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Hans A. Bethe Prize: Neutron Stars and Core-Collapse Supernovae[1]

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Core-collapse supernovae lead to the formation of neutron stars, and both are sensitive to the dense matter equation of state. Hans Bethe first recognized that the matter in the collapsing core of a massive star has a relatively low entropy which prevents nuclear dissociation until nuclei merge near the nuclear saturation density. This recognition means that collapse continues until the core exceeds the saturation density. This prediction forms the foundation for modern simulations of supernovae. These supernovae sample matter up to about twice nuclear saturation density, but neutron stars are sensitive to the equation of state both near the saturation density and at several times higher densities. Two important recent developments are the discovery of two-solar mass neutron stars and refined experimental determinations of the behavior of the symmetry energy of nuclear matter near the saturation density. Combined with the assumption of causality, they imply that the radii of observed neutron stars are largely independent of their mass, and that this radius is in the range of 11 to 13 km. These theoretical results are not only consistent with expectations from theoretical studies of pure neutron matter, but also accumulated observations of both bursting and cooling neutron stars. In the near future, new pulsar timing data, which could lead to larger measured masses as well as measurements of moments of inertia, X-ray observations, such as from NICER, of bursting and other sources, and gravitational wave observations of neutron stars in merging compact binaries, will provide important new constraints on neutron stars and the dense matter equation of state.

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