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Elemental abundance analyses with DAO spectrograms – VII. The late normal B stars Pi Ceti, 134 Tauri, 21 Aquilae, and Nu Capricorni and the use of Reticon spectra

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SUMMARY

Elemental abundance analyses of the sharp-lined normal late B stars π Ceti, 134 Tauri, 21 Aquilae and ν Capricorni are performed consistent with previous papers of this study. These stars have mostly near solar abundances, but each star also shows a few abundances which are a factor of 2 less than solar. The abundances of S, Ti, Fe, and Ni appear to be correlated.

Reticon data supplement the co-added photographic spectrograms. Comparison of 261 equivalent widths on 2.4 Å mm^{-1} spectra of sharp-lined B and A stars shows that the Reticon equivalent widths are about 95 per cent of the co-added equivalent widths with subsets of the data showing differences of order 5 per cent from this mean. The Hγ profiles of the co-added and Reticon spectra for eight sharp-lined stars show generally good agreement. The derived values of log g are larger by 0.11 dex on average using the Reticon data. These findings confirm the generally high quality of the co-added data produced from 10 or more spectrograms using the REDUCE graphics oriented computer reduction code. For five stars previously studied in this series metal lines which fall in the gap between the U and V plates are analysed using Reticon data.

1 INTRODUCTION

Studies of superficially normal B and A stars both establish local temperature standards for the analyses of peculiar stars and compare their abundances with those of the Sun. Papers III and IV (Adelman 1988a, b) contain elemental abundance analyses of the main sequence stars θ Leonis (A2 V), τ Herculis (B5 IV) and o Pegasi (A1 IV). Adelman *et al.* (1987) studied α Draconis (A0 III) and Adelman & Gulliver (1990) Vega (A0 V) using the same analysis techniques, but with Dominion Astrophysical Observatory (DAO) spectra which differ in signal-to-noise and/or wavelength coverage. The star o Peg is the prototype of hot Am stars, θ Leo is a mild Am star, and Vega is somewhat metal-poor compared to the Sun. Further τ Her and α Dra also show a few abundance anomalies with respect to the Sun.

The analyses of superficially normal B and A and of HgMn stars presented in this series show that the hottest stars have derived microturbulences near 0 km s^{-1} while the coolest stars have values of order 2 km s^{-1}. The onset of microturbulence occurs near 10 500 K. This may coincide with the appearance of a weak convective zone high in the atmosphere. The superficially normal stars also exhibit trends in some of their derived abundances.

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The photographic region spectra of the moderately sharp-lined stars π Cet (=HR 811=HR 17081) (B7 V), 134 Tau (=HR 2010=HD 38899) (B9 IV), 21 Aql (=HR 7287=HD 179761) (B8 II–III), and ν Cap (=HR 7773=HD 193432) (B9.5 V) were last analysed by Adelman (1984a) with a variety of spectroscopic material whose equivalent width scale was normalized to that of 4.3 Å mm^{-1} IIaO spectrograms taken with the coudé spectrograph of the 2.5-m telescope of Mt Wilson Observatory. The derived abundances were similar to those of the Sun. These stars are re-analysed with higher signal-to-noise DAO data to improve the quality of their derived analyses as well as to determine whether increasing the signal-to-noise ratio by a factor of at least 2 will confirm some of the minor abundance anomalies. Gulliver *et al.* (1991) reported that the profiles of the weak lines of ν Cap obtained with a Reticon are somewhat anomalous. One possibility is that this star is a rapid rotator seen nearly pole-on.

2 THE USE OF RETICON SPECTROGRAMS

Adelman (1989) compared equivalent and line widths in co-added photographic and Reticon 2.4 Å mm^{-1} spectra of three sharp-lined stars obtained with the 96-inch camera of the coudé spectrograph of the 1.2-m telescope of the DAO. The co-additions were assembled using the computer graphics package REDUCE (Hill & Fisher 1986). The photographic calibrations used Baker densities. Initial reductions of the observations made with a bare 1×1872 Reticon with 15-μm pixels were made with the program RET72 (Hill & Fisher 1986) which allows for division by the lamps, normalization of amplifier gains, and FITS file output. The instrumental profile of the spectrograph plus Reticon has a FWHM of 0.074 Å (Gulliver & Hill 1990). Metal lines of equivalent widths 5–75 mÅ in α Dra and ι CrB showed systematic differences of order 4 per cent with an uncertainty of order 3 per cent and a rms scatter of 2.0–3.7 mÅ about the mean equivalent-width differences.

As it is important to characterize systematic differences between data taken with the same spectrograph but with different detectors, additional studies of co-added photographic and Reticon equivalent widths are presented for the 96-inch camera of the DAO coudé. Hγ profiles of eight stars are also examined from co-added photographic spectra obtained with the 96-inch camera and from Reticon observations with the 32-inch camera. Systematic errors in the Reticon data are expected to be far smaller than in photographic data as the former can be operated as highly linear detectors (see Schaefer, Zalewski & Geist 1983).

2.1 Comparison of Reticon and co-added photographic metal line data

The DAO co-added and Reticon spectra were measured as in Adelman (1989) using REDUCE to determine the line parameters. Thus the continua are defined in a similar manner. Table 1 summarizes the least squares comparisons of the equivalent widths. The co-added spectrograms typically have signal-to-noise ratios of order 50 per cent of the Reticon spectrograms. The α Dra and ι CrB results are from Adelman (1989) while those for the other stars are new measurements. The ensemble gives a better idea of the systematics between selected spectra regions of co-added photographic spectrograms and Reticon observations. The line widths on the co-added and Reticon spectra are similar for a given star and region. Fig. 1 and Table 1 contain a least squares comparison for all 261 equivalent widths. While the different subsets indicate systematic differences of order 6 per cent with zero point offset differences of order 0.5 mÅ, the results for individual lines may show somewhat larger differences. The 0.63 mÅ intercept, although not large, might reflect a slight difference in the continuum placement due to the different signal-to-noise ratios of the co-added and Reticon spectra. The α Dra co-addition, which shows the worst agreement with the average, is based on only 6 spectra while those for the other stars are based on at least 10 spectra.

The line profiles of the θ Leo Adelman (1988a, hereafter Paper III) and ν Cap (see Section 3) are fit with rotational profiles. For θ Leo the mean line widths for the 28 lines of both the co-added and the Reticon spectra centred at λ4465 are almost identical 21.0 ± 3.2 km s^{-1} versus 21.6 ± 2.8 km s^{-1}. The 2 mÅ offset, the b term, is of some concern. For ν Cap the mean line widths for 15 lines of both the co-addition and the Reticon spectrum centred at λ4190 are quite similar, 22.3 ± 4.5 km s^{-1} versus 23.4 ± 2.8 km s^{-1}, respectively.

The line profiles of o Peg are dominated by the instrumental profile and can be fit using Gaussians (Paper III). Reticon spectra centred at λ4080 and λ4190 were obtained. The equivalent width comparisons for the two different regions with the co-addition show systematic differences of about 7 per cent. But the co-addition line widths (FWHM) 0.160 ± 0.026 Å for the former region and 0.174 ± 0.027 Å for the later compare with 0.162 ± 0.031 Å and 0.173 ± 0.024 Å, respectively, for the Reticon spectra.

Adelman (1988b, hereafter Paper IV) fit Gaussian line profiles through the spectroscopic data of the HgMn stars 28 Her and ϕ Her. The Reticon spectra are centred near λ4190. The mean FWHM for the co-added spectrum was 0.205 ± 0.038 Å versus 0.219 ± 0.037 Å for the Reticon spectrum for 28 Her and 0.233 ± 0.057 Å and 0.236 ± 0.060 Å, respectively, for ϕ Her.

2.2 Hγ profile comparisons

Hγ profiles have been extracted for some normal and peculiar B and A stars from co-added DAO 2.4 Å mm^{-1} spectrograms for comparison with the predictions of model atmospheres (see for example, Papers III & IV). Spectrum curvature, noise, and metal lines affect the determination of continuum levels. The residual intensities were found as a function of distance from the line centre with allowance for metal lines by reading intensities from the spectra. A 4 per cent correction was made for scattered light.

Table 1. Least squares comparison of equivalent widths in the form $W_\lambda(\text{Reticon}) = m W_\lambda(\text{co-add}) + b$.

Star	Number of Lines	m	b	Notes
α Dra	25	1.043 ± 0.044	0.27 ± 1.20	
ι CrB	56	0.959 ± 0.019	0.15 ± 0.45	
28 Her	16	0.950 ± 0.031	1.01 ± 0.88	
o Peg	44	0.906 ± 0.010	0.92 ± 0.32	λ4080 Region
o Peg	43	0.972 ± 0.010	0.55 ± 0.32	λ4190 Region
θ Leo	27	0.961 ± 0.014	2.01 ± 0.62	
φ Her	35	0.903 ± 0.021	1.16 ± 0.42	
ν Cap	15	0.904 ± 0.047	0.90 ± 0.88	
All	261	0.945 ± 0.007	0.63 ± 0.21	

In the summer of 1989 observations centred on Hγ were obtained of several stars with the 32-inch camera of the DAO coudé spectrograph in the 3261 configuration which has a reciprocal dispersion of 19.6 Å mm^{-1}. These spectra show a definite curvature after division by the flat field which produced uncertainties in placing the continuum.

