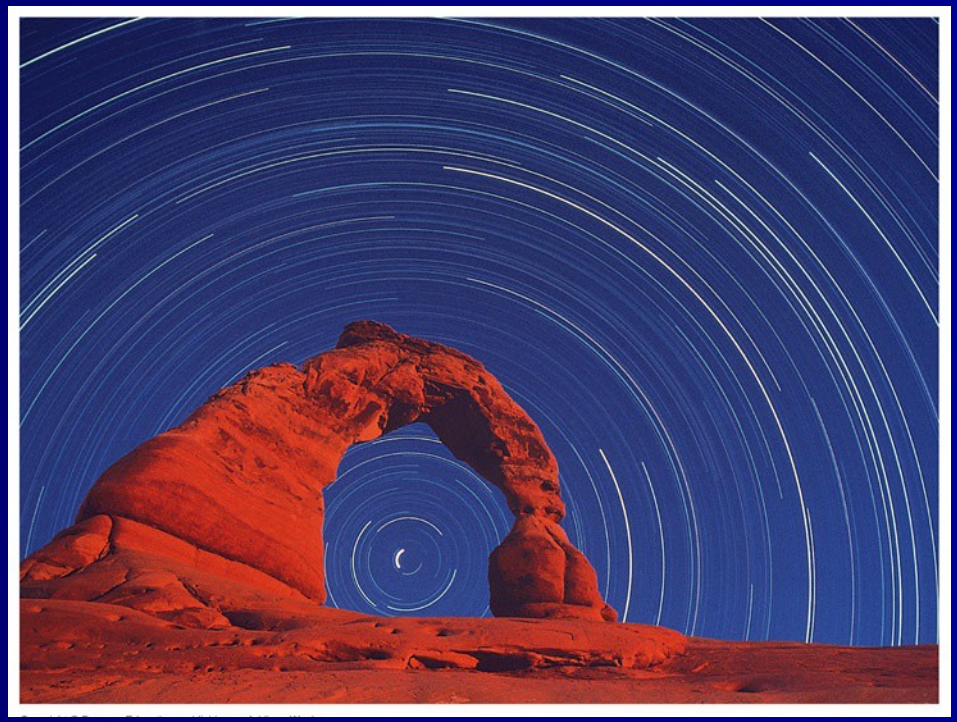
A Model Reveals Itself

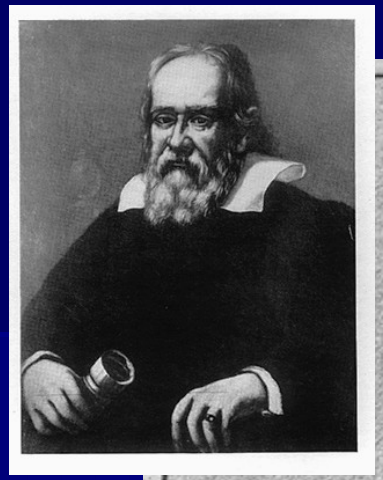


Geocentric vs. Heliocentric Reaction of Contemporaries

- Martin Luther (1483-1546): [Copernicus] "is a fool who wishes to reverse the entire scheme of astronomy; but sacred scripture tells us that Joshua commanded the Earth to stand still, not the Sun."
  - Conservative who wanted to reform Church by returning it to a simpler, less corrupt time.
  - Agitator for the abolishment of indulgences (payment to lessen time of deceased in purgatory).
  - A founder of the Protestant branch of Christianity.
- Response of Catholic Church to threat posed by the Reformation Movement:
  - At first, tolerance of dissent and liberal treatment of new ideas.
  - Later, institution of the Counter-Reformation and the Inquisition.
- Giordano Bruno (1548-1600): burned at the stake for advocating that stars are suns in their own right, and that there is a plurality of worlds like the Earth.
- Galileo (1564-1642):
  - Ah! Here is the person to decide the debate.

Galileo Galilei (1564 – 1642)

"Eppur Si Muove"
"(And, yet it moves!")

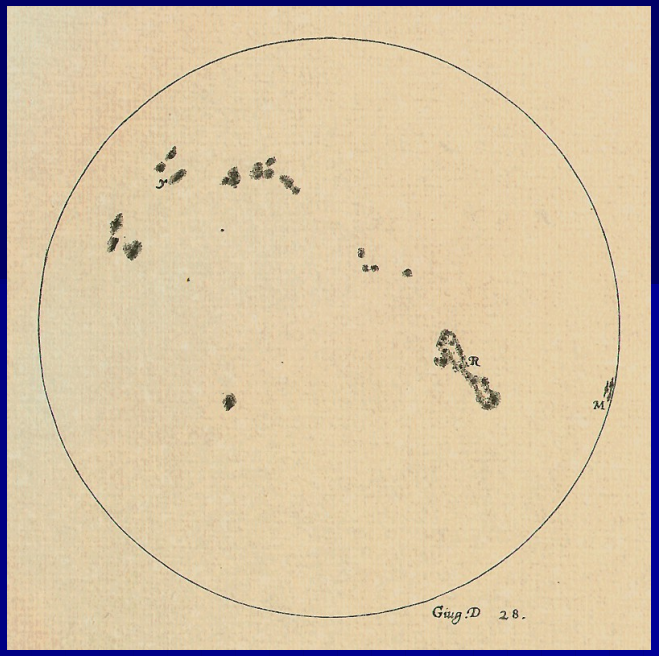


1610 "Siderius Nuncius" (The Starry Messenger)

