



# Astronomy

with your host:

## Lecture 2: The Copernican Revolution



Coop

# Astronomy is OLD

- Half of the time, it's dark. Electricity is new.
  - Astronomy is *useful*.
  - The celestial sphere is mysterious!

# Stonehenge



- Salisbury Plain, England
- Built over 1700 years, beginning around 2800 BC
  - 50 ton stones from miles away

# Chaco Canyon Sun Dagger



- Chaco Canyon, New Mexico

# Muslim Astronomy

- Known as ‘Anwa’, astronomy in the Arab world was very empirical in nature, much more modern than its Greek and Babylonian counterparts.
- Greek knowledge of the heavens was translated into Arabic and the Ptolemaic system was refined under the support of the caliphs.
  - Islamic Golden age (700-1400 AD)
- The world’s center of advanced astronomical measurement and modeling was Baghdad and Damascus

## al-Khwarizmi (Algoritmi)

- Born in modern Uzbekistan 650 AD - 780
- Introduced decimals to the western world
- Invented algebra (after al-jabr after a particular operation used in solving linear and quadratic equations)
- Combined with knowledge from India, invented modern trigonometry
- Contributed original research to advancing the ptolemaic system



(Muhammad ibn Musá al-Khwārizmiyy al-Majūsiyy al-Qutrubbaliyy)



al-Haytham (Alhazen)

- Born in Basra, Iraq (ancient Sumer) 965 - 1040
- Made numerous contributions to optics
- Invented... science.
- The heavens must be *physical* bodies
- Insanity plea

(Abū ‘Alī al-Ḥasan ibn al-Ḥasan ibn al-Haytham)

# House of Wisdom, Baghdad, Abbasid Caliphate



790 - 1258

...Mongols!

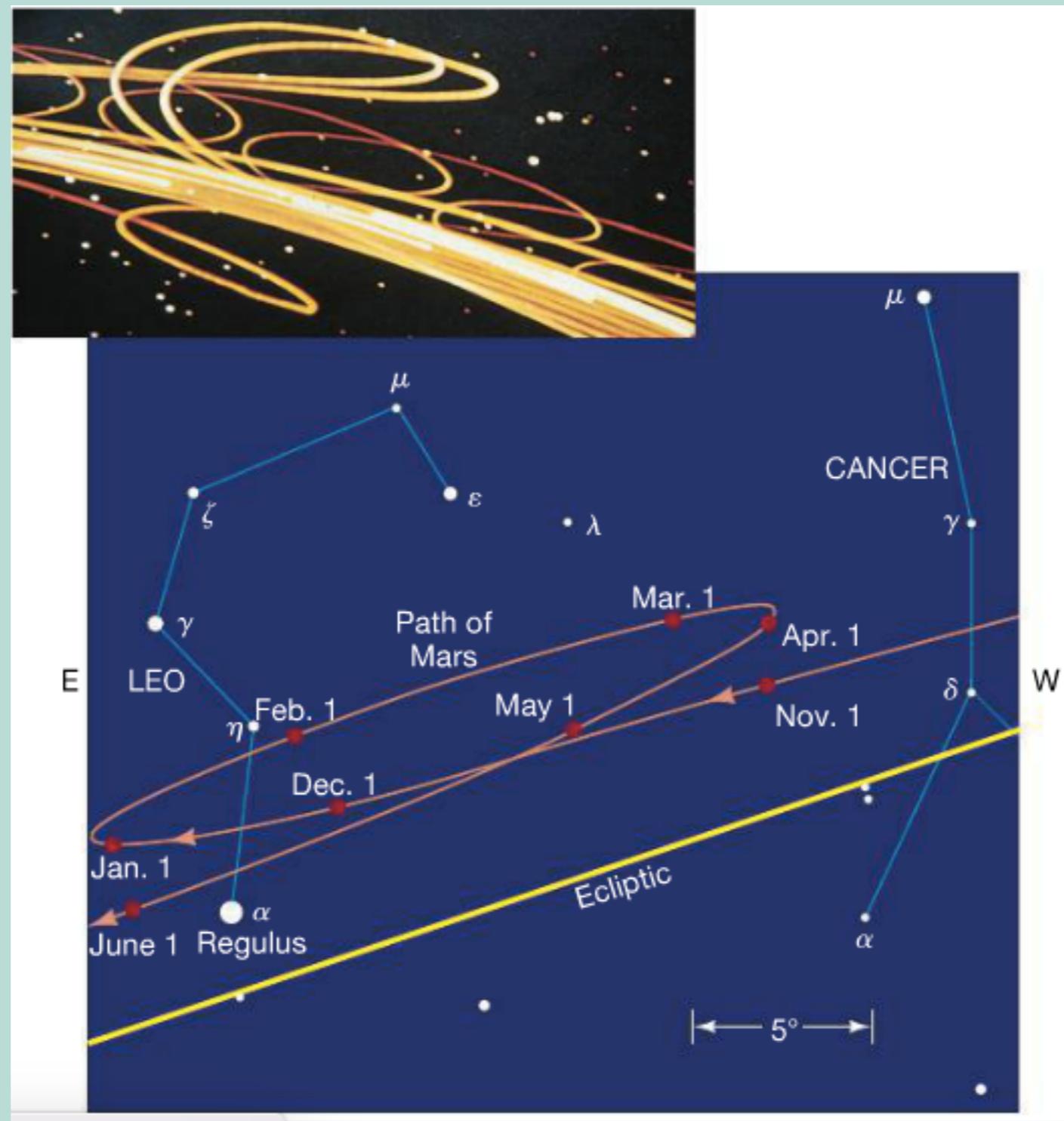
# The Wanderers

## The Sun and the Moon

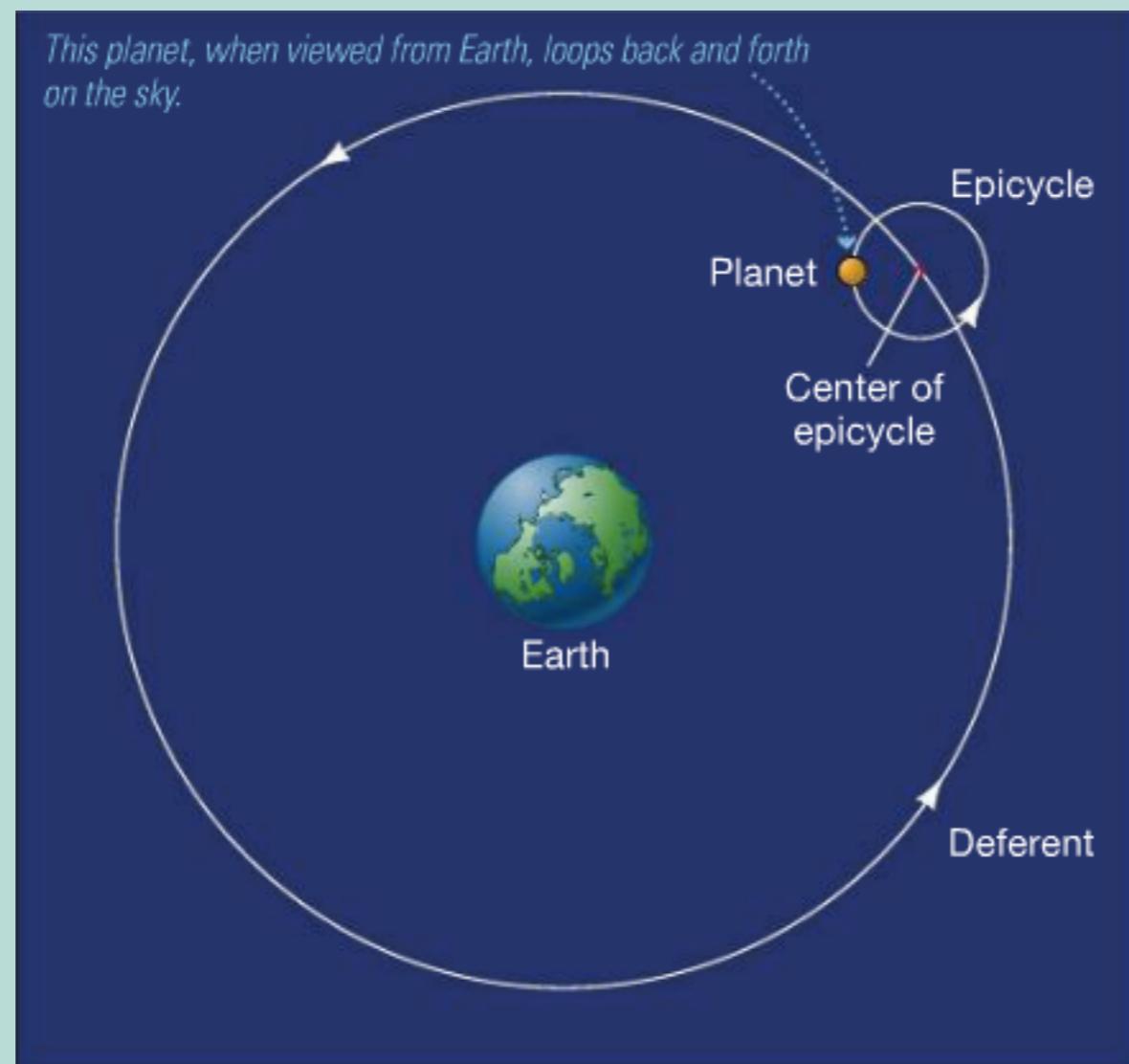
- Very Regular Motion
- Regular Brightness (or at least *predictable* brightness)