Normalized Reticon and co-added spectra centred on Hγ, corrected for scattered light, were compared for 21 Aql, α Dra, 28 Her, ϕ Her, τ Her, o Peg, π Cet, and ν Cap. That the spectral resolution of the co-added spectra is about one-fourth of the Reticon spectra appears to be unimportant for these stars, but not necessarily for more heavily line blanketed stars. The discrepancies usually were relatively small which makes them difficult to display graphically. The largest differences were seen for α Dra. Fig. 2 shows its normalized co-added and Reticon observations plotted on top of one another. Within ±20 Å of the line core differences of 5 per cent in residual intensity occur with the Reticon values less than those for the co-addition. Similar 2 per cent differences are see for τ Her and 28 Her. In o Peg, the co-addition shows residual intensities which are about 5 per cent greater than those seen in the Reticon for λλ4300–4320. For ϕ Her the largest disagreement between the co-addition and the Reticon spectra are between ±10 to 40 Å from line centre where the Reticon indicates lower intensities by about 2 per cent. The Reticon spectrum of 21 Aql shows of order 1 per cent lower intensities within ±10 Å of line centre which increase to about 2 per cent near ±20 Å and then rapidly decrease. In π Cet and ν Cap there are differences of up to 2 per cent within 5 Å of line centre, but otherwise the agreement is better. This degree of agreement is far better than is usually seen among Hγ profiles derived from individual photographic spectra for the same star.

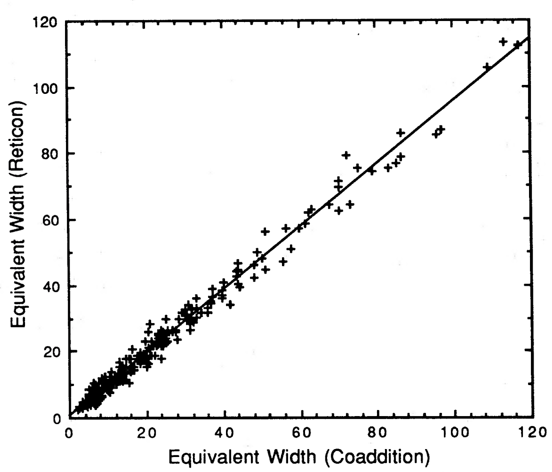

Figure 1. The least squares comparison of 246 equivalent widths from DAO Reticon and co-added 2.4 Å mm^{-1} spectra.

2.3 Implications of the Reticon data for elemental abundance analyses

Errors in the measured Hγ profiles lead to errors in the surface gravities of B and early A stars and in the temperatures for somewhat cooler stars. They in turn produce errors in the derived elemental abundances. Recently I ported the spectrum synthesis code SYNTHE (Kurucz, private communication) to The Citadel VAX cluster. The normalized spectral data can be matched with the spectral calculations using model atmospheres computed with the ATLAS code (see Kurucz 1979). This allows one to explicitly see the effects of line blanketing which are lost when one extracts a Balmer line profile.

For o Peg, the model Hγ profile is an excellent fit to the Reticon data while the co-addition shows the discrepancies described in Section 2.2 (also see Adelman 1988a). The Reticon and co-added data (this paper) for ν Cap both match the same $\log g = 3.90$ model while those for π Cet the same $\log g = 3.85$ model. For the other stars, the Reticon data indicate $\log g = 3.50$ instead of 3.35 for ν Aql (this paper),

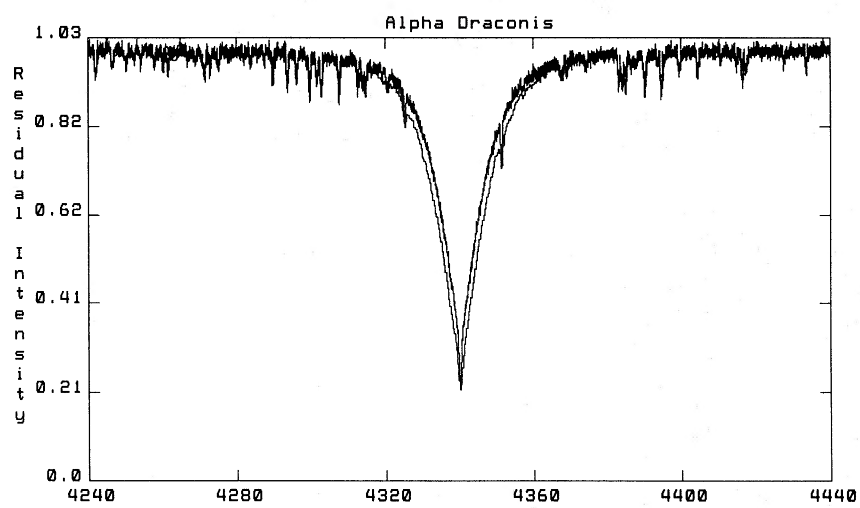

Figure 2. Co-added and Reticon spectra of the Hγ region of α Draconis are plotted on top of one another. They coincide in the line wings ±20 Å from the line centre. In the line core the Reticon spectrum falls systematically below the co-addition typically by about 5 per cent in residual intensity.

3.60 rather than $\log g=3.30$ for α Dra (Adelman *et al.* 1987), $\log g=3.80$ instead of 3.70 for ϕ Her (Paper IV), $\log g=3.95$ instead of 3.75 for τ Her (Paper III), and 3.75 instead of 3.65 for 28 Her (Paper IV). This mean shift of 0.11 dex in $\log g$ will produce small changes especially for abundances derived from non-dominant atomic species.

Reticon observations of the Hγ region of 9 other single stars with published optical spectrophotometry were compared with the predictions of solar composition ATLAS8 models to derive the effective temperatures and surface gravities (see Table 2). For stars cooler than about 8000 K, the Hγ profiles are overlain with considerable metal line blanketing which makes the continuum locations rather uncertain. For these objects it is probably better to obtain observations of the less heavily line blanketed Hβ region. There is also a change of reflectivity in the blue wing of Hβ due to the superblue optics (see CFHT Manual). This affects the Reticon observations less than the photographic as the light for the lamp exposures is reflected by the last superblue mirror. This reflectivity change probably produces only a small effect, but should be checked.

Both the Am and the Ap stars are metal-rich objects and the derived values are also uncertain due to the metallicity differences between the stars and the model atmospheres. The previous determinations (Table 2) are representative of recent values in the literature, selected if possible from those which used spectrophotometric and Balmer line data. This paper's values of $\log g$ are often somewhat larger than those given in the literature. The effective temperature values of the two F stars are slightly cooler than those found by Malagnini *et al.* (1986) and Morossi & Malagnini (1985).

For HR 8216, Table 2 gives a value based on $u-b$ and b-y colours. Fitting the spectrophotometry of the Balmer Jump region gave 8750 K, $\log g=3.0$ and the Paschen continuum region 8500 K, $\log g=4.0$ (Adelman 1981a). The adopted match indicates that this Ap star is somewhat evolved. The derived value for γ Equ, the other Ap star studied, also indicates this. However, the atmospheric parameters of both slowly rotating stars need to be rederived with model atmospheres which incorporate sufficient line opacity.

Lane & Lester (1987) found somewhat cooler effective temperatures than this study for the two Am stars. But Kocer *et al.* (1987) derived $T_{\text{eff}}=7450$ K, $\log g=3.20$ for 32 Aqr which is in better agreement. Dworetsky & Moon (1986) suggested that the effective temperatures found by Lane & Lester (1984) for the Am stars are systematically too small by about 400 K on average.

Table 2. Stellar parameters.

Star	Spectral Type	Teff (K)	log g	Spectro- photometry	Previous Determination		Source
γ Peg	B2 IV	21250	4.20	1	21500	3.70	7
ι Her	B3 IV	17000	4.00	2	17500	3.75	8
υ Her	HgMn	11900	3.70	3	11900	3.50	9
HR 8216	Ap	8250	3.25	4	8450	3.00	4*
15 Vul	Am	7700	3.30	5	7500	3.50	10
γ Equ	Ap	7650	3.85	6	7500	3.50	6
32 Aqr	Am	7550	3.30	5	7300	3.30	10
σ Boo	F2 V	6800	4.30	2	6950	4.27	11
θ Cyg	F4 V	6750	3.50	2	6880	...	12

Notes: 1 = Adelman (1978); 2 = Breger (1976); 3 = Adelman & Pyper (1979); 4 = Adelman (1981a); 5 = Lane & Lester (1980); 6 = Adelman (1981b); 7 = Peters (1976); 8 = Peters & Polidan (1985); 9 = Adelman (1984b); 10 = Lane & Lester (1987); 11 = Malagnini *et al.* (1986); 12 = Morossi & Malagnini (1985).
*From $u-b$ and $b-y$ colours.

Reticon observations centred at λ4190 near where two pieces of glass which make up the U and V plates are abutted in the 96-inch coudé camera at DAO were made of α Dra, ι CrB, ϕ Her, 28 Her, τ Her, and o Peg which were previously analysed with co-added DAO photographic spectra and of ν Cap which is analysed in this paper. These Reticon observations can supplement the co-added spectrograms. The gap between where the spectra are of good quality is typically between 6 and 16 Å. Abundances of those lines which fall in this gap are given in Table 3 for the previous analysed stars. The total number of lines n and the average species abundance are also given. (As a considerable portion of the spectrum of ι CrB is being observed with a Reticon to clarify the relative contributions of its components, this star is not considered at this time.)

There are between 1 and 11 new lines which are analysable for each star. The agreement between the derived values and those found previously from co-added spectra are good. Thus the new averages are almost identical with the previously published values.

Beginning with this paper, Reticon data when it has been obtained will be used in the analyses. To indicate this change the term 'co-added' has been deleted from the title of this series of papers. Since the Reticon data usually has the higher signal-to-noise ratio, it will be the preferred source of the equivalent width values. Equivalent widths from Reticon spectra, when available, will replace the co-added values when the analyses of stars previously analysed in this series are re-examined using ATLAS9 models which incorporate the new opacity distribution functions of Kurucz (private communication).

3 SPECTRAL REDUCTIONS

Nine, 10 U and 11 V, 11, and 11 spectrograms of π Cet, 134 Tau, 21 Aql, and ν Cap, respectively, were co-added using the procedures described in Papers I (Adelman & Hill 1987) and II (Adelman 1987a). A Reticon spectrum of ν Cap centred on λ4190 was also obtained. Rotationally broadened profiles were fit through most of the stellar lines of π Cet, 134 Tau, 21 Aql, and ν Cap except for very strong lines in which case Gaussian or Lorentzian profiles were used as appropriate. The apparent rotational velocities were found to be 20 km s^{-1}, 27 km s^{-1}, 16 km s^{-1}, and 23 km s^{-1}, respectively, based on moderately strong lines near λ4481. No correction was applied for the instrumental profile. For the λ4190 centred Reticon spectrum of ν Cap, $v \sin i$ was 22 km s^{-1}. Values in the literature include 18 km s^{-1} for π Cet, 22 km s^{-1} for 134 Tau, 19 km s^{-1} for 21 Aql, and 17 km s^{-1} for ν Cap (Hoffleit 1982).

