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PHOTOELECTRIC PHOTOMETRY OF ASTEROIDS 84 KLIO AND 678 FREDEGUENDIS

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Photoelectric observations of the asteroids 84 Klio and 678 Fredeguendis were made from Gila Observatory. Observations of 84 Klio were made between the dates of October 12 and October 14, 1985, while those of 678 Fredeguendis were made between the dates of October 26 and November 5, 1986. The following synodic rotational periods and lightcurve amplitudes are reported: 84 Klio, P=5.80 hours, ΔM=0.04 and 678 Fredeguendis, P=11.64 hours, ΔM=0.25. The rotational periods of these asteroids have not been previously reported in the literature.

Observations

During October of 1985 the asteroid 84 Klio came to an unusually favorable opposition with an opposition B magnitude of 11.6. During October of 1986 the asteroid 678 Fredeguendis reached opposition with a B magnitude of 12.2. Observations of these minor planets were conducted by the authors as part of a program directed towards the determination of the synodic rotational periods of main belt asteroids. This research program is conducted in conjunction with the astronomy education program at Globe High School in Globe, Arizona. The photometric observations described here were conducted from Gila Observatory, located three miles west of Globe, during October of 1985 and October and November of 1986.

The photometric observations were made using the V filter of an uncooled EMI Gencom Starlight 1 photon counting photometer equipped with an EMI 9924A end window photomultiplier tube. The photometric data was recorded and reduced using a TRS-80 model 4 microcomputer which was interfaced with the photometer. All photometric observations of these asteroids were made using the 14 inch Schmidt Cassegrain telescope.

For each asteroid, a nearby comparison star of spectral class G (when possible) was selected to minimize the effects of color dependent variations in atmospheric extinction between the asteroid and comparison star. The selected comparison stars were in all cases within one degree of the asteroid, thus reducing the corrections of differences in atmospheric extinction to less than 0.01 magnitude. The comparison stars were standardized using a nearby standard star (Landolt 1973) and the brightness of the asteroids are expressed in V magnitudes.

Only one asteroid was observed during the course of a single night. A 60 arc second diameter diaphragm was used in obtaining photometric measurements of both the comparison star and asteroid. During each night 45 second photometric integrations of the asteroid and comparison star were accompanied by a 15 second integration of the sky background. By making frequent measurements of the sky background, short term variations in the sky background could be compensated for. The standard procedure followed in the observation of these asteroids was to initially obtain a photometric measurement of the comparison star. This measurement was followed by a single 45 second photometric integration of the asteroid, after which the comparison star-asteroid photometric sequence was repeated. By making frequent photometric observations of the comparison star, short term variations in atmospheric extinction could be monitored and compensated for. Individual photometric measurements of 84 Klio and 678 Fredeguendis are subject to an average uncertainty of 0.015 magnitude. Typically 7 to 10 photometric measurements of the asteroid were obtained during each hour of the observing run. After every tenth asteroid photometric measurement of each night's observing the raw photometric data was stored on a computer disk file. By frequent updating of this disk file the accidental loss of an entire night of photometric data was prevented.

Results

From the results of each night's observations a computer generated lightcurve was constructed by means of a Radio Shack FP-215 flat bed plotter. On the basis of the individual lightcurves, the synodic rotational period was deduced and a composite lightcurve was constructed. In the construction of the lightcurve, variations in the V magnitude of the asteroid on different nights due to changing asteroid phase angle, heliocentric distance, and geocentric distance were adjusted for by the computer. An assumed linear phase coefficient of 0.03 magnitude/degree was used to make this adjustment.

84 Klio

84 Klio was discovered on August 25, 1865 by R. Luthur. 84 Klio is listed as a C-type asteroid with a diameter of 86.6 kilometers by Bowell et al. (1979). 84 Klio was observed on the nights of October 12, 13, and 14, 1985 using the 14 inch Schmidt Cassegrain telescope at Gila Observatory. On the basis of these three nights of observation a rotational period of 5.80±0.02 was deduced. The amplitude of the lightcurve of this asteroid is 0.06±0.01 magnitude. The composite lightcurve shown in Figure 1 is constructed on the basis of a 5.80 hour rotational period. The lightcurve is characterized by three very low amplitude maxima and minima during each rotational cycle. One broad and flat minimum is seen in Figure 1 between 6.2 and 8.1 hours U.T., while a shallower and narrower minimum occurs between 3.6 and 5.0 U.T. The minima appearing at 3.6 and 9.4 hours U.T. are the same minimum separated by one rotational cycle. The three lightcurve maxima occur at 3.1, 4.3, and 5.8 hours U.T.

There exists no previously published lightcurve for 84 Klio in the literature. Therefore, this lightcurve is among the first published for this asteroid.

678 Fredeguendis

The asteroid 678 Fredeguendis was discovered by W. Lorenz in 1909. No published lightcurve exists for 678 Fredeguendis, however this asteroid has been observed photometrically by Harris (private communication) who quotes a rotational period of 11.75 hours on the basis of his unpublished data. 678 Fredeguendis was observed on October 26 and 28, and on November 5, 1986 using the EMI Gencom Starlight 1 photometer attached to the 14 inch Schmidt Cassegrain telescope at Gila Observatory. On the basis of these observations a rotational period of 11.64±0.02 hours was determined for this asteroid. The composite lightcurve shown in Figure 2 is constructed on the basis of a 11.64 hour rotational period. The amplitude of the lightcurve is 0.23±0.01 magnitude. The proposed composite lightcurve displays two maxima and two minima during each rotational cycle. A lightcurve for 678 Fredeguendis exhibiting only a single maximum and minimum during each rotational cycle cannot be positively ruled out on the basis of the obtained photometric data. This situation, requiring the brightness changes of the asteroid to be largely attributed to albedo variations across the surface, is viewed as being less likely on the basis of the relatively large lightcurve amplitude observed for this asteroid. A single periodic lightcurve would yield a rotational period of Fredeguendis of 5.82 hours.

