Galileo & Scientific Revolution

Kepler's Third Law: Relating Orbits

The square of a planet's orbital period is proportional to the cube of its orbital semi-major axis:

$$P^2 \propto a^3$$

Jupiter: $5^3 / 12^2 = 125/144 \sim 1$

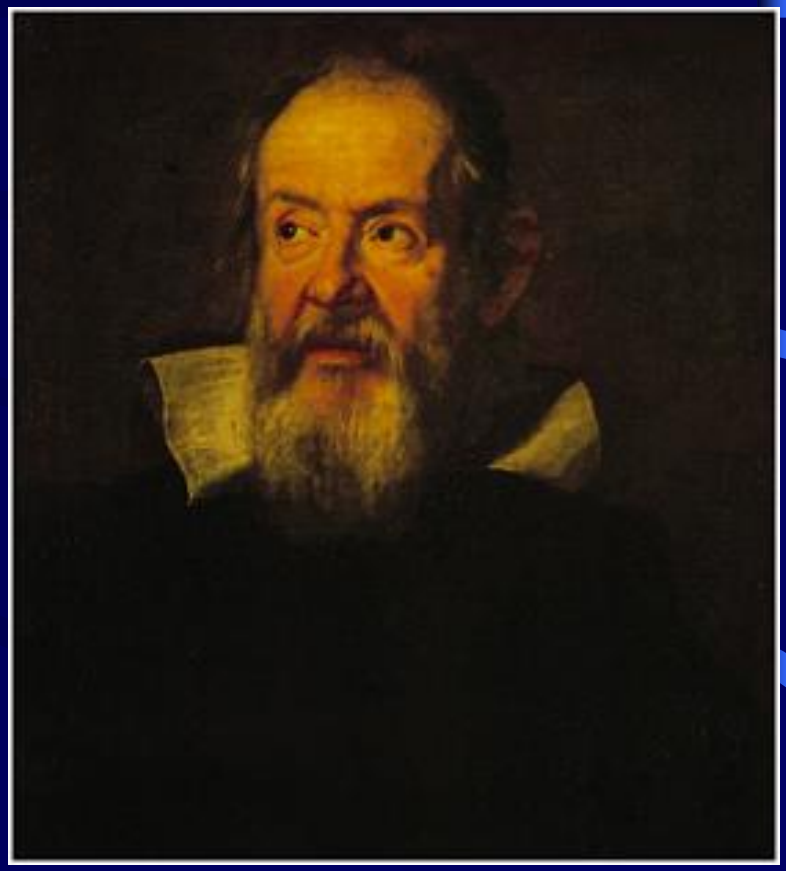
	a	**P**		
Planet	Semi-Major Axis	Orbital Period	Eccentricity	P^2/a^3
Mercury	0.387	0.241	0.206	1.002
Venus	0.723	0.615	0.007	1.001
Earth	1.000	1.000	0.017	1.000
Mars	1.524	1.881	0.093	1.000
Jupiter	5.203	11.86	0.048	0.999
Saturn	9.539	29.46	0.056	1.000
Uranus	19.19	84.01	0.046	0.999
Neptune	30.06	164.8	0.010	1.000
Pluto	39.53	248.6	0.248	1.001
	(A.U.)	**(Earth years)**		

The Baroque Setting

- In the 1600s church through counter-reformation (Council of Trent 1545-1563) much stricter
- G. BRUNO (Italian; 1548) proposes that the Sun is just one star out of an infinite number ➔ burned at the stake for heresy 1600
- 30 Years War (1618-1648) between religions
- New inventions: telescope, air pump, etc.

Galileo Galilei – The Experimentalist

Did experiments (falling bodies) rather than studying Aristotle



(1564–1642)

Major Works

- Siderius Nuntius (1610)
- Dialogue concerning the Two Chief World Systems (1632)

