Occultation Newsletter

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Joan Bixby Dunham, Editor

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FROM THE PUBLISHER

For subscription purposes, this is the second issue of 1994. It is the fourth issue of Volume 6. IOTA annual membership dues, including ON and supplements for

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for all others	25.00

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Although they are available to IOTA members without charge, nonmembers must pay for these items:

Local circumstance (asteroidal appulse) predictions	1.00
Graze limit and profile predictions (per graze)	1.50
Papers explaining the use of the predictions	2.50

Asteroidal occultation supplements will be available at extra cost: for South America via Orlando A. Naranjo (Universidad de los Andes; Dept. de Fisica; Merida, Venezuela), for Europe via Roland Boninsegna (Rue de M ariembourg, 33; B-6381 DOURBES; Belgium) or IOTA/ES (see below), for southern Africa via M. D. Overbeek (Box 212; Edenvale 1610; Republic of South Africa), for Australia and New Zealand via Graham Blow (P.O. Box 2241; Wellington, New Zealand), and for Japan via Toshio Hirose (1-13 Shimomaruko 1-chome; Ota-ku, Tokyo 146, Japan). Supplements for all other areas will be available from Jim Stamm (11781 N. Joi Drive; Tucson, AZ 85737; U.S.A.) for $2.50.

Observers from Europe and the British isles should join IOTA/ES, sending DM 40.-- to the account IOTA/ES; Bartold-Knaust Strasse 8; D-30459 Hannover, Germany; Postgiro Hannover 555 829 - 303; bank-code-number (Bankleitzahl) 250 100 30.

IOTA NEWS

David W. Dunham

Asteroidal/Planetary Occultations and the Next Issue: The main purpose for this issue is to publish (finally!) the predictions for asteroidal and planetary occultations for the second half of 1994 (after Edwin Goffin's article about the best asteroidal occultations during the rest of this century) to document the local circumstance/appulse predictions that IOTA distributed early in July. You should first look at the regional map to see what events are about to occur in your area, and consult the tables, world maps (if any), and article (especially the notes about individual events at the end) for more information about them. Some other important communications, including minutes of the May IOTA meeting and standards for videorecording solar eclipses (important for those preparing for the November 3rd eclipse), are also included, and hemispheric grazing occultation supplements for the rest of 1994 are enclosed. This issue is already so large that we will leave some material already received for the next issue, which is planned for late October. For example, articles Joe Carroll has written on lunar occultation tallies for 1981-1985 years will be in that issue. We should have your input for the next issue by the first week of October.

PHESAT95 Meeting: A meeting, "CCD and Photometric Receptors Applied to the Observation of the Satellites of Saturn during the 1994-1996 Opportunity", will be held in Bucharest, Romania, September 19-21. This workshop, organized through the French CNRS and the Romanian Academy of Sciences, is mainly devoted to help astronomers from eastern Europe to participate in the observation of the mutual occultations and eclipses of the Saturnian satellites that will occur next year and in 1996. These events are harder to observe than the similar phenomena involving the much brighter Galilean satellites, and are valuable not only because they happen only every 15 years, but also because planning for the extensive Saturn satellite tour by the Cassini spacecraft can benefit from the improved orbital data that can be obtained from these events. Henk Bulder will be representing IOTA at this meeting and will present a paper on reducing video observations of such events, since special processing is needed to remove the gradient of the planet's background light for proper photometric analysis. Those wanting more information about this meeting should contact Jean Arlot in Paris, fax (33) 1 46332834, E-mail arlot@iap.fr.

IOTA/ES Business Meeting: A business meeting of the European Section of IOTA will be held in Hannover, Germany, on Saturday, November 26, but some technical discussions, such as about observations of the solar eclipse earlier that month, will also be held. For more information, contact Hans Bode (see back page).

ESOP-XIII: The 13th European Symposium on Occultation Projects was held in Cracow, Poland, on August 12-17. The program was very interesting, including presentations by professional astronomers from France, Germany, and Russia. Plans were developed for manufacturing small, relatively inexpensive CCD devices that can be used with a PC to record occultations or star fields with virtually any integration time, from milliseconds for bright objects to several minutes. Late in July, I calculated the PC-Evans program Besselian elements file (befile) for 1995 for stars and nebulae. Copies of this 1995 befile were distributed to all of the European national and regional coordinators at the meeting. Eberhard Riedel also distributed maps of 1995 grazes for several countries. Proceedings of ESOP-XIII were distributed at the meeting. More details, including a list of the presented papers, will be given in a future issue.

Graze Corrections: The corrections that we think should be applied to the ACLPPP version 80N profiles for grazing occultations remain unchanged; see p. 60 of the last issue.

THE 1994 IOTA ANNUAL MEETING

Walter V. Morgan

The annual meeting of IOTA was held in a conference room of Insights--The El Paso Science Museum on May 7-8, 1994, as noted on p. 49 of the last issue. Insights is a hands-on facility, patterned after the Exploratorium in San Francisco, where touching the exhibits is considered the ideal. A 30-meter long echo tube hung on the wall outside our meeting room; throughout the Saturday meeting our ears gave testimony to the vigor and frequency with which at least that one experiment was visited by the patrons. On behalf of IOTA, I have sent a letter of appreciation to Insights for making a meeting room available.

Business Meeting: The business meeting of IOTA was called to order by President David Dunham at 10:20 a.m. Mountain Daylight Time. He presented a financial report from the Treasurers, published elsewhere in this issue. Finances are in the black, but the trend is toward the red. A decision on whether to increase IOTA's dues for membership and publications needs to be made in September if new rates are to appear in the January 1995 issue of **Sky and Telescope**. The financial statement was accepted.

IOTA is incorporated in Texas, which was clearly the best choice in the early years. For various reasons it might be preferable to re-incorporate in Kansas or Maryland. Mark Trueblood described possible complications of such action; he will provide copies of the paperwork associated with his observatory, a non-profit organization incorporated in Maryland. A motion was made and accepted to investigate the feasibility of re-incorporating. Future annual meetings could then be small business meetings in the State of incorporation, freeing technical meetings to be held elsewhere, in conjunction with an eclipse, important occultation, or other amateur convention. The goal is to increase attendance at technical IOTA meetings. A motion was made and accepted to adjourn the business meeting at 10:47.

A number of persons had come in after the business meeting started, so introductions were made at this point. Present were: President David Dunham; Derald Nye, Jim Stamm and Mark Trueblood from Arizona; MacPherson Morgan from New Mexico; Walt Morgan from California; Eberhard Riedel, Hans Bode and Heliga Bode from Germany. Others from Germany arrived later: Peter Dreesen, Michael Mushardt and Anite Sewalt. So IOTA/ES was represented about as well at this meeting as IOTA.

IOTA Software: The technical meeting of IOTA began with a presentation by Walt Morgan of the three IOTA software packages which are now available to run on IBM PC-class computers. EVANS is the code which was used for years at USNO to prepare total occultation predictions. It has been re-written by IOTA/ES member Claudio Costa, of Rome, Italy to run on PC's. A rather bulky package (about 60 Megabytes), it is now being used by several IOTA members; see pp. 55-56 of the last issue. On the most modern of the PCs it can calculate a full year's predictions, with low O-code, in 10 minutes.

OCCULT version 2.0, written by IOTA member David Herald, of Woden, ACT, Australia, will compute both total and grazing occultations. It especially fills the needs of individuals who wish to supplement their IOTA predictions, by making it possible to prepare predictions for alternate locations, for example. OCCULT-2 is very portable--it is shipped on three 1.44 Mb diskettes--and may be purchased from Walt Morgan. The price to IOTA members is only $5 ($10 for all others), including postage. (Add $2 for first class postage outside North America). The amount of each sale which exceeds the cost of materials and postage is remitted to IOTA. OCCULT 2.0 is reviewed on pages 56 and 57 of the last issue.

Hans Bode, President of IOTA/ES, described the ES methods of preparing and distributing predictions. Total occultation predictions are provided without charge only for members. (IOTA provides the same service, but through an announcement in the January issue of **Sky and Telescope** also provides total occultation predictions for others who provide stamped, self-addressed envelopes.)

David Dunham described observations of grazes seen during the lunar eclipse last November 29. These were reported in **ON 6** (2), p. 43 and p. 60 of the last issue.

Eberhard Riedel described his effort in preparing GRAZEREG, the PC-based software now used by the graze computors preparing graze predictions. Fortran listings of the old programs and some documentation were useful as guides, but most of the program was written from scratch to enable a more comprehensive and efficient system for PC use. GRAZEREG has been used to prepare graze predictions beginning this year. Each star in a catalog of 43,000 is examined independently, and a star-Moon-Earth relationship determined for each day; sufficient precision is obtained so that interpolation to various point on the Earth is possible. A magnitude limit of 8.5 is normally used, but fainter stars are used during eclipses. Thirty regions world-wide are prepared separately, and suitable sets of those are sent to the regional computors, who also receive Watts files, and station decks from IOTA. Graze lines are presently calculated in increments of 10′ of longitude; a program prepared by David Dunham interpolates to 7.′5 for use in North America. A number of changes being worked on include: The ability for the regional computors to select the longitude increment; an inclusion of umbral distance during eclipses; a statement of the GRAZEREG version used; and plotting capability. GRAZEREG was also described on p. 57 of the last issue.

Data Reduction: Over the years, data have been reported to different agencies, using different formats. No standard data reduction method applies to all, and there is not a compatible means of reading all past observations. With the new "Riedel standard" for graze predictions, it becomes increasingly desirable to make comparisons with old data.

Asteroidal Occultations: Good results tie directly to having good astrometric data. There were three successes in 1993, two of those by only one observer. Obtaining data for multiple stations is very important. Petr Pravec at Ondrejov Observatory in the Czech Republic obtained astrometric updates for many asteroidal occultations early this year. Accuracy of 0.″03 to 0.″05 is good enough, when it can be achieved. Astrometry with the 61-inch USNO Flagstaff telescope can achieve nearly 0.″01 accuracy, and resulted some observations of two occultations by Chiron; see **ON 6** (2), p. 45. The station project was described; see p. 58 of the last issue.

Jim Stamm described his coordination of asteroidal occultation efforts. Ed Goffin produces world-wide predictions, which Stamm sends to eight regional coordinators. Questionable observations present a continuing problem. The key element needed is better astrometry; getting more observers to participate by more accurately targeting the path is the best way to increase the amount of good data obtained.

David Dunham described the paper, "Natural and Artificial Satellites of Asteroids", that he presented March 29th in Kingsville, TX; see p. 54 of the last issue. Herculina, in 1978, was the first occasion when two stations independently observed a secondary asteroidal occultation--Flagstaff Observatory, and Jim McMahon in the Mojave Desert. [Your recorder should have been a third: I observed near Las Vegas, NV with excellent skies (but without a clock drive), and saw nothing. It was before I owned a TimeKube, and my WWV signal was fading badly. While giving attention to tuning for a minute or more, dawn progressed rapidly, and when I resumed observing I must have picked up the wrong star.] In spite of the Ida satellite, some still harbor doubts about these observations.

The Clementine lunar mapping mission was reviewed. The probe left lunar orbit on May 3, but failed during a test on May 7, preventing completion of its mission to fly by (1620) Geographos. Reprints of a paper about Clementine's trajectory, by David Dunham and Robert Farquhar, were handed out.

European Work: Hans Bode described his photometric work. He has a set of 30 Zeiss filters covering the full optical spectrum. A 50 mm f/0.275 lens used with an image intensifier allows a six-inch telescope to record magnitude 12.5 stars. A 25 nm wide filter at 800 nm has been particularly successful. An expedition to the Canary Islands to record an occultation of a 7th-mag. star by Jupiter on November 29th failed to obtain data because of technical problems.

The European Symposium on Occultation Projects -- ESOP -- has been a very successful forum. Seventy persons from all over Europe met for ESOP 12 in Holland last year, discussing equipment and techniques. ESOP is meeting in Cracow, Poland in August 1994; in Pilsen, Czech Republic in 1995 (the city's 700-year anniversary); and in England in 1996.

The May 10th Eclipse: Observing sites for the three planned expeditions, and their alternates, were described. The method of applying a shift to the calculated path because of elevation was discussed.

The meeting was adjourned at 5 p.m. Many gathered later in a hotel room to view slides of the Bode expedition to the Canary Islands, and continue informal discussions on other occultation topics.

The meeting re-convened at Insights at 9:20 a.m. on Sunday, May 8, with the May 10 eclipse the primary topic. Data analysis techniques were discussed, and videos of earlier annular eclipses were viewed. The videos were especially helpful to those observers who were inexperienced in annular eclipses. It was pointed out that no one seemed equipped to record the event using the very simple method of eyepiece projection onto a screen, and video-taping the projected image. Since that must be done without a filter, the setup cannot be tested on the full Sun; an artificial light source must be rigged for testing prior to the eclipse. Recording WWV on video tapes is very desirable for data reduction. A device made by Peter Manly can translate the audio signal into a precision visual signal. More about observing this eclipse was published in **ON** 6 (2).

SL-9: Plans for the Shoemaker-Levy 9 comet collisions on Jupiter were discussed; see pp. 50-53 of the last issue. Z.C.: It was announced that a few copies of Isao Sato's J2000 version of the Zodiacal Catalog were available for $15 at the meeting and for $17 by mail.

G.P.S.: Mark Trueblood gave an excellent, and comprehensive, presentation on the Global Positioning System -- GPS. It was based on an article which he authored for GPS World, November 1993. Portable versions of GPS receivers are now available for about $500; in general some accessories will add $100 or more to the cost. "Selective Availability" is the term used to describe the addition of noise to the coded signals, the method used to prevent civilians (and therefore enemies) from obtaining the ultimate accuracy of a few meters. With SA activated--and it usually is--accuracy is limited to about 100 meters, not adequate for most occultation work, as noted in **ON** 6 (2), p. 42. To overcome this problem, Differential GPS (DGPS) must be used. This technique uses two specialized GPS receivers--one of which is at a carefully surveyed location--to simultaneously record data. Even with SA active, it may then be possible to achieve accuracy of a few meters. Accurate information about DGPS is given in an article by Maley, Gilbert, and Fluter that will appear in the next **ON**.

A demonstration with a GPS receiver showed seven satellites in range, with the receiver locked on to the required minimum of four satellites. It was noted that the North American grid is accurate to about two meters, with local accuracies as good as a few centimeters. Other GPS comments: During the May 10 eclipse, a message on WWV stated that the GPS constellation currently consists of 25 satellites. Coordinates for the eclipse sites in south-central New Mexico were recorded with GPS; comparison with accurate coordinates--about 10 meters--from a map found differences of from 25 meters to 200 meters, with 90% of the differences being in the range of 60 to 140 meters. The consistent east/southeast nature of the errors was probably a bias resulting from the particular geometric relationship of the satellites being monitored during the half hour when values were being recorded with GPS. The observed errors confirm the inability of single GPS receivers to achieve the required 30-m accuracy needed for reporting eclipse and occultation observation.

The meeting adjourned at 11:20 a.m.

IN MEMORIAM

Kyril Fabrin: Kyril was the first person to successfully transport the complex EVANS total occultation prediction program, and its large datasets, away from USNO to run on a CDC computer at Ålborg, Denmark. He used the program to provide detailed total occultation predictions to Danish observers for many years, and an expansion of his service to others in Europe was considered when USNO withdrew their support for occultation work in 1991. The formatted Befiles that Kyril needed formed the basis of the Befiles now used by the PC-Evans program developed by Claudio Costa and now used around the world. Kyril was the local organizer of the very successful ESOP-VI meeting held in Ålborg in 1987.

Neils P. Wieth-Knudsen: Dr. Wieth-Knudsen was one of the most prolific lunar occultation observers, having been among the top five observers in number of timings for many years. This is remarkable considering the generally poor weather at his observatory in Tisvildeleje, Denmark. He travelled to meetings around the world, where he entertained hundreds with his detailed presentations about timing occultations. He travelled to Barbados to observe the 1976 April occultation of ϵ Geminorum by Mars, and went to northern Sweden in January and to the Faeroe Islands to observe grazing occultations of Aldebaran. His wife was his constant companion for all of his observations. In March 1993, he died in peace, for three days before he had completed putting all of his work and papers in order.

1994 IOTA FINANCIAL REPORT
1993 Sept. 1 through 1994 May 5

Craig and Terri McManus

Category Description	Amount	% of Total
INCOME/EXPENSE		
INCOME		
Full Memberships	$2,426.00	81.42%
Gifts from Members	20.00	0.67%
Interest on Checking	52.49	1.76%
Non-member Predictions	10.00	0.34%
O.N. Subscription Only	430.00	14.43%
Sale of IOTA Items	41.00	1.38%
TOTAL INCOME	$2,979.49	100.00%
EXPENSES		
Ast. & Graze Supplements	$565.34	15.95%
Credit Card Costs	18.11	0.51%
EMail	52.35	1.48%
Mailing Costs All	1,214.91	34.27%
Misc Printing	264.93	7.47%
Newsletter Only	774.52	21.85%
Office Expenses	111.09	3.13%
Total occ'n work, Edm. RASC	400.00	10.28%
Expenses - Other	143.52	4.05%
TOTAL EXPENSES	$3,544.77	100.00%
TOTAL INCOME-EXPENSE	-$565.28	-15.95%

As of 1994 May 5, the balance was $2,905.99.

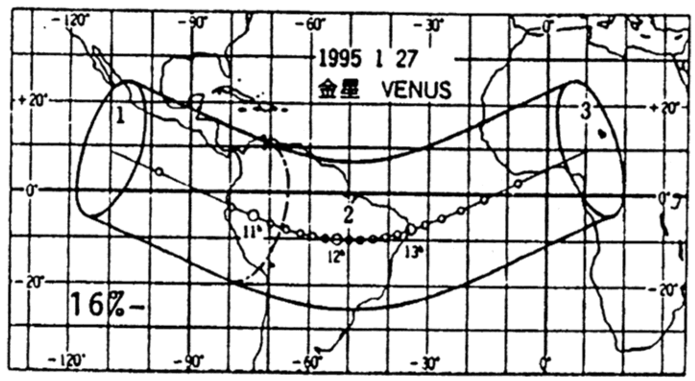
LUNAR OCCULTATIONS OF PLANETS

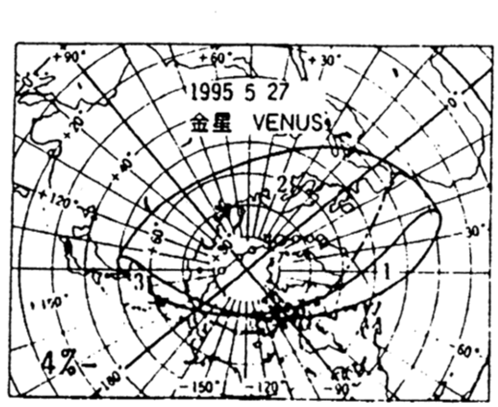
David W. Dunham

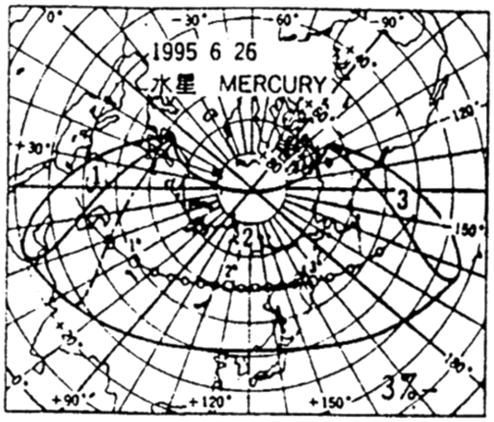
The maps showing the regions of visibility of lunar occultations of planets are reprinted by permission, from the Japanese Ephemeris of 1995, published by the Hydrographic Department of the Maritime Safety Agency of Japan. In region 1, only the reappearance is visible; in region 2 both the entire occultation is visible, and in region 3, only the disappearance may be seen. Reappearance occurs at sunset along a dashed curve, while disappearance is at sunrise along a curve of alternating dots and dashed. We have added a legend to each map indicating the phase of the Moon at event time.

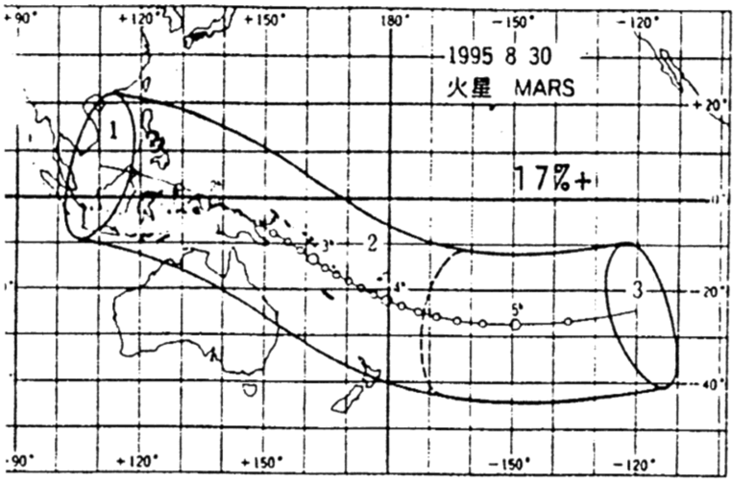
These maps may be more important for 1995 than those for previous years since lunar occultations of planets have not been included in the 1995 input data (Besselian elements file, or befile) that I created late in July. Fortunately, lunar occultations of major planets can now be computed with the OCCULT program (version 2; see p. 56 of the last issue), so this will be necessary to augment the predictions computed by the PC Evans program for the four dates during 1995 when these events occur. Except for a daytime occultation of Mercury in Alaska and Yukon, none of these will be visible from the USA or Canada, and one daytime occultation of Venus will be visible from most of Europe. If you do not receive predictions for one of these events that the maps here show will be visible from your location, you can request OCCULT 2 predictions for your location from your national or regional coordinator. Later this year, I hope to resurrect the USNO software that was used to generate the befile data for lunar occultations of both major and minor planets, but it is doubtful that this will be done before most of the coordinators will distribute the 1995 lunar occultation predictions.

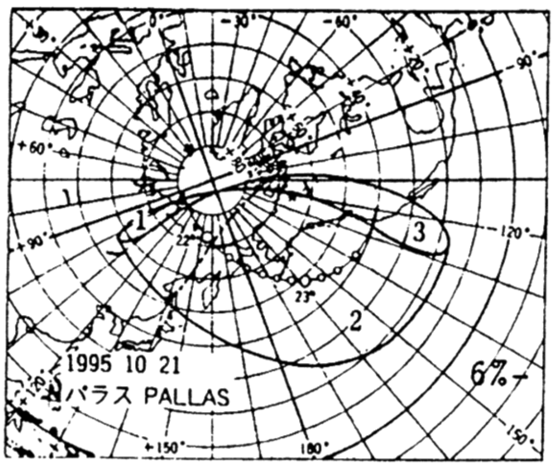
Those interested in observing partial occultations should request predictions at least three months in advance (if possible) from Joseph Senne; P. O. Box 643; Rolla, MO 65401; U.S.A.; phone 314,363-6233; E-mail c0458@umrvmb.umr.edu.











FAVORABLE MINOR PLANET OCCULTATIONS FOR 1995-2005

Edwin Goffin

The one unspoken wish of every observer of minor-planet occultations is to once be able to observe and successfully time the occultation of a first-magnitude star by Ceres, both placed in a clear summer sky not too far from the zenith and with the moon at least 179 degrees away. At least that's what I imagine must cross the mind of an observer each time he has to conclude that the track of the occultation he just has been monitoring painstakingly for tens of minutes, missed his observing location by a few hundred kilometers - despite the most accurate star position available, freshly updated orbital elements and last-second astrometry.

Certainly that's what must have been in Henk Bulder's mind when, during the ESOP Symposium last year in Roden, he asked me whether there wasn't any spectacular minor-planet occultation in the near future, "something to look out for", he added. That reminded me that the answer to Henk's question was lying for more than two years in my room, buried under a pile of other papers. Indeed, in 1991 I had computed the occultations by minor planets larger than 200 km for a number of years in the future, but never had done anything with that material.

The description given in the first sentence, with a few minor additions (visible from three cities with more than one million inhabitants, ...) could serve as the definition for the Ideal Minor-Planet Occultation. But let's be realistic. Though occultations of stars by minor planets occur every day, the Ideal Occultation must be of an extreme rarity; and when it will happen, the law of You-Know-Who will ensure that it will only be observable from the Pacific Ocean in broad daylight. However, when relaxing the conditions somewhat, a few less-than-ideal events might show up in the coming years. With that in mind, I started browsing through the graphs I had made and selected a number of cases which in my opinion deserve the label "Favorable". I didn't use fixed values for the parameters that obviously are of importance (stellar magnitude, duration, ...), but instead considered each case separately.

The events I selected are given in the table below. The contents of the different columns should be clear. Note that, at the time, the computations were done in the FK4/B1950.0 system with the provisional version of the PPM South catalogue. Also, for stars where only the photographic magnitude was given, I derived the visual magnitude by subtracting 0.9, a value certainly too optimistic for a number of stars.