References

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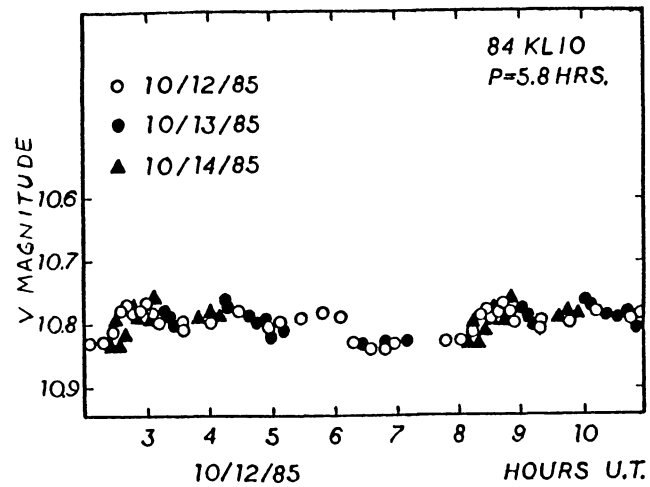

Figure 1

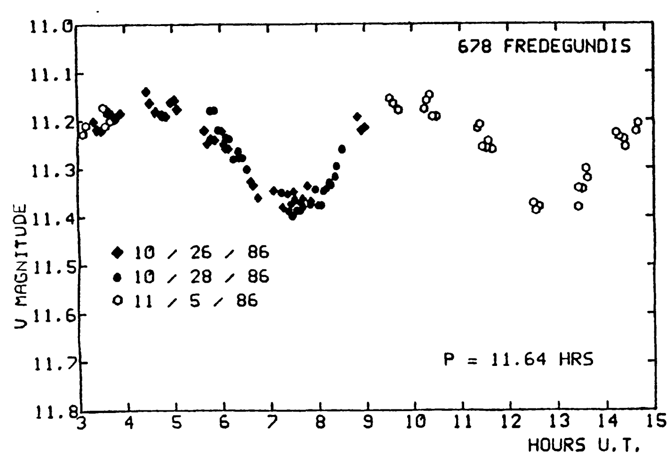

Figure 2

Asteroid Aspect Data

Asteroid	Date (U.T.)	1950 R.A. h m	1950 Dec. ° '	1950 Long. °	Lat. °	r (AU)	Δ (AU)	Comparison Star
84	10/12/85	0 35.2	+20 22	16.3	+15.2	1.873	0.891	SAO 74154
Klio	10/13/85	0 34.2	+20 20	16.0	+15.2	1.874	0.894	SAO 74154
	10/14/85	0 33.2	+20 18	15.8	+15.3	1.876	0.897	SAO 74154
678	10/26/86	2 48.6	+27 00	47.8	+10.3	2.019	1.053	SAO 75594
Fredeguendis	10/28/86	2 47.0	+26 52	47.4	+10.3	2.019	1.048	SAO 75594

PLANETARY ATTRACTIONS

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It was found that the order of the attractions by perturbing major planets on minor planets in the central Main Belt (2.5-2.8 AU) is as follows: Jupiter, Saturn, Earth, Venus, Mercury, Mars, Uranus, Neptune, Ceres, Vesta, Pluto. Direct and indirect attractions tend to add up for the inner planets, but they tend to cancel each other out for the outer planets. This is another reason why perturbations by the inner major planets cannot be ignored.

During extensive testing of a computer program which I wrote some time ago, I discovered some facts which may be of interest to readers of the *Minor Planet Bulletin*. The program computes perturbations of minor planet orbits, and is based on Section 3 of Tattersfield (1984). One question which persisted in my mind as I was writing and testing out the program was, "Which major planets are the strongest perturbers of minor planet orbits, and what are their relative attractions?" I was unable to find an answer to this in any book on Celestial Mechanics, or any other literature which dealt with the subject of planetary attractions. When I finally arrived at an answer to this question, the relative order of the planetary attractions came as a surprise.

Tattersfield strongly suggests that calculating attractions by only Jupiter and Saturn are sufficient for calculating orbits of comets, and by extension, minor planets, in the Solar System. He does not say this specifically, but he certainly implies it. Eckart et al. (1951) use attractions by Jupiter through Neptune in their calculations, and say that "The attractions of the inner planets . . . are scarcely perceptible . . ." The masses of the inner planets are merely added to the mass of the Sun. In Duncombe (1969), perturbations are computed for all planets from Venus through Pluto, but the mass of Mercury is merely added to the mass of the Sun. This is typical of references which can be found in the literature.

However, Brian Marsden, in a private communication, said that the attractions by all major planets except Pluto should be taken into account. He was quite right that the attractions by Mercury cannot be ignored. In fact, these turned out to be greater than the attractions by Uranus, Neptune and Mars, except that Mars exceeds Mercury for the Flora and inner Main Belt (2.0-2.5 AU) zones.

After I programmed in attractions for the eight planets from Mercury through Neptune, the relative attractions by these planets upon the orbits of Ceres and Pallas were printed out. As expected, Jupiter was the strongest perturber, and Saturn was second, but the rest turned out to be a surprise. The third strongest perturber was not Uranus, but Earth, with Venus a close fourth. Uranus, in fact, was seventh. The Earth and Venus sometimes switch places. The actual order of the attractions on the majority of objects was found to be: Jupiter, Saturn, Earth, Venus, Mercury, Mars, Uranus, Neptune, Ceres, Vesta, Pluto. These results are shown in Tables I and II. Mercury has consistently stronger attractions for minor planets than does Mars (except for the Floras and the inner Main Belt) despite being farther away and containing less mass. The reason for this is explained below.

