IAA Transactions, No. 8, “Celestial Mechanics”, 2002

Dynamic evolution of resonance orbits of exoplanets in system 47 Uma

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The orbits of the major and minor planets of the Solar system indicate that their dynamic evolution is essentially influenced by the effects of orbital resonance interactions. Among dynamic systems the most amplitudes are caused by the resonances of Lindblad – orbital commensurabilities of the first order with different multiples k:

$$|kn_1 - (k+1)n_2| \leq n_2\sqrt{\mu}O(1)$$

This inequality executes at initial moment of time. Here n_1, n_2, are average motions (frequencies) of material points P_1, P_2 with masses $m_1 = \mu\alpha_1$, $m_2 = \mu\alpha_2$, in units of mass of the ‘central body P_0’ (the star), $\mu \ll 1$, $k \in N$, and α_1, α_2 are some real constants.

In the row of events (under libration type of motion) the resonance effects can lead to stable orbital motions. One may expect that the orbital resonances can exist not only in the Solar system, but also in other star systems. But presently, there is no due attention to this question in celestial mechanics studies.

The improvement of observing facilities and methods of search permitted to find significant number (~ 100) of exoplanets outside the Solar system. The rate of discovery of exoplanets steadily increases. All exoplanets were discovered by indirect methods based on analysis of the interference for stars with expected presence of planetary systems (accuracy of the method based on the variations of beam velocities approaches to 1 m/s in these measurements). For eight discovered exoplanet systems there exist more than one planet and in all these cases there are orbital resonances.

In preceding works [1-3] an analytical theory of the duel–frequency dynamic systems has been elaborated allowing to interpret the evolution of orbital elements of gravitational bodies for time lags of order $1/\mu$. The use of rigorously motivated asymptotic methods results in mathematically correct analytical solution in terms of double periodic elliptic functions of Weierstrass. High sensitivity to initial conditions involves dynamical unstability and the possibility of arising of chaos preventing to determine realistically–significant result for time lags $t \gg \mu^{-1}$.

The developed theoretical technique was applied to predetermine the exoplanet system 47 Ursa Majoris (resonance 2:1) in which the first component was discovered eight years ago, but the second (external) one was discovered on August 15, 2001. At present, among all known exoplanets this external component possesses the largest semi–major axis $a_2 = 3,73$ a.e., so the system 47 Uma looks like our Solar system.

Within inaccuracy in values of initial orbital elements (resulted from observations) and values of masses of the gravitational bodies one may conclude that in system 47 Ursa Majoris there exist three families of stationary solutions in the configuration (phase) space. One of them is unstable in the sense of Lyapunov (the type 'turn gray'), but two other represent the 'centers of stability'. The trajectories of motion in the considered system can be located in vicinities of a stable stationary point in accordance with the circulation nature of motion. The evolution periods of changing of the semi–major axes of the orbits of components P_1 and P_2 in system 47 Ursa Majoris have been evaluated permitting to perform qualitative studies of the orbital features of these components.

Thus, the orbital resonances are widespread not only in the Solar system, but also in exoplanet systems and represent an important stage in the orbital evolution. The developed analytical techniques for major and minor planets, comets, objects of Kuiper belt, satellite systems of the bodies of the Solar system can be successfully applied in the case of exoplanets as well.

This work is supported by grant RSSI 00-02-17744.

References

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