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ASTEROID OCCULTATIONS: A 1981 STATUS REPORT

Paul D. Maley

Ford Aerospace & Communications Corp.
NASA Johnson Space Center
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RESUMEN

Se presenta un resumen de observaciones históricas, de métodos de predicción y de los resultados de observación desde la tierra de ocultaciones estelares por planetoides, hasta fines de 1981. Se esbozan técnicas para fomentar uniformidad en la selección de sitios, registro de datos y en el entrenamiento de observadores.

ABSTRACT

A summation is presented of the historical observations, methods of prediction, and results of the known earth-based sightings of occultations of stars by minor planets through the end of 1981. Techniques are outlined to encourage uniformity in site positioning, data recording, and observer training.

Key words: STARS-OCCULTATIONS – MINOR PLANETS

Ever since D.W. Dunham and the author wrote of possible satellites of asteroids in 1977 much attention has been given to the technique of observing occultations of stars by the minor planets (Dunham and Maley 1977). The first such event was recorded in Sweden in 1958 when (3) Juno occulted BD+6°808 (Taylor 1962); in the 19 years that elapsed following this occultation, only 5 other such observations had been actually logged. But from 1977 through the end of 1981 the total number of asteroid occultations successfully monitored rose 500% to 29. A principal factor which gave occultation science a much needed boost was the unique observation and discovery of the rings of Uranus at the beginning of this period. Yet even though more appulses are being determined for study each year, only a mere 7 out of 108 computed events for 1981 were actually seen.

The nature of the event and the method by which it is predicted and the information disseminated have not changed much, nor have changed the persons who provide the astrometric plates used for prediction refinement.

a) *Predictions.*

1. Performed using existing ephemeris data provided on minor planets by the late P. Herget and by the Institute for Theoretical Astronomy, Leningrad, USSR.
2. Late astronomical position refinement done from 14 days to one day prior to an occultation, generally from the USA and Britain.

b) *Dissemination of Prediction.*

1. Early data: publications such as the *Astronomical Journal, Sky & Telescope,* and other popular astronomical publications; also through the International Occultation Timing Association newsletter and *Circulars* of the International Astronomical Union.
2. Late data: by telex and telephone from G.E. Taylor (Britain) and D.W. Dunham (USA).

c) *Observational Methods.*

1. Photoelectric.
2. Visual (telescopic).
3. Photographic.

d) *Techniques of Observation.*

1. Random intercept by an observatory located in the predicted path.
2. A "fence line" of telescopes oriented perpendicular to the occultation track.
3. Two observer team concept.
4. Light curve analysis.
5. Speckle interferometry.

The case for asteroid duplicity or multiplicity is still very much open to discussion. Only one occultation appears to show a time coincident observation of a secondary occultation from two remotely located and independent observation ties –that of (532) Herculina in 1978 (Bowell *et al.* 1978). Another occultation involving (216) Kleopatra just two years afterward produced a claim of a secondary event by two telescopic observers separated by over 600 meters, also time coincident (Dunham 1981*a*). Roughly one of every two occultations observed has produced a reported occultation, however brief, outside the path of the main event or within it. But 4 events that can be classed as well monitored and producing a large number of chords across the disc of the asteroid have resulted in only one suspected secondary occultation.

Awareness of what to look for and the proper procedures by which observation is made have been publicized elsewhere in an effort to prevent erroneous reports from

