



Astronomy 350L

(Spring 2005)



The History and Philosophy of Astronomy

(Lecture 14: Newton II)

Instructor: Volker Bromm
TA: Amanda Bauer

The University of Texas at Austin

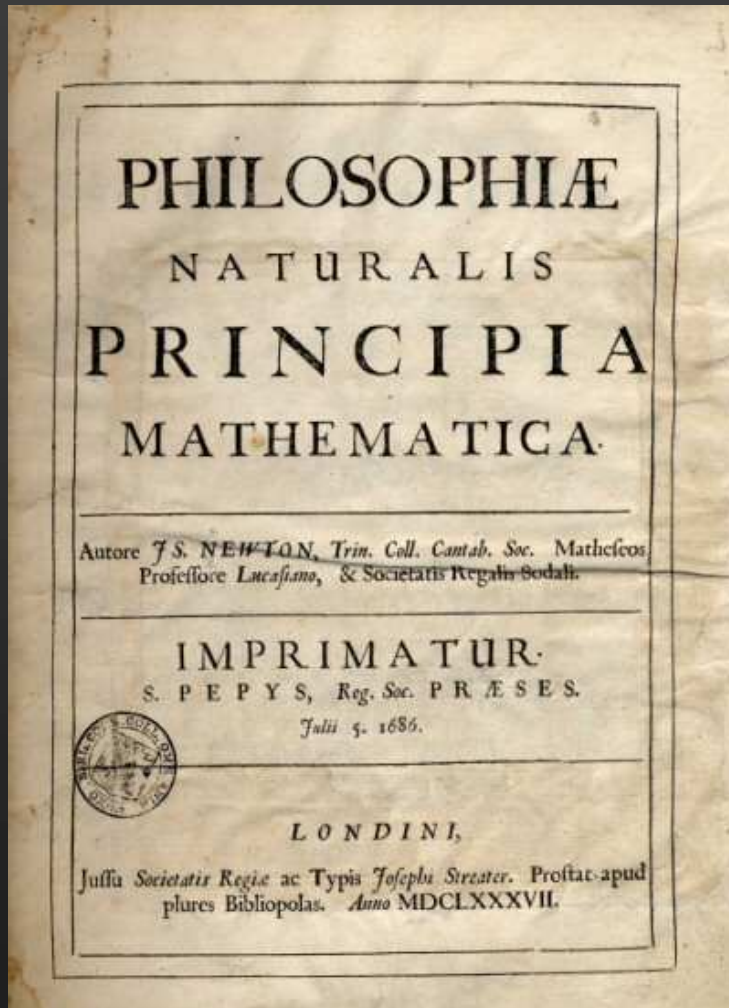
En Route to the Principia

- Newton was *very* reluctant to publish!



- Edmond Halley (1656-1742)
- member of Royal Society
- Halley's Comet
- first astronomer to observe Southern Sky (from St Helena)
- Convinced Newton to publish *Principia*

Newton's Principia (1687)



- *Philosophiæ Naturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy)
- Challenges Descartes' *Principia Philosophiæ* (1644)
 - Descartes: qualitative
 - Newton: quantitative, predictive
- *The foundational text for modern physics and astronomy!*

Newton's Principia: Overall Structure

Book 1: Basic Laws

Book 2: Demolition of Cartesian System

Book 3: *System of the World* (applications)

Principia Book 1: Basic Laws

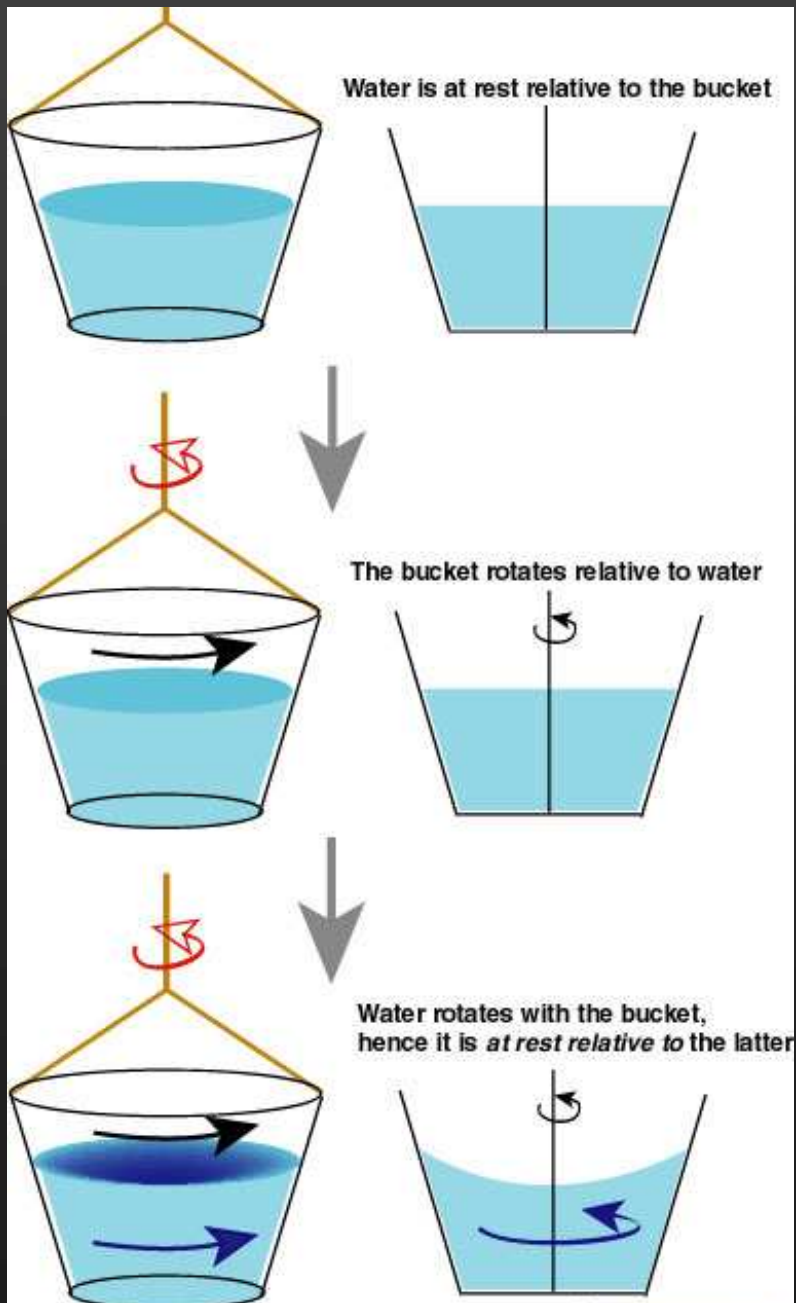
- Scholium: Absolute Space and Time

“Absolute space...without relation to anything external, remains always similar and immovable”

“Absolute, true, and mathematical time, of itself,... flows equably without relation to anything external ”

- Passive stage for all motion

Principia Book 1: Basic Laws

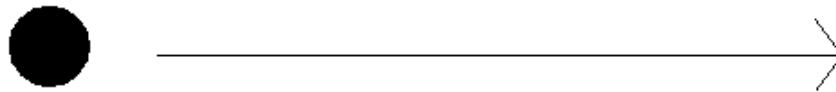


- Newton's bucket experiment

Principia Book 1: Basic Laws

- Newton's 1st Law of Motion:

A body stays at rest or moves in uniform straight-line motion unless acted on by a net external force.

