SOME INFRARED PHOTOMETRIC CHARACTERISTICS OF Be STARS

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Abstract. A photometric study of a large sample of Be stars is reported. Infrared homogeneous observational data in the *JHKL* system are used to derive some photometric characteristics of Be stars, as a class. New infrared observations of 34 Be stars are included in the present paper. Infrared two-colour diagrams are used to investigate the presence of infrared emission in Be stars. The origin of infrared excess in relation to Balmer line emission in Be stars is discussed.

1. Introduction

The distinguishing feature of Be stars is the presence of Balmer emission lines superposed on the broad underlying stellar absorption in the visible region. It is also known that some Be stars exhibit infrared excess as compared with the radiation of normal B-type stars. To gain a better understanding of the Be phenomenon, it is necessary to study the infrared behaviour of these objects collectively. The earlier infrared photometric studies of Be stars (Johnson, 1967; Woolf *et al.*, 1970; Gehrz *et al.*, 1974; Neto and Pacheco, 1982; Dachs and Wamsteker, 1982; Feinstein, 1982; and Ashok *et al.*, 1984) have proved their importance in investigating the physical conditions prevailing in the circumstellar envelopes of these objects.

In the present paper, we have collected the available infrared observational data (*JHKL*) to discuss their photometric behaviour. We have also included the new infrared measurements of 34 Be stars for which no earlier observations are available. The analysis of the combined data leads us to derive several interesting results.

2. The Observational Data

In our discussion we have included the observational data taken from different sources. The *JHKL* measurements have been taken from Whittet and Breda (1980), Dachs and Wamsteker (1982), Mendoza (1982), and Ashok *et al.* (1984). The criterion was to include B0.5–B9.5 type Be stars. We have restricted ourselves to a selection, which naturally is based by our own interest.

We have also used our own recent observations (Bhatt *et al.*, 1984) of 23 Be stars to be discussed herein. The infrared measurements of these stars were made by us in December 1983 with a PbS detector cooled with liquid nitrogen and standard filters (*JHK*), attached to the 104-cm reflector at Uttar Pradesh State Observatory. Our measurements contain 14 Be stars for which no previous infrared observations are available. The measurements by Ashok *et al.* (1984) contains 20 Be stars for which infrared observations are new.

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3. Two-Colour Diagrams

The analysis of the combined data permit us to derive several important results. The two-colour diagrams have been used to locate the position of Be stars with respect to normal Main-Sequence stars. In Figures 1 to 6 are plotted the two-colour diagrams for all the Be stars included in the present study. In each diagram the solid curve represents the Main-Sequence normal stars according to Whittet and Breda (1980).

In all the diagrams one can see that the position of most of Be stars deviate from the Main-Sequence normal stars. The deviation of the stars position from the normal stars are the result of the infrared excess plus some interstellar reddening. Whittet and Breda (1980) have concluded from the analysis of their own infrared observations of Be stars that the interstellar reddening cannot produce so much deviation in this way. The infrared excess is responsible for such deviation.

One interesting feature to be noticed in Figures 2 to 6 is that all the observations show a linear relation between each set of colours. But Figure 1 shows apparently no systematic relation between colours. The most convincing interpretation of this fact is the systematic attribution to an excess radiation in the L band as compared to that in the JHK bands. Figures 2 to 6 also show that an excess radiation is stronger in the L band.

