

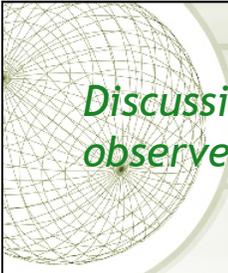
Lecture 2 : Early Cosmology

- ★ Getting in touch with your senses...
- ★ Greek astronomy/cosmology
- ★ The Renaissance (part 1)

COSMOLOGY MARCHES ON



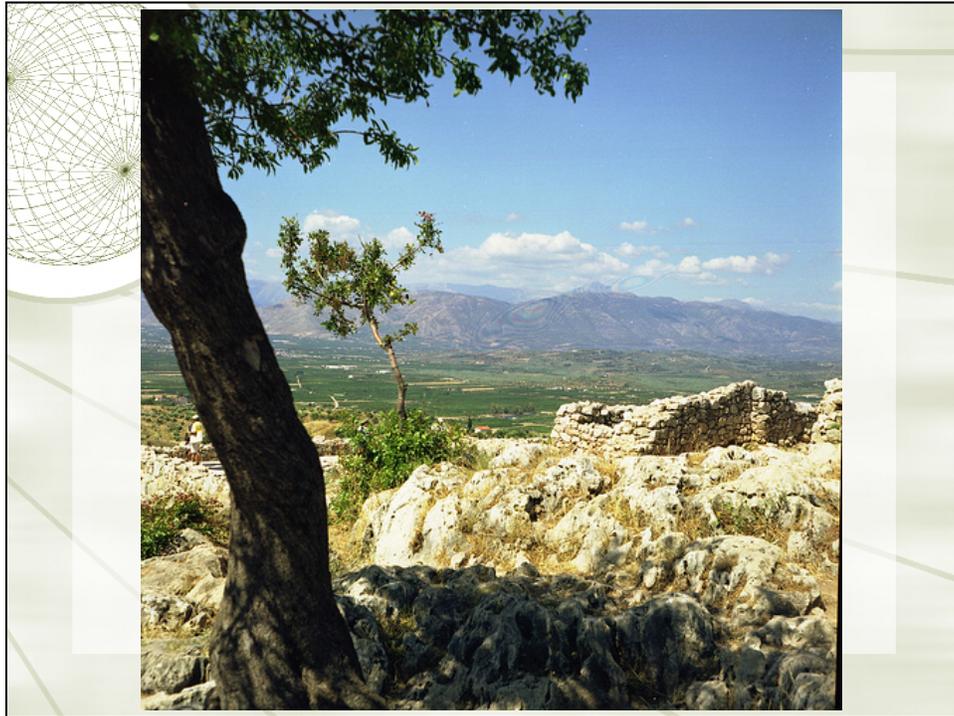
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Discussion : What would an unaided observer deduce about the Universe?

9/6/10

2



II : GREEK COSMOLOGY

- ★ First culture to look at world in the “modern scientific way”
- ★ They...
 - ★ Understood the idea of **cause and effect**
 - ★ Applied logic to try to understand the world
 - ★ Assumed that the Universe is fundamentally knowable
 - ★ Sought to describe the Universe mathematically
 - ★ Understood the importance of comparing theory with data
- ★ **BUT...**
 - ★ Theoretical principles -- especially geometric symmetry -- came first, with observations subsidiary

9/6/10

4



The spherical Earth

- ★ Greeks knew the Earth was a sphere!
 - ✦ View of constellations changes from N → S
 - ✦ Observations of ships sailing over the horizon (mast disappears last)
 - ✦ Observations of the Earth's shadow on the Moon during lunar eclipses



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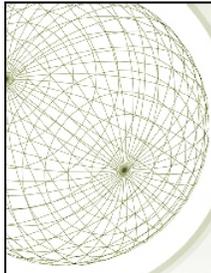


