Nuclear Constraints and Multimessenger Signatures: Probing the Equation of State of Neutron-Rich Matter

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The density dependence of the nuclear symmetry energy is a key ingredient in determining the equation of state of neutron-rich matter, with significant implications for both finite nuclei and neutron stars. Recent experimental advances — including parity-violating electron scattering on ^{48}Ca (CREX) and ^{208}Pb (PREX-2), as well as measurements of electric dipole polarizability — provide valuable constraints on isovector nuclear properties. In this work, a class of relativistic energy density functionals is employed to quantify cor- relations between nuclear observables — such as neutron skin thickness, weak charge form factors, and dipole polarizability — and macroscopic neutron star properties, including radius and tidal deformability. These theoretical correlations are compared with data from both terrestrial experiments and multimessenger observations of the binary neutron star merger GW170817, yielding constraints on the symmetry energy and the equation of state at supranuclear densities. The results demonstrate that finite-nucleus measurements play a critical role in constraining the equation of state, particularly when higher-order terms in the symmetry energy expansion are included. Persistent discrepancies among constraints from different nuclear probes highlight the need for more precise measurements and additional astrophysical input to advance our understanding of dense matter.