Astronomy 350L

(Fall 2006)

The History and Philosophy of Astronomy

(Lecture 8: Copernicus)

Instructor: Volker Bromm
TA: Jarrett Johnson

The University of Texas at Austin

Astronomy during the Renaissance (c. 1450 – 1600)

- Rebirth of cultural activity in Europe!

Intellectual Climate: Reformation (1517 onwards)

- Restore lost original (pure) state of Church!

Intellectual Climate: Humanism

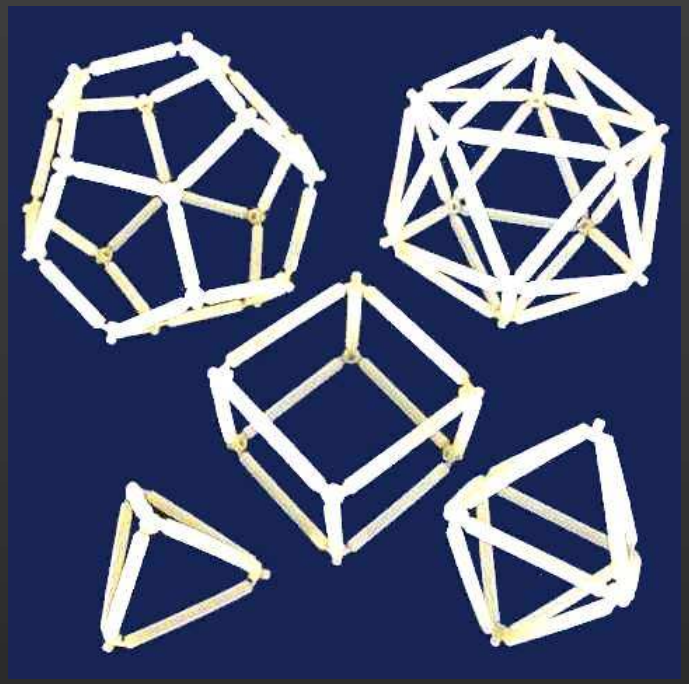
Erasmus of Rotterdam

Pico della Mirandola

- Anti-Aristotelian strain, desire for classics!

Intellectual Climate: Neoplatonism

Marsilio Ficino

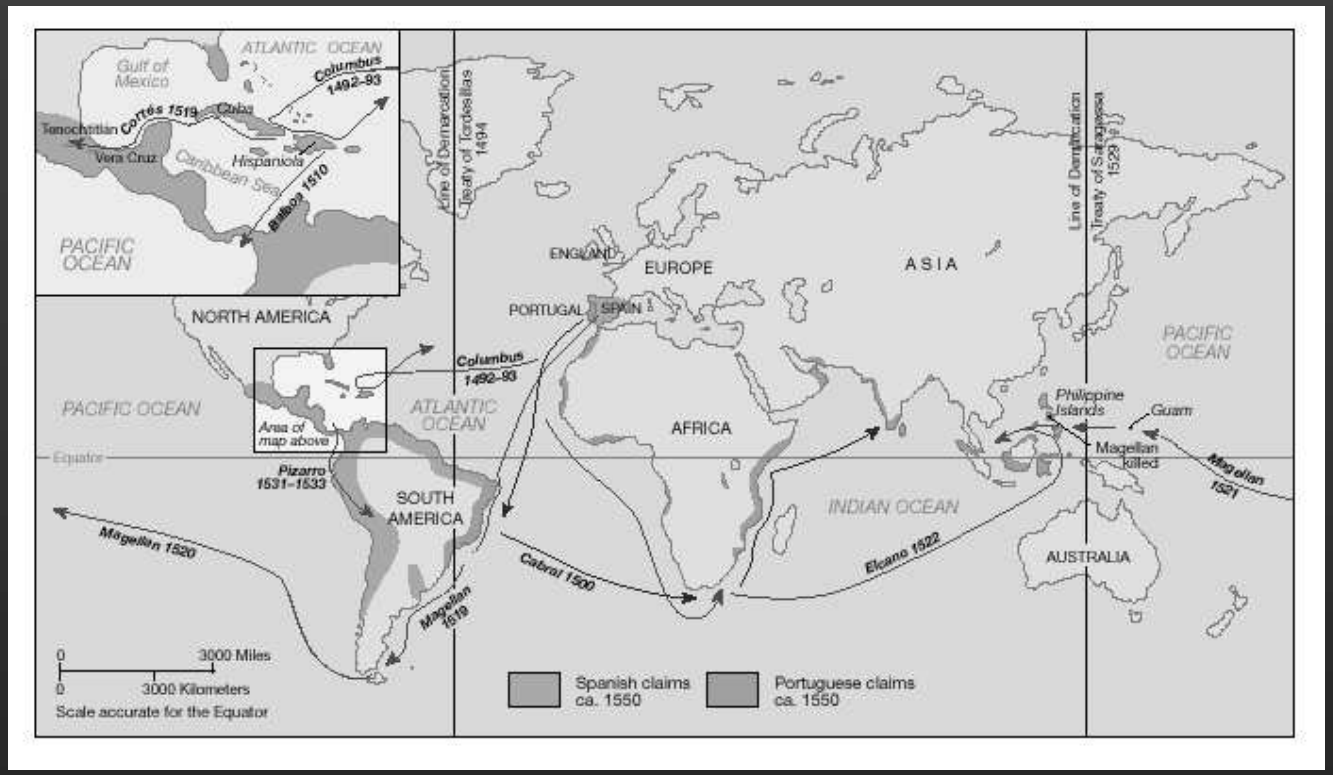


- mathematical harmony
- Sun worship
- Search for underlying (mathematical) structure of reality!

Intellectual Climate: Voyages of Discovery

Columbus

(1451-1506)



Spanish and Portuguese exploration

- New spirit of discovery!

Intellectual Climate: Fall of Constantinople 1453

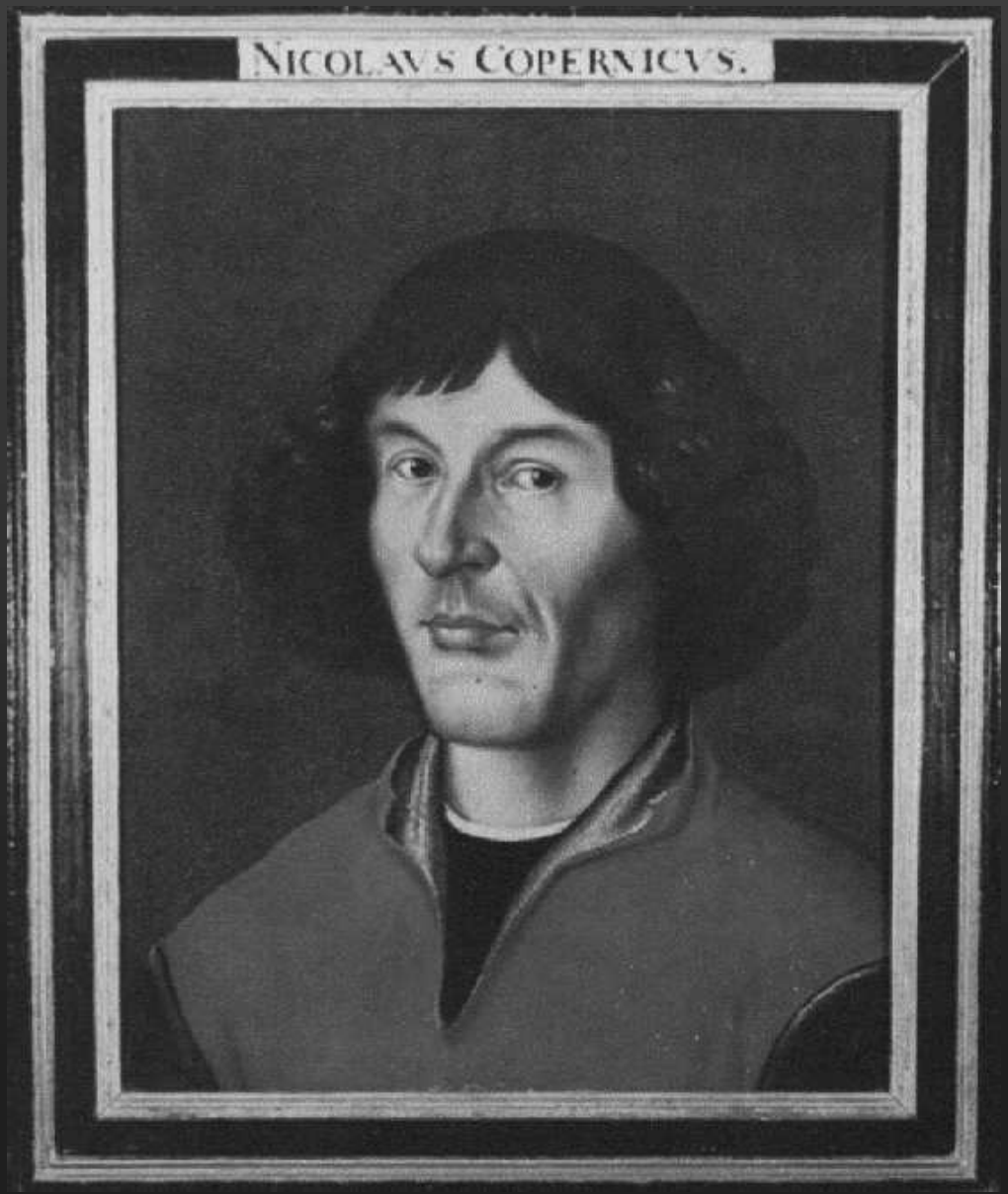
- Escape of Greek scholars and texts to Italy!

