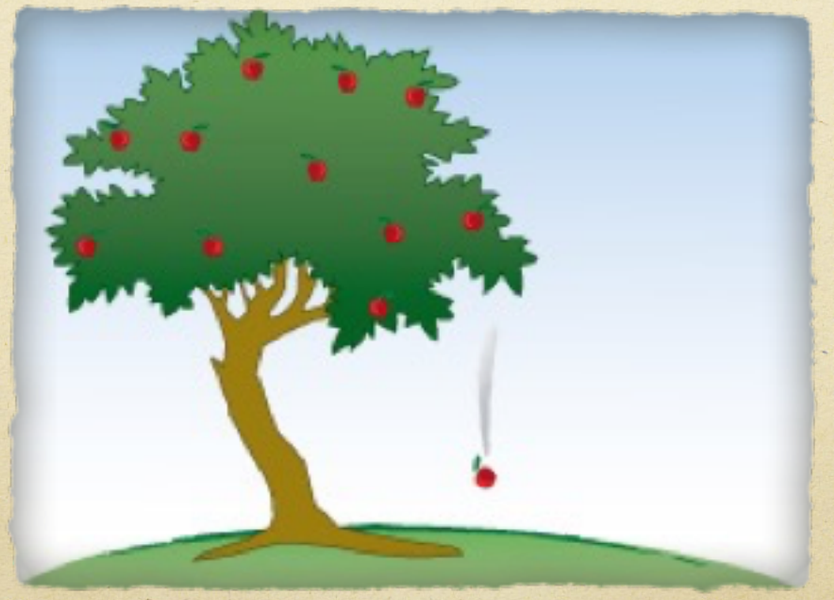
Understanding the Heavens

Presentation by Dean Bretland

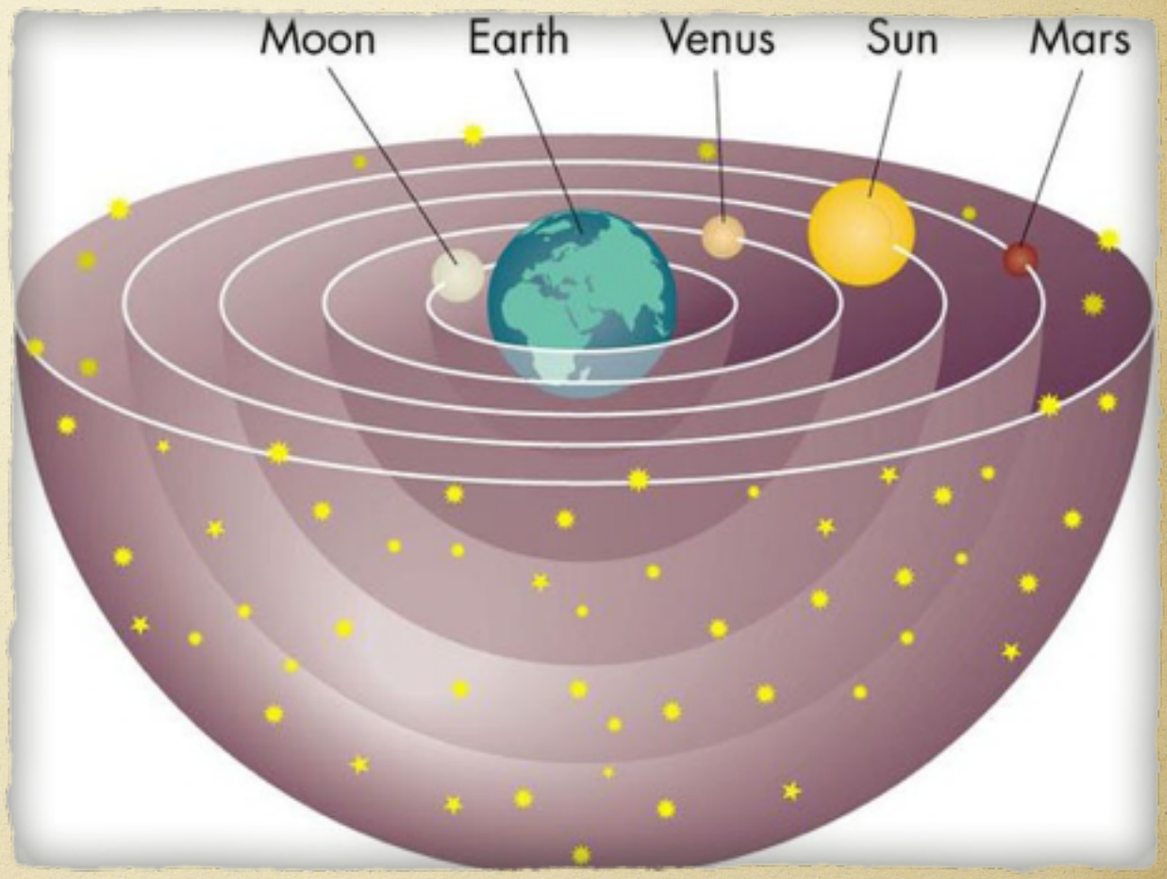
The Agenda

- Follow the evolving views of the universe
  - 100 B.C. up to ~1700 A.D.
- Related inventions and discoveries