The way I indicated the area of visibility deserves some explanation :

- the order of the locations given indicates the direction is which the shadow moves
- the letters N,S,E,W indicate the cardinal directions (thus, S Australia refers to the southern parts of Australia and not only to the state of South Australia)
- a question mark means that the shadow just misses the country indicated.

Date (U.T.)	Minor planet	Star (J2000.0) α	δ	Vm	Δm	Max. dur. (s)	Area of visibility + Remarks
		h m	° '				
1995 Jan 4.36	15 Eunomia	8 02.49	+16 49.3	8.9	2.1	7.2	SE Australia (low altitude)
1995 Feb 8.17	52 Europa	14 46.22	− 7 47.8	7.4	4.5	22.3	N Africa, S Spain ?
1995 Mar 11.97	94 Aurora	5 40.76	+31 52.9	8.7	4.4	14.4	Ireland, SW England, France
1995 May 27.73	7 Iris	0 41.20	+ 9 21.3	5.8	4.3	5.1	New Zealand ? (low altitude)
1995 Jun 25.58	3 Juno	17 42.42	− 4 46.1	8.5	1.7	18.4	N parts of Australia
1995 Dec 21.30	29 Amphitrite	6 01.66	+33 46.1	9.1	0.6	21.0	S Canada
1996 Jan 9.71	532 Herculina	10 49.03	+20 53.2	8.1	1.7	25.3	E China, Japan ? (full moon 17°)
1996 Feb 6.37	2 Pallas	14 38.25	+ 0 53.0	8.9	0.7	27.9	E Venezuela, W Brazil, N Peru
1996 Feb 18.48	532 Herculina	10 35.72	+29 06.2	8.1	1.2	20.2	S Japan, S Korea, Peking (low altitude)
1996 Apr 1.44	31 Euphrosyne	10 21.06	+41 51.0	5.8	5.6	17.9	Japan
1996 Jun 10.11	1 Ceres	16 20.49	−18 41.4	7.9	0.5	80.2	S Africa ? (low altitude), S Argentina, S Chili
1996 Jul 20.95	15 Eunomia	12 22.91	−14 39.8	7.9	3.3	11.4	Chili, N Argentina, Paraguay, S Brazil
1996 Aug 3.54	4 Vesta	15 09.57	−13 33.7	9.1	0.2	31.9	S Australia
1996 Sep 30.76	121 Hermione	4 25.49	+17 55.7	3.5	9.0	149.4	S Thail./N Malays.,Cambod.,N Vietn.,E China (68 Tau)
1997 Jan 24.24	16 Psyche	11 14.49	+ 5 15.8	7.7	3.3	38.4	Brazil, Colombia (full moon 37°)
1997 Mar 26.64	532 Herculina	19 15.43	−16 06.0	8.0	3.0	9.8	N New Zealand ?
1997 Apr 16.02	324 Bamberga	7 52.82	+23 30.0	8.4	4.1	13.7	SE USA
1997 Jun 30.65	87 Sylvia	20 38.73	−29 15.7	8.9	3.1	25.6	SE Australia (Sydney ?, Melbourne ?)
1997 Jul 22.13	1 Ceres	23 20.95	−18 59.3	8.1	0.8	132.2	E Venezuela, W Brazil, S Peru
1997 Jul 25.44	7 Iris	13 16.85	−11 46.2	8.5	2.8	10.1	S Australia
1997 Aug 14.42	1 Ceres	23 10.94	−21 43.7	9.1	0.3	78.8	Venezuela, Colombia, N Peru
1997 Sep 18.97	532 Herculina	18 56.45	−27 30.4	9.2	2.0	25.8	E coast USA (Greenbelt ?, low altitude)
1997 Sep 30.97	13 Egeria	14 57.46	−21 24.9	6.0	6.3	5.4	Hawaii ? (FK4 star = 33 Lib)
1997 Nov 2.55	2 Pallas	19 27.86	+ 2 10.5	7.8	2.8	19.8	SW tip of Australia ? (low altitude)
1998 Jul 23.67	7 Iris	19 04.14	−17 45.6	8.8	0.8	18.6	N Australia (Darwin ?)
1998 Jul 23.84	15 Eunomia	2 06.82	+25 42.3	5.0	4.7	11.3	Sunda Islands, Sulawesi (star = 11 Ari)
1998 Aug 25.53	24 Themis	15 21.01	−18 53.2	8.6	4.4	11.6	SW, S and Mid-E Australia
1998 Sep 30.03	52 Europa	5 31.55	+15 19.3	7.8	3.8	27.3	S Africa
1998 Nov 21.03	45 Eugenia	5 17.77	+13 38.4	7.3	4.6	18.3	N Russia, Finland, Mid Sweden, S Norway
1998 Dec 23.51	3 Juno	15 32.18	−10 20.9	9.1	2.5	7.1	Midd. of East USA

1999 Apr 3.44	121 Hermione	12 14.45	+ 8 46.9	7.4	5.6	14.2	NW USA, SW Canada
1999 Jul 27.89	4 Vesta	11 13.54	+10 50.9	8.8	0.4	12.2	Brazilian coastal area (Sao Paulo ?)
1999 Oct 2.80	2 Pallas	7 16.71	−13 27.3	8.3	1.1	18.8	N Japan
2000 Mar 1.31	704 Interamnia	18 06.86	−30 43.9	8.6	3.7	12.8	N coast of S America
2000 Apr 21.48	532 Herculina	5 47.49	+22 55.3	8.1	3.1	6.6	NE China (Shangai ?), S Japan (Kyushu)
2000 Oct 4.43	4 Vesta	19 42.39	−26 26.6	8.2	0.4	37.5	Sunda Islands, New Guinea, N Australia ?
2000 Nov 16.40	324 Bamberga	2 47.37	+39 54.9	7.9	1.3	39.4	NE China, Japan ?
2000 Nov 23.74	3 Juno	21 33.75	−13 31.1	9.1	1.2	11.9	S Africa
2001 Feb 16.33	107 Camilla	11 28.78	+ 1 12.2	7.6	4.5	21.4	S Brazil, Paraguay, Bolivia
2001 Feb 16.86	31 Euphrosyne	3 17.32	+42 54.8	9.9	1.8	14.6	N Norway, N Sweden, Finland, Russia
2001 Mar 15.95	423 Diotima	13 37.26	+ 4 25.1	8.2	3.8	21.7	Mid India, Turkey, N Italy, Switzerland, Mid France
2001 Mar 22.18	121 Hermione	19 35.04	−24 21.8	8.8	4.8	8.1	S coast of S Africa (morning twilight)
2001 Jul 12.13	702 Alauda	19 41.47	−20 05.1	8.7	2.9	13.9	N Brasil, Colombia
2001 Nov 28.75	48 Doris	6 08.51	+13 58.3	5.9	5.4	22.9	N Australia
2002 Mar 18.15	87 Sylvia	13 53.66	+ 0 55.2	8.3	4.3	24.2	Brazil, Colombia
2002 Dec 7.13	29 Amphitrite	21 01.97	−19 14.7	8.8	2.4	6.5	Mid W coast USA (low altitude)
2003 Feb 2.61	7 Iris	0 32.39	+ 6 57.3	5.7	4.1	5.4	N Russia (FK4 Sup star = 51 Psc)
2003 Mar 23.4	704 Interamnia	7 27.15	+11 57.3	6.5	5.3	66.2	N Japan (Hokkaido)
2003 Sep 25.22	94 Aurora	8 03.52	+27 43.7	5.0	8.4	7.3	Newfoundland, Iceland, N UK ? (FK4 star = χ Gem)
2004 Jul 20.69	3 Juno	18 55.88	− 5 44.7	8.2	1.7	19.9	N Japan, China, NW India
2004 Dec 12.40	375 Ursula	6 56.68	+42 46.2	9.1	3.3	16.8	NE USA (Wash.?, Chicago?), SW Canada (Vancouver?)
2005 Feb 17.67	7 Iris	16 47.36	−24 42.4	9.1	2.3	9.0	Mid-W Australia (low alt.), New Zealand
2005 Feb 28.07	52 Europa	8 47.44	+19 55.3	7.7	3.0	34.3	N coast of S America, Mexico
2005 Apr 27.92	13 Egeria	11 17.96	+21 28.1	9.0	2.1	23.6	Russia, Hungary, Croatia, Italy
2005 Jun 5.82	1 Ceres	14 50.07	− 8 57.1	8.6	0.3	112.0	S Africa
2005 Aug 24.54	48 Doris	21 09.62	− 9 40.5	8.1	3.5	17.5	N Australia
2005 Dec 3.55	52 Europa	13 54.97	− 5 43.9	8.4	3.9	7.2	W parts of N USA

ASTEROID PRO

David W. Dunham

"Asteroid Occultations Made Easy" proclaims the headline for an add for Asteroid PRO, sold for $169.95 by Pickering Anomalies, on p. 79 of the 1994 October issue of **Sky and Telescope**. "Accurately locates over 400 world wide occultations per month, compared to the one or two for North America found in popular publications". Interesting, but how accurate? The larger number of events is found by considering all numbered minor planets (over 5500), most of them much smaller than the 50-km limit considered by even Edwin Goffin in the searches that he performs for IOTA. Like Goffin, Asteroid PRO uses the PPM and ACRS catalogs totaling about 340,000 stars, so there is nothing new there. Asteroid PRO uses an exclusive perturbation scheme that claims to represent the asteroid paths to the highest accuracy, but this accuracy is no better than the 1″ accuracy of most observations used to determine the orbits. At the current epoch, the PPM and ACRS positions are accurate to 0.″2 or a little worse, so the overall accuracy of most asteroid occultation predictions will be just over the ephemeris accuracy of about 1″. Since most of the asteroids have angular diameters of less than 0.″01, you will have less than one chance in 100 of seeing the large majority of events predicted by Asteroid Pro. Even if you're lucky enough to be in one of these narrow paths, you better not blink, since most events will last less than 1 second, making it pretty hard to make a timing good to 5% of the diameter. You're better off sticking with the larger objects predicted by IOTA, without the distracting clutter of a large number of unproductive small objects. As experienced observers know, it's hard enough to catch the big asteroid shadows. If you want to get a lot more practice finding star fields, or if you have a large telescope and just want to find many asteroids, Asteroid PRO can help you, but it will not make asteroid occultations any easier.

SOLAR SYSTEM OCCULTATIONS DURING LATE 1994

David W. Dunham

General: The predictions of occultations of stars by major and minor planets are given in two tables whose contents are described in subsequent sections of this article. Most of the asteroidal occultation prediction material distributed by IOTA was prepared by Edwin Goffin in Belgium and is discussed in the fifth section. Sources of the predictions, other information, including stellar diameters (when significant) and a priority list, and notes about individual events, are given in the last sections. Much of this article has been modified from previous versions, and some important new techniques for astrometric updates are discussed near Table 4 (priority list) below; maybe you could help with this interesting work. The discovery of Ida's satellite makes it more important to try to observe asteroidal appulses from pairs of independent stations, as discussed on pages 53-55 of the last issue.

Other more urgent demands have delayed preparation of this article until August. For earlier this year, observers have needed to rely on the predictions by Edwin Goffin. The input data for the local circumstances appulse program for the rest of 1994 were finally produced in early July and given to the graze computors for distribution to IOTA and IOTA/ES members. My distribution to the computors was accomplished about a week before the first Shoemaker-Levy 9 impact on Jupiter (see p. 53 of the last issue), so many observers received their local circumstance predictions in time for some of those events. All of my predictions for occultations by (1620) Geographos around the time of its close flyby late last month are not included in Goffin's coverage, so a major purpose of this article is to give B1950 and apparent place right ascensions and declinations of those occulted stars, given in Tables 1 and 2 described below. A preliminary ASCII version of this article and these tables was distributed by e-mail so that many observers could get this information before most of these events occurred. Very preliminary versions of the tables, without explanation, were distributed to the graze computors and to some others with the local circumstance prediction data. Lack of time has prevented producing finder charts for these events, but for Aug. 28 to Sept. 4, the chart on p. 75 of the August issue of **Sky and Telescope**, or the more detailed charts covering Geographos' track from late Aug. 27 to mid-September on pages 58 and 59 of the August issue of **Astronomy**, can be used. The Geographos predictions are mainly for those who want to see the asteroid pass near relatively bright stars. The chances of really seeing an occultation, as was the case for Toutatis for its close flyby in December 1992 [see **ON 5** (9), pp. 233-240], are very small. They might be improved by radar observations, but updated orbital elements and occultation paths from these will probably not be available until near the end of August at best.

Reporting Observations: Reports of observations of any of these events should be sent to Jim Stamm; 11781 N. Joi Drive; Tucson, AZ 85737; U.S.A.; see his article in **ON 6** (2), p. 46. Report positive or negative observations made under good conditions, but clouded-out attempts need not be reported. If a definite occultation is seen that could use some analysis for comparison with others, also send copies of the report to me at 7006 Megan Lane; Greenbelt, MD 20770-3012; U.S.A.; e-mail David_Dunham@jhuapl.edu, 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 Lawrence Wasserman; Lowell Observatory; Mars Hill Road, 1400 West; Flagstaff, AZ 86001; U.S.A.; e-mail lhw@lowell.edu. Alternatively, observers may send their reports to their local or regional coordinators, who can then send the results to Stamm, and, when appropriate, to Lowell Observatory. The addresses of the regional coordinators are given in "From the Publisher" on p. 25 of this issue. Forms for reporting the observations can be obtained from Stamm or from the regional coordinators. Please indicate on the forms to whom copies are being sent. These forms are preferred, but the forms of the International Lunar Occultation Centre (ILOC), or the equivalent IOTA/ILOC graze report forms, can be used for reporting timed occultations or appulses. The main 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 be sent to neither ILOC in Japan nor to Richard Wilds. Also, if the asteroid is visible, the time that it merged with the star to form one apparent object, and the time the two were again noticeably separated, should be reported, with an estimate of whether the asteroid passed north or south of the star, if possible. Copies of the ILOC forms can be obtained from ILOC, the IOTA secretary-treasurer (the McManuses in Topeka, KS), or from Richard Wilds; 3630 S.W. Belle Ave.; Topeka, KS 66614-4542.

Event Selection: I made computer comparisons of my combined catalog with ephemerides of all of the major planets and the giant comet P/Schwassmann-Wachmann 1 (P/Sm-Wm-1) for all of 1994 late last year, and all minor planets during the 2nd half of 1994 for which Edwin Goffin predicted (see section below) at least one event under the selection conditions that we used for the main part of the North American Asteroidal Occultation Supplement for 1994: The star must be brighter than mag. 12.6; the magnitude drop must be at least 0.5; and for angular diameters smaller than 0".021, the star must be brighter than mag. 5.1; 0".021 to 0".050, brighter than mag. 6.1; 0".051 to 0".060, brighter than mag. 7.1; 0".061 to 0".070, brighter than mag. 8.1; and 0".071 to 0".079, brighter than mag. 9.1. In a few cases, these conditions were violated, such as for interesting objects (mainly, unusual light curves that may indicate duplicity) like 44 Nysa, 624 Hektor, 1220 Crocus, 2060 Chiron, 3123 Dunham, and 5145 Pholus. In a few cases, stars just slightly fainter than these limits were accepted when Goffin's prediction indicated that the path might pass over areas with large numbers of observers. The numbers of the minor planets included in my combined catalog searches were 1, 2, 4, 9, 10, 11, 13, 15, 16, 18, 19, 29, 38, 44-49, 51, 52, 56, 57, 59, 70, 72, 85, 90, 91, 94, 120, 139, 145, 146, 156, 168, 185, 206, 211, 216, 230, 243, 308, 318, 324, 326, 346, 401, 405, 416, 442, 451, 476, 488, 489, 508, 511, 514, 521, 532, 624, 704, 747, 758, 773, 1220, 1620, 2060, 3123, and 5145. Some of these were computed last year for all of 1994 to get data for North American events in preparation for my article, "Planetary Occultations for 1994", in **Sky and Telescope 87** (2), pp. 72-74, but most were searched only for the second half of 1994, for the appulse prediction database (see below) and for this article. Most of these asteroids were selected because occultations by them had been found earlier by Goffin or by Lawrence Wasserman at Lowell Observatory (Wassermann published a list of possible 1994 North American asteroidal occultations in the **R.A.S.C. Oberver's Handbook** for 1994, but has not prepared an article about events worldwide). In addition, Fresneau Astrographic Catalog (FAC; contains stars to 13th magnitude from declinations +4° to +32°) comparisons were made for 49, 52, 216, 423, 1220, 1620, 3123, 5145, and P/Sm-Wm-1. No FAC searches were done for some interesting objects simply because the Ephemeris of the object remained outside the declination range of the FAC during the second half of 1994. There is one 1994 prediction of an occultation by Ceres listed in my 1992 article in **ON 5** (8), p. 205; see the individual note about this event. Occultations of additional faint stars by (2060) Chiron, observable only with relatively large telescopes using photoelectric or CCD detectors, are given by S. Bus *et al.* in **Astron. J. 107** (5), p. 1814 (May 1994).

Occultations by Major Planets: The predictions of these events given here, including those for two bright stars for past events, have not been published by others, as far as I know. No occultations by Saturn were found, but some very difficult events, perhaps visible in infrared bands with large telescopes, are given by Bosh and McDonald in **AJ 103** (103), p. 983. Similarly, some difficult occultations of faint stars by Uranus and Neptune are given by D. Mink and A. Klemola in **AJ 102**, p. 389. Possible occultations by Pluto or by Charon are listed by D. Mink, A. Klemola, and M. Buie in **AJ 101**, p. 2255.

Asteroidal Occultation Predictions by E. Goffin: The 1994 Asteroidal Occultation Supplement for North

American Observers, prepared by Edwin Goffin with finder charts annotated by David Werner, was distributed with **ON** 6 (1) last November for IOTA members and **ON** subscribers in North America. Copies of Goffin's predictions and charts applicable to other parts of the world were sent by Jim Stamm a few months earlier to regional coordinators for distribution to members and subscribers in their regions. Goffin has continued to improve the orbits for many asteroids, and we have both used these for our predictions. Goffin is now using mainly the new PPM catalog, and is using the Hubble Guide Star Catalog (GSC) for fainter stars. He has augmented the PPM with ACRS data and my versions of the Lick-Voyager and Zodiacal Zone catalogs that he converted to the J2000 system. I've had to continue to use my Combined Catalog (CC), and my version of Fresneau's Astrographic Catalog (FAC), since I am still using B1950 data, having lacked the time to convert my software to J2000. Even with these differences, most of our predicted events are in common, and our predicted paths are generally in good agreement. Of the events found by Goffin that I tried to compute, my most significant failure was for an occultation on September 7th by 773 Irmintraud. I calculated that the path missed the star by about 40", but I found another occultation on August 25. Goffin found a typographical error in the orbital elements he used, and confirmed my event when the error was corrected. But since both events are now past, they are not listed in the table. The correct event was included in the local circumstances dataset distributed in early July. Other events for which Goffin did not produce charts, because the events missed the Earth's surface by a short distance or were potentially visible only from areas like the South Pacific and Indian Oceans with few or no known observers, include the occultations by asteroid numbers 15 (Dec. 26), 44 (Dec. 5), 168 (July 22 and 30), 185 (Aug. 24), 308 (Dec. 26 and 31), 521 (July 23 and Oct. 17), and 624 (Aug. 28).

Most of the PPM stars have SAO numbers, which I prefer to use, considering the more widespread availability of the SAO catalog. For the Lick-Voyager catalogs, DM numbers are often given (especially for L 3 and L 5 (Lick-Uranus and Lick-Neptune) stars in Sagittarius and Capricornus. Goffin only gave the four least significant digits of the DM numbers of these stars, most of which are from the Cordoba Durchmusterung (all Lick DM numbers south of -22°), where the numbers are all in the 10,000's for stars in Sagittarius and Capricornus. So 10,000 needs to be added to the DM numbers for these stars in Goffin's predictions.

David Werner's comparison of Goffin's finder charts with the True Visual Magnitude Atlas (TVMA) for North American events often shows that some GSC stars are brighter, fainter, or very faint relative to their plotted magnitudes, indicated with B, F, or VF, respectively. "N" indicates that the star is not shown in TVMA.

Explanation of data in Table 1: Read especially the important discussion about Δm given in the last paragraph of this section. The ranges of Universal Time give the time of central occultation (apparent closest approach to the center of the object) as seen from the predicted central line while it is on the Earth's surface and, except for bright stars, not in daylight. Only one time is given if the occultation shadow is on the Earth's surface in darkness (except for very bright stars) for less than two minutes. Under PLANET, m_v is the visual magnitude (photoelectric V-mag. when available), and Δ is the geocentric distance in astronomical units. For calculating m_v for asteroids, I have not used the new H and G magnitudes, using instead the B and B-V magnitudes published in the 1979 *Asteroids* book. I have written a subroutine that uses the more complex H and G magnitude calculations, but have not yet had time to incorporate it into my asteroidal occultation software. Under STAR, m_v is the visual magnitude (photoelectric V-mag. when available), except when the source is AC or GSC, and for some PPM stars not in the SAO, when a photographic magnitude, closer to B-mag., is given. The star's spectral type, Sp, and its approximate equinox 1950 position are also given. If a star does not have an SAO number, see the DM/Id number in Table 2 for its preferred designation. Under OCCULTATION, Δm is the change in visual magnitude of the coalesced images that is expected if an occultation does occur, dur is the duration of a central occultation computed using the expected diameter of the occulting object. In some cases, diameters derived from previous occultations have been used. The 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, and consequently both the possible area of visibility and P, can be reduced considerably by last-minute astrometric photographs, preferably with the asteroid and star on the same plate, which may be possible only 2 or 3 days before the event. No values are listed under Δm for occultations by major planets, except in the cases where the star is less than five magnitudes fainter than the planets. The extent of the planet, and the fact that events can occur against its dark side, make Δm meaningless for most occultations by major planets.

Under Possible Path, three pairs of numbers are listed, giving in integral degrees the longitude (Lo_, east of Greenwich positive) and latitude (La_) of the first (suffix "1"), middle ("m"), and last (or end, "e") points of the predicted observable occultation path, respectively. The corresponding central times for the first and last points are given under the Universal Time column. The path coordinates can be used to locate the paths on my quarterly maps showing the paths of all events worldwide, just as the coordinates for the center of graze paths are used to locate lunar occultation limits plotted in the grazing occultation supplements. You should know your own longitude and latitude so that you can tell which events are near you, but it is easier to estimate this from the direct calculations in the local circumstance predictions distributed by Carroll and Bode, or from examination of the regional maps. If the centerline of the occultation misses the Earth's surface, I have manually inserted a description of the possible region of visibility, enclosed in parentheses and followed by a ? and either an "n" or "s" to indicate whether a northward or southward correction, or shift, from the nominal path is needed to move the path into the possible area. If a shift of more than 1″ is needed, the approximate amount of the shift is indicated. Also not on the quarterly maps are polar-region paths entirely north of latitude +65° or south of latitude -50°, and all asteroidal occultations where the path does not intersect the Earth's surface at locations where the star is sufficiently above the horizon and the Sun enough below it for possible observation.

After Possible Path, the elongation of the Sun from the target star is given under the El Sun column. Under Moon, the elongation from the target star is given under El, the percent sunlit ("+" for waxing and "-" for waning phases) is given under %Snl, and the longitudes from which the Moon will be above the horizon along the possible path 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, along the entire possible path 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 asteroids and comets, I have generated the ephemerides by numerically integrating the orbital elements given in the specified source. For the major planets, NAO001 is a U.S. Naval Observatory data set, used for Venus through Uranus. The other planets are obtained by my n-body integration of a Jet Propulsion Laboratory (JPL) Development Ephemeris #130 (DE130) solar system state provided by Doug Mink at the Center for Astrophysics in Cambridge, MA. Most of the asteroidal orbital elements have been published in recent issues of the **Minor Planet Circulars** (MPC), and many have been obtained automatically using the JPL DASTCOM3 database, a recent (late May) version of which was kindly supplied by Don Yeomans. I have converted the J2000 orbital elements to B1950 for use with my software. EMP stands for the Institute of Theoretical Astronomy (St. Petersburg, Russia) **Ephemerides of Minor Planets**. For some objects, orbital elements by Kristensen (University of Aarhus, Denmark), Landgraf (then at the Max-Planck Institut für Aeronomie, Lindau, Germany), Marsden (Minor Planet Center, Cambridge, MA), Schmadel (Astronomisches Rechen-Institut, Heidelberg, Germany), Sitarsky (Poland), and Yeomans (JPL) have been used. One of the most important columns in the table is Δm, since it specifies the observability of the event. If a photographic magnitude has been used for the star (the case for source GSC or A.C. noted above in the discussion of m_v for stars), it will usually be brighter visually than the tabulated value (by a magnitude or more for reddish spectral-type K and M stars; no brighter for the less common bluish type O, B, and A stars), so that the actual Δm may be much larger than the given value. I plan to correct this problem with a future star catalog update. A Δm value much less than 1.0 in general means that the event can be reliably observed only photoelectrically or with video equipment. The chances of seeing smaller Δm's visually is increased if the star is relatively bright, or if a larger telescope is used to increase the apparent brightness of a faint star; variable star observers familiar with estimating small magnitude differences may also have some advantage with small magnitude drops. Good atmospheric seeing (low scintillation) and bluer stars (to produce a color change, since asteroids are mainly orangish in color, like a spectral type K star) also help. Δm's of 0.4 and smaller have been detected visually, but usually with unacceptably long reaction times.