Intellectual Climate: Invention of Printing Press

Johannes Gutenberg

- Rapid dissemination of knowledge!

Nicolaus Copernicus



- 1473 – 1543
- *De Revolutionibus Orbium Coelestium*

  (1543, On the Revolution of the Heavenly Spheres)
- What was he:
  - first modern astronomer?
  - last ancient astronomer?

Nicolaus Copernicus: Geography of his Life

Copernicus: Studies in Italy

Bologna

Padua

- Bologna and Padua: astronomy, mathematics, medicine, law
- Eventually: Doctorate in church law (Ferrara)

Copernicus: Canon at Frombork Cathedral

- Q: What is a canon?

Copernicus: War in Varmia (1519-1521)

- Poland vs Teutonic Knights, Copernicus involved in defence

Copernicus: *De Revolutionibus* (1543)

— DVLCES ANTE OMNIA MVSÆ

NICOLAI
COPERNICI TO-
RINENSIS DE REVOLVTIONI-
bus orbium cœlestium,
Libri VI.

IN QVIBVS STELLARVM ET FI-
XARVM ET ERRATICARVM MOTVS, EX VETE-
ribus atq; recentibus obseruationibus, restituit hic autor.
Præterea tabulas expeditas luculentasq; addidit, ex qui-
bus eosdem motus ad quoduis tempus Mathe-
matum studiosus facillime calcu-
lare poterit.

ITEM, DE LIBRIS REVOLVTIONVM NICOLAI
Copernici Narratio prima, per M. Georgium Ioachi-
mum Rheticum ad D. Ioan. Schone-
rum scripta.

Cum Gratia & Priuilegio Cæs. Maiest.

BASILEAE, EX OFFICINA
HENRICPETRINA.

- heliocentric model
- Q: What motivated him?
- Q: Structure of book?
- Q: In which way was it revolutionary?

De Revolutionibus: Basic Structure

- Book 1: Popular justification for Earth's motion
- Book 2-6: Mathematical details to account for celestial (planetary) motions

- Book 1: not original, not really convincing
- Book 2-6: highly specialized ("Mathematics is for mathematicians")

De Revolutionibus: Basic Principles (Book 1)

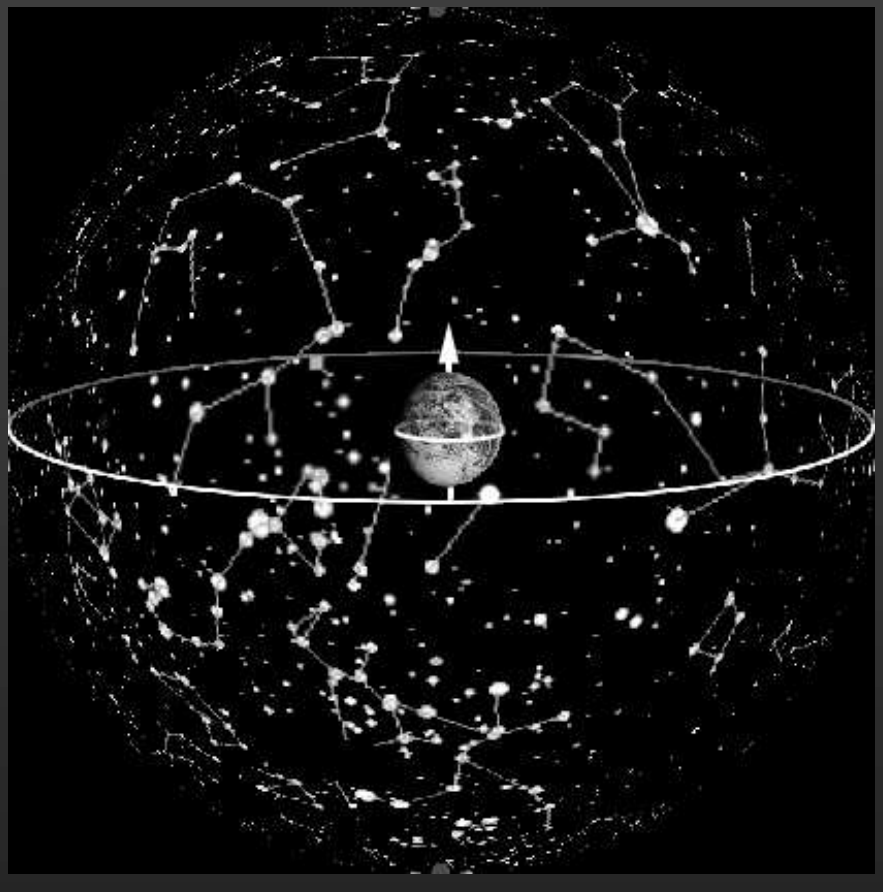

NICOLAI COPERNICI

net, in quo terram cum orbe lunari tanquam epicyclo contineri diximus. Quinto loco Venus nono mense reducitur. Sextum denique locum Mercurius tenet, octuaginta dierum spacio circũ currens. In medio uero omnium residet Sol. Quis enim in hoc

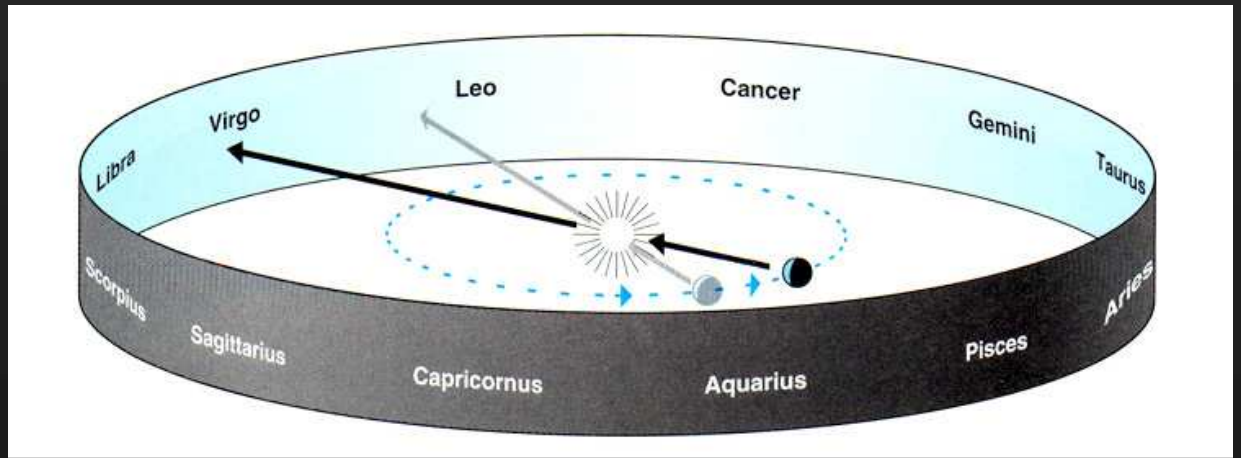
pulcherimo templo lampadem hanc in alio uel meliori loco ponere, quàm unde totum simul possit illuminare? Siquidem non inepte quidam lucernam mundi, alij mentem, alij rectorem uocant. Trimegistus uisibilem Deum, Sophoclis Electra intuentẽ omnia. Ita profecto tanquam in solio regali Sol residens circum agentem gubernat Astrorum familiam. Tellus quoq; minime fraudatur lunari ministerio, sed ut Aristoteles de animalibus ait, maximã Luna cũ terra cognationẽ habet. Concipit interea à Sole terra, & impregnatur annuo partu. Inuenimus igitur sub hac

