Chaotic scattering of main belt asteroids from Centaurs and Trans-Neptunian Objects

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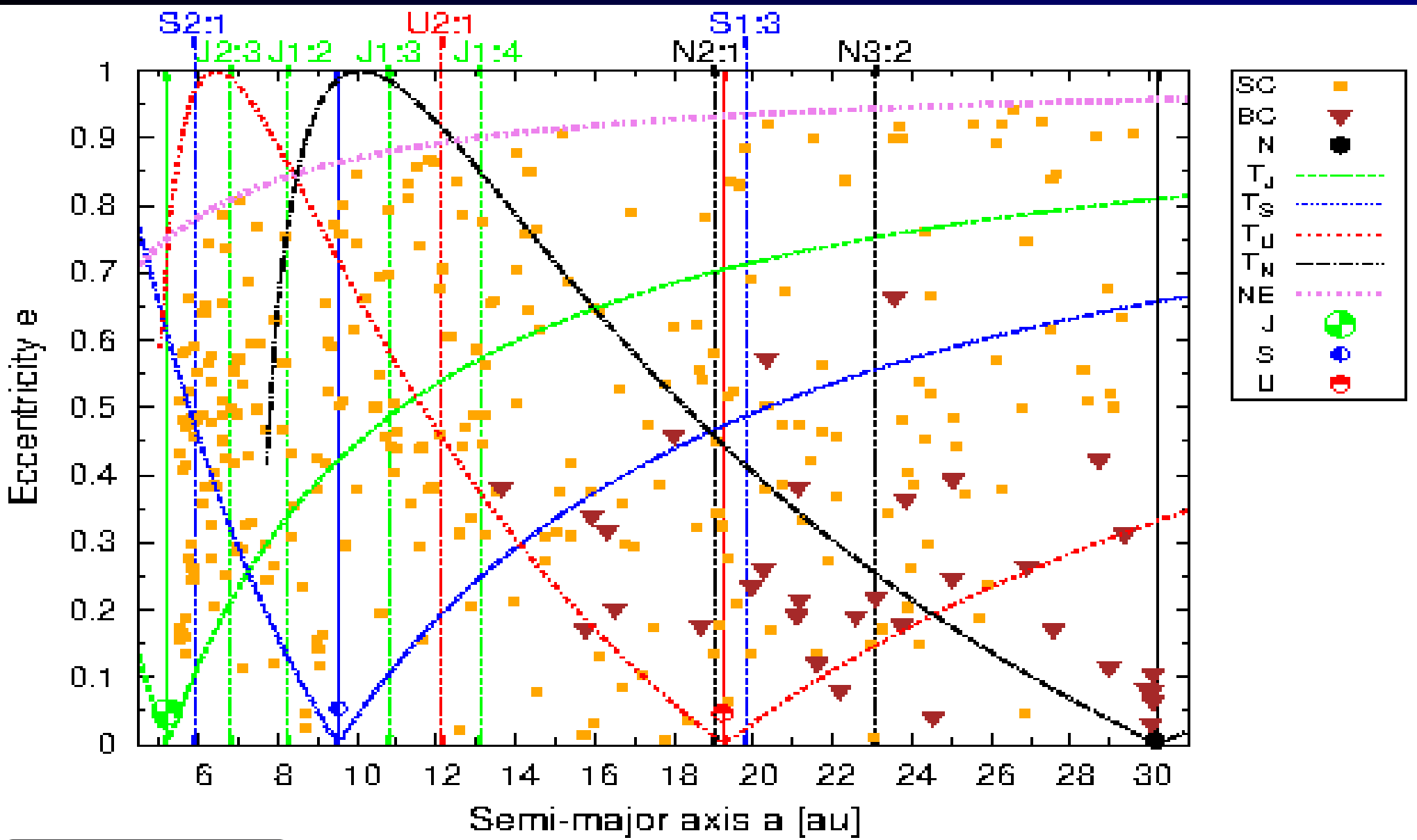
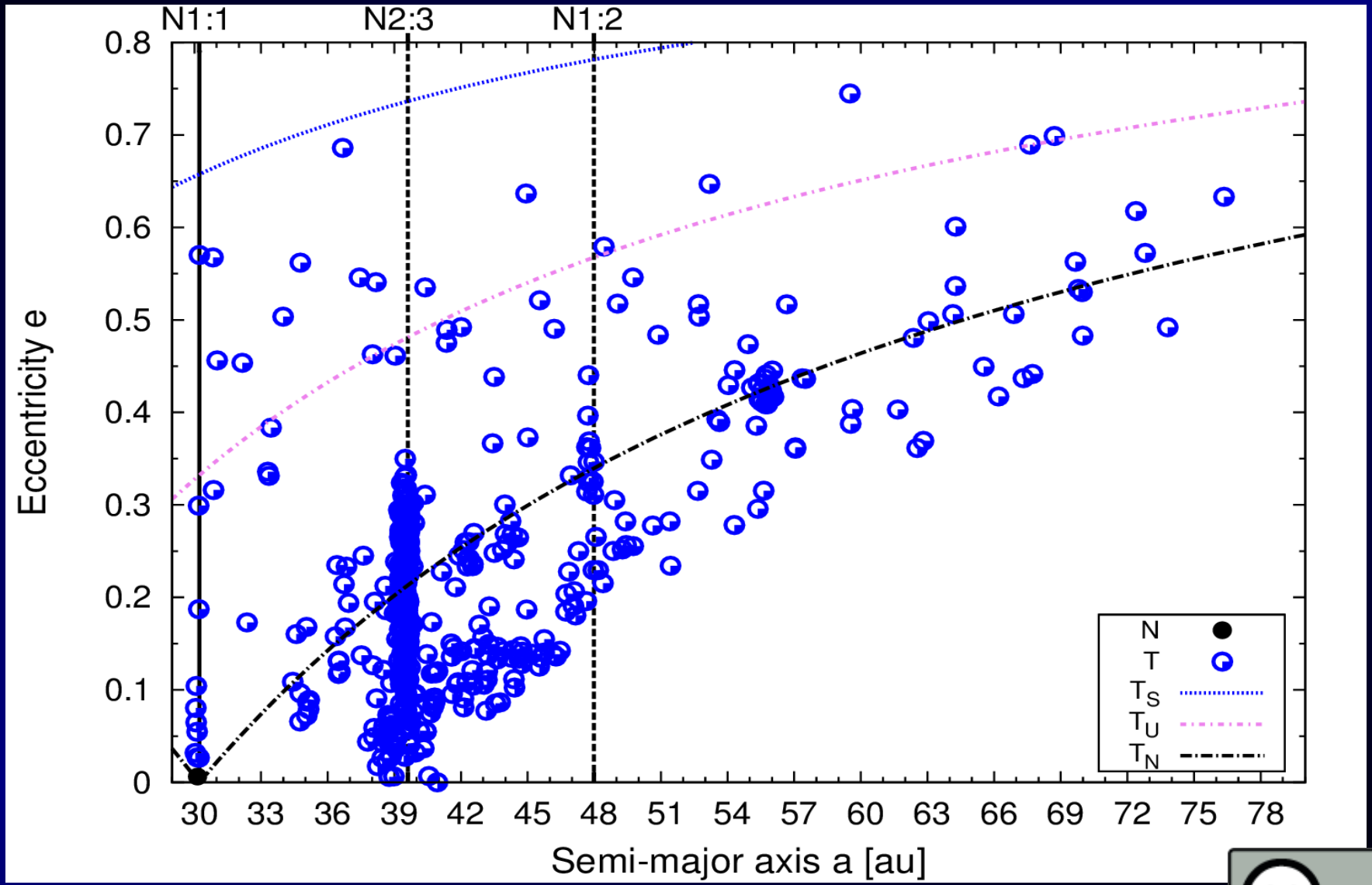
Known Centaurs in a-e space