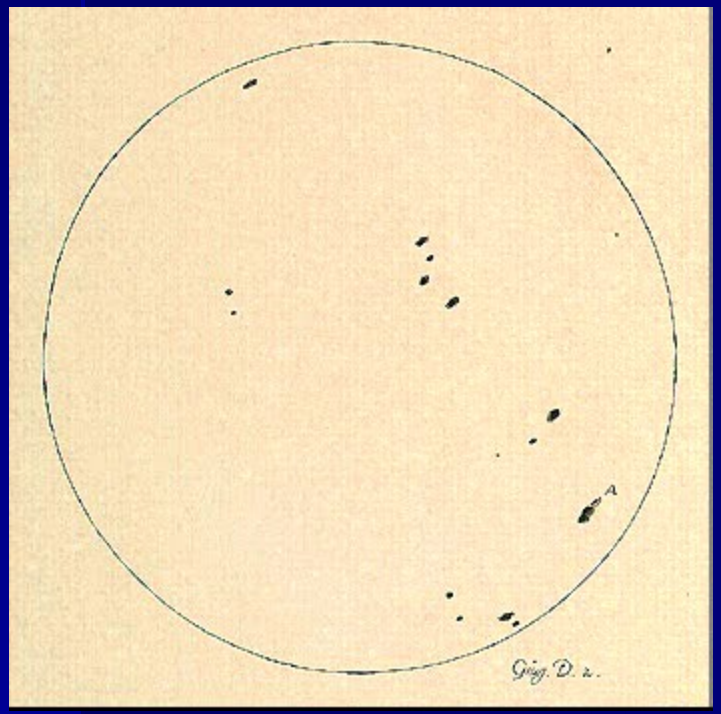
- "Spots" on the Sun!
- The Moon has mountains, craters, rocky surface with imperfections!
- The "planet" Jupiter is not a pinpoint star – but a disc in the sky! WITH MOONS!
- Venus has "PHASES" like the MOON

Galileo Galilei (1564 – 1642)

"Revealing great, unusual and remarkable spectacles, opening these to the consideration of every man, and especially of philosophers and astronomers…."

