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STELLAR OXYGEN ABUNDANCES. V. ABUNDANCES OF TWO HYADES DWARFS DERIVED FROM THE 6300 Å [O I] LINE

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ABSTRACT

We present observations of the 6300 Å [O I] spectral region in two cool Hyades dwarfs, vB 79 and vB 25. We derive a mean iron abundance, [Fe/H]$\sim+0.11$, in good agreement with recent analyses of F and G Hyades dwarfs. The O abundance derived from spectrum synthesis, [O/H]$\sim+0.15$, is between the values deduced by Garcia Lopez *et al.* (1993, ApJ, 412, 173; [O/H]$=-0.05$ to -0.10) and King (1993, Ph. D. Dissertation, University of Hawaii; [O/H]$=+0.26$), who employed the 7774 Å O I triplet in hotter Hyades dwarfs. An accounting of differences between these two 7774 Å analyses is given. Our [O I]-based determination suggests the Hyades O abundance itself is super-solar, though [O/Fe]~0.0; however, systematic errors as large as $0.10-0.15$ dex cannot be ruled out. The Hyades giants show an unexpected ~0.23 dex O deficit relative to our dwarf value. While some suggestive evidence for non-standard nuclear processing and mixing in the Hyades giants may exist, we find it unconvincing. Rather, model atmosphere deficiencies or [O I]-region blending features that are still unrecognized by laboratory and theoretical efforts may contribute to the giant-dwarf O discrepancy. Finally, our high O abundance is marginally consistent with values claimed to provide a solution to the Hyades Li problem from standard stellar models. However, it is not clear that these models do in fact reproduce the extant Li data. Our Li abundance upper limit for vB 25 is at least 0.5 dex lower than the abundances of two tidally locked binaries of similar $T_{\rm eff}$. Standard stellar models of uniform composition and age are not able to reproduce such scatter in Li. © *1996 American Astronomical Society.*

1. INTRODUCTION

Oxygen is a potentially important interior opacity source in stellar models (e.g., Simoda & Iben 1970; Swenson *et al.* 1994), and can serve as a probe of nuclear processing and mixing in stellar interiors (e.g., Lambert & Ries 1981). Like other open clusters, the Hyades, which is the nearest well-studied stellar aggregate, has been an important source of observational data for comparison with stellar models (e.g., Lambert & Ries 1981; Michaud 1986; VandenBerg & Poll 1989; and Thorburn *et al.* 1993). Accurate O abundances of Hyades stars, then, can play a role in evaluating stellar model and evolution calculations as well as assessing the validity of abundance analyses using the 7774 Å O I lines. Relatively few studies have discussed O abundances of late-type Hyads, and a similar situation exists for all Galactic open clusters. Using the 7774 Å O I triplet, Garcia Lopez *et al.* (1993, hereafter GL93) and King (1993, hereafter K93) determined O abundances for Hyades dwarfs. GL93's NLTE analysis of 25 Hyads (we exclude the Am star vB 38) yielded a mean [O/H] of -0.05 ± 0.14 (1 standard deviation). Neglecting their five "Group A" stars (which show larger [O/H] values) gives [O/H]$=-0.10\pm0.07$. The four Hyads observed by K93 were cooler than the vast majority of the GL93 stars. He claimed his LTE analysis was justified (instead of a NLTE analysis) by results presented in King & Boesgaard (1995). The mean LTE abundance found was [O/H]$=0.27\pm0.08$.

The $0.3-0.4$ dex discrepancy cannot be explained by differences in stellar parameters or the data themselves (though differences in the data may exist). Most of the difference apparently lies in the LTE vs NLTE analysis assumptions and the normalization of stellar abundances to the solar value. Due to possible complications from NLTE effects (e.g., Kiselman 1991) or surface inhomogeneities (e.g., Nissen & Edvardsson 1992; Kiselman & Nordlund 1995), O abundances derived from the 7774 Å lines have previously been questioned. Determining which (if either) abundance value is more accurate might shed some light on these issues, which are also important in the analysis of halo dwarfs.

The Hyades O abundance is also an important ingredient of stellar models. Swenson *et al.* (1994) performed calculations using the high O abundance of K93 and found that PMS Li burning in their models can reproduce the observed gross Li abundance morphology of Hyades G and K dwarfs. This resolution of the classical Hyades Li problem might exclude non-standard physics in the stellar models, but such a conclusion is not, by any means, certain. Lambert & Ries (1981) and Gratton (1985) reported O analyses of the Hyades giants. These studies employed the 6300 and 6363 Å [O I] lines, which are believed to yield abundances free from systematic errors which may affect the 7774 Å lines (though see King & Boesgaard 1995). The ~0.1 dex offset between

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the two analyses is probably due to differences in the adopted gravities. The range of abundances, roughly $-0.10 \lesssim [\mathrm{O/H}] \lesssim +0.05$, is close to GL93's dwarf abundance. However, if K93's dwarf abundances are correct, they imply O depletion (unexpected in standard models) in the Hyades giants.

It is now thought that some source of "extra mixing" is necessary to reconcile stellar models with observed properties of Pop I giants older (i.e., less massive) than the Hyades (e.g., Gilroy 1989 and El Eid 1994). Venn (1993) has studied CNO abundances in three massive ($M \sim 10$ $M_\odot$), apparently post-first-dredge-up supergiants. She finds [N/C] and [N/O] ratios significantly larger than theoretical predictions, possibly suggesting extra mixing of ON-cycled material. The Hyades giants, however, are believed immune from the need for enhanced mixing. Their $^{12}\mathrm{C}/^{13}\mathrm{C}$ ratios (relative to cluster giants with $M \gtrsim 2.0$ $M_\odot$ anyway) are consistent with standard stellar evolution calculations (Fig. 8 of El Eid 1994). Duncan *et al.* (1995) reach the same conclusion based on their comparison of observed and predicted depletions of Li, Be, and B– though the uncertainties (in NLTE effects, model predictions, and the data themselves) remain annoyingly large.

A Hyades dwarf O abundance determination employing other transitions would be valuable. The 6300 Å [O I] line is a reasonable choice of transition to employ. This feature should yield abundances most consistent with the giant determinations. Unfortunately, the line is weak in dwarfs ($5-6$ mÅ in the Sun) and is obliterated by even mild rotational velocities. Crowding in the 6300 Å region further complicates the analysis of this feature. Observing the slower rotating later (K) type Hyades dwarfs can overcome the first problem, but makes high resolution and S/N observations (necessary to overcome the second problem) more difficult. Here, we describe observations made with the efficient, high-resolution Sandiford spectrograph on the McDonald Observatory 2.1-m telescope.

2. OBSERVATIONS AND DATA REDUCTION

2.1 *Selection of Stars*

We selected low $v \sin i$ dwarfs on the Hyades lower main sequence from the rotational period study of Radick *et al.* (1987). Because our data were taken during another program and the integrations were lengthy, only two objects (vB 79 and vB 25) could be observed. Membership (on the basis of photometry, radial velocities, and proper motions) for these stars has been considered by Griffin *et al.* (1988). They consider both stars members on the basis of all three criteria.

