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The Many Faces of Dense Baryonic Matter inside of Neutron Stars[1]

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Gravity compresses the matter in the core regions of neutron stars to densities that are several times greater than the density of ordinary atomic nuclei. This provides a high-pressure environment in the core regions of neutron stars where several different subatomic particle processes are expected to compete with each other and even novel states of matter exist. The most spectacular possibilities involve the generation of hyperons and baryon resonances, boson condensates, and/or the formation of color superconducting quark matter. Combined with the unprecedented progress in observational astrophysics, this makes neutron stars superb astrophysical laboratories for a range of physical studies which shed light on the structure and equation of state of dense baryonic matter. In this talk I will begin with providing an overview of our current understanding of the core-composition of neutron stars. Models for the equation of state of dense neutron star matter will then be presented, which are constrained by the latest nuclear and astrophysical data. Particular emphasis will be put on the quark-hadron phase transition in the core regions of neutron stars, which could be driven by changes in the rotation periods of neutron stars. Finally, the phase diagram of hot and dense proto neutron star matter will be discussed and possible instabilities in such matter will be pointed out. The information gained from these investigations provides information about the nuclear equation of state that is complementary to what is expected from the study of gravitational waves from neutron star-black holes and binary neutron star mergers, high baryon density QCD from lattice calculations, and high baryon density physics from low energy heavy-ion collisions at RHIC and GSI.

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