

## The “Age of Reason” (continued)



## Giordano Bruno (1548-1600)



- called a “*martyr of science*” (may be an *overstatement*)
- believed in “*free thinking*”; explored ideas such as *Arab astrology* in *forbidden books*
- *critical* of church's “dogmatic theology”
- vocal *proponent* of *heliocentric model*

- *Earth* was just one of many celestial bodies
- advanced a *plurality of worlds* (like *quantum*?)
- believed in a *homogenous* universe, with *everything made of same materials*
- heavens *not* composed of *quintessence*

• his universe was *stable & permanent* (*eternal*)

*Q: Why did his ideas not sit well with church?*

- convicted of *blasphemy, immoral conduct, heresy*
- *burned in Rome* as a *heretic* by *Inquisition*

## Bruno's Trial

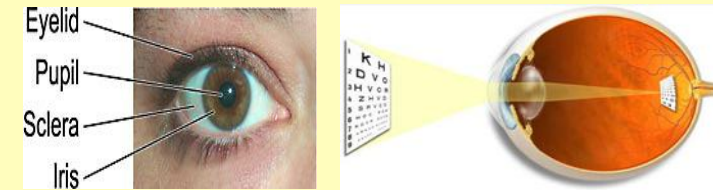


## Campo de' Fiori, Rome



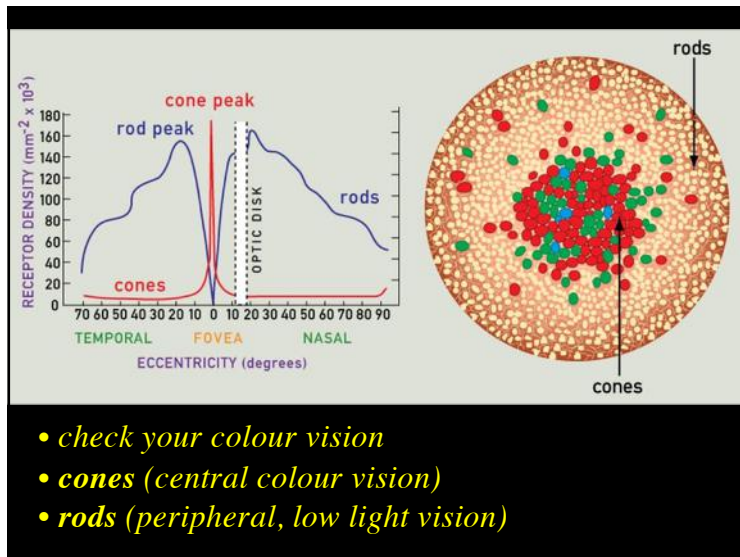
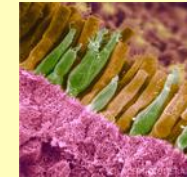
## Viewing the Sky

*Q: What was the major astronomical tool for millenia?*

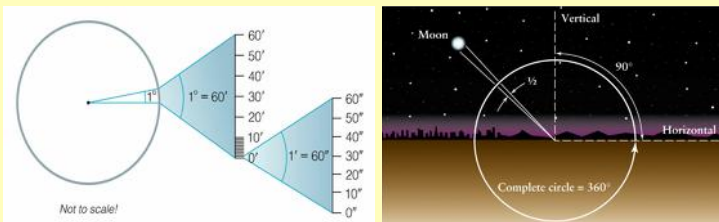


*Q: How does the eye work?*

- light passes through **pupil** and is focused onto **light sensitive cells** of the **retina**



- adult **pupil** can adjust from  $\sim 2\text{-}8$  mm diameter (eg) smaller than the width of your pinky finger
- **dimmest** stars we see:  $1/100$ th of brightest stars
- **angular resolution** of eye  $\sim 1$  arcmin (“detail”)



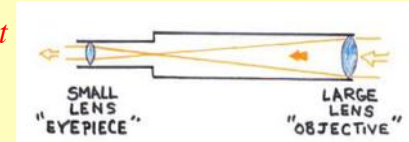
- (eg) **Moon** is  $\sim 30$  arcminutes across in size;
- Jupiter**, at closest to Earth,  $\sim 0.8$  arcminutes



