Seeing 'Strange' Stars

Could what we see as neutron stars really be so-called strange stars? Prashanth Jaikumar and his fellow researchers think so. They recently published a letter in *Physical Review Letters* that redefines the characteristics of a star composed mainly of strange quark matter.

Right now, physicists postulate that if strange stars exist they possess enormous density gradient at surface and exhibit a luminosity beyond that of other stars. The conventional wisdom is that the electric field of a strange star at its surface would be so large that it would be impossible to determine that the strange star is anything but. This paradigm has existed in astrophysics since the possibility of stars made from strange quark matter was acknowledged.

Jaikumar, working out of Argonne National Laboratory in Illinois, and his two partners from Los Alamos National Laboratory in New Mexico want to challenge that. Working with Sanjay Reddy and Andrew W. Steiner, Jaikumar has developed a new theory about what a strange star would look like. And it is not as obvious as once thought.

“We haven’t found strange stars yet,” Jaikumar explains. “But that doesn’t mean they don’t exist. Maybe we have found them. Maybe some of these neutron stars are really strange stars. According to our theory, it would be very difficult to tell a strange star from a neutron star.”

So, if strange stars look like neutron stars by observation, how would physicists tell the two apart? Jaikumar admits that there might be some difficulty there. “There might be a slight difference. You’d look at surface temperature and see how stars are cooling in time. If it is quark matter, the emission rates are different, so the strange star may cool a little faster. People thought there would be a distinction, but we’re saying it might not be that easy.”

Jaikumar, Reddy, and Steiner also explain the surface characteristics of a strange star. Under the traditional view, a strange star surface is smooth, hence the need for the super density gradient at surface and the large electric field. The strange star view espoused by Jaikumar and his colleagues includes a crust with strange quark nuggets.

“It’s like taking water,” Jaikumar says, “with a flat surface. Add detergent and it reduces surface tension, allowing bubbles to form. In a strange star, the bubbles are made of strange quark matter, and float in a sea of electrons. Consequently, the star's surface may be crusty, not smooth. The effect of surface tension had been overlooked before.”

And it also explains that a strange star wouldn’t need a large electrical field at surface or be super-luminous. It also allows for a strange star to be less dense than originally thought. Any star core is going to be dense, but a strange star surface does not need to be as dense as once thought to be neutral.

Scientists believe that at high density strange quark matter is more stable than regular matter, which is comprised of up and down quarks. These sub-atomic particles are constituent parts of protons and neutrons. Jaikumar believes that as a neutron star spins down and its core density increases, it may convert to the more stable state of strange quark matter, thus forming a strange star.

Jaikumar, Reddy, and Steiner make a few assumptions in their theory. The letter published in *Physical Review Letters* assumes small Coulomb and surface costs. It also calls for relaxing conditions of local charge neutrality in order to reduce quark matter strangeness fraction and lower a quark’s free energy. And the letter assumes that corrections due to Debye screening and curvature energy will be negligible.

The problem, Jaikumar explains, is the difficulty in obtaining exact numbers from the theory of Quantum Chromodynamics (QCD), which is the fundamental description of the forces discussed in the letter. “The uncertainties are large enough that we are unable to form a conclusive statement on whether these nuggets could actually form. We want to be able to quantify the assumptions better.”

However, the new view of strange stars has far-reaching applications. Jaikumar explains: “Finding a strange star would improve our understanding of QCD, the fundamental theory of the nuclear force. And it would also be the first solid evidence of stable quark matter.”

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