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

Number 5911

Konkoly Observatory
Budapest
16 November 2009

HU ISSN 0374 – 0676

OPTICAL LIGHT CURVES OF THE HIGH MASS X-RAY BINARY 4U 2206+54

BUGNO, J. L.; HINTZ, E. G.; JONER, M. D.

Brigham Young University, Dept. of Physics and Astronomy, Provo, UT 84602, USA; e-mail: batgirl3220@aim.com; doctor@tardis.byu.edu; jonerm@forty-two.byu.edu

The high-mass X-ray binary system (HMXB) 4U 2206+54 (BD 53°2790) was first seen as an X-ray source in *Uhuru* observations examined in Giacconi et al. (1972). The system has been examined for periodicity a number of times using X-ray data. Corbet & Peele (2001) reported a period of 9.568 ± 0.004 days from *Rossi X-ray Timing Explorer* (*RXTE*) All-Sky Monitor (ASM) data. Corbet et al. (2007) found that data from the *Swift* Burst Alert Telescope (BAT) along with recent ASM data indicate a period of 19.25 ± 0.08 days and note that this is almost exactly double the previous period. They conclude that the lengthening is likely a recent secular change. In Negueruela & Reig (2001) they report published optical photometry of this system and report all observations at that time were consistent with no optical variability. However, Blay et al. (2006) report seven optical measurements over an eleven year time line that show a long term change, but with insufficient coverage to estimate any periodicity. They also report that their IR data, when folded with the 9.6 days period, showed no clear pattern. As part of an undergraduate summer research program, we examined the HMXB system 4U 2206+54 with time-series observations in the V filter to check for possible correlations in variability with the X-ray data.

The observation and data reduction details for the 22 nights secured for this study have been previously given in Hintz et al. (2009). Although it should be noted here that reductions were done using IRAF aperture photometry packages. The only differences between the two data sets are that there are two additional nights of 0.41-m data and the data for three of the 0.31-m nights were saturated for the bright star 4U 2206+54 in the current study. The finder chart for 4U 2206+54 can be found in Hintz et al. (2009). As noted by Hintz et al. (2009), all observations were done using a standard V filter (Bessell, 1990). Since 4U 2206+54 shows variations during a single night it is hard to get an estimate of the error per observation from this object. However, for star #6, a star about two magnitudes fainter, we find single night error per observation values on the order of 0.003 to 0.004 mag, with the majority nearer 0.003 mag. From the one relatively flat night for 4U 2206+54 on HJD2454658 we find an error per observation of 0.0038 mag, or a value consistent with those seen for star #6. The standard deviation in the nightly zeropoint correction values ranged from 0.003 to 0.005 mag, except for one poor night of data with a zeropoint error of 0.012 (HJD2454651). The observational data are available on the IBVS website as `5911-t1.txt`.

The light curves for each of the 22 nights are presented in Fig. 1. It should be noted that it is not possible to distinguish differences in the dense portions of the curves when simultaneous data were obtained with different combinations of three different telescopes. Each of the graph panels is scaled to cover 6 hours of time. There is variation within each night as well as night to night variation for 4U 2206+54. In Fig. 2, we show the long term run of data for 4U 2206+54 and comparison star #6 over the 55 days covered by this study. Even though star #6 is almost two magnitudes fainter than 4U 2206+54, it is clear from the internal scatter within each night that the variation for the comparison star is smaller than for the HMXB. Further, the night to night variation is present in the data for 4U 2206+54, while the fainter comparison star is flat within the size of the errors. We do note one night, HJD2454651, for star #6 which is systematically higher. This is the previously reported night with an exceptionally high zeropoint error. Finally, from our analysis of the δ Scuti variable star, GSC 3973-1698 (Hintz et al., 2009), we see no zero point drift from night to night. Based on these three evidences, we judge the variations seen for 4U 2206+54 to be actual variability and not an observational artifact due to photometric error.

Using the `Period04` package (Lenz & Breger, 2005), we looked for the most likely period of 4U 2206+54 and found 25.1 ± 0.1 days to be the best fit for the visual data. It is possible that the visual and X-ray data are not well correlated. In Fig. 3 we show a phased light curve for the visual data using our period of 25.1 days along with published periods of 9.568 days and 19.25 days. We selected a starting epoch for phasing of HJD2454679.0 since this was near a maximum brightness point in our data curve. It is worth noting that both of the X-ray periods connect some of the data in an interesting manner but in general produce an irregular phase curve.

An examination of the individual curves shown in Fig. 1 reveals that many nights show short term variation. This could be an indication of more complex variability. After removing the long 25.1 day curve, we examined the remaining variations using `Period04`. We found a frequency of 2.5726 ± 0.0005 cycles/day, or a period of 9.33 hours. The signal-to-noise ratio for this frequency was found to be 5.5, which puts it near the cut-off point for significance detailed by Breger et al. (1993, 2007). A much larger data set would be needed to confirm this underlying oscillation.

