Galileo in Your Classroom

International Year of Astronomy 2009

http://www.astro.utoronto.ca/~percy/stao.pdf

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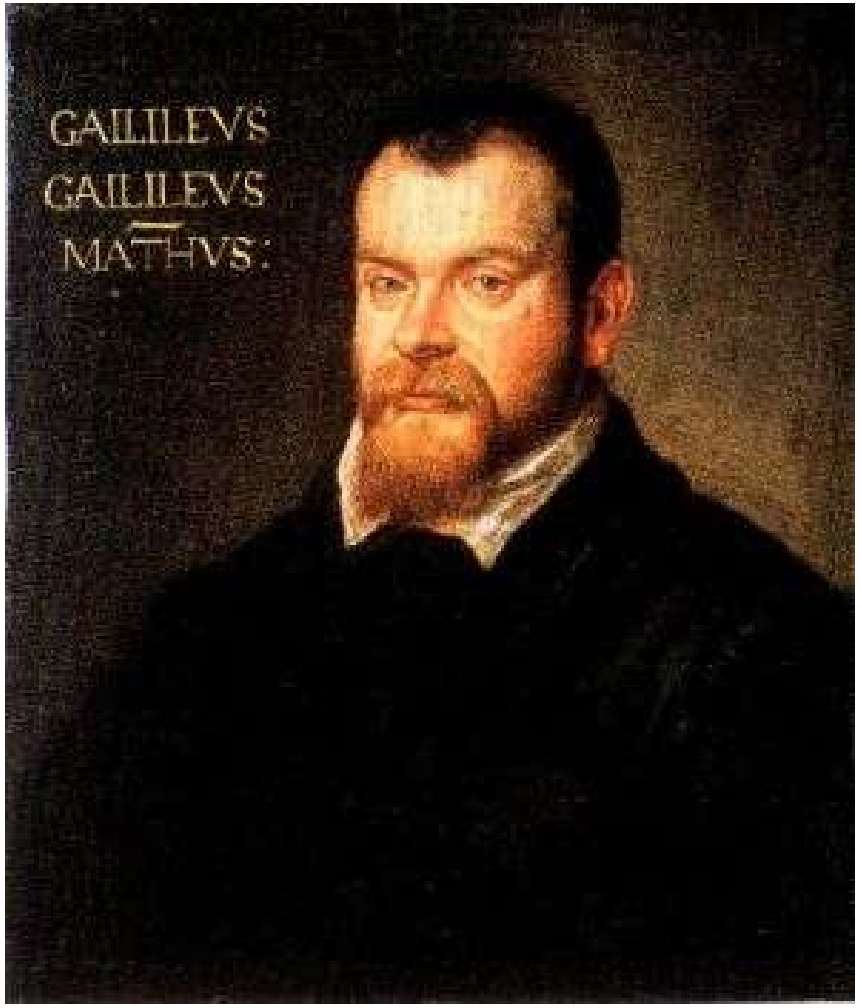
Outline

- International Year of Astronomy
- Galileo
- Pre-Galileo
- Galileo in context
- Galileo: his contributions and discoveries
- Their connections to the curriculum
- Celebrating IYA, and the multidisciplinary potential of astronomy

International Year of Astronomy 2009



- Celebrates the 400th anniversary of Galileo's development and first use of the astronomical telescope
- Led by the International Astronomical Union, supported by UNESCO, and endorsed by the UN General Assembly
- Being celebrated in 147 countries

IYA – The Logo and Slogan

http://www.astronomy2009.org

THE UNIVERSE
YOURS TO DISCOVER

INTERNATIONAL YEAR OF
ASTRONOMY
2009

IYA: Vision and Aims

- Vision: to help the citizens of the world rediscover their place in the Universe through the day and night-time sky, to appreciate the impact of astronomy and basic sciences on our daily lives, and to understand better how scientific knowledge can contribute to a more equitable and peaceful society.
- Aim: to stimulate worldwide interest, especially among young people, in astronomy and science under the central theme “The Universe, Yours to Discover”. IYA events and activities will promote a greater appreciation of the inspirational aspects of astronomy, that embody an invaluable shared resource for all countries.

IYA: Objectives

- to illustrate the remarkable cultural influence of astronomy over time, and its connections with culture today
- to demonstrate the inspirational nature of astronomy, especially for young people
- to remind humanity that we are responsible for the long-term future of our planet
- to show astronomers as a global family of peaceful, international collaborators
- to encourage scientific and critical thinking in society

IYA: Global Cornerstone Projects

- These deal with the deeper cultural aspects of astronomy: bringing astronomers and the public together; inspiring young people; preserving dark skies and astronomical heritage; appreciating the aesthetic value of astronomy; promoting gender equity, and participation by underserved and underdeveloped communities
- One cornerstone project is the **Galileo Teacher Training Program,** whose goal is to train thousands of teachers to not only teach astronomy better, but to train their colleagues.

IYA 2009 in Canada

- Vision: To offer an engaging experience or Galileo Moment to every person in Canada, and to cultivate partnerships that sustain public interest in astronomy.
- Goal: a million Galileo Moments; achieved in October.
- Success: Partnerships between professional and amateur astronomers, and other organizations and individuals in “the astronomical community”; thousands of volunteers.
- Website: http://www.astronomy2009.ca

My School-Support Projects

Partner: **Science Teachers Association of Ontario**

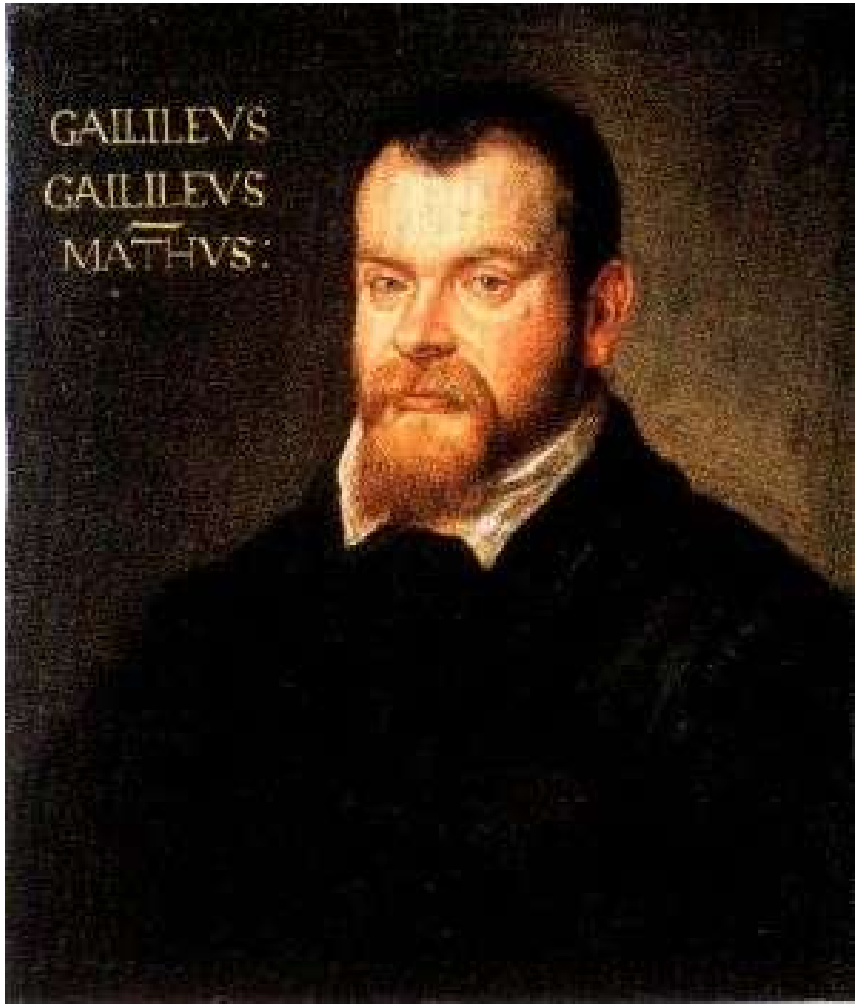
- On-line resource to provide grade nine teachers with a strategy and framework for teaching the unit on astronomy and space [almost done]
- A similar resource for grade six teachers [under development]
- A three-day Summer Institute for Teachers (mostly grade nine), August 17-19, 2009, at University of Toronto.
- A project to connect the IYA GalileoScope with the Ontario optics and astronomy curricula [just starting]

The Science Curriculum and How Galileo Relates.

