Fachbereich Physik

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Vorträge im Physikalischen Kolloquium

Sommersemester 2015

Mittwochs 16 Uhr c.t., Hörsaal _.111 (EG), Max-von-Laue-Str. 1

29.04.15 **Prof. Dr. Raoul-Martin Memmesheimer**, Department for Neuroinformatics, Donders Center, Radboud University Nijmegen, Netherlands

Learning precisely timed spikes

Neurons (nerve cells) communicate with short electrical pulses, called spikes. This discontinuous interaction at discrete time points makes the dynamics of neuronal networks very different from those of conventional dynamical systems and a challenging subject of theoretical physics research.

Neurobiological experiments have revealed precisely timed patterns of spikes in several neuronal systems, raising the possibility that precise spiking is used by the brain to encode and transmit information. I will present recent research showing how neurons may learn to generate temporally precise patterns of spikes. The derived learning rules can be used to compute the memory capacity of neurons and its scaling. Further, they propose novel ways to analyze information content of spike data and to reconstruct underlying anatomical connectivity. Finally, they can be generalized to an arbitrary neuronal network architecture that includes feedback and recurrent connections.

13.05.15 **PD Dr. Hubert Klar**, Max-Planck-Institut für Astronomie, Heidelberg

The formation of Earth and other habitable planets

Planets are a beneficial side effect of star formation. They are believed to form in the dust rich gas disks around new born stars. These disks have an observed lifetime of a few million years. After the gas has dispersed one can often find a planetary system around the star, a system that in some cases shows similarities to our own Solar system, but very often can be radically different. The formation process itself is not observable because everything happens deep inside the dusty disk, which is opaque to our observers. Thus theory has to formulate a theory that is able to qualitatively and quantitatively connect the observed properties of circumstellar disks to the properties of the meanwhile more than 1000 planets around other stars that the sun.

I will present our current understanding of the planet formation process, highlighting work done in Heidelberg based on magneto- and radiation hydro dynamical simulations of turbulence in the gas disks around young stars and the role of turbulence in the accumulation of planetary bodies from dust grains. These simulations will provide the key information on the likelihood to find other worlds in the universe that can provide conditions to sustain life. Life that will produce observational signatures that we will be able to detect in the not too far future.

20.05.15 **PD Dr. George Bruls**, Physikalisches Institut, Goethe-Universität

Abbe, Bessel, Newton: Focal length measurement and thin-lens theory

We show that recent developments in non-paraxial geometrical optics(1) allow highly accurate numerical and analytical descriptions of the optical properties of real-life lens systems, including focal length, (position of) principal planes and typical (cushion and barrel) image distortions.

(1) Dr. G.Bruls, Exact formulas for a thin-lens system with an arbitrary number of lenses; accepted for publication in Optik (Elsevier), April 2015

27.05.15 **Prof. Dr. Gilles Laurent**, Max-Planck-Institut für Hirnforschung, Frankfurt

Neural Information Dynamics

I will present a few examples of work in my lab (past, at Caltech, and present, at MPI Brain Research) that touch upon emergent properties of networks of neurons, and aim at identifying both the mechanisms and the potential functions of these phenomena, using “simpler" nervous systems (insects, cephalopods, fish, reptiles) as experimental model systems.

03.06.15 **Prof. Dr. Karl-Heinz Kampert**, Bergische Universität Wuppertal, Lehrstuhl für Astroteilchenphysik

Cosmic Rays: The Most Energetic Particles in the Universe

Cosmic Rays have been known for more than a century and their discovery by Victor Hess was awarded with the Nobel Prize in Physics in 1936. Their flux at Earth amounts to about 20% of the natural radioactive dose and particle physicists profit from using them to calibrate their detectors. However, despite being so prominent in our daily life, very little is known about their origin. Furthermore, their energies have been measured to reach out to more than a 100 million times the beam energy in the most powerful man-made Particle accelerator, the Large Hadron Collider at CERN. Exploring the nature and origin of these particles is the goal the Pierre Auger Observatory, the worlds largest cosmic ray observatory located in Argentina. This talk addresses the open questions and reports latest results that have advanced our understanding of the most extreme cosmic messengers.

