Astronomy C10 - Midterm 1 Review Sheet

Distance and Time

speed of light: $c = 3 \times 10^8$ m/s

finite speed → we see things as they were in past ("fossil record" of universe's history)

light year (9.5 trillion km): distance light travels in one year

$d = vt$ — distance covered in time t at constant speed v

time scales:
- Universe: 14 billion years
- Solar System: 4.5 billion years

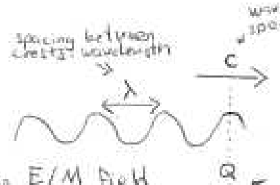
distance scales:
- Universe: ~14 billion light years
- nearby galaxies: few million light years
- nearby stars: few light years
- planets: few A.U.

Light

light = "electromagnetic radiation" (oscillating electric/magnetic fields)

acts as waves or particles, depending on the circumstances

wave model:



oscillating E/M field moving through space at speed c.

ν "nu" wave crests pass through this line every second: frequency

$\lambda \nu = c$ — frequency and wavelength are inversely proportional

light is usually composed of many different colors/wavelengths

short λ, high ν ← → long λ, low ν

gamma rays, X-rays, UV, visible (V B G Y O R — violet, blue, green, yellow, orange, red), infrared, radio

← "white" = all colors

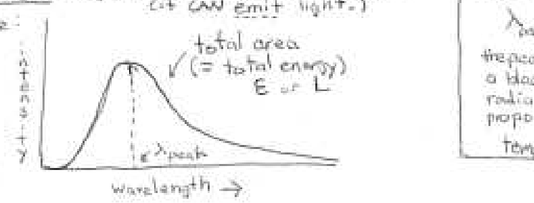
particle model:

individual particles = "photons", each carrying energy = E

$E = h\nu$ — photon energy is proportional to wave frequency

"blackbody" — an opaque object that reflects no light. (it CAN emit light.)

spectrum looks like:



note: don't have to have a perfect blackbody to get a (pretty good) blackbody spectrum, just needs to be opaque.

Wien's Law: $\lambda_{peak} T = $ const — the peak wavelength of a blackbody's emitted radiation is inversely proportional to temperature. temp. ↑, λ_{peak} ↓

Stefan-Boltzmann Law: $E = \sigma T^4$ — energy per surface area emitted by a blackbody is proportional to the 4th power of the temperature. temp. ↑, E WAY ↑

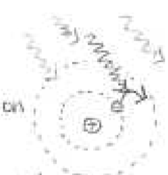
$L = 4\pi R^2 E$ — Luminosity (total power emitted by an object) is proportional to surface area

spectral lines:

emission

electron jumps down an energy level → photon emitted

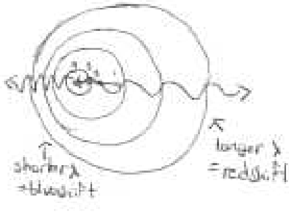
absorption



incoming photon hits electron, causes it to jump up to higher level → photon absorbed

in either case: pattern of lines tells us the composition (elements, etc.) of distant objects.

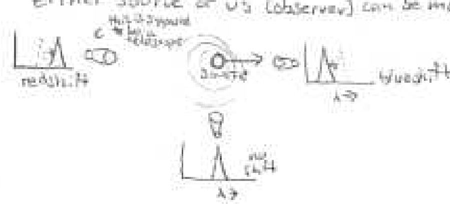
doppler effect: effect of moving emitter



Doppler effect:
$$\frac{\Delta\lambda}{\lambda} = \frac{v_r}{c}$$
$\Delta\lambda$ = change in λ, λ = wavelength, v_r = radial velocity

describes how much a spectral line shifts for a source moving towards/away from us

only line-of-sight motion matters! either source or us (observer) can be moving.



Telescopes

primary purpose: collect more light

light-collecting power depends on area (prop. to square of radius or diameter)

$P \propto D^2$ — power of a telescope

also: larger telescope → better resolution but atmosphere blurs image unless you use adaptive optics

types of telescopes:
- refracting (lens) → problem: chromatic abberation
- reflecting (mirror) → no problems, but need a hyperboloid/paraboloid mirror to avoid spherical aberration

telescopes in space:
- no atmosphere blurring
- darker sky (e.g. no light pollution)
- can see gamma-ray, X-ray, UV, IR (normally blocked by atmosphere)

twinkling - distortion due to turbulence in atmosphere

· star ○ planet

planets twinkle very little because they are much closer and look bigger. (stars are basically points because they are so far away)

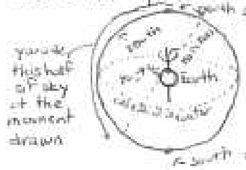
sky/sunsets

blue light scatters in air → blue sky

Sun is white - but at sunset, air scatters (and dust absorbs) the blue light away so it looks yellow/red.

Moon Phases, Eclipses, Sky & Celestial Sphere

Celestial sphere - imaginary sphere stars are "glued" to



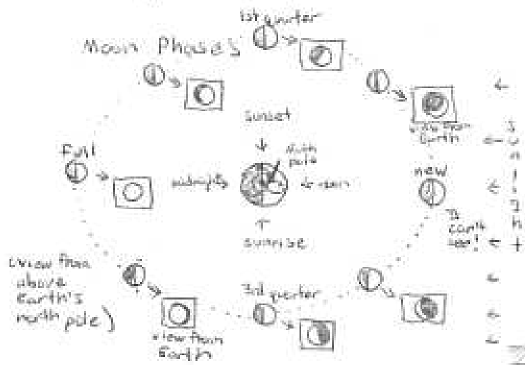
see half at any time.
Earth rotates → stars move in sky

Seasons - tilt of Earth's axis

when tilted away from sun → sunlight incident at large angle, fewer daylight hours.

