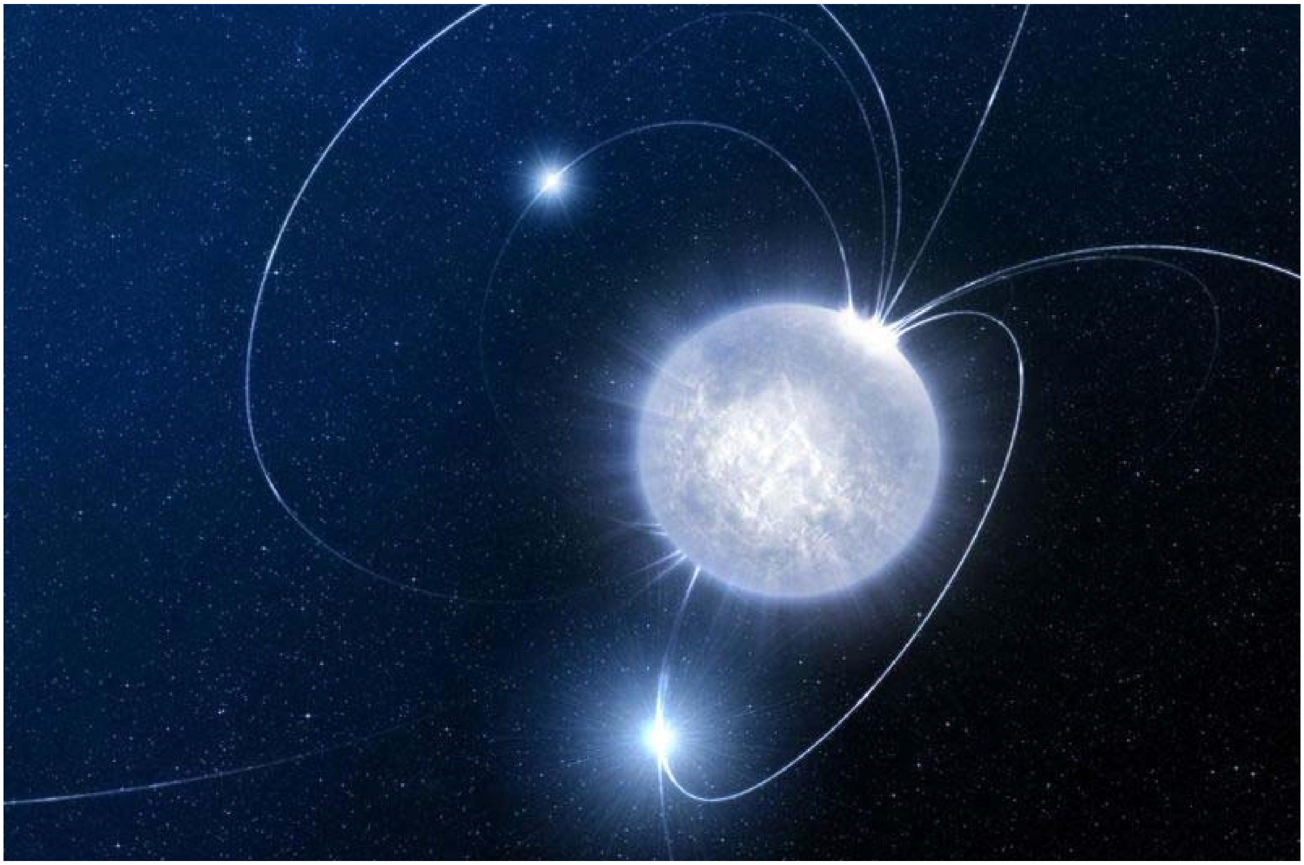
DiscoveryNews

Why Are Quark Stars So Strange?

By Ian O'Neill | Tue Jan 19, 2010 10:35 PM ET



What happens if a stellar remnant is too massive to be a neutron star, but not massive enough to become a black hole? Actually, until recently, astrophysicists didn't think there was a grey area between neutron stars and black holes; stellar remnants from a massive star's death had to be one or the other.

Now, it is thought there is another bizarre creature out there, more massive than a neutron star, yet too small to collapse in on itself to form a black hole. Although they have yet to be observed, 'quark stars' should should exist, and scientists are only just beginning to realize how strange these things are.

The Birth of Strangeness

First things first, neutron stars, quark stars and black holes are all born via the same mechanism: a supernova. But each of the three are progressively more massive, so they originate from supernovae produced by progressively more massive stars.

