

# Elliptical Orbits of the Planets

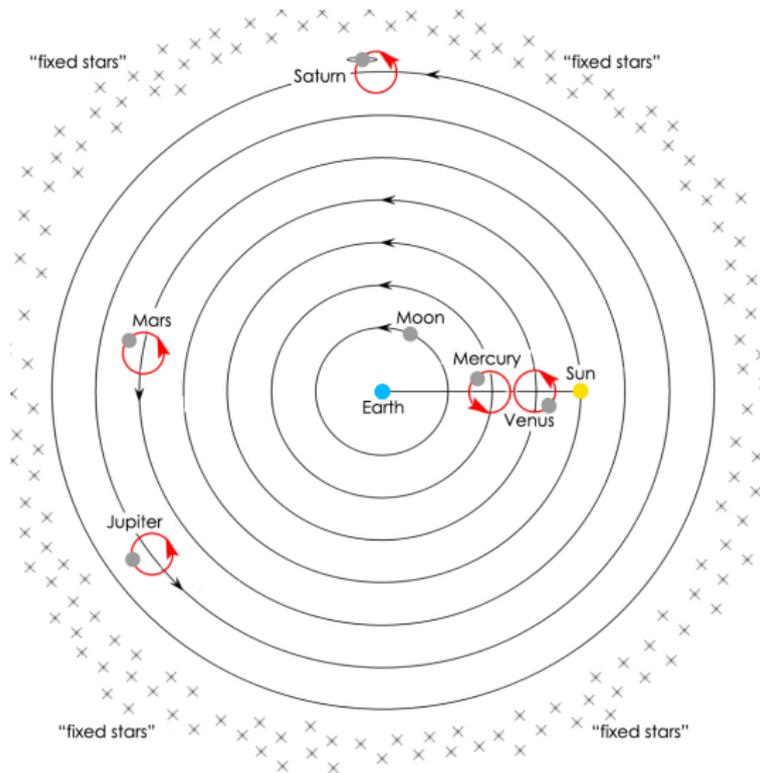
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# Solar System according to the Ancient Greeks

