An observational test of a new convection theory

B. Smalley[1], **F. Kupka**[2], **N. Rogers**[3]

[1] Department of Physics, Keele University, Staffordshire ST5 5BG, UK

[2] Institute for Astronomy, University of Vienna, Türkenschanzstr. 17, A-1180 Vienna, Austria

[3] Department of Astronomy, University of Southern California, Los Angeles, CA 90089-1342, USA

1 Introduction

The gross properties of a star, such as broad-band colours and flux distributions are significantly influenced by the microscopic effects of convection in stars later than mid A-type. Consequently, our treatment of convection in stellar atmosphere models can significantly alter our interpretation of observed phenomena. While the Kurucz (1979) ATLAS6 model atmospheres have generally had considerable success in the interpretation of stellar fluxes and spectra, the models for A and F stars have always been somewhat discrepant. Relyea & Kurucz (1978) discussed several possible reasons for discrepancies between theoretical and observational Strömgren *uvby* colours, including the effects of missing opacity and convection.

Several attempts have been made to improve the models for stars cooler with $T_{\rm eff} < 8500$ K. For example, Lester, Lane & Kurucz (1982) studied the effect of using a modified mixing-length theory and found that the effects are readily observable. Others have taken the model Strömgren *uvby* colours and adjusted them until they agreed better with colours of stars with known $T_{\rm eff}$ and $\log g$ (Moon & Dworetsky 1985, Lester, Gray & Kurucz 1986, see also Smalley 1996). The latest generation of Kurucz (1991, 1993) ATLAS9 models contain much-improved line opacities and ought to give better agreement with observations. Indeed they do, but there are still some discrepancies. Could these be due to the treatment of convection in the models?

2 Turbulent Convection

The Kurucz ATLAS models, in there various generations, have always used some form of mixing-length theory for the treatment of convection in the stellar atmosphere. The latest ATLAS9 models even include an approximate treatment of convective overshooting. Recently, there have been advances in the theory of turbulent convection (Canuto & Mazzitelli 1991, 1992). This theory, referred to as the CM model, has been incorporated into the ATLAS9 code (Kupka 1996, Canuto & Kupka 1996).

Here we compare the effects of different treatments of convection on the Strömgren *uvby* colours for models with $T_{\rm eff} < 8500$ K. We discuss the predicted colours of three sets of solar-composition Kurucz (1993) ATLAS9 models:

1. Standard ATLAS9 models using mixing-length theory with convective overshooting. The original models were in error due to a bug in the code, this has now been fixed (Castelli & Kurucz 1995).
2. Standard ATLAS9 models using mixing-length theory, but without convective overshooting.
3. Modified ATLAS9 models using the CM model of turbulent convection.

The model colours are compared to with those of the fundamental stars listed in Smalley & Dworetsky (1995). The preliminary results are now presented.

3 Results

The results of the comparison of the various model colours with those of the fundamental stars are shown in Figure 1. The CM models give $T_{\rm eff}$ and $\log g$ that are in very good agreement with the fundamental stars. The models without overshooting are in less of an agreement, while the standard ATLAS9 colours with overshooting are clearly discrepant, especially for cooler stars.

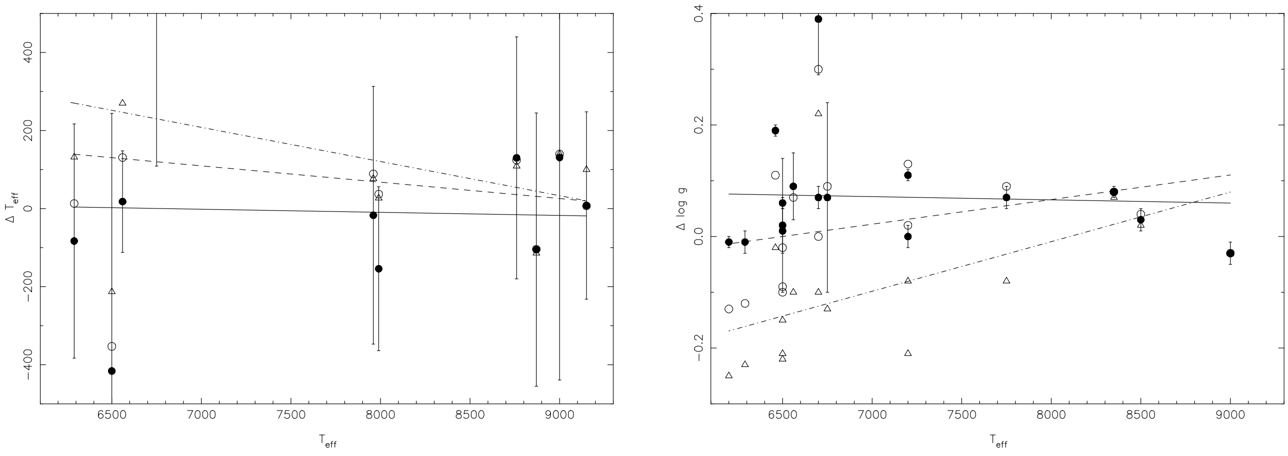

Figure 1: Comparison of different grids with fundamental stars. In all cases the differences are model minus fundamental values. The lines are weighted least squares fits. The filled circles and solid line are for the CM models, the open circles and dashed line are for mixing-length models without overshooting, and the open triangles and dot-dashed line are for mixing-length model with overshooting. The errorbars are the uncertainties on the fundamental values, and for clarity are given only for the CM data points.

4 Conclusion

The results of this initial comparison indicate that model atmospheres using the Canuto & Mazzitelli (1991, 1992) turbulent convection theory are very successful in recovering the colours of the fundamental stars. Further work is in process to confirm these findings, but the initial results are very encouraging. Full results will be presented in Smalley, Kupka & Rogers (1996).

References

Canuto V.M., Kupka F., 1996, in preparation

Canuto V.M., Mazzitelli I., 1991, ApJ, 370, 295

Canuto V.M., Mazzitelli I., 1992, ApJ, 389, 724

Castelli F., Kurucz R.L., 1995, private communication

Kupka F., 1996, in Model Atmospheres and Spectrum Synthesis, Adelman S.J., Weise W.W., Kupka F., eds., ASP Conf Series, (in preparation)

Kurucz R.L., 1979, ApJS, 40, 1

Kurucz R.L., 1991, in Precision Photometry: Astrophysics of the Galaxy, Philip A.G.D., Upgren A.R., Janes K.A., eds., L. Davis Press, Schenectady, p. 27

Kurucz R.L., 1993, Kurucz CD-ROM 13: ATLAS9, SAO, Cambridge, USA.

Lester J.B., Gray R.O., Kurucz R.L., 1986, ApJS, 61, 509

Moon T.T., Dworetsky M.M., 1985, MNRAS, 217, 305

Relyea L.J., Kurucz R.L., 1978, ApJS, 37, 45

Smalley B., 1996, in Model Atmospheres and Spectrum Synthesis, Adelman S.J., Weise W.W., Kupka F., eds., ASP Conf Series, (in preparation)

Smalley B., Dworetsky M.M., 1995, A&A, 293, 446

Smalley B., Kupka F., Rogers N., 1996, in preparation.

email: bs@astro.keele.ac.uk