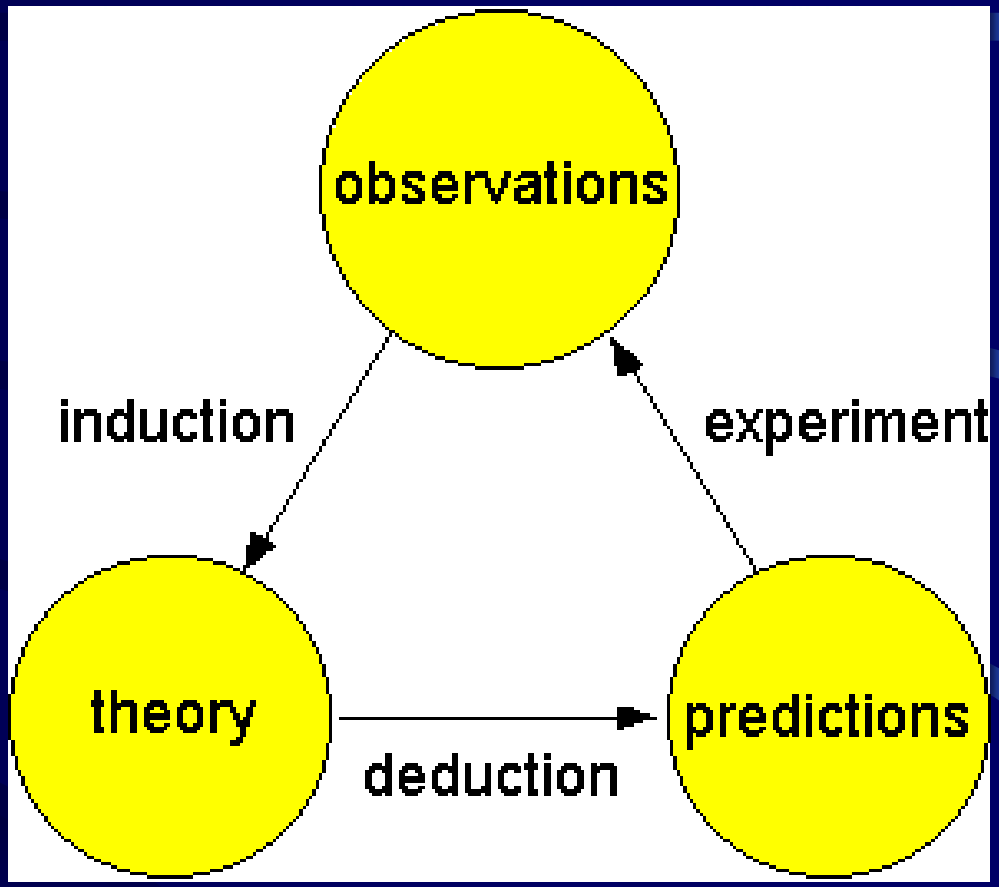
The latter discusses Copernicus vs Ptolemy ➔ban by Church (1633)

– revoked by pope 1992

– Quotable: "The book of the universe is written in the language of **mathematics.**"

The Scientific Method

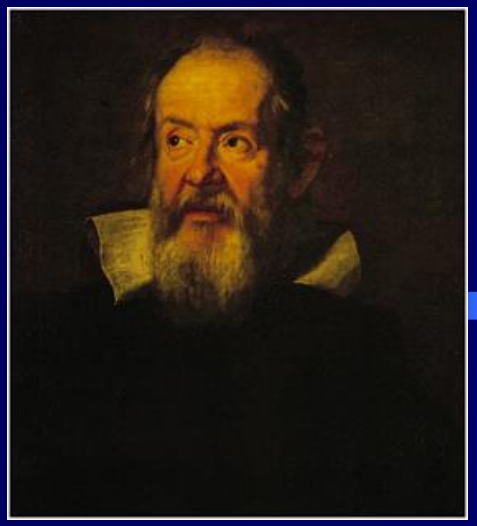
- Systematized by Francis Bacon, Descartes and Galileo in the 17th century
- Not the only way of knowing, but a very successful one
- A method to yield conclusions that are independent of the individual
- Conclusions are based on **observation**



Galileo's Telescopes

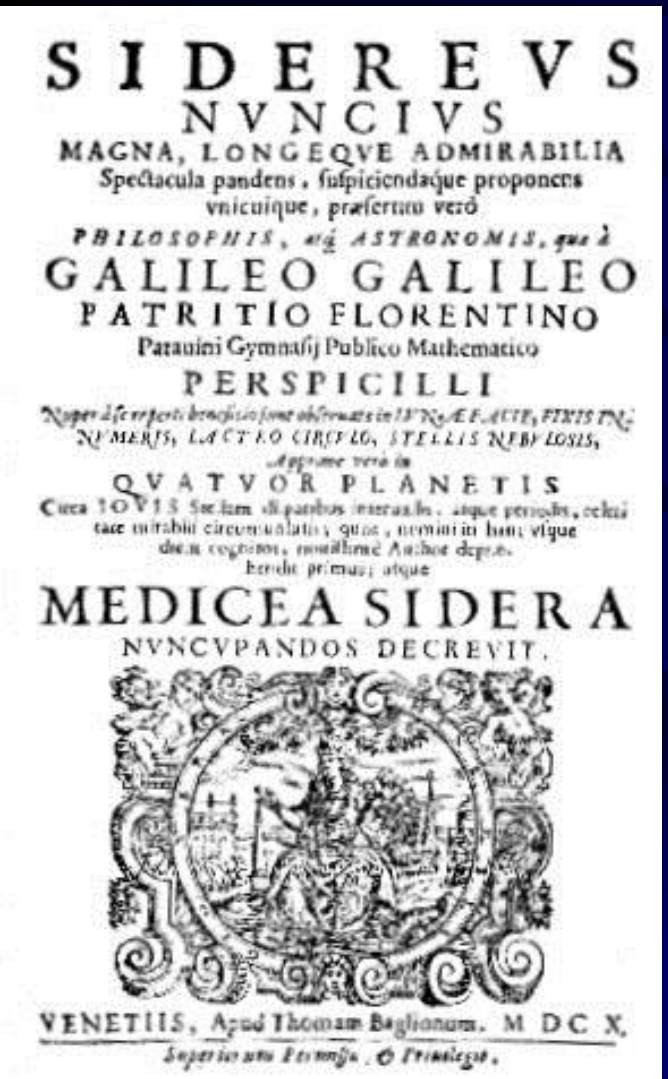
- Galileo's first telescope was 3x magnifying
- his last one 32 x

