solution obtained by means of Green function method is the form

$$f_0(t) = t^{\alpha-\beta}E_{\alpha-\beta,\alpha+1-\beta}(-bt^{\alpha-\beta})$$

and conforms with results of numerical simulation according to the integral equation system.
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Dynamic behaviors in directed networks: Synchronization and opinion dynamics.

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Synchronization behavior of nonidentical Kuramoto-type phase oscillators [1] and the opinion dynamics of a simple voter

model [2] are numerically studied in a directed network which embeds a hierarchical tree. We start from the directed pure tree structure, and visit each edge one by one. At a given splitting probability p, each incoming edge weight is halved and an additional incoming edge of the half weight is added from a randomly chosen other vertex. The resulting directed network contains the original tree structure and the in-strength of each vertex is conserved to be unity.
The equations of motion for Kuramoto-type nonidentical phase oscillators put on vertices of the above built network of the size N are written as

$$\frac{d\,\theta_i}{d\,t} = \Omega_i + K \sum_{j=1}^{N} W_{ij} \sin\left(\theta_j - \theta_i\right),$$

where θ_i is the phase of the ith oscillator, Ω_i is the uncorrelated quenched intrinsic frequency, K is the coupling strength and W_{ij} is the weighted adjacency matrix element for the directed link from j to i. As more edges are split, i.e., as p is increased, the synchronization order parameter first decreases, and then increases beyond the value for the original tree structure corresponding to $p = 0$.
In order to study opinion dynamics of the voter model in directed networks, we slightly break the Z_2 symmetry in the conventional voter model and let one opinion ($\sigma = 1$) has a bigger chance to be accepted than the other ($\sigma = -1$) with the opinion of the top vertex fixed to $\sigma = -1$. Via extensive numerical simulation, it is seen that if the number of split edges is not so big, the whole system often falls into a situation that majority of population agrees on the worse opinion ($\sigma = -1$). As more and more edges are split to make the network structure much different from the one of the pure tree, more voters are found to agree on the better opinion. From these findings, we conclude that network structures with a more abundant bidirectional information channels can yield a bigger scale of collective emergent behaviors.

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Topological phases in the Kitaev honeycomb lattice model on tours.

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We investigate low energy spectral properties of quantum lattice models which are believed to form topologically ordered states known also as topological phases. Our particular focus is on the Kitaev honeycomb spin-1/2 lattice model [1]. In the absence of external magnetic field, the model is exactly solvable and its phase diagram exhibits a gapless phase and an abelian topological phase whose effective description is given by the $Z_2 \times Z_2$ topological field theory. As known from the perturbation theory, a weak magnetic field has no dramatic effect on the abelian topological phase but turns the gapless phase into a non-abelian topological phase whose effective description is given by the $SU(2)_2$ theory. The quasiparticle excitations of this phase are nonabelian anyons satisfying the Ising fusion rules.
We particularly study the Kitaev honeycomb lattice on torus [2]. We describe symmetries of this model and review the perturbative mapping of its abelian topological phase onto the $Z_2 \times Z_2$ square lattice model known as the toric code. We provide the classification of finite size effects on the model low-energy spectral properties [3]. In this context, special attention is given to the thin-torus limit and related conformal field theory data. We then investigate properties of the model's vortex excitations. We complete this part with discussion of topological degeneracy of the model [2].
We then proceed to numerical investigation of the non-abelian topological phase in the perturbative limit of weak magnetic field [4] and beyond. The weak field is modeled by an effective three body interaction term which does not commute with the bare Hamiltonian but commutes with the vortex operators. In this regime, we observe that the magnetic field is able to induce level crossing of states belonging to the same vortex sector. We also investigate the model in strong field regime modeled by the full Zeeman term which allows for dynamics of vortices.
We conclude with discussion of the topological phase transitions in the model and brief review of other lattice models whose low energy spectra provide realization of topological field theories.

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Dynamics of three interacting species in single compartment and in spatially extended system by moment equations.

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Real ecosystems are influenced by random fluctuations of environmental parameters, such as temperature, food resources, migrations, genetic changes. This caused, during last decades, an increasing interest on the role played by the noise in population dynamics [1]. In systems governed by nonlinear dynamics the presence of noise sources can give rise to counterintuitive phenomena like stochastic resonance, noise enhanced stability, resonant activation, noise delayed extinction [2,3]. Therefore, the stability of biological systems in the presence of noise sources has become one of the most relevant topics both in experimental and theoretical investigations on complex systems [4]. In this work we consider the dynamics of three interacting species, two preys and one predator, in the presence of two different kinds of noise sources. To describe the spatial distributions of the species we use a model based on Lotka-Volterra (LV) equations. A correlated dichotomous noise acts on β, the interaction parameter between the two preys, and a multiplicative white noise affects directly the dynamics of each one of the three species. Using low levels of multiplicative noise we analyze the system dynamics for two different values of β, β_{down} and β_{up}, which determines respectively the coexistence

and exclusion regimes for the system. Successively we consider β as a stochastic process governed by a periodical driving force in the presence of a dichotomous noise. This causes the interaction parameter β to switch quasi-periodically between β_{down} and β_{up}. As a consequence, a dynamical regime appears where coexistence and exclusion alternatively take place. In this condition we study the time behaviour of the three species in a single compartment system, for different values of the multiplicative noise intensity. Afterwards we consider a spatially extended system formed by a two-dimensional spatial domain, i.e. a square lattice with $N \times N$ sites, and we write the three species equations adding a diffusion term [5]. Then, by applying a mean field approach, we obtain the corresponding moment equations in Gaussian approximation. Within this formalism we get the time behavior of the first and second order moments for different values of the multiplicative noise intensity, according to the procedure followed in the single compartment case.

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Fracture and earthquake physics in a non extensive view.

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It is well known that the Gutenberg-Richter (G-R) power law distribution has to be modified for large seismic moments because of energy conservation and geometrical reasons. Several models have been proposed, either in terms of a second power law with a larger b value beyond a crossover magnitude, or based on a magnidute cut-off using an exponential taper. In the present work we point out that the non extensivity viewpoint is applicable to seismic processes. In the frame of a non-extensive approach which is based on Tsallis entropy we construct a generalized expression of Gutenberg-Richter (GGR) law. The existence of lower or/and upper bound to magnitude is discussed and the conditions under which GGR lead to classical GR law are analysed. For the lowest earthquake size (i.e., energy level) the correlation between the different parts of elements involved in the evolution of an earthquake are short-ranged and GR can be deduced on the basis of the maximum entropy principle using BG statistics. As the size (i.e., energy) increases, long range correlation becomes much more important, implying the necessity of using Tsallis entropy as an appropriate generalization of BG entropy. The power law behaviour is derived as a special case, leading to b-values being functions of the non-extensivity parameter q.
Furthermore a theoretical analysis of similarities presented in stress stimulated electric and acoustic emissions and earthquakes are discussed not only in the frame of GGR but taking into account a universality in the description of intrevent times distribution. Its particular form can be well expressed in the frame of a non extensive approach. This formulation is very different from an exponential distribution expected for simple random Poisson processes and indicates the existence of a non-trivial universal mechanism in the generation process. All the aforementioned similarities within stress stimulated electrical and acoustic emissions and seismicity suggests a connection with fracture phenomena at much larger scales implying that a basic general mechanism is "actively hidden" behind all this phenomena.
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Thermodynamics of relativistic fluids.