The next question to answer is, "Is the program working correctly?" To answer that question, I took the orbits of Ceres and Pallas from the 1986 *Ephemerides of Minor Planets* (EMP), and ran them through the perturbation program to see how close I could get to the elements in the 1988 volume of EMP. Although the new elements of Ceres were slightly off, the elements of Pallas came out very close to the printed values. I did the same for orbits of typical planets from Aten to Chiron, and got similar results.

My conclusions here are as follows:
1. For all orbits beyond the Hungarias, integration of the orbits at ten day intervals was sufficient to give satisfactory results in most cases. Integration at four day intervals gave a small improvement.
2. Integration of the orbits of the Hungarias and Mars Crossers at four day intervals gave very good results. For the Apollos, Amors and Atens, it was a bit more complicated, as indicated in Table III.

For the Apollos, Atens and Amors, the best integration interval depended on the number and degree of close approaches to the major planets. (1566) Icarus never did come out exact, even at half day intervals, but I did not go further because of the complexities involved. Icarus was really a rare exception, because it had three rather close approaches to major planets within a 400 day period, namely, June 19, 1986 to July 24, 1987. The orbits of planets in Table III were computed for only 400 days.

Having satisfied myself that the program was working correctly, I next turned to the question of why Venus attracted minor planets as strongly as Earth, and why Mercury attracted them stronger than Mars. I broke up the attractions separately into direct and indirect attractions, and printed them out. To my amazement, the indirect attractions exceeded the direct for all planets from Mercury through Mars, and at times, even for Jupiter. The indirect attractions on (2060) Chiron exceeded the direct attractions by every major planet.

Tattersfield discusses the direct and indirect attractions to be calculated on page 86 of his book. He does not derive these formulae, or even discuss the theoretical basis for them. The clearest exposition I could find was in Watson (1868, p. 426), a very thorough treatment of the subject. He gives the perturbing function as follows:

$$\Omega = \frac{m'}{1+m}\left(\frac{1}{\rho} - \frac{xx'+yy'+zz'}{r'^3}\right) + \frac{m''}{1+m}\left(\frac{1}{\rho'} - \frac{xx''+yy''+zz''}{r''^3}\right) + \&c.,$$

The partial differential coefficients with respect to the coordinates are:

$$\frac{d\Omega}{dx} = \frac{m'}{1+m}\left(\frac{x'-x}{\rho^3} - \frac{x'}{r'^3}\right) + \frac{m''}{1+m}\left(\frac{x''-x}{\rho'^3} - \frac{x''}{r''^3}\right) + \text{\&c.},$$

$$\frac{d\Omega}{dy} = \frac{m'}{1+m}\left(\frac{y'-y}{\rho^3} - \frac{y'}{r'^3}\right) + \frac{m''}{1+m}\left(\frac{y''-y}{\rho'^3} - \frac{y''}{r''^3}\right) + \text{\&c.},$$

$$\frac{d\Omega}{dz} = \frac{m'}{1+m}\left(\frac{z'-z}{\rho^3} - \frac{z'}{r'^3}\right) + \frac{m''}{1+m}\left(\frac{z''-z}{\rho'^3} - \frac{z''}{r''^3}\right) + \text{\&c.},$$

Each term of the partial differentials of the perturbing function has a factor of the form $\left(\frac{x'-x}{\rho^3} - \frac{x'}{r'^3}\right)$. $\frac{x'-x}{\rho^3}$ is the direct attraction, and $\frac{x'}{r'^3}$ is the indirect attraction, "ρ" is the distance from the minor planet to the perturbing planet, and "r" is the distance from the perturbing planet to the Sun. Each attraction is multiplied by a factor containing the mass of the perturbing planet. When summed up and integrated, it results in the numerical value of the perturbing function.

The direct attractions are actually vectors directed along the line segment between the minor planet and the perturbing planet. The indirect attractions are vectors directed along the line between the perturbing planet and the Sun. Each attraction is the algebraic sum of the components divided by the cube of the distance. To take an example, since the distance between Mercury and the Sun (indirect attraction) is much smaller than the distance between Mercury and the minor planet (direct attraction) and we are dividing by the cube of that distance, it stands to reason that the indirect attraction should be stronger than the direct. The direct attractions do not become dominant until we are out beyond the orbit of Jupiter, because the distance between the perturbing planet and the Sun now becomes greater than the distance between the perturbing planet and the minor planet.

The system of masses used in the perturbation programs is the IAU (1976) system described by Kaplan (1981). Although I'm sure the program itself is working, I suspect that the heliocentric coordinates I am using for the outer planets are defective because of the ignoring of the indirect attractions of the inner planets when the coordinates were created. Main belt objects do not give exact results, mainly because of more opportunities for close approaches to major planets. Minor planets with high inclinations tend to spend a large fraction of the time above or below the ecliptic, with consequent less close approaches to major planets, and hence their orbits tend to remain more stable. My next project is to recreate heliocentric coordinates for the outer planets.

Suggestions for Improvement of Minor Planet Orbits:

A. Unnumbered minor planets.
   Removing perturbing planets one at a time shows that Mercury, Mars, Uranus and Neptune really do make a difference in the final results, but removal of any of these four is not too critical. On the other hand, removal of Earth or Venus from the perturbation scheme can give results which are quite far off. Therefore, unnumbered planetary orbits should be computed with an absolute minimum of using Jupiter, Saturn, Earth and Venus as perturbing planets.

