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THE OPTICAL VARIABILITY OF THE X-RAY SOURCE 1E1806.1+6944

The X-ray source 1E1806.1+ 6944 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 18:06:03.4 and Declination 69:44:51 (Epoch 1950), brightness of 10.5 in the V band and spectral class of F9 were given by Fleming et al. (1989). A finder chart adapted from Papadopoulos et al. (1980) is given for this star in figure 1.

We observed this star using the 0.5 meter reflector of the Climenhaga Observatory at the University of Victoria on ten nights between 22 June 1989 and 11 August 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. Thus the data are gathered in a very consistent manner and with 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 17785, whose constant brightness was checked with thirteen observations of the check star SAO 17740. The mean check star minus comparison star magnitude was 0.360±.013 in V and -0.219±.007 in (V-R) and -0.218±.014 in (R-I). The errors are standard deviations about the mean, and assure the constancy of the comparison and check stars at this level.

The V 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 larger than the amount of uncertainty seen in the check minus comparison values and is due in part to significant night to night differences. Variations such as these, seen clearly at phase 0.25 for example, 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 is plotted in figure 3 and shows only a small reddening at the primary minimum. This is 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 Roche lobe filling companion system such as Her X-1.

Times of minimum and maximum 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,

Table I.
Heliocentric Julian Date of Extrema - 2440000.

Primary Minima	Secondary Minima	First Maxima	Second Maxima
7716.8710 ±3	7701.8201 5	7700.8605 ±8	7721.8459 ±6
7727.8971 ±3	7715.8125 ±4	7734.7863 ±6	7727.7916 ±10
7730.8650 ±4	7734.8902 ±5		7730.7622 ±5

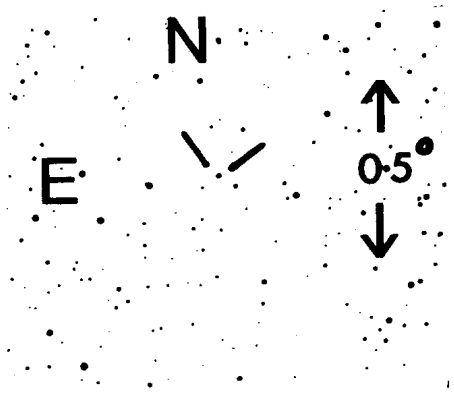

Figure 1. - Finder chart for X-ray source, 1E1806.1+6944; centred on Right Ascension 18:06:03.4 and Declination 69:44:51 (1950.0).

they were combined in a mean, weighted inversely by the error in each color's determination. The heliocentric times of extrema based on all points within 0.04 days of the extrema are given in Table 1. The times of maximum light were used to help determine the period of the system by removing the aliases. The ephemeris best fitting the minima is found to be:

$$\text{Helio. J.D. of Primary Minimum} = 2447700.7602 \pm 11 + 0.42400 \pm 2\ E.$$

The average deviation of a time of minimum from this ephemeris is 0.0013 days. No systematic difference was found in the (O-C)'s indicative of a displaced secondary minimum or either maximum. This period is in good agreement with the period-color relation of Eggen (1967) for contact binaries.

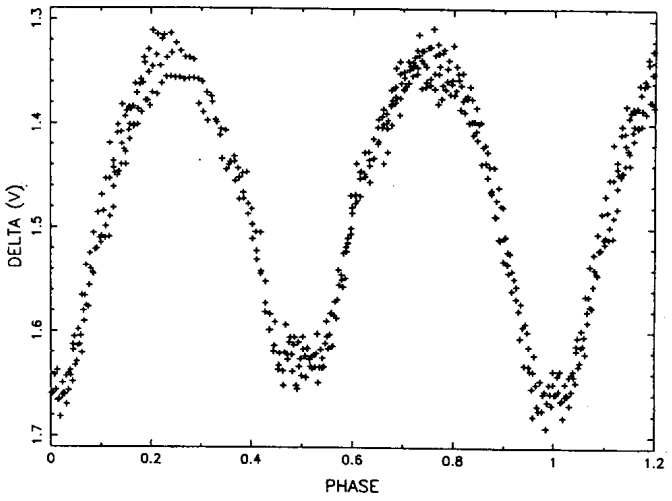

Figure 2. - V filter light curve plotted with PHASE=(JULIAN DATE-2447700.7602) / 0.42400.

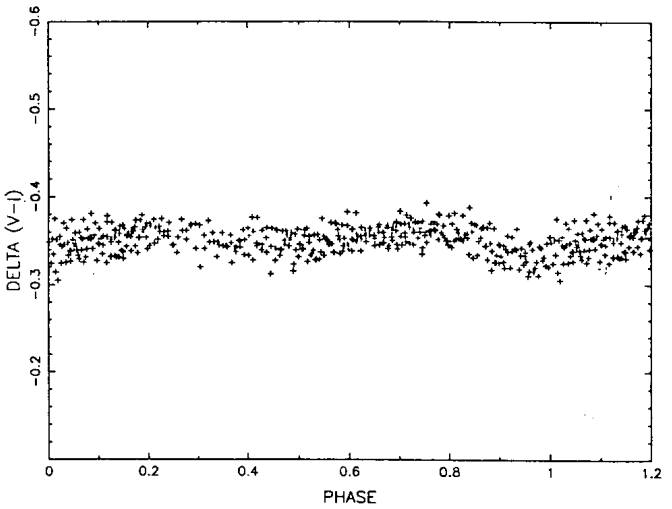

Figure 3. - Color (V-I) plotted as a function of Phase.

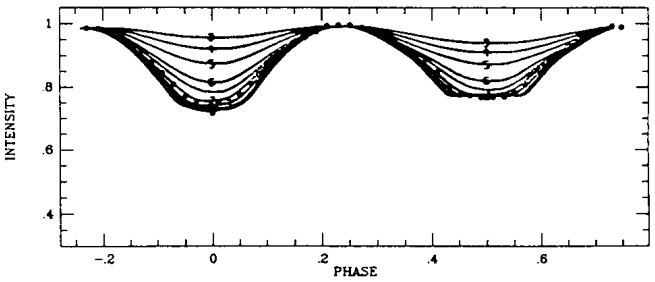

Figure 4. - Average of V, R and I normal points plotted with theoretical light curve from Anderson and Shu (1979) for a convective atmosphere with full limb darkening, a mass ratio of 0.1, and a filled fraction of 1.0. Curves are plotted in 10 degree increments of inclination.

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 1E1806.1+6944 has a F9 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 1.0, mass ratio q of 0.1 and an inclination of 80 degrees. 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 and night to night variation in the brightness of both the maxima and minima.

The X-ray source 1E1806.1+6944 is thus a W UMa system with a period of 0.424 days and an amplitude of 0.34 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 and to permit a more detailed solution than we have attempted here. For example sufficient observations in the maxima and minima are needed to give reliable averages of the scatter we have seen before a solution is undertaken.

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