AAS DPS 2008, Ithaca, NY, October 11–15

Resonant Asteroid Families

a Wealthy Source of Information on Planetary Migration

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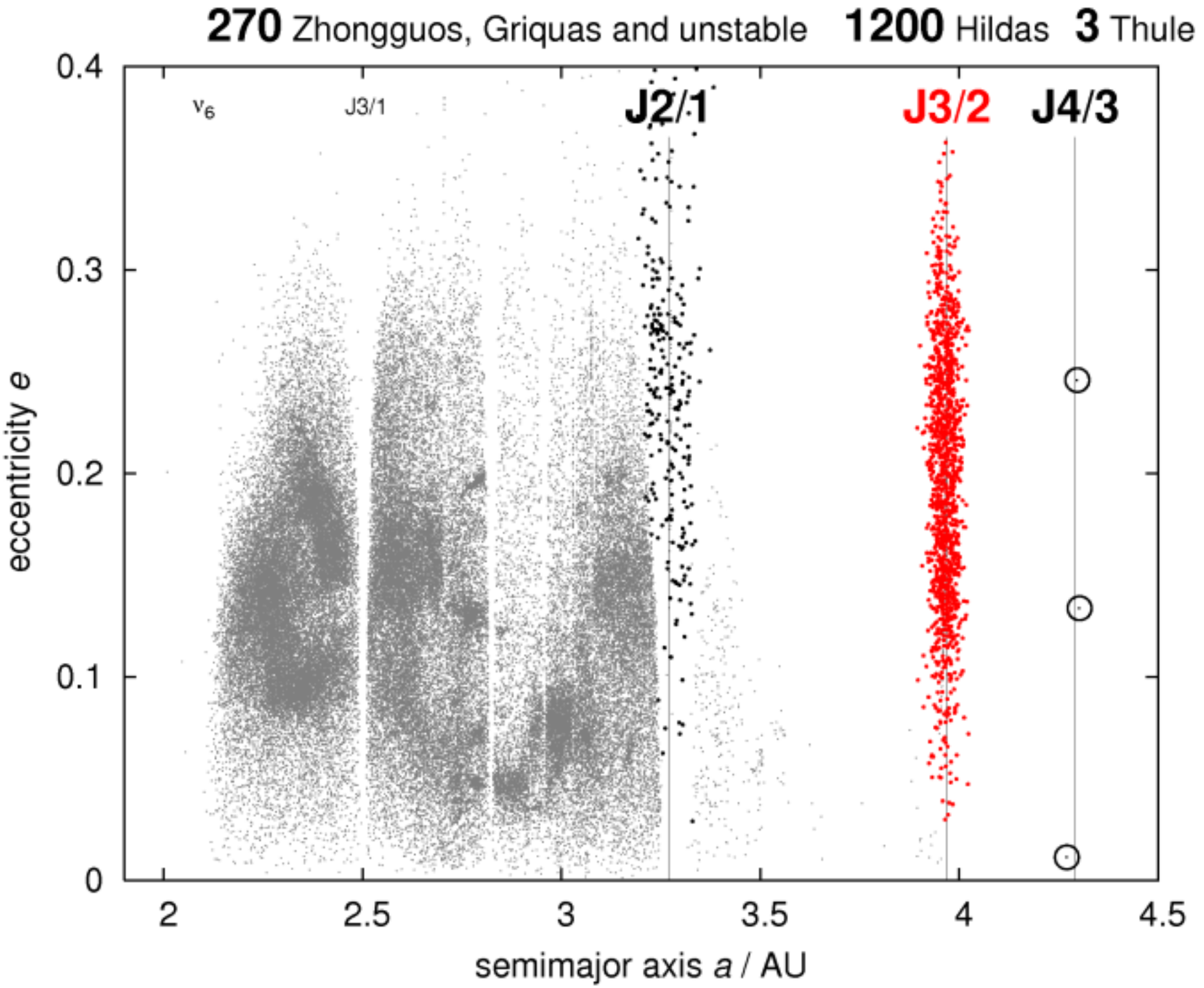
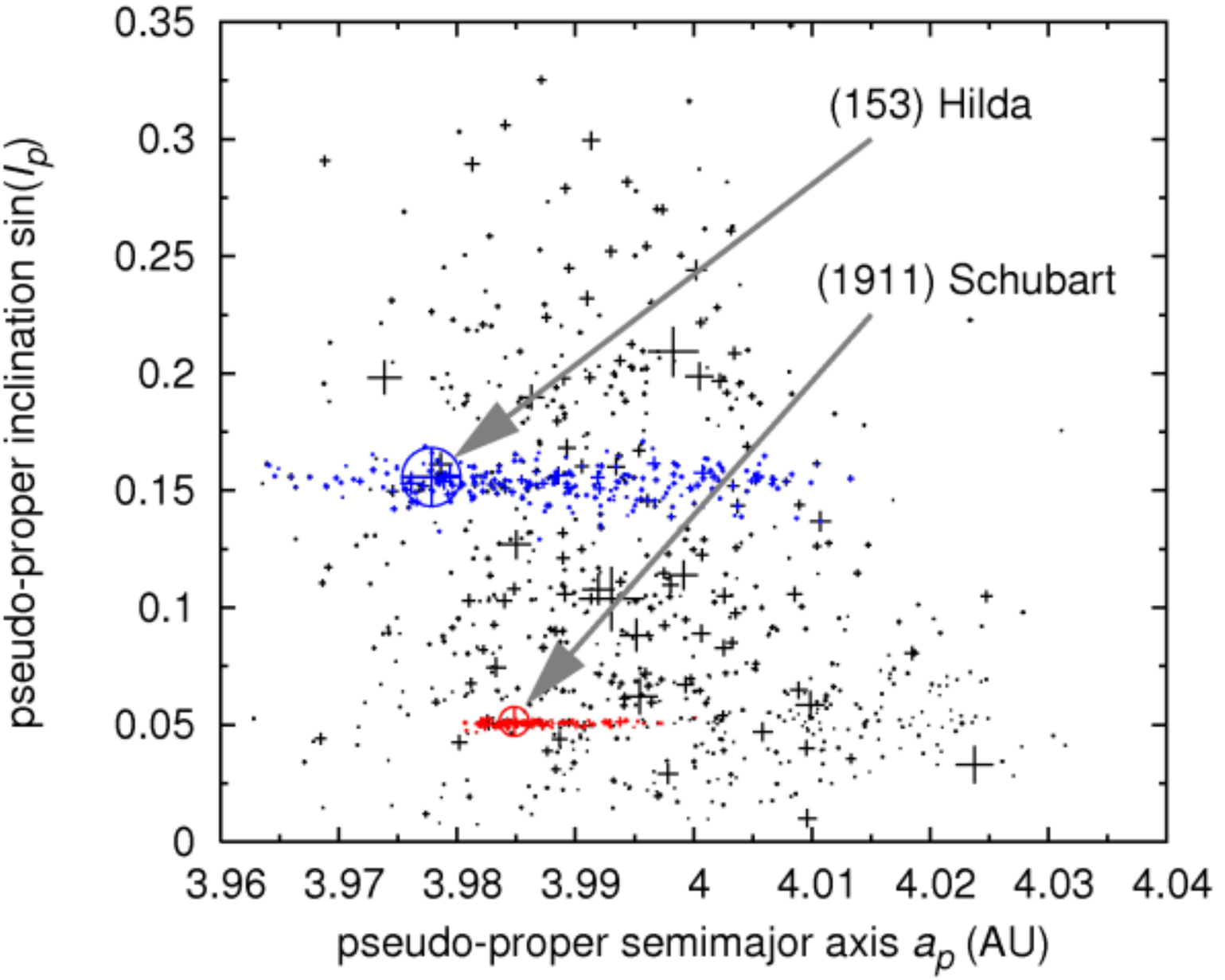
Update of resonant populations (Aug 2007):

