Subcatastrophic collisions between asteroids

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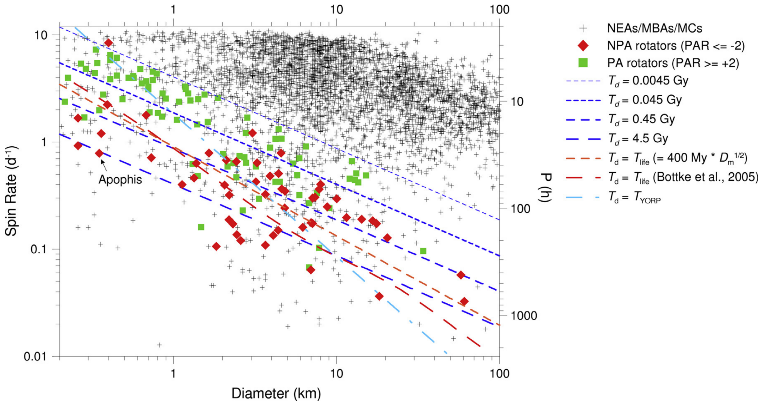
introduction

- subcatastrophic collisions are usually only crudely approximated in numerical models investigating asteroid rotations evolution – we seek a better description of them
- they act upon asteroids almost permanently (power-law distribution of projectile sizes with an exponent $p < -2$) – cumulative effects may be important
- motivation – the origin of tumbling asteroids (freely precessing or in non-principal axis rotation state)
- subcatastrophic collisions may be responsible for excitation of rotation of asteroids (Henych & Pravec 2013)

tumblers

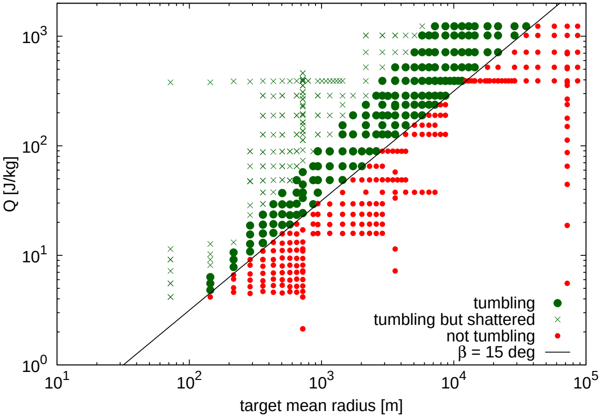


dichotomy of slow rotators (Pravec et al. 2014)

subcatastrophic collision model

- a projectile collides with a target asteroid (triaxial ellipsoid rotating in a basic state) forming an impact crater on its surface
- crater dimensions are calculated acc. to scaling laws (Holsapple 1993, 2003)
- linear and angular momentum (AM) exchange occurs between the two bodies during the collision
- part of the momentum and AM carried away by ejecta (AM transfer efficiency acc. to Yanagisawa et al. 1996 and Yanagisawa & Hasegawa 2000)
- we calculate the inertia tensor of the target asteroid and then its lightcurve
- we compare the specific impact energy to the shattering threshold energy

excitation of rotation



specific impact energy vs. target size

excitation of rotation

- we found that subcat. collisions can excite the rotation of small asteroids (sizes $\gtrsim 100\,\mathrm{m}$) without shattering them
- tumbling is detectable in lightcurves from Earth for the rotational axis misalignment angle greater than about 15°
- determining parameter is the ratio of the projectile orbital angular momentum to the target rotational angular momentum
- alternatively: a torque related to YORP effect may spin-down asteroid rotation and excite it (Vokrouhlický et al. 2007)

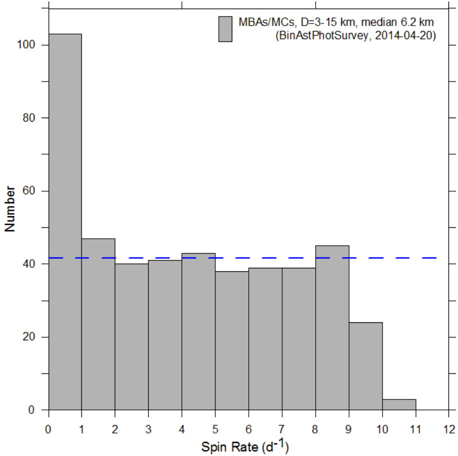
main questions of the present research

- Q are collisions alone sufficient to explain tumbling?
- Q how probable is to observe tumbling asteroid with rotation excited by collisions?
- Q are collisions able to explain observed characteristics of tumblers (mainly the dichotomy of slow rotators)

model of many small collisions

- goal: to build a synthetic population of asteroids colliding with small projectiles and compare it with observed sample of slow rotators
- only describe the period of asteroid lifetime between large collisions
- targets and projectiles sizes – power-law incremental distribution (Bottke et al. 2005)
- isotropic geometry of collisions – inclinations span some 35° and rotational axes may be randomly oriented
- small targets (1-km) may be in Slivan state, but possibly they may escape this resonant state (Vokrouhlický et al. 2003)

