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Evolution of Yarkovsky-driven Orbits of Meteoroids

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Numerical integrations:

- **150 Myr** numerical integration of **1500** asteroid fragments
- symplectic integrator SWIFT_RMVS3, time step = 36 days
- gravitational forces, Yarkovsky effect, simple collisional dynamics
- output: mean elements (432 yr) $\sim$ 1 GB of data per 100 particles

Initial conditions:

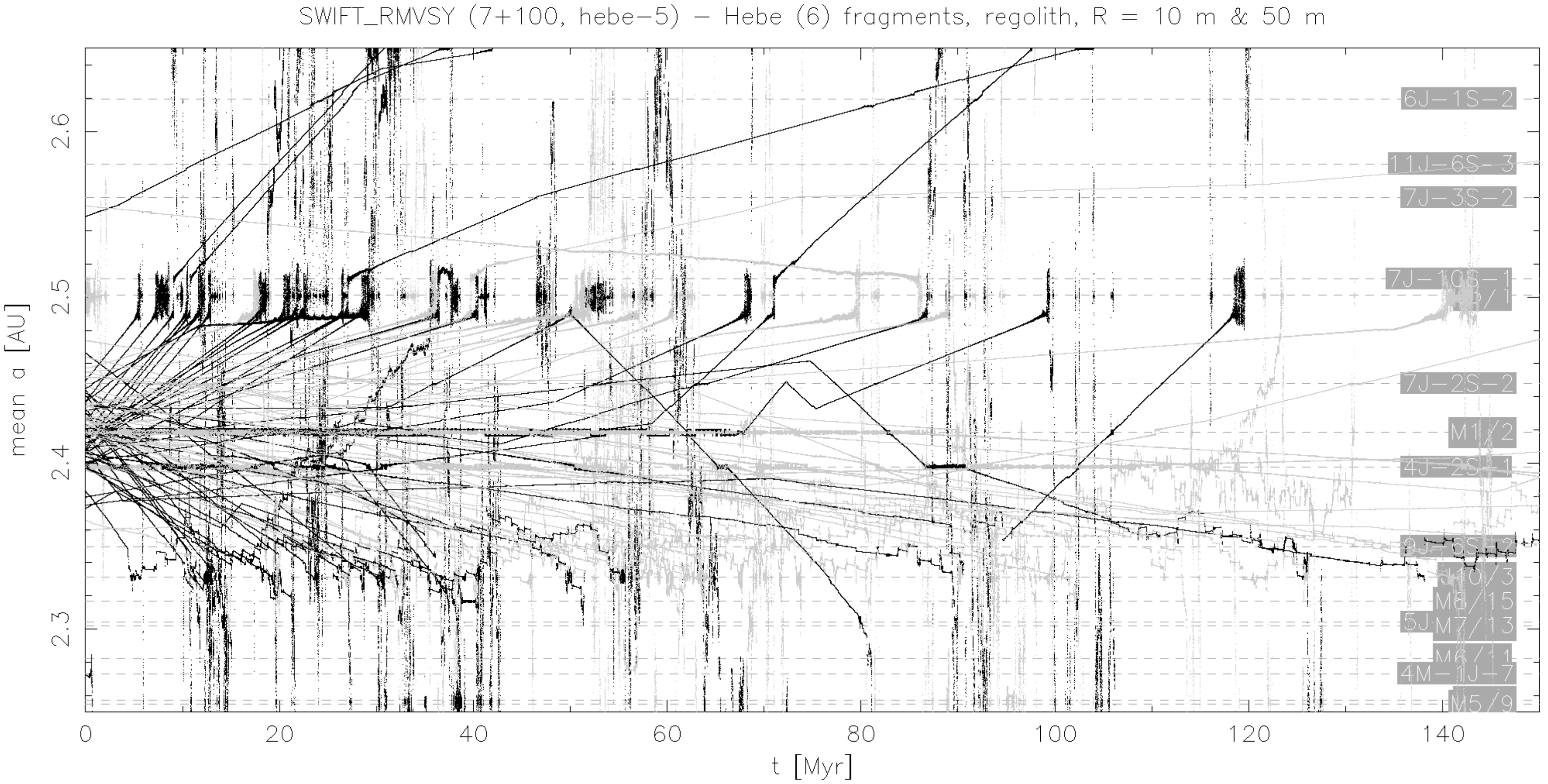
- 7 planets (excluding Mercury and Pluto), DE 405 ephemeris
- parent asteroids: (8) **Flora**, (6) **Hebe**, (170) **Maria**
- five different sizes: R = 1 m, 10 m, 50 m, 100 m and 500 m
- isotropic power-law velocity distribution
- surface conductivity: K = 0.0015 W/m/K and K = 2.65 W/m/K

Data analysis:

- temporal decay of the main–belt population
- 3:1 crossing probability for different meteoroids' sizes
- ν_6 vs. pre-ν_6 extraction from the main belt
- interaction with higher–order, mixed mean motion, secular resonances

