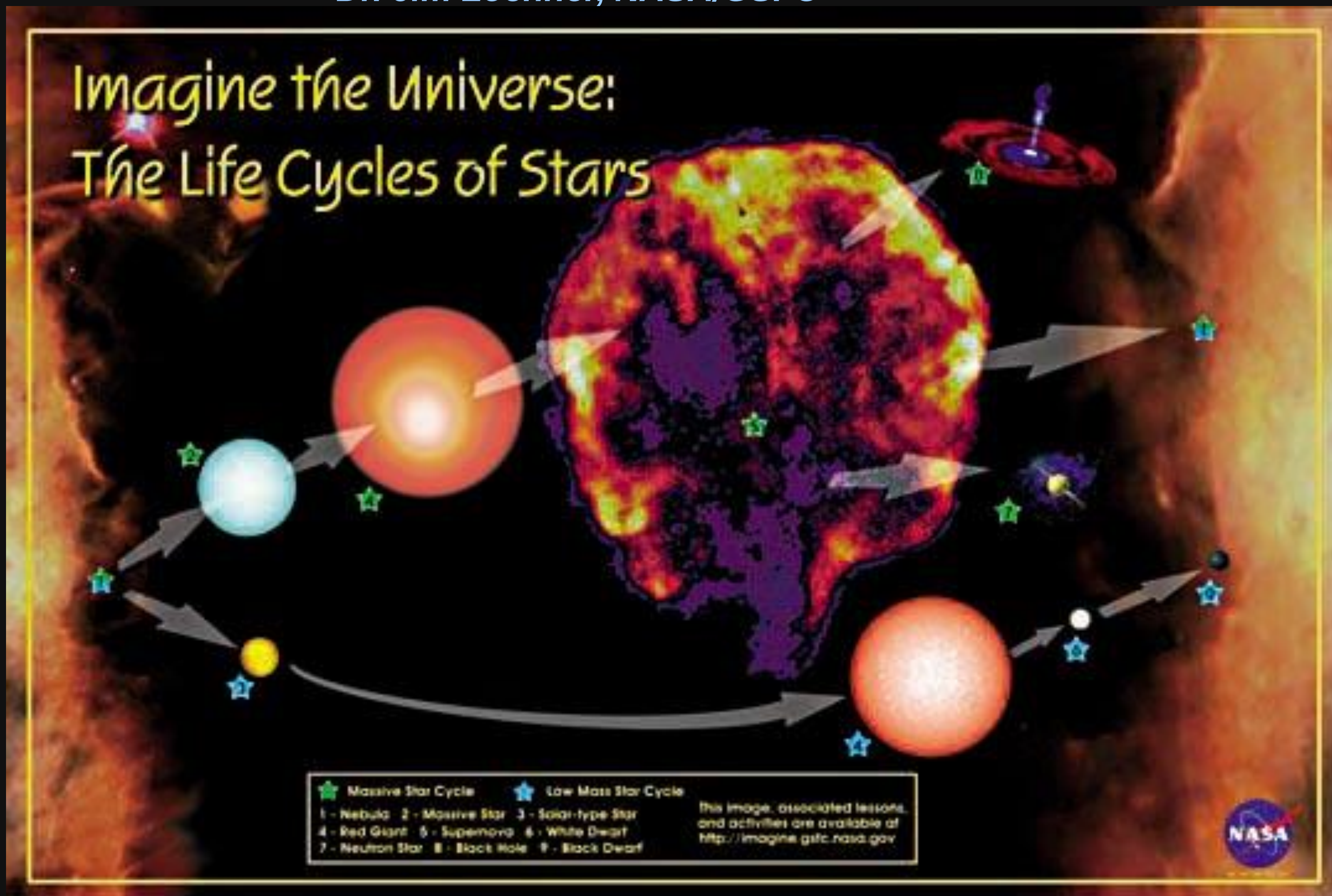
The Life Cycles of Stars

Modified from Information provided by:
Dr. Jim Lochner, NASA/GSFC



Twinkle, Twinkle, Little Star ...

How I Wonder What You Are ...

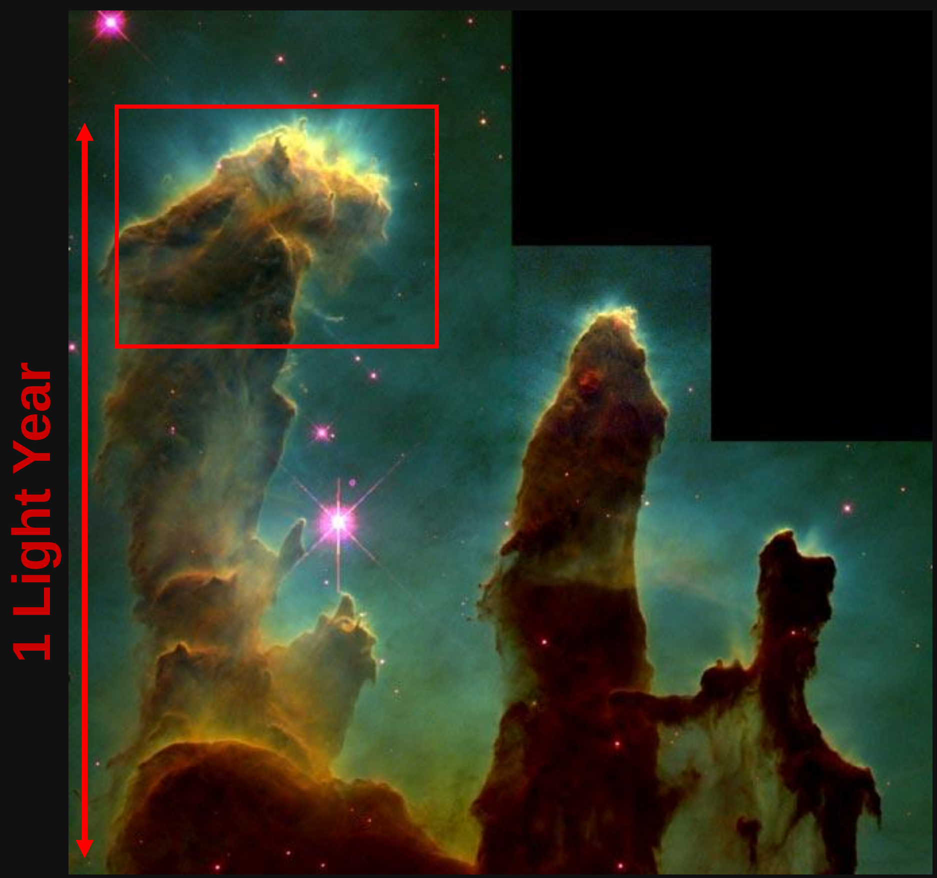
Stars have:

- **Different Colors**
  - **- Which indicate different temperatures.**

- **The hotter a star is, the faster it burns its fuel and the <u>shorter</u> its life span.**

Stellar Nebula

Space is filled with the "stuff" to make stars.



Movie from: J. Hester and P. Scowon (Arizona St. Univ.), November 2, 1995. Taken with NASA Hubble Space Telescope, WFPC2

The M16 "Eagle Nebula" – a birth place for new stars.

Stars start from clouds (nebula’s)

Stellar Nebula’s

NGC1977

Heart of Orion

Images from: http://www.robgendlerastropics.com/Nebulas.html

- provide the gas and dust from which stars form.
- can be light years in width.
- have no definite shape, and are either light or dark.
- have gases that run in chaotic currents all throughout it.

Collapse to Protostar

Nebulas → Protostars

- Stars begin to form by the slow accumulation of gas and dust.
- Gravitational attraction of these "clumps" attract more material.

$$F = \frac{Gm_1m_2}{r^2}$$

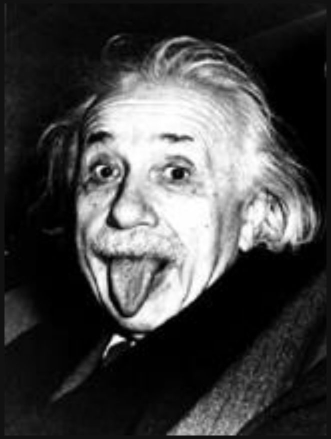
- Contraction causes Temperature and Pressure to slowly increase.

Nuclear Fusion !

When the temperature in the star reaches 15 million degrees Celsius, ***FUSION*** begins!

4(H) --> $^{4}He + 2\ e^{+} + 2$ neutrinos + energy

Where does the energy come from ?



$E = mc^2$

How much Energy?

