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Elemental abundance analyses with the EBASIM spectrograph of the 2.1-m CASLEO Observatory Telescope

I. The late B and early A stars ξ Octantis, α Sextantis, and 68 Tauri[⋆]

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Abstract. We used data from the EBASIM spectrograph of the 2.1-m CASLEO telescope to study three rather sharp-lined late B to early A stars ξ Oct (B6 IV), α Sex (B9.5 III), and 68 Tau (A2 IV). These measurements are compared with those from the Anglo-Australian Telescope for the first star and to those from the coudé spectrograph of the 1.22-m telescope of the Dominion Astrophysical Observatory (DAO) for the other two stars. The equivalent width scales of the EBASIM and the DAO data are similar. Thus for the latter two stars the DAO data is also used in the analyses. Both ξ Oct and α Sex generally have abundances close to those of the Sun in the range of values found for other normal stars with similar effective temperatures. The abundance pattern for 68 Tau is that of a metallic-lined star as is well known.

Key words. stars: abundances – stars: individual: ξ Oct – stars: individual: α Sex – stars: individual: 68 Tau – stars: chemically peculiar

1. Introduction

We report observations made using the new EBASIM (Echelle de Banco Simmons) spectrograph at the 2.1-m telescope of the Complejo Astronómico El Leoncito (CASLEO) of three relatively sharp-lined stars. A modern analyses of ξ Oct had been performed with the echelle spectrograph of the Anglo-Australian Telescope (AAT) and of 68 Tau with the coudé spectrograph of the 1.22-m telescope of the Dominion Astrophysical Observatory (DAO). Spectra for α Sex were obtained at the DAO, but had been not previously analyzed. In the regions of overlap we compared the equivalent widths. For the two stars which also had DAO spectrograms we use both sets of spectrograms for elemental abundance studies.

ξ Oct (HD 215573, HR 8663, HIP 112781), spectral type B6 IV, is one of the few known normal mid-B stars with very sharp spectral lines, and thus is an object of particular interest. Optical region studies include those of Adelman et al. (1993a) and Pintado & Adelman (1996) and ultraviolet region studies those of Smith & Dworetsky (1993) and Adelman et al. (1993b). Recently De Cat & Aerts (2002) found it was a slowly pulsating B star with two frequencies with similar amplitudes in Hipparcos photometry.

α Sex (15 Sex, HD 87887, HR 3981), spectral type B9.5 III, was selected for analysis as it was a bright moderately sharp-lined star which could be observed easily from both CASLEO and the DAO. Abt & Morrell (1995) derived $v \sin i = 10$ km s^{-1}.

Conti (1965) found 68 Tau (δ^2 Tau, HD 27962, HR 1389), spectral type A2 IV, $v \sin i = 15$ km s^{-1} (Abt & Morrell 1995) to be one of the prototypes for the extension of the metallic-line (Am) stars into the early A stars. It is a single-lined spectrosciopic binary and blue straggler in the Hyades. Elemental abundances studies by Conti et al. (1965), Smith (1971), Lyubimkov & Savanov (1985), Okyudo & Sadakane (1990), and Adelman (1994) have confirmed it is an Am star. But the lines of the companion remain to be found.

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[⋆] Tables 5 to 7 are only available in electronic form at the CDS via anonymous ftp to `cdsarc.u-strasbg.fr (130.79.128.5)` or via `http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/406/987`

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2. The EBASIM spectrograph

The EBASIM is a fiber-feed bench echelle spectrograph at the 2.1-m Jorge Sahade Telescope of the Complejo Astronómico El Leoncito (CASLEO). The spectrograph, designed by H. Levato and J. Simmons, was built at CASLEO (A. Casagrande 2002, private communication). It is mounted on a 122 cm × 183 cm × 21.4 cm optical bench. The echelle grating with 31.6 l mm^{-1} has rulings perpendicular to the horizontal surface upon which it is mounted. The spectrograph has two gratings for use as cross dispersors. One has 226 l mm^{-1} with its blaze at 650 nm, with an aproximate spectral range of 180 nm and can be used in 360–800 nm. The second has 150 l mm^{-1} with a blaze at 1100 nm. Its spectral range is about 200 nm with a wavelength range of 600–1000 nm. In the blue and in the red different 18 m long fibers are used. Both have the following diameters: core 100 μm, cladding 110 μm, and buffer 125 μm. Spectra with wavelengths ≤600 nm are best taken with the blue fiber and the 226 l mm^{-1} cross disperser while longer wavelength spectra require the red fiber and the 150 l mm^{-1} cross disperser (Medina et al. 2001).

