What You Should Know about Stars

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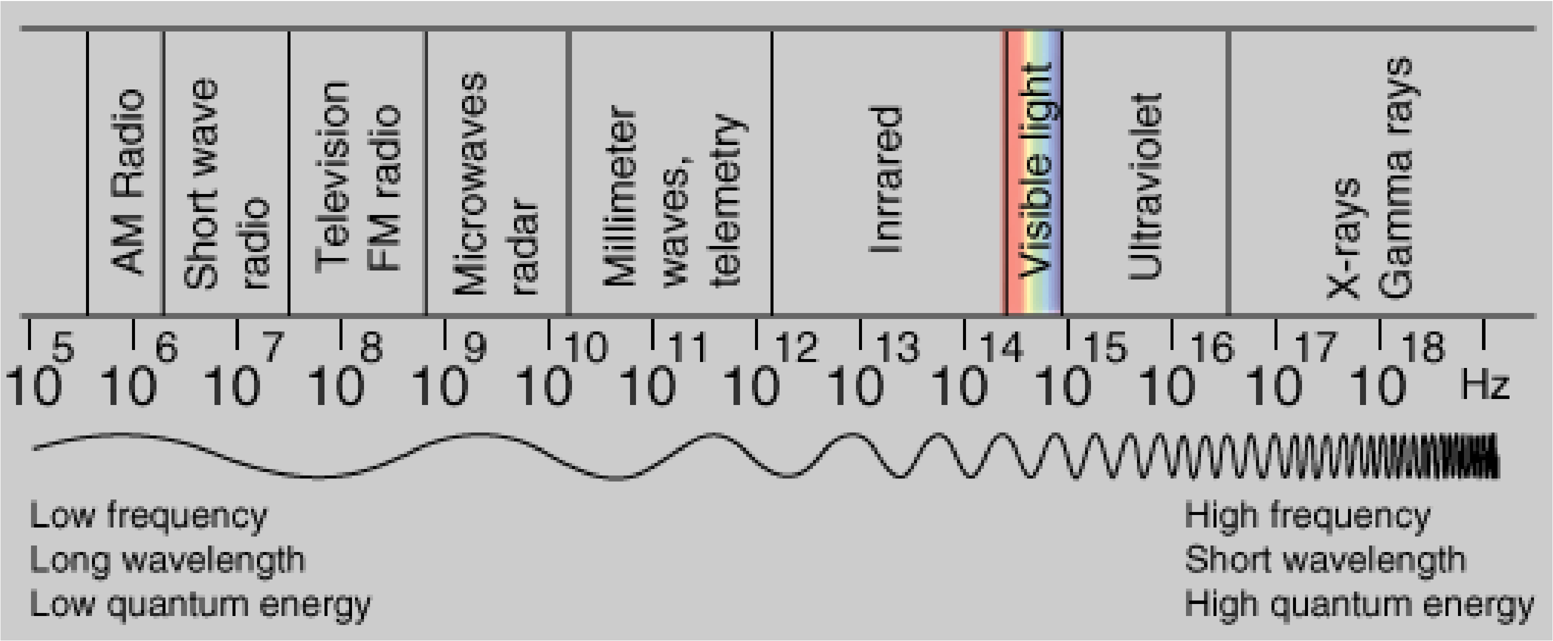
Stars Create Energy

- Stars convert **matter** into pure **energy**
- Einstein first explained this:

$$E = Mc^2$$

- Energy is produced at all wavelengths, but most of the energy is in the **visible light, infrared (IR/heat),** and **ultraviolet (UV)** portions of the **electromagnetic (EM) spectrum**



