Asteroid Disruptions of the Datura Family

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Summary

To research the Datura Family of asteroids, a prewritten dynamical IDL code was run to track the orbital decay of asteroid fragments released in an asteroid disruption. Different particle sizes were used to analyze the outputs of each size including the semi-major axis, eccentricity, and inclination in order to observe how certain particle sizes' orbital elements evolve. Using a young asteroid family like the Datura family gives more insight into their original structure and formation because the time is closer to before the asteroid's breakup. We use these models to constrain the parameters of the dust by comparing the conditions to infrared satellite data sets. The semi-major axis utilizes Poynting-Robertson drag while the eccentricity and inclination are related to the effects of Jupiter. But all of these orbital elements relate to the role of the radiative forces. This research is important to understand potential Earth hazards from space.

Scientific Motivation

Asteroids have these rare catastrophic events, and looking into one yields lots of scientific information, as shown in Figure 1 [1]. It is important to look at young asteroid families, like the Datura family, because young asteroid families are more recently formed so more of their original structure and formation can be observed. The zodiacal cloud shown, as shown in Figure 2 is a debris disk that is sunlight reflecting off of dust particles [2]. These dust particles are threats to astronauts and aircraft, especially long-term missions like Artemis.


Figure 1


Figure 2

Background

The Datura family is a young asteroid family that is 450,000 years old [3]. This family was chosen for research because of its young age and prior knowledge of these families' dust formations. We can use these models to constrain the parameters of the dust by comparing the conditions to infrared satellite data. The Poynting-Roberston drag acts as a headwind of photons that slow down the moving pieces after the asteroid disruption. Thus, causing the particles to slow down and lose energy. This research was conducted to look at how things change over time based on looking at what is happening to different particle sizes. The utilized IDL code integrates backward in time to find out where the particles were at breakup and now after they experience radiation forces. After, the code integrates it forward in time to the dispersed orbital elements as the outputs.

Theory

For the role of radiative forces, they act only on the surface of bodies therefore they are more important for large surface areas relating to its mass. Radiation pressure pushes dust particles out from the sun affecting the particle sizes differently. Equation 1 shows the Beta equation while Equation 2 shows the PR Drag Time Scale. Figure 3 shows the representation of how dust bands of asteroids form. Moreso, how the asteroid debris undergoes orbital evolution to form band pairs. The gravitational perturbations by Jupiter influence the debris orbits. The debris' orbits complete a band pair after enough variations and these band pairs are the dust bands

