ASTR 314 : Survey of Astronomy

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Office Hours: Tues/Thurs 1-2
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Textbook:

Carroll & Ostlie

*An Introduction to Modern Astrophysics*

(Amazon.com has it for cheaper than bookstore...)
Grading

• Final grade: 2 mid-terms (20% each), final exam (35%), homework and quizzes (25%).

• Exams: two in-class mid-terms (Tues, Feb 23 and Tues, April 12), and final exam (Thursday, May 5).

• Homework: normally due two weeks after it is assigned
Expectations from You:

• Honor Code: I expect that you will uphold the Aggie principle, “An Aggie does not lie, cheat, or steal or tolerate those who do.”

  - Quizzes, exams, and essay: Abide by the Aggie code of conduct, "On my honor as an Aggie, I have neither given nor received unauthorized aid on this academic work."

  - Homework: I encourage you to talk to other students and to help each other as you will all learn better this way. However, the work you turn in should be your own, never copied from another student.

• ADA: The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact the Department of Student Life, Services for Students with Disabilities, in Room 126 of the Koldus Building or call 845-1637.
Expectations from You:

- This is a 300-level science course, PHYS 208 or 219 are prerequisites. There will be math, which is necessary to understand the details of many of the topics we will cover.

- For this class, you need to be familiar with the mathematics of freshman-level physics (including trigonometry, vector sums, and basic derivatives and integrals). If you have questions or concerns, please see me.
The Human perception of Cosmology is a long, arduous journey. Scientists postulate theories to explain observations of the Universe. Subsequent evidence from observations will either make or break theories. I expect you to question everything you hear and read. If you don’t believe something, say so. Why don’t you believe something?

- Watch the night sky! Stare at the sky a lot, and think about what we learn in class.
Scientific Process

Make Observations (take data)

Ask Questions

Suggest Hypothesis

Make Predictions

Make new Experiments to Test Predictions

Results of new Experiments does not support hypothesis. Revise hypothesis or choose new one.

Test supports hypothesis, make additional predictions and test them too. Repeat ad nauseam.
What do you know? How do you know it?

• Where is the center of the Universe?

• How big is the Earth? How far away is the Sun? The next nearest Star? The center of the galaxy? The nearest galaxy? How big is the Universe?

• How old is the Earth? How old is the Sun? How old is the Galaxy? How old is the Universe? How did all these things form?

• What is a black hole? Dark Matter? Dark Energy?

• What is the fate of the Universe? Will it end?

• How do you know these things?
What is our “address” in the Universe?

- Local super cluster of galaxies
- Local group of galaxies
- Milky Way Galaxy
- Solar System
- The Planet Earth
- Mitchell Physics Building
- Texas A&M University
What is a Light Year?

A light year is the defined to be the distance light travels in 1 year.

Light travels at approximately 300,000 km / s.

\[
1 \text{ light year} = \left( 300,000 \frac{\text{km}}{\text{s}} \right) \times (1 \text{ yr})
\]

\[
= \left( 300,000 \frac{\text{km}}{\text{s}} \right) \times \left( 1 \text{ yr} \times 365 \frac{\text{day}}{\text{yr}} \times 24 \frac{\text{hr}}{\text{day}} \times 60 \frac{\text{min}}{\text{hr}} \times 60 \frac{\text{s}}{\text{min}} \right)
\]

\[
= 9,460,000,000,000 \text{ km} = 9.46 \times 10^{12} \text{ km}
\]

1 Light Year = 9.46 trillion km (≈ 10 trillion km)
Distances in Astronomy are really astronomical!

- From the Sun to Neptune: $4 \times 10^{12}$ meters ($2793 \times 10^6$ miles).
- To the next nearest star, Alpha Centari: 4.23 light years (about $4 \times 10^{16}$ meters, or $\sim 30$ trillion miles)
View of Crowd at 1963 March on Washington, DC
San Francisco, CA = Grapefruit-sized Star "Alpha-centauri"

Washington, DC = Grapefruit-sized "Sun"
The Universe as a Time Machine

Because Light Speed is Finite, we see things not as they are, but as they were in the past.

<table>
<thead>
<tr>
<th>Destination</th>
<th>Light Travel Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students in front row</td>
<td>three billionths of a second</td>
</tr>
<tr>
<td>Students in back row</td>
<td>100 billionths of a second</td>
</tr>
<tr>
<td>Moon</td>
<td>1 second</td>
</tr>
<tr>
<td>Sun</td>
<td>8 minutes</td>
</tr>
<tr>
<td>The star Sirius</td>
<td>8 years</td>
</tr>
<tr>
<td>Andromeda Galaxy</td>
<td>2.5 million years</td>
</tr>
</tbody>
</table>
Example: This photo shows the Andromeda Galaxy as it looked about 2 million years ago.
We measure the sky using angles.

Stretch out your arm as shown here.
Angular Measurements

360° (degrees) = circumference of a great circle
60' (arcminutes) = 1°
60″ (arcseconds) = 1’

1 arcminute is approximately 1 inch at a distance of 100 yards.
1 arcsecond is the size of a dime seen at a distance of 1 mile.
In humans, 20/20 vision is the ability to resolve a spatial pattern separated by a visual angle of 1 arcminute.
The full moon is about 0.5° = 30’ = 1800″.
Ancient Astronomy: Observations of sun, moon, stars, and planets formed the basis for timekeeping, and navigation.
Northern Summer/Southern Winter: In June, sunlight falls directly on the Northern hemisphere, which makes it summer there because (1) sunlight is more concentrated and (2) Sun follows a longer and higher path (up longer).

Southern hemisphere experiences the opposite, making it winter.
Ancient Astronomy: Observations of sun, moon, stars, and planets formed the basis for timekeeping, and navigation.

