

Topic B

"The New Astronomy" Part 1. The Old Astronomy

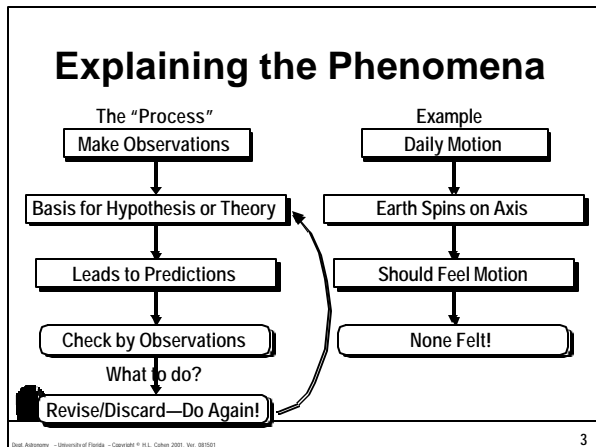
[Early Greek to Copernicus]
(Web Version: 08-15-01)

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Planetary Motions


Order in Science

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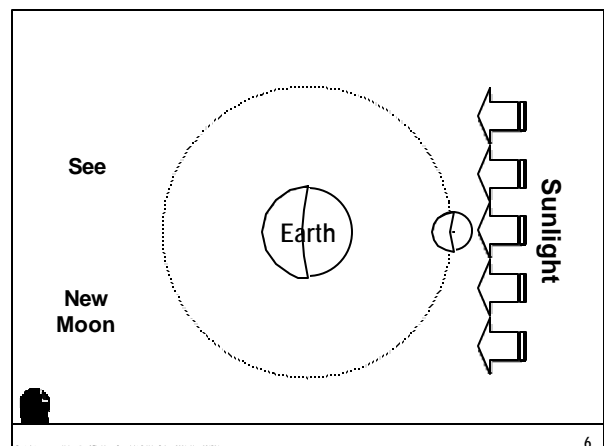
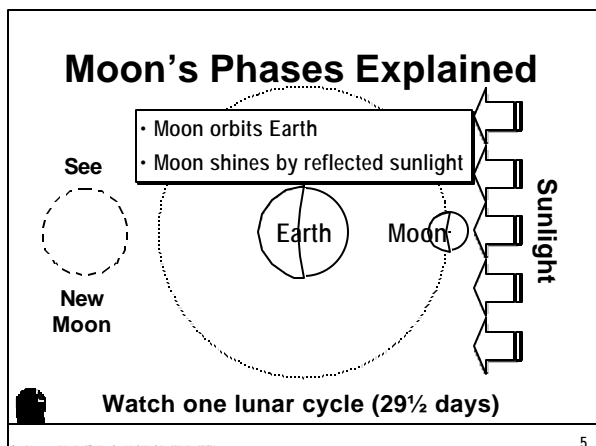