$$\beta = \left|\frac{F_{rad}}{F_{grav}}\right| \quad (1)$$

$$\beta \propto \frac{1}{\rho R} \quad (2)$$

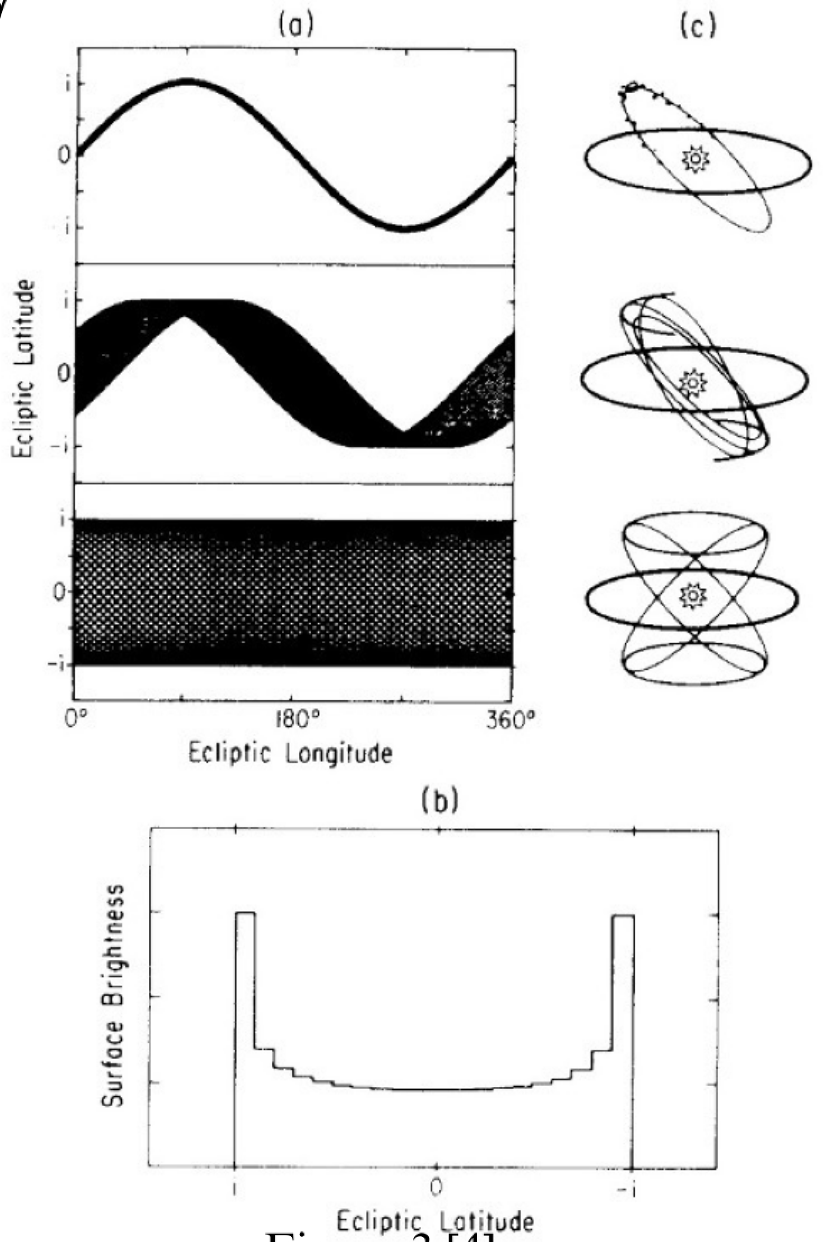

Figure 3 [4]

