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# *UBV* PHOTOMETRY OF THE ASTEROIDS 9 METIS, 87 SYLVIA AND 247 EUKRATE DURING THEIR OPPOSITIONS IN 1978 WITH RESPECT TO LIGHTCURVES*

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The minor planets 9 Metis, 87 Sylvia and 247 Eukrate were observed during their oppositions in 1978, using the 50-cm telescope of the European Southern Observatory, ESO, Chile. Prior to late 1978 no rotation periods for 87 Sylvia and 247 Eukrate were known. For 9 Metis we derived a rotation rate of $P = 5^h.067 \pm 0^h.004$ and a lightcurve amplitude of $0^m.10$, well in agreement with earlier observing reports.

For 87 Sylvia we derived a rotation rate of $P = 5^h.183 \pm 0^h.001$ with a lightcurve amplitude of $0^m.40$.

The lightcurve of 247 Eukrate was not measured over a complete rotational cycle. From two fragmentary observing runs we are able to indicate only a minimum lightcurve amplitude of $0^m.10$ at least and a rough period of $P = 12^h$ or $24^h$ probably.

We have measured color indices $B-V$ and $U-B$ for all three asteroids during all phases of rotation covered by observations. We did not find any variation of the indices exceeding the mean scatter of the measurements. Mean $V(1,0)$ are computed for all three asteroids using a phase coefficient of $\varphi = 0.039$ mag/deg ($\varphi = 0.034$ for 9 Metis) given by Gehrels and Tedesco (1979).

*Key words:* asteroids – minor planets – photoelectric photometry – 9 Metis, 87 Sylvia, 247 Eukrate

## 1. INTRODUCTION

Rotational data of asteroids are one of the fundamental physical characteristics of these objects. In recent years several groups of observational astronomers have added to our statistical knowledge on asteroidal rotation data. The value of such studies is also strengthened by the discovery of correlations between the physical data and rotational or orbital properties of asteroids, as has been shown recently by Tedesco and Zappalà (1979) or by Harris and Burns (1979).

In August and September 1978 we have observed some minor planets at the European Southern Observatory in Chile, using the 50-cm ESO photometric telescope, described elsewhere by Debehogne *et al.* (1978). The results obtained for 9 Metis, 87 Sylvia and 247 Eukrate are presented in this paper.

Observations were carried out by HJS, and reductions were made by JS. We used the standard ESO photometer in pulsecounting mode, and for almost all the observations a diaphragm of 0.53 mm (corresponding to 15 arc sec) was used. Transformations to the standard *UBV* system were made with *E*-region standard stars.

Table 1 gives the aspect data; daily ephemerides and distances were kindly computed by Batrakov (1979). The comparison stars used are indicated, as are the scatter of the nights, the lighttime, figure number and remarks. In table 2 are given data relating to *UBV* standard values of the comparison stars and the asteroids observed. We use mean values in $V$; $V(r,\alpha)$ is the actually measured mean magnitude, $V(1,\alpha)$ is reduced to unit distance, and $V(1,0)$ is the magnitude for zero phase angle, using only the mean phase correction from $\varphi = 0.039$ mag/deg ($\varphi = 0.034$ for 9 Metis, Gehrels and Tedesco 1979) as we did not derive phase factors from our observations.

* Based on observations collected at the European Southern Observatory, ESO, La Silla, Chile.

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## 2. OBSERVATIONS AND RESULTS FOR 9 METIS

The minor planet 9 Metis was observed for an IR programme. Those results will be reported elsewhere (Wamsteker *et al.* 1979) here we present the optical lightcurves. 9 Metis is one of the well observed asteroids, and a complete list of references is found in Tedesco and Zappalà (1979), where a mean rotation period of $P = 5^h.064$ with amplitudes between $0^m.06$ and $0^m.31$ is given. Bowell *et al.* (1978) list in their taxonomy system 9 Metis as S type asteroid with 153 km diameter.

