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Evidence for the Hydrodynamic Character of Microturbulence

Worrall and Wilson[1] have questioned the validity of determinations of the chemical composition of stellar atmospheres from observations of absorption lines in stellar spectra. Their main argument is directed against the concept of "microturbulence", which has been used for several decades to explain the high level of the flat part of the curve of growth. It was first introduced by Struve and Elvey[2] to account for the apparent systematic variation of the abundances with the total amount of absorption (equivalent width) of the spectral lines from which they are derived. Microturbulence is thought of as a statistical velocity field in the stellar atmosphere, with moving gas elements whose optical depths for the photons to be absorbed are smaller than unity. This small scale velocity field widens the frequency interval for the absorption of photons; this has no influence on the strength of the weak lines, but the equivalent width of saturated lines is increased. In the curve of growth, which represents the relation between the effective number of absorbing particles in the stellar atmosphere and the equivalent width of the absorption line, the flat part of the saturated lines is lifted. Thermal motion of the absorbing atoms frequently fails to account for the level of the flat part of the curve of growth; according to Worrall and Wilson this is the only independent evidence for the existence of small scale turbulent motion in stellar atmospheres. Their statements on this point are strong: " . . . There are no independent observations even suggesting that such small-scale, non-thermal motion exists, much less defining its amplitude. . . . ". Worrall and Wilson

