PHOTO-ELECTRIC MEASURES OF Hα AND Hβ IN THE SCORPIO-CENTAURUS ASSOCIATION

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Abstract. Photo-electric measures of Hα and Hβ have been made in an attempt to confirm the scatter in the Luminosity-Balmer line relation predicted by Hardorp and Strittmatter as an effect of Stellar rotation.

There is a well known correlation between luminosity and Balmer line strength for early type stars. In this connection Jones (1971) derived new luminosities for stars in the Scorpio-Centaurus association and compared them with luminosities derived from a number of Balmer line indices. In a recent paper, Hardorp and Strittmatter (1968b) have suggested that comparisons of the kind performed by Jones should suffer from an irreducible scatter because of the effects of Stellar rotation. A cosmic scatter may also arise from differences in temperature and gravity at constant luminosity, or from emission lines arising in a shell surrounding the star. The present investigation was undertaken in an attempt to evaluate the irreducible scatter in the luminosity-Balmer line relation after all identifiable sources of dispersion had been removed.

The two-channel scanner at the Cassegrain focus of the Mt. Stromlo 50 in. telescope was used to observe Hα and Hβ in stars in the Scorpio-Centaurus association listed by Jones (1971). The scanner was set to an exit slit width of 30.6 Å, and programmed to read at six wavelengths. These instrumental readings $R(\lambda)$ were combined into two indices.

$$I\beta = \frac{2 \times R(4861)}{R(4961) + R(4761)}$$

$$I\alpha = \frac{2 \times R(6563)}{r(6642) + R(6487)}.$$

The $I\alpha$ index is the reciprocal of the $R\alpha$ defined by Andrews (1968) who used a slightly different bandwidth, 36 Å. Even when the bandwidth difference is ignored, the correspondence between them is

$$R\alpha^{-1} - I\alpha = +\,0.004 \pm 0.008 \text{ s.e. per star}$$

for 25 absorption line stars. The correspondence for emission line stars is not so good but this almost certainly arises from intrinsic variability.

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In general Hα and Hβ are formed by the same processes in stellar photospheres and may be expected to correlate strongly. On the other hand if the Balmer lines appear in emission in an optically thin region surrounding a star their decrement is very different with Hα much the stronger. Several stars have $I\alpha > 1.$ and are indisputably emission line objects: HD 105435, 112091, 120324, 142983 and 148184. In Figure 1 the other stars show a strong correlation between $I\alpha$ and $I\beta$ with only one deviant star, HD 142184. This is also a known emission star (de Vancouleurs, 1957).

In Figure 2, M_v from Jones (1971) is plotted against $I\beta$. The emission line stars are arrowed and the curved line refers only to the remainder. Apart from errors of observation the residual scatter is a combination of variation in $I\beta$ with temperature,

