PAIRS OF ASTEROIDS IN CLOSE ORBITS.

E. D. Kuznetsov[1], D. V. Glamazda[1], G. T. Kaiser[1], V. V. Krushinsky[1], A. A. Popov[1], V. S. Safronova[1], A. A. Shagabutdinov[1], D. S. Ustinov[1] and Yu. S. Vibe[1], [1]Ural Federal University, Lenin Avenue, 51, Yekaterinburg, 620000, Russia, eduard.kuznetsov@urfu.ru.

Introduction: A large number of asteroid pairs exist in the main belt as it has been showed in [1]. In these cases, both asteroids in the pair have nearly identical osculating Keplerian orbits. They may represent remnants of yet-to-be-characterized asteroid collisions, be fragments of asteroids that underwent rotational fission and/or components of dissolved binaries.

Methods: We apply natural metrics (Kholshevnikov metrics) [2] defined in the space of Keplerian orbits to search for asteroids in close orbits. We use as a metric ρ the distance between two orbits in the five-dimensional space of Keplerian orbits. We have used 582 120 orbits of asteroids (using both numbered and multiopposition objects) from the Asteroids Dynamic Site — AstDyS (http://hamilton.dm.unipi.it/astdys) (06.03.2018 release). The metric ρ has been calculated to search for asteroids on close pairs. We have identified new asteroid pairs with a possible common origin. Once the asteroid pairs candidates are identified, we analyze their dynamical evolution. We consider dynamical evolution of 87 the tightest pairs with $\rho < 0.002$ (au)$^{1/2}$ ($\rho^2 < 600$ km). To carry out high accuracy numerical simulation is necessary to take the Yarkovsky effect into account. We numerically integrated the orbits of pairs with backward in time (a time span of 2×10^5 years) with the code known as Orbit9 (the OrbFit Software Package (http://adams.dm.unipi.it/orbfit/)). The numerical integrations were made taking the nominal orbits given by AstDyS database as initial conditions. The eight planets and the dwarf planet Pluto were integrated consistently. In total, we used 7 test orbits for each of the two paired orbits that were assigned different values of da/dt (secular value of the semimajor axis drift rate due to the Yarkovsky effect). The test values were chosen as $da/dt = 0, \pm 10^{-5}, \pm 10^{-4}, \pm 10^{-3}$ au/Myr. In total, we produced 49 possible past orbit histories for each asteroid pair that differ by magnitude of Yarkovsky thermal drag. In this context, this calculation is of great importance because the slow drift in semimajor axis due to the Yarkovsky effect can produce amplified effects on other orbital elements (e.g., [3]).

Results and discussion: To simulate the long-term dynamical evolution of small asteroids, required to calculate the proper orbital elements involved in the computation of the metrics, the Yarkovsky effect has been taken into account. The Yarkovsky effect produces a small but significant force that affects the orbital motion of asteroids smaller than 30–40 km in diameter [4]. The secular perturbations of the semimajor axis induced by the Yarkovsky effect produce a drift that amounts from 0.0001 to 0.01 au/Myr [5]. The diurnal component of the Yarkovsky effect can produce a positive or negative change of the semimajor axis, being maximum at 0° and 180° which are the asteroid spin axis obliquity values [4], [5]. Investigating the dynamical evolution of asteroid pairs on close orbits implies to carry out both astrometric and photometric observations that let us calculate the values of the parameters involved in the computation of the Yarkovsky effect [6]. The use of extensive photometric observations of an asteroid together with the light curve inversion technique may lead us directly to determine its rotation state and shape. We point out the fact that spectroscopic observations can provide more data to decide about possible genetic relationships of the asteroid pair members (see e.g. [7]).

This research is part of the **K**ourovka **AS**teroid **PA**irs **R**esearch (KASPAR) project that started in Kourovka Astronomical Observatory of the Ural Federal University in September 2017. The KASPAR project includes not only the observational side, involving astrometric and photometric observations of asteroid pairs on close orbits, but also its theoretical and computational counterpart involving numerical simulations of the dynamical evolution of such candidate pairs that take the Yarkovsky effect into account to calculate their proper orbital elements. The drifting minima method [8] is using to determinate direction of rotation (prograde or retrograde). The photometric observations have been made for the asteroids (1270) Datura, (6070) Rheinland, (8008) 1988 TQ_4 and (56048) 1998 XV_{39}, and the asteroid pair (28816) Kimneville and (85834) 1998 XM_{74}.

Conclusions: We showed that the Yarkovsky effect was required to take into account accurately to carry out precise simulation of dynamical evolution of the asteroid pairs. Determination of physical and rotational parameters of asteroids is needed to solve this problem.

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