# Occultation Newsletter

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## FROM THE PUBLISHER

For subscription purposes, this is the second issue of 1978; it is the sixteenth and final issue of Volume I. An index to the volume will follow, without extra cost to those who are paid up through this issue.

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## A COMPARISON OF USNO VERSIONS FOR GRAZES

David W. Dunham

I have made some fairly extensive comparisons of USNO versions 78A and earlier versions (75G, 75H, 76A, and 76B) for graze predictions. The comparisons involved both grazes which have been observed and have had reduction profiles drawn during the past few years, and a large set of predicted data. The computed height differences for the observed grazes, involving mainly brighter stars with good star positions, were generally quite small, usually less than 0".2. This indicates that the 78A system of ephemerides and corrections are basically rather similar to earlier versions, so that no extensive changes to the ACLPPP empirical corrections are needed. However, the observations seem to show that the ACLPPP north-shift corrections applied to northern-limit grazes for large positive latitude librations are generally too large and should be reduced; the computors will be notified to make the appropriate changes soon.

There are large differences for some grazes due to the changed (apparently improved) 78A star positions. Note that the only improvement over earlier versions for stars south of declination -3° are for Perth 70 stars. Some non-Perth 70 stars south of -3° still use the relatively poor Z.C. or G.C. positions; graze predictions for them might still be improved using Yale catalog data. A list of these stars might be published in a future issue of *O.N.* In the meantime, for stars south of declination -3° with position sources listed as G.C. or Z.C., you can learn whether the star is in Perth 70 (in which case, the 78A data are the best possible since they use Perth 70) or not by sending me a self-addressed card or envelope, with date, USNO reference number, and P.A. of graze, if three or more stations are planned to observe it. If the star is in Perth 70, as most should be, I will simply indicate this in my reply. If the star is not in Perth 70, I will hand the request over to Wayne Warren or others, so that shift information computed from Yale catalog data can be computed and sent to you. Such requests should be received at least two, and preferably more than four, weeks before the event.

[Ed: Volunteers still are needed, to prepare sections of the Vol. I Index. Please contact David Dunham.]

## IOTA PHOTOELECTRIC OCCULTATION ANALYSIS

David W. Dunham

Wayne Warren, Bill Stein, and I recently successfully tested a copy of the University of Texas' TIMER3P program on a CDC computer in Dahlgren, Virginia, where Stein works. We will try to analyze all high-speed digital photoelectric occultation data collected by IOTA members and sent to us in suitable machine-readable form. Format and data specifications can be obtained from me. The final results of the analysis will be listed in a form ready for joint formal publication. Unfortunately, the TIMER3P uses many features (mainly, the sixty-bit word size) available only on CDC machines, so that conversion to other types of computers will take a large effort, which will not be accomplished in the near future.

## SKYMAP

David W. Dunham

[Ed: This article was prepared for inclusion in an earlier issue; it now has been postponed so long that the work probably has been completed.]

During the past couple of years, David Gottlieb and coworkers at Computer Sciences Corp. have crossreferenced and merged various machine-readable star catalogs to produce SKYMAP, a catalog intended to be as complete as possible to B and V magnitude 9.0 with the most accurate available information on positions, magnitudes and colors for each star. The primary purpose for the catalog is for use with artificial satellites which determine their precise orientation with star sensors. The magnitudes and colors are important as well as the positions since the responses of different sensors depend on these quantities. The catalog has been more-or-less completed with over 255,000 stars whose positions have been obtained from the SAO AGK3, and Henry Draper catalogs. If photoelectric B and V magnitudes are not available for a given star, reasonable values of B and V are computed from the star's visual magnitude, photographic magnitude, and/or spectral type using complex algorithms. Because of my experience with star catalogs for occultation work, I have been asked to lead a task to "quality assure" SKYMAP, using internal and external catalog comparison checks for completeness and accuracy tests. I will be working quarter-time on this task for the next couple of months with the help of three others. One of the first things I will do is crossreference SKYMAP with USNO's SZ catalog. The B and V magnitudes available from SKYMAP will be useful for improving the SZ magnitudes; they also can be used to calculate an estimate of the star's angular diameter, using the Warner formula. This should eventually be included in USNO's total occultation predictions for photoelectric observers.

# OBSERVATIONAL PROBABILITIES AND STRATEGIES FOR OCCULTATIONS OF STARS BY MINOR PLANETS, by David W. Dunham

## 1. Probabilities

Last-minute astrometry has been attempted to refine the predictions for 6 occultations by minor planets. The refined predictions for 2 of these passed over areas with no astronomers and were not seen. The other 4 were successfully observed from 2 or more stations, the observations agreeing with the refined prediction to about 0".1 or better in each case.

| Date | Minor Planet | Star | Predicted by | Astrometry by |
|---|---|---|---|---|
| 1975 Jan 25 | 433 Eros | κ Geminorum | B. Marsden | A. Upgren, Van Vleck Observatory, Middletown, CT, 1 day before |
| 1977 Mar 5 | 6 Hebe | γ Ceti A | D. Dunham | R. Harrington, USNO, Washington, DC, 2 days before |
| 1978 May 29 | 2 Pallas | SAO 85009 | L. Wasserman | L. Wasserman, et al. Lowell and USNO, Flagstaff, AZ, 1 day before |
| | | | G. Taylor | G. Taylor, Royal Greenwich Observatory, Herstmonceux, 3 days before |
| 1978 Jun 7 | 532 Herculina | SAO 120774 | D. Dunham | W. Penhallow, Quonochontaug Obs., Quonochontaug, RI, 2 days before |

It appears that, in general, the prediction can be refined to ± 0".1 one or two days in advance via last-minute astrometry, when the star and minor planet are 1° or less apart and can be photographed on the same plate in the same local stellar reference frame. This means that, with last-minute astrometry, the quantity P (inverse probability of seeing the event, for possible errors of ± 1".0) which I have given in the tables of events in the last two issues, can be divided by ten. Expressed another way, the number of stations, N, needed to ensure observation of n occultation chords can be calculated as a function of P: $N = n(1+P/10)$; ignore remainders. Hence, for $n = 2$, $N = 2(1+P/10)$, so that for $P = 9$, $N = 3$ and for $P = 10$, $N = 4$, for a prediction accuracy of ± 0".1. I have made a computer study, calculating N for all minor planets when they are at favorable perihelic opposition (when they subtend a maximum angle as seen from earth) for $n = 2$ and $n = 3$ assuming different astrometric accuracies. All minor planets were printed for $N \leq 10$, to see how many, and which planets are most promising for occultations. Diameters of the minor planets for this study were taken from "Taxonomy of Minor Planets," which will be published in *Icarus* later this year. Ted Bowell, one of the co-authors, sent me a pre-print of the article; Ray Finkleman keypunched the data for me. The frequency of observable occultations can be judged by the fact that about one occultation of an SAO or AGK3 star occurs for each minor planet as seen somewhere on the earth's surface during a year. Star positions accurate enough for search purposes are available from the Astrographic Catalogs for about ten times as many stars, to mag. 12 as are in the AGK3. The first 38 of 385 minor planets selected for $n = 3$ and ± 0".1 accuracy are listed in the second table, where N is given for both perihelic OPposition and CoNjunction, for accuracies of ± 0".1 and ± 0".2. Limiting observable stellar magnitudes are listed for perihelic OPPosition and CONJunction for VISual observers (star and asteroid magnitude equal) and PHoToelectric observers (star 3.2 mag. fainter than asteroid for a 5% intensity drop if an occultation occurs). If the number of chords, n, is only required to be 2, 885 asteroids were selected. If the astrometric accuracy is not as good, ± 0".2, the numbers for $N \leq 10$ are 281 selected for $n = 2$ and 90 for $n = 3$.

Second Table. Number of Stations Needed to Observe 3 Chords (up to 10 Stations) and Observable Limiting Stellar Magnitudes, for Perihelion. 385 Minor Planets Selected.

| MINOR PL. NO. | DIAM KM | NO. STATIONS 0.10 OP | 0.10 CN | 0.20 OP | 0.20 CN | LIMITING MAGNITUDES OPP. VIS | OPP. PHOT | CONJ. VIS | CONJ. PHOT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1020 | 3 | 4 | 4 | 6 | 6.7 | 9.9 | 8.5 | 11.7 |
| 2 | 630 | 3 | 5 | 4 | 7 | 6.4 | 9.6 | 8.6 | 11.9 |
| 4 | 549 | 3 | 5 | 4 | 7 | 5.5 | 8.8 | 7.7 | 10.9 |
| 3 | 248 | 4 | 8 | 6 | 13 | 7.1 | 10.3 | 9.5 | 12.7 |
| 7 | 210 | 4 | 8 | 6 | 14 | 7.0 | 10.2 | 9.6 | 12.8 |
| 10 | 450 | 4 | 6 | 6 | 10 | 9.4 | 12.6 | 11.0 | 14.2 |
| 31 | 333 | 4 | 7 | 6 | 12 | 9.3 | 12.5 | 11.2 | 14.4 |
| 324 | 251 | 4 | 7 | 5 | 12 | 7.8 | 11.0 | 10.5 | 13.7 |
| 6 | 195 | 5 | 9 | 7 | 16 | 7.2 | 10.4 | 9.6 | 12.9 |
| 8 | 153 | 5 | 11 | 7 | 19 | 7.8 | 11.1 | 10.5 | 13.7 |
| 12 | 135 | 5 | 12 | 8 | 21 | 8.4 | 11.6 | 11.0 | 14.3 |
| 13 | 241 | 5 | 9 | 7 | 15 | 9.9 | 13.1 | 11.9 | 15.1 |
| 15 | 246 | 5 | 8 | 7 | 14 | 7.4 | 10.7 | 9.6 | 12.9 |
| 16 | 252 | 5 | 9 | 8 | 15 | 9.1 | 12.3 | 10.9 | 14.1 |
| 18 | 152 | 5 | 11 | 7 | 19 | 7.5 | 10.7 | 10.2 | 13.4 |
| 19 | 221 | 5 | 9 | 7 | 15 | 9.4 | 12.6 | 11.7 | 14.9 |
| 41 | 177 | 5 | 10 | 8 | 17 | 9.3 | 12.5 | 11.7 | 14.9 |
| 45 | 228 | 5 | 9 | 8 | 16 | 10.5 | 13.7 | 12.3 | 15.6 |
| 52 | 290 | 5 | 8 | 8 | 14 | 9.9 | 13.1 | 11.5 | 14.8 |
| 54 | 177 | 5 | 10 | 8 | 18 | 10.2 | 13.4 | 12.3 | 15.6 |
| 65 | 308 | 5 | 8 | 8 | 14 | 11.2 | 14.5 | 12.7 | 16.0 |
| 88 | 207 | 5 | 9 | 8 | 16 | 9.8 | 13.0 | 11.8 | 15.0 |
| 89 | 169 | 5 | 10 | 8 | 18 | 9.1 | 12.4 | 11.4 | 14.6 |
| 132 | 91 | 5 | 15 | 8 | 28 | 9.4 | 12.6 | 12.5 | 15.8 |
| 194 | 193 | 5 | 9 | 7 | 16 | 9.6 | 12.8 | 12.0 | 15.2 |
| 216 | 219 | 5 | 9 | 7 | 15 | 9.0 | 12.2 | 11.2 | 14.5 |
| 344 | 146 | 5 | 11 | 7 | 19 | 9.2 | 12.4 | 11.9 | 15.1 |
| 372 | 208 | 5 | 10 | 8 | 17 | 10.1 | 13.4 | 12.1 | 15.3 |
| 409 | 208 | 5 | 10 | 8 | 17 | 10.2 | 13.4 | 12.1 | 15.3 |
| 451 | 327 | 5 | 8 | 7 | 13 | 10.9 | 14.2 | 12.5 | 15.8 |
| 511 | 341 | 5 | 7 | 7 | 12 | 9.7 | 12.9 | 11.4 | 14.6 |
| 532 | 230 | 5 | 9 | 7 | 15 | 8.4 | 11.6 | 10.4 | 13.7 |
| 704 | 339 | 5 | 7 | 7 | 12 | 9.6 | 12.9 | 11.4 | 14.7 |
| 747 | 205 | 5 | 9 | 7 | 15 | 9.5 | 12.7 | 11.9 | 15.2 |
| 1036 | 39 | 5 | 27 | 7 | 52 | 7.1 | 10.3 | 12.2 | 15.4 |
| 5 | 122 | 6 | 14 | 10 | 25 | 9.2 | 12.4 | 11.5 | 14.7 |
| 9 | 153 | 6 | 11 | 9 | 20 | 8.7 | 11.9 | 10.9 | 14.2 |
| 11 | 152 | 6 | 12 | 9 | 21 | 9.1 | 12.3 | 11.2 | 14.4 |

## 2. Astrometry

The Herculina event showed that ephemeris errors can be relatively large for the higher-numbered asteroids. The corrections to R.A. and Dec. due to errors in the orbital elements change as the minor planet moves in its heliocentric orbit and as its geocentric distance varies. The orbital elements could be improved by re-analyzing all available observations of the minor planet, including several made in recent years after the last solution was made, a relatively large job for the minor planet centers. This is the best long-term solution, and continues to be done for some objects as time goes on. But more often, reasonably good corrections can be obtained by observations 1 to 4 months before the occultation, to allow an improvement to somewhat better than ± 1".0. This would be in time to alert observers by mail, in case there were a significant change in the expected path, as happened for Herculina. I will call this "early astrometry."