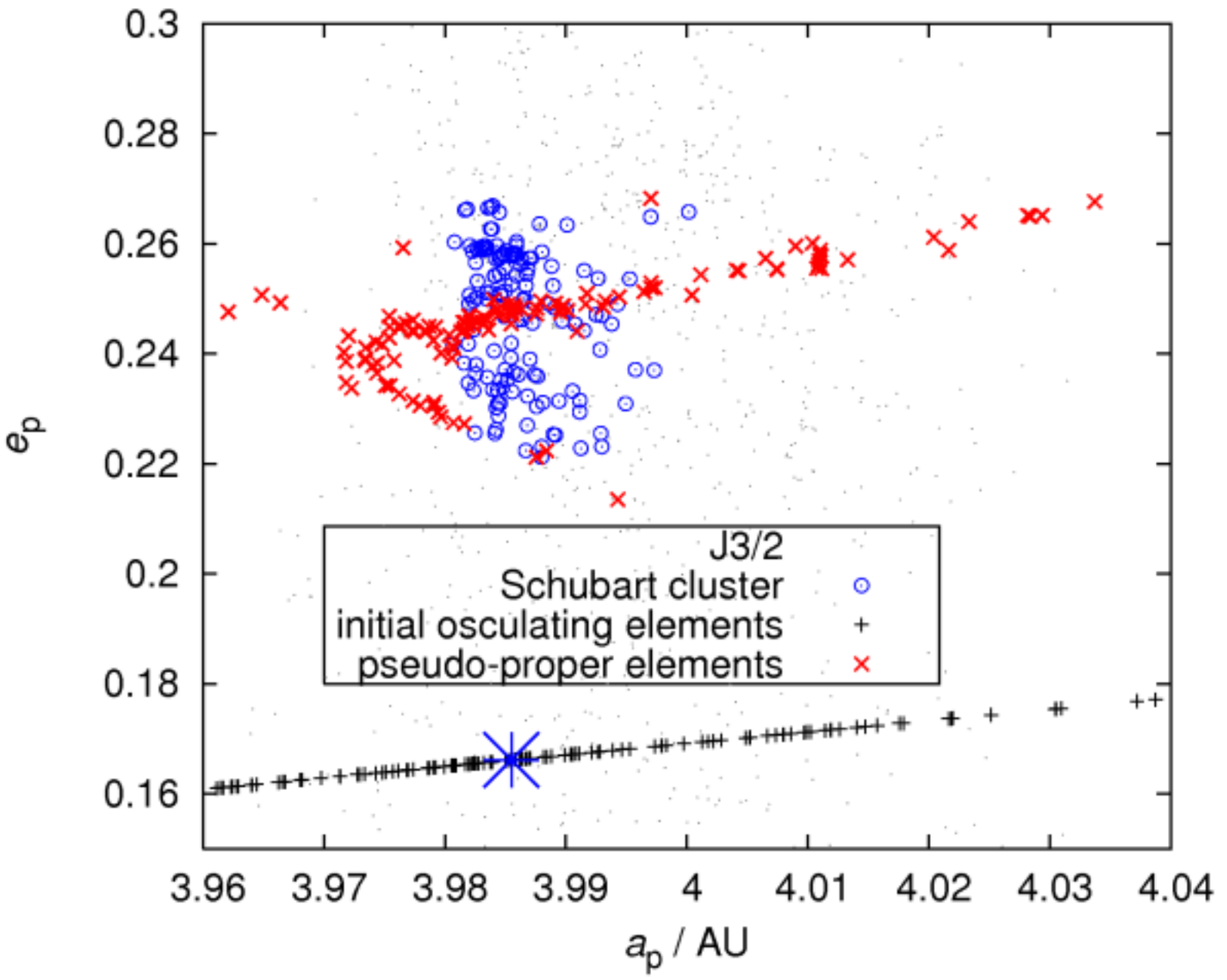


J3/2 — pseudo-proper elements:



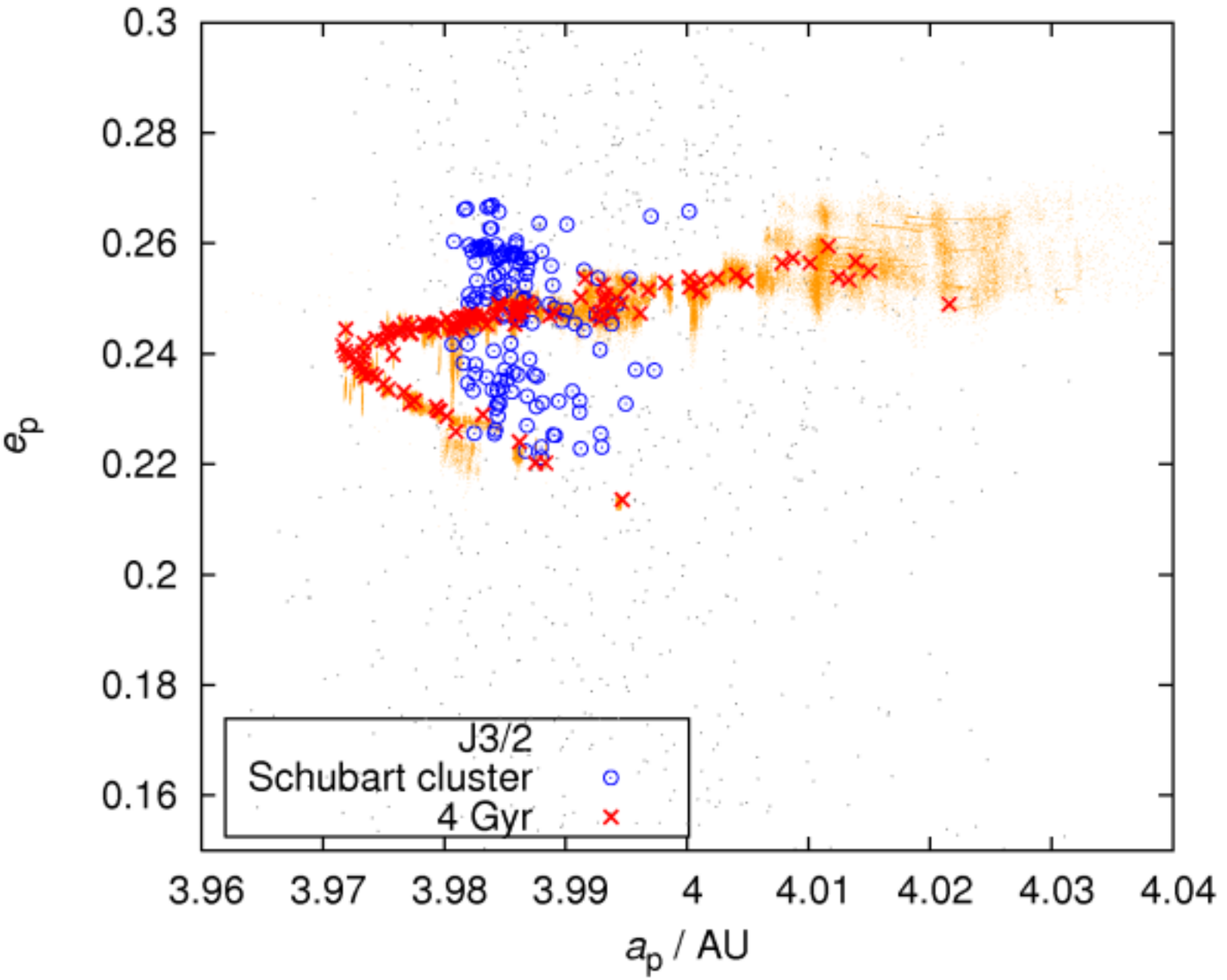
- a distinct collisional Schubart family (Schubart 1991); $v_{\rm cutoff} \simeq 60\,{\rm m/s}$, $\sim 100\,{\rm km}$ parent body, LF/PB $\simeq 0.25$, C/X-type members, SFD steeper than J3/2.
- Hilda family at higher inclinations; $\sim 200\,{\rm km}$ PB

Simulated impact in J3/2:



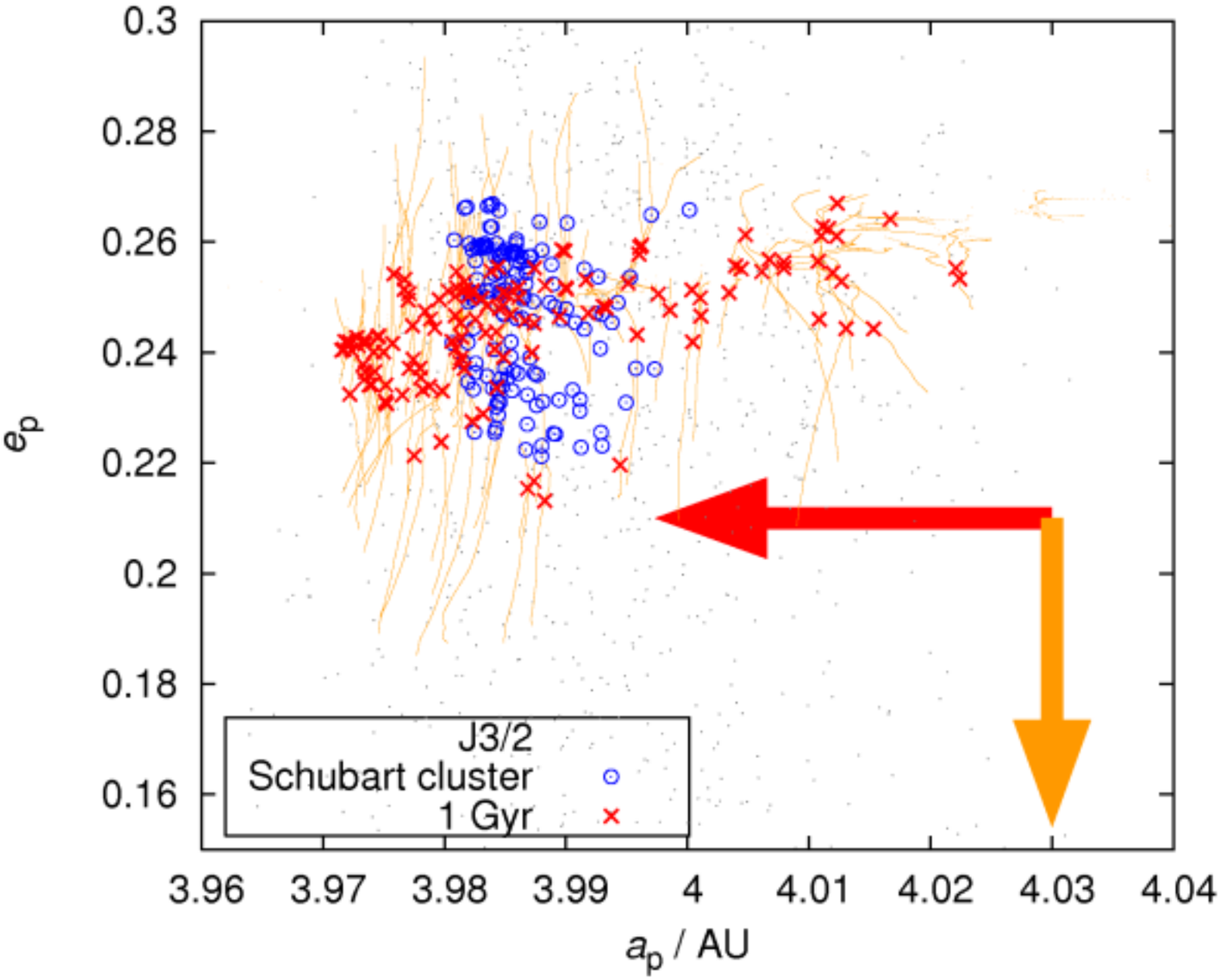
- a disruption of a 100 km PB; isotropic velocity field with $v_{\mathrm{mean}} = 50\,\mathrm{m/s}$, $f = 0$, $\omega + f = 180°$
- 'mapping' of the osculating elements into pseudo-proper

