Approximation of Asteroid Family Ages

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INTRODUCTION

Asteroid families are defined by both physical and orbital characteristics, and as the families evolve in time, members of a family migrate from the original location of the parent body (the center) due to various forces, one of which is the Yarkovsky effect.

Since the Yarkovsky drift rate is inversely proportional to the diameter of an asteroid [1], a parameter C is used to normalize the distance of an asteroid from the family center by its size, so members of the same family migrating outwards only along the semi-major axis (i.e., neglecting changes in eccentricity and inclination) would ideally share the same C value. Consequently, the center of the family before the family drifted apart, distance that members of the family have traveled away from the original parent body, and the timing of the collision event that caused them to break apart can be determined.

This study attempts to calculate the formation ages of seven asteroid families using absolute magnitude, semi-major axis, and C parameter [1].

Sample: Seven asteroid families (namely 31 Euphrosyne, 163 Erigone, 434 Hungaria, 702 Alauda, 1911 Schubart, 3548 Eurybates, and 4203 Brucato in Table 1) include C-type and X-type asteroids.

Orbital Data: Semi-major axis and absolute magnitude data for probable members of each of these families were extracted from JPL Small-Body Database using a range of values for semi-major axis, eccentricity, and inclination as parameters[1].

Other Necessary Parameters: All the asteroids have known thermal conductivity estimate of 0.01 W m^{-1} K^{-1} [3].

METHODS

All the families exhibit the characteristic V shape in their semi-major axis (a) vs. absolute magnitude (H) distribution (Fig. 1), which is typical of asteroid families as a result of size dependent semi-major axis drift of family members due to the Yarkovsky effect. Here, the absolute magnitude is proportional to the size of the asteroid body.

For each family, multiple C distributions[2] were calculated using different a_{int} in each, to generate a frequency distribution (Fig. 2) with a bin size of 4 x 10^{-6} AU. The a_{int} value used to find the distribution with the highest peak became the estimate for the family's center (Fig. 3).

The diameter of each asteroid was calculated using the following equations, where p_v is geometric albedo [3]:

$$H = 15.617 - 5\log D - 2.5\log p_v$$
$$D = \frac{1329}{\sqrt{p_v}} * 10^{-H/5}$$

Using a preexisting model [4] and a fitted function using diameter, da/dt for each asteroid was estimated, and da/dt was assumed to be constant for each asteroid since the formation of the family.

$$C = \frac{da}{dt} * T * 10^{-H/5}$$

was then used to calculate values of T, and mean T was determined.

As an example, the 31 Euphrosyne family is shown in the figures.

[1]Asteroids for which H values were not provided were excluded from calculations

[2]The C parameter is defined as $C = \frac{da}{dt} * T * 10^{-H/5}$, where H is absolute magnitude of the asteroid, and $\Delta a = \frac{da}{dt} * T$ is the distance from a_{int}, the center of the family, that the asteroid has drifted at rate da/dt over the age of the family T [1].

DATA AND RESULTS

Table 1. Family Age Comparisons

Family	Type[a]	p_v[a]	Center (AU)	C (10^{-5} AU)	Calculated Age (Gyr)	Accepted Age (Gyr)
31 Euphrosyne	C	.06	3.167	2.46373	0.648	0.680[b]
163 Erigone	CX	.06	2.290	2.42309	0.695	0.280[c]
434 Hungaria	E	.35	1.904	1.08762	0.127	0.5[d]
702 Alauda	B	.07	3.127	5.65764	1.399	0.640[e]
1911 Schubart	C	.03	3.962	1.7741	2.160	1.7[f]
3548 Eurybates	CP	.06	5.181	5.88551	1.822	1 – 2[g]
4203 Brucato	CX	.06	2.5877	2.74789	0.971	1.3[h]

Table 1. Our calculations and work were solely based off the Bottke 2006 model; the literature from which we found ages may have run other more elaborate models. Despite this difference, the calculated ages are close to the ones reported in literature.

