Both size-frequency distribution and sub-populations of the main-belt asteroid population are consistent with YORP-induced rotational fission

S. Jacobson[1], D. Scheeres[2], A. Rossi[3], F. Marzari[4], and D. Davis[5]

[1]Observatoire de la Côte d'Azur
[2]University of Colorado at Boulder
[3]IFAC-CNR
[4]Università di Padova
[5]Planetary Science Institute

From the results of a comprehensive asteroid-population-evolution model, we conclude that the YORP-induced rotational-fission hypothesis has strong repercussions for the small size end of the main-belt asteroid size-frequency distribution and is consistent with observed asteroid-population statistics and with the observed sub-populations of binary asteroids, asteroid pairs and contact binaries. The foundation of this model is the asteroid-rotation model of Marzari et al. (2011) and Rossi et al. (2009), which incorporates both the YORP effect and collisional evolution. This work adds to that model the rotational fission hypothesis (i.e. when the rotation rate exceeds a critical value, erosion and binary formation occur; Scheeres 2007) and binary-asteroid evolution (Jacobson & Scheeres, 2011).

The YORP-effect timescale for large asteroids with diameters $D >\sim 6$ km is longer than the collision timescale in the main belt, thus the frequency of large asteroids is determined by a collisional equilibrium (e.g. Bottke 2005), but for small asteroids with diameters $D <\sim 6$ km, the asteroid-population evolution model confirms that YORP-induced rotational fission destroys small asteroids more frequently than collisions. Therefore, the frequency of these small asteroids is determined by an equilibrium between the creation of new asteroids out of the impact debris of larger asteroids and the destruction of these asteroids by YORP-induced rotational fission. By introducing a new source of destruction that varies strongly with size, YORP-induced rotational fission alters the slope of the size-frequency distribution. Using the outputs of the asteroid-population evolution model and a 1-D collision evolution model, we can generate this new size-frequency distribution and it matches the change in slope observed by the SKADS survey (Gladman 2009). This agreement is achieved with both an accretional power-law or a truncated "Asteroids were Born Big" size-frequency distribution (Weidenschilling 2010, Morbidelli 2009).

The binary-asteroid evolution model is highly constrained by the modeling done in Jacobson & Scheeres, and therefore the asteroid-population evolution model has only two significant free parameters: the ratio of low-to-high-mass-ratio binaries formed after rotational fission events and the mean strength of the binary YORP (BYORP) effect. Using this model, we successfully reproduce the observed small-asteroid sub-populations, which orthogonally constrain the two free parameters. We find the outcome of rotational fission most likely produces an initial mass-ratio fraction that is four to eight times as likely to produce high-mass-ratio systems as low-mass-ratio systems, which is consistent with rotational fission creating binary systems in a flat distribution with respect to mass ratio. We also find that the mean of the log-normal BYORP coefficient distribution $B \approx 10^{-2}$.

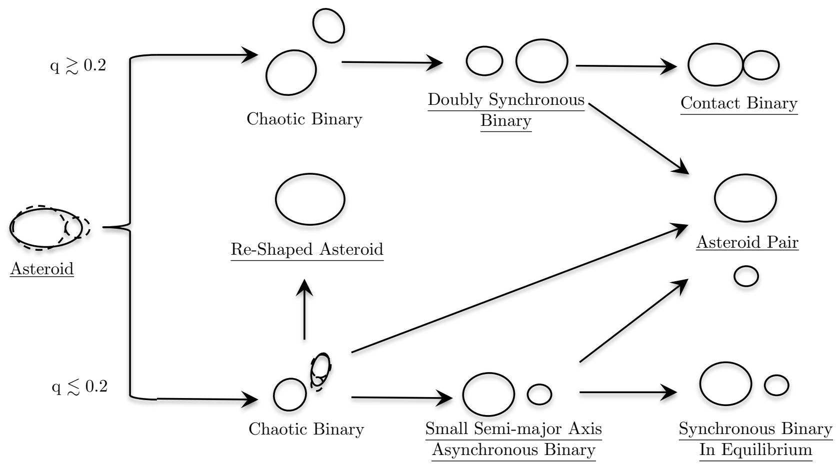

Figure: Binary-asteroid-system evolution after a rotational-fission event. The upper pathway corresponds to high mass ratio $q > 0.2$ and the lower pathway corresponds to low mass ratio $q < 0.2$.