# OPTICAL VARIATIONS OF THE Be STAR HDE 245770/A 0535+26

A. Guarnieri, C. Bartolini, A. Piccioni
Osservatorio Astronomico dell'Università di Bologno

A. Giangrande, F. Giovannelli
Istituto di Astrofisica Spaziale, CNR, Frascati

## ABSTRACT

Results of photoelectric observations of HDE 245770 spreaded over six years are presented. No variations greater than some hundreths of magnitudes are evident in contrast with the ancient light history, which is more complex. A sensible variation of the colour indices is present on a time scale of tens of years. The temporal analysis of these data shows some evidence of orbital periodicity.

## INTRODUCTION

The 9th magnitude early type star HDE 245770 was proposed as the optical counterpart of the recurrent transient X-ray pulsar A 0535+26 by several authors (e.g. : Liller, 1975 ; Murdin, 1975 ; Soderblom, 1975 ; Giangrande et al. 1976). The identification became virtually certain after the observation, made by Bartolini et al. (1978) and independently by Rössiger (1978a, 1978b), of an optical enhancement during the December 1977 X-ray flare-up (Chartres and Li, 1977 ; Rakhamimov et al., 1980). The X-ray source, discovered by the ARIEL V satellite, was found to be modulated at 104 s (Rosemberg et al., 1975). The observed assimmetry of the UV resonance lines (Giovannelli et al., 1980) and the IR excess of HDE 245770 (Persi et al., 1979) confirm the presence of an expanding envelope surrounding the star. The main characteristics of HDE 245770 are reported in the papers by Giangrande et al. (1980) and Giovannelli et al. (1980) and in the references therein.

Under the commently admitted hypothesis of the binarity of this system, it is crucial to know its orbital elements for a better understanding of the underlying physical processes.

In this paper we present the results of photoelectric measurements of HDE 245770 spread over six years after the discovery of the X-ray source A 0535+26, in order to complete the long term history of this system and to find evidence of orbital motion.



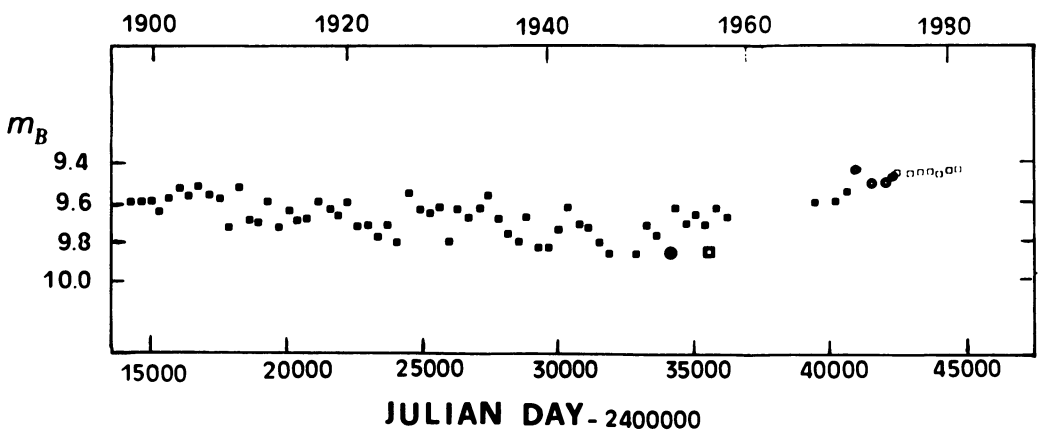
*M. Jaschek and H.-G. Groth (eds.), Be Stars, 69–74.*

OBSERVATIONS AND DISCUSSIONS

Fifty eight nights of photoelectric observations were carried out at the Loiano 60 cm telescope of Bologna Observatory during the years 1976-1981. The blue annual mean values are reported in Fig. 1 along with the photoelectric observations of Rössiger (1976), Lenouvel and Flogere (1957) and Hiltner (1956). For the sake of completness, the historical photographic light curve by Stier and Liller (1976) is also reported. In Table 1 the photoelectric results of these last years are summarized.