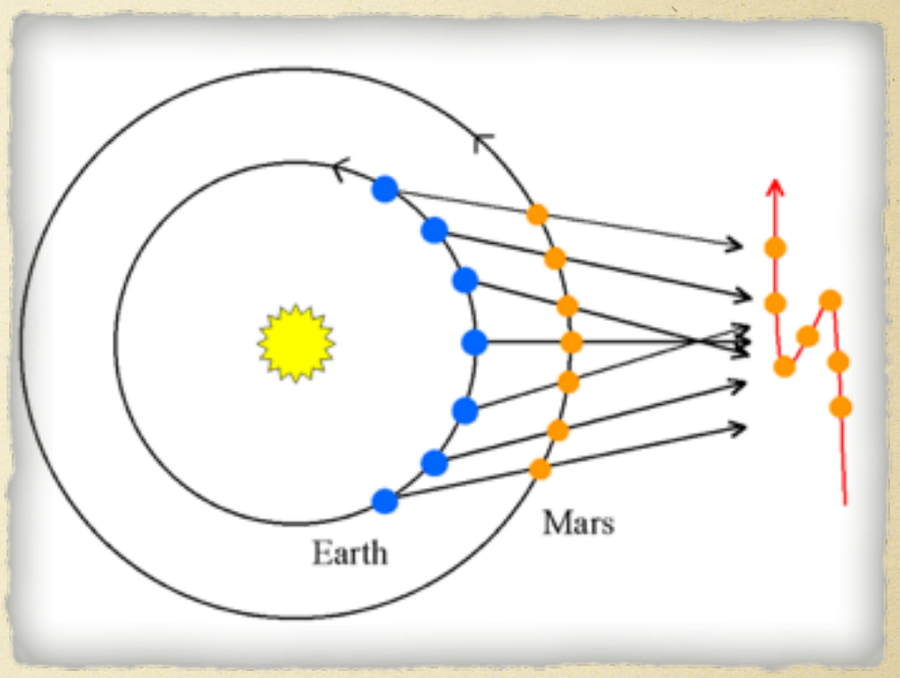
Aristotle's Model (400 B.C.)

- Earth is center of everything
- Perfectly spherical planets
- Uniform, circular orbits

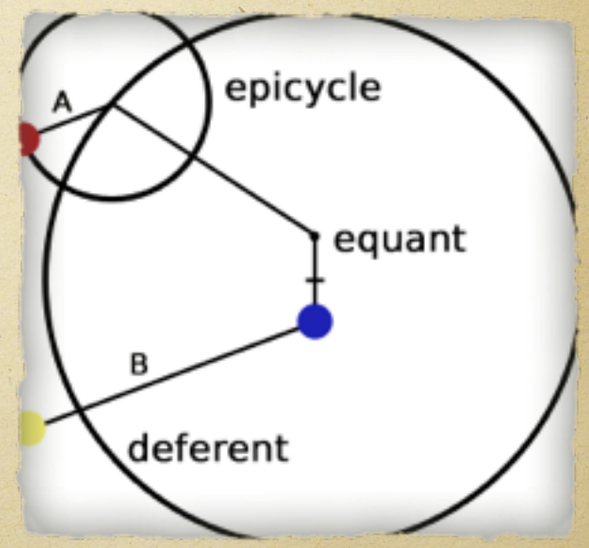


Ptolemy's Model (100 A.D.)