http://hyperphysics.phy-astr.gsu.edu/hbase/ems1.html

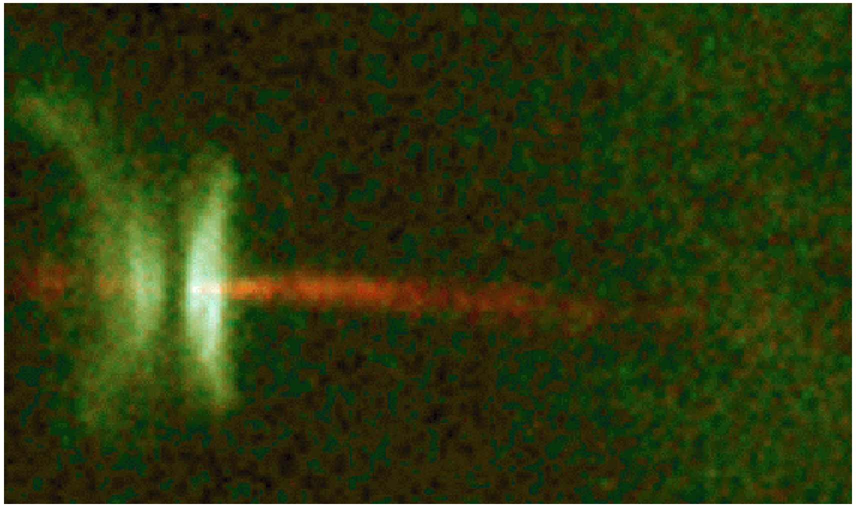
Beginning of a Star: Nebula

Orion Nebula

- Stars begin when huge masses of dust and gas particles come together under the pull of gravity to form a **nebula**

http://www.astro.keele.ac.uk/workx/starlife/StarpageS_26M.html

Protostar



- Condensing matter heats up (friction) to form a **protostar.**
- Temperatures may exceed 15 million degrees.

http://www.astro.keele.ac.uk/workx/starlife/StarpageS_26M.html

Nuclear Fusion Begins

- Hydrogen makes up most of the nebula and protostar, with some He and trace amounts of other elements
- After a *critical temperature* is reached, the H begins to **fuse** (combine) to form He
- This is sometimes shown as “4 H → He,” but it is really more complicated

‘Neutron Addition’

- ${}_1H^1 + n \rightarrow {}_1H^2$ + energy (Deuterium)
- ${}_1H^2 + n \rightarrow {}_1H^3$ + energy (Tritium)
- ${}_1H^3$ + n: nothing happens

BUT about 1 out of 2000 times something very unusual happens!

- ${}_1H^3$ spontaneously changes into ${}_2He^3$

  One of the neutrons changes into a proton and electron!
- Now the process can continue:

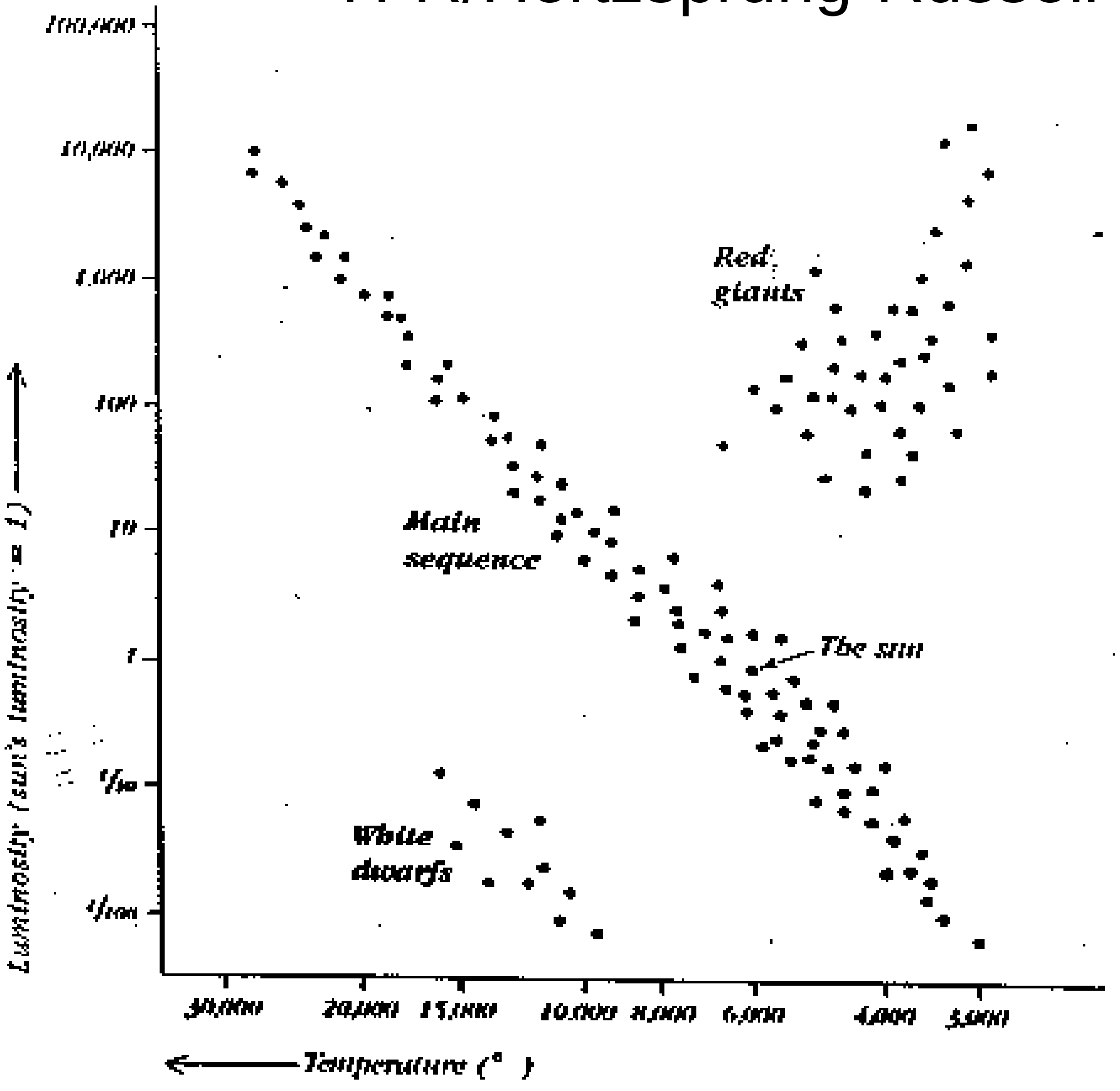
$${}_2He^3 + n \rightarrow {}_2He^4 + \text{energy}$$

