Occultation Newsletter

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FROM THE PUBLISHER

For subscription purposes, this is the fourth and final issue of 1978.

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IOTA membership, subscription included, is $7/year for residents of North America (including Mexico) and $9/year for others, to cover costs of overseas air mail. European (excluding Spain and Portugal) and U. K. observers should join IOTA/ES, sending DM 10.-- to Hans J. Bode, Bartold-Knaust Str 6, 3000 Hannover 91, German Federal Republic. Spanish, Potuguese, and Latin American occultation observers may have free membership in IOTA/LAS, including *Occultation Newsletter en Español*; contact Sr. Francisco Diego Q., Ixpantenco 26-bis, Real de los Reyes, Coyoacan, Mexico, D.F., Mexico.

IOTA NEWS

David W. Dunham

The total solar eclipse of February 26 is currently the biggest item on IOTA's agenda. Information about IOTA's project for obtaining observations of 2nd and 3rd contact timings, and timings of other Baily's phenomena, is given on p. 5 of the last issue; on pages 102 and 103 of the January issue of *Sky and Telescope*; and in an article entitled "Eclipse Maps Off" on p. 5 of the 1978 December issue of *Astro-Directory News* (Gail Publications, Toronto). Richard Linkletter has prepared much useful information about the project and has done much to encourage and organize observations from Washington and Oregon. Paul Asmus is providing IOTA's service of supplying copies of 1:250,000 maps showing the predicted path edges to those who send him a self-addressed stamped envelope and extra stamps for duplication and handling. He is also working with Keith Strait and me to prepare a special mailing to 150 high schools, 50 newspapers, and 43 television stations in cities and towns very close to the path edges, in order to encourage useful observations in these areas. Some of this material, especially a list of the plans and addresses of several IOTA members who are leading path-edge expeditions for coordination of observations in various areas, has been sent separately to subscribers who live in the western half of Canada and in the western and north-central U.S.A. If this information has not been sent to you, and you are interested in observing the eclipse from near the path edge, telephone me at 301, 585-0989. Two new addresses should be noted: Paul Asmus, 4655 S. Zang St., Morrison, CO 80465, phone 303, 978-0321; and Berton Stevens, 2112 E. Kingfisher, Rolling Meadows, IL 60008, phone 312, 259 2107. Payments, change of address, and other IOTA business should be sent to IOTA's post office box in Tinley Park, as given in the masthead.

The occultation by Melpomene, including the prediction phases, the data collection and organization, analysis, and continuing preparation of a journal publication of the results, has consumed a great deal of my time, during a period when the upcoming solar eclipse had already greatly overextended my schedule. I hope to make the most of IOTA's contribution, past and future, at a major conference about asteroids to be held in Tucson, AZ, in early March. Professional interest in satellites of asteroids is increasing rapidly. Consequently, I am making a major effort to have the Melpomene results, and asteroidal occultation prediction data for 1979, in as final a form as possible by the end of this month. This has completely disrupted most of my other IOTA-related work, especially that connected with lunar occultations; overdue projects are being postponed even further. This underscores the continuing vulnerability of my occultation work, as long as it has no official support and relatively little local help.

Hardest hit have been the extended-coverage total occultation predictions. Most of the K-catalog stars are included in USNO's X-catalog, but as has been mentioned previously, a few hundred K stars are not in the X-catalog. The prediction data for the J-catalog for 1979 have errors which need to be corrected, and a new catalog is needed to include the 1979 September 6 lunar eclipse star field and Southern Astrographic Catalog project data for the -19° zone, which are now available. Since it won't be possible even to begin the catalog work until mid-March, the extended-coverage predictions for 1979 likely will not be distributed until April or even May. This means that we will miss the March 4th Hyades passage which is so favorable for North America, the March 13 deep partial lunar eclipse in the Eastern Hemisphere, and the favorable northern Milky Way passage in early April. Disappearances still can be timed during these events without the aid of predictions, and postdictions can be computed to help with the identification of any non-X-catalog stars whose occultations are timed.

There is a substantial amount of information about new double stars from various sources, but publication of it will have to wait for a future issue of *O.N.*, to be distributed in late March or April. An article on grazes is long overdue, but it also will be delayed. The 1977 total occultation tally, and the index for *O.N.*, *Volume I*, probably will not be prepared until after April, after the more urgent items mentioned above are handled. Some of the *O.N.* index material being prepared by others still has not been received. If you are working on this, please try to send it in by early April, or if this appears not to be possible, let me know as soon as possible so that another volunteer can be found for the task.

David Herald reports that the Southern Astrographic Catalog project is virtually complete. The task of keypunching the data is progressing satisfactorily, and Robert Clyde has been doing a good job of proofreading lists of the keypunched data. Wayne Warren has received the Algiers zone of the Astrographic Catalog on magnetic tape from the Stellar Data Center in Strasbourg, France. As time permits, he and I will work on the A.C. data, to eventually form a vast, comprehensive star catalog suitable for asteroidal occultation searches, but work on the project will be rather slow, due to the press of other urgent duties. The large computer runs which will be needed most likely will have to wait until USNO obtains a new computer, which probably will occur in April. Another task which will require the new computer is the integration of ephemerides for many more minor planets for which accurate orbital elements have become available during the past year.

JUNO LARGER THAN EXPECTED; PROBABLE GRAZE BY DISTANT SATELLITE

David W. Dunham and Yaron Sheffer

On July 13, William Penhallow made astrometric observations in an attempt to improve the prediction for the July 19th occultation of 7.1 mag. SAO 144072 by (3) Juno, the path of which was expected to cross northwest Africa and the eastern Mediterranean Sea, according to the Perth 70 star position and the published ephemeris for Juno, both of which are considered highly reliable (see o.n. 1 (14), 144). Consequently, Dunham was amazed that Penhallow's data indicated a 2"1 south shift, moving the path down to Brazil and central Africa. IOTA sent a telegram to Jorge Polman in Recife, asking him to notify other observers in Brazil, but he was out of town and did not return and read the telegram until the day after the event. Later, correction of a computer error, which affected only southern declination calculations, showed that the shift should have been 1"[illegible] south. But the corrected value turned out to have considerable error, since 6 days before the event, Juno and the star were near opposite edges of Penhallow's plates; apparently, a separation of [illegible] or less, as was obtained for Herculina on June 5, is needed for accurate results. But cloudy skies prevented Penhallow from obtaining plates closer to the time of the occultation.

Gordon Taylor was more fortunate, obtaining a plate at Royal Greenwich Observatory four nights before the event, when Juno was 53' from the star. His path showed a 0"2 shift south of the nominal prediction, which turned out to be very accurate, and more in line with expected accuracies for the Perth 70 star position and Juno ephemeris, although the time he predicted was just over two minutes too late. His path crossed Israel, so he telexed data to the Wise Observatory there. They could not spare their own telescope for it but they were going to inform local amateurs. Unfortunately, no observations are known to have resulted from this effort.

Yaron Sheffer, at Kfar-Saba, Israel, alerted to the event by Dunham's article on occultations in the 1978 January issue of *Sky and Telescope*, made the only known observation of the occultation. Observing under excellent conditions with a 6-cm refractor, he timed a 19s7 occultation starting at 23h01m20s55 UTC. This gives a chord length of 256 km, several kilometers larger than the diameter expected from infrared radiometry and polarimetry, so that the occultation was apparently nearly central at Kfar-Saba. Four minutes before the main occultation, the star disappeared for a quarter of a second. Sheffer is confident that it was not an atmospheric effect; during the 20-minute observation period, the star's light remained very stable, except for the two occultations. Immersion and emersion for the occultation of Juno appeared sharp, as would be expected for visual observations. The time expected for a noticeable fade due to Fresnel diffraction enhanced by the star's angular diameter would be less than 0s04 for a central occultation. But for the secondary occultation, Sheffer noted that disappearance and reappearance were not instantaneous, estimated that each lasted about [illegible]. This implies that the secondary occultation was nearly grazing, so that he observed a [illegible] km chord for an object perhaps [illegible] km in diameter.

Sheffer's secondary occultation occurred four minutes before the occultation by Juno, indicating a separation of 2"3, or about 3000 km in the plane of the sky at Juno's distance. This is the largest distance of a satellite from a minor planet observed during an occultation, showing that these objects very well might be completely separated from the primary via direct earth-based observation. The observation for this particular satellite would be difficult, since its magnitude was probably about 17, while Juno's magnitude was 9.4, but it would be reasonable to expect larger, brighter satellites whose direct detection would be easier. The satellite is well beyond the point where the attraction by Juno equals the attraction by the sun, about 1400 km or 1"1 in this case. Satellites noted during previous asteroidal occultations have been near, or less than, this distance, although we can not be sure since the third dimension, distance from the observer, is unknown. The Juno satellite, like the earth's moon and several other solar system satellites, shows that the true radius of the sphere of influence is not determined by the ratio of the attracting forces, which are inversely proportional to the square of the distance, but is determined by the ratio of the tidal forces, which are inversely proportional to the cube of the distance. The true radius of the sphere of influence, as calculated from the theory of motion of three bodies, is actually 94,000 km or 71", far beyond the object seen by Sheffer, for Juno. The radius of the sphere of influence changes as the distance from the sun varies, but is never less than 60,000 km, probably much greater than the distance of Sheffer's satellite. Future asteroidal occultations perhaps could be observed profitably from the entire nighttime area of the earth facing the star, at least for very favorable events.

