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Elemental abundance analyses with DAO spectrograms – XX. The early A stars ϵ Serpentis, 29 Vulpeculae and σ Aquarii

Saul J. Adelman[1]* and Berahitdin Albayrak[2]

[1]*Department of Physics, The Citadel, Charleston, SC 29409, USA*
[2]*Ankara University, Science Faculty, Astronomy and Space Sciences Department, 06100 Tandogan, Ankara, Turkey*

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ABSTRACT

Elemental abundances of the early A stars ϵ Ser, 29 Vul and σ Aqr are derived consistently with previous studies of this series using spectrograms obtained with Reticon and CCD detectors. The derived abundances confirm that ϵ Ser is a definite Am star. 29 Vul shows evidence for a weakly operating Am star phenomenon. σ Aqr, a hot Am star prototype, has abundances similar to those of o Peg, another class prototype.

Key words: stars: abundances – stars: individual: ϵ Ser – stars: individual: 29 Vul – stars: individual: σ Aqr.

1 INTRODUCTION

Inspection of high-quality photographic region spectra of superficially normal early A-type stars shows that these stars are a chemically rather inhomogeneous group (Holweger, Gigas & Steffen 1986a; Holweger, Steffen & Gigas 1986b). Abt & Morrell (1995) found that by assuming random orientations of rotational axes, all rapidly rotating A stars have normal spectra and nearly all slow rotators have abnormal spectra with the distributions overlapping. However, some of their standards such as Vega and α Dra exhibit subsolar abundances. In fact, Vega is a fast rotator seen nearly pole-on (Gulliver, Hill & Adelman 1994). The peculiarities of the slowly rotating stars are a result of the radial diffusion of ions between the two outer convection zones in the absence of meridional circulation which is associated with rapid rotation as well as gravitational settling (Michaud 1970). Abt (1979) found that peculiar A stars appear in open clusters with times of formation generally consistent with the calculations of Michaud et al. (1976). There is still much theoretical work to be done on these stars, which should be among the easiest to model and to understand. Lemke (1989, 1990), Hill (1995) and others have investigated the considerable star-to-star abundance differences among the superficially normal early A stars which provide the data for theoretical tests.

This paper continues the studies of superficially normal relatively sharp-lined stars near spectral type A0 most recently presented in Paper XVIII of this series (Caliskan & Adelman 1997) by analysing ϵ Serpentis (= HR 5892 = HD 141795), 29 Vulpeculae (= HR 7891 = HD 196724) and σ Aquarii (= HR 8573 = HD 213320). These stars provide additional examples using more extensive spectral coverage than those of Lemke and Hill. ϵ Ser is the second classical Am star to be studied in this series, the first being the sharp-lined star 32 Aqr. ϵ Ser and 29 Vul continue the trend to analyse stars exhibiting moderate rotational velocities. The hot Am star σ Aqr is just cooler than the coolest HgMn star HD 147550 (Lopez-Garcia & Adelman 1994), and how or if the two sequences of non-magnetic CP stars merge is still unclear.

Abt & Morrell (1995) classified ϵ Ser as Am (A3/A7V/A7) and measured $v \sin i = 37\,\mathrm{km\,s^{-1}}$. Gray & Garrison (1989) by comparison denoted it as kA2hA5mA7. Roby & Lambert (1990) used $T_{\mathrm{eff}} = 8600\,\mathrm{K}$, $\log g = 4.1$, and a microturbulence of $3.8\,\mathrm{km\,s^{-1}}$, and derived underabundances of C, N and O. Sadakane & Okyudo (1989) used Savanov's (1987) values of $T_{\mathrm{eff}} = 8400\,\mathrm{K}$, $\log g = 4.0$, and a microturbulence of $5.0\,\mathrm{km\,s^{-1}}$, and found N to be underabundant and S and Fe to be solar. Savanov (1983) performed a curve-of-growth analysis using equivalent widths from photographic plates with reciprocal dispersions of 4 to 12 Å $\mathrm{mm^{-1}}$, and found deficiencies of Ca and Sc which are characteristic of Am stars.

According to Abt & Morrell (1995), 29 Vul has a spectral type of A0IV and a $v \sin i$ value of $40\,\mathrm{km\,s^{-1}}$. Gray & Garrison (1987) classified it as A0Va (shell), and noted that it is probably a protoshell star. Optical spectrophotometry was obtained by Wolff, Kuhi & Hayes (1968) (see also Breger 1976).

Conti (1965) classified σ Aqr as a sharp-lined, hot Am star, since the ratio of Sc II λ4246/Sr II λ4215 was less than 1. Elemental abundance analyses using primarily Mt. Wilson Observatory spectrograms were performed by Adelman, Young & Baldwin (1984), and Adelman & Nasson (1980) showed that this A0IV star (Gray & Garrison 1987) was slightly metal-rich. They found $T_{\mathrm{eff}} = 10\,125\,\mathrm{K}$, $\log g = 3.75$, and a microturbulence of $1.5\,\mathrm{km\,s^{-1}}$. Optical spectrophotometry was obtained by Adelman (1978). Abt & Morrell (1995) measured $v \sin i = 10\,\mathrm{km\,s^{-1}}$ and gave a spectral type of A0III.

2 THE SPECTRA

For each star, 17 Dominion Astrophysical Observatory (DAO) 2.4 Å $\mathrm{mm^{-1}}$ Reticon or CCD spectrograms with a typical

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* Visiting observer, Dominion Astrophysical Observatory.

signal-to-noise ratio of 200 and a wavelength coverage of 67 or 63 Å, respectively, were obtained, except for the spectrogram centred at 3970 Å for σ Aqr. For a few regions a second spectrogram was obtained. In these cases they were co-added to increase the signal-to-noise ratio. The central wavelengths between 3830 and 4740 Å used 55-Å offsets. In addition, 20 Å mm^{-1} DAO spectrograms containing the Hγ region were obtained for ϵ Ser and 29 Vul, and one containing the Hβ region for σ Aqr. A 2.4 mm^{-1} Å CCD spectrogram centred at 5015 Å was also acquired for σ Aqr. Using the exposures of an incandescent lamp placed in the coudé mirror train as viewed through a filter to eliminate first-order light, the exposures were flat-fielded. A central stop removed light from the beam, as does the secondary mirror of the telescope. The spectra were rectified using the interactive computer graphics program REDUCE (Hill, Fisher & Poeckert 1982). A scattered light correction of 3 per cent was applied in the analyses (Gulliver, Hill & Adelman 1996).

Rotationally broadened profiles were fitted through the weak metal lines of our three stars, while Gaussian profiles were fitted through stronger lines. The rotational velocity estimates based on clearly single, medium-strength lines near λ4481 are 33 km s^{-1} for ϵ Ser, 49 km s^{-1} for 29 Vul, and 21 km s^{-1} for σ Aqr. For comparison, Hoffleit (1992) gives values of 37 km s^{-1}, 54 km s^{-1} and 23 km s^{-1} respectively.

A comparison of 145 equivalent widths of σ Aqr as measured by Adelman & Nasson (1980), who had four 4.3 Å mm^{-1} photographic coudé spectrograms from the 2.5-m telescope of Mt. Wilson Observatory and one 8.9 Å mm^{-1} photographic coudé spectrogram from the coudé feed telescope of Kitt Peak National Observatory, with those of this paper show that for equivalent widths in mÅ,

$$W_\lambda(\mathrm{DAO}) = (0.859 \pm 0.21) W_\lambda(\mathrm{A\&N}) + 0.029 \pm 0.002,$$

which is fair agreement, and indicates that we should expect a reduction in the derived abundances for similar stellar parameters.

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 Moore (1965) for Si II, Huldt et al. (1982) for Ti II, Nave et al. (1994) for Fe I, and Dworetsky (1971), Johansson (1978), Guthrie (1985) and Adelman (1987) for Fe II. For all three stars, lines of H I, Mg I, Mg II, Al I, Al II, Si II, Ca I, Ca II, Ti II, V II, Cr II, Mn I, Fe I, Fe II, Ni I, Ni II, Zn I, Sr II, Zr II and Ba II were identified. Lines of S I, Cr I, Co I, Y II, La II, Ce II, Eu II, and possibly Ti I, Cd I and Nd II are seen in the spectrum of ϵ Ser, lines of He I, C II and Sc II in 29 Vul, and lines of He I, S II, Sc II, Cr I, Mn II, Y II and possibly Co I in σ Aqr.

