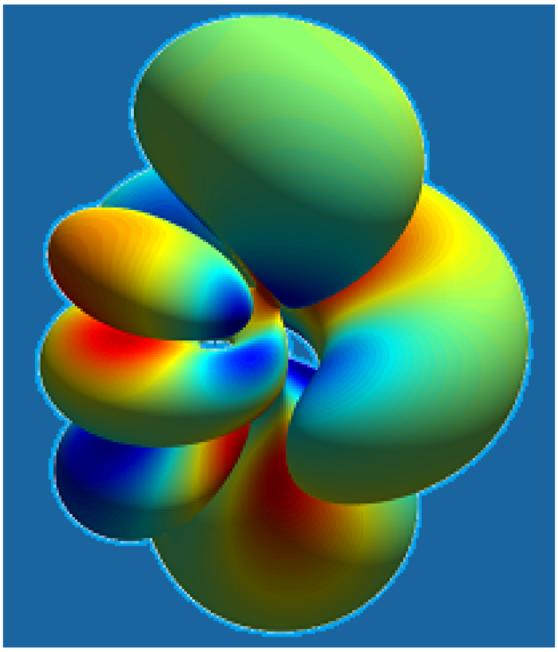
2nd International Summer School on Advanced Quantum Mechanics



Thursday 02 September 2021 - Saturday 11 September 2021

na Physics, Academy of Sciences of the Czech Republic, Za Slovankou 1782/3, 18200 Prague 8

Scientific Programme

Courses:
Indicators of many-body quantum chaos and time scales for equilibration

(Lea Santos, Yeshiva University, New York)
Constrained quantum dynamics

(Pavel Exner, Doppler Institute, Prague)
The Coupled Cluster Formalism for Atomic and Molecular Electronic Structures

(Arie Landau, Technion, Haifa)
An introduction to renormalization in atomic physics

(Milan Šindelka, Institute of Plasma Physics, Prague)
Extended operators and defects in quantum field theory

(Ondřej Hulík, Vrije Universiteit, Brussel and Institute of Physics, Prague)
A gentle introduction to Supersymmetry

(Rikard von Unge, Masaryk University, Brno)

Scientific talk:
Multiphoton multiple ionization dynamics of Xe atoms at ultrahigh hard X-ray intensity
(Koudai Toyota, DESY, Hamburg)

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Abstracts:

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Indicators of many-body quantum chaos and time scales for equilibration

Lea Santos, Yeshiva University, New York

Quantum chaos, specially when caused by interactions between particles, has experienced a remarkable resurgence in the last decade due to its close relationship with a broad spectrum of problems at the forefront of theoretical and experimental physics. In these lectures, I will compare different indicators of quantum chaos and use them to address some of these problems. I will explain why quantum chaos ensures thermalization, hinders localization, and leads to the fast scrambling of quantum information in many-body quantum systems. Particular attention will be given to systems studied in experiments with cold atoms, ion traps, and nuclear magnetic resonance platforms.

Computer codes used in this course are available at:
https://www.yu.edu/faculty-bios/santos/computer-codes

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Constrained quantum dynamics

Pavel Exner, Doppler Institute, Prague

The aim of these lectures is to introduce students to problems concerned with modeling motion of quantum particles constrained in various ways to regions of the configuration space having the form of tubes, layers, graphs, or networks of nontrivial geometry and topology. This rapidly developing field draws inspiration primarily from the progress in fabrication of nanostructures and helps to understand their spectral and transport properties; at the same time it raises interesting questions concerning both mathematics and of our understanding of quantum mechanics.

Lecture I:
Quantum graphs and waveguides, where they come from and what they are good for.

Lecture II:
How to match the wavefunctions at the branching points and what it does mean physically.

Lecture III:
Transport in quantum graphs: resonances, spectral bands, and the Bethe-Sommerfeld property.

Lecture IV:
Graphs violating the time-reversal invariance. Taking quantum tunneling into account:
the leaky graph model.

Lecture V:
Asymptotical properties of leaky graph spectra. Spectral optimization problems for graphs
and waveguides.

Lecture VI:
Spectral effects caused by magnetic fields. Soft quantum waveguides and an outlook.

