ON THE VARIATION OF THE MICROTURBULENCE PARAMETER WITH CHEMICAL COMPOSITION

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ABSTRACT

It is shown that the correlation found by previous investigators between the value of the microturbulent velocity parameter ξ_t and the iron to hydrogen ratio for G dwarfs results from invalid assumptions implicit in the differential curve-of-growth techniques used to derive ξ_t. By using model atmosphere abundance analyses, the deduced values of ξ_t will be very close to the mean value found for stars for approximately solar composition.

Several authors (e.g., Wallerstein 1962, Aller and Greenstein 1960) have suggested on the basis of differential curve-of-growth (DCOG) analyses that extreme subdwarf atmospheres are characterized by unusually small values of the turbulent velocity parameter ξ_t. Wallerstein (1962) has presented evidence that the turbulent velocity decreases along with the iron-to-hydrogen ratio and thus, in a crude way, with age. This suggestion has led to the speculation that the lower values of ξ_t ($\xi_t \lesssim 1$ km/sec) for the most metal-deficient subdwarfs are related to the decrease of chromospheric activity with age. Recent work by Cohen and Strom (1968), based on detailed model atmospheres, contradicts the results of previous investigations in that for two extreme subdwarfs, HD 19445 and HD 140283, they find, respectively, $\xi_t \sim 2$ km/sec and $2 \lesssim \xi_t \lesssim 3$ km/sec.

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In this note we present arguments that demonstrate that the lower values of ξ_t derived previously for subdwarfs are a result of the assumptions implicit in the DCOG analyses, and that the true values of ξ_t are likely to be close to those found for normal G dwarfs.

Computation of stellar abundances using DCOG techniques have long been popular because errors in the assumed transition probabilities, atmospheric structure, and thermodynamic state of the gas, as well as observational errors, tend to cancel if two stars of fairly similar temperature, gravity, and composition are compared and if homogeneous plate material is used. In the previous work on subdwarfs quoted above, the authors all performed DCOG analyses using the sun as the primary abundance standard. Since the temperatures and gravities of the subdwarfs under analysis differed only slightly from the solar values of these quantities, the DCOG technique would be expected to yield reasonable results. However, the difference in composition between a subdwarf and the sun produces a somewhat subtle but essential change in the temperature structure of the atmosphere. In particular, the subdwarf has a lower metal-to-hydrogen ratio and hence a lesser degree of blanketing, owing to the presence of spectral lines. The temperature structures of the sun and of a subdwarf of matching emergent continuum flux in the visible are compared in Figure 1, where we sketch the qualitative behavior of the $T(\tau)$ relation for the sun and the subdwarf. Note that, owing to the greater line blanketing, the sun has a lower temperature for $\tau \lesssim 5 \times 10^{-2}$. The temperature difference at the boundary can be as great as $\Delta T_b \sim 0.05\, T_{eff}$, or approximately 300°K for stars of near-solar effective temperature.

The lines on the weak-line part of the curve of growth are formed primarily in the optical depth region marked W in Figure 1, whereas the lines on the saturated part of the curve are formed in region S. Only lines of Fe I appear in sufficient quantity in the subdwarfs to obtain reliable values of ξ_t from the curve of growth. Since the temperature for subdwarfs in region S is higher than is the case for the sun, the fraction of Fe that is Fe I is consequently lower relative to region W, where the solar and subdwarf temperatures are almost the same. In both the solar and subdwarf cases, Fe is almost entirely singly ionized. A qualitative comparison between the solar and subdwarf curves of growth that result for Fe I is shown in Figure 2. The linear parts of the curve have been shifted to take account of the differing iron-to-hydrogen ratio. The difference in electron pressure caused by the differing compositions of the sun and the subdwarf has little effect on the shapes of the curves of growth, since we are comparing the strengths of the saturated lines relative to those of the weak lines.

If one uses the solar curve of growth to analyze the subdwarf, one would deduce that ξ_t is lower in the subdwarf. This is precisely the result obtained from the DCOG techniques. The model atmosphere approach used by Cohen and Strom (1968) avoids this difficulty, however, and higher values of ξ_t are deduced.

An argument analogous to the one outlined above may explain why stars having higher iron-to-hydrogen ratios than does the sun appear to have somewhat higher values of ξ_t. In these metal-rich stars we expect the boundary temperature to be lower, owing to the increase in the importance of line blanketing. Therefore, the Fe I lines on the saturated part of the curve of growth are somewhat stronger relative to the solar curve of growth and lead to an overestimate of the turbulence.

