The Evolution of Stars – from birth to death

Dr Richard Young gave a talk on the life and death of stars at the latest meeting of the the Athenaeum Astronomy Association, held in the Walled Garden Meeting Room, at Nowton Park, in Bury St Edmunds.

He told how stars vary in brightness because of the amount of energy they give out and their proximity to Earth and the brightest star in the sky, Sirius, is relatively non-energetic but is only eight light years from our own planet.

Some of the elements he described included the fact that Deneb is one of the brighter stars but is in the order of 1,500 light years from us; the term “luminosity” is used to distinguish energy output from brightness; stars vary in colour, cooler stars are red, hotter are white, hotter still are blue and they are classified by letters O B A F G K M in terms of decreasing surface temperature ... with each letter group being subdivided into 10 divisions.

When the spectra of stars are studied they are found to have black lines in them where light of
specific wavelengths is being absorbed by the star’s atmosphere.

The lines indicate the presence of elements in the star’s atmosphere. The elements can be
identified by the position of their lines on the star’s spectrum.

If a graph is plotted of stars’ luminosity against their temperature (known as the Hertzprung Russell diagram) it is found that most stars lie in a band between hot blue and cool red stars. This is known as the “main sequence”.

Stars move around the main sequence. Some increase in luminosity and move above the main sequence to become e.g. red giants. Others fall below the main sequence to become e.g. white dwarves.

Stars convert hydrogen into helium with the release of energy by a process of nuclear fusion. The more massive the star the quicker the reaction. Massive stars live longer than less massive stars.

Stars can be divided into two groups, low mass stars and high mass stars. The dividing point is a mass of 8x the mass of the Sun.

The greater the mass of the star, the greater the pressure on the star’s core and the faster the star burns its fuel. A high mass star will run out of fuel quicker than a low mass star.

Stars spend most of their time converting hydrogen into helium with the release of energy.

Stars of very low mass use their fuel slowly. Their cores are not separate from the rest of the hydrogen in the star so all the hydrogen in the star is available for burning.

Such stars are capable of burning for longer than the current age of the universe. Such stars are known as red dwarves.

A more massive star has a bigger core than a red dwarf and its core does not interact with the hydrogen in the rest of the star (the convection zone) As hydrogen is converted to helium, more and more helium accumulates in the core, the pressure in the core gets greater and thus gets hotter. Our Sun is such a star and has become hotter and more luminous during its lifetime. It is now 40% brighter than it was at its birth.

Eventually the shell of hydrogen around the core will start to burn and the Sun will begin to swell. It will be giving off more energy but will have more surface area. As it swells it will become cooler and become red. Gravity at the surface, being further from the core, will become weaker so gas will be blown off the Sun and it will loose a third of its mass at this stage.

The Sun will now contract again and become hotter and turn orange. Helium will begin to burn to produce carbon which will build up in the core. The star will expand to become a red giant and will loose up to 50% of its remaining mass.

The helium/carbon reaction does not progress smoothly and the Sun will contract when the reaction slows and swells when it quickens. When it swells it becomes a red giant. It may visit the red giant stage several times as the helium/carbon reaction peaks.

Eventually the Sun will run out of helium but its mass is not sufficient to burn the carbon. A combination of solar wind and lack of sufficient mass will blow off the remaining gasses exposing the core which will be white hot. Such objects are known as white dwarves and will slowly cool.

White dwarves are extremely dense and consist of carbon nuclei and free electrons. They have a size similar to that of the earth but are much more massive. They produce very strong “solar” winds. Prior to becoming white dwarf they will have blown off a lot of gas which will still be in the vicinity of the star. The strong radiation from the white dwarf will cause the gas to glow forming a planetary nebula.

Planetary nebulae are very short lived - in the order of a few thousand years - which accounts for why they are not more numerous. The glowing gas has structure. It is thought that the patterns in the nebulae are made by multiple stars in close orbits or by planets orbiting the star.

It is believed that the Sun is not massive enough to hold on to enough gas to produce a planetary nebula. Stars more massive than the Sun but less than eight times the Sun’s mass will go through a planetary nebula phase.

Stars have an uneasy balance between gravity trying to crush the star and energy trying to inflate it. At times during the lifetime of the star one force will dominate and the star will either expand or contract according to the force.

Lower mass stars like the Sun fuse hydrogen into helium which sinks into the core. Following this it fuses helium to produce carbon. It does not have enough mass to fuse carbon.

Higher mass stars can fuse carbon. The more massive the star the more elements it can fuse, each fusion period creating a heavier element than the previous.

Each period ends with the star running out of that particular fuel, thus reducing the energy produced by the core causing the star to shrink.

This generates more heat and if there is sufficient mass the next layer of fuel begins to fuse causing the star to expand again.

By now iron has built up in the core and thus the fusion reaction stops and the star begins to collapse under gravity.

Unlike in previous periods of shrinking where heat restarts burning, here energy is absorbed accelerating the shrinking.

The core collapses at speeds of a fraction of the speed of light. A shock wave moves outwards and meets the rest of the star falling in on it.

The resulting explosion is a supernova and can outshine all the stars in a galaxy.

Neutrinos are produced which carry away 100 times as much energy as our Sun will produce in its lifetime.