- The curriculum emphasizes the scientific process, science skills, and STSE: science, technology, society, and environment.
- The telescope is the most important technology for astronomy.
- Galileo's discoveries are specifically related to expectations of the astronomy and physics curriculum.
- He made use of the scientific method to draw his conclusions.
- His results had a strong impact on society, including philosophy and religion.

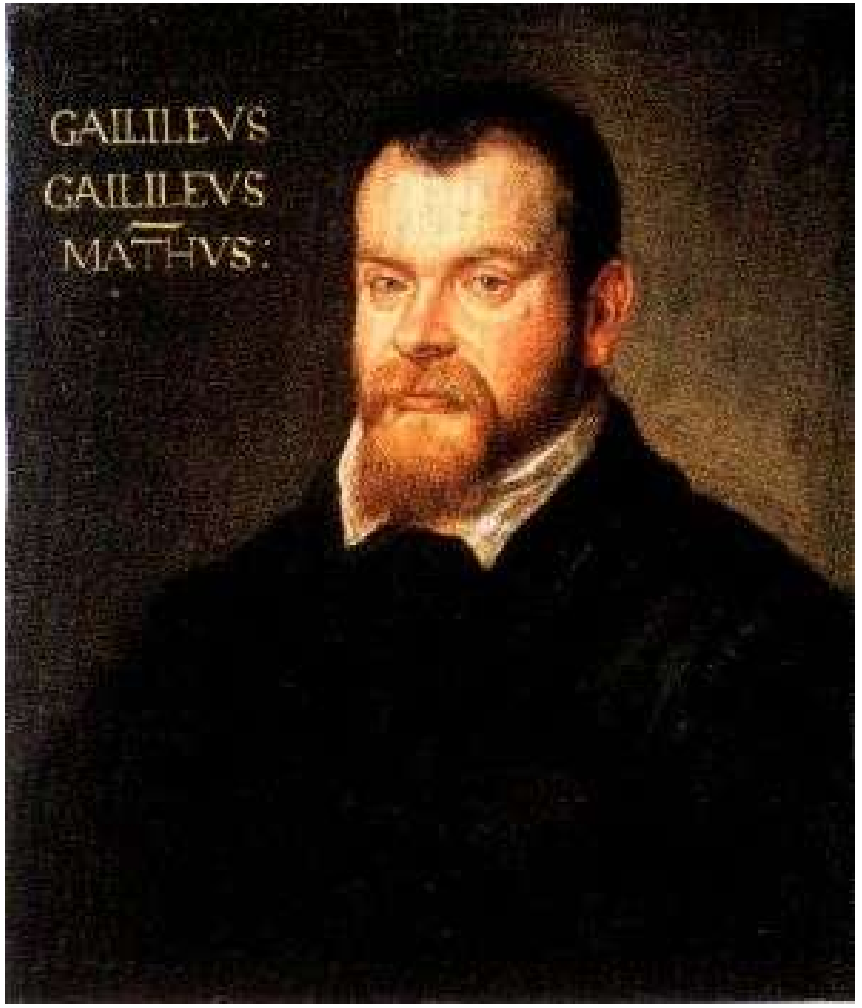
Who Was Galileo?

http://galileo.rice.edu



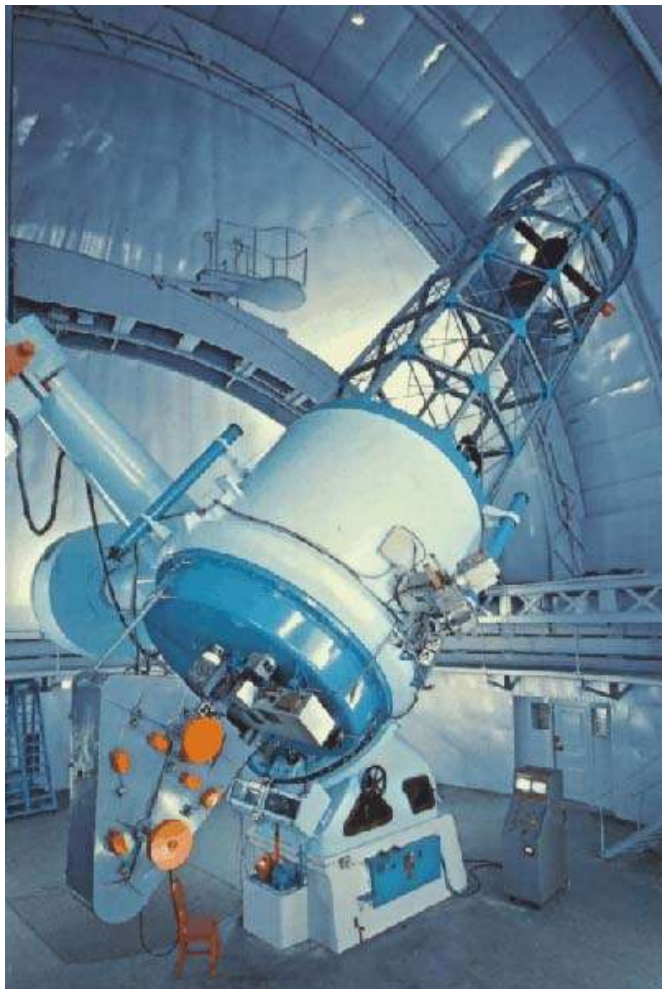
- Developed and first used the astronomical telescope
- Made observations that revolutionized our understanding of the universe, and our place in it
- Advanced “the scientific method”

Who Was Galileo?



- Son of a musician (lutenist), music theorist, with an interest in the physics of music
- Mathematics professor, then mathematician and philosopher to the Medici court
- Had younger siblings, and three illegitimate children to support

Astronomy: What and How

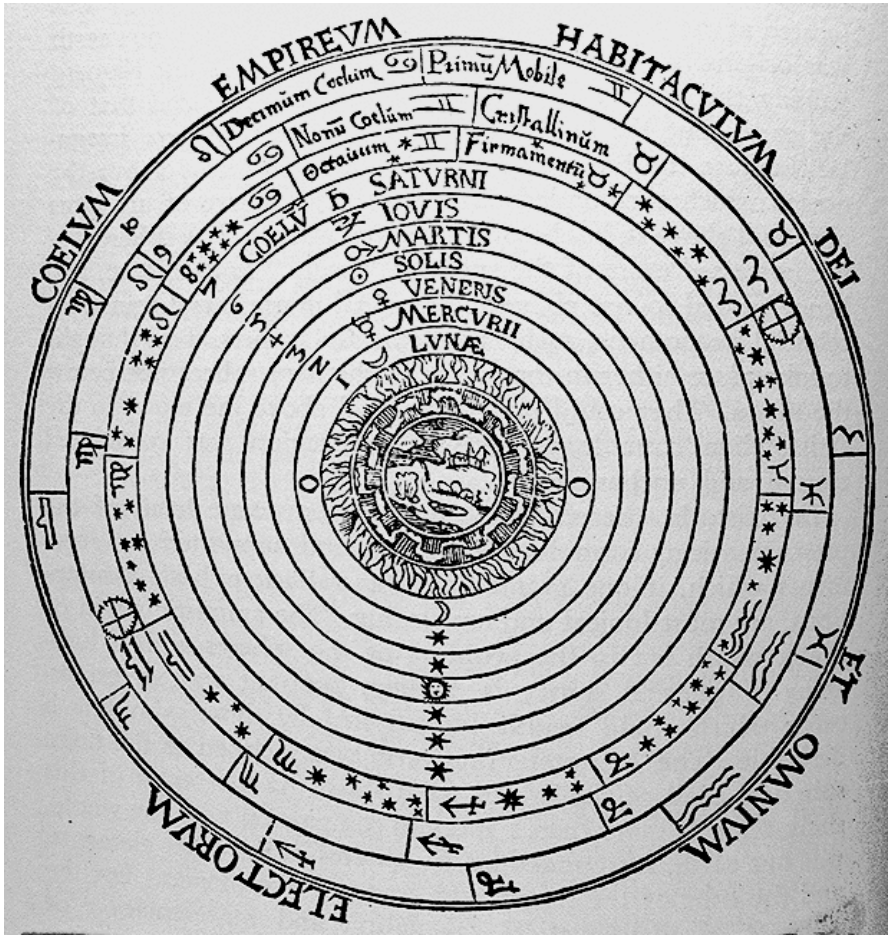


- **Astronomy** is the study of the universe
- It makes use of careful **observations,** using a variety of ground-based and space **telescopes** ...
- ... and the laws of **physics** ...
- ... and **computer simulations** or models ...
- ... and the **scientific method**

