OSCAR[1] Reports–

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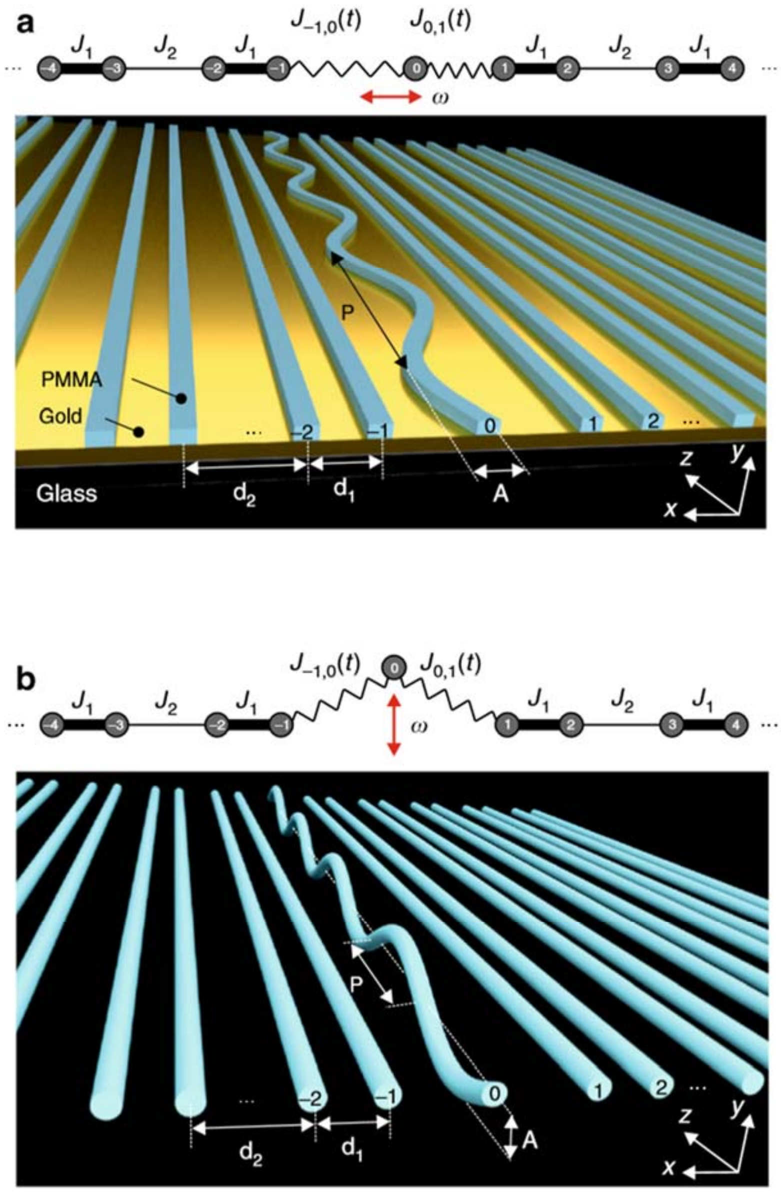

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[1] stands for **O**pen **S**ystem **C**ontrol of **A**tomic and Photonic Matte**R;** funded by the Deutsche Forschungsgemeinschaft since July 01, 2016

Fluctuation-Induced Quantum Zeno Effect

H. Fröml, A. Chiocchetta, C. Kollath, and S. Diehl

Phys. Rev. Lett. **122**, 040402 (2019).

It lies at the heart of quantum mechanics that the process of measurement can modify the state of a microscopic system. In an extreme limit, a rapidly repeated measurement can suppress otherwise allowed transitions between eigenstates of a quantum system and block its coherent time evolution – manifestations of the quantum zeno effect (QZE). In simple words the QZE can be described as a quantum phenomenon where the system cannot change while you are watching it. Recently, the QZE was demonstrated in an ultracold Bose gas experiment by the group of H. Ott. In this experiment a local loss implemented by an electron beam plays the role of a continuous measurement and the QZE manifests itself in a non-monotonic behaviour of the number of atoms lost from the condensate: while for small dissipation this number scales linearly with dissipation strength for strong dissipation starting from a critical value it scales inversely proportional to dissipation strength. The latter regime is the zeno regime where reflection takes the leading role. Locally, due to the infinitely strong dissipation the loss site cannot be entered anymore by nearby particles and transport is blocked.

This transport behaviour induced by a spatially localized loss process is reminiscent to what happens in a one-dimensional quantum wire in the presence of a single impurity. It is the great achievement of the above Letter to establish this connection and investigate it in detail in the presence of interactions. Research on transport in inhomogeneous interacting quantum wires has a long history. It was established early on that even the smallest impurity potential in an effectively one-dimensional wire can introduce dramatic effects at low temperatures. In particular, Kane and Fisher predicted the possibility of a quantum phase transition between a metallic state, unaffected by the impurity, and an insulating state in which the impurity blocks the conductance. This phase transition is controlled by the Luttinger parameter which effectively takes into account all interaction effects. A priori, it is unclear how the openness of a system changes the Kane and Fisher physics, or maybe even more, it is unclear how to tackle such a problem at all where RG methods, at the heart of the Kane-Fisher problem, are not yet developed.