- Sun-centered
- Earth is planet (3rd from Sun)
- Earth's motions:
  - daily rotation
  - annual revolution around Sun
- Celestial motions uniform and circular
- finite universe

De Revolutionibus: Basic Principles (Book 1)



- daily rotation of celestial (fixed star) sphere

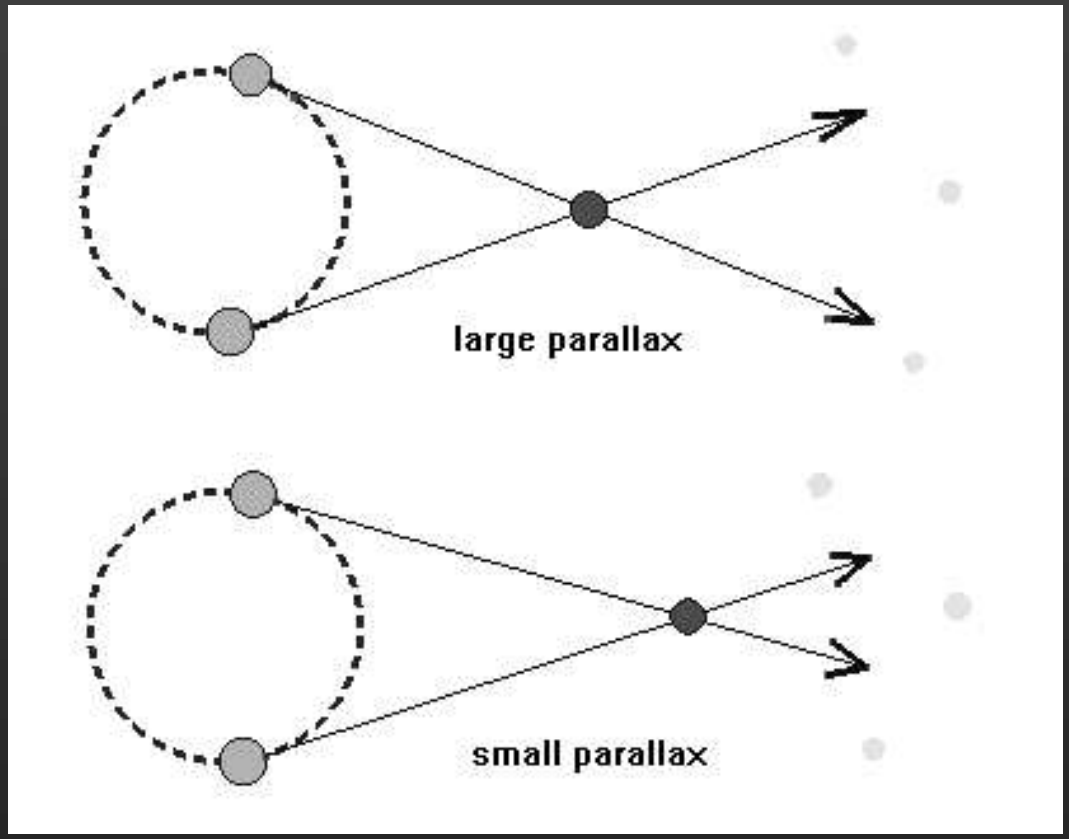


- yearly motion of Sun along ecliptic (zodiac)

Big Problem: Missing Stellar Parallax

- Not observed (too small) until 1838 (Bessel)!

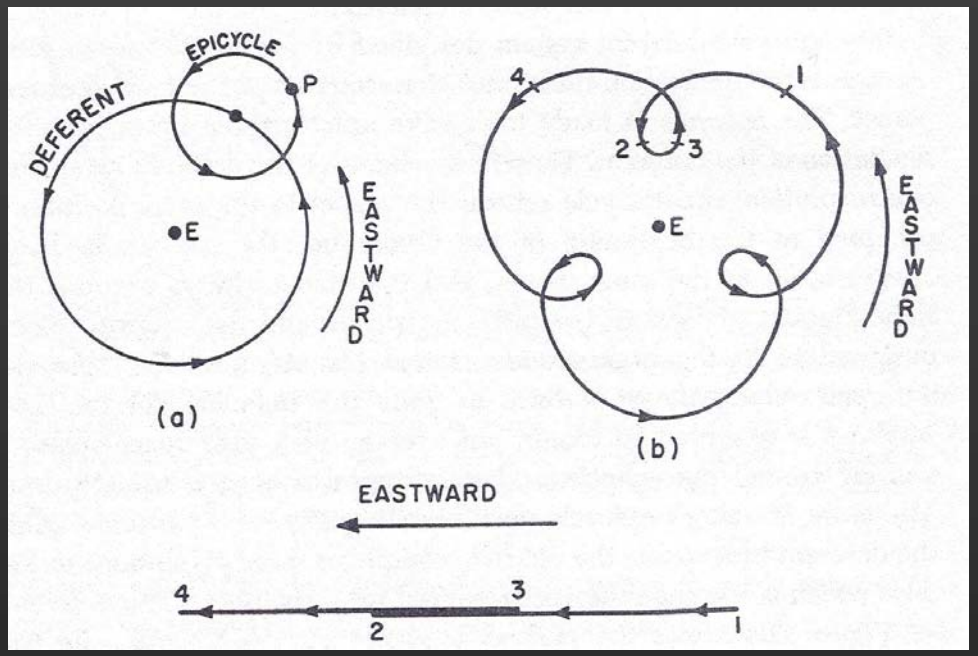
Big Problem: Missing Stellar Parallax



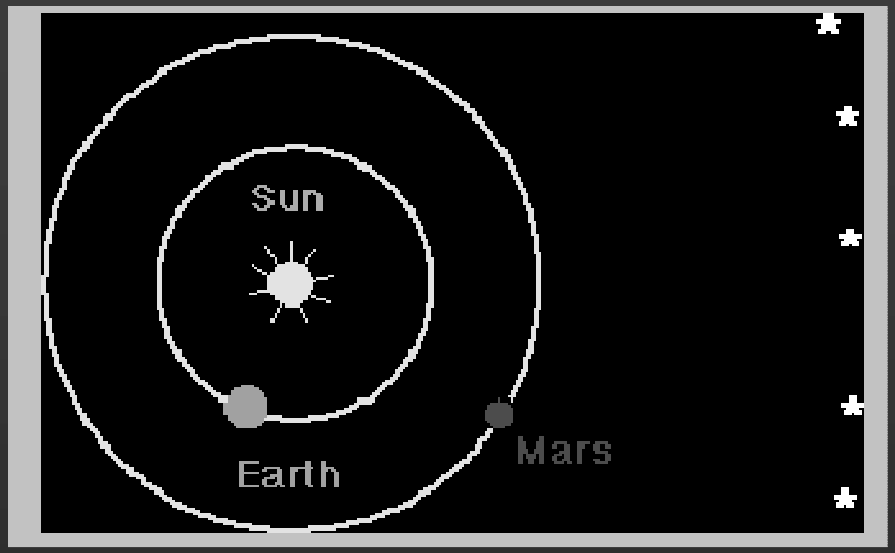
- Copernicus (correct) idea: Stars are at immense distance (same idea as suggested by Aristarchus)
- Copernican universe (although still finite) much larger than Ptolemaic one