Pre-Renaissance Astronomy

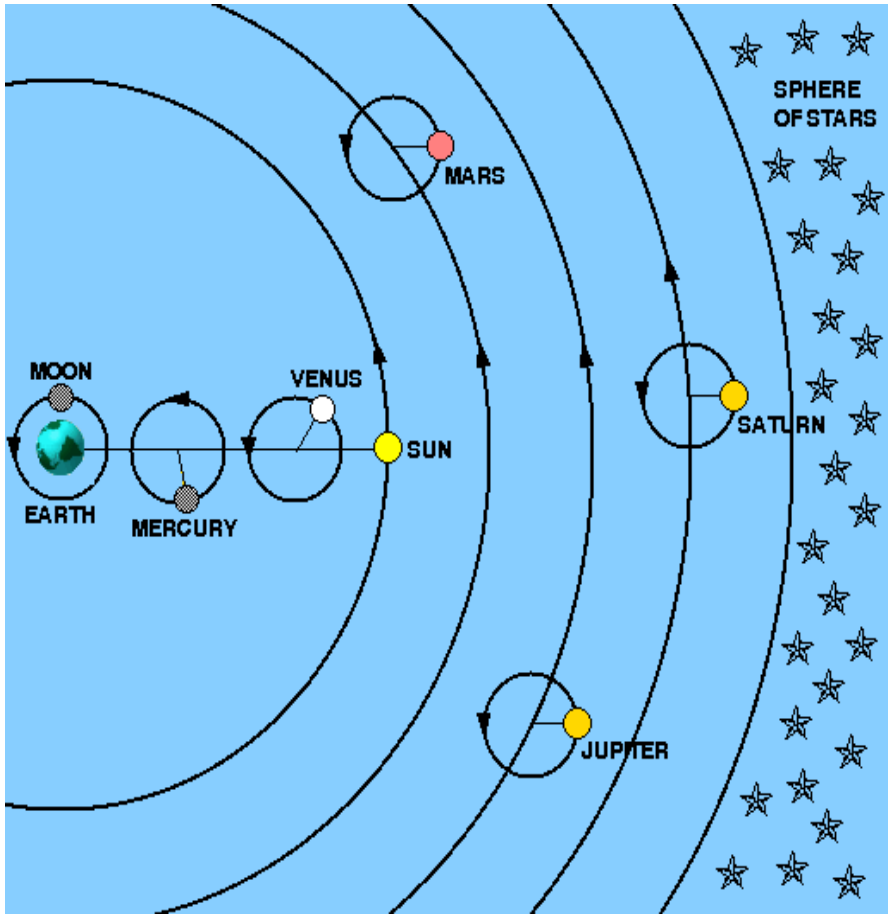
- Practical astronomy: the use of the sky to measure time of day or night, time of year (calendar), and direction
- Constellations: culturally-dependent mythology in the sky
- Sun, moon, and five naked-eye planets: seven days of the week
- Connection of sun, moon, and planets with gods
- Astrology; “it's not in the stars!”
- The determination of the size and scale of the earth, moon, and sun by geometry
- Observations of planetary positions and motions, especially by Islamic astronomers
- **Project: investigate the uses of astronomy in various cultures over time.**

Aristotelian Astronomy



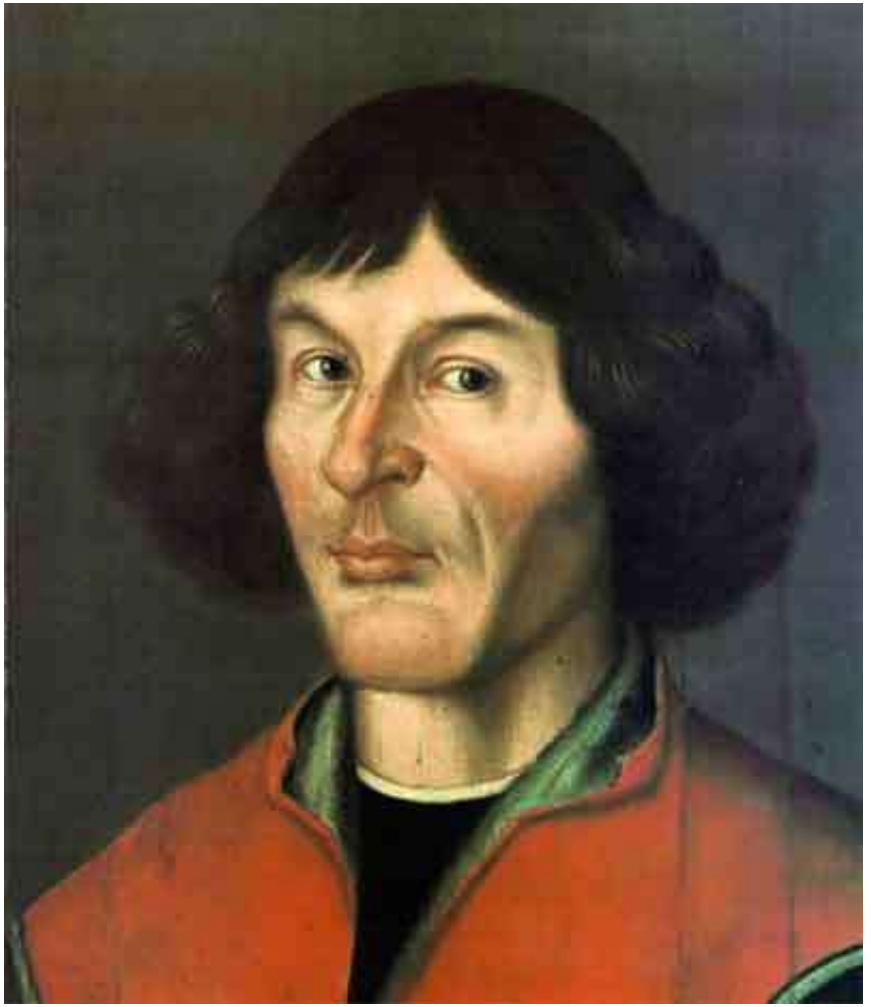
- Earth-centered
- Four elements: earth, water, air, fire
- The heavens were made of perfect, unchanging "quintessence"
- The heavenly bodies were moved by "spheres", making "music" that could be heard only by the mind -- "the music of the spheres"

The Ptolemaic Model



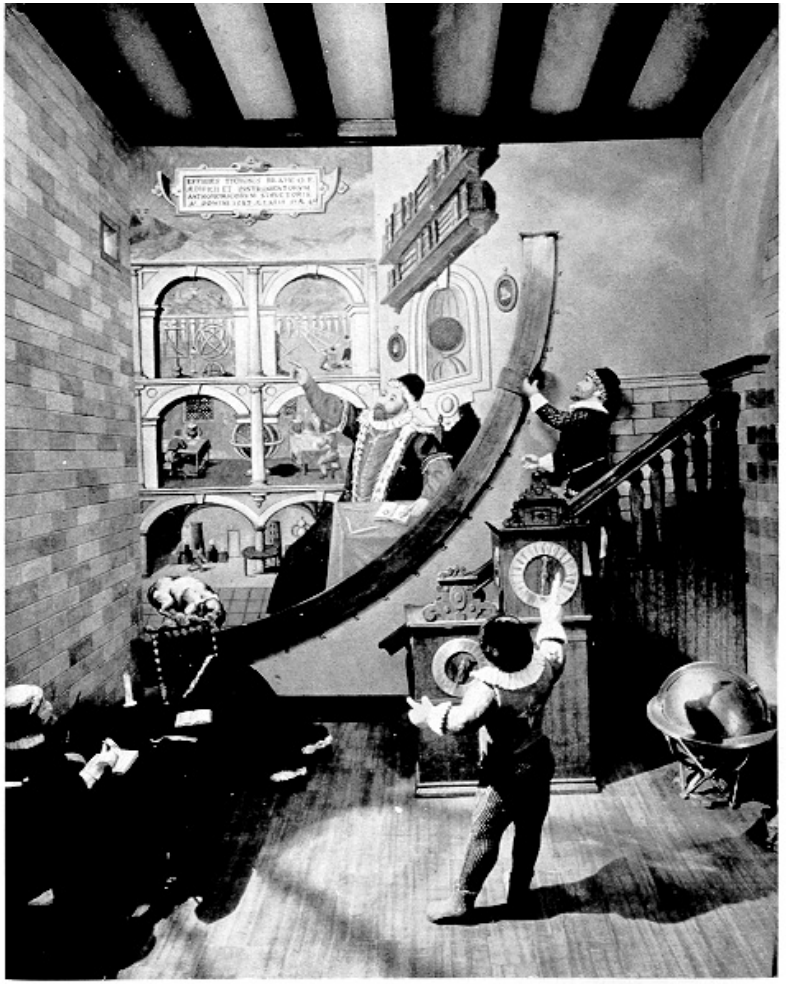
- Earth-centered model
- Based on circular motion, since the circle was the perfect geometrical figure
- Successfully predicted the positions and motions of the planets until the Renaissance

