Solar Energy and Space Exploration

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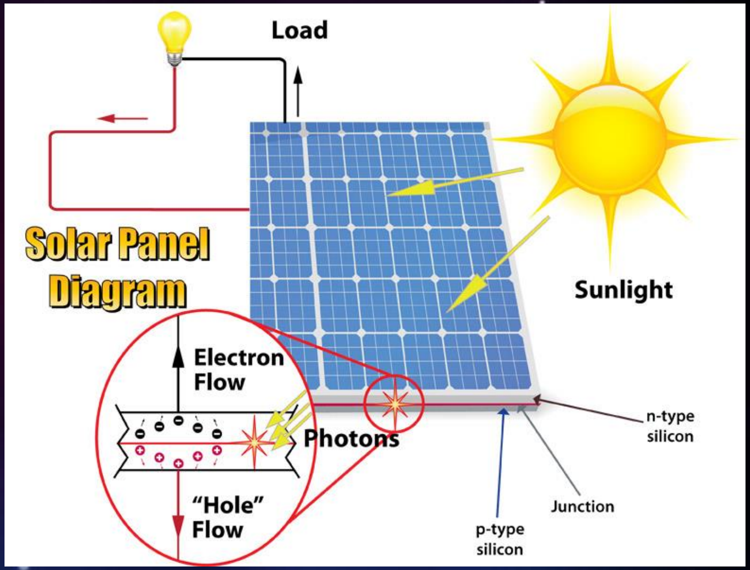
Solar Cell Basics

- Photovoltaic Module
- Just a *fancy* way to say "Solar Panel"
- Converts light into electricity (needs to be a specific energy level)
- What year was the first solar panel used?
- ***1954***
- How about in space?
- ***1958 – Vanguard I***



Would Solar Panels work on Mars?

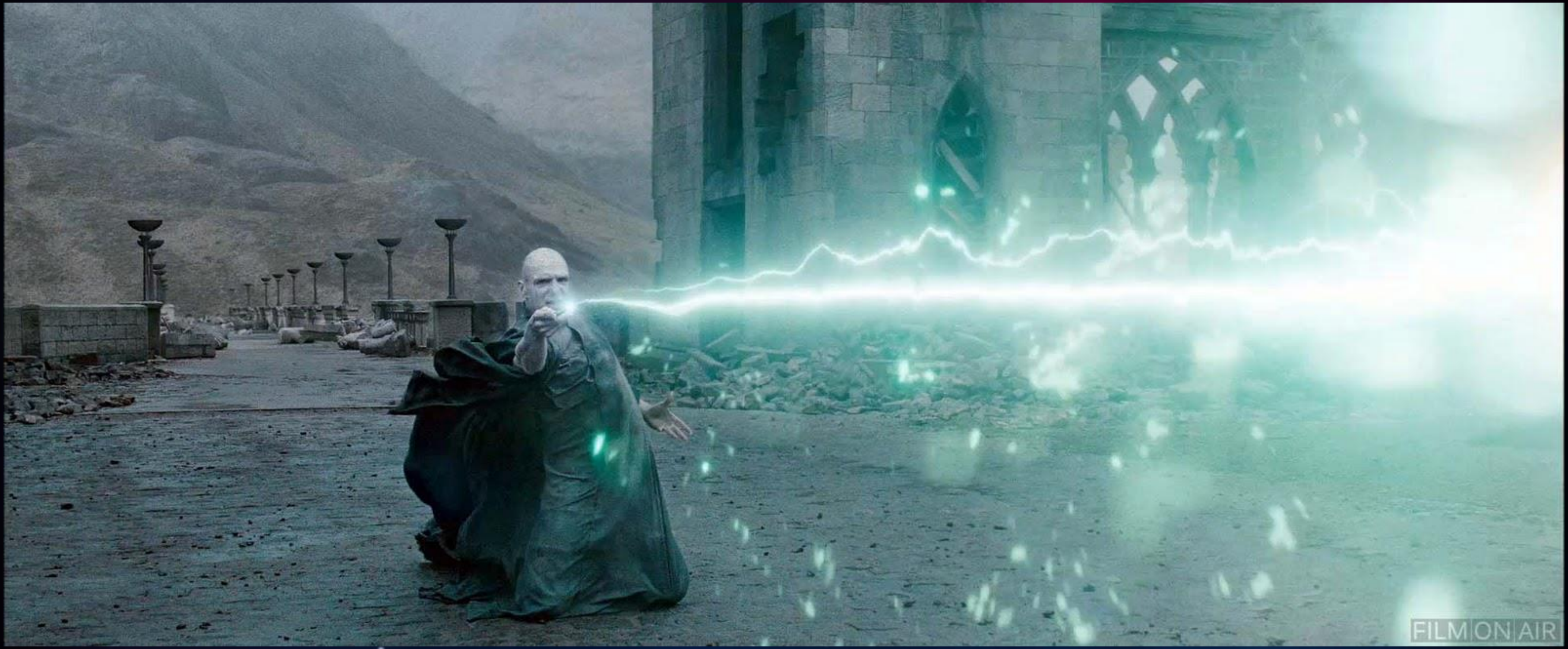
- Apparent Brightness = Luminosity/(4π*distance^2)
- Distance from Sun to Mars ~1.5 AU
- Apparent Brightness of the Sun from Mars as compared to Earth?
- What about from Pluto? (39.5 AU from Sun)

Earth

Mars

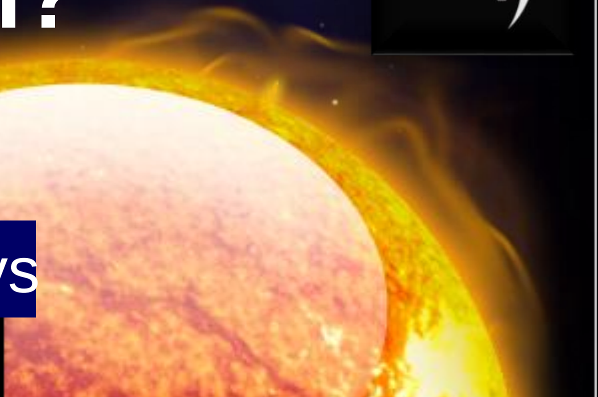
Solar Cell Basics

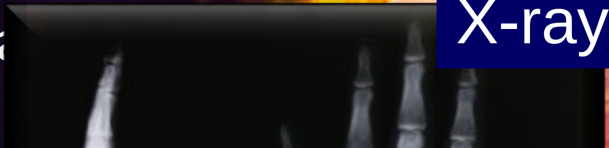
- But, not ALL light is good…



What is Radiation?