Night sky - changes depending on time of year

Moon Phases



Eclipses:
normally no eclipse each month, since Moon's orbit is tilted from Earth's. But sometimes they line up:

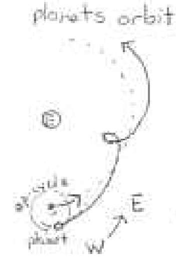
Solar eclipse (new moon w/ perfect alignment)

Lunar eclipse (Full moon w/ perfect alignment)

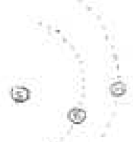
Sun is 390x larger and 390x farther away from Moon, so they look the same angular size and solar eclipses are "perfect"

Solar System / Orbits

Ptolemy: geocentric
planets orbit Earth...
but also execute "epicycles" to explain the observed retrograde motion (short-term periods)



Copernicus: heliocentric
planets orbit Sun

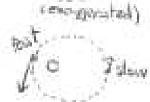


retrograde motion due to "passing" of one planet by another

Galileo confirmed using phases of Venus →

Kepler: improved heliocentric
laws
1. Orbits are ellipses. Sun at one focus (nothing at other focus)

2. Planet moves faster when closer to Sun.



3. $P^2 = kR^3$
P = period - time to orbit Sun
R = avg. distance from Sun
So, outer planets move slower (take longer to orbit)

← note that for Earth, R = 1 AU, P = 1 yr

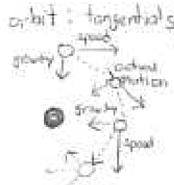
Newton's version

$$P^2 = \frac{4\pi^2}{GM} R^3$$

M = mass of thing you're orbiting (usually Sun)
k in Kepler's third law is NOT a constant (but it is close for planets)

Newton: laws of physics, even more improvements
1. Inertia: velocity is constant unless there's a force.
2. $F = ma$
3. Forces come in equal/opposite pairs
"G." $F_G = \frac{G m_1 m_2}{d^2}$ m_1, m_2 = masses of each object, d = distance between them

orbit: tangential speed + gravity



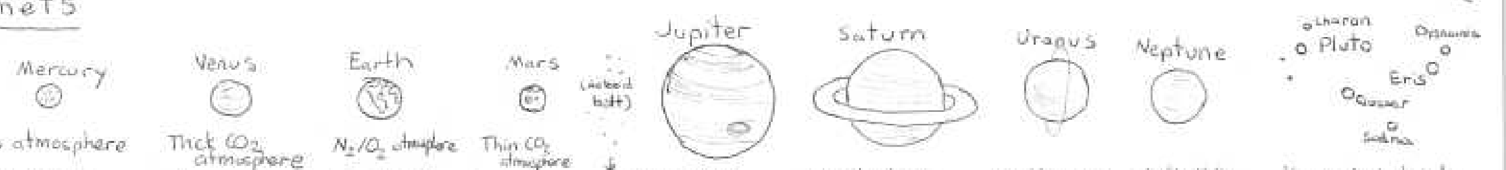
constantly "falling"

Tides (on Earth)
due to differential gravitational pull (usually of the Moon on Earth)

two high tides per day (one when facing Moon, other when facing away)

Strongest tides when Sun/Moon/Earth aligned (full/new moon)
→ differential forces add

Planets



Mercury
No atmosphere
No moons
Very hot during day, cold at night
Hard to study - sets/rises almost when Sun does
Old, cratered (like Moon)

Venus
Thick CO_2 atmosphere
No moons
HOT - greenhouse gas traps heat (light gets in, but IR can't easily get out)

Earth
N_2/O_2 atmosphere
One large moon
Plate tectonics: crust broken into plates which are carried around by churning mantle
Moon
No atmosphere or erosion
Maria - large lava flows
Formed by giant impact?

Mars
Thin CO_2 atmosphere
Two tiny moons
Large volcanoes, polar caps, many craters
Previous water? (channels, etc.)
Orange color due to rust

Jupiter
Huge planet mostly H, He (gases)
Strong winds, big storms
Atmospheric bands
Io
Extremely volcanic due to tidal forces
Europa
Surface of fractured ice. Ocean beneath?
Ganymede
Callisto
Old, many craters

Saturn
Mostly H, He (like Jupiter, though lower density)
Rings
very prominent
icy rocks
Failed to form a moon due to tidal forces
Titan
Nitrogen atmosphere
hydrocarbon haze (methane, ethane)
lakes, rivers of methane
Enceladus
Icy surface
Water underneath?

Uranus
Mostly H, He, ammonia, methane
Axis almost in orbital plane: extreme tilt/seasons
Narrow rings kept narrow by shepherd moons
discovered by star occultation

Neptune
Mostly H, He, ammonia, methane
Discovered by gravitational tug on Uranus!
Very strong winds
Triton
Complex terrain
Ice volcanoes

Kuiper belt objects
Very small, mostly ice.
Far from sun.

Terrestrial planets:
Small, mostly rock (dense)
Few moons.

Ceres
Asteroids:
Very small, either rocky or metallic.
Couldn't form a planet due to Jupiter's gravity.

Jovian planets:
Large, mostly gas/liquid (not dense)
Many moons.
Rapid rotation

Comets:
Kuiper belt or Oort cloud object that falls into inner solar system (perturbation of passing star)
made of ice and rock, some carbon-rich compounds (primitive material)