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Eurybates — a single asteroid family among Trojans

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ABSTRACT
???

Key words: celestial mechanics – minor planets, asteroids – methods: N-body simulations.

1 INTRODUCTION

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Trojans as an important test of the planetary migration theory

inclination distribution, namely large spread of I

the Late Heavy Bombardment provides the timing of the Jupiter–Saturn 1:2 resonance

quite many families were proposed by Roig et al. (2008), based on a relatively sparse SLOAN data

Eurybates is a C-type family

REF Brož and Vokrouhlický (2008) studied Hilda group in the J3/2 resonance and reported 2 families: Hilda and Schubart with approximately 200 and 100 km parent bodies.

REF Bottke on delivery of D-types

Section 2 Section 3 Section 4 Section 5

2 METHODS

In order to characterise possible groups in Trojan region, we need the following information

2.1 Resonant elements

numerical integrator, on-line digital filter

resonant elements: libration amplitude d, eccentricity e, inclination $\sin i$

definition in Milani (1993)

The values of elements agree with that of Milani & Knezevic

there are few outliers, because we have a different time scale of the computation

how many orbits were calulated

Figure 1

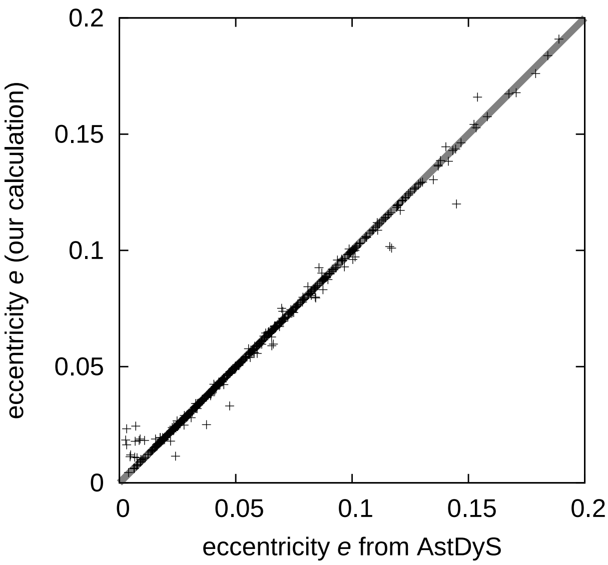

Figure 1. Comparison of our resonant elements to that of Milani & Knezevic (AstDyS catalogue). line $x = y$.

2.2 Hierarchical clustering

HCM method (REF Zappala et al.) d_1 metrics in the space of resonant elements (not proper) code by D. Nesvorný

$N(v_{\rm cutoff})$ dependence is useful

comparison to random background

Eurybates, Aneas, 1998 RG_{10} seem to be concentrated towards the center

Figure 2

Figure 3

2.3 Size-frequency distribution

assume a single value of albedo for a real family

we also test different albedo distribution dependent on size, as discovered by Jewitt et al. ???

Figure 4

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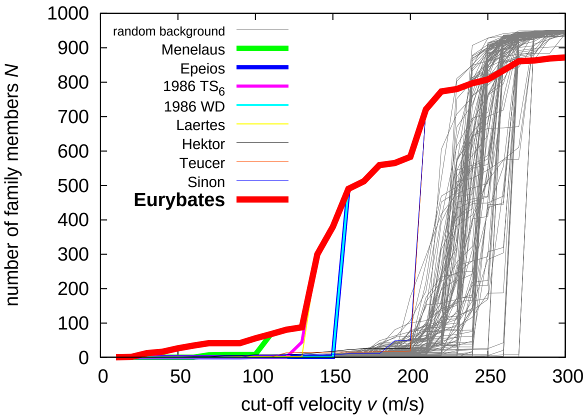

Figure 2. Dependence of number of family members N versus cutoff velocity $v_{\rm cutoff}$ for HCM. L4 cloud.