B. Numbered minor planets.
   1. Pluto.
      Calculation of elements using Pluto as a perturbing planet shows exactly the same results with or without Pluto. Indeed, the attraction of Pluto on minor planets averages to less than one part in 8200 of that of Neptune. Therefore, Pluto can be safely eliminated from the perturbation scheme.
   2. Vesta.
      Calculation of elements using Vesta as a perturbing planet shows exactly the same results with or without Vesta, although only nine minor planets were tested out. Therefore, Vesta can be safely ignored except in rare circumstances.
   3. Ceres.
      The attractions due to Ceres averaged 137.4 times that of Pluto, and 8.9 times that of Vesta. Most minor planets tested showed no difference when perturbations by Ceres were included. One planet, (37) Fides, was found to differ by one digit in the last place in each of five of the orbital elements. Thus on rare occasions, putting in perturbations by Ceres can make a difference. If a program using perturbations by nine planets is being used, it would be better to use Ceres rather than Pluto.

References

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Eckert, W. J., Brouwer, D., and Clemence, G. M., (1951), *Astronomical Papers* prepared for the use of the American Ephemeris and Nautical Almanac, Volume XII, U. S. Government Printing Office, Washington, D. C., page v.

Kaplan, G. H. (1981), U. S. N. O. Circular No. 163, U. S. Naval Observatory, Washington, D. C., page 4.

Tattersfield, D., (1984), *Orbits for Amateurs with a Microcomputer*, John Wiley & Sons, New York, page 86.

Watson, J. C., (1868), *Theoretical Astronomy*, Dover Publications, New York, (1964), page 426.

Table I

(1) Ceres

EPOCH	ANOMALY	PERI.	NODE	INCL.	ECCEN.	MOTION	AXIS
46600.5	28.88057	72.54848	80.04503	10.60449	0.0783578	0.21411421	2.7671905

Increment: 4 Days. - FILES: VS868804.XYZ ELEMENTS.R01 ELEMENTS.R09

(1) Ceres
Epoch 1988 Aug. 27.0 ET = JDE 2447400.5

M 200.82869		(1950.0)		P	Q
n	0.21429637	Peri.	72.00942	-0.86734810	-0.46350731
a	2.7656221	Node	80.04029	0.35777159	-0.83387992
e	0.0784300	Incl.	10.60692	0.34598664	-0.29967525
P	4.60	H	3.32	G 0.11	

MAJOR PLANET	JULIAN DATE OF C.A.	CLOSEST APPROACH A.U.	SUM DIRECT ATTRACTIONS X 10^7	SUM INDIRECT ATTRACTIONS X 10^7	SUM TOTAL ATTRACTIONS X 10^7
Jupiter	47412.5	4.4509	240.595735	374.265808	220.925946
Saturn	46924.5	7.2186	44.263702	28.534636	15.829288
Earth	46964.5	1.8301	2.453351	3.746775	6.068599
Venus	46604.5	1.8705	2.157737	4.127463	6.182341
Mercury	46600.5	2.1805	0.148595	0.903771	0.972751
Mars	47412.5	1.6126	0.151058	0.286821	0.427617
Uranus	46960.5	16.3755	1.469147	1.192685	0.276886
Neptune	47024.5	27.3603	0.650475	0.571214	0.079336
Vesta	46588.5	4.7706	0.000269	0.001069	0.000800

Table II

(2) Pallas

EPOCH	ANOMALY	PERI.	NODE	INCL.	ECCEN.	MOTION	AXIS
46600.5	17.31081	309.89515	172.64548	34.80188	0.2338349	0.21350221	2.7724760

Increment: 4 Days. - FILES: VS868804.XYZ ELEMENTS.R01 ELEMENTS.R09

(2) Pallas
Epoch 1988 Aug. 27.0 ET = JDE 2447400.5

M 188.27443		(1950.0)		P	Q
n	0.21368189	Peri.	309.78416	-0.55366936	-0.82951167
a	2.7709216	Node	172.62999	0.82393471	-0.53294598
e	0.2343847	Incl.	34.80387	-0.12075527	0.16696997
P	4.61	H	4.13	G 0.15	

MAJOR PLANET	JULIAN DATE OF C.A.	CLOSEST APPROACH A.U.	SUM DIRECT ATTRACTIONS X 10^7	SUM INDIRECT ATTRACTIONS X 10^7	SUM TOTAL ATTRACTIONS X 10^7
Jupiter	47412.5	6.4572	172.130558	373.033265	219.735816
Saturn	47124.5	7.5654	43.849944	29.499963	15.608328
Earth	46916.5	2.0688	2.529918	4.782922	6.335227
Venus	46588.5	1.5066	2.212384	4.105266	6.043793
Mercury	46592.5	1.8347	0.155708	0.917284	1.056396
Mars	47340.5	2.2999	0.194924	0.336752	0.473298
Uranus	47152.5	16.6706	1.483243	1.237506	0.269077
Neptune	47240.5	27.4507	0.657911	0.592484	0.073154
Vesta	46588.5	4.4031	0.000292	0.001042	0.000783

Table III

Minor Planet	Integration Interval	Close Approaches	Remarks
(1566)	0.5 day	4	Approach to Mars within 10,000,000 km.
(1627)	4 day	0	No close approaches.
(3352)	1 day	2	Venus approach to 102,000,000 km.
(3360)	4 day	0	No close approaches.
(3361)	1 day	4	Approach to Earth at 44,000,000 km.
(3362)	0.5 day	4	Mars approach to 42,000,000 km.

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BIBLIOGRAPHY OF MINOR PLANET BOOKS: A SUPPLEMENT

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To supplement a bibliography of minor planet books previously published in the *MPB*, a list of 34 more books, catalogues and monographs is presented.

