PHOTOMETRIC VARIABILITY OF B AND Be STARS

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ABSTRACT

Rapid variability (≤ 3.5 d) of B and Be stars can be explained as the consequence of non-radial pulsations or a rotational modulation. Such a variability has been searched for in a sample of 26 B and 23 Be bright stars (V ≤ 5) with photometric measurements by Hipparcos. Among B stars, quoted in the literature as NSV (New Suspected Variable) stars, 14 of them have been confirmed by Hipparcos data as microvariables. Almost all the Be stars of the sample have shown a rapid variability superimposed on long-term changes. The total amplitude of the long-term variability ranges between about 0.05 and 0.3 mag depending on the considered star. The total amplitude of the short-term variations seems to be higher for Be stars than for B stars. Furthermore some Be stars have shown during the Hipparcos mission, recurrent outbursts with a variable strength and/or fading events. Finally, short periodicities (P ≤ 3.5 d) have been suspected or confirmed in more than half of Be stars and in a few B stars of the sample.

Key words: B stars; Be stars; variables; oscillations; rotation.

1. INTRODUCTION

The revision of opacities data has allowed to explain the origin of the β Cep star pulsations and to predict a large region of instability in the Main Sequence B band. As quoted by Dziembovski (1994) 'this new instability domain nearly bridges the gap in spectral types between δ Sct and β Cep stars'.

Two distincts groups could be explained by the opacity mechanism: β Cep stars characterized by low-order p- and g-modes with periods ranged between 0.1 and 0.3 d, and SPB stars (Slow Pulsating B stars) characterized by high-order g-modes with periods P ≤ 4 d. Short-term periodic variability of B stars can be thus explained as the consequence of non-radial pulsations. In the case of B stars surrounded by an extended atmosphere, so-called B emission-line stars or Be stars, non-radial pulsations are competing with rotational modulation to explain their short-term periodic variations (Baade & Balona 1994). For these stars, the origin of the envelope is still badly understood. However it has been proposed (Ando 1986, Osaki 1986, Lee & Saio 1989, 1993) that non-radial pulsations coupled with high rotation could help trigger the start of episodic mass loss in Be stars. Another ejection process could be due to magnetic activity which could explain sudden brightness episodes detected in some early Be stars.

Photometric variability in Be stars is rather complex; three time scales are often present and superimposed: (i) a short-term (hours, days) variability of low amplitude (several hundredths of magnitude); (ii) a mid-term (weeks, months) variability, the amplitude goes up to 0.2 mag; (iii) a long-term (years, decades) variability, the amplitude goes up to 0.8 mag.

The availability of accurate individual photometric measurements of Hipparcos magnitudes (Hp) (ESA 1997) for bright stars (V ≤ 5) over 3.5 years has given an excellent opportunity for the detection of new variable stars, the determination or the confirmation of periods of variation, and the study of recurrent mass-loss episodes useful for constraining envelope models.

2. RESULTS

Our sample is composed of 15 early B stars (B0–B4), 11 late B stars (B5–B9) and 23 early Be stars. All the B stars of this sample are quoted as NSV (New Suspected Variable) in the INCA catalogue (Turon et al. 1992). We only took into account early Be stars because, following Hirata & Hubert-Delplace (1981) mass-loss episodes are more frequent in early Be stars than in late Be ones. Among the B stars of this sample, 14 of them have been confirmed by Hipparcos data as microvariables. Fourier analysis and Clean algorithm were applied to search for frequencies in Hp data. Short periodicities (P ≤ 3.5 d) have been suspected or confirmed in 7 early B stars (see Table 1 and Figure 1) and can be associated in most of cases to a low degree g-mode (gravity mode) of non-radial pulsations. The microvariability has been observed in late B stars. However, the amplitude of variations is so weak that an accurate estimation of the period could not be obtained. Almost all the Be stars of the sample have shown a rapid variability superimposed on long-term changes (see Table 2). The total amplitude of the long-term variability ranges from about 0.05 to 0.3 mag. Some Be stars of our sample such as λ Eri, ω CMa, HD57150, 66 Oph and υ Cyg have shown during the Hipparcos mission one or several outbursts with a variable strength. Other stars such

Table 1. Early B stars.

Name	HD	HIP	Var. flag	Sp. Type	Possible Period	Remarks
ϵ Cas	11415	8886	M	B3III	P = 17.77 d?	
45 Per	24760	18532	M	B0.5V	P1 = 0.15 d	close to value given
					P2 = 0.21 d	by Smith et al. (1987)
η Aur	32630	23767	M	B3V	P = 1.28 d	
η UMa	120315	67301	M	B3V	P = 1.31 d	
ι Lup	125238	69996	M	B3V	P = 0.75 d	
ι Her	160762	86414	P	B3IV	P1 = 3.487 d	periodic variable found by Hipparcos
					P2 = 1.61 d	
η Lyr	180163	94481	M	B2.5IV	P1 = 19.73 d	P1 $\sim$ 5P2
					P2 = 3.92 d	
α Pav	193924	100751	M	B2IV	P = 0.45 d ?	