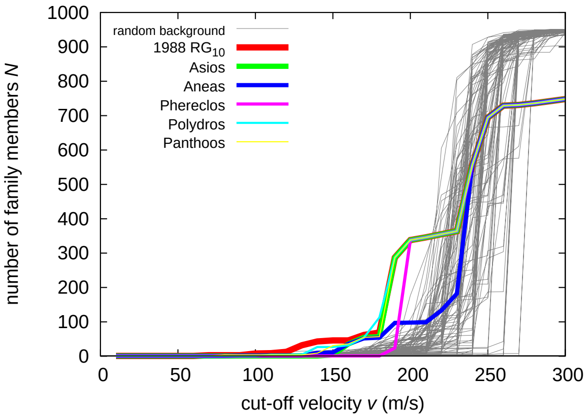

Figure 3. Dependence of number of family members N versus cutoff velocity $v_{\rm cutoff}$ for HCM. L5 cloud.

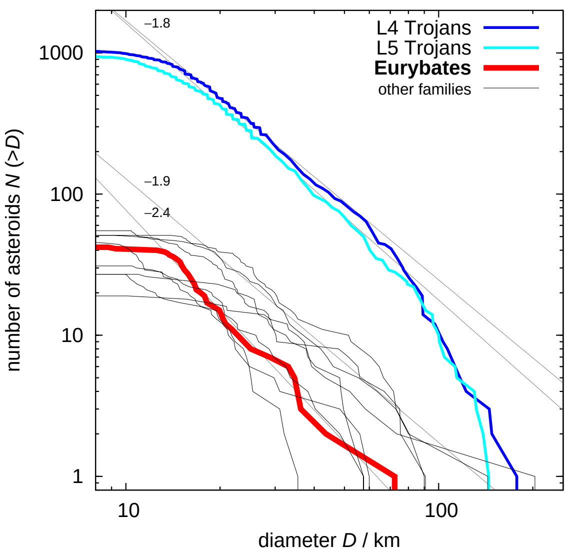

Figure 4. Size distribution of L5 Trojans and the Eurybates family.

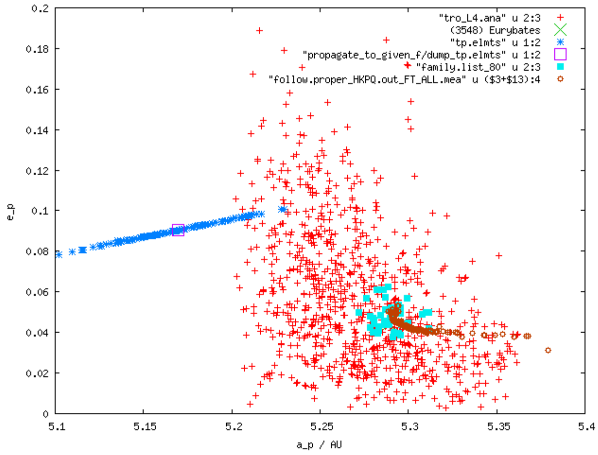

Figure 5. The synthetic family just after the impact disruption event. $f = 0°$ A different geometry in f, ω produces a slighly different cluster, nevertheless, it is always smaller than the observed Eurybates family.

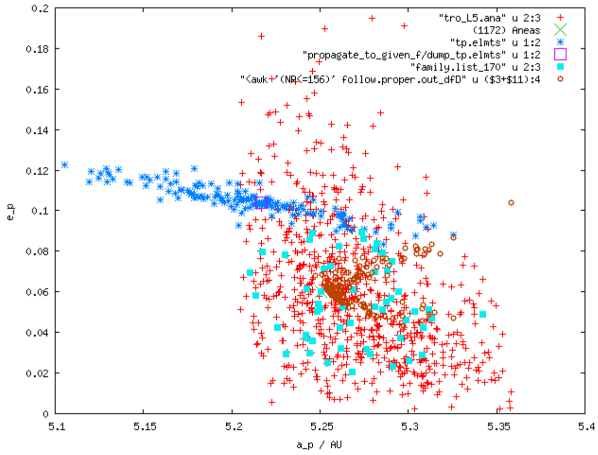

Figure 6. The synthetic family, which should correspond to the Aneas group, just after the impact disruption event. $f = 135°$ A different geometry in f, ω produces a slighly different cluster, nevertheless, it is way too smaller than the observed Aneas group.