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The relativistic fluid dynamical approach to describe the evolution of matter created in heavy-ion collisions was initially proposed by Landau. Ever since then, it has been successfully applied to model and predict the outcome of colliding different heavy ions at wide range of energies. Recently dissipative phenomena was detected at RHIC, hence the different theories of viscous heat conducting relativistic fluids is revisited and applied in the evaluation of the experiments. Therefore the theory of relativistic dissipative fluids is subject of intensive research.
It is well known, that the simplest generalization of Fourier-Navier-Stokes equations is acausal and shows generic instabilities. There are several competing alternate theories to resolve these problems, most of them are extending the set of independent fields to create a hyperbolic set of equations and to suppress the instabilities.
Our analysis of the stability problem reveals, that the physical background of the instabilities is in the identification of the local rest frame time-spacelike and space-timelike components of the energy-momentum tensor, the energy flux and the momentum density. In simple fluids they should be equal because of the symmetry of the energy-momentum tensor T^{ab}, but the former is related to dissipative and the later to nondissipative

phenomena. A second law analysis shows that the internal energy of relativistic dissipative fluids should be the absolute value of the energy vector $E = \sqrt{E^a E_a} = \sqrt{u_b T^{ba} T_{ac} u^c}$ instead of the energy density $e = u_a T^{ab} u_b$ [1,2]. The mentioned generic instabilities are eliminated with the new definition.
The corresponding consequences to equilibrium thermodynamics are treated. Equilibrium and non-equilibrium temperatures, transformation properties (Planck-Ott paradox, etc.) are investigated. Some implications to statistical physics and kinetic theory are mentioned.

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Superstatistical distributions from maximum entropy principle.

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In this poster we will present some very recent results about the application of the maximum entropy principle in the context of superstatistics. The crucial assumption of the latter theory is that the statistical description of certain complex, non-equilibrium systems can be split into two levels that have a large time scale separation [1]. The total system is divided into cells that are in local equilibrium but the temperature of the different cells don't have to be equal. As a consequence, it is a very good approximation to describe the properties of the different cells using the standard Boltzmann-Gibbs formalism. The major problem is the determination of the distribution of the temperature at the higher level of the total non-equilibrium system. Usually, the only information available about a system are the average values of some observables. Therefore, it is natural to use the maximum entropy principle to obtain the least biased distribution, given some constraints, for the distribution of the temperature. It is known that the outcome of the maximum entropy principle is crucially dependent on the choice of constraints. To illustrate this in the present context we study some theoretical examples and discuss different choices of constraints from a quantum mechanical and from a classical point of view. We derive explicit formulas for the distribution of the temperature for a set of non-interacting quantum harmonic oscillators and for a classical ideal gas. As a practical example we apply the general theory to velocity time series measured in turbulent Taylor-Couette flow [2]. The velocity differences in turbulent Taylor-Couette flow are already studied in the context of superstatistics [3]. The authors show that a clear time scale separation shows up in the time series and that the log normal distribution gives a very good fit to the distribution of the temperature. We expect that the theory of superstatistics will also be usable to study directly the velocity time series measured in turbulent Taylor-Couette flow and that one can extract a distribution of the temperature from the time series along the lines of [3].

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Seismic electric signals and natural time.

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Seismic Electric Signals (SES) activities are low frequency ($\leq$ 1Hz) electric signals that precede earthquakes and are emitted from the focal area when the stress reaches a critical value [1]. It is the first aim of the present paper to review the current efforts towards distinguishing SES from similarly looking signals of artificial origin (e.g., cultural noise). We show that modern techniques (e.g. detrended fluctuation analysis (DFA), multifractal DFA, etc.), when treated in the usual (conventional) time domain, cannot distinguish SES activities from artificial signals, but they do when applied to a new time time domain -termed *natural time*- suggested recently [2]. The same is achieved when employing the entropy in natural time [3].
Beyond the distinction of SES activities (critical dynamics) from similar looking signals of different dynamics, natural time enables the shortening of the time-window of the impending mainshock [4]. Precise examples are presented for the following earthquakes (EQs) of various magnitudes (M) that occurred in Greece [5]: (a) The three magnitude 6.0 class EQs in the Aegean sea on October 2005, (b) The two ≈M6.0 EQs close to Zakynthos island in western Greece during April 2006, (c) An M5.8 EQ on June 29,2007 in Northwestern Greece, (d) The M6.5 EQ in southwestern Peloponese on January 6,2008 that was also felt in adjacent countries (South Italy and Western Turkey), (e) The M6.9 EQ close to southwestern Peloponese on February 14, 2008. In *all* these cases, the relevant SES activities have been recognized (and submitted for publication) well in advance and, in addition, their time-window was determined to be a few days at the most.

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Absorbing phase transitions in coevolving networks.

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Since the investigation of networks by statistical physicists began, the research has been focus in many aspects. One of this is related to the study of different dynamical processes on networks, such as epidemic spreading in biology, reaction-diffusion in chemistry, opinion formation in sociology, etc. Most of these

studies assume that the network of interactions is fixed. However, in many real cases, the topology of the network is affected by the state of the nodes and vice versa, so that the network adapts to the process. In recent studies on adaptive networks people have observed a peculiar type of absorbing phase transition [1,2,3]. In these models, a node can change its state by interacting with its neighbors, and at the same time, links can be rewired depending on the state of the nodes at their ends. In this way, the dynamics of nodes and links are not independent, but they coevolve. It is found that when the rewiring is fast enough compare to the rate at which nodes update their states, the network breaks into disconnected components, each composed by nodes holding the same state. In order to understand the mechanism of this fragmentation transition I introduce a simple model [4], that possesses all the ingredients of related models, and has the advantage of being analytically tractable. A mean-field approximation reveals an absorbing transition from an active to a frozen phase at a critical value of the rewiring probability $p_c = \frac{\mu-2}{\mu-1}$ that only depends on the average degree μ of the network. In finite-size systems, the active and frozen phases correspond to a connected and a fragmented network respectively. The transition can be seen as the sudden change in the trajectory of an equivalent random walk at the critical point, resulting in an approach to the final frozen state whose time scale diverges as $\tau \sim |p_c - p|^{-1}$ near p_c. The mean-field approach can be extended to study the time evolution of the system in generic interacting agents models on complex networks.