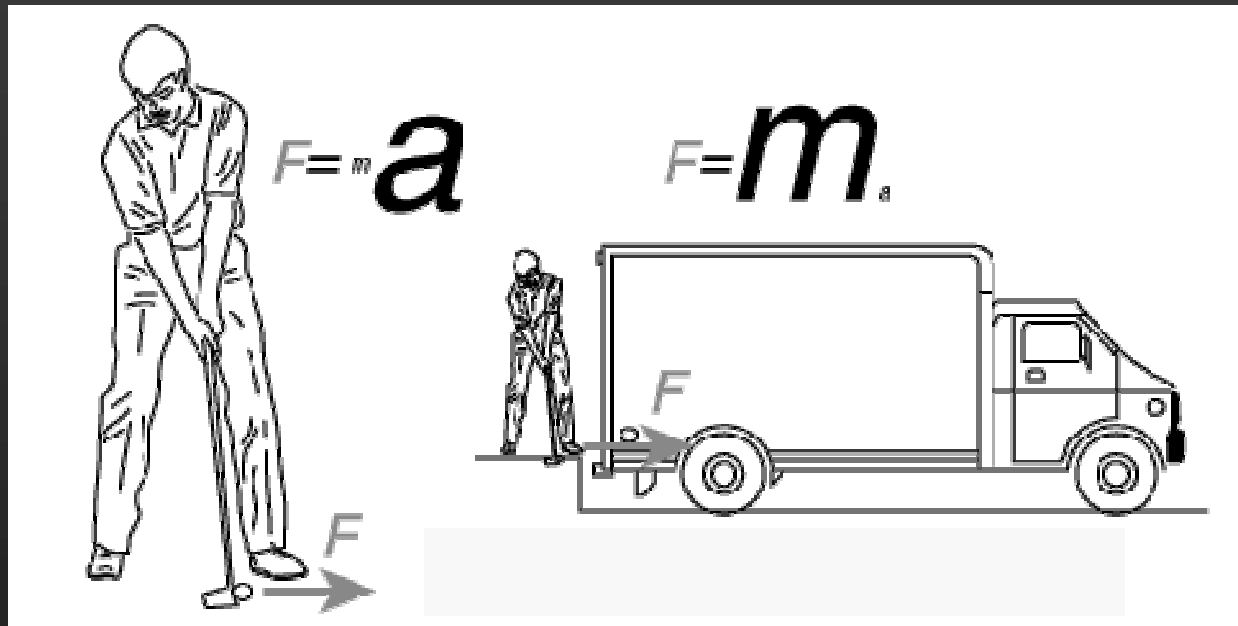


- Law of inertia (Galileo, Descartes)
- State of rest and uniform motion are equivalent (relative to observer)

Principia Book 1: Basic Laws

- Newton's 2nd Law of Motion:

$$\text{Force} = \text{mass} \times \text{acceleration}$$

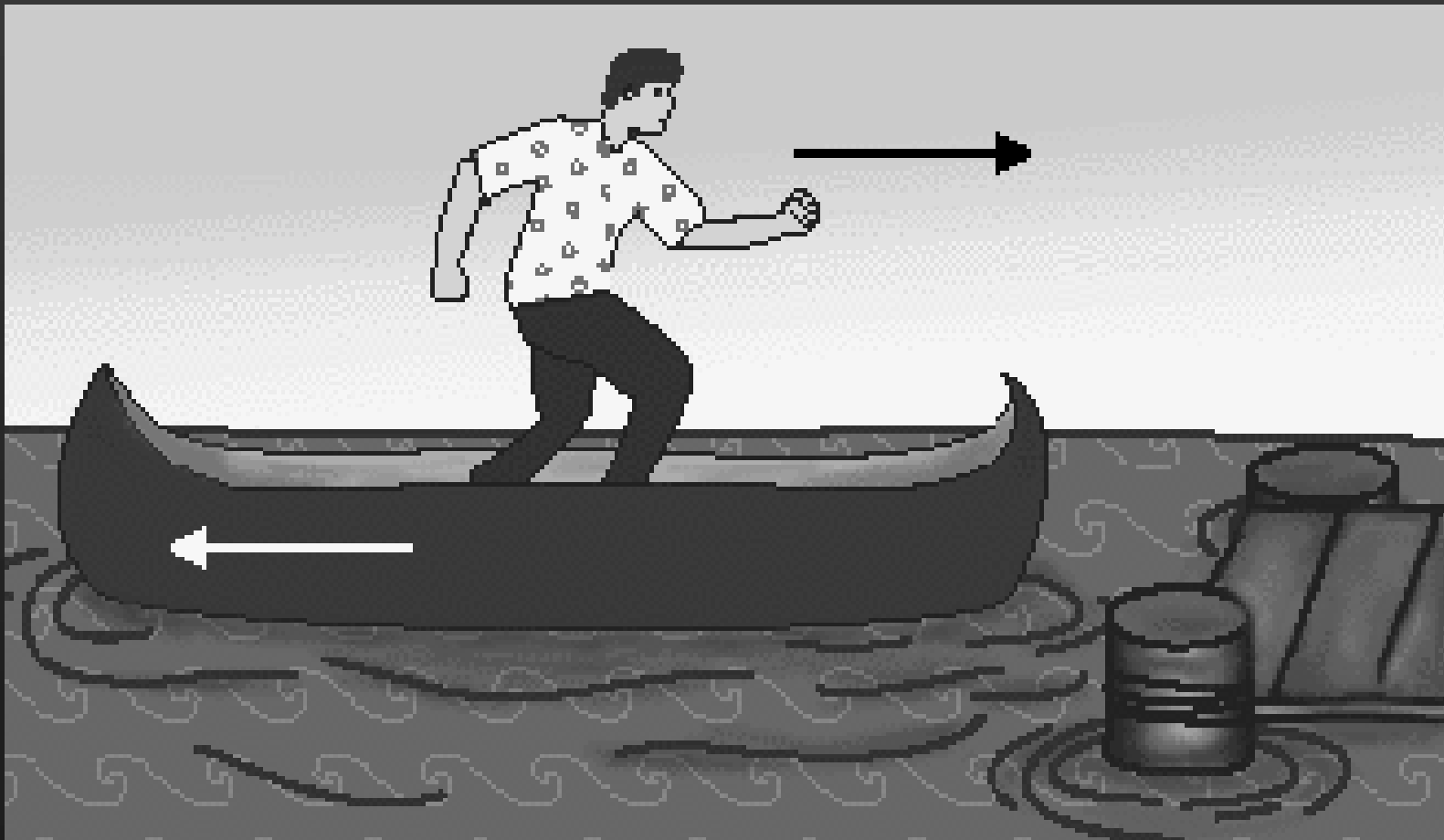


- Same force (F) exerted on a larger mass (m) produces a correspondingly smaller acceleration (a)

