

Astro 350
Lecture 2
Aug 29, 2011

Announcements:

- Discussion Question 1 posted on Compass today due by start of class next Wednesday
- **register** your iClicker; link on course webpage

Last time: Overview and Appetizer

Today: Start your engines

iClicker Poll: Homework Printout

HW1 will be posted online; printouts also available. I am happy to give printouts if you will use them; but no sense in wasting paper for the paperless readers among you.

Would you like a printout of the homework and other assignments?

A yes

B no

Online Notes

Class notes will be posted online and available all semester

Cosmo-Tip:

Each class meeting has a webpage and notes like these

They will remain on the course website throughout the semester

So no need to write what's in this file...

also: when printing out pdf notes, you may find 2 or 4 slides per page is legible, saves paper

Notes are posted right before each class

but best to wait about 1 hour after class:

ω updated/corrected notes posted

Class Notes Online: A Good Thing?

Pros:

- you are not a stenographer—can use your brain to think and not transcribe
- don't have to read my bad handwriting

Cons:

- tempting to be cosmo-hypnotized
so: I'll ask Socratic (=annoying) questions and iClicker polls throughout
- might give incorrect impression that there's no reason to come to class
but: I'll give extra pearls of wisdom verbally
...and you'll miss the *required & easy* iClicker participation points
not to mention demos, music, and movies

Bargain:

- ↳ • I'll avoid railroading you
- you pay attention, ask questions when confused/interested

Cosmologies

Official Cosmology Membership Certificate

For this semester (at least!):

You are hereby declared to be a cosmologist!

Welcome to the club!

Q: so what does membership involve—what is cosmology?

Cosmologies

Cosmology: study of/ideas about the big picture

→ origin and nature of “the world/the universe”

- what is the size & shape of the universe?
- what is it made of?
- what rules does it obey?
- how does our everyday experience fit into this picture?

A big subject! And many possible ways to approach it...

ASTR350: *Scientific or Physical* Cosmology

Q: *what other kinds could there be?*

There are many ways to look at the world!

Cosmologies—ideas about the origins and nature of things—existed long before science invented

narratives: “creation myths” give context to experience
each relies on some idea of how the world works,
and what counts as an explanation
(turtle story)

A broad, rich subject; we’ll focus on the view offered by *science*

The Cosmos Observed: Night Sky

The Night Sky

First step in science: collect **data**

Most basic goal of cosmology (and *main* goal pre-telescopes)
→ explain contents and motion of sky

Contents:

You know this, so we'll go fast, but still...

Q: what naked-eye celestial data/objects exist?

Q: how might these be classified?

Geometry:

note that your eye cannot tell **distance**
to objects in the sky

for example, no sense of “depth” of stars, planets

Q: so what is geometry of observed sky?

Census of the Sky

permanent stuff: always look the same in brightness, shape

sun

moon

stars

planets

Milky way

fuzzy nebulae

...also transient stuff: change with time, or appear/disappear

comets

meteors

aurorae

and **darkness** between stars → important cosmo-clue!

II ⇒ these are the main *actors*
so what is the *action*—how do they *change/move*?

iClicker: Star Trails

The Experiment

fix a camera on a tripod, open lens and expose to night sky
as each star moves, leaves “trail” on film

Imagine you could see all trails made by all stars
over one night, as seen from Champaign-Urbana.

What pattern would you see?

- A arcs of circles
- B arcs of ovals
- C parallel line segments
- D none of the above

Dynamics: Star Motions

- stars don't seem to move relative to each other (“fixed”)
i.e., constellations don't morph
(at least not on human timescales)
 - move as if rigid structure on sky
- stars rise in east, set in west
www: star trails
each star moves in circle on sky (some go below horizon)

Geometry of the Sky

In reality: celestial objects arranged in 3-D space

But: your eye can't tell distance to these objects
no "sense of depth"

So observed sky appears "flattened" → "cosmic roadkill!"

★ **Crucial fact of life in science:**

have to connect

(a) what you can actually *observe/measure: data*

(b) with what is "really" going on—*models/theory*

Celestial Sphere

In astronomy: observe objects in sky

can measure position = direction on sky

→ star positions are 2-number “addresses” (N-S, E-W)

so the sky is *2-dimensional*

but sky gives *no* direct information about *distance*

→ observed sky flattens the 3-dimensional arrangements

down to **2-D sphere** projection

“*celestial sphere*” defined by stars and their constellations

“hub” of star circles: celestial poles

North star: near N cel pole (“Polaris”)

Sun and Planets: Geometry of Motion

Sun

stays on a circle (a great circle*!) of cel sphere (“ecliptic”)

great circle = largest circle on sphere: share same center

great circle = intersection of sphere and plane going thru center

Sun moves among constellations *Q: how would you know?*

www: Soho coronagraph

Planets

Greek: “wanderers” – move among constellations

more or less: found on same ecliptic path as Sun

www: Moon, Mercury, Venus

Now go from 2-D sky to 3-D space:

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Q: what do these observations mean about the 3-D arrangement of solar system?

Sun, Earth, planets, (and Moon) all lie in \approx one single *plane*

www: Clementine--Sun, Moon, Saturn, Mars, Mercury
highly ordered! hint as to solar system origin...

Other patterns found:

- Mercury, Venus always near the Sun, never opposite on sky
- other planets can be near or opposite
- planet motions thru cel sphere usually same direction
...but sometimes backwards “zigzag” → retrograde motion

www: retrograde animation

Clearly: then naked-eye sky is highly organized
motions show clear patterns
these cry out for explanation!

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Our first task as cosmologists: understand these patterns
We have collected data: on to theories!

Classical Greek Cosmology: Geocentric

Classical Greek Cosmology

Pythagoras (Mr. Triangle!) and followers believed:
universe founded on **geometry**, which is perfected in *spheres*

- Earth: spherical shape

Eratosthenes (276-195 BC) calculated size of Earth
got very close to the correct answer!

- Moon, Sun, planets, stars fixed on spheres
spinning around us in uniform circular motion

Aristotle (284-322 BC)

Two realms, where different physical principles apply

	heavenly	terrestrial
realm	above moon	below moon
status	“incorruptible” unchanging, perfect	“corruptible” changeable, imperfect
natural motion in realm	uniform circular rotation	earth, air, water, fire: toward natural place in universe earth lowest, then water, air, fire

Geocentrism

Ancient Greeks: **Earth is center of universe** (“geocentric”)

★ rise & set of sun/moon/planets can be explained

Q: how does this model explain star trails?

★ if Earth spins, we move at 900 mph w.r.t. Earth center!
but we don't *feel* this!

→ why aren't we flung off?

★ apparent lack of **stellar parallax**

Proof by contradiction: *what if* earth orbits sun?

diagram: Sun, Jan, July, star, lines of sight

foreground star should appear to *shift* w.r.t. background stars

⇒ but parallax effect *not* observed!

Why? eye cannot resolve angles $\lesssim 1' = 1 \text{ arc min} = 60 \text{ arc sec}$

but typical shift on sky: $\sim 1'' = 1 \text{ arc sec}$ – very small effect!

parallax not detected until $\sim 1830(!)$