Explanation of data in Table 2: 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 kilometers (km), and the apparent angular diameter in arc seconds ("), are given. For the source of diameters of asteroids, see the discussion of occultation duration above. Under RSOI, "Radius of Sphere Of Influence," the distance in km from the object is given where its gravitational attraction is equal to that of the Sun, assuming (pessimistically) that the mean density of the object 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 extinctions have actually been reported 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. For major planets, no value is listed under the RSOI column, since it is always greater than 99999 km.

After RSOI, the taxonomic Type is given for asteroids, as specified in pages 1139 - 1150 of *Asteroids II*, using the types given by David Tholen in his 1984 Ph.D. dissertation and amended by him for the book. A brief description of most of the classes is given below:

B C subclass, mainly members of Themis family
C carbonaceous, low albedo, most common outer belt
D dark (very low albedo), common for Trojans
E enstatite achondrites, high albedo
F flat spectrum, C subclass, mainly Nysa family
G C subclass, includes Ceres
I inconsistent data, can't classify
M metallic, moderate albedo
P pseudo-M, low albedo, spectra like M
Q Apollo (almost unique spectrum)
S silicate, moderate albedo, most common in the inner asteroid belt
T transition between S and D; not real sub class
V Vesta (almost unique spectrum)
X E or M or P (current data can't distinguish; these have similar spectra, and differ only in albedo)

Tholen notes that his spectral/albedo "cluster analysis" defines 7 major classes: A (no special description), C, D, E, M, P, and S. In some cases, an asteroid's characteristics place it in an area between 2 or 3 of these classes, in which case each of the applicable class letters are used. Besides the other subclass and special types given above, Tholen also uses the following suffixes:

U unusual spectrum, far from class cluster center
: noisy data
:: very noisy data
— data too noisy to permit classification.

The first value under Motion is the geocentric angular velocity of the occulting object in degrees/day. Multiply it by 2.5 to obtain the angular rate in seconds of arc per minute, which is useful for estimating when the asteroid's and star's images will merge, and how long it will be before they 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 P.A.

The star's Bonner Durchmusterung (BD) or Cordoba Durchmusterung (CD) declination zone and catalog numbers are given under the DM/Id No column, when available. The first character of the zone column identifies the catalog:

character	identification
+	BD (Bonner Durchmusterung)
-	BD (usually the southern part, sometimes called S.D.)
C	CD (Cordoba Durchmusterung; -)
P	Cape Photographic Durchmusterung (-)
L	Lick Voyager catalogs; the five Lick "zones" are given below; the number within the zone is sequential in 1950 R.A.
L 1	Lick Jupiter, or LJ (Gemini, Cancer)
L 2	Lick Saturn, or LS (Leo, Virgo)
L 3	Lick Uranus pre-encounter, or LU (Sgr)
L 4	Lick Uranus post-encounter, or LV (Gem)
L 5	Lick Neptune, or LN (Capricornus)
M	PPM catalog number, not in SAO
A	Northern Astrographic Catalog (AC, +) The first 2 digits are usually the R.A.-sequential plate no. in the zone, while the last 3 are the number on the plate.
B	Southern AC (- zones); the number is usually sequential throughout the zone, approximately by R.A.
Q	Measured from a Palomar Schmidt plate (only a few in Scorpius)
#	If the entire DM/Id No. field is filled with 8 digits, the designation is the star's number in the Guide Star Catalog.

Following the star's numbers is the column D, the star's double star code. 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 previously from the U.S. Naval Observatory (USNO), but now the double star code explanations are included in the detailed total occultation prediction (PC-Evans) explanation now distributed by IOTA national and regional coordinators. For double

1994 Date	Universal Time h m	PLANET Name	m_v	Δ, AU	STAR SAO No	m_v	sp	R.A.(1950) h m	Dec.	Occultation Δm	dur s	DF	P	Possible Path LolLa1	LomLam	LoeLae	El Sun	MOON El	%Snl	up	Ephem. Source
Mar 5	10 26	Venus	-3.9	1.670	146915	5.5	K0	23 45.4	-3° 2'		194	4	1	(e.China, Ph.Is.),low			12°	94°	44-	all	NA0001
Jun 12	0 54	Mars	1.2	2.091	93113	6.8	K0	2 45.2	15 18		146	6	1	52-18	62-15	73-11	37	72	11+	none	NA0001
Jul 13	6 21	Mars	1.2	1.991	76548	5.3	B8	4 16.5	21 1		161	7	1	S.Atlantic;s.Africa-day			44	99	21+	none	NA0001
Jul 14	14 7-21	Kleopatra	10.9	1.739	0	11.9		23 22.7	13 9	0.4	27	31	11	133-12	165 11	-167 44	114	163	32+	none	Goffin89
Jul 21	1 59-62	Pallas	9.5	2.762	130232	8.2	K5	2 57.5	-0 51	1.6	19	12	8	0-51	40-62	110-80	76	130	92+	w 36E	Goffin87
Jul 21	16 37-53	Princetonia	12.5	2.158		10.4		19 56.9	-39 39	2.3	12	23	21	-178 4	114-37	21-20	161	42	95+	all	MPC19475
Jul 22	22 45	Sibylla	13.0	2.715	109306	7.8	F5	0 33.5	6 53	5.2	23	48	26	Europe?s			109	67	97-	all	MPC14159
Jul 23	3 12	Brixia	12.3	2.521	94158	7.1	F8	4 47.5	17 7	5.2	3	8	30	S. Africa? 2"n			47	126	97-	all	MPC22573
Jul 23	9 58-66	Geographos	14.6	0.236	177454	6.8	A0	9 24.4	-23 57	7.8	1	25	68	108-45	128-51	154-49	48	153	97-	e126E	Yeomans
Jul 26	10 47-67	Antiope	11.9	1.674		9.5		21 27.6	-18 18	2.5	14	29	19	-75-13	-138-44	116-50	164	30	85-	e145E	MPC12190
Jul 27	2 15-30	Magdalena	14.1	2.427	163665	5.6	G5	20 29.7	-10 1	8.4	6	22	42	46 15	-30-14	-122-28	170	47	81-	e 76W	MPC12304
Jul 30	13 56-92	Sibylla	12.9	2.617	109320	9.5	G0	0 35.3	7 4	3.5	43	90	25	132 -3	171 9	-147 29	116	27	54-	e146E	MPC14159
Aug 1	13 17-33	Hermentaria	10.5	1.690	189736	8.4	F0	20 46.4	-26 32	2.3	10	23	22	-113 -6	-172-49	52-57	172	105	36-	e178E	MPC22200
Aug 3	9 2-18	Vaticana	11.1	1.545	207479	6.6	G0	16 11.0	-31 32	4.5	12	34	25	121-51	-163-65	-94-43	116	144	20-	e 97W	MPC22473
Aug 6	22 48	Geographos	13.6	0.134	200417	7.5	MB	9 27.2	-33 27	6.1	1	20	39	-68-12	-67-12	-66-12	50	36	2-	none	Yeomans
Aug 7	8 21-26	Geographos	13.6	0.131	200421	7.9	F8	9 27.4	-33 49	5.7	1	19	38	-24-51	-39-51	-55-46	51	35	2-	e 34W	Yeomans
Aug 8	22 55-69	Magdalena	14.1	2.435	163517	9.0	K0	20 20.5	-11 3	5.1	6	22	43	78 24	7 -6	-74-26	166	147	4+	w 58W	MPC12304
Aug 11	21 43-59	Winchester	10.7	1.456		9.7		1 9.4	-12 11	1.4	16	21	12	20 28	70 -8	129-53	125	168	22+	none	MPC22386
Aug 13	9 20-29	Leda	13.2	2.180		9.9		19 48.2	-19 45	3.4	10	25	26	-115 47	-160 35	153 39	156	82	36+	w156W	MPC14158
Aug 15	16 1-26	Nysa	10.8	1.729	128590	9.2	K0	0 4.6	-3 0	1.8	12	43	34	-158 0	157-32	81-64	142	112	63+	w131E	MPC11982
Aug 15	19 28-30	Thia	12.5	2.086		9.7		14 7.0	-15 20	2.9	4	9	23	-19-30	9-29	41-23	73	42	64+	all	MPC13443
Aug 18	4 59-65	Geographos	11.7	0.061	237068	7.7	B9	9 29.7	-53 35	4.0	1	7	18	21-51	-9-49	-31-36	67	119	87+	w 24W	Yeomans
Aug 19	21 58-78	Psyche	9.8	1.733		10.6		20 36.4	-17 14	0.4	28	27	10	79 25	15 -4	-56-17	161	17	96+	all	Goffin87
Aug 20	18 56-58	Bamberga	12.7	3.846		9.8		13 12.8	-17 44	3.0	8	13	24	-7-18	9-17	29-13	57	121	98+	all	MPC22200
Aug 21	17 32-48	Adeona	12.6	2.012	191848	8.6	G0	23 19.7	-24 31	4.0	12	22	19	175 20	115-27	16-38	158	29	99-	all	MPC15527
Aug 22	0 3- 9	Geographos	10.5	0.041		8.8	K5	9 36.5	-74 34	1.9	1	4	12	-94-60	-57-48	-42-23	87	105	99-	e 84W	Yeomans
Aug 23	17 52	Hygiea	10.7	3.146	158139	9.2	K0	13 42.4	-13 36	1.8	13	10	11	2-46	26-47	54-44	59	149	94-	e 28E	Goffin86
Aug 23	19 51-60	Geographos	9.8	0.035		8.4	G0	19 44.9	-87 58	1.7	0	3	10	154-48	107-40	90 -7	103	89	94-	all	Yeomans
Aug 23	20 42-52	Geographos	9.8	0.035	258853	8.2	G0	20 4.2	-87 38	1.8	0	3	10	-146-86	38-51	37 -7	104	88	94-	e 77E	Yeomans
Aug 24	8 26-37	Geographos	9.6	0.034	258880	6.9	G0	21 1.2	-82 14	2.8	0	3	10	104-81	-149-47	-146 0	109	85	92-	e178E	Yeomans
Aug 24	16 41-43	Eunike	12.2	2.443	112411	8.7	K0	5 3.0	0 16	3.6	6	12	21	134 37	159 34	-174 30	77	67	90-	all	MPC14753
Aug 24	22 5-14	Geographos	9.4	0.033	257904	6.6	A0	21 12.9	-75 33	2.9	0	3	10	-67-60	-20-34	-13 6	115	81	89-	e 23W	Yeomans
Aug 24	22 40-51	Geographos	9.4	0.033	257903	8.4	K2	21 12.1	-75 14	1.4	0	3	10	115-60	46-41	34 3	115	81	88-	all	Yeomans
Aug 25	2 9-19	Geographos	9.4	0.033	257908	8.8	F5	21 14.3	-73 31	1.1	0	3	10	-131-70	-70-40	-64 6	117	80	88-	e 82W	Yeomans
Aug 25	2 40-50	Geographos	9.4	0.033	257905	6.9	K0	21 13.4	-73 14	2.6	0	3	10	53-43	4-33	-8 4	117	80	87-	all	Yeomans
Aug 25	9 37-39	Aurora	13.5	3.723	158404	9.3	G5	14 8.2	-18 55	4.2	8	14	25	132 -9	153 -8	175 -4	65	156	86-	e168E	MPC23324
Aug 25	10 39-43	Geographos	9.3	0.033	254975	8.5	A2	21 15.6	-69 13	1.2	0	3	10	-73-14	-88-14	-97 -4	121	79	85-	all	Yeomans
Aug 25	15 15-28	Geographos	9.2	0.033	254982	8.1	A2	21 17.2	-66 53	1.5	0	3	10	-120-76	133-41	128 12	123	79	84-	all	Yeomans
Aug 25	19 44-55	Geographos	9.2	0.033		7.7	M1	21 17.7	-64 37	1.8	0	3	10	157-45	103-32	92 9	125	78	83-	all	Yeomans
Aug 25	22 59-74	Irmintraud	12.4	1.666	164424	8.5	F5	21 26.3	-14 1	4.0	8	21	24	93-38	5-43	-75-25	168	63	82-	e 26W	MPC19478
Aug 26	4 4-17	Geographos	9.1	0.034	254988	9.3	G0	21 19.1	-60 28	0.7	0	3	10	36-71	-52-38	-57 18	129	78	80-	all	Yeomans
Aug 26	12 0-11	Geographos	9.1	0.034	247008	9.8	F8	21 20.4	-56 37	0.5	0	3	10	90-58	131-27	133 18	133	79	78-	none	Yeomans
Aug 26	13 44-58	Geographos	9.1	0.034	247006	7.5	F8	21 20.1	-55 45	1.8	0	3	10	-108-63	170-35	165 21	133	79	77-	all	Yeomans
Aug 26	15 21-35	Geographos	9.1	0.034	247009	9.1	K0	21 20.4	-54 59	0.7	0	3	10	-79-86	116-34	115 25	134	79	77-	all	Yeomans
Aug 26	16 37-48	Geographos	9.1	0.034	247007	9.8	G0	21 20.2	-54 23	0.4	0	3	10	-159-45	148-29	141 14	135	79	76-	all	Yeomans
Aug 26	20 47-56	Geographos	9.1	0.035	247010	9.1	K2	21 20.5	-52 27	0.7	0	3	10	136-35	96-24	88 11	136	80	75-	all	Yeomans
Aug 27	2 17-21	Io	11.4	1.901		9.5		16 44.4	-8 22	2.1	11	19	18	-95 52	-73 42	-48 39	98	145	73-	e 62W	MPC15525
Aug 27	3 27-43	Geographos	9.0	0.035	230668	8.5	K0	21 21.3	-49 24	1.0	0	3	10	116-86	-67-33	-67 30	139	81	73-	all	Yeomans
Aug 27	5 44-60	Geographos	9.0	0.036	230669	9.3	A0	21 21.3	-48 23	0.6	0	3	10	9-76	-86-31	-87 30	140	82	72-	all	Yeomans
Aug 27	11 29-61	Kleopatra	9.9	1.304		11.9		23 21.1	14 36	0.2	40	39	8	-106 41	-177 17	123-14	151	53	70-	e157E	Goffin89
Aug 27	12 45-53	Geographos	9.0	0.036	230676	7.2	A0	21 22.1	-45 23	2.0	0	3	11	79-33	99-10	95 19	143	84	70-	none	Yeomans
Aug 27	13 1-17	Geographos	9.0	0.037	230674	8.8	K0	21 21.8	-45 14	0.9	0	3	11	33-87	146-29	145 34	143	84	69-	e140E	Yeomans
Aug 27	15 19-36	Geographos	9.0	0.037	230675	9.3	A0	21 21.9	-44 16	0.6	0	3	11	-120-86	118-30	117 35	144	85	69-	all	Yeomans
Aug 27	21 5-22	Geographos	9.0	0.038	230678	7.5	M1	21 22.3	-41 55	1.8	0	4	11	-59-77	13-24	10 39	146	87	66-	none	Yeomans
Aug 28	3 28-45	Geographos	9.0	0.038	212988	8.5	A2	21 22.6	-39 26	1.1	0	4	11	-148-70	-88-23	-93 38	148	89	64-	none	Yeomans
Aug 28	3 32-49	Geographos	9.0	0.038	212987	9.4	G8	21 22.5	-39 24	0.6	0	4	11	-152-82	-77-24	-80 40	148	89	64-	none	Yeomans
Aug 28	12 38-57	Geographos	9.1	0.040	212992	7.7	K0	21 22.8	-36 3	1.7	0	4	12	-75-80	162-25	163 45	150	93	60-	all	Yeomans
Aug 28	12 53-71	Geographos	9.1	0.040	212991	10.0	G	21 22.7	-35 58	0.4	0	4	12	-100-77	163-27	164 40	150	93	60-	all	Yeomans
Aug 28	14 12	Hektor	14.4	4.369	190058	7.7	K2	21 6.2	-27 19	6.7	14	26	28	(N.Z., Tasmania)? 2"n			155	97	60-	e135E	MPC22797
Aug 29	6 23-42	Leda	13.4	2.297		10.7		19 38.8	-19 47	2.8	17	43	28	-45-40	-106-55	172-51	138	126	53-	e101W	MPC14158
Aug 29	11 53-73	Geographos	9.2	0.044	190338	8.9	K0	21 23.6	-28 34	0.9	1	4	13	90-68	142-16	131 47	156	103	51-	none	Yeomans

Table 2, Part A.

1994 Date	Minor Planet No.	Name	km-Diam.	-//	RSOI	Type	Motion °/Day	P.A.	Star SAO No	DM/ID No	D	Min. U. T. h m	Geocentric Sep. "	S	Comparison Data AGK3 No	Shift "	Time m	Apparent R.A. h m	Dec.
Mar 5		Venus	12220	10.09			1.246	65°8	146915	- 3°5707		10 25.9	3.29N	FU		0.06	-0.1	23 47.6	-2°48'
Jun 12		Mars	6782	4.47			0.734	72.0	93113	+14 469		0 56.4	0.31S	UR	N15° 243	0.02	0.1	2 47.7	15 29
Jul 13		Mars	6782	4.70			0.700	79.2	76548	+20 733	V	6 21.2	4.63S	UZ	N21 404	-0.29	0.0	4 19.1	21 8
Jul 14	216	Kleopatra	230	0.18	1051	M	0.161	45.1		11680464		14 17.5	2.35N	C				23 25.0	13 24
Jul 21	2	Pallas	533	0.27	4297	B	0.340	106.0	130232	- 1 429		2 0.5	2.92S	A	S 0 322	0.35	-0.5	2 59.8	-0 42
Jul 21	508	Princetonia	147	0.09	720	C	0.190	255.2		M 299641		16 45.0	0.10N	M				19 59.9	-39 32
Jul 22	168	Sibylla	154	0.08	786	C	0.082	66.5	109306	+ 6 76		22 45.0	3.50N	UX	N 6 60	-0.07	0.6	0 35.8	7 8
Jul 23	521	Brixia	121	0.07	338	C	0.547	80.0	94158	+16 657		3 12.2	3.39S	UR	N17 425	-0.07	-0.1	4 50.1	17 12
Jul 23	1620	Geographos	5	0.03	1	S	0.540	171.7	177454	C23 8373		9 42.4	19.14E	YG		0.09	-0.9	9 26.4	-24 9
Jul 26	90	Antiope	125	0.10	480	C	0.174	247.2		M 238935		10 56.1	2.34S	M				21 30.1	-18 6
Jul 27	318	Magdalena	83	0.05	334	CXF	0.193	247.2	163665	-10 5423		2 22.7	0.30S	FU		0.16	0.6	20 32.1	-9 52
Jul 30	168	Sibylla	154	0.08	785	C	0.045	67.5	109320	+ 6 81		14 23.9	0.98N	UX	N 7 66	0.10	-4.0	0 37.6	7 19
Aug 1	346	Hermentaria	110	0.09	401	S	0.222	242.9	189736	C2615283		13 25.4	2.62S	US		0.09	-1.3	20 49.1	-26 21
Aug 3	416	Vaticana	90	0.08	241	S	0.155	108.2	207479	C3112689		9 4.9	2.81S	G				16 13.9	-31 39
Aug 6	1620	Geographos	5	0.05	1	S	0.908	178.7	200417	C33 6109		22 43.4	64.03E	S				9 29.1	-33 39
Aug 7	1620	Geographos	5	0.05	1	S	0.934	178.8	200421	C33 6113		8 3.8	42.38W	S				9 29.2	-34 0
Aug 8	318	Magdalena	83	0.05	334	CXF	0.189	243.7	163517	-11 5313		23 2.1	0.11N	UP		-0.39	1.2	20 22.9	-10 54
Aug 11	747	Winchester	178	0.17	673	PC	0.253	135.2		M 209865		21 52.0	1.31S	M				1 11.7	-11 56
Aug 13	38	Leda	120	0.08	530	C	0.175	267.5		L 5 1427		9 24.8	3.31N	H				19 50.8	-19 38
Aug 15	44	Nysa	73	0.06	209	E	0.115	229.8	128590	- 3 5761		16 10.5	2.13S	UX		-0.53	0.4	0 6.9	-2 44
Aug 15	405	Thia	129	0.09	383	C	0.487	99.7		M 228379		19 26.9	0.91S	M				14 9.4	-15 32
Aug 18	1620	Geographos	5	0.11	1	S	3.695	178.9	237068	P53 2513		4 53.2	90.17W	S				9 31.2	-53 46
Aug 19	16	Psyche	264	0.21	1497	M	0.183	248.5		L 5 4210		22 8.9	0.84N	H				20 39.0	-17 5
Aug 20	324	Bamberga	228	0.08	1510	CP	0.248	107.3		M 227018		18 53.9	0.25N	M				13 15.2	-17 58
Aug 21	145	Adeona	155	0.11	739	C	0.209	234.6	191848	C2417617	A	17 40.2	0.18S	S				23 22.1	-24 17
Aug 22	1620	Geographos	5	0.17	1	S	7.958	177.5		C74 622		0 0.2	103.15E	P				9 36.6	-74 46
Aug 23	10	Hygiea	429	0.19	3163	C	0.352	108.1	158139	-13 3763		17 49.8	1.16S	UX		-0.56	0.5	13 44.8	-13 50
Aug 23	1620	Geographos	5	0.20	1	S	10.955	17.9		P88 169		19 52.8	163.66E	P				20 11.3	-87 50
Aug 23	1620	Geographos	5	0.20	1	S	10.853	15.0	258853	P87 295		20 42.7	4.30E	G				20 26.4	-87 29
Aug 24	1620	Geographos	5	0.20	1	S	11.530	4.8	258880	P82 843		8 28.3	31.29W	G				21 8.7	-82 3
Aug 24	185	Eunike	165	0.09	663	C	0.357	105.6	112411	+ 0 940		16 45.0	1.33N	A	N 0 492	-0.64	0.1	5 5.3	0 19
Aug 24	1620	Geographos	5	0.21	1	S	11.994	2.6	257904	P75 1697		22 6.1	127.29W	PG		-0.39	0.0	21 17.8	-75 22
Aug 24	1620	Geographos	5	0.21	1	S	12.008	2.6	257903	C75 1695		22 43.5	125.90E	P				21 16.9	-75 3
Aug 25	1620	Geographos	5	0.21	1	S	12.073	2.3	257908	P73 2206		2 11.3	84.02W	G				21 18.9	-73 19
Aug 25	1620	Geographos	5	0.21	1	S	12.081	2.3	257905	P73 2205		2 43.4	186.79E	G				21 18.0	-73 3
Aug 25	94	Aurora	212	0.08	1361	CP	0.245	108.0	158404	-18 3763		9 35.4	0.67N	UX		-0.38	0.9	14 10.7	-19 7
Aug 25	1620	Geographos	5	0.21	1	S	12.139	1.9	254975	P69 3163		10 40.9	254.42E	PS		0.80	0.0	21 19.7	-69 2
Aug 25	1620	Geographos	5	0.21	1	S	12.118	1.7	254982	P67 3792		15 19.5	56.10E	G				21 21.1	-66 41
Aug 25	1620	Geographos	5	0.21	1	S	12.060	1.5		C64 4124		19 48.3	178.58E	P				21 21.4	-64 26
Aug 25	773	Irmintraud	99	0.08	338	D	0.236	278.2	164424	-14 6038		23 6.3	2.58S	UX		0.13	0.7	21 28.8	-13 49
Aug 26	1620	Geographos	5	0.20	1	S	11.856	1.4	254988	P60 7469		4 9.2	80.19E	S				21 22.6	-60 16
Aug 26	1620	Geographos	5	0.20	1	S	11.559	1.2	247008	P56 9638		12 3.0	128.69W	S				21 23.7	-56 25
Aug 26	1620	Geographos	5	0.20	1	S	11.479	1.2	247006	P56 9636		13 49.6	110.56E	G				21 23.3	-55 34
Aug 26	1620	Geographos	5	0.20	1	S	11.403	1.2	247009	P55 9579		15 26.4	6.79E	S				21 23.6	-54 48
Aug 26	1620	Geographos	5	0.20	1	S	11.342	1.2	247007	P54 9857		16 42.1	176.55E	S				21 23.4	-54 12
Aug 26	1620	Geographos	5	0.20	1	S	11.126	1.1	247010	P5211865		20 51.0	203.82E	S				21 23.6	-52 15
Aug 27	85	Io	157	0.11	574	FC	0.249	111.7		M 199998		2 18.0	4.10N	M				16 46.8	-8 27
Aug 27	1620	Geographos	5	0.19	1	S	10.739	1.0	230668	P4911409		3 33.7	2.62E	S				21 24.4	-49 12
Aug 27	1620	Geographos	5	0.19	1	S	10.599	1.0	230669	P4810570		5 50.8	55.16E	S				21 24.4	-48 11
Aug 27	216	Kleopatra	230	0.24	1007	M	0.146	240.5		11680215		11 43.3	1.17N	J		1.04	-7.8	23 23.4	14 51
Aug 27	1620	Geographos	5	0.19	1	S	10.152	1.0	230676	C4514332		12 47.4	192.80W	G				21 25.1	-45 11
Aug 27	1620	Geographos	5	0.19	1	S	10.129	1.0	230674	P4510144		13 8.0	6.32W	PS		-0.83	0.0	21 24.8	-45 2
Aug 27	1620	Geographos	5	0.19	1	S	9.975	1.0	230675	P4410012		15 26.2	16.58E	S				21 24.9	-44 4
Aug 27	1620	Geographos	5	0.18	1	S	9.581	0.9	230678	C42 9273		21 12.2	48.74W	PS		-0.87	0.1	21 25.2	-41 43
Aug 28	1620	Geographos	5	0.18	2	S	9.138	0.9	212988	C3914245		3 35.2	71.69W	S				21 25.4	-39 14
Aug 28	1620	Geographos	5	0.18	2	S	9.133	0.9	212987	C3914244		3 39.3	28.26W	PS		0.37	0.0	21 25.4	-39 12
Aug 28	1620	Geographos	5	0.17	2	S	8.500	0.9	212992	C3614794		12 46.6	31.27E	PG		-1.04	-0.1	21 25.5	-35 51
Aug 28	1620	Geographos	5	0.17	2	S	8.483	0.9	212991	C3614793		13 1.4	48.15E	S				21 25.5	-35 46
Aug 28	624	Hektor	225	0.07	2304	D	0.118	273.6	190058	C2715275		14 12.2	2.25S	PS		-0.47	-5.4	21 8.8	-27 8
Aug 29	38	Leda	120	0.07	529	C	0.100	271.6		L 5 595		6 35.0	2.29S	H				19 41.4	-19 41
Aug 29	1620	Geographos	5	0.16	2	S	6.978	0.9	190338	C2817274		12 2.3	68.45W	US		-0.59	0.0	21 26.2	-28 22

