THEORETICAL PHYSICS

Field-theoretic renormalization group methods in stochastic dynamics: Study of non-equilibrium processes with fluctuating number of particles

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consultant: RNDr. Tomáš Lučivjanský, PhD.
study form: full time

Annotation: In recent years there was a steady interest in interdisciplinary research field devoted to the class of reaction-diffusion models. Such models serve for description of various phenomena such as proliferation of defects in material, infection spreading in biological system, and even spreading of political opinions. Apart from these models we will consider related problems of active matter physics, which presents non-trivial application of phase transitions models on biological systems. Main focus of the work will be on study of specific chemical reaction schemes and percolation processes. Dynamic processes with non-conserved number of interacting entities can be formulated microscopically via master equation approach for probability distributions. This can be then recast into equations for state vectors employing Doi formalism. The ensuing models are tantamount to certain field-theoretic actions. The common property of such models is a presence of strong fluctuations in scaling regions, which effectively make ordinary perturbation theory useless. Methods that goes beyond mean-field like theories are needed. The aim of this work is therefore to employ perturbation methods of quantum field theory, functional integration and renormalization group. From experimental and practical point of view the situation is similar to that in phase transitions. Very important role is played by critical indices that control behavior of statistical correlations of interacting agents. Higher order calculations provides obvious possibility to extent existing research status. In this work thus main practical method will be field-theoretic renormalization group.

Stochastic dynamics and turbulence: Calculation of relevant parameters and anomalous exponents in higher orders of perturbation theory.

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Annotation: PhD thesis will be devoted to a theoretical analysis of complex classical systems using sophisticated methods of quantum field theory. Classical systems in consideration are formulated in a form of stochastic models, which describe a whole class of phenomena. Most relevant models are reaction-diffusion problems, equilibrium and non-equilibrium phase transitions, turbulent flows and others. A common feature of such systems is presence of strong fluctuation effects, which precludes use of the ordinary perturbation theory. It is necessary to go beyond and apply non-trivial perturbation methods of quantum field theory, functional integrals and renormalization group. From experimental point of view we are interested in master observable parameters (Prandtl number, skewness and flatness factors, Kolmogorov constant etc.) and critical indices, because they determine behavior of statistical correlations of random fields on large spatial scales. Research in this area has achieved a point in which parameters and critical indices are known in the leading order. Calculations of such quantities in higher orders of perturbation theory (two- and three-loop) belong to a current task in modern theoretical physics. Concrete calculations of multi-loop Feynman diagrams are very demanding and challenging problem. They require development of new numerical and symbolic algorithms, which can be implemented on computers. Besides adequate knowledge

of modern physics it is expected that a candidate is well acquainted with programming languages and techniques.

Prediction of space-time data using models from statistical physics
supervisor: prof. RNDr. Milan Žukovič, PhD. (milan.zukovic@upjs.sk)
Annotation: The ever increasing amount of space-time data, e.g. from Earth observation through various remote sensing techniques, requires the development of new, efficient (often real-time) and automated processing methods that also include the prediction of missing data. Traditional prediction methods are not suitable for such massive data, particularly due to high computational complexity as well as other limitations [1]. The proposed research aims to develop strategies for efficient prediction methods inspired from statistical physics models [2] that would be flexible and suitable for automated processing using massively parallel algorithms implemented on graphics processor units (GPU) [3].

Bound magnons as a consequence of destructive quantum intereference of frustrated Heisenberg and Hubbard models
supervisor: doc. RNDr. Jozef Strečka, PhD. (jozef.strecka@upjs.sk)
Annotation: Geometric spin frustration of quantum Heisenberg and Hubbard models may under certain circumstances lead to existence of unusual bound quantum states known as localized magnons. The dissertation thesis will be devoted to a theoretical study of selected frustrated quantum Heisenberg and Hubbard models, whose low-temperature behavior can be described within the classical lattice-gas models on account of bound states with character of localized magnons.

Theoretical investigation of phase separation in binary and ternary liquid mixtures
supervisor: doc. RNDr. Jozef Strečka, PhD. (jozef.strecka@upjs.sk)
Annotation: The phase separation of binary and ternary liquid mixtures will be investigated within the framework of the lattice-statistical models such as the generalized Frenkel-Louis and Lin-Taylor models. In particular, the main emphasis will be laid by accounting for the multiparticle (e.g. three-body) interactions, which may play a crucial role in determining possible non-universal critical behavior. Besides, the dissertation thesis will focus on a problem of reentrant miscibility of some binary and ternary liquid mixtures with highly orientation-dependent forces (e.g. hydrogen bonding).

The study of the electronic properties of graphene fullerene onions with a reactive atom inside
supervisor: RNDr. Richard Pinčák, PhD. (pincak@saske.sk) - Institute of Experimental Physics Slovak Academy of Sciences Košice
study form: full time
Annotation: Different types of graphene onions will be studied by methods of quantum theory and statistical physics. In particular, the C20 @ C80, C60 @ C240 and C240 @ C540 onions will be selected as subjects of the basic study because they are among the most stable ions. But even these fullerenes have different diameters, charges and also electron properties, so we can draw more conclusions for them with examples of similar inner and outer shells. Individual reactive atoms such as Ni, Fe and Co are incorporated inside each of these fullerenes (Figure 1). The aim of this study is to find new stable onion structures with suitable electronic

properties required by the nano-industry. Basic theories and approaches to solving a given topic without a reactive atom inside are published in the works [1-3].

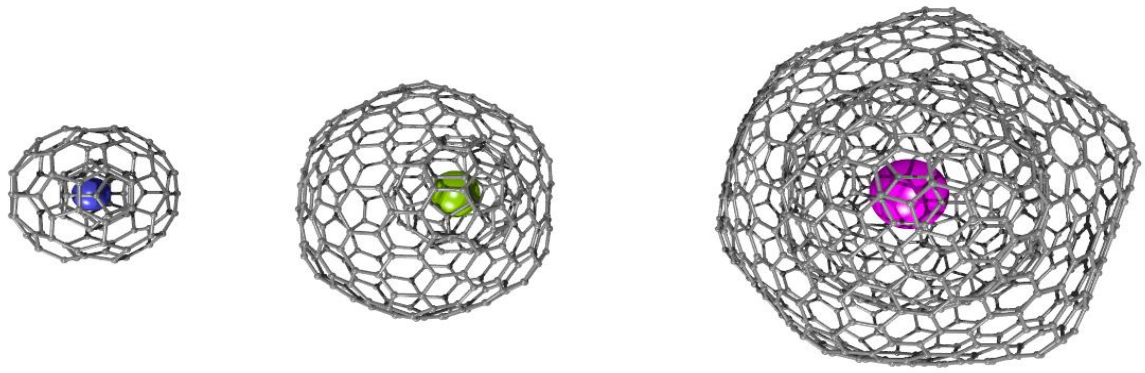

Fig. 1. Atomic structures of a) C20@C80+Ni; b) C60@C240+Fe; c) C240@C540+Co