Impact in J3/2 — evolution over 4 Gyr:



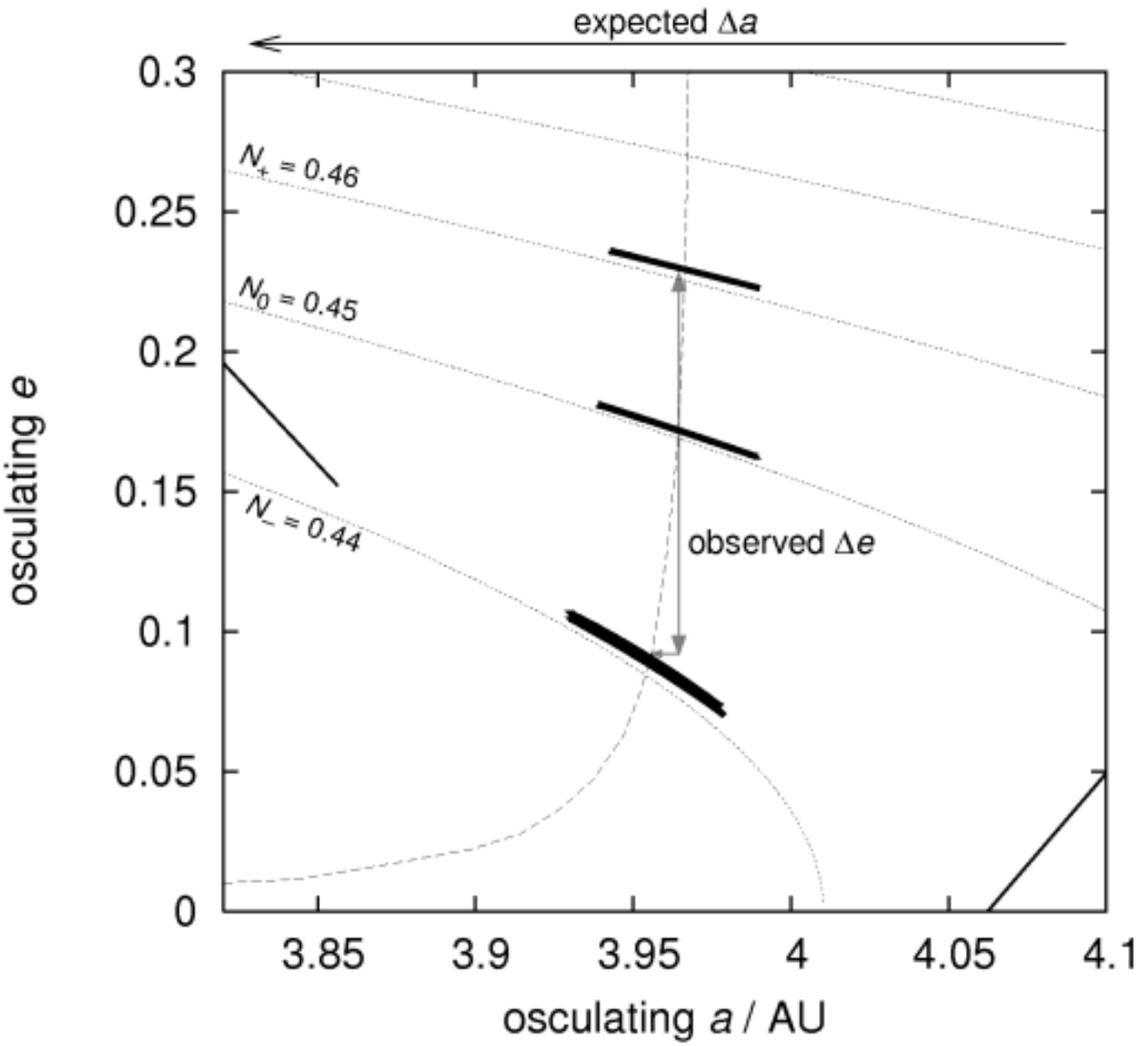
- N-body simulation, SWIFT integrator, 4 planets only
- the shape of the swarm is well preserved for 4 Gyr
- problem: observed Schubart family has larger spread in e

Impact in J3/2 — Yarkovsky effect:



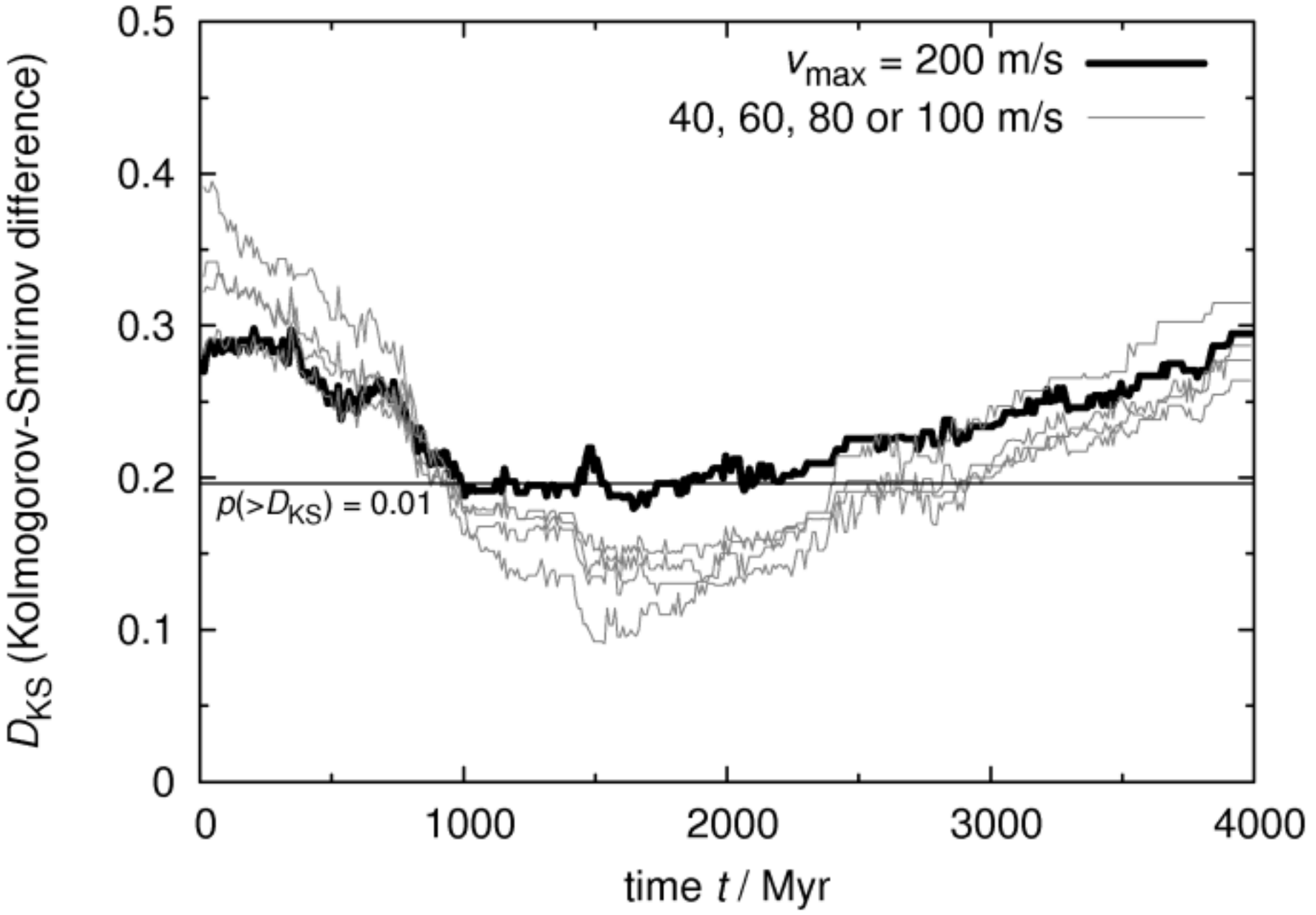
- the Yarkovsky induces the drift in eccentricity
  → different mechanism than for Main Belt families!

