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MICROTURBULENCE VS. METAL ABUNDANCE:

AN OBSERVATIONAL TEST

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Conti and Deutsch (1966) have proposed that variations in the Strömgren $\underline{m}_1$ index observed in solar type dwarfs are due to differences in microturbulence. More recently, Conti and Deutsch (1967) have corrected an error in their expression for the line blocking occurring in each of the pass-bands of the uvby system but again state that $\underline{m}_1$ remains appreciably more sensitive to changes in microturbulence than to changes in abundance. A statistical analysis of uvby and Hβ photometric data for late F dwarfs has been made in order to determine quantities directly comparable to Conti and Deutsch's corrected numerical values for the sensitivities of the Strömgren indices $\underline{m}_1$ and b-y to changes in abundance and microturbulence. This analysis indicates, however, that the observed variation in the $\underline{m}_1$ index is due primarily to variations in abundance - not to differences in microturbulence. Furthermore, it shows that the β index is less affected by abundance blanketing than the b-y index and is therefore a more accurate indicator of effective temperature.

Conti and Deutsch (1967) have given the sensitivity of the Strömgren indices to microturbulent blanketing in the form $\delta \underline{m}_1/\delta[V]$ and $\delta(\underline{b}-\underline{y})/\delta[V]$ - where [V] is a parameter incorporating the velocity of microturbulence and the partial derivatives are from their (1966) formalism. A ratio of the sensitivities of the two indices to changes in microturbulence of 6.4 is obtained by dividing their tabulated numerical value of the first quantity by that of the latter. Similarly, $\delta \underline{m}_1/\delta[Fe/H]$ divided by $\delta(\underline{b}-\underline{y})/\delta[Fe/H]$ is the ratio of the sensitivities of the Strömgren indices to a change in metallic abundance. Its value is 1.6.

For the purpose of making an observational test, the partial derivatives may be replaced by small differential changes in the indices due to small differential changes in either microturbulence or abundance while holding the effective temperature constant. Specifically, if the observed ratio of the deviation in m_1 to the deviation in b-y ($\Delta m_1/\Delta[b-y]$) from the values of these indices in a normal solar type dwarf of the same effective temperature were found to be 1.6 rather than 6.4, we would conclude that the cause of the deviations is an abundance difference rather than a difference in microturbulent velocities.

The β index described by Crawford and Mander (1966) has been found in a preliminary investigation by the author to be a relatively accurate indicator of effective temperature for the late F dwarfs. It is felt that a detailed theoretical calculation of the sensitivity of the β index to turbulence blanketing would confirm these results. Since the effect of turbulence blanketing is to increase slightly the strength of Hβ while greatly increasing the strength of the nearby metallic lines, the net effect on the β index would be expected to be very small. Abundance blanketing, however, will tend to decrease the β index by raising the opacity and decreasing the strength of Hβ while leaving the nearby metallic lines largely unaffected.

Crawford, Barnes, Faure, Golson and Perry (1966) have published β indexes for the 1217 A and F type stars measured on the uvby system by Strömgren and Perry (1967). Using a mean representation of their β - (b-y) relation (Crawford, et al., 1966), it is possible to determine the color a dwarf of a given effective temperature and abnormal abundance would have had if it were of normal metallic abundance. The difference between this color and the observed color is a measure of the change in color index due to a change in metallic abundances at a fixed effective temperature.

The change in the m_1 index due to a change in abundance for a star of fixed effective temperature is found by subtracting the m_1 value for a normal star of that effective temperature from the observed m_1 value. A mean relation between m_1 and $b-y$ is required for this calculation. This mean relation shown in Figure 1 was obtained by plotting all of the dwarf stars having uvby photometry (Strömgren and Perry, 1967) on an m_1 - ($b-y$) diagram and drawing in a smooth curve along the apparent center line of the distribution. All high luminosity stars were eliminated from the discussion by making use of the c_1 index as described by Strömgren (1963). The same relation for the Hyades (Crawford and Perry, 1966) is shown approximately $0^{m}.015$ above the mean relation for normal dwarfs.

