ABSOLUTE MAGNITUDES OF Be STARS

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ABSTRACT

Absolute magnitudes of Be stars of luminosity classes IV and V are studied by comparison with those of B stars of the same spectral type. On average, Be stars are brighter than B stars of the corresponding spectral type, which agrees with some previous results. However, a very new and interesting result is that this over-luminosity is larger for later Be stars, while it is well known that emission characteristics are fainter for these stars. The very fast rotation of late Be stars, close to the break-up velocity, is the most likely physical explanation.

Furthermore, a very preliminary study of the B2e stars shows that the absolute magnitude is influenced by the anisotropic envelope.

Key words: absolute magnitude; Be stars; stellar rotation.

1. INTRODUCTION

1.1. What are Be Stars?

Be stars are B stars which present, or have presented, some emission in the hydrogen lines, sometimes in the Fe II lines, and more rarely in He I lines. These stars are very rapid rotators. Actually, they are the fastest rotators among the non-degenerate stars. More information can be found in Slettebak (1988), Slettebak & Snow (1987) as well as in Balona et al. (1994).

Emission lines are interpreted as originating in an extended circumstellar envelope. Though these objects have been known for a long time, the origin of this envelope is still badly explained. We do not know if the 'Be phenomenon' represents a distinctive stage in the evolutionary track of B stars, or only of some B stars, or if it depends on initial conditions during star formation. The strength of emission characteristics decreases, on the average, from the earlier to the later spectral types. The mean frequency of Be stars among B stars is 17 per cent and the highest ratio is 34 per cent for B1 stars (Zorec & Briot 1997).

1.2. The Situation before Hipparcos

Because they are a minor constituent of the galactic disc, B stars, with and without emission, are scarce in the solar neighbourhood. Most of them are quite remote and beyond reach of ground parallax measurements. It is for this reason that no reliable trigonometric parallaxes were obtained before the Hipparcos mission. In particular, absolute magnitudes for B emission stars were only determined by indirect methods.

Since Merrill (1933), many studies have investigated the absolute magnitudes of Be stars by various methods, and the location of these objects in the H-R diagram remains controversial: some studies set the Be stars on the main sequence, others conclude that they are located 0.5 to 1 magnitude above the main sequence, and finally, certain studies find that some Be stars are on the main sequence while others are above. Extensive references are given in Zorec & Briot (1991). A reliable determination of the absolute magnitude of Be stars is then an important clue for the understanding of the status of these objects. It should be specified that the absolute magnitude studied here concerns the Be stars as a whole, that is to say the central star plus the circumstellar regions.

2. THE SAMPLE STUDIED

Our observational programme contains about 5300 B stars, with and without emission. We eliminated from the study the stars for which the parallax obtained is negative, as well as double stars. We do not consider the giants and devoted this study to the stars of luminosity class V or IV.

The sample of Be stars is defined from the Be star catalogue of Jaschek & Egret (1982) as well as from B stars noted with emission in the Hipparcos Catalogue. The sample so established contains 2077 B stars and 213 Be stars. The number of Be stars, as well as B stars, studied for each spectral sub-type is illustrated in Figure 1.

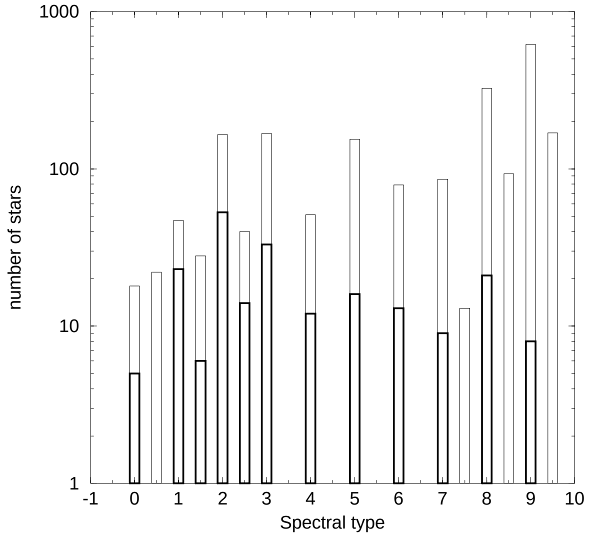

Figure 1. Number of B and Be stars studied here in each sub-spectral type. Thick lines correspond to Be stars and thin lines to B stars.