Marco Cavagna, near Milan, Italy, also watched SAO 144070, but he was far north of the occultation path and saw no fading of the star. Hans-Joachim Bode distributed information about the event to many European observers, most of whom apparently had cloudy skies; no observations of secondary occultations or fadings have been received from them.

DUPLICITY OF BOTH (18) MELPOMENE AND SAO 114159 DISCOVERED DURING OCCULTATION

David W. Dunham

The occultation of SAO 114159 by (18) Melpomene on December 11 was successfully timed by four visual observers and three photoelectric stations in the Washington-Baltimore area. Stair-step events in the photoelectric records clearly reveal the star's duplicity. In addition, a 5.8-second occultation was recorded photoelectrically at Fernbank Science Center, near Atlanta, GA, over 600 km south of the path for the main event. The Atlanta record also shows steps attributable to the stellar secondary, giving strong evidence that a large satellite of Melpomene occulted the star there. Unfortunately, this and a few other reported secondary events have not been confirmed by observations at other stations; no other stations so far known, have been close enough to the tracks for the observers reporting the secondary events to have a reasonable chance for an occultation by the same satellite. This underscores more than ever the need for observations from pairs of stations a few kilometers apart. Nevertheless, the evidence from this occultation, as well as from Herculina and the numerous isolated observations from other occultations, leaves little room to doubt the idea that most minor planets have many satellites.

Observations of the Occultation by Melpomene. I was elated to join the ranks of less than 100 observers in the world who have seen a star occulted by an asteroid. It seemed a just reward for the hard work I had done to organize for the event locally and nationally, to publicize the occultation, and to verify that what I felt to be the best prediction (indicating that the event probably would occur in the Washington area) was actually best. The change in the combined light, a drop of over a magnitude, was startling as seen with my 25-cm reflector. I was even more amazed to notice a second small drop half a second later; I remarked that the star was probably double. The duration for the primary's occultation was 12s5 at my site near Phoenix, MD, about 25 km north of Baltimore and on the 0"20 north shift line on the map on p. 8 of the last issue. Joan Dunham and Fred Espenak saw an occultation lasting just over 14½ seconds near Columbia, MD, at 0"16 north. IOTA member David [illegible]man, using digital equipment which he designed and assembled after regular working hours, recorded a 15.96-second occultation with a 31-cm reflector at Goddard Space Flight Center's Optical Facility, near Beltsville, MD, at 0"144 north. Unfortunately, the 92-cm telescope there was out of order. Michael A'Hearn recorded the event photoelectrically with a 51-cm telescope at the University of Maryland's observatory in College Park, MD, at 0"139 north; this was the third occultation of a star by a minor planet which he recorded during 1978! Thomas Van Flandern and Richard Schmidt recorded the occultation photoelectrically at the U. S. Naval Observatory at 0"127 north. Bob Bolster recorded the southernmost chord visually at 15s1 from Alexandria, VA, at 0"11 north. The next known observer north of Phoenix, MD, was Emil Volcheck at West Chester, PA, at 0"26 north; he had no occultation. Similarly, Larry Junkelman saw no occultation by Melpomene at his site near Lady-

Smith, VA, at 0.06 north, the next successful observer [illegible] at Alexandria.

The Size and Shape of Melpomene. The maximum observed chord was 132 km at the Goddard site. The mean diameter is probably near 135 km, about 10% smaller than expected. Departures from a spherical or elliptical shape, according to the photoelectric records, are at least a few kilometers, although the three photoelectric chords are rather closely spaced. If all of the observations except those near Columbia are considered, the outline is roughly circular with irregularities of nearly ten kilometers. Since the motion was 8 km/sec., the visual timings should be accurate to 3 km or better. The observations at Columbia, when compared to the others, imply a very irregular shape, with a 20-km-deep valley on the advancing edge of Melpomene and a similarly high mountain on the other side. Although it can not be completely ruled out that the observers may have been 2 to 3 seconds late in their timings (neither saw both events), the trend of the other data does favor a large mountain on the reappearance side.

The center of the path apparently was near 0.15 north, with the central time 4.7 minutes before the nominal times shown on the map on p. 8 of the last issue (hereafter called simply "the map"). The northern limit was probably near 0.22 north and the southern limit probably near 0.06 north. If there is any observer who observed either an occultation or a miss near this path, who has not yet sent me a report of his observation, please do so as soon as possible. According to the National Weather Service and some observers, clouds prevented observation from the path in the Midwest and Pacific Northwest. It may have been clear in Wyoming, but as far as I know, nobody attempted observations there.

The Stellar Duplicity. There is no previous record of duplicity for this spectral type K0 star. In the three photoelectric records, the close secondary both disappeared and reappeared before the primary. My disappearance observation is the only known visual timing of an event involving the secondary star. I was well north of the Washington area, so the event position angles were very different at my site from those at the photoelectric stations.

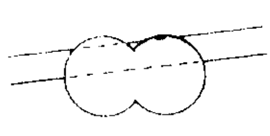
A very preliminary analysis of the observations gives an approximate separation of the secondary from the primary of 0.04 in a position angle about 30°.

According to Skillman's photoelectric data, the primary was seven times as bright as the secondary, giving Δm = 2.1. Skillman used an unfiltered 1P21 photometer. If the star's total magnitude is 8.35, the V-mag. determined by Rick Binzel, the component magnitudes would be 8.5 and 10.6. If the asteroid was at minimum, its V-mag. was 9.4, according to Binzel's data. If the primary is occulted, an occultation event of the secondary would produce a Δm of 0.3 (the asteroid would be three times as bright as the secondary). I was able to see this drop visually due [illegible] and the fact that it occurred soon after the primary [illegible] probably would not [illegible] such a small change. The secondary [illegible] reappeared at my [illegible] primary still was occulted [illegible] not notice such an event. In the USNO and University of Maryland records, the secondary had about one fourth the intensity of the primary [illegible] response [illegible] there is not yet known, [illegible] from Goddard could be due to a difference in the colors of the stellar components, which probably are of different spectral [illegible] density corresponds to [illegible] component [illegible]. In this case, an occultation event of the secondary would produce a Δm of 0.4, if the primary is behind the asteroid.

The reappearance of the secondary occurred 2.5 seconds before that of the primary at Goddard, but [illegible] interval was only one second at USNO, only 13 km away. [illegible] corresponds to a similar linear distance. Since the secondary was north of the primary, it followed a more northerly track behind the asteroid for each station. Hence, the short chord for the secondary seen at Goddard is probably close to the chord for the primary seen visually near Columbia, strengthening the idea of a large dent, or other topographic feature, on Melpomene discussed above.

Skillman notes [illegible] small level change about 1.6 seconds before the reappearance of the secondary. It is only about $1/_{20}$ of the drop due to the primary. If it is due to the reappearance of a third star, it would be about mag. 11.8. Van Flandern notes that a third star may be present in the USNO record, but noise makes it hard to tell. Due to the unreliable drive on the telescope, a 3' diaphragm was used, so perhaps the level change was due to a faint, unrelated star which passed out of the field. Arnold Klemola notes that on one of his two plates, there is evidence for a star of perhaps 12th mag. about 7" east of SAO 114159, but thinks it may be a plate defect. Such a star would have been occulted about [illegible] minutes before the primary. With the primary in view, such an occultation would be lost in the noise of even a good photoelectric record.

Occultations by Secondary Objects. Richard Williamon obtained the most striking photoelectric record of a secondary occultation, using a 91 cm reflector at Fernbank Observatory, Atlanta, GA. The duration for the occultation of the primary corresponds to a chord length of 48 km, on the likely assumption that it was caused by a satellite of Melpomene. There is a further drop of about [illegible] the main drop about one second after the disappearance to about one second before the reappearance, in good agreement with the stellar secondary events in the USNO and University of Maryland records. There is a spike in the light curve near the center of the event, as if the secondary reappeared briefly, but it could be noise. Such a "flash" would be possible if the satellite were a coalesced pair of objects, each nearly 25 km in diameter. The primary star would then be occulted by nearly the long axis of the two objects, while the secondary star would cut a northern path, reappearing briefly in the gap between the two objects; see the diagram below (a noisy secondary occultation in Reitsema's photoelectric record of the May 29th occultation by Pallas may have a similar explanation; note also the quick double events described by Poss and Nolthenius below). The sky was about 75% covered with thick cirrus at the time; Williamon was fortunate to have a break in the clouds for several minutes around the time of the event. But other observers in the Atlanta area and in northern Georgia were not so lucky and, due to the clouds, obtained no observations which might have confirmed the satellite. Unlike "cloud" events, the level changes for the Fernbank secondary occultation are sharp. The analysis about the satellite given on I.A.U. Circular No. 3315 (1978 December 14), where it is designated 1978 (18) 1, is wrong because the stellar components were incorrectly assumed to be "roughly equal in brightness."



Atlanta was at about 0.56 south and the event was 5.5 minutes before the nominal time of closest approach by Melpomene. The star-asteroid separation in the plane of the sky was 0.95, 750 km, or 5.5 Melpomene diameters. If the satellite were a 45-km spherical object, it would be about 2½ mag. fainter than Melpomene. This is favorable enough that James Christy (discoverer of Charon) and others at USNO are attempting direct double star observations (One night in late December, when the seeing was good and the altitude was about 10°, well short of culmination, they visually noticed an elongated image. They waited for culmination to try to photograph it, but the seeing had deteriorated by then). The satellite could offset the center of light from Melpomene by several hundredths of a second of arc. But if the satellite is a smaller coalesced double object, it will be fainter, and difficult to detect.

