Two New Eclipsing Binary Systems: GSC 1393-1461 and GSC 2449-0654, and One New Flare Star: GSC 5604-0255

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Abstract We introduce three new variable stars discovered during asteroid photometry. This includes two new eclipsing binary stars, GSC 1393-1461 (P = 0.311145d) and GSC 2449-0654 (P = 0.343802d), and one new flare star: GSC 5604-0255, which had a 35% ± 2% intensity increase with a decay half-life of 20 ± 1 minutes. This paper presents light curves along with basic models and analysis of the data.

1. Introduction

The Universidad de Monterrey Observatory (MPC 720) in Mexico has been making photometric observations of asteroids since 2000 in order to derive the rotation periods from their light curves. At times variable stars have been detected in the asteroid field-of-view in the process of selecting suitable comparison stars for differential photometry. Some of these have been previously unknown variables and were targeted for follow-up studies. Short period variable stars are particularly suited for discovery using this method, since each field is observed over the span of only one night as part of the asteroid program. The current paper presents observations and analysis of three rapid variables discovered in this way, including two short period variable stars and one flare star. The short period variables are the stars GSC 1393-1461 and GSC 2449-0654, and the flare star is GSC 5604-0255.

2. Observations

The Universidad de Monterrey Observatory uses an SBIG STL-1301E/LE CCD camera attached to a 36-cm SCT inside a 2-m automated dome. The discovery observations were made unfiltered as this is our normal mode for asteroid photometry. The flare star was discovered in unfiltered images on one night only, hence the images are unfiltered. Follow-up observations of the two short period variable stars were made in the V and R_c bandpasses using filters according to the Bessell prescription for the Johnson Cousins system (Persha 1999 and references therein). All images were acquired in 2 × 2 binning mode, giving an image scale of ~1 arcsec/pixel over a 21.1 × 16.9 arcmin field of view.

Exposures ranged from 120 to 240 seconds, depending on the particular filter used. Typical 1-sigma uncertainties for observations of ~14th magnitude stars, like the ones presented here, are ~0.007 magnitude for unfiltered exposures and ~0.011 magnitude for filtered ones.

Table 1 lists a log of observations which includes basic information for the stars and observing details such as filter and number of photometric measurements obtained. P_{mag} is the photographic magnitude, *JD* is the date of the observation, *Filters* are the bandpasses used during the observing session, and N_{obs} the number of photometric measurements obtained per night. *R.A., Dec.,* and P_{mag} are taken from the GSC-ACT star catalog. The filter labeled "clear" indicates that no filter was used; hence the effective wavelength is that of the CCD response, about 645 nm, which is similar to the effective wavelength of the R_c filter. Photometric measurements were made using differential photometry against other stars in the same image. The same comparison stars were used in each frame, hence only small residual corrections were needed to combine the light curves obtained from observations made on different nights. All photometry was done using custom applications written in IDL.

3. Analysis

3.1. GSC 1393-1461 and GSC 2449-0654

3.1.1. Period analysis

For the eclipsing binary stars the best-fit period was obtained by computing the power spectrum of the time series of data (Scargle 1982; Horne and Baliunas 1986). The linear ephemeris equations were determined to be:

$$\text{GSC 1393-1461} \quad \text{Min I (hel.)} = \underset{\pm 0.0015}{2454473.9731} + \underset{\pm 0.000001}{0.311145}\,E$$

$$\text{GSC 2449-0654} \quad \text{Min I (hel.)} = \underset{\pm 0.0015}{2454478.7207} + \underset{\pm 0.000001}{0.343802}\,E$$

3.1.2. Light Curve Analysis

Light curves for the two eclipsing binary stars are presented in Figure 1. The individual observations are represented by dots and the smooth curves show preliminary model fits to the data. These models were constructed by varying the main parameters in the commercially available program BINARY MAKER 3.0 (Bradstreet 2005). This java-based program employs Roche geometry to accurately compute light and radial velocity curves and is widely used by professionals and amateurs for solving eclipsing binary light curves. The resulting model parameters are presented in Table 2. Starspots were excluded from the solution because including them in the model did not significantly change the resulting essential model parameters and only slightly improved the light curve fits. From the shape of their light curves it is clear that both are ordinary over-contact eclipsing binary systems. GSC 2449-0654 in particular was best modeled by a system of two stars of equal mass, while GSC 1393-1416 required a mass ratio of 1.80 ± 0.10 to produce the best fitting model.

