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Dynamical properties of Watsonia asteroid family

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Abstract. In recent years, a rare class of asteroids has been discovered by Cellino *et al.* (2006), with its distinguishing characteristic being the anomalous polarimetric properties of its members. Named Barbarians, after (234) Barbara, the prototype of the class, these asteroids show negative polarization at unusually high phase-angles compared to normal asteroids. Motivated by the fact that some of the few discovered Barbarians seemed to be related to the Watsonia asteroid family, Cellino *et al.* (2014) performed a search for more Barbarians among its members. A positive result of this search led to the conclusion that Watsonia is indeed an important repository of Barbarian asteroids. Based on these findings, we decided to analyze this family in detail.

Keywords. asteroids, methods: numerical, asteroid families, transport mechanisms

1. Identification of family members

The first step in our study is to derive a list of Watsonia family members. To this purpose, we first calculate the synthetic proper elements (Knežević & Milani (2003)) of the numbered, multi- and single-opposition asteroids in a wide region around the family. To this set of proper elements we apply the Hierarchical Clustering Method (HCM) (Zappala *et al.* (1990)) to determine the membership of the family. As seen in Fig. 1a, the well defined plateau ($d_c = 92 - 103\,m/s$) reveals that the family is well separated from the background asteroids. The dynamical family is found to have 83 members.

Afterwards, in order to have a better insight of the family properties, we used the so-called "V-shape" method to determine its age (Vokrouhlicky *et al.* (2006), Milani *et al.* (2010)). The low number of family members did not allow for a precise estimation, so we were only able to achieve a rough result of the order of 1 Gyr.

2. Simulation of fictitious family fragments

The next step of our analysis was to study the orbital evolution of a fictitious population of family members. The location of the family in the proper orbital elements space, close to the 5/2 mean motion resonance (MMR) with Jupiter, with low to moderate eccentricities and high inclinations, suggests that over the age of the family, a significant number of fragments must have entered the resonance. This resonance has been shown by Gladman *et al.* (1997) to be efficient at transporting asteroids to the near-Earth region, therefore we wanted to simulate the inflow of Watsonia family fragments into this resonance, as well as in other resonances relevant for the transport.

We created a population of fictitious family fragments with initial orbital elements near (729) Watsonia, and integrated their orbits for 1 Gyr. The dynamical model included five planets (Mars to Neptune), and the asteroids (1) Ceres and (2) Pallas, and accounted

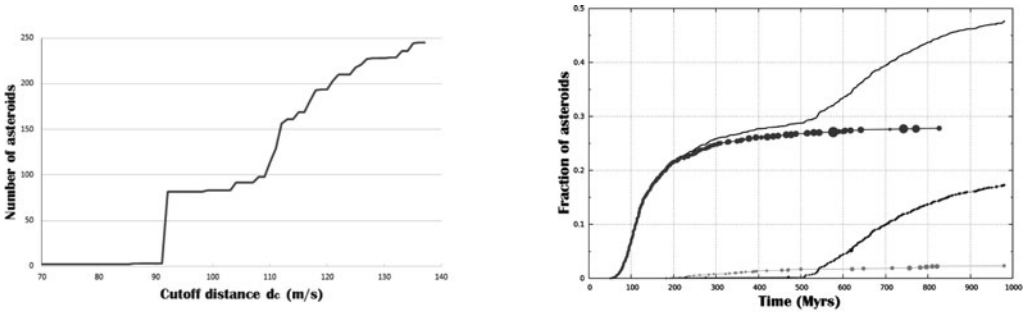

Figure 1. (a):Number of asteroids associated with (729) Watsonia as a function of cutoff velocity (d_c). The family is defined by the plateau around 100 m/s. (b):Fraction of the initial population asteroids entering the near-Earth region over time. In dark-gray the fraction of asteroids driven through the 3/1 MMR, in medium-gray through the 5/2 MMR and in light-gray through the 8/3 MMR. The black continuous line denotes the total fraction of asteroids becoming NEA.

for the Yarkovsky thermal force (Broz (2006)), set to have maximum drift rate for all objects. The outcome of the simulation is an initial drift of fragments to the 5/ MMR with Jupiter at 2.82 AU, which leads them to terrestrial planet-crossing orbits or out of the solar system. After about 500 Myr, fragments also reach the 3/1 MMR with Jupiter at 2.5 AU, with most of them entering the near-Earth region. A small number of asteroids is also driven to the planet-crossing region via the 8/3 MMR with Jupiter.

As seen in Fig. 1b, the major fraction of fragmens reaching the near-Earth region, is coming through the 5/2 MMR. However, taking into account the age of the family as estimated above, we expect that the 3/1 MMR is responsible for most of the inflow of fragments at the present time. We can thus conclude that the transport of Barbarians to terrestrial planet-crossing orbits is plausible, and will be further studied.

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