Towards exascale simulations of quantum superfluids far from equilibrium

Abstract

Superfluidity is a generic feature of various quantum systems at low temperatures. It has been experimentally confirmed in many condensed matter systems, in ^{3}He and ^{4}He liquids, in nuclear systems including nuclei and neutron stars, in both fermionic and bosonic cold atoms in traps, and it is also predicted to show up in dense quark matter. The time dependent density functional theory (TDDFT) is, to date, the only microscopic method which allow to investigate fermionic superfluidity far from equilibrium. The local version of TDDFT is particularly well suited for leadership class computers of hybrid (CPU+GPU) architecture. Using the most powerful supercomputers we are currently able to study a real-time 3D dynamics without any symmetry restrictions evolving up to hundred of thousands of superfluid fermions. It represents a true qualitative leap in quantum simulations of nonequilibrium systems, allowing to make quantitative predictions and to reach limits inaccessible in laboratories. During the talk I will review several applications and results concerning nuclear induced fission and collisions, dynamics of nuclear matter in neutron stars, dynamics of topological excitations in ultracold atomic clouds and prospects to produce a quantum turbulent flow.

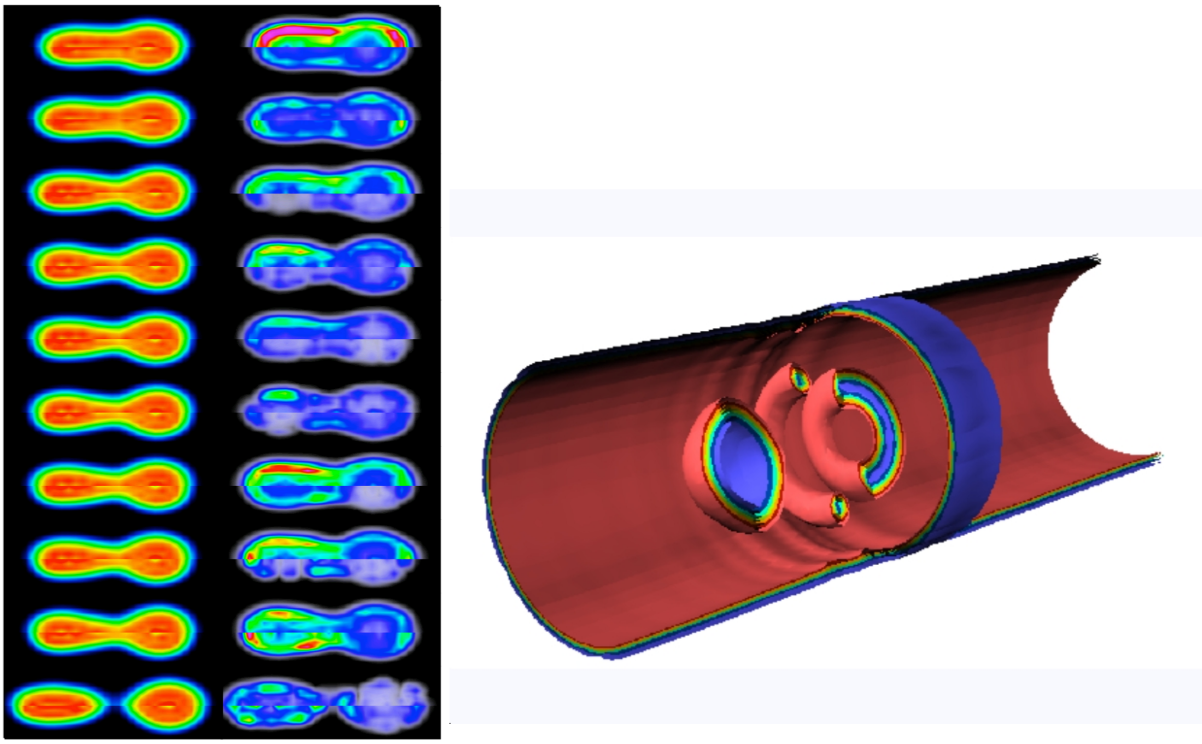

Figure 1: The left panel: Nuclear dynamics within TDDFT. Snapshots of the fissioning ^{240}Pu excited to the energy of about 8 MeV are shown. In the left column the neutron/proton densities are shown in the top/bottom half of each frame. In the right column the pairing field for the neutron/proton systems are displayed in the top/bottom of each frame respectively. In the right panel: Dynamics of superfluid atomic Fermi gas. A spherical projectile flying along the symmetry axis leaves in its wake two vortex rings.