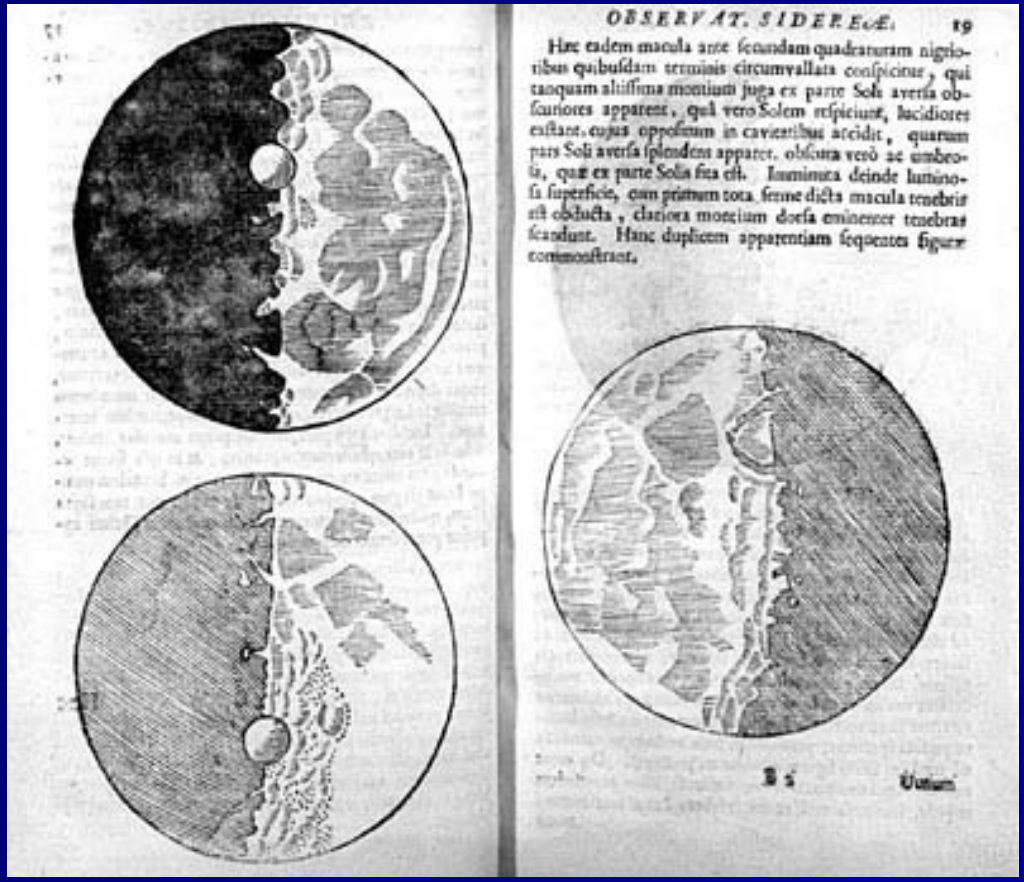


SUNSPOTS



Galileo Galilei (1564 – 1642)

The Moon Has Mountains and Valleys



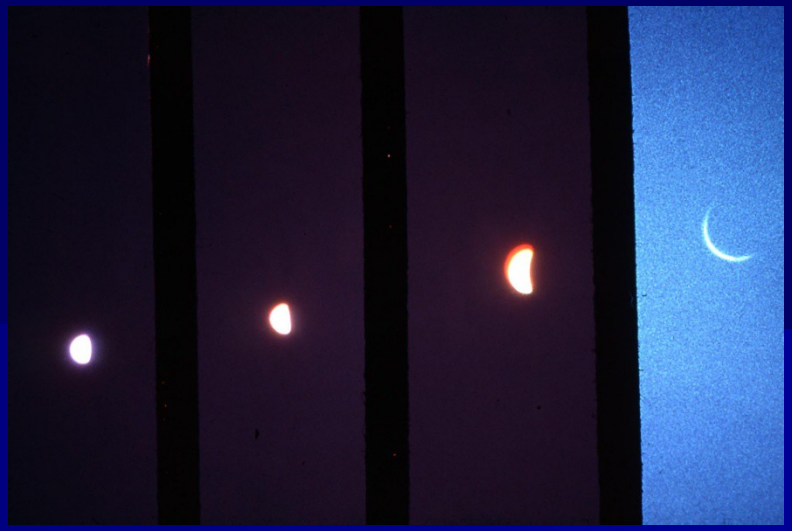
OBSERVAT. SIDEREÆ. 19

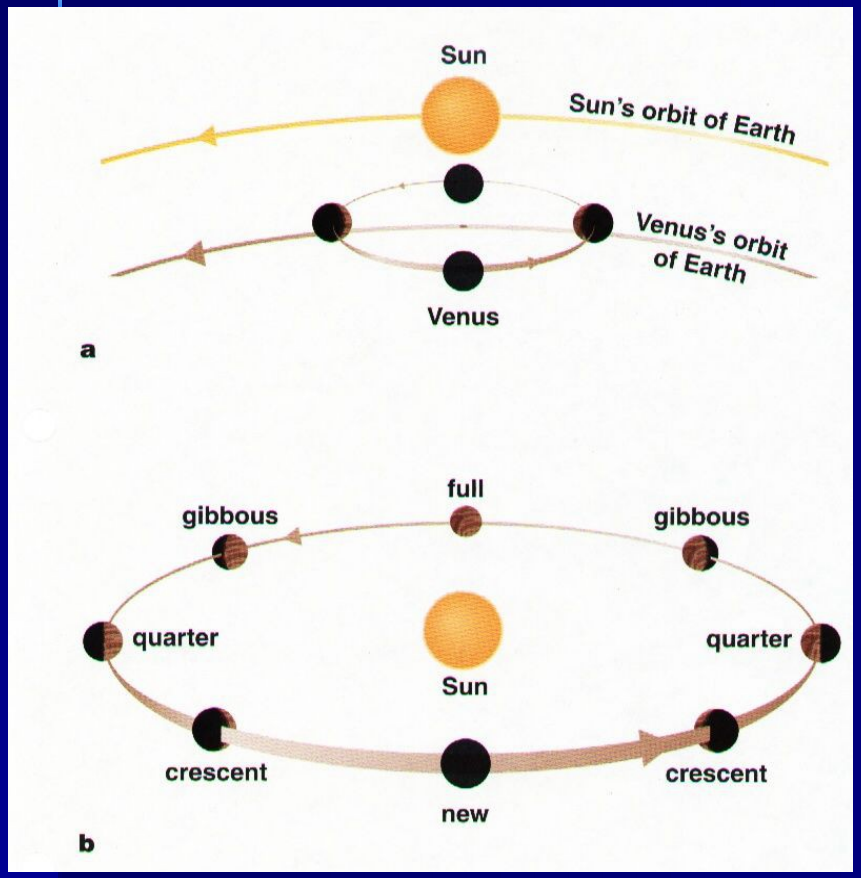
Hinc eadem macula ante secundam quadraturam nigrioribus quibusdam terminis circumvallata conspicitur, qui tanquam altissima montium juga ex parte Solis aversa obscuriores apparent, qui vero Solem respiciunt, lucidiores existant, cujus oppositum in cavitatibus accidit, quarum pars Soli aversa splendens apparet, obscura verò ac umbrosa, quæ ex parte Solis sita est. Luminosa deinde luminosa superficie, cum primum tota ferme dicta macula tenebris est obducta, clariora montium dorsa eminenter tenebras scandunt. Hanc duplicem apparentiam sequentes figuræ commonstrant.

