

# The life-cycle of stars



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## Stellar Nebula

A nebula consists of dust and gas, and there are places where gravity causes these to clump together. This means their gravitational attraction to other atoms increases, pulling more atoms into the clump. The process where atoms fall into the clump and become part of the protostar is called accretion. To become a star, the protostar will need to achieve hydrostatic equilibrium by balancing the gravity, pulling atoms in, and the radiation pressure pushing heat and light out. When equilibrium is achieved, if a specific mass is not reached (around 0.08 times the mass of the Sun), the protostar will become a brown dwarf, but if this critical mass is reached, then nuclear fusion is able to begin, and the star is born, entering the main sequence [Figure 1].

## Main Sequence

The majority of a star's lifetime is spent during the main sequence, although the duration of this stage varies dramatically, depending on the mass of the star; our Sun is in the main sequence at the moment. This stage is spent fusing hydrogen into helium in the core of the star. When the hydrogen supply begins to run out in the core, the core becomes unstable and contracts. The outer shell, which is still mostly hydrogen, starts to expand, cooling and glowing red [Figure 2].

## High Mass Stars

The most massive stars can have masses 100 times

that of the Sun and emit millions of times more light, but they only live for a few million years.

## Low Mass Stars and Brown Dwarfs

Stars which have just too little mass to become full stars are known as brown dwarfs. Although the boundary between what is a high-mass planet and what is a brown dwarf is fuzzy, if an object has more than 13 times Jupiter's mass, it is called a brown dwarf, and if it has less mass, it is called a giant planet. Although some fusion can take place in a brown dwarf of fewer than 80 Jupiter masses, it is only fusion of deuterium and lithium-not enough to supply the brown dwarf with enough energy to counteract



Figure 1: Stellar Nursery in the Rosette Nebula [available from [http://www.nasa.gov/multimedia/imagegallery/image\\_feature\\_1653.html](http://www.nasa.gov/multimedia/imagegallery/image_feature_1653.html)]

gravity's inward pressure. It is only at around 80 Jupiter masses that the brown dwarf has enough mass to fuse hydrogen, and be a fully-fledged star. Bizzarely, a 2006 article suggests that it may rain liquid iron on a brown dwarf [Figure 3].<sup>[1]</sup>

## Red Supergiants

Stars with more than 10 solar masses become red supergiants, after burning all their hydrogen, during the stage when they fuse helium into carbon. These supergiants have relatively cool surface temperatures (3500-4500 K) and radii between 200 and 800 times the Sun's radius. As the helium turns into carbon, the core temperature increases, gravity continues to pull carbon atoms together and fusion creates all the elements up to iron. When the core contains mainly iron, fusion stops, as no energy is released by fusing iron nuclei together; indeed, energy must be put in to fuse iron.<sup>[2]</sup>

## Supernovae

Since energy is no longer being radiated from the core, the star collapses, causing the temperature to rise as the atoms are crushed together. The repulsive force between the nuclei overcomes gravity and the core recoils out in what we see as a supernova. As the shock wave hits material in the star's outer layers the material is heated, fusing to form further elements. All heavy elements, including uranium and plutonium, are formed in supernovae. The material blasted into space by this explosion is known as the supernova remnant. This is the most common type of supernova (called a core-collapse supernova), but there are other, more exotic supernovae that may happen when extremely large stars collapse [Figure 4].

## Black Hole

If the remnant of a red supergiant core is more than three times the size of the Sun after a supernova, gravity overcomes the nuclear forces holding the protons and neutrons in the atoms apart. The core is then swallowed by its own gravity, eventually becoming a black hole. The black hole theoretically contains a 'singularity', a point of infinite density with a region of space around it, called an 'event horizon', beyond which it is impossible to escape from the black hole's gravitational pull [Figure 5].