Assignment of excitation temperatures for stars of differing composition may also result owing to the differences in temperature structure caused by line blanketing.

This work suggests that the correlation between turbulence and composition found previously may not be real. The correlation appears to result primarily, if not entirely, from the failure of the DCOG method of analysis to take account of the differential changes in atmospheric structure caused by line blanketing.

REFERENCES

Aller, L. H., and Greenstein, J. L. 1960, Ap. J. Suppl. **5**, 139.

Cohen, J. G., and Strom, S. E. 1968, Ap. J. (in press).

Wallerstein, G. 1962, Ap. J. Suppl. **6**, 407.

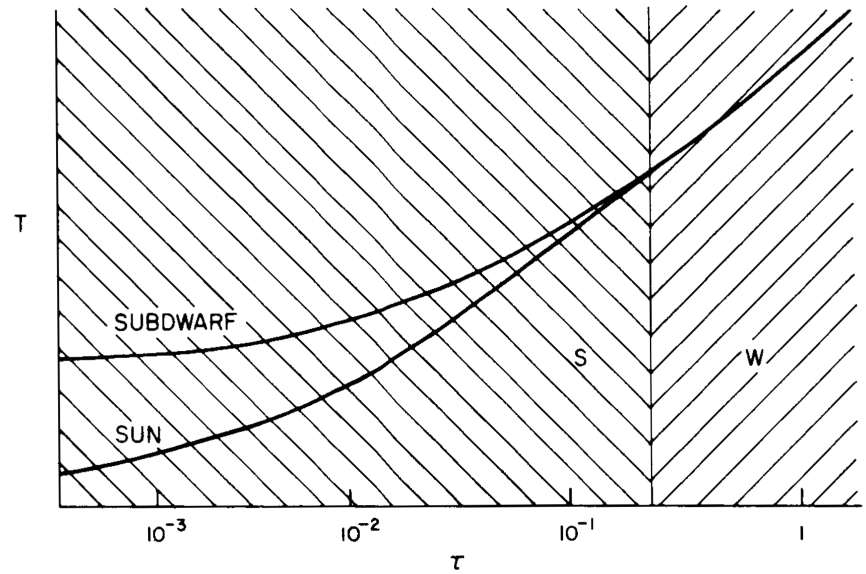

Fig. 1 — The behavior of the temperature-optical depth relations for the sun and for a typical subdwarf. The regions of weak (W) and saturated (S) line formation are indicated.

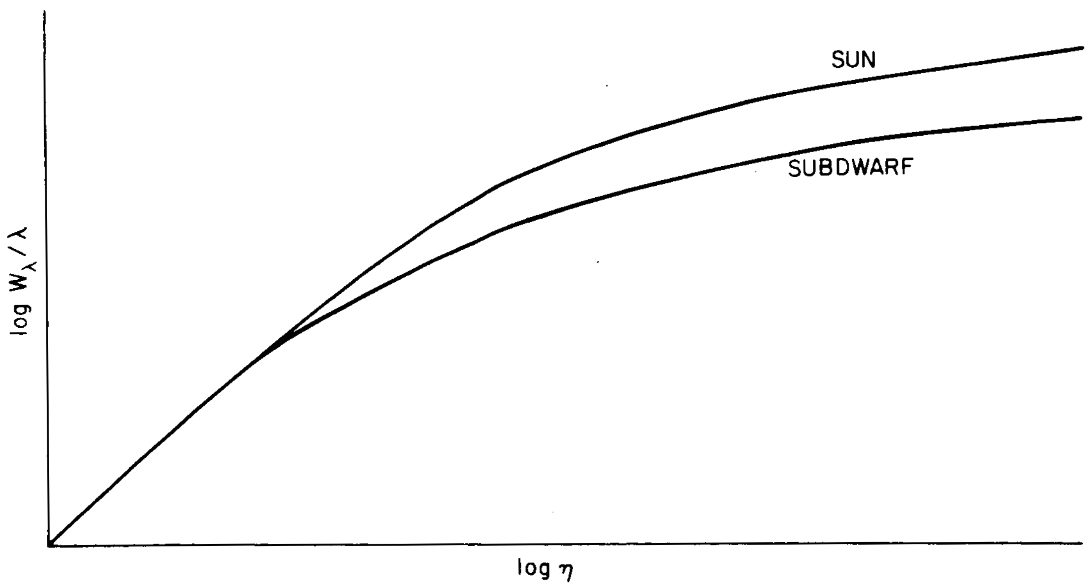

Fig. 2 — The qualitative behavior of the curve of growth for Fe I for the sun and for a typical subdwarf.