DANCES WITH JUPITER- HILDAS AND TROJANS

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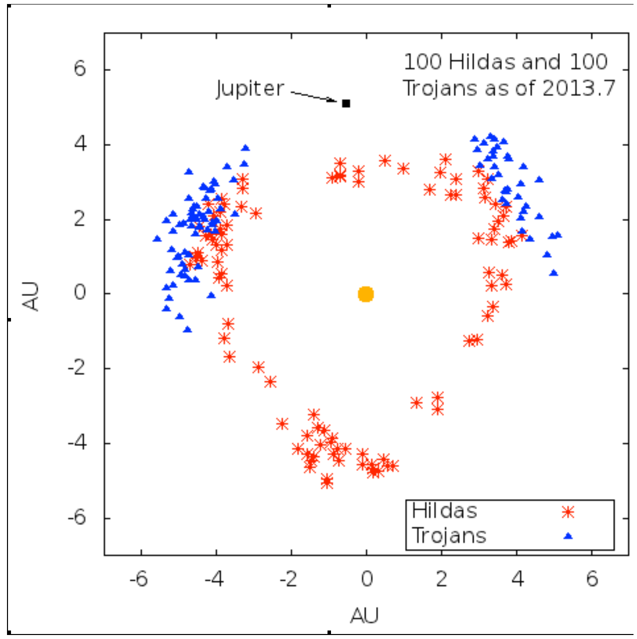
The Hildas and Jovian Trojans are minor bodies closely linked dynamically to Jupiter. Recent ideas on the history of the solar system suggest these objects may be more akin to minor bodies in the outer solar system (Kuiper belt objects) than to the rocky bodies in the main asteroid belt. Here I review the present status of lightcurve observations of these objects. I introduce a web site that has information on observing the Hildas.

The Hildas and Trojans are minor solar system bodies in orbital resonance with Jupiter. The Trojans are in a 1:1 resonance with Jupiter, meaning they orbit with the Sun with same period as Jupiter (11.86 yr). They have average semi-major axes equal to that of Jupiter (5.20 AU). These objects are found near the L4 and L5 Lagrangian points of the Sun-Jupiter system, in two clouds each centered 60 degrees away from Jupiter along its orbit.

The Hildas are in a 3:2 resonance with Jupiter, meaning that they orbit the Sun 3 times for every 2 times that Jupiter does. Therefore the Hildas have orbital periods 2/3 that of Jupiter, 7.91 yr, and they have semi-major axes around 3.95 AU. The Hildas have orbital eccentricities averaging about 0.2, so that a typical Hilda ranges between ~ 3.2 and ~ 4.7 AU from the Sun each orbit. A plot of the positions of the Hildas at any instant in time shows them spread on a quasi-triangular array. Jupiter is always located along one of the sides of the triangle, so that no Hilda approaches Jupiter closer than 1 AU or so. The triangular *pattern* rotates around the Sun with the period of Jupiter, yet each Hilda orbits the Sun every 7.91 yr on its own elliptical orbit. Each Hilda must move through the pattern and is not fixed relative to the pattern. The pattern is due to the fact that the orbital orientation of each Hilda ellipse and its orbital phase is related so that each object is always near perihelion when it crosses the line between the Sun and Jupiter. If there were no such relationship, a Hilda would soon find itself at aphelion near Jupiter, and it would be gravitationally scattered by Jupiter or impact Jupiter.

The above is only an outline of the motions of the Hildas. The motion is much better explained by an animation. I have created a web site (Romanishin 2012) that has an animated gif showing the motion of 100 Hildas and 100 Trojans. One frame of the gif, showing the positions of the Hildas, Trojans, Jupiter and the Sun, projected onto the plane of the Solar System for an arbitrary date, is shown in the accompanying Figure.

Origin and physical properties. What are the basic physical properties of the Hildas and Trojans? Recent ideas on the ancient history of the solar system suggest the Jovian Trojans may have been captured into their present orbits from a place of origin much farther from the Sun (Morbidelli *et al*. 2005). This may also be true for the Hildas (Broz *et al.* 2011). This capture may have occurred during a possible dramatic rearrangement of the giant planets about 3.8 billion years ago. This basic idea is called the Nice model (Levison *et al.* 2008). If anything like the Nice model is actually correct, then the Hildas and Trojans may be more akin to the minor bodies in the outer solar system, the Kuiper belt objects and Centaurs, than to the rocky bodies of the main asteroid belt.