Principia Book 1: Basic Laws

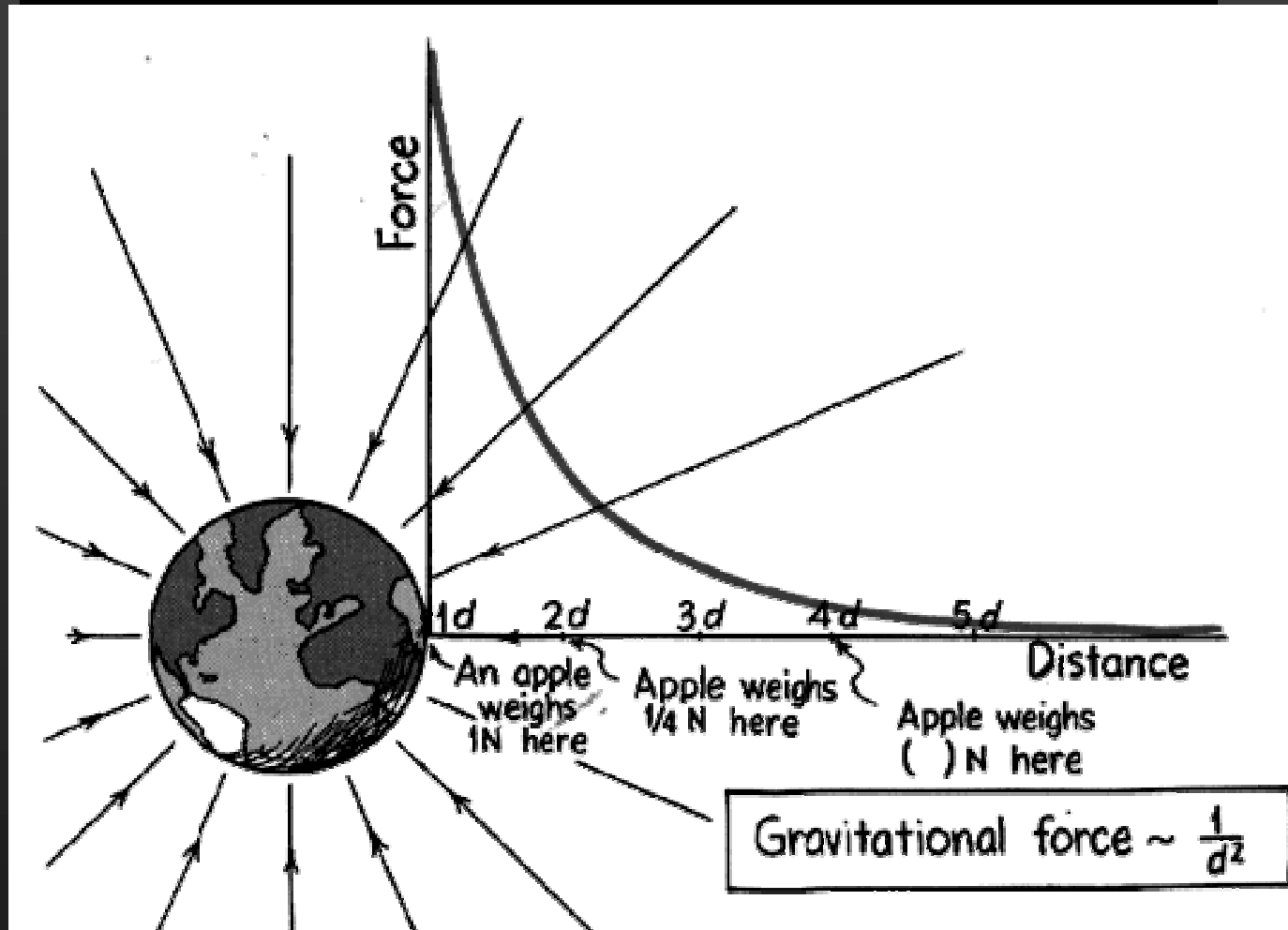
- Newton's 3rd Law of Motion:

Force = Counter-force



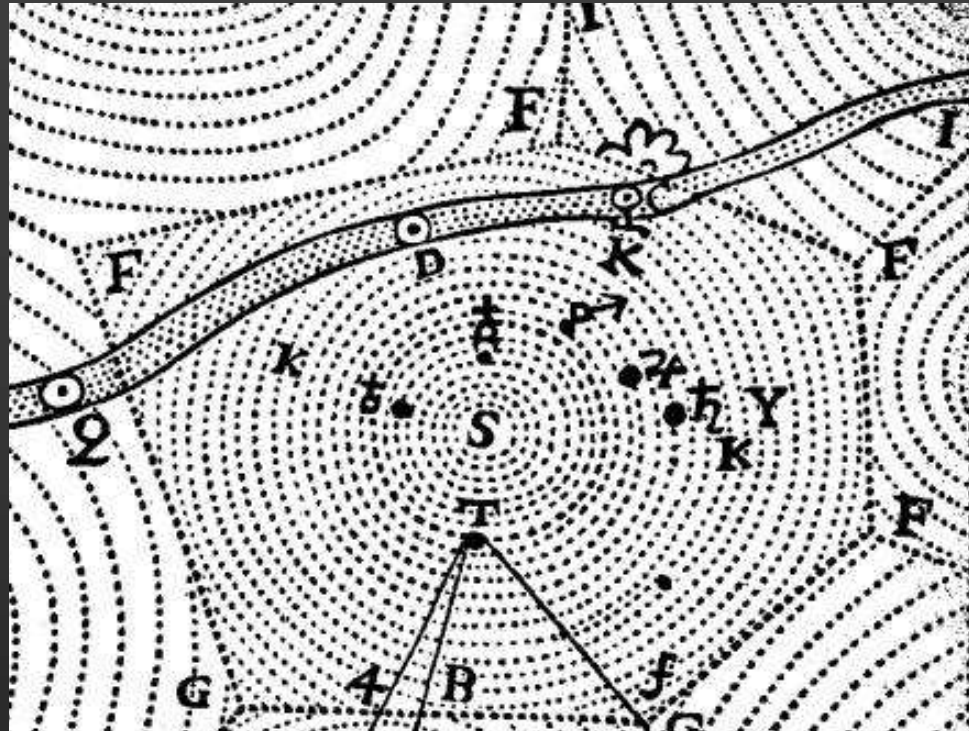
Principia Book 1: Basic Laws

- Newton's Law of Gravity:



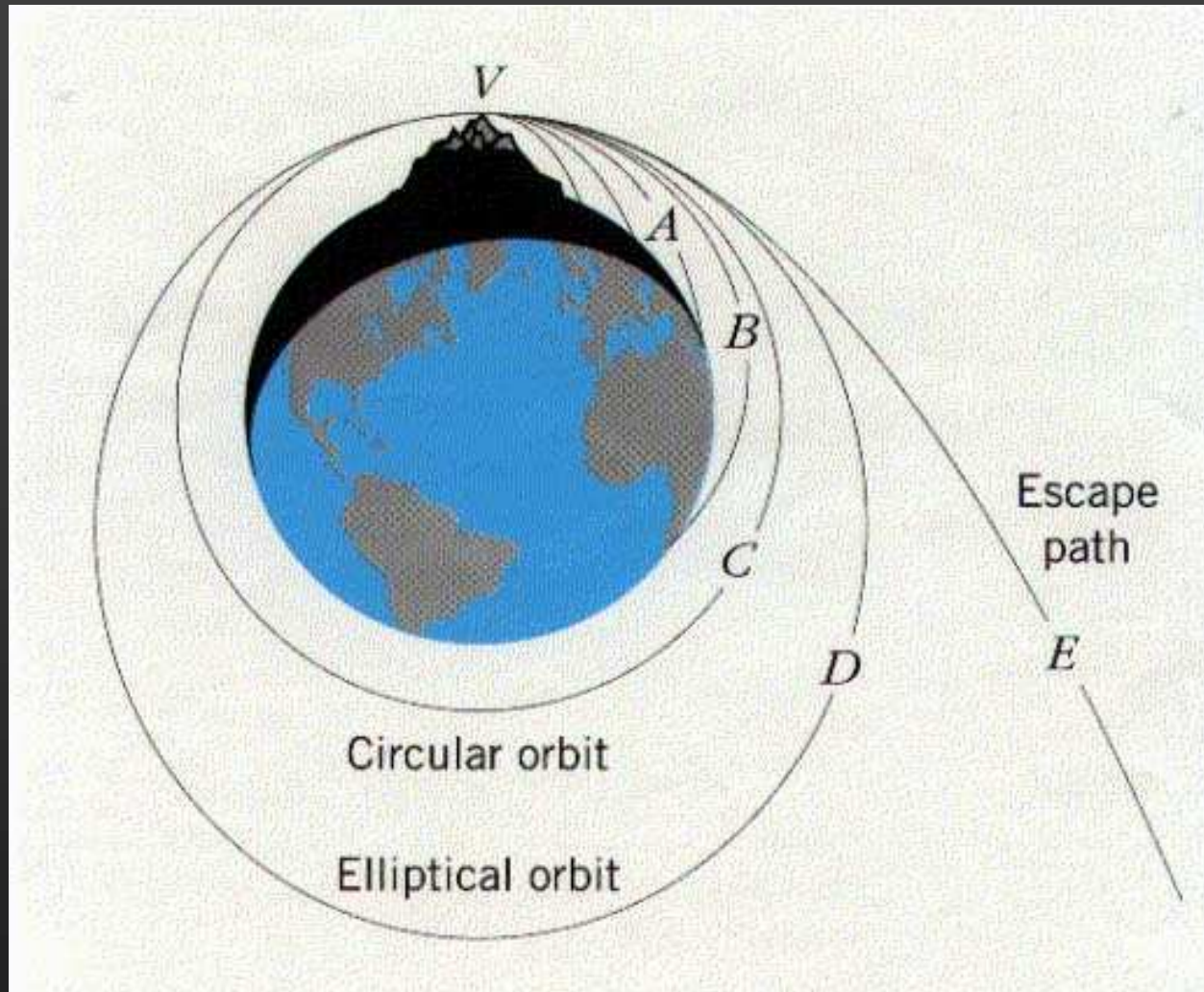
- Gravity is universal and follows inverse-square law!

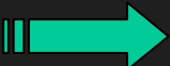
Principia Book 2: Demolish Descartes



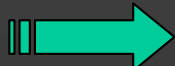
- Newton proves mathematically:
 - Descartes' vortex motion cannot be sustained!
 - it would soon stop because of friction (objects have to move through 'plenum')

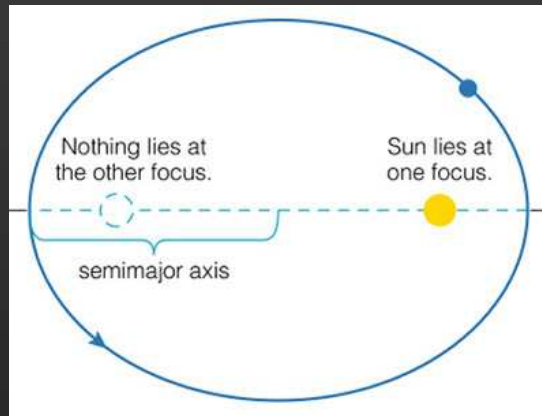
Principia Book 3: New System of the World



- Newton's laws  celestial motions (ellipse, parabola, hyperbola, circle)

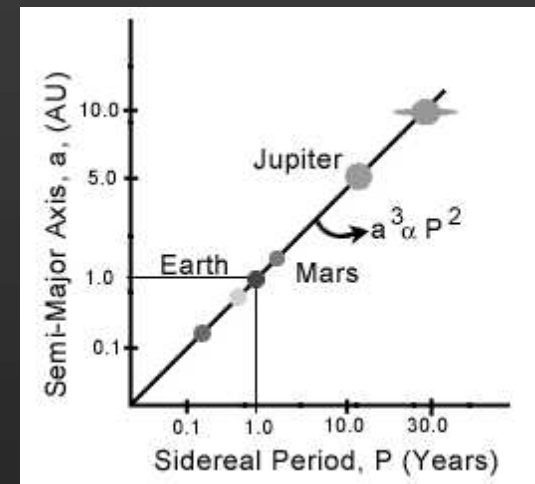
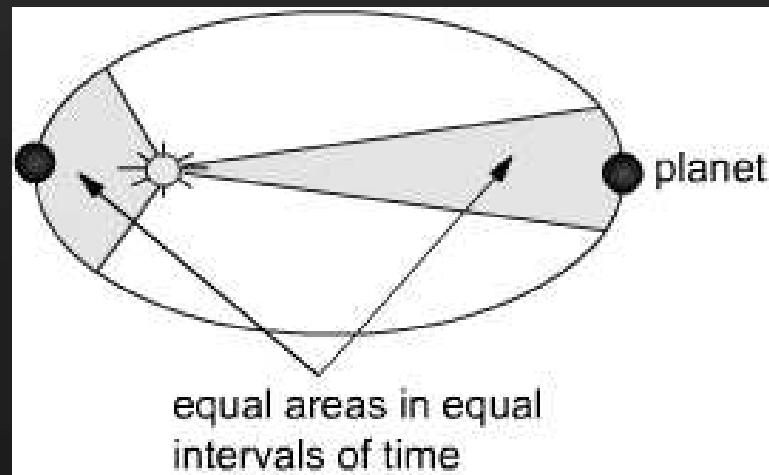
Principia Book 3: New System of the World

