MANMADE OBJECTS–A SOURCE OF CONFUSION TO ASTEROID HUNTERS?

KAARE AKSNES
Jet Propulsion Laboratory
California Institute of Technology

On October 7, 8, and 9, 1970, Charles Kowal, in search of fast-moving asteroids, exposed three photographic plates of an area of the sky near the ecliptic with the 122 cm Schmidt reflector of the Hale Observatories. Several weeks later Eleanor Helin of the California Institute of Technology examined the plates under a blink microscope and discovered a fast-moving object of about 15 mag. During the 15 min exposures the object had left a slightly bumpy trail indicating light variations with a period of a few minutes.

Four positions of the object were reported to the author, who derived the heliocentric orbit defined in table I. From table II it is seen that the residuals of that orbit are not very satisfactory. Note that the third and the fourth position represent the end points of the same trail. There is a clear indication that after October 9, the predicted heliocentric positions would soon diverge from the actual positions. This circumstance, and the fact that the orbit is so similar to that of Earth, suggested that the object could actually be moving in an Earth-centered orbit. The orbital elements listed in the second column of table I were derived by means of a computer program for heliocentric orbits simply by introducing Earth's mass in place of the mass of the Sun, whose geocentric coordinates were replaced by zeros.

Interestingly enough, as seen from table I, most of the elements of the geocentric orbit fall between those of the strongly perturbed Earth satellite Explorer 33 (IMP 4) at two different epochs. Unfortunately, a complete and accurate set of orbital elements could not be obtained for this and most other satellites orbiting Earth at great distances. The elements shown in the table are taken from two issues of NASA Goddard Space Flight Center's *Satellite Situation Report* (1969, 1970). The rather different eccentricities may preclude that the object in question is Explorer 33, but there are many other candidates, including payloads and spent rockets.

The two sets of residuals listed in table II favor the geocentric orbit rather strongly. Not included in this table is a highly uncertain December 3, 1970, observation that agreed with the predicted geocentric position to within a degree, however. A fictitious fifth observation has been added to illustrate that

TABLE I.–*Orbital Elements*

Orbital elements	Heliocentric orbit[a]	Geocentric orbit[a]	Explorer 33 (IMP 4)[b]	
Epoch, ephemeris time	Oct. 8, 1970	Oct. 8, 1970	July 15, 1969	Nov. 30, 1970
T, ET	Dec. 6.8113, 1970	Oct. 13.1275, 1970		
ω (1950.0), deg	238.656	314.861		
Ω (1950.0), deg	196.888	226.071		
i (1950.0), deg	0.108	4.403	56.7	23.4
q	0.977 00 AU	60 934 km	267 000 km	197 000 km
e	0.052 38	0.859 74	0.523	0.444
a	1.031 00 AU	434 444 km	560 000 km	354 000 km
n, deg/day	0.941 50	10.914 54	7.34	14.47
P	1.0469 yr	32.9835 days	49.08 days	24.88 days

[a]Orbit referred to ecliptic.
[b]Orbit referred to celestial equator.

TABLE II.—*Residuals*

U.T. (1970)	α (1950)	δ (1950)	Heliocentric orbit		Geocentric orbit	
			$\Delta\alpha \cos\delta$	$\Delta\delta$	$\Delta\alpha \cos\delta$	$\Delta\delta$
Oct. 7.35088	$01^h\ 22^m\ 12^s.40$	10° 17′ 03″.0	−2″.6	−1″.0	−0″.3	0″.0
Oct. 8.36112	01 36 49.40	11 24 09.0	4.3	1.2	.5	−.1
Oct. 9.45256	01 56 10.00	12 51 35.0	4.9	.9	−2.0	.2
Oct. 9.46298	01 56 14.90	12 52 10.0	−4.0	−1.3	1.8	−.1
Oct. 10.00000[a]	02 11 25.80	14 06 18.0	990	360	0	0

[a]Fictitious observation satisfying geocentric orbit exactly

after October 9 the heliocentric motion falls very rapidly behind the geocentric motion. This is even more obvious from figure 1 where the object's geocentric angular velocity *df/dt* has been plotted against time. It seems that if the last observation had occurred a little later, the possibility of a heliocentric orbit could probably have been ruled out entirely, whereas if it occurred a little sooner it might not have been possible to distinguish the two types of orbits at all. For comparison, the apparent angular velocities of the asteroid Hermes, when it was closest to Earth in 1937, and of a fast-moving object recently observed by Lynds (Federer and Ashbrook, 1971; Marsden, 1971) are indicated in the figure. Apart from the Earth crossers, a typical asteroid would appear to move across the sky at a rate of a fraction of a degree per day.

It is, of course, important to establish as early as possible whether an observed fast-moving object is an asteroid or a manmade object of some type.

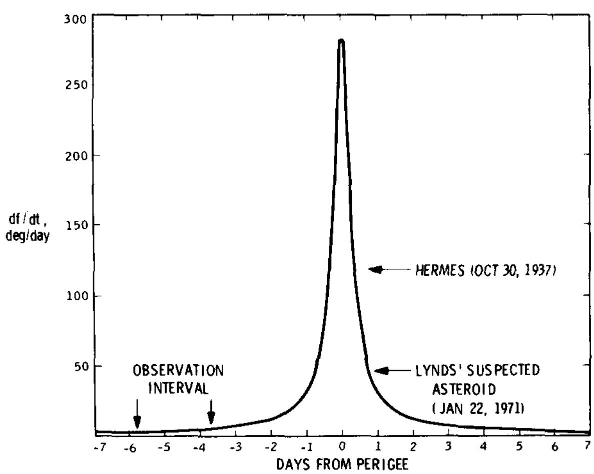

Figure 1.—Angular velocity versus time in geocentric orbit. a = 434 000 km, e = 0.860, and n = 10.915 deg/day.

We have just seen that the apparent motion of the object is not a reliable criterion for making such a distinction. What about the orientation of the orbital plane? Unfortunately, the artificial objects that get far enough away from Earth to be of interest here move in direct orbits close to the ecliptic, as do most of the asteroids. The best clue as to the true nature of a fast-moving object is probably to be found in its physical appearance. Unless a space probe is stabilized, it is likely to tumble with a consequent light variation having a period of perhaps a few minutes, as was the case with Helin's object. An asteroid would have to be very small to tumble that fast, the shortest period of light variation on record being $2^h\ 16^m\!.4$ for Icarus (Gehrels et al., 1970).

If the distance of the object can somehow be estimated (e.g., from its observed angular velocity), its size can be calculated on the basis of its apparent magnitude and an assumed albedo. Thus, when Helin's object was observed at about 15 mag, it was about 450 000 km from Earth, according to both orbits derived for it. On the assumption of full-phase illumination and an albedo of 0.07, typical for asteroids, a diameter of roughly 12 m (40 ft) results. This number can be reduced to one more appropriate for a space probe by adopting a much higher and presumably more realistic albedo. For the sake of argument, let us assume that Lynds' object has the same size. The reported magnitude of 10.5 to 11 then puts the object at a distance of about 60 000 km from Earth, which is close to the pericentric distance derived for Helin's object. It is therefore, perhaps, more likely that Lynds was observing an Earth satellite rather than an asteroid.

The main purpose of the above discussion has been to draw attention to the probably increasing problem of distinguishing fast-moving asteroids from manmade objects, and to establish the reality of the problem through an actual example. Unfortunately, a satisfactory solution to this problem has not been found.

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