COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5780

Konkoly Observatory
Budapest
21 June 2007

HU ISSN 0374 – 0676

CL AURIGAE: A TRIPLE SYSTEM WITH MASS TRANSFER

WOLF, M.[1]; KOTKOVÁ, L.[2]; BRÁT, L.[3]; HANŽL, D.[4]; HORNOCH, K.[5]; LEHKÝ, M.[6]; ŠMELCER, L.[7]; ZASCHE, P.[1]

[1] Astronomical Institute, Charles University Prague, V Holešovičkách 2, CZ-180 00 Praha 8, Czech Republic, e-mail: wolf@cesnet.cz

[2] Astronomical Institute, Academy of Sciences, CZ-251 65 Ondřejov, Czech Republic, e-mail: lenka@asu.cas.cz

[3] Private Observatory, Velká Úpa 193, CZ-542 21 Pec pod Sněžkou, Czech Republic, e-mail: brat@snezkou.cz

[4] Faculty of Science, Masaryk University, Kotlářská 2, CZ-611 37 Brno, Czech Republic

[5] Private Observatory, CZ-664 31 Lelekovice 393, Czech Republic, e-mail: k.hornoch@centrum.cz

[6] Observatory and Planetarium, Zámeček 456, CZ-500 08 Hradec Králové, Czech Republic

[7] Observatory, Vsetínská 78, CZ-575 01 Valašské Meziříčí, Czech Republic, e-mail: lsmelcer@astrovm.cz

The semi-detached eclipsing binary CL Aurigae (GSC 2393.1455, FL 439, HV 6886; $B_{\max} = 11.7$ mag) is a relatively faint but frequently observed binary with a short orbital period about 1.24 days. CL Aur was discovered to be a variable star photographically by Hoffleit (1935). Later Kurochkin (1951) derived the first light elements

$$\text{Pri. Min.} = \text{HJD } 24\,32967.262 + 1^{\text{d}}.2443666 \times E.$$

Next visual observations were made by Szafraniec (1960), the spectral type was determined by Götz & Wenzel (1968). Wolf et al. (1999) in their period study predicted a third body in eccentric orbit ($e = 0.4$) with a period of about 22.5 years. To our knowledge this star has not been measured spectroscopically since discovery.

We observed eclipses of CL Aur regularly every year and obtained 18 new precise times of minimum light. Our CCD photometry was carried out from 2001 until March 2007 at six observatories: Brno, Lelekovice, Hradec Králové, Ondřejov, Pec pod Sněžkou and Valašské Meziříčí observatories, Czech Republic. Different telescopes, CCD cameras and filters were used (see Table 1). The nearby star GSC 2393.1532 ($V = 11.4$ mag) on the same frame as CL Aur served as a primary comparison star during these observations. See also http://nyx.asu.cas.cz/~lenka/dbvar/ for more information. The new times of primary minimum and their errors were determined using the least squares fit of the data by the bisecting chord method. These times of minimum are presented in Table 1. In this table, N stands for the number of observations used in the calculation of the minimum time, the others are self-evident. The epochs were calculated according to the new ephemeris given in the text.

The change of period of CL Aur was studied by means of an $O - C$ diagram analysis. We took in consideration all older visual and photographic times of minima found in

Table 1: New times of minimum light of CL Aur

JD Hel. − 24 00000	Epoch	Error (days)	N	Observatory Telescope, camera, filter
51901.6065	1450.0	0.0002	107	Hradec Králové 40-cm, ST-7, V
51901.6070	1450.0	0.0003	89	Lelekovice 35-cm, ST-6V, R
52017.3345	1543.0	0.0003	52	Lelekovice 35-cm, ST-6V, R
52252.5171	1732.0	0.0001	80	Ondřejov 65-cm, AP7p, R
52333.4014	1797.0	0.0001	88	Ondřejov 65-cm, AP7p, R
52522.5455	1949.0	0.0001	46	Ondřejov 65-cm, AP7p, R
52684.3143	2079.0	0.0001	77	Ondřejov 65-cm, AP7p, R
52899.5915	2253.0	0.0002	31	Ondřejov 65-cm, AP7p, R
52964.2991	2304.0	0.0001	90	Ondřejov 65-cm, AP7p, R
53425.3416	2674.5	0.0001	98	Ondřejov 65-cm, AP7p, R
53713.4178	2906.0	0.0001	83	Ondřejov 65-cm, AP7p, R
53746.3945	2932.5	0.0002	73	Ondřejov 65-cm, AP7p, R
53769.4149	2951.0	0.0001	64	Ondřejov 65-cm, AP7p, R
54070.5565	3193.0	0.0002	65	Pec pod Sněžkou 20-cm, ST-8, R
54141.4868	3250.0	0.0002	104	Brno 20-cm, ST-6V, R
54171.3516	3274.0	0.0001	137	Brno 20-cm, ST-6V, R
54176.3298	3278.0	0.0001	33	Valašské Meziříčí 28-cm, ST-7, V, R
54186.2843	3286.0	0.0002	16	Valašské Meziříčí 28-cm, ST-7, V, R

