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"Elusive" Zhongguos and Griquas — long-lived asteroids inside the J2/1 resonance

M. Brož [1,5], D. Vokrouhlický [1], F. Roig [2], D. Nesvorný [3], W.F. Bottke [3], A. Morbidelli [4],

[1] Charles University, Prague
[2] Nacional Observatory Brazil, Rio de Janeiro
[3] Southwest Research Institute, Boulder
[4] Observatoire de la Côte d'Azur, Nice
[5] mira@sirrah.troja.mff.cuni.cz

Abstract:

The 2/1 mean motion resonance with Jupiter has attracted attention of researches for tens of years. Today, the dynamics in this resonance and the existence of both highly unstable regions and stable islands is generally understood. We observe approximately 50 short-lived (unstable) asteroids, which have been successfully interpreted as a steady-state Yarkovsky-driven flow of objects from the neighbouring background population and the Themis family, or as dormant Jupiter-family comets (Brož *et al.*, 2005).

However, we observe another 100 long-lived asteroids (traditionally called Zhongguos and Griquas), confined to the stable islands or their close surroundings. And there are several contradictions with respect to them:

1. marginally stable Griquas cannot be primordial, because they cannot survive 4.6 Gyr of orbital and collisional evolution, and no Griqua-like orbits were produced by the above Yarkovsky-driven model;
2. Zhongguos might be remains of a protoplanetary disc, but their size-frequency distribution (SFD) is too steep, not collisionally relaxed;
3. Griquas have shallower SFD then Zhongguos, so they cannot be interpreted as Zhongguos leaking due to Yarkovsky effect, which always produces steeper SFD.

We present observed properties of Zhongguos and Griquas and results of new simulations of orbital evolution spanning 4 Gyr. We discuss the long-term stability of resonant orbits with respect to the Yarkovsky effect.

Definitions:

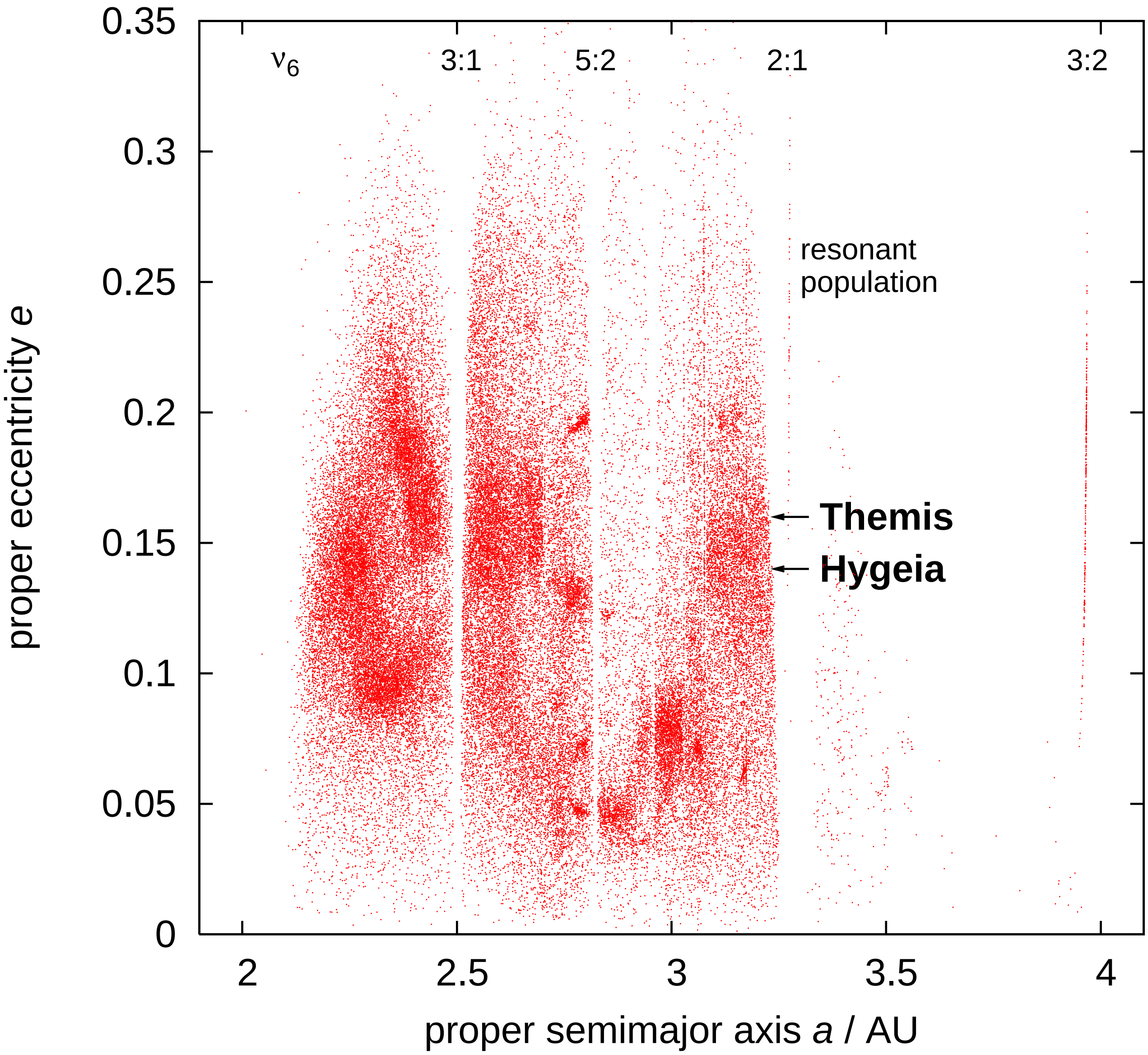
- dynamical lifetime $t_{\mathrm{J2/1}}$ — the time spent inside the J2/1 resonance, until the body is ejected from this zone; we calculate it as a median value for the original orbit and 12 close-clones
- pseudo-proper resonant elements a_p, e_p, I_p — osculating elements at the time when $|\sigma| < 5^\circ \wedge \frac{\Delta\sigma}{\Delta t} > 0 \wedge |\varpi - \varpi_{\mathrm{J}}| < 5^\circ$

