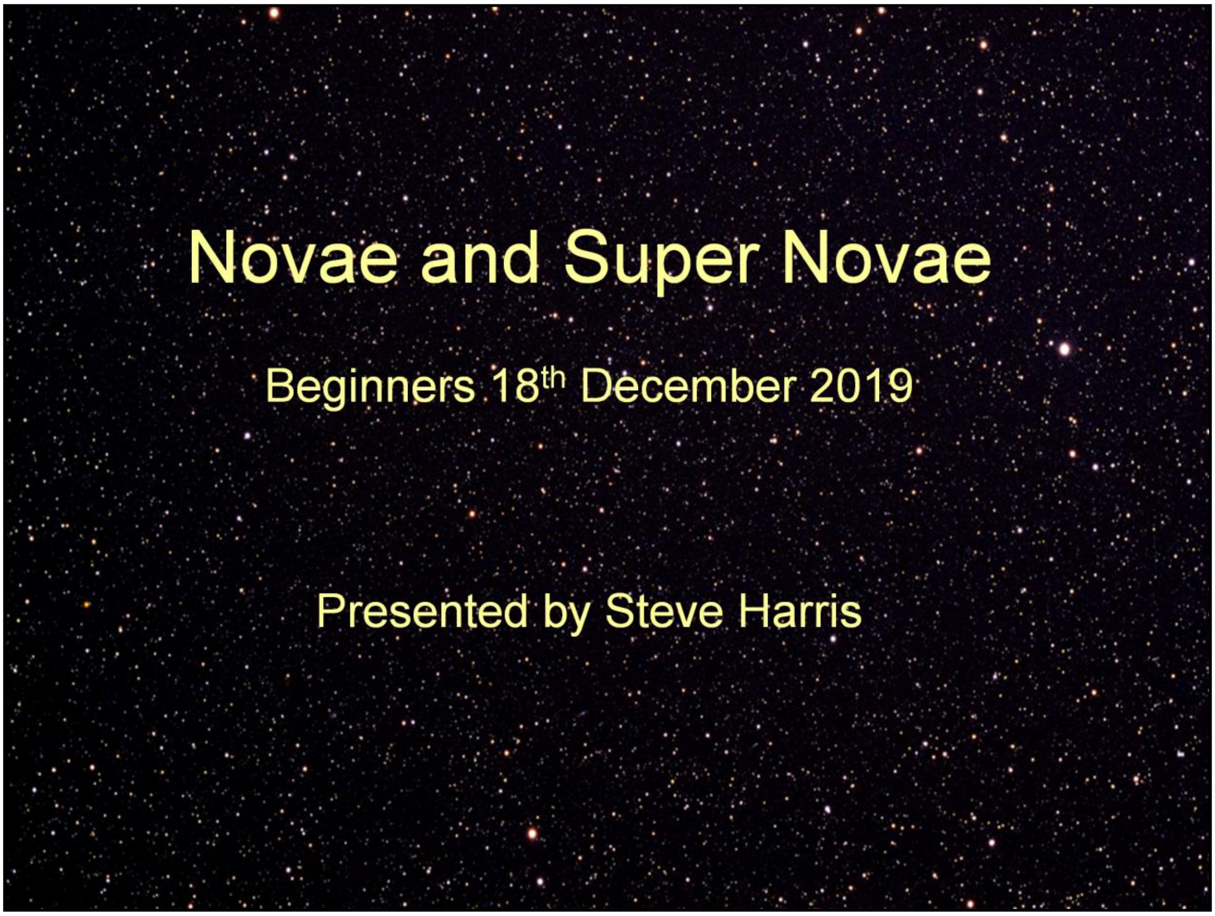
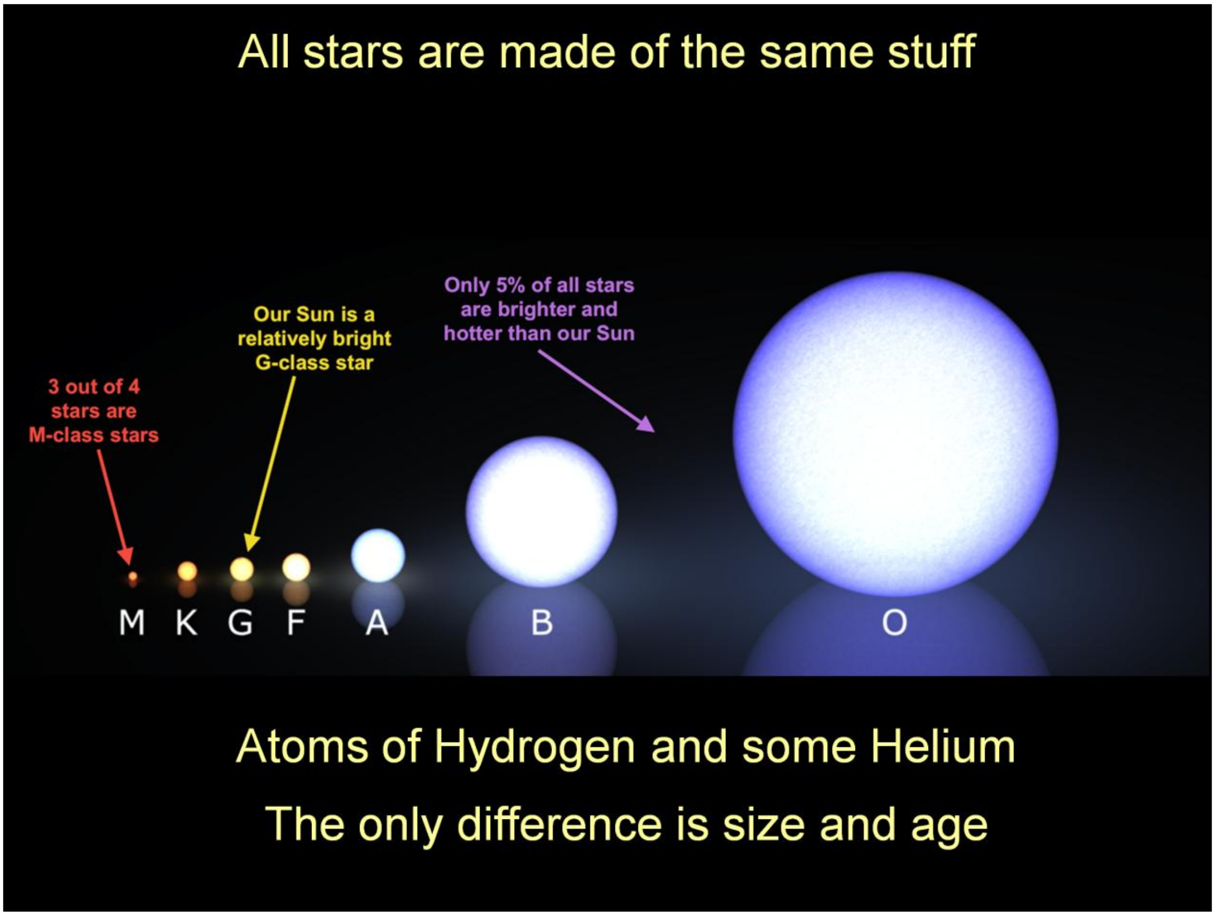