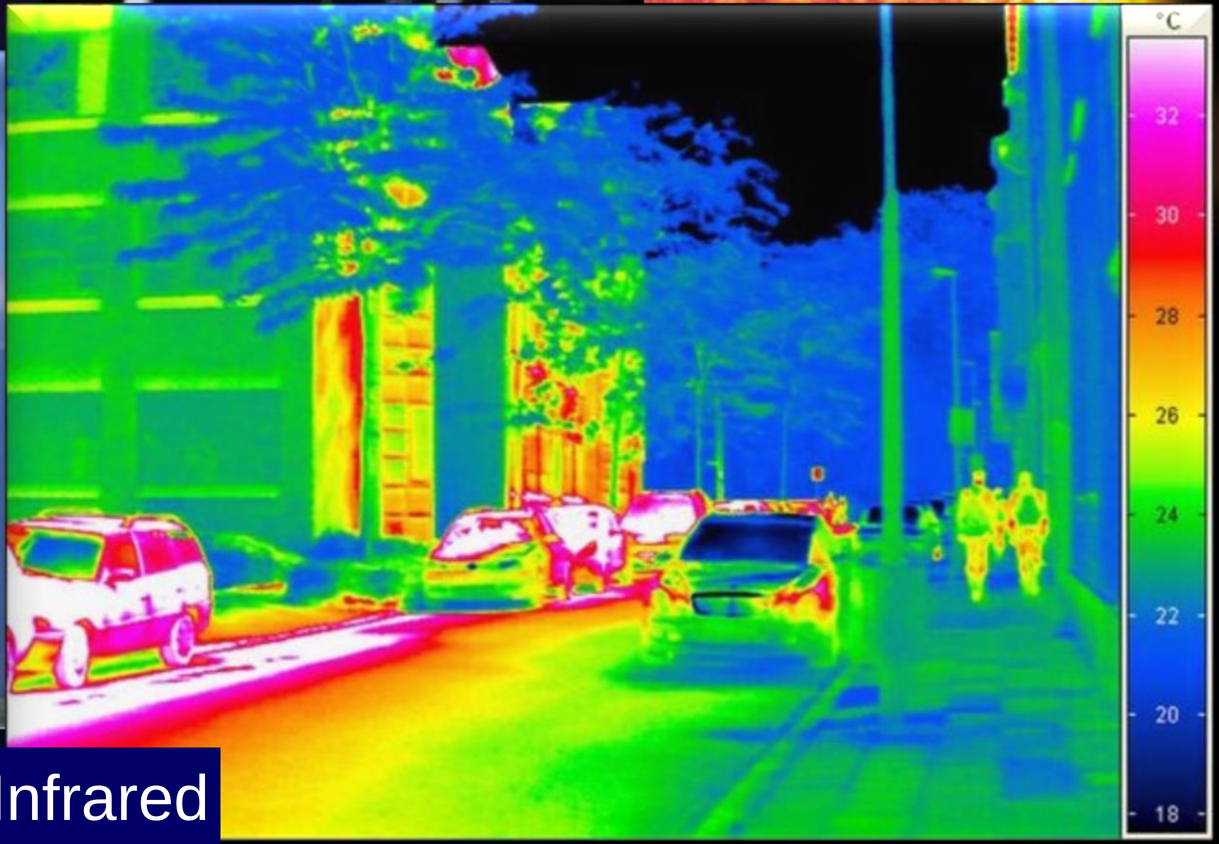
- Where does it come from?
- What do we get from the Sun?
- Energy – waves and pa
- Is all light the same?





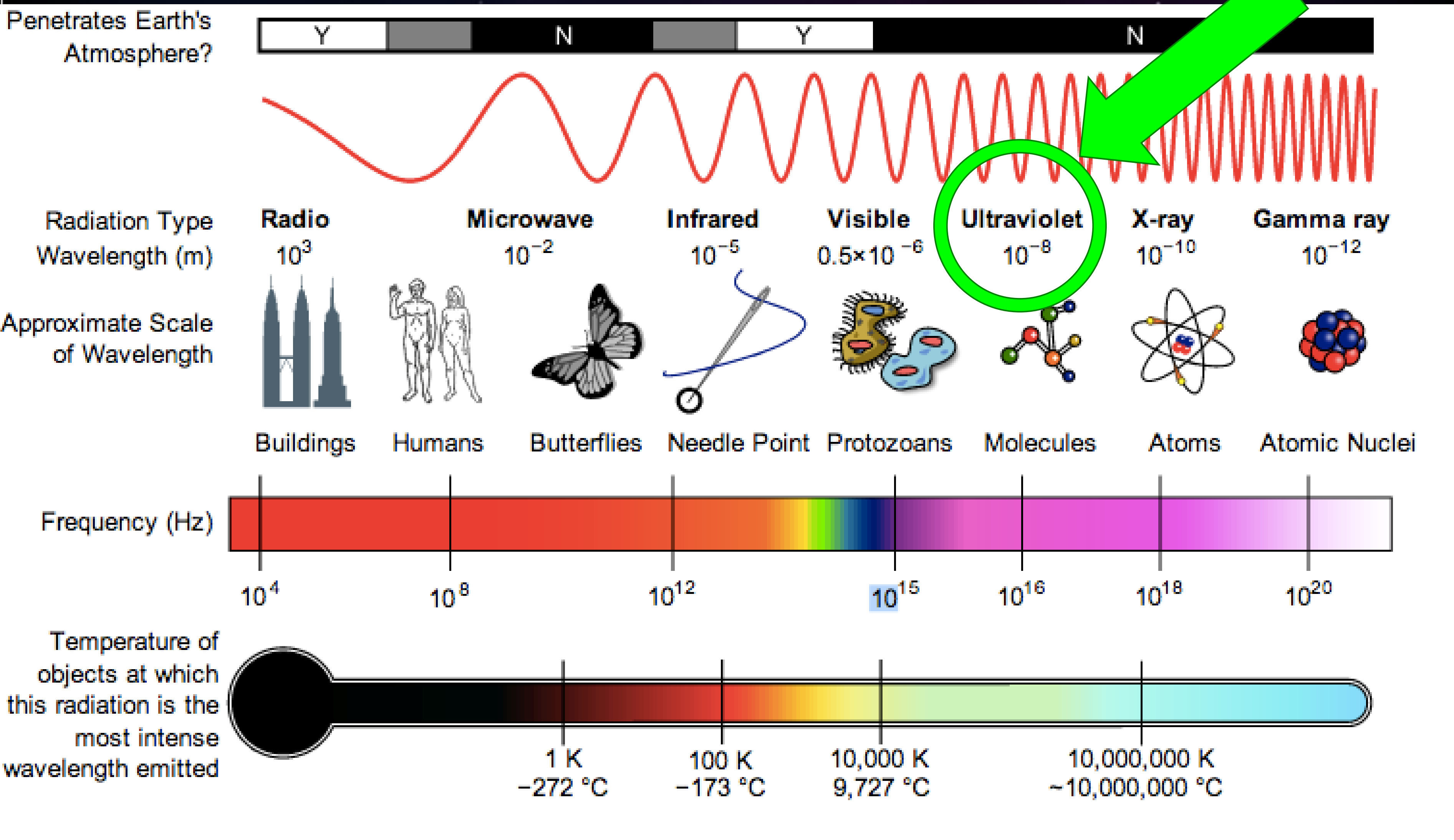
X-rays

Visible Light



Infrared

Electromagnetic Spectrum



Ultraviolet Radiation

- Can be good – Vitamin D!
- Too much can be harmful
- How do we stay safe?
- Does Earth protect us?
- Ozone Layer absorbs UV

Radiation in Space

- No atmosphere – so what do astronauts do?