10.06.15 **Prof. Dr. Jochen Kuhn**, TU Kaiserslautern, FB Physik/Didaktik der Physik

physics.move: Experiment-basierte Aufgaben in den klassischen Übungen zur Experimentalphysik 1

Der Vortrag diskutiert die Konzeption und Untersuchung eines Lehr-Lernszenarios zur „Experimentalphysik I“ (Mechanik/Thermodynamik), das im Rahmen des „Regelbetriebs“ der universitären Studieneingangsphase umgesetzt wird. In den wöchentlichen Übungen zur Vorlesung bearbeiten die Studierenden neben klassischen auch sogenannte Videoanalyse-Aufgaben, in denen Videos von Laborexperimenten analysiert werden. Darüber hinaus führen die Studierenden selbst Experimente mit Alltagsmaterialien durch, nehmen diese mit Tablets auf und analysieren sie. Unsere Vermutung ist, dass in diesem Sinne adäquate Aufgabenstellungen das Wechselspiel zwischen Theorie und Experiment akzentuieren und naturwissenschaftliche Arbeitsweisen und Repräsentationskompetenz fördern. Nach Präsentation der Konzeption und umfangreicher Aufgabenbeispiele wird eine Interventionsstudie mit Versuchs-Kontrollgruppen-Design vorgestellt, mit dem die Ziele dieses Vorhabens (Steigerung der Leistung, Motivation, Neugierde) untersucht werden. Eine semesterbegleitende Belastungsmessung, Kontrollfragen zu Instruktionsparametern (z.B. Time-on-Task) sowie Studierendeninterviews tragen zur Einschätzung des Interventionserfolgs bei. Exemplarische Aufgabenstellungen und erste Ergebnisse aus vier Semestern konkretisieren den Vortrag.

17.06.15 **Dr. Kerstin Sonnabend,** Institut für Angewandte Physik,
Goethe Universität Frankfurt

Peanuts im Studentenfutter – Zur Nukleosynthese der p-Kerne

Die Frage nach der Entstehung der schweren Elemente mit Ordnungszahlen größer als Eisen ist eines der ungelösten Probleme der modernen Physik. Während ein Großteil dieser Isotope durch Prozesse entsteht, die eine Abfolge von Neutroneneinfangreaktionen und β-Zerfällen beinhalten, ergeben sich bei genauerer Betrachtung dieses komplexen Themas viele faszinierende Fragen. Ein besonders rätselhafter Fall ist die Produktion von etwa 35 protonenreichen, seltenen Isotopen, die nicht mittels Neutroneneinfangreaktionen erzeugt werden können, den sogenannten *p*-Kernen. Da die *p*-Kerne in der Regel nur relative Isotopenhäufigkeiten im Promille- und Prozentbereich aufweisen, sind sie die Peanuts der Solaren Häufigkeitsverteilung.

Die leichtesten *p*-Kerne können auch in einer Folge von Protoneneinfangreaktionen während thermonuklearer Supernova-Explosionen (sog. Supernovae Typ Ia) entstehen. Ein exaktes, auf Experimenten basierendes Wissen um die wichtigsten Reaktionsquerschnitte ist der Schlüssel, um diese Hypothese zu testen. Damit bietet die Nukleosynthese der *p*-Kerne über die Einschränkung der astrophysikalischen Parameter die Möglichkeit ins Innere dieser explosiven astrophysikalischen Ereignisse zu sehen und dient damit dem besseren Verständnis der Physik dieser kosmologischen Standardkerzen.

24.06.15 **JProf. Dr. Marc Wagner**, Institut für Theoretische Physik,
Goethe Universität Frankfurt

Antrittsvorlesung

Untersuchung von Mesonen und Tetraquarks im Rahmen der Gitter-QCD

Die Quantenchromodynamik (QCD) beschreibt Quarks, Gluonen und deren Wechselwirkungen. Sie erklärt, warum sich Quarks zu sogenannten Hadronen zusammenfinden, entweder Mesonen (i.d.R. Quark-Antiquark-Paare) oder Baryonen (Systeme von drei Quarks oder Antiquarks). Experimentell wurde eine Vielzahl von Mesonen beobachtet, die sich z.B. in den Quarkflavors, im Gesamtspin oder der Parität unterscheiden. Ein großer Teil dieser Mesonen ist aus theoretischer Sicht im genannten Quark-Antiquark-Bild gut verstanden. Einige Mesonen weisen jedoch unerwartete Eigenschaften auf (Massen, Zerfälle) und scheinen eine Struktur zu besitzen, die über die eines einfachen Quark-Antiquark-Paars hinausgeht. Eine in diesem Zusammenhang häufig und aktuell diskutierte

aber weder experimentell noch theoretisch eindeutig nachgewiesene Struktur ist die von Tetraquarks, mesonische Zustände bestehend aus zwei Quarks und zwei Antiquarks.
Nach einer kurzen Einführung in die QCD wird in diesem Vortrag erläutert, wie die komplizierten-Gleichungen der QCD numerisch mit Hilfe von Gitter-QCD gelöst werden können, mit dem Ziel Aussagen über die Eigenschaften von Mesonen, insbesondere deren Massen und Quarkstruktur, zu machen. Besonderer Fokus liegt dabei auf den oben angesprochenen Tetraquarkkandidaten.