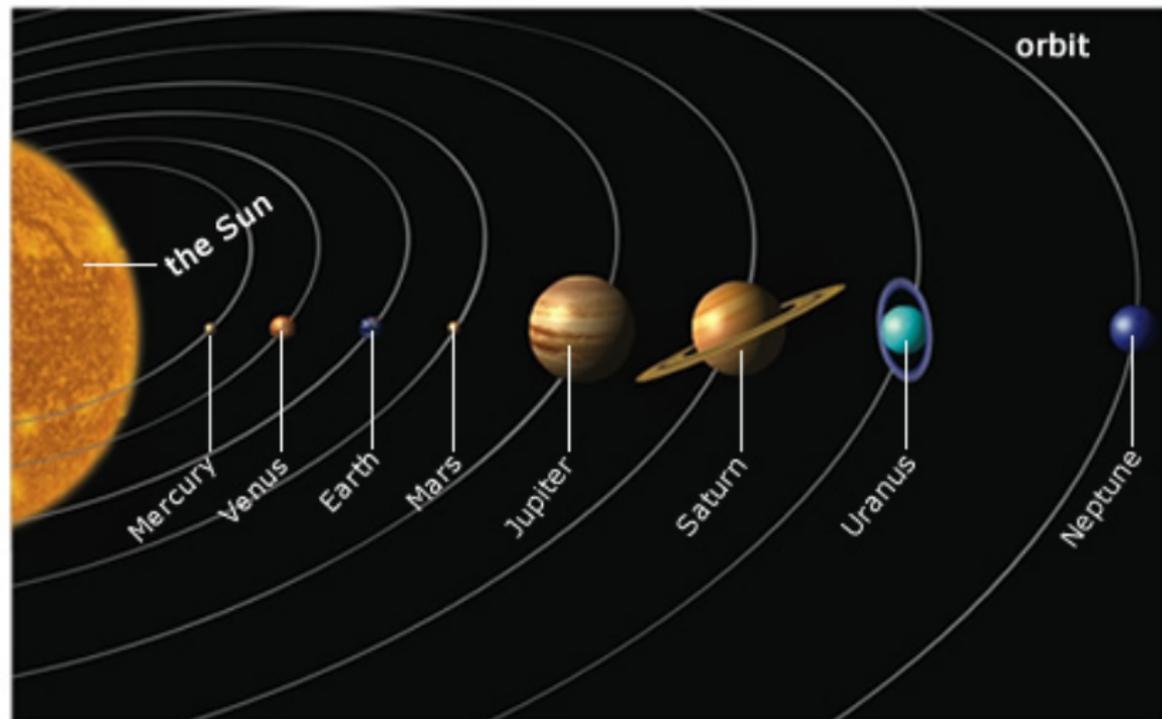
## Geocentric model of Ptolemy

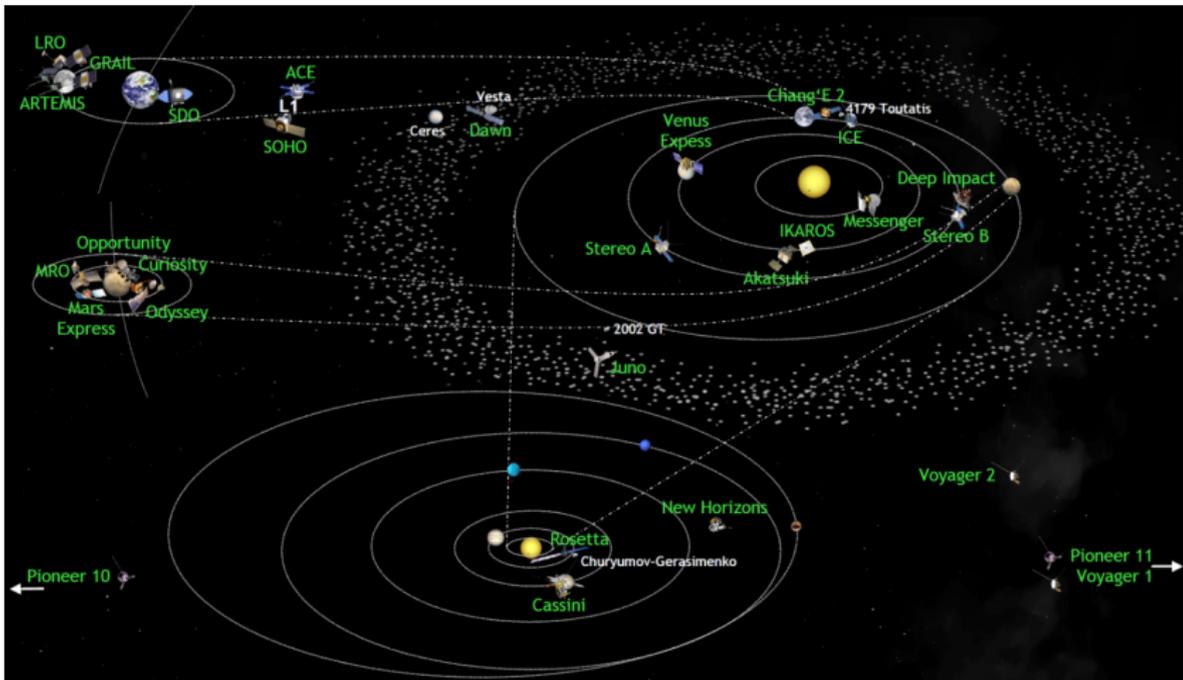


# Solar system according to NASA

Heliocentric model of Copernicus

## The solar system





### Upcoming Events

2012

Dec: GRAIL EOM  
Dec: Chang'E 2 FB 4179 Toutatis

2013

Sep: LADEE Launch/OI Moon  
Oct: Juno FB Earth  
Nov: MAVEN Launch

Nov: Mangalyaan Launch  
Chang'E 3 Launch

2014

Jan: Rosetta Wake-up  
May: Rosetta App Churyumov-Ger.  
Aug: ICE FB/OI? Earth  
Sep: MAVEN OI Mars

