# Subcatastrophic collisions between asteroids

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# introduction

- mutual collisions between asteroids affect their size distribution, spins and surface morphology
- asteroid families formed mostly by catastrophic collisions
- catastrophic disruption threshold – the largest fragment is half the original asteroid mass
- subcatastrophic collisions – form an impact crater on the surface of an asteroid (even though the crater may be huge)

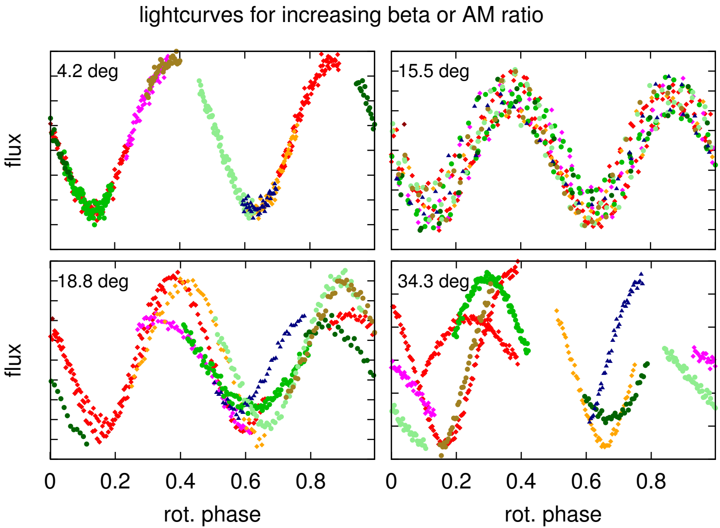
# 253 Mathilde

NASA

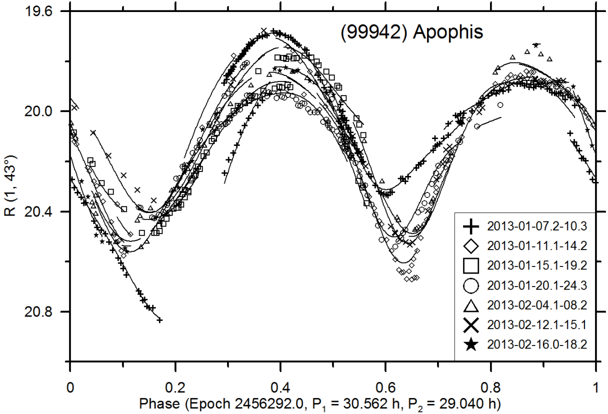
# introduction

- subcatastrophic collisions are thought not to play very important role – we investigate this more thoroughly
- 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 asteroid rotations (Henych & Pravec 2013)