Relative size of Earth and Moon



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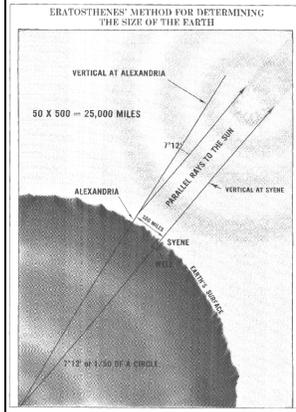
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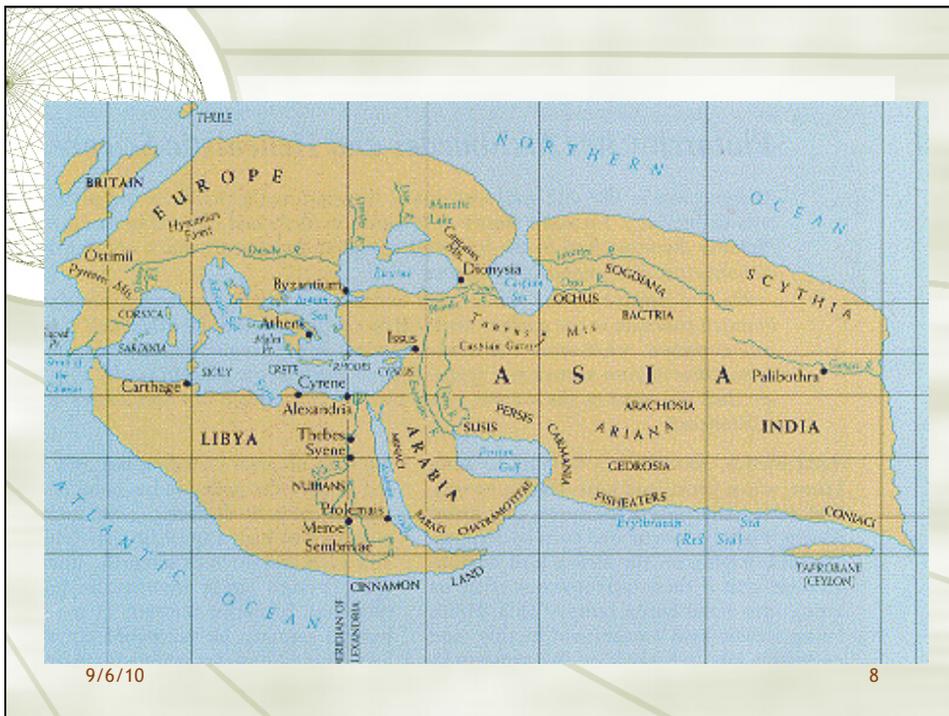
Eratosthenes



- ✦ Astronomer/mathematician in Hellenistic Egypt (c.275-195 BC)
- ✦ Calculated circumference of Earth
 - ✦ Measured altitude of Sun at two different points on the Earth (Alexandria & Syene): found 7° difference
 - ✦ Multiplied $(360^\circ / 7^\circ) \times 800\text{km}$ to obtain circumference=40,000km



