Contribution ID: **1007** Type: **Talk in the parallel session**

Probing the dense matter physics of neutron star cores with transiently-accreting neutron stars

Wednesday 7 July 2021 11:10 (20 minutes)

The composition of neutron stars is an open research problem. In particular, the lack of information on the behavior of the symmetry energy above saturation density has prevented a reliable first-principle calculation of neutron stars equation of state. However, recently, new observational data has become available, which allows for better constraining of the internal properties of the star, leading to an improved understanding of its behavior and characteristics. In particular, the long time search for a definite observation of a star with direct Urca reactions came to an end recently with the x-ray spectrum measurements of the neutron star in system MXB 1659-29. This was the first observation to unambiguously suggest the presence of fast neutrino-cooling processes in the star's interior, as described by [1]. These measurements come from long term observations of outburst-quiescent cycles of neutron stars in low-mass X-ray binary (LMXB) systems, which allow us to calculate their cooling processes rate, in turn helping constrain the star's proton fraction. This calculation was performed in [1], where it was shown in a simple model that direct Urca reactions take place in 1% of the volume of the core of that neutron star, implying that its proton fraction is above threshold. In this presentation we use neutron star models that include detailed neutron star equations of state and superfluid/superconductivity gaps to calculate a star's direct Urca luminosity and compare to the predictions in [1]. We also discuss the implications of a star's high proton fraction on its core heat capacity. This is an important step towards a universal equation of state for neutron stars and therefore, towards a better understanding of the phase diagram of asymmetric matter at high densities.

[1] Brown et al. Rapid Neutrino Cooling in the Neutron Star MXB 1659-29, Physics Review Letters, 10.1103/PhysRevLett.120.182701, ArXiv: 1801.00041

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Session Classification: Dense Matter in Compact Stars

Track Classification: Neutron Stars: Dense matter in compact stars