Introduction

In a previous list (Cunningham, 1986), 22 books devoted primarily or exclusively to asteroids, and a further 27 books containing some asteroid material were given. Additional material has been uncovered, due in large part to translation work and advice from researchers in the Soviet Union, Japan, the United States and Canada. Like the original list, this one includes, wherever possible, author, publisher, date and number of pages. A capsule description following this usually includes a grading system ranging from young reader through amateur, advanced and professional level.

<u>Books devoted largely or exclusively to asteroids:</u>

Piazzi, Guiseppe (1802). *Della Scoperta Nuovo Pianeta Cerere Ferdinandea.* Palermo; 65 pages. The original book of discovery, in Italian, by the man who found the first asteroid. Professional level.

Schroter, Johann (1805). *Lilienthal Beobachtungen der neu entdeckten Planeten Ceres, Pallas und Juno.* Gottingen; 378 pages. A historical gem, this is the official report of the asteroid search committee organized by Baron von Zach in 1800. Professional level.

Savich, A. (1855). *Historical View of the Discovery of Minor Planets or Asteroids.* St. Petersburg. In Russian.

Hirayama, Seiji (1935). *Asteroids.* Iwanami Zensho Series #46; 168 pages. This Japanese book contains 12 chapters, covering the history of discovery, numbers and names, and families of asteroids. Professional level.

Reinmuth, K. (1953). *Catalogue of 6500 Precise Photographic Positions of Minor Planets.* Veroff. Staatl. Sternw. Heidelberg-Konigstuhl; 156 pages. Includes number and name, date, instrument used and coordinates. In German, professional level.

Reinmuth, K. (1960). *Catalogue of 6000 Precise Photographic Minor Planet Positions.* Veroff Landessternw. Heidelberg-Konigstuhl; 142 pages. In German, professional level.

Paluzie-Borrell, Antonio (1963). *The Names of the Minor Planets and their meanings.* Published by Jean Meeus, Kessel-Lo, Belgium. Amateur level.

Ross, Stanley (ed.). (1966). *Space Flight Handbooks: Volume III* Planetary Flight Handbook Part 5 Trajectories to Jupiter, Ceres and Vesta. NASA SP-35; 512 pages. This massive numerical tome gives trajectory data from 1970-1980 and position & velocity data from 1969-2000. Professional level.

O'Handley, Douglas A. (ed.) (1968). *Studies on Two Asteroids for use in the Mass Determination of Jupiter.* Georgetown Observatory Monograph No. 22; 95 pages. A mathematical treatise at the professional level.

Bohrmann, A. (1969). *Catalogue of 700 Precise Photographic Positions of Minor Planets.* Veroff. Landessternw. Heidelberg-Konigstuhl; 27 pages. In German, professional level.

Samoilova-Yachontova, N. (ed.) (1973). *Minor Planets.* State Publication of Phys.-Mathem. Literature "Nauka", Moscow; 360 pages. In Russian. This book surveys all aspects of asteroid research at the professional level.

Delsemme, A. H. (ed.) (1977). *Comets Asteroids Meteorites.* Univ. of Toledo, Ohio; 585 pages. Parts IV and V consider the physical nature of asteroids, and their orbital evolution. Professional level.

Branham, Richard L. (1979). *The orbits of Five Minor Planets and Corrections to the FK4 Equator and Equinox.* Nautical Almanac Office, U.S. Naval Obs.; 459 pages. Primarily a book of numerical data. Professional level.

Simonenko, A. N. (1979). *Meteorites- fragments of asteroids.* State Publication of Phys.-Mathem. Literature "Nauka", Moscow; 224 pages. In Russian. There is an 82-page chapter on asteroids in this professional review.

Berger, Melvin (1981). *Comets Meteors and Asteroids.* Putnams; 79 pages. A fine survey at the juvenile level.

Marsden, Brian G. and Bardwell, Conrad M. (1982). *Catalogue of Discoveries and Identifications of Minor Planets.* Minor Planet Center, IAU; 111 pages. More than 29,000 entries are listed according to provisional designation. Professional level.

Marsden, Brian G. and Bardwell, Conrad M. (1982). *Catalogue of Orbits of Unnumbered Minor Planets.* Minor Planet Center, IAU; 106 pages. Contains orbital elements for 2,471 unnumbered asteroids observed from 1900-1982. Professional level.

Faughnan, Barbara and Maryniak, Gregg (eds.) (1985). *Space Manufacturing 5 Engineering with Lunar and Asteroidal Materials.* American Institute of Aeronautics and Astronautics. Proceedings of the seventh Princeton AIAA/SSI Conference. Professional level.

Gibilisco, Stan (1985). *Comets Meteors Asteroids: How they affect Earth.* Tab Books, Penn.; 208 pages. The impact extinction theory is presented. Amateur level.

Simonenko, A. N. (1985). *Asteroids.* State Publication of Phys.-Mathem. Literature "Nauka", Moscow; 201 pages. This review at the advanced level was published posthumously, Dr. Simonenko having died in 1984.

Matson, Dennis (ed.) (1986). *Infrared Astronomical Satellite Asteroid and Comet Survey.* JPL D-3698; 392 pages. A professional presentation of physical data on asteroids. Contains IRAS and ground-based results.

McSween, Harry Y. (1987). *Meteorites and Their Parent Planets.* Cambridge Univ. Press; 237 pages. A modern survey for the advanced amateur.

Some books with chapters on asteroids:

Oberth, Hermann (1957). *Man Into Space.* Harper & Brothers, N.Y.; 171 pages. Chapter IV considers a space telescope on an asteroid. Amateur level.