1994 Date	Universal Time h m	PLANET Name	m_v	Δ AU	STAR SAO No	m_v	sp	R.A. (1950) h m	Dec.	Occultation Δm	dur s	DF	P	Possible Path Lo1La1 LomLam LoeLae	El Sun	MOON El	%Snl	up	Ephem. Source
Aug 30	9 1	Metis	11.1	2.958		9.3	F8	8 36.6	21 30	2.0	4	7	23	-68 14 -64 15 -56 18	30	55	42-	all	MPC11234
Aug 31	1 23-50	Geographos	9.4	0.052	164395	7.8	K2	21 24.2	-19 17	1.9	1	6	15	150-88 -40-15 -40 62	160	123	35-	e150E	Yeomans
Sep 1	19 34-66	Geographos	9.8	0.062	164405	6.8	F5	21 24.9	-11 53	3.0	1	7	18	-39-83 38-11 28 69	161	146	19-	none	Yeomans
Sep 5	23 41-43	Interamnia	11.7	3.534		9.5		15 1.2	-26 27	2.3	12	14	15	-80-47 -50-39 -23-26	68	64	0+	none	MPC22386
Sep 7	16 35-76	Geographos	11.1	0.101	126828	8.6	A3	21 26.8	0 55	2.6	1	16	29	158-55 118 -2 153 48	155	134	4+	none	Yeomans
Sep 11	11 37	Ceres	8.9	3.124	79805	6.7	B8	7 53.1	23 45	2.3	26	10	5	(Alaska, Yukon)?s	52	122	37+	none	MPC12187
Sep 11	11 52-96	Geographos	11.7	0.129	126853	9.2	K5	21 28.3	4 51	2.6	2	22	37	-135-46-164 -3-134 34	152	78	37+	none	Yeomans
Sep 12	3 38-106	Geographos	11.8	0.133	126860	8.4	M0	21 28.7	5 21	3.4	2	24	39	-118-70 -94 2 -75 78	151	69	45+	all	Yeomans
Sep 17	10 35	Venus	-4.5	0.501	158446	8.4	F0	14 12.0	-18 12		1131	13	1	117-39 132-38 149-35	43	112	94+	all	NAO001
Sep 17	21 19-40	Aglaja	11.6	1.658	109626	8.1	A0p	1 0.2	7 14	3.6	15	28	18	120 30 44 21 -26 6	157	44	96+	w104E	MPC15524
Sep 21	8 12-106	Geographos	12.9	0.203		9.9		21 33.6	9 40	3.0	3	45	59	-167-68-149 -3 -98 36	144	50	98-	all	Yeomans
Sep 25	6 27-46	Egeria	11.4	2.075		10.2		21 19.0	-38 31	1.5	26	35	14	-49-17-106-10-131 40	125	98	76-	all	Goffin87
Sep 26	20 21-98	Geographos	13.4	0.248		10.0		21 37.4	10 53	3.5	3	52	72	-28 7 -4 43 84 70	141	115	61-	e 22E	Yeomans
Sep 27	12 49-105	Geographos	13.5	0.253		11.5		21 37.9	11 1	2.1	3	52	73	150-64 159-31-172-14	140	123	55-	e155E	Yeomans
Sep 30	0 23-44	Kleopatra	9.7	1.217		11.4		23 0.3	9 31	0.2	26	25	8	52 36 -11 0 -53-65	158	134	29-	e 15E	Goffin89
Sep 30	3 10-13	Lachesis	13.0	2.999	186005	9.4	B8	17 54.9	-29 4	3.7	8	16	24	-128-34 -95-21 -66 -4	83	137	28-	none	MPC22665
Oct 1	0 34-79	Geographos	13.8	0.283		11.5		21 40.8	11 29	2.4	2	51	82	-90 39 -61 61 24 73	138	163	20-	e 14E	Yeomans
Oct 8	7 57-72	Juewa	12.7	2.518	164827	6.4	G5	21 59.5	-18 9	6.3	24	47	23	-59-59-139-64 157-45	131	94	14+	w171W	MPC22472
Oct 9	17 58	Parthenope	12.0	2.838	97974	9.0	K0	8 34.8	17 15	3.0	6	13	25	s.e. Australia?n	69	127	28+	none	MPC12686
Oct 12	3 0-15	Sibylla	12.3	2.212		10.0	F8	0 5.6	3 0	2.4	13	25	21	16 -1 -42-21-114-57	164	68	56+	w 42W	MPC14159
Oct 12	8 10-61	Geographos	14.6	0.383		9.8		21 51.8	12 23	4.8	2	39111		152 8-160 18-104 15	132	34	58+	w127W	Yeomans
Oct 16	16 17	Egeria	11.7	2.306	212936	9.1	K2	21 18.2	-35 39	2.7	19	27	16	(Libya, Greece)? 2"s	107	45	93+	all	Goffin87
Oct 17	1 6- 8	Fortuna	11.3	2.047		10.3	F5	7 59.0	19 8	1.4	9	14	17	12-28 33-25 54-25	85	123	94+	w 43E	MPC13923
Oct 17	8 55-59	Brixia	11.8	1.800		10.3	M2	7 35.2	20 21	1.8	7	15	22	-143 53-109 66 -45 74	91	114	95+	w 70W	MPC22573
Oct 19	5 9-13	Fortuna	11.3	2.024		10.7	K0	8 1.8	18 58	1.1	9	15	17	-74 38 -38 45 3 44	86	101	99+	all	MPC13923
Oct 20	6 7	Eunike	11.7	1.899	132640	9.2	A0	5 52.4	-7 32	2.6	17	28	17	(swMex.,Galap.I.)?2"n	114	56	99-	all	MPC14753
Oct 20	8 25-27	Fortuna	11.3	2.012	97553	8.9	A5	8 3.2	18 53	2.5	9	15	17	-94-38 -77-36 -57-37	87	88	99-	all	MPC13923
Oct 20	15 44-60	Mancunia	12.0	1.920	128781	8.1	G0	0 26.7	-6 11	4.0	9	29	32	-174-20 128-35 51-52	156	30	98-	all	MPC16393
Oct 22	10 34-38	Polyxo	13.1	2.534		9.5	K8	7 25.6	17 3	3.6	12	26	25	-178 63-126 68 -71 62	98	55	92-	all	MPC16004
Oct 23	16 1-30	Geographos	15.2	0.490	107680	7.8	A5	22 5.5	12 49	7.5	1	29142		24 36 80 42 141 35	125	102	84-	e 68E	Yeomans
Oct 24	15 50	Jupiter	-1.7	6.328	159074	8.0	A0	15 8.4	-16 47		1718	12	2	eastern Africa	19	138	76-	none	NAO001
Oct 25	13 41	Mnemosyne	11.2	1.909	111817	6.1	B5	4 23.6	8 29	5.2	12	28	24	China? 2"s	144	32	68-	all	MPC12189
Oct 26	18 2-11	Hektor	14.9	5.097	189876	8.2	K2	20 54.8	-25 5	6.7	19	38	33	7-21 27 10 52 42	97	148	57-	none	MPC22797
Nov 1	18 1- 4	Pales	13.0	2.871		9.5		9 29.8	13 58	3.6	7	16	27	100 54 139 56 179 50	78	50	6-	e148E	MPC15524
Nov 3	18 45-49	Leda	14.2	3.125	163198	9.0	G0	19 59.6	-18 3	5.2	6	16	38	1-26 28-16 57 -4	78	80	2+	none	MPC14158
Nov 4	17 44-66	Hestia	10.9	1.219		9.2	F5	3 14.9	14 55	1.9	15	25	14	173 4 101 -3 26-33	171	163	4+	none	Yeomans
Nov 6	14 21	Venus	-4.0	0.271	158462	6.3	G5	14 14.3	-18 21		2376	20	1	W.USA-low,dawn or day	7	54	16+	none	NAO001
Nov 6	21 3- 9	Kreusa	12.7	2.561	129246	7.0	G0	1 18.8	-6 25	5.8	13	25	24	71 67 14 62 -42 63	149	110	18+	w 1W	MPC22666
Nov 13	13 22-24	Comacina	13.7	3.291	118521	8.2	K2	10 47.5	2 44	5.5	5	13	33	-170 34-142 32-113 26	68	164	80+	w165W	MPC11725
Nov 18	5 0-23	Eichsfeldia	13.5	1.658		8.6		1 18.7	-1 23	4.9	11	40	36	-36 45-109 40-179 34	142	33	97+	w175W	MPC15529
Nov 18	17 0-10	Parthenope	11.6	2.324	98463	8.6	F5	9 13.2	15 6	3.0	15	28	21	105 2 142 7-178 3	99	80	97-	all	MPC12686
Nov 18	23 12-26	Elpis	11.5	1.870		9.8		23 13.9	-8 54	1.9	21	32	16	-65-17 -23 -7 19 3	110	73	97-	all	MPC13145
Nov 26	3 7-29	Armida	13.1	2.032		9.8	G5	1 49.6	15 39	3.4	14	35	27	7 49 -80 37-137 0	148	122	50-	e 50W	MPC22797
Nov 28	18 18	Doris	12.7	3.320	164340	8.9	G0	21 19.1	-12 35	3.9	9	14	22	-27 57 -15 61 0 66	73	133	26-	none	MPC12188
Dec 1	9 21	Pallas	8.1	1.670	194337	10.2		3 27.9	-30 29	0.1	60	29	5	n.Chile?n,N.Z.? 2"n	126	149	7-	none	Goffin87
Dec 3	6 20-27	Mars	.3	1.074		8.7	K	9 59.8	14 52		673	20	1	-86-28 -59-25 -31-29	103	103	4+	none	NAO001
Dec 3	15 3	Venus	-4.6	0.379	158399	8.8	K5	14 8.0	-11 24		2710	27	1	HI, nw USA, W. Canada	37	48	4+	none	NAO001
Dec 5	9 10-16	Kleopatra	10.7	1.689	128204	9.0	K0	23 26.4	1 0	1.9	15	16	11	109 55 162 54-144 52	100	65	12+	w164E	Goffin89
Dec 5	16 4-12	Nysa	11.3	2.117	146718	9.2	G5	23 25.6	-7 48	2.2	6	22	42	37 -4 69 13 109 27	96	61	14+	w 64E	MPC11982
Dec 7	5 45-46	Venus	-4.6	0.402	158465	9.0	K0	14 14.5	-11 25		2067	21	1	25 66 29 65 35 64	39	99	27+	none	NAO001
Dec 7	13 16	Lucina	12.7	2.231		10.0	F5	9 52.2	23 52	2.7	16	34	23	China (low)	112	154	30+	none	MPC15384
Dec 9	5 30	Pholus	17.4	10.025	81980	8.9	K2	11 44.1	20 52	8.6	12	39	73	(ne USA,e.Canada)?s	89	153	45+	none	MPC19850
Dec 12	13 3	Lucina	12.6	2.167	81103	8.8	G5	9 54.3	24 15	3.9	18	38	22	(Japan,e.Siberia)?s	117	127	72+	all	MPC15384
Dec 13	10 48-64	Eunomia	8.0	1.390		8.8	M9	6 43.9	30 20	0.4	28	24	7	-85 -7-142 -6 163-34	160	76	78+	w127W	DASTCM94
Dec 18	15 39-45	Winchester	10.7	1.513		10.0		1 10.6	-18 28	1.2	11	15	12	113-57 116-29 136 -7	102	75	96-	all	MPC22386
Dec 25	5 9-14	Geographos	17.5	1.187		10.0	K	23 50.4	16 59	7.5	0	13344		-172 32-130 36 -87 30	92	162	57-	e 87W	Yeomans
Dec 26	14 17-23	Polyxo	12.1	1.892	96743	8.0	A0	7 15.1	15 50	4.1	12	22	19	-96 63-152 81 42 74	164	84	44-	e156E	MPC16004
Dec 28	8 34-36	Elpis	12.0	2.356		9.9		23 51.5	-5 44	2.3	7	13	20	163-24-172-15-147 -8	80	141	27-	none	MPC13145
Dec 28	21 28	Mercury	-0.9	1.375	187718	6.2	B9	19 5.2	-24 44	0.0	73	3	1	-131-44 ALT 70 SUN 67	9	64	22-	19	DE130
Dec 29	13 45-54	Panopaea	12.4	2.138	60448	9.5	F8	7 52.3	35 51	2.9	9	20	24	-108 36-153 75 39 58	158	112	16-	e161W	MPC20607
Dec 31	4 27	Polyxo	12.1	1.880	96651	7.8	F5	7 11.0	15 56	4.3	12	21	18	(Scand.,Greenl.,AK)?s	169	149	6-	e 20E	MPC16004

Table 2, Part B.

1994 Date	Minor Planet No.	Name	km-Diam.	"//	RSOI	Type	Motion °/Day	P.A.	Star SAO No	DM/ID No	D	Min. U.T.	Geocentric Sep.	S	Comparison Data AGK3 No	Shift	Time	Apparent R.A.	Dec.
												h m	"			"	m	h m	
Aug 30	9	Metis	190	0.09	724	S	0.511	102°2		+21°1881		9 3.6	0.03S	XA	N21° 964	0.08	-0.1	8 39.2	21°20'
Aug 31	1620	Geographos	5	0.13	2	S	5.008	1.0	164395	-19 6098		1 36.2	2.25E	UZ		0.26	0.0	21 26.8	-19 5
Sep 1	1620	Geographos	5	0.11	2	S	3.504	1.2	164405	-12 5998		19 49.8	12.03W	UZ		-0.37	0.0	21 27.4	-11 41
Sep 5	704	Interamnia	333	0.13	2579	F	0.251	90.0		M 263747		23 39.9	1.02S	M				15 3.9	-26 38
Sep 7	1620	Geographos	5	0.07	2	S	1.321	3.7	126828	+ 0 4732		16 55.7	51.57E	RP	N 0 2698	0.69	0.1	21 29.1	1 7
Sep 11	1	Ceres	946	0.42	9860	G	0.382	94.5	79805	+24 1806		11 36.5	3.19N	MU	N23 897	-0.30	0.3	7 55.8	23 38
Sep 11	1620	Geographos	5	0.05	2	S	0.810	7.4	126853	+ 4 4693		12 13.8	50.42E	A	N 4 2916	0.81	0.2	21 30.6	5 3
Sep 12	1620	Geographos	5	0.05	2	S	0.750	8.2	126860	+ 4 4694		4 12.3	3.68W	AG	N 5 3142	1.33	0.0	21 30.9	5 34
Sep 17		Venus	12220	33.65			0.714	118.8	158446	-17 4039		10 26.7	1.76S	UX		-0.10	0.0	14 14.5	-18 24
Sep 17	47	Aglaja	135	0.11	528	C	0.181	258.6	109626	+ 6 147		21 28.5	1.50N	UX	N 7 115	-0.42	-1.0	1 2.6	7 29
Sep 21	1620	Geographos	5	0.03	2	S	0.325	28.7				8 58.8	18.16S	C				21 35.8	9 53
Sep 25	13	Egeria	215	0.14	1129	G	0.131	327.2		M 3 1323		6 36.6	2.85N	QM		-2.41	-1.3	21 21.8	-38 19
Sep 26	1620	Geographos	5	0.03	2	S	0.253	47.1		+10 4598		20 49.3	16.07N	A	N10 2938			21 39.6	11 6
Sep 27	1620	Geographos	5	0.03	2	S	0.249	49.2				13 16.6	29.05S	C				21 40.1	11 13
Sep 30	216	Kleopatra	230	0.26	980	M	0.240	211.1		11600140		0 33.5	2.76S	C				23 2.6	9 45
Sep 30	120	Lachesis	178	0.08	930	C	0.233	80.5	186005	C2914259		3 8.3	0.46S	HX		-0.32	0.6	17 57.7	-29 4
Oct 1	1620	Geographos	5	0.02	2	S	0.240	60.0				0 42.0	20.94N	C				21 43.0	11 42
Oct 8	139	Juewa	162	0.09	867	CP	0.087	292.3	164827	-18 6056		8 9.0	2.13S	PU		-0.12	1.2	22 1.9	-17 56
Oct 9	11	Parthenope	162	0.08	703	S	0.306	102.9	97974	+17 1891		17 58.1	3.09S	UX	N17 928	0.40	0.1	8 37.3	17 5
Oct 12	168	Sibylla	154	0.10	784	C	0.175	238.8		+ 2 2		3 7.8	2.12S	A	N 2 9			0 8.0	3 15
Oct 12	1620	Geographos	5	0.02	2	S	0.274	79.2				8 27.7	1.29N	C				21 54.0	12 36
Oct 16	13	Egeria	215	0.13	1125	G	0.161	19.4	212936	C3514723		16 17.3	4.29N	MP		-1.02	-0.6	21 20.9	-35 27
Oct 17	19	Fortuna	171	0.12	632	G	0.318	104.0		L 4 3280		1 9.3	3.22S	H				8 1.6	19 1
Oct 17	521	Brixia	121	0.09	355	C	0.322	87.1		L 4 1932		8 58.3	3.97N	H				7 37.8	20 15
Oct 19	19	Fortuna	171	0.12	633	G	0.309	104.3		+19 1910		5 14.1	1.67N	HX	N18 818	0.00	0.1	8 4.4	18 51
Oct 20	185	Eunike	165	0.12	676	C	0.167	161.2	132640	- 7 1211		6 7.1	5.98S	MS		-1.06	0.0	5 54.6	-7 32
Oct 20	19	Fortuna	171	0.12	634	G	0.304	104.5	97553	+19 1925		8 27.5	3.76S	UR	N18 823	-0.07	0.0	8 5.8	18 46
Oct 20	758	Mancunia	87	0.06	299	X	0.164	253.4	128781	- 6 79		15 53.0	2.69S	G				0 29.0	-5 56
Oct 22	308	Polyxo	148	0.08	659	T	0.155	108.5		L 4 1147		10 40.0	2.41N	H				7 28.2	16 57
Oct 23	1620	Geographos	5	0.01	2	S	0.320	83.9	107680	+12 4760		16 10.2	8.42N	A	N12 2610	0.23	0.9	22 7.7	13 3
Oct 24		Jupiter	140904	15.35			0.214	106.0	159074	-16 4020		15 49.5	13.94N	U7		0.14	0.3	15 10.9	-16 57
Oct 25	57	Mnemosyne	116	0.08	446	S	0.168	215.2	111817	+ 8 687		13 40.8	6.73N	P	N 8 458			4 26.1	8 35
Oct 26	624	Hektor	225	0.06	2306	D	0.076	35.3	189876	C2515138		18 1.6	0.09N	UP		-0.57	-2.3	20 57.4	-24 54
Nov 1	49	Pales	154	0.07	699	CG	0.244	112.0		+14 2107		18 5.3	1.56N	XA	N13 960	0.07	-0.2	9 32.2	13 46
Nov 3	38	Leda	120	0.05	520	C	0.225	76.4	163198	-18 5574		18 43.8	0.75S	UH		0.52	0.8	20 2.2	-17 55
Nov 4	46	Hestia	131	0.15	426	P	0.240	250.5		+14 547		17 54.6	2.33S	XA	N14 296	0.02	0.1	3 17.5	15 5
Nov 6		Venus	12220	62.08			0.627	311.1	158462	-17 4053		14 21.6	7.02S	7P		-0.25	-0.5	14 16.8	-18 34
Nov 6	488	Kreusa	158	0.09	883	C	0.162	267.3	129246	- 6 256		21 5.7	3.18N	UP		-0.30	0.0	1 21.1	-6 11
Nov 13	489	Comacina	144	0.06	682	C	0.272	108.6	118521	+ 3 2423		13 25.9	0.74N	M				10 49.9	2 30
Nov 18	442	Eichsfeldia	68	0.06	179	C	0.127	264.3		- 1 177		5 12.5	3.44N	M	S01 119			1 21.0	-1 8
Nov 18	11	Parthenope	162	0.10	709	S	0.151	102.1	98463	+15 2012		17 9.9	0.79S	UX	N15 1034	0.08	0.0	9 15.7	14 54
Nov 18	59	Elpis	173	0.13	703	CP	0.149	77.8		M 207357		23 13.9	0.58S	M				23 16.3	-8 39
Nov 26	514	Armida	110	0.07	433	XC	0.131	236.9		+15 274		3 19.6	1.15N	XA	N15 157	0.00	0.3	1 52.0	15 52
Nov 28	48	Doris	219	0.09	1323	CG	0.248	78.8	164340	-12 5976		18 17.3	2.46N	UX		-0.30	0.6	21 21.6	-12 23
Dec 1	2	Pallas	533	0.44	3783	B	0.176	257.4	194337	C30 1352		9 21.5	3.47S	S				3 29.8	-30 20
Dec 3		Mars	6782	8.70			0.310	104.5		+15 2155		6 27.3	5.93S	XA	N14 1076	0.09	-0.3	10 2.2	14 39
Dec 3		Venus	12220	44.49			0.394	86.6	158399	-10 3838		15 2.9	25.64N	UX		-0.17	0.5	14 10.4	-11 37
Dec 5	216	Kleopatra	230	0.19	944	M	0.307	91.1	128204	+ 0 5003		9 11.6	4.18N	MX	N 0 2905	0.38	-0.2	23 28.7	1 15
Dec 5	44	Nysa	73	0.05	195	E	0.203	62.8	146718	- 8 6116		16 4.0	0.17N	UX		0.46	0.3	23 27.9	-7 33
Dec 7		Venus	12220	41.96			0.487	93.7	158465	-10 3865	M	5 49.5	20.89N	UX		-0.05	-0.9	14 16.9	-11 38
Dec 7	146	Lucina	140	0.09	588	C	0.130	56.5		+24 2149		13 16.2	3.90N	MA	N23 1052	0.44	-1.1	9 54.8	23 39
Dec 9	5145	Pholus	200	0.03	3661		0.053	66.1	81980	+21 2354		5 30.1	1.65N	A	N20 1291	-0.20	1.6	11 46.4	20 37
Dec 12	146	Lucina	140	0.09	588	C	0.118	43.7	81103	+24 2156		13 3.2	4.33N	LU	N24 1115	0.44	-0.1	9 56.9	24 2
Dec 13	15	Eunomia	272	0.27	1351	S	0.235	256.1		+30 1329		10 55.2	3.69S	A	N30 730			6 46.8	30 17
Dec 18	747	Winchester	178	0.16	601	PC	0.345	40.0		M 209887		15 41.1	4.64S	M				1 12.8	-18 14
Dec 25	1620	Geographos	5	0.01	2	S	0.476	76.7		+16 5009		5 8.5	1.87N	A	N16 2636			23 52.7	17 14
Dec 26	308	Polyxo	148	0.11	661	T	0.213	275.8	96743	+16 1442		14 20.1	4.31N	UX	N15 773	-0.08	-0.6	7 17.7	15 45
Dec 28	59	Elpis	173	0.10	701	CP	0.332	68.9		M 208102		8 32.2	1.77S	M				23 53.8	-5 29
Dec 28		Mercury	4880	4.89	18878		1.614	84.1	187718	C2415041		21 27.6	2.14S	ZY		0.34	0.0	19 7.9	-24 40
Dec 29	70	Panopaea	127	0.08	567	C	0.221	294.5	60448	+36 1710		13 48.9	2.71N	A	N35 791			7 55.3	35 44
Dec 31	308	Polyxo	148	0.11	662	T	0.224	276.8	96651	+16 1420		4 26.7	4.67N	UX	N15 764	0.14	-0.3	7 13.6	15 51

stars, component magnitudes, separation and PA, and expected magnitude drops (when calculable) are given in notes about individual events at the end of this article. It is important to note that exceedingly accurate information about double stars can be gleaned from asteroidal occultations - more than an order of magnitude better than from lunar occultations, due to the slower apparent angular motion of the occulting body with respect to the star, especially with the widely ranging PA's of occultation that will be seen by observers separated by even a few km. Asteroidal occultations provide especially good opportunities to resolve spectroscopic binaries.