Nicolaus Copernicus (1473-1543)



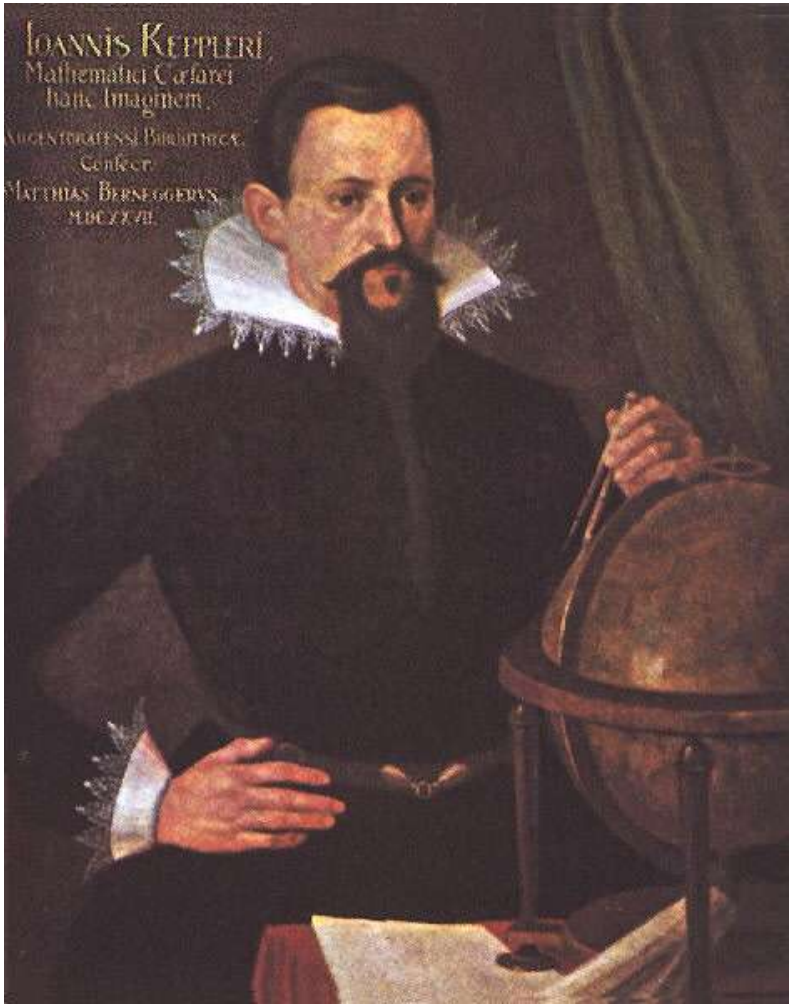
- Polish priest
- Developed a sun-centered model of the solar system, but still based on circles
- Published this, at the end of his life, in *De Revolutionibus*
- This was a very influential book!

Tycho Brahe (1546-1601)



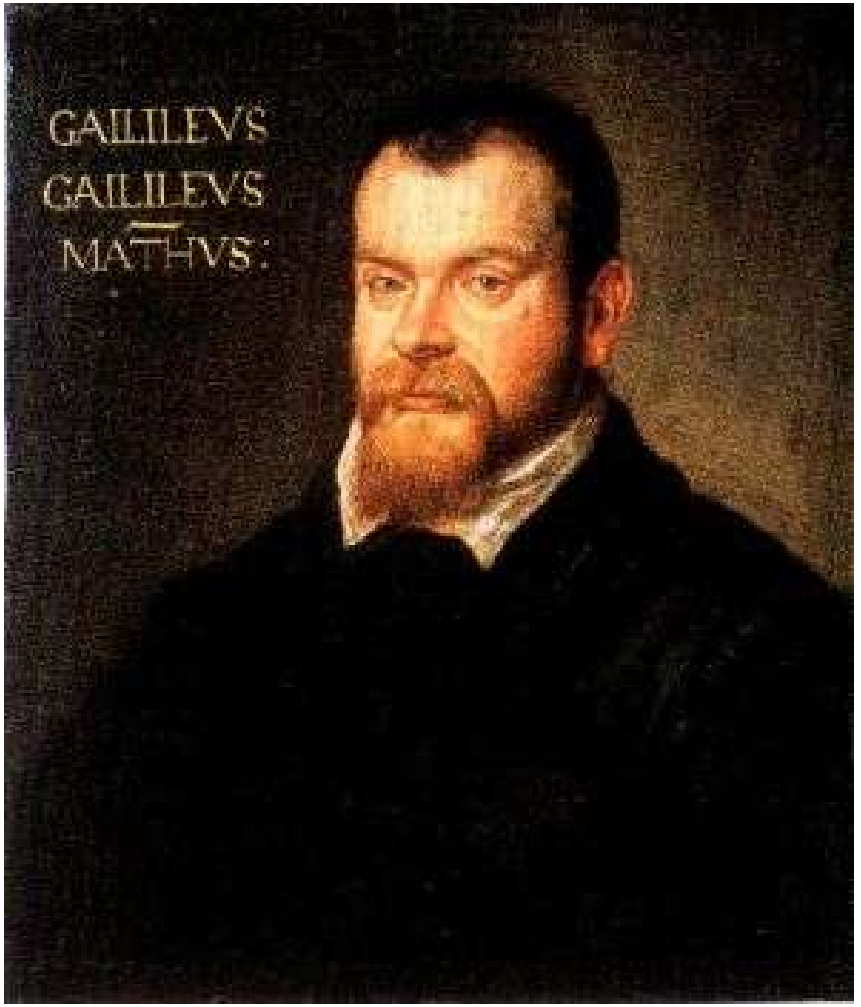
- Danish; (initially) well-supported by the court
- Had the finest observatory of pre-telescopic times
- Made careful, sustained measurements of the positions and motions of the planets, especially Mars

Johannes Kepler (1571-1630)



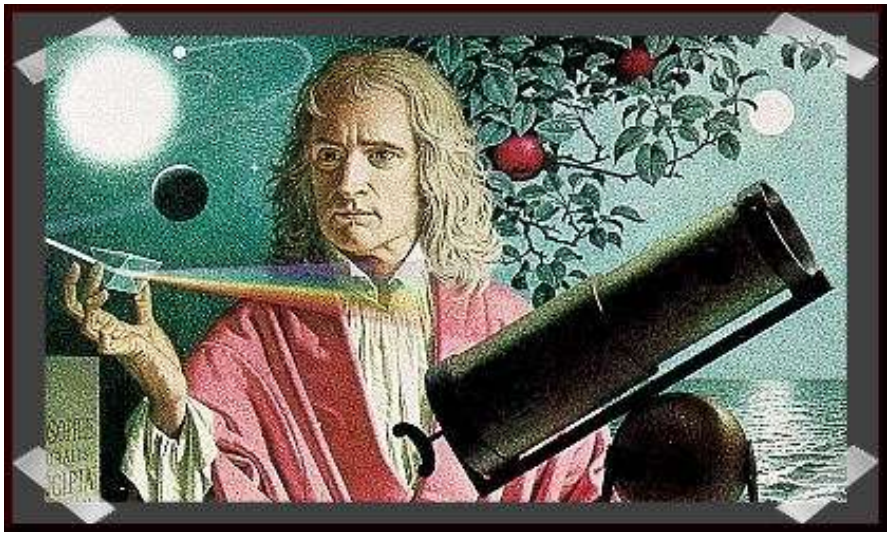
- Interested in mathematical relationships and shapes
- Prague-based mathematician, astronomer, mystic and astrologer
- Using Tycho Brahe's data, he derived three **empirical** laws of planetary motion
- (after about 20 years of effort)

Galileo Galilei (1564-1642)