Nieto, Michael Martin (1972). *The Titius-Bode Law of Planetary Distances: Its History and Theory.* Pergamon Press; 161 pages. A superb historical treatment of the empirical formula that led to the search for an object between Mars and Jupiter. Advanced level.

O'Leary, Brian (1981). *The Fertile Stars.* Everest House Pub., N.Y.; 132 pages. The mining of asteroids is considered in pages 39-50, 69-75 and 83-86. Amateur level.

O'Leary, Brian (ed.) (1982). *Space Industrialization* Volume 1. CRC Press Inc., Boca Raton, Florida. Several contributed papers in this professional review consider asteroid mining.

Meadows, Jack (1985). *Space Garbage: Comets, Meteors and other Solar-System Debris.* George Philip Pub., London. Amateur level.

Wasson, John T. (1985). *Meteorites: Their Record of Early Solar-System History.* W. H. Freeman & Co.; 267 pages. Chapter IX considers the question Relationship to the Planets, Asteroids and Comets: At What Solar Distances Did the Meteorites Form? Professional level.

Bakker, Robert T. (1986). *The Dinosaur Heresies.* William Morrow & Co., N.Y.; 481 pages. The asteroid extinction theory is considered in Chapter 21. Amateur level.

Dodd, Robert T. (1986). *Thunderstones and Shooting Stars: The Meaning of Meteorites.* Harvard Univ. Press; 196 pages. Considers several asteroid-related matters, including the extinction hypothesis. Advanced level.

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Burke, John G. (1987). *Cosmic Debris: Meteorites in History.* Univ. of California Press. The origin of meteorites and their impact on Earth is considered. Advanced level.

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Acknowledgements

Thanks to following people: Dr. Victor Shor of the Institute for Theoretical Astronomy in Leningrad and Dr. D. F. Lupishko of the Kharkov Observatory for their advice on Russian sources. Dr. Deborah Steinhoff, a Kitchener native living in Sapporo, Japan, for her translation of the paper by Sibata (1938). Dr. and Mrs. Aldo Patirani for their translation of Piazzi's book. Dr. Peter Broesche of the Observatorium Hoher List in Bonn for a copy of Schroter's book. Dr. Edward Bowell of Lowell Observatory in Arizona for his advice.

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PHOTOELECTRIC PHOTOMETRY OF 690 WRATISLAVIA

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(Received: 23 November Revised: 1 February)

Photoelectric observations of the asteroid 690 Wratislavia were made from Mercedes Observatory during the 1987 apparition. The determined synodic rotational period and lightcurve amplitude are: P=6.31 hours, Δm=0.13. No rotational period for asteroid 690 Wratislavia has been previously reported.

During the early spring of 1987 the asteroid 690 Wratislavia was favorably placed for photometric study. Observations of this minor planet were conducted by the author as part of a program directed toward the study and determination of the synodic rotational periods of asteroids at the Mercedes Observatory, 100-km west of Buenos Aires.

The photometric measurements were made using the V filter of our photon counting photometer equipped with an EMI 9781A uncooled photomultiplier tube attached to the 0.6-m Cassegrain telescope. A nearby comparison star of spectral class G was selected to minimize the effects of color dependent variations in the atmospheric extinction between the asteroid and comparison star.

The comparison star was in all cases within one degree of the asteroid thus reducing the corrections for differences in atmospheric extinction to less than 0.01 magnitude. During each observing night 60 second photometric integrations were used on the asteroid and comparison star, and 20 seconds on the sky. The standard observing procedure followed was to initially obtain a photometric measurement of the comparison star. This measurement was followed by a 30 second integration of the asteroid, 20 seconds on the sky and 30 seconds on the asteroid again. Thereafter this comparison star-asteroid sequence was repeated. Typically 8 to 10 photometric measurements of the asteroid were obtained during each hour of the observing run. Magnitude measurements of 690 Wratislavia are subject to an average uncertainty of 0.015 magnitude.

Results

690 Wratislavia was discovered on October 16, 1909 by J. H. Metcalf. 690 Wratislavia is listed by Bowell et al. (1979) as a CEU type asteroid with a diameter of 175-km. A review of the astronomical literature reveals that the rotational period of 690 Wratislavia has not as yet been published. Photometric observations of 690 Wratislavia were conducted using the 0.6-m Cassegrain telescope at Mercedes Observatory on the nights of September 14, 17 and 20, 1987 U.T., on which 16, 41 and 39 photometric measurements were made, respectively. Observational circumstances are shown in Table I. On the basis of the photometric data obtained during these three nights of observation it was determined that a synodic rotational period of 6.31±0.02 hours best conformed to the observations. A composite lightcurve based upon this rotational period is shown in Figure 1. In the construction of this composite lightcurve, variations in the V magnitude on different nights due to changing asteroid heliocentric and geocentric distance as well as changing phase angle were adjusted by sliding up and down the nightly lightcurves. The lightcurve of 690 Wratislavia shows one maximum and one minimum per rotational cycle, both well defined, with a lightcurve amplitude of 0.13±0.015 magnitude. Despite the relatively noisy condition of the composite lightcurve the times at which lightcurve maxima and minima were observed conform well to the reported rotational period. A lightcurve with a double maximum and minimum per rotational cycle yielding a rotational period of 12.62 hours is viewed by the author as being unlikely.

Acknowledgement

The author would like to thank the authorities of the Dirección De Cultura De La Municipalidad De Mercedes for their help during the course of this research program.