A sample of 72 late F dwarfs of abnormally high m_1 was selected for a statistical analysis of the ratio of the change in m_1 to the change in $b-y$. A positive value of $\Delta(b-y)$ was found for most of these unreddened stars by using the β - ($b-y$) relation in the usual fashion for determining color excesses. Values of Δm_1 (positive) for each star were obtained by subtracting the m_1 value given by the mean relation in Figure 1 (normal star) at the normal color index (as indicated by the β index) from the measured m_1 for each star.

The absolute frequency function of the ratio

$$R = \Delta m_1 / \Delta(b-y) \quad (1)$$

is given in Figure 2. The high frequency of occurrence of values of $1 < R < 2$ as compared with $6 < R < 7$ strongly indicates that the effect on the m_1 index of differences in microturbulence among these stars is completely dominated by the effect of variations in the metallic abundances.

A second test was carried out using a sample of 61 late F dwarfs of abnormally low $\underline{m}_1$. Most of these were found to have negative color excesses - i.e., their measured colors are too blue for their respective effective temperatures. The absolute frequency function of R for this group is given in Figure 3. The high frequency of occurrence of $1 < R < 2$ gives further evidence of the dominance of abundance variations over variations in microturbulent velocities as the chief source of variations in $\underline{m}_1$ at a fixed effective temperature.

The effect of interstellar reddening on these results would be to destroy the peak at $1 < R < 2$ in Figure 3 while shifting the peak in Figure 2 to lower values of R. The effect of abundance blanketing on the β index would be to destroy the peaks in both distributions. Hence, neither effect can alter the frequency distribution of R toward the [V] value.

The numerous but statistically insignificant negative values of R in Figures 2 and 3 are probably caused by scatter in the photometry. The distribution of negative values of R is found to be very sensitive to the mean β - ($\underline{b}$-$\underline{y}$) relation used. For example, if the mean relation were drawn redward by $0\overset{m}{.}008$, a large number of the negative ratios (R) in the low $\underline{m}_1$ sample would become positive and make the distribution even more convincing. However, this same shift would make a number of positive values of R in the high $\underline{m}_1$ diagram become negative such that the peak at $1 < R < 2$ would disappear. Since the distributions of the negative values of R in Figures 2 and 3 are similar we feel that the β - ($\underline{b}$-$\underline{y}$) relation used in this paper adequately represents the mean of the distribution given in Figure 2 of Crawford, Barnes, Faure, Golson and Perry (1966).

Further support for this conclusion and for the assumption that the β index is a blanketing free indicator of effective temperature, and further evidence that the m_1 index actually is a measure of differences in abundance is given by the Hyades photometry of Crawford and Perry (1966). Since the Hyades have abnormally high metallic abundances by $0^{m}.015$ (Figure 1), the above interpretation leads one to expect that the Hyades β - ($b-y$) relation for late F dwarfs will lie approximately $0^{m}.009$ to the red [$\Delta(b-y) = 0^{m}.015/R = 0^{m}.009$ for $R = 1.6$] of the same relation for normal dwarfs. A comparison of the mean relation used in this paper with that of Hyades does reveal a shift of $0.008 \pm .002$ magnitudes.

Wallerstein (1962) has obtained spectroscopically the variation of [V] with [Fe/H] for G dwarfs. Its slope is such that the effect of a given change in [Fe/H] is four times more effective in changing m_1 than is the corresponding variation in [V] and is therefore compatible with the evidence given by the photometry.

We can conclude from the above photoelectric data alone, that $b-y$ is affected by abundance blanketing in the late F dwarfs; that the β index is a more accurate indicator of effective temperature than $b-y$; and that the m_1 index primarily measures changes in the metallic abundances of these stars.