If there were any observations made between 0.5 south and 0.6 south on the map which have not yet been reported, please send them to me, whether positive or negative. The south suburbs of Memphis, TN, and the north suburbs of Sacramento, CA, are especially well-situated near the path. Larry Wasserman reports the closest currently known observation, negative, from the University of Oklahoma's observatory, near Norman, OK, 30 km south of the Fernbank track, at about 0.59 south. The closest observation I know north of the path was made by Paul McBride, Green Forest, AR, at 0.44 south, but one of the portable photoelectric stations in Utah or Colorado was probably closer to the Fernbank track. McBride timed some short (about 0.5 duration) blinks, some of which he felt were probably not atmospheric, and one of which corresponded to the time of the Atlanta satellite. However, since he was 15 km north of the Atlanta path, it is very unlikely that the event was part of the Atlanta satellite, but it could be an occultation by a small satellite of the Atlanta satellite. No events were noted at the observatory of the University of the South, Sewanee, TN, which, at 0.41 south, was close to McBride's path.

A possible two-second secondary occultation is evident in Howard Ross' photoelectric trace obtained at Ambler, PA, about 0.29 north and 4.5 minutes earlier than the nominal time. Emil Volcheck was the next observer south, at 0.26 north, while Keith Holloway and John Church also saw no occultation near Princeton, NJ, at 0.33 north. This is not surprising, since the path for the Ambler object might be only about 15 km (0.02) wide. The path is perhaps smaller, since the record has three dips during the two seconds, perhaps caused by two or three close small objects.

Richard Nolthenius, Mountainview, CA, (0.6 south) reported two 5-second occultations, separated by one second, which he observed visually under good conditions, 5.8 minutes earlier than the nominal time for his location. Perhaps the events were caused by a separated pair of 10-km objects. James Van Nuland, observing from a site in San Jose, CA, many km to the south, saw a 0.5 blink, but three minutes after Nolthenius' pair of events. Rick Baldridge, observing with a 41-cm reflector at Foothill College Observatory, 2 km south of Nolthenius' path, reported no occultation, but nobody was that close north of Nolthenius. There are several other visual "blink" observations, and a few reports of sudden brightenings where a corresponding dimming was missed. Many of these are probably atmospheric seeing variations, but some could be caused by 1- to 2-km-sized objects.

One spike event in USNO's trace goes down to the asteroid light level, not to the bottom, as would be expected for an instrumental glitch. A few similar spikes, possibly caused by very small objects, occur in other traces made as far away as Tucson, AZ (1.24 south). For a period after the reappearance, USNO's photoelectric record was about three times noisier than usual for several seconds. Tom Van Flandern noticed the star flickering as he observed through the guide scope. Charles Worley, observing with the 66-cm refractor about 100 meters away, remarked to Tom when they met after the event, "Too bad the seeing went to pot at the reappearance." I also noticed some flickering after the reappearance at my site, causing me to call out some false (stellar) secondary reappearance times (knowing that the star was double at disappearance). Similar phenomena may be present in the other photoelectric records in the DC area. Seeing variations can't yet be ruled out, but the post-emersion "noise" may have been due to a cloud of small objects (10 meters or less) near Melpomene, which passed over the star (which subtended a few hundred meters at the asteroid's distance). This hypothesis might be tested during a future occultation by a pair of photoelectric stations in line, separated by several hundred meters. They should record similar noise structure, separated a small amount in time corresponding to the motion of the asteroid occultation shadow, if the hypothesis is true.

Astrometry. As noted on p. 8 of the last issue, Gordon Taylor issued a prediction based on early astrometry, indicating a 0.2 south path. The biggest astrometric effort by far was made by Larry Wasserman and co-workers at Lowell Observatory, Flagstaff, AZ. Besides some preliminary astrometry, over 15 plates were obtained, taken every clear night starting November 28th. By December 5, their results, obtained with a small-field 33-cm telescope and using a secondary network of faint reference stars tied to SAO positions, seemed conclusive. Their predicted path, at 0.49 south, was published on I.A.U. Circular 3312, with the statement (audacious and too optimistic, in retrospect) that "The formal standard error in the north-south direction is less than half the track width of about 160 km." I started to make plans for an expedition to South Carolina. Five observers from the DC area were willing to undertake the long trip. Dr. John Safko at the University of South Carolina, Columbia, SC, established a message center, and observers in South Carolina, northern Georgia, and westward along the track were mobilized.

On Friday, December 8, the picture began to change. Wasserman telephoned, saying that their most recent astrometry, when combined with their earlier results, indicated a linear northward shift which, extrapolated to Dec. 11, indicated that the path might be in the Washington, DC area. Late that afternoon, Arnold Klemola telephoned his data obtained on Dec. 6 at Lick Observatory, CA. My calculations using his data also put the path in the DC area. Fifteen hours before the occultation, however, the following five predictions were available:

1. 0.34 north. Based on plates taken with the 155-cm small-field USNO telescope at Flagstaff, AZ, on Dec. 9 and 10, U.T. The field was too small to show any reference stars other than SAO 114159, so only differential measurements were made between it and Melpomene, using a trailed image of the star to determine orientation and the motion of Melpomene between the two nights for the plate scale.
2. 0.16 north. Klemola's result using 10 AGK3 reference stars on a 4"x6" plate.
3. 0.07 north. Flagstaff 33-cm extrapolated result.
4. 0.16 south. Based on two 2-minute unguided exposures by Penhallow at Quonochontaug Observatory, RI, on Dec. 7. The objects were separated by about 1°, so that both barely fit on one plate; to obtain this configuration, no guide star was available.
5. 0.39 south. A result obtained by making a straight average of all the Flagstaff 33-cm results. Wasserman said that a couple of the data points were not in agreement with the linear trend noted above, and felt that a straight average might be applicable.

All astrometry, including Taylor's early result, correctly predicted that the event would occur from 4 to 5 minutes earlier than the nominal predictions. Bad weather in England prevented Taylor from getting any "last-minute" astrometry for the event.

I felt that predictions 2 and 3 were most likely correct, canceled our expedition to South Carolina, and encouraged observation from the DC area. Klemola's astrometric equipment and measurements are of the highest quality; the prediction of the 1977 March occultation by Uranus using his results was the most accurate. An average of the less certain predictions 1 and 4 also strengthened the idea of predictions 2 and 3 being correct. Prediction 1 was the latest result, with the objects closest together; past occultations have shown that the latest results are usually the best. Consequently, I encouraged observers in the New York City area and New Jersey to observe (by then, it was apparent that clouds probably would prevent observation farther west). But Wasserman and I realized it was a new, untested technique; a small error in measuring the star trail could produce a substantial error. Penhallow remarked that his plates were not of the highest quality; we suspected that 1° separation was too much for an accurate result (for his good astrometry for Herculina, the objects were 5' apart). Bad weather prevented observation when the objects were closer.

Wasserman and others at Flagstaff decided to cover prediction 5. Seven portable photoelectric stations (2 from Lowell Observatory, 3 from the University of Arizona, Tucson, led by William Hubbard; 1 from Cornell University, Ithaca, NY; and 1 from New Mexico) were deployed across west-central Utah and southern Colorado. Prediction 5 was selected partly for expediency, to minimize travel distance. The weather also dictated southern locations, since overcast skies were predicted for central Idaho, and prospects were not encouraging for more distant Wyoming. Also, they realized that the northern predictions would be covered by established observatories; the locations they selected filled a gap in photoelectric coverage.

The prediction using Klemola's data (2) turned out to be the best, apparently accurate to within 0.01. The time also was good to 0.1 minute. The Flagstaff extrapolated prediction (3) was also very good. The data are being reanalyzed with AGK3 reference star data to see if that could eliminate the linear trend and give a consistently accurate position. The very last astrometric observations, double star observations (visual and photographic) by Charles Worley, the night of the event at USNO, Washington, DC, should also be noted. As the night progressed, Worley kept remarking to Van Flandern, "The position angle is not changing!"

Other observations. Besides the observations reported above, reports have been received from many other observers reporting no occultations. These define a large region of space around Melpomene devoid of satellites, at least to the kilometer level. The "miss" reports which have been received so far are tabulated below.

Observer, Location	Shift Value on Map
W. Liller, Harvard, MA[b]	0"59 N
A. McRobert, Newton, MA	0.58 N
T. Hayward, Otego, NY	0.52 N
J. Bortle, Stormville, NY	0.46 N
R. Tuthill, Mountainside, NJ	0.37 N
W. Nissen, Quantico, VA[d]	0.08 N
J. Prideaux, Richmond, VA[f]	0.03 S
C. Brooks, Chatham, VA	0.14 S
D. Nye, Longmont, CO	0.21 S
P. Asmus, Denver, CO	0.25 S
G. Erickson, Davis, CA[b,f]	0.67 S
R. Bryant, Orinda, CA	0.70 S
?, Chabot Obs., Oakland, CA[c]	0.72 S
D. Wallentinsen, Albuquerque, NM[d]	0.75 S
G. Rattley, San Jose, CA[c]	0.76 S
P. Newman & R. Price, Garland, TX[b]	0.9 S

I expect that the above list is rather incomplete. In particular, the positions of the portable photoelectric stations are not yet available. I plan to publish a diagram, like the one for the occultation by Herculina on p. [illegible] of the last issue, in a future issue.

