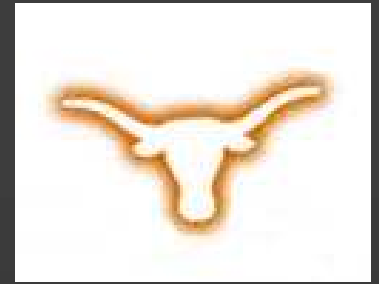




Astronomy 350L
(Spring 2005)



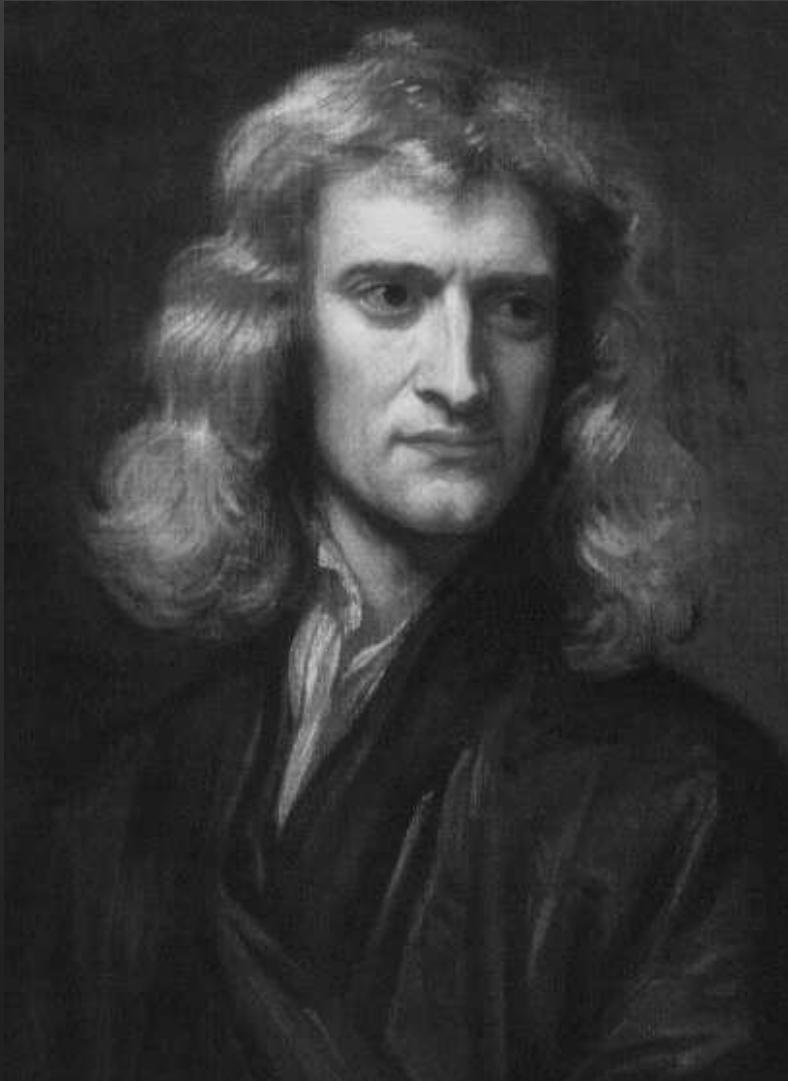
**The History and Philosophy
of Astronomy**

(Lecture 13: Newton I)

Instructor: Volker Bromm
TA: Amanda Bauer

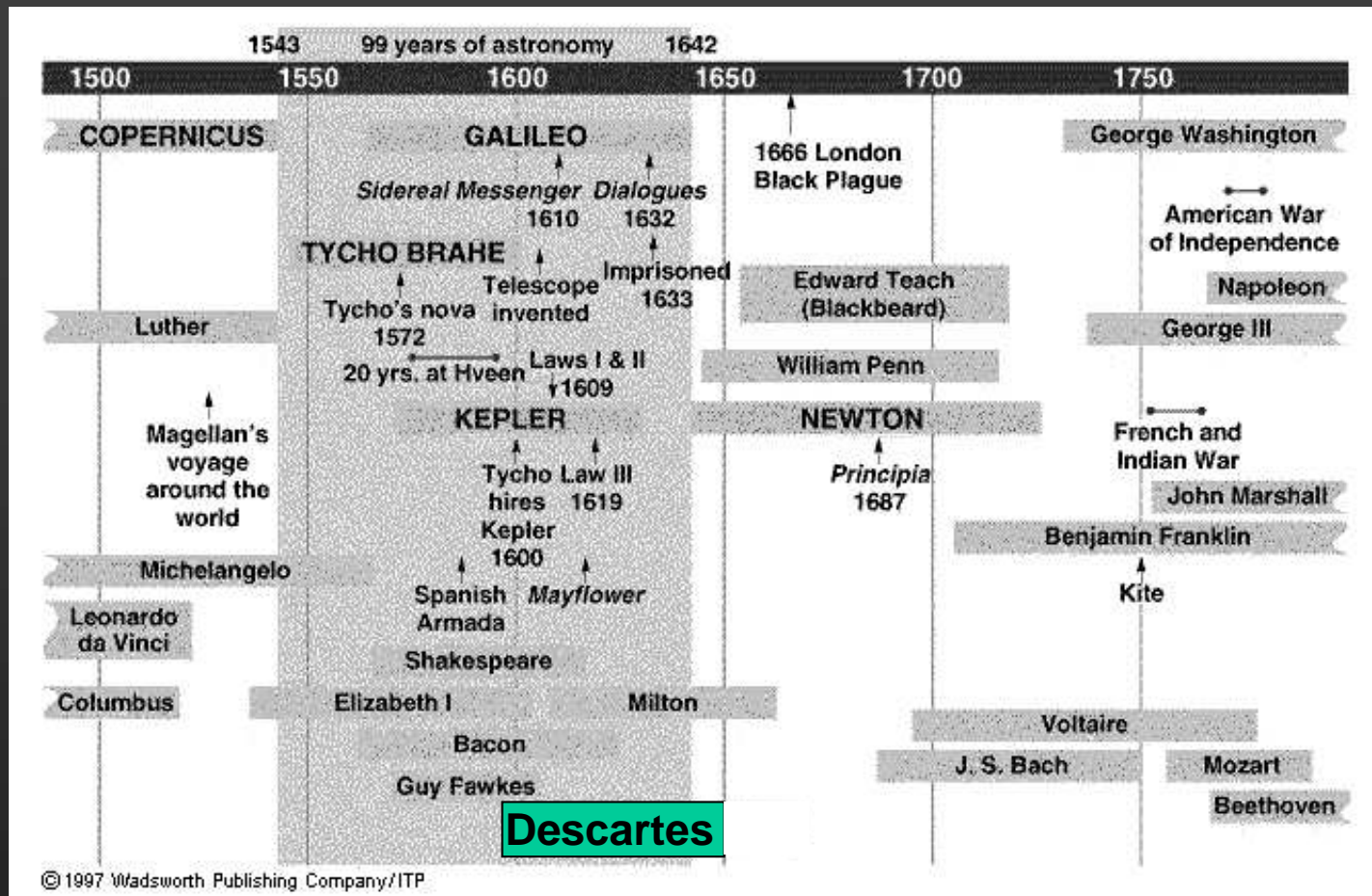
The University of Texas at Austin

Isaac Newton: Founding Father of Physics



- 1642 (Woolsthorpe) – 1727 (London)
- *Principia Mathematica Philosophiae Naturalis*
(“Mathematical Principles of Natural Philosophy”, 1687)
 - universal gravity
(inverse-square law)
 - three laws of motion
- invented calculus
(differentiation and integration)

Newton: Timeline and Context



- building upon Galileo, Kepler, and Descartes
- completes Copernican Revolution!

