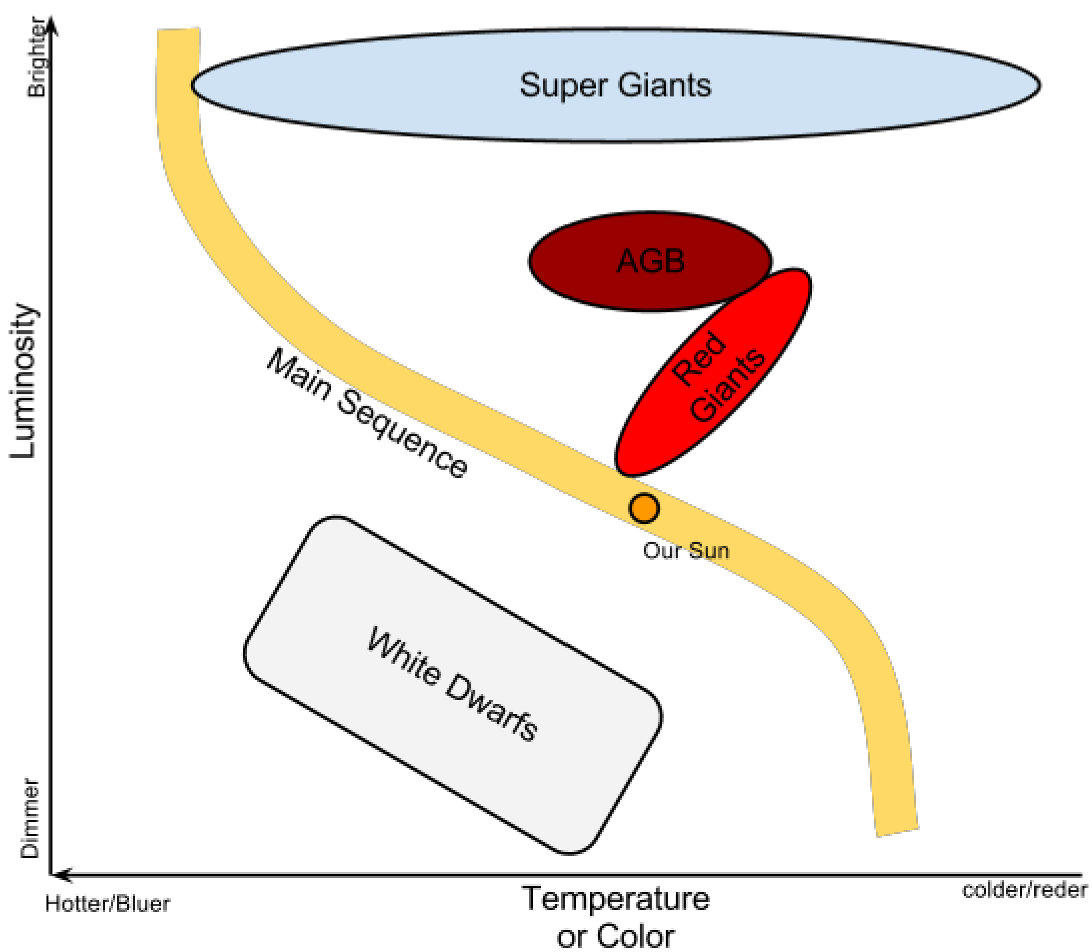
When stars go *off road*!

