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Elemental abundance studies of CP stars

The helium-weak stars HD 19400, HD 34797 and HD 35456*

M. S. Alonso[3], Z. López–García[1,2,3], S. Malaroda[1,3,4], and F. Leone[5,6]

[1] Complejo Astronómico El Leoncito, CC 467, 5400 San Juan, Argentina
[2] Member of the Carrera del Investigador Científico, CONICET, Consejo Nacional de Investigaciones Científicas y Técnicas de la República Argentina
[3] Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de San Juan, Argentina
[4] Comisión de Investigaciones Científicas de la Provincia de Buenos Aires, Argentina
[5] Osservatorio Astrofisico di Catania, Citá Universitaria, 95125 Catania , Italy
[6] Visiting Astronomer at Complejo Astronómico El Leoncito operated under agreement between Consejo Nacional de Investigaciones Científicas y Técnicas de la República Argentina and the National Universities of La Plata, Córdoba and San Juan

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Abstract. An analysis of the abundances of the helium-weak CP stars HD 19400, HD 34797 and HD 35456, is presented using ATLAS9 model atmospheres and observational material taken with a REOSC echelle spectrograph attached to the *Jorge Sahade* 2.15 m telescope at CASLEO. The light elements are deficient except silicon which is overabundant in HD 19400 and HD 34797. The *iron peak* elements are all overabundant by factors between 5 and 60. The heavy elements show an overabundance in the three stars studied.

Key words. stars: chemically peculiar – stars: abundances – stars: individual: HD 19400 – stars: individual: HD 34797 – stars: individual: HD 35456

1. Introduction

This research is part of our current program for deriving elemental abundances among "Chemically Peculiar (CP)" stars. For this paper we selected the helium-weak stars HD 19400, HD 34797 and HD 35456. The helium-weak stars are a class of stars that when examined spectroscopically at classification dispersion (approximately 100 A/mm) show approximately normal metal line strengths, but have helium lines that are too weak for the photospheric temperatures inferred from intrinsic photometric colours and hydrogen line profiles. Norris (1971) has shown that He-weak stars have an effective temperature corresponding to early or intermediate B-types and gravities similar to those of main sequence objects.

HD 19400 (= HR 939 = θ Hyi) was included in the list of Jaschek et al. (1969) as an Ap star of the helium-weak group. *uvbyβ* photometry has been published by Hauck & Mermilliod (1998) and there are Δa measures by Maitzen (1981). Borra et al. (1983) from only four magnetic observations that do not confirm the existence of a magnetic field, although they tentatively estimated a rms strength of B_l of 198 G. Maitzen (1984) suggests the presence of a magnetic field in this star from the λ5200 feature.

Send offprint requests to: Z. López-García,
e-mail: zlgarcia@casleo.gov.ar

HD 34797 (= HR 1754 = TX Lep) has been classified as a B7p-He weak Silicon star (= CP4) by Abt & Cardona (1983). It was also classified as a λ Boo star in the Bright Star Catalogue. However it was rejected by Faraggiana et al. (1990) as a member of this group when they examined the spectral characteristics of this star in the UV region. Waelkens (1985) emphasized that the Z-parameter of the Geneva Photometry is clearly that of a magnetic star, a fact that was already noted by Hauck & North (1982). Waelkens (1985) estimated the light period for HD 34797 in 2.28704 ± 0.00004 days. The epoch of maximum light is JD $2\,445\,257.70 \pm 0.02$. The light and colour variations are in phase and the amplitude is largest in the U-band. HD 34797 forms a visual pair with another sixth magnitude variable B3 star (HD 34798) with a mutual separation of 39 arcsec. Uesugi & Fukuda (1970) included HD 34797 in their catalogue of rotational velocities with a value of 72 km s^{-1} and a period of 2.29 days. After, Levato et al. (1996) estimated it as 30 km s^{-1}. Cramer & Maeder (1980) estimated from the Z parameter of the Geneva photometry a surface magnetic field of 1.2 kG. *uvbyβ* photometry has been published by Hauck & Mermilliod (1998) and there are Δa measures by Vogt et al. (1998).