- Motivation: observations were inconsistent with Aristotle's model
- Planets move in "mini-orbits" called Epicycles
- From equant point, movement of epicycle centers is uniform
- Incorrect, but very good model
- Accepted for the next 1300 years
- Used in planetariums today



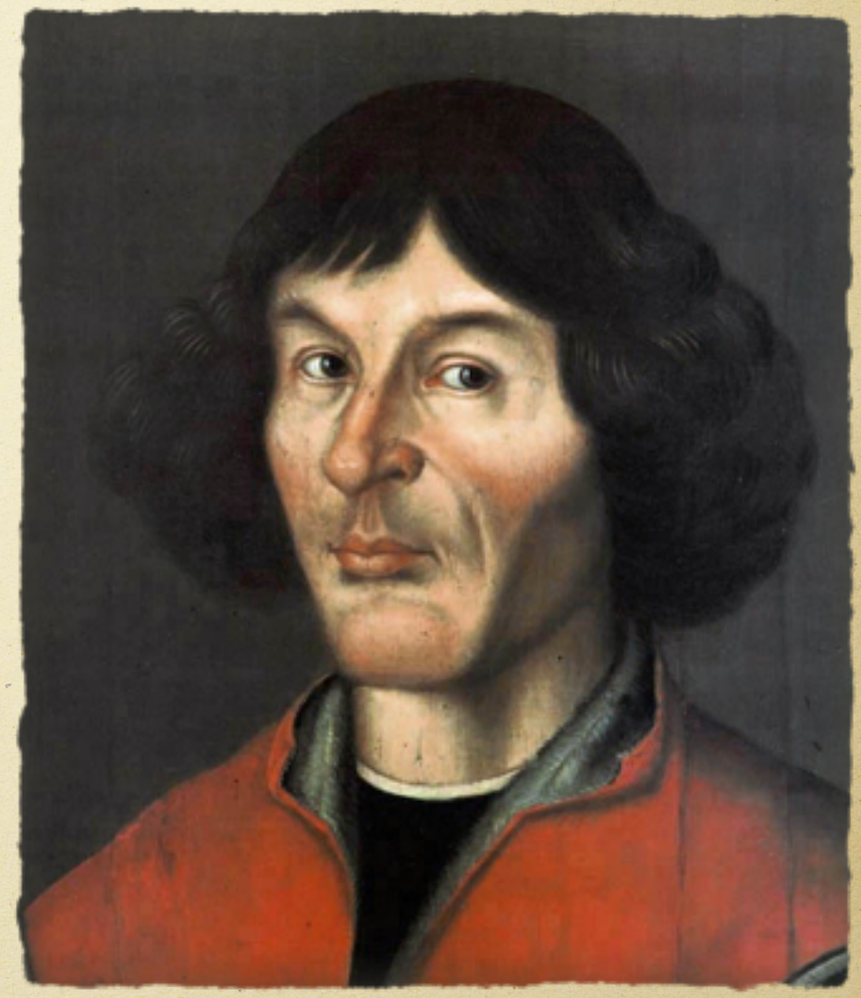
Retrograde motion



Ptolemy's model

Nicolaus Copernicus (1473-1543)

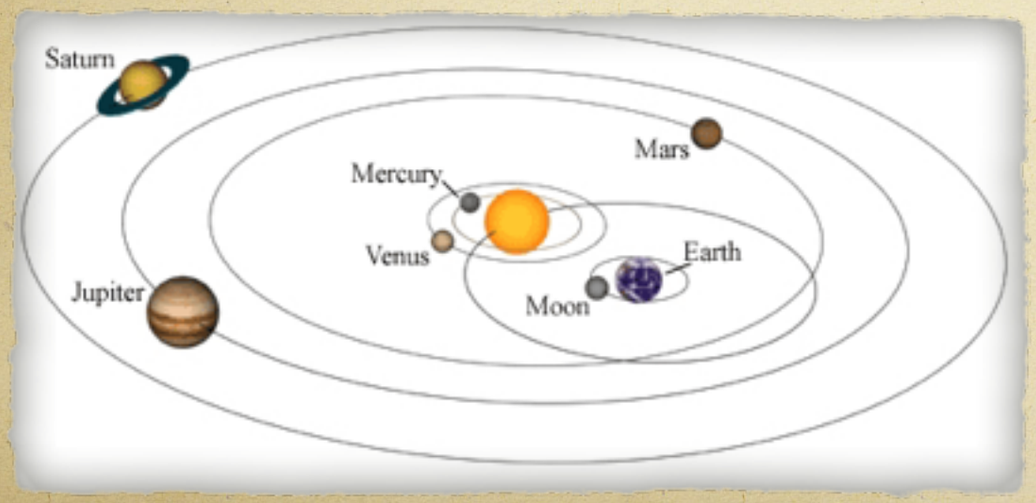
- Disliked Ptolemy's equant
  - Desperate to agree with Aristotle
- Suggested heliocentric model
  - Not the first to do so
  - Explained retrograde motion
- Believed universe to be much larger than previously thought