I wish to express thanks to H. Abt, R. Cromwell, W. Fitch, T. Swihart, and R. Weymann for helpful discussions of this problem. I am also grateful to P. Conti and A. Deutsch, B. Strömgren and C. Perry for making preprints of their papers available.

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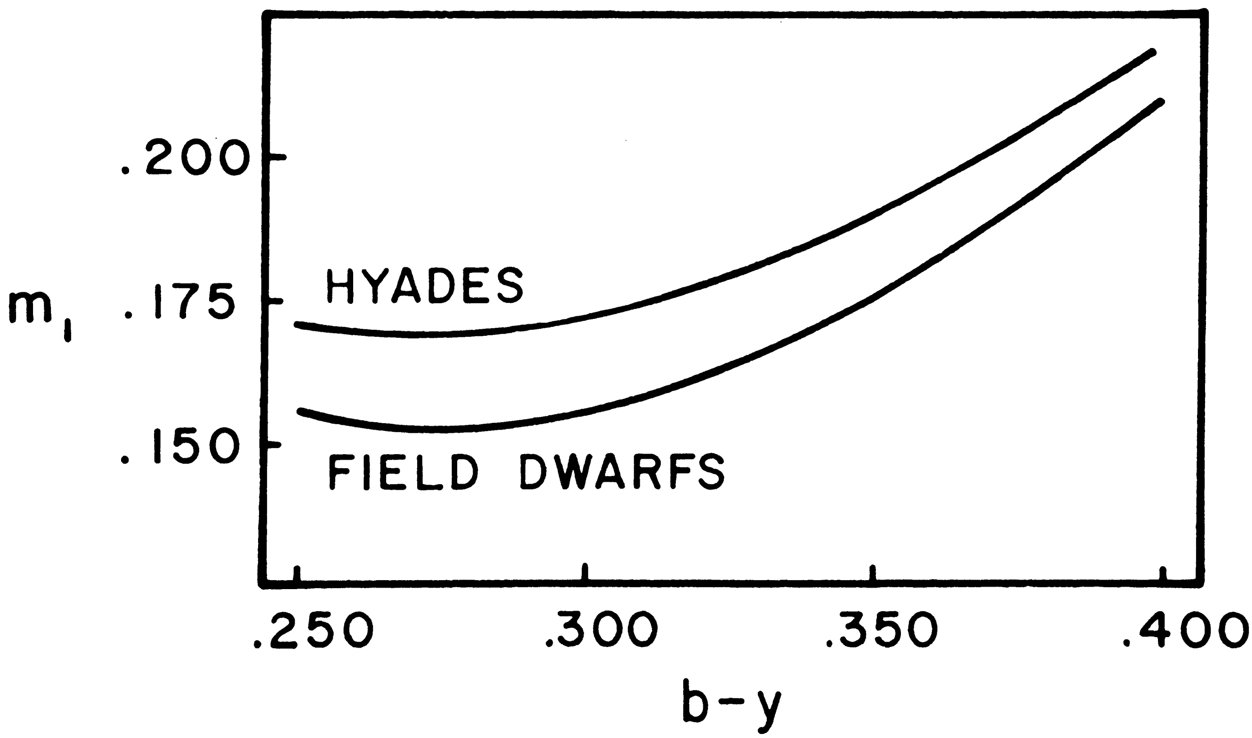

Fig. 1. - The mean $\underline{m}_1$ - ($\underline{b}$-$\underline{y}$) relation for the late F dwarfs in the solar neighborhood lies below the same relation for the Hyades.