The procedures of Paper II are followed to derive criteria for the presence of the weakest lines which are measured with sufficient accuracy for use in the elemental abundance analyses. For π Cet, the weakest lines retained had equivalent widths of 3.1 mÅ with uncorrected values of $v \sin i$ between 15 and 25 km s^{-1} while the comparable values for 134 Tau are 4 mÅ with uncorrected values of $v \sin i$ between 20 and 34 km s^{-1}, for 21 Aql 2.8 mÅ with uncorrected values of $v \sin i$ between 12 and 20 km s^{-1}, and for ν Cap

3.5 mÅ with uncorrected values of $v \sin i$ between 17 and 29 km s^{-1}.

4 THE LINE SPECTRA

A Multiplet Table of Astrophysical Interest (Moore 1945) and *Wavelengths and Transition Probabilities for Atoms and Atomic Ions, Part 1* (Reader & Corliss 1980) were the primary sources used to identify the stellar lines. These references were supplemented for specific atomic sources by Moore (1965) for Si II; Pettersson (1983) for S II; Huldt *et al.* (1982) for Ti II; Dworetsky (1971) for Cr II; Catalan, Meggers & Garcia-Riquelme (1964) for Mn I; Iglesias & Velasco (1964) for Mn II; Kiess, Rubin & Moore (1961) for Fe I; Johansson (1978) and Adelman (1987b) for Fe II; and Iglesias (1979) for Co II. Most lines belonged to species previously found by Adelman (1984a). Lines of atomic species not previously identified are Mg I, Al I, Al III, and Fe III for π Cet, S II and Ca I for 134 Tau, Mg I, Al I, Al III, Si III, Fe III, and Sr II for 21 Aql, and S II and Zr II for ν Cap.

The radial velocities (and the standard deviation about the mean) of the co-additions found by comparison of the stellar and laboratory wavelengths are 12.38 ± 1.74 km s^{-1} for π Cet, 20.51 ± 0.54 km s^{-1} for 134 Tau, -3.30 ± 1.92 km s^{-1} for 21 Aql, and -0.77 ± 1.74 km s^{-1} for ν Cap. The standard deviation for three of these stars is somewhat larger than expected for non-variable stars. This might indicate low-level variability or simply that there are relatively few lines to well determine the cross-correlation. The radial velocity values for all four stars are within the ranges of the references cited by Abt & Biggs (1972).

This study's equivalent widths (in mÅ) were compared with those of selected previous analyses. For π Cet, a least squares fit with 60 lines from Adelman (1984a) yields

$$W_\lambda(\text{DAO}) = \underset{\pm 0.016}{0.938}\ W_\lambda(\text{A}) - \underset{\pm 1.02.}{4.65}$$

Table 3. New and revised lines based on Reticon observations centred near λ4190.

Star	Species	λ(Å)	W_λ(mÅ)	log gf	Ref	line log N/H	n	mean log N/H
α Dra	Ti II	4174.05	7	-1.25	MF	-7.31		
		4184.39	6	-2.46	KX	-7.06	40	-7.27
	Cr II	4179.43	13	-1.77	KX	-6.64	21	-6.61
	Fe I	4181.76	9	-0.18	MF	-4.82		
		4187.04	7	-0.55	MF	-4.80	46	-4.90
	Fe II	4178.86	51	-2.48	MF	-4.87	49	-4.93
φ Her	Fe I	4184.90	3	-0.55	MF	-4.47		
		4187.04	4	-0.55	MF	-4.03		
		4187.82	10	-0.55	MF	-4.09	52	-4.32
τ Her	Fe II	4178.86	16	-2.48	MF	-4.94	30	-4.80
28 Her	Cr II	4179.43	17	-1.77	KX	-6.29	35	-6.28
	Mn II	4174.32	12	-3.55	KX	-5.87	42	-5.62
	Fe I	4175.64	3	-0.67	MF	-4.71		
		4181.76	7	-0.18	MF	-4.63	86	-4.48
	Fe II	4173.45	61	-2.65	MF	-4.25		
		4178.86	54	-2.48	MF	-4.52	102	-4.50
o Peg	Ti II	4184.33	20	-2.46	KX	-6.64	65	-6.86
	V II	4183.44	20	-0.95	KX	-7.65	27	-7.31
	Cr II	4179.43	31	-1.77	KX	-6.21	37	-6.17
	Fe I	4175.65	17	-0.67	MF	-4.39		
		4181.86	30	-0.18	MF	-4.56		
		4182.38	4	-1.19	MF	-4.47		
		4184.90	14	-0.86	MF	-4.30	251	-4.32
	Fe II	4177.70	46	-3.68	KX	-4.18		
		4178.86	93	-2.48	MF	-4.36		
		4182.69	2	-3.67	KX	-4.60	111	-4.35
	Zr II	4179.81	8	-0.91	GB	-8.22	28	-8.43

Notes: References for *gf* values; GB = Grevesse *et al.* (1981); KX = Kurucz (in preparation); MF = Martin, Fuhr & Wiese (1988) for Sc through Mn and Fuhr, Martin and Wiese (1988) for Fe through Ni.

For 134 Tau, 23 lines were compared with the values of Kodaira & Takada (1978):

$$W_\lambda(\mathrm{DAO}) = 0.768\ W_\lambda(\mathrm{KT}) - 12.41$$
$$\pm 0.059 \qquad \pm 5.00;$$

and 100 lines with the values of Adelman (1984a),

$$W_\lambda(\mathrm{DAO}) = 0.900\ W_\lambda(\mathrm{A}) - 4.38$$
$$\pm 0.019 \qquad \pm 0.95.$$

The comparison with Kodaira & Takada (1978)'s results shows the worst zero point shift for those stars studied so far in both series of analyses. For 21 Aql, 57 lines were compared with the values of Adelman (1984a)

$$W_\lambda(\mathrm{DAO}) = 0.938\ W_\lambda(\mathrm{A}) - 6.24$$
$$\pm 0.027 \qquad \pm 1.30.$$

For ν Cap, 96 lines from the co-addition were compared with values from Adelman (1973):

$$W_\lambda(\mathrm{DAO}) = 0.818\ W_\lambda(\mathrm{A}) - 3.52$$
$$\pm 0.017 \qquad \pm 1.20;$$

while when 8 lines of the Reticon spectra were used,

$$W_\lambda(\mathrm{DAO}) = 0.800\ W_\lambda(\mathrm{A}) - 5.98$$
$$\pm 0.055 \qquad \pm 2.60.$$

These are consistent given the errors in the derived fits. The comparisons with Adelman (1973, 1984a) are similar to that found in Paper III for τ Her especially in regard to the substantial b terms which suggests a difference in the location of continuum levels.

5 THE ABUNDANCE ANALYSES

Optical region spectrophotometry ($\lambda\lambda$3300–7100) for all four stars (Adelman 1978) and the Hγ spectral regions were compared with the predictions of LTE model atmospheres calculated with the ATLAS8 code (Kurucz 1979). The program SYNTHE (Kurucz, private communication) calculated synthetic spectra centred on Hγ. The line broadening theory of Vidal, Cooper & Smith (1970, 1971, 1973) was used for Hγ. The adopted values using co-added spectra are $T_{\mathrm{eff}} = 13\,150$ K, $\log g = 3.85$ for π Cet, $T_{\mathrm{eff}} = 10\,825$ K, $\log g = 3.88$ for 134 Tau, $T_{\mathrm{eff}} = 12\,900$ K, $\log g = 3.35$ for 21 Aql, and $T_{\mathrm{eff}} = 10\,250$ K, $\log g = 3.90$ for ν Cap. For π Cet and ν Cap, Reticon spectra confirm these values of $\log g$. These values are similar to those based on this spectrophotometry and Hγ profiles derived from Mt Wilson Observatory spectrograms: $T_{\mathrm{eff}} = 13\,150$ K, $\log g = 3.65$ for π Cet, $T_{\mathrm{eff}} = 10\,825$ K, $\log g = 3.9$ for 134 Tau, $T_{\mathrm{eff}} = 13\,000$ K, $\log g = 3.3$ for 21 Aql, and $T_{\mathrm{eff}} = 10\,250$ K, $\log g = 3.9$ for ν Cap (Adelman 1984a). The small shifts reflect slight differences in the Hγ profiles. However, the Mt Wilson values are as observed and DAO values are as corrected for scattered light.

Programs OMEGA (Shipman, private communications; Shipman & Strom 1970) and WIDTH6 (Kurucz, private communication) were used to derive the helium and metal abundances, respectively. The metal line damping constants were derived for neutral and singly ionized Ca–Ni lines from Kurucz (private communication), for Si II lines from Lanz, Dimitrijevic & Artru (1988), and for other lines from semi-classical approximations in WIDTH6 except the Stark broadening for lines of C II multiplet 6, Mg II multiplet 4, and S II multiplet 44 which were based on Sahal-Brechot (1969).

To derive the microturbulence, abundances were calculated from Fe I and Fe II lines for a range of possible values. For the adopted ξ value, there is no (or minimal in case of $\xi = 0$) dependence of the abundances of the equivalent widths (Table 4). Values for both species were derived using lines with *gf*-values only from Fuhr, Martin & Wiese (1988) and also with lines with *gf*-values from the apparently compatible source, Kurucz (private communication) (see Adelman & Fuhr 1985). For all four stars $\xi = 0.0$ km s^{-1}. Also given are the values of ξ found by minimizing the rms scatter of the abundances derived from lines of Fe I and Fe II (see, e.g. Blackwell, Shallis & Simmons 1982). The agreement of these techniques indicates well determined microturbulences.

