LIFE AND DEATH OF ASTRONOMICAL BODIES

RIP PLANETS

1. Planets' Life

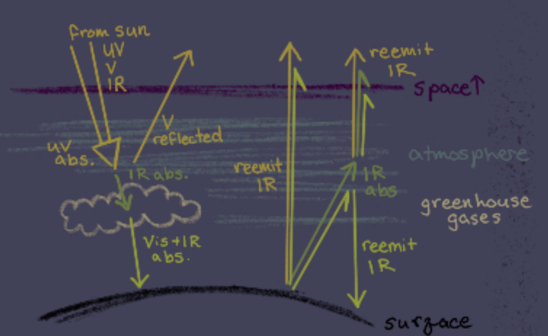
- We can start by thinking about our own solar system, and apply those ideas to other planets…
- Our Solar System was formed by the left-over material from a star being formed, a **protoplanetary disk**
- This flat disk revolved around a central obj. Slower spinning material fell to the center, little bits of dust attracted by gravity came together to make planets.
- **Terrestrial Planets** → mercury, venus, Earth, and Mars, 4 planets closest to sun. Close enough to sun (warm enough) that only metals and rocks are solid. Since metals and rocks are less abundent these planets tend to be smaller. Temp↑ size↓
- **Giant Planets / Jovian Planets** → Far from sun ⇒ cooler so ices can be solid. Since ices much more abundant these tend to be much bigger planets. Since bigger, can also pull in more gasses, and this means thicker atmosphere. Temp↓ size↑
- Each planet has a dif. temp based on a couple of factors…

$$T_{planet} = T_{sun}(1-A)^{1/4}\sqrt{r_{sun}/2d}$$

planet temp; sun temp; **Albedo** → fraction of light planet reflects; radius of sun; dist. between planet + sun

⇒ so two planets in the same stellar system differ in temp based on distance and Albedo.

- But this assumes no atmosphere for the planet, and planets like Earth + Venus very influenced by atmosphere heating…
- **Green house gasses** → gas that absorbs and re-emit's IR light, but transmits visible light. When a planet's atmosphere is made up of greenhouse gasses it further heats planet.
- Still, amount of energy going out and in a planet will always be equal…



↑ Earth Case Study

energy into Earth = energy out
energy into atmosphere = energy out
energy into surface = energy out

- When describing a terrestrial planet we also want to talk about the surface. 4 processes shape a planetary surface… **impact cratering**, **volcanism**, **tectonics**, **erosion**.
  - impact cratering: impact rate constant in our solar system, so we see more craters if older surface
  - volcanism, tectonics: need thin lithosphere (outer layer) ↳ planets start hot and cool off cooler ⇒ thicker lithosphere. ↳ bigger planets cool slower → depend on size
  - erosion: ↳ need wind, ice, or water → depend on temp ↳ dist. from sun
  - ↳ depend on less volcanism + errosion + tectonics
- **Old Surface** → very old rocks, more craters, less errosion, tectonics, and volcanism.
- **New Surface** → young rocks, less craters, covered up by other processes.

2. Death by Collision

- Planets can't neccessarily "die", but their make up can change so much that they look like completely new planets. One way this can happen is mass extinctions of life on a planet like Earth. This can happen by asteroids colliding w/ Earth.
- diameter of a crater left by an **impactor** is typically 10 times larger than the impactor's diameter.
- like we said above impacts happen at constant rate in our solar system, so we can estimate the rate that impactors hit by looking at the # of craters on an Old surface like the moon.
- We can also estimate likely hood of Earth being hit by a certain size impactor. And we can estimate kinetic energy of the object…

$$K = \frac{1}{2}mv^2$$

Kinetic Energy; → objects velocity / speed; ↳ object's mass = density · volume

- To try to detect and prevent life ending impactors from hitting Earth NASA searches for NEO's ⇒ **near Earth objects**.

3. Death by Temp. Change

- Much more likely than death by collision is a planet "dying" by massive climate change.
- As we know greenhouse gasses in our atmosphere heat a planet's surface. Runaway greenhouse effect can make it so less energy is leaving from the atmosphere, further heating the planet.
- This happened on Venus a long time ago, Venus made too much CO_2, it acted as a greenhouse gas in the atmos. Venus got hotter until it could no longer maintain liquid water (which can break down CO_2) ⇒ which lead to runaway heating.
- How do we know this is happening on Earth now? And how do we know it's our fault? (**Human caused climate change**)

① CO_2 is a greenhouse gas + ② human activity is adding a bunch of CO_2 to the atmosphere ⇒ ③ our planet will warm

↳ We know this from the isotype of CO_2 we're seeing now
↳ a subtype of an atom of a certain element, the # ≡ # of particles in nucleius ≡ protons + neutrons

