Not So Hot

Physicist Raph Hix and Colleagues Find a Cooling Mechanism in Neutron Stars

December 13, 2013

When it comes to neutron stars, there really is more going on beneath the surface than you might suspect. Associate Physics Professor William R. (Raph) Hix and his colleagues have recently found a layer inside the crust of these stars that actually cools them down instead of heating them up, challenging common scientific perceptions. The results were published in the journal *Nature* and appeared online December 1.

When massive stars come to their end via a supernova explosion, gravity causes their centers to collapse to the point that protons and electrons combine, forming neutrons, and thus a neutron star. When such a neutron star is part of a binary star system, hydrogen-rich matter from the companion star can accrete onto the surface of the neutron star. Thermonuclear burning at the surface of these stars creates ashes, which accumulate over time at greater pressure and density, forming a crust. This is the territory Hix and his fellow scientists investigated. They found that just below the crust is a shell only a few meters thick where nuclear reactions (electron capture and beta decay), cycle rapidly back and forth. In the *Nature* letter, they showed that these reactions cause a strong emission of neutrinos in what's called the "Urca" process, which throws off heat and *cools* the crust. Even in cases where the deeper crust sends a large amount of heat toward the surface, these Urca shells will re-emit the heat as neutrinos. These findings contrast previously held views that reactions within the crust of a neutron star actually helped *heat up* the surface.

Further, the research means additional questions regarding "superbursts:" flashes on the surface of neutron stars thought to be caused by carbon burning. If Urca shells prevent heat from coming to the surface of these stars, then Hix and his collaborators propose that some other, unidentified heat source between the surface and the Urca layer must be the cause of this phenomenon.

The Urca mechanism has been studied before in White Dwarfs and Type Ia supernovae, but this work is the first time it has been investigated in neutron star crusts. Hix, who is also part of the Oak Ridge National Laboratory Physics Division, is among authors from Michigan State University (including the National Superconducting Cyclotron Laboratory); the Joint Institute for Nuclear Astrophysics at the University of Notre Dame; the Indian Institute of Technology Ropar (India), Los Alamos National Laboratory; the Instituto de Fisica da Universidade de Sao Paulo (Brazil), and the University of Washington. For more information, please see the following:

- "Strong neutrino cooling by cycles of electron capture and β− decay in neutron star crusts" in *Nature*, published online December 1, 2013 (to appear in the print version January 2, 2014): **http://www.nature.com/nature/journal/vaop/ncurrent/full/nature12757.html (http://www.nature.com/nature/journal/vaop/ncurrent/full/nature12757.html)**
- From Michigan State University: "The Mystery of Neutron Stars Heats Up" **http://msutoday.msu.edu/news/2013/the-mystery-of-neutron-stars-heats-up/ (http://msutoday.msu.edu/news/2013/the-mystery-of-neutron-stars-heats-up/)**