In the above Letter, a single *dissipative* impurity in a one-dimensional system of interacting spinless fermions is considered. Fröml et al. investigated the locally dissipative system within two approaches: firstly, they considered the long wave-length limit and described the system and its corresponding Lindbladian in Luttinger liquid language. They performed a mapping of the master equation onto an effective Keldysh action for which in turn RG techniques are applicable. Remarkably, the flow of the dissipative coupling under a change of length or energy scale is similar to the one obtained for the renormalization of a Kane and Fisher potential barrier despite the fact that the present system is subject to dissipation and is out of equilibrium. In particular, the authors find that for attractive interactions, the perturbation is irrelevant in the RG sense as interaction strength goes to zero and, thus, the flow suppresses the dissipation strength. In contrast, for repulsive interactions the strength of the localized loss is relevant in the RG sense and flows to infinity, such that losses become suppressed by the QZE as illustrated in Fig.1.

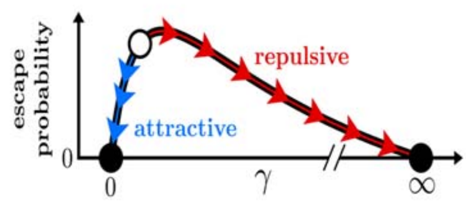

Figure 1*: Non-monotonic behaviour of the escape probability as a function of the dissipation strength.*

In a second approach, the authors performed numerical computations and an RG analysis for the microscopic model treating the interactions perturbatively. The results are in fully agreement with the Luttinger liquid description, see forward Fig. 2. In particular, the escape probability at the Fermi momentum is strongly renormalized by fluctuations, which suppress it. For repulsive interactions, this happens as if there is an infinite potential barrier thus producing a QZE; for attractive interactions, instead, this happens as if the dissipation vanishes.

$CeCu_6$Finally, it should be noted that the escape probability approaches the fixed point in qualitatively different ways depending on the sign of the interactions. Such asymmetry is only due to the dissipative character of the system and not present in the original Kane and Fisher problem.

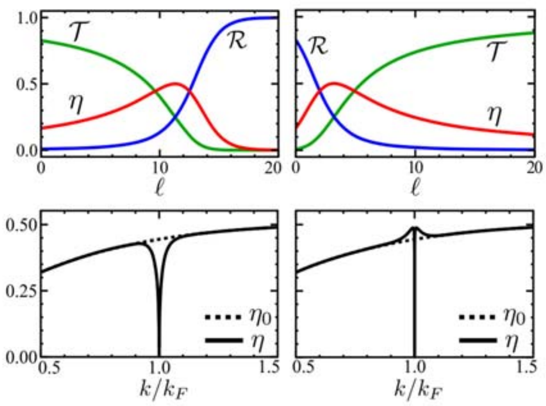

Figure 2: *Top: RG flow of transmission T, reflection R, and escape probability η. For repulsive interactions (left) a fully reflective fixed point is approached, while for attractive interactions (right) the system is perfectly transmissive at the fixed point. Bottom: renormalized η as a function of momentum in comparison to the non-interacting value η_0 (left: repulsive and right: attractive interactions).*

Fermi Volume Evolution and Crystal-Field Excitations in Heavy-Fermion Compounds Probed by Time-Domain Terahertz Spectroscopy

S. Pal, C. Wetli, F. Zamani, O. Stockert, H.v. Löhneysen, M. Fiebig, and J. Kroha

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One of the most powerful concepts of many-particle theories is Landau's Fermi liquid describing the normal state of a large number of metals at low temperatures. The interactions among the particles of the many-body system are captured by means of a quasi-particle description in terms of weakly interacting fermions which carry the spin, charge and momentum of the original particles but renormalized dynamical properties such as mass and magnetic moment. The quasi-particles form a Fermi sea at zero temperature. An accompanying concept is Luttinger's theorem which states that the volume inside the Fermi surface is invariant by the interaction, if the number of particles is held fixed. The validity of Luttinger's theorem, however, has been questioned in some intricate materials such as heavy-fermion compounds which are under investigation in the above Letter.

In heavy-fermion compounds, a lattice of rare-earth ions with local magnetic moments in the 4f shell is embedded in a metallic host. The emergent quasi-particles develop an unusually strong effective mass enhancement due to the Kondo effect. The coupling of the individual spins to the metallic environment leads to a Kondo singlet formation at sufficiently low temperatures and part of the 4f spectral weight is driven to the Kondo resonance near the Fermi energy. A band of lattice-coherent, heavy quasi-particles is formed where the band width is of order of the Kondo temperature. In consequence, the Fermi volume expands so as to accommodate the extra number of indistinguishable 4f electrons in the Fermi sea which is in remarkably agreement with Luttinger's theorem.

