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Anderson-Bogoliubov phonon in inner crust of neutron stars

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Background: The Anderson-Bogoliubov (AB) phonon, called also the superfluid phonon, has attracted attentions since it may influence the thermal conductivity and other properties of inner crust of neutron stars. However, there are limited number of microscopic studies of the AB phonon where the presence of lattice nuclei is explicitly taken into account.

Purpose: We intend to clarify how the presence of lattice nuclei affects the AB phonon in order to obtain microscopic information relevant to the coupling between the AB phonon and the lattice phonon.

Methods: The Hartree-Fock-Bogoliubov model and the quasiparticle random-phase approximation formulated in a spherical Wigner-Seitz cell are adopted to describe neutron superfluidity and associated collective excitations. We perform systematic numerical calculations for dipole excitation by varying the neutron chemical potential and the number of protons in a cell.

Results: The model predicts systematic emergence of the dipole AB phonon mode, which however exhibits strong suppression of phonon amplitude inside the nucleus. We find also that the phonon amplitude around the nuclear surface varies as the neutron density. At higher densities the AB phonon mode exhibits behaviour similar to the pygmy dipole resonance in neutron-rich nuclei.

Conclusions: The dipole AB phonon mode does not penetrate into the lattice nuclei. This suggests that the coupling between the AB phonon and the lattice phonon may be weak. It also may depend on the neutron density in a non-trivial way.

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