Last-minute astrometry (to achieve ± 0".1 accuracy) is more difficult. The number of observatories which can and will do this is limited, and they may all be clouded out during the critical few days before the event. If the elongation from the sun is small, especially when it is increasing (morning events), there may be no astrometric opportunities. At least one Southern Hemisphere observatory is needed; at declination -37°, Interamnia could not be photographed for astrometric purposes for the occultation in April. Since resources are limited, last-minute astrometry will need to be confined to asteroids with larger angular diameters which early astrometry indicates will probably be visible from areas with many photoelectric observers, or with many visual observers for events with expected central durations of about 5 seconds or greater (visual timing accuracies become troublesome for shorter occultations).

## 3. International Coordination

When we have an improved prediction a day or so before the event, there is then a problem in communicating it to observers, especially on a worldwide basis. Prospective national coordinators in overseas countries should contact me, giving U.T. hours when they can be reached at home and/or office telephones. If TELEX messages can be received, please send details to me or to Gordon Taylor. Taylor can send last-minute predictions by TELEX from the Royal Greenwich Observatory, while Wayne Warren has arranged through the National Space Science Data Center to do this from Goddard Space Flight Center in Greenbelt, MD. In case TELEX communication can not be arranged, IOTA will, on a provisional basis, reimburse the personal costs to Gordon Taylor or me for telephoning or sending a telegram to the national coordinator in a country which will probably be crossed by a minor planet occultation, according to the last-minute astrometry. IOTA's relatively good financial situation permits this in the near future. We probably will seek outside aid for such important international communications in the future, when IOTA funds are committed to other projects, such as publication and distribution of the long-delayed graze manual. A national coordinator receiving an updated prediction shortly before a predicted occultation will be expected to try to alert all IOTA members in his country within the possible zone by telephone. If IOTA coverage in the area is sparse, he should try to notify others in the area who might be able to observe the event. If the coordinator lives in a small country, he may be asked to notify national coordinators in adjacent countries as well. Hans Bode will be notified for European events; potential national coordinators for European countries should contact him to receive last-minute updates within the framework of the European section of IOTA. A similar arrangement might be made for the Latin American section. If a regional prediction map has been distributed (see PREDICTIONS OF OCCULTATIONS OF STARS BY MINOR PLANETS on p. 165), a telegram or TELEX message could be quite brief. An example follows: 3 PLATES BY HARRINGTON USNO AUG 20 SHOW PATH HERCULINA AUG 22 CROSSES CEN. CHILE, N. ARGENTINA. REF. ON EN ESP. 8, P. 79, SHIFT 0.5N +-0.2, TIME 2 MIN. +-1 EARLY. Expanded, this would be: "3 astrometric plates taken by Harrington at USNO on August 20 show that the path for the occultation by Herculina on August 22 probably will cross central Chile and northern Argentina. Referencing the map in *Occultation Newsletter en Español* (#8), p. 79, the expected path shift is 0".5 north ± 0".2, with the occultation occurring 2 ± 1 minutes earlier than the predicted time."

4. Positioning Observers

When last-minute astrometry shows that a minor planet occultation may occur in your area, as many observers as possible should be notified to try to observe the event. Some can watch from observatories and back-yard sites across the metropolitan area in which you live, but those with portable equipment should be encouraged to travel to rural sites well to the north and south, to form an observing fence. This would be similar to what is being done during lunar grazing occultation expeditions, but on a larger scale, with separations of several kilometers between stations. The separation between stations should be dictated by the number of available portable observers and the total north-south distance (actually, distance measured perpendicularly to the expected occultation path) to be covered. You might coordinate your plans with observers in other cities to prevent redundancy; for example, your northernmost observer should not be north of an observer traveling south from a city 150 km north of you. With more observers fielded, more occultation chords can be measured to obtain the size and shape of the asteroid more accurately, and the chances of recording occultations by asteroidal satellites are increased. Due to the possibility of seeing secondary occultations caused by asteroidal satellites, visual observers in the fence should set up stations in pairs, with the two stations of a pair separated by 1 to 2 km, so that their timings are independent. Although this doubles the spacing in the fence, it is the only way, except for photoelectric observation, to confirm observations of small asteroidal satellites, via coincidental timing of short secondary occultations. Due to the larger spacing between observers, there is more freedom for selecting sites than one usually has for lunar grazes. Convenient road intersections whose coordinates can be accurately scaled from a detailed map can be selected. If ground fog or insects threaten, a high ridge or hilltop site can be used. Conversely, if the wind is blowing, observations can be made from a small valley or from another location protected by trees or buildings. Observers should be able to specify their geographical locations accurately, although positional accuracies are not as stringent as for lunar events; an accuracy of ± 0'.1 in latitude and longitude, and ± 200 meters in height, is usually sufficient. Positions of photoelectric stations should be specified more accurately, so that the geographical location is known to an accuracy comparable to the photoelectric timing accuracy multiplied by the transverse velocity of the minor planet. The transverse velocity can be obtained by dividing the expected diameter of the minor planet in km by the expected occultation duration.

If you do not receive word that last-minute astrometry shows the occultation to be probable in your area, it means that either no last-minute astrometry was performed or that last-minute astrometry shows that the occultation probably will not occur in your area. If you want to know which is the case, you could find out by telephoning either me or Gordon Taylor at HMNAO, but in either case, you probably would not want to make a major effort, as described above. We don't want observers to make a large effort when the chances of making a significant observation are very small. But due to the possibility of discovering satellites, at least relatively easy back-yard observations should be attempted, hopefully with at least one other observer in your city also watching, for confirmation; also encourage observation by those living in extreme northern and southern suburbs. For asteroids with diameters around 200 km, satellites are possible at distances of several thousand kilometers, so that there is some possibility of a secondary occultation at all night locations on earth where the star is above the horizon when the asteroid passes it. In practice, such objects seem most likely within about 1000 km or about ± 1" of 200-km asteroids. Early astrometry is more accurate than this, so if early astrometry indicates that the event may occur in your area, observations definitely should be planned. In this case, at least limited observing fences with some stations in rural areas might be planned for asteroids with strong evidence of satellites, including (2) Pallas, (6) Hebe, (433) Eros, (532) Herculina, and (624) Hektor.

5. Observing Techniques and Recommendations

Since transverse velocities generally range from 10 to 40 km/sec., visual observers should be very careful when making timings, especially when estimating personal equation [reaction time plus any (usually negligible) equipment delay]. Timing methods used for grazing occultations can be employed; as the occultation by Herculina showed, observers should be prepared to time more than two events, and any interruptions during the observing period. The total observing duration should be about ten minutes centered on the expected time of the event. Plenty of time (a half hour or more, depending on the distance from bright, easily identified stars) should be allowed for locating the star to be occulted. If the event occurs at a low altitude in the east, time will be limited, in which case, the star should be located some night before the event so that it can be found quickly through practice. This is also recommended for high-altitude events, since on the night of the event, time may run short for some unforeseen reason. Pay attention to low altitude, twilight, and cloudy conditions which may change rapidly, washing out fainter stars used to recognize the star field; this is a danger mainly for telescopes without clock drives. If the magnitude drop, $\Delta m$, which occurs in case of an occultation, is 2.0 or greater, the event probably will be easily recognizable to visual observers. If the star's angular diameter is large enough that the fade it causes may be noticed visually, or if the star turns out to be a previously unknown close double which disappears in steps, a large aperture would be advantageous. For $\Delta m$ less than 2.0, Gordon Taylor recommends smaller-aperture telescopes in which the minor planet is not visible, so that the coalesced image of the star and asteroid will drop below the visibility threshold if an occultation occurs. In case of small $\Delta m$'s, comparison with nearby stars of about the same brightness as the coalesced image of asteroid and star-to-be-occulted should help in visually recognizing when an occultation occurs. The brighter minor planets are generally the bigger ones which could have satellites at greater distances, 1".0 or more. For them, there is a possibility of a secondary occultation of the star before its image merges with that of the asteroid, so that the secondary occultation could be seen visually while the $\Delta m$ which would occur in case of an occultation by the minor planet itself would be too small to see.

## ANGULAR DIAMETERS OF STARS TO BE OCCULTED BY MINOR PLANETS

David W. Dunham and
Wayne H. Warren, Jr.

[Ed: written in May, 1978, as part of IOTA Special Bulletin #5]

Brian Warner derived a formula for computing approximate angular diameters of stars from their photoelectric B and V magnitudes (*Mon. Not. Royal*

*Astron. Soc.*, *158*, 1P, 1972). We have used it to compute the expected angular sizes of stars which are occulted during the rest of this year. For V, we have used the photovisual magnitude as given in the SAO catalog, while values of B-V have been obtained from the spectral types according to tables prepared by David Gottlieb for SKYMAP (see p. 161). In the table under *Diameter*, the calculated angular diameter is given first in milliseconds of arc (m"), second in terms of diffraction fringe separation (df), and last in the form of the (time) it will take to cover the star in milliseconds if the occultation is central and if diffraction is ignored. If df is about 3 or more, diffraction is not significant and the occultation of the star will be essentially a geometric decline. 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 largest star is SAO 120774, occulted on June 7; the star is mag. 6.2, with spectral type M0. Since it will take at least 0ˢ3 to disappear (or reappear), its fade will be easily noticed visually; there will be 3-km-wide partial occultation zones at the northern and southern occultation limits. Fading might also be noticed visually during the occultation by Metis on July 12, especially if the occultation is not central. Photoelectric observations will most likely be needed to notice the effects of stellar diameter for the other listed events. The star which may be occulted by Chiron on July 24 (see p. 158) is not in the SAO, so its AGK3 number is given instead. Other information about the occultations has been tabulated in *O.N.*, *1* (13 and 14), pp. 134 and 142.

| 1978 Date | Minor Planet | SAO # | Diameter m" | df | time |
|---|---|---|---|---|---|
| Jun 7 | Herculina | 120774 | 2.40 | 10.9 | 306 |
| Jul 12 | Metis | 165132 | 0.39 | 1.9 | 106 |
| Jul 17 | Melpomene | 93624 | 0.56 | 2.9 | 23 |
| Jul 19 | Eugenia | 140167 | 0.59 | 3.1 | 81 |
| Jul 19 | Juno | 144070 | 0.12 | 0.6 | 13 |
| Jul 24 | Chiron | +13°203 | 0.09 | 1.6 | 130 |
| Aug 1 | Cybele | 93064 | 0.16 | 1.1 | 26 |
| Aug 22 | Herculina | 140552 | 0.47 | 2.8 | 35 |
| Oct 25 | Victoria | 161878 | 0.49 | 2.4 | 21 |
| Oct 31 | Pallas | 122731 | 0.10 | 0.7 | 8 |
| Nov 4 | Hygiea | 187163 | 0.05 | 0.3 | 3 |
| Nov 9 | Vesta | 187470 | 0.08 | 0.4 | 4 |
| Nov 17 | Hygiea | 187576 | 0.08 | 0.6 | 6 |
| Nov 21 | Davida | 190782 | 0.17 | 1.1 | 22 |
| Dec 6 | Amphitrite | 146788 | 0.11 | 0.6 | 12 |
| Dec 11 | Melpomene | 114159 | 0.33 | 1.3 | 33 |
| Dec 11 | Daphne | 111443 | 0.20 | 1.2 | 27 |

We are working to calculate angular stellar diameters for USNO's lunar occultation predictions for photoelectric observers, using a B-V calibration which is best suited for the spectral types given in USNO's SZ catalog. A message will be printed if the star has an angular diameter large enough that it might be detected photoelectrically during a lunar occultation, one arc millisecond or greater.

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## OBSERVATIONS OF APPULSES BY MINOR PLANETS

David W. Dunham

Unfortunately, bad weather prevented any astrometric observations of (15) Eunomia and ζ Cancri from being made in the United States in January; apparently for the same reason, I have received no reports of observations of the appulse from North America. Mr. F. Van Looy, Rayleigh, Essex, England, observed Eunomia pass near the components of the triple star, noting that it passed north of B and C, as would be expected from his location. Eunomia was also seen at times between clouds from Darmstadt, West Germany. Many observers were clouded out, including Dr. N. Wieth-Knudsen, who traveled to latitude +64°43' in Sweden, and Richard Nolthenius, who attempted observation from high in the mountains east of San Diego, California, where ζ Cancri would be scarcely more than 1° above the horizon. A couple of weeks before, he had located the star at an altitude of only ½° and noted its position with respect to the street lights of a distant desert town near the horizon, since on the day of the occultation, twilight would be strong. Unfortunately, the edge of a layer of clouds from an approaching storm reached his eastern horizon only about 20 minutes before the appulse (and before the star rose). Richard also wrote: "Set-up was hampered by a local resident and her dog. She insisted on telling us about her ouija board, UFO experiences, and her ESP. Her huge dog would not let our dog alone, apparently because (according to this lady) it got a big kick out of being 'dominated' by smaller dogs."

