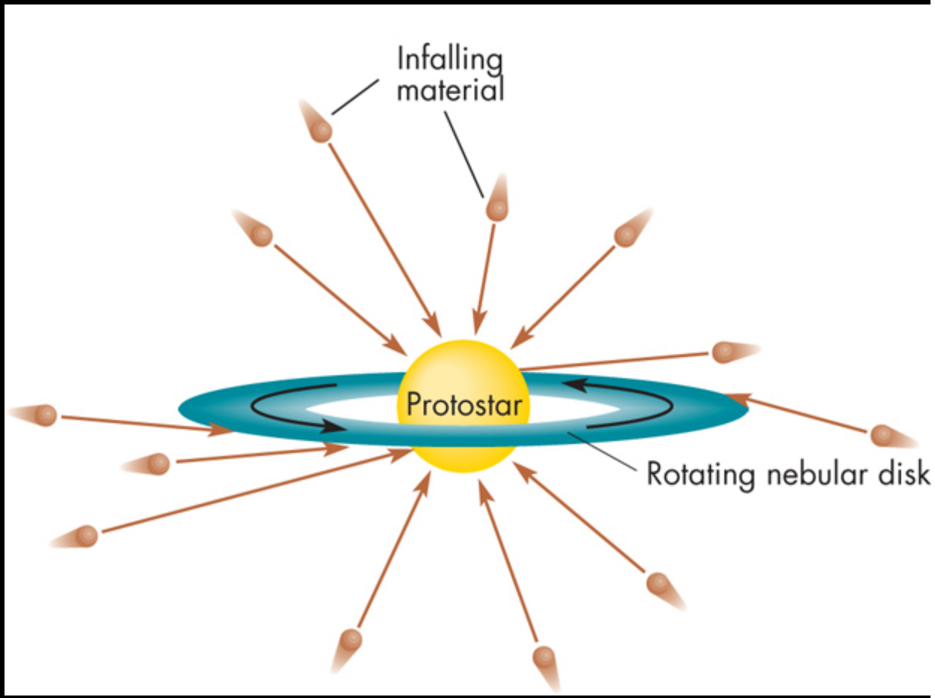
The Lives of Stars

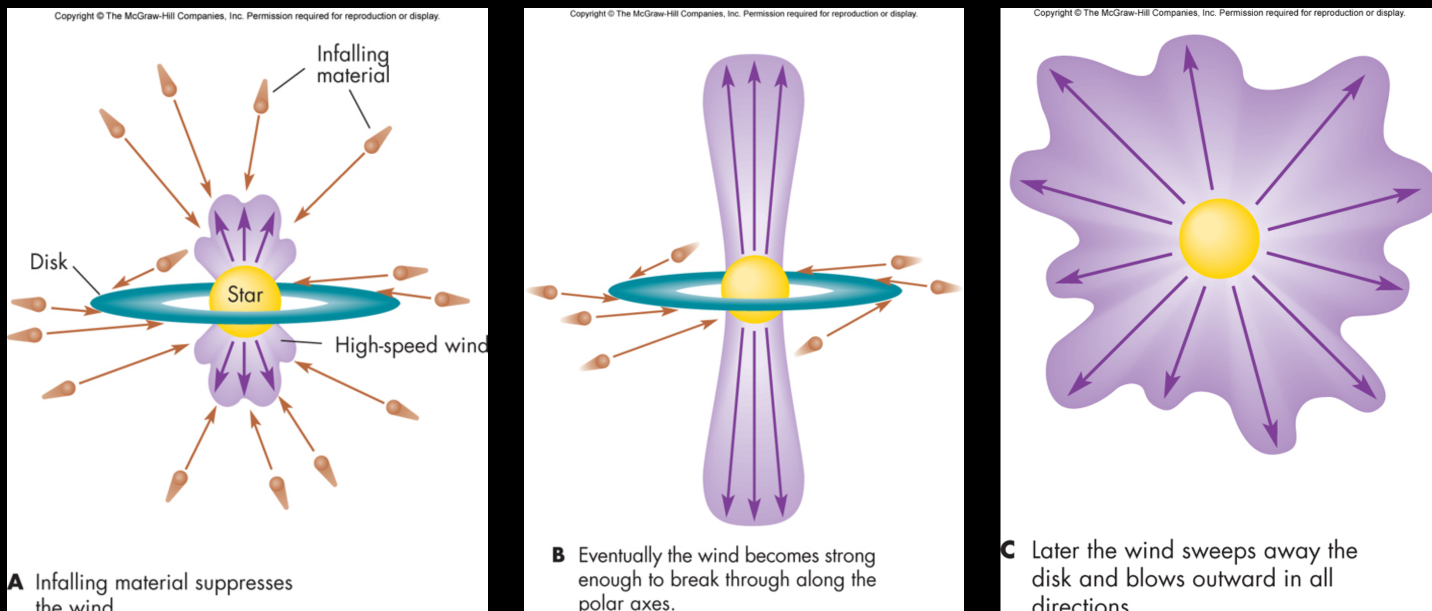
Reading: 18.2-4, 19.1-4

Formation from Solar Nebula



Protoplanetary disk in the Orion Nebula.
(image taken on 29 December 1993 with the HST's Wide Field and Planetary Camera)

Bipolar Flow and Stellar Winds



