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GSC 4232.2830, AN ECLIPSING BINARY WITH ELLIPTICAL ORBIT

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GSC 4232.2830 ($20^h01^m28^s.407$, $+61°10'17''.18$, 2000.0, v=$12^m.1$) was suspected to be variable by V.P.G. in the routine overview of photographic plates taken with 40-cm astrograph of SAI Crimean station. Two weakenings by $\approx 0^m.7$ with time difference of $8^d.1$ were observed in 1990 September, which suggested that this star was an Algol type variable star. However, no other eclipses were found in the SAI plate collection of this sky region including 95 plates taken in 83 nights in the time range JD 2444665–2449358. The analysis of SAI observations excluded the period $8^d.1$, and other possible periods with P=$8^d.1$/N (N = 2,3,4,...).

To define orbital elements of the binary, we searched for observations the Sonneberg Observatory plate collection, NSVS database (Wozniak et al., 2004), and carried out visual monitoring with a small telescope equipped with an electronic image tube, an analogue of a night vision device. Later, when we had found a preliminary solution, we carried out accurate CCD photometry to improve the orbital elements. A total of our efforts is reflected in the Table 1. We used the nearby star, GSC 4232.2395 as a comparison star for CCD photometry, measured its $UBVR_C$ magnitudes relative to V.M.Lyuty's standard near Cyg X-2 (Basko et al., 1976), and create the uniform standards for eye estimates. The photometric data for the comparison star, and for the eclipsing binary GSC 4232.2830 in maximum light are given in Table 2.

We should note, that the depths of eclipses in the NSVS database do not exceed $0^m.2$, what contradicts to other observations. We suppose that NSVS measurements concern to integral light of two stars, a variable star, and a nearby brighter star, GSC 4232.2395, due to low resolution of this survey, that is $72''$. The data given in Table 2 imply the integral V magnitude $11^m.22$, what is brighter than the NSVS value, $11^m.68$, by $0^m.46$. With this correction to NSVS magnitudes, and $V = 11^m.70$ for GSC 4232.2395, we extracted NSVS light curve of the eclipsing binary.

Using all the available observations, we found an orbital solution with an elliptical orbit and with the period of $11^d.6$. The center of the secondary mimimum occurs at the orbital phase $0^p.69835 \pm 0.00002$ or $8^d.1$ after the primary minimum. The improved ephemeris derived using accurate CCD observations is the following:

$$\text{HJD Min I} = 2453278.3185(2) + 11^d.628188(5) \times E.$$

Table 1. The observations of GSC 4232.2830

Source (J.D. range)	No. obs. (nights)	ptm system	No. eclip.	Telescope	Recording	Observer
Moscow SAI collection (2444665-2449358)	95 (83)	pg	2	40-cm, plates	eye estimates	V.P.G.
Sonneberg collection (2426091-2448771)	262 (183)	pg	4?	plates	eye estimates	S.Yu.Sh.
NSVS Database (2451274-2451630)	525 (142)	V	7	Canon lense	Thomson TH7899M CCD	Wozniak, et al.
Nizhny Arkhyz, SAO, home observatory (2452704-2453279)	443 (71)	r	3	25-cm + IP-10 image tube	eye estimates	V.P.G.
Crimean Observatory (2453278)	118 (1)	R_J	1	38-cm	Apogee-47 CCD	A.G.
Crimean Observatory (2453321)	370 (1)	BVR_J	1	38-cm	Apogee-47 CCD	S.Yu.Sh.
SAI Crimean station (2453243-2453244)	389 (2)	V	1	50-cm Maksutov	Meade Pictor-416 CCD	S.Yu.Sh.
SAI Moscow (2453263, 2453278)	792 (2)	BVR_J	1	70-cm	Apogee-7p CCD	S.Yu.Sh.
Special Astrophysical Observatory (2453321)	118 (1)	$UBVR_C$	1	100-cm	EEV42-40 CCD	V.P.G.

Table 2. $UBVR_C$ magnitudes of the nearby (comparison) star, and out-of-eclipse magnitudes of the eclipsing binary

Star	U	B	V	R_C
GSC 4232.2395	$11\overset{m}{.}910$	$11\overset{m}{.}956$	$11\overset{m}{.}702$	$11\overset{m}{.}77$
	±0.020	±0.021	±0.028	±0.03
GSC 4232.2830 (Max)	13.198	12.960	12.239	11.96
	±0.020	±0.018	±0.005	±0.02

