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Superfluid phonon in inner crust of neutron stars

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Inner crust of neutron stars, which consists of lattice of neutron-rich nuclei immersed in dilute neutron superfluid, may exhibits distinct low-lying excitations. Collective oscillation of displacement motion of nuclei leads to the lattice phonon while another phonon excitation is also possible in neutron superfluid, known as the superfluid phonon or the Anderson-Bogoliubov mode. The superfluid phonon has attracted attention in connection with the astrophysical issues such as the colling of inner crust in the magnetar and the quasi-periodic oscillation after the X-ray burst, etc[1,2]. The two kinds of phonon may couple to each other, and this coupling influences the matter property such as the heat conductivity and the phonon dispersion relation.

We study the superfluid phonon and its coupling to the nuclear lattice using the Skyrme-Hartree-Fock-Bogoliubov model (HFB) and the quasiparticle random phase approximation (QRPA), in which all the nucleon degrees (of both nuclei and neutron superfluid) are treated on an equal footing. Numerical calculations are performed using a Wigner-Seitz approximation (describing a single spherical cell with a large radius) and the standard Skyrme and pairing parameters. We found that the superfluid phonon mode appears as the lowest energy excitation modes of the QRPA solutions. The superfluid phonon interacts with the nucleus in such a way that it does not penetrate into the nucleus[3].

The HFB+QRPA results can be utilized to evaluate the macroscopic properties such as the thermal conductivity. For this purpose, we introduce an equivalent boson model in which the neutron superfluid is represented by a Bose-Einstein condensate interacting with the nuclear lattice. We will discuss the implication of the HFB+QRPA results in terms of this boson model. We found that the coupling between the superfluid phonon and the nuclear motion is much weaker than an estimate assuming a non-interacting superfluid phonon. It implies a large thermal conductivity.

[1] D. N. Aguilera et al., Phys. Rev. Lett. 102, 91101 (2009).
[2] N. Chamel et al., Phys. Rev. C 87, 035803 (2013).
[2] T. Inakura and M. Matsuo, Phys. Rev. C 96, 025806 (2017).

Type of contribution

Are you a student or postdoc?

no

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