Occultation Newsletter

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FROM THE PUBLISHER

This is the third issue of 1986. It is the first issue of *Volume 4*.

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for U.S.A., Canada, and Mexico[2]	7.28	7.00
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by air (AO) mail[3]		
for area "A"[4]	8.91	8.56
for area "B"[5]	10.32	9.92
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(There are 16 issues per volume, all still available)		

Although they are available to IOTA members without charge, non-members must pay for the following items:

Local circumstance (asteroidal appulse) predictions (entire current list for your area)	1.04	1.00
Graze limit and profile prediction (each graze)	1.56	1.50
Papers explaining the use of the predictions	2.60	2.50

Supplements for South America will be available at extra cost through Ignacio Ferrin (Apartado 700; Merida 5101-A; Venezuela), for Europe through Roland Boninsegna (Rue de Mariembourg, 33; B-6381 DOURBES; Belgium), for southern Africa, through M. D. Overbeek (Box 212; Edenvale 1610; Republic of South Africa), for Australia and New Zealand, through Graham Blow (P. O. Box 2241; Wellington, New Zealand), for Japan, through Toshio Hirose (1-13 Shimomaruko 1-chome; Ota-ku, Tokyo 146, Japan). Supplements for all other areas will be available from Jim Stamm (Route 13, Box 109; London, KY 40741; U.S.A.) by surface

mail at the low price of	1.23	1.18
or by air (AO) mail at	2.04	1.96

Observers from Europe and the British Isles should join IOTA/ES, sending DM 50.-- to Hans-J. Bode, Bartold-Knaust Str. 8, 3000 Hannover 91, German Federal Republic. Full membership in IOTA/ES includes the supplement for European observers.

[1] Single issue available at ¼ of price shown.
[2] Price includes any supplements for North American observers.
[3] Not available for U.S.A., Canada, or Mexico.
[4] Area "A" includes Central America, St. Pierre and Miquelon, Caribbean islands, Bahamas, Bermuda, Colombia, and Venezuela. If desired, area "A" observers may order the supplement for North American observers by surface mail @ 1.23 1.18
or by air (AO) mail @ 1.56 1.50
[5] Area "B" includes the rest of South America, Mediterranean Africa, and Europe (except Estonia, Latvia, Lithuania, and U.S.S.R.).

IOTA NEWS

David W. Dunham

As *O.N. 3* (16) was being assembled, it became clear that it would be much larger than most recent issues. This, coupled with the fact that we are about three months behind our overall publication schedule, made DaBoll and me decide that this would be a good time to split the issue in two. We expect the next issues to be smaller. The disadvantage of doing this now is that we also have to split volumes. This is the first issue of Volume 4, starting the thirteenth year of *O.N.* publication.

Those whose subscriptions expire with *O.N. 3* (16) are being sent this issue anyway, to prevent the need to send it when subscription is renewed. Subscribers and IOTA members are reminded that all payments and questions about subscription and renewal should be sent to the address in the masthead. Anything sent to the old address in Columbus, OH, can result in long delays, including lapse of service.

Normally, in the first issue of a volume, we publish explanations of the tables of grazing occultation observations, and of the planetary/asteroidal prediction tables, maps, and finder charts. However, Don Stockbauer published an explanation of the graze observation table only three issues ago, in *O.N. 3* (13), 273, so we will probably wait until the first issue of 1987 before repeating it.

The explanation of planetary/asteroidal occultation predictions is given in a separate article, although the only new events published here are the few by (46) Hestia, for which the stellar data are incomplete. Edwin Goffin's comprehensive predictions and charts have changed coverage for these events, as discussed in *O.N. 3* (14), p. 301 and 303. In this issue, we include complete finder charts only for those events for which Goffin did not send us information. Detailed one-degree Astrographic Catalog (A.C.) charts only are published for several of Goffin's events in this issue. The corresponding AGK3-based and fifteen-degree field finder charts by Goffin (the latter annotated by others) have been published in *O.N. 3* (14) Supplement for North American Observers. An addition to this supplement was distributed with *O.N. 3* (15) in April.

(3123) Dunham (see *O.N. 3* (16), 351) is 17th magnitude at mean opposition distance, near the center of the main asteroid belt. The estimated diameter is

13 km. The orbital inclination is only 2° to the ecliptic, and the perihelion distance is 2.13 A.U. It is now near conjunction with the Sun and will have a favorable opposition early in 1987.

Since the May 10th IOTA meeting (see p. 339 of the last issue), Derald Nye has succeeded in developing the software for his IBM PC so that he now can take over the work that Berton Stevens has been doing in keeping IOTA's computerized records. We sincerely thank Bert for the important work he has performed for IOTA for such an extended period.

OCCULTATIONS OF ASTROGRAPHIC CATALOG STARS BY (46) HESTIA

David W. Dunham

The asteroid (46) Hestia has become of special interest recently, since it has been found to be the best asteroidal target for the CRAF (Comet Rendezvous and Asteroid Flyby) spacecraft mission proposed by the Jet Propulsion Laboratory (JPL). Remarkably, the same asteroid is also the best asteroidal target, and easiest to reach, for a multi-comet flyby mission proposed by R. Farquhar of Goddard Space Flight Center, even though the spacecraft trajectory and Hestia encounter time and speed are completely different from those envisioned by CRAF. Although the planned Hestia flyby dates are a decade away, now is a good time to start more detailed studies of this object, since we are approaching a favorable northern-declination opposition in November. Consequently, Hestia will be well-placed for observation during the next twelve months. Hestia is an F-class asteroid with an expected diameter of 133 km.

I recently compared Herget's orbit for Hestia with Astrographic Catalog data to find occultations by Hestia during the next several years. This search revealed six occultations from June 14 to July 6 that might be observed. I distributed a special notice about these events to IOTA coordinators in the possible areas, which included southern South America, Mexico, and southeastern Australia.

On June 14th, nine days after I distributed the notice, I received *Minor Planet Circular* 10,752, dated May 23rd, that contained an updated orbit for Hestia determined by Don Yeomans, JPL, using 149 observations made during 33 oppositions from 1912 to 1985. Fortunately, the new orbit passed only 0".6 north of Herget's orbit, and just under a minute ahead of it, during June 14 – July 6.

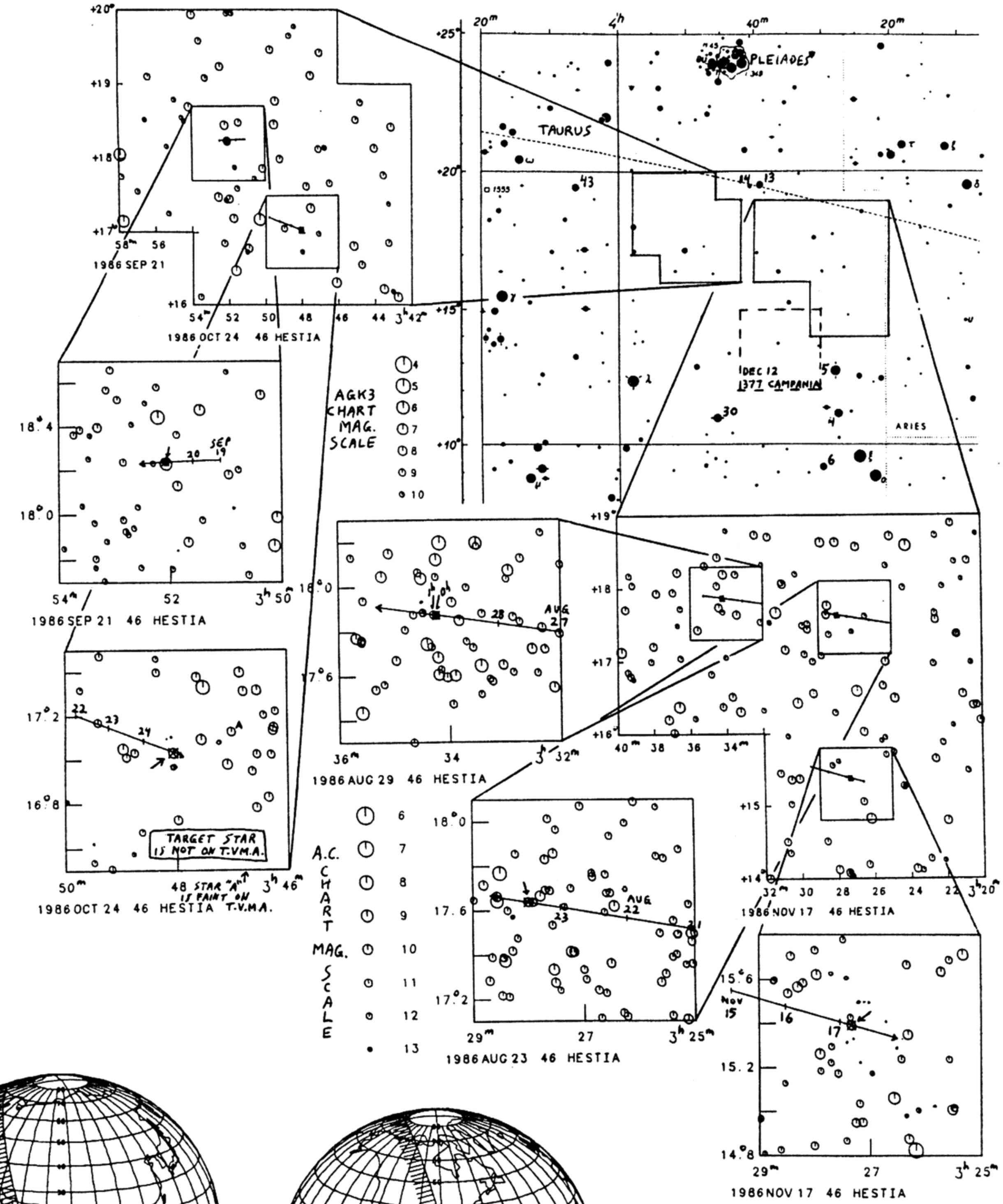
A table given in the usual *o.N.* format is included here, with several columns of constant or unavailable information deleted. For example, since spectral types are not available for these A.C. stars, their angular diameters, and associated parameters, can not be computed. Yeomans' new elements were used to compute the data in the table. Mitsuru Sôma used Herget's data to prepare his maps; I have drawn a solid line on each of them to indicate the path calculated with Yeomans' elements. The "possible area" for the listed events is quite uncertain due to possibly larger-than-usual errors in the stellar positions. Although the star positions could be improved from existing plates, the relatively small elongation from the sun will hinder astrometry for Hestia before mid-July. The finder charts for the events published here have been compared with Papadopoulos' True Visual Magnitude Atlas (T.V.M.A.).

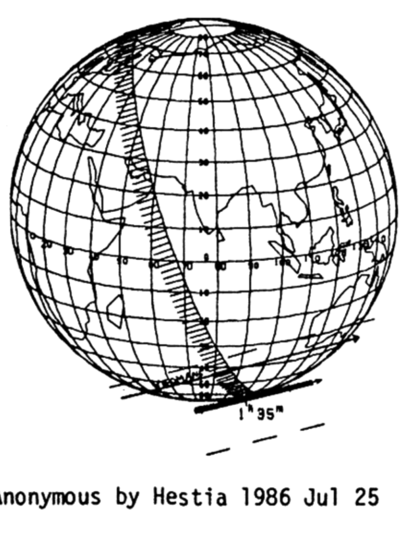
Mitsuru Sôma used ephemeris data supplied by me that were computed using Herget's orbital elements for Hestia. The time differences, in the sense Yeomans – Herget, that should be applied to the times shown on Sôma's world maps are given in the table below:

1986 Date	Time difference
July 25	$-1^m.0$
Aug. 23	-1.8
Aug. 29	-2.0
Sept. 21	-6.4
Oct. 24	+4.0
Nov. 17	+3.3

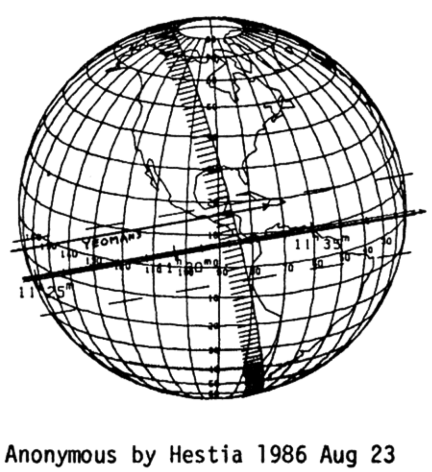
Two of the occultations by (46) Hestia that I computed, the ones on June 17 and 19 (predictions of which were distributed in the special notice of June and early July events), were also found by E. Goffin and were published in pages T22 and T23 of the *o.N. 3* (14) Supplement for North American Observers. Goffin's paths are substantially north of mine; he used Herget's formal elements published in M.P.C. 4363, and AGK3 data for the stars, which are certainly better than the A.C. star positions that I used. His June 17th path crossed the northernmost part of Baja California, while the one on the 19th passed near Acapulco, Mexico. The star occulted on June 17th was AGK3 N10°186 = X02406 = BD +09°208, mag. 9.2, spectral type G0, while the star on June 19th was AGK3 N10°240 = SAO 92625 = X02491, mag. 8.7, spectral type A0. None of the A.C. stars that I predict will be occulted later this year are in the AGK3 catalog.