Yarkovsky drift in e (RTBP):



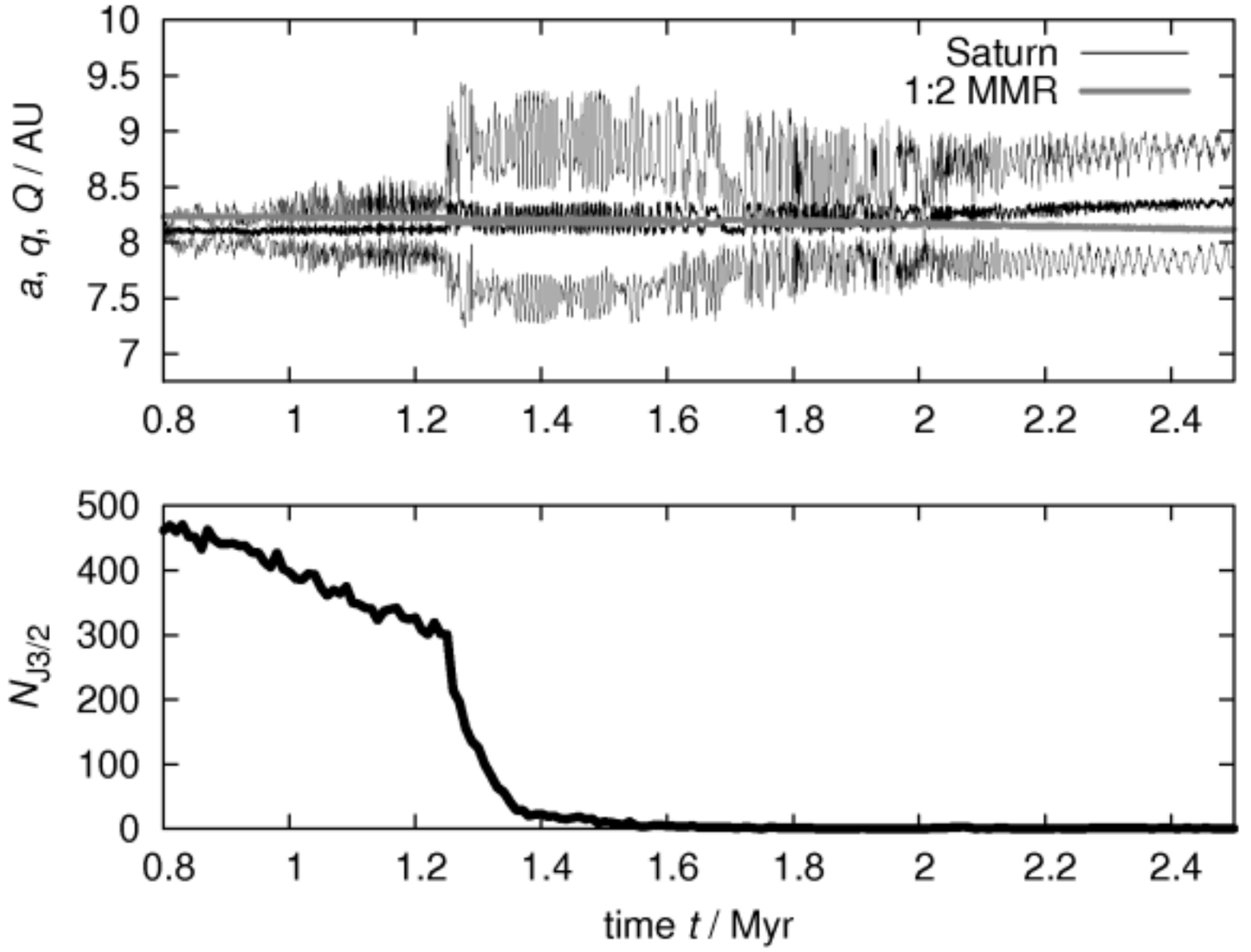
- object is locked in the libration centre, a is almost fixed
- adiabatic invariant $N = \sqrt{a}\left(\frac{p+1}{p} - \sqrt{1-e^2}\cos i\right)$ evolves linearly

Schubart and Hilda families — ages:



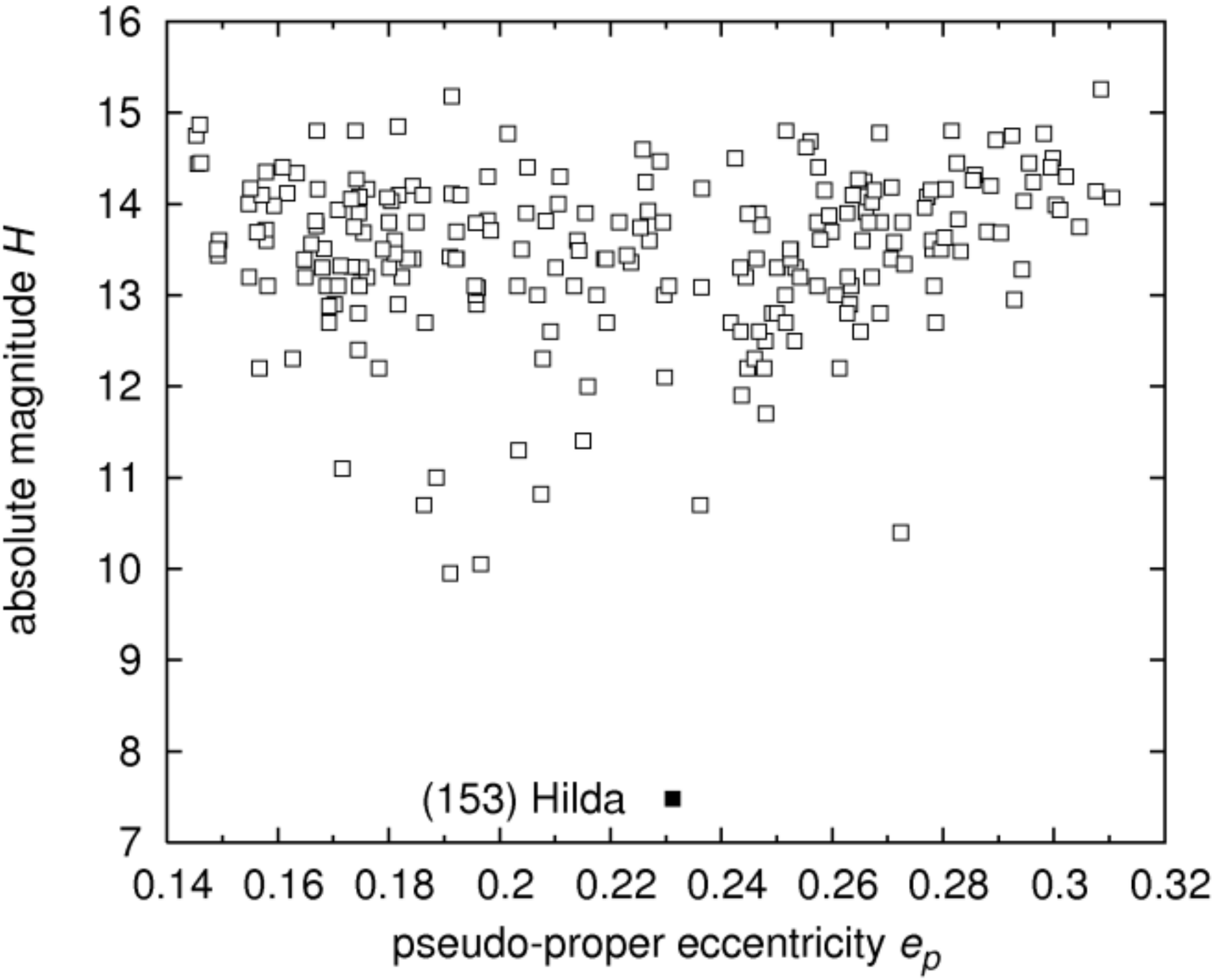
- K-S test of e-distributions for Schubart $\Rightarrow$ 1–2.5 Gyr old
- $\gtrsim 4$ Gyr for Hilda (LHB origin?)

