FIRST PRINCIPLE STUDIES OF FULLY IONIZED STRONGLY COUPLED QUANTUM ION PLASMA WITH APPLICATIONS TO WHITE DWARF PHYSICS

Baiko D.A.

Ioffe Institute, Saint Petersburg, Russia
baiko.astro@mail.ioffe.ru

Strongly coupled plasma of fully ionized atomic nuclei (ions) immersed into an incompressible electron gas is a good model of matter in interior layers of white dwarfs (WD) and outer neutron star crust. Under realistic astrophysical conditions, the plasma can be in a liquid or crystallized state. Due to strong coupling, first-principle simulations are necessary to obtain a reliable description of the system. Moreover, there is an important corner of the parameter space, where relatively light ions (e.g. helium or carbon) occur at fairly high densities. In this regime, ion quantum effects are already pronounced, and first-principle *quantum* simulations are desirable.

In this contribution, we describe recent progress in quantum ab initio (path-integral Monte Carlo, PIMC) simulations of strongly coupled one-component ion plasma (OCP) with applications to compact stars. In particular, based on Monte Carlo energies obtained from simulations, we have developed accurate expressions for various thermodynamic functions for liquid and solid quantum plasma. Besides that, the problem of ion screening of the Coulomb barrier, impeding nuclear fusion reactions, has been solved from the first principles in the liquid plasma regime.

Ion quantum effects in liquid cores of WDs have been shown to affect heat capacity, cooling, thermal compressibility, pulsation frequencies, and radii of sufficiently cold WDs, especially with relatively massive helium and carbon cores. By combining liquid and solid quantum thermodynamics, we have determined density dependences of the Coulomb coupling strength at melting, specific heat and ion density jumps at melting, latent heat.

Phase diagrams of fully ionized binary ionic mixtures have been considered. We have followed a transformation of azeotropic phase diagrams into peritectic and eutectic types with increase of the charge ratio. For solid C/O and O/Ne mixtures, we have found extensive miscibility gaps. The gaps are sensitive to binary mixture composition and physics, being strongly different for C/O and O/Ne mixtures and for several variants of corrections to linear-mixing solid-state energies available in the literature. When matter cools to its miscibility gap temperature, the exsolution process takes place. It results in a separation of heavier and lighter solid solutions. This may represent a significant reservoir of gravitational energy and should be included in future WD cooling simulations.

Supported by RSF grant 19-12-00133-P.