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

Number 5229

Konkoly Observatory
Budapest
30 January 2002

HU ISSN 0374 – 0676

LIGHT ELEMENTS AND LIGHT CURVE OF THE ECLIPSING BINARY GSC 2605.0545

HOWELL, J.A.[1]; HENDEN, A.A.[2]; BALDWIN, M.E.[3]; GUILBAULT, P.R.[4]; HAGER, T.[5]; WEST, D.[6]; KUEBLER, P.[7]; TERRELL, D.[8]

[1] 3522 NW 18th Avenue, Gainesville, FL 32605, USA, e-mail: astrogator@mindspring.com

[2] Universities Space Research Association/U.S. Naval Observatory, P.O. Box 1149, Flagstaff, AZ 86002-1149, USA, e-mail: aah@nofs.navy.mil

[3] 8655 N. Co. Road 775 E, Butlerville, IN 47223, USA, e-mail: mbald00@hsonline.net

[4] P.O. Box 287, Chepachet, RI 02814, USA, e-mail: pete1199@aol.com

[5] 34 Mount Tom Road, New Milford, CT 06776, USA, e-mail: thager@pcnet.com

[6] P.O. Box 517, Derby, KS 67037, USA, e-mail:dwest61506@aol.com

[7] 1550 Blackstone Drive, Columbus, OH 43235, e-mail: pkueb@aol.com

[8] Dept. of Space Studies, Southwest Research Institute, 1050 Walnut St., Suite 426, Boulder CO 80302, USA, e-mail: terrell@boulder.swri.edu

A group of AAVSO members continues to observe variables discovered by the ROTSE1 survey (Akerlof et. al., 2000). In this note, we report our findings that pertain to GSC 2605.0545 = ROTSE1 J172601.97 +304710.4. Our results include precision light elements and a light curve, as well as standard BVR_cI_c magnitudes for the variable and comparison stars.

The first reported period of the variable was $10\overset{d}{.}93$ days, derived using the original CCD ROTSE1 data (Diethelm, 2000). Independently, Baldwin conducted a visual program to monitor the star. A total of 109 observations were made over 41 nights, and the star was seen in eclipse on three of those nights. About the same time, Guilbault and Hager examined 158 photographic plates of Harvard College Observatory, spanning the years 1931 to 1989. Their results suggested a period of $11\overset{d}{.}0697$ days, rather than the shorter value of $10\overset{d}{.}93$ days.

Five observers collected 621 CCD observations on 53 different nights, all between May 14 and October 30, 2001 except for two nights in October, 2000. All observers used the V filter, except Henden, who obtained standardized BVR_cI_c data. The table summarizes observers, equipment used, and the number of nights observed.

Observer	Telescope	Camera	Nights
Henden	1.00-m	SITe 1024 x 1024 (Tektronix)	5
Howell	0.46-m	ST-9E (SBIG)	35
Kaiser	0.36-m	ST-9E (SBIG)	2
Kuebler	0.36-m	IMG512 (FLI)	7
West	0.25-m	ST-8 (SBIG)	9

At the US Naval Observatory (USNO) Flagstaff Station, Henden used the 1.0-m telescope and an SITe Tektronix to observe a 11 × 11 arc-minute field surrounding GSC 2605.0545. The field included 124 stars whose magnitudes and colors were measured (Henden, 2001, see also 5229-t3.txt). The precision of the photometry was better than 0.01 magnitude for objects brighter than V = $15^{\mathrm{m}}_{.}0$. Two stars were chosen to be the comparison (GSC 2605.0791) and check (GSC 2605.0693) stars, as shown in Table 1. The variable's RA and DEC coordinates (J2000) are $17^{\mathrm{h}}26^{\mathrm{m}}02^{\mathrm{s}}_{.}13$ and $+30°47'13''_{.}33$, respectively. Astrometry was performed using USNO-A2.0 (Monet et. al., 1998), with internal errors under 100 milli-arcseconds.

Table 1. Comparison and check stars

Star	RA (J2000)	DEC	V	$B-V$	$V-R_c$	R_c-I_c
Comp	17:25:52.57	+30:47:03.19	11.956	0.969	0.530	0.465
Check	17:26:20.30	+30:46:29.37	11.752	0.933	0.533	0.451

Henden observed a primary eclipse on the evening of June 29/30, 2001. Seven hours of coverage centered on the middle of the eclipse were obtained, using BVR_cI_c passbands. The data showed that the eclipse is total, with a duration of 3.2 ± 0.1 hours. The minimum occurred at HJD = 2452090.8153 ± 0.0005, derived using the method of Kwee and van Woerden (1956). Figure 1 shows the light curve of the eclipse.