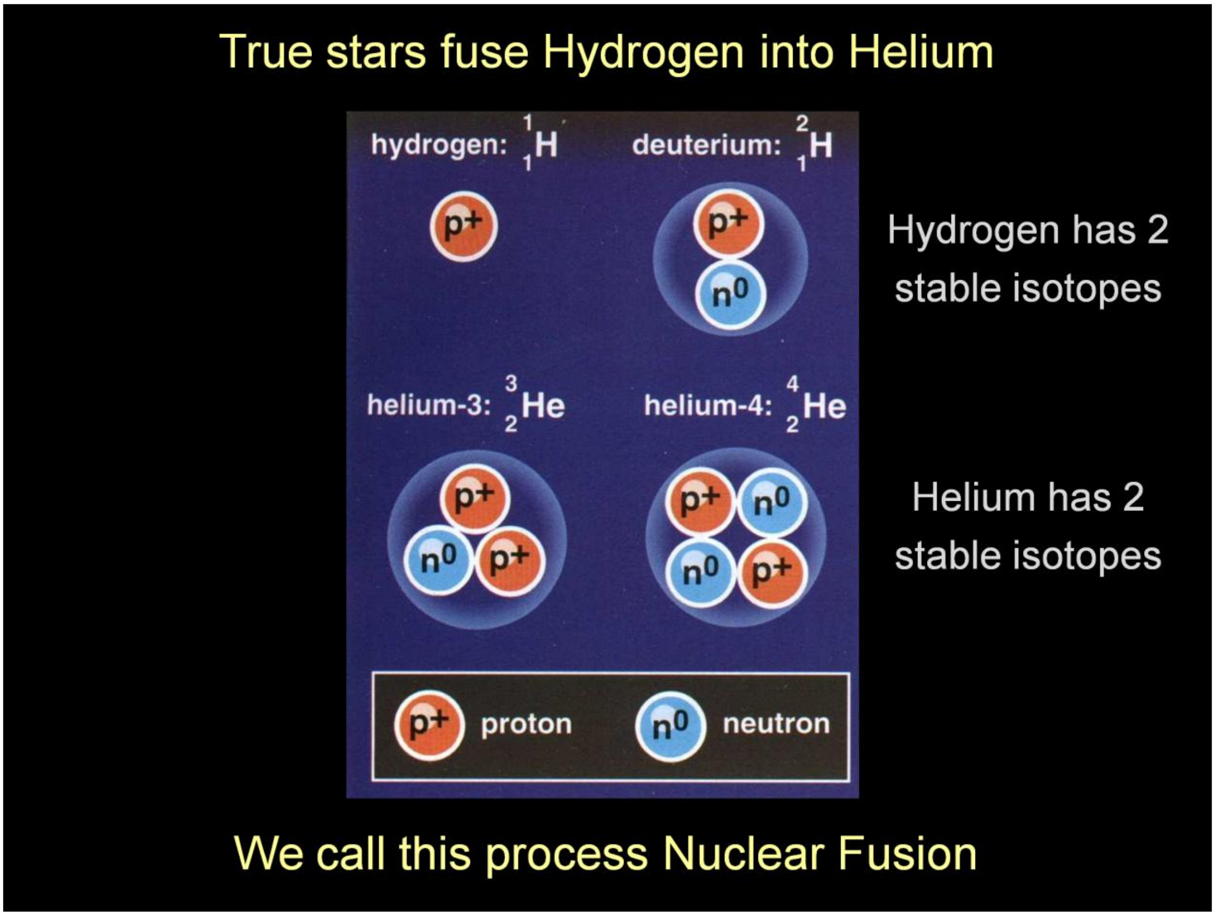
At the November Beginners meeting the question was asked: ‘What is the difference between a Nova and a Supernova?’ so here is an explanation:



All stars are the same in respect of what they are made of, this is mainly Hydrogen gas with about 11% Helium. This is predominately the stuff produced by the Big Bang when the Universe was created.

The main differences in stars is their size as they form. Their size dictates how much energy they produce (how much they shine) and how long they 'live'. Large stars consume their fuel much faster than smaller stars.

The very smallest stars (called Red Dwarfs) may live for trillions of years. Medium sized stars like our Sun (called Yellow Dwarfs) live for about 10 billion years. The very largest stars may only live for a few million years.

