SOME PECULIARITIES IN THE HILDAS' MOTION

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Some new peculiarities in the motion of the asteroids of the Hilda group are revealed with the help of the EPOS software package. The most interesting is the *Hildas' Triangle* – the stable dynamical structure that specifically interacts with Jupiter, Trojans and with the external part of the Main Belt of asteroids.

The study of the asteroids of the Hilda group (or simply the Hildas) has a long history and the wide variety of methods: analytical and numerical, statistical and astrophysical (see for example: Moons, 1997; Dahlgren and Lagerquist, 1995; Gil-Hutton and Brunini, 2000) and others. The tools developed within the EPOS software package allowed the use of additional approach – the phenomenological one. By this way some new peculiarities in the motion of the Hilda-type asteroids were revealed.

EPOS (**E**phemeris **P**rogram for the **O**bjects of the **S**olar system) is the software package (the authors: V.N.L'vov, R.I.Smekhacheva, S.D.Tsekmejster) created at Pulkovo and now being developed as the Windows application. EPOS is useful for solution of a set of tasks including the modeling of the orbital motion of the Solar system objects. The heliocentric rectangular coordinates obtained by integration of the equations of the object's perturbed motion are mapped to the screen coordinates. The picture is generated as if it would be observed by the camera with some fixed field of view that is able to move with respect to longitude, latitude and radius-vector. One can look at and save to a file a frame with the image of all necessary objects for every specified moment. A series of such frames forms the basis of a computer animation that can be generated by the program in the real time mode or later by other packages.

The program can work in two modes – "Orbits" and "Swarms". The fist mode illustrates the motion of alone or of many objects along with the images of orbits and axes, apsidal and nodal lines and the fragments of the ecliptic plane. The useful property of this mode is the opportunity to accumulate the images of lines that helps to follow their evolution in time. The second mode shows simultaneously a great number of objects from one or several catalogs that correspond to a multitude with some specified qualities. The objects can be drawn as the points or the circles of predefined size. It is possible to distinguish a few objects from the swarm in order to better illustrate their motion. As for the others one can get the data simply by a mouse clicking when a cursor is pointed to an object. The second mode in particular allowed to reveal some new peculiarities in the Hildas' motion.

It is well known that in the most cases the asteroids are ejected from the regions they occupy due to the resonances in a mean motion with respect to Jupiter, and it is the reason of the existence of the Kirkwood gaps in the Main Belt of asteroids. But there are the resonances that, on the contrary, promote the existence of some stable groups, for example 1:1 and 3:2. The asteroids in the 1:1 mean motion resonance with Jupiter are called the Trojans in honor of the members of the Trojan War. They are situated near the Lagrangian triangular libration points of Jupiter L_4 (the Greeks) and L_5 (the Trojans). The third apex of this equilateral triangle is situated behind the Sun and opposite to Jupiter. On the whole Jupiter can be said to move surrounded by two swarms of asteroids one of which is ahead of Jupiter at 60 degrees of longitude and the other remains behind it at the same value.

The Hildas demonstrate another nature of stability. They are the asteroids in the 3:2 mean motion resonance with Jupiter. They move along the orbits with a semimajor axis near 4.0 AU and the moderate values of eccentricity (up to 0.3) and inclination (up to 20°). Unlike the Trojans they may have any difference in longitude with Jupiter nevertheless avoiding the dangerous approaches to the planet.

The data are used here from the ASTORB catalog of E.Bowell (ftp://ftp.lowell.edu/pub/elgb/astorb.html) that for September 21, 2004 included the orbital elements and other information for all 260102 asteroids known at the moment. Within the interval of 440" - 465" of daily motion 1020 objects were selected, though not all of them may be related to the Hildas (see below). The numerical integration of the each object's equations of motion is performed by the Everhart method taking into account the perturbations from all major planets. The heliocentric rectangular coordinates are transformed to the screen positions that are the base of the drawing reflecting the asteroidal configurations for specified moment. At that the following peculiarities were found.

The Hildas taken together constitute the figure of triangle with slightly convex sides and trimmed apexes in the triangular libration points of Jupiter – the **"Hildas' Triangle"**. The thickness of the asteroidal stream within the sides of the triangle is about 1 AU, and in the apexes this value is 20–40 % greater. The Fig. 1 shows the positions of the Hildas (black) against a background of all known asteroids (gray) up to Jupiter's orbit for the date January 1, 2005.

