TUT 1: Dynamics and Fluctuations in Economic and Financial Markets (joint session SOE/DY/TUT/AKjDPG)

Financial and economic markets display nontrivial fluctuation statistics that called attention among physicists. Methods from statistical physics have demonstrated to be able to derive stylized facts from microscopic models, to extract networks from data, and to relate multivariate economic time series to the underlying mechanisms.

Time: Sunday 16:00–18:30 Location: H 0104

Tutorial TUT 1.1 Sun 16:00 H 0104
Market microstructure: dynamics of the stock markets — •Thomas Guhr — Fakultät für Physik, Universität Duisburg-Essen

At first sight, stock prices look like random walks. Indeed, Brownian motion models and related stochastic processes do a good job in describing some of the features which are empirically found in financial data. This is consistent with Fama's celebrated Efficient Market Hypothesis (EMH) which states that price changes are unpredictable. However, the closer one looks, the less reliable are those schematic models. This is so, because the way how the trading proceeds in time, i.e. the rules imposed and the ensuing dynamics, is largely ignored. Traders submit their buy and sell orders to the order book, whose content is made available to all market participants. The order flow eventually leads in a highly complex fashion to the realized prices.

Market microstructure is a quickly growing field in which economists, physicists, data scientists and mathematicians try to clarify these dynamical processes. An appealing feature, particularly for physicists, is the wealth of data available for analysis and subsequent model building. I am going to present large-scale data analysis to identify non-Markovian features. Fundamental economic reasoning as in the EMH favors Markovian models in which prices develop (apart from a deterministic drift) without memory. Sizeable memory effects could be exploited to make profit. I will present large-scale data analyses which show that there are various non-Markovian effects due to the highly complex market dynamics. Thus, there are limits to market efficiency which, furthermore, can be quantitatively identified.

Tutorial TUT 1.2 Sun 16:50 H 0104
Maximum-entropy models in economics and finance — •Tiziano Squartini — IMT School for Advanced Studies Lucca, P.zza San Francesco 19, 55100 Lucca (IT)

Entropy-maximization represents the unifying concept underlying the definition of a number of methods which are now part of the discipline known as "network theory". Despite the perfect generality of this approach, a particularly fruitful application of it has been observed in disciplines like economics and finance. This tutorial will be devoted to illustrate the methodological aspects of the aforementioned approach, with particular emphasis on the definition of null models. The latter can be employed in a number of applications, ranging from pattern detection to network reconstruction: examples will be provided of both, by taking as case studies real-world systems, as the World Trade Web and the Dutch Interbank Network. The aforementioned framework also allows one to properly model fluctuations: the latter can be interpreted as errors affecting the estimation of the quantities of interest and strongly depend on the kind of constraints defining the maximization procedure. In order to illustrate how different reconstruction algorithms perform, a comparison of proposed approaches on the aforementioned real-world systems will be also carried out.

Tutorial TUT 1.3 Sun 17:40 H 0104
350 years of puzzles in economics – and a solution. — •Ole Peters — London Mathematical Laboratory — Santa Fe Institute

In 1654 Fermat and Pascal puzzled over a gambling problem and invented probability theory. Three years later, Huygens declared that random quantities and their expectation values are "the same thing." Economics was the first adopter of the budding theory and to this day maintains much of the spirit of Huygens's early proclamation. Problems arising from this view of randomness have led to numerous puzzles in economic theory and beyond. An early example is the St. Petersburg paradox of 1713, a recent example is the insurance puzzle in general competitive equilibrium theory.

Economics has responded to these puzzles largely with labels. Humans are labelled irrational or risk averse.

An alternative treatment emerged from physics, where randomness entered in the 1850s with the development of statistical mechanics. Here, the question of ergodicity arose: are expectation values indicative of temporal behavior? The insight that in many cases an expectation value does not reflect the dynamics can be used to resolve the class of economics puzzles I will discuss. It leads to an alternative economic formalism that makes testable predictions. It can answer economic questions by assessing systemic stability where previously only moral assessments were available.

More at https://ergodicityeconomics.com/lecture-notes/

TUT 2: Quantum Technologies (joint session HL/TT/TUT)

This tutorial features both the high hopes in Europe regarding quantum technologies and the underlying physics of several promising routes towards economically relevant quantum information science as well as the physics of a whole range of novel quantum devices.

Organized by Christian Enss (Heidelberg) and Erich Runge (Ilmenau) on behalf of the divisions TT and HL.