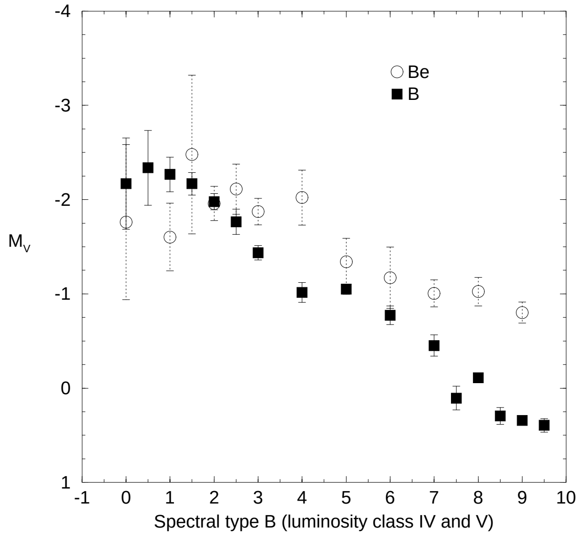

Figure 2. Mean sequences of absolute magnitudes for B and Be stars, as a function of the spectral type.

3. RESULTS

We present a study of the mean absolute magnitudes as a function of the spectral type for the B and Be stars.The interstellar absorption Av has been computed by using the tridimensional model of Arenou et al. (1992). Because of the intrinsic variable reddening of Be stars, we do not study the HR diagram as a function of the $(B-V)$ index, but we do prefer to use the spectral type. The spectral types used here for B and Be stars are those of the Hipparcos Catalogue. It is well known that the determination of the spectral types is very difficult for the Be stars. However, as the results presented here are mean results per spectral type, and as no bias has been detected in the spectral type determinations, the mean values should not be deeply modified by eventual inaccurate spectral type determinations.

We establish the mean sequences of absolute magnitudes for B and Be stars. The error bars are determined taking into account errors in the parallaxes as well as errors in Av. The results are presented in Figure 2.

All parallaxes are considered here whatever the uncertainty in the measurements. We have to note that the results obtained for the hottest B and Be stars (B0-B1) are rather unreliable, firstly because of the smallness of these samples, secondly because the main sequence is significantly wider than for later spectral types, as we shall see below, and lastly because stars of these spectral types are very distant and so the accuracy of their parallaxe determination is rather poor.

In the case of B stars without emission, the mean absolute magnitudes are fainter than those of previous determinations, e.g. that of Zorec & Briot (1991) or the compilation of Schmidt-Kaler (1982).

The general trend for Be stars is an over-luminosity as compared with B stars of the same spectral type. Moreover, the slope of the mean sequence of B IV and V stars is less steep for Be stars than for B stars without emission. A very new and interesting result is that the over-luminosity of Be stars is higher for later spectral types. This result remains the same even when stars with $\sigma_\pi/\pi < 20$ per cent are only considered. Moreover a preliminary study taking into account the Malmquist bias gives similar results.

The widths of sequences of B and Be stars are shown in Figure 3. The sequences are wider than expected, specially for earlier type stars. This later result can be explained by the very rapid evolution of these stars.

4. A PHYSICAL INTERPRETATION

We wish now to give a brief physical explanation of the larger over-luminosity of the late Be stars, as compared with B stars. This cannot be explained by some re-emission in the circumstellar envelope, since all the characteristics of emission, originating in the circumstellar regions, decrease with the temperature of the central star. A possible explanation can be suggested by the very fast rotation of late Be stars. Indeed late Be stars rotate very near their break-up velocity ($v \simeq 0.9 v_{\rm crit}$ for B9e stars), whereas early Be stars do not. The influence of the fast rotation on the absolute magnitude has been often studied (see for example Collins et al. 1991), but it is a really complicated matter. Rotation produces a geometrical deformation of the star, which induces non-uniformity of gravity and temperature on the stellar