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Generalized fractional Fokker-Planck equation for anomalous diffusion: The Gaussian statistics recovered.

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The problem of anomalous diffusion is important for a wide variety of systems, such as fluids, glasses, polymers, proteins etc. It is characterized by a mean square displacement evolving in time as a power-law $\langle x^2 \rangle = 2\, D_0\, t^{\alpha}$, where α is called the anomalous diffusion exponent. However, a Fokker-Planck-like equation which can describe a stationary Gaussian process with anomalous-diffusion behavior, such as the one described by the Generalized Langevin equation, is still missing. We propose a generalization to the fractional Fokker-Planck equation [1], based on a series expansion in spatial and fractional time derivatives and powers of the Fokker-Planck operator. The proposed generalized fractional Fokker-Planck equation (GFFPE), in one spatial dimension, is of the form

$$\partial_t P(x,t) = \sum_k {}_0D_t^{1-k\alpha} C_k \partial_x^k \left(\beta\, U'(x) + \partial_x\right)^k P(x,t) \ ,$$

where $P(x,t)$ is the probability distribution function (PDF); ∂_t and ∂_x stand for space and time derivatives respectively; ${}_0D_t^{1-\alpha}$ is the fractional Riemann-Liouville operator defined through [1,2]:

$${}_0D_t^{1-\alpha} \equiv \frac{1}{\Gamma(\alpha)} \frac{\partial}{\partial\, t} \int_0^t \frac{P(x,t')}{(t-t')^{1-\alpha}} dt' \ ,$$

and is a fractional extension of an integer derivative; $\beta \equiv 1/k_B T$ is the reciprocal temperature and $U(x)$ is the potential. Note that the operator $(\beta\, U'(x) + \partial_x)$ appears also in the common Fokker-Planck equation. Naturally, our GFFPE maintains the Boltzmann distribution as its equilibrium solution.
In the potential-free case, $U = 0$, the moments of x are required to obey the Gaussian statistics by means of Wick's theorem. This is achieved by an appropriate choice of the coefficients C_k, performed order-by-order. Consequently, our expansion is equivalent to writing the approximate PDF by means of its moment expansion. We can obtain the Gaussian distribution to the desired accuracy by keeping the expansion to the appropriate order.
In order for our GFFPE to be physically meaningful, the coefficients C_k should not depend on the potential U. However, they may depend on the characteristics of the anomalous diffusion (e.g., on α), which are attributed to the properties of the embedding medium. When applying our GFFPE to the case of the constant force, we obtain the Einstein relation, $\langle (x - \langle x \rangle)^2 \rangle = 2\langle x \rangle / \beta f$ (where f is the constant force). Higher order moments obey, again, Wick's theorem to the prescribed order of the expansion.
We apply our GFFPE to first passage time problems of the potential-free and constant-force cases, and compare the results to the corresponding solutions of the fractional Fokker-Planck equation [1] and the fractional diffusion equation [2]. We further propose to use our GFFPE for treating other outstanding problems, such as the anomalous diffusion under an harmonic potential and the Kramers' escape problem [1,3-5], that is used in chemical and biochemical reactions.

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Generating function approach to thermodynamics based on time averages.

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We derive the statistical-mechanical expressions obtained via the method of time averages [1,2] by considering a renewal stochastic process. Our approach is based on the introduction of a generating function for the n-th event occurrence. This involves weighting the probability distribution function $\psi_n(t)$ for the n-th event taking place at time t by a factor z^n. For identical independent events (IIEs) the $\psi_n(t)$ are determined in turn from the distribution function for a single event $\psi(t)$ occurring at time t, and this is provided in the usual straightforward way by repeated convolutions of $\psi(t)$. When the weight parameter z is assigned a functional dependence on the system's

relevant parameters the generating function is seen to represent the partition function of a statistical-mechanical system from which a free energy (or Massieu entropy function) is obtained via standard procedures. Within the consideration of IIEs, and according to the specific choice of the functional form of z on, say, the configurational energy of the system, we obtain, amongst other possibilities, the Boltzmann-Gibbs or the Tsallis general expressions. Boltzmann-Gibbs statistics is obtained by assuming an exponential dependence inside z while Tsallis statistics follows from a q-deformed exponential form. Thus, the type statistical-mechanical structure produced by our generating function approach is determined by the manner in which the renewal events are weighted and not by the nature of the renewal process itself. We further illustrate our formalism by considering the Weierstrass renewal processes of IIEs introduced by Hughes, Montroll and Schlesinger that consists of a single event distribution $\psi(t)$ composed of an infinite number of exponentially decaying processes [3]. Depending on the relative presence of low frequency events the Weierstrass process exhibits either exponential or power law time decay in the limit of infinite events $n \to \infty$. In the former case our generating function approach recovers the Botzmann-Gibbs statistics. For the latter case we determine the resultant statistical-mechanical structure.

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Tsallis statistics framework for the information bottleneck method in unsupervised learning applications.

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The information bottleneck (IB) method [1] is formulated within the ambit of the generalized statistics of Tsallis [2,3]. The IB method, which has recently received much attention in machine learning and communications theory significantly improves upon rate distortion (RD) theory in lossy data compression [4].
Given a *source alphabet* $X \in \mathcal{X}$ and its compressed representation (*reproduction alphabet*) $\tilde{X} \in \tilde{\mathcal{X}}$, RD theory possesses an intrinsic shortcoming, in that it *a-priori* specifies the nature of the distortion measure. This is tantamount to an *a-priori* specification of the features of interest in X to be contained in $\tilde{X}$. RD theory lacks the framework to specify the features of interest in $\mathcal{X}$ that are relevant to a given study. To ameliorate this drawback, the IB method introduces another variable $Y \in \mathcal{Y}$ (the *relevance variable*). *The crux of the IB method is to simultaneously minimize the compression information* $I_q(X;\tilde{X})$ *and maximize the relevance information* $I_q(\tilde{X};Y)$.
Specifically, the IB method extracts structure from X via data compression, followed by a quantification of the information contained in the extracted structure with respect to Y. Thus, the IB method "squeezes" the information between X and Y through a *bottleneck* $\tilde{X}$, via the Markov condition $Y \leftarrow X \leftarrow \tilde{X}$. A recent study [5] is extended to formulate a generalized Information Bottleneck (gIB) method. Solution of the gIB model employs the *data processing inequality*, possessed by un-normalized Tsallis entropies for values of $q > 1$. A candidate gIB model is obtained via variational extremization of a Lagrangian obtained by subjecting the generalized mutual entropy for $q > 1$ to the additive duality $q^* = 2 - q$ [5]:

$$L_{gIB}^{q^*}\left[p(\tilde{x}\,|x\,)\right] = I_{q^*}\left(X;\tilde{X}\right) - \tilde{\beta}_{gIB} I_{q^*}\left(\tilde{X};Y\right), \quad (1)$$

contingent to the normalization of $p\,(\tilde{x}\,|x\,)$. Here, $\tilde{\beta}_{gIB}$ is the *nonadditive trade-off parameter* for the simultaneous minimization and maximization described by (1). Next, employing *normalized* Tsallis mutual entropies [6] expressed in terms of the *escort* probability, the following gIB Lagrangian is subjected to variational minimization for $0 < q < 1$:

$$L_{gIB}^{q}\left[P(\tilde{x}\,|x\,)\right] = I_{q}^{E}\left(X;\tilde{X}\right) - \tilde{\beta}_{gIB}^{E} I_{q}^{E}\left(\tilde{X};Y\right),$$

contingent to the normalization of the *escort* transition probability $P\,(\tilde{x}\,|x\,)$. Here, $\tilde{\beta}_{gIB}^{E}$ is the *nonadditive trade-off parameter*.
The unique result of IB theory defining the Kullback-Leibler divergence between $p(Y|X)$ *and* $p(Y|\tilde{X})$ *as the effective distortion measure, is shown to carry over into the nonadditive regime.* Iterative algorithms for the gIB models are formulated based on a *nonadditive alternating minimization* procedure [5], in conjunction with the marginal distributions and the Markov consistency conditions. Numerical simulations demonstrate the superior performance of the the gIB models for data clustering, *vis-á-vis* the Boltzmann-Gibbs-Shannon model.

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Collective dynamics of interacting neural networks in competition

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In the last decades social phenomena have been a subject of study of statistical physics through models for opinion dynamics [1] and for collective actions resulting of inductive agents individual decison making (so called Keynesian beauty contests) [2]. Extensive work have also been published on the

statistical mechanics of inductive agents modeled as artificial neural networks [3]. We here propose two scenarios involving interacting adaptive agents represented by simple Boolean perceptrons trained by on-line Perceptron learning rules. In the first scenario, we extend [4] by introducing a population with two kinds of perceptrons playing the minority game. The first group composed by $\alpha\sqrt{K}$ highly adaptive (high learning rate) perceptrons and the second composed by K conservative (small learning rate) perceptrons. At each round in the game, agents that successfully predict the minority opinion receive a payoff inversely proportional to the size of this minority. Using simulations we observe that for α small an exploitative phase with adaptive agents obtaining higher than the average gains emerges. For α large enough we have observed a self-defeating phase where adaptive agents under-perform conservative agents. We also study this scenario using genetic algorithms to co-evolve efficient algorithms for playing the game, the best on-line learning rule that evolves significantly differs from the usual Perceptron algorithm. In the second scenario we study the opinion dynamics of a population of Boolean perceptrons deciding on the classification of an issue. This scenario being an extension of a model with continuous opinions and discrete decisions (CODA) recently proposed in [5]. At each interaction, agents react to the observed decisions of their neighbors in a social network. By simulation, we observe the spontaneous emergence of dominions with extremely confident (strong synaptic connections) agents with opposite opinions. For both scenarios we simulate a number of variations and discuss possible strategies for analytical treatment.

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First-passage times in complex scale invariant media.

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How long does it take a random walker to reach a given target point? This quantity, known as a first passage time (FPT), has led to a growing number of theoretical investigations over the last decade. The importance of FPTs originates from the crucial role played by first encounter properties in various real situations, including transport in disordered media, spreading of diseases or target search processes [1]. Most methods to determine the FPT properties in confining domains have been limited to effective 1D geometries, or for space dimensions larger than one only to homogeneous media.
I will first introduce a general theory which allows one to evaluate the mean FPT (MFPT) in complex media [2]. This analytical approach provides a universal scaling dependence of the MFPT on both the volume of the confining domain and the source-target distance. I will show that this analysis is applicable to representative models of transport in disordered media and fractals.
Second, I will show that this framework is relevant to study anomalous diffusion. Subdiffusive motion of tracer particles in complex crowded environments, such as biological cells, has been shown to be widepsread. This deviation from brownian motion is usually characterized by a sublinear time dependence of the mean square displacement (MSD). I will show that first-passage observables provide tools to unambiguously discriminate between possible microscopic scenarios of subdiffusion, and suggest experiments based on first-passage observables which could help in determining the origin of subdiffusion in complex media.

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The future poverty hiding in cities.

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Expected urban population doubling calls for a compelling theory of the city. Random walks and diffusions defined on spatial city graphs spot hidden areas of geographical isolation in the urban landscape going downhill.
Sociologists think that isolation worsens an area's economic prospects by reducing opportunities for commerce, and engenders a sense of isolation in inhabitants, both of which can fuel poverty and crime. Unfortunately, urban planners and governments have often failed to take such isolation into account when shaping the city landscape, not least because isolation can sometimes be difficult to quantify in the complex fabric of a major city. Many neighbourhoods are cut off from other parts of the city by poor transport links and haphazard urban planning, which can often lead to social ills [1].
We consider the representations of the set of automorphisms of undirected graphs in a class of stochastic matrices that can be interpreted as random walks and diffusions. We demonstrate that the accessibility to a node in the graph can be estimated by the expected first-passage time to it. Random walks induce the structure of Euclidean space on undirected graphs. It is remarkable that the first-passage times play the role of the metric distances in the $(N-1)$-dimensional probabilistic Euclidean space set by random walks defined on an undirected graph of size N [2].
The method accounting the average number of random turns at junctions one would take to reach any particular place in the city from various starting points could easily be used to identify isolated neighbourhoods in big cities with a complex web of roads, walkways and public transport systems. For instance the Bowery, which was a deprived district of New York for most of the 20th century, can be seen as isolated from nearby areas at the time. Another example we have studied is the labyrinthine network of canals in Venice. We have found that

one district - the Venetian Ghetto - jumped out as by far the most isolated, despite being apparently well connected to the rest of the city. On average, it took 300 random steps to reach Ghetto, far more than the average of 100 steps for other places in Venice [3].
In existing cities, efforts should be made to reconnect isolated districts, perhaps by building tunnels and bridges.

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Generalized log-likelihood functions and Bregman divergences.