2.4 Colour data

Sloan DSS

we expect the family to be homogeneous

comparison with Roig et al. (2008)

2.5 Impact disruption model

similar to Brož & Vokrouhlický (2008)

PB size, escape velocity and the current extent of the family should agree at least to some level

Of course, there is further evolution by Yarkovsky drift too.

Figure 5

Figure 6

2.6 Planetary migration

numerical integrator

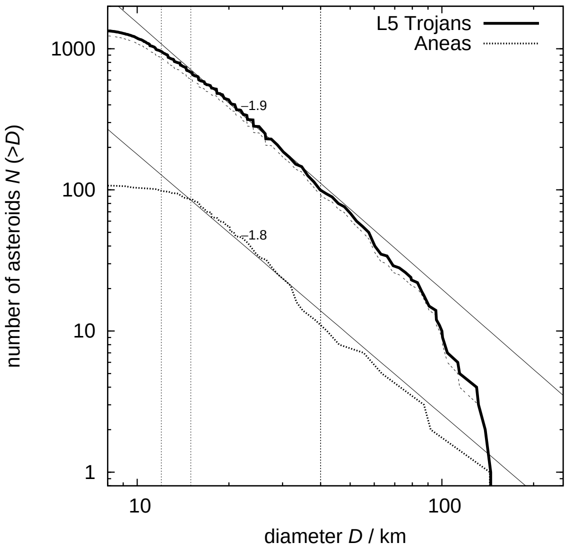

Figure 7. Size distribution of L5 Trojans and the Aneas group.

semi-analytical treatment of migration
eccentricity damping

2.7 Yarkovsky/YORP effect

numerical integrator
both diurnal and seasonal effects
YORP is not taken into account directly, only random reorientations the time scale $\tau_{\rm YORP}$ is anyway too long to significantly change orbits
evolution over 4 Gyr

3 ASTEROID FAMILIES AND INSIGNIFICANT GROUPINGS

3.1 Eurybates collisional family

description of the group, decision on velocity $v_{\rm cutoff}$, SFD, colours
the group fullfils all criteria to be considered a collisional family
Figure $N(v_{\rm cutoff})$
???

3.2 Group denoted Aneas

???
small PB size
impossible to match an impact with the current spread, even if we account for 4 Gyr of orbital evolution due to Yarkovsky effect
it looks like a portion of the L4 cloud, with approximately backgroud density
heterogeneous colours
not a real collisional family
Figure 7

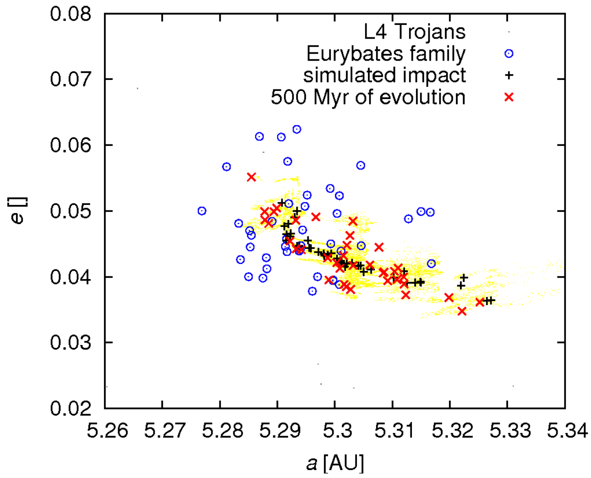

Figure 8. Evolution of the synthetic family over 500 Myr versus the observed Eurybates family. The spread in e is not sufficient to match the observations.

3.3 Group denoted 1988 RG_{10}

???
small PB size
impossible to match an impact with the current spread
heterogeneous colours
not a real collisional family

4 LONG-TERM EVOLUTION OF TROJAN FAMILIES

4.1 Evolution due to Yarkovsky effect

detailed long-term evolution by Yarkovsky effect over 4 Gyr
Kolmogorov-Smirnoff test of the eccentricity distribution
estimate of age: more than 1 Gyr
evolution in inclination is negligible, very slow
???
Figure 8
Figure 9
Figure 10
Figure 11
Figure 12

4.2 Stability during planetary migration

all families are strongly unstable even during very late stages of migration
there are practically no migration scenarios, which would produce a sufficiently compact group, especially if we further evolve the orbits by the Yarkovsky effect till today
Figure 13
$\tau_{\rm mig} = 30$ Myr
try also different values of $\tau_{\rm mig}$
???