Table 5 gives ξ values for non-iron atomic species. For π Cet, the Cr II lines yield $\xi = 0.0$ km s^{-1}, but analyses of both 18 S II and 13 Ti II lines result in indeterminant values of ξ. For 134 Tau both Ti II and Cr II lines yield $\xi = 0.0$ km s^{-1} as do the iron lines. But for 21 Aql S II and Cr II lines indicate large values of ξ while Ti II lines yield $\xi = 0.0$ km s^{-1} in agreement with the iron lines. For ν Cap, both Ti II and Cr II lines yield $\xi = 0.0$ km s^{-1}. Compared with Adelman & Fuhr (1985) ξ for π Cet has remained at $\xi = 0.0$ km s^{-1}, for 134 Tau ξ has decreased from 1.6 to 0.0 km s^{-1}, for 21 Aql from 0.2 to 0.0 km s^{-1}, and for ν Cap from 1.2 to 0.0 km s^{-1}.

The helium abundances (Table 6) were derived by comparing the helium line profiles with the theoretical values

Table 4. Determination of the microturbulent velocity from iron lines.

Star	Species	Number of Lines	ξ (km/s)	log Fe/H	gf-values	ξ (km/s) min.scatter
π Cet	Fe II	59	0.0	−4.60±0.21	MF & KX	0.0
		33	0.0	−4.64±0.18	MF	0.0
134 Tau	Fe I	39	0.0	−4.49±0.19	MF & KX	0.0
		38	0.0	−4.51±0.18	MF	0.0
	Fe II	58	0.0	−4.62±0.17	MF & KX	0.0
		36	0.0	−4.63±0.14	MF	0.0
21 Aql	Fe II	63	0.0	−4.80±0.18	MF & KX	0.0
		40	0.0	−4.80±0.19	MF	0.0
ν Cap	Fe I	79	0.0	−4.57±0.24	MF & KX	0.0
		73	0.0	−4.59±0.24	MF	0.0
	Fe II	67	0.0	−4.45±0.20	MF & KX	0.0
		38	0.0	−4.48±0.12	MF	0.0

convolved with rotational and instrumental profiles. The adopted values for some lines are a compromise between the best fit to the line core and the best fit to the line shoulders. But these differences are relatively small. Other He I lines are seen in the spectra of this paper's stars. But these profiles are not suitable for analysis due to blending or weakness or as the line broadening theory is not available or not incorporated into OMEGA. The helium abundances of π Cet, 134 Tau, and 21 Aql are essentially solar while that of ν Cap is slightly subsolar. This may reflect similar values seen in stars with its effective temperature and somewhat cooler. If we correct the surface gravity of ν Cap for the difference between the observed He/H ratio and that used by the model, then $\log g$ is increased by 0.04 dex (see Auer *et al.* 1966).

Table 7 contains the analyses of the metal lines. For each line, the multiplet number (Moore 1945), the laboratory wavelength in Å the logarithm of the *gf* value and its source, the equivalent width in mÅ and the deduced abundance are given with the scatter of the abundances about the mean. Table 8 compares these new results with selected previous analyses. For 134 Tau there are somewhat large differences with the results of Kodaira & Takada (1978) which is not surprising in due to the equivalent width differences. Compared with Adelman & Fuhr (1985), the new analyses show that π Cet, 134 Tau, 21 Aql, and ν Cap have abundances which on the average are -0.27 ± 0.39, -0.09 ± 0.48, -0.16 ± 0.37, and -0.14 ± 0.37 dex, respectively smaller, in part a result of the systematically smaller equivalent width and microturbulences. But there are also a few larger differences due to marked changes in the oscillator strengths, especially for lines of Ni II.

Table 9 compares the mean values from previous papers of this series and Cowley & Adelman (1990) for O I with the solar values of Anders & Grevesse (1989). The analyses of ν Cap and α Dra suggest that the onset of microturbulence occurs near 10 200 K. Inspection of this table indicates that most abundances are not temperature dependent. Non-LTE corrections have not been applied although for species such as O I they probably should be if they were known.

As there are abundances for all nine stars as derived from He I, Mg II, Ti II, Fe II, and Ni II lines, linear correlation coefficients (r) were calculated between pairs of these values and with the effective temperature and $\log g$. The correlation is significant if there is less than one chance in 20 that this value will occur by chance. For nine items, the absolute value of r has to be greater than 0.666. The significant correlations occur for the He and Mg abundances (0.844), the He abundance with effective temperature (0.690), the Mg and Fe abundances (0.761), the Ti and Fe abundances (0.912), the Ti and Ni abundances (0.907), and the Fe and Ni abundances (0.868).

For all stars except Vega, abundances were derived from Si II, S II, and Ca II lines. These values were correlated against those listed above and themselves. In this case $r\geq0.707$ for significance. Of the previous correlations only those between Ti, Ni, and Fe are verified. We now have Mg and Si abundances correlating (0.754), Ti and effective temperature (0.763), Ti and S (0.896), Fe and S (0.840), Ni and S (0.917). From both comparisons S and the iron peak elements Ti, Fe, and Ni have correlated abundances. The other apparent correlations need additional stars for verification. These results suggest that the iron peak and some other key elemental abundances are correlated, but there is no temperature dependence of the metallicity. If hydrodynamic processes such as diffusion are producing the non-solar abundances in these stars, then such effects are masked in the correlation analysis by the differing stellar ages.

Table 5. Microturbulent velocities from non-iron lines.

Star	Species	Number of Lines	ξ (km/s)	log N/H
π Cet	Cr II	15	0.0	−6.59±0.19
134 Tau	Ti II	31	0.0	−7.06±0.23
	Cr II	40	0.0	−6.41±0.18
21 Aql	S II	18	>2.0	...
	Ti II	12	0.0	−7.46±0.17
	Cr II	13	>2.0	...
ν Cap	Ti II	39	0.0	−7.05±0.23
	Cr II	20	0.0	−6.18±0.17

Table 6. He/H ratios.

Line λ(Å)	Star: π Cet	134 Tau	21 Aql	ν Cap
4472	0.080	0.100	0.080	0.070
4026	0.100	0.100	0.090	0.060
4388	0.100	0.100	0.080	...
4144	0.080	...	0.100	...
4009	0.080	...	...	...
3820	0.070	...	...	...
Average	0.085	0.100	0.090	0.065

Table 7. Abundances from metallic lines.

Mult.	λ(Å)	log gf	Ref.	π Cet W_λ(mÅ)	π Cet log N/H	134 Tau W_λ(mÅ)	134 Tau log N/H	21 Aql W_λ(mÅ)	21 Aql log N/H	ν Cap W_λ(mÅ)	ν Cap log N/H
C II			log C/H =		−3.77±0.07		−3.45±0.25		−3.92±0.28		−3.39±0.26
4	3920.68	−0.24	WS	32	−3.76	21	−3.36	36	−3.76	20	−3.15
	3918.98	−0.54	WS	24	−3.71	16	−3.26	21	−3.95	10	−3.33
6	4267.15	+0.97	WS	...	...	19	−3.74	...	...	...	...
	4267.25	+0.73	WS	34	−3.86	...	...	24	−4.30	9	−3.75
	4267.02	+0.58	WS	33	−3.74	...	...	39	−3.67	14	−3.30

Table 7. – *continued*

Mult.	λ(Å)	log gf	Ref.	π Cet W_λ(mÅ)	π Cet log N/H	134 Tau W_λ(mÅ)	134 Tau log N/H	21 Aql W_λ(mÅ)	21 Aql log N/H	ν Cap W_λ(mÅ)	ν Cap log N/H
N II			log	N/H =	-3.88±0.15		...		-4.15±0.20		...
5	4630.54	+0.13	WM	6	-3.96	...	...	4	-4.37	...	...
	4643.09	-0.34	WM	...	...	...	...	4	-3.89	...	...
	4601.48	-0.37	WM	4	-3.71	...	...	...	...	...	...
12	3995.00	+0.19	WM	11	-3.97	...	...	10	-4.21	...	...
15	4447.03	+0.28	WM	...	...	...	...	3	-4.11	...	...
O I			log	O/H =	-3.30		...		...		-3.33
3	3947.29	-1.94	WS	8	-3.34	...	...	...	...	17	-3.38
5	4368.30	-1.77	WS	9	-3.27	...	...	...	...	19	-3.27
Mg I			log	Mg/H =	-4.84		-5.19±0.30		-4.89±0.11		-4.71
3	3829.35	-0.19	WS	...	...	47	-4.85	4	-4.77	59	-5.00
	3832.30	+0.27	WS	...	...	48	-5.29	7	-4.97	...	...
	3838.29	+0.49	WS	20	-4.84	53	-5.47	12	-4.93	...	...
15	4167.27	-0.81	SC	...	...	...	...	...	...	16	-4.42
Mg II			log	Mg/H =	-4.52±0.08		-4.53±0.12		-4.59±0.10		-4.61±0.13
4	4481.23	+0.97	WM	266	-4.59	323	-4.67	244	-4.44	330	-4.74
5	3848.24	-1.60	WM	20	-4.53	25	-4.58	19	-4.57	20	-4.74
	3850.39	-1.88	WM	15	-4.41	19	-4.46	12	-4.47	...	...
9	4433.99	-0.90	WS	26	-4.54	26	-4.65	22	-4.66	28	-4.60
	4428.00	-1.20	WS	16	-4.54	18	-4.58	12	-4.69	20	-4.52
10	4390.58	-0.53	WS	50	-4.41	53	-4.47	40	-4.60	56	-4.42
	4384.64	-0.78	WS	29	-4.60	47	-4.33	25	-4.69	31	-4.66
Al I			log	Al/H =	-5.81		-5.85		-6.14		-6.03
1	3944.01	-0.64	WS	6	-5.73	38	-5.55	...	...	43	-5.80
	3961.52	-0.34	WS	8	-5.89	25	-6.13	4	-6.14	35	-6.25
Al III			log	Al/H =	-5.32		...		-5.93		...
1	4529.18	+0.67	WS	...	...	...	...	3	-5.93	...	...
	4512.54	+0.42	WS	4	-5.32	...	...	...	...	...	...
Si I			log	Si/H =	...		-4.55		...		...
3	3905.53	-1.09	WM	...	...	35	-4.55	...	...	...	...
Si II			log	Si/H =	-4.52±0.12		-4.51±0.28		-4.40±0.05		-4.69±0.16
1	3856.02	-0.49	LA	113	-4.67	125	-4.68	122	-4.41	101	-4.90
	3862.59	-0.74	LA	106	-4.54	109	-4.63	114	-4.33	97	-4.71
	3853.66	-1.44	LA	76	-4.48	59	-4.80	80	-4.43	58	-4.76
3	4130.89	+0.53	LA	134	-4.34	117	-4.24	119	-4.40	105	-4.52
	4128.07	+0.38	LA	103	-4.57	110	-4.18	109	-4.45	92	-4.54
Si III			log	Si/H =	-4.99		...		-4.58		...
1	4552.62	+0.29	WM	...	...	...	...	13	-4.34	...	...
	4567.82	+0.07	WM	...	...	...	...	5	-4.82	...	...
5	3806.54	+0.71	WS	4	-4.99	...	...	...	...	...	...
S II			log	S/H =	-4.82±0.18		-4.53		-5.04±0.19		-4.85
40	4524.95	+0.17	WM	9	-4.87	6	-4.49	8	-5.19	...	...
	4524.68	-0.94	WS	3	-4.48	...	...	...	...	...	...
43	4463.58	-0.02	WS	6	-4.72	...	...	7	-4.76	...	...
	4483.43	-0.43	WS	4	-4.54	...	...	...	...	...	...
44	4162.70	+0.78	WS	21	-4.81	...	...	19	-4.96	5	-4.85
	4153.10	+0.62	WS	22	-4.62	...	...	16	-4.98	...	...

