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SATELLITE OF MINOR PLANET 532 HERCULINA DISCOVERED DURING OCCULTATION

by Dr. David W. Dunham

A satellite of 532 Herculina was discovered visually and confirmed photoelectrically at another station when the asteroid occulted 6.2 magnitude SAO 120774 on 1978 June 7. Two nights before the event William Penhallow obtained three astrometric plates of Herculina and the star at Quonochontaug Observatory, Rhode Island, U.S.A. He reduced his measurements of the plates and telephoned the writer the observed positions 32 hours before the event. I recalculated the path, finding that it would shift 2".1 north of the nominal prediction; the expected path now crossed Arizona (at very low altitude) and the San Gabriel Mountains north of Los Angeles! A plate taken a few weeks earlier could have spotted such a large ephemeris error and shown that the probability of the event occurring in the southwestern USA was good. In any case, I telephoned many IOTA members and professional astronomers interested in occultations, throughout California and Arizona. Observers in Mexico, Nevada, and Hawaii also were alerted.

The occultation shadow crossed California's Mojave Desert, where it was timed visually by IOTA members Keith Horne at Rosamond (duration 17^{s}3) and James McMahon near Four Corners (duration 20^{s}6). Mike A'Hearn, visiting from the University of Maryland, and Ted Bowell also recorded a 23^{s}5 occultation photoelectrically with Lowell Observatory's 107 cm telescope. Fortunately observing conditions were excellent and the observation successful in spite of the 2½° altitude above the western horizon (with the Sun 9° down in the east)! G. Taylor's and my recent analyses of the observation showed that the diameter of Herculina is 243 km, assuming the disc is circular. [This is about 10 per cent larger than the determinations based on radiometry and polarimetry. -- Editor]

McMahon waited until the following weekend to analyze his tape recording carefully before telephoning me the results. He said that observing conditions were good at his site, and claimed that the star disappeared completely six times within ± 2 minutes of the main event. During the 6 minutes he observed before this interval, and the 4 minutes that followed it (after which he stopped observing), the star appeared fuzzy due to the ≈ 8° altitude, but its brightness remained steady. Most of the secondary events were quite short, perhaps involving objects too small to occult the star at the other stations, but one event 97 seconds before the primary occultation had a 4^{s}0 duration. The Lowell photoelectric trace was examined at the corresponding point, and a 5^{s}3 occultation is evident there, with indications of the fade due to the star's diameter. The observations are consistent with a dynamically possible satellite 46 km in diameter and 0".866 or 977 km from Herculina projected in the plane of the sky.

The southern limit of the satellite occultation should have passed a few km north of Horne, so the fact that he saw no secondary occultation is consistent.

The satellite should be about 3.6 magnitudes fainter than Herculina, which was magnitude 9.3 at the time. At favorable elongations, such an object should be detectable with area scanners or by visual or photographic observation techniques; such observations are in progress at Lowell. The period of revolution about Herculina is probably 60 ± 30 hours.

Although this is the first confirmed satellite of a minor planet to be found, a number of such objects have been suggested by previous observations. [See the case of 6 Hebe in MPB 5, 16-17 (1977) -- Editor]. Herculina's satellite was nearly in line with its apparent motion, while the object which may be orbiting Hebe was perpendicular to that asteroid's movement. Some special observing strategies are recommended to establish whether the causes of secondary occultations are terrestrial or celestial:

1. Visual observers should observe in pairs about 1 km apart, close enough to see the same secondary occultation but far enough apart for truly independent observation; coincidental timings would imply a celestial origin.
2. Photoelectric observers should also observe visually, if the expected magnitude drop is great enough to see, either with a guide scope or (better, to prevent inadvertently bumping the main instrument) with another telescope nearby. Visual observations can establish whether dips in the photoelectric record are due to guiding or other instrumental problems, or due to the star's actually disappearing.
3. High-speed (usually digital recording is needed) photoelectric observations can record the Fresnel diffraction pattern as the star is occulted by the asteroid. The diffraction pattern will be modified by the star's angular diameter, and perhaps by close duplicity. Hence, if the star's signature appears in the diffraction pattern for a secondary occultation, it safely can be assumed to be celestial.

Since asteroidal satellites are probably common objects, it may be useful to record all negative (miss) observations reported during asteroidal occultations which are observed somewhere. I have received negative reports of the Herculina event from observers in Tokyo, Japan; San Jose, Fresno, Wrightwood, Glendora, and San Diego, California, USA; Honolulu and Mauna Kea, Hawaii, USA; and Woden, Australia. The northern limit of the Herculina occultation probably passed about 15 km south of Fresno, while the southern limit probably passed just north of Palmdale in California, in accord with the miss observations.

It will be important to watch all future occultations by minor planets carefully, to see which types of asteroids have the most satellites. They may provide important clues about the formation of the asteroid belt. Due to greater geographic dispersion, amateurs may be more likely than professionals to discover asteroidal satellites, but observations must be made carefully for confirmation.

Dr. Brian G. Marsden of the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, and editor of the IAU Circulars, suggests that the satellite be provisionally designated "1978 (532) 1," indicating that it is the first satellite of (532) Herculina to be discovered in 1978. This essentially follows the adopted I.A.U. practice for satellites of major planets. If direct observations of the satellite are obtained so that an orbit can be determined well enough to predict its future motion, a permanent designation such as "(532) I" will be assigned.

THE DISCOVERY OF A SATELLITE OF AN ASTEROID

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[The following are excerpts from a paper presented at the conference ASTRONOMY WEST '78 held at San Luis Obispo, California, July 27-30, 1978, and kindly communicated by its author for publication in MPB. Mr. McMahon is one of the discoverers of the 532 Herculina satellite. The full paper is rather long for complete inclusion in MPB; parts of it overlap the discussion set forth in Dr. Dunham's article above.-Ed.]

Abstract: The occultation of the star SAO 120774 by minor planet 532 Herculina on June 7, 1978 was observed by three independent observers. A total of seven extinctions were timed by the author. The primary occultation, timed at all three stations, has led to a determination of the diameter of Herculina. A secondary occultation, timed by the author and at one other station, was probably caused by a satellite of Herculina. The five other extinctions observed only by the author suggest the possibility of additional satellites or low-density rings.

... I observed from a site on the west side of U.S. Highway 395 approximately 3.54 miles north of Kramer Junction. The observing site was not established by choice. Carroll Evans and I stopped here about 3:40 a.m. PDT on June 7 to refer to our topographic maps. We noted that just above the horizon in the west was a several-degree wide area of intense glare from mercury vapor lamps. The lamps themselves were below the horizon and are presumed to be at an open pit borax mine five to seven miles (8 to 11 km) to the west of the observing site. Because of the glare, we decided to go farther south ... but Evans' truck would not start!

Observations. It was expected that, if the observing site were properly situated for observing an occultation of the star by Herculina, only one extinction would be detected. However, I observed seven extinctions! The times of the seven disappearances and seven reappearances, fourteen events, corresponding to these seven extinctions, are listed in Table I.

The period of continuous observation lasted for 14 minutes 15 seconds, from $11^h15^m45^s$ to $11^h30^m00^s$ UT. It can be divided into three periods: First, a period of 5 minutes 53 seconds during which no events occurred. Second, a period of 4 minutes 2 seconds during which all fourteen reported events occurred. Third, a period of 4 minutes 20 seconds during which no events occurred.

