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A NEW LONG-PERIOD U Gem VARIABLE IDENTIFIED WITH THE X-RAY SOURCE 1RXS J224342.3+305526

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During a programme of optical identification of X-ray sources the uncatalogued variable, NSVS 8915780 at $22^{\mathrm{h}}43^{\mathrm{m}}40\overset{\mathrm{s}}{.}7$ $+30°55'22''$ in the ROTSE1 database (Woźniak et al., 2004), has been found to be coincident the X-ray source 1RXS J224342.3+305526 from the ROSAT all-sky survey faint source catalogue (Voges et al., 1999). The separation between the two sources is $22''$, which is consistent with the uncertainty of $19''$ in the position of the X-ray source. The star is also identified as GSC 02736-01067 and is catalogued by 2MASS at $22^{\mathrm{h}}43^{\mathrm{m}}40\overset{\mathrm{s}}{.}71$ $+30°55'20\overset{''}{.}1$ (2000).

The ROTSE1 light curve is shown in Figure 1 and is available from the Northern Sky Variability Survey (NSVS) website (see reference Woźniak et al., 2004). The data show a cyclical variation between $R \sim 16.0$ and 13.5, with a period ~ 16 days. However, the data are better fitted by a period of twice this value, with alternate maxima having slightly different magnitudes. The large amplitude and short time scale, and the possible association with a X-ray source suggest that this is a U Gem type cataclysmic variable (CV). The 2MASS colours of $J - H = 0.09 \pm 0.02$ and $H - K = 0.06 \pm 0.02$ (Cutri et al., 2003) suggest a star with a spectral type of mid-to-late A. While in general the IR colours of CVs tend to match later-type main sequence stars, these colours are consistent with the bluest CVs seen in the 2MASS data (Hoard et al., 2002). The optical colours from the USNO-B1.0 (Monet et al., 2003) of $b - r \sim 0.6$ although approximate, are consistent with this. Although these are not particularly blue they are again consistent with those of CVs. The pattern of variability is similar to that seen in several well-observed U Gem stars, e.g., AH Her, RX And, HL CMa, SY Cnc, CN Ori and Z Cam. All vary in a relatively periodic way on time scales of ~ 20 days with amplitudes of 2–3 magnitudes. All of these are UGZ stars, possibly indicating that the new variable also belongs to this class.

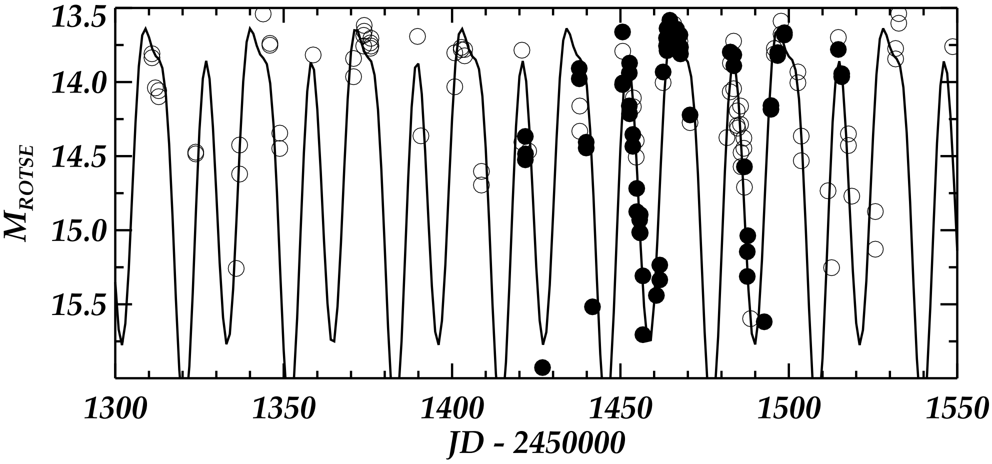

Figure 1. All the ROTSE1 data showing the 16 day outburst cycle with the 32 day period fitted. Flagged (suspect) data, open circles; unflagged data, filled circles