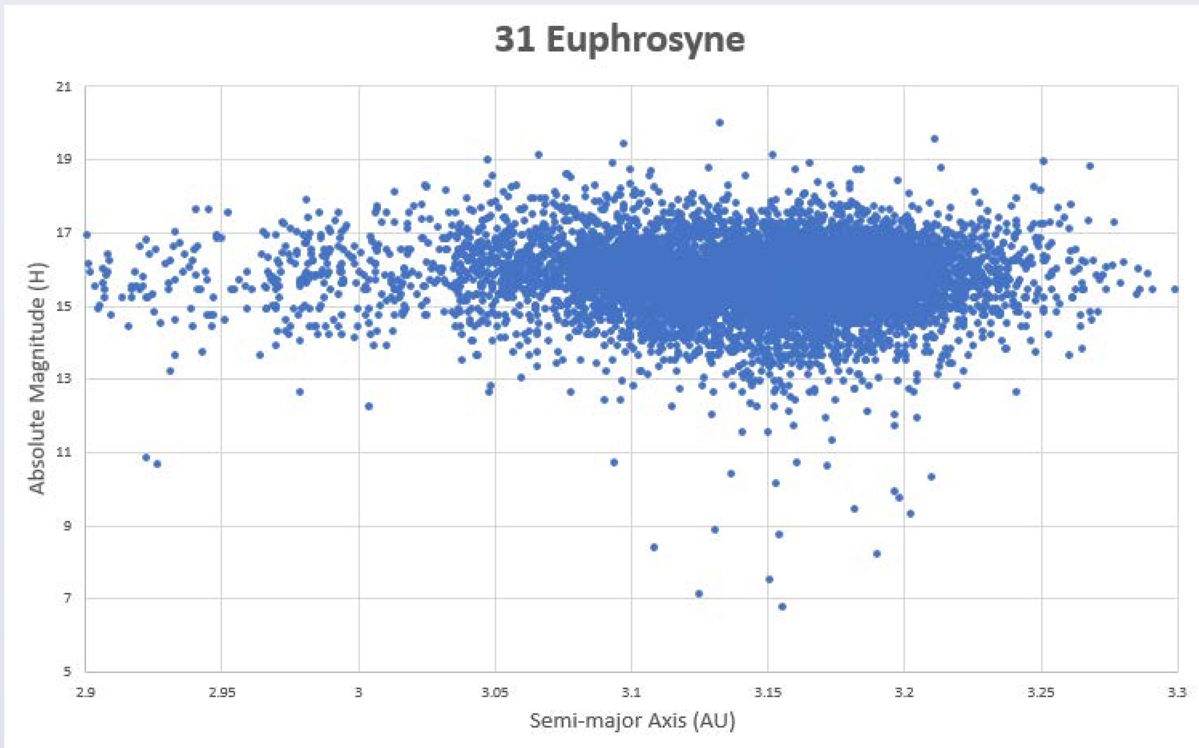

Fig. 1. Semi-major axis vs. absolute magnitude. Family shows characteristic V shape associated with Yarkovsky effect