Hildas vs 2:1 Jupiter–Saturn resonance:



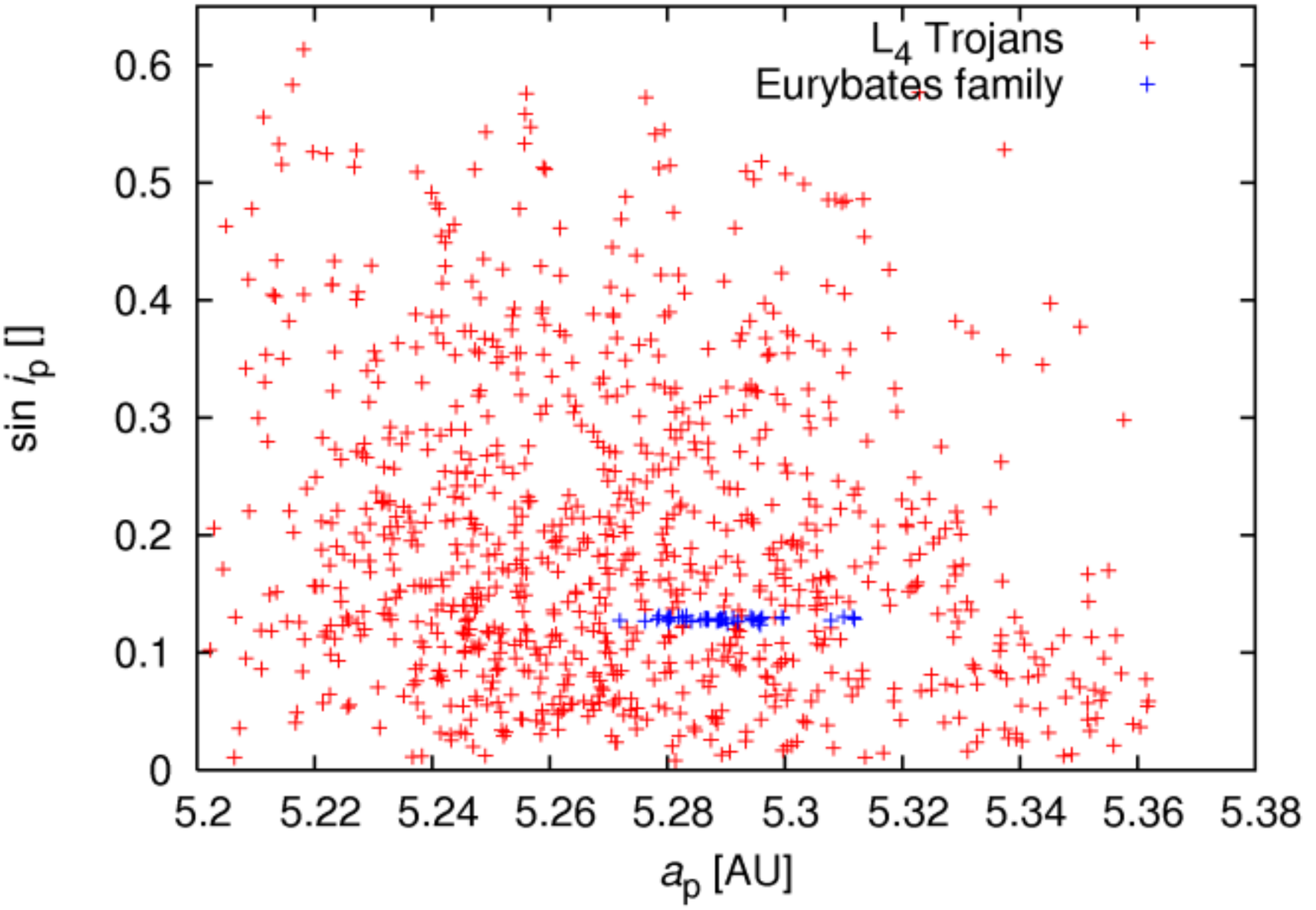
- J3/2 population is strongly unstable during 2:1 resonance crossing (Brož & Vokrouhlický 2008)
- all families have to be younger than the time of 2:1 (collisional probabilities might be higher early after 2:1)

Hilda family — (e, H) plot:



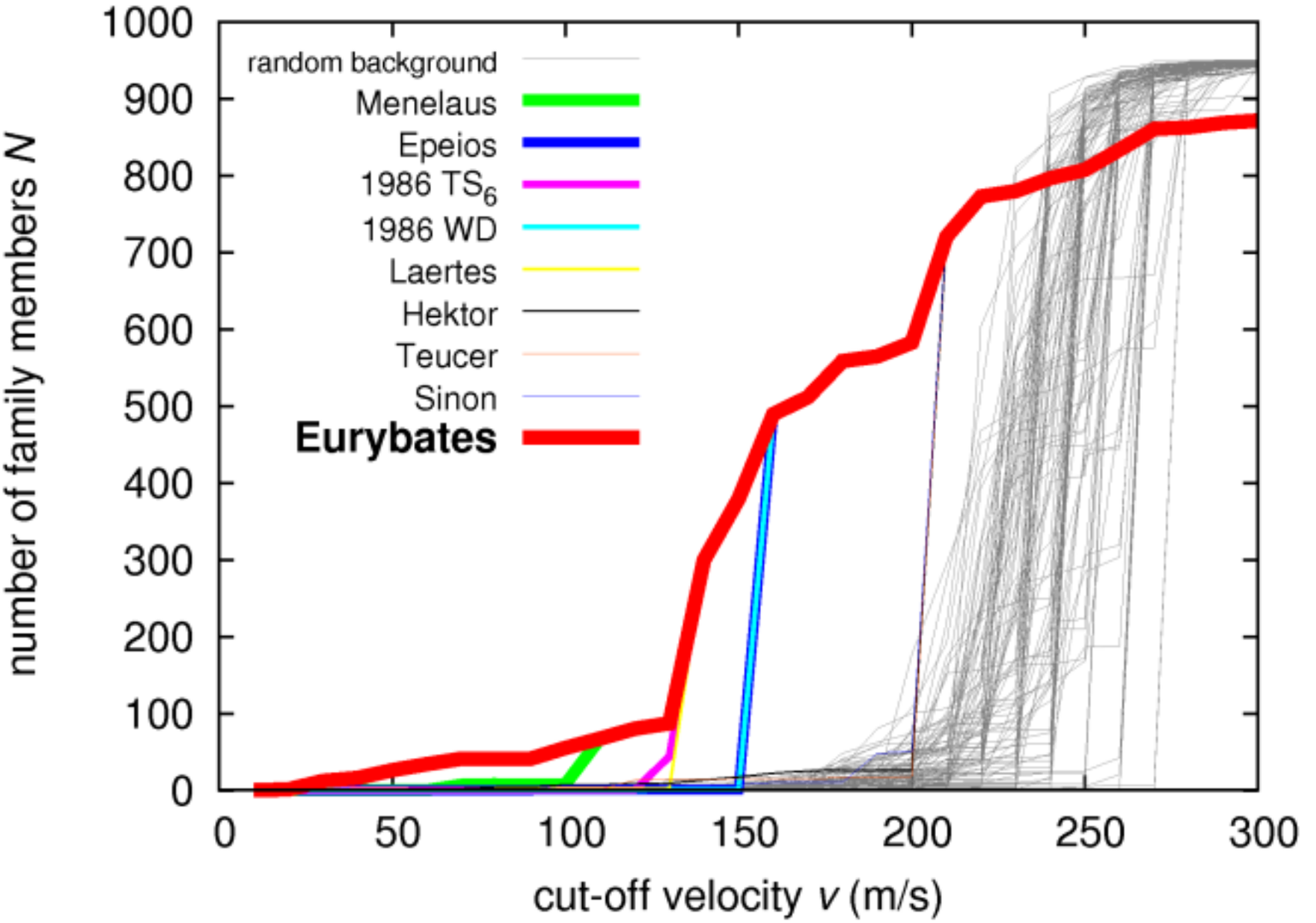
- 'ears' like in (a, H) for Eos, Erigone, Massalia, Merxia, . . .
- YORP effect changes spins ⇒ more precise age?

Trojans — how many families?:



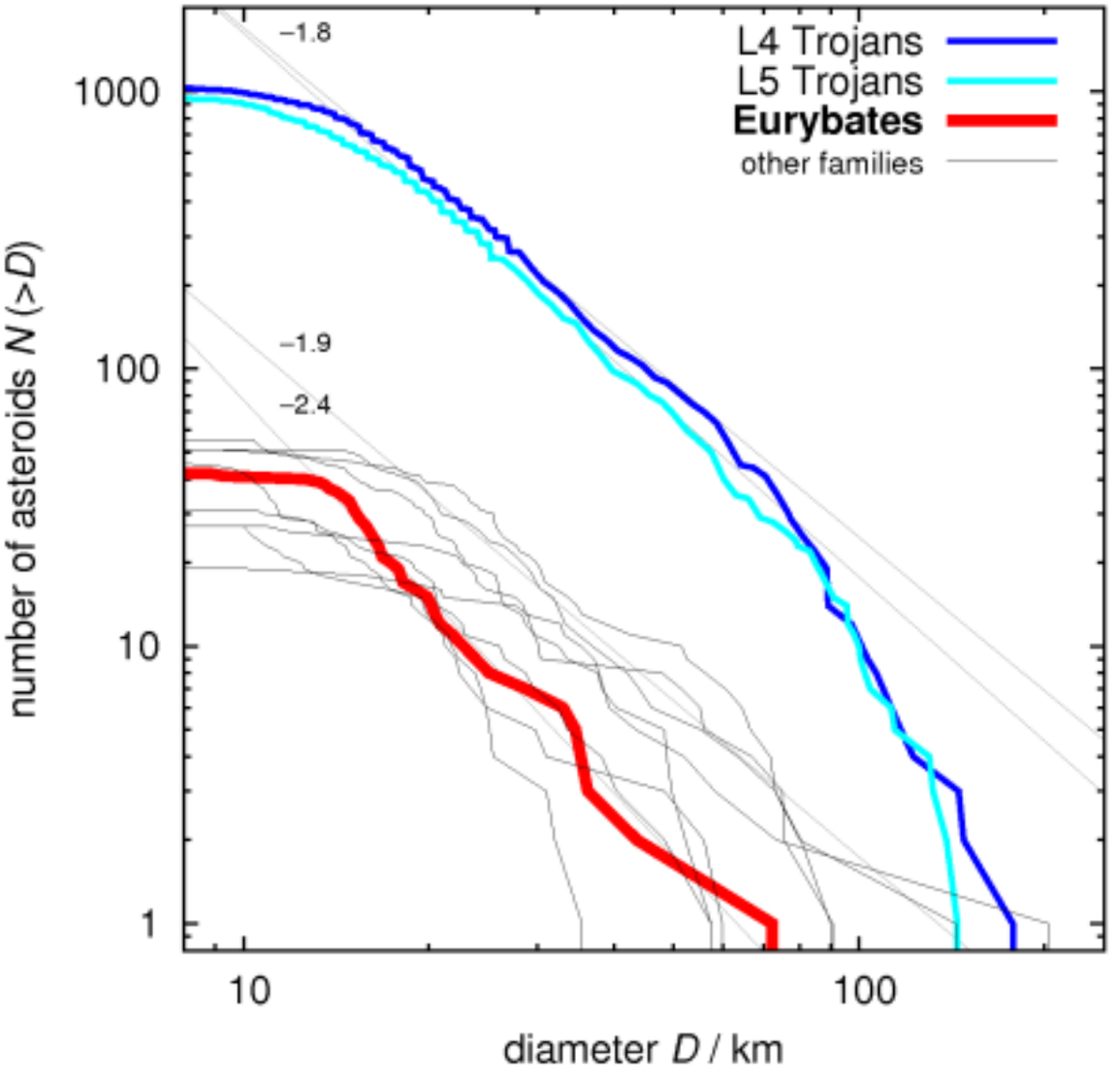
- $\sim$1000 bodies in each L_4 and L_5 cloud
- definitely not many prominent clusters. . .