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It is well known that likelihood function plays a key role in many fields of statistics, e.g., statistical inference, statistical physics, parameter estimation, maximum likelihood method. Kullback-Leipler divergence (KLD) also has been well known and often used as a distance-like measure between two probability density functions. Instead Naudts [1] and Topsøe [2] recently have shown that the importance and usefulness of Bregman divergences (BD) [3], which is defined in terms of any convex function, and for an appropriate choice of this convex function, the BD reduces to KLD.
On the other hand, the ubiquitous of Gaussian functions is originally derived by Gauss himself, and his proof is now known as Gauss's law of error, in which log-likelihood function was used. It is shown recently that two different kinds of one-parameter extensions [4] of Gauss' law of error, in which the standard log-likelihood function is generalized by utilizing either q-logarithm or κ-logarithm. These different one-parameter deformations can be further unified in the two-parameter extensions, which was originally proposed in information theory by Sharma, Taneja and Mittal [5] as a two-parameter extension of Shannon entropy. During further developing Gauss' law of error to the two-parameter extension, it is found that the relation between the generalized log-likelihood functions and Bregman divergences. This relation reduces to the known equivalence between standard Maximum likelihood method and minimum KLD when the corresponding BD reduces to KLD.

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Variational principles in physics: from regular to irregular statistical dynamics.

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From the point of view of variational calculus for mechanics, physics is divided into two realms. The first is the regular dynamics of mechanistic system whose deterministic laws of motion can be derived from variational principle such as least action principle and virtual work principle, among other more or less equivalent ones. The second realm is the random dynamics or statistical mechanics whose probabilistic laws of motion can be accounted for from variational principles such as maximum entropy or entropy production. A matter of investigation is that actually there is no link between the two axiomatic families. And worse, they are even contradictory and mutually exclusive [1]. A trivial example for that is the failure of the statistical interpretation of the second law marked by the incompatibility between H theorem (entropy increase) and Liouville's theorem. In this work, we describe a global framework capable of unifying the two families of principles for Hamiltonian system. The starting point is an extension of the virtual work principle (VWP) to noised system. The effect of noise is taken into account by probabilistic description of random dynamics following more than one path between two given states and reaching many possible states from a given state. VWP becomes $\overline{\delta W} = 0$ with the average over all possible microstates at a given moment. From this, a stochastic least action principle [2] $\overline{\delta A}_{ab} = 0$ follows with the variation of Lagrangian action A_{ab} averaged over different paths between two fixed points a and b in phase space. The *outcomes* in this framework are the following. 1) For equilibrium system [3], $\overline{\delta W} = 0$ is equivalent to a maximum entropy algorithm $\delta(S - \beta\, U) = 0$ where S is the second laws entropy and U the internal energy. 2) For nonequilibrium system, $\overline{\delta W} = 0$ is equivalent to a maximum entropy production algorithm $\delta[\sigma - \eta\,(V + E)] = 0$, where E is the kinetic energy related to nonequilibrium transport, V is a potential related to the thermodynamic force driving the motion, and σ is an entropy production. The second law is justified through the applications to free gas expansion and heat conduction. 3) $\overline{\delta A}_{ab} = 0$ is equivalent to a maximum path entropy algorithm $\delta(S_{ab} - \eta\, \overline{A}_{ab}) = 0$ which can yield exponential path probability distribution of action. 4) For the motion satisfying $\overline{\delta A}_{ab} = 0$, the Hamilton's equations exist only statistically. A consequence is $d\rho/dt = (\partial R/\partial P)\,\rho \neq 0$ for given path where ρ is the phase space distribution, R the random forces and P the momentum. This invalids the Liouville's theorem and the Poincaré's recurrence theorem for random noised dynamics.
The last point of this work is about the origin of variational (maximum/minimum) principles in physics. Without resort to teleological and metaphysical arguments, an answer is given through a dialectical variational principle: *any smooth motion is determined by the interplay and balance of pairs of opposite, mutually exclusive but complementary, mutually rooted and transformable parts*, say, Y_i and Y_a. $\sum(\delta Y_i - \lambda\, \delta Y_a) = 0$. Derivation of several known principles of physics is given.

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Generalized simulated annealing on complex networks for modelling memory in psychology.

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We have previously described neurosis in terms of memory functioning and proposed a neural network mechanism, whereby neurotic behavior may be understood as an associative memory process in the brain. Memory was first modeled by a Boltzmann machine (BM), represented by a complete graph. Since it is known that brain neural topology is selectively structured, we have further developed the memory model, including known microscopic mechanisms that control synaptic properties, showing that the network self-organizes to a hierarchical, clustered structure.
The resulting power-law and q-exponential behavior for the node degree distribution of the network's topology suggest that memory dynamics and associativity may not be well described by Boltzmann-Gibbs (BG) statistical mechanics. We thus model memory access dynamics by a generalization of the BM called Generalized Simulated Annealing (GSA), derived from the nonextensive formalism. In GSA, the probability distribution of the energy states of the system's microscopic configurations is not the BG distribution, assumed in the BM, and this should affect the chain of associations of ideas which we are modelling. We illustrate the model with computer simulations.

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Quantum transport of atoms in optical lattices of variable inversion symmetry.

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It is well known that transport properties of quantum objects subject to a period potential depend critically on the particle's band structure. In this picture, the more than 20 orders of magnitude difference in electrical conductivity between an isolator and a good conductor finds a natural physical explanation. In recent years, atoms confined in periodic optical potentials, so called optical lattices, have developed as powerful tools for the observation of solid state physics effects. So far, the band structure has been exploited only for sinusoidal lattice potentials, as can be realized with the ac Stark shift of optical standing waves. In interesting experiments with such standing wave lattices, Bloch oscillations and Landau-Zener transitions have been observed [1].
In my talk, I will report on experiments studying the band structure of optical lattices with variable inversion symmetry and shape, as a step towards simulating the variety of potential forms that nature provides us in the system of electrons in natural crystals. We use a scheme that allow us to Fourier-synthesize in principle arbitrarily shaped periodic potentials for atoms. For the fundamental spatial frequency, a usual standing wave lattice with $\lambda/2$ spatial periodicity is used. Higher harmonics can be generated using the dispersion of multiphoton Raman transitions. A lattice potential of spatial periodicity $\lambda/2\,n$, where n is an integer number, can be realized with a transition of order $2\,n$. By superimposing lattice potentials of different spatial periodicities, variable periodic potentials for atoms can be Fourier-synthesized. At present, lattice potentials with a spatial periodicity down to $\lambda/6$ for a rubidium Bose-Einstein condensate are experimentally observed.
In subsequent work, the band structure of both symmetric and ratchet-type asymmetric lattice potentials was investigated. The required variable lattice potential was generated by superimposing a conventional standing wave lattice of $\lambda/2$ spatial periodicity with a $\lambda/4$ spatial periodicity multiphoton lattice. We experimentally observe that the Landau-Zener tunnelling rate between the first and second excited Bloch-band critically depends on the relative phase of the two lattice harmonics [2]. Also, Bloch-oscillations have been recorded in the developed lattice structures. It was observed that in pure multiphoton lattices of period $\lambda/2\,n$ the Bloch-period increases due to the stronger localization in comparison to a usual standing wave lattice [3]. The high spatial localization leads to a modification of the effective atomic mass. In future, we plan to study quantum transport in driven dissipationless ratchet-type lattice structures, which holds prospects for Hamiltonian quantum ratches [4].

