1st International Summer School on Advanced Quantum Mechanics



Monday 09 September 2019 - Thursday 19 September 2019 Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, Prague

Scientific Programme

List of lectures:

Quantum Phase Transitions in Finite Systems (Pavel Cejnar)

Laser Experiments in Atomic Physics (Miroslav Krůs) Resonances and Non-Hermitian Singularities in Nature (Nimrod Moiseyev)

Nonhermitian Scattering Theory (Milan Šindelka)
Electroweak Interactions in Atomic Spectroscopy (Jaroslav
Zamastil)

Annotation of lectures:

<u>Quantum phase transitions in finite systems</u>

Pavel Cejnar

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Physics, style="color:#A	Charles \52A2A''>cejna	University, ar@ipnp.troja.m	Prague, ff.cuni.cz <th>Czech n></th> <th>Republic,</th> <th><span< th=""></span<></th>	Czech n>	Republic,	<span< th=""></span<>
The course will be focused on various aspects of quantum phase						
transitions (QPTs) and related quantum critical phenomena in bound						
many-body systems, particularly the systems with a finite number of						
effective degrees of freedom corresponding to some collective modes of						
motions.						
The QPT represents a non-analytic ("sudden") change of the system's						
ground-state energy and structure, driven by a variable non-thermal						
control parameter (such as an external field intensity or an internal						

coupling strength). Examples of QPTs in several bosonic and fermionic

many-body models based on finite dynamic algebras will be

demonstrated, and some experimental evidence of QPTs in the framework

of quantum optics and nuclear physics will be outlined. The topics that will be further addressed include: comparison of QPTs with thermal phase transitions, relation of QPTs to avoided level crossings and consequences for adiabatically driven systems, links of QPTs to non-Hermitian degeneracies of the spectrum (exceptional points), and consequences for entanglement properties of the system.

The ground-state QPTs will then be generalized to so-called excited-state quantum phase transitions (ESQPTs). These represent singularities in the density and flow of the quantized energy spectrum in the plane "excitation energy versus control parameter" along the lines that issue from the critical points of the ground-state QPTs.

<u>Laser experiments in atomic physics</u>

Miroslav Krůs

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This lecture will introduce the laser-based experimental techniques used in studying low-energy electroweak interactions and in the search for exceptional points (EPs) in non-Hermitian quantum physics. The first part of the course will focus on fundamentals of the laser physics and technology, including OPCPA and few-cycle lasers; furthermore, the generation of of high-order harmonic frequencies will be introduced as well. The second part will aim at detection techniques, detectors, and the typical experimental setups used in the search of fingerprints of the electroweak interaction in atoms and molecules, and in exploring the fingerprints of EPs.

<u>Resonances and Non-Hermitian Singularities in
Nature</u>

Nimrod Moiseyev

Schulich Faculty of Chemistry and Department of Physics, Technion - Israel Institute of Technology, Haifa, 32000, Israel, nimrod@technion.ac.il

Basic concepts of nonhermitian quantum mechanics will be introduced, and their theoretical & computational advantages relevant to atomic/molecular/optical physics (AMOP) will be highlighted. In particular, scattering resonances will be identified with poles of the S-matrix in the complex energy plane. It will be shown then how can the resonance phenomenon be studied numerically in concrete systems, via employing adequately generalized computational methods developed originally for the bound states. Subsequently, the nonhermitian singularities (the so called exceptional points) will be described, and their physically observable fingerprints will be discussed.

[1] N. Moiseyev, Non-Hermitian Quantum Mechanics, Cambridge University Press (2011).

<u>Nonhermitian Scattering Theory</u>

Milan Šindelka

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Nonhermitian scattering theory will be introduced, based upon the Siegert pseudostate formalism developed by Tolstikhin (see the seminal article [1] and followup papers). An equivalence of this nonhermitian approach with the standard hermitian scattering theory will be demonstrated. Conceptual advantages of the nonhermitian (Siegert based) mode of description will be highlighted. The Siegert pseudostate method will be then illustrated explicitly on the case of 1D scattering. We shall focus in particular on the calculation of transmission probability for a quantum particle penetrating through a potential barrier. Finally, some open as yet unsolved conceptual problems in nonhermitian scattering theory will be listed and discussed.

[1] Oleg I. Tolstikhin, Phys. Rev. A, 74, 042719 (2006).

<u>Electroweak Interactions in Atomic Spectroscopy</u>

Jaroslav Zamastil

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First, the current state of fundamental physics will be shortly reviewed and motivation for high-precision low-energy tests of the current theory of electroweak interactions will be given. Starting with quantization of Dirac field, we then explain the part of the theory necessary for understanding low-energy manifestation of the electroweak interactions. Finally, the detection of electroweak interactions by atomic spectroscopy, namely optical rotation and Stark interference experiments, will be described in some detail.