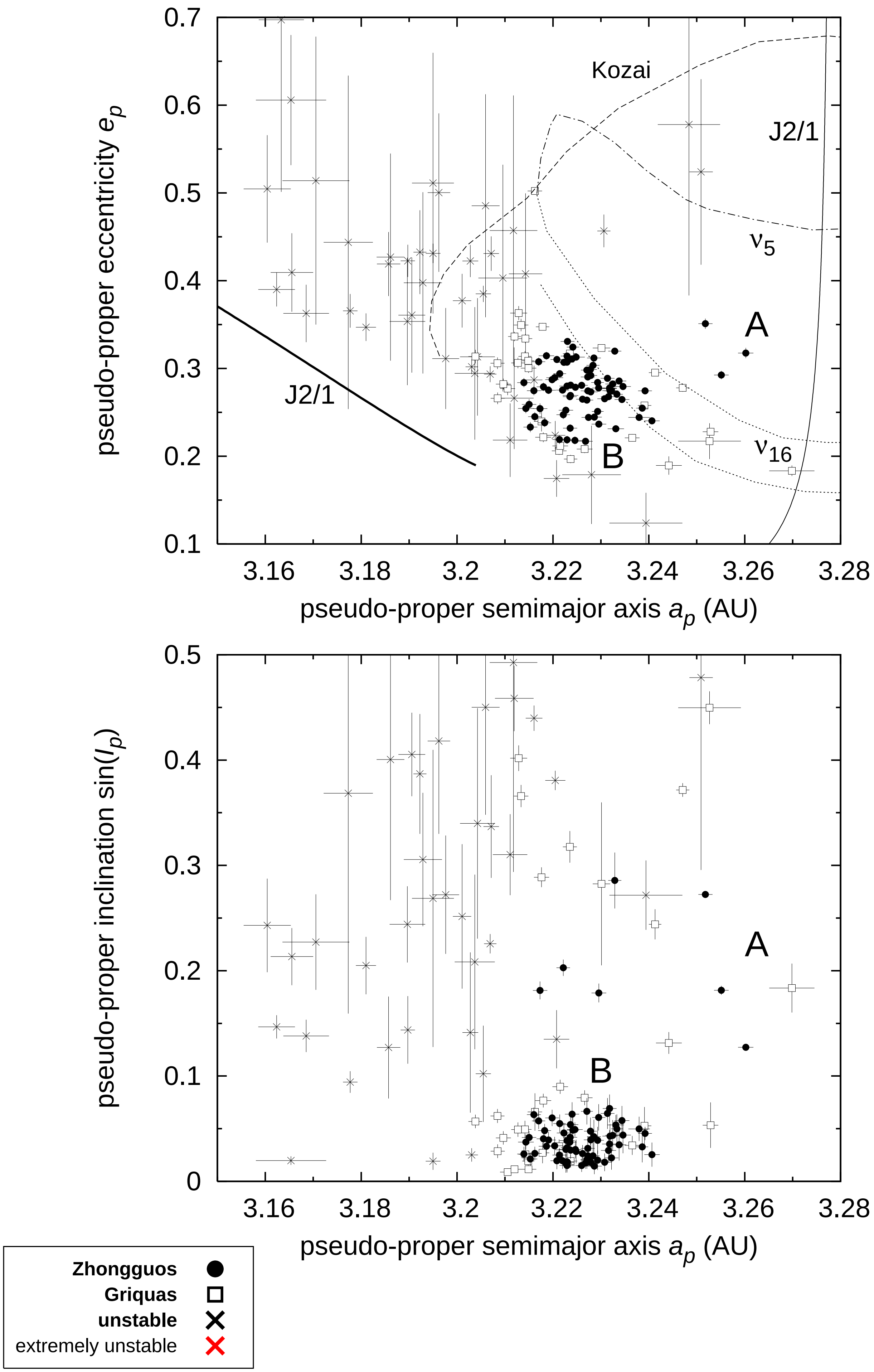
What is the asteroids classification wrt. $t_{J2/1}$?

- long-lived: $t_{J2/1} > 70\,\mathrm{My}$
  - stable (“Zhongguos”): $t_{J2/1} > 1\,\mathrm{Gy}$
  - marginally stable (“Griquas”): $t_{J2/1} \in (70, 1000\rangle\,\mathrm{My}$
- short-lived (unstable): $t_{J2/1} \le 70\,\mathrm{My}$
  - extremely unstable: $t_{J2/1} \le 2\,\mathrm{My}$

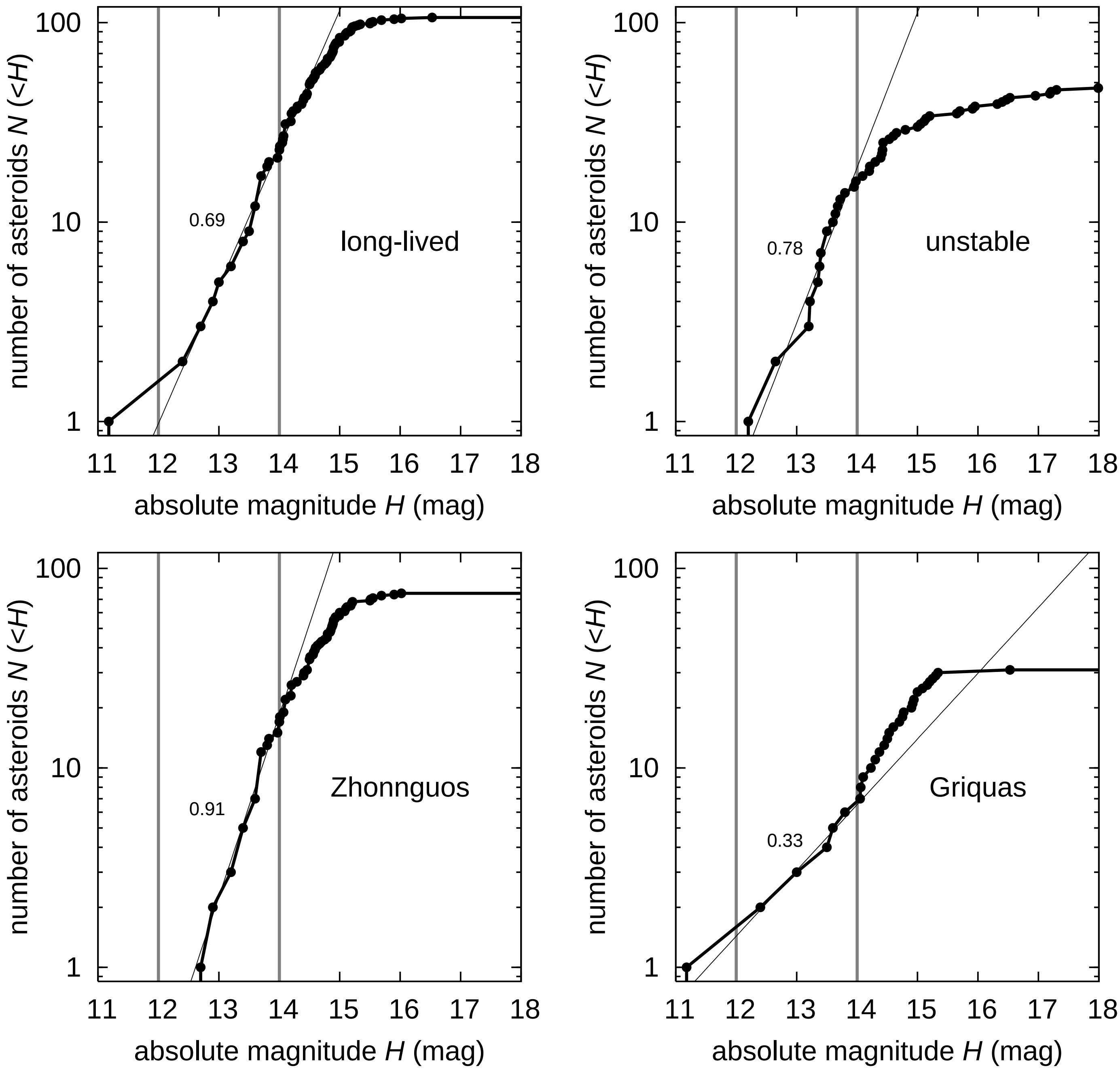
detailed list @ `http://sirrah.troja.mff.cuni.cz/yarko-site/`

Where are they located?