Lessons Learned Concerning Observing Strategies and Techniques. Perhaps the biggest lesson learned is that already mentioned, the need for observations from pairs of stations to confirm occultations by small satellites. Observers need to coordinate more with others in their areas to arrange this, and to be willing to travel to other locations to give better coverage for the main event. Due to the unseasonable cold (about -8° C, necessitating the wearing of tape recorders under jackets, as successfully done during winter grazes) and the fact that the event occurred at 4 AM local time Monday morning, most DC-area observers were unwilling to attempt observations [illegible] their home locations. The [illegible] coverage in the area made visual observations there almost redundant. The Washington-area observations covered [illegible] km, or about 26% of the diameter of Melpomene. The observers who traveled north to the Baltimore area extended the coverage to 76 km or [illegible]% of the diameter, which substantially strengthens the analysis for Melpomene's size and shape, making it perhaps the best determined for any asteroid, although there are probably more than 70 larger minor planets. Fortunately, seven of the more experienced occultation observers were willing to travel outside the area, so that one station was set up about 100 km south of Washington, and three pairs of stations were established at the following approximate road distances from Washington: 50 km south; 50 km north; and 100 km north. Three of the stations failed to obtain data for various reasons (including both at 50 km south), and a miss occurred at the southernmost station. We expected observers at Charlottesville and Richmond, VA, to provide coverage to the south, and observers in the Philadelphia area and Delaware to give northern coverage. Unfortunately, those in Delaware, near the northern limit, failed. In any case, Melpomene showed that observers with portable equipment willing to travel to fill in gaps can make an extremely valuable contribution.

Unfortunately, most visual observers in our area (about 15 others who tried) failed to [illegible] observations. The most experienced [illegible] observers were, in general, the most successful, although a few of them also failed. I notified many observers who live more than 25 km and less than 100 km from Washington, but all of them failed. Cirrus clouds prevented observation at Fredericksburg, VA. One observer with portable equipment was at a critical location near the southern limit. The site was near the Potomac River, whose waters were much warmer than the air. Convective air currents from the river produced such poor seeing that the observer was unable to obtain data. Large bodies of water should be avoided during cold weather unless a substantial layer of ice prevents convection. Short-wave time signal radio reception was poor that night due to solar activity; I obtained a good recording by holding the tape recorder microphone close to the speaker of my Timekube played at full volume. One observer saw the occultation and tried to record local telephone time signals which I calibrated against WWV. When he played back his tape, there was a [illegible] tone, since the telephone company installed equipment which automatically terminates a call to the time number after one minute. One observer saw the occultation from a site about 2 km southeast of the Goddard site, but his timings were late due to interference from headlights of a passing auto.

By far the most common reason for no observation was failure to locate the correct star, or to find it too late (I noted the time to most of those to whom I talked by telephone, and the minus 4.5 minute correction was published in the last issue and in other updates which I distributed, but a few still went by the time inferred from the map). The need to practice locating the star beforehand can not be overemphasized. Variable star and asteroid observers are more skilled at finding objects in odd parts of the sky than are most lunar occultation observers. A good finder, and a very low-power (wide-field) eyepiece for the main telescope, help in locating the star. Know the angular diameter of the field of view of your finder and main telescope when various eyepieces are used (the moon's approximate ½° diameter can be used for calibration). Some complained, "they all look the same," or, "the star was in a crowded Milky Way field." But a dense field provides many signposts which should help identification. Form simple triangular or quadrilateral patterns to move from bright, familiar stars to the star to be occulted. If you have any doubts about locating the star, take your telescope to a more experienced observer a few nights before the event so that he can help you locate the star. Remember that the presence of the asteroid may affect the appearance of the field (on future finder charts, we should indicate the asteroid's position 24 hours before the event). Some observers easily located the star around 10 PM local time, but had difficulty in re-locating it just before the event 6 hours later, when the orientation was different; try locating the star at the same time a previous night [Ed: or if you can avoid rotating the tube of your Newtonian in its cradle, until after the star has been re-located, the re-orientation problem will be minimized]. If you use a refractor, or short folded telescope design (e.g., a Schmidt-Cassegrain), with a diagonal, you will see a mirror image of the field (one direction reversed). Such observers will find it useful to redraw the important parts of the star field on tracing (or other translucent) paper, and use the back side by shining a flashlight through it. Stockbauer's detailed chart was helpful in zeroing in on the star, but some noted that some of the plotted stars were somewhat off position. This is because the charts were freehand sketches made at the telescope. Better detailed charts might be prepared from a plate taken for early astrometry of the star, but since most plates are blue sensitive, such charts should be checked to gauge the visual brightness of the stars. Most detailed photographic atlases do not have a large enough scale for our purposes, but might be of use in preparing detailed charts. We have a continuing need for volunteers with access to detailed star atlases, to help with the preparation of good-quality finder charts.

I feel that a larger aperture is advantageous for seeing an asteroidal occultation event since the change in light received by the eye is proportional to the light-gathering power of the telescope. I think this is more important than the threshold argument for using a small telescope, especial-

[a] Began observing 4.0 min. before nominal time. A short occultation by Melpomene probably occurred at this site 0.7 minute earlier.

[b] Photoelectric.

[c] A blink was observed, but no timing preserved. The event was attributed to seeing at the time.

[d] A dimming of the star for a few seconds was attributed to watering eyes caused by a cold wind. Details have been requested to check for possible coincidence with Nolthenius' pair of blinks.

[e] "Numerous seeing events."

[f] Some gradual dips in the record are attributed to cirrus.

[g] Began observing late, 4.4 minutes before nominal time.

[h] Some relatively gradual brightenings and fadings were recorded photoelectrically and seen visually.

ly for relatively faint stars, when seeing variations may also drop the star's light below the threshold. Note that, using a 25-cm telescope, I was the only visual observer to see an event involving the close stellar secondary. Some observers using smaller telescopes, who watched Melpomene and the star the previous night, felt that observation might be difficult, since the objects seemed of "similar brightness," but the star appeared substantially brighter with my telescope. One last remark: As for lunar grazing occultations, be sure to record exactly when you began and ended observation, and note the start and stop times of all intervals when observation was interrupted for any reason, such as a cloud, telescope adjustment, or checking a comparison star in a distant part of the field.

In summary, much interesting data has been collected during this occultation. We learned a great deal, and should be able to do much better with future events. Unfortunately, there are no asteroidal occultations as favorable for North America during 1979.

MORE ON MELPOMENE

David W. Dunham

Bob Bolster also observed the occultation of the secondary star visually, timing its reappearance only 0.3 before the emersion of the primary. This establishes the primary-secondary separation at 0"05 in P.A. 30°, accurate to 5 km or so at Melpomene's distance, and confirming a large (over 10 km) "mountain" at emersion, according to Espenak's timing. D. Skillman calculates that the secondary star had $^1/_5$ the light of the primary star from his data, more than the $^1/_7$ value I estimated, and in better agreement with the results from the other photoelectric records. E. Bowell notes that the occultation diameter is in good agreement with a recent polarimetric result. A. Harris, who observed at Table Mountain Observatory, Wrightwood, CA (1"04 south) had no occultation, but recorded Melpomene's light curve. The magnitude range was 0.3, with the occultation occurring near minimum light. According to his data, the asteroid was 0.71 mag. fainter than the star (mag. 9.06 if the star was 8.35), so that the total occultation Δm was 1.16 (1.01 for the primary star and 0.35 for the secondary, assuming that the other component was occulted).

The 0"05 (42 km at Melpomene's distance) separation of the stellar components poses problems with the interpretation of the light curve for the occultations by secondary objects. The model I proposed for the Fernbank occultation probably is incorrect, with at least some of the features in the trace previously attributed to occultation of the secondary star probably due to atmospheric seeing instead. If the secondary star was occulted at Ambler, PA, it must have been by a separate satellite, one whose primary occultation path was north of Princeton, NJ, rather than by the satellite (or debris?) which apparently occulted the primary star there.

The portable photoelectric stations from the University of Arizona were set up in Utah, while those from Lowell Observatory and Cornell were in Colorado, according to the table; all recorded no events:

Observer, Location	Shift Value on Map
E. Bowell, Hugo, CO	0"30 S
N. White, Eads, CO	0.36 S
D. Godia, Price, UT	0.38 S
R. Millis, Lamar, CO	0.41 S
B. Zellner, Moab, UT	0.45 S
D. Walker, Monticello, UT	0.53 S

Monticello was 42 km north of the Atlanta path, so if the object occulted the secondary star at Atlanta, nearly corresponding events involving the primary star should have occurred at Monticello. Unfortunately, due to temperatures below -10° C, the observers at Monticello had much trouble with guiding, and it's possible that the star drifted out of the field of the photometer within seconds of an occultation. Moab was within a km or so of the path for any objects which might have occulted the star at Green Forest, AR. None of the possible brief visual fadings noted at Green Forest are confirmed in the Moab photoelectric record, where no guiding problems were experienced.

