Theory of kinetically-constrained-models dynamics

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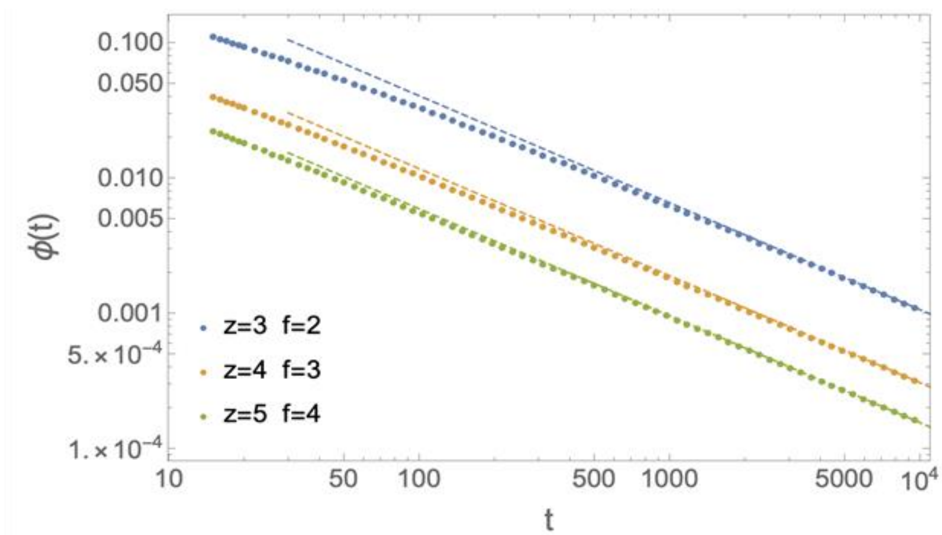
The question of whether glassy behavior is a result of a genuine thermodynamic transition has long been a topic of debate in the field of glass physics. In this debate, Kinetically-Constrained-Models (KCMs) are frequently cited as models capable of reproducing the essential features of glasses without exhibiting a thermodynamic transition. However, up to now their knowledge was mainly based on numerical simulations, which are complicated by the divergence of equilibration times and large finite size effects. In this work [1], using certain properties of the dynamics observed in actual numerical experiments, we provide the first analytical solution of the mean-field dynamics of a class of KCMs, by considering the Fredrickson-Andersen model (FAM) on the Bethe lattice. We derive asymptotic dynamical equations that are equivalent to those of Mode-Coupling-Theory (MCT). In this way we resolved the long-standing issue of proving that MCT provides the correct description of the long-time dynamics in these models. We present analytical predictions for the dynamical exponents, which are successfully verified by new numerical data, and explain earlier numerical results. Our analytical predictions are validated through numerical simulations in a wide range of models, including cases with generic values of connectivity and facilitation, random pinning, and fluctuating facilitation. Our theory is thus confirmed for both continuous and discontinuous transitions, as well as in the case of higher order critical points characterized by logarithmic decays. The possible extension of our analysis to models with conserved dynamics, notably the Kob-Andersen model, is an interesting open problem and it is left for future work. In the attached figure we show the persistence function in the case of the FAM for different values of the facilitation f, which is the parameter defining the kinetic constraint of the model. The persistence function plays the role of ergodicity breaking parameter for the FAM. At a critical value of the temperature, below which the ergodicity is broken and the system enters a glassy phase, the persistence goes to a plateau value with a power-law behavior. The numerical data, represented by the points, are in excellent agreement with our analytical predictions, which are denoted by the dashed lines. The numerical simulations are performed on Bethe lattices with coordinations z=3,4,5, and a number of nodes $N=16\times10^6$.



References

[1] G. Perrupato, T. Rizzo, Exact Dynamical Equations for Kinetically - Constrained-Models, arXiv preprint arXiv:2212.05132 (2022).