1986 DATE	UNIVERSAL TIME h m	PLANET mv	PLANET Δ AU	STAR mv	STAR R.A.(1950) h m	STAR DEC. ° '	OCCULTATION Δm	DUR s	DF	P	POSSIBLE AREA	EL SUN °	MOON EL °	MOON %SNL	MOON UP	(46) HESTIA DIAM.	RSOI	MOTION "/DAY	PA °	APPARENT R.A. h m	APPARENT DEC. ° '
JUL 25	1 31	13.0	2.08	11.6	2 46.3	15 24'	1.7	5	11	23	southern Africa?2"n	78	55	83-	all	0".09	416	0.401	75	2 48.3	15 34'
AUG 23	11 27–33	12.7	1.78	10.7	3 28.0	17 38	2.1	9	17	19	Hawaii?2"n; s. Mexico	95	38	85-	all	0.10	421	0.286	80	3 30.1	17 46
AUG 29	0 43–50	12.6	1.73	11.2	3 34.2	17 53	1.7	10	19	19	n.Africa, Mideast, Baku	99	28	34-	e 5°W	0.11	422	0.257	82	3 36.3	18 0
AUG 29	1 43–51	12.6	1.73	10.9	3 34.3	17 53	1.9	10	19	19	central Africa	99	29	34-	e 5 W	0.11	422	0.256	82	3 36.4	18 0
SEP 21	0 33–61	12.2	1.51	11.6	3 52.1	18 14	1.1	27	50	16	central Africa	117	29	92-	all	0.12	427	0.107	93	3 54.2	18 21
OCT 24	19 15–30	11.4	1.28	10.1	3 48.0	17 2	1.6	20	34	14	n.Europe,n.USSR?3"s	152	50	61-	e60 E	0.14	436	0.171	249	3 50.2	17 9
NOV 17	4 59–80	10.9	1.26	10.5	3 27.3	15 24	1.0	14	24	14	Guinea,n.S.Amer.,Tahiti	177	11	99-	all	0.15	443	0.246	253	3 29.4	15 31



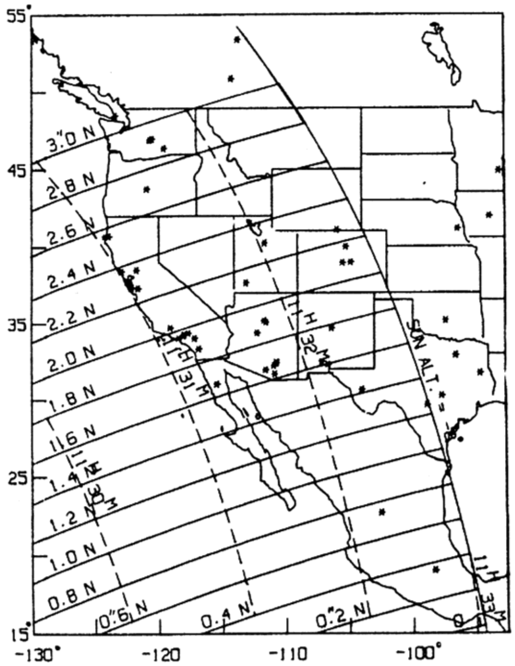


Anonymous by Hestia 1986 Jul 25



Anonymous by Hestia 1986 Aug 23

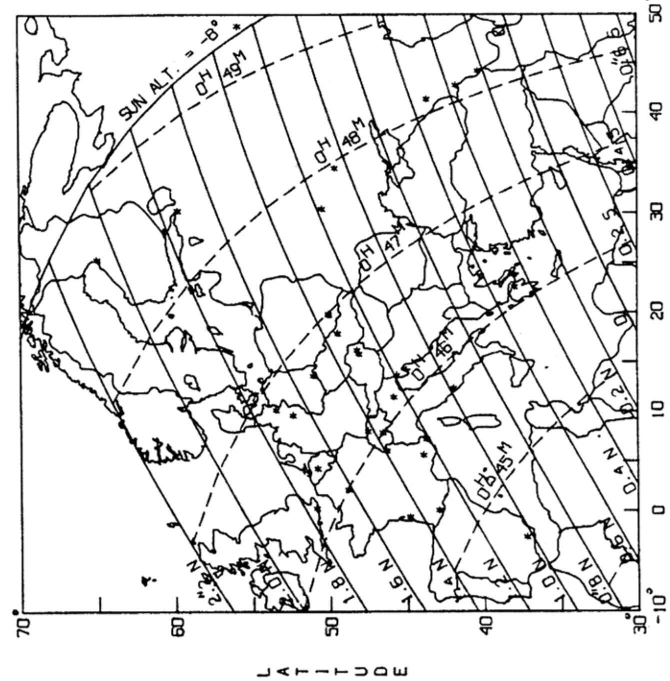
1986 8 23 (46) HESTIA
DIAMETER 133 KM = 0.″10



LONGITUDE

EPHEMERIS SOURCE = YEOMANS

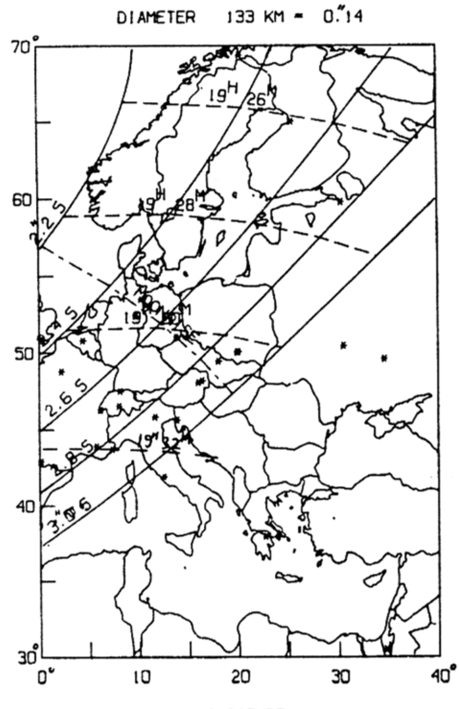
1986 8 29 (46) HESTIA
DIAMETER 133 KM = 0.″11



LONGITUDE

EPHEMERIS SOURCE = YEOMANS

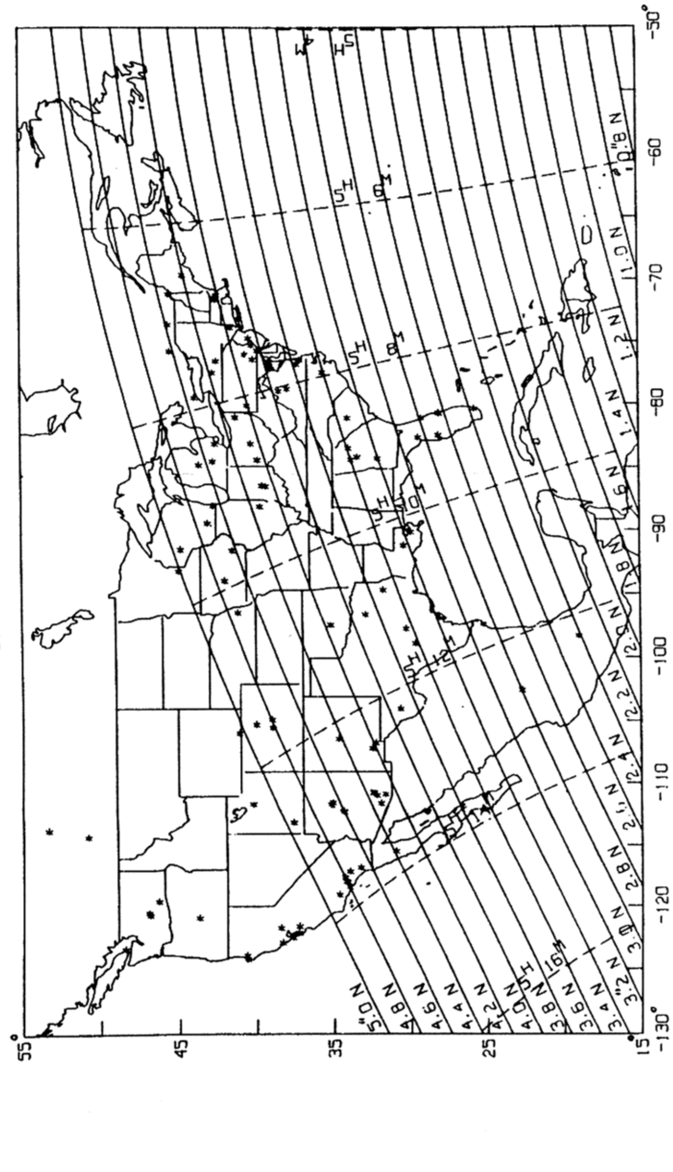
1986 10 24 (46) HESTIA
DIAMETER 133 KM = 0.″14



LONGITUDE

EPHEMERIS SOURCE = YEOMANS

1986 11 17 (46) HESTIA
DIAMETER 133 KM = 0.″15

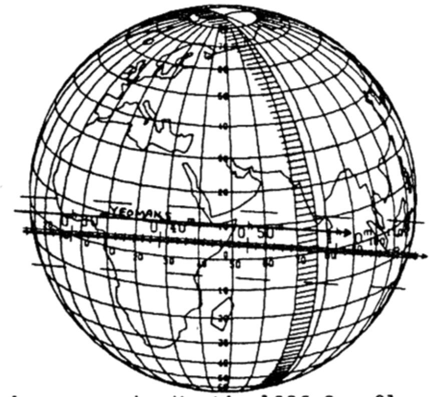


LONGITUDE

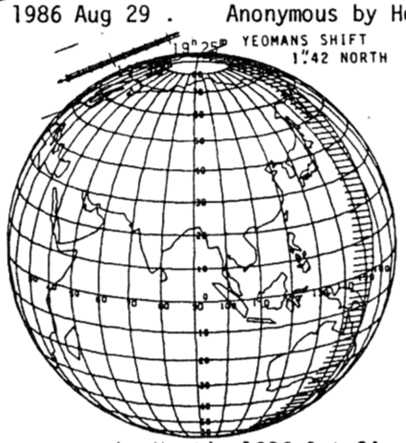
EPHEMERIS SOURCE = YEOMANS

Anonymous by Hestia 1986 Aug 29 .

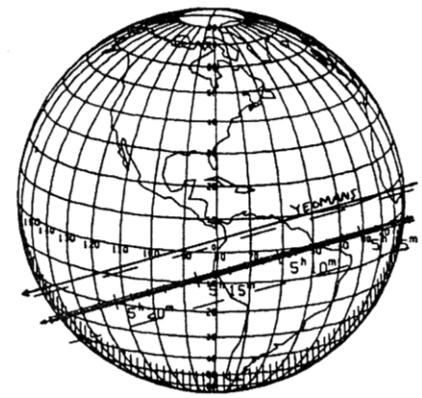
Anonymous by Hestia 1986 Aug 29



Anonymous by Hestia 1986 Sep 21



Anonymous by Hestia 1986 Oct 24



Anonymous by Hestia 1986 Nov 17

FROM THE EDITOR

With the advent of Volume 4, and at the request of David Dunham, we initiate a minor change of style; henceforth, we plan to capitalize *Sun*, *Moon*, and *Earth*, in contrast with our dictionary's admonition, "A capital is used as the initial letter of . . . (17) Names of planets, constellations, asteroids, stars, and groups of stars, but not *sun*, *earth*, and *moon* unless these are listed with other astronomical names."

There will be one other change: from now on, we plan to number the first page of each issue, as well as the succeeding pages.

PLANS FOR ASTEROIDAL OCCULTATION UPDATES

David W. Dunham

Mitsuru Sôma recently joined the staff of the Tokyo Astronomical Observatory, where he is working with the photoelectric meridian circle. This instrument seems to have capabilities similar to the one in Bordeaux, France, being able to detect objects down to about 12th magnitude when they cross the meridian (so that their elongation from the Sun must be greater than 90°). He asked me for a list of events which they might be able to observe, which I sent by scanning the asteroid magnitudes and elongations in the list of 1986 events starting on *O.N. 3* (14), page 302.

Also, Robert Millis recently wrote to me, saying that they have improved the guiding for their 18-inch astrograph, and hoped to provide astrometric updates for several events during the rest of the year. He listed the events, and asked whether there were any other good events that might be included. I suggested that he might add the events on July 18, Sept. 29, and Nov. 28. He also said that he was trying to reorganize the I.A.U. Commission 20 Working Group on Occultations, and asked if I would maintain a liaison between the working group and IOTA. I agreed to this.

In the list of events below, those that might be observable with a photoelectric meridian circle (asteroid brighter than 12th mag., elongation greater than 90°) are indicated with an "x" under the "PMC" column, while those listed by Millis that will be attempted with the 18-inch astrograph are noted under the "Lowell" column.

1986 Date	Minor Planet	PMC	Lowell
July 18	(679) Pax	x	
July 31	(52) Europa	x	x
Aug. 5	(19) Fortuna	x	
Aug. 6	(41) Daphne	x	x
Sep. 29	(148) Gallia	x	
Oct. 1	(598) Octavia	x	
Oct. 4	(38) Leda	x	x
Oct. 27	(93) Minerva	x	x
Nov. 4	(94) Aurora		x
Nov. 13	(9) Metis	x	x
Nov. 16	(27) Euterpe	x	x
Nov. 28	(104) Klymene	x	
Dec. 4	(11) Parthenope	x	
Dec. 17	(145) Adeona		x
Dec. 28	(87) Sylvia	x	x

PLANETARY/ASTEROIDAL OCCULTATION PREDICTIONS

David W. Dunham and Jim Stamm

[Ed: This article is a review of the standard information needed for interpreting the tables, for observing the events, and for reporting the results, connected with planetary/asteroidal occultations. It consists of extracts from articles by Dunham and Stamm, which appeared in *o.N. 3*, with some minor editorial changes, plus previously unpublished figures for predicted occultations during 1986, including world maps by Mitsuru Sôma, and regional maps and finder charts by David Dunham.