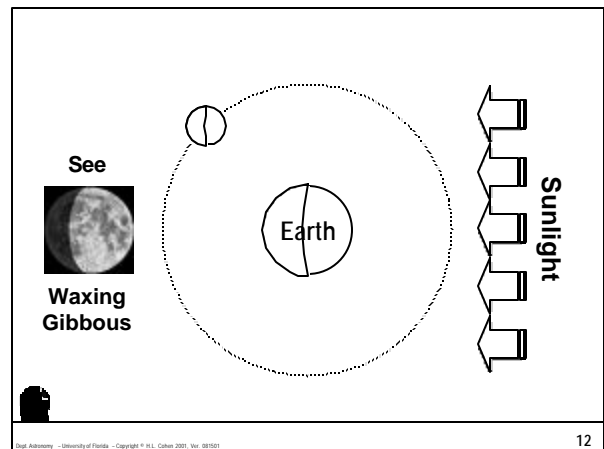
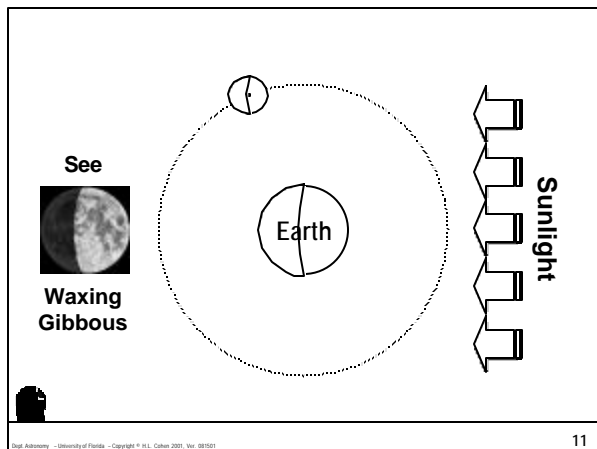
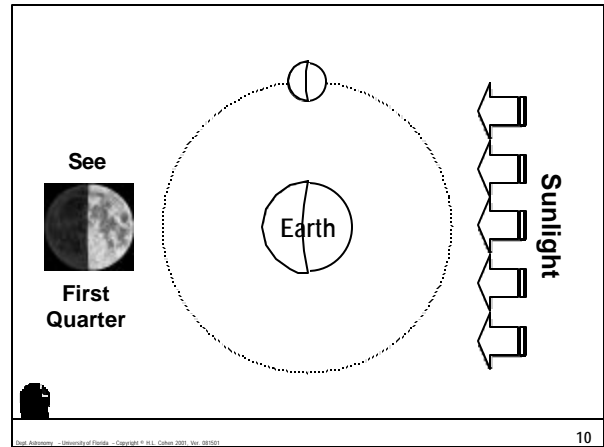
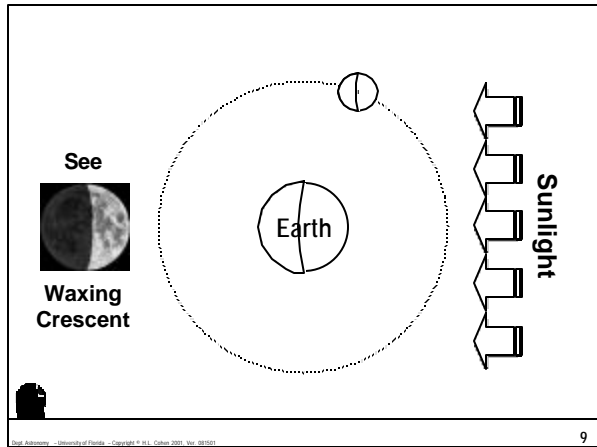
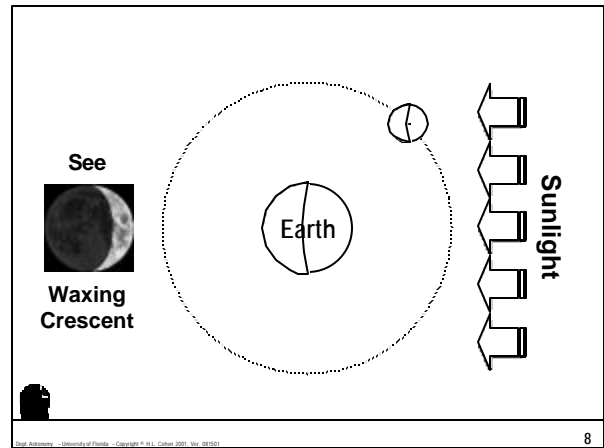
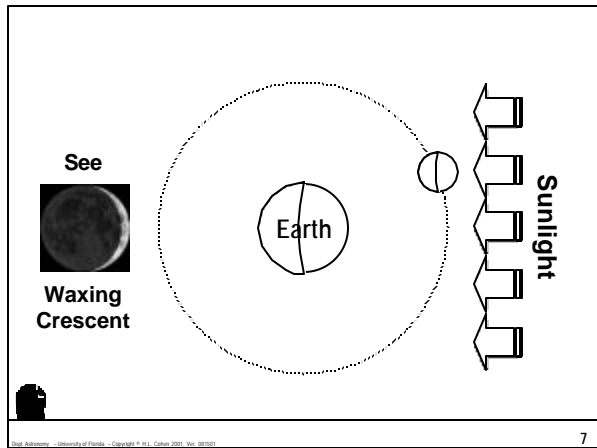
Explaining Moon's Phases