The geocentric Universal Time and distance of closest approach of the center of the planet to the star are given under the columns Min. Geocentric U. T. and Sep. Following the separation value is a letter indicating its direction, usually (N)orth or (S)outh. But when the motion is nearly due north-south, with the motion in declination four or more times that in right ascension, the direction is given as (E)ast or (W)est. These quantities, along with the position angle of the object's motion and its distance from the Earth "Δ,AU" from Table 1, can be used with a linear approximation of the motion to calculate the path of the occultation on the Earth's surface, or the time and distance of closest approach for a specified station. Leif Kristensen, Institute of Physics, Aarhus University, Aarhus C, DK 8000 Denmark can provide a program to do these calculations with a Texas Instruments hand calculator. Readers with some familiarity with astronomical computations can figure out how to do this from discussions of occultation calculations in books such as Jean Meeus' Astronomical Tables of the Sun, Moon, and Planets (Willmann-Bell, 1983); the Explanatory Supplement to the American Ephemeris and Nautical Almanac; or Isao Sato's "Catalog of 3539 Zodiacal Stars for the Equinox J2000.0" described in ON 4 (5) [although he uses standard notation in his formulae, the discussion is in Japanese]. A useful PC project would be to program the use of these quantities to produce paths or local circumstances, and distribute this software to the many other IOTA PC users. Then, they could quickly update paths or compute new local circumstances when an update is obtained from "last-minute" astrometry, which would be especially useful if a detailed regional map or IOTA local circumstance prediction is not available.

Following the minimum geocentric separation time and angular distance is the star's position and proper motion source catalog code specified under S. The catalog codes are listed below; the value at the end of each description is the current estimated positional accuracy in arc seconds:

A AGK3 (Astronomische Gesellschaft, 3rd Katalog), quite accurate at the epoch of the last plates taken in 1960, but now having a mean accuracy of about 0."5, with many stars now having errors of about 1".

B ACRS (Astrographic Catalog Reference Stars), a new catalog organized by Tom Corbin at USNO, accuracy now about 0."3.

C Carte du Ciel, or Astrographic Catalog (AC). The mean epoch is around 1900, and no proper motions are available. Most of the AC stars are faint and distant, with small proper motions, so that the current mean error is about 1". However, many AC stars have significant proper motions so that current actual positions can differ by a few to several arc seconds. When possible, the positions of AC stars involved with important occultations should be updated with modern astrometric observations.

D Positions from measurement of Palomar Schmidt plates, with an absolute accuracy of about 1". Mainly includes several stars in Scorpius whose positions were measured from 1954-5 Palomar Sky Survey plates to provide predictions of stars in the 1975 May lunar eclipse star field.

E Eichhorn's Pleiades (USNO P) catalog, accuracy now about 0."5.

F FK4 (4th Fundamental Katalog). FK5 positions are better and will be added later. Less than 0."2.

G Albany General Catalog (G.C., via SAO; mean epoch is in late 1800's, so current positions are usually in error by more than 1" or 2").

H Positions of generally fainter stars measured by Arnold Klemola with the 20-in. twin astrograph at Lick Observatory on Mt. Hamilton, Calif., current accuracy about 0."3.

I IRS (International Reference System), a new reference star catalog that gives improved positional data for about 1 star per square degree, to supersede the AGK3R and Perth 70 catalogs. NIRS is the northern half of IRS. Generally less than 0."2.

J Guide Star Catalog, absolute accuracy about 1", but may be 0."5, in rare cases, 2".

K USNO K-catalog of zodiacal stars, including some AGK3 stars and southern Yale stars with no proper motions determined. The accuracy is the same as the AGK3, except for the Yale stars, whose current accuracy is about 1" (worse for some stars with large proper motions).

L High-precision subset of PPM (see M below), mainly from observations by the Carlsburg photoelectric meridian circle, La Palma, Canary Is. 0."15.

M PPM (Positions and Proper Motions, a new catalog from the German Astronomisches Rechen Institut that is effectively an update of AGK3 and SAO).

Generally less than 0.″3.

N N30 is a compilation catalog formed in the late 1930's for astrometric observations of Pluto. Only stars common to the ZC are included, and more recent observations included in the formation of the XZ catalog have been used. The current accuracy is only slightly better than the XZ (see X below).

O PPM stars with problems; the current positions are generally significantly worse than the PPM average errors. ("O" for "Oops"). Also includes PPM double stars.

P Perth70 photoelectric meridian circle catalog covering the southern sky at a density of about 1 star per square degree. Mean epoch is about 1970; proper motions were taken from earlier catalogs. Current accuracy is about 0.″3.

Q PPM or combined catalog star position has been changed to get better agreement of my predicted path with that predicted by E. Goffin.

R AGK3R, reference star catalog for the photographic AGK3. 0.″4.

S SAO catalog with SAO source Yale, last plate epochs usually in the early 1930's. 1".

U USNO preliminary Zodiacal Zone catalog (ZZ87), 0.″3.

W AC position altered to obtain better agreement of my path with that computed by E. Goffin.

X USNO XZ where the data were not simply taken from the SAO or ZZ87. 0.″6.

Y Yale, see K (most of these have unknown proper motion) and S above. In the combined catalog, all of the Yale declination proper motions were erroneously taken as positive, so events with a code of Y need to be checked and manually corrected, when appropriate.

Z Robertson's Zodiacal Catalog (ZC), with some later catalog data added when the XZ was created. 0.″6 to 1".

2 FK5 extension catalog. 0.″2.

3 FK3, the predecessor of the FK4. 0.″4.

5 FK5, current accuracy 0.″1 or less.

7 Combination of Perth70 and XZ data. 0.″3.

If there are two letters under <u>S</u>, the second letter is the position and proper motion source for the comparison shift data following the AGK3 number. The path shift, in the (occultation path) sense, second catalog minus first catalog, is given under <u>Shift</u>, which is expressed in seconds of arc, to the north if positive and to the south if negative. The value in minutes to be added to the U.T. is given under <u>Time</u>. A "B" precedes the shift value if the comparison data (shift and time) are for the path of the star's B-component relative to the A-component, rather than the second star source catalog relative to the main source catalog. In these cases, the latter is the same for both components, so it is sufficient to list the second source catalog comparison only for the primary (A-component).

The last columns give the star's apparent R.A. and Dec. computed for the time of geocentric conjunction, for direct use with setting circles.

Table 3. Stellar Angular Diameters

1994 Date	Planet No.	Planet Name	Star SAO/DM/ID	Star D	Stellar Diameter m″	m	Time	df
Jul 21	2	Pallas	130232		0.80	1611	57	4.9
Jul 22	168	Sibylla	109306		0.19	365	54	1.1
Jul 27	318	Magdalena	163665		0.73	1280	91	4.2
Jul 30	168	Sibylla	109320		0.12	224	63	0.7
Aug 3	416	Vaticana	207479		0.78	870	120	3.5
Aug 15	44	Nysa	128590		0.30	375	62	1.4
Aug 28	624	Hektor	190058		0.63	1994	128	4.8
Oct 16	13	Egeria	212936		0.39	644	57	2.2
Oct 22	308	Polyxo	L 4 1147		0.35	636	54	2.0
Oct 26	624	Hektor	189876		1.64	6066	521	13.6
Nov 6	488	Kreusa	129246		0.37	688	55	2.2
Nov 18	442	Eichsfeldia	-1° 177		0.31	379	60	1.5
Dec 9	5145	Pholus	81980		0.35	2569	159	4.1
Dec 13	15	Eunomia	+30° 1329		0.82	828	84	3.6
Dec 29	70	Panopaea	60448		0.67	1046	73	3.6

<u>Explanation of Data in Table 3:</u> Information about the estimated angular diameter of the occulted stars is given in Table 3 only for events for which the stellar angular diameter is large enough for the edge of the asteroid or planet to require more than 0.05 second to geometrically pass across the star during a central occultation. For these events, the effect of the stellar diameter might be noticed by visual observers, especially for nearly grazing events when the observer is near one of the edges of the occultation path. The double star code is given in the <u>D</u> column just after the SAO/DM No. Parameters relating to the stellar angular diameter are given in the last four columns. The first of these, <u>m"</u>, is the angular diameter in milli-arc seconds (units of 0.″001). Under <u>m</u> is given the distance in meters that the star subtends at the asteroid's distance from the Earth. The time in milliseconds that it takes the edge of the asteroid to geometrically pass across the star during a central occultation is given under <u>time</u>. Lastly, under <u>df</u>, the subtended diameter of the star is expressed in units of Fresnel diffraction fringe separation. If it is 3 or larger, diffraction will be negligible and the occultation light curve will be essentially geometric. If it is 0.3 or less, the star's angular diameter will manifest itself only as a very slight modification to a point-source Fresnel diffraction pattern, which could only be measured from a high signal-to-noise-ratio photoelectric recording. Between these values, the occultation light curve will be

a complex combination of the two effects. This information is available for all events listed in Tables 1 and 2, of possible use to those who want to analyze high signal-to-noise photoelectric records, upon request to me.

Local Circumstance/Appulse Predictions: The asteroid appulse/local circumstance (LOCM) predictions are now computed by the IOTA grazing occultation computors using a PC version of the "LOCM" program that is used for this purpose. The IOTA graze computors have the station data for IOTA members in their regions (from their graze calculations) and this distributes the work so that it is not too big a job for any one person. Joseph E. Carroll; 4261 Queen's Way; Minnetonka, MN 55345; USA, can also compute these predictions, and for many years before 1994, he supplied the appulse predictions to all IOTA members, a job for which we are very thankful.

The data for the occultation by (13) Egeria, whose nominal path crosses northern South America and passes just off the west coast of North America on September 25th, was left out of the 1994 database when it was distributed to the graze computors, so it will not appear in your LOCM predictions. The basic circumstances can be inferred from the world charts for this event, given in the 1994 **Asteroidal Occultation Supplement for North America**. Those who might need LOCM data for this event might request it from the graze computor for your region, or from me. Note that the star source code logic of this program has not been updated, so that the source codes in the appulse predictions will sometimes differ from that given under S in Table 2 described above. In case of disagreements, use the Table 2 code. Hans-Joachim Bode distributes similar predictions to IOTA/ES members.

The format of these predictions is nearly self-explanatory and contains virtually all of the information that an observer needs. Columns headed D and S following the SAO number give the double star code and star position source code (but see the remark above), respectively. Next are the star's DM/ID No., then the star's MAG (visual mag.), OCC. DMAG (occultation magnitude drop), and DUR SEC (central occultation duration in seconds). This is followed by the U.T. and distances (in arc seconds, kilometers on the sky plane, and in terms of object diameter) of local closest approach. The distances are positive if the asteroid passes north of the star (this means that the path would be south of the observer's location). The elongation (ELG, angular distance from the star) of the Sun and Moon are given, as is also the Moon's percent sunlit (PSNL).

Steve Hutchinson has written a short basic Basic program that he calls OPEC (for Occultation Probability Electronic Calculator) that uses the information in the LOCM predictions and the accuracies of the different star catalogs listed above to calculate the probability of seeing an occultation at a given location.

World Maps: World maps by Mitsuru Sôma, National Observatory, Tokyo, Japan, show the Earth as seen from the asteroid at the time of the event; the hatched curve marks the sunrise or sunset terminator, with hatches on the night side. The maps are published here only if the event is not included in Goffin's predictions; or if the star is mag. 8.0 or brighter; or if the star is double, and I have drawn a line showing the 2nd component path; or if there is a recent astrometric update; or if there is more than about 0."5 path or 3-minute time discrepancy with Goffin's prediction. In case of such a time discrepancy, the time difference in minutes, Goffin - my prediction, is written usually in the upper left corner of the world figure; since Goffin's predictions tend to be more accurate than my predictions, it is recommended that this time correction be added to the U.T. of closest approach given in your local circumstance/appulse predictions discussed above.

Geographos' passage close to the Earth, and within 1° of the south celestial pole in late August, presented special computational problems. Like Toutatis during its close approach, I computed the Geographos ephemeris at 0.1-day intervals rather than 1-day intervals, but still the right ascension changed by more than 6 hours between the end two of the six ephemeris times for two events on August 23. I did not change my programs to calculate these paths correctly, but Mitsuru Sôma noticed the problem and solved it by transforming the R.A. and Dec. to a system with a pole on the celestial equator, so that the equator of the new system passes through the south celestial pole. This solved the problem, so the path shown on Sôma's maps of the Aug. 23rd events are more accurate than the paths shown on my regional charts. The error in my path is less than 200 km, but that is many diameters of this small asteroid. Only a few of the world maps for the occultations by Geographos (abbreviated "Geog." in the figure captions) are included here, since for most of them, the main parts of their tracks are shown on the regional maps.

Regional Maps: The three regional maps showing quarterly Solar System occultations (actually, for 1994 August 8 - October 15) between latitudes +65° and -50° start on the next page. The longitude range is 180° W. to 30° W. for the map showing the Americas and the eastern Pacific Ocean; 30° W. to 70° E. for the map showing Europe, Africa, and western Asia; and 70° E. to 180° E. for the map showing eastern Asia, Australia, and the western Pacific Ocean. The occultation paths are calculated using the diameters given in Table 2. The paths have time lines at 2-minute intervals. The beginning and end U.T. of the paths are given in Table 1, which also lists the coordinates of the start, middle, and end of the paths. The maps do not have longitude or latitude tick-marks or labels, and the paths are hand-labelled. "A" or "S" written at the start and end of the path indicates whether the path is terminated due to low altitude or sunlight (or twilight), respectively. "Time lines" that seem out of sequence, or slant the wrong way, are moonrise or moonset lines. The enclosing rectangles will have the same latitudes and longitudes, and the plots are still false projections with horizontal and vertical scales both linear to facilitate plotting or measuring of coordinates. Due to its small size, all of the paths for 1620 Geographos are plotted only as single curved lines, many of them almost due north-south due to the motion of this asteroid being mainly in declination during its close approach to the Earth. Due to these distinctive characteristics and to avoid cluttering the map, the name "Geographos" has not been written along these paths, only the date and U.T. hour (when more than one event occurs during one day) of the event. If more than one event occurs during an hour, the occulted star's SAO number is given instead of the hour. Unless otherwise indicated, the Geographos paths start in the south when twilight becomes dark enough (most of these south ends of the path are in the Antarctic and are not on the maps) and end in the north when the star's altitude becomes too low to observe.

Finder Charts: Previously, I produced 3° and 1° charts for events not predicted by E. Goffin. I have not had time to regenerate this capability in a practical way. For events not originally predicted by Goffin, I have often been able to get charts from him, but there has not been time to do this for the Geographos occultations. Some published finder charts for Geographos are mentioned early in this article.

Astrometric Updates and Priority List: In Table 4 below, EAON is the European Asteroidal Occultation Network and I (IOTA) usually refers to attempts that will probably be made by Petr Pravec at Ondrejov Observatory in the Czech Republic. Arnold Klemola often helps by providing measurements of secondary faint reference stars from existing Lick Observatory plates, but due to the relatively old epoch of the Lick plates, we prefer to use new plates taken no more than a few months before the occultation and reduced with PPM catalog data. This removes astrometric errors caused by unmodelled proper motions of the reference stars, shown to be a significant problem during last-minute updates for the (56) Melete occultation last March. Thierry Pauwels at Uccle Observatory in Belgium has agreed to try to make such observations, but it would be useful to have more help in this area, especially from observatories in the Southern Hemisphere.

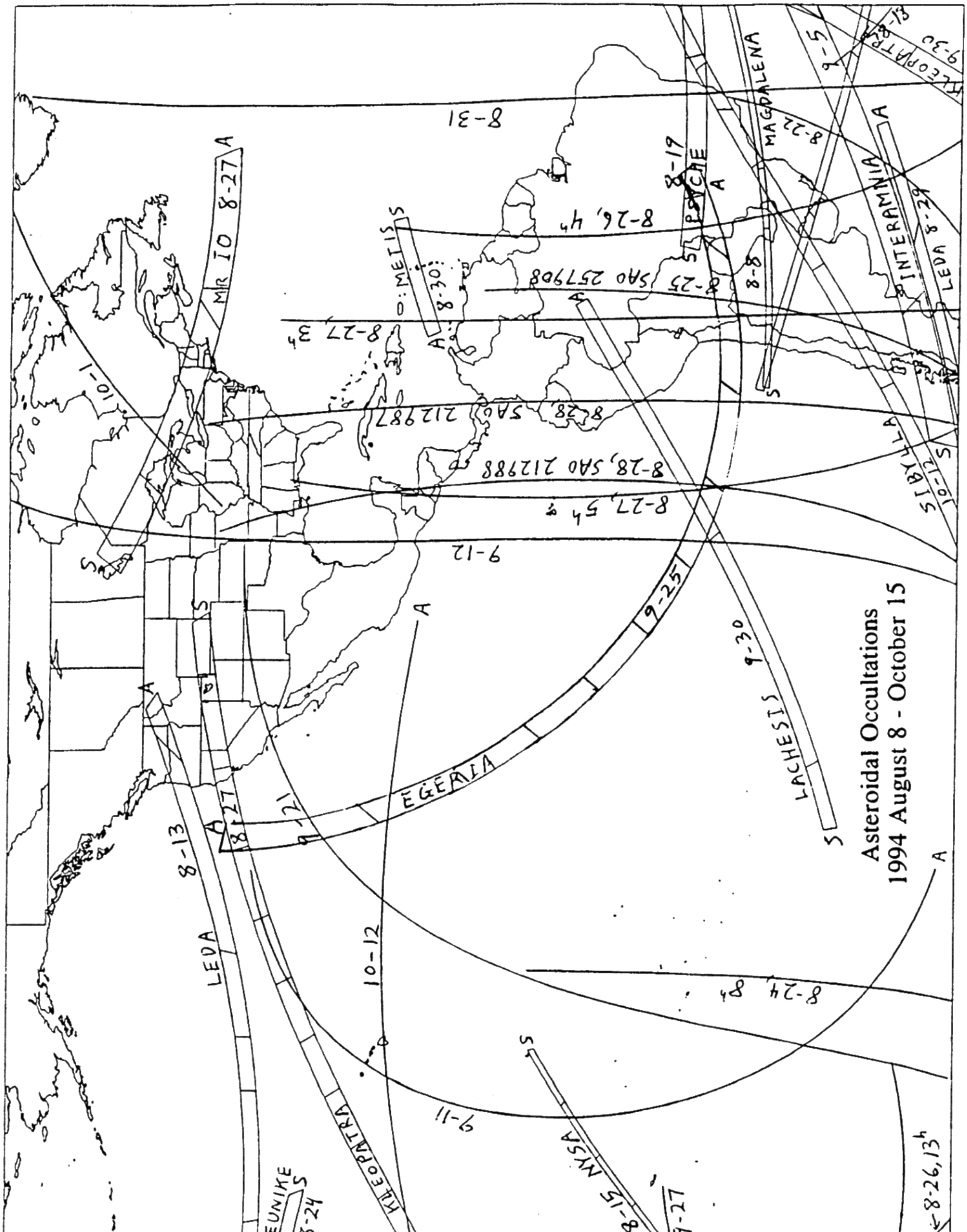
The EAON events are from their "observational program"; astrometric updates might not be attempted for all of them. Similarly, most events in the "I" column constitute an "observing program" of events on which North Americans should concentrate. A "2" indicates an event of secondary importance.

When astrometric updates are obtained, they are distributed as widely as possible by E-mail. If I don't have your E-mail address, or that of a co-worker or friend who could relay messages to you, I would like to receive it so that you can be notified of these events. When I learn about astrometric updates, the updated paths are described on the IOTA Occultation Line phone message in Greenbelt, MD, at 301,474-4722. For events possibly visible from the central USA, they are usually given also on answering machines at 708,259-2376 (Chicago) and 713,488-6871 (Houston).

Table 4. Priority List for Astrometric Updates.

1994 Date	Asteroid	EAON	I	1994 Date	Asteroid	EAON	I
Sep 11	Ceres		x	Oct 26	Hektor	x	
Sep 12	Geographos		2	Nov 6	Kreusa	x	
Sep 17	Aglaja	x		Nov 13	Comacina		2
Sep 25	Egeria		x	Nov 18	Eichsfeldia		2
Sep 30	Kleopatra	2		Nov 26	Armida	2	2
Oct 8	Juewa		x	Nov 28	Doris	x	
Oct 16	Egeria	2		Dec 9	Pholus	x	x
Oct 17	Brixia		2	Dec 29	Panopaea		x
Oct 19	Fortuna	x	x	Dec 31	Polyxo	x	2
Oct 22	Polyxo		2				

Unfortunately, no astrometric updates are obtained for many events. However, Petr Pravec and others at Ondrejov Observatory have developed an efficient and relatively inexpensive system for obtaining astrometric updates with a 65-cm telescope, so when the weather is clear in the Czech Republic, when other programs do not interfere, and if the objects are not too far south, some events are updated. It would be very useful to have others duplicate the Ondrejov system, for example, by someone in the southern USA where the weather is relatively good and more southerly declinations could be reached. The heart of the system is the SBIG ST-6 CCD Imaging Camera, already in use at many observatories, and PC-based software for the astrometric reductions. The system is described in "CCD Astrometry of Asteroids and Comets using the Guide Star Catalog" by Petr Pravec *et al.*, Astronomical Institute, CS-25165,



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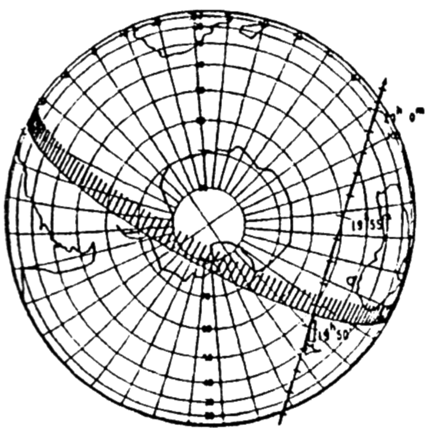
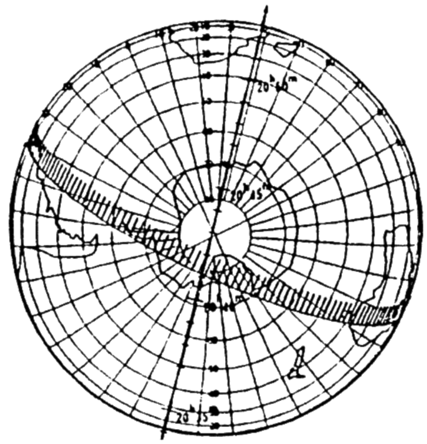
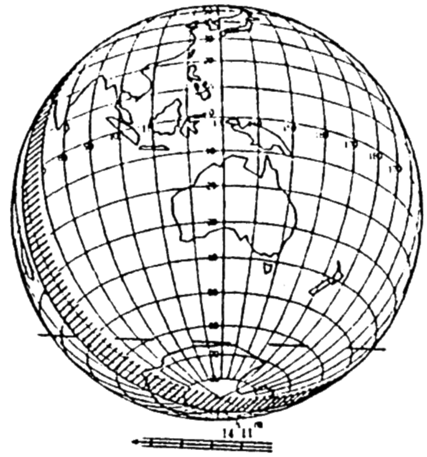


