Non-equilibrium dynamics of open systems, fluctuation-dissipation theorems and quantum transport theory

<u>Václav Špička</u>
Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic

The talk will address the problem of a description of electron dynamics of open systems when initial conditions, quantum interference and decoherence processes play important roles. The aim is to understand the full time development of many-body open systems out of equilibrium from its initial state over its transient dynamics to its very long time (if e.g. steady state exists) dynamics.

First, the non-equilibrium Fluctuation-Dissipation Theorem is formulated within the Non-Equilibrium Green Function (NEGF) formalism [1]. The relation of this theorem to a simplified kinetic theory of non-equilibrium dynamics will be addressed. The components of the NEGF retain some inner interconnection which may be termed the fluctuation-dissipation structure out of equilibrium; there is an exact formulation in terms of reconstruction equations generating the correlation components in terms of the propagators and the non-equilibrium distribution function either of particles, or, under restrictive conditions, of the non-equilibrium quasi-particles. These equations can lead to a Non-Markovian Generalized Master equation or even to a Markovian master equation without memory. To deal with the task to find out a proper description of the dynamics of open systems and to test the used approximations, we consider a simple structure which represents well open quantum systems: a molecular bridge between two leads [1, 2].

Second, we will discuss the transport in neural networks. We have developed an approach to the transfer of electrical signals via neural network [3, 4] that is alternative to the standard theories of Hodgkin, Huxley and Rall. Our theory, which is based on generalized Ohm-Kirchhoff's law and a modified model of submarine cable, enables one to extend the description into the microphysical domain. In contrast to the standard theory, but in agreement with the experimental evidence, the transfer of the signal front has a character of diffusion with diffusion constant DE. It has been further shown that this process, actually the forming of a current carrying sphondyloid, is physically realized by quantum diffusion of Na+ and K+ cations in axoplasm with diffusion constant $D\Omega \ll DE$. According to our approach $DQ \rightarrow \hbar / 2M$, where M is ion mass and ħ Planck's constant; a signal transfer through nerves is thus essentially a quantum process.

References

[1] V. Špička, B. Velický, A. Kalvová, Eur. Phys. J. Spec. Top., 230, 771 (2021).
[2] A. Kalvová, B. Velický, V. Špička, EPL, 121, 67002 (2018).
[3] J. J. Mareš, P. Hubík, V. Špička, Eur. Phys. J. Spec. Top., 227, 2329 (2019).
[4] J. J. Mareš, V. Špička, P. Hubík, Eur. Phys. J. Spec. Top., 230, 1089 (2021).