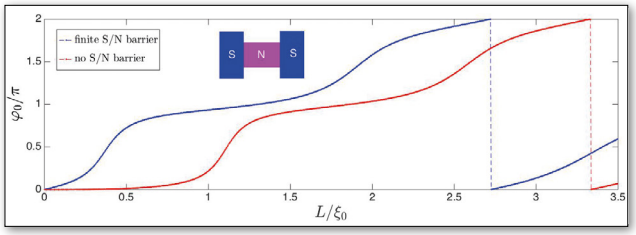
Highlights from European journals

CONDENSED MATTER

Revealing the microscopic origin of φ_0 Josephson junctions.

A spontaneous dissipationless current (supercurrent) can flow in a superconducting ring even in the absence of a magnetic flux, if the ring is interrupted by a so-called φ_0 junction. In the present work the authors present a full microscopic theory that explains the appearance of the anomalous φ_0 phase in junctions with an intrinsic spin-orbit coupling (SOC) and a spin-splitting field like the exchange field in ferromagnets. The SOC generates the spin precession of moving particles, and, in addition, it causes a spin-dependent deflection of electron trajectories. The latter can be interpreted in terms of an effective spin- dependent SU(2) magnetic field that in normal systems is the origin of the intrinsic spin Hall effect and the existence of spin currents in the equilibrium state. A finite φ_0 in a Josephson junction is directly related to the appearance of an equilibrium spin current with a spin projection parallel to the exchange field. These findings are the first steps towards spin-orbitronics with superconductors by making a natural connection between charge-spin conversion in dissipative and superconducting structures. ■



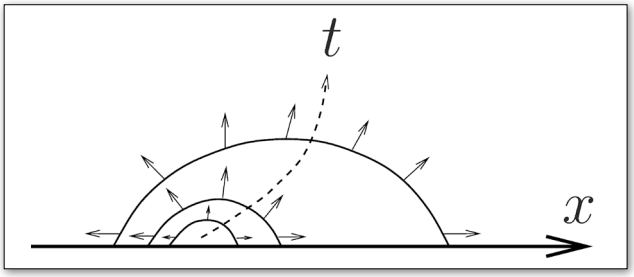
▲ The dependence of φ_0 on the length L of the N bridge (see inset) with an intrinsic SOC and spin-splitting field.

■ **F. S. Bergeret** and **I. V. Tokatly**, 'Theory of diffusive φ_0 Josephson junctions in the presence of spin-orbit coupling', *EPL* **110**, 57005 (2015)

MATHEMATICAL PHYSICS

Ever-growing disturbances leading to freak waves

Physicists like to study unusual kinds of waves, like freak waves found in the sea. Such wave movements can be studied using models designed to describe the dynamics of disturbances. The authors have focused on finding ways of best explaining how wave disturbance occurs under very specific initial conditions that are key to the genesis of these disturbances. They looked for solutions to this puzzle by resolving a type of equation, called the nonlinear Schrödinger equation. It is solved by applying a method designed for studying instabilities tailored to these initial conditions. Their approach makes it possible to locate exactly where and how pertinent information used to identify disturbance patterns can be extracted from localised disturbances' characteristics. The findings have been published recently. They therefore contribute to a better understanding of the complex dynamics of systems subjected to such disturbances. For example, they could be used to better understand waves appearing on fluid surfaces, whose evolution is influenced by gravity, or light waves propagated in optical fibres.■



▲ A schematic one-dimensional illustration of the spatiotemporal evolution of the envelope of wave-train in the absolutely unstable case.

■ **S. Coulibaly**, **E. Louvergneaux**, **M. Taki** and **L. Brevdo**, 'Spatiotemporal wave-train instabilities in nonlinear Schrödinger equation: revisited', *Eur. Phys. J. D* **69**, 186 (2015)

BIOPHYSICS

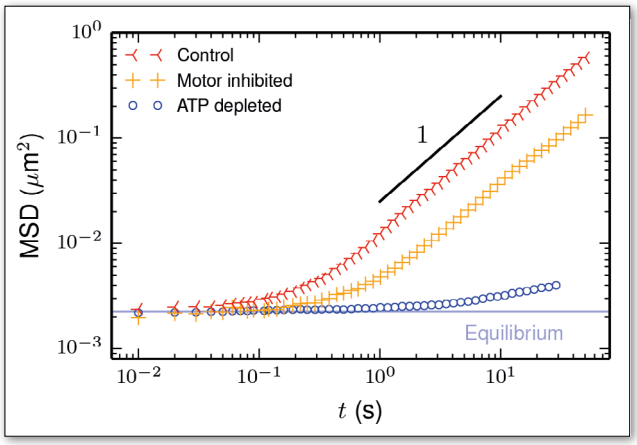
Activity–driven fluctuations in living cells

Living cells operate far from equilibrium due to the permanent injection of energy provided by ATP supply. The dynamics of the intracellular components is driven by both thermal equilibrium fluctuations, and active stochastic forces generated by the molecular motors.

