"Who" Orbits "What" in the Solar System

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Abstract

This study analyzes the net velocity of an observer positioned on the "surface" of each of the eight major planets, with the surface for gas giants defined as a theoretical reference level. Net velocity is determined by combining the effects of planetary rotation and orbital motion around the Sun. Inner planets tend to rotate slowly but move quickly in their orbits, while outer planets rotate rapidly and orbit more slowly. Comparing these factors shows how rotational motion contributes to total heliocentric velocity. This type of calculation is not often addressed in standard astronomical literature.

The study also explores the paths of natural satellites (moons) relative to the Sun. Diagrams often show the Moon's orbit as a looping pattern, but accurate calculations reveal an *inward-only* curving path around the Sun. By determining satellite positions in a heliocentric reference frame, these paths can be plotted and compared. This allows for analysis of whether the Moon's motion is unusual compared to other moons. This can be demonstrated with the Earth–Moon system, but it prompts the question of what patterns might emerge when applied to the moons of the outer planets.

Code & Mathematical Methods

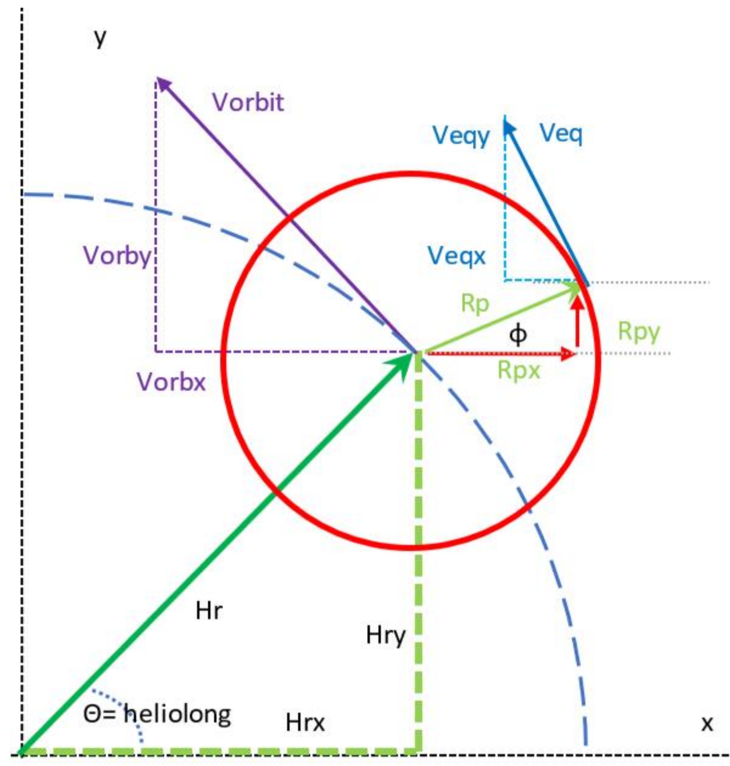
Using Python and Astronomy Libraries:

Heliocentric Motion:
Calculate the planet's heliocentric radius (**Hr**) and longitude (**Θ**), then resolve them into components (**Hrx**, **Hry**). Compute the orbital velocity (**Vorbit**) and its components (**Vorbx, Vorby**).

Equatorial Rotation:
Using the planet's radius (**Rp**) and rotational period (**φ**), compute the equatorial velocity (**Veq**) and resolve it into components (**Veqx**, **Veqy**).

