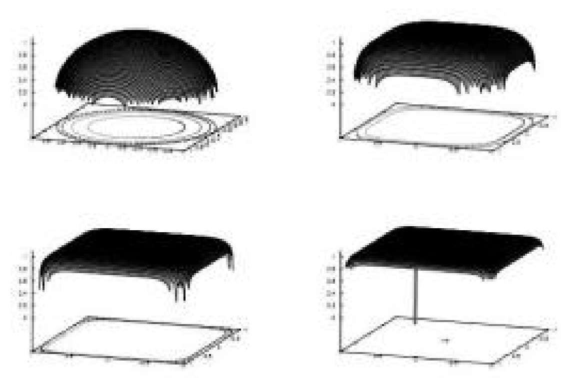
# Researchers theorize that neutrons may be squished into cubes in neutron stars

August 18 2011, by Bob Yirka



Trial wavefunction that interpolates between sphere, and cube. Image: arXiv:1108.1859v1 [nucl-th]

(PhysOrg.com) -- Neutrons, those particles that reside here on Earth inside the nucleus of atoms, along with protons, collectively called nucleons, are thought to exist in the far reaches of the universe inside of so-named neutron stars, which are the remnants of stars that have exploded. In a paper published on the preprint server *arXiv*, Spanish physicists Felipe Llanes-Estrada, and Gaspar Moreno Navarro, suggest that the densities in the cores of certain sizes of such neutron stars might be so great as to squash the neutrons down from their normal spherical shape, into cubes.

The key is in the size of the neutron star, the researchers say; too big and they'd collapse down to black holes. Too small and they'd simply exist as run of the mill neutron stars. Since the tipping point is believed to be such stars that are of twice the density as the sun, the discovery of a neutron star last year, PSR J1614-2230 (the largest ever found) with a solar masses of 1.97 seems to fit the bill as it's about as dense as a neutron star can get without collapsing. The researchers speculate that in order to achieve such a density, the neutrons at its core would have to facilitate a means of having the same number of neutrons in a smaller space. And because cubes are more efficient, they theorize that those neutrons closet to the core, would be the ones squished down to cube shapes.

Llanes-Estrada likens it to a stack of oranges sitting on a grocer's shelf. Normally spherical they begin to flatten as more and more are piled on top. If the same amount of weight (gravity) were applied in all directions, the oranges would flatten from both above and below, but also on all sides as well.

In their natural state, as spheres, neutrons have a packing density of about 74%; collapsing them down to cubes, creating a sort of crystal lattice such as happens when diamonds from carbon in the Earth, could possibly bring that number up to nearly 100%.
Not everyone agrees with the results of the duo's paper, some even suggesting that the huge density numbers could come about as the result of the blurring of lines between individual neutrons; but the two researchers seem undaunted, suggesting that pushing boundaries, is all a part of science.

**More information:** Cubic neutrons, arXiv:1108.1859v1 [nucl-th] arxiv.org/abs/1108.1859

**Abstract**
The neutron is largely spherical and incompressible in atomic nuclei. These two properties are however challenged in the extreme pressure

environment of a neutron star. Our variational computation within the Cornell model of Coulomb gauge QCD shows that the neutron (and also the Delta-3/2 baryon) can adopt cubic symmetry at an energy cost of about 150 MeV. Balancing this with the free energy gained by tighter neutron packing, we expose the possible softening of the equation of state of neutron matter.

via [Arxiv Blog]