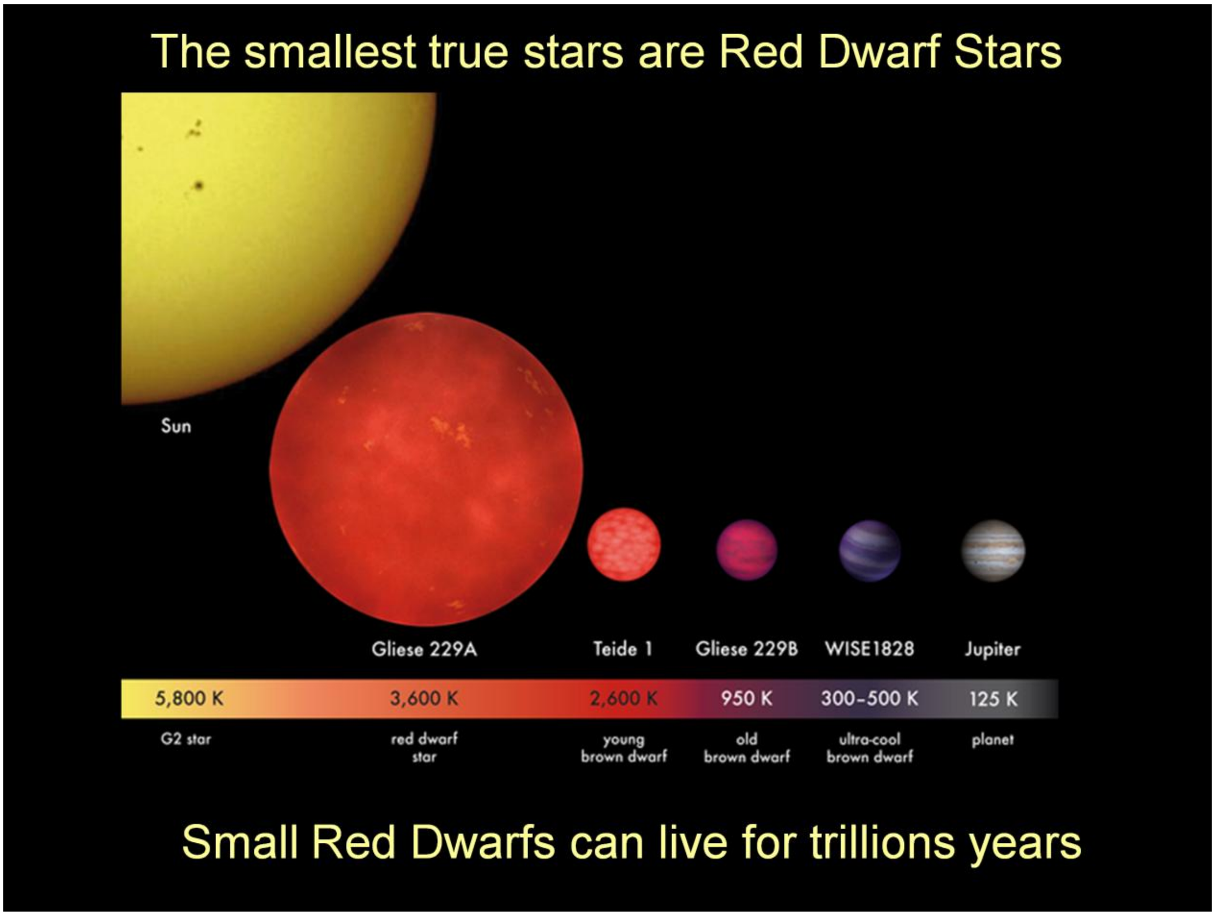


Stars do not burn like wood or coal they produce energy and heat from Nuclear Fusion. As a star forms from a cloud of Hydrogen the mutual gravity of the atoms compress the gas into a sphere. As it is compressed the core pressure rises to millions of times the pressure on the surface of Earth (1 bar). This enormous pressure also produces heat and raises the gas temperature to millions of degrees. At this pressure and temperature the Hydrogen atoms are forced together and pairs of atoms become joined together (called Nuclear Fusion). The fusion produces atoms of Helium-3 or Helium-4. The Helium atom produced actually has less mass (weight) than the two Helium atoms that fused together to create it. This lost mass was converted into a flash of X-Rays in accordance with Albert Einstein's famous equation $E = mc^2$. Where E = energy, m = mass and c = the speed of light. As the speed of light is a large number multiplying the mass(lost) by the speed of light squared produces a huge amount of X-Ray energy that heats the star and it shines.

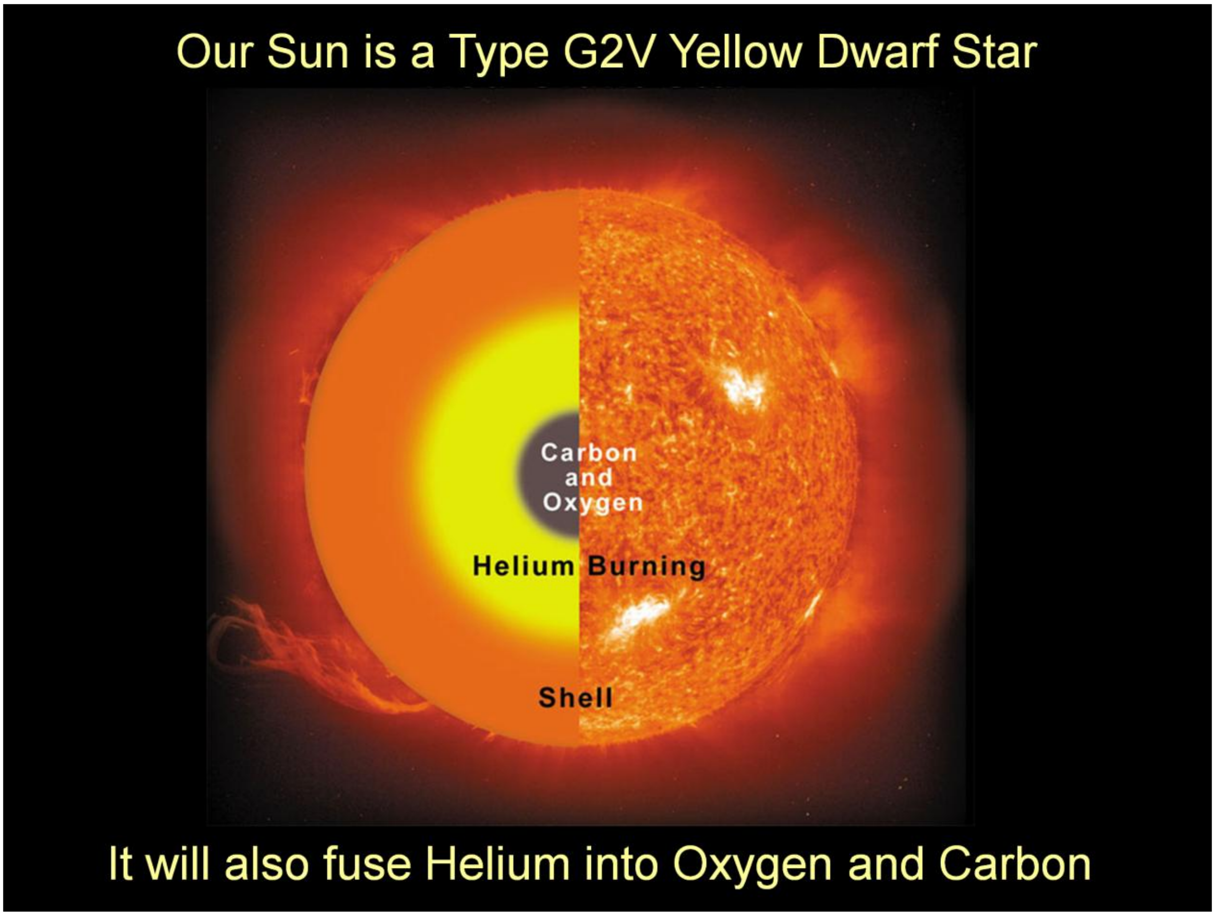
We class stars by comparing them to our Sun
Our Sun is classified as a Type G2