Galileo Galilei (1564–1642)



- Astronomical observations that contradict Aristotle:
  - Observed mountains on the Moon, suggesting that the Earth is not unique
  - Sunspots; suggests that celestial bodies are not perfect and can change
  - Observed four moons of Jupiter; showed that not all bodies orbit Earth
  - Observed phases of Venus (and correlation of apparent size and phase); evidence that Venus orbits the Sun
- Also observed
  - the rings of Saturn
  - that the Milky Way is made of stars

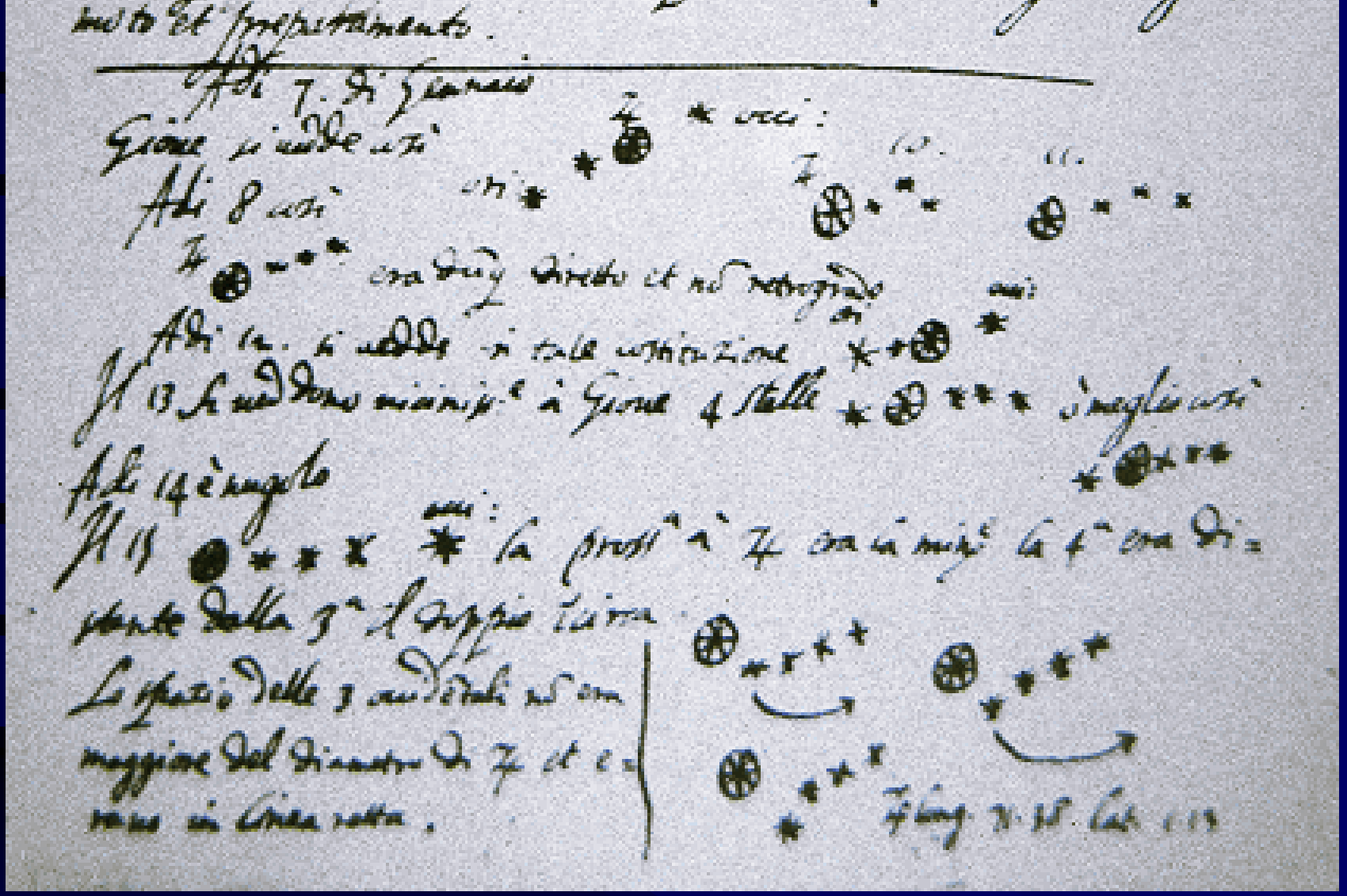
The Starry Messenger



SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in IVNÆ FACIE, FIXIS IN-
NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprimè verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeri-
tate mirabili circumvolantibus; quos, nemini in hanc vsque
diem cognitos, nouissimè Author deprę-
hendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum permissu, & Priuilegio.