Wear Spacesuits

Visors

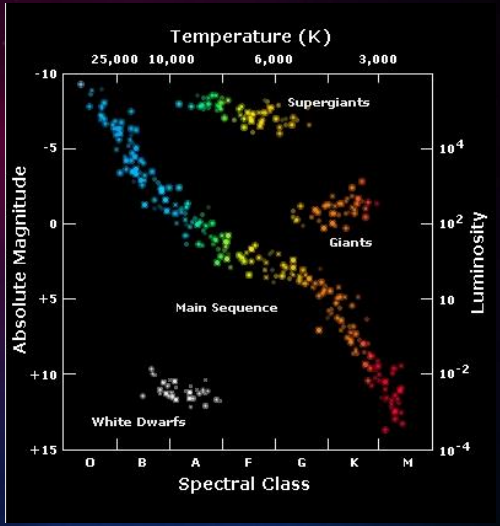
Live in stations

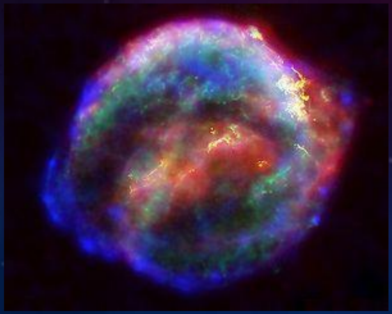
Radiation in Space

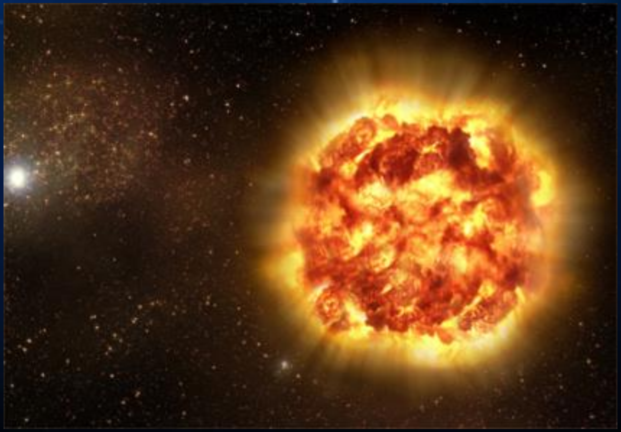
- Even with all of this protection, some radiation gets through
- Each day = 8 chest X-rays!
- 10x's what we experience on Earth
- Astronauts wear **dosimeters**
- High energy X-rays
- Gamma Rays
- Cosmic Rays

Overview of Stars

- Stellar Formation
- Why do the Sun and other stars shine…?
- Nuclear Fusion!
- Types of Stars
- H.R. Diagram
- Death of Stars





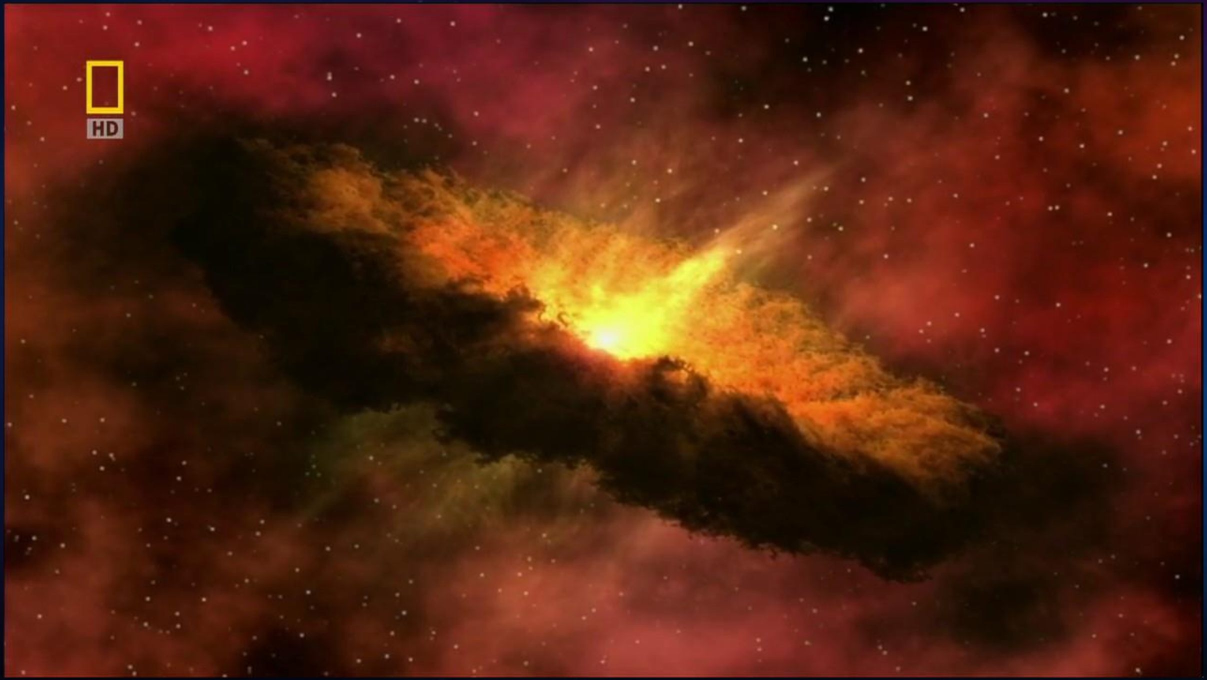


Stellar formation

- Star formation occurs in giant molecular clouds – cold, dense clouds of gas and dust
- 10s of parsecs in size
- 10,000 to 10 million solar masses
- Stars typically form in clusters and then disperse as they evolve.

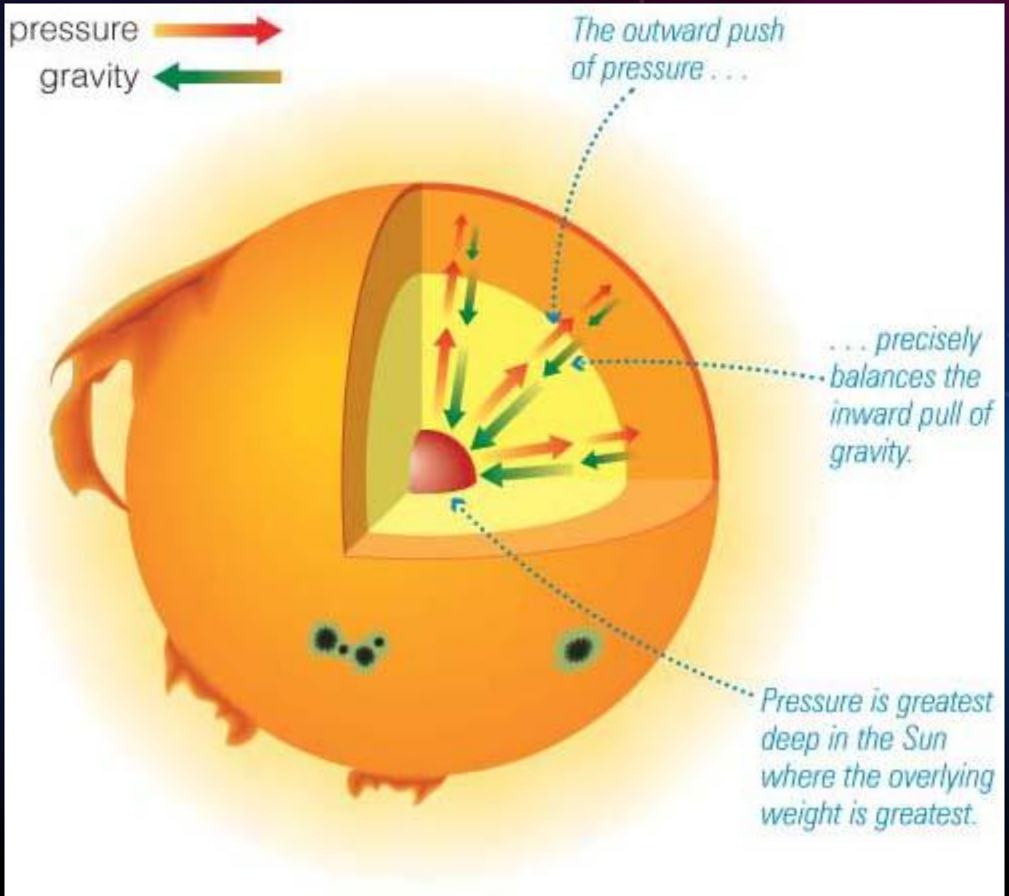
The Start of our Sun

- Collapsing cloud forms <u>protostars</u> (clumps of gas) that each become their own star
- Exchange of energy allowed for the temperature of the Sun to increase
- Gravitational Potential Energy -> Kinetic and Thermal Energy