$4(^{1}H) \rightarrow {}^{4}He + 2\ e^{+} + 2$ neutrinos + energy

Energy released = 25 MeV (1 mega-electron volt = 1.6 × 10-13 Joules)

$= 4 \times 10^{-12}$ Joules

$= 1 \times 10^{-15}$ Calories

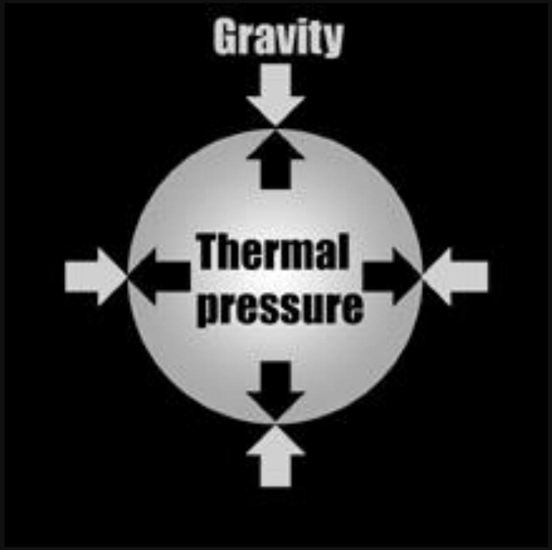
But the sun does this 10^{38} times a second !

Sun has 10^{56} H atoms to burn !

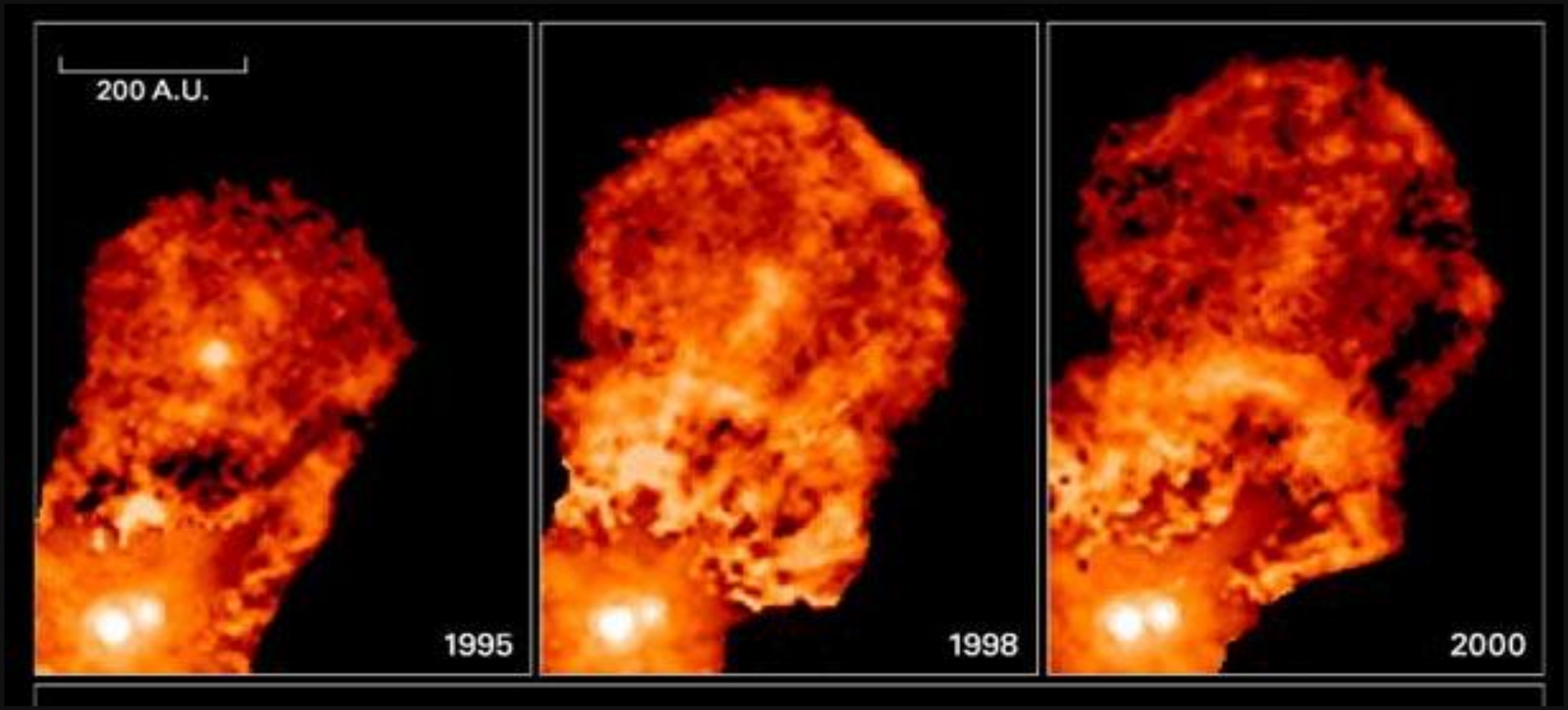
A Balancing Act

Energy released from nuclear fusion counteracts the inward force of gravity.

Throughout its life, these two forces determine the stages of a star's life.



New Stars are not quiet !



Expulsion of gas from a young binary star system.

(Note the size of the gas plume)

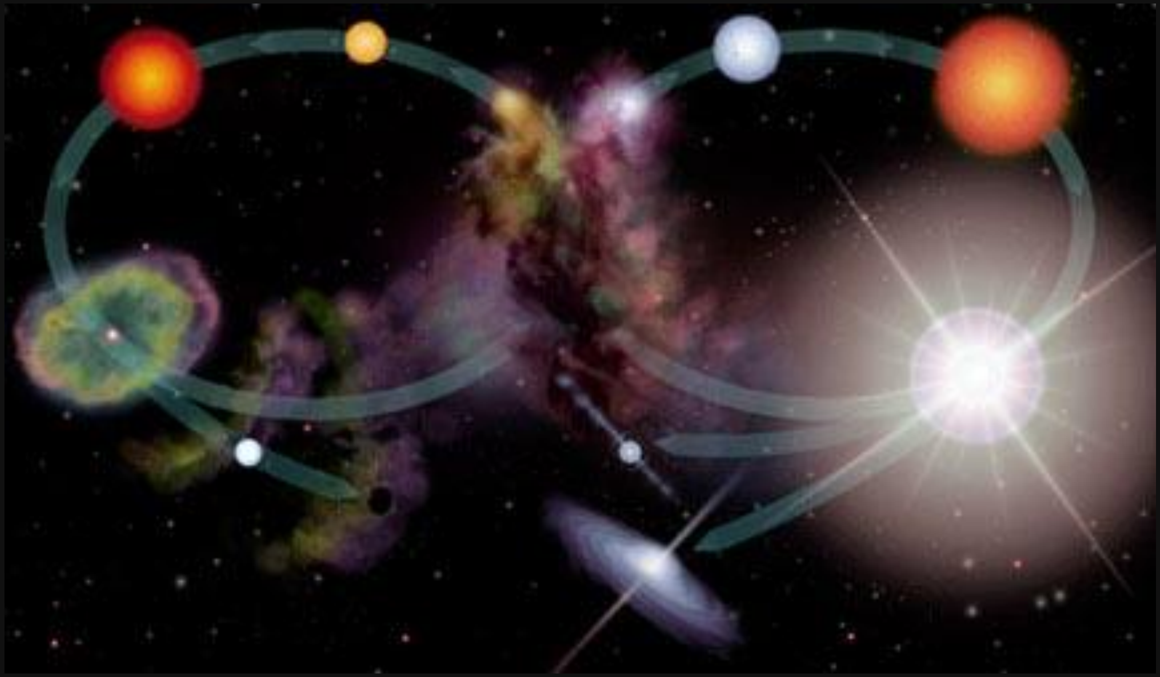
All Types of Stars

Remember:

Stars have Different colors

which indicate different temperatures

The Life Cycle of Stars



“Average” Stars (Sun-like)

Massive Stars

The direction a star takes is based on its MASS.

Fate of “Average” Stars

1) Main Sequence Stars (Sun - like)

- longest, most stable period of stars life.
- converts hydrogen to helium in its core
- generates heat and light.

A very active X-ray Sun (1991).