# sample lightcurves

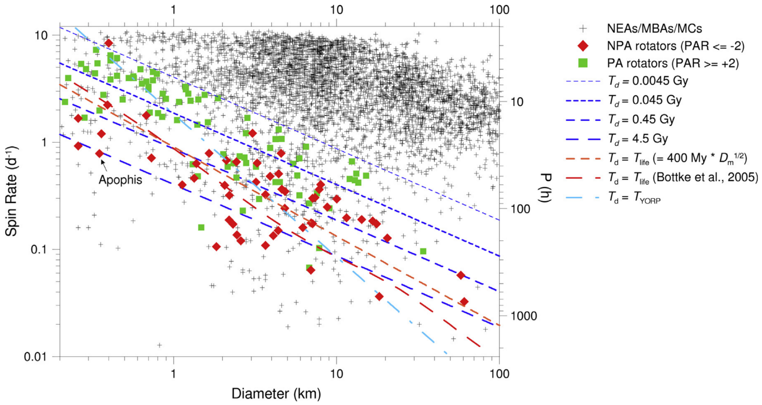


# 99942 Apophis lightcurve



Pravec et al. 2014

# tumblers

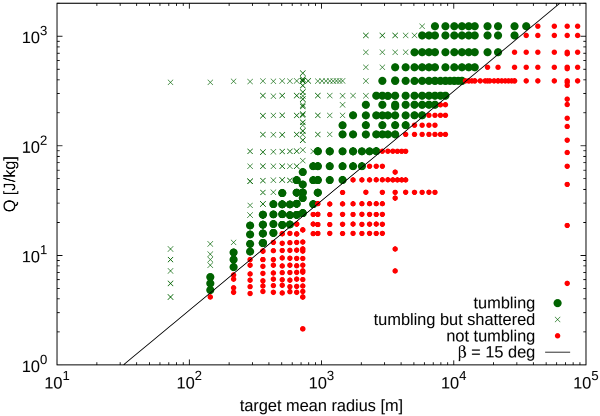


slowly rotating asteroids (Pravec et al. 2014)

# 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 catastrophic collision threshold energy

# excitation of rotation



specific impact energy vs. target size

# main questions of the present research

- Q how probable is to observe tumbling asteroid with rotation excited by collisions?
- Q are collisions able to explain observed characteristics of tumblers?
- Q are collisions alone sufficient to explain tumbling?

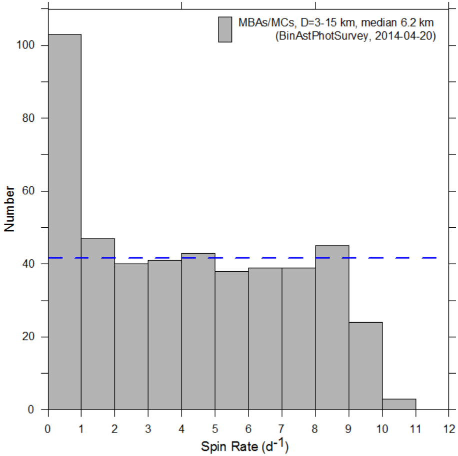
# how to do it?

- target asteroid subject to consecutive collisions by a population of projectiles
- larger projectiles may excite its rotation
- its rotation gradually damps to a basic state
- we observe it at random time (including observation biases)
- finally build a synthetic population and compare it qualitatively with observed sample of slow rotators

# model input characteristics

- targets and projectiles sizes – power-law incremental distribution (Bottke et al. 2005)
- targets sizes 0.4–18 km
- isotropic geometry of collisions – orbit inclinations span some 35° and rotational axes may be randomly oriented
- impact speed of 5 km/s (median encounter speed in the inner Main Asteroid Belt)
- random initial spin of targets based on observed spins of small asteroids

# model input characteristics



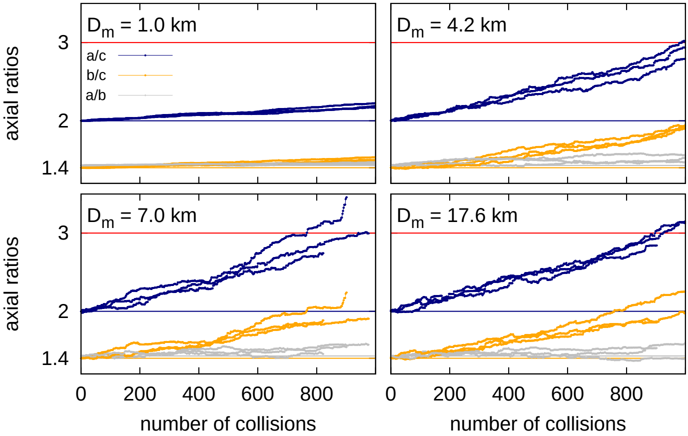
initial spins of targets according to Pravec et al. (2008), updated 2014-04-20

# model features – erosion

- increasing elongation of nonspherical asteroids caused by consecutive collisions (basically erosion)
- explanation: craters erode all dimensions of the ellipsoidal target by the same amount on the average, smaller dimensions decrease relatively quicker than larger, hence axial ratio is growing (Harris 1990)
- estimated timescale: much longer than collisional lifetime (catastrophic disruption occurs)
- not very important effect