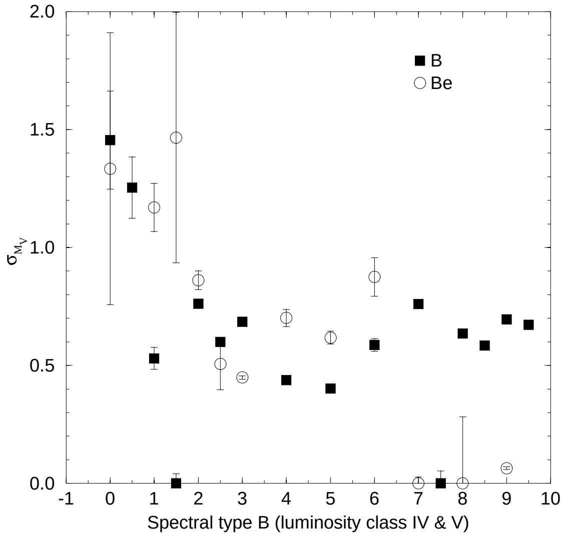

Figure 3. Width of the mean sequences of B and Be stars. It can be seen how sequences are wider for early spectral types.

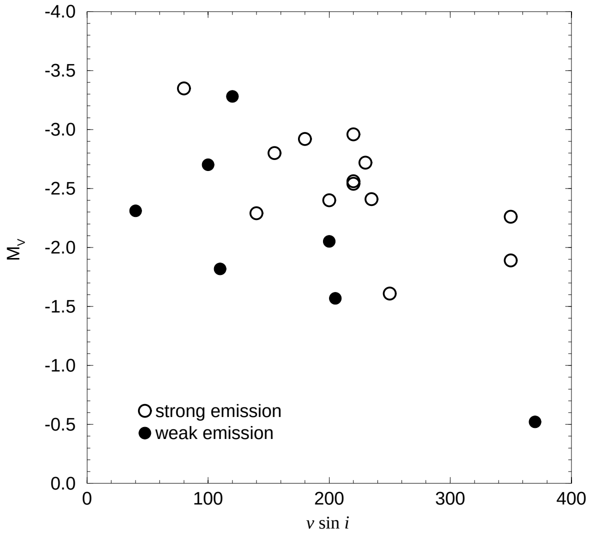

Figure 4. Absolute magnitudes of B2e stars as a function of the rotational velocity. Be stars with strong and weak emission are separately considered.

surface. Fast rotation affects the determination of the spectral classification of the star both in spectral type and in luminosity class. These causes shift rapid rotating stars above the main sequence.

The result obtained here can be compared with a recent result obtained by Lamers et al. (1997) from the absolute visual magnitude of a small sample of OB stars derived from Hippparcos parallaxes measurements. Slowly rotating stars have been found to be fainter (about 1 magnitude) than stars with $v \sin i > 100$ km/s of the same spectral type and luminosity class. These authors investigated the influence of the rotation on the determination of stellar parameters.

5. STUDY FOR B2e STARS

As a preliminary study, we investigate the largest sample of Be stars, that is to say B2e stars. The absolute magnitudes are examined as a function of $v \sin i$. Only Be stars with $\sigma_\pi/\pi < 30$ per cent are considered here. As strong emission Be stars are thought to be rotating faster than weak emission Be stars (Briot 1986), both samples are considered separately. We can see in Figure 4 that in each sample, Be stars with a smaller $v \sin i$ are more luminous. This result can be interpreted in the frame of an anisotropic circumstellar envelope: in this case, the absorption by the envelope is maximum for stars seen with a large inclination angle, and the re-emission by the envelope is maximum for stars seen with a small inclination angle. No such result was obtained from the study of the B9 star sample. If we take into consideration that the effect of the envelope is very small for these stars, this agrees with the former explanation.

6. CONCLUSION

We have studied absolute magnitudes of B and Be stars for every spectral type from B0 to B9. We found that B stars are fainter than previous determinations. On average, Be stars are located above B stars in the HR diagram, and the over-luminosity of Be stars as compared with B stars is larger for the later spectral types. A special study of the B2e stars shows that absolute magnitude is larger (so the star is fainter) for large $v \sin i$. In a first approach, we explain these results by two physical processes which can be responsible of the absolute magnitudes of Be stars: rotational velocity near the break-up for late Be stars and inclination angle of an anisotropic envelope for early Be stars.

A more detailed study is in progress taking into account the Malmquist and Lutz and Kelker biases. A correction will be also applied for the undetected Be stars in the sample of B stars, especially for faint and so less studied B stars. Finally, a more accurate determination of spectral types will be used, particularly for Be stars. Absolute magnitudes of Be stars so determined will give new constraints to model these stars.

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