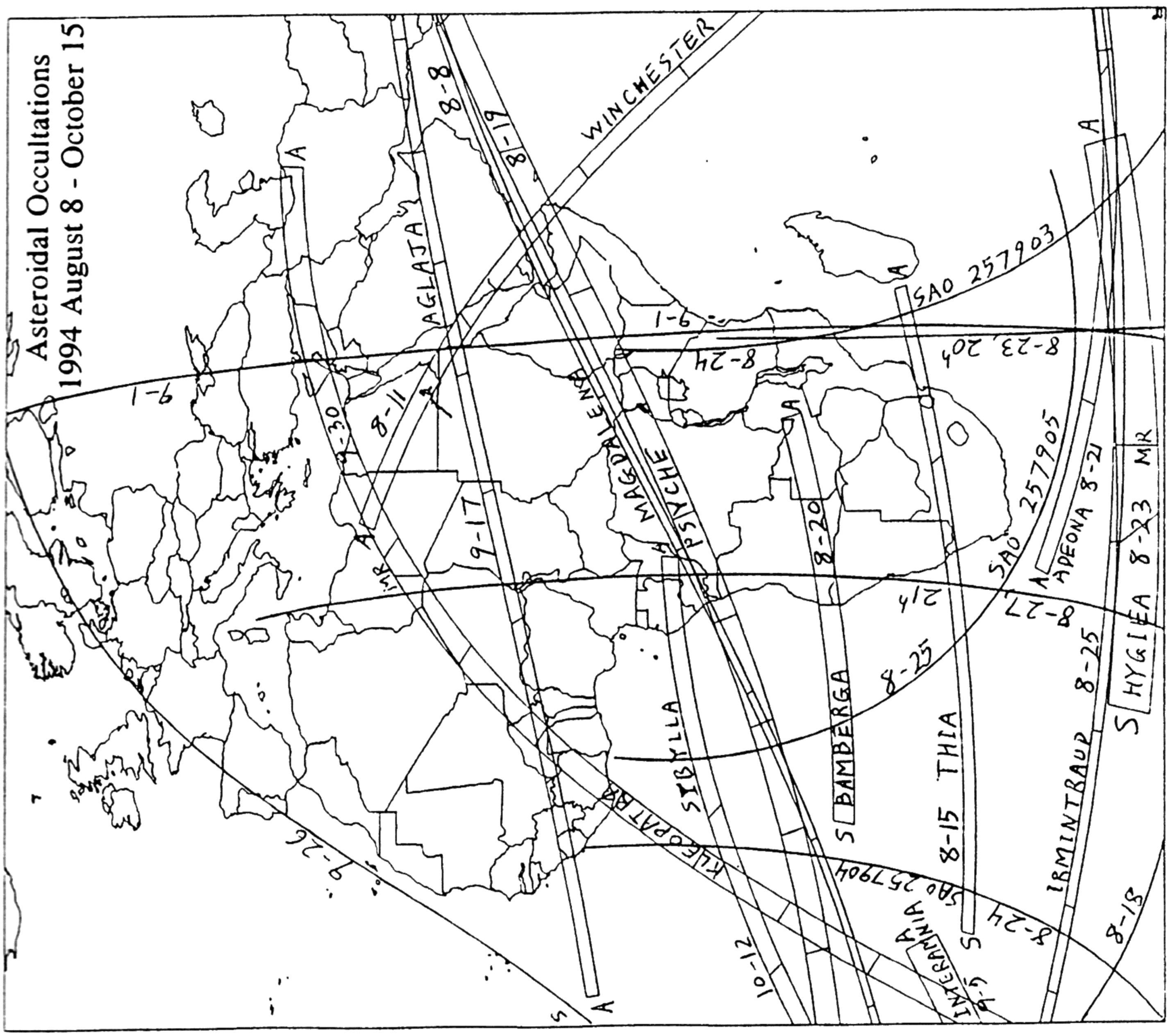
P88° 169 by Geog. 94 Aug 23

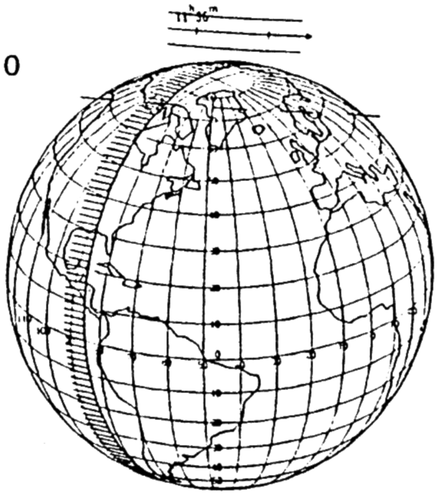


SAO 258853 by Geog. 94 Aug 23



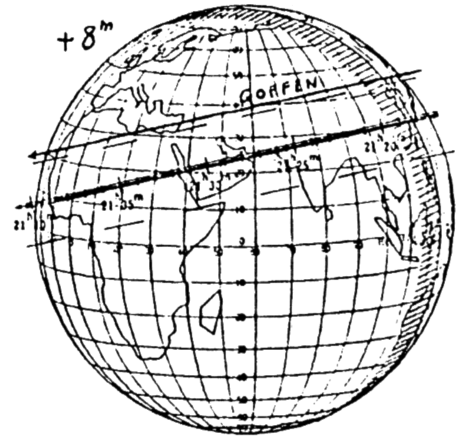
SAO 190058 by Hektor 94 Aug 28



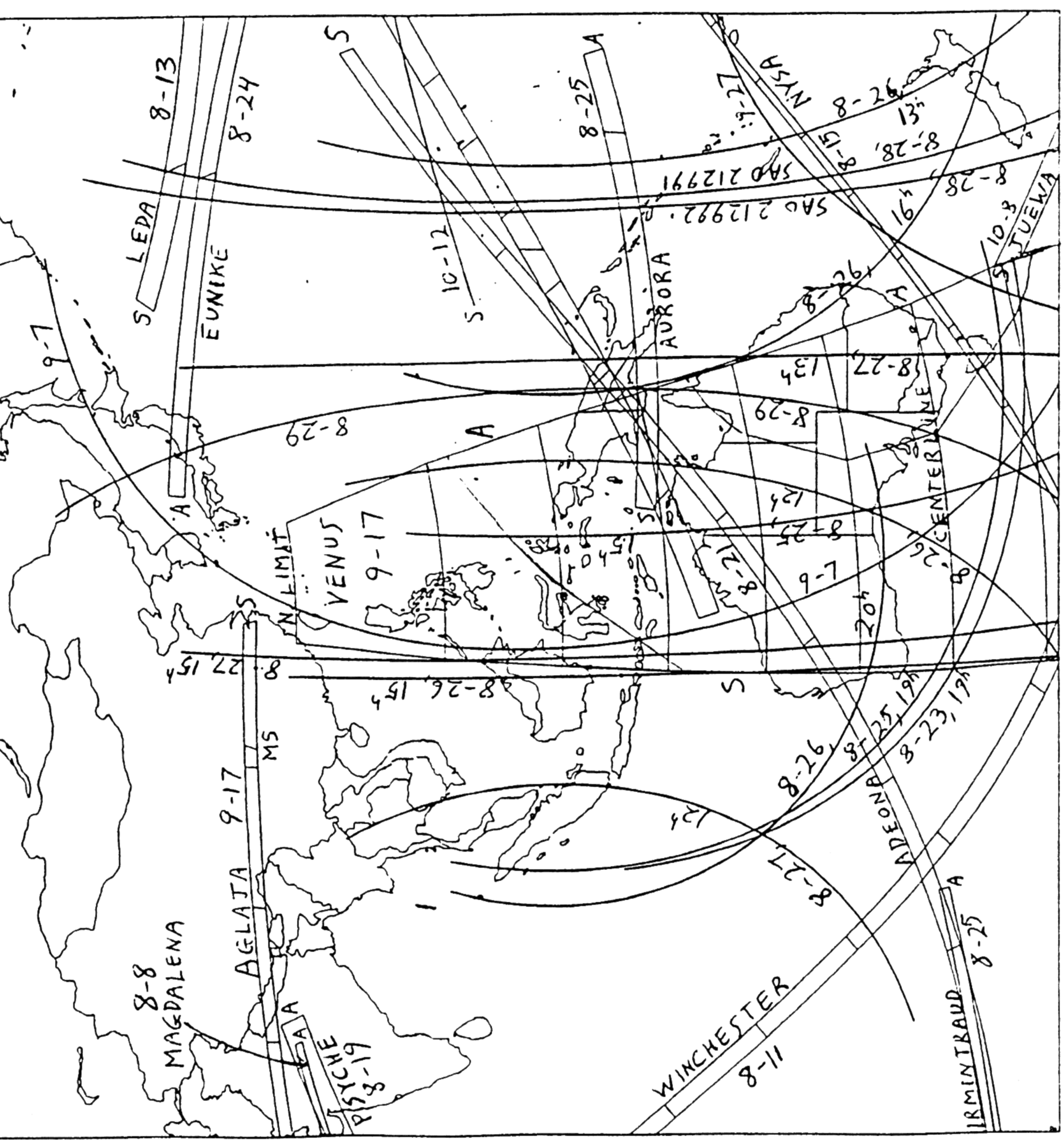


ZC 1195 by Ceres 94 Sep 11

SAO 158446 by Venus 94 Sep 17



SAO 109626 by Aglaja 94 Sep 17



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Czech Republic, E-mail ppravec@asu.cas.cz. The article has been published in **Planetary and Space Science 42** (4), pp. 345-348 (1994 April). Another paper that might be obtained by those seriously interested in this project is "Operational Testing of the SBIG - ST-6 CCD Camera", by P. Pravec, R. Hudec, and J. Soldán, Preprint No. 151 of the Centre of Scientific Information of the Czech Academy of Sciences, January 1994. Possibly helping the first reductions of CCD astrometry using the GSC is some PC software and a database of GSC - PPM corrections developed by A. Lopez Garcia *et al.* at Valencia, Spain (E-mail obsast@vm.ci.uv.es), and reported at the recent International Astronomical Union General Assembly in the Hague, Netherlands. Nevertheless, more astrometricists who can obtain accurate wide-field (about 2° by 2°, not Schmidt) plates are sought to provide good secondary reference star positions, a job that will not be needed in a couple of years when the Hipparcos Tycho catalog becomes available.

1995 Events: The better occultations for the rest of this decade are given in Edwin Goffin's article preceding this one. He has also provided to me by e-mail the basic stellar and asteroidal ephemeris data for all of the events that he selected for 1995. I will soon write a small computer program to convert his data into the exact form needed by my software, which should provide better agreement with our predictions and allow me to dispense with most, or all, of my star catalog - ephemeris comparison occultation search runs. This will save me considerable work, so that my 1995 predictions (and LOCM data) should be available before that year, without the delays that have plagued my predictions (especially for 1994!) in recent years. For 1995, Goffin has also computed predictions by major planets (responding to a request by Dr. Arlin Crotts at Columbia University that I passed on to Edwin). He found that on 1995 September 24, there will be a grazing occultation of 4th-mag. Theta Ophiuchi by the south pole of Jupiter, with the southern limit passing just south of James Bay and about 200 km north of Quebec City. West of James Bay, twilight will be too bright, and Jupiter will be below the horizon, or just a few degrees above it, east of Quebec. Unfortunately, an incorrect prediction for this event, with the southern limit much farther south (over the Amazon Basin) because the equatorial rather than the polar diameter of Jupiter was used, will appear in the **RASC Oberver's Handbook** for 1995. If possible, observations will be attempted; more about this interesting event, discovered independently earlier by Jean Meeus, will be given in future issues.

Notes about Individual 1994 Events:

Mar. 5: SAO 146915 = 20 Piscium = Zodiacal Catalog (ZC) number 3505. Disappearance was on the dark side of Venus' 98% sunlit disk.

June 12: SAO 93113 = ZC 413, which disappeared on the sunlit side of Mars' 95% sunlit disk.

July 13: SAO 76548 = 53 Tauri = ZC 633, a spectroscopic binary that was not resolved with graze observations made during the total lunar eclipse last Nov. 29th reported on pages 60-61 of the last issue and in **ON 6** (2), p. 43. This was the brightest star occulted by a planet in 1994; it disappeared on the sunlit side of Mars' 94% sunlit disk. The only place where the event might have been seen was Namibia and western South Africa, where it occurred about an hour after sunrise.

Aug. 21: SAO 191848 = Aitken Double Star (A.D.S.) 16703 with component magnitudes of 8.6 and 10.4. An extrapolation of the latest observations (1965) indicates that the separation is now 0".7 in position angle (P.A.) approximately 198°. Wayne Warren provided the latest-available information about this system.

Aug. 23, Geographos: Computational problems caused by Geographos' close approach to the south celestial pole produced errors of nearly 200 km in the location of the two Geographos occultation paths on this date shown on my regional maps. The correct paths for these events are shown on Sôma's world maps; see the discussion in the world map description above.

Aug. 25, Irmintraud: This event was not found by Goffin so we do not have a finder chart for it; see the discussion about Goffin's predictions above.

Aug. 31: SAO 164395 = ZC 3140.

Sep. 1: SAO 164405 = ZC 3145.

Sep. 11: The star is ZC 1195. This occultation was listed in my article in **ON 5** (8), p. 205. The better PPM data for the star now available indicates that this event will probably be a near miss, but observers throughout western North America are encouraged to monitor the event, preferably from pairs of independent stations a km or so apart, to look for short occultations by possible satellites of Ceres.

Sep. 17, Venus: Disappearance will be on the dark side of Venus' 34% sunlit disk. The graze at the northern limit will be 5° from the north cusp on the sunlit side.

Sep. 25: The data for the occultation by (13) Egeria, whose nominal path crosses northern South America and passes just off the west coast of North America on September 25th, was left out of the 1994 database when it was distributed to the graze computors, so it will not appear in your LOCM predictions. The basic circumstances can be inferred from the world charts for this event, given in the 1994 **Asteroidal Occultation**

Supplement for North America.

Oct. 8: SAO 164827 = ZC 3227.

Oct. 17, Fortuna: My path is the same as Goffin's, but his time is 4 minutes earlier than mine.

Oct. 20, Fortuna: My path agrees with Goffin's, but his time is 3 minutes earlier than mine.

Oct. 24: Jupiter will be 100% sunlit; there will be no observable defect of illumination (dark crescent).

Oct. 26: Hektor is the largest Trojan asteroid and is probably a contact binary object.

Nov. 4: Hestia has an unusual lightcurve, indicating an unusual shape or possibly even a satellite.

Nov. 6, Venus: SAO 158462 = ZC 2045. Disappearance will be on the dark side of Venus' 1% sunlit disk.

Dec. 3, Mars: Disappearance will be on the sunlit side of Mars' 90% sunlit disk.

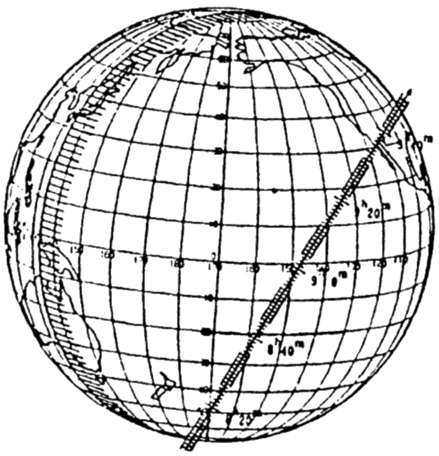
Dec. 3, Venus: Disappearance will be on the sunlit side of Venus' 22% sunlit disk. The graze at the southern limit will occur 25° from the southern cusp on the sunlit side.

Dec. 7, Venus: Venus' disk will be 22% sunlit; the star will disappear on the sunlit side, below the horizon in Hawaii. The reappearance on the dark southern quadrant will occur at a reasonable altitude above the horizon in Hawaii. The star is A.D.S. 9200, with component magnitudes of 9.7 and 9.9. According to an extrapolation of the latest (1991) observations of this rapidly-moving pair supplied by Wayne Warren, the separation will probably be about 0.″15 in P.A. about 180°.

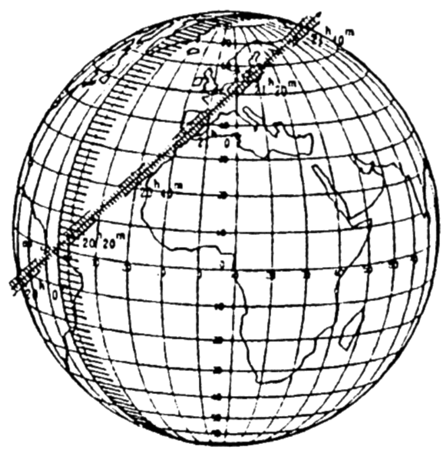
Dec. 7 and 12, Lucina: Lucina may have a small satellite, based on a Meudon Observatory video record of a secondary occultation recorded in 1982.

Dec. 9: Little is known about the large and very red outer Solar System object, Pholus. It does not seem to have a coma like Chiron.

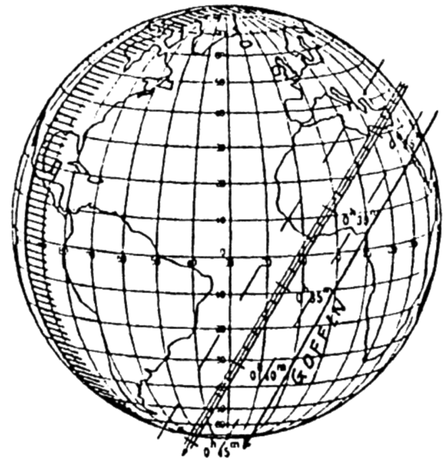
Dec. 28, Mercury: SAO 187718 = ZC 2790 will disappear on the dark side of Mercury's 97% sunlit disk, but there will be no significant defect of illumination (dark crescent).



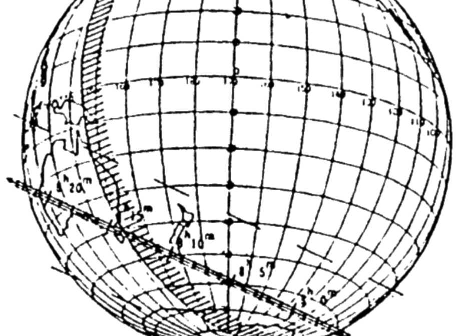
Anonymous by Geog. 94 Sep 21



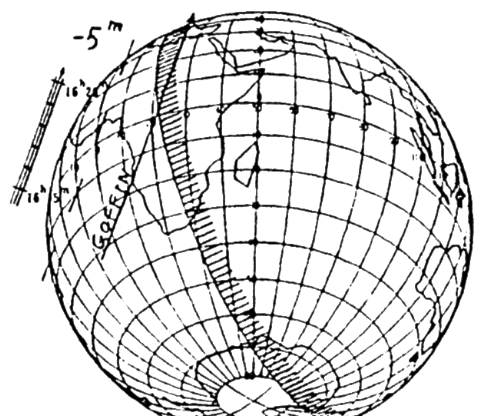
+10° 4598 by Geog. 94 Sep 26



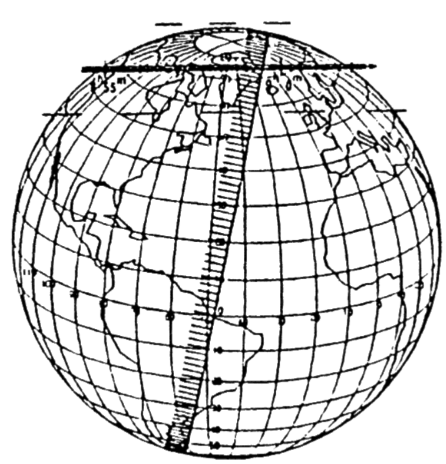
11600140 by Kleopatra Sep 30



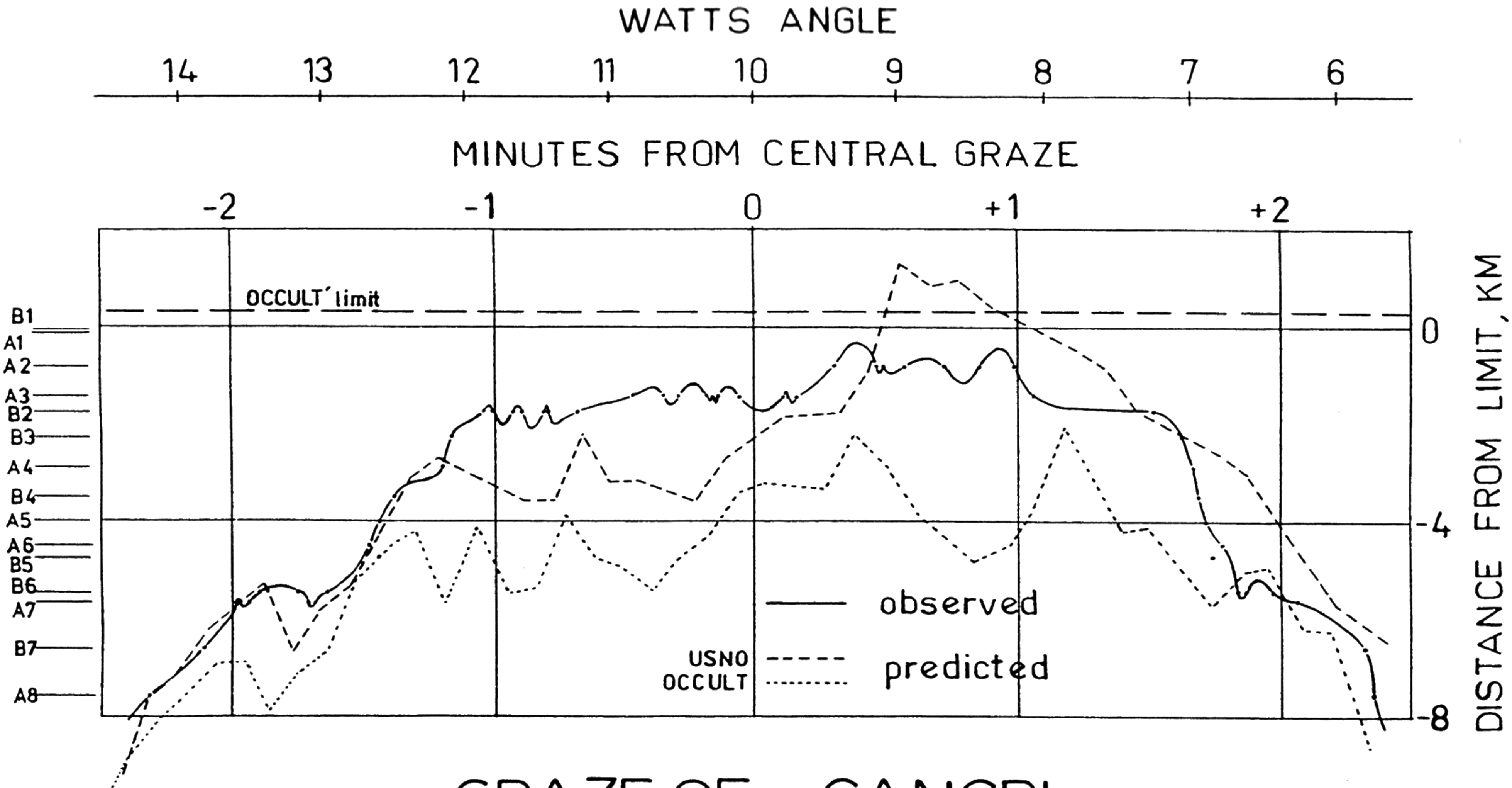
ZC 3227 by Juewa 94 Oct 8



SAO 212936 by Egeria 94 Oct 16



L 4 1932 by Brixia 94 Oct 17



GRAZE OF α CANCRI
1993 IV 29 20.6 UT

BOLIMÓW (A)
LUBACZÓW (B) POLAND

This graze was tabulated and discussed in **ON 6** (1), p. 15 (Nov. 1993).
A similar graze of the same star was seen in the USA a month later, reported in the tables of the above reference and on p. 61 of the last issue. It would be interesting to compare this profile with a similar one prepared for the 1993 May graze, since the same parts of the Moon were involved.

NASA BULLETIN FOR THE 1995 OCTOBER 24 SOLAR ECLIPSE

Fred Espenak and Jay Anderson

A new NASA solar eclipse bulletin titled "Total Solar Eclipse of 1995 October 24" (NASA RP 1344) became available in early August. The 74 page publication contains detailed predictions for this event and includes besselian elements, geographic coordinates of the path of totality, physical ephemeris of the umbra, topocentric limb profile corrections, local circumstances for 400 cities, maps of the eclipse path, weather prospects, the lunar limb profile and the sky during totality. NASA's eclipse bulletins are prepared in cooperation with the IAU's Working Group on Eclipses and are provided as a public service to both the professional and lay communities, including educators and the media.

Response to the first two eclipse bulletins was overwhelming and the demand quickly exhausted the our supplies. Serious eclipse observers are urged to order the 1995 bulletin without delay since a limited number have been printed. Single copies of RP 1344 are available at no cost and can be ordered by sending a 9 x 12 inch self-addressed stamped envelope (SASE) with sufficient postage (11 oz. or 310 g.). Use stamps only since cash or checks cannot be accepted. Requests within the U. S. may use the Postal Service's Priority Mail for $2.90. Please print either the NASA RP number or the eclipse date (year & month) in the lower left corner of the SASE. Requests from outside the U.S. and Canada may use international postal coupons sufficient to cover postage. Exceptions to the postage requirements will be made for international requests where political or economic restraints prevent the transfer of funds to other countries.