B 5 Ultimo

Galileo Galilei (1564 – 1642)

Phases of Venus



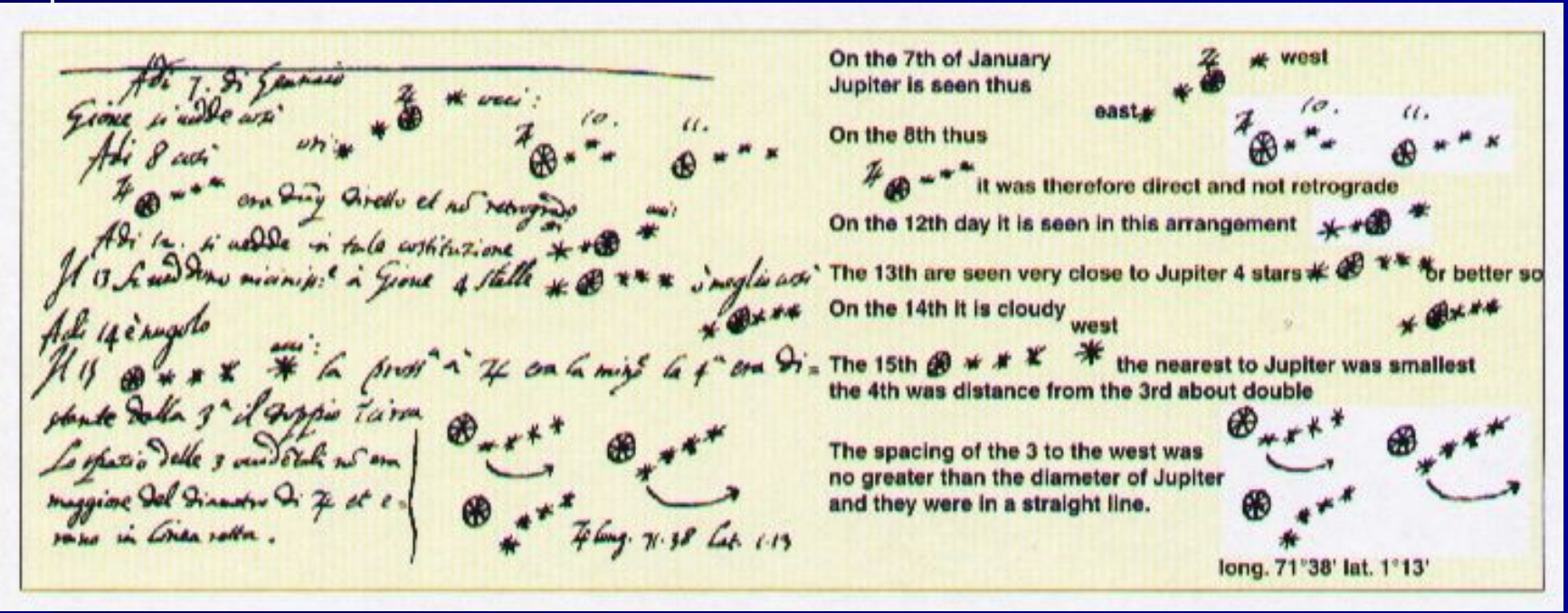


Galileo observed that Venus showed phases entirely like those of the moon from full to crescent, which it must do if the Copernican theory was correct.

According to the Ptolemaic theory Venus would have to be a perpetual crescent.

Galileo Galilei (1564 – 1642)

