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From Nuclei to Stars with a Relativistic Density Functional

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A generalized relativistic density functional with density-dependent meson-nucleon couplings is developed for a unified description of nuclei and strongly interacting matter, in particular for astrophysical applications. The parameters of this phenomenological model are obtained from a fit to nuclear binding energies, charge form factor data and spin-orbit splittings of a set of nuclei. The resulting nuclear matter parameters are very reasonable and the predicted neutron matter equation of state (EoS) is consistent with ab-initio calculations using chiral effective field theory. The nuclear symmetry fulfills current experimental and theoretical constraints. Light and heavy nuclei are included as explicit degrees of freedom. Their dissolution is described with the help of medium-dependent mass shifts that mainly originate from the action of the Pauli principle. Consistency with the virial EoS at very low densities is achieved by including two-nucleon correlations in the continuum in an effective way. The emission of light nuclei in heavy-ion collisions and α-particle correlations at the surface of Sn nuclei are studied as examples for experimental tests of the model. EoS tables for astrophysical simulations, e.g., core-collapse supernovae and neutron star mergers, are generated in a wide range of densities, temperatures and isospin asymmetries. Thermodynamic properties and the chemical composition of compact star matter are extracted. A first-order phase transition at high densities can be modeled with a modified excluded-volume mechanism. Finally, some problems and recent developments are discussed and an outlook is given.