As we enter the 'Information Highway' age, it seems fitting that the eclipse bulletins should be served electronically. Thanks to Dr. Joe Gurman (GSFC/Solar Physics Branch), the first three eclipse bulletins are all available over the Internet. Formats include a Bin-Hex-encoded version of the original MS Word file + PICT + GIF (scanned GNC maps), as well as a hypertext version. They can be read or downloaded via the World-Wide Web server with a mosaic client from the SDAC (Solar Data Analysis Center) home page:

http://umbra.gsfc.nasa.gov/sdac.html

Most of the files are also available via anonymous ftp.

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METHODOLOGY FOR OBSERVING BAILY'S BEADS DURING SOLAR ECLIPSES

Paul D. Maley and David W. Dunham

Introduction: The British Astronomer Francis Baily (1774-1844) was the first to publicize tiny points of light on the edge of the moon during an eclipse of the Sun when he set up at the wrong location during an eclipse expedition nearly two hundred years ago. A four time president of the Royal Astronomical Society and famed for his star catalog work, he was also a scientific consultant to the government. He calibrated a new standard yard and helped refine the Nautical Almanac. Baily's Beads were observed extensively during the annular solar eclipse of 1994 May 10 in the USA. Expeditions conducted by the International Occultation Timing Association (IOTA) in New York, Ohio, Ontario, Michigan, Indiana, Kansas, Oklahoma, New Mexico, and Texas contributed to the bulk of information gathered which will be used in an ongoing project to define historical variations in the size of the Sun. These data were gathered using portable telescopic and video recording devices accompanied by bench marked time signals. It was obtained within narrow corridors describing the inner and outer limits at northern and southern edges of the eclipse path.

Although numerous solar eclipses will occur over the next 20 years, those of us in the USA will not be favored with a total eclipse until 2017 August 21. The purpose of this paper is to describe techniques used during the eclipse which worked well and those which did not, so that observers in the forthcoming years will be able to benefit. Today there are two basic types of observations: 1) direct video either through an optical device or afocally and 2) projection of the sun onto a screen via a telescope which is then videotaped. There are also two types of geographic position determination: 1) topographic maps and 2) Global Positioning System (GPS) receivers.

A preliminary version of this paper was published in the Proceedings of the ESOP-XIII meeting that was recently held in Cracow, Poland. The authors thank Alan D. Fiala of the U.S. Naval Observatory for many helpful suggestions that have been incorporated in this version of the paper. Especially helpful were his many suggestions that have made our table summarizing previous eclipses more comprehensive. A rearranged version of this article will be included in the next version of the IOTA Occultation Manual.

Bead Appearance: Light passing between lunar mountain peaks can create shafts of light traveling the 400,000 km to the Earth so that when arriving the light beams will take on the form of points of varying intensity, or linear or curvilinear shapes. The object of the video record is to correlate the exact moment of a) the appearance of a bead, b) creation of secondary beads from primary ones as the latter break into pieces, c) the merging of two beads, d) the disappearance of a bead. Because these phenomena are delayed at the edge, they appear suspended compared to the center line where the motion of the Moon relative to the Earth is most rapid as seen by the observer. The video record occurs at 30 frames per second, which is enough to provide the time and image resolution needed for analysis. Direct filtering will dim the appearance of some beads between different types of telescope/video systems which is why two such systems placed side by side will record differently. Using the same technique from eclipse to eclipse affords a systematic approach to recording the beads. A projected image, while generally more difficult to control, will usually offer just as good a resolution provided the contrast is properly controlled. Placing the screen in an enclosure to protect it from ambient light is a good idea. When viewing beads on a monitor, particularly the LCD type, it helps to place a shield around the monitor screen to shield it from surrounding light in order to focus and maintain vigil of the solar image.

Standards: There have been no true standards of observation in the Baily's Beads activity defined up to now. This is largely because of the variety of equipment available to observers around the world, three basic formats of video signals and differing sources of time. The latter is of the least concern, since all time signal bases can be converted, or are referenced, to Coordinated Universal Time (UTC). The geodetic datum (such as the 1927 North American datum) is a reference frame in which the site longitude, latitude, and height above sea level must be specified. Positions in different datums can be converted to a standard World Geodetic System for analysis. In the USA the NTSC video format is the standard for analysis and most types of commercial video cameras or camcorders (VHS, VHS-C, 8mm, Hi-8) can be copied or converted for processing. The standard recording speed is SP. Telescope platforms are generally equatorial or alt-azimuth but the former is preferred as a standard since automatic tracking of the Sun is preferred versus manual tracking. A standard optical focal length would be on the order of 1000mm which would yield an image covering an arc of about 120° around the solar periphery. Still photographs are normally not able to be used for this project except as a benchmark for bead activity at specific locations.

Sample equipment and setup checklists are documented in **ON 6** (2), page 39, although a few additions to those are suggested below. Projection screens have been employed in earlier eclipses so that solar filters are not needed. If a transmitted image is videotaped, a standard translucent projection screen should be used. For a reflected image, a flat (not glossy) white surface should be used. In either case, the screen should be shielded from ambient light rays and mounted so that it tracks with the telescope, thus minimizing potential for optical axis misalignment with the passage of time. Coordinated Universal Time (UTC), such as that broadcast by WWV and WWVH, is the standard time reference. WWV and WWVH can best be received at frequencies of 5.0, 10.0 and 15.0 MHz; this signal has been successfully received on numerous IOTA expeditions we have conducted in Asia, Europe, Africa, South America and the Pacific Ocean area. Positional standards must yield an accuracy no worse than 30 meters (100 feet). This can generally be achieved with careful measurement of 1:50,000- scale topographic maps or through use of differentially corrected GPS receiving devices. Methods of using GPS will be documented for IOTA purposes in a separate future article, an ASCII version of which will be sent soon by e-mail to leaders of expeditions to the edges of the path of totality of the November 3rd eclipse. In the meantime, see some GPS cautions in **ON 6** (2), page 42 and in **ON 5** (1), page 12. The solar filter used during annular, annular-total, and total eclipses should be about ND4 or ND5, in any case, strong enough so that the gain of your system allows sharp focusing of the solar disk without blooming.

Timings: Usable video records have really only been collected for a few eclipses. This is because technology has changed since IOTA's first eclipse expeditions. There are two rationales for collecting data. The first is to collect the best bead data with whatever technique. The second is to look for variations by comparing to past eclipses. In the latter case visual timings, tape recordings of visual timings from watching a projected image, timing the duration between second and third contact by direct visual observation and direct visual observation by many observers (where a few are placed to report a bare instant of totality) are all useful techniques. But for current and future video observations, we want to establish the standardized procedures described here.

The minimum number of video records required is two--one at each limit. But the observers need to be in the proper locations to obtain bead events fairly close to the polar regions. If the observers are situated 3 or more km from the limb-feature-corrected edge either at a total or annular eclipse, this will not happen. In the case of an annular-total eclipse such as occurred in the USA on 1984 May 30, one observer can get bead events at both poles. However, the idea is to minimize the field of view and maximize resolution so having one observer look at one pole and a second covering the other is optimum. Having two videos at each limit at slightly different depths (covering a range of one km for the lunar north polar beads, and about 3 km or more for the lunar south polar beads) should be the standard mode of operation. This is synonymous with having two or more observers for a grazing occultation. In the recent past, observers have tended to be too far from the true limits, especially for total eclipses. With the more accurate predictions now available observers can position themselves closer to the true limits without fear of being outside the path of totality.

A minimum of two beads measurements is required from each video tape--one before central eclipse and one after. But more are required to obtain a good statistical result. At least 10 measurements should be within 20° of the pole (half before and half after) with an additional 10 to make a total of 20 bead measurements. If the observer is in the correct location and focus is good, it should be practical to obtain 30 to 60 measurements. The more the better, first, to reduce the very large error in a single Watts value and second, to increase the odds of getting bead timings of the <u>same</u> lunar features that caused beads during past eclipses.

If video is not used, an observer only needs to time the duration of totality--that is 2nd to 3rd contact, if he/she is located within a few tenths of a kilometer of the limit where either an instant or short duration totality is seen.

Timing accuracy of 0.1 second is useful for beads far from the poles that are used to calculate the difference in ecliptic longitude of the Moon's center relative to the Sun's center. Considering the gradual nature of bead events, 0.1 seconds is the best that can be recovered from video tape analysis in most instances. However, a 0.5 second accuracy (the minimum required for grazes) is alright for the polar bead events, where the radial motion is slower and the occurrence of beads depends more on the observer's position than the timings themselves.

What if you record a tape and there is no time signal on it? Can it be used? The answer may be "yes". Even a tape with no timing on it can sometimes be used by inserting a relative time scale on it. By examining the tape it should be possible to infer the central eclipse time to less than 5 seconds and this can also be predicted accurately for the site. The difference of the computed time of central eclipse and the observed relative time of central eclipse ("time correction") can be added to all of the relative timings. Then a reduction of the bead timings will show an imbalance of the residuals before and after central eclipse caused by the error of the time correction (that is, of the "observed" time of central eclipse). The reductions can be repeated using a different time correction to give a different imbalance number. Here, imbalance is defined as the difference of the mean residuals of events well before central eclipse minus the mean residuals of events well after central eclipse. Iteratively, a time correction can be found that drives the imbalance to zero. If a systematic trend remains in the residuals, a rate correction can be computed. Better than all of this would be analysis of beads far from central eclipse from another tape with good timing. By comparing residuals for the same bead events (that is, those caused by the same Watts features), a better time correction can be determined for the tape without recorded time. The end result will be a reduction that will be useless for determining the Moon-Sun longitude difference. But the result will be quite useful for finding the Moon-Sun latitude difference and the polar diameter difference. Nevertheless, observers are encouraged to record a good time base, since we would prefer not to make this extra effort. If a good quality well-timed tape is available, we will not reduce tapes with no timing information.

<u>The Search for Solar Radius Variation:</u> IOTA expeditions and historical analysis of old records have been employed to determine the solar radius variation with some degree of success. In some cases data have not been reduced but there is substantive belief that the data could be used for the variation determination. A summary of the status of all eclipses for which edge observations are known to us is given in the table on the next page. Results from eclipses that have been reduced are given by Alan Fiala, David Dunham, and Sabatino Sofia in "Variation of the Solar Diameter from Solar Eclipse Observations, 1715-1991", **Solar Physics 152** (1), pp. 97-104 (June 1994). This was a special conference issue, for International Astronomical Union Colloquium 143, "The Sun as a Variable Star," held in Boulder, CO, in June 1993.

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DATE	TYPE	USABLE	MORE WORK REMAINS	NOTES
1715 MAY 03	TOTAL	YES	YES	RE-REDUCE
1869 AUG 08	TOTAL	YES	YES	DATA COLLECTED FROM LITERATURE
1878 JUL 02	TOTAL	YES?	YES	LOTS OF DATA,POOR POSITIONS
1900 MAY 28	TOTAL	YES?	YES	DATA IN LITERATURE, NOT EXAMINED
1912 APR 17	ANNULAR-TOTAL	YES	YES	DATA IN LITERATURE, NOT EXAMINED
1922 SEP 21	TOTAL	YES	YES	GOOD DATA, POOR POSITIONS
1925 JAN 24	TOTAL	YES	YES	RE-REDUCE
1966 MAY 20	ANNULAR-TOTAL	YES?	NO	RECORDS NOT AVAILABLE
1970 MAR 7	TOTAL	NO	NO	USEFUL TIMINGS AT N.LIMIT
1972 JUL 10	TOTAL	NO	NO	CLOUDS; FEW USEFUL TIMINGS
1973 JUN 30	TOTAL	NO	NO	POOR POSITIONS; FEW N. LIMIT TIMINGS
1974 JUN 20	TOTAL	NO	NO	S.LIMIT OVER OCEAN - NO DATA POSSIBLE
1976 OCT 23	TOTAL	YES	YES	RE-REDUCE
1979 FEB 26	TOTAL	YES	YES	RE-REDUCE
1980 FEB 16	TOTAL	YES	YES	RE-REDUCE
1981 FEB 04	ANNULAR	YES	YES	RE-REDUCE
1981 JUL 31	TOTAL	NO	NO	FIRST VIDEO OF BEADS; FEW CLEAR BEADS, POOR VISUAL DATA AT S.LIMIT & POOR POSITIONS
1983 JUN 11	TOTAL	YES	YES	RE-REDUCE
1984 MAY 30	ANNULAR	YES	YES	OVERLOAD OF BEADS; NEED AUTOMATED ASSISTANCE
1984 NOV 22	TOTAL	NO	NO	ONLY PHOTOS AT S.LIMIT; POOR POSITIONS
1986 OCT 03	ANNULAR-TOTAL	NO?	NO?	STILL PHOTOS ONLY FROM FLIGHT NEAR ICELAND
1987 MAR 29	ANNULAR-TOTAL	YES	YES?	
1987 SEP 23	ANNULAR	YES	YES	NEED TO COMPLETE WORK ON IOTA DATA
1988 MAR 18	TOTAL	YES	YES	VISUAL DATA AT BOTH LIMITS IN SUMATRA
1990 JUL 22	TOTAL	NO	NO	CLOUDS AND INABILITY TO ENTER SIBERIA
1991 JAN 15	ANNULAR	NO	NO	CLOUDS
1991 JUL 11	TOTAL	YES	YES	MARGINAL DUE TO POOR DATA AT N.LIMIT
1992 JAN 04	ANNULAR	NO	NO	PROBABLY MARGINAL; ONLY PHOTOS
1994 MAY 10	ANNULAR	YES	YES	

Observing Lessons Learned: We summarize below specific possible failure points or weak areas based on viewing of nearly 20 video tapes, as well as direct field experience.

Focusing: One of the main reasons some bead videos are not very useful is failure of the observer to constantly monitor focus. Focus can change at any time during the recording process. During projection, any tilting of the optical axis of the telescope to the screen can result in defocusing. A manually focused lens such as a Celestron 90 telephoto can actually slip and lose focus as it is tilted in elevation. The observer should focus on the edge of the Moon, not the Sun, in order to maintain an initial focus. As the beads begin to form, refine the focus quickly by going in and out of focus until the optimum is reached. Note that an apparently clear focus prior to bead formation may fool the observer into false confidence and letting the video run unattended. Always monitor the focus and image orientation 100% of the time during central eclipse. Use two aperture stops on opposite sides of the full telescope aperture, not just one, to ensure good focus when the stop is removed; see **ON 6** (2), p. 37.

Contrast: Setting up the correct contrast for the brightness of the Sun's limb should be carefully organized so that a bright, sharp dynamic difference exists between the Moon and Sun. Ideally the range of brightness can be expressed as a gray scale of 0 to 255 where 0 is the background Moon and 255 is the Sun. Several videos showed contrast ranges that were much more compressed. The beads on those tapes were recognizable but not distinct and pristine. In at least one case the observer changed the gain of the video camera when clouds were present or had manual iris control which achieved the same result. The beads were weak under mild cloud cover which had been present earlier when the gain was left alone. As the beads appeared the observer recognized their weak contrast and increased the dynamic range although too late to avoid losing a significant portion of the data.

Blooming: Bead images can bloom or become larger than they should be when too much light is allowed into the camera. Any of the recording methods may cause this to occur, including light leakage around a solar filter that has not been properly attached. Increasing the focal length of the system through aperture stops will help prevent this. Caution should be used so that the Sun's light is not dimmed too much by the hole size. During the partial phases an overexposed direct color video image can be detected by a whitening effect toward the middle of the sun with better color contrast toward the edges. A simple aperture stop test can consist of putting one's hand in front of the telescope opening. Then look at the video image and see if the color (or brightness, if you are using a black-and-white camera) is symmetric all over the solar disc. If removing your hand causes the color to shift, then a stop is needed. One way is to have an iris that can be manually opened and closed or a card/aperture mask with two one inch diameter holes (one at either side) which creates a similar effect. For total eclipses, knowing when to remove and reinstall the ND filter can be difficult to determine. Light can flood in and overexpose the beads. As filters are removed or added, great care must be used to avoid inducing vibration.

Under/Overexposure: Camcorders offer manual adjustment of exposure times which is an advantage over most video cameras which operate at a fixed shutter speed. Using a standard neutral density (ND) 5 filter will work for brighter beads, but smaller ones may be underexposed. Changing shutter speed from 1/250 to 1/125 would allow more light in and thus enhance the fainter beads. Another suggestion is to use an ND4 filter with an aperture stop to alter the focal ratio as needed. Manual gain control on a CCD type camera is preferred over use of auto gain since it provides added flexibility.

Time Signal Anomalies: Without accurate time references any data taken is usually useless. Since the ionosphere fluctuates during an eclipse, having a short-wave receiver with multiple frequencies for reception is a must. Do not set up near high tension lines which might create interference in time signal reception as well as generate noise in the video system. One should always test the recording prior to central eclipse to be sure the radio is positioned properly relative to the microphone of the recording system. A connecting cable feeding the time signal directly to the "audio in" connector of the video system is the preferred method. But if this is done, earphones should be used to monitor the sound as it is recorded. Tom Campbell's VTACT can be used to enhance voice and WWV signals; see **ON 5** (7), p. 178. Do not talk during the minute tones. Operating an automobile engine near the site will also generate noise in the short-wave RF spectrum.

Lap Timers: Lap timers are excellent to use when the accuracy displayed is down to hundredths of a second. The only concern for any lap timer displayed during real-time recording is that some bead events may become masked by the characters being generated in the display. The observer should be especially cognizant of this. It is better to not have any lap timer display and instead, verify that WWV (or other time signal source) is strongly recorded on a separate audio channel. Peter Manly's Mark II time inserter is the only one that can automatically trigger from the WWV or WWVH time signal, so it is the recommended timer for real-time eclipse recording (Cuno in Germany has a similar time inserter that triggers from the DCF ground wave time signal available in Europe). If you record WWV or WWVH, IOTA can create a time-inserted copy of your tape, as discussed in **ON 6** (2), p. 35-36.

Tracking: Automatic tracking of the Sun is mandatory when attempting bead recording. A clock drive tracking at the solar or sidereal rate is a must. Avoid using an alt-azimuth mount. A driven mount will permit stable images of the beads and allow the observer to focus all concentration on the task at hand. One major problem especially during annular eclipses is tracking the active cusp(s). The field of view should have both cusps as much of the time as possible, especially during the two minutes around central eclipse. If both cannot be fit, the field should always have at least one cusp in view with as much of the area between the two cusps in the middle as possible. If the video frame format is rectangular in shape, always have the longer axis parallel to the point of tangency so that as central eclipse approaches all activity at the point can be recorded and no data lost.

In several cases the observers "toured" the cusps swinging around the entire arc of the bright limb rather than staying with the cusps alone. This was due to either ineffective manual control ability of the system or confusion on part of the observer to know which area was experiencing beads at the time. Because it can be difficult for a first time observer to easily spot which cusp is active if his/her system has a very small field of view, it is important to choose a system that will image about a 120° arc around the solar limb. Much more than this and you will lose resolution needed to record the smaller beads.

Another common problem when manually adjusting for a moving Sun was the appearance of jerkiness as the observer made corrections. In some instances the Sun swung completely out of the field of view or kept going from one side to the other during critical bead activity.

Tape Problems: Both video and audio tapes should be rewound to the beginning and new tapes used in all cases. The tapes should be clearly labeled. Assure that any "write protect" features are not enabled prior to attempting to record. Always bring backup tapes. Tape jams in VCR's can occur in extremely humid weather. One must always carry at least one spare tape in the event an unrecoverable jam occurs. Circuits inside recorders are enabled to prevent recorder activation until the humidity levels are acceptable. Equipment should be left out long enough to acclimatize it to the surrounding conditions, unless it is below 0° C, when recorders should be kept warm enough to prevent freezing of lubrication grease and exposure to ice.

Condensation: One penalty for exposing telescope (or camera) surfaces to air conditioning in either hotel rooms or automobiles (especially when the telescope is enclosed in a container) is the presence of condensation when the lens is opened to the ambient air. A dew cap and/or (if electrical power is available) a hair dryer for the telescope may be required in extremely humid situations to mitigate condensation.

Failure to Pay Attention: Awareness of what was happening along the Sun's limb was a major contributor to loss of data. The observer would watch the video output and place a cusp with obvious beads either near the center or in some cases at the edge. The latter choice was a key mistake in that beads would form off the edge and the observer either was totally unaware of this or was assuming the beads would migrate toward the bright limb from that cusp. For an annular eclipse the beads migrate the opposite way. In fact both cusps at the same time had beads forming, but one more rapidly than the other. Unless the observer had both cusps in view he/she could not be aware of this either through lack of familiarity (first time eclipse observer at the edge) or simply a lack of suspicion that activity was going on elsewhere.

There should be no distractions of any kind during eclipse observation. People of all ages who see someone with a telescope often will stop to converse or stand about and this presented problems for at least 2 sites that prevented the observer from maintaining constant vigilance on the moving cusps. Some onlookers just will not go away. It is preferable that no talking be the rule and that each site be composed of only one person unless security is of consideration. Be aware of persons who may bring flash cameras and decide to use them during central eclipse. Keep extra small strips of mylar on hand which may enlist goodwill and cooperation by onlookers. Watch to be sure that any small children are kept far away from the equipment. The observer should avoid idle chatter being recorded on the tape. Any critical comments should be voiced by one person only on the tape.

Another result of failure to pay close attention or to take corrective action occurred in two cases. In the first instance, one limb of the Sun was obviously out of focus while the other was in focus. In a second case, the observer commented about the poor focus but made no attempt to refocus. Both video records could have been of superior quality instead of just average had the proper measures been taken. See **ON 6** (2), p. 40 for a checklist of things to do just before recording.

Vibration: It is easy to induce vibrations either from wind, bumping the telescope or simple manual slow motion activation. Timing bead events is very sensitive to all of these and they should be avoided. A stable mount can be created by locating rocks or carrying plastic bottles which can be filled with water at the observation site and either hanging these from a plastic bag suspended on a string or from tape. Avoid attaching any other experiments to the platform carrying the Baily's beads equipment. You should not be executing any other task (such as still photography) simultaneously with the video; let a companion take any still photos.

Clouds and Wind: A common item overlooked is the presence of wind and clouds during eclipse. Clouds will diffuse beads, rendering them weak or useless. The so-called "eclipse wind" can arise at the onset of central eclipse, causing movement in the telescope and shaking any beads. Without clear unambiguous evidence of each bead's formation, merging and dissipation, your video record becomes either marginal or worthless. Any site chosen should be sheltered from wind and a plan developed in case wind does form. If setting up a station behind a weather system which has cleared skies, wind may be a constant problem. Even the slightest shaking can cause loss of timing of a bead event.

Acquiring the Sun: In a clear sky there is usually plenty of time to acquire and track the Sun. But when clouds are present or you are driving to the site to avoid clouds and time is getting short, you may have to deploy quickly with inadequate setup time. Then locating the Sun with your telescope can be a problem. One way is to mount a small pinhole projection device parallel to the telescope axis or a cardboard tube that will cast the Sun's image to a translucent back surface. It should be boresighted before leaving for the site, either the previous night or earlier in the day so that both axes are verified as parallel. This way, when the telescope is secured on the mount, the Sun can be rapidly found even in partly cloudy skies. Relying on the shadow of the Sun to form behind the telescope is not a reliable way to align the telescope.

Maintaining the Sun in the field of view is probably the biggest problem of all. Mishandling a drive corrector or failure of the drive system to track properly or the need for constant manual correction while attending to other details can spell doom. If the Baily's Beads cannot be stable in the final video record, the whole mission could be in jeopardy. Every effort must be made to minimize the need for any manual tracking of the solar image.

Inadequate Field Tools: Another problem is to forget a critical tool after having left for the eclipse site. The best way to prevent this is to add all tools to your check list, and check off all items on a copy of the list off before you leave; take the same list after the eclipse is over and check it off to be sure all of your equipment is present when ready to leave from the eclipse site. Couplers and rings which have tiny screws may come loose during alignment and tracking. Always carry the smallest screwdrivers needed to tighten these rings. Wrenches, screwdrivers, nuts and bolts are all vital. Keep these in transparent plastic bags. Seal also the suggested checklist in **ON 6** (2), p. 39.

Overloading the Mount: A common mistake is to put too much mass on the mount, thus causing it to fail to track properly in the "eclipse position". This is defined as the pointing and balance configuration at central eclipse. Another pitfall is to fail to carry enough counterweights to cover unanticipated situations. A roll of duct tape or similar strong tape can be used to secure an impromptu weight addition. Tape can be wrapped around a rock, or plastic bag of dirt or water, found on site and then draped on the needed axis to add temporary balance in field conditions. Overloading the mount can also be achieved by improperly planning your work load. Some observers attempt to shoot video and still photos and end up doing a poor job on one or both. Do one thing and do it well!