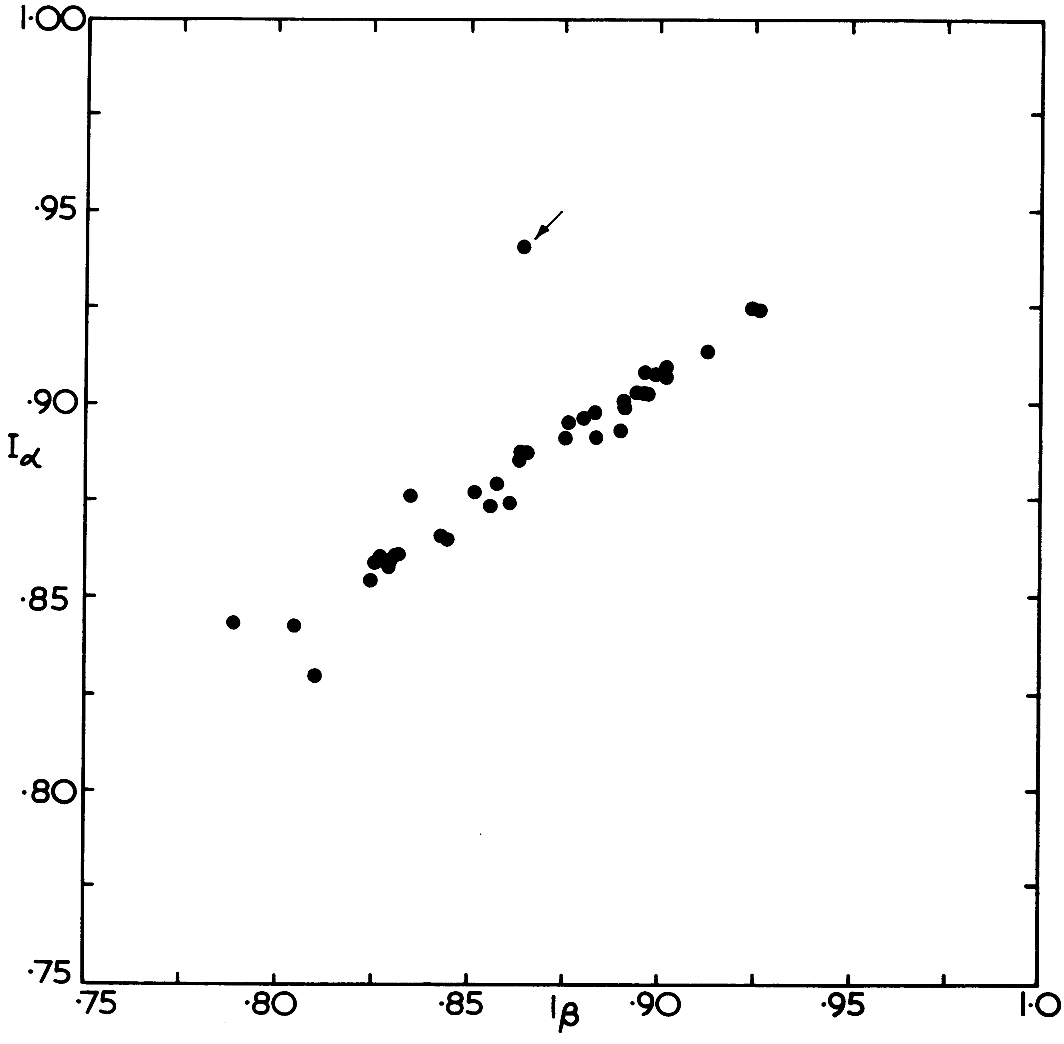

Fig. 1. Correlation of $I\alpha$ with $I\beta$, stars with $I\alpha > 1.$ (strong Hα emission omitted). The arrowed star is HD 142 184 which is also a known emission line star (de Vaucouleurs, 1957).

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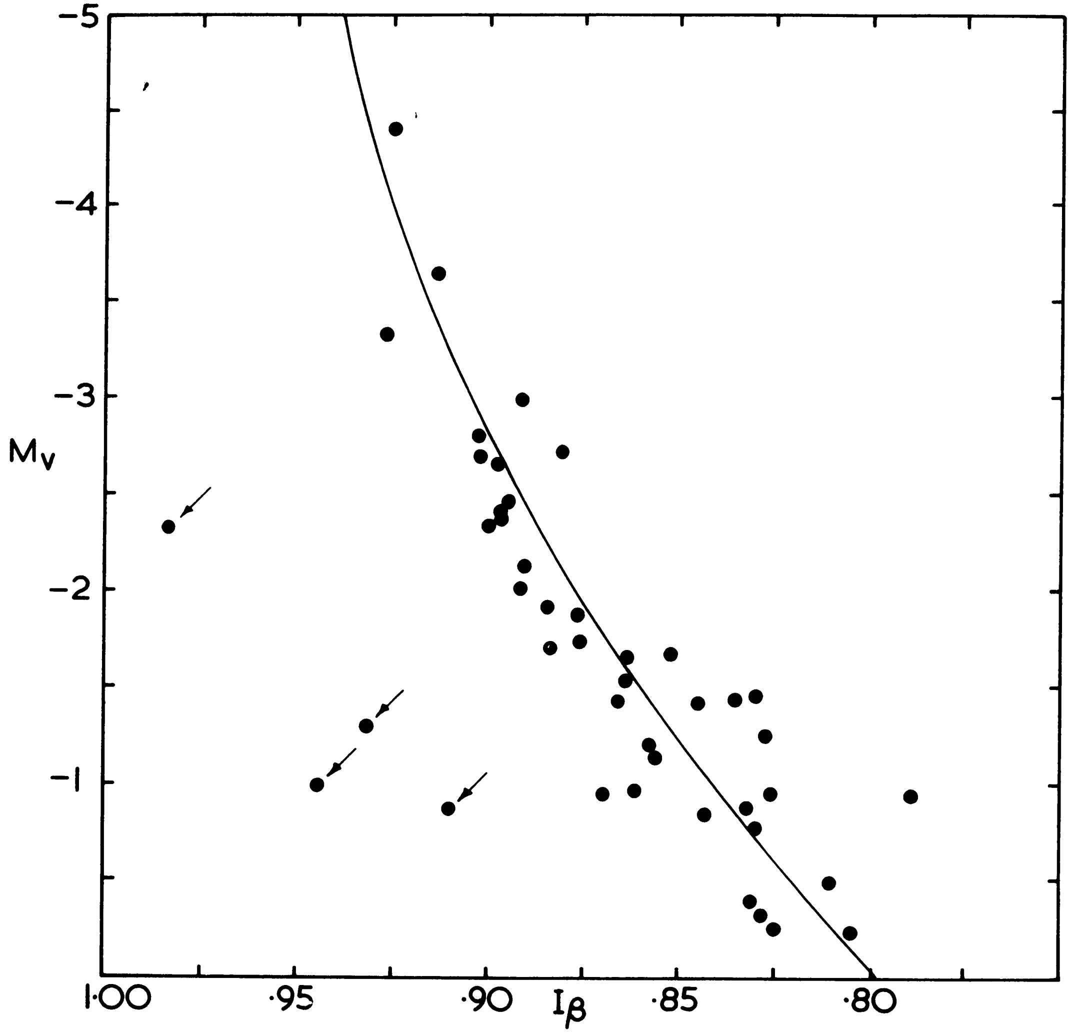