- 5 objects moved against the regular motion of the celestial sphere (Mercury, Venus, Mars, Jupiter, Saturn)
- These objects varied in brightness noticeably

# The Wanderers



# Epicycles



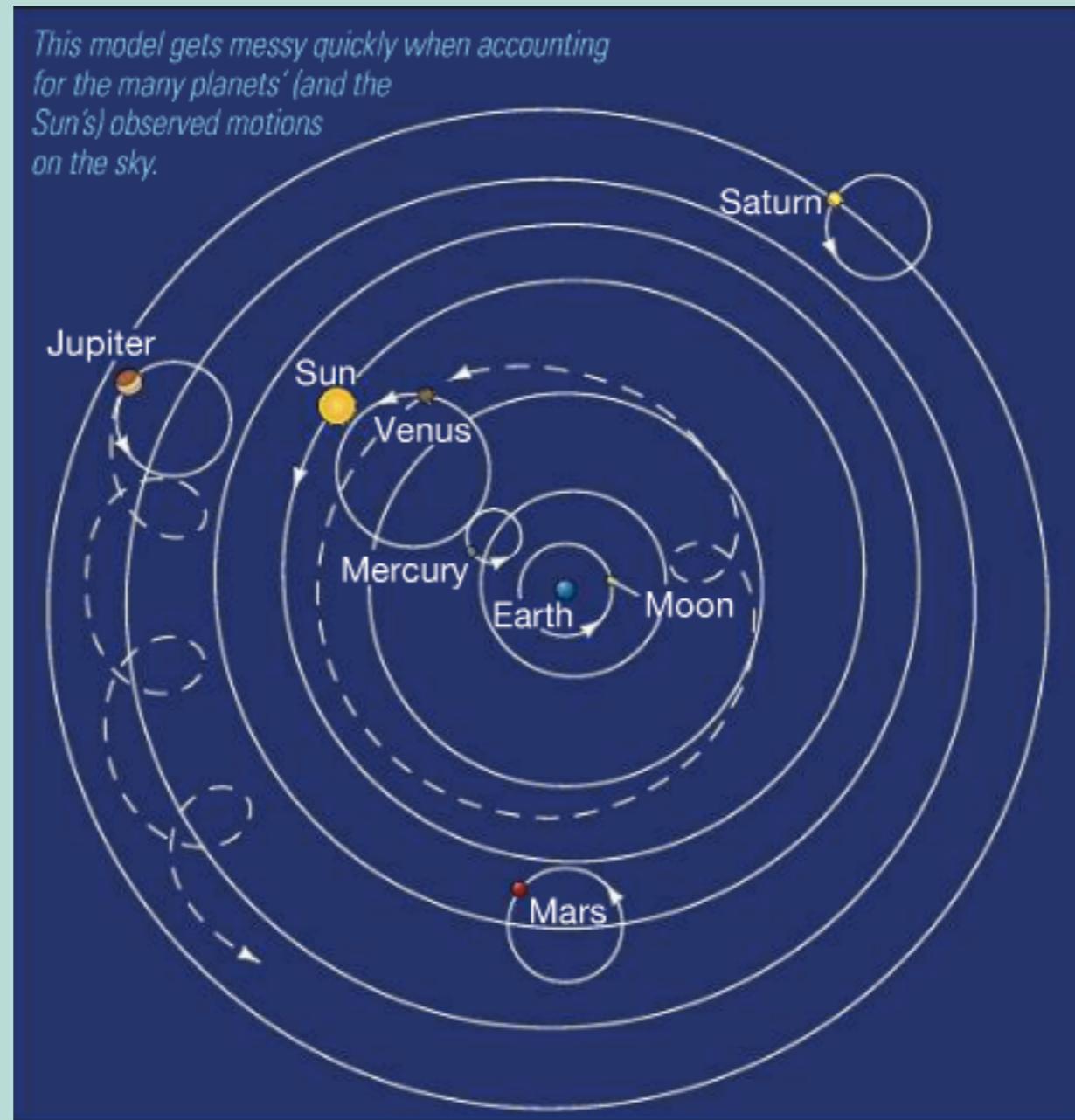
# Claudius Ptolemy



“The Almagest”

- Born in Egypt, Rome
  - 100AD - 170AD

# The Geocentric Universe



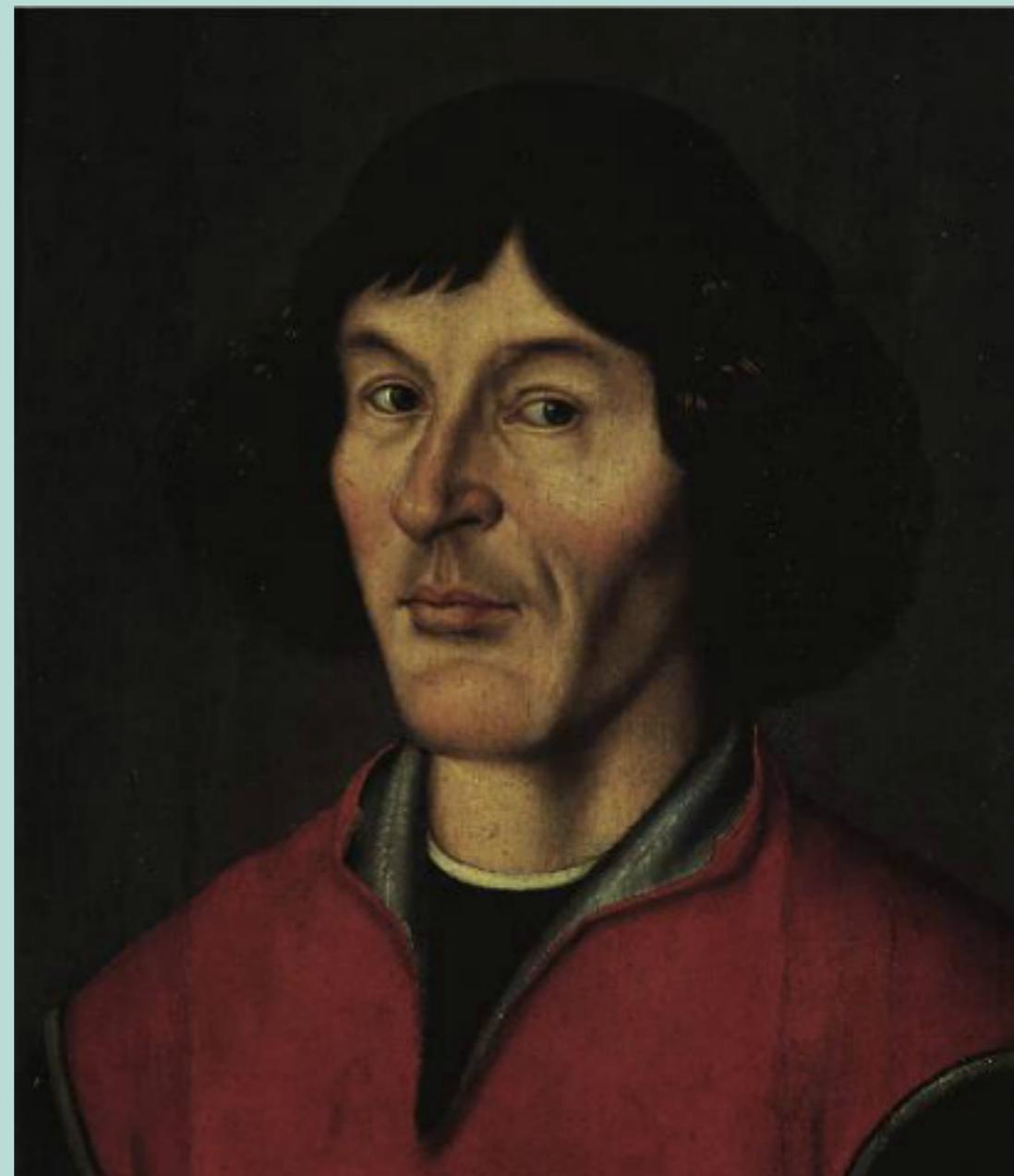
- No Stellar Parallax
- We don't feel like we're moving

