Stellar Evolution

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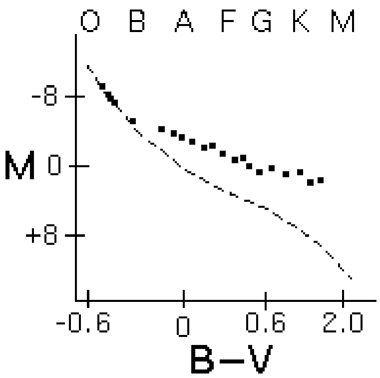
Orion Nebula (M42), credit *NASA*

All stars begin in the same way. Over a long period of time, a cloud of hydrogen gas accumulates. This is known as a *nebula*. As it does so, the force of gravity pulling it together increases, causing it to become denser, with its centre gradually heating up until the hydrogen nuclei start fusing together to make helium. This process releases energy, generating an outward force that counteracts the force from gravity. When the two forces are balanced, the star is considered stable and it enters the *main sequence*. Stars, like our sun, will spend 90% of their lives in this stage, or quite a few billion years, converting hydrogen into helium. Stars slowly increase in luminosity as the helium builds up in the core. Once the hydrogen runs out, gravity takes over and the core begins to shrink, heating the gas further, causing helium fusion to start in the dense layer just outside the core. This fusion causes the star to expand in size; as the surface gets further away from the core it cools down and glows red instead. The star has now become a *red giant*. When all nuclear reactions are over, a relatively small star like the Sun may shrink due to gravity. The outer gases are ejected into space and the hot exposed core is called a white dwarf due to its small size. In the Ring Nebula, the dwarf at the centre is difficult to see, however, it causes the gases around it to fluoresce. (see *Ring Nebula*, left) A larger star, on the other hand, will continue fusing together elements to form heavier ones (*stellar nucleosynthesis*) until iron is formed at the core. The core then rapidly shrinks to the size of a small town in less that a second, forming a *neutron star* (called so due to the fusion of protons and electrons to form neutrons and neutrinos) and a large explosion called a *supernova*, in which elements heavier than iron are formed. Particularly large stars may form a black hole at the centre, whose gravity is so great that even light cannot escape, causing it to be completely black.

Ring Nebula (M57), credit *NASA*

Hertzsprung-Russel diagrams

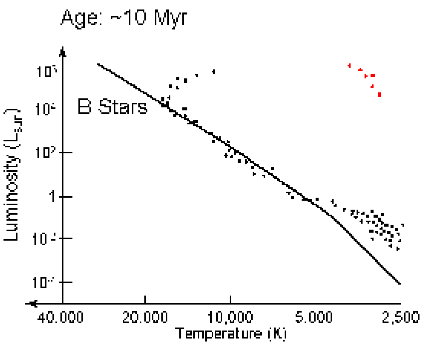
These types of diagrams were independently discovered by Ejnar Hertzsprung and Henry Norris Russel in the early 20th century. They plotted the brightness of stars against their colour, usually for a given cluster, since that way all the stars are practically the same distance away from us.

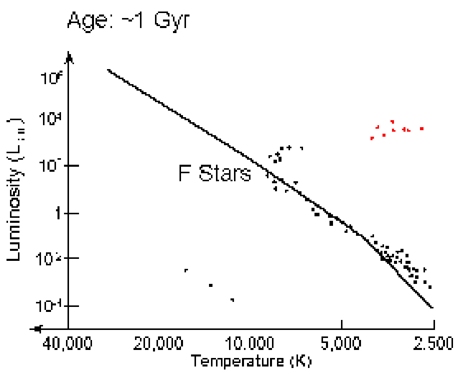


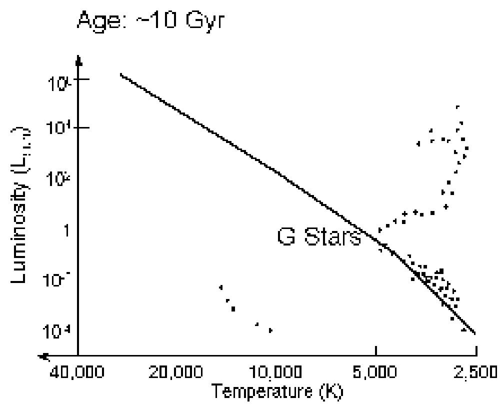
Massive stars form first, very bright and blue. A very young cluster has only the largest stars on the main sequence.

The larger a star, the faster it evolves. The largest stars can go through the whole process in as little as 12 million years. In the 2nd diagram, some stars are already beginning to leave the main sequence.

The point at which the stars “turn off” towards giant stars is called the *main sequence turn-off*. This point is used to tell the age of a cluster. As the cluster becomes older, the stars at the turn-off point are of lower mass as the larger stars have already evolved and died.







Cluster Hertzsprung-Russel diagrams change with age. If we assume that all the stars in a cluster were formed at the same time (observations show that this does happen) the hot, luminous main sequence stars die before the cool, dim main sequence stars. Stars are classified using the Harvard spectral classification system using the letters (from hot to cold, historical) *O, B, A, F, G, K*, and *M*.