2.2 *Observations*

We observed vB 79 and 25 on 1994 September 20 and 25 using the Sandiford cassegrain echelle spectrograph and a Reticon 1200×400 CCD on the McDonald Observatory 2.1-m telescope. This prism-cross-dispersed instrument, which provides high resolution and wide ($\lesssim 1500$ Å) wavelength coverage, is described by McCarthy *et al.* (1993). The slit width employed ($\sim 1.0''$) provided resolution of $R \sim 46{,}400$ (0.135 Å at 6300 Å) and spectral coverage ranged from 5550 to 6850 Å. We obtained exposures of 190 and 201 minutes for vB 79 and 25 ($V = 8.96$ and 9.60). Prior to each object exposure, we also acquired very high S/N spectra of rapidly rotating, early-type stars at airmasses similar to our objects. Internal Th-Ar lamp spectra were secured after both object frames. We also obtained flat-fields (from internal lamps), bias, and dark frames during the nights.

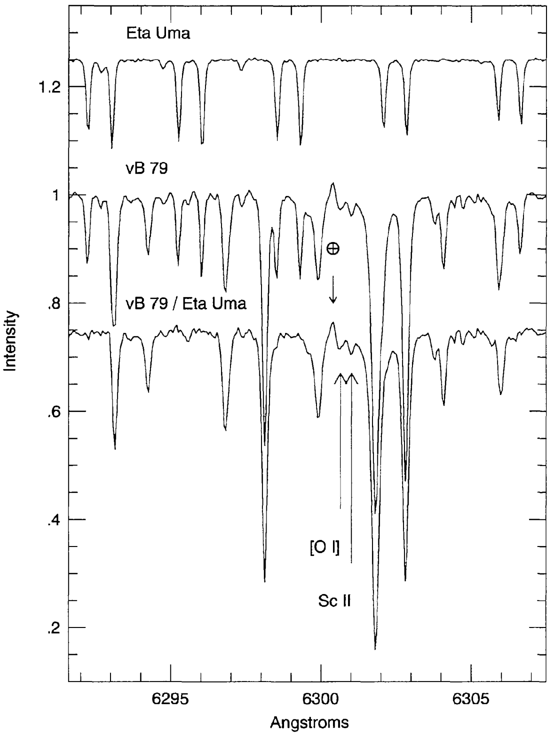

FIG. 1. The telluric division process is shown. The top spectrum is that of the hot rapid rotator, η UMa, showing telluric absorption features. The middle spectrum is vB 79. The bottom spectrum, showing the successful removal of the atmospheric absorption lines, is the resulting quotient.

2.3 *Data Reduction*

Standard IRAF routines were used for preliminary data reduction, which included overscan removal, bias and dark current subtraction, and trimming. The order tracing, flat-fielding (using a master flat constructed from ~20 individual frames), scattered light removal, and extraction must be handled carefully given the closely spaced orders and 2-d nature of the data. We used the specialized suite of routines, developed by McCarthy and Tomaney, imported into the IRAF package at the University of Texas to accomplish these tasks. The Th-Ar frames were reduced in a similar fashion and dispersion solutions were performed in IRAF by fitting low order polynomials to the measured arc line positions. We used the single-order software package SPECTRE (Fitzpatrick & Sneden 1987) to divide the final object spectra by the hot star spectrum. This procedure is shown in Fig. 1. Fortunately, there are no telluric absorption features in the immediate vicinity of the 6300.3 Å [O I] line in our spectra. The S/N (per pixel, as measured by photon statistics) of our final spectra, is ~385 for both the 6300 and 6700 Å regions.

TABLE 1. Adopted parameters and O abundances.

Object	Method	$T_{\rm eff}$ (K)	log g (cgs)	ξ (km s^{-1})	EW(O) (mÅ)	log ϵ(O) (dex)	[O/H] (dex)	EW(Li) (mÅ)	N(Li) (dex)
Sun	SYN	5770	4.44	1.0	(5.4)	8.93	0.	–	–
vB 79	SYN	5190	4.50	1.0	(7.1)	9.07	+0.14	(1.9)	$\leqslant+0.2$
vB 25	SYN	4790	4.55	1.0	(7.6)	9.09	+0.16	(2.2)	$\leqslant-0.1$
γ Tau	COG	4965	2.65	2.1	26.0	8.84	−0.09	–	–
δ Tau	COG	4940	2.69	2.1	26.6	8.87	−0.06	–	–
ϵ Tau	COG	4955	2.59	2.1	27.4	8.84	−0.09	–	–
θ Tau	COG	5015	2.76	2.0	24.3	8.85	−0.08	–	–

3. ABUNDANCE ANALYSIS

The O abundance analyses were carried out via spectrum synthesis using an updated version of the LTE analysis package MOOG (Sneden 1973) and the new generation of Kurucz (1992) model atmospheres. Dr. C. Sneden kindly provided the [O I] 6300 Å region line list, which is the same as that used by Kraft *et al.* (1992, 1993) in their analysis of globular cluster giants, used in our syntheses. We note that we have utilized the well-determined oscillator strength of log $gf=-9.75$ for the 6300 Å [O I] feature (Lambert 1978). Our Fe abundances were derived from measured equivalent widths using MOOG. Before proceeding to the analysis of the Hyades dwarfs, we first apply our techniques to the Sun so that consistently derived abundances are used to normalize the stellar values.

3.1 The Sun

We acquired spectra of the 6300 Å [O I] region of the day time sky in 1994 January with 2D-Coude spectrograph (Tull *et al.* 1995) of the McDonald Observatory 2.7-m telescope. The resolution ($R\sim80{,}000$) is higher than the Hyades observations and the S/N (per pixel) in the 6300 Å region is 660. Unfortunately, the hot divisor star spectrum was noisier, leading to a S/N degradation in telluric division process; the final effective S/N is 305. Additionally, Dr. K. Cunha kindly provided equivalent widths for 14 Fe I and 2 Fe II lines, having gf values from the list of Lambert *et al.* (1996; the "raw list"), measured on a high S/N, reflected solar spectrum (Cunha *et al.* 1995), obtained using the same instrumentation as for our Hyades dwarfs, from the minor planet Ceres.

We adopted $T_{\rm eff}=5770$ K, log $g=4.44$, and $\xi=1.0$ km/s for our solar analysis. The derived Fe I abundances show no trend with excitation potential and the Fe II values agree to within ~0.02 dex of the mean Fe I abundance. These satisfactory results indicate no gross systematic errors. For convenience, we scaled the raw list log gf values by a constant 0.03 dex so that our mean solar Fe abundance, log ϵ(Fe) $=7.55$ forcibly agreed with a near-meteoritic value of ~7.52.

Using the equivalent widths from Meylan *et al.* (1993, MFWK), we found a mean Fe abundance 0.05 dex larger. Hence, our Hyades [Fe/H] values would be 0.05 dex smaller if the MFWK data were used instead. We prefer the Ceres data, however, since the data were acquired with instrumentation identical to our own. We also compared gf values for 42 other Fe lines having data from both MFWK and the raw list so that additional Fe lines (in MFWK but not the raw list) could be used in our analysis. The mean offset is small (~0.02 dex), but the MFWK gf values were scaled to the scaled raw list values since the s.d. per line is comparable (±0.03 dex).