# Aristarchus of Samos



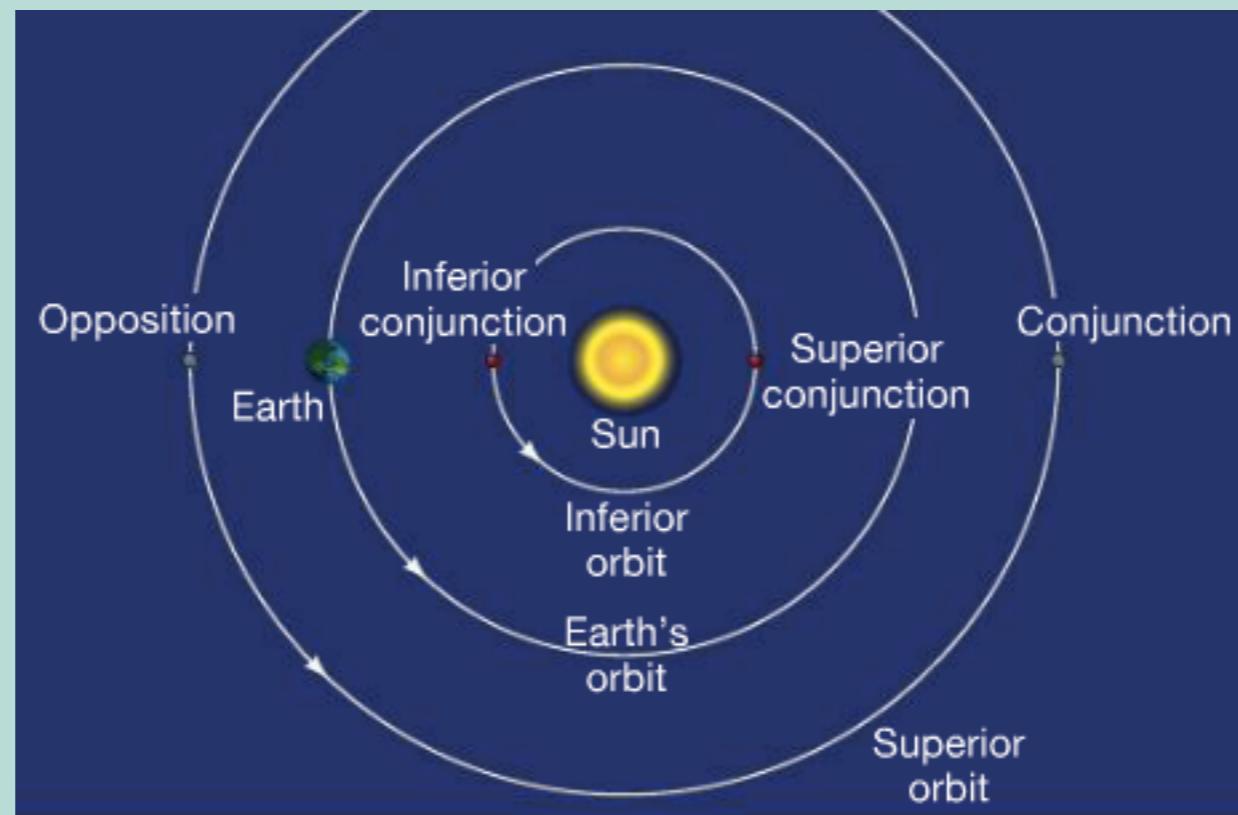
• 310 - 230 BC

# Nicolaus Copernicus



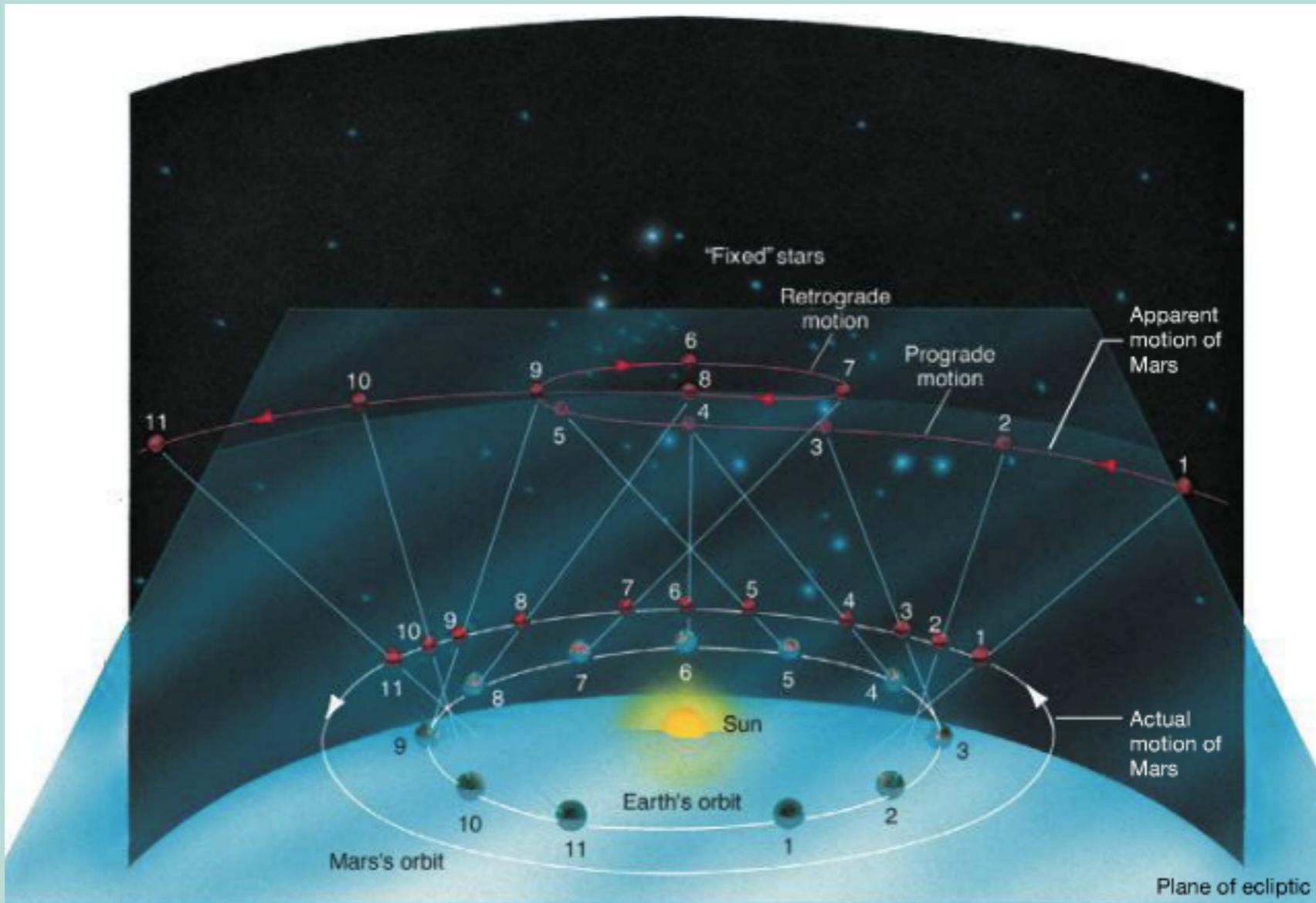
- Born in Thorn, Prussia (Poland)
  - 1473 - 1543

