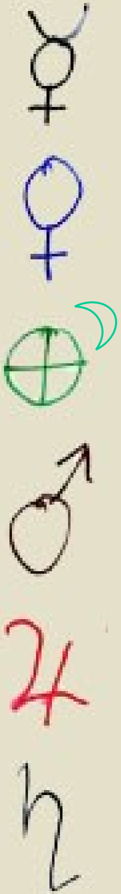


MARS

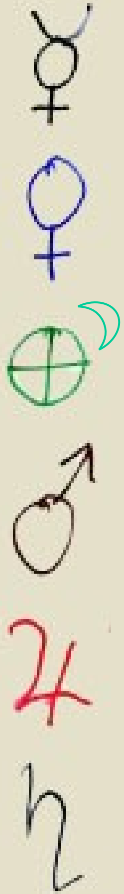
JOHANNES KEPLER

THE SOLAR SYSTEM

LAWS OF PLANETARY MOTION

Danish astronomer Tyco Brahe (1546-1601) had an island observatory and the best measurements of the positions for all known planets (Mercury, Venus, Mars, Jupiter, and Saturn) and the Moon.

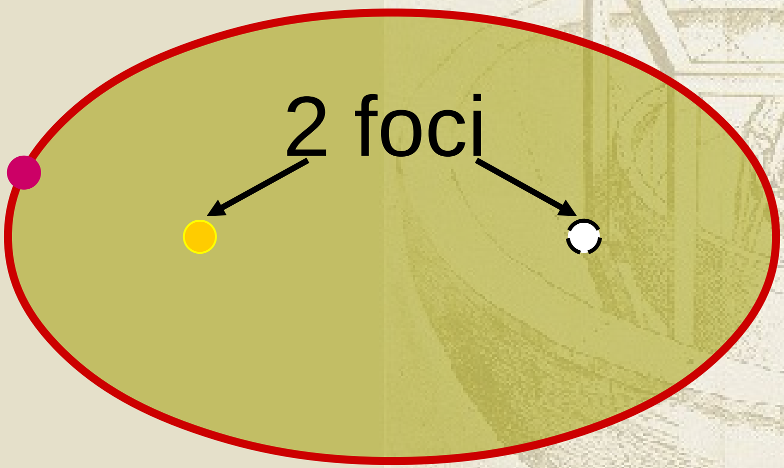
Austrian mathematician **Johannes Kepler** (1571-1630), interested in how the planets move around the sun, went to Tyco’s island to get these accurate measurements.



At that time, many astronomers believed that planets orbited around the sun in perfect circles, but Tyco's accurate measurements for Mars didn't fit a circle.

Instead, the mathematician Johannes Kepler found that the orbit of Mars fit an ellipse the best…

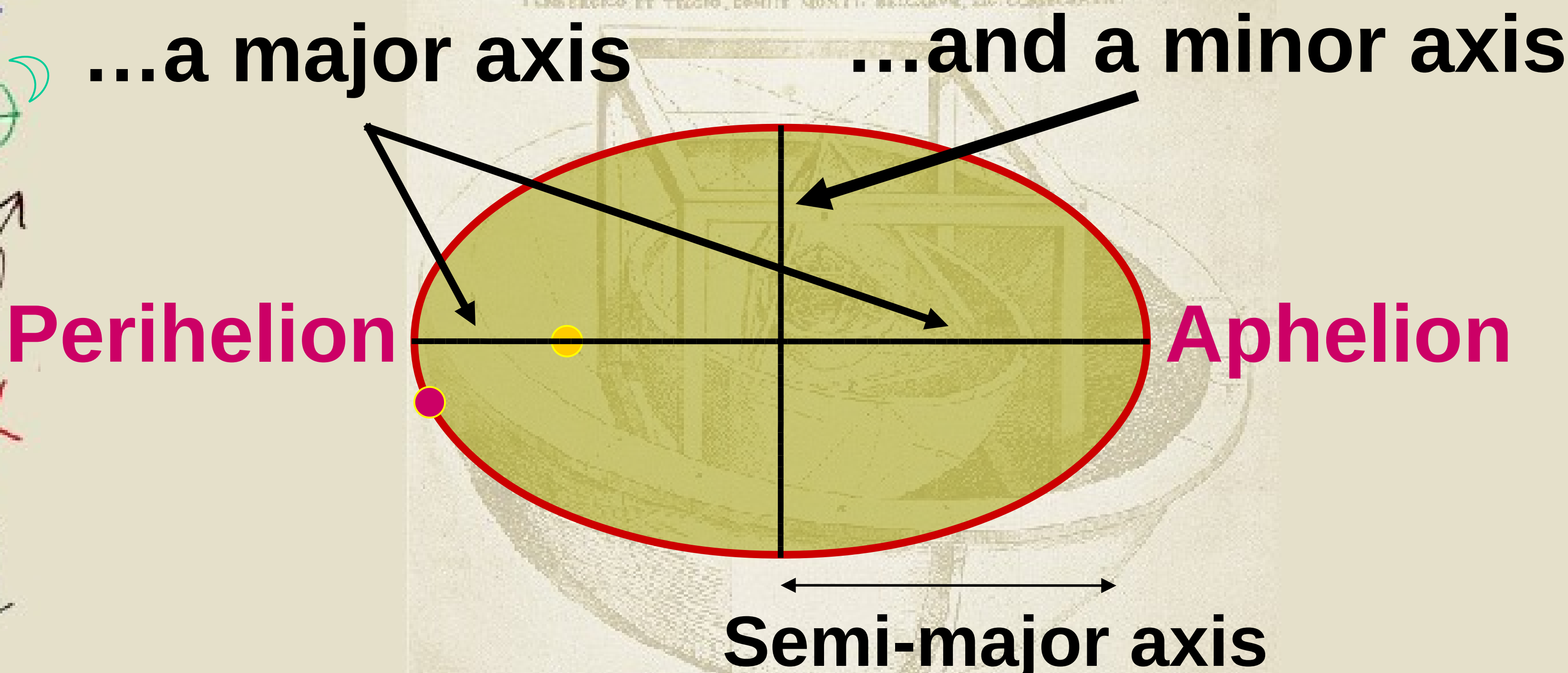
What is an **ellipse**?