Synthetic spectra, computed with varying oxygen content, were compared with our McDonald sky spectrum to determine the O abundance. Molecular equilibrium calculations were directly included using C and N abundances of 8.56 and 8.05. CO is the only molecule of any importance in these calculations, but we included 13 others. A ±0.15 dex change in C abundance yields a ±0.01 dex change in derived O abundance. Changing N by a factor of 2 has no effect. Though the corrections are small (0.02 to 0.03 dex) for the Sun, we include them for consistency since they are not negligible for our Hyades dwarfs. The best fit to our spectrum gave log ϵ(O)$=8.93$, in good agreement with determinations from other transitions (e.g., the IR OH analysis of Sauval *et al.* 1984). The internal uncertainty, dominated by photon noise, is estimated to be ~0.04 dex. This result is listed in Table 1, where we also include the computed equivalent width for the [O I] feature corresponding to our derived abundance in order that comparison can be made by others utilizing different model atmospheres, abundance software, etc.

We checked our result using the Kurucz *et al.* (1984) solar flux atlas data renormalized in the same fashion as our Hyades and sky spectra. The resulting match of our synthesis to the 6300 Å region line profiles (including the 6299.6 Si I, 6300.7 Sc II, and 6301.5 Fe I lines) was excellent using input abundances from Anders & Grevesse (1989)– log ϵ(Fe) $=7.52$, log ϵ(Si)$=7.55$, and log ϵ(Sc)$=3.10$. Fortuitously, the best match to the [O I] feature was for an abundance ϵ(O)$=8.93$– the same value determined from our sky spectrum.

3.2 Hyades Dwarfs

3.2.1 Parameters and Fe abundances

Using Voigt profile fitting described in Beveridge & Sneden (1994), we measured equivalent widths of 60 Fe I and 6 Fe II unblended, "case a" lines from Thevenin (1990) in the vB 79 and 25 spectra. We determined abundances with MOOG for varying $T_{\rm eff}$, log g, and ξ. Kurucz (1992) [M/H] $=+0.10$ model atmosphere grids were employed and the gf values were those described in Sec. *3.1*. Values of $T_{\rm eff}=5190$ and 4790 K, log $g=4.50$ and 4.55, and $\xi=1.0$ km/s for vB 79 and 25 satisfy the usual abundance versus excitation potential, abundance versus line strength, and ionization equilibrium constraints. $T_{\rm eff}$ uncertainties are $\pm 60-70$ K, values for which the slope in the log $N({\rm Fe})-\chi$ plane becomes significant at the 1σ level according to the correlation coefficient. Errors in log g are $0.10-0.15$ dex, somewhat larger than formally expected due to the Fe ionization equilibrium evidently being a sensitive function of temperature for the cool vB 25.

As a check on these parameters, we also estimated $T_{\rm eff}$ values for vB 79 and 25 using the photometric relation of Thorburn *et al.* (1993, THDP), who note their zero point is "well anchored to the known solar $\rm T_{eff}$." Accuracy of the $T_{\rm eff}$ values at the cool end of their relation is difficult to assess, however. We note that our O abundances are insensitive to $T_{\rm eff}$ *itself* (change of $\pm 0.02-0.03$ dex per ± 100 K change). For vB 79, 5185 K is the mean of the THDP photometric and spectroscopic values. For vB 25, the corresponding value is 4760 K [for $(B-V)=0.99$]. These $T_{\rm eff}$ are in excellent agreement with our spectroscopically derived ones and we simply adopt the latter here.

Gray's (1992; equation 16.3) photometric calibration to eclipsing binary data would yield log $g=4.55$ and 4.61 for vB 79 and 25. The Revised Yale Isochrones (Green *et al.* 1987) and Gray's theoretical calibration (equation 16.2) suggest values larger by $0.05-0.2$ dex. The photometric values are in good agreement with our spectroscopically derived ones, which we retain since they are the lower values and lead to a conservative assumption in the sense that our Hyades O abundances would be too small if Gray's or the isochrone's values were more nearly correct. We point out that the Hyades gravities cannot in fact be much smaller since the Sun provides a lower bound to their values. We note that a $\pm 0.10-0.15$ dex variation in gravity corresponds to a ± 0.06 dex change in derived O abundance and that the weak [O I] lines are insensitive to our derived value of $\xi=1.0$ km/s.

For vB 79 and 25, our measured equivalent widths yield $[{\rm Fe/H}]=+0.08$ and $+0.13$, with a per line s.d. of ± 0.10 dex. Our [Fe/H] values agree with the high precision Hyades results of Cayrel *et al.* (1985; $[{\rm Fe/H}]=+0.12$) and Boesgaard & Friel (1990; $[{\rm Fe/H}]=+0.15$), suggesting no large $T_{\rm eff}$ errors relative to the other two studies. For vB 79, Cayrel *et al.* (1985) favor $T_{\rm eff}=5235$ K, only 45 K larger than our value. The abundance agreement also suggests our $T_{\rm eff}$ scale is consistent with K93's and GL93's since these latter scales are very close to those of Cayrel *et al.* (1985) and Boesgaard & Friel (1990). Taylor's (1994a) large $T_{\rm eff}$ value of 5340 K for vB 79 is likely excluded. Gravity scale consistency is addressed in Sec. 4.1.2.

3.2.2 O abundance determination

MOOG was used to synthesize spectra having varying O abundance to compare to our Hyades spectra. The calculations were performed with the Kurucz (1992) $[{\rm M/H}]=+0.10$ atmospheres (this value being very close to our derived [Fe/H]) with input abundances scaled from the solar mixture of Anders & Grevesse (1989). Molecular equilibrium corrections were calculated after adopting a C abundance. Friel & Boesgaard (1990) determine $[{\rm C/H}]=+0.04$ for 13 Hyades dwarfs. Tomkin *et al.* (1995; their Fig. 2) measure systematically larger C I equivalent widths than Friel & Boesgaard, but the former's final [C/H] values are smaller by ~ 0.1 dex. If the Hyades [C/Fe] ratio follows the general trend seen in Tomkin *et al.*'s (1995) Fig. 7, where there is large scatter at $[{\rm Fe/H}]\sim+0.1$, then $[{\rm C/Fe}]\sim-0.1$ (roughly solar) is expected. We adopt $[{\rm C/H}]=0.0$ for the molecular calculations and find that a ± 0.15 dex change in [C/H] alters the final O abundance by ± 0.02 and 0.03 dex for vB 79 and 25. There is no sensitivity to the N abundance, which we also take as solar. These equilibrium corrections amount to ~ 0.10 dex for vB 79 and 25.

Figure 2 shows the observed and synthetic spectra of vB 79 and 25. The overall agreement is quite satisfactory– the only glaring discrepancy being the 6299.6 Å Si I line. While Cayrel *et al.* (1985) found $[{\rm Si/Fe}]\sim+0.1$ (slightly larger than our scaled value) for vB 79, the notable blueward asymmetry in the observed spectrum suggests a contaminating blend, not apparent in our solar synthesis, unsatisfactorily accounted for. We find O abundances of log $\epsilon({\rm O})=9.09$ and 9.07 (or $[{\rm O/H}]=+0.16$ and $+0.14$) for vB 79 and 25. The results are listed in Table 1 along with the calculated [O I] line strength expected from our synthesis-based abundance. We estimate the 1σ level internal uncertainties (based on, e.g., uncertainties in the adopted stellar parameters and photon noise) in our O abundances to be ± 0.08 dex.

Figure 2 shows the observed 6300.3 Å feature is slightly broader than the synthesized feature on the redward side. This could result from (a) blending features omitted from the synthesis or (b) errors in gf values for the 6300.34 Å Ni I or 6300.48 Å CN features (though see Sec. *4.2*). Closer inspection of the spectra, however, reveals that most of the asymmetry is apparently an artifact of the telluric division. Systematic error could also arise from telluric [O I] emission eating into the stellar profiles' blue wing and from continuum placement, though such effects are not apparent in Fig. 2. Given these additional error sources, systematic errors could be as large as $\pm 0.10-0.15$ dex.