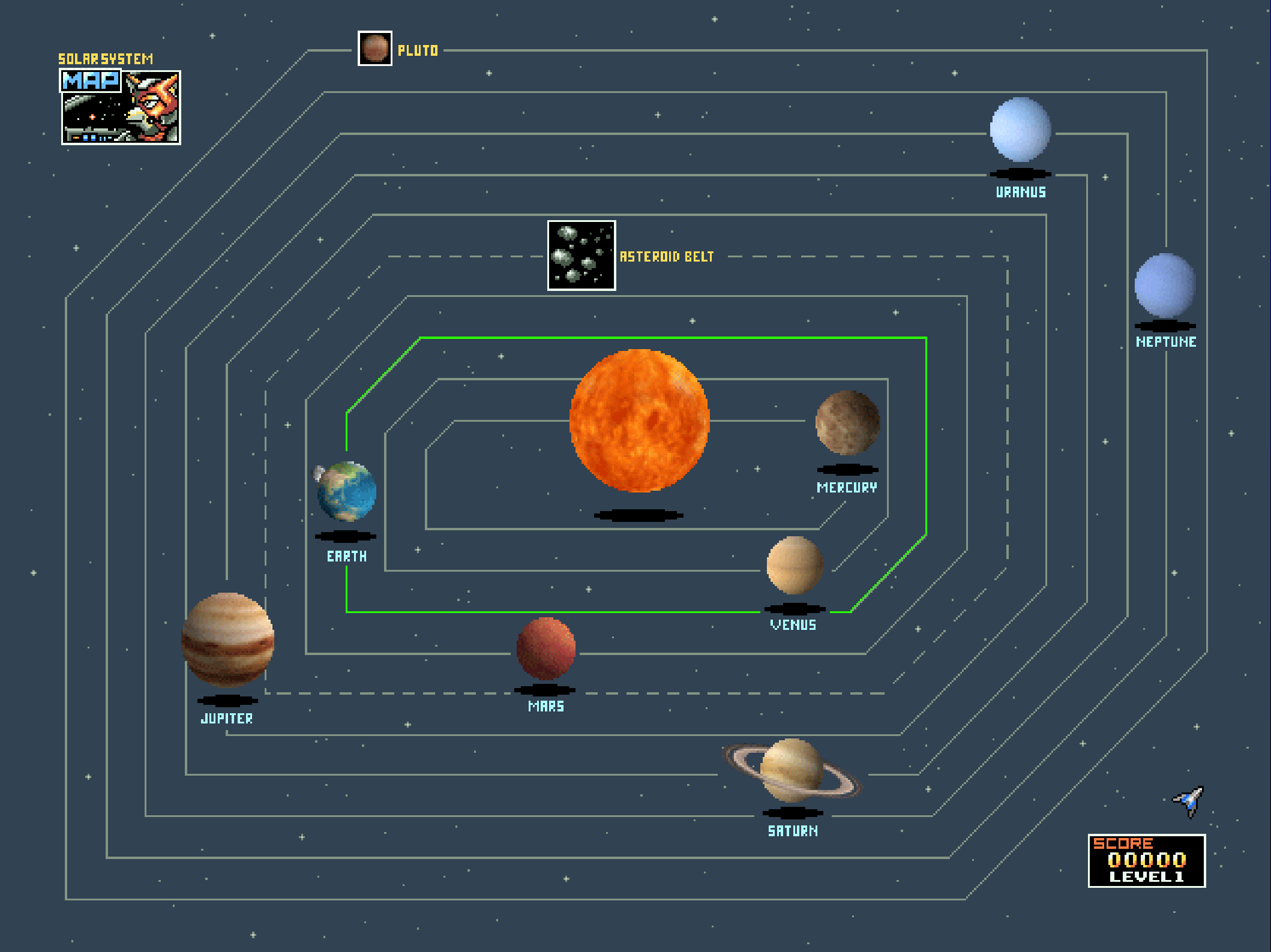


(Tp=3 and i=0°)

$$T_P = \frac{a_P}{a} + 2 \cdot \sqrt{\frac{a}{a_P}(1-e^2)}\cos i$$

Known TNOs (D>100km) in a-e space




SOLAR SYSTEM
MAP
PLUTO
URANUS
ASTEROID BELT
NEPTUNE
MERCURY
EARTH
VENUS
JUPITER
MARS
SATURN
SCORE
00000
LEVEL 1

Aims

- Main belt families interlopers raises the question of whether:
- **the interlopers raised only from (a) the initial stage of the solar system or (b) also after, meaning after the LHB?**
- Our work aim to simulate case (b), considering the evolution of Centaurs and TNOs (C+TNOs, from now on) of nowadays and just after the LHB (~3.8-3 Ga).

  We also try to understand the possible asteroids in the belt which were former TNOs.

Orbital analysis of the evolution of external larger (D>100 km) minor bodies: importance of close encounters.

Methods

- We performed numerical computations of orbits via Lie-integrator, a numerical integrator with an adaptive stepsize able to handle close encounters in details (Hanslmeier & Dvorak, 1984, Eggl & Dvorak 2010, Galiazzo, Baszo & Dvorak 2013a, 2013b, 2014a).

- Forward integration for 50 Myrs, only gravitational forces, Centaurs (1023 orbits) and TNOs (2061 orbits at 5.5<a<80 au and q<40 au) with D>100km for the present population (PP).

