TURBULENT SOUND GENERATION IN RED DWARF STARS

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INTRODUCTION

Since the acoustic heating theory (c.f. Ulmschneider 1979) has been proven successful for the solar chromosphere, it was common practice to extend this concept to other stars. However, as it appeares from observed chromospheric and coronal emissions, the usual theoretical acoustic fluxes for red dwarf star, particularly, are too small to account for the heating of chromospheres and coronae (e.g. Blanco et al 1974; Vaiana et al, 1981). It is therefore the intention of this paper to discuss improvements on the current model calculations for turbulent sound generation from outer convection zones.

IMPROVED MODEL CALCULATIONS

A grid of convection zone models with effective temperatures between 2500 K and 9500 K and log g=4 and 4.5 representing the physical parameters of red dwarf stars has been constructed using the standard mixing length theory (Cox and Giuli, 1968). The chemical composition has been chosen as X : Y : Z = 0.68 : 0.30 : 0.02 by mass as for population I stars. The ratio of mixing length to pressure scale height, α, was assumed to be 1.0 for all models.

The opacity was interpolated from the third generation Los Alamos tables by Cox and Tabor (1976). For temperatures below 5500 K, where absorption by dust and molecules becomes dominant, the corresponding tables by Alexander (1976) were taken instead. At low temperatures this absorption coefficient is several orders of magnitude larger than the Cox and Tabor (1976) opacity.

The thermodynamical quantities have been calculated by the simultaneous solution of Saha equations for particle densities and an equivalent equation for the H_2-dissociation. Due to this molecular dissociation the adiabatic temperature gradient reaches a low value

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(< 0.4) at low temperatures and high pressures which facilitates convective instability.

Previous calculations of stellar acoustic fluxes rely on the Lighthill - Proudman theory (Lighthill, 1952; Proudman, 1952). Therefore a homogeneous atmosphere without mechanical boundaries is assumed which implies a pure quadrupole source term in the inhomogeneous wave equation. It has been known for some time, however, that for gravitationally stratified stellar atmospheres dipole and monopole sound generation can also be expected (Unno, 1964).

Stein (1967) generalized Lighthill's theory for density stratifications due to stellar gravity. With his method it is possible to solve the inhomogeneous wave equation numerically after a multipole expansion of the source term. Stein's (1967) code was used to calculate the turbulent sound generation in the convection zones, so monopole- and dipole-terms superpose the usual quadrupole emission. A comparison of the pure quadrupole-, dipole-, and monopole- fluxes revealed an increasing importance of monopole and dipole sound generation for stars of later than solar type. Monopole emission even becomes dominant for dwarfs cooler than 4000 K.

Figure 1 exhibits the total acoustic fluxes from this work (drawn line) in relation to the results of DeLoore (1970; broken line) and the chromospheric CaII fluxes from Blanco et al. (1974). It is evident that the revised acoustic fluxes are comfortably larger than the absolute CaII emissions and the claim that chromospheres are heated by sound waves can be maintained. In the same way, a comparison of the total acoustic flux with observed X-ray emissions of main sequence stars in Figure 2 shows that even acoustic heating of coronae can no more be ruled out by mere insufficiency arguments (thin lines: results of Renzini et al., 1977; fully drawn histogram: observations by Vaiana et al. 1981).

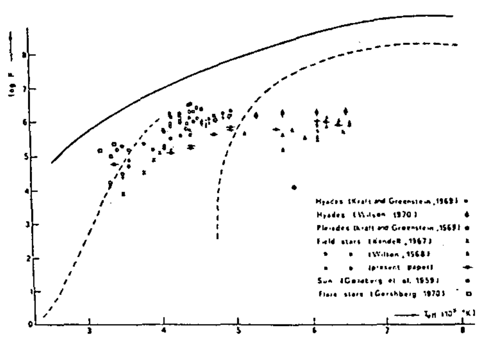

Figure 1

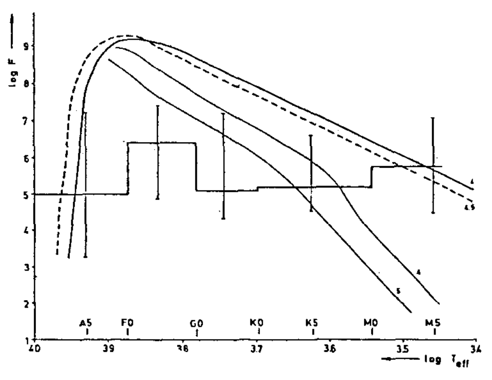

Figure 2

CONCLUSIONS

The refined calculation of acoustic energy generation from red dwarf stars carried out in this work appears to have removed the insufficiency argument (Linsky, 1980) against the theory of acoustic heating of stellar chromospheres and coronae. This is especially true in view of the conservative assumption which led to these results, as the assumed value of $\alpha = 1.0$ in the mixing length theory is at the lower end of the usual range. It has to be pointed out that the enhancement of acoustic energy generation for the latest dwarfs is a consequence of physical effects which have been neglected in former work and is in no way maximized by adjusting free parameters in the convection theory. Therefore, these calculated fluxes represent lower bounds for possible acoustic emission from stellar convection zones.

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DISCUSSION

Vaiana: Did I understand correctly that you said in the case of the Sun the acoustic heating succeeds in explaining the solar atmosphere or did you say that the energy problem does not exist for the Sun?

Bohm: I said that I can balance the solar atmosphere numerically in

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energy terms with acoustic heating. There are problems however with the mechanism of bringing mechanical energy to the chromosphere and corona.

Vaiana: The OSO IV data would also point in that direction.