Small, regolith covered meteoroids with high drift–rate

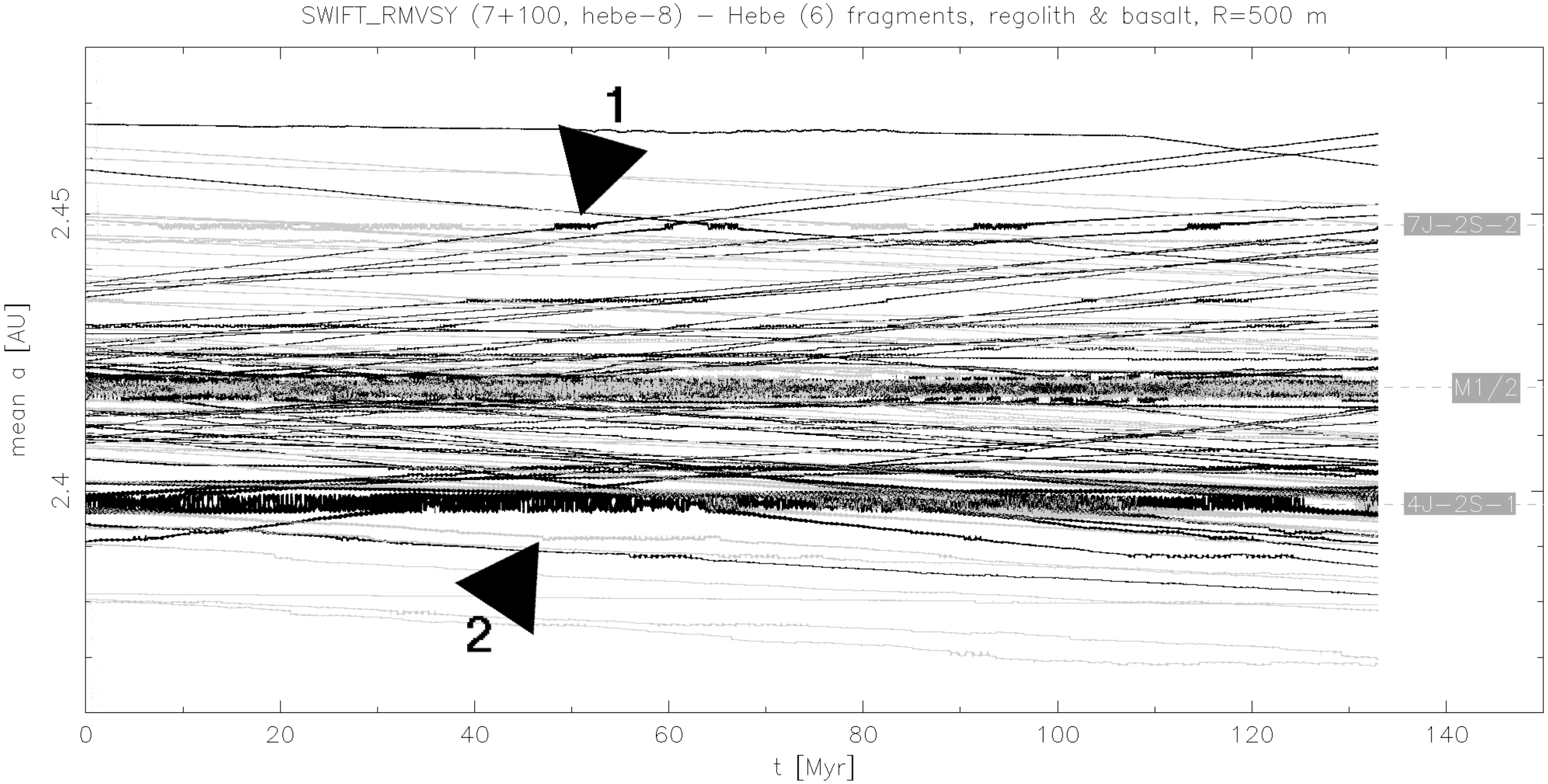
- “100” ejecta/fragments isotropically released from (6) **Hebe**
- low-conductivity surfaces assumed (“diurnal Yarkovsky effect dominates”)
- “50” fragments R = 10 m (**dark**) and “50” fragments R = 50 m (**light**)



