On the Spectroscopic Properties of the Retired A Star HD 185351

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Abstract. Doppler-based planet surveys have shown that, besides metallicity, the planet occurrence is also correlated with stellar mass, increasing from M to F-A spectral types. However, it has recently been argued that the subgiants (which represent A stars after they evolve off the main sequence) may not be as massive as suggested initially, which would significantly change the correlation found. To start investigating this claim, we have studied the subgiant star HD 185351, which has precisely measured physical properties based on asteroseismology and interferometry. An independent spectroscopic differential analysis based on excitation and ionization balance of iron lines yielded the atmospheric parameters $T_{\rm eff}$ = 5035 ± 29 K, log g = 3.30 ± 0.08 and [Fe/H] = 0.10 ± 0.04. These were used in conjunction with the PARSEC stellar evolutionary tracks to infer a mass M = 1.77 ± 0.04 $M_\odot$, which agrees well with the previous estimates. Lithium abundance was also estimated from spectral synthesis (A(Li) = 0.77 ± 0.07) and, together with $T_{\rm eff}$ and [Fe/H], allowed to determine a mass M = 1.64 ± 0.06 $M_\odot$, which is independent of the star's parallax and surface gravity. Although a variation of up to ∼0.4 $M_\odot$ can be observed between the different measurements, all values are higher than 1.6 $M_\odot$, which supports the correlation between planet occurrence and stellar masses.

1. Introduction

It is well-known that giant planet occurrence is strongly dependent on stellar metallicity for main-sequence and subgiant stars (e.g., Fischer & Valenti 2005). Recent works suggest that planet occurrence is also correlated with stellar mass, increasing from 0.2 to 2.0 $M_\odot$

(e.g., Johnson et al. 2010). However, it has recently been argued that the subgiants studied at the massive end off the planet-host mass distribution (representing A stars after they evolve off the main sequence) may not be as massive as initially suggested (Lloyd 2011, 2013; Schlaufman & Winn 2013), which would significantly change the correlation found. An accurate assessment of the stellar masses of subgiants and giants is thus required to understand the apparent planet occurrence-stellar mass correlation. In this work, we start to address this question by performing a spectroscopic analysis of the giant/subgiant star HD 185351.

2. Observations and Analysis

Three spectra were obtained for HD 185351 using the High Resolution Echelle Spectrometer (HIRES) on the Keck I 10-meter telescope (Mauna Kea, Hawaii). They have a nearly complete wavelength coverage from 3650 to 7950 Å, resolution R = 77,000 and S/N $\sim$ 250 per resolution element at $\sim$6700 Å.

We measured the atmospheric parameters ($T_{\rm eff}$, log g, [Fe/H] and ξ) in LTE using an iterative method based on the excitation and ionization equilibria of Fe I and Fe II lines, ARES (Sousa et al. 2007), MOOG (Sneden 1973) and Kurucz ODFNEW model atmospheres (Castelli & Kurucz 2004). The results were: $T_{\rm eff} = 5035 \pm 29$ K, log g $= 3.30 \pm 0.08$, [Fe/H] $= 0.10 \pm 0.04$ and $\xi = 1.08 \pm 0.03$ km s^{-1}.

We also measured the lithium abundance in LTE using a spectral synthesis technique, the atmospheric parameters above and MOOG. Our iterative procedure (see Ghezzi et al. 2010 for details) tested different combinations for A(Li) and a single Gaussian broadening FHWM$_{Gauss}$. A reduced χ^2 minimization was used to find the best fit between the observed and synthetic spectra, which occurred for the following parameters: A(Li) $= 0.77 \pm 0.07$ and FHWM$_{Gauss} = 0.152$ Å (see Figure .1).

3. Preliminary Results and Discussion

We measured the physical parameters of HD 185351 using the atmospheric parameters $T_{\rm eff}$ and [Fe/H], the V magnitude (5.18 $\pm$ 0.01) from the Hipparcos catalog (ESA 1997), the revised Hipparcos parallax (24.49 $\pm$ 0.22 mas; van Leeuwen 2007), and the PARAM web interface[1] with the PARSEC evolutionary tracks (Bressan et al. 2012). The results were: M $= 1.77 \pm 0.04$ M$_\odot$, R $= 4.85 \pm 0.11$ R$_\odot$, log g $= 3.29 \pm 0.02$, and Age $= 1.79 \pm 0.09$ Gyr. Following the analysis of Do Nascimento et al. (2009), we also obtained an independent estimate of the stellar mass from the analysis of the non-standard mixing history of HD 185351: M $= 1.64 \pm 0.06$ M$_\odot$ (see Figure .2). The independently measured masses are not only consistent, but also lie within the interval ($\approx$1.6 $-$ 2.0 M$_\odot$) defined by the extensive analysis of Johnson et al. (2014), which includes results from interferometry, spectroscopy, and asteroseismology (see their Figure 7).