Observing conditions. Astronomical twilight began at the observing site at 3:51 a.m. PDT. This is approximately the time that the search for SAO 120774 was begun. At that time the faintest star that could be seen with the unaided eye in the vicinity of the occulted star was 110 Virginis at magnitude 4.4. SAO 120774 was found with the telescope and identified by reference to the Atlas Eclipticalis. For finding the star I used a 32 mm Brandon eyepiece which gives a magnification of 14X and an object field angle of 3.2°. SAO 120774 is in the extreme eastern part of Virgo at right ascension $14^h56^m.9$ and declination + 4°46' (1950).

... Throughout the period of locating and identifying SAO 120774, the star images were sharp and steady. The seeing was good. There was no wind.

When the period of continuous observation was begun at $11^h15^m45^s$ UT, the 32 mm eyepiece was removed from the telescope and a 24 mm eyepiece was inserted, giving a magnification of 18X. This brought about a substantial brightening of the star image.

At $11^h19^m28^s$ UT, I commented on the tape that there now appeared to be a haze; the image of SAO 120774 had become somewhat diffuse. However, the star image remained steady. This haze condition prevailed until $11^h25^m25^s$ UT when I commented on the tape that the star image had once more become sharp again. About 10^s later the star image had once more become somewhat diffuse. Finally at $11^h27^m25^s$ UT I commented that the star image had again become sharp. Thus all fourteen events timed occurred while the star image was somewhat diffuse.

At the beginning of continuous observation at $11^h15^m45^s$ UT the altitude of the star has been calculated to be 8.6 degrees. At the time of the midpoint of the occultation of Herculina (extinction number 5), the altitude of the star was 7.0 degrees. At the end of continuous observation at $11^h30^m00^s$ UT, the altitude of the star was 5.8 degrees. (No correction for atmospheric refraction).

Throughout the entire period of continuous observation, except for the seven periods when the star image is reported as having been extinguished, the star image was steady. There was no flickering. The air was completely calm.

At the time of the occultation of the star by Herculina (extinction number 5), it was 33 minutes after the beginning of astronomical twilight. Despite the twilight, despite the low altitude of the star, despite the slight haze, and despite the glare low in the sky to the west, the star image was readily observed. Each of the reported fourteen events was highly certain. (Certainty Code I). No distinction can be made among the seven extinctions reported, except for their durations. During all seven periods that the star image is reported as being extinguished, the image of the asteroid could not be seen by me.

...

Personal equation. Articles in the Occultation Newsletter (IOTA) indicate that personal equation is larger when timing the occultations of fainter stars. For a simulated bright star, my personal equation has been determined to be $0^s.3$ minimum. For the observing conditions reported herein, my personal equation may have ranged as high as $0^s.5$. I have suggested that the value $0^s.4$ be used. The times for the events reported in Table I are times as reduced from the tape; the personal equation has not been applied.

...

On Saturday, June 10, when Donald Kusterer and I were reducing the tape, I made note on the data sheet of the duration of the extinctions and of the duration of the intervals between extinctions. As the duration of the final interval was being recorded

Table I. Extinction data for the observation of the occultation of SAO 120774 by 532 Herculina on 1978 June 7 by J.H. McMahon

Extinction number	Type of event	Time of event, UTC (1)	Time of midpoint of extinction, UTC (1)	Duration of extinction (seconds)	Time from extinction # 5, midpoint to midpoint, (seconds)
1	D	$11^{h}21^{m}37^{s}.8$	$11^{h}21^{m}38^{s}.9$	2.1	- 127.1
	R	11 21 39.9			
2	D	11 21 45.6	11 21 46.3	1.3	- 119.7
	R	11 21 46.9			
3	D	11 21 54.0	11 21 56.0	4.0	-110.0 satellite
	R	11 21 58.0			
4	D	11 23 24.3	11 23 24.9	1.2	- 21.1
	R	11 23 25.5			
5	D	11 23 35.7	11 23 46.0	20.6	0.0 Herculina
	R	11 23 56.3			
6	D	11 24 05.3	11 24 06.1	1.5	+20.1
	R	11 24 06.8			
7	D	11 25 39.5	11 25 39.7	0.5	+113.7
	R	11 25 40.0			

Footnote: (1) Personal equation not applied.

(see Table I above), the symmetry about the time of occultation of the asteroid (extinction number 5) of extinctions number 2 and 7 and also of extinctions number 4 and 6, became evident. Immediately, I thought "Rings!", as does everyone to whom I describe this symmetry in the data.

[The symmetry noted by McMahon could also be explained in terms of fortuitous placement of small satellites in orbit around Herculina. If extinction 2 and 7 constitute a ring, one would have to conclude that the thickness is very uneven. Thus far rings have only been found within Roche's Limit (cf. Saturn, Uranus); all of these events would lie outside that limit. That is not impossible, but it seems unlikely. One should also realize that it is also highly unlikely that the satellites of a planet would be all at elongation at the time of the occultation. Readers should understand that while the thought of "Rings!" crossed Mr. McMahon's mind, he is not advocating that interpretation in his paper. His later investigations indicated that the ring hypothesis was untenable. -- Editor]

On Sunday, June 11, I telephoned Dr. Dunham and reported the timings which are in Table I. ... On Wednesday, June 28, Dr. Bowell told me that "These two independent observations constitute incontrovertible evidence of a secondary occultation for which the most likely explanation is a satellite of Herculina."

<u>The size and shape of Herculina</u>. The analysis of the data of the three observers and the computations have been done, of course, at Lowell Observatory. ...

For a model of circular cross-section for Herculina, a diameter of 243 ± 1.4 km was derived from the results of the six occultation timings among the three successful observers. The largest residual for this solution was 1.23 km. It turns out, however, that such a solution puts Fresno, California, well inside the northern limit. There were three observers ... at Fresno, of whom Garrett Wimer was the most southerly. None of these observers detected any occultation. That they were observing the correct star is certain, since they were set up for observing sufficiently early to actually see Herculina approaching SAO 120774.