We found the stellar radial velocities from comparisons of the stellar and laboratory wavelengths after corrections were applied for the Earth's orbital velocity. The radial velocity values compiled by Abt & Biggs (1972) are between −4 and −11 km s^{-1} for ϵ Ser, between −15 and −26 km s^{-1} for 29 Vul, and between −18 and 14 km s^{-1} for σ Aqr. Morse, Mathieu & Levine (1991) found -12.0 ± 3.7 km s^{-1} compared with −17.8 km s^{-1} Fekel (private communication; see Morse et al. 1991) and −19.0 km s^{-1} Liu, Janes & Bania (1989) for 29 Vul. We found -9.14 ± 1.94 km s^{-1} for ϵ Ser, -20.50 ± 4.93 km s^{-1} for 29 Vul, and 15.49 ± 4.37 km s^{-1} for σ Aqr. Thus both 29 Vul and σ Aqr are definitely single-lined spectroscopic binaries. Our values for ϵ Ser range from −3 to −11 km s^{-1}, and do not conflict with the conclusion of Abt & Levy (1985), who measured 37 spectrograms, that ϵ Ser has a constant radial velocity of −8.7 km s^{-1}. Our radial velocity values for 29 Vul and σ Aqr are given in Table 1.

Table 1. Radial velocity measurements.

λ(Å)	Heliocentric Julian Date	RV (km s^{-1})
29 Vul		
3860	24449918.895608	-20.49
3915	24450309.011921	-11.82
3970	24449615.656001	-24.21
4025	24449919.944120	-23.34
4080	24449894.941632	-19.84
4080	24450753.630554	-20.88
4135	24450308.012257	-10.63
4190	24450601.926996	-18.03
4245	24449618.700428	-24.21
4300	24450657.001041	-19.96
4355	24449621.726696	-24.69
4355	24450658.002800	-32.05
4410	24449892.956765	-19.16
4465	24450305.014084	-14.27
4520	24449531.915353	-19.39
4520	24448143.797564	-20.77
4575	24449538.946117	-22.90
4630	24449891.958634	-23.42
4685	24450662.003194	-16.78
4740	24449891.958634	-22.14
σ Aqr		
3860	24449918.941510	19.19
3915	24450309.011921	11.96
4025	24450654.991486	19.95
4080	24448849.915503	13.11
4135	24447336.961000	18.46
4190	24447750.880700	10.68
4245	24447748.893100	11.67
4300	24447337.948300	18.48
4355	24449621.751985	11.51
4410	24450306.013507	10.30
4464	24448474.892216	12.12
4520	24450304.012540	9.61
4575	24448093.982240	20.18
4630	24450661.009010	20.00
4685	24450662.003194	21.45
4740	24450694.950769	19.70
5015	24450649.989456	20.98

3 THE ABUNDANCE ANALYSES

Table 2 contains our effective temperature and surface gravity estimates with the last values for each star being those we adopted. We started with the computer program of Napiwotzki, Schönberner & Wenske (1993) and the homogeneous *uvbyβ* data of Hauck & Mermilliod (1980). To refine these values, program SYNTHE (Kurucz & Avrett 1981) was used to calculate synthetic spectra of the Hγ region (Hβ for σ Aqr), which were compared with observations. The effective temperature and surface gravity of 29 Vul were found by comparing spectrophotometry by Wolff et al. (1968) as converted to the Hayes & Latham (1975) calibration of Vega (Breger 1976) and the Hγ profile with the predictions of LTE model atmospheres calculated with the ATLAS9 program (Kurucz 1995). For σ Aqr, a similar procedure was followed with spectrophotometry by Adelman (1978) and the Hβ profile. For ϵ Ser, we could only compare the Hγ regions. For its models, we used the turbulent convection theory of Canuto & Mazzitelli (1991, 1992) (see Smalley & Kupka 1997), which should be more realistic than mixing-length theory (Castelli, Gratton & Kurucz 1997). We estimate errors of ±150 K in T_{eff} and ±0.2 dex in $\log g$.

Table 2. Effective temperature and surface gravity determinations.

Star	T_{eff}(K)	Log g	Method
ε Ser	8422	4.30	Napiwotzki et al. (1993) with uvbyβ photometry
	8420	4.30	Hγ profile fitting, solar model, ξ =2.0 km s^{-1}
	8420	4.30	Hγ profile fitting, solar model, ξ =4.0 km s^{-1}
29 Vul	10397	4.14	Napiwotzki et al. (1993) with uvbyβ photometry
	10200	4.10	Flux and Hγ profile fitting, solar model, ξ =0.0 km s^{-1}
	10200	4.10	Flux and Hγ profile fitting, solar model, ξ =1.0 km s^{-1}
σ Aqr	10182	4.11	Napiwotzki et al. (1993) with uvbyβ photometry
	10125	4.00	Flux and Hβ profile fitting, solar model, ξ = 0.0 km s^{-1}
	10125	4.00	Flux and Hβ profile fitting, solar model, ξ = 1.0 km s^{-1}

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

Species	Number of Lines	ξ_1 (km s^{-1})	log N/N$_T$	ξ_2 (km s^{-1})	log N/N$_T$	gf values
ε Ser						
Fe I	148	5.3	-4.35±0.27	5.4	-4.36±0.27	MF+KX
	130	5.4	-4.37±0.26	5.5	-4.38±0.26	MF
Fe II	37	5.1	-4.27±0.25	5.0	-4.26±0.25	MF+KX
adopted		5.2				
29 Vul						
Fe I	60	0.9	-4.50±0.24	0.8	-4.49±0.24	MF+KX
	57	1.0	-4.51±0.23	0.8	-4.50±0.23	MF
Fe II	42	1.5	-4.52±0.17	1.4	-4.52±0.17	MF+KX
	32	1.8	-4.62±0.14	1.7	-4.61±0.14	MF
adopted		1.2				
σ Aqr						
Fe I	106	0.9	-4.39±0.28	0.6	-4.37±0.28	MF+KX
	94	1.1	-4.42±0.27	0.9	-4.41±0.27	MF
Fe II	98	0.9	-4.29±0.22	1.0	-4.30±0.22	MF+KX
	40	1.2	-4.38±0.18	1.4	-4.42±0.18	MF
adopted		1.0				

gf-value references: KX = Kurucz (1995), MF = Fuhr, Martin & Wiese (1988)

Table 4. He/H ratios.

Line	29 Vul	σ Aqr
4026	0.06	0.09
4388	...	0.10
4472	0.06	0.08
4713	...	0.10
average	0.06	0.09

Programs SYNSPEC (Hubeny, Lanz & Jeffrey 1994) and WIDTH9 (Kurucz, private communication) were used to determine the helium and metal abundances respectively. Our metal-line damping constants were the default semiclassical approximations, except for those of iron-peak element lines whose values are based on the data of Kurucz (1995), those for lines of C II multiplet 6, Mg II multiplet 4, and Ca II multiplet 1, whose Stark broadening values are from Sahal-Bréchot (1969) and Chapelle & Sahal-Bréchot (1970), and those for Si II multiplets 1 and 3, whose damping constants are from Lanz, Dimitrijevic & Artru (1988).

Abundances from Fe I 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) and minimal scatter about the mean (ξ_2) (Blackwell, Shallis & Simmons 1982). We followed Adelman & Fuhr (1985) in using lines with *gf*-values only in Fuhr, Martin & Wiese (1988), and then lines with *gf*-values in a compatible source, which in this case was Kurucz (1995). The values for 29 Vul and σ Aqr are slightly larger than those for other stars in this series with similar temperatures. The value for ϵ Ser is similar to those for other Am stars (Adelman et al. 1997) and is close to Sadakane & Okyudo's (1989) value.

The helium abundances (Table 4) were found by comparing the line profiles with theoretical predictions which were convolved with the rotational velocity and the instrumental profile. ϵ Ser is too cool and has too complicated a spectrum to see He I lines. 29 Vul appears to be slightly helium-poor, while σ Aqr is helium-normal.

Table 5, the analyses of the line spectra, contains 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. To convert log N/N$_T$ values log N/H values, the deduced He/H values were used for 29 Vul and σ Aqr, and the solar value for ϵ Ser.

4 DISCUSSION

In general, our results for σ Aqr are smaller than those of Adelman

Table 5. The analyses of the metal lines.