Type	Surface Temp.	Radius (Sun=1)	Mass (Sun=1)	Absolute Magnitude (Visual)	Luminosity (bolometric) (Sun=1)	Habitable Zone (AU)	Lifetime (million y)	Abundance (% of all stars)
O3	53 000K	15	120	-6.0	1 400 000	1200	2	0.00001% 1 in 10m
O5	45 000K	12	60	-5.7	790 000	890	3	
O8	35 000K	8.5	23	-4.9	170 000	410	6	
B0	30 000K	7.4	17	-4.0	50 000	220	9	0.1% 1 in 1000
B3	19 000K	4.8	7.6	-1.6	1900	44	30	
B5	15 000K	3.9	5.9	-1.2	830	29	50	
B8	12 000K	3.0	3.8	-0.2	180	13	150	
A0	9 500K	2.4	2.9	+0.6	54	7.3	300	0.7% 7 in 1000
A5	8 200K	1.7	2.0	+1.9	14	3.7	1 000	
F0	7 200K	1.5	1.6	+2.7	6.5	2.5	1 900	2%
F5	6 400K	1.3	1.3	+3.5	3.2	1.8	3 200	
G0	6 000K	1.1	1.05	+4.4	1.5	1.2	8 000	3.5%
G2	5 800K	1.0	1.00	+4.8	1.0	1.0	10 000	
G5	5 700K	0.92	0.92	+5.1	0.79	0.89	12 000	
K0	5 200K	0.85	0.79	+5.9	0.42	0.65	22 000	8%
K5	4 300K	0.72	0.67	+7.4	0.15	0.39	45 000	
M0	3 800K	0.60	0.51	+8.8	0.08	0.28	68 000	80%
M5	3 200K	0.27	0.21	+12.3	0.011	0.10	200 000	
M8	2 600K	0.15	0.06	+16.0	0.001	0.03	700 000	

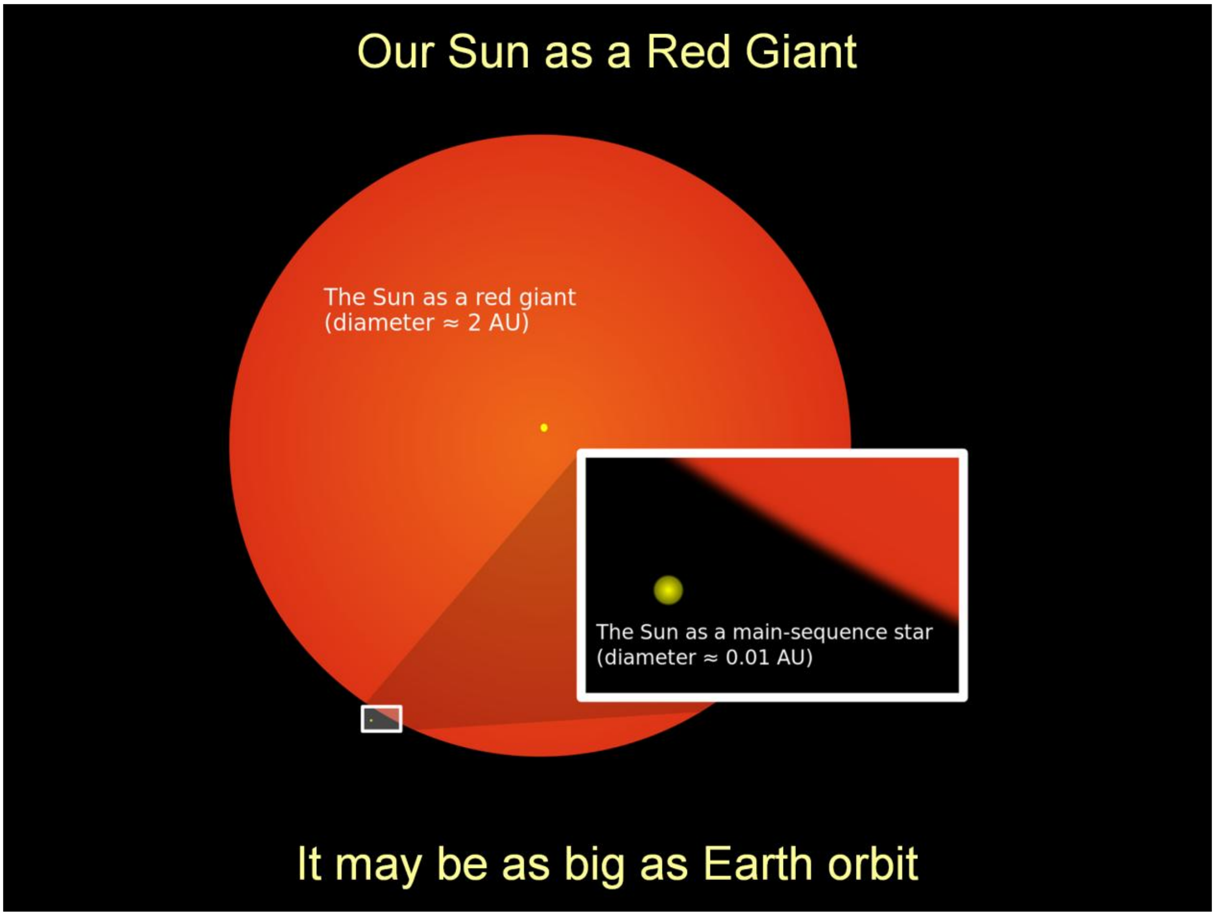
Larger stars produce much more energy than smaller stars. It may be thought that a star of a certain mass would produce twice as much energy as a star half its size but a larger star produces much more energy from its larger size. A doubling of mass produces more like 10 times the energy. This also means larger stars use up their Hydrogen fuel much faster and run out of fuel much sooner. The chart above shows how more mass affects the physical properties of the star. The smallest stars are at the bottom of the chart and the largest at the top. It can be seen that as the mass increases the Luminosity (energy produced) increases much more. The Lifetime of the larger stars also decreases much quicker.