- Forward integration for 200 Myrs of the synthetic TNOs (255 clones, $M>10^{-9}\, m_{sun}$)distributed like suggested by Adams et al. (2014). All solar system apart Mercury, whose mass was added to the Sun -> 3.8-3.6 Gyrs ago. (AP)

Methods (Interaction with main belt)

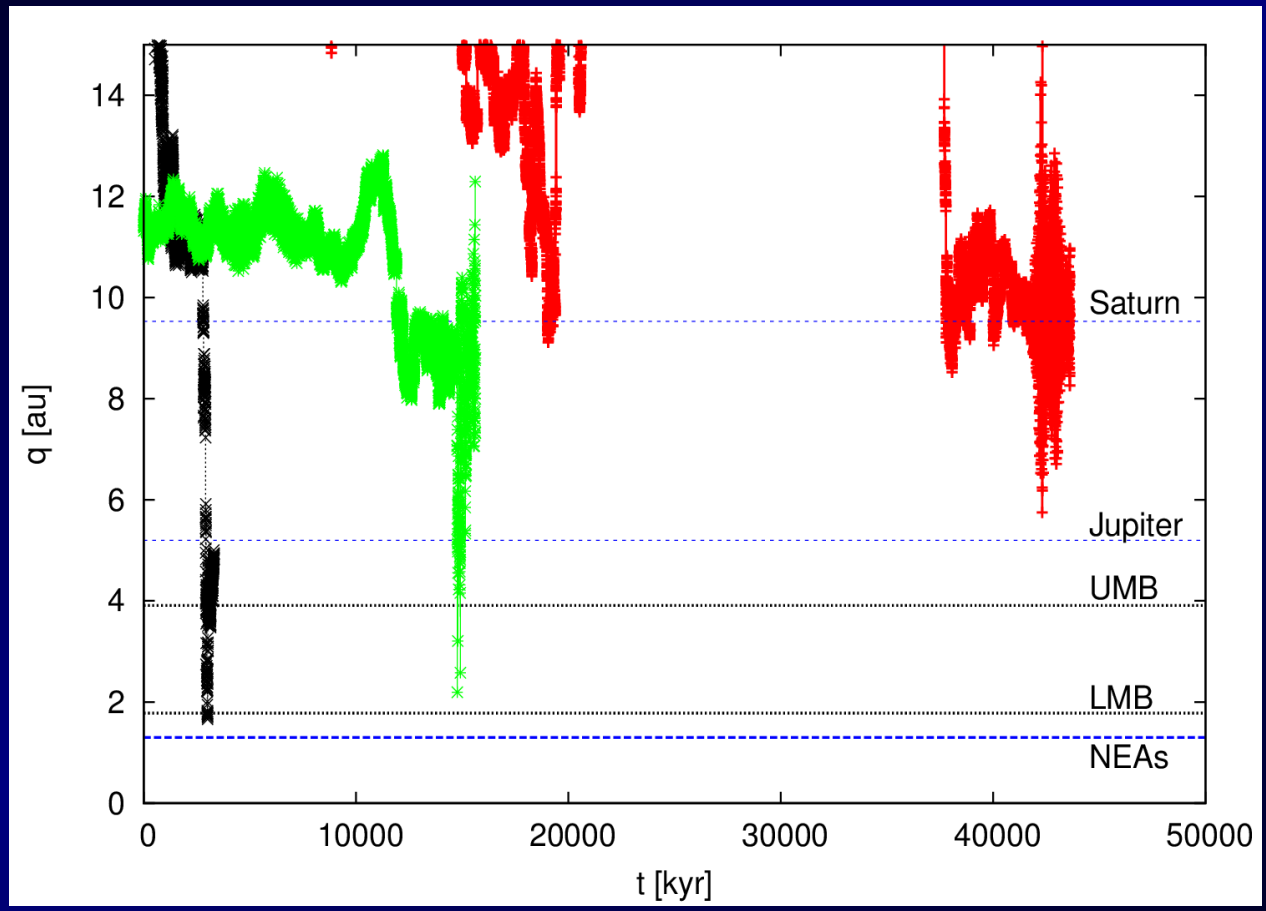
- We consider a close encounter when the clones reach a distance of 0.0025 au (~1LD) with the massive body.
- The orbital evolution is considered until collision or escape. A body is considered escaped when its instataneous eccentricity, e>0.99, its period, P>1000 yrs and a >80 au.
- If the perihelion of a C+TNOs is less than 3.8 au, it is considered interacting with the main belt -> second integration considering also the main belt objects (a subsample of km-size, H<14 (D=4-9km), 528 Vestoids+1054 main belt asteroids proportionally distributed among the main belt, divided by i=17.16°):

GROUP	Δa [au]	# low	# high
IMB	$1.78 \leq a \leq 2.5$	146	29
MMB	$2.5 < a \leq 2.83$	306	19
OMB	$2.83 < a \leq 3.8$	476	72

Methods (analysis)

- A main belt family can potentially lose one of its members once a close encounter causes the asteroid a real semi-major axis change of more than 0.0003 au (K_{kill}).
- K_{kill} is enough to affect the proper semi-major axis at a level that may affect the apparent membership of the asteroid in an asteroid family (Knezevic & Milani 2003).
- We assume ~3-5% of affected asteroids as an optimal limit for a significative perturbation of the main belt.