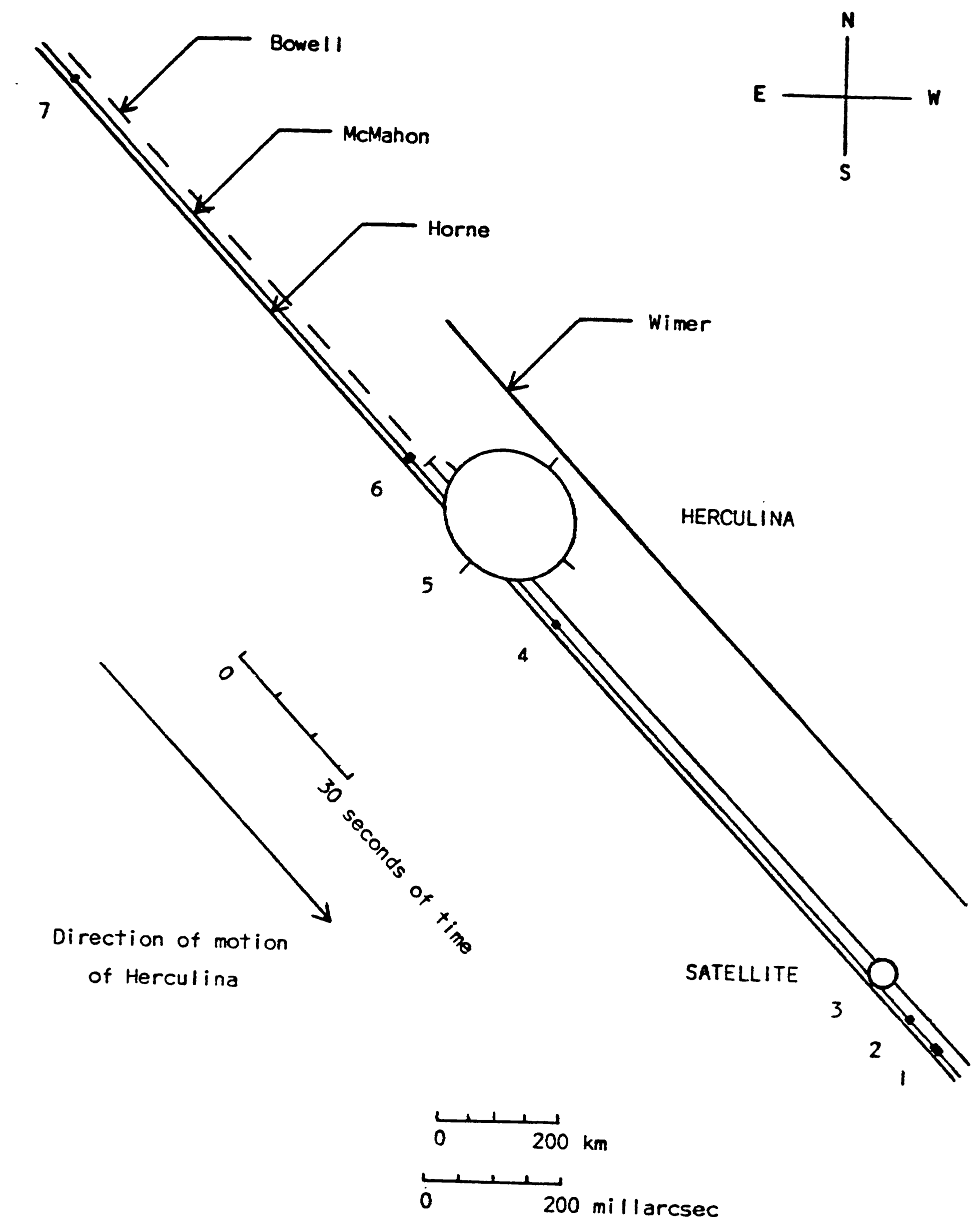
Because of this anomaly, three other circular solutions were tried for which constraints were placed on the solutions. The first of these circular solutions was for a northern limit graze at Fresno. This yielded a diameter of 235 km. The largest residual for this solution was 1.38 km. For the two other circular solutions tried, constraints were placed on the northern limit for successively greater distances south of Fresno. These solutions yielded successively smaller diameters and successively larger residuals. That is, good fits were not obtained.

When the rotational light curve for Herculina is invoked and applied to the solution, most interesting results are obtained. Recent light curve data obtained independently at the Jet Propulsion Laboratory and at Lowell Observatory during late May and June 1978 indicate an amplitude of 0.15 magnitude. That is, at minimum brightness the asteroid was 0.87 as bright as at maximum brightness. Assuming a uniform albedo and assuming also the shape of a biaxial ellipsoid, it follows that the <u>maximum possible</u> ratio of minor axis to major axis would be 0.87.

Another result of the recently determined light curve is that at the time of the occultation on June 7 the brightness of the asteroid was at maximum. That is, for the assumed ellipsoidal shape, the major axis was oriented perpendicularly to the line of sight.

Three elliptical solutions were undertaken, each involving the occultation timings from the three observing sites and an assumed axial ratio for the projected ellipse. All three solutions yielded substantially lower residuals than did the circular solutions. The following data were derived from these solutions:

	Assumed axial ratio		
	0.954	0.869	0.818
Major axis, km	242	232.0	227.6
Minor axis, km	231	201.6	186.2
Mean diameter, km	235	216.3	205.6
Maximum residual, km	1.18	0.99	0.92
Position angle of minor axis	338°	321°	319°



Spacial relationships for observations of the occultation by Herculina on June 7, 1978. The solution for Herculina corresponds to an ellipse having an axial ratio of 0.87. Black rectangles represent unexplained secondary extinctions observed by McMahon. Dashed line represents period after end of observing by Bowell. Wimer observed at Fresno.

These residuals (bottom, previous column) correspond to timing errors of about 0.1 second. The elliptical solution for an axial ratio of 0.954 corresponds to a graze at Fresno at the time of occultation.

The elliptical solution for an axial ratio of 0.869 is the limiting solution for the recently determined rotational light curve. It is this limiting solution for Herculina which is plotted in the figure at the top of this page. In this figure the tick marks on the ellipse for Herculina indicate the locations of the major and minor axes. ...

The limiting solution presented here must be regarded as an interim solution since, with additional light curves obtained during future apparitions of Herculina when the asteroid is in different directions in the sky, and with data from future occultations of stars, it should become possible not only to describe an approximation to the true size and shape of Herculina, but to define the orientation of its axis of rotation.

The maximum possible mean diameter of Herculina as determined by timing the occultation of June 7 and by consideration of the recently determined light curve, is compared below with current results by the new methods of radiometry and polarimetry.

Method	Diameter, km
Radiometry	203 ± 20
Polarimetry	227 ± 12
Occultation	217 ± 15?

The Satellite. Using a circular model for the provisional satellite corresponding to my extinction number 3, the diameter of the satellite is 45.6 ± 3.6 km. Low residuals indicate that the object was moving at the same angular velocity with respect to the star as Herculina, and therefore support the satellite hypothesis. Horne obtained a miss on the satellite by 4.8 km.

The angular separation of the satellite from Herculina at the time of observation was 0.866 ± 0.001 arcsecond. The corresponding distance projected onto the plane of the sky was 977 ± 1 km. The data do not allow assignment of orbital elements for the satellite. Assuming that Herculina and its satellite have a similar albedo, the latter should be about 3.3 magnitudes fainter than the planet.

Could the postulated satellite really be a line-of-sight asteroid? Probably not. Main-belt and Earth-approaching asteroids of the right angular size would be bright (about visual magnitude 13) and would certainly be known. A Trojan asteroid of the right angular size would be about visual magnitude 15.5 and might have escaped detection, but, like an Earth approacher, would almost certainly not be moving with an apparent velocity similar to Herculina's.

Extinctions number 1,2,4,6,7. How are extinctions 1, 2,4,6, and 7 to be explained. These extinctions are so brief, ranging in duration from $0^{s}.5$ to $2^{s}.1$ that they could easily have been caused by small satellites not scanned by the other two observers. But what is the probability that I would have detected six satellites, while one of the other observers detected only one and the other observer detected none?

In favor of the validity of my observations is the fact that I observed all six secondary extinctions within $2^{m}8^{s}.2$ of the time of central occultation of Herculina and that my period of uninterrupted observing lasted 14^m15^s. Furthermore, at Lowell Observatory the star was only 2 degrees above the western horizon at the time of the observation of Herculina. Also at Lowell it was 57^m after the beginning of astronomical twilight. However, I have examined a copy of the Lowell photometer trace and it clearly shows only one total secondary extinction, the one which corresponds to my extinction number 3.