- Newton's laws (gravity + laws of motion)  Kepler's Three Laws of Planetary Motion



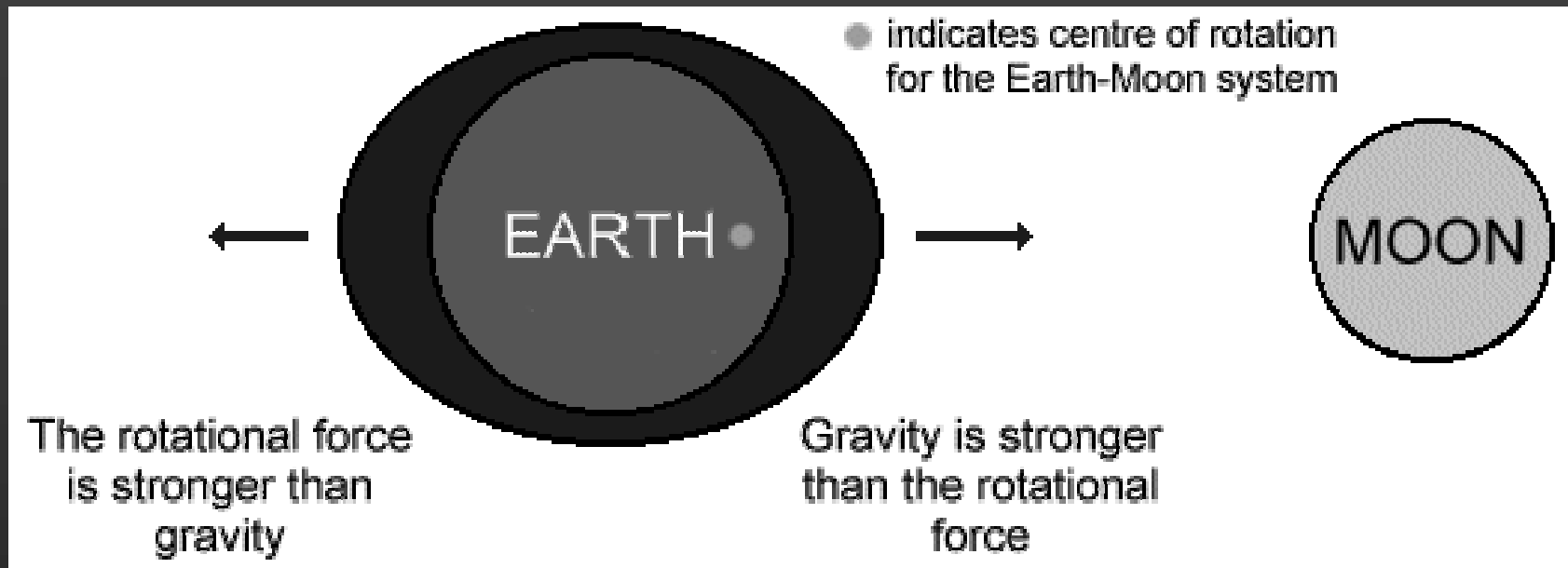
Kepler 1

Kepler 2



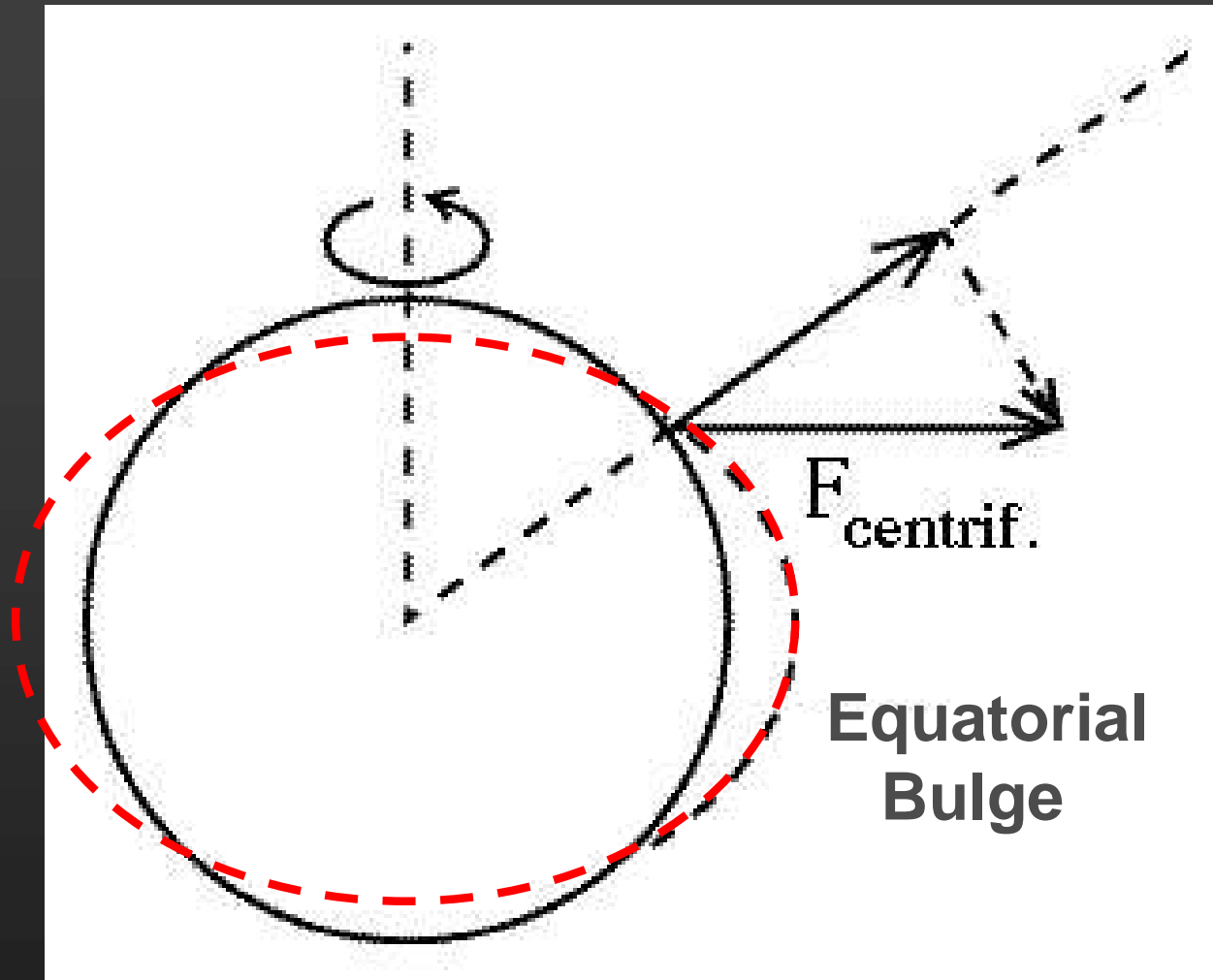
Kepler 3

