

Physical Studies of Asteroids

VI. Asteroid 201 Penelope, a Fast Rotator*

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Summary. Photoelectric *UBV* lightcurves of the CMEU-type asteroid 201 Penelope, observed during September and October 1980 at the European Southern Observatory and at the Torino Observatory, are presented.

A large amplitude (~ 0.56 mag), not observed to change with phase angle, and a rapid spin rate ($P = 3^{\text{h}}7474 \pm 0^{\text{m}}0001$) are found. These rotational properties place this asteroid in the LASPA class (Farinella et al., 1981) having possible peculiar origin from catastrophic impact with shape relaxing in triaxial equilibrium ellipsoids.

The parameters characterizing the magnitude-phase relation of the asteroid according to the Lumme and Bowell (1981) radiative transfer theory are found to be: $Q = 0.075 \pm 0.015$ and $V(0^\circ) = 8.21 \pm 0.01$ mag.

Key words: asteroids – minor planets – photoelectric photometry – 201 Penelope

Observations

The asteroid 201 Penelope, classified as a CMEU-type object with an estimated diameter of 144 km (Bowell et al., 1979), had a favourable opposition ($B_{\text{opp}} = 11.6$ mag) in September 1980. Photoelectric observations were planned by the authors. Lagerkvist performed four runs at the European Southern Observatory on September 3, 4, 7, and 8 using the ESO 50 cm telescope. Details about these observations are given by Lagerkvist and Rickman (1981a). Scaltriti and Zappalà obtained two full-cycle lightcurves on October 27 and 28 using a photoelectric photometer equipped with a refrigerated EMI 6256S photomultiplier attached to the 45 cm reflector of the Torino Observatory.

The observations, reductions, and transformation to the standard *UBV* system were performed in the usual way. The aspect data of 201 Penelope are shown in Table 1. They were derived using a computer program developed by one of us (V.Z.) for the calculation of Earth and Sun distances and phase angles.

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* Based upon observations partly collected at the European Southern Observatory (ESO), La Silla, Chile

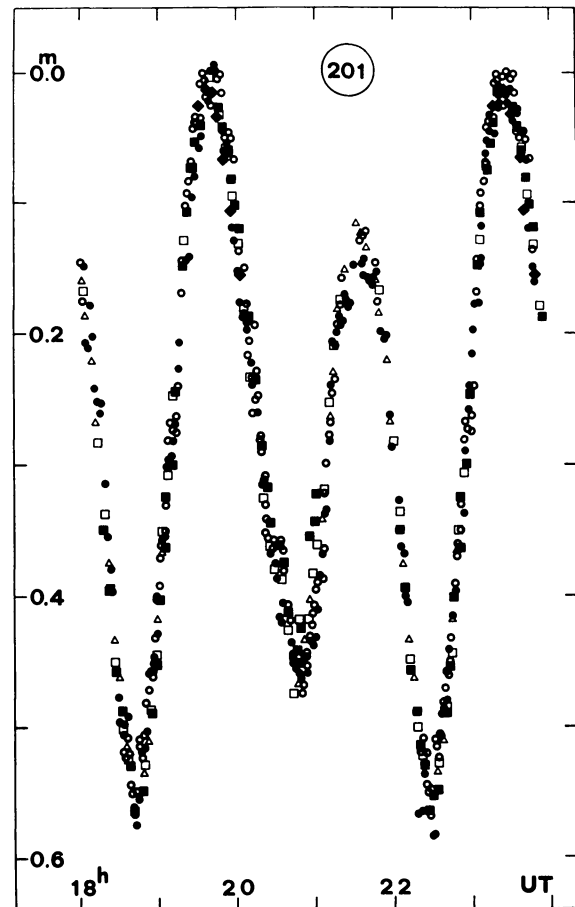


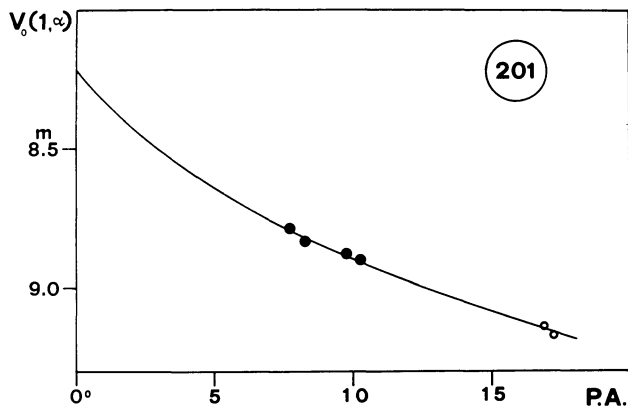
Fig. 1. Composite lightcurve of 201 Penelope constructed assuming a period $P = 3^{\text{h}}7474$: \square (September 3), \triangle (September 4), \blacklozenge (September 7), \blacksquare (September 8), \bullet (October 27), \circ (October 28). The times of observation are reduced to the night October 27. The zero point of the *V* magnitude scale (ordinate axis) corresponds to 9.14 mag

