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A HIGH-RESOLUTION SPECTRUM OF THE TrES-1 PARENT STAR

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The Trans-Atlantic Exoplanet Survey (TrES) network have just announced their first discovery of a transiting planet in front of the bright parent star GSC02652-01324 (Alonso et al. 2004). The planet has been designated TrES-1 and has a mass of 75% of Jupiter and a radius of 1.08 Jupiter radii. The orbital period is 3.030065 days. This makes the TrES-1 system similar to HD209458b (Charbonneau et al. 2000, Henry et al. 2000) except for maybe its radius which is 20% smaller than HD209458b. As has been mentioned by several authors in the past, the diverse nature of exoplanets and their evolutionary status can only be understood if the astrophysical parameters of the parent star become known to very high precision.

In this note we present a single high-resolution (R=120,000) spectrum of the parent star in a 10nm wide wavelength region centered at 671nm (Fig. 1). Our intention is to determine the lithium and iron abundance of the host star and to obtain an accurate value of its rotational line broadening. Alonso et al. (2004) have already obtained "moderate resolution" spectra of GSC02652-01324 at Palomar and Keck and classified the star as a single K0V star with $v \sin i \leq 5$ km s^{-1} and with solar metallicity. Our spectrum of the neutral lithium line 670.8nm may also allow a rough estimation of the age of the star and, somewhat indirectly, an estimate of whether there is photospheric surface activity or not. Starspots tend to deform spectral line profiles while the star rotates. In the worst case this can even mimic radial velocity and photometric variations with amplitudes of the order observed for the transit of a planet. Moreover, the extremely short orbital period of TrES-1 of just 3 days suggests that interaction with the parent star via a magnetic field and its associated flaring and heating is most likely (e.g. Cuntz & Shkolnik 2002).

We used the 3.6m CFH (Canada-France-Hawaii) telescope and the fiber fed f/8 *Gecko* spectrograph on the night of UT Aug. 31st, 2004. *Gecko* provides a spectral resolution of 120,000 in 8th order and, with the 4600×2048 13.5μm-pixel EEV1 CCD, gives a 10nm wide wavelength range. A total of 5×900 sec exposures enabled a signal-to-noise ratio of around 100:1 per pixel. Spectra of 70 Oph A (K0V; well separated from the K4 B-component) and HD166620 (K2V) were used as comparisons. All data reductions and analysis were carried out with IRAF and included bias subtraction, flat fielding, optimal aperture extraction, wavelength calibration with a Th-Ar comparison, and continuum setting with a low-order polynomial fit.