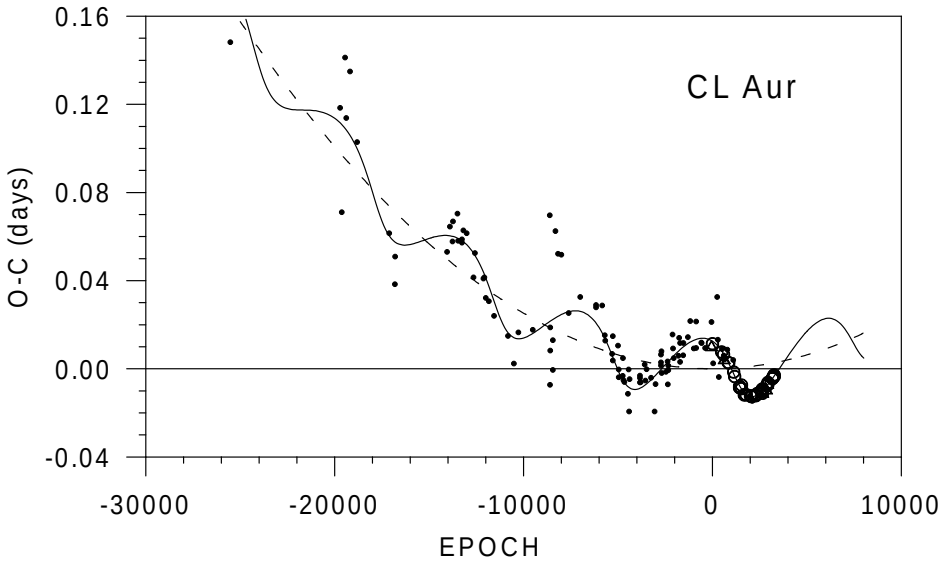

Figure 1. The complete $O - C$ diagram for CL Aur. The numerous visual and photographic times are denoted by dots, the primary and secondary CCD times are denoted by circles and triangles, resp. The sinusoidal curve corresponds to the third body orbit, the dashed curve denotes a period increase of about 1.3 seconds per century

special databases of AAVSO[1] and BRNO[2] observers, all times given in Wolf et al. (1999, their Table 1), as well as current numerous CCD timings given in Hübscher et al. (2005, 2006), Nelson (2006), Bíró et al. (2007), Dogru et al. (2007), Hübscher & Walter (2007) and Smith & Caton (2007). The period increase and sinusoidal deviations of the $O-C$ values caused by a light-time effect are well remarkable. Our analysis of the third body gives the following parameters:

P_3 (period)	$= 7910 \pm 80$ days
	$= 21.7 \pm 0.2$ years
T (time of periastron)	$=$ J.D. 24 43880 $\pm$ 80
A (semi-amplitude)	$= 0.0138 \pm 0.0012$ day
ω (length of periastron)	$= 209.2 \pm 1.2$ degrees
e_3 (eccentricity)	$= 0.32 \pm 0.02$

These values were obtained by the least squares method together with the quadratic light elements

$$\text{Pri. Min.} = \text{HJD } 2450097.2712(5) + 1\overset{\text{d}}{.}24437505(18) \times E + 2\overset{\text{d}}{.}52(4) \times 10^{-10} \times E^2.$$

The period increase resulting from these elements is 5.04×10^{-10} day/cycle or 1.48×10^{-7} day/year or 1.3 seconds per century, respectively. For this solution all times were used with different weights, their list is given in an electronic table available through the IBVS website as file 5780-t2.txt. The corresponding $O-C$ diagrams are plotted in Fig. 1 and Fig. 2.