01.07.15 **Dr. Olga Smirnova**, Max Born Institut Berlin

New effects in optical tunnelling

Tunnelling is a ubiquitous quantum process playing fundamental role in many areas of physics, chemistry, and biology. It can occur naturally or be induced by an external field, whether static or a low-frequency oscillating. In this talk I will discuss several effects associated with tunnel ionization induced by an intense low-frequency laser field, starting with atoms and moving on to chiral molecules. First, I will discuss opportunities to use precisely controlled, circularly polarized few-cycle laser pulses to measure the so-called tunnelling delay times – the time an electron can spend while moving in the classically forbidden region under the barrier. I will show that delays during tunnel ionization of one-electron systems are equal to zero (at least within non-relativistic quantum mechanics), but that electron-electron correlation may be modifying this picture [1]. Next, I will discuss unexpected consequences of tunnelling from states with non-zero angular momentum in circularly polarized laser fields. I will show that states co-rotating and counter-rotating with the laser field tunnel differently, leading not only to the different electronic spectra but also to the generation of few-femtosecond long, spin-polarized electron bunches [2]. Finally, I will show that tunnel ionization of molecules can create holes that move, that the motion of these holes can be sensitive to the topology of the molecule, and that it can be used to follow the dynamics of the chiral response with both high sensitivity and sub-femtosecond time resolution [3].

[1] L. Torlina, F. Morales, J. Kaushal, I. Ivanov, A. Kheifets, A. Zielinski, A. Scrinzi, H. G. Muller, S. Sukiasyan, M. Ivanov and O. Smirnova, Interpreting attoclock measurements of tunnelling times, Nature physics, 11, 503, (2015)
[2] R. Cireasa, A. E. Boguslavskiy, B. Pons, M. C. H. Wong, D. Descamps, S. Petit, H. Ruf, N. Thire, A. Ferre, J. Suarez, J. Higuet, B. E. Schmidt, A. F. Alharbi, F. Legare, V. Blanchet, B. Fabre, S. Patchkovskii, O. Smirnova, Y. Mairesse, V. R. Bhardwaj, Probing molecular chirality on sub-femtosecond time-scale, Nature physics, (2015)
[3] I. Barth and O. Smirnova, Spin-polarized electrons produced by strong-field ionization, Phys. Rev. A, 88, 013401 (2013)

08.07.15 **Dr. Markus Röllig,** I. Physikalisches Institut, Universität Köln

Sunblock Extreme - Astrophysics and Astrochemistry in Photo-dissociation Regions

The visible universe is dominated by stars. Their distribution, their starlight and their cycle of birth and death determine the structure of all galaxies. Only a few percent of the total baryonic matter exists in the form of gas and dust in molecular clouds, the interstellar medium (ISM). The ISM is despite its little mass fraction in permanent interaction with the surrounding stars: clouds collapse and form new stars, stellar winds and supernova explosions return material and enrich the ISM with heavier elements, and energetic starlight determines the chemical and physical structure of molecular clouds and thus controls the clouds capacity for further star formation.
The regions where the energy balance and the chemical composition of an interstellar cloud is dominated by far-ultraviolet photons are called photo-dissociation regions (PDRs) and their emission carries information on the local conditions in the gas and dust. Up to now, almost 180 different molecules have been identified in the ISM, some of them composed of more than 12 atoms. How can such complex molecules form and survive in an hostile environment with very low temperatures and densities and under extremely intensive UV illumination, and what can we learn from their observation. I will present our current understanding of the physical and chemical conditions in PDRs and discuss recent observational results from latest instruments and missions,

such as Herschel and SOFIA as well as our efforts in modeling and interpreting the data. The latest progress in numerical PDR modeling will be discussed using example of the Cologne PDR model KOSMA-.

15.07.15 **Prof. Dr. Ralph Claessen,** Physikalisches Institut and Röntgen Research Center for Complex Material Systems (RCCM), Universität Würzburg

Interface physics of complex oxide heterostructures: New opportunities for electronics

The physics of modern semiconductor technology is based on interface physics, i.e. on charge carriers moving at the boundary between differently doped regions or different materials. While the properties of Si- or GaAs-derived heterostructures is governed by relatively simple one-electron physics, fascinating new functionalities can arise when interfacing complex transition metal oxides with their rich many-body physics, ranging from magnetism to metal-insulator transitions to superconductivity. Recent progress in epitaxial thin film growth of ternary (or even more complex) compounds by, e.g., pulsed laser deposition (PLD) has made it possible to fabricate oxide heterostructures and superlattices with atomically sharp interfaces. Additionally, new methods based on x-ray and electron spectroscopy have been developed which provide direct experimental access to the electronic properties of the buried interfaces. In my presentation I will discuss various examples of the new field of "oxide electronics". I will particularly focus on the two-dimensional electron liquid (2DEL) forming at the interface between the insulators LaAlO3 and SrTiO3, which not only displays an unusually high mobility, but can also be controlled by electric field effect.