Portrait by unknown artist, 1580

Tycho Brahe (1546-1601)

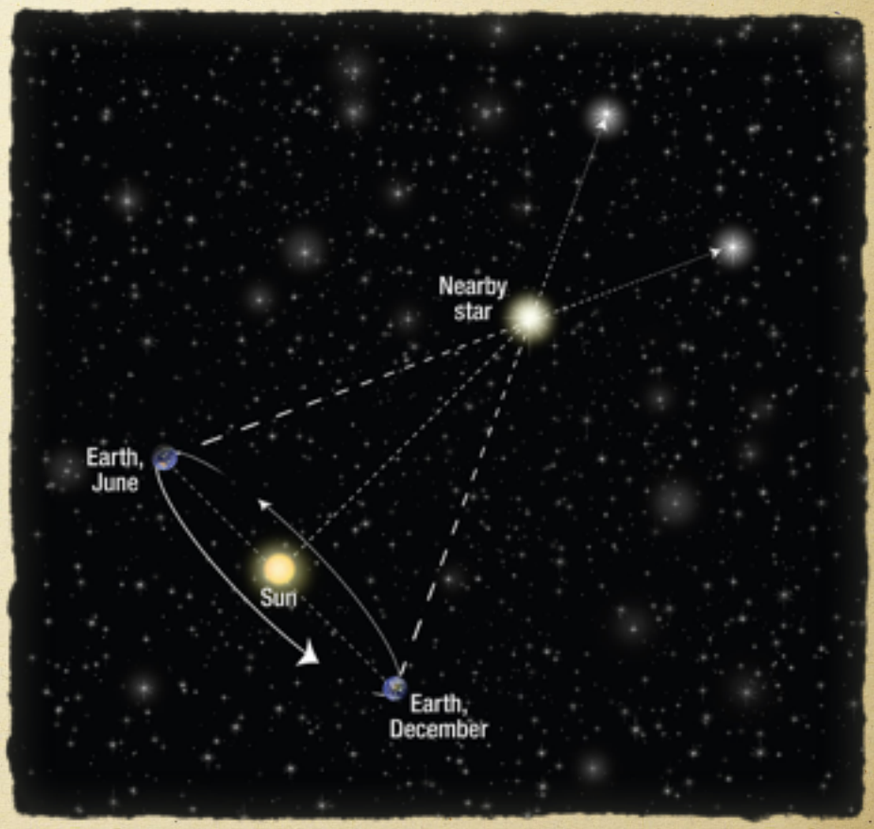
- Greatly admired Copernicus
- Insisted on geocentric model
- Compiled accurate data of Mars and other bodies
- Accurate instruments—no telescope
- Lost tip of nose in duel



Portrait by Eduard Ender, 1863

Brahe's Work

- Observed supernova —no parallax (1572)
  - Either Earth is the center of everything OR
  - The stars are too far away to measure their parallax
- Parallax measurement of comet (1577)
  - Motion not uniform or circular!



