Eliptical Orbits:

A Topic of Interest to Both Physicists and Astronomers
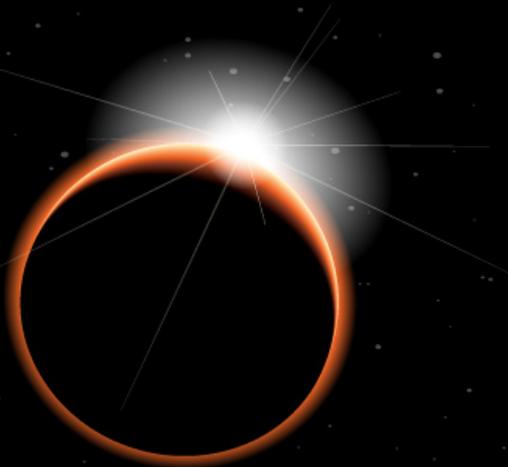
Historical Background

- Prehistoric cultures and civilizations realized that the planets move against a celestial background in a predictable way.

- The ancient Babylonians were the first to use mathematics to predict planetary motion. They also realized that the planets rotated about the Sun giving rise to what we now understand to be an orbit.

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Historical Background Cont.

- In western civilizations philosophers, astronomers, and astrologers held the view of the ancient Greek philosophers' that the Earth was at the center of the Universe.

- Aristotle was also a proponent of geocentrism and his influence remained strong vis-à-vis his influence through St. Thomas Aquinas and the Church.

Nicolaus Copernicus

- Produced a model of the Solar System that had the planets orbiting in circles around the Sun (heliocentrism).
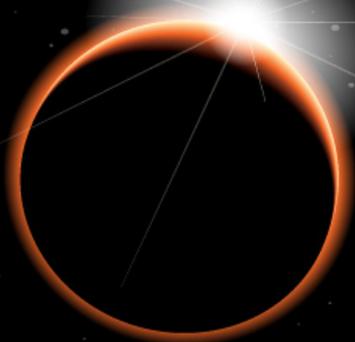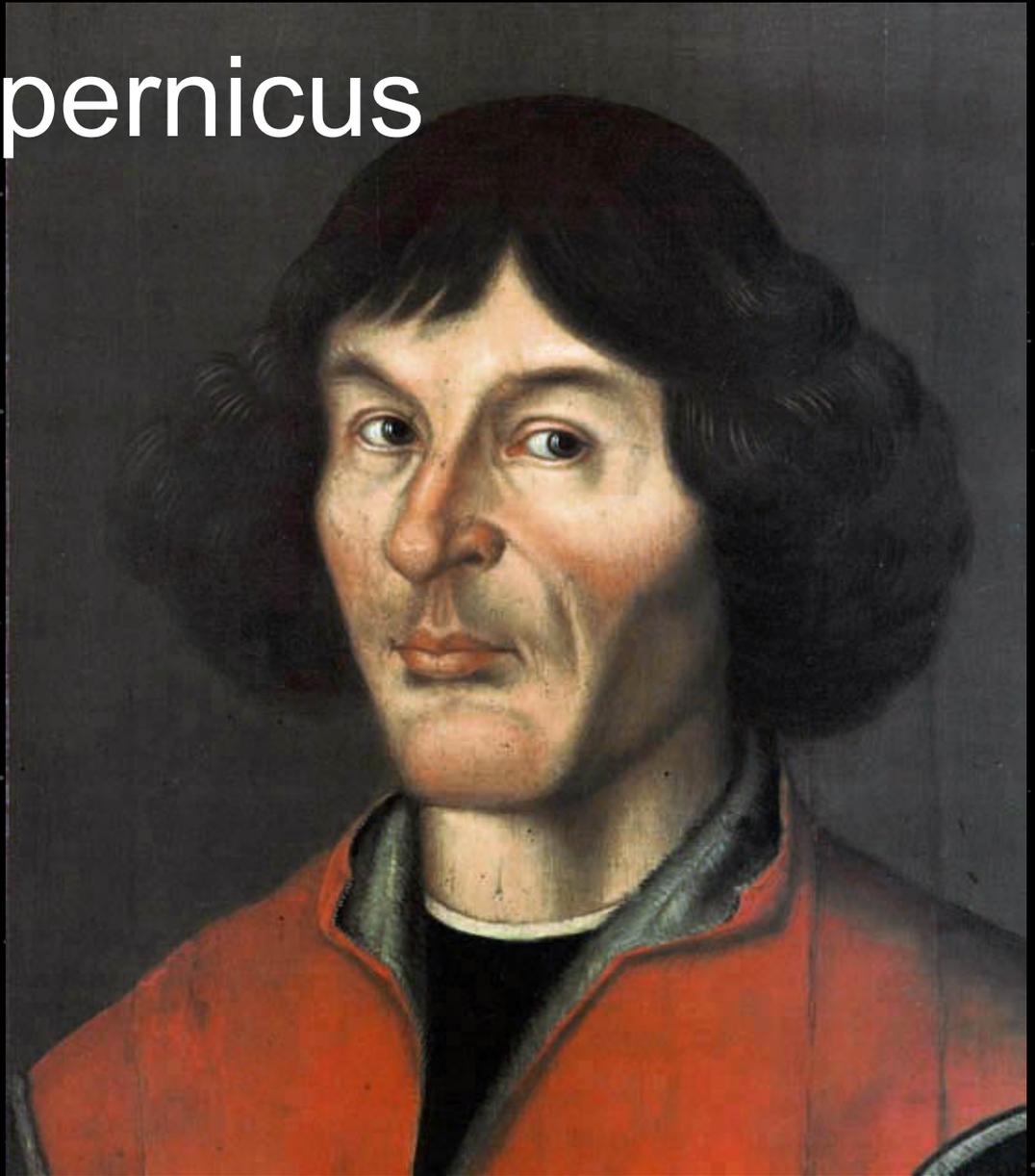
Johannes Kepler

- Using Tycho Brahe's astronomical tables of observations, Kepler produced a mathematical model of the Solar System that had the orbits of the planets in ellipsis about the Sun.