# Some Definitions

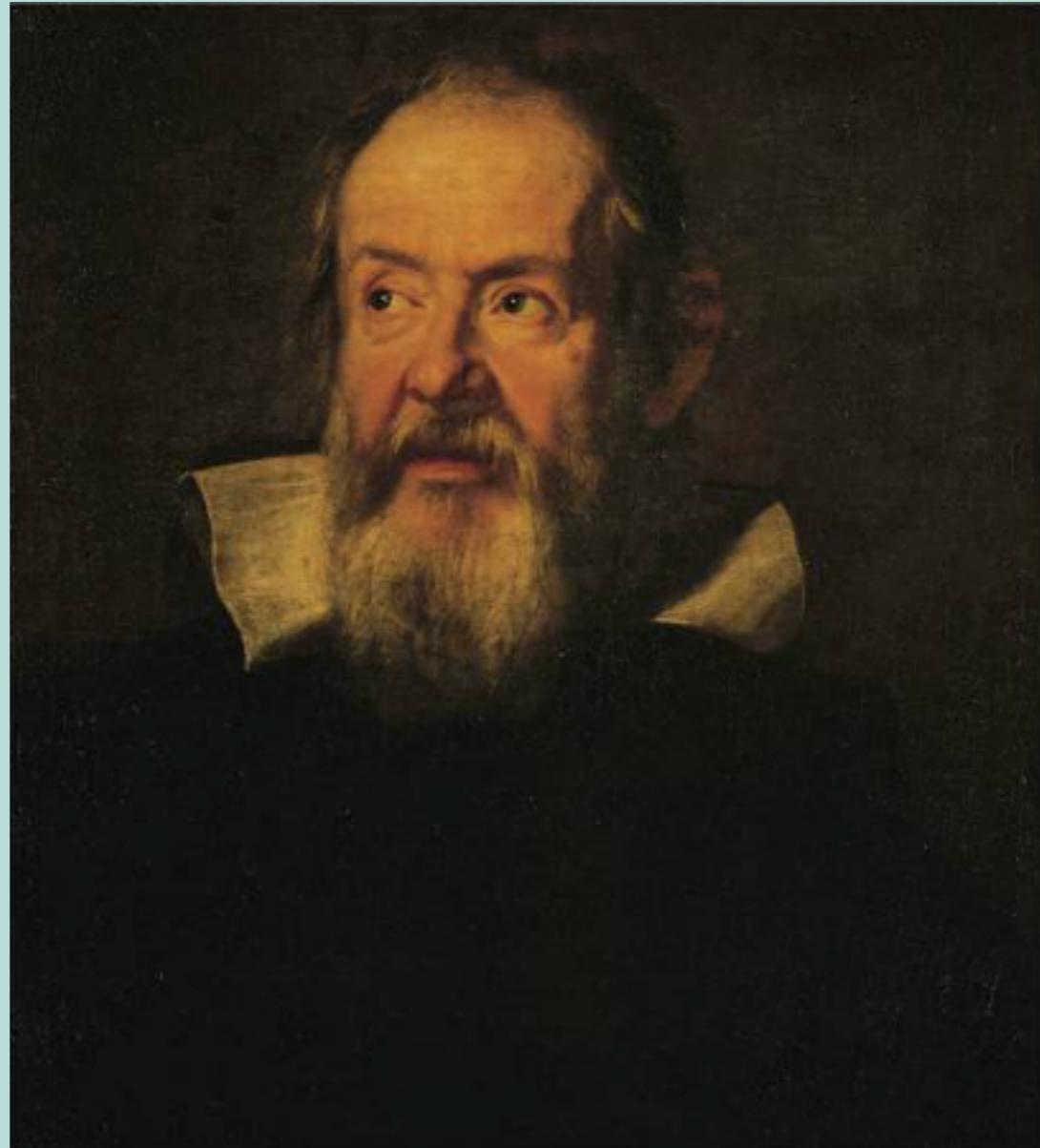


- Inferior Planets never stray too far from the sun. At inferior conjunction they exhibit retrograde motion while at superior conjunction, prograde
- Superior planets, aren't tied to the sun at all, are in prograde motion with the sun, but exhibit retrograde motion when diametrically opposed to the sun.
- Superior planets are brightest at opposition, inferior planets just before/after inferior conjunction.