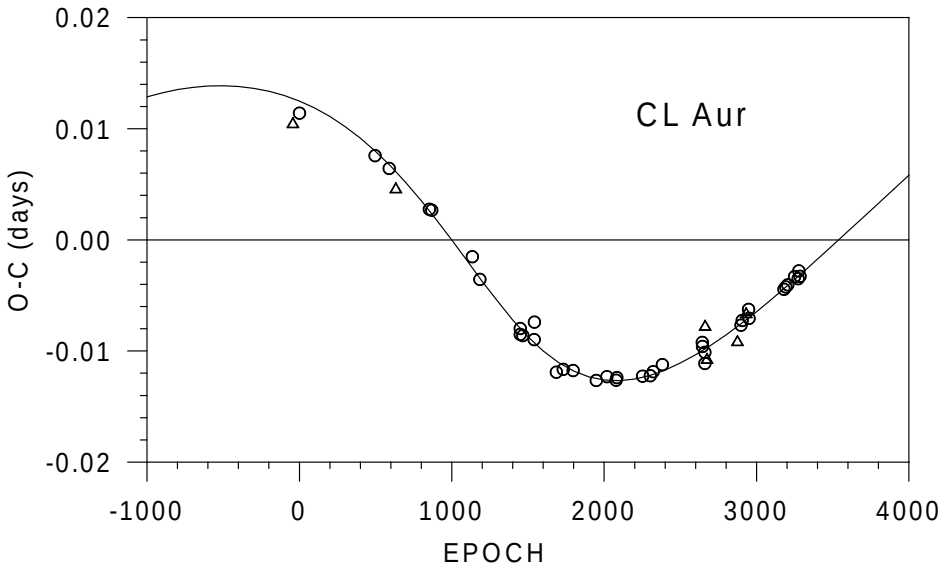

Figure 2. The $O-C$ diagram of CL Aur based on current CCD measurements. Primary and secondary times are denoted by circles and triangles, resp. The sinusoidal curve corresponds to the third body orbit with a short period of about 22 years and a semi-amplitude about 20 minutes

[1] http://www.aavso.org/observing/programs/eclipser/ebtom.shtml
[2] http://var.astro.cz/ocgate

Assuming a coplanar orbit ($i_3 = 90°$) and adopting a total mass of the eclipsing pair with A1 primary to be $M_1 + M_2 \simeq 3.0\ M_\odot$, we can obtain a lower limit for the mass of the third component $M_{3,\mathrm{min}}$. The mass function has a value $f(M) = 0.034\ M_\odot$, from which the minimum mass of the third body follows as $0.79\ M_\odot$. A possible third component of spectral type about K2 with the bolometric magnitude of $m_3 \simeq 5.7$ mag (Harmanec, 1988) produces a hardly detectable third light of $L_3 \simeq 1.5\%$ of the total light.

Our result indicates, that CL Aur is probably the next member of a group of triple systems with mass transfer deserving a regular monitoring (e.g. RR Dra, TZ Eri; Zasche, 2007). Approx. 50% of the third-body orbit is well-covered by the precise photoelectric and CCD observations. Therefore, new high-accuracy timings of this eclipsing system are necessary in order to cover the third-body orbit and to improve parameters given above.

Acknowledgements. This investigation was supported by the Grant Agency of the Czech Republic, grants No. 205/04/2063 and No. 205/06/0217. We also acknowledge the support from the Research Program MSM0021620860 of the Ministry of Education. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France, and of NASA's Astrophysics Data System.

References:

Bíró, I.B., Borkovits, T., Hegedüs, T., et al., 2007, *IBVS*, No. 5753
Dogru, S.S., Donmez, A., Tuysuz, M., et al., 2007, *IBVS*, No. 5746
Götz, W., Wenzel, 1968, *Mitteilungen Ver. Sterne*, **5**, 5
Harmanec, P., 1988, *Bull. Astr. Inst. Czech.*, **39**, 329
Hoffleit, D., 1935, *Harvard Bulletin*, **901**, 20
Hübscher, J., Walter, F., 2007, *IBVS*, No. 5761
Hübscher, J., Paschke, A., Walter, F., 2005, *IBVS*, No. 5657
Hübscher, J., Paschke, A., Walter, F., 2006, *IBVS*, No. 5731
Kurochkin, N.E., 1951, *Variable Stars*, **8**, 351
Nelson, R.H., 2006, *IBVS*, No. 5672
Smith, A.B., Caton D.B., 2007, *IBVS*, No. 5745
Szafraniec, R., 1960, *Acta Astronomica*, **10**, 99
Wolf, M., Šarounová, L., Brož, M., Horan, R., 1999, *IBVS*, No. 4683
Zasche, P., 2007, *AJ*, submitted

ERRATUM FOR IBVS 4683

CL Aur is not BD +33°0975.

The Editors