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Neutron Stars 1

Equation of State and Structure

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Neutron stars play a unique role in physics and astrophysics. On the one hand, they contain matter under extreme physical conditions, and their theories are based on risky and far extrapolations of what we consider reliable physical theories of the structure of matter tested in laboratory. On the other hand, their observations offer the unique opportunity to test these theories. Moreover, neutron stars are important dramatic personalities on the stage of modern astrophysics; they participate in many astronomical phenomena. Neutron stars contain the matter of density ranging from a few g/cm³ at their surface, where the pressure is small, to more than 10¹⁵ g/cm³ at the center, where the pressure exceeds 10¹⁵ dyn/cm². To calculate neutron star structure, one needs the dependence of the pressure on density, the so called equation of state (EOS), in this huge density range, taking due account of temperature, more than 10⁹ K in young neutron stars, and magnetic fields, sometimes above 10¹² G. The present book is mainly devoted to the theory of the EOS of neutron star matter and its consequences for neutron star structure. As one moves from the neutron star surface to the center, the methods to calculate the EOS change. Atomic structure and plasma theories are used for the surface stellar layers. Deeper layers of the neutron star crust require nuclear theory combined with plasma physics, both in very exotic density-temperature regimes. Finally, the neutron star core necessitates many-body theory of dense strongly interacting systems, together with the physics of strong interactions of elementary particles.

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