AN IMPROVED CALIBRATION OF THE MIXING-LENGTH BASED ON SIMULATIONS OF SOLAR-TYPE CONVECTION

H.-G. LUDWIG
Astronomical Observatory, Niels Bohr Institute, DK-2100 Copenhagen, Denmark, [hgl@astro.ku.dk]

B. FREYTAG
Institut für Astronomie und Astrophysik der Universität Kiel, D-24098 Kiel, F.R.G., [Freytag@astrophysik.uni-kiel.de]

AND

M. STEFFEN
Astrophysikalisches Institut Potsdam, D-14473 Potsdam, F.R.G., [MSteffen@aip.de]

Based on detailed 2D numerical radiation hydrodynamics (RHD) calculations of time-dependent compressible convection, we have studied the dynamics and thermal structure of the convective surface layers of stars in the range of effective temperatures and gravities between $4500\,\mathrm{K} \leq T_{\mathrm{eff}} \leq 7100\,\mathrm{K}$ and $2.54 \leq \log g \leq 4.74$. Although our hydrodynamical models describe only the shallow, strongly superadiabatic layers at the top of the convective stellar envelope, they provide information about the value of the entropy s^* of the deeper, adiabatically stratified regions. E.g. in the solar case the helioseismically measured entropy jump is predicted within 9% of its actual value.

Despite the complex interplay of hydrodynamics and radiative transfer we find a rather simple functional dependence $s^*(T_{\mathrm{eff}}, \log g)$ across the HR diagram. s^* can be translated into an effective mixing-length parameter α_{MLT} suitable for constructing standard stellar structure models by matching s^* in envelope models basing on mixing-length theory (MLT) (see Fig. 1). The α_{MLT}'s are derived adopting the formulation of MLT by Böhm-Vitense (Zs. Ap. 46, p.108, 1958). The atmospheric $T(\tau)$ relation in the envelope models was chosen to mimic closely the average structure of the RHD atmospheres in order to eliminate its influence on the calibration of α_{MLT}. We find a moderate, nevertheless significant variation of α_{MLT} — primarily with effective temperature — over the range studied. A similar calibration of the convection theory by Canuto & Mazzitelli (Ap.J. 370, p.295, 1991) extended by including a variable amount of overshoot does not lead to a smaller variation of the controlling parameter α_{CM} (Fig. 2). The presented calibrations were derived for solar metallicity and helium content. Preliminary results of RHD models for lower metallicity show a complex dependence of α_{MLT} on T_{eff} and $\log g$. The MLT calibration is improved with respect to an earlier version (cf. Ludwig/Freytag/Steffen, in: *Solar Convection and Oscillations*, eds. F.P. Pijpers, J. Christensen-Dalsgaard, & C. Rosenthal, in press).

F.-L. Deubner et al. (eds.), New Eyes to See Inside the Sun and Stars, 115–116.

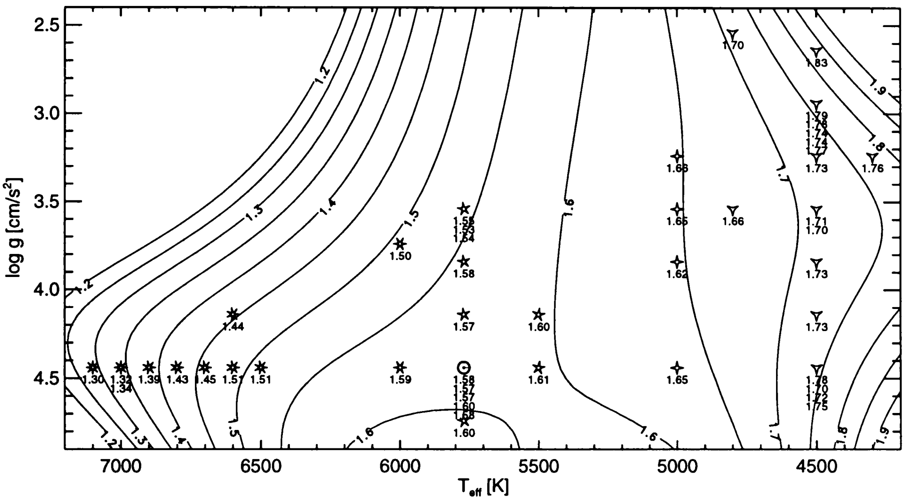

Figure 1. $\alpha_{\rm MLT}$ for standard mixing-length theory with $l_{\rm mix} = \alpha_{\rm MLT} H_{\rm p}$ ($l_{\rm mix}$: mixing-length, $H_{\rm p}$: local pressure scale height) derived from radiation-hydrodynamics (RHD) simulations as a function of effective temperature and gravitational acceleration. Symbols indicate RHD models. Attached to the symbols the actual data values are given, the contour lines present a polynomial fit to them. For some parameters several RHD models were computed. They differ in numerical details to provide an estimate of the internal uncertainty of the calibration.

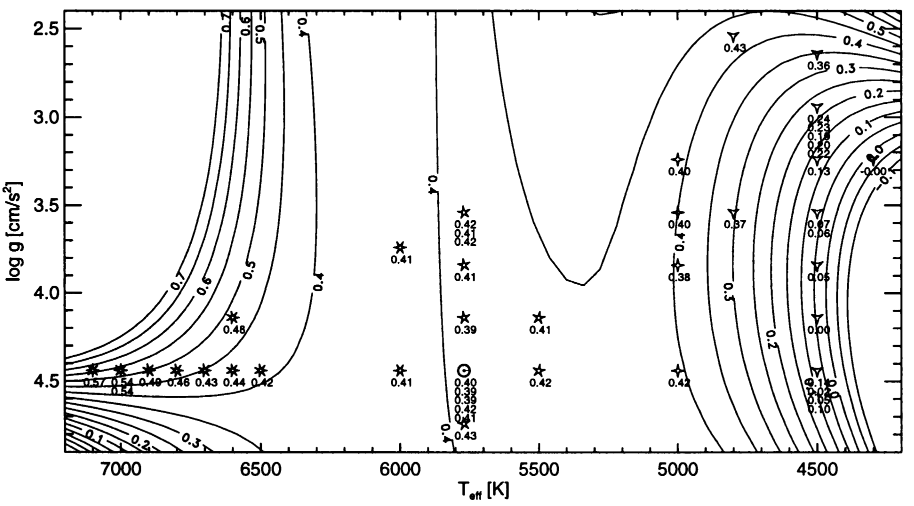

Figure 2. $\alpha_{\rm CM}$ for the Canuto & Mazzitelli convection theory with $l_{\rm mix} = \Lambda + \alpha_{\rm CM} H_{\rm p,top}$ (Λ: distance to the upper (Schwarzschild) boundary of the convective zone, $H_{\rm p,top}$: pressure scale height at the upper boundary). The $\alpha_{\rm CM}$-calibration reproduces the same underlying s^*-distibution as the $\alpha_{\rm MLT}$-calibration shown in Fig. 1.

https://doi.org/10.1017/S0074180900238394 Published online by Cambridge University Press