The chart above shows the comparative sizes of stars smaller than our Sun and their temperature.



Our Sun fuses its Hydrogen into Helium and produces X-Rays to heat the gases and shine. Helium atoms are heavier than Hydrogen so they sink to the centre of the star. As the Helium accumulates in the core it begins to fuse into atoms of Carbon and Oxygen which being heavier sink to the centre of the star. Stars like our Sun are not massive and hot enough to fuse the Carbon and Oxygen into even heavier atoms so the Carbon and Oxygen build up in the core. The additional energy from the fusion of Helium at the interface between the Helium and Carbon zones increases the outward pressure of the radiation and the star begins to grow into a Red Giant.

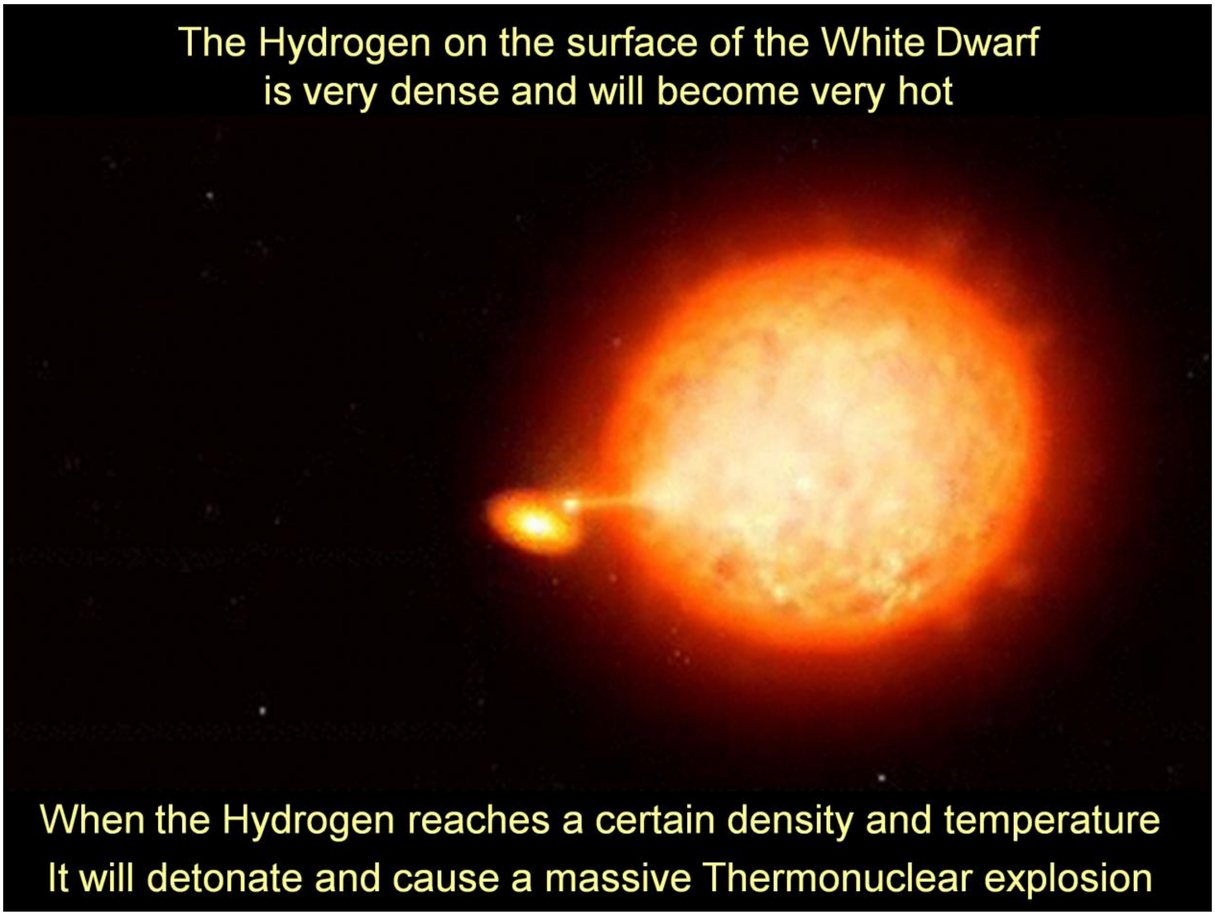


As more mass is converted into Helium and then into Carbon and Oxygen more of the mass of the star falls inward to the Carbon/Oxygen core. With less mass on the outside of the fusion energy production zones the outer regions are pushed further and further outwards until the star (like our Sun) will have a diameter out to the orbit of Earth. At this point the energy produced in the core is dissipated over a much larger surface area so the surface temperature falls and the star becomes redder.

Eventually the Hydrogen fuel supply begins to run out so the energy output reduces. With less energy available to push outwards the inward gravitational forces start to pull the star inwards towards the core and the star slowly collapses. The tenuous outer layers of the star are left behind and form a bubble of gas around the collapsing star that we call a 'Planetary Nebula'. This is nothing to do with a planet but they just looked like a planet through the relatively primitive telescopes of early astronomers.