PLANETARY OCCULTATIONS DURING 1979

David W. Dunham

The first table below gives information about planetary occultations during 1979 in a form similar to the tables for 1978 events published in earlier issues. All but one of the occultations by minor planets were found by Gordon Taylor, Royal Greenwich Observatory (he made computer comparisons of accurate astrometric ephemerides of 49 asteroids with the SAO and AGK3 star catalogs). The occultation by Euterpe on December 9th was published in the Swiss almanac, *Der Sternenhimmel 1979*; Euterpe is not one of the objects considered by Taylor. Jean Meeus first pointed out the occultation by Mars. A second table gives further information about the occultations.

Notes about Information in the First Table. The ranges of Universal Time are given in increasing order; if the occultation shadow will sweep across land areas during nighttime in two minutes or less, only one time is given. Under PLANET, m_v is the visual magnitude (usually photoelectric V-mag.), and Δ is the geocentric distance in astronomical units at the time of the occultation. Under STAR, m_v is the visual magnitude (converted to a photoelectric V mag. scale using data from the Skymap Catalog described in *o.N.* 1 (16), 161) and Sp is the spectral type; the approximate ecliptic 1950 position is also given. Under OCCULTATION, Δm is the change in visual magnitude of the coalesced images which is expected if an occultation does occur. Dur is the duration for a central occultation computed using the expected diameter of the planet, df is a measure of the diffraction effects for a central occultation (It is the time in milliseconds between fringes for an airless planet), and P is the inverse of the probability that an occultation will occur in the possible area, assuming a combined stellar ephemeris positional error of [illegible] (That is, P is essentially the ratio of the width of the possible area of visibility to the width of the expected occultation path.) The combined area can be considerably reduced with modern astrometric observations, and the width of the possible area narrowed to substantially reduce P, but as explained before, this can be accomplished best when the planet and star can be photographed on the same plate, perhaps only 2 to 3 days before the event. Under Possible Area, the regions from which the events may occur with the sun below the horizon are listed in the chronological order in which the occultation shadow will sweep over them. A "?" indicates that an occultation will occur in the area just mentioned only if the actual path shifts n(orth) or s(outh) (the direction indicated by the letter following the "?") of the predicted path, usually by at least a few tenths of an arc second in the sky. The elongation of the sun from the planet is given under El Sun. Under MOON, the elongation from the planet is given under El, the percent sunlit ("+" for waxing and "-" for waning phases) is given under % Snl, and the approximate longitudes from which the moon will be above the horizon in the possible area are specified under Up. For the latter, the moonrise or moonset terminator is specified in degrees of longitude E(ast) or W(est) of Greenwich, preceded by a letter w(est) or e(ast) to specify the direction in which the moon will be above the horizon. "All" or "none" is used to specify whether or not the moon is up in the entire possible area if it is not crossed by the moonrise or moonset terminator.

One of the most important columns in the table is Δm, since it specifies the observability of the event. A value less than 1.0 in general means that the event can only be reliably observed photoelectrically. In case of exceptionally good atmospheric seeing, smaller magnitude drops might be detected visually. Consequently, the occultations of Oct. 6, and by Juno on Dec. 11 likely will not be noticed visually.

Notes about Information in the Second Table. The date, asteroid or planet name, and the star's SAO number are repeated for identification. The minor planet's number, and the expected diameter in kilometers, and the apparent angular diameter in arc seconds, are given. The diameters for (2) Pallas, (3) Juno, (6) Hebe, (18) Melpomene, and (532) Herculina were determined from previous occultations. The diameters for the other minor planets are the best current estimates from infrared radiometry, polarimetry, and related taxonomic information. The diameter of Mars is an average value derived from spacecraft radio signal occultation data. Under RSOI, the distance in km from the asteroid is given where the gravitational attraction of the asteroid is equal to that of the sun, assuming (pessimistically) that the mean density of the asteroid is twice that of the sun. Satellites are possible for much greater distances, since tidal or differential forces determine satellite capture; according to the theory of three-body motion, these forces are proportional to the cube of the ratio of the distances, not the square. Although some secondary occultations have been seen at distances greater than RSOI (the cube ratio gives a distance larger than the earth's diameter for all events), they are most numerous within the RSOI distance of the asteroid. The position angle of the asteroid's motion is given under PA.

The star's B.D. or C.D. number is given under the DM NO. column. For declination zones north of -22°, the number is a B.D. number, while to the south, it is C.D. The -22° zone can be either, although the B.D. number usually is used. C.D. numbers in the -22° zone are about twice as large as the corresponding B.D. number for the same star, or for stars with similar right ascensions. The star's double star code is given under D.

The star's angular diameter is expressed in four ways: in milliseconds of arc (0″001); in meters subtended at the asteroid's geocentric distance; the geometric (ignoring diffraction) TIME in milliseconds for the asteroid's limb to cover the star's disk in case of a central occultation (for nearly grazing events, this time will be prolonged, in some cases enough that the fade might be noticed visually), and in terms of diffraction fringe separation (df). For values of df from 0.1 to 3, the diffraction pattern will be modified enough that the stellar diameter could be computed from an analysis of a good quality high-speed photoelectric record. If df is less than 0.1, the diffraction pattern will be modified so slightly by the star's diameter that a determination will likely not be possible with even a good quality record, but note that none of the stars in the table are this small (i.e., the diameters of all are potentially measurable from suitable occultation observations). The stellar angular diameter is computed from the Warner formula (given

1979 DATE	UNIVERSAL TIME	PLANET NAME	PLANET m_v	PLANET Δ,AU	STAR SAO No	STAR m_v	STAR Sp	STAR R.A. (1950)	STAR Dec.	OCCULTATION Am	OCCULTATION Dur	OCCULTATION df	OCCULTATION P	Possible Area	El Sun	MOON El	MOON %Sn	MOON Up
Jan 26	15^h25^m	Amphitrite	10.9	2.65	109262	5.7	A0	$0^h29^m.9$	6°41'	5.2	6	10	79	n.e. Europe?s	64	86	4-	none
Jan 27	9 08	Laetitia	11.0	2.48	110311	8.5	G5	2 01.0	1 22	2.6	7	14	22	New Guinea, mid-Pacific	82	95	1-	none
Feb 28	3 41	Egeria	12.2	3.05	92603	9.5	G5	1 41.6	11 03	2.8	7	9	18	w. North America	49	29	3+	w124 W
Mar 16	20 00	Pallas	10.5	4.03	126160	9.1	K5	20 42.1	6 10	1.7	15	11	11	central Australia?n	46	103	92-	all
Mar 17	11 25	Fortuna	11.9	2.76		11.1	K2	2 08.0	12 30	1.2	5	7	18	Indonesia; Philippines?n	38	175	87-	none
Apr 6	0 18	Laetitia	11.5	3.29		10.8	F8	3 36.4	10 56	1.2	4	9	29	e. USA; e. Canada?n	40	68	65+	all
Apr 24	19 20	Pallas	10.4	3.63	107061	6.8	F5	21 18.9	10 07	3.6	23	16	10	se Asia;Philippines;Japan?n	70	51	4-	e138 E
Apr 27	6 58	Psyche	11.1	2.73	163921	8.1	G5	20 47.8	-15 42	3.1	13	16	16	central S. America	86	96	1+	none
May 19	17 45-54	Interamnia	11.3	2.50	164174	8.1	K0	21 6.3	-11 01	3.3	25	23	11	n.w. Australia; Indonesia; Japan?n	102	22	42-	e105 E
May 23	5 41	Parthenope	12.0	3.45	78148	9.4	F5	6 12.4	22 10	2.7	4	9	33	n.e. Pacific; Hawaii?s	32	67	9-	none
May 31	11 19	Patientia	12.8	3.47	129290	9.0	F5	1 22.8	-5 17	3.8	9	10	15	(Mexico;Arizona; N.Mex.)?n	53	114	27+	none
Jun 9	7 13	Melpomene	11.5	3.08		8.8	K0	8 21.6	18 03	2.8	4	9	33	New Zealand?n	46	118	98+	all
Jun 21	10 21	Dembowska	11.9	3.34		10.5	G5	10 55.3	11 37	1.6	6	15	33	New Guinea; n. Australia?s	72	109	10-	none
Jun 27	8 39	Themis	13.2	3.33		10.5	A0	4 04.0	20 57	2.8	6	9	27	Brazil	32	64	8+	none
Jun 28	19 11	Flora	11.5	2.83		10.7	F5	10 27.1	14 34	1.2	5	10	27	s. Atlantic	57	11	17+	all
Jul 15	20 13	Metis	11.1	2.89	77128	8.5	K0	5 19.0	22 54	2.7	3	7	27	e. Australia	32	66	57-	all
Jul 20	10 06	Dembowska	12.0	3.70	118857	9.4	G0	11 23.6	7 41	2.7	4	11	37	Australia	52	94	13-	none
Jul 29	21 35-51	Interamnia	10.2	1.79	144829	9.0	K5	20 45.9	-3 47	1.5	27	21	8	w.Indonesia?n;centr.Africa	165	122	28+	w 5 E
Aug 5	5 36	Metis	11.1	2.76	78005	8.2	B8	6 05.0	23 45	3.0	4	8	26	n.w. Africa	41	175	88+	none
Sep 19	4 53	Antigone	12.8	3.76	97988	8.9	G0	8 35.5	14 30	4.0	3	11	47	s. Atlantic	48	24	4-	e 0
Sep 27	5 00	Juno	9.2	1.90	114497	8.5	A0	6 47.9	9 19	1.2	10	11	11	Brazil	81	146	30+	none
Oct 6	23 33-40	Mars	1.2	1.69	98024	6.3	A2	8 37.6	19 43	0.0	230	9	0	e.Europe; U.S.S.R.	66	98	98-	all
Oct 17	20 36-57	Cybele	13.2	3.41		9.7	M2	6 33.2	19 27	3.5	56	65	16	Mideast;e.Europe?n,cen.Asia	106	71	9-	e95 E
Nov 8	11 41-46	Herculina	11.4	2.97	190681	9.1	F8	21 48.2	-27 57	2.4	17	26	20	Australia	95	136	79-	e150 E
Nov 23	20 12	Hebe	10.5	3.13	161146	8.5	G5	18 07.8	-17 09	2.2	4	8	24	Azores?n	32	20	18+	all
Dec 8	5 28-43	Euterpe	9.1	0.97	77426	8.9	K2	5 39.2	22 35	0.9	17	29	12	n.e. Europe?s; Arctic	170	43	80-	all
Dec 11	8 05-17	Metis	10.0	1.50	80950	6.8	B9	9 36.1	20 31	3.2	29	47	14	nwS.America;e.Caribbean?n	119	26	52-	all
Dec 11	8 52-87	Juno	8.2	1.28	115946	9.0	K0	7 45.4	0 36	0.4	66	58	7	Canada; n&w USA; Hawaii?s	136	52	52-	e145 W