Principia Book 3: New System of the World



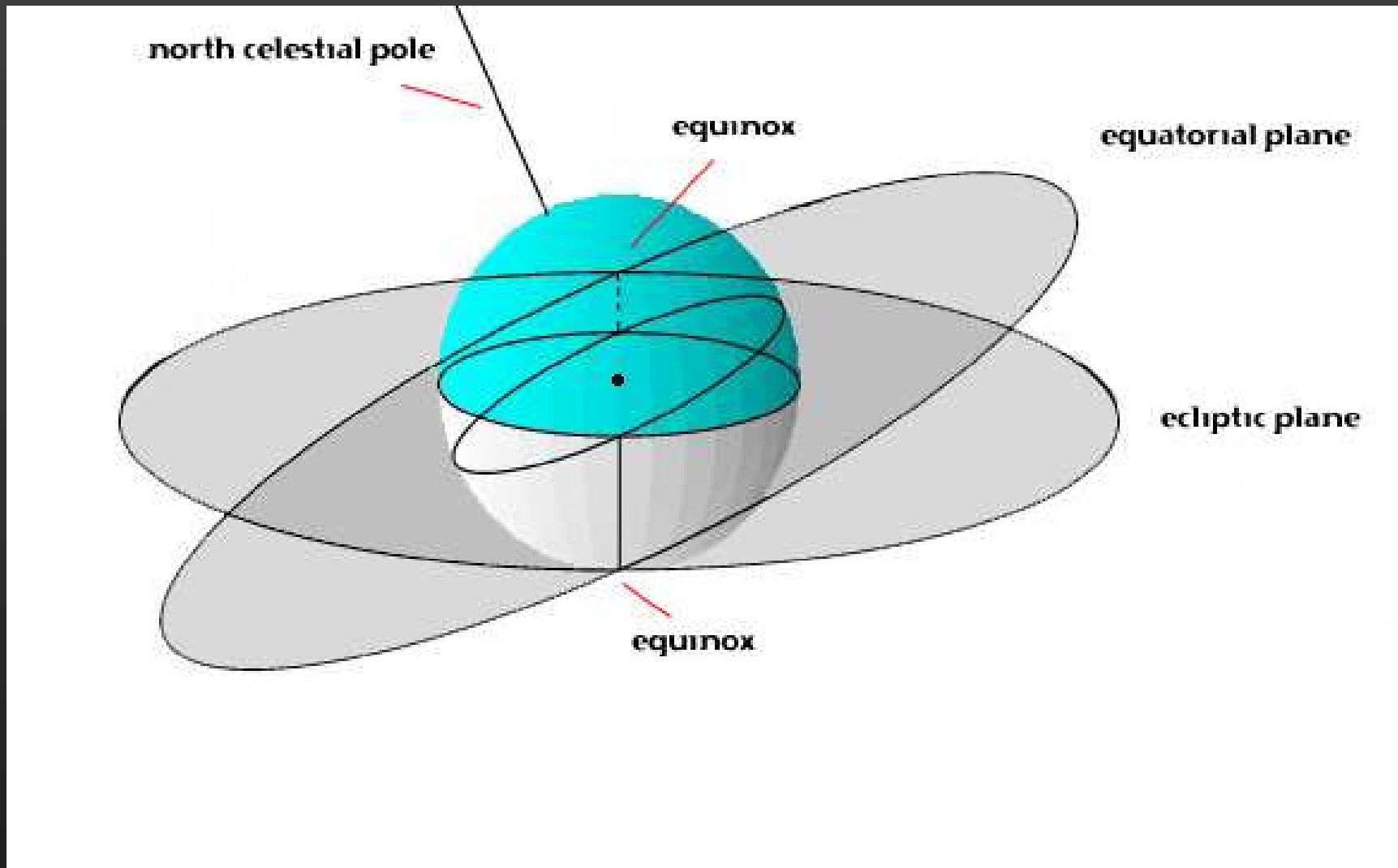
- Newton's laws  ocean tides!

Principia Book 3: New System of the World



- Newton's laws  true (bulged) shape of Earth!