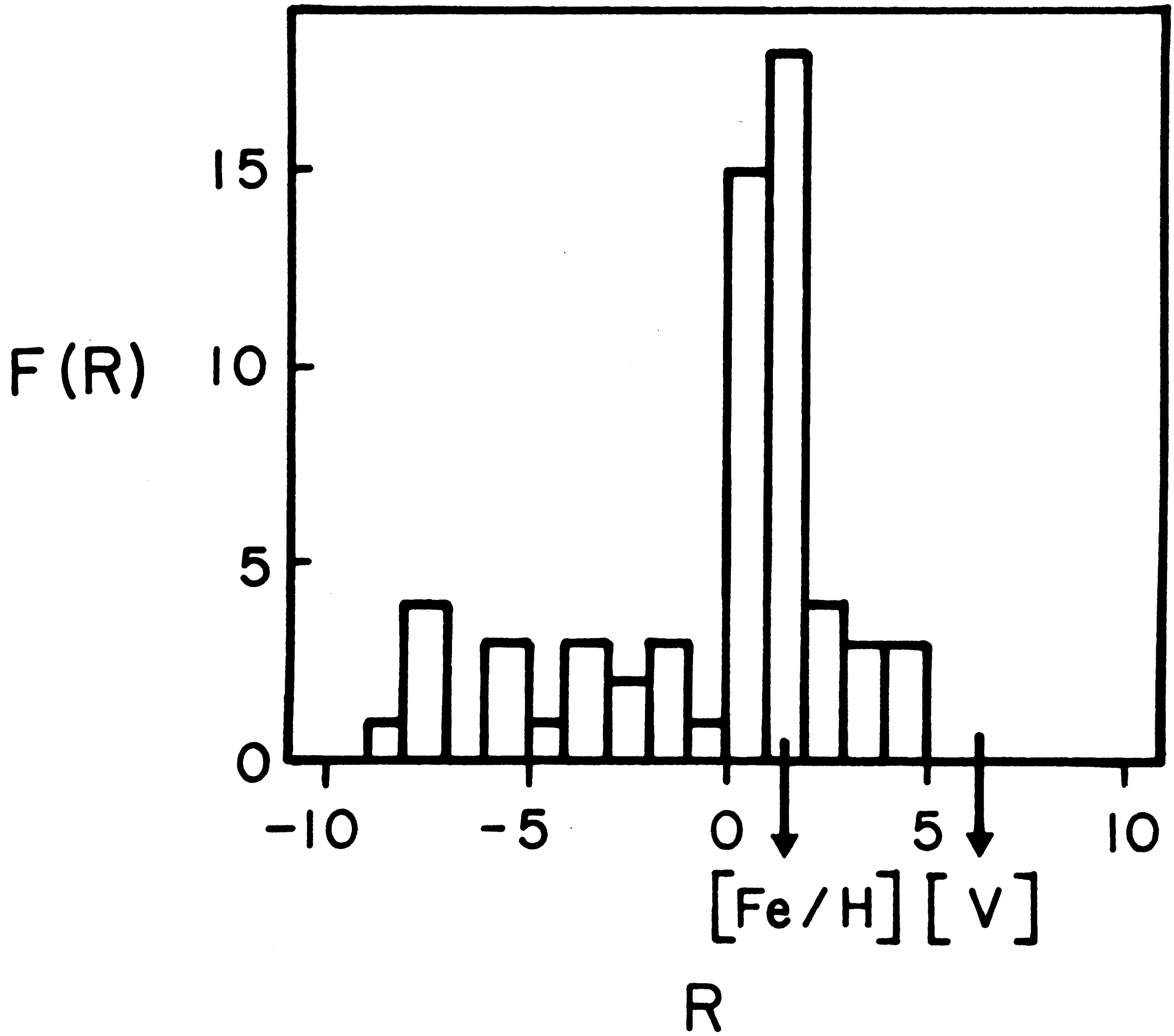

Fig. 2. - The absolute frequency function of R [cf. eq. (1)] for 72 late F dwarfs of abnormally high $\underline{m}_1$. Five of these stars gave R < -10 while six others gave R > +10.