1979 DATE	MINOR PLANET No.	MINOR PLANET Name	km-diam	-"	RSOI	PA	STAR SAO No	STAR DM	STAR No.	D	STELLAR DIAMETER M"	M	Time	df	S	COMPARISON DATA AGK3 No	Shift	Time	MOTION °/Day	APPARENT R.A.	APPARENT Dec
Jan 26	29	Amphitrite	195	0.10	838	66	109262	+06°	64	1	0.22	429	14	1.3	P				0.390	$0^h31^m.3$	+6°5[illegible]
Jan 27	39	Laetitia	163	0.09	681	62	110311	+00	341		0.28	501	22	1.6	S	N01° 222	0″15n	$+1^m.0$	0.300	2 02.5	+1 30
Feb 28	13	Egeria	241	0.11	1210	61	92603	+10	232		0.15	328	9	1.0	X	N11 171	0.07s	+0.2	0.398	1 43.2	+11 12
Mar 16	2	Pallas	538	0.18	5487	71	126160	+05	4596		0.49	1432	40	3.6	S	N06 2804	0.82n	-0.8	0.290	20 43.5	+6 19
Mar 17	19	Fortuna	221	0.11	877	71		+12	294		0.12	236	5	0.7	A	N12 232			0.536	2 09.5	+12 39
Apr 6	39	Laetitia	163	0.07	699	73		+10	465		0.05	118	3	0.3	S	N10 367			0.417	3 38.0	+11 [illegible]
Apr 24	2	Pallas	538	0.20	5495	61	107061	+09	4786	Q	0.31	819	35	2.2	S	N10 2885			0.214	21 20.3	+10 15
Apr 27	16	Psyche	252	0.13	1466	74	163921	-16	5709		0.78	561	28	1.7	S				0.242	20 49.4	-15 35
May 19	704	Interamnia	339	0.19	2318	40	164174	-11	5533		0.47	849	63	2.7	S				0.178	21 07.9	-10 54
May 23	11	Parthenope	152	0.06	639	89	78148	+22	1245		0.09	235	6	0.6	X	N22 669	0.35n	+0.2	0.405	6 14.1	+22 09
May 31	451	Patientia	327	0.13	2265	74	129290	-05	254		0.11	284	8	0.8	S				0.340	1 24.3	-5 08
Jun 9	18	Melpomene	135	0.06	682	98		+18	1934		0.29	640	17	1.9	X	N18 860	0.16n	-0.6	0.411	8 23.2	+17 58
Jun 21	349	Dembowska	145	0.06	713	121		+12	2277		0.09	227	9	0.6	X	N11 1271	0.05n	-0.1	0.245	10 56.9	+11 28
Jun 27	24	Themis	210	0.07	1218	79		+20	700		0.02	70	2	0.2	X	N20 371	0.06n	-0.1	0.353	4 05.7	+21 02
Jun 28	8	Flora	153	0.07	593	113					0.05	106	3	0.3	X	N14 1123	0.32n	-0.7	0.390	10 28.7	+14 25
Jul 15	9	Metis	153	0.07	511	83	77128	+22	884		2.09	4390	96	13.1	X	N22 520	0.52n	-0.1	0.526	5 20.7	+22 56
Jul 20	349	Dembowska	145	0.05	715	119	118857	+08	2504		0.11	298	9	0.8	X	N07 1537	0.23n	+0.1	0.302	11 25.1	+7 31
Jul 29	704	Interamnia	339	0.26	2237	281	144829	-04	5264		0.51	666	53	2.5	S				0.230	20 42.4	-3 40
Aug 5	9	Metis	153	0.08	511	88	78005	+23	1208		0.08	167	4	0.5	X	N23 610	0.45s	-0.0	0.513	6 06.8	+23 44
Sep 19	129	Antigone	115	0.04	504	102	97988	+14	1937		0.14	381	11	1.0	X	N14 930	0.09n	-1.7	0.309	8 37.1	+14 24
Sep 27	3	Juno	256	0.19	1058	106	114497	+09	1404		0.07	100	4	0.4	S	N09 782	0.49s	+0.8	0.426	6 49.5	+9 17
Oct 6		Mars	6782	5.53		103	98024	+20	2171	V	0.24	290	10	1.1	X				0.576	8 39.3	+19 37
Oct 17	65	Cybele	309	0.12	2661	108		+19	1399		0.52	1287	231	3.5	X	N19 599	0.11n	-0.4	0.054	6 34.9	+19 25
Nov 8	532	Herculina	217	0.10	1318	55	190681	-28	17479		0.11	232	18	0.7	S				0.143	21 49.9	-27 49
Nov 23	6	Hebe	183	0.08	768	96	161146	-17	5052		0.24	534	12	1.5	S				0.465	18 09.6	-17 09
Dec 8	27	Euterpe	136	0.16	313	273	77426	+22	999		0.31	218	32	1.1	X				0.23?	5 41.0	+22 35
Dec 11	9	Metis	153	0.14	526	71	80950	+20	2351		0.13	147	28	0.6	P	N20 1121	0.20n	+2.5	0.114	9 37.9	+20 23
Dec 11	3	Juno	256	0.28	1111	247	115946	+00	2091		0.31	288	75	1.3	S	N00 1022	0.87s	+0.8	[illegible]	[illegible]	[illegible]

in *Mon. Not. Royal Astron. Soc.*, 158, 1P, 1972) using photoelectric B and V magnitudes for the stars from SKYMAP (*O.N.* 2 (16) 163). For stars not in SKYMAP, the catalog photovisual magnitudes have been assumed equal to the V-mags., while B-V values have been inferred from the spectral types.

The source used for the star's position and proper motion is given under S, according to the following codes. X, USNO X2 catalog for stars within 6°40' of the ecliptic and north of declination -3° (P or S, described below, are used by X2 for southern stars); P, Perth 70; S, SAO; A, AGK3, and G, Albany General Catalog (via SAO, positions especially poor).

If the star is in the AGK3 catalog, but another source is given under S, AGK3 comparison data are listed. If only an AGK3 position is available, no comparison data are given, but the AGK3 number is listed. AGK3 positions are often better than SAO positions, but are generally inferior to X2 and Perth 70 positions. The path shift based on AGK3 data is given under Shift, which is expressed in seconds of arc, "n" or "s" indicating whether the shift is to the north or south, respectively. For instance, 1"00s would mean that the path would be at the southern edge of the possible area described in the first table, according to the AGK3. Besides a path shift, there is a correction to the time of the event if the AGK3 position of the star is used for a comparison. The value in minutes to be added to the Universal Time is given under Time. Gordon Taylor uses AGK3 data for all of his predictions, except south of declination -3°, where he uses SAO data. A few months before the occultation, he often takes plates to improve both the asteroid and star position, to compute a better prediction. The next column gives the asteroid's angular motion, in degrees per day. Multiply the listed numbers by 2.5 to obtain the angular rate in seconds of arc per minute, which is useful for estimating when the asteroid's and star's images will merge, and how long it will be before they might be resolved again. Normally, a separation of one or two seconds of arc will be needed to resolve the objects, but if seeing conditions are very good, a fraction of a second of arc might be resolved. The last two columns give the star's apparent R.A. and Dec. computed for the time of geocentric conjunction, for direct use with setting circles.

