MODELLING THE OUTER ATMOSPHERES AND WINDS OF K GIANT STARS

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ABSTRACT. It is shown how empirically derived constraints affect models of the outer atmospheres and winds of K giants, taking α Boo (K 2III) as an example. The importance of *empirical* approaches prior to making *semi-empirical* models is stressed. The reliability of recent wind models is assessed.

1. INTRODUCTION

The majority of cool, luminous stars (i.e. cooler and brighter than the sun) are giants (luminosity class III) between spectral types ~ G5-K5. For such stars, the only observational "evidence" for substantial mass loss ($\dot{M} \geq 10^{-10}$ $M_{\odot} yr^{-1}$) is the redward asymmetries of resonance lines of e.g. MgII and CaII (e.g. Ref. 1.), since narrow 'circumstellar' absorption components are observed in giants only later than ~ K4. The interpretation of redward asymmetries is known to be ambiguous (e.g. Ref. 1.), and the mass-loss interpretation is an extension of work by Hummer and Rybicki (Ref. 2.).It has never been demonstrated that the outflowing material has $v > v_{esc}$ in a K giant. The present paper assesses this interpretation and the reliability of recent semi-empirical modelling based on the asymmetric profiles in the light of recently derived empirical constraints (Ref. 3.).

2. EMPIRICAL CONSTRAINTS

An important result from studies of UV emission lines observed with IUE in the spectra of cool giants is that the regions where the line fluxes are *created* are close to hydrostatic equilibrium (Refs. 3,4). The conclusion is based on measurements of linewidths, electron densities, column densities and emission measures. The emitting regions are supported largely be the pressure of non-thermal motions (e.g. waves) leading to geometrical thicknesses ≥ those of early hydrostatic models (Ref. 5)., with $\Delta h_{emission} \leq 0.3\ R_*$ (and not ~ R_* as suggested in Ref. 6). The success of the hydrostatic models implies that the large-scale ordered flows inferred from line symmetries are unimportant (to first order) in the momentum balance of the *emitting* regions: the asymmetries

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in MgII k must be associated with flowing regions overlying the emitting regions which scatter the resonance radiation. A further important result for α Boo is the empirical evidence for strong temperature and density inhomogeneities in the chromosphere (Ref. 7, 3) implied by CO absorption and CII] emission lines.

3. EMPIRICAL CONSTRAINTS: HOW DO THESE AFFECT SEMI-EMPIRICAL MODELS?

Semi-empirical models are required for the interpretation of line profile asymmetries, since assumptions concerning the atmospheric structure (e.g. spherical symmetry) must be made to perform radiative transfer calculations. Recently, Drake (Ref. 8) has attempted to model the 'wind' of α Boo using the calculations of MgII k profiles in spherically symmetric outflowing wind models.

Spherical symmetry restricts flowing material to one degree of freedom only: with steady-state outflows the matter *must* eventually reach the local escape velocity (at distances >> R_*). The empirical evidence of inhomogeneities in the flux creation regions shows that spherical symmetry cannot be correct. At worst, the extra degrees of freedom will allow *circulation* of matter in the chromosphere, leading to very small mass loss rates. This must be regarded as a serious possibility given that the flow velocities implied from the line asymmetries are << v_{esc} (R_*). Comparisons show that the model of Drake (Ref. 8) has electron densities which are substantially lower than those derived empirically, and that the model is too extended geometrically in the regions where the UV line fluxes are created. The validity of the model where the line asymmetries are produced must therefore also be in question. The interpretation of radio fluxes in terms of spherically symmetric winds (Ref. 9) must also be re-examined in the light of the empirical constraints. It may be possible to reproduce observed asymmetries and radio fluxes with circulating models radically different from the wind models.

4. CONCLUSIONS

In conclusion, sufficient *empirical* evidence exists to question the use of *semi-empirical* methods in interpreting line profiles in one-component models of K giants. Current mass loss estimates may be seriously in error. Direct imaging of CS shells in e.g. MgII k with HST (suggested in Ref. 8) is required to confirm or reject current wind models.

REFERENCES

1. Stencel R.E. and Mullan D.J., 1980, Astrophys. J. 238,221.
2. Hummer D.G. and Rybicki G.S., 1969, Astrophys. J. 153, L107.
3. Judge P.G., 1986.Mon. Not. R. astr. Soc. 221, 119.
4. Judge P.G., 1986.Mon. Not. R. astr. Soc. in press.
5. Linsky J.L., 1980. Ann. Rev. Astron. Astrophys. 18, 439.
6. Carpenter K.G., Brown A. and Stencel R.E.,1985,Astrophys. J. 289,676.
7. Heasley J.N. et al.,1978. Astrophys. J. 219, 970.
8. Drake S.A., 1986,"Progress in Spectral Line Formation Theory",Reidel: Dordrecht, p. 351.
9. Drake S.A. and Linsky J.L., Astron. J. 91, 602.