Time series of the Sun’s position at the Summer Solstice (June 21) at the Artic Circle
Ancient Astronomy

Observations of sun, moon, stars, and planets formed the basis for timekeeping, and navigation.

Stonehenge in southern England: stones are aligned with rising Sun of the Summer Solstice

Stonehenge upon its completion around 1600-1500 B.C.

Stonehenge ruins today

Stonehenge in southern England: stones are aligned with rising Sun of the Summer Solstice
Ancient Astronomy

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Anasazi Native Americans occupied Colorado Plateau from ~100-1100 AD. Used Sun Dials to mark equinoxes.
Ancient Astronomy

Observations of sun, moon, stars, and planets formed the basis for timekeeping, and navigation.

Anasazi Sun dials at noon on Winter Solstice

Anasazi Sun dials at noon on Summer Solstice - the “Sun dagger”.
Historical Cosmology

Cosmology: the science of the origin and development of the universe.

Greeks attributed with developing “Geocentric Cosmology”. Geo=Earth, “Earth-centered” Cosmology

Pythagoras: Taught that the Earth is a sphere.

Plato: Asserted that heavenly motion must be in perfect circles.

Eratosthenes: Accurately measures circumference of the Earth.

Aristarchus: Suggests that the Earth goes around the Sun.

Apollonius: Introduces circles upon circles to explain retrograde motion.

Hipparchus: Develops first accurate star map and star brightness catalog of nearly 1000 stars.

Ptolemy: “Perfected” Earth-centered model, which becomes convention for next 1,500 years...
Lunar Eclipse - August 28, 2007 Hawaii

This is a video response to What Causes an Eclipse of the Moon?

Copy and paste this link into an email or instant message:
http://www.youtube.com/watch?v=2dk–IPAl04

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**Historical Cosmology**

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At Syene (Egypt), the Sun is directly overhead near the Summer equinox. No shadow at “high noon”. Thus, the distance from Syene to Alexandria is 7° of the 360° of the circumference of the Earth.

On same day at Alexandria (Egypt), the Sun casts a shadow of 7°.

Distance from Syene to Alexandria is 5000 stade.

Circumference = 5000 stade * 180 m/stade * 360/7 = 46,286 km

(present day measurement is 40,075 km !)
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Problem with Geocentric Model?

Retrograde Motion

Position of Mars in the sky from June-July 2003
Position of Jupiter (brighter) and Saturn (fainter) over 11 months.
Problem with Geocentric Model?
Retrograde Motion
Problem with Geocentric Model?
Retrograde Motion solved: Circles of circles

In Ptolemy's model the planet goes around this small circle

... while the small circle goes around the big one

Result: planet follows this dashed path.
Problem with Geocentric Model?
Retrograde Motion solved: Circles of circles
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What have we learned?

- Early Astronomy used for Timekeeping, Seasons and Navigation.
- Ancient peoples (Greeks, but many other cultures) determined that the Earth was a sphere, with a measured circumference.
- Motion of Planets explained with stationary Earth, with “epicycles” that accurately reproduced planets and retrograde motion.

Evidence for Geocentric Universe

- No perceived motion of the Earth. No steady breeze, ground does not move.
- All objects fall toward Earth. Earth must be center of the Universe.
- Lack of movement in positions of the stars. If Earth moved, one would see them shift their positions.
Nicolaus Copernicus (1473-1543)

First astronomer to offer scientific evidence for Helio-centric Cosmology (Helio=Sun; Sun-centered).

The major parts of theory (published in De Revolutionibus orbium coelestium - On the Revolutions of the Celestial Spheres) are:

1. Heavenly motions are uniform, eternal, and circular or compounded of several circles (epicycles).
2. The center of the universe is near the Sun.
3. Around the Sun, in order, are Mercury, Venus, Earth and Moon, Mars, Jupiter, Saturn, and the fixed stars.
4. The Earth has three motions: daily rotation, annual revolution, and annual tilting of its axis.
5. Retrograde motion of the planets is explained by the Earth's motion.
6. The distance from the Earth to the sun is small compared to the distance to the stars.
Galileo Galilei (1564-1642)

Major role in scientific revolution of the Renaissance. Developed ideas about gravity that influenced Newton later.

Of many accomplishments, was first to use a telescope to study the sky.

He observed features on the moon which showed it was not a perfect sphere.

He observed that Jupiter has moons, which showed that not all celestial objects orbit the Earth.

Also observed that Venus has “phases” much like the Moon.

Both of these observations lent strong support to Copernican - Heliocentric Cosmology.
Notice shadows in craters in “bright” portion of Moon.

Notice sunlight on mountains and tall crater rims in “dark” portion of Moon.

Problems with Geocentric Model:
1. Features on Moon.
Problems with Geocentric Model:
2. Moons of Jupiter
Problems with Geocentric Model:

3. Phases of Venus

a In the Ptolemaic system, Venus orbits Earth, moving around a small circle on its larger orbital circle; the center of the small circle lies on the Earth-Sun line. Thus, if this view were correct, Venus’s phases would range only from new to crescent.

b In reality, Venus orbits the Sun, so from Earth we can see it in many different phases. This is just what Galileo observed, allowing him to prove that Venus really does orbit the Sun.
Problems with Geocentric Model:
3. Phases of Venus
Evidence toward a Heliocentric Universe

- Galileo credited with using “scientific method” to discern that the celestial bodies (in the Solar System) orbit the Sun, not the Earth.

1. Moon shows surface “imperfections”. It is not a perfect sphere.

2. Jupiter has moons that orbit it (not the Earth). This showed not all objects orbit the Earth.

3. Venus shows phases like the Moon, which is only explicable if Venus orbits the Sun.

What have we learned?