A Search for High-Inclination Minor Planets

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There is a renewed interest in the Solar System and its planets. Incredible photos are transmitted back from distant space probes and on-site physical investigations have become possible. An increasing number of new planets are being discovered with large, ground-based telescopes. However, most of the known objects lie in or near the plane of the Earth's orbit, the Ecliptic. Little is known about the objects that presumably exist high above or far below this plane. How many are there and how did they get there? Drs. Lutz Schmadel and Joachim Schubart from Astronomisches Recheninstitut in Heidelberg, Fed. Rep. of Germany, describe a search programme with the ESO Schmidt telescope that aims at the discovery of out-of-the-Ecliptic minor planets.

Most searches for faint minor planets have been based on photographic plates of fields close to the Ecliptic. However, Schubart recently indicated the possible existence of faint, resonant asteroids of Hilda und Thule types at high inclination and predicted favourable conditions for discovery of such objects at rather high ecliptical latitudes (35 to 60 degrees). We have therefore carried out two pilot surveys with the ESO 1 m Schmidt in order to discover highly-inclined asteroidal orbits. The ESO astronomers H.E. Schuster and R.M. West participated in this programme.

Earlier surveys that aimed at the detection of faint minor planets clearly favoured objects with a small orbital inclination relative to the plane of the Ecliptic. This is particularly true for the now famous Palomar-Leiden Survey which was based on plates taken with the 48-inch Palomar Schmidt telescope in September-October 1960, since all the observed fields were comparatively close to the Ecliptic. Only a few attempts have so far been made in order to detect objects with high inclinations; e.g. the search by Schubart in 1960 with the 40 cm astrograph at the Sonneberg Observatory. By the way, the recently numbered minor planet (2000) HERSCHEL is a result of this work. It is of the so-called *Phocaea-type* (the elements of the prototype, (25) PHOCAEA, are a = 2.4 AU, e = 0.25 and i = 22°).

Orbital resonances

Asteroids with a resonance between their orbital periods and that of Jupiter have been known for many decades. Typical cases are the *Trojan* asteroids (1:1 resonance, that means that the respective periods are nearly equal) and the *Hilda* group planets (3:2 resonance). However, other theoretically possible resonances show no or only very few examples in nature. There are for instance only three numbered objects corresponding to the 2:1 or *Hecuba* case. These three objects are characterized by rather high orbital inclinations (20° to 35°). In this connection it is also interesting to note the recent ESO discovery of the Trojan-type planet 1976 UQ (see *Messenger* No. 8) which has a very large inclination, 39°.

Schubart has called attention to the possibility of the existence of different kinds of resonant motions in orbits with high inclinations. This refers to the *Hilda* (3:2) and *Thule* (4:3) resonance types. Theoretical considerations show a certain analogy to the resonance between the major planets Neptune and Pluto. The orbital periods of these planets are approximately characterized by a 2:3 ratio, and the orbit of Pluto is highly inclined with respect to that of Neptune so that close encounters cannot occur. In the same way the possible asteroids of Hilda and Thule type can avoid close approaches to Jupiter, both because of the resonance and because of a high inclination. Especially, the parts of the orbits with the largest heliocentric distances are always far above or below the orbital plane of Jupiter.

A Search with the ESO Schmidt

Minor planet surveys require telescopes of considerable aperture and with sufficiently wide field. The Palomar Schmidt and the ESO Schmidt are very well suited for this purpose. In a cooperation between the Astronomisches Recheninstitut and ESO we have started a small-scale survey for high-inclination asteroids. Two such searches took place during September/October and December 1977. The first one was aimed at the discovery of Thule-type objects, the second one especially at Hilda's. No objects with the predicted resonant periods were found in either of the investigations. This is not too surprising in first attempts since the objects are certainly very rare if they exist at all. Otherwise they would already have been detected by chance on plates taken for other purposes. Further attempts to discover such objects are scheduled for the near future.

Even if the whole project should not lead to the discovery of the expected types, it will make a valuable contribution to our knowledge about the statistics of highly-inclined minor planets, as seen from the by-products of the first survey. The most surprising event was the discovery of Comet Schuster 1977o (see *Messenger* No. 11). Besides this, Schuster found the fast-moving planet 1977 RC, a *Pallas*-type planet with a = 2.7 AU, e = 0.46, and i = 30°. This asteroid headed further south from the discovery field at latitude –40° and reached –50° in October 1977. While it was followed to this latitude, two further planets appeared on the plates. They are probably of the so-called *Hungaria* group which is characterized by a small semi-major axis and a high inclination. Together with 1977 RC, we discovered six additional minor planets on the very first plates including another Hungaria asteroid and a new Phocaea-type object.

The December 1977 search comprised two fields centered at ecliptical latitudes of –58° and –51°. We discovered no moving objects. Nevertheless, this result is statistically important since the observed field is larger than the field of our first attempt. By-products at such very high latitudes may sometimes occur, as was demonstrated by the above-mentioned 1977 RC or, for instance, by Object Lovas, which was discovered late in 1977 at a northern declination of about 80 degrees. This object was first believed to be a comet (1977 t) but was later found to be a minor planet of Pallas type.

Our next survey is scheduled for September 1978 and will be under way when this note appears in print. We shall again look for Hilda's but at the more moderate latitude of about –42°. Hopefully, there will at least be some interesting Phocaea or Pallas objects this time.