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CCD PHOTOMETRY OF THE ECLIPSING BINARY HP AURIGAE

The detached eclipsing binary HP Aurigae (HDE 280 603 = GSC 2401.1263 = BV 185; $\alpha_{2000} = 5^{\rm h}10^{\rm m}21^{\rm s}\!.8$, $\delta_{2000} = +35°47'47''$, Sp. G0 + G8, $V_{max} = 10.9$ mag) is a relatively well-known binary with a short orbital period of about 1.42 days. This binary was selected as a possible system for the study of the apsidal motion (Giménez, 1994) and thus it was also included in our observational project of eclipsing binaries with eccentric orbit (e.g. Wolf & Šarounová, 1995).

HP Aur was discovered to be a variable star by Strohmeier (1958), who obtained also the first photographic light curve and determined an orbital period of 1.422818 days. The first UBV photoelectric observations were made by Meinunger (1980), who found that its orbital period is 1.4228132 days and its secondary minimum is shifted to phase 0.502. These B and V lightcurves were later analyzed using Wood's (1972) model by Giuricin et al. (1983). The next UBV photoelectric photometry was obtained by Liu et al. (1989). They derived a photometric solution using the Wilson–Devinney method and discussed also the quasi-periodic transient variability of brightness. Analysing light fluctuations, they concluded that HP Aur has a transient disk in its system. Recently multi-colour $WBVR$ photoelectric observations were carried out by Kozyreva (1990). Using the light-curve solution in two different epochs with difference $\Delta T \approx 7$ years, she derived the rate of apsidal motion $\dot{\omega} = 0.93$ deg yr^{-1}, which was almost three times smaller than predicted theoretically.

Our new CCD photometry of HP Aur was carried out during four nights in October 1995 and January 1996 simultaneously at the Ondřejov Observatory, Czech Republic and R. Szafraniec Observatory, Metzerlen, Switzerland. At Ondřejov Observatory a 65cm reflecting telescope with a CCD-camera SBIG ST-6 was used. The measurements were done using the standard Johnson R filter with 60 or 90 s exposure time. At R. Szafraniec Observatory a 35cm Cassegrain telescope with the same type of CCD camera without filter was used. The nearby stars GSC 2401.1128 ($V = 11.7$ mag) and GSC 2401.268 ($V = 11.1$ mag) on the same frame as HP Aur served as comparison and check stars, respectively. The CCD data were reduced using software developed at Ondřejov Observatory by P. Pravec and M. Velen (Pravec et al., 1994). The precise times of minimum and their error were determined using the Kwee–van Woerden (1956) method. These new times are presented in Table 1. In this table, N stands for the number of observations used in the calculation of the minimum time. The measurements of primary and secondary minimum published by Kozyreva (1990) were recalculated according to her original data and are also given in Table 1. The epochs were calculated using the linear light elements given by same author:

$$\text{Pri. Min.} = \text{HJD}\,24\ 46353.2351 + 1.4228192 \times \text{E}.$$

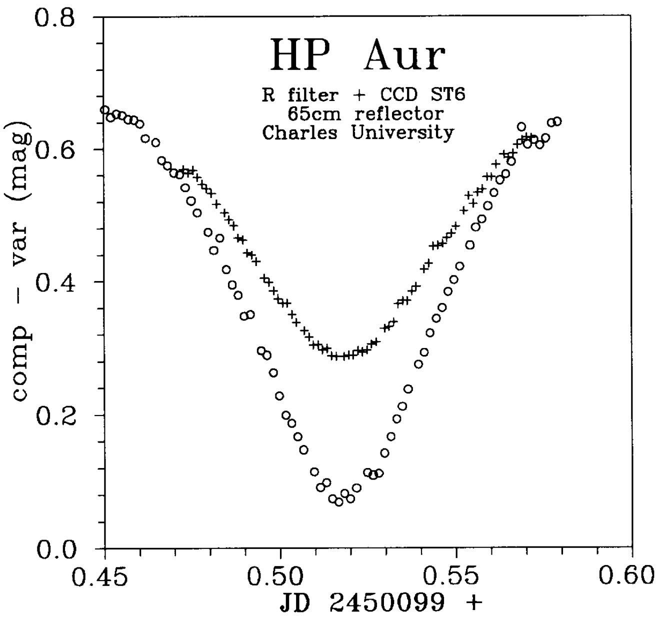

Figure 1. A plot of differential R magnitudes obtained during primary eclipse of HP Aur on 16 January 1996 (circles). The measurements of secondary minimum obtained on 19 October 1995 were shifted in time by +62.5 periods and are plotted as crosses together with primary minimum.