A Infalling material suppresses the wind.

B Eventually the wind becomes strong enough to break through along the polar axes.

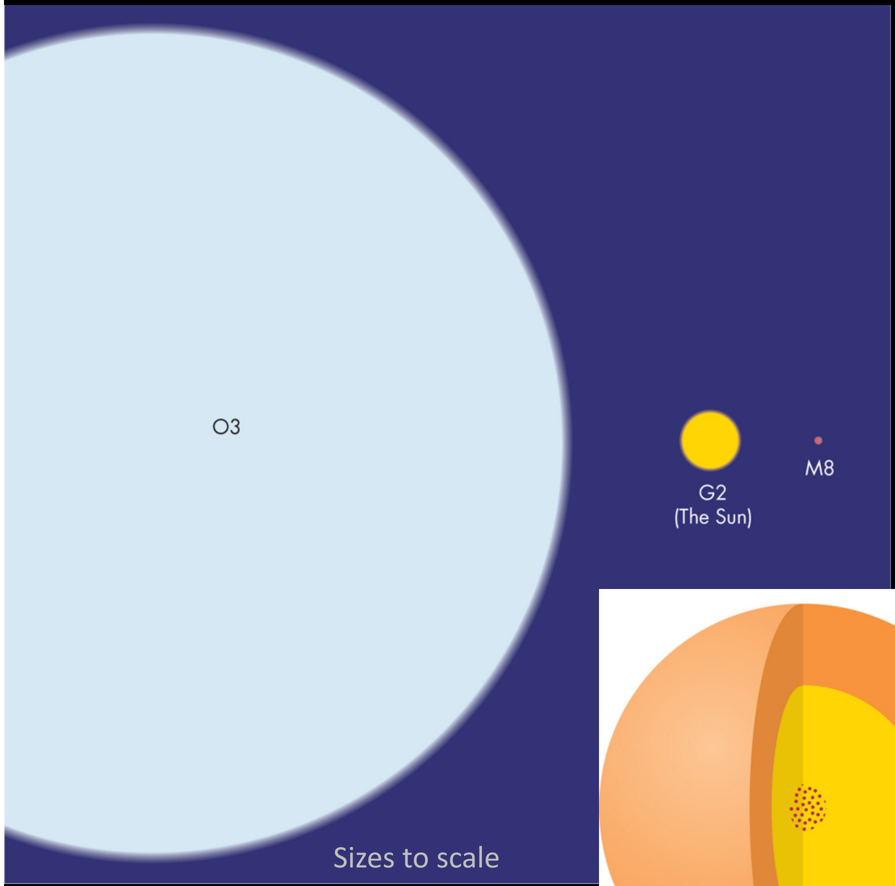
C Later the wind sweeps away the disk and blows outward in all directions.

#BAFact: Much like humans, when stars are babies they blow gas out of both ends.