- ${}_2He^4$ is very stable.
- Most of a star’s “lifetime” is spent in **“hydrogen burning”**

H-R Diagram

- Two scientists—Hertzsprung and Russell—separately plotted the *luminosity* (brightness) of stars against their *color* (temperature), and revealed patterns
- Most stars fell into a band from the upper left to lower right—the **Main Sequence**
- Some grouped in the upper right—**Red Giants**
- Others grouped as **White Dwarfs**

H-R/Hertzsprung-Russell Diagram



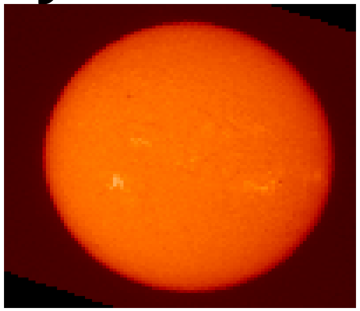
http://www.astro.keele.ac.uk/workx/starlife/StarpageS_26M.html

Characteristics of Our Sun

- About average in mass
- About average in temperature (about 6000 K)
- At this temperature, most of the energy is emitted in the yellow portion of the EM spectrum, which is why we see it as this color
- Also emits smaller amounts of IR and UV energy

From a graph to a theory

- The H-R diagram was the first time that ‘blind’ data-plotting led to discovery of a major scientific idea
- Astronomers realized that the Main Sequence stars—including our Sun—were undergoing ‘hydrogen burning’



- Red Giant and White Dwarf stars were in other phases of the star’s lifecycle

What happens next?

- Eventually, the H starts to be used up.
- As this happens, the temperature falls and the volume decreases
- This increases the pressure, but this raises the temperature and the volume starts to expand
- At a critical point, a new phase begins—**‘He burning’**

Red Giant Phase

- With He burning, the star expands to a much larger volume, but lower temperature, than in the Main Sequence phase—**“Red Giant”phase**
- $_2He^4 + {}_2He^4 \rightarrow {}_4Be^8$ + energy
- $_4Be^8 + {}_2He^4 \rightarrow {}_6C^{12}$ + energy
- $_6C^{12} + {}_2He^4 \rightarrow {}_8O^{16}$ + energy

Red Giant phase, cont'd.

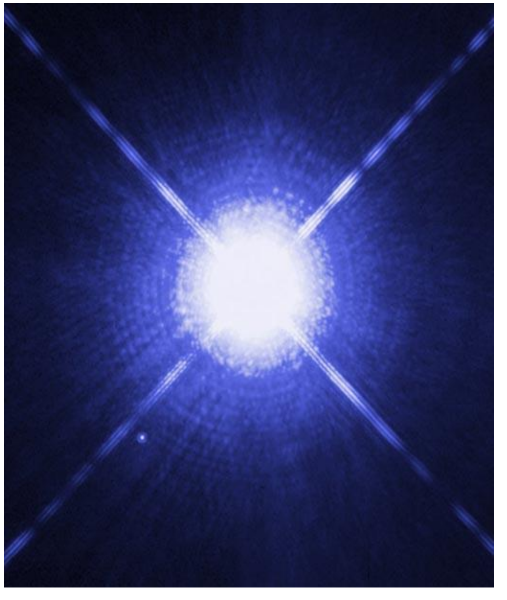
Other processes are also going on:

- $_{2}He^{4} + {}_{1}H^{1} \rightarrow {}_{3}Li^{5}$ + energy
- $_{6}C^{12} + {}_{1}H^{1} \rightarrow {}_{7}N^{13} + n \rightarrow {}_{7}N^{14}$ + energy
- These can produce isotopes up to $_{26}Fe^{56}$

What happens next?