An ellipse is a geometric shape with 2 foci instead of 1 central focus, as in a circle. The sun is at one focus with nothing at the other focus.

FIRST LAW OF PLANETARY MOTION

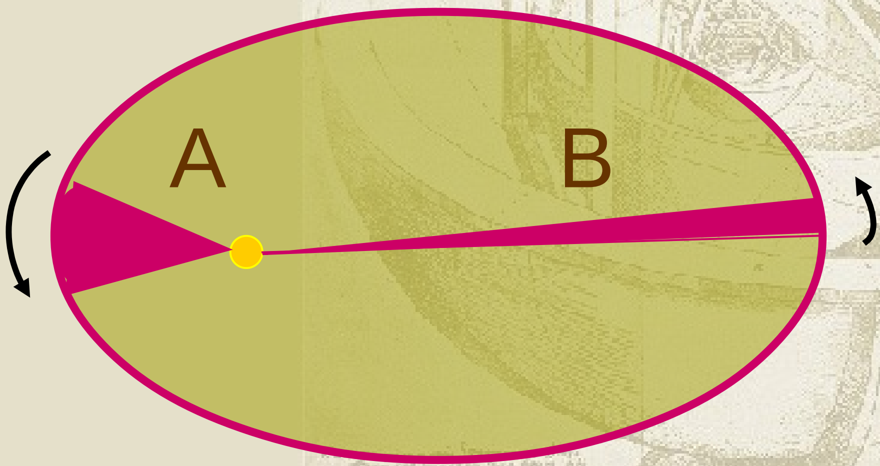
An ellipse also has…



Perihelion: When **Mars** or any another planet is closest to the **sun**.

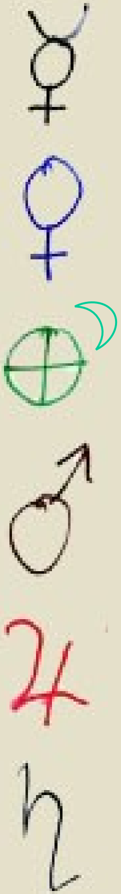
Aphelion: When **Mars** or any other planet is farthest from the **sun**.

Kepler also found that Mars changed speed as it orbited around the sun: faster when closer to the sun, slower when farther from the sun…