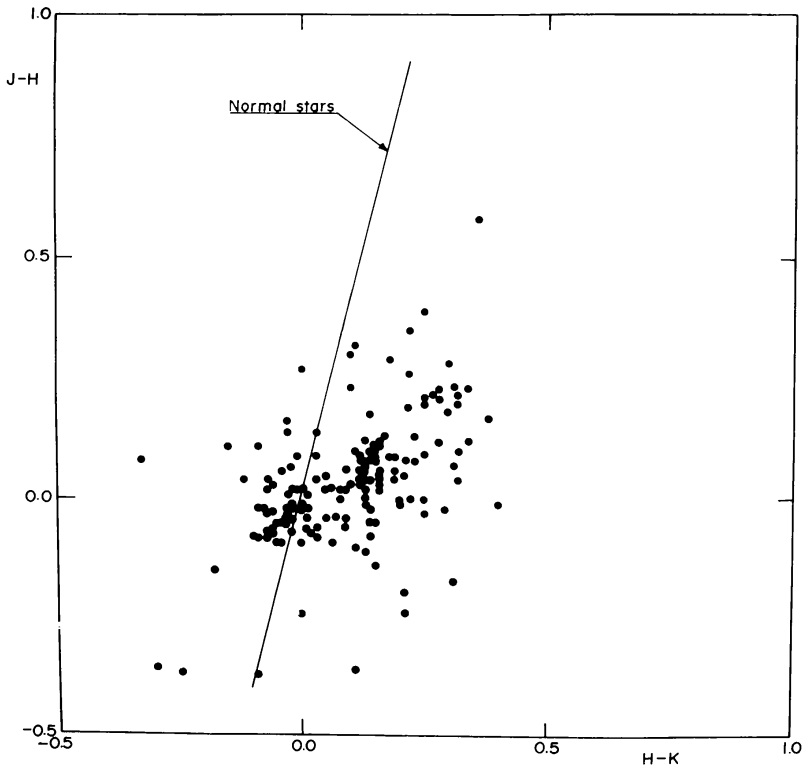

Fig. 1. The ($J-H$, H–K) array for Be stars. The solid line corresponds to the normal Main-Sequence stars.

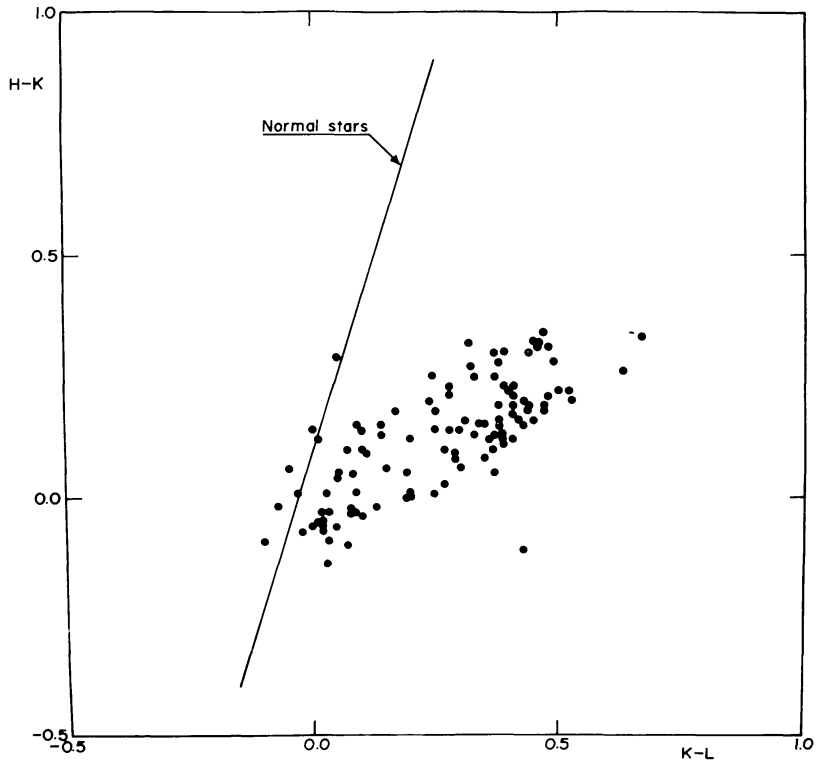

Fig. 2. The (*H–K*, *K–L*) array for Be stars. The solid line corresponds to the normal Main-Sequence stars.