TABLE 1
ASTEROID OCCULTATIONS OBSERVED

No.	Date	Asteroid	Star	Location	Method	Total Chords	Secondary Events	Source	Notes
1	2/19/58	(3) Juno	BD+6°808	Sweden	V	1	0	(Taylor 1962)	A
2	2/10/61	(2) Pallas	BD−5°5863	India	P	1	0	(Taylor 1962	B
3	6/02/73	(2) Pallas	BD+2°2913	Colorado (USA), Canada	P	1	0	(Binzell and van Flandern 1979)	D
4	12/10/74	(129) Antigone	SAO 097913	Florida (USA)	V	0	1	(Binzell 1978)	
5	25/01/75	(433) Eros	Kappa Gem	Massachusetts (USA)	P,V	8	2	(O'Leary *et al.* 1978)	...
6	10/10/76	(2) Pallas	SAO 153844	Arizona (USA)	V	0	1	(Binzell and van Flandern 1979)	...
7	5/03/77	(6) Hebe	Gamma Ceti	México, Texas (USA)	V	5	1	(Taylor and Dunham 1978)	...
8	29/05/78	(2) Pallas	SAO 85009	Illinois, Maryland, Nebraska, Wyoming (USA)	P	7	1	(Wasserman *et al.* 1979)	
9	7/06/78	(532) Herculina	SAO 120774	Arizona, California (USA)	P,V	3	6	(Bowell *et al.* 1978)	E
10	19/07/78	(3) Juno	SAO 144070	Israel	V	2	1	(Dunham and Sheffer 1979)	...
11	25/10/78	(12) Victoria	SAO 161878	California, Washington (USA)	P,V	2	1	(Dunham 1979*a*)	
12	11/12/78	(18) Melpomene	SAO 114159	Pennsylvania, Georgia, Virginia, District of Columbia (USA)	P,V	8	2	(Williamson 1980)	...
13	6/04/79	(39) Laetitia	BD+10°465	New York (USA)	V	1	0	(Dunham 1979b)	...
14	17/08/79	(51) Nemausa	SAO 14417	USSR	P	2	0	(Kristensen 1981)	...
15	17/10/79	(65) Cybele	BD+19°1399	USSR	P,V	3	1	(Marsden 1979)	...
16	8/12/79	(27) Euterpe	SAO 77426	Finland	V	0	1	(Dunham 1980)	...
17	11/12/79	(9) Metis	SAO 80950	Guyana, Venezuela	V,C	1	1	(Dunham 1979*c*)	F
18	11/12/79	(3) Juno	SAO 115946	California, Hawaii, Wisconsin (USA), China	P,V	15	0	(Millis *et al.* 1981)	G
19	4/09/80	(78) Diana	SAO 75392	Texas, Oklahoma (USA)	V	10	0	(Dunham 1981*a*)	H
20	10/10/80	(216) Kleopatra	SAO 128066	Washington (USA), Canada	P,V	9	1	(Dunham 1981*a*	I
21	24/11/80	(134) Sophrosyne	SAO 74963	California (USA)	V	5	0	(Dunham 1981*a*)	...
22	10/12/80	(739) Mandeville	SAO 118438	Japan	V	1	1	(Dunahm 1981*b*)	...
23	8/01/81	(44) Nysa	SAO 119165	France	V	1/2	0	(Dunham 1981*a*)	...
24	19/03/81	(48) Doris	SAO 118832	Washington (USA), Canada	P,V	3	0	(Dunham 1981*b*)	...
25	4/04/81	(91) Aegina	SAO 158864	Oklahoma, Arizona (USA)	V	0	2	(Dunham 1981*b*)	...
26	14/06/81	(9) Metis	SAO 184440	USSR			0	(Dunham 1981*b*)	J
27	7/08/81	(18) Melpomene	SAO 145972	Hawaii (USA), Australia	P,V	3	0	(Dunham 1981*b*)	...
28	5/10/81	(105) Artemis	BD−0°2683	South Africa	P	1	0	(Dunham 1981*b*)	...
29	7/10/81	(88) Thisbe	SAO 187124	Colorado, Minnesota, Wyoming (USA)	P,V,C	11	0	(Green 1982)	H

Nomenclature: P = photoelectric; V = Visual/telescopic; C = photographic.

Notes: A = First visual observation; B = First photoelectric observation; D = Two other observatories were in conflict, one reported an occultation, the other did not. E = Visual and photoelectric observations of one of the secondary events were time coincident. F = First photograph of asteroid occultation. G = Best observed event thus far.

H = Coverage confined to one hemisphere of asteroid. I = Secondary event reported to be time coincident by 2 stations 600 meters apart. J = Incomplete data.

being generated from the variety of observers worldwide. Because asteroid occultations tend to occur over any part of the globe and are of such short duration, the data obtained tend to be singular, unconfirmed accounts relying on subjective reporting by isolated professional and amateur observers.

Most of the reported secondary events have lasted a second or less, therefore qualifying in the perception of critics as artifacts of fatigue, local seeing conditions or the imagination. These "augenblick" phenomena continue to defy an easy solution.

