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Probing the origins of extreme neutron stars

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(PhysOrg.com) -- Neutron stars are the unimaginably dense corpses of what were once much more massive stars that died while being ripped apart in a supernova explosion. Their average density is typically more than one billion tons per teaspoonful, even denser than the nucleus of an atom that is composed of protons and neutrons. Because these densities can never be reproduced on the Earth, these objects are great extraterrestrial laboratories for the study of how matter and exotic particles behave under extreme conditions.

Their existence was predicted in 1934 just one year after the discovery of the neutron, but it took another 30 years before the first neutron star was actually observed. Since that time, nearly all of the neutron stars that have had their masses accurately measured fall in a narrow range centered approximately on 1.4 times the mass of the Sun. Last October a group of astronomers using the Green Bank Radio Telescope found a neutron star that has a mass of nearly twice that of the Sun. The measurement of the mass is extremely precise because the neutron star is actually a pulsar (PSR J1614-2230) that spins on its axis at 317 times per second with clock-like regularity. What makes this discovery so remarkable is that the existence of a very massive neutron star allows astrophysicists to rule out a wide variety of theoretical models that claim that the neutron star could be composed of exotic subatomic particles such as hyperons or condensates of kaons.

One of the big questions that arises is "how does Nature produce these very massive neutron stars?" Are they born that way or did they grow because they gravitationally strip mass from a nearby star? One of the clues to the origin of this pulsar is that it is not alone. It is found in a very close 9-day binary orbit with another dead star known as a white dwarf. According to Professor Lorne Nelson (Bishop's University) and his colleagues at MIT, Oxford, and UCSB, the neutron star was likely spun up to become a fast-rotating (millisecond) pulsar as a result of the neutron star having cannibalized its stellar companion many millions of years ago, leaving behind a dead core composed mostly of carbon and oxygen. According to Nelson, "Although it is common to find a high fraction of stars in binary systems, it is rare for them to be close enough so that one star can strip off mass from its companion star. But when this happens, it is spectacular."

In order to understand how this binary formed, their strategy was to compute a grid of theoretical models that would describe how binary systems evolve over the entire lifetime of the Universe. Thanks to the incredible number-crunching power of supercomputers, Nelson and his collaborators were able to calculate the evolution of more than 40,000 plausible starting cases for the binary and determine which ones were relevant. As they describe at this week's CASCA meeting in Ontario, Canada, they found several cases where the neutron star could grow significantly in mass at the expense of its companion, but as Nelson says, "It isn't easy for Nature to make such high-mass neutron stars, and this probably explains why they are so rare."

Provided by Canadian Astronomical Society

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