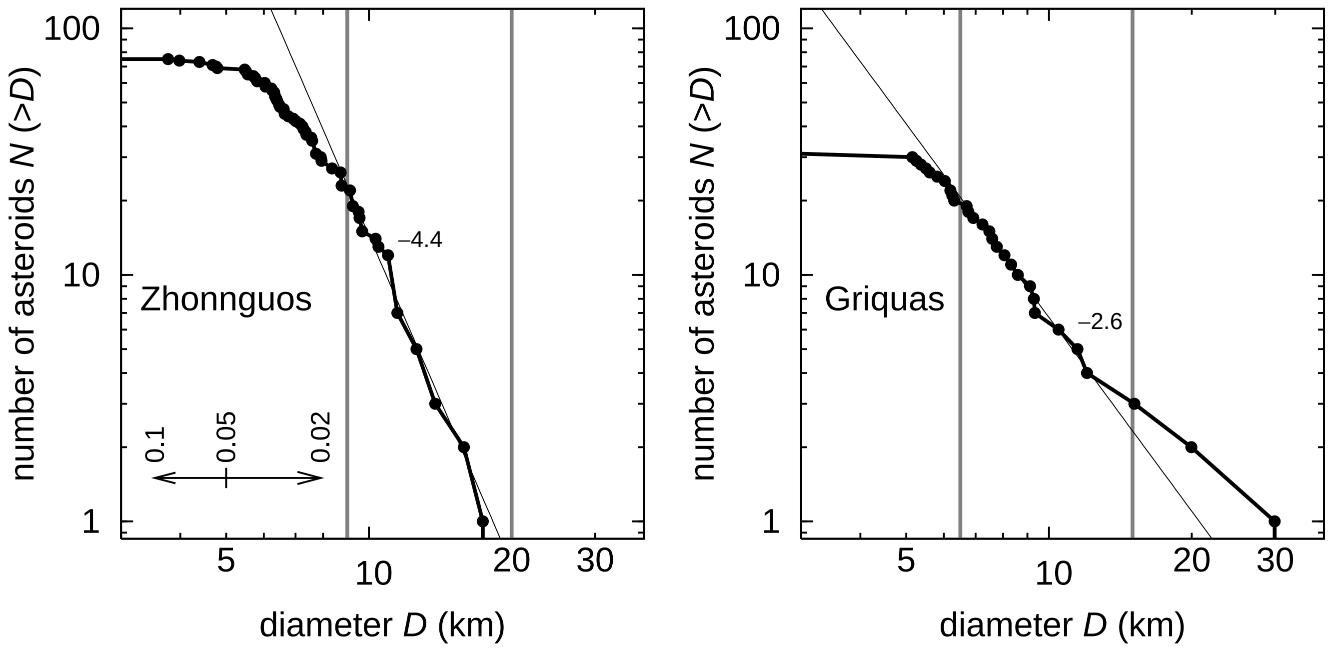


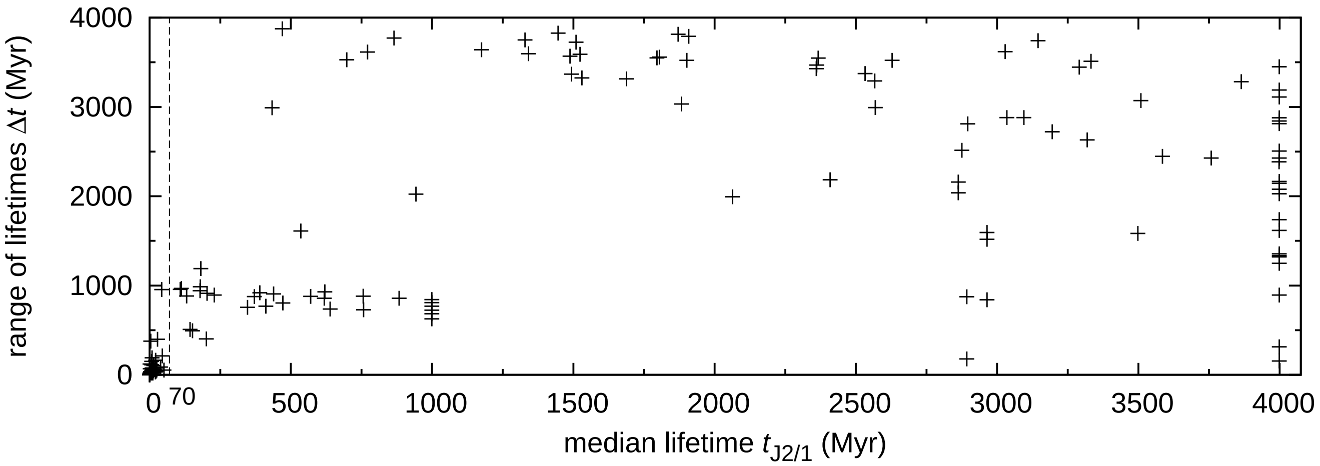

0.7
0.6
0.5
0.4
0.3
0.2
0.1
pseudo-proper eccentricity e_p
Kozai
J2/1
ν_5
A
J2/1
B
ν_{16}
3.16
3.18
3.2
3.22
3.24
3.26
3.28
pseudo-proper semimajor axis a_p (AU)
0.5
0.4
0.3
0.2
0.1
0
pseudo-proper inclination $\sin(I_p)$
A
B
3.16
3.18
3.2
3.22
3.24
3.26
3.28
pseudo-proper semimajor axis a_p (AU)
Zhongguos
Griquas
unstable
extremely unstable

What are their absolute magnitude distributions?