Table 1. Summary of photoelectric data

| Year | V | B-V | U-B | Authors |
|---|---|---|---|---|
| 1953 | 9.39 | +0.45 | -0.54 | Hiltner (1956) |
| 1956 | 9.38 | +0.46 | -0.53 | Lenouvel and Flogère (1957) |
| 1970 | 8.86 | +0.53 | -0.66 | Rössiger and Wenzel (1974) |
| 1973 | 8.93 | +0.57 | -0.55 | Rössiger (1976) |
| 1974 | 8.94 | +0.57 | -0.61 | " " |
| 1975 | 8.92 | +0.54 | -0.57 | " " |
| 1976 | 8.91 | +0.57 | | This paper |
| 1977 | 8.91 | +0.56 | | " " |
| 1978 | 8.91 | +0.54 | | " " |
| 1979 | 8.94 | +0.53 | | " " |
| 1980 | 8.89 | +0.56 | | " " |
| 1981 | 8.91 | +0.54 | | " " |




Black squares : Stier and Liller - Black circles : Hiltner - Empty squares : Lenouvel and Flogere - Double circles : Rössiger - Small squares : This work.

Fig. 1. Long term photometric history of HDE 245770.

From Fig. 1 some features can be outlined :

1. the star is at present at its highest luminosity level ;
2. no long term variations greater than some hundreths of magnitude are evident in the last years, in contrast with the ancient light history, which appears more complex ;
3. a light-minimum can be located around the beginning of the fifties. After that time the source brightened (regularly ?) by about 0.4 mag in twenty years ; a less marked secular fading is observed from 1900 to 1950. This behaviour on a time scale of decades is not atypical for a Be star and can be probably connected with circumstellar matter or shell ;
4. from the photoelectric data quoted in the literature and ours, a diverging trend of colour indices is also evident : the star had B-V = +0.45 mag and U-B= -0.54 mag in the fifties (Hiltner, 1956 ; Lenouvel and Flogère, 1957) and now it has mean values B-V=+0.56 mag and U-B≈0.60 mag (Rössiger, 1976 ;this paper).

Fig. 2 shows our V and B-V photoelectric light-curves (dayly mean values) and Rössiger's (1976, 1978). From all our data we deduce the mean magnitudes : V=8.903 $\pm$ 0.002 and B = 9.461 $\pm$ 0.003 (mean errors of the mean). The standard deviation of the dayly individual means reported in Fig. 2 is 0.018 mag and 0.025 mag in V and B colours, respectively. Since dayly individual means are much better defined, these figures are representative of an actual scatter in the luminosity of the star. Therefore, we emphasize the substantially quiet trend of the optical light-curve in this time interval, which is characterized by eight observed X-ray flares, marked with arrows in the plot. The optical enhancement observed simultaneously with the December 77 X-ray flare-up can be considered from this point of view only as an episode without consequences on a long time scale light-curve.

The binary nature of this system is generally admitted (see e.g. Rappaport et al., 1978) and many authors (e.g. Rappaport et al., 1976 ; Hutchings et al., 1978 ; Li et al., 1979) have made serious efforts to search for a direct evidence of it. From period variations of the X-ray 104 s pulse, Rappaport et al. (1976) suggested a permitted range 17 d $\lesssim$ P $\lesssim$ 77 d for the orbital period and the more probable range 39 and 77 d. From spectral lines anlysis Hutchings et al. (1978) suggested some possible periods, the more convincing ones, after their thorough discussion, being 28, 48 and 94 days.