3.2.3 Li abundance determinations

THDP determined Li abundances for a large number of cool Hyades stars including vB 79. The G and K star Li abundances can potentially discriminate the mechanism(s) responsible for the steep decline in Li abundance with decreasing $T_{\rm eff}$. Since our echelle data contain the Li I 6707 Å feature(s), we can confirm TDHP's vB 79 result and extend their non-binary data to cooler $T_{\rm eff}$ with vB 25. Using the same parameters as for the [O I] computations, we conducted spectrum synthesis using the linelist of Hiltgen (1996), which takes into account numerous weak atomic and CN features in the Li I region. The ^{7}Li atomic data are those of Andersen *et al.* (1984). The observed (points) and synthetic (solid line) spectra are shown in Fig. 3. We deduce upper limits of $N({\rm Li})\leq+0.2$ and ≤-0.1 for vB 79 and 25; these values are listed in Table 1 along with the line strengths, calculated from our synthesis-based abundance, for the Li I feature in isolation.

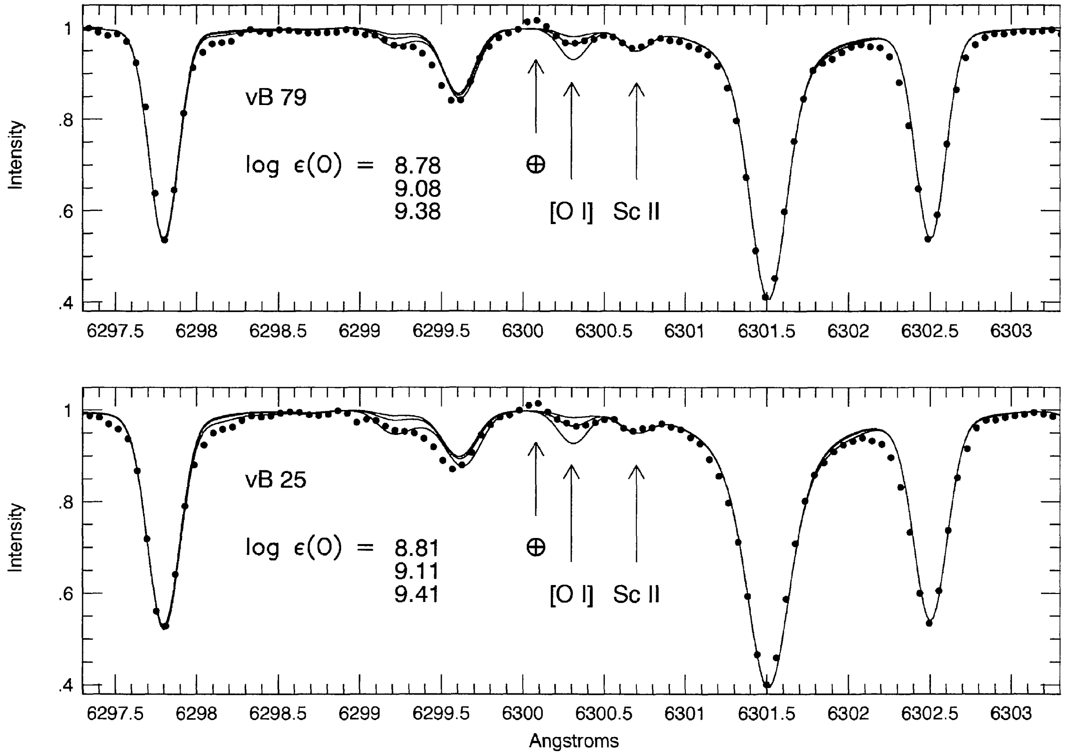

FIG. 2. Observed (points) and synthetic (lines) spectra of the 6300 Å [O I] region for vB 79 (top) and vB 25 (bottom). The input O abundance of the synthetic spectrum is varied by a factor of two between successive steps. The telluric [O I] emission near 6300.1 Å is labeled.

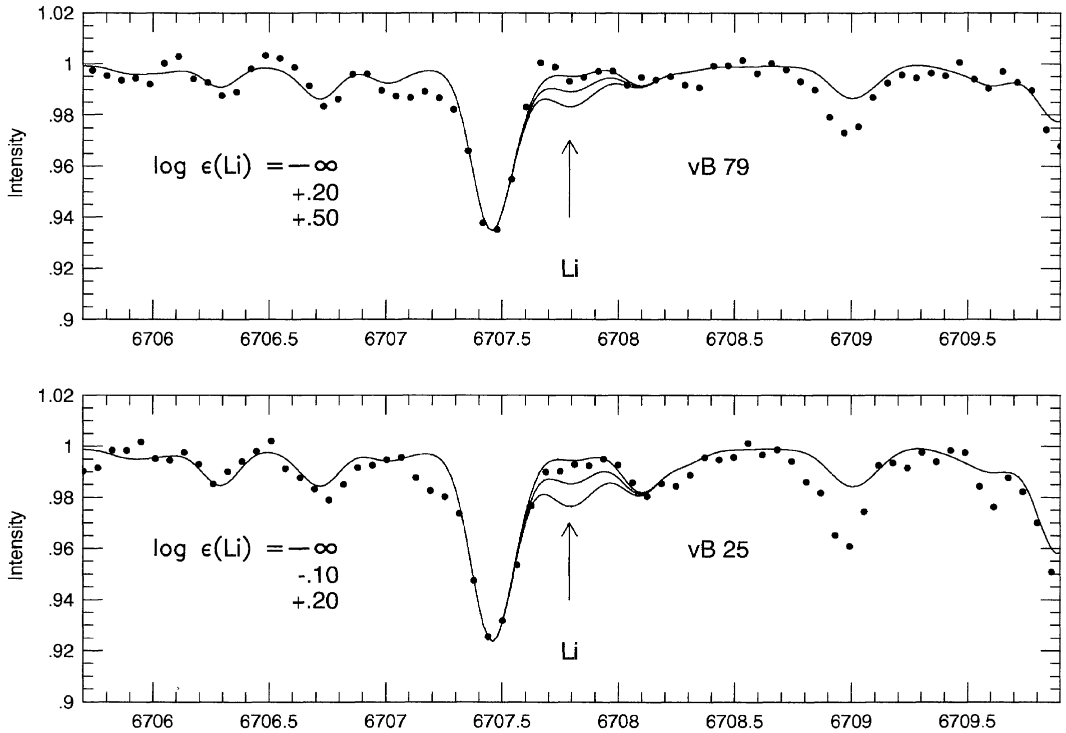

FIG. 3. Observed (points) and synthetic (solid line) spectra of the 6707 Å Li I region for vB 79 (top) and vB 25 (bottom). No Li feature is readily apparent. The three syntheses displayed have no Li, the favored Li upper limit, and twice the favored abundance limit.

3.3 Hyades Giants

3.3.1 Parameters

We now derive 6300 Å O abundances for the Hyades giants to compare with the dwarfs. Since we do not have giant data, we use equivalent widths from the literature. Because we cannot consistently derive parameters, values must be adopted for the giants. We regard $T_{\rm eff}$ estimates from the infrared flux method as the most reliable for the Hyades giants. Blackwell *et al.* (1991) and Blackwell & Lynas-Gray (1994) report values of 4965, 4940, and 4955 K for γ Tau, δ Tau, and ϵ Tau. Since θ Tau was not included in these studies, we estimated an approximate IRFM scale value, 5015 K, using McWilliam's (1990) relative $T_{\rm eff}$ values of the four giants. A fair estimate of the 1σ random uncertainty is ± 50 K, which *per se* yields an O abundance error of ~ 0.015 dex.

