19th International Conference on QCD in Extreme Conditions (XQCD 2023)

Contribution ID: **25** Type: **Talk**

What is the nature of the HESS J1731-347 compact object? Does it confirm the early deconfinement phase transition?

Wednesday 26 July 2023 16:10 (25 minutes)

Compact stars are the most exotic and dense laboratories in the Universe to test the properties of strongly interacting matter. Understanding the complex phenomena observed in neutron and hybrid stars requires profound knowledge in a wide range of scientific disciplines. In addition to the experimental data on nuclear and hadron matter, the realistic equation of state (EoS) should be consistent with the astrophysical, and gravitational wave observations. While details of the phase transitions and properties of quark matter are traditionally investigated in the accelerator experiments on heavy-ion collisions, compact astrophysical objects recently gained a big interest since observational data on their radii, masses, surface temperature, etc. significantly constrain the properties of strongly interacting matter. We will discuss the recently announced lightest compact star HESS J1731-347 which has raised a lot of questions about its nature. We will show the use of the latest data on the mass, radius, and surface temperature together with the multi-messenger observations of neutron stars and their mergers to investigate the possibility that HESS J1731-347 is the lightest observed neutron star, a strange star, a hybrid star with an early deconfinement phase transition, or a dark matter admixed compact star.

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Session Classification: Parallel session A