1 km large, slowly drifting fragments

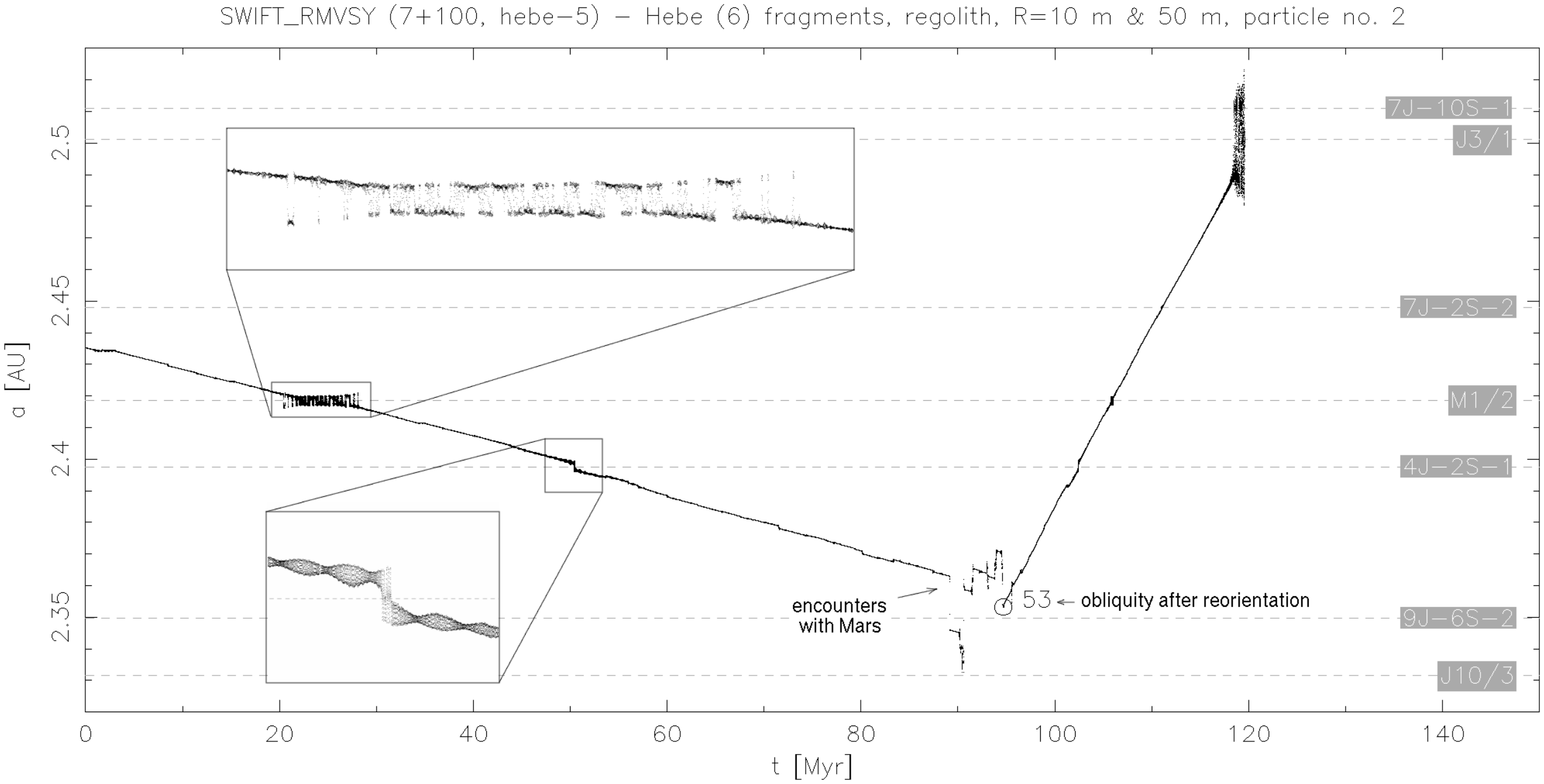
- “100” ejecta/fragments isotropically released from (6) **Hebe**
- all fragments **R = 500 m**
- “50” fragments K = 0.0015 W/m/K (**dark**) and “50” fragments K = 2.65 W/m/K (**light**)
- **slow drift rate**, particles do not reach 3:1 or ν_6 resonance within 150 Myr

(1) observable captures in 7J − 2S − 2 resonance, which do not affect drift rate
(2) captures in unidentified resonances, decrasing drift rate by $\sim$ 10 %