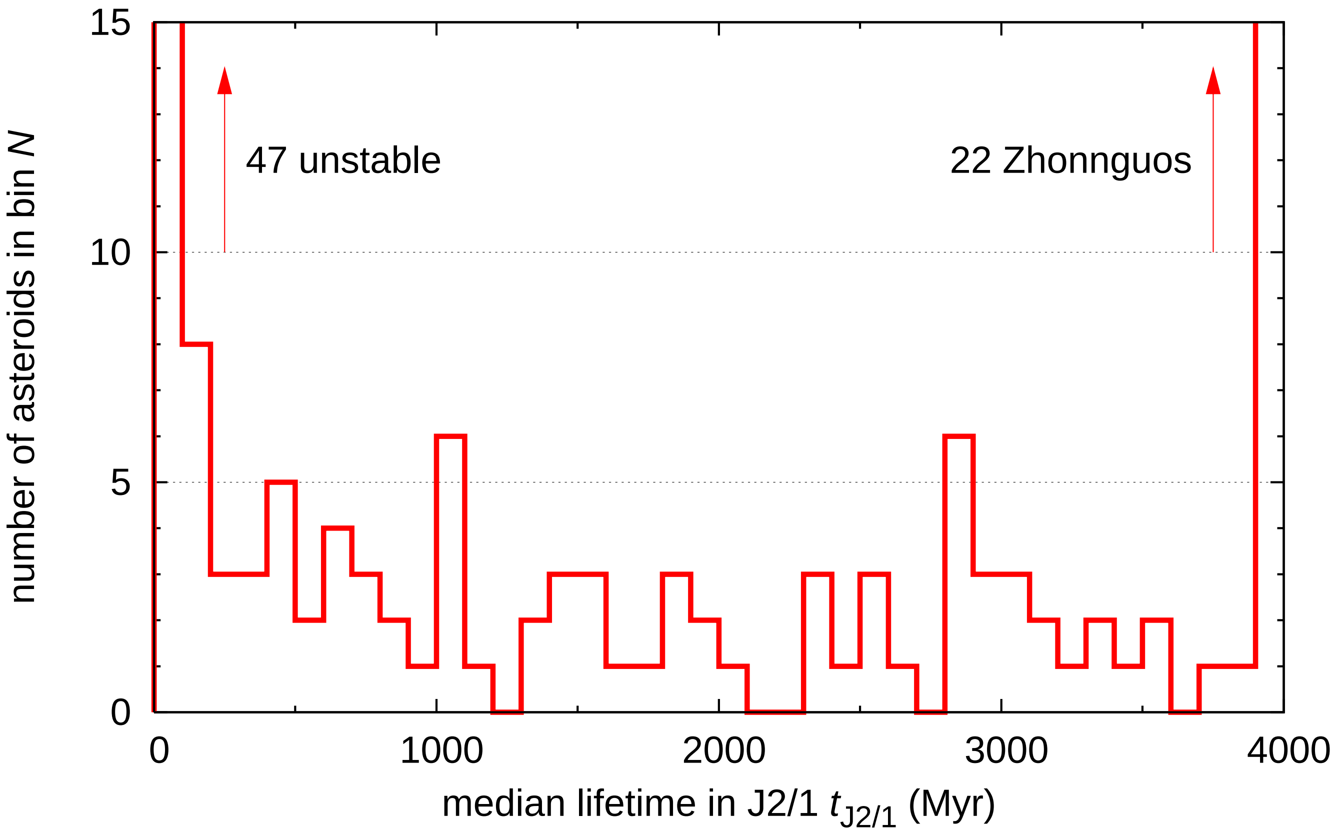


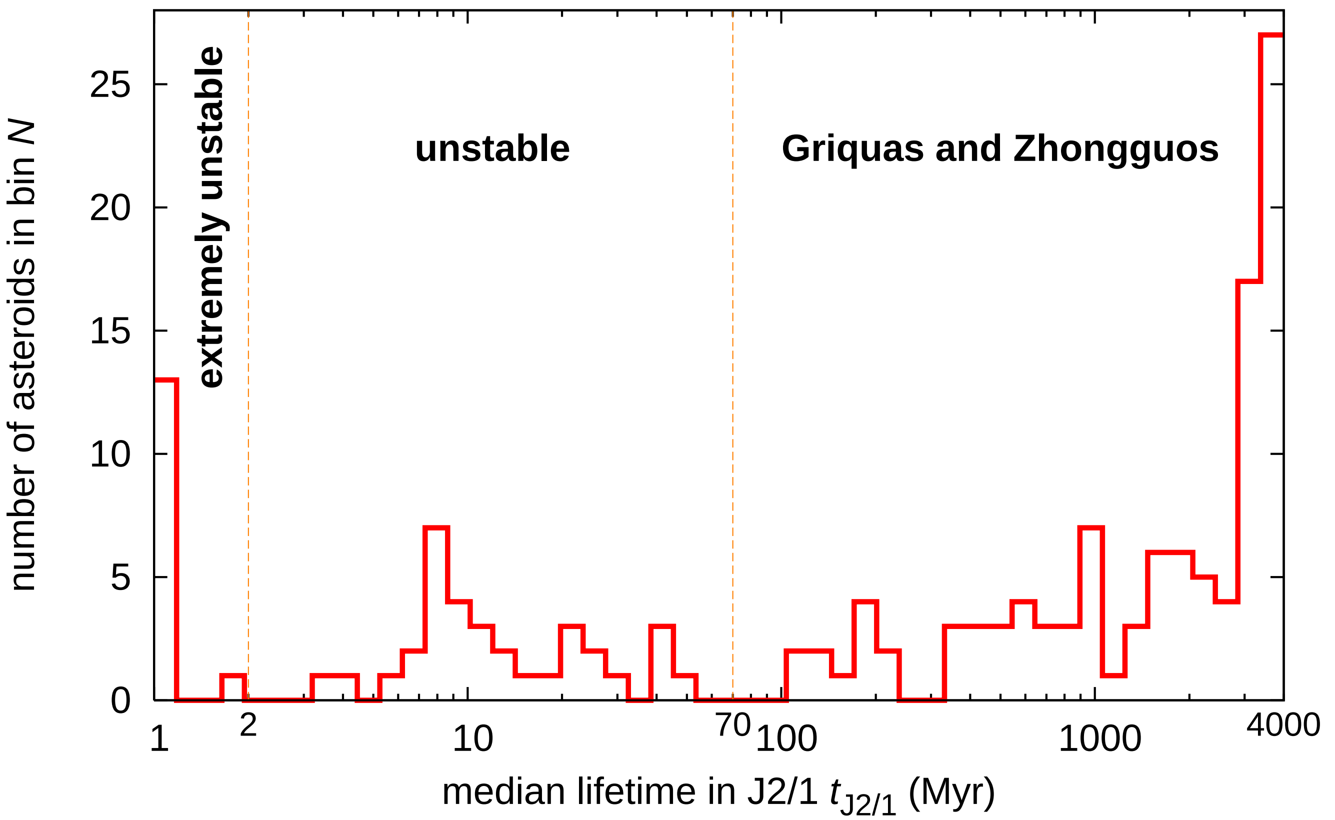
What sizes are they? (If we *assume* albedo 0.05...)





What is the lifetime ($t_{J2/1}$) distribution upto 4 Gyr?

