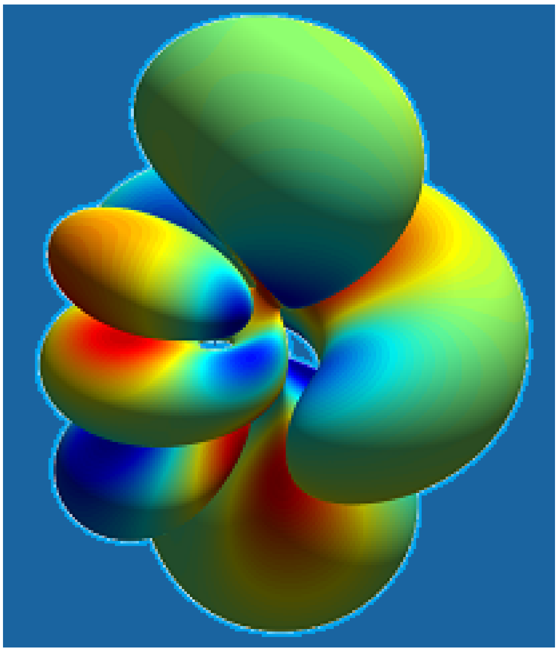
1st International Summer School on Advanced Quantum Mechanics



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

Institute of Particle and Nuclear Physics, Faculty of Mathematics and

Physics, Charles University, Prague, Czech Republic, cejnar@ipnp.troja.mff.cuni.cz

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

Institute of Plasma Physics, Academy of Sciences of the Czech Republic, Za Slovankou 1782/3, 18200 Prague 8, Czech Republic, krus@ipp.cas.cz

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

Institute of Plasma Physics, Academy of Sciences of the Czech Republic, Za Slovankou 1782/3,

18200 Prague 8, Czech Republic, sindelka@ipp.cas.cz

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

Department of Chemical Physics and Optics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 121 16 Prague 2, Czech Republic, zamastil@karlov.mff.cuni.cz

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.