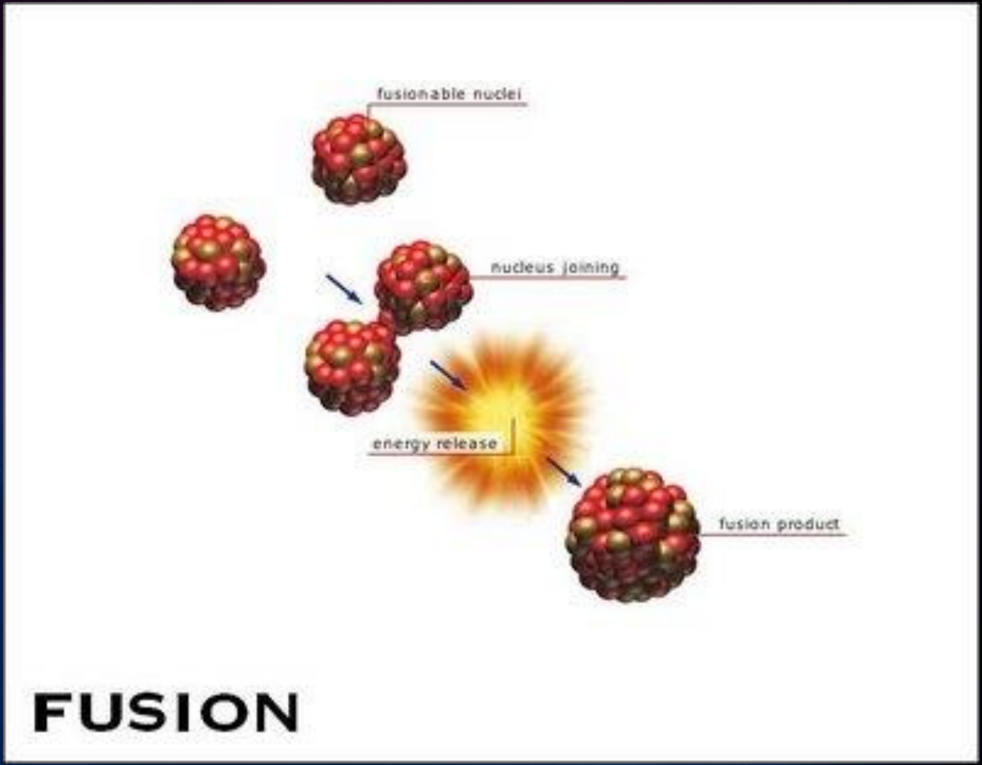
Nuclear Fusion

- Gravitational contraction made the Sun hot enough to sustain Nuclear Fusion
- Stable state between energy generation and loss = reached



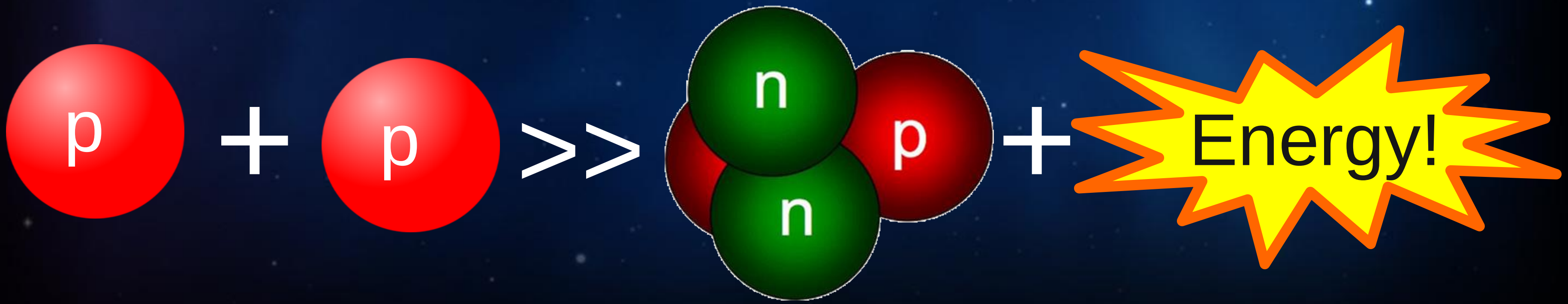
Nuclear Fusion

- Different process than energy generation on Earth
- Earth's nuclear power plants use <u>nuclear fission,</u> or the splitting of elements.
- <u>Nuclear Fusion</u> – combining or *fusing* two or more small nuclei into a larger one
- Possible due to high pressure and temperature



Nuclear Fusion

- Core of Sun = "Soup" of hot (~15 million Kelvin) gas with (+) charged atomic nuclei and (-) charged electrons bouncing around at high speeds
- *Collisions*!
- Most common reaction in Sun involves = Hydrogen atoms -> Helium nuclei
- Hydrogen nuclei = individual protons
- Helium = 2 protons and 2 neutrons



Proton-proton reaction (PP I)

- The proton-proton reaction has three stages; the first stage is the most important in terms of energy release.

- **PP I:** $^{1}H + {}^{1}H \rightarrow {}^{2}H + e^{+} + \nu$ (1.44 MeV)

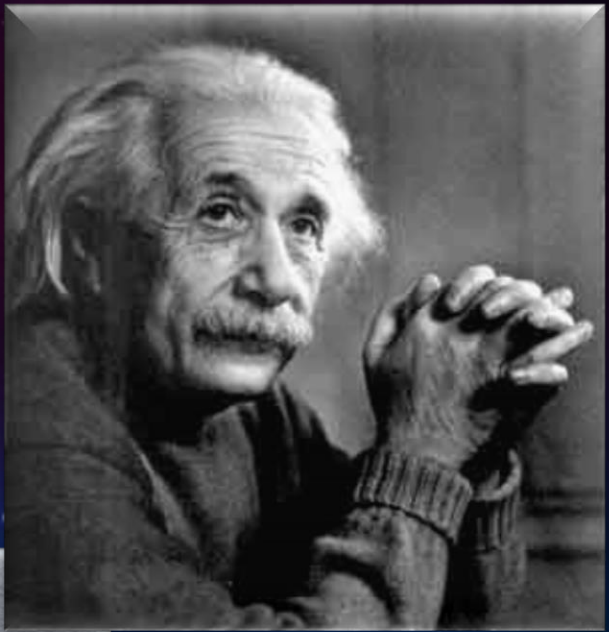
  $^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma$ (5.49 MeV)

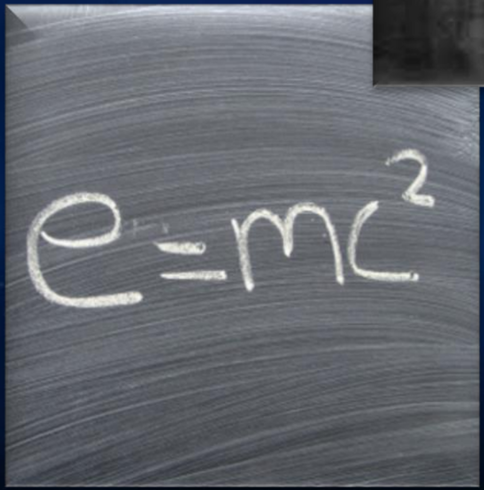
  $^{3}He + {}^{3}He \rightarrow {}^{4}He + {}^{1}H + {}^{1}H$ (12.9 MeV)

- The numbers in the parentheses to the right represent the energy releases.
- The first two reactions must occur before the third can occur.
- The above reaction is dominant in the Sun (91% of the time).