Inadequate Simulation: Simulating the eclipse should be done many days beforehand. View a prior video tape of Baily's Beads that will jog your memory and renew familiarity with the task at hand. For new observers, the video will be especially instructive to demonstrate the rapidity and fidelity of the images that need to be obtained. It will also show the prolonging of the bead phenomena at the edge and how easy it is to make a mistake. The eclipse process is unforgiving.

Conduct a "dry run" in which all of your equipment is packed and move to a place where you can unpack it and test it outside in a clear sky. A clock drive should be a mainstay of the hardware and should be tested and retested. The Sun should be positioned roughly in the area where it will be during the eclipse (if practical). Here you can find out what has been left behind, what does not work, and what should be done differently. When the eclipse is in the Southern Hemisphere of the Earth, be assured the telescope motor drive is configured to operate properly. The observer should time him-self/herself when setting up equipment to become familiar with the reality of budgeting time in the field.

Power Problems: One should carry at least one or two backup power sources (including a battery charger and multivoltage converter kit) for critical components such as short-wave receivers, VCR's or camcorders, and monitors. Designing a custom configuration to power the recording device from an automobile battery is also useful. When relying on battery powered devices operated from camcorder batteries, 9v or others, always bring either new batteries or freshly charged ones. Purchasing a battery at a remote location such as a foreign country may prove disastrous unless you keep in mind that it generally takes 12-24 hours to charge the battery up to a full charge state. Carrying a portable voltmeter is very helpful in assessing the battery charge status.

Mount Alignment: A mount can be aligned in azimuth in the field during daylight hours using a common compass (reference topographic maps for the appropriate magnetic correction to be applied). Even a compass isn't needed if you set up along a north-south road, or any straight road whose direction you have measured from the map. For this, a protractor is useful to determine the direction of north. An inclinometer (bubble level) is handy for setting the elevation of the polar axis which only needs to be done to the nearest degree or so. If it is possible to be at the site during the previous night, the mount can be properly aligned to the celestial pole.

Site Location: Location of the site should take into account roads where there is high pedestrian or auto traffic. In the former case, this could present an unnecessary security risk as well as invite the curious. In the latter, heavy vehicles such as tractor trailers can impart vibrations through the ground which can be received by the telescope mount and translate into interference in the video process. If the site is located in a possibly unsafe zone, contact the local police before occupying it. Sites should be easily locatable on maps with adequate protection from the elements when possible.

Stability of Surface for Mount and Components: Find solid ground on which to set the telescope mount and other equipment. Assure that neither is set up in wet or soft areas and also verify that stinging insects such as ants or scorpions are not on the site. Do not set up on an inclined surface.

Failure to Record (Audio/Video): Be sure all wire connections are tight and secure. Tapes, whether audio or video) should be new, rewound and verified at the start point. A test should be conducted with the entire configuration well before central eclipse where about 15 seconds worth of audio/video is collected and replayed. It is recommended that this be done an hour before central eclipse to allow plenty of time to fix any problems that the test(s) reveal. Be sure the record mode is set to SP.

GPS Reception: GPS receiving devices may be affected by objects which obstruct a full 360° horizon. Buildings, cars, power lines, mountains, etc. may prevent the receiver from picking up at least 4 satellites which is the minimum required to obtain a 3-dimensional position fix. Be sure the receiver memory which stores data has plenty of file space available to record the positional information. As noted in the references and discussion about GPS in the standards section near the beginning of this article, differential GPS (DGPS) using two receivers is needed to measure positions with sufficient accuracy for this project. When using DGPS, assure that the base and rover units are recording data simultaneously.

Length of Video Record: Beads can form many minutes prior to or following central eclipse. Begin recording at least 8 minutes before and after the predicted central eclipse time and always keep track of the time and view simultaneously to be sure that there is no significant error in the actual time of eclipse at the site. Make sure you read the times from the predictions for the limit from which you will be observing.

Image Scale: Some observers tend to zoom in and out during the eclipse, causing the resolution of beads to vary in appearance. Settle on one scale and maintain it throughout the recording period. When using a projection screen that is not tracking with the telescope, the image can drift onto the edge of the screen, causing loss of data while the observer struggles to manually put it back in the center. The projected image scale needs to be large enough to resolve the beads but not so large that it would drift off the screen.

Contingency Scenarios: What if a critical piece of gear fails prior to the eclipse? Bring a backup for everything that is practical. If teaming with another observer, then combine observations only if one person has had a major unrecoverable failure. Otherwise, never waste valuable resources by having more than one independent observer with fully operational equipment at the same site (however, if there are many observers, observations with different methods by a pair of observers at the same site can be useful for comparison purposes).

Traveling by Automobile: Many observers have had the opportunity to frantically drive away from impending clouds prior to central eclipse. Because time is of the essence, the observer's equipment should be spread out and partly assembled as much as possible in the car, either the night before or the morning of the eclipse, in order to minimize setup time. This assembly and prepositioning may be the difference between success or failure. If using a GPS receiver, utilize the waypoint feature if available. Enter two points in longitude and latitude between which you are certain to observe. The receiver can be mounted in the car and used real-time to determine cross track differences relative to the limit line. Maley used this during the May 10th annular eclipse and never had to check or use any maps. Simply driving about and looking for an optimum site would allow periodic glancing at the GPS readout in order to determine where one was within .01 km perpendicular to an imaginary line drawn between these waypoints. But if you don't have a way of using DGPS (see the GPS reception section above), you should be sure that you select a site whose position can be measured from a detailed topographic map of the area.

Protecting Equipment: Bring plastic bags to protect all equipment from moisture or neutral color coverings to place over exposed surfaces to protect from dust and heat. Thermal blanket (mylar) is a good heat protector, and it can be used for visual filters in a pinch.

Examples of Video Frames and Composite Tape: The following graphic illustrates typical views of the beads at varying distances from the northern and southern edges at the May 10th annular eclipse. Each tape is examined for image and time quality. Those tapes that are acceptable for entry into the post eclipse analysis were collected and, if a time stamp is not present on the video image, one is inserted afterwards which shows time to hundredths of a second, the time being synchronized to a source like WWV for absolute time, as discussed above. The tape is then rolled forwards and stopped at points where a candidate bead event is identified. The single-frame mode will be used to determine the bead event times to within two or three frames. The time for each event is then logged and entered in a file in the standard IOTA Soleclob format for reduction; see **ON 6** (2), pages 35 and 36. We have collected what we believe are all usable (and some unsuitable) video records made near the limits of the May 10th annular eclipse, and have made a composite of all of these tapes (about two minutes from the center of each) which we will soon distribute to the observers who sent us tapes. A little later, we will sell or loan (maybe rent) copies of the composite tape to anyone who wants it.

Determining the Solar Radius Variation: Once timings are determined for each bead event, they can be entered as data into the OCC or OCCRED computer programs to produce a bead information file which is organized by event, date, time, bead event type, lunar librations, and the topocentric differences in the apparent position of the Moon-Sun center. A separate bead reduction software program (BBEADR) takes this input file and generates a detailed chart of the Watts profile and the Sun's limb in the vicinity of where they intersect for each observation. These are examined to manually select the Watts feature that caused the bead event, usually the valley bottom closest to the Sun's limb for disappearances and reappearances, or the mountain top closest to the Sun's limb for bead form and merge events. Sometimes the video record or photo can be compared with the charts to see the pattern of beads to help with this selection. Once the selection has been made, the Watts angle of the selected feature of each event is entered into the bead information file above.

The bead reduction program is then rerun to produce an output residual file which for position angles (or Watts angles) of the event which gives the height of the Sun's limb above (positive) or below (negative) the Watts feature (the residual) at that time. If the prediction were perfect, the residual would be zero. Each observation can be weighted.

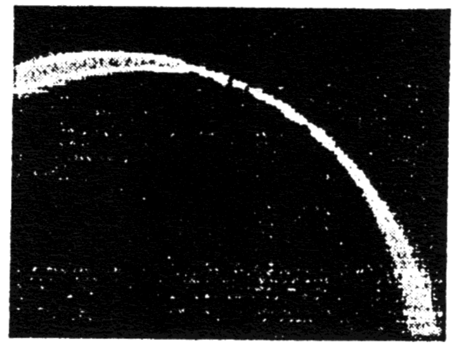
The residual file is processed by a least squares program that computes corrections to the Moon-Sun ecliptic longitude and latitude, and the Sun-Moon radius. Since the Moon radius is considered fixed at its value determined from thousands of occultation observations, this is really the correction to the standard value of the Sun's radius. The accuracy of the results depends on the quality and number of observations in the residual file and the distribution around the Moon's limb. To get an idea of how the process works, if all of the residuals were $+0\overset{''}{.}1$, the solution would give $+0\overset{''}{.}1$ for the correction to the solar radius, and zero for the longitude and latitude differences. If all of the north limb residuals were $+0\overset{''}{.}1$ and all the south limb residuals were $-0\overset{''}{.}1$, with good distribution around the limb, the solution would give $-0\overset{''}{.}1$ for the Moon-Sun ecliptic latitude and zero for the other corrections.

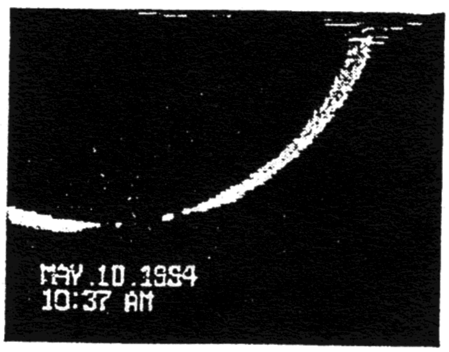
In practice the solution process can become quite complex. The observations that yield large residuals are re-examined to see if the Watts feature for the event may have been incorrectly identified or there is another problem, perhaps with definition on the video tape. Spurious or uncertain observations are discarded and the process repeated. Once a good solution with all of the accepted observations is obtained, another solution is made fixing the longitude difference at the first solutions's value and determining the latitude difference and solar radius difference using only the observations within 30° of a Watts angle of 0° and 180°, that is, within 30° of the lunar poles. Solutions like this can also be made using only the observations at specific Watts angles that were observed at two different eclipses, which virtually eliminates errors in the Watts data in determination of the solar radius correction at the two eclipses.

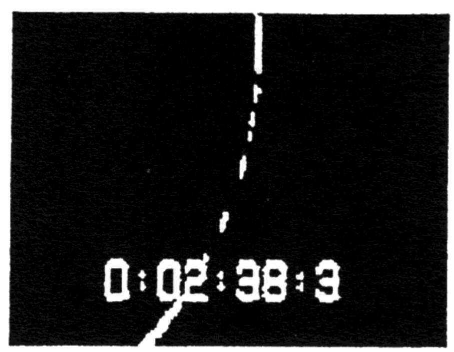
Note that the determination of the solar radius is always relative to the adopted values for both the Sun and Moon. If the lunar polar diameter can be defined for lunar eclipse grazes, then a correction can be applied to the adopted lunar radius, and the Sun's size can be determined absolutely. That is, the lunar polar radius correction would be added to the adopted solar radius, then the correction determined from the solution program for the solar radius can be added to that to get the Sun's size at mean distance.

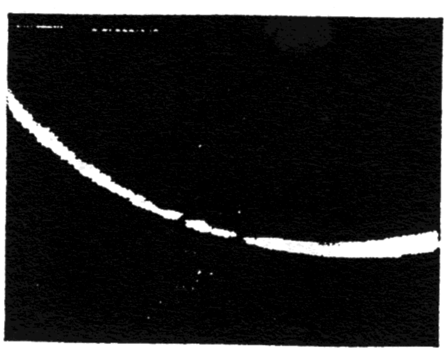
EXAMPLES OF VIDEO FRAMES

The following graphic illustrates typical views of the beads at varying distances from the edge at the 10 May 1994 eclipse.









The International Occultation Timing Association was established to encourage and facilitate the observation of occultations and eclipses. It provides predictions for grazing occultations of stars by the Moon and predictions for occultations of stars by asteroids and planets, information on observing equipment and techniques, and reports to the members of observations made. IOTA is a tax-exempt organization under section 509(a)(2) of the (USA) Internal Revenue Code, and is incorporated in the state of Texas.

The ON is the IOTA newsletter and is published approximately four times a year. It is also available separately to non-members.

The officers of IOTA are:

President	David W. Dunham
Executive Vice President	Paul Maley
Executive Secretary	Rocky Harper
Secretary-Treasurer	Craig and Terri McManus
VP for Grazing Occultation Services	Joe Senne
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IOTA/ES Treasurer	Alfons Gabel
IOTA/ES Research & Development	Wolfgang Beisker
IOTA/ES Public Relations	Eberhard Riedel

Addresses, membership and subscription rates, and information on where to write for predictions are found on the front page.

The Dunhams maintain the occultation information line at 301-474-4945. Messages may also be left at that number. When updates become available for asteroidal occultations in the central U.S.A., the information can also be obtained from either 708-259-2376 (Chicago) or 713-488-6871 (Houston).

Observers from Europe and the British isles should join IOTA/ES, sending DM 40.-- to the account IOTA/ES; Bartold-Knaust Strasse 8; 3000 Hannover 91; Postgiro Hannover 555 829 - 303; bank-code-number (Bankleitzahl) 250 100 30. Full membership in IOTA/ES includes the supplement for European observers (total and grazing occultations) and minor planet occultation data, including last-minute predictions, when available.

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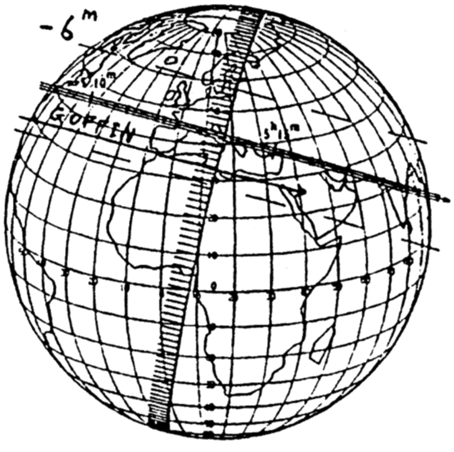
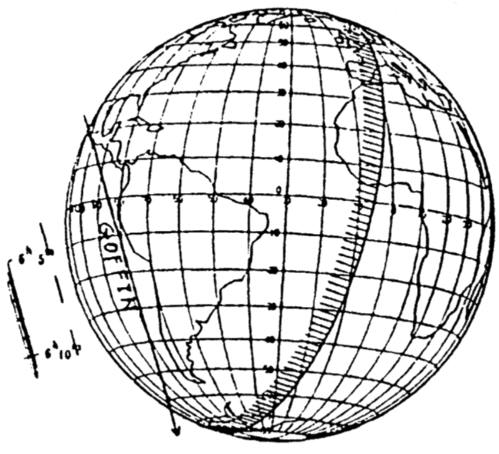
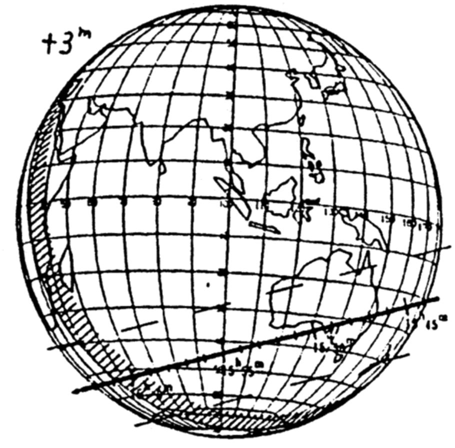
-2388-3658	-511-424696
Fax -2381-36770	-511-233112



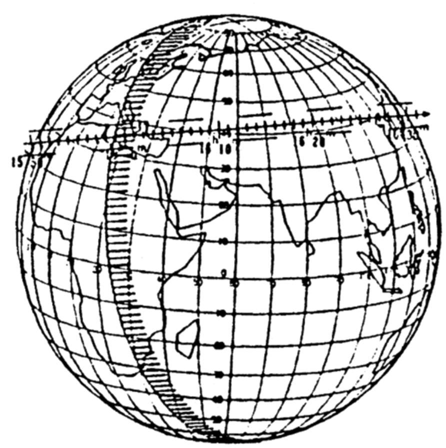
+19° 1910 by Fortuna 94 Oct 19



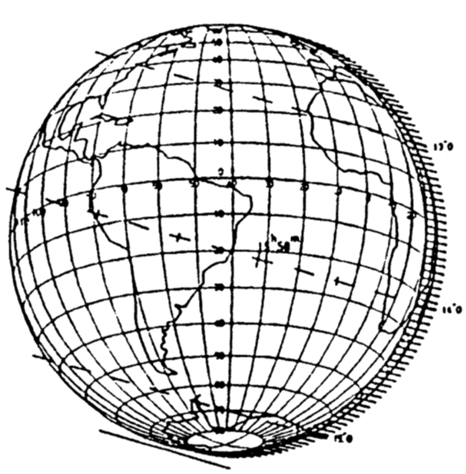
SAO 132640 by Eunike 94 Oct 20



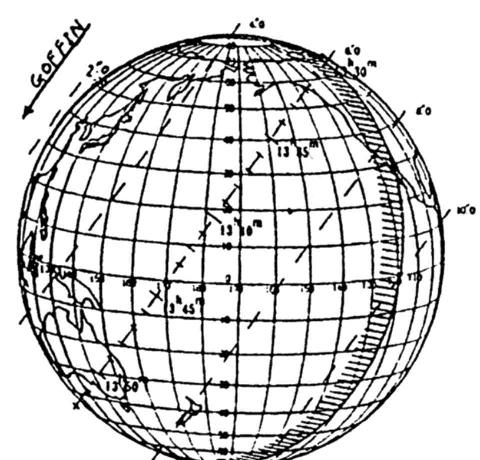
SAO 128781 by Mancunia Oct 20



SAO 107680 by Geog. Oct 23

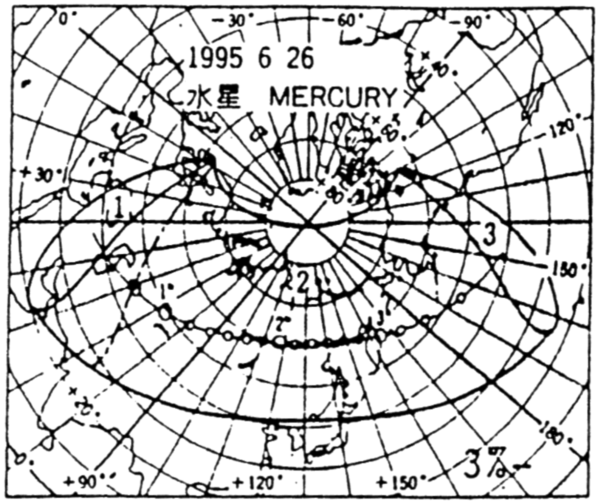


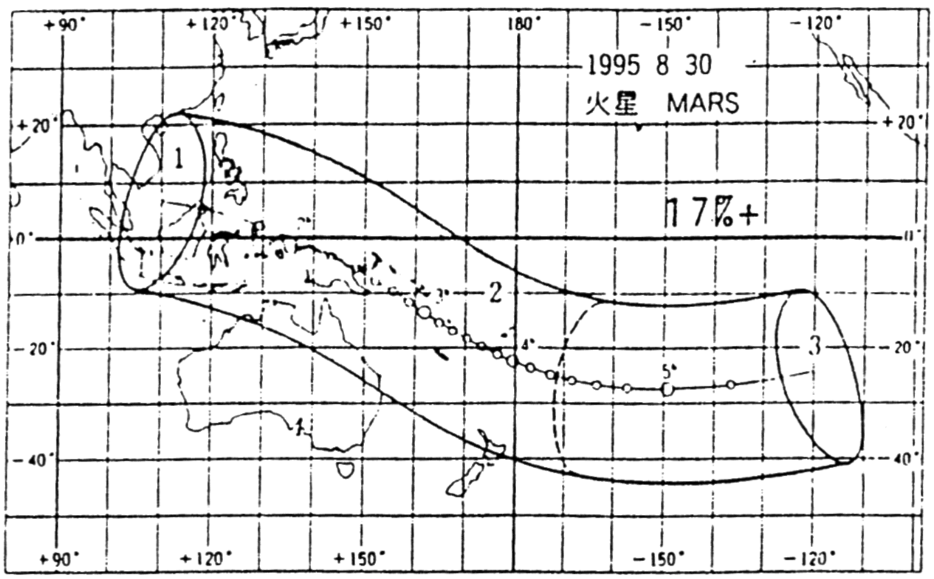
SAO 159074 by Jupiter 94 Oct 24

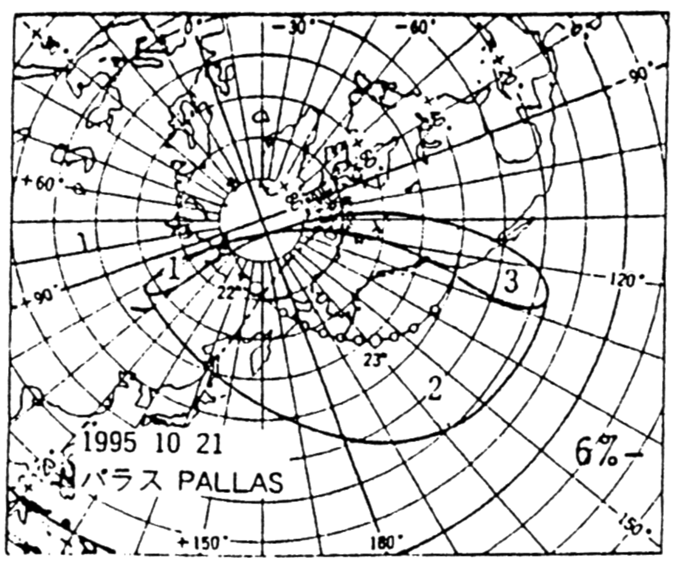


SAO 111817 by Mnemosyne Oct 25

2

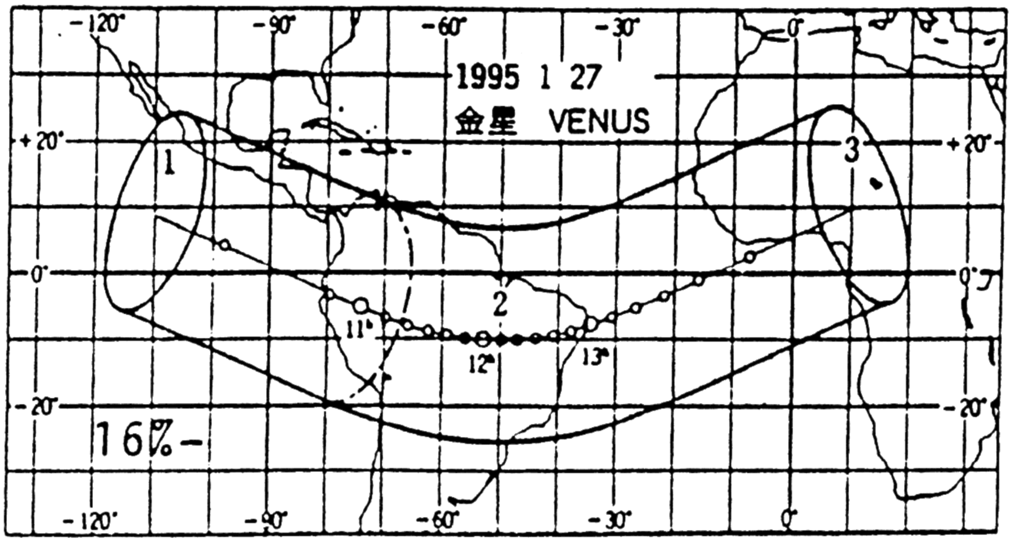






FAVORABLE MINOR PLANET OCCULTATIONS FOR 1995-2005

Edwin Goffin



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金星 VENUS
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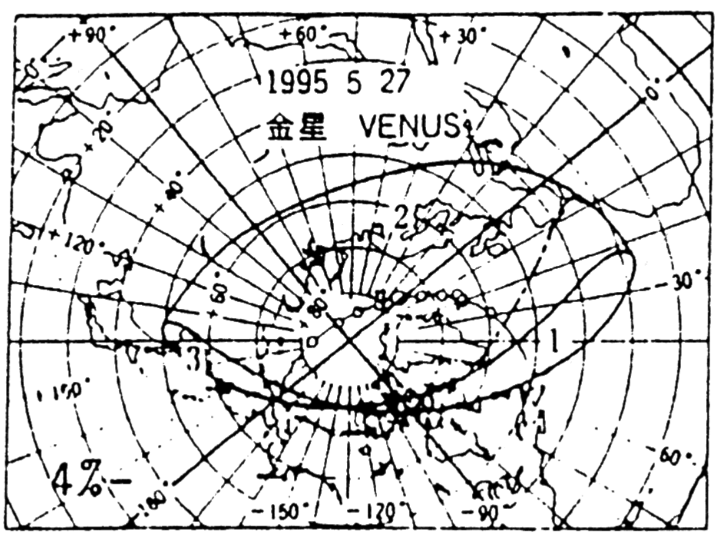

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金星 VENUS
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