Predictions of occultations of stars by major and minor planets are given in two tables [tables probably will appear in *o.N. 4* (2)].

Reports of observations of these events should be sent to Jim Stamm; Rt 13 Box 109; London, KY 40741; U.S.A.; phone 606,864-7763. Report positive or negative observations made under good conditions, but clouded-out attempts need not be reported. If a definite occultation is seen which could use some analysis for comparison with others, also send copies to David Dunham; P.O. Box 7488; Silver Spring, MD 20907; U.S.A., and to the chairman of the International Astronomical Union's (I.A.U.) Commission 20 Working Group on Predictions of Occultations by Satellites and Minor Planets, who is Robert Millis; Lowell Observatory; P.O. Box 1269; Flagstaff, AZ 86002; U.S.A. Alternatively, observers may send their reports to their local or regional coordinators, who can then send the results to Stamm. Europeans can send their reports to R. Boninsegna; Rue de Mariembourg, 33; 6381 Dourbes; Belgium. Please indicate on the form to whom copies are being sent. Preferably, the report forms of the International Lunar Occultation Centre (ILOC), or the equivalent IOTA/ILOC graze report forms, should be used for reporting timed occultations or appulses. The only difference from reporting lunar events is that the name of the occulting body should be written prominently at the top of the form, and the report should not be sent to the ILOC in Japan. Copies of the report form can be obtained from ILOC, from IOTA (address in masthead), from Stamm, From Dunham, or from Don Stockbauer; 2846 Mayflower Landing; Webster, TX 77598; U.S.A.

Sources of Planetary Occultations: [The sources for these predictions vary from time to time, so this subject will be covered in individual future articles, but codes for ephemeris sources are listed in the next section.]

Explanation of Data in the First Table: The ranges of Universal Time are the time of central occultation (apparent closest approach to the center of the object) and are given in increasing order. If the occultation shadow will sweep across land areas during nighttime within four minutes, only one (middle) time is given. Under PLANET, m_V is the visual magnitude (usually, photoelectric V-mag.), and Δ is the geocentric distance in astronomical units. Under STAR, m_V is the visual magnitude (converted to a photoelectric V-mag. scale using data from the SKY-MAP Catalog described in *o.N. 1* (16), 161) and Sp is the spectral type; the approximate equinox 1950 position also is given. Under OCCULTATION, Δm is the change in visual magnitude of the coalesced images which is expected if an occultation does occur, Dur is the duration for a central occultation computed using the expected diameter of the occulting object, df is a measure of the diffraction effects for a central occultation (it is the time in milliseconds between fringes for an airless planet; depending on the brightness of the star, a visual observer can notice a gradual fade or brightening of the star for 2 or 3 times df, which also can be magnified greatly by a nearly grazing geometry), and P is the inverse of the probability that an occultation will occur at a given place in the possible area, assuming a combined stellar-ephemeris positional error of 1".0 (that is, P is essentially the ratio of the width of the possible area of visibility to the expected width of the occultation path). The combined positional error can be reduced considerably with astrometric observations, and the width of the possible area narrowed to reduce P substantially, which can be accomplished best when the planet and star can be photographed on the same plate, perhaps only 2 or 3 days before the event. Under Possible Area, the regions from which the events may occur with the Sun below the horizon (unless the star is bright enough to possibly see in daylight) are listed in the chronological order in which the occultation shadow will sweep over them. A "?" indicates that an occultation will occur in the area just mentioned only if the actual path shifts n(orth) or s(outh) (the direction indicated by the letter following the "?") of the nominally predicted path, usually by at least a few tenths of an arc second in the sky. The elongation of the Sun from the planet is given under El Sun. Under MOON, the elongation from the planet is given under El, the percent sunlit ("+" for waxing and "-" for waning phases) is given under % Snl, and the approximate longitudes from which the Moon will be above the horizon in the possible area are specified under Up. For the latter, the moonrise or moonset terminator is specified in degrees of longitude E(ast) or W(est) of Greenwich, preceded by a letter w(est) or e(ast) to specify the direction in which the Moon will be above the horizon. "All" or "none" is used to specify whether the Moon is up, or not, respectively, in the entire possible area if it is not crossed by the moonrise or moonset terminator. The source for the occulting body's ephemeris is given in the last column. For most asteroids, Dunham has generated the ephemeris by numerically integrating the orbital elements given in the specified source. For the major planets, NA0001 is a U. S. Naval Observatory data set; empirical corrections have been added in the case of Neptune to make it agree with the better Jet Propulsion Laboratory's DE96 ephemeris. The orbital elements by the late Paul Herget, Cincinnati Observatory, all have been published in the *Minor Planet Circulars* (M.P.C.s), numbers 4360-4390 (1978 June), 4736-4739 (1979 June), 4824-4825 (1979 August), and 6190-6191 (1981 August). EMP stands for the Lenigrad *Ephemerides of Minor Planets*, while ITA-B stands for their *Institute of Theoretical Astronomy Bulletin*, followed by its number. APAENAXX refers to *Astronomical Papers Prepared for use of the American Ephemeris and Nautical Almanac* 20. Some orbital elements were supplied by R. Branham, U. S. Naval Observatory, before he published them in the *Astron. J.* Orbital elements by Schmadel (Astronomisches Rechen-Institut, Heidelberg, German Federal Republic) and Sitarsky (Poland) have been published in recent M.P.C.s. Kristensen (University of Arhus, Denmark) has supplied some ephemerides. *U. S. Naval Observatory*

Circular No. 162 has been used as the ephemeris source for Pluto. W. Landgraf, Max-Planck-Institut für Aeronomie, Lindau, German Federal Republic is another provider of ephemerides. International Halley Watch (IHW) ephemerides for comets Giacobini-Zinner and Halley have been provided by Don Yeomans, Jet Propulsion Laboratory.

One of the most important columns in the table is Δm, since it specifies the observability of the event. A value much less than 1.0 in general means that the event can be reliably observed only photoelectrically; during the occultation by (3) Juno in 1979 Dec. 11, a Δm of 0.4 was timed visually, but photoelectric data showed that the reaction times were 1 second or more. For any occultations by Uranus or Neptune, the Δm is for the photoelectric infrared I-magnitude, to take advantage of the planet's methane absorption bands in the infrared; the Δm is much smaller, usually unobservable, at visual wavelengths. For occultations by these planets, only an occultation by possible rings, and not by the planet itself, is possible if the name is followed by "-R."

Explanation of Data in the Second Table: The date, occulting object's name, and the star's SAO number are repeated for identification. The minor planet's number, the expected diameter in km, and the apparent angular diameter in arc seconds, are given. Under RSOI, "Radius of Sphere of Influence," the distance in km from the object is given where the gravitational attraction of the object is equal to that of the Sun, assuming (pessimistically) that the mean density of the asteroid is twice that of the Sun. Satellites are possible for much greater distances, since tidal or differential forces determine satellite capture; according to the theory of three-body motion, these forces are proportional to the cube of the ratio of the distances, not the square. Very few secondary occultations actually have been seen at distances greater than RSOI. The cube ratio usually gives a distance about 100 times the asteroid's diameter, which is usually larger than the Earth's diameter. After RSOI, the taxonomic TYPE is given for asteroids, as specified in the Tucson Revised Index of Asteroid Data (TRIAD) as published in pages 783-806 of the book *Asteroids* (see *O.N. 2* (9), 104) and recently updated by Tedesco. The types are determined mainly from observations of albedo (reflectance) and spectral characteristics (color), and are named from meteorites with similar properties. Hence, specific mineralogies are implied, which may not be completely correct. However, most asteroids of a given type probably do have similar compositions. The nine types are described below:

C low albedo, carbonaceous
S moderate albedo, silicate
D low albedo, dark
F low albedo, flat spectrum
M moderate albedo, metallic
P pseudo-M, low albedo, spectra like M
E high albedo, enstatite achondrites
R moderate to high albedo, red (iron silicates)
U unclassifiable in the other categories above

Composite types, such as "CMEU," only mean that the observations exclude the other types, but in such cases, "M" really means "M or P," and some asteroids currently classified M may be P. The first value under MOTION is the geocentric angular velocity of the occulting object in degrees/day. Multiply the listed numbers by 2.5 to obtain the angular rate in seconds of arc per minute, which is useful for estimating when the asteroid's and the star's images will merge, and how long it will be before they can be separated again. Normally, a separation of two or more seconds of arc will be needed to resolve the objects clearly. The position angle of the occulting object's motion is given under PA.

The star's B.D. or C.D. number is given under the DM NO. column. For declination zones north of -22°, the number is a B.D. number, while to the south, it is C.D. The -22° zone can be either, although the B.D. number is then usually used. C.D. numbers in the -22° zone are about twice as large as the corresponding B.D. numbers for the same stars, or for stars with similar right ascensions. The star's double star code is given under D. If separate predictions are given for the two components, "A" and "B" are used, "A" indicating the brighter component. Otherwise, the code is the same as that used for lunar occultation predictions as described in "Notice to Observers" dated 30 September 1976 distributed by the U. S. Naval Observatory. [The important thing is to note that exceedingly accurate information about double stars can be gleaned from timings of asteroidal occultations — more than an order of magnitude better than from lunar grazing occultations, due to the slower apparent motion of the occulting body with respect to the star, especially with the widely ranging position angles of occultation that will be seen by observers separated by even a few kilometers.]

The source used for the star's position and proper motion is given under S, according to the following codes: A, AGK3; F, FK4; G, Albany General Catalog (G.C., via SAO; positional data old and usually very poor; G.C. data are used in the SAO for most stars of 6th and 7th mag.); H, positions of faint stars derived by A. Klemola from astrographic plates taken at Lick Observatory, Mt. Hamilton, CA; L, positions determined from plates taken at Lowell Observatory; P, Perth 70; R, positions determined from plates taken at the Royal Greenwich Observatory; S, SAO; X, USNO XZ-catalog for stars within 6° 40' of the ecliptic, the limit for Earth-based lunar occultations (with some exceptions; see *O.N. 2* (6), 60; stars with code X south of declination -3° use SAO data, but are indicated here for possible double star codes derived from lunar occultations or spectroscopy); Y, Yale (for stars south of decl. -3°, Yale data are better than Z.C. or G.C.; Wayne Warren, Greenbelt, MD, provided these data); and Z, Zodiacal Catalog (Z.C.; but positional data improved with other catalog data for stars north of declination -4°; the Z.C. is a subset of the brighter stars of the XZ, but with some positional information independent of the SAO for the southern stars; C, Carte du Ciel (Astrographic Catalog); K, USNO K-catalog (Yale stars with no proper motions available); N, N30; and 3, FK3 or AGK3R. If there are two letters under S, the second one is the position and proper motion source for the comparison shift data following the AGK3 number. AGK3 positions are often better than SAO positions, but are generally inferior to XZ and Perth positions. The path shift, in the (occultation path) sense, second catalog minus first catalog, is given under Shift, which is expressed in seconds of arc, to the north if positive and to the south if negative. For instance, -1.00 would mean that the path would be at the southern edge of the possible area described in the first table, according to the second star catalog. The value in minutes to be added to the U.T. is given under Time. The last two columns give the star's apparent R.A. and Dec. computed for the time of geocentric conjunction, for direct use with setting circles.

Ephemerides: [Dunham often computes the paths of asteroidal occultations using ephemerides from two different sources. When a significant difference is found from the nominal prediction given in the first table, the information is shown in a third table.] The value in the Shift column gives the path differences in arc seconds measured perpendicular to the asteroid's geocentric motion; the letter following it tells which direction the occultation path will be displaced on the Earth's surface from the nominal prediction given in the first table. The value in the Δt column tells whether the geocentric time of closest approach will be early (negative) or late (positive) in minutes relative to the nominal prediction. The EPHEMeris SOURCE is given in the last column; the shifts are in the same sense of the source specified in this column minus the nominal source listed in the first table. Many of the differences are quite small so that comparison with even relatively recent observations in the M.P.C.s yield only insignificant differences in the residuals. In these cases, Dunham's predictions usually agree well with those by Wasserman *et al.*, except sometimes when different stellar data are used; they usually use AGK3 data, whereas Dunham uses data from other catalogs, when available.

Maps and Finder Charts: A map showing Dunham's predicted paths of asteroidal occultations during the year in the U.S.A., southern Canada, and northern Mexico is routinely published in the January issue of *Sky and Telescope*. Dunham's finder charts are published in *O.N.* for individual events potentially visible from North America and Europe. Others usually are distributed to observers or to regional coordinators who further distribute the charts. [The charts may or may not contain a small-scale section taken from a published star atlas, depending on whether or not there are familiar stars or star groupings in an accompanying computer-produced 3°-square enlarged chart; the 3°-square chart may constitute the only chart, or there may be a further enlargement to a 1°-square chart; or the 1°-square chart may stand alone.] On at least the largest-scale chart, the path of the path of the asteroid is shown, with 0^h U.T. tick marks for four dates starting with the date two days before the date of the event. Hence, there will be three tick marks on the side of the occulted star before the event, and one mark after. Close double stars are underlined. For stars fainter than 8th magnitude, Dunham has compared the detailed charts with Papadopoulos' *True Visual Magnitude Atlas* to add some 11th and even 12th mag. stars in the vicinity of the star to be occulted. This comparison also serves as a final check of the chart against a very close equivalent of the visual appearance of the actual sky.