Lightcurves of Hildas and Trojans

Lightcurve observations, in particular at multiple epochs so that shapes can be determined, are a simple (and low cost) way to learn something about the physical characteristics of minor bodies. How many of the Hildas and Trojans objects have currently measured lightcurves? As of August 2012, more than 5000 Jovian Trojans and 4000 Hildas are known (JPL Small Body Database Search Engine). To narrow down the numbers to a more manageable size, I have made lists of the 100 Hildas and the 100 Trojans with the lowest absolute mag (H mag) values. These objects, assuming all objects in each class have the same albedo, would be the largest such objects. The lists can be found on my web site. These lists provide samples of objects chosen without regard to the rotational periods of the objects. Measuring periods for such an unbiased sample is important to do proper statistical comparison of rotational properties of different classes of objects. The selection of objects with currently known lightcurves undoubtedly has biases in it. For example, objects with very long periods are probably underrepresented, simply because of the large amount of time needed to measure such objects.

The Hilda100 and Trojan100 lists were compared with the June 2012 Asteroid Lightcurve Database (LCDB) (Warner *et al*., 2012). For the Trojans, 87 objects have a definite value for rotational period listed, and 1 object has a lower limit. The 88 object lightcurves comprise 47 with quality code of 3 or 3-, 37 with code 2, 2- or 2+ and 4 with code 1. For the Hildas, the situation is much less sanguine. Only 44 objects have definite period values, and 8 have lower limits. Quality code 3 or 3- apply to only 22 Hildas, quality code 2, 2- or 2+ to another 22, and 8 have code 1.

The rotational period of a minor body is the most fundamental datum we can learn about a body from its lightcurve. Far more physically valuable is to measure the amplitude and shape of a lightcurve at various places in the orbit of a body. From these, information on the basic shape and rotational pole position of the object can be obtained. In the LCDB, the existence of published data on pole position/shape model is given by the SAM flag. Only 2 of the Trojan100 and 5 of the Hilda100 have published information on pole position/ shape as indicated by a "Y" in the SAM column in LC_SUM_PUB.TXT.

Information for observing Hildas. To assist observers who might wish to observe lightcurves of Hildas, I have prepared tables on my website showing the basic circumstances of the oppositions of each of the Hilda100 objects for the next 8 years. For example, here is the entry for 1911 Schubart, the first object in the Hilda100 list that has no published lightcurve information:

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1911 Schubart (1973 UD)
2012-Sep-24  δ=+02  mag=15.7  elong=177.9  r=4.1
2013-Nov-21  δ=+21  mag=14.9  elong=178.3  r=3.5
2015-Feb-04  δ=+15  mag=14.7  elong=178.8  r=3.4
2016-Apr-09  δ=-09  mag=15.5  elong=177.8  r=3.9
2017-May-26  δ=-22  mag=16.1  elong=178.5  r=4.4
2018-Jul-05  δ=-22  mag=16.3  elong=179.9  r=4.6
2019-Aug-13  δ=-13  mag=16.2  elong=178.8  r=4.5
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The first column gives the date on which the object has the greatest elongation angle from the Sun. This is very close to the instant of opposition. The second column (δ) gives the declination of the object on the date in column 1. The third column gives an estimate of the apparent mag of the object. The fourth column is the solar elongation angle in degrees and the last column is the heliocentric distance of the object in AU. Perusal of columns 2 and 3 will quickly allow an observer to find objects that might be bright enough and at an acceptable declination for their observatory. All data comes from the JPL online ephemeris generator (JPL Horizons).

Final words. The Hildas and Trojans are interesting minor bodies that may help delineate an important ancient era in the history of the solar system. Lightcurve observations, particularly those that can yield shapes, are a practical way to study these objects. I hope that web site I have developed will help encourage observers to observe these objects, particularly the Hildas.

References

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JPL Small Body Database Search Engine *http://ssd.jpl.nasa.gov/sbdb_query.cgi*

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