Trojans — only 1 family in L4?:



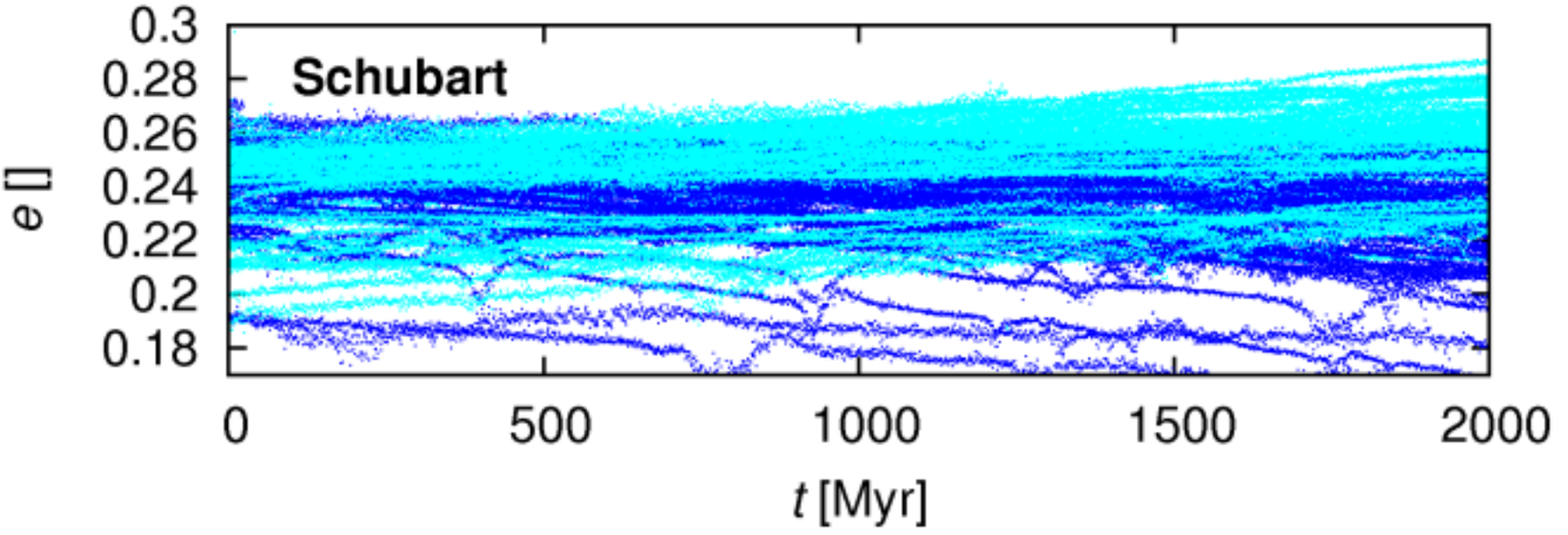
- $N(v_{\mathrm{cutoff}})$ plots compared with (random) background
- Eurybates family is the most robust case; it has only C-type members, no D-types (Roig *et al.* 2008)

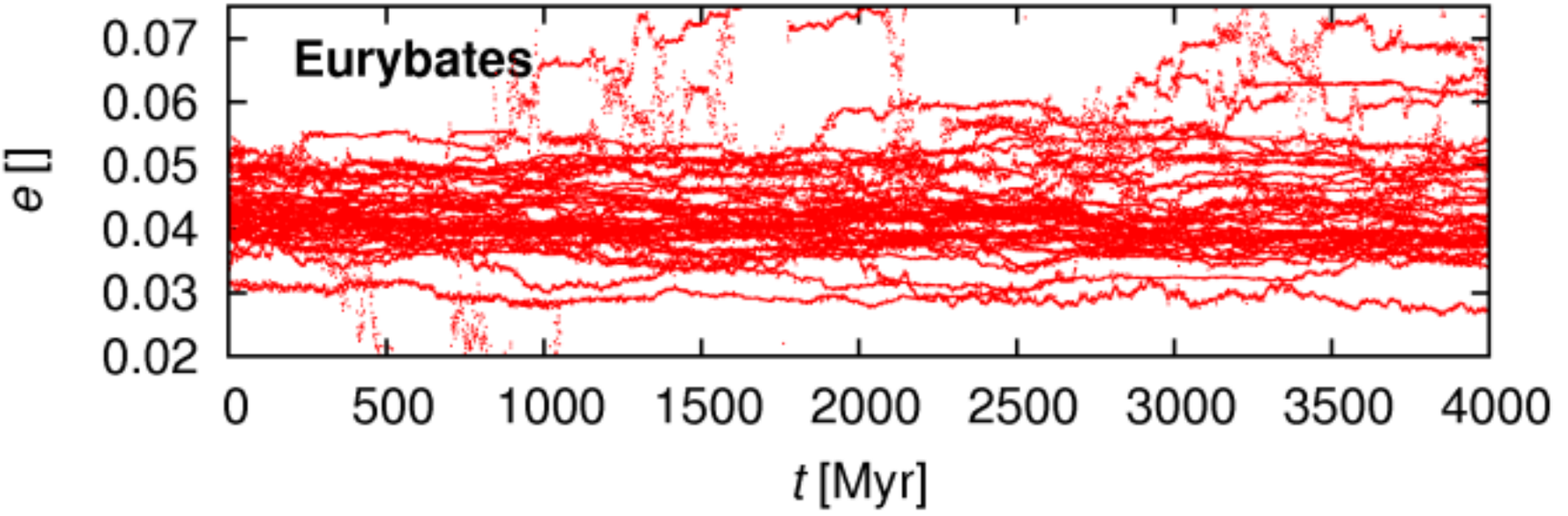
Eurybates family — SFD:



- only Eurybates has steeper SFD than the background
  $\Rightarrow$ consistent with collisional origin
- 1 collisional family among Trojans consistent with J3/2
  $\Leftarrow$ mean collisional probabilities are comparable:
  16 and 11 $\times 10^{-18}\,\mathrm{km}^{-2}\,\mathrm{yr}^{-1}$ (Dahlgren 1998)

