MICROTURBULENCE : AGE DEPENDENCES

R. Foy
Observatoire de Paris
92190 Meudon/France

The study of microturbulence in stars for itself,and not as a by-product of abundance determinations,is relatively recent.The first comprehensive study on this topic was carried out in 1966,by Bonsak and Culver.They found general trends of the behaviour of microturbulence ξ in the HR diagram.A decisive advance occured when Garz and Kock (1969) revised the scale of oscillator strengths of iron and,as a consequence, the value of the microturbulent velocity in the solar photosphere.The use of microturbulent velocities determined before 1969 should be avoided.

Before describing what we know about the behaviour of microturbulence with stellar age,I shall make some statements,and describe how the microturbulent velocity is found,from observations,to depend on the atmospheric parameters.

First,we shall be concerned here with stars in the spectral type range A5 - K5.Second,I shall distinguish the changes in microturbulence as a function of mass at fixed evolutionary stage,namely the main sequence,from the changes on microturbulence during the stellar evolution at fixed mass.Lastly,I shall consider the so-called microturbulent velocity as a physical atmospheric parameter,and not as an artificial parameter.

I determined microturbulent velocities for a sample of nearly 120 stars,from the vertical shift of the neutral iron curve of growth;I used our equivalent widths in Meudon,or published data;thus we considered large sample of stars measured in a homogeneous way.Equivalent widths were rescaled,using stars studied in common in at least two data sets.

Abscissae of the curves of growth were computed with model atmospheres,rescaled either from Gustafsson et al (1975) for giants or from Peytremann (1974) for dwarfs.Oscillator strengths were taken from my compilation (1972) or determined in the same scale from the weak line part of my solar curve of growth by Cayrel et al (1977).

https://doi.org/10.1017/S0252921100075333 Published online by Cambridge University Press

DWARFS

In the case of dwarfs, the splitting of the damping part of the curve of growth is already present on the plateau of the curve of growth. The resultant dispersion of the flat part of the curve of growth has been interpreted in terms of random errors in the measurements either of the line equivalent widths, or from the abscissae of the curves of growth : this also led to systematic enhancements of the microturbulent velocity. This effect is dependent on the stellar gravity, as shown by Cayrel et al (1977), so that microturbulence measurements in dwarfs are often biased with respect to those for giants.

So the determination of ξ in dwarfs appears to be difficult for four reasons. First, the plateau is not at all horizontal; second, a slight error in the damping constant affects the level of the plateau; it means that in differential analysis, a difference in gas pressure does the same; third, the low excitation lines, which are less affected by damping, are not numerous; finally fourth, the microturbulent velocity is small as compared to the thermal velocity. Consequently noise is a severe problem.

I reanalysed published equivalent width data of dwarfs, observed with a reciprocal dispersion ranging around 3 Å/mm. The splitting in the damping part of the curve of growth is clearly visible, but this is not the case on the flat part, because of experimental errors. Therefore only an upper limit to the microturbulent velocity can be proposed.

The determination of the microturbulent velocity in solar type dwarfs does not appear very reliable to me. Note that this conclusion applies to the currently available spectroscopic material, but not to the very high resolution data obtained with modern techniques.

Consequently, the wellknown increase of microturbulence with increasing temperature along the main sequence should be reconsidered. Andersen (1973) found an increased microturbulence near spectral type A5, which is of particular interest. If it is real, it could be interpreted in terms of ages. The microturbulent velocity would be decreasing with increasing age, since A type stars are much younger on the average than G type stars. But I suspect that this trend could be interpreted in another way. Indeed a lot of Am stars which are in fact subgiants or giants are included in ξ versus T_{eff} relations, so that these relations could provide a valuable check of the change in microturbulence with stellar evolution.

https://doi.org/10.1017/S0252921100075333 Published online by Cambridge University Press

GIANTS

Such a change is now well established for yellow stars : the microturbulent velocity in G and K giants is significantly larger than in dwarfs, provided the Sun is not an exception. Figure 1 shows the distribution of