Time: Sunday 16:00–18:25 Location: H 0105

Tutorial TUT 2.1 Sun 16:00 H 0105
Quantum Technology - how is research funded? — •Gerd Leuchs — Max Planck Institute for the Science of Light, Erlangen, Germany

Quantum technology is a field in physics which experienced considerable growth recently and is about to generate real world applications with significant economic potential. Scientists and research oriented companies succeeded raising the awareness of politicians in Germany and Europe.

As a consequence, the European Quantum Flagship, which will be supported by national initiatives (in Germany, QUTEGA, a BMBF funded project), is currently in the process of being established. The goal is to provide infrastructural and financial support to projects associated to Quantum Technologies. The major focus is on connecting scientific groups with players from industry who are interested in investing into emerging quantum technologies such as quantum communication, quantum metrology, quantum simulation and quantum computing.

For younger scientists, the structure and the political initiation process of such funding initiatives is often lacking transparency. As the national coordinator of the quantum initiative in Germany, I will try to shed some light on this topic by reporting about the currently ongoing foundation of the Quantum Flagship and the associated national initiatives. Since the final structure of the Flagship is not yet fully established, I will also share my experience with similar projects from the past.

5 min. break

Tutorial TUT 2.2 Sun 16:40 H 0105

Superconducting Quantum Circuits — •Rudolf Gross — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — Physik-Department, TU-München, Garching, Germany — Nanosystems Initiative Munich, München, Germany

Superconducting quantum circuits, consisting of inductors, capacitors and Josephson junctions, can be flexibly engineered using modern thin film and micro/nano-fabrication techniques. These quantum electronic circuits behave quantum coherently with coherence times approaching the millisecond regime. They are successfully used to study fundamental quantum effects and develop components for applications in quantum technology. Examples are the tailoring of light-matter interaction, the development of sources and detectors for quantum light, or the implementation of quantum information processing, quantum metrology and quantum simulation systems. Meanwhile, several companies such as Google, IBM or Intel have started the race towards a universal quantum computer based on a superconducting hardware platform.

Superconducting quantum circuits can also be successfully coupled to nano-mechanical and magnetic systems. In the resulting hybrid quantum systems different quantum degrees of freedom can be strongly coupled, allowing for the coherent exchange of elementary excitations such as pho-tons, phonons and magnons on a single quantum level.

I will give an introduction into the field of superconducting quantum circuits and address recent advancements in the rapidly growing field of superconducting quantum technology.

Tutorial TUT 2.3 Sun 17:15 H 0105

Josephson junction based interferometers and amplifiers — •Sebastian Kempf — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany.

Advances in science, health care or other areas of everyday life are often accompanied by progress in physical instrumentation. The development of ultra-sensitive detectors and sensors is therefore of great importance and will not only influence our understanding of nature but also future examination methods in medical care or search strategies for natural resources. Quantum technology plays an important role in these developments as superconducting quantum devices (SQDs) are among the most sensitive measurement instruments presently existing and enabling fascinating investigations of tiniest signals.

Josephson junction based interferometers and amplifiers are a special class of SQDs which are very well suited for measuring variations of tiny magnetic fields or any other physical quantity that can be naturally converted into magnetic flux. They are based on the Josephson effects as well as magnetic flux conservation and are used not only for measuring biogmagnetic signals as induced for instance by the electrical currents within the human brain but also to read out cryogenic particle detectors, to explore mineral deposits within geoscience or for magnetic sensing at nanoscale level.

I will give an introduction into this fascinating field, discuss different kinds of devices such as the well-known superconducting quantum interference device and highlight several applications for which Josephson junction based interferometers and amplifiers are a key technology.

Tutorial TUT 2.4 Sun 17:50 H 0105

Manipulation of quantum bits based on defect centres in diamond — •Oliver Benson — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstrasse 15, 12489 Berlin

Quantum information processing relies on initialisation, manipulation, read-out and transmission of individual quantum bits. Defect centres in diamond are an example of stable, optically addressable single quantum systems in a solid-state matrix [1-4]. Their electronic states couple efficiently to light, and their energy level structure allows for long spin coherence time in the ground state. Moreover, coupling to nuclear spins in the diamond host provides storage of quantum bits for seconds. With this all ingredients for a full quantum information processing (QIP) architecture are present in one material platform. In this presentation, we introduce the fundamental concepts of QIP in diamond. We then describe recent breakthroughs, such as stationary to flying quantum bit conversion and entanglement of distant quantum bits [5]. Other applications of defect centres in diamond for quantum sensing [6] will be discussed as well.