Newton: Geography of his Life



1642: Birth in Woolsthorpe



- born in rural Lincolnshire
- father died *before* his birth ('posthumous child')

1642 – 49: The English Civil War



- bitter struggle between King (Charles I Stuart) and Parliament (“Cavaliers” vs “Roundheads”)
- King desires to rule without Parliament

1649: Execution of the King



- King Charles I (Stuart) beheaded

1642 – 49: The English Civil War



- Victory for Parliament
- Republic (“Commonwealth”)
- Oliver Cromwell (1599-1658)
 - Lord Protector
- Anarchy after his death
- Army recalls son of former (executed) king from exile

1660: The Restoration



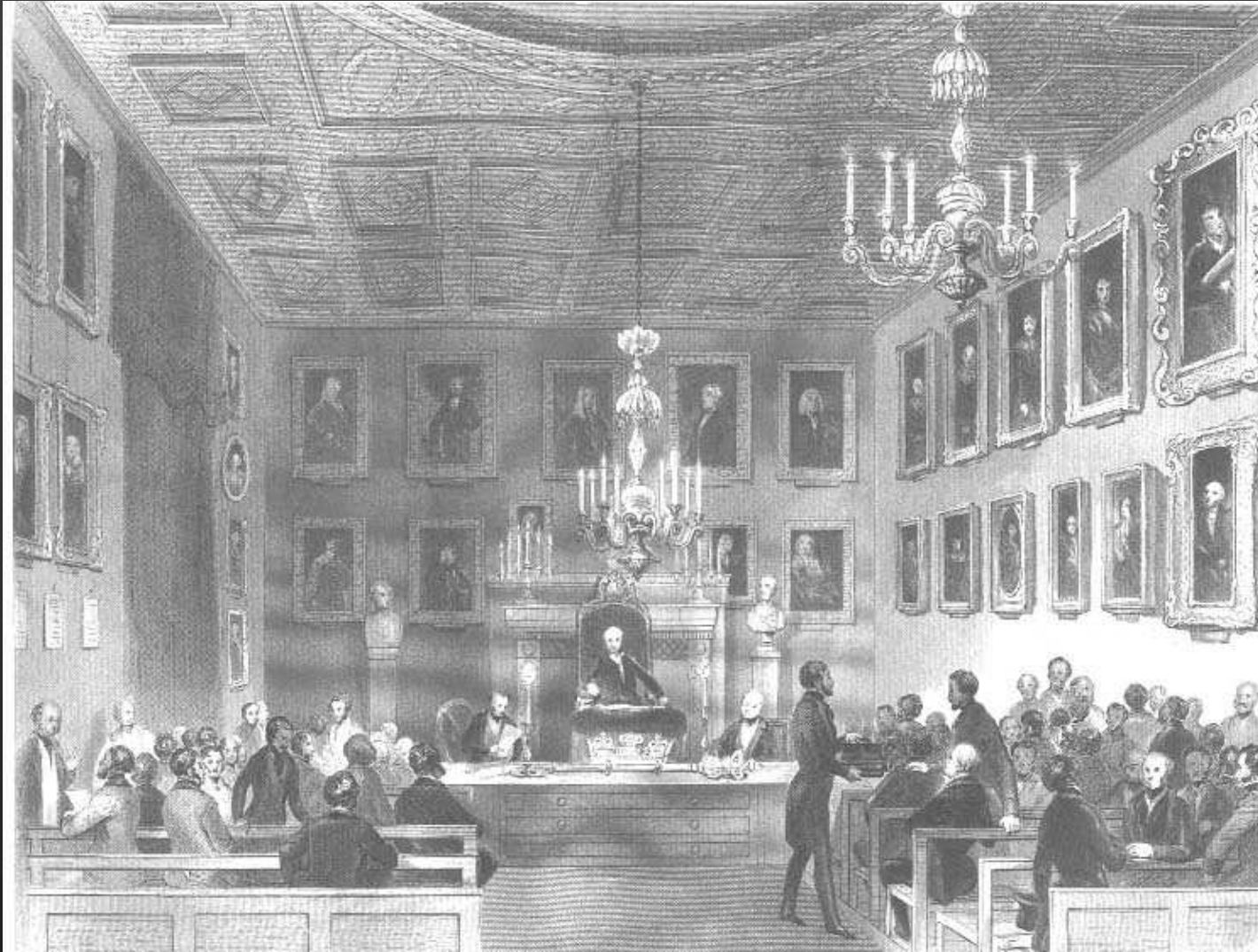
- Return of the Stuarts: Charles II (son of beheaded king)

London Coffee-House Culture



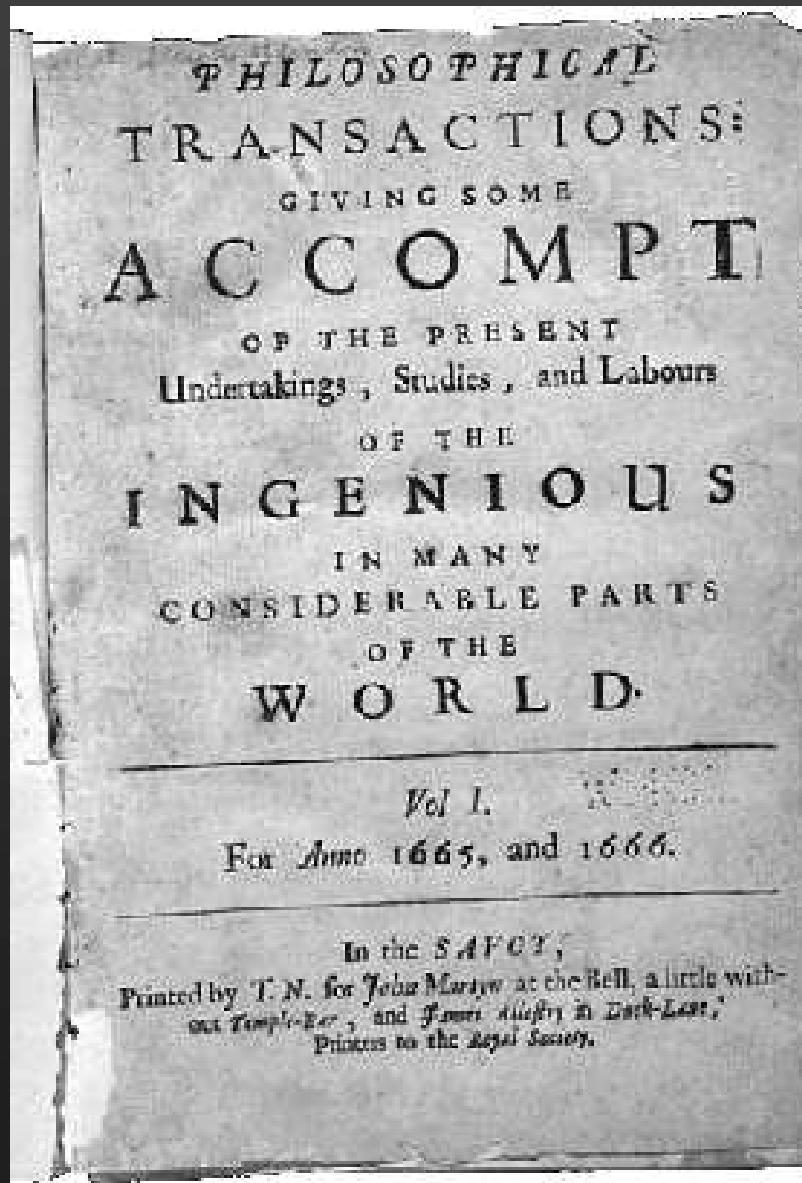
- New venue for meetings of intellectuals