At larger doping a heavy-fermion material exhibits a quantum phase transition driven by the competition between the direct Kondo coupling and the indirect RKKY-interaction. Each magnetic moment induces Friedel oscillations in the spin density around the magnetic ion which in turn generate long range interactions among the spins on different sites, the RKKY interaction. The RKKY-interaction favours antiferromagnetic alignment while the Fermi liquid state induced by the direct Kondo coupling is paramagnetic. The existence of an enlarged Fermi volume is, thereby, a unique signature of the Kondo-induced heavy Fermi-liquid phase, its absence a signature of heavy quasi-particle destruction. An unbiased experimental measurement of the Fermi surface of the heavy quasi-particles, however, has been challenged several times. Reasons for this are that typical measurement techniques are performed at a finite energy scales or that the low-energy Kondo resonance competes with satellite resonances which originate from the same strong correlation effect that generates the low-energy Kondo resonance itself. This is for example the case for crystal electric field (CEF) effects.

Pal et al. have now managed to separately measure the Kondo and the CEF contributions to the Fermi volume using time-resolved terahertz spectroscopy for the heavy-fermion compound $CeCu_{6-x}Au_x$. Terahertz reflection thereby acts as a time filter separating the CEF excitations from the Kondo resonance by different reflex delay times. Fig. 3 shows the correlation-induced and background-subtracted time traces for $CeCu_6$. At high temperatures the Fermi volume is enlarged by the CEF excitations, both in the Fermi liquid phase for $CeCu_6$ and in the quantum-critical compound $CeCu_{6-x}Au_x$ with x=0.1. At low temperatures the large Fermi volume is carried by the ground-state Kondo band in $CeCu_6$, but collapses at the quantum phase transition at x=0.1. For this work J. Kroha has both proposed the experiment and performed supporting temperature-dependent dynamical mean-field theory calculations.

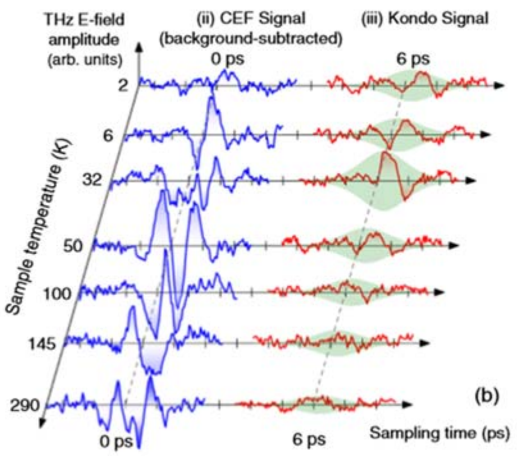

Figure 3*: Evolution of the background-subtracted signal (−2.5 to +2.5 ps) and the Kondo signal (+3.5 to +8.5 ps) as the temperature decreases from 290 to 2 K.*

Limits of topological protection under local periodic driving

Z. Fedorova (Cherpakova), C. Jörg, C. Dauer, F. Letscher, M. Fleischhauer, S. Eggert, S. Linden, and G. von Freymann

Light: Science & Applications **8**, 63 (2019).

Topological insulators, which insulate in the bulk but conduct along the surfaces, have attracted intense interest in recent years. The current carrying edge states along the surfaces, since being topological protected, are very stable against static defects. In the above paper, the question is addressed of how a dynamic deformation of the surface affects this robustness of the edge states.

The problem has been approached from several sides. A local periodic drive has been implemented in two complementary photonic waveguides, a plasmonic and a dieletric one. Theoretical support is given by a full Floquet analysis using one of the most basic models for topological excitations, the Su-Schrieffer-Heeger (SSH) model, see Fig. 4. The most important result of the work is that the edge state is depopulated in certain frequency ranges. Since a local drive cannot change bulk topological properties the change in the occupation and spectral characteristics of the edge state can only be explained by hybridisation with bulk states.

These findings are a result of a collaboration between the groups of M. Fleischhauer, S. Eggert, S. Linden, and G. von Freymann, all members of OSCAR.

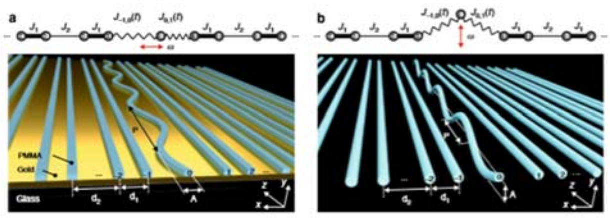

Figure 4: *Sketches of the SSH chains with time-periodic perturbations of a single lattice site at the interface between two distinct dimerisations (top) and the corresponding experimental realisations (bottom).*