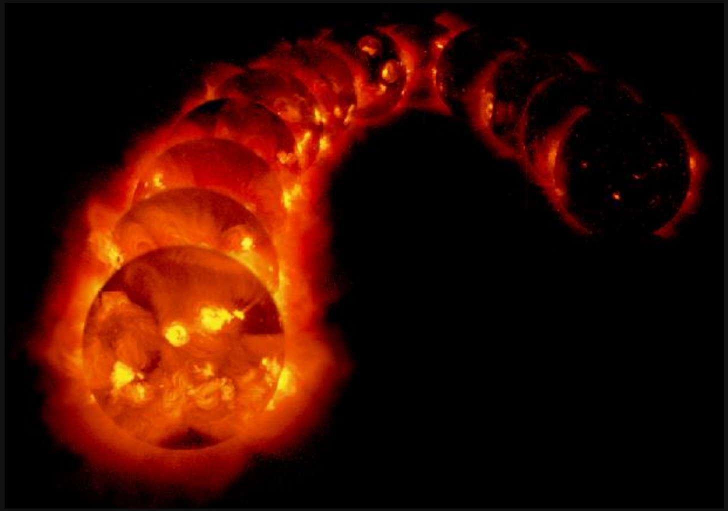
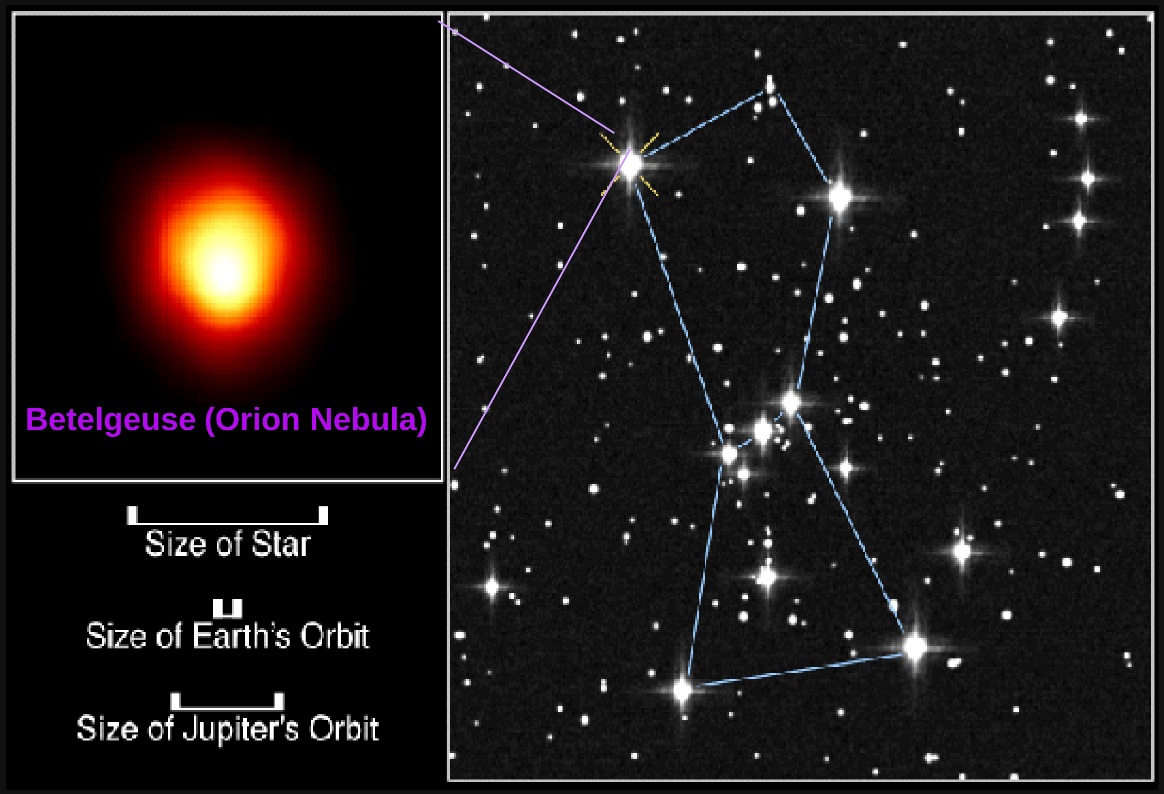


Image from:

http://solar.physics.montana.edu/YPOP/Spotlight/Tour/tour07.html

2) Red Giant Stage



- end of hydrogen fusion.
- core of the star is now hotter than it was during its "normal life".
- Thermal pressure (heat) causes the outer parts of the star to swell.
- radiation from the fusing shell has grown weak by the time it reaches the surface of the star.

Weak radiation is red on the electromagnetic spectrum, so the star becomes a "red" giant.

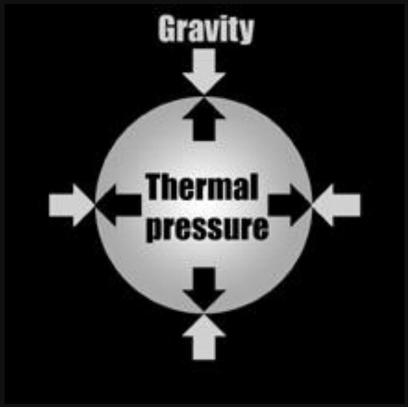
The Beginning of the End:

Red Giants

After Hydrogen is exhausted in core ...

Energy released from ***nuclear fusion*** counteracts inward force of gravity.

- This heat expands the outer layers.



Meanwhile, as the core collapses,

- Temperature and Pressure increase.

More Fusion !

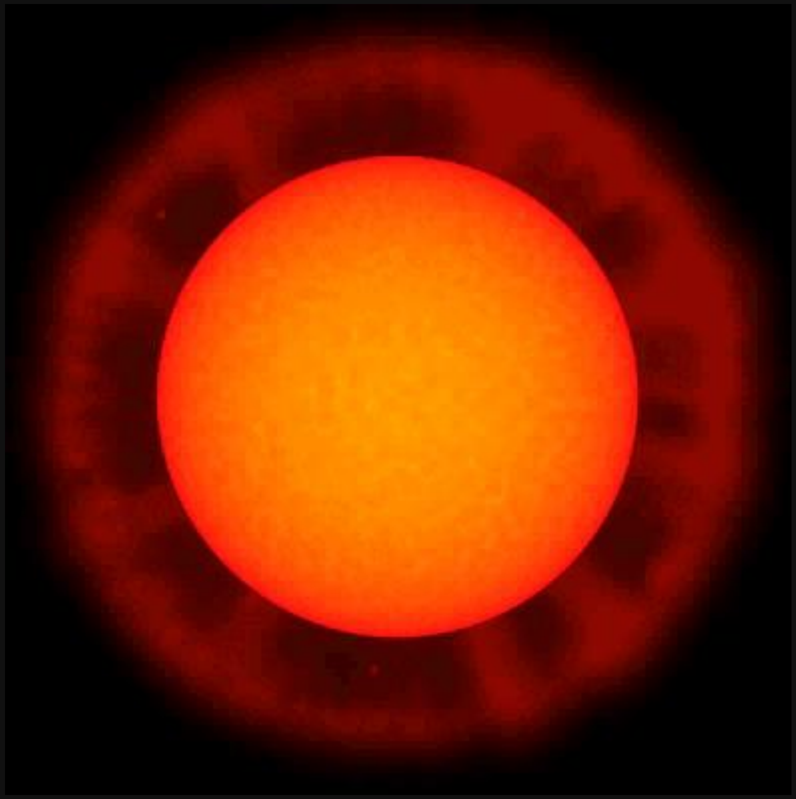


Image from:
http://www.historyoftheuniverse.com/starold.html

At 100 million degrees Celsius (C):

Helium fuses:

$3\ (^{4}He) \dashrightarrow {}^{12}C + \text{energy}$

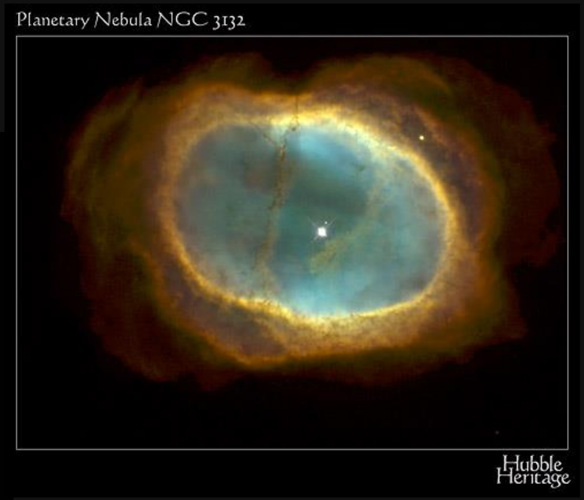
Nuclear energy (thermal pressure) sustains the expanded outer layers of the Red Giant.

The end for Sun-like stars:

3) Planetary Nebula

After helium fuel is exhausted, the outer layers of the star are expelled to form a:

Planetary Nebulae



The end for Sun-like stars:

3) Planetary Nebula

Images from:

http://www.noao.edu/image_gallery/.html

- forms when a star can no longer support itself by the fusion reactions in its center.
- gravity from the material in the outer part of the star forces the inner parts to condense and heat up.
- high temperature central regions drive the outer half of the star away in a brisk stellar wind.