The Royal Society of London



- founded 1660: institution to foster exchange of scientific knowledge

Philosophical Transactions



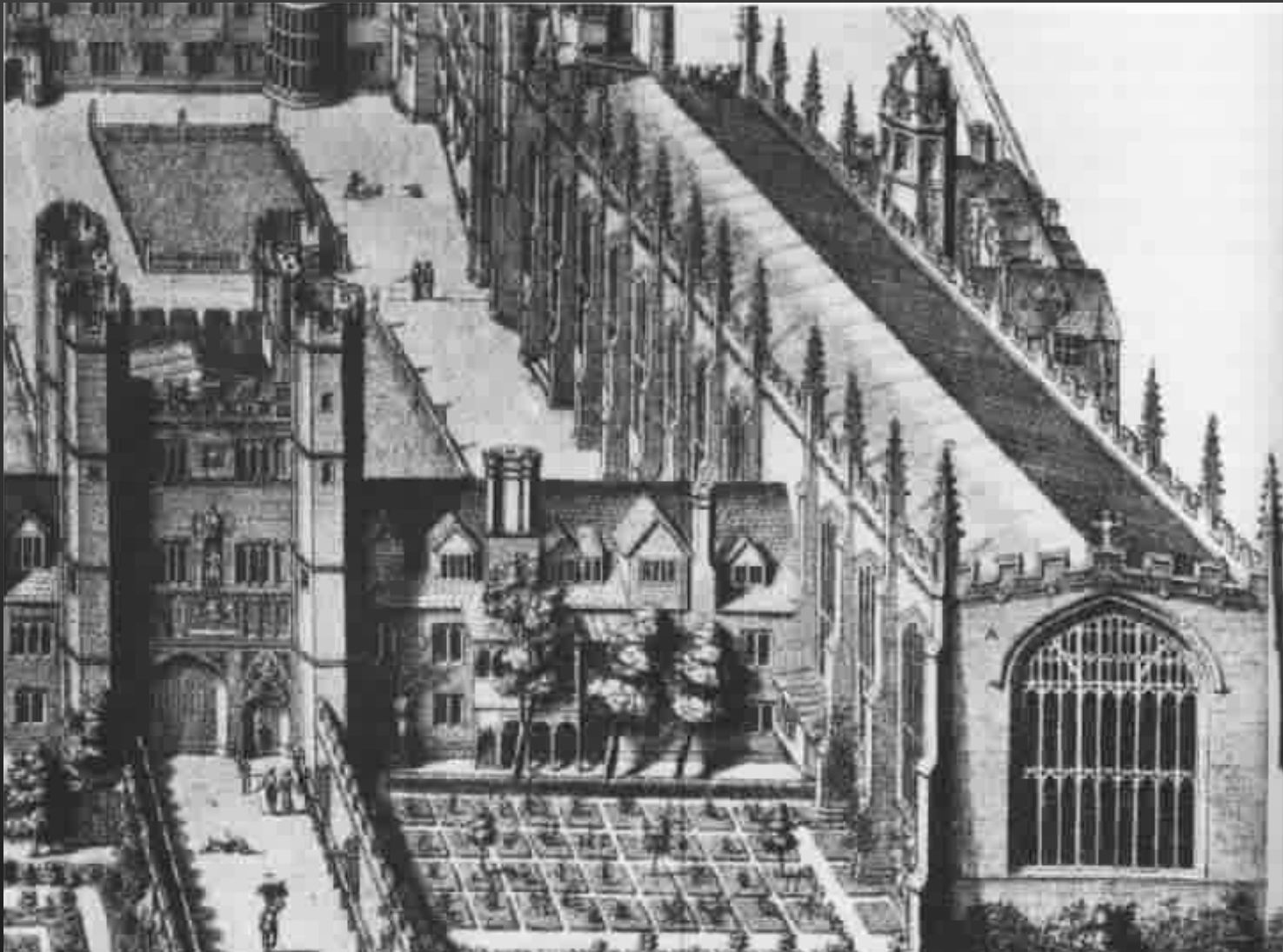
- published by Royal Society
- first scientific journal
- a public registry of new scientific ideas
- professionalization of science

1661: Newton enters Cambridge University



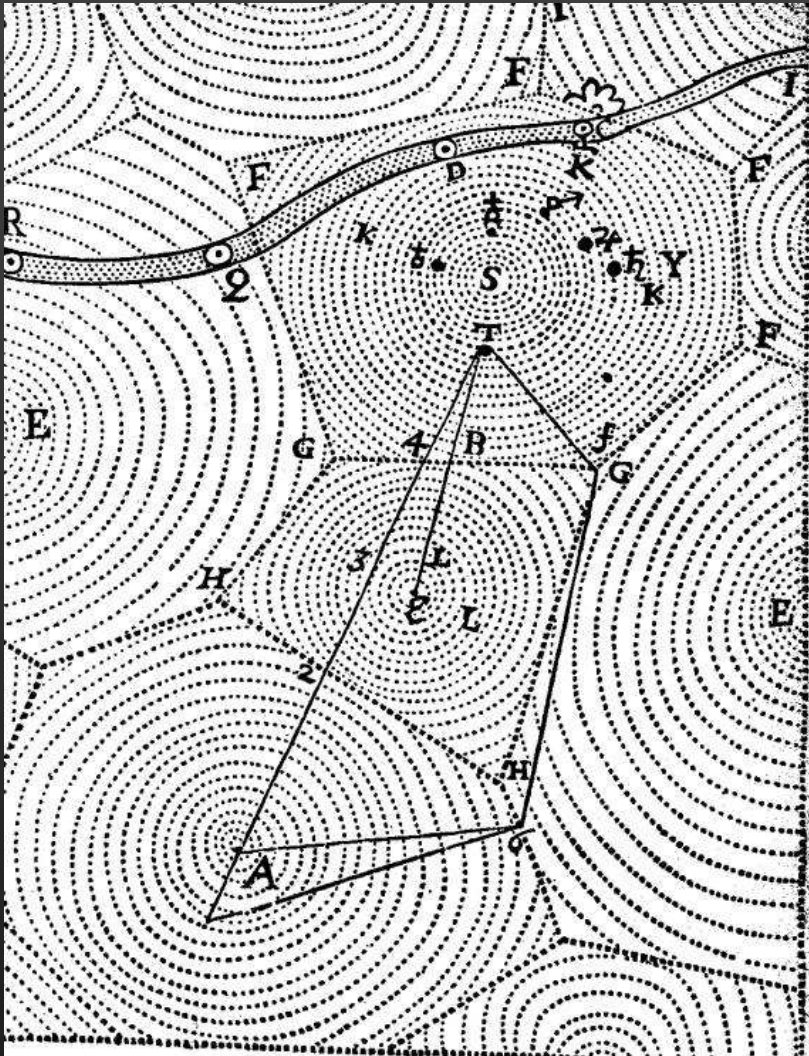
- one of oldest universities in the world

1661: Newton admitted to Trinity College



- admitted as “subsizar” (has to perform menial duties for older or richer students)

Student in Cambridge (1661-65)



- Study Descartes' mechanical philosophy!
- *Principia Philosophiae* (1644)
- No vacuum, no atoms!
- Force by direct contact (pressure and tension)