World Maps: Mitsuru Sôma, Tokyo, Japan, produces the world maps published in *O.N.* by computer, using stellar and ephemeris input data supplied by Dunham in machine-readable form. For asteroids and satellites, the three closely spaced parallel lines show the predicted central occultation line, and the northern and southern limits, with U.T. marked at one-minute intervals and labeled at five-minute or ten-minute intervals along the central path. For major planets, the limits are not near the central line, and usually only one limit will be shown. Sometimes, no limit will be shown, but only a parallel line, or lines, labeled with the distance in arc seconds from the center of the planet. This is often the case for Uranus and Neptune, when only occultations by possible rings are predicted. The two parallel dashed lines show the central occultation path in case the minor planet passes $1\overset{''}{.}0$ north or south (measured perpendicularly to its path in the sky) of its predicted path with respect to the star. Combined ephemeris and star position errors can cause path shifts this large or larger. Other parallel lines are sometimes drawn and labeled by hand to indicate alternative predictions based on ephemerides or star positions other than the ones Dunham used. The sunrise and/or sunset terminator is shown, with hatches indicating the side of nighttime visibility. The star and occulting object are in the zenith for an observer at a site indicated by the center of the circular projection of the Earth; the objects are on the horizon for sites at the edge of the circle. The altitude above the horizon can be estimated for any site shown on the map; the cosine of the altitude is the distance of the site from the center of the circle divided by the radius of the circle. The Sun altitude can be estimated from the terminator.

Regional Maps: The more detailed regional maps are prepared with a computer program originally written by Fred Espenak at Goddard Space Flight Center, and extensively modified by Dunham. The parallel curves represent the path of the center of the occultation shadow, considering several different shifts of the occulting object from its predicted path with respect to the star. The nominal path is labeled "0" and is drawn slightly heavier than the other paths. The parallel curves show the central path for multiples of $0\overset{''}{.}1$ shifts of the asteroid from its predicted path in the sky, measured perpendicularly to the path. Curves are labeled in the map margins with "N" or "S" showing shift direction; "E" or "W" are used if the occulting object's motion is nearly due north-south. Dashed curves show predicted U.T. of central occultation, or of closest approach. Low star altitude or twilight boundaries are drawn when appropriate. A stippled line marks the moonrise or moonset line, if either is present. The expected diameter of the occulting object, in km and in arc seconds, is given in the heading. The ephemeris source is indicated below the map; the stellar data used are indicated by the first entry under the "S" column of the second table. Dashed curves parallel to the solid curves indicate predictions for the path center based on other stellar and/or ephemeris data, as labeled. Asterisks show the locations of observatories from which photoelectric occultation observations have been attempted in the past, as far as Dunham knows. The regional maps are "false" projections, plotted with a constant linear scale (constant degrees per centimeter) in both longitude and latitude, so that the reader could, for example, plot updated computed path points which might be provided by Lowell Observatory. An updated prediction by Dunham usually is given as a path shift in arc seconds, which can be interpolated between the adjacent solid curves on the regional map, and a correction to the time, either earlier or later than the time estimated for a given location from the map by interpolating between the dashed U.T. curves. If the correction to the time is very large, the continents will be shifted in longitude relative to the occultation curves due to the rotation of the Earth, and the path shifts consequently will be slightly different along curved paths. This effect is greatest for paths extending nearly due north-south, and is inconsequential for east-west paths. Dunham takes this effect into account when he derives an updated path shift value, using an average value for a given regional map since the error in doing this is almost always less than the uncertainty of the astrometric update. Regional maps usually will be published in *O.N.* only for occultations potentially visible from Europe or North America. Regional maps for other areas with at least a few IOTA members are distributed to coordinators for further distribution.

Dunham finds that his paths often differ from Goffin's by a few to several tenths of an arc second, so that producing Sôma's world maps for all listed events does not always duplicate Goffin's maps, and also gives the better events worldwide, rather than just regional, distribution. He is now producing fewer finder charts, because Goffin's charts usually are adequate. His finder charts are mainly for faint stars (where the A.C. plots are helpful), for some events (mainly due to star catalogs not used by Goffin) found by Lowell but not by Goffin, and for some bright stars where not enough faint stars to be seen in a telescopic field are included in Goffin's charts.

Local Circumstances: Predictions of local circumstances of planetary occultations and appulses, which supplement the tables of general data given in *O.N.*, are computed and distributed to all IOTA members by Joseph E. Carroll; 4261 Queen's Way; Minnetonka, MN 55345; U.S.A., telephone 612,938-4028. These predictions are available to non-IOTA members by sending Mr. Carroll accurate geographical coordinates and $1.00, payable to IOTA; processing of requests will be speeded up by supplying a S.A.S.E.

Since the computer program producing these predictions was originally written by Dunham, and since he provides the input data used by Carroll, Dunham's and Carroll's calculations are mutually consistent. For each input event, the local circumstances printed include the U.T. and distance (in arc seconds, kilometers, and diameters of the occulting object) of closest approach, and the altitude and azimuth of the occulted star, the Sun, and the Moon. No data are printed if the star is below the horizon more than an amount proportional to an estimate of the occulting object's along-track (time) error, or if the star is fainter than 6th mag. in daylight.

Observational Methods: Numerous techniques and hints for observing planetary occultations have been discussed in previous articles on predicted and observed events in *O.N.* and in *Sky and Telescope*, especially in Dunham's annual article in the January issue of the latter. Some of the more important methods and considerations are described below.

Use the telescope with the largest aperture available, to give the brightest-possible image of the target star. Also, with a larger aperture, you are more likely to see the asteroid approaching the star, 30 to 10 minutes (depending on the motion) before the time of closest approach; this will give confidence that the correct star has been identified. With a larger aperture, there will be a higher signal-to-noise ratio, so that an occultation will be more clearly visible. If the asteroid is not visible, and the star appears faint, dimmings due to atmospheric seeing variations are likely to be mistaken for occultation events. Since separations of only a few thousandths of an arc second often can be resolved during an asteroidal occultation, very close double stars sometimes are discovered. The ability to see immersions and emersions occur in steps due to duplicity is better if the star appears brighter.

The value of practice in locating the target star before the night of the occultation can not be overemphasized. A good finder scope, able to see stars to about 8th mag. and with at least a 5° field of view, is highly recommended. On your first try, allow at least 30 minutes to find a star in a difficult field, such as one more than 2° from a 3rd-mag. star, especially if strong moonlight is present. After a little practice, you will be able to locate the target star quickly, an ability which may be important during the night of the event, especially for those traveling relatively great distances with portable equipment. If your telescope is equatorially mounted and has setting circles, practice using them to offset from a nearby bright star to the target star.

The best current method of recording an occultation is with a high-speed photoelectric photometer. Although this has been almost exclusively the domain of professional astronomers at major observatories, designs and components for relatively inexpensive photometric systems have been, or are being, assembled at the University of Texas and at Lowell Observatory. News of these systems will be announced in *O.N.* as they become available; eventually, it is hoped that at least one of the systems will be marketed commercially in completely assembled (or nearly so) form. Other automatic recording methods include video and photography. Paul Maley has photographed breaks in star trails during occultations of relatively bright stars with an unguided 9-cm aperture telescope.

The best way to record a visual observation is to tape record event marks and comments along with short-wave radio time signals. This is better than using a stopwatch since the record can be replayed several times, to refine the time of marked events; multiple events in quick succession can be recorded; and remarks about observing conditions and interruptions can be included in the timed record. Events can be marked either by voice or (perhaps preferably, since hand reactions may be quicker than voice) by a mechanical clicker or electronic tone generator, such as a doorbell. Valuable practice can be gained by timing some lunar occultations; see Dunham's "Occultation Highlights" articles in each January's issue of *Sky and Telescope* if you currently do not have predictions for your location. Field experience gained from timing multiple events during a lunar grazing occultation can be especially useful for observing asteroidal occultations with portable equipment

Single observations of asteroidal occultations provide a very accurate astrometric measurement of the asteroid relative to the star, but tell us little about the occulting object. Asteroidal occultations are best observed as a group or regional project. An example of such is Stamm's Asteroid Research Project (A.R.P.), which was organized for the pupose of confirming asteroid duplicity, by having as many observers as possible monitor asteroid appulses as well as occultations, within the contiguous 48 states; additional participants are sought (see *o.N. 3* (7), 148); contact Stamm. At least two, and preferably three or more, well-distributed chords (ideally, one near the center and one near each of the limits) are needed in order to determine the asteroid's mean diameter reliably. Consequently, when last-minute astrometry shows that an occultation might be visible from your region, as many observers as possible in cities and towns throughout the region should be notified. Gall's *Astronomical Directory* and the *International Directory of Amateur Astronomical Societies* are both arranged geographically and, along with some directories of national professional societies, are useful for contacting potential observers. For events visible from North America, finder charts often are published in *Sky and Telescope*, to which most non-*o.N.* subscribers can be referred. But most important, observers with portable equipment are needed to travel to locations between cities with observers, to fill gaps in coverage and increase the chances of obtaining enough well-distributed chords. The deployment is a little like that for a lunar grazing occultation, but on a much larger scale. The observing "fence" is much longer, to cover both the asteroid's diameter and the prediction uncertainty; observers generally are separated by tens of kilometers. When possible, visual observers should observe in pairs, separated by a km or more to confirm each other's timings by independent observation not affected by the same local atmospheric seeing cell or cloud. If the motion of the occultation shadow is relatively slow, the observers of a pair might separate themselves along the direction of motion by a distance large enough to produce a time difference of 2 seconds or more; the regional map can be measured to tell how large a distance this would be. This will not only allow confirmation of observed occultations, but also will permit a rough measurement of the motion of the occulting object. This would be valuable for establishing that a secondary occultation was caused by a body which shared the motion of the asteroid. Coordinators need to balance the need for a large-enough number of observers across the zone of prediction uncertainty to obtain enough well-distributed chords across the asteroid, with the need for confirmed observations by pairs of observers; the available manpower is always limited. Observers in cities relatively far from the predicted path, who can not travel to it, should observe also, in case of astrometric error or to observe a possible secondary occultation. But in such cases, visual observers always should make an effort to observe in separated pairs, as noted above, for confirmation. A secondary occultation by an asteroidal satellite is possible for anyone who has the star above his horizon at night during the appulse, but the possibility of such an event occurring, though always low, increases considerably as one approaches the actual occultation path. Secondary occultations almost never have been reported more than ten diameters away from the asteroid. This fact also can be used to plan the period of observation and recording (be sure you have enough tape). Start observing at least ten times the predicted central duration before the predicted time of closest approach (and add to this the uncertainty of the time of closest approach), and continue for at least as long a period afterward. Stamm previously suggested observing for the number of minutes equal to the number of seconds of maximum duration, with a minimum of 10 minutes, and a maximum of 40 minutes, but now feels that the minimum observing time should be extended to 15 or 20 minutes (see *o.N. 3* (15), 327). But be careful not to become too fatigued; try to arrange a comfortable observing position, and take a brief break (note when you do this) if you start to become too tired. Be sure to be especially alert during the three or four minutes bracketing the time of closest approach.

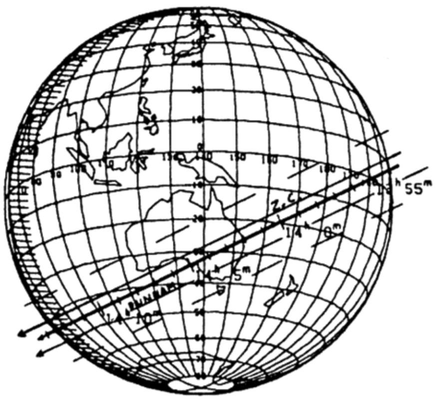
Prediction Updates: The predictions for asteroidal occultations can be improved by astrometric observations to update the ephemeris and the star's position a few months in advance. The improvement can be quite good if the asteroid happens to pass near the star, perhaps during its retrograde loop, so that both objects can be photographed on the same plate. Sometimes these preliminary prediction improvements are published in *o.N.* or in *Sky and Telescope*, or distributed by Lowell Observatory astronomers or by Dunham. However, a very accurate prediction generally can not be made until the objects are close enough together to photograph on the same astrographic plate during their final approach, only a few days before the event. In these cases, those involved with computing the final predictions must concentrate on notifying those near the path; this is facilitated if those contacted will telephone other observers in their areas.