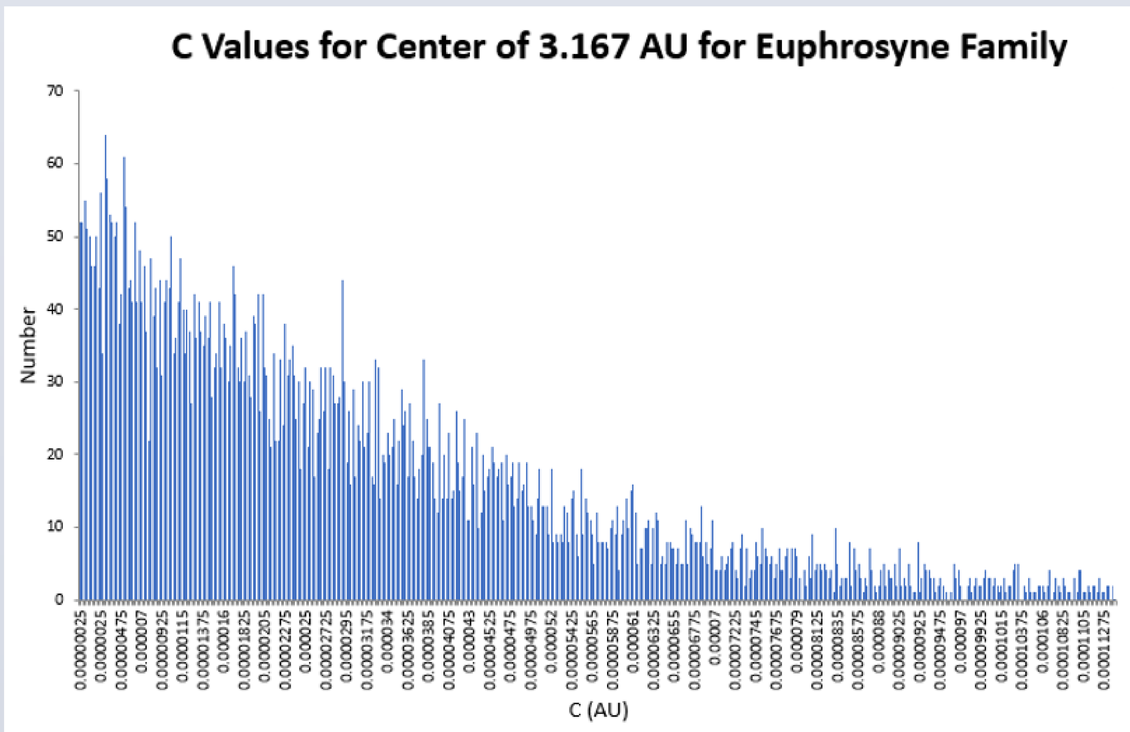

Fig. 2. Frequency distribution of C values. Asteroids should cluster to a single C value at the peak of the histogram.

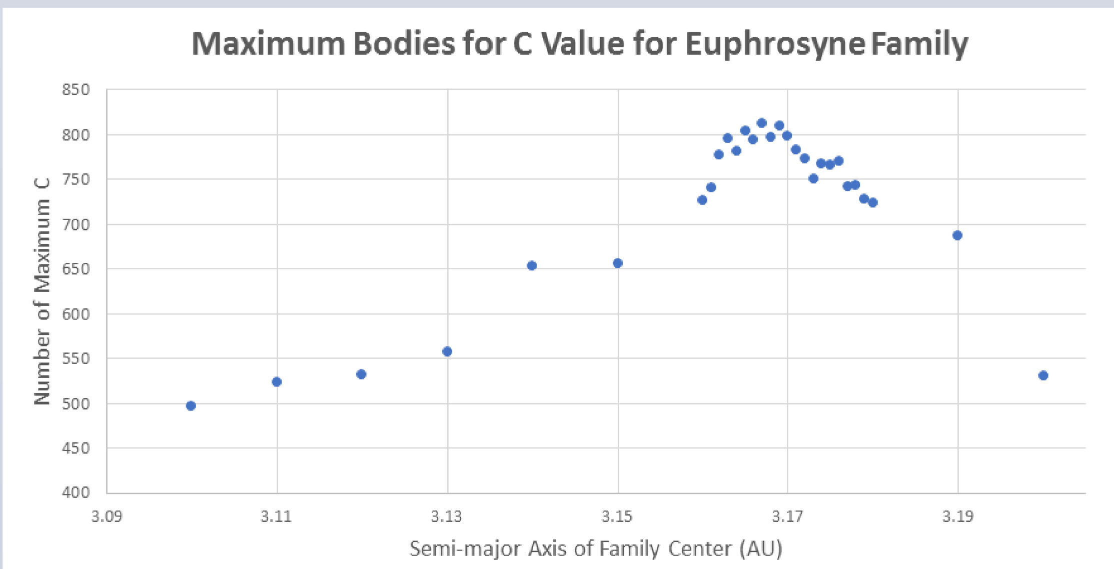

Fig. 3. The peak of each frequency distribution (such as Fig. 2) vs. a_{int} used to calculate C values.