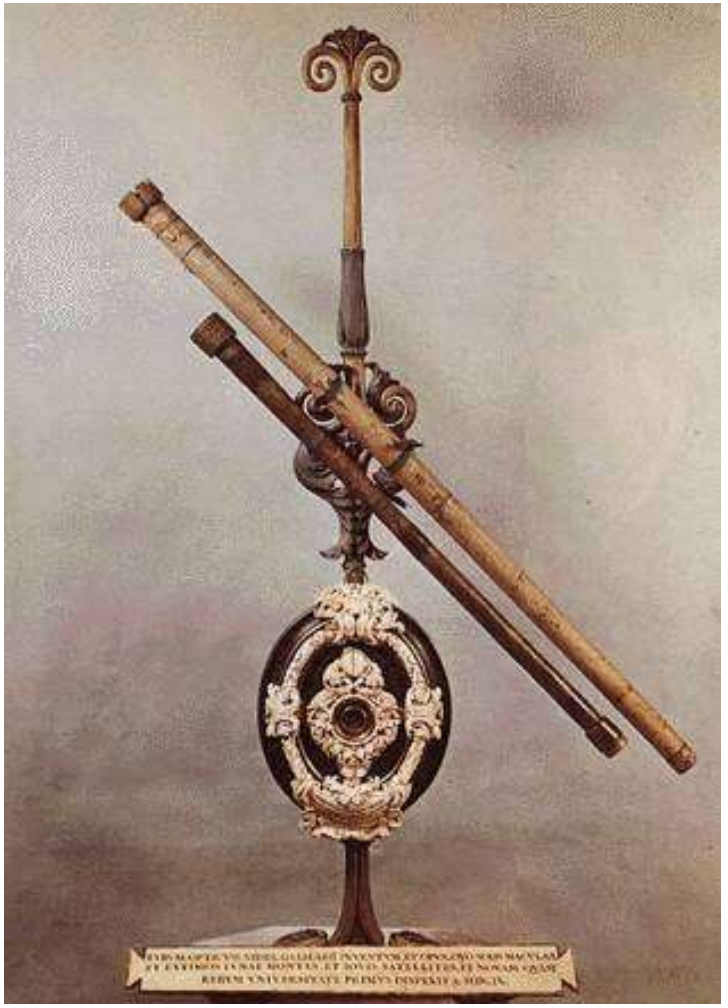
- Developed and first used the astronomical telescope
- Made discoveries that revolutionized our understanding of the universe, and our place in it
- Made significant contributions to physics
- Advanced the scientific method

Isaac Newton (1642-1727)



- Built on Galileo's work to derive three laws of motion
- Formulated the law of universal gravitation
- Published these in his book, the *Principia*
- Developed the reflecting or mirror telescope
- Observed and studied the spectrum of sunlight

The Astronomical Telescope



- The two functions of a telescope are: (i) to gather light [**light-gathering power**] and (ii) to show detail [**resolving power**]
- The telescope is the "enabling technology" of astronomy
- Astronomers now use the reflecting (mirror) telescope developed by Newton

The GalileoScope

http://www.galileoscope.org

A replica of Galileo's telescope, optimized for education

The Galileoscope is more than a telescope — it's a strategic initiative to improve math, science, and technology literacy worldwide. With this easy-to-assemble kit, anyone can explore how optics work and then go outside at night to see the celestial wonders first glimpsed by Galileo 400 years ago!

The Moons of Jupiter

36 OBSERVAT. SIDERAE

Stella occidentaliori maior, ambæ tamen valde conspicuæ, ac splendidæ: vtraque distabat a Ioue scrupulis primis duobus; tertia quoque Stellula apparere cœpit hora tertia prius minime conspecta, quæ ex parte orientali Iouem fere tangebat, eratque admodum exigua. Omnes fuerunt in eadem recta, & secundum Ecliptice longitudinem coordinatæ.

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Ori. * * * * Occ.

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Die 14. nubilosa fuit tempestas.

Die 15. hora noctis tertia in proxime depicta fuerunt habitudine quatuor Stellæ ad Iouem;

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RECENS HABITAE. 37

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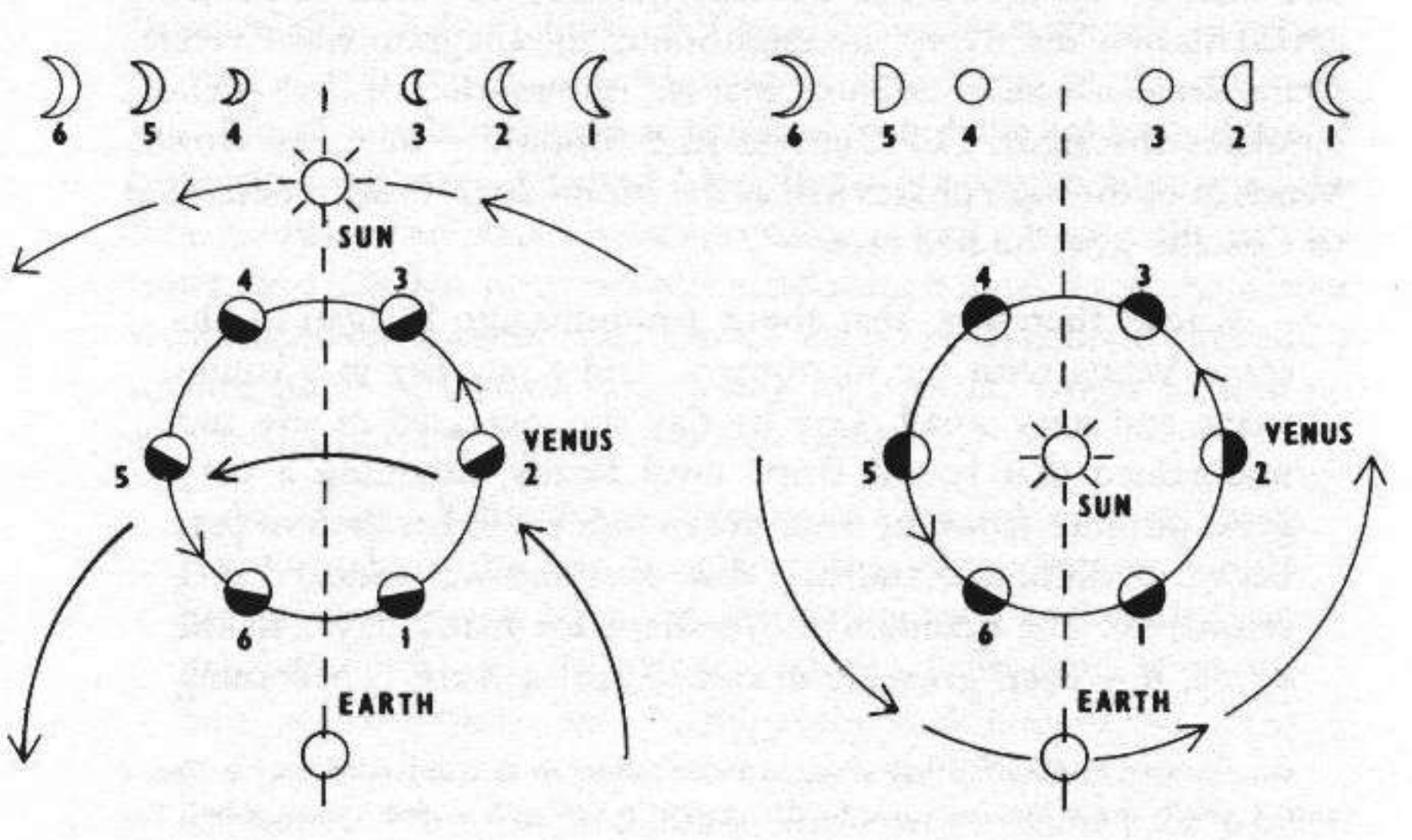
- Galileo observed four satellites revolving around Jupiter
- This contradicted the Aristotelian belief that everything revolved around the earth