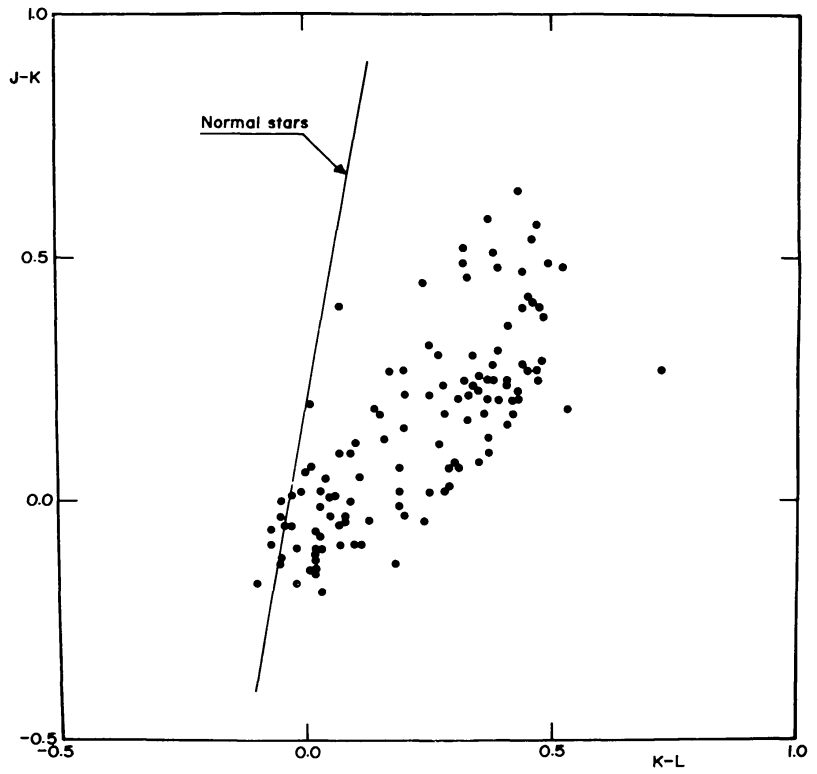

Fig. 3. The (*J–K*, *K–L*) array for Be stars. The solid line corresponds to the normal Main-Sequence stars.