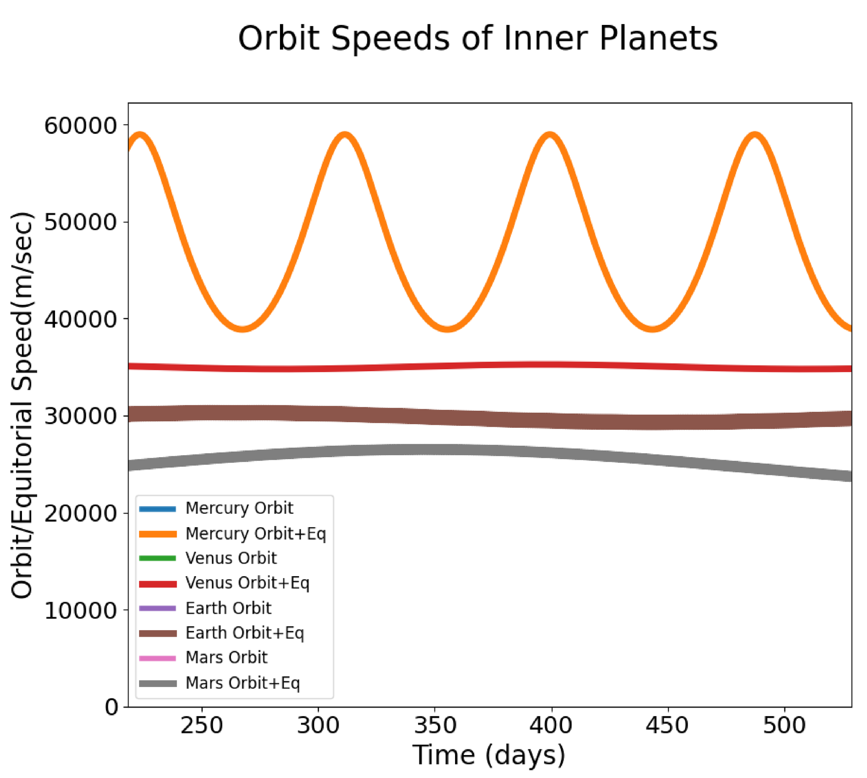
Net Motion:
Position: Add **Hrx/Hry** and the equatorial position vector to get the total distance and angle from the Sun.
Velocity: Add **Vorbx/Vorby** and **Veqx/Veqy** to find the observer's net velocity.

Moons:
Apply the same method to moons by using their orbital radii and angular velocities. Use **Kepler's Equation** to model their elliptical paths accurately over time.



Orbit & Equator Speeds

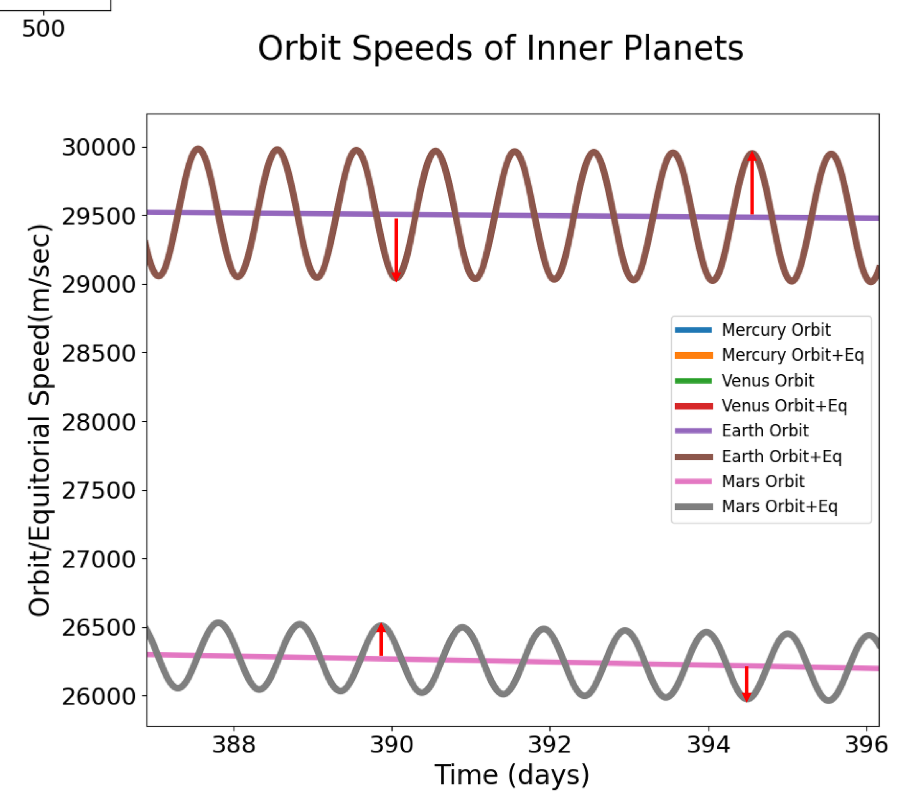
Inner planets: These exhibit faster orbital speeds but slower rotation speeds compared to the outer planets, which rotate quickly but orbit more slowly.



Mercury & Venus:
There is little notable difference between Mercury and Venus with their slow rotational speed; however, that is not the case with Earth and Mars.

