Resonant Asteroid Families
a Wealthy Source of Information on Planetary Migration

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Table of contents:
(PART 1) asteroid families in the J3/2 resonance
(PART 2) resonant Yarkovsky effect, age determination
(PART 3) are there any Trojan families?
Resonant populations:

- families in J3/2 and J1/1, no families in J2/1, J4/3
- motivation: migration of Jupiter, collisional models
J3/2 — pseudo-proper elements:

- a distinct collisional Schubart family (Schubart 1991); \( v_{\text{cutoff}} \approx 60 \text{ m/s, } \sim 100 \text{ km parent body, } \text{LF/PB} \approx 0.25, \) C/X-type members, SFD steeper than J3/2.

- Hilda family at higher inclinations; \( \sim 200 \text{ km PB} \)
Simulated impact in J3/2:

- a disruption of a 100 km PB; isotropic velocity field with $v_{\text{mean}} = 50 \text{ m/s}$, $f = 0$, $\omega + f = 180^\circ$
- '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:

- usually, YE causes a drift in semimajor axis, but...
- Yarkovsky effect and resonant lock combined
  $\Rightarrow$ systematic drift in eccentricity
Schubart family — age:

- K-S test of e-distributions for Schubart $\Rightarrow$ 1–2.5 Gyr old
- $\gtrsim$ 4 Gyr for Hilda (LHB origin?)
Hilda vs 2:1 Jupiter–Saturn resonance:

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

- $\sim1000$ bodies in each $L_4$ and $L_5$ cloud
- definitely not many prominent clusters...
Trojans — only 1 family in L4?

- $N(v_{\text{cutoff}})$ 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
- 1 collisional family among Trojans consistent with J3/2 \( \leftrightarrow \) disruption of a 100 km parent body is a rare event \( \approx 1 \) per 4 Gyr (Dahlgren 1998)
Eurybates family — no Yarkovsky effect:

- evolution with/without Yarkovsky effect is the same
- different dynamics in 0\textsuperscript{th} order resonance
  \(\Rightarrow\) no systematic drift in \(e\), only chaotic diffusion
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 (in 1st order resonances)
- two collisional families in the J3/2 resonance (probably old, shallower SFD ← different from MB)
- one collisional family among Trojans

Future work:

- \((e, H)\) plot with a signature of the YORP effect \(\Rightarrow\) more precise ages of resonant families?
- stability of resonant families during planetary migration
- repopulation efficiency from the main belt
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)
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
Hilda family — \((e, H)\) plot:

- ‘ears’ like in \((a, H)\) for Eos, Erigone, Massalia, Merxia, …
- YORP effect changes spins \(\Rightarrow\) more precise age?
A comparison with Merxia family \((a, H)\):
Hilda — expected $\Delta a$ vs observed $\Delta e$:

- linear dependence $\Rightarrow$ the same code as for $(a, H)$
Trojans — is clustering in L5 real?

- e.g., the proposed Aneas family is essentially a middle portion of the cloud, not a distinct grouping; it contains more D- than C-types (Roig et al. 2008), but this can be due to the overall inclination-taxonomy dependence