model of many small collisions

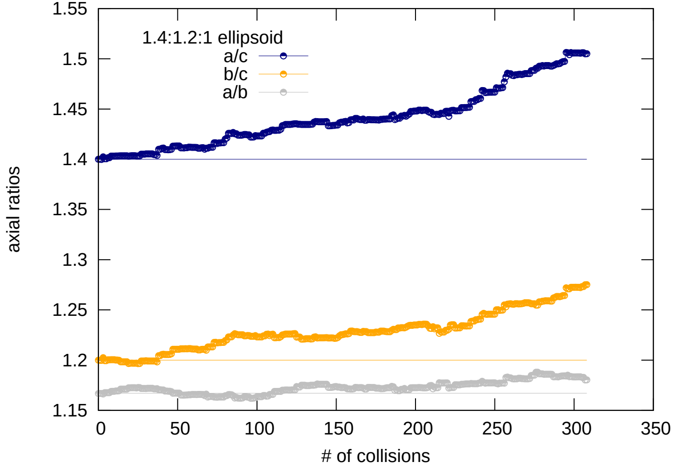


initial rotation frequency of targets according to Pravec et al. (2008), updated 2014-04-20

preliminary results

- increasing elongation of nonspherical asteroids caused by consecutive collisions (basically erosion)
- indicated by growing axial ratio of dynamically equivalent ellipsoid (calculated from target's inertia tensor)
- estimated timescale: tens to about hundred million years for a 1-km asteroid orbiting in the inner Main Belt
- explanation: craters erode all dimensions by the same amount on the average, smaller dimensions decrease relatively quicker than larger, hence axial ratio is growing (Harris 1990)

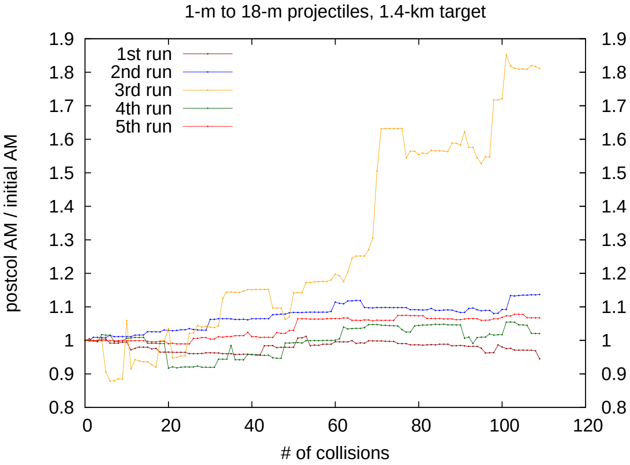
preliminary results



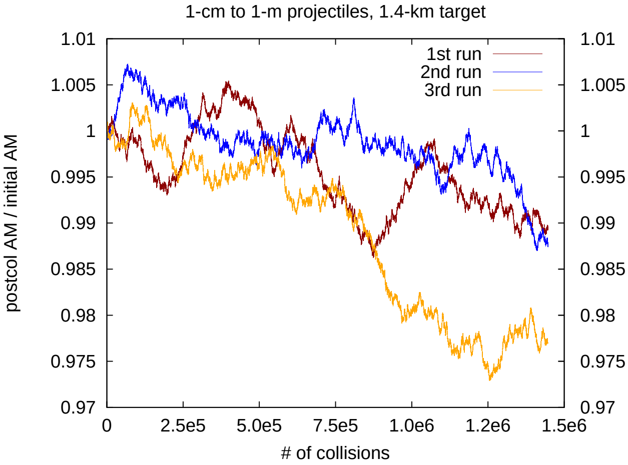
preliminary results

- 1-km target asteroid changes of rotation
- larger projectiles (decimeters to meters only) – incresing spin rate on the average, observable excitation
- smaller projectiles (milimeters or centimeters to meters) – decreasing spin rate in about 60% of runs
- consistent with Harris (1979) theoretical model
- looking for a cutoff size of projectiles – analytical approximation of their effect to decrease computational burden

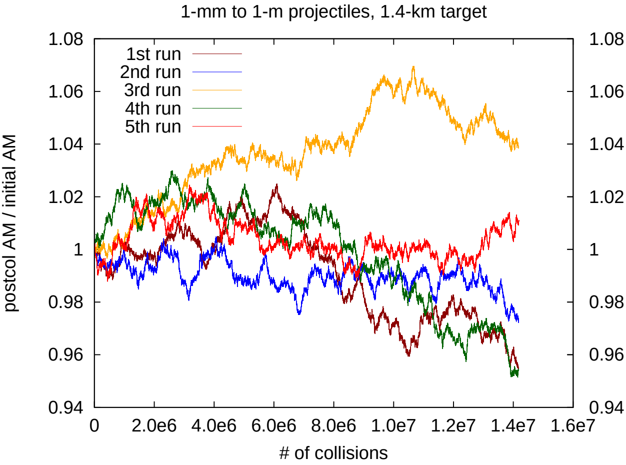
preliminary results



preliminary results



preliminary results



further work

- find an analytical approximation of collisions with projectiles below the cutoff size
- include damping of the excited rotation – two models (Breiter et al. 2012, Sharma et al. 2005)
- calculate collision probabilities
- run simulations to build a synthetic population of asteroids
- simulate photometric observation biases

references

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