ON WAVELENGTH Shifts OF He I LINES 
IN RotATING B STARS

B. E. J. Pagel and J. E. Drew*

Royal Greenwich Observatory, Hertsmonceux, Sussex 
and 
Physics Department, Durham University

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SUMMARY

The wavelength shift between He I triplet and singlet lines in the binary system 68u Her is due to imperfections in the standard wavelength system for B stars rather than to any isotope effect.

I. INTRODUCTION

In a study of the spectroscopic binary 68u Her (B2 V; \( v \sin i \approx 120 \text{ km s}^{-1} \)) using an oscilloscope comparator, Hilditch & Hill (1975; hereinafter referred to as HH) discovered that five He I singlet lines are apparently always shifted to the red relative to four He I triplet lines in the primary spectrum by an average amount of 13.8 km s\(^{-1}\), closely corresponding to the shift of 13.6 km s\(^{-1}\) that would have been observed for the same lines from pure \(^3\)He. A similar shift (12.0 km s\(^{-1}\)) was found for C II \( \lambda 4267 \), which was the only other line that could be accurately measured. HH concluded that most of the helium in this star is in fact \(^3\)He, and that carbon may also be affected by a large isotope shift for which, however, the necessary laboratory data do not exist.

Before accepting these dramatic conclusions, it is necessary to examine carefully the wavelength system adopted, since all the triplet lines measured by HH are affected by nearby lines which are resolved in sharp-lined stars but blended when the projected rotational velocity is high; for example, three of the four triplet lines are from the diffuse series and have electric field induced P–F components (Struve 1929), while the fourth has significant features of O II. All these features (which have previously been noted by Petrie 1953) tend to shift the centre of gravity of the blended line to the blue, whereas corresponding effects in the singlet lines are comparatively insignificant, so that the triplet–singlet difference might very well be due to a blue-shift of the triplets rather than a red-shift of the singlets; the behaviour of C II \( \lambda 4267 \) greatly strengthens the suspicion that this is actually the case. In what follows we examine this hypothesis quantitatively.

2. METHOD AND RESULTS

We assume that the spectrum of 68 Her is a convolution of the spectrum of \( \gamma \) Peg—a sharp-lined star of similar spectral type (B2 IV) to 68 Her and normal

* Vacation Student.
chemical composition (Watson 1971; Peters 1973) for which extensive data are available both in the literature (e.g. Aller & Jugaku 1958; Wright et al. 1964; Leckrone 1971) and in plate files at the RGO—with a rotational profile (Unsöld 1955; Patchett, McCall & Stickland 1973) corresponding to $v \sin i = 120 \text{ km s}^{-1}$. The peak of each triplet line is assumed to be at a ‘laboratory’ wavelength corresponding to a weighted mean of the two fine-structure components weighted by the square root of their $gf$ values; the resulting wavelengths (which are not very sensitive to the precise system of weighting adopted) were found to give consistent radial velocities for $\gamma$ Peg within the standard error of $\pm 3 \text{ km s}^{-1}$ or $\pm 0.04 \text{ Å}$. Profiles taken from a tracing of a $10 \text{ Å mm}^{-1}$ coudé plate of $\gamma$ Peg were then convolved with the rotational profile as shown in Figs 1–4 and the wavelength of the centre of

**Fig. 1.** Profiles of $\lambda 4471$ from RGO 30-in. coudé plate no. 1631 of $\gamma$ Peg taken on 1970 December 8, original dispersion $10 \text{ Å mm}^{-1}$. The thick curve shows the profile read from the tracing, while the light line shows the profile after convolution with a rotational broadening function corresponding to $v \sin i = 120 \text{ km s}^{-1}$. The vertical broken line shows the location of the centroid of the convolved profile. The blue-shift from peak to centroid is $0.20 \text{ Å}$.

**Fig. 2.** Profiles of $\lambda 4121$, as in Fig. 1. The blue-shift from peak to centroid is $0.27 \text{ Å}$.
gravity determined, and compared with the wavelengths adopted by HH following Petrie (1953), Batten et al. (1971) and laboratory data (Moore 1945) so as to derive the blue-shift that one would expect them to have obtained as a result of blending. From the Figures we note that the convolved profiles are smooth with little noticeable asymmetry, so that any method of setting on the line with an oscilloscope comparator is likely to give a setting corresponding quite closely to the centre of gravity. Our results are given in Table I, where they may be compared with the blue-shift of each line relative to the average singlet line deduced from the results of HH (column 6) and the corresponding isotope shift (column 7). The error of our blue-shifts is estimated to be about ±0.04 Å.

**Fig. 3.** Profiles of λ 4026, as in Fig. 1. The blue-shift from peak to centroid is 0.21 Å.

**Fig. 4.** Profiles of λ 3819, as in Fig. 1. The blue-shift from peak to centroid is 0.12 Å.
### Table I

**Wavelengths of He I triplet lines**

<table>
<thead>
<tr>
<th>Our laboratory wavelength (Å)</th>
<th>Petrie wavelength (Å)</th>
<th>HH wavelength (Å)</th>
<th>Wavelength of centre of gravity of convolved profile (Å)</th>
<th>Predicted blue-shift relative to HH wavelength (3)-(4) (Å)</th>
<th>Observed blue-shift relative to mean singlet line after HH (Å)</th>
<th>Isotope shift relative to mean singlet line (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4471.53</td>
<td>71.32(IS)</td>
<td>71.51</td>
<td>71.33</td>
<td>0.18</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>4120.88</td>
<td>20.84(IM)</td>
<td>20.84</td>
<td>20.61</td>
<td>0.23</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>4026.23</td>
<td>26.14</td>
<td>26.14</td>
<td>26.02</td>
<td>0.12</td>
<td>0.19</td>
<td>0.20</td>
</tr>
<tr>
<td>3819.65</td>
<td>—</td>
<td>19.64</td>
<td>19.53</td>
<td>0.11</td>
<td>0.17</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Mean: 0.16 0.20 0.20 0.20
3. DISCUSSION

While individual blending shifts (column 5) do not agree quite as well with the observed shifts (column 6) as do the isotope shifts (column 7), there is satisfactory agreement in relation to the obvious uncertainties. Furthermore, if the intrinsic spectrum of 68 Her resembles that of γ Peg, then the blending shifts must in any case be subtracted from the observed ones before they can be compared with the isotope shifts and when this is done then clearly no convincing correlation with the isotope effect remains. We conclude that the correct radial velocity is near to that given by the concordant 4He singlet and 12C II λ 4267 systems at any given phase.

This result implies, in turn, that the currently adopted wavelength system for B stars (Batten et al. 1971) has to be treated with reserve when applied to rapidly rotating stars, particularly in view of the high setting precision that can now be obtained with the aid of photoelectric scanning measuring machines. Such a conclusion is strongly reinforced by inspection of the standard wavelengths and residuals derived by Petrie (1953) for three of the four lines in Table I in main sequence stars observed at IS (low) dispersion. For λ 4471, Petrie’s IS wavelength is identical to that in column 4 and over and above this the B2 stars have a mean residual blue-shift of 0.1 Å, while for λ 4026 there is again a mean residual blue-shift of 0.09 Å; λ 4121 is rejected altogether at this dispersion. Since the effects of rotation and low dispersion must be very similar, these results of Petrie are in good overall agreement with those of the present paper.

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REFERENCES