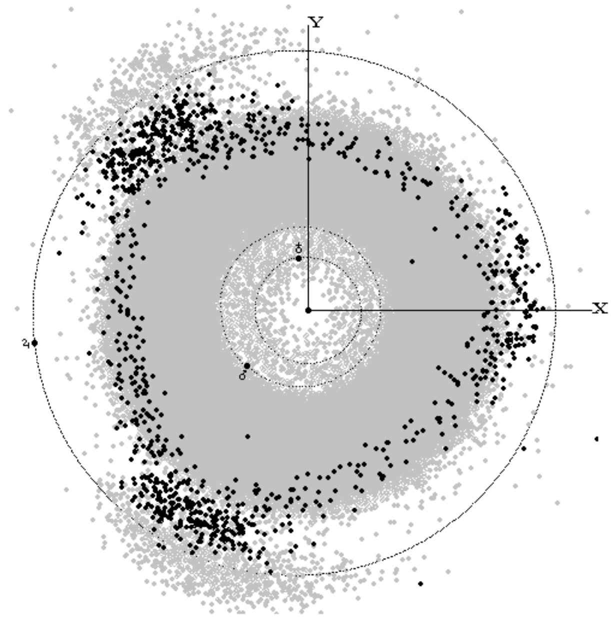

Fig.1. The Hildas' Triangle against a background of all known asteroids up to Jupiter's orbit

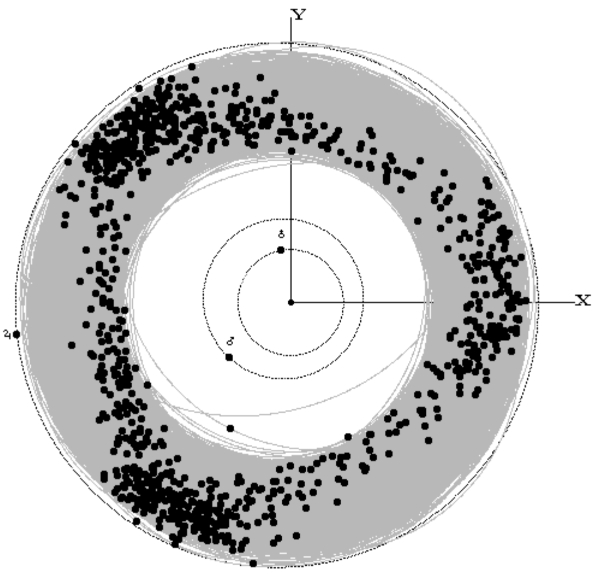

Fig.2. The positions of the Hildas against a background of their orbits

Let us emphasize once more: at any moment the Hildas constitute this triangular configuration although each of the objects moves along its elliptic orbit, and all orbits together form quite predicted ring. The Fig. 2 illustrates this statement showing the Hildas' positions (black) against a background of their orbits. For majority of these asteroids their position in orbit may be arbitrary except for the external parts of apexes (the objects near aphelion) and the middles of the sides (the objects near perihelion).

The numerical integration of the equations of motion of these objects confirms this phenomenon for the time interval as long as at least 6 thousand years (±3 thousand years from Christmas). It turns out that **the Hildas' Triangle is dynamically stable for rather long time span**. How long is this span it is the question for future research.

The typical Hildas have a retrograde perihelion motion. At the average the lesser is the orbital eccentricity the greater is the velocity of perihelion motion. At the same time the nodes move more slowly. All typical objects in aphelion seemingly would approach closely to

Jupiter that should be very dangerous for them. But the specific evolution of the orbital elements helps to avoid this situation, and the conjunctions with Jupiter occur only near the perihelion of an asteroid. Moreover the line connecting Jupiter and asteroid oscillates near the apsidal line with different amplitude and the period of 2.5 – 3.0 centuries. This fact is known long ago (Schubart, 1982) and is confirmed in the present work. The Fig. 3 shows the variation of osculating elements of the asteroid Hilda where the notations are as follows: ω - argument of perihelion, Ω - longitude of node, e - eccentricity, i – obliquity, a - semimajor axis, and Q - aphelion distance.