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Uncertainty relations in terms of Tsallis entropy.

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Quantum-mechanical uncertainty relations for position x and momentum p in the form of inequalities involving Shanon or Renyi entropies had been derived by I. Białynicki-Birula some time ago [1,2]. Here we present derivation and discussion of the analogous uncertainty relations emerging from Tsallis entropy H_α, which (for $\alpha \geq \beta$ when $H_\alpha^{(p)} \leq H_\beta^{(x)}$) have the following inequality form

$$H_\alpha^{(p)} + H_\beta^{(x)} \geq \frac{1}{1-\alpha}\left[\left(\frac{\beta}{\alpha}\right)^{\frac{1}{2\alpha}}\left(\frac{2\beta}{h}dxdp\right)^{\frac{\alpha-1}{\alpha}} - 1\right].$$

The simplicity of these relations indicate that Tsallis entropy is suitable characteristic of uncertainties quantum measurements. The resulting limitations on the information content characterizing quantum system generalize results obtained from Shanon entropies (to which they converge when $\alpha \to 1$ and $\beta \to 1$. In particular, we shall pay special attention to the following observation: whereas standard uncertainty relation, $dxdp > h/2$, is not a statement about accuracy of our measuring instruments, the entropic uncertainty relations do depend on it because they explicitly contain the volume of the corresponding phase space, $dxdp$, determined by the accuracy of measuring instruments. It turns out that for all entropies considered so far (Shanon, Renyi and Tsallis) the sum of entropies $H_\alpha^{(p)} + H_\beta^{(x)}$ becomes negative for large relative size of the phase-space area $dpdx/h$. However, whereas for Shannon and Renyi entropies this sum tends to $-\infty$ when $dpdx \to +\infty$, in the case of Tsallis entropy it is negative but remains finite and equals to $-1/(\alpha-1)$. This fact makes the Tsallis entropy more attractive for formulations of uncertainty relations because only with it one gets the sum of entropies limited in the sense mentioned above. One can then *renormalize* the respective probability counting and obtain $H_\alpha^{(p)} + H_\beta^{(x)} > 0$ for all phase-space areas $dxdp$. All these is connected with the fact that, when the size of an object $dpdx$ is bigger than the cell dimension h, it can be found in many cells at the same time, i.e., events are not *mutually exclusive* as in the case of standard entropy counting.

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Interplay between chaos and external noise in an extended system: Intrinsic stochastic resonant phenomena.

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Through the analysis of the Lorenz'96 model [1], we have investigated the effect of noise on an extended chaotic system. Such a system is described by

$$\dot{x}_j(t) = -x_{j-1}(x_{j-2} - x_{j+1}) - x_j + F; \quad j = 1, 2, 3, \ldots, N,$$

and in order to simulate a scalar meteorological quantity extended around a latitude circle, we consider periodic boundary conditions: $x_0 = x_N; x_{-1} = x_{N-1}$. To take into account external fluctuations we assume that F has two parts, a constant and a random one $F_j(t) = F_0 + \Psi_j(t)$, with $\Psi_j(t)$ a dichotomic process.
Such a system is a kind of *toy* model used for climate studies, that has been heuristically formulated as the simplest way to take into account certain properties of global atmospheric models. The terms included in the equation are intended to simulate advection, dissipation and forcing respectively. In contrast with other toy models used in the analysis of extended chaotic systems and based on coupled map lattices, the Lorenz'96 system exhibits extended chaos ($F > 9/8$), with a spatial structure in the form of moving waves.
The numerical analysis of system's time evolution and its time and space correlations gave us strong evidence for two stochastic resonance-like behavior [2]. Such behaviour are seen when two forms of the signal-to-noise ratio function, the usual and a generalized one, are depicted as a function of both, the external noise intensity or the system size. It arises without submitting the system to an external signal –similarly to the case of *internal-signal-SR* [3]– as a response to a system's internal periodic behaviour. The underlying novel mechanism seems to be associated to a noise-induced chaos reduction instead of the usual reinforcement of the peak high respect to the noisy background. We have also analyzed the response and competition in case of having an external driving. The possible relevance of these and other findings for an optimal climate prediction are also discussed [4].

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PCA and wavelet PCA analyse of packet switching network traffic.

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The dominant technology of data communication networks is *Packet Switching Network* (PSN). Packet traffic data of PSN networks show complexity often difficult to be analyzed by standard techniques. We apply novel technique that combines wavelets (e.g., [1,2]) with principal component analysis (PCA) (e.g., [3,4]) method to analyse packet traffic data of PSN model. Our PSN model (see [5] for details) is an abstraction of the Network Layer of the ISO OSI Seven Layer Reference Model. In our model we consider two different dynamic routing cost metrics (i.e., when the costs of transmission of packets from one router to another incorporate the information about how congested the routers are) and static routing (i.e., when the cost of transmission of packets from one router to another is constant over time). We focus our analysis on mean treatment effects for various factors, i.e. the pairs (*routing cost metric, source load value*), when the response metric is a network performance indicator "*number of packets in transit*", *NPT*. The *NPT* is an important aggregate measure of network performance because it provides information about the packet traffic level and if the network is congested or not. We focus our study on source loads near phase transition point from free flow to congested states of a PSN model where the transmission efficiency is the highest.
We apply fixed effect functional ANOVA (Analysis of Variance) framework, in which the mean treatment effects are deterministic time dependent functions that are estimated from the calculated mean treatment effects. Our results show that there are significant differences among mean treatment effects for different PSN model setups, i.e. factors. To uncover the

main features of the behaviors of these functional mean treatment effects we apply denoising procedures and reconstruct these signals from the wavelet decompositions. We present results of the application of the multi-scale PCA for different PC selection rules that are used for constructing the final signal. We obtain the best results when only fewer PC in the details are retained, i.e. where only first PC of approximation and the first component of the final PCA after wavelet reconstruction are retained. In this case, the total variation explained by the retained PC is almost identical to the variations of the other two cases.
Our study shows that the applied wavelet method is useful for de-noising the signals and in particular, it becomes a classifier when combined with principal component analysis. As wavelet PCA it is able to separate the features contributed by edge cost function from those contributed by source load. Thus, multi-scale PCA, a non-parametric method, is able to detect the dynamical behavior of mean treatment effect and is useful in classification of data traffic coming from different PSN model setups. The regression method is useful for picking up the main pattern of each mean treatment effect, in particular, in the congested states of PSN model.

