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FOUR NEW VARIABLE STARS NEAR CL AURIGAE

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Abstract: Four stars (USNO-B1.0 1234-0103195, 1235-0097170, 1236-0100293 and 1236-0100092) were discovered as new variable stars in the vicinity of CL Aur by means of $BVRI$ CCD photometry. Light curves of the first three stars show those of W UMa-, short period Algol- and eccentric Algol- types eclipsing binary stars with orbital periods of 0.513743 d, 0.86983 d and 4.005584 d, respectively. Only a part of one ascending branch has been observed for the last star (USNO-B1.0 1236-0100092). Fourteen times of minimum light for these stars were presented.

We report that four stars (USNO-B1.0 1234-0103195, 1235-0097170, 1236-0100293 and 1236-0100092) in the vicinity of CL Aur were found to be new variable stars during the multi-color observations of CL Aur using a SITe 2K CCD camera and a $BVRI$ filter set attached to the 61 cm reflector at Sobaeksan Optical Astronomy Observatory (SOAO) in Korea.

The observations of CL Aur were made on 22 nights from 2003 November to 2005 February. The CCD camera has 2048×2048 pixels and an FOV of about $20.'5 \times 20.'5$. The exposure times were 75∼140 s for B, 45∼85 s for V, 33∼65 s for R, and 30∼60 s for I, respectively, depending on weather conditions. A 2×2 binning mode was selected. The nearby stars GSC 2393-1424 and GSC 2393-1418, imaged on the chip at the same time as the variable, were chosen as comparison and check stars, respectively. The details of our observations of CL Aur were given by Lee et al. (2010). The coordinates and photometric characteristics of CL Aur, comparison, check and four new variable stars were given in Table 1 and their finding chart was drawn in Figure 1.

Table 1: Coordinates and photometric data for the program stars.

Star	Catalogue	RA (J2000)	DEC (J2000)	$V^{\dagger}$	$\triangle V^{\ddagger}$
	GSC				
CL Aurigae	2393-1455	$05^h12^m54.^s19$	$+33°30'28.''4$	+11.65	−0.818
Comparison	2393-1424	$05^h13^m27.^s48$	$+33°26'46.''3$	-	0.000
Check	2393-1418	$05^h12^m19.^s08$	$+33°26'31.''5$	+12.30	−0.341
	USNO B1.0				
V1	1236-0100293	$05^h12^m50.^s56$	$+33°36'36.''78$	-	+3.95
V2	1235-0097170	$05^h13^m23.^s92$	$+33°35'36.''20$	-	+3.44
V3	1236-0100092	$05^h12^m26.^s66$	$+33°39'11.''07$	-	+2.95
V4	1234-0103195	$05^h12^m19.^s03$	$+33°25'49.''23$	-	+1.53

† : From the Tycho-2 Catalogue (Hog et al. (2000)).

‡ : Instrumental V magnitude difference $\triangle V$(program − comparison) at phase 0.25 measured from our photometric system.

From our observations fourteen times of minimum light for the variable stars were determined with the Kwee and van Woerden (1956) method and listed in Table 2. The last timing (HJD 2454120.9884) was measured using a ST-8 CCD camera attached to a

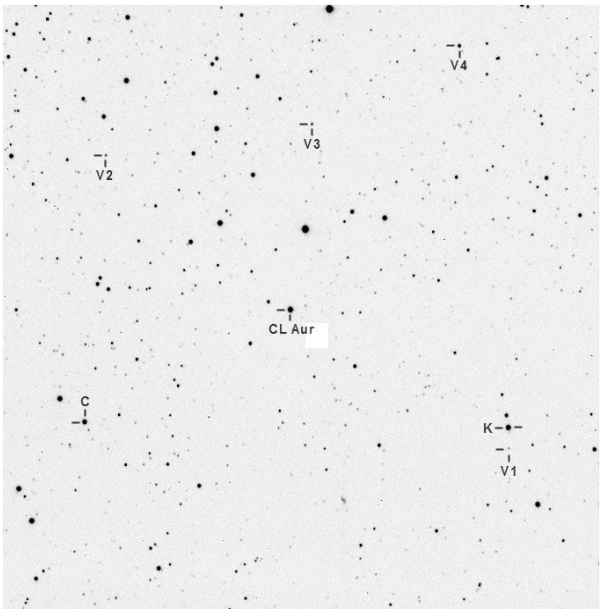

Figure 1: Finding chart for new variable stars (designated as V1, V2, V3 and V4) near CL Aur. The field of view is about $20.'5 \times 20.'5$. CL Aur is located at the chart center. "C" and "K" denote comparison (GSC 2393-1424) and check (GSC 2393-1418) stars, respectively. Left is east, Up is north.