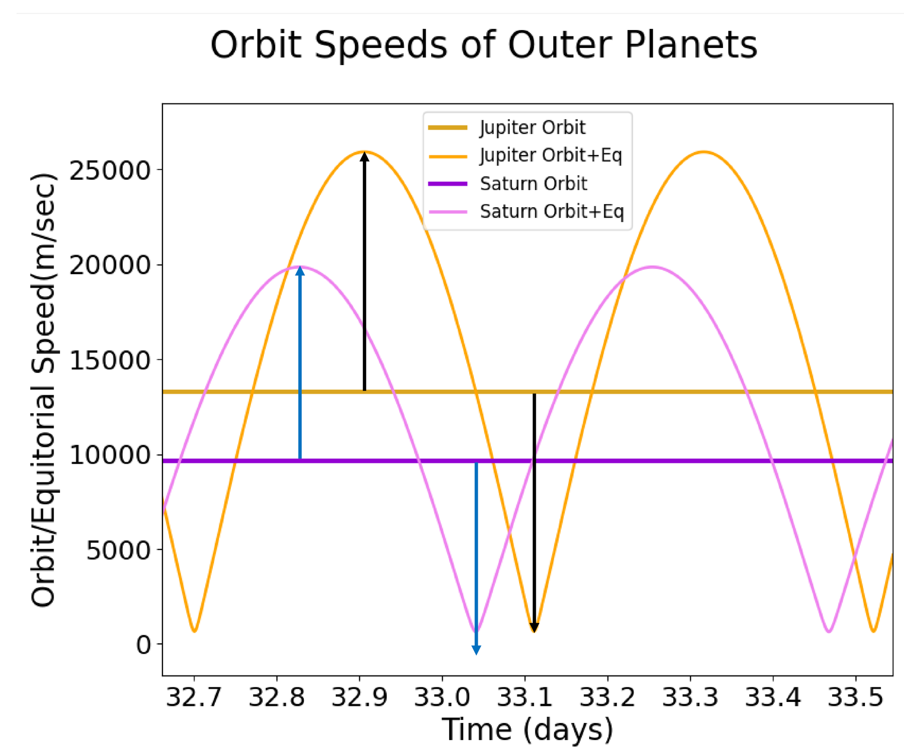
Earth vs. Mars:
As shown on the left, Earth completes approximately 9 cycles, while Mars completes fewer due to its longer day.

The equatorial speed of Mars is slower due to the smaller radius (with reasonably the same periods).



