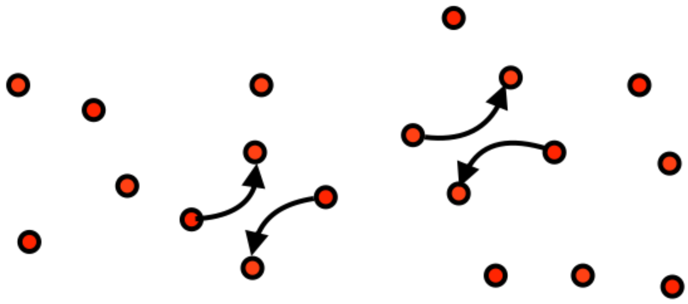
Master project: Simulation of relaxation timescales in 2D Fermi liquids

Background: Many properties of metals, such as their specific heat or compressibility, can be explained by assuming that electrons behave like free particles. This is a priori very surprising since the interaction between electrons (for example, the Coulomb repulsion) is actually quite strong, and there seems to be no obvious reason why a simple noninteracting theory should describe the system. In order to explain this surprising behaviour, the Fermi statistics of electrons is important, which implies the Pauli exclusion principle that causes electrons to fill all available energy states up to a maximum Fermi energy. This in turn implies that the effect of interactions, even if they are strong, is suppressed. It is possible to develop a theory of metals starting with this observation, which is known as Landau's theory of the Fermi liquid. The central object of Fermi liquid theory is no longer a single electron but a "quasielectron" that behaves very much like an electron (for example, it has a fixed mass or velocity). However, different from electrons, it also has a lifetime, which measures how quickly the quasielectron disintegrates into other quasiparticles. If the lifetime is large, the free-fermion description discussed above applies, which is the case at low temperatures.

Recently, Fermi liquid theory has been revisited for electrons restricted to move in two space dimensions. Such restrictions are common in many experiments, for example, in graphene systems or for electrons that are located at the interface between two materials.



The claim is that Fermi liquid theory is much more complex in two dimensions than it is in three dimensions, with several different lifetimes that describe the decay of quasielectrons. A better understanding of this problem is important in order to describe recent transport experiments, which claim to observe hydrodynamic flow of electrons in metals, very much like water, which is very surprising for condensed matter systems.

Project proposal: The aim of the project is to propose experimental setups where corrections to Fermi liquid theory can be observed. In order to do this, you will derive an expression for the lifetime of electrons in a Fermi liquid and evaluate it numerically for realistic interaction potentials and parameters.

A basic knowledge of quantum mechanics and condensed matter physics is essential for this project. This work has an analytical component, but the calculation of the lifetime will have to be done numerically, which involves the computation of multidimensional integrals, hence some programming experience would be useful. Office space in the physics department is available.

Supervisor:
Johannes Hofmann, johannes.hofmann@physics.gu.se, Department of Physics, Gothenburg University.