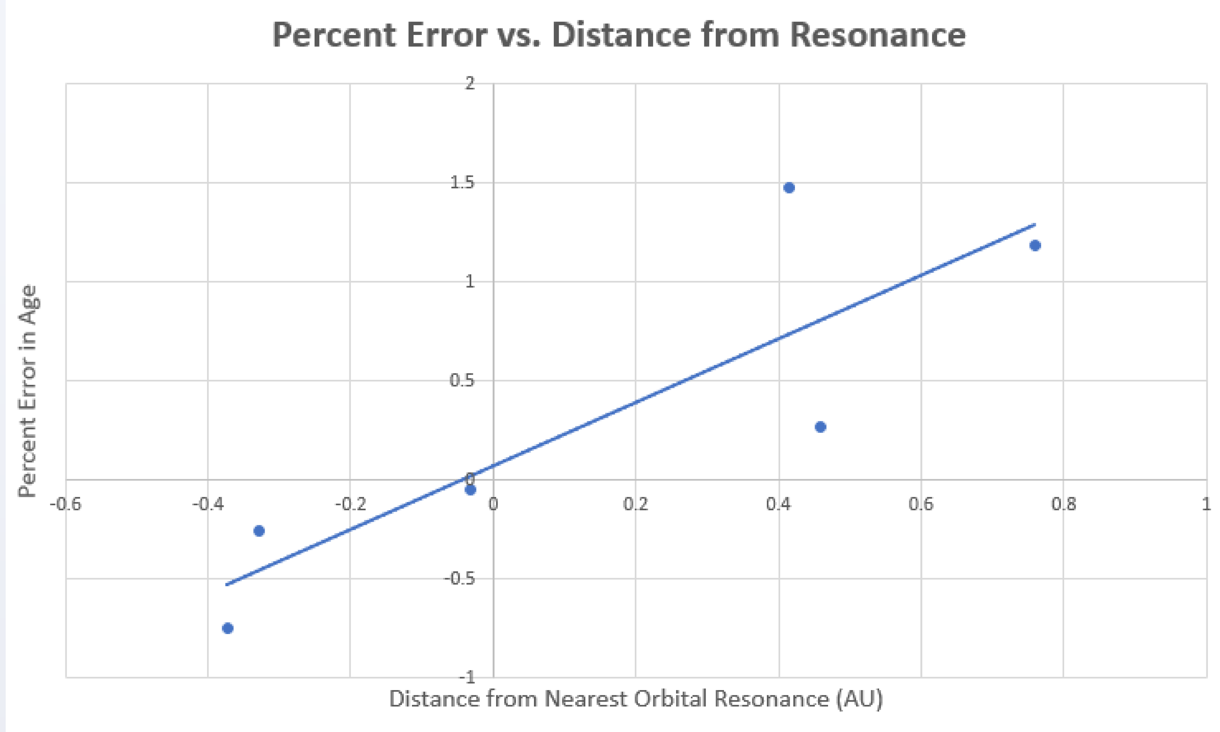

Fig. 4. There appears to be a positive correlation between percent error and proximity to orbital resonance. The R^2 value of the line of best fit is .74.

DISCUSSION AND CONCLUSIONS

This study investigates a technique to predict asteroid family age using absolute magnitude and semi-major axis. The method used to gather data resulted in a large number of non-family bodies in the data set; not all asteroids extracted from the JPL Small-Body Database belonged to one single family. Additionally, asteroids without known absolute magnitudes were excluded from the data sets. This would skew our data towards larger asteroids for which these values were given.

A positive correlation was found between distance to the nearest orbital resonance and percent error. One implication of this correlation would be that asteroids with more chaotic orbits and false family members are thrown out by the influence of the resonance, which would leave only the more stable asteroids from which we collected our data.

Further investigation can involve:

- Using purely family-based data to analyze ages and history.
- Studying the link between error and proximity to the nearest resonance to evaluate resonances as a data filter.
- The age estimation method could be used for asteroids with known p_v values rather than an estimated family p_v value.
- A filter could be used to remove interlopers from the data set to achieve more accurate results.

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DATA MINED FROM:

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