MICROTURBULENCE AS A THIRD DIMENSION IN THE G-K GIANT REGION OF THE HR DIAGRAM

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The structure of the HR diagram in the G-K giant region is complex, because of the funneling effect and of the intersection of evolutionary tracks for different stellar masses. Therefore it is impossible to derive the age of a cool giant from its location in the HR diagram alone. To remove this indeterminacy a third dimension is needed, and we suggest microturbulence as the appropriate observational parameter.

Three points have to be discussed before supporting this idea:

1) microturbulence is not a spurious effect due to departures from LTE,
2) microturbulence is related to physical parameters of stellar atmospheres, and,
3) microturbulence is a function of stellar evolution.

1. MICROTURBULENCE AND NON-LTE EFFECTS

If microturbulence is a spurious parameter resulting from non-LTE effects in stellar detailed analyses, it is expected to increase with decreasing atmospheric gaseous pressure or with decreasing gravity. Some star to star comparisons do not confirm this relation. For instance ε Vir (HD113226) and HD 192947 have the same effective temperature T_{eff}, gravity g and metal content. Their saturated spectral lines have to be equally sensitive to non-LTE effects. On the contrary, ε Vir and HD 192947 have markedly different microturbulent velocities: 1.8 and 0.8 km/s respectively. Hence, for such stars as ε Vir, departures from LTE cannot dominate in the interpretation of the line saturation level.

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2. MICROTURBULENCE VERSUS ATMOSPHERIC PHYSICAL PARAMETERS

We have searched for relations between ξ and T_{eff}, g and metal content. For this purpose we have reanalyzed a set of 98 G-K giants and supergiants for which reliable equivalent width data are available (22 from Helfer and Wallerstein (1964), 19 from Luck (private communication), 12 from Oinas (private communication), 11 from Pilachowski (private communication), and the 34 remaining from our group in Meudon: Cayrel, G. and R., Foy, Kovacs, Pasinetti, and Spite, F. and M.

Here all stars have been analyzed in the same way, so that if systematic errors occur, they do not affect our actual results, since we are interested in relative effects only. The effective temperatures have been deduced from the (R-I) versus T_{eff} relation by Johnson (1966), and the gravities from the condition of ionization equilibrium applied to iron for the assumed values of T_{eff}, i.e.: weak lines of both Fe I and Fe II must lead to the same iron abundance. The abscissae of the curves of growth have been computed using model atmospheres rescaled from those of Gustafsson et al. (1975). Iron abundances and microturbulent velocities have been derived from the Fe I curves-of-growth. We have found reliable results for 84 stars out of 98.