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Complex duffing system driven by Gaussian colored noise.

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This paper is to study complex Duffing system of the form

$$\ddot{z} + w_0^2 z + \varepsilon^2 \dot{z} f(z, \bar{z}, \dot{z}, \dot{\bar{z}}) = \alpha u(t)$$

where $z(t) = x(t) + iy(t)$ is a complex function($i = \sqrt{-1}$), the bar denotes the complex conjugate, $\alpha = (1+i)\varepsilon$ is a complex parameter, the frequency w_0^2 and ε are positive constant and small parameter, f is non-linear analytical function of its arguments, $u(t)$ is an exponentially correlated Gaussian colored noise of vanishing mean.
The Duffing oscillator has attracted many peoples' attention, and it's an important different equation with often appearance in many physical, engineering and biological fields [1]. The method of stochastic averaging [2] is first proposed by Stratonovich to analyze certain classes of random differential equations. We have used standard stochastic averaging in our previous work [3,4]. Another version of stochastic averaging is based on a perturbation theoretic approach to the Fokker-Planck-Kolmogorov equation [5]. By choosing $f(z, \bar{z}, \dot{z}, \dot{\bar{z}}) = z\bar{z} - 1$, Eq (1) becomes

$$\ddot{z} + w_0^2 z + \varepsilon^2 (z\bar{z} - 1)\dot{z} = \varepsilon(1+i)u(t) \ .$$

The process $u(t)$ is an Markovian process driven by Gaussian white noise $\Gamma(t)$. We aims to seek the transition probability density function in terms of a perturbation expansion of the parameter. And then the method of stochastic averaging and the method of characteristics is used to derive Fokker-Planck equation for the transition probability density function up to order ε^0. The result is identical to what was derived from the Stratonovich-Khasminskii theorem for the model under a broad-band excitation. Furthermore, the exact stationary probability density function is obtained.

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Evaluation of pedodiversity in terms of generalized entropy.

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Generalized entropy has been widely used as a useful index of various diversities such as biodiversity and geodiversity. In this work we have evaluated the diversity of soil, that is the pedodiversity which is one of geodiversity, in terms of the generalized entropy.
Pedodiversity is closely related to biodiversity, on the other hand, pedodiversity might determine land use. In this work, we have proposed diversity indexes by which we can evaluate the pedodiversity in the composition distribution and the spatial distribution in terms of generalized entropy, both objectively and quantitatively. We have calculated pedodiversities in various regions of Hokkaido, Japan. In this work, we have developed the following formula:

$$Y_A = \frac{-\sum_{k=1}^{n} p_k \log p_k}{\log n} \ .$$

Where n and p_k are defined as follows.

1. In the case of the pedodiversity in the composition distribution, n represents the number of types of soils, and p_k is defined as the area ratio of kth soil to the total area of region A. In this case, pedodiversity Y_A indicates diversity in components making up soil composition in each region.
2. In the case of the pedodiversity in the spatial distribution, n represents the number of spatial meshes, and p_k is defined as the area ratio of kth spatial mesh to the total area of soil A. In this case, pedodiversity Y_A indicates diversity in spatial locations of each soil.

It can be inferred that the higher a value of pedodiversity in the spatial distribution is, the higher a value of the diversity of land use in the spatial distribution becomes, and a network between small elements of land use, such as farms of various crops, can be realized. This network is expected to make some significant circulation in various industries.
In order to ascertain the above conjecture in which the correlation between diversity of soil and land use is supposed, we also used the relative entropy based on the information theory, and we have evaluated its correlation quantitatively in each region. The formula is as follows.

$$\begin{aligned} I(A,B) &= S(A)+S(B)-S(A,B), \\ r(A,B) &= \frac{1}{2}I(A,B)\left(\frac{1}{S(A)}+\frac{1}{S(B)}\right), \end{aligned}$$

where A and B represent the soil and land use respectively, and $S(A)$ and $S(B)$ represent the entropy of the distribution of soil and land use respectively, $S(A,B)$ is the entropy of the simultaneous distribution of soil and land use, $I(A,B)$ is the relative entropy between soil and land use and $r(A,B)$ represents the index of correlation between soil and land use. We have calculated in various regions of Hokkaido and Kyushu, Japan. We would like to show our calculation results in our presentation.
We believe the index $r(A,B)$ can be useful in evaluating suitable crops for land in the future.

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q-Gaussian critics of the transient current through Al-PMMA-Al thin films.

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Recently, Hacinliyan, Skarlatos, Yıldırım and Şahin analyzed the chaotic behavior of the transient current through aluminum-polymetylmethacrylate- aluminum (referred to as Al-PMMA-Al in this work) thin films for times ranging up to 30000s, in the temperature range 293-363K for applied voltages in the range 10-80V [1]. In Ref. [1] they also reported that the time series analysis reveals a positive Lyapunov exponent consistently and reproducibly throughout this range and concluded that the positive Lyapunov exponent show parallel behaviours as a function of applied electric field.
In this work we analyse the q-Gaussian curves [2] of the transient current through thin film Al-PMMA-Al (a polymer with the formula ($[-CH_2-(CH_3)C(COOCH_3)-]_n$) data sets at 22^oC and 40^oC under an applied voltage of 10V, measured at 10s intervals as given in Ref. [1]. We have fitted the temperature dependence of the q-Gaussian curve characteristics and discussed the validity of a central limit theorem for the thermal behaviour of Al-PMMA-Al [3]. We also have tried to interpret the relations between the q-Gaussian curve characteristics and the mechanism of thermal behavior of Al-PMMA-Al.

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Analysis of chaotic dynamical system by extended ensemble Monte Carlo.