				ε Ser		29 Vul		σ Aqr	
mult.	λ(Å)	log gf	Ref.	W_λ (mÅ)	log N/N$_T$	W_λ (mÅ)	log N/N$_T$	W_λ (mÅ)	log N/N$_T$
C II		log C/N$_T$ =			...		-4.09		...
6	4267.15	+0.96	WF	...	...	6	-4.09		
Mg I		log Mg/N$_T$ =			-4.70±0.13		-4.87±0.08		-4.76±0.10
11	4702.99	-0.38	FW	148	-4.79	17	-4.93	20	-4.83
15	4167.27	-0.79	JK	126	-4.61	9	-4.81	12	-4.69
Mg II		log Mg/N$_T$ =			-4.48±0.32		-4.84±0.04		-4.74±0.24
4	4481.33	+0.97	FW	439	-4.92	344	-4.80	353	-4.74
5	3848.24	-1.60	WM	...	...	...	...	18	-4.80
	3850.39	-1.88	WM	...	...	...	...	5	-5.20
9	4427.99	-1.21	WS	11	-4.66	10	-4.88	17	-4.61
	4433.99	-0.90	WS	47	-4.23	17	-4.89	25	-4.69
10	4390.58	-0.53	WS	100	-4.11	37	-4.79	59	-4.40
Al I		log Al/N$_T$ =			-5.70		-5.88±0.22		-5.55
1	3944.01	-0.64	FW	230	-5.70	54	-5.72	63	-5.55
	3961.52	-0.34	WS	...	...	52	-6.03	...	...
Al II		log Al/N$_T$ =			-5.12		-5.36		-5.05
2	4663.10	-0.28	FW	24	-5.12	26	-5.36	37	-5.05
Si II		log Si/N$_T$ =			-4.61±0.27		-4.73±0.27		-4.58±0.26
1	3853.66	-1.44	LA	79	-4.79	54	-4.87	69	-4.58
	3856.02	-0.49	LA	...	...	139	-4.47	95	-5.06
	3862.59	-0.74	LA	159	-4.82	74	-5.19	109	-4.58
3	4128.07	+0.38	LA	...	...	92	-4.59	110	-4.34
	4130.89	+0.53	LA	176	-4.23	112	-4.50	123	-4.36
S I		log S/N$_T$ =			-4.76±0.06		...		...
2	4694.11	-1.77	WS	12	-4.72	...	...	...	...
	4695.45	-1.92	WS	7	-4.81	...	...	...	...
S II		log S/N$_T$ =			...		...		-4.31±0.24
7	5009.54	-0.28	WM	...	...	...	...	3	-4.49
9	4716.23	-0.52	WM	...	...	...	...	5	-4.10
15	5014.03	+0.03	WM	...	...	...	...	6	-4.25
40	4552.41	-0.13	WM	...	...	...	...	4	-4.19
44	4142.91	+0.24	WM	...	...	...	...	6	-4.23
	4145.10	+0.44	WS	...	...	...	...	9	-4.07
	4162.70	+0.78	WS	...	...	...	...	5	-4.82
Ca I		log Ca/N$_T$ =			-6.28±0.15		-6.16		-6.15
2	4226.73	+0.24	FW	219	-6.30	24	-6.16	24	-6.15
4	4425.44	-0.36	FW	25	-6.33	...	...	...	...
	4434.96	0.00	FW	54	-6.28	...	...	...	...
	4435.69	-0.52	FW	37	-5.96	...	...	...	...
5	4283.01	-0.22	FW	30	-6.37	...	...	...	...
	4318.65	-0.21	FW	27	-6.42	...	...	...	...
Ca II		log Ca/N$_T$ =			-6.56		-5.87		-5.94
1	3933.66	+0.13	WM	1051	-6.56	475	-5.87	452	-5.94
Sc II		log Sc/N$_T$ =			...		-9.39		-9.43±0.10
7	4246.83	+0.24	LD	...	...	31	-9.39	26	-9.55
14	4374.46	-0.42	LD	...	...	...	...	8	-9.32
	4400.36	-0.53	LD	...	...	...	...	5	-9.45
	4415.56	-0.68	LD	...	...	...	...	5	-9.31
15	4305.72	-0.30	LD	...	...	...	...	7	-9.54
Ti I		log Ti/N$_T$ =			-6.28		...		...
12	4008.93	-1.07	MF	14	-6.28	...	...	...	...
Ti II		log Ti/N$_T$ =			-6.99±0.31		-7.19±0.21		-7.06±0.26
18	4518.33	-2.55	KX	18	-7.13	...	...	4	-7.06
	4443.80	-0.70	MF	277	-6.41	...	...	61	-7.11
	4450.49	-1.45	MF	120	-7.13	...	...	24	-7.22
19	4395.03	-0.66	MF	225	-6.99	61	-7.15	71	-6.87
	4443.80	-0.70	MF	...	...	50	-7.38	...	...
	4450.49	-1.45	MF	...	...	13	-7.54	...	...
20	4287.89	-2.02	MF	106	-6.66	...	...	16	-6.87
	4344.30	-2.09	MF	34	-7.28	...	...	6	-7.31
	4506.74	-3.32	KX	12	-6.52	...	...	...	...
	4545.14	-2.78	KX	19	-6.84	...	...	3	-6.96
21	4184.33	-2.46	KX	...	...	7	-6.85	10	-6.68
31	4468.49	-0.60	MF	209	-7.18	54	-7.36	67	-7.04
	4501.27	-0.75	MF	186	-7.29	47	-7.38	53	-7.24

Table 5 – *continued*

mult.	λ(Å)	log gf	Ref.	ε Ser W_λ (mÅ)	ε Ser log N/N_T	29 Vul W_λ (mÅ)	29 Vul log N/N_T	σ Aqr W_λ (mÅ)	σ Aqr log N/N_T
Ti II (continued)									
34	3882.28	-1.71	MF	66	-7.23	13	-7.22	7	-7.57
	3913.46	-0.53	MF	230	-6.91	56	-7.36	74	-6.80
	3932.01	-1.78	MF	...	...	32	-6.61	33	-6.62
40	4417.72	-1.43	MF	136	-6.97	20	-7.26	35	-6.94
	4441.73	-2.41	MF	18	-7.21	...	...	2	-7.45
	4464.46	-2.08	MF	93	-6.65	7	-7.16	14	-6.87
	4470.86	-2.28	MF	103	-6.38	...	...	8	-6.95
41	4290.22	-1.12	MF	...	...	41	-7.10	53	-6.85
	4300.05	-0.77	MF	228	-6.76	59	-7.05	65	-6.88
	4301.93	-1.16	MF	178	-6.89	20	-7.55	31	-7.29
	4312.86	-1.16	MF	136	-7.22	29	-7.30	42	-7.04
	4320.96	-1.87	MF	76	-6.99	...	...	...	...
	4330.71	-2.04	MF	28	-7.37	...	...	5	-7.35
48	4764.53	-2.77	KX	23	-6.70	...	...	...	...
49	4708.65	-2.21	MF	...	...	5	-7.19	4	-7.26
50	4563.76	-0.96	MF	167	-7.17	51	-7.01	52	-6.99
51	4394.06	-1.59	MF	55	-7.43	...	...	15	-7.29
	4399.77	-1.27	MF	...	...	24	-7.28	29	-7.18
	4418.34	-2.40	MF	32	-6.90	...	...	10	-6.69
59	4657.21	-2.15	MF	...	...	...	...	9	-6.97
60	4544.02	-2.40	MF	14	-7.30	...	...	...	...
61	4395.85	-2.17	MF	...	...	...	...	11	-6.84
	4409.24	-2.29	KX	29	-7.06	...	...	...	...
	4409.51	-1.84	KX	...	...	...	...	5	-7.52
82	4529.46	-2.03	MF	70	-6.61	...	...	11	-6.78
	4571.97	-0.53	MF	222	-6.84	59	-7.07	67	-6.84
87	4028.33	-1.00	MF	...	...	16	-7.38	29	-7.05
	4053.81	-1.21	MF	123	-6.76	18	-7.10	28	-6.88
93	4421.95	-1.77	MF	25	-7.09	4	-7.22	6	-7.05
94	4316.81	-1.42	MF	...	...	...	...	6	-7.41
	4330.24	-1.51	MF	17	-7.54	...	...	4	-7.57
	4350.83	-1.40	MF	17	-7.63	...	...	6	-7.36
104	4386.86	-1.26	MF	...	...	11	-6.93	11	-6.95
105	4163.64	-0.40	MF	...	...	29	-7.24	45	-6.91
113	5010.21	-1.34	KX	...	...	...	...	5	-7.03
115	4411.08	-1.06	MF	66	-6.58	...	...	14	-6.77
	4488.32	-0.82	MF	...	...	11	-7.09	16	-6.90
H	4188.98	-0.59	KX	...	...	...	...	4	-6.55
V II			log V/N_T =		-7.74±0.21		-8.10±0.22		-7.65±0.12
9	4002.94	-1.45	BG	48	-7.52	...	...	9	-7.26
	4036.78	-1.59	BG	...	...	...	...	5	-7.73
10	3896.15	-1.80	KX	11	-7.91	...	...	...	...
	3916.42	-1.05	BG	...	...	...	...	14	-7.79
	3951.97	-0.78	BG	...	...	7	-8.33	...	...
11	3866.74	-1.55	BG	30	-7.64	...	...	...	...
25	4178.39	-1.56	BG	...	...	...	...	8	-7.45
	4202.35	-1.52	BG	...	...	...	...	7	-7.51
32	4023.39	-0.69	BG	92	-7.62	13	-7.95	...	...
	4023.39	-0.69	BG	...	...	...	...	25	-7.62
	4035.63	-0.77	BG	...	...	6	-8.23	...	...
37	4183.44	-1.12	BG	...	...	...	...	9	-7.60
	4205.08	-1.05	KX	...	...	...	...	10	-7.64
43	4005.71	-0.52	BG	65	-8.00	20	-7.87	30	-7.66
156	3847.34	-0.61	KX	...	...	...	...	6	-7.89
Cr I			log Cr/N_T =		-6.14±0.30		...		-6.29±0.17
1	4254.35	-0.11	MF	164	-6.39	...	...	22	-6.11
	4274.80	-0.23	MF	127	-6.59	...	...	9	-6.45
	4289.72	-0.36	MF	90	-6.75	...	...	10	-6.31
21	4651.28	-1.46	MF	9	-6.22	...	...	...	...
	4652.15	-1.03	MF	19	-6.27	...	...	...	...
	4646.15	-0.70	MF	41	-6.20	...	...	...	...
23	3908.76	-1.00	KX	43	-5.85	...	...	...	...
32	4600.08	-1.26	MF	17	-6.11	...	...	...	...
33	4540.49	-0.49	MF	13	-5.94	...	...	...	...
67	3992.84	-0.43	KX	11	-5.94	...	...	...	...
69	3857.63	-0.18	KX	12	-5.72	...	...	...	...
133	4622.45	-0.04	MF	9	-5.91	...	...	...	...
186	4718.43	+0.09	MF	3	-6.12	...	...	...	...

