

Analyzing Asteroid Orbital Parameters as a Method of Discovering General Characteristics of  
the Solar System and Orbital Mechanics: A Project Proposal

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## **Introduction**

The orbital characteristics of asteroids have been the direct cause of several discoveries. For instance, Kirkwood gaps in the Asteroid Belt are notable locations of orbital resonance with Jupiter. They contain a conspicuously low number of asteroids, which can be demonstrated when one creates a histogram of number of asteroids with respect to semi-major axis of their respective orbits (Minton and Malhotra, 2009). Asteroid families are thought to be asteroids which belonged to a parent source and which were placed on similar orbits through a collision, and were discovered by means of analysis of the proper orbital elements inclination and semi-major axis or eccentricity (Hirayama, 1918). These two simple methods of analysis revealed new and important features of the Solar System which not only inform scientists about the accuracy of current models of physics, but also give insight into the history of the Earth's planetary neighborhood.

The goal of the present study is to analyze the osculating and proper orbital parameters of several thousand asteroids and demonstrate that analysis of asteroid orbits can reveal characteristics of the Solar System based on trends in these orbital parameters and the known laws of physics. By analyzing these parameters and combining trends with mathematics one can potentially demonstrate that broad patterns can emerge from the relative complexity of each individual small-body interaction and that there are aspects of the Solar System yet to be fully understood.

## **Methodology**

If one creates a histogram showing the number of asteroids as a function of distance from the sun (given by the semi-major axis), one can notice distinct trends in the distribution of asteroids (Figure 1). For instance, the noticeable gaps in the distribution between the orbit of

between Mars and Jupiter (1.5 – 5.2 au) are Kirkwood Gaps in the Asteroid Belt, where asteroids experience destabilizing resonances with Jupiter. These resonances are simply a result of an asteroid orbiting the sun a whole number of times in the same period that it takes Jupiter to orbit a whole number of times, with the result that these asteroids experience the strongest gravitational influence of Jupiter more frequently than asteroids in alternate orbits. Thus, these asteroids tend to be destabilized and enter other, more stable orbits, resulting in the gaps observed. One can also note the abundance of asteroids at 5.2 au, corresponding to Jupiter's orbit. Asteroids at this location orbit 60° in front of and behind Jupiter at its Lagrange points (Carroll and Ostlie, 2017). Thus, using only a single orbital characteristic, a large asteroid dataset, and orbital dynamics, one can deduce that a very large object exists at 5.2 au (corresponding to Jupiter). This finding is also applicable to the rings of Saturn, whose gaps correspond to resonances with its moons (Carroll and Ostlie, 2017).

An analysis of the inclinations of asteroids with respect to their semi-major axis yields a unique-looking plot (Figure 2) which demonstrates the presence of asteroid families, as well as giving a sense of the distribution of asteroids in the solar system.

Each analysis will follow the above methods, by either creating histograms of a certain orbital parameter, or by plotting two parameters with respect to each other. The major parameters analyzed will include mass, inclination, semi-major axis, and eccentricity, among other orbital elements. Relationships will be considered with respect to what is physically plausible or known about the solar system and a conceptual “map” and history of the solar system will be constructed with the observed data.

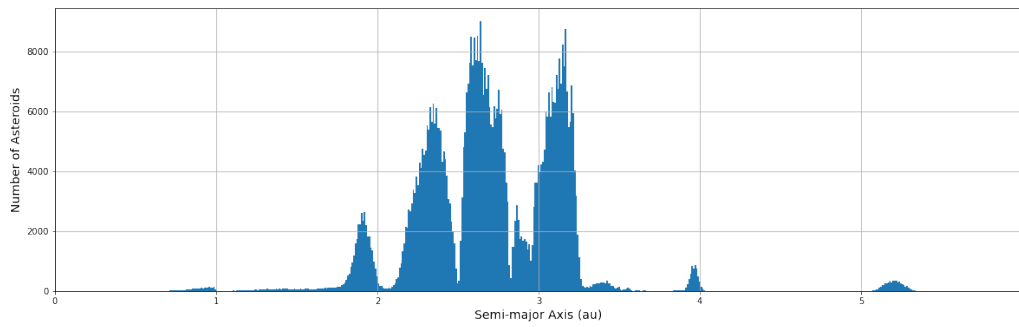


Figure 1.) A histogram showing the number of asteroids as a function of distance from the sun (au). Gaps in the distribution where  $a = \text{semi-major axis}$  and  $1.5 \text{ au} < a < 3.3 \text{ au}$  indicate the distance from the Sun at which asteroids have destabilizing orbital resonances with Jupiter. Data provided by NASA's small body database.

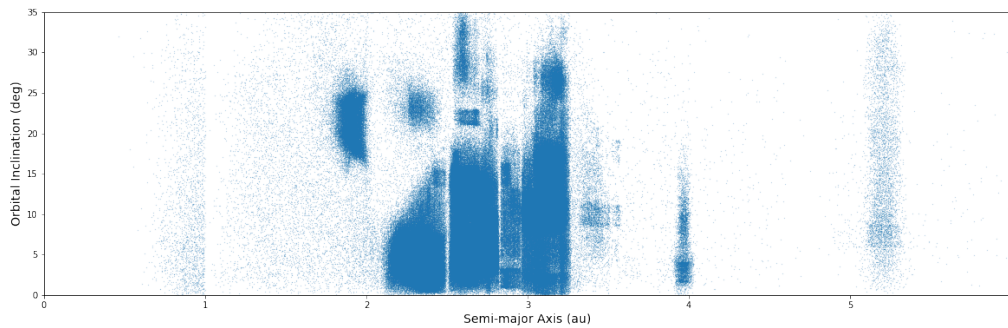


Figure 2.) A plot showing the inclinations of asteroids as a function of their distance from the Sun. Clusters likely represent asteroid “families” – asteroids which share a parent source and which formed after a collision (Carroll and Ostlie, 2017). Data provided by NASA's small body database.

## References

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