Occultation Newsletter

Volume II, Number 6 November, 1979

Occultation Newsletter is published by the International Occultation Timing Association. Editor and Compositor: H. F. DaBoll; 6 N 106 White Oak Lane; St. Charles, IL 60174; U.S.A. Please send editorial matters to the above, but send address changes, requests, matters of circulation, and other IOTA business to IOTA; P.O. Box 596; Tinley Park, IL 60477; U.S.A.

FROM THE PUBLISHER

For subscription purposes, this is the fourth and final issue of 1979, but please note that the next issue probably will come out in December, 1979, so members and/or subscribers receiving expiration notices with this mailing are urged to be especially prompt in renewing.

O.N.'s price is $1/issue, or $4/year (4 issues) including first class surface mailing, and air mail to Mexico. Air mail is extra outside the U.S.A., Canada, and Mexico: $1.20/year in the Americas as far south as Colombia; $1.68/year elsewhere. Back issues also are priced at $1/issue. Please see the masthead for the correct ordering address.

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 12.-- to Hans J. Bode, Bartold-Knaust Str. 6, 3000 Hannover 91, German Federal Republic. Spanish, Portuguese, 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, Coyoacán, Mexico, D.F., Mexico.

SATELLITES OF MINOR PLANETS

David W. Dunham

Although I feel that the currently available evidence from occultations is very strong, the existence of satellites of minor planets will not be proved conclusively until the orbit of one has been determined, so that future apparitions can be predicted and observed. These guidelines are the ones which Brian Marsden has reasonably set for the assignment of permanent designations to solar system objects. I apologize for some of the statements made in articles in some of the recent issues of *O.N.*, where the asteroidal satellite hypothesis has been assumed in the description of certain observations whose origins might more likely be terrestrial (e.g., atmospheric seeing fluctuations). My articles about asteroid events on pages 34-35 of the August, 1979, issue were written over a year ago, shortly after the 1978 June Herculina event, when the idea of asteroidal satellites dominated my thinking.

Observations made from pairs and from triples of photoelectric stations by University of Arizona astronomers this year show that claims of secondary events during asteroidal occultations must be carefully evaluated; see "Reliability of Minor Planet Satellite Observations," H. Reitsema, *Science 205*, 185. Seeing fluctuations render unreliable visual observations of asteroidal occultations of faint stars, or those with small Δm's. My impression of the occultation of SAO 114159 by (18) Melpomene last December (V-mag. of star 8.4, occultation Δm = 1.0) was that it was only slightly above the limit of reasonably reliable visual observation. I feel that visual observations of asteroidal occultations of 9th-mag. stars are useful only with relatively large aperture telescopes under excellent atmospheric conditions in the case of large Δm's. Even with good conditions, others will not pay much attention to visual secondary extinction timings unless they are confirmed by another independent observer. When possible, photoelectric observations are much preferred, for their better timing resolution and for quantification of the light variations. If the light levels of the sky background, star, and asteroid are measured separately before and after they merge, measurements of a sudden drop in the light level followed by a sudden rise can decide whether the drop was probably an occultation or not. During an occultation, the light level would be the sum of dark current, sky, and asteroid, while just before and after, the level would be augmented by the star's light. During the approach of (13) Egeria to 9.5-mag. SAO 92603 in February, the Arizona observers claimed some double coincidences which were all disproved by a record obtained with a third telescope in line, but these records have not been published; I expect that the "double coincident" events would not pass the test described in the preceding sentence. Other photoelectric and visual observers monitored the event in California, and all reported that they could not tell whether any occultation events had occurred or not, due to atmospheric seeing fluctuations. Many of the specialists who attended the conference on asteroids in Tucson, AZ, last March, remain skeptical about the existence of asteroidal satellites. There was more acceptance of the asteroidal satellite hypothesis when I gave a talk on the subject during a session of the Double Star Commission at the general assembly of the International Astronomical Union in Montreal, Quebec, in August; double star observers seem to have a greater appreciation of the value and limitations of visual observations than many other astronomers.

In his *Science* article, Reitsema called James McMahon's five unconfirmed secondary events (see *O.N.* 1 (15), 151-2 and *O.N.* 2 (1), 23) "apparently spurious" without further explanation, and made other derogatory statements about visual observations. There is no doubt that photoelectric observations of occultation events are preferred. The reliability of visual observations has been studied previously, especially for lunar events.[1] Visual observers of asteroid occultations usually tape record voiced calls or manually generated tones along with short-wave radio time signals. Hence, a permanent record is produced which can be carefully examined to determine accurate times when the observer reacted to perceived occultation events. The success of this method is shown by the good fit to an ellipse of the six timings, four visual and two photoelectric, obtained during the occultation of 6th-magnitude SAO 120774 by (532) Herculina on 1978 June 7. All timing residuals were less than 0.20 s.[2]

Tests of observers watching the sudden dimming and brightening of a bright artificial star were recently conducted at Lowell Observatory.[3] The observers usually had great difficulty detecting brightness changes less than one magnitude (60% intensity), but signaled greater changes quite reliably. Another check is provided by lunar grazing occultations observed from several stations. The geometry of the mountains dominating the lunar profile dictates that observers deeper in the occultation zone have successively longer occultation durations. Analyses of these observations[4] show that over 95% of events in which observers express confidence are consistent.

McMahon was equally confident in the reality of all of the seven extinctions (including the main occultation of the asteroid) he recorded; the star was relatively bright (the decrease in light at occultation was 2.9 magnitudes or 93%); and atmospheric conditions were reported to be excellent. The five extinctions which Reitsema labelled "apparently spurious" were considerably shorter than the one confirmed event, indicating occultations by bodies too small to be occulted at the other stations. We can not yet say what mechanisms are involved to produce the reported events. I feel that it is premature to either postulate a ringlike swarm of satellites or to reject the observations as "spurious."

The Astronomical Society of the Pacific was more appreciative of McMahon's observations. James McMahon received the A.S.P. Amateur Achievement Award for 1979 in June.

Reitsema states that the altitude of the Herculina event at Lowell Observatory was "a mere 2° above the horizon." According to my calculations, the altitudes ranged from 3° (secondary event) to 2½° (asteroid occultation) at Lowell. Although the seeing fluctuations consequently were very large, during both events the star was obstructed from view, as can be seen clearly in the published records.[5] There is some question about the interpretation of even a photoelectric record; we have to rely on the observer for an assessment of the conditions (e.g., presence of clouds). A'Hearn and Bowell, the observers at Lowell, report that conditions were excellent (no clouds). They were unable to produce a record even remotely resembling the recorded secondary event by purposely guiding off the star during subsequent tests.

Most of the other reported secondary events have involved stars fainter than SAO 120774. These fainter stars are more subject to atmospheric variations which can be confused with occultation events, especially in the case of visual observations.

The initial interpretations of the photoelectric record obtained at Atlanta, GA, during the (18) Melpomene event (*O.N. 2* (2), 13 and *I.A.U. Circular* #3315) are wrong. Unlike the photoelectric records obtained in the DC area, the noise in the Atlanta record did not decrease during the event, and the small fluctuations claimed to show the stellar duplicity must have been atmospheric scintillation. Williamon reanalyzed his records, and determined that the Δm of his light drop, poorly determined due to clouds before and after the period of merged images, was less than 0.3. This would be consistent with an occultation of only the fainter component of SAO 114159; if the primary star had been occulted, at least the secondary star would have been occulted by the Atlanta object at Norman, OK, 25 km south of the Atlanta track, but there is no evidence for any occultation in the Oklahoma photoelectric record. The evidence for a satellite of Melpomene is not as strong as that for one of Herculina, the only object observed from two stations.