Jupiter Has Moons

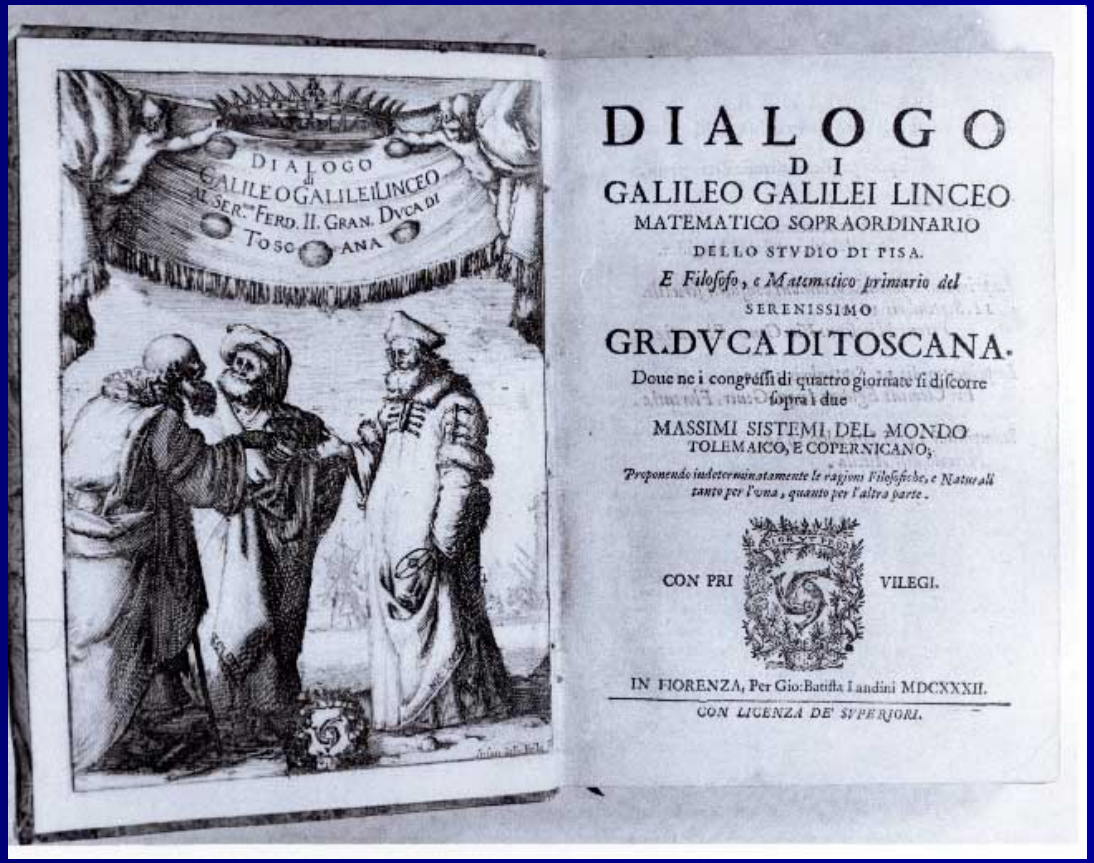


Galilean Moons – 4 Largest "moons" of Jupiter
Io, Europa, Callisto, & Ganymede

Galileo Galilei (1564 – 1642)

1632: "**Dialogo Dei Massimi Sistemi**" (In Italian! Not Latin! For the common people!) He published his masterpiece, **Dialogue on the Two Chief World Systems**, in which he had two people, one representing the view of Ptolemy and other the view of Copernicus, present their arguments before an intelligent layman. Galileo of course gave the Copernican the brilliant best of the battle.

The Pope was persuaded that Simplico, the character who upheld the views of Ptolemy in the book, was a deliberate and insulting caricature of himself. The book was all the more damaging to those who felt themselves insulted, because it was written in vigorous Italian for the general public (and not merely for the Latin-learned scholars) and was quickly translated into other languages -- including Chinese!



Galileo Galilei (1564 – 1642)

Scientific Martyr

- Teaches Heliocentric Ideas
- Claims "proof" for Earth's motion.
- Trial by Church (threatened with instruments of torture), forced to recant views (1633).
- Confined to house arrest. Formulates "new science" of mechanics.
- Loses his sight (blinded) by Sun observations
- Most influential combination of experimentalist and theorist world has ever seen.
- Often credited rightly with having started modern science.

Still, there are problems to solve....

"...a sickly child, with thin limbs and a large, pasty face surrounded by dark curly hair. He was born with defective eyesight-myopia plus anocular polyopy (multiple vision). His stomach and gall bladder gave constant trouble; he suffered from boils, rashes, and possibly from piles, for he tells us that he could never sit still for any length of time..."

