COMMISSION 27 OF THE I. A. U.
INFORMATION BULLETIN ON VARIABLE STARS
Number 3346

Konkoly Observatory
Budapest
3 July 1989

HU ISSN 0374 - 0676

The Optical Variability of the X-Ray Source 1E1654+3515

The X-ray source 1E1654+3515 was discovered serendipitously in the Einstein Observatory Extended Medium Sensitivity Survey, and was suspected of being a W UMa system by Fleming et al. (1989). Its position at Right Ascension 16:53:59.3 and Declination 35:15:38 Epoch 1950 and brightness of 10.1 in the V band were given by Fleming et al. (1989). A finder chart adapted from Papadopoulos et al. (1980) is given for this star in Figure 1.

I observed this star using the 0.5 meter reflector of the Climenhaga Observatory at the University of Victoria on nine nights between 31 May 1989 and 11 June 1989. The telescope is computer controlled to the extent that it is pointed to each of the stars at the beginning of the night and then left to follow a program of observations until dawn the next day. Thus the data are gathered in a very consistent manner and at a minimum of effort by the observer. Due to the proximity of the variable, comparison and check stars both in position and color, mean extinction and transformation coefficients were used to correct the differential magnitudes to the Johnson V and Cousins R and I system (Landolt 1983). The observations of the variable star were bracketed by observations of the comparison star SAO 65642, whose constant brightness was checked with 22 observations of the check star, SAO 65670. The mean check star minus comparison star magnitude was 0.138±.013 in V and 0.520±.010 in (V-R) and 0.456±.007 in (R-I). The errors are standard deviations about the mean, assuring the constancy of the comparison and check stars at this level.

The R band light curve is plotted in Figure 2 folded with the ephemeris discussed below. This curve clearly shows the variation expected for a W UMa system as predicted by Fleming et al. (1989). The difference in height of the maxima and in depth of the minima indicate that the system is not a single spotted star like FK Com. The dispersion seen in the maxima and minima of the light curve is consistent with the amount of uncertainty seen in the check minus comparison values. However variations such as those seen at phase 0.2 are intrinsic to the system and are not unusual in W type W UMa systems. Spotted regions are the likely source of both light curve variations and the X-rays. The (V-I) color curve plotted in Figure 3 is constant, consistent with the system being a W UMa system and inconsistent with a light variation due to temperature changes, as would be expected from a hot compact object and a companion filling its Rochelobe such as Her X-1.

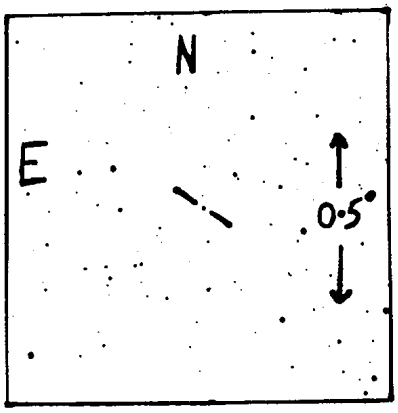

Figure 1.- Finder chart for X-ray source, 1E1654+3515; centred on Right Ascension 16:53:59.3 and Declination 35:15:38 (1950.0).

Table I. Heliocentric Julian Date of Extrema - 2440000.

Minima	Maxima
7680.8883	7678.8335
7681.7883	7680.7984
7682.8607	7681.8770
7684.8283	7682.7770
7687.8751	7683.8442
7689.8448	7685.8153

Times of minimum light were found using a program based on the method of Kwee and Van Woerden (1956) and checked using the tracing paper method. Observations in each color were treated individually, but since there were no significant differences between the times obtained, they were combined in a mean, weighted by the error in each color's determination. The heliocentric times of minimum based on all points within 0.03 days are given in Table 1. Similarly the times of maximum light are included, to help determine the period of the system. The best fitting ephemeris is found to be:

$$\text{Cycle} = (\text{JD} - 2447680.8912) \;/\; 0.35813$$
$$10 \qquad\qquad 9$$

The errors in the times of extrema ranged from 0.0022 to 0.0004 days with the maxima and minima equally well determined. The average deviation of a time of extrema from this ephemeris is 0.0026 days, only slightly larger than the most poorly determined maxima. Therefore the use of the maxima has removed the aliases without adding noise to the period determination. No systematic difference was found in the (O-C)'s indicative of a displaced secondary minima or either maxima. This period is in good agreement with the period-color relation of Eggen (1967) for contact binaries.

