INTERNSHIP PROPOSAL

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Internship location: CPHT, Ecole Polytechnique, Palaiseau

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding:

From Boltzmann transport to hydrodynamics

In this doctoral project, we will study strongly-correlated Condensed Matter systems (such as are found in high Tc superconductors) and the effective theories describing their low-energy dynamics. Fermi liquid theory is the effective low-energy theory of conventional metals. It assumes that microscopic electrons form a Fermi sea in momentum space at low energies. Low-energy excitations originate from its surface and are quasiparticles, ie particles with the same spin and charge as the microscopic electrons but with a mass renormalized by interactions. At zero temperature, these quasiparticles are infinitely-lived. The resulting spectrum of collective excitations includes a so-called zero sound mode, a branch cut and a particle-hole continuum. At nonzero temperatures, phase space constraints cause the quasiparticles to disintegrate with a finite lifetime. Observables of experimental interest such as the electric conductivity can be computed in the semi-classical approximation through the Boltzmann equation from kinetic theory. At the longest times, which is the relevant regime for transport measurements, all quasiparticles have decayed and only global symmetries of the system remain: this is the hydrodynamic regime. Hydrodynamic theories are constructed by truncating the set of microscopic degrees of freedom to the conserved quantities originating from global symmetries, such as energy, momentum and charge. It is known in a number of simple cases how to explicitly derive hydrodynamics from the Boltzmann equation, for instance when the Fermi surface is spherical. The hydrodynamic theory which is found is invariant under Galilean boosts, which forbids so-called incoherent transport of charge, ie without momentum flow. On the other hand, various experiments in cuprates high critical temperature superconductors point towards such an incoherent component to transport, both in the strange metallic regime at optimal doping, and in overdoped compounds.

The goal of the doctoral project is to elucidate the hydrodynamic theories resulting from anisotropic Fermi surfaces and quasiparticle relaxation times. We will first treat the Boltzmann equation semi-classically. We will also include the effects of disorder, which breaks spatial translations weakly, and compare to existing hydrodynamic theories with relaxed momentum. Finally, in collaboration with Gaël Grissonnanche (LSI, IPP), we will solve the Boltzmann equation and study the hydrodynamic theories for Fermi surfaces realistic from cuprates, obtained from ARPES (angle-resolved photo-emission spectroscopy) or ADMR (angle-dependent magneto-resistance) measurements.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: NO Theoretical Physics: YES