ASTR 100 EXAM I Review

What's out there?

Definitions; Scale

- Planet
- Dwarf Planet
- Moon
- Asteroid
- Comet
- Star
- Solar System
- Nebula
- Galaxy
- Universe

Universe >> Galaxy >> Star >> Planet >> Moons, etc. >> us.

The universe is incomprehensibly large and perhaps spatially infinite

It is also incredibly ancient, but has a finite age — if we scale the 14 Billion years of the Universe to a 12-month calendar, all of human civilization happens in the last minute of the last da

Scientific Method

Hallmarks of Science

#1 : Must explain natural phenomena with only Natural Causes (NO MAGIC)

#2 : Progress through hypothesis testing

- simplicity preferred : Occam's razor

#3 : Scientific hypotheses must be testable and subject to falsification

Importance of measurement accuracy

A measurement is only as good as its error bar -

A scientific experiment not only measures something, but it also specifies how well that something is measured.

Appearance of the Sky

Local sky specified by 2 angles : Altitude
& Direction (Azimuth)

Horizon : plane tangent to observer

Zenith : point on sky directly above observer (⊥ to horizon)

Meridian : N-S line passing through zenith.
Divides sky into Eastern (AM) and Western (PM) halves.

Objects rise in East, cross meridian, & set in West.
↳ Sun, stars, etc.

Angular measures : 360° in circle
$60'$ in 1° — 60 arcminutes in 1 degree
$60''$ in $1'$ — 60 arcseconds in 1 arcminute

Rising & Setting motions depend on lattitude
Stars do not rise ⊥ to horizon except at the equator
∠ of rising & setting = co lattitude
For a northern hemisphere observer,
- the North Star remains in a [nearly] fixed position
- circumpolar stars [far enough north] never set
  e.g. the Big Dipper is always above the horizon in Cleveland

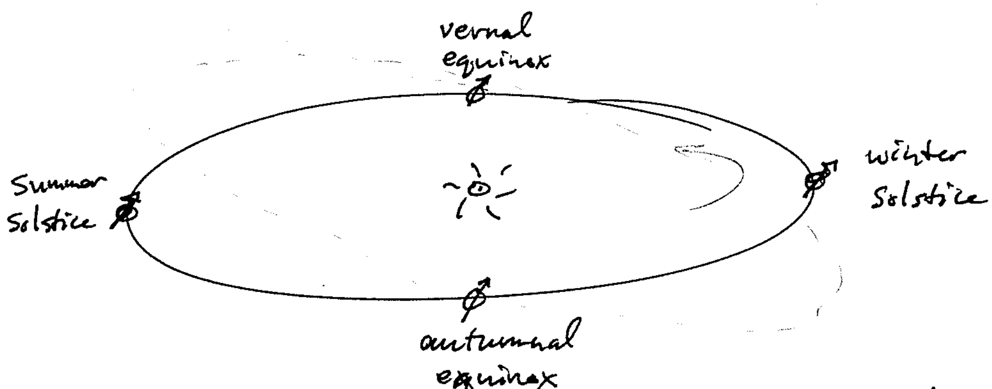
Constellations of the Zodiac gradually appear & disappear as the Earth orbits the sun.

Latitude & Longitude on Earth project to Declination & Right Ascension on Celestial Sphere

Solar Day = 24^h. SIDEREAL DAY = $23^h 56^m$
There would still be one day per year if the Earth stopped spinning

SEASONAL VARIATIONS dominated by AXIAL TILT of Earth, NOT DISTANCE

Solstices & Equinoxes



- Solstice : maximum north/south position of sun on sky — longest/shortest day of year
- Equinox : half-way point between solstices.
  - Only day on which northern & southern hemispheres equally illuminated

- Ecliptic : — path of sun across sky
- Celestial Equator : — extension of Earth's equator onto sky

These planes tipped wrt each other by axial tilt (23.5°)

The sun's extremal N-S positions vary by 47° from solstice to solstice!