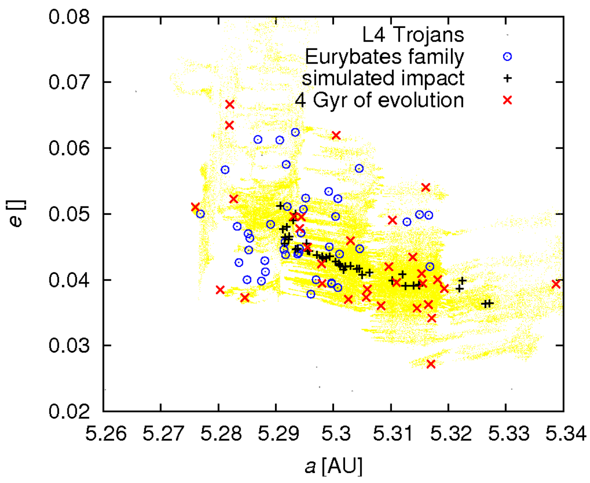

Figure 9. Evolution of the synthetic family over 4 Gyr versus the observed Eurybates family. The spread of eccentricities is too large compared to the observed family.

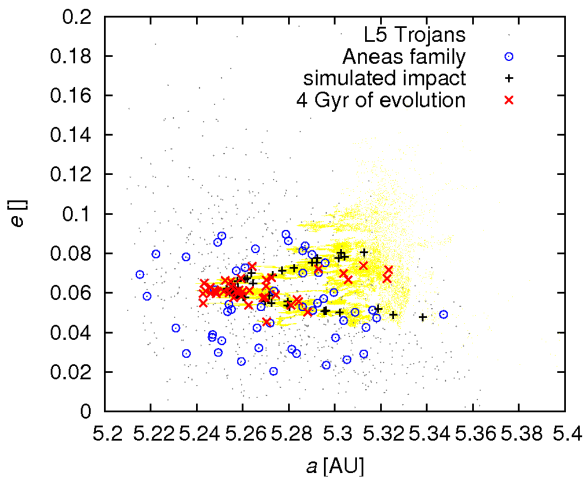

Figure 11. Evolution of the synthetic family over 4 Gyr versus the observed Aneas group. The spread of eccentricities is too large compared to the observed family.

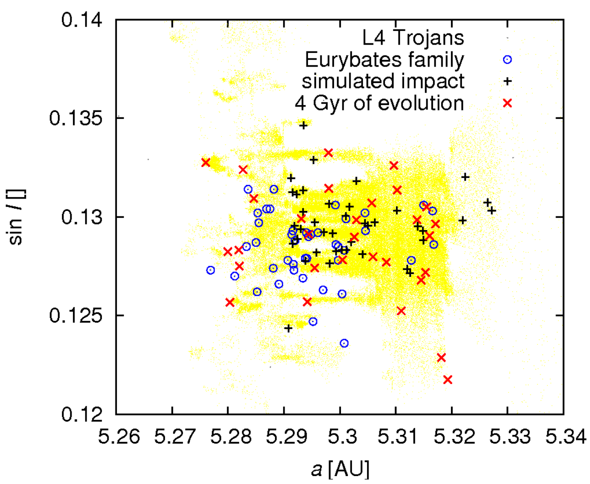

Figure 10. Evolution of the synthetic family over 4 Gyr compared to the observed Eurybates family. Inclinations evolve only barely.

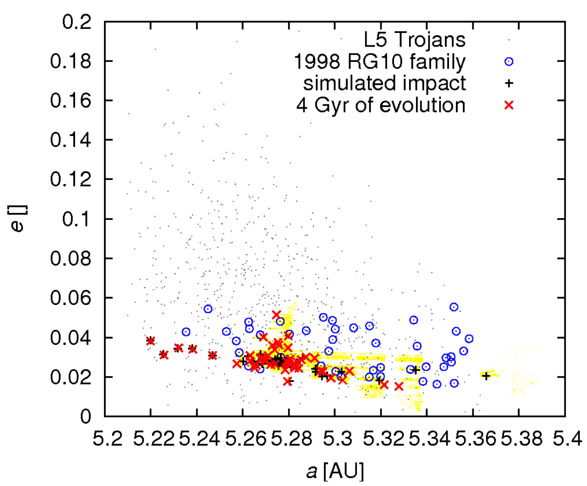

Figure 12. Evolution of the synthetic family over 4 Gyr versus the observed 1988 RG_{10} group. The spread of eccentricities is too large compared to the observed family.