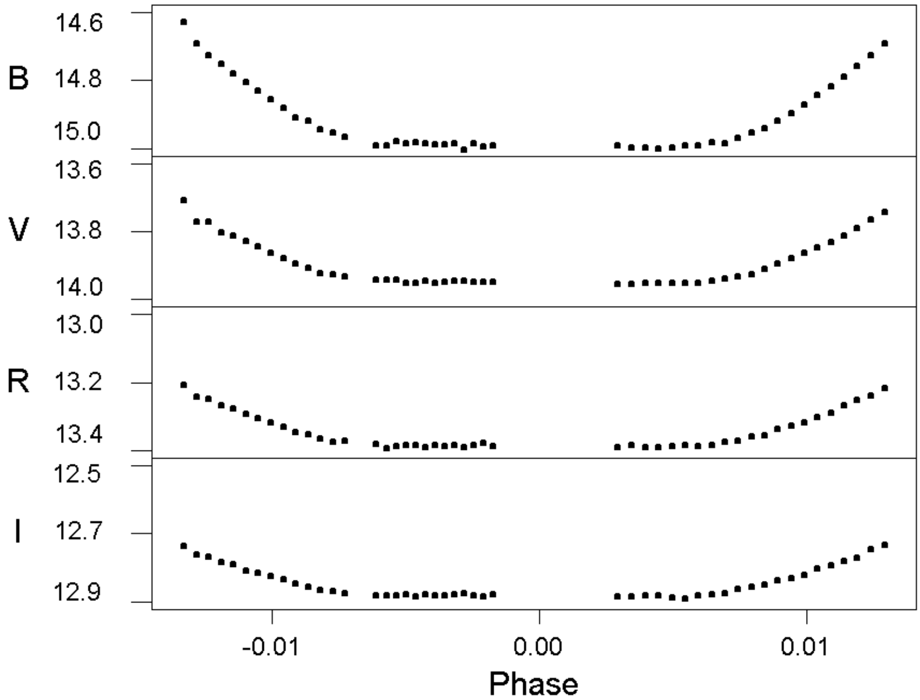

Figure 1. Primary eclipse of GSC 2605.0545 in $BVRI$ colors, 29/30 June 2001.

A key parameter of an eclipsing binary is its orbital period. Unfortunately, the three minima that Baldwin observed visually in the year 2000 could not discriminate between the two competing periods of $10^{\mathrm{d}}_{.}93$ days and $11^{\mathrm{d}}_{.}0697$ days proposed by Diethelm and Hager/Guilbault, respectively. The solution was to get more data. One year after

Baldwin's observations, Howell obtained CCD observations just after the variable passed through minimum phase. Then, during a dedicated period of observing from May-August, 2001, we were able to observe two different minima separated by five cycles. The results demonstrated that the longer period was correct.

To obtain a precise estimate of the period using all data, we pooled our observations, summarized in Table 2.

Table 2. Observed minima of GSC 2605.0545

HJD 2400000 +	S.E. (day)	Epoch	$O-C$	Observer	Type
43688.7390	0.1400	−759	−0.047	Harvard	photographic
51725.6200	0.0400	−33	+0.110	Baldwin	visual
51747.6200	0.0400	−31	−0.029	Baldwin	visual
51758.6900	0.0400	−30	−0.029	Baldwin	visual
52090.8153	0.0005	0	0.000	Henden	CCD
52146.1634	0.0054	+5	−0.004	Howell	CCD

We used the *AVE* program (Barbera, V2.5) to obtain the time of minimum light from the CCD data. This software implements the method of Kwee and van Woerden (1956) to calculate minimum light and the standard error (S.E.). To assess Baldwin's visual observations, which were made at random times and dates (109 observations total), we used a different approach. On three different occasions, he observed the star near minimum. If any given observation were phased randomly within the 3.2 hour duration of the total eclipse, then the standard error could be estimated using the properties of the uniform distribution. This turned out to be $0^{\rm d}_{\cdot}04$ day (1.0 hour). A similar method was used to estimate the standard error of the one photographic plate when the variable appeared to be close to minimum. The error was estimated as $0^{\rm d}_{\cdot}14$ day (3.4 hours).

Using a least squares analysis, we fitted a linear model to the observed HJD times of minimum. The observations were weighted by the inverse square of the standard errors. Model fits and residuals ($O-C$) were computed using *Minitab* statistical software. The $O-C$ values in Table 2 were calculated using the light elements from the least squares fit:

$$\begin{array}{rl}\text{Min. I} = \text{HJD } 2452090.8153 + 11^{\rm d}_{\cdot}0699 \times E. \\ \pm 0.0008 \quad \pm 0.0003\end{array}$$

Examination of the $O-C$ residuals shows that everything fits well, with the possible exception of Baldwin's first visual observation. It lies nearly three standard errors from the fitted value. His observing notes suggest that the variable was observed after the minimum had occurred, so the positive residual makes sense. All other residuals are consistent with their standard errors, and we conclude that the calculated model is good.