You can find out the latest predicted shift and time correction for upcoming asteroidal occultations by telephoning one of the following:

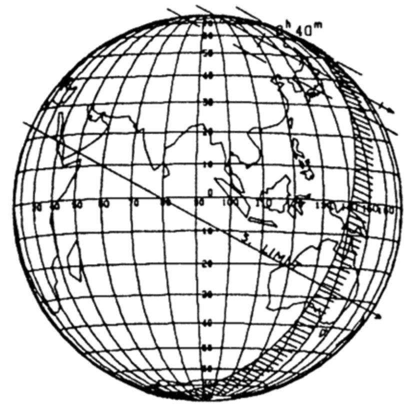
Hans-J. Bode, Hannover, G.F.R.	City code 511,424288
Astr. Soc. of Harrisburg Obs. (PA)	717,938-6041
David Dunham, Silver Spring, MD	301,585-0989
Astro-Alert, Chicago, IL	312,259-2376
Paul Maley, Houston, TX	713,488-6871
Lowell Observatory, Flagstaff, AZ	602,774-3358

Also in Silver Spring, Joan Dunham's ASTBBS probably will make updates available to anyone with a terminal (or personal computer) and modem 301,495-9062

For some very important events in North America, arrangements will be made to broadcast prediction updates on WWV at hourly intervals during the few days before the occultation.



SAO 163645 by Russia 1986 Aug 10



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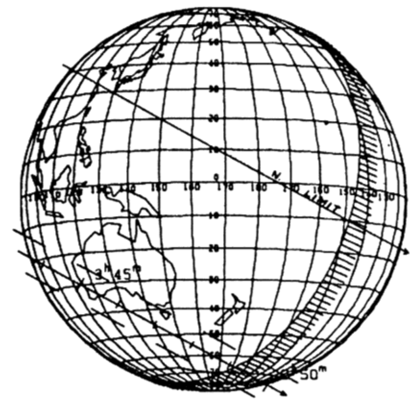

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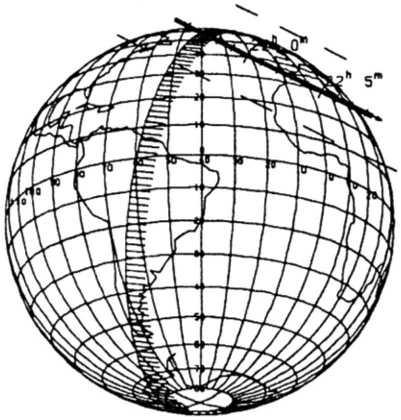

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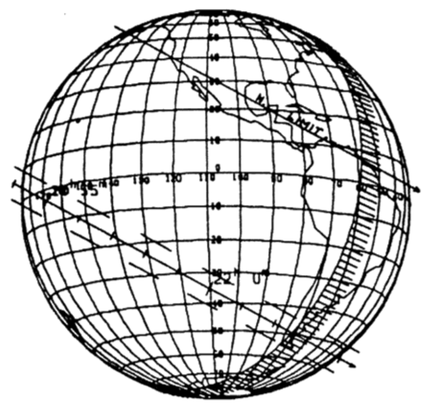

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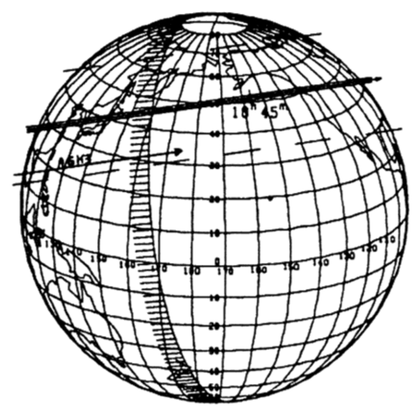

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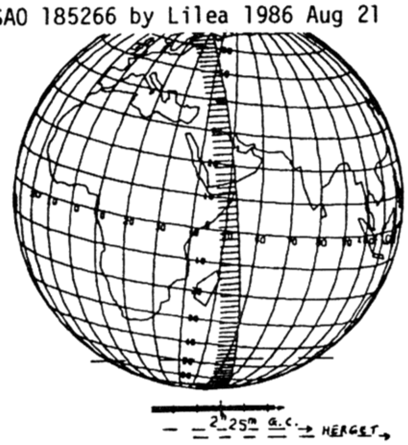

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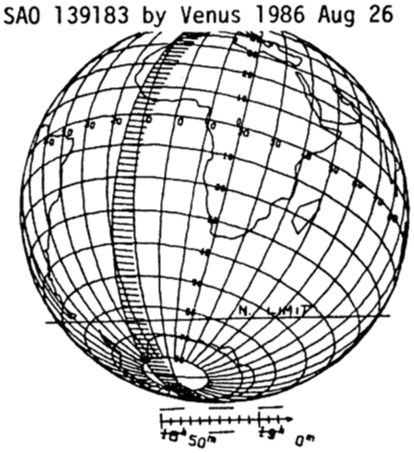

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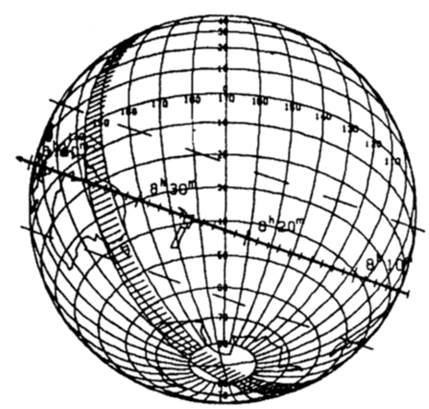

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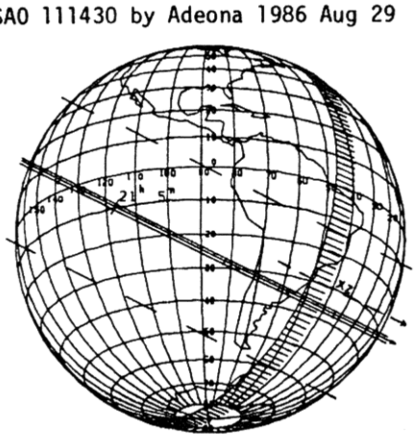

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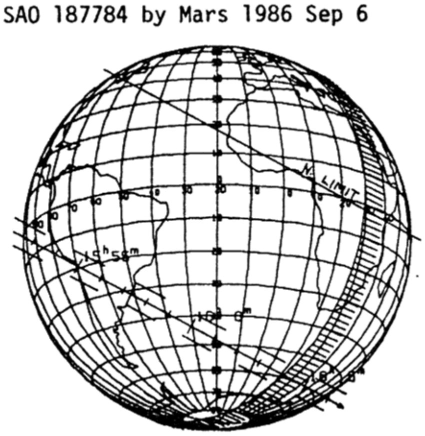

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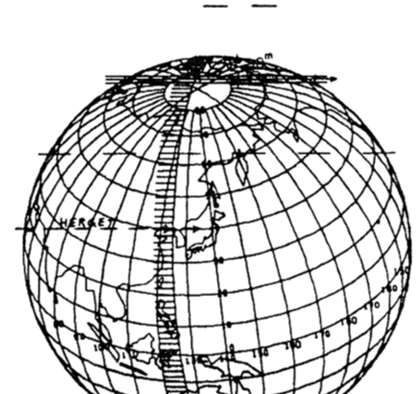

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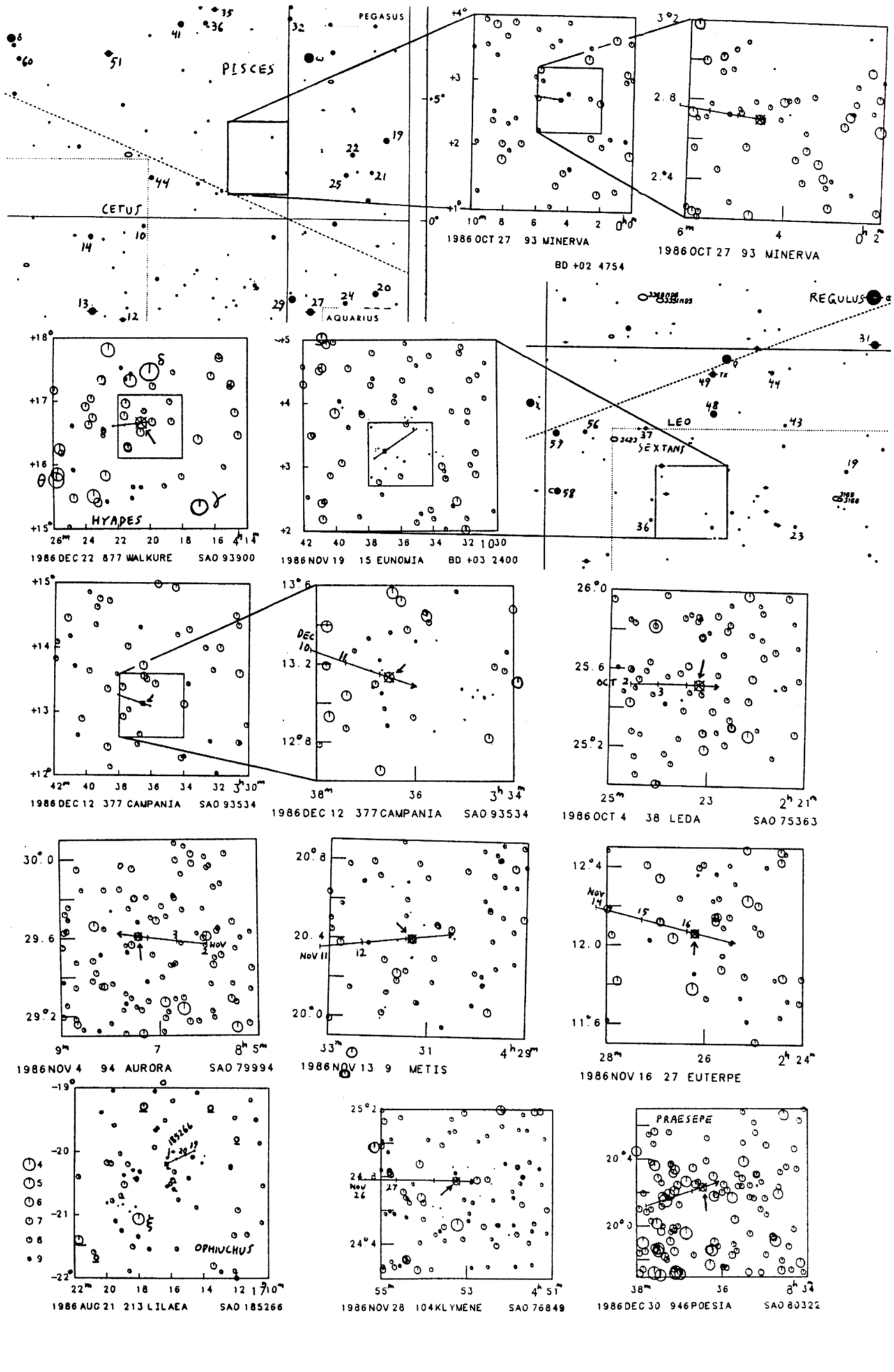
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1986 DEC 12 377 CAMPANIA SAO 93534
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1986 NOV 4 94 AURORA SAO 79994
1986 NOV 13 9 METIS
1986 NOV 16 27 EUTERPE
OPHIUCHUS
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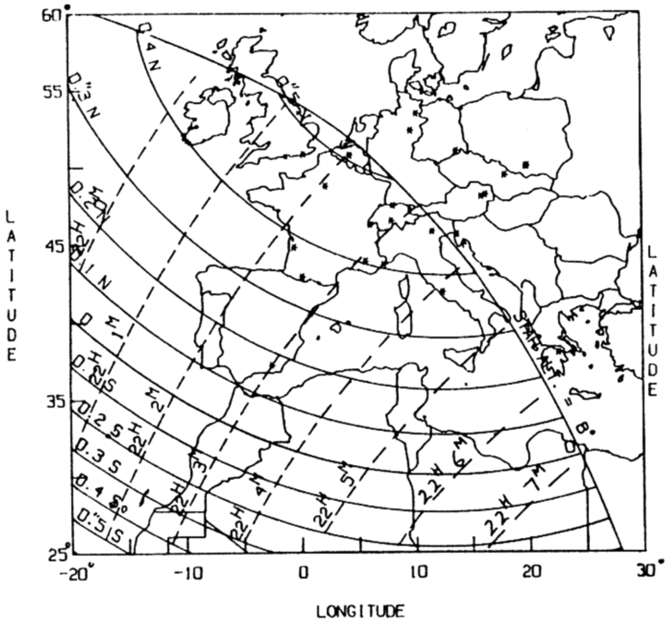

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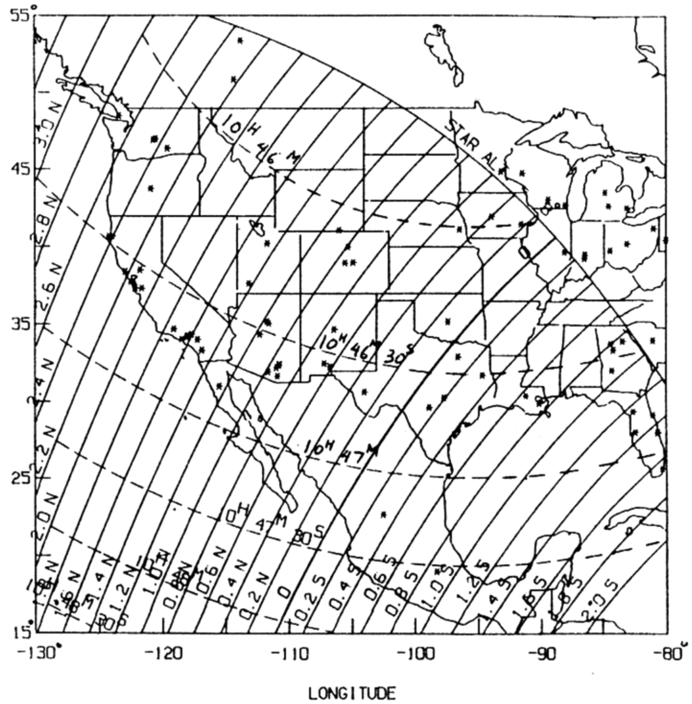