The detector is a CCD TEK1024[1], with 1024 by 1024 pixels each of which is 24 $\mu \times 24\ \mu$. The resolution of the spectrograph is approximately 40 000 at 500 nm compared to 25 000 for the REOSC instrument which was previously used with the 2.1-m telescope at CASLEO and to 70 000 for the long camera of the DAO's coudé's spectrograph.

3. Reduction of the spectrograms

The EBASIM spectral reductions were made with IRAF 2.11[2]. Using bias, darks and flat fields we obtain a combined flat field which was used to divide the specta to remove pixel-to pixel variatons. The extraction was performed with APALL and the wavelength calibration with ECIDENTIFY and DISPCOR, using the exposures of a Th-Ar comparison lamp.

Table 1 lists the EBASIM spectra we obtained. Many were taken while we were learning to optimize the quality of the spectrograms made using EBASIM. The signal-to-noise ratios (S/N) of the coadded spectra are typically 350–400 in the centers and 50–200 at the ends of the orders.

For 68 Tau Adelman (1994) coadded photographic Dominion Astrophysical Observatory (DAO) 2.4 Å mm^{-1} spectrograms to achieve a S/N ratio of about 80 and wavelength coverage of $\lambda\lambda$3701–4639. Later $S/N \geq 200$ spectrograms, which were 67 Å long, were obtained with a Reticon detector centered at λ3860, 4190, 4300, 4355, 4410, 4630, 4685, 4740, 4795, 4850, and 5180. Where there was wavelength overlap they replaced existing data. For α Sex, Reticon exposures centered at λ4245, 4355, 4410, 4465, 4520, 4575, and 4630 were obtained. Later using the SITe 2 CCD, which is 63 Å long, we made similar quality exposures centered at λ3970, 4025, 4135, 4190, 4300, 4465, 4685, 4740, and 5015 and exposures centered at λ3898 and 4864 using the SITe 4 CCD with 147 Å of spectra. Further 20 Å mm^{-1} DAO spectrograms containing the Hγ region were acquired for both 68 Tau and α Sex.

Table 1. Observing Log.

Star	Date	Wavelength range (nm)	Grating l mm^{-1}	Fiber	Number of Spectra
68 Tau	Sep. 1999	572-757	226	red	3
	Feb. 2001	735-892	226	red	3
		675-904	150	red	2
		391-517	226	blue	2
α Sex	Jun. 2000	407-592	226	blue	1
	Feb. 2001	735-892	226	red	2
		657-904	150	red	3
		538-720	226	red	1
		391-517	226	blue	2
ξ Oct	Sep. 1999	572-757	226	red	3
	Oct. 2000	410-592	226	blue	3
		453-639	226	red	3

We rectified the exposures with the interactive computer graphics program REDUCE (Hill et al. 1982) and applied a 3.5% correction for scattered light in the dispersion direction (Gulliver et al. 1996) for the Reticon and SITe 2 spectrograms. The scattered light for the SITe 4 spectrograms was removed during the extraction procedure using the program CCDSPEC (Gulliver & Hill 2002). The EBASIM spectra were coadded order by order with TSTACK (Hill et al. 1982) to reduce the noise. Finally the spectra were measured using VLINE (Hill et al. 1982). The radial velocities were found from comparisons of the stellar and laboratory wavelengths after corrections were applied for the Earth's orbital velocity.

Using DAO spectrograms the rotational velocity of 68 Tau is 9 km s^{-1}, Adelman's (1994) value. That of α Sex is 21 km s^{-1} which about twice the value of Abt & Morrell (1995). Using EBASIM spectrograms our value for ξ Oct is 8 km s^{-1} which a higher resolution instrument might find to be an upper limit.

