Convection in Astrophysics
Proceedings IAU Symposium No. 239, 2006
F. Kupka, I. W. Roxburgh & K. L. Chan, eds.

doi:10.1017/S1743921307000361

Effect of the microturbulence parameter on the Color-Magnitude Diagram

J. Montalbán[1], J. Nendwich[2], U. Heiter[3], F. Kupka[4], E. Paunzen[2] and B. Smalley[5]

[1]Institut d'Astrophysique et Géophysique, Université de Liège, 4000- Liége, Belgium
email: j.montalban@ulg.ac.be

[2]Institut für Astronomie, Vienna, Austria,
email:nendwich, ernst.paunzen@astro.univie.ac.at

[3]Department of Astronomy and Space Physics, Uppsala University, Uppsala, Sweden,
email: ulrike@astro.uu.se

[4]Max-Planck-Institute for Astrohysics, Garching, Germany,
email: fk@mpa-garching.mpg.de

[5]Keele University, Keele, UK
email: bs@astro.keele.ac.uk

Abstract. Microturbulence is usually treated in model atmospheres as a free parameter ($\xi_{\rm t}$) that allows to re-establish agreement among abundances derived from different lines. Even if this parameter is a consequence of treating a 3D problem as a 1D one, it seems clear that microturbulence is linked to the velocity field within the atmosphere, and therefore to convection in the external layers. The values of the parameter as determined from observations show a dependence both on effective temperature and on surface gravity. In this paper we study how the microturbulence parameter used in the atmosphere models affects the theoretical color-magnitude diagram (CMD). First, in the Main Sequence (MS) domain due to the dependence of the microturbulence parameter on $T_{\rm eff}$; and second, in the giant branch (Pre-main sequence and Red Giant Branch) where several photometric indexes show a large variation due to the increase of the microturbulence parameter as the stellar gravity decreases. We predict then a significant change in the CMD, as well as in the color-temperature calibrations, if variations of $\xi_{\rm t}$ such as those observationally determined are included in theoretical CMD computations.

Keywords. Convection, stars: fundamental parameters, (stars:) Hertzsprung-Russell diagram, stars: atmospheres

1. Introduction

Gray, Graham & Hoyt (2001) studied the dependence of the observational microtubulence parameter on the luminosity class for A, F and G type stars. In Fig. 1 we plot their $\xi_{\rm t}$ data as a function of the gravity for all the spectral types (right panel), and also the $\xi_{\rm t}$ values versus effective temperature for three different gravity domains (left panel). Following the suggestion by Smalley (2004), we fit the microturbulence parameter for main sequence A-F type stars with a function of the effective temperature $\xi_{\rm t} = \xi_{\rm t}(\log T_{\rm eff})$ (solid curve in Fig. 1).

The current procedure to translate the theoretical plane to the CMD is to use color transformation tables derived from a particular grid of atmosphere models. Usually the color transformation is done for a particular and fixed value of the microturbulence parameter. Often, $\xi_{\rm t} = 2$ km s^{-1}.

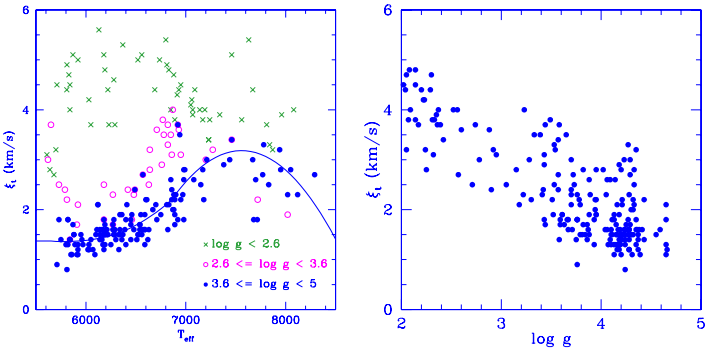

Figure 1. Gray, Graham & Hoyt (2001) microturbulence values as a function of effective temperature (left), and as a function of surface gravity (right). The curve in the left panel corresponds to the fit of the microturbulence parameter values for stars with $\log g$ from 3.6 to 5.

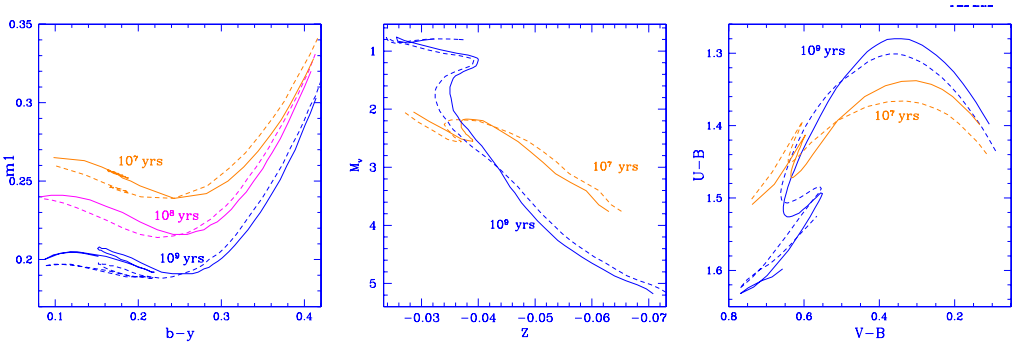

Figure 2. Difference between color transformation of isochrones by using $\xi_{\rm t}$=2 (dashed lines), and the function $\xi_{\rm t} = \xi_{\rm t}(T_{\rm eff})$ in Fig. 1 (solid lines). Left panel: Strömgren m_1 index versus $b-y$ for three different isochrones ages. Middle panel: Visual magnitude versus Geneva index Z. Right panel: Geneva photometric indexes $U-B$ *vs.* $V-B$.

