Overview: Brownian Motion and Dephasing due to Dynamical Disorder

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Abstract. The motion of a particle under the influence of a dynamical disorder is described by the DLD model. One motivation is to understand the motion of an electron inside a metal; Another is to understand quantal Brownian motion. The overview is based on a research report for 1996-1998.

A generic toy model for quantal Brownian motion that takes into account the disordered nature of an environment (See Fig.1) has been defined and explored [P1-P5]. The treatment of diffusion localization and dissipation (DLD) has been unified, the propagator of the reduced probability-density-matrix has been calculated, and its non-classical structure has been explained.

One motivation for studying this effective 'DLD model', which constitutes a non-trivial generalization of Zwanzig-Caldeira-Leggett (ZCL) model, is the wish to understand the motion of an electron inside a metal, taking into account both the the static disorder configuration and also the Coulomb interaction with the rest of the Fermi sea.

An important issue [P3] is the study of decoherence using Wigner's phase-space representation for the description of the evolving quantum-mechanical state. In case of the ZCL model the propagator of the Wigner function is just a Gaussian kernel. In case of the DLD model the propagator contains a singular term that corresponds to an unscattered component of the wavepacket. Consequently it is possible to distinguish between *smearing mechanism* and *scattering mechanism* for decoherence. This distinction is essential in order to get a proper understanding of *dephasing*.

The extension of the latter study [P4] to the low-temperatures regime has been done in collaboration with *Y. Imry*. The limitations of the semiclassical strategy have been clarified. The work was motivated by a controversy regarding the effect of 'zero point fluctuations' [1], following experimental observation by *Mohanty*, *Jariwala* and *Webb* [2].

The study of dephasing has been extended [P3] to various types of transport, which are illustrated by Fig.2. The main goal was to derive results for all these cases using a general formula for dephasing that applies to any temperature. The final result can be written in terms of two functions: the form-factor of the environment and the power spectrum of the motion under consideration. The introduction of ad-hoc or ambiguous cutoffs into the calculations, as in the works of Chakravarty and Schmid [3] and followers, is not required.

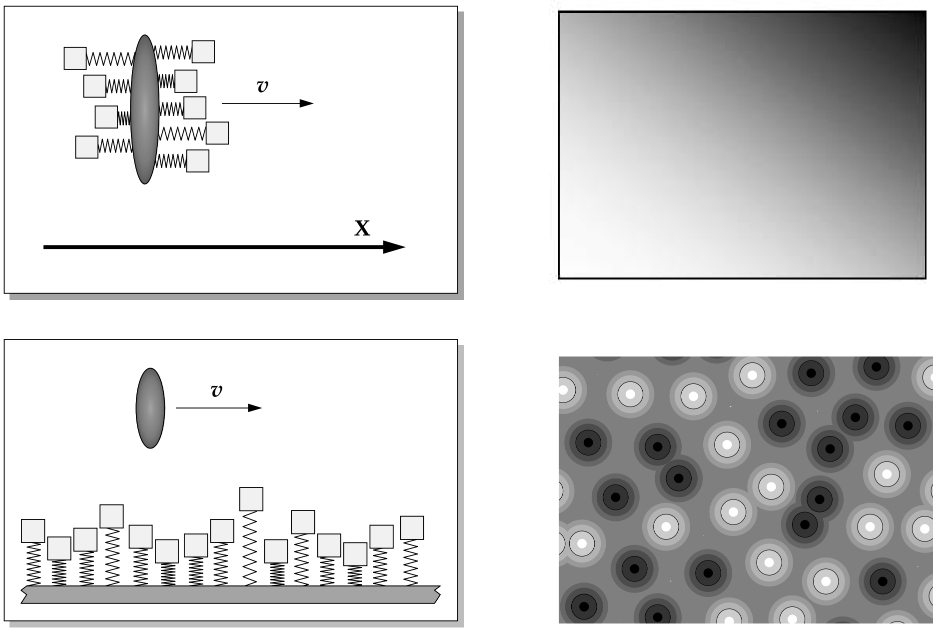

Fig.1. Illustration of the Zwanzig-Caldeira-Leggett model (upper drawings), versus the DLD model (lower drawings). DLD stands for 'Diffusion Localization and Dissipation', which are the three main dynamical effects that are associated with the motion in dynamical disorder. The instantaneous potential that is experienced by the particle is either linear (right upper drawing), or of disordered nature (right lower drawing) respectively. If the fluctuations are uncorrelated in time, then the two models are classically equivalent. There is no such equivalence in the quantum-mechanical case!

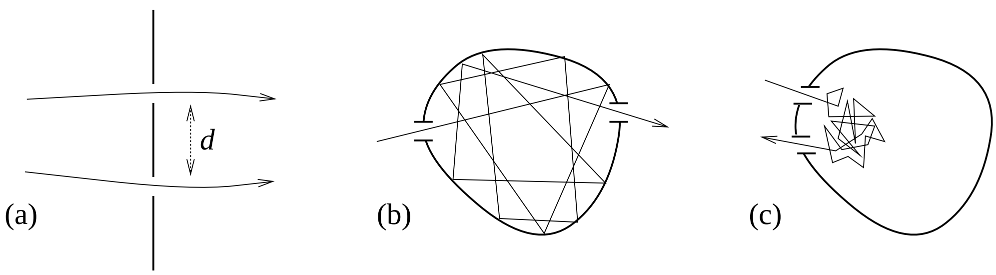

Fig.2. Various types of transport problems that have been studied: (a) Ballistic transport as in the two-slit experiment; (b) Transport via a chaotic cavity; (c) Transport via diffusive cavity, as in weak localization experiments. The dephasing factor that suppresses the interference contribution can be determined once the properly-defined power-spectrum of the motion is calculated.

References:

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