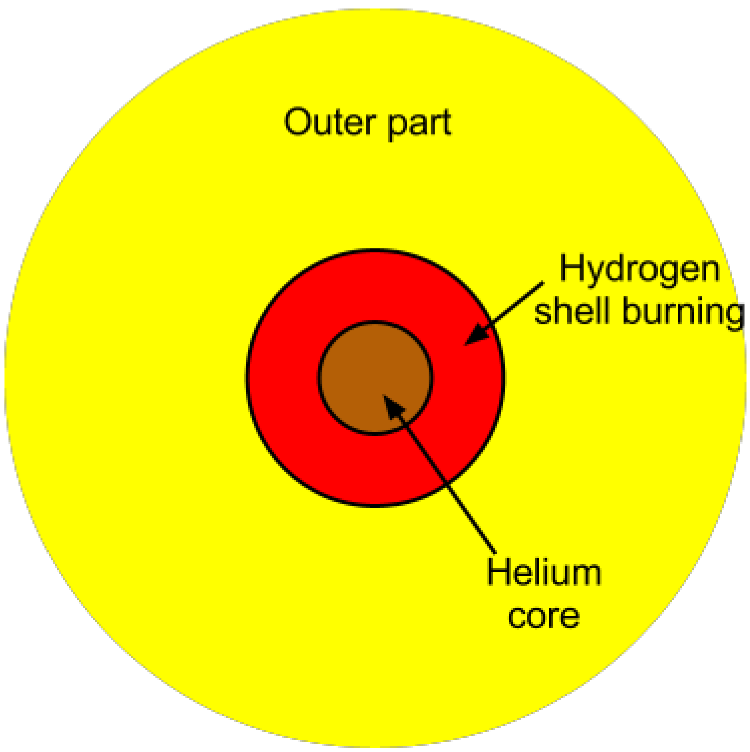
We've seen how stars shine, and there are at least a couple of ways they go about converting hydrogen to helium. In the process releasing a lot of energy, which is what makes them shine. You may have heard of the main sequence, which is a portion of a particular type of graph where most stars sit. It is the Hertzsprung Russell diagram, and is the staple of a lot of visual astronomy. It was invented independently by Ejnar Hertzsprung, a Danish astronomer, and Henry Norris Russell, an American astronomer. It's also known as a colour-magnitude diagram (CMD). It's often the case if you mess around with data you start to see patterns appear, and this can be the first stages to understanding something.
All astronomy students now have to be able to draw them, and if you study astronomy in detail you'll come across many of them in different guises. There is a cartoon sketch of one here, just to see if I've still got it!



HR DIAGRAM

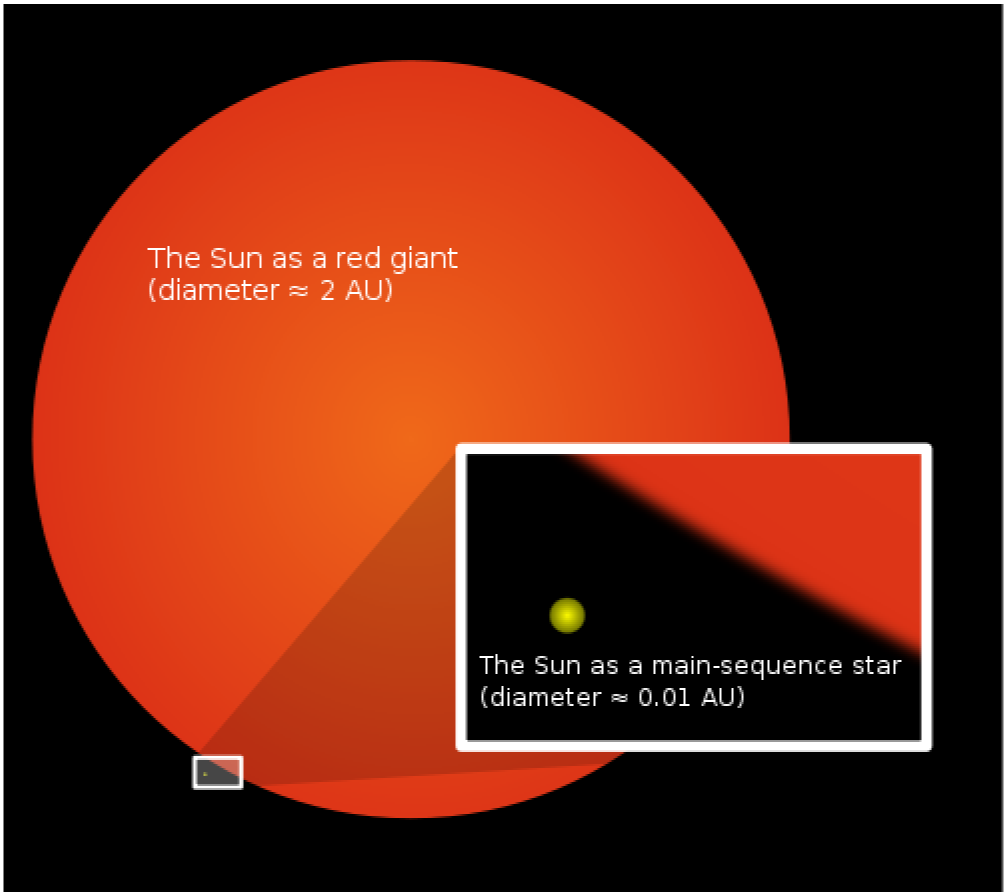
Its a plot of colour along the X axis with brightness along the Y axis of a graph. The colour of a star is tied very closely to temperature, so the bluer the star, the hotter it is burning, and in general the bigger it is. Both axes are log scales, so that means that things change greatly over the axis distance. When H&R first did this, they found stars tended to appear in groups, and strips.
Brightness, or luminosity as it is more commonly called, can be measured in many ways, but a common way is to use absolute magnitude. This is just working out how bright a star would appear if you were standing a certain distance away from it, 10 parsecs to be precise.