I feel that the available evidence does indicate the existence of asteroidal satellites. Considering the lack of confirmed secondary events during last December's Melpomene occultation, asteroidal satellites, especially ones larger than 1 km, do not seem to be as numerous as some have claimed. [Note inserted October 19th: Abstracts of papers to be presented at the 11th annual meeting of the Division for Planetary Sciences of the American Astronomical Society have been published in *Bull. Am. Astron. Soc. 11* (3), 19 (9 October). Alan Harris is presenting a paper, "The Dynamical Plausibility of Asteroidal Satellites," in which he claims that the rate of tidal evolution is considerably overestimated by Binzel and Van Flandern (*Science 203*, 903-5 (1979)) and notes that collisional disruption of asteroids is smaller than previously supposed (Davis *et al.*, in *Asteroids*, T. Gehrels, ed., 1979). He concludes, "Hence, the existence of at least some satellites of asteroids need not imply a steady state formation process rather than formation at the time of solar system origin." However, he notes that the maximum density of satellites which can exist in mutually stable orbits about an asteroid yields a low probability of even one secondary occultation for an observer in the path of the primary occultation. This seems to have been confirmed by observations of the Melpomene occultation. Even for the 1978 June Herculina event, McMahon was one of about a dozen visual observers who attempted the observation, and was the only one of them to report any secondary events. At the same meeting, W. K. Hartmann and D. P. Cruikshank report that new observations prove that (624) Hektor's unusual light curve is due to an elongated shape rather than to albedo variations over an approximately spherical surface. They note that detailed observations during Hektor's apparition in early 1980 could confirm their "contact binary" (actually, "crushed-together binary") model for Hektor]

The current controversy reminds me a little of a similar controversy over satellites of Jupiter nearly four centuries ago. Many astronomers are now where I was in 1977 after Paul Maley's observation (*O.N. 1* (11), 115-7), only willing to say "maybe." All are agreed upon the need for *confirmed* observations of secondary events under good conditions. That is why some of us are willing to go to considerable effort and expense to observe the very favorable occultation by (9) Metis in December (see p. 44). The good prediction record from last-minute astrometry for the 1978 events gives us confidence in locating observers in or near the occultation path where secondary occultations would be most likely. But others, far from the path, should also watch from *pairs* of stations, since the possibility of making a confirmed secondary occultation observation exists for the whole nighttime part of the hemisphere facing the asteroid.

Direct observations of asteroids near perihelic opposition, using interferometer techniques or long-focus photography, may reveal asteroidal satellites. The table shows parameters of possible asteroidal satellites according to some of the occultation observations. The problem of detection is similar to that for the satellite of Pluto, only the asteroids are generally about five magnitudes brighter (9th mag. for each of the asteroids in the table). Hopefully, an approximate orbit will be determined for at least one asteroidal satellite before the Shuttle-launched Space Telescope becomes operational.

Observed Parameters for Satellites of Minor Planets

Minor Planet	Diameters, km M. P.	Sat.	Δm	Separation
(532) Herculina	217	46	3.4	977 km = 0".866
(18) Melpomene	135	48	2.2	697 km = 0".863
(6) Hebe	186	20	5	900 km = 0".7
(3) Juno	256	10	8	3100 km = 2".3
Pluto - Charon	3000	1200	2	17000 km = 0".8

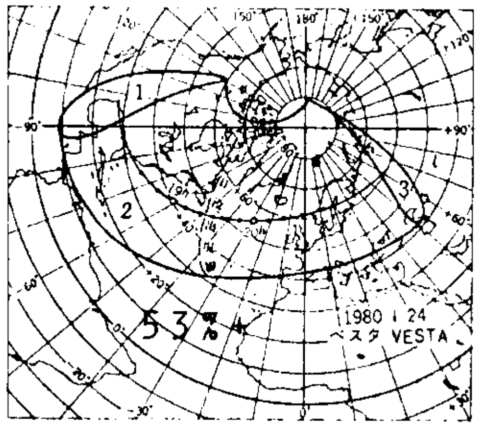
References

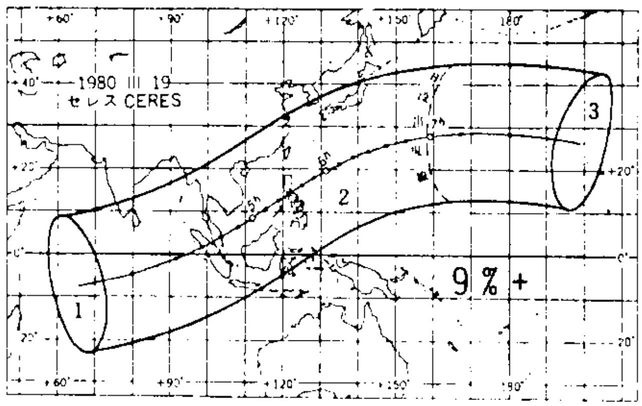
1. A. Sinzi and H. Suzuki, *Report of Hydrographic Researches* No. 2, 75 (1967).
2. E. Bowell *et al.*, *Bull. Am. Astron. Soc. 10*, 594, and *O.N. 2* (1), 2.
3. R. Millis and J. Elliot, "Direct Determination of Asteroid Diameters from Occultation Observations." Submitted to *Asteroids*, Univ. of Ariz. Press, T. Gehrels, ed. (1979).
4. L. Morrison, *Mon. Not. R. Astron. Soc. 149*, 81 (1970).
5. Anonymous, "532 Herculina as a Double Asteroid," *Sky Telesc.* 56, 210 (1978).

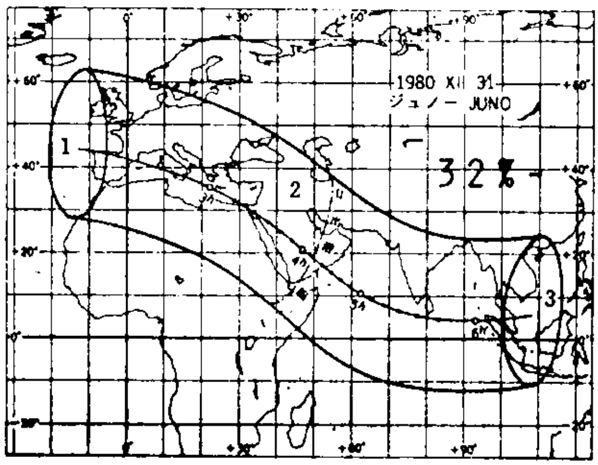
LUNAR OCCULTATIONS OF MINOR PLANETS DURING 1980

David W. Dunham

Each of the first four asteroids will be occulted by the moon during 1980, providing opportunities to measure their diameters by photoelectric observations. Maps from the Japanese Ephemeris (see LUNAR OCCULTATIONS OF PLANETS; PARTIAL OCCULTATIONS on p. 54) below show the regions of visibility for occultations of 6.9-mag. Vesta on Jan. 24, 9.1-mag. Ceres on Mar. 19, and 11.3-mag. Juno on Dec. 31. Another occultation of Vesta on February 21st, with the moon 35% sunlit, and another occultation of Ceres on April 16, with the moon only 3% sunlit, occur only in the Indian Ocean and part of Antarctica, so maps for them are not reproduced here. The moon will be 12% sunlit, waning, when it occults Pallas on May 11, after sunrise in South America. The only area of night visibility is an island-less part of the Pacific Ocean between latitudes 30° S and 70° S, so a map for it is also not included here. The occultation of Vesta by a first-quarter moon on Jan. 24 is certainly the most promising event, visible from most European observatories. Expected durations range from 0^s.8 for the disappearance at Hamburg, Germany, to 7^s.8 at Nice, France, where immersion occurs only 5° from the south cusp. Accurate timings should be made from two nearby observatories, on the order of a kilometer apart in the north-south direction, in order to separate the effects of a local lunar limb slope from the diameter of the asteroid (both affect the duration, but only the former affects the U.T.C. of the events). This was success-







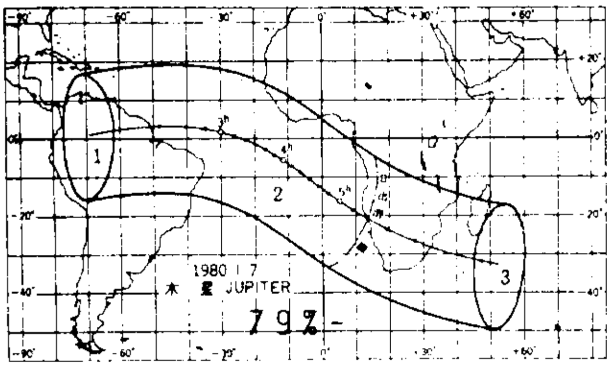
fully accomplished for the determination of the diameters of five of Saturn's satellites during occultations recorded photoelectrically at Mauna Kea, Hawaii, in 1974 March.