Table 5 – *continued*

mult.	λ(Å)	log gf	Ref.	ε Ser W_λ (mÅ)	ε Ser log N/N_T	29 Vul W_λ (mÅ)	29 Vul log N/N_T	σ Aqr W_λ (mÅ)	σ Aqr log N/N_T
Cr II		log Cr/N_T =			-5.93±0.24		-6.28±0.23		-6.14±0.22
18	4113.24	-2.27	KX	...	...	...	...	4	-6.95
19	4088.83	-3.30	KX	14	-5.85	...	...	...	...
26	4086.14	-2.42	KX	...	...	...	...	7	-6.20
	4179.43	-1.77	KX	85	-5.95	...	...	23	-6.14
	4207.35	-2.47	KX	...	...	...	...	4	-6.32
31	4242.36	-1.33	KX	...	...	35	-6.25	46	-5.99
	4252.62	-2.02	KX	72	-5.80	14	-6.13	19	-6.02
	4261.92	-1.53	KX	109	-5.98	23	-6.35	31	-6.16
	4269.28	-2.17	KX	73	-5.64	7	-6.33	11	-6.16
	4275.57	-1.71	KX	...	...	19	-6.27	25	-6.14
31	4284.21	-1.86	KX	85	-5.84	10	-6.50	22	-6.08
39	4565.78	-2.11	MF	...	...	...	...	16	-5.90
44	4555.02	-1.38	MF	61	-6.41	...	...	31	6.19
	4558.66	-0.66	MF	193	-6.01	61	-6.19	73	-5.87
	4588.22	-0.63	MF	157	-6.37	48	-6.54	65	-6.10
	4592.09	-1.24	MF	152	-5.80	23	-6.55	36	-6.23
	4616.64	-1.33	MF	106	-6.08	26	-6.39	30	-6.33
	4618.82	-1.11	MF	181	-5.68	44	-6.14	56	-5.87
	4634.10	-1.24	MF	120	-6.06	34	-6.25	44	-6.03
162	4145.77	-1.16	KX	...	...	13	-6.23	21	-6.01
	4224.85	-1.73	KX	...	...	13	-5.65	...	...
165	4082.28	-1.23	KX	...	...	...	...	9	-6.38
	4098.44	-1.47	KX	...	...	...	...	6	-6.38
179	4362.93	-1.89	KX	...	...	...	...	3	-6.10
183	3979.51	-0.73	KX	...	...	10	-6.62	...	...
	4022.38	-2.02	KX	...	...	...	...	3	-5.93
193	4070.84	-0.75	KX	57	-5.50	...	...	...	...
194	4003.23	-0.60	KX	...	...	16	-6.09	...	...
	4038.03	-0.56	KX	32	-6.01	...	...	...	...
Mn I		log Mn/N_T =			-6.39±0.31		-6.59		-6.49±0.25
2	4030.76	-0.47	MF	240	-5.68	10	-6.59	10	-6.65
	4034.49	-0.81	MF	109	-6.65	...	...	4	-6.78
5	4070.27	-0.95	MF	12	-6.26	...	...	...	...
	4079.42	-0.42	MF	23	-6.48	...	...	...	...
	4083.63	-0.25	MF	72	-6.05	...	...	...	...
16	4754.04	-0.09	MF	27	-6.71	...	...	...	...
21	4761.51	-0.14	MF	11	-6.65	...	...	...	...
	4765.85	-0.08	MF	24	-6.33	...	...	...	...
	4766.42	+0.10	MF	22	-6.57	...	...	...	...
22	3833.31	-1.03	MF	34	-4.94	...	...	...	...
	3876.04	-2.82	MF	20	-4.44	...	...	...	...
	4453.01	-0.49	MF	16	-6.09	...	...	...	...
	4498.90	-0.34	MF	13	-6.34	...	...	...	...
	4502.22	-0.34	MF	5	-6.78	...	...	...	...
23	4281.10	-0.42	MF	17	-6.15	...	...	...	...
Mn II		log Mn/N_T =			...		...		-6.30±0.28
5	4730.36	-2.15	KX	...	...	...	...	3	-5.97
	4755.73	-1.24	KX	...	...	...	...	14	-6.18
I	4206.37	-1.57	KX	...	...	...	...	4	-6.54
	4251.74	-1.06	KX	...	...	...	...	4	-6.63
	4518.96	-1.33	KX	...	...	...	...	3	-6.17
Fe I		log Fe/N_T =			-4.35±0.27		-4.52±0.23		-4.40±0.27
2	4375.93	-3.03	MF	60	-4.40	...	...	...	...
	4427.31	-2.91	KX	85	-4.28	...	...	8	-3.88
3	4216.19	-3.36	MF	28	-4.47	...	...	...	...
4	3856.37	-1.29	MF	...	...	...	...	54	-4.07
	3859.91	-0.71	MF	...	...	50	-4.82	47	-4.89
	3899.71	-1.53	MF	213	-4.37	13	-4.94	19	-4.75
	3906.48	-2.25	MF	...	...	8	-4.43	9	-4.43
	3920.26	-1.75	MF	221	-4.06	17	-4.56	14	-4.69
	3922.91	-1.65	MF	198	-4.47	15	-4.76	19	-4.64
	3927.92	-1.59	MF	242	-3.96	19	-4.65	27	-4.44
	3930.30	-1.59	MF	...	...	32	-4.34	41	-4.11
20	3840.44	-0.51	MF	...	...	24	-5.10	...	...
	3849.97	-0.87	MF	...	...	27	-4.65	27	-4.64
	3878.02	-0.91	MF	...	...	25	-4.67	24	-4.71
	3917.18	-2.16	MF	41	-4.77	...	...	...	...
22	3850.82	-1.73	MF	116	-4.50	...	...	6	-4.59