Typical orbits (PP): evolution of clones which cross Jupiter's orbit



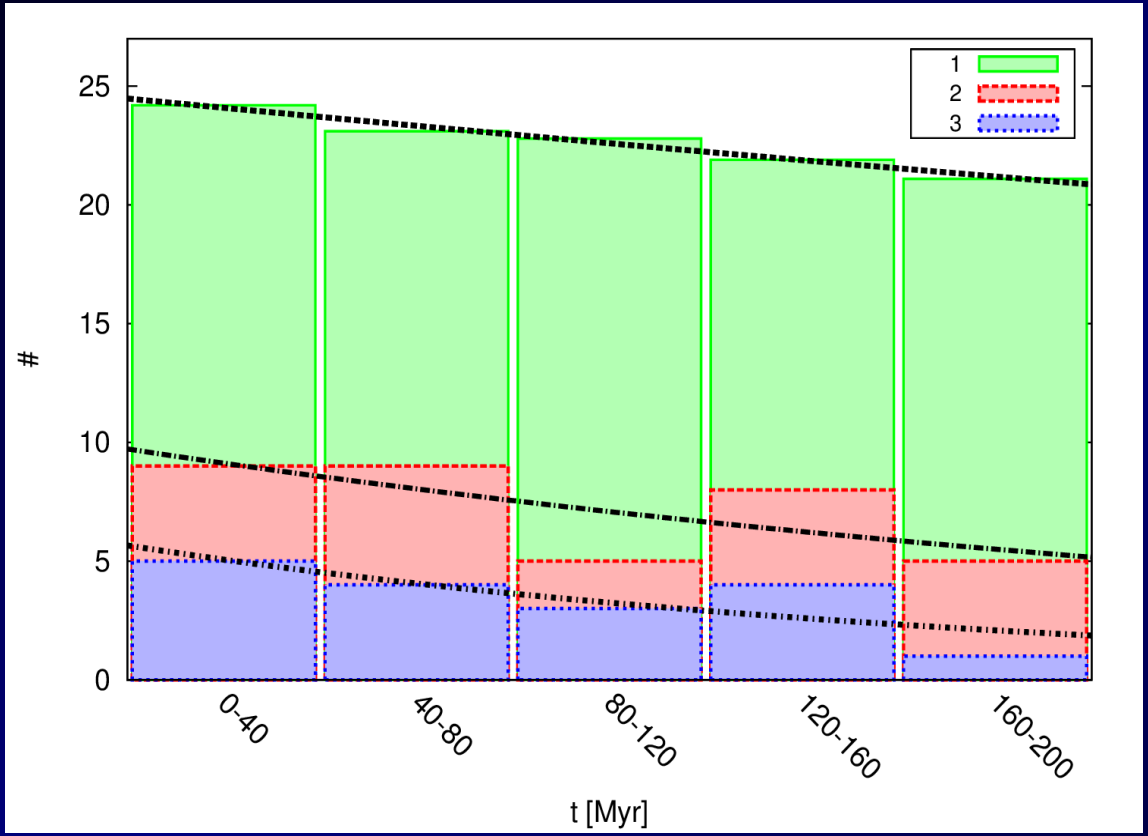
A former Centaur = black, a former KBO (green) and a former SDO.

Evolution to the main belt

Group	T_{max}	$< T >$	T_a
Centaurs (PP)	3050	116	10047
TNOs (PP)	1886	97	16739
TNOs (AP)*	3733	246	85232

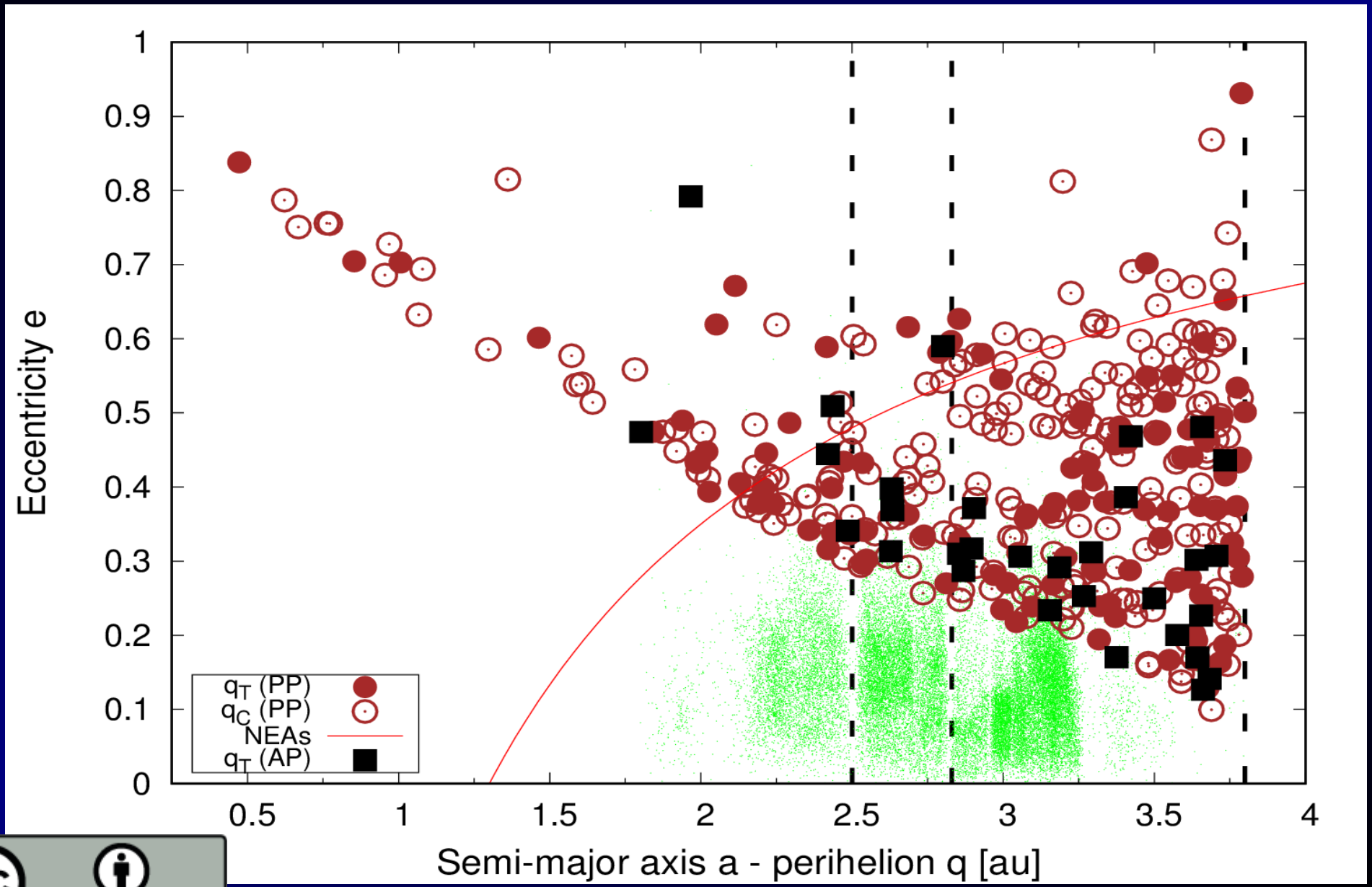
- Maximum (T_{max}) and average (<T>) total life and arrival time (T_a) in the main belt in Myrs
- Only C+TNOs with q< 34 au ---> main belt [no SDOs]: 23% Centaurs in PP and ~3% TNOs in PP, 8.5% in AP.