## The Telescope

*Q: What do telescopes do?*

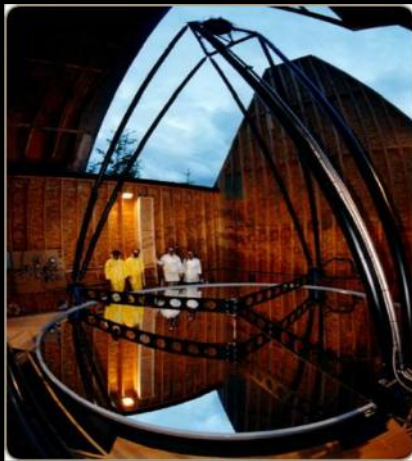
- collect & focus light
- **refractor** (lens)
- **reflector** (mirror)



(eg) rain & buckets

- **telescopes** (“light buckets”) allow us to see fainter objects & more detail (**resolution**)
- **refractor** invented in **Netherlands** (~1600)
- used by **sailors**

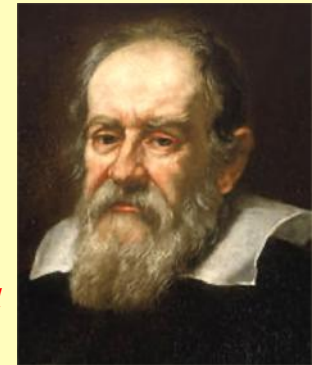
## UBC's 6 m liquid mirror



## Galileo Galilei

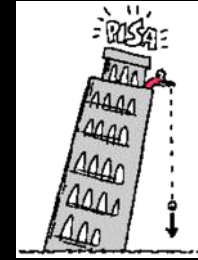
(1564 - 1642)

- born in **Pisa, Italy**
- grew up in **Florence**
- intended to enter **priesthood**
- ended up in **medical school** then studied **mathematics**
- **Roman Catholic**; had 3 **illegitimate children**
- daughter **Virginia (Maria-Celeste)** sent to **convent**



- pioneer in field of **quantitative experimentation** (eg) rolling balls on inclined planes, Tower of Pisa
- believed **laws of nature are mathematical**:  
“the universe ... is written in the language of mathematics”
- **tried** to be a good **Catholic** but his adherence to objective interpretation of experimental results led to a rejection of **dogma** (unsupported arguments)
- willing to **change views due to observations**
- separation of **science** from **philosophy, religion**

- **DEMO**: objects fall **independent of mass**

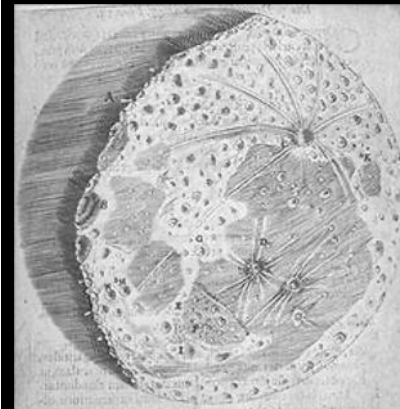


- verified on **Apollo 15 (Dave Scott)**

- in 1609 he learned of **telescopes**
- early **telescopes** were optically **poor** & only **3x magnification**, but Galileo made better ones (**30x**)
- observed **mountains on Moon**, **phases of Venus**, **moons orbiting Jupiter**, **sunspots**, **supernova**
- convinced him **heliocentric model** was **correct**
- went to **Rome (1611)** to share his findings (!)
- **Vatican** unconvinced - **alternative explanations** (eg) telescope “made things up”, flocks of birds...