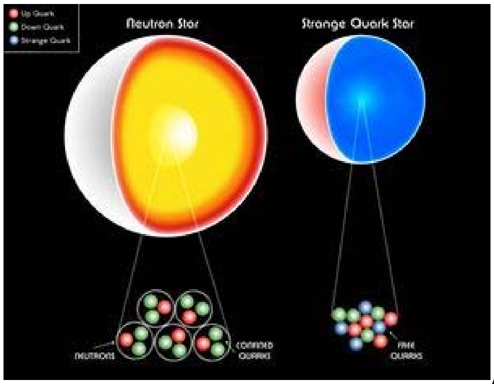
So, what if a star exploded, producing something a little too massive to be called a neutron star? Well, neutron stars resist collapsing under their own gravitational pull by a characteristic of matter known as neutron degeneracy. This produces an outward force called neutron degeneracy *pressure*.

What if the neutron star born after a supernova is too massive for this neutron degeneracy pressure to hold up against the neutron star's own gravity?

In this case, it's up to the quarks that make up the neutrons to take over, preventing the body from collapsing any further. Single neutrons are composed of three quarks (two "down" quarks and one "up" quark).

When quark degeneracy pressure kicks in, a quark star may be produced; the free "up" and "down" quarks get converted into "strange" quarks. Therefore, a quark star (also known as a "strange star") is made up of strange matter.

An Unconventional Discovery



A conventional view of the size of a quark star compared to a neutron star (NASA)

Conventional thinking so far has been that quark stars should be smaller than neutron stars (this seems reasonable, as the matter should be crushed closer together, therefore making them more dense, taking up less volume), but according to new calculations made by an international collaboration of scientists, quark stars might actually be larger than their neutron star cousins. But how can this be?

Aleksi Vuorinen of the University of Bielefeld in Germany and collaborators from Switzerland and the US carried out sophisticated calculations on the "equations of state" for neutron stars and quark stars. Their results suggest that a quark star 2.5 times the mass of our sun should swell larger than a neutron star weighing in at twice the mass of our sun.

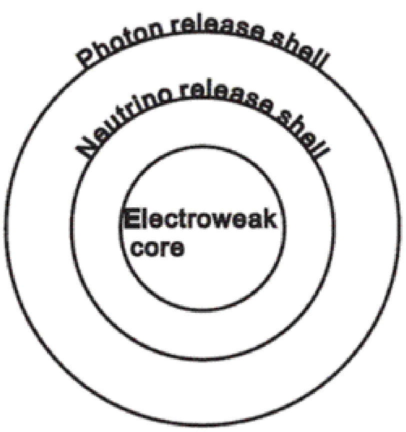
These findings are very interesting for the potential discovery of quark stars. If astronomers spot something that looks like a large neutron star of 2.5 solar masses, perhaps they are actually looking at a ball of strange matter in the form of a quark star.

"The main conclusion of our work is that there is a clear signature for the possible detection of quark stars -- and thus stable strange quark matter," said Vuorinen.

The discovery of such an object could have some incredible benefits not only for astronomers, but for physicists working at CERN; they could gain a lot of information about naturally occurring "strange quark matter." This state of matter cannot be created in the lab (whereas hot "quark gluon plasmas" can be generated by accelerators such as the LHC), so the discovery of quark stars would be beneficial for astrophysicists and particle physicists alike.

But it doesn't stop there; quark stars could be even stranger than that.

A Big Bang Laboratory?



In research carried out by another group of physicists, led by De-Chang Dai of the State University of New York in Buffalo, the quark star is examined and pushed to its limit. An interesting question arises: What happens to the most massive quark stars? Is there another phase beyond a quark star before this bizarre object collapses as a black hole?

Using what we know from the Standard Model of particle physics, a massive quark star may have enough gravitational energy to start 'burning' strange matter. The quarks inside the core of the quark star may be abused so badly by gravitational pressure that the quarks will be converted into pure energy and neutrinos.

The fascinating thing with this scenario is that the quark star matter will be so dense that even the neutrinos cannot escape. However, this release of energy and generation of neutrinos creates an outward pressure countering the relentless inward gravitational pull.

Dai calls this extreme strange matter-burning quark star an "electroweak star" and the calculations suggest that these ultimate stars could be stable for approximately 10 million years, destroying strange matter in the core. The electroweak star core would be as big as an apple, but as massive as two Earths.

Saving the best till last, the electroweak star's core would therefore be as extreme as the universe was only 10^{-10} seconds (that's 0.0000000001 seconds) after the Big Bang. These extreme objects would be like mini-Big Bang laboratories, maintaining a pressure where the electromagnetic and weak forces are so intertwined, they cannot be distinguished.

Leading image: ESO/Luís Calçada

Sources: physicsworld.com, arXiv, New Scientist