Astronomy 100

Midterm 2 The Tools

Many things in space are too far away to study in person, so we need some tools to study space from Earth...

LAWS

Kepler's

- Kepler had three laws of planetary motion...
- 1) The orbit of all planets are ellipses w/ the sun at one foci
- 2) The area between the sun and two points seperated by time t on the planets orbit is always equal...

⇒ planets speed up as they come closer to the sun.

- 3) when P (orbital period of a planet) is measured in Earth years and when a (a planet's semimajor axis or their average distance from the sun) is measured in Astronomical Units, then...

$P^2 = a^3$ ... and in general... $P^2 \propto a^3$

Newton's

- 1) every object will be in a state of rest or constant motion unless acted on by an outside force.
- 2) change of motion of a body is proportional to and in the direction of the force acting on it.
- 3) for every action there is an equal and opposite reaction.
- Then why don't planets just move in a straight line across space? what forces are acting on them?

Gravitation

- gravity → the force pulling stuff to Earth, that also causes the pushes and pulls of planets in space.
- gravity is a property of mass. more mass ⇒ more gravity.
- gravitational force between two objects $= F_{gravity} = G\frac{M_1 M_2}{R^2}$ (G: universal gravitational constant; M_1, M_2: masses of 2 objects; R: seperation of objects)
- using his ideas Newton also updated Kepler's third law...

$$a^3 = (M_1 + M_2) \times P^2$$

(M_1: mass of sun = 1; M_2: mass of planet in unit of sun's mass)

in practice very close to 1

PHYSICS BASICS

Definitions

- some words to describe an objects motion...
- mass → measure of the amount of material within an object.
- volume → physical space an object occupies.
- density → the mass vs volume of an object. A measure of heavy vs light.

density = mass/volume

- some words to describe an objects motion...
- speed → how fast an object is moving
- velocity → speed and direction of a motion
- acceleration → rate of change in an objects velocity.
- momentum → a measure of a bodies motion.

momentum = mass • velocity

- angular momentum → rotation of a body as it revolves around some fixed point.

angular momentum = mass • velocity • dist. from fixed point

- force → something acting on a body, that has size and direction.

WAVES

Radiation

- Radiation → a general term for waves that radiate from a source.
- Electric Fields → forces produced by stationary electric charges
- Magnetic Fields → produced by moving electric charges
- Electromagnetic Radiation → type of outward moving electromagnetic disturbances.
- when talking about radiation we imagine outward moving waves that are all types of light.

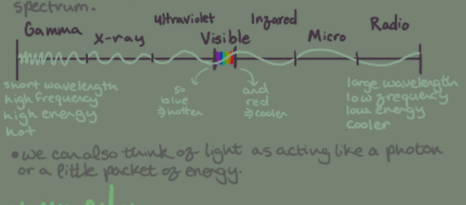
Light

- we talk about light as Waves, w/ a wavelength and frequency.

- all waves of light move at the speed of light (when unimpedied)
- wavelength and frequency are related...

speed of light ← $c = \lambda f$ → frequency; ↳ wavelength

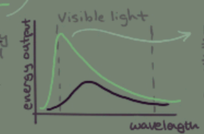
- All electromagnetic radiation fits on a light spectrum.



- we can also think of light as acting like a photon or a little packet of energy.

Luminosity

- Luminosity → a measure of how much energy an obj. emits as light per second.
- we imagine Blackbodys or idealized objects that only absorb energy.
- for these objects luminosity relies on temp and size...
- Stefan-Boltzmann Law → luminosity $L = \sigma A T^4$ (σ: constant; A: surface area; T: temperature)
- thinking more about temperature of black bodies...
- Wein's Law → temp in Kelvin $T = \frac{.29\,cm \cdot K}{\lambda_{peak}}$ (peak wavelength)
- So temp of a blackbody only relies on peak wavelength and is inverse to it.
- We can visualize all this in Spectral Curves



higher λ_{peak} ⇒ higher temp ⇒ higher energy output (Luminosity) at all levels

Spectra

- When we disperse a beam of white light through a prism we get a **continuous spectrum**

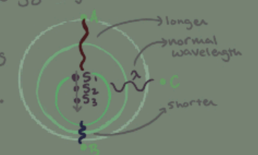
- if we pass this light through a cool cloud of low density gas we will get a spectra w/ black lines of missing parts, this is a **absorbtion spectrum**

- if we heat the cool cloud of low density gas til it emits light we will get a spectra w/ only a few colored lines, an **emission spectrum.**

- These spectra are caused by the electrons of the atoms that make up our hypothetical gas either absorbing or emiting the exact amount of energy it needs for its electrons to jump between orbital levels.
- This amount of energy corresponds to the frequency of the missing line in the spectra.
- And since each element has different orbital levels we can actually figure out which element a spectra comes from.
- This is very useful when exploring light from far away points in the universe. We can learn about the elemental composition of the universe.

Doppler Effect

- One thing to be careful of when studying waves from across the universe is how they can get distorted.
- One way is the **Doppler Effect** → or how a light source moving towards you will cause the waves to squish, or if it's moving away from you will cause the waves to stretch...

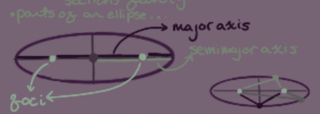


- A viewer standing parallel to the movement will notice no change.
- This can cause emission and absorbtion spectra to shift toward one end of the spectrum.
- moving toward you ⇒ shrinking λ ⇒ **blueshift**
- moving away from you ⇒ growing λ ⇒ **redshift**
- an equation...

velocity of obj / speed of light $\frac{v}{c} = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$ (observed wavelength; λ at rest)

Ellipses

- ellipse → a closed curve belonging the conic sections family.
- parts of an ellipse



- foci are special, because the summed dist. of each foci to a point on the edge is the same for any edge point.

- eccentricity → measure of roundness of an ellipse. 1 ⇒ flat, 0 ⇒ wide ellipse

eccentricity = dist. between foci / length of major axis

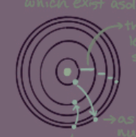
Atoms

- atoms are the tiny building blocks of everything in the universe.

electrons → neg. charged part of the atom in motion around the...
nucleus → tiny center of the atom that contains protons (pos.) and neutrons (no charge)

- an atom in its natural state is electronically neutral.
- every element has a diff # of protons in its nucleus (that's how we define an element)

- atoms typically have multiple energy levels, which exist as orbits of an electron.



- the dist. between each energy level/orbit gets progressively smaller, meaning it takes less energy to transfer between orbits further from the nucleus.
- as an electron moves away from the nucleus it absorbs energy
- as an electron moves toward the nucleus it emits energy