Astronomy 350L

(Fall 2006)

The History and Philosophy of Astronomy

(Lecture 9: Tycho/Kepler I)

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The University of Texas at Austin

Between Epochs: Renaissance – Baroque (1550-1650)

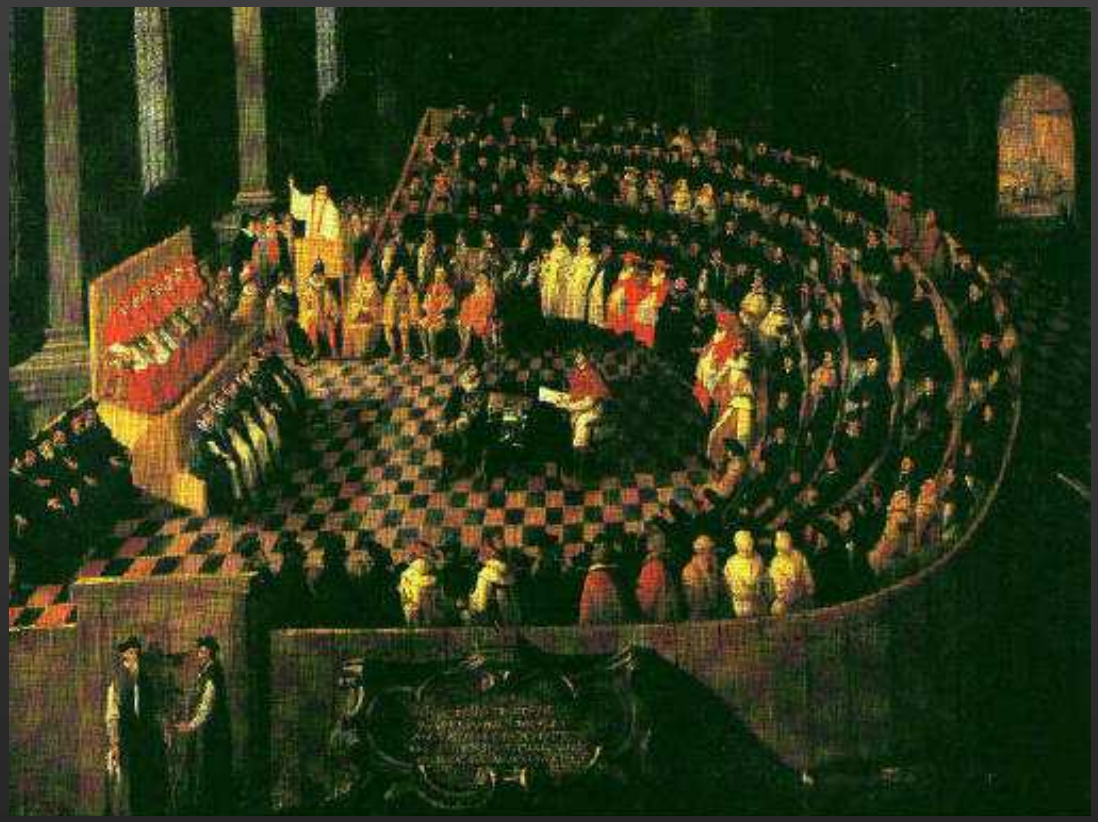
El Greco (1541-1614)

Lucas Cranach (1515-1586)

- Crisis in Europe: Religious conflict (Catholic vs Protestant)

Europe: Deeply divided into multiple confessions

Reformation vs Counter Reformation



- Reformation:
  - Bible in vernacular
- Sola Scriptura

- Counter Reformation:
  - Council of Trent (1545-63)

Counter Reformation: The Jesuits

Ignatius of Loyola (1491-1556)

- Intellectual avantgarde against Reformation
  - eventually: arch-enemies of Galileo (~1633)

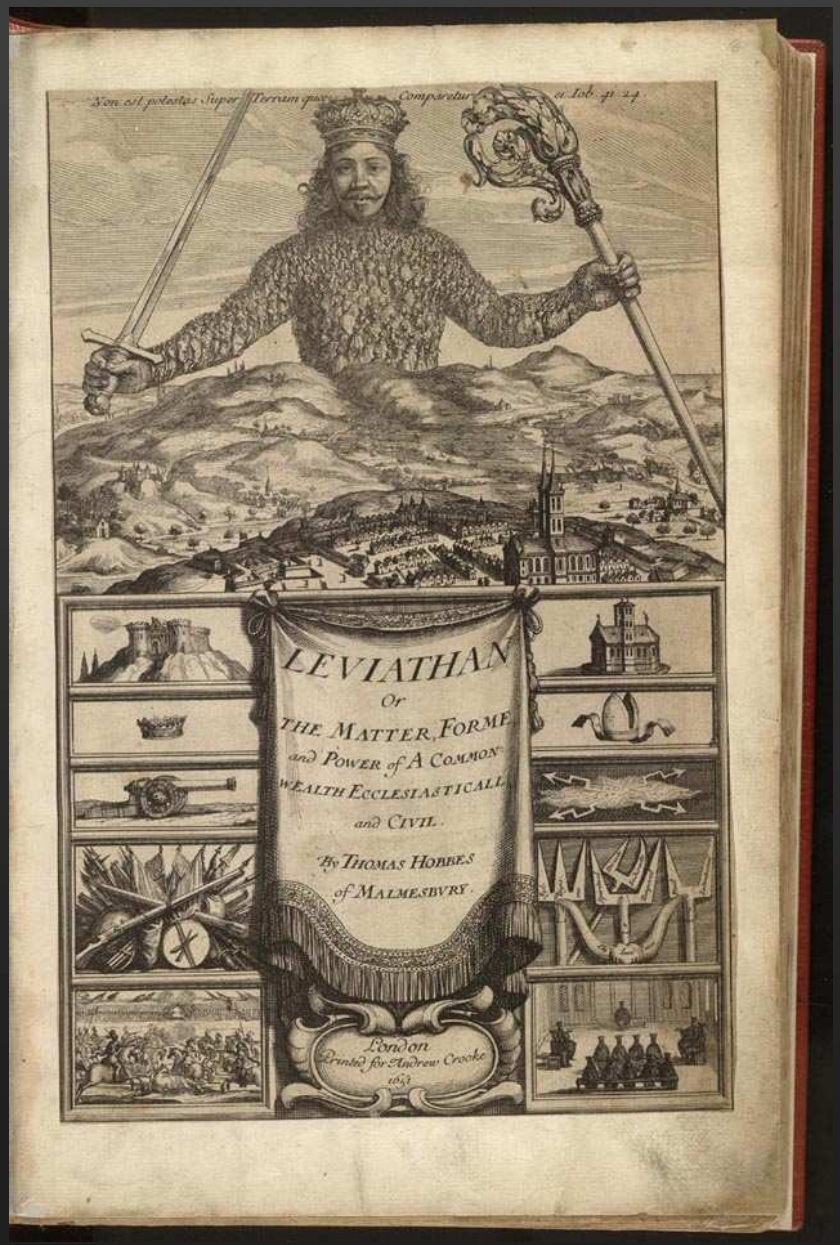
War: England defeats Spanish Armada (1588)

F. WALTON (Great Britain) WRECK OF THE SPANISH ARMADA

The Thirty Years War (1618 - 1648)

- Utterly devastated Germany (1/2 of population dies)