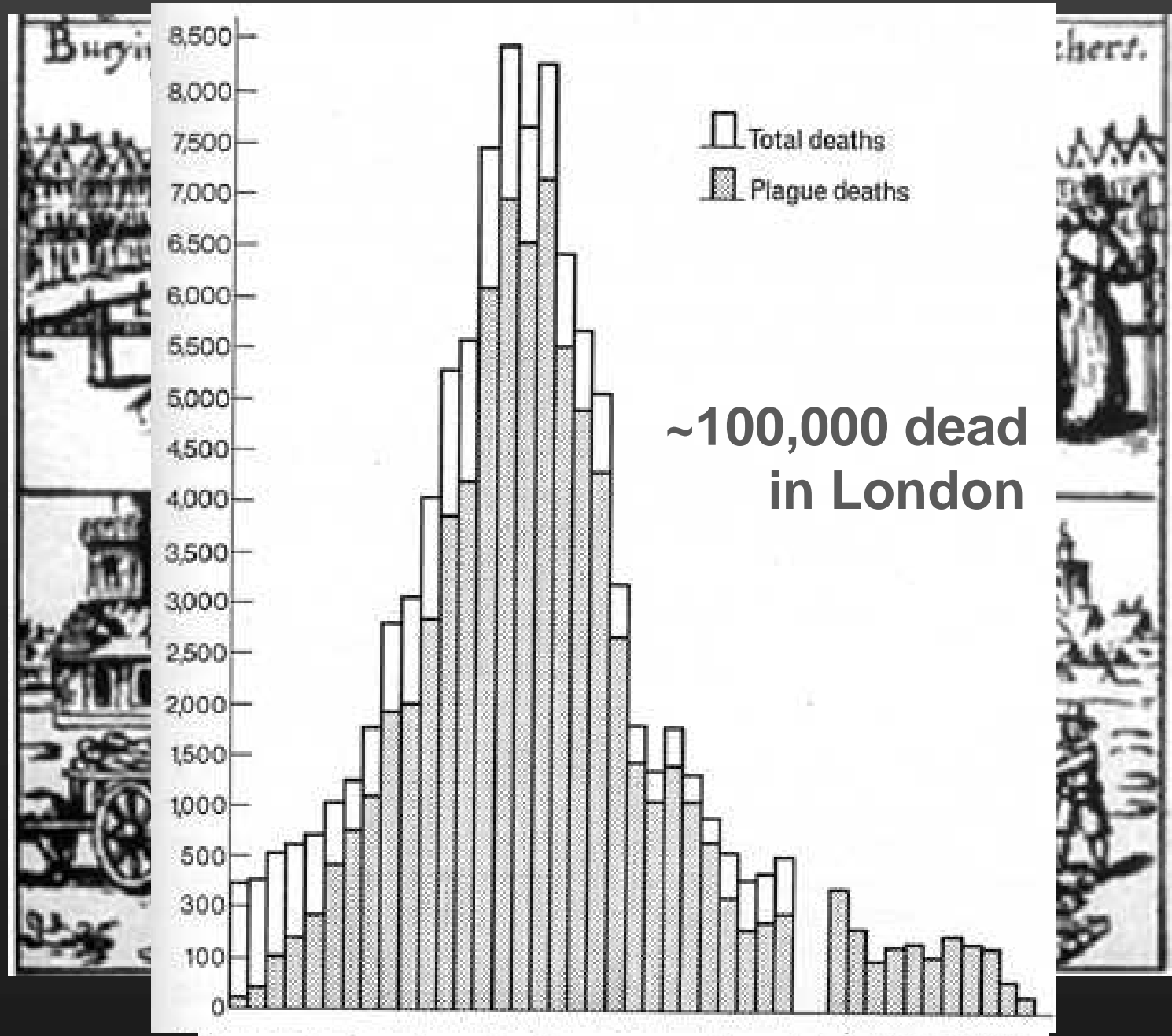
Student in Cambridge (1661-65)



- Study all the mathematics that there is to know!
- John Wallis *Arithmetica Infinitorum* (1656):
 - predecessor of integral calculus
 - introduces symbol for infinity (∞)

John Wallis, 1616-1703

1665: The Great Plague



1666: The Great Fire of London



Christopher Wren: England's Greatest Architect



Christopherus Wren Eques Artificiarum Regalium per totam ANGLIAM

- 1632 – 1723
- Rebuilt London after Great Fire of 1666
- > 50 new churches
- St Paul's Cathedral
- Savilian professor of astronomy at Oxford

Wren: Rebuilding London



- St Paul's Cathedral

Newton during Plague Year: Annus Mirabilis

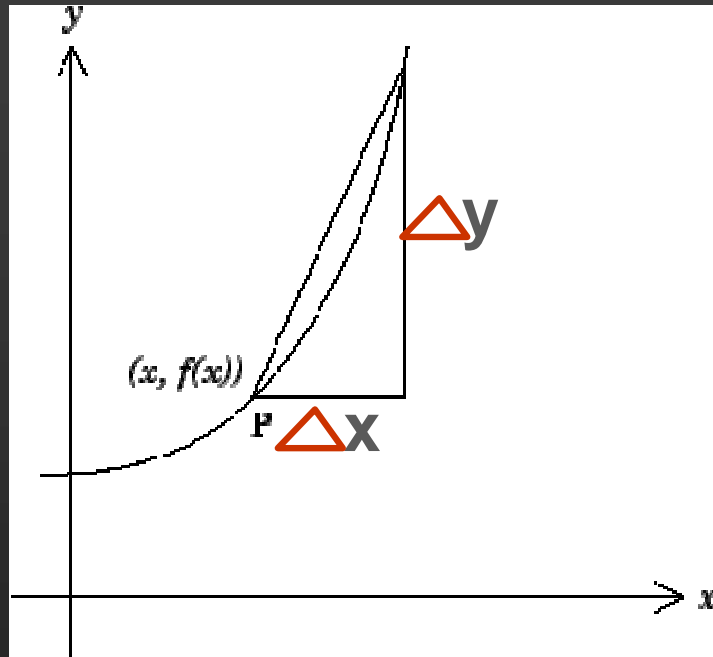


“The Miraculous Year”
(1665-66)

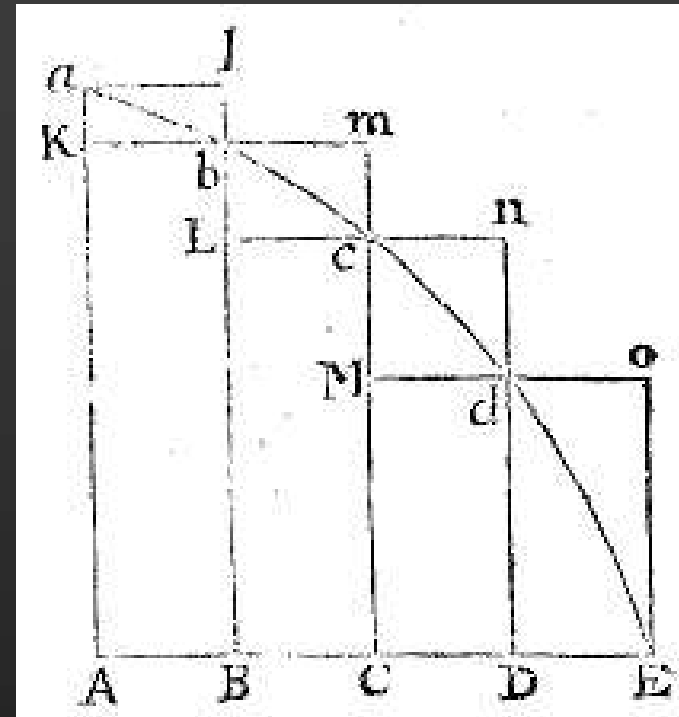
- Return to Woolsthorpe
- 3 Great Discoveries:
 - Calculus
 - Nature of Light
 - Universal Gravity