Opposition of 9 Metis in 1978 occurred on Aug. 22 with $B_{opp} = 10^m.0$. We have observed 9 Metis on Aug. 23, Sept. 14 and 15, 1978, and the resulting lightcurves are shown in figures 1-3. Identifications of the extrema are found in fig. 3. Using all the epochs of extrema listed in table 3 we get from a least-square solution (with weighted means according to the number of completed rotational cycles) a resulting rotation period of

$$P_{syn} = 5^h.067 \pm 0^h.004 \text{ or}$$
$$0^d.2111 \pm 0^d.0002$$

which is in close correspondence with other values reported in the literature. Maximum lightcurve amplitude is $0^m.10$, and mean colors of 9 Metis are $B-V = 0^m.861 \pm 0^m.007$ and $U-B = 0^m.48 \pm 0^m.01$. Chapman *et al.* (1975) report $B-V = 0^m.85$. For $V(1,0)$ we get $6^m.44$, while Gehrels and Tedesco (1979) indicate $B(1,0) = 7^m.49$. In the 1979 updated TRIAD-file (Bender *et al.*, 1978) we find $B(1,0) = 7^m.49$. From our measurements of color indices we did not find any variation of the colors exceeding the mean scatter during the rotational phases.

## 3. OBSERVATIONS AND RESULTS FOR 87 SYLVIA

Opposition of 87 Sylvia was predicted for Sept. 9, 1978 with $B_{opp} = 12^m.5$. Prior to late 1978 no reports about rotation periods were made. Bowell *et al.* (1978) classified 87 Sylvia as type CMEU, which means that only the S type property excluded, but no secured classification is possible; the diameter about 225 km is rather uncertain, too. Harris (1979) reported on photoelectric measurements and deduced a rotation rate of $P = 5^h.182$ with amplitude of $0^m.42$.

We have observed 87 Sylvia in 1978 on Aug. 27, Sept. 8, 9 and 15. Resulting lightcurves are shown in figures 4-6. The epochs of the extrema, used for the rotation period determination are listed in table 4. The resulting period of rotation from our observations is

$$P_{syn} = 5^h.183 \pm 0^h.001 \text{ or}$$
$$0^d.21595 \pm 0^d.00005$$

with a maximal lightcurve amplitude of $0^m.40$. The composite lightcurve, based on this rotation period obtained, is shown in figure 7, together with the extrema identification. The mean absolute magnitude is $V(1,0) = 7^m.18$, whereas Gehrels and Tedesco (1979) indicate $B(1,0) = 7^m.88$. We get as mean colors $B-V = 0^m.70 \pm 0^m.02$ and $U-B = 0^m.25 \pm 0^m.03$. By monitoring 87 Sylvia also during the rotation phases for colors we did not find any variations exceeding the scatter.

## 4. OBSERVATIONS AND RESULTS FOR 247 EUKRATE

Opposition for 247 Eukrate was predicted for Sept. 8, 1978 with $B_{opp} = 12^m.0$. No rotation rate was known for this asteroid by late 1978. Bowell *et al.* (1978) classified 247 Eukrate as C-type with diameter 143 km, and Morrison (1977) gives the albedo $p_v = 0.031$. Harris (1979) reported a possible rotation period of $P = 10^h.36$ or $11^h.23$, values that were combined by Tedesco and Zappalà (1979) for the rotation period list as $P \sim 11^h$ with $0^m.15$ amplitude of the lightcurve.

We observed 247 Eukrate on Sept. 8 and 9, 1978, and briefly on Aug. 27. The apparent path of 87 Sylvia was nearby, and we used the same comparison star for the two objects.

From the resulting short lightcurves in figures 8 and 9 we can only conclude that the period of rotation must be near $P=12^h$ or $24^h$, if the decreasing branches in the lightcurves are identified as being the same. However, we find the amplitude being at least $0^m.10$ from our short observations. Both results are in correspondence with Harris (1979), see the note.

No variation in the color indices during the rotation as far as observed was remarked. We find $B-V=0^m.69\pm0^m.02$ and $U-B=0^m.30\pm0^m.02$. The absolute magnitude obtained from our observations is $V(1,0)=8^m.30$, whereas Gehrels and Tedesco (1979) indicate $B(1,0)=9^m.04$.

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NOTE ADDED IN PROOF:

Harris (1979) found a composite lightcurve for 247 Eukrate, which combines his observations with ours and obtained a secured rotation period of $P=12^h.103\pm0^h.008$ ($\hat{=}0^d.5043\pm0^d.0004$).

Tedesco wants us to inform that the discrepancy for 9 Metis probably is due to the fact that its phase coefficient is not well known and it does display aspect variations. For none of the three asteroids we have taken into account a possible opposition effect.

Table 1 Aspect data and observing parameters on dates of observations in 1978 for 9 Metis, 87 Sylvia and 247 Eukrate

| Date of observation $0^h$ UT | R.A. 1950.0 | Decl. 1950.0 | λ 1950.0 | β 1950.0 | Δ AU | r AU | α deg | Light time | Comp.star | Qual. of night | Fig. | Rem. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 Metis: | | | | | | | | | | | | |
| Aug.23,1978 | $21^h59^m7$ | $-22°09'$ | $324°.31$ | $-9°.28$ | 1.438 | 2.439 | $4°.3$ | $0^d.00831$ | HD 208402 | $0^m.008$ | 1 | short |
| Sep.14,1978 | 21 40.1 | -23 26 | 319.56 | - 8.95 | 1.497 | 2.410 | 12.8 | 0.00865 | HD 205831 | 0.007 | 2 | |
| Sep.15,1978 | 21 39.5 | -23 27 | 319.42 | - 8.93 | 1.502 | 2.408 | 13.2 | 0.00868 | HD 205831 | 0.007 | 3 | |
| 87 Sylvia: | | | | | | | | | | | | |
| Aug.27,1978 | 23 28.2 | -20 39 | 344.38 | -15.62 | 2.191 | 3.162 | 6.1 | 0.01265 | BD-22°6058 | 0.032 | - | worse |
| Sep.08,1978 | 23 19.8 | -21 36 | 342.13 | -15.86 | 2.180 | 3.161 | 5.1 | 0.01259 | BD-22 6058 | 0.005 | 4 | clouds |
| Sep.09,1978 | 23 19.1 | -21 41 | 341.92 | -15.87 | 2.181 | 3.161 | 5.1 | 0.01260 | BD-22 6058 | 0.007 | 5 | clouds |
| Sep.15,1978 | 23 14.7 | -22 02 | 340.82 | -15.78 | 2.192 | 3.160 | 5.9 | 0.01266 | BD-22 6058 | 0.009 | 6 | short |
| 247 Eukrate: | | | | | | | | | | | | |
| Aug.27,1978 | 23 19.0 | -22 24 | 341.61 | -16.51 | 1.486 | 2.465 | 7.5 | 0.00858 | BD-22 6058 | 0.032 | - | worse |
| Sep.08,1978 | 23 03.3 | -21 53 | 338.38 | -14.57 | 1.449 | 2.434 | 6.5 | 0.00837 | BD-22 6058 | 0.005 | 8 | clouds |
| Sep.09,1978 | 23 02.0 | -21 49 | 335.11 | -14.38 | 1.448 | 2.432 | 6.6 | 0.00836 | BD-22 6058 | 0.007 | 9 | clouds |

Table 2 *UBV* standard values of the used comparison stars, of 9 Metis, 87 Sylvia and 247 Eukrate

| Object | V(r,α) | B - V | U - B | V(1,α) |
|---|---|---|---|---|
| HD 208402 | 9.30 | 0.77 | 0.29 | |
| HD 205831 | 9.64 | 0.72 | 0.31 | |
| BD-22°6058 | 10.75 | 0.58 | 0.11 | |
| 9 Metis | | | | |
| Aug.23,1978 | 9.26 | 0.85 | 0.46 | 6.53 |
| Sep.14,1978 | 9.66 | 0.86 | 0.48 | 6.88 |
| Sep.15,1978 | 9.67 | 0.86 | 0.48 | 6.88 |
| 87 Sylvia | | | | |
| Aug.27,1978 | 11.60 | 0.68 | 0.25 | 7.40 |
| Sep.08,1978 | 11.52 | 0.70 | 0.24 | 7.33 |
| Sep.09,1978 | 11.55 | 0.70 | 0.25 | 7.36 |
| Sep.15,1978 | 11.60 | 0.71 | 0.26 | 7.40 |
| 247 Eukrate | | | | |
| Aug.27,1978 | 11.26 | 0.69 | 0.31 | 8.44 |
| Sep.08,1978 | 11.30 | 0.69 | 0.30 | 8.56 |
| Sep.09,1978 | 11.30 | 0.69 | 0.30 | 8.56 |

Table 3 Epochs and lapses of time between the same extrema appearing in the lightcurves of 9 Metis (see text)

| Epoch UT, 1978 | Extremum | Lapse of time | Deduced no of cycles |
|---|---|---|---|
| Aug. 23 $3^h.150$ | m2 | $526^h.900$ | 104 |
| Sep. 14 2.050 | m2 | | |
| Aug. 23 3.150 | m2 | 531.995 | 105 |
| Sep. 14 7.145 | m2 | | |
| Aug. 23 3.150 | m2 | 552.300 | 109 |
| Sep. 15 3.450 | m2 | | |
| Sep. 14 2.050 | m2 | 5.095 | 1 |
| Sep. 14 7.145 | m2 | | |
| Sep. 14 2.050 | m2 | 25.400 | 5 |
| Sep. 15 3.450 | m2 | | |
| Sep. 14 7.145 | m2 | 20.305 | 4 |
| Sep. 15 3.450 | m2 | | |
| Sep. 14 4.850 | m1 | 20.350 | 4 |
| Sep. 15 1.200 | m1 | | |
| Sep. 14 3.190 | M2 | 25.410 | 5 |
| Sep. 15 4.600 | M2 | | |
| Sep. 14 1.150 | M1 | 5.065 | 1 |
| Sep. 14 6.215 | M1 | | |
| Sep. 14 1.150 | M1 | 25.300 | 5 |
| Sep. 15 2.450 | M1 | | |
| Sep. 14 6.215 | M1 | 20.235 | 4 |
| Sep. 15 2.450 | M1 | | |

Table 4 Epochs and lapses of time between the same extrema appearing in the lightcurves of 87 Sylvia (see text)

| Epoch UT,1978 | Extremum | Lapse of time | Deduced no of cycles |
|---|---|---|---|
| Sep. 8 $1^h.690$ | m1 | $25^h.900$ | 5 |
| Sep. 9 3.590 | m1 | | |
| Sep. 8 4.175 | m2 | 20.710 | 4 |
| Sep. 9 0.885 | m2 | | |
| Sep. 8 4.175 | m2 | 171.035 | 33 |
| Sep. 15 7.210 | m2 | | |
| Sep. 9 0.885 | m2 | 150.325 | 29 |
| Sep. 15 7.210 | m2 | | |
| Sep. 9 2.315 | M2 | 150.315 | 29 |
| Sep. 15 8.630 | M2 | | |

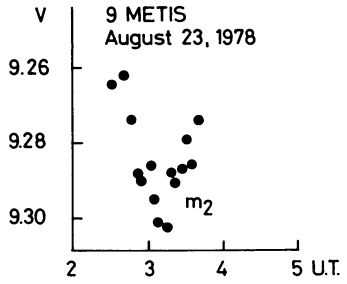


Figure 1 Part of a lightcurve of 9 Metis, obtained on Aug. 23, 1978.

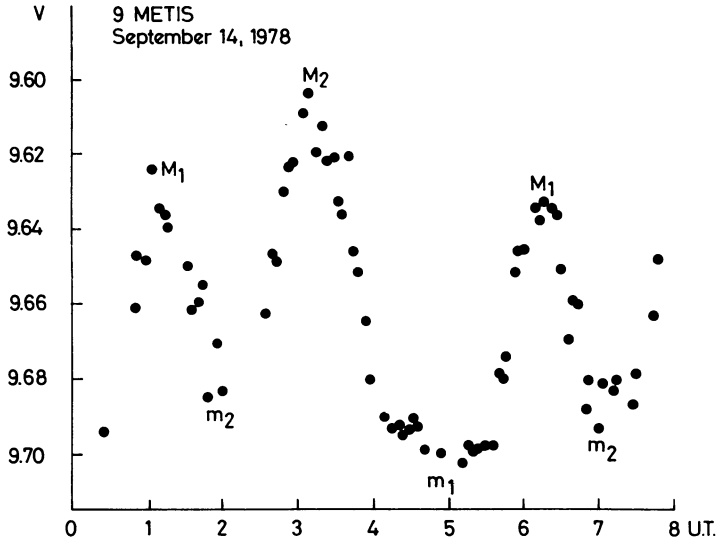


Figure 2 Lightcurve of 9 Metis on Sept. 14, 1978.

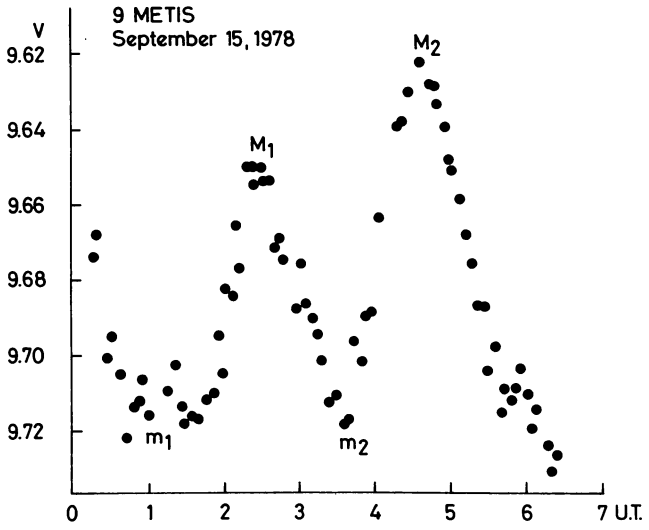


Fig. 3 Lightcurve of 9 Metis on Sept. 15, 1978.

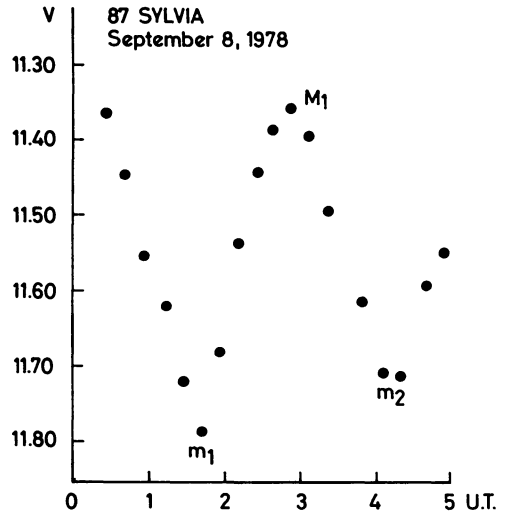


Fig. 4 Lightcurve of 87 Sylvia obtained on Sept. 8, 1978.

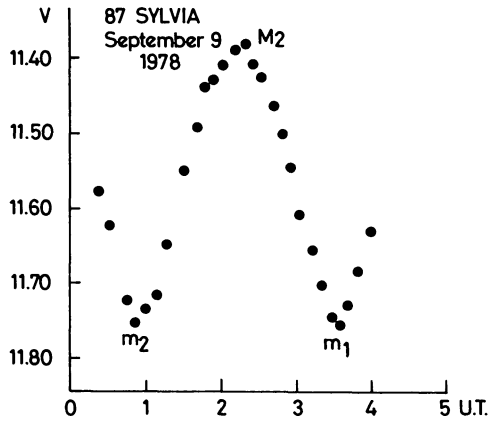


Fig. 5 Lightcurve of 87 Sylvia obtained on Sept. 9, 1978.

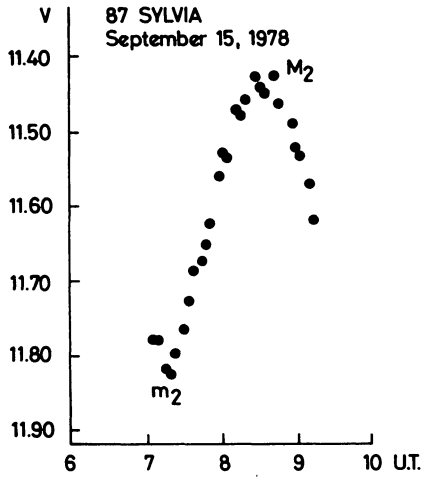


Fig. 6 Part of a lightcurve of 87 Sylvia on Sept. 15, 1978.

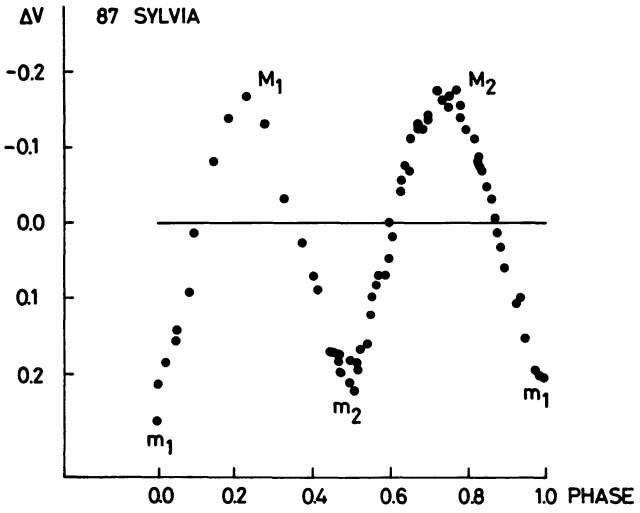


Figure 7 Composite lightcurve of 87 Sylvia, based on a rotation period of $5^{h}.183$.

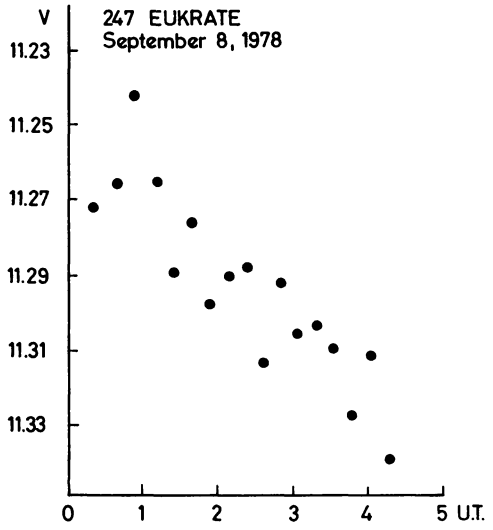


Figure 8 Partial lightcurve of 247 Eukrate obtained on Sept. 8, 1978.

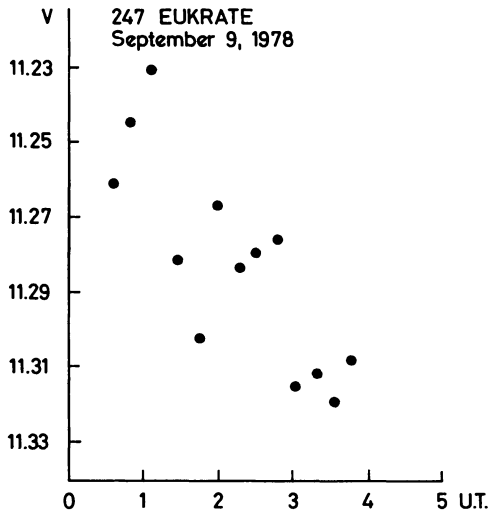


Figure 9 Partial lightcurve of 247 Eukrate obtained on Sept. 9, 1978.