GSC 4232.2830, AN ECLIPSING BINARY WITH ELLIPTICAL ORBIT

GORANSKIJ, V. P.; SHUGAROV, S. Yu.; KROLL, P.; GOLOVIN, A.

1 Sternberg Astronomical Institute, Moscow University, 119992, Russia
2 Sternwarte Sonneberg, Sternwartestrasse 32, D-96515, Germany
3 Crimean Astrophysical Observatory, Ukraine, visiting amateur astronomer

GSC 4232.2830 (20h01m28.407, +61°10′17″.18, 2000.0, v=12m.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 ≈0.7 with time difference of 8.1 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 8.1, and other possible periods with P=8.1/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 0.2, 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 11m22, what is brighter than the NSVS value, 11m68, by 0.46. With this correction to NSVS magnitudes, and $V = 11m70$ 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 11.6. The center of the secondary minimum occurs at the orbital phase 0.69835 $±0.00002$ or 8.1 after the primary minimum. The improved ephemeris derived using accurate CCD observations is the following:

$$\text{HJD Min I} = 2453278.3185(2) + 11.628188(5) \times E.$$
Table 1. The observations of GSC 4232.2830

| Source                                | No. obs. (nights) | ptm system | No. eclips. | Telescope          | Recording            | Observer             |
|---------------------------------------|-------------------|------------|-------------|--------------------|----------------------|----------------------|
| Moscow SAI collection                 | (2444665-2449358) | pg         | 2           | 40-cm, plates      | eye estimates         | V.P.G.               |
| Sonneberg collection                  | (2426091-2448771) | pg         | 4?          | plates              | eye estimates         | S.Yu.Sh.             |
| NSVS Database                         | (2451274-2451630) | V          | 7           | Canon lense         | Thomson               | Wozniak, et al.      |
| Nizhny Arkhyz, SAO, home observatory  | (2452704-2453279) | r          | 3           | 25-cm + IP-10 image tube | eye estimates         | V.P.G.               |
| Crimean Observatory                   | (2453321)         | RJ         | 1           | 38-cm               | Apogee-47 CCD         | A.G.                 |
| Crimean Observatory                   | (2453324-2453244) | BVJR       | 1           | 38-cm               | Apogee-47 CCD         | S.Yu.Sh.             |
| SAI Crimean station                   | (2453263, 2453278) | V          | 1           | 50-cm               | Meade                | S.Yu.Sh.             |
| SAI Moscow                            | (2453263, 2453278) | BVJR       | 1           | 70-cm               | Maksutov             | S.Yu.Sh.             |
| Special Astrophysical Observatory     | (2453321)         | UBVR       | 1           | 100-cm              | EEV42-40 CCD          | V.P.G.               |

Table 2. UBVR<sub>C</sub> magnitudes of the nearby (comparison) star, and out-of-eclipse magnitudes of the eclipsing binary

| Star                                 | U       | B       | V       | R<sub>C</sub>   |
|--------------------------------------|---------|---------|---------|-----------------|
| GSC 4232.2395                        | 11<sup>m</sup>910 | 11<sup>m</sup>956 | 11<sup>m</sup>702 | 11<sup>m</sup>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 | Obs. | JD hel. 2400000+ | Min | O – C | Obs. |
|------------------|-----|-------|------|------------------|-----|-------|------|
| 31204.512: II    | 0.0019 | Sonneberg | 51452.68 | I | −0.0130 | NSVS |
| 31739.392: II    | −0.0148 | Sonneberg | 51487.60 | I | 0.0225 | NSVS |
| 37960.305: 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, $\approx 0.60$, but essentially different duration, $\theta_028$ (7.8) for Min I, and $\theta_0175$ (4.9) 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 $U - B = 0^{m}238\pm0^{m}027$, and $B - V = 0^{m}721\pm0^{m}019$ 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.
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.

References:
Basko, M.M., Goranskij, V.P., Lyuty, V.M., et al., 1976, Variable Stars, 20, 219
Milone, E.F., Schiller, S.J., Munari, U. & Kallrath, J, 2000, AJ, 119, 1405
Mossakovskaya, L.V., 1993, Astron. Letters, 19, 35
Torres, G. & Stefanik, R.P., 2000, AJ, 119, 1914
Wozniak, P.R., Vestrand, W.T., Akerlof, C.W., et al., 2004, AJ, 127, 2436