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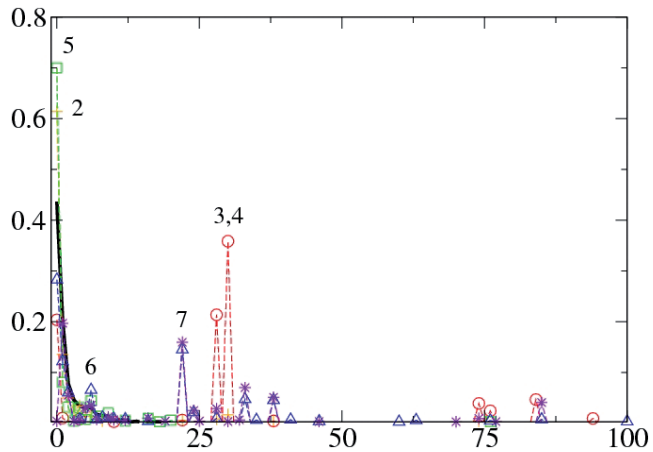
Highlights from the previous volumes

The game of go as complex network

The study of complex networks has attracted more and more interest in the recent past, fueled in particular by the development of communication and information networks. It turned out that many important aspects of the physical world or of social interactions can also be modelized by such networks. However, these powerful tools have never been applied to the study of games.

Games have been played for millenia, and besides their intrinsic interest, they represent a privileged approach to the working of human decision making. They can be very difficult to modelize or simulate: only recently were computers able to beat chess champions. The old Asian game of go is even less tractable, as no computer program has been able to beat a very good player.

The paper presents the first study of the game of go from a complex network perspective. It constructs a directed network which reflects the statistics of tactical moves. The study of this network for datasets of professional and amateur games shows that the move distribution follows Zipf's law, an empirical law first observed in word frequencies. Differences between professional and amateur games can be seen, *e.g.*, in the distribution of distances between moves. The constructed network is scale free, with statistical peculiarities, such as a symmetry between ingoing and outgoing links distributions. The fine study of eigenvalues and eigenvectors of the matrices used by ranking algorithms singles out certain strategic situations (see figure), and vary between amateur and different professional tournaments. These results should pave the way to a better modelization of board games and other types of human strategic scheming.



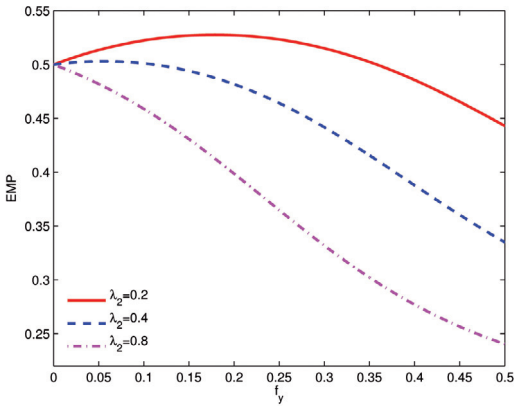
Moduli squared of right eigenvectors of the 7 largest eigenvalues of the Google matrix for the first 100 most frequent moves, showing that each eigenvector is localised on specific moves.

Original article by Georgeot B. and Giraud O.
EPL, **97** (2012) 68002

Efficiency of molecular machines with continuous phase space

Molecular motors exploit the free energy released in the hydrolysis of energetic molecules like ATP to perform work useful for the cell. It is therefore important to know the efficiency of this process, *i.e.*, the ratio between the performed work and the released free energy. The efficiency could reach 100% if the motor worked reversibly, *i.e.*, infinitely slowly, but then its output power would vanish. Thus, the relevant quantity is the Efficiency at Maximum Power (EMP). It has been shown that the EMP reaches 50% when the motor operates in the linear regime close to equilibrium. However, it has only recently been investigated further from equilibrium in models describing the motor as a discrete random process.

One can provide a more fundamental model of a molecular motor as a Brownian particle evolving in a two-dimensional continuous space, in which one coordinate represents its spatial position on the substrate and the other coordinate the advancement of the ATP-hydrolysis reaction, subject to a periodic "egg-carton" potential, whose tilt in the direction of the chemical coordinate expresses the free-energy imbalance. We have evaluated the EMP for such a model, with special choices of the potential, and found that it reaches the highest values when the displacements in the spatial and chemical coordinates are tightly bound: in this regime, efficiencies larger that 50% can be reached sufficiently far from equilibrium. When the binding is not tight, the EMP decreases since the motor can perform a chemical hydrolysis cycle without advancing. Our formalism thus allows us to gain a deeper insight into the connection between the mechanics and the thermodynamics of molecular motors.