Philip Plait
Mar 1, 2012

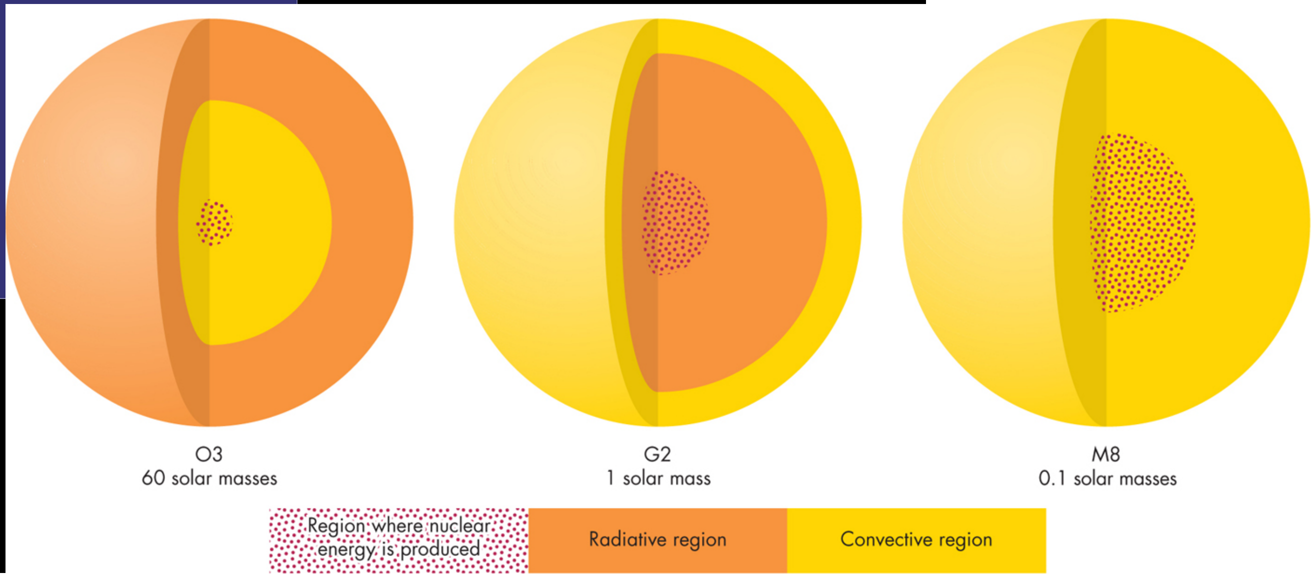
Herbig Haro 34 in Infrared / Spitzer Space Telescope

Other stars



Larger stars burn brighter, so generally both mass and size increase with spectral class (on the Main Sequence).

Sizes not to scale!



Lifetimes of Stars

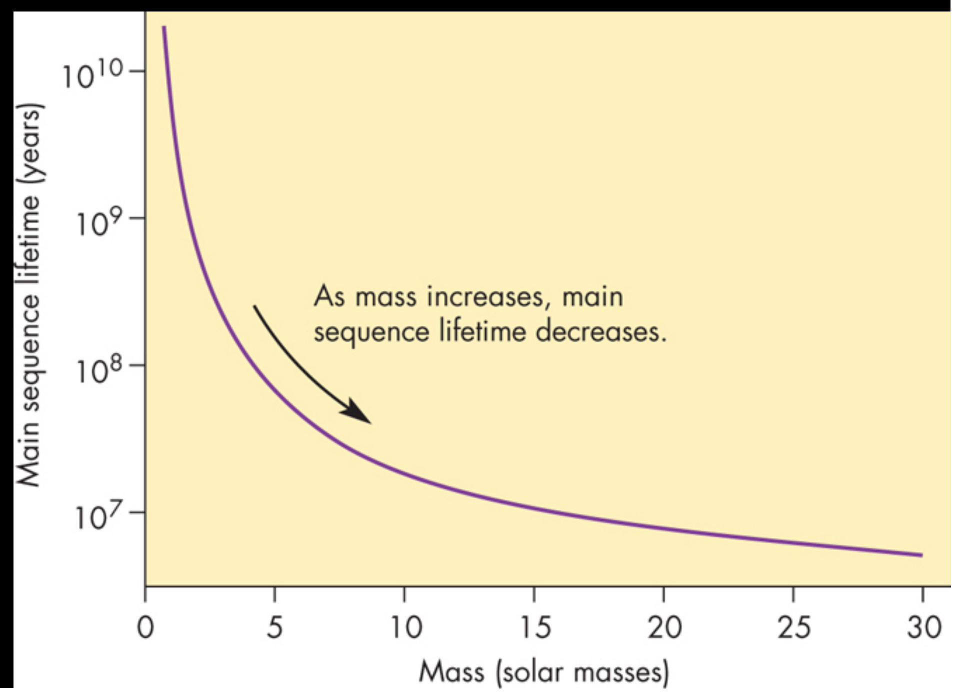
1) Larger stars have more fuel

2) Larger stars burn their fuel more quickly

Which of these "wins"?