Nov: Rosetta Ld Churyumov-Ger.  
Hayabusa 2 Launch

2015

Mar: Dawn App Ceres  
Jul: New Horizons FB Pluto  
Aug: Bepi-Colombo Launch  
Chang'E 4 Launch

Luna Glob 1 Launch  
2016

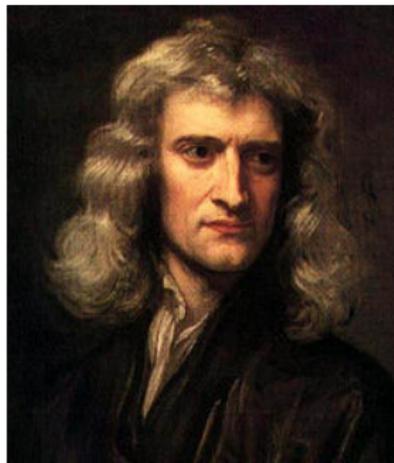
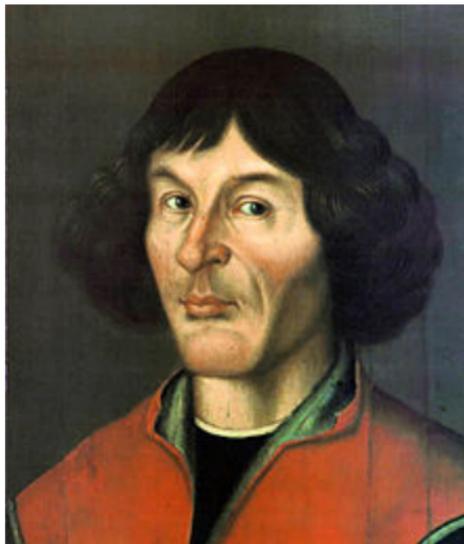
Mar: InSIGHT Launch  
Jul: Juno OI Jupiter  
Dec: Akatsuki OI Venus  
OSIRIS-REX Launch  
Exomars-TGM Launch

Luna-Glob 2 Launch  
2017

Sep: Cassini EOM  
Oct: Juno EOM  
Solar Orbiter Launch  
2018 —  
Deep Impact FB 2002 GT (2020)

FB: Flyby; OI: Orbit Insertion; App: Approach; Dep: Departure;  
EDL: Entry, Descent and Landing; Ld: Landing; EOM: End of Mission

The scientific revolution  
*... and yet it moves ...*



# Orbits

- All systems follow **universal laws**:
  - planets around the Sun
  - satellites around the Earth
  - Solar System around galactic centre
  - Stars around a supermassive black hole, etc.

# Orbits

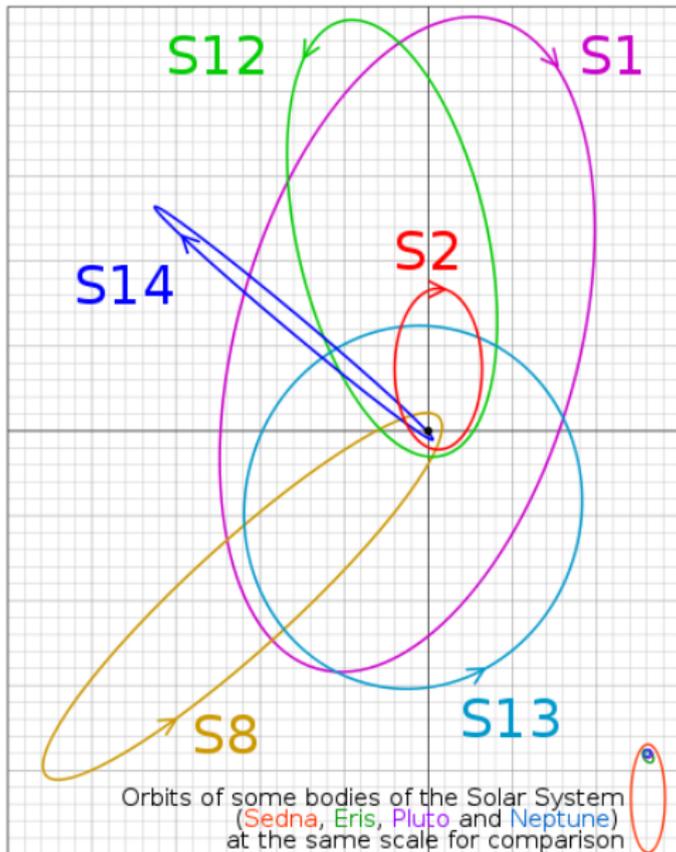
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# Kepler's Laws of Planetary Motion



**1609 – 1619:** Johannes Kepler deduced three empirical laws from the astronomical observations of Copernicus, Galileo and Tycho Brahe.