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The Coupled Cluster Formalism for Atomic and Molecular Electronic Structures

Arie Landau, Technion, Haifa

We will start by reminding the principles of the Hartree-Fock (HF) approximation, which is a mean-field approach that neglects the explicit interaction between electrons. HF is the basis of the wave-function approach to describe electronic states in molecules. In addition, technical aspects like, basis sets, second-quantization and diagrammatic (Feynman-like) representation will be emphasized. We will continue with post-HF methods, which provide the correlation-energy for the ground-state of a chemical system. Methods such as, perturbation theory, configuration interaction (CI) and coupled cluster (CC) will be presented. Finally, methods for treating excited states, such as equation-of-motion CC and Fock-space CC, will be presented. If time permits, we will discuss resonance states within electronic structure theory. Resonances are meta-stable states that undergo an auto-ionization process after a finite period of time.

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An introduction to renormalization in atomic physics

Milan Šindelka, Institute of Plasma Physics, Prague

The purpose of this course is to provide a pedagogical introduction to the concept of renormalization in atomic physics. We study quantum dynamics of a model of a nonrelativistic single electron atom coupled to the quantum radiation field in the dipole approximation. An interaction between the electron and the radiation field is regularized, using a suitable cutoff prescription which eliminates the coupling of the electron to the highly ultraviolet (UV) field modes. Subsequently, we analyze the corresponding Heisenberg picture equations of motion, and focus on behavior of physical observables in the limit of a pointlike electron (i.e., in the limit when the above mentioned UV cutoff is gradually lifted to infinity). We identify the radiation reaction force acting on the electron, and show that this force actually diverges towards infinity when gradually removing the UV cutoff. Such an analysis leads ultimately to an unique renormalization prescription for the electron mass, as well as to determination of the Abraham-Lorentz force acting on the electron. Dependence of the just sketched renormalization procedure upon the spatial dimension is highlighted. Finally, we present an example calculation of the atomic level shifts by means of the renormalized perturbation theory, and formulate also the renormalized mean field theory.

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Extended defects and excitations in quantum field theory

Ondřej Hulík, Vrije Universiteit, Brussel and Institute of Physics, Prague

The quantum field theory (QFT) as usually studied is mainly focused on point-like excitations. Some phenomena, however, are outside of reach of such standard QFT techniques. In this series of lectures, I will discuss various topics of QFT where we meet the need for description of the extended objects:

1) Classical solutions of extended character (domain walls, vortices,...).
2) Extended observables, Wilson/t'Hooft lines, surface operators.
3) Higher symmetries (symmetries associated with higher extended objects).
4) Breaking of extended/topological symmetries, beyond Landau Ginsburg phase transition.

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A gentle introduction to Supersymmetry

Rikard von Unge, Masaryk University, Brno

Starting in a two dimensional toy world, these lectures will give an introduction to Supersymmetry. After gently familiarizing ourselves with all the relevant theoretical concepts we will discuss the relevance of Supersymmetry in both Physics and Mathematics. We will talk about the role of Supersymmetry in the Standard Model of Particle Physics as well as a tool for studying purely mathematical concepts. In all parts of the lectures we aim to present concrete examples rather than abstract constructions.

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Multiphoton multiple ionization dynamics of Xe atoms at ultrahigh hard X-ray intensity

Koudai Toyota, DESY, Hamburg

In this talk, we report the results on the multi-photon multiple ionization dynamics of Xe atoms in

X-ray free electron laser pulses (XFELs) at ultrahigh intensity (~10^{19} W/cm^2). Theoretical calculation was performed using the xatom tookit, a set of versatile computer codes to calculate the atomic structure and ionization dynamics in XFELs [1]. Charge state distributions (CSDs) obtained by the calculations were compared with the experimental results. It is shown that the relativistic energy corrections and resonant excitations from core to the Rydberg orbitals play a critical role in the formation of highly charged Xe ions that are indispensable to reproduce the experimental results [2]. To conduct the comparisons between theory and experiment, theoretical CSDs have to be averaged over a spatial intensity distribution at focal spot. To perform the focal averaging in theory, focal parameters were calibrated using the CSDs of light atoms using the xcalib toolkit [3] based on the reinforcement learning technique.

[1] S.-K. Son, K. Toyota, O. Geffert, J. M. Slowik, and R. Santra, XATOM—an integrated toolkit for x-ray and atomic physics, CFEL, DESY, Hamburg, Germany, 2016, Rev. 2508
[2] B. Rudek, K. Toyota et al., Nat. Comm. 9, 4200 (2018)
[3] K. Toyota, Zo. Jurek, S. -K Son, H. Fukuzawa, K. Ueda, N. Berrah, B. Rudek, D. Rolles, A. Rudenko, R. Santra, J. Synch. Rad. 26, 1017 (2019)

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