We calculated gravities using the V magnitudes, above $T_{\rm eff}$ estimates, an assumed mass (2.3 $M_\odot$; Gilroy 1989, Gratton *et al.* 1981), distance modulus (3.30; Gunn *et al.* 1988, and references therein), bolometric corrections (~ 0.3 mag), and $M_{\rm Bol}(\odot)=4.76$. The resulting log g values are 2.65, 2.69, 2.59, and 2.76 for γ, δ, ϵ, and θ Tau. The propagation of a ± 100 K error in $T_{\rm eff}$ and a ± 0.10 mag error in both distance modulus and bolometric correction leads to uncertainties in log g of ± 0.12 dex, which translates to a ± 0.05 dex error in O abundance. We assume [Fe/H] $=+0.10$ and use microturbulent velocities (2.0 km/s for θ Tau and 2.1 km/s for the other three giants) similar to the values of Gilroy (1989), McWilliam (1990), and Gratton (1985). A ± 0.2 km/s (typical of literature differences) change leads to a $\leqslant \mp 0.01$ dex change in O abundance.

3.3.2 Abundances

The [O I] equivalent widths are averages of values from Lambert & Ries (1981), Kjaergaard *et al.* (1982), and Gratton (1985). These multiple measurements suggest measurement uncertainties of ~ 2 mÅ, giving abundance uncertainties of ± 0.035 dex. The MOOG package was used with Kurucz (1992) atmospheres appropriate for the adopted parameters to construct curves of growth. Molecular equilibrium calculations were again included. Based on the above literature studies, we adopt for the giants [C/H]$=-0.12$, giving O abundance corrections of $\sim +0.08$ dex. Varying [C/H] by ± 0.2 dex changes the O abundance by ± 0.03 dex. There is no significant sensitivity to N abundance.

As listed in Table 1, we find log ϵ(O)$=8.84$, 8.87, 8.84, and 8.85 for γ, δ, ϵ, and θ Tau. The normalized abundances are [O/H]$=-0.09$, -0.06, -0.09, and -0.08. Estimated random uncertainties from the various sources listed above are ± 0.06 dex. The abundances are in better agreement than this, though, with mean [O/H]$=-0.08\pm 0.014$ (1 s.d.). This value is 0.23 dex less than our synthesis result for vB 79 and 25.

3.3.3 Possible systematic errors

Megessier (1994) found differences of ~ 100 K in IRFM temperatures derived using MARCS models (used by Blackwell *et al.* 1991) and the new Kurucz (1992) models (used by Blackwell & Lynas-Gray 1994). The $T_{\rm eff}$ difference, 1 and 10 K, for the two Hyades giants in these IRFM studies is very small and, at first, suggests no large systematic $T_{\rm eff}$ errors. The perhaps unexpected agreement could be due to the perceived improved opacity and convection treatment by Blackwell *et al.* (1991) compared to Megessier (1994). Nevertheless, convection and opacities may still be sources of error.

Indeed, recourse to observation or an *ad hoc* altering of surface boundary conditions is often needed force agreement between theoretical stellar models and observed giant branches in star clusters. Hence, analyzing both dwarfs and giants with model atmospheres having, e.g., identical mixing lengths may not be valid. A rigorous propagation of errors indicates that increases in $T_{\rm eff}$ alone and log g alone of 500 K and 0.5 dex are needed to yield giant O abundances consistent with the dwarfs. Parameter errors this large seem unlikely since the Hyades giant IRFM angular diameter estimates yield log g values within ~ 0.03 dex of our $T_{\rm eff}$- and distance-based estimate. However, excluding errors in the detailed model atmosphere structure which mimic parameter errors is more difficult.

4. DISCUSSION

4.1 Comparison of Hyades Dwarf Oxygen Abundances

4.1.1 GL93 versus K93 7774 Å abundances

Our vB 79 and 25 O abundance, [O/H]$\sim +0.15$, is intermediate to the 7774 Å triplet results of GL93 (-0.05 to -0.10) and K93 ($+0.26$). The O results for four stars in the latter study were used in Hyades stellar models by S94, who perceived (correctly or not) significant implications for the Li evolution in cool Hyades dwarfs. It is therefore of some interest to compare the GL93 and K93 studies to identify the cause of the large O abundance differences. We have reproduced Table 17 of K93, which contains his relevant Hyades data, here as Table 2. Table 2 contains the four Hyades dwarfs observed by K93 (referred to below as "JRK-stars") and six Hyades dwarfs of the GL93 study ("RGL-stars"), which were not observed by K93 but had their GL93 equivalent widths analyzed by K93 in an identical fashion as the JRK-stars.

Shown in Table 2 are the stellar parameters ($T_{\rm eff}$, log g, ξ) utilized by K93, the 7774 Å O I triplet equivalent width (from GL93 for the RGL-stars and from K93 for the JRK-stars), and the LTE [O/H] values derived in the K93 analysis. We make four peripheral notes before proceeding with the abundance comparison. First, the LTE absolute O abundances [i.e., log ϵ(O)] of K93 can be found from the [O/H] values in Table 2 and his derived solar abundance log ϵ(O) $=8.88$. Second, the O I *gf* values employed by K93 and GL93 are identical. Third, though it does not affect the abundance comparisons, the Hyades membership for the RGL-stars vB 88 and 61 is in question due to Schwan's (1991) results. Finally, new high resolution Hyades spectra obtained with the McDonald Observatory 2.7-m telescope indicate that K93's equivalent width for vB 15 is 10%–15% too large. As a result, the mean abundance of the four JRK-stars is lowered to [O/H]$\sim +0.22\pm 0.04$ (s.d.).

TABLE 2. K93 LTE O abundances.

Star	$T_{\rm eff}$ (K)	log g (cgs)	ξ (km s^{-1})	EW(O) (mÅ)	σ (mÅ)	EW Ref.	[O/H] (LTE)	σ (dex)
vB 15	5772	4.31	1.30	254	14	K93	+0.38	0.12
vB 31	6094	4.26	1.65	326	10	GL93	+0.37	0.09
vB 48	6207	4.28	1.70	367	20	GL93	+0.44	0.12
vB 61	6245	4.28	1.75	360	20	GL93	+0.38	0.12
vB 65	6118	4.24	1.70	344	20	GL93	+0.41	0.14
vB 66	6103	4.28	1.60	285	12	K93	+0.19	0.08
vB 73	5914	4.22	1.55	271	13	K93	+0.27	0.10
vB 88	6174	4.27	1.70	336	20	GL93	+0.34	0.12
vB 97	5887	4.28	1.45	250	12	K93	+0.22	0.10
vB 105	6081	4.30	1.55	283	20	GL93	+0.21	0.14

The mean difference (in the sense K93−GL93) between K93's and GL93's $T_{\rm eff}$ values for the (six) RGL-stars is only -10 ± 47 K. Hence, $T_{\rm eff}$ scales play no part in the discrepant mean [O/H] values. The mean log g difference (K93−GL93) between the K93 sample and the single value of 4.20 utilized by GL93 is $+0.07\pm0.03$ dex, accounting for only $\sim$0.02 dex of the final [O/H] discrepancy. The small mean differences, $+0.10\pm0.05$ km s^{-1} (K93−GL93), in the microturbulent velocity values employed by GL93 and K93 give O abundance differences of $\lesssim$0.02 dex, but in the wrong direction to explain to explain their final [O/H] differences. Thus, the small differences in the adopted stellar parameters play no role in the discrepant final [O/H] values of the K93 (LTE) analysis and GL93 (NLTE) analysis.