The end result (s) of a Planetary Nebula:

4) White Dwarfs

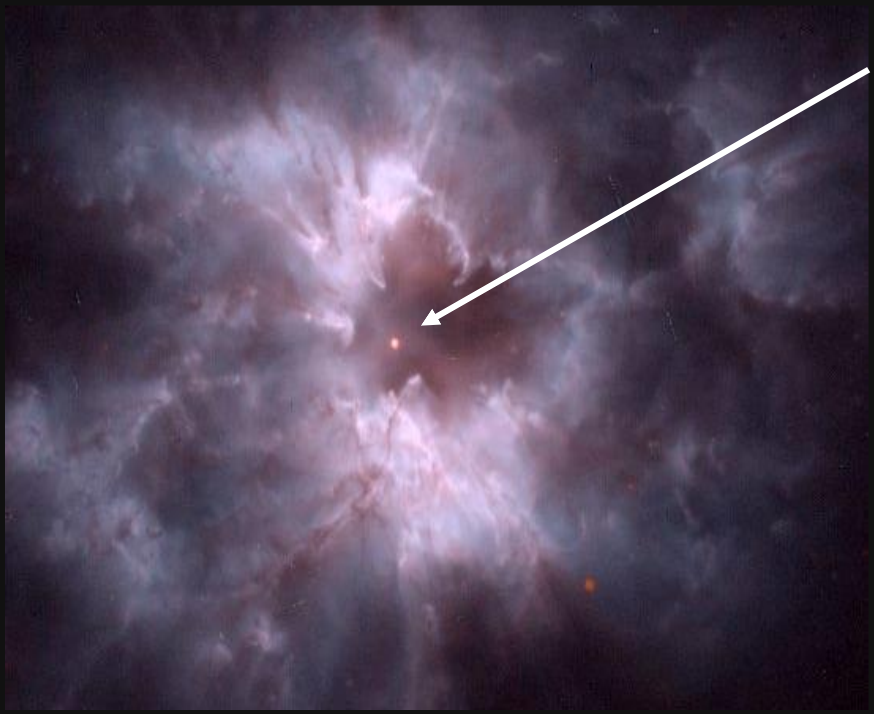


Image from: "Windows to the Universe"

http://www.windows.ucar.edu/windows.html

- the core of the planetary nebula remains intact and is exposed as a white dwarf.

- size of the Earth with the Mass of the Sun.

  "A ton per teaspoon"

- no longer able to create internal pressure, gravity crushes down until even the very electrons that make up a white dwarf's atoms are mashed together .

The end result of a Planetary Nebula:

5) Brown Dwarfs

- begins a long cooling period as it slowly radiates its heat to space.
- central temperature must be less than 3 million degrees.
- temperature of the outer part is around 1000 K - this will depend on its age. It will cool down as it get older.
- low surface temperature means that they are not very luminous.

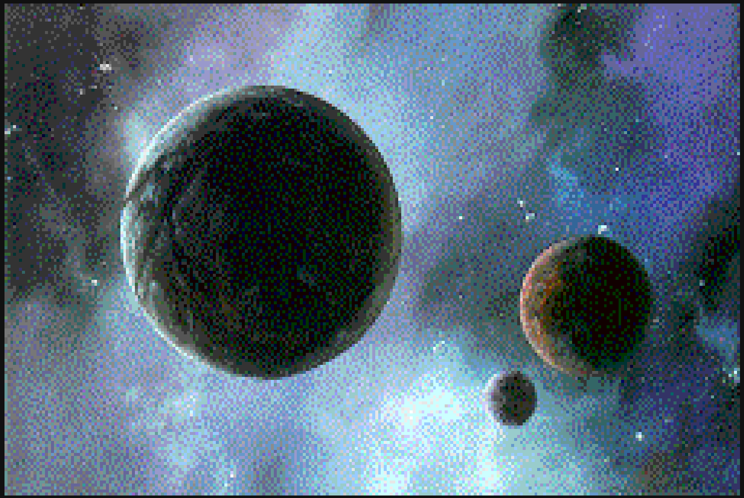
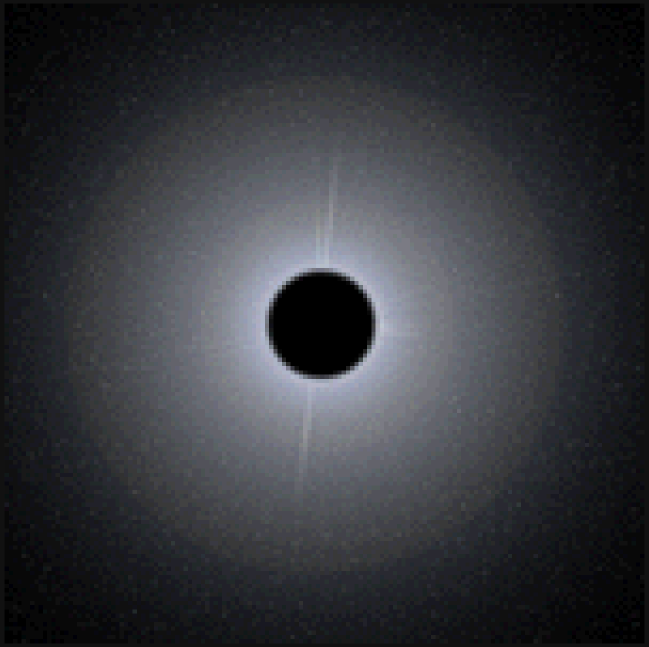


Image from: The Infrared Universe

http://www.ipac.caltech.edu/Outreach/Edu/missing.html

The end result of a Planetary Nebula:

?)Black Dwarfs (?)



- hypothetical end point for the evolution of an average star.
- takes tens-to-hundreds of billions of years for it to cool down entirely.
- the Universe hasn't been around that long--therefore there are no black dwarfs yet ….. but there will be in the future.

