SOME EXAMPLES OF CLOSE ASTEROID PAIRS INTERACTIONS WITH RESONANCES.

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Introduction: The dynamic evolution of asteroids in the vicinity of resonances can lead to the transition of the main belt asteroids into the near-Earth asteroids. The picture becomes much more complicated when the evolution of pairs of asteroids in close orbits is considered. For young pairs in the inner region of the Asteroid Belt, along with resonances, can have an approach by Mars, which can accelerate the transition of the asteroid to the near-Earth asteroids. Some examples of the resonance interactions of young families and pairs are known; first of all, it is Datura family in 9:16 resonance with Mars [1]. Pravec et al. [2] note that pair (49791) 1999 XF31 and (436459) 2011 CL97 chaotic orbits may be explained by 15:8 mean motion resonance with Mars (15–8M). Duddy et al. [3] pointed that pair (7343) Ockeghem and (154634) 2003 XX38 is in 2–1J–1M three-body resonance with Jupiter and Mars. This paper gives some new examples of resonance perturbed asteroid pairs that can have close approaches by Mars.

Method: The equations of the motion were numerically integrated to study the dynamic evolution of asteroid families. The orbits integrated over 800 kyr in the past using the N-body integrator Mercury [4] and the Everhart integration method and over 1 Myr in the past using Orbit9 software [5].

To study interaction considered pair with resonance and determine the position of resonance center (chaotic zone center), we apply the method described in [6]. In particular, we use the integration of orbits of asteroids with significant values of the Yarkovsky effect. We used absolute values of the Yarkovsky acceleration $|A_2| = 1 \cdot 10^{-13}$ au/day^2 and semi-major axis drift $|da/dt| = 10^{-4}$ au/Myr. For each asteroid, three variants of evolution were considered: without considering the Yarkovsky effect, with positive and negative values of acceleration A_2 or rate of drift da/dt.

Results: Among the pairs of asteroids studied in [2], four young pairs were found, which, in addition to resonant interaction, can also experience close encounters with Mars: (9068) 1993 OD – (455327) 2002 OP28, (88666) 2001 RP79 – (501710) 2014 UY23, (313701) 2003 UN3 – (531260) 2012 KL9, and (348452) 2005 RU20 – (418312) 2008 FF88. Approaches to Mars have the strongest effect on the orbital evolution of pairs (9068) 1993 OD – (455327) 2002 OP28 and (88666) 2001 RP79 – (501710) 2014 UY23, moving in the vicinity of the 10–7S–3J three-body resonance with Saturn and Jupiter. Approaches to Mars make it much more difficult to estimate the age of pairs. For the pair (88666) 2001 RP79 – (501710) 2014 UY23, the first close encounter with Mars occurs 36400 years after the start of modeling and, in all considered integration options, leads to an abrupt change in the semi-major axes of both asteroids of the pair. A similar character of behavior is realized for the pair (9068) 1993 OD – (455327) 2002 OP28, in which approaches to Mars begin 47 years after the start of integration. The closest encounters with Mars give in table 1. Time t is counted from MJD 58800 (13 November 2019).

Table 1. The closest encounters of the asteroid pairs in close orbits with Mars

da/dt [au/Myr]	Asteroid pair	t [years]	Δr [au]	Asteroid pair	t [years]	Δr [au]
0	(88666) 2001 RP79	–49 696	0.15	(9068) 1993 OD	–324 240	0.035
0	(501710) 2014 UY23	–37 500	0.20	(455327) 2002 OP28	–852 756	0.059
10^{-4}	(88666) 2001 RP79	–40 543	0.13	(9068) 1993 OD	–282 992	0.050
10^{-4}	(501710) 2014 UY23	–38 638	0.12	(455327) 2002 OP28	–77 941	0.028
-10^{-4}	(88666) 2001 RP79	–38 339	0.036	(9068) 1993 OD	–497 234	0.084
-10^{-4}	(501710) 2014 UY23	–47 287	0.20	(455327) 2002 OP28	–808 215	0.050

Discussion: For the four selected pairs, a probabilistic evolution study is being carried out to investigate the conditions conducive to the preservation or decay of asteroid pairs in close orbits during the asteroid transition from the main belt to the group near-Earth asteroids.

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