## Neutron Star/Pulsar

When a supernova explodes, if the remaining core is

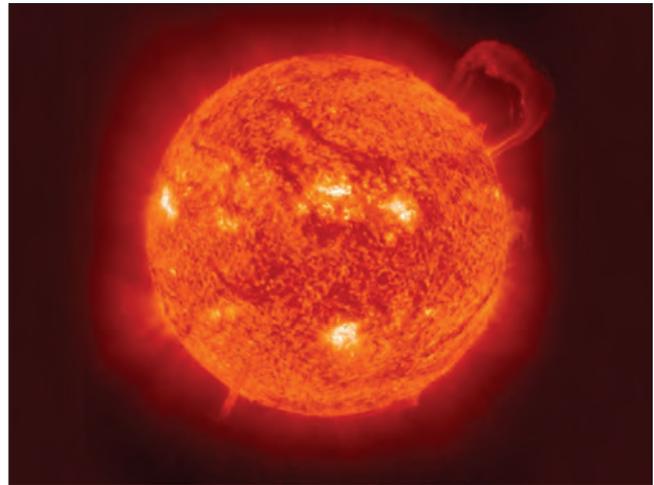


Figure 2: The Sun [available from [http://www.nasa.gov/multimedia/imagegallery/image\\_feature\\_21.html](http://www.nasa.gov/multimedia/imagegallery/image_feature_21.html)]



Figure 3: V838 Monocerotis (red supergiant) [available from [http://www.nasa.gov/multimedia/imagegallery/image\\_feature\\_784.html](http://www.nasa.gov/multimedia/imagegallery/image_feature_784.html)]



Figure 4: Supernova 1994D in the outskirts of the galaxy NGC 4526 [available from <http://en.wikipedia.org/wiki/File:SN1994D.jpg>]

relatively small, the protons and neutrons combine to form neutrons. Neutron stars are very dense ( $10^{17}$  times denser than water), having diameters of just 20 kilometers, yet masses three times that of the Sun [Figure 6].<sup>[3]</sup>

Some neutron stars emit radio waves. These neutron stars are called pulsars. The waves seem to flash on and off, but this is only the case due to the beam of radio waves rotating around the poles of the stars, while the Earth remains relatively fixed relative to the rotating beams [Figure 7].<sup>[4]</sup>

## Red Giant

These are formed when low mass stars run out of hydrogen; they are very bright due to their large diameters, but they have lower surface temperatures

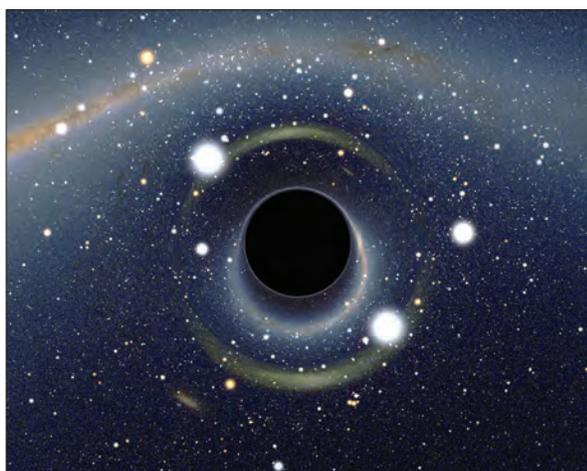


Figure 5: Simulated view of a black hole in front of the Large Magellanic cloud [available from [http://en.wikipedia.org/wiki/File:BH\\_LMC.png](http://en.wikipedia.org/wiki/File:BH_LMC.png)]

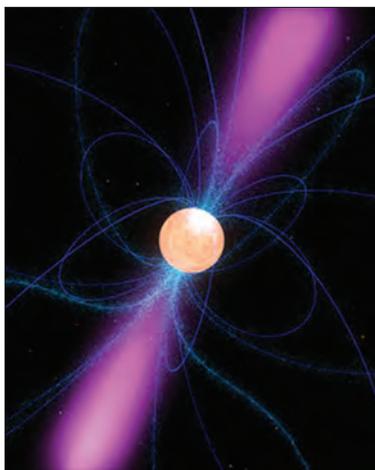


Figure 7: Still from an animation of a pulsar [available from [http://www.nasa.gov/mission\\_pages/GLAST/multimedia/pulsar\\_stills.html](http://www.nasa.gov/mission_pages/GLAST/multimedia/pulsar_stills.html)]

than the Sun (2300-3300 K). Like the red supergiants, they fuse helium into carbon in this phase. When all the helium in the core is used the core collapses again [Figure 8].<sup>[5]</sup>

## Planetary Nebula

These are the outer layers of a star that are lost when a star of around the Sun's mass changes from a red giant to a white dwarf. The hot core of the star drives the outer half away in a stellar wind that lasts a thousand years. The remaining core is left, which heats the gases it has pushed away, causing them to glow [Figure 9].<sup>[6]</sup>