A few days before the January 28th occultation by Iris, I received a notice from Gordon Taylor giving a new predicted track passing over Georgia, Oklahoma, and northern California. He noted a problem with the star's AGK3 position and indicated that the shift, over 1" south of the original prediction, was largely due to an improved position for the star. I alerted many observers in the new possible area by telephone, knowing that severe winter storms would prevent many of them from receiving Taylor's bulletin in time. Unfortunately, weather and pressing other commitments prevented astrometric observations from being made from the United States, except for one plate that was obtained by Dennis Dawson at Van Vleck Observatory, Middletown, CT, the night before the event. The plate was badly exposed by moonlight, so that unfortunately the image of the star was not measurable. Ten hours before the event, Dawson telephoned me his position of Iris as computed from his measures of the plate. I used this position of Iris, and Taylor's position of the star, to compute a new path crossing North Carolina, Missouri, Colorado, and Washington, but I knew that considerable uncertainty must remain since there were no simultaneous astrometric observations of the star and Iris. Checking with the weather service showed that it was (and would be) cloudy in the Northwest, but mostly clear, especially to the south, in most areas east of the Rocky Mountains. Wayne Warren and I telephoned many observers in the central and east-central parts of the country, some after local midnight, to inform them of the new prediction. We also set up an observing fence across Virginia and Maryland; a wide band of clouds north of DC prevented observation from Maryland. All observers with clear skies reported that the two objects merged around the predicted time, but that it was virtually impossible to tell whether an occultation occurred since in fact the star was at least 0.5 mag. fainter than Iris, rather than 0.1 mag., as predicted. I have received no reports of photoelectric observations during the period when an occultation might have occurred. Visual reports have been sent by the following: B. Bolster, Alexandria, VA; W. Nissen, Quantico, VA; W. Stein, Fredericksburg, VA; E. Volcheck, Richmond, VA; M. Reynolds, Jacksonville, FL; H. DaBoll, St. Charles, IL; D. Olds, Clinton, MS; B. Hudgens, Clinton, MS; P. Asmus, Denver, CO; D. Wallentinsen, Albuquerque, NM; W. Morgan, n. of Las Vegas, NV; E. Grayzeck, Las Vegas, NV; and R. Nolthenius, San Diego, CA. Olds noted a possible dimming of about 0.3 mag. for 15 seconds slightly outside the expected time interval for a possible occultation, but Hudgens, a more experienced observer less than two miles away noticed no dimming at the same, or other, times during the observing period. An early report of separation being seen at closest approach turned out to be from an inexperienced observer who was hampered by partly cloudy skies; others nearby using large telescopes reported merged images. DaBoll notes that the sky cleared early enough that many of the approximately 2 dozen northern Illinois and southern Wisconsin participants could have observed, but late enough that most of them had already decided it was too cloudy to try; one of the three who actually followed the star, F. Klicar, Lemont, IL, believes he saw clockwise rotation of the coalesced image, which would mean that Iris passed north of the star at his location, but he described the seeing as very poor, due to his line of sight passing directly over a neighbor's chimney. In apparent contradiction, Hudgens in Mississippi could not tell whether Iris passed north or south. I suspect that the path did cross the United States somewhere, probably the southern part, but we don't know where due to the faintness of the star making visual observations unreliable and due to the lack of photoelectric data. There were cirrus clouds at Wallentinsen's and Nolthenius' sites, making the predicted 22° elongation of the star from the moon a problem; variable background glare from a lunar halo hampered observations considerably. Nolthenius again had a bad experience with a dog, or rather with what one had left in his path to the telescope. Problems were also caused by an announcement sent to about 900 Astronomical League members giving the time of the event as $1^h$ UT rather than $10^h$, and the finder chart (see *O.N., 1* (13), 135) prepared from *Atlas Eclipticalis (AE)*. Some observers were confused by other stars near the star to be occulted of about the same brightness, and closer to it than any of the stars shown on *AE*. The *AE* has essentially the same stars as the SAO catalog, but the occulted star, and the others near it, are AGK3 stars that are not in the SAO. The chart in Taylor's bulletin showed these stars, and was therefore superior, but it was not as widely distributed, and some received it after the event. Iris was brighter than the unplotted stars, so observers who set up before it merged with AGK3 +2° 1358 could see which star would be occulted from Iris' motion. I can now produce finder charts from the AGK3 by computer (although these need to be annotated before they are suitable for publication), so we intend to publish these in *O.N.* or otherwise distribute them to IOTA members for future occultations of AGK3 stars not in SAO. The visual mag. of the star was converted from the photographic mag. in the AGK3, difficult for a spectral type K0 star.

I sent predictions for some occultations of stars by minor planets which occurred in February to observers in the predicted areas of possible occultation. One of these was an occultation of SAO 100072 by (471) Papagena which I predicted might occur in southwestern Europe on Feb. 13. Jean Meeus wrote saying that it was probably cloudy in Belgium. Taylor distributed a bulletin, probably utilizing recent astrometric data, with the predicted path crossing Africa, a shift of over 1" south from my prediction.

## ATTEMPTS TO OBSERVE OTHER OCCULTATIONS BY MINOR PLANETS

David W. Dunham

During 1978 February - April, some attempts were made to observe other occultations by minor planets, but as far as I know, no last-minute astrometry was accomplished (except for Vesta in March) and no conclusive observations were obtained.

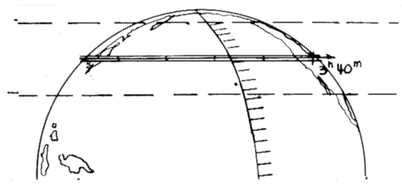
I sent a prediction for the occultation of SAO 100072 by (471) Papagena to Hans Bode in Germany, indicating that there was some possibility for the event to occur in Europe. He telephoned several observers, and the event was monitored photoelectrically at Hannover University, where no occultation occurred. Taylor issued a prediction using the AGK3 position of the star which showed that the path crossed northern Africa.

Members of the Occultation Section of the Royal Astronomical Society of New Zealand tried two events in February, one of AGK3 +9° 1412 by (52) Europa on the 16th, and one of SAO 159250 by (16) Psyche on the 25th. Christchurch was within the path for the Europa event, according to Taylor's prediction, but photoelectric observers there had no occultation, according to Ron Cross. It rained during the event in Auckland and Gisborne, but conditions were better on the 25th at those two cities, from which no occultation by Psyche was seen. A plate was taken with a 16-inch Cassegrain at Carter Observatory in Wellington, showing that Psyche passed 0"7 south of SAO 159250, implying that the path was well south of New Zealand.

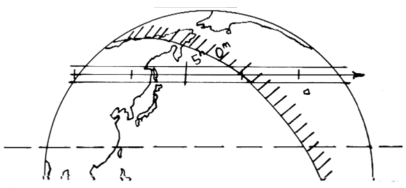
Photoelectric observers in Washington and western Canada were alerted when plates taken March 17 and 18 at Lowell Observatory indicated a 0"8 north shift for the March 22 occultation of SAO 160266 by Vesta. Apparently, no occultation occurred at the University of Washington's observatory. There was one gradual fading in the light curve at the wrong time, almost certainly due to a cloud.

## PREDICTIONS OF OCCULTATIONS OF STARS BY MINOR PLANETS

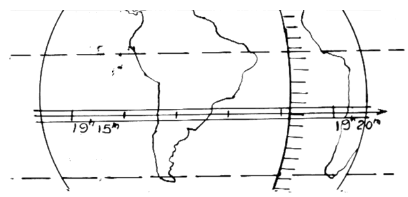
See *Occultation Newsletter, 1* (15), pp. 157-8, for a full explanation.



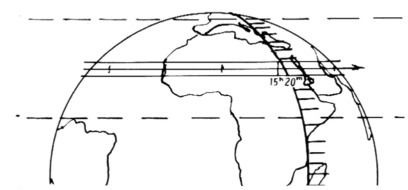

SAO 161878 by Victoria, 1978 Oct 25



SAO 122731 by Pallas, 1978 Oct 31



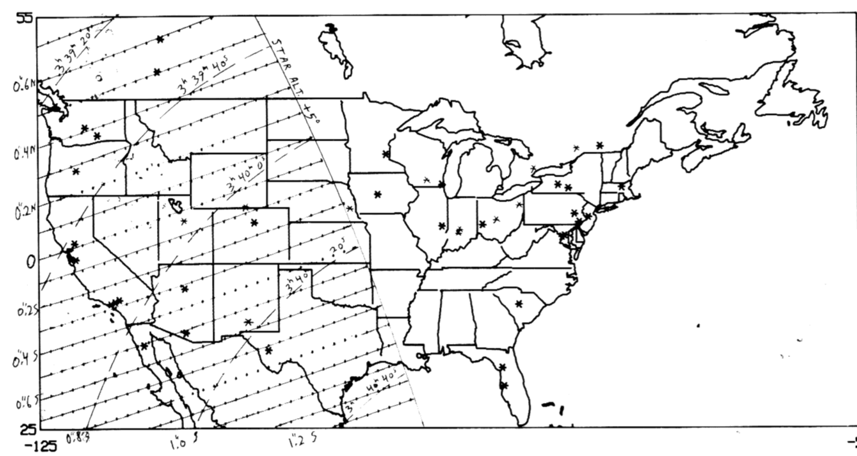

SAO 187163 by Hygiea, 1978 Nov 4




SAO 187470 by Vesta, 1978 Nov 9

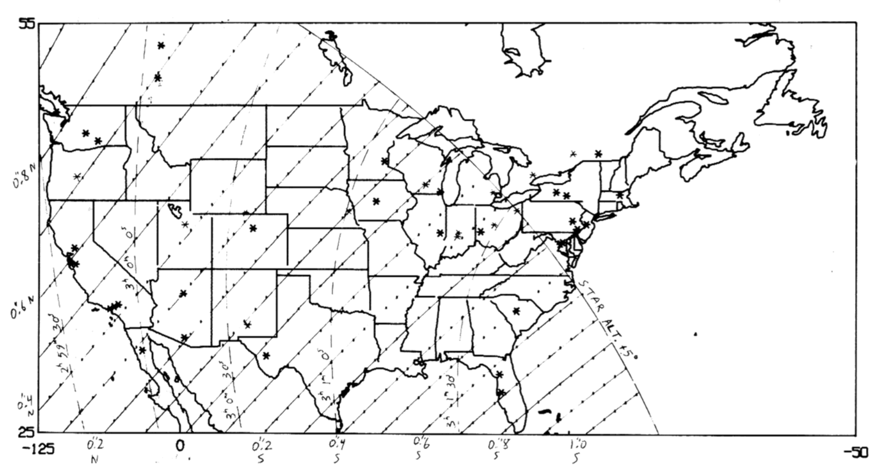
Occultation of SAO 161878 by (12) Victoria, 1978 October 25

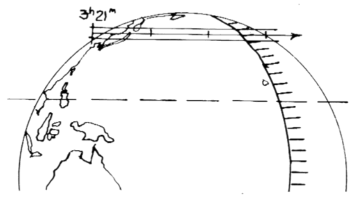
Diameter 126 km = 0"09



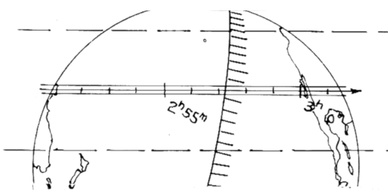

Occultation of SAO 190782 by (511) Davida, 1978 November 21

Diameter 323 km = 0"14

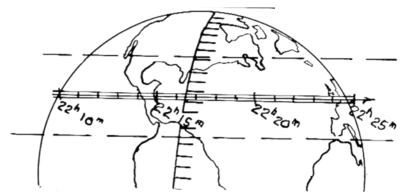





SAO 187576 by Hygiea, 1978 Nov 17



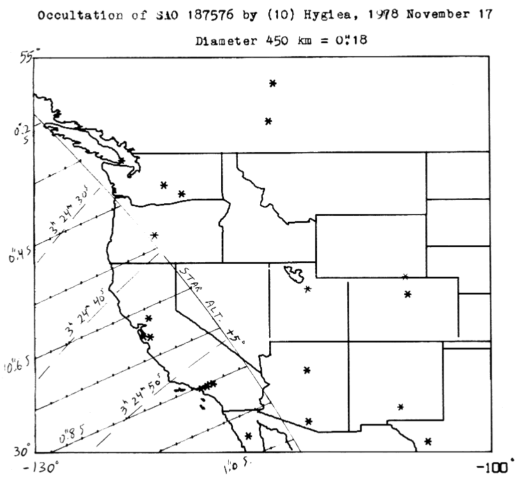

SAO 190782 by Davida, 1978 Nov 21

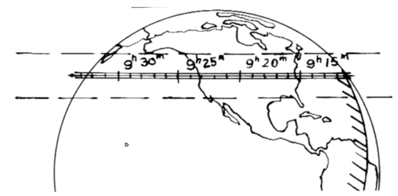



SAO 146788 by Amphitrite, 1978 Dec 6

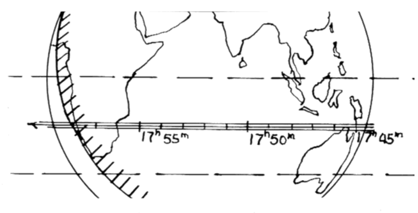
## ERRONEOUS STAR POSITIONS FROM OCCULTATIONS

David Herald




SAO 114159 by Melpomene, 1978 Dec 11




SAO 111443 by Daphne, 1978 Dec 11

Please send all reports of occultations which are observed to occur outside of the accuracy range of the USNO predictions to me at PO Box 254, Woden, A.C.T. 2606, Australia.