Table 7. – *continued*

Mult.	λ(Å)	log gf	Ref.	π Cet W_λ(mÅ)	π Cet log N/H	134 Tau W_λ(mÅ)	134 Tau log N/H	21 Aql W_λ(mÅ)	21 Aql log N/H	ν Cap W_λ(mÅ)	ν Cap log N/H
S II (continued)			log	S/H =	-4.82±0.18		-4.53		-5.04±0.19		-4.85
44	4145.10	+0.44	WS	8	-5.18	7	-4.55	18	-4.71	...	...
	4142.29	+0.24	WS	7	-5.07	...	...	11	-4.89	...	...
	4189.68	-0.04	WS	...	...	...	...	3	-5.32	...	...
45	4028.75	0.00	WS	7	-4.82	...	...	5	-5.13	...	...
	3990.40	-0.30	WS	5	-4.73	...	...	5	-4.86	...	...
49	4294.40	+0.56	WS	9	-5.05	...	...	10	-5.11	...	...
	4267.80	+0.28	WS	12	-4.59	...	...	7	-5.08	...	...
	4269.72	-0.12	WS	4	-4.86	...	...	3	-5.14	...	...
	4282.60	-0.10	WS	4	-4.96	...	...	3	-5.24	...	...
	4278.50	-0.12	WS	4	-4.86	...	...	4	-4.99	...	...
55	3933.27	+0.58	WS	14	-4.86	...	...	12	-5.10	...	...
	3923.46	+0.44	WS	10	-4.99	...	...	11	-5.05	...	...
59	3998.76	+0.05	WS	7	-4.76	...	...	6	-4.98	...	...
66	4259.15	+0.52	WS	...	...	...	...	3	-5.30	...	...
Ca I			log	Ca/H =	...		-5.92		...		-5.98
1	4226.73	+0.24	WS	...	...	8	-5.92	...	...	24	-5.98
Ca II			log	Ca/H =	-5.72		-5.33		-5.66		-5.55
1	3933.66	+0.13	WM	139	-5.72	485	-5.33	142	-5.66	626	-5.55
Sc II			log	Sc/H =	...		-9.25		...		-9.34±0.12
7	4246.83	+0.32	MF	...	...	23	-9.25	...	...	32	-9.43
14	4374.46	-0.44	MF	...	...	...	...	...	...	19	-9.15
	4400.36	-0.51	WF	...	...	...	...	...	...	6	-9.33
15	4314.08	-0.10	MF	...	...	...	...	...	...	13	-9.46
	4320.74	-0.26	MF	...	...	...	...	...	...	12	-9.23
	4325.01	-0.44	MF	...	...	...	...	...	...	6	-9.41
Ti II			log	Ti/H =	-7.17±0.24		-7.06±0.23		-7.46±0.17		-7.05±0.23
11	4025.14	-1.98	MF	...	...	...	...	...	...	16	-7.13
12	3813.39	-2.02	MF	...	...	...	...	...	...	7	-7.50
13	3759.30	+0.20	MF	...	...	102	-6.57	...	...	...	...
	3761.33	+0.10	MF	64	-7.52	22	-7.80	...	...	75	-7.42
19	4395.03	-0.66	MF	11	-7.19	47	-7.09	6	-7.53	61	-6.97
	4443.80	-0.70	MF	4	-7.64	36	-7.33	4	-7.68	50	-7.25
	4450.49	-1.45	MF	...	...	13	-7.24	...	...	18	-7.33
20	4287.89	-2.02	MF	...	...	8	-6.92	...	...	11	-7.00
21	4161.52	-2.36	MF	...	...	...	...	...	...	12	-6.64
31	4468.49	-0.60	MF	13	-7.14	38	-7.35	6	-7.57	58	-7.10
	4501.27	-0.75	MF	4	-7.57	37	-7.23	4	-7.61	49	-7.21
34	3900.56	-0.45	MF	17	-7.13	49	-7.18	14	-7.27	...	...
	3913.46	-0.53	MF	10	-7.34	51	-7.05	12	-7.28	60	-7.05
	3932.01	-1.78	MF	...	...	...	...	...	...	20	-6.89
40	4417.72	-1.43	MF	...	...	18	-7.04	...	...	27	-7.05
	4464.46	-2.08	MF	...	...	...	...	...	...	12	-6.89
41	4300.05	-0.77	MF	13	-6.94	46	-6.94	7	-7.30	63	-6.74
	4290.22	-1.12	MF	6	-6.99	34	-6.90	3	-7.35	46	-6.88
	4301.93	-1.16	MF	...	...	22	-7.18	...	...	30	-7.24
	4312.86	-1.16	MF	7	-6.87	23	-7.14	...	...	40	-6.98
	4314.98	-1.13	MF	5	-7.07	28	-7.05	...	...	38	-7.07
	4320.96	-1.87	MF	...	...	12	-6.81	...	...	9	-7.23
50	4533.97	-0.77	MF	...	...	...	...	...	...	52	-7.04
	4563.76	-0.96	MF	5	-7.21	31	-7.12	...	...	42	-7.11
	4589.92	-1.67	KX	...	...	10	-7.08	...	...	...	...
51	4399.77	-1.27	MF	6	-6.81	22	-7.03	...	...	31	-7.07
	4394.06	-1.59	MF	...	...	6	-7.41	...	...	9	-7.49
	4418.34	-2.40	MF	...	...	...	...	...	...	6	-6.86
61	4395.85	-2.17	MF	...	...	...	...	...	...	8	-6.95
	4409.51	-1.84	KX	...	...	5	-7.24	...	...	...	...
72	3741.64	-0.11	MF	...	...	41	-7.46	12	-7.48	...	...