- As the He starts to run out, the Red Giant begins another contracting process—T decreases, V decreases, and P increases
- A star like the Sun will eventually explode to be a brief **“Nova**” (bright for several weeks or months)

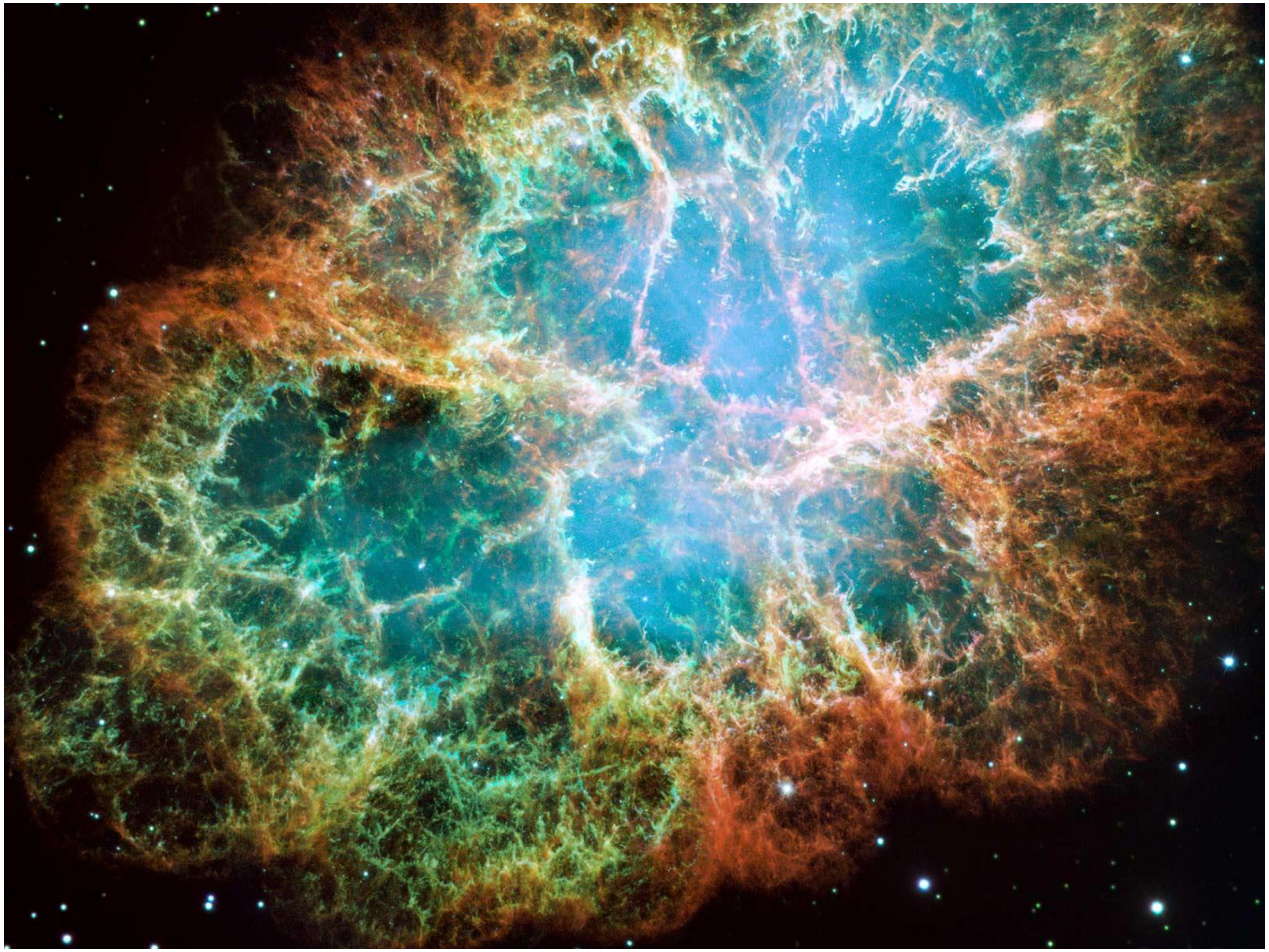
What remains will be a small, hot **White Dwarf.** It gradually fades into a dead, invisible **Black Dwarf** drifting through space.



