HOW CONSISTENT ARE \textit{AB-INITIO} MODELS OF GIANT STAR CHROMOSPHERES WITH OBSERVATIONS?

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Abstract We discuss the first steps towards combining \textit{ab-initio} theoretical model chromospheres of cool giant stars with observational constraints obtained mainly from IUE spectra. The theoretical models are based upon time-dependent calculations of propagating acoustic waves.

INTRODUCTION

Until now, models of the outer atmospheres of red giant stars have been based upon either empirical/semi-empirical approaches or \textit{ab-initio} methods. We report initial results in combining these methods for Arcturus.

Our theoretical models are based upon time-dependent acoustic wave calculations, prompted by the following: (i) Schrijver (1987a,b) identified slowly rotating “basal flux” stars, including “non-coronal” single giants lying to the right of the Linsky-Haisch dividing line in the HR diagram. He suggested that acoustic waves could be an appropriate heating mechanism for these stars. (ii) Short-period wave models produce heating rates per gram which are largely independent of atmospheric height, a characteristic property of semi-empirical model chromospheres (e.g. Ayres and Linsky, 1975; Judge, 1986a,b; Anderson and Athay, 1989). (iii) These models can also account for the simultaneous presence of hot and cool chromospheric material (Cuntz and Muchmore 1989), as observed in Arcturus (Heasley et al. 1978).

Cuntz (1990a,b) showed that acoustic shocks generated in photospheric models by Bohn (1981, 1984) lead to chromospheric structures which agree qualitatively with many of the empirical results obtained by Judge (1986a,b), based upon IUE data. However, short-period shock waves are unable to reproduce the observed mass-loss rate of Arcturus (Drake 1985), because significant mass loss rates occur only when the damping length of the mechanical energy flux is \( \geq R_* \) (Holzer and MacGregor 1985; Cuntz, 1990b).
SYNTHETIC SPECTRA FROM AB-INITIO MODELS

Using the program MULTI (Carlsson 1986), we have computed emergent spectra from the monochromatic, short-period wave model shown in Figure 1. Figure 2 shows computed and observed data for the (density-sensitive) C II emission lines in Arcturus.

Comparing these and other observed and computed emission line profiles, we conclude that the models appear to be capable of explaining many of the observed features of "basal-flux" chromospheres, when more realistic ab-initio calculations are performed (see below).

In our calculations for Arcturus, the preliminary model produces electron densities which are in agreement with the empirical determinations, temperatures which are too high, and turbulent velocities which are too low.

We anticipate improvements between theoretical and observed line profiles with more realistic calculations planned in the near future, including (i) a better treatment of the radiation loss function (Judge and Neff, this meeting) and hydrogen ionization, (ii) spectra computed from models using stochastic waves, (iii) averaging several transfer calculations from models computed at various times, (iv) starting the ab-initio calculations from photospheric layers, (v) using photospheric wave spectra constrained by recent observations.

References

Models of Giant Star Chromospheres

Figure 1: Model chromosphere of Arcturus used in the radiative transfer calculations. Radiative losses were treated using the function of McWhirter et al. (1975). The calculations were started at a column mass of 0.01 g cm$^{-2}$, below this the Ayres and Linsky (1975) model was used.

Figure 2: A comparison of observed and computed line profiles for the density-sensitive multiplet of C II. We find: (i) Total fluxes $\simeq 3 \times$ observed fluxes (ii) Linewidths are $<<$ observed. (iii) Line ratios $\simeq$ observed. We conclude for the model: (i) $< T_e >$ is too high, probably because we have used an inappropriate cooling function (Judge and Neff, this meeting) (ii) $< N_e >$ is OK. This suggests that the shock models are more appropriate than previous semi-empirical models (e.g. Ayres and Linsky 1975). (iii) $\sqrt{V^2}$ is too low. This suggests that we need to use stochastic waves which lead to higher flow speeds (Cuntz 1987).