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Nuclear reactions in the deep ocean and crust of neutron stars: Implications of superbursts and cooling transients[1]

EDWARD BROWN, Michigan State University

Accreting neutron stars provide a fascinating natural laboratory for processes in dense matter. Over the lifetime of a neutron star accreting from a solar-mass companion, the crust, where the mass density is less than that of saturated nuclear matter, is gradually replaced with material synthesized from the accreted hydrogen and helium. The resulting compositional and thermal structure of the crust is essential input for the neutron star's magnetic field evolution, the detectability of the neutron star via gravitational wave emission from a "mountain," and the strength of neutrino emissivity from the core. In this talk, I will present our current understanding of the nuclear reactions in the deep ocean and crust of accreting neutron stars; that is, at depths where the hydrogen and helium have already fused to heavier elements. In addition to highlighting recent theoretical and experimental work on these reactions, I will emphasize what observations of superbursts—rare explosions some 1000 times more energetic than regular X-ray bursts—and of cooling from neutron star transients can tell us about the thermal structure of the neutron star crust. There is one source, KS 1731−260, that not only exhibited a superburst, but also cooled following the apparent cessation of active accretion. There is an interesting tension between the rapid cooling, which implies a high crust thermal conductivity and hence a cool crust, and the inferred (shallow) superburst ignition depth, which requires a hot crust. I will discuss solutions to this puzzle, including a strong resonance in the $^{12}C + {}^{12}C$ cross-section.

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