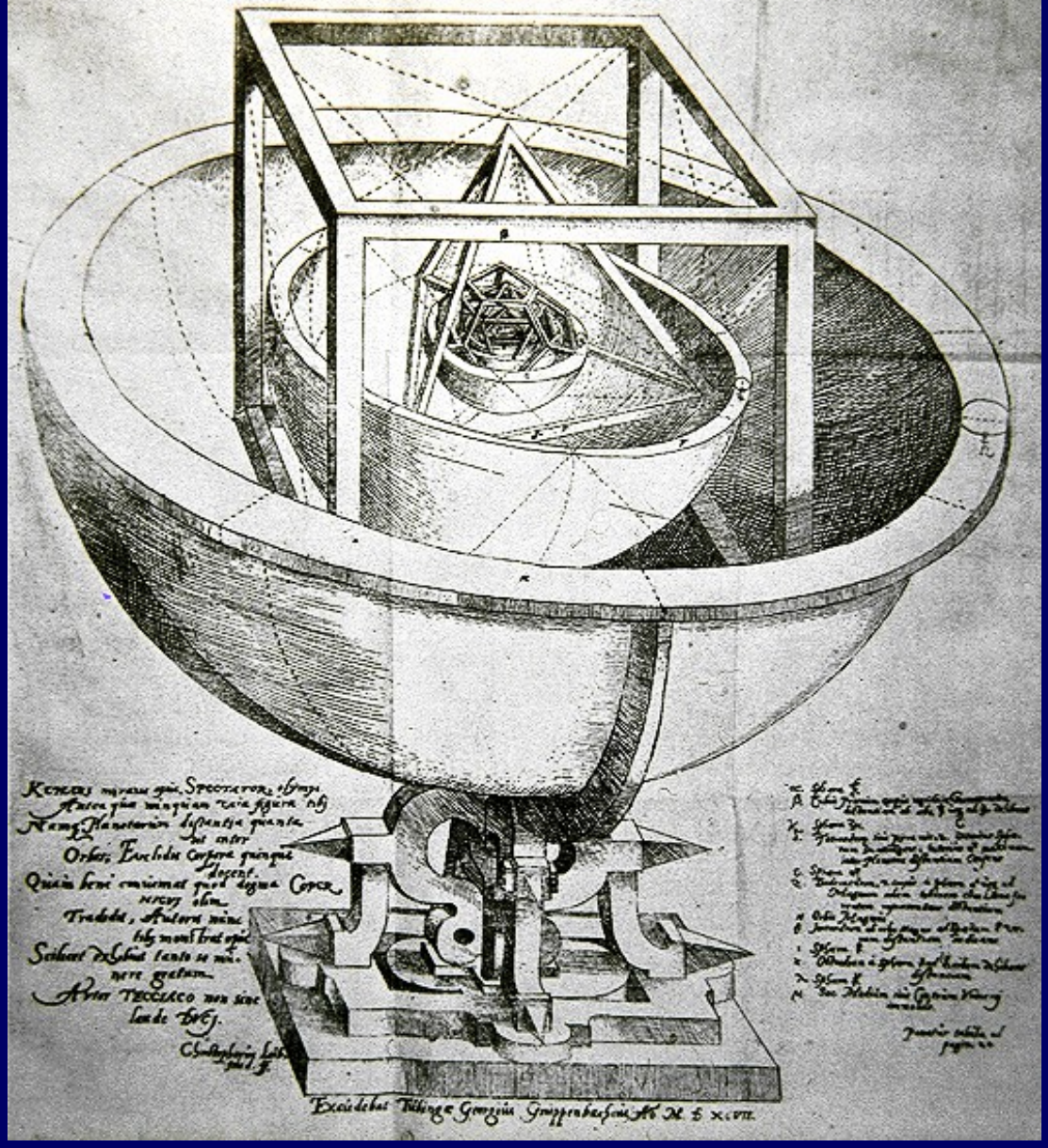
Johannes Kepler's Work

Advancing science, more than ethics, Kepler simply stole the observations upon the sudden and ironic death of Tycho

Math skills - Kelper's skills were extraordinary. He could not reconcile Tycho's very careful observations with the Models of Ptolemy, Copernicus, nor Tycho!!!

TABVLA III. ORBIVM PLANETARVM DIMENSIONES, ET DISTANTIAS PER QVINQVE REGVLARIA CORPORA GEOMETRICA EXHIBENS.

ILLVSTRISS: PRINCIPI, AC DNO. DNO. FRIDERICO, DVCI WIRTENBERGICO, ET TECCIO, COMITI MONTIS BELGARVM, ETC. CONSECRATA.



Excudebat Tubingæ Georgius Gruppenbachius Anno M. D. XCVII.

An Idea! Orbits are not Circles!