The stellar lines were identified with the general references A Multiplet Table of Astrophysical Interest (Moore 1945) and Wavelengths and Transition Probabilities for Atoms and Atomic Ions, Part 1 (Reader & Corliss 1980) as well as with more specialized references for Si I (Moore 1970), Si II (Moore 1965), Mn II (Iglesias & Velasco 1964), Fe II (Johansson 1978), and Dy II (Meggers et al. 1975).

There are problems in comparing our EBASIM equivalent widths with those from the other two spectrographs. For ξ Oct the published equivalent widths (Adelman et al. 1993a) from the echelle spectrograph of the Anglo-Australian Telescope (AAT) cover only a relatively limited spectral range. Unfortunately the best quality EBASIM values are for spectral regions longward of the those from the AAT.

The spectrum of 68 Tau exhibits a greater line density than that of α Sex. For a comparison of equivalent widths especially shortward of λ4600, it is better to use those of α Sex since it

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Table 2. Effective temperature and surface gravity determinations.

Star	$T_{\rm eff}$ (K)	Log g	Method
68 Tau	9025	3.95	Napiwotzki et al. (1993) with *uvbyβ* photometry
	9000	4.00	Spectrophotometry and Hγ fitting from Adelman et al. (2002), +0.2 dex metal enhanced model
α Sex	9950	3.54	Napiwotzki et al. (1993) with *uvbyβ* photometry
	9875	3.55	Spectrophotometry and Hγ fitting from Adelman et al. (2002)
ξ Oct	14127	3.94	Napiwotzki et al. (1993) with *uvbyβ* photometry
	14051	3.94	same with correction from Adelman et al. (2002)

is easier to define the continuum and there are fewer significant line blending components. Due to the lower resolution of the EBASIM spectrum the best fits to the line profiles are made with Gaussian profiles, while for the DAO spectra rotational line profiles are used for most of the lines of α Sex and Gaussian line profiles for 68 Tau. When we use 170 unblended lines in the region $\lambda\lambda$3840–4930, we find for α Sex

$$W_\lambda(\text{EBASIM}) = 0.9769\ W_\lambda(\text{DAO}) - 0.7168$$

but if we use only the strongest lines (≥8 mÅ)

$$W_\lambda(\text{EBASIM}) = 0.9573\ W_\lambda(\text{DAO}) + 0.6900$$

and finally if we use the 24 cleanest lines with equivalent widths between 15 and 80 mÅ in the region $\lambda\lambda$4450–4630, we find

$$W_\lambda(\text{EBASIM}) = 0.9807\ W_\lambda(\text{DAO}) + 1.6679.$$

If we average the coefficients and correct the DAO equivalent widths for 3.5% scattered light (Gulliver et al. 1996), we find

$$W_\lambda(\text{EBASIM}) = 1.0056\ W_\lambda(\text{DAO}_{\text{no scattered light}}) + 0.5470.$$

Thus the equivalent width scales are the nearly the same. However, our comparison is based only on lines from just part of the echelle spectral format. We plan to extend it with high signal-to-noise ratio ($S/N \geq 500$) spectra of sharp-lined stars hopefully using regions with mainly unblended lines. For our studies of α Sex and 68 Tau, we did not apply any additional corrections to the equivalent widths of the EBASIM and DAO spectra.

4. Stellar parameters

Table 2 lists our effective temperature and surface gravity estimates with the last values for each star being those adopted. We began with the computer program of Napiwotzki et al. (1993) and the homogeneous *uvbyβ* data of Hauck & Mermilliod (1998). The uncertainties are about ±150 K and ±0.2 dex (Lemke 1989). For ξ Oct, which has no published spectrophotometry, we corrected the effective temperature as did Adelman et al. (2002). For α Sex and 68 Tau, we adopted the effective temperatures and surface gravities which we derived in Adelman et al. (2002) using published spectrophotometry and the Hγ profiles derived from 20 Å mm^{-1} DAO spectrograms.

