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Cascade disruption in Rampo family

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Abstract. We have found three new members of the Rampo asteroids family: 2009 HD_{95}, 2010 VO_{19}, 2013 JF_{69}. We estimated the Yarkovsky semimajor axis drift rate. Based on the simulation results, estimates of the asteroid pairs' age included in the family are obtained. In the scenario of the cascade disruption of the parent body of the asteroid (10321) Rampo, one can note the concentration of estimates of the pairs' age to values of 900, 750, 500, and 250 kyr.

Keywords. Celestial mechanics, methods: numerical, minor planets, asteroids.

Pravec and Vokrouhlický (2009) discovered the Rampo family with only three members since that number of members belonging to this cluster has increased up to 7 (Pravec et al. 2018). Kuznetsov and Vasileva (2019) discovered six new members.

Search for new members of the Rampo family was carried out by calculating the Kholshevnikov metrics ρ_2 and ρ_5 (Kholshevnikov et al. 2016). The selection criterion was the simultaneous fulfillment of two conditions: $\rho_2 < 0.008$ au$^{1/2}$ and $\rho_5 < 0.002$ au$^{1/2}$. As a result, three new members of the (10321) Rampo family were found: 2009 HD_{95}, 2010 VO_{19}, 2013 JF_{69}.

The dynamic evolution of Rampo family asteroids was simulated numerically using the Orbit9 program of the OrbFit complex for 1 Myr. Perturbations from major planets and the dwarf planet Pluto, the Sun oblateness, relativistic effects, and the Yarkovsky effect's influence were considered. For each asteroid, based on nominal orbital elements, five evolution scenarios were considered for different values of the semimajor axis drift rate $\dot{a}$ corresponding to the different orientation of the asteroid rotation axis relative to its orbit plane: $\dot{a} = 0$ at $\varphi = 90°$ or 270°; $\dot{a} = \pm|\dot{a}|_{max}$ at $\varphi = 0°$ or 180°, respectively; $\dot{a} = \pm 0.5 \times |\dot{a}|_{max}$ at $\varphi = 60°$ or 240°, respectively. The maximum absolute values of the semimajor axis drift $|\dot{a}|_{max}$ caused by the Yarkovsky effect were estimated by normalization using the asteroid's parameters (101955) Bennu (Del Vigna et al. 2018).

We assume the scenario of cascade disruptions of the parent body of asteroid (10321) Rampo. In this case, four groups of orbits can be distinguished in the Rampo family. Asteroids whose orbits approach the orbit of the asteroid (10321) Rampo about 900 kyr ago – (451686) 2013 BR_{67}, 2009 HD_{95}, 2009 SR_{371}, 2013 JF_{69}, 2015 TM_{372} and 2017 UH_{21}; about 750 kyr ago – 2006 UA_{169}, 2010 VO_{19}, 2013 RL_{101}, 2013 VC_{30},

2014 HS_9, 2015 HT_{91} and 2016 TE_{87}; about 500 kyr ago – (294272) UM_{101}; about 250 kyr ago – 2015 TA_{367}.

We can conclude that there is a very low possibility that the Rampo family was formed in a single breakup event. This conclusion agrees with a novel idea about the cascade breakup of some young asteroid families (Fatka et al. 2020).

At the stage of current knowledge about the physical and dynamic properties of members of this family, without accurate estimates of the semimajor axis drift rates or non-gravitational parameter A_2, it is impossible to reconstruct the true picture of the formation of the family.

The next necessary step in studying the Rampo asteroids family will be to obtain information about the surface's thermophysical properties, the shape, and the parameter of the axial rotation of asteroids and refine the orbital parameters. These data will help determine the Yarkovsky semimajor axis drift rate and simulate realistic scenarios of the evolution of asteroids within limits of parameter determination errors.

Rampo family asteroids have very small but nonzero eccentricities. For this reason, the perihelion argument sometimes has change precession to regression motion. This fact complicates the condition of the orbital elements convergence and required future studying.

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