Table 7. – *continued*

Mult.	λ(Å)	log gf	Ref.	π Cet W_λ(mÅ)	π Cet log N/H	134 Tau W_λ(mÅ)	134 Tau log N/H	21 Aql W_λ(mÅ)	21 Aql log N/H	ν Cap W_λ(mÅ)	ν Cap log N/H
Ti II (continued)			log Ti/H =		-7.17±0.24		-7.06±0.23		-7.46±0.17		-7.05±0.23
72	3756.70	-0.46	MF	...	...	...	...	...	...	28	-7.72
82	4571.97	-0.53	MF	7	-7.32	42	-7.08	7	-7.35	53	-7.06
	4529.46	-2.03	MF	...	...	9	-6.59	...	...	6	-7.04
87	4028.33	-1.00	MF	...	...	18	-7.05	...	...	24	-7.11
	4053.81	-1.21	MF	...	...	14	-6.98	...	...	30	-6.75
93	4421.95	-1.77	MF	...	...	...	...	...	...	10	-6.77
94	4316.81	-1.42	MF	...	...	...	...	...	...	7	-7.30
104	4367.65	-1.13	MF	...	...	...	...	...	...	16	-6.71
	4384.86	-1.26	MF	...	...	...	...	...	...	11	-6.92
105	4163.64	-0.40	MF	...	...	29	-6.96	4	-7.27	39	-6.94
	4171.92	-0.51	MF	...	...	23	-6.96	...	...	35	-6.88
115	4488.32	-0.82	MF	...	...	15	-6.68	...	...	19	-6.76
	4411.08	-1.06	MF	...	...	9	-6.72	...	...	9	-6.94
V II			log V/H =		...		-8.11		...		-7.64±0.14
10	3951.97	-0.74	MF	...	...	6	-8.27	...	...	15	-7.48
	3916.42	-1.58	YF	...	...	...	...	...	...	9	-7.46
32	4005.71	-0.76	YF	...	...	...	...	...	...	22	-7.57
	4023.39	-0.88	YF	...	...	6	-7.95	...	...	13	-7.76
	4035.63	-0.96	YF	...	...	...	...	...	...	13	-7.69
37	4205.08	-1.04	KX	...	...	...	...	...	...	6	-7.85
56	4564.59	-1.45	YF	...	...	...	...	...	...	3	-7.65
Cr I			log Cr/H =		...		-5.87		...		-6.20±0.10
1	4254.35	-0.11	MF	...	...	12	-5.87	...	...	18	-6.09
	4274.80	-0.23	MF	...	...	...	...	...	...	10	-6.29
	4289.72	-0.36	MF	...	...	...	...	...	...	9	-6.23
Cr II			log Cr/H =		-6.54±0.19		-6.41±0.18		-6.64±0.19		-6.13±0.16
19	4051.96	-2.19	KX	3	-6.48	6	-6.69	...	...	18	-6.25
20	3738.38	-1.97	KX	...	...	8	-6.75	...	...	...	...
	3754.49	-2.19	KX	...	...	10	-6.42	...	...	...	...
26	4179.43	-1.77	KX	...	...	...	...	...	...	14	-6.41
	4072.56	-2.41	KX	...	...	...	...	...	...	9	-6.07
31	4242.38	-1.33	KX	8	-6.53	30	-6.21	11	-6.43	42	-6.01
	4261.92	-1.53	KX	6	-6.47	21	-6.26	4	-6.73	36	-5.97
	4275.57	-1.71	KX	4	-6.49	15	-6.30	3	-6.69	26	-6.07
	4284.21	-1.86	KX	...	...	12	-6.27	...	...	20	-6.10
	4252.62	-2.02	KX	...	...	9	-6.26	...	...	19	-5.97
	4269.28	-2.17	KX	...	...	9	-6.11	...	...	11	-6.13
44	4558.66	-0.66	MF	23	-6.51	47	-6.30	21	-6.64	64	-5.90
	4588.22	-0.63	MF	19	-6.66	40	-6.53	19	-6.73	54	-5.97
	4618.82	-1.11	MF	10	-6.54	27	-6.40	8	-6.73	42	-6.13
	4634.10	-1.24	MF	9	-6.47	27	-6.26	6	-6.73	36	-6.15
	4555.02	-1.38	MF	7	-6.46	19	-6.37	5	-6.67	28	-6.22
	4592.09	-1.22	MF	4	-6.88	18	-6.56	4	-6.94	31	-6.30
	4616.64	-1.29	MF	3	-6.98	17	-6.53	...	...	25	-6.39
162	4145.77	-1.16	KX	...	...	11	-6.25	5	-6.32	21	-5.97
167	3865.60	-0.78	KX	9	-6.35	...	...	5	-6.69	...	...
	3905.64	-0.90	KX	9	-6.23	...	...	10	-6.23	...	...
183	3979.51	-0.73	KX	5	-6.54	8	-6.67	3	-6.82	15	-6.42
194	4038.03	-0.56	KX	3	-6.57	6	-6.57	...	...	19	-6.01
	4003.33	-0.60	KX	...	...	...	...	...	...	16	-6.09
Mn II			log Mn/H =		...		...		...		-6.69
-	4326.63	-1.25	KX		...		...		...	5	-6.69
Fe I			log Fe/H =		...		-4.50±0.18		-4.71±0.16		-4.58±0.24
4	3859.91	-0.71	MF	...	...	31	-4.70	...	...	32	-5.10
	3824.44	-1.36	MF	...	...	...	...	...	...	29	-4.53

Table 7. – *continued*

				π Cet		134 Tau		21 Aql		ν Cap	
Mult.	λ(Å)	log gf	Ref.	W_λ(mÅ)	log N/H	W_λ(mÅ)	log N/H	W_λ(mÅ)	log N/H	W_λ(mÅ)	log N/H
Fe I (continued)			log Fe/H =	...			-4.50±0.18		-4.71±0.16		-4.58±0.24
4	3856.37	-1.29	MF	...	...	...	...	...	...	28	-4.60
	3922.91	-1.65	MF	...	...	14	-4.27	...	...	12	-4.78
	3930.30	-1.59	MF	...	...	22	-4.04	...	...	26	-4.35
	3878.58	-1.35	MF	...	...	20	-4.34	...	...	...	...
	3927.92	-1.59	MF	...	...	...	...	...	...	19	-4.55
	3920.26	-1.75	MF	...	...	...	...	...	...	14	-4.56
20	3820.43	+0.12	MF	...	...	40	-4.81	...	...	54	-4.75
	3825.88	-0.04	MF	...	...	33	-4.82	4	-4.77	43	-4.92
	3840.44	-0.51	MF	...	...	...	...	...	...	24	-4.98
	3878.02	-0.91	MF	...	...	13	-4.56	...	...	12	-5.00
	3872.50	-0.93	MF	...	...	10	-4.66	...	...	24	-4.54
	3917.18	-2.16	MF	...	...	...	...	...	...	5	-4.17
21	3758.24	-0.03	MF	...	...	...	...	5	-4.65	...	...
	3763.79	-0.24	MF	...	...	...	...	...	...	37	-4.86
	3787.88	-0.86	MF	...	...	14	-4.53	...	...	11	-5.05
22	3182.96	-1.27	KX	...	...	14	-4.15	...	...	...	...
41	4383.54	+0.20	MF	...	...	37	-4.66	...	...	49	-4.70
	4404.75	-0.14	MF	...	...	28	-4.53	...	...	43	-4.50
	4415.12	-0.62	MF	...	...	19	-4.30	...	...	21	-4.62
42	4271.76	-0.16	MF	...	...	30	-4.49	...	...	38	-4.66
	4325.76	-0.10	MF	...	...	32	-4.52	4	-4.49	44	-4.57
	4202.03	-0.71	MF	...	...	15	-4.41	...	...	17	-4.72
	4250.79	-0.71	MF	...	...	13	-4.45	...	...	19	-4.62
43	4045.82	+0.28	MF	...	...	43	-4.56	4	-4.83	55	-4.56
	4063.59	+0.07	MF	...	...	32	-4.62	...	...	49	-4.50
	4071.74	-0.02	MF	...	...	25	-4.70	...	...	40	-4.66
	4005.25	-0.61	MF	...	...	12	-4.59	...	...	25	-4.52
	4132.06	-0.65	MF	...	...	14	-4.44	...	...	22	-4.55
45	3815.84	+0.30	MF	...	...	37	-4.73	3	-4.97	46	-4.85
	3827.82	+0.06	MF	...	...	...	...	...	...	36	-4.87
	3841.05	-0.05	MF	...	...	...	...	...	...	27	-4.98
	3902.95	-0.47	MF	...	...	18	-4.49	3	-4.57	31	-4.49
68	4528.62	-0.82	MF	...	...	9	-4.21	...	...	8	-4.64
	4459.12	-1.28	MF	...	...	...	...	...	...	4	-4.49
71	4282.40	-0.81	MF	...	...	...	...	...	...	12	-4.43
72	3977.74	-1.08	MF	...	...	...	...	...	...	11	-4.18
	3949.95	-1.16	MF	...	...	...	...	...	...	6	-4.41
	4009.71	-1.20	MF	...	...	...	...	...	...	6	-4.34
152	4260.48	-0.20	MF	...	...	20	-4.26	...	...	29	-4.54
	4235.94	-0.34	MF	...	...	11	-4.45	...	...	18	-4.53
	4222.20	-0.97	MF	...	...	...	...	...	...	5	-4.55
	4210.35	-0.87	MF	...	...	...	...	...	...	4	-4.73
	4198.31	-0.72	MF	...	...	...	...	...	...	16	-4.23
	4187.79	-0.55	MF	...	...	11	-4.23	...	...	18	-4.32
	4187.04	-0.55	MF	...	...	7	-4.45	...	...	10	-4.63
	4191.44	-0.74	MF	...	...	...	...	...	...	7	-4.60
	4299.24	-0.46	MF	...	...	10	-4.38	...	...	13	-4.60
	4271.16	-0.35	MF	...	...	9	-4.52	...	...	14	-4.65
	4250.12	-0.40	MF	...	...	12	-4.32	...	...	17	-4.48
277	3983.90	-0.90	MF	...	...	...	...	...	...	4	-4.56
278	3956.68	-0.58	KX	...	...	7	-4.28	...	...	16	-4.23
	3997.39	-0.39	MF	...	...	5	-4.61	...	...	15	-4.41
350	4466.55	-0.59	MF	...	...	...	...	...	...	12	-4.29
	4476.02	-0.73	KX	...	...	4	-4.38	...	...	...	...
354	4181.75	-0.18	MF	...	...	...	...	...	...	11	-4.74
	4156.80	-0.62	MF	...	...	...	...	...	...	5	-4.68
357	4134.68	-0.49	MF	...	...	...	...	...	...	6	-4.73
367	3786.18	-0.90	MF	...	...	...	...	...	...	10	-4.04
522	4199.10	+0.25	MF	...	...	...	...	...	...	21	-4.67
523	4143.20	-0.47	KX	...	...	...	...	...	...	11	-4.33
528	3843.26	-0.14	MF	...	...	...	...	...	...	5	-5.04
559	4067.98	-0.43	MF	...	...	...	...	...	...	4	-4.76
560	4030.50	-0.70	KX	...	...	...	...	...	...	11	-3.99
606	3916.73	-0.52	MF	...	...	...	...	...	...	8	-4.32
608	3765.54	+0.49	MF	...	...	13	-4.74	...	...	26	-4.63
	3821.18	+0.30	MF	...	...	...	...	...	...	14	-4.83
	3805.34	-0.37	MF	...	...	14	-4.54	...	...	12	-4.96

