induce the formation of hairpin defects, i.e. of a structural feature *beyond* the 30 nm fiber. In our simulations the hairpin opening led to a pseudo-plateau at 2 pN in the force-extension curve. Quite interestingly, the characteristic length scale associated with the observed hairpin defects coincides with the observed diameters of chromonema fibers.

Currently we are working on local structural transitions in chromatin fibers triggered by changes of the internucleosomal interactions, on an extensive comparison between solenoid and crossed-linker conformations of 30 nm-fibers and on topological aspects of the folding of DNA into chromatin fibers.

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3.1.20 Mesoscopic transport beyond universality

Henning Schomerus

One of the main goals in the theory of mesoscopic systems is to describe their equilibrium and non-equilibrium properties without resorting to microscopic details. Disordered mesoscopic systems indeed enjoy a large degree of universality, both in their spectral statistics (for closed systems) as well as in their transport properties (for open systems). Prominent examples are universal degrees of level repulsion, which follow

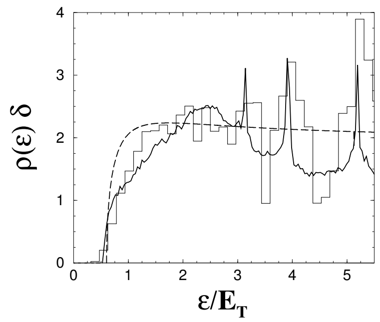

Figure 1: *The density of states $\rho(\varepsilon)$ (rescaled with the mean-level spacing $\delta = h/t_H$) for a model of a quantum dot next to a superconductor with $t_D/t_B = 5$ and $t_{\rm Ehr}/t_B \approx 4.4$ (solid line) is compared to SRMT (histogram) and the RMT prediction (dashed line).*

the Wigner surmise, and universal conductance fluctuations of the order of the conductance quantum e^2/h. An all-encompassing framework to describe these phenomena is random-matrix theory (RMT), which is applied either to the Hamiltonian or to the scattering matrix. RMT assumes that all modes are well mixed, hence, that the system displays well-developed wave-chaos. Impurities serve well for this purpose, since s-wave scattering couples into all directions with the same strength.

In clean ballistic systems, scattering is off the boundaries, which is not as diffractive as the scattering from an impurity, and hence wave chaos takes a longer time to establish itself. Does this imply deviations from universality, and to which extent? This question interests us for various reasons: i) it forces us to understand the limits and conditions of universality and RMT, ii) it forces us to extent both concepts, iii) the deviations themselves are interesting, since present-day experiments (and future device physics) aim at the accentuation and intensification of quantum effects, not at their leveling-out.

A good starting point to investigate the departure from universality is the setting of classically chaotic systems, for which limits are known in which RMT *does* apply. Classical ergodicity restricts the number of relevant parameters to four time scales: The mean time between encounters with the boundary t_B, the mean dwell time t_D, the inverse Lyapunov exponent λ^{-1}, and the Heisenberg time t_H. Wave chaos is established for times larger than the Ehrenfest time, which comes in three different variants depending on the quantity studied:

(a) $t_{\rm Ehr} = \lambda^{-1} \ln(t_B t_H/t_D^2)$ for transport properties,
(b) $t_{\rm Ehr} = \lambda^{-1} \ln(t_H/t_D)$ for escape out of the system, and
(c) $t_{\rm Ehr} = \lambda^{-1} \ln(t_H/t_B)$ for spectral properties of closed systems.

The differences originate in the number of passages through the openings of the system (two in the case of transport; one for escape; and none for closed systems). Cases (a) and (b) refer to open systems, with the dwell time t_D in the typical range $t_B \simeq \lambda^{-1} \ll t_D \ll t_H$. Universality breaks down when $t_{\rm Ehr}$ becomes of order t_D, which is achieved in the classical limit $t_H/t_B \to \infty$. Case (c) applies to closed systems and is less interesting since the relevant time scale is $t_H \gg t_{\rm Ehr}$.

We systematically studied transport- and escape properties in open quantum systems and identified the phenomenology of the deviations from universality. The results can be explained by an amended RMT which incorporates the short-time dynamics semiclassically (SRMT). Results are presented in Figures 1-4.

Figure 1 shows the density of states in a model of a quantum dot coupled to a superconductor [1], which falls into the class (a) because of Andreev particle-hole conversion at the interfaces. At the Fermi energy this process is accompanied by total destructive interference, which gives rise to a gap of order $E_T = h/t_D$. A finite Ehrenfest time

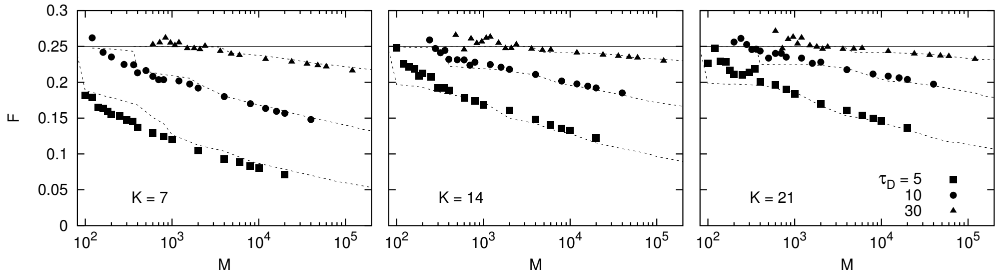

Figure 2: *Shot noise (normalized to the Poissonian value) as a function of $M = t_H/t_B$, for various degrees of chaos K and dwell times t_D (both in units of t_B). The curves are the prediction of SRMT.*