A satellite corresponding to my extinction number 1 would have a minimum diameter of 18.6 km. Such a satellite would have been missed at Lowell and at Rosamond. If such a satellite were larger than this minimum size and its center had been on the side toward Rosamond, its diameter would have to be at least 19.8 km to have been detected by Horne. On the other hand, if such a satellite were larger than this minimum size and its center had been on the side toward Lowell, its diameter would have to be at least 21.4 km to have shown an indication on the recording photometer there. Extinction number 1 could have been caused by a satellite of Herculina.

[Mr. McMahon in his paper then considers the hypothesis of rings as the explanation for the near-symmetries of extinctions 2 and 7, and of 4 and 6. He concludes the ring hypothesis is untenable. He then emphasizes the need for more observations -- particularly occultation observations -- of Herculina to resolve the remaining mysteries including the question of additional satellites.

The above two papers by David Dunham and James McMahon are much appreciated. Dunham's was, of course, written shortly after the occultation, and reflects interpretation of data using a spherical model for Herculina. McMahon's paper, revised substantially from an earlier one, reflects the ellipsoidal model based in part on the new light curve data. It is exciting to note these rapid developments of thought on a matter of considerable historical significance -- the first confirmed case of a satellite of a minor planet.

The Editor is delighted to learn of satellites of minor planets since he wrote about the possibility of them in the first issue of The Minor Planet Bulletin (1, 4 (1973)), and was strongly criticized by one professional astronomer for imagining such things!

-- Editor]

REFLECTIONS UPON 532 HERCULINA AND ITS SATELLITE(S)

by Richard G. Hodgson

Abstract: The satellite reported orbiting 532 Herculina is apparently fairly massive relative to its primary. At a distance of somewhat less than 1000 km, tidal forces would be strong, yet Herculina has a $9^h.4$ rotation period, remarkably short considering the probable period of the relatively massive satellite.

Reflection upon the recent Herculina observations is in order. Assuming that the revised elliptical model for Herculina described by McMahon (MPB 6, 15) is essentially correct (the model with the assumed axial ratio of 0.869 which satisfies the light curve data is here in view), it would appear that the mean diameter of Herculina is about 216.3 km, and that the diameter of the satellite, assumed to be spherical, is about 45.6 km. These figures are, of course, overprecise but they will be used as starting points in the discussion to follow.

From the approximate diameters given above one can readily calculate the volume of Herculina to be approximately $5.3 \times 10^{21} cm^3$, and that of the satellite to be approximately $4.96 \times 10^{19} cm^3$. If this is reasonably accurate (overlooking surface irregularities), the ratio of their volumes is 106.7 to 1 -- making the satellite very large relative to its primary planet compared with other planet-satellite systems known to us in the Solar System. Only in the case of the Earth-Moon system, where the ratio of volumes is 49.26 to 1, and possibly in the recently discovered case of Pluto and its satellite, does the volume of a satellite appear to be so large in comparison to that of its planet. In most cases it is far, far less.

If Herculina and its satellite are made of similar materials and therefore have similar densities, their masses would be in the same ratio, i.e., about 106.7 to 1. (In terms of mass the Earth-Moon system involves a ratio of 81.3 to 1). In the case of the Herculina system the masses are not known, but the mass ratio, given reasonable assumptions regarding density and composition, probably lies somewhere between 90 to 1 and 140 to 1. In any case a relatively massive satellite for so small a planet is clearly indicated.

Since the separation between Herculina and its reported satellite is approximately 1,000 km (977 km is the value determined for the time of occultation), the tidal forces between planet and satellite must be very strong indeed, far stronger than that between the Earth and Moon in the modern era, because tidal forces are inversely proportional to the cube of the distance, and differential tidal forces are inversely proportional to the sixth power of the distance between the two bodies. Thus at a distance of about 20,000 km Pluto's satellite has managed to despin that planet over the age of the Solar System, with the result that the period of Pluto's rotation and the satellite's orbital period are the same -- $6^d.3867$.

Why has Herculina's satellite not succeeded in doing the same for Herculina? It is possible that Pluto's satellite might be somewhat larger proportionally, but at 1/20th the distance Herculina's satellite should have a considerable advantage in terms of tidal forces. At present there is no good answer for this question.

The rotation period of $9^h.4$ reported for Herculina is typical of that of many of the larger asteroids. It shows no evidence of significant slowing as a result of tidal forces. Nor can the problem be solved by supposing that the reported satellite orbits Herculina in $9^h.4$ -- that period is far too short for a satellite 977 km distant. (Assuming a density of 3 g/cm^3 -- a plausible value for an S-type minor planet -- Herculina's mass would be about 1.59×10^{22} grams, and its escape velocity at mean radius would be 0.140 km/sec. On the basis of these data one can calculate the orbital period of a satellite in circular orbit at a distance of 977 km (9.0337 mean radii). The period of such an object would be $51^h.76$ -- quite a difference from $9^h.4$! Even supposing a highly eccentric orbit, and that the satellite was at apo-planet at the time of the occultation, and doubling the assumed density and therefore the mass of Herculina, the orbital period cannot be reduced to anything approaching $9^h.4$. A highly eccentric orbit, moreover, would bring the satellite close to the planet at peri-planet, and Herculina's distinctly non-spherical shape might well introduce perturbations which would affect the satellite's long-term orbital stability. A low-eccentricity orbit ($e = 0.1$ to $e = 0.25$) would be more stable and therefore is more likely. This means an orbital period in the 40^h to 70^h range, assuming Herculina's density is about 3 g/cm^3. The problem remains.)

Several solutions to the problem may be suggested: (1) the secondary occultation, interpreted as a satellite, may in fact be something else. In the light of the evidence presented in the previous two papers the

case in favor of the existence of the satellite is overwhelming. Its path of motion, the diffraction signature of the star, the absence of any other 13th magnitude object in the area at the time, and the large geographical separation of the two witnesses seem to rule out this solution to the problem.
(2) the reported satellite may not have been a satellite of Herculina until fairly recent times in the history of the Solar System. Perhaps it was captured in the last few million years. Against this hypothesis one can argue (a) capture is a very unlikely event, since a third body has to be at the right place at the right moment to carry away excess energy. Possibly the fairly rapidly rotating, non-spherical planet might assist in this process.(b) Any capture would have had to happen moderately recently, however, since the rotation is still fairly rapid, and that makes it more unlikely.
(3) the orbit of the satellite was formerly much smaller (period near 9^h) and the planet was then in a condition of having been despun, but a moderately recent collision with another object (asteroid, comet nucleus) radically modified and enlarged the satellite's orbit, and terminating the synchronous periods. While possible, this also seems improbable. Collisions are fairly rare, even in the asteroid belt, and it would have to have been fairly recent.

Thus the problem remains. The writer would welcome comments regarding these and other plausible solutions to the problem. It is obvious we will need many more observations of the Herculina system before some of these questions can be solved.