Bigger stars burn fuel more quickly and thus have shorter lifetimes!

$$\frac{t}{t_\odot} = \left(\frac{M}{M_\odot}\right)^{-2.5}$$

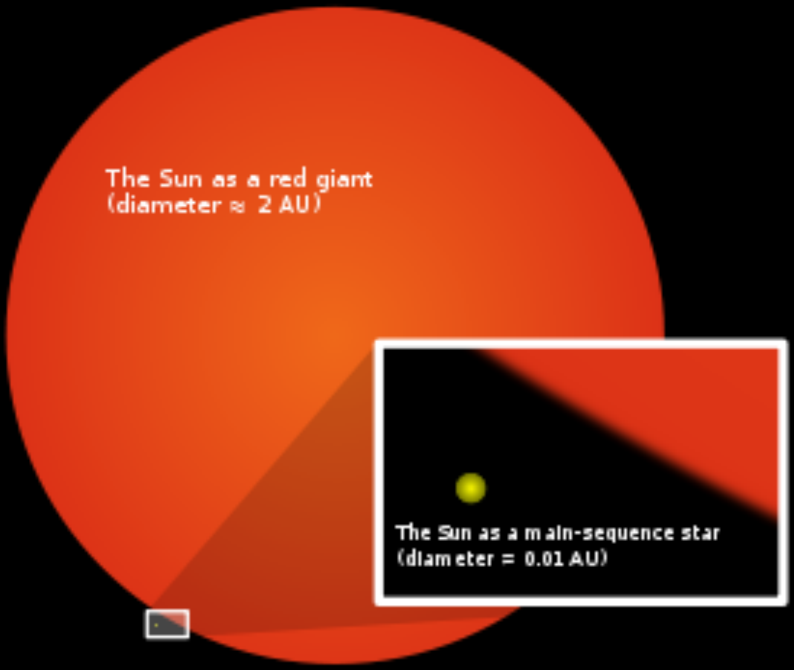


The Sun's story

The sun is now about 4.5×10^9 years old

When it is about 10×10^9 years old it will have used up 90% of the hydrogen

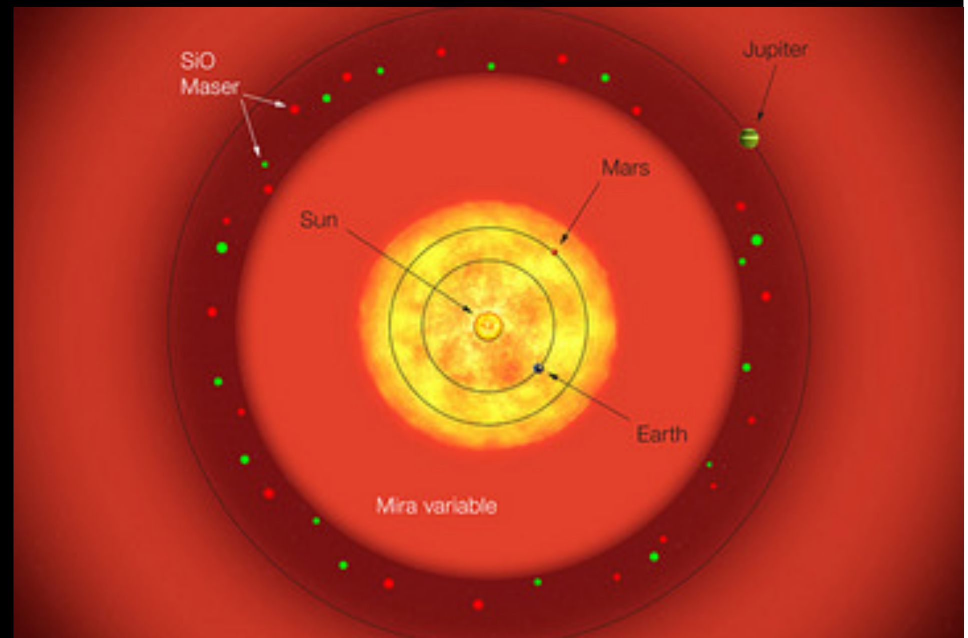
The core will shrink and grow hotter,
burning more Hydrogen.
The increased outflow of energy will push out the outer layers,
which will cool and become red.
The sun will become a "Red Giant".



