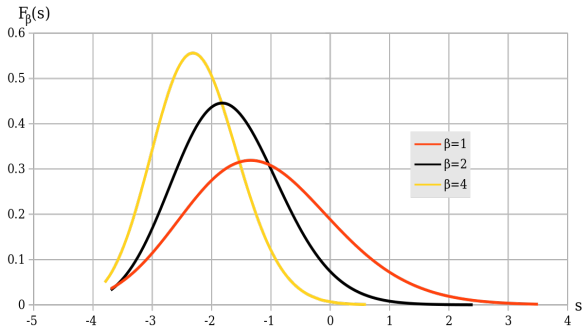
**Master project:** <u>Universal correlations in non-interacting Fermi gases</u>

**Background:** Assume that we know the position of every particle in a glass of water and that we can predict the trajectory for each of these particles over time. What, then, have we learned about that system? Of course, the answer is 'nothing' — knowing the trajectory of every single particle in such a complex system is not useful. What we are after is a statistical description that tells us, for example, which fraction of the particles have certain velocities or what the probability is to detect particles in a certain volume, since this can be connected to experimental observables.

For quantum particles, any description must include the quantum statistics, i.e., whether particles are bosons or fermions, which gives rise to interesting correlations effects even if the particles are noninteracting. A simple example of this is the Pauli principle, which gives rise to the Fermi-Dirac distribution, but there are even more intricate consequences: For example, it has recently been realised that even non-interacting quantum particles have a statistical description that was previously only seen in complicated systems like atomic nuclei (which have strong interactions between their constituents) or models that describe the spread of forest fires and avalanches. This is both surprising and very exciting, because these quantum systems can be created in experiments with ultracold gases and nanostructures.




*Examples of so-called Tracy-Widom distributions, which describes the properties of one-dimensional fermions.*

**Project proposal:** In this project, you will analyse the statistical properties of non-interacting fermions. Starting from the quantum-mechanical many-particle wavefunction, you will first develop a statistical theory for the distribution of the particle positions, which is something that can be observed in experiments with quantum gases. The aim of the project is to model current experimental setups and make predictions that could be tested in experiments.

A basic knowledge of quantum mechanics and statistical physics is essential for this project. The work has a strong analytical component. It would be useful (but not essential) if you can perform simple numerical computations, for example using Mathematica or Phyton. Office space in the physics department is available.

**Literature:** A review paper with (rather advanced) theory: D. Dean, P. Le Doussal, S. Majumdar, G. Schehr, *"Non-interacting fermions at finite temperature in a d-dimensional trap: universal correlations"*, Phys. Rev. A **94**, 063622 (2016)
https://arxiv.org/abs/1609.04366

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