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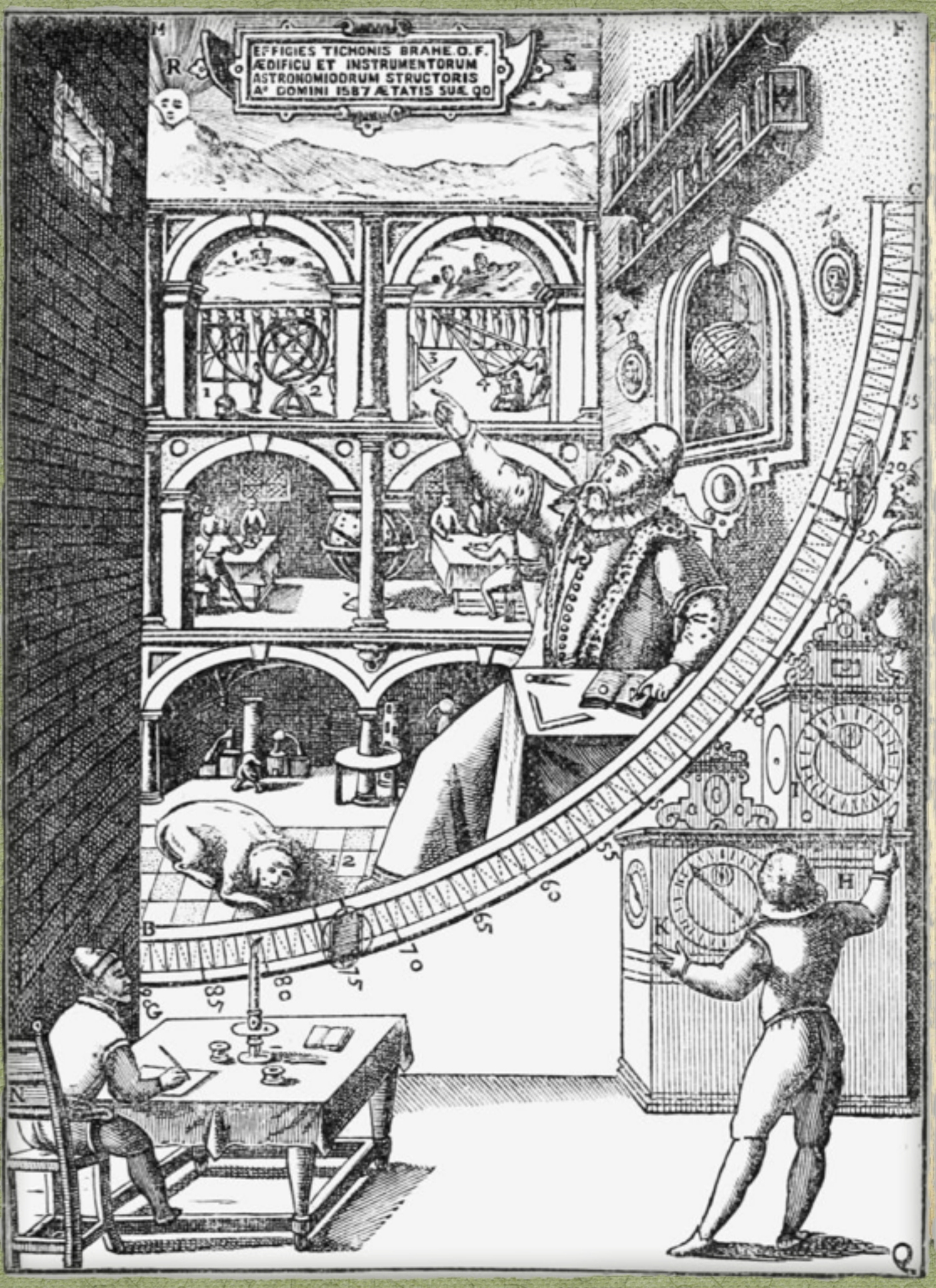


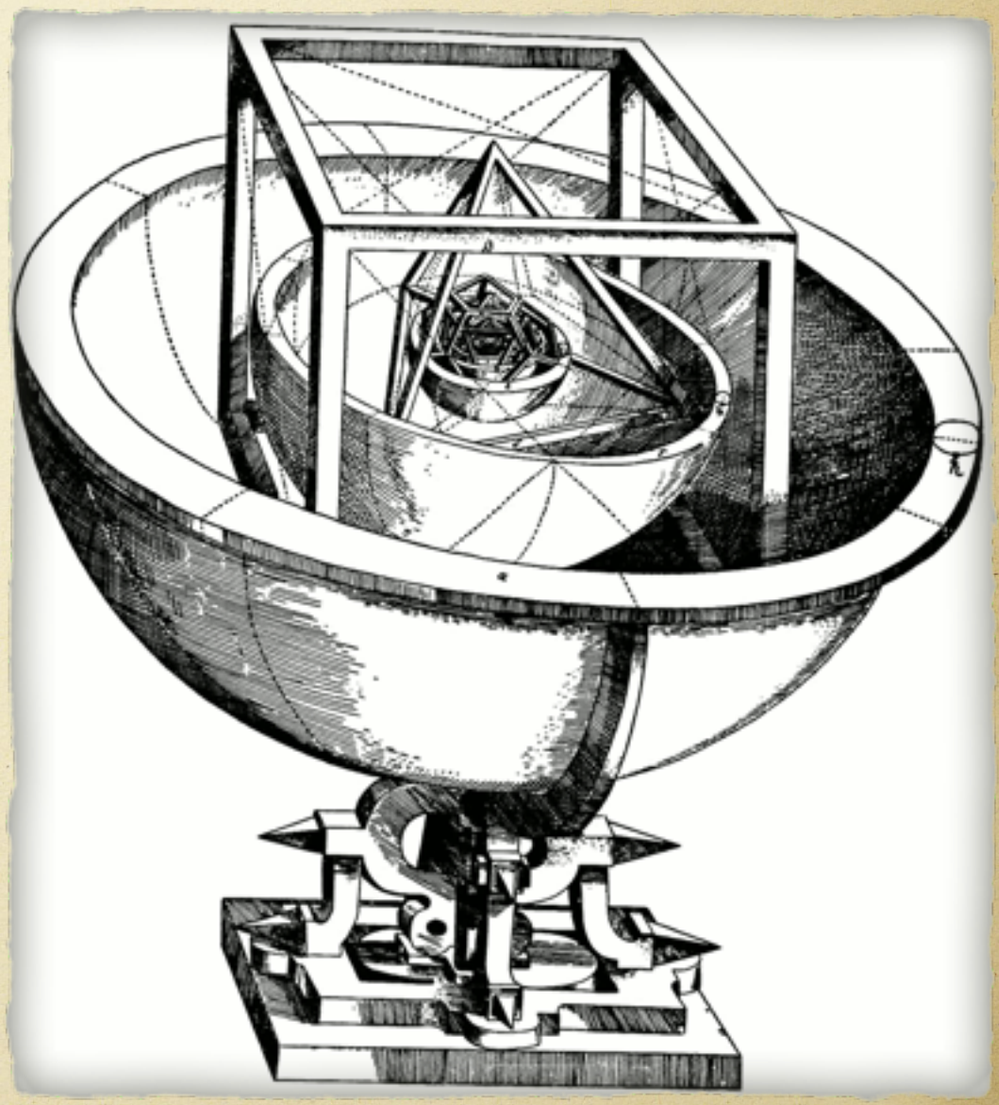
Johannes Kepler (1571-1630)

