

Astro 350  
Lecture 2  
Aug 24, 2011

Announcements:

- Discussion Question 1 posted on Compass today due by class next Wednesday
- **register** your iClicker; link on course webpage
- pick up Syllabus if you didn't get one last time

Last time: Overview and Appetizer

Today: Start your engines

## 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:

↳ 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 iCliker 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* iCliker participation points  
not to mention demos, music, and movies

## Bargain:

- ω • 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”

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

ASTR350: *Scientific or Physical* Cosmology

Q: *what does this mean?* [Kolb/Schramm story]

Q: *what other kinds could there be?* [turtle story]

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

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

*Q: T-shirt definition of science?*

# Science

science is a human activity → actual real-life practice  
very interesting and very complicated  
will see complexity through examples, but for starters:

science is a systematic, logical set of ideas about Nature  
and the test of all scientific knowledge is **observation**.  
→ **Experiment** is the final judge of scientific truth.

If experiment is the Judge, then the Court is the  
**Scientific Method**:

observation & experiment → tentative model → predictions  
∞ → further experiment → refined model → repeat ↑  
end product: **theory**

Scientific Models must:

- explain *all* existing observations
- predict future observations
- *change* or even be *abandoned*  
if in conflict with *any* observations

sounds simple—but surprisingly complex in practice

this process has forced us, kicking and screaming,  
to take seriously ideas like dark matter, dark energy

Cosmologist Richard Feynman

The scientific method is a way of *finding what works*

The first principle is that you must not fool yourself  
—and you are the easiest person to fool.

Cosmologist Henri Poincaré:

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.

10 Also note: scientific theory  $\neq$  offhand idea or wacky notion!  
despite common usage...

from *Webster's Collegiate Dictionary*

## **theory**

1 : the analysis of a set of facts in their relation to one another

2 : abstract thought : SPECULATION

6 (a) : a hypothesis assumed for the sake of  
argument or investigation

(b) : an unproved assumption : CONJECTURE

¶ *Not* how we will use the term!

## Cosmology as a Science

We wish to apply the scientific method to understand the universe

*Q: this is a hopeless task—why?*

*Q: what more limited goals can we hope to achieve?*

to fully understand the Universe in all its complexity means understanding *everything* in the entire universe for example:

- ▷ Why isn't the Earth 1cm to the left of where it is now?
- ▷ What's up with the French and Jerry Lewis?
- ▷ Why do fools fall in love?

Hopelessly broad! Impossible to answer.

Fortunately, the big questions are more tractable; we will stick to these:

- ★ What is the origin and evolution of the universe?
- ★ What is the composition of the Universe—what is it made of?

Some answers we now know! But other major questions raised!

# 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!

16 ⇒ 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” (NS, EW)

⇔ 2-dimensional sky

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

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:

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

Note: great circle = intersection of sphere and plane

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 rief backwards “zigzag” → retrograde motion

www: retrograde animation

22 Our first task as cosmologists: understand these patterns

## 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