We used the program WIDTH9 (Kurucz 1993) to determine the metal abundances. The adopted metal-line damping constants were from Kurucz & Bell (1995) or the default semi-classical approximations in their absence. Abundances from Fe I (if observed) and Fe II lines were derived for a range of possible microturbulences whose adopted values (Table 3) result in the derived abundances being independent of the equivalent widths (ξ_1) or having a minimal scatter about the mean (ξ_2) (Blackwell et al. 1982). Those of ξ Oct, α Sex, and 68 Tau are similar to the values for other stars in their effective temperature ranges. As the results for Fe I and Fe II lines agree better for 68 Tau than for α Sex, we regard the microturbulence as better determined for the former star.

5. The elemental abundance analyses

To find the helium abundances (Table 4) we compared the line profiles with theoretical predictions calculated using program SYNSPEC (Hubeny et al. 1994) which were convolved with the rotational velocity and the instrumental profile. For ξ Oct the He/H ratio is 0.07 which is about 70% of solar similar to our previously found value (Pintado & Adelman 1996). For α Sex, He/H = 0.09, which is close to solar. For 68 Tau, we should have been able to detect both λ4026 and λ4472 at least at the 10 mÅ level. But as they were not definitely found, He/H $\leq$ 0.03, which is much less than found by Adelman (1994).

Tables 5–7[3] contain the analyses of the line spectra for ξ Oct, α Sex, and 68 Tau, respectively. They present for each line the multiplet number (Moore 1945), the laboratory wavelength, the logarithm of the gf-value and its source, the equivalent width in mÅ as observed, and the deduced abundance. Source references are given at the end of Table 5.

In Table 8 we compare the ξ Oct abundances obtained with Anglo-Australian Telescope (Adelman et al. 1993a) with those from the EBASIM and REOSC echelle spectrographs of CASLEO (Pintado & Adelman 1996). Our abundance values are generally similar to those from our REOSC study and are greater than those of the AAT study due to the differences in the adopted temperature. Unfortunately we did not derive any Ca abundances in our current study to settle the discrepany between the AAT and REOSC results.

Table 9 compares derived abundances for ξ Oct with those of some other sharp-lined stars, which were analyzed in a comparable manner using the DAO spectrograph. The mean

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[3] Table 5–7 are only available in electronic form at the CDS.

Table 3. Microturbulence determinations from Fe I and Fe II lines.

Star	Species	Number of Lines	ξ_1 (km s^{-1})	log N/N_T	ξ_2 (km s^{-1})	log N/N_T	Ref.
68 Tau	Fe I	363	2.2	–4.24 ± 0.20	2.3	–4.25 ± 0.20	MF+KX
		299	2.2	–4.25 ± 0.20	2.3	–4.26 ± 0.20	MF
	Fe II	190	2.2	–4.14 ± 0.20	2.3	–4.15 ± 0.20	MF+KX
		46	2.4	–4.22 ± 0.17	2.5	–4.24 ± 0.17	MF
		adopted	2.3				
α Sex	Fe I	94	0.0	–4.59 ± 0.22	0.0	–4.59 ± 0.22	MF+KX
		85	0.0	–4.60 ± 0.21	0.0	–4.50 ± 0.22	MF
	Fe II	109	0.4	–4.45 ± 0.22	0.4	–4.45 ± 0.22	MF+KX
		54	1.1	–4.62 ± 0.21	0.9	–4.59 ± 0.20	MF
		adopted	0.3				
ξ Oct	Fe II	102	0.0	–4.77 ± 0.20	0.6	–4.78 ± 0.20	MF+KX
		35	0.0	–4.76 ± 0.16	0.2	–4.76 ± 0.16	MF
		adopted	0.2				

gf value references: MF = Fuhr et al. (1988), KX = Kurucz & Bell (1995).

Note: For ξ_1 and ξ_2 the abundances are found so that there is no trend of values for lines of different equivalent widths and have minimum scatter about the mean, respectively.

Table 4. He/H determinations.

λ(Å)	He/H ξOct	He/H α Sex
4026	...	0.10
4121	0.07	...
4143	0.07	...
4169	0.09	...
4388	0.07	...
4437	0.06	...
4472	0.09	0.08
4713	0.06	...
4921	0.08	...
average	0.07 ± 0.01	0.09 ± 0.01

Table 8. Comparison of ξ Oct abundances (log N/H).