- Wanted to fit orbit data
  - Copernicus' data too inaccurate
  - Eventually hired by Brahe—used Mars data
- *Astronomiae Pars Optica* (1604)
  - Parallax
  - Inverse square law (intensity)
  - Pinhole cameras
- *Astronomia Nova* (1609)
  - Laws of planetary motion

Portrait by unknown artist, 1610

Kepler's Model

- Subscribed to heliocentric theory
- Orbits inscribed in polyhedrons
- Good predictor of planet position *except* for Mercury

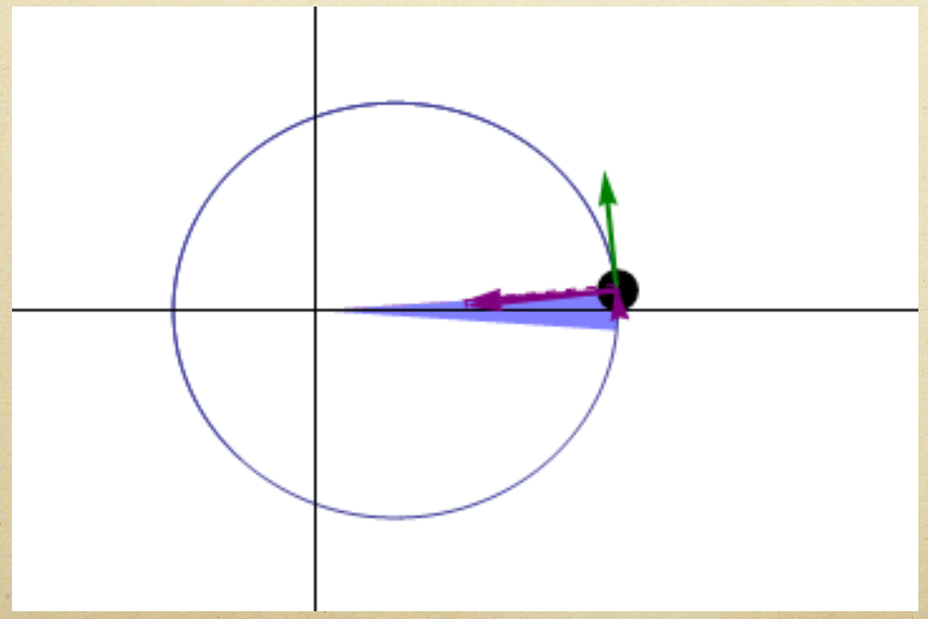


Mysterium Cosmographicum (1596)