We have made such a search on our photometric data in the range 17-200 d. Indications for about 32, 63 and 77 days periodicities were found, with some better evidence for 32 d. Clearly this deserves more investigations and more time-extened observations because the lenght of such periods, because of the shallowness of the variations ( $\lesssim$ 0.03 mag)

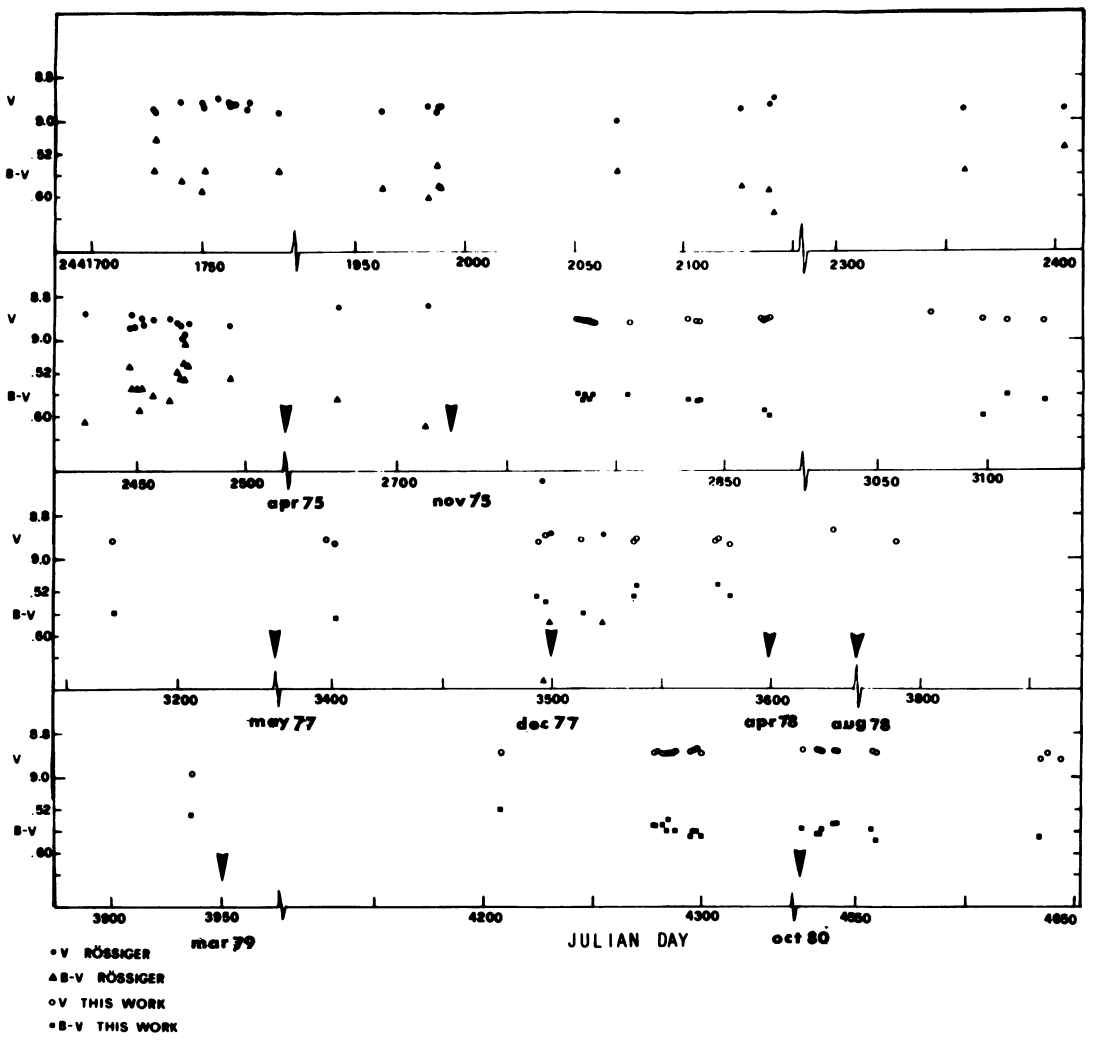



Fig. 2. Short term photoelectric history of HDE 245770.

and because of possible complications connected with Be-type like phenomena.