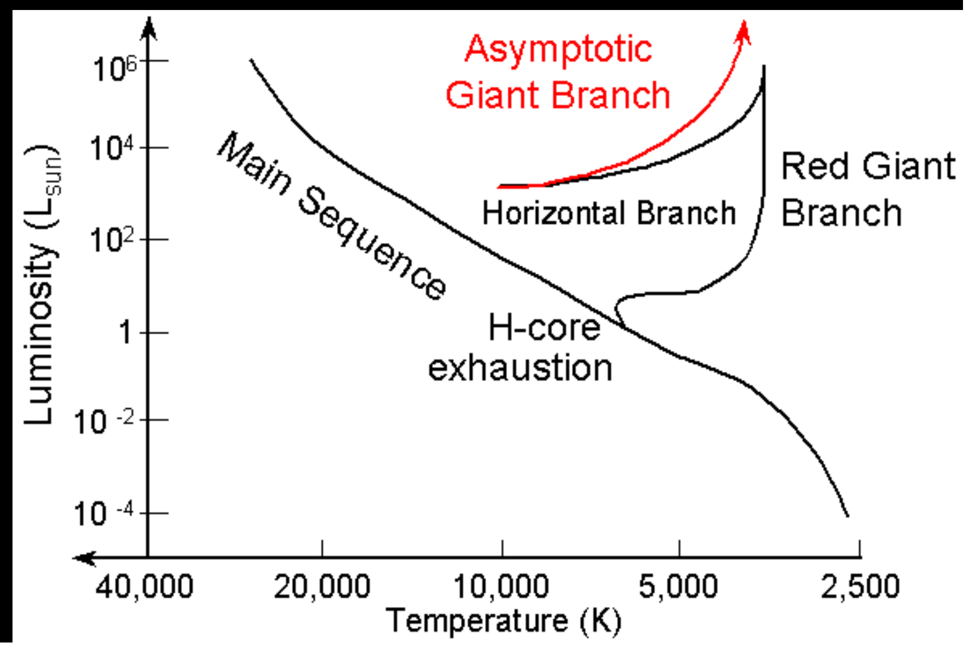
After another 10^9 years or so the core shrinks again, and becomes hot enough to "burn" Helium.

The sun will become a "Yellow Giant"

This star will pulsate.



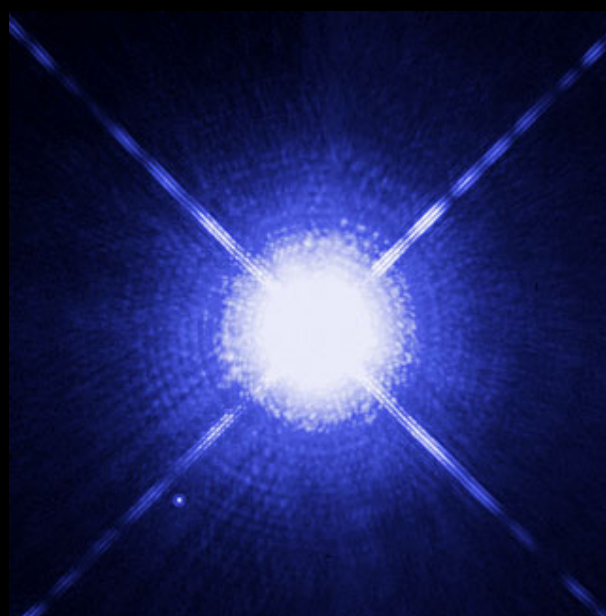
When the Helium is consumed the core shrinks again, the star grows again to an even larger, brighter Red Giant, called an Asymptotic Giant Branch (AGB) star.