Evolution to the main belt

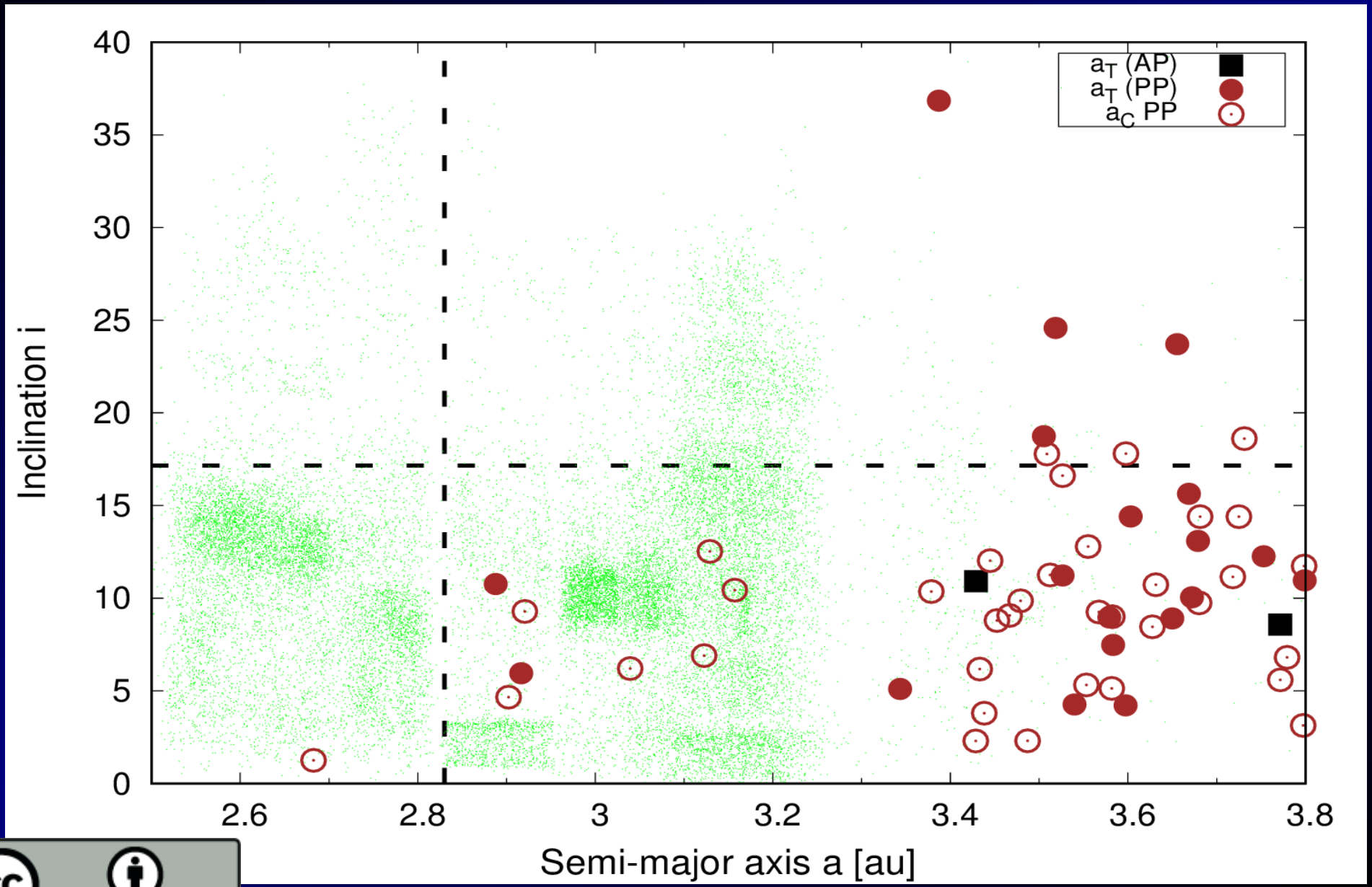


- Survival rate of (1) TNOs (Classical and N2:3 classes), number/10; (2) TNOs entering the main belt and (3) TNOs like (2) but also providing a $\Delta a > K_{kill}$.

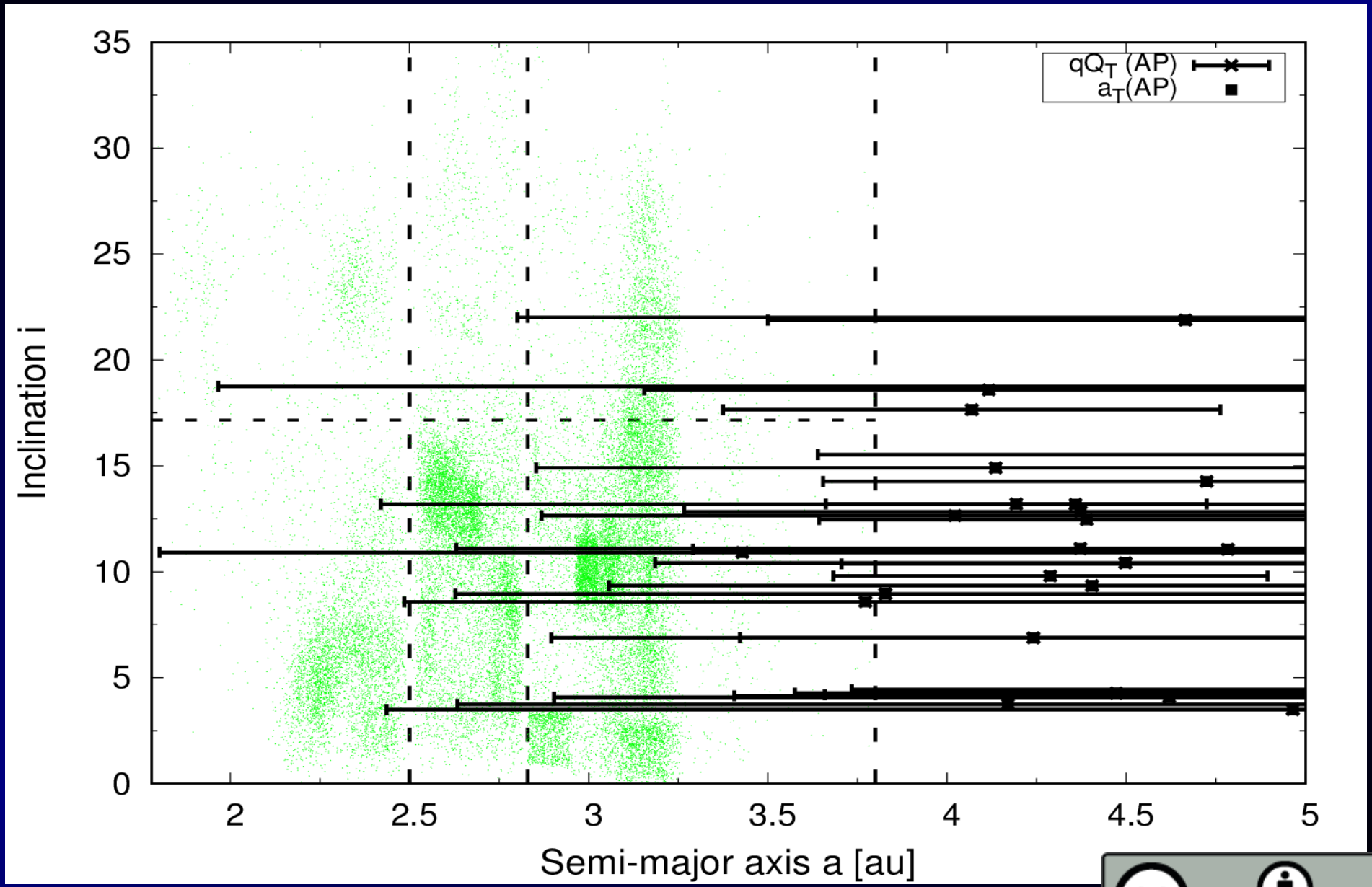
C+TNOs typical orbits in the belt (a-e) space