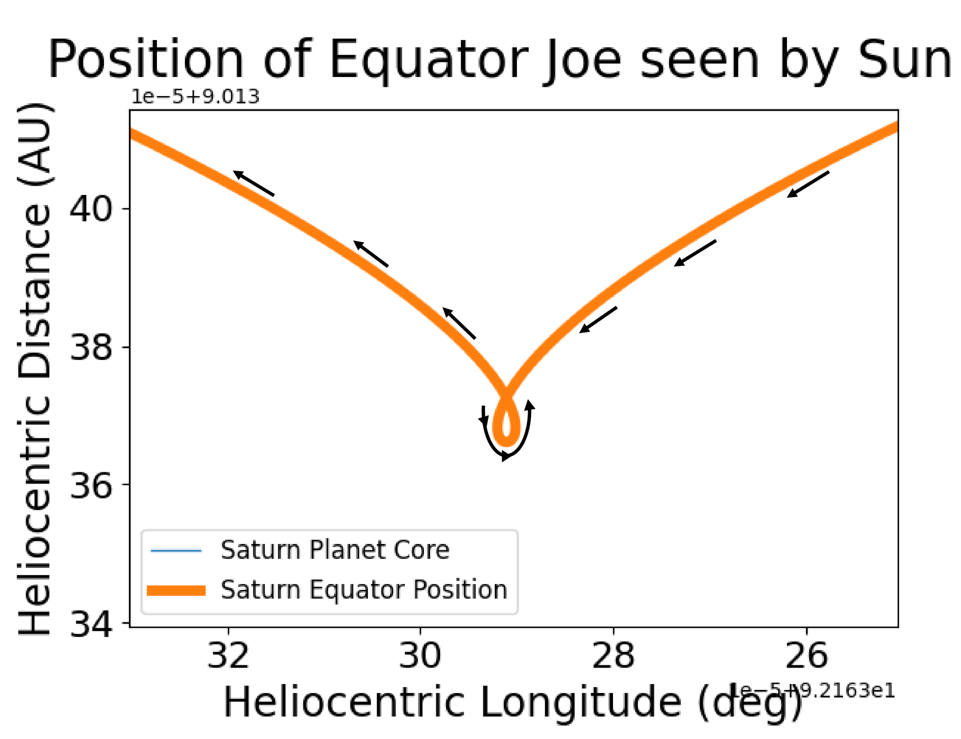
Jupiter & Saturn

Outer Planets: Short days but long years. Their rapid rotation contrasts with their slow orbital motion, resulting in short day lengths despite their vast distance from the Sun.



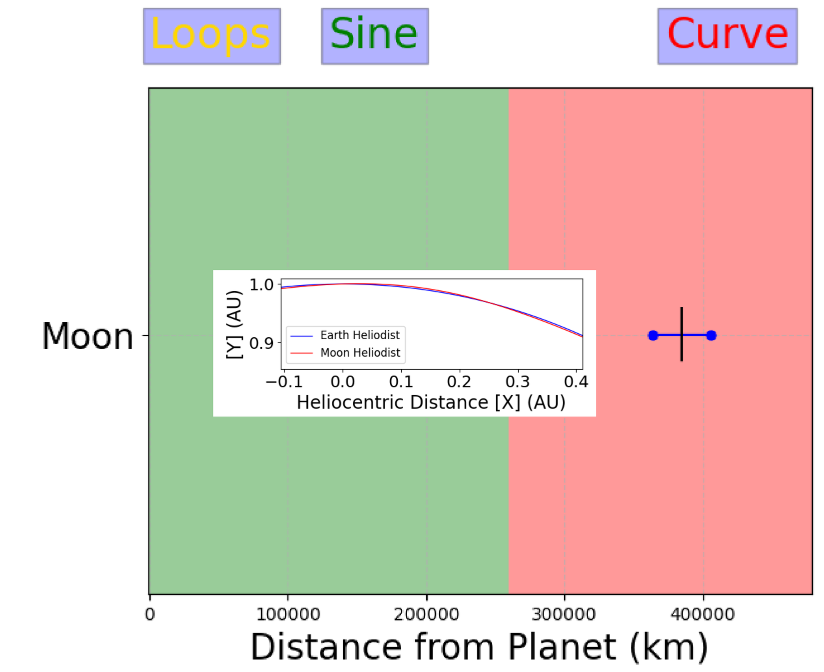
Jupiter and Saturn: When graphing the outer planets, notable differences are observed for both Jupiter and Saturn, indicating unique rotational or orbital dynamics that may warrant further investigation.

Saturn's Loop:
From the Sun's perspective, a person on the surface of Saturn would temporarily appear to move backward. This is because the equator rotates faster than Saturn orbits the Sun, creating a brief retrograde motion.



Moon Orbit Paths

Orbit Modeling: The orbital trajectories of the outer moons of planets such as Jupiter and Saturn can be modeled using equations provided by Meeus.