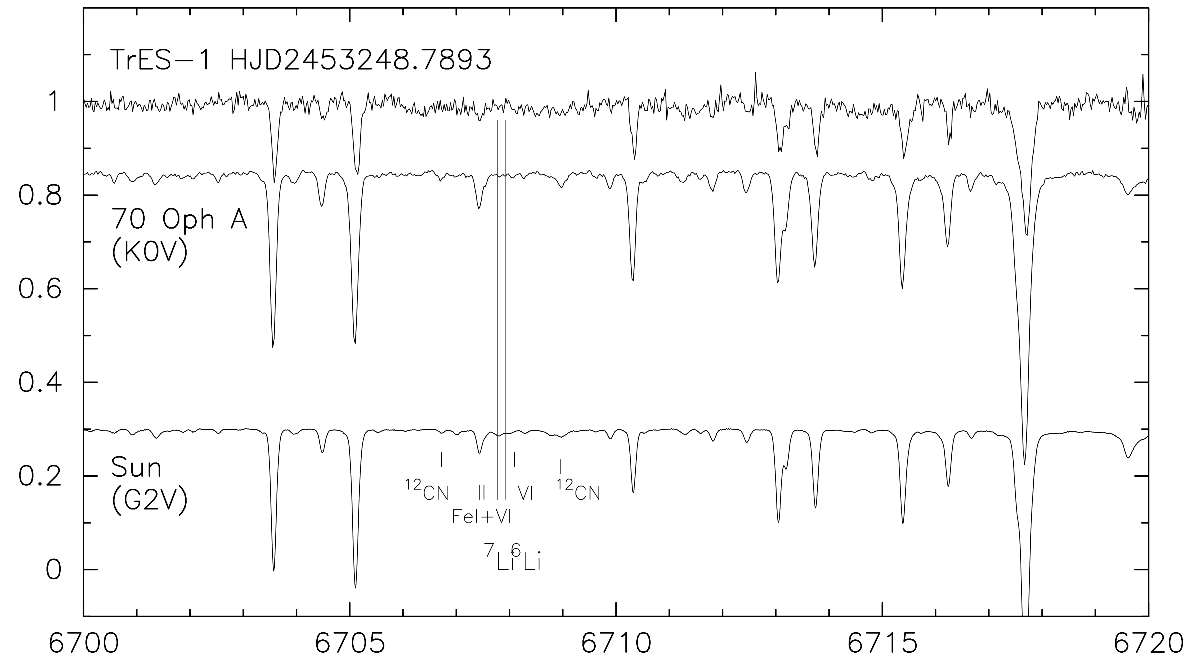

Figure 1. R=120,000 spectrum of the lithium region of the TrES-1 parent star (top). The other spectra are comparisons and arbitrarily shifted. Middle spectrum: the K0V-standard star 70 Oph(A) obtained with the same equipment. Lower spectrum: a R=600,000 spectrum of the Sun.

Cross correlating the TrES-1 spectrum with 70 Oph(A) (v_r=–10.4±0.5 km s^{-1} ; Nordström et al. 2004) yields a radial velocity difference of –14.76±0.20 km s^{-1} at the time of observation HJD2453248.726.

Rotational line broadening was measured by several techniques. Firstly, we determine a FWHM of 0.113 Å from several unblended lines like Fe I 6703.56Å, Fe I 6713.77Å etc. and the calibration of FWHM and $v \sin i$ from Fekel (1997). Secondly, the width of the cross-correlation function with respect to 70 Oph(A) ($v \sin i$=3.1 km s^{-1} , Fekel 1997; 1.6–2.6 km s^{-1} , Gray 1984) is used as a comparison (see Griffin 1991) and, thirdly, a line-profile fit with a synthetic model (see below). The "best" weighted average value is $v \sin i$(TrES-1)=2.8±0.2 (rms) km s^{-1} with an adopted macroturbulence of 2.0 km s^{-1} and a microturbulence of 0.5 km s^{-1} , appropriate for a K0V star (taken from Fekel 1997).

Line equivalent widths were measured with the `splot` routine in IRAF. An upper limit for the Li I 670.8-nm equivalent width is 2.3±0.2 mÅ as compared to 6 mÅ for the nearby Fe I/V I blend. The upper limit for 70 Oph(A) is even smaller, 1.5±0.2 mÅ. The uncertainty of just 0.2 mÅ is estimated from different types of fits to the line profile, e.g. with a Gaussian profile of variable width where only the profile points of the red profile wing are used for the least-squares fit, from a normal Gaussian fit or from a simple profile-area integration. For the well-studied K0V star 70 Oph(A), the Fe I/V I blend on the blue side of the Li line amount to 11.5 mÅ. Our upper-limit Li equivalent width for TrES-1 is still the sum from the two isotopes ^{6}Li and ^{7}Li that remain unresolved in our spectra. The non-LTE curves of growth of Pavlenko & Magazzú (1996) for a 5250 K/$\log g$ =4.5 model convert an equivalent width of 2.3 mÅ of a K0 dwarf into a Li abundance of <1.0 (on the $\log n$(H)=12.00 scale). Using the same abundance scale, the observed solar photospheric Li abundance listed by Grevesse & Sauval (1998) is 1.16±0.1, and the Li 670.8-nm line appears to have an equivalent width of around 2 mÅ as measured from daylight spectra with the same setup (Strassmeier et al. 1999). This indicates that the upper limit given above for Li in TrES-1 is reasonable.

