

Astro 210
Lecture 3
Jan 22, 2018

Announcements

- HW1 available; due **online** in **pdf** at 5:00pm Friday
- Office hours: Instructor 2-3pm Wed; TA 3:30-4:30pm Thurs
- **register** your iClicker; link on course moodle site
- if this is your first class: see me afterward!

Last time:

Began gathering data $\Rightarrow$ the naked-eye sky

- to naked eye, no distance info
3-D universe flattened/projected $\rightarrow$ 2-D sky
- full sky: celestial sphere

Q: what is it? How is is “celestial”? Why is it a sphere?

Q: what’s motion of stars relative to each other? relative to the horizon?

Q: does celestial sphere appear differently at different latitudes?

Q: for an observer, how does direction to celestial poles change over time?

- Sun: wrt horizon, 24 hour noon-noon period = solar day

Today:

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Motions of the Sun and Moon

Sun Motion: Annual Pattern

yearly movement: sun moves east w.r.t. fixed stars along a specific path: the **ecliptic**

- a *great circle* (Q: *what's that?*) on celestial sphere
- passes through 13 constellations: **Zodiac**

sketch: ecliptic on celestial sphere

www: Sun path diagram, Sun motion animation

Q: how can we figure out observationally where sun is if can't see surrounding stars during the day?

ω *Q: what does Sun's path on 2-D sky imply for 3-D nature of Earth-Sun motion?*

Solar Motion on the Sky, and in Space

Zodiac known to ancients:

note changing pattern of constellations you can see at night
and around sunrise/set; can work out where Sun is

More modern techniques now exist:

www: SOHO LASCO movie

ecliptic on *sky* is a *great circle*

i.e., intersection of sphere and *plane*

which goes through sphere center

4 in 3-D *space*, earth-sun motion lies in a plane
⇒ the **ecliptic plane**

The Tilt

- Earth-Sun orbit axis $\neq$ Earth spin axis
- ecliptic plane tilted w.r.t. celestial equator by 23.5°
 www: ecliptic animation
→ Sun spends part of year in northern celestial hemisphere
 and part in southern
- cel sphere axes fixed w.r.t. stars: over human timescales,
observers see directions to celestial poles, equator always *same*
 Polaris always $\sim$ NCP
- 2nd fundamental measure of time:
 year of seasons: Earth-Sun orbit period

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Q: how about the Moon–motion? effects to be explained?

Moon Motions

daily: rises in east, sets in west

also: *east*ward motion w.r.t. fixed stars; through zodiac
(close to ecliptic, but not exactly)

completes one orbit in ~ 27 days

(rises about 49 min later each day)

Lunar phenomena:

- phases
- eclipses

○ to understand, helps to appreciate relative scales

iClicker Poll: Earth vs Moon Sizes

Vote your conscience—all get credit!

If the Earth were the size of the globe, then

which represents the proportional size of the Moon?

A

softball

B

baseball

C

golf ball

D

marble

iClicker Poll: Earth vs Moon Distance

If the Earth were the size of the globe, then

how far from the Earth should the Moon ball be?

Hint: the Moon's angular diameter is 0.5°

A arm's length

B front row

C middle row

D back row

∞

E closest point on Green St.

Earth vs Moon: Scales

size: radii in ratio

$$\frac{R_{\text{Moon}}}{R_{\text{Earth}}} \approx \frac{1}{4} \quad (1)$$

orbit distance:

we observe angular diameter $\theta = 0.5^\circ$: small angle
set by Moon diameter $D_{\text{Moon}} = 2R_{\text{Moon}}$ and distance r_{Moon}
using the small-angle approximation $\tan \theta \approx \sin \theta \approx \theta$

$$\theta|_{\text{radians}} \approx \frac{D_{\text{Moon}}}{r_{\text{Moon}}} = 2 \frac{R_{\text{Moon}}}{r_{\text{Moon}}} \quad (2)$$

$$= 2\pi \frac{0.5^\circ}{360^\circ} \text{ radians} \approx 0.009 \quad (3)$$

and so $r_{\text{Moon}} \approx 220R_{\text{Moon}} \approx 60R_{\text{Earth}}$

if $R_{\text{globe}} = 10 \text{ cm}$, then $r_{\text{ball}} \approx 600 \text{ cm} = 6 \text{ m} = 18 \text{ feet}$

◊

Lesson: Moon is small, far away!

→ shadow easy to miss!

Phases of the Moon

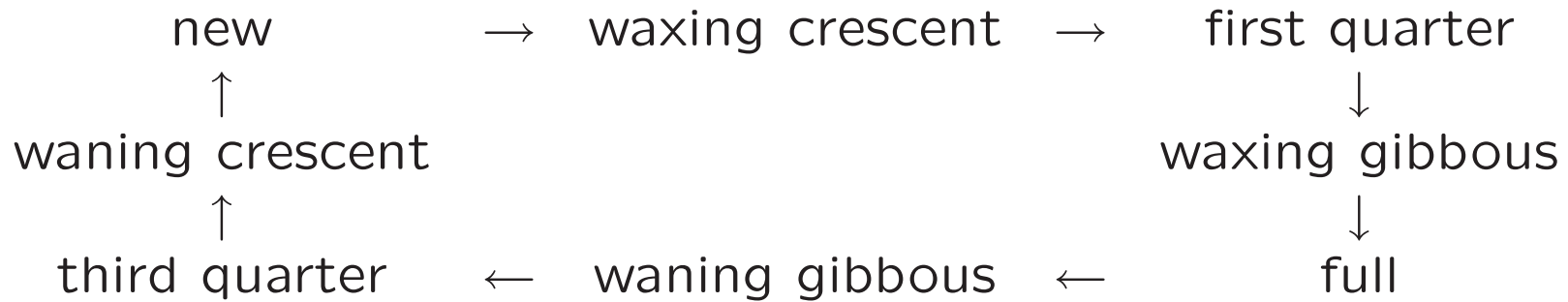


diagram: phases as seen on sky

www: phase cycle

Q: what is basic physical origin of phases? Why do we sometimes see only part of the Moon illuminated?

phases simple but beautiful

basic effect: **see illuminated moon from different angles**

phases **not** due to Earth blocking sunlight

i.e., phases are not eclipses!

diagram: top view, sky views

excellent exercise in translating situation in 3-D space

to 2-D projection on sky

for each Sun-Earth-Moon position, ask:

Q: how much of Moon's surface is illuminated by the Sun?

Q: how much of the illuminated portion can we see from Earth?

Q: what does this look like in the sky?

iClicker Poll: Moon Phase and Rise Time

Note: each phase rises and sets at a specific time of day

When does the 1st Quarter moon rise?

- A noon
- B 3pm
- C dusk
- D midnight
- E 3am

my suggestion: practice!

do the experiment in real life!

when moon up: point to moon, then sun, look at angle!

complete cycle of lunar phases in 29.5 days

⇒ 3rd fundamental measure of time: **month of phases**

Any questions?

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!

solar eclipse: observer in moon's shadow

Note: Earth larger than Moon

Q: what does this immediately imply for solar eclipses?