Nuclear Fusion

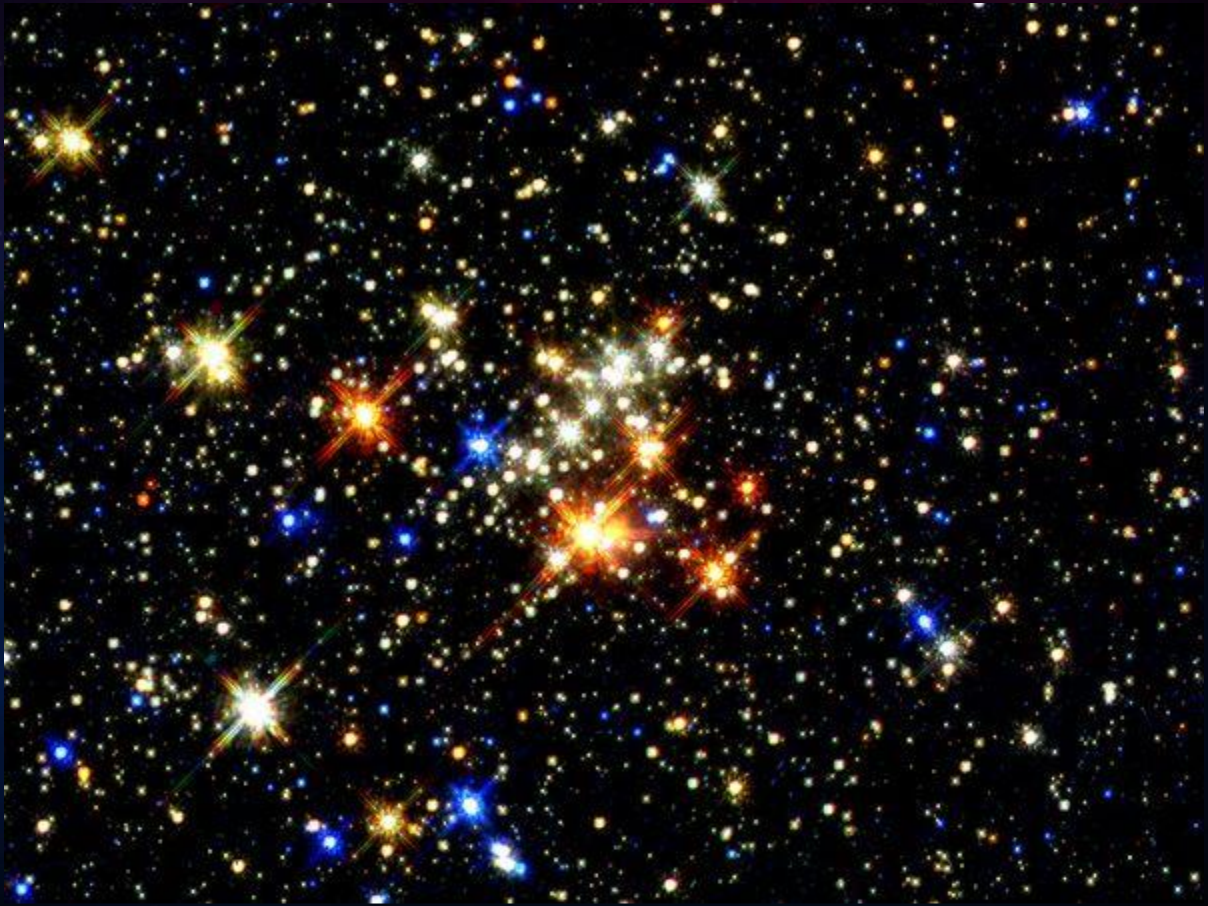
- Release of energy is due to Einstein's famous equation
- Mass of Helium < 4 Hydrogen nuclei
- 4 million tons of matter = converted to energy in our Sun every second!





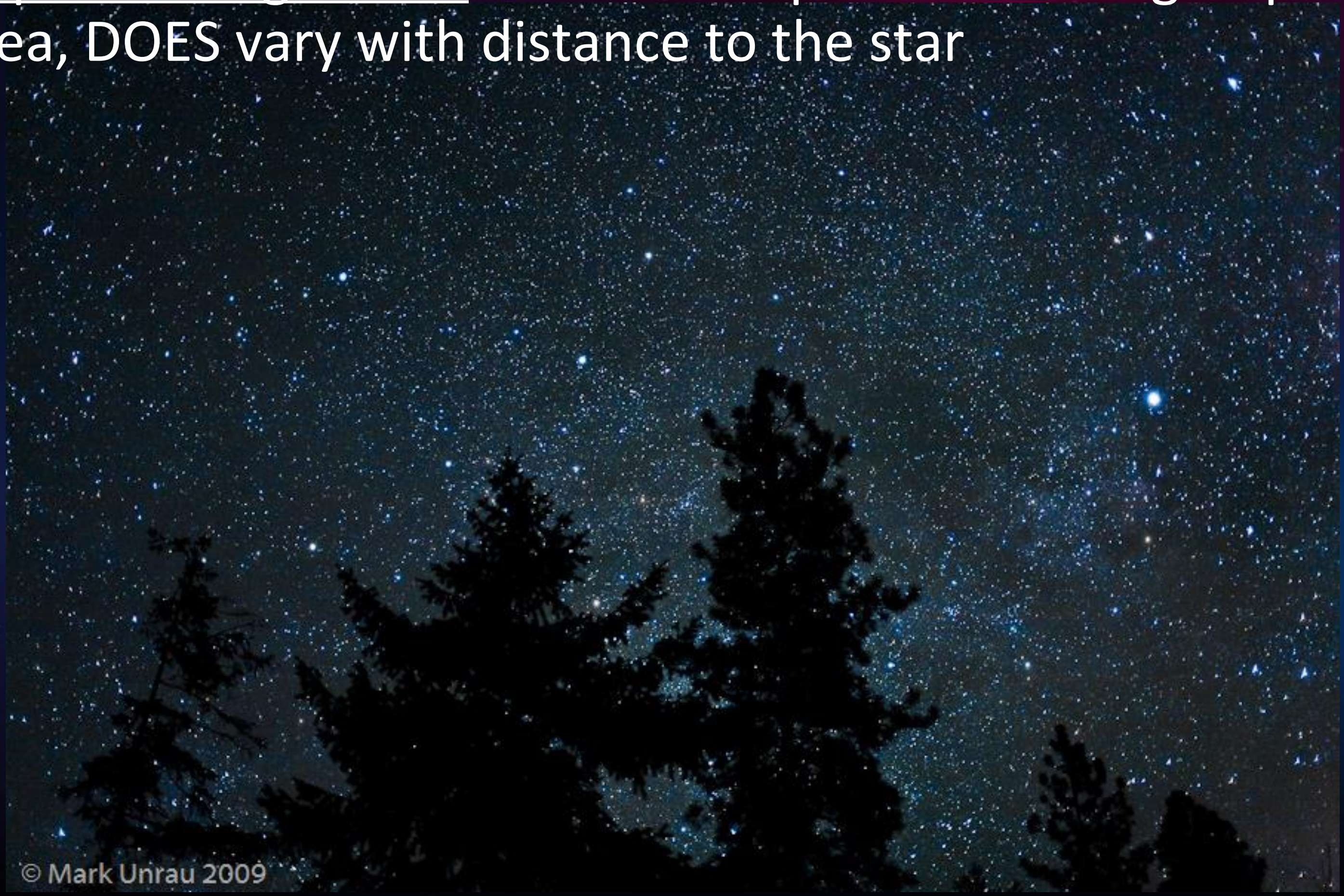
Classifying Stars

- How do they differ from one another?
- Brightness
- Distances
- Temperature
- Size



