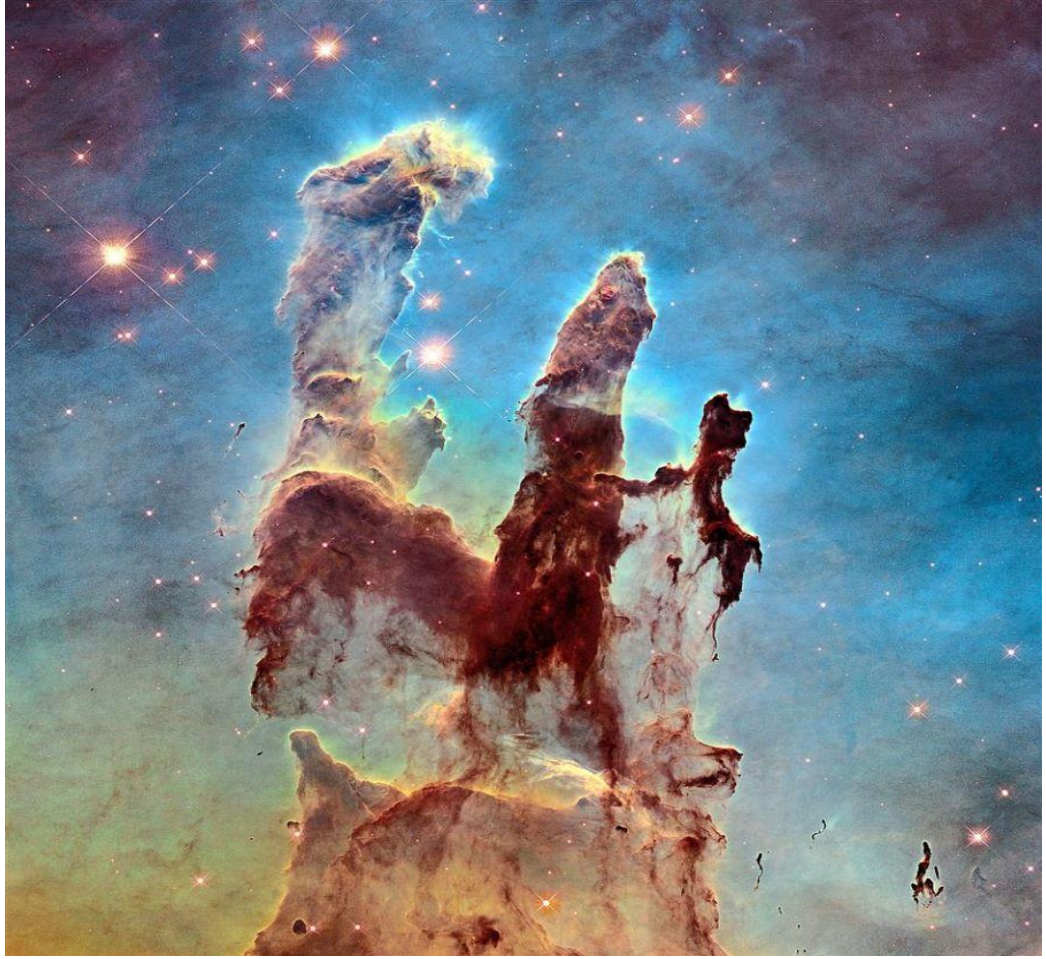
Stars

just a lot of gravity and hydrogen

Where Do Stars Form?

- Space is not a desolate, empty vacuum! (Well, it kinda is)
  - Space, or the technical definition, the **Interstellar Medium (ISM)** is composed of 99% gas and 1% dust
  - Properties of the ISM gas
    - 70% Hydrogen
    - 28% Helium
    - 2% heavier elements (Oxygen, Carbon, Iron, etc.)
  - The densest regions are called **Molecular Clouds** (Often referred to as **Dark Nebulae**)
    - Very cold (10-100K), causes gases to clump to higher and higher densities
    - Very dense (allows molecules to form)
    - Most common molecules
      - H2 (2 bonded Hydrogens)
      - CO (Carbon Monoxide)



The Pillars of Creation

What Kicks It All Off?

