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Excluding interlopers from asteroid families

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Abstract. To study an asteroid family it is crucial to determine reliably the list of its members, i.e. to reduce the number of interlopers as much as possible. However, as the number of known asteroids increases fast it becomes more and more difficult to obtain robust list of members of an asteroid family. To cope with these challenges we are proposing a new approach that may help to significantly reduce presence of interlopers among the family members.

Keywords. asteroids: general, impact processes, asteroid families

1. Introduction

Asteroid families are first discovered in 1918 by Japanese astronomer Hirayama, and since then a large number of families have been discovered in the main-belt (e.g. Zappala *et al.*, 1990; Nesvornỳ *et al.*, 2005; Novaković *et al.*, 2011; Brož *et al.*, 2013; Milani *et al.*, 2014). These groups, which are believed to be products of catastrophic collisions between asteroids, are typically identified in the space of proper orbital elements: semi-major axis (a_p), eccentricity (e_p) and sine of inclination ($\sin I_p$). Proper elements have been used because they are nearly constant over time (Knežević and Milani, 2003).

For family identification the Hierarchical Clustering Method (HCM, Zappalà *et al.*, 1990) is often used. HCM identifies an asteroid as part of family if its distance from closest neighbor is smaller than an adopted cut-off distance (v_c). However, there is no strict rule to determine v_c, because it depends on various factors, for example a location of family within the main-belt. Moreover, HCM can not distinguish whether an asteroid is really part of a family or an interloper. These impose important constraints in the ability to reliably identify members of a family. Here we propose a new, HCM based, approach to exclude interlopers from the list of family members.

2. Method

The proposed approach consists of four main steps. In the first step, HCM is applied to the catalog of proper elements using different cut-off values. Starting from $v_c = 5$ m/s, it increases until family merges with background asteroids. For a threshold value we use the one two steps below the distance at which family merges with background. In this way, we get an initial list of the family members.

The second step is to identify interlopers among members of the initial family. As it is well known, to identify interlopers we have to use physical and spectral properties of candidate family members. For this purpose we use the SDSS colors (Ivezić *et al.*, 2001), WISE albedos (Masiero *et al.*, 2011) and other available spectroscopic data. For each data-set we defined criteria to decide if an asteroid is interloper or not. For example, we use average albedo and its standard deviation to distinguish between C and S classes. Three sigma range is used to create confidence interval for each taxonomy class. DeMeo

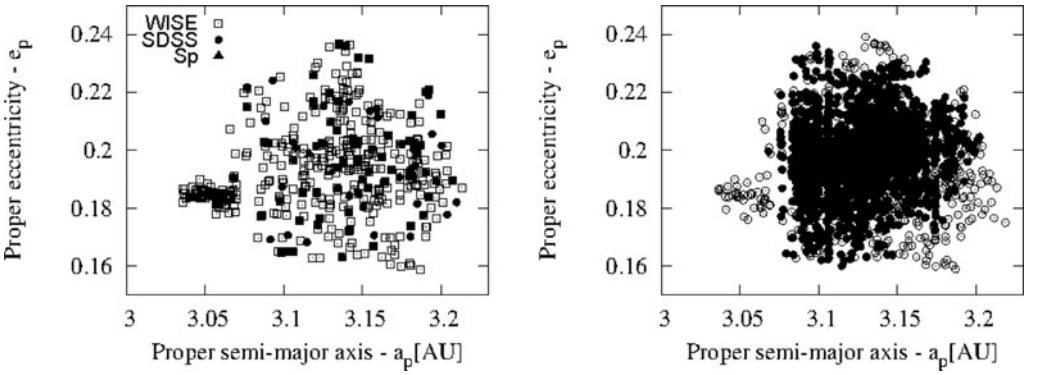

Figure 1. Results for the Klumpkea family. Left image shows interlopers discarded because of different properties. Empty squares are discarded due to its WISE albedo, filled circles due to SDSS colors and filled triangles because of its taxonomy type. Right image shows the Klumpkea family obtained in the first step (empty circles) and in the last (filled circles).

and Curry (2013) found that average albedo of C-type asteroids is 0.06 ± 0.01, thus, the confidence interval is $[0.03, 0.09]$. Than, an asteroid with geometric albedo p_v and standard deviation σ, is not a member of C class if value of $p_v - 3\sigma$ is greater than 0.09.

In third step, asteroids identified as interlopers are excluded from the initial catalog of proper elements. The point of this step is to reduce the chaining effect in the HCM. By removing interlopers from the catalog, we have also removed objects linked to the family through some of these interlopers.

Finally, in fourth step, HCM analysis is performed again using the modified catalog.

3. Results: the case of Klumpkea family

We choose (1040) Klumpkea family as a test case due to its location and spectral type. Klumpkea is situated in the outer part of the main-belt where most of asteroids belong to C-type. However, members of the Klumpkea family are S-type. Hence, a relatively large fraction of the interlopers are expected to be found. Obtained results are shown in Fig. 1. In the first step we identified 2794 asteroids as a family members. Then, in the second step, among these objects we found 447 interlopers. After removing interlopers, using the same v_c as in the first step, HCM identified 2107 family members. Thus, the final family has 687 members less than the initial one.

In conclusion, our approach could significantly reduce number of interlopers in families, and help to get much more reliably the list of family members.

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