The accompanying table details recent observations indicating erroneous star positions. There are two observations I have not included in this table, as they were in some doubt due to observing conditions. The first, by DaBoll, involved one of SAO 93414/5. The AGK3 positions for these stars differ significantly from SAO, but not enough to give rise to the reported discrepancy. The other, by Stockbauer, was of SAO 98360, recorded late in R. For this star, AGK3 lists a slightly greater RA, but it is not sufficient to explain the observation, which in any case was doubtful in itself.

From Jean Bourgeois came an interesting observation of mag. 8.5 SAO 92929: "Its magnitude was about 7 instead of 8.5. It was also checked two hours later, after reappearance. Since then bad weather has persisted." I, too, have noted instances where star magnitudes are apparently erroneous, e.g., two stars of similar magnitude, occulted on the one night, the fainter being much easier to see. I would be interested in any reports indicative of *substantial* errors in magnitudes. It should be remembered, though, that estimates must be made relative to other stars under similar conditions, and not just on the basis of visibility at the time of occultation.

| Z.C. | S.A.O. | Date | PH | AC | O-C | Observer | Comments |
|---|---|---|---|---|---|---|---|
| | 96547 | 77 Sep 8 | R | 3 | -16 | Hays | Double star: SAO position is for the following star, hence timing is O.K. However, AGK3 position differs by 2" in Dec at current epochs. |
| | 96566 | 77 Sep 8 | R | 4 | +5 | Hays | AGK3 position is in accord with SAO/GC. However, proper motion in RA is in gross disagreement. |
| | 117890 | 77 Sep 11 | R | 2 | -5 | Hays | SAO/GC and Yale are wrong; they differ from AGK3 by 2".6 in RA at 1978. |
| | | 77 Nov 5 | R | 4 | -5 | Bourgeois | |
| | 118470 | 77 Nov 6 | R | 3 | +5 | Stockbauer | The small difference between AGK3 and SAO accounts for the observation. |
| 2114 | 158821 | See *O.N.*, *1* (13), 133 | | | | | The new Perth 70 catalogue gives a recent position for this star; it is 1".6 north of ZC, and 0".5 north of SAO. |
| 2494 | 160458 | 77 Oct 17 | D | 2 | +4 | Hays | ZC proper motion in Dec is too large. |
| 2497 | 160474 | 77 Sep 19 | D | 2 | +4 | Boninsegna | The ZC position is bad in both RA and Dec. The SAO/GC position is bad in RA. The Yale position satisfies the observations. |
| | 161033 | 77 Oct 17 | D | 3 | -7 | Bourgeois | No comparison. Investigate in S.A.C. project. Poor residual. |
| 2698 | 163471 | 77 Oct 20 | D | 3 | +4 | Hays | ZC and SAO/GC agree. Near graze. Satisfactory residual. |
| | 163473 | 77 Dec 13 | D | 3 | +4 | Bourgeois | No comparison. Poor residual. |
| | 164068 | 77 Nov 17 | D | 6 | +8 | Hays | No comparison. Residual of -1".2, so probably O.K. |

## LUNAR OCCULTATIONS OF MINOR PLANETS FOR 1978 AND 1979

David W. Dunham

Thomas Van Flandern, others at USNO, and I recently completed and successfully tested a system of computer programs and ephemeris data for computing predictions of lunar occultations of 125 minor planets whose photographic magnitudes, computed by David Laird at Cincinnati Country Day School with my guidance, are 13.0 or less under the most favorable circumstances (perihelic quadrature) for observing such events. Using a list of events for 1978 supplied by HMNAO, I computed and distributed detailed predictions for these events for the rest of 1978 to photoelectric occultation observers. The lunar occultations of these minor planets during 1979 already have been selected at USNO; predictions for them will be included in the regular USNO total occultation predictions for stars, etc., for all active observers in USNO's list for 1979 onwards. In USNO's predictions, the minor planets are given USNO reference numbers equal to 5000 plus the minor planet's number. The minor planet number, the first eight characters of its name, and the expected duration of the disappearance or reappearance in milliseconds, computed assuming no local lunar slope, and with diameters generally being those published in *Sky and Telescope*, *53*(3), 182 (1977 March), are printed in a special line similar to that for occultations of major planets.

During the rest of 1978, predictions for only a few events were printed, since the minor planets are quite faint so that their occultations are usually not observable (O-code = 0). Predictions were generated for the following events in the list in *O.N.*, *1*(14), 141: Minor planet 15 on April 15 (w. U.S.S.R.,ne Poland), 16 on July 14 (S. Africa), 14 On July 29, 16 on Aug. 11, 19 on Nov. 9 (Japan), and 19 on Dec. 7. In addition, an occultation of 11 Parthenope, moon elongation 109°, was predicted for Washington and British Columbia at $13^h$ UT of Sept. 22 and an occultation of 532 Herculina, elongation 55°, was found for South Africa east of Sutherland at $17^h$ UT of October 6.

The only known observation of a lunar occultation of a minor planet so far this year is the one of 15 Eunomia seen visually with the 107-inch reflector at McDonald Observatory, Ft. Davis, Texas, on March 19. Cirrus clouds prevented their attempt to record the event photoelectrically.

## OCCULTATIONS OF SAO STARS BY URANUS AND ITS SATELLITES, 1979-89

Gordon E. Taylor

A search of all stars in the SAO star catalog with an ephemeris of Uranus and its satellites up to 1989 November 12 has yielded the following possibilities.

(1) The only occultation by Uranus and its rings will occur on 1985 June 25.92 when the centre of Uranus passes 2"1 south of the star SAO 184819 ($m_v$ 9.2, spectrum G5). An occultation by the rings should be visible from Africa, Europe, and western Asia. Since the star position was obtained in 1933 it is clear that there is no point in issuing detailed predictions until a reliable modern position is obtainable. Note that final predictions could be issued after plates taken in 1985 January, when Uranus (with direct motion) will be passing close to the star (the occultation in June occurs when Uranus has a retrograde motion).

(2) The following is a list of stars which might possibly be occulted by satellites of Uranus if it is found that there is a large correction to the catalogue position of the star. Orbital elements for the satellites by D. Dunham were used.

| Date | Star | Satellite |
|---|---|---|
| 1980 May 21 | SAO 159243 | I |
| 1981 Sept. 2 | SAO 159394 | IV |
| 1981 Oct. 3 | SAO 159450 | V |
| 1984 Apr. 30 | SAO 184624 | III |
| 1984 June 21 | SAO 184501 | II, V |
| 1989 March 15 | SAO 186736 | III |

## A BADERIAN ANALYSIS

Niels Wieth-Knudsen

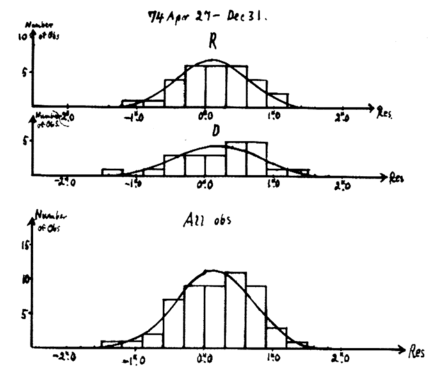
[Ed: The author has submitted an excellent article, but unfortunately, we can present only these few excerpts, due to space limitations. A photocopy of the entire original article will be mailed directly to any subscriber who sends a request to the editor.]

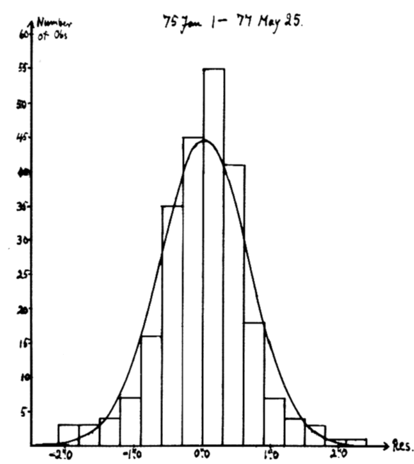
As to the heading above: I think that the proposal of analysing HMNAO residuals made by Clifford J. Bader, in *O.N., 1*, 106 (#10), and 112-113 (#11) (1977), is so ingenious in its simplicity that he deserves to have it named after him, as done here (analogously to: a *Newton*ian reflector).

Since the publications mentioned, I have felt particularly obliged to make such an analysis of my own contributions, due to their amount; - first of all as I would feel it as unconscientious to uncritically contribute with such an amount without utilising any opportunity of evaluating its quality, - secondly, as that amount will allow a subdivision into separate groups, according to periods of time, and characteristics of quality of observation, etc., without having the essential majority of the groups to include as small a number of observations as to make them meaningless. - A third reason will be mentioned below [Ed: not in this abbreviated version].

*  *  *  *  *

Graphically are presented a few of these samples - above all those from the spurious [Ed: less than a full year is represented because HMNAO applied a different personal equation to his timings pre-dating April 27] period 1974 April 27 - December 31, - together with the corresponding curves of the Gaussian distribution, adjusted to the number of observations, the width of the interval chosen, and the standard deviation of the group in question. No serious discordance seems obvious.




Amen; - so are my thoughts by my view of my results presented here. If anyone else might think useful for some purpose of interest to him, other subdivisions of my material than here made, I shall try to get time for meeting such a want.

Note No. 1. The 0"4/s estimated by Bader as a reasonable guess, even if surely so, may be a trifle too high, according to the following attempt at considering a little further that complex function of position on the limb and other variables mentioned by him.

*  *  *  *  *

Finally, the fact of the different planes of motion of moon and observer, preliminarily omitted, may be allowed-for, - here just merely as an estimate, as the correction is but small, - by multiplying the last quantity above by the mean of 1 and the cosine of the obliquity of the ecliptic, resulting in the following expression for the angular residual - time relationship for an observer at lat. $\phi$:

"431/s-("119/s)cos$\phi$,

giving for the latitudes:

| | | |
|---|---|---|
| 0° | | "312/s, |
| 45 | | .347 , |
| 56 | (my lat.) | .364 , |
| 60 | | .372 , |

respectively.

*  *  *  *  *

## 1976 TOTAL OCCULTATION TALLY

Raymond Finkleman

The most prolific observer of total occultations in 1976 was Robert Hays, Jr., who had 305 observations (see the complete tally, overleaf). His effort is the best since records have been collected, and compares to 263 observations, for the most observations by an observer in 1975. The 1976 total occultation tally was consolidated primarily from the observers' coupons and the Czechoslovakian Bulletin, as well as Japanese and Soviet publications. McDonald Observatory has an ongoing photoelectric observing program, and their observations are included. Still, the tally is not comprehensive. The HMNAO incorporated a change in their tape format so that we will be able to identify individual observers. Unfortunately, we do not have the time to make the necessary changes in the USNO program which we had used for the 1975 tally, and to incorporate the HMNAO data into this article. We hope to be able to utilise the HMNAO tape listing in the future, to produce a more complete, worldwide representation.

The ranking of observers is by the value of their observations. This was determined by the formula V = D + cR, where V = value, D = total number of disappearances observed, R = total reappearances observed, and c is a correcting factor. The correcting factor is the ratio of R/D for the complete listing. For this tally, one reappearance observation is the equivalent of 2.51 disappearance observations.

If only the observatory or station name is given in the listing, there is probably more than one observer at that station. After the location there may be an asterisk indicating photoelectric observations. The observer's principal observing site is given after his name.

Please continue to send in the observers' coupons. Observers are also reminded to send their observations to HMNAO, to be included on their tape listing of observations (address: H. M. Nautical Almanac Office, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex BN27 1RP, England).