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Chaotic dynamics has very complex structures in phase space. Invariant manifolds, fixed points, periodic orbits and their basin structures are examples of them. It is difficult to capture these global structures by usual time evolution method of dynamical system because most of them are unstable and some of them are very rare. To analyze these structures, we will introduce Markov Chain Monte Carlo (MCMC) as an anatomical tool for nonlinear dynamical systems, especially for chaotic dynamics.
Monte Carlo methods are very important in computational physics, physical chemistry, and related applied fields, and have diverse applications. In statistical mechanics, sampling of microscopic states from Gibbs distributions is used to calculate physical quantities [1]. A microscopic state is corresponding to a spin configuration for Ising model. Instead, we consider initial condition of dynamical system as microscopic state, and extract trajectories that have "atypical" property by MCMC. Because a finite precision number is represented by a bit sequence in computer, a initial condition can be considered as a product of spin configuration and the change of it corresponds to spin flip. Thus, the initial conditions, which have atypical property can be sampled in the same way as spin configurations sampled from canonical ensemble.
In order to find such initial conditions, which satisfy a given atypical property, we have to construct an "energy" function. For example, the energy function of initial condition for periodic orbit can be constructed by the following fact. The orbit starting from a state in phase space returns to the original state after some time evolution, i.e., period, if the state initially ocates on a periodic orbit. Then, the energy will have to satisfy the following condition; it will have minima if the state backs to the initial state after some time evolution. Using this constructed energy, we can extract the sets of points in phase space that approximately stand on periodic orbits whether they are stable or not.
Sensitive dependence on initial conditions in chaotic dynamical system may leads to highly multimodal energy function. For the rugged energy landscape, we need the way to facilitate mixing of Markov chain. The use of methods known as Extended Ensemble MCMCs is quite effective for speeding up the convergence of MCMC in multimodal problems arising in

our applications [3,4]. Here, we have used Metropolis method [2], and adopt parallel tempering so as to avoid capturing the local minima of energy landscape.
The implementation of the method is easier than other methods, e.g., sample from orbits. The several examples of finding a set of "special" initial conditions will be shown. We will show the following examples: unstable periodic orbit of Lorenz system, stable manifold of unstable fixed point of chaotic pendulum. Furthermore, extension of sampling to parameter space enables us to investigate bifurcation structures of nonlinear dynamical systems. When we use product of initial conditions and parameter as a state space, global bifurcation structures can be revealed by MCMC. It is also shown that rare event and its statistics for chaotic saddle.

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Thermal conductivity of a classical one dimensional spin-phonon system.

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Motivated by recent experimental and theoretical interest on a magnetic mode heat transport [1], we present results related to the thermal conductivity of a classical spin chain as well as a spin chain coupled to phonons. For the pure spin chain we employ the Green-Kubo approach using both Monte Carlo and Langevin simulations as well as direct numerical determination of the microscopic heat transfer processes. All three approaches show that the magnetic heat conductivity is normal [2,3] at all finite temperatures and magnetic fields. In ferromagnets, heat conduction grows linearly with the magnetic field while in antiferromagnets this holds only at high fields. At smaller fields, a quadratic decay of heat conduction, leading to a minimum value, provides a distinct nonlinear manifestation of spin mode propagation resonant suppression[3].
In the case of coupled spin-phonon chains we use a one dimensional lattice of atoms carrying classical spins and coupled vibrationally [4]. The spin degrees of freedom interact via a classical Heisenberg interaction while the vibrational degrees of freedom are coupled through nearest-neighbor linear as well as nonlinear forces. The thermal conductivity in spin-phonon systems has both a phononic as well as a magnetic contribution.
We use extensive numerical simulations to evaluate the magnetic and phononic thermal current correlation functions as well as the combined thermal conductivity coefficient. We employ two distinct numerical approaches; the first is based on the linear response theory and proceeds through evaluation of the energy current correlation function using the Green-Kubo formula. The second is through simulation of stochastic baths and subsequent direct numerical evaluation of the magnetic and phononic heat current. We find anomalous thermal conductivity when the spins are coupled to an harmonic acoustic phonon chain. However, when the harmonic phonon chain contains additionally an optical mode, we find that the thermal conductivity is normal for a certain regime of on-site force parameters while it becomes anomalous when the on-site frequency becomes larger than a certain value. Coupling thus to an harmonic system with an optical mode provides a case of tunable conductivity that switches from being diffusive to ballistic as a function of structural model parameters or temperature. When the spins are coupled to anharmonic chains we find anomalous conductivity when the phonon chain is acoustic, such as for instance in the Fermi-Past-Ulam case, or normal when the nonlinearity is of optic type. For the cases analyzed we provide quantitative information on the exponent characterizing the power law decay of the energy current correlation function and determine size and temperature dependencies of the conductivity coefficient. Finally, we also address the dependence of thermal conductivity of spin-phonon chains on an externally applied magnetic field and find that in the harmonic case it generally increases with the field.

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Simulations of environmental spatial data using Ising and Potts models.

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We employ the Ising [1] and Potts models [2] to represent the spatial dependence in environmental data sets, and to generate simulations conditioned on samples of limited coverage or resolution. The approach is based on discretizing the original environmental variable into a finite number of levels, thus converting it to a "spin" representation. The spatial dependence between the "spins" is imposed in the form of short-range interactions. The conditional simulations of the "spin system" are forced to respect the sample values locally and the first-order statistics globally. The second constraint is enforced by minimiz- ing a cost function that describes the deviation between normalized correlation energies of the simulated and the sample distributions. In the method based on the q-state Potts model, each sample point is assigned one of q levels. All the lattice points are involved in the simulation and their levels are assigned simultaneously. In the Ising model approach, a hierarchical scheme is used: the discretization at each stage is binomial (i.e., ± 1). The discretization is performed sequentially, with respect to a predefined set of levels. The simulation results at one level propagate to the higher levels, leading to a hierarchical estimation of the levels at the prediction points. We compare the two approaches in terms of their ability to reproduce the target statistics (e.g., the histogram and the variogram of the sample distibution), to predict data at unsampled locations, as well as in terms of their computational

complexity. The proposed models are capable of integrating various data and scales, without any assumptions about the probability distribution. Hence, they are suitable for modeling non-Gaussian data, which often arise in environmental applications. We apply the models to a real-world environmental data set, compare the results, and discuss the impact of some relevant parameters, such as the domain size, the number of discrete levels, and the initial conditions used in the simulation.

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Why square root? Statistical physics and voting in European Union.

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We review statistical theory of indirect voting and the Penrose-Banzhaf power index, used to quantify an a priori voting power. According to the classical work of L. Penrose the voting power of a member of a voting body of size N decreases as $N^{-1/2}$. This law implies that the voting weights attributed to each member state for voting in the Council of the European Union should scale as $N^{1/2}$.

The voting power of each state depends also on the quota for the qualified majority. We show existence of a critical quota (equal to 61.4% for EU-27), for which the voting power of a single citizen in each member state of EU is equal. Combinging square root weights of Penrose with the proposed formula for the majority quota allows us to construct an objective, effective and easily expandable system of voting for the EU Council.

Making use of a statistical approach we consider a model union consisting of M member states with population drawn randomly. Assuming that the distribution of population is uniform in the simplex of M–point probability distributions we derive the formula for the optimal quota, $R_{\rm opt} = \frac{1}{2} + \frac{1}{\sqrt{\pi M}}$. In the large union limit $M \to \infty$, the optimal quota tends to 50%.

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