7



9/6/10

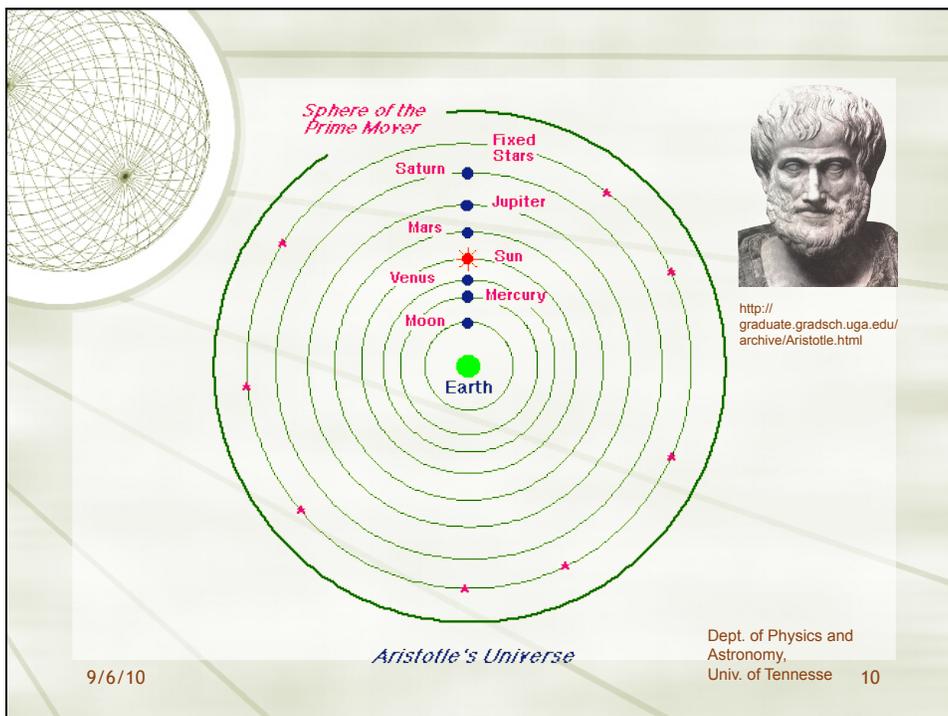
8

Cosmology of Eudoxus and Aristotle

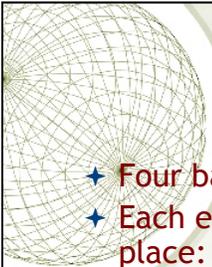
- ★ Fundamental “principles”:
 - ★ Earth is motionless
 - ★ Sun, Moon, planets and stars go around the Earth: *geocentric model*
- ★ Eudoxus (408-355 B.C.) & Aristotle (384-322 B.C.)
 - ★ Proposed that all heavenly bodies are embedded in giant, transparent spheres that revolve around the Earth.
 - ★ Eudoxus needed a complex set of 27 interlocking spheres to explain observed celestial motions
 - E.G., need to have 24-hr period =day and 365-day period=year for the Sun

9/6/10

9



9/6/10



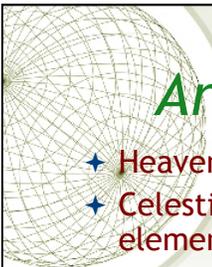
Aristotle's terrestrial physics

- ★ Four basic elements: earth, water, air, fire
- ★ Each element *tends to move* toward its “natural” place:
 - ✦ Rock (earth) in air falls, air bubble in water rises

1	2	3	4
E	W	A	F
Earth	Water	Air	Fire
			5
			Et Ether

- ★ “Natural motions” of earthly objects are straight lines toward center of Earth
 - ✦ Bodies in motion naturally tend to come to rest on Earth
 - ✦ An applied force can cause deviation from natural motion
 - ✦ A body at rest on Earth will remain at rest unless a force is applied
 - ✦ Continual application of force is needed to sustain any motion other than natural motion

9/6/10 11



Aristotle's celestial physics

- ★ Heavens are governed by *different* laws from Earth
- ★ Celestial bodies are composed of “ether,” a fifth element not present on Earth
- ★ “Natural motions” of celestial spheres are different from terrestrial motions:
 - ✦ circular, constant, and eternal
 - ✦ Aristotle needed 55 spheres to explain observed motions of Sun, Moon, planets, stars
- ★ Space is finite, bounded by outer sphere
 - ✦ But the edge is unreachable: motions become circular in the ethereal domain
- ★ Time is infinite
- ★ (But why is such a perfect universe centered on such an imperfect Earth?)

9/6/10 12

Aristarchus of Samos (310-230 B.C.)

- ★ Using eclipse data and geometry:
 - ★ Measured relative sizes of Earth, Moon
 - ★ Measured distance to Moon (how?)
- ★ Attempted to measure distance to Sun
 - ★ Need to measure (using time interval ratios) the angle of Sun when Moon is exactly at 1st or 3rd quarter
 - ★ Then use trigonometry and known Earth-Moon distance to get Sun's distance
 - ★ Very difficult measurement... He deduced that Sun is 20 times further from Earth than Moon... actual answer is that Sun is 400 times further.
 - ★ First to propose a **heliocentric model!**