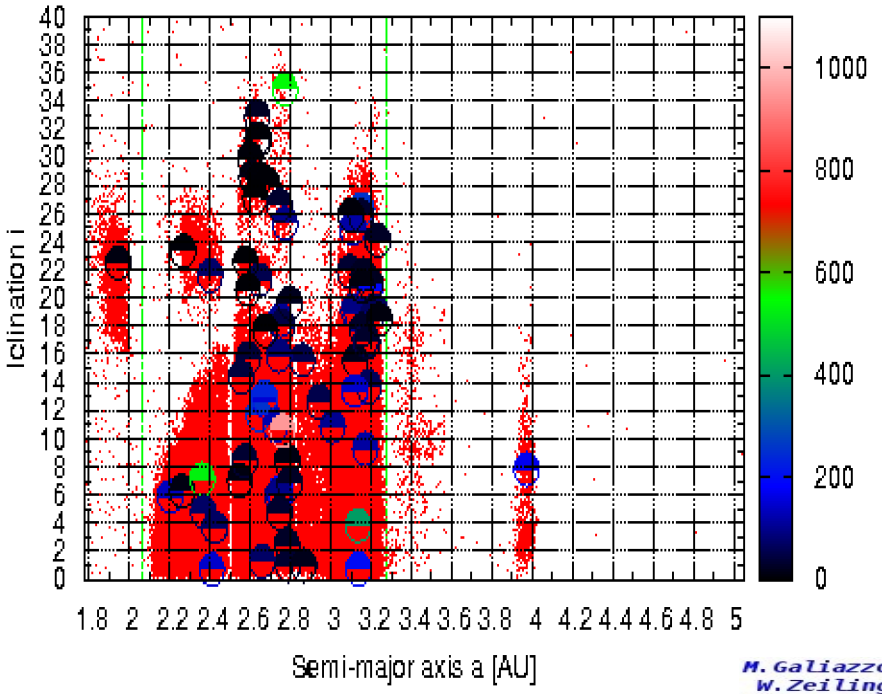
C+TNOs typical orbits in the belt (a-i) space