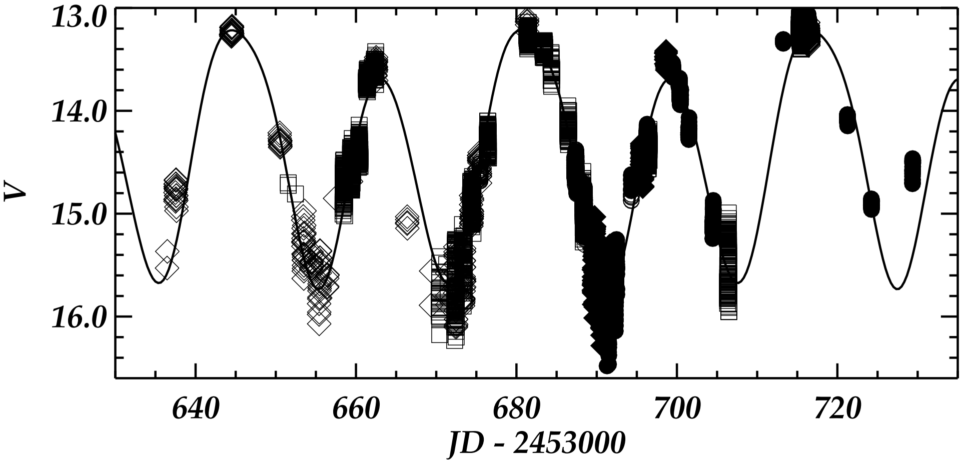

Figure 2. The recent data with different observers shown as different symbols. Small offsets have been applied to each data set as part of the fitting process

The X-ray source was observed by the ROSAT PSPC with a count rate of 0.0195 ± 0.00771 cts/s so assuming optical magnitudes $V = 16$ and $V = 13$ this leads to $F_X/F_{\rm opt} = -0.9$ and -2.1 respectively. Despite this uncertainty the $F_X/F_{\rm opt}$ ratio is consistent with the less X-ray bright grouping of CVs. The hardness ratios are poorly defined with $\mathrm{HR1} = 0.55 \pm 0.40$ and $\mathrm{HR2} = 0.78 \pm 0.46$ and these are consistent with both of the main groupings of CVs in the hardness ratio plane (see Motch et al., 1998).

Further optical observations have been made between September and December 2005 by Bernhard, using a 20-cm SCT with a Starlight Xpress SX CCD-camera unfiltered

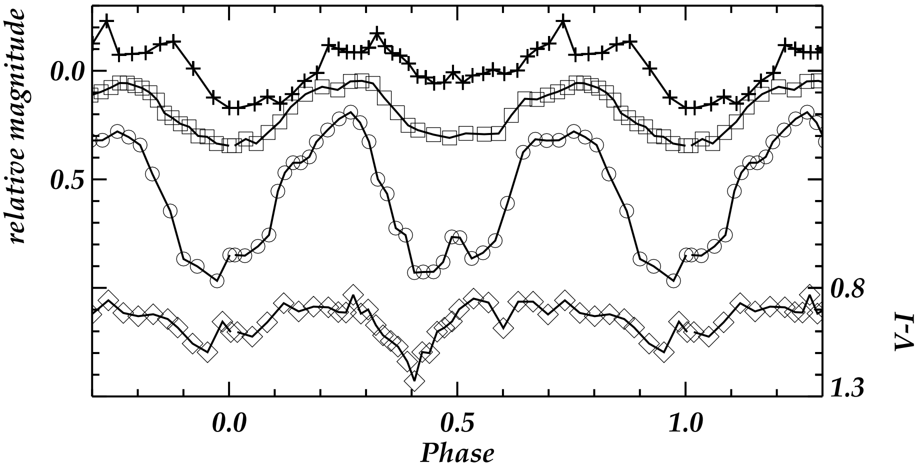

Figure 3. The phase diagram showing the averaged C and V data when the system is bright (top; expanded by a factor of 4), in mid range, and at the minimum of the outburst cycle. The bottom plot show the orbital variation of $V - I$ at the minimum of the outburst cycle.

(C[lear]) and in B, V and R; Boyd, using a 35-cm SCT with a Starlight Xpress SXV-H9 CCD-camera in C, V and I; Pietz using a 28-cm SCT with an ST-6B CCD camera unfiltered and Jones using a 28-cm SCT with an ST-7 CCD camera and V filter. All these observations are shown in Figure 2. The filtered observations have been reduced using a calibration provided by Henden (private communication) while the C observations have either been reduced as V or in the natural system.

