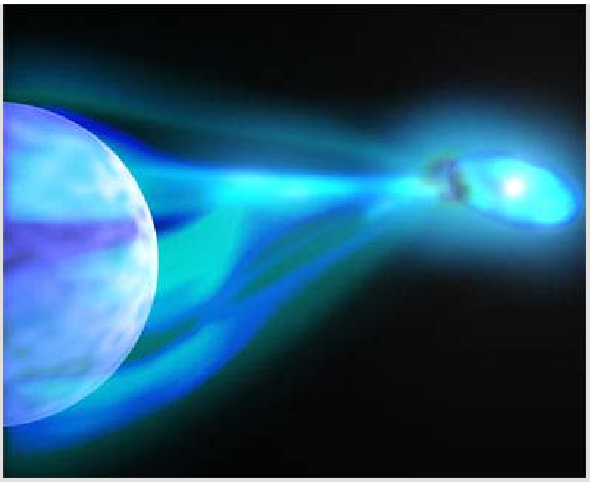
The Joint Institute for Nuclear Astrophysics

Accreting neutron stars hotter than previously thought



Artist's view of a stellar binary system where material is streaming from a regular star (left) onto a neutron star (bright dot on the right) via an accretion disk. X-ray bursts occur on the surface of the neutron star burning the nuclear fuel obtained from the companion star. Credit: ESA

Neutron stars that accrete matter from a companion star are observed as bright X-ray sources that occasionally show X-ray bursts. More recently a new, relatively rare class of X-ray bursts, so called superbursts, had been discovered. While normal X-ray bursts are a very frequent phenomenon with more than 70 sources repeating their bursts within hours to days, only a dozen superbursts have ever been observed. They are thought to occur in a subset of systems with recurrence times of the order of a few years and are most likely triggered by fusion reactions on carbon nuclei contained in the ashes of the regular bursts.

Surprisingly, despite their rarity, a major puzzle in our understanding of superbursts has been that they occur still much more frequently than models would predict. JINA scientists at Michigan State University, Los Alamos National Laboratory, and the University of Mainz in Germany now got a step closer to solving this puzzle by showing that the crust of the neutron star involved is heated by nuclear reactions that release much more energy than previously assumed. As a consequence the crust is hotter and therefore superbursts are ignited more frequently, though still not quite as frequently as observed.

The advance was possible by incorporating more realistic nuclear physics in a neutron star crust model such that nuclear electron capture reactions on hundreds of isotopes could be accurately tracked for the first time. These reactions occur in the ashes of the regular X-ray bursts as it is pushed through the neutron star crust by the ongoing accretion of matter from the companion star. Compared to previous estimates, the use of realistic ash composition and reaction rates that include transitions to excited nuclear states leads to less energy being lost by neutrino emission and therefore to

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a 5 fold increase in heating. In contrast to previous studies the heating is found to be very sensitive on the initial composition because of nuclear structure effects such as shell closures. This initial composition is set by the ashes of the X-ray bursts and superbursts that occur near the neutron star surface further underlining the close interplay between crust physics and observable surface phenomena.

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