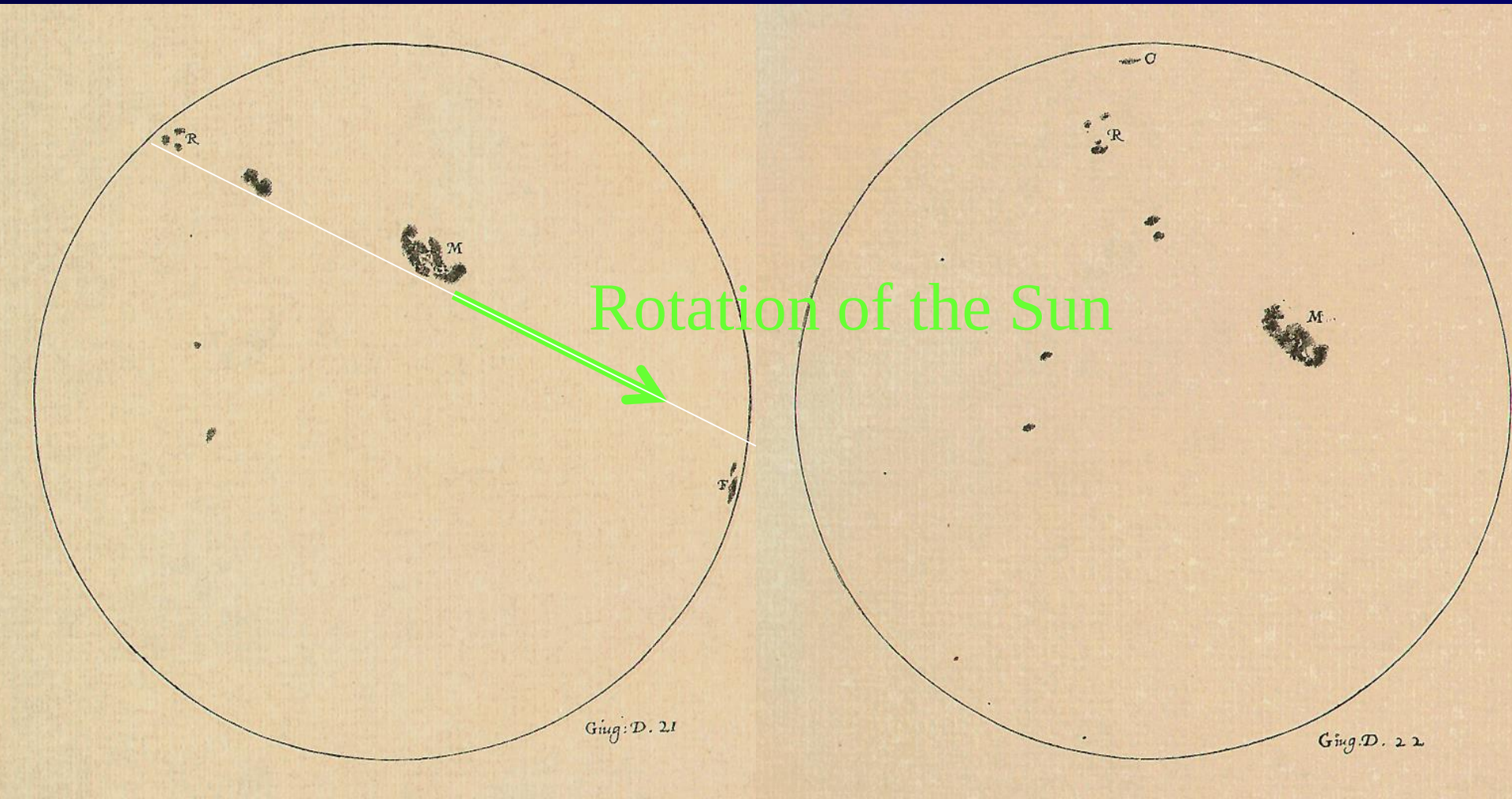
- Revealing great, unusual, and remarkable spectacles, opening these to the consideration of every man, and especially of philosophers and astronomers;
- As observed by Galileo Galilei, gentleman of Florence, Professor of Mathematics in the University of Padua
- With the aid of a Spyglass recently invented by him
- In the surface of the moon, in innumerable fixed stars, in nebulae, and above all:
- In four planets, swiftly revolving about Jupiter at differing distances and periods, and known to no none before the Author recently perceived them and decided that they should be named
- THE MEDICEAN STARS
- Venice, 1610