Thomas Hobbes (1588 - 1679): Apologist of Absolutism



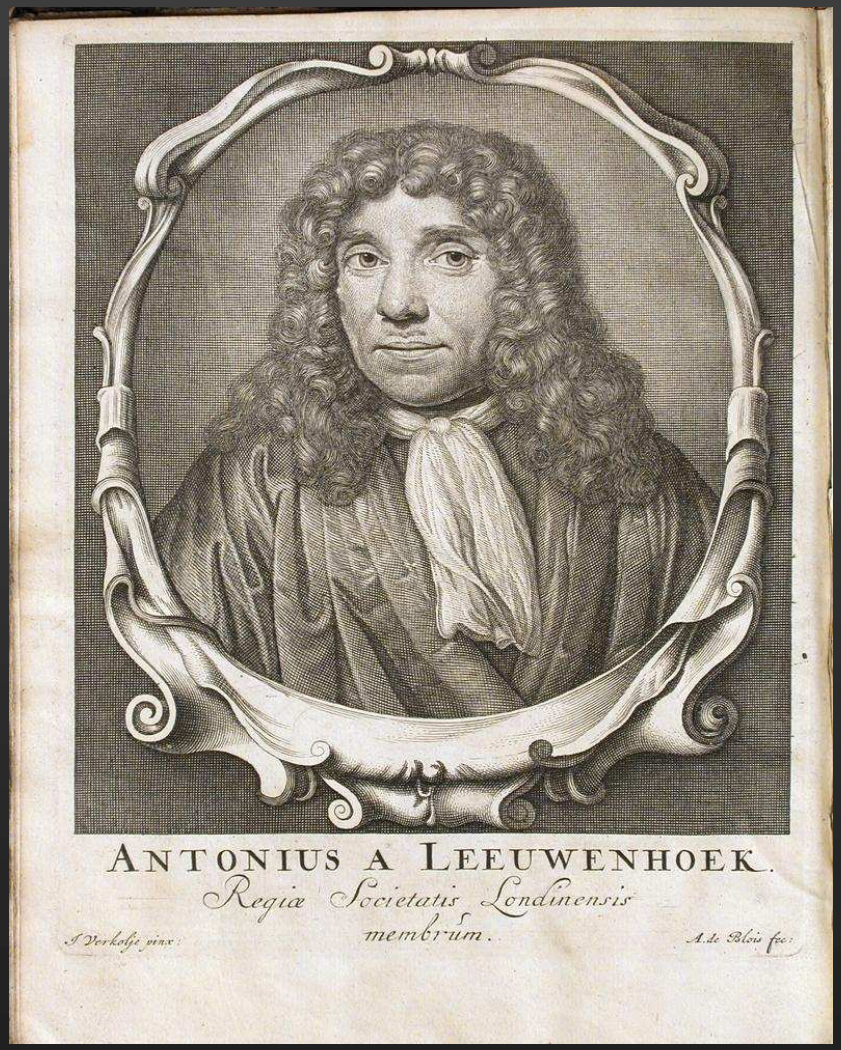
- homo lupus homini
  (Man is a wolf to man)

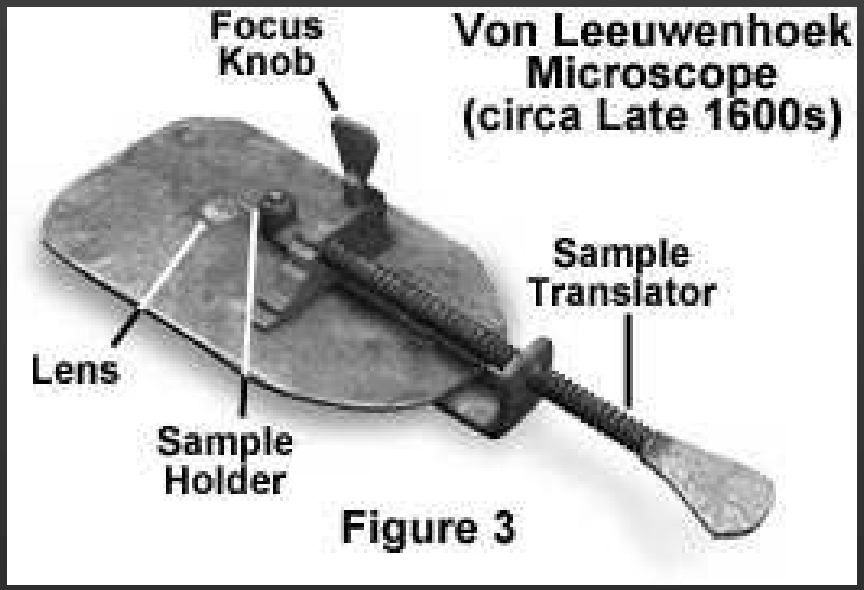
- Need strong, absolute state to keep society in check and to preserve peace!

Innovation: The Dutch Invent the Telescope

- around 1600
- soon to be used by Galileo

Innovation: The Dutch Invent the Microscope





- inception of microbiology

Hugo Grotius (1583 - 1645): The Law of Nations

- De iure belli ac pacis
  (On the Law of War and Peace)

- concept of *Natural Law:*
  man has certain unalienable rights

- man is fundamentally sociable

The Making of the New Astronomy:

Tycho and Kepler

- Tycho Brahe: Greatest Observer of the Age
- Johannes Kepler: Greatest Theorist

Tycho Brahe: The Great Danish Observer

- 1546 (Skaane) – 1601 (Prague)
- born into nobility:
  - lived privileged life
- State-sponsorship of Danish king

Extensive University Education: Wittenberg

Martin Luther: 1517

- Birthplace of Protestant Reformation!

A Royal Patron: King Frederik II of Denmark

- provides Tycho with generous, sustained funding for astronomical research
- Construction of greatest observatory in Europe

Tycho’s Island: Hven

Best pre-Tycho tables: Erasmus Reinhold (1511-53)


PRVTENI
CÆTABV
LÆ COE
LESTIVM
MOTVVM.

AVTORE ERASMO REIN
holdo Saluelden.

Cum gratia & priuilegio Cæsareæ & Regiæ Maiestatis.

TVBINGAE PER VLRICVM
Morhardum. Anno M. D. LI.