De Revolutionibus: Aesthetic Appeal

Ptolemy

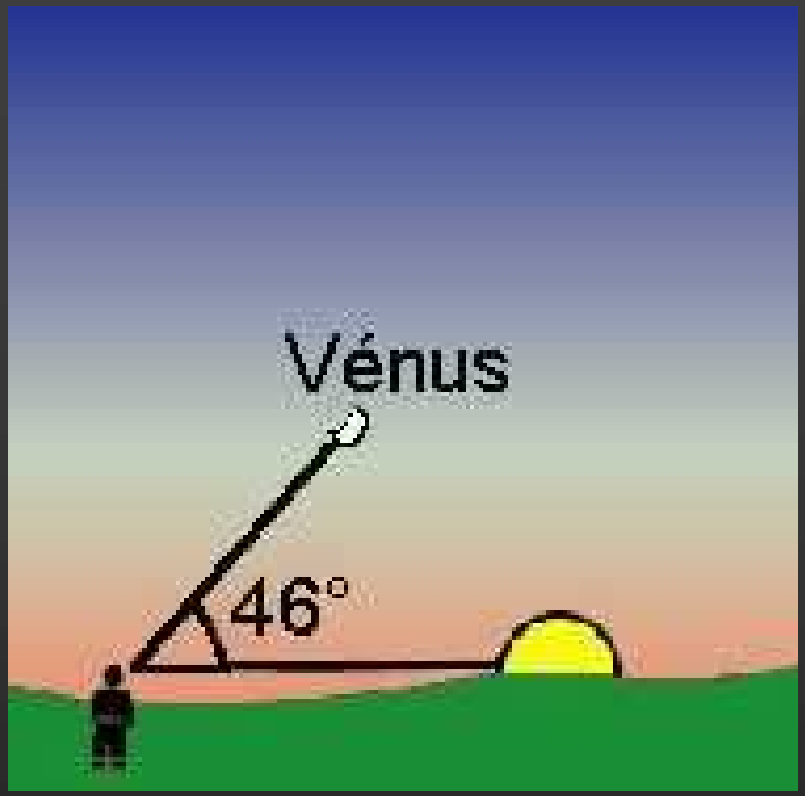


Copernicus



- Conceptually simpler explanation for retrograde motion (7 spheres vs 12)
- Retrograde motion of planets natural outcome of Earth's motion!

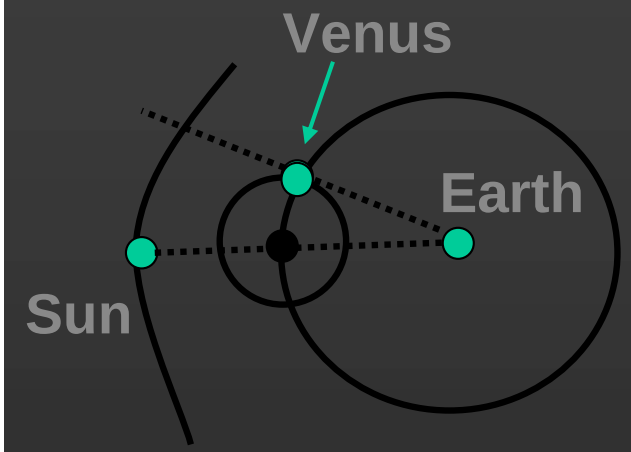
Copernicus vs Ptolemy: Elongation of Venus



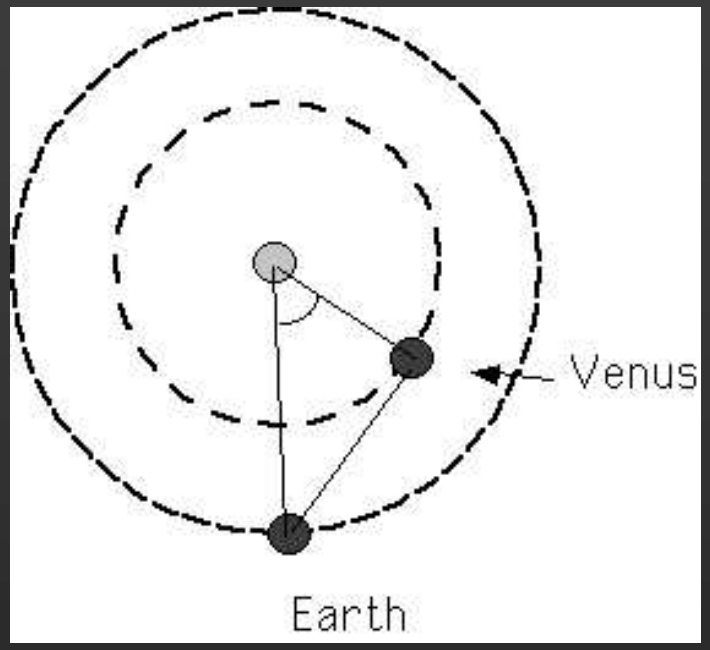
- Observational fact: Venus and Mercury never stray much (in angular distance) from Sun
- Q: How to explain?