Galileo's Journal on the Discovery of Jupiter's Moons



Sometimes sees 2,3,4 objects, sometimes left, sometimes right of Jupiter

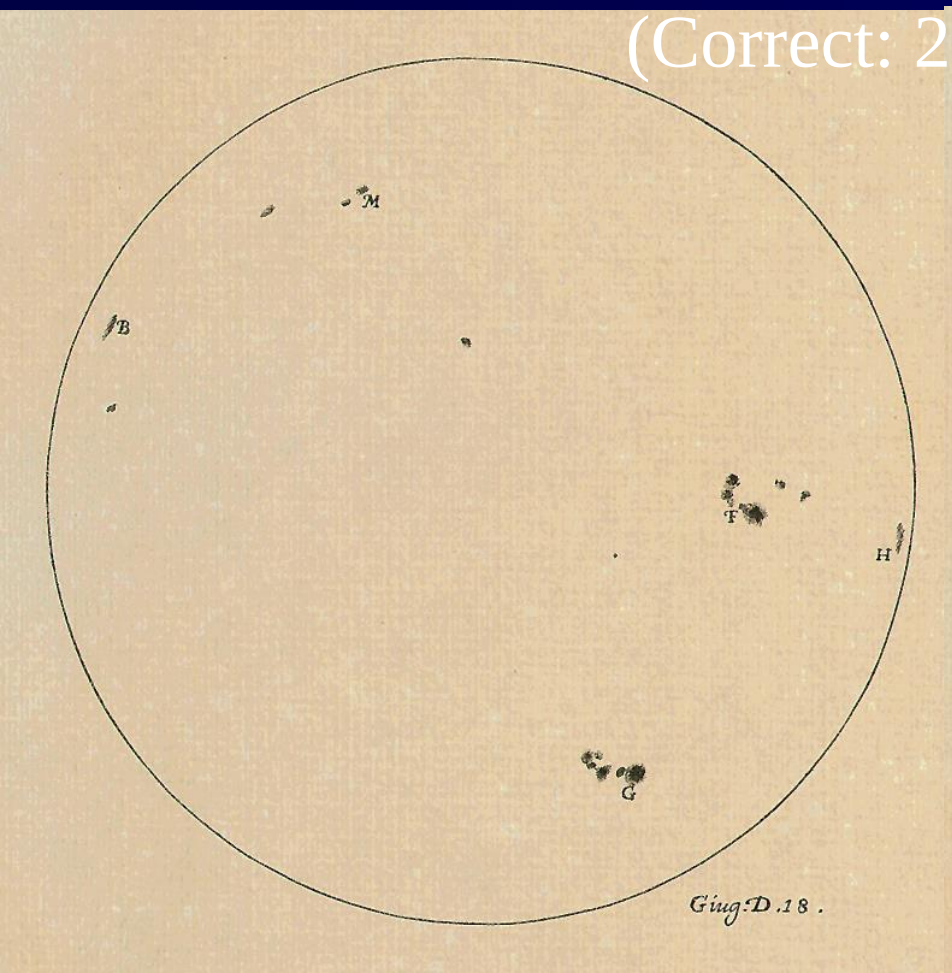
Sunspots (Video)