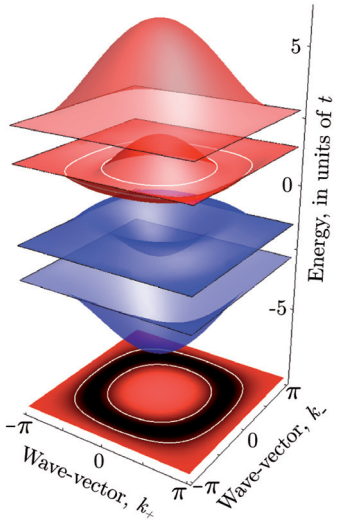
EMP for a tightly coupled motor as a function of the chemical driving force, for different values of the asymmetry. Note the regime in which the EMP exceeds 50%.

Original article by Golubeva N. *et al.*
EPL, **97** (2012) 60005

Spin-charge-density wave in a rounded-square Fermi surface for ultracold atoms

Ultracold atoms in optical lattices can nearly ideally realize the simple Hamiltonians that model the behavior of real condensed-matter systems, but with full control of parameters. Here, we show that Raman coupled ultracold fermions in a two-dimensional square optical lattice can have a different behavior depending on their position in the lattice: at a certain site, the system gains energy if the fermion flips its spin, whereas in the sites around this one, the same process costs energy. This physical system is described by a tight-binding model with a Zeeman coupling that is different for neighboring sites, thus dividing the lattice into AB sublattices. The single-particle spectrum has four bands; the third of which is shaped like a squarish Mexican hat, see the figure below. By filling up the energy levels up to the third band, the Fermi surface is squircle shaped. This squarish circle favors nesting and the system develops a coupled modulation in the density and spin, analogous to a spin-charge-density wave in solid-state systems.

Using field-theoretical methods, we develop a generalized formalism, which allows us to account for coupled charge and spin degrees of freedom simultaneously. We then determine the critical value of the parameters for the occurrence of the phase transition to this inhomogeneous density and spin state, which occurs at an incommensurate wave vector. Our results could be observed with state-of-the-art spectroscopic techniques. The investigation of spin-dependent optical lattices is an important direction of research in the field of spintronics with ultracold atoms, which will further strengthen the bonds between condensed matter and atomic physics.



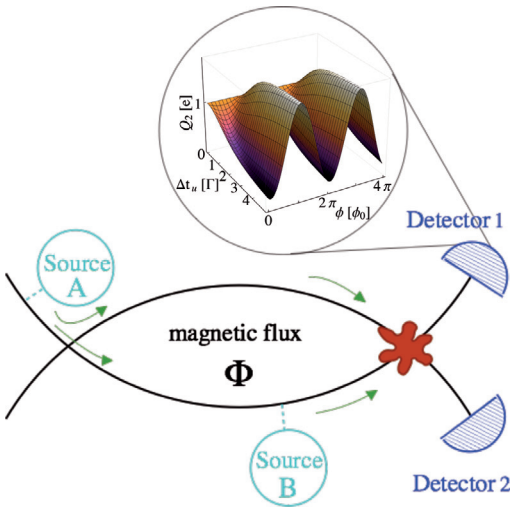
Band structure: the Fermi energy (concentric squircles) is depicted by white contours (see also projection into the momentum plane).

Original article by Makogon D. *et al.*
EPL, **97** (2012) 33002

Single-particle interference versus two-particle collisions

The recent experimental realization of an on-demand coherent single-electron source (Fève G. *et al.*, *Science* (2007)) allows to exploit the individual particles' quantum nature in controlled single- and multi-particle effects in solid-state devices. In particular, it inspires to perform interference studies in electronic interferometers into which well-separated single particles —electrons or holes— are injected.

Stimulated by these possibilities, this article proposes a setup where the single-particle interference in an electronic interferometer is influenced by the presence of a second particle-emitting source placed in one of the interferometer arms. The two sources can be synchronized with respect to each other creating tunable and coherent modulation, and even suppression, of interference. *Importantly, this study envisions and theoretically analyzes an experimental setup, in which both aspects of the quantum nature of electrons can be observed simultaneously: its wave-like and its particle-like behavior.* The time-dependent current shows an interference pattern, to which the second source adds a peculiar time-dependent phase determined by its working mode: this intriguing interference effect is convincingly explained by the particles' wave-like behavior. Yet at the same time, a tunable coherent suppression of the interference is expected in the total transmitted charge, which is shown to be a feature of the particles' ability to collide. The coexistence of the two effects leading to an interference suppression in the absence of dephasing is a fascinating challenge for our understanding of quantum mechanics.



Electronic interferometer fed by two independent single-particle sources. The magnetic-field–dependent interference, as a function of the phase difference ϕ, in the transmitted charge Q_2 is found to be suppressed with the occurrence of particle collisions at time difference $\Delta t_u = 0$.

Original article by Juergens S. *et al.*
EPL, **96** (2011) 37011