Maps and Finder Charts. Worldwide and more detailed regional area-of-visibility maps for many of these events, especially the ones occurring early in the year, will be published in the next issue, which we expect to distribute before the end of February. We also plan to include finder charts for some of the early events in that issue. We plan to change the finder charts. The wide area chart would be more like the *Atlas Coeli*, showing stars to 7th mag., so that it would correspond approximately to the view in many finder scopes. Perhaps only one bright star, labeled on the sky maps such as those in *Norton's Star Atlas* or those published monthly in *Sky and Telescope* would be shown (such maps are presumably available to all O.N. readers). The detailed map, showing stars to about 9½ mag., would be published at a more generous scale, but would cover an area only 3° or 4° on a side. See also the comments about finder charts in the article about the Melpomene occultation on p. 15. The path of the asteroid will be shown, with 0h U.T. marked for four dates starting with the date two days before the date of the event. Hence, there will be three marks on the side of the occulted star before the event, and one mark after. Close double stars will be underlined. If you have any comments about this plan, or other ideas for improving our finder charts in the limited space available, let us know. Volunteers are sought to make good ink drawings of finder charts and/or world maps traced from Soma's computer plots, for publication in *Occultation Newsletter*.

World Maps. Mitsuru Soma, Tokyo, Japan, has produced world maps by computer, showing the paths of occultations of stars by minor planets. The three closely spaced parallel lines show the predicted central occultation line, and the northern and southern limits, with U.T. marked at one-minute intervals and written at five minute intervals. The two parallel dashed lines show the central occultation path in case the minor planet passes 1"0 north or south (measured perpendicularly to its path in the sky) of its predicted path with respect to the star. Combined ephemeris and star position errors can cause path shifts greater than 1", as the occultation by Herculina on June 7 demonstrated. The sunrise and/or sunset terminator is shown, with hatches indicating the side of nighttime visibility. The star and asteroid are in the zenith for an observer at a site indicated by the center of the circular projection of the earth; the objects are on the horizon for sites at the edge of the circle. The altitude above the horizon can be estimated for any site shown on the map. The cosine of the altitude is the distance of the site from the center of the circle divided by the radius of the circle. The sun altitude can be estimated by the distance from the terminator.

Regional Maps. The more detailed regional maps were prepared with a computer program written by Fred Espenak, Bowie, MD, using path data on magnetic tape generated by me at USNO. The parallel curves represent the path of the center of the occultation shadow, considering several different shifts of the minor planet from its predicted path with respect to the star. The nominal path is labeled "0". The parallel curves show the central path for multiples of 0"1 shifts of the asteroid from its predicted path in the sky, measured perpendicularly to the path. Curves are labeled in the map margins at 0"2 intervals, "N" or "S" showing shift direction. Dashed curves show predicted U.T. of central occultation. Low star altitude or twilight boundaries are drawn when appropriate. A stippled line marks the moonrise or moonset line, if either is present. The expected diameter of the minor planet, in km and in arc seconds, is given in the caption. The nominal paths were computed using data for the stars obtained from the sources indicated under the S column of the second table, and accurate astrometric ephemerides which I computed using precise osculating orbital elements supplied by the minor planet centers in Cincinnati and Leningrad; some exceptions to obtain improved predictions, when better data have been available from other sources, have been noted when appropriate. Asterisks show the locations of observatories from which photoelectric occultation observations have been attempted in the past, as far as I know. The regional maps are "false" projections, plotted with a constant linear scale (constant degrees per centimeter) in both longitude and latitude, so that the observer could, for example, plot updated computed path points which might be computed by Gordon Taylor. Note that the width of the occultation path can be estimated on the map from the expected angular diameter. Regional maps will be published in *O.N.* only for areas with many subscribers. They often will be distributed as separate pages to those in areas with relatively few subscribers, such as Japan, southern Africa, and Australia. Maps of South American events will be shown in *Occultation Newsletter en Español*.

Notes about 1979 Events. Observational strategies and recommendations are discussed in an article in *O.N.* 1 (16) 162-163, and in the article about the occultation by Melpomene in this issue. Unfortunately, the elongations from the sun for many of this year's events are relatively small. This causes difficulties for observing the occultation and for obtaining good astrometry to improve the prediction. Also, the geographical area of possible observations is narrowed. Early astrometry is impossible for events with small elongation in the morning sky, unless it is done several months in advance, before the asteroid and star are in conjunction with the sun. Unfortunately, buildings and trees obstruct the western horizons of some of the observatories where many astrometric plates are taken, making last-minute astrometry of small-elongation evening events impossible from these sites. Small elongations also mean that the asteroids are fainter than usual, so that large Δm's occur, making all but two of the listed events potentially observable visually. Unfortunately, the asteroid motions are then also rapid, shortening many of the occultation durations to the point where inaccuracies of visual timings start to become troublesome. For these reasons, although there are many opportunities this year, especially in Australia, I don't think that we will get as many observations in 1979 as we got in 1978, unless even more events are identified. On this last point, plate scans conducted at Lowell for (1) Ceres, and manual comparison of ephemerides with the SAO by Wallentinsen, could turn up additional events. Notes about individual events are giv-

[illegible]

Sep [illegible]: This event occurs [illegible] days after a total solar eclipse, and may be visible from the vicinity of the eclipse path, as indicated by the map.

Mar 16: Gordon Taylor indicates "Indonesia" as the possible area.

Mar 17: Taylor and I agree on the path, both having used ephemerides computed from orbital elements computed at the Institute of Theoretical Astronomy, Leningrad. However, my calculation using an ephemeris computed from accurate orbital elements supplied by Cincinnati Observatory shows that the path misses the earth's surface by many earth radii! The ephemerides agree in declination, but differ by 6s in R.A. We suspect that the Cincinnati elements are right, so that there will be no occultation, but an astrometric check is needed to be sure.

Apr 6: The Δm is small enough that it might be useful to refine it by observing the magnitudes of the objects photoelectrically. Bright twilight will hinder many observers, as it did for the occultation by (29) Amphitrite last December.

Apr 24: This is the most interesting asteroidal occultation of the year. The star is A.D.S. 14893, whose components are each mag. 7.7. According to F. R. West (*Astrophysical Journal*, 205, 194, 1976), the orbit is highly elliptical. He predicts that periastron will occur during 1979, with a separation of perhaps less than 0″02. Even so, disappearances or reappearances of the two stars by Pallas likely will be separated by more than one second of time. One of the components is, in turn, a spectroscopic binary, the third star perhaps being a white dwarf. The time between events for the spectroscopic pair probably will be less than 0s1, requiring photoelectric recording to resolve them. Observations of the event would be valuable for studies of Pallas' shape, supplementing the information obtained during the well-observed occultation by Pallas on 1978 May 29. The stellar duplicity will provide two chords for each observing station, as was the case for the occultation by (18) Melpomene last December. If one star disappears, while the other component is unocculted, the Δm will be 0.7, which may be hard to detect visually if the seeing is bad. If one of the components disappears or reappears while the other star is behind Pallas, the Δm will be 2.9, very easily noticeable. Since the two drops probably will occur only about a second apart, both drops probably will be readily apparent, the large drop calling the smaller magnitude drop to the observer's attention. Taylor computes a more northerly path for the occultation, citing "China" as the possible area.

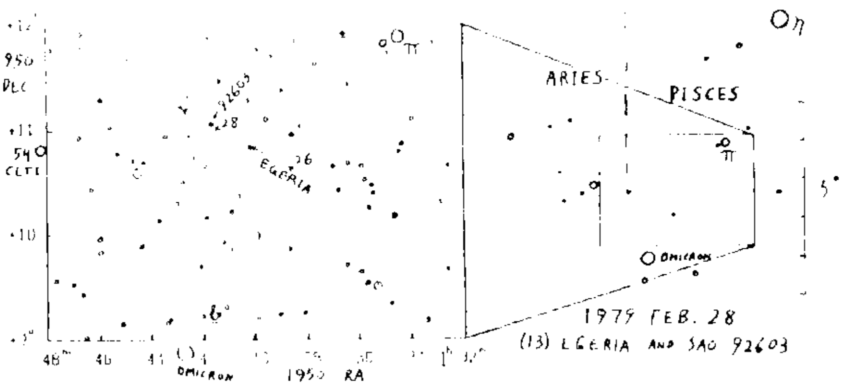
Sep 27: The Δm could be refined by photoelectric observation of the objects.

Oct 6: The star is ε Cancri, a spectroscopic binary and the brightest member of the Praesepe cluster. The Δm will be only [illegible], although effectively it will be higher, since Mars' disk will be at least partly resolved. The effective Δm should be computed from a part of Mars' disk equal in size to the atmospheric seeing disk. For a 1" seeing disk, the effective Δm would be 0.3; with very good seeing, the Δm might even be noticed visually. However, it would be impossible to make a reliable visual timing of the star's relatively gradual fade as its light is progressively refracted by the Martian atmosphere. No dark-limb event will be evident, since at most the dark crescent will be 0″5 wide, and lost in irradiation. Due to the star's spectral type, photoelectric observers could profit by observing with a blue filter. An occultation by a Martian satellite, far enough from the planet so that the star still would be seen separated from Mars' edge, would be noticed easily visually. An occultation by Phobos could last as long as 1 second, although just what would be seen would depend on the unknown (but probably very close) separation, p.a., and relative brightness of the stellar components. I hope that the predicted paths for the occultations by Phobos and Deimos can be computed and published in a future issue of o.N. In any case, an occultation by a currently unknown satellite is possible. During the occultation of ε Geminorum in 1976, a dip in a photoelectric record obtained at Villanova University may be due to a large close satellite.

Oct 17: The asteroid's motion is very slow, since it is near a stationary point. This, combined with the star's relatively large angular diameter, implies that observers with large telescopes will be able to see the star fade, the duration being 0s2 or more. The very slow motion also will facilitate astrometric improvement of the prediction a few days before the event.

