Internship in theoretical nuclear astrophysics

Neutron-star crusts at finite temperature

Neutron stars are among the densest objects in the Universe. Being born from core-collapse supernova explosions, they are initially very hot. Therefore, their outer layers (the so-called crust) are expected to be made of a dense liquid composed of various nuclear species immersed in a background of electron (and eventually neutron/proton) gas. At the bottom of the crust, more “exotic” non-spherical nuclear configurations, collectively known as “pasta” phases, may also exist. As the neutron star cools down, it is generally assumed that this plasma crystallizes and remains in full thermodynamic equilibrium until eventually reaches a cold solid crystalline phase.

In the latter hypothesis, the final structure of the crust would be that made of layers, each of which consists of only one nuclear species. However, it is likely that the star does not maintain full equilibrium after crystallization. Therefore, the picture of the crust made of one-species layers is challenged, and a co-existence of various nuclear species, and eventually various geometries, could still persist. This, in turn, can have important consequences on the neutron-star properties and dynamics, such as its cooling.

Although the crust accounts for only around 1% of the neutron-star mass and about 10% of its radius, it is crucial for different astrophysical phenomena. Currently, several questions remain open concerning the physics of the neutron-star crust. These include, among others, a proper treatment of the clusters immersed in a dense medium of nucleons and electrons, and its surface properties. In this respect, two aspects can be considered in order to improve in the cluster modelling: (i) the existence of a neutron “skin”, and (ii) a better determination of the maximum temperature at which the nuclear clusters can coexist with the nucleon “gas”. Both points require benchmarks of current estimations with more microscopic calculations and, possibly, accounting for beyond mean-field effects.

During the Master internship, a theoretical study of the neutron-star crust at finite temperature will be performed. In particular, the internship will focus on an improved description of the cluster surface (point (i)), while the second and more involved part (point (ii)) of the project could be further developed within a PhD.

Expected skills
physics and programming

This work can be pursued by a PhD-thesis

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