

Things to do today

- After this lecture, please pick up:
 - Review questions for the final exam
 - Homework#6 (due next Tuesday)
- No class on Thursday (Thanksgiving)
- Final exam on December 2 (next Thursday)

Terminal, “Astronomy is Fun”

November 23: The Science of Astronomy
November 25: No Class Day
November 30: Telescopes

Lecture 24 The Science of Astronomy

Reading: Chapter 3

Scientific Thinking

- It is a natural part of human behavior.
- We draw conclusions based on our experiences.
- Progress is made through “trial and error.”

Ancient Astronomy

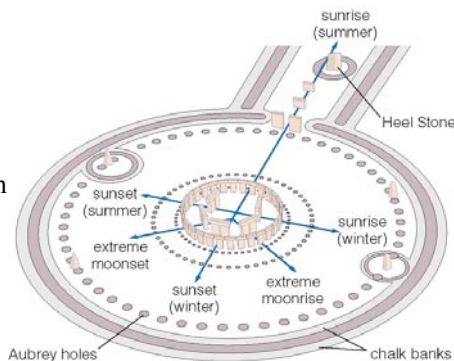
- Many cultures throughout the world practiced astronomy.
- They made careful observations of the sky.
- Over a period of time, they would notice the cyclic motions of:
 - Sun
 - Moon
 - planets
 - celestial sphere (stars)



Stonehenge (completed 1550 BC)

This famous structure in England was used as an observatory.

- If you stand in the middle:
 - the directions of sunrise & sunset on the solstices is marked.
 - the directions of extreme moon rise & set are marked.
- The Aubrey holes are believed to be an analog eclipse computer.



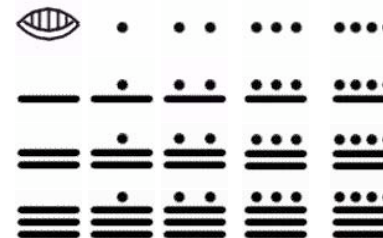
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Mayans (fl. A.D. 400 – 1200)



the Observatory at Chichén Itzá

- lived in central America
- accurately predicted eclipses
- Venus was very important
 - Still standing observatory at Chichén Itzá has a window strategically placed for observing Venus.
- marked zenial passages
- Mayan mathematics
 - base 20 system
 - invented the concept of “zero”



Claudius Ptolemy (AD 100-170)

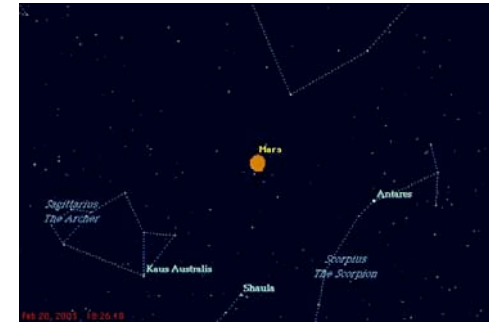
Almagest

- star catalogue
- instruments
- motions & **model** of planets, Sun, Moon



His model fit the data, made accurate predictions, but was horribly contrived!

How does one explain *retrograde* motion?

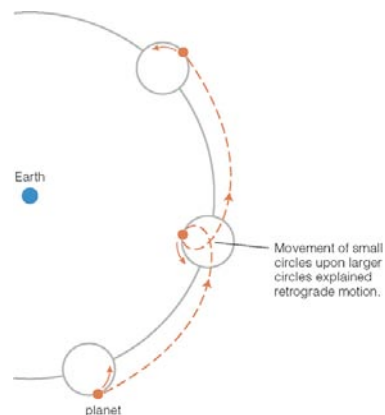


Movie. Click to play.

Over a period of 10 weeks, Mars appears to stop, back up, then go forward again.

Ptolemy's Geocentric Model

- Earth is at center
- Sun orbits Earth
- Planets orbit on small circles whose centers orbit the Earth on larger circles
 - [the small circles are called **epicycles**]



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Ptolemy's Geocentric Model

- This explained retrograde motion
- Inferior planet epicycles were fixed to the Earth-Sun line
- This explained why Mercury & Venus never strayed far from the Sun!

Nicolaus Copernicus (1473-1543)

He thought Ptolemy's model was contrived
Yet he believed in circular motion

Copernican Revolution



Copernicus' Heliocentric Model

- Sun is at center
- Earth orbits like any other planet
- Inferior planet orbits are smaller
- Retrograde motion occurs when we “lap” Mars & the other superior planets

- But, it didn't do so much better than the geocentric model because Copernicus believed the “perfect circle” conjecture.

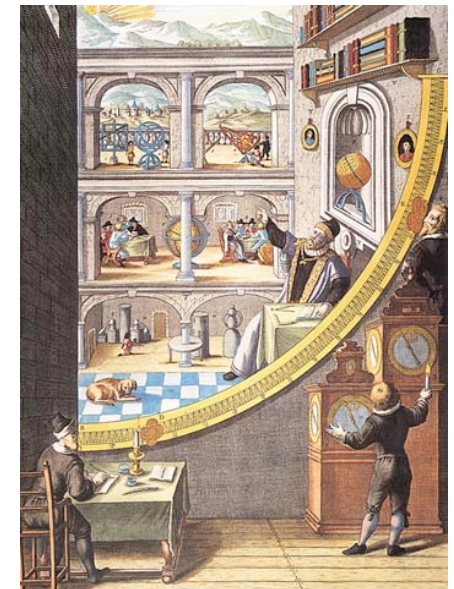
Tycho Brahe (1546-1601)

- Greatest observer of his day
- Naked Eye!!
- Charted accurate positions of planets

- Observed a “nova” in 1572
 - It was actually a supernova



- He observed a planet through the rectangular hole in the wall.
- An assistant used a sliding marker to measure the angle on the protractor.