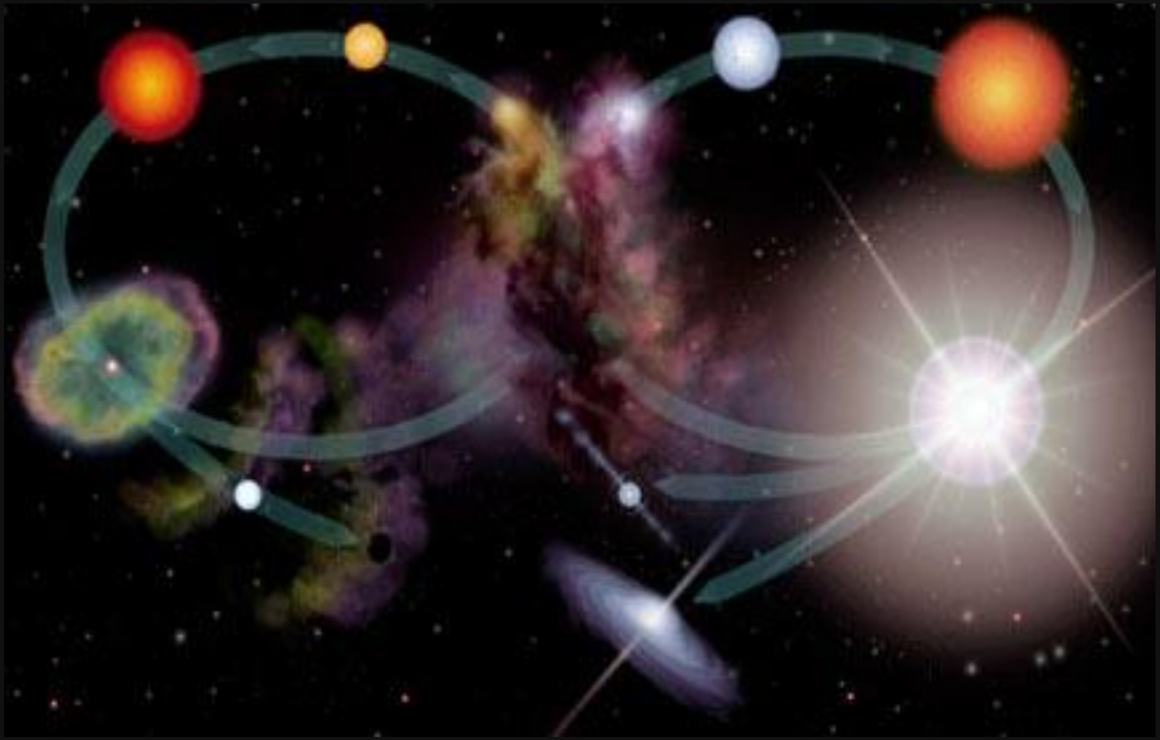
Brown Dwarf Stars

BDA Crash Course #28

Low Mass Stars

BDA Crash Course #29

The Life Cycle of: Massive Stars



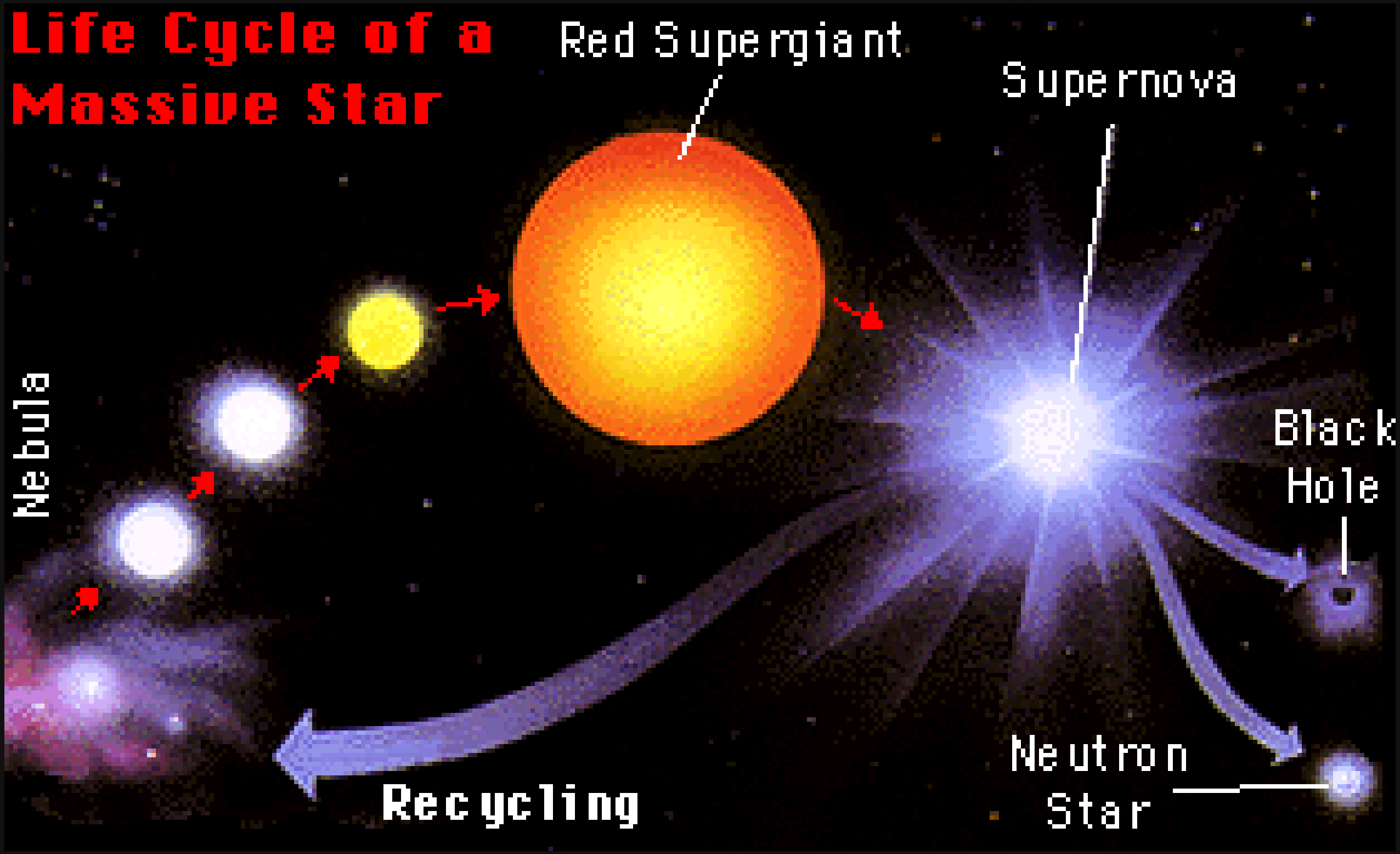
Massive Stars

Remember:

The direction a star takes is based on its MASS.

The Life Cycle of a Massive Star

Stages in the life of Massive Stars



Collapse to Protostar

Nebulas → Protostars

Just as with “average stars”:

- Stars begin to form by the slow accumulation of gas and dust.
- Gravitational attraction of these “clumps” attract more material.

$$F = \frac{Gm_1m_2}{r^2}$$

- Contraction causes Temperature and Pressure to slowly increase.

Fate of Massive Stars

After Helium is exhausted, the core collapses again until it becomes hot enough to fuse Carbon into Magnesium or Oxygen.

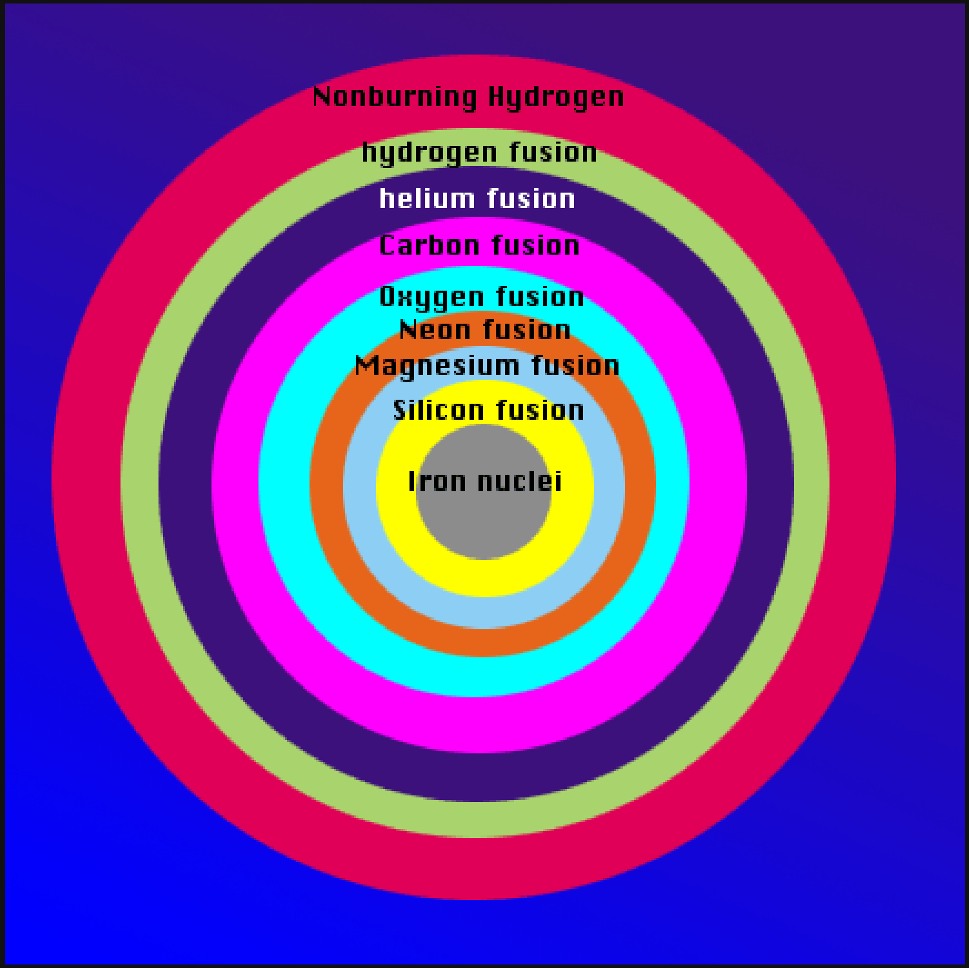
$^{12}C + ^{12}C \text{ --> } ^{24}Mg$

or

$^{12}C + ^{4}H \text{ --> } ^{16}O$

Through a combination of processes, successively heavier elements are formed and burned.

The End of the Line for Massive Stars

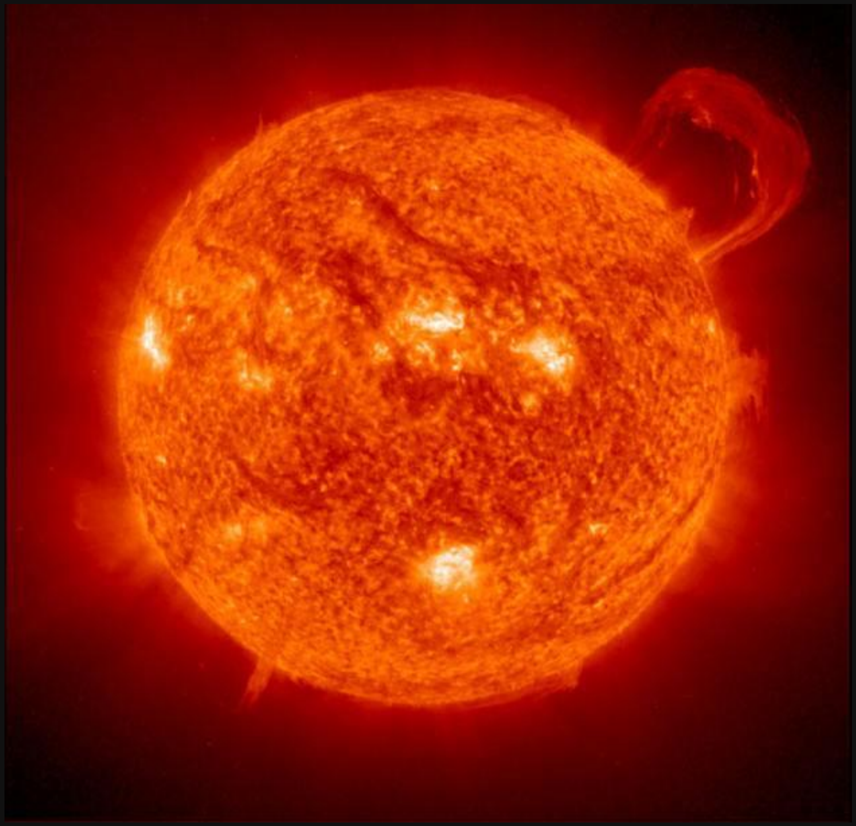


Massive stars burn a succession of elements.

Iron is the most stable element and cannot be fused further.