Maintaining our attention on the RGL-stars alone, we note the mean difference (GL93−K93) between the absolute K93 LTE O abundances and GL93's LTE values (from the fourth column of their Table 2) is $+0.19\pm0.05$ dex. K93 finds that $\sim$0.05 dex of this is due to van der Waal damping differences. Hence, based on the same equivalent width data, GL93's LTE absolute O abundances are 0.14 dex *larger* than K93's. Such differences may be due to choice of model atmospheres, analysis software, etc. In any case, these LTE absolute O abundance differences are also in the wrong sense to explain those in the final K93/G93 normalized O abundances.

If NLTE effects were negligible and if K93's and GL93's solar normalization were identical, then the [O/H] values in the last column of GL93's Table 2 and in column 8 of Table 2 from this work (which reflects the K93 results) for the RGL-stars alone should be $\sim+0.19$ dex larger than K93's values— due to the apparent analysis (model atmospheres, software, etc) and damping differences noted above. In fact, the mean difference (GL93−K93) is -0.42 ± 0.07 dex, implying a $\sim$0.61 dex abundance swing due to GL93's NLTE corrections and/or differences in the studies' solar abundances. *If* the systematic LTE analysis and damping differences (0.19 dex from above) discussed also held for the Sun, thus being removed from the normalized [O/H] values, this and GL93's larger solar equivalent width (200 mÅ versus K93's value of 176 mÅ, a 0.13 dex effect) can account for $\sim$0.32 dex of the 0.61 dex swing, leaving a $\sim$0.29 dex difference seemingly due to NLTE corrections.

GL93's *Hyades* absolute O abundance NLTE corrections (inferred from columns 4 and 5 of their Table 2) amount to 0.32 ± 0.03 dex for the six RGL-stars. However, their *solar* absolute O abundance NLTE correction is $\sim$0.1 dex (Garcia Lopez 1995). Thus, the effective decrease in the RGL-stars' [O/H] values due to NLTE is $\sim$0.22 dex. Comparison with the inferred above value of 0.29 dex indicates a remaining 0.07 dex difference whose precise origin is not completely clear. We believe, however, the likely cause is that the LTE analysis differences may not be uniformly systematic (the explicitly stated assumption in the above paragraph), but are themselves different for the (hotter) Hyades stars and the Sun. This can be seen by noting that, based upon the above RGL-star comparisons, taking the K93 LTE absolute O abundance of 8.86 and adding the 0.19 dex GL93−K93 analysis differences and the 0.13 dex GL93−K93 solar equivalent width differences should reproduce the GL93 LTE solar abundance ($\sim$9.26). In fact, the sum (9.18) falls 0.08 dex short.

We now summarize these comparisons. Analyzing identical equivalent width data for the 6 RGL-stars in Table 2, the K93 and GL93 analyses arrive at final [O/H] values differing by $\sim$0.42 dex. The adopted stellar parameters of each study play no part in this difference. Only $\sim$0.22 dex of this difference is due to the NLTE corrections utilized by GL93 and ignored by K93. Another 0.13 dex of the difference is due to the different solar equivalent widths employed by GL93 and K93. The remaining $\sim$0.07 dex difference appears to be a residual effect– the 0.19 dex LTE absolute O abundance analysis differences of GL93 and K93 apparently do not completely cancel in the differential solar analysis.

Finally, we note that the [O/H] difference between the full sample of K93 (which includes the RGL-stars and the JRK-stars) and the mean of the RGL-stars in the GL93 analysis is somewhat less than the value of 0.42 dex noted above. This is due to the fact that the K93 abundances for the four JRK-stars (upon which the S94 models were based) are 0.10–0.15 (depending on whether one uses the new McDonald data for vB 15) dex lower than the K93 values for the RGL stars. Such a difference could arise from differences in the raw data (i.e., differences in equivalent width scales); indeed, our new McDonald 2.7-m 7774 Å data suggest that there may be real systematic differences, possibly as large as 10%–15%, in measured line strengths between various data sets. Alternatively, the difference could be due to NLTE corrections, ignored in the K93 analysis, being larger for the (typically) stronger-lined RGL-stars than the weaker-lined JRK-stars.

4.1.2 O I versus [O I] abundances

Examination of the log *g* scales indicates that the K93 gravities are not precisely consistent with those used here. Gray's (1992) equation 16.3, which yields gravities very close to our cool dwarf spectroscopic determinations and values inferred via the Stefan-Boltzmann relation, gives log *g* values ~0.13 dex larger than K93's. This would lead to 7774 Å O I abundances larger by ~0.035 dex, giving (with the new vB 15 data) revised K93 abundances nearly identical to his original value ([O/H]~+0.26) for the four JRK-stars. For the GL93 objects having $T_{\rm eff}$ similar to the JRK-stars, gravity revisions raise the O abundances by ~0.05 dex.

Our [O I]-synthesis-based abundance for vB 79 and 25, [O/H]~+0.15, remains between the LTE and NLTE results of K93 (+0.26) and the GL93 (~−0.05). At face value, our result indicates a super-solar Hyades O abundance. The difference between the present [O I]-based value and the O I-based values of either K93 or GL93 could reflect shortcomings (e.g., ignoring NLTE effects, inaccurate NLTE corrections, errors in the solar O I equivalent width, the mysterious 0.07 dex residual analysis difference, etc) in one or both of the latter analyses. Alternatively, it remains difficult to rule out the systematic errors (e.g., unknown blending features) in the present [O I] analysis.

4.2 The Hyades Giant-Dwarf Oxygen Discrepancy

Our vB 79 and 25 O abundance, [O/H]~+0.15, is ~0.23 dex larger than the Hyades giants' abundance. We first consider possible causes of the discrepancy related to the giants (though we must bear in mind systematic error in our dwarf results). The first possibility is a genuine difference– that we are observing dredged, ON-cycled material in the giants. Because this is unexpected from standard stellar model calculations, we examine several lines of evidence to suggest non-standard processing in the Hyades giants.

Lambert & Ries (1981), Kjaergaard *et al.* (1982), and Gratton (1985) determine CNO abundances in the Hyades giants. Interpreting the derived [C/H] and [N/H] values with respect to model predictions is somewhat problematical since any such comparison must consider the absolute solar C and N abundances and the method of normalizing the absolute stellar abundances with respect to the solar value. Often, this information is unclear or absent. If one retains these studies' *relative* abundances (e.g., [C/H] or [C/Fe]) and uses recently favored *absolute* solar abundances of log ϵ(C)=8.56 and log ϵ(N)=8.05 (which give a *number* abundance ratio of C/N=3.24, significantly smaller than, e.g., the value of 4.8 employed by Lambert & Ries 1978) then C/N *mass* fractions of 0.58±0.07 (s.d.) and 0.48±0.13 are deduced from the results of Lambert & Ries (1978) and Gratton (1985), whose adopted parameters are most similar to ours. These values are some ~30% smaller than El Eid's (1994, Table 3a) recent model calculation of $X_{12}/X_{14}=0.76$.