Copernicus vs Ptolemy: Elongation of Venus

Ptolemy



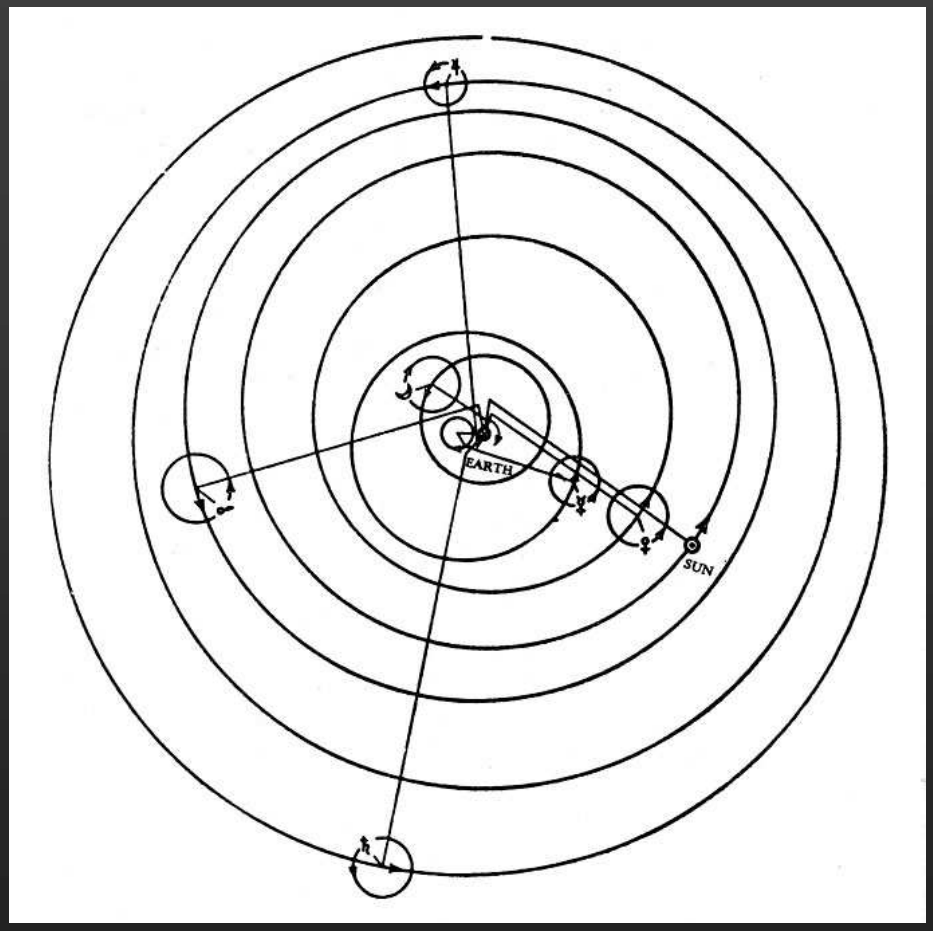
Copernicus



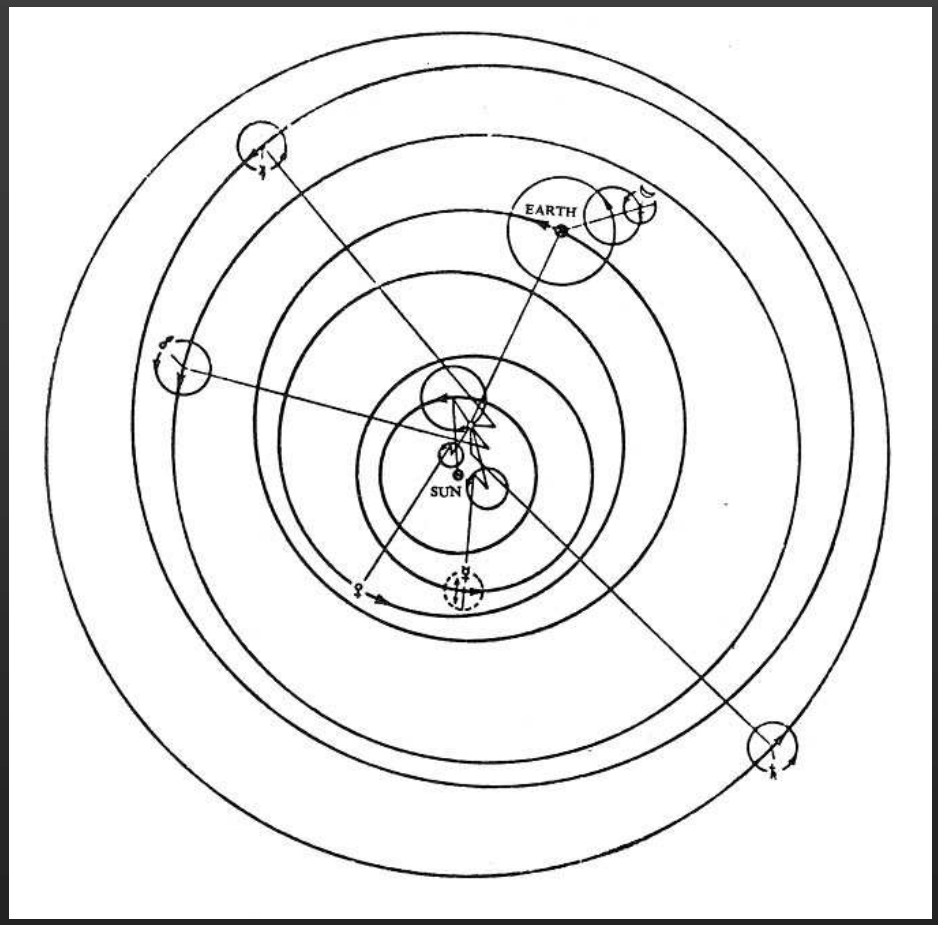
- Copernican system: Maximum elongation natural consequence
- Ptolemy: Need to make ad-hoc assumption

De Revolutionibus: Final Result (Books 2-6)

Ptolemy



Copernicus

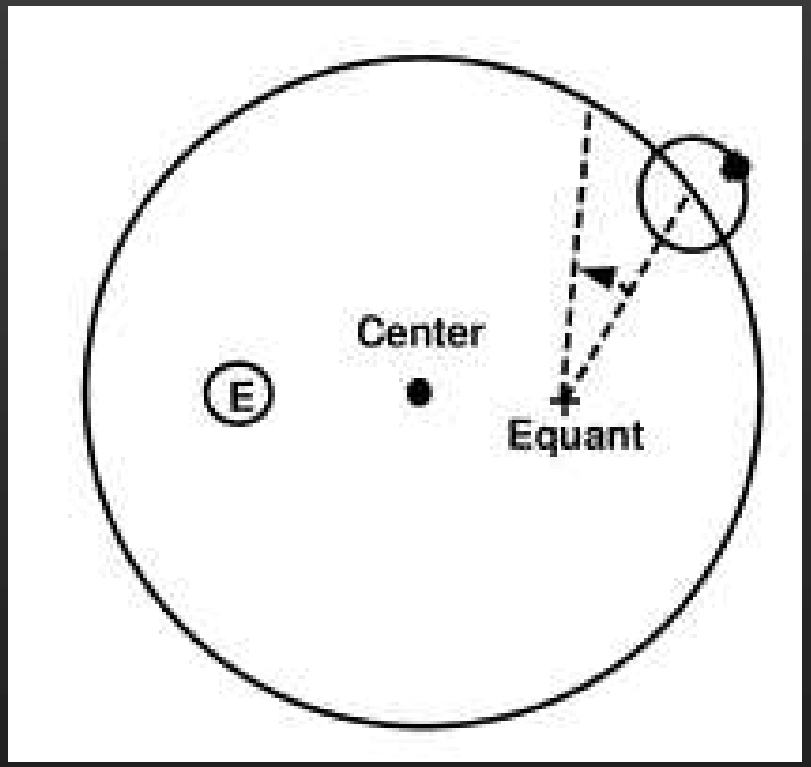


- As messy as Ptolemy, not more accurate:
  - a failure really (according to original claim)

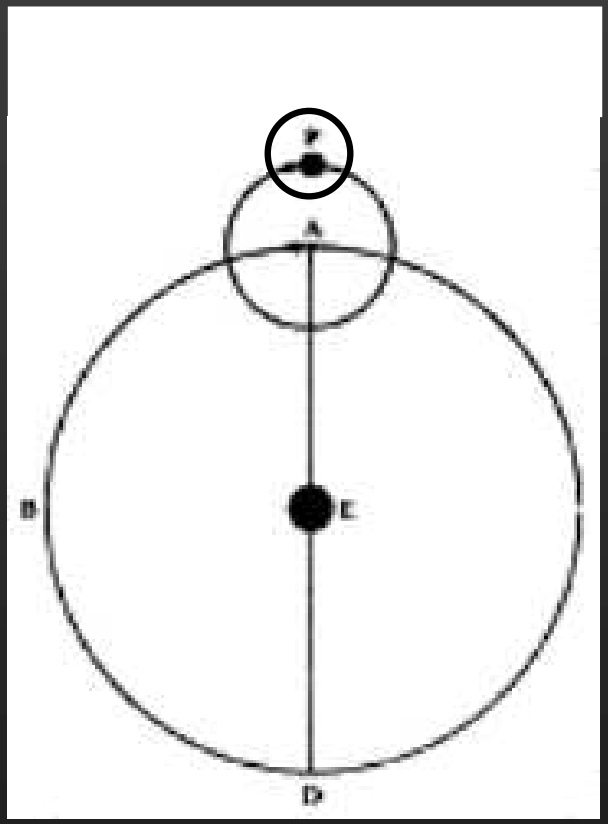
Principle of Perfect Uniformity

- eliminate un-Platonic equant with double epicycle!

equant



double-epicycle



- Same device as used by Arabs: Did he know?