Annus Mirabilis I: Calculus

Differentiation

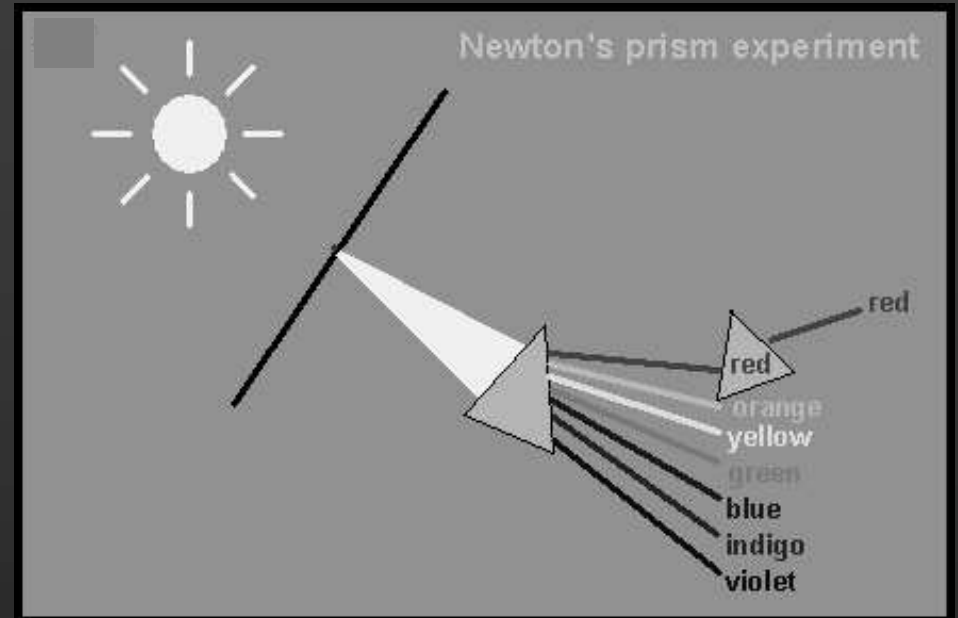


Integration



- independently discovered by Leibniz in Germany (giving rise to ugly priority dispute later on...)

Annus Mirabilis II: Optics



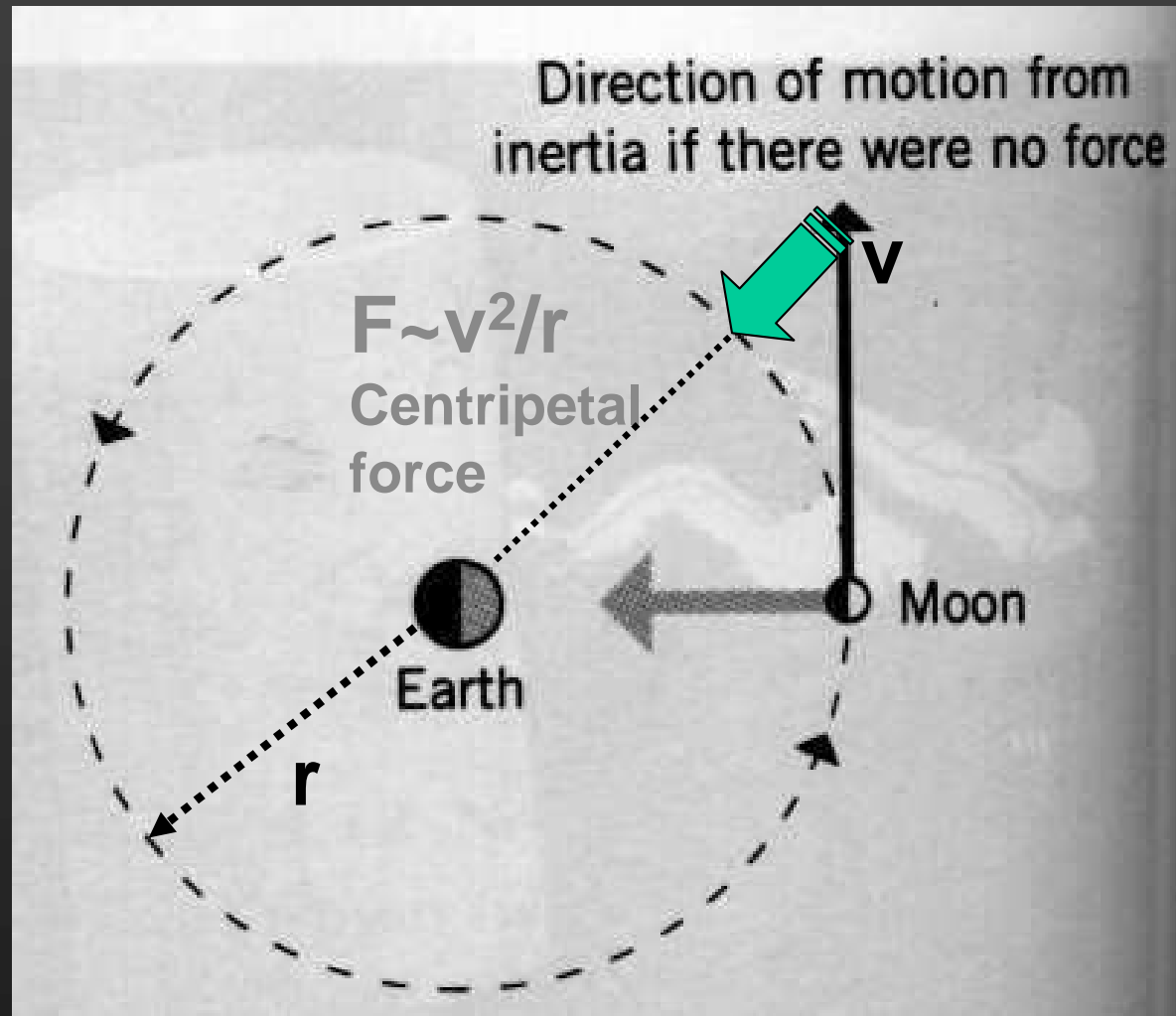
- white light is composed of different colors!

Annus Mirabilis III: Universal Gravity



- Newton asks: What if the *same* force (gravity) causes fall of apple and keeps Moon in orbit around Earth???

Annus Mirabilis III: Universal Gravity

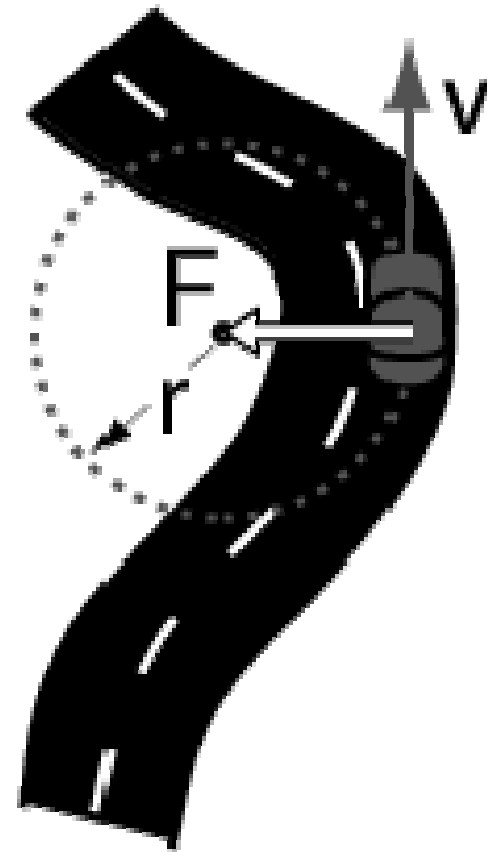


- Moon is constantly falling toward Earth (as is apple)!