Table 2: Times of minimum light of new variable stars.

Star (USNO B1.0)	HJD (HJD 2450000+)	Error (day)	Type
1236-0100293	3019.0681	0.0038	I
	3055.0165	0.0031	II
	3056.0405	0.0034	I
	3059.1420	0.0033	I
	3353.0005	0.0031	I
	3353.2617	0.0046	II
	3410.0322	0.0023	I
	3414.1392	0.0014	I
1235-0097170	3019.2283	0.0030	I
	3353.2418	0.0021	I
	3361.0736	0.0015	I
	3414.1326	0.0007	I
1236-0100092	3412.000	0.002	I
	4120.9884	0.0005	I

Table 3: Light elements of new variable stars.

Star (USNO B1.0)	T_o (HJD 2450000+)	Period (day)	Type
1236-0100293	3353.2598 ±0.0003	0.5137580(±0.0000005)	EW
1235-0097170	3353.244 ±0.036	0.86983(±0.00019)	EA
1236-0100092	3412.0000 ±0.0005	4.0055842(±0.0000040)	EA

35 cm reflector at the campus station of the Chungbuk National University Observatory (CbNUO) in Korea. The details of the CbNUO observations were given by Kim et al. (2006).

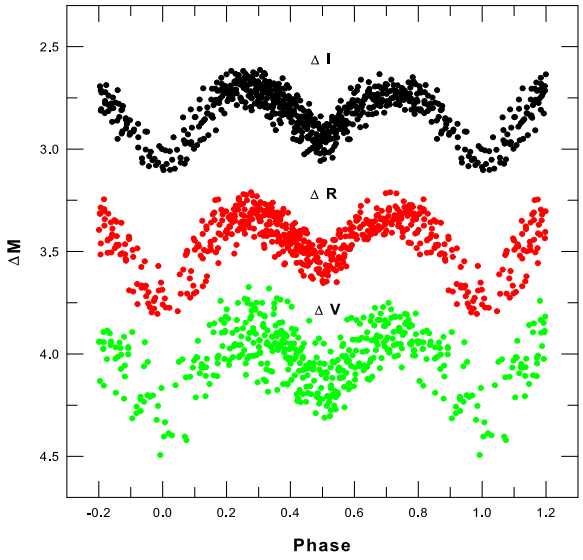

Figure 2: Light curves of USNO B1.0 1236-0100293.

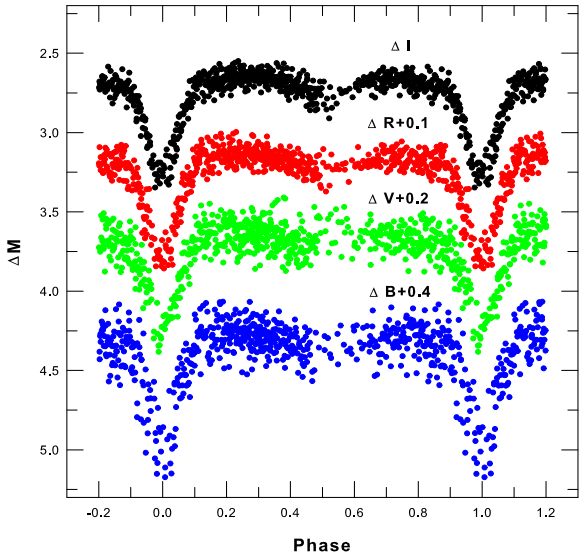

Figure 3: Light curves of USNO B1.0 1235-0097170.

The Scargle (1982) algorithm was used to find the variability periods with our photometric measurements. The resultant light elements of three stars except USNO B1.0 1234-0103195 were given in Table 3 with their possible binary morphologies which were deduced from the light curves shown in Figure 2 $\sim$ 4. The light curves of USNO B1.0 1234-0103195 were drawn in Figure 5.