- Tropic : latitude where the sun can reach the zenith (± 23.5)
- [Ant] Arctic : latitude where the sun never sets on the summer solstice $|\ell| > 66.5°$
- Precession : wobbling of the Earth's axis
  very slow change of the orientation of the spinning Earth with respect to the Celestial Sphere (26,000 yr period)
  → Polaris won't be the North Star in a few thousand years
  → Discovered by Hipparchus back in the day (280 BC

Lunar Phases

- Phase determined by viewing angle wrt sun
- Consequence of the moon's orbit around the Earth

Siderial Period : 27.3^d

Synodic Period : 29.5^d ← what we observe as a consequence of the combined orbit of the moon around Earth and Earth around the sun.

Phases :
- New
- crescent (waxing)
- first quarter (half illuminated)
- gibbous (waxing)
- full
- gibbous (waning)
- last quarter
- crescent (waning)
- repeat

(crescent (waxing), first quarter, gibbous (waxing): } most prominent in early evening)

(gibbous (waning), last quarter, crescent (waning): } most prominent before sunrise)

Synchronous rotation : the moon keeps the same face towards us because it is tidally locked into a 1:1 spin-orbit resonance – it turns once on its axis for every one orbit

Eclipses occur when the shadow of the Earth/Moon is cast on the Moon/Earth

Lunar Eclipse : the moon passes through Earth's shadow

Solar Eclipse : the moon's shadow crosses the surface of the Earth

Eclipses can only occur when the moon is

i) either new or full,

AND ii) at a node of its orbit, which is 5° inclined wrt the ecliptic

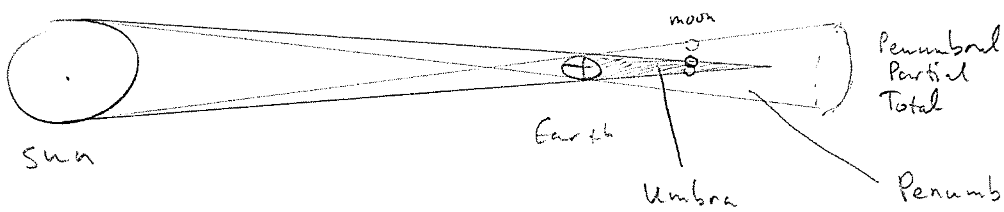
Eclipses (con.)

Lunar eclipses occur only at full moon

can be

Penumbral	Penumbral passage
Partial	Partial umbral passage
Total	complete umbral coverage

depending on how closely aligned the moon-earth-sun line is



Total Lunar Eclipse coming up Sunday evening 9/27/15 "Blood moon"
Penumbral eclipse starts shortly after sunset, but not dramatic
Umbral eclipse reaches totality at 10:47 PM (starts ~ 10:11 PM)
Takes several hours. 2016: Next lunar eclipse in February

Solar Eclipses occur only at New moon

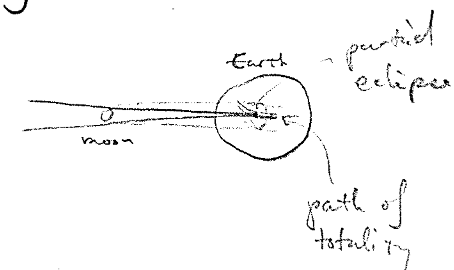
Very rare, because the moon is smaller than the Earth.
Its angular size is about the same as the sun's,
so the tip of the umbra just barely reaches the
surface of the Earth. The path of totality is restricted
to a narrow geographical swath, and lasts only a few minutes.

can be

Partial 

Total 

Annular 



depending on where the moon is in its slightly ~~ec~~ eccentric orbit

Eclipses (con.)

Eclipses do not occur every new & full moon because near-perfect alignment is required. The moon's orbit is tipped 5° wrt the plane of the ecliptic, so it must additionally be at the point where these planes intersect (the line of nodes)

This alignment happens twice a year ("eclipse seasons")

Even then, the details depend on exactly when & where the Earth – Moon – Sun align as to how much (if any) eclipse occurs.

