ASTR 201 EXAM II Review

Electromagnetic Radiation

Light is just one form

Radio Microwave Infrared Optical Ultraviolet X-ray γ-ray

λ Long wavelength
f low frequency
low energy

$$\lambda f = c$$

$$E = hf$$

h = Planck's constant

short wavelength
high frequency
high energy

we see by scattered light

Hot objects emit light (thermal radiation, sometimes called "blackbody" radiation)

e.g., a
- hot stove top
- the sun

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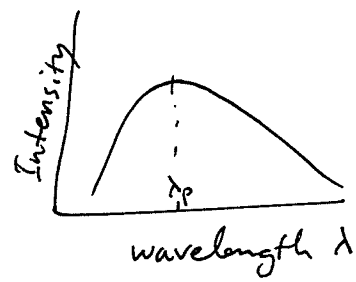
Physics of Light

Thermal radiation

Hot objects cool by emitting electromagnetic radiation over a broad spectrum.

The peak intensity occurs at a wavelength λ_p that depends on Temperature through



- Wien's Law : $\lambda_p T = 2.9 \times 10^6 \text{ nm} \cdot \text{K}$
  ↳ hotter object emit shorter wavelengths

- Stefan-Boltzmann Law $L = 4\pi R^2 \sigma T^4$
  ↳ hotter objects emit more light

  L — luminosity (absolute brightness)
  $4\pi R^2$ — surface area of sphere
  σ — constant
  T — Temperature

So hotter objects
- emit more energy
- are bluer

& bigger objects are brighter at a given Temperature

e.g., a star the same size as the sun but twice as hot will be $\left(\frac{T_*}{T_\odot}\right)^4 = 2^4 = 16$ times brighter than the sun

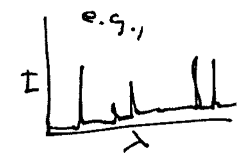
similarly for sizes:
doubling the radius → $A \propto R^2 = 2^2 = 4$ times as brig

Apparent brightness b is related ~~to~~ to the luminosity by the inverse square law : $b = \frac{L}{4\pi d^2}$

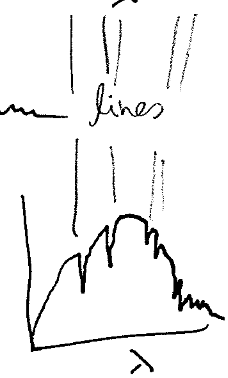
→ a star becomes fainter to our eyes as it gets farther away.

Kirchoff's Laws

- Hot, dense objects emit a continuous (thermal) spectrum
- Hot, diffuse gas emits an emission line spectrum



- Cool gas obscuring a background light source will ~~~~ result in an absorption line spectrum



Every element & molecule has its own specific set of emission/absorption lines, allowing them to be identified in the spectra of distant objects & their abundance measured.

Doppler effect

Motion causes a shift in wavelength : $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

The larger the velocity, the greater the shift

Approaching : blue shift

Receding : red shift

Telescopes : Bigger is Better : Light collecting are $\propto D^2$

The biggear the diameter D, Resolution $\propto D^{-1}$

Solar System

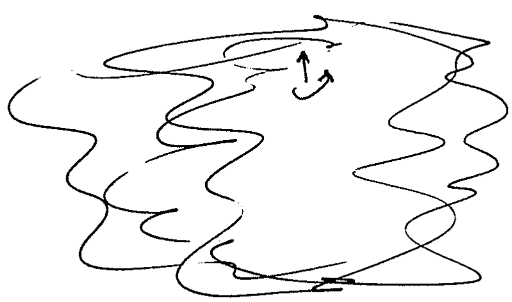
Know – contents & layout

names & order of major planets

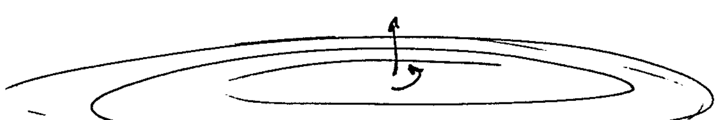
location of Asteroid & Kuiper belts ; Oort cloud

Distinctions between major planets, dwarf planets, moons, asteroids, & comets

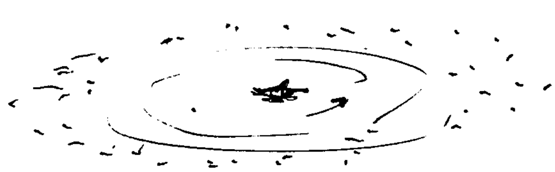
Formation : solar nebular hypothesis



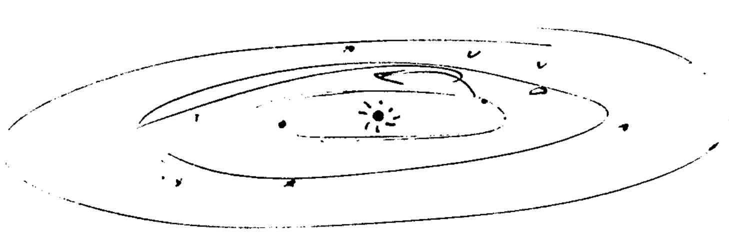
Initial cloud of interstellar gas



Collapse gravitationally into a preferred plane that spins up through the conservation of angular momentum



Sun starts to form in the center of the solar nebula. Solid particles condense out of gas with a composition that depends on the temperature



Solid particles agglomerate into planetesimals which collide until

Major planets have formed by sweeping up (or out) all

Condensation sequence

Nearest the young sun the solar nebula is hottest. Only the most refractory materials (mostly metals) can condense into solids. Hence the relatively large iron core of Mercury.