## Blue/White Dwarf

This is a very small, hot star with a similar mass to the Sun, but the same diameter as the Earth, that is

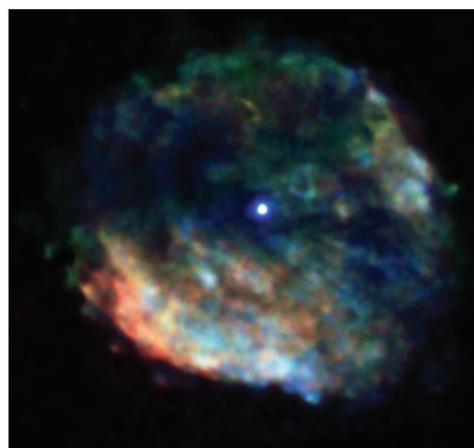


Figure 6: The white dot in the centre of the image is the neutron star [available from [http://www.nasa.gov/mission\\_pages/chandra/multimedia/photos07-080.html](http://www.nasa.gov/mission_pages/chandra/multimedia/photos07-080.html)]

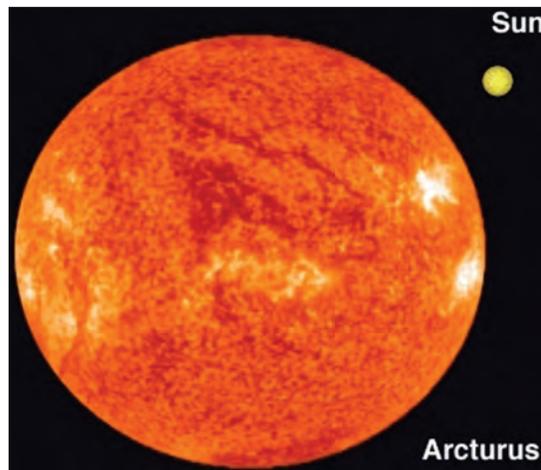


Figure 8: The red giant Arcturus in comparison with The Sun [available from <http://en.wikipedia.org/wiki/File:Arcturus-star.jpg>]



Figure 9: Helix nebula [available from [http://www.nasa.gov/multimedia/imagegallery/image\\_feature\\_77.html](http://www.nasa.gov/multimedia/imagegallery/image_feature_77.html)]

formed from the core of a red giant when it collapses. They are not very bright despite having temperatures of more than 8000°C. They cool and fade over billions of years [Figure 10].<sup>[3]</sup>

## Black Dwarf

Black dwarfs are hypothetically what would remain once a white dwarf has cooled to around temperatures where they are not hot enough to emit light. However, none are expected to exist simply because the universe has not existed long enough to allow any white dwarfs to cool down enough to become black dwarfs.

## About the Author

**Cleodie Swire** is doing Biology, Chemistry, Physics, Further Maths and Spanish at AS Level, and has already taken French. She is currently at The King's School, Canterbury, and hopes to do Medicine at University. She enjoys doing sport - especially hockey - and travelling.

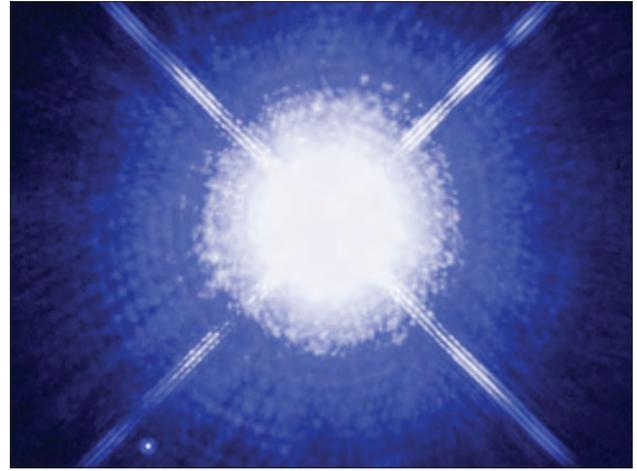


Figure 10: Sirius A (white dwarf) [available from [http://www.nasa.gov/multimedia/imagegallery/image\\_feature\\_468.html](http://www.nasa.gov/multimedia/imagegallery/image_feature_468.html)]

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