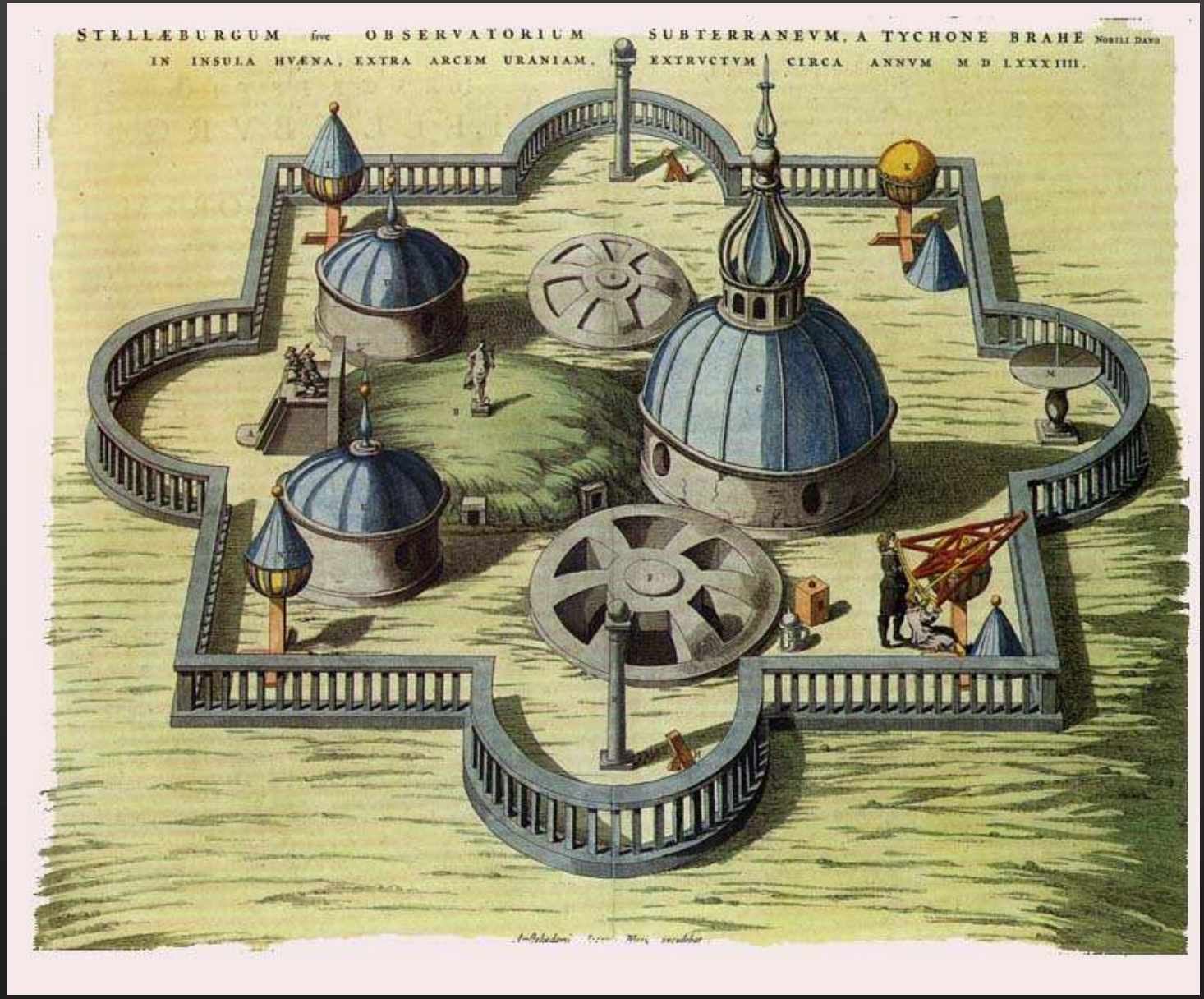
- professor of mathematics in Wittenberg
- uses *De Rev.* to calculate new tables of celestial motions
- *Prutenic Tables* (1551) widely used
- Indirect fame for Copernicus

Hven: Uraniborg

- Pinnacle of naked-eye observations!

Great Mural Quadrant

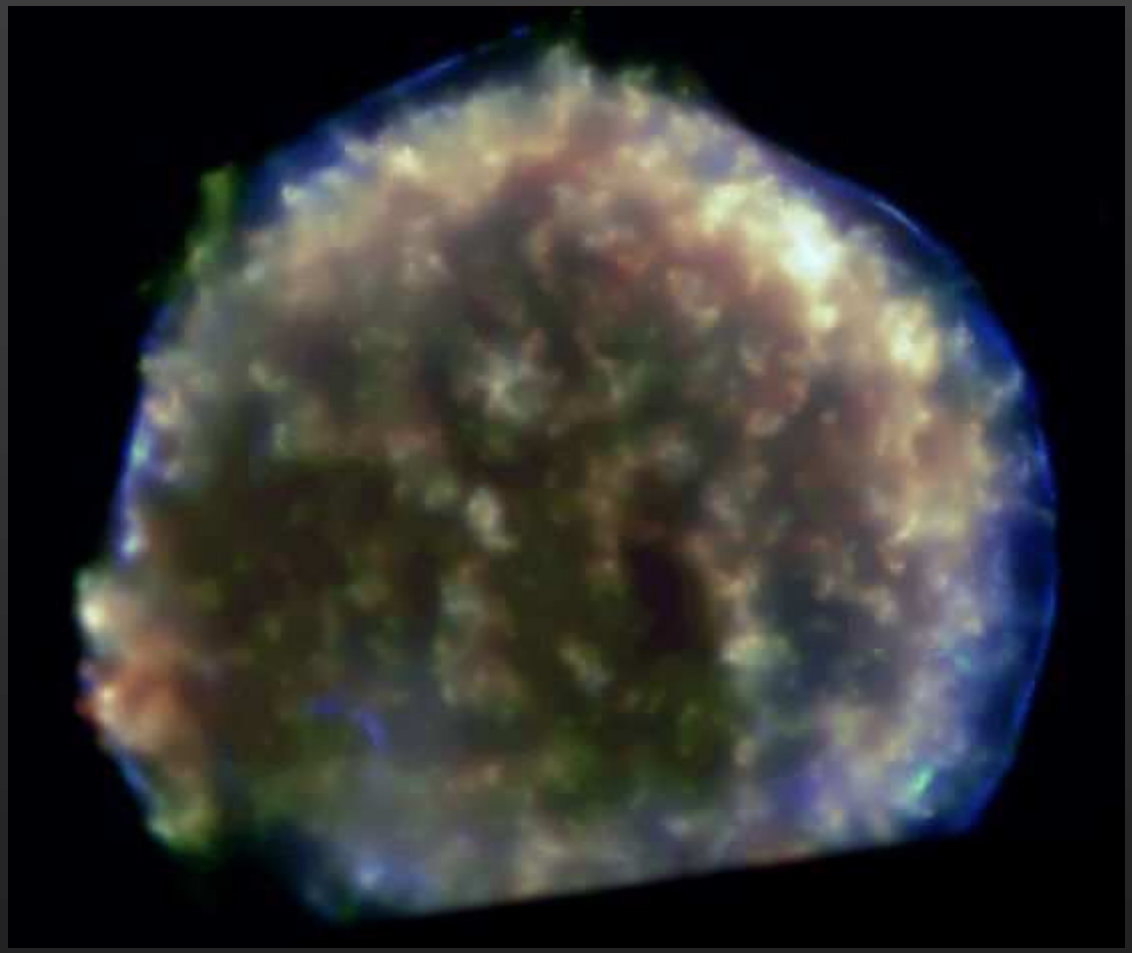
Hven: Stjerneborg



Tycho on Hven: Important Achievements

- Precise (~4 arcmin) positions of planets
  over extended period of time (used by Kepler)
- Demonstrate that comets are superlunar (1577)
- Demonstrate that (Super-) Novae are stellar (1572)
- Failure to find stellar parallax
  - rejection of Copernican model (Tychonic model)
- **Establish regard for precision data in astronomy**