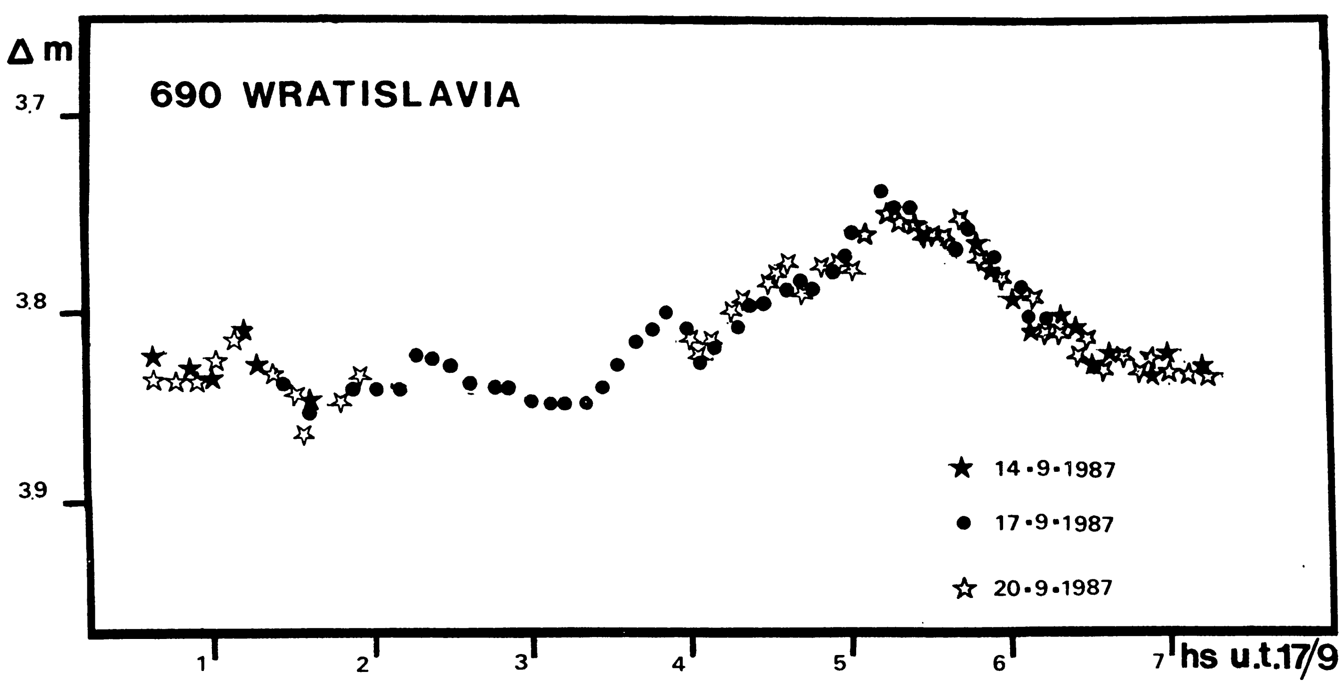
Reference

Bowell, E., Gehrels, T., and Zellner, B. (1979). "Magnitudes, Colors, Types and Adopted Diameters of the Asteroids". In *Asteroids* (T. Gehrels, Ed.), pp. 1108-1129. University of Arizona Press, Tucson.

Table I

DATE	RA(1950)DEC		LONG(1950)LAT		r	DELTA	Comp.Star
14/9/87	22h30.6m	10°11.1'	343°3	18°1	2.598	1.627	SAO 107959
17/9/87	22 28.7	09 55.5	342.7	18.0	2.596	1.631	SAO 107959
20/9/97	22 26.8	09 37.0	342.2	17.9	2.593	1.637	SAO 107959

Figure 1



PHOTOELECTRIC PHOTOMETRY OPPORTUNITIES MAY-JULY

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The table below lists asteroids which come to opposition during the months of May through July that represent useful targets for photoelectric photometry observations. Observations are needed because the asteroid has either an unknown or ambiguous rotational period or because the asteroid will be observable at a very low phase angle. The table also includes asteroids which are candidates for pole determinations (see the article by Di Martino and Zappalá in issue 12, No. 1), are targets for radar observations (see the article by Ostro in *MPB* 10, No. 4), or are subjects for shape modelling (see the article by Davis and Binzel in *MPB* 14, No. 3). The table gives (in order of opposition dates) the asteroid number and name, opposition date, opposition B magnitude (the V magnitude is about 0.8 brighter), the rotational period (in hours), the estimated lightcurve amplitude (in magnitudes), and the designation PER if observations are needed to determine the rotational period. AMB implies that previous period determinations have given ambiguous results and these alternate periods are listed in the table. PHA indicates observations of the phase curve are desired because the asteroid will be at an unusually low phase angle, POL indicates the asteroid is a pole position candidate, RAD indicates the asteroid is a planned radar target, and MOD denotes an asteroid at a critical longitude for shape modelling. Question marks are used to denote uncertain or unknown values. An outline of recommended observing procedures in given in *MPB* 11, No. 1, page 7. Also recommended is the book *Solar System Photometry Handbook* (see the review by Tholen in *MPB* 11, No. 4). Ephemerides for all of the asteroids in the table are included in this issue. Some of these may appear on finding charts in *Tonight's Asteroids* prepared by Mr. Joseph F. Flowers, Route 4 Box 446, Wilson, NC 27893, USA. These charts are free for a self-addressed stamped envelope.