Table 5 – *continued*

				ε Ser		29 Vul		σ Aqr	
mult.	λ(Å)	log gf	Ref.	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T
Fe I (continued)									
38	4733.59	-2.71	KX	7	-4.76	...	...	...	...
39	4531.15	-2.16	MF	79	-4.11	...	...	...	...
	4632.91	-2.91	MF	13	-4.21	...	...	...	...
41	4383.54	+0.20	MF	287	-4.42	67	-4.47	68	-4.38
	4404.75	-0.14	MF	231	-4.68	53	-4.46	49	-4.54
	4415.12	-0.62	MF	218	-4.31	30	-4.50	34	-4.42
42	4147.67	-2.10	MF	46	-4.46	...	...	...	...
	4202.03	-0.71	MF	230	-4.13	28	-4.53	29	-4.50
	4250.79	-0.71	MF	214	-4.26	25	-4.56	28	-4.49
	4271.76	-0.16	MF	226	-4.73	57	-4.38	48	-4.59
43	4005.25	-0.61	MF	...	...	32	-4.47	29	-4.55
	4132.06	-0.65	MF	...	...	19	-4.76	...	...
	4045.82	+0.28	MF	359	-3.92	68	-4.53	75	-4.24
	4063.59	0.07	MF	...	...	51	-4.72	61	-4.40
	4071.74	-0.02	MF	227	-4.73	41	-4.82	42	-4.80
	4132.06	-0.65	MF	167	-4.77	...	...	24	-4.61
45	3827.82	+0.06	MF	248	-4.52	46	-4.82	...	...
	3902.95	-0.47	MF	219	-4.37	35	-4.54	53	-4.07
	3966.07	-1.64	MF	36	-4.95	...	...	...	...
50	3872.50	-0.93	MF	237	-4.07	...	...	26	-4.62
68	4407.71	-1.92	MF	...	...	...	...	4	-3.95
	4408.42	-1.71	MF	54	-4.30	...	...	38	-4.99
	4430.62	-1.66	MF	90	-4.00	...	...	3	-4.40
	4442.34	-1.26	MF	...	...	8	-4.30	6	-4.43
	4447.72	-1.34	MF	86	-4.36	6	-4.30	...	...
	4459.12	-1.28	MF	...	...	...	...	11	-4.12
	4494.57	-1.41	MF	...	...	9	-4.07	9	-4.08
	4528.62	-0.82	MF	...	...	13	-4.47	21	-4.23
71	4282.41	-0.81	MF	144	-4.44	11	-4.56	18	-4.31
72	4009.71	-1.20	MF	73	-4.57	...	...	5	-4.54
73	3852.57	-1.24	MF	78	-4.51	...	...	9	-4.24
82	4727.39	-1.01	KX	33	-4.28	...	...	...	...
84	4704.95	-1.57	MF	13	-4.15	...	...	...	...
116	5012.07	-2.64	MF	...	...	...	...	3	-4.16
152	4187.04	-0.55	MF	176	-4.22	13	-4.57	18	-4.42
	4187.79	-0.55	MF	169	-4.30	30	-4.11	41	-3.83
	4191.44	-0.74	KX	155	-4.22	10	-4.50	18	-4.24
	4198.31	-0.72	MF	...	...	19	-4.23	27	-4.04
	4210.35	-0.87	MF	116	-4.40	...	...	9	-4.43
	4222.22	-0.97	MF	109	-4.38	...	...	10	-4.34
	4233.61	-0.60	MF	...	...	...	...	7	-4.83
	4235.94	-0.34	MF	209	-4.11	18	-4.63	20	-4.58
	4250.12	-0.40	MF	125	-4.81	23	-4.40	26	-4.34
	4260.48	-0.02	MF	230	-4.23	31	-4.62	38	-4.47
	4271.16	-0.35	MF	142	-4.74	...	...	22	-4.50
154	4067.98	-0.43	MF	82	-4.61	...	...	...	...
175	3859.21	-0.68	MF	117	-4.59	...	...	9	-4.70
	3873.76	-0.79	MF	110	-4.52	...	...	6	-4.75
	4266.96	-1.68	MF	18	-4.51	...	...	...	...
217	4078.36	-1.50	KX	57	-4.17	...	...	...	...
253	4143.42	-0.47	KX	...	...	...	...	8	-4.58
276	3998.05	-0.84	MF	80	-4.55	...	...	6	-4.53
278	3937.33	-1.45	MF	47	-4.27	...	...	...	...
	3952.61	-0.98	MF	...	...	7	-4.31	...	...
	3956.68	-0.58	KX	...	...	8	-4.66	...	...
	3981.77	-1.08	MF	87	-4.24	...	...	...	...
	3997.39	-0.39	MF	195	-3.96	18	-4.42	13	-4.58
	4021.87	-0.66	MF	119	-4.38	...	...	9	-4.53
280	3890.84	-1.34	MF	16	-4.88	...	...	...	...
	3907.94	-1.11	MF	55	-4.48	...	...	...	...
283	3826.84	-1.64	MF	48	-4.03	...	...	...	...
	3861.34	-1.65	KX	62	-3.90	...	...	...	...
284	3872.92	-1.75	MF	65	-3.75	...	...	...	...
350	4443.19	-1.02	MF	...	...	...	...	7	-4.20
	4466.55	-0.59	MF	125	-4.39	6	-4.74	9	-4.53
352	4207.13	-1.46	MF	75	-3.91	...	...	...	...
354	4107.49	-0.73	MF	...	...	...	...	6	-4.57
	4156.80	-0.62	MF	...	...	6	-4.67	6	-4.72

Table 5 – *continued*

				ε Ser		29 Vul		σ Aqr	
mult.	λ(Å)	log gf	Ref.	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T
Fe I (continued)									
354	4175.64	-0.67	MF	...	...	3	-4.92	...	...
	4181.75	-0.18	MF	158	-4.49	10	-4.88	17	-4.61
355	4184.89	-0.86	MF	...	...	...	...	6	-4.43
	4213.65	-1.29	MF	37	-4.48	...	...	...	...
357	4109.81	-0.91	MF	...	...	...	...	7	-4.30
	4114.45	-1.22	MF	31	-4.64	...	...	...	...
	4132.90	-0.92	MF	...	...	10	-4.13	...	...
	4134.68	-0.49	MF	113	-4.55	...	...	8	-4.68
359	4044.61	-1.08	MF	58	-4.44	...	...	...	...
	4062.45	-0.78	MF	99	-4.37	9	-4.34	4	-4.76
361	3964.52	-1.55	MF	16	-4.61	...	...	...	...
364	3942.44	-0.98	MF	137	-3.84	...	...	...	...
388	4067.98	-0.43	MF	...	...	...	...	7	-4.57
409	4647.43	-1.31	MF	48	-4.28	...	...	...	...
	4691.41	-1.45	MF	29	-4.38	...	...	...	...
	4710.28	-1.63	KX	16	-4.46	...	...	...	...
413	4373.56	-1.97	KX	23	-3.92	...	...	...	...
423	4120.21	-1.17	MF	...	...	...	...	2	-4.57
426	4000.46	-1.63	MF	53	-3.83	...	...	...	...
429	3871.75	-0.78	MF	...	...	...	...	9	-4.25
	3903.89	-0.70	MF	92	-4.39	...	...	...	...
430	3893.39	-0.48	MF	78	-4.76	...	...	...	...
	3918.64	-0.74	KX	...	...	17	-3.91	...	...
430	3919.07	-1.10	MF	...	...	...	...	5	-4.22
472	4517.53	-1.84	MF	16	-4.21	...	...	...	...
476	4387.90	-1.47	MF	22	-4.41	...	...	...	...
476a	4182.38	-1.19	MF	60	-4.19	...	...	...	...
482	4170.91	-1.10	MF	...	...	...	...	8	-3.97
	4220.34	-1.29	MF	41	-4.27	...	...	4	-4.06
	4267.83	-1.11	MF	36	-4.50	...	...	4	-4.29
488	3867.22	-0.42	MF	93	-4.64	...	...	...	...
	4006.31	-0.99	MF	59	-4.23	...	...	...	...
514	4514.19	-2.05	MF	14	-4.06	...	...	...	...
515	4480.14	-2.04	MF	25	-3.80	...	...	...	...
520	4298.04	-1.37	MF	29	-4.39	...	...	...	...
522	4199.10	+0.25	MF	190	-4.45	24	-4.70	31	-4.53
527	4017.16	-0.92	MF	101	-4.07	...	...	...	...
526	3994.11	-1.47	MF	39	-4.11	...	...	...	...
528	3843.26	-0.14	MF	152	-4.55	...	...	17	-4.55
554	4598.12	-1.57	MF	22	-4.18	...	...	...	...
	4625.05	-1.34	MF	33	-4.24	...	...	...	...
	4707.27	-1.08	MF	...	...	...	...	2	-4.54
	4736.77	-0.74	MF	87	-4.30	6	-4.39	7	-4.32
558	4070.77	-0.79	MF	...	...	...	...	6	-4.31
	4073.76	-0.92	MF	75	-4.15	...	...	...	...
	4076.64	-0.36	MF	120	-4.38	10	-4.50	...	...
559	4085.31	-0.71	MF	118	-4.03	...	...	8	-4.22
560	4030.50	-0.70	KX	...	...	...	...	11	-4.09
561	3946.99	-0.95	MF	52	-4.37	...	...	...	...
562	3941.28	-1.01	MF	51	-4.29	...	...	...	...
	3948.10	-0.26	KX	137	-4.30	...	...	...	...
	3955.34	-1.01	MF	41	-4.40	...	...	...	...
	3963.10	-0.70	MF	29	-4.88	...	...	...	...
565	3909.66	-1.22	MF	61	-3.95	...	...	3	-4.20
594	4595.36	-1.72	MF	18	-4.12	...	...	...	...
597	4285.44	-0.85	KX	57	-4.43	...	...	4	-4.39
604	3948.78	-0.34	MF	...	...	9	-4.54	...	...
606	3916.73	-0.52	MF	111	-4.25	8	-4.41	7	-4.51
641	4533.13	-1.94	MF	...	...	...	...	2	-3.76
649	4268.75	-1.46	MF	16	-4.43	...	...	...	...
655	3986.18	-1.51	KX	32	-4.05	...	...	...	...
659	4158.79	-0.67	MF	124	-3.91	5	-4.43	...	...
661	3985.39	-1.10	MF	15	-4.78	...	...	...	...
663	3883.28	-0.60	MF	40	-4.83	...	...	6	-4.48
664	3846.80	+0.01	MF	180	-4.11	11	-4.78	...	...
689	4200.92	-1.00	MF	59	-4.14	...	...	...	...
	4224.18	-0.41	MF	107	-4.34	...	...	7	-4.57
	4238.03	-1.29	KX	66	-3.78	...	...	5	-3.79
692	4264.20	-1.48	KX	20	-4.26	...	...	...	...