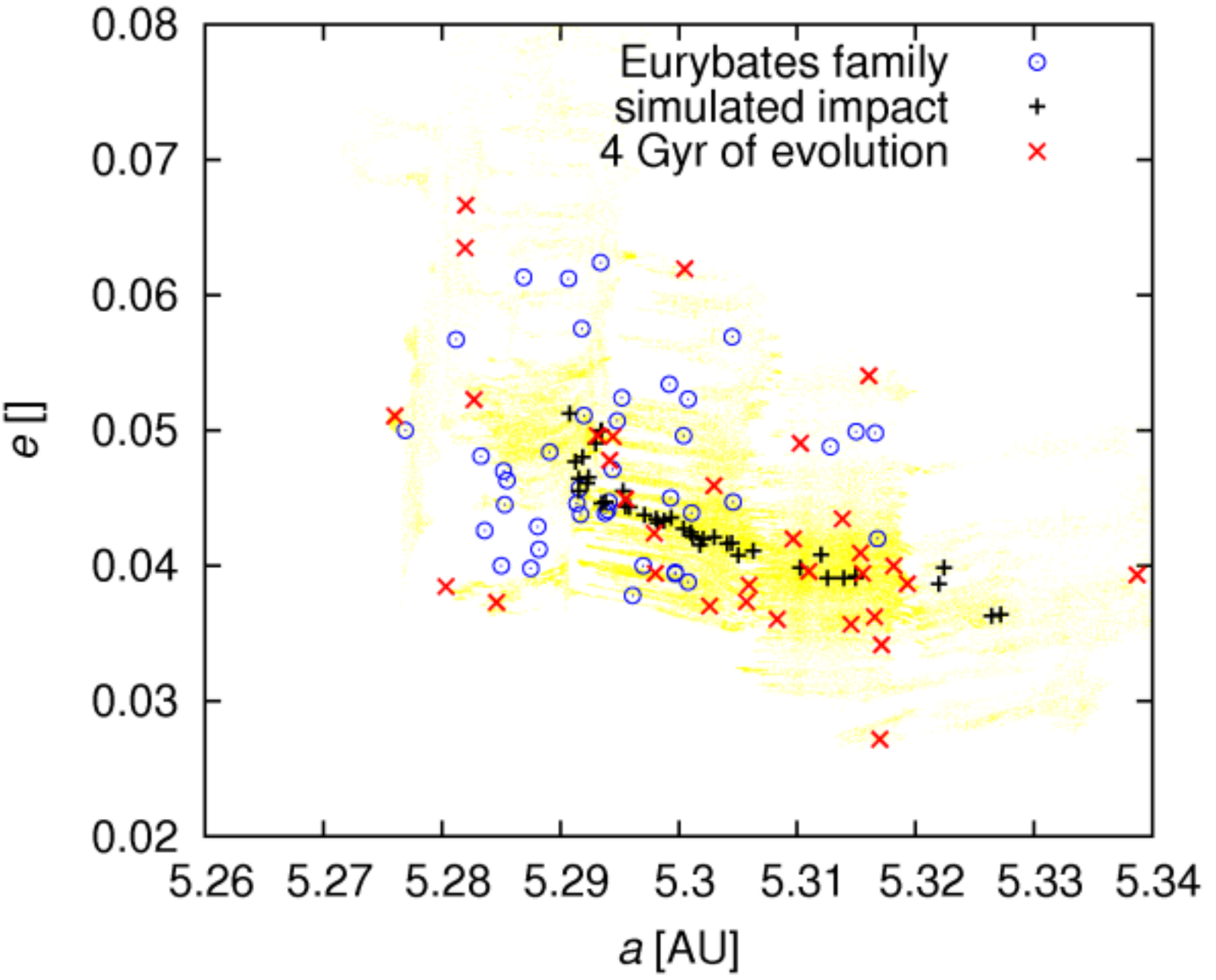
Eurybates family — no Yarkovsky effect:





- evolution with/without Yarkovsky effect is the same (even for strenghten thermal forces)
- different dynamics in 0th order resonance
  $\Rightarrow$ no systematic drift in e, no precise age

Eurybates family — chaotic diffusion:



- present shape was attained due to the chaotic diffusion
- age might be 1–4 Gyr ('filament' must disappear)

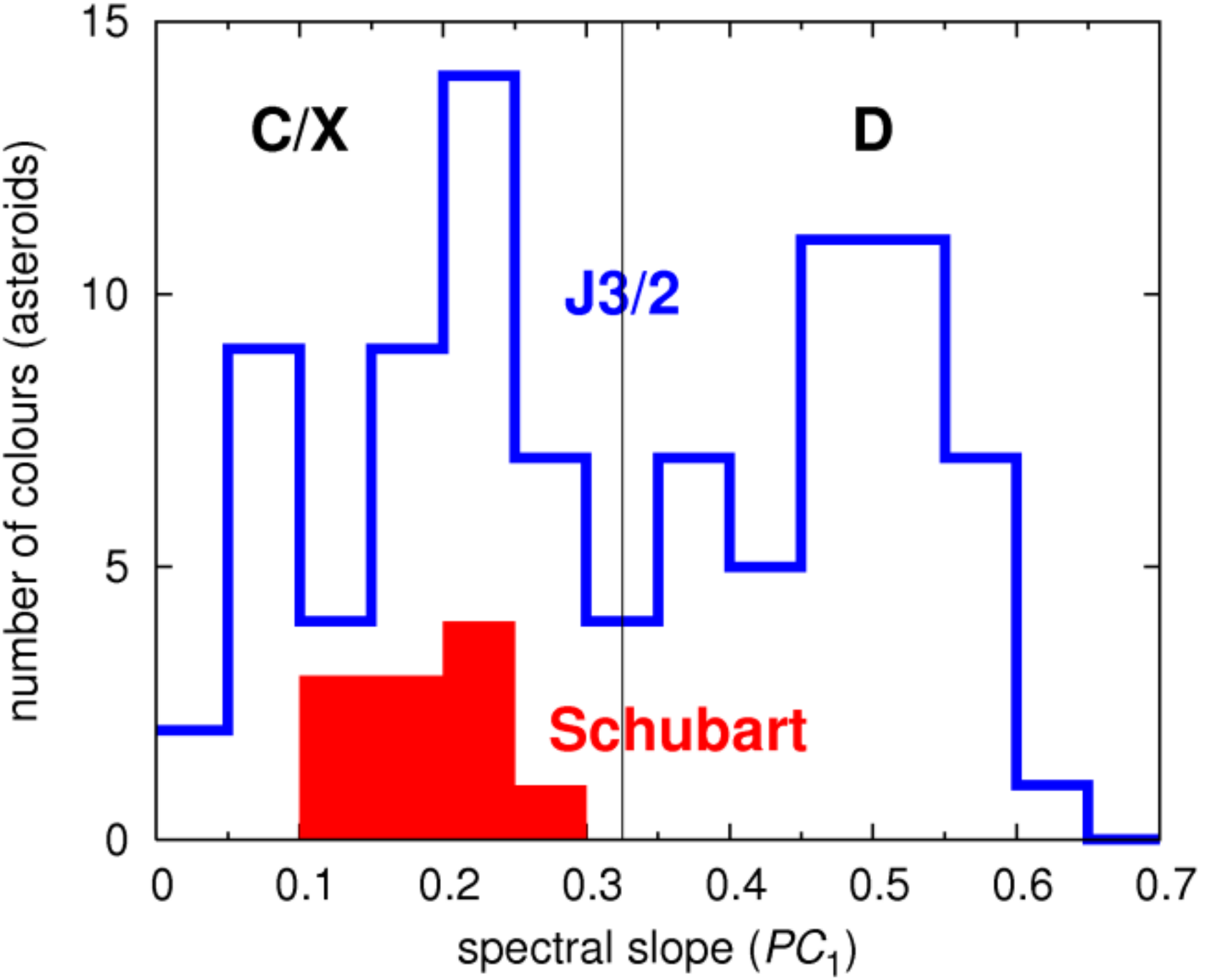
Conclusions:

- resonant Yarkovsky effect operates
- two collisional families in the J3/2 resonance (probably old, shallower SFD — different from MB)
- one collisional family among Trojans

Future work:

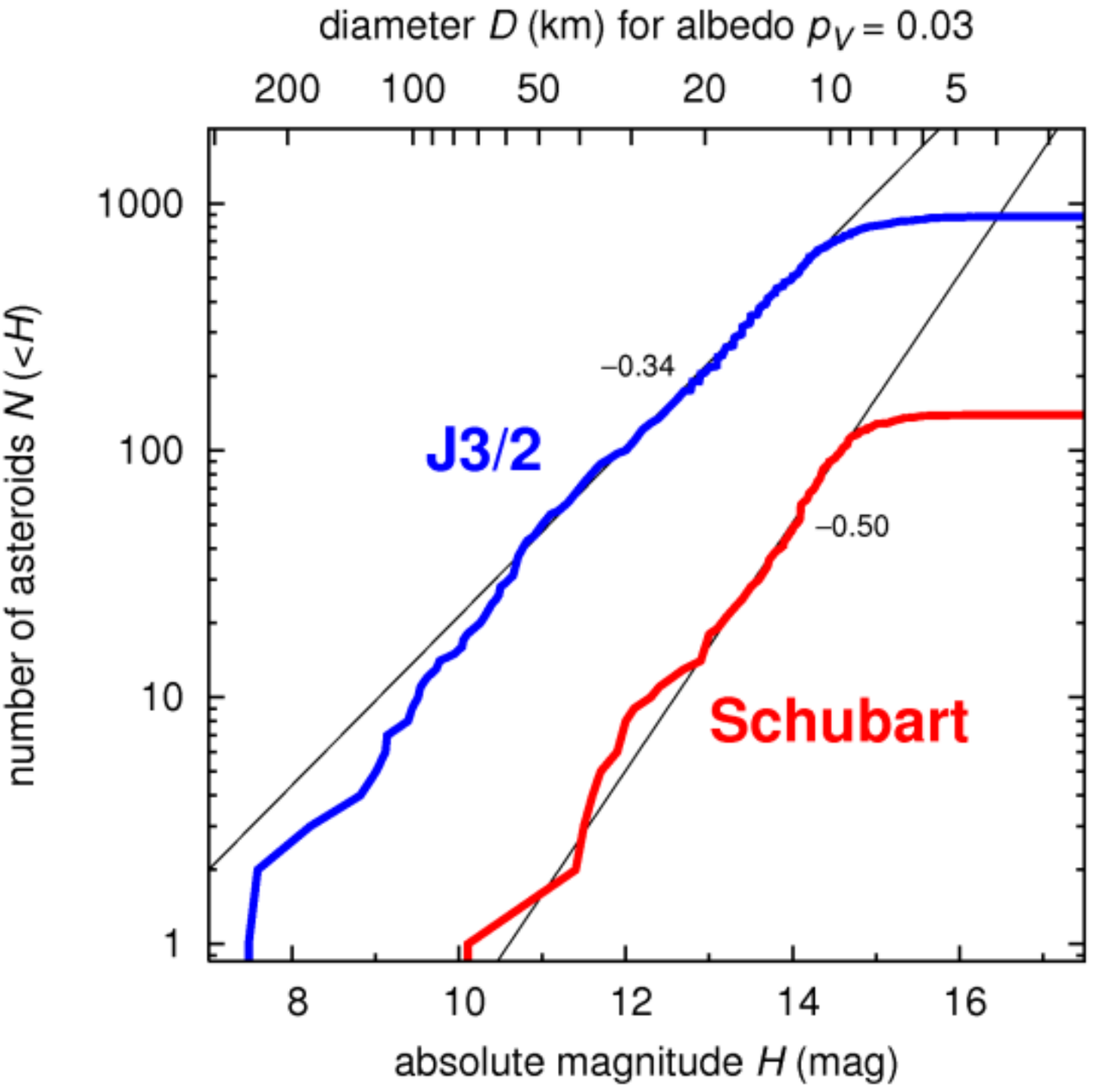
- (e, H) method $\Rightarrow$ more precise ages of resonant families
- stability of resonant families during planetary migration
- repopulation efficiency from the planetesimal disc

