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CL AURIGAE: A NEW PHOTOMETRIC TRIPLE STAR

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The detached eclipsing binary CL Aurigae (= BD +33°0975 = GSC 2393.1455 = HV 6886 = FL 439; $\alpha_{2000} = 5^{\rm h}12^{\rm m}54\overset{\rm s}{.}2$, $\delta_{2000} = +33°30'28''$, Sp. = A0, $V_{\max} = 11\overset{\rm m}{.}7$) is a photoelectrically neglected variable with a short orbital period of about 1.24 days. This system was selected as a possible candidate for the study of the apsidal motion (Hegedüs 1988) and thus it was also included to our observational project of eclipsing binaries with eccentric orbit (e.g. Wolf & Šarounová 1995).

CL Aur was discovered to be a variable star photographically by Hoffleit (1935). The first photographic light curve was obtained by Kurochkin (1951), who also determined the first light elements:

$$\text{Min. I} = \text{HJD } 2\,432\,967.262 + 1\overset{\rm d}{.}244\,366\,6 \times E.$$

Next visual observations were made by Szafraniec (1960), the spectral type was determined by Götz & Wenzel (1968). The photographic plates of the GAIS (Nos. 39052–40649 and Moscow observatories (Nos. 16869–35540) were examined by Fadeyev (1973). Due to the relatively deep primary minimum this variable was often observed visually, mostly by BBSAG observers (K. Locher, H. Peter, R. Diethelm). To our knowledge this star has not been measured photoelectrically since discovery.

Our new CCD photometry of CL Aur was carried out during eight nights between November 1995 and December 1998 at the Ondřejov Observatory, Czech Republic. Primarily, a 65-cm reflecting telescope with a CCD-camera (SBIG ST-6 or ST-8) was used. The measurements were done using the standard Cousins R filter with 60 or 90 s exposure time. Two additional measurements were done using 18-cm Maksutov-Cassegrain (Ondřejov) and 25-cm Newtonian (Hradec Králové) telescopes without filter. The nearby stars GSC 2393.1532 ($V = 11.4$ mag) — listed also as star b by Kurochkin (1951) — and GSC 2393.1435 ($V = 11.9$ mag) on the same frame as CL Aur served as a comparison and check stars, respectively. Flat fields for the reduction of the CCD frames were routinely obtained from exposures of regions of the sky taken at dusk or dawn. Standard error of measurements varies from 0.01 mag to 0.02 mag. The new moments of primary and secondary minimum and their errors were determined using the least squares fit to the data, by the bisecting chord method or by the Kwee–van Woerden algorithm. These seven times of minimum are presented in Table 1. In this table, N stands for the number of

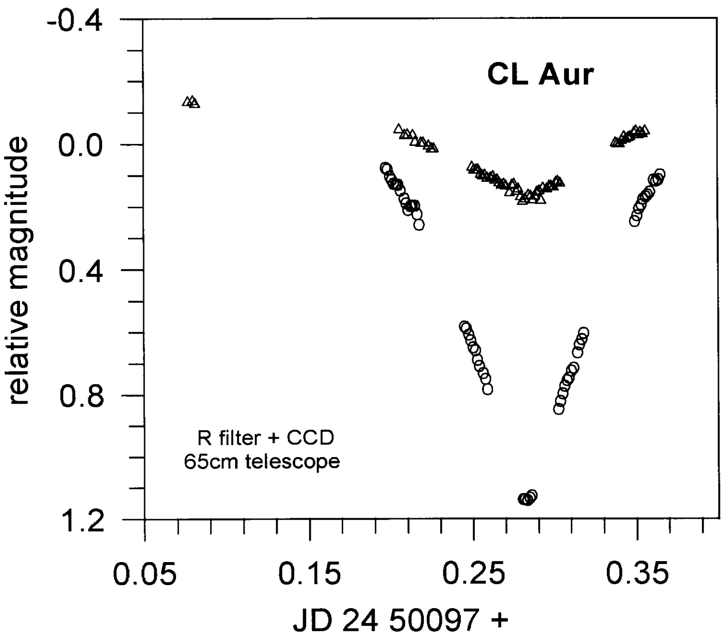

Figure 1. A plot of differential R magnitudes obtained during primary eclipse of CL Aur on 14 January 1996 (circles). The measurements of secondary minimum obtained on 22 November 1995 were shifted in time by +42.5 periods and are plotted as triangles together with primary minimum.

observations used in the calculation of the minimum time. The epochs were calculated according to the light elements of Kurochkin (1951).

Figure 1 shows the differential R magnitudes during the primary minimum observed at JD 2450097 (circles). Our measurements of secondary minimum (triangles) were shifted exactly by 42.5 periods (+52.8858 d) and are also plotted. The light amplitude in R colour for primary minimum according to our measurement is $A_1 = 1.28$ mag, for secondary minimum we found $A_2 = 0.32$ mag. The duration of both minima seems to be almost identical, $D_1 \simeq D_2 \simeq 0.22$ days = 0.176 phase.