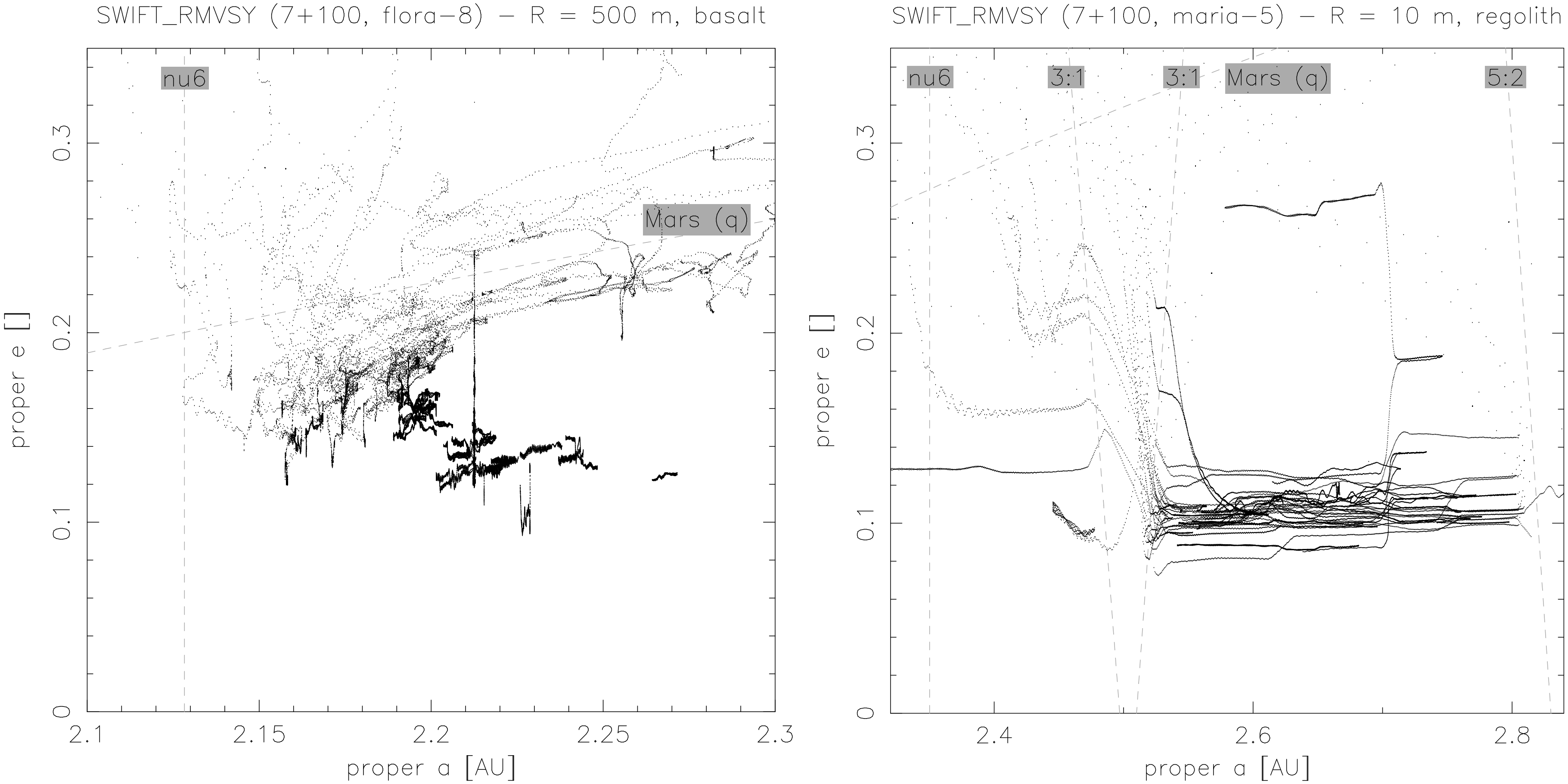
Orbital evolution of a fast drifting particle — capture and "jump" events

- **Hebe** fragment, R = 10 m, regolith covered
- The capture by the M1/2 resonance spans the same time as a drift through this region.
- The "jump" over the 4J − 2S − 1 resonance yields a higher effective drift rate.



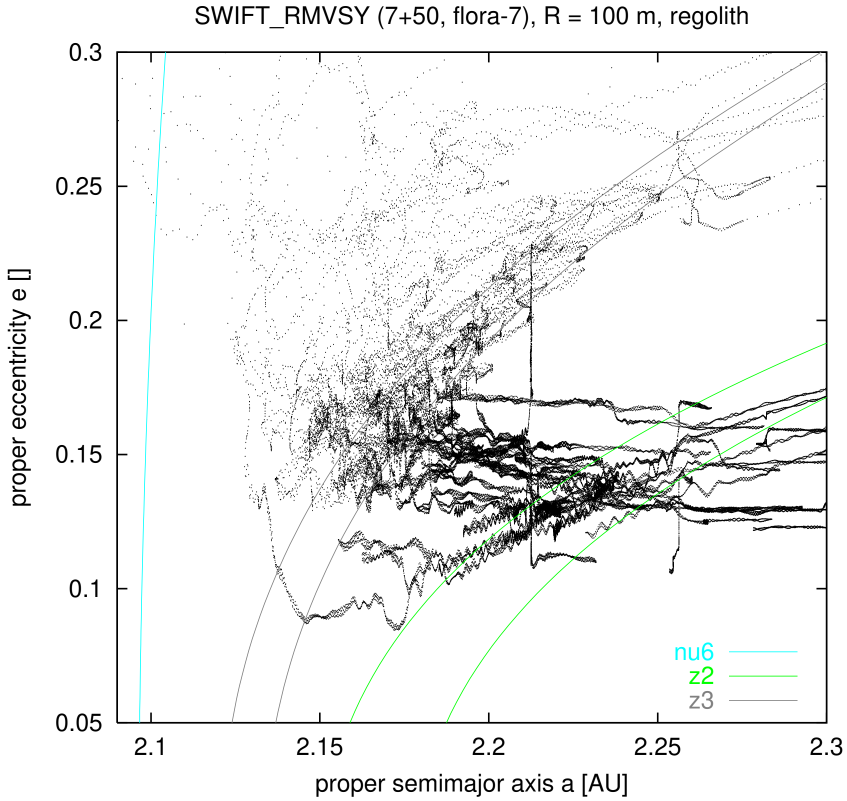
Inner and middle belt — comparsion of slow and fast TPs