FURTHER SUPPORT FOR MINOR PLANET MULTIPLICITY

by Richard P. Binzel

Paul Maley's observation of an event occurring well outside the main path of the 1977 occultation of the star Gamma Ceti by the minor planet 6 Hebe was initially greeted with much skepticism. Because of the experienced Maley's certainty in his observation, David Dunham recognized that Maley had probably observed an occultation by a satellite of Hebe. (Cf. Occultation Newsletter, 1977 July; MPB 5, 16-17 (1977)) The question of minor planet multiplicity has been raised several times previously in astronomical literature but has never gained much attention. Now in the light of recent occultation observations,multiple minor planet systems are becoming more widely accepted.

Minor planet multiplicity was first conjectured in 1901 by the French astronomer Ch. Andre.[1] Andre was struck by the similarity in the light curve of 433 Eros and the eclipsing variable star β Lyrae. This led him to conclude that Eros is actually a double planet system. Recent theoretical work has also proposed that Trojan planet 624 Hektor is a "binary asteroid."[2]

Interestingly, several visual observers have reported actually seeing Eros as double. During the 1924 opposition of Eros, the well-known double star observer R.T. Innes at the Union Observatory in Johannesburg, South Africa, noted on one night that as seen through their 22.5 cm refractor Eros appeared "bar-like, or similar in appearance to a close double star." W.H. van den Bos and W.S. Finsen, observing with the 56 cm refractor at Johannesburg in 1930, noted on several nights near opposition the image of Eros appeared, "certainly a figure-of-eight, resembling that of a 'notched' or nearly separated double star of about $0\rlap{.}''18$ distance."[4] Their observations listed a 0.2 magnitude difference between the components and a period of revolution of 5^h17^m.

Van den Bos and Finsen also made an additional very interesting observation involving another minor planet in 1926. While sweeping a zone in search of new double stars, they found and measured one which they could not identify in any atlas. Further research revealed that the new "double star" was actually 2 Pallas![5] Van den Bos also stated that he had observed Titan to be double in 1929 and 1930 (unpublished).[4]

Only in the last few years have observers had success in observing the not particularly rare phenomena involving occultations of stars by minor planets. In each case where such an occultation has been successfully observed, there have been observations which support the notion of minor planet multiplicity. [Note: This last statement is inaccurate: the few observed occultations prior to 1973 did not present such evidence. Cf. J. Meeus letter in MPB 4, 40 for references. -- Editor]

An occultation of a star by 2 Pallas in February 1973 was observed from three locations near the shadow path and yielded seemingly confusing results. The observers at the extremes both reported certain occultations, while the central observer was certain he saw no occultation at all. In October, 1973, Harold Povenmire observed a brief occultation of a star by 129 Antigone from southern Florida, even though astrometric measurements made shortly after the event showed the the main path had passed far south of Povenmire, crossing Colombia. Larry Nadeau and several other observers located well outside the main path of the occultation of Kappa Geminorum by 433 Eros in 1975 also reported brief or "partial" occultations.[6] However, even after Maley's observation of 6 Hebe which led Dunham to propose the idea of satellites of minor planets, most preferred to rationalize away the secondary events, all by visual observers, as being spurious or due to atmospheric conditions.

Confirming evidence for the existence of minor planet satellites occurred when one of the secondary events observed visually by Jim McMahon during the occultation of a star by 532 Herculina on June 7, 1978, was in full agreement with a secondary event later found in the photoelectric record of the occultation made by Ted Bowell at Lowell Observatory. This event has been recognized to have been caused by a satellite of Herculina and this object has been officially designated as "1978 (532) 1" in IAU Circular 3241.

In retrospect, Richard Radick of Prairie Observatory in Illinois found that he had recorded photoelectrically a secondary event during the 1978 May 29 occultation of a star by 2 Pallas. One other observer of the Pallas occultation recorded a possible secondary event.

If the resulting discovery of a satellite of Herculina allows us to infer that the observations of secondary events seen during each prior occultation of a star by a minor planet were actually due to the presence of satellites, then it is obvious to conclude that in order for us to be fortunate enough to have detected them, minor planets must be surrounded by swarms of such bodies. Furthermore, since it seems these bodies have been detected during each observed occultation, it indicates that multiple minor planet systems may be the rule, rather than the exception.

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[The Editor wishes to thank Mr. Binzel for his very timely paper. We need more articles which involve historical research into relevant areas of observational and theoretical astronomy. The case of 2 Pallas which he presents clearly needs more investigation. While the Editor believes that a number of the larger minor planets may be binary or have satellites, he is hesitant to speak of "swarms." Observers need to maintain a critical caution in this matter, or they will loose their credibility. Multiple observations of the same event must be secured.

It is unlikely that small asteroids (the vast majority) have sufficient gravitational fields to maintain companions, although just where the line should be drawn is uncertain. It should be noted that all of the major planets with moderately rapid rotations are now known to have one or more satellites. Apparently for them possession of satellites is the rule rather than the exception, and the same might apply for the larger minor planets. The only major planet exceptions (Mercury and Venus) rotate so slowly that tidal dynamics would cause the inward spiralling and impact of any satellites on their surfaces in a time considerably less than the age of the Solar System. For this same reason probably most if not all satellites of satellites in our Solar System have by now ceased to exist. For discussion of satellite orbits and their evolution, see Planetary Satellites edited by Joseph A. Burns, pp. 27-168 (1977). -- RGH]

MINOR PLANET ROTATIONS: 1977-1978

by Alain C. Porter and Derek Wallentinsen

This report covers observations submitted to the Photometry Co-ordinators from 1977 June to 1978 July. Only objects which were no longer being observed at the latter time are included. It is good to see the rise in observing activity during this period: two dozen observations were received in the first half of 1978 compared with just two for the first half of 1977.

Table: The Observations

Planet Number	Observer DH	PK	TM	FP	AP	Planet Total
18					2	2
45		1	1		1	3
56	3				2	5
63					5	5
85					1	1
89		2				2
124					1	1
140					1	1
335	1				2	3
554		1				1
1978 CA				3		3
1978 DA				1		1
Observer Total	4	4	1	4	15	28

Observers

DH = David Hough, South Plainfield, New Jersey,USA
15 cm f/8 reflector
PK = Philip Kirby, Springfield, Ohio, USA
15 cm f/8 reflector
TM = Thomas McFaul, Hopewell Junction, New York, USA
20 cm Celestron
FP = Frederick Pilcher, Jacksonville, Illinois, USA
36 cm Celestron
AP = Alain C. Porter, Narragansett, Rhode Island, USA

The current batch of observations provides convincing evidence that several high quality light curves are needed before a rotation period can be well determined for an asteroid. It is not usually sufficient just to "get a light curve." Single observations are vulnerable to too many errors. A lone light curve may be too short to use, as was the case for 140 Siwa. It may indicate a period contrary to one previously determined, as in the case of 85 Io. Even if two or three light curves are available, if each is short they cannot be used to determine a unique period, as in the case of 45 Eugenia.

Of course bad weather and other commitments may interfere, but the more observers involved the easier the task of determining rotation periods will become.

Here are the results for the 1977-1978 period:

45 Eugenia

Three timings, all minima, were obtained:

UT May 3 4:56 Kirby
May 8 4:23 McFaul
June 10 4:24 Porter

Kirby's light curve began at UT 3:48. Eugenia's visual magnitude was 11.1. The decline to minimum (11.4) began at 4:30. Eugenia reached 11.1 again at 5:20, and showed some signs of rising farther, but then the light curve "stalled," remaining at $m_V = 11.1$ until the end of the observations at 7:47. The asteroid was not in the same field of view as the comparison stars; this may have contributed to the difficulties.

