Investigation of stability of NEAs orbital resonance motions by numerical methods

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The problem of orbital stability of resonance Near-Earth asteroids (NEAs) is considered. Most of NEAs have multiple close approaches to the inner major planets. The investigation of motion of such objects presents a complicated problem of celestial mechanics related with the instability of solutions of differential equations and motions in the vicinity of close approaches. Investigation of stability of orbital resonances in the motion of NEAs is very important because the stable resonances make it possible to preserve certain relative geometric configurations of an asteroid and a planet [1] including minimal distances between orbits. Depending on the initial parameters of orbits the resonances either protect asteroids from close encounters and collisions with planets prolonging the time of their life or promote 'sweeping up' of asteroids from the neighborhood of the orbit of the corresponding planet.

The technique of the investigation of NEAs orbital stability has been developed by author on the basis of the construction of possible motion domains (R) of asteroids.

By assuming that the distribution law for errors of observations is close to the normal one, the initial domains R_0 of possible motion for the object under investigation have been constructed on the basis of the estimation of the vector $\hat{q}_0$ of initial dynamical parameters and the covariance matrix $\hat{D}_0$ of their errors obtained from analyzing the observations by the least-squares method (LSM)

$$R_0 : R_0(\hat{q}_0, k^2\hat{D}_0), \quad k = 1, 2, 3, \dots. \tag{1}$$

Here k is the gain factor of LSM-estimations of the covariance matrix $\hat{D}_0$ ($k = 3$ corresponds to the 'three sigma' rule).

First of all, the initial domain R_0 has been determined at $k = 1$ and the evolution of the domain has been considered over a certain time interval. The initial set of orbits has been obtained for n test particles with respect to a given center (an initial epoch) with the help of the random number generator according to the normal distribution law and the covariance matrix $\hat{D}_0$ of errors. Further, several initial domains R_0 (1) have been constructed at various values of k . If the scattering of the trajectories of the test particles is not extensive over the considered time interval then new initial domains are constructed at $k > 1$ (e. g. $k = 10, 20, \ldots$). Otherwise it is done for $k < 1$ (e.g., $k = 0.1, 0.01, \ldots$). Varying the coefficient k by this way and considering the evolution of the initial sets of the test orbits for each k, we have determined the domain of the initial parameters $\hat{q}_0$ in which the resonant relations of mean motions (if they are present) remain to be stable over a time interval under consideration.

This approach has been used to investigate the stability of the orbital resonances of some single NEAs [2] and of NEAs assembly close to the 3:1 resonance with Jupiter. For each asteroid the problem has been solved beginning from the analysis of observations and refining the initial parameters of the orbit. The differential equations of motion [3] have been integrated numerically by Everhart 19th order method. Perturbations of the major planets and the Moon have been taken into account using the positions of the planets given by DE200/LE200 and DE406. The initial osculating elements of orbits have been taken from Bowell catalog.

Domains of possible motions have been constructed over the time interval 6000 years. The evolution of osculating orbital elements, resonance band α ($\alpha = k_1 n_a - k_2 n_p$, where n_a is the mean motion of the asteroid, n_p is the mean motion of a planet and k_1, k_2 are integers) and critical arguments has been considered for each investigated object and for corresponding ensembles of 100 clones.

References

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3. Bordovitsyna T. V, Avdyushev V. A. and Titarenko V. P. Numerical integration in the general three-bodies problem. Research in Ballistics and Contiguous Problems of Dynamics, Tomsk: Tomsk State University Publishers, 1998, **2**, 164–168 (in Russian).