[1] F. Jelezko and J. Wrachtrup, Phys. Status Solidi A, 203, 3207 (2006). [2] V. Acosta, P. Hemmer, MRS Bull. 38, 127 (2013). [3] J. R. Weber, et al., PNAS 107, 8513 (2010). [4] I. Aharonovich, et al., Rep. Prog. Phys. 74, 076501 (2011). [5] H. Bernien, et al., Nature 497, 86 (2013) [6] S. Hong, et al., MRS Bull. 38, 155 (2013).

TUT 3: Spin-Orbit Coupling

The last decade of research in solid state physics has been marked by the realisation that the spin-orbit interaction can have a very important impact on the electronic properties of materials as diverse as semiconductors, magnets, and superconductors. The peculiar role of spin-orbit coupling is at the basis of many exotic electronic states in condensed matter, such as the spin-Hall insulator, topologically protected states, or topological superconductivity. It is also at the basis of booming research into possible novel applications in the realm of (spin-)electronics. Therefore, the thorough understanding of spin-orbit coupling and its possible effects should be an essential ingredient of the intellectual luggage of any student of solid state physics. It is the purpose of this tutorial to review some of the main ideas at hand.

Organizer: Kees van der Beek (Paris), Chair of the EPS Condensed Matter Division

Time: Sunday 16:00–18:15 Location: H 1012

Tutorial TUT 3.1 Sun 16:00 H 1012

Role of spin in the structure of matter and spin-related phenomena — •Michel I. Dyakonov — Laboratoire Charles Coulomb, Université Montpellier, France

While it can seem that the existence of the internal angular momentum - spin and the associated magnetic moment of the elementary constituents of matter (proton, neutron, electron) is a minor detail compared to their strong and electromagnetic interactions, in reality this property defines the whole structure of our world. The reason for this is that these particles are fermions, which obey the Pauli principle. This defines the fundamental properties of atoms, molecules, and solids.

A brief review will be presented of not so fundamental, but still quite interesting, spin-related phenomena, which have been studied for a long time and especially intensively in recent years:

Optical spin effects in atomic and solid state physics

- Optical spin orientation and detection
- Hanle effect
- Hyperfine interaction and nuclear magnetic fields

Electrical spin-related effects

- Spin resonance
- Anomalous Hall effect
- Spin currents
- Spin Hall Effect
- Spin Hall magnetoresistance
- Swapping spin currents
- Perspectives

Tutorial TUT 3.2 Sun 16:45 H 1012

From the Spin Hall Effect to the Quantum Spin Hall Effect — •Hartmut Buhmann — Physikalisches Institut, Universität Würzburg, Würzburg, Germany

Each Hall effect appears to show up with a quantum version where the related conductance is quantized. In solid state materials spin orbit interaction provides a source which leads to a distinct charge separation. In this case the charges deflected to the sides perpendicular to a current flow are characterized by an opposite spin polarization referred to a spin Hall effect. In narrow gap materials spin orbit interaction can lead to a bulk band inversion. In those materials an opposite spin current is observed at the edge of the sample. Due to a quantized charge current this effect is call the quantum spin Hall effect. In this lecture the consequences of a strong spin orbit interaction in semiconductor materials are discussed. Since the spin orbit effect is strongest in narrow gap materials containing heavy elements I will focus here on transport experiments and HgTe quantum well systems which can be viewed as a prototype material for the realization of the spin Hall [1] and quantum spin Hall effect [2].

[1] C. Brüne et al., Nature Physics, 8, 485 (2012).
[2] König et al., Science 318, 766 (2007).

Tutorial TUT 3.3 Sun 17:30 H 1012

Spin Orbit Coupling in Doped Mott Insulators — •Alessandra Lanzara — Physics Department, University of California, Berkeley — Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley

Two types of interactions commonly drive new emergent phenomena beyond textbook band theory in quantum materials: electron correlation and spin orbit coupling. The first, born from the observation of Mott that strong electron correlation can drive a system, otherwise metallic, on the verge of being an insulator, has excited the condensed matter community over the past several decades and lies at the core of many unsolved phenomena, such as unconventional superconductivity. The second, derives from the relativistic correction to the hydrogen-like atom, and has been vastly explored in the previous decades in the context of Rashba effect. Recently, the realization that strong spin orbit coupling can induce dramatic effect on the band structure of weakly interacting systems driving new phases of matter such as the topological band insulators has sparked huge interest in this emerging field. The real frontier today is to understand whether strongly interacting systems can exhibit any type of intrinsic topological order, distinct from band topology in insulators and what consequences this might have.