To sort out genuine nonequilibrium fluctuations from purely thermal effects, we inject tracer particles in ATP depleted cells. By testing the fluctuation-dissipation theorem (FDT), we identify these cells as an equilibrium-like reference in which the tracers remain locally confined by the elastic cytoskeletal

network that permeates the cytoplasm. In contrast, we highlight a violation of the FDT and a diffusion-like motion at long time scales in untreated and selective motor inhibited cells. Removing the thermal contribution in the tracer fluctuations, we estimate the spectrum of the active forces. Eventually, we report non-Gaussian tails in the tracer displacement distribution as a result of directed motion events.

▾ Mean square displacement of tracers in living cells.



We recapitulate theoretically the observed fluctuations by modeling the dynamics with a confining harmonic potential which experiences random bursts as a result of motor activity. This minimal model allows us to quantify the time scales of the active forces, along with the energy injected by the ensuing fluctuations. ■

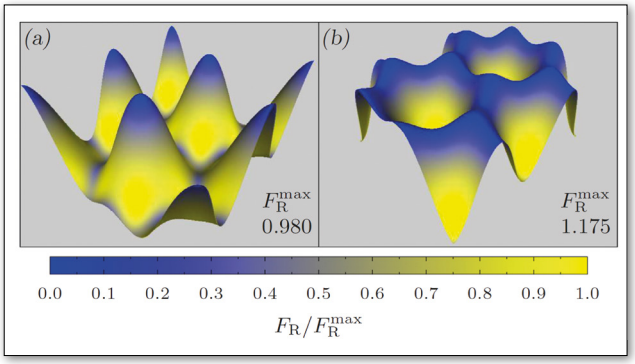
▮ **E. Fodor**, **M. Guo**, **N. S. Gov**, **P. Visco**, **D. A. Weitz** and **F. van Wijland**,
'Activity-driven fluctuations in living cells', *EPL* **110**, 48005 (2015)

CONDENSED MATTER

Shaping the hilly landscapes of a semi-conductor nanoworld

A new study reveals how hexagonal-patterned, self-organised hill structures emerge in 2D at the nanoscale due to redeposition following semi-conductor bombardment with low-energy ions.

Nanoscale worlds sometimes resemble macroscale roller-coaster style hills, placed at the tip of a series of hexagons. Surprisingly, these nanohills stem from the self-organisation of particles – the very particles that have been eroded and subsequently redeposited following the bombardment of semi-conductors with ion beams. Now, a new theoretical study constitutes the first exhaustive investigation of the redeposition effect on the evolution of the roughening and smoothing of two-dimensional surfaces bombarded by multiple ions. The



▴ Redeposition on hexagonally arranged dots.

results demonstrate that the redeposition can indeed act as stabilising factor during the creation of the hexagonally arranged dot patterns observed in experiments. These findings have been published recently. ■

▮ **C. Diddens** and **S. J. Linz**,
'Continuum modeling of particle redeposition during ion-beam erosion', *Eur. Phys. J. B* **88**, 190 (2015)

QUANTUM PHYSICS

Single-photon observables and preparation uncertainty relations

The escalating requests for highly accurate manipulation of single photons call for an appropriate description of their observables. The authors provide a unified procedure for treating all single-photon observables in terms of Positive Operator-Valued Measures (POVMs), allowing for the evaluation of corresponding probability distributions.

The suppression of longitudinal (or equivalently 0-helicity) photon states is identified as a projection from an extended Hilbert space onto the physical one, carrying an irreducible spin-1 mass-0 representation of the Poincaré group.

▾ Increase of uncertainty relations for circularly polarized Gaussian states as a function of the momentum spread. In the paraxial limit ($\Delta P \to 0$) $\hbar/2$ is retrieved.