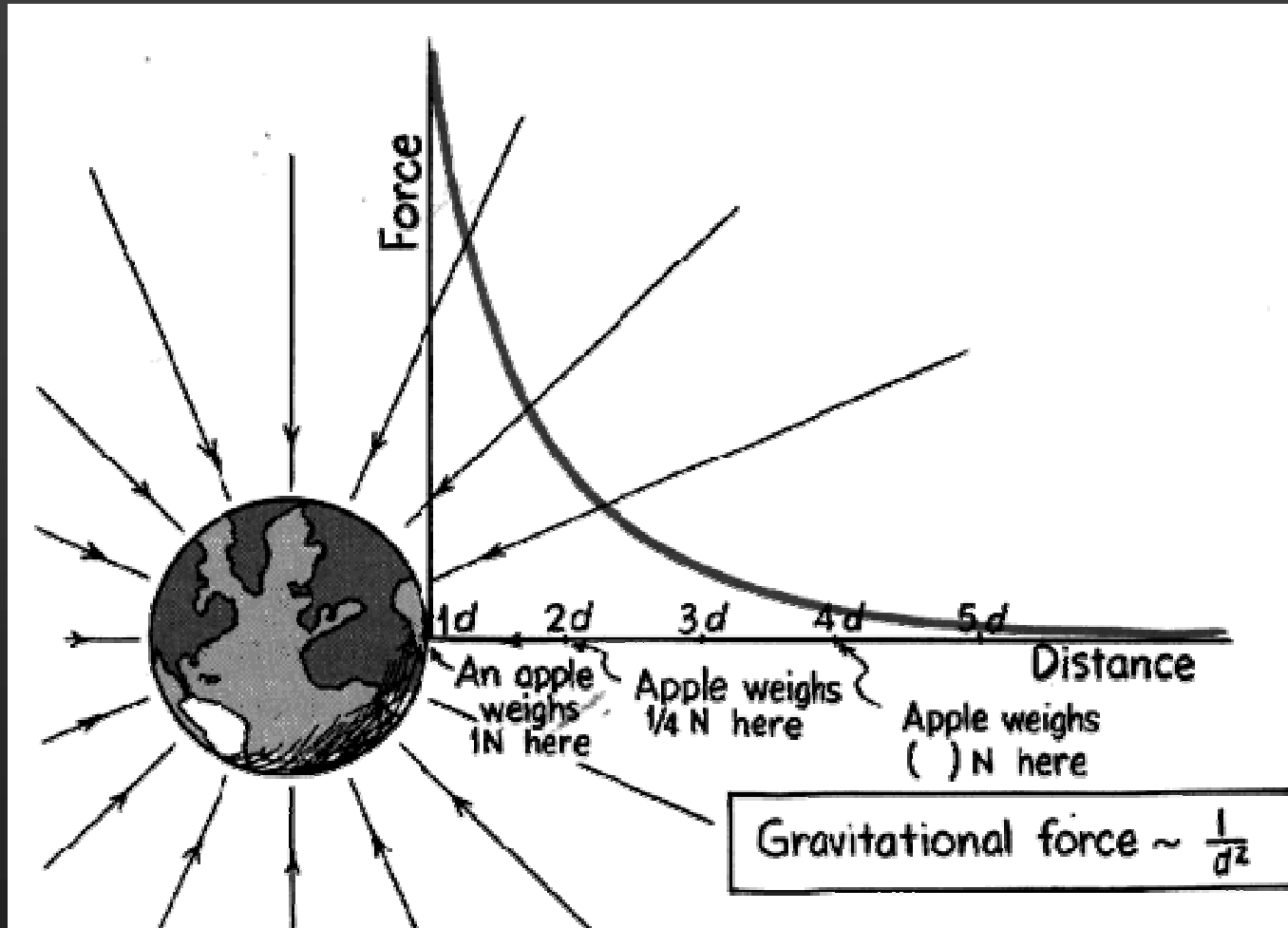
Experiencing the Centripetal Force

$$F_{\text{centripetal}} = m \frac{v^2}{r}$$

$\frac{v^2}{r}$ is the centripetal acceleration

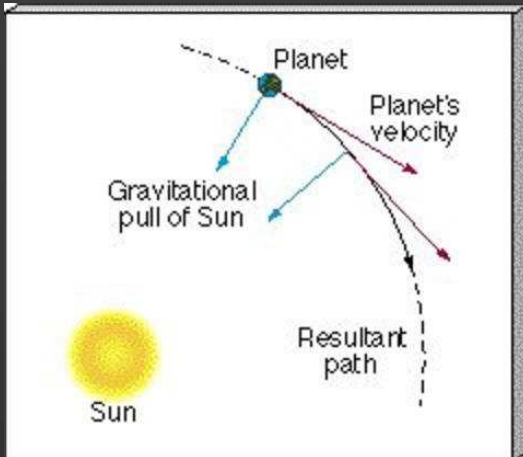


Annus Mirabilis III: Universal Gravity



- Earth's gravitational pull is $\sim 1/3600$ weaker at location of Moon compared to surface (apple)!

Annus Mirabilis III: Universal Gravity



$$F \sim v^2/r$$

Centripetal force

+

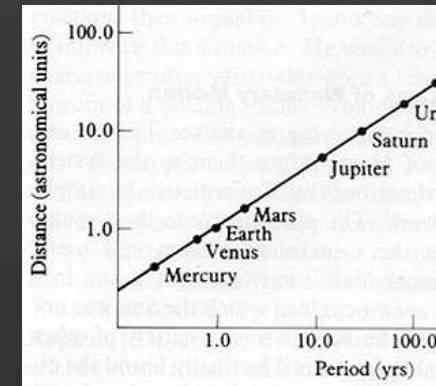
$$P^2 = r^3$$

Kepler's 3rd Law



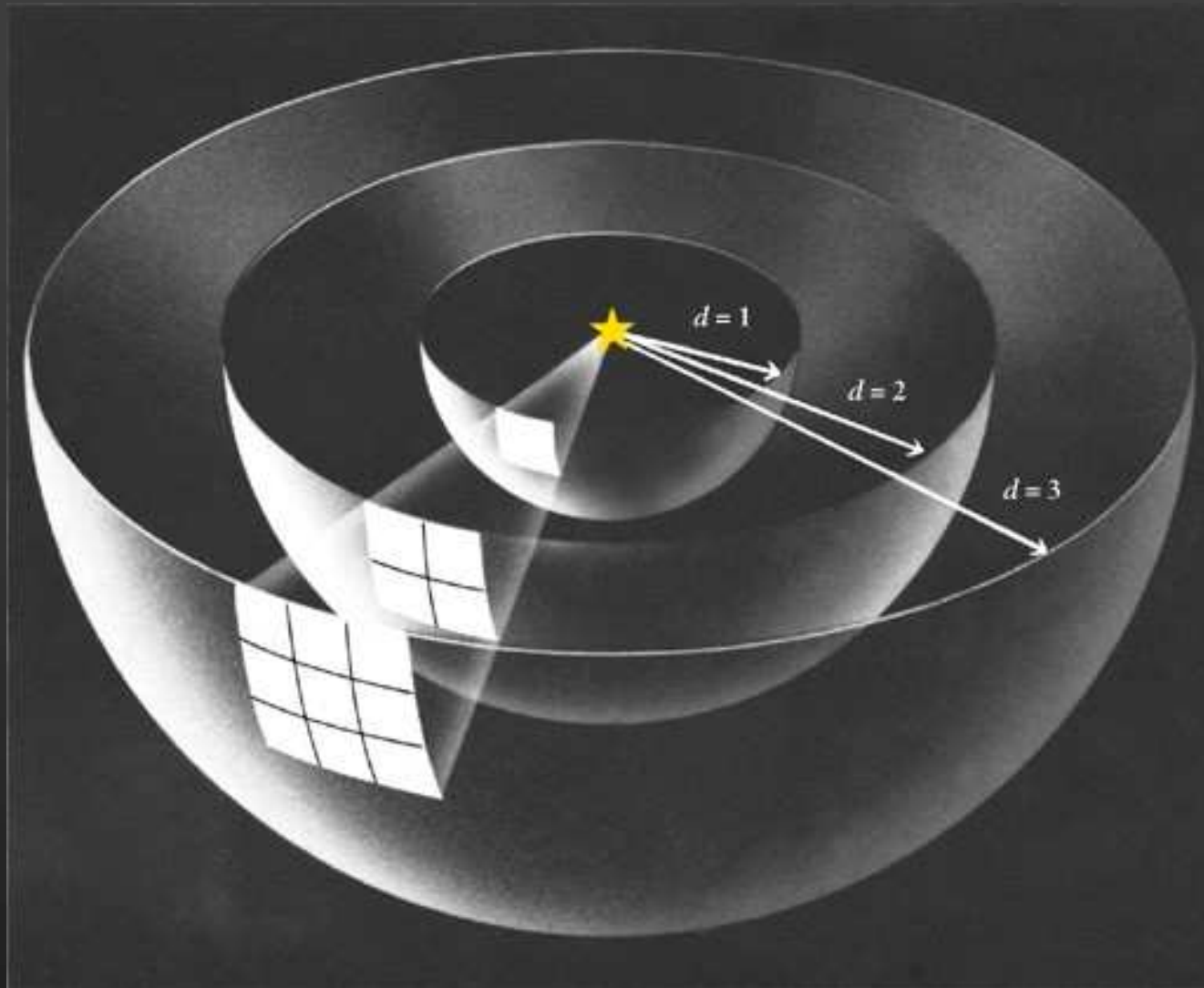
$$F \sim 1/r^2$$

Inverse-square law



- Kepler 3 + Galilean inertia = inverse-square law!