Although we do find a period of 25.1 days in the visual data for 4U 2206+54, we must note this is a preliminary result covering just over two of the proposed cycles. A longer data run covering more cycles, over a number of years, would help in the determination of a period of the optical light variation. The larger data set might also help clarify the short period variation suspected in our data set. In addition, it would be useful to examine this system in different wavelengths in order to search for better correlations with the X-ray observations.

Acknowledgements We would like to acknowledge the Brigham Young University Department of Physics and Astronomy for its continued support. We acknowledge a grant from the Theodore Dunham, Jr. Grant for Research in Astronomy. Finally, we acknowledge NSF grant PHY-0552795 for providing REU student support as well as NSF grant AST-0618209 for observing support at the West Mountain Observatory.

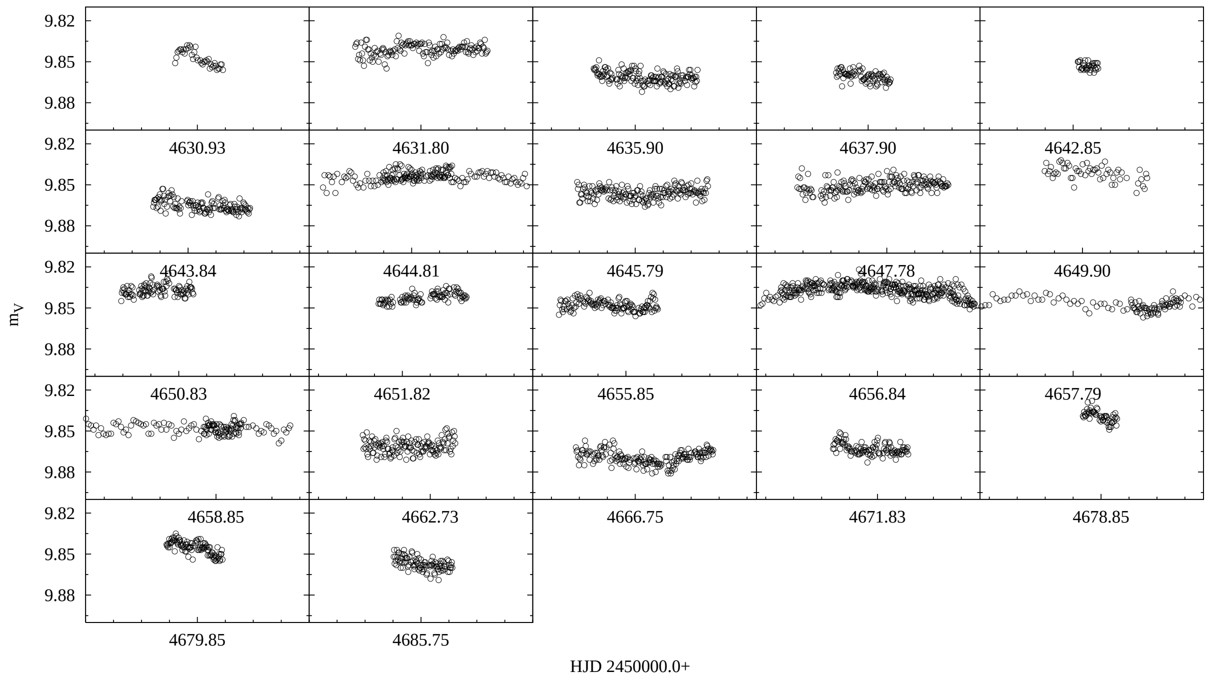

Figure 1. The 22 reported nights of V filter photometry for 4U 2206+54 plotted on the same scale in both time and magnitude. Each tick mark on the time axis is 0.03 days and each panel covers 6 hours.

