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Identification of a new asteroid family 3854 George in the Hungaria group

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Abstract. A search for asteroid families was performed in the Hungaria group. Proper elements needed for this procedure were calculated by the empirical method using distributions of osculating elements. All, more than 30 000 multi-opposition asteroids, discovered in this region to date, were used for this aim. An approach similar to the hierarchical clustering method was applied for the identification of families. As a result, two asteroid families were found: 434 Hungaria and 3854 George. 434 Hungaria family is a well known one, it includes a large fraction of asteroids in this region. A new family 3854 George was identified in the high inclination region 24°–26°. It is composed by small asteroids with diameters less than 1 km and includes about 400 members now.

Keywords: celestial mechanics; asteroids: general, minor planets; individual: 434 Hungaria, 3854 George

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1 Introduction

The Hungaria group is a nearest to the Earth part of the asteroid belt roughly defined by semi-major axis $1.8\,\mathrm{AU} < a < 2.0\,\mathrm{AU}$, eccentricity $e < 0.2$, and inclination $15^\circ < i < 30^\circ$. There are no large asteroids in this region. Diameters of the most large asteroids seem not to exceed 15 km. One of the questions related to this group is a number of families in this region. The existence of one family is not in doubt today. The Hungaria region really contains a large family, called the Hungaria family. The family includes a large fraction of the Hungaria asteroids. Besides, there were some indications of a possible second family at higher inclinations, but up to now only small groupings have been detected here. Due to a large number of newly discovered asteroids the identification of the second family in this region became possible. More than 30 000 multi-opposition asteroids are discovered in this region to date. The source of initial osculating elements is the MPC catalogue, version Feb 2024.

2 Calculation of forced and proper elements by the empirical method

Osculating elements cannot be used for a family identification because an inclination and eccentricity oscillate periodically over a long time span under the action of perturbations. Proper elements are required for this aim. The empirical method (Vinogradova 2019) was used to calculate proper elements for all multi-opposition asteroids in this zone. Oscillations of the osculating inclination i and eccentricity e manifest themselves very clearly in the distributions of pairs: inclination–longitude of ascending node (i, Ω) in Fig. 1a, and eccentricity–longitude of perihelion (e, ϖ) in Fig. 1b. These oscillations represent classical secular perturbations. An amplitude of the oscillations and the position of the maximum correspond to forced elements i_f, Ω_f in Fig. 1a and e_f, ϖ_f in Fig. 1b.

It is possible to calculate the parameters of these curves by the least-squares method. For the population of the Hungaria group as a whole the following forced elements were calculated: $i_f = 3.^\circ1 \pm 0.^\circ02$, $\Omega_f = 115.^\circ6 \pm 0.^\circ3$, $e_f = 0.0202 \pm 0.0004$, $\varpi_f = 47.^\circ91 \pm 1.^\circ01$.

Classical secular perturbations can be excluded from osculating elements using a coordinate transformation formula if the corresponding forced elements are known (Vinogradova 2019). After eliminating the classical secular perturbations, Lidov–Kozai perturbations (Lidov 1962; Kozai 1962) may become visible in element distributions. The Lidov–Kozai perturbation is a secular one which causes long-period oscillations in the orbital inclination and eccentricity depending on the perihelion argument ω.

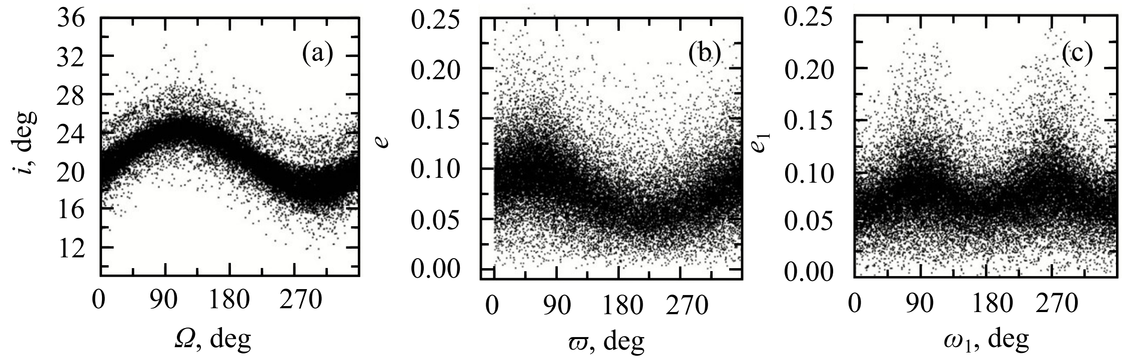

Fig. 1. Distributions of orbital elements in the Hungaria group: i, Ω (a); e, ϖ (b); e_1, Ω_1 (c) after excluding classical secular perturbations.