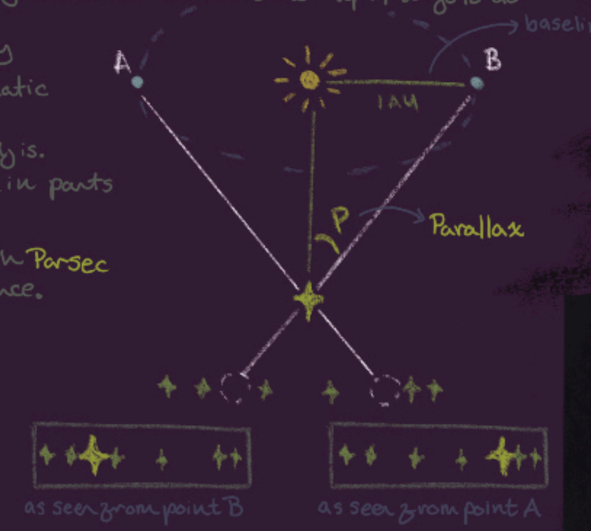
Here Lies STARS

1. Analyzing Stars

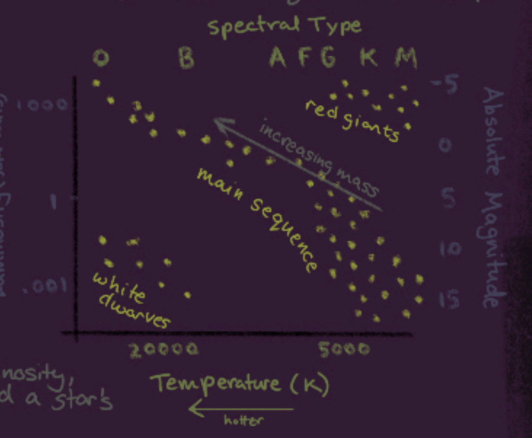
- Stars are so far away in space that if we want to study them we need to come up w/ ways to do it from Earth…
- **Parrallax** → The apparent change in location of faraway objects (like stars) from dif. vantage points. Most dramatic when objects are close and vantage points are far apart.
- We can use the shift to find out how far away star actually is.
- Since most stars so far, parallax angle is very small. Measure in parts of degrees, **arcminutes** $= \frac{1}{60} 1°$, **arcseconds** $= \frac{1}{60} 1' = \frac{1}{60}\cdot\frac{1}{60}\cdot 1°$
- We use trig to solve for distance, typically measured in **Parsec** → an object w/ parallax dist of 1 arcsec = 1 parsec distance.

$$D = \frac{1}{p}$$

dist in parsecs; parallax angle in arcsecs; → reciprocals!



- But objects actually have to be pretty close to measure distance using parallax. So instead we try…
- **apparent magnitude** → How bright a star looks from Earth. (smaller # ⇒ brighter) Depends on a stars luminosity and distance from Earth
- **Absolute magnitude** → what a stars magnitude would be at 10 pc. Only depends on luminosity.
- If $M > m$ ⇒ M is dimmer than m ⇒ a star is dimmer at 10pc than it is now ⇒ the star is closer than 10 pc
- If $M < m$ ⇒ M is brighter than m ⇒ a star is brighter at 10 pc than now ⇒ the star is farther than 10 pc
- Using these measures of brightness we can make an **H-R Diagram**…
- We can locate stars on the HR Diagram based on temperature ≡ spectral type and luminosity ≡ absolute magnitude.
- A star's place on HR Diagram can also tell us about the star's mass, type and lifespan.
  - as stars travel left on main sequence, mass↑
  - **White Dwarf**, **Main Sequence**, **Red Giant**
  - ↳ more massive stars have shorter lifespans



- We can learn a star's spectral type from their absorbtion spectra, which can also tell us if it's main sequence, white dwarf, or red giant.
- From learning the place on the graph we can learn it's luminosity, which, together w/ apparent magnitude can help us find a star's distance.

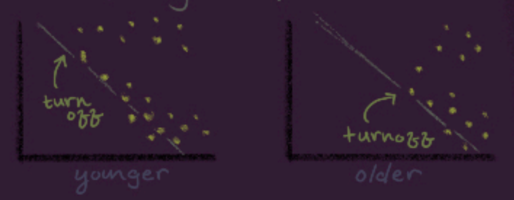
2. Star's Life

- Our Sun (and all stars) shine because of **Fusion** → The process of nuclei of atoms combine (specifically hydrogen combine and turn into helium.)
- To form Helium (^4H) it takes 2 hydrogen protons and 2 neutrons. But if you do the math Helium is less than the sum of its parts (less mass) where does the extra mass go?
- That mass was turned into energy…
- This energy is what lets the sun shine. In the very hottest parts of stars (core) this fusion takes place. This happens in all Main Sequence stars.

$$E = m \cdot c^2$$

energy; mass; speed of light; → mass can be turned into equivalent energy

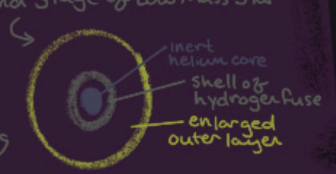
- All stars spend 90% of their life on one spot on the **Main Sequence** fusing hydrogen in their core. They don't move off until they start dying.
- Since high mass stars have expensive luminositys to maintain, they use up their store of hydrogen quicker and have a shorter main sequence lifespan.
- This fact helps us judge the age of starclusters, if more "cool" sters have turned off the main sequence then the cluster is older, since it takes longer for cooler less massive stars to "die".



3. Star's Death

- For **Low Mass Stars**…
- A stars life starts to end when it runs out of Hydrogen to fuse in it's core. When this happens star contracts until its temp. is hot enough for hydrogen just outside core to fuse to helium. This causes outer layer to enlarge to a **Red Giant**.
- Helium fusion releases less energy, eventually becomes inert, star sheds outer layer, leaving planetary nebula and it's core → a **white dwarf**. Electron degeneracy stops further contraction of the white dwarf.
- But for **High Mass Stars**…
- In high mass stars cores actually get hot enough for helium fusion, and beyond…
- Eventually gets to an inert iron core that cannot create energy from fusion or fision.
- Does not become white dwarf… The core has so much pressure not even electron degeneracy can save it. Electrons combine w/ protons and make neutrinos, which as a spark, blowing apart the core into a **Supernova**
- Afterwards extremely dense and small **neutron star** is left, or in rare cases, if even neutron degeneracy can't keep the star from collapsing, a **black hole** is created.

End Stage of Low Mass Star



End Stage of High Mass Star