The change of period and possible apsidal motion of CL Aur were studied by means of an $O - C$ diagram analysis. We took into consideration all visual and photographic measurements found in the literature as well as the CCD times given in Table 1. The $O - C$ graph for all moments of minimum are shown in Figure 2. The photographic

Table 1: New precise times of minimum of CL Aur

JD Hel. 24 00000+	Epoch	Error (days)	N	Instrument Filter
50044.3958	13723.5	0.0007	63	65-cm, ST6, R
50097.2826	13766.0	0.0002	56	65-cm, ST6, R
50714.4888	14262.0	0.0006	52	18-cm, ST6, -
50831.4589	14356.0	0.0001	39	65-cm, ST8, R
50884.3431	14398.5	0.0003	68	65-cm, ST8, R
51157.4815	14618.0	0.0006	24	25-cm, ST5, -
51177.3914	14634.0	0.0001	51	65-cm, ST8, R

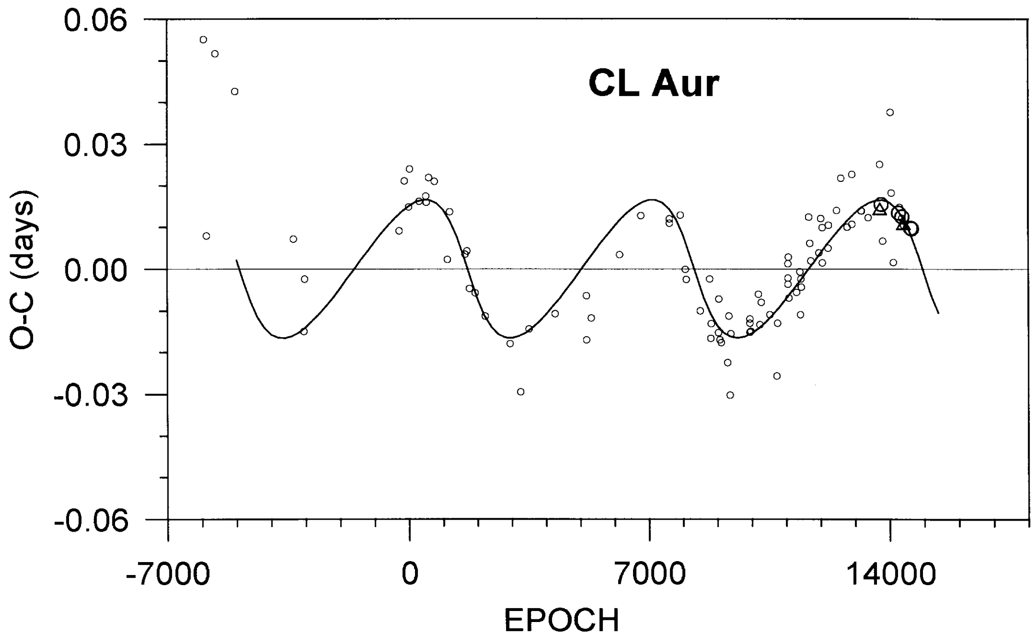

Figure 2. $O - C$ diagram of CL Aur. The individual times of primary and secondary minimum are denoted by circles and triangles, respectively. Larger symbols are our CCD measurements. The curve corresponds to a third body orbit.

times or visual estimations obtained by Kurochkin (1951) 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 significant eccentric orbit. According to our timings, the secondary minimum occurs at 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.

Secondly, quasi-sinusoidal deviations of the $O - C$ values are remarkable after zero epoch and could be caused by a light-time effect. Preliminary analysis of the third body period gives the following parameters:

$$
\begin{aligned}
P_3 \text{ (period)} &= 8240 \pm 70 \text{ days} = 22.5 \text{ years} \\
T_0 \text{ (time of periastron)} &= \text{J.D. } 2\,443\,315 \pm 35 \\
A \text{ (semiamplitude)} &= 0.0166 \pm 0.0012 \text{ day} \\
e &= 0.405 \pm 0.025 \\
\omega &= 179^\circ \pm 2^\circ
\end{aligned}
$$

These values were obtained together with the new linear ephemeris

$$
\begin{array}{rl}
\text{Min. I} = \text{HJD } 2\,432\,967.2472 + & 1^{\rm d}\!.244\,371\,63 \times E, \\
\pm 0.0006 & \pm 0.000\,000\,17
\end{array}
$$

by the least squares method. Assuming a coplanar orbit ($i_3 = 90^\circ$) and a total mass of the eclipsing pair $M_1 + M_2 \simeq 3M_\odot$ (Harmanec 1988) we can obtain a lower limit for the mass of the third component $M_{3,\rm min}$. The present explanation is supported by the quite reasonable value of the mass function $f(M_3) = 0.0614 M_\odot$, from which the minimum mass of the third body is $1 M_\odot$.

New high-accuracy timings of this interesting eclipsing system are necessary in the future in order to confirm and/or improve the light-time effect parameters given above. For the current use we propose the following linear light elements:

$$\text{Min. I} = \text{HJD}\ 2\,451\,177.3914 + 1\overset{\text{d}}{.}244\,365 \times E.$$

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ERRATUM FOR IBVS 4683

CL Aur is not BD +33°0975.

The Editors