Species	AAT	EBASIM	REOSC
He	–1.07	–1.15	–1.11
C	–3.64	–3.59	–3.59
N	–4.33	–4.07	...
O	–3.26	–3.14	...
Mg	–4.73	–4.61	–4.67
Si	–4.77	–4.53	–4.44
S	–4.92	–4.84	–4.85
Ca	–6.24	...	–5.52
Ti	–7.28	–6.82	...
Cr	–6.62	–6.48	–6.35
Fe	–4.81	–4.72	–4.76
Ni	–5.96	–5.39	...
T_{eff}	13 625	14 051	14 130
log g	4.00	3.94	3.93
ξ	0.0	0.2	0.0

References:
AAT: Adelman et al. (1993a).
REOSC: Pintado & Adelman (1996).

of 12 elemental abundances relative to the Sun for ξ Oct is -0.05 ± 0.22 dex (He excluded). Most of these values are slightly less than solar, but Ne and Ni are overabundant (0.3 dex or more) and Al is underabundant and Fe is marginally underabundant (order 0.2 dex). In general the values derived for ξ Oct are within the ranges seen in the other stars. But the He/H value is slightly smaller.

Table 10 shows this study's abundances for α Sex along with those for other stars with similar spectral types. The calculated abundances are in the range of those of other stars. For 18 non-He abundances, the average value relative to solar is -0.03 ± 0.18 dex which is solar. Sc is underabundant, S and Ca marginally underabundant, Mn marginally overabundant, and Ba overabundant. Our spectra have a greater wavelength range than those used to study the other stars. Thus it is possible to identify some lines in α Sex, which were not studied in comparable stars. The values for α Sex are in the center of the metallicity range with Vega and 7 Sex at the extremes.

Table 11 shows abundances of 68 Tau calculated from Adelman (1994) and this study which replaces some of the DAO spectrograms and supplements them with EBASIM

Table 9. Comparison of the abundances of ξ Oct, Normal B stars, and the Sun (log N/H).

Species	134 Tau	21 Aql	π Cet	ξ Oct	22 Cyg	τ Her	η Lyr	ι Her	Sun
He	–1.00	–1.05	–1.07	–1.15	–0.96	–0.96	–0.89	–1.07	(–1.01)
C	–3.45	–3.92	–3.77	–3.59	–3.53	–3.53	–3.59	–3.49	–3.45
N	...	–4.15	–3.88	–4.07	–4.22	–4.09	–4.20	–3.84	–4.03
O	...	–3.24	–3.30	–3.14	–3.04	–3.36	–3.09	–2.91	–3.13
Ne	...	...	...	–3.64	...	...	...	...	–3.92
Mg	–4.86	–4.70	–4.64	–4.61	–4.42	–4.60	–4.35	–4.78	–4.42
Al	–5.85	–5.99	–5.81	–5.90	–5.68	–5.71	–5.70	–5.76	–5.53
Si	–4.53	–4.49	–4.76	–4.53	–4.36	–4.46	–4.15	–4.45	–4.45
S	–4.53	–5.04	–4.82	–4.84	–4.76	–4.76	–4.70	–4.77	–4.67
Ca	–5.62	–5.66	–5.72	...	–5.31	–5.74	–5.24	–6.13	–5.64
Ti	–7.06	–7.46	–7.17	–6.82	...	–6.76	...	...	–6.98
Cr	–6.14	–6.64	–6.54	–6.48	–6.81	–6.55	...	...	–6.33
Fe	–4.56	–4.75	–4.70	–4.72	–4.78	–4.67	–4.55	–4.75	–4.50
Ni	–5.85	–6.04	–5.98	–5.39	...	–6.72	...	...	–5.75
$T_{\rm eff}$	10 825	12 900	13 150	14 051	14 156	15 000	16 045	16 500	
log g	3.88	3.35	3.85	3.94	3.35	4.10	3.15	4.00	
ξ	0.0	0.0	0.0	0.2	0.0	0.0	0.0	2.5	

References:
134 Tau, 21 Aql, and π Cet: Adelman (1991); 22 Cyg and η Lyr: Adelman (1998); τ Her: Adelman et al. (2001); ι Her: Pintado & Adelman (1993); Sun: Grevesse et al. (1996).