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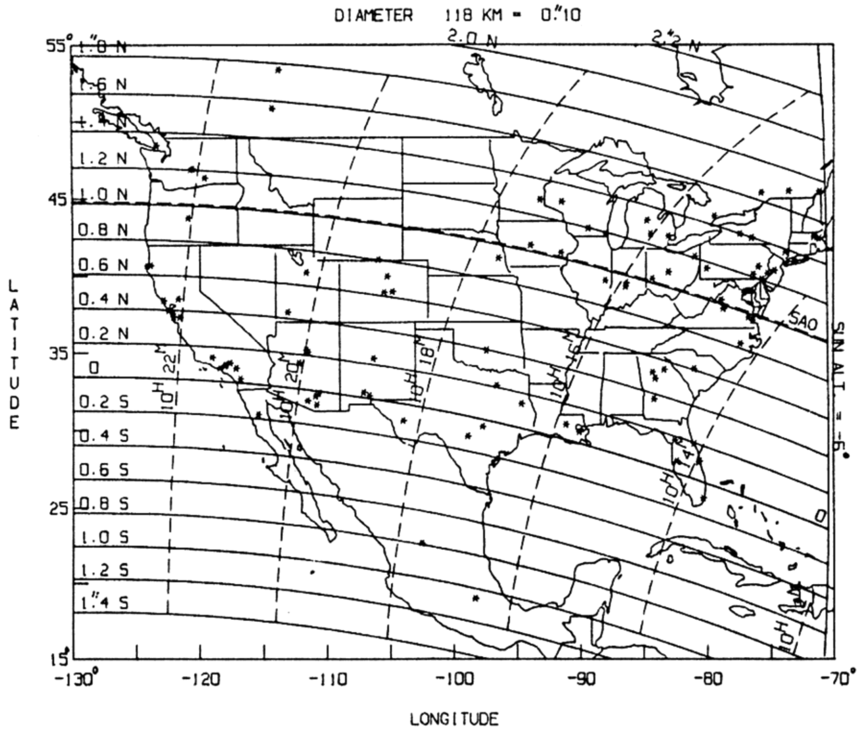

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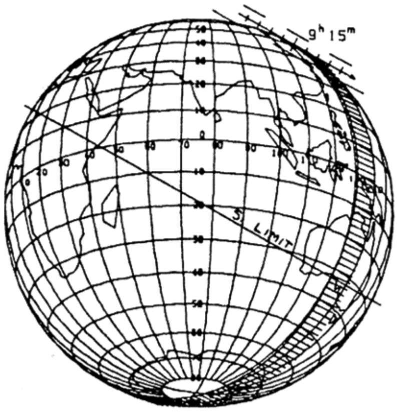

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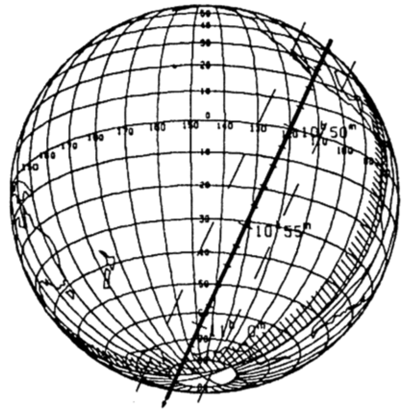

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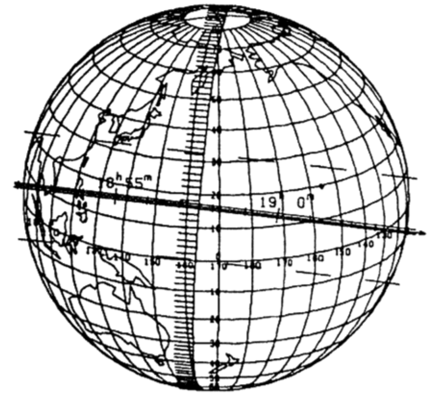

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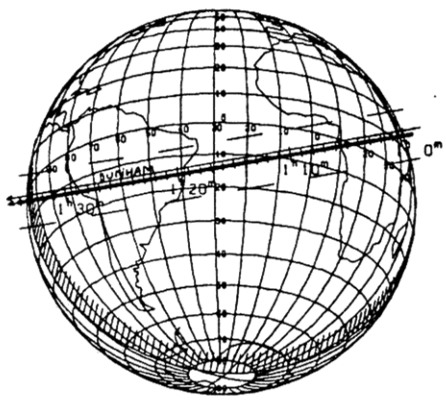

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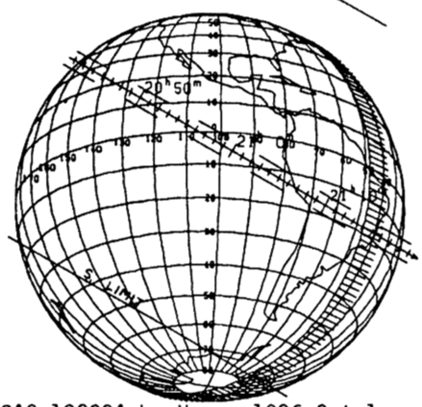

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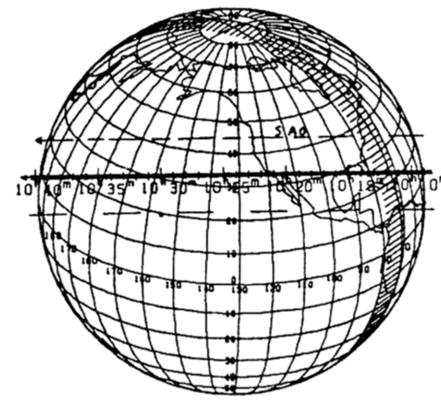

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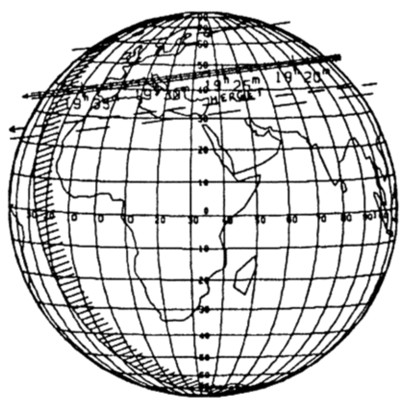

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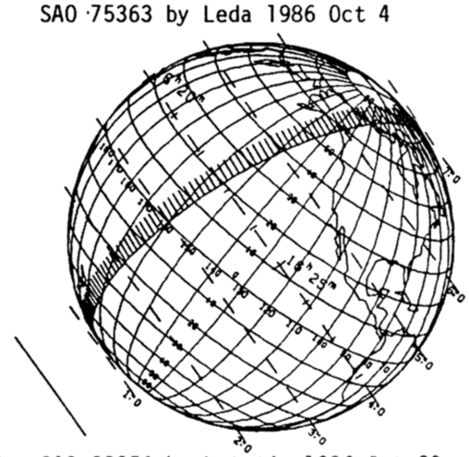
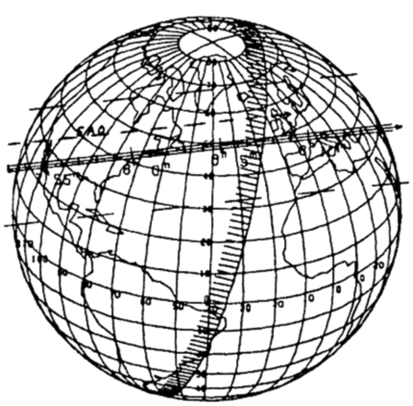
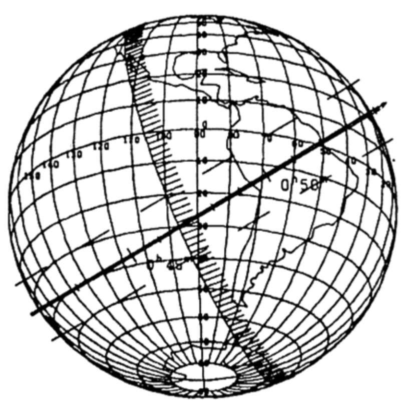


