Studying the 'mountains' and 'starquakes' that develop on neutron stars

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(PhysOrg.com) -- Neutron stars have the potential to play an important role in understanding some of the mysteries of the universe. One of factors that could help lead to an understanding of gravitational waves and the mechanisms involved in giant flares in magnetars is the strength of the crust that forms on the outside of a neutron star. In an effort to better understand the neutron star crusts, Charles Horowitz, at Indiana University in Bloomington, and his colleague Kai Kadau, at Los Alamos National Laboratory in New Mexico, have used molecular dynamics to model neutron stars and come up with improved estimates of the breaking strain.

“In 2004, a giant flare was detected coming from a magnetar. It had a huge amount of energy.” Horowitz tells *PhysOrg.com*. (A magnetar is a neutron star with a very powerful magnetic field.) “We think that this mechanism only makes sense if the crust is really, really strong. Such a large flare should only be possible if, by the time the crust broke, there was tremendous energy stored in the crust and magnetic field.” Horowitz hopes that the simulations run with Kadau will help shed more light on the workings of neutron stars, and even perhaps answer other questions about the universe. Their work is presented in *Physical Review Letters*: “Breaking Strain of Neutron Star Crust and Gravitational Waves.”

Horowitz says that for many years, scientists have been studying neutron stars and the “mountains” that develop on them. The bulges that create gravitational waves are the results of temperature-dependent nuclear reactions near hot spots. “People have wondered how big they can get, how massive they could become before the crust breaks because of forces from the strong magnetic field," he explains. It is this collapse that releases the flares that are sometimes detected.

There are two main aims for studying the possibilities for the crust of a neutron star: Learning more about these stars - what the crust is made of and how they might function - and using neutron stars as a way to possibly detect gravitational waves. Horowitz and Kadau's model might be able to help in both of these areas, since it offers a more detailed look at what goes on when a mountain is formed - and when it collapses, causing a "starquake."

In the first case, the simulation Horowitz and Kadau is working with shows that the crust is likely made up of ions. "It's more or less composed of normal atoms," Horowitz explains, "but they've been ionized. The huge pressure of the star squeezes the electrons in such a way as to create ions. We think that the material is slightly heavier than iron, possibly selenium."

Understanding neutron star mechanisms, however, may also help scientists find gravitational waves. "The mountains that form on these rapidly rotating neutron stars generate gravitational waves quite efficiently. If we understand how this works, we might be able to make better predictions of which neutron stars would be most likely to produce the strongest gravitational waves. It would give scientists a better place to look."

Horowitz explains that gravitational waves are curves in space-time, predicted by Einstein's theory of general relativity. "To actually find these waves would be a major discovery and a confirmation of general relativity. And I think our model can help in that aim."

More information: C.J. Horowitz, Kai Kadau. "Breaking Strain of

Neutron Star Crust and Gravitational Waves," *Physical Review Letters* (2009). Available online: link.aps.org/doi/10.1103/PhysRevLett.102.191102 .