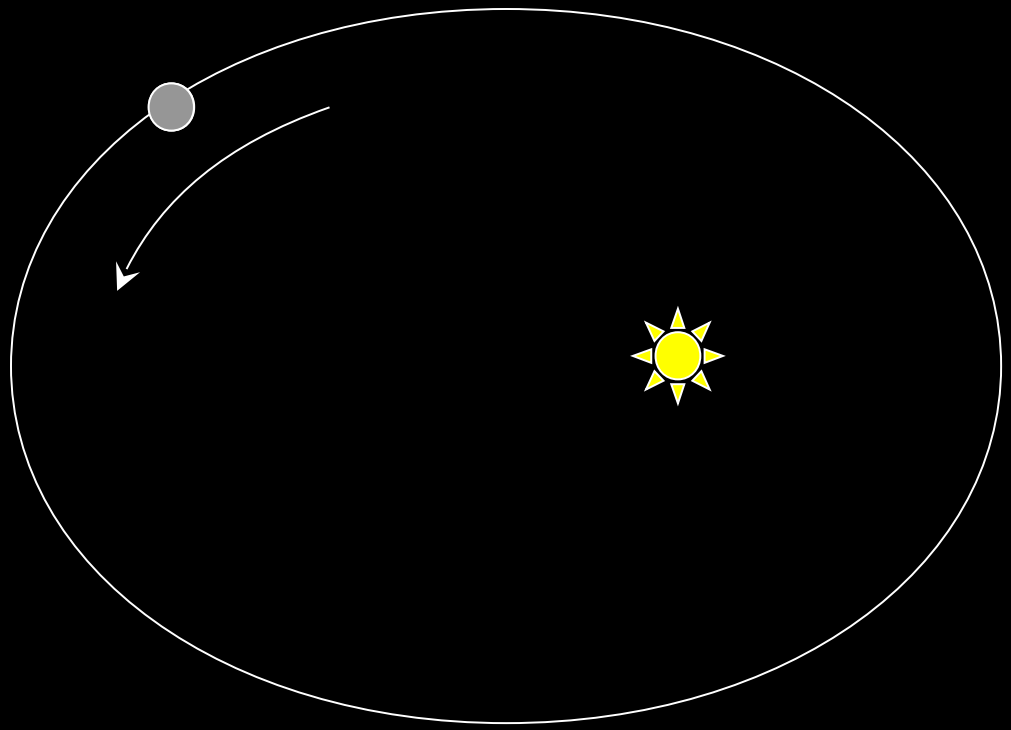
His incredible effort took 29 years!! He waged a "war" on understanding the orbit of Mars.

Heliocentric Model fits the observations best from a simple view point (Copernician) But *not* circular orbits.

Ellipses

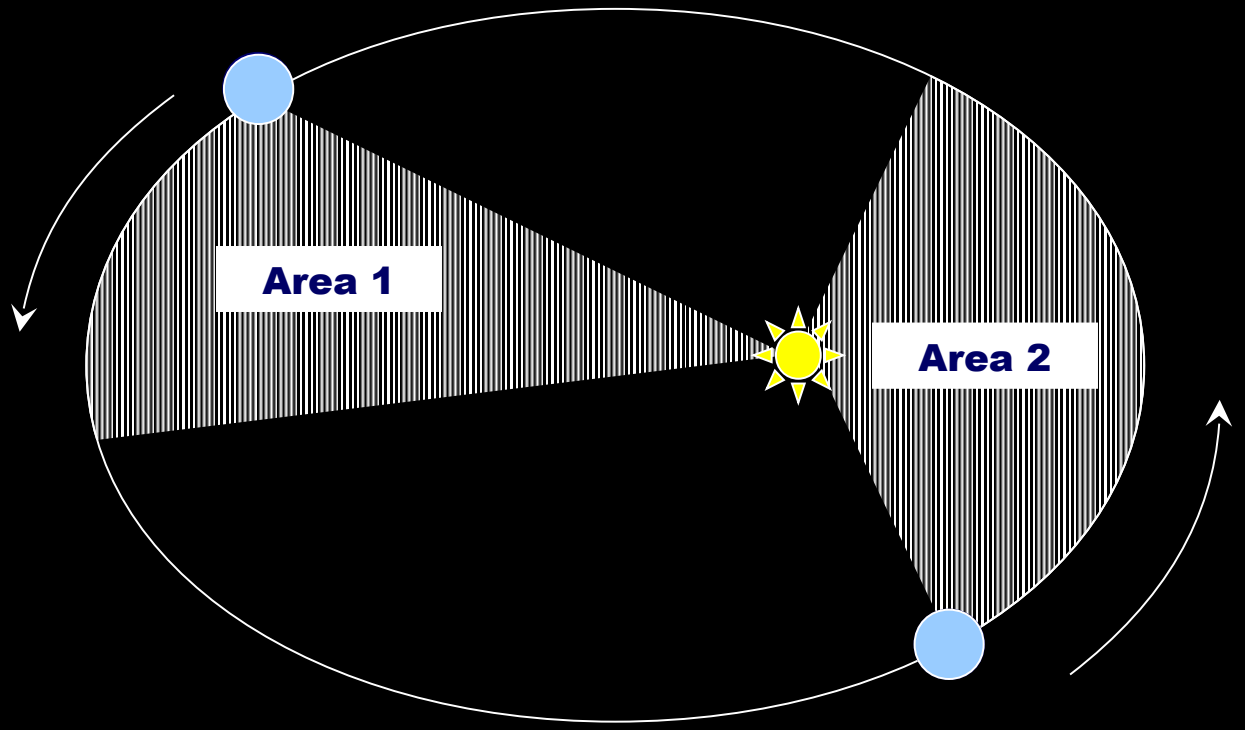
Kepler's Three Empirical Laws of Planetary Motion