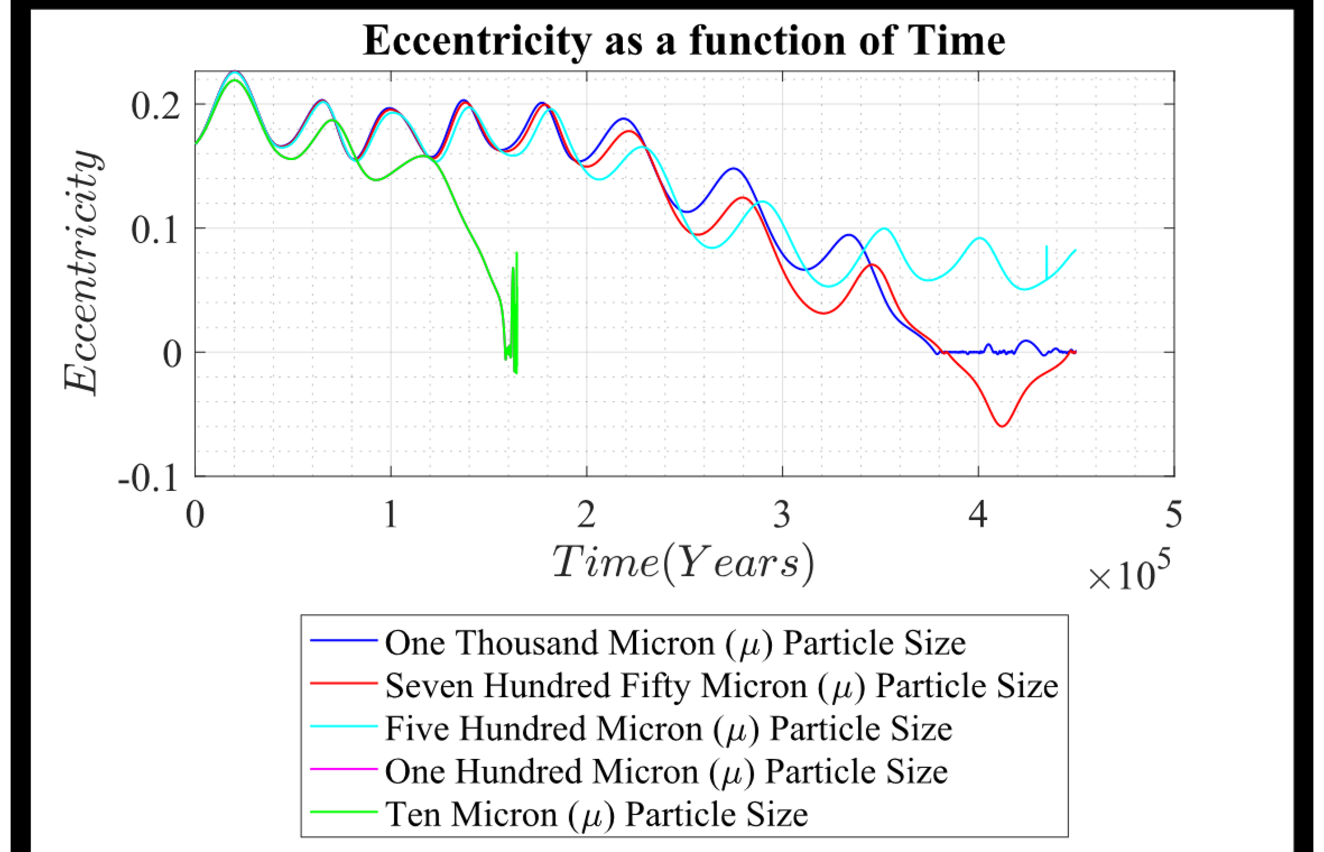

Figure 4

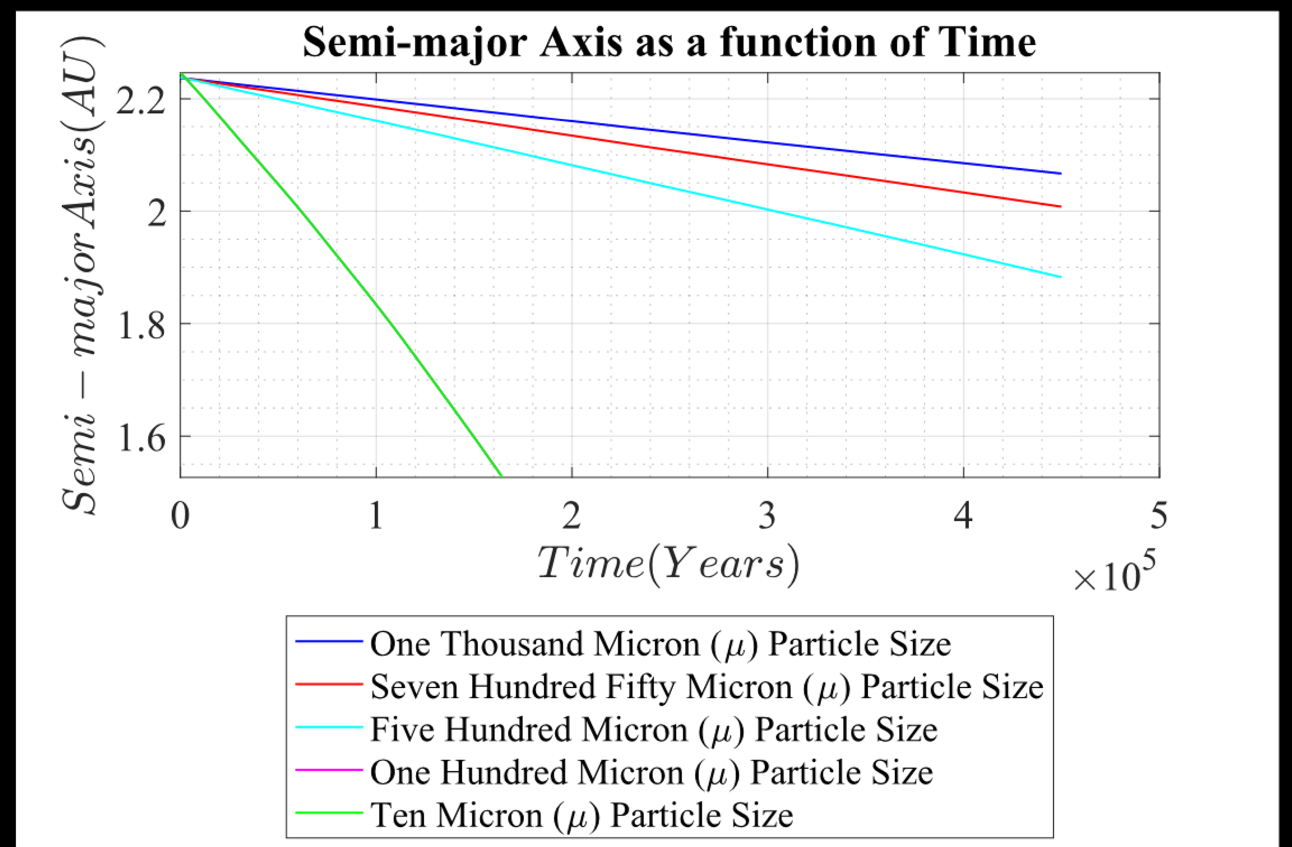

Figure 5

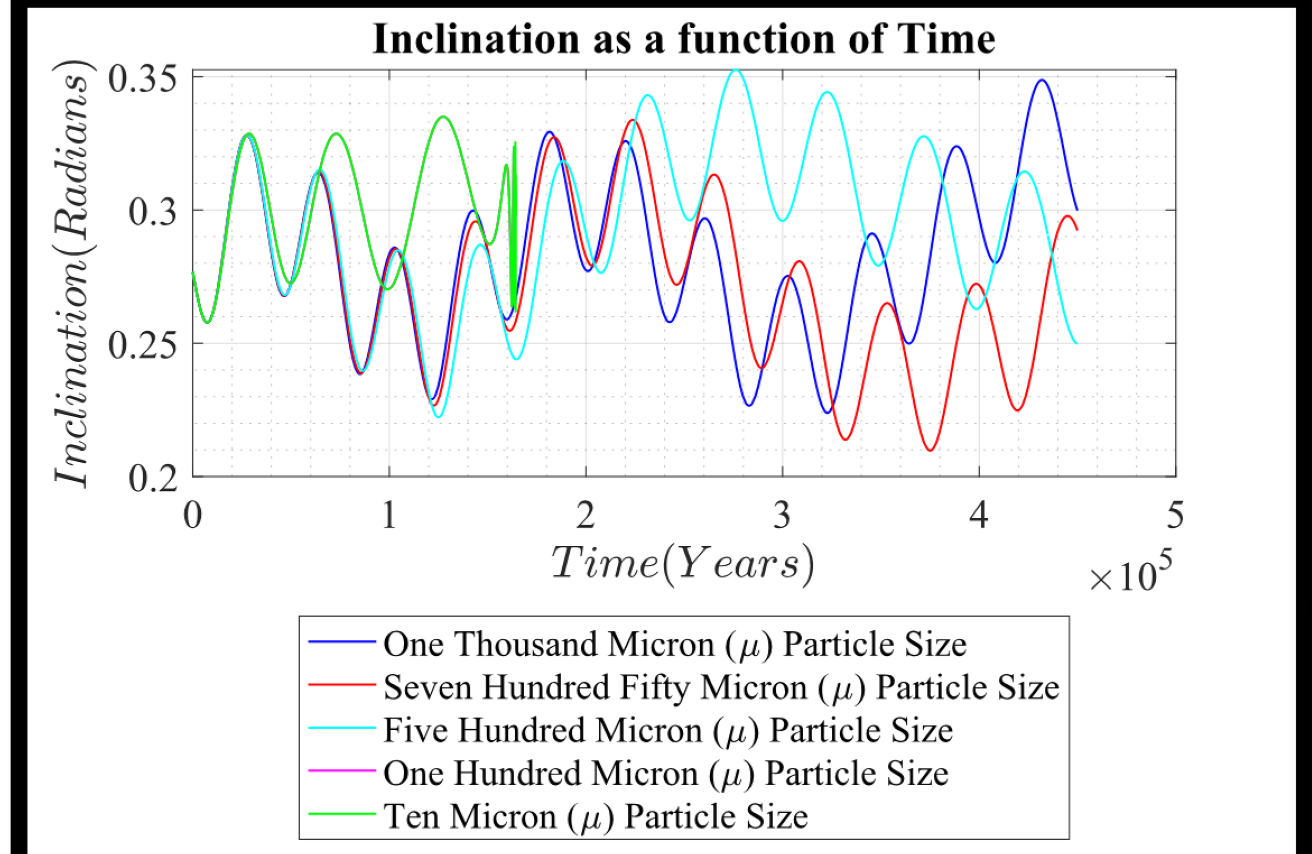

Figure 6

Summary of Results

Eccentricity:

The domination of Jupiter, the most massive planet in the Solar System shows its force on the particles based on its own period. A larger particle travels distance as a function of time since they do not move as easily due to its size. The larger particles stay grouped near the source because they are not as affected by radiation forces. These radiation forces push the particles out from each other as shown by equations 1 and 2. A larger particle will have a larger R based on equation 2 and in turn, create a longer PR drag timescale. PR drag works to circularize the orbit while reducing the semi-major axis. Overall, for greater the eccentricity the greater its effect on the PR Drag. The eccentricity is expected to oscillate as shown in Figure 3.

Semi-Major Axis:

Small particles have really circular orbits based on PR Drag and this causes the axis to decay as a function of time. Larger particle sizes have much longer decay times because they do not move as quickly. As shown in Figure 4, the slope of each