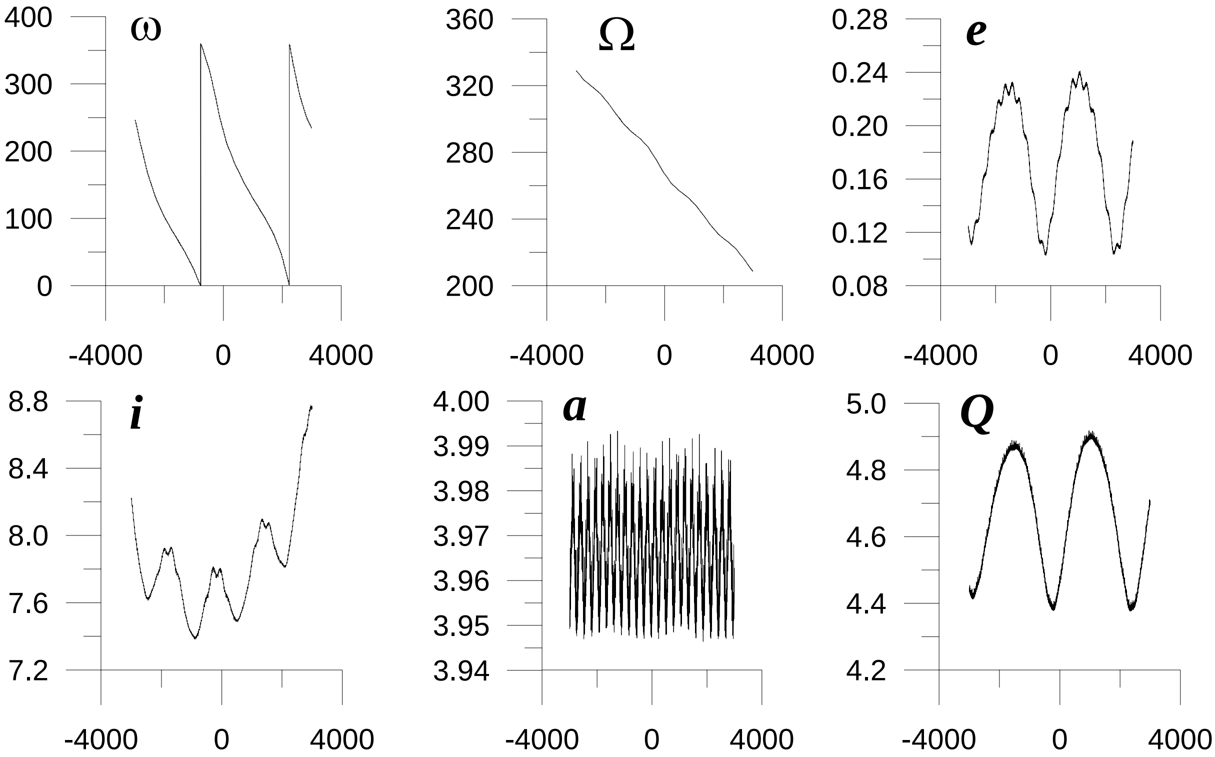

Fig. 3. The variations of osculating elements of the asteroid Hilda.

It is impossible to relate some of selected asteroids to the Hilda group because their orbits exceed the bounds of Jupiter's orbit. Their part may run up to 25–30 % of the total amount. These objects show the signs of chaotic motion. Many of them have gone through the close approaches to Jupiter and their orbits have undergone very large changes. Whether all of them are ejected beyond the limits of Jupiter's orbit or some of them will have another virtue? To answer this question one should test their motion for much more long time spans.

In addition to the fact that the Hildas' triangle revolves connected to Jupiter the quasi-periodical waves of the stream density of asteroids in every point are noticed, as if the triangle breathes. But at any time the density of objects in the apexes is more than twice larger than the density of objects within the sides. It is to be added that the Hildas rest at the apexes 5.0–5.5 years on the average whereas they move along the sides more quickly, for 2.5–3.0 years.

Despite the fact that the triangle is close to the equilateral one some asymmetry still exists in it. Due to the eccentricity of Jupiter's orbit the side L_4–L_5 slightly differs from two other sides. When Jupiter is in aphelion the mean velocity of the objects moving along this side is somewhat smaller than that of the objects related to the other sides. For Jupiter's position in perihelion the picture is reverse.

At the apexes of the triangle corresponding to the points L_4 and L_5 the Hildas are the neighbors of the Trojans and at the mid-sides they are close to the asteroids of the external part of the Main Belt. The velocity dispersion of Hildas is more evident than that of Trojans in the regions of their intersection. It is to be noted that the dispersion of the Trojans in inclination is as twice as the Hildas' one. Due to this not less than a quarter of the Trojans could not intersect with the Hildas, and a great deal of others is situated beyond the limits of Jupiter's orbit. Therefore these regions of intersection can not be too vast. This statement is illustrated by the Fig. 4 that along with Jupiter in the foreground shows the Hildas (black) and the Trojans (gray) visible from the point in the ecliptic plane with the longitude near 190 degrees for the date January 1, 2005. One can see the spherical form of the Trojan swarms.

Fig. 4. The Hildas and the Trojans visible in the ecliptic plane

When moving along each side of the triangle the Hildas undergo less long as compared with the Trojans but more numerous neighborhood with the asteroids of the outer Main Belt. But here the velocity dispersion is much smaller.

The revealed peculiarities in the Hildas' motion base on the data for a few hundred objects known to the date and generate still more questions. The new observations are urgent for the growth of the list of Hildas. And these observations are most favorable when the Earth is near conjunction with the mid-sides of the Hildas' Triangle. These moments occur each 4 and 1/3 months. And the gain in brilliance for the objects of the same size as compared to the apexes could run up to 2.5 magnitudes.

Thus the Hildas can visit the regions of the Solar system located within the ring at least 2 AU wide up to Jupiter's orbit. This will entail the variety of physical conditions and the neighborhood with various groups of asteroids. But this fact could result in the revision of some formed conceptions about the nature of these objects.

References

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