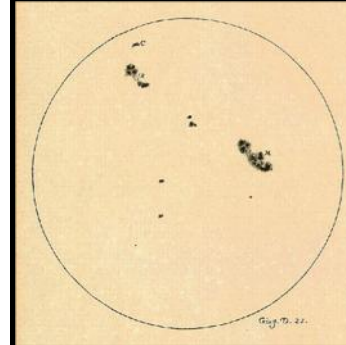
## Galileo's drawings



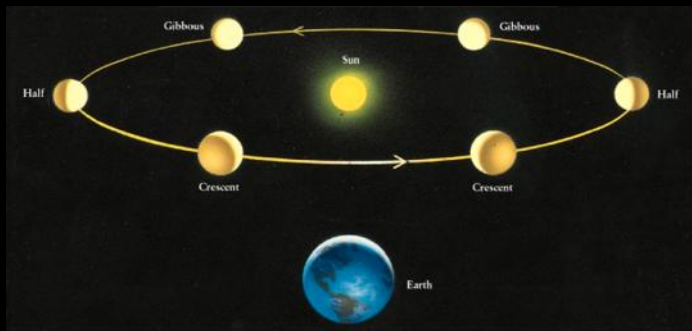
## Imperfect Moon



## Sunspots

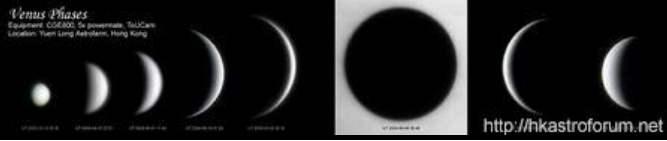


## Phases of Venus



### Venus Phases

Experiment: COSMOS in Government, Tai Chi Center, Yuen Long, Antiklinik, Hong Kong



<http://hkastroforum.net>

## Moons of Jupiter



*Observations of Jupiter*

20.10.1997	0 **
30.10.1997	** 0 *
2.11.1997	0 ** *
3.11.1997	0 * *
3.11.1997	* 0 *
4.11.1997	* 0 **
6.11.1997	** 0 *
8.11.1997	* ** 0
10.11.1997	* * * 0 *
11.11.1997	* * 0 *
12.11.1997	* 0 *
13.11.1997	* ** 0 *
14.11.1997	* * * 0 *

## Stars of the Milky Way



*Q: How did observations support helio model?*

- *mountains on the Moon, sunspots: imperfections*
- *phases of Venus: in geocentric model only new & crescent phases of Venus should be visible*
- *supernova (1604): new star - heavens DO change*
- *Jupiter's moons: not everything orbits the Earth!*
- books *Siderius Nuncius* ("*Starry Messenger*"), (1610) & *Dialogo...* ("*Dialogue...*"), (1632)

*"In this present small treatise I set forth some matters of great interest for all observers of natural phenomena to look at and consider..."*

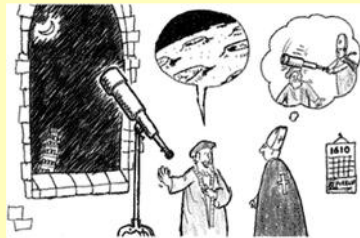
- believed *Copernicus*, but *De Revolutionibus...* placed on *banned list*

- warned by church to "cease & desist" (1616)

*Q: Why such a big deal?*

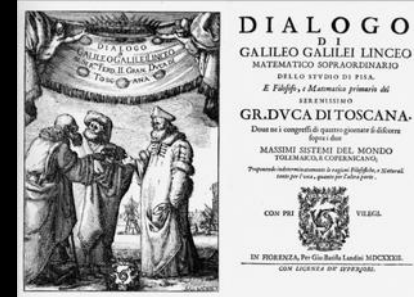
- since Middle Ages scholars had taught that *understanding came through faith (St. Augustine): "Believe in order to understand."*

- *Galileo: "Bible tells us how to go to heaven, not how the heavens go."*



Galileo discusses his discoveries with the church.

## Dialogue concerning the two chief world systems



- "conversation" on *helio vs. geocentric models*
- *geocentric view presented by "Simplicio"*

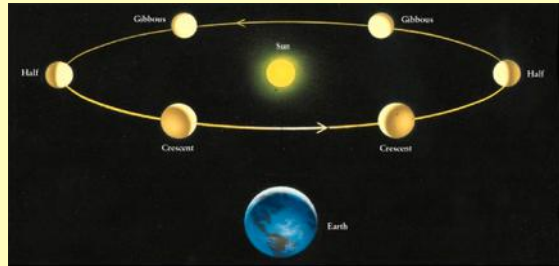
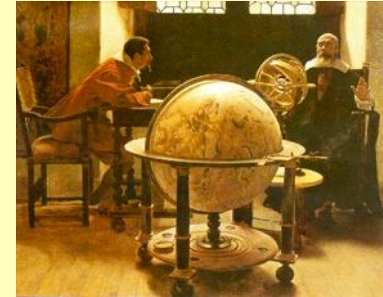
# Galileo & Inquisition



