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Universal Love-C relation for hybrid stars with crystalline quark core

The extreme conditions within neutron stars provide a unique laboratory for probing QCD phases, like the crystalline colour superconducting (CCS) phase. We investigate the observable properties of hybrid stars (HSs) with a solid quark matter core in the CCS phase. These HS models are characterized by a sharp phase transition with a significant density discontinuity, which softens the equations of state. We found that the maximum masses and the corresponding radius of HS models with a solid core increase with larger stiffness parameterized by the speed of sound. Our results also show substantial deviations in the tidal Love number-Compactness (Love-C) relations of HS with a solid core from those for fluid neutron stars when HS models have a larger shear modulus, lower transition pressure, and large density gap. Notably, we observe a non-monotonic behaviour in the deviations of the Love-C relations of HS models as the density gap increases, which can also be found in Newtonian incompressible two-layer models. However, current observational data from events like GW170817 and measurements from NICER have not yet been able to distinguish neutron stars and HSs due to their limited sensitivity. The advancement of detectors with higher precision may help us further understand the likelihood and nature of the CCS phase in neutron stars.

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