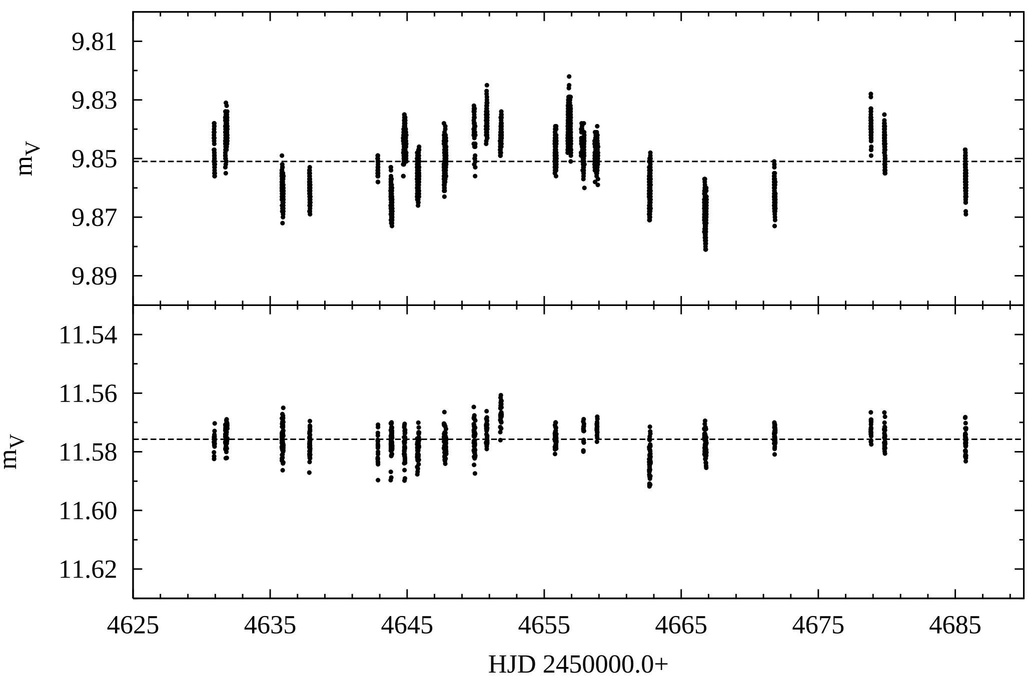

Figure 2. Magnitudes of 4U 2206+54 and the fainter comparison star #6 over 55 days.

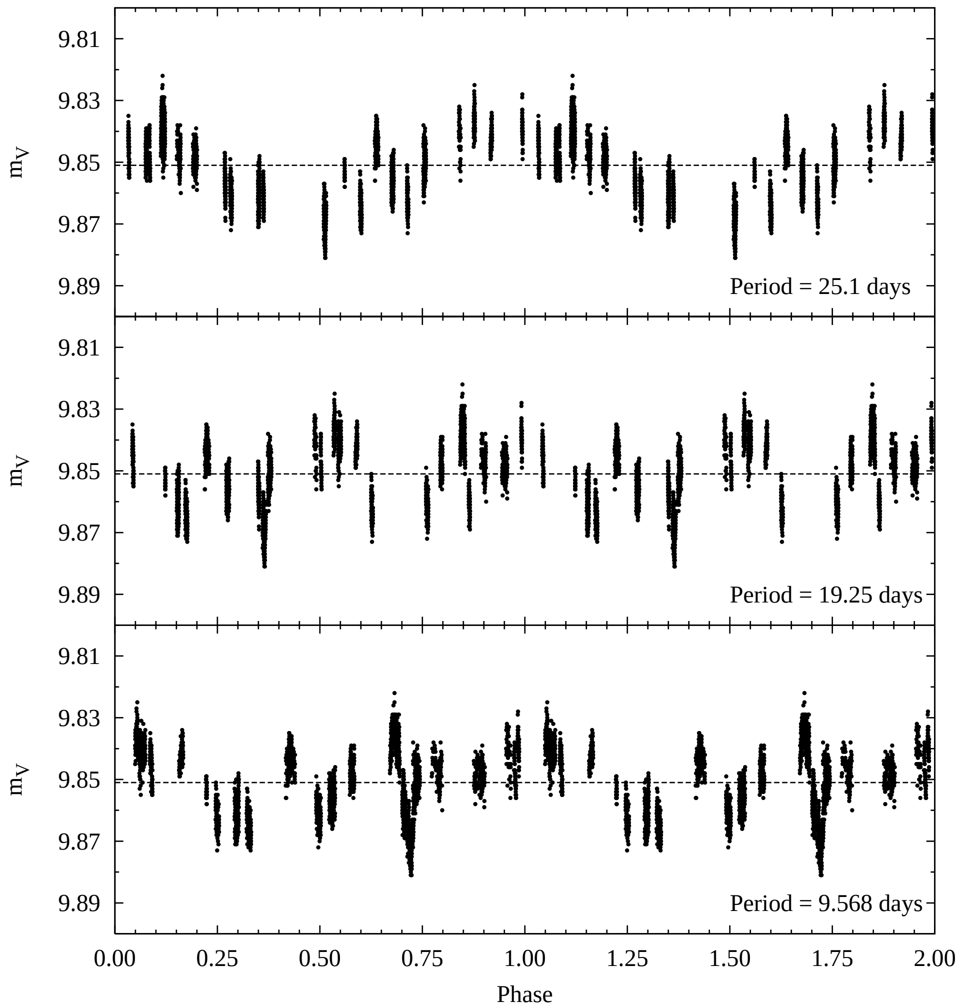

Figure 3. Phased light curves for 4U 2206+54 calculated with different periods as noted. The starting epoch in all cases is 2454679.0.

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