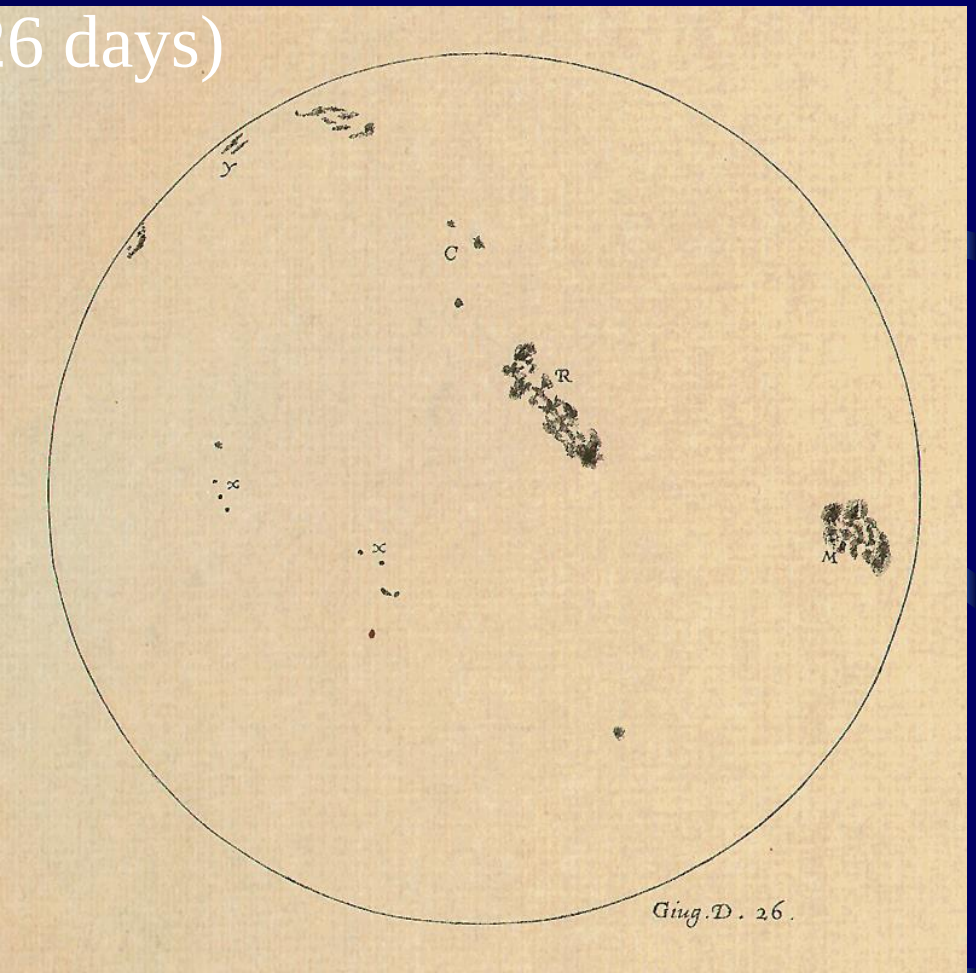


Rotation Period of the Sun

Sunspot moves about ¾=75% of diameter in 8 days➔ rotation period roughly 8*2*4/3=21 days

(Correct: 26 days)





Debate over Sunspots

- Who saw them first? Scheiner vs Galileo
  - Neither!
- What are the sunspots?
  - Could they be clouds across the sun or inner planets transiting the Sun to save Aristotle?
  - No! Appear to move with the sun, no parallax, show appearance like dots painted on a rotating ball

Scientific Method – Applied by Galileo to Sunspots

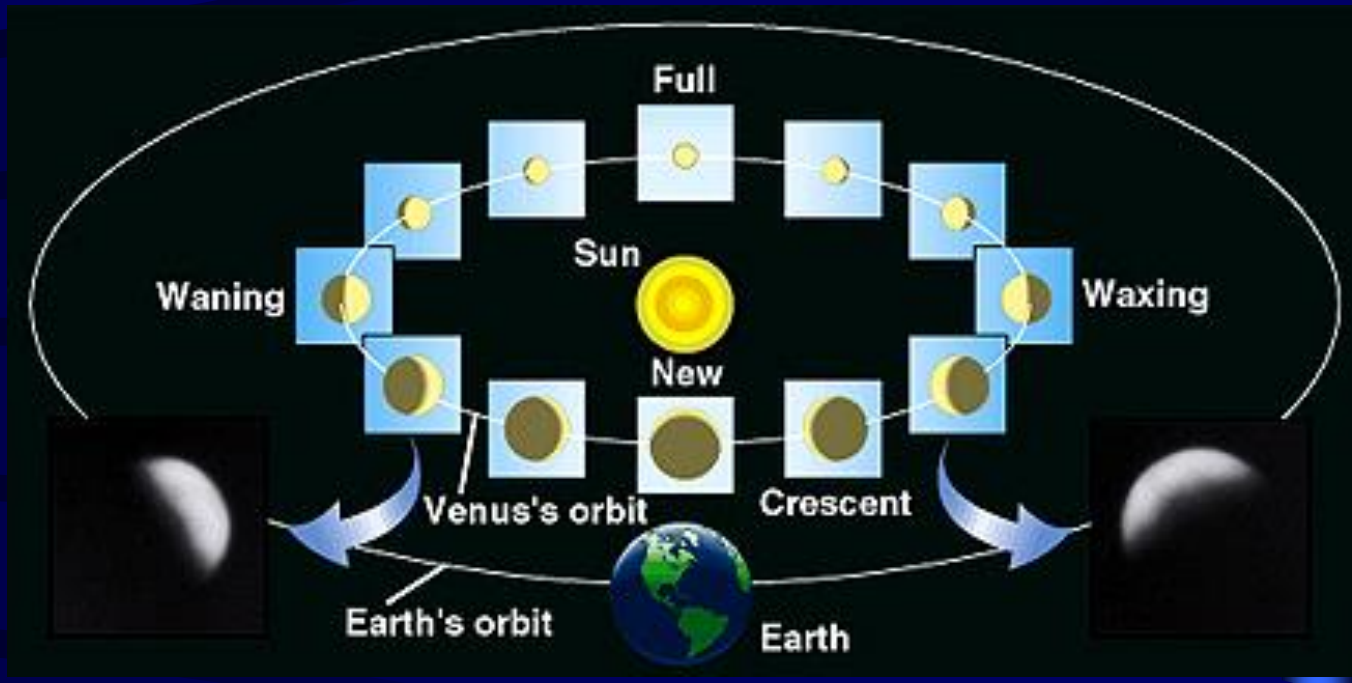
- Careful observation of a phenomenon
  - Observes sunspots (as did others before him)
  - Follows them over several weeks
- Deriving conclusions from "data"
  - Concludes that these are things very close to the Sun's surface
- Making new predictions
  - Deduces that the sun rotates around itself in 26 days
  - Makes a prediction as to the Sun's rotational axis
- Publishing results "for everyone" [in Italian]
  - "Letters on Sunspots" (1612)
- Anticipates his opponents arguments, and nullifies them by using stringent logic
  - Shows that sunspots can't be inner planets