- He also discovered three empirical laws that describe the motion of orbiting bodies.

Kepler's Laws

I.   Each planet moves in an elliptical orbit, with the sun at one focus of the ellipse.

II. A line from the sun to a given planet sweeps out equal areas in equal times.

III. The periods of the planets are proportional to the 3/2 powers of the major axis lengths of their orbits.

Isaac Newton

- Three generations after Kepler, Isaac Newton was able to derive Kepler's empirical laws using his own three laws of motion and another relationship he discovered (the law of gravitation) to derive from first principles Kepler's laws of planetary motion.
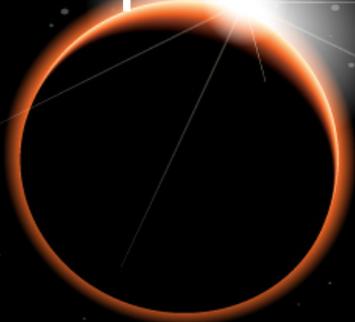
Newton's Laws

I.   Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

II. The relationship between an object's mass m, its acceleration a, and the applied force F is F = ma. Acceleration and force are vectors; in this law the direction of the force vector is the same as the direction of the acceleration vector.

III. For every action there is an equal and opposite reaction.

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# Law of Gravitation

$$F = G\frac{mm'}{r^2}$$

- F=force between gravitationally interacting bodies.

- G=universal gravitational constant.

- m and m prime – the two masses interacting.

- r=the distance between the objects

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Kepler's 1ˢᵗ Law

- An ellipse is a geometric figure formed by imagining a loop of string loosely strung around two push pins.

- If one places a pencil at a third point to draw the loop taught, we can trace an oval shaped object specifically known as an ellipse.

Kepler's 1ˢᵗ Law cont.
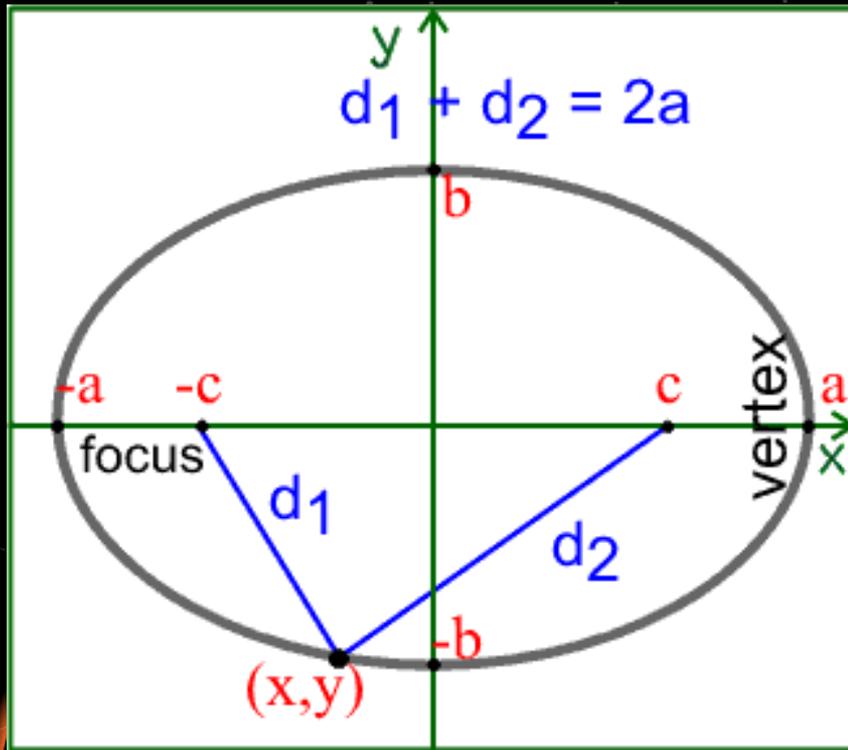
- a=semi major axis
- c=linear eccentricity
- e=c/a eccentricity
- The ellipse is formed at the points (x,y) where 2a=d1+d2 is true.

Kepler's 2nd Law

- Is an extension of Newton's first law as applied to rotating systems.

- It is an expression of the law of conservation of angular momentum.

- When angular momentum is conserved, because gravitational pull from the Sun is a central force.

Kepler's 2nd Law cont.

- Envision an ice skater – as this ice skater pulls in their arms, their rotational speed increases.

- Likewise, as a planet is closer to the Sun, its orbital speed increases.

- This makes a short broad triangle for a given sweep time when the planet is close, but when the planet is far little distances is covered – making a much narrower/longer triangle.

- Kepler discovered that these two areas are equal.

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Kepler's 3rd Law

- Kepler's 3rd law was established empirically based on his mentor's (Tycho Brahe) planetary observations.
- a=semi-major axis
- T=orbital period.

$$T \propto a^{3/2}$$