McFaul's light curve (UT 3:33-5:22) shows a shallow 0.1 magnitude minimum, the weakest of the three.

Porter's light curve runs from about UT 2:46 to 6:01. It shows a fairly well defined minimum, the time of which was calculated after the omission of two points isolated from the others by two steps in brightness. (An arbitrary magnitude scale was used and the observed amplitude was four steps). Due to stopwatch failure, most of the estimates, and therefore the minimum, may have an error of five minutes.

Apparently the rotation period of Eugenia is not unusually short. Porter's light curve may have started at about the time of maximum. His second estimate is higher than his first, and thereafter there is a steady decline to minimum. This, and the possible maximum in Kirby's curve, would indicate possibly a five hour period of about five hours, but such indications from meager data are often deceptive. A definite period must await another apparition.

56 Melete

Nothing in the $9^h.75$ of observations could not easily be attributed to observational scatter. Results negative; no light curves longer than 2.5 hours.

63 Ausonia

Ausonia was observed photoelectrically by Scaltriti and Zappala in 1976.[1] They reported a period of $9^h17^m 48^s \pm 5^s$, and an amplitude of 0.47 magnitude.

Some visual observations were reported to the Photometry Co-ordinators that same year, and were discussed in an earlier report.[2] It appears they were incorrect, for they showed a variation with a period of no more than 4^h, and did not include individual timings in agreement with the photoelectric observations.

Visual observations in 1977 yielded the following:

UT 1977 July 23 5:11 MAX Porter
Aug 21 4:29 min Porter
Sep 15 4:25 min Porter
Sep 15 4:39 min Porter

The September timings were made using independent comparison sequences in the same field of view. Maxima shown in the first few data points of the August and September observations are not listed here because they are weaker than the minima, and if we are to accept the photoelectric period, one or the other must be discarded. These four timings fit Scaltriti and Zappala's period very well. Using the formula derived previously,[3] we arrive at a period of $9^{h}18^{m}.1$, which amounts to an insignificant difference.

Without the previously reported observations, we would probably have proposed a period of 210-215^{m} for Ausonia, 3/8ths of the true value, and only because of misinterpretation of apparent scatter as weak maxima. Once again, we see it is harder to interpret observations correctly than to make them well.

No amplitude is available for 1977 since arbitrary magnitude scales were used. However, the observer felt that the variation was about $\frac{1}{4}$ to $\frac{1}{2}$ magnitude -- close to Scaltriti and Zappala's amplitude.

<u>85 Io</u>

The one light curve showed a minimum at UT 4:22 on August 21, 1977. However, it also showed a maximum at 5:17, and a possible, although uncertain, maximum at 3:46. This would seem to indicate a period of 3.5 hours. Photoelectric observations of Io, however, indicate a period of 7 hours.[4] This observation will probably have to be rejected. [These data may be better than Porter and Wallentinsen think: most minor planets show two maxima and two minima per rotation with only subtle differences distinguishing them, and this does not seem to have been taken into account here; 3.5 x 2 = 7. This problem of interpretation may be present elsewhere. -- Editor]

<u>89 Julia</u>

Kirby's observing runs of about 3 hours on 1978 February 7, and of 2 hours the following night showed no variation. Julia has a period of $11^{h}23^{m}14^{s}$ and an amplitude of $\frac{1}{4}$ magnitude. Its light curve has shown irregularities in the past. No data are available on its axial orientation.[5,6]

<u>554 Peraga</u>

Kirby's $3^{h}10^{m}$ light curve (1977 December 17) showed an irregular, but possibly periodic, variation of 0.4 magnitudes. The following extrema were noted:

UT 1977 Dec. 17,	2:45	$11.7m_v$	min
	3:20	11.3	MAX
	4:10	11.5	min

Again no other observations are available. Mr. Kirby pointed out that Peraga was a magnitude fainter than predicted; a revision of its absolute magnitude may be in order.

<u>1978 CA</u> and <u>1978 DA</u>

Frederick Pilcher's observations of these newly discovered planets were probably the most successful of the period. They were discussed in an earlier issue of MPB, together with the photoelectric observations that were made.[7] His visually determined period for 1978 CA, $3^{h}46^{m}$, was only 3^{m} and 1^{m} longer than the two professionally determined results -- clear proof that a skilled observer can make useful observations if the amplitude is moderate (0.8 magnitudes in this case).

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CONJUNCTIONS OF MINOR PLANETS WITH BRIGHT STARS IN 1979

by Jean Meeus

The following conjunctions have been calculated by means of accurate ephemerides of minor planets provided by Dr. David W. Dunham.

The times of the conjunctions are rounded to the nearest hour, Universal Time. Most conjunctions are conjunctions in right ascension, and the fourth column indicates the difference in declination between the minor planet and the star; thus 0°32' N indicates that the planet passes 0°32' North of the star. In a few cases, when the minor planet moves due north or south, the conjunction in declination is given; at that instant the two bodies have the same declination, and the fourth column indicates at what distance the planet passes East (E) or West (W) of the star.

The <u>visual</u> magnitudes of the star and minor planet are given in the last columns.

					Vis. magn.	
Planet	Date	UT	Distance	Star	star	planet
5 Astraea	Jan 2	8h	0°21' N	η Vir	4.0	10.9
31 Euphrosyne	9	4	0 02 N	49 Cam	6.4	9.9
79 Eurynome	11	11	0 17 S	129 Tau	5.9	10.6
18 Melpomene	16	3	0 16 N	μ Ori	4.2	9.3
192 Nausikaa	19	17	1 32 S	θ Gem	3.6	10.4
29 Amphitrite	26	15	0 00 N	51 Psc	5.7	10.9
5 Astraea	26	22	0 17 N	γ Vir	2.9	10.5
29 Amphitrite	Feb 6	15	1 11 N	δ Psc	4.5	11.0
349 Dembowska	13	3	0 09 N	θ Leo	3.4	10.6
8 Flora	15	11	0 32 S	ξ Cnc	5.2	9.2
6 Hebe	17	1	1 20 S	ε Oph	3.3	10.8
14 Irene	27	2	0 13 S	95 Tau	6.2	10.8
31 Euphrosyne	27	14	0 47 E	15 Lyn	4.5	10.4
18 Melpomene	Mar 11	17	0 32 N	69 Ori	4.9	10.7
40 Harmonia	31	19	0 33 S	ι Vir	4.2	10.4
2 Pallas	Apr 16	6	0 35 S	δ Equ	4.6	10.6
8 Flora	27	1	0 21 S	ξ Cnc	5.2	10.8
1 Ceres	May 3	19	1 30 N	3 Cet	5.2	9.3
6 Hebe	7	1	1 05 S	λ Oph	3.8	9.6
1 Ceres	15	10	1 04 N	ι Cet	3.7	9.3
6 Hebe	17	15	0 27 N	σ Ser	4.8	9.5
22 Kalliope	19	22	0 15 S	ν Sco	4.3	10.8
5 Astraea	23	21	0 13 N	11 Vir	5.7	10.8
22 Kalliope	26	24	0 00 S	$β_1$ Sco	2.9	10.8
3 Juno	Jun 3	14	0 03 S	μ Cet	4.4	9.3
22 Kalliope	9	11	0 09 N	λ Lib	5.1	11.0
26 Proserpina	14	3	0 59 S	σ Sgr	2.1	10.9
7 Iris	17	4	0 35 S	ι Lib	4.7	10.1
80 Sappho	18	6	1 30 S	ν Oph	3.5	10.6
6 Hebe	22	19	0 58 S	ω Ser	5.3	9.6
1 Ceres	23	9	0 09 N	25 Cet	5.7	9.1
3 Juno	23	23	0 56 S	5 Tau	4.3	9.8
26 Proserpina	24	19	0 45 S	φ Sgr	3.3	10.7
3 Juno	Jul 7	2	0 20 N	λ Tau	var	9.8
354 Eleonora	11	23	0 11 S	ζ Aqr	5.7	10.9
4 Vesta	14	7	1 09 S	$ξ_2$ Cet	4.3	8.1
3 Juno	19	12	0 12 N	79 Tau	5.1	9.7
354 Eleonora	24	18	1 53 S	ε Aqr	3.8	10.8
704 Interamnia	30	18	1 28 N	3 Aqr	4.6	10.4
3 Juno	31	20	0 11 S	9 Ori	4.3	9.7
6 Hebe	Aug 2	1	1 28 W	μ Ser	3.6	10.1
15 Eunomia	4	7	0 25 N	57 Vir	5.3	10.9
7 Iris	5	4	0 56 N	ι Lib	4.7	10.8
4 Vesta	12	17	0 18 S	λ Cet	4.7	7.8
704 Interamnia	20	8	0 14 S	69 Aql	5.1	10.5
704 Interamnia	21	22	0 14 N	68 Aql	6.0	10.5
3 Juno	25	15	0 15 S	134 Tau	4.9	9.5
6 Hebe	28	24	0 55 N	50 Lib	5.5	10.4
20 Massalia	30	19	0 44 S	14 Psc	6.0	10.0

