Formation of action potential in neuron and the quantum diffusion of somatic ions

Jiří J. Mareš, Václav Špička, and Pavel Hubík

Institute of Physics, v.v.i., Czech Academy of Sciences, Cukrovarnická 10, 162 00 Praha 6, Czech Republic

The talk will review our efforts to improve the understanding of physical processes which control information transfer and processing in biological neural networks. The essential component of any model of action potential is traditionally based on the existence of gated ionic channels in neurons membranes. Nevertheless, as we have recently shown, the kinetics of K^+ and Na^+ ions are governed by the quasi-selective quantum diffusion for which the gated channels are, at least for initial phase of action potential, not necessary. For this purpose, temporary fissures, spontaneously created in neuron membrane by flexoelectric effect, are quite sufficient. On the other hand, for the recovery phase of action potential, which brings the neuron back to the homeostasis, gated channels and natrium/potassium ion pumps are necessary.

In the second part of the talk, the two competing models of signal transmission (action potential) through the neuron, Hodgkin-Huxley electrochemical theory and Heimburg thermomechanical soliton theory, will be introduced and their shortages discussed. Based on this discussion a novel minimal model of transmission of the all phases of the action potential via neuron will be presented. This minimal model is based on the scenario which considers fundamental experimental facts and undeniable elements of both leading theories [1-4].

[1] J. J. Mareš, P. Hubík, V. Špička: *Diffusive propagation of nervous signals and their quantum control* . Eur. Phys. J. Spec. Top. 227 (2019) 2329–2347.

[2] J. J. Mareš, V. Špička, P. Hubík: *Possible role of extracellular tissue in biological neural networks*. Eur. Phys. J. Spec. Top. 230 (2021) 1089–1098.

[3] J. J. Mareš, V. Špička, P. Hubík: *On physical processes controlling biological neural networks*. Eur. Phys. J. Spec. Top. 232 (2023) 3561–3576.

[4] J. J. Mareš, V. Špička, P. Hubík: *Quantum diffusion of biologically active cations in aqueous solutions*. Eur. Phys. J. Spec. Top. (2026). https://doi.org/10.1140/epjs/s11734-026-02138-9