- **Catholic Church** tried **Galileo** for **heresy** in **1633** “for following the position of Copernicus, contrary to the ... Holy Scripture” & forced him to **recant**

**Q:** Why didn't he “stick to his guns?”

- tried in the **same room** as **Giordano Bruno**
- put under **house arrest** for remainder of his life
- went **blind** by **1638**
- **church** “apologized” **1992 & 2000 (JP II)**



**CLICKER:** How did the *observed* phases of Venus support the *heliocentric* over the *geocentric* model?

- (a) **more phases could be seen than expected**
- (b) **Venus is always fully lit being nearer the Sun**
- (c) **the phases were opposite to those of the Moon**
- (d) **the phases took place faster than expected**

# Isaac Newton

(1642 - 1727)



- **English**
- born **just after Galileo died**
- studied at **University of Cambridge** (at age 19)
- had an **undistinguished** undergraduate career
- exposed to works of **Descartes, Galileo, Kepler**
- **Bubonic Plague ("Black Death")** hit in **1665** & **Newton** returned to family's country manor

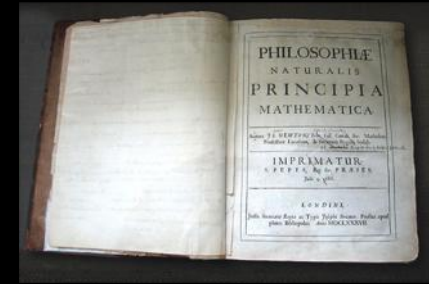
- co-invented *differential & integral calculus*
- responsible for many mathematical theorems  
(eg) *generalized binomial theorem, root finding*

- *Lucasian Prof Mathematics at Cambridge (1669)*
- *Stephen Hawking* later held the same position

- invented **reflecting telescope**
- revolutionized the study of *optics*  
(eg) *showed white light contained colours which could be separated and then rejoined again*



## Newton's Principia



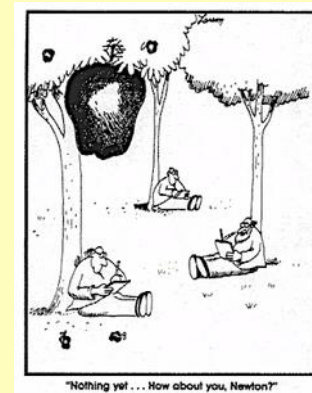
## Newton's Reflector



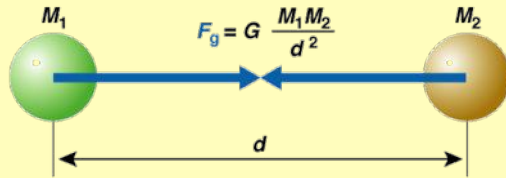
## Law of Gravitation

- discovered in **1666**  
(in an *apple orchard?*)
- likely that *falling apples* caused him to muse on *strength & reach* of Earth's pull...

(eg) *if Earth could pull on apple, why not Moon?*







- any objects with mass **attract** each other
- attraction occurs **even over large distances**
- **6 months** to derive Kepler's laws!! (**calculus**)
- showed **gravity** was the **reason** for those laws

**Q:** Why was this so important?

- **united** heavens & Earth - **same laws** for both

## Newton's Personal Life

- dispute over **invention of calculus** with **Gottfried Leibniz** (whose **notation** we use today):  
*"I have never grasped at fame... but I am very desirous to preserve my character for honesty."*
- **ill-will** with scientist **Robert Hooke** (**elasticity**, **microscope**) over work in **optics & gravitation**
- **paid** for university via **money-lending** operation
- dabbled in **alchemy**
- remained **celibate** during his (entire?) adult life

## Newton's Tomb



- buried in **Westminster Abbey, London**
- tomb used in the **"Da Vinci Code"**

## We still remember them...



## *Review: Age of Reason*

- Greek knowledge was *preserved* and *rediscovered*
- *heliocentric model* made sense but *little evidence*
- *Brahe's* observations & *Kepler's* math: *revolution*
- *Galileo's observations* provide further *proof*
- *Newton: same laws* govern the *heavens & Earth*