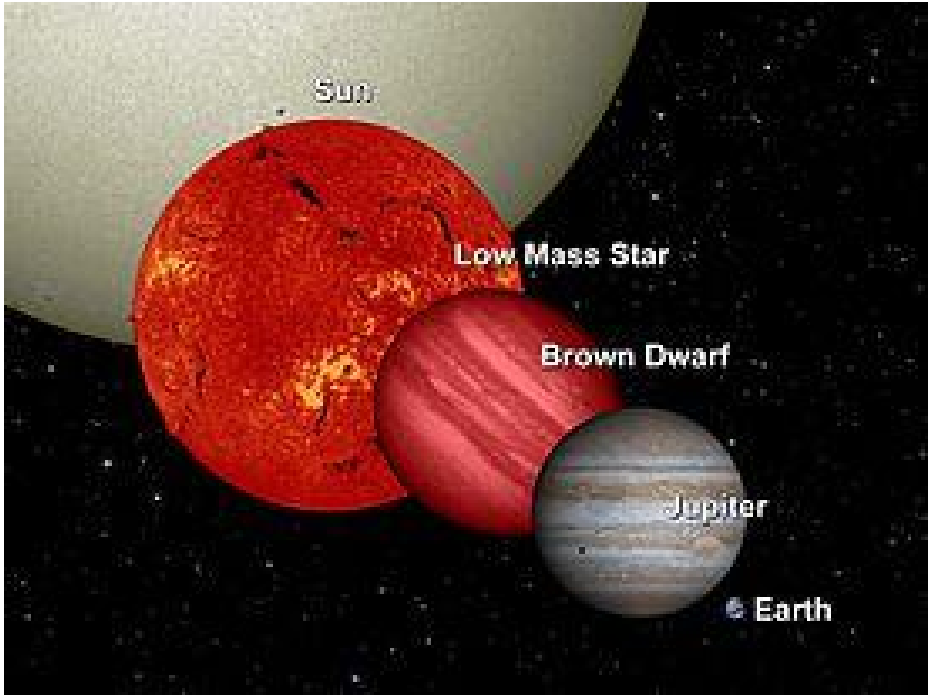
- Typically, a molecular cloud collapses from events such as
  - A nearby exploding star
  - Two clouds colliding
- This upsets the balance and three major things happen
  - **Heating**
    - The GPE of the gas particles becomes KE as they fall inward, then the KE becomes thermal energy
  - **Spinning**
    - As the nebula’s radius shrinks, its rotation speed increases (like an ice skater tucking
  - **Flattening**
    - The cloud flattens into a disk
- The collapse continues until the pressure pushing out is stronger than the gravity pushing in

A Protostar Is Born?

- As collapse goes on, density and temperature increases which leads to the molecules interacting more which make the pressure increase
- Once the pressure reaches a certain threshold, it starts to balance out the gravitational force
- This is now a **protostar**
  - A protostar isn't a real star because its energy comes from the pressure of the molecules as opposed to fusion
- To fuse Hydrogen into Helium, the core must reach a temperature for 10,000,000ºK
- Simulation: http://lasp.colorado.edu/education/outerplanets/solsys_star.php#where

Quick Side Note: A Failed Star?