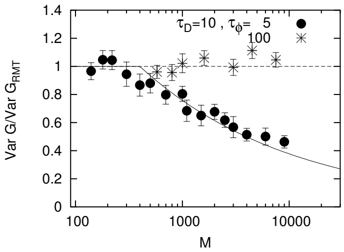

Figure 3: *Variance of the conductance fluctuations (normalized to the RMT value) as a function of $M = t_H/t_B$. Each data set is for a fixed value of t_D and dephasing time τ_ϕ (in units of t_B). The curves are the prediction of SRMT.*

weakens the destructive interference because it allows to form states along sufficiently short classical trajectories. Hence, if $t_{\rm Ehr} \gtrsim t_D$ the gap is reduced and the density of states develops system-specific fluctuations, which are amenable to SRMT.

Figure 2 shows the shot noise in the model of the quantum dot [2] as a function of $M = t_H/t_B$. This transport property [class (a)] is suppressed below the RMT value by a factor $\exp(-t_{\rm Ehr}/t_D)$ when the degree of wave chaos is reduced by either increasing $M = t_H/t_B$ or the Lyapunov exponent $\lambda \simeq \ln K/2$.

Universal conductance fluctuations and the weak-localization correction also fall into class (a), but turn out to be more robust than the mean density of states and the shot noise, since only a few wave-chaotic channels are needed in order to bring these quantum-interference effects into existence. We verified that departure from universality *does* occur when dephasing is taken into account [3]. Figure 3 exemplifies this for the case of universal conductance fluctuations, which are suppressed below the RMT value by a factor $\exp(-t_{\rm Ehr}/\tau_\phi)$, where τ_ϕ is the dephasing time.

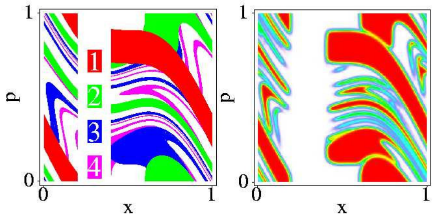

Figure 4: *Classical phase-space regions of escape after $n = t/t_B < t_{\rm Ehr}/t_B$ bounces off the boundary (left) are compared to the support of fast-decaying states.*

Deeper insight into the effect of the Ehrenfest time can be obtained by studying the quasi-bound states of an open system [4]. This concerns the escape out of the system and hence falls into class (b). We find that a large number of very short-lived states is formed in the part of the classical phase space where escape is quicker than $t_{\rm Ehr}$. The fraction of states with RMT characteristics shrinks to zero in the semiclassical limit. This can be translated into a fractal Weyl law for the long-living states (which are associated to the universal fluctuations in the RMT regime). Such laws have been previously predicted by quantization of the classical repeller, based on the Gutzwiller trace formula for chaotic systems. We find that the effect can be explained on the mean-field level, which allows us to consider non-chaotic situations as well. Figure 4 demonstrates the mean-field correspondence of short-lived states with classical regions of fast escape for the case of a soft-chaotic system (the phase space is divided into stable and unstable regions).

Traditionally, semiclassics and random-matrix theory have been viewed as complimentary methods. It is good to see that they can be combined to open up new areas of applicability where each method by itself was at a failure.

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3.1.21 Multiscaling in Anderson localization

Mikhail Titov and Henning Schomerus

Anderson localization is one of the most remarkable phase-coherent phenomena. It reveals itself in an exponential decay of the wave function of a classically free particle. This phenomenon is a result of multiple phase-coherent backward scattering, which is especially pronounced for a particle restricted to a single spatial dimension (to a line). Small fluctuations in the potential landscape do not affect the classical motion of a particle, while quantum-mechanically they can act as an effective potential barrier.

Unlike many other phase-coherent phenomena, Anderson localization cannot be understood within the well-developed framework of quasi-classical theory and requires a thorough theoretical investigation. At present, the detailed theory is limited to a simple class of one-dimensional non-interacting systems, which have many specific features of their own. It remains to be a challenge to distinguish the universal properties of these systems from those which are model-dependent.

In a series of recent works [1–4] we expand the existing theory of localization to a broader class of models. In particular we study the effects of lattice symmetry on the universal properties of the conductance, density of states, time-delay etc. The analytical method developed in Ref. [1] appears to be very successful in the scaling analysis of the universal fluctuations of these quantities. The general arguments given by Anderson, Thouless, Abrahams, and Fisher as early as in 1980 on the basis of scaling theory provide us with the conjecture that the conductance fluctuations in disordered metals are universally characterized by a single parameter. Our analytical approach