# model features – erosion

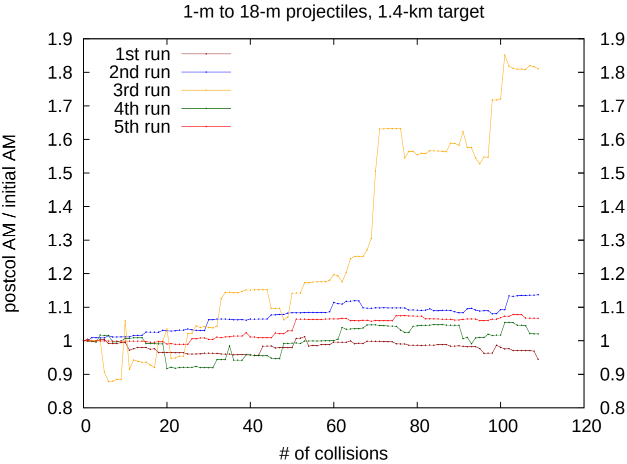
2:1.4:1 ellipsoids, 3 runs each target size



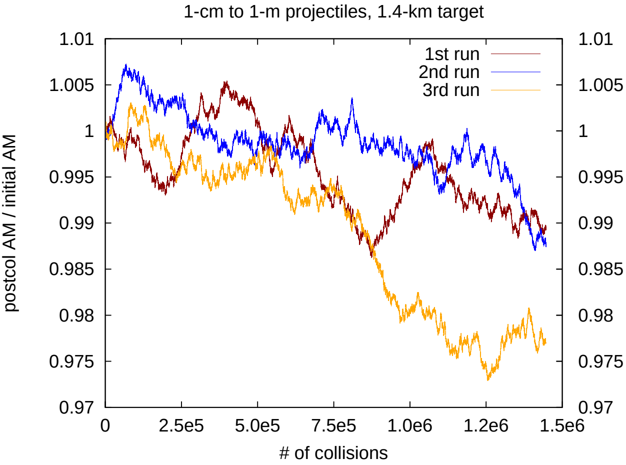
# model features – rotation changes

- 1-km target asteroid changes of rotation, several hundred runs with random initial conditions
- larger projectiles (decimeters to meters only) – incresing spin rate on the average, observable excitation of rotation
- smaller projectiles (milimeters or centimeters to meters) – decreasing spin rate in about 60% of runs
- consistent with Harris (1979) theoretical model

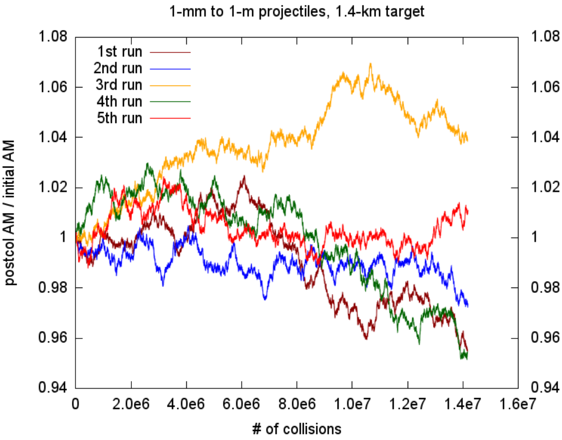
# model features – rotation changes



# model features – rotation changes



# model features – rotation changes



# problems & further work

- include damping of the excited rotation – three models (Breiter et al. 2012, Sharma et al. 2005, Efroimsky 2001)
- unknown quality factor for asteroids (damping)
- approximation of collisions with small projectiles (computationally expensive)
- calculate collision probabilities
- run simulations to build a synthetic population of asteroids
- simulate photometric observation biases

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