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High-Density Nuclear Symmetry Energies from Observations of Neutron Stars and Gravitational Waves

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The high-density behavior of nuclear symmetry energy is the most uncertain part of the Equation of State (EOS) of dense neutron-rich nucleonic matter [1]. It has significant ramifications in understanding properties of nuclear reactions induced by rare isotopes, neutron stars and gravitational waves from various sources. Using a new technique of inverting numerically the Tolman-Oppenheimer-Volkov (TOV) equation and Bayesian inferences, we show that a firmly restricted EOS parameter space is established using observational constraints on the radius, maximum mass, tidal deformability and causality condition of neutron stars [2,3,4]. The constraining band obtained for the pressure as a function of energy (baryon) density is in good agreement with that extracted recently by the LIGO and Virgo Collaborations from their improved analyses of the tidal deformability of neutron stars involved in the GW170817 event. Rather robust upper and lower boundaries on nuclear symmetry energies are extracted from the observational constraints up to about twice the saturation density of nuclear matter. Moreover, by studying variations of the causality surface where the speed of sound equals that of light at central densities of the most massive neutron stars within the restricted EOS parameter space, the absolutely maximum mass of neutron stars is found to be about 2.40 Msun. Implications of these findings on the recently reported mass 2.17 Msun of PSR J0740+6620 [5,6], calculations of the EOS of dense neutron-rich matter, heavy-ion reactions in terrestrial laboratories as well as the frequencies and damping times of oscillating modes of neutron stars are discussed [7].

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