Astro 210
Lecture 4
Aug 30, 2010

Announcements
- HW1 available; due in class Friday
- **register** your iClicker; link on course webpage

Last time: the naked-eye Moon
on celestial sphere: path is great circle
motion is eastward w.r.t stars
phases of the moon: caused by changing Earth viewpoint
of the Sun-facing illuminated half of Moon

my suggestion: practice! do the experiment in real life!
point to moon, then sun, find Moon-Earth-Sun angle

complete cycle of lunar phases in 29.5 days
$\Rightarrow$ 3rd fundamental measure of time: **month of phases**

Eclipses

Lunar Eclipse: moon in earth's shadow

diagram: Sun, Earth, Moon

`www: lunar eclipses`

note: can still see Moon even when totally in Earth's shadow!
appears much dimmer, and red

Q: what's going on? why the red color?

note that *direct* sunlight is totally blocked
so light must be indirect, in fact:
scattered light from earth's atm.
red b/c blue is scattered more strongly, so only red is left
in other words:
  glow is from all the sunrises and sunsets on Earth!

Note: lunar eclipse coming up: Dec 21
watch it over break, impress someone with your ASTR210 skills!

solar eclipse: observer in moon's shadow
Note: Earth larger than Moon
Q: what does this immediately imply for solar eclipses?

since Moon smaller than earth, whole earth cannot be in shadow
in fact, only a small region, $\sim$ 100 mi, at a given time
"eclipse path"

interesting coincidence: Moon and Sun have
almost identical angular size
and what's more: Moon's distance changes (not circular orbit)
`www: moon perigee/apogee comparison`

together this means: two kinds of solar eclipses
`www: annular eclipse`
`www: total eclipse`
`www: looking back on Earth's shadow`

Note: there is *not* a solar or lunar eclipse every month!

iClicker Poll: Eclipses and Lunar Orbit

Eclipses do *not* occur most months

What does this imply about the Moon's 3-D motion around Earth?

A Moon-Earth orbit not confined to a plane

B Moon-Earth orbit is planar,
but not in ecliptic (=Earth-Sun orbit plane)

C Moon-Earth orbit is planar and is in ecliptic,
but Moon orbit is in opposite direction as Earth-Sun orbit

D trick question! eclipse does occur monthly
$\longrightarrow$ that's the new moon

if Moon's orbit plane around Earth
were same as Earth's around the Sun (i.e., the ecliptic)
then *would* have eclipses monthly

the fact that we *don't* means that
the two orbits are *not* coplanar!

⋆ moon's orbit plane slightly tilted w.r.t. ecliptic
so moon is typically below or above ecliptic

iClicker Poll: Eclipse Frequency

Earth-Moon orbit plane *not coplanar*
with Earth-Sun orbit (=ecliptic)

Therefore, how many times a year should be have eclipses?

A 1 eclipse (of either kind) per year

B 2

C 3

D 4

`www: eclipse diagram`

only eclipse when Moon orbit crosses ecliptic plane
happens *twice* a year $\longrightarrow$ "season of eclipses"

geometrically: intersection of planes is a *line*
and intersection of line with closed orbits is 2 points

Any questions?

Planets

Known since ancient times:
Mercury, Venus, Mars, Jupiter, Saturn

Discovered later, with telescopes:
Uranus, Neptune, Pluto

daily motion: westward w.r.t. horizon
i.e., .rise in east, set in west

w.r.t. fixed stars:
always stay close to ecliptic
usually move eastward
`www: SOHO LASCO planet movie`
but sometimes westward: "retrograde motion"
`www: retrograde motion of Mars`
so motion not uniform in angular speed
in fact, not uniform even when in "direct" (non-retro) motion

retrograde motion not random in occurrence!
key patterns observed:

- for each planet, retrograde onset is *periodic*
  with different periods for different planets
- retrograde occurence *correlated* with position relative to Sun:

Mercury, Venus	Mars, Jupiter, Saturn (& others)
always stay close to sun on sky *never* seen opposite Sun	can move freely along ecliptic can be opposite sun
retro when in **conjunction** (i.e., when closest to Sun on sky)	retro when in **opposition** (i.e., opposite Sun on sky)

These Patterns Cry Out For Explanation

you may have noticed–I've heaped a lot of facts on you.
Do you have to memorize them? Do *I* have them memorized?
No! There's a simpler way of remembering.
→ build a **model** of the solar system's geometry and dynamics
organize, explain all of this data!

> Science is built up with facts, as a house is with stones.
> But a collection of facts is no more a science
> than a heap of stones is a house.
> —Henri Poincaré

Crucial point:
when making model for motions of planets
have to explain *all* observed features;
turns out the retrograde motion, in all its detail,
gave people the hardest time...

Building a Scientific Model

Scientific Models must:

- explain observations
- predict future observations

> The principle of science, the definition, almost, is the following: *The test of all knowledge is observation.* Experiment is the *sole judge* of scientific "truth."
>
> The first principle is that you must not fool yourself–and you are the easiest person to fool.
>
> —Richard Feynman

Cosmological Models: Naked-Eye Sky

any viable model must explain all observations
including retrograde motion of planets

models change:
- when predictions fail
- when new observations require new explanations

model refined $\longrightarrow$ **theory**
theory is *end product*
  not mere speculation or offhand/wacky idea

Greek Cosmology

Pythagoreans

- earth: spherical shape
- stars and planets on spheres

  (Note aesthetic preference for spheres: symmetry!

→ pure geometry

Aristotle (284-322 BC)

Two realms, where different physical principles apply

Realm	**Heavenly** [incorruptible]	**Terrestrial** [corruptible]
location:	above moon	below moon
natural motion:	uniform circular rotation	earth, air, water, fire: toward natural place in universe earth lowest, then water, air, fire
status:	perfect, unchanging	imperfect, changeable

earth stationary, and at center of universe

experimental evidence

Earth is round:

- shadow of earth during lunar eclipse

- altitude of Polaris: varies with latitude

Q: where is Polaris highest? lowest?

Seen from Chambana, does Polaris' height change with seasons?

A yes

B no

- observations of Eratosthenes ($\sim$ 276-195 BC)

diagram: Syene at equator, Alexandria 7° away, R, d

$7°/360° = d/R$, $d \sim 800$ km

$\Rightarrow R \sim 6700$ km: close!