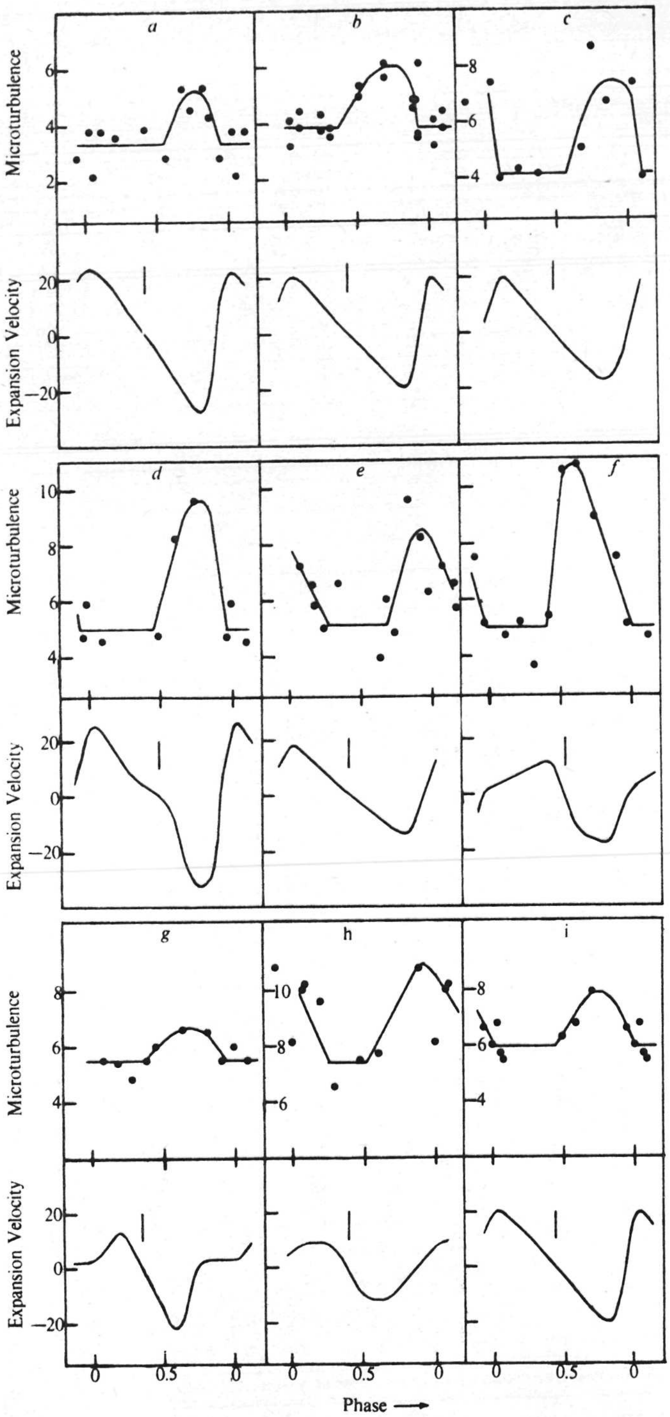

Fig. 1 The variation of the microturbulence and the radial pulsation velocity (in km s^{-1}) for a number of classical cepheids. The small vertical line in the radial velocity diagram denotes the phase of largest expansion. *a*, RT Aur; *b*, δ Cep; *c*, U Sgr; *d*, η Aql; *e*, κ Pav; *f*, S Nor; *g*, β Dor; *h*, Y Oph; *i*, l Car.

suggest that the level of the flat part of the curve of growth is determined by non-local thermodynamic equilibrium (LTE) effects. I show here that other observations, supporting the concept of microturbulence, do exist.

In all abundance analyses from high dispersion spectra of cepheid variables, which have been reported[3–14], a common feature is that microturbulence is variable with phase. Furthermore, in all stars considered, this variation of the microturbulence is strongly correlated with the variation of the radial pulsation velocity. The variation with time of these properties is shown in Fig. 1. A general feature is that the microturbulence is increasing after the star has reached its largest radius and the atmosphere is falling downward. The phase of largest expansion is indicated by a small vertical line in Fig. 1. A straightforward interpretation of this correlation is that in the falling atmosphere there is a transfer of turbulent kinetic energy from large scale to small scale motion, similar to the case of homogeneous turbulence[15]. A correlation between irregular changes in microturbulence and radial velocity has also been found in some "non-variable" supergiants[16]. The influence of departures from LTE on the level of the flat part of the curve of growth would be expected to depend on the electron pressure, since collision with electrons is the most important mechanism yielding LTE. A comparison of the variation of electron pressure with that of microturbulence shows that there are difficulties with an explanation in terms of non-LTE processes only. Often the electron pressure hardly changes, whereas the microturbulence does so, and the other way around.

These observations strongly suggest that the microturbulence as used in coarse curve of growth analyses is, at least in part, a real hydrodynamic effect.

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1 Worrall, G., and Wilson, A. M., *Nature*, **236**, 15 (1972).
2 Struve, O., and Elvey, C. T., *Astrophys. J.*, **79**, 409 (1934).
3 Bappu, M. K. V., and Raghavan, N., *Mon. Not. Roy. Astron. Soc.*, **142**, 313 (1969).
4 Shane, W. W., *Astrophys. J.*, **127**, 573 (1958).
5 Paradijs, J. A. van, *Astron. Astrophys.*, **11**, 299 (1971).
6 Joy, A. H., *Astrophys. J.*, **86**, 393 (1937).
7 Schmidt, E. G., *Astrophys. J.*, **170**, 109 (1971).
8 Schwarzschild, M., Schwarzschild, B., and Adams, W. S., *Astrophys. J.*, **108**, 207 (1948).
9 Stibbs, D. W. N., *Mon. Not. Roy. Astron. Soc.*, **115**, 363 (1955).
10 Rodgers, A. W., and Bell, R. A., *Mon. Not. Roy. Astron. Soc.*, **125**, 487 (1962).
11 Rodgers, A. W., and Bell, R. A., *Mon. Not. Roy. Astron. Soc.*, **127**, 471 (1963).
12 Rodgers, A. W., and Bell, R. A., *Mon. Not. Roy. Astron. Soc.*, **138**, 23 (1968).
13 Sanford, R. F., *Astrophys. J.*, **81**, 140 (1935).
14 Dawe, J. A., *Mon. Not. Roy. Astron. Soc.*, **145**, 377 (1969).
15 Batchelor, G. K., *The Theory of Homogeneous Turbulence* (Cambridge University Press, London, 1956).
16 Rosendhal, J. D., and Wegner, G., *Astrophys. J.*, **162**, 547 (1970).

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