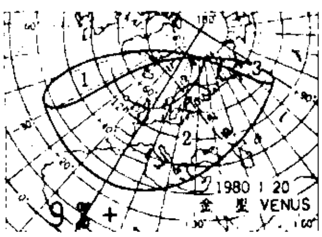
Predictions of lunar occultations of 125 asteroids now are included in USNO's regular predictions of occultations of stars. Predictions for just these events have been computed for several observatories and are available upon request to me. During 1980, only Ceres and Vesta are bright enough that occultations of them might be observed visually. From Hawaii, the disappearance of Ceres on March 19 will occur with the asteroid only 2° above the horizon at Honolulu, Oahu, and only 1° high at Haleakala, Maui.

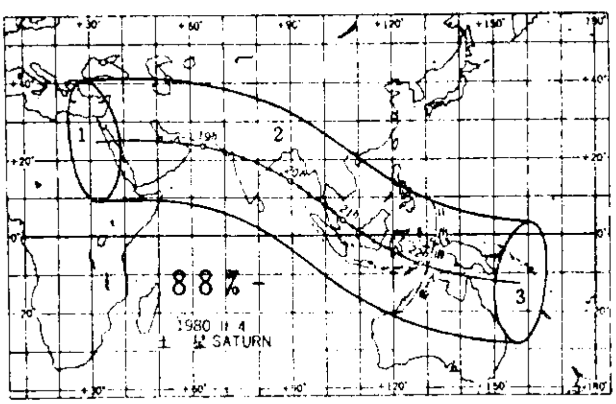
LUNAR OCCULTATIONS OF PLANETS; PARTIAL OCCULTATIONS

David W. Dunham

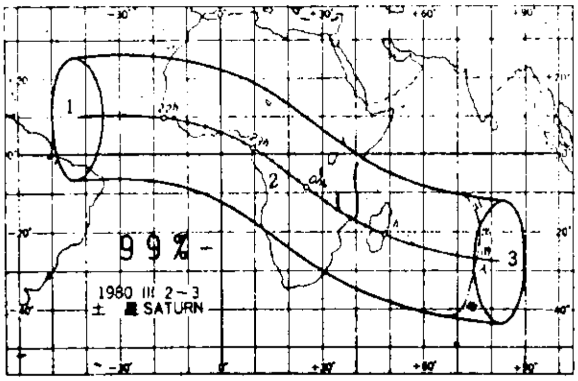
The maps showing the regions of visibility of lunar occultations of planets are reprinted by permission, from the Japanese Ephemerides for 1979 and 1980, published by the Hydrographic Department of the Maritime Safety Agency of Japan. In region 1, only the reappearance is visible; in region 3, only disappearance may be seen. Reappearance occurs at sunset along a dashed curve, while disappearance is at sunrise along a curve of alternating dots and dashes.

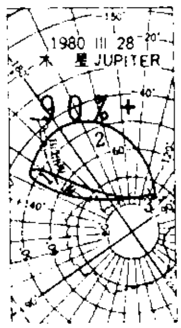


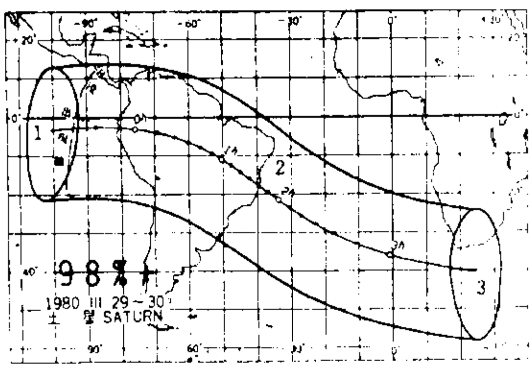


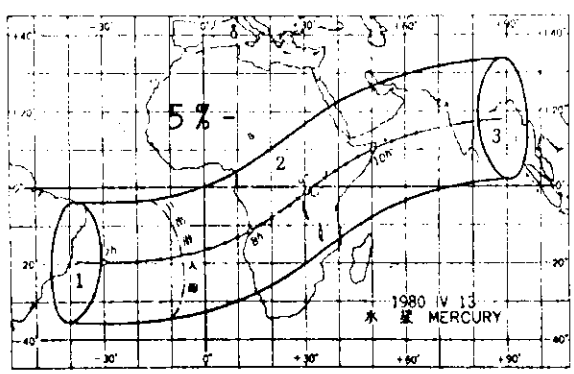


A partial occultation occurs near the northern and southern limits of the regions of visibility of the occultations shown on the maps. At the inside edges of these narrow partial occultation zones, the planet's disk will just completely disappear at central occultation, producing an effect similar to that of a graze of a star, but with the phenomena generally appearing gradual. Berton Stevens has been sending predictions of these events to IOTA members during the past four years, and will do so for events dur-