There is a big strip snaking across the graph called the main sequence. All the stars on this main sequence are burning hydrogen by one of the techniques discussed. This is where stars spend most of their lives. However as they get older, they start to have issues. There is increasing amounts of helium in the core as the result of fusion, clogging things up like fire ash. As the star gets to the end of its life, this core of helium starts to damp down the reactions, and instead it starts to burn in a shell of residual hydrogen around the core.



SHELL BURNING

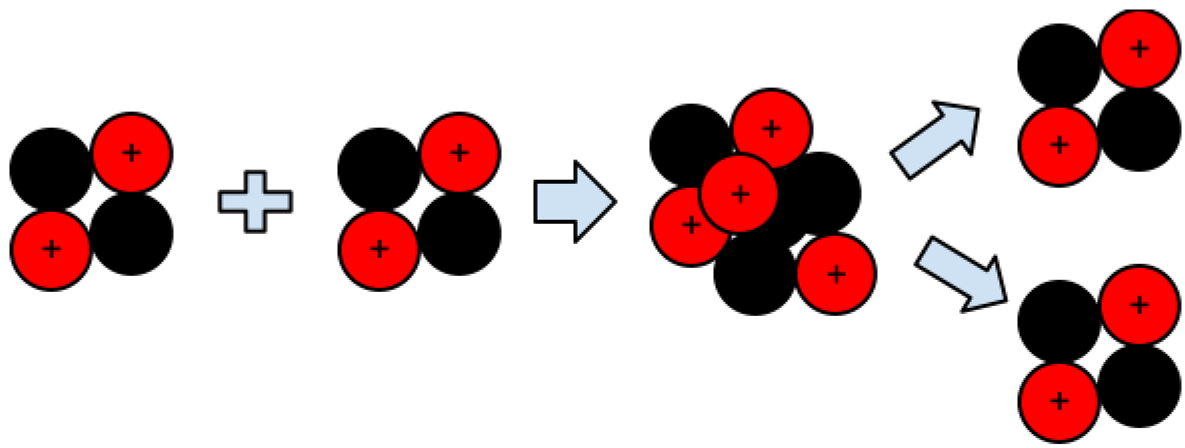
This forces the outer regions of the star outwards, and into what is known as a red giant. It swells up hugely, in the case of our Sun, when it's turn comes, maybe up to the orbit of the Earth. Its a case of middle age spread gone wild!



Wikipedia diagram showing how big the sun gets.