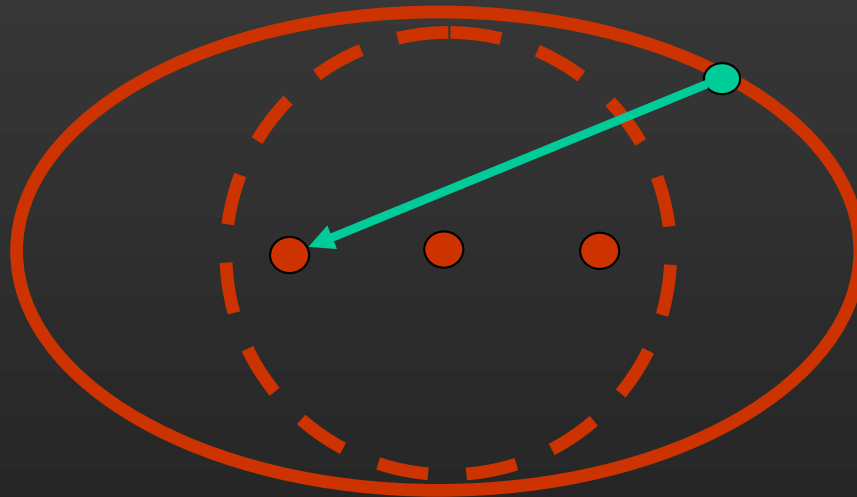
Annus Mirabilis III: Universal Gravity



- Intuitive nature of inverse-square law!
(compare to dilution of light over growing surface)

Annus Mirabilis III: Universal Gravity

- Inverse-square law for force of gravity
 → Big remaining problem:



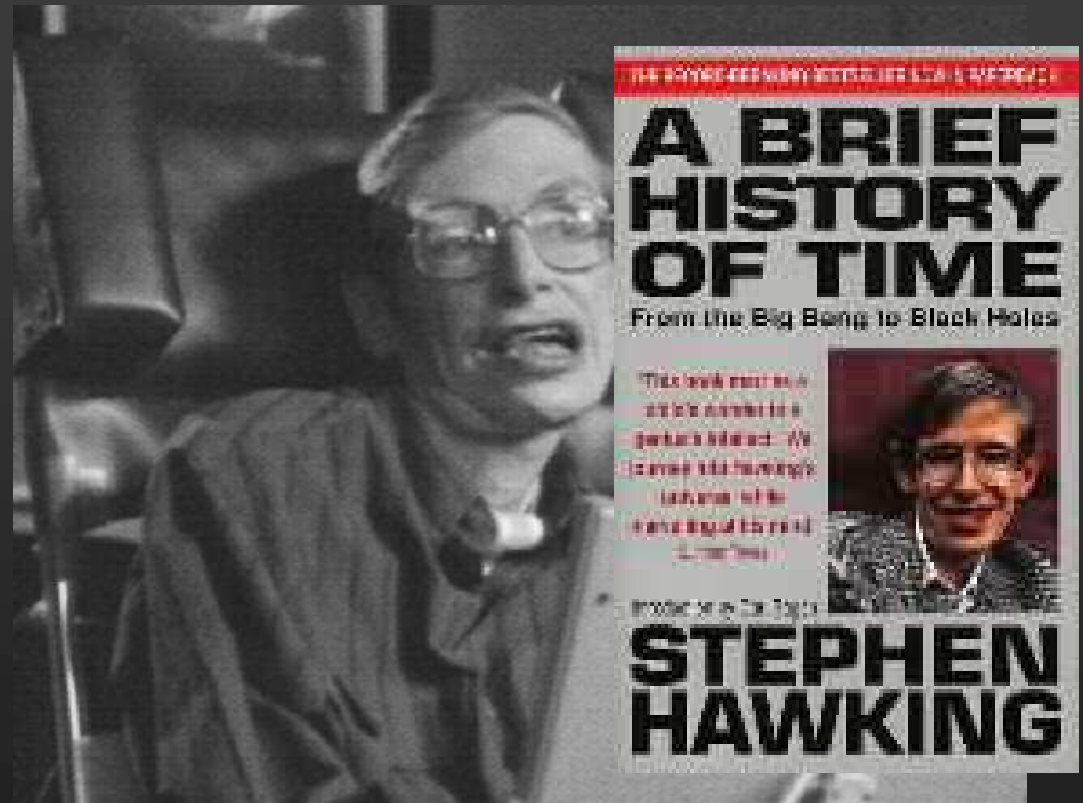
- Does it also work for *elliptical* orbits???