Globular cluster giants show anticorrelated O and Na intra-cluster abundances varying by an order of magnitude (Kraft *et al.* 1992, 1993). The cause is believed to be ON cycling and proton capture Na production (Denisenkov & Denisenkova 1990), which is consistent with the homogeneous n-capture abundances (Armosky *et al.* 1994). El Eid (1994) notes the observed ~0.3 dex enhancement, over models including Ne-Na cycling during H-burning, in Pop I F-K giants' and supergiants' [Na/Fe] ratios. The Hyades giants also show abundant Na: Komarov *et al.* (1986) and Cayrel de Strobel *et al.* (1970) find [Na/Fe]=+0.23 and +0.28 for the four giants, Helfer & Wallerstein (1968) determine [Na/Fe]=+0.39 for three giants, and Griffin & Holweger (1989) deduce [Na/Fe]=+0.33 for γ Tau. The predicted first dredge-up value (El Eid 1994, Table 3a) is [Na/Fe]~+0.13 for 2.2 $M_\odot$.

We find the non-standard cycling and mixing evidence unconvincing, however. First, the Hyades giants' ^{13}C/^{12}C ratios are consistent with predicted values. Second, the C and N abundances, while interesting, should be given low weight. Interpreting the Kjaergaard *et al.* (1982) results in the same manner as above gives a C/N mass ratio of 1.92, in clear conflict with the other values. Until such uncertainties are sorted out, we do not believe the C/N ratios provide convincing evidence either for or against non-standard processing. Third, El Eid's calculations assume an initial value of [Na/Fe]=0., but Cayrel de Strobel *et al.* (1970) find [Na/Fe]~+0.18 in their reanalysis of two Hyades dwarfs. Hence, the inferred increase in the giants' [Na/Fe] agrees with prediction. Finally, Gilroy's (1989) Hyades giant Li abundance is *N*(Li)=0.9, which may be an underestimate since NLTE effects (Pavlenko 1991; Carlsson *et al.* 1994) were not considered. The presence of even depleted Li seems inconsistent with the processing and mixing required for ON cycling effects to become manifest.

In fairness, we note counter arguments to our objections. De la Reza & da Silva (1995) find *N*(Li)=3.5−4.5 (NLTE) for three field K giants (one having ^{12}C/^{13}C=7), suggesting some giants may be Li producers. Pilachowski (1986) found the Li abundances of NGC 7789 giants (age 1.5×10^9 yr) to be larger than average for low mass, Pop I giants. Indeed, their ^{12}C/^{13}C ratios lie below standard model predictions (El Eid 1994, Fig. 8), yet the LTE Li abundances of her three "Group IV" ($T_{\rm eff}$=4600 K, log *g*=2.5) giants are +1.3, +1.5, and +2.5, while the *higher* mass Hyades values are ~+0.9. NGC 7789 #301 has a large *LTE* Li abundance (+2.5) *and* the lowest observed cluster ^{12}C/^{13}C ratio (~10; Sneden & Pilachowski 1986). Pilachowski (1986) suggested that #301 may be an evolved blue straggler, but this seems doubtful given more recent observations indicating cluster and field blue stragglers all have very large Li depletions. Based on the observed Li, Be, B, Na, C, and N abundances and ratios, we conclude that it is not clear that standard model calculations (even with known deficiencies) are in error for the Hyades giants.

Alternatively, the dwarf-giant discrepancy may arise from systematic errors such as those reflected by the cautionary analysis of γ Tau by Griffin & Holweger (1989), who find [Fe/H]=−0.06 from 76 Fe lines. This value conflicts with numerous Hyades F and G dwarf studies which indicate

[Fe/H]$\gtrsim +0.10-+0.15$.[2] Their Fe ionization balance analysis yields log $g=2.1$, which is at odds with the value we find from the assumed distance modulus, T_{eff} (only 25 K lower than Griffin & Holweger's), and mass; such conflicts between spectroscopic and physical gravities persist in more recent studies of Pop I giants (e.g., Luck & Challener 1995). Since Griffin & Holweger suggest that chromospheric activity may play some role, we recall Langer's (1991) suggestion that [O I] emission from a cool expanding envelope may weaken the [O I] line in globular cluster giants. However, the Hyades giant O abundances we derive are identical despite the large observed spread in their transition region and chromospheric fluxes. Others have suggested that NLTE effects or convective effects may affect the [O I]-based abundances in Pop I or II giants or dwarfs, but the needed detailed calculations are lacking.

Finally, the referee has suggested that the presence of a blending neutral metal in the immediate 6300 Å [O I] region might affect the weak [O I] feature of the cooler Hyades dwarfs, while not significantly affecting the stronger feature of the Hyades giants or the (substantially hotter) Sun. The blending feature that is usually most carefully considered in this spectral region is the 6300.336 Å, $\chi=4.3$ eV Ni I feature (Lambert 1978), which was included in our linelist. Because of its high excitation potential, however, it is very unlikely that this feature can be the cause of the high Hyades O abundances relative to the Sun or the Hyades giants. Even with an assumed Hyades abundance of [Ni/H]$=+0.15$, the Ni I feature is only a few tenths of a mÅ stronger in the much cooler Hyades dwarfs than in the Sun. One would require ratios of [Ni/Fe]$\gtrsim +0.65$ for this feature to account for the 3.0−3.5 mÅ difference in [O I] which would move the Hyades dwarf O abundances in line with those of the giants.

We have also investigated the log gf value of the Ni I feature since it apparently lacks an accurate laboratory measurement. Based on observed wavelengths, line symmetry, and predicted [O I] equivalent widths derived from high resolution solar spectra, Lambert (1978) and Kjaergaard *et al.* (1982) give limits ranging from $\leqslant 0.1$ to $\leqslant 0.6$ mÅ for the disc centre equivalent width of the Ni I line. Performing an inverted analysis using the solar Ni abundance, log ϵ(Ni)$=6.25$ (Anders & Grevesse 1989), yields log gf values of $\leqslant -3.38$ and $\leqslant -2.60$ for the two equivalent width limits. These values are significantly less than that, log $gf=-1.87$, listed in Kurucz & Peytremann (1975). This latter value is easily excluded by comparison with our solar spectrum— even if the entire 6300.3 Å feature were assumed to be due entirely to Ni I, synthesis with log $gf=-1.87$ yields a feature which is still too strong. The value, log $gf=-3.00$, utilized in our syntheses is intermediate to the above two upper limits found in the inverted solar analysis. Our relative O abundances would not have changed, however, had we adopted the larger upper limit (log $gf=-2.60$) since the (small) differential effects are virtually identical for the Sun and the Hyades dwarfs. For the sake of completeness, we also note that neighboring low excitation potential CN features in our 6300 Å linelist would need to be enhanced by $7-8$ orders of magnitude for them to significantly affect the [O I] results; moreover, any such enormous increase would also adversely affect the Hyades giant O abundances. While a search of the literature and various atomic databases has been unable to locate any low excitation potential neutral features in the 6300.3 Å [O I] region which might affect the Hyades dwarf O abundances, it remains impossible to definitively exclude features, having the needed atomic parameters and abundance, which have escaped notice in laboratory and theoretical studies to date.