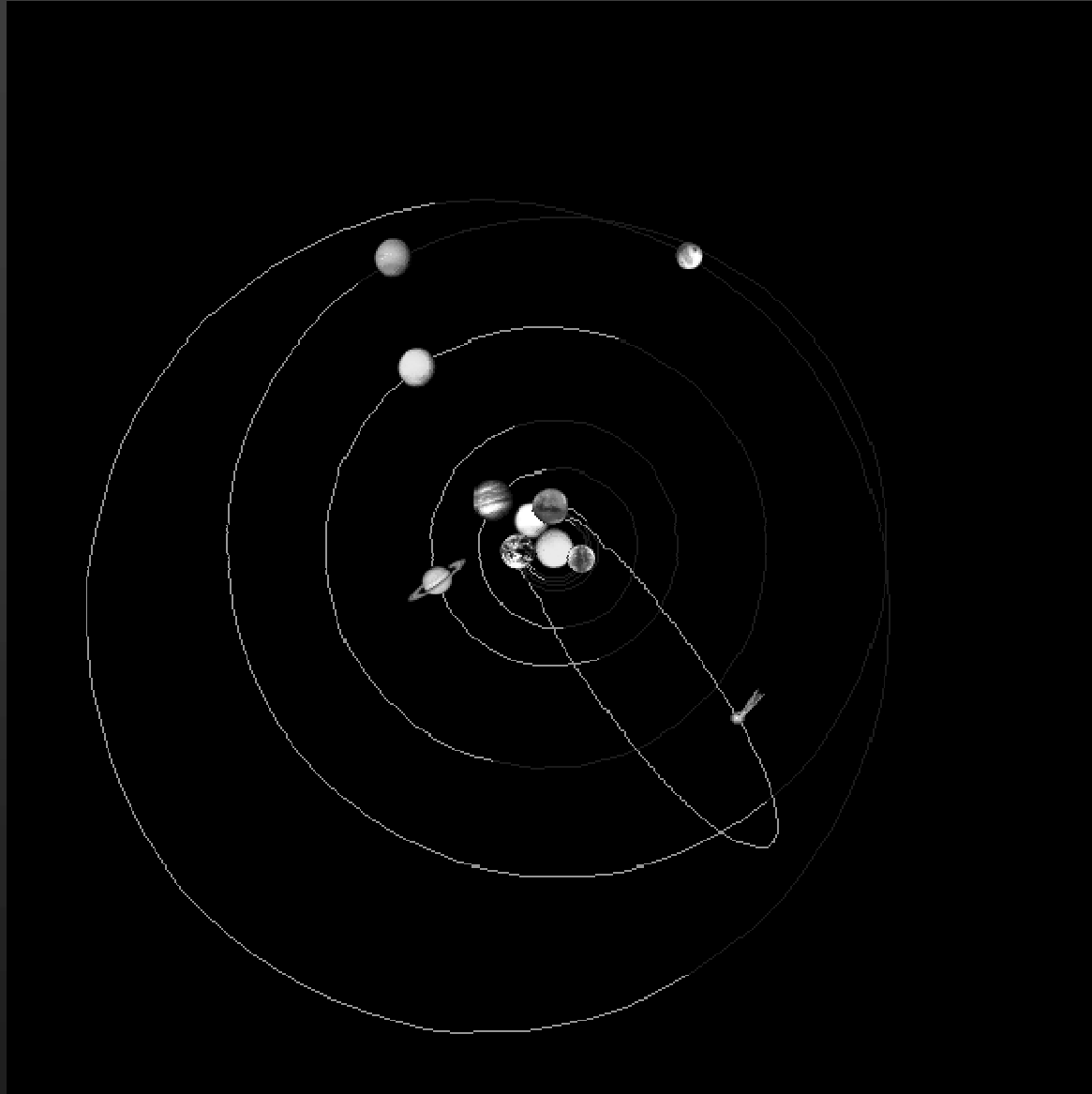
Principia Book 3: New System of the World



Precession of the Equinoxes

- physical explanation for Hipparchus' observation!

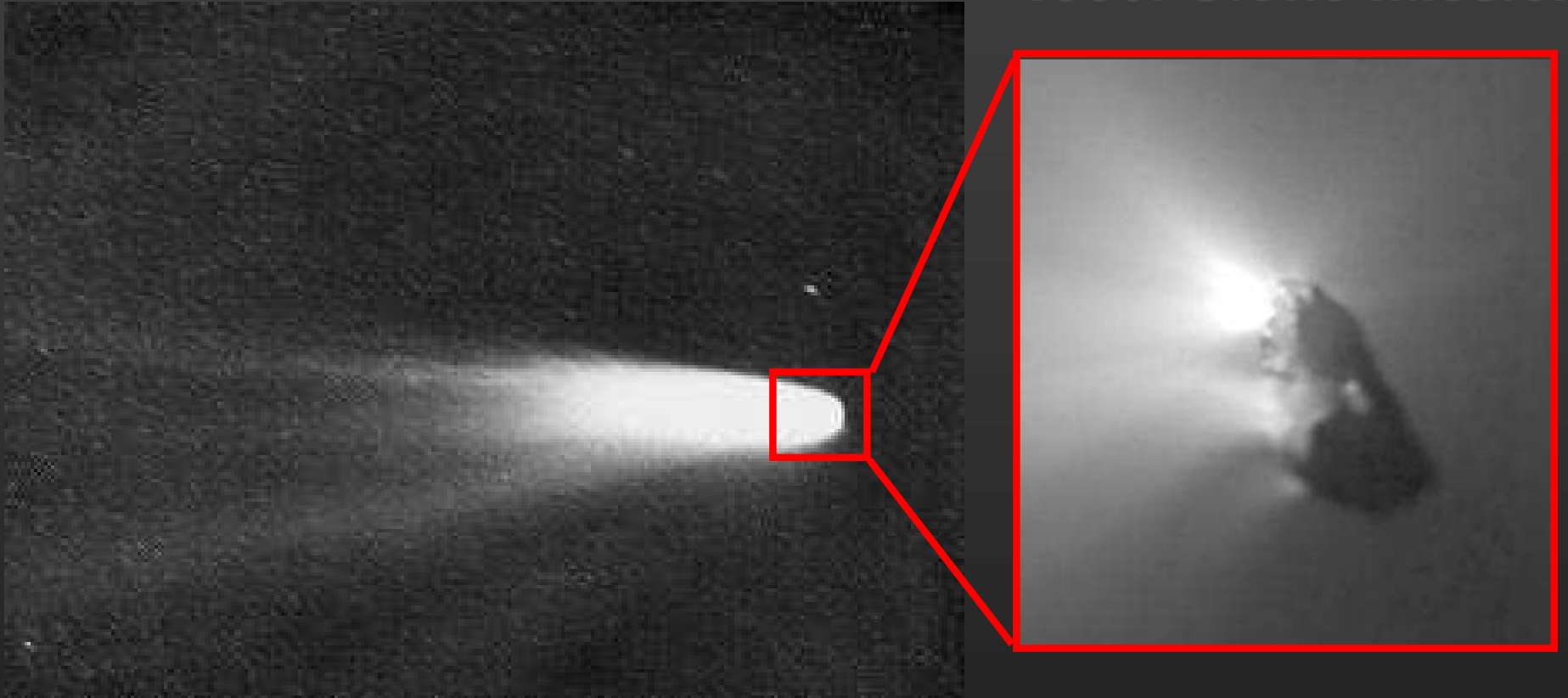
Principia Book 3: New System of the World



- comets move on highly eccentric orbits around Sun!