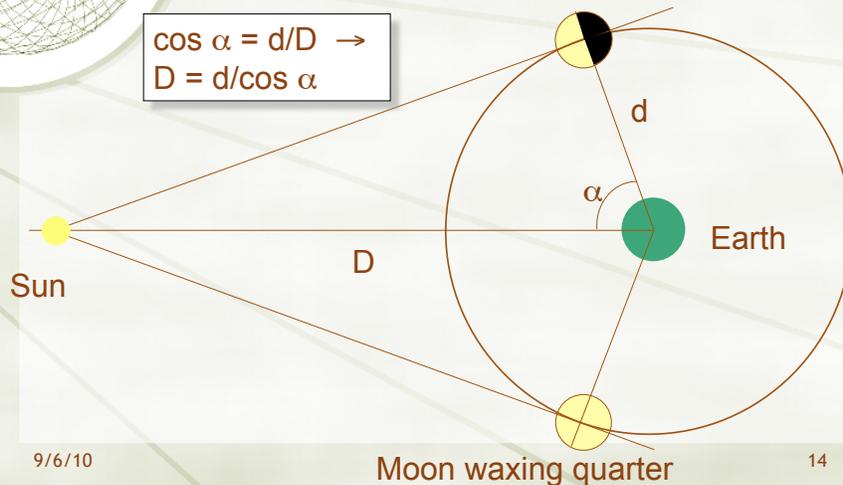
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13

Aristarchus Earth-Sun distance

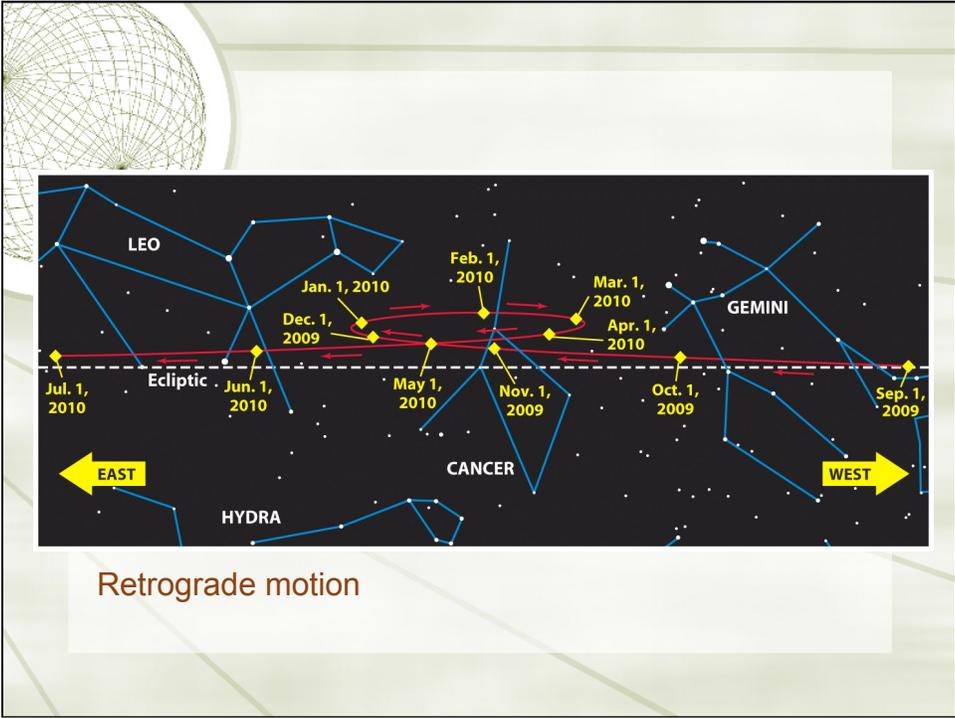
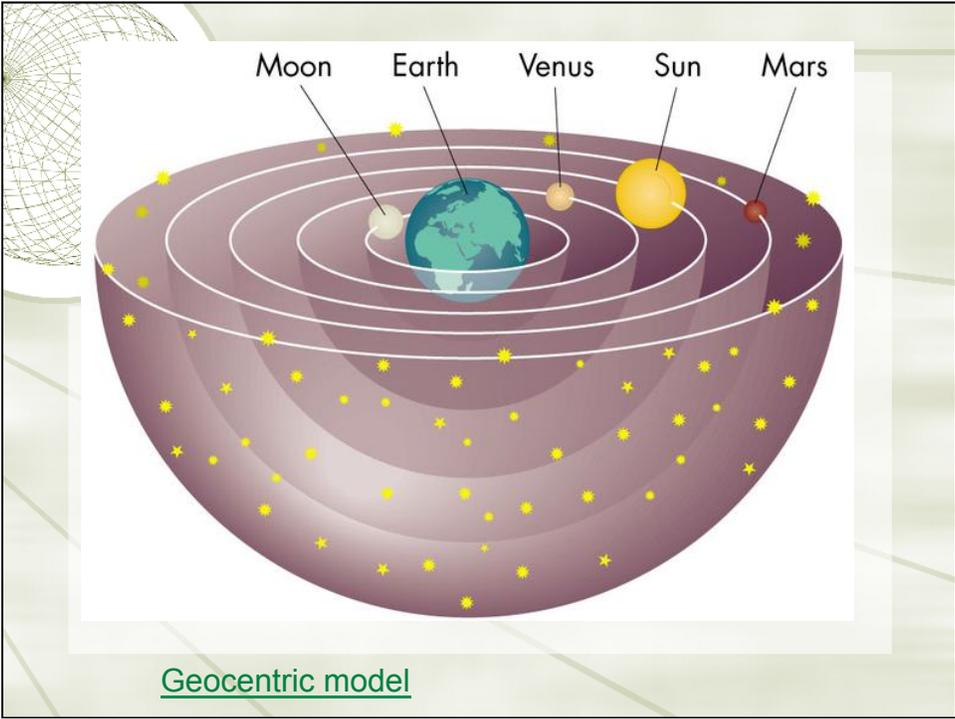
Moon waning quarter