Sirius A, a white dwarf star

But what if a star has great mass?

- Bigger stars have very interesting ends!
- A much large **Supernova** explosion forces atoms and neutrons together to form elements heavier than Fe^{56}. These include Au, Ag, Pb, and all other natural elements up to ${}_{92}U^{238}$.
- Atoms blasted outward in the supernova may eventually become part of a new nebula, which may become a next-generation star, and possibly a solar system, or possible even you!



https://academics.skidmore.edu/weblogs/students/scheng/Supernova.jpg

You Are Made of Exploded Star Matter!

- The atoms that now form your body’s molecules came from substances here on Earth that were part of the nebula which formed our solar system 4.5 billion years ago!
- These have been in many things before becoming part of you.
- You are part of a larger process than you ever imagined!

What Happens to What's Left of the Star?

- The remnants of the massive star begin to cool and contract.
- Nothing can stop this process, so eventually even protons and electrons contract to become neutrons.

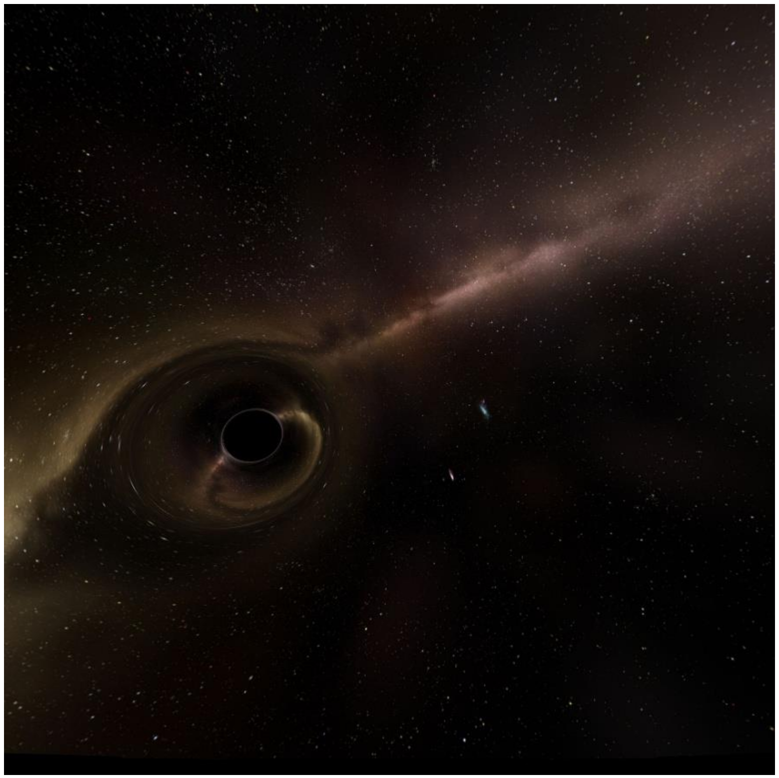
This Chandra image shows the supernova Kes 75. The pulsar is in the center of the blue area at the top. Credit: NASA/CXC/M. Gonzalez/F. Gavriil/P. Slane

LGMs

- Jocelyn Bell, a PhD student at Cambridge in England, discovered regularly-spaced radio pulses in 1967.
- These were first referred to as LGMs, but Bell realized that they were coming from an object that was rotating incredibly fast.
- She named it a "pulsar," and later found it was a neutron star.

http://www.rkm.com.au/ASTRONOMY/Pulsar.html

Black Hole in Space



http://www.dmns.org/NR/rdonlyres/91739ACF-EFAE-4A11-903C-B5D7E44C2404/768/BH04314.jpg

- With nothing to stop its contraction, the neutron star in theory would continue to shrink until not even light could escape: a **black hole in space**

Key Questions You Should Be Able to Answer

- What two elements compose most of a star?
- What creates energy in a star?
- What are the stages in a star’s lifecycle?
- How is the fate of a small or medium star different from that of a massive star?
- How does this story connect with the atoms that make up your body?