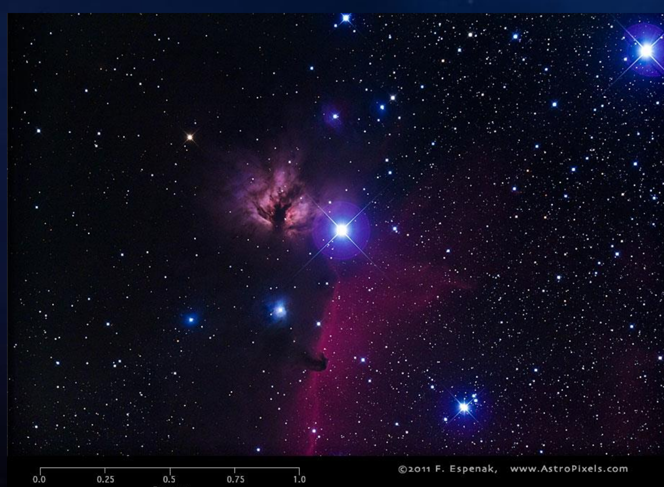
Classifying Stars

- <u>Luminosity</u> – total amount of power that a star emits into space, does NOT vary with distance to the star
- <u>Apparent Brightness</u> – amount of power reaching us per unit area, DOES vary with distance to the star



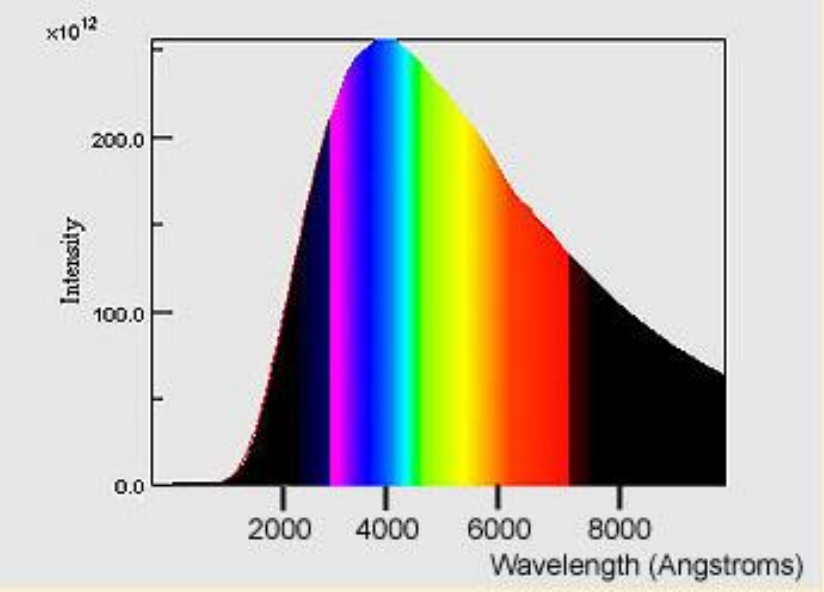
Classifying Stars

- Apparent Magnitude – Scale describing the brightness of the star as it appears on the sky.
- Lower magnitudes = brighter stars (Mag 1 = 100 x's brighter than 6)
- Absolute Magnitude – the apparent magnitude a star *would* have if it were at a distance of 10 parsecs (32.6 LY) from Earth
- Apparent Magnitude of Sun = -26.74
- Absolute Magnitude of Sun = 4.8



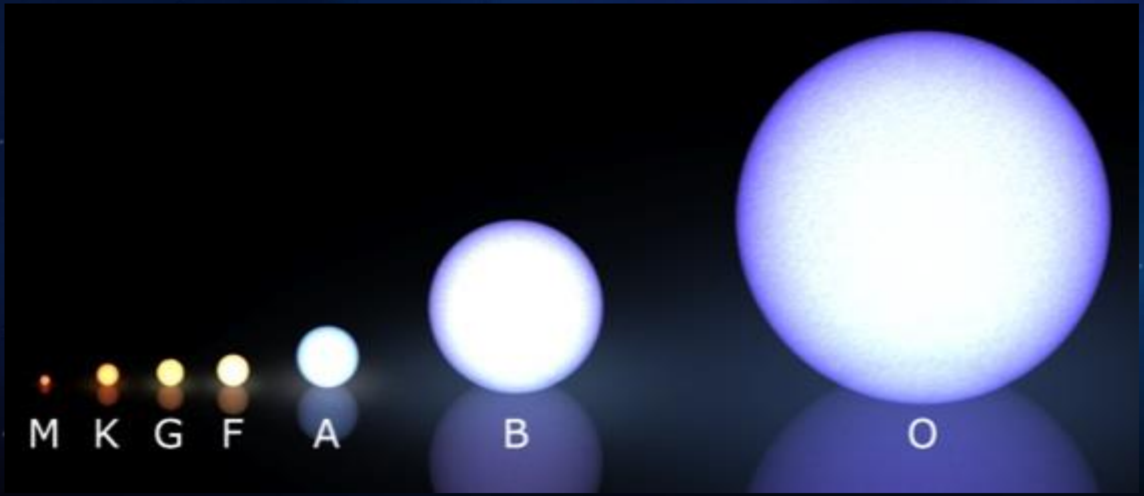
Classifying Stars

- Surface Temperature – can be determined directly from star's color or spectrum
- Stars emit thermal radiation: Red stars are cooler than blue stars
- Sun = 5800 K at surface, emitting strongly in yellow part of spectrum

