‘WHAT IS THE STARS?’
By
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Mankind has been fascinated by the stars since Ancient times. Ever eager to find order and pattern in nature, observers drew imaginary lines between stars to form outlines of familiar things like ploughs, bears and bulls. However, it was not until the last few hundred years, and particularly this century, that real progress was made in understanding the heavens. In a remarkable chapter of twentieth-century science, astronomers have worked out the main details of how stars are born, live their lives and die - stellar evolution.

Because stars live very long lives (billions of years), it is not possible to see the birth, lifespan, and death of an individual star. However, when astronomers look at the sky, they see different stars at different stages of life and they can therefore piece together the full life-story of an individual star.

The universe is filled with a very dilute gas and small particles of dust. The gas is mostly hydrogen, with a small amount of helium. Here and there the gas and dust clump together to form interstellar gas clouds. Gravitational attraction causes the cloud to contract, making it denser, with the centre densest of all. At the centre, individual clumps form, and the temperature in the middle of each clump rises to an incredible 10 million degrees Centigrade. Nuclear fusion reactions start at this temperature, where hydrogen is converted into helium, and huge amounts of energy are released causing the clump to shine. This is how a star is born.

As the gas clump condenses to form a star, the central part condenses quickly, while the outer parts fall inwards more slowly. The condensing clump rotates and spins more quickly as the outer parts fall inwards. This causes the infalling gas/dust to form a disc around the central star. The material within the disc eventually forms planets that orbit the new star.

The mass of a star is fixed at birth, and this mass determines the subsequent history of the star, i.e. how long it will live and how it will die. Our sun is a typical star and it is convenient to use it as a standard when stating the mass of any other star. The mass of newborn stars covers a wide range, from 0.07 to 100 suns.

The bigger a star, the hotter is its centre, the faster its nuclear reactions run, the hotter is its surface and the shorter its life. Our sun has a surface temperature of 6,000^{o}C. Heavy-weight stars can shine as brightly as 100,000 suns, with a surface temperature of 30,000^{o}C. The mass of a star also determines how long it lives. Very massive stars quickly use up their hydrogen fuel, whereas very small stars, although having much smaller fuel supplies, burn the hydrogen slowly and live for a much longer time.

When a star is fusing its hydrogen into helium and burning brightly, it is said to be in its main sequence. Our sun will spend about 10 billion years as a main sequence star. A very massive star might survive only a thousandth of this time; a very light star might live one hundred times longer than our sun.

Smaller stars die in a different manner to the most massive stars. When the hydrogen at the core of a star like our sun is used up, nuclear reactions still proceed in a thin shell surrounding the core. These reactions produce more energy than before and this pushes out, swelling the outer parts of the star. As these outer layers cool, they radiate a red colour. The star has become a ‘red giant’, about 100 times its original size.

The outer regions of the red giant comprise a very thin gas. Eventually this outer gas drifts away into space leaving just a tiny, very hot, dense core which glows white hot - a 'white dwarf'. The white dwarf gradually cools down (it is generating no energy) and slowly fades from sight.

Our sun was born 5 billion years ago. It has enough hydrogen to continue in main sequence for another 5 billion years, then it will swell into a red giant. It will engulf Mercury, then Venus, and it will boil away the oceans on Earth before engulfing the Earth altogether. Eventually it will shrink back to a white dwarf, around which the charred remnants of the planets will revolve.

Heavyweight stars end their lives more dramatically than the lighter stars. When the hydrogen in the core has all been converted into helium, the star expands into a giant. However, pressure and temperature in the core continue to rise until helium fuses to form carbon. Further increases in temperature and pressure cause carbon to change into heavier elements - neon, silicon and iron. Eventually the star's centre becomes unstable and it collapses. The wave of collapse energy blows the star apart - a supernova.

The collapsing core of a supernova contracts into a super dense ball which is entirely composed of neutrons (a neutron is one of the main sub-atomic particles present in the nucleus of almost every atom). A neutron star is only about 25km in diameter and a piece the size of the roller ball in your ballpoint pen has a mass of a million tonnes. It would not be a good idea to land on a neutron star. The gravity is so strong that, if you did, you would be crushed and spread out in a layer over the surface one atom thick.

If the collapsing core of a supernova exceeds a certain mass (more than 3 suns) it cannot end its days as a neutron star. Its gravity is so strong that it continues to condense until it reaches a single point with infinite density. This, and the space around it, is the black hole - ‘black’ because no light can escape from it, and ‘hole’ because anything that goes into it can never escape again.

The blast from a supernova helps to start the process of star birth all over again. It compresses gas in space into clouds where gravity can get to work as already described. Also, by spewing out the heavier elements that it has formed - carbon, iron, etc. - it ensures that new stars will start out with slightly more of these heavier elements.

Smaller stars, like our sun, are only capable of forging the lighter elements by nuclear reactions, but the massive stars that end their lives in supernova explosions can forge the full range of the elements. The earth is rich in silicon, oxygen, aluminium and iron. Our bodies are rich in carbon, nitrogen and oxygen. Apart from hydrogen and helium, almost every atom on the earth and in our bodies was bred in a star. We are, in our very essence, star dust.

(This article first appeared in The Irish Times, January 29, 1996.)