Ancient Astronomy

Ancient peoples kept a close eye on the sky – the earliest written records display an advanced knowledge of astronomical cycles (e.g., the Babylonians knew about eclipse seasons even if they couldn't predict eclipses). This implies a long oral tradition before civilization.

All cultures developed calendars; many built elaborate structures marking celestial events & locations (e.g., Stonehenge)

The Greeks even built an analog computer (the Antikythera device)

Eratosthenes made an accurate estimate of the circumference of the Earth (c. 240 BC)

Competing Cosmologies

Geocentric	**Heliocentric**
Ptolemaic	Copernican
Earth at center	Sun at center

The sun is the source of light in both models

Explains	**Explains**
• **Motion of Sun**	• **Motion of Sun**
• **Motion of Moon**	• **Motion of Moon**
• **Solar and Lunar Eclipses**	• **Solar and Lunar Eclipses**
• **Phases of Moon**	• **Phases of Moon**

Retrograde Motion

Needs epicycles	Consequence of Lapping	**nicer**

Inferiority of Mercury & Venus

Must tie to sun	Interior to Earth's Orbit	**nicer**

Predicts

- No parallax ✓	- Parallax X
- Venus: crescent phase only X	- Venus: all phases ✓

Galileo's telescopic discoveries

- Stars in the Milky Way
- Mountains on the Moon
- Sun spots (celestial spheres NOT perfect)
- Rings of Saturn (barely resolved)
- Moons of Jupiter ("Medicean stars")
  - Earth NOT center of all revolution
- Phases of Venus
  - Good test of geocentric hypothesis

Galileo also helped overcome common misconceptions about the nature of motion

- All motion is relative (Galilean relativity)
- Objects fall with the same rate of acceleration irrespective of composition (Equivalence Principle)
  - Horizontal motion is decoupled from verticle acceleration
    - a bullet falls to the ground equally fast whether shot or dropped

Tycho Brahe

- Last great naked eye observer (pre-Galileo)
  - Compiled accurate positions of planets ~1' accuracy (vs. Ptolemy's 10')
  - Measured parallax of comet, placing it between planets
  - Could not detect parallax of stars

Kepler's Laws

1. Planetary orbits are ellipses (not just circles) with the sun at one focus (not center)

2. Equal areas are swept out in equal times by a (imaginary!) line connecting a planet to the sun (Conservation of Angular Momentum

3. $P^2 = a^3$

   P = Period of orbit in years (sidereal period)

   a = semi-major axis of ellipse in AU

Newton's Laws of Motion

1. An object at rest remains at rest and an object in motion maintains a constant velocity unless acted upon by an external force.

2. $\vec{F} = m\vec{a}$ a force F applied to a mass m causes an acceleration $\vec{a}$.

3. For every action there is an equal and opposite reaction.

Conserved physical quantities

Mass

Energy e.g., kinetic energy $= \frac{1}{2}mv^2$

Momentum linear momentum $= m\vec{v}$

Angular momentum $= m\vec{r}\times\vec{v}$

$E = mc^2$

Mass in a very condensed form of energy

Kepler's 2[nd] law is a consequence of the conservation of angular momentum. As a planet nears the sun, its separation ($\vec{r}$) shrinks, so its velocity ($\vec{v}$) must increase, and vice-versa, to keep the product mrv costant.

Newton's Universal Law of Gravity

$$F = \frac{GMm}{d^2}$$

expresses the gravitational force attracting mass M to mass m (and vice-versa) separated by a distance d.

G is a constant of nature describing the strength of the force.

Newton's Law of gravity is the cause of Kepler's 3[rd] Law:

$$MP^2 = \left(\frac{4\pi^2}{G}\right)a^3$$ in arbitrary units.

In solar system units, with M is solar masses, $\frac{4\pi^2}{G} = 1$, so

$$MP^2 = a^3$$ – Newton's generalization of Kepler's 3[rd] law

→ circular speed: $V_{circ} = \sqrt{\frac{GM}{r}}$

escape speed: $V_{esc} = \sqrt{\frac{2GM}{r}} = \sqrt{2}\, V_{circ}$