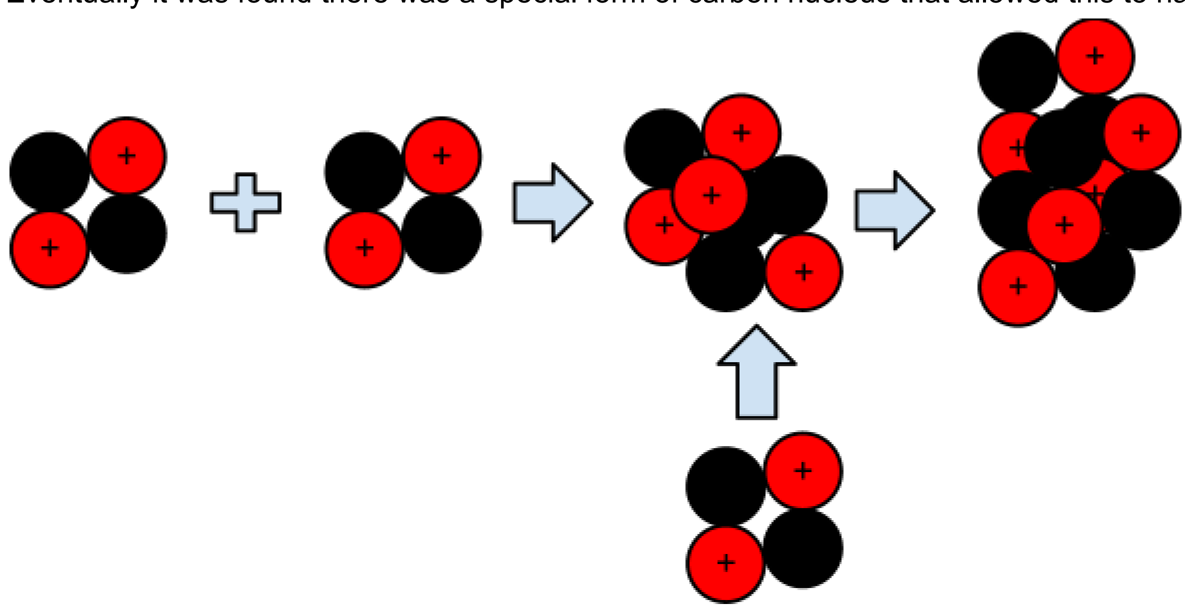
For small stars this is as much as they can do. However in stars like ours and bigger, things get more interesting. The helium in the core gets more and more squashed, and hotter and hotter. Soon it gets hot enough to attempt for the helium itself to start to fuse. Now helium doesn't give as much "bang-for-the-buck" as hydrogen fusion (we'll explore why in the next article), but beggars can't be choosers, its all it has left.

But - and there is always a but, the most obvious fusion doesn't work. Fusing two ^{4}He atoms together to make ^{8}Be (Beryllium) would seem the obvious step. However ^{8}Be is extremely unstable, falling apart into two ^{4}He in one quintillionth of a second. So this reaction actually consumes energy rather than making it.



He + He → Be → He + He

Luckily - there is a way, if conditions are hot enough and dense enough, you can get 3 ^{4}He nuclei to collide within a quintillionth of a second, and they can make carbon - ^{12}C. It turns out if you do the calculation, this seems very improbable to happen energetically. It was Fred Hoyle who suggested there must be a way this can happen, because there is a lot of carbon around. Eventually it was found there was a special form of carbon nucleus that allowed this to happen.



He + He → Be + He → C

This process is known as the triple alpha process, a ^{4}He nucleus being also known for historic reasons as an alpha particle. Stars that are burning helium are usually on a special part of the H-R diagram called the asymptotic giant branch, or AGB more commonly as its less of a mouthful. The rate of burning helium is very sensitive to temperature. The rate is proportional to temperature to the 40th power ($R \sim T^{40}$). This means if the temperature of the star doubles, the rate it burns helium would increase by a trillion times - a truly staggering increase!
In stars less than about 2.5 times this size of our own, the ignition of the helium burning phase is

quite dramatic. By the time it gets hot enough for the helium to burn, the core is so squashed that it has gone into a funny degenerate state, which once it does start to burn, it goes off at quite a rate. This degenerate matter burns very fast, so the whole core lights up in almost one go, in a process known as a helium flash. Given most solar processes take millions or billions of years, this is one of a few processes that happens in seconds. Despite that, it happens deep in the middle of a star, so nothing is seen outwardly :(

As I said, helium burning is not as efficient as hydrogen burning. It needs much hotter temperatures to start it, so it is not for everyone, and there is much less energy returned. It can keep a star burning for a bit longer though, typically about 10% of the time spent burning hydrogen. So for our Sun, that’s an extra billion years in the reserve tank.