4.3 Families lost by ballistic transport

How many families cannot be identified, because the breakup occured at the outskirts of the stable libration zone?

probably most of families should be visible ???

(this was suggested by Bill Bottke) ???

4.4 Collisional rates

collisional rates are low in the current Solar System

Trojan-Trojan collision play a major role, orbits are practically detached from the Main Belt

in concert with only one family among Trojans

4.5 An application to extrasolar planetary system HD 209458

what happens to Trojans of HD 209458, if the planet approaches the star from a large (Jupiter-like) distance?

a numerical test

REF Vokrouhlický on observability of Trojans

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5 CONCLUSIONS

no D-type families anywhere in the Solar System

may be, D-type parent bodies are too weak and the targer is pulverized during a collision?

implications for collisional models

REF Bottke on delivery of D-types

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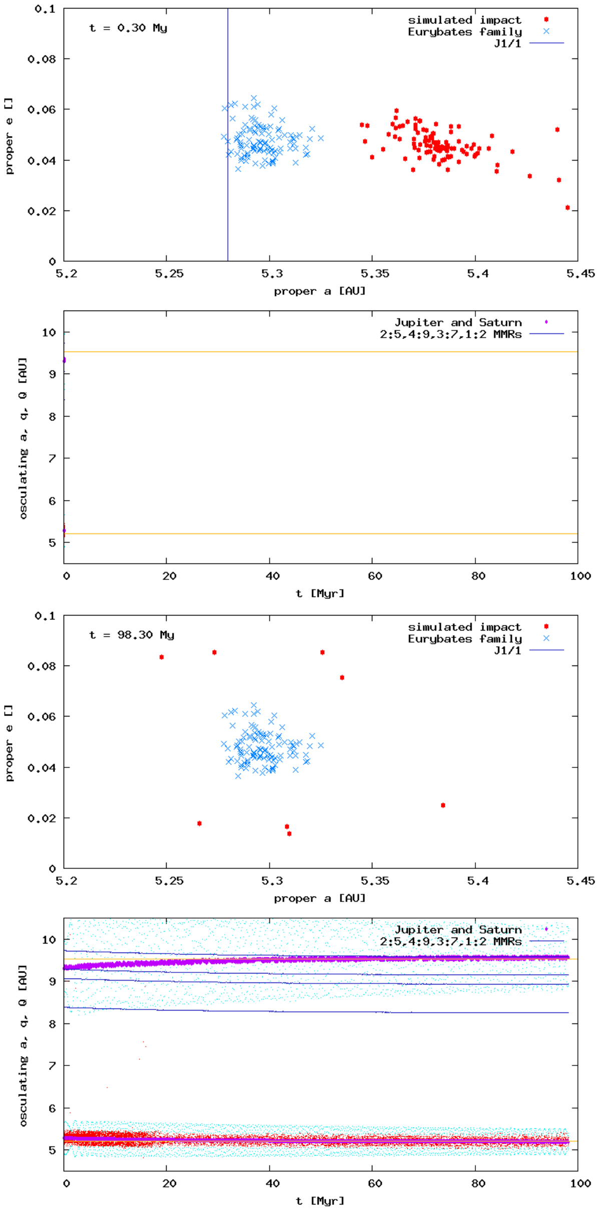

Figure 13. Evolution of a synthetic family during late phase of planetary migation, Left: state at 0 Myr. Right: 100 My. The family is almost destroyed and it is definitely imcompatible with the observed Eurybates family.

on the subject. The work has been supported by the Grant Agency of the Czech Republic (grants 205/08/P196 and 205/08/0064) and the Research Program MSM0021620860 of the Czech Ministry of Education.

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Jewitt et al. ???

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