Quasi-satellite regime of motion of small celestial bodies: Formation and destruction

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The investigations on long-term evolution of asteroid's orbits are crucial to understanding the route through which the present configuration of the Solar System came to be. The so-called coorbiting asteroids (which share their orbits with major planets) attract the special attention in this connection: are they the primordial remnants of the building blocks of the corresponding major planet or migrants from the other parts of the Solar System?

The most well known examples of co-orbits in natural objects are provided by Trojan groups of asteroids and by asteroids moving in horseshoe orbits. These asteroids are precluded from having relatively close encounters with their host planets. However, there exists another class of coorbiting objects in which the opposite is true: they remain very near to the host planet eternally or, at least, for long enough time. Since typically they never enter the planet's Hill sphere, they cannot be considered as satellites in the usual sense of the word. In order to emphasize this specific they are called quasi-satellites (QS).

Under the scope of three-body problem ”Sun-planet-asteroid” the motion of asteroid in QS-orbit corresponds to 1:1 mean motion resonance. In the case of mean-motion resonance three dynamical processes can be distinguished: ”fast” process corresponds to planet and asteroid motions in orbit, ”semi-fast” process is variation of the resonance argument (which describes the relative position of the planet and the asteroid in their orbital motions), and, finally, ”slow” process is the secular evolution of the orbit shape (characterized by the eccentricity) and orientation (it depends on the ascending node longitude, inclination and argument of pericenter).

To study the ”slow” process we have constructed the evolutionary equations by means of numerical averaging over the ”fast” and ”semi-fast” motions. As a specific feature of these evolutionary equations we should mention that their right hand sides are not uniquely defined by values of the ”slow” variables in some domains of these variables. The ambiguity appears since the averaging can be done over ”semi-fast” processes with different qualitative properties — in other words, it can be done over QS-orbit, HS(horseshoe)-orbit, etc. The consideration of this ambiguity provides us an opportunity to predict whether the motions in QS- or HS-orbits are permanent or not; for non-permanent motions in QS-orbits the conditions of capture into this regime and escape from it can be established.

To illustrate the typical rates of the orbital elements' secular evolution, the dynamics of the near-Earth asteroid 2004 GU_9 was studied. This asteroid will keep describing a QS-orbit for the next several hundreds of years.

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