In this talk I will present experimental results for a variety of materials spanning the entire range of interaction, from strong correlation (Mott insulators), to strong spin orbit coupling (topological insulators) and intermediate interaction regime (spin orbit coupled Mott insulators). I will present intriguing results on the interplay between these two interactions. The future of the field is discussed.

TUT 4: Semiconductor Optics (joint session HL/TUT)

The field of semiconductors optics explores the interaction of semiconductors and their nanostructures with light. This includes on the one hand the optical control of semiconductors via light fields. On the other hand, semiconductors can act as light sources like lasers or single and entangled photon sources. In particular the latter plays a decisive role for applications in photonic quantum technology and often a quantum description of the semiconductor and the light field is required to describe the underlying physics. In the tutorial "Semiconductor Optics" various aspects of light-matter interaction in nanostructures will be discussed from both the experimental and theoretical point of view.

Organizers: Doris Reiter (U Münster) and Stephan Reitzenstein (TU Berlin)

Time: Sunday 16:00–18:25 Location: H 1058

Tutorial TUT 4.1 Sun 16:00 H 1058

Quantum dots for photonic quantum technologies — •Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

This tutorial aims to provide a general introduction to the physics of quantum dots and an overview of recent exciting developments in the field of semiconductor quantum optics with quantum dots (QDs). Semiconductor QDs have been identified as promising hardware for implementing the basic building blocks of novel quantum technologies, such as quantum computing, quantum communication, quantum metrology and quantum sensing. This is because individual charge carriers in QDs can be generated, manipulated, and coherently controlled. Moreover, miniaturized and integrated solutions with existing semiconductor technology are foreseeable. The topics addressed in this tutorial are two-photon interference with remote QDs, quantum dots in photonic integrated circuits, quantum sensing with QD photons, and hybrid atom-quantum dot systems.

5 min. break

Tutorial TUT 4.2 Sun 16:50 H 1058

Non-classical light emission and superradiant emitter coupling in semiconductor nanolasers — •Frank Jahnke — Institute for Theoretical Physics, University of Bremen, 28334 Bremen, Germany

Quantum effects of the light-matter interaction in nanolasers can lead to highly unusual effects not known in conventional lasers, such as a strongly reduced laser threshold and non-classical light emission. The emission properties can be characterized using the second-order photon correlation function $g^{(2)}$. Lasers usually exhibit a change from $g^{(2)} = 2$ for thermal light to $g^{(2)} = 1$ for coherent emission. For a nanolaser with a small number of atom-like quantum-dot emitters in an optical cavity we demonstrate that radiative coupling of the emitters via the cavity field can establish a superradiant state of the active material, which reveals itself via a giant photon bunching with $g^{(2)} >> 2$ in the emitted radiation. Furthermore, superradiant pulse emission and excitation trapping are demonstrated for quantum-dot based nanolasers.

[1] J. Wiersig, C. Gies, F. Jahnke, M. Aßmann, T. Berstermann, M. Bayer, C. Kistner, S. Reitzenstein, C. Schneider, S. Höfling, A. Forchel, C. Kruse, J. Kalden, and D. Hommel, Nature 460, 245 (2009).
[2] F. Jahnke, C. Gies, M. Aßmann, M. Bayer, H.A.M. Leymann, A. Foerster, J. Wiersig, C. Schneider, M. Kamp, and S. Höfling, Nature Communications 7, 11540 (2016).

5 min. break

Tutorial TUT 4.3 Sun 17:40 H 1058

Semiconductor spin-photon interfaces for quantum repeaters and cluster state generation — •Ruth Oulton — QET Labs, School of Physics and Department of Electrical and Electronic Engineering, University of Bristol, Tyndall Avenue, Bristol, BS8 1FD, UK

In this tutorial I will describe how one may use the spin of carriers in semiconductor quantum dots to store quantum information, and transfer or entangle that information with the polarization state of a photon. With efficient photonic structure surrounding the quantum dot, one may efficiently entangle a photon input into the structure with the QD a spin-photon interface. This is the basic building block of many functionalities, including a means to achieve a quantum repeater in quantum communication networks, and to generate entire strings of photons, all of which are entangled with each other after interacting with a mediating spin.