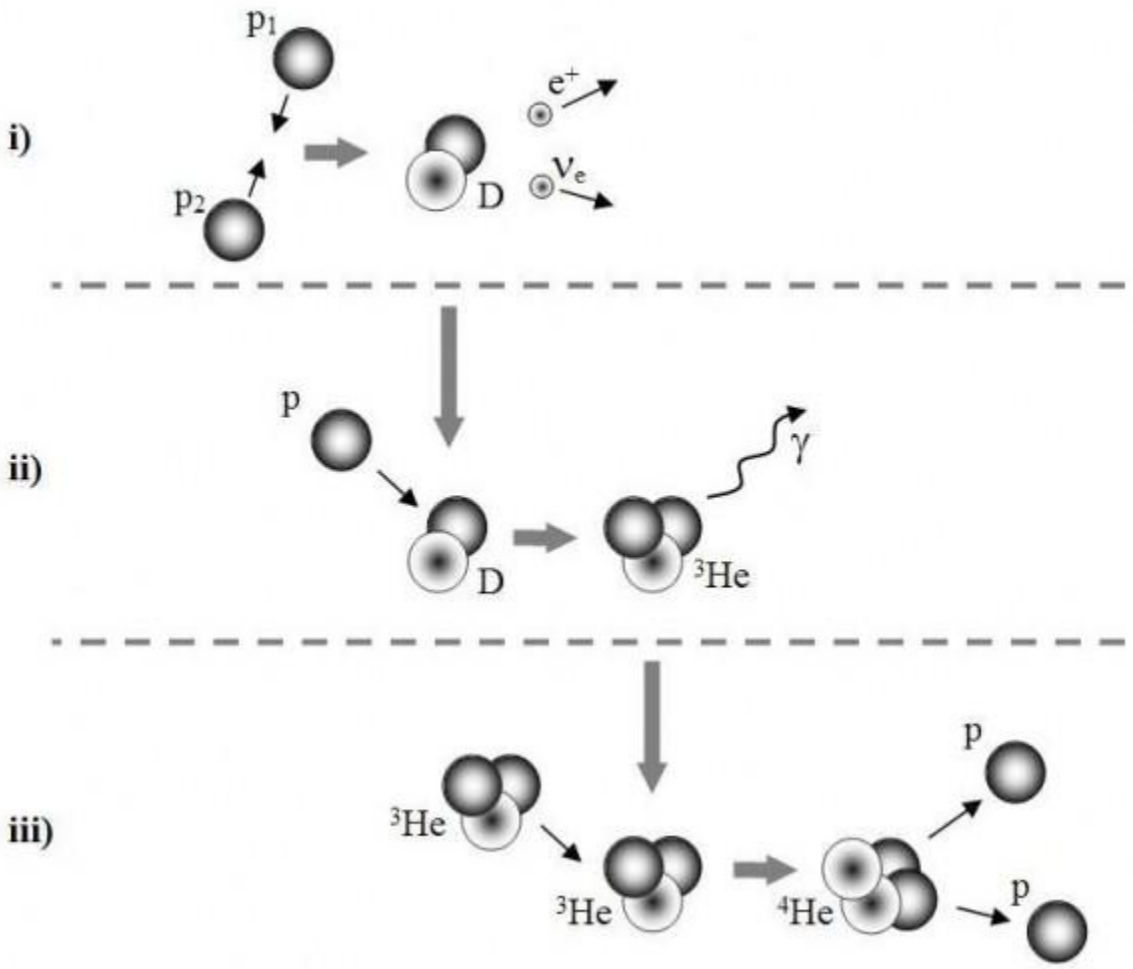
- If a protostar can't reach the heat needed for fusion it becomes a **Brown Dwarf**
- Essentially, Brown Dwarfs are just hanging out with cores at 1,000,000 degrees K, fusing Deuterium (Hydrogen isotope) to stay at that temp
    - H fusion doesn't happen till 10 million degrees K



So What Is Fusion?

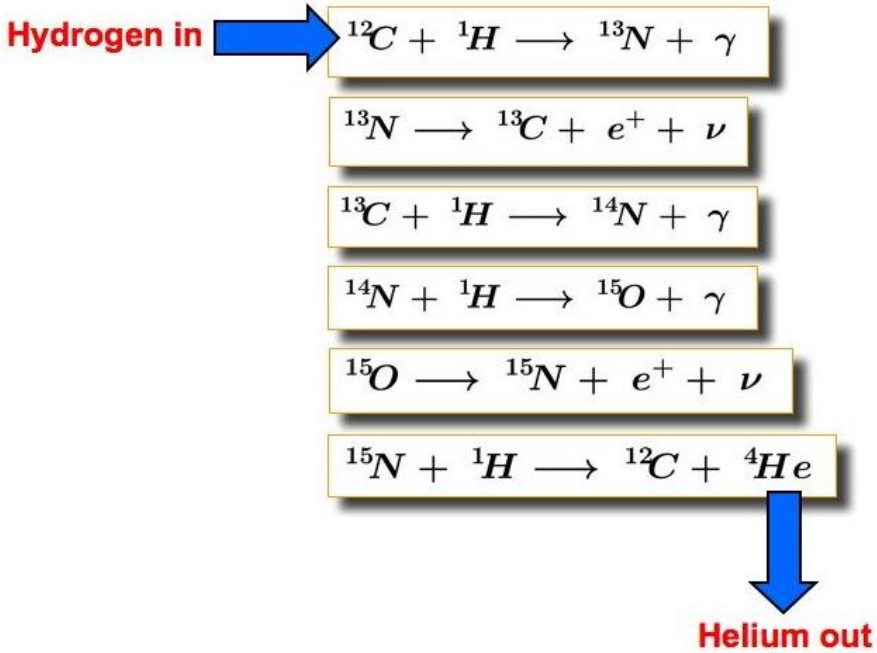
- Taking Hydrogen and making it into heavier and heavier elements
- 2 Types
  - **Proton-proton chain** (if star less than 1.5 **Solar Masses**)
  - **Carbon-Nitrogen-Oxygen (CNO) Cycle (**if star is more than 1.5 SM)
- Proton-Proton
  - Two Hydrogen atoms smash together and makes Deuterium (an isotope of Hydrogen with 1 proton and 1 neutron) and releases a **neutrino** and a **positron** (Positron= antimatter electron, **Neutrino=** electrically neutral fundamental particles)
  - Then, the Deuterium atom gets a proton smashed into it and becomes Helium-3 (2 protons and 1 neutrons) and a gamma ray is released
  - Finally, two Helium-3 atoms smash together and become Helium-4 (2 protons and 2 neutrons plus 2 extra protons)
  - Most common route, but not the only one