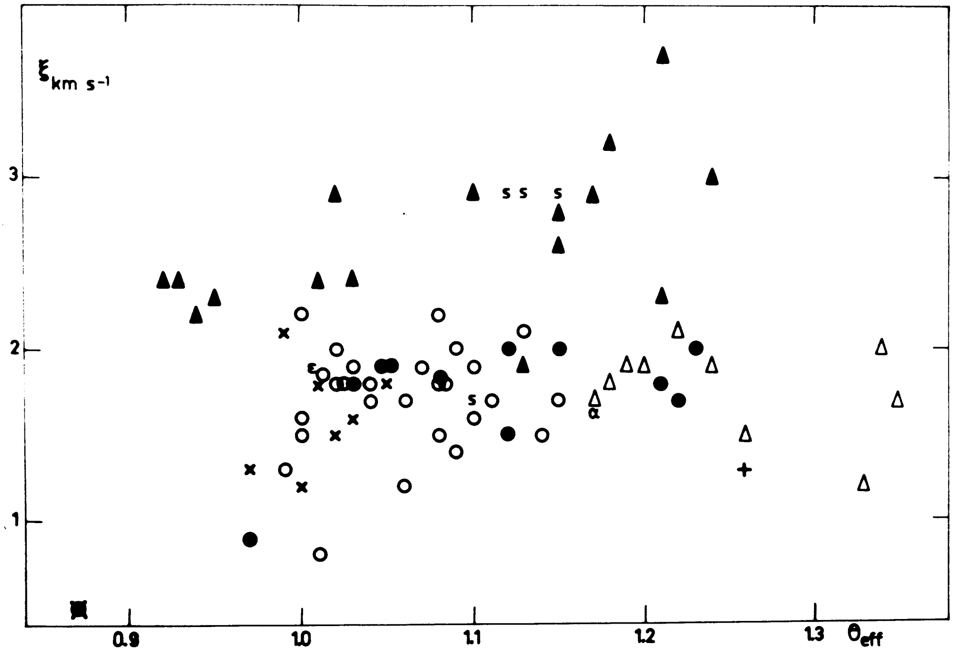

Fig. 1. Microturbulence ξ as a function of Θ_{eff}. Symbols; supergiants = ▲. giants = log g > 3.0 = X; 2.5 < log g < 3.0 =O; 2.0 ≤ log g < 2.5 = ●; 1.0 ≤ log g < 2.0 = Δ; log g < 1.0 = +; very metal-poor stars = S.

The interpretation of the results has demonstrated the following points:

1) ξ does not correlate with Fe/H;

2) ξ correlates with $\theta_{eff} = 5040/T_{eff}$ and g (Fig. 1). For supergiants there is a trend of increasing ξ with increasing θ_{eff}. A similar trend occurs for giants, except in the coolest part of the diagram. A main feature of Fig. 1 is also the dependence with g. In spite of the spread of the relation, one sees that ξ is a function of T_{eff} and g. Thus we confirm the preliminary results given in Foy (1976, 1977) for a smaller sample of stars.

This θ_{eff}/ξ relation does not fit the relation: $\xi \approx T^{1.1}g^{-0.2}$ predicted by Reimers (1973, 1975) from a compilation of ξ measurements in literature, and from a relation between ξ and M_V derived from the H and K emission lines.

3. VARIATION OF ξ WITH EVOLUTION

Note that during the evolution of a star near and along the first asymptotic branch both T_{eff} and g decrease. It is clear on a log g/θ_{eff} diagram that the observed log g/θ_{eff} relation of Fig. 1 fits the theoretical evolutionary tracks in the vicinity of the Hayashi boundary. Furthermore it appears that ξ is lower at the base than at the tip of the asymptotic branch. Thus microturbulence is related to stellar evolution.

The low-ξ giant HD 192947 markedly departs from the mean ξ/log g relation. It appears that it is evolving not in the hydrogen burning shell, as most of the analyzed stars, but in the helium burning core phase. The same conclusion occurs for the few low-ξ stars for which an evolutionary state can be determined, so that ξ could the the third parameter needed for this part of the HR diagram.

An improvement of this study could be an analysis of a set of stars as numerous as the present one, but based on spectra obtained with a same spectrograph, in order to minimize the scatter of the correlations.

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DISCUSSION

BELL: Firstly, how have you checked that your material is homogeneous? Different observers draw continua differently.

Secondly, have you compared your results with those of Gustafsson, Kjaergaard and Andersen (Astr. Astrophys. 34, 99)? Their very narrow band photometry using two bands, one containing lines sensitive to abundance and the other containing lines sensitive to microturbulence, allows them to obtain very precise measures of both quantities.

FOY: I have rescaled the equivalent width sets, using stars studied in common, generally ε Vir.

Too few stars are in both the list by Gustafsson et al. and my list to allow this comparison. I would mention that the gravity and microturbulent velocity ranges in the sample by Gustafsson et al. is much smaller than the present one. This would make such a comparison more difficult.

STENCEL: I am pleased to see your correlation between microturbulence and gravity for G and K stars since it agrees with my own work on this from the Ca II lines. However, we should be perhaps more cautious in deducing log g from the ionization equilibrium of iron in K stars due to departures from LTE recently demonstrated by Ramsey (1977 Astrophys. J.).

Do you have any results on the variation of macroturbulence with temperature and gravity?

FOY: I think it is possible that departures from LTE cause decreasing ξ in the coolest part of the ξ versus θ_{eff} diagram for giants. But I do not think that NLTE effects give a significant bias for most of my sample. Indeed Oinas (1974) had mentioned problems with the ionization equilibrium for K giants. But Perrin, et al. (1975) have removed these difficulties and Oinas (1977) now thinks that problems occur only after spectral type K3III.

I am just now beginning to study macroturbulence.

CAYREL de STROBEL: I have a comment on Oinas' unknown absorber: It is difficult to imagine that the departure from ionization equilibrium is due to an unknown absorber in late K stars. For us, it is easier to attribute this departure to effects of NLTE.