Harmony of Copernican System

NICOLAI COPERNICI

net, in quo terram cum orbe lunari tanquam epicyclo contineri diximus. Quinto loco Venus nono mense reducitur. Sextum denique locum Mercurius tenet, octuaginta dierum spacio circũ currens. In medio uero omnium residet Sol. Quis enim in hoc

pulcherimo templo lampadem hanc in alio uel meliori loco poneret, quam unde totum simul possit illuminare? Siquidem non inepte quidam lucernam mundi, alij mentem, alij rectorem uocant. Trimegistus uisibilem Deum, Sophoclis Electra intuentẽ omnia. Ita profecto tanquam in solio regali Sol residens circum agentem gubernat Astrorum familiam. Tellus quoq; minime fraudatur lunari ministerio, sed ut Aristoteles de animalibus ait, maxima Luna cũ terra cognationẽ habet. Concipit interea à Sole terra, & impregnatur annuo partu. Inuenimus igitur sub hac

- No clear-cut proof possible for heliocentric model
  - actually: problem with missing fix-star parallax
- But Copernicus claims that his system is more elegant ("harmonious") than Ptolemy's, e.g.:
  - **retrogression of planetary motion**
  - **ordering of planets**
  - **maximum elongation of Venus and Mercury**
  - **correlation of opposition and brightness (Mars, Jupiter, Saturn)**

De Revolutionibus: The Long Road to Publication

— DVLCES ANTE OMNIA MVSÆ

NICOLAI
COPERNICI TO-
RINENSIS DE REVOLVTIONI-
bus orbium cœleſtium,
Libri VI.

IN QVIBVS STELLARVM ET FI-
XARVM ET ERRATICARVM MOTVS, EX VETE-
ribus atq; recentibus obſeruationibus, reſtituit hic autor.
Præterea tabulas expeditas luculentasq; addidit, ex quibus eoſdem motus ad quoduis tempus Mathematum ſtudioſus facillime calculare poterit.

ITEM, DE LIBRIS REVOLVTIONVM NICOLAI
Copernici Narratio prima, per M. Georgium Ioachimum Rheticum ad D. Ioan. Schonerum ſcripta.

Cum Gratia & Priuilegio Cæſ. Maieſt.

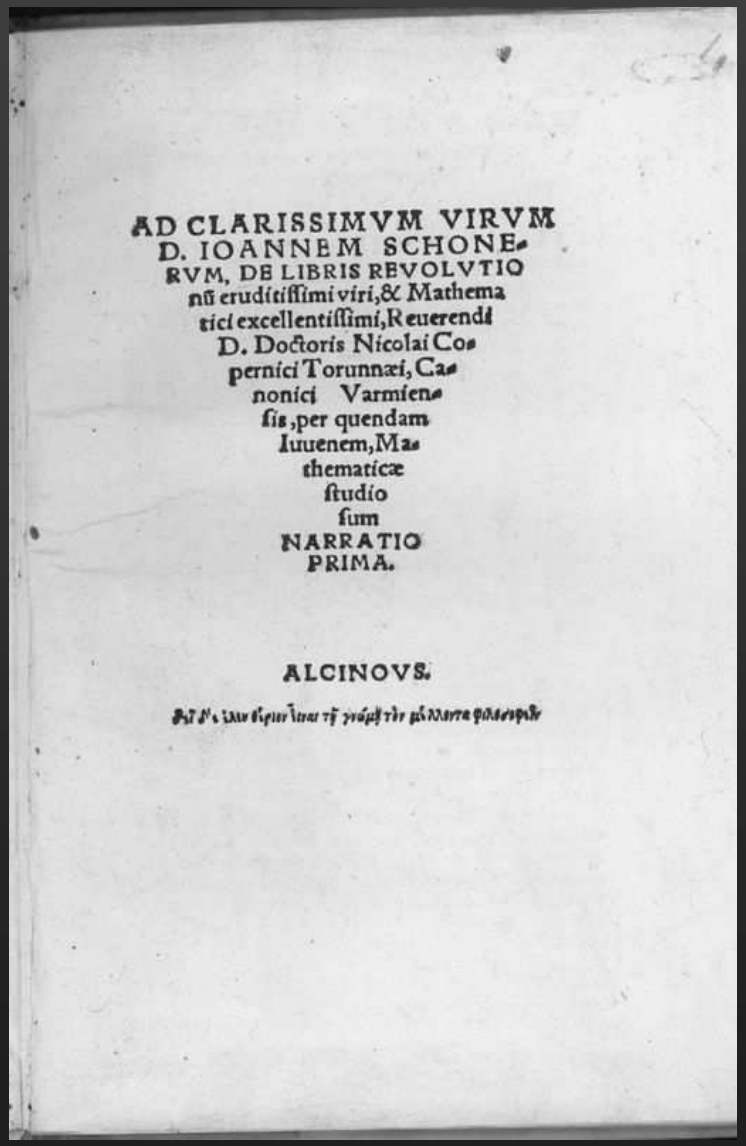
BASILEAE, EX OFFICINA
HENRICPETRINA

- appeared in print 1543
  - year of Copernicus death
- Q: Why did it take so long?
- Commentariolus (basic ideas):
  - already ~1510
- First (hand-written) draft:
  - already ~1530

De Revolutionibus: Reasons for Procrastination

- Copernicus *was* a busy man (canon, war,…)
- He was afraid of ridicule because of seemingly counter-intutive notion of Earth's motion
  - attempt to perfectionize his new system
- Anticipation of counter-reaction from Church
  - Earth's motion contradicted by Scripture
- Doubts whether he got it right:
  - it never quite fits

Enter Joachim Rheticus (1514-76)



AD CLARISSIMVM VIRVM
D. IOANNEM SCHONE-
RVM, DE LIBRIS REVOLVTIO
nũ eruditiſſimi viri,& Mathema
tici excellentiſſimi,Reuerendi
D. Doctoris Nicolai Co-
pernici Torunnæi, Ca-
nonici Varmien-
ſis,per quendam
Iuuenem,Ma-
thematicæ
ſtudio
ſum
NARRATIO
PRIMA.

ALCINOVS.

- professor of mathematics in Wittenberg
- visits Copernicus in Frauenburg
- prods Copernicus toward publication
- *Narratio Prima* (1540, first report):
  - summary of full *De Rev.*

Early Reception of *De Revolutionibus*

Important Early Role of Wittenberg

Martin Luther: 1517

- Birthplace of Protestant Reformation!

Enter Erasmus Reinhold (1511-53)