- **Proton-Proton Fusion**



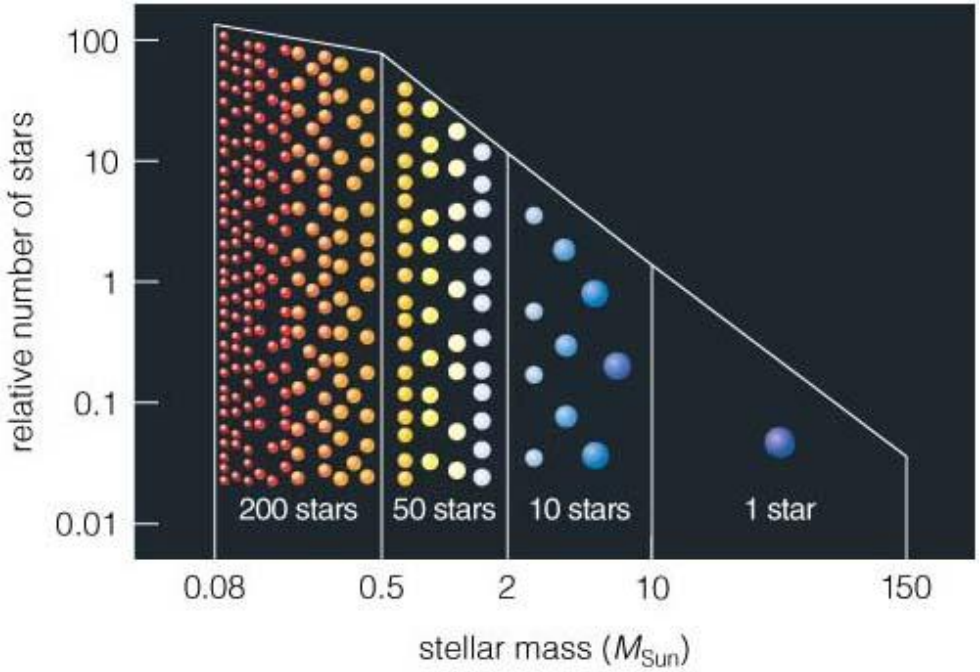
So What Is Fusion? (cont.)

- CNO Fusion
  - More efficient
  - Carbon, Nitrogen, and Oxygen act as catalysts (facilitate the series of reactions



It’s A Main Sequence Star?!

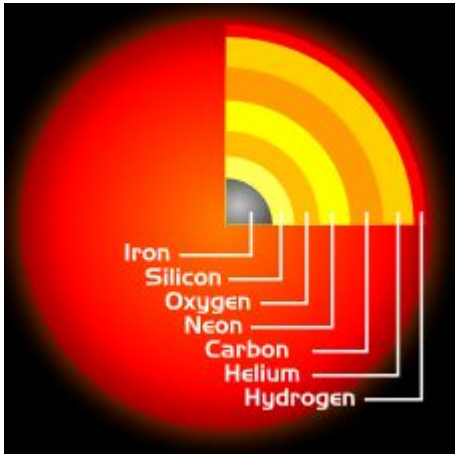
- Lowest mass= .08 SM
- Highest mass= 150 SM
- At this point the star is nice and stable, burning Hydrogen at a steady rate, creating energy in the form of light and heat until it runs out