Moving outwards from the sun, the temperature steadily drops and progressively more materials can condense into solids. Hence the bulk composition of Venus, Earth, & Mars includes silicates and other rocky minerals in addition to their iron cores.

Still further out, one crosses the frost line (also called the ice line) around 3.5 AU. Here the temperature becomes cool enough for water (and other hydrogen compounds) to freeze into solid grains of ice.

Ice is effectively another mineral in the outer solar system, being an important part of the bulk of the moons of the gas giant planets and dwarf planets.

Terrestrial planets form by the agglomeration of rocky & metallic planetesimals

Jovian planets form as miniature solar systems within the solar nebula, perhaps seeded by large planetesimals. Accrete abundant hydrogen & helium gas to become massive

Asteroids & Comets are the rocky & icy (respectively) left overs of planet formation. There are relatively few left now — the sum of all asteroids is much less mass than any of the terrestrial planets. There were more in the past, especially in the distant past going back to the era of "late heavy bombardament" about 3.8 billion years ago (vs. the 4.5 billion year age of the solar system)

The conservation of angular momentum during the collapse of the solar nebula explains why the major planets all orbit prograde and also (mostly) spin prograde. Exception (like the extreme axial tilt of Uranus) can be attributed to the individuality of the last major collision during formation (such an event is thought to have formed the Earth's moon.)

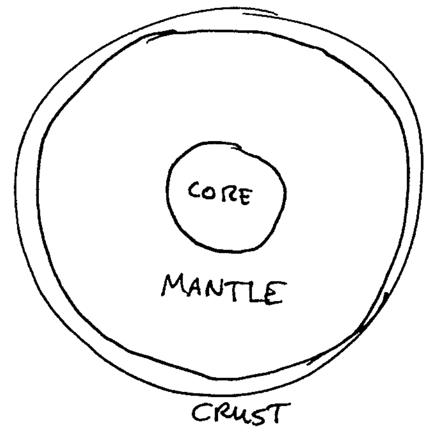
The isotopic composition of moon rocks & the Earth's mantle suggest a common origin. Ages can be dated through radioactive decay:

$$N = N_0 e^{-t/\tau}$$

τ is related to the half life

Terrestrial Planets

Interior structure



CORE : high density,
metallic (iron, nickel)

MANTLE : mid-density,
rocky material

CRUST : lowest density rocks
Part of rigid lithosphere
floating on more plastic, hotter rocks of ~~the~~ mantle

In the case of the Earth, the core is further divided into a solid inner core and a liquid outer core. The other terrestrial planets probably had such a structure in the past, but they've cooled off & mostly solidified.

This CRUST – MANTLE — CORE structure is a natural consequence of differentiation during planet formation. The planets were initially molten from the heat of the many collisions that built them. Dense material (like iron) sank to the center to form the CORE while lighter materials floated on top.

Geological activity like volcanoes & earthquakes is driven by the escape of heat from the interior. Initially this is just the heat leftover from formation; later the major contributor to keeping the interior warm is the decay of long lived radioactive elements (like Uranium).

In both cases, larger planets have and retain more heat for longer as the trapped heat scales as the volume (R^3) while the cooling only happens through the surface (R^2).

→ Small planets like Mercury have mostly cooled off and are now geologically dead.

→ Bigger planets like the Earth retain some interior heat, so remain geologically active.

Terrestrial Planet Surfaces Shaped By

- Impact Cratering – the dominant effect on most planets, but not Earth
- Volcanism – active everywhere; mostly in the past
- Plate Tectonics – mostly on the Earth
- Erosion
  - wind
  - water – rivers, rain, ice & glaciers

Old surfaces have lots of craters: the accumulated scars of time

Surfaces lacking many craters must be younger, getting re-paved

Individual Cases - every planet is unique in some way

by increasing size

- The Moon : geologically dead. Heavily cratered surface. Darker maria regions where lava filled in larger craters after the period of heavy bombardment but still in the ancient past (~ 3.5 billion years ago)

- Mercury : geologically dead. Heavily cratered, but also with smoother spots covered by ancient lava (like the moon). Additionally, Mercury shrank substantially in radius as it cooled, leaving huge, planet-spanning stretch-mark cliffs ("scarps").

- Mars : Many craters but also many other features: giant extinct volcanoes, enormous canyons, wind-blown sand dunes, erosion features that are apparently ancient river beds. We now have good evidence that water once flowed on the surface of Mars, and still seeps from crater rims on occasion.

- Venus : Fewer craters, mostly large. Volcanoes (mostly extinct but maybe not all) plus dome-like features not seen elsewhere. Some hints of fractures attributed to failed plate tectonics.

- Earth : Geologically active. Plate tectonics with mountain building and seabed spreading and plate subduction. Volcanoes at plate boundaries and also over hot spots (e.g. Hawaii). Very active erosion (wind,