The long period of the variable challenged us to obtain precision photometry over the many nights needed to obtain the light curve. The V light curve in Figure 2 suggests that the system is an Algol-type variable. Our data shows that the star fades from a maximum of $V = 12^{\rm m}_{\cdot}50 \pm 0^{\rm m}_{\cdot}01$ to $V = 13^{\rm m}_{\cdot}95 \pm 0^{\rm m}_{\cdot}01$ at primary minimum. A secondary minimum appears to occur at phase 0.50, although we did not completely cover the secondary eclipse. By extrapolating from our data at phase 0.49, we estimate that the magnitude at secondary minimum is $V = 12^{\rm m}_{\cdot}85 \pm 0^{\rm m}_{\cdot}04$. The duration of the primary minimum is 30 ± 3 hours, and the duration of the total eclipse is 3.2 ± 0.1 hours.

Analysis of the light curve using the Wilson-Devinney program (Wilson and Devinney, 1971; Wilson, 1979) is underway and will be published separately, but preliminary results indicate that the mass ratio is far from unity and that the system is detached. The totality of the primary eclipse and the appreciable amount of ellipsoidal variation do severely reduce the available parameter space. We are confident that high-quality, multi-bandpass photometric data coupled with radial velocities will result in unambiguous parameters for this system.

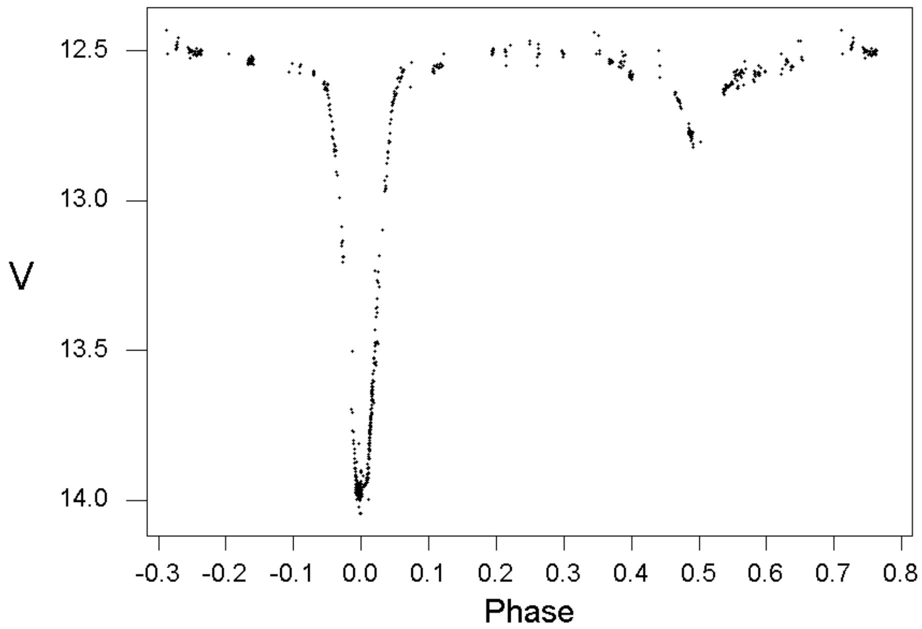

Figure 2. Phased light curve, GSC 2605.0545- V-filtered CCD.

We thank Dan Kaiser (Crescent Moon Observatory) for his submission of two nights of CCD data. We also thank Alison Doane, acting Curator of the Harvard College Observatory Astronomical Photograph Collection, for the use of the plates on this and other variable star projects.

References:

Barbera, R., AVE software (V2.5), `http://www.gea.cesca.es`
Diethelm, R., 2000, *IBVS*, No. 5060
Henden, A.A., 2000, `ftp://ftp.nofs.navy.mil/pub/outgoing/aah/sequence/g2605.dat`
Kwee, K. K., and Van Woerden, H., 1956, *BAN*, **12**, 327
Minitab Statistical Software, 2000 (V13.3), Minitab, Inc., `http://www.minitab.com`
Monet, D., et. al., 1998, *USNO-A2.0*, U.S. Naval Observatory, Washington DC
Wilson, R.E., 1979, *ApJ*, **234**, 1054
Wilson, R.E., and Devinney, E.J., 1971, *ApJ*, **166**, 605