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Upper limits on the observational effects of nuclear pasta in neutron stars

M. Gearheart, W.G. Newton, J. Hooker, Bao-An Li

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The effects of the existence of exotic nuclear shapes at the bottom of the neutron star inner crust - nuclear `pasta' - on observational phenomena are estimated by comparing the limiting cases that those phases have a vanishing shear modulus and that they have the shear modulus of a crystalline solid . We estimate the effect on torsional crustal vibrations and on the maximum quadrupole ellipticity sustainable by the crust. The crust composition and transition densities are calculated consistently with the global properties, using a liquid drop model with a bulk nuclear equation of state (EoS) which allows a systematic variation of the nuclear symmetry energy. The symmetry energy J and its density dependence L at nuclear saturation density are the dominant nuclear inputs which determine the thickness of the crust, the range of densities at which pasta might appear, as well as global properties such as the radius and moment of inertia. We show the importance of calculating the global neutron star properties on the same footing as the crust EoS, and demonstrate that in the range of experimentally acceptable values of L, the pasta phase can alter the crust frequencies by up to a factor of three, exceeding the effects of superfluidity on the crust modes, and decrease the maximum quadrupole ellipticity sustainable by the crust by up to an order of magnitude. The signature of the pasta phases and the density dependence of the symmetry energy on the potential observables highlights the possibility of constraining the EoS of dense, neutron-rich matter and the properties of the pasta phases using astrophysical observations.

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