Thanks to T. C. Van Flandern and D. W. Dunham for assisting in this tally.

| RANK | OBSERVER | | VALUE | TOTAL | R'S | NON ZC | NON SAO |
|---|---|---|---|---|---|---|---|
| 1 | UNITED STATES OF AMERICA | ( 46 OBSERVERS) | 3803.67 | 2636 | 775 | 1631 | 125 |
| 2 | JAPAN | ( 30 OBSERVERS) | 1566.97 | 1008 | 371 | 702 | 0 |
| 3 | UNION OF SOVIET SOCIALIST REPS. | ( 45 OBSERVERS) | 397.40 | 307 | 60 | 129 | 12 |
| 4 | SOUTH AFRICA | ( 2 OBSERVERS) | 383.53 | 263 | 80 | 178 | 1 |
| 5 | DENMARK | ( 1 OBSERVER ) | 254.49 | 143 | 74 | 96 | 4 |
| 6 | NEW ZEALAND | ( 14 OBSERVERS) | 193.79 | 129 | 43 | 51 | 1 |
| 7 | AUSTRALIA | ( 3 OBSERVERS) | 189.08 | 171 | 12 | 118 | 2 |
| 8 | CZECHOSLOVAKIA | ( 35 OBSERVERS) | 145.11 | 121 | 16 | 30 | 0 |
| 9 | BELGIUM | ( 7 OBSERVERS) | 133.59 | 114 | 13 | 62 | 3 |
| 10 | SPAIN | ( 3 OBSERVERS) | 104.68 | 64 | 27 | 20 | 7 |
| 11 | GERMAN FEDERAL REPUBLIC | ( 6 OBSERVERS) | 98.59 | 79 | 13 | 19 | 0 |
| 12 | BRAZIL | ( 3 OBSERVERS) | 67.51 | 66 | 1 | 40 | 2 |
| 13 | ENGLAND | ( 1 OBSERVER ) | 59.56 | 46 | 9 | 23 | 0 |
| 14 | CANADA | ( 3 OBSERVERS) | 42.51 | 41 | 1 | 21 | 0 |
| 15 | SWITZERLAND | ( 1 OBSERVER ) | 34.52 | 30 | 3 | 12 | 1 |
| 16 | PORTUGAL | ( 3 OBSERVERS) | 21.00 | 21 | 0 | 19 | 0 |
| 17 | NORWAY | ( 1 OBSERVER ) | 14.01 | 11 | 2 | 4 | 0 |
| 13 | NETHERLANDS | ( 1 OBSERVER ) | 10.00 | 10 | 0 | 3 | 0 |
| 19 | ANONYMOUS (COUNTRY UNKNOWN) | ( 0 OBSERVERS) | 0.0 | 0 | 0 | 0 | 0 |
| | | R/D = | 2.51 | 5260 | 1500 | 3158 | 158 |