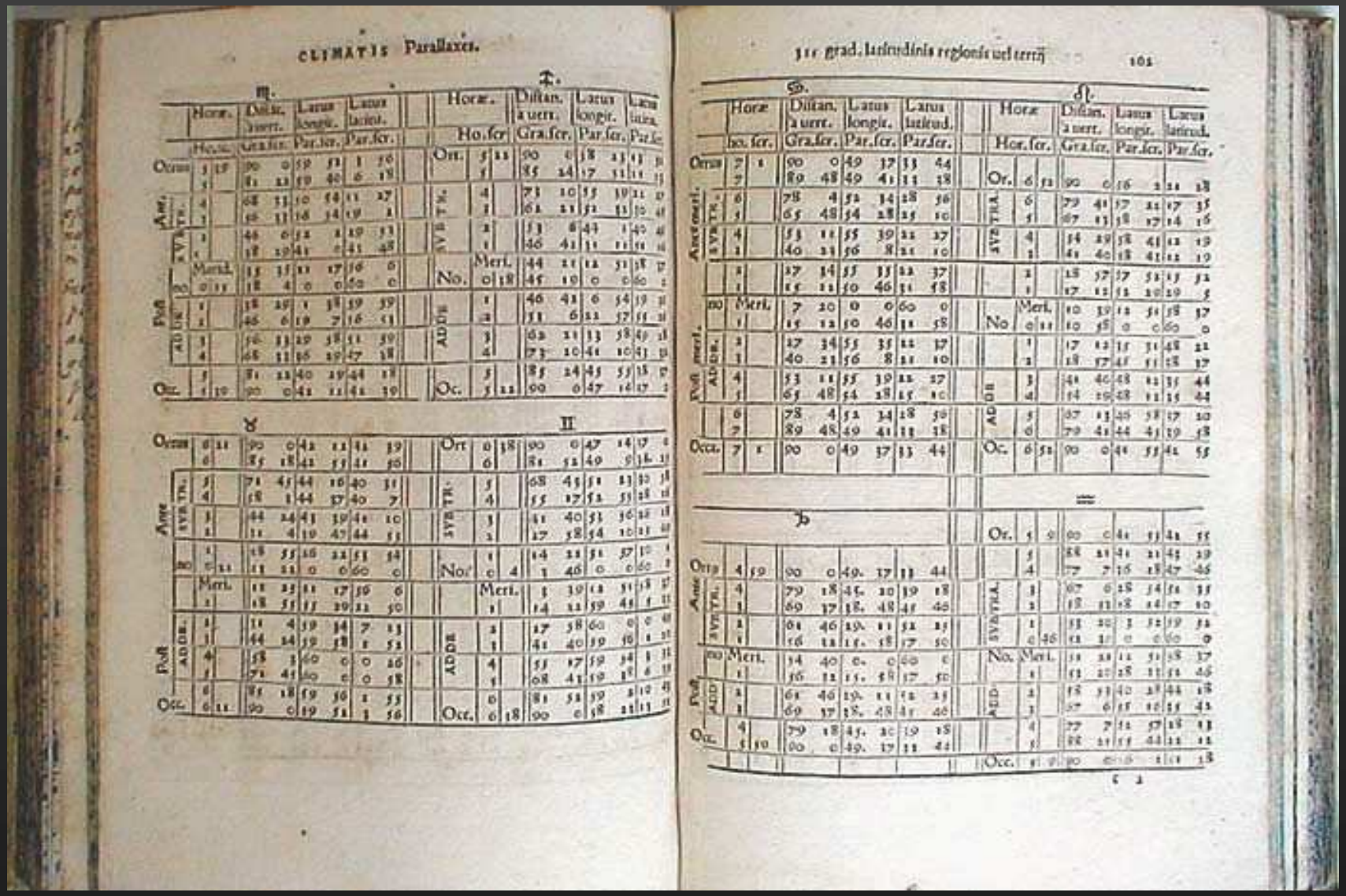

PRVTENI-
CÆTABV-
LÆCOE-
LESTIVM
MOTVVM.
AVTORE ERASMO REIN-
holdo Saluelden.
Cum gratia & priuilegio Cæsareæ & Regiæ Maiestatis.
TVBINGAE PER VLRICVM
Morhardum, Anno M. D. LI.

- professor of astronomy in Wittenberg
- uses *De Rev.* to calculate new tables of celestial motions
- *Prutenic Tables* (1551) widely used
- Indirect fame for Copernicus

Copernicus fame as “Second Ptolemy”

Strasbourg Cathedral: Astronomical Clock (1574)

Copernicus: Victory by Infiltration



- Practical value of Reinhold's *Prutenic Tables*

Early Reception: Need for better calendar

(Pope Gregory XIII)

- Uses *De Revolutionibus*!

Copernicus: Victory by Infiltration

- Astronomers got used to *De Rev.* as practical tool for predicting celestial motions
- Use despite, not because of, idea of Earth's motion
- Thus: *De Rev.* never went away (starting point for Kepler and Galileo)
- Copernicus in-built defence: Make book unreadable for nonastronomers ("mathematics is for mathematicians")
- Osiander's introduction: Heliocentric hypothesis just convenient device of mathematical astronomy, not real!

Copernican Revolution: A New Generation

- Next generation of astronomers (Kepler, Galileo, …, Newton)
- Address problems of *New Astronomy* (E.g., consequences of Earth's motion…)
- Copernicus addressed problems of *Old Astronomy* (E.g., a planetary model without equants…)

De Revolutionibus: Reaction from Church

(Pope Paul III)

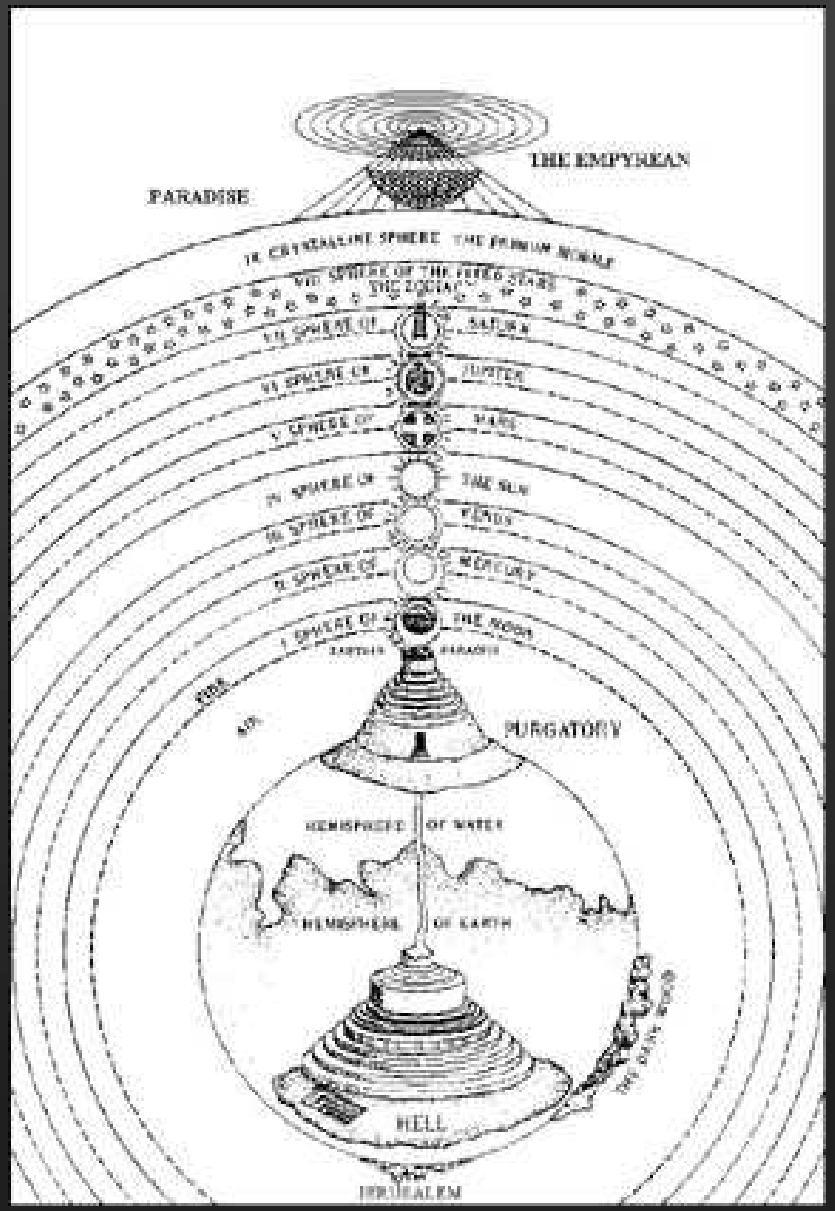
- Initially: Very friendly!
- In preface of *De Rev.*: Dedication to Pope

De Revolutionibus: Reaction from Church

(Pope Clement VII)

- Requested to be briefed about new Copernican theory in 1533
- Q: How could things have turned so sour a short time later???