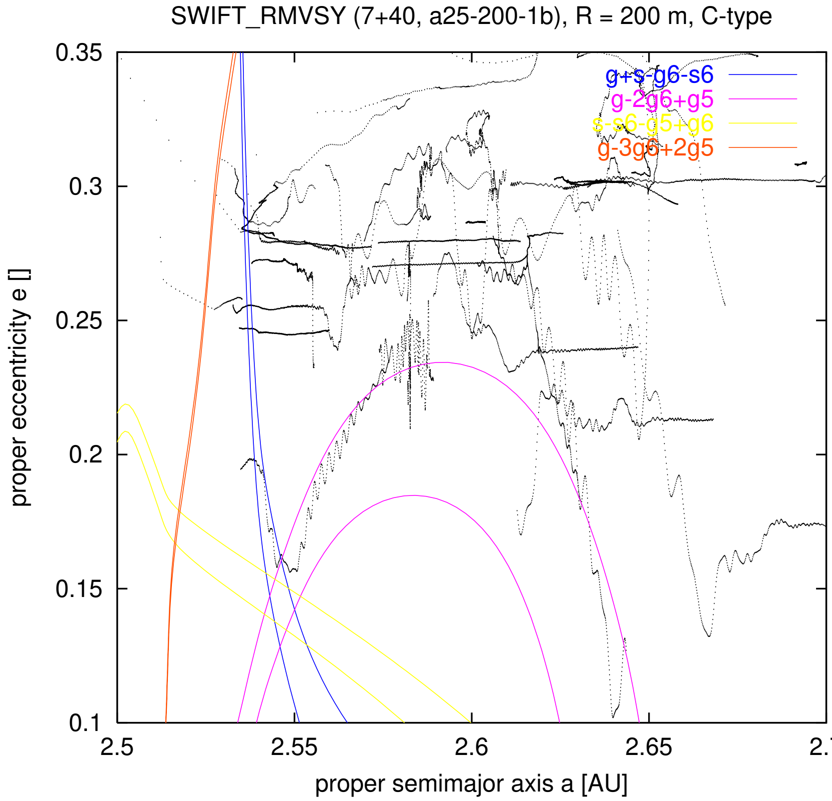
- (8) **Flora** fragments, R = 500 m, high conductivity — slow drift in a, **chaotic diffusion** in e and i
- meteoroids released from (170) **Maria**, R = 10 m, low conductivity — fast drift rate, depletion through 3:1, 5:2 and 8:3 resonances, $\sim$ 10 % of TPs crossed 3:1 resonance



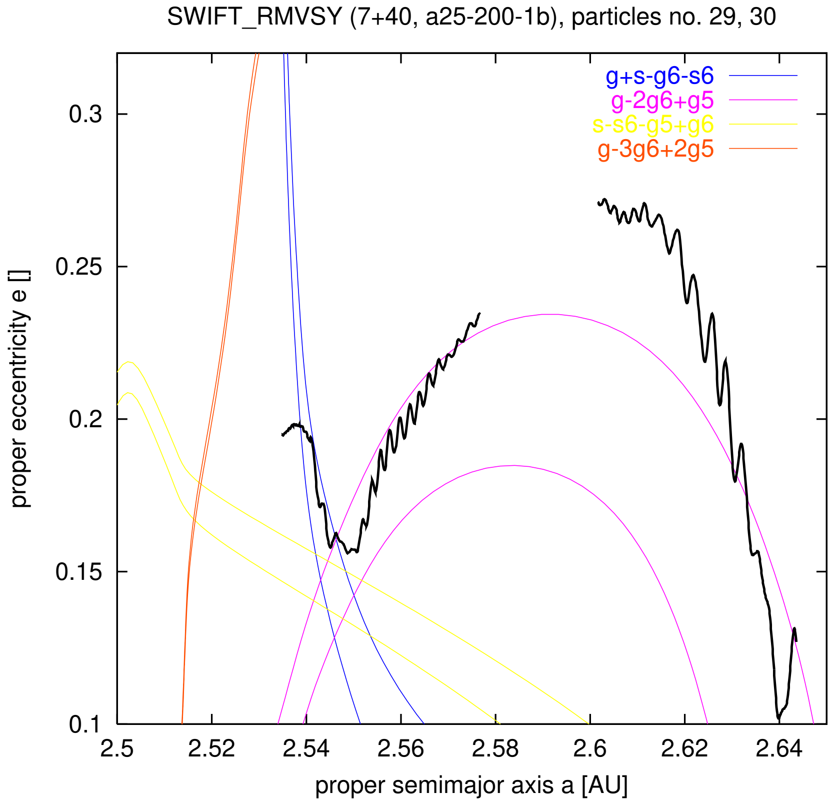
Examples of orbits driven by secular resonances