The radiation from the inner core will blow the outer layers off the star, forming a *planetary nebula.*

The Cat's Eye nebula (NGC 6543) Composite image using optical images from the HST and X-ray data from the Chandra X-ray Observatory

The inner core, very hot but with no more fuel to burn, becomes a tiny *White Dwarf* star

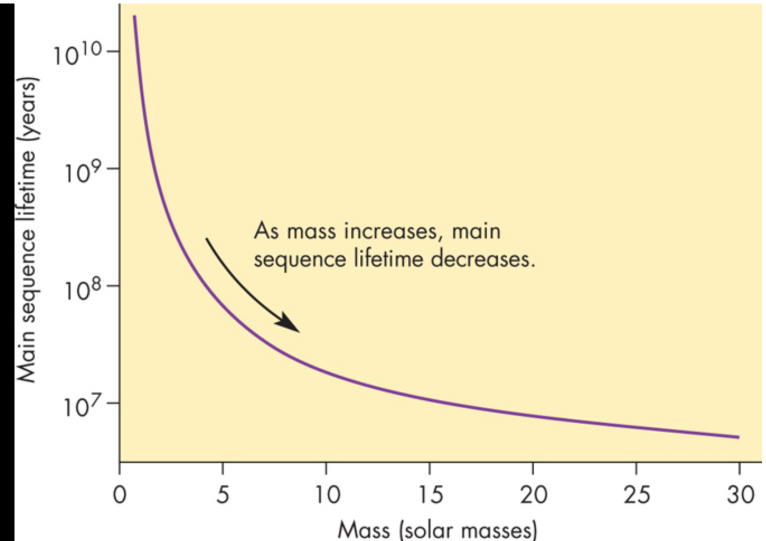


Sirius A and Sirius B

The sun dies with a whimper, not a bang.

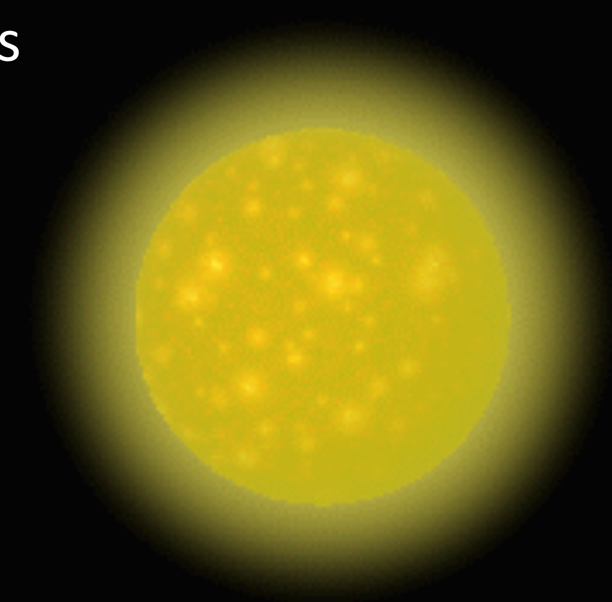
Larger Stars

If a star is larger, about 8 or 10 $M_{\odot}$, the story has a different ending



The larger star has more mass, so more luminosity, and burns much more quickly. Hydrogen is depleted in less than 10^8 years (100 Million years)