# The Wanderers (revisited)



# Galileo Galilei

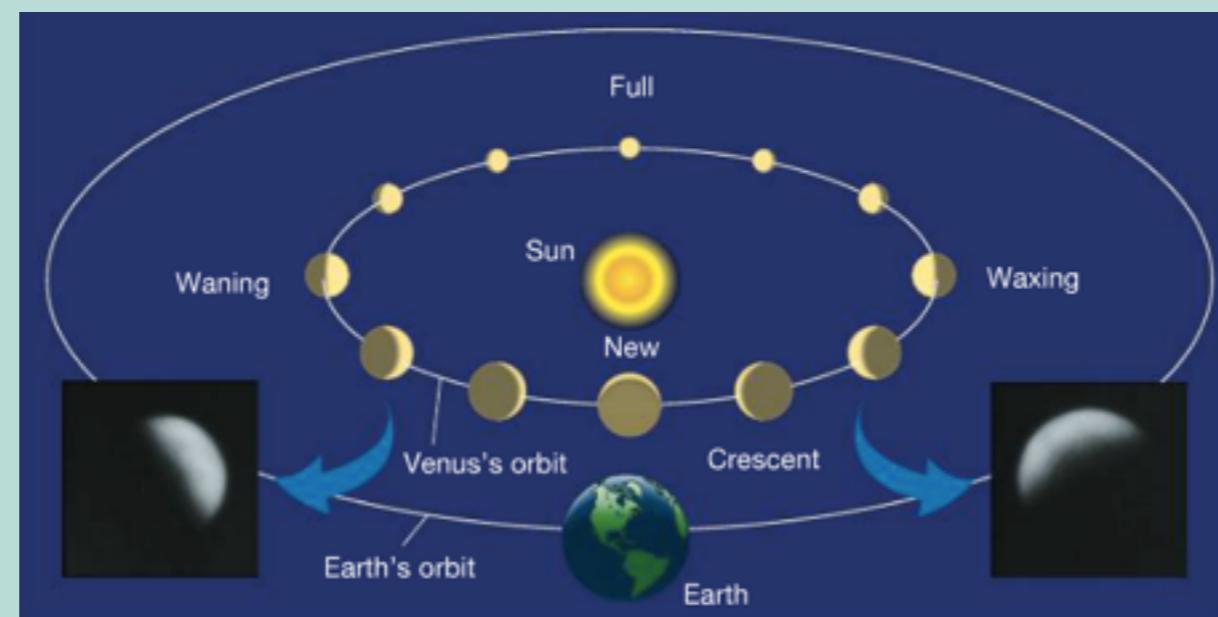


- Born in Pisa, Italy
  - 1564 - 1642

# Phases of Venus

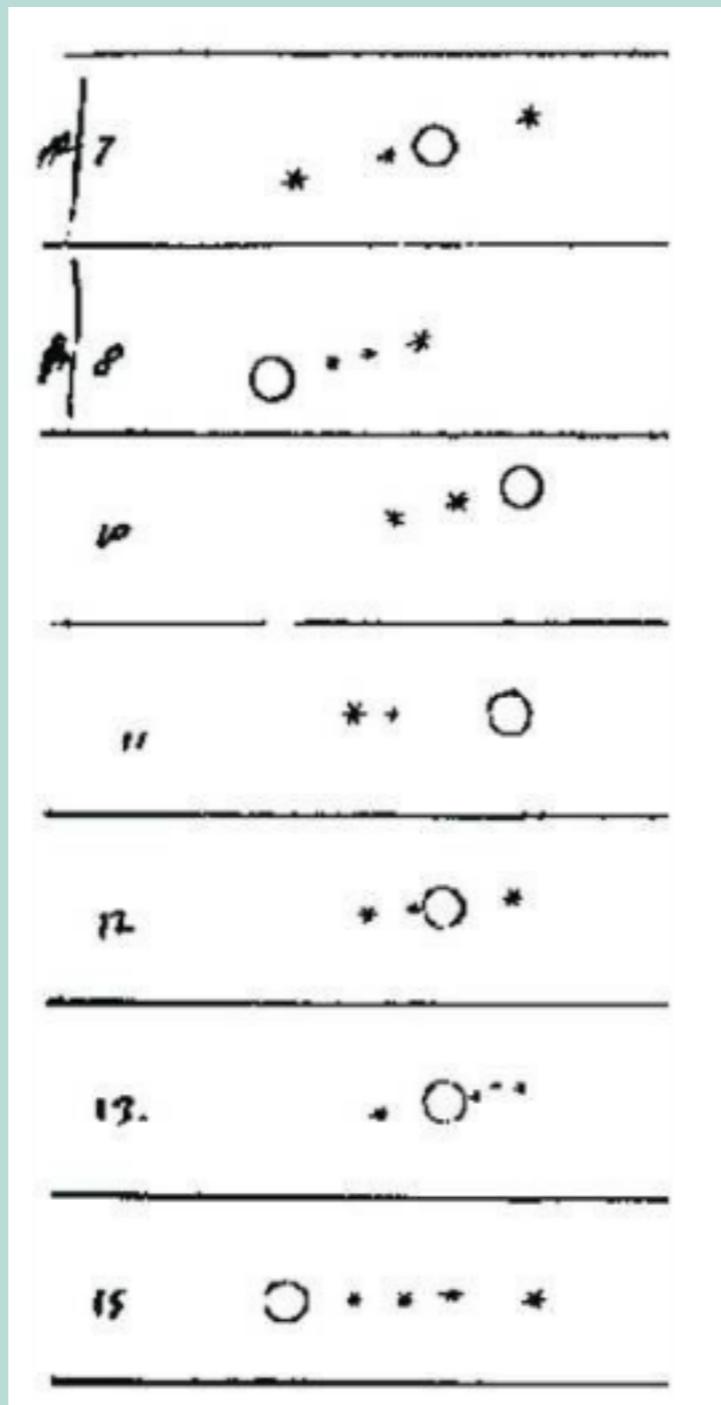


## Epicycle Phenomenology



## Copernican Phenomenology

# Jupiter has moons too!



Io, Europa, Ganymede, Callisto  
... sorry Aristotle

# Johannes Kepler



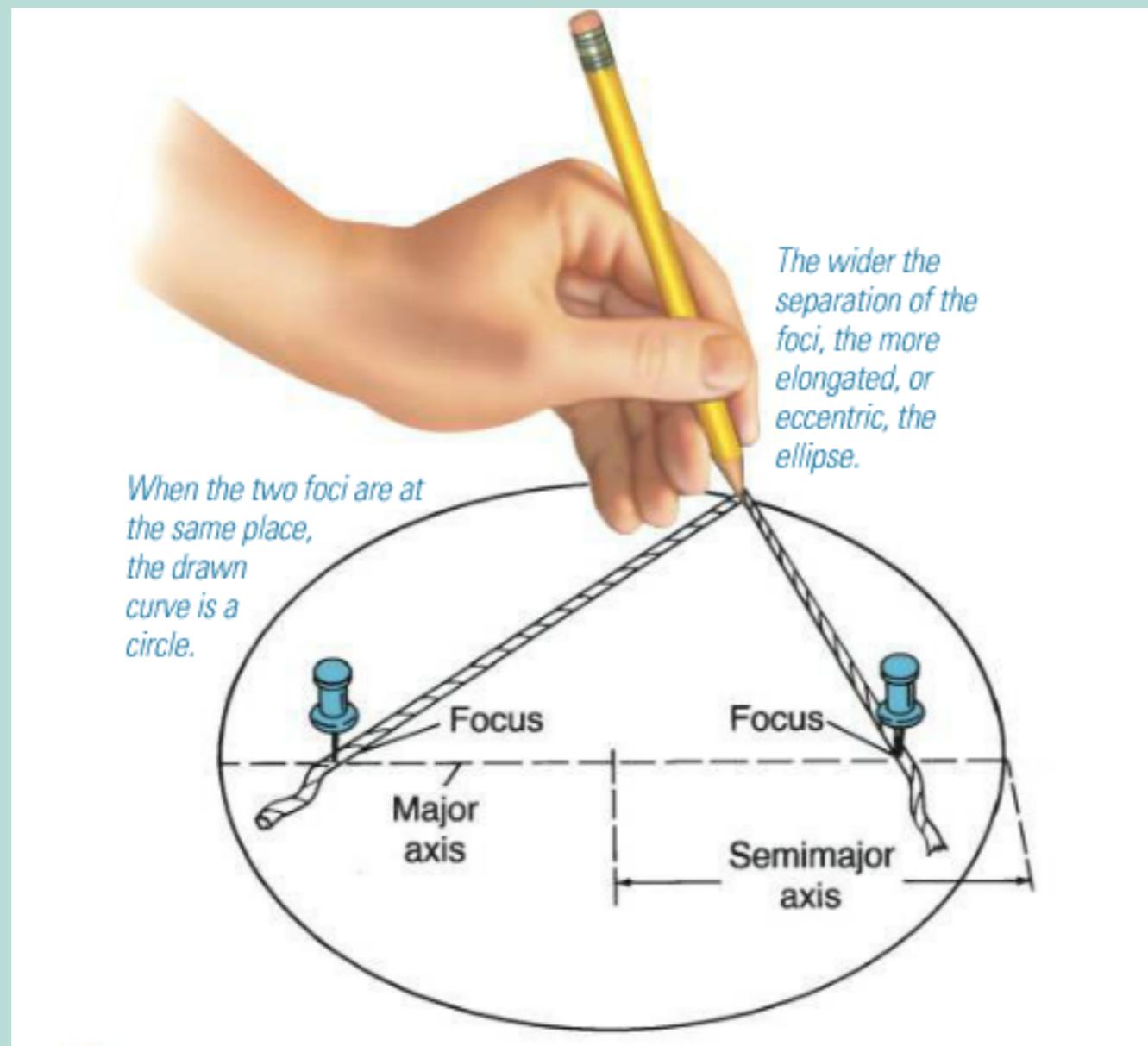
- Born in Weil der Stadt, Holy Roman Empire
  - 1571 - 1630

