Neutron Stars and Pulsars

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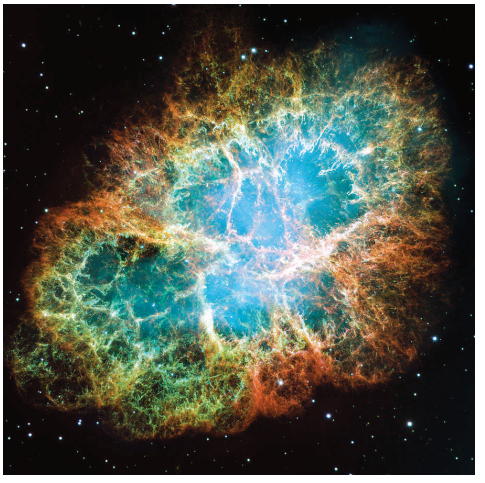
When you hear the word *neutron*, you might think of the tiny, neutrally charged subatomic particles inside atoms. However, neutrons play a role in much larger objects too, especially in neutron stars. No, a neutron star is not a giant neutron inflated to incredible size – it is a star made almost entirely of neutrons.

A neutron star is created when a very massive star (anywhere from 8 to 30 times the mass of our Sun) "dies". Stars release energy primarily by fusing lighter elements, like hydrogen and helium, into heavier elements, like carbon. Nuclear fusion releases photons, the particles that make up light, creating radiation pressure inside the star and puffing it up. A star can fuse elements up to the weight of iron but no heavier. When the fusion stops, the radiation pressure inside the star can no longer support the star's weight, and the star collapses in on itself before exploding into a supernova. A classic example of the mess left behind, called a supernova remnant, is shown at right.



Crab Nebula, a supernova remnant (Credit: NASA/ESA/HST, J. Hester and A. Loll, Arizona State University).

Combination of optical and X-ray images of the Crab Pulsar system (Credit: NASA/HST/ASU/CXC/ASU/J. Hester et al. 2002)

During the collapse of the supernova, before its explosion, the pressure inside becomes high enough to turn electrons and protons into neutrons and neutrinos. The neutrinos escape during the supernova explosion, along with most of the star's material. All that remains are the neutrons, which form an incredibly dense and compact object called a neutron star. The neutron star's density is approximately 10^{17} kg/m^3 – a single teaspoon worth of neutron star material would weigh almost a billion tonnes.

Neutron stars are cosmic lighthouses. As the supernova star collapses into a much denser object, its rotation speeds up dramatically, much like that of figure skaters when they pull their arms inward to spin. Neutron stars can have extreme magnetic fields, causing them to emit a beam of penetrating X-ray and radio waves in a particular direction. The rapid rotation of the neutron star spins the beam around, creating an effect similar to that of the lamp and lens of a lighthouse. In fact, this was how neutron stars were first discovered by Jocelyn Bell and Antony Hewish in 1967; they observed a regular, pulsing signal coming from the sky and deduced that it must be a rotating neutron star. These rotating neutron stars are usually called *pulsars*.

Since the discovery of the first pulsar, more than 300 have been discovered in our galaxy. And just this year, the first pulsar in the Andromeda Galaxy was discovered. Neutron stars are interesting in their own right, but combined with information about the surrounding nebula, they are also extremely useful for testing theories about how stars live and die.