The star becomes a pulsating Yellow Giant



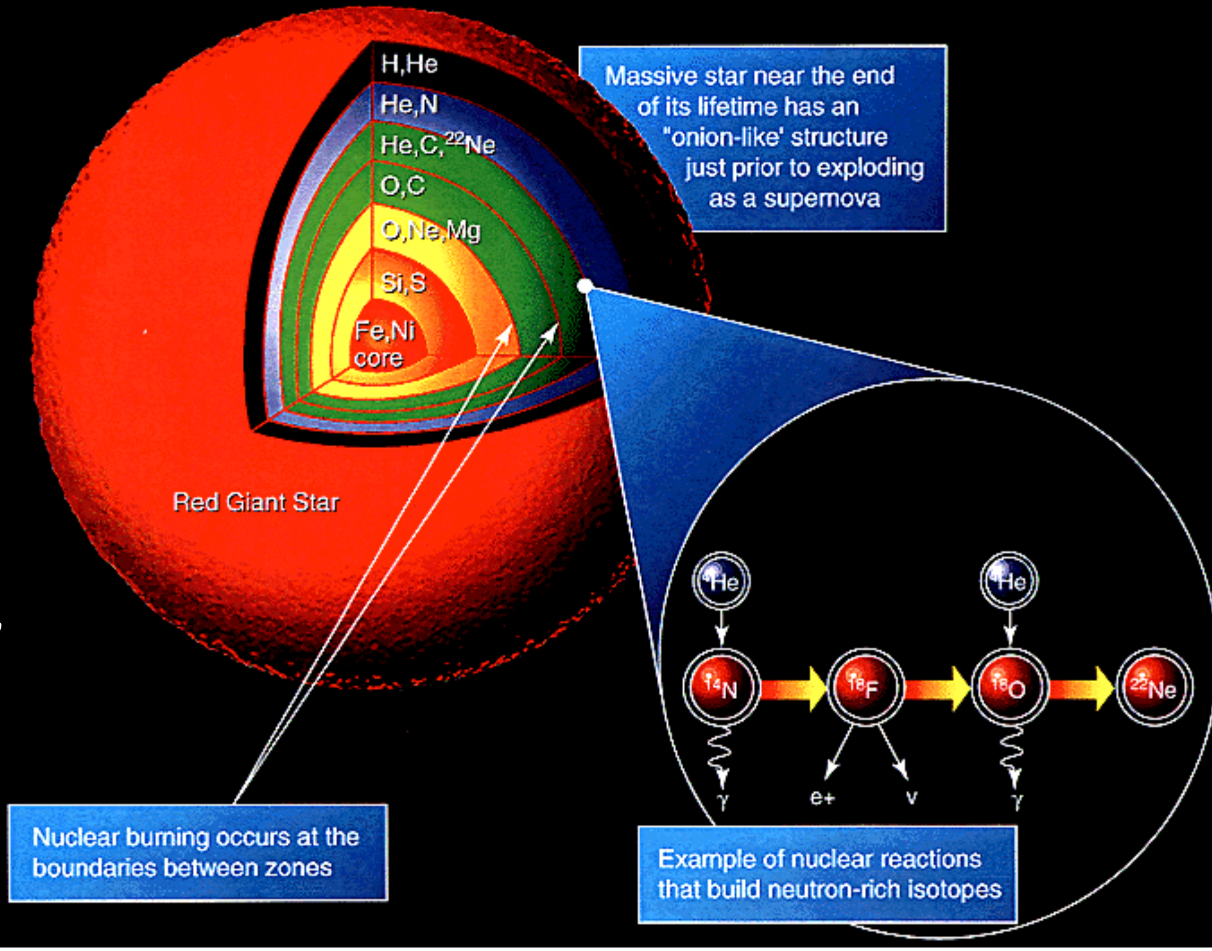
and then it too becomes a Red Giant

Stellar Nucleosynthesis

The larger star burns Helium into Carbon and Oxygen, then forms Neon and Magnesium…

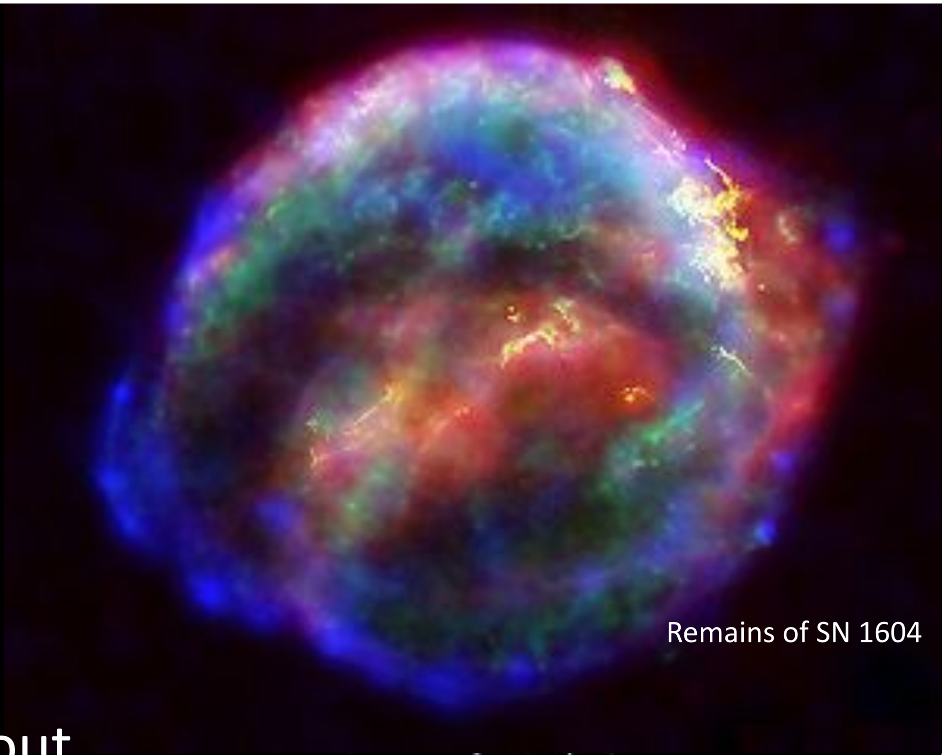
…eventually the star creates Silicon, and then Iron

Iron cannot be “burned”
(further fusion reactions do not release energy)



Supernova!