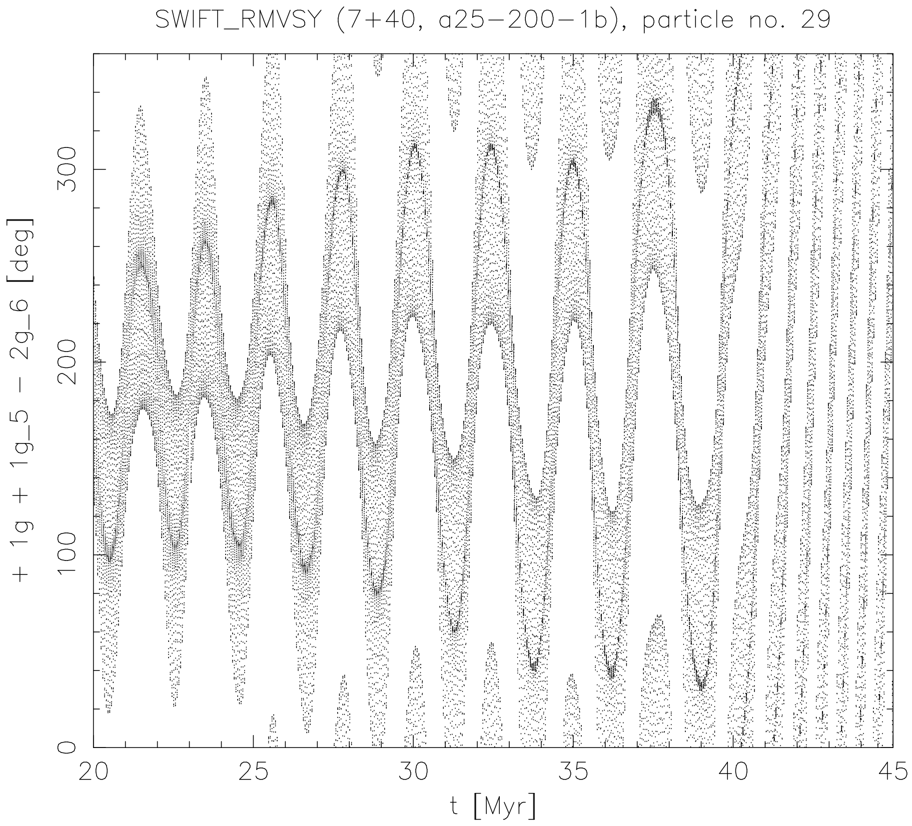
- 150 Myr integration of 7+50 particles in the inner belt, R = 100 m, regolith surface — (a, e) plane, borders of secular resonances ν_6, z_2 (Milani and Knežević, 1997), dependence on inclination
- 50 Myr integration of 7+40 particles in the middle belt, R = 200 m, C-type thermal parameters — captures in resonances $g_5 - 2g_6 + g$ and z_1





- run `a25-200-1b`, particle no. 29 (R = 200 m, C-type) — transition between $g_5 - 2g_6 + g$ and $g + s - g_6 - s_6$
- critical angle $\dot{\varpi}_5 - 2\dot{\varpi}_6 + \dot{\varpi}$ of resonance $g_5 - 2g_6 + g$ — librations between 0 and 40 Myr

