Gravities of Metal-Poor Halo Dwarfs and the Age of the Universe

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Abstract. We report on the methodology of an ongoing project to determine accurate stellar parameters ($T_{\rm eff}$, $\log g$, [Fe/H], [α/Fe]) for a number of metal-poor halo stars located *at the turnoff* (TO). With the aid of *shift-free* unified stellar evolutionary models we envision to derive *absolute* ages for these stars. Their ages will set stringent lower limits to the age of the Galaxy and the Universe.

Ingredients needed

Despite the fact that "[Fe/H] is a clock without hands" (Simon White, this conference), low-mass low-metallicity stars at the turnoff cannot be young objects. To derive their ages to within $\Delta t \sim 1-2$ Gyr we need:

1. high-quality spectra (R $\sim$ 40 000, S/N $\sim$ 200)
2. reliable effective temperatures ($\Delta T_{\rm eff} \sim 50$ K)
3. reliable surface gravities ($\Delta \log g \sim 0.1$ dex)
   1., 2. & 3. $\Rightarrow$ accurate abundances (Δ[X/H] ~ 0.1 dex) and
4. state-of-the-art evolutionary tracks respectively isochrones.

Naturally, points 2 and 3 entail the full complexity of model atmospheres (empirical vs. theoretical) and line formation (LTE vs. NLTE).

1 Spectra

We have obtained spectra of local halo TO stars down to 11.5$^{\rm th}$ magnitude using FOCES [1] on the Calar Alto 2.2m telescope. According to Carney et al. [2] they have photometric metallicities [m/H] between -2.2 (HD 84937) and -3.5 (G 64-12). The spectra have $R = 40\,000$ and cover the wavelength range of 3900 – 9000 Å. For the fainter targets the required S/N ratio is achieved by coadding individual exposures.

2 Effective Temperatures

Together with $\log g$ from Mg Ib (see Section 3), $T_{\rm eff}$ derived from fitting Balmer profiles yields results fully compatible with HIPPARCOS parallaxes (cf. [3]). In the framework of the convection theory by Canuto & Mazzitelli [4] a *single* α parameter ($\alpha_{\rm CM} \sim 0.8$) is capable of fulfilling the constraints of both stellar structure and Balmer profile fitting (cf. Section 4). The typical uncertainty of this step is 50 K for spectra with S/N ratios of ~ 200.

3 Gravities

Balancing Fe I and Fe II in LTE has been shown to yield gravities that are incompatible with HIPPARCOS for stars hotter than the Sun [3,5]. The *strong line method* (using pressure-broadened lines of Mg Ib) becomes inapplicable below $[m/\mathrm{H}] \sim -2.4$ due to the weakening of the spectral features [5].
For the most metal-poor stars we therefore concentrate our efforts on

- the Fe I/II ionization equilibrium (numerous yellow lines) and
- the Ca I/II ionization equilibrium (Ca I λ4226 vs. Ca II $\lambda\lambda$8498/8542/8662).

Both Fe I and Ca II are subject to strong NLTE effects which are currently under investigation. After calibration an internal accuracy for $\log g$ of 0.05 to 0.1 dex ought to be within reach of a *differential* analysis with respect to the Sun.

4 Evolutionary models

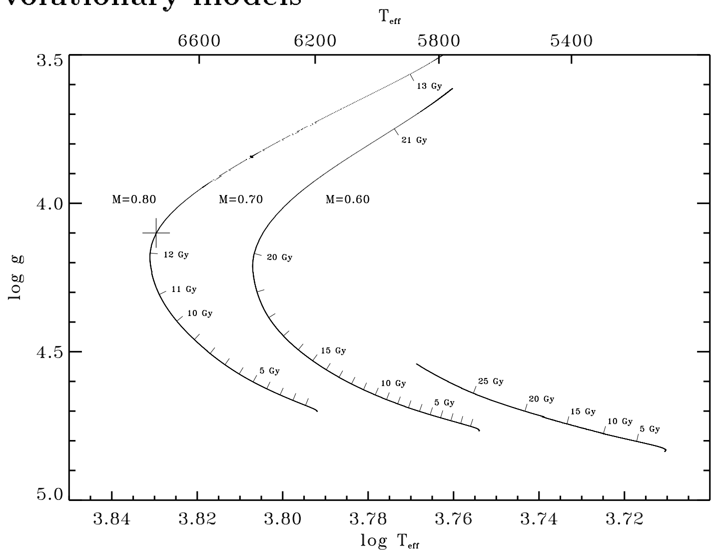

Fig. 1. Evolutionary tracks by Bernkopf (priv. comm.) for [Fe/H]=−3, Y=0.23 and $[\alpha/\mathrm{Fe}] = +0.4$. A fictitious TO star with $\Delta T_{\mathrm{eff}} = 50$ K and $\Delta \log g = 0.05$ is indicated.

The stellar evolutionary calculations by Bernkopf [6] include convection according to Canuto & Mazzitelli [4] and gravitational diffusion. Model atmospheres are taken into account as the surface boundary condition.
With $\Delta \log g \sim 0.05$ dex an accuracy of $\Delta t \sim 1$ Gyr will become feasible, far more accurate than what can currently be achieved by cosmological methods.

References

[1] Pfeiffer, Frank, Baumüller, Fuhrmann & Gehren, 1998, A&AS, 130, 381 **[2]** Carney, Latham, Laird & Aguilar, 1994, AJ, 107, 2240 **[3]** Fuhrmann, 1998, A&A, 338, 161 **[4]** Canuto & Mazzitelli, 1991, ApJ, 370, 295 **[5]** Fuhrmann, 1998, A&A, 330, 626 **[6]** Bernkopf, 1998, A&A, 332, 127