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)

- *Philosophiae Naturalis Principia Mathematica*  
  (Mathematical Principles of Natural Philosophy)

- Challenges Descartes’ *Principia Philosophiae* (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 2\textsuperscript{nd} 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:
  
  \[
  \text{Force} = \text{Counter-force}
  \]
Principia Book 1: Basic Laws

• Newton’s Law of Gravity:

• Gravity is universal and follows inverse-square law!
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  \( \rightarrow \) Kepler’s Three Laws of Planetary Motion
  (gravity + laws of motion)

Kepler 1

Kepler 2

Kepler 3
Principia Book 3: New System of the World

- Newton’s laws explain 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

- physical explanation for Hipparchus’ observation!
• comets move on highly eccentric orbits around Sun!
Halley’s Comet

- Next return scheduled for 2061!

1986: Giotto mission
• 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…”