Ellipsoidal type light variations of the primary component of the binary system (Avni and Bachall, 1975 ; Hutchings, 1978) could be invoked to explain such a periodic variation, if confirmed.

REFERENCES

Avni Y. and Bachall J.N. : 1975, Ap. J. 197, 675
Bartolini C., Guarnieri A., Piccioni A., Giangrande A. and Giovannelli F. : 1978, IAU Circ. N° 3167
Chartres M. and Li F. : 1977, IAU Circ. N° 3154
Giangrande A., Giovannelli F., Bartolini C., Guarnieri A. and Piccioni A. : 1977, IAU Circ. N° 3129
Giangrande A., Giovannelli F., Bartolini C., Guarnieri A. and Piccioni A. : 1980, Astron. Astrophys. Suppl. 40; 289
Giovannelli F., Ferrari Toniolo, M., Giangrande A., Persi P., Bartolini C., Guarnieri A., Piccioni A. and Rucinski S.M. : 1980, ESA SP-157, 159
Hiltner W.A. : 1956, Ap. J. Suppl. 2,389
Hutchings J.B., Bernard J.E., Crampton D., and Cowley A.P. : 1978, Ap. J. 223,530
Hutchings J.B. : 1978, Ap. J. 226, 264
Lenouvel F. and Flogère C. : 1957, Jour. des Obs. 40, 37
Li F., Rappaport S., Clark G.W. and Jernigan J.G. : 1979, Ap. J. 228, 893
Liller W. : 1975, IAU Circ. N° 2780
Persi P., Ferrai Toniolo M. and Spada G. : 1979, Mass Loss and Evolution of O-Type Stars, P.S. Conti and C.W.H. de Loore eds. 139
Murdin P. : 1975, IAU Circ. N° 2784
Rakhamimov S.Y., Estulin V., Vedrenne G. and Niel M. : 1980, Soviet Astron. Letters, 6,10
Rappaport S., Joss P.C., Bradt H., Clark G.W. and Jernigan J.G. : 1976 Ap. J. Letters 208, 109
Rappaport S., Clark G.W., Cominsky L., Joss P.C. and Li F. : 1978, Ap. J. Letters 224, 1
Rosemberg F.D., Eyles C.J., Skinner G.K. and Willmore A.P. : 1975, Nature, 256, 628
Rössiger S. : 1976, Mitteil. Veränd. Sterne, 7, 105
" : 1978, IAU Circ. N° 3184
" : 1978, IBVS N° 1393
Rössiger S., and Wenzel W. : 1974, Astr. Nach. 295, 47
Soderblöm D.R. : 1976, IAU Circ. N° 2971
Stier M. and Liller W. : 1976, Ap. J. 206, 257

DISCUSSION

Pakull: How large was the "optical flare" you observed coincident with the x-ray outburst in 1977?

Guarnieri: Combining our data with Rössiger's the amplitude of the "optical flare" was about .15 magnitudes. Our own observations were made during the decay phase of the flare and we observed a fading of about $^{m}.04$ in four hours. Considering the recently published results of the satellite Prognos 6, the source reached the maximum about on January first 1978, so the optical flare of HDE245770 entered the maximum brightness about 10 days earlier than the x-ray source. The FWHM of the optical flare was of the order of 2-3 days.

Thomas: Your mass-loss figure is very interesting, lying around the highest quoted for Be stars. Could you say how you got it?

Guarnieri: The value $M \leq 5 \times 10^{-6}$ $M_{\odot}$/year is a upper limit derived by IR measurements at 3.6 $\mu$m by Persi and colleagues.

Persi: (comment): We recently derived the mass-loss rate of HDE245770 from our observations at 10 $\mu$m using a spherically envelope model. Our value of $3 \times 10^{-6}$ $M_{\odot}$ /year is in agreement with the upper limit reported by Guarnieri.