Attempts to separate a possible companion from its parent asteroid by photographic means has not succeeded completely. Recent series of exposures made in China of (9) Metis appears to show an object very closely oriented (Sichao and Yuezhen 1981); yet the photos do not correlate well with a claimed sighting of a satellite of Metis during an event in 1979. Considerable interest is being given to the new tool of speckle interferometry which to date has revealed the possibility that (2) Pallas and (12) Victoria could have parasitic satellite companions (Hege *et al.* 1980).

Table 1 contains a chronology of occultation events where observations have been made of either a primary event (i.e., an occultation of a star by the asteroid disc) or a secondary event (i.e., an occultation outside the computed path of the main asteroid shadow or a brief occultation inside the path but not due to the asteroid itself). Some reported events have been deleted from this article due to lack of precise observation made under relatively controlled conditions (such as a valid observing technique) or due to uncertainty in local atmospheric conditions.

Table 2 comprises an added list of related events that are important in understanding the progression of knowledge on the subject.

Though the final step in the occultation process involves the actual observation of the asteroidal passage in front of the target star, the most important pieces of information are the precise location of the minor planet and the star position. Inherent catalog errors in those used (e.g., AGK3, FK4, SAO) can mean initial prediction discordances of thousands kilometers when combined with a given asteroid ephemeris. This is why a succession of astrographic plates taken with asteroid and star in the same field of view are so valuable in reducing this type of uncertainty to as little as one asteroid diameter. Urgently needed are other observatories with astrometric capability to become involved in the prediction process. This would help alleviate the crisis of the 2 or 3 institutions presently doing virtually 100% of the work. This shortage of active observatories has culminated in the prevention of accurate path shifts from being calculated for a number of occultations in recent years. Localized weather problems, commitment of observatory personnel to other programs on key nights, or computing facilities being locked on weekends have all been instrumental in interdicting late astrometry. Often only one set of "final" data is available just before the event with enough scatter in the reference stars or asteroid position to preclude a good path of the visibility zone from being obtained.

As the limiting magnitude of occulted stars extends into the fainter regions the importance of observer training increases. Recognizing the proper star from those about it must be done before the event, preferably as early as a lunation if moonlight is to be a governing factor. When a targeted star is known to be variable or even located in a field where one or more variables is present may cause an element of confusion, especially when a star atlas and actual visual inspection of the field seem to present a dilemma. Photoelectric observers are advised to practise the loss of acquisition and then recovery of the star in the shortest possible time. Simulated chart recorder anomalies due to presence of intervening clouds, power losses and loss of the star are important when reducing photoelectric records, especially when no simultaneous visual observation is made from the same location. The scintillation of the atmosphere and actual eclipse of the star should be

TABLE 2
RELATED EVENTS

Date	Event	Source
1901	Eros proposed to be a double asteroid after light curve comparison to Beta Lyrae.	(Andre 1901)
1924	Eros observed as "double".	(Innes 1931)
1926	Pallas observed as "double".	(Finsen 1926)
1930	Eros observed as "double.	(Van den Bos and Finsen 1931)
1980	Photographs show elongation of (9) Metis and possible motion of proposed satellite.	(Sichao and Yuezhen 1981)
1980	Space Telescope Design Reference Mission includes several asteroids for potential satellite investigation.	(Sherrill and Hutchinson 1979)
1980	Speckle interferometry data shows Pallas and Victoria may each have a companion.	(Hege *et al.* 1980)

simulated as well. Knowing how a specific set of equipment sponds to these stimuli provide the credibility needed for accurate data interpretation.

e) *Future work.*

The outlook for asteroid occultation work in the near term is expected to be much the same. Use of larger ground based telescopes capable of high resolution photography (such as with charge coupled devices) should be carried out. One new area on the horizon is the deployment of the Space Telescope sometime in 1985. Short of this it is clear that a need exists to encourage the observation of predicted occultation events regardless of their uncertainty. Astronomers are recommended to utilize the two observer team concept where a pair of stations are set up at least 1 or 2 kilometers apart. Single records of suspected asteroid satellite phenomena cannot be relied on without some form of time-coincident independent observation outside the influence of the same atmospheric air cells.

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Paul D. Maley: Ford Aerospace & Communications Corp., CH6 NASA Johnson Space Center, Houston, TX 77058 USA.