The Phases of Venus

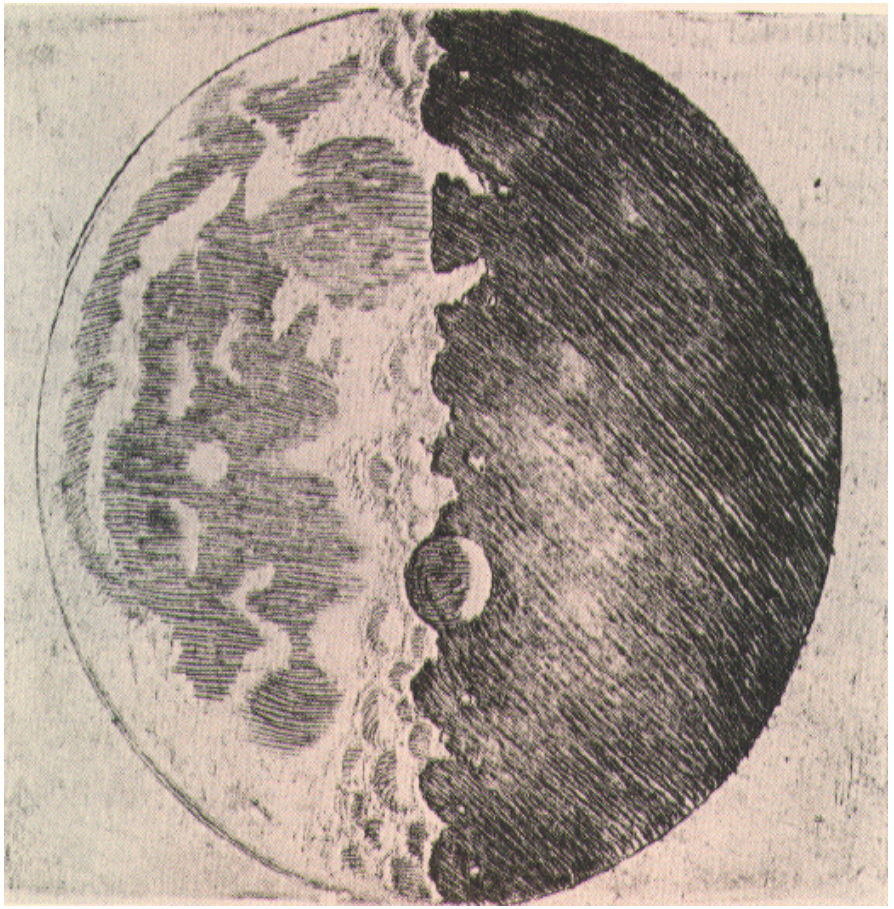
an excellent demonstration of the scientific method!



Modelling the Phases of the Moon and Venus

- Conventional diagrams are 2D, not to scale, and show different frames of reference
- Model the phases of the moon with a lamp, and Styrofoam balls
- Model the phases of Venus, showing how and why they differ in the earth-centered and sun-centered models

The Mountains on the Moon

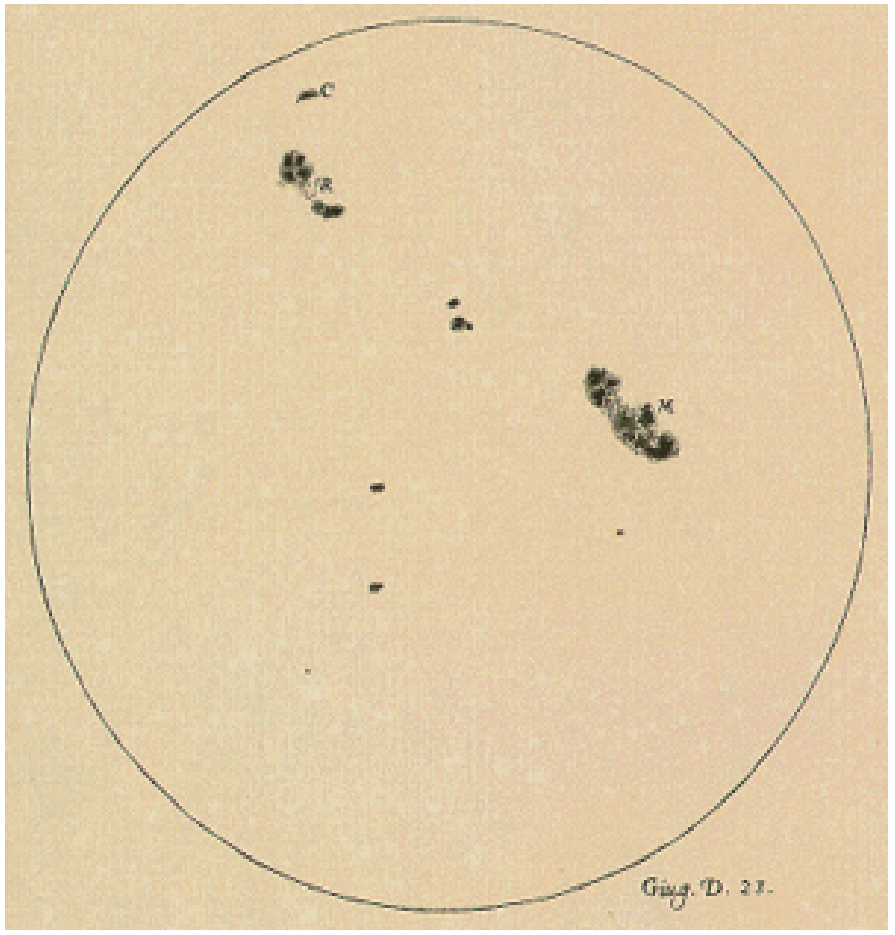


- Galileo observed mountains and valleys on the moon
- Using shadowing and geometry, he could determine their heights and depths
- The moon was, in this sense, earthlike, contrary to Aristotelian belief
- **Project: use binoculars, a small telescope, or the Internet to study the features on the moon.**

Modelling the Formation of Craters

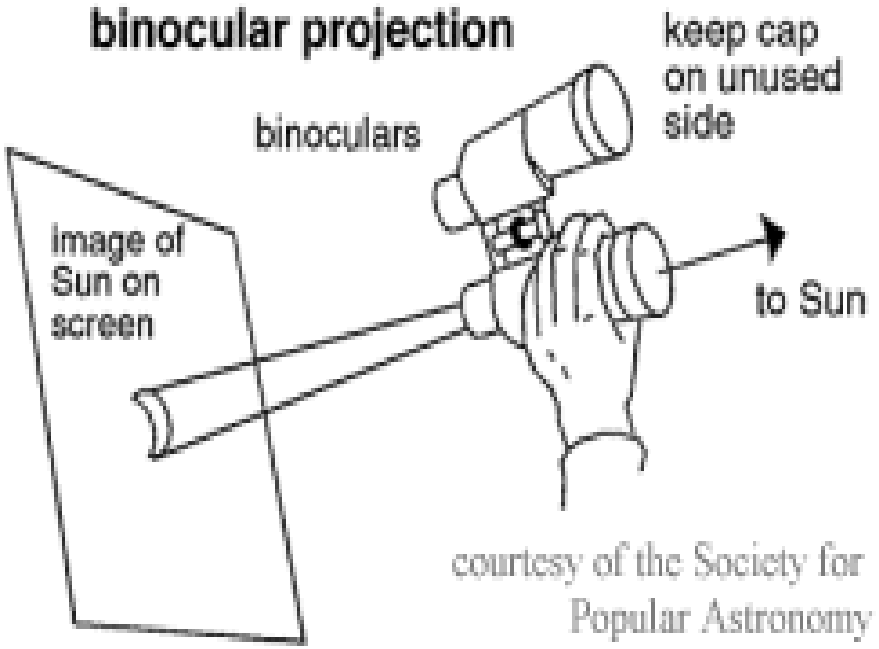
- Model the process with a tray of flour, with a thin layer of cocoa on top
- Experiment with projectiles of various masses, speeds, and directions
- One of the few experiments in astronomy!

Sunspots



- Sunspots had been observed by others, with the unaided eye
- Galileo was able to study them systematically, in detail with his telescope – safely, by projection
- They changed with time, contrary to Aristotelian belief

