Contribution ID: **142** Type: **Talk in a parallel session**

Neutron stars with a dark-energy core from the Chaplygin gas

Thursday, 11 July 2024 16:00 (15 minutes)

As a potential candidate for the late-time accelerating expansion of the Universe, the Chaplygin gas and its generalized models have significant implications to modern cosmology. In this study we explore the effects of dark energy on the internal structure of a neutron star composed of two phases, which leads us to wonder: Do stable neutron stars have a dark-energy core? To address this question, we focus on the radial stability of stellar configurations composed by a dark-energy core — described by a Chaplygin-type equation of state (EoS) — and an ordinary-matter external layer which is described by a hadronic EoS. We examine the impact of the rate of energy densities at the phase-splitting surface, defined as $\alpha = \rho_{\rm dis}^{-}/\rho_{\rm dis}^{+}$, on the radius, total gravitational mass, oscillation spectrum and tidal deformability. The resulting mass-radius diagrams are notably different from dark energy stars without a common-matter crust. In particular, we found that both the mass and the radius of the maximum-mass configuration decrease as α becomes smaller. Furthermore, we compare our theoretical predictions with several observational mass-radius measurements and tidal deformability constraints. The analysis of the normal oscillation modes reveals that there are two regions of instability on the $M(\rho_c)$ curve when α is small enough indicating that the usual stability criterion $dM/d\rho_c > 0$ still holds for rapid phase transitions. Nevertheless, this is no longer true for the case of slow transitions.

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Session Classification: Dark energy and the accelerating universe

Track Classification: Dark Energy and Large Scale Structure (DE): Dark Energy and the accelerating universe