INFRARED PHOTOMETRY OF Be STARS

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A photometric study of Be stars in the JHKL system is reported here. Early papers (see Feinstein and Marraco, 1980) about bright southern Be stars observed photoelectrically in the UBVRI system and in the Balmer-lines: Hα, Hβ and Hγ, permit us to derive several conclusions about their light variability, the amount of emission in the α and β indices, and some correlations about these data. On the other hand, we recently found (Feinstein and Marraco, 1981) that the emission strengths of the hydrogen lines are well correlated to the amount of excess radiation in the near-infrared of the RI system.

It is already known that Be stars exhibit an infrared excess at wavelengths longer than 1 micron as compared with the radiation of normal B-type stars. This is interpreted as the contribution of free-free radiation from a circumstellar shell surrounding the star. Therefore, for the same bright southern Be stars cited above, it should be interesting to look for the JHKL data already published, which we completed with measurements for some stars observed by us. The latter were carried out with a PbS detector cooled with liquid nitrogen and standard filters, attached to the 83-cm reflector at La Plata. A mechanical choper was used to switch beams. Our measures are referred to the list of standard stars given by Glass (1974) having an error estimated of ± 0.05 for the J, H and K bands, while at L it may reach about ± 0.08.

The analysis of the combined data permit us to derive several conclusions: two-color diagrams have been used to locate the Be stars with respect to the normal B main sequence stars (Figures 1 and 2).

The deviations of the stars' positions from the main sequence are the result of the infrared excess plus some interstellar reddening. The only significant influence is due to the former, which we have computed for each star as the difference in the K-L index between its actual location and the main sequence. We assumed that the effect takes place only in this K-L index, which we called $E_K$ . One star with an unusual high K-L value is HD 178175. Perhaps a large error in the L magnitude could be responsible for this extreme value.



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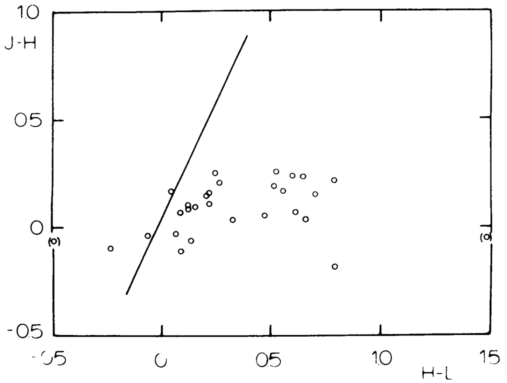


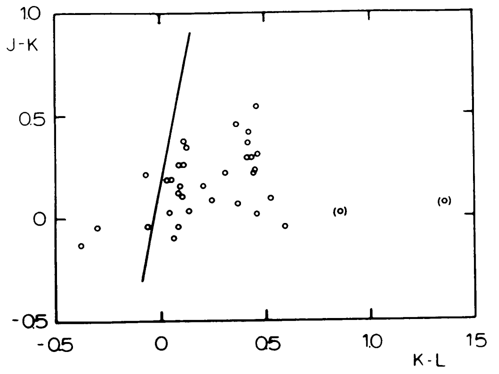


Figure 1. Left: The (J-H,H-L) array for Be stars. Figure 2. Right: The (J-K,K-L) array for Be stars. In both diagrams the solid line corresponds to the normal main sequence stars.

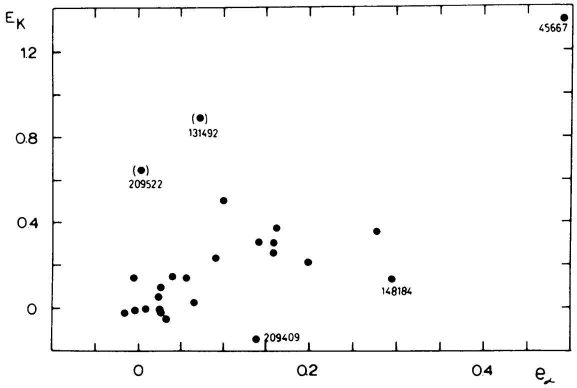


Figure 3. The infrared excess $E_K$ versus the amount of the emission in the Hα-line given by the $e_\alpha$ index.

Then, we compared the infrared excesses with the amount of emission in the Hα-line, which we displayed in Figure 3. With the exception of some stars, slightly far from the mean relation and plotted with their HD numbers, there is a quite good relation between the two sets of values.

On the other hand we looked for a correlation of the $E_K$ values with the ultraviolet excess through the use of the Q values, as defined by Johnson. But, in Figure 4, which gives the ($E_K$, ΔQ) array, no correlation at all appears between infrared and ultraviolet excesses. However, it is interesting to notice that a few stars which are far from the mean relation in the ($E_K$, $e_\alpha$) diagram are also discordant in Figure 3.

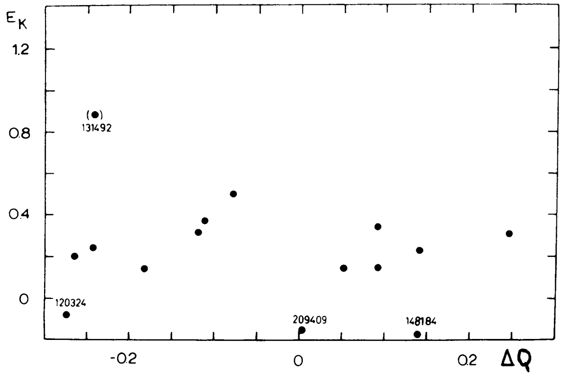


Figure 4. The infrared excess $E_K$ versus the ultraviolet excess given by $\Delta Q$.