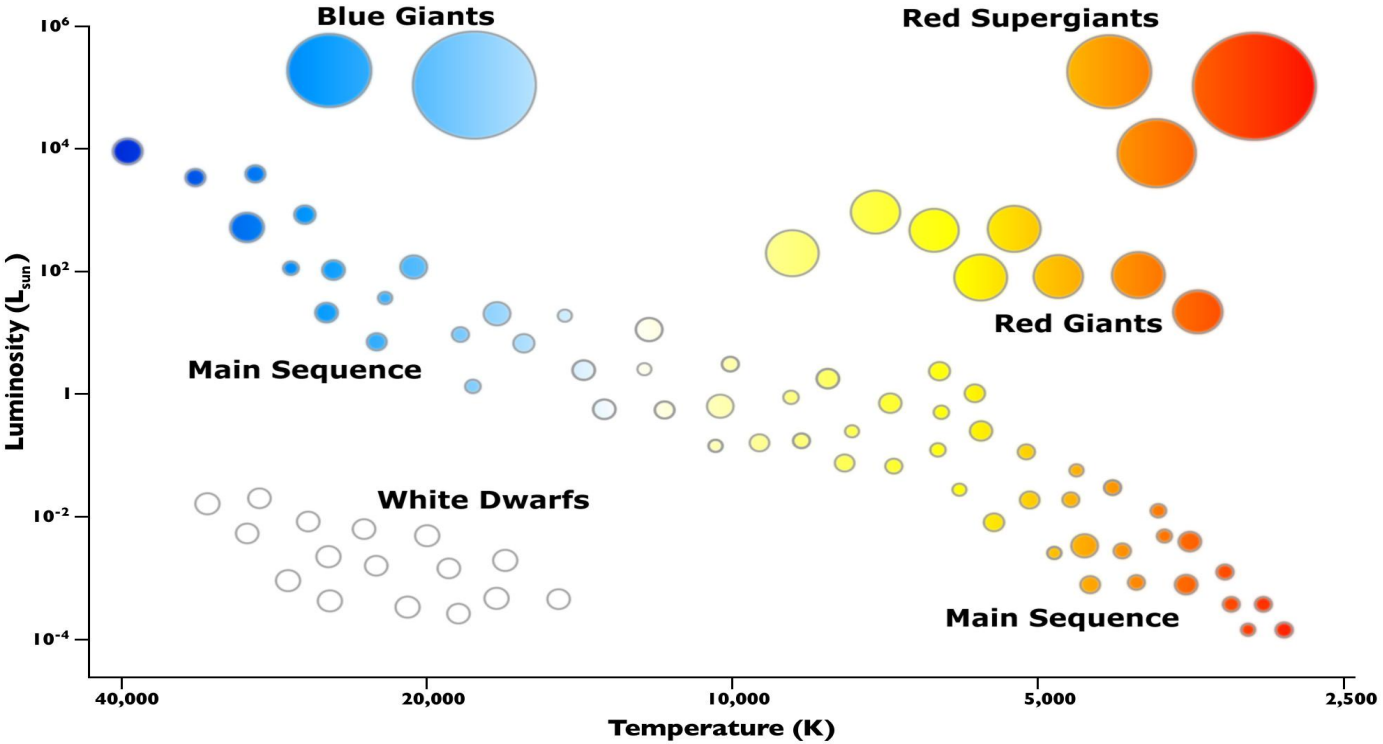
What Happens to Old Stars?

- Low Mass
  - We don’t know!
  - Lowest mass stars are called **Red Dwarfs** and, since lower mass results in a lower speed of fusion, their Main Sequence is so long that none of the Red Dwarfs in the universe have actually made it out of the stage.
- Medium Mass (Like Ours!)
  - When Medium sized stars run out of Hydrogen, it starts to collapse and the gravitational energy starts to heat the core up more and then pushes out more, making the Hydrogen in the outer layers start fusing, fueling the expansion even more until the star becomes much much bigger but also cooler. This is called a **Red Giant**.
  - This stage only lasts a few million years until the core blows the whole outer shell away, leaving behind a **Planetary Nebula**

What Happens to Old Stars? (cont.)