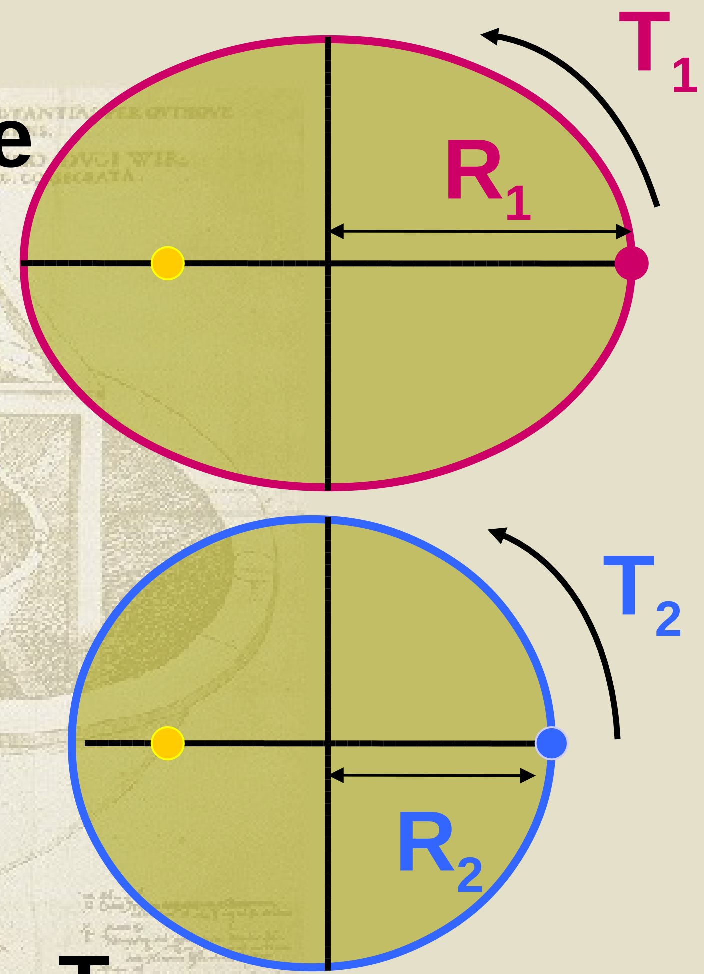


But, areas A and B, swept out by a line from the sun to Mars, were equal over the same amount of time.

SECOND LAW OF PLANETARY MOTION

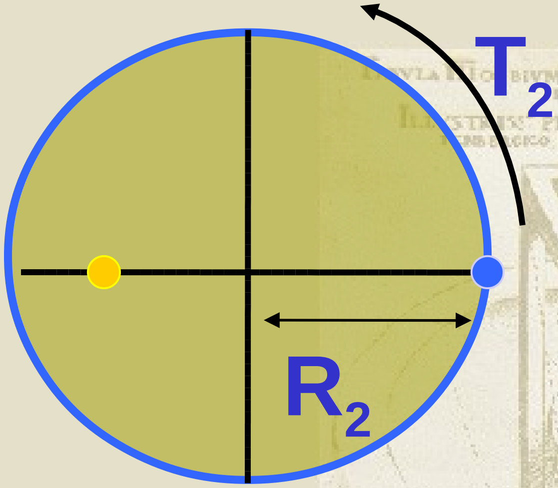


Kepler found a relationship between the time it took a planet to go completely around the sun (T, sidereal year), and the average distance from the sun (R, semi-major axis)…



$$\frac{T_1^{\,2}}{T_2^{\,2}} = \frac{R_1^{\,3}}{R_2^{\,3}} \qquad \left(\begin{array}{c} T^2 = T \times T \\ R^3 = R \times R \times R \end{array} \right)$$

THIRD LAW OF PLANETARY MOTION



Earth's sidereal year (T) and distance (R) both equal 1. The average distance from the Earth to the sun (R) is called 1 astronomical unit (AU).

Kepler's Third Law, then, changes to

$$\frac{T_1^{\,2}}{T_2^{\,2}} = \frac{R_1^{\,3}}{R_2^{\,3}} \quad \text{or} \quad \frac{T_1^{\,2}}{1} = \frac{R_1^{\,3}}{1} \quad \text{or} \quad T_1^{\,2} = R_1^{\,3}$$

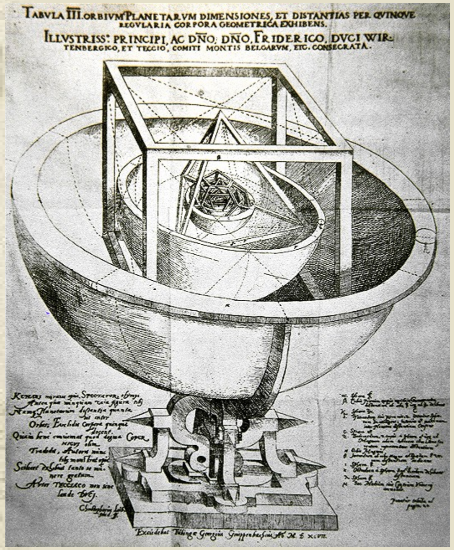
When we compare the orbits of the planets…

Planet	T(yrs)	R(au)	T^2	R^3
Venus	0.62	0.72	0.38	0.37
Earth	1.00	1.00	1.00	1.00
Mars	1.88	1.52	3.53	3.51
Jupiter	11.86	5.20	141	141

We find that T^2 and R^3 are essentially equal.

Kepler’s Laws apply to any celestial body orbiting any other celestial body.

- Any planet around a sun
- The moon around the Earth
- Any satellite around the Earth
- The international space station
- Any rings around any planet



Later, Isaac Newton built upon Kepler's Laws to confirm his own Law of Gravitation.

If it wasn't for Mars and its complicated travels across the night sky, Johannes Kepler may not have derived his Laws of Planetary Motion. Isaac Newton might not have had a foundation for his Law of Gravitation...

THE RED PLANET MARS IS FOREVER LINKED TO OUR UNDERSTANDING OF THE SOLAR SYSTEM AND ONE OF THE 4 BASIC FORCES OF NATURE.