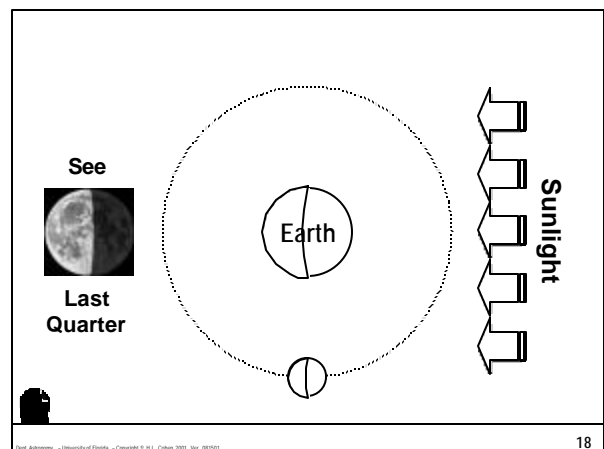
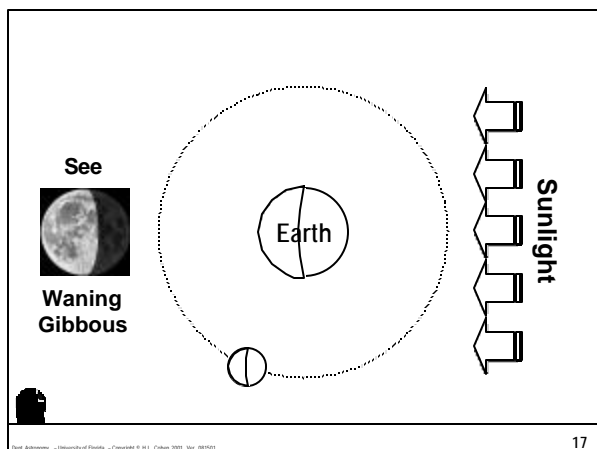
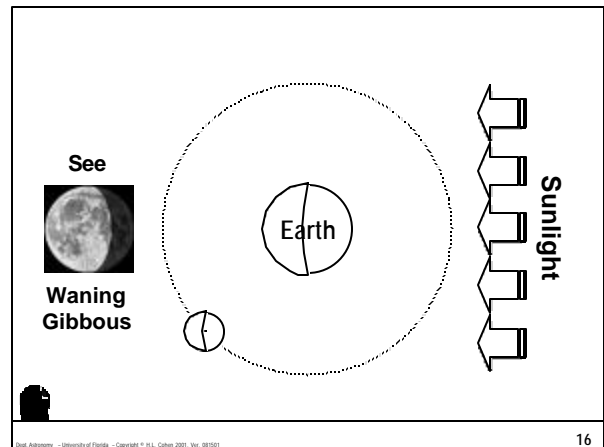
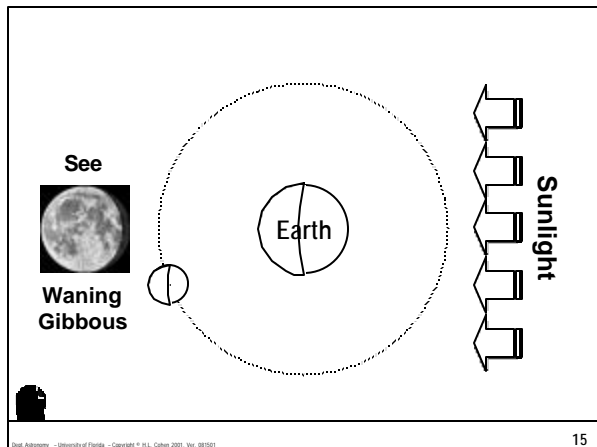
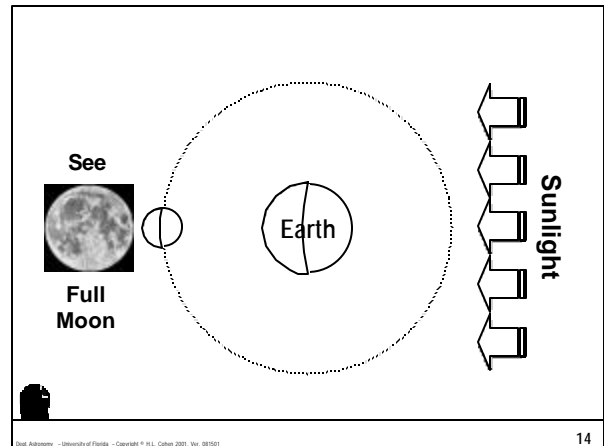
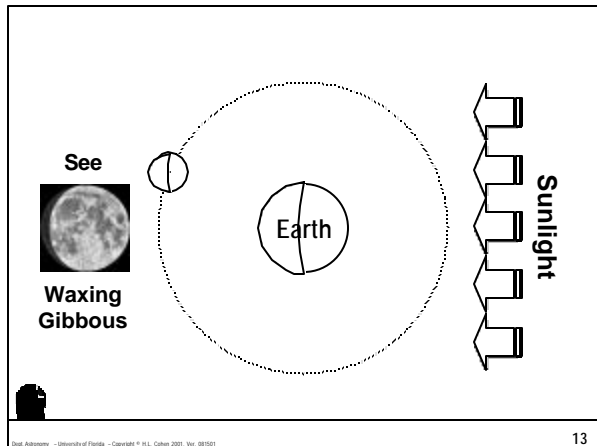
- Observation:
 - Moon changes appearance (phases)
 - Phases synchronous with aspects
- Hypothesis to explain why Moon disappears:
 - Dragon eats Moon every month
 - Dragon a messy eater!
 - Crumbs left over regenerate Moon

