Astronomy 350L
(Fall 2006)

The History and Philosophy of Astronomy
(Lecture 7: Middle Ages/Islam II)

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Medieval Astronomy and Cosmology

• **Middle Ages I (Sep. 19)**
  - Decline of Western (Mediterranean) Civilization
    - Early Middle Ages (“Dark Ages”): 500 – 1000 AD
  - Ascendancy of Islamic Astronomy (800 – 1400 AD)
    - Preservation and transformation of ancient knowledge

• **Middle Ages II (Sep. 21)**
  - Recovery of European Civilization
    - High and Late Middle Ages (c. 1000 – 1450 AD)
  - Setting the Stage for the Copernican Revolution
    - Recasting of the Ancient Tradition
Europe Recovers: Later Middle Ages (c. 1000 – 1450)

- Romanesque: e.g., Dome in Speyer (1030–1061)
- Gothic: e.g., Chartres Cathedral (1145–1220)
Europe Recovers: Later Middle Ages (c. 1000 – 1450)

- Art in the Age of Chivalry
Europe Recovers: New Spirit of Exploration

Marco Polo
(1254-1324)

Journey to China: 1271-95
Rediscovery of Ancient Knowledge: Arabic Transmission

- multiple sources: e.g., Spain, Crusades
Rediscovery of Ancient Knowledge:
- via Moorish Spain

- Translations:
  Arabic → Latin

- Later: directly
  Greek → Latin

- Transfer of know-how:
  - computation
  - astrolabes

Alhambra, Granada
Rediscovery of Ancient Knowledge:  
- via Crusades

Siege of Antioch, 1098 AD

- Europe becomes aware of high level of Islamic civilization
Rediscovery of Ancient Knowledge:
Emergence of the University

- Universities: A European Invention (12th and 13th cent.)
- Objective: Understand ancient, rediscovered texts!
Structure of Medieval University

Seven liberal Arts (Septes Artes Liberales): Trivium

Logic (Dialectic)  Grammar  Rhetoric
Structure of Medieval University

Seven liberal Arts (Septes Artes Liberales): Quadrivium

- Arithmetic
- Music
- Geometry
- Astronomy
Scholasticism: inconsistencies in ancient astronomy

• Aristotle and Ptolemy:
  - 500 years apart in real time
  - scholastics rediscover it at same instant
    → Fiction of unified body of “ancient wisdom”

• But: two systems are inconsistent!
  - Aristotelian concentric spheres vs
    Ptolemy’s deferent/epicycle system
  - Aristotle wants to explain real mechanism behind
    planetary motion (“physics’)
  - Ptolemy (“mathematical astronomy”) wants
    to predict motions, but does not claim that planets
    really move according to his constructions!
Adopting Ptolemy’s Almagest: Sacrobosco

- John of Holywood (d. 1256) Sacrobosco
- taught in Paris
- wrote *De Sphaera (Sphere)*
- standard textbook for 400 yrs
- simplified version of Almagest
The Christian Universe: Thomas Aquinas

- St. Thomas (1225-74)
- Dominican monk
- Reconciled Aristotle with Christian Theology
- *Summa Theologiae*
The Christian Universe: Thomas Aquinas
The Christian Universe: Dante’s *Divine Comedy*

- Astronomy = Theology
- Central Earth becomes essential ingredient of Christian Theology
The Empyrean: Dante and Beatrice behold Paradise
Scholastic Critique of Aristotle:

Motion of Projectile (Impetus Theory)

- Jean Buridan (14th cent.)
- taught in Paris
- member of Nominalists
- Buridan’s ass: The Tyranny of Choice
**Projectile Motion: Aristotle’s Theory**

- **Basic principle:** heavy bodies (elements earth or water) are at rest or move straight to center of Earth (= center of universe)

- To deviate from Aristotelian natural motion: need external influence!

- For projectile: influence comes from pushed-aside air bubble!
** Projectile Motion: Buridan’s Theory **

- **Basic principle**: heavy bodies are at rest or continue to move according to *impetus* initially imparted to them.

  *impetus = (modern) momentum (Galileo, Newton)*

  \[(\text{mass } \times \text{ speed})\]

- **crucial step in allowing Earth to move!**
Scholastic Critique of Aristotle:
Demonstrating Possibility of Earth’s Motion

• Nicole Oresme (14th cent.)
• taught in Paris
• pupil of Buridan
• demonstrates logical possibility of Earth’s motion
Motion of Earth is possible: Nicole Oresme

• Idea 1: Earth could move in circles around center of universe! then Earth would be a planet, one among many!
Q: What would happen?

Aristotle: 1st Earth 2nd Earth

center of universe

Two Earth’s would collide: Earth is unique!
Motion of Earth is possible: Nicole Oresme

• Idea 1: Earth could move in circles around center of universe!
  then Earth would be a planet, one among many!
Q: What would happen?

Oresme: 1st Earth 2nd Earth
two different centers of gravity!

Each heavy body (e.g., planet) has its own center of attraction: Earth _could_ be a planet!
Aristotelian Argument against Earth’s Rotation:

- **Basic principle**: heavy bodies follow natural motion towards center of Earth = cent. of universe

Aristotle argued: Stone would be left behind if Earth rotated!
Oresme’s Argument for Earth’s Rotation:

- **Basic principle:** impetus theory!
  - stone or arrow has sideways impetus → stone follows Earth

Oresme argued: Stone would *not* be left behind if Earth rotated!
Oresme’s Argument for Earth’s Rotation:

- two equivalent ways to understand daily motion of fixed stars!

- Optical relativity: both models can explain appearance
A Universe without limit: Nicolaus of Cusa

- Cusanus (1401-64 AD)
- lived in Southern Germany
- was a Cardinal of Roman Catholic Church
- Of Learned Ignorance (De Docta Ignorantia)
A Universe without limit: Nicolaus of Cusa

• **Basic principle:** Opposites coincide (become the same) in the process of going to infinity (coincidential oppositorum)
  
  - E.g., curve and straight line

• But also: Center and circumference
  
  - Coincide in the limit of the absolute smallest

• The realm of the absolute is God!
  
  - material universe cannot attain this!

→ Universe has no center and no edge!
Astronomy in the Middle Ages (Scholastic Period)

- Rebirth of intellectual, scientific activity
- Rediscovery of ancient texts (via Arabic transmission)
- Founding of Universities (Scholastic Philosophy)
- Recasting of tradition at Dawn of Copernican Revol.:  
  - Aristotelian-Ptolemaic system incorporated into Christian theology opposes Copernicus!
  - New theory of motion establishes plausibility of Earth’s motion crucial precondition for Copernicus!