| RANK | OBSERVER | | VALUE | TOTAL | R'S | NON ZC | NON SAO |
|---|---|---|---|---|---|---|---|
| 1 | ROBERT H. HAYS, JR. | PALOS HILLS, IL | 479.77 | 305 | 116 | 222 | 27 |
| 2 | SIRAHAMA OBSERVATORY | SIRAHAMA, JAPAN* | 299.03 | 180 | 79 | 143 | 0 |
| 3 | K. G. FUHR | CAPE TOWN, SOUTH AFRICA | 290.97 | 184 | 71 | 120 | 0 |
| 4 | T. TAKEMURA | KURASIKI, JAPAN | 263.89 | 175 | 59 | 124 | 0 |
| 5 | N. P. WIETH-KNUDSEN | TISVILDELEJE, DENMARK | 254.49 | 143 | 74 | 96 | 4 |
| 6 | ROBERT SANDY | KANSAS CITY, MO | 251.91 | 160 | 61 | 71 | 4 |
| 7 | JAMES L. FERREIRA | FREMONT, CA | 251.89 | 163 | 59 | 129 | 9 |
| 8 | RICHARD NOLTHENIUS | TUCSON, AZ | 243.29 | 177 | 44 | 116 | 29 |
| 9 | SIMOSATO OBSERVATORY | SIMOSATO, JAPAN* | 235.40 | 145 | 60 | 101 | 0 |
| 10 | JOHN AFRICANO | McDONALD OBSERVATORY, TX* | 223.03 | 217 | 4 | 177 | 14 |
| 11 | ROBERT CLYDE | STREETSBORO, OH | 211.87 | 129 | 55 | 104 | 7 |
| 12 | JOHN KORINTUS | PALM BAY, FL | 191.73 | 139 | 35 | 108 | 0 |
| 13 | ROBERT LASCH | GREEN VALLEY, AZ | 177.28 | 114 | 42 | 0 | 0 |
| 14 | M. D. OVERBEEK | MALVERNE, NY | 171.67 | 134 | 25 | 114 | 0 |
| 15 | KURASIKI OBSERVATORY | KURASIKI, JAPAN* | 170.24 | 116 | 36 | 76 | 0 |
| 16 | RICHARD BINZEL | WASHINGTON COURT HOUSE, OH | 160.27 | 100 | 40 | 73 | 4 |
| 17 | WILLIAM H. FISHER | COLFAX, CA | 149.31 | 80 | 46 | 35 | 0 |
| 13 | ROBERT WALKER | SAYRE, OK | 145.75 | 90 | 37 | 55 | 10 |
| 19 | DAVID HERALD | CANBERRA, AUSTRALIA | 133.07 | 118 | 10 | 92 | 2 |
| 20 | H. F. DaBOLL | ST. CHARLES, IL | 127.16 | 91 | 24 | 65 | 1 |
| 21 | WALTER MORGAN | LAS VEGAS, NV | 114.67 | 77 | 25 | 52 | 0 |
| 22 | T. HIRAIWA | KURASIKI, JAPAN | 103.75 | 48 | 37 | 38 | 0 |
| 23 | CLIFFORD J. BADER | WEST CHESTER, PA | 96.17 | 57 | 26 | 18 | 0 |
| 24 | A. SALAZAR | SAN FERNANDO, SPAIN | 95.68 | 55 | 27 | 18 | 7 |
| 25 | JAN HERS | RANDBURG, SOUTH AFRICA | 92.56 | 79 | 9 | 58 | 1 |
| 26 | T. YAMAMOTO | SIMOSATO, JAPAN | 91.67 | 54 | 25 | 43 | 0 |
| 27 | LARRY YOKSH | OVERLAND PARK, KS | 79.59 | 60 | 13 | 31 | 4 |
| 28 | BEN HUDGENS | CLINTON, MS | 76.63 | 48 | 19 | 26 | 2 |
| 29 | B. SINCHESKUL | POLTAVA, UKRAINE, USSR | 75.52 | 71 | 3 | 55 | 2 |
| 30 | Y. GANEKO | TOKYO, JAPAN | 71.13 | 41 | 20 | 31 | 0 |
| 31 | JAMES VAN NULAND | SAN JOSE, CA | 69.55 | 59 | 7 | 37 | 0 |
| 32 | LIONEL E. HUSSEY | CHRISTCHURCH, NEW ZEALAND | 62.60 | 40 | 15 | 25 | 1 |
| 33 | ALFRED WEBBER | CHADDS FORD, PA | 62.03 | 56 | 4 | 2 | 2 |
| 34 | MARK GINGRICH | OAKLAND, CA | 60.07 | 45 | 10 | 31 | 0 |
| 35 | DOUGLAS HALL | LEICESTER, ENGLAND | 59.56 | 46 | 9 | 23 | 0 |
| 36 | H. F. COCHRAN | BROWNWOOD, TX | 59.05 | 47 | 8 | 23 | 0 |
| 37 | WAYNE COSKREY | STARKVILLE, MS | 58.11 | 34 | 16 | 18 | 0 |
| 38 | JEAN BOURGEOIS | MONTIGNIES-LE-T, BELGIUM | 56.59 | 37 | 13 | 23 | 1 |
| 39 | Y. SOMEYA | SIRAHAMA, JAPAN | 56.57 | 40 | 11 | 26 | 0 |
| 40 | A. OSIPOV | KIEV, UKRAINE, USSR | 52.61 | 27 | 17 | 15 | 2 |
| 41 | RONALD CROSS | CHRISTCHURCH, NEW ZEALAND | 51.59 | 32 | 13 | 17 | 0 |
| 42 | Y. KIMOTO | SINAGAWA, JAPAN | 51.53 | 44 | 5 | 18 | 0 |
| 43 | ROGER GILLER | ENGADINE, AUSTRALIA | 50.01 | 47 | 2 | 26 | 0 |
| 44 | JOSEPH ZODA | MAPLE PARK, IL | 46.55 | 36 | 7 | 21 | 0 |
| 45 | JORGE POLMAN | RECIFE, PERN., BRAZIL | 45.51 | 44 | 1 | 34 | 2 |
| 46 | N. WATANABE | SIMOSATO, JAPAN | 44.60 | 22 | 15 | 20 | 0 |
| 47 | HARALD MARX | KORNTAL-MUNCHINGEN, G. F. R. | 43.04 | 34 | 6 | 19 | 0 |
| 48 | ROBERT N. BOLSTER | ALEXANDRIA, VA | 39.07 | 24 | 10 | 4 | 0 |
| 49 | ROGER LAUREYS | DIEPENBEEK, BELGIUM | 39.00 | 39 | 0 | 28 | 1 |
| 50 | A. SUZUKI | SIRAHAMA, JAPAN | 38.56 | 25 | 9 | 15 | 0 |
| 51 | DAVID DUNHAM | GREENBELT, MD | 37.60 | 15 | 15 | 15 | 11 |
| 52 | KLAUS KLEBERT | FELLBACH-SCHMIDEN, G. F. R. | 37.03 | 31 | 4 | 0 | 0 |
| 53 | ROBERT GERMANN | WALD, SWITZERLAND | 34.52 | 30 | 3 | 12 | 1 |
| 54 | K. E. McNAMARA | MONTREAL, CANADA | 34.51 | 33 | 1 | 20 | 0 |
| 55 | DAVID EVANS | McDONALD OBSERVATORY, TX* | 32.00 | 32 | 0 | 27 | 0 |
| 56 | GRAHAM BLOW | AUCKLAND, NEW ZEALAND | 29.05 | 17 | 8 | 3 | 0 |
| 57 | K. KUMAGAWA | SIMOSATO, JAPAN | 27.05 | 15 | 8 | 15 | 0 |
| 58 | WILLIAM D. YOUNG | ARLINGTON, VA | 26.01 | 23 | 2 | 1 | 1 |
| 59 | A. ZHITETSKI | KIEV, UKRAINE, USSR | 25.55 | 15 | 7 | 6 | 0 |
| 60 | PAUL J. NEWMAN | GARLAND, TX | 24.55 | 14 | 7 | 6 | 0 |
| 61 | V. MASIR | KIEV, UKRAINE, USSR | 24.53 | 17 | 5 | 10 | 2 |
| 62 | WAYNE CLARK | ST. LOUIS, MO | 23.52 | 19 | 3 | 12 | 0 |
| 63 | J. POGODA | OLOMOUC, CZECHOSLOVAKIA | 23.04 | 14 | 6 | 7 | 0 |
| 64 | STEVE J. ZVARA | WHITTIER, CA | 23.00 | 23 | 0 | 17 | 0 |
| 65 | J. BARATA ARAUJO | RECIFE, BRAZIL | 19.00 | 19 | 0 | 5 | 0 |
| 66 | J. OSCRIO | VILA NOVA DE GAIA, PORTUGAL | 19.00 | 19 | 0 | 17 | 0 |
| 67 | A. MOROSOV | TOMSK, SIBERIA, USSR | 17.52 | 13 | 3 | 1 | 0 |
| 68 | U. ONISHENKO | DONETSK, UKRAINE, USSR | 17.03 | 11 | 4 | 0 | 0 |
| 69 | H. ABE | OSYAMANBE, JAPAN | 17.00 | 17 | 0 | 7 | 0 |
| 70 | WILLY VERHAEGEN | WETTERSON, BELGIUM | 16.00 | 16 | 0 | 11 | 1 |
| 71 | Y. KIRPATOVSKI | KHARKOV, UKRAINE, USSR | 15.01 | 12 | 2 | 7 | 0 |
| 72 | JOHN CHURCH | PRINCETON JUNCTION, NJ | 14.52 | 10 | 3 | 5 | 0 |
| 73 | STEIN HOYDALSVIK | TROMSO, NORWAY | 14.01 | 11 | 2 | 4 | 0 |
| 74 | P. VOZAR | BANSKI BYSTRICA, CZECHOSLOVAKIA | 14.01 | 11 | 2 | 4 | 0 |
| 75 | I. CHUGINOV | KAZAN, TATAR, USSR | 14.00 | 14 | 0 | 13 | 4 |
| 76 | V. TCHACHENKO | KHERSON, UKRAINE, USSR | 13.52 | 9 | 3 | 0 | 0 |
| 77 | WILLIAM WESTBROOKE | SAN FRANCISCO, CA | 13.52 | 9 | 3 | 1 | 0 |
| 78 | JAMES PERILLAT | OAKLAND, CA | 13.03 | 7 | 4 | 5 | 0 |
| 79 | S. KANEKO | SAKURA, JAPAN | 13.01 | 10 | 2 | 3 | 0 |
| 80 | H. TOMIOKA | HITATI, JAPAN | 13.01 | 10 | 2 | 0 | 0 |
| 81 | V. HAUT | CHEB, CZECHOSLOVAKIA | 13.01 | 10 | 2 | 0 | 0 |
| 82 | V. GOLOBEV | GORNOTAUZHNI, SIBERIA, USSR | 12.51 | 11 | 1 | 0 | 0 |
| 83 | MAURICE STOKER | AUCKLAND, NEW ZEALAND | 12.51 | 11 | 1 | 3 | 0 |
| 84 | P. PAVLENKO | KHARKOV, UKRAINE, USSR | 12.00 | 12 | 0 | 8 | 0 |
| 85 | A. LOSUK | VORONEZH, RUSSIA, USSR | 11.52 | 7 | 3 | 0 | 0 |
| 86 | S. DOZYUN | SIMOSATO, JAPAN | 11.51 | 10 | 1 | 9 | 0 |
| 87 | KRAJCIR | HLOHOVEC, CZECHOSLOVAKIA | 11.51 | 10 | 1 | 2 | 0 |
| 88 | JOZEF VAN CAMP | HOVE, BELGIUM | 11.00 | 11 | 0 | 0 | 0 |
| 89 | N. TAKEISI | KAMI IGUSA, JAPAN | 10.00 | 10 | 0 | 2 | 0 |
| 90 | D. SCHMIDT | HUIZEN N. H., THE NETHERLANDS | 10.00 | 10 | 0 | 3 | 0 |
| 91 | P. DRABEK | GOTTWALDOV, CZECHOSLOVAKIA | 9.51 | 8 | 1 | 1 | 0 |
| 92 | HANS-JOACHIM BODE | HANNOVER, G. F. R. | 9.01 | 6 | 2 | 0 | 0 |
| 93 | S. KOCHAN | BROUMOV, CZECHOSLOVAKIA | 9.00 | 9 | 0 | 2 | 0 |
| 94 | S. R. IZMAILOV | KHARKOV, USSR | 9.00 | 9 | 0 | 6 | 0 |
| 95 | JEAN MEEUS | ERPS-KWERPS, BELGIUM | 8.00 | 8 | 0 | 0 | 0 |
| 96 | WOLFGANG BEISKER | HANNOVER, G. F. R. | 7.51 | 6 | 1 | 0 | 0 |
| 97 | P. HAZUCHA | HLOHOVEC, CZECHOSLOVAKIA | 7.51 | 6 | 1 | 3 | 0 |
| 98 | GEORGE WINGATE | AUCKLAND, NEW ZEALAND | 7.51 | 6 | 1 | 1 | 0 |
| 99 | A. G. KIRICHENKO | UZHGOROD, USSR | 7.01 | 4 | 2 | 0 | 0 |
| 100 | E. NISIMURA | TOKYO, JAPAN | 7.00 | 7 | 0 | 5 | 0 |
| 101 | JEZIK | HLOHOVEC, CZECHOSLOVAKIA | 7.00 | 7 | 0 | 3 | 0 |
| 102 | D. G. STANKEVICH | KHARKOV, USSR | 7.00 | 7 | 0 | 0 | 0 |
| 103 | M. FEDYNIN | TOMSK, SIBERIA, USSR | 6.51 | 5 | 1 | 0 | 0 |
| 104 | V. LAZAREV | TOMSK, SIBERIA, USSR | 6.01 | 3 | 2 | 0 | 0 |
| 105 | TRIXIE STEWART | AUCKLAND, NEW ZEALAND | 6.01 | 3 | 2 | 1 | 0 |
| 106 | K. KOYAMA | TOKYO, JAPAN | 6.00 | 6 | 0 | 5 | 0 |
| 107 | MARK TAYLOR | CANBERRA, AUSTRALIA | 6.00 | 6 | 0 | 0 | 0 |
| 108 | PAT HARVEY | POMONA, CA | 6.00 | 6 | 0 | 2 | 0 |
| 109 | LUIS F. CASTELLANOS | SAN FERNANDO, CADIZ, SPAIN | 6.00 | 6 | 0 | 2 | 0 |
| 110 | VICTOR SLABINSKI | ARLINGTON, VA | 6.00 | 6 | 0 | 1 | 0 |
| 111 | DAVID BROCK | AUCKLAND, NEW ZEALAND | 6.00 | 6 | 0 | 0 | 0 |
| 112 | K. KENMOTU | SIMOSATO, JAPAN | 5.51 | 4 | 1 | 3 | 0 |
| 113 | V. SINCHESKUL | POLTAVA, UKRAINE, USSR | 5.51 | 4 | 1 | 2 | 0 |
| 114 | P. KASYRIN | CHERKASSI, UKRAINE, USSR | 5.51 | 4 | 1 | 0 | 0 |
| 115 | V. HAREVIC | YENISEYSK, SIBERIA, USSR | 5.51 | 4 | 1 | 0 | 0 |
| 116 | HOWARD BARNES | AUCKLAND, NEW ZEALAND | 5.51 | 4 | 1 | 0 | 0 |
| 117 | WAYNE H. WARREN | GREENBELT, MD | 5.01 | 2 | 2 | 2 | 0 |
| 118 | K. VANEK | OLOMOUC, CZECHOSLOVAKIA | 5.01 | 2 | 2 | 1 | 0 |
| 119 | M. SASAKI | TOKYO, JAPAN | 5.00 | 5 | 0 | 4 | 0 |
| 120 | H. J. WIDDOP | PIERREFONDS, CANADA | 5.00 | 5 | 0 | 0 | 0 |
| 121 | SUSAN BERAN | POMONA, CA | 5.00 | 5 | 0 | 0 | 0 |
| 122 | CHROMEK | BANSKI BYSTRICA, CZECHOSLOVAKIA | 4.51 | 3 | 1 | 0 | 0 |
| 123 | BARRY MENZIES | AUCKLAND, NEW ZEALAND | 4.51 | 3 | 1 | 1 | 0 |
| 124 | A. M. SINZI | SIRAHAMA, JAPAN | 4.00 | 4 | 0 | 1 | 0 |
| 125 | FRED SCHUMACHER | OAKLAND, CA | 4.00 | 4 | 0 | 3 | 0 |
| 126 | BOB FISCHER | POMONA, CA | 4.00 | 4 | 0 | 1 | 0 |
| 127 | J. BOCEK | JINDRI, HRADEK, CZECHOSLOVAKIA | 4.00 | 4 | 0 | 2 | 0 |
| 128 | A. HOUSKA | TURNOV, CZECHOSLOVAKIA | 4.00 | 4 | 0 | 0 | 0 |
| 129 | P. T. VELESHUK | KIEV, USSR | 4.00 | 4 | 0 | 0 | 0 |
| 130 | M. SHPEKIN | KAZAN, TATAR, USSR | 4.00 | 4 | 0 | 3 | 1 |
| 131 | O. KVARATCHILIA | ABASTUMAN, GEORGIA, USSR | 4.00 | 4 | 0 | 0 | 0 |
| 132 | S. HUTINOUE | TOKYO, JAPAN | 3.51 | 2 | 1 | 0 | 0 |
| 133 | RAY MAGDZIARZ | WOOD DALE, IL | 3.51 | 2 | 1 | 0 | 0 |
| 134 | K. A. KUDAK | UZHGOROD, USSR | 3.51 | 2 | 1 | 0 | 0 |
| 135 | A. ZAPOROZHETZ | KIEV, USSR | 3.51 | 2 | 1 | 0 | 0 |
| 136 | I. GOROSHAK | UZHGOROD, UKRAINE, USSR | 3.51 | 2 | 1 | 0 | 0 |
| 137 | T. JOJO | TOKYO, JAPAN | 3.00 | 3 | 0 | 2 | 0 |
| 138 | K. ONODERA | TOKYO, JAPAN | 3.00 | 3 | 0 | 3 | 0 |
| 139 | T. KANAZAWA | TOKYO, JAPAN | 3.00 | 3 | 0 | 0 | 0 |
| 140 | K.KUBO | TOKYO, JAPAN | 3.00 | 3 | 0 | 2 | 0 |
| 141 | LUIS Q. SANCHEZ | SAN FERNANDO, CADIZ, SPAIN | 3.00 | 3 | 0 | 0 | 0 |
| 142 | PAUL GORDON | POMONA, CA | 3.00 | 3 | 0 | 0 | 0 |
| 143 | ALAN DEVAULT | POMONA, CA | 3.00 | 3 | 0 | 0 | 0 |
| 144 | PATTI CUNTHER | POMONA, CA | 3.00 | 3 | 0 | 0 | 0 |
| 145 | P. C. A. BARRETTO | RECIFE, PERNAMBUCO, BRAZIL | 3.00 | 3 | 0 | 1 | 0 |
| 146 | E. V. BLAGOVESHENSKI | ULYANOVSK, RUSSIA, USSR | 3.00 | 3 | 0 | 0 | 0 |
| 147 | A. EFIMOV | ULYANOVSK, RUSSIA, USSR | 3.00 | 3 | 0 | 0 | 0 |
| 148 | I. EDANCHUK | CHERNIGOV, UKRAINE, USSR | 3.00 | 3 | 0 | 0 | 0 |
| 149 | ROBERT PIKE | MISSISSAUGA, CANADA | 3.00 | 3 | 0 | 1 | 0 |
| 150 | GERRY ALLCOTT | AUCKLAND, NEW ZEALAND | 3.00 | 3 | 0 | 0 | 0 |
| 151 | THOMAS VAN FLANDERN | WASHINGTON, DC | 2.51 | 1 | 1 | 1 | 0 |
| 152 | THOMAS H. CAMPBELL | TEMPLE TERRACE, FL | 2.51 | 1 | 1 | 0 | 0 |
| 153 | U. TOMASH | UZHGOROD, USSR | 2.51 | 1 | 1 | 0 | 0 |
| 154 | FAYE WILLIAMS | AUCKLAND, NEW ZEALAND | 2.51 | 1 | 1 | 0 | 0 |
| 155 | M. MATYSEK | GOTTWALDOV, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 0 | 0 |
| 156 | F. ONO | SIRAHAMA, JAPAN | 2.00 | 2 | 0 | 2 | 0 |
| 157 | S. KANAGAWA | TOKYO, JAPAN | 2.00 | 2 | 0 | 2 | 0 |
| 158 | M. KAWADA | TOKYO, JAPAN | 2.00 | 2 | 0 | 2 | 0 |
| 159 | J. PSZENICZUO | HOUE, ANTWERP, BELGIUM | 2.00 | 2 | 0 | 0 | 0 |
| 160 | M. SEDLACEK | UHERSKY BROD, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 1 | 0 |
| 161 | F. PAVLAS | HOLESOV, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 0 | 0 |
| 162 | L. CERNY | HURBANOVO; CZECHOSLOVAKIA | 2.00 | 2 | 0 | 0 | 0 |
| 163 | A. NOVAK | TEPLICE, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 1 | 0 |
| 164 | B. MALECEK | VAL. MEZIRICI, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 1 | 0 |
| 165 | E. BELDA | TURNOV, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 0 | 0 |
| 166 | O. SANDOR | TEPLICE, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 1 | 0 |
| 167 | KADLECIK | HLOHOVEC, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 1 | 0 |
| 168 | CVRKOVA | VAL. MEZIRICI, CZECHOSLOVAKIA | 2.00 | 2 | 0 | 0 | 0 |
| 169 | A. V. BACHONSKI | KIEV, USSR | 2.00 | 2 | 0 | 1 | 0 |
| 170 | G. V. MOSKALEVA | KIEV, USSR | 2.00 | 2 | 0 | 0 | 0 |
| 171 | V. VASILIEV | LENINGRAD, RUSSIA, USSR | 2.00 | 2 | 0 | 0 | 0 |
| 172 | D. GALICH | LVOV, UKRAINE, USSR | 2.00 | 2 | 0 | 0 | 0 |
| 173 | V. BOROVSHIC | KAZAN, TATAR, USSR | 2.00 | 2 | 0 | 1 | 1 |
| 174 | ALVIN FLESHER | BALTIMORE, MD | 2.00 | 2 | 0 | 0 | 0 |
| 175 | E. OTTO | EILENBURG, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 176 | F. DUJKA | GOTTWALDOV, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 177 | N. REGO | PORTO, PORTUGAL | 1.00 | 1 | 0 | 1 | 0 |
| 178 | A. CUNHA | PORTO, PORTUGAL | 1.00 | 1 | 0 | 1 | 0 |
| 179 | L. DE HERT | HOUE, ANTWERP, BELGIUM | 1.00 | 1 | 0 | 0 | 0 |
| 180 | HELIGA BODE | HANNOVER, G. F. R. | 1.00 | 1 | 0 | 0 | 0 |
| 181 | LIBANT | HLOHOVEC, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 182 | V. SKODOVA | VAL. MEZIRICI, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 183 | J. TEPLY | BROUMOV, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 184 | M. NEUBAUER | VAL. MEZIRICI, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 185 | Z. SKODA | VAL. MEZIRICI, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 186 | K. JUZA | VAL. MEZIRICI, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 187 | P. SPURNY | KUNZAK, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 188 | HROSSO | HLOHOVEC, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 189 | PATROVIC | HLOHOVEC, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 190 | ING. VASICEK | UHERSKY BROD, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 191 | V. STRNAD | KLADNO, CZECHOSLOVAKIA | 1.00 | 1 | 0 | 0 | 0 |
| 192 | P. SERGIENKO | DONETSK, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 193 | M. MICHALKIN | DONETSK, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 194 | V. VASH | UZHGOROD, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 195 | V. E. MICHNO | CHERKASSI, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 196 | A. M. KALININ | KIEV, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 197 | E. E. TZIRKIN | KIEV, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 198 | E. VOVCHIK | LVOV, UKRAINE, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 199 | U. FRIDELV | LVOV, UKRAINE, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 200 | P. DROSDOV | YENISEYSK, SIBERIA, USSR | 1.00 | 1 | 0 | 0 | 0 |
| 201 | A. CHIESHKOV | KIEV, UKRAINE, USSR | 1.00 | 1 | 0 | 1 | 0 |
| 202 | M. KNITSCH | HANNOVER, G. F. R. | 1.00 | 1 | 0 | 0 | 0 |
| 203 | ROSA TYSON | AUCKLAND, NEW ZEALAND | 1.00 | 1 | 0 | 0 | 0 |
| 204 | PETER CONNOLLY | AUCKLAND, NEW ZEALAND | 1.00 | 1 | 0 | 0 | 0 |
| 205 | GLEN ROWE | AUCKLAND, NEW ZEALAND | 1.00 | 1 | 0 | 0 | 0 |
| | | R/D = | 2.51 | 5260 | 1500 | 3158 | 158 |