Tycho's Supernova of 1572



- Chandra sees remnant in X-rays

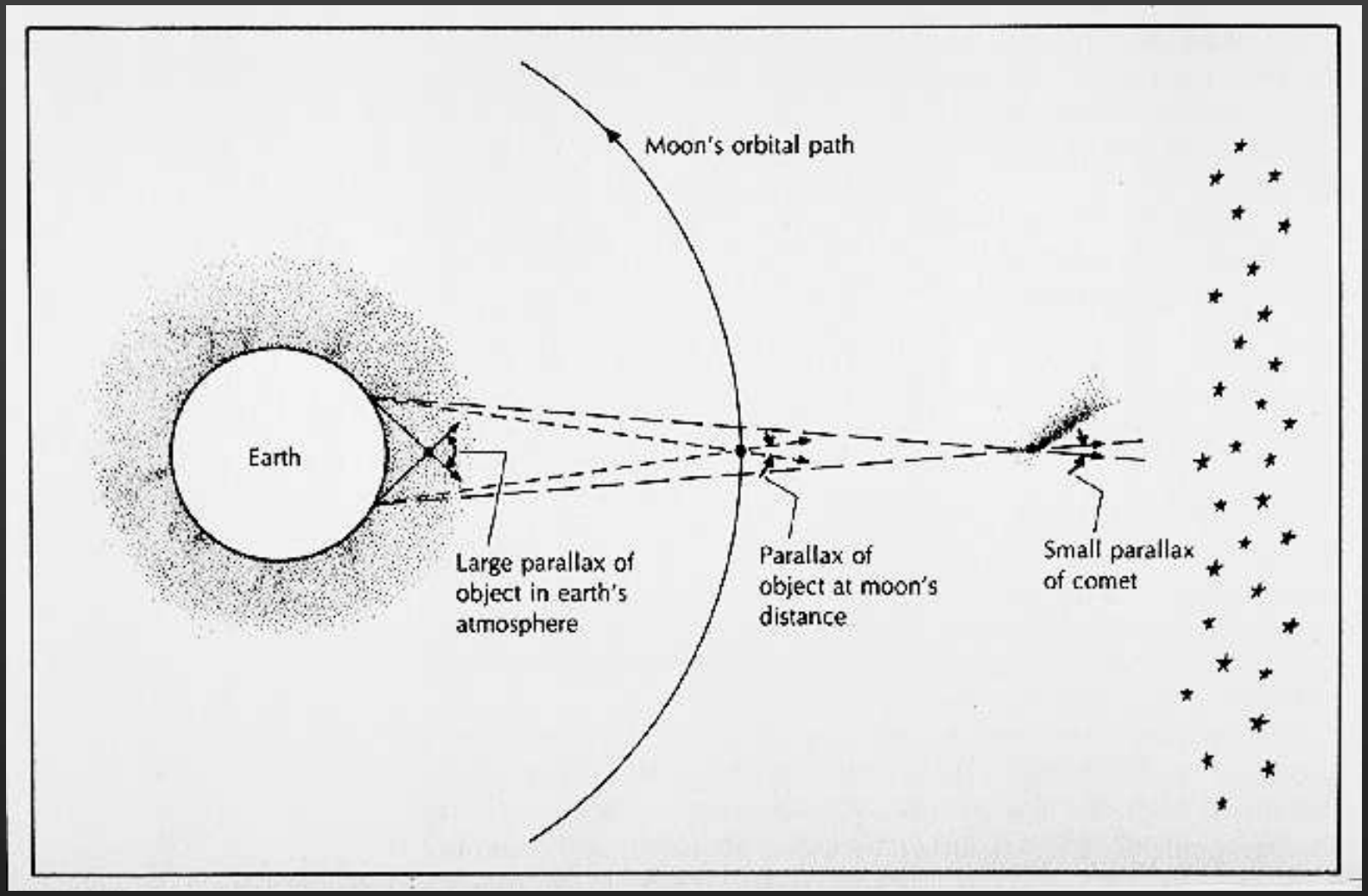
- Tycho can prove that Nova is fixed wrt stars!

The Comet of 1577

- Big Q: Are comets sub- or supralunar?

  (According to Aristotle, they are atmospheric effects)

The Comet of 1577

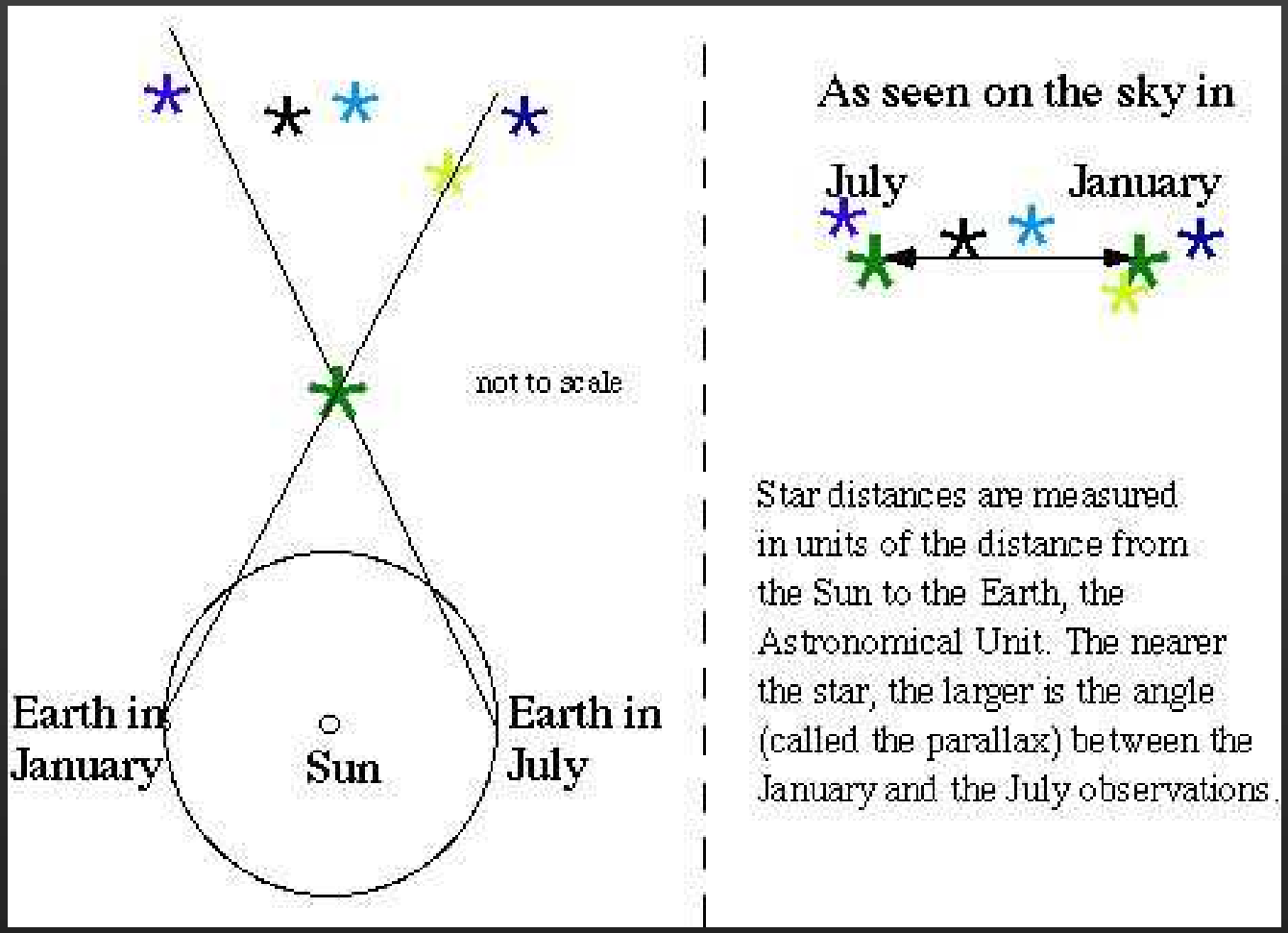


- Tycho's A: Comets are supralunar?