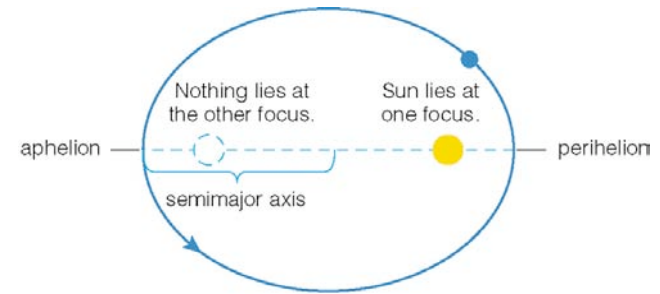
Johannes Kepler (1571-1630)

- Greatest theorist of his day
- a mystic and very religious
- Believed a perfect circle
- there were no heavenly spheres
- *forces* made the planets move
- Could not stand 8 arc-minutes difference between his predictions and Tycho's data -
-> discard a perfect circle



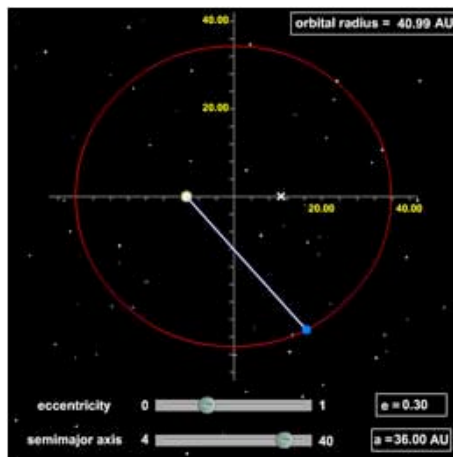
Kepler's Laws (later explained by Newton)

- 1 Each planet's orbit around the Sun is an ellipse, with the Sun at one focus.



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Eccentricity of an Ellipse



Kepler's Laws

- 2 A planet moves along its orbit with a speed that changes in such a way that a line from the planet to the Sun sweeps out equal areas in equal intervals of time.

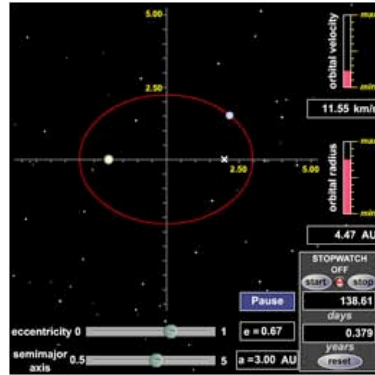


Kepler's Laws

- 3 The ratio of the cube of a planet's average distance from the Sun to the square of its orbital period is the same for each planet.

$$a^3 / P^2 = 1$$

$$a^3 = P^2$$



Galileo Galilei (1564-1642)

- First man to point a telescope at the sky
- wanted to connect physics on earth with the heavens
- *Dialogue Concerning the Two Chief World Systems* [written in Italian]



This book got him in trouble with the Church!

Galileo's Observations



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- Galileo saw shadows cast by the mountains on the Moon.
- He observed craters.
- The Moon had a landscape; it was a "place", not a perfect heavenly body.

Galileo's Observations

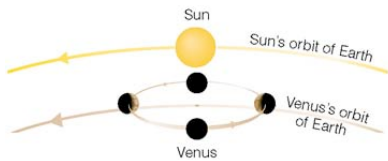
- Galileo discovered that Jupiter had four moons of its own.
- Jupiter was the center of its own system.
- Heavenly bodies existed which did not orbit the earth.



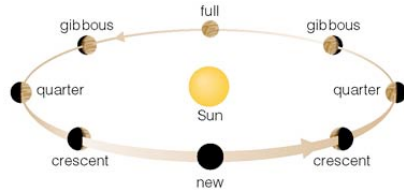
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Galileo's observation of the phases of Venus was the final evidence which buried the geocentric model.

GEOCENTRIC



HELIOCENTRIC



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No gibbous or full phases!

All phases are seen!

Galileo observed **all** phases!

The Scientific Method

1 Question

2 Hypothesis

– a tentative explanation

3 Prediction

4 Test

5 Result

– confirm, reject, or modify

should be the same no matter who conducts the test

Hallmarks of Good Science

- Science seeks explanations for *observed* phenomena that rely solely on natural causes.
- Science progresses through the creation and testing of models of nature that explain the observations as simply as possible.
! Occam's Razor
- A scientific model must make testable predictions that could force us to revise or abandon the model.

Theory -- a model which survives repeated testing

Bad Scientific Practice

- **pseudoscience** – masquerades as science, but does not follow the scientific rules of evidence
- **nonscience** – establishes “truths” through belief

Astrology

- claims to study how the positions of the Sun, Moon, & planets among the stars influence human behavior
- was the driving force which advanced ancient astronomy
- Kepler & Galileo were the last astronomers to cast horoscopes... since then astronomy grew apart from astrology into a modern science
- modern scientific tests of astrology fail ...it is a *pseudoscience*

The last lecture: Telescope (Chap 7)

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