Fig. 2. M_v from Jones (1971) plotted against $I\beta$. The arrowed stars have emission lines. The curved line is drawn to fit only the others.

variation in gravity with luminosity and any effects of Stellar rotation. It is practically impossible to determine the dependence of $I\beta$ on temperature because of the high internal correlation of $I\beta$ on M_v and, in turn, of M_v on temperature. The dependence must be determined theoretically and we are calculating the required quantities from the van Citters and Morton (1970) model atmospheres in co-operation with Drs B.A. and V. A. Peterson. To date we have computed $I\alpha$ and $I\beta$ only for the asymptotic Griem theory and do not wish to present any results until the difference between different broadening theories has been explored.

In Figure 3 the deviations $\Delta I\beta$ from the line in Figure 2 are plotted against $\Delta(U-B)_o$, the deviation of each star in Figure 10 of Jones (1971) from the lower envelope in that figure defined as

$$(U - B)_0 = - 0.672 + 0.1215M_v .$$

Figure 3 exhibits a definite correlation but some such correlation is expected from the scatter in M_v which affects both $\Delta I\beta$ and $\Delta(U-B)_o$. The expected rms scatter of ± 0.16 in M_v should produce the scatter shown by vector **A** in Figure 3. The approximate effects of rotation are shown by the vectors **B** and **C**. If a non-rotating star corresponding to Hardorp and Strittmatter's (1968a, b) model II is placed at the origin then the corresponding pole-on star at break up velocity will be carried along the vector **B** while the corresponding equator-on star is carried along the vector **C**.