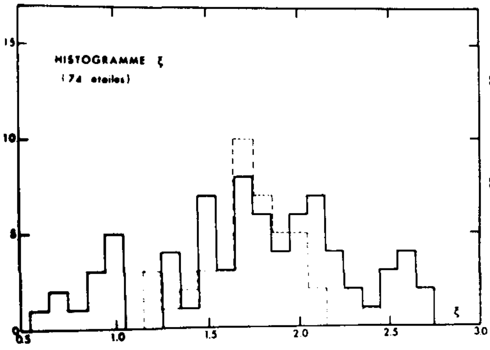

Figure 1. Distribution of microturbulence among G - K giants.

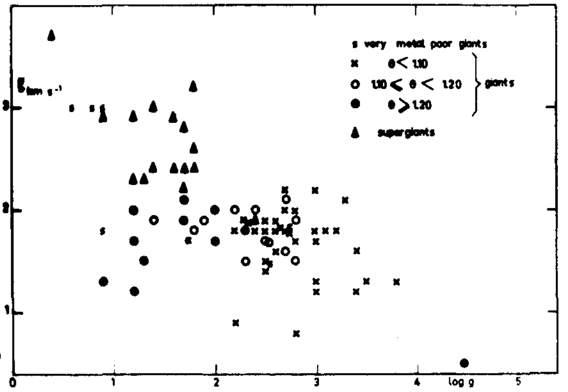

Figure 2. Microturbulent velocity versus surface gravity for giants.

the microturbulent velocity among giants : it is systematically larger than the solar value. The dotted line shows the distribution of microturbulence among giants obtained by Gustafsson et al (1974), from a sample having a narrower gravity range, using narrow band photometry.

The microturbulence appears to be strongly correlated with the surface gravity (Figure 2). However I do not venture to propose an analytical expression for this dependence. It tends to disappear when we remove supergiants and the Sun, i.e. when we reduce the gravity range of the sample. Inversely, it is better defined when removing only stars cooler than $\theta_{eff} = 5040/T_{eff} = 1.20$. The dependence of the microturbulence on the effective temperature is also better defined when removing the coolest stars (Figure 3). Could this be due to model effects? Or to a more complicated relationship?

Figure 4 shows that this is likely the case. Here we plot the gravity versus the effective temperature, with three microturbulent velocity ranges. Evolutionary tracks for 2 and 2.5 solar masses are shown for the asymptotic branch phase. From this diagram, the proportion of low values

https://doi.org/10.1017/S0252921100075333 Published online by Cambridge University Press

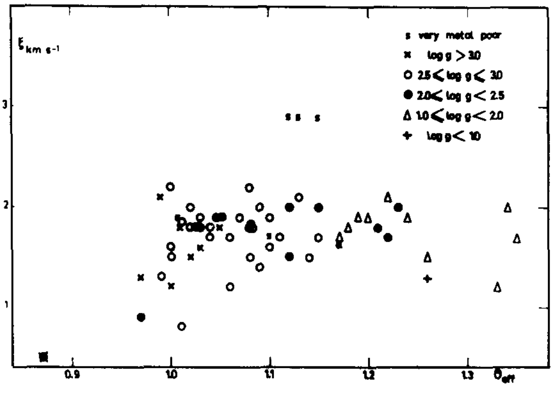

Figure 3. Microturbulent velocity versus effective temperature for giants.

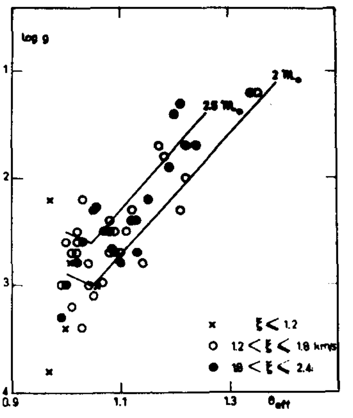

Figure 4. Behaviour of microturbulent velocity as compared to evolutionary tracks in the log g versus θ_{eff} plane.

of ξ relative to high values is smaller near the red giant tip than near the base of the asymptotic branch.Note that here we are concerned with a relatively small gravity range,but with a quite large effective temperature range.In this case no relation is clear on figures 2 and 3.