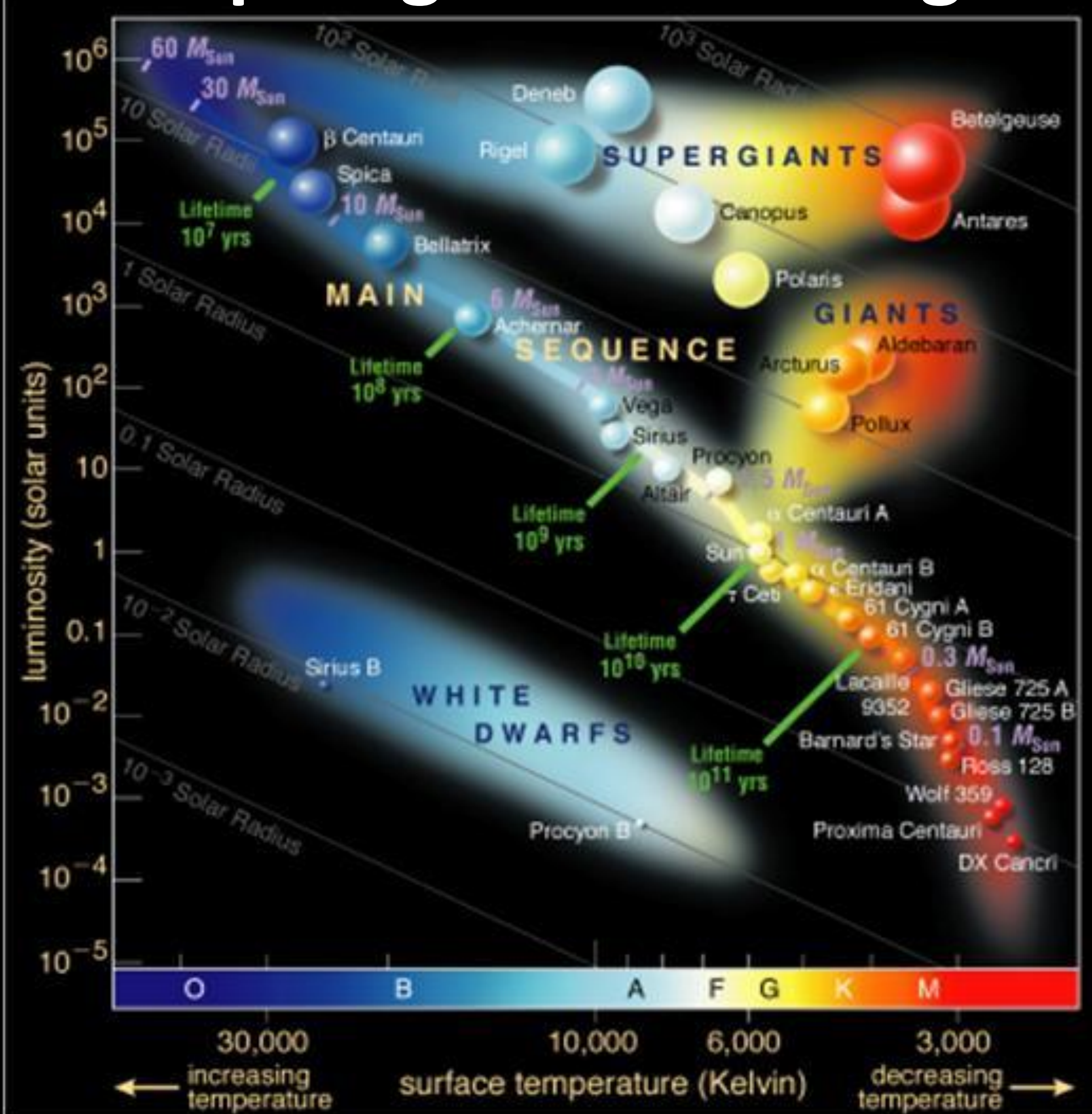


Classifying Stars

- Spectral Type – determined from spectral lines of a star
- **O B A F G K M**
- "Oh, Be A Fine Girl/Guy, Kiss Me!"
- Hottest (40,000 K) ----> Coolest (3000 K)
- Sun = Type G2
- Used to be classified by strength of Hydrogen lines (A – O)

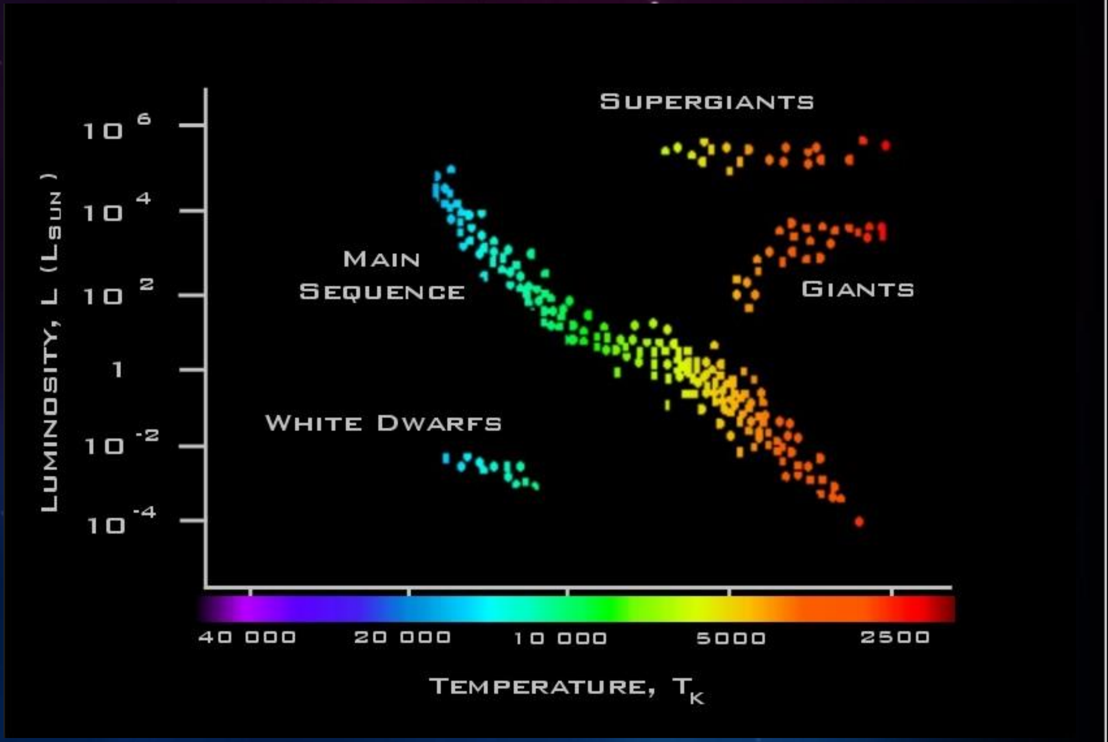


Hertzsprung – Russell Diagram



Main Sequence Star

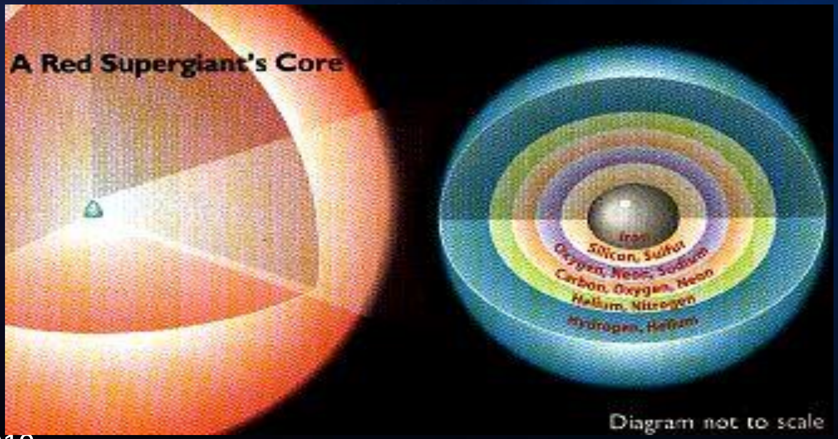
- Young stars evolve onto the main sequence, where they live the majority of their lives
- Stable Hydrogen burning phase of star's life
- Star's position along M.S. = closely related to its mass
- Between 150 and .08 solar masses

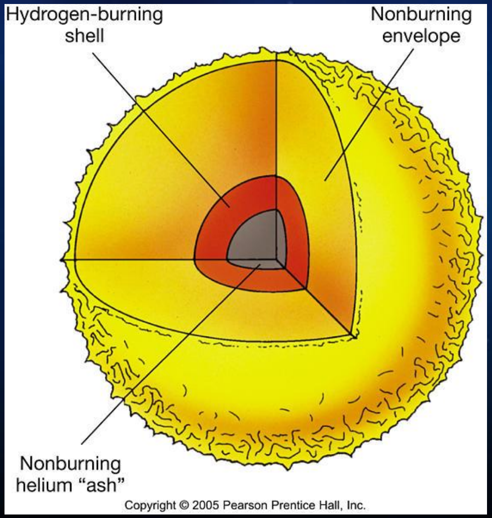


More massive stars live much shorter lives because they fuse hydrogen at a much greater rate.