Downfall of Aristotelian Physics

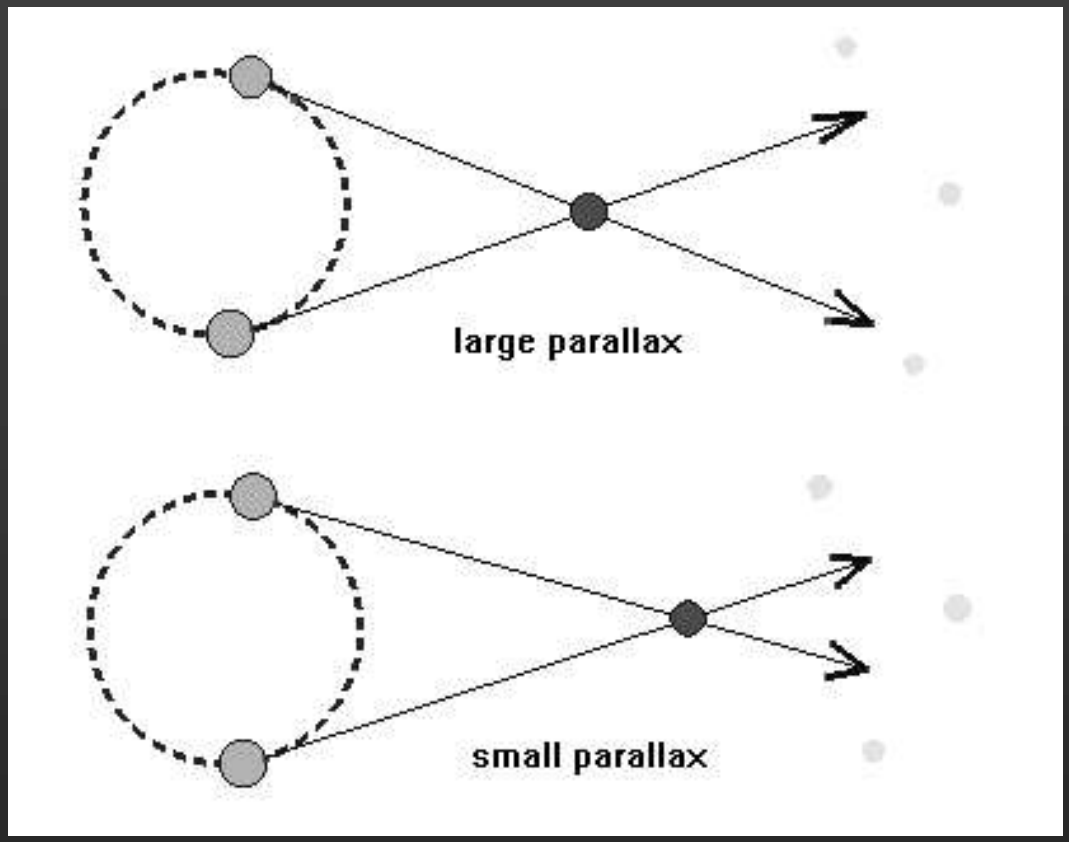
- Tycho demonstrates: (Super-) Novae and Comets located beyond orbit of Moon (i.e., supralunar)
- Thus: Heavens are *not* immutable
  (as claimed by Aristotle)
- Only one (and the same) physics for heaven and Earth

Tycho asks anew: **What about Stellar Parallax?**



- Copernican model predicts this!
- Tycho's precision data does not confirm this?

Tycho rejects Copernicus' Argument for missing parallax

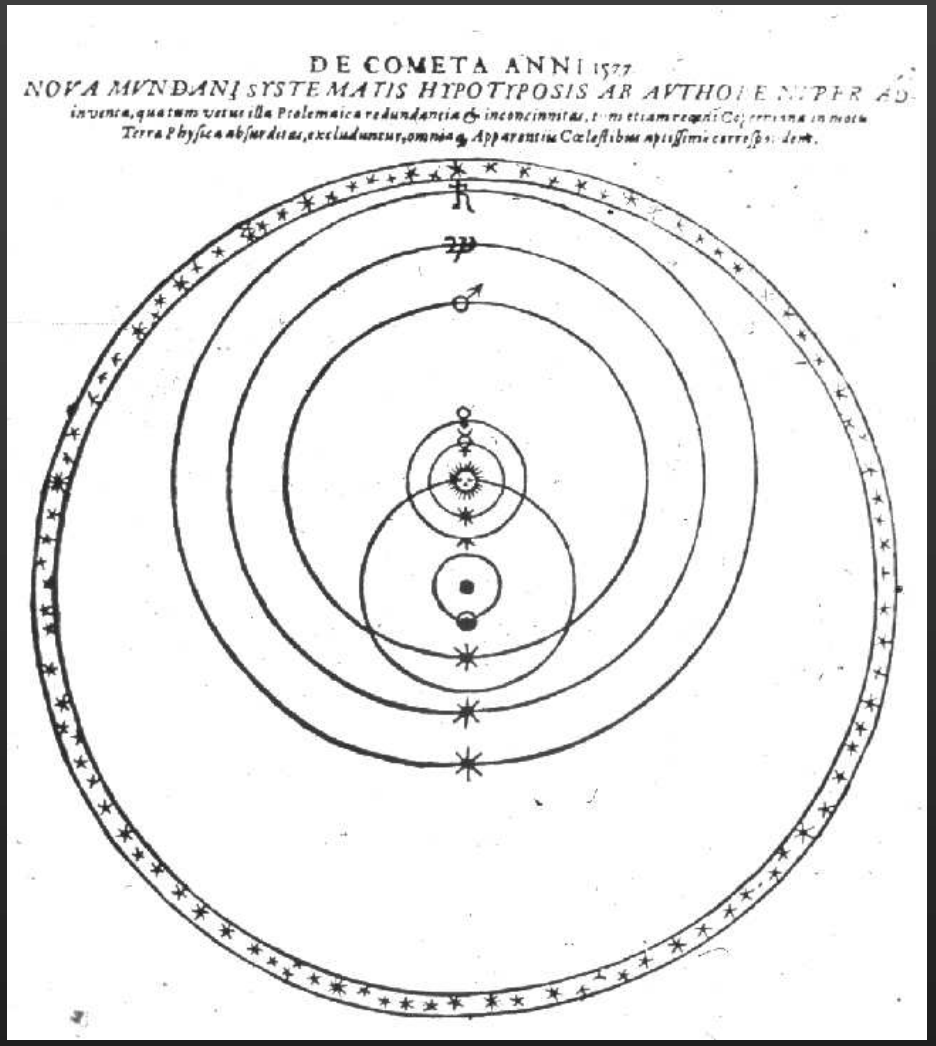


- *If* stars really were that distant:
  - vast empty space between Saturn and fixed stars
  - stars (apparent size known) would be too large