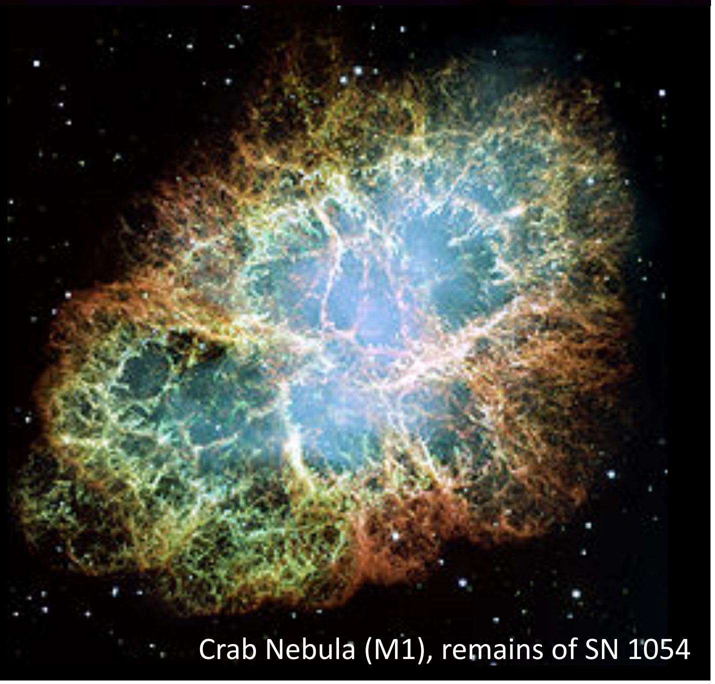
The core cannot support itself or the mass above it, and so it collapses.



Remains of SN 1604

The collapse "rebounds" as a huge explosion, scattering the elements out into space.

The remaining core is a *neutron star*, which might also be a *pulsar.*
Or it could form a *Black Hole*.

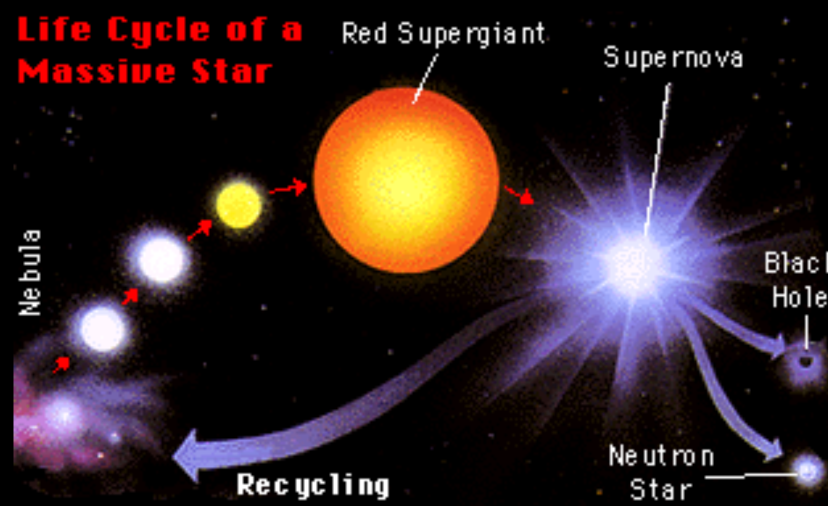


Crab Nebula (M1), remains of SN 1054

Larger mass stars end with a bang, not a whimper

Stellar Nucleosynthesis II

Elements heavier than Iron are formed in the fireball of the supernova by fusion and neutron capture.



The mixture of newly created elements go into molecular clouds to become a new generation of stars – the ultimate in Recycling.

The Carbon, Silicon and Iron found on Earth were all created inside a Red Dwarf star (or stars).

The Lead, Gold, Silver, Uranium and other heavy elements were created in a supernova explosion.

Neil DeGrass Tyson:
The most astounding fact…

Earth and almost everything on it, including us, is made of stardust.