Kepler's Laws

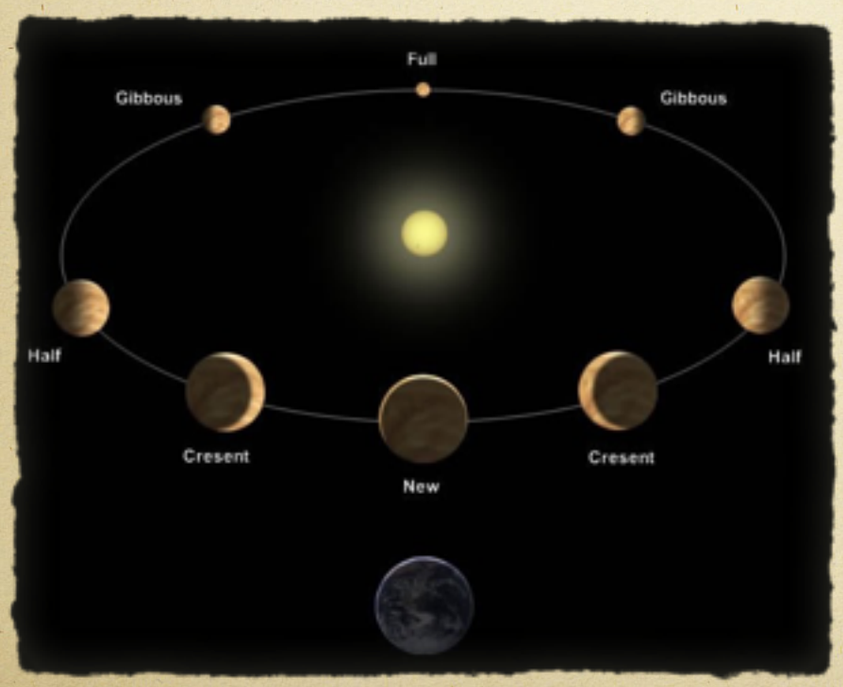
- Inferred from data on Mars' orbit

1. Orbits are elliptical with the sun at one focus
2. Orbits sweep out equal areas in equal times
3. P^2 is proportional to a^3



Galileo Galilei (1564-1642)

- Made first telescope
- Observed the phases of Venus (1610)
- Evidence against geocentric theory



Portrait by Justus Sustermans, 1636

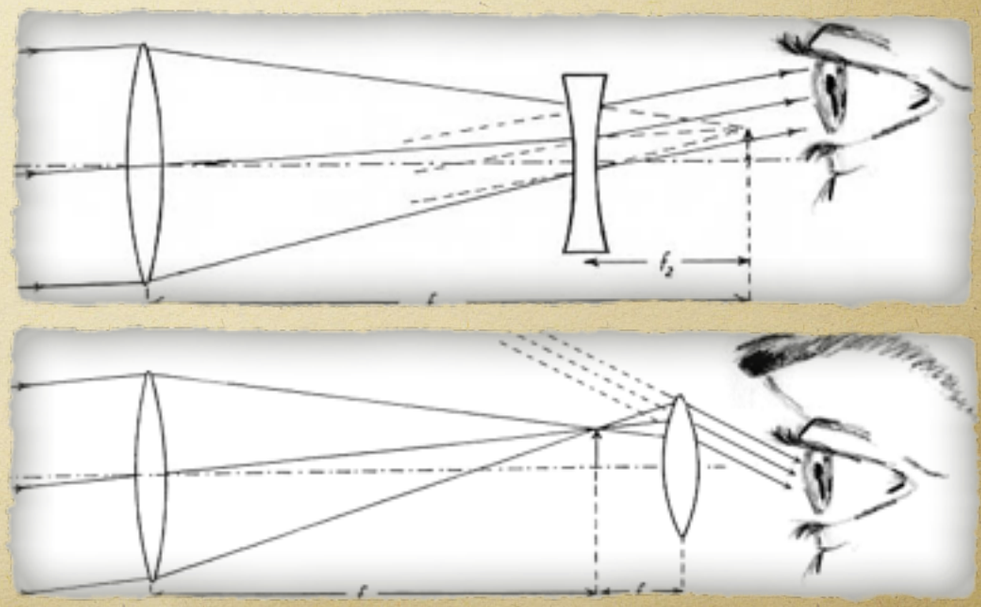
Equipment

Two of Galileo's telescopes

- First telescopes were refractors
- Kepler improved the design
  - Eyepiece concave → convex
  - Higher M, wider FOV
- Reflecting telescope (Newton)
  - All light reflected at same angle
- Compass and straightedge
  - For precise geometry