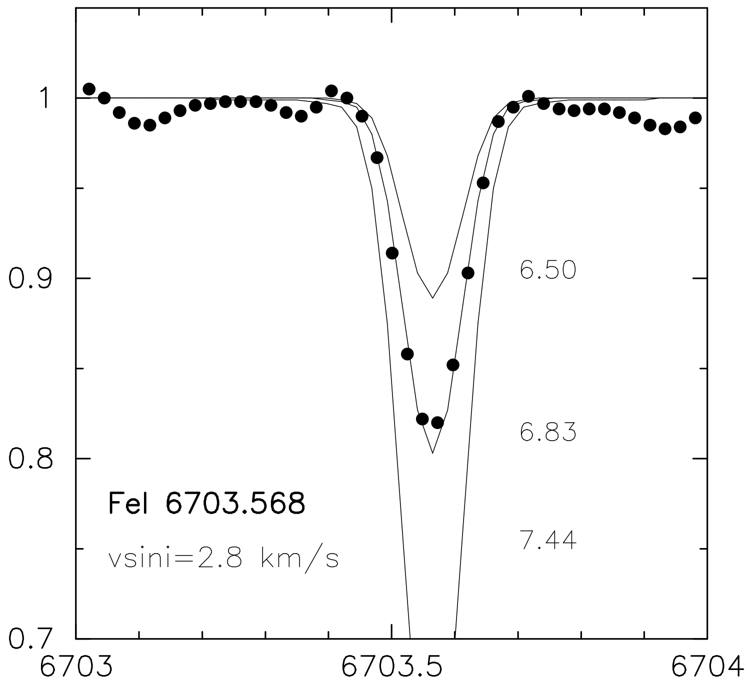

Figure 2. Synthetic fits to the observed (dots) Fe I 6703.568-Å line profile of TrES-1. Shown are fits with three logarithmic iron abundances of 6.50, 6.83, and 7.44 (=solar). The best fit is with 6.83±0.02.

Various line ratios of TrES-1 clearly resemble 70 Oph(A) but individual lines show residual intensities weaker by a factor ≈2, e.g., the unblended Fe I 6703.568Å has an equivalent width of 22.1±1.5 mÅ and a residual intensity of 0.826 in TrES-1 but 53.5±1.0 mÅ and 0.625 in 70 Oph(A), respectively (the equivalent width errors come again from various types of fits to the line profiles but are larger here because of line asymmetries due to unresolved blends). This suggests a significantly lower metallicity for TrES-1 than for 70 Oph(A). Note that Nordström et al. (2004) already list [Fe/H]=–0.25 for 70 Oph(A). Therefore, we computed synthetic fits for parts of the TrES-1 spectrum using the TempMap code (Rice 2002) with a $\log g$=4.5 and $T_{\rm eff}$=5250-K ATLAS-9 atmosphere (Fig. 2). We first fit a R=600,000 spectrum of the Sun to verify or revise some of the transition probabilities of weaker lines from current line lists, e.g., Kurucz (1993) lists $\log gf$=–3.160 for Fe I 6703.568Å, which we revise to –3.050. A minimization of the O-Cs then yields a logarithmic iron abundance of 6.83±0.02 for TrES-1 (on the $\log n$(H)=12.00 scale), as compared to the solar value of 7.44 (e.g Bellot Rubio & Borrero 2002). Note that the abundance error is just an internal error from the fits to several Fe I line profiles. A standard value for the microturbulence of 0.5 km s^{-1} and a radial-tangential macroturbulence of 2.0 km s^{-1} were adopted. As noted before, $v \sin i$ was refined during the fitting process to be 2.8±0.2 km s^{-1} . The differential logarithmic iron abundance of approximately –0.6 (with $\log n(\mathrm{Fe}_\odot)$=7.44) is therefore not compatible with the assumption of solar metallicity in the preliminary analysis of Alonso et al. (2004). Finally, we emphasize that having a metallicity less than solar is apparently unusual for stars that have extrasolar planets (Santos et al. 2004).

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ERRATUM FOR IBVS 5566

See erratum in IBVS 5648.