Planet	Date	UT	Distance	Star	Vis. magn. star	Vis. magn. planet
10 Hygiea	Sep	1 17^h	0°36'N	19 Psc	var	10.3
6 Hebe		9 5	0 54 N	ψ Sco	4.9	10.4
6 Hebe		9 8	0 38 S	16 Sco	5.5	10.4
44 Nysa		10 13	0 32 S	14 Cet	5.9	10.3
16 Psyche		12 23	0 24 N	ο Cap	6.1	10.0
1 Ceres		17 20	0 59 N	θ Cet	3.8	7.7
3 Juno		21 12	0 02 N	15 Mon	4.7	9.3
16 Psyche		28 3	0 04 N	ο Cap	6.1	10.2
10 Hygiea		28 19	0 54 N	κ Psc	4.9	10.2
6 Hebe		29 11	1 24 S	ζ Oph	2.7	10.5
9 Metis		30 16	0 14 S	9 Cnc	6.2	10.9
1 Ceres		30 21	0 23 S	37 Cet	5.2	7.5
9 Metis	Oct	1 11	0 47 N	μ Cnc	5.4	10.9
29 Amphitrite		4 6	0 24 N	30 Cnc	5.7	10.9
1 Ceres		5 22	0 14 N	32 Cet	6.6	7.5
44 Nysa		16 12	0 48 N	33 Psc	4.7	10.2
16 Psyche		19 18	0 09 S	ν Cap	5.3	10.5
44 Nysa		21 7	0 46 N	30 Psc	4.7	10.3
9 Metis		21 22	0 14 S	γ Cnc	4.7	10.7
29 Amphitrite		31 2	0 32 N	ξ Cnc	5.2	10.7
3 Juno	Nov	4 13	1 09 S	α CMi	0.5	8.8
16 Psyche		5 11	0 21 N	19 Cap	5.9	10.7
9 Metis		8 20	1 38 S	ξ Cnc	5.2	10.5
4 Vesta		14 3	0 59 S	ν Cet	5.0	6.7
16 Psyche		15 14	0 19 N	θ Cap	4.2	10.8
3 Juno		23 14	0 36 W	ζ CMi	5.1	8.6
2 Pallas	Dec	1 13	0 18 S	15 Aqr	5.7	10.4
42 Isis		3 10	0 40 N	97 Tau	5.1	10.9
12 Victoria		5 4	0 04 S	130 Tau	5.5	10.9
694 Ekard		6 4	0 02 N	18 Ori	5.5	11.0
511 Davida		11 0	0 48 N	10 Tau	4.4	10.1
12 Victoria		14 13	0 06 N	122 Tau	5.4	10.8
2 Pallas		14 22	0 15 N	β Aqr	3.1	10.5
12 Victoria		24 12	0 02 S	113 Tau	6.2	10.9
14 Irene		29 18	0 54 N	ι Vir	4.2	10.7

Remarks:

January 9. - In January 1979 the minor planet Euphrosyne reaches the high declination of +63°.

January 26. - Very close conjunction between Amphitrite and 51 Piscium. For a geocentric observer the conjunction in right ascension will occur at 15^{h}26^m UT, when the asteroid will be 6".2 north of the star; the least separation will be 5".6 at 15^{h}23^m UT. There will be no occultation, however, because the horizonal parallax of the minor planet will be only 3".3.

May 26. - Kalliope will pass 28" south of β_1 Scorpii.

[The labors of Jean Meeus in preparing this list are very much appreciated. Let's hope that Section members will use this list and observe some of these conjunctions -- it should make finding some of the planets easier! A similar list, for the year 1980, has also been received and will appear in a subsequent issue of MPB. -- Editor]

LETTER

In a letter to the Editor dated 1978 July 5 Prof. Frederick Pilcher, Illinois College, Jacksonville, Illinois USA wrote the following:

"... It has been my experience that near the limit of visibility of an instrument one can intercompare asteroid magnitudes quite critically even if no standard stars are available and the asteroids are not in the same field. For brighter asteroids this method becomes much less sensitive. Thus smaller instruments are effective in intercomparing brighter asteroids, and large instruments for faint asteroids.

"Ray Fabré and William Watson both reported that in 8-inch (20 cm) telescopes planet 925 Alphonsina looked considerably fainter than predicted in February 1978. The effect was less certain for me this year with a Celestron 14-inch (36 cm), but I suspected much the same with a Celestron 10-inch in February 1969 and August 1971. I believe Alphonsina is at least 0^{m}5 fainter than published.

"William Watson, with a Celestron 8-inch (20 cm) also reports that 404 Arsinoë seemed considerably fainter than 760 Massinga despite the latter's lower altitude and 0^{m}5 fainter predicted brightness.

"And with the Celestron 14-inch (36 cm) I found 310 Margarita to be 0^{m}5 to 0^{m}8 brighter than the predicted B = 14.5. Other observers, when examining asteroids near their instrument limits, should be alerted to the possibility of other magnitude discrepancies for other asteroids. I consider all the above observations significant even though they were made without any photometers or comparison sequences."

Observers should take note of these cases. It would be well to repeat the intercomparisons several times a night if a magnitude discrepancy is suspected, or better yet, secure light curves for several nights. Some variations might be due to rotational light variations -- a usually fainter planet might sometimes be at maximum when compared with another planet that is usually brighter, but just then happens to be at minimum -- so one should check the matter several times. There are, however, many errors when it comes to the brightnesses of minor planets, and these need to be reported. The cases mentioned by Pilcher are good examples.