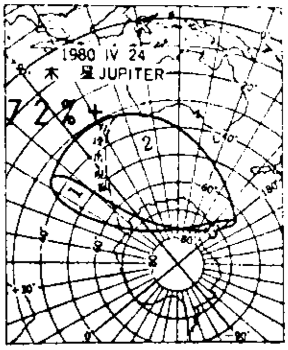


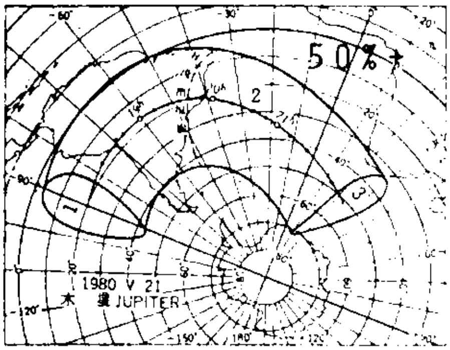


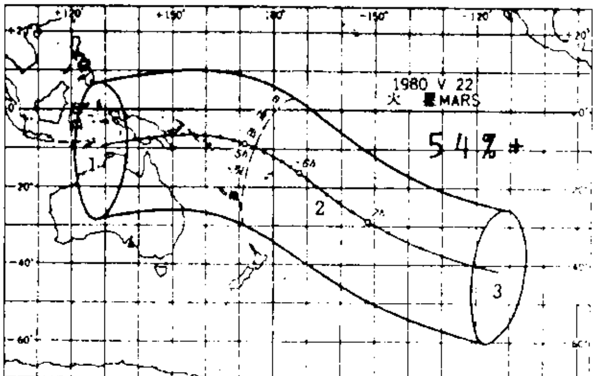


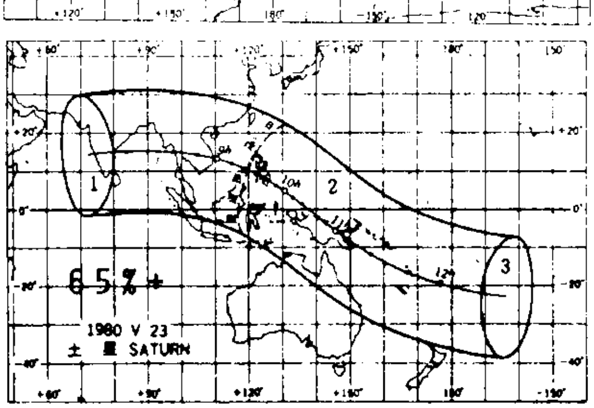


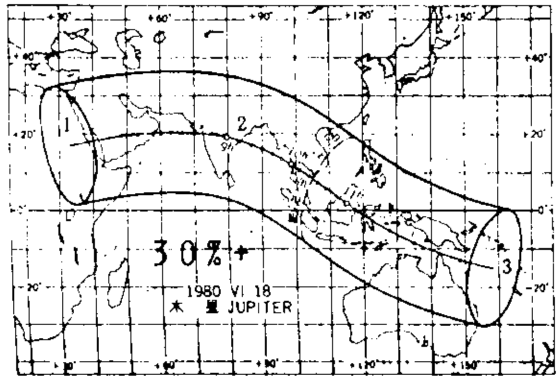
ing the remainder of 1979. He has made useful modifications to my original version of the program, including the observer scan capability and the modification to compute the desired inner edge of the partial occultation zone, rather than its center. Starting with the events for 1980, Joseph Senne, P.O. Box 643, Rolla, MO 65401, U.S.A., telephone 314,364-6233, will be computing predictions of these events using a copy of Stevens' version of the program. Due to the manual work involved in preparation of these predictions, for 1980 onwards they will be supplied only upon request to Senne, who is currently also handling special requests for graze predictions of stars. Due to the delays in preparation of these predictions, especially profiles for them, we will try to keep about 6 months ahead in the publication of the maps from the Japanese Ephemeris. You should check the maps to see whether there are any

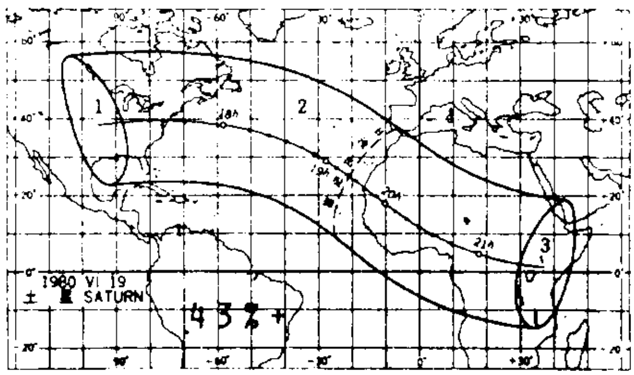


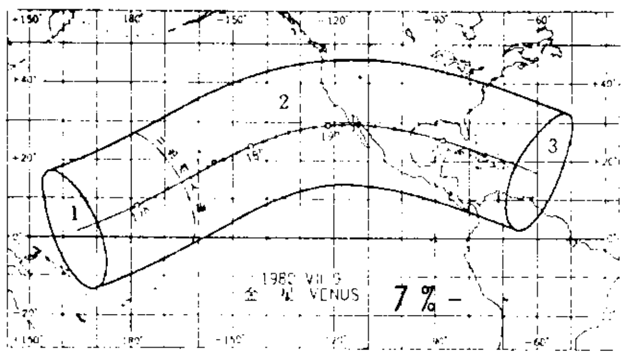


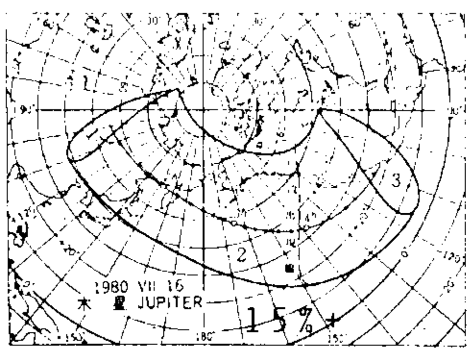




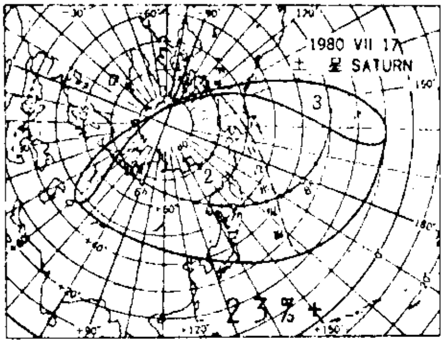


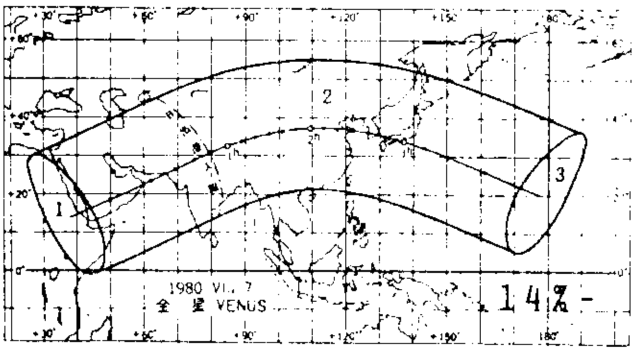


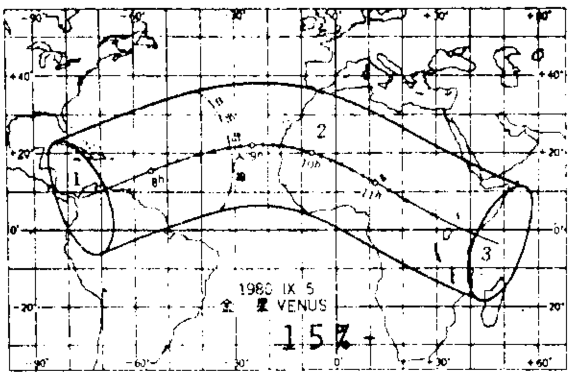


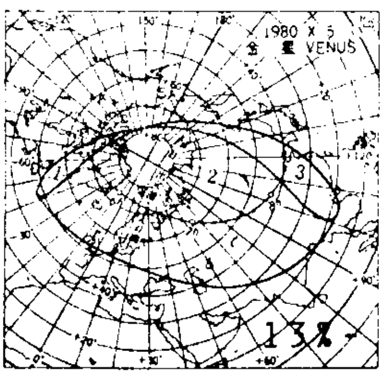


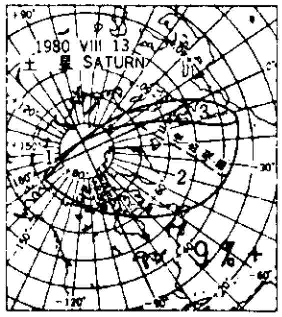
events which you might be interested in observing, and if so, request predictions at least three months in advance. Once someone has requested predictions for a particular event, other IOTA observers near the limits usually will be checked using their graze travel radii, and sent predictions, if appropriate. 1980 partial occultation predictions already have been requested by me for the following five events: January 24, Vesta; July 9, Venus; July 16, Jupiter; October 5, Venus; and December 31, Juno.











EARLY 1979 ASTEROIDAL OCCULTATIONS

David W. Dunham

(13) Egeria and SAO 92603, February 28. Predictions of occultations of stars by asteroids during 1979 were published on pages 16-20 of *O.N. 2* (2), including a finder chart and regional map for the February 28th event. No astrometric updates of the prediction are known. Glen Erickson monitored the appulse photoelectrically at Davis, CA, but noted that, due to the faintness of the star (mag. 9.5) and its relatively low altitude, the atmospheric seeing variations were so large that it was not possible to tell whether there were any occultation events or not. James Van Nuland and another visual observer in the San Jose, CA area sent similar reports. Ben Zellner, William Hubbard, and others from the University of Arizona made photoelectric observations from three stations in an east-west line (in the direction of the occultation shadow's motion). The Steward Observatory and two portable 14-inch Celestrons were used. See the article, SATELLITES OF MINOR PLANETS, on p. 51, for further discussion of this event.