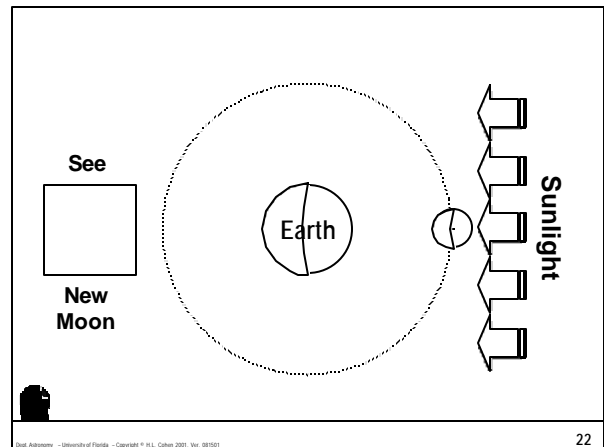
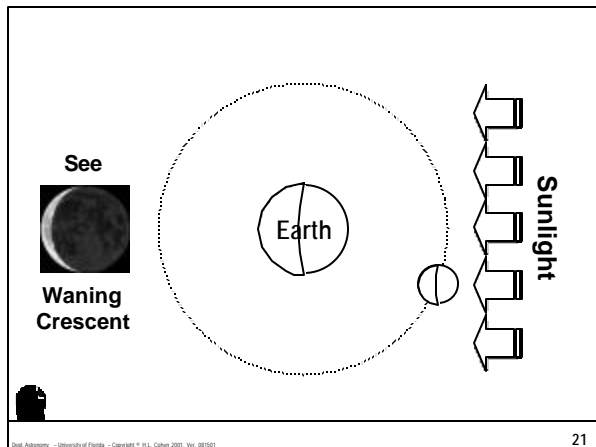
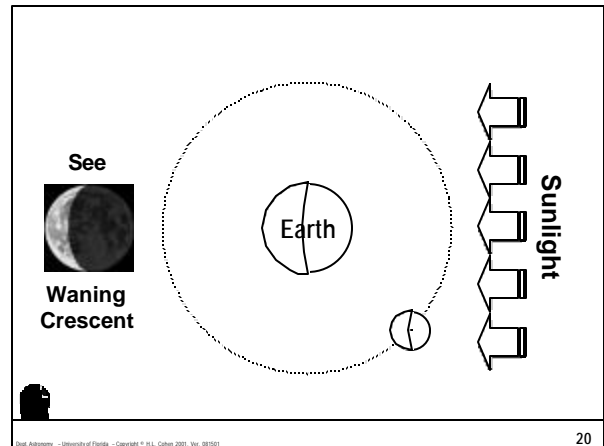
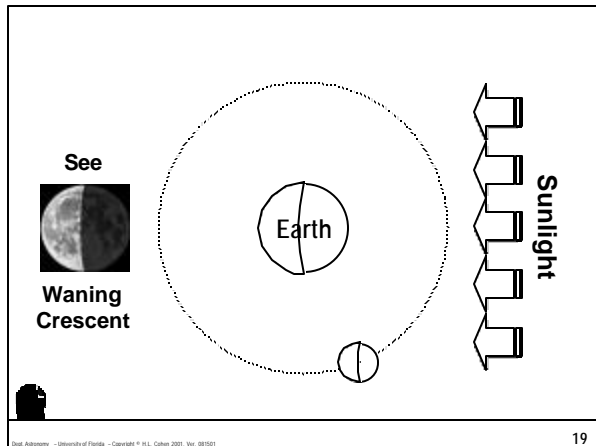


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Overview

But explaining most other motions challenged thought for thousands of years.