## OCCULTATIONS OF ZUBENELGENUBI BY THE ORBITS OF THE SATELLITES OF URANUS

David W. Dunham

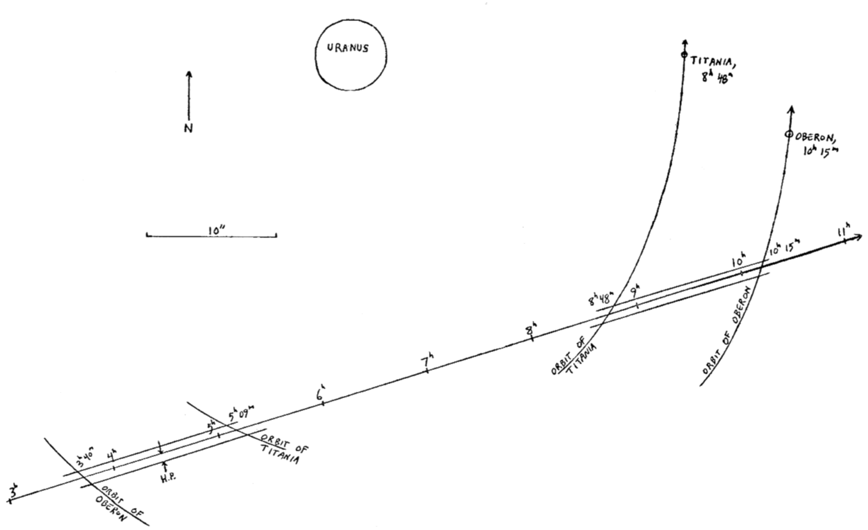
The passage of the satellite system of Uranus across 2.9-mag. $\alpha^2$ Librae (Z.C. 2118, Zubenelgenubi) during 1978 October 8 was mentioned in *O.N., 1* (13), 136. In 1971, I calculated improved orbital elements for the satellites of Uranus using all available photographic observations, for my Ph. D. dissertation. I recently converted the main computer program used in that study so that it would successfully reproduce the results at USNO, and calculated predictions for the October 8 appulse. The results are tabulated below, and shown in a diagram, where "H.P." is the earth's horizontal parallax, the amount subtended by the earth's equatorial radius at Uranus' distance. At the time of closest approach, Oberon will be 9" north of the star, and Titania will be farther away, so there is no chance for an occultation by those satellites as seen from earth. However, perhaps there is material within the orbits of the satellites, perhaps like the Uranian rings, or like the the sodium cloud of Io, which could be detected photoelectrically; nobody has previously attempted observations of occultations by material within the orbits of any of any of the natural satellites. A photoelectric record of a lunar occultation of Z.C. 2118 has shown that the star is a close double, component magnitudes 3.4 and 3.8, separated by 0".01 as projected in position angle 110°.

Occultation of $\alpha^2$ Librae by the Orbits of Titania and Oberon, 1978 October 8

| Event & U. T. | Area of Visibility |
|---|---|
| Oberon - D - $3^h40^m$ | Night - E. Pacific just west of North America<br>Day - Hawaii, Australia, Japan, eastern Asia |
| Titania - D - $5^h09^m$ | Night - Hawaii, approx. star alt. 6°, sun -12°<br>Day - Australia, Japan, Asia east of Pakistan |
| Titania - R - $8^h48^m$ | Night - Japan; eastern Australia (approx. star alt. 12°, sun -18°)<br>Day - Asia, southern and eastern Africa |
| Oberon - R - $10^h15^m$ | Night - eastern Asia, western Australia (at Perth, approx. star alt. 24°, sun -6°)<br>Day - western Asia, Africa, eastern Europe |

U.T. is for night area of visibility; the time is a few minutes earlier in the day area.

PASSAGE OF $\alpha^2$ LIBRAE BEHIND THE ORBITS OF TITANIA AND OBERON 1978 OCTOBER 8




## ANALYZING HMNAO RESIDUALS — III

Clifford J. Bader

Although response to my request for statistical data or for raw preliminary residuals (*O.N., 1* (11), 113) has been disappointing, the data base has been extended to a total of 897 timings through the courtesy of Roger Giller, Engadine, NSW; of Doug Hall, Leicester, England; and of Al Webber, Chadds Ford, PA. Partial breakdowns have been made according to HMNAO accuracy class and disappearances vs. reappearances. In additon, some reported personal equations have been sorted with respect to the same breakdowns, with interesting implications regarding PE estimates.

The overall residual mean (with disappearance signs changed) has dropped somewhat from its last reported value, to 0".055 ± 0".023 (late) at 68% confidence. The overall standard deviation remains essentially unchanged at 0".70. The individual means for each of the observers fall within the ± (0.05 + e) limit defined by L. V. Morrison in his letter (*O.N., 1* (11), 112).

Previous indications of a tendency toward later residuals for the less-certain timings have been reinforced by recent data from Mr. Hall, Mr. Giller, and me. For a total of 381 HMNAO accuracy class 1 timings, the mean is -0".007 ± 0".032, while for 123 class 2 and up timings, the mean is 0".206 ± 0".060. It is thus virtually certain that a real, rather than chance, difference in the means exists, and since the implied average time difference is on the order of $0^s.5$, the effect is of sufficient magnitude to be worthy of concern.

The poorer-quality timings would be expected to exhibit a larger variance than those of better quality. While a difference in the standard deviations does appear to exist (0".68 vs. 0".62), an accurate assessment is hindered by the root-mean-square predominance of the large observer-independent component. If the latter is taken to be 0".6, the observer contribution is 0".32 for class 2 up and 0".16 for class 1. These values are rather dubious due to the various uncertainties, but are at least of plausible magnitude.

A difference of means also exists for disappearance vs. reappearance residuals. Here the available data are confined to Mr. Hall and me; the mean for 292 disappearances was found to be -0".021 ± 0".035, while 124 reappearances yielded 0".163 ± 0".056. Again, a time difference of significant magnitude is implied.

It was immediately suspected that the D/R and accuracy class mean differences were related, due to a high proportion of R's in the less-certain accuracy classes. However, both class 1 R's and class 2-up D's were found to show significant positive mean shifts, so there is reason to believe that the two effects are at least partially independent.

The existence of a correlation between mean and accuracy class implies that observers are generally capable of differentiating between good and poor timings; however, their quantitative estimates of time appear to be reliable only for the former. For reappearances, observer judgment of reaction delay seems to suffer even under favorable circumstances.

Available data for reported PE's indicate that observers are aware of the presence of extended reaction times, but that they underestimate the required allowances. This is clearly shown in the following summary:

| | Average Reported PE (sec) Hall | Bader |
|---|---|---|
| Overall | 0.434 | 0.423 |
| Class 1 | 0.378 | 0.398 |
| Class 2 up | 0.766 (1.2) | 0.571 (1.0) |
| D's | 0.377 | 0.388 |
| R's | 0.626 (1.2) | 0.463 (0.8) |

The numbers in parentheses are the average PE values which would be required to reduce the associated residual means to values comparable with those for the class 1 timings and for disappearances, assuming 1 second of time to be equivalent to 0.4 seconds of arc in typical total occultations. It is interesting to note that excellent agreement exists between the two observers for the certain events, but that divergent (although uniformly optimistic) estimates arise for uncertain timings and reappearances.

The foregoing results pose a dilemma. In the face of strong evidence that PE tends to be underestimated for some types of timings, should an attempt be made to revise future estimates? It is obviously inadmissible to tailor personal equation until one's residual mean approaches zero, since this would destroy any observer-independent component of the mean.

It would, however, appear legitimate to adjust the less-certain and reappearance estimates in order to bring the corresponding residual means into gradually better agreement with the more-certain and disappearance means. Obviously, caution is required, and any corrections should be of a conservative nature; the desire to overcompensate in order to "pull down the average" should be resisted.

Perhaps some of the late residuals are attributable to the optimistic assessment of questionable timings in the unconscious interest of swelling observation counts. This is the dark side of the competitive factor implicit in the publication of observer totals; the bright side is the increased activity which is undoubtedly stimulated by the desire to achieve a high ranking. At any rate, a little soul searching should be done in the interest of scientific objectivity before one succumbs to the temptation of including a dubious timing.

Other aspects of residual statistics remain to be investigated. Roger Giller reports a marked improvement in his residuals with experience; have others noticed this effect, and if so, how quickly does it progress? A sizable difference exists between the standard deviations for Australia (0".80 for 350 timings by 2 observers) and for Britain and the U.S.A. (0".63 for 547 timings by 3 observers). Is a geographical effect involved? More data are needed to explore these and other questions and to generalize the basis for those already discussed. Your inputs will be welcomed and acknowledged.

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## OCCULTATIONS DURING THE LUNAR ECLIPSE OF 1978 SEPTEMBER 16

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[Ed: This note primarily consists of postponed portions of the article OCCULTATIONS DURING LUNAR ECLIPSES AND CLUSTER PASSAGES, *o.n.*, *1* (14), 145-7. For fuller coverage, please refer to that article.]

The chart for the September 16th eclipse on [appended pages 170a and 170b, is being distributed to Eastern Hemisphere subscribers, and to anyone else who requests a copy from the editor, and] was prepared in the same style as that for the March eclipse, with the dots marking $17^h$ to $21^h$ U.T. The vertical ticks indicate the moon's position for the following September eclipse events: first contact, $17^h20^m.2$ U.T.; start of totality, $18^h24^m.4$; end of totality, $19^h43^m.9$; and last contact, $20^h48^m.1$. Mid-eclipse occurs at $19^h04^m.2$, shortly after the $19^h$ mark, so it is not plotted. On September 16, the position angle of the lunar equator will be 245°, to help in locating reappearing stars using lunar features if Watts angles are not included in your predictions. The star field can also be used to locate emerging stars. [John Phelps re-worked the computer-generated charts, for publication.]

The Leningrad ***Ephemerides of Minor Planets*** shows that there will be no occultations of any of these objects during the September eclipse.

For a non-Z.C. SAO star, add 146000 to the number from the chart to obtain the full SAO number.

The non-SAO AGK3 stars in the September eclipse field are J6150 = K7626, J6172 = K7629, J6406 = K7661, and K7665, a 10.4-mag. sp. G0 star at 1950 R.A. $23^h40^m34^s.1$, Decl. -1°41'12" which is not in J probably because it is near the edge of the field and probably will not be occulted under favorable eclipse circumstances.

Stations for the September 16 lunar eclipse tracks shown on the chart are as follows: 1, Auckland, New Zealand; 2, Dunedin, New Zealand; 3, Brisbane, Australia; 4, Melbourne, Australia; 5, Tokyo, Japan; 6, Khabarovsk, Siberia; 7, Taipei, Taiwan; 8, Manila, Philippines; 9, Nanking, China; 10, Perth, Australia; 11, Lembang, Indonesia; 12, Tomsk, Siberia; 13, Naini Tal, India; 14, Kodaikanal, India; 15, Basrah, Iraq; 16, Moscow, Russia; 17, Salisbury, Rhodesia; 18, Johannesburg, South Africa; 19, Athens, Greece; 20, Cape, South Africa; 21, Herstmonceux, England; and 22, San Fernando, Spain.

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## STARS IN M23, M25, AND THE 1978 SEPTEMBER 16 ECLIPSE FIELD

David Herald, Woden, Australia, has provided the following information regarding inter-catalog correlations for M23, M25, and the 1978 September 16 lunar eclipse field, as well as double stars and a variable star in the latter.