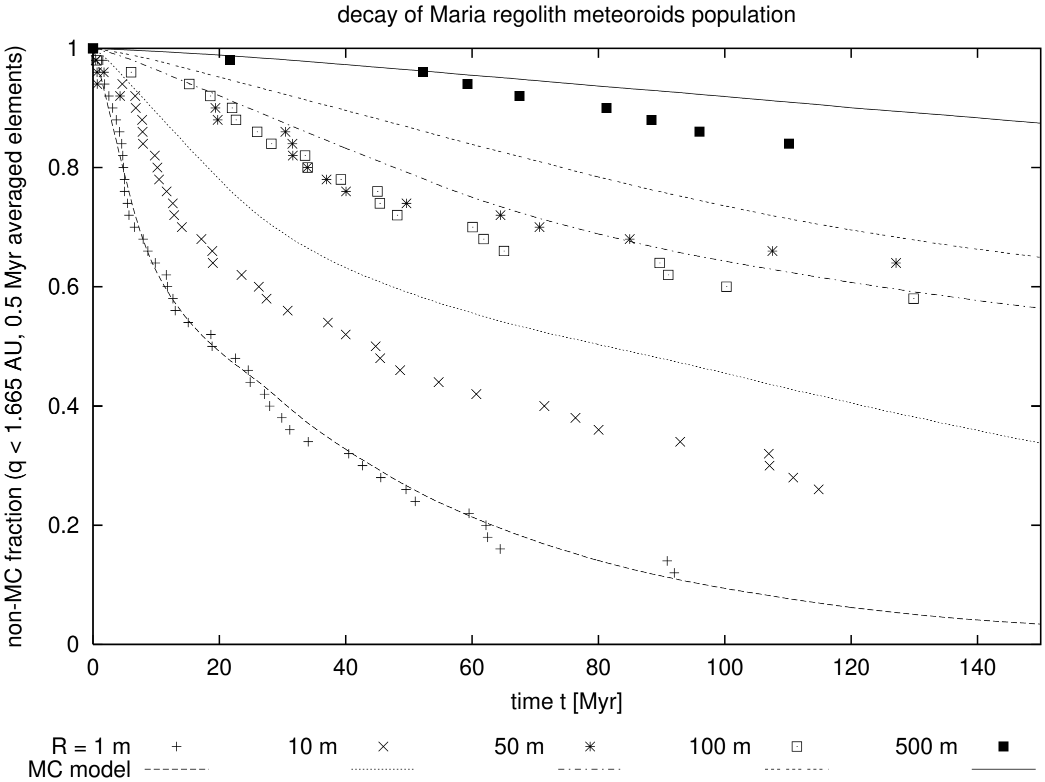


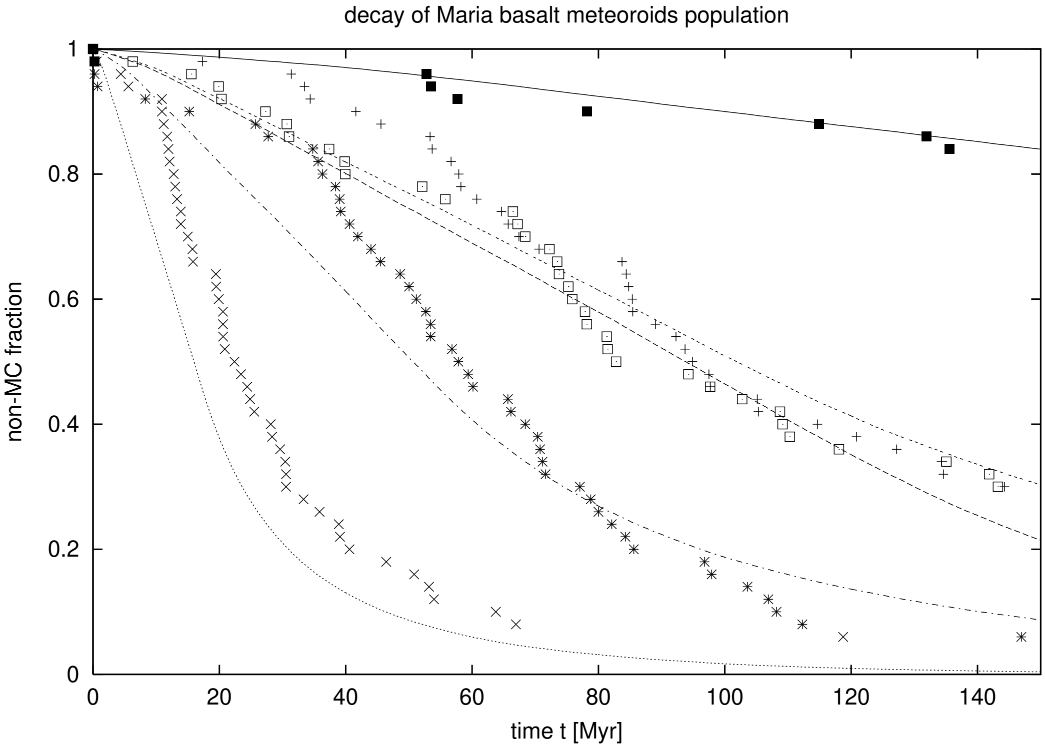


Temporal decay of meteoroids population

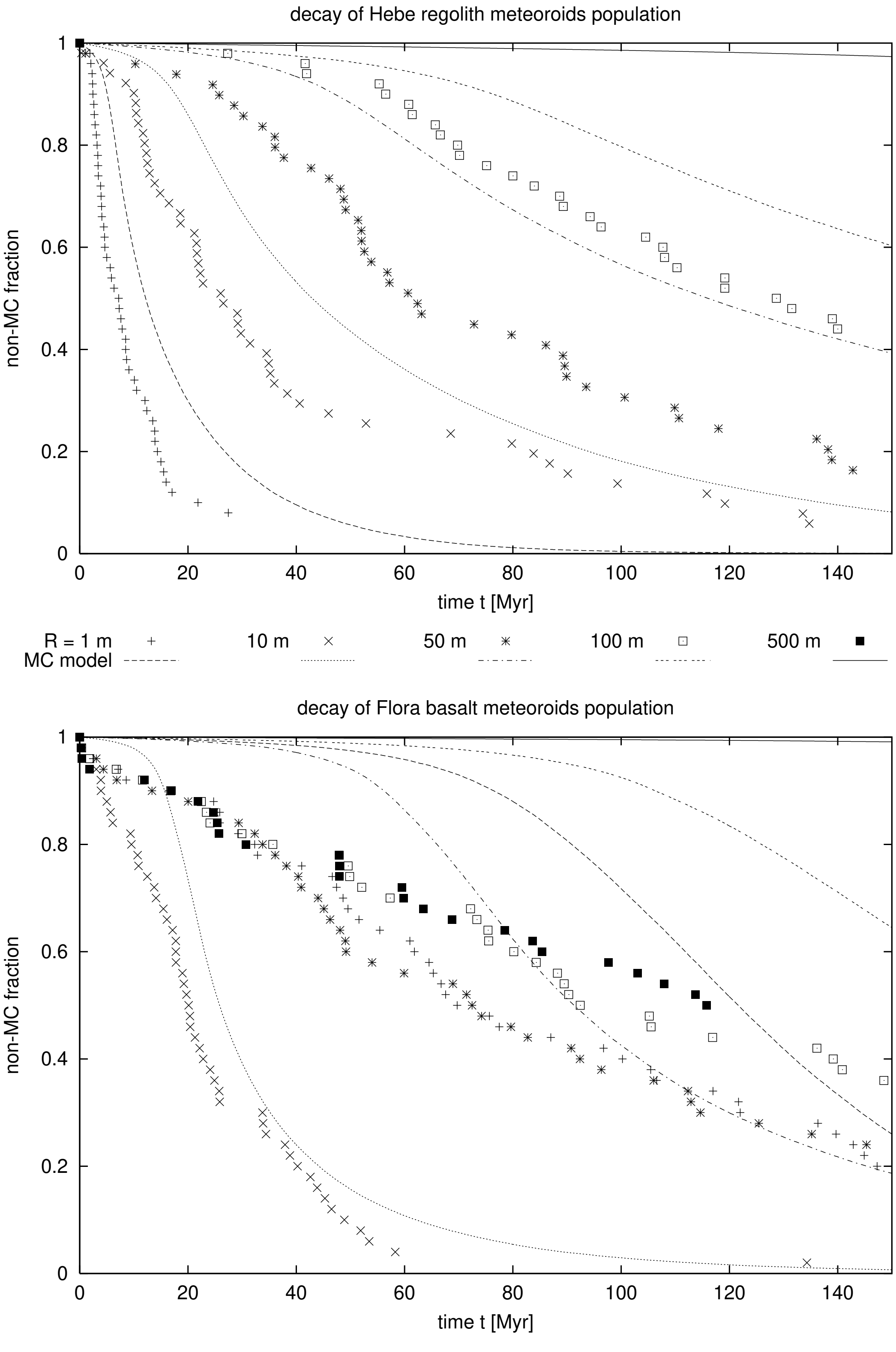
- comparsion of **numerical integrations** (1, points) and **Monte Carlo model** (Vokrouhlický & Farinella, 2000) (2, solid lines)
- different criteria: (1) Mars–crossing orbit, (2) reaching the "nominal" position of ν_6 resonance