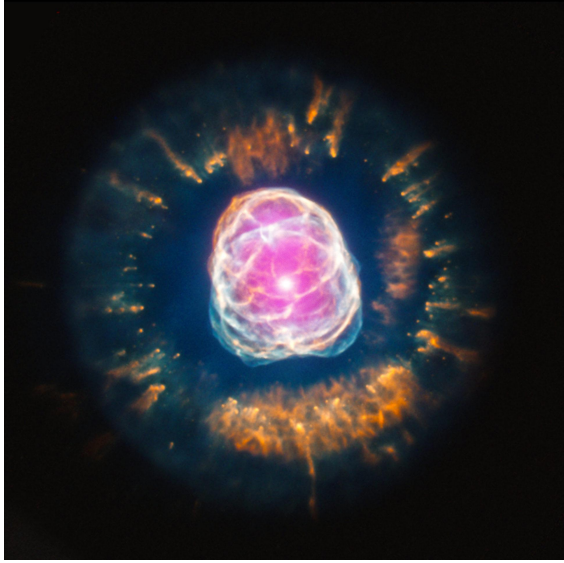
- Massive Stars
  - Massive= 10 SM or more, called **Supergiants**
  - Pass through the Main Sequence stage really quickly
  - Go through their Hydrogen and are hot enough to fuse Helium immediately
  - After all the Helium is fused, the core starts to collapse and heat up until it can fuse heavier and heavier elements (Carbon, Neon, Oxygen, Silicon, Iron)
  - Why stop at Iron?
    - Fusing Iron requires more energy than it produces
  - Once the core becomes Iron, the supergiant collapses and explodes (**Supernova**)



The Hertzprung-Russel Diagram

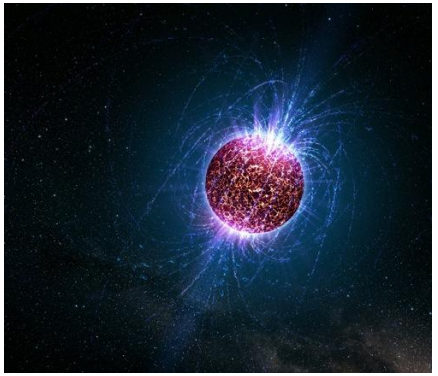
What Remains?

- **Planetary Nebulae**
  - The outer core of a Red Giant ejected into space
  - Has H and He plus traces of heavier elements
- **White Dwarfs**
  - The exposed cores of Red Giants
  - Gravity is combatted by **electron degeneracy pressure**, a force exhibited by electrons when they're too close together
  - Very small, but very hot and bright (about the same mass as the Sun compressed in the space of the Earth)
  - Extremely long lasting, but will eventually cool



What Remains? (cont.)

- **Supernova**
  - The explosion of a supergiant star
  - Huge amounts of radiation and energy are released
    - Result in heavier elements (nickel, gold, lead) get created
  - Once the explosion is over, the dust and gas creates a new nebula
- **Neutron Stars**
  - The core of a supergiant that is left after a supernova
  - Since the electrons get stripped from the atom during the supernova, protons absorb them and the charge balances, making them neutrons
  - They resist gravity with **neutron degeneracy pressure**, but Neutron Stars are typically much smaller and denser than other stars
  - Additionally, they spin very rapidly and some, called **pulsars**, emit EMR radiation out of their poles which we see as constant pulsing of X-rays and radio waves



And Finally.... Black Holes?

- For next week!

Sources

- http://lasp.colorado.edu/education/outerplanets/solsys_star.php#where
- https://www.youtube.com/watch?v=X06Tk_DvEPM
- http://abyss.uoregon.edu/~js/ast122/lectures/lec13.html
- https://science.nasa.gov/astrophysics/focus-areas/how-do-stars-form-and-evolve
- http://www.universetoday.com/24190/how-does-a-star-form/
- http://www.universetoday.com/25247/nuclear-fusion-in-stars/
- http://burro.cwru.edu/academics/Astr221/StarPhys/ppchain.html
- http://astronomy.swin.edu.au/cosmos/c/cno+cycle
- http://sunshine.chpc.utah.edu/Labs/StarLife/fusion.html
- http://sunshine.chpc.utah.edu/Labs/StarLife/remnants.html