Schubart family — colours:



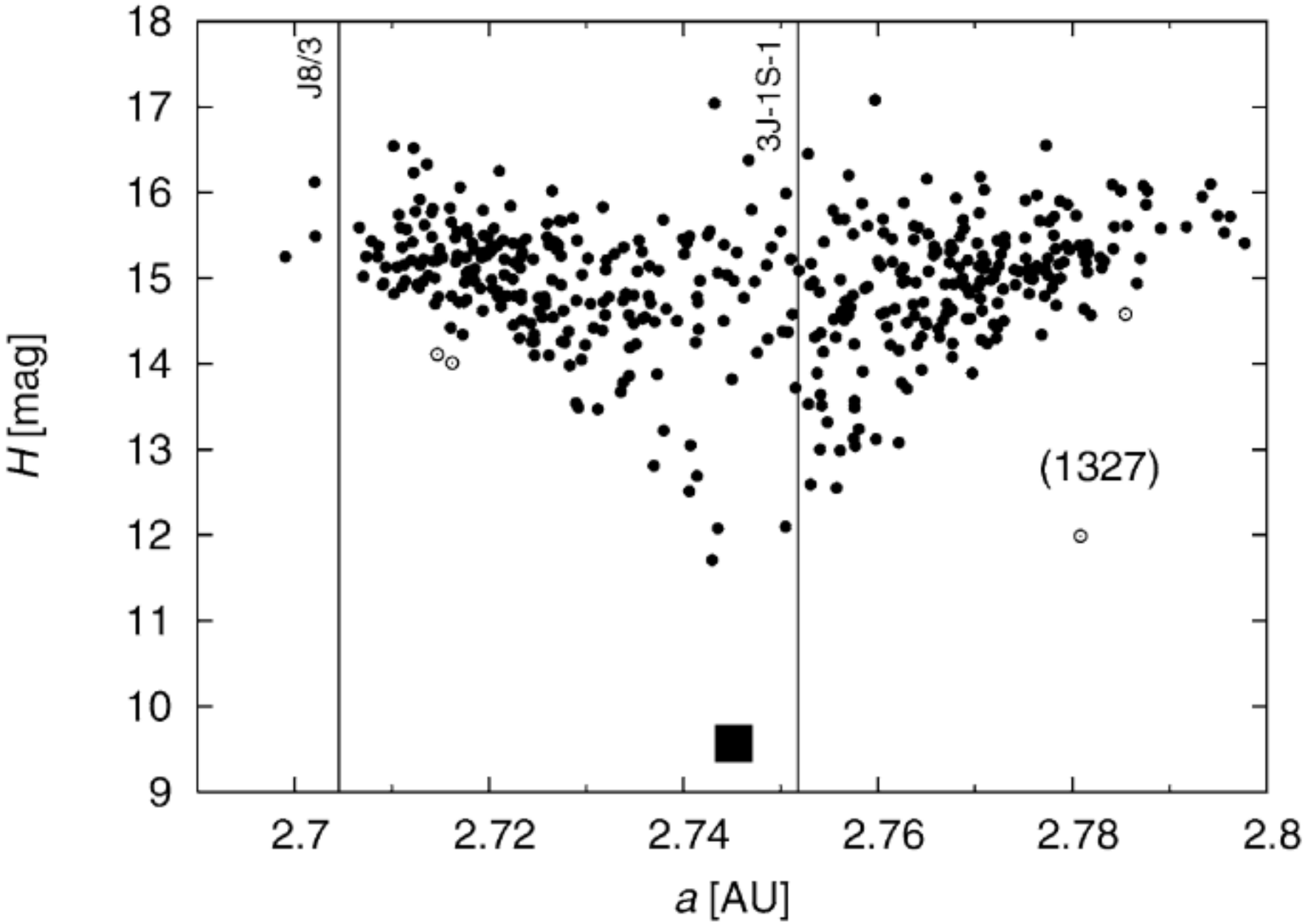
- SLOAN colours of J3/2 bimodal (C/X- and D-types)
- Schubart cluster only C/X-type ⇒ collisional origin

Schubart family — SFD:

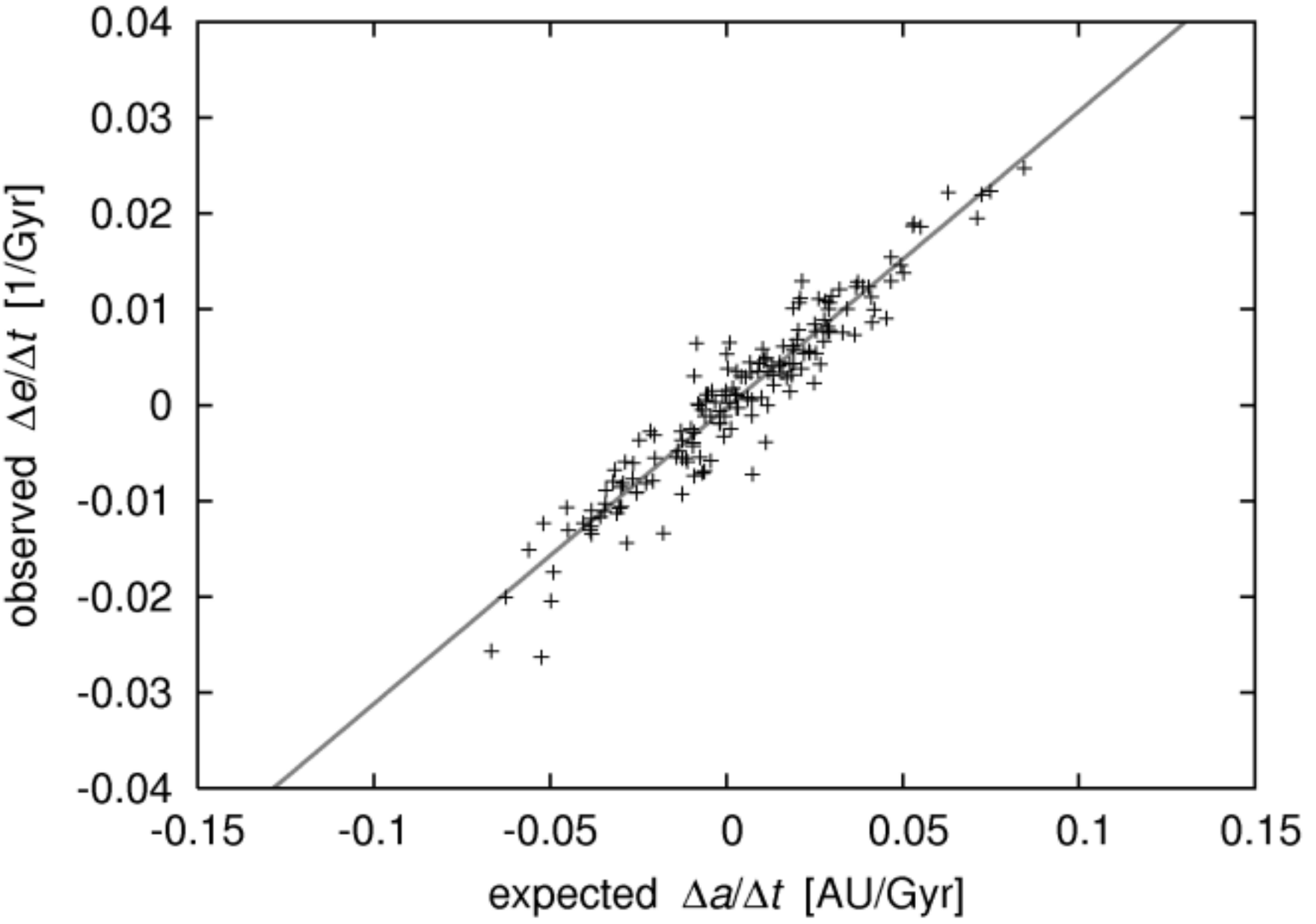


- Schubart family significantly steeper than the rest of J3/2 ⇒ collisional origin (but not as steep as MB families)

A comparison with Merxia family (a, H):



Hilda — expected Δa vs observed Δe:



- linear dependence $\Rightarrow$ the same code as for (a, H)