$$\cos \alpha = d/D \rightarrow D = d/\cos \alpha$$



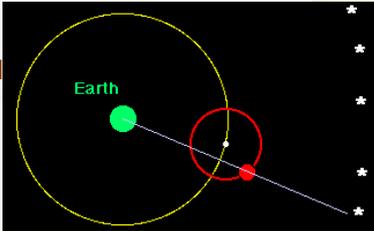
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14

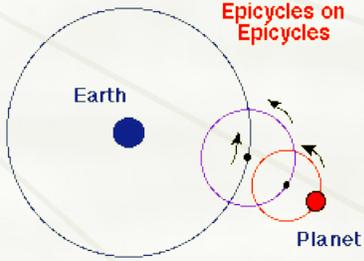


Ptolemy's epicycles

- ✦ Ptolemy's original "epicycles"
- ✦ Larger circle ("deferent") not centered on the Earth
- ✦ Motion appeared uniform from "equant" (offset from Earth and from center of "deferent")



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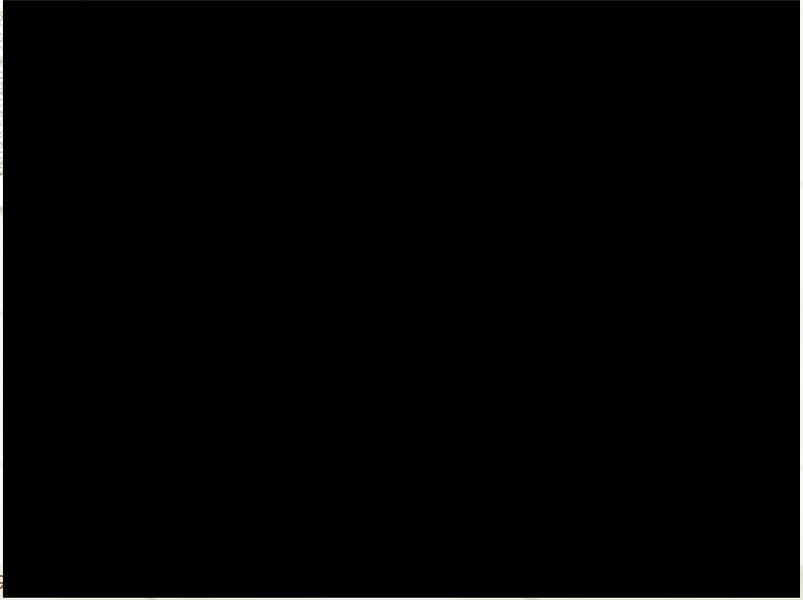


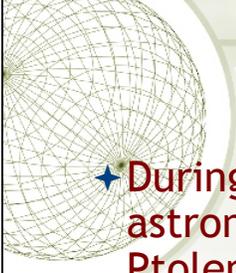
Needed more and more epicycles to fit observed angular motion

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17

Ptolemy and Homer...