Table 10. Comparison of the abundances of α Sex, late B and Early A stars, and the Sun (log N/H).

Species	Vega	α Sex	α Dra	7 Sex	ν Cap	κ Cep	134 Tau	HR 7926	Sun
He	–1.52	–1.04	–1.04	–1.00	–1.19	–1.08	–1.00	–1.00	(–1.01)
C	–3.81	–3.38	–3.71	–2.89	–3.39	–3.70	–3.45	–3.48	–3.45
N	...	–3.96	...	...	...	...	...	–4.24	–4.03
O	...	–3.16	–3.49	–2.94	–3.33	...	...	–3.29	–3.13
Mg	–5.09	–4.52	–4.74	–4.13	–4.66	–4.48	–4.86	–4.54	–4.42
Al	–6.63	–5.63	–5.92	–5.82	–6.03	–5.82	–5.85	–5.53	–5.53
Si	...	–4.59	–4.89	–4.40	–4.69	–4.56	–4.53	–4.70	–4.45
S	...	–4.90	–4.60	–3.99	–4.85	–4.65	–4.53	–4.89	–4.67
Ca	–6.21	–5.85	–5.61	–5.14	–5.76	–5.56	–5.62	–5.45	–5.64
Sc	–9.62	–9.23	–9.41	–8.64	–9.34	–9.20	–9.25	...	–8.87
Ti	–7.47	–7.03	–7.10	–6.78	–7.05	–6.91	–7.06	–7.15	–6.98
V	...	–7.95	–8.04	–7.88	–7.64	–8.03	–8.11	...	–8.00
Cr	–6.77	–6.28	–6.30	–5.88	–6.16	–6.17	–6.14	–6.58	–6.33
Mn	–7.18	–6.38	–6.69	–5.65	–6.69	–6.28	...	–6.07	–6.61
Fe	–5.08	–4.50	–4.76	–4.26	–4.52	–4.56	–4.56	–4.58	–4.50
Ni	–6.32	–5.70	–5.91	–5.64	–5.67	–5.84	–5.85	–6.03	–5.75
Sr	...	–9.05	–9.52	–9.12	–8.77	–8.79	–9.23	...	–9.03
Zr	...	–9.45	...	–8.92	–9.36	–8.99	...	...	–9.40
Ba	–10.58	–9.34	–10.07	–9.69	–9.29	...	...	...	–9.78
$T_{\rm eff}$	9400	9875	10 025	10 135	10 250	10 325	10 825	13 306	
log g	4.03	3.55	3.70	3.69	3.90	3.70	3.88	3.55	
ξ	0.6	0.3	0.0	1.7	0.0	0.3	0.0	0.0	

Vega: Adelman & Gulliver (1990); ν Cap, 134 Tau: Adelman (1991); α Dra, HR 7926: Adelman et al. (2001); κ Cep: Adelman (1996); 7 Sex: Adelman & Pintado (1997); Sun: Grevesse et al. (1996).

Table 11. Comparison of 68 Tau abundances.

Species	DAO log N/H	This Paper log N/H	This Paper [N/H]
He	–1.05	≤–1.52	≤–0.51
C	–3.80	–3.87	–0.58
N	...	–4.27	–0.24
O	...	–3.43	–0.30
Na	...	–4.67	+1.00
Mg	–4.44	–4.51	–0.09
Al	–5.12	–5.06:	+0.46:
Si	–4.40	–4.50	–0.05
S	–4.13	–4.50	–0.17
Ca	–5.74	–5.84	–0.30
Sc	–9.82	–9.89	–1.02
Ti	–6.73	–6.74	+0.24
V	–7.31	–7.32	+0.68
Cr	–5.70	–5.84	+0.49
Mn	–6.08	–6.17	+0.44
Fe	–4.15	–4.16	+0.34
Co	–6.35	–6.52	+0.56
Ni	–4.94	–4.95	+0.80
Cu	...	–6.74	+1.05
Zn	–6.59	–6.77	+0.63
Sr	–7.88	–7.93	+1.10
Y	–8.94	–9.04	+0.72
Zr	–8.32	–8.46	+0.96
Ba	–8.53	–8.65	+1.22
La	–9.76	–10.08	+0.75
Ce	–8.96	–9.37	+1.05
Pr	–9.24	–9.68	+1.61
Nd	–9.56	–9.58	+0.92
Sm	–9.25	–9.34	+1.65
Eu	–10.70	–10.64	+0.85
Gd	–9.31	–9.09	+1.79
Dy	–9.89	–9.77	+1.09
$T_{\rm eff}$	9025	9000	
log g	3.95	4.00	
ξ	2.7	2.3	