SAO 98854 by Lutetia 1986 Oct 29



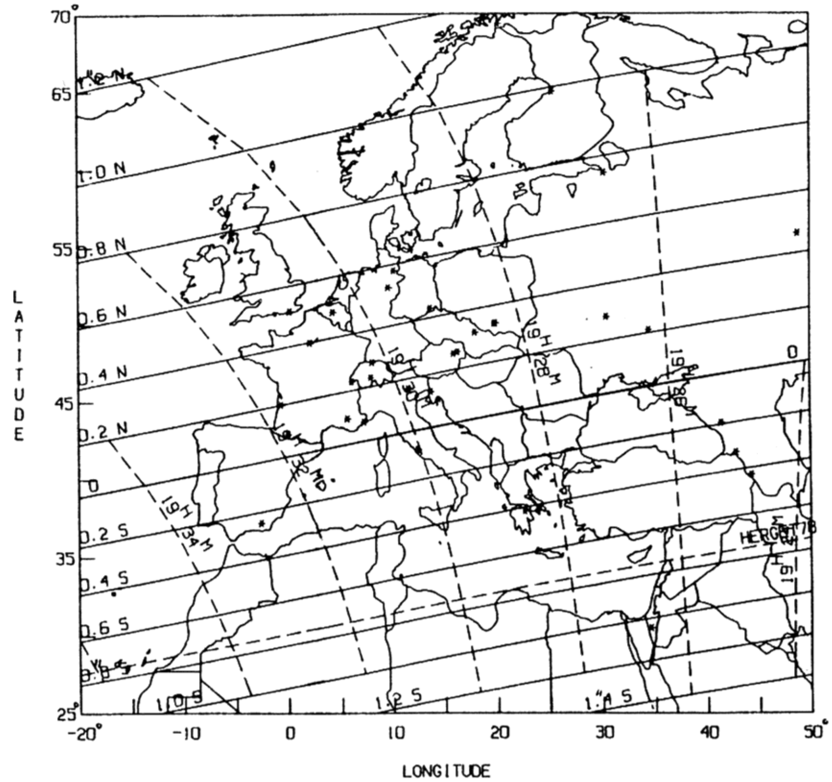
SAO 79994 by Aurora 1986 Nov 4



SAO 190724 by Isis 1986 Nov 6

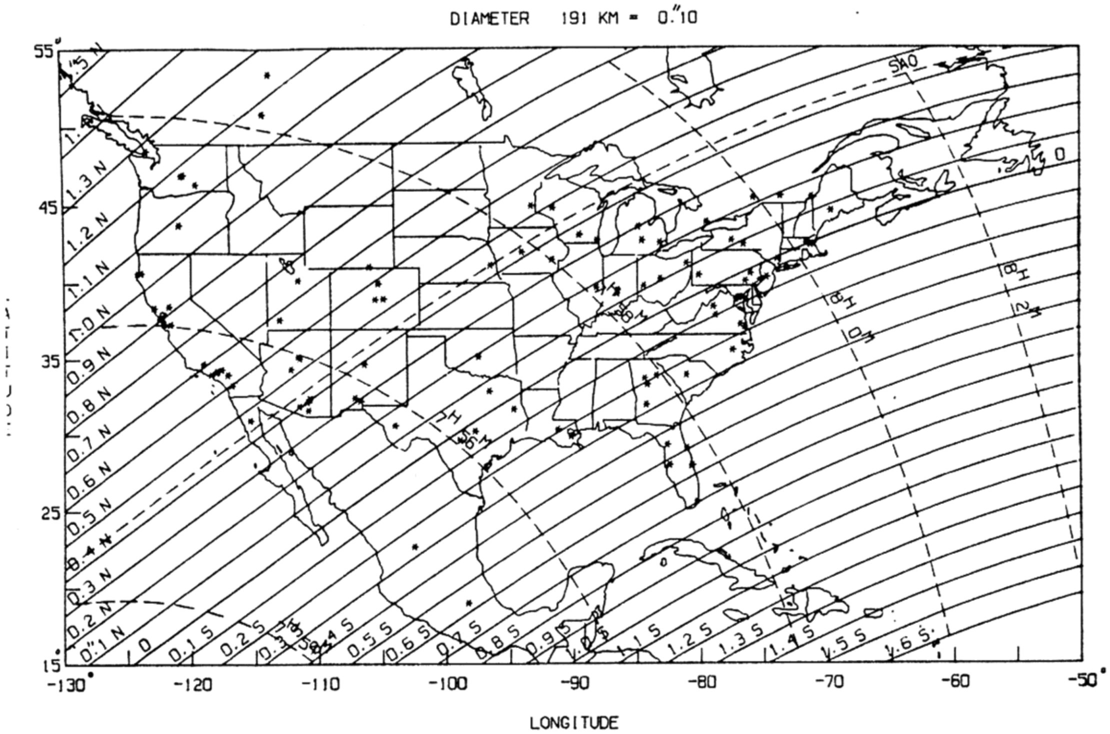
SAO 190516 by Dembowska '86 Nov 10

1986 10 27 (93) MINERVA BD +02° 4754
DIAMETER 173 KM = 0."13

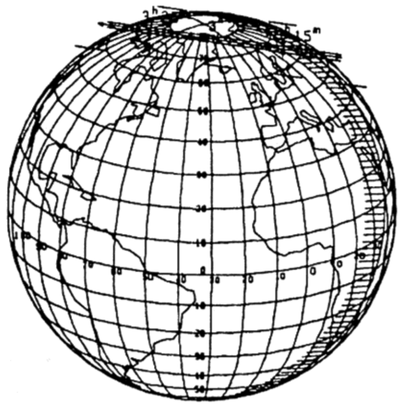


EPHEMERIS SOURCE = EMP 1981

1986 11 4 (94) AURORA SAO 79994
DIAMETER 191 KM = 0."10

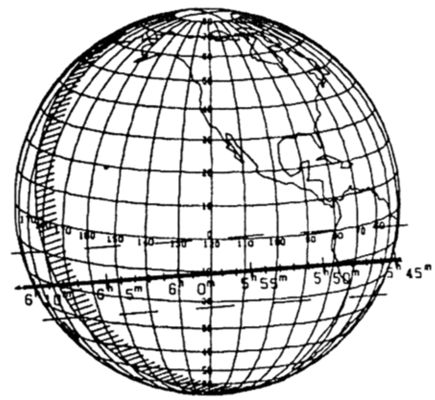


EPHEMERIS SOURCE = EMP 1981

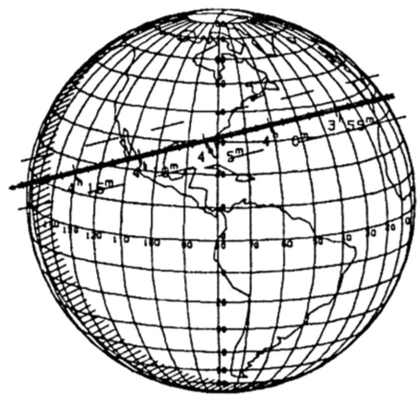


DM +20°775 by Metis 1986 Nov 13

DM +18°721 by Prymno 1986 Nov 14

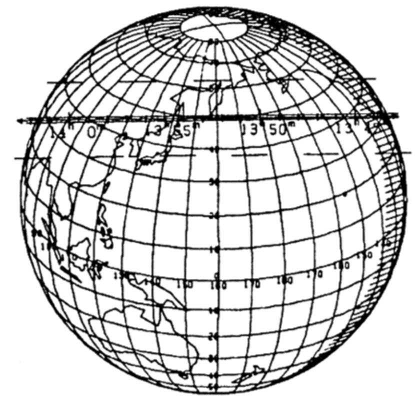


N10 154 by Havnia 1986 Nov 15

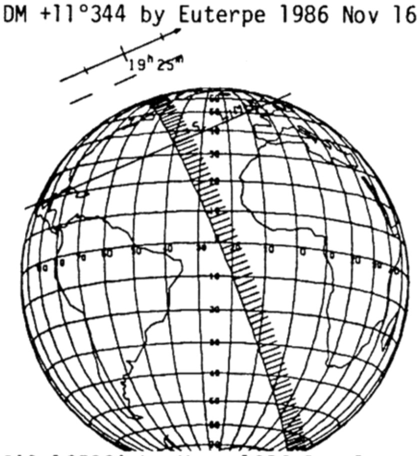


DM +11°344 by Euterpe 1986 Nov 16

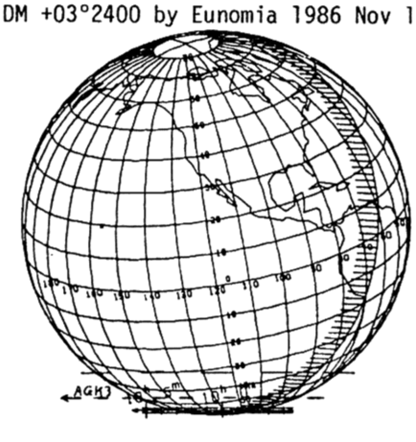
DM +03°2400 by Eunomia 1986 Nov 19



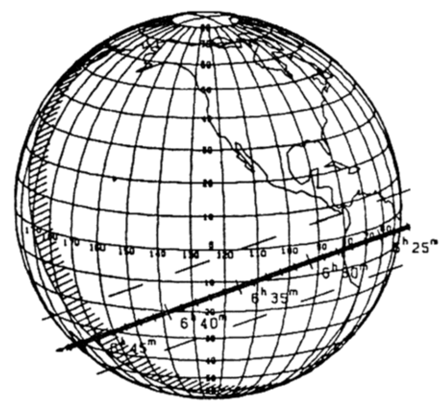
SAO 76849 by Klymene 1986 Nov 28



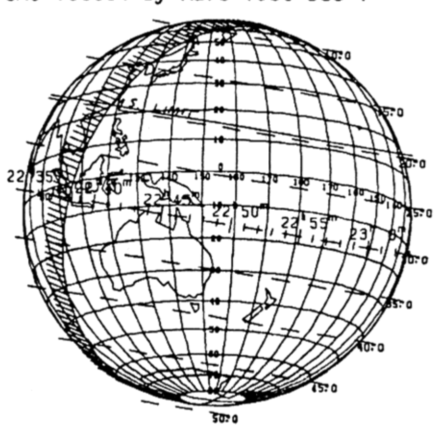
SAO 165064 by Mars 1986 Dec 1



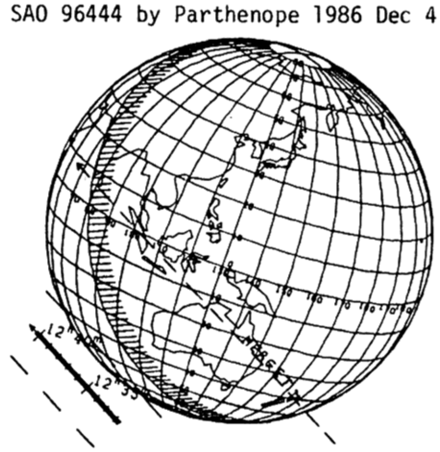
SAO 96444 by Parthenope 1986 Dec 4



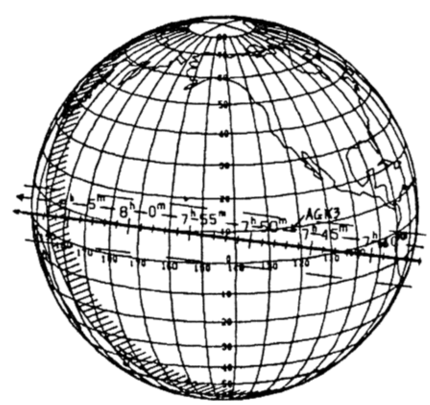
SAO 93534 by Campania 1986 Dec 12



SAO 158670 by Venus 1986 Dec 13



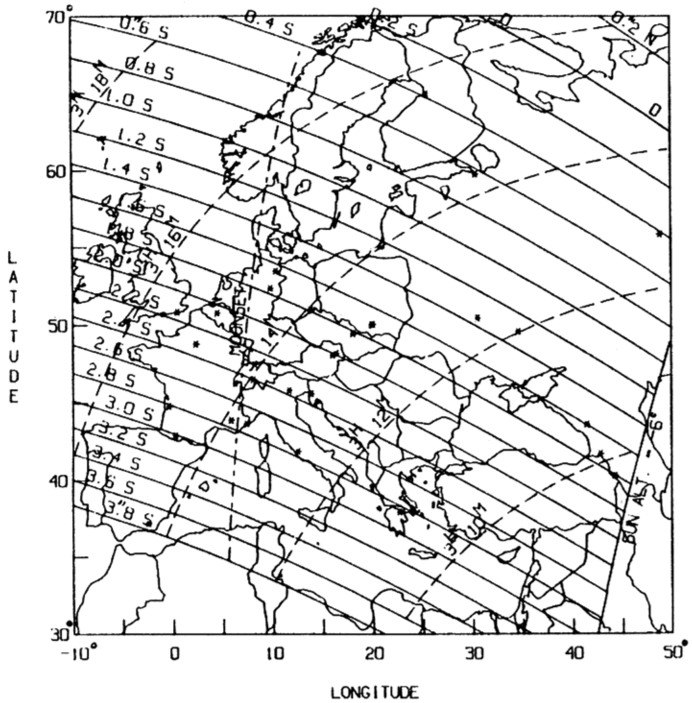
SAO 93262 by Adeona 1986 Dec 17



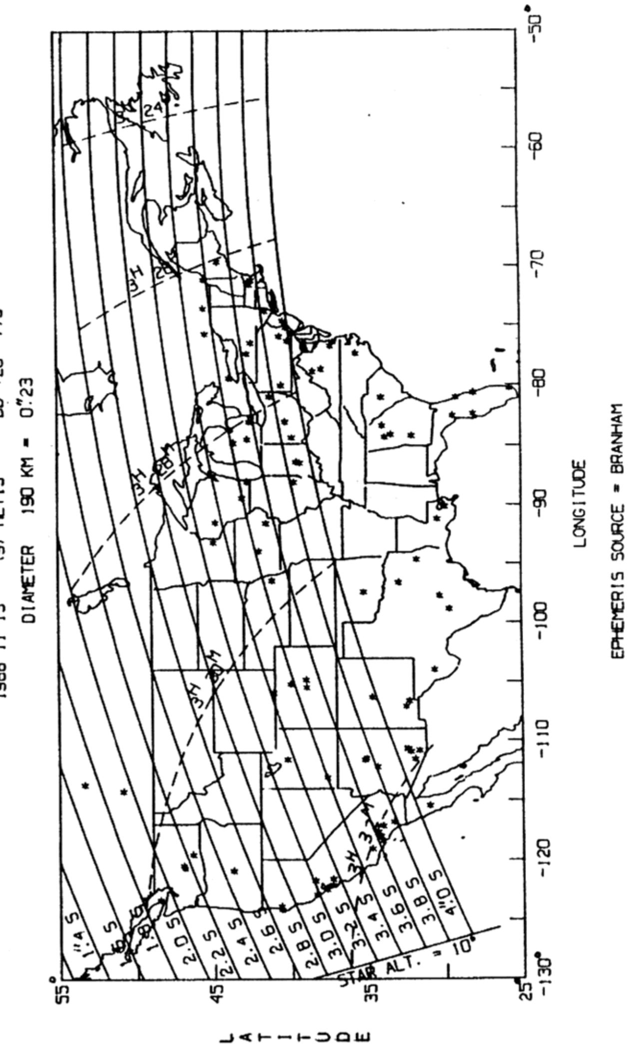
SAO 93900 by Walkure 1986 Dec 22

1986 11 13 (9) METIS BD +20° 775