[1] http://stev.oapd.inaf.it/cgi-bin/param

4. Conclusions

The mass of HD 185351 was determined using different methods and all estimated values are higher than 1.5 $M_\odot$. These measurements are consistent with HD 185351 being the evolved counterpart of an A dwarf, which supports the results from Johnson et al. (2010). We plan to extend the spectroscopic analysis described here to the entire sample of ≈300 evolved stars.

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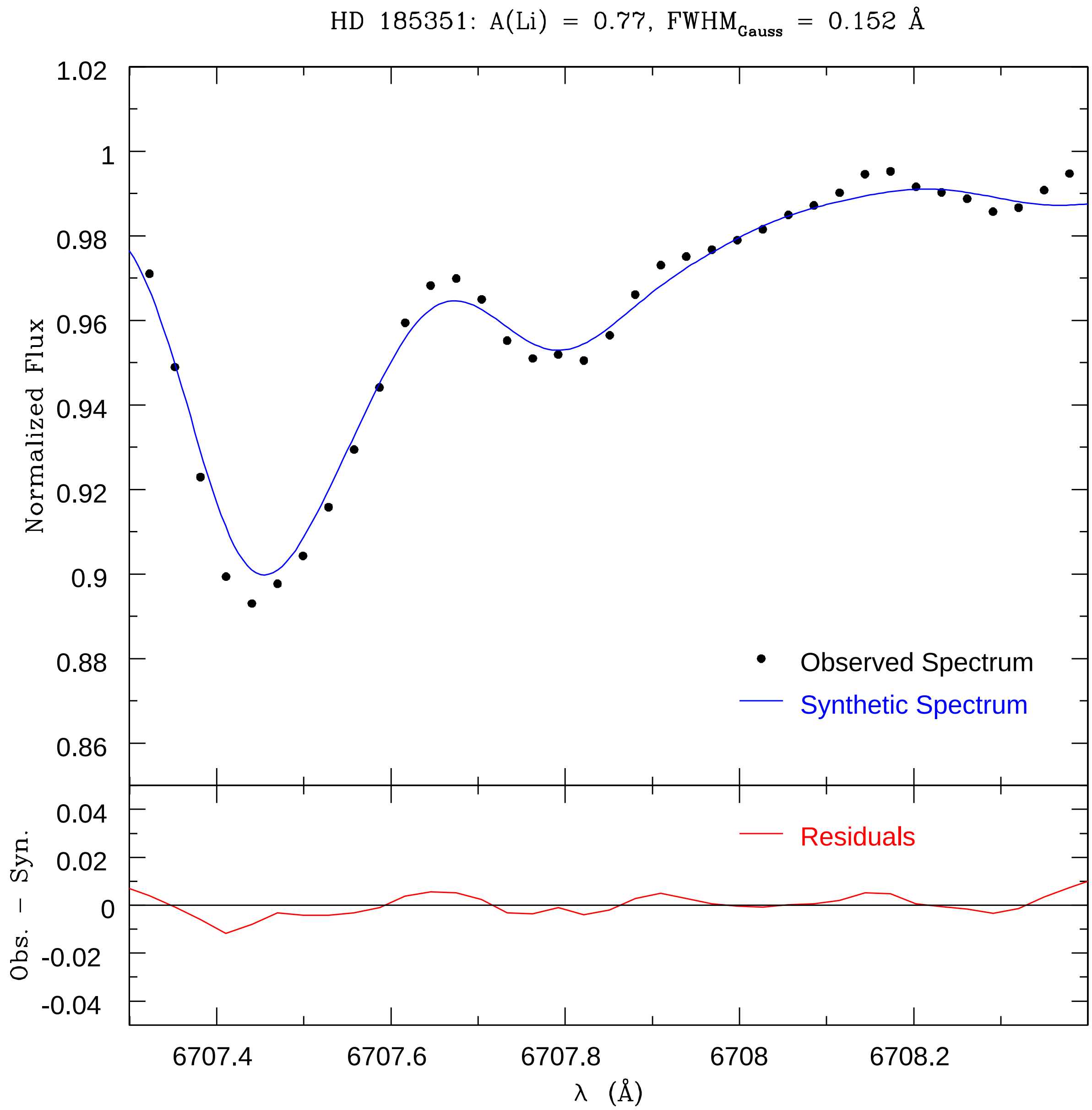

Figure .1: *Top panel:* Best fit between the observed (black points) and synthetic (blue line) spectra for HD 185351 in the region around the Li I line (∼6708 Å). The lithium abundance and Gaussian broadening used to construct the synthetic spectrum are shown on the top of the figure. *Bottom panel:* Residuals of the fit (red line), showing an overall good agreement.