Table 7. – *continued*

Mult.	λ(Å)	log gf	Ref.	π Cet W_λ(mÅ)	π Cet log N/H	134 Tau W_λ(mÅ)	134 Tau log N/H	21 Aql W_λ(mÅ)	21 Aql log N/H	ν Cap W_λ(mÅ)	ν Cap log N/H
Fe I (continued)			log Fe/H =	...			-4.50±0.18		-4.71±0.16		-4.58±0.24
661	3951.16	-0.38	MF	...	...	...	...	...	...	5	-4.67
689	4224.18	-0.41	MF	...	...	...	...	...	...	4	-4.70
693	4227.43	+0.26	KX	...	...	9	-4.67	...	...	22	-4.49
	4238.82	-0.28	MF	...	...	...	...	...	...	12	-4.28
	4225.46	-0.50	MF	...	...	...	...	...	...	6	-4.39
	4217.55	-0.51	MF	...	...	...	...	...	...	8	-4.24
	4196.22	-0.74	MF	...	...	...	...	...	...	5	-4.25
694	4154.81	-0.37	MF	...	...	...	...	...	...	12	-4.20
695	4153.91	-0.27	MF	...	...	...	...	...	...	8	-4.49
	4158.79	-0.67	MF	...	...	...	...	...	...	6	-4.22
726	4137.00	-0.54	MF	...	...	...	...	...	...	5	-4.44
800	4219.36	+0.12	MF	...	...	...	...	...	...	12	-4.58
801	4118.55	+0.28	MF	...	...	6	-4.76	...	...	16	-4.57
802	4014.53	-0.20	MF	...	...	...	...	...	...	5	-4.69
Fe II			log Fe/H =	-4.62±0.20			-4.63±0.16		-4.80±0.18		-4.47±0.16
3	3981.62	-4.84	KX	4	-4.09	...	...	...	...	...	...
	3938.29	-3.89	MF	9	-4.67	20	-4.59	10	-4.72	28	-4.48
	3945.21	-4.25	MF	6	-4.56	8	-4.74	6	-4.61	18	-4.48
	3914.48	-4.05	MF	...	...	14	-4.66	6	-4.82	22	-4.50
14	3783.35	-3.16	KX	20	-4.67	24	-4.89	19	-4.81	38	-4.60
	3821.95	-3.82	KX	...	...	...	...	4	-4.93	14	-4.64
21	4177.69	-3.68	KX	...	...	...	...	...	...	26	-4.28
	4119.53	-4.90	KX	...	...	...	...	...	...	5	-3.98
22	4124.79	-4.20	MF	...	...	4	-4.68	3	-4.59	10	-4.34
26	4580.06	-3.65	KX	...	...	8	-4.87	...	...	10	-4.86
27	4233.17	-2.00	MF	59	-4.52	...	...	54	-4.78	...	...
	4351.76	-2.10	MF	36	-4.96	54	-4.85	38	-5.12	61	-4.63
	4416.82	-2.60	MF	32	-4.65	42	-4.67	28	-4.87	50	-4.56
	4173.45	-2.18	MF	...	...	...	...	35	-5.18	...	...
	4303.17	-2.49	MF	34	-4.68	48	-4.65	34	-4.85	59	-4.36
	4385.38	-2.57	MF	28	-4.80	46	-4.59	30	-4.85	50	-4.59
	4128.74	-3.77	MF	...	...	13	-4.50	9	-4.48	22	-4.29
	4273.32	-3.34	MF	13	-4.56	18	-4.68	11	-4.75	26	-4.53
28	4178.86	-2.48	MF	...	...	...	...	...	...	54	-4.65
	4296.57	-3.01	MF	22	-4.57	33	-4.56	22	-4.67	41	-4.44
	4369.40	-3.67	MF	4	-4.78	12	-4.54	4	-4.88	23	-4.25
	4122.64	-3.38	MF	16	-4.46	22	-4.57	14	-4.63	30	-4.44
	4258.16	-3.40	MF	9	-4.70	20	-4.55	8	-4.86	24	-4.53
29	3824.91	-3.41	MF	7	-4.86	19	-4.64	12	-4.68	23	-4.61
	3872.76	-3.22	KX	12	-4.72	13	-4.99	11	-4.86	17	-4.93
	3974.16	-3.51	MF	...	...	...	...	4	-5.07	...	...
	4002.08	-3.37	KX	7	-4.82	...	...	10	-4.73	14	-4.86
32	4384.33	-3.50	MF	10	-4.56	...	...	6	-4.92	24	-4.45
	4314.29	-3.60	KX	11	-4.41	18	-4.43	7	-4.74	19	-4.50
	4278.16	-3.83	KX	6	-4.47	10	-4.52	3	-4.89	16	-4.37
	4413.60	-3.87	MF	...	...	...	...	...	...	12	-4.49
37	4629.34	-2.37	MF	35	-4.78	44	-4.83	29	-5.06	50	-4.76
	4555.89	-2.29	MF	34	-4.72	44	-4.89	29	-5.13	56	-4.49
	4515.34	-2.48	MF	33	-4.71	45	-4.67	33	-4.82	56	-4.45
	4491.40	-2.70	MF	24	-4.68	36	-4.70	23	-4.88	45	-4.48
	4520.22	-2.60	MF	28	-4.75	40	-4.71	28	-4.86	47	-4.62
	4489.18	-2.97	MF	22	-4.55	29	-4.64	19	-4.75	42	-4.39
	4472.92	-3.43	MF	16	-4.29	20	-4.44	10	-4.65	20	-4.54
	4582.84	-3.10	MF	13	-4.58	22	-4.71	11	-4.93	27	-4.50
	4534.17	-3.47	MF	...	...	...	...	...	...	24	-4.37
38	4583.83	-2.02	MF	46	-5.02	65	-4.54	46	-4.92	73	-4.63
	4522.63	-2.03	MF	41	-4.72	52	-4.91	40	-5.12	64	-4.44
	4508.28	-2.21	MF	36	-4.90	48	-4.85	34	-5.05	60	-4.59
	4620.51	-3.28	MF	8	-4.82	16	-4.74	8	-4.92	22	-4.63
	4576.33	-3.04	MF	20	-4.54	29	-4.56	17	-4.74	33	-4.55
	4541.52	-3.05	MF	19	-4.56	25	-4.66	18	-4.69	39	-4.38
126	4032.95	-2.83	KX	...	...	17	-4.31	12	-4.39	24	-4.13

Table 7. – *continued*

				π Cet		134 Tau		21 Aql		ν Cap	
Mult.	λ(Å)	log gf	Ref.	W_λ(mÅ)	log N/H	W_λ(mÅ)	log N/H	W_λ(mÅ)	log N/H	W_λ(mÅ)	log N/H
Fe II (continued)			log Fe/H =	-4.62±0.20		-4.63±0.16		-4.80±0.18		-4.47±0.16	
127	4024.55	-2.48	MF	...	...	27	-4.33	10	-4.83	33	-4.21
	3845.18	-2.26	KX	7	-5.15	14	-5.00	10	-5.05	...	...
	3863.96	-2.33	KX	...	...	11	-4.95	...	...	12	-4.94
151	4031.44	-3.14	KX	...	...	...	...	...	...	7	-4.41
153	3827.08	-2.64	MF	12	-4.38	10	-4.69	11	-4.51	17	-4.43
	3814.12	-2.41	MF	...	...	27	-4.29	18	-4.45	...	...
154	3755.63	-2.53	KX	...	...	...	...	5	-5.01	...	...
172	4048.83	-2.09	KX	12	-4.56	20	-4.40	8	-4.85	26	-4.24
	4044.01	-2.36	KX	...	...	9	-4.60	...	...	...	...
	4041.64	-3.11	KX	...	...	...	...	...	...	6	-4.08
173	3935.94	-1.86	MF	23	-4.39	26	-4.45	22	-4.49	31	-4.33
	3906.04	-1.83	MF	20	-4.51	26	-4.47	19	-4.62	23	-4.60
186	4635.33	-1.65	MF	16	-4.64	23	-4.49	18	-4.65	28	-4.37
	4549.21	-1.87	MF	23	-4.20	...	...	...	...	...	...
	4625.91	-2.22	KX	...	...	5	-4.80	...	...	...	...
188	4111.88	-2.29	KX	3	-4.86	...	...	...	...	...	...
	4069.88	-2.80	KX	...	...	...	...	...	...	7	-4.15
190	4002.55	-2.13	KX	9	-4.50	16	-4.32	...	...	...	...
	3938.97	-1.85	MF	15	-4.52	18	-4.55	14	-4.63	21	-4.47
192	3762.89	-1.54	KX	14	-4.85	...	...	12	-5.01	...	...
212	3960.90	-1.41	KX	11	-4.53	...	...	5	-5.00	...	...
213	4507.10	-1.87	KX	4	-4.34	...	...	...	...	5	-4.26
219	4628.82	-1.60	KX	...	...	...	...	...	...	5	-4.48
220	4313.03	-1.66	KX	7	-4.28	...	...	...	...	...	...
	4319.68	-1.69	KX	6	-4.30	...	...	...	...	7	-4.26
	4057.46	-1.54	KX	6	-4.71	13	-4.39	6	-4.77	17	-4.25
-	3898.62	-1.66	KX	4	-4.67	...	...	...	...	...	...
	3903.76	-1.51	KX	11	-4.33	9	-4.51	6	-4.69	...	...
	3908.11	-1.25	KX	...	...	...	...	...	...	7	-4.14
	4263.90	-1.64	KX	...	...	6	-4.48	4	-4.67	6	-4.47
	4286.28	-1.61	KX	6	-4.44	...	...	...	...	...	...
	4325.44	-2.32	KX	...	...	...	...	4	-4.68	...	...
	4357.58	-2.10	KX	6	-4.66	8	-4.64	8	-4.60	11	-4.49
	4361.25	-2.08	KX	...	...	...	...	4	-4.93	...	...
	4402.88	-2.75	KX	...	...	...	...	...	...	8	-3.98
	4451.54	-1.82	KX	10	-4.66	14	-4.57	9	-4.79	18	-4.44
	4455.26	-1.99	KX	12	-4.35	13	-4.41	7	-4.71	15	-4.34
	4461.71	-2.03	KX	7	-4.59	10	-4.51	6	-4.74	...	...
	4487.50	-2.12	KX	4	-4.12	...	...	...	...	...	...
	4579.52	-2.36	KX	...	...	5	-4.53	4	-4.60	7	-4.38
	4596.02	-1.82	KX	11	-4.56	12	-4.61	8	-4.81	16	-4.46
	4638.05	-1.47	KX	...	...	6	-4.60	...	...	...	...
Fe III			log Fe/H =	-4.78		...		-4.77±0.13		...	
4	4419.50	-2.22	KX	5	-4.78	...	...	6	-4.90	...	...
	4395.78	-2.59	KX	...	...	...	...	4	-4.76	...	...
	4430.95	-2.57	KX	...	...	...	...	5	-4.65	...	...
Ni I			log Ni/H =	...		...		...		-5.67	
33	3807.14	-1.18	MF	...	...	...	...	...	...	8	-5.67
Ni II			log Ni/H =	-5.98±0.14		-5.85		-6.04±0.11		-5.66±0.10	
9	4362.10	-2.72	KX	...	...	...	...	4	-6.07	5	-5.94
10	4192.07	-3.05	KX	...	...	...	...	3	-5.88	...	...
11	4067.05	-1.83	KX	22	-5.92	29	-5.76	19	-6.15	36	-5.60
	3849.58	-1.88	KX	21	-5.90	...	...	23	-5.97	36	-5.56
12	4015.48	-2.42	KX	5	-6.14	9	-5.94	7	-6.11	18	-5.57
Sr II			log Sr/H =	...		-9.23		...		-8.77	
1	4077.71	+0.15	WM	...	...	25	-9.24	...	...	52	-8.64
	4215.52	-0.17	WM	...	...	17	-9.22	...	...	39	-8.99