So we will discuss . . .

- 1) Early Greek Astronomy to Copernicus
- 2) Kepler's Model ← The "New Astronomy"
- 3) Newton's Contributions

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Helio & Geocentric Models

Attempts to explain motions of heavens historically follow two paths:

Sun Centered

Heliocentric

Earth Centered

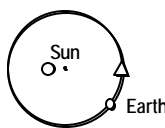
Geocentric

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Helio & Geocentric Models

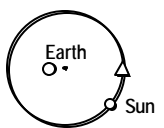
Note: Sun (or Earth) not necessarily at center of orbit . . . can be "off-center"

Sun Centered



Heliocentric

Earth Centered



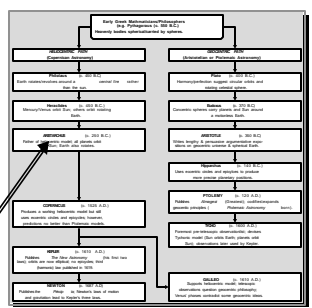
Geocentric

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Heliocentric vs. Geocentric

Brief History in Study Guide (Fig. 3)

Pay special attention to names in CAPITAL LETTERS



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Two World Views

Early Greek Mathematicians/Philosophers
(e.g., Pythagoras, c. 550 BC)
Heavenly bodies spherical & carried by spheres

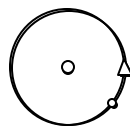
HELIOCENTRIC PATH
(Copernican Astronomy)

GEOCENTRIC PATH
(Aristotelian or Ptolemaic)

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Circles & Uniform Motion?

- Why preferred?
- Greek philosophy teaches "perfection"
 - Appear "natural"
 - Simple to use
- Latter remains a contemporary principle . . . "Occam's Razor"



Circles & Uniform Motion Used

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Occam's Razor*


A rule in science and philosophy . . .

"The simplest of two or more competing theories is preferable"

* Originally due to William of Ockham (c. 1300 AD), an English philosopher

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Geocentric Models (A Few Principle Players*)



- Eudoxus (c. 370 BC) . . . concentric spheres (circles)
- ARISTOTLE (c. 350 BC) . . . argues for geocentrism
- Hipparchus (c. 140 BC) . . . geocentric tools refine model
- PTOLEMY (c. 120 AD) . . . Ptolemaic Astronomy
 - Publishes *Almagest* ("Greatest")
 - Summarizes & expands geocentric principles

* See Figure 3 in Study Guide

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Ptolemaic Astronomy

Goal	— <i>Predict planetary positions</i>
Accuracy	— Few degrees (continually improved)
Successful	— Yes!
Competition	— Little
Result	— <i>Dominates for 2000 years (into 16th Century)</i>

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Heliocentric Models (A Few Early Principle Players*)

<ul style="list-style-type: none"> ▪ Philolaus (c. 450 BC) . . . Earth orbits & spins ▪ ARISTARCHUS (c. 250 BC) . . . argues for heliocentrism <ul style="list-style-type: none"> • “Father” of heliocentric model • All planets orbit Sun • Earth spins on axis
--

* See Figure 3 in *Study Guide*

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Early Heliocentrism

Goal	— <i>Predict planetary positions</i>
Accuracy	— Poor (little development/improvements)
Successful	— No!
Competition	— Ptolemaic Astronomy
Result	— <i>Disappears until 16th century</i>

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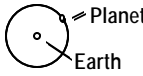

Models Must Predict

All items discussed in Topic A

- 1) Diurnal motions
- 2) Secondary motions including
 - *Motions* of Sun & Moon (incl. nonuniform rates)
 - *Moon's phases*
 - Greatest elongations of inferior planets
 - Retrograde motions of inferior & superior planets
 - Times of greatest brilliancy