Fate of Massive Stars

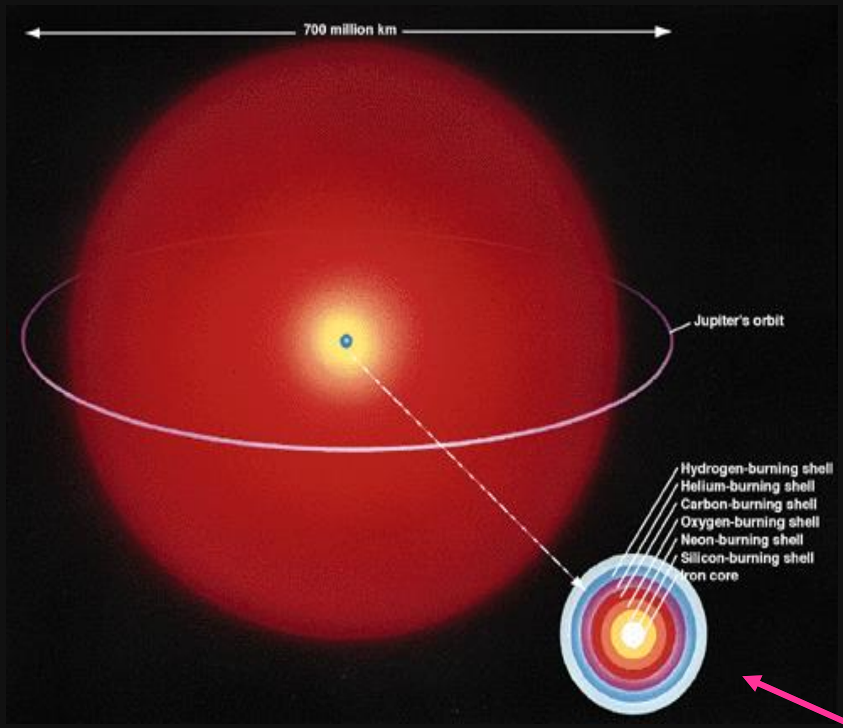
1) Massive Stars



- live their lives more rapidly than do solar-type stars, they …….. "live fast and die young."
- require higher central temperatures to balance the greater pull of gravity.
- more advanced nuclear burning stages producing a wider range of elements, up to iron.
- end their lives with a dramatic explosion, becoming either neutron stars or black holes.

Fate of Massive Stars

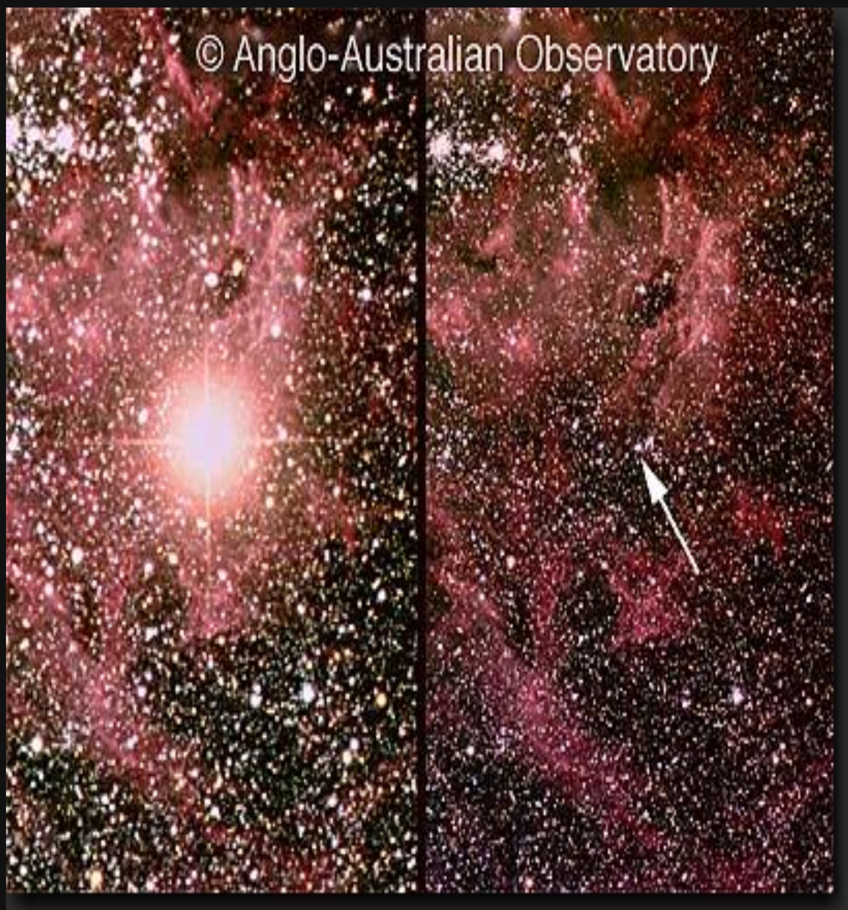
2) Red Supergiants



- enormous, cool stars with high luminosity.
- about 100 times larger than a red giant.
- hydrogen burns in outer shell around the core.
- heavier elements burn in inner shells.

Fate of Massive Stars

3) Supernova !

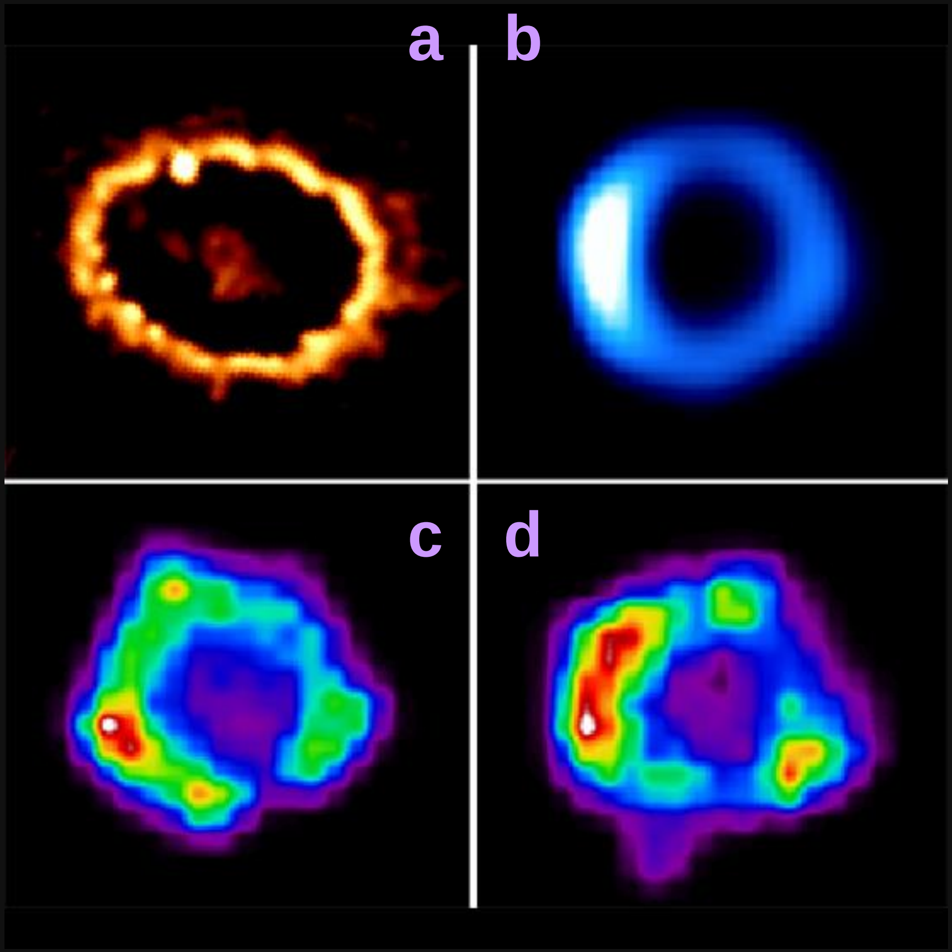


- occur when there is no longer enough fuel for fusion in the core of the star to create an outward pressure to combat gravity.
- core temperature rises to over 100 billion degrees Kelvin
- material that is exploded away from the star
- distributes heavy elements throughout the Universe.