Evidence that a few of the Be stars may suffer variations in the infrared bands is provided by the comparison of measures obtained at different times and by different observers. The results are summarized in Table 1, where only those stars with significant changes are listed. Syste-

Table 1. Variable Be stars in the infrared.

| | J | H | K | L | n | |
|---|---|---|---|---|---|---|
| HD 45677 | | | | | | |
| 1971/72 | - | 6.49 | 4.62 | 2.15 | - | Allen (1973) |
| Dec 1975 | 6.95 | 6.03 | 4.74 | 2.16 | 3 | Feinstein |
| Feb 1981 | 7.19 | - | 4.93 | 2.19 | 5 | Feinstein |
| HD 120324 | | | | | | |
| 1971/72 | - | 3.72 | 3.61 | 3.20 | - | Allen (1973) |
| May 1975 | 4.01 | 4.03 | 4.15 | 4.5: | 1 | Feinstein |
| Mar 1981 | 3.93 | - | 3.96 | 3.55 | 1 | Feinstein |
| HD 148184 | | | | | | |
| Jul 1974 | 3.69 | 3.37 | 3.19 | 2.79 | 3 | Feinstein |
| 1976/77 | 3.50 | 3.29 | 3.04 | 2.71 | 2 | Whittet and van Breda (1980) |
| Aug 1976 | 3.46 | 3.26 | 2.98 | 2.64 | 4 | Feinstein |
| May 1980 | 3.46 | - | 2.89 | 2.28 | 1 | Daminelli |
| HD 158427 | | | | | | |
| Aug 1976 | 2.99 | 2.98 | 2.76 | 2.30 | 5 | Feinstein |
| Aug 1980 | 3.11 | - | 2.94 | 2.42 | 3 | Feinstein |
| HD 178175 | | | | | | |
| 1974/75 | 5.69 | 5.74 | 5.66 | - | 5 | Feinstein |
| 1977 | 5.31 | 5.20 | 5.16 | 4.96 | 1 | Whittet and van Breda (1980) |
| Aug 1980 | 5.71 | - | 5.45 | - | 1 | Feinstein |

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matic differences among observers may, however, affect these conclusions, but it becomes difficult to judge how large they are, because these are the only available data we have at hand, and not very many stars are included.

In conclusion, our results confirm the idea that the same region of the envelope is responsible for the infrared excess and the Balmer line emission.

An observational program to measure more Be stars in the infrared is in course.

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DISCUSSION

Metz: Would you briefly comment the surprising fact that there is no correlation between IR excess and UV excess.

Feinstein: The data suggest that no relation appears between IR and UV excess. Perhaps it would be necessary to add another information to clear this point.

Houziaux: 1. What is the typical rms error on the H,K,L magnitudes for the stars observed, i.e. at which level can you talk about variability?
2. What do you think about the band pass of H,K,L filters of different observers? Can they been considered as identical?
3. What is the limiting magnitude you can reach with your instrument?

Feinstein: 1. The rms error depends on the magnitudes of the star. For the B band the rms error is about $0^m\!.05$ in a $5^m$ star.
2. There may be some differences, but I think these differences larger than .1 or .2 must be considered as variabilities.
3. In the L band the limiting magnitude is about $5^m\!.5$.

Coyne: To determine IR and UV excesses is the normal colour-colour curve in the IR determined from the same group of stars as for the colour-colour curve in the UV?

Feinstein: It is assumed that these are the same stars or at least stars with the same characteristics.

Poeckert: What do you call an excess? What is the excess relative to?

Feinstein: The (colour) excess in K-L is the difference between the observed colour index K-L minus the K-L of the standard relation for main sequence stars in the J-K, K-L diagram.

Snow: I don't know much about IR photometry, but my understanding is that due to a variety of causes (difficulties of calibration, variable atmospheric conditions, differences between observing systems) there can be large uncertainties in IR magnitudes. You have shown data taken from different observers at different times, without showing error bars, and indicated from this that the star is variable, at levels as small as only a few tenths of a magnitude. In view of the uncertainties, how confident are you that the variations are real?

Feinstein: All the stars which I show are bright in the IR, so assumed errors about $^m\!.05$ mean that differences larger than a few tenths of a magnitude must be variations.

Viotti: I would like to make a general comment about the problem of IR excess in Be stars. Dr. Thomas told us that one needs non-uniform models to understand the IR system, but I think that no models can be built up without knowing what happens at the "base" of the atmospheres. Since in the middle UV the continuum opacity is smaller, one has more chances to go deeper in the atmosphere and to have a more realistic value of the classical stellar parameters, effective temperature, gravity, etc. So I strongly suggest IR astronomers not to restrict themselves to start from scanner and high resolution optical spectra used to discribe the "underlying" star, but to use IUE high resolution spectra to look at the continuum spectra and the excited lines to derive the "stellar" parameters, and not only the resonance lines which are formed at higher levels. In other words, don't make a model without making its feet before.