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Geocentric Devices ("Tools of the Trade" — Partial List*)

- Circular Orbits 
- *Uniform motion* (about center of some circle) 
- Eccentric Circles
- Deferent – Epicycles

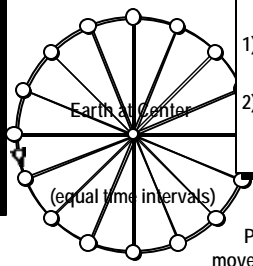
“Enhancements”

} Require some elaboration

* From time of Hipparchus (c. 140 BC)

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A Simple Geocentric Model

<p><u>Features</u></p> <ul style="list-style-type: none"> • Circular orbit • Earth at center • Uniform motion about center 		<p><u>Results</u></p> <ol style="list-style-type: none"> 1) Planet appears to move around sky 2) Motion appears <i>uniform</i> as seen from Earth
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Problem

Recall planets appear to move at *nonconstant* rates

- Sun — averages 1°/day but varies about 2%
- Moon — averages 13°/day but varies about 5%
- Planets — rates vary & have retrograde motion

How can you produce this?

Answer: *Geometric tools (eccentric circles, etc.)*

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The Eccentric Circle

Again watch Planet/Sun/Moon) move with constant speed

Features

- Circular orbit
- Earth off-center
- Motion still uniform about center of circle

Result

Motion appears non-uniform as seen from Earth

(equal time intervals)

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The Epicycle

Features

- Circular orbit
- Epicycle carries planet
- Deferent carries epicycle

Can produce nonuniform motion in either *prograde* or *retrograde* directions

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An "Orrery"

- ◆ Working model of solar system
- ◆ Originally mechanical ("spheres & gears")
- ◆ Early Version (1713)
- ◆ For Charles Boyle, 4th Earl of Cork & Orrery)

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Oliver's Orrery*

A computer simulation showing how epicyclic motions produce observed motions on sky

Prof. John P. Oliver
Department of Astronomy
University of Florida

* © 1996-97 John Oliver

Tools Can Be Combined!

Many Ptolemaic models produced through middle ages

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A Simple Ptolemaic Model

Sphere of Stars

Earth in middle of "sphere of stars"

Stationary Earth

- Does not move
- Does not spin

Earth

See Textbook, Fig. 1.3 (pg. 26)

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A Simple Ptolemaic Model

Sphere of Stars

Earth in middle of "sphere of stars"

Sphere of Stars

- All celestial objects "ride" sphere of stars
- Spin of sphere causes daily motion

Earth

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A Simple Ptolemaic Model

Planet brightest during retrograde motion because nearest Earth!

Superior Planet

Inferior Planet

Earth

Sun

Planetary orbits are all eccentric circles (Earth not at center)

Notice epicycle lines up with Sun to keep planet near Sun (So how long does it take epicycle to move around Earth?)

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Geocentric View Point

- Objects move: As "naturally appear"
- Observed motions: Actual movement about stationary Earth
- Diurnal motion: Actual spin of heavens

Stationary Earth

Heavens "spin"

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Renaissance Heliocentrism

Subtitle — "Copernican Revolution"

What done — Heliocentrism *reintroduced* by Copernicus

(See Study Guide Fig. 3)

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Copernicus (c. 1525 A.D.)

- Goal — *better planetary predictions*
- What done
 - Produces *working heliocentric model*
 - Uses nearly all "Ptolemaic Tools" !!!
 - So model includes

Circular Orbits	Uniform Motion	Eccentric Circles	Deferents & Epicycles
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Copernicus (c. 1525 A.D.)

- Goal — *better planetary predictions*
- What done
 - Produces *working heliocentric model*
 - Uses nearly all “Ptolemaic Tools” !!!


➔ Why same tools used?

Needs Ptolemaic tools to get accurate planetary positions!