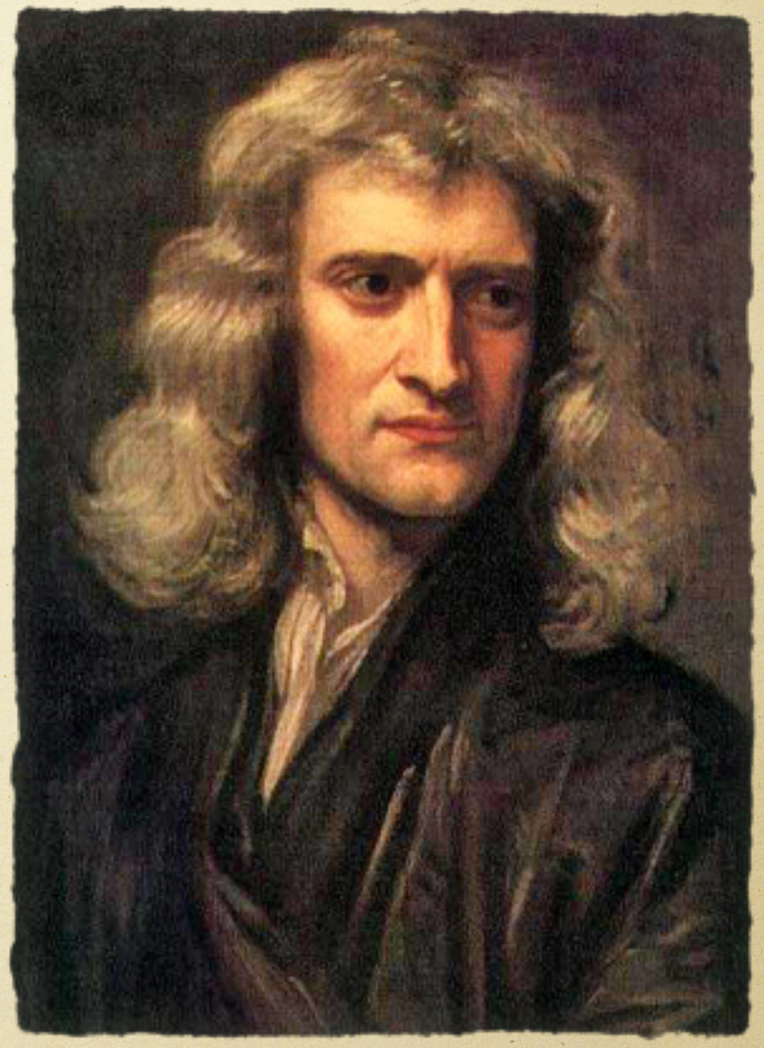
Galileo's compass, c. 1604

Newton's reflecting telescope, 1668



Isaac Newton (1643-1727)

- Helped develop calculus
  - Integration by infinite series
- Communicated with Robert Hooke about how orbits from a $1/r^2$ force would look
  - Elliptical!
- The Principia (1687)
  - Laws of motion
  - Law of universal gravitation
  - Application of laws to our solar system
- First reflecting telescope



Portrait by Godfrey Kneller, 1689

Calculus Controversy

- Isaac Barrow: method of algebraic tangents (by 1663)
- Isaac Newton: fluxions and inverse fluxions (by 1666)
- Gottfried Leibniz: differential and integral calculus (1675)
- Ideas mingled, dispute ensued

absolutæ; dico quod vires illæ absolutæ sunt in progressione Geometrica.

Exponatur enim vis gravitatis per datam lineam AC; resistentia per lineam indefinitam AK; vis absoluta in descensu corporis per differentiam KC; velocitas corporis per lineam AP (quæ sit media proportionalis inter AK & AC, ideoq; in dimidiata ratione resistentiæ) incrementum resistentiæ data temporis particula factum per lineolam KL, & contemporaneum velocitatis incrementum per lineolam PQ; & centro C Asymptotis rectangulis CA, CH describatur Hyperbola quævis BNS, erectis perpendiculis AB, KN, LO, PR, QS occurrens in B, N, O, R, S. Quoniam AK est ut AP q., erit hujus momentum KL ut illius momentum $2APQ$, id est ut AP in KC. Nam velocitatis incrementum PQ, per motus Leg. 2, proportionale est vi generanti KC. Componatur ratio ipsius KL cum ratione ipsius KN, & fiet rectangulum $KL \times KN$ ut $AP \times KO \times KN$; hoc est, ob datum rectangulum $KC \times KN$, ut AP. Atqui areæ Hyperbolicæ

Summary

- Models were adapted to explain observations
- How quickly a model evolves can be limited by the available instruments
- Science is an ongoing process

References

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Questions?