Tycho asks anew: **What about Stellar Parallax?**

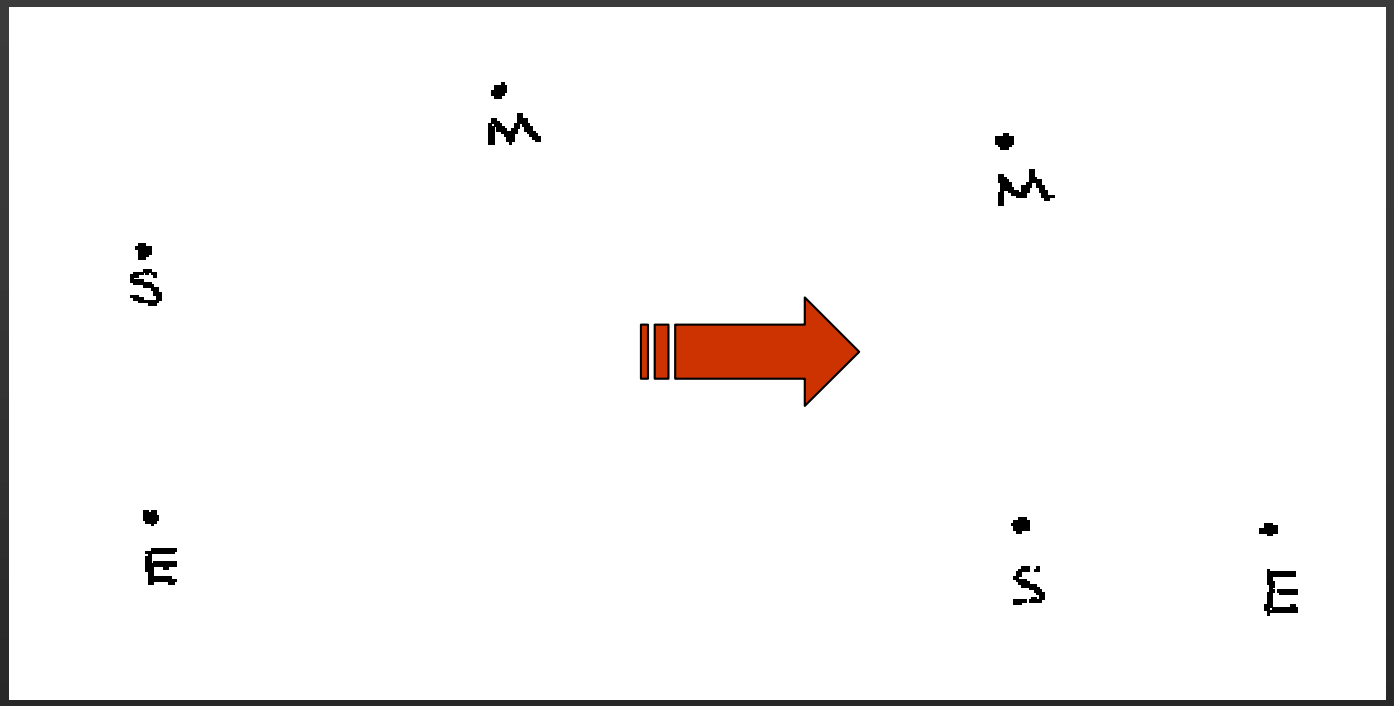
- Stellar parallax *not* found!
- Reason: Tycho's star positions are accurate to within ~ 1 arcmin, but real parallaxes are smaller than 1 arcsec (1/60 of armin)
- Therefore: Tycho concludes that Earth does not move?
- But: Tycho is also aware of important advantages of Copernican model (e.g., maximum elongation of Venus, simple explanation for retrogression)
- What to do?

The Tychonic World System



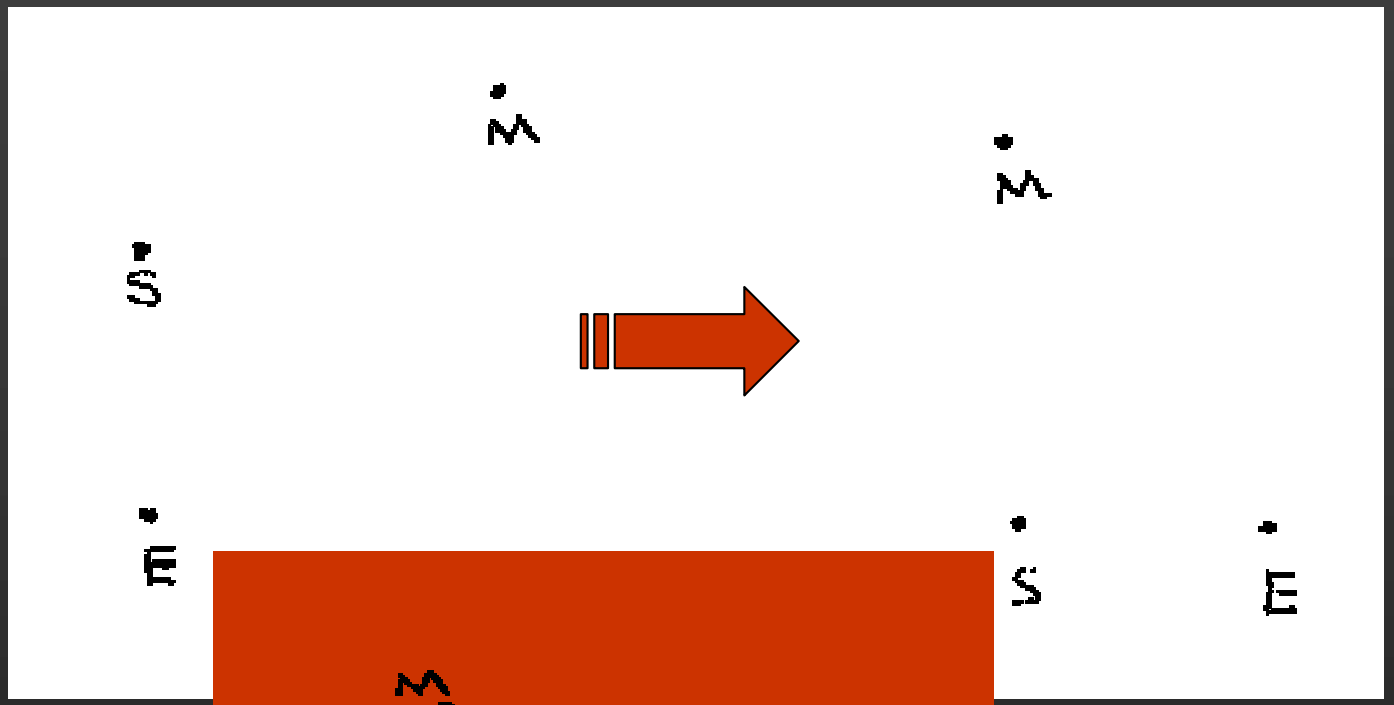
- Geo-heliocentric (compromise) model!

