

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

Andreas J. Korn and Thomas Gehren

Universitäts-Sternwarte München (USM), Scheinerstr. 1, 81679 München

**Abstract.** We report on the methodology of an ongoing project to determine accurate stellar parameters ( $T_{\text{eff}}$ ,  $\log g$ ,  $[\text{Fe}/\text{H}]$ ,  $[\alpha/\text{Fe}]$ ) 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  $\Delta t \sim 1\text{--}2$  Gyr we need:

1. high-quality spectra ( $R \sim 40\,000$ ,  $S/N \sim 200$ )
2. reliable effective temperatures ( $\Delta T_{\text{eff}} \sim 50$  K)
3. reliable surface gravities ( $\Delta \log g \sim 0.1$  dex)
  - 1., 2. & 3.  $\Rightarrow$  accurate abundances ( $\Delta [X/\text{H}] \sim 0.1$  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<sup>th</sup> magnitude using FOCES [1] on the Calar Alto 2.2m telescope. According to Carney et al. [2] they have photometric metallicities  $[m/\text{H}]$  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),  $T_{\text{eff}}$  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*  $\alpha$  parameter ( $\alpha_{\text{CM}} \sim 0.8$ ) 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  $\sim 200$ .

### 3 Gravities

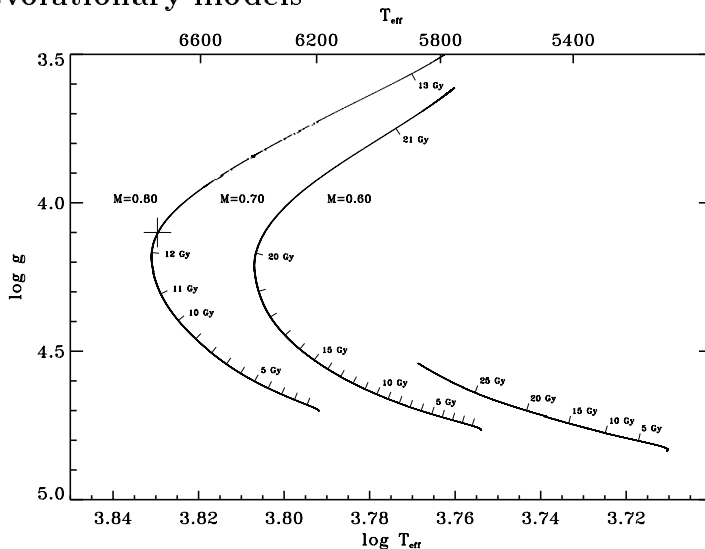
Balancing Fe I and Fe II in LTE has been shown to yield gravities that are incompatible with HIPPARCOS for stars hotter than the Sun [3,5]. The *strong line method* (using pressure-broadened lines of Mg I b) becomes inapplicable below  $[m/H] \sim -2.4$  due to the weakening of the spectral features [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  $\lambda 4226$  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  $[\alpha/Fe]=+0.4$ . A fictitious TO star with  $\Delta T_{\text{eff}}=50$  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