Lightcurves, Rotational Period, Magnitude-phase Relation

A rather large amplitude (~ 0.56 mag) not observed to change with phase angle, characterizes the full-cycle lightcurve (Fig. 1). This lightcurve shows well-defined and nearly equally spaced

Table 1. Aspect data, magnitude information, and observational circumstances of 201 Penelope

Date (0 ^h UT)	R.A. (1950.0)	Decl. (1950.0)	λ (1950.0)	β (1950.0)	r (AU)	Δ (AU)	α	$V_0(1, \alpha)$	Observatory
1980 09 03	00 ^h 15 ^m .1	-01°27'	2°89	-2°83	2.205	1.240	10°2	8 ^m .89	ESO
09 04	00 14.6	-01 34	2.72	-2.89	2.206	1.237	9.7	8.88	ESO
09 07	00 12.9	-01 58	2.18	-3.08	2.207	1.228	8.3	8.83	ESO
09 08	00 12.3	-02 06	1.99	-3.14	2.208	1.225	7.7	8.79	ESO
10 28	23 44.3	-07 16	353.51	-5.11	2.250	1.404	16.9	9.14	Torino
10 29	23 44.1	-07 17	353.45	-5.11	2.251	1.413	17.2	9.17	Torino

**Fig. 2.** Magnitude-phase relation of 201 Penelope with $Q=0.075$ and $V(0^\circ)=8.21$ mag: ● (ESO observations), ○ (Torino observations)

extrema, suggesting an ellipsoidal shape of the body. It can be noticed, however, that the levels attained by the two maxima (and similarly for the minima) differ by about 0.12 mag. This suggests the presence of different illuminated projected areas rather than regions of different reflectivity.

The well-defined extrema and the rather long interval between the ESO and Torino observations allowed us to find an unambiguous value of the period: $\bar{P}_{\text{syn}} = 3^{\text{h}}7474 \pm 0^{\text{h}}0001$, which was used to construct the composite lightcurve in Fig. 1.

The colour indices $B-V$ and $U-B$ were extensively observed on September 3 and 4. No significant colour variation over the lightcurve was observed (Lagerkvist and Rickman, 1981b), and the average values of $B-V$ and $U-B$ for the two nights are in very good agreement. They are: $\bar{B-V} = (0.70 \pm 0.01)$ mag, and $\bar{U-B} = (0.24 \pm 0.02)$ mag. The calculation of the probable errors is described by Carlsson and Lagerkvist (1981).

The absolute magnitudes at maximum light $V_0(1, \alpha)$ listed in Table 1 are well suited for deriving the magnitude-phase relation of Penelope due to the quite large interval of phase angles covered by our observations. The resulting phase curve is shown in Fig. 2. In the framework of the generalized radiative transfer theory given by Lumme and Bowell (1981) a single parameter Q (the multiple-scattering factor) is sufficient to derive the whole phase relation. We find: $Q = 0.075 \pm 0.015$ and $V(0^\circ) = (8.21 \pm 0.01)$ mag.

Discussion

The absence of significant colour variation lends support to the belief that the 0.12 mag difference between the two lightcurve maxima of Penelope is due to somewhat irregular shape rather than surface variation. The observed colour indices place the asteroid in the CMEU domain of the two-colour diagram, remarkably close to the lower limit of $U-B$. Hence identification as an M -type asteroid appears likely. It may be noticed that the value of Q indicated by our observations agrees with the ranges of Q for classes C and M as given by Bowell and Lumme (1979) but not with the range for class E .

In the TRIAD file (Bowell et al., 1979) 58 CMEU-type asteroids are listed. At present only a small percentage (21%) have known periods. However, it can be noticed that most of them have spin periods shorter than 8 h and that they have relatively large lightcurve amplitudes (see Lagerkvist and Rickman, 1981b).

Penelope is a typical LASPA (Large Amplitude Short Period Asteroid) (Tedesco and Zappalà, 1980; Farinella et al., 1981) in a size range (100–200 km) where such objects are common. The very rapid spin implies a high density for this asteroid according to the triaxial ellipsoid model of LASPAs by Farinella et al. (1981). We recall that the origin of such objects could be major impacts in which a significant fraction of collisional debris and fragments cannot escape but create a deep regolith of very low cohesive strength. This layer would tend to relax into the triaxial equilibrium shape like a liquid.

It appears that the CMEU class has a high percentage of LASPAs. The reason for this is not yet clear. We strongly suggest that high priority be given to observing these asteroids.

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