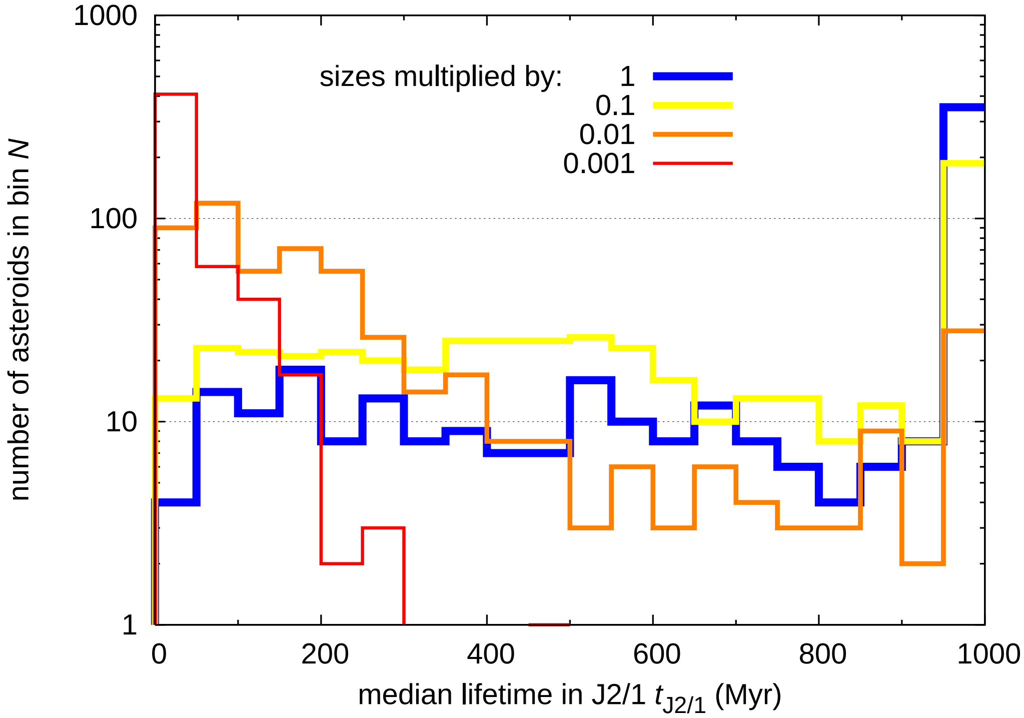




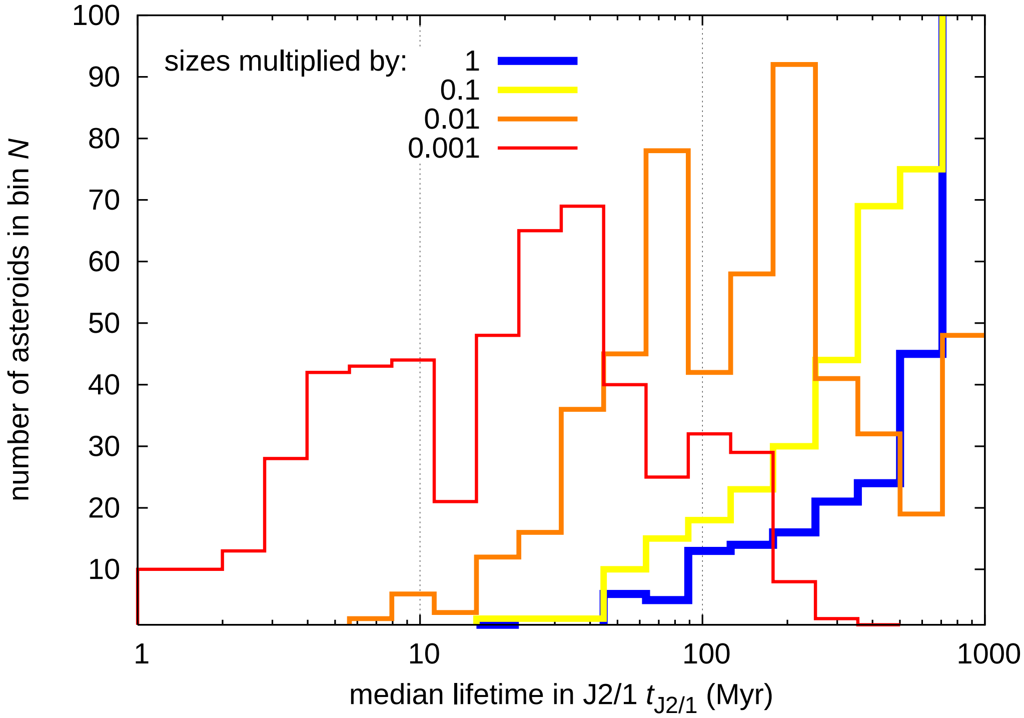
Are small Zhongguos stable wrt. Yarkovsky effect?

- nominal sizes D multiplied by factors: 1, 0.1, 0.01 and 0.001 $\Rightarrow$ Yarkovsky drift-rate scales as $1/D$
- thermal parameters: $\varrho = 1300\,\mathrm{kg/m^3}$, $K = 0.01\,\mathrm{W/m/K}$, $C = 680\,\mathrm{W/kg/K}$ (ie., C-type bodies), $\gamma \in [0°, 180°]$

lin–log scale



log–lin scale

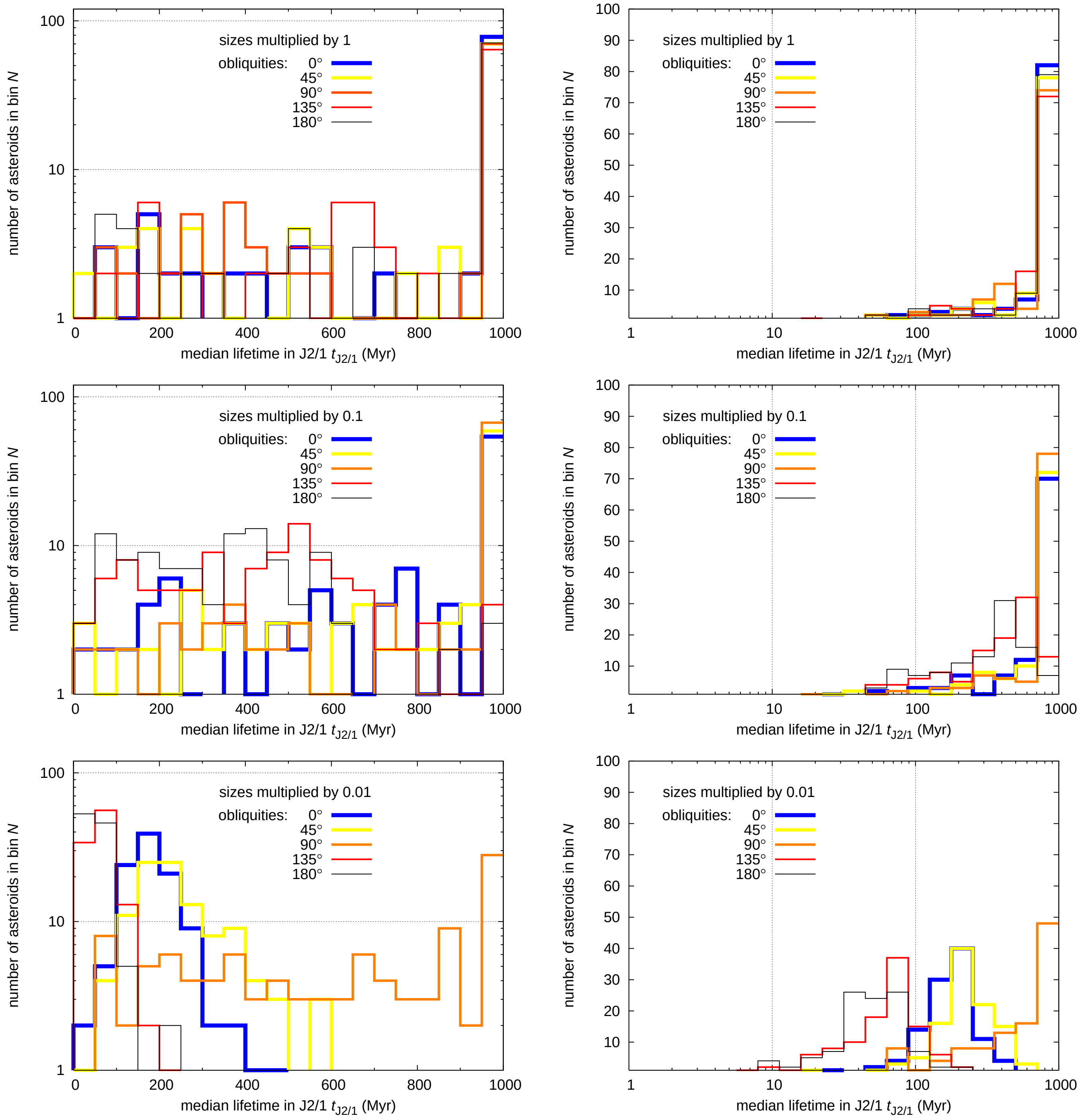


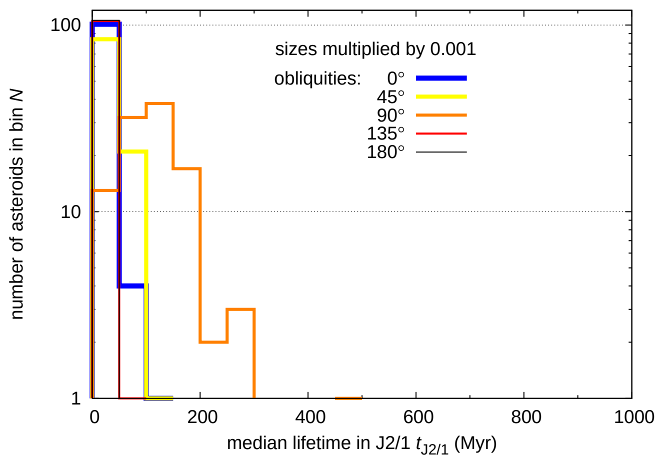
What is the dependence of escape on the obliquity?