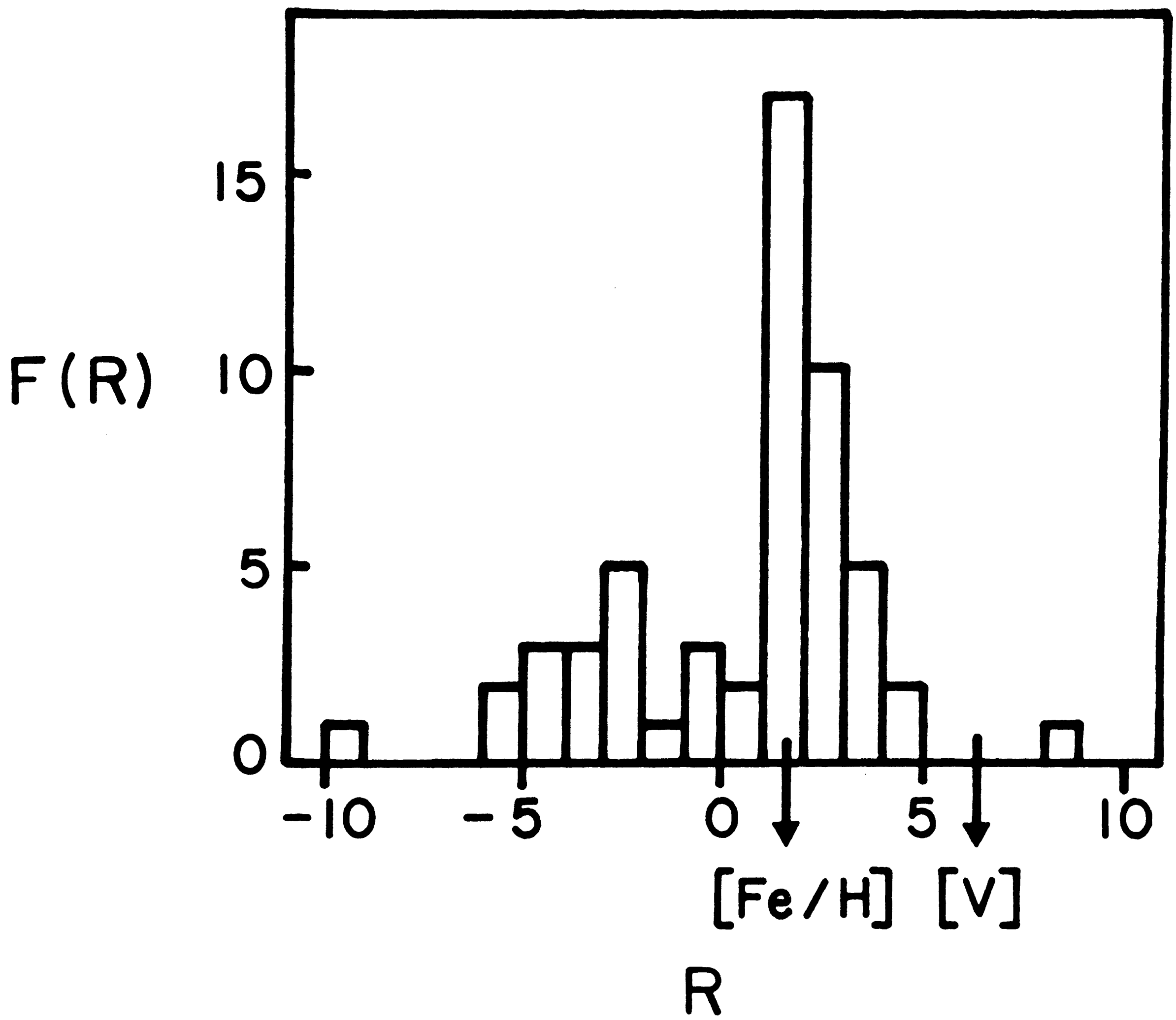

Fig. 3. - The absolute frequency function of R [cf. eq. (1)] for 61 late F dwarfs of abnormally low $\underline{m}_1$. Four of these stars gave R < -10 while two others gave R > +10.