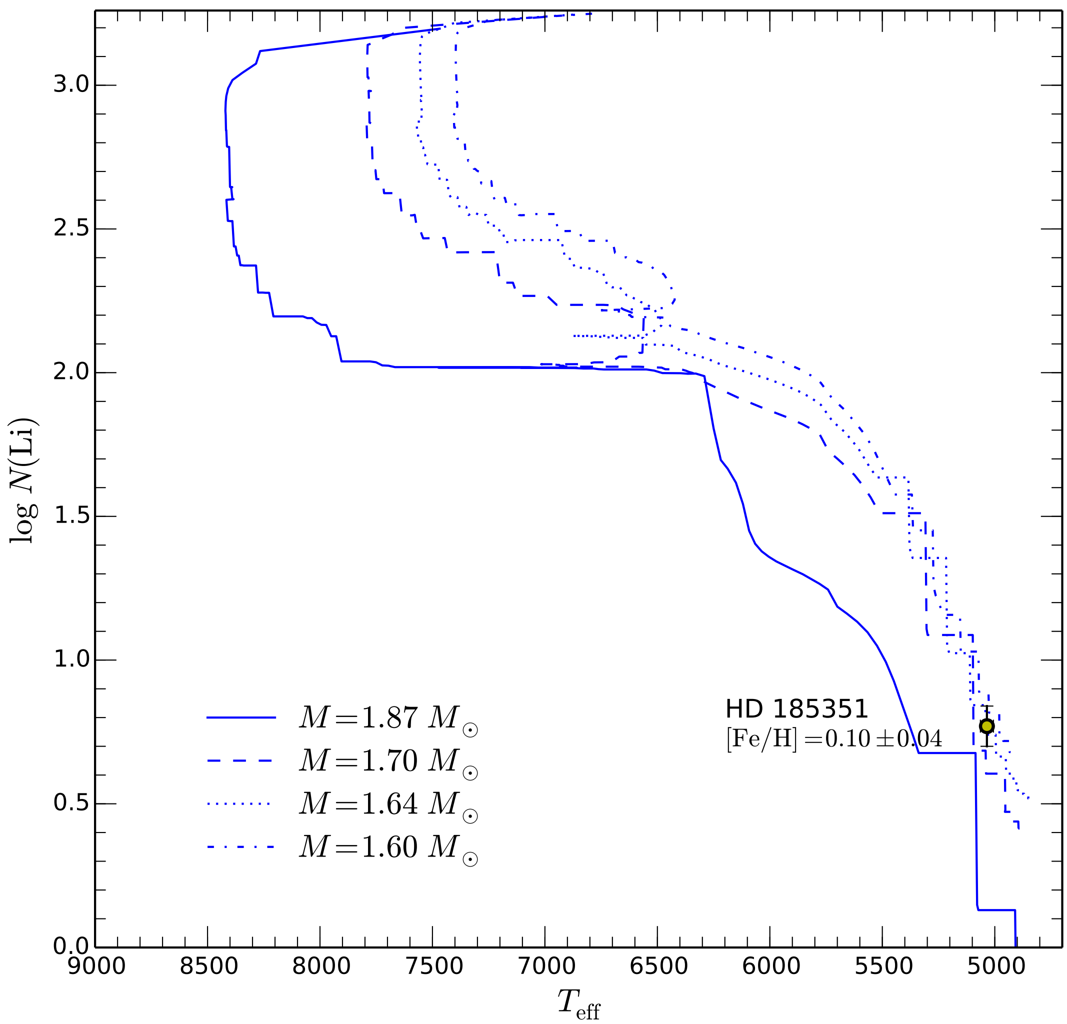

Figure .2: Mass determination for HD 185351based on its non-standard mixing history. The grid of models describing the evolution of the Li abundance (blue lines) was computed with the Toulouse-Geneva code (Hui-Bon-Hoa 2008) for [Fe/H] = 0.10 (from spectroscopy) and different masses. Interpolation of the observed values of $T_{\rm eff}$ and A(Li) (also from spectroscopy; yellow point) yielded the mass M = 1.64 ± 0.06 $M_\odot$.