HE 1327–2326:
stellar parameters, atomic diffusion and Li abundance

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HE 1327–2326 is a hyper-metal-poor star with [Fe/H] = −5.4. Previous analyses found it to be in either a main-sequence or subgiant stage of evolution (Frebel et al. 2005, Aoki et al. 2006). Here we constrain the stellar parameters by combining various effective-temperature estimates with a spectroscopic surface-gravity indicator, the Ca I/II ionization equilibrium in non-LTE (Mashonkina et al. 2007). Furthermore, we investigate whether the non-detection of lithium (log ε(Li) < 1.0) can be explained by effects of atomic diffusion.

Stellar parameters

Aoki et al. (2006) find an effective temperature from broad-band photometry calibrated on the infrared-flux method (IRFM) of Alonso et al. (1996) of 6180 K. At this effective temperature, two surface-gravity solutions are possible: main sequence (log g = 4.5) and subgiant (log g = 3.7). To constrain the surface gravity, an ionization equilibrium can be used. However, the only element detectable in two ionization stages is calcium. Assuming local thermodynamic equilibrium (LTE), the abundances derived from lines of Ca I and Ca II differ by 0.57 dex. This could indicate significant departures from LTE (non-LTE effects).

Using the revised IRFM of Ramírez & Meléndez (2005), a higher effective temperature is obtained: 6450 K (Melendez et al. 2006). This would indicate a turnoff-point surface gravity of around 4.0.

Here we apply the NLTE model atom of Mashonkina et al. (2007) to the observed lines of calcium in HE 1327–2326. Establishing the ionization equilibrium of Ca I 4226 with the log g-sensitive line Ca II 8498 (see Figs. 1 & 2) we find a surface gravity close to 3.7. This result is supported by Balmer-profile analyses (see Fig. 3). Assuming $T_{\rm eff}$ = 6450 K (see above), a log g of 4.0 is indicated.

Atomic-diffusion calculations

Using stellar-structure models including atomic diffusion (that is, gravitational settling, diffusion due to concentration gradients, thermal diffusion and radiative acceleration; Richard et al. 2002), we evolve a star to reach the turnoff point at 6500 K after 13.5 Gyr. At that point, the surface abundance of iron has been raised by 0.7 dex. Simultaneously, the surface abundance of lithium has been lowered by 0.8 dex. Similar abundance changes are predicted for the subgiant solution.

These calculations show that atomic diffusion may have significantly altered the chemical surface composition of HE 1327–2326.

Conclusion

- From the analysis of the Balmer lines and the Ca I/II ionization equilibrium in non-LTE, HE 1327–2326 is a subgiant. We recommend to use the subgiant solution of Aoki et al. (2006) when modelling the abundance pattern.
- Non-LTE effects on calcium lines can be rather large in stars as metal-poor as HE 1327–2326.
- Atomic diffusion may have significantly altered the surface abundances of HE 1327–2326, but it is unlikely to fully explain the non-detection of lithium.

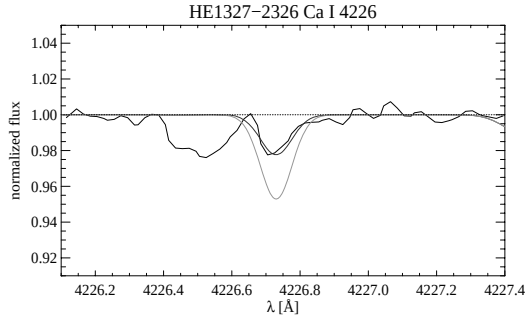

Figure 1: Fit to the observed profile of Ca I 4226 (W_λ = 2.7 mÅ) at a calcium abundance of log ε(Ca) = 1.24 (black: non-LTE, grey: LTE). In spite of the line's weakness, the non-LTE effect amounts to +0.34 dex.

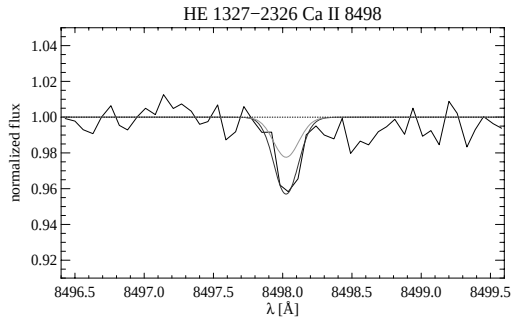

Figure 2: Fit to the observed profile of Ca II 8498 (W_λ = 10 mÅ) at a calcium abundance of log ε(Ca) = 1.28 (black: log g = 3.7, grey: log g = 4.5). To establish the Ca I/II ionization equilibrium therefore requires a surface gravity of around 3.7. HE 1327–2326 is a subgiant.

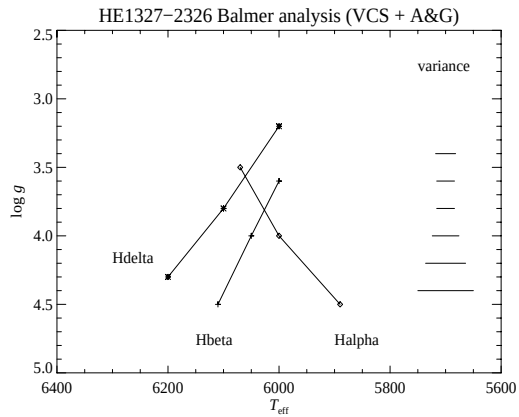

Figure 3: Different lines of the Balmer series depend differently on effective temperature and surface gravity. In particular, an analysis of Hα vs. the higher-order Balmer lines provides constraints on the surface gravity. This also points to the subgiant solution for HE 1327–2326.