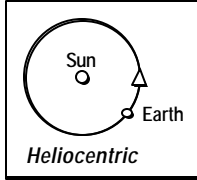
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“Copernican Models”



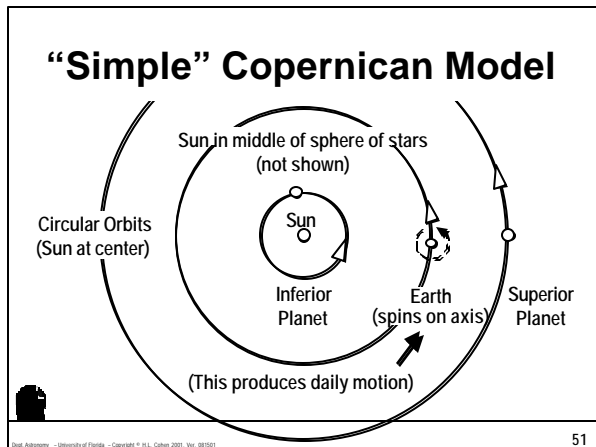
Self-Portrait

- Copernican models often *oversimplified*
(Use only *simple circles* like *Aristarchus*)
- Why?
 - Enhancements unnecessary to explain *basic* motions (annual, retrograde, etc.)
- Misleading . . .
 - Appears “simple” *but*
 - Cannot produce *accurate planetary positions!*



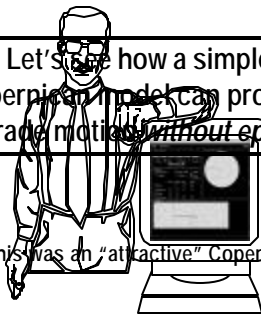
Heliocentric

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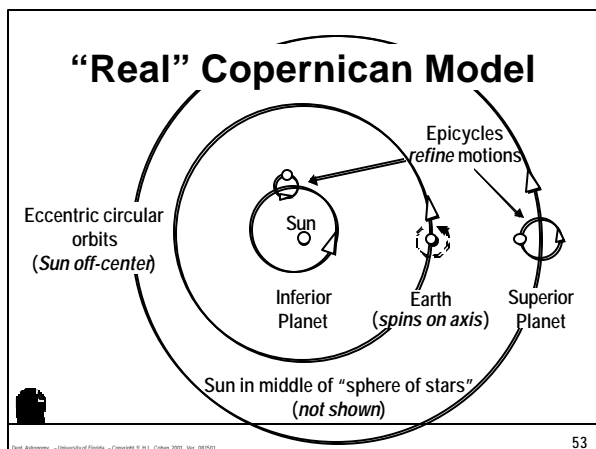
Oliver’s Orrery

Let’s see how a simple Copernican model can produce retrograde motions *without epicycles**







*For some this was an “attractive” Copernican feature

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Why Enhancements?

- If heliocentric model produces retrograde motion without epicycles, then why use enhancements?
- Answer: Predictive accuracy poor!
- Result: Still need “Ptolemaic tools”

Circular Orbits	Uniform Motion	Eccentric Circles	Deferents & Epicycles
			

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Heliocentric Orientation

- Annual motion:
From orbiting Earth
- Retrograde motion:
Illusion caused by planets passing each other
- Diurnal motion:
From spinning Earth

All planets orbit Sun

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Accuracy: Geo vs. Helio

- Typical accuracy
 - Geocentric — a few degrees
 - Heliocentric — a few degrees (no better!)
- Conclusions
 - Accuracy *equivalent* for each
 - Copernicus *failed to achieve his goal*
(Better predictions not realized)

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Side Note

- Geocentric models still used today
- Used in some planetarium planetary projectors!
- Why?
 - Simple to construct
 - Works well enough

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Galileo (c. 1610)

- Argued for Copernican Model
 - Insisted only heliocentric model correct
 - Publicly ridiculed “Aristotleans”
 - Arrogant with Roman Catholic Church
- Roman Catholic Church
 - Heliocentrism OK if only used to predict positions
 - Geocentrism must remain “world view”
- Galileo refused

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“The Dialogue”

(Published by Galileo, 1632)

Title: “*Dialogue Concerning The Two Chief World Systems*”

About: Comparison of Ptolemaic & Copernican models

Three “Panelists”:

- Salviati —
- Sagredo —
- Simplicius —

Result — House arrest for life!

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Helio or Geocentricism?

- Which model “better” (“correct”) ?
- How judge?
 - Work better (predictions more accurate)?
 - Other (e.g., “aesthetically nicer”)?
 - Simpler (Occam’s razor)?

See *Study Guide* Table 4 for comparisons of Ptolemaic and Copernican Models

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Simplicity?

Compare "Real"
Ptolemaic & Copernican Models

You judge . . .

Which appears "simpler"? ➡

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