Reference:
DAO: Adelman (1994).

measurements. Besides the re-evaluation of the He/H ratio, the other major discrepancies (0.2 dex and greater) are for S, La, Ce, Pr, and Gd due in part to accepting fewer lines as unblended and/or well measured. We also give the abundances with respect to solar.

Table 12 compares the 68 Tau abundances of our study with those of at least moderately sharp-lined Am sharp-lined stars. Most of these stars have similar effective temperatures, but both 15 Vul and 32 Aqr are cooler. The abundances of 68 Tau generally are within the ranges defined by the other Am stars. In most cases its values tend to be slightly metal rich. For N, Na, and Cu there are no Am star values for comparison. C, N, and O tend to be underabundant. Na and Al, which are overabundant, need confirmation. Si and S are solar while Ca is underabundant and Sc is very underabundant. The iron peak values are greater than solar with those for Zn, Sr, Y, Zr, and Ba being even more so and the observed rare earth elements being extremely overabundant.

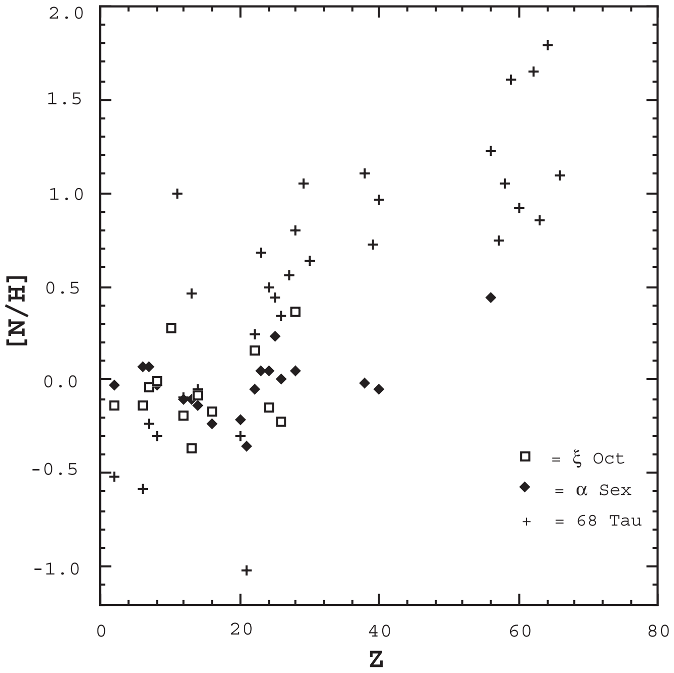

Fig. 1. The abundance anomalies relative to solar [N/H] of 68 Tau (plus signs), α Sex (solid diamonds), and ξ Oct (open squares). The pattern seen for 68 Tau is that of an Am star, for α Sex that of a solar composition early A star, and for ξ Oct that of middle B star in the solar neighborhood.

Figure 1 shows the abundance anomalies relative to solar $[N/{\rm H}] = \log N/{\rm H} - (\log N/{\rm H})_\odot$ for our three stars as a function of atomic number Z. For ξ Oct and α Sex the values scatter about solar. On the other hand for 68 Tau, the values tend to increase with Z, but the Sc underabundance is an exception to this trend.

6. Final comments

We have found preliminary evidence for the EBASIM equivalent width scale being close to that from the DAO coudé spectrograph. But this comparison needs to redone with high S/N data and greater coverage of the entire echelle format. Our analyses show that EBASIM produces data which can usefully be analyzed for elemental abundances.

