Astro 210

Lecture 3

Jan 24, 2011

Announcements

- HW1 available; due at *start* of class Friday
  note juicy 10-point bonus (requires planning & digital camera)
- Office hours: Instructor 2-3pm Wed; TA 10:30-11:30am Thurs
- **register** your iClicker; link on course webpage
- first Planetarium show one week from today
  info online: schedules, directions, report form
- 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?

Today:

Motions of Sun, planets

Sun Motion

daily motion w.r.t. horizon: rise in east, set in west
when at highest point: noon
fundamental measure of time: **solar day**
$\Rightarrow$ interval from one noon to next (*Earth spin period*)

maximum angular elevation varies with seasons
in Chambana:
$\sim$ June 21, summer solstice: 73.5°
$\sim$ March 20, Sept 23, equinoxes: 50°
$\sim$ Dec 22, winter solstice: 26.5°
$\rightarrow$ variation is *periodic*, with period *same* as seasons

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?

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

in 3-D *space*, earth-sun motion lies in a plane
$\Rightarrow$ 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`

$\rightarrow$ 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

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

$\leadsto$ 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 Springfield Ave.

Earth vs Moon: Scales

size: radii in ratio

$$\frac{R_{\text{Moon}}}{R_{\text{Earth}}} \approx \frac{1}{4} \tag{1}$$

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 $\tan\theta \approx \sin\theta \approx \theta$

$$\begin{aligned} \theta|_{\text{radians}} &\approx \frac{D_{\text{Moon}}}{r_{\text{Moon}}} = 2\frac{R_{\text{Moon}}}{r_{\text{Moon}}} && (2) \\ &= 2\pi\frac{0.5^\circ}{360^\circ} \text{ radians} \approx 0.009 && (3) \end{aligned}$$

and so $r_{\text{Moon}} \approx 220 R_{\text{Moon}} \approx 60 R_{\text{Earth}}$
if $R_{\text{globe}} = 10$ cm, then $r_{\text{ball}} \approx 600 \text{ cm} = 6 \text{ m} = 18$ feet

Lesson: Moon is small, far away!
$\rightarrow$ shadow easy to miss!

Phases of the Moon

$$\begin{array}{ccccc}
\text{new} & \rightarrow & \text{waxing crescent} & \rightarrow & \text{first quarter} \\
\uparrow & & & & \downarrow \\
\text{waning crescent} & & & & \text{waxing gibbous} \\
\uparrow & & & & \downarrow \\
\text{third quarter} & \leftarrow & \text{waning gibbous} & \leftarrow & \text{full}
\end{array}$$

diagram: phases as seen on sky

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?