(39) Laetitia and B.D. +10° 465, April 6. A notice about this occultation was sent to all *O.N.* subscribers in the possible area of visibility. A telex message had been received from Gordon Taylor stating that there was no significant error in the asteroid ephemeris or the star position, based on plates taken at Royal Greenwich Observatory on March 23.8. Deane Peterson has reported that Douglas Smith apparently observed the occultation at the State University of New York's observatory on the campus at Stony Brook, Long Island. He located the star in evening twilight with the 20-cm guide telescope, checked the finder chart and verified that he had the right star, saw the star disappear when he

looked again through the eyepiece, and then saw the star reappear. Unfortunately, observation with the 31-cm main telescope was not possible due to focusing problems. The observed time was close to that predicted by Taylor. Brighter twilight foiled attempts to monitor the event in the DC area. Edward Brooks, in Massachusetts, and John Bortle, Stormville, NY, found the faint star, but reported that they could not tell whether any occultation had occurred or not, since the star repeatedly faded out of view due to atmospheric seeing variations. Both observers could have been north of the narrow occultation path.

(2) Pallas and SAO 107061, April 24. Plates taken by James Christie at USNO on April 20, and measured by Robert Harrington, indicated a 1".0 north shift. Plates by Penhallow on April 21 (reduced using SAO data) and by Gordon Taylor on April 22 showed 0".7 north shifts from my predictions, in agreement with Taylor's original prediction; he sent a telegram to observers in the path in China. They reported that cloudy skies prevented observation of this interesting event. I had prepared IOTA Special Bulletin No. 7 about the event, and distributed it to observers throughout southeastern Asia and eastern Siberia. M. Pishnenko, Khaborovsk, Siberia, was in Taylor's predicted path, but like the Chinese, reported that thick clouds prevented observation. The discrepancy between Taylor's (correct) original prediction and my original prediction was found to be caused by an error (now fixed) in my computer program for retrieving AGK3 data for asteroid occultation calculations. A discrepancy in the right ascension solutions reducing Penhallow's measurements with AGK3 and then SAO data has not been resolved. Spectroscopists at the general assembly of the International Astronomical Union in Montreal in August reported that the star has reached periastron this year, as predicted by West (see *o.n.* *2* (2), 19).

(16) Psyche and SAO 163921, April 27. A record for last-minute astrometry was set for this event when, twelve hours before it occurred, David Herald obtained a plate of the rapidly approaching objects with the small-field Yale-Columbia refractor at Mt. Stromlo, Australia. During the next five hours, he developed, measured, and reduced the plate, and calculated the implied shift (about 1".2 south), which he telephoned to me. This path crossed southern Chile and southern Argentina, where we do not know any observers. With seven hours to spare, I considered notifying Eduardo Przybyl in Argentina about the result, but decided not to when a call to the N.O.A.A. satellite weather center showed that a front was producing extensive cloud cover over the area; the forecast indicated no chance of clearing in time for the event. Mr. Przybyl and Jorge Polman sent me some reports of negative observations from Brazil and northern Argentina.

(451) Patientia and SAO 129290, May 31. Astrometry for this event would have been extremely difficult, and as far as I know, none was accomplished. The University of Arizona astronomers Wieslaw Wicniewski, William Hubbard, and Ed Tedesco successfully monitored this difficult event with the 60-inch and 61-inch telescopes on Mt. Lemmon, AZ. Wicniewski reported that the asteroid seemed to pass south of the star, in agreement with my prediction. Hubbard concludes in his letter, "We are reporting these negative observations so that you will know that we are adding them to our lengthening list of unsuccessful attempts to detect asteroid satellites."

(1) Ceres and B.D. -4°217, July 31. Astrometry for this occultation was obtained a few nights in advance with the 33-cm astrograph at Lowell Observatory. These observations, which were transmitted to Gordon Taylor at the Royal Greenwich Observatory, indicated virtually no correction to the original published prediction of occultation visibility from much of Europe. At about the same time, a summer assistant obtained a plate with the Astrographic Catalog camera at RGO. The star and Ceres were not centered on the plate, so Taylor didn't know whether to believe the result: A strong south shift of about 1", putting the path across north Africa. When European observers contacted Taylor, he suggested that they attempt observation, assuming that Lowell might be right. Negative observations were obtained at Vienna, Austria, and Asiago, Italy, implying a south shift of 0".5 or more. The Lowell astronomers conclude that there must be something wrong with their 33-cm astrograph to produce such a large error with both objects on the same plate; the last observation with the same telescope, for last December's Melpomene event, was also in error by several tenths of an arc second.

(3) Juno and SAO 114497, September 27. Jorge Polman reported good conditions at Recife, Brazil; the objects merged, but no occultation was seen. He had the impression that Juno passed north of the star, but wasn't sure. Observers to the north, at Fortaleza, were clouded out. As far as I know, no last-minute astrometry was obtained for the event.

A BADERIAN ANALYSIS FROM "DOWN UNDER"

David Herald

After Cifford Bader's ANALYZING HMNAO RESIDUALS - III (*o.n.* *1* (16), 169), and particularly the last paragraph of that article, where he suggests, among other things, a geographical effect to explain an apparently larger standard deviation for the two Australian observers (I being one), I decided to investigate my residuals over the entire span of my observing life, to see if there is any apparent cause. To this end, I went over all the HMNAO residuals for ordinary occultations since 1968, excluding those in *obvious* error (but did not attempt to locate *all* those stars observed at graze sites). The following table lists the mean, m; standard deviation, s; and standard deviation of the mean, sm; together with the number of stars, for each year. Also listed are the percentage of stars that were ZC, and the percentage of stars having positive declination.

Year	m	s	sm	no.	%ZC	%+δ
1968	+".39	".84	".28	9	100	22
1969	+.15	.83	.18	21	100	39
1970	-.21	.64	.10	41	100	29
1971	+.30	.67	.13	25	100	24
1972	+.07	.66	.07	95	45	42
1973	+.10	.54	.10	28	43	89
1974	+.35	.76	.15	25	16	12
1975	+.18	.71	.08	78	20	9
1976	-.07	.81	.08	114	23	43
1977	+.10	.77	.06	168	17	26
1968-1977	+".07	".74	".03	604		

As can be seen from this table, there is no doubt that my standard deviation is greater than that reported for the Northern Hemisphere observers - Bader gives ".63. At first sight this was rather disturbing to me, as it could imply a lower quality of observation. But on closer consideration, I think there are several reasons for the difference, which underline inherent limitations in the simple analysis.

The first thing to be noticed from the table is the relatively large relative variations in the value of the standard deviation; ".54 to ".84, with several years having a value in the low to mid-.6's, the same order of magnitude as the Northern Hemisphere observers. Did I improve with experience? I think the figures do indicate this. With further experience, did I then become 'sloppy'? I think not. Certainly I hope not! My method of timing throughout the whole period has been using a stopwatch (prior to 1970, a $^1/_5$-sec. watch, which may explain the sudden drop in s), with an occasional eye-ear timing. It is my practice to have the time signal audible at the event, so that if the event is difficult, an eye-ear timing can be made. Often, I do both, concurrently. It is extremely rare for the timings to differ by more than 0^{s}2. Usually, they differ by 0^{s}1. I am thus reasonably confident that my timings are as good as those of any typical observer. So why the increase of m from 1974 onwards?

In making the analysis, certain inherent sampling problems occur. On going through a list of residuals, it is immediately obvious that, on any one night, the residuals tend to be of similar sign. Indeed, when observing a large number of occultations on one night, one gets to know whether they will occur earlier or later than predicted. So the first point of bias is on just how many nights were the observations obtained? Were the observations uniformly distributed throughout the year, or clumped? My observations certainly tend toward 'clumpiness'. However, another sampling problem exists, and it probably gives rise to the 'geographical' effect to which Bader refers. In the Northern Hemisphere, it is much easier to see the moon when it has a positive declination, when the moon is above the horizon for a longer period of time. The converse applies in the Southern Hemisphere. It therefore follows that generally, a Northern Hemisphere observer will observe more stars with a positive declination than with a negative declination, and vice versa.