Table 3. Times of Minima

JD hel. 2400000+	Min	$O-C$ day	Obs. set	JD hel. 2400000+	Min	$O-C$ day	Obs. set
31204.512:	II	0.0019	Sonneberg	51452.68	I	−0.0130	NSVS
31739.392:	II	−0.0148	Sonneberg	51487.60	I	0.0225	NSVS
37960.505	II	0.0176	Sonneberg	51603.95	I	0.0906	NSVS
38673.319	I	0.0046	Sonneberg	52906.303	I	0.0864	it
48150.318	I	0.0304	SAI	53150.41	I	0.0016	it
48158.427	II	0.0188	SAI	53193.413	II	−0.0006	it
51324.758	I	−0.0249	NSVS	53243.4335	I	−0.0004	CCD
51359.73	I	0.0625	NSVS	53263.1827	II	−0.0001	CCD
51382.86	I	−0.0639	NSVS	53278.3185	I	0.0000	CCD
51402.69	II	0.0225	NSVS	53321.3237	II	0.0000	CCD

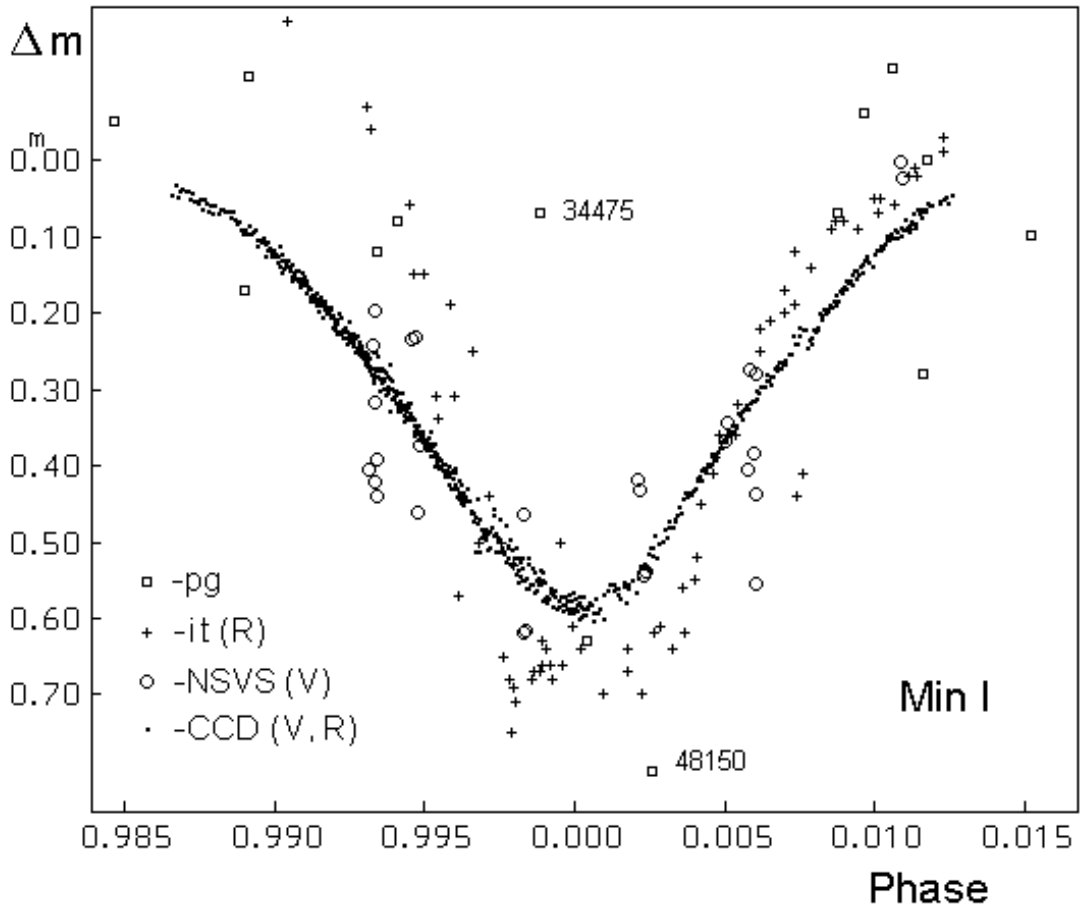

Figure 1. Observations of GSC 4232.2830 in the primary minima.

The moments of weakenings and mid-eclipses are given in Table 3. $O-C$ analysis does not show orbital period variations during the time interval of observations, or any evidence of the apsidal motion.

The results of all the observations are shown in Fig. 1 for Min I, and in Fig. 2 for Min II. The magnitudes in different filters are calculated relative to out-of-eclipse level, and combined together with small shifts along the magnitude axis, if needed.