Table 5 – *continued*

				ε Ser		29 Vul		σ Aqr	
mult.	λ(Å)	log gf	Ref.	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T
Fe I (continued)									
693	4196.22	-0.74	MF	99	-4.05	3	-4.52	8	-4.14
	4217.55	-0.51	MF	...	...	7	-4.37	8	-4.32
	4225.46	-0.50	MF	86	-4.39	...	...	...	...
	4238.82	-0.28	MF	113	-4.41	8	-4.55	5	-4.81
	4247.43	-0.23	MF	166	-4.04	...	...	8	-4.66
695	4126.19	-0.96	MF	38	-4.47	...	...	...	...
	4150.26	-1.26	MF	37	-4.13	...	...	3	-4.12
	4153.91	-0.27	MF	...	...	...	...	9	-4.53
	4157.79	-0.56	KX	80	-4.38	...	...	4	-4.57
698	4065.40	-1.32	MF	11	-4.65	...	...	...	...
	4084.50	-0.59	MF	36	-4.86	...	...	3	-4.71
726	4137.00	-0.54	MF	67	-4.51	9	-4.26	10	-4.20
755	4547.85	-0.78	MF	32	-4.62	...	...	4	-4.37
761	4327.09	-0.96	MF	37	-4.35	...	...	...	...
766	4059.73	-1.22	MF	13	-4.56	...	...	...	...
800	4219.36	+0.12	MF	111	-4.70	10	-4.74	14	-4.59
801	4118.55	+0.28	MF	...	...	14	-4.76	21	-4.51
820	4643.46	-1.29	MF	19	-4.29	...	...	...	...
	4673.16	-0.98	MF	24	-4.49	...	...	...	...
821	4669.17	-1.41	MF	36	-3.86	...	...	...	...
	4678.84	-0.66	MF	63	-4.33	9	-4.03	...	...
	4745.80	-0.79	KX	17	-4.85	...	...	...	...
822	4667.45	-1.36	KX	...	...	...	...	3	-3.89
	4728.54	-1.44	KX	34	-3.85	...	...	...	...
826	4525.14	-0.95	KX	...	...	...	...	6	-3.91
	4611.28	-1.02	KX	48	-4.08	...	...	...	...
828	4446.84	-1.33	MF	40	-3.85	...	...	...	...
	4484.23	-0.72	MF	56	-4.33	...	...	...	...
830	4388.41	-0.59	MF	70	-4.32	10	-4.03	4	-4.48
	4433.22	-0.70	MF	44	-4.45	...	...	...	...
	4469.38	-0.26	MF	...	...	...	...	10	-4.97
	4485.68	-1.02	MF	21	-4.49	...	...	...	...
849	4309.04	-1.10	MF	...	...	...	...	6	-3.75
906	4243.37	-1.53	KX	10	-4.34	...	...	...	...
918	5006.12	-0.77	KX	...	...	...	...	8	-4.45
940	4189.56	-1.33	MF	...	...	...	...	3	-3.80
965	5014.94	-0.25	MF	...	...	...	...	8	-4.32
984	5005.71	-0.18	KX	...	...	...	...	6	-4.52
1042	4735.84	-1.22	MF	7	-4.58	...	...	...	...
1065	4991.27	-0.67	MF	...	...	...	...	7	-3.78
1103	4112.97	-0.33	MF	36	-4.56	...	...	...	...
N	4279.48	-1.46	MF	14	-4.09	...	...	...	...
	4741.53	-2.00	MF	13	-4.32	...	...	...	...
		log Fe/N_T =			-4.28±0.25		-4.52±0.16		-4.34±0.19
Fe II									
3	3914.48	-4.05	MF	...	...	18	-4.62	...	...
	3938.29	-3.89	MF	...	...	23	-4.64	35	-4.35
21	4119.53	-4.90	KX	...	...	...	...	7	-3.81
	4177.69	-3.68	KX	...	...	...	...	36	-4.09
23	3896.10	-4.04	KX	...	...	...	...	7	-4.63
25	4648.94	-4.51	KX	...	...	10	-3.98	6	-4.24
	4670.17	-3.97	KX	42	-4.36	9	-4.55	14	-4.40
26	4461.43	-4.20	KX	...	...	...	...	11	-4.26
	4580.06	-3.65	KX	...	...	20	-4.48	17	-4.61
27	4128.74	-3.77	MF	67	-4.27	14	-4.55	23	-4.30
	4273.32	-3.34	MF	108	-4.29	23	-4.63	33	-4.40
	4303.17	-2.49	MF	214	-4.19	53	-4.76	60	-4.57
	4351.76	-2.10	MF	...	...	95	-4.06	64	-4.87
	4385.38	-2.57	MF	197	-4.26	62	-4.41	53	-4.64
	4416.82	-2.60	MF	158	-4.59	63	-4.36	66	-4.24
28	4087.27	-4.71	MF	...	...	...	...	4	-4.26
	4122.64	-3.38	MF	...	...	24	-4.63	36	-4.36
	4178.86	-2.48	MF	235	-4.02	...	...	59	-4.66
	4258.16	-3.40	MF	...	...	18	-4.71	33	-4.34
	4296.57	-3.01	MF	...	...	39	-4.57	49	-4.34
	4369.40	-3.67	MF	...	...	14	-4.53	19	-4.41
29	3872.76	-3.22	KX	...	...	...	...	27	-4.66
	3974.16	-3.51	MF	36	-4.79	...	...	...	...
	4002.08	-3.37	KX	80	-4.41	...	...	18	-4.75
32	4278.16	-3.83	KX	...	...	...	...	18	-4.32
	4314.29	-3.49	KX	67	-4.49	29	-4.35	37	-4.18