Table 2. Be stars.

Name	HD	HIP	Var flag	Sp. Type	Long-term	Mid-term	Short-term	Remark
ϕ Per	10516	8068	U	B0.5IV		binary	P = 0.47 d	1
	20336	15520	U	B2.5V		P = 8.15 d	P = 0.49 d	
λ Eri	33328	23972	U	B2IV	3 outbursts		P = 0.70 d	2
ψ^1 Ori	35439	25302	U	B1V	slow decrease		P1 = 0.59 d	
							P2 = 3.63 d?	
ζ Tau	37202	26451	U	B2IV	2.35 yrs		P = 0.76 d	3
κ CMa	50013	32759	U	B1.5IV	fading events		P = 1.34 d	4
ω CMa	56139	35037	U	B2IV-V	3 bursts			
	57150	35363	D	B2V+B3IV	slow decrease			
o Pup	63462	38070	U	B0V		P = 91.13 d?	yes	
MX Pup	68980	40274	U	B1.5III	fading event	P = 11.55 d	P = 1.99 d	
	75311	43105	U	B3V	yes, 2		P = 0.93 d	
					weak bursts			
	78764	44626	P	B2IV		P = 137.99 d	P = 0.698 d	5
	102776	57669	U	B3V	weak bursts		P = 0.27 d?	
χ Oph	148184	80569	U	B2IV	yes		P $\geq$ 0.5 d	6
66 Oph	164264	88149	U	B2V	bursts			
λ Pav	173948	92609	U	B2II-III	1 burst		P = 0.6 d?	
59 Cyg	200120	103632	U	B1V	slow decrease		P = 0.28 d	
υ Cyg	202904	105138	U	B2V	1 strong burst		multi-periodic	
ϵ Cap	205637	106723	U	B2.5V	2 fading events			
π Aqr	212571	110672	U	B1V	yes			

Remarks:
1: Phase-locked variations of Hp with the orbital motion (P = 126.6 d)
2: Previous photometric period confirmed (P = 0.70 d, Balona 1990)
3: Value close to spectroscopic and UV photometric periods (P = 0.8 d, Gies 1994)
4: Value close to previous photometric period (P = 1.41 d, Balona 1990)
5: Long period given by Hipparcos
6: Previous photometric period of 13.77 d not confirmed (Balona 1990)

as ϵ Cap and χ Oph have shown one or several fading events. An illustration of long-term variations is given in Figure 2 for υ Cyg; an increasing brightness over 100 d has been followed by a slow fading phase of the envelope ($\geq$ 300 d). It seems related to a mass loss episode which built or fed the circumstellar envelope. In the case of ω CMa, 2 minor outbursts preceded the major one (see Figure 3). Ejection process, responsible of discrete outbursts, could be due to magnetic stellar activity (Smith 1995, Hanuschik et al. 1993).

Periodic or quasi-periodic variations on time scales of days or months have been detected in some cases. One Be star of our sample, HD 78764 (HR 3642, $v \sin i = 120$ km s^{-1}) has been discovered with a non-sinusoidal light curve of period P = 138 d, and of a total amplitude 0.07 mag. We searched for an hypothetic low-mass companion (X-ray compact object or cool giant). However HD 78764 was not found among optically bright OB stars detected in the ROSAT all-sky survey (Berghöfer et al. 1996). On the other hand, Baade (1992) did not succeed in finding spectral lines of a cool companion in HD 78764. Due to the lack of radial velocity data, we cannot assign the photometric variability of HD 78764 neither to an orbital motion of a secondary nor to the propagation of a density wave in the circumstellar disc. Finally it should be stressed that recently Sterken et al. (1996) detected also two cases of Be stars with such long periods and no direct evidence of companions.

Furthermore, in the case of the Be variable shell star ζ Tau, the behaviour of the magnitude Hp follows

Figure 1. Short-term variation for the B star η Aur. HJDo was taken at 2447920.0.

Figure 2. Long-term variability of the Be star υ Cyg.

Figure 3. Long-term variability of ω CMa.

the V/R (Violet and Red emission components in doubled-peaked Balmer emission line profiles) curve provided by Guo et al. (1995) with a minimum of brightness at maximum of the V/R ratio. Such a correlation would be very important to test disc models of Be stars.

Short-term variations have been detected in the majority of Be stars (see Figure 4 for HD 75311, Figure 5 for ζ Tau and Figure 6 for HD 78764). For ζ Tau the long term variation has been removed before the search for short-term variability and for HD 78764 the long period (P = 137.99 d) has also been removed before the search for short-term variations. In several cases our determination of periods has allowed a discrimination between values found in the literature.

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Figure 4. Short-term variations of the Be star HD 75311. HJDo was taken at 2447863.0.

Figure 5. Short-term variation of the Be star ζ Tau. Long-term variation has been removed. HJDo was taken at 2447962.0.

Figure 6. Short-term variation of the Be star HD 78764 obtained after removing the period of P = 137.99 d discovered by Hipparcos. HJDo was taken et 2447887.0.