Animation of a supernova explosion, ending in a pulsing neutron star

Animation from: http://imagine.gsfc.nasa.gov/docs/science/know_l1/supernovae.html

Supernova Remnants: SN1987A



a) Optical Image –
(February 2000)
Illuminating material ejected from the star thousands of years before the SN

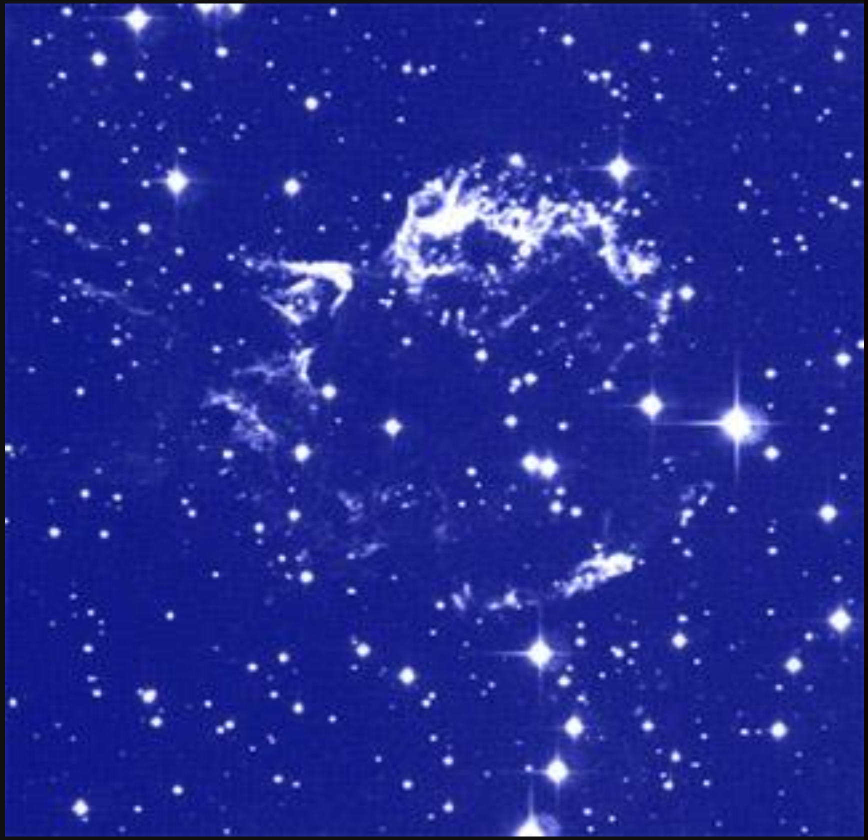
b) Radio Wave Image -
(September 1999)

c) X-ray Image - Oct 1999

d) X-ray Image - Jan 2000
The shock wave from the supernova heating the gas

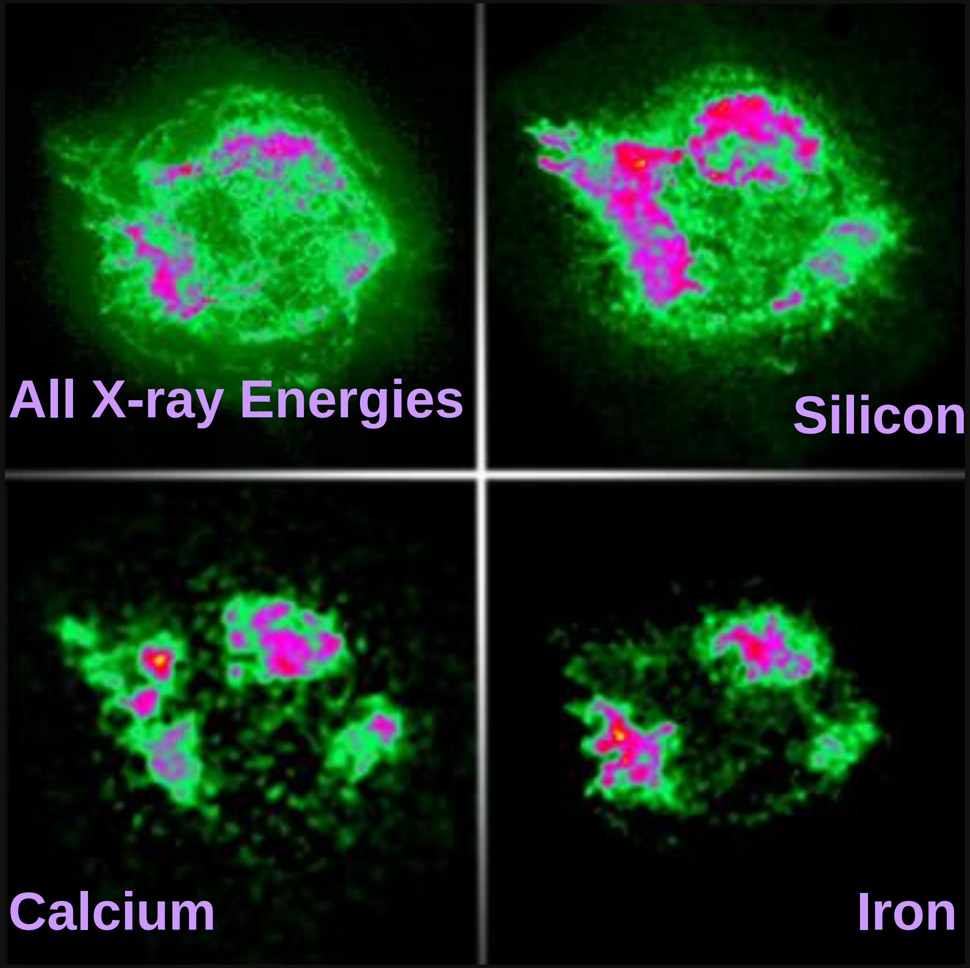
Supernova Remnants: Cas A

Optical Image



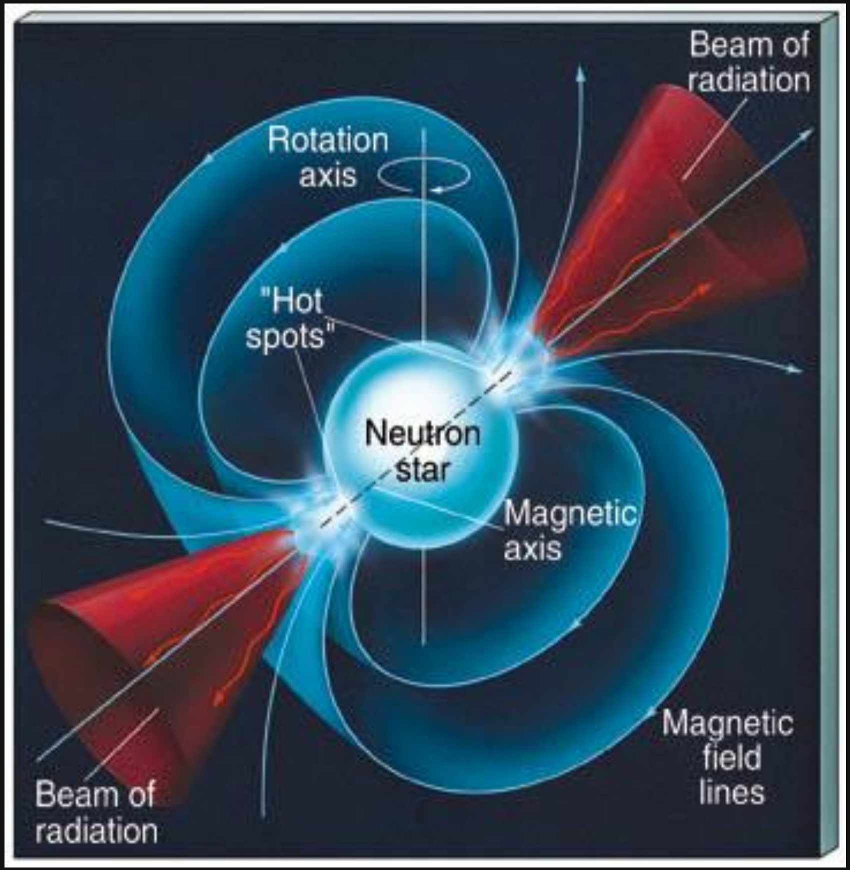
X-ray Image

Elements from Supernovae



What's Left After the Supernova:

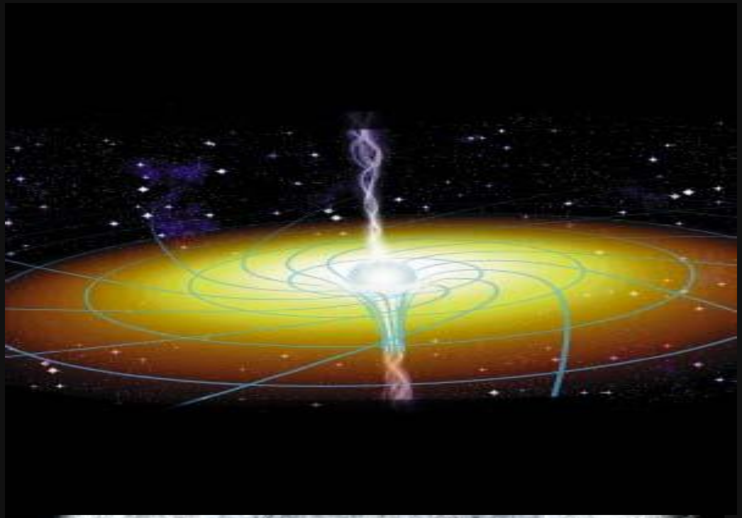
4) Neutron Star (If mass of the core < 5 x solar masses)

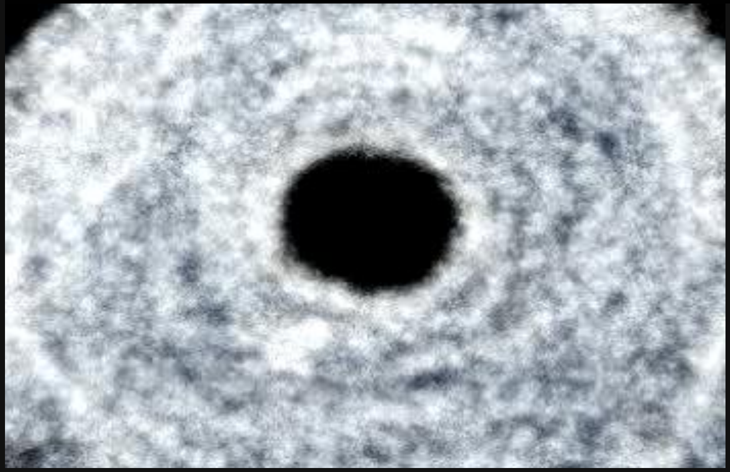


- are the collapsed cores of some massive stars.
- have the mass of our Sun into a region the size of a city (±10 km).
- start out as massive stars with 15-30 times the mass of our Sun.