Newton's Return to Cambridge

- 1669: Lucasian Professor for Mathematics



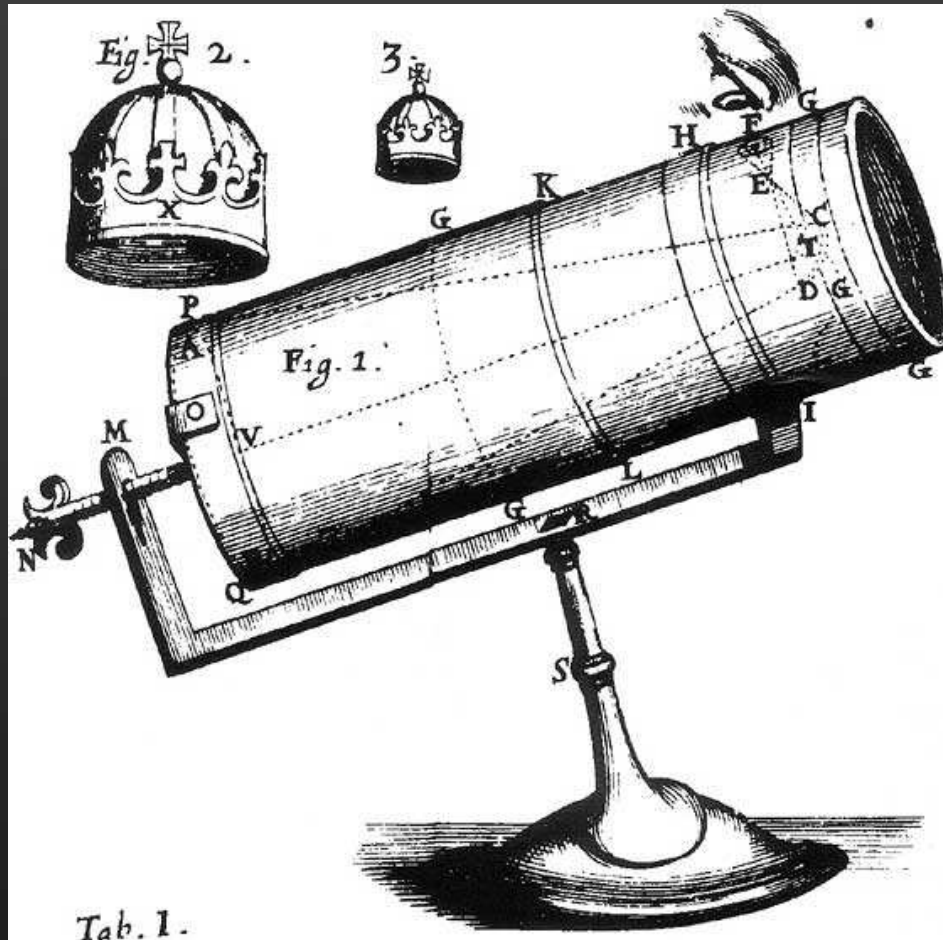
Isaac Barrow:
1st Lucasian Professor



Stephen Hawking:
17th Lucasian Professor

Newton's Return to Cambridge

- 1671: Design for new (reflecting) telescope



- earns him membership (as fellow) in Royal Society

En Route to the Principia

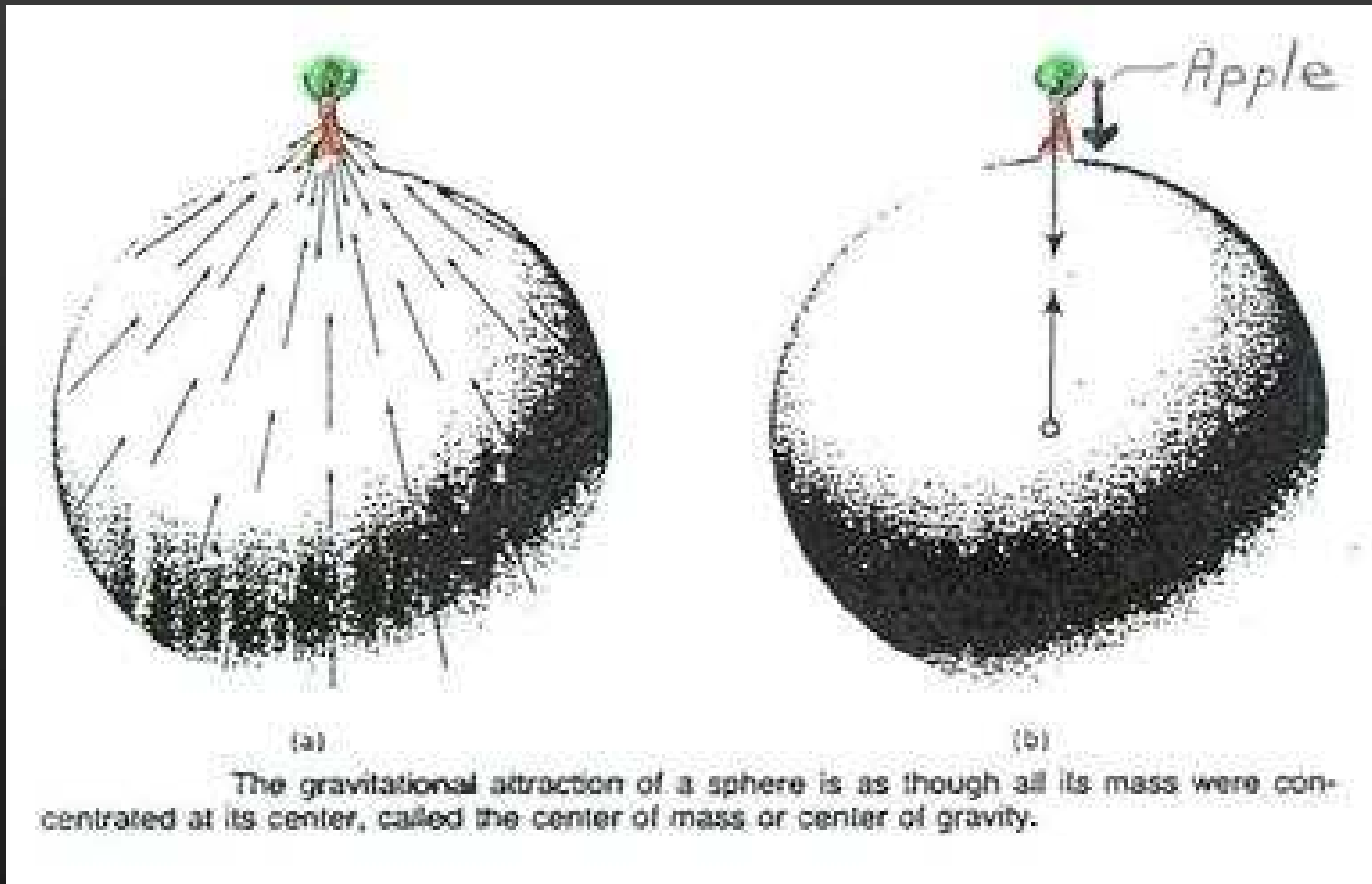
- Newton was *very* reluctant to publish!



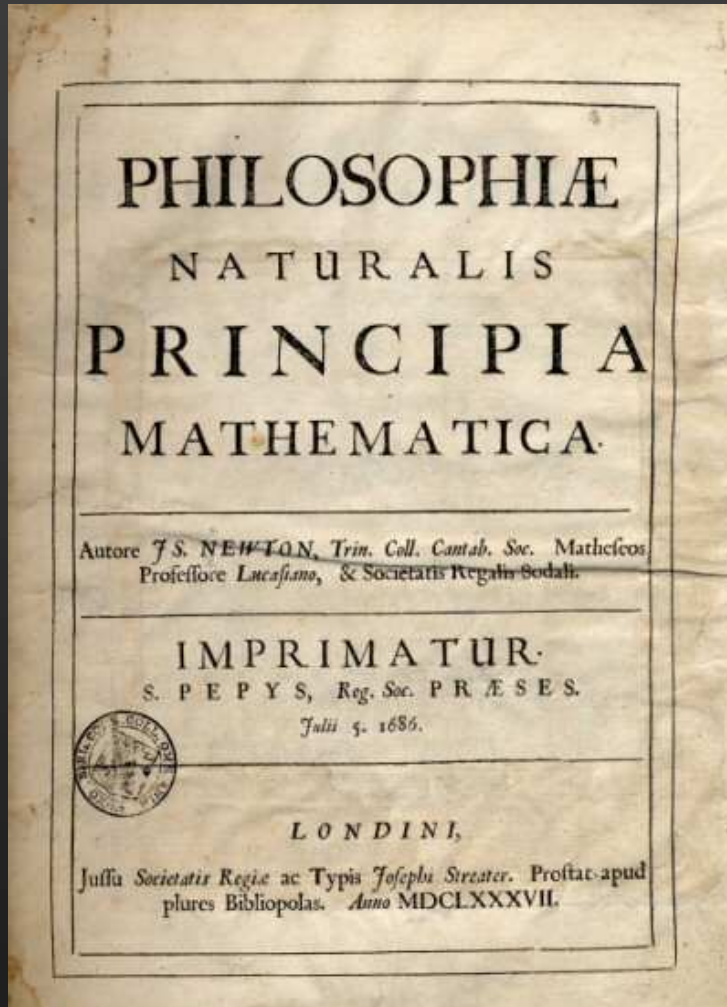
- Edmond Halley (1656-1742)
- member of Royal Society
- Halley's Comet
- first astronomer to observe Southern Sky (from St Helena)
- Convinced Newton to publish *Principia*

En Route to the Principia

- Remove difficulty 2:
 - gravitational force near surface of Earth!



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 (part 1)

- Isaac Newton:
 - founder of modern physics and astronomy
 - led reclusive anti-social life in Cambridge
 - made Lucasian Professorship (Cambridge) famous
- Invented Calculus
 - differential and integral calculus
 - independently discovered by Leibniz (priority dispute)
- Principia
 - the foundational text for modern physics and astronomy
 - laws of motion
 - universal gravity (inverse-square law)