4.3 Oxygen Abundances and the Hyades Li Problem

Our [O I]-based abundance ([O/H]$\sim +0.15$) generally supports the enhanced values used in S94's Hyades calculations. While it is lower than their preferred value of $+0.30$, even $+0.20$ provides an improved fit to the cool Hyades star N(Li) vs T_{eff} data than previous models lacking an O enhancement. Additionally, S94 find that enhancements in Si, Ne, and Mg could mimic the effects of larger O abundances, possibly leading to improved agreement. Nevertheless, even if revised future opacities based on observed abundances could lead to agreement between the model calculations and the observed Li abundances in cool Hyades dwarfs, it is not at all clear that standard PMS Li burning satisfactorily accounts for cool stars' Li evolution. Instead, as S94 themselves concede, additional mechanisms (not included in standard models) may be important.

First, four Hyades tidally locked binaries (TLBs) observed by THDP all show underdepleted Li− behavior seen in other systems and suggesting that rotational history (excluded from standard models) plays a role. Our Li results are consistent with THDP's. For vB 79, our line strengths (inferred from the synthesis-based abundance in our case) and abundance upper limits agree closely (more so when neglect is made of blending features as in THDP). Our upper limit for vB 25, an object of particular interest since it is cooler than any of THDP's single stars, fits THDP's abundance trend well. The two coolest stars observed by THDP, BD +22 669 and BD+23 635 (T_{eff} of 4859 and 4736 K vs ~4790 for vB 25), are both tidally locked binaries (TLBs) having abundances, N(Li)$=+0.90$ and $+0.69$, significantly greater than our vB 25 upper limit [N(Li)$\leqslant -0.1$]. Higher Li abundances apparently are a common feature of some TLBs of sufficiently short period in various stellar populations and these can be understood in terms of TLB theory and stellar models that consider angular momentum evolution (e.g., Ryan & Deliyannis 1995).

Second, THDP's Li line strengths and abundances suggest a dispersion in apparently single cool Hyades dwarfs. Such a spread is not predicted by standard models of uniform composition and age, regardless of overall opacities. Third, the difference in the Li abundances and ages between cool Hyades and Pleiades stars (and, as the referee notes, the Sun) suggests that significant main-sequence Li depletion has occurred. This too is in conflict with standard stellar models, which (for the stellar masses considered here anyway) do not burn significant amounts of Li during main-sequence evolution compared to that burned during PMS evolution (e.g.,

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[2] Examining archival data, Taylor (1994b) suggests there is no difference in the Hyades dwarf and giant [Fe/H] abundances greater than 0.06 dex.

Figs. 1 and 2 of Pinsonneault *et al.* 1990). Thus, even with enhanced opacities, current standard stellar models (e.g., S94) may not satisfactorily explain the Hyades Li data, let alone the complete picture painted by Li abundances in other clusters and the Sun.

However, S94's counterargument to these obstacles apparently cannot readily be dismissed at the present time. As they note, their models suggest that star-to-star or cluster-to-cluster variations in Si, Mg, Ne, and O abundances, which may significantly affect PMS Li burning, could be the cause of the dispersion noted in the cool Hyades dwarfs and the cluster-to-cluster variations in Li abundance usually ascribed to age.[3] While Fe abundance determinations are available for several of the cool Hyades dwarfs and global values (mainly from earlier-type stars) are available for other clusters such as the Pleiades or M67, there is a clear lack of, e.g., Mg, Si, and Ne abundance data. If the model calculations of S94 are correct in suggesting that it is inaccurate, for the purposes of PMS Li burning calculations, to simply equate [Fe/H] with "metallicity" in a solar-scaled sense, then both *inter-* and *intra-*cluster Si, Mg, and Ne abundance differences do merit investigation.[4] New calculations using these future abundances may then be able to methodically exclude opacity as a possible culprit responsible for the so-called "Hyades Li problem."

5. SUMMARY

Using spectrum synthesis of the 6300 Å [O I] line region, we derive O abundances for the cool Hyades dwarfs vB 79 and 25. Our spectroscopic $T_{\rm eff}$ estimates agree with THDP's photometric values and (non-independent) spectroscopic estimates, K93's and GL93's $T_{\rm eff}$ scale, and the $T_{\rm eff}$ scale for F and G dwarfs of Cayrel *et al.* (1985) and Boesgaard & Friel (1990). Our mean Fe abundance, $[\mathrm{Fe/H}] = +0.11$, is in good agreement with recent fine analyses of Hyades dwarfs.

Our O abundance of $[\mathrm{O/H}] \sim +0.15$ is intermediate to those of K93 ($+0.26$) and GL93 (-0.05), who have analyzed the 7774 Å O I triplet in hotter dwarfs. The difference between the [O I] and O I analyses could reflect deficiencies in the latter analyses— e.g., neglect of NLTE, inaccurate NLTE corrections, errors in the solar 7774 Å equivalent width, etc. An accounting of differences between the 7774 Å O I-based [O/H] abundances of K93 and GL93 shows (a) a $\sim$0.22 dex difference from inclusion of NLTE effects by GL93, (b) a $\sim$0.13 dex difference arising from differences in the employed solar equivalent widths, (c) a residual $\sim$0.07 dex difference in the abundance analyses— due to choice of model atmospheres, software, etc.— which apparently is not removed in the differential comparison with respect to the Sun (however, another $\sim$0.12 dex of such analysis differences is apparently removed), and (d) The four JRK-stars seem to yield O abundances $\sim$0.1 dex lower than then RGL-stars in the analysis of K93. This could be due to raw data differences and/or differential NLTE effects, which were not considered by K93.

The Hyades giants' [O I]-based O abundance is 0.23 dex lower than our [O I]-based cool dwarf value. Possible resolutions are discussed, but none are particularly palatable. While standard stellar models fail to explain abundance patterns in some evolved stars of lower and significantly higher mass, there is no unambiguous evidence that they fail for the Hyades giants. A possible explanation for the discrepancy is inadequacies in red giant model atmospheres. This may be consistent with Griffin & Holweger's (1989) γ Tau analysis and the well-known discrepancy between spectroscopic and physical gravities derived for Pop I giants (Luck & Challener 1995).

Our [O I]-based O abundance is only marginally consistent with that claimed by S94 to be needed to resolve the Hyades Li problem using standard models. In any case, these (uniform composition) models are not able to explain the observed scatter in Li abundances of stars having similar $T_{\rm eff}$. For example, even if our Li abundance limit for vB 25 ($T_{\rm eff}=4775$) is doubled, it is still $\geqslant$0.5 dex less than the measured abundances for BD+22 669 ($T_{\rm eff}=4860$ K) and BD+23 635 ($T_{\rm eff}=4735$ K). However, fuller constraints on the ability of opacity enhancements to explain the Li abundance evolution in a variety of stellar populations would seem to require additional stellar abundance data which is not available. Finally, we also note that if our [O I] spectrum synthesis results are correct, then vB 79 and 25 could be added to the list of cool local dwarfs (including the Sun) having significantly larger O abundances than measured in, e.g., young disk H II regions and planetary nebulae— the so-called present day oxygen abundance problem.

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[3] We note, though, that the Pleiades O abundance determined by K93 is similar (perhaps slightly larger) to his Hyades abundance. This would run counter to S94's sort of counter-arguments in explaining the lower Hyades Li abundances compared to the Pleiades as due to a larger O abundance in the former cluster.

[4] How one will determine the Ne abundances in these cool dwarfs would, unfortunately, seem to represent a formidable challenge.

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