# Tycho Brahe

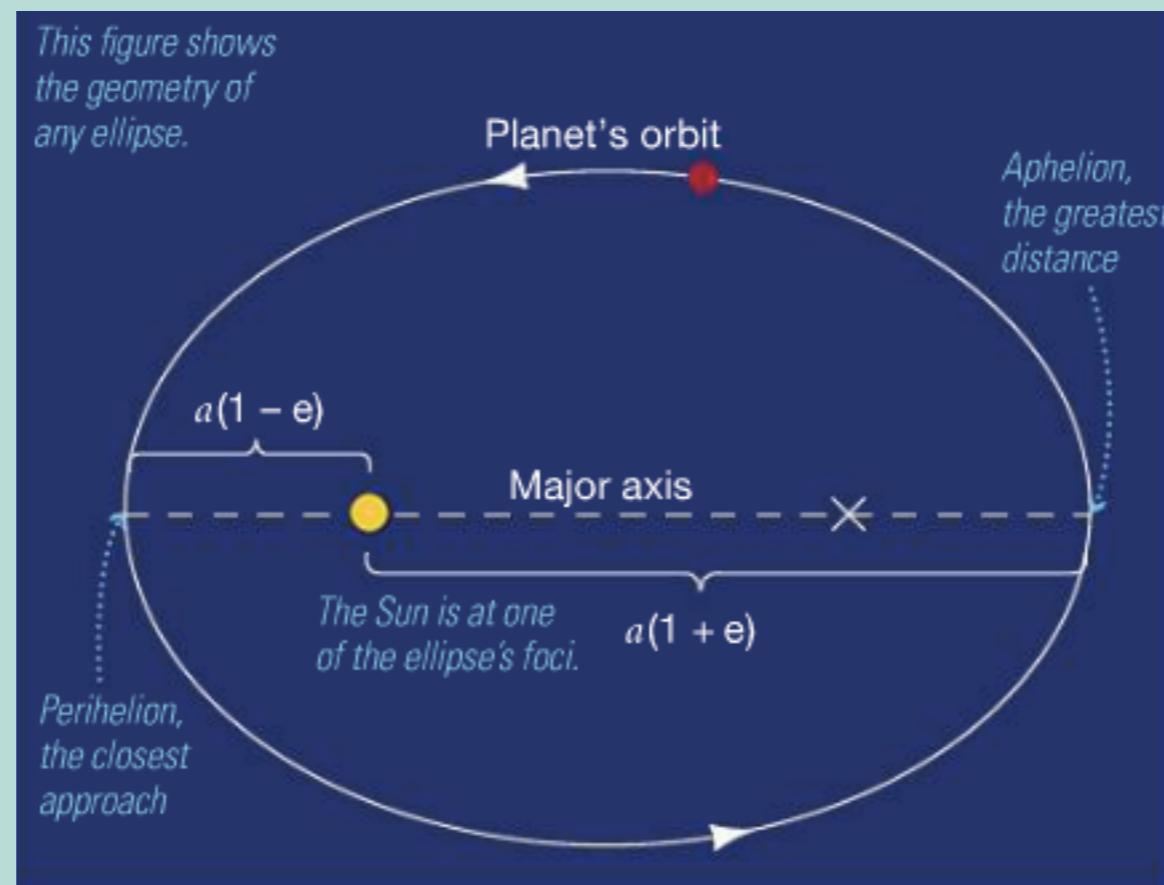


- Born in Knutstorp Castle, Denmark
  - 1546 - 1601

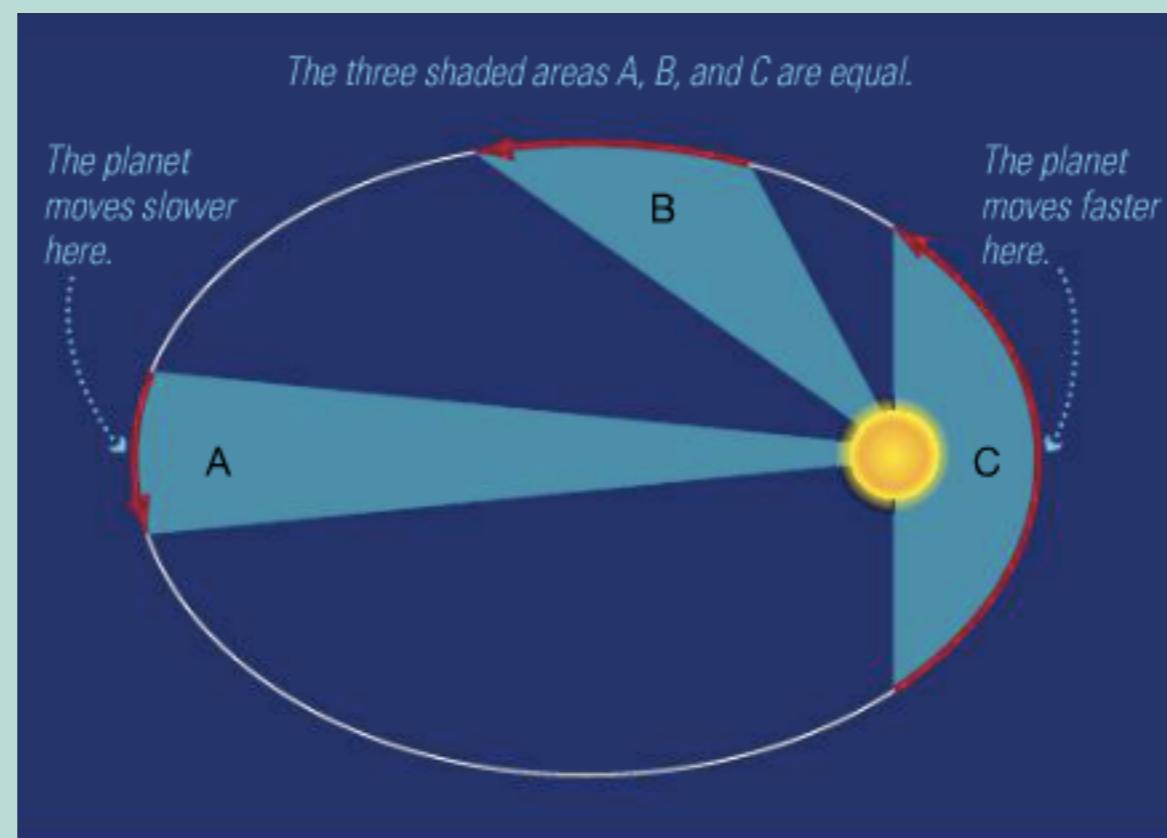
# Kepler's First Law



# Orbital Parameters



# Kepler's Second Law

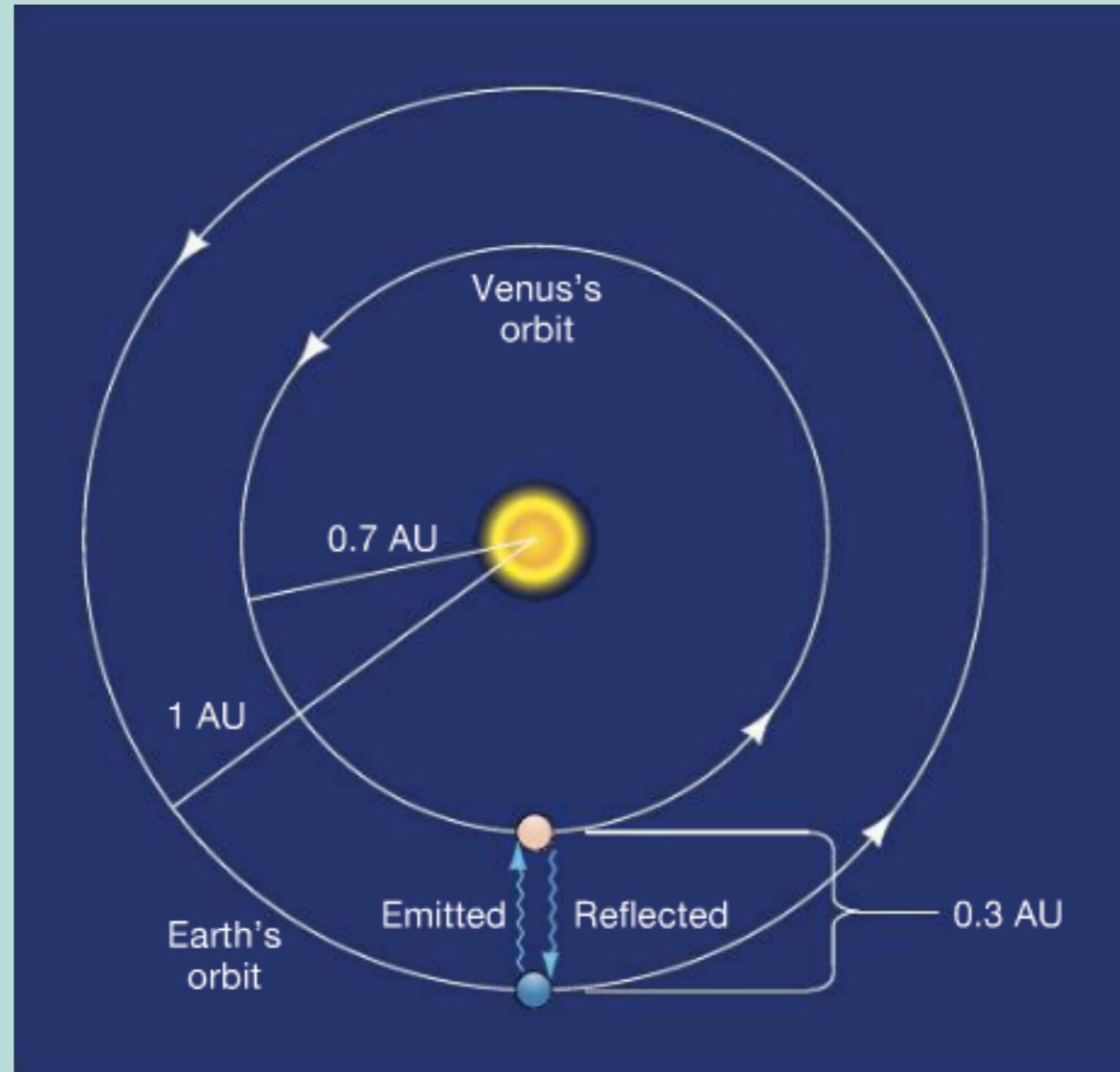


# Kepler's Third Law

$$P^2 \text{ (earth years)} = a^3 \text{ (AU)}$$

Planet	Orbital Semimajor Axis, $a$ (AU)	Orbital Period, $P$ (years)	Orbital Eccentricity, $e$	$P^2/a^3$
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	9.537	29.42	0.054	0.998
Uranus	19.19	83.75	0.047	0.993
Neptune	30.07	163.7	0.009	0.986