To see if this has any effect, I identified those stars with positive declinations (SAO number less than 130000 is a convenient test for zodiacal stars). As can be seen from the table, only about 39% of the stars I observe have positive declination. Then I looked at the 1977 timings, and broke them up into + and - declination groups. The m, s, and sm values are respectively +.04, .65, .10 and -.15, .80, .07, with there being 44 and 124 observations in each group. It is immediately apparent that the northern stars have a low deviation, southern ones high, and this suggests the actual cause of the difference. On further investigation, I computed the typical standard deviation for zodiacal stars in the SAO catalogue based on Yale source catalogues, for R.A. 6 hours and 18 hours, for 1978. For 6^h, the typical standard deviation in RA is ".75, for 18^h, ".90, a difference of ".15. It is thus clear that any series of observations with a bias towards southern declination stars will be expected to show a considerably greater standard deviation of the residuals, due solely to the accuracy limitations of the catalogues used for obtaining the star positions. Throw in clumpiness of observations, and/or a tendency to observe at either similar phases of the moon (first quarter) or certain parts of the sky (Taurus - Gemini, Sagittarius), and further bias creeps in, due to non-randomness.

A final comment on the accuracy of the "Class 2 up' timings: I would suggest that even here, it is necessary to consider the reasons why it was a poor timing - whether the star was faint and the telescope small, or the star bright with a bright moon, poor weather conditions, observer experience, etc. For anyone who has access to an astronomical library and is interested in the accuracy of star positions, it may be well worth his while to scan through the introductions to the various Yale catalogues, to appreciate the number of empirical corrections that are applied, including corrections which are dependent on star magnitude. A small correction of ".005 to the proper motion of a star becomes of great significance after 50 years.

ERRORS IN USNO'S XZ CATALOG

David W. Dunham

Several observers have complained to me that they have not been able to find 5.8-magnitude X05404 during predicted occultations. The first indication that something is wrong is indicated by the fact that no SAO number is given for the star. It would be remarkable for such a bright star to have been omitted from the SAO Catalog. However, as explained on pages 4 and 5 of Last November's issue of *O.N.*, admittedly not very prominent in the text of an article on new double stars, the star does exist, but its magnitude is 11.3, too faint to be seen near the moon except with large telescopes under the most favorable of circumstances. Apparently, the error was caused by an incorrect calculation of the visual magnitude from the star's photographic magnitude and spectral type during compilation of a preliminary magnetic tape version of the AGK3 which was used in construction of the XZ catalog. The error was known, along with the omission of variable star information, before the calculation of USNO's total occultation predictions for 1980 began, so it is probably corrected in the 1980 predictions.

In order to more systematically find errors such as that for X05404, I recently made a computer comparison of my K-catalog (described in *O.N. 1* (13), 138-140) with the non-SAO stars of the XZ catalog. The main problem found was the omission of about 1000 K-catalog stars from the XZ. 404 of these stars were the southern Yale Catalog stars which were not included in the SAO due a lack of proper motions; none of these stars were in XZ. The brightest of these is magnitude 7.7. All non-SAO Z.C. stars are included in both K and XZ. Surprisingly, about 600 AGK3 stars in the K-catalog are not in XZ. There doesn't appear to be any pattern to the omissions; they simply might not have been in the preliminary AGK3 used for XZ. Virtually all are faint, tenth and eleventh magnitude, with only a few 9th-magnitude stars. One of them, AGK3 N18°367 = B.D. +18°684 = K2424, has a magnitude of 7.9 and G5 spectral type.

I listed all of the successfully matched XZ-K stars when the magnitudes disagreed by more than 1.0. There were 699 stars in this category! In order to make a more manageable list, I changed the discrepancy limit to 1.5. The results, 178 stars, are given in Table 1. The XZ data (number, magnitude, and spectral type) are given first, then the corresponding data for K. The difference in Magnitude, K-XZ, is given in the ΔMag column. The double star code from XZ is given in the last (D) column.

X05643 = AGK3 N25° 421 was found to have a magnitude of -9.4! At declination +25° 31', the star will not be occulted until about 1985, giving us plenty of time to correct the error. The star is number 2242 in the K-catalog, which gives magnitude 5.4, still too bright for a non-SAO star. The star is the secondary of ADS 3161; the primary is χ Tauri = Z.C. 647 = SAO 76573, mag. 5.5. The secondary star's (X05643's) magnitude is listed as 7.6 by the Lick IDS, which is correct; I remember observing the star during 2 occultations of Z.C. 647 several years ago.

All but two K-magnitudes are fainter than the corresponding XZ-magnitudes. The two exceptions are variable stars: X06139 = K02468 = RV Tauri, Mag. 8.6 - 11.6, and X11889 = K04242 = U Geminorum, mag. 8.2 - 14.9 (usually faint).