Red Giants and Supergiants

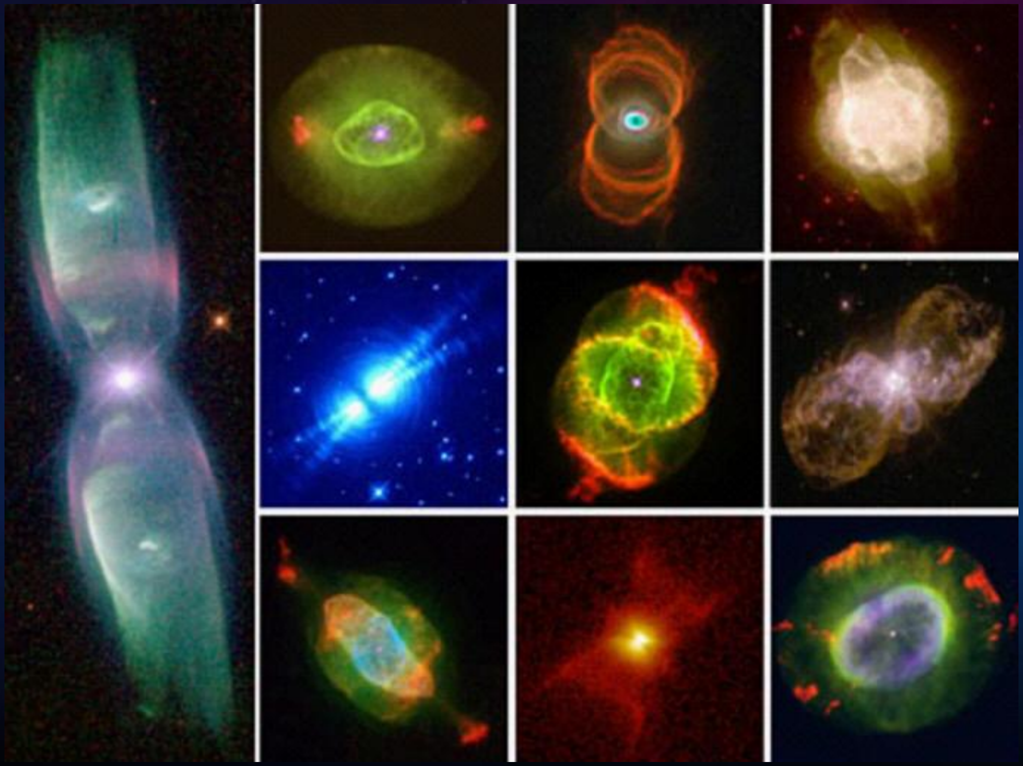
- Star converts core's hydrogen to helium and evolves off the main sequence
- Balance of nuclear fusion pressure and gravity = disrupted
- <u>Hydrogen Shell Burning</u> - Hydrogen still exists in outer shell of core – shrinks to high temperature, allows for FAST rate of nuclear fusion
- Outer layers of the star expand to become a Red Giant
- When temperature of core increases to 100 million K, Helium burning begins





Planetary Nebula

- As the Sun continues to expand, outer layers become less bound by gravity
- Mass loss through generation of <u>Stellar Wind</u>
- Surrounding dust = ionized by radiating hot core

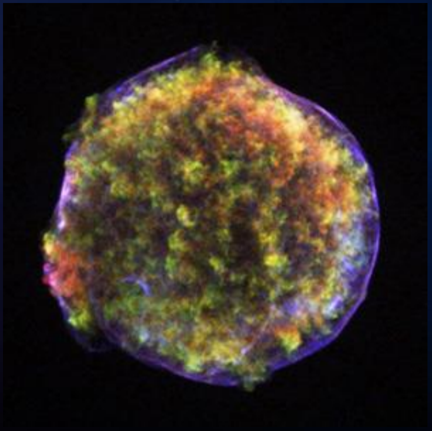


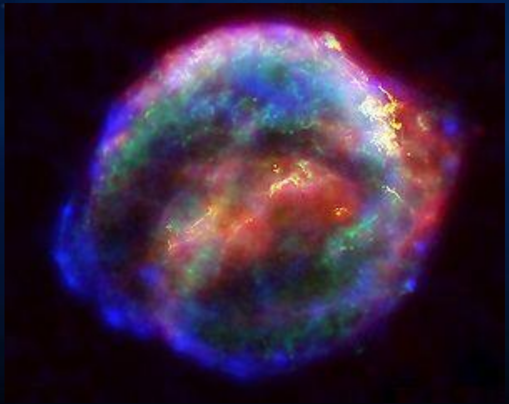
White Dwarfs

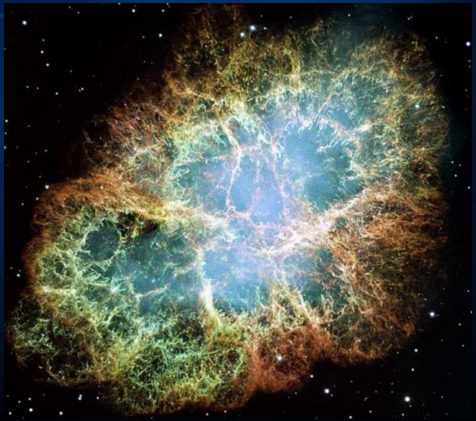
- White Dwarf Star – Left behind when a giant with a mass similar to that of our Sun ejects off its outer layers, leaving behind an exposed stellar core
- Hot and Dim (no nuclear fusion)
- Extremely Dense - Can be the same size as Earth, but have the same mass as the Sun

Supernovae!

- High mass stars follow similar path, but *much more quickly*
- Higher core temperatures allow for fusion of higher mass elements
- Helium, Carbon, Nitrogen, Oxygen, Silicon, Sulfur, Iron
- Fusion stops at Iron, because reactions are no longer energy efficient
- Gravitational collapse of core releases energy
- Stellar explosion scatters elements into space







Neutron Star

- Neutron Star – stellar remnant resulting from gravitational collapse during supernovae
- ~1.5 solar masses with 12 km radius
- Extremely Dense –object dropped from a 1 meter height hits the surface at 7.2 million km/hr

Black Holes

- <u>Black Hole</u> – Not even light can escape!
- Remember $E = mc^2$
- Mass *and* Energy exert gravitational attraction
- Energy associated with the enhanced internal temperature and pressure acts like mass, adding strength to the gravity present
- *The more the star collapses, the stronger gravity gets.*
- *Supermassive* black holes lie at center of galaxies

Important stellar properties

- **A 0.09 solar mass star: life time ~254 billion years(!)**

- A 0.5 solar mass star: lifetime ~49 billion years.
- A 2 solar mass star: lifetime ~ 2 billion years.
- A 5 solar mass star: lifetime ~250 million years.
- A 10 solar mass star: lifetime ~50 million years.
- A 20 solar mass star: lifetime ~10 million years.
- A 50 solar mass star: lifetime ~1.2 million years.
- **A 100 solar mass star: lifetime ~250,000 years(!)**

Lifecycle of Star

- http://www.youtube.com/watch?v=H8Jz6FU5D1A
- Cruise ship fact = too small