# How big is an AU?

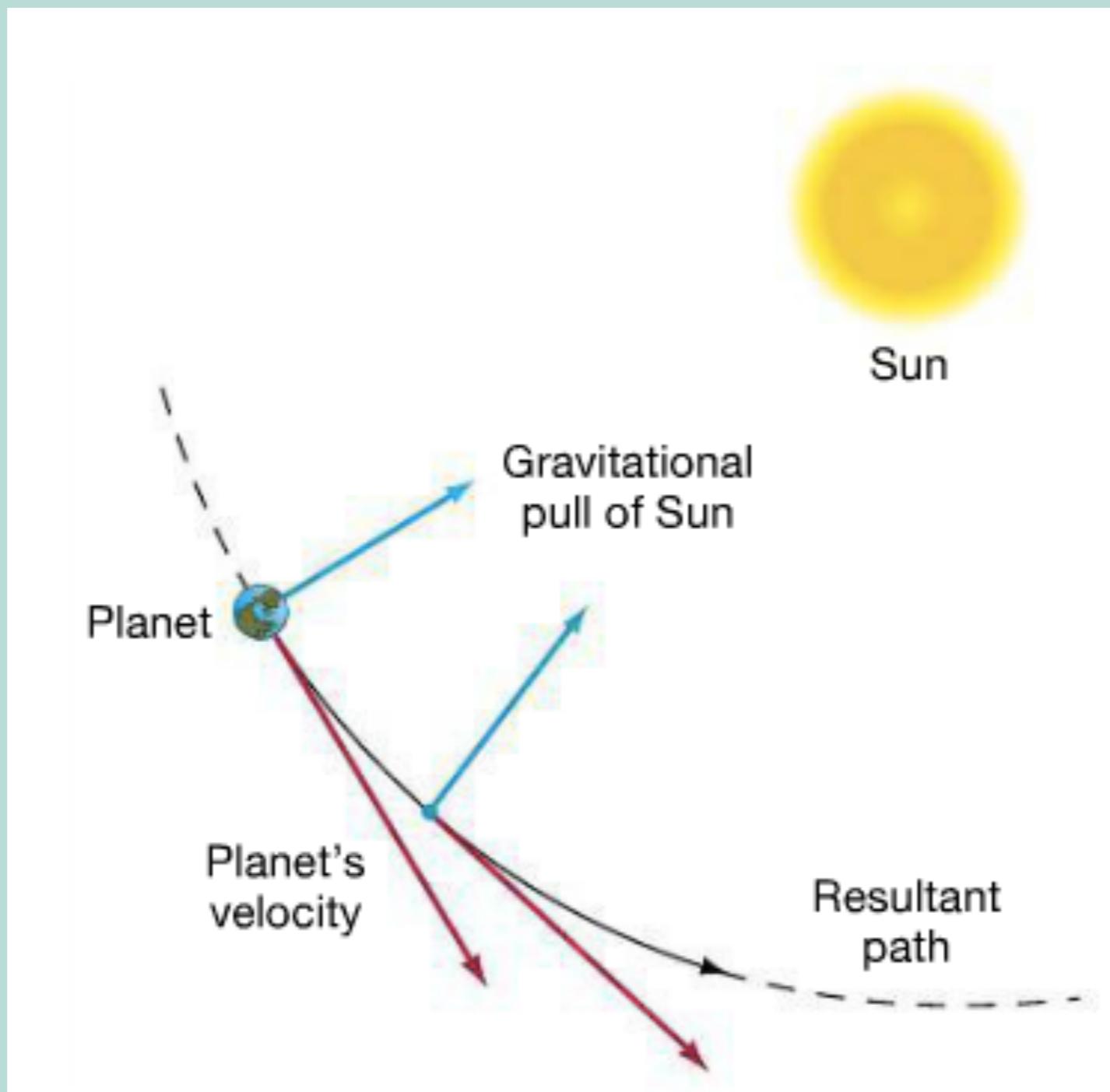


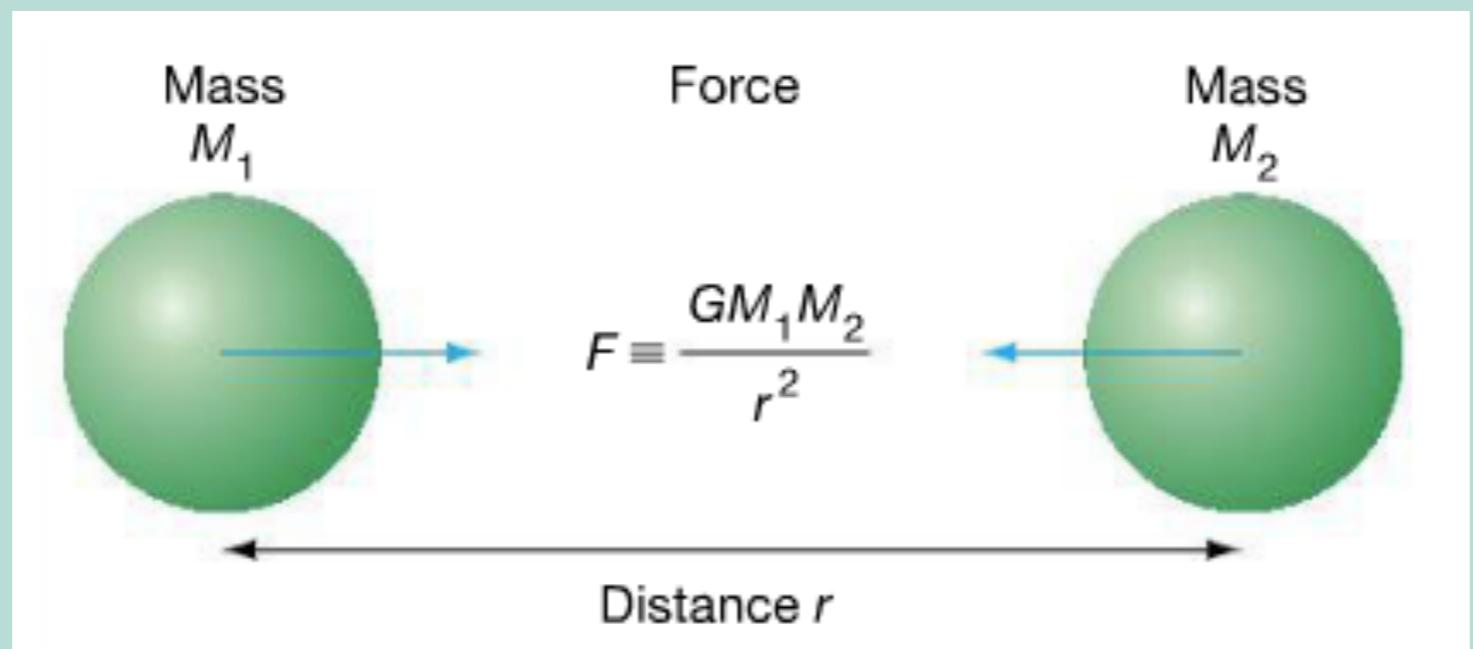
# Isaac Newton



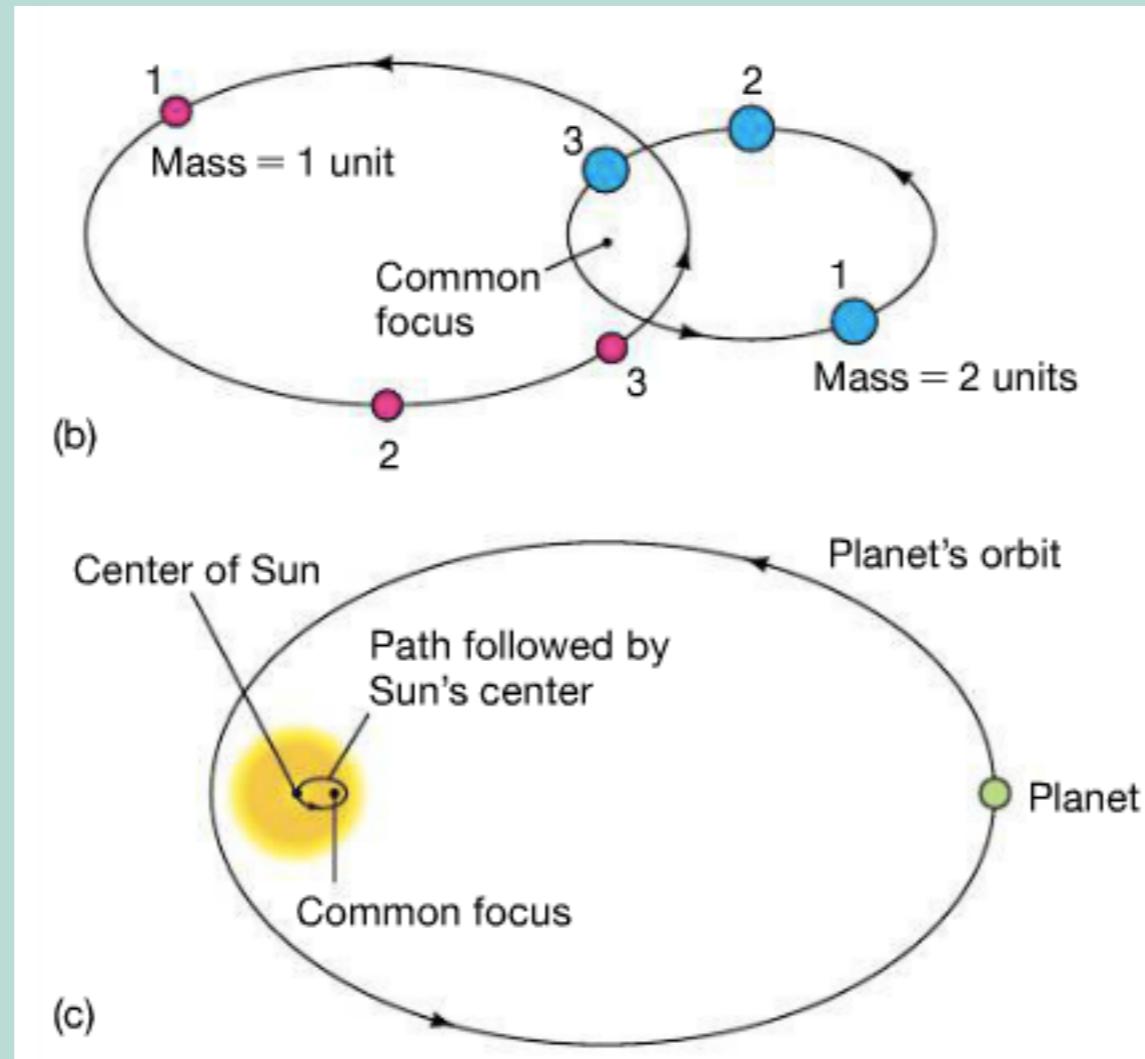
- Born in Lincolnshire, England
  - 1642 - 1627

- Realized that these physical objects in the sky obeyed mathematical principles the same as everything else.
- Most importantly, he realized that gravity, the reason why things fall towards the earth, is the same as the reason that planets orbit around each other. That elliptical motion would result if things ‘fell’ at each other.