Geocentric vs Heliocentric: How do we know?

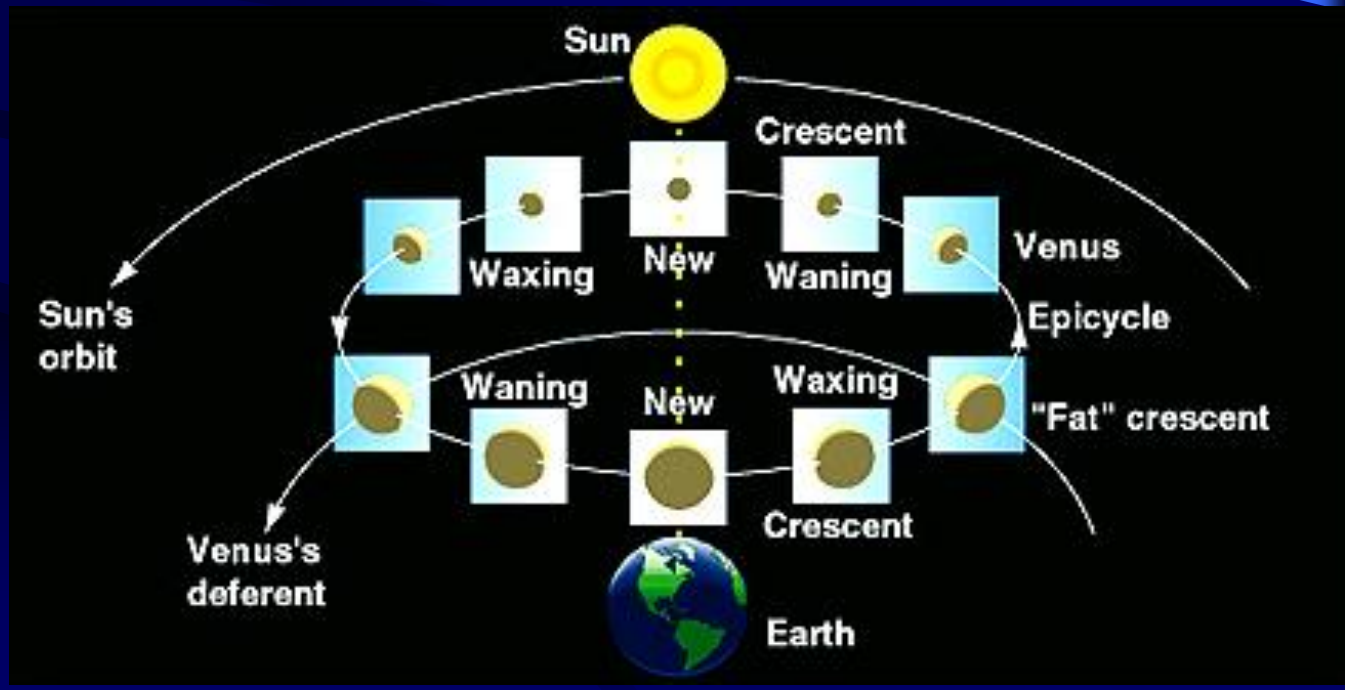
- Is the Earth or the Sun the center of the solar system?
- How do we decide between these two theories?
- Invoke the scientific method:
  - both theories make (different) predictions
    - NOT about planetary motion BUT phases of Venus
  - Compare to observations
  - Decide which theory explains data