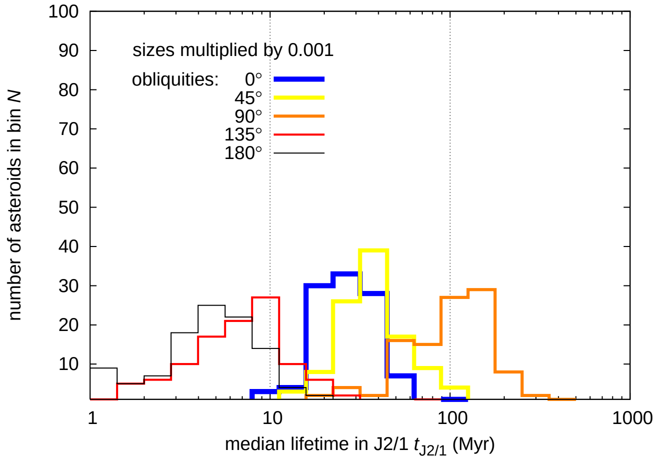
- obliquity $\gamma = 0°$ and $45° \Rightarrow$ outward (diurnal) drift
- $\gamma = 90° \Rightarrow$ very slow (seasonal) inward drift
- $\gamma = 135°$ and $180° \Rightarrow$ inward drift

