PHOTOMETRY OF EX HYA

B. S. SHYLAJA
Indian Institute of Astrophysics, Bangalore, India

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Abstract. Photometric observations of EX Hya in B and V filters are reported. The 67 min modulation of the light curve also is found to be in good agreement with the results of earlier studies. The $(B - V)$ colour variation with respect to the 67 min variation is found to be opposite to those of typical colour variation during hump/superhump activity in other dwarf novae. The model of an intermediate polar is discussed.

1. Introduction

In recent years, EX Hya has been considered as one of the most interesting dwarf novae because of several spectroscopic and photometric peculiar features. Photoelectric observations by Mumford (1964, 1967) have established it as an eclipsing binary with the elements as

$$T_{\min} = \text{J.D. } 2437699.9414 + 0.06823386E\,. \tag{1}$$

Thus, EX Hya falls in the category of 'very short-period cataclysmic variables'. Its supermaximum is attained once in 547 days (Bateson, 1979). A detailed analysis of the photoelectric observations between 1964–1976 by Vogt *et al.* (1980) revealed a modulation of the light curve with 67 min period. Such a modulation, further confirmed by Sterken *et al.* (1983), has not been seen in other systems as yet.

Detailed spectroscopic studies by Breysacher and Vogt (1980) and Gilliland (1982) showed a variation of the intensity of emission lines in phase with the 67 min period but not with the orbital period. Gilliland (1982) also noticed that the residuals of V/R followed a 33.6 min periodicity: this periodicity was not detected for any other type of variation.

In the present paper, we present optical photometric observations carried out by us and discuss these observations in terms of the already proposed models.

2. Observations

The B and V observations were obtained at the Cassegrain focus of the 102 cm reflector of the Kavalur Observatory during 1979–1980. A photometer employing cooled EMI 9558B was used: the photoelectric data was recorded in the pulse counting mode with the help of an on line TDC-12 computer. The integration time was chosen as 1 s. A 9 arc sec diaphragm was used to minimise the sky background. The star SAO 181183 marked as 'A' by Walker and Olmsted (1958) was used as comparison and the nearby star marked 'A' by Mumford (1964) was used as a check star.

The data consist of continuous observations of 10 min and at very low hour angles

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the duration was reduced to 5 min. The intervening comparison observations were used for obtaining the extinction corrections.

In order to look for the 67 min modulation of the light curve, the extinction corrected data points were averaged over 10 s. Figure 1 shows a sample of observations through

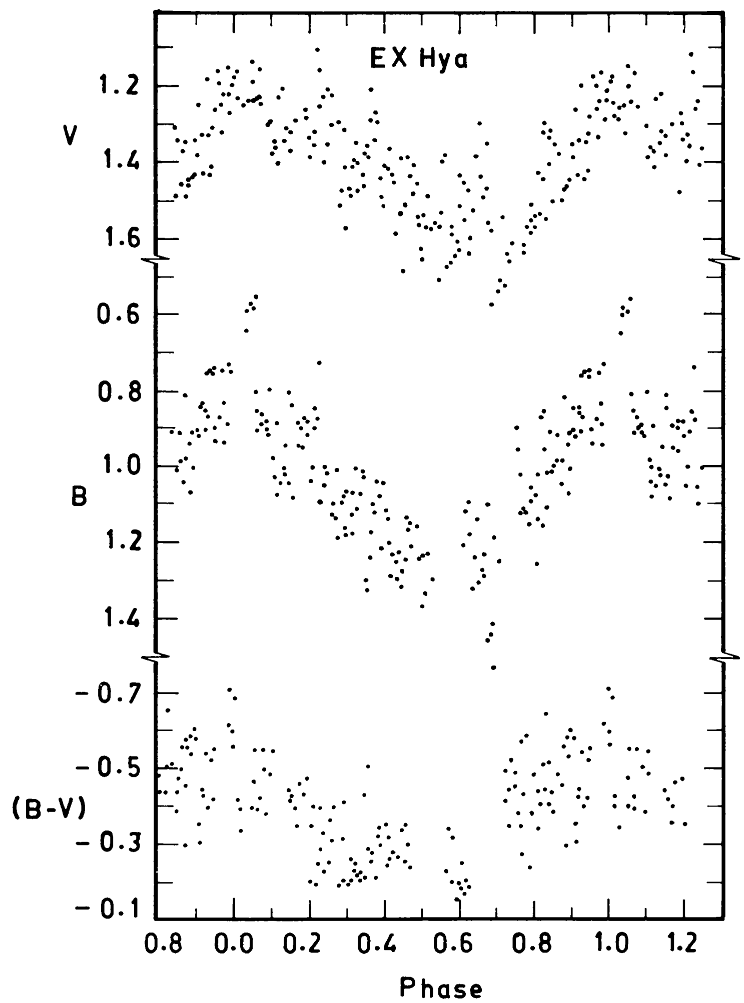

Fig. 1. Light and colour curves of EX Hya with respect to 67 min phase. Each point represents an integration over 10 s.

the two filters and the colour ($B - V$). The error on no occasion was more than $\pm 0\overset{m}{.}01$, as judged from the comparison star observations.

The times of observed minima (orbital) and the 67 min maxima are tabulated in Table I.

It was also noticed that the depth of eclipses remained constant irrespective of the phase of 67 min modulation at that instant. This was also noticed by Warner and McGraw (1981).