Table 1:   XZ-K Mag. Discrepancies Greater than 1.5

XZ No	Mag.	SP	K No	Mag.	SP	ΔMag	AGK3	No.	B.D.	No.	D
7	9.0	K2	2	10.8	K2	1.8	N 4°	1	+ 3°	4923	
11	8.4	K5	3	10.8	K5	2.4	N 7	3	+ 6	5237	P
13	8.4	K5	4	10.8	K5	2.4	N 2	2	+ 1	4821	
15	8.6	K5	6	11.0	K5	2.4	N 6	1	+ 6	5238	
25	8.9	K2	8	10.7	K2	1.8	N 0	1	- 0	4613	
27	9.2	K2	10	11.0	K2	1.8	N 4	4	+ 4	5085	
28	8.7	M2	11	11.1	M2	2.4	N 2	3	+ 1	4823	
47	9.2	K0	15	10.8	K0	1.6	N 3	5	+ 2	4751	
48	9.2	K0	16	10.8	K0	1.6	N 4	5	+ 3	4929	
66	8.7	K0	23	10.3	K0	1.6	N 5	4	+ 5	5261	
92	9.4	K2	31	11.2	K2	1.8	S 0	8	- 1	4530	
96	8.0	M5	32	10.4	M5	2.4	N 1	9	+ 0	2	
114	8.3	K	41	10.7	K	2.4	N 7	12	+ 7	4	
117	8.7	K0	42	10.3	K0	1.6	N 3	11	+ 3	6	
120	9.2	K0	43	10.8	K0	1.6	N 3	12	+ 2	6	
127	8.5	K5	44	10.9	K5	2.4	N 0	10	+ 0	7	
135	8.5	K	46	10.9	K	2.4	N 7	15	+ 7	8	
139	8.3	K5	47	10.7	K5	2.4	N 4	16	+ 3	9	
142	9.0	K0	48	10.6	K0	1.6	N 2	13	+ 1	7	
146	8.0	K5	50	10.4	K5	2.4	N 7	16	+ 6	2	
155	9.1	K0	56	10.7	K0	1.6	N 6	12	+ 6	3	
168	8.6	K5	61	11.0	K5	2.4	N 2	16	+ 1	14	
170	9.5	K0	63	11.1	K0	1.6	N 5	13	+ 5	8	
176	9.7	K0	64	11.3	K0	1.6	S 0	14			
179	8.8	K2	65	10.6	K2	1.8	N 6	14	+ 6	5	
192	8.5	M8	74	10.9	M8	2.4	N 2	18	+ 1	18	
197	8.7	K2	76	10.5	K2	1.8	N 3	19	+ 2	14	
199	8.7	K0	78	10.3	K0	1.6	N 5	15	+ 4	15	
202	8.7	K0	80	10.3	K0	1.6	N 4	23	+ 4	16	
203	9.3	K0	81	10.9	K0	1.6	N 4	24	+ 3	21	
215	9.2	K0	84	10.8	K0	1.6	N 4	25	+ 3	22	
230	9.0	K2	88	10.8	K2	1.8	N 4	26	+ 3	24	
232	9.3	K0	89	10.9	K0	1.6	N 5	20	+ 5	21	
242	9.4	K0	92	11.0	K0	1.6	S 0	21	- 0	23	
245	8.6	K0	93	10.2	K0	1.6	N 7	20	+ 6	12	
252	8.6	K	97	11.0	K	2.4	N 7	21			
253	9.0	K0	99	10.6	K0	1.6	N 7	22	+ 7	20	
257	9.2	K2	101	11.0	K2	1.8	N 2	21	+ 2	23	
269	9.2	K0	106	10.8	K0	1.6	N 4	29	+ 4	26	
281	9.4	K0	109	11.0	K0	1.6	N 6	25	+ 5	29	
316	8.6	K0	121	10.2	K0	1.6	N 0	25	- 0	36	
322	8.9	M	123	11.3	M	2.4	N 5	27	+ 5	32	
328	9.1	K0	126	10.7	K0	1.6	N 7	31	+ 7	33	
339	9.0	K0	130	10.6	K0	1.6	N 4	34	+ 4	31	
341	9.8	K0	131	11.4	K0	1.6	S 0	28	- 0	43	
344	8.8	K5	133	11.2	K5	2.4	S 1	26	- 1	26	
348	9.2	K0	134	10.8	K0	1.6	S 1	27	- 2	37	
357	9.0	K0	138	10.6	K0	1.6	S 0	30	- 1	28	
359	8.6	M2	139	11.0	M2	2.4	N 7	34	+ 6	25	
360	9.2	K2	140	11.0	K2	1.8	N 6	28	+ 6	24	
381	9.2	K0	148	10.8	K0	1.6	N 1	28	+ 1	44	P
404	9.6	K0	159	11.2	K0	1.6	N 1	32	+ 1	48	
409	9.1	K2	161	10.9	K2	1.8	N 4	41	+ 3	36	
413	8.6	K0	163	10.2	K0	1.6	N 8	36	+ 7	42	
421	9.2	M0	166	11.4	M0	2.2	S 1	31	- 2	45	
423	8.6	K0	167	10.2	K0	1.6	S 0	38	- 1	40	
425	9.2	K2	168	11.0	K2	1.8	N 5	36	+ 4	44	
441	9.0	K0	172	10.6	K0	1.6	N 2	36	+ 2	45	
455	9.2	K0	178	10.8	K0	1.6	N 1	39	+ 1	54	
483	8.8	K	190	11.2	K	2.4	N 3	40	+ 3	40	D
493	8.9	M	194	11.3	M	2.4	N 0	34	- 0	61	
504	9.3	K0	200	10.9	K0	1.6	N 3	45	+ 2	50	
519	9.6	K2	205	11.4	K2	1.8	S 0	46			
522	9.0	K0	208	10.6	K0	1.6	N 4	47	+ 4	56	P
2288	8.3	A3	909	11.4	G5	3.1	N13	136	+13	251	
2324	9.9	K0	926	11.6	K	1.7	N14	139	+14	254	
2359	8.5	A5	934	12.1		3.6	N16	158			
2469	9.3	F5	982	11.9	K0	2.6	N16	165	+15	258	
2518	8.7	K2	1003	11.7	G5	3.0	N15	154	+14	280	
2584	7.2	F0	1032	10.6	G5	3.4	N16	174	+15	272	
2690	9.2	G0	1063	12.3		3.1	N14	166	+14	308	P
2693	8.6	G5	1064	12.3		3.7	N13	162			
2752	7.7	F5	1092	11.9	K0	4.2	N16	187	+15	287	
2782	7.9	G0	1105	11.7	G5	3.8	N15	168			
2808	7.9	F5	1111	11.6	G5	3.7	N13	169			
2844	9.8	F5	1128	12.1	K	2.3	N11	195	+10	273	
2862	9.3	G5	1135	11.5		2.2	N12	225	+12	275	F
2932	7.9	F8	1165	10.6		2.7	N15	175	+14	342	P
3194	9.5	G0	1293	12.5		3.0	N16	212			
3300	10.0	K5	1337	11.6	K0	1.6	N14	220	+14	403	
3312	8.9	G5	1341	12.0	K	3.1	N15	210			
3339	9.5	G0	1355	11.6	K2	2.1	N16	222	+16	295	
3493	9.1	K2	1423	11.3		2.2	N11	250	+11	358	F
3513	8.5	A3	1432	12.0	M	3.5	N17	222	+17	406	
3600	8.2	A2	1480	10.5	F	2.3	N16	235	+16	326	
3730	9.7	G5	1533	11.5		1.8	N10	296	+10	372	
3858	8.5	F8	1588	11.8	M5	3.3	N21	266	+21	389	
3901	10.2	K5	1606	12.3	K2	2.1	N22	269	+21	392	
4079	8.1	G0	1677	9.7	G0	1.6	N20	278	+19	458	
4219	7.1	K0	1724	10.4	G	3.3	N22	293	+22	457	F
4246	8.7	F5	1737	11.1	G5	2.4	N11	317	+11	455	
4258	8.2	A0	1741	10.9	F8	2.7	N20	295	+20	531	
4270	7.7	K0	1745	9.9	F5	2.2	N19	249	+18	445	
4302	8.6	K0	1758	10.9	F8	2.3	N18	252	+18	454	
4306	8.1	G5	1759	10.0	K0	1.9	N18	254	+18	455	
4424	6.0	B9	1806	10.8	M2	4.8	N20	310	+19	526	
4479	8.3	G0	1832	10.2	K0	1.9	N19	267	+19	538	
4588	7.6	K0	1875	9.7	F	2.1	N18	274	+17	573	F
4617	8.2	G5	1884	11.1		2.9	N18	276			
4644	9.5	K0	1894	11.7	K	2.2	N22	324	+22	517	
4653	8.8	G0	1897	11.2	K0	2.4	N22	326	+22	520	
4663	8.8	F8	1902	11.2		2.4	N19	282			
4706	9.1	K0	1912	10.9		1.8	N17	322			
4861	8.1	A0	1960	10.8	K0	2.7	N16	321	+15	530	
4896	8.9		1970	11.1		2.2	N23	317	+23	533	
4942	8.1	K0	1983	9.7	G5	1.6	N22	351	+21	529	
5062	8.0	G5	2011	11.3	K0	3.3	N14	342	+14	622	
5075	7.8	K0	2015	10.8	G5	3.0	N16	330			
5077	8.0	K7	2016	9.6	A2	1.6	N21	351	+20	653	
5087	10.0	K0	2021	11.9	K0	1.9	N14	345	+14	626	