Asteroid	Opp'n Date	Opp'n B Mag	Per	Amp	
110 Lydia	May 13	12.1	10.927	0.1	PHA
70 Panopaea	May 25	11.5	15.87?	0.1	AMB
914 Palisana	May 28	12.0	?		PER
230 Athamantis	Jun 3	11.3	23.99?	0.2	AMB
511 Davida	Jun 5	12.4	5.130	0.2	MOD

Photoelectric Photometry Opportunities

DATE	R.A. (1950) HR	MIN	DEC. DEG	MIN	MAG V	PHASE ANGLE
Minor Planet 70 Panopaea						
1988 Apr 14	16	35.51	-23	36.7	11.78	18.0
24	16	33.03	-24	32.0	11.51	14.9
May 4	16	27.28	-25	25.8	11.22	11.0
14	16	18.64	-26	15.4	10.92	6.6
24	16	08.01	-26	57.5	10.65	2.8
Jun 3	15	56.74	-27	30.2	10.75	5.1
13	15	46.38	-27	53.8	10.97	9.8
23	15	38.28	-28	11.3	11.18	14.3
Jul 3	15	33.37	-28	26.6	11.39	18.3
Minor Planet 110 Lydia						
1988 Apr 4	15	43.26	-17	45.2	12.31	14.3
14	15	39.07	-17	44.8	12.09	11.2
24	15	32.55	-17	38.5	11.86	7.6
May 4	15	24.25	-17	27.2	11.61	3.6
14	15	15.01	-17	12.7	11.37	0.8
24	15	05.83	-16	57.8	11.65	5.0
Jun 3	14	57.72	-16	45.6	11.87	9.0
13	14	51.45	-16	39.3	12.06	12.6
23	14	47.51	-16	41.1	12.25	15.6
Minor Planet 230 Athamantis						
1988 Apr 24	17	12.93	-22	17.3	11.25	16.8
May 4	17	09.34	-21	32.7	11.03	13.5
14	17	02.91	-20	40.9	10.81	9.5
24	16	54.25	-19	43.4	10.59	5.0
Jun 3	16	44.35	-18	43.0	10.38	1.5
13	16	34.46	-17	44.0	10.57	5.2
23	16	25.76	-16	51.2	10.77	9.8
Jul 3	16	19.21	-16	08.6	10.96	13.9
13	16	15.38	-15	38.6	11.15	17.4
Minor Planet 511 Davida						
1988 Apr 24	17	19.03	-10	11.7	12.18	11.6
May 4	17	14.99	-10	01.9	12.02	9.5
14	17	09.31	- 9	56.1	11.85	7.2
24	17	02.37	- 9	55.4	11.69	4.9
Jun 3	16	54.68	-10	01.0	11.58	3.4
13	16	46.86	-10	13.4	11.65	4.2
23	16	39.52	-10	32.8	11.81	6.4
Jul 3	16	33.22	-10	58.9	11.99	8.8
13	16	28.36	-11	30.9	12.17	10.9
Minor Planet 914 Palisana						
1988 Apr 14	16	39.07	-38	08.0	12.35	20.9
24	16	37.51	-37	08.3	12.06	17.9
May 4	16	32.13	-35	37.1	11.75	14.1
14	16	23.53	-33	29.9	11.42	9.5
24	16	12.97	-30	46.9	11.10	5.0
Jun 3	16	02.11	-27	36.0	11.05	5.1
13	15	52.68	-24	12.6	11.26	10.0
23	15	45.97	-20	54.9	11.49	15.3
Jul 3	15	42.67	-17	57.9	11.73	19.9

CALL FOR OBSERVATIONS

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Observers of precise and approximate positions of minor planets during calendar 1987 are urged to submit them to this writer before April 15, 1988. This will be the deadline for inclusion in the "General Report of Positions of Minor Planets for the Year 1987," scheduled to appear in *MPB* Volume 15, Number 3.

ERRATUM

"Close Mutual Approaches of Minor Planets in 1988"
MPB 15, 4-5.

The following three predictions must be deleted:

Date	Minor Planets	
1988 May 12 :	211 Isolda	216 Kleopatra
Aug 15 :	2774 Tenojoki	1264 Letaba
Dec 6 :	769 Tatjana	1093 Freda

The impossibility of the first event was pointed out to me by Jean Meeus. I there upon checked the computer program and discovered the error that had caused the spurious result. Next I completely recomputed the predictions for 1988 and found the other two false predictions. I want to thank Jean Meeus and offer my apologies for any inconveniences caused by this error. —E. Goffin

THE MINOR PLANET BULLETIN is the quarterly journal of the Minor Planets Section of the Association of Lunar and Planetary Observers. The Minor Planets Section is directed by its Recorder, Prof. Frederick Pilcher, Department of Physics, Illinois College, Jacksonville, IL 62650 USA. The *MPB* is edited by Dr. Richard P. Binzel, Planetary Science Institute, 2030 E. Speedway, Tucson, AZ 85719 USA. Bob Werner, Route 1 Box 237A, Solon, Iowa 52333 USA, produces the *MPB* and Derald D. Nye, Route 7 Box 511, Tucson, AZ 85747 USA serves as the Distributor. The subscription rate is $7.00 US a year for surface mail and $9.00 US a year for overseas air mail. Checks or money orders should be made payable to the "Minor Planet Bulletin". Subscription payments, address changes, or other subscription business should be sent to Mr. Nye. The numbers in the upper-right corner of your mailing label indicate the volume and issue number with which your subscription expires.

Articles for submission to the *MPB* should be sent to the editor who also serves as the Photoelectric Photometry Coordinator. Authors with access to Apple Macintosh or IBM-PC compatible computers are strongly encouraged to submit their manuscripts on diskette. Files should be saved as *text-only* and a printed version of the file must accompany the diskette. All authors should follow the guidelines given in "Instructions for Authors" in *MPB* 14-3. Visual photometry observations, positional observations, any type of observation not covered above, and general information requests should be sent to the Recorder.

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The deadline for the next issue (15-3) is May 1, 1988. The deadline for issue 15-4 is August 1, 1988.