For ξ Oct the derived abundances are based on a larger number of lines than previous studies. The analysis of α Sex shows that this giant's abundances are generally solar. Our extended analysis of 68 Tau has provided some new abundances as well as improved those of other atomic species.

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Table 12. Comparison of the abundances for 68 Tau and some representative sharp-lined Am stars with solar values (log N/H).

Species	15 Vul	32 Aqr	68 Tau	π Dra	θ Leo	21 Lyn	ϕ Aql	o Peg	Sun
He	...	...	≤1.52	–1.22	–1.22	–1.10	–1.52	–1.26	(–1.01)
C	–3.44	...	–3.87	–3.62	...	–3.71	...	–4.40	–3.45
N	...	...	–4.27	...	...	...	...	...	–4.03
O	...	...	–3.43	...	...	...	–3.43	–3.36	–3.13
Na	...	–5.55	–4.67	...	...	...	...	...	–5.67
Mg	–4.66	–4.61	–4.51	–4.50	–4.60	–4.82	–4.48	–4.62	–4.42
Al	–6.11	–5.52	–5.06:	–5.23	–6.03	–6.06	–5.24	–5.58	–5.53
Si	–4.59	–4.54	–4.50	–4.41	–4.46	–4.53	–4.31	–4.56	–4.45
S	–4.63	–4.68	–4.50	–3.70	–4.32	...	...	–4.00	–4.67
Ca	–6.00	–6.11	–5.84	–5.66	–5.66	–5.83	–5.59	–5.52	–5.64
Sc	–9.39	–9.99	–9.89	–9.25	–9.27	–9.39	...	–9.30	–8.83
Ti	–7.21	–7.11	–6.74	–6.77	–6.95	–7.15	–6.64	–6.86	–6.98
V	–8.06	–7.62	–7.32	–7.41	–7.45	–7.79	–7.20	–7.31	–8.00
Cr	–6.38	–6.06	–5.84	–5.91	–6.32	–6.46	–5.80	–6.16	–6.33
Mn	–6.53	–6.46	–6.17	–6.15	–6.50	–6.67	–6.36	–6.32	–6.61
Fe	–4.74	–4.42	–4.16	–4.18	–4.48	–4.66	–4.09	–4.34	–4.50
Co	–6.94	–6.47	–6.52	–6.34	–6.95	–6.67	–6.45	–6.54	–7.08
Ni	–5.55	–5.14	–4.95	–4.98	–5.34	–5.60	–4.92	–5.16	–5.75
Cu	...	...	–6.74	...	...	...	...	...	–7.79
Zn	–7.14	–6.85	–6.77	–6.01	...	...	...	...	–7.40
Sr	–8.58	–8.26	–7.93	–7.83	–8.31	–8.30	–8.30	–8.01	–9.03
Y	–9.45	–8.96	–9.04	–8.70	–9.48	–9.65	–9.20	–9.13	–9.76
Zr	–8.81	–8.47	–8.46	–8.22	–8.72	–8.94	–8.46	–8.43	–9.40
Ba	–9.28	–8.98	–8.65	–8.36	–8.98	–9.29	–8.28	–8.49	–9.87
La	–10.16	–9.58	–10.08	–9.47	–10.36	–10.40	–8.85	–9.94	–10.83
Ce	–9.52	–8.99	–9.37	–8.61	...	...	...	...	–10.42
Pr	–10.26	–9.82	–9.68	...	...	...	...	...	–11.29
Nd	–10.11	–9.58	–9.58	–9.42	...	...	...	–9.29	–10.50
Sm	–10.23	–10.06	–9.34	–9.04	...	...	...	...	–10.99
Eu	–10.77	–10.43	–10.64	–10.04	...	...	...	–10.21	–11.49
Gd	–9.98	–9.95	–9.09	–9.67	...	...	...	...	–10.88
Dy	–10.82	–10.45	–9.77	...	...	...	...	–10.31	–10.86
T_{eff}	7700	7700	9000	9125	9250	9534	9534	9600	
log g	3.50	3.65	4.00	3.80	3.55	4.05	4.05	3.60	
ξ	4.0	4.5	2.3	3.5	1.7	1.6	3.1	1.8	

References:
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