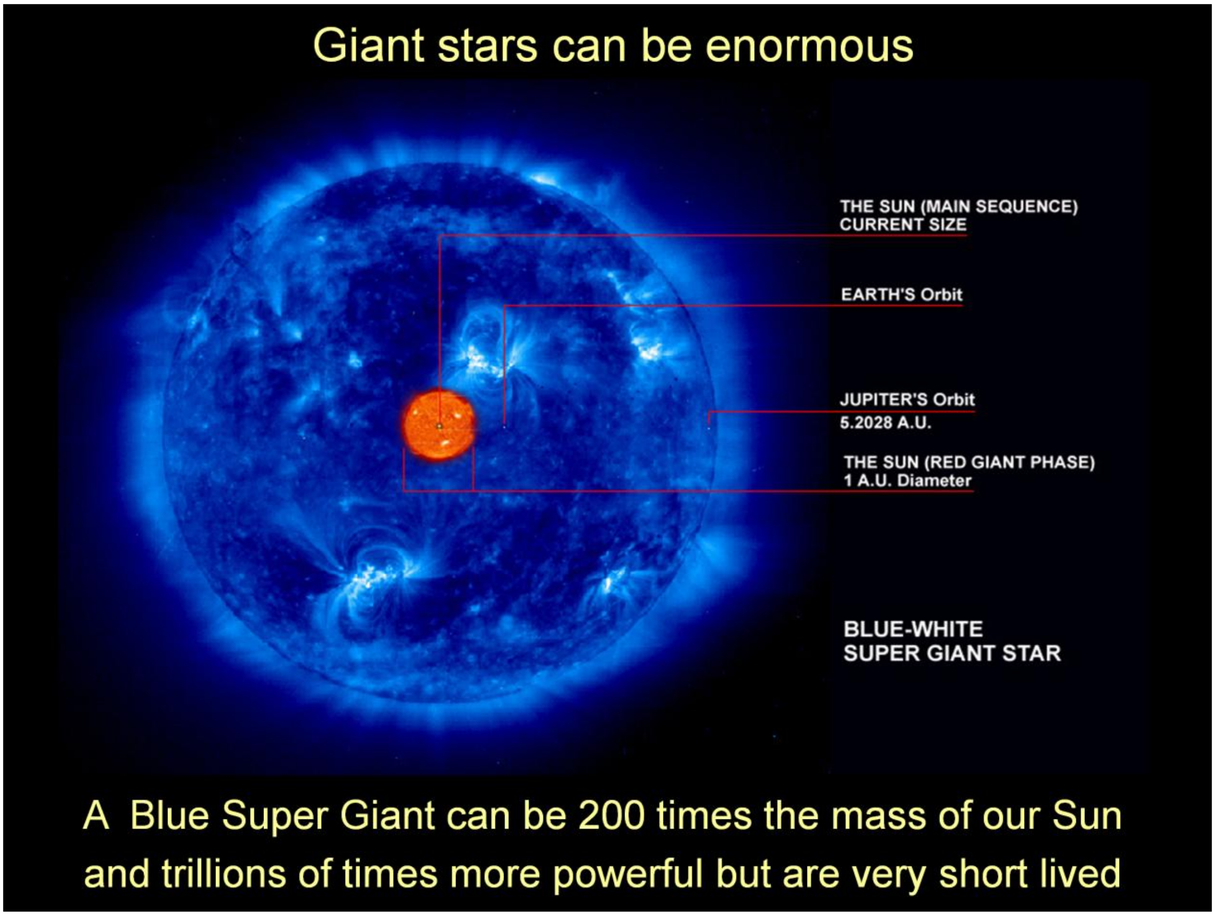
A star of about the same size as our Sun will gently collapse to become a White Dwarf Star. Gravity will pull the atoms together until they reach a density where Electron Degeneracy Pressure prevents further collapse. At this point the star would have collapsed to about the size of Earth (about 12,500 km diameter). White Dwarfs can only reach a maximum mass of 1.44 $M_\odot$ (times the mass of the Sun) then the Electron Degeneracy Pressure will be overcome and the star will continue to collapse to create a Neutron Star with a diameter of about 20 km.

Most stars (up to 60%) are members of double or multiple stars systems. When the stars in a double are of a size that will lead to the formation of white Dwarfs, they can together cause a Nova explosion. In a binary star system one of the stars is likely to be little more massive than the other. This larger star will use up its Hydrogen supply quicker than the smaller twin. It will be the first to become a Red Giant and then collapse to form a White Dwarf. The white Dwarf will still have a similar mass to the second star but will be tiny in comparison. As the second star becomes a Red Giant the gravity of the White Dwarf may draw the thin outer layer of Hydrogen off the Red Giant and it will spiral down on to the surface of the White Dwarf.

