The Relativistic Equation of State and Neutron Star Properties

H. Huber, F. Weber [a], M. K. Weigel, and Ch. Schaab

[a] Lawrence Berkeley Laboratory, Nuclear Science Division, MS 70A - 3307, Berkeley, CA 94720, U.S.A.

A necessary ingredient for solving the structure equations for (rotating) neutron stars (NS) is the knowledge of the equation of state (EOS). For NSs the EOS has to cover a wide range of densities ranging from super–nuclear densities (up to 5 to 10 times normal nuclear matter density) in the star's core down to the density of iron at the star's surface. At present, neither heavy–ion reactions nor NS data are capable to determine the EOS accurately, and the behaviour of high–density matter is still an open and one of the most challenging problems in modern physics, containing many ingredients from different branches of physics. The theoretical determination of the EOS over such an enormous range has therefore to rely mainly on theoretical arguments and extrapolations for which no direct experimental conformation exists. The best one can do in such a situation is a steady improvement of the available models for the EOS. Since the central density of the NS is so extreme, both the Fermi momenta and the effective nucleon mass are of the order of 500 MeV, one should prefer a relativistic description.

In order to follow this aim, we applied for the two outer crusts reliable EOS's from the literature. In the uniform region ($\rho \geq 4 \times 10^{13} g/cm^3$) we use an EOS resulting from a microscopic relativistic Brueckner–Hartree–Fock calculation (RBHF) of nucleonic/leptonic matter composition in generalized β–equilibrium. For densities, where hyperons and deltas enter the game, we used a relativistic Hartree and/or Hartree–Fock scheme, with couplings adjusted to the outcome of the microscopic RBHF–treatment. For the couplings of the hyperons several possibilities are considered (general coupling, SU6–relations, etc.) The resulting EOSs are then implimented in the calculation of the properties of rotating neutron stars using Einstein's equations for a generalized Schwarzschild metric. Special attention is given to the stability of the rotating configuration. In this respect Kepler's criterion – generalized for the case of general relativity – and gravitation–radiation instabilities, respectively, determine the limits of the rotation frequencies. Furthermore the cooling history of the star is calculated and compared with the experimental data. So far we can conclude that all these calculated data are in accordance with a pure hadronic/leptonic composition of the neutron star.