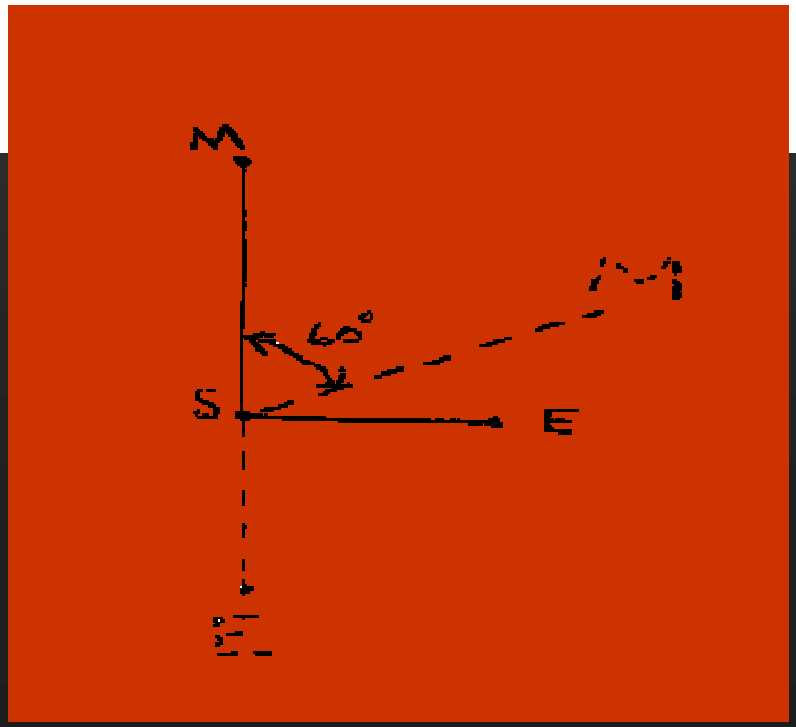
Equivalence of Tychonic and Copernican System



- How to explain this motion relative to Earth?

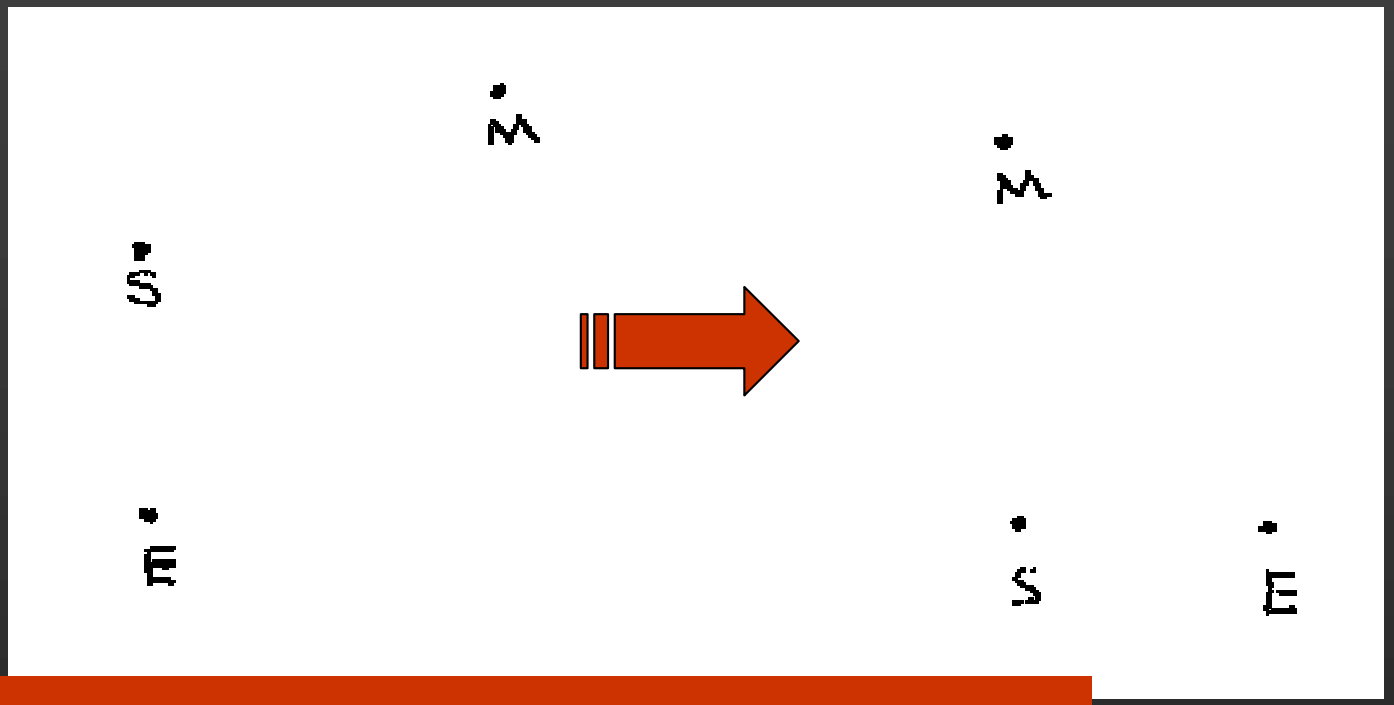
Equivalence of Tychonic and Copernican System