What's Left After the Supernova:

5) Black Hole (If mass of the core > 5 x solar masses)

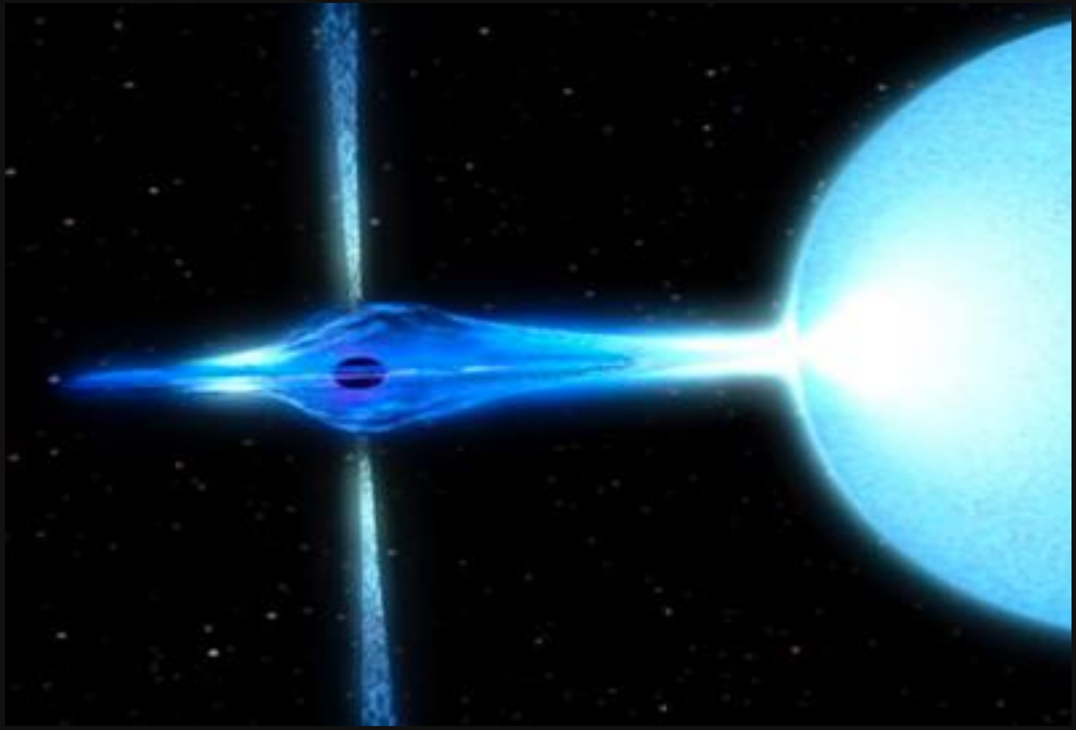




- is a region of *space-time* from which nothing can escape, even light.
- If a neutron star is too large, the gravitational forces overwhelm the internal thermal pressure gradients.
- the neutron star continues to shrink until it finally becomes a **black hole.**

A whole new life: X-ray binaries

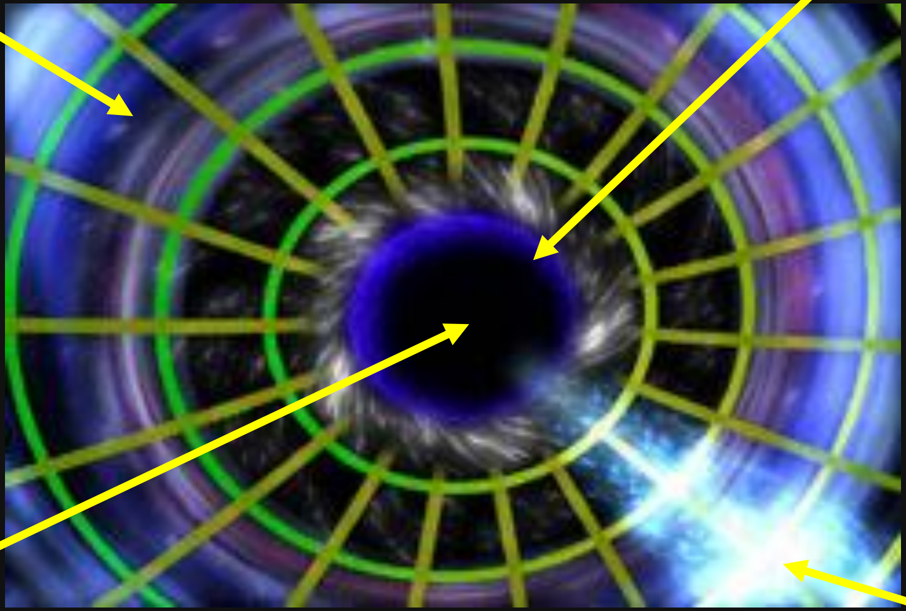
In a close binary systems, material flows from a normal star to a Neutron Star or Black Hole. X-rays are emitted from disk of gas around Neutron Star/Black Hole.



Black Holes - Up Close and Personal

Accretion Disk

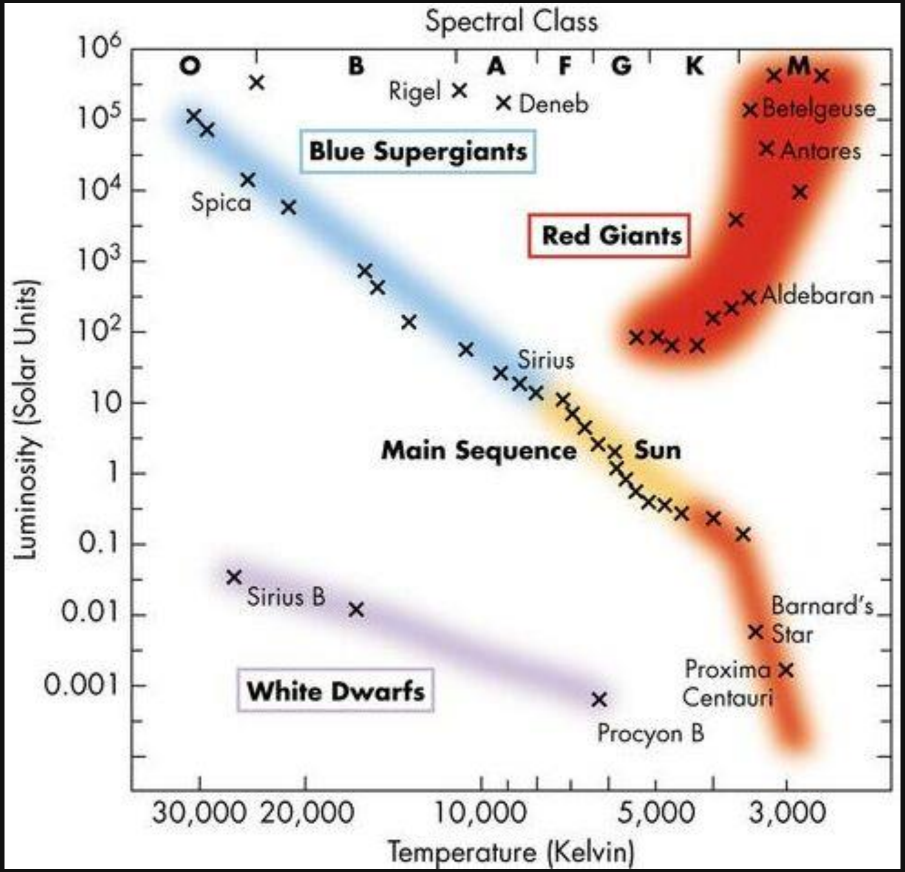
Event Horizon



Singularity
(deep in center)

Jet
(not always present)

All Types of Stars



The H-R Diagram:

Allows you to plot stars based on:

- **Temperature**
- **Luminosity**
- **Size**

*** It can also be an indication of the relative "age" of the star.**

Which Brings us Back to ...