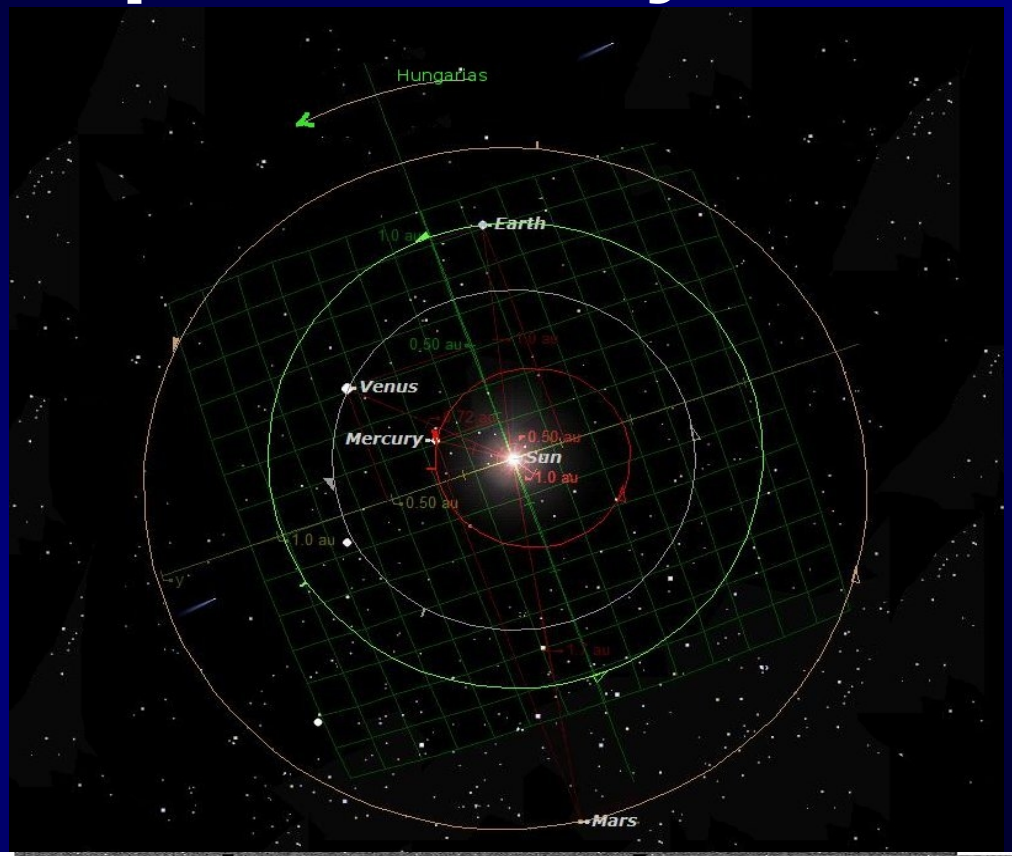


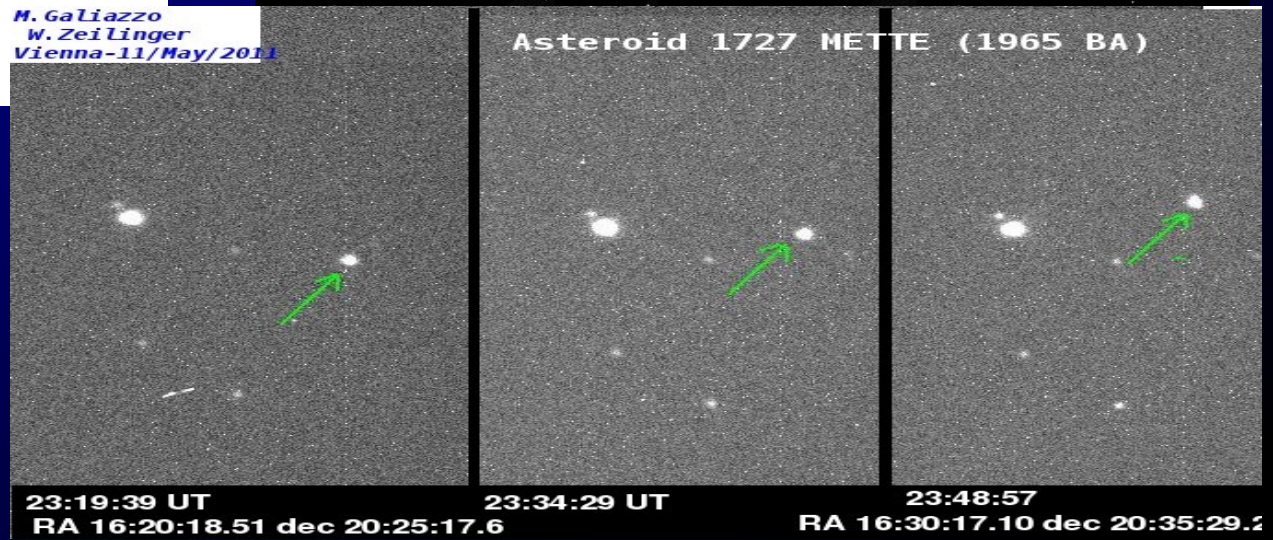
AP-TNOs typical orbits in the belt (a-i) space