3.2. GSC 5604-0255

We were fortunate to register a full flare episode for this star during our five-hour observing period. The star increased in brightness by 35% ± 2% in the time span of three two-minute exposures (~7 minutes including download time) beginning at JDH 2454617.717, and then proceeded to decrease in brightness with a decay half-life of 20 ± 1 minutes. Figure 2 shows the flare star observations (symbols) and the model fit (curve). Note that the brightness of the star did not decrease to its pre-flare state until an additional small drop occurred at JD 2454617.815, which was ~140 minutes after outburst. The increased scatter near the beginning and end of the data results from high airmass at both ends of the observational timeline. We used a least squares technique to fit the light curve using a simple exponential function in which the peak intensity and decay rate were the parameters of the fit. The best solution was found for both parameters simultaneously since fitting the peak intensity first and then the decay rate yielded a poorer fit to the data. Points between JD 2454617.760 and JD 2454617.815 were subjectively excluded because modeling this "residual afterglow" also yielded a poorer fit to the data, and the modeling of a higher order function would have been required.

4. Conclusions

The asteroid light curve observing program at the Universidad de Monterrey Observatory has been successful in identifying previously unknown short-period variable stars. In this paper we presented a preliminary analysis of three such objects. The flare star GSC 5604-0255 was observed through a complete flare event, including pre-flare baseline observations. In addition, GSC 1393-1461 and GSC 2449-0654 were discovered to be short period over-contact binary systems. Follow-up observations allowed determination of the fundamental characteristics of both systems. Additional observations are necessary to better constrain the initial system parameters derived in this paper.

5. Acknowledgements

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References

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Table 1. Basic data and observing log for the stars studied herein.

Star	*R.A. (2000)* *h m s*	*Dec. (2000)* *° ′ ″*	*Pmag*	*JD*	*Filters*	*Nobs*
GSC1393-1461	08 26 16.26	+20 57 08.9	14.7	2454472	clear	115
				2454473	clear	214
				2454524	V, R_c	41, 42
				2454528	V, R_c	41, 42
				2454886	clear	151
GSC2449-0654	06 56 48.52	+36 06 50.9	13.6	2454478	clear	220
				2454503	V, R_c	50, 50
				2454522	V, R_c	38, 38
				2454523	V, R_c	36, 36
				2454885	clear	176
GSC5604-0255	15 39 28.65	–12 33 40.9	14.7	2454617	clear	124

Table 2. Model Parameters for the eclipsing binary stars.

	GSC1393-1461	*GSC2449-0654*
i	67° ± 1°	58° ± 1°
T_1	5000K (assumed)	5050K (assumed)
T_2	5600K ± 40K	5050K ± 50K
q_0 (m_1/m_2)	1.80 ± 0.10	1.00 ± 0.05
$g_1 = g_2$	0.32 (assumed)	0.32 (assumed)
fill-out–*f*	0.15 ± 0.10	0.15 ± 0.05
HJD_0	2454473.9731 (15)	2454478.7207 (15)
P	0.311145 (1) day	0.343802 (1) day

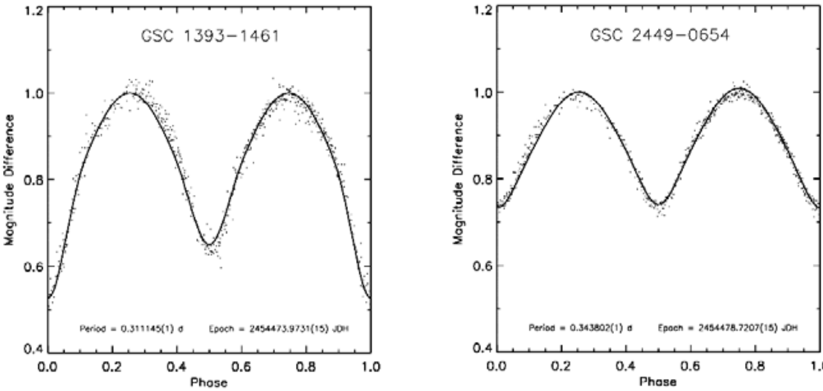

Figure 1. Light curves of the eclipsing binary stars. Data are represented by the points and the curve represents the basic models parameters from Table 2.

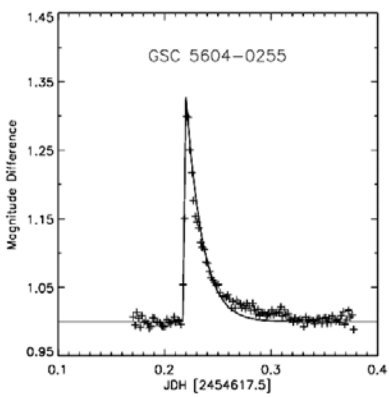

Figure 2. Registered flare for GSC5604-0255. Symbols represent data and the curve is the model described in the text.