1. The orbital paths of the planets are elliptical, with the Sun at one focus



Kepler's Three Empirical Laws of Planetary Motion

2. An imaginary line connecting the Sun to any planet sweeps out equal areas in equal time..



Kepler's Three Empirical Laws of Planetary Motion

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

$$P^2_{\text{(years)}} = A^3_{\text{(astronomical units)}}$$

1 Astronomical Unit = The Earth-Sun Distance (98 million miles)

Kepler's Third Law

Object	a (AU)	P (year)	a**3	P**2
Mercury	0.387	0.241	0.058	0.058
Venus	0.723	0.615	0.378	0.378
Earth	1.00	1.00	1.00	1.00
Mars	1.52	1.88	3.51	3.53
Jupiter	5.20	11.9	141.	142.
Saturn	9.54	29.5	868.	870.
Uranus	19.2	84.0	7,080.	7,060.
Neptune	30.1	165.	27,300.	27,200.
Pluto	39.5	248.	61,600.	61,500.

But!!.....

Kepler did not know

WHY

planet's move as they do.

Isaac Newton (1642-1727)

Born in England on Christmas day.

Bubonic Plague 1665?

While home for 2 years with nothing to do he made his most profound discoveries and proposed his most startling theories.

Time Marches On

In 1684 – was in a discussion with Edmund Halley, when Halley remarked "But why do planet's move the way they do?"

Newton astounded everyone with the answers (from his work 20 years earlier!).

"Philosophiae Naturalis Principia Mathematica"

Newton's Three Laws of Motion

The laws explained not only why planets move as they do, but why objects in general move as they do.

Newton's First Law

- Objects at rest stay at rest unless a "net force" is applied.
- Objects in uniform straight line motion stay in straight line motion unless a "net force" is applied.

- **Note**: Newton's First Law Does **NOT** say…
  - This law **does not say** that every moving object has a "force" acting on it!
  - This law **does not say** an object at rest has "no force(s)" acting on it!

Newton's Second Law

The acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the mass of the object.

$$a = F_{net}/m$$

OR

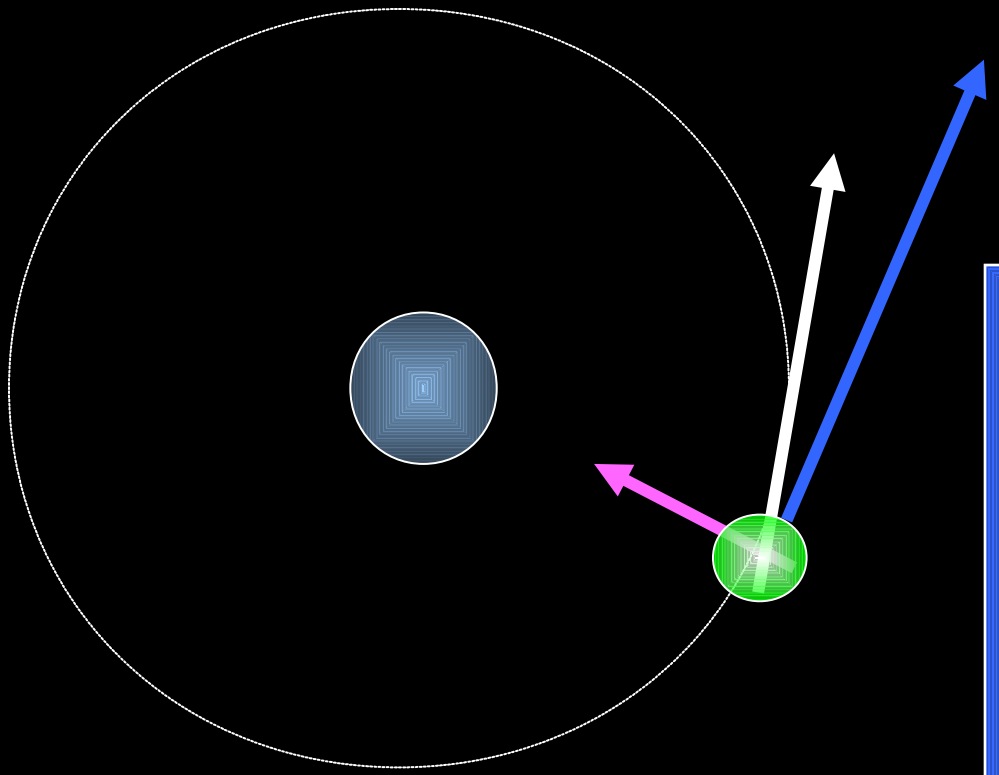
$$F_{net} = ma$$

Newton's Third Law

Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

"To every action there is an equal and opposite re-action."

Law of Universal Gravitation



Matter attracts matter

$$F = \frac{GM_1M_2}{R^2}$$