Table 5 – *continued*

mult.	λ(Å)	log gf	Ref.	ε Ser		29 Vul		σ Aqr	
				W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T
Fe II (continued)									
32	4384.33	-3.50	MF	87	-4.33	...	...	34	-4.26
	4413.60	-3.87	MF	43	-4.38	7	-4.73	11	-4.55
36	4993.35	-3.65	MF	...	...	...	...	20	-4.38
37	4472.92	-3.43	MF	90	-4.26	23	-4.46	29	-4.32
	4489.18	-2.97	MF	158	-4.19	39	-4.54	47	-4.37
	4491.40	-2.70	MF	158	-4.45	44	-4.69	52	-4.47
	4515.34	-2.48	MF	189	-4.38	56	-4.63	71	-4.16
	4520.22	-2.60	MF	172	-4.44	53	-4.60	64	-4.28
	4555.89	-2.29	MF	243	-4.06	72	-4.39	68	-4.47
	4629.34	-2.37	MF	202	-4.41	64	-4.54	73	-4.26
	4666.75	-3.33	MF	...	...	20	-4.65	35	-4.28
38	4508.28	-2.21	MF	190	-4.65	69	-4.55	78	-4.26
	4522.63	-2.03	MF	244	-4.29	69	-4.75	79	-4.42
	4541.52	-3.05	MF	131	-4.32	39	-4.45	45	-4.32
	4576.33	-3.04	MF	128	-4.36	35	-4.55	45	-4.32
	4582.84	-3.10	MF	...	...	27	-4.68	38	-4.44
	4583.83	-2.02	MF	243	-4.35	90	-4.23	103	-3.87
	4620.51	-3.28	MF	108	-4.28	29	-4.47	31	-4.44
42	5018.45	-1.22	MF	...	...	...	...	131	-3.87
43	4601.34	-4.40	KX	...	...	...	...	8	-4.09
	4656.87	-3.63	MF	93	-4.02	19	-4.34	...	...
	4731.44	-3.36	MF	125	-4.03	31	-4.30	37	-4.17
44	4663.70	-4.28	KX	...	...	...	...	11	-4.01
127	3863.96	-2.33	KX	...	...	...	...	17	-4.75
	4024.55	-2.48	MF	...	...	...	...	44	-3.99
151	4031.44	-3.14	KX	...	...	...	...	5	-4.61
153	3827.08	-2.64	MF	...	...	...	...	14	-4.58
168	5019.46	-2.70	KX	...	...	...	...	13	-4.02
173	3906.04	-1.83	MF	...	...	...	...	37	-4.26
186	4549.21	-1.87	MF	...	...	...	...	21	-4.42
	4625.91	-2.22	KX	23	-4.22	...	...	10	-4.49
	4635.33	-1.65	MF	64	-4.23	28	-4.39	36	-4.20
187	4446.24	-2.58	KX	40	-3.57	...	...	7	-4.32
188	4069.88	-2.80	KX	...	...	...	...	7	-4.16
	4111.88	-2.29	KX	...	...	...	...	7	-4.64
190	3938.97	-1.85	MF	19	-4.73	19	-4.53	29	-4.27
213	4354.34	-1.74	KX	...	...	...	...	6	-4.35
	4507.10	-1.87	KX	...	...	...	...	11	-3.85
219	4625.91	-2.22	KX	...	...	10	-4.46	...	...
	4628.82	-1.60	KX	...	...	...	...	5	-4.45
	4631.90	-1.82	KX	...	...	...	...	3	-4.51
220	4319.68	-1.69	KX	...	...	...	...	6	-4.30
222	4431.64	-1.93	KX	...	...	...	...	5	-4.14
	4449.66	-1.60	KX	...	...	...	...	6	-4.36
D	3920.64	-1.20	KX	...	...	...	...	22	-4.29
	4418.98	-1.97	KX	...	...	...	...	5	-4.06
	4487.50	-2.12	KX	...	...	...	...	4	-4.11
	4596.02	-1.82	KX	...	...	15	-4.48	21	-4.30
G	4512.06	-2.13	KX	...	...	...	...	5	-4.00
J	4263.90	-1.64	KX	...	...	...	...	16	-3.92
	4286.28	-1.61	KX	...	...	4	-4.61	10	-4.25
	4357.58	-2.10	KX	18	-4.38	18	-4.20	14	-4.35
	4361.25	-2.08	KX	13	-4.53	...	...	7	-4.71
	4451.54	-1.82	KX	...	...	14	-4.59	23	-4.30
	4455.26	-1.99	KX	...	...	13	-4.43	20	-4.16
	4480.69	-2.34	KX	...	...	...	...	14	-4.05
	4499.71	-1.76	KX	...	...	...	...	3	-4.65
	4579.52	-2.36	KX	21	-3.94	...	...	14	-4.00
	4638.05	-1.47	KX	...	...	...	...	12	-4.21
	4984.48	+0.01	KX	...	...	...	...	10	-4.40
	4990.51	+0.18	KX	...	...	...	...	14	-4.38
	4999.18	-0.48	KX	...	...	...	...	5	-4.36
	5004.20	+0.50	KX	...	...	...	...	24	-4.36
	5006.80	-0.43	KX	...	...	...	...	7	-4.11
	5009.02	-0.42	KX	...	...	...	...	5	-4.36
	5021.59	-0.30	KX	...	...	...	...	12	-4.00
	5022.42	-0.06	KX	...	...	...	...	12	-4.21
	5022.79	-0.02	KX	...	...	...	...	11	-4.31
	5026.81	-0.22	KX	...	...	...	...	9	-4.24
	5030.63	+0.40	KX	...	...	...	...	17	-4.48
	5032.71	+0.11	KX	...	...	...	...	13	-4.33

Table 5 – *continued*

mult.	λ(Å)	log gf	Ref.	ε Ser W_λ (mÅ)	ε Ser log N/N_T	29 Vul W_λ (mÅ)	29 Vul log N/N_T	σ Aqr W_λ (mÅ)	σ Aqr log N/N_T
Fe II (continued)									
-	4402.88	-2.75	KX	19	-3.67	...	...	10	-3.88
	4522.84	-3.10	MF	110	-4.43	...	...	...	...
	4640.84	-1.81	KX	12	-3.86	...	...	5	-4.30
Co I		log Co/N_T =			-6.08±0.05		...		-6.36
16	4020.88	-2.07	MF	12	-6.03	...	...	...	...
31	3995.31	-0.22	MF	...	...	...	...	6	-6.36
34	3845.47	+0.01	MF	155	-6.14	...	...	...	...
Ni I		log Ni/N_T =			-5.31±0.20		-5.47±0.24		-5.31±0.20
32	3858.30	-0.97	MF	171	-5.60	15	-5.64	21	-5.47
86	4401.54	+0.08	MF	...	...	...	...	10	-5.39
98	4604.99	-0.29	MF	48	-5.37	...	...	4	-5.28
	4648.64	-0.16	MF	85	-5.18	...	...	...	...
	4686.20	-0.64	MF	15	-5.53	...	...	...	...
	4714.42	+0.23	MF	106	-5.43	...	...	15	-5.20
	4715.78	-0.34	MF	34	-5.47	...	...	5	-5.14
	4756.51	-0.34	MF	36	-5.47	...	...	...	...
100	4606.23	-1.00	MF	17	-5.10	...	...	...	...
111	5017.58	-0.08	MF	...	...	...	...	8	-5.14
132	4752.42	-0.70	MF	27	-5.15	...	...	...	...
133	4703.80	-0.74	KX	19	-5.27	...	...	...	...
136	4231.04	-1.42	KX	9	-4.99	...	...	...	...
137	3844.26	-0.27	KX	28	-5.58	...	...	3	-5.42
141	4754.76	-1.14	KX	10	-5.18	...	...	...	...
143	4984.11	+0.35	KX	...	...	...	...	4	-5.70
163	4512.97	-1.47	MF	6	-5.02	...	...	...	...
198	4714.42	+0.23	MF	...	...	13	-5.30	...	...
235	4701.53	-0.39	MF	29	-5.13	...	...	...	...
	4732.46	-0.55	MF	8	-5.56	...	...	...	...
261	4546.92	-0.27	KX	...	...	...	...	3	-5.06
Ni II		log Ni/N_T =			-5.14±0.09		-5.40±0.22		-5.18±0.16
9	4244.80	-3.11	KX	...	...	8	-5.30	12	-5.12
	4362.10	-2.72	KX	39	-5.24	21	-5.16	18	-5.27
10	4192.07	-3.05	KX	24	-5.16	10	-5.22	17	-5.00
11	3849.58	-1.88	KX	...	...	32	-5.73	45	-5.41
12	4015.50	-2.42	KX	90	-5.02	18	-5.58	36	-5.09
Zn I		log Zn/N_T =			-6.97±0.18		-6.31		-6.72±0.30
2	4680.14	-0.82	KX	27	-6.84	...	...	3	-6.51
	4722.16	-0.34	KX	40	-7.10	12	-6.31	3	-6.94
Sr II		log Sr/N_T =			-8.54±0.02		-8.54±0.07		-8.17±0.14
1	4077.71	+0.15	WM	323	-8.53	71	-8.49	72	-8.32
	4215.52	-0.17	WM	296	-8.56	60	-8.59	70	-8.14
3	4161.79	-0.50	KX	...	...	...	...	10	-8.04
Y II		log Y/N_T =			-8.81±0.11		...		-9.06±0.25
5	4309.62	-0.75	HL	...	...	...	...	13	-8.89
	4358.73	-1.32	HL	68	-8.79	...	...	...	...
	4398.02	-1.00	HL	91	-8.90	...	...	4	-9.24
6	3950.35	-0.49	HL	180	-8.64	...	...	...	...
12	4682.32	-1.51	HL	27	-8.91	...	...	...	...
Zr II		log Zr/N_T =			-8.56±0.20		-9.03±0.27		-8.71±0.12
15	4211.88	-0.98	GB	43	-8.64	3	-8.92	4	-8.79
16	3958.24	-0.26	GB	77	-8.99	...	...	...	...
	3998.98	-0.67	GB	106	-8.33	...	...	12	-8.59
17	3915.94	-0.77	BG	...	...	...	...	7	-8.75
29	4090.52	-1.10	GB	24	-8.65	...	...	3	-8.64
	4156.24	-0.71	GB	...	...	...	...	4	-8.94
30	3991.14	-0.30	GB	...	...	6	-9.16	...	...
40	4496.97	-0.86	BG	60	-8.47	...	...	4	-8.91
41	4149.22	-0.03	GB	...	...	6	-9.39	24	-8.65
42	4161.20	-0.58	GB	...	...	9	-8.67	11	-8.62
43	4048.68	-0.35	KX	...	...	...	...	16	-8.57
	4050.32	-1.00	BG	53	-8.36	...	...	...	...
79	4359.74	-0.56	GB	...	...	...	...	5	-8.72
	4370.96	-0.71	GB	42	-8.46	...	...	...	...
88	4379.78	-0.35	GB	45	-8.57	...	...	7	-8.65
Cd I		log Cd/N_T =			-6.75		...		...
16	4678.16	-0.89	FW	24	-6.75	...	...	...	...