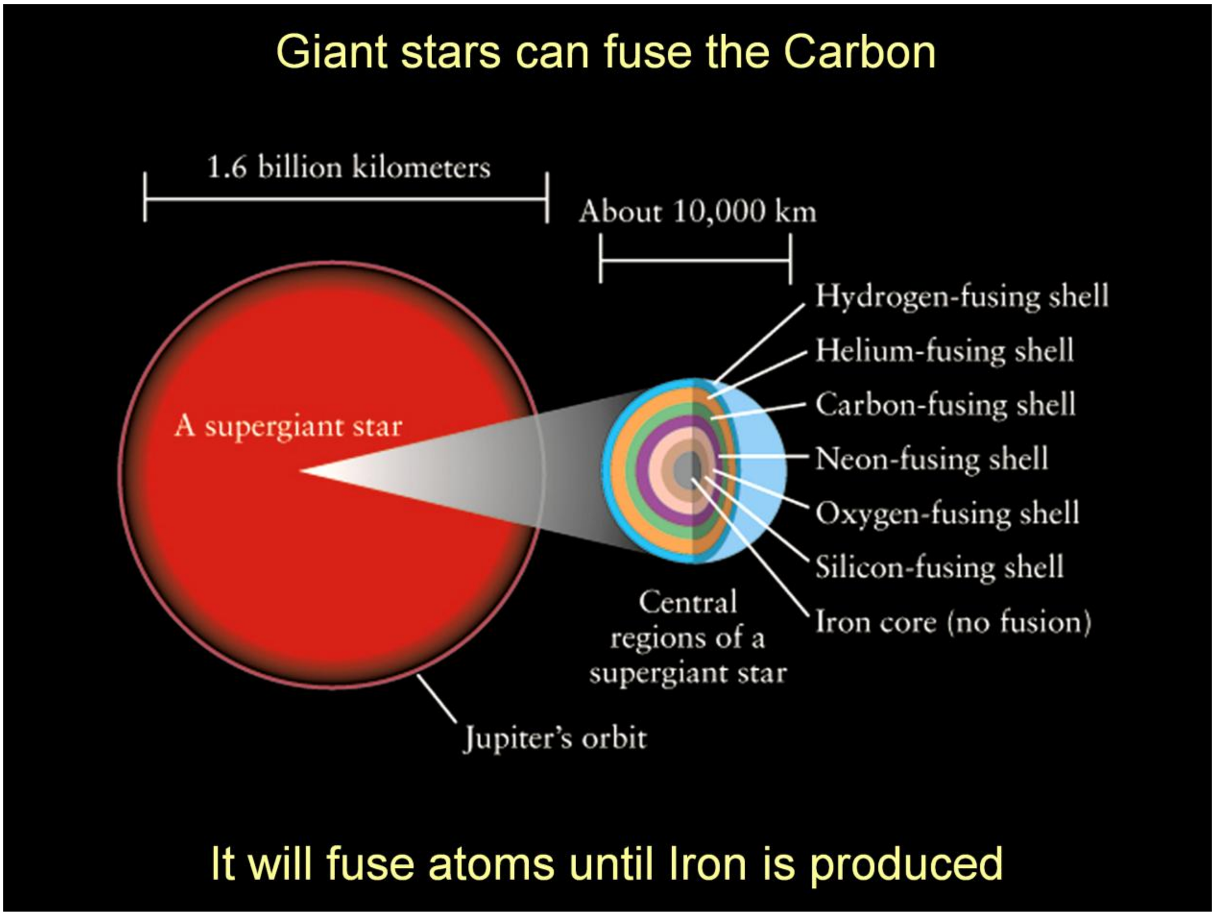


The Hydrogen will create a very dense atmosphere on the surface of the White Dwarf but it will be so compressed that the atmosphere may be just a metre or less deep. Being so compressed the atmosphere will become very hot.

As the atmosphere builds up and becomes very hot it will reach a critical mass then detonate as a Thermal Nuclear Explosion. The two stars will usually survive this massive explosion and will do the whole thing again.



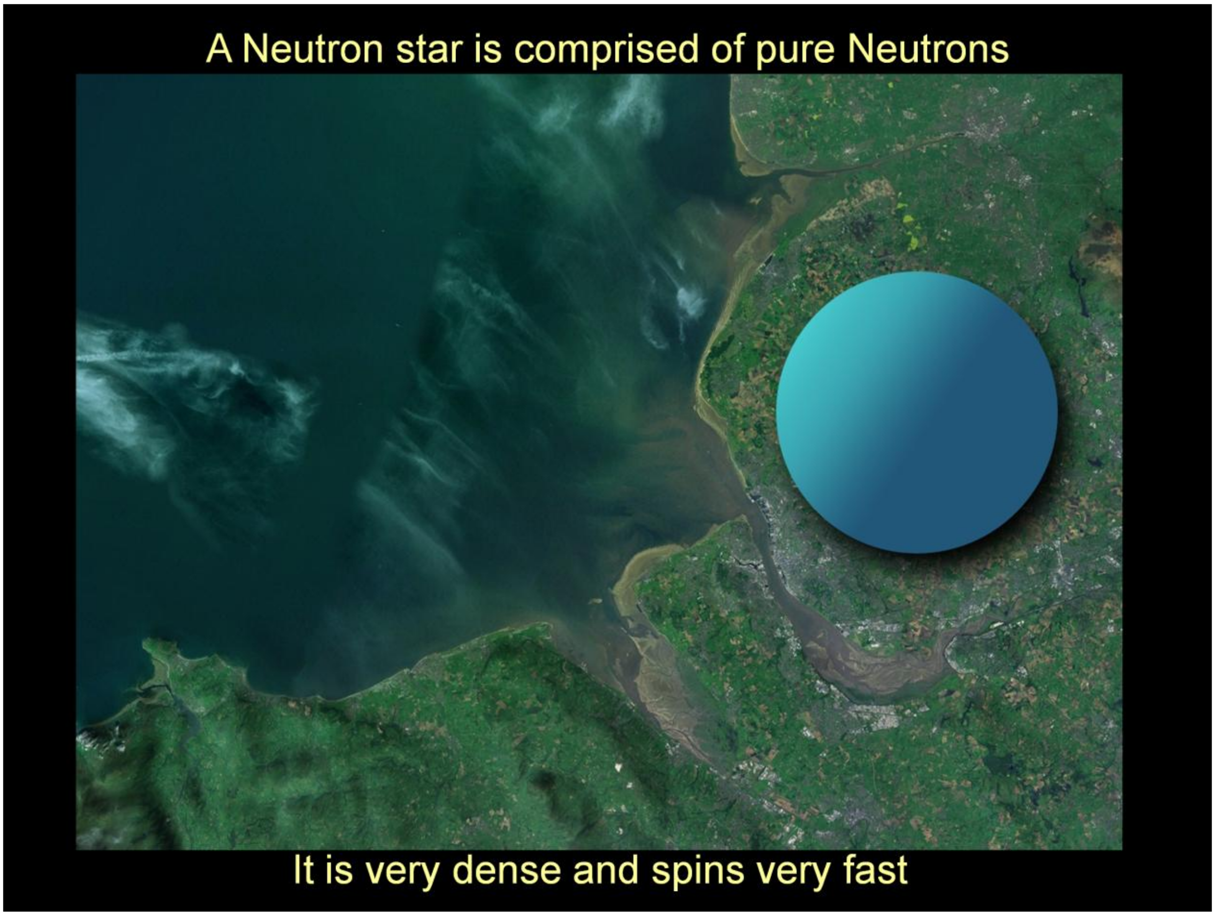
Super Giant Stars are very rare because they are not around for very long. They use up their Hydrogen at a furious rate.