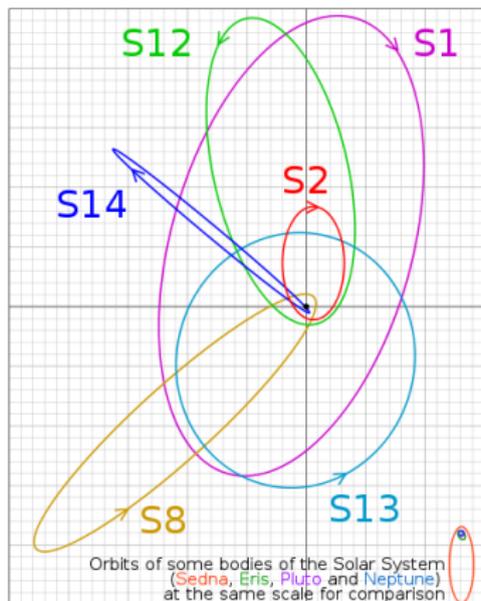
# Orbits of stars at centre of our galaxy



# Kepler's Laws of Planetary Motion

## Kepler's First Law

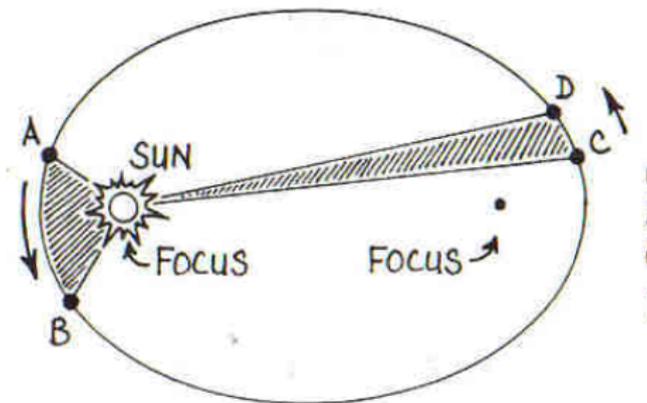
The orbit of each planet is an **ellipse** with the Sun at a **focus**.



# Kepler's Laws of Planetary Motion

## Kepler's Second Law

The line joining a planet to the Sun sweeps out **equal areas** in equal intervals of time.

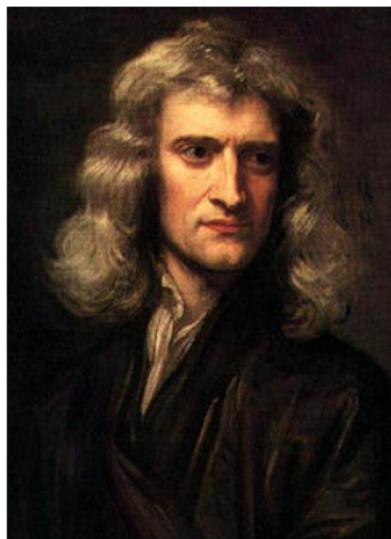


# Newton's laws

- Kepler's laws were empirical (deduced from data)

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- **1687:** In the *Principia Mathematica*, Newton showed that Kepler's laws are a mathematical consequence of Newton's laws of motion + gravitation



# Newton's laws

- Newton's 2nd law of motion:  $\mathbf{F} = m\ddot{\mathbf{r}}$
- Newton's law of gravitation:

$$\mathbf{F} = -\frac{GMm}{r^2}\hat{\mathbf{r}}$$

where  $G \approx 6.67 \times 10^{-11} \text{ N kg}^{-2} \text{ m}^2$  is Newton's gravitational constant.

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