- He wasn’t the first to think about gravity or physical objects tugging on each other, but he was the first to invent a whole new field of mathematics to quantify and prove Kepler’s laws from first principles.
- If Alhazen invented the idea of science, Newton invented the scope and application of that idea.

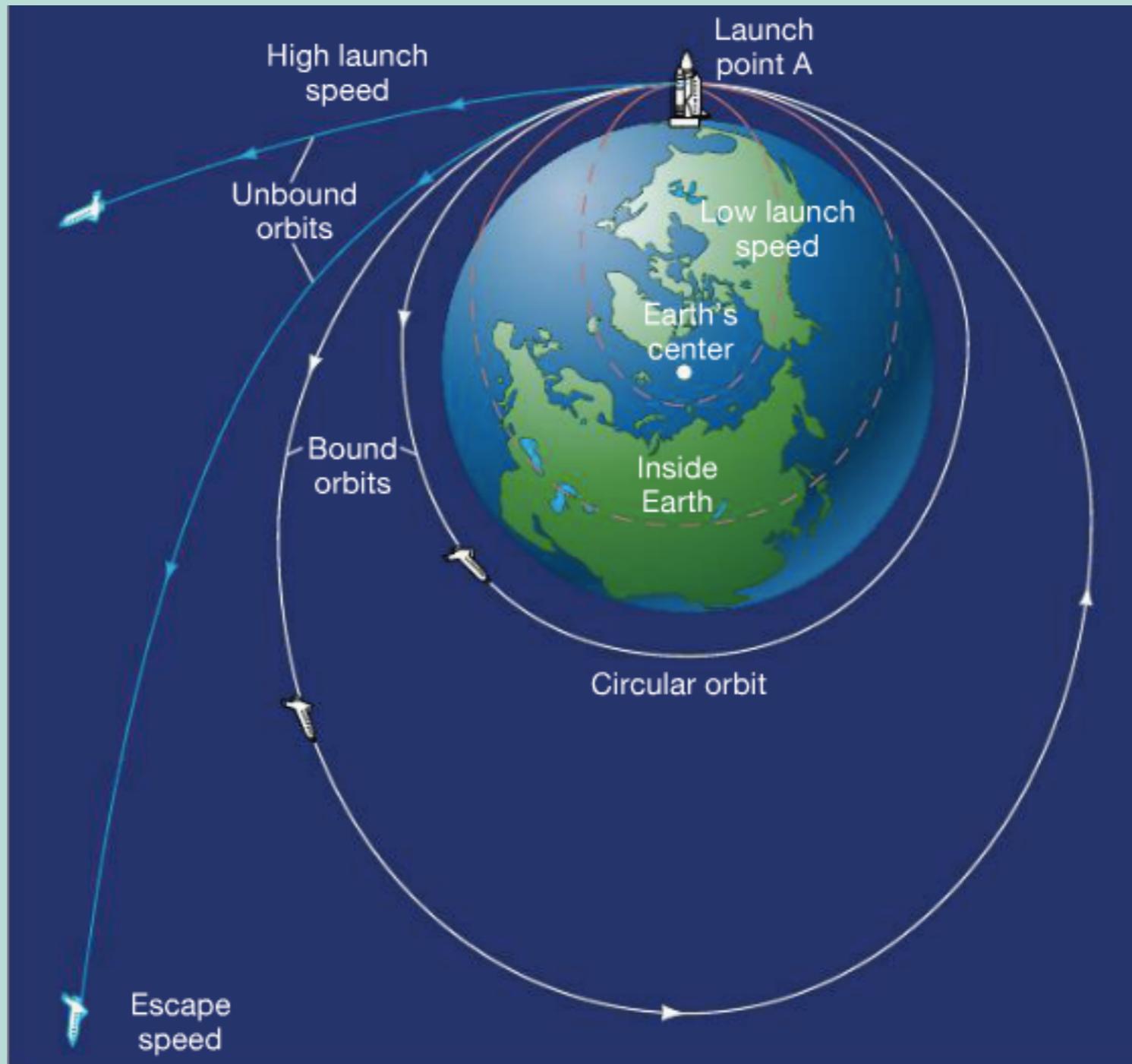




# Kepler 1 revised



# Escape Velocity



11.2 km/s or Mach 33  
( 10.735 km/s relative to Cape Canaveral)