Table 5 – *continued*

				ε Ser		29 Vul		σ Aqr	
mult.	λ(Å)	log gf	Ref.	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T	W_λ (mÅ)	log N/N_T
Ba II			log Ba/N_T =		-8.88		-8.62		-8.65
1	4554.03	+0.16	WM	257	-8.88	47	-8.62	44	-8.65
La II			log La/N_T =		-9.69±0.22		...		...
10	4086.72	+0.13	MC	114	-9.52	...	...	...	...
24	4333.74	-0.15	KX	30	-9.96	...	...	...	...
40	3988.52	+0.32	MC	69	-9.78	...	...	...	...
41	3949.10	+0.64	MC	156	-9.36	...	...	...	...
66	4042.91	+0.50	MC	46	-9.84	...	...	...	...
Ce II			log Ce/N_T =		-9.16±0.16		...		...
1	4306.72	-0.23	MC	21	-8.99	...	...	...	...
	4562.36	-0.04	MC	18	-9.30	...	...	...	...
	4628.16	-0.11	MC	22	-9.11	...	...	...	...
2	4137.65	+0.03	MC	37	-8.95	...	...	...	...
	4382.17	-0.02	MC	14	-9.27	...	...	...	...
	4460.21	+0.17	MC	23	-9.40	...	...	...	...
4	4081.21	-0.24	MC	12	-9.26	...	...	...	...
6	4593.93	-0.11	MC	18	-9.09	...	...	...	...
57	4486.91	-0.48	MC	11	-9.23	...	...	...	...
81	4255.79	-0.12	MC	14	-9.15	...	...	...	...
134	3992.39	-0.22	MC	17	-9.12	...	...	...	...
186	4202.94	-0.19	MC	30	-8.89	...	...	...	...
195	3921.76	+0.00	MC	24	-8.98	...	...	...	...
204	4270.19	-0.27	MC	7	-9.44	...	...	...	...
Nd II			log Nd/N_T =		-9.64		...		...
10	4061.09	+0.57	WV	32	-9.64	...	...	...	...
Eu II			log Eu/N_T =		-10.57:		...		...
1	4129.73	+0.20	BK	37	-10.57:	...	...	...	...

Note: *gf*-value references follow:
BG = Biémont et al. (1989) for V II; Biémont et al. (1981) for Zr II
BK = Biémont et al. (1982)
FW = Fuhr & Wiese (1990)
GB = Grevesse et al. (1981)
HL = Hannaford et al. (1982)
JK = Jönsson et al. (1984)
KX = Kurucz (1995)
LA = Lanz & Artru (1985)
LD = Lawler & Dakin (1989)
MF = Fuhr, Martin & Wiese (1988) & Martin, Fuhr & Wiese (1988)
MC = Magazzu & Cowley (1986)
WF = Wiese, Fuhr & Deters (1996)
WM = Wiese & Martin (1980)
WS = Wiese, Smith & Glennon (1966) & Wiese, Smith & Miles (1969)
WV = Ward (1985)

et al. (1984) by about 0.25 dex due to the differences in equivalent widths. The largest changes are around 0.7 dex. Some are due to improved oscillator strengths and to the adopted model atmospheres. For ϵ Ser we find S and Fe to have solar abundances, as do Sadakane & Okyudo (1989).

Table 6 contains the average values for our three stars and compares them to solar values (Anders & Grevesse 1989; Biémont et al. 1991, 1993a; Biémont, Quinet & Zeippen 1993b; Biémont & Lowe 1993; Bizzarri et al. 1993; Holweger et al. 1991; Pinnington et al. 1992, 1993). When we calculated the mean abundance anomalies, we found +0.44 ± 0.54 dex for ϵ Ser (20 values excluding Co I and Cd I), −0.09 ± 0.33 dex for 29 Vul (15 values excluding Zn I and Ba II), and +0.24 ± 0.43 dex for σ Aqr (17 values excluding Co I and Ba II). The abundance pattern for ϵ Ser is that of an Am star with nearly solar light elements, a large Ca deficiency, no Sc II lines seen, iron-peak elements on the whole slightly metal-rich, substantial SrYZr enrichment, and even larger rare-earth anomalies. ϵ Ser's abundances are in general similar to those of 32 Aqr (Adelman et al. 1997), another Am star which shows the classical pattern of Am star abundances and is 700 K cooler. The fact that we were unable to derive the Sc abundance may be due to its apparent rotational velocity being greater than that of 32 Aqr, which is relatively sharp-lined. It might be possible to deduce a Sc/H value using spectrum synthesis techniques. Both stars have large microturbulent velocities compared to more normal stars. The Cd abundance is large, but similar to those of other stars.

The study of 29 Vul continues the extension of this series of abundance analyses toward stars exhibiting some rotation. Its pattern of abundance anomalies is slightly subsolar light elements including calcium with more nearly solar iron-peak elements, except for Sc which is underabundant and Ni which is over-abundant.

Table 6. Comparison of derived and solar abundances (log N/H).

Species	ε Ser	29 Vul	σ Aqr	Sun
He I	...	-1.22±0.00	-1.04±0.05	(-1.00)
C II	...	-4.06	...	-3.43
Mg I	-4.65±0.13	-4.84±0.08	-4.71±0.10	-4.42
Mg II	-4.43±0.32	-4.81±0.04	-4.69±0.24	-4.42
Al I	-5.65	-5.85	-5.50	-5.53
Al II	-5.07	-5.33	-5.00	-5.53
Si II	-4.56±0.27	-4.70±0.27	-4.53±0.26	-4.45
S I	-4.71±0.06	...	...	-4.67
S II	...	...	-4.26±0.24	-4.67
Ca I	-6.23±0.15	-6.13	-6.10	-5.64
Ca II	-6.51	-5.84	-5.89	-5.64
Sc II	...	-9.36	-9.38±0.10	-8.90
Ti I	-6.23	...	...	-7.01
Ti II	-6.94±0.31	-7.16±0.21	-7.01±0.26	-7.01
V II	-7.69±0.21	-8.07±0.22	-7.60±0.12	-8.00
Cr I	-6.09±0.30	...	-6.24±0.17	-6.26
Cr II	-5.88±0.24	-6.25±0.23	-6.09±0.22	-6.26
Mn I	-6.34±0.31	-6.56	-6.44±0.25	-6.45
Mn II	...	...	-6.25±0.28	-6.45
Fe I	-4.30±0.27	-4.49±0.23	-4.35±0.27	-4.52
Fe II	-4.23±0.25	-4.49±0.16	-4.29±0.19	-4.52
Co I	-6.03±0.05	...	-6.31	-7.08
Ni I	-5.26±0.20	-5.44±0.24	-5.26±0.20	-5.75
Ni II	-5.09±0.09	-5.37±0.22	-5.13±0.16	-5.75
Zn I	-6.92±0.18	-6.28	-6.67±0.30	-7.40
Sr II	-8.49±0.02	-8.51±0.07	-8.12±0.14	-9.10
Y II	-8.76±0.11	...	-9.01±0.25	-9.76
Zr II	-8.51±0.20	-9.00±0.27	-8.66±0.12	-9.44
Cd I	-6.70	...	...	-10.14
Ba II	-8.83	-8.59	-8.60	-9.87
La II	-9.64±0.22	...	...	-10.87
Ce II	-9.11±0.16	...	...	-10.45
Nd II	-9.59	...	...	-10.50
Eu II	-10.52:	...	...	-11.49

Sr, Y and Zr are overabundant, and Ba is very over-abundant. This is the pattern expected for a weak Am star.

σ Aqr is a prototype hot Am star, as are 68 Tau, θ Leo and o Peg (Conti 1965). Its abundances are more similar to those of o Peg than either 68 Tau or θ Leo (Adelman 1988, 1994). How or if the hot Am star sequence joins the HgMn star sequence remains to be determined, as σ Aqr, the hottest hot Am star, has some abundances, in particular Sc, that are quite different from those of ν Cnc, the coolest HgMn star studied in this series (Adelman 1989). The problem might be resolvable if there are two subtypes for each sequence (see Ryabchikova, Zakharova & Adelman 1996 for a discussion of two types of HgMn stars).

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