Astro 210

Lecture 4

Jan 24, 2018

Announcements

- HW1 due 5:00 pm Friday
  upload single **pdf** file on moodle
  check pdf to see that it is legible!
  can use scanner or scanning apps like Camscanner
- Office hours: Instructor today 2-3pm, or by appointment
  TA hours *3:30-4:30pm Thurs*
- **register** your iClicker; link on course moodle
- if this is your first class: see me afterward!

Our dynamic sky: the story thus far

the stars

Q: Motion wrt horizon? Natural timescale(s)?*

the Sun

Q: Motion wrt horizon? Motion wrt stars? Natural timescale(s)?

the Moon

Q: Motion wrt horizon? Motion wrt stars? Natural timescale(s)?

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*wrt = texting abbreviation for: *with respect to*

Stellar, Solar, Lunar Motions Summarized

the stars

- wrt horizon: rise in east, set in west; period ≈ 1 day
- "fixed" stellar patterns on celestial sphere
- available sky depends on latitude (HW1)
  but nightly view changes over year *Q: why?*

the Sun

- wrt horizon: rise in east, set in west; Period ≈ 1 day
  noon to noon period: **solar day**
- wrt celestial sphere: path = great circle = ecliptic
- noontime elevation changes, period **year of seasons**

the Moon

- wrt horizon: rise in east, set in west; Period ≈ 1 day
- shows phases, period **lunar month** 29.5 days
  wrt celestial sphere: great circle, near ecliptic, period $\approx$ month

Phases and Latitude

Note: lunar phase pattern depends on observer latitude
i.e., which from hemisphere you look

all of the above discussion was for *northern* observers

Q: what aspects of the situation change for southern observers?
Q: what aspects do not change

Lunar Phases: Southern Exposure

southern observers: "upside-down" relative to north
$\rightarrow$ moon image same (illuminated vs dark portion identical)
but "upside-down"

unchanged:

- waxing or waning nature of phase
  (i.e., increasing or decreasing illumination)
- type of phase (crescent, gibbous, etc)

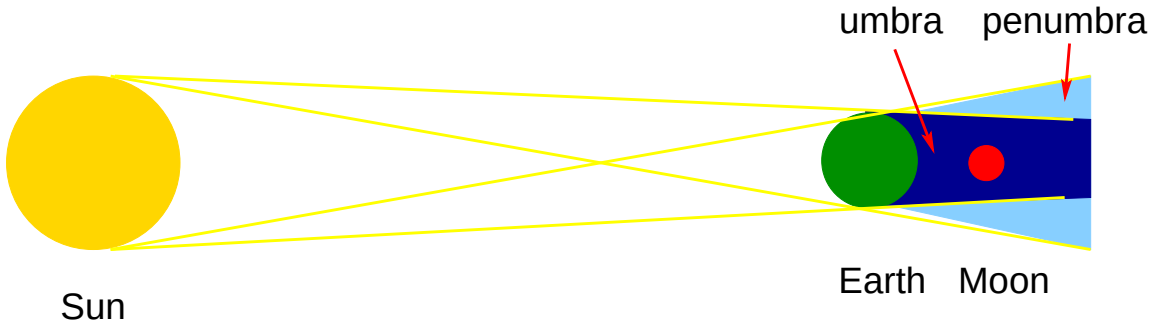
different:

- southern observers see reversed moon right $\leftrightarrow$ left
  relative to northern observers
- e.g., waxing crescent illuminated on *left* side
  waning gibbous illuminated on *right* side

For all homework, exam problems: assume *northern* observers
on earth (and on the Moon!)

Eclipses

Lunar Eclipse: moon in earth's shadow



Full shadow = Sun *completely* blocked: **umbra**
Partial shadow = Sun *partly* blocked: **penumbra**

`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?

The Red Eclipsed Moon

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!

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moving to solar eclipses
Q: why do they occur?
Note: Earth larger than Moon
Q: what does this immediately imply for solar eclipses?

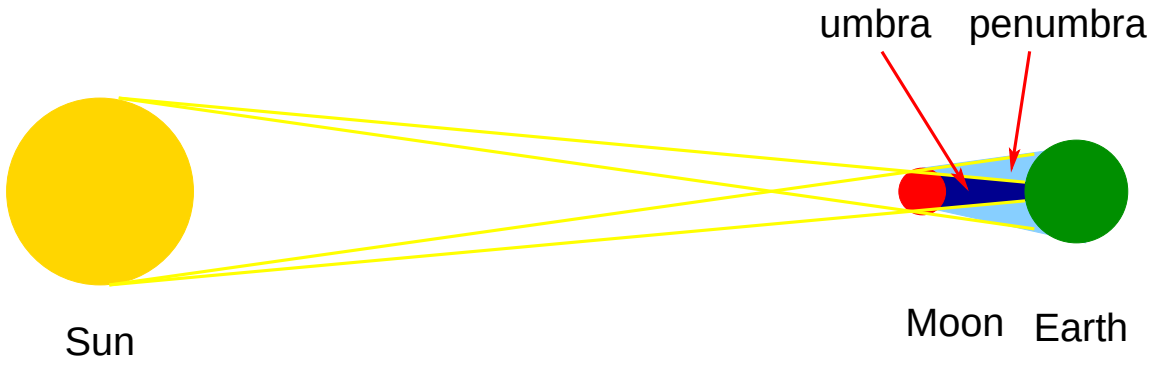
Solar Eclipses

solar eclipse: observer in moon's shadow

since Moon smaller than earth, whole earth cannot be in shadow

in fact, only a small region, ~ 100 km, at a given time

"eclipse path"



also: Moon's shadow fast!

umbra movies up to ~ 1 km/s ≈ 2000 mph

Q: implications?

- only observers along narrow eclipse path
  fall in umbra and see **totality**

- eclipse duration brief: $\leq$ 8min, usually shorter

- only some of remaining sun-side observers see penumbra = partial eclipse

lesson: Solar eclipses are brief, and dramatic
if you want to see them, usually have to travel

Cosmic Coincidence

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

Note: eclipse "season" last about ~ 1 month
i.e., time window of alignment about equal to Moon orbit period
$\longrightarrow$ can sometimes have two or three eclipses in same season

ABCs of Eclipses: Always Bee "C"eeing Eclipses

Eclipses are spectacular examples of astronomy intervening in our daily lives Total solar eclipses are deeply beautiful and for many, emotional

Astro-Tip: you **must** *see* ≥ 1 *total solar eclipse!*

Aug 21, 2017: Great American Eclipse

- Coast-to-Coast across United States
- possibly the most viewed eclipse in human history
- maximum duration of totality was in Southern Illinois: Makanda

`www: 2017 Eclipse images and movies`

Upcoming Eclipses–Mark Your Calendars!

Go! Bring friends and family, impress with your ASTR210 skills!

Solar

Date	Type	Where Visible
15 Feb 2018	Partial	Antarctica, S. America
2 Jul 2019	Total	Chile, Argentina
26 Dec 2019	Annular	India, Sumatra, Borneo
21 June 2020	Annular	south Asia, China
24 Oct 20203	Annular	western US, central America
8 Apr 2024	**Total**	**Mexico, US, Canada**

Lunar

Date	Type	Where Visible
31 Jan 2018	Total	Western US
21 Jan 2019	**Total**	**N. and S. America**

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 occurrence *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