The same increase in ξ with stellar evolution occurs on the HR diagram (Figure 5).The less evolved giants have,on the average,lower microturbulent velocities than giants ascending the first asymptotic branch.There is a relatively clear cut division just at the beginning of the asymptotic branch,corresponding to the abrupt decrease in the atmospheric opacities and the rapid inward growth of convection.

It is also possible that microturbulence decreases after stars leave the red giant tip when they burn Helium in their core;during the Helium burning core,the efficiency of convection is rapidly decreasing (Iben,1967).I found (Foy,1978) indications that field giants with low microturbulent velocities would be evolving in the Helium burning core phase.An exemple is HD 71369,a G5 giant member of the Hyades group.Eggen (1972) found that it is one magnitude brighter than other giants having the same value of the R-I colour index;he suggested that its evolutionary state is different from that of the other giants in the Hyades group : it could evolve on a loop following the Helium core ignition.I found its microturbulent velocity to be as low as 0.8 km/s.

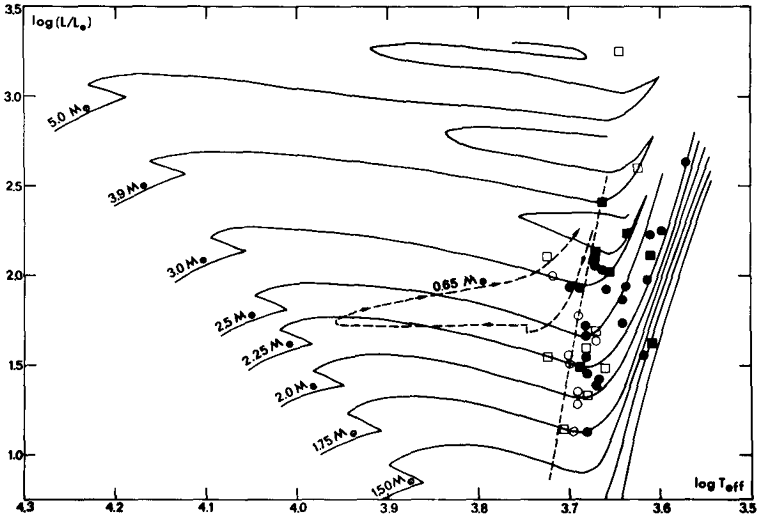

Figure 5. Behaviour of microturbulent velocity as compared to evolutionary tracks in the HR diagram.

To derive firm conclusions concerning this last relationship would require a comparison between the microturbulence in horizontal branch and asymptotic branch giants in a cluster;indeed the location on the horizontal branch is less questionable in the case of a cluster than for field stars.

Another program would be to use very high resolution techniques for a sample of bright field dwarfs,selected in two ways : firstly along the zero age main sequence,and secondly,perpendicularly to it.This program should provide information about the dependence of microturbulence on age,independently of the gravity and the temperature.

REFERENCES

Andersen,P.H.:1973,Publ.Astron.Soc.Pacific 85,666
Bonsack,W.K.,Culver,R.B.:1966,Astrophys.J. 145,767
Cayrel,G.,Cayrel,R.,Foy,R.:1977,Astron.Astrophys. 54,797
Eggen,O.J.:1972,Publ.Astron.Soc.Pacific 84,406
Foy,R.:1972,Astron.Astrophys. 18,26
Foy,R.:1978,Astron.Astrophys. 67,311
Garz,T.,Kock,M.:1969,Astron.Astrophys. 2,274
Gustafsson,B.,Bell,R.A.,Erikson,K.,Nordlund,A.:1975,Astron.Astrophys. 42,407

Gustafsson,B.,Kjaergaard,P.,Andersen,S.:1974,Astron.Astrophys. 34,99
Iben,I.Jr.:1967,Ann.Rev.Astron.Astrophys. 5,571
Peytremann,E.:1974,Astron.Astrophys. 33,203