The Christian Universe: Dante's *Divine Comedy*



- Astronomy = Theology
- Central Earth becomes essential ingredient of Christian Theology

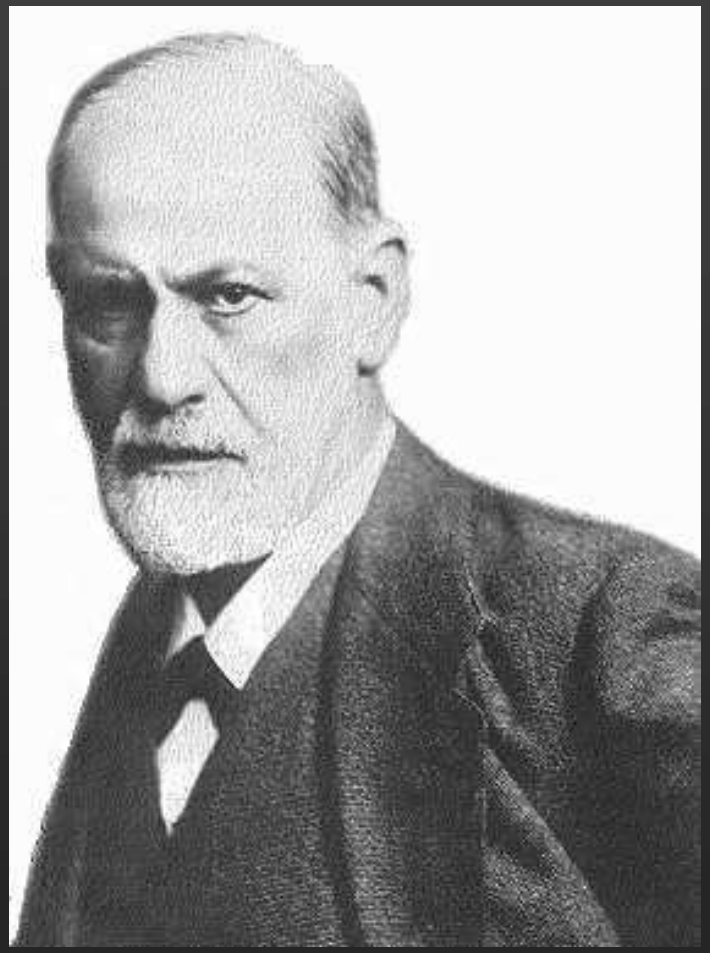
The Copernican Revolution as Paradigm Shift

Thomas Kuhn (1922-96)

1. “Normal” science
2. Anomalies, conflicts
3. New framework (paradigm)
4. “Normal” science
5. …

- *The Structure of Scientific Revolutions* (1962)

Freud's Three Demotions of Humanity

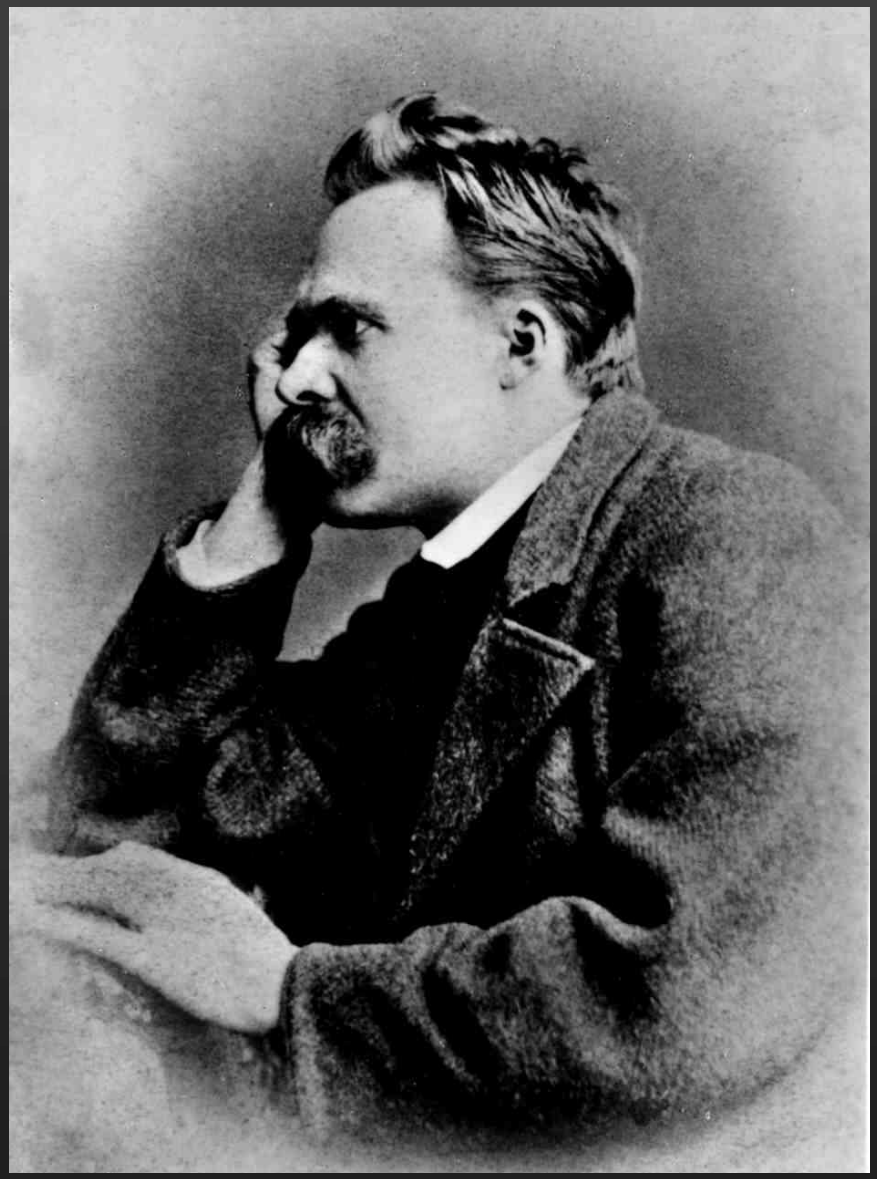


Sigmund Freud (1856-1939)

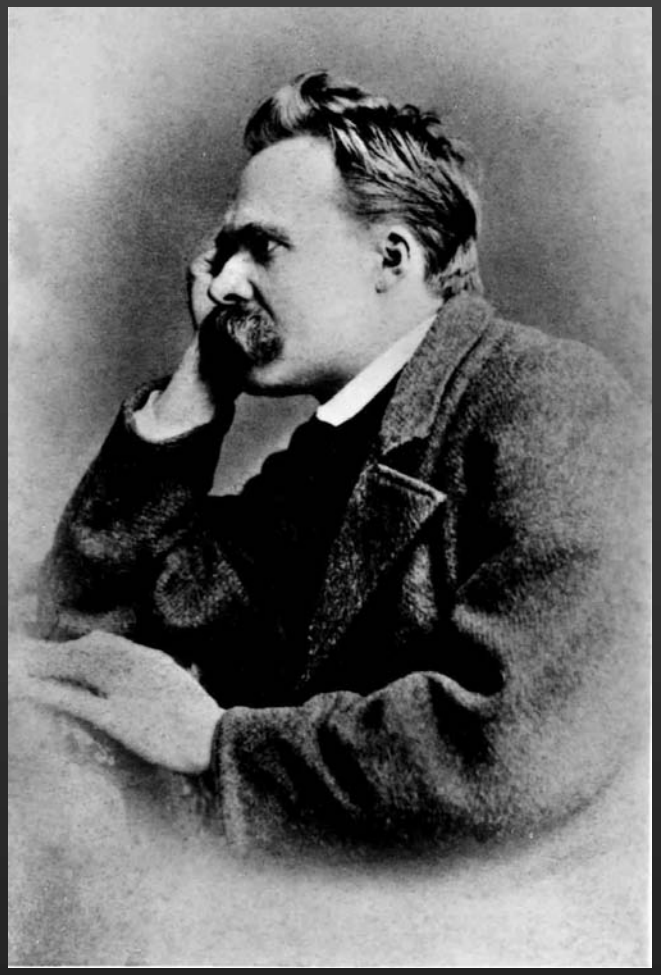
- Copernicus:
  - mankind not special in space
- Darwin:
  - mankind not specially designed
- Freud:
  - human mind ("ego") not fully in charge, influence from subconscious ("id")

- in *Introductory Lectures into Psychoanalysis* (1917)

Copernicus and the Invention of Nihilism



Copernicus and the Invention of Nihilism



- Nietzsche blames Copernicus and modern science for spiritual erosion and cosmic forlornness
- “Since Copernicus, humanity is rolling from the center into nothingness…”

Friedrich Nietzsche (1844-1900)

Copernicus

- *De Revolutionibus:* Not a revolutionary book, but a revolution-making one!

- Slow, but inexorable ascendancy of Copernican system
  - initially based on practical utility
  - Earth's motion largely ignored
  - provides starting point for New Astronomy (Kepler…)
  - some advantages in (Neoplatonic) elegance

- Great struggle with Church slowly emerging

- After Copernicus: Humankind enters modernity