XZ No	Mag.	SP	K No	Mag.	SP	ΔMag	AGK3	No.	B.D.	No.	D
5160	9.2	G0	2045	11.2	K0	2.0	N21	363	+21	563	
5251	9.7	A5	2077	11.6	K	1.9	N17	350	+17	670	
5343	10.1	G5	2111	12.0	K	1.9	N16	346	+ 0	0	
5388	6.6	K0	2124	11.3	K0	4.7	N17	363	+17	685	
5404	5.8	F0	2130	11.3	G0	5.5	N15	346	+14	660	
5447	10.2	B5	2157	12.0	G	1.8	N21	393			
5495	7.8	F0	2177	9.9	F2	2.1	N18	320	+18	599	
5516	8.2	K0	2186	11.2	K0	3.0	N18	323	+18	604	
5529	7.8	F8	2194	11.4	F	3.6	N19	326	+19	684	
5556	9.1	A3	2211	10.7	A2	1.6	N22	406			
5578	5.5	A5	2219	11.4	A2	5.9	N21	402	+21	622	
5580	7.4	F5	2220	11.4	K0	4.0	N22	409	+21	621	
5643	-9.4		2242	5.4		14.8	N25	421	+25	707	F
5645	6.9	F5	2244	11.7	K0	4.8	N18	333	+18	630	
5653	10.6	A2	2245	12.5	K0	1.9	N21	409	+21	633	
5739	8.7	G5	2278	12.2	K	3.5	N20	398	+19	720	
5743	8.7	G5	2279	11.9	A0	3.2	N20	400	+19	722	
5757	8.8	G5	2288	11.9	K	3.1	N18	340	+18	638	
5803	10.3	K0	2308	12.1	G5	1.8	N18	343	+17	736	
5896	7.7	F8	2349	12.0	K	4.3	N15	384	+15	652	
5988	9.5	F2	2390	11.9	G0	2.4	N20	427	+20	795	
5993	8.8	A2	2393	11.9	G0	3.1	N20	429	+20	797	
6006	9.2	M0	2400	11.5	K0	2.3	N20	432	+20	801	
6014	9.1	A5	2404	11.9	K	2.8	N22	451			
6038	9.1	K0	2412	11.9	K5	2.8	N21	441	+20	806	
6055	9.9	K0	2423	12.0	M0	2.1	N16	407			
6091	8.5	F5	2443	12.1	K	3.6	N16	409	+16	648	
6102	8.5	B9	2450	10.4	A0	1.9	N19	386	+18	707	
6139	10.9	K0	2468	8.6	K0	-2.3	N26	443	+25	732	
6216	9.0	A2	2496	11.3	R5	2.3	N15	414	+15	691	
6287	7.7	K5	2523	11.1	F2	3.4	N18	395	+17	806	
6342	8.8	F8	2539	11.6	K0	2.8	N18	401	+18	759	
6574	9.0	B5	2641	11.1	A2	2.1	N21	487			
6602	9.4	A0	2653	11.7	A0	2.3	N17	459			
6788	9.0	B9	2723	11.1	F8	2.1	N20	492	+20	914	
7150	9.2	F0	2838	11.8		2.6	N16	488	+16	806	
7325	8.3	F0	2888	11.0	F0	2.7	N21	559			
7956	9.3	K2	3034	11.7	F	2.4	N16	525			
8458	6.0	M9	3178	9.2	B2	3.2	N20	640	+20	1287	
9047	9.1	K2	3348	11.8	M0	2.7	N20	678	+20	1416	
9048	9.1	K2	3349	11.1	K7	2.0	N20	679	+20	1417	
9388	7.7	G0	3471	12.0		4.3	N18	622			
10157	9.5	G0	3736	12.1	K	2.6	N23	755	+23	1556	P
10161	9.5	G0	3738	11.1	K7	1.6	N23	756	+23	1556	
10311	9.2	A5	3778	11.0	K0	1.8	N22	811			
10786	9.8	G0	3921	12.7	K	2.9	N22	852			
10819	8.5	K0	3934	11.3	K0	2.8	N16	753	+16	1439	
11265	9.2	A0	4060	11.7		2.5	N19	739	+19	1751	
11435	9.5	K0	4116	11.8	K2	2.3	N21	843	+22	1735	
11557	8.9	A0	4147	10.8	F2	1.9	N21	856			
11610	9.5	B8	4165	12.3	K	2.8	N23	868			
11760	10.5	K0	4199	12.5	G	2.0	N23	882	+24	1784	F
11889	10.8	F8	4242	8.2	F8	-2.6	N22	942	+22	1807	D
11990	9.6	K5	4275	11.4	F0	1.8	N20	917	+20	1963	P
12063	8.4	F8	4298	11.4		3.0	N14	853	+15	1729	
12276	9.4	K5	4374	12.3		2.9	N21	902	+21	1764	F
12371	6.3	A0	4417	9.2	G5	2.9	N14	885	+14	1844	
12406	8.4	K2	4432	11.8		3.4	N13	816	+13	1862	
12510	10.2	A0	4472	12.7	K	2.5	N22	983			
14000	9.3	F8	4970	11.0	F2	1.7	N20	1078	+21	1994	P
14089	8.4	G5	5016	11.0	G0	2.6	N21	1026	+21	2008	
14166	8.7	K5	5044	11.0		2.3	N20	1089	+20	2303	P
14594	9.0	A2	5225	11.1	K	2.1	N15	1088	+15	2092	
14663	8.1	F5	5251	11.0		2.9	N13	976			
14772	9.1	F0	5306	10.9	G5	1.8	N14	1049			
15559	8.8	K5	5661	11.4	K2	2.6	N10	1317	+11	2214	
16162	9.0	K0	5932	11.1	K	2.1	N11	1254	+11	2279	
17006	9.8	F0	6314	11.7	K	1.9	N11	1311	+12	2323	

185 non-SAO stars in the XZ catalog had no counterparts in the K-catalog. The position of one of these stars, X03454 = AGK3 N19° 218 = B.D. +18° 372, is in error by several degrees due to a foulup in the AGK3 proper motions. The correct position of the star, taken from the AGK2 catalog, is used in the K-catalog, where it is number K01586. A few of the extra X stars, listed in Table 2, are duplicates, usually caused by the failure of B.D. number matching when the AGK3 and SAO data were merged to form XZ (in these cases, the B.D. number usually was omitted from the SAO). There were a few matching problems involving close double stars. Some stars for which no reason for omission from the K-catalog was evident are listed in Table 3. All of the other non-K XZ stars are south of the equator and have an ecliptic latitude less than the southern occultable limit of -6° 40', obviously the result of a computer program error when the zodiacal subset of the AGK3 was formed for the XZ. Since these stars are never occulted, their presence in XZ does no harm.

90 stars in the XZ have SAO numbers ranging from 1 to 12. These small "SAO" numbers are actually error codes from the AGK3 catalog, which is the source for these stars. The codes indicate discrepancies in the following quantities: 1, DM number; 2, magnitude and/or spectral type; 4, right ascension; and 8, declination. These codes are summed to indicate two types of error: 3 is 1 and 2, 12 is 4 and 8, etc. Several of these stars are the secondaries of double stars with code 1 and/or 2 discrepancies which often have been corrected in the latest version of the AGK3. The brightest occultable star in this group is X07879, mag. 7.9 according to the AGK3, but as noted in Table 2, it equals X07880 = SAO 077730 = the Mira variable U Orionis, mag. range 5.2 to 12.9. The other occultable stars in the group are 9th, 10th, and 11th magnitude.

The declination of X15763 and K5759 = AGK3 N14° 1125 differ by 30' (the right ascensions differ by $0^{s}7$), although +15° 2214 is given as the B.D. number of both stars. The declination of 10.7-mag. M2 spectral type X16894 is -3° 26' $13''51$, south of the occultable zodiac and south of the AGK3 southern limit of about -2° 50' declination. The star's right ascension is $11^{h}\ 11^{m}\ 37^{s}891$; no B.D. number is given.

Table 2. Duplicates in the XZ Catalog

Duplicated XZ Stars	S.A.O.	B. D.
X 02262 = X 02263	110017	+06° 0248
X 02786 = X 02787	110269	+05° 0275
X 06143 = X 06144	076752	+20 0821
X 07879 = X 07880	077730	+20 1171a
X 08390 = X 08391	078021	+22 1186
X 09017 = X 09018	078353	+21 1231
X 09452 = X 09453	078565	+23 1432
X 15197 = X 15198	098943	+11 2163
X 17419 = X 17420	118945	(none)
X 32172 = X 32173	128522	-00 5077

Table 3. Apparently Valid non-SAO Stars Missing From the K-Catalog

XZ Number	Magnitude	Spectrum	B. D.
X 14709	10.5	K2	+09° 2231
X 14720	10.7	K	(none)
X 14823	10.4	G5	+09 2243
X 15416	11.2	G5	(none)