Spectral classification has been carried out for B-type stars in Orion OBI Association by Bernacca et al. (1972); they classified HD 35456 (=BU 556) as a B5-6V He-weak variable

Table 1. Observational data for the three helium-weak stars.

Parameter	HD 19400	HD 34797	HD 35456
$B-V$	−0.145	−0.106	−0.05
$U-B$	−0.500	−0.446	−0.49
V	5.52	6.54	6.94
$(b-y)$	−0.066	−0.049	−0.064
m_1	0.111	0.127	0.096
c_1	0.512	0.511	0.496
(β)	2.708	2.748	2.706
(Δa)	20	0.02	28
RV[km s^{-1}]	+11.8	+15	+21.8

star. Borra (1981) calculated the root-mean-square magnetic field for HD 35456 in 615 G. Joncas & Borra (1981) using the photometric Δa peculiarity index measured the strength of the λ5200 continuum flux depression and observed that most of the He-weak stars do not have a detectable depression. The exception is HD 35456 in which this depression is definitely detected. Morrel & Levato (1991) estimated the rotation velocity of the brighter members of Ori OBI association. They have obtained an average of 10 spectra and the result in HD 35456 is 55 km s^{-1}.

Table 1 presents some relevant observational data for the three stars.

2. Observational material and line identifications

The stellar spectra of HD 19400, HD 34797 and HD 35456 were obtained by FL with the *Jorge Sahade* 2.15-m telescope at Complejo Astrónomico El Leoncito (CASLEO) equipped with a REOSC echelle spectrograph[1] and a TEK 1024 × 1024 CCD detector. Five spectra of each star were obtained covering the visual range $\lambda\lambda$3500–6500. The REOSC spectrograph uses gratings as cross dispersers. We have used one grating with 400 lines mm^{-1}. The S/N ratio of the spectra is around 100 and they were obtained from December 5 to 11, 1995.

There is no more than a 20% difference among the equivalent widths measurements of the same lines in different spectra. The spectra were reduced by MSA and SM using IRAF[2] standard procedures for echelle spectra, and were normalized order by order with the *splot* task of the same package. The resolution of the spectra is 0.17 Å/px. Extensive description of observational material reduction obtained with the same equipment, and results derived from them have been published recently by López–García et al. (2001). The equivalent widths were measured by fitting Gaussian profiles through the stellar metal lines using the same task.

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 the more specialized references for P II: Svendenius et al. (1983), S II: Pettersson (1983), Ti II: Huldt et al. (1982), Mn II: Iglesias & Velasco (1964), and Fe II: Johansson (1978). Lines of H I, C II, Mg II, Si II, S II, Sc II, Ti II, Cr II, Mn II, Fe II, Fe III, Ni II, Sr II, Ce II, are definitely present in their spectrums. Lines of N II, O I, Ne I, P II, Y II, Zr II, the Rare Earths Pr II, Nd II, Sm II, Eu II, Gd II and Dy II are probably present.

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3. Atmospheric parameters

For HD 19400, HD 34797 and HD 35456 we have adopted the parameters $T_{\rm eff}$ and $\log g$ published by Leone et al. (1997).

They are:
For HD 19400: $T_{\rm eff}$ = 13 350 K, $\log g$ = 3.76;
For HD 34797: $T_{\rm eff}$ = 13 000 K, $\log g$ = 4.25;
For HD 35456: $T_{\rm eff}$ = 13 450 K, $\log g$ = 3.79.
Another estimation of the effective temperature was done by Glagolevskij (1994), who used the Shallis-Blackwell method starting with the total flux emitted by the stars, and he found an average temperature of 12 900 K for HD 19400 and 14 020 K for HD 35456. With the values of effective temperature and $\log g$ chosen we have computed a model atmosphere using the Kurucz ATLAS9 (1992) code with [M/H] = +0.5, which seems to be adequate for these stars.