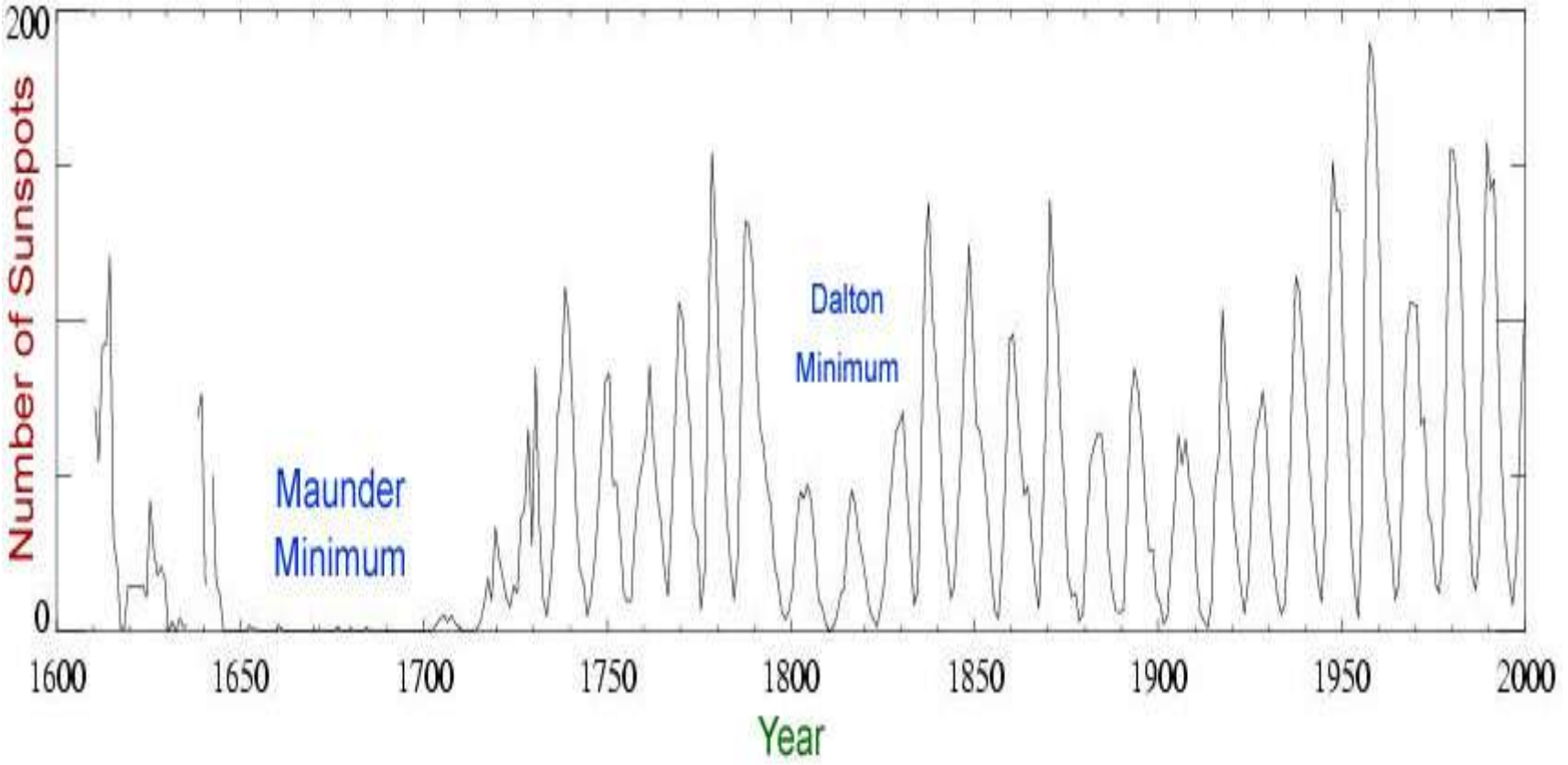
Observing the Sun



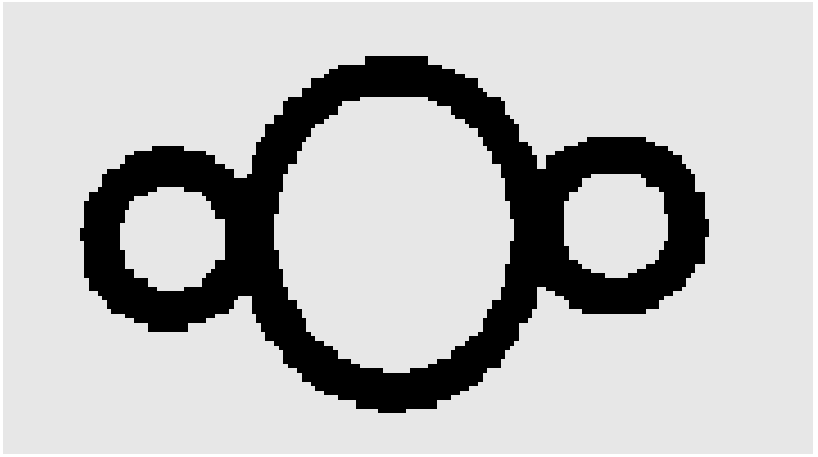
- Focus the binoculars on infinity (not by looking at the sun!)
- Hold them steady, or set them on a tripod or stand
- Project the image on a sheet of white cardboard or paper
- You can supplement these images with ones from the Internet
- **Never look directly at the sun, especially through binoculars or a telescope!**

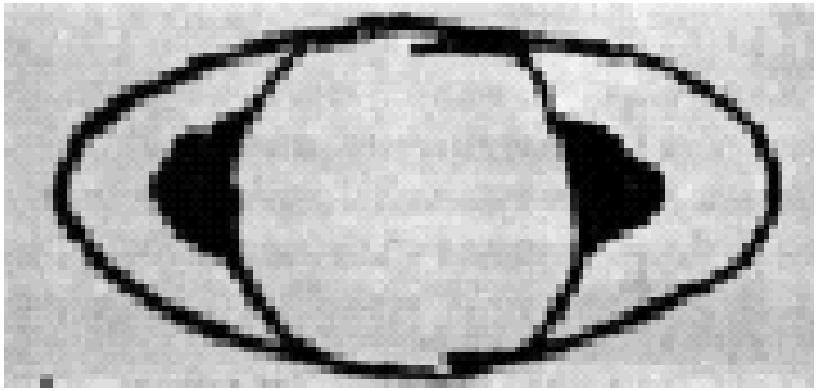
Sunspot Numbers

an excellent topic for graphing skills



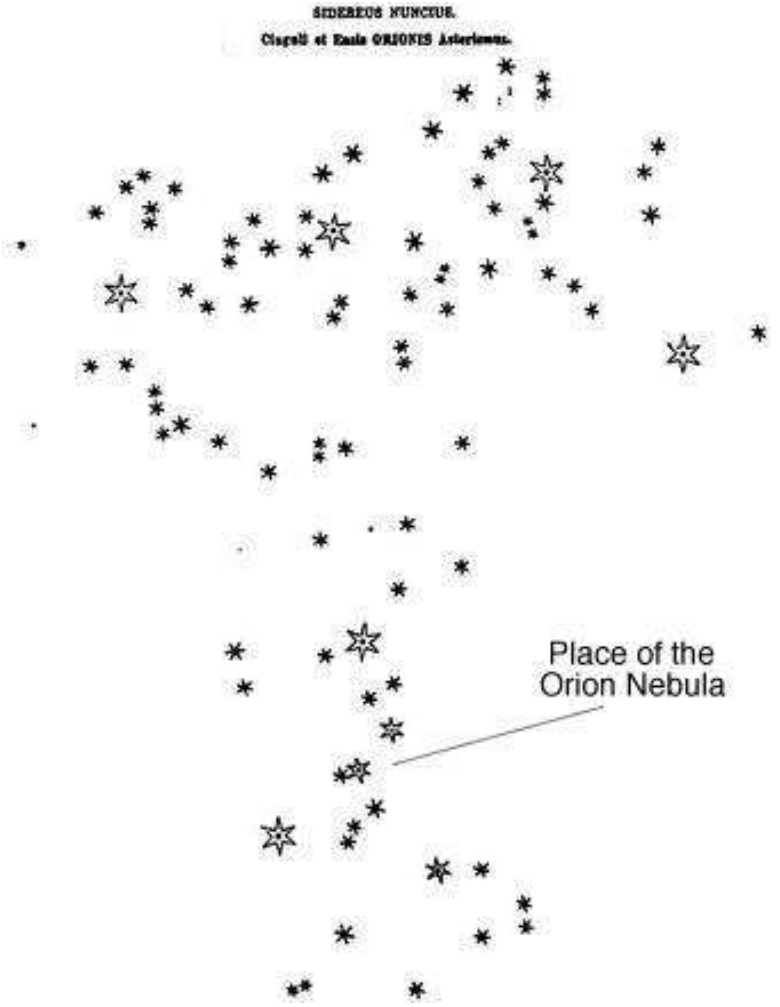
The “Ears” of Saturn





- Since Saturn is smaller and further away than Jupiter, Galileo's image was not as distinct
- What he first thought were satellites turned out to be the rings
- Their nature was not clear until much later

The Stars of the Milky Way



- The Milky Way is a faint band of light across the sky
- Galileo, with his telescope, observed that it was made up of large numbers of faint stars
- They were presumably faint because they were distant

Star Projects

- Observe and study images of the Milky Way, nebulae, and star clusters
- Yes – you can make scientific observations from images, as well as from the real sky!
- Demonstrate the principle of parallax
- Demonstrate the principle of the inverse-square law of brightness: the apparent brightness of a light source varies inversely as the square of its distance