Non-SAO Stars in M23

| J# | BD # | J# | BD # | J# | BD # |
|---|---|---|---|---|---|
| | -18° | | -18° | | -19° |
| 4749 | 4692 | 4823? | 4714 | 4746 | 4754 |
| 4760 | 4697 | 4829 | 4716 | 4752 | 4755 |
| 4762 | 4698 | 4830 | 4717 | 4755 | 4756 |
| 4764 | 4699 | 4835 | 4718 | 4761 | 4758 |
| 4768 | 4700 | 4836 | 4719 | 4765 | 4759 |
| 4775 | 4702 | 4844 | 4721 | 4766 | 4760 |
| 4777 | 4704 | 4846 | 4724 | 4769 | 4761 |
| 4783 | 4705 | 4852 | 4725 | 4771 | 4762 |
| 4801 | 4706 | 4857 | 4726 | 4781 | 4763 |
| 4799 | 4707 | 4860 | 4727 | 4795 | 4766 |
| 4798 | 4708 | 4862 | 4728 | 4805 | 4767 |
| 4806 | 4709 | 4871 | 4730 | 4808 | 4768 |
| 4812 | 4710 | 4877 | 4731 | 4819 | 4769 |
| 4813 | 4711 | 4876 | 4732 | 4822 | 4770 |
| 4815 | 4712 | 4878 | 4733 | 4839 | 4771 |
| 4821 | 4713 | 4879 | 4734 | 4850 | 4773 |

Non-SAO Stars in M25

| J# | BD # | J# | BD # |
|---|---|---|---|
| 5576 | -19°5024 | 5647 | -18°4991 |
| 5581 | -18 4979 | 5649 | -19 5046 |
| 5587 | -19 5027 | 5652 | -19 5048 |
| 5588 | -18 4980 | 5655 | -19 5049 |
| 5591 | -18 4981 | 5661 | -19 5054 |
| 5600 | -18 4983 | 5662 | -19 5055 |
| 5603 | -19 5031 | 5663 | -19 5056 |
| 5605 | -19 5032 | 5664 | -19 5058 |
| 5615 | -19 5034 | 5665 | -18 4993 |
| 5616 | -19 5035 | 5666 | -19 5057 |
| 5623 | -19 5037 | 5671 | -19 5061 |
| 5624 | -19 5038 | 5679 | -18 4995 |
| 5625 | -19 5039 | 5681 | -19 5063 |
| 5626 | -19 5040 | 5691 | -18 4998 |
| 5628 | -18 4989 | 5693 | -19 5068 |
| 5629 | -19 5041 | 5703 | -18 5002 |
| 5632 | -18 4990 | 5704 | -19 5072 |
| 5634 | -19 5043 | 5710 | -19 5073 |
| 5636 | -19 5044 | 5724 | -18 5008 |
| 5638 | -19 5045 | | |

Non-SAO Stars in the Eclipse Field

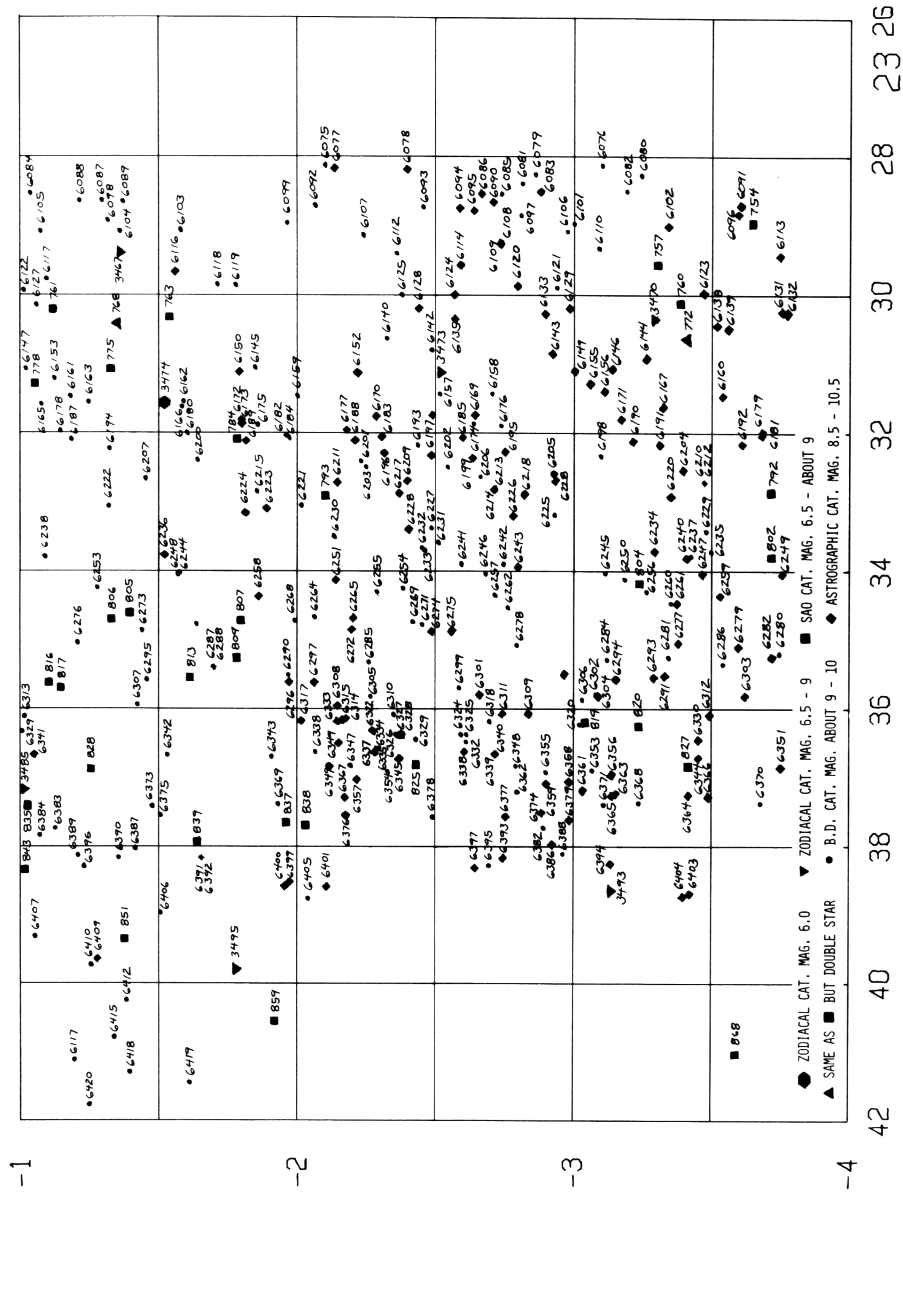
| J# | BD # | J# | BD # |
|---|---|---|---|
| 6078 | -2°5980 | 6301 | -3°5673 |
| 6094 | -3 5650 | 6308 | -2 6001 |
| 6114 | -3 5652 | 6309 | -3 5674 |
| 6116 | -2 5981 | 6311 | -3 5675 |
| 6124 | -3 5653 | 6314 | -2 6002 |
| 6135 | -3 5656 | 6316 | -2 6003 |
| 6140 | -2 5983 | 6317 | -2 6004 |
| 6143 | -3 5658 | 6323 | -1 4467 |
| 6144 | -3 5659 | 6330/6331* | -3 5678 |
| 6149 | -3 5660 | 6336 | -3 5679 |
| 6150 | -2 5984 | 6340 | -3 5680 |
| 6152 | -2 5985 | 6342 | -2 6006 |
| 6156 | -3 5662 | 6344 | -3 5681 |
| 6168 | -3 5663 | 6349 | -2 6008 |
| 6170 | -2 5987 | 6356 | -3 5683 |
| 6173 | -2 5988 | 6367 | -2 6009 |
| 6177 | -2 5989 | 6373 | -2 6010 |
| 6185 | -3 5664 | 6374 | -3 5685 |
| 6189 | -2 5991 | 6376 | -2 6001 |
| 6197 | -3 5665 | 6377 | -3 5686 |
| 6208 | -3 5666 | 6391 | -2 6015 |
| 6209 | -2 5992 | 6393 | -3 5687 |
| 6214 | -3 5667 | 6399 | -2 6016 |
| 6218 | -3 5668 | 6400 | -2 6017 |
| 6223 | -2 5994 | 6401 | -2 6018 |
| 6228 | -2 5995 | 6403 | -3 5689 |
| 6236 | -2 5996 | 6404 | -3 5690 |
| 6248 | -2 5997 | 6406 | -2 6019 |
| 6265 | -3 5670 | 6407 | -1 4475 |
| 6293 | -3 5671 | 6410 | -1 4479 |
| 6294 | -3 5672 | 6415 | -1 4482 |
| 6295 | -1 4464 | 6417 | -1 4483 |

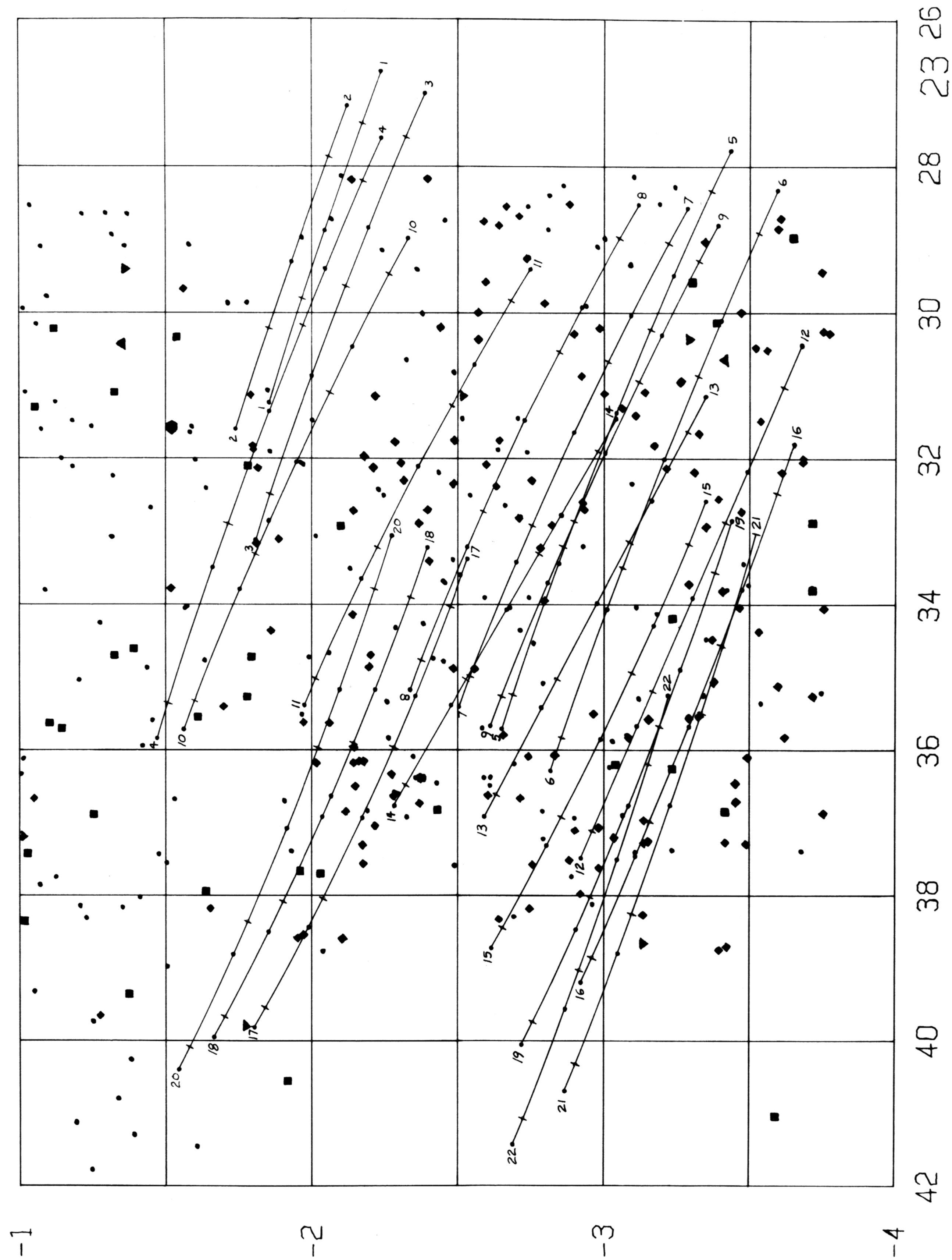
Double Stars (IDS) in Eclipse Field

| | MAG1 | MAG2 | SEP. | P.A. |
|---|---|---|---|---|
| J6244 & 6248 | 10.8 | 11.3 | 19".3 | 254° |
| J6327 (SAO) & 6328 | 10.7 | 11.3 | 16.4 | 41 |
| J6330 & 6331* | 10.9 | 11.4 | 4.6 | 236 |
| J6403 | 9.9 | 14.0 | 1.9 | 248 |

Variable Star in the Eclipse Field

J6340 ≡ SVS 5772, magnitude range 9.5 to 10.0, period $369^d.1934$, irregular.


ZODIACAL CAT. MAG. 6.0
SAME AS ■ BUT DOUBLE STAR
ZODIACAL CAT. MAG. 6.5 - 9
B.D. CAT. MAG. ABOUT 9 - 10
SAO CAT. MAG. 6.5 - ABOUT 9
ASTROGRAPHIC CAT. MAG. 8.5 - 10.5
42
40
38
36
34
32
30
28
23 26
-1
-2
-3
-4


26
23
28
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-3
-4