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Neutron star matter equation of state: current status and challenges

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Neutron star matter has a variety of constituents and structures depending on the density; neutron-rich nuclei suronded by electrons and drip neutrons in the crust, pasta nuclei at the bottom of inner crust, and uniform isospin-asymmetric nuclear matter in a superfluid state in the outer core. In the inner core, the neutron Fermi energy becomes so large that exotic constituents such as hyperons, mesons and quarks may emerge. Radioactive beam and hypernuclear experiments provide information on the symmetry energy and superfluidity in the crust and outer core and on the hyperon potentials in the inner core, respectively. Cold atom experiments are also helpful to understand pure neutron matter, which may be simulated by the unitary gas. An equation of state (EOS) constructed based on these laboratory experiments has to be verified by the astronomical observations such as the mass, radius, and oscillations of neutron stars. One of the key but missing ingredients is the three-baryon interactions such as the hyperon-hyperon-nucleon (YYN) interaction. YYN interaction is important in order to explain the recently discovered massive neutron stars consistently with laboratory experiments. We have recently found that the $\Lambda\Lambda$ interaction extracted from the $\Lambda\Lambda$ correlation at RHIC is somewhat stronger than that from double Λ hypernuclei. Since these two interactions corresponds to the vacuum and in-medium $\Lambda\Lambda$ interactions, respectively, the difference may tell us a possible way to access the YYN interaction based on experimental data. In the presentation, after a review on the current status of neutron star matter EOS studies, we discuss the necessary tasks to pin down the EOS. We also present our recent study of $\Lambda\Lambda$ interaction from correlation data at RHIC.