linear scale logarithmic scale

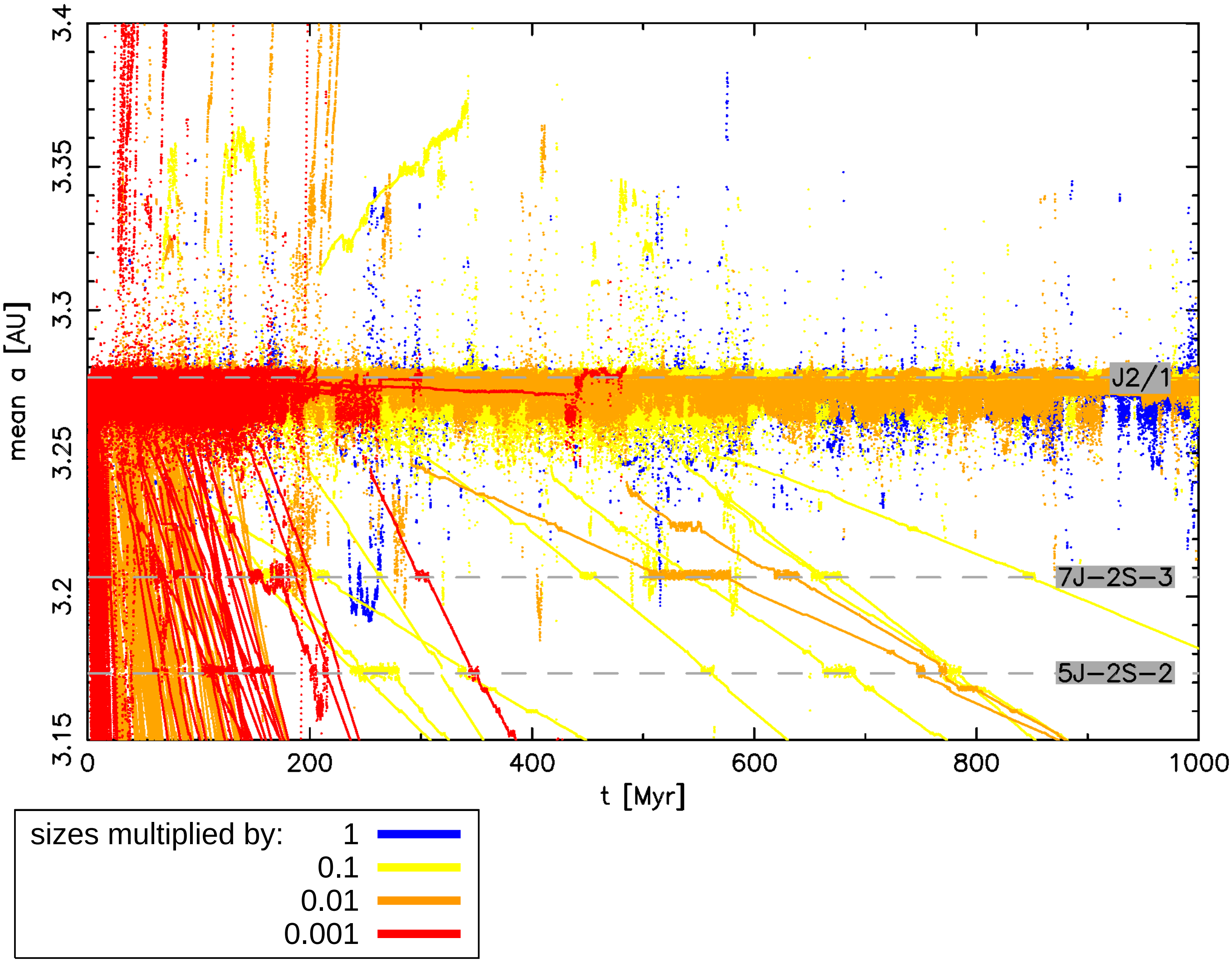
$\Leftarrow$ decreasing size

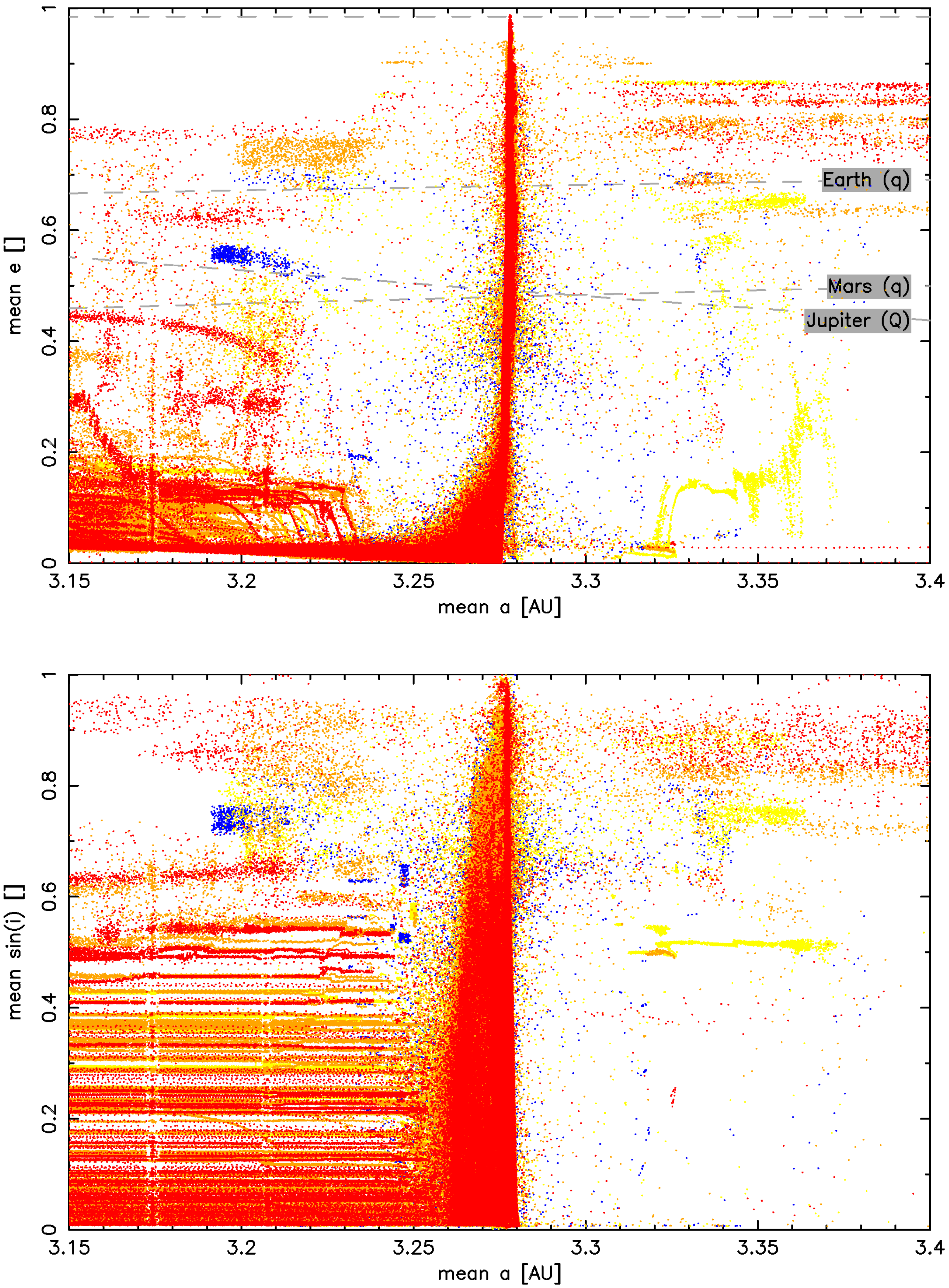




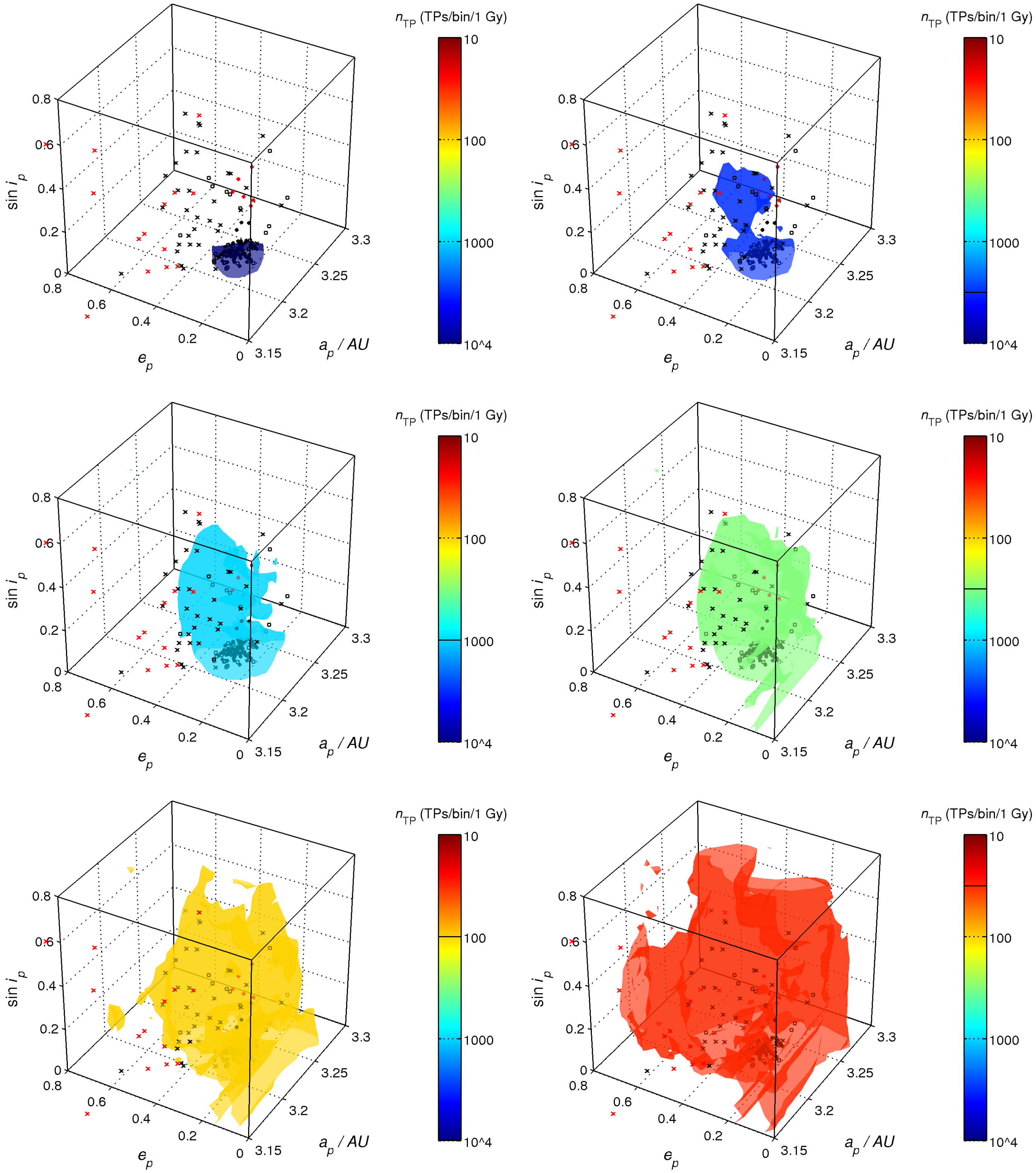


Which way do they escape from the J2/1?



