Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Big stars.*

At least theoretically, it is quite possible that a higher order pan-dimensional being that can roam across the entire multiverse would be able to deduce from first principles that if you fill a universe with hadrons and that universe has particular default settings - like c the speed of light and alpha the fine structure constant - then you will end up with a universe where *it's full of stars*.

Stars come in all shapes and sizes... and ages. There are some white dwarfs out there that may be nearly as old as the universe itself. But a great many generations of much bigger and much shorter-lived stars have come and gone over the same period. And we are still really not sure just how big such stars can get. Debate still continues about whether the stars of the early universe where really big or whether you need metals, that is elements heavier than hydrogen and helium to make really big stars. On the one hand the early universe was more dense - creating opportunities for larger volumes of stuff to clump together - but on the other hand the early universe was much hotter. Many theorists doubt that hot ionised hydrogen could clump very effectively and what you really need is cool stable molecular hydrogen, or $H_2$. This $H_2$ does seem to be the main constituent of the stellar nurseries where stars get born in our modern universe.

The presence of metals produced by previous generations of stars, probably assists the local cooling of raw hydrogen by absorbing extra radiation. So it may be that the first stars in the universe were small - and it's the ones we see today that are the really big ones. We probably need the James Webb Space Telescope to put this particular controversy to bed.

In any case, today there are some mighty big stars out there. The biggest star we know about, in terms of size, is VY Canis Majoris which may be close to three billion kilometres in radius - meaning it would occupy the orbit of Saturn in our Solar System... but that is partly because it's a red giant, or a red supergiant to be more specific. When the Sun goes to red giant in about five billion years it will grow to 300 million kilometres in radius and hence occupy the orbit of the Earth - so arguably VY Canis Majoris is kind of cheating.

It's kind of cheating because VY Canis Majoris wasn't nearly as big when it was a main sequence star. If we define the biggest stars in terms of mass instead of volume, the story changes. The confirmed most massive star is NGC 3603-A1a at 116 solar masses - which puts VY Canis Majoris in its place, since it is only 30 or 40 solar masses. And we have even detected a star which seems to have an estimated mass of around 265 solar masses, R136a1 - which is what some people would call an impossibly massive star.

You see, some say that you can't have stars bigger than about 150 solar masses because there should be a point beyond which no star can assimilate more mass. This is because the more massive a star gets, the hotter and more luminous it gets - until you reach a point where a star's radiation pressure exceeds its self-gravity - so it just blows off mass as stellar wind. And here we are talking about some serious stellar wind.

If it's true that R136a1 has a mass of over 265 solar masses, then it may have had over 300 solar masses in its earlier life - and it can be expected that it will continue blowing of huge amounts of mass until it has lost more than 50% of the mass that it started with.

Once very massive stars have blown off lots of mass in this manner, they become surrounded by thick clouds of gas, which we call wind nebulae - and we call stars with such wind nebulae Wolf-Rayet stars. Most confirmed Wolf-Rayet stars are well below 150 solar masses. Indeed, most stars that have initially been estimated to have more than 150 solar masses have subsequently had their masses revised downwards as measurement technologies have improved.

It's thought that a star greater than 140 solar masses will destroy itself relatively quickly as a pair instability supernova, where quantum effects prevent the star's radiation pressure from holding back the star's collapse. Less massive stars will undergo a conventional core collapse as they grow an iron core within themselves that will collapse when it reaches its Chandrasekhar limit - and the more massive the star is the quicker this limit will be reached.

It's thought that any star above about 40 solar masses doesn't live long enough to ever make it to red giant phase and goes to hypernova - an explosion about 100 times more luminous than a standard supernova. A hypernova produces a black hole and two brief but very intense gamma ray bursts from each pole.

Below 40 masses, big stars do persist long enough to produce red giants and supergiants - and weighing in right at the upper limit is VY Canis Majoris - which may well be one of the biggest red supergiants in the universe. But since it is this massive, VY Canis Majoris is still going to go supernova sometime. Most of the mass of a red giant remains concentrated in its core which is where all the action is.

Stars go to red giant because the hydrogen fusion in a star's core puffs the star out, but this effect weakens as hydrogen supplies run low - this makes the star's volume contract - and that makes the core hot enough to start fusing the helium that has accumulated around it. Helium fusion is a much more energetic process than hydrogen fusion - so a more powerful radiation pressure puffs the star right out - although it really is just the outer layers that get puffed out in this way.

Since any star over eight solar masses can be expected to go to supernova, then any red giant over eight solar masses will go supernova too. And like we said before any star over 40 solar masses won't even make it to the red giant phase. And of course stars under eight solar masses will still go to red giant - they just won't go to supernova. This is the ultimate fate of the Sun and any stars bigger than 0.5 solar masses - any less mass than that and you just get red and brown dwarfs.

**But anyway, could you really get a star over 150 or even 300 solar masses - which R136a1 allegedly is?** If more massive stars like R136a1 are real they might be a result of two big stars that merged to form a huge and unstable star that won't last because it will blow most of its mass off as stellar wind or otherwise it will go to supernova.

The merger of two massive stars into one humungously massive star is a very unlikely event, since massive stars are pretty rare to start with - but in a universe this big and with this many stars - very unlikely scenarios will tend to happen somewhere, almost inevitably.

In any case, there are some nearby massive stars that we have more reliable data about:

- Rigel, a blue super giant at 17 solar masses. It's future is to become a red giant, then a supernova and then a black hole.
- Betelguese is a red supergiant with 1,200 times the radius of the Sun. Size-wise this puts it between the asteroid belt and the orbit of Jupiter and at almost 20 solar masses it's going to supernova sometime soon and leave a black hole behind.
- Eta Carinae is something else altogether. It's a binary system containing a more than 100 solar mass variable blue giant star that's already undergone a supernova impostor event in the year 1843 when it blew out a huge chunk of its initial mass, but this was really just a massive stellar hiccup. It also has a companion Wolf-Rayet star of around 30 solar masses. This is a system that has unstable hypernova candidate written all over it. Watch the skies.

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