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EXPLODING STARS

Ken Tapping, 6th June, 2017

In the year 1054 Chinese, Japanese, Arab and North American aboriginal astronomers noticed a new star in the constellation of Taurus, the Bull. It rapidly brightened until it was easily visible during the day, and then, over the following year or so, gradually faded until it was lost to view. What they had witnessed was one of the biggest explosions in the universe, a supernova – the death of a giant star. When we look in that location today we see a rapidly growing cloud of hot gas, with the remnant of the star compressed into a ball of neutrons a few kilometres across, spinning in the centre. The first recorded supernova occurred in the year 185. Today we can detect supernovas in other galaxies. Spotting them is now a major activity for amateurs.

A star's future depends upon the mass of material – mainly hydrogen gas – it collects when it forms. The more material a star collects, the more vigorously it shines and the sooner it runs out of fuel. For example a star with double the Sun's mass will burn its fuel 16 times more rapidly, which means at best it will only last a billion years or so. A star with ten times the mass of the Sun will burn about 3000 times brighter than the Sun, and last maybe 30 million years. This does not leave much time for life to appear on any of its planets.

Indian physicist Subrahmanyan Chandrasekhar found that the fate of ageing stars depends on one simple thing. If the core of a star never exceeds 1.4 times the mass of the Sun, it will end its days fairly quietly by stellar standards. When it starts to run out of fuel, it will swell into a red giant star. It will then sneeze off its outer layers, leaving its naked core as a white dwarf star, about the size of the Earth and so compressed a teaspoonful may weigh several tonnes. Having no remaining fuel it will then very slowly cool off, glowing dimly for billions of years. This value of 1.4 solar masses is now referred to as Chandrasekhar's Limit.

Stars exceeding Chandrasekhar's limit end their lives dramatically. They arrive at the red giant phase sooner, and when energy production drops off, there is insufficient outward pressure to stop the star collapsing, which it does; then it explodes. For maybe a year the star may shine so brightly it exceeds the combined brightness of the billions of other stars in its home galaxy.

There is another way we can get supernova explosions. Many stars in the universe are partnered with other stars, orbiting each other. Most are double stars, like Albireo in the constellation of Cygnus. Others are multiple; for example Epsilon Lyrae, in the constellation of Lyra is a double star system where each of the two stars is itself a close double, making a quadruple star system. Both these stars are a spectacular sight in small, backyard telescopes.

In a close, double star system, inevitably one of the stars gets old first and turns into a white dwarf. Then, later the other star shows signs of age and swells into a red giant. Its gravitational hold over its outer parts gets weak and the white dwarf pulls in material from its partner. If the additional material pushes that white dwarf beyond Chandrasekhar's Limit, the white dwarf collapses and explodes. Since white dwarf stars have a fairly narrow range of masses compared with stars in general, the mass of additional material needed to push the star over the limit does not change much from supernova to supernova. This means the energy radiated in the explosion does not change that much either. The result is that we can use them as "standard candles". If we see a supernova in a distant galaxy we can measure how bright the supernova gets, and how that brightness varies, and infer how far away it is. Much of our current understanding of the expansion of the distant universe comes from these cosmic catastrophes.

Jupiter lies in the south after sunset. Saturn rises soon after dark, and Venus about 3am. The Moon will be Full on the 9th.

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