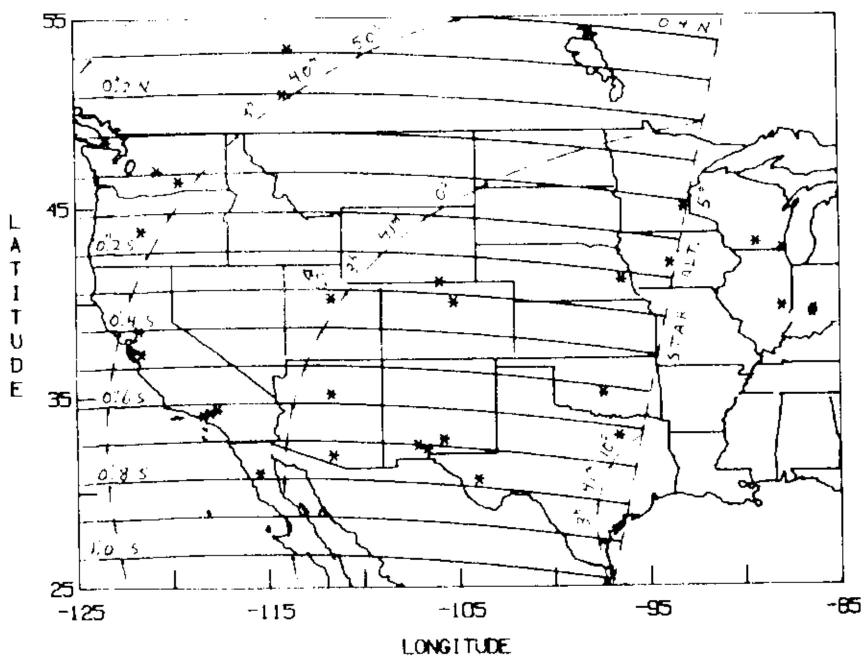
Nov 8: Taylor gives "Indonesia" as the possible area.

Dec 8: According to *Der Sternenhimmel*, the path will cross Greece, northern Italy, and France, corresponding to a shift over 2" south of my prediction.



Occultation of SAO 92603 by (13) Egeria, 1979 February 28

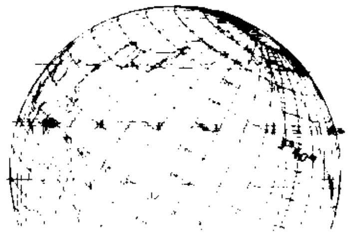
Diameter 241 km = 0″11



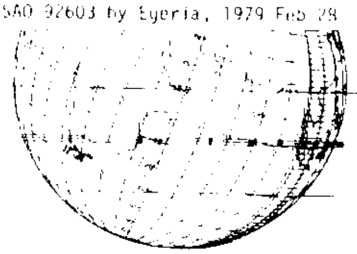
The different star catalogs are in relatively good agreement, the ephemerides which were used for the two predictions must be different. Early astrometry would be useful to resolve the discrepancy. Also, the Δm should be refined by photoelectric observations to give a better assessment of the possibility for visual observation of the occultation.

Dec 11, Metis: The path for this occultation of one of the brightest stars to be occulted by an asteroid during 1979 probably will be rather close to the nominal prediction, since the star is in the Perth 70 catalog and the ephemeris is also very good. It might be a good time for North Americans to travel to the Caribbean, to observe the event as well as to escape from the cold. Due to the slow motion, it should be possible to get good astrometry a few days before the event, to calculate an accurate prediction. In any case, observers throughout the Western Hemisphere should watch the star as Metis passes by it, to check for satellites.

Dec 11, Juno: The small Δm virtually rules out visual observation, but photoelectric observations should be made to check this. Again, the motion is slow, so that astrometric prospects for a good prediction refinement are excellent. Potential observers of this event also should monitor SAO 80950 about an hour earlier, to catch possible satellites of Metis, as discussed above.



SAO 92603 by Egeria, 1979 Feb 28



+12 294 by Fortuna, 1979 Mar 17

Use a tracing of this cosine scale to estimate star altitude from the world maps: place the 90° mark at the center of the circular arc, and read the star altitude at the observing site.

EGERIA OCCULTATION UPDATE?

David W. Dunham

As I plan to observe the total solar eclipse, I will not be able to compute an updated prediction for the occultation of SAO 92603 by (13) Egeria on 1979 February 28 U.T. If "last-minute" astrometry is obtained, after noon of February 25, it should be relayed to Robert McCutcheon in Silver Spring, MD, at 301, 681-7631, or during business hours, at Computer Sciences Corp., 301, 589-1545, ext. 385. He will compute an updated prediction using data which I will supply him before I depart, and observers can phone him for the result, if there is one, i.e., if anyone does obtain any last-minute astrometry.

PROPOSAL FOR ASTEROID STUDIES BY SPACE TELESCOPE

Paul D. Maley

Conventional ground-based studies of asteroids in order to detect satellite companions will be permanently hindered as long as telescopes have to view through the earth's atmosphere. The expected close separation distances of satellites from primary asteroids (on the order of an arc-second or less) implies that a finer tool must be applied. A 2.4-meter aperture Space Telescope is in the design stages for launch on the Space Shuttle in the 1984-85 time frame. It will have the ability to attach variable instrumentation for use at viewing ports, the equipment intended to be serviceable by astronauts in extra-vehicular activities.

One instrument that is ideal for studies of asteroidal companions is the Wide Field Camera, sporting a planned 3-arc-minute field of view, and capable of reaching to 26th magnitude in a 30-minute integration period. I suggested, in a January 1978 letter to Bradford A. Smith (University of Arizona), who is involved with the instrumentation design team for the WFC, that it might be used in an extensive survey of the larger minor planets. This was approximately 9 months after the anomalous secondary occultation I observed in connection with the (6) Hebe event. A planned program to scan the near vicinity of planetoids larger than 100 km might more easily reveal the presence or absence of satellites than the hit-and-miss efforts currently conducted. The outlined resolution element is 0.1 arc-second/pixel. Since the image is not photographic, but electronic, there should be no hazard involving image spillover from long exposure times, allowing dim sub-arc-second adjacent images to show up. Repeating exposures on the same asteroid every 2 or 3 earth orbits might reveal satellite motion and permit elimination of spurious images generated as artifacts. Integration times would depend on detector sensitivity and wavelength response. Analysis of reflectivity in different spectral bands could shed light on whether parent and child were mutually formative by virtue of similarity in albedo; captured satellites might be identified by large variations in thermal absorption/emission.

A.A.S. DIVISION FOR PLANETARY SCIENCES: ECLIPSES OF CHARON, ETC.

David W. Dunham

At the beginning of 1978 November, the American Astronomical Society's Division for Planetary Sciences held its 10th annual meeting in Pasadena, CA. Abstracts of the papers presented at this interesting meeting are published in *Bull. A.A.S. 10*, #3, Part II. L. E. Andersson, Lunar and Planetary Lab., Univ. of AZ, points out that 0.2-mag. eclipses with a duration of up to 5 hours will occur when the earth passes through the plane of Charon's orbit around Pluto. If Charon is approaching us at northern elongation from Pluto, eclipses should occur from now until about 1982. Andersson gives a very approximate ephemeris for transits of the satellite across Pluto. (1979 Jan. 5.0 + n×6ᵈ387) - 0ᵈ3. Occultations and eclipses of Charon by Pluto should occur about midway between these times. He notes: "Photometric observations of Pluto in 1979 are strongly urged."

Occultations of stars by asteroids were the subjects of several papers: "A Possible Satellite of Herculina," by E. Bowell and others involved in the analysis, observation, and prediction of this event; "A Reliable Diameter for Pallas," by L. Wasserman *et al* (based on the seven photoelectric timings of the 1978 May 29 occultation, the axes of an elliptical outline were determined to be 559 ± 6 and 526 + 10 km); "The Shape, Albedo, and Density of Pallas," by J. Elliot *et al* (based on the above and light-curve analysis, the mean diameter is 538 ± 12 km; combined with Schubart's mass determined from perturbations on Ceres, the density is 2.8 + 0.5 gm/cm³); "Radiometric and Polarimetric Diameter and Albedo of 532 Herculina," by J. Gradie *et al* (good agreement with the occultation result); "A Critique of Asteroid Diameter Measurements," R. Millis *et al* (radiometric and polarimetric results were about 15% too large for Pallas; more occultation observations are needed to see if there are systematic errors in the other methods; accurate predictions and mobile telescopes are the key to further successful occultation observations); and "Dynamical Features of Minor Planet Satellites," by T. Van Flandern ("No minor planet has been observed to occult a star and not show evidence of a satellite; the time scale for tidal evolution of large satellites is about 10^6 years; many satellites would have tidally decayed from orbit and would now be resting on the surfaces of their primaries; it is possible that comets and meteorites could be similar closely bound multiple-body systems").

Van Flandern reports that most astronomers coming to the meeting were skeptical about satellites of minor planets, but nearly everyone was convinced after Bowell's and his presentations. There was considerable interest in a special informal meeting about asteroidal occultations. They would like to see more events recorded by many observers, especially photoelectrically. Hopefully, this will give more impetus to various projects to develop a relatively inexpensive photoelectric system which could be duplicated and used by amateur astronomers.