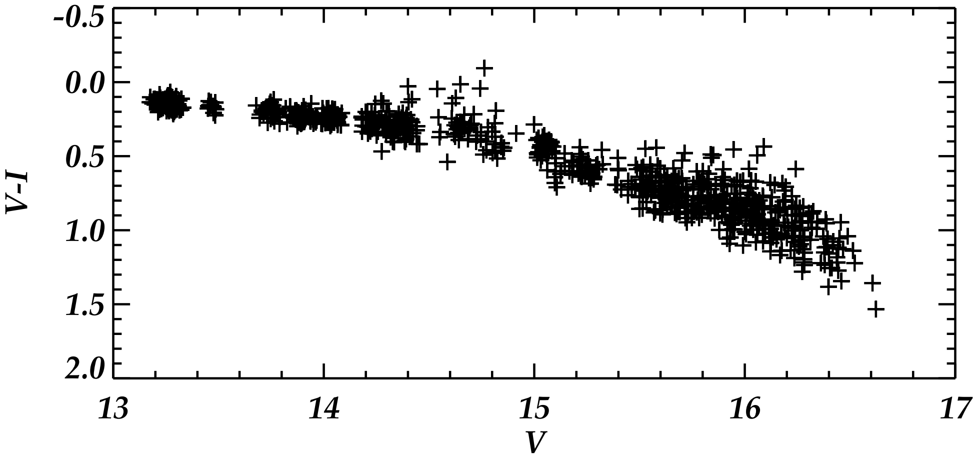

Figure 4. The $V - I$ data showing the change with V

The new observations mirror the ROTSE1 data with a slightly longer cycle at 18 days again with alternately bright and faint maxima. The minimum magnitude is relatively constant from cycle to cycle. The variation is very sinusoidal (e.g., AH Her, RX And) and not triangular (SY Cnc) or saw toothed (Z Cam). On a seasonal time scale the variation also seems to be remarkably repeatable, both within the ROTSE1 and recent data.

The nightly runs of observations have been subjected to a wavelet analysis and the results have been used to construct scalegrams that are widely used to examine flickering in CVs (see Fritz & Bruch, 1998). The scalegrams show the behaviour typical of flickering which is usually taken as direct evidence of accretion processes. By itself this confirms the variable as a CV and strengthens the identification with the X-ray source.

The new observations also reveal a sinusoidal variation with a period of about 5 hours that is consistent with an orbital hump. While this type of variation is seen in many CVs the amplitude seen here is particularly large, reaching as much as $0\overset{\mathrm{m}}{.}6$ at minimum of the outburst cycle and reducing to $< 0\overset{\mathrm{m}}{.}04$ at maximum. The range of variation is entirely consistent with the orbital variation being diluted as the system brightens. However, differences between alternate cycles suggest that the system shows a double orbit hump with the ephemeris of

$$\mathrm{HJD_{MinI}} = 2453679.90(1) + 0\overset{\mathrm{d}}{.}42234(3) \times E$$

for the data in the middle of the range. The light curve (Figure 3) appears to migrate to later phases as the system brightens, in particular the primary minimum and the following maximum. The secondary minimum appears to be relatively stable in phase but flattened, possibly suggesting a partial eclipse. The orbital variation in $V-I$ at minimum brightness (also shown in Figure 3) shows a dramatic increase near secondary minimum, presumably when the cool star dominates the light curve.

Multi-colour photometry reveals a dramatic increase in temperature as the object brightens with $V-I \sim 1.0$ at minimum and $B-V \sim 0.05$, $V-R \sim 0.06$ and $V-I \sim 0.1$ at maximum (Figure 4).

The system probably contains a relatively massive cool star which dominates at the minimum of the outburst cycle, and the large orbital variation suggests that the system is seen at high inclination. The shape of the secondary minimum possibly hints at a grazing eclipse of the accretion disc by the cool star. The changing shape of the light curve can probably be explained by changes in the brightness and distribution of emission from the accretion disc and hot spot as the outburst progresses.

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