4. Abundance analyses

We have calculated the HeI abundance using the method outlined by Leone & Lanzafame (1998). We found a mean value = 0.03 (or log He/H = −1.52), 0.09 (or log He/H = −1.04) and 0.03 (or log He/H = −1.52) for HD 19400, HD 34797 and HD 35456, respectively. We have used the following lines for determining the HeI abundance: λ4437, λ4472, λ4713 and λ4922. We conclude that He is very deficient in these stars. We determined the metal abundances from the average equivalent widths of the five spectra using the WIDTH9 code (Kurucz 1992). The adopted metal line damping constants were the default semi-classical approximations except for those of neutral and singly-ionized Ca-Ni lines, whose values are based on the data of Kurucz & Bell (1995). For lines of CII, multiplet 6, and MgII, multiplet 4, adopted values for the Stark broadening were based on data of Sahal-Brechot (1969), and for SiII and CaII, the damping constants are those of Lanz et al. (1988), and Chapelle & Sahal-Brechot (1970) respectively. We prefer this choice of gf values to the VALD database (Piskunov 1996) for homogeneity with our previous work. In spite of the few stars studied, we see a relation between Δa and helium abundance, in the sense that for larger values of Δa, the helium abundance is lower. Future studies will add more data that probably will permit us to confirm or not the above result.

For calculating the microturbulent velocity we have used the standard method. We calculated abundances from Fe II lines for HD 19400, HD 34797 and HD 35456 for a range of possible microturbulent velocities (ξ). To determine the final values, we looked for the conditions in which the abundances of FeII were not dependent on the equivalent widths (ξ_1) or do not minimize the rms scatter of the abundances (ξ_2). Values

Table 2. Determination of microturbulent velocity.

Star	Species	n	(ξ_1) (km s^{-1})	log N/N_T	(ξ_2) (km s^{-1})	log N/N_T	gf-values
HD 19400	Fe II	132	1.30	−3.75 ± 0.31	1.30	−3.75 ± 0.31	MF&KX
		35	1.10	−3.96 ± 0.27	1.10	−3.96 ± 0.27	MF
	mean ξ:	1.20 km s^{-1}					
HD 34797	Fe II	138	1.10	−3.77 ± 0.32	1.10	−3.77 ± 0.32	MF&KX
		28	0.00	−3.83 ± 0.27	0.00	−3.83 ± 0.27	MF
	mean ξ:	0.80 km s^{-1}					
HD 35456	Fe II	165	0.30	−3.59 ± 0.30	0.30	−3.59 ± 0.30	MF&KX
		35	0.00	−3.77 ± 0.32	0.00	−3.77 ± o.32	MF
	mean ξ:	0.20 km s^{-1}					

Table 3. Comparison of derived and solar abundances.