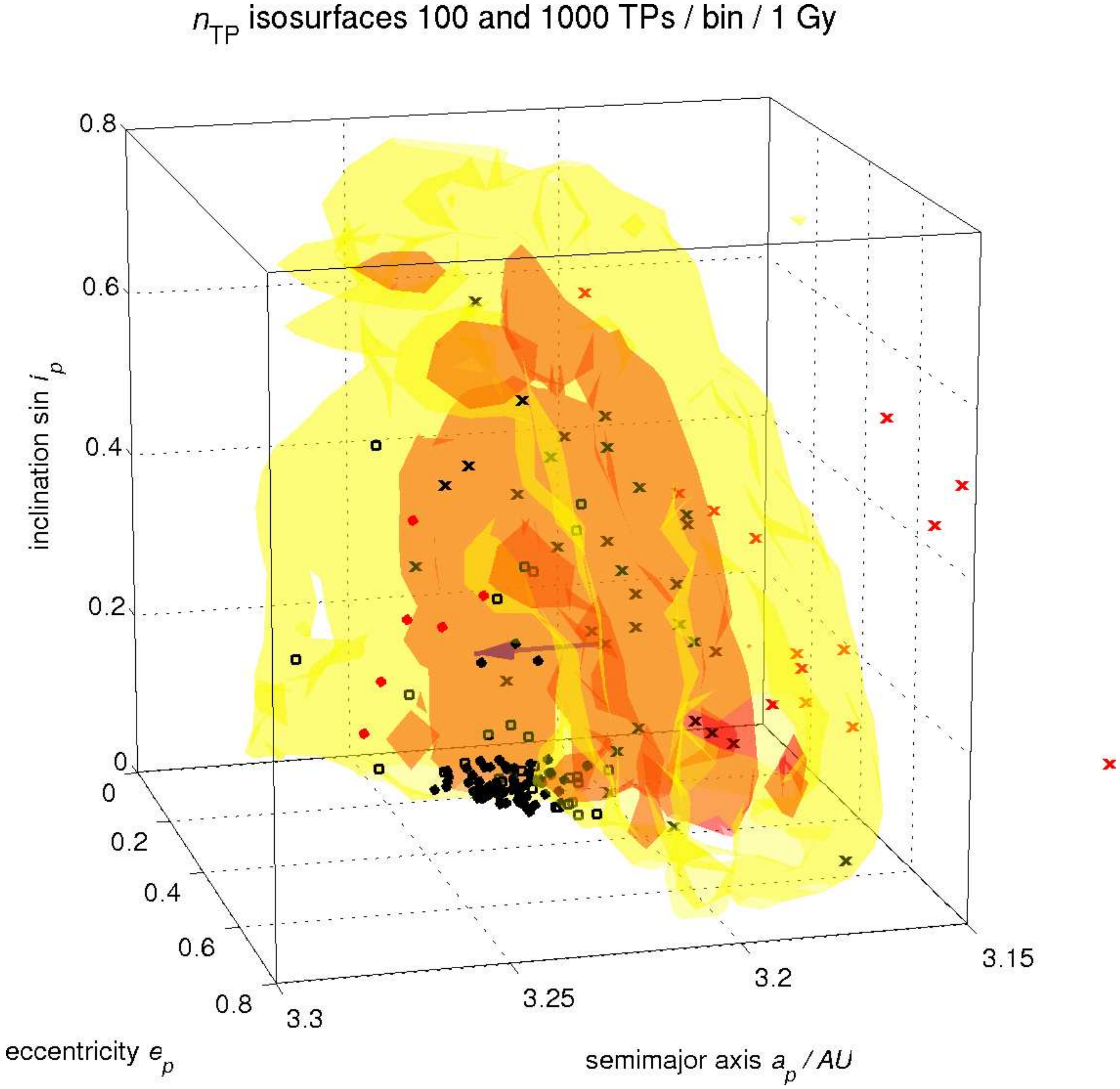

mean e []
mean a [AU]
Earth (q)
Mars (q)
Jupiter (Q)
0
0.2
0.4
0.6
0.8
1
3.15
3.2
3.25
3.3
3.35
3.4
mean sin(i) []
mean a [AU]
0
0.2
0.4
0.6
0.8
1
3.15
3.2
3.25
3.3
3.35
3.4

- isosurfaces of particle density n_{TP} in log-colour scale (for the case of sizes multiplied by 0.01)

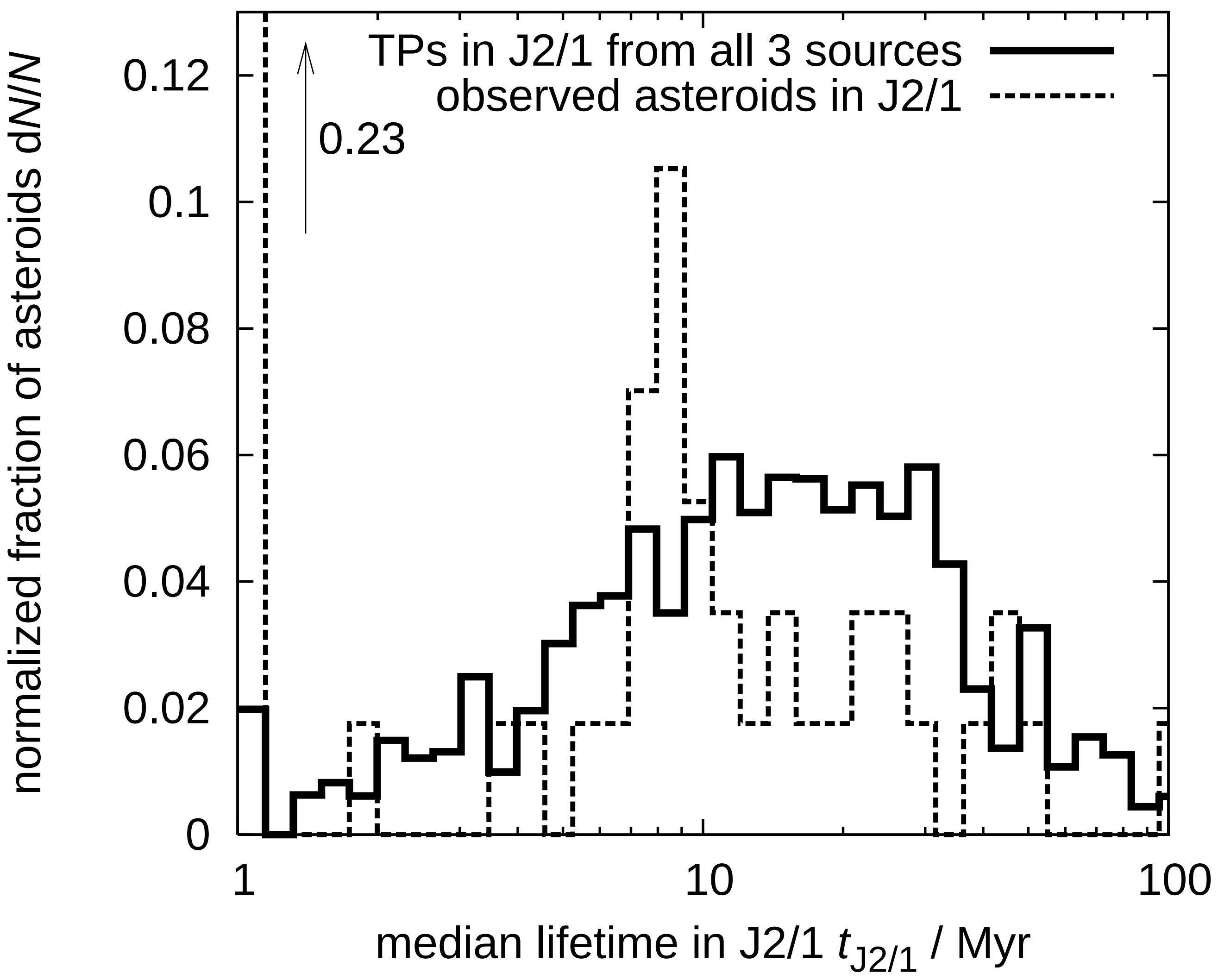


Why they cannot originate as MBA's pushed by Yarkovsky effect?

- asteroids pushed into the J2/1 resonance from neighbouring MB zone do not visit locations of most Zhongguos and Griquas:



- ...and they have short lifetimes (corresponding rather to unstable resonant asteroids):



Why they cannot be primordial?

- The slope of SFD of Zhongguos seems to be too steep for a primordial population.
- A capture of planetesimals in J2/1 MMR with Jupiter at the end of the period when Jupiter and Saturn were in their mutual 2/1 resonance (a mechanism which worked for the Trojan region — Morbidelli *et al.* (2005)), does not produce Zhongguos and Griquas. Maybe, another Jupiter—Saturn resonant capture is responsible, or resonance sweeping?

Conclusions:

- Zhongguos and Griquas cannot be simply divided by a criterion based on dynamical lifetime, even on 4 Gyr time scale
- Yarkovsky-driven instability (at the time scale of 100 Myr) occurs at sizes $< 100\,\mathrm{m}$
- small retrograde rotating asteroids are more unstable than prograde ones

References:

[1] Brož, M., Vokrouhlický, D., Roig, F., Nesvorný, D., Bottke, W.F., Morbidelli, A., 2005, MNRAS, 359, 1437.

[2] Brož, M., Vokrouhlický, D., Roig, F., Nesvorný, D., Bottke, W.F., Morbidelli, A., 2005, in Z. Knežević and A. Milani, eds, Dynamics of Populations of Planetary Systems, The Cambridge University Press, Cambridge.

[3] Morbidelli, A., Levison, H.F., Tsiganis, K., Gomes, R., 2005, Nature, 435, 7041, 462.

[4] Roig, F., Nesvorný, D., Ferraz-Mello, S., 2002, MNRAS, 335, 417.