Galileo and Physics

- He began the development of the laws of motion
- To determine whether unequal masses fall at the same rate, he reputedly did the experiment from the Leaning Tower of Pisa; **do the experiment yourself!**
- He attempted to measure the speed of light – 300,000 km/s

Retracing Galileo's Observations

- Plan an observing session, using a star chart, planisphere, or sky software such as Starry Night ...
- ... or observe the sky, and use these tools to determine what you observed
- Investigate light pollution – an excellent STSE topic
- **Safety warning: observe the night sky safely, in the company of family or friends**

Galileo's Record-Keeping

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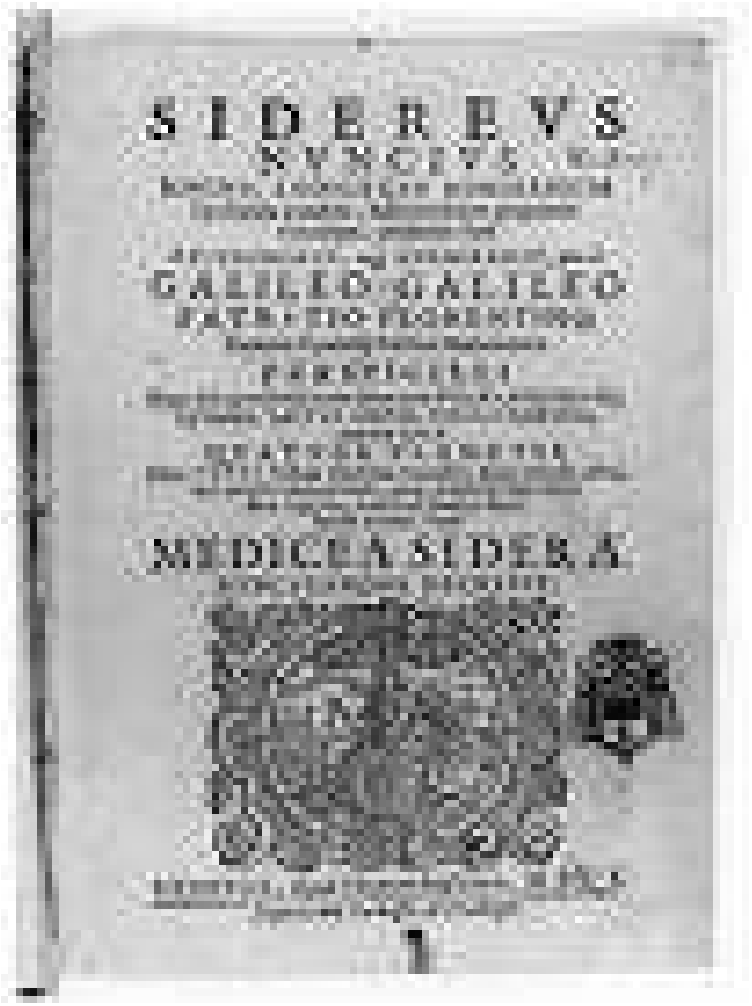
- Copies of Galileo's notebooks are available on-line
- His book *The Sidereal Messenger* is an excellent and still-readable example of good scientific record-keeping and communication
- **Project: read and comment on his record-keeping.**

Galileo's Scientific Communication

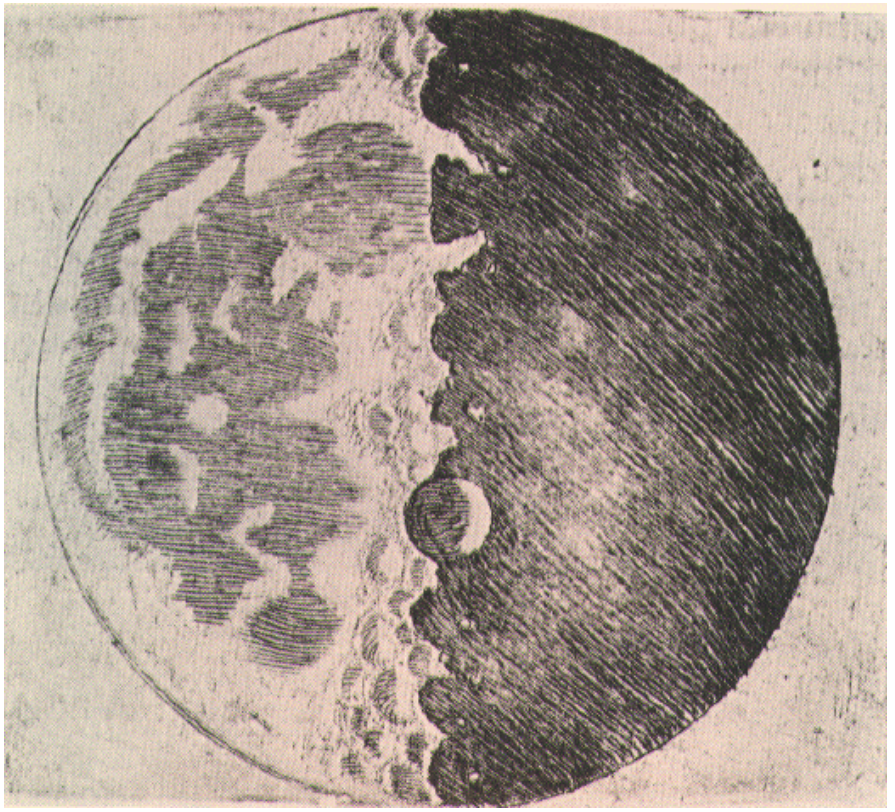
- In 1609, there were no scientific journals, and no Internet
- When Galileo made an important discovery, he wrote a short article, made several copies (or got a scribe to do it), and sent them to other scholars by “pony express”.
- If his discoveries or thoughts were sufficient, he published a book

Galileo's Salary and Research Support



- In 1609, there were no government research grants; scientists had to be well-to-do, or have a patron
- Galileo had siblings and three illegitimate children to support
- He successfully cultivated the Medicis as patrons, and sold telescopes to wealthy people of the time.
- **Project: Compare Galileo's life and career with those of famous scientists today.**

Galileo and the Scientific Method



- **Project: clearly explain how Galileo used "the scientific method" to distinguish between the earth-centered and sun-centered models of the solar system**

Galileo and The Church

- Galileo was a devout Catholic
- His conflict with the Church (and with other philosophers) was based partly on the wording of his article on sunspots, and partly on his *Dialogue Concerning the Two Chief World Systems*
- **Project: consider whether there must be a conflict between science and religion.**

The Vatican Observatory

- Although the “Galileo Affair” was not resolved until the 1990's, Jesuits have operated a Vatican Observatory for over a century, with a more modern branch in Arizona
- I recommend *Galileo's Sons* [Inigo Films, Toronto] as an excellent window on science and religion

Summary: Curriculum Links

- General: scientific investigation skills, scientific method, science and society
- SNC1D: “people use observational evidence of the properties of the solar system and the universe to develop theories to explain their formation and evolution”
- SNC1D, SNC1P: the telescope as a key technology in astronomy
- SNC2D, SNC2P: optics; nature of the telescope
- SNC1P: excellence in the use of the telescope, computer, and other astronomical technologoes
- **Project: Investigate the nature of “amateur” astronomy, and the activities of amateur astronomers.**

Celebrating IYA in Your Classroom

- Astronomy is the ultimate interdisciplinary subject, and cross-curricular connections are highly valued
- Language arts example: prepare non-technical print and multimedia science articles; explore the science in science fiction; read and evaluate non-fiction books about science and scientists
- Art example: create an exhibit of astrophotographs and astronomy-inspired art
- Music example: perform astronomy-inspired music, both classical and popular, old and new

An IYA Project
Tafelmusik Baroque Orchestra
"The Galileo Project"

- Multimedia program: music, drama, images, movement
- Brought astronomy to 10,000+ non-scientists
- Creative, effective educational version reached several thousand grade six students
- Outstanding reviews!

An IYA Project
Canada Post Circulating Stamps

- These were issued by Canada Post in April 2009
- They show two of Canada's important observatories – the Dominion Astrophysical Observatory, and the Canada France Hawaii Observatory
- They are among Canada Post's most popular stamps

An IYA Project
A Tour of Astronomical Heritage Sites

- A partnership project with Heritage Toronto
- 21 June 2009 tour of astronomical heritage sites (1839 – present) around the University of Toronto Campus
- Demonstrates the many roles of astronomy in society