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Superfluid fraction in the inner crust of neutron stars

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In the inner crust of neutron stars, exotic nuclear clusters are probably arranged in a periodic lattice, and surrounded by a superfluid gas of unbound neutrons. The superfluid component of the crust is involved in some of the mechanisms to explain pulsar glitches. But, for the comparison with observations, one needs to know the neutron superfluid fraction. In order to compute it, the crucial point is the evaluation of the so-called "entrainment", that is a non-dissipative force between the superfluid component and the lattice. Attempts to compute it have been done in the context of band theory without explicitly including superfluidity [1], leading to values of the superfluid fraction too small to explain observed Vela glitches [2][3]. However, the validity of this approximation in the neutron star crust has been questioned [4][5]. Moreover, there is a strong tension between these band theory calculations and what one obtains in the formalism of superfluid hydrodynamics [6]. In order to solve this issue, we analyzed the inner crust of neutron stars within the Hartree-Fock-Bogoliubov framework, in the lasagna [7] and spaghetti [8] phase. Recently, we also extended our formalism to the 3D crystal case. In order to well describe the interplay between band structure and superfluidity, periodicity of the lattice has been taken into account using Bloch boundary conditions. By introducing a stationary relative flow between clusters and the surrounding neutron gas, we computed the actual neutron superfluid fraction. Our results are significantly larger than previous ones obtained in normal band theory. Also, we found the analytical explanation why the obtained entrainment is in reality much weaker than in normal band theory calculations.

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