The observations show that both eclipses have about equal depth, $\approx 0\overset{\mathrm{m}}{.}60$, but essentially different duration, $0\overset{\mathrm{p}}{.}028$ ($7\overset{\mathrm{h}}{.}8$) for Min I, and $0\overset{\mathrm{p}}{.}0175$ ($4\overset{\mathrm{h}}{.}9$) for Min II. The eclipses are partial. Using the displacement of the secondary minimum and eclipse width ratio, we calculate the orbital eccentricity of 0.39, and $\omega = 322^\circ$. CCD photometry gives mean colours $U-B = 0\overset{\mathrm{m}}{.}238 \pm 0\overset{\mathrm{m}}{.}027$, and $B-V = 0\overset{\mathrm{m}}{.}721 \pm 0\overset{\mathrm{m}}{.}019$ without notable colour variations in the eclipse phases. These colours suggest that the components of the system are solar type main sequence stars.

We used the same set and magnitudes of comparison stars to reduce the photographic eye estimates. The old Sonneberg photographic observations indicate that the eclipses were shallower in the middle of the past century than in the present time. There are some contradictions between observations marked in Fig. 1 and 2, when the observer does not notice weakening in the eclipse phases. One photographically traced eclipse, and 2-2 outstanding data points are marked with their Julian dates (JD−2400000) in these Figures.

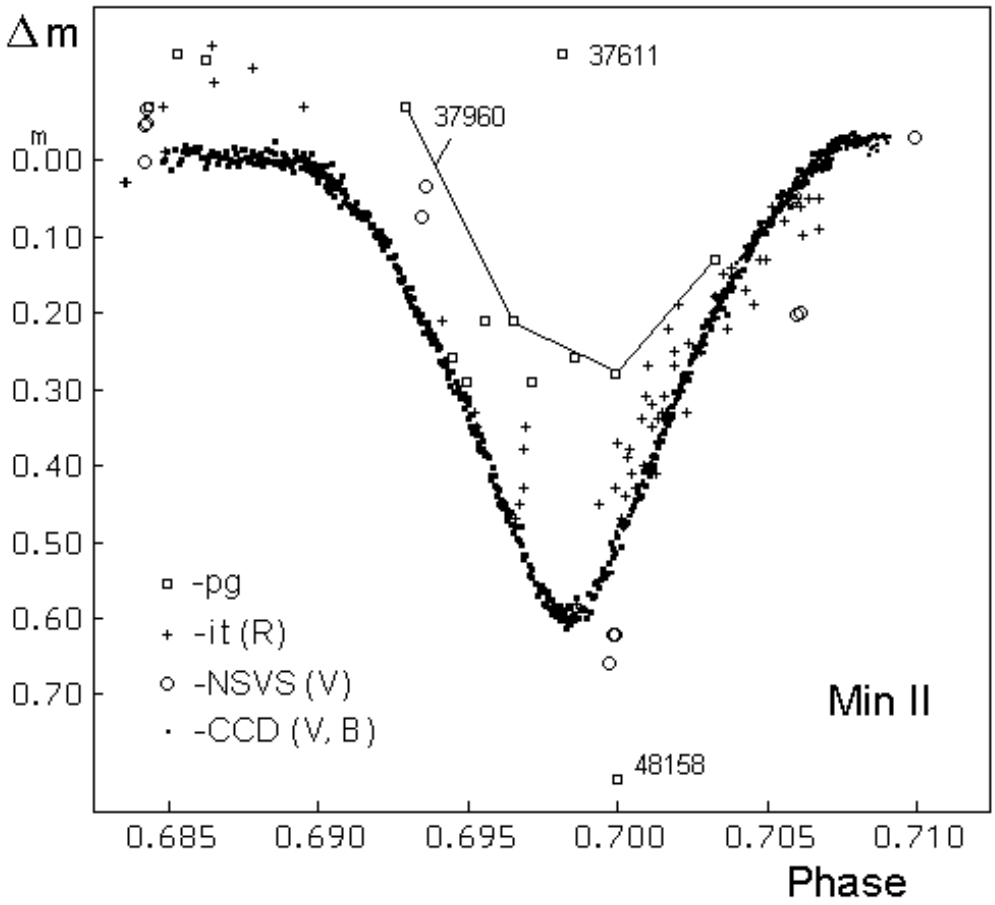

Figure 2. Observations of GSC 4232.2830 in the secondary minima

The contradictions may suggest that the depth of eclipses varied, as in the well known system SS Lac (Mossakovskaya, 1993; Milone et al, 2000; Torres and Stefanik, 2001). The eclipse depth variations should be verified with more precise observations taken during a longer time interval.

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