Dwarf Stars

By Ka Chun Yu
Center for Astrophysics and Space Astronomy, University of Colorado, Boulder

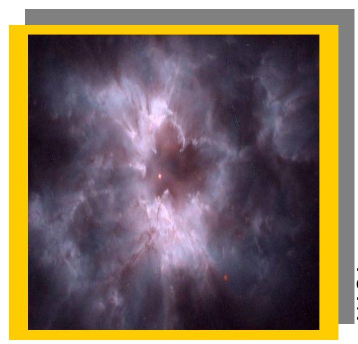
Stars come in a variety of sizes. Despite the fact that our sun has a mass of 2x10^{30} kg (or nearly a million times the mass of the Earth), and a radius of 7x10^{5} km (about 100 times greater than the radius of the Earth), it is a typical, average-sized star. It belongs to the category of **dwarf stars**, which includes all stars with masses less than five **solar masses** (that is, five times that of the mass of the sun).

Stars can form with masses ranging from 0.08 solar masses to around 100 solar masses (which would place a star in the **giant star,** or even **supergiant** category). However, the process of star formation seems to create more small stars than large stars. When astronomers count the number of stars in the vicinity of the sun, they find that stars with one solar mass are about 10 times more common than stars with two solar masses. Stars with two solar masses are about 10 times more common than stars with four solar masses, and so on. The most common type of star turns out to be one with about 0.25 solar mass. Even though dwarf stars may not be as spectacular as giant stars, there are far more of them in the universe.

The most important property of a star is its mass, which determines its temperature, its size, its brightness or **luminosity**, and how long it will eventually live. Massive stars have high pressures and densities in their central cores, due to the weight of the outer portion of the star pushing down on the center, squeezing and heating it. Only the core has the high gas densities and 10 million °K temperatures that are necessary for **nuclear fusion** (which generates the energy in a star) to occur. The more massive a star, the greater the rate at which nuclear reactions can take place in the core, and the greater the amount of energy generated. Massive stars will radiate more energy and will be hotter than dwarf stars, but at the same time they will use up their hydrogen fuel much faster (despite the fact that they start off with more fuel because of their greater mass).

How luminous are dwarf stars? The sun radiates energy at the rate of 4x10^{26} watts, or enough energy in one second to keep one billion 100 watt light bulbs running 100 million years! In its core, the sun has enough hydrogen to keep its nuclear reactions running for 10 billion years. The sun and our solar system are thought to be about five billion years old, so the sun has lived out only half of its expected lifetime.

What about other dwarf stars? The most massive stars that can still be called dwarf stars are stars with about six to eight solar masses. Their luminosities, or brightnesses, are about 100 times that of the sun, and they use up the hydrogen fuel in their cores in only 100 million years. The least massive dwarf stars are puny compared to the sun's luminosity: they are only 1/100th as bright, but because they use up their fuel so slowly, their lifetimes are expected to be in the many tens to hundreds of billions of years. Many scientists theorize that the universe began with a Big Bang. According to the Big Bang theory, the universe is thought to be only 15 billion years old and the smallest dwarf stars that might have formed are still shining now. These stars will continue to shine long after our sun has exhausted its nuclear fuel.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White Dwarf in Planetary Nebula

When dwarf stars reach the end of their hydrogen fuel, they go through a **red giant** stage, by ballooning up to enormous sizes, and throwing off their outer envelopes of gas into space. After the outer layers of the star are blown off, what remains of the core collapses into a compact, hot object called a **white dwarf**, that is roughly the size of the Earth.

Can stars form with masses less than 0.08 solar mass? There is nothing preventing such an object from forming. However, it would technically not be a star: the core of such a low-mass **brown dwarf** would be too cool for hydrogen fusion to take place. Brown dwarfs wouldn't shine as brightly as normal stars because of this lack of hydrogen fusion. They are very difficult to detect because they are so small and dim. Recently astronomers have observed evidence for such "failed" stars.