Phases of Venus

Heliocentric

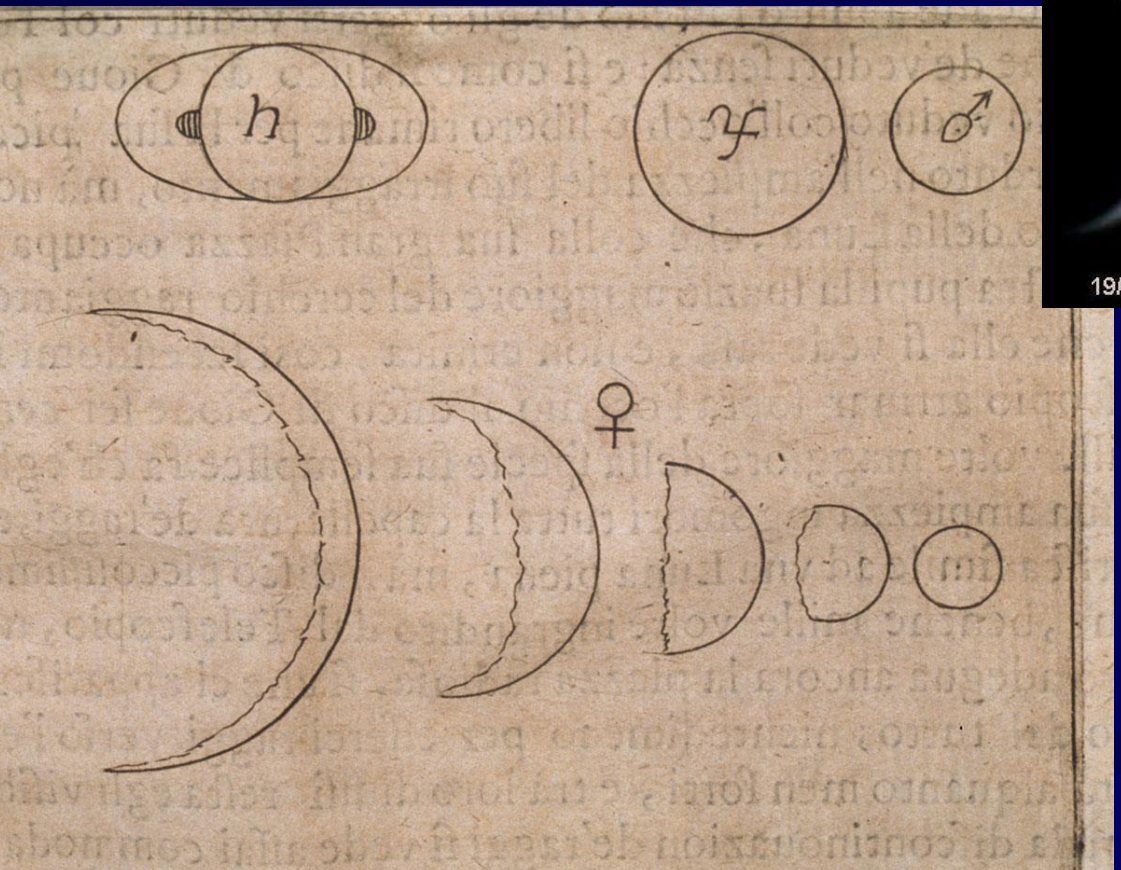


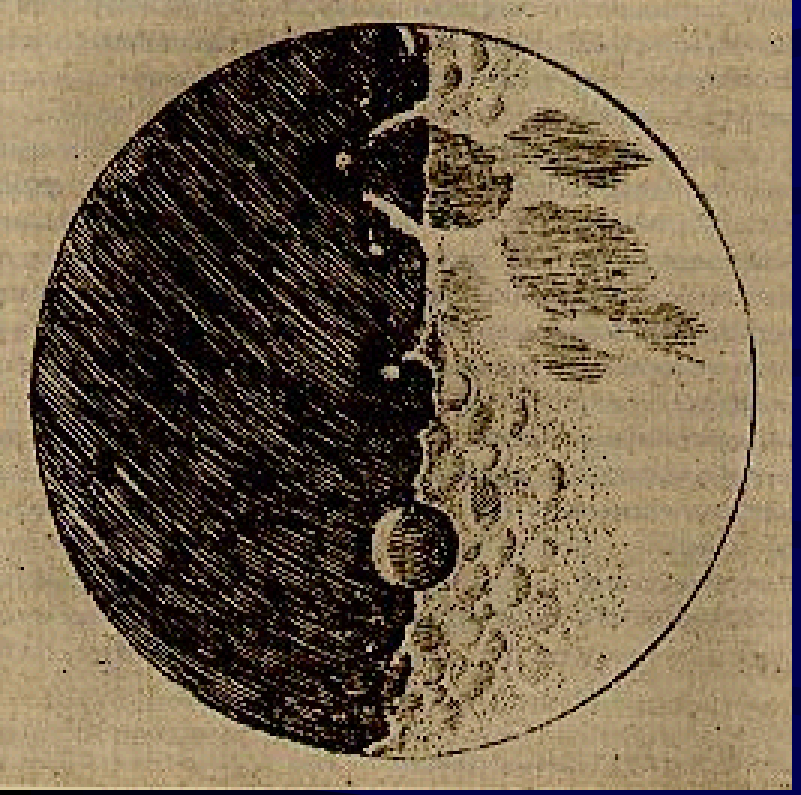
Geocentric



Venus Phases

- Galileo's eyepiece sketches





Mountains on the Moon

- Galileo observed the mountains of the Moon with his telescope
- Estimated their elevation correctly