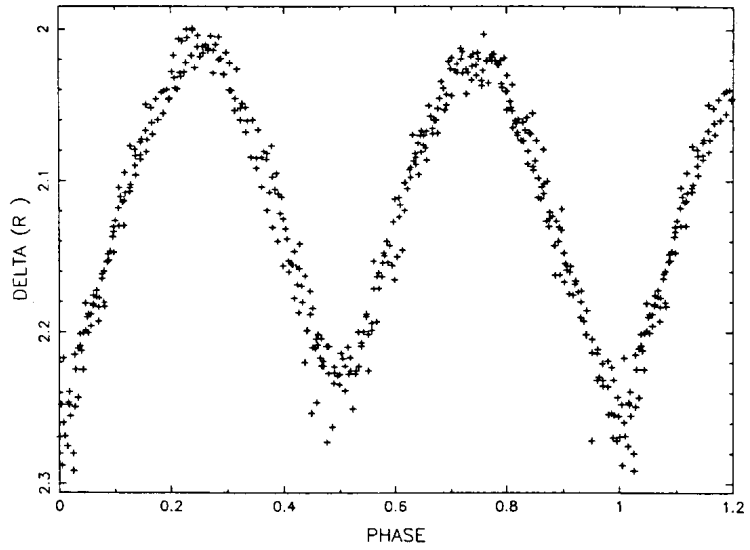

Figure 2. - R filter light curved plotted with PHASE = (JULIAN DATE - 2447680.8912) / 0.35813

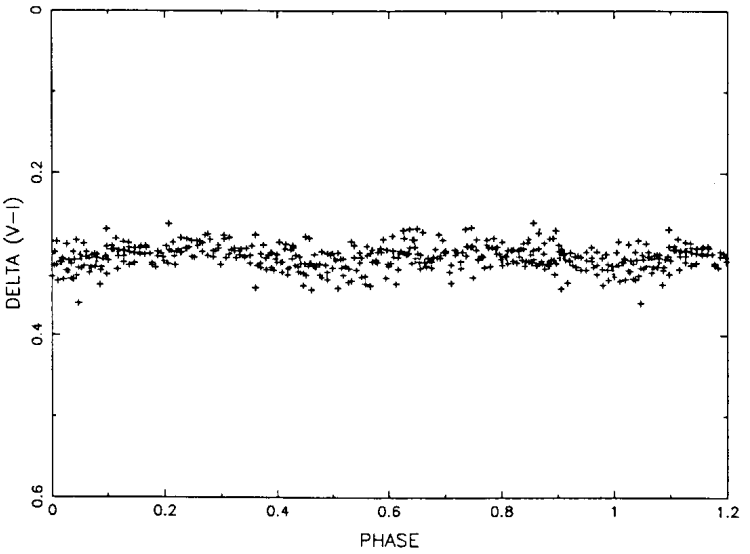

Figure 3. - Color (V-I) plotted as a function of Phase.

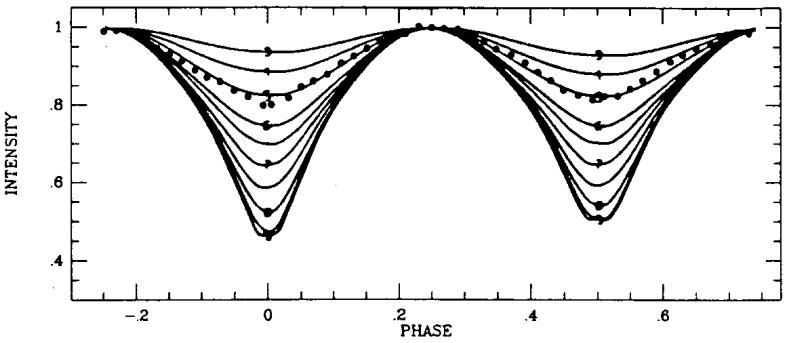

Figure 4. - Average of V, R and I normal points plotted with theoretical light curve from Anderson and Shu (1979) for a convective atmosphere with full limb darkening, a mass ratio of 0.6, and a filled fraction of 0.5. Curves are plotted in 10 degree increments of inclination.

An atlas of theoretical light curves of contact binary stars has been published by Anderson and Shu (1979), for different mass ratios, filled fraction, orbital inclination, and type of atmosphere. Since 1E1654+3515 has a G2 spectral type (Fleming et al. 1989), a convective envelope with full limb darkening was assumed. As shown in Figure 4 the best match was found for a filled fraction f of 0.5, mass ratio q of 0.6 and an inclination of 50. degrees. Nearly as good a match could be found for inclinations ranging from 40. degrees (f=1.0, q=1.0) to 60. degrees (f=0.0, q=0.4). These numbers must be regarded as preliminary values, since the theoretical light curves are for bolometric intensity and the data are the average of the V, R and I band normal points. The observed light curve also shows some asymmetry in the brightness of both the maxima and minima.

The X-ray source 1E1654+3515 is a W UMa system with a period of 0.358 days and an amplitude of 0.26 magnitudes. Spectroscopic observations of this system will be important to find the component masses and mass ratio. Further photometric observations will be important to refine the orbital period. Because this system is an X-ray source, it is to be expected that magnetic braking may be a source of period change.

R.M. ROBB
Climenhaga Observatory
University of Victoria
Victoria, B.C. Canada

References:

Anderson, L. and Shu, F.H., 1979, Ap. J. Supp. 40, p667-697.
Eggen, O.J., 1967, Mem. R. Astr. Soc., 70, p.111-164.
Fleming, T.A., Gioia, I.M. and Maccacaro, T., 1989, Preprint.
Kwee, K.K and Van Woerden, H., 1956, Bull. Astr. Inst. Neth., 12, 327.
Landolt, A.U., 1983, A.J. 88(3), p439-460.
Papadopoulos, C. and Scovil, C., 1980, The True Visual Magnitude Photographic Star Atlas (Pergamon Press, Toronto, Canada).