2. Theoretical models

Non-grey stellar models have been computed by using the ATON2.0 evolution code (Ventura *et al.* 1998). The atmospheric boundary conditions at optical depth $\tau = 10$ were provided by the NEMO grid of atmosphere models (Heiter *et al.* 2002). Convection in the atmosphere and in the interior is described by the Canuto, Goldman & Mazzitelli (CGM) formalism. We have computed models for masses from 0.4 to 1.3 $M_\odot$ for [M/H]=-2.0, and from 0.7 to 2.2 $M_\odot$ for [M/H]=0.0 for two different $\xi_{\rm t}$ values and verified that the effect of $\xi_{\rm t}$ on the theoretical plane ($T_{\rm eff}$, $\log L/L_\odot$) is negligible.

To transform $\log T_{\rm eff}, \log L/L_\odot$ into the Color-Magnitude Diagram (CMD) we have used the NEMO color transformations for CGM atmosphere models (Nendwich *et al.* 2004). NEMO atmosphere models are available for $T_{\rm eff}$ = 4000 – 10000 K, $\log g$ = 2.0–5.0, [M/H]=+0.1 to −2.0, and ξ_t =0, 1, 2 and 4 km s^{-1}.

3. Isochrones

We computed three different isochrones for solar metallicity models, for ages 10^7, 10^8 and 10^9 yrs, and we translated the corresponding $\log T_{\rm eff}, \log g$ on the CMD for Strömgren and Geneva photometric systems by interpolating in NEMO color transformation tables: color=color($\log T_{\rm eff}$,$\log g$,$\xi_{\rm t}$), where $\xi_{\rm t}$ is given by $\xi_{\rm t}(\log T_{\rm eff})$ in Fig. 1. For comparison, we

https://doi.org/10.1017/S1743921307000361 Published online by Cambridge University Press

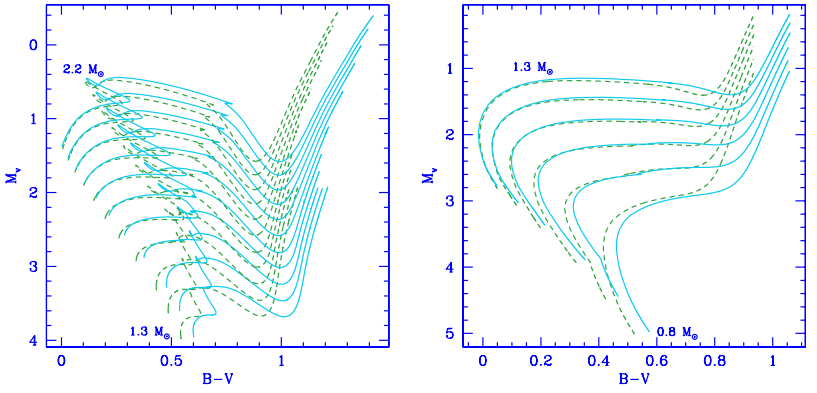

Figure 3. Visual magnitude *vs.* Johnson color $B-V$ for MS and Post-MS models. Left panel: solar metallicity evolutionary tracks for masses from 1.3 to 2.2 $M_\odot$, with $\delta M = 0.1$. Right panel: low metallicity ([M/H]=-2.0) evolutionary tracks for masses from 0.8 to 1.3 $M_\odot$, with $\delta M = 0.1$. Solid lines: ξ_t=4; dashed lines: ξ_t=2.

have also computed colors assuming $\xi_t = 2$. Some results are shown in Fig. 3. Particularly interesting is the effect on the Strömgren index m_1.

4. Color-Magnitude Diagram

Given the high dependence of ξ_t on $\log g$ (Fig. 1), we expect that evolutionary phases with low $\log g$ will be particularly affected by the choice of $\xi_t = 2$ km s^{-1}. The evolutionary tracks for metallicity [M/H]=0.0 and -2.0 have been translated on M_V *vs.* Johnson color $B-V$ assuming $\xi_t = 2$ km s^{-1} (dashed lines) and $\xi_t = 4$ km s^{-1} (solid lines). Since giant branch models have low superficial gravity, PMS and Red Giant models will probably be better represented by a $\xi_t = 4$ color transformation than by a $\xi_t = 2$ one.

5. Conclusion

A calibration of ξ_t as a function of $T_{\rm eff}$ and $\log g$ is needed to obtain reliable CMDs.

Acknowledgements

J.M acknowledges financial support from the Prodex 8 COROT (C90199), FNRS and IAU GA grant number 12259. UH acknowledges support from the funds of the Swedish Royal Academy of Sciences.This work was partly supported by the project P17580 of the Austrian Fonds zur Förderung der wissenschaftlichen Forschung (FwF).

References

Canuto, V., Goldman, I. & Mazzitelli, I. 1996, *ApJ* 473, 550

Gray R. O., Graham, P. W. & Hoyt, S. R. 2001, *AJ* 121, 2159

Heiter, U., Kupka, F., Van't Veer-Menneret, C., Barban, C., Weiss, W. W., Goupil, M.-J., Schmidt, W., Katz, D. & Garrido, R. 2002, *A&A* 392, 619

Nendwich, J., Heiter, U., Kupka, F., Nesvacil, N. & Weiss, W.W. 2004, *Communications in Asteroseismoloty* 144, 43

Smalley, B. 2004, in: J. Zverko, J. Ziznovsky, S. J. Adelman & W. W. Weiss (eds.) *The A-Star Puzzle* , IAU Symposium 224, 131

Ventura, P., Zeppieri, A., Mazzitelli, I. & D'Antona, F. 1998, *A&A* 334, 953

https://doi.org/10.1017/S1743921307000361 Published online by Cambridge University Press