Maria regolith and basalt fragments:





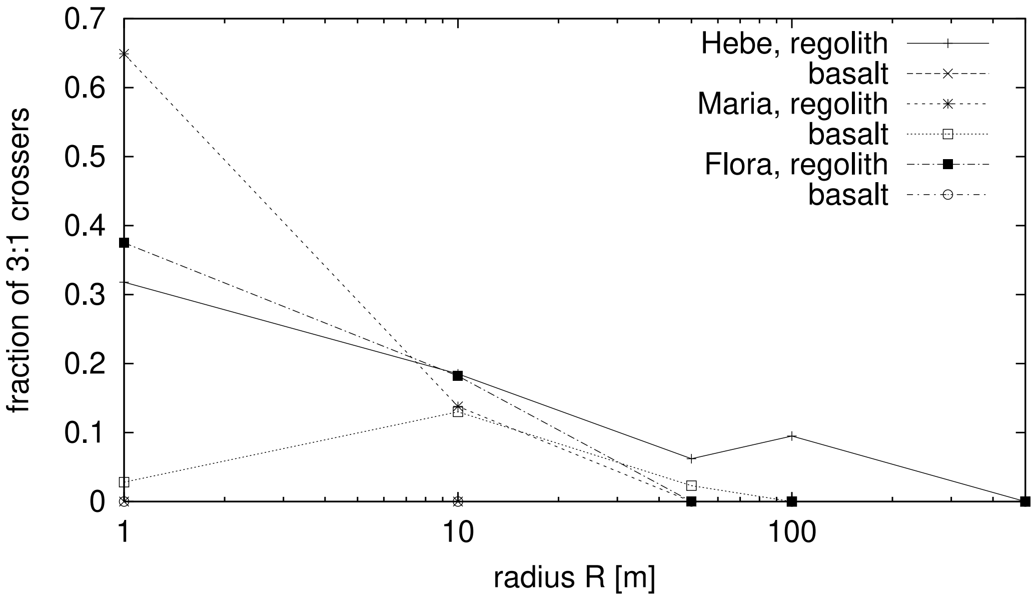
Hebe and Flora fragments:



- **high order resonances** with Mars, mixed mean motion resonances with Jupiter and Saturn in the Flora region affect large bodies $\Rightarrow$ diffusion in e, extraction without Yarkovsky, differences in decay-plots

3:1 resonance crossing and interaction with ν_6 resonance

- significant number of 3:1 crossers: $\sim$ 60 % for Maria, $\sim$ 30 % for Hebe and Flora regolith fragments with R = 1 m



- values of $\dot{\varpi}$, when TPs become Mars-crossers, comparsion with g_6

Applications:

- improvement of complex collisional models with only simple dynamics — resonance crossing, chaotic diffusion in e, I

References:

- Vokrouhlický, D., Farinella, P.: **Delivery of stony meteorites from the asteroid belt: A dynamical–collisional Monte Carlo model.** Nature, submitted (2000)

- results also on Inet: `http://sirrah.troja.mff.cuni.cz/~mira/mp/`