USNO B1.0 1236 – 0100293

As seen in Figure 2, the light curves of USNO B1.0 1236-0100293 are similar to those of late-type W UMa stars although the light curve scatter are very large due to insufficient exposure times. The depths of primary and secondary eclipses relative to brightness at

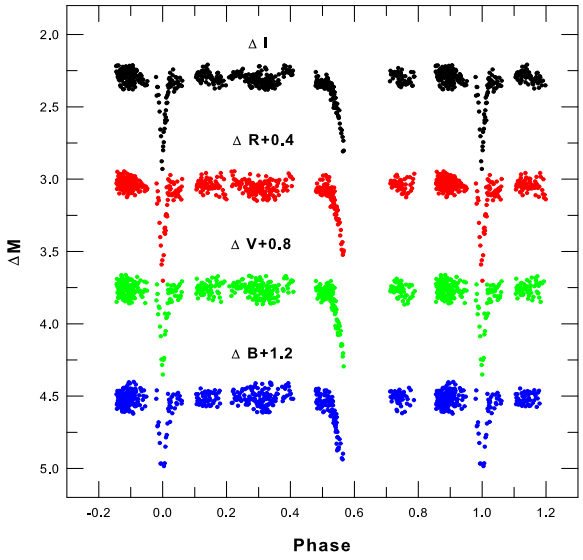

Figure 4: Light curves of USNO B1.0 1236-0100092.

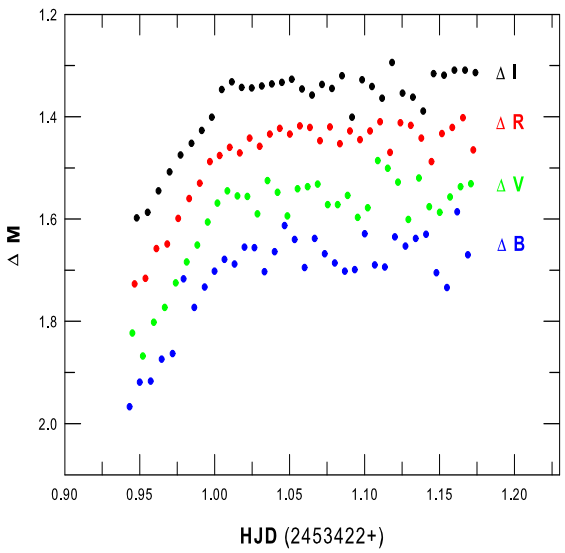

Figure 5: Light curves of USNO B1.0 1234-0103195.

0.25 phase (Max. I) were roughly deduced as $0.^{\rm m}27$ and $0.^{\rm m}22$ in $\triangle V$, $0.^{\rm m}43$ and $0.^{\rm m}23$ in $\triangle R$, and $0.^{\rm m}39$ and $0.^{\rm m}26$ in $\triangle I$, respectively. Small O'Connell effect (Max. I is brighter than Max. II) were seen in all three bandpasses. The $\triangle B$ light curve, not shown in Figure 2, showed no meaningful eclipse pattern due to very large scatter of it.

USNO B1.0 1235 – 0097170

The light curves of USNO B1.0 1235-0097170 in Figure 3 seem to resemble those of short- period Algols such as near-contact binary stars (cf. Shaw, 1990; Manimanis et al., 2009), although the secondary eclipses were poorly defined. The depth of primary eclipse relative to Max. I was roughly measured as $0.^{\rm m}80$ in $\triangle B$, $0.^{\rm m}63$ in $\triangle V$, $0.^{\rm m}74$ in $\triangle R$,

and $0.^m61$ in $\triangle I$, respectively.

USNO B1.0 1236 – 0100092

Figure 4 shows the light curves of USNO B1.0 1236-0100092. We see relatively sharp primary eclipses, flat outside-eclipse, and secondary eclipses displaced largely far from 0.5 phase, indicating a detached Algol binary with an eccentric orbit. The depth of primary relative to Max. I was roughly measured as $0.^m49$ in $\triangle B$, $0.^m60$ in $\triangle V$, $0.^m66$ in $\triangle R$, and $0.^m64$ in $\triangle I$, respectively.

USNO B1.0 1234 – 0103195

The light curves of USNO B1.0 1236-0100092, which were observed on February 21, 2005, were drawn in Figure 5 where the ascending branches were secured. The star may be an eclipsing binary star with a period longer than four days because the lights are relatively flat after the end of the ascending branch and the variable event occurred only once during our 22 nights observations.

We are planning to observe these stars systematically in the coming observing seasons.

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