Halley's Comet

1986: Giotto mission



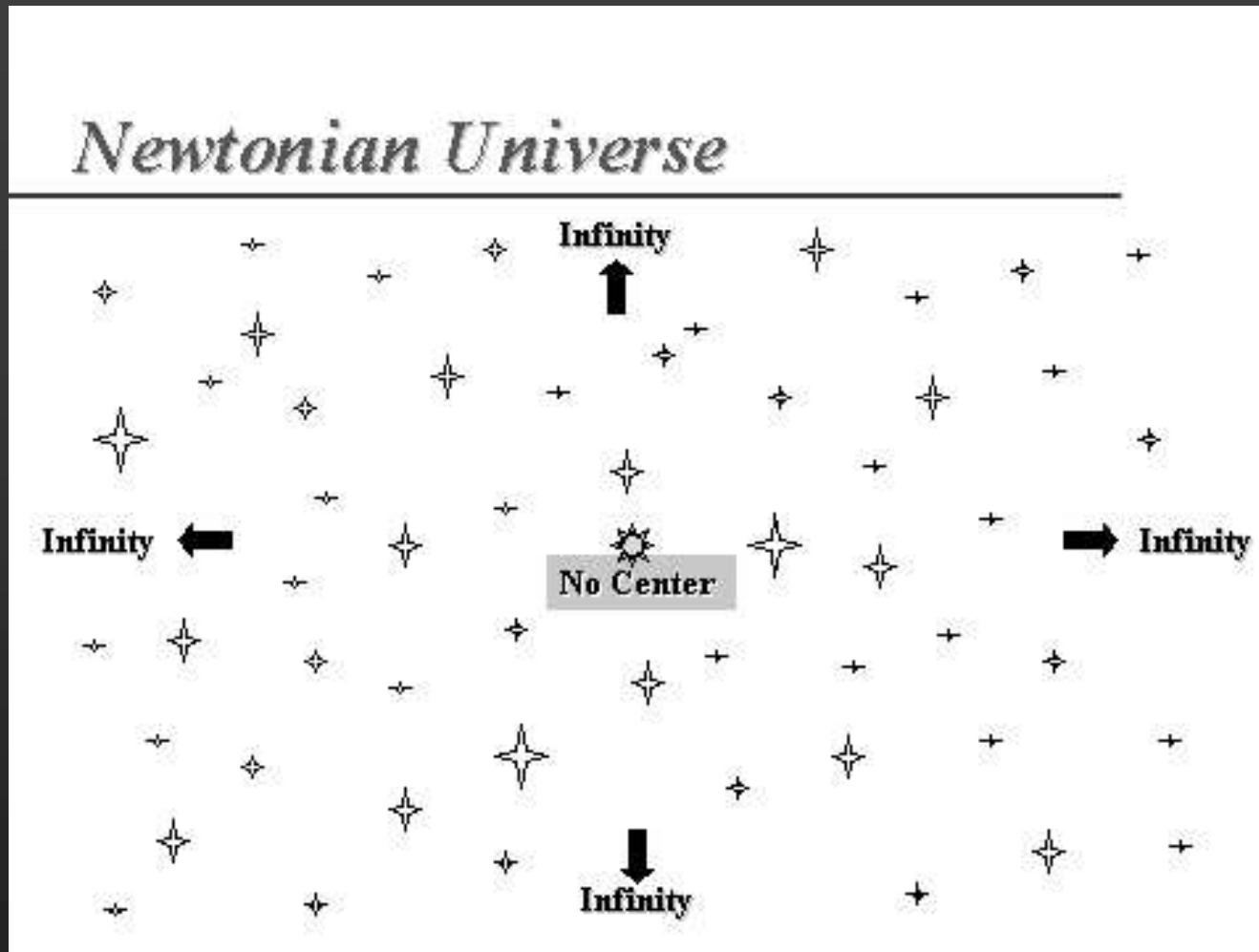
- Next return scheduled for 2061!

Principia Book 3: New System of the World



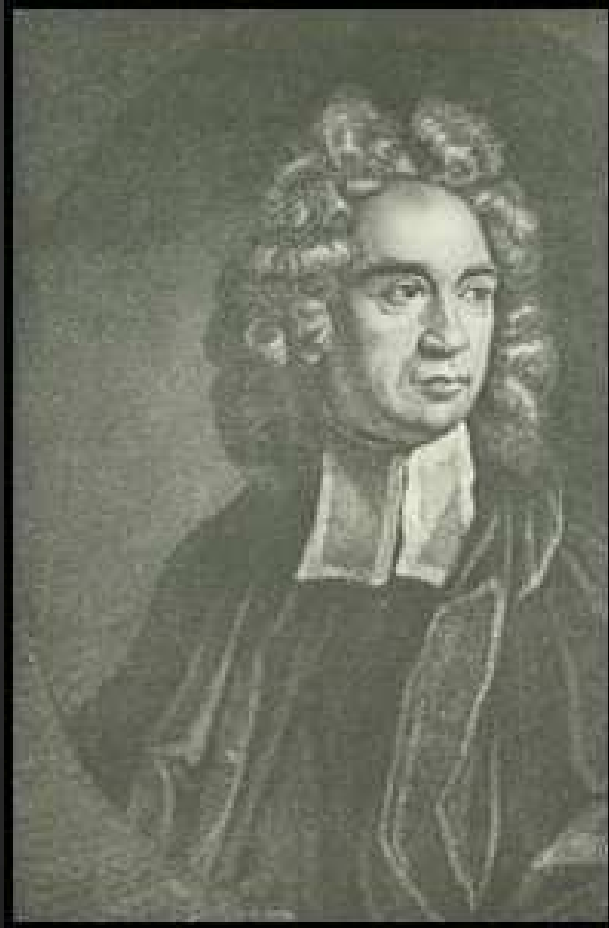
- stoic universe (infinite space, finite matter) is unstable!

Principia Book 3: New System of the World



- Need Epicurean universe (infinite space, infinite matter)!

The Infinite Universe: Letters to Bentley (1692-93)



- Richard Bentley (1662-1742)
- erudite theologian
- lectured on how to combat atheism
- basic idea: God's perfection requires infinite universe
- double-check with Newton on technical details

1688: Glorious Revolution



- last Stuart king (James II) wants to re-catholicize England
- Parliament asks Protestant ruler of the Netherlands (William of Orange) for help
- William invades, James II flees
- William (III) and Mary crowned new king and queen
- Beginning of constitutional government ('Bill of Rights')

Newton permanently moves to London



- 1696-1727
- “affairs of state”:
 - member of Parliament
 - master of the Royal Mint (oversees large-scale re-coinage program; becomes very rich)
- President of the Royal Soc.
- stops doing science!

Journey's End: Death in 1727



- buried in Westminster Abbey

Newton: The Legend

“Nature and Nature’s Laws lay hid in night;
God said, *Let Newton be!* And all was *Light*.”

(Alexander Pope)

“Newton with his prism and silent face,
The marble index of a mind for ever
Voyaging through strange seas of Thought, alone.”

(William Wordsworth)

Newton: The Legend



(William Blake, 1795)

- cold, unfeeling rationalist and law-giver, a demigod

Newton (part 2)

- Isaac Newton:

- founder of modern physics and astronomy
- early life: led reclusive anti-social life in Cambridge
- later life: tended to affairs-of-state in London (master of the Mint)

- Principia

- foundational text for modern physics and astronomy
- laws of motion
- universal gravity (inverse-square law)
- demolished Cartesian model
- explains large number of hitherto unrelated phenomena
within one unified theoretical framework

- The Legend:

- “the marble index of the mind for ever...”