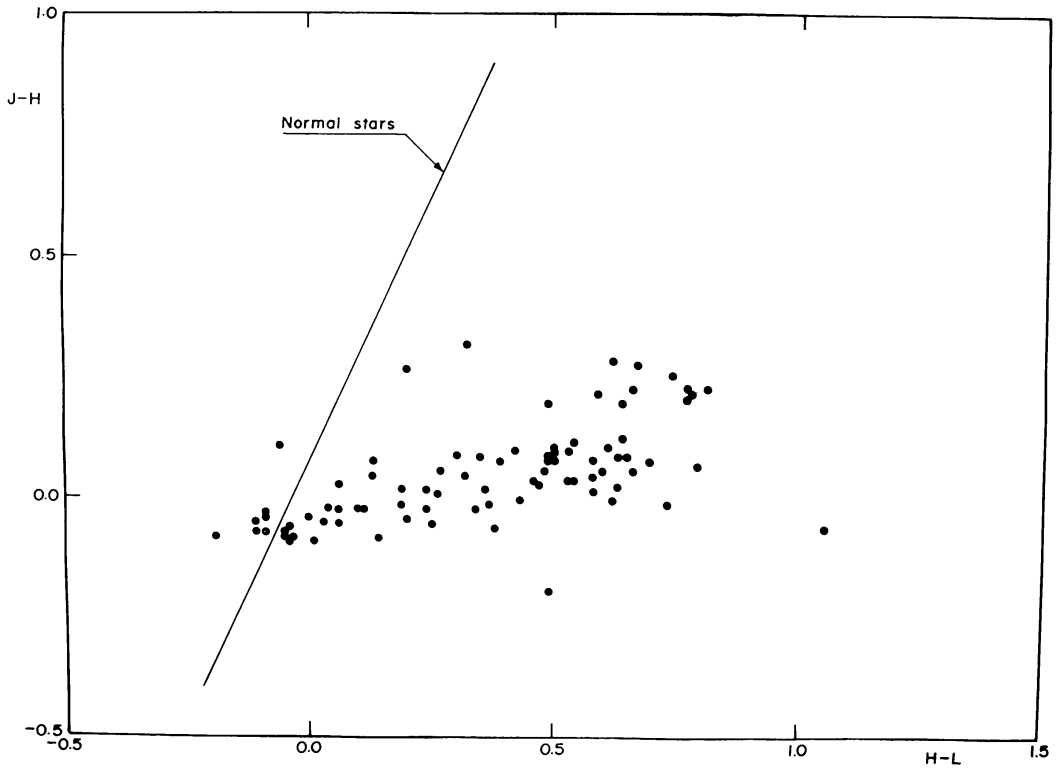

Fig. 4. The (*J–H*, *H–L*) array for Be stars. The solid line corresponds to the normal Main-Sequence stars.

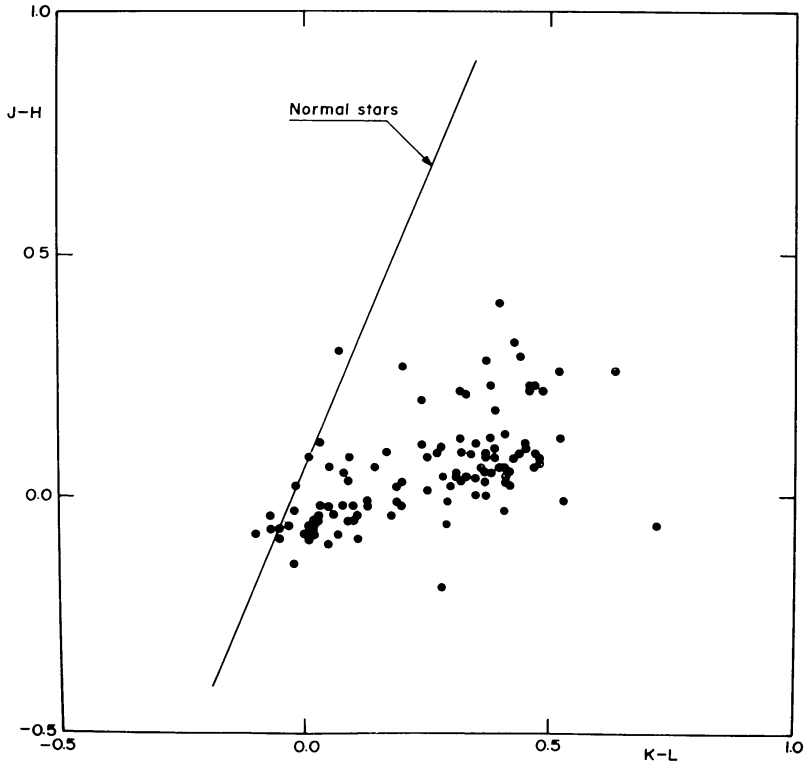

Fig. 5. The (*J–H*, *K–L*) array for Be stars. The solid line corresponds to the normal Main-Sequence stars.