DIAMETER 190 KM = 0."23

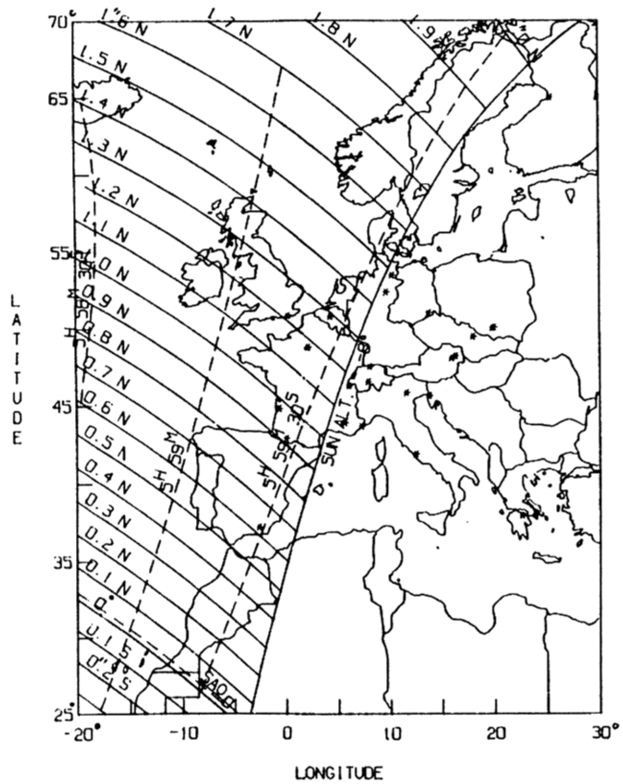


EPHEMERIS SOURCE = BRANHAM



1986 11 19 (15) EUNOMIA BD +03° 2400

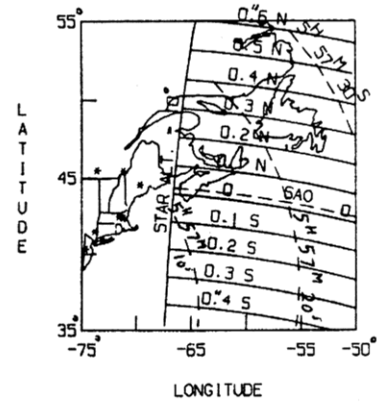
DIAMETER 261 KM = 0."13



EPHEMERIS SOURCE = BRANHAM

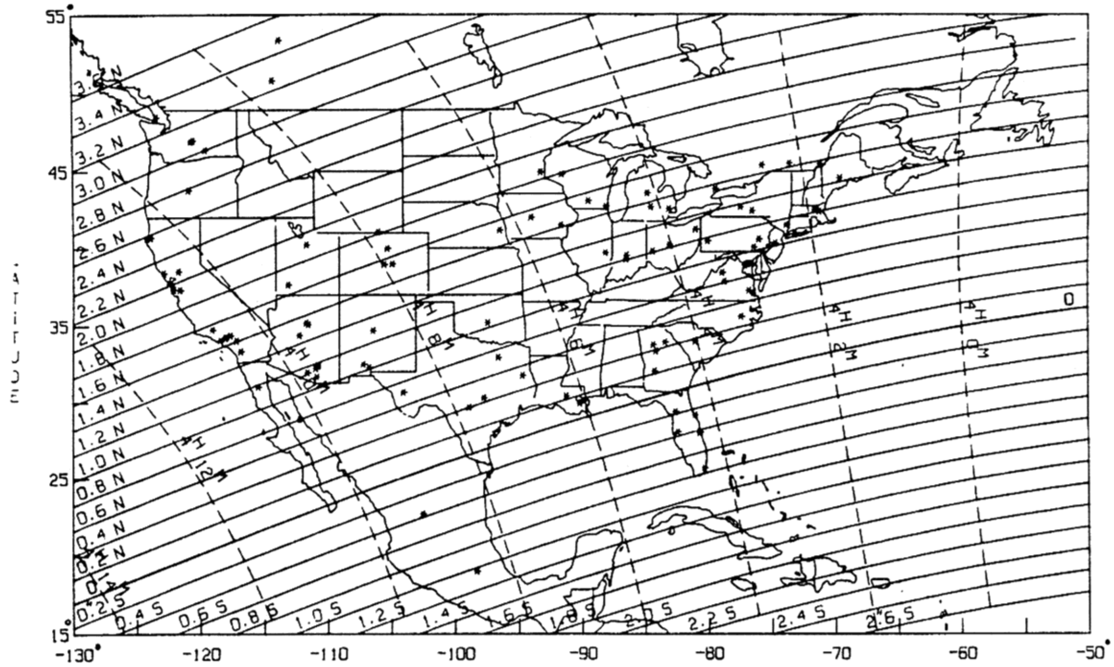
1986 11 19 (15) EUNOMIA BD +03° 2400

DIAMETER 261 KM = 0."13



EPHEMERIS SOURCE = BRANHAM

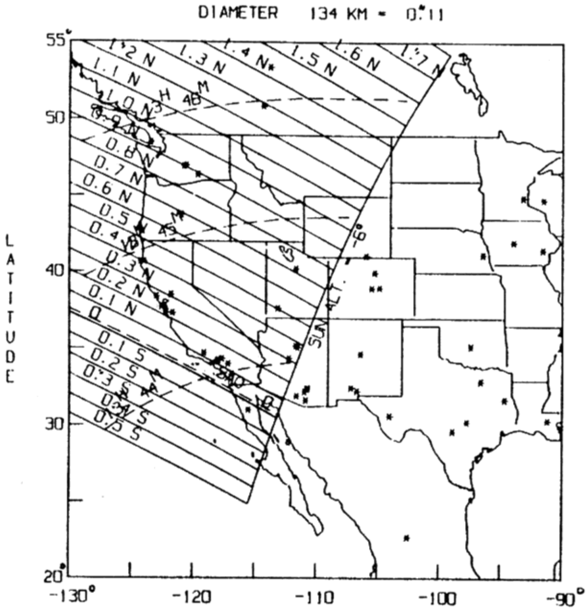
1986 11 16 (27) EUTERPE BD +11° 344
DIAMETER 116 KM = 0.″15



LONGITUDE

EPHEMERIS SOURCE = HERGET77

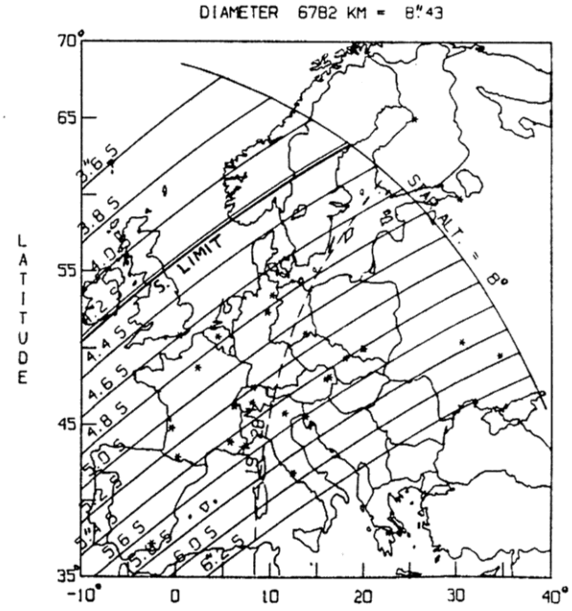
1986 11 28 (104) KLYMENE SAO 76849
DIAMETER 134 KM = 0.″11



LONGITUDE

EPHEMERIS SOURCE = EMP 1983

1986 12 1 MARS SAO 165064
DIAMETER 6782 KM = 8.″43

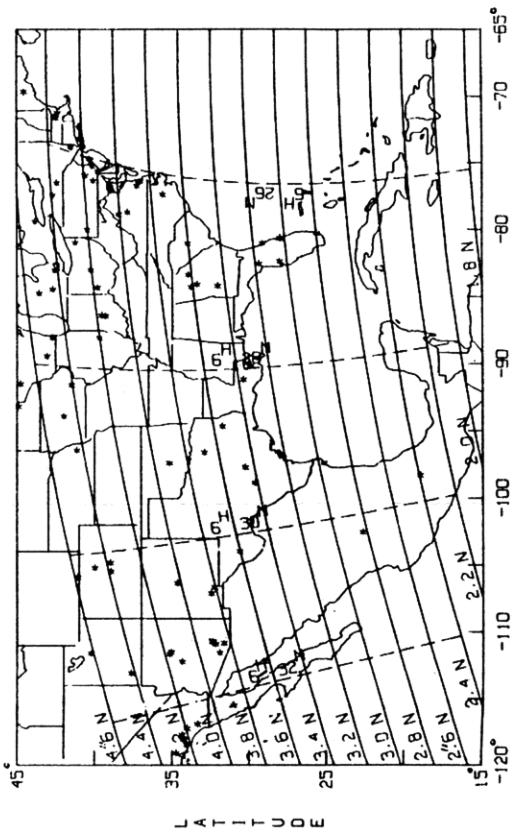


LONGITUDE

EPHEMERIS SOURCE = NA0001

1986 12 12 (377) CAMPANIA SAO 93534

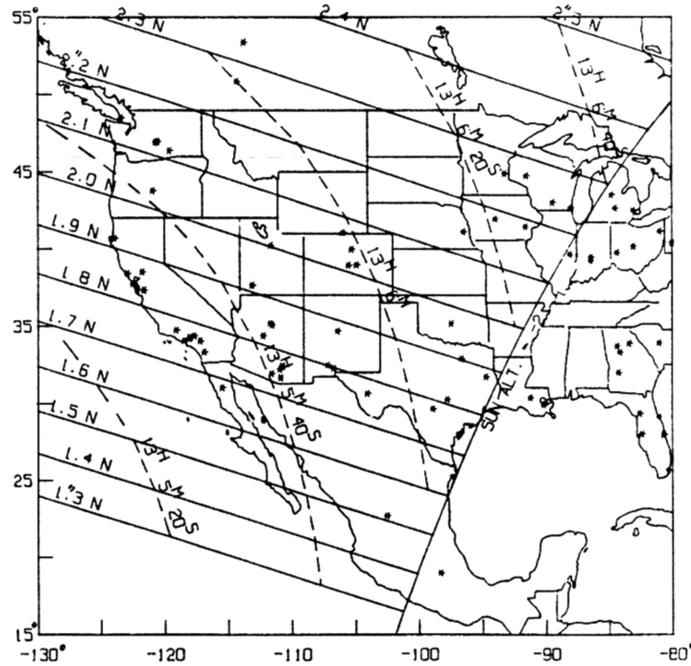
DIAMETER 103 KM = 0."09



EPHEMERIS SOURCE = EMP 1981

1986 12 26 (238) HYPATIA SAO 159042

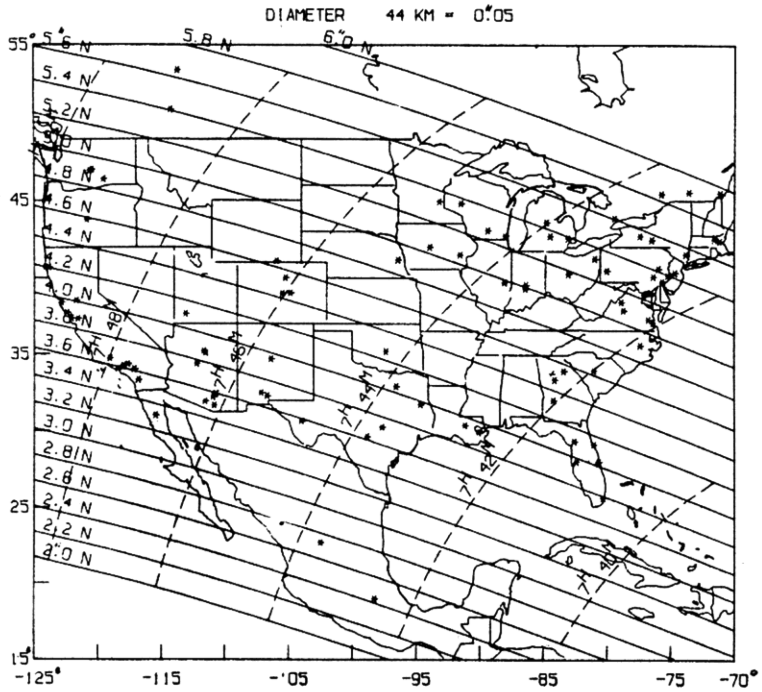
DIAMETER 155 KM = 0."06



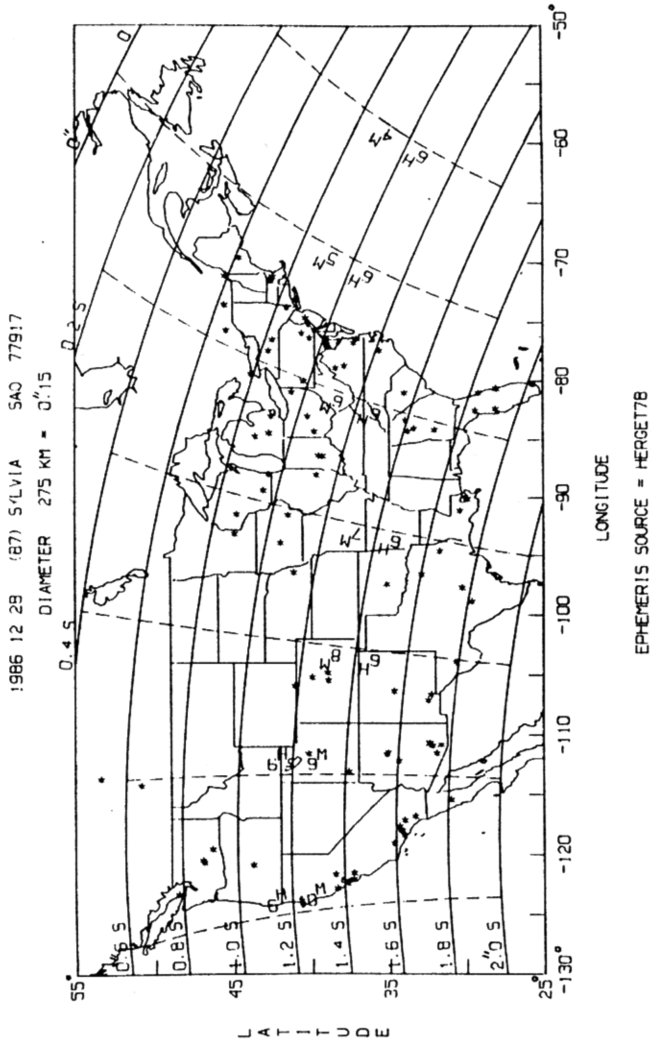
EPHEMERIS SOURCE = EMP 1983

1986 12 22 (877) WALKURE SAO 93900

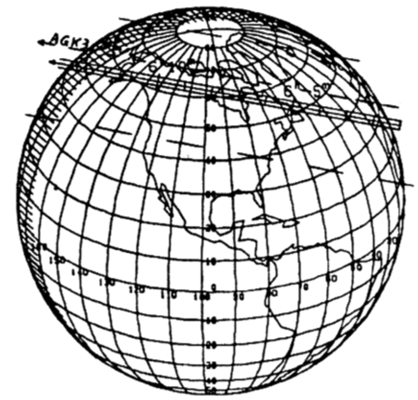
DIAMETER 44 KM = 0."05



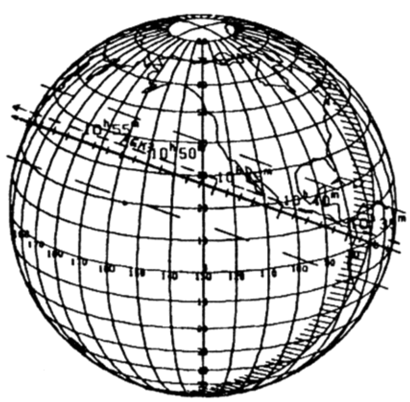
EPHEMERIS SOURCE = EMP 1986



SAO 159042 by Hypatia 1986 Dec 26



SAO 77917 by Sylvia 1986 Dec 28



SAO 80322 by Poesia 1986 Dec 30