Cold atoms and QMC: equilibrium and transport

Cold Fermi gases are known to share similar properties to dilute nuclear matter, starting from 1999 when George Bertsch issued the MBX challenge.

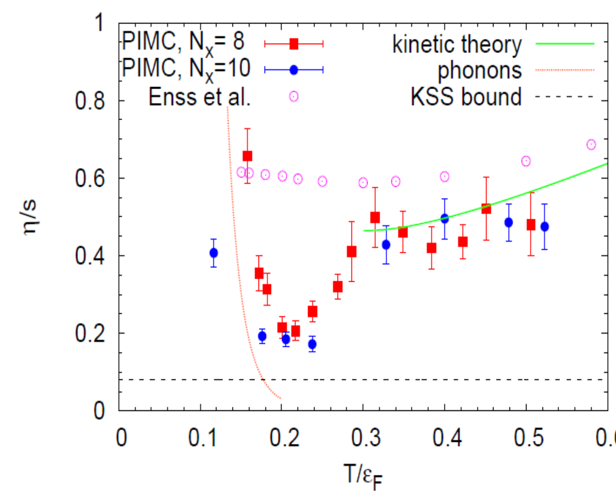
Universality of ultra cold atomic gas in the unitary regime allows cold atom physics to emulate, validate, and study complex and challenging aspects of many body physics of superfluid systems in a highly non-perturbative regime under otherwise impossible to realize experimental conditions.

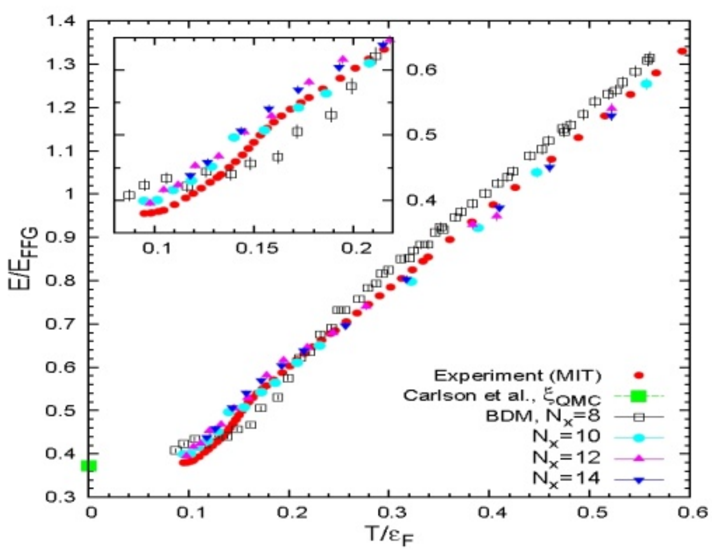
The unprecedented progress in experimental techniques give a unique possibility to access the information about the properties of the system in a highly controllable external conditions, which include the precisely adjusted strength of atom-atom interaction, the temperature or the shape of the trapping potential.

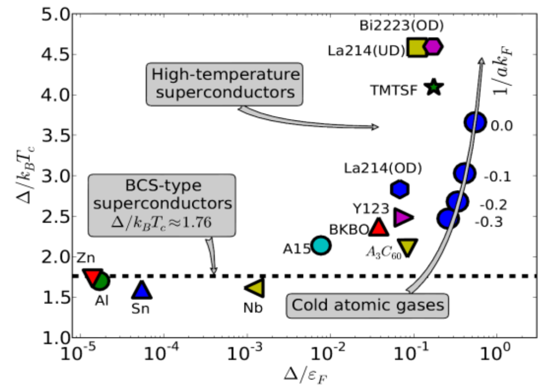
The Path Integral Monte Carlo (Auxiliary Field MC) provides a theoretical tool allowing for *ab-initio* determination of equilibrium properties of strongly correlated Fermi system at finite temperatures. Application of the fluctuation-dissipation theorem allows also to extract various transport properties of the system.

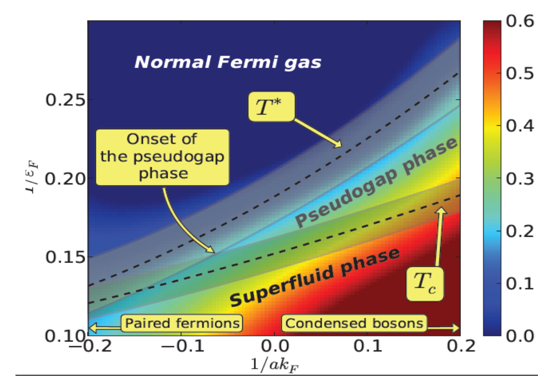
Achievements:

- Determination of the equation of state for the unitary Fermi gas: energy, free energy, entropy as a function of temperature (in a remarkable agreement with the newest experimental data).
- Determination of the critical temperature for the normal-to-superfluid phase transition.
- Determination of the pairing gap as a function of temperature around the unitarity.
- Evidence for the pseudogap phenomenon. (In agreement with *rf*-spectroscopy data).
- The only full *ab-initio* determination of the shear viscosity of a quantum system.
- Determination of the spin susceptibility of the unitary Fermi gas; both static and dynamic (in agreement with experimental data).
- Determination of the spin drag coefficient.









Future plans:

- The development of the QMC approach will make it possible to study in an *ab-initio* approach:

➢ Properties of topological excitations: vortices and domain walls
➢ Spin asymmetric systems with a special emphasis on conditions at which LOFF phase exists, relevant to the study of nuclear symmetry energy
➢ Periodic systems with application to optical lattices
➢ Bose-Fermi mixtures
➢ Properties of systems formed by species with different masses

QMC will provide strong constraints for the energy density functionals designed for these systems