Table 7. – *continued*

Mult.	λ(Å)	log gf	Ref.	π Cet W_λ(mÅ)	π Cet log N/H	134 Tau W_λ(mÅ)	134 Tau log N/H	21 Aql W_λ(mÅ)	21 Aql log N/H	ν Cap W_λ(mÅ)	ν Cap log N/H
Zr II			log Zr/H =		...		...		...		-9.36
41	4149.22	-0.03	GB	...	...	...	...	...	...	6	-9.36
Ba II			log Ba/H =		...		...		...		...
1	4554.03	+0.16	WM	...	...	...	...	...	...	19	-9.29

Notes: *gf* value References; GB = Grevesse *et al.* (1981); KX = Kurucz (private communication); LA = Lanz & Artru (1985); MF = Fuhr, Martin & Wiese (1988) and Martin, Fuhr & Wiese (1988); SC = Schaefer (1971); WF = Wiese & Fuhr (1975); WM = Wiese & Martin (1980); WS = Wise *et al.* (1969) and Wiese, Smith & Glennon (1966), YF = Younger *et al.* (1981).

Table 8. Comparison of derived abundances.

π Cet

Species	AF(85)	This Paper
He I	-1.09	-1.07
C II	-3.45	-3.77
N II	-3.87	-3.88
O I	-3.50	-3.30
Mg II	-4.31	-4.52
Si II	-4.40	-4.52
Si II	-4.05	-4.99
S II	-4.72	-4.82
Ca II	-5.93	-5.72
Ti II	-6.87	-7.17
Cr II	-5.72	-6.54
Fe II	-4.45	-4.62
Ni II	-6.82	-5.98

134 Tau

Species	KT(78)	AF(85)	This Paper
He I	...	-1.13	-1.00
C II	-2.58:	-3.48	-3.45
Mg I	...	-4.12	-5.19
Mg II	...	-4.40	-4.53
Al I	...	-5.88	-5.85
Si II	-4.26	-4.60	-4.51
Ca II	-5.64	-6.10	-5.33
Sc II	-8.75	-9.24	-9.25
Ti II	-6.97	-6.95	-7.06
V II	...	-7.27	-8.11
Cr I	...	-5.81	-5.87
Cr II	-6.19	-5.80	-6.41
Fe I	-4.83	-4.28	-4.50
Fe II	-4.60	-4.47	-4.63
Ni II	...	-6.67	-5.85
Sr II	...	-9.18	-9.23

Table 8. – *continued*

ν Cap

Species	AF(85)	This Paper
He I	-1.26	-1.19
C II	-3.40	-3.39
O I	-3.04	-3.33
Mg I	-4.13	-4.71
Mg II	-4.11	-4.61
Al I	-5.86	-6.03
Si II	-4.42	-4.69
Ca I	-5.76	-5.98
Ca II	-6.17	-5.55
Sc II	-9.14	-9.34
Ti II	-6.82	-7.05
V II	-7.54	-7.64
Cr I	-6.02	-6.20
Cr II	-5.60	-6.13
Fe I	-4.34	-4.58
Fe II	-4.23	-4.47
Ni II	-6.39	-5.67
Sr II	-8.88	-8.77
Ba II	-9.44	-9.29

21 Aql

Species	AF(85)	This Paper
He I	-1.13	-1.06
C II	-3.59	-3.92
N II	-3.61	-4.15
Mg II	-4.35	-4.59
Si II	-4.38	-4.40
S II	-4.69	-5.04
Ca II	-5.70	-5.66
Ti II	-7.19	-7.46
Cr II	-6.11	-6.64
Fe II	-4.40	-4.80
Ni II	-6.82	-6.04

Table 9. Comparison of derived and solar abundances.

Species	τ Her log N/H	π Cet log N/H	21 Aql log N/H	134 Tau log N/H	ν Cap log N/H	α Dra log N/H	o Peg log N/H	Vega log N/H	θ Leo log N/H	Sun log N/H
He I	-1.04	-1.07	-1.05	-1.00	-1.19	-1.40	-1.26	-1.52	-1.22	(-1.00)
C I	...	...	...	...	...	...	...	-3.81	...	-3.31
C II	-3.71	-3.77	-3.92	-3.45	-3.39	-3.78	-4.40	...	...	-3.31
N II	-4.30	-3.88	-4.15	...	...	...	...	...	...	-4.01
O I	...	-3.30	-3.24	...	-3.33	-3.60	-3.36	...	...	-4.01
O II	-2.65:	...	...	...	...	...	...	...	...	-3.09
Mg I	...	-4.84	-4.89	-5.19	-4.71	-4.75	-4.49	-5.07	-4.53	-4.42
Mg II	-4.65	-4.52	-4.59	-4.53	-4.61	-4.82	-4.54	-5.11	-4.66	-4.42
Al I	...	-5.81	-6.14	-5.85	-6.03	-6.11	-5.58	...	-6.03	-5.53
Al II	...	...	...	...	...	...	...	-6.63	...	-5.53

Table 9 – *continued*

Species	τ Her log N/H	π Cet log N/H	21 Aql log N/H	134 Tau log N/H	ν Cap log N/H	α Dra log N/H	o Peg log N/H	Vega log N/H	θ Leo log N/H	Sun log N/H
Al III	-5.79	-5.32	-5.93	...	...	...	...	...	...	-5.53
Si I	...	...	...	-4.55	...	-4.63	-4.69	...	...	-4.45
Si II	-4.50	-4.52	-4.40	-4.51	-4.69	-4.94	-4.43	...	-4.46	-4.45
Si III	-4.54	-4.99	-4.58	...	...	...	...	...	...	-4.45
S II	-5.04	-4.82	-5.04	-4.53	-4.85	-5.03	-4.00	...	-4.32	-4.79
Ca I	...	...	...	-5.92	-5.98	-6.16	-5.61	-6.21	-5.76	-5.64
Ca II	-5.57	-5.72	-5.66	-5.33	-5.55	-5.64	-5.43	...	-5.57	-5.64
Sc II	...	...	...	-9.25	-9.34	-9.81	-9.30	-9.62	-9.27	-8.90
Ti II	-7.39	-7.17	-7.46	-7.06	-7.05	-7.27	-6.86	-7.47	-6.95	-6.98
V II	...	...	...	-8.11	-7.64	-7.92	-7.31	...	-7.45	-8.00
Cr I	...	...	...	-5.87	-6.20	-6.36	-6.16	...	-6.31	-6.33
Cr II	...	-6.54	-6.64	-6.41	-6.13	-6.61	-6.17	-6.77	-6.32	-6.33
Mn I	...	...	...	...	...	-6.73	-6.42	-7.16	-6.70	-6.55
Mn II	...	...	...	...	-6.69	...	-6.22	-7.20	-6.31	-6.55
Fe I	...	...	-4.71	-4.50	-4.58	-4.91	-4.32	-5.05	-4.52	-4.33
Fe II	-4.84	-4.62	-4.80	-4.63	-4.47	-4.93	-4.35	-5.12	-4.43	-4.33
Fe III	-4.74	-4.78	-4.77	...	...	...	-4.00	...	...	-4.33
Co I	...	...	...	...	...	-6.11	-6.54	...	-6.95	-7.08
Co II	...	...	...	...	...	...	-7.04	...	...	-7.08
Ni I	...	...	...	...	-5.67	...	-5.31	-6.38	-5.35	-5.75
Ni II	-6.17	-5.98	-6.04	-5.85	-5.67	-5.92	-5.00	-6.29	-5.34	-5.75
Sr II	...	...	...	-9.23	-8.77	-9.58	-8.01	...	-8.31	-9.10
Y II	...	...	...	...	...	...	-9.13	...	-9.48	-9.76
Zr II	...	...	...	...	-9.36	...	-8.43	...	-8.72	-9.44
Ba II	...	...	...	...	-9.29	>-10.05	>-8.49	-10.58	>-8.98	-9.87
La II	...	...	...	...	...	...	-9.94	...	-10.36	-10.78
Nd II	...	...	...	...	...	...	-9.29	...	...	-10.68
Eu II	...	...	...	...	...	...	-10.21	...	...	-11.49
Dy II	...	...	...	...	...	...	-10.31	...	...	-10.90
Er II	...	...	...	...	...	...	-10.17	...	...	-11.07
Hf II	...	...	...	...	...	...	-10.30	...	...	-11.12
Teff	14750	13150	12900	10825	10250	10075	9600	9400	9250	
log g	3.65	3.85	3.35	3.88	3.90	3.30	3.60	4.03	3.55	
ξ (km/s)	0.0	0.0	0.0	0.0	0.0	0.4	1.8	0.6	1.7	

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