TABLE I

Observed maxima and minima

Orbital minima			67-min maxima		
J.D.$_{(ET)}$	Filter used	O–C 10^{-3} d	J.D.$_{\odot}$	Filter used	O–C 10^{-3} d
2440000 +			2440000 +		
3938.465	*V*	1.4	3938.391	*V*	− 6.3
3939.300	*B*	2.7	4255.470	*V*	9.7
4255.507	*V*	1.0	4264.406	*B*	9.0
4263.422	*V*	− 1.6	4289.401	*B*	− 4.1
4264.445	*B*	− 1.5	4291.490	*V*	2.5
4289.351	*B*	− 1.1	4312.387	*B*	0.0
4291.462	*V*	− 5.5			
4312.406	*B*	− 9.6			

3. Results

Vogt *et al.* (1980) have obtained two periodicities independent of each other after compiling 14 yr of data. This was further improved by Sterken *et al.* (1983). The orbital period has the elements as

$$T_{\min} = \text{ET } 2437699.94177 + 0.0682338422E\,, \tag{2}$$

which corresponds to 98 min, whereas the modulation maxima are given by

$$T_{\max} = \text{Hel. J.D. } 2437699.8895 + 0.04654656E - 1.2 \times 10^{-12}E^2\,, \tag{3}$$

which corresponds to a period of 67 min.

Based on (2) and (3) the calculated O–C value are also included in Table I.

In our light curves it is clearly seen that the rapid flickering, which is a prominent feature in all cataclysmic variables, is pronounced at the maxima of the 67 min modulation. The runs of 10 min (5 min on some occasions), were subjected to power spectral analysis by direct Fourier transform techniques (Blackman and Tukey, 1958) after pre-whitening. The number of lags were restricted to one fifth of the total number of data points, limiting the detectable periods to 100 s on longer runs and 50 s on shorter ones. This analysis showed that a range of periodicities from 10 to 30 s existed at all phases and the amplitude also was variable from $0\overset{m}{.}08$ to almost $0\overset{m}{.}20$.

We also tried to look for any other types of modulation, by the method used by Raveendran *et al.* (1982), since a 33.5 min variation of intensities, was indicated by Gilliland (1982). But no such modulation was detectable.

4. Discussion

Two models have been suggested for the 67 min modulation of the light curve. The first model relates this to the hump (superhump) activities as seen in other dwarf novae, while the other attributes it to a magnetised white dwarf as in an 'intermediate polar' model (Warner, 1983; Breysacher and Vogt, 1980; Gilliland, 1982; Sterken *et al.*, 1983).

The IR observations of Sherrington *et al.* (1980) have shown the evidence for the modulation in K (2.2 μ) to be very little compared to that in V light. They have also estimated the contribution of the late type companion at 2.2 μ to be only 9%. It is further evident from our Figure 1 the amplitude of modulation is more in B light than in V light. It is also observed that this amplitude through the U filter is still more (Sterken *et al.*, 1983). The indications are that the source of modulation is a hot region.

While describing the colour variation of dwarf novae, Bailey (1980) has considered the disc as the most important contributor. The aperiodic outbursts are attributed to a sudden increase in the mass transfer rate from the secondary. Such models may be extended to EX Hya as well, so as to see in the colour-colour diagram, a reddening on the rise and then a blue shift. However, Figure 1, which represents the colour variation with respect to he 67 min phase, shows the bluest colour corresponding to the maximum and the reddest to the minimum. A similar behaviour of $(U - B)$ is noticeable in Figure 5 of Sterken *et al.* (1983). Thus, the colour behaviour is exactly opposite compared to other dwarf novae. A similar conclusion has been arrived at by Sterken *et al.* (1983) also.

Now, we may refer to the other alternative model, which explains the modulations based on 'intermediate polar' models. Here an obliquely rotating white dwarf primary emits an X-ray beam at its pole. These X-rays are available at the outer disc as optical radiations. It is shown that in case of polars the magnetic fields are so high that the disc is disrupted. However, among the intermediate polars the magnetic fields (10^5–10^7 G) are believed to be effective in channelising the accretion flow on to the poles, but not enough to cause observable Zeeman-splitting. The presence of a thin disc is thus anticipated. A model for AO Psc, based on this, successfully explains the modulation as a beat period between the orbital period and the white dwarf rotation period (Hassall *et al.*, 1981). A similar calculation by Warner and McGraw (1981) suggested a white dwarf rotation period of 40 min. But no optical or spectroscopic evidence is found for this periodicity. The argument put forward by Sterken *et al.* (1983) that the orbital inclination prevents the direct observations of X-rays, may be a right explanation for not detecting the hard and soft X-rays from the white dwarf. However, Warner (1983) has put forward a similar model in which the rotation period of the white dwarf itself is 67 min. Furthermore, because of the system orbital inclination ($\sim 75°$) it may be possible to see the accretion columns at both the poles. This gives rise to a modulation of line intensities of half the rotation period (33.5 min) as seen by Gilliland (1982). Thus, the rotation period can be 67 min. The heating of the X-ray beam emitted from poles causes luminosity modulation. Consequently there is an increase in intensities of lines as well. Thus the colour also is bluer at the 67 min maximum. This also explains the non-detection of the 67 min modulation of X-rays. The soft X-rays that arise in the outer disc by a degradation of the original beam as suggested by Sterken *et al.* (1983) will be modulated similar to the optical light. Judging from all these indications, it is possible that EX Hya presents a case of an intermediate polar.

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