Asteroid families and parent body size

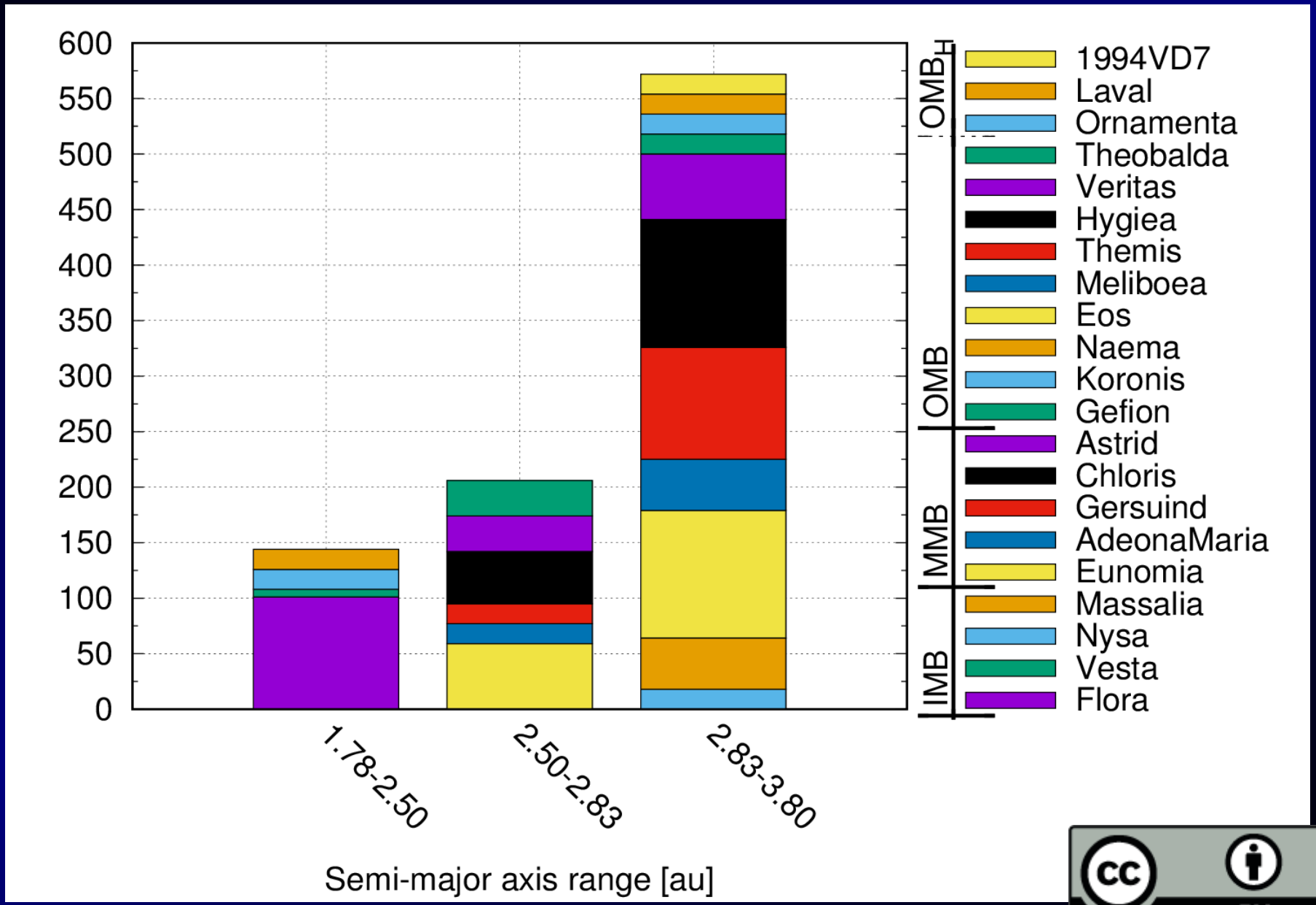






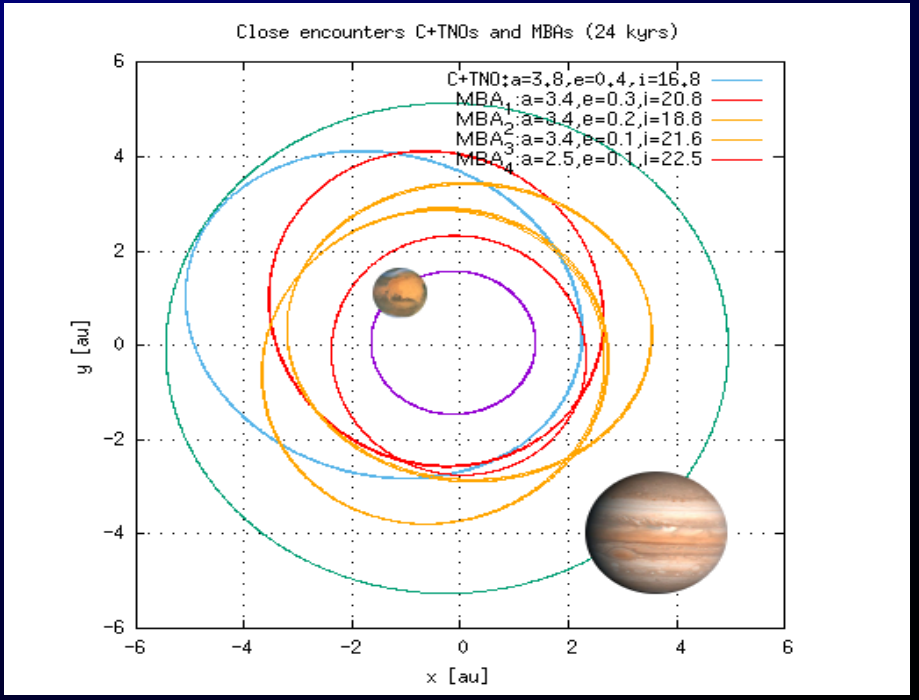
Galiazzo 2013, Phd Thesis

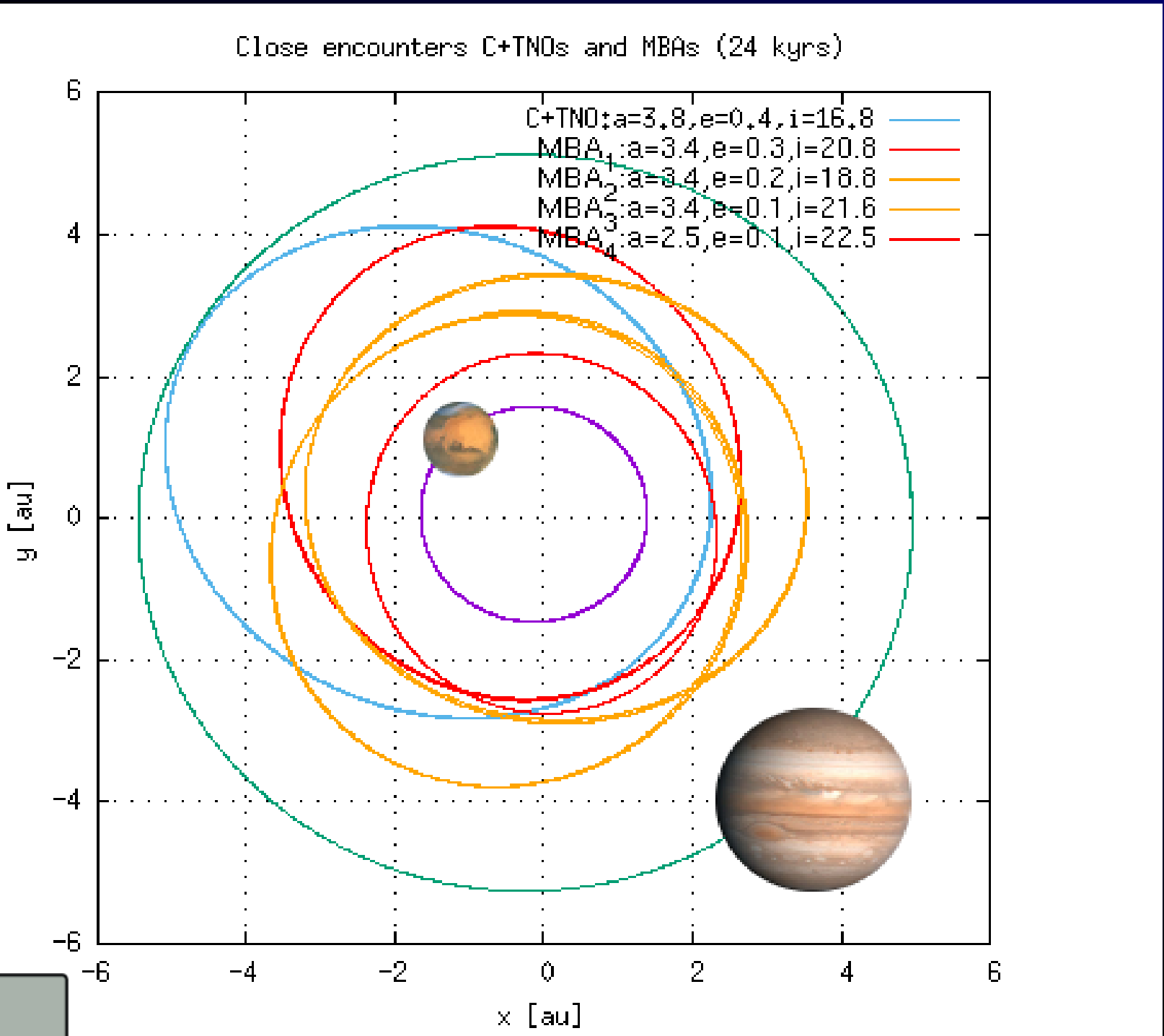
Family dispersion of the Ancient population



Conclusions

- 23% of the Centaurs and 3% of the TNOs of the present population enter in the main belt for at least 2 kyrs.They stay in the main belt up to 3Myrs (usually ~0.1 Myrs).
- <0.1% main belt asteroids are perturbed by present C+TNOs.
- Typical eccentricities and inclinations of the C+TNOs when they reside in the belt are respectively e>0.16 and i<25°.
- at least 3% of the main belt significantly perturbed in the first hundreds of million of years after the LHB --> The most affected region: Outer main belt.
- The orbits of TNOs during their belt-crossing phases resemble those of known large main-belt asteroids --> more investigation on some dark, primitive main belt asteroids on short-lived orbits as former TNOs.




Close encounters C+TNOs and MBAs (24 kyrs)
C+TNO:a=3.8,e=0.4,i=16.8
MBA1:a=3.4,e=0.3,i=20.8
MBA2:a=3.4,e=0.2,i=18.8
MBA3:a=3.4,e=0.1,i=21.6
MBA4:a=2.5,e=0.1,i=22.5
y [au]
x [au]
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6

PALDIES!

GRAZIE!

No humans, only sheeps, in which stage of human evolution are we, here?

I am a clone out of the keyhole for the Oort Cloud!

YOU reporter.it

TENCAROLA (PD) – CAPUT MUNDI