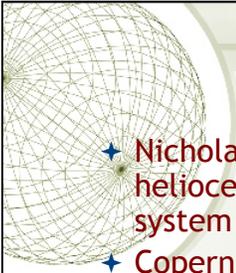


II : The Renaissance

- ✦ During European “dark ages,” Arab astronomers preserved and extended Ptolemy’s work
- ✦ Aristotelian/Ptolemaic view prevailed in Europe, through 1400’s
 - ✦ Geocentric model
 - ✦ Creation at finite time in past, for consistency with Christian theology
 - ✦ Earth known to be round (Columbus battling against flat Earthers is myth!)

9/6/10

19



Copernicus (1473-1543)

- ✦ Nicholas Copernicus was modern founder of the heliocentric (Sun centered) model for the solar system
- ✦ Copernicus was born in Poland; studied in Krakow, Bologna, Padua, Ferrara
 - ✦ Rejected Ptolemy’s geocentric model because it was too complicated
 - ✦ Preferred heliocentric model with perfect circular motions
 - ✦ **The Copernican Principle : The Earth is not at a special location in the Universe.**
 - ✦ Later, we will come across the **Generalized Copernican Principle: There is no special place in the universe, i.e., the universe has no center.**

9/6/10

20

Copernicus's first work

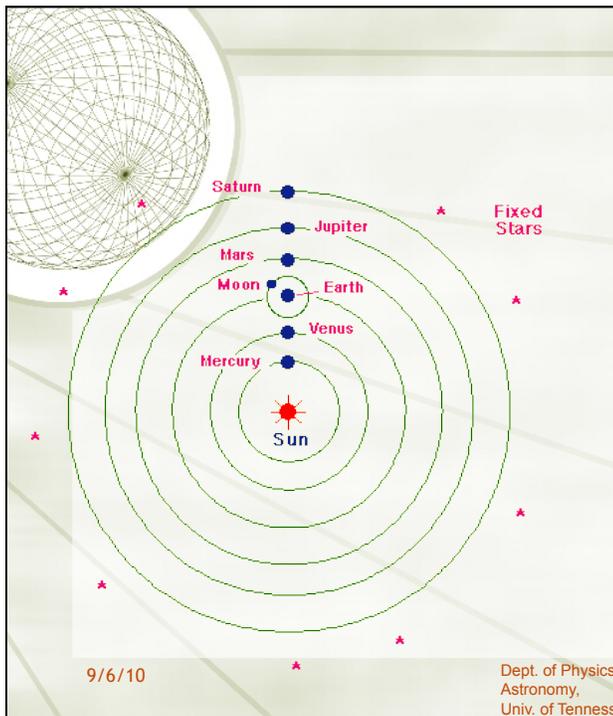
★ Wrote and distributed to friends the *Little Commentary* (1514)

Axioms:

1. *There is no one center in the universe.*
2. *The Earth's center is not the center of the universe.*
3. *The Earth and planets revolve around the Sun.*
4. *The distance from the Earth to the Sun is imperceptible compared with the distance to the stars.*
5. *The rotation of the Earth accounts for the apparent daily rotation of the stars.*
6. *The apparent annual cycle of movements of the Sun is caused by the Earth revolving round it.*
7. *The apparent retrograde motion of the planets is caused by the motion of the Earth from which one observes.*

9/6/10

21



Portrait from 1597
by Teodor de Bry

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22

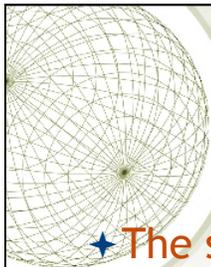


Tycho Brahe (1546-1601)

- Flamboyant and tyrannical aristocrat, but devoted to science
- Lived and observed on island off the coast of Denmark
- Last of the great “naked eye” observers
- Made planetary observations much more accurate than any previous... first to estimate error bar of a measurement
- Observed “new star” (Tycho’s supernova; 1572)
- Demonstrated that comet was beyond Moon’s orbit
- From parallax observations of new star, comet:
 - knew they were not in Earth’s atmosphere
 - evidence that heavens were not immutable
- **Collected the premiere dataset on the motion of the planets**

9/6/10

23



Next time...

★ The scientific revolution:

- ◆ Kepler
- ◆ Galileo
- ◆ Newton

READING: *Finish reading Chapter 2 of text*

9/6/10

24