The plot of the eccentricity against the perihelion argument ω in Fig. 1c clearly shows how eccentricities of asteroid orbits in this region change under the action of the Lidov–Kozai perturbation. An amplitude of i oscillations is not significant here. In the high inclination region, amplitudes of the Lidov-Kozai oscillations can reach the values of 0.025 for eccentricities and $0^\circ\!.25$ for inclinations. These forced elements, related to Lidov-Kozai perturbation, were excluded in the same way as for classical secular perturbations. As a result, proper elements e_p, i_p were calculated.

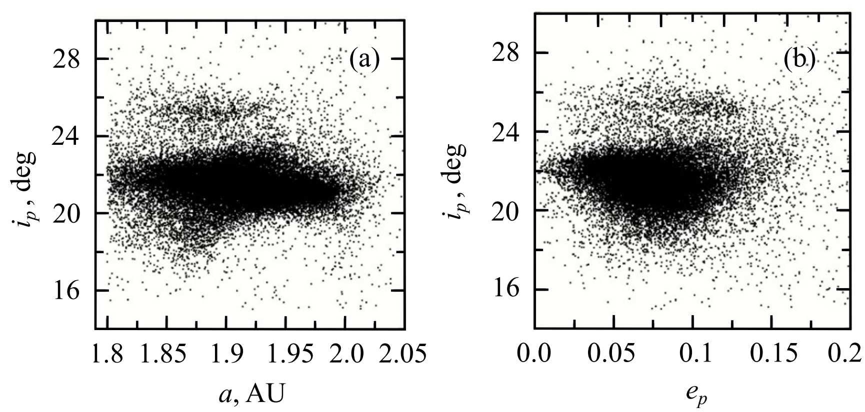

Fig. 2. Distribution of proper elements (i_p, a) and (i_p, e_p) in the Hungaria group.

Distributions of the proper elements (i_p, a) and (i_p, e_p) in the Hungaria group can be seen in Fig. 2. These distributions show well the presence of two families here. Although, it should be said that these families can be seen already in the Fig. 1a. They can be seen, but cannot be separated in osculating elements.

3 Family identification

An approach similar to the hierarchical clustering method (Zappalà et al. 1990) was used for the identification of families. This method was described in Vinogradova (2019). As a result, besides the large and well known 434 Hungaria family, a new family 3854 George was identified in the high inclination region 24°–26°. 434 Hungaria family includes about 25 000 asteroids now.

3854 George family includes about 400 members now. The family is composed by rather small asteroids with diameters less than 1 km. The distribution of absolute magnitude H of family members against a semimajor axis (H, a) is shown in Fig. 3a. The triangular shape of the distribution suggests that this population of asteroids is a real collisional family. A position of the main asteroid 3854 George is marked with a cross.

Also, a differential magnitude distribution of the 3854 George asteroids was considered in Fig. 3b. Almost all asteroids with H up to $18\overset{\mathrm{m}}{.}5$ are discovered in this region. The best fit for the family graph in the interval $17\overset{\mathrm{m}}{.}0$–$18\overset{\mathrm{m}}{.}5$ of H is a straight line with a slope of 0.48. This line is shown on the plot by a dotted line. Such slope is consistent with a young collisional family.

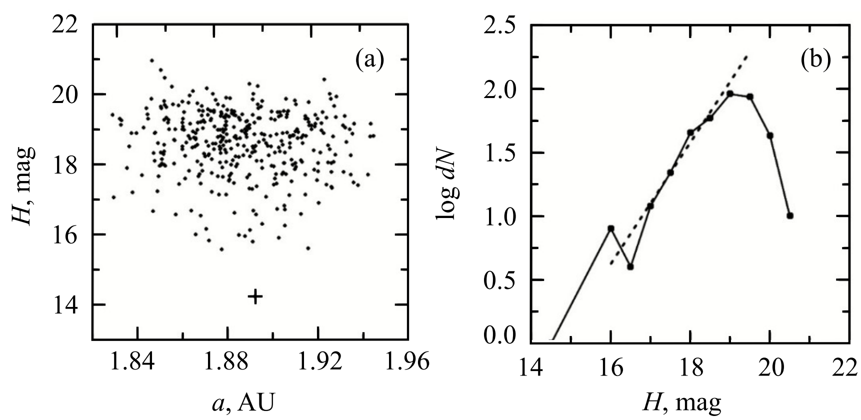

Fig. 3. Distributions for 3854 George family asteroids. Absolute magnitudes H versus semimajor axis a (a); a differential number of asteroids dN versus H (b).

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