Excited rotation of asteroids

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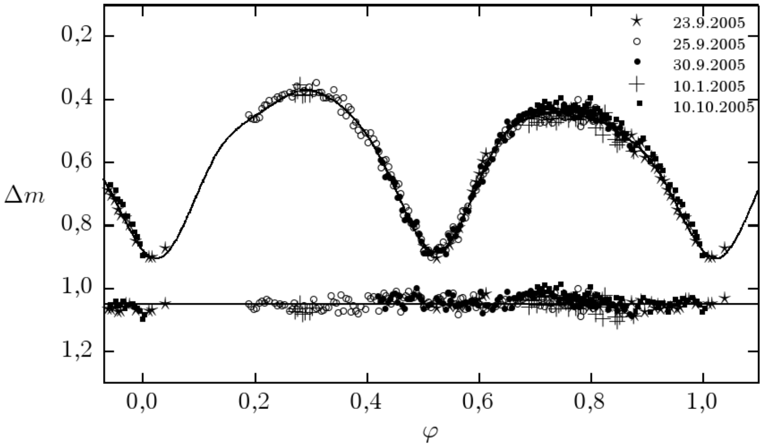
just relax

- most asteroid lightcurves are single-periodic
- it means the observed asteroids rotate in a relaxed state
- relaxed state rotation of a rigid body around its principal axis of the maximum moment of inertia which is aligned with the angular momentum vector
- noted by Kopal (1970)

714 Ulula



single-periodic phase curve of 714 Ulula

damping

- various events in the asteroid's life can lead to the rotational excitation
- Burns &Safronov (1973) derived the damping time scale is pretty short for larger asteroids
- damping relaxation of the rotational state (energy dissipation)
- till then only single-periodic lightcurves observed
- but in December 1992 – close approach of 4179 Toutatis to Earth (flyby less than ten lunar distances from Earth)

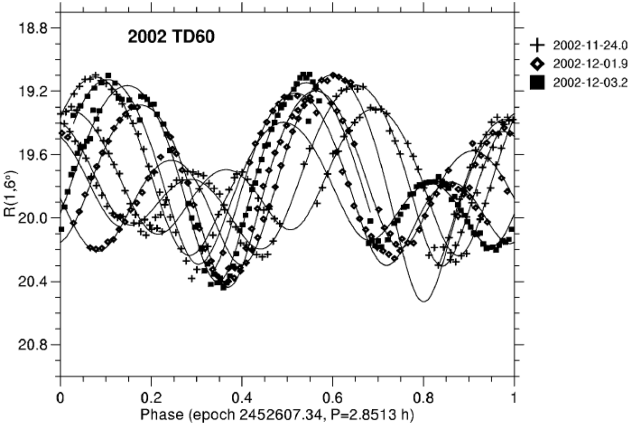
4179 Toutatis

- lightcurve and radar observation revealed very slow and peculiar rotational state
- other suspects – 3288 Seleucus (1982 observations)
- Harris (1994) showed that for several asteroids the damping time scale could be considerably longer than the age of the Solar System
- at the time of writing their article Burns&Safronov (1973) didn't know any asteroid with unusually long period of rotation

being excited

- when trying to explain the observed lightcurves, Harris (1994) proposed non-principal axis rotation (excited state of rotation)
- for extremely irregularly shaped bodies may lead to *tumbling* in space, therefore these bodies are called tumblers
- rotation of the body consists of two periods: rotation about the extremal axis and precession about angular momentum vector (Kaasalainen, 2001)

complex lightcurve



complex lightcurve of 2002 TD_{60} (Pravec *et al.*, 2005)

inverse problem

- lightcurves generally enable the construction of physical model of the asteroid
- precessing asteroids require slightly different set of parameters
- there is a huge advantage in modelling tumblers

inverse problem

- only short observation is needed to construct sufficient model, because all parts of the asteroid are seen and illuminated during one approach to Earth
- 'decent' bodies need to be observed in more apparitions (and hence more viewing geometries) to construct unique model
- Kaasalainen (2001)

to tumble or not to tumble?

what could cause non-principal axis rotation?

- many tumbling asteroids are slow or superslow rotators
- it seems probable they were slowed down from faster rotations (Pravec&Harris, 2000)
- possible spin-down mechanism could be YORP effect

YORP or . . .

YORP could also be responsible for NPA rotation in two ways

- YORP directly leads to NPA rotation
- YORP slowed-down asteroid are more sensitive to excitation of rotation (by impacts or tidal forces during planetary encounters)

. . . impact

another mechanism causing rotational excitation could be sub-catastrophic collision with another body

- vast majority of asteroids are *rubble-piles*, not a coherent bodies
- hence they are able to absorb much more energy during impact
- many impacts can shatter but do not disperse these bodies
- these impacts could possibly lead to the rotational excitation

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