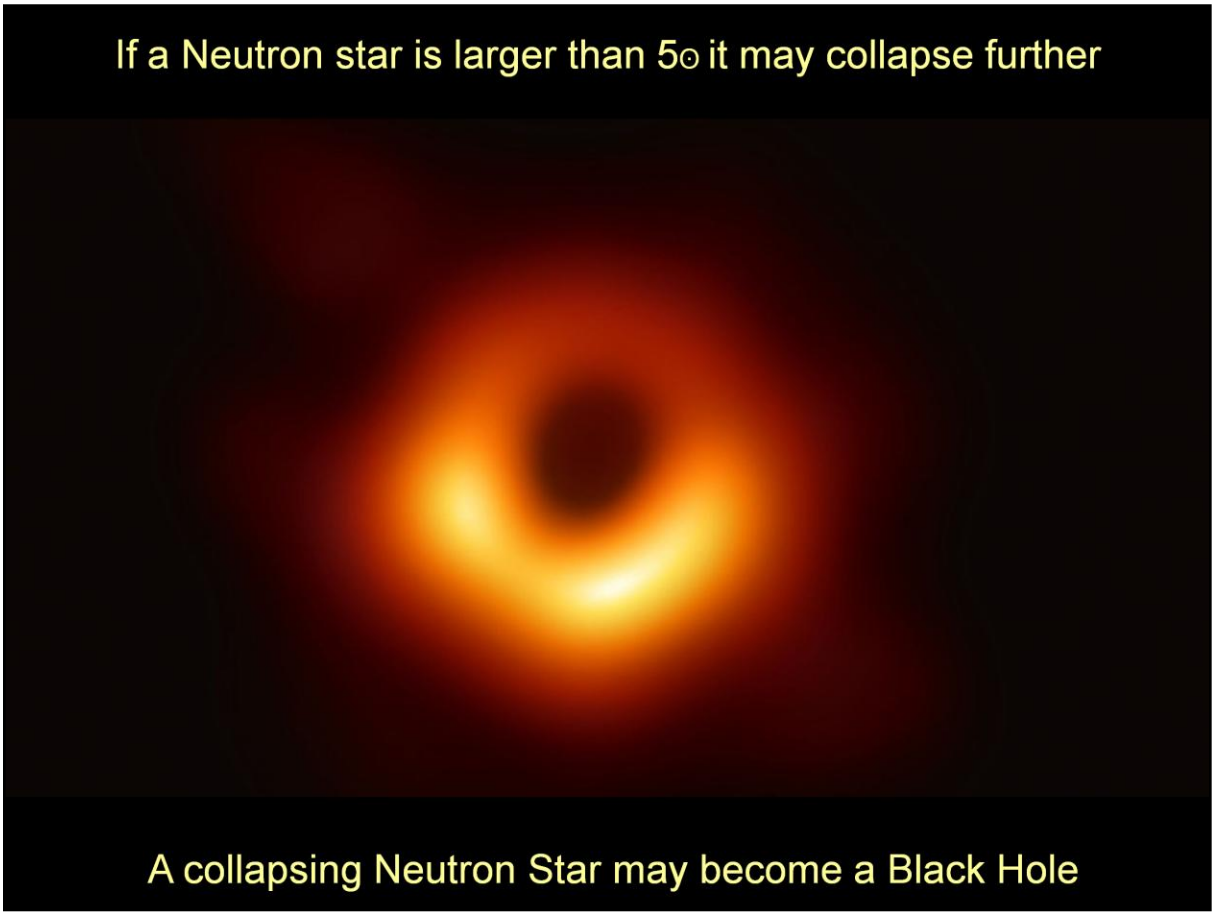
Giant stars Fuse their Hydrogen into Helium through Nuclear Fusion in the same way as smaller stars. However the core is much denser and hotter which allows the Helium to be fused into heavier elements. There is a tendency for certain key elements to be formed in sequence. The sequence is Helium → Carbon → Neon → Oxygen → Silicon → Iron. Each fusion stage creates additional energy that forces the star to grow in diameter. It will first become a giant (in size) and very hot blue star. Eventually it will develop into a huge Red Super Giant Star with a diameter equal to the orbit of Jupiter. Finally it will fuse Silicon into Iron which does not produce any additional energy to feed the giant star. It becomes unstable as the Iron very quickly builds up in the core. This Red Super Giant pulsates and throws off huge plumes of material as it struggles for survival. Then in just a moment the Iron core will collapse inwards. As the core collapses the rest of the star suddenly falls inwards toward the core. As the in falling star meets the surface of the core a gigantic nuclear explosion tears the star apart in a massive Supernova explosion.

For a few seconds the Supernova produces the equivalent energy as all the stars in a giant galaxy put together. The outer layers of the star are propelled into space at tremendous speed to create what is called a Supernova Remnant that will expand over a vast area. The collapsed core of the star will momentarily pass through the White Dwarf Stage but will exceed the 1.44 $M_\odot$ Electron Degeneracy Pressure limit to create a Neutron Star. If the Neutron Star is more massive than 2.16 $M_\odot$ then it may continue to collapse to form a Stellar Black Hole.

A Neutron Star is a collapsed White Dwarf with a diameter of about 20km. They are composed completely of Neutrons packed very closely together. Neutron Stars generally spin very fast typically hundreds of rotations per second but can spin at speeds of up to thousands of rotations per second. Some Neutron Stars are highly magnetised and may produce jets from their poles. If the jets are ejected away from the axis of rotation (pole) the jet may sweep across space in a circular trace. If the jet sweeps past Earth in its path we can detect a radio pulse as the jet sweeps across Earth. These were first called Pulsars (because they produce rapid radio pulses) but they are now known to be a kind of Neutron Star.



Neutron Stars are very dense with their atoms very tightly packed. They are so dense that a normal-sized matchbox containing neutron-star material would have a weight of approximately 3 billion tonnes.



It is thought that if a Neutron star forms with a mass greater than about 5.0 $M_\odot$ then it will continue to collapse to create a Stellar Black Hole although this figure is not certain. The image above was recently released as the first image of a Black Hole. The Black Hole itself cannot be seen in the centre of the central void. The bright halo is material (gas and dust) that is spiralling around as it is falling into the Black Hole. As the gas and dust spirals in, it gains speed and becomes heated and is seen glowing in the image. As the material crosses the Event Horizon (the point of no return) it disappears into the grasp of the gravity well of the Black Hole. Not even light can escape the gravity of the Black Hole.

Different types of Nova and Supernova

Nova Type	Cause	Result
Nova Type Ia	Accumulation of Hydrogen from a companion	Recurring
Non-standard Supernova Type Ia	Merger of two White Dwarfs	Supernova and creation of a Neutron Star
Supernova Type II - P	Core Collapse of a large star of $10_{\odot}$ to $25_{\odot}$	Supernova and creation of a Neutron Star
Supernova Type II - P or b	Core Collapse of a large star of $25_{\odot}$ to $50_{\odot}$	Supernova and creation of a Black Hole
Hyper-nova Type II-P	Core explosion of a large star of $140_{\odot}$ to $250_{\odot}$ may produce Gamma Ray Burst	Complete destruction of the star due to Pair Instability
Hyper-nova Type II-P	Core Collapse of a large star of $> 250_{\odot}$ will produce a Gamma Ray Burst	Massive Black Hole

The chart above shows the different types of Nova and Supernova explosions.

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