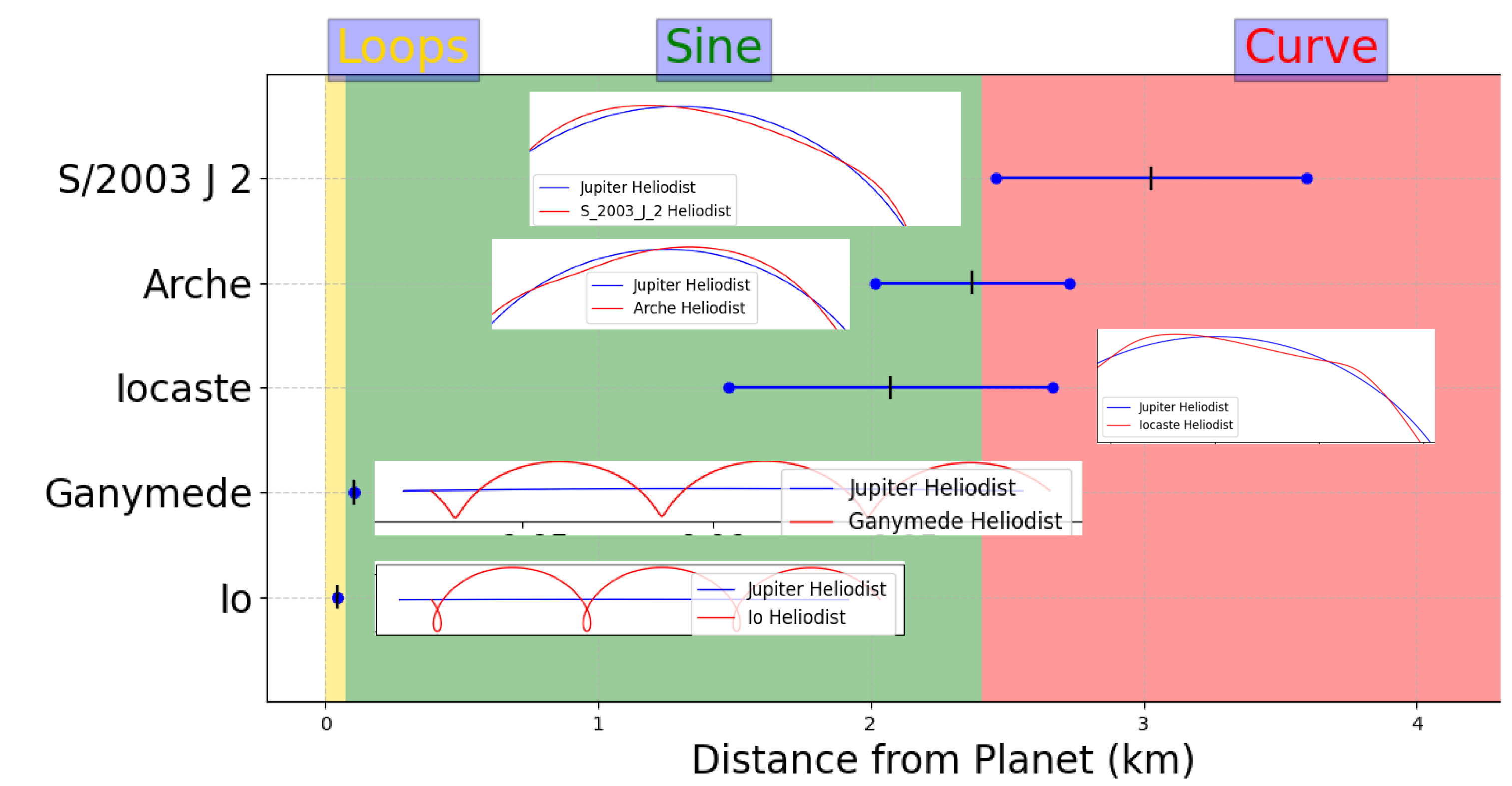


Orbit Paths: The shapes of the orbit paths can be predicted based on certain parameters.

$\frac{a}{a'} = \beta$ (a: planet distance from sun. a'- (semi major axis of the moon)

$\mu = \frac{M}{m}$ (M: sun mass, m: planet mass)

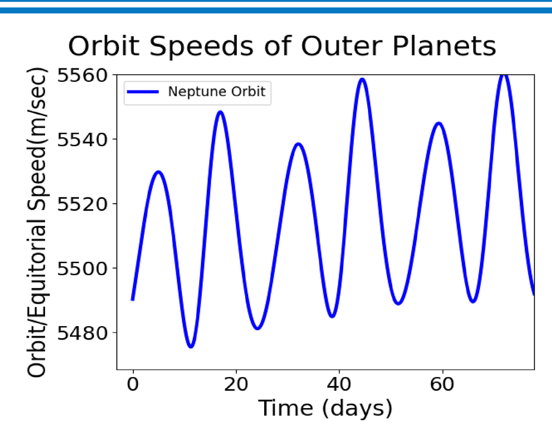
$\beta^2 < \mu$: concave only (Salmon)
$B < \mu < \beta^2$: sine-type (Green)
$\mu < B$: loop-de-loop (Yellow)



Future Work

Newly Discovered Saturn Moons: With 128 new moons now identified, it's possible that the more distant ones may exhibit patterns similar to Earth's Moon—specifically, curving only inward.

Neptune's Graph: An unexpected fluctuation appears in Neptune's data. One possible explanation is the gravitational influence of its large moon, Triton. However, since Triton's orbital period is 6 days and the observed signal has a 12-day period, other contributing factors may be involved. Fast Fourier Transforms would be used to analyze the signal.



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