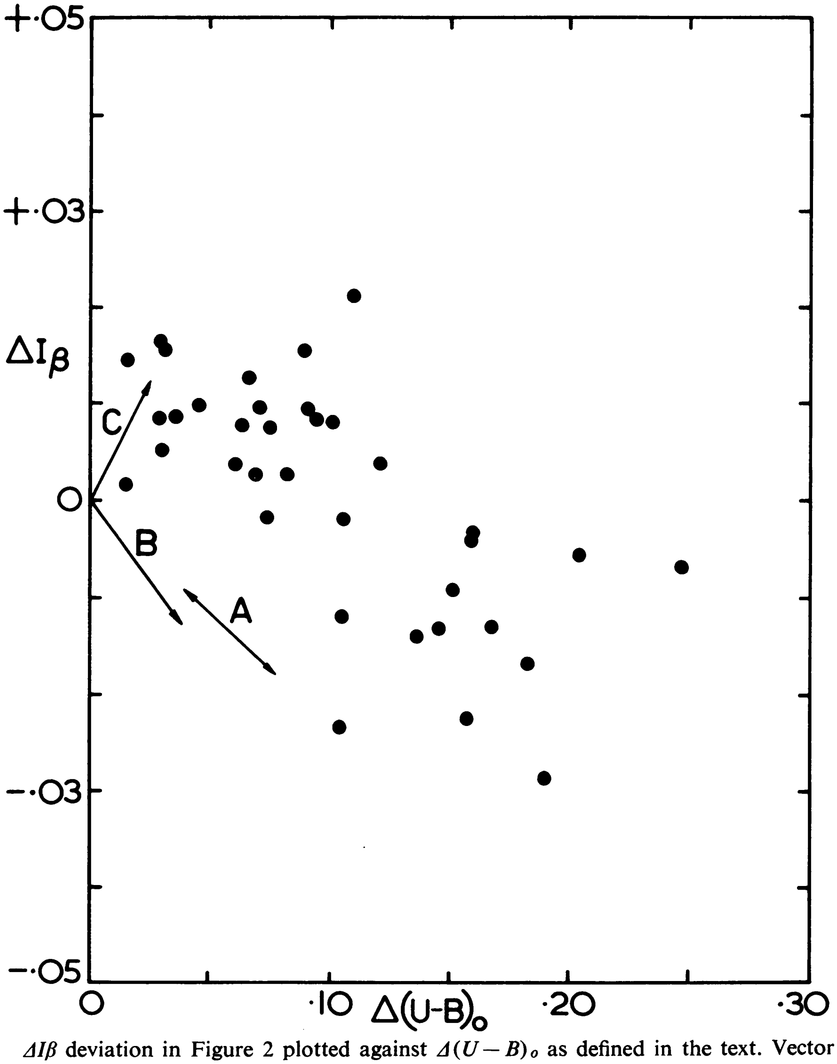

Fig. 3. $\Delta I\beta$ deviation in Figure 2 plotted against $\Delta(U-B)_o$ as defined in the text. Vector **A** represents the effect of the expected errors in M_v (two standard errors in Length). The vectors **B** and **C** represent the effect of rotation at break up velocity (**B** pole-on and **C** equator-on).

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The work completed so far is thus qualitative confirmation of Hardorp and Strittmatter predictions. It is hoped to make this confirmation quantitative in the near future.

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DISCUSSION

McCarthy: (1) Can you tell us the spectral range of the Scorpio-Centaurus stars observed here? (2) How many B8 stars were included?

Jones: From B0 to B8, with at least one of the latter.

Newell: Have you considered the possibility of a range in mass existing at each (g, θ_{eff})-pair, and whether or not such an effect can contribute to the scatter that you observe?

Jones: While a unique mass-luminosity law exists, gravity and luminosity will be linked at constant θ. When the star leaves the main-sequence there will be a change in luminosity which will break the perfect correlation with gravity. In Figure 3 this will appear as an error in luminosity, and will move the stars in a parallel direction to the vector A. Motion in a perpendicular direction cannot be explained by this effect.

Garrison: I will discuss this work tomorrow in more detail during the session on calibration of the MK system, but I would like to take a minute discuss one of the results which is relevant to the distance of the Hyades.

There is a problem which arises if the distance modulus of the Hyades is changed from 3.0 to 3.2 or 3.4. I have constructed a composite HR diagram, using MK classifications by either Morgan or myself or both of us, of 3 moving clusters with distances determined by the convergent point method. These are the Hyades, α Persei, and the Inner Region of Upper Scorpius. (See Figure 1, page 120.) The point relevant to today's discussion is that, assuming a distance modulus of 3.0 for the Hyades, I get a distance modulus of 6.2 for Upper Scorpius, which is exactly what Bertiau obtained in 1958. However, Derek Jones has recently redetermined the Scorpius distance modulus and has obtained 5.8. If the Hyades is moved further away, then Upper Scorpius must be moved by about the same amount. This will be in the wrong direction, however, and the discrepancy between the cluster fitting and Derek Jones' distance then becomes more than half a magnitude, which is not easy to explain away.

Jones: Within the errors of observation my convergent point for Scorpio-Centaurus agrees with that of Bertiau. In any case the stars are nearly 90° from the vertex on the average and luminosities are insensitive to changes in the convergent point. The only critical quantities are the size of the proper motions on the FK4 system and the correction to Newcomb's precession and motion of the equinox.

Thomas: Could there be differences in the mean rotation of the clusters, which would alter your conclusions?

Garrison: There seems to be a considerable difference of opinion, as illustrated by todays' discussion, concering the effect of rotation on photometry. It is, in any case, unlikely that small differences in mean rotation will make a difference. Extremely rapidly rotating stars have been left out of the formation of the main sequence, mostly because it is difficult to determine a unique spectral type for such stars which exhibit a range in excitation.

Newell: Have you considered the possible effects of abundance differences on the positions of the main sequences in the HR-diagram? There are two distinct effects. I am referring to the effect of abundance on the *intrinsic* location of the main sequence in the HR-diagram.

Garrison: It is possible, by spectral classification, to detect metal abundance differences as peculiarities, even though the MK system is defined in only two dimensions. In the case of the Hyades stars and the α Persei stars, there seem to be no significant differences.