particle size shows how the larger particle sizes take longer in order for the particle to decay. The semi-major axis does not evolve faster than the inclination or eccentricity but because the semi-major axis is changing, the perturbing effects of Jupiter on the inclination and eccentricity are changing based on the differing distances from Jupiter.

Inclination:

Inclination determines the location of the band pairs and allows for a link between the material and its source body. Jupiter's influence is shown as Jupiter's inclination is the forced inclination of the system. Therefore, the correlation is shown by how the larger particles are harder to move and thus stay near Jupiter. Along with this, the PR drag helps to circularize the orbit. The values are still expected to oscillate as shown in Figure 6.

Future Work & Conclusion

The outputs of each graph represent the dynamical evolution of the particles and as a test of the code evolution compared to expected results. The semi-major axis decays as a function of time due to PR drag. The eccentricity and inclination rely heavily on Jupiter and are represented by the changing oscillation due to the particles' differing distances from Jupiter. All of these orbital elements determine where the particle ends up. Our research illuminates the dynamic evolution of the Datura asteroid family to understand possible space endeavors for safety and Earth's security. All of these particles are evolving as we expect them to under the radiation forces. We constrain these outputs for further research, in which we will feed these outputs as inputs into other codes. These other codes will produce 3-D models of the dust to compare them to infrared observations. We then will use these graphed outputs to be put into a Fortran code that calculates the infrared observations (dust bands) of the material would look like. These will then be compared to large satellite data sets like the NASA WISE (Wide-field Infrared Survey Explorer) and the IRAS (Infrared Astronomical Satellite) data.

References

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2.Beletsky, Y. (European Southern Observatory).
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4. M. V. Sykes, R. Greenberg, The Formation and Origin of the IRAS Zodiacal Dust Bands as a Consequence of Single Collisions between Asteroids. Publications of the Astronomical Society of the Pacific. 97, 904 (1985).