Pilcher also mentions that 99 Dike, coming to opposition October 17, 1978 at 15^{m}5 may well be brighter than predicted. Pilcher found an error of about one magnitude in February 1976. (Cf. MPB 3, 51) Observers with apertures of 30 cm or more should investigate it.
-- RGH

NEWS NOTES

1977 HB. C.T. Kowal of Hale Observatories reports recovery of this Apollo-type object in exposures made May 9 and 10, 1978, using the 122-cm Schmidt camera at Mt. Palomar. It was magnitude 19 at the time. Cf. IAU Circular 3223.

1978 CA. Improved orbital elements for this Apollo type planet by Brian G. Marsden were published in IAU Circular 3239. They represent greater precision than those published in MPB 5, 31 from IAU Circular 3191, but involve no substantial changes.

1978 PA. H.-E. Schuster, European Southern Observatory, reported discovery of this fast-moving asteroidal object on August 11. At first thought to be an Amor type planet, it now appears that 1978 PA is a minor planet of the Hungaria type. It was magnitude 16 when discovered.

1978 RA (= 1975 TB). Eleanor Helin of the California Institute of Technology reported discovery of a fast-moving asteroidal object on September 10. J.G. Williams of Jet Propulsion Laboratory found this object to be identical to 1975 TB, a probable Apollo object observed only two nights. E. Bowell, Lowell Observatory observed this planet on September 12 and found V = 13.23, B-V = +0.71, U-B = +0.31; observed range in V was about 0.1 magnitude. The orbital period is the shortest yet found for an Apollo planet. The orbital elements, by

Brian G. Marsden, Smithsonian Astrophysical Observatory, were published in IAU *Circular* 3265, and are as follows:

T = 1979 Jan. 24.9376 ET	Epoch = 1978 Oct. 19.0 ET
ω = 355°8699 } 1950.0	e = 0.436476
Ω = 170.3359 } 1950.0	a = 0.832007 AU
i = 15.7517 } 1950.0	n° = 1.298713
q = 0.468856 AU	P = 0.759 year

The diameter of 1978 RA = 1975 TB is estimated to be about 2.0 km.

LOW SPIN RATES. H.J. Schober published a paper on "Minor Planets with Low Spin Rate" in *Mitt. Astron. Ges.* 43, 126 (1978) in which he summarized work in this field: Photoelectric observations of asteroids during recent years have shown few objects have rotation periods of more than 18 hours, e.g. 654 Zelinda, 164 Eva, 139 Juewa, and 200 Dynamene. Normal rotation periods range between 4 and 11 hours. Of special interest are minor planets with diameters of more than 150 km. Rotation periods for most S-type asteroids are known; in the case of C-type planets only 20% are known he reports.

22 KALLIOPE. F. Scaltriti, V. Zappalà and R. Stanzel reported on the light curve, phase function, and polar orientation of 22 Kalliope in *Icarus* 34, 93-98 (1978). They give its dimensions roughly as 215 x 160 x 130 km^3.

MINING APOLLO AND AMOR ASTEROIDS. June LoGuirato has called attention to serious discussion of missions to the Apollo and Amor-type asteroids before the end of the present century for the purpose of mining raw materials in a competitive economic way. Among these we may note "Mining the Apollo and Amor Asteroids" by Brian O'Leary of the Department of Physics, Princeton University in *Science* 197, 363-365 (1977 July 22), "Space Prospect: Factories and Electric Power" by Richard S. Lewis in *The Smithsonian* 8, 94-98 (1977 December), and "Mining the Asteroids" by Michael Gaffey and Thomas McCord in *Mercury* 6, 1-6,9 (1977 November/December). While many may greet these proposals with a smile, one should recall the laughter concerning the possibility of space flight in the twentieth century that was heard in the early 1950's.

SECTION NEWS

PHOTOMETRY PREDICTIONS. Derek Wallentinsen will soon have visual photometry predictions for 1979 available. Selected planets from his list will probably be published in the next issue of *MPB*, but Section members who desire the complete list from Mr. Wallentinsen should send him a self addressed stamped envelope with 2 oz. postage affixed (US!), or its equivalent in US funds if residing outside U.S.A. Address at right.

EPHEMERIDES OF MINOR PLANETS FOR 1979. Western Hemisphere readers of the *Minor Planet Bulletin* who wish to order the *Ephemerides of Minor Planets for 1979* should note the following changes in the ordering procedure from last year. The price is now $ 6.00 (U.S.), although subscribers to the *Minor Planet Circulars* may receive it for $ 3.00. Checks should be made payable to the "Minor Planet Center" and orders should be placed to

Minor Planet Center
Smithsonian Astrophysical Observatory
60 Garden Street
Cambridge, Massachusetts 02138
U.S.A.

MPB PUBLICATION PLANS. The next issue of *MPB* will be published in late November rather than late December, so items for publication should reach the Editor by about November 20 to be considered for inclusion. The earlier publication date will permit predictions pertaining to early 1979 to be in the hands of observers sooner. The next issue, incidentally, will include Prof. Frederick Pilcher's 1979 list of planets at unusually favorable opposition -- an important piece of information observers have come to rely upon year by year.

MPB now has approximately 140 subscribers, approximately 30% of whom are outside the U.S.A. and/or are institutions. To help meet rising costs (particularly due to postage increases) we would like to increase the number of subscribers. If you have friends who might be interested in minor planets, please bring *MPB* to their attention. A few of our readers have been so enthusiastic they have entered gift subscriptions for others, a most welcome idea. (Subscription information is given below).

* * * * *

THE A.L.P.O. MINOR PLANETS SECTION is directed by its Recorder, Prof. Richard G. Hodgson, who is also Editor of *MPB*. Items for publication, subscriptions, and reports of unusual observations should be communicated to him. (He would also appreciate receiving reprints of articles and papers on minor planets published by subscribers in other journals: it is becoming impossibly expensive to subscribe to all the journals!) Address him either at his home, 316 South Main Avenue, Sioux Center, Iowa 51250 U.S.A. (faster during holiday periods) or at Dordt College, Sioux Center, Iowa 51250 U.S.A. His home telephone is (712)-722-4081.

POSITIONAL OBSERVATIONS of minor planets should be submitted to Prof. Frederick Pilcher, Assistant Minor Planets Section Recorder, Illinois College, Jacksonville, Illinois 62650 U.S.A. Please note that single observations of a given planet will no longer be received to avoid any cases of misidentification.

OBSERVATIONAL REPORT FORMS may be obtained from the Section Recorder Richard G. Hodgson at a rate of 20 forms for $ 1.00 US, or 80 forms for $ 3.00 US, postpaid.

PHOTOMETRY OBSERVATIONS should be sent to Alain C. Porter, 10 Sea Lea Drive, Narragansett, Rhode Island 02882 U.S.A. Photometry Report Forms may be obtained free from him (U.S. residents should send a large, stamped, self-addressed envelope to defray costs).

VISUAL PHOTOMETRY PREDICTIONS are available from Derek Wallentinsen, 3131 Quincy N.E., Albuquerque, New Mexico 87110, U.S.A.

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