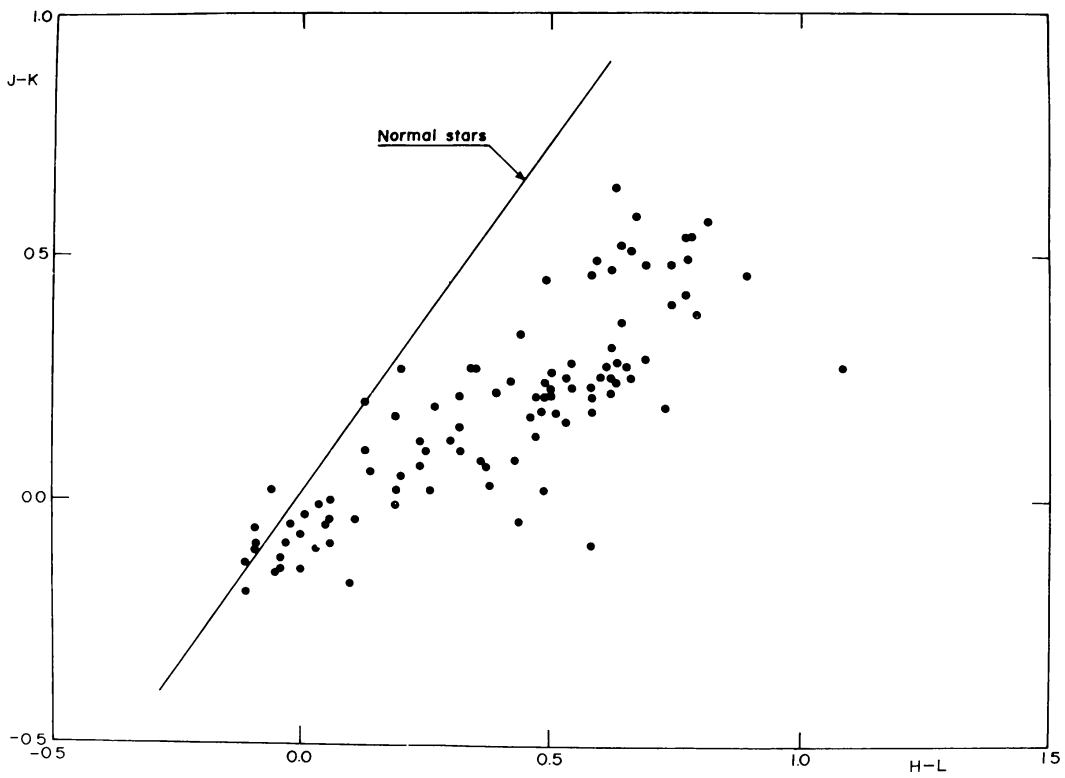

Fig. 6. The (*J–K*, *H–L*) array for Be stars. The solid line corresponds to the normal Main-Sequence stars.

4. Discussion and Results

It has been seen in the present study that most of the Be stars possess infrared excess. The most widely accepted explanation for the infrared excess exhibited by the majority of Be stars is the free-free and bound-free emission originating from the ionized circumstellar envelopes (Gehrz *et al.*, 1974; Scargle *et al.*, 1978). Many of the Be stars in the present study have also been known to undergo variations in their infrared fluxes (Whittet and Breda, 1980; Dachs and Wamsteker, 1982; Mendoza, 1982; Feinstein, 1982; and Ashok *et al.*, 1984). Elias *et al.* (1978) have suggested that the infrared variations are produced by changes in an ionized region around the star, and Balmer lines are seen more strongly in emission when the infrared excess is greater.

From a study of southern Be stars, Feinstein and Marraco (1981) have found that the amount of excess emission in the near-infrared is well correlated with the emission strength of the hydrogen lines. Other studies (Neto and Pacheco, 1982; Feinstein, 1982; Dachs and Wamsteker, 1982; and Ashok *et al.*, 1984) have also detected, independently, the correlation between infrared colour excess and Hα line strengths for many Be stars.

A common origin of infrared excess and Hα emission radiation in Be stars is clearly suggested by the above correlations. In Be stars, Balmer line emission is primarily caused by recombination of ionized hydrogen in an extended envelope. Therefore, the correlation between the intensities of the infrared continuum and Balmer line radiation

emitted from the star can be taken as the strong evidence for free-free and bound-free emission of ionized hydrogen in the same circumstellar envelope of Be stars. The same conclusions about the origin of infrared excess have been drawn by Gehrz *et al.* (1974), Elias *et al.* (1978), and Poeckert and Marlborough (1978) from their analysis of the infrared radiation for northern Be stars.

In conclusion, our results support the earlier suggestion that most of the Be stars possess infrared excess and the infrared excess emission and the Balmer line emission originate from the same region of the envelope.

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