Elements	HD 19400 log N/H	HD 34797 log N/H	HD 35456 log N/H	α Scl log N/H	Sun log N/H
C II	−3.52 ± 0.28(4)	−3.72 ± 0.66(2)	−3.05 ± 0.93(3)	−3.40	−3.45
N II	−3.68 ± 0.14(2)*	...	−3.28 ± 0.22(2)*	−3.89	−4.03
O I	−3.31 ± 0.07(2)*	...	...	−3.57	−3.13
Ne I	...	−4.17 ± 0.00(1)*	−4.18 ± 0.12(2)*	−3.76	−3.92
Mg II	−4.65 ± 0.30(4)	−4.69 ± 0.28(4)	−4.60 ± 0.16(4)	−4.64	−4.42
Si II	−4.28 ± 0.31(6)	−4.35 ± 0.60(5)	−4.73 ± 0.39(5)	−4.07	−4.45
Si III	...	...	−4.50 ± 0.27(3)	−4.09	−4.45
P II	−5.95 ± 0.16(2)*	−6.55 ± 0.00(1)*	−5.56 ± 0.00(1)*	−6.17	−6.55
S II	−5.07 ± 0.47(7)	−4.94 ± 0.29(4)	−5.40 ± 0.23(6)	−5.08	−4.67
Cl II	...	...	...	−5.39	−6.5*
Sc II	...	−7.44 ± 0.31(4)	−7.43 ± 0.34(5)	−7.51	−8.83
Ti II	−5.69 ± 0.37(21)	−5.23 ± 0.34(19)	−5.56 ± 0.31(24)	−5.61	−6.98
Cr II	−5.45 ± 0.42(15)	−5.13 ± 0.31(22)	−5.28 ± 0.35(24)	−5.58	−6.33
Mn II	−4.57 ± 0.33(5)	−4.66 ± 0.32(4)	−4.77 ± 0.36(4)	−4.92	−6.61
Fe II	−3.75 ± 0.31(132)	−3.65 ± 0.32(142)	−3.59 ± 0.30(165)	−4.00	−4.50
Fe III	−3.67 ± 0.30(4)	−3.48 ± 0.26(3)	−3.16 ± 0.56(5)	−3.80	−4.50
Ni II	−5.51 ± 0.34(4)	−5.45 ± 0.25(3)	−5.40 ± 0.26(4)	...	−5.75
Sr II	−6.95 ± 0.38(3)	−7.33 ± 0.35(3)	−6.74 ± 0.39(4)	...	−9.03
Y II	−6.88 ± 0.10(2)*	−6.42 ± 0.11(2)*	−6.79 ± 0.07(2)*	...	−9.76
Zr II	−6.43 ± 0.46(4)	−6.06 ± 0.39(4)	−6.37 ± 0.24(4)	...	−9.40
Ce II	−6.29 ± 0.36(16)	−6.16 ± 0.31(14)	−6.28 ± 0.36(12)	...	−10.42
Pr II	−6.21 ± 0.02(3)	−5.93 ± 0.18(3)	−6.03 ± 0.14(3)	...	−11.29
Nd II	−6.14 ± 0.18(3)	−5.91 ± 0.26(3)	−5.76 ± 0.16(3)	...	−10.50
Sm II	−5.76 ± 0.33(6)	−5.80 ± 0.30(5)	−5.82 ± 0.28(7)	...	−10.99
Eu II	−6.75 ± 0.00(1)*	−7.01 ± 0.00(1)*	−6.93 ± 0.00(1)*	...	−11.49
Gd II	−6.45 ± 0.28(5)	−6.26 ± 0.30(4)	−6.54 ± 0.30(5)	...	−10.88
Dy II	−6.57 ± 0.35(2)*	−5.94 ± 0.16(2)*	−6.56 ± 0.15(2)*	...	−10.86
Hg II	−4.43 ± 0.00(1)*	...	...	...	−10.83
$T_{\rm eff}$	13350	13000	13450	13900	
log g	3.76	4.25	3.79	3.25	

NOTE: * indicates that the abundance is determined from one or two lines only.

for this species were derived using lines with gf values from Martin et al. (1988) (MF values) and also with gf-values from compatible sources, in this case from Kurucz & Bell (1995) (KX values). From Fe II a mean microturbulence of 1.20 km s^{-1} is found for HD 19400. For HD 34797 Fe II lines indicate a microturbulence of 0.8 km s^{-1} and for HD 35456 a value of 0.20 km s^{-1} was determined. We have used only Fe II lines to determine the microturbulent velocity because it is the element represented with the greatest number of lines.

5. Discussion

Table 3 compares the derived abundances for HD 19400, HD 34797 and HD 35456 with α Scl, another helium-weak star analyzed with similar spectra (López–García et al. 2001) and the solar values (Grevesse et al. 1996). We have included the rms of the average abundance for each specie, and between parenthesis we have indicated the number of lines involved in the average. No serious blended lines were included. Compared to the sun, the light elements are slightly deficient except Si, which is overabundant by a factor 1.5 and 1.8 in HD 19400 and HD 34797 respectively and normal in HD 35456; S is deficient by a factor 2.5, 2 and 5 in HD 19400, HD 34797 and HD 35456, respectively.

All the heavier elements are greatly overabundant. Ti is overabundant in the three stars studied by factors of 20, 55 and 26 in HD 19400, HD 34797 and HD 35456, respectively, Cr is nearly 10 times solar