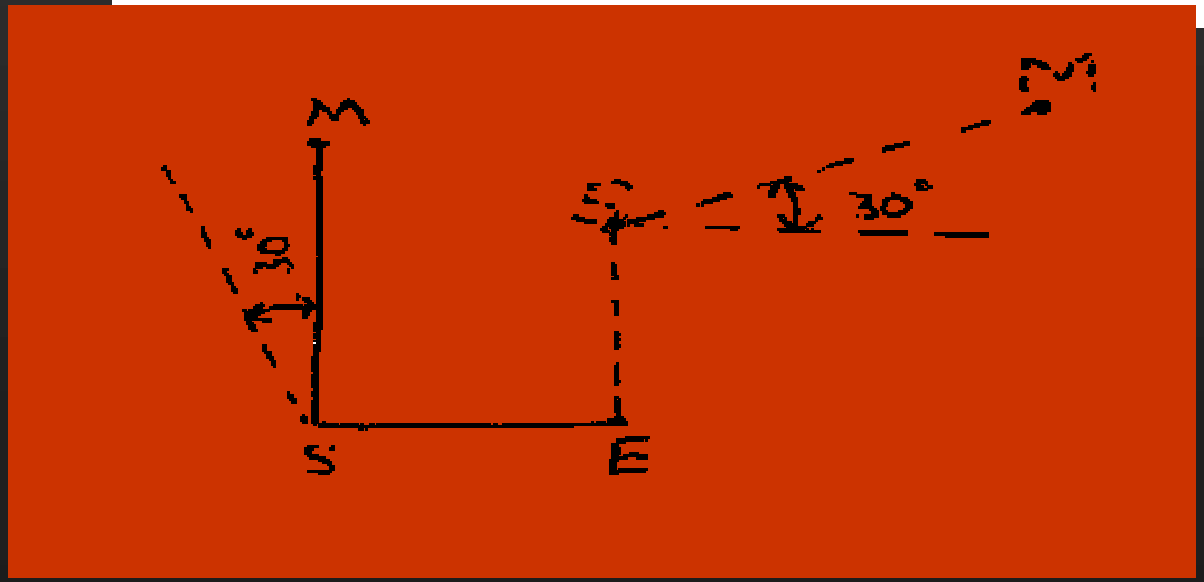




Copernicus

Equivalence of Tychonic and Copernican System



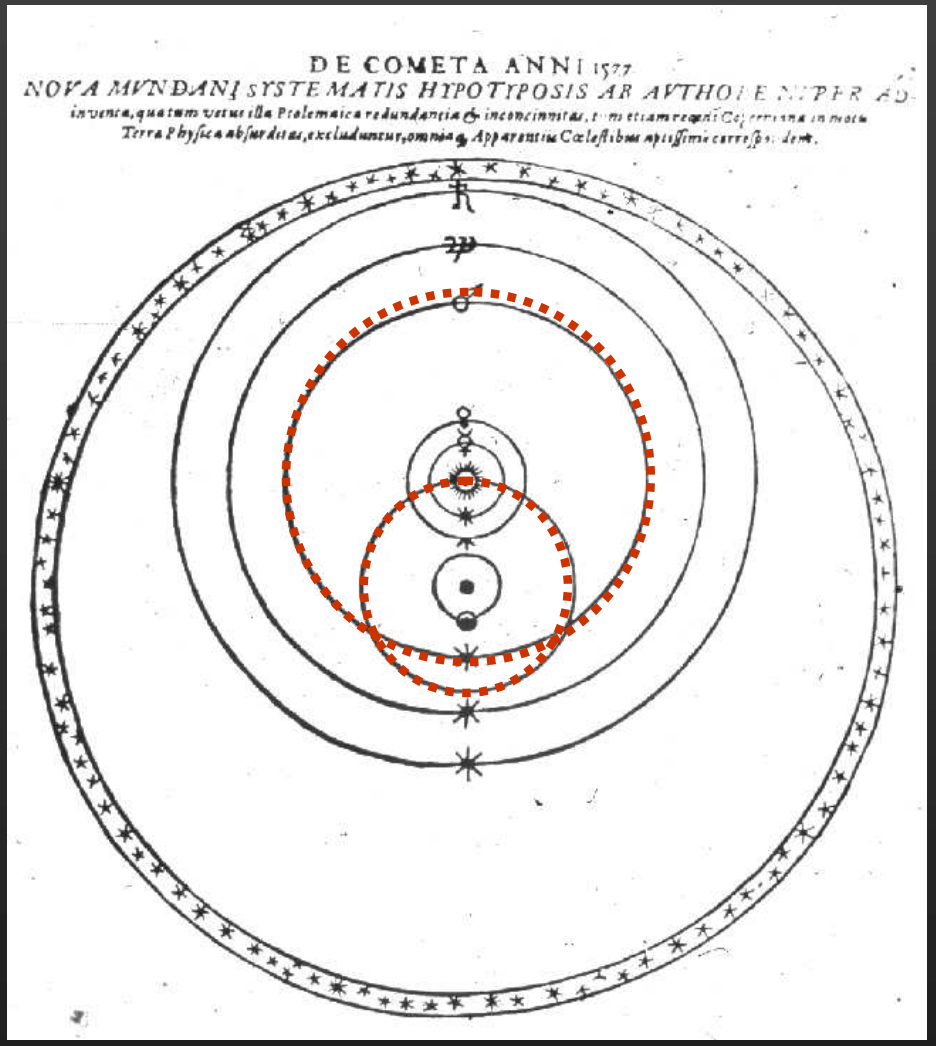


Tycho

Equivalence of Tychonic and Copernican System

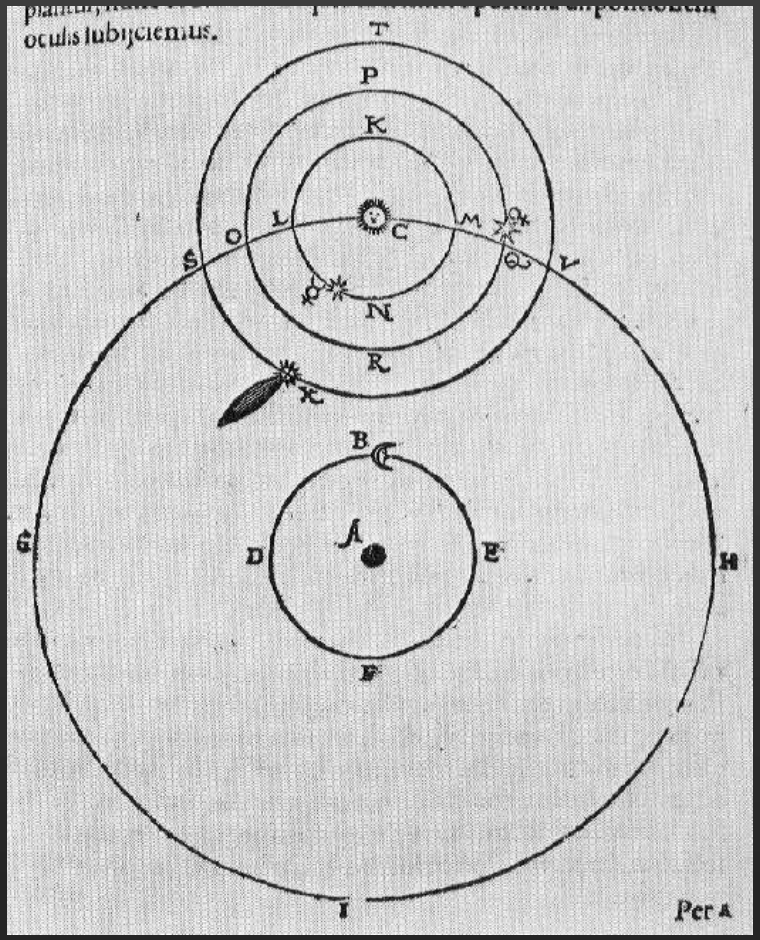
- Relative motions are the same
- Absolute position of Earth is different:
  - Tycho: Center of Universe, Earth does not move!
  - Copernicus: Earth moves, both rotation and revolution
- Tycho's system quickly became fashionable
- Maintain advantages of Copernican model, but does not have to face conflict with theory of motion (common-sense) and with Scripture

Tychonic System: Problem of Intersecting Spheres



- Crystalline (solid) spheres of Mars and Sun intersect!

Tychonic System: Problem of Intersecting Spheres



- Comet of 1577: Tycho shows motion across celest. Spheres
- Abandon concept of crystalline spheres altogether!

Tycho: Journey's End in Imperial Prague (1599)

Tycho: Journey's End in Imperial Prague

Rudolph II
- Emperor (1576-1612)

- Great Patron of Arts and Sciences (Tycho, Kepler)

Tycho: Journey's End in Imperial Prague

Benatky Castle: Final Domicile (1599 – 1601)

- Tycho invites upstart young Johannes Kepler!

Tycho and Kepler meet in Prague (1600-01)

- Tycho needs Kepler:
  - difficult calculations to figure out orbit of Mars
- Kepler needs Tycho:
  - precision data to figure out true orbits of the planets
- Together embark on improved astron. tables (*Tabulae Rudolphinae*)

Tycho: Journey's End in Imperial Prague

- Died 1601
- Buried in Prague
- Epitaph:

"Neither wealth nor power remain, only the arts and sciences"

Tycho/Kepler (part 1): Tycho Brahe

- Tycho Brahe:
  - establishes precision observation into astronomy
  - shows that comets and supernovae are celestial phenomena (downfall of Aristotelian dogma of immutability of heavens)
  - abandons concept of solid (crystalline) sphere

- Tychonic world system: geo-heliocentric model
  - compromise between Ptolemy and Copernicus ("Best of two worlds")
  - can account for apparent absence of stellar parallax

- Kepler inherits Tycho's data after his death in prague