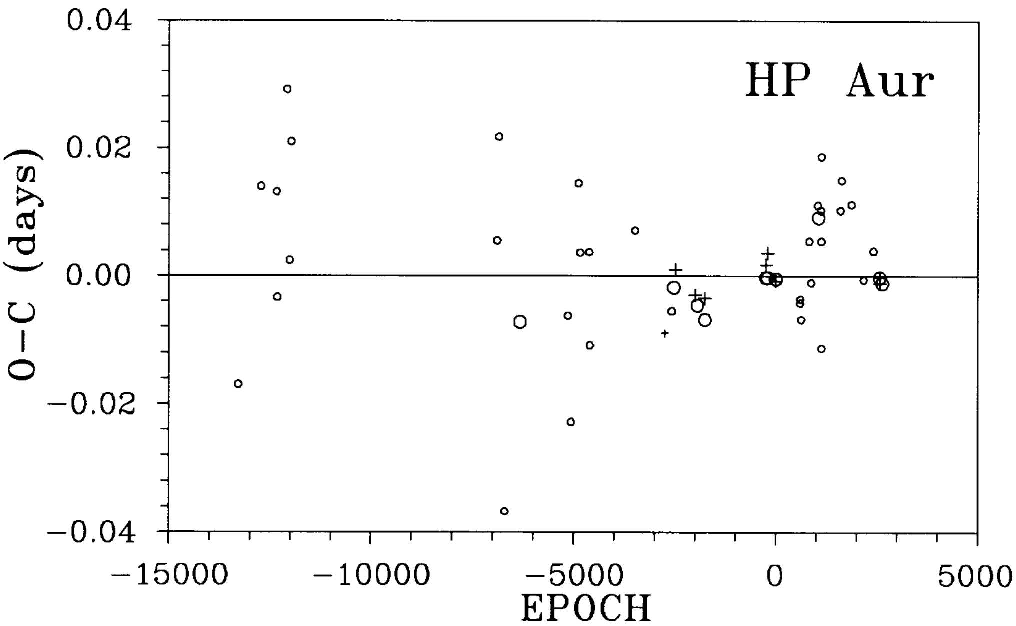

Figure 2. $O-C$ residuals for the times of minimum of HP Aur. The individual primary and secondary minima are denoted by circles and crosses, respectively. Larger symbols correspond to the photoelectric or CCD measurements and two precise photographic data.

Table 1. New precise times of minimum of HP Aur

JD Hel.− 24 00000	Epoch	Error (days)	N	Observatory
46353.2355*	0.0	0.0004	31	Tien-Shan
46355.3694*	1.5	0.0003	64	Tien-Shan
50008.4580	2569.0	0.0002	46	Metzerlen
50010.5913	2570.5	0.0001	71	Ondřejov
50013.4379	2572.5	0.0004	69	Metzerlen
50099.5175	2633.0	0.0001	72	Ondřejov

* *recalculated original data of Kozyreva (1990)*

Figure 1 shows the differential R magnitudes during the primary minimum observed at JD 2450099 (circles). Our measurements of secondary minimum (crosses) were shifted exactly by 62.5 periods (+ 88.9262 d) and are also plotted to the same date. The light amplitude in R colour for primary minimum according to our measurement is $A_1 = 0.60 \pm 0.02$ mag, for secondary minimum we found $A_2 = 0.38 \pm 0.02$ mag. The duration of both minima seems to be almost identical, $D_1 \simeq D_2 \simeq 0.13$ days = 0.092 phase.

The change of period and possible apsidal motion of HP Aur were studied by means of an O−C diagram analysis. We took into consideration all photoelectric measurements found in the literature as well as the photographic times of minimum obtained by Splittgerber (1971) and Frank (1994). The $O - C$ residuals for all times of minimum are shown in Figure 2. The photographic times or visual estimations obtained by Perova (1960), Mallama et al. (1977) and BBSAG observers are also plotted.

We analysed the O−C diagram and the light curve using the current observations. Our results indicate that this binary has no significantly eccentric orbit. According to our timings, the secondary minimum occurs in the phase $\Phi_{II} = 0.5000 \pm 0.0001$ and the duration of primary and secondary eclipses is practically identical. This system could be excluded from the list of possible candidates for apsidal motion study. Nevertheless, the remarkable deviation of the $O - C$ values in Meinunger's (1980) results ($E \approx -2000$) could be caused by a light-time effect. Such phenomenon with an orbital period of a third body about 7300 day (20 years) and an amplitude about 0.01 days cannot be ruled out.

For the current use we propose the following linear light elements:

$$\text{Pri.Min.} = \text{HJD } 24\ 46353.2360 + 1.4228191 \times \text{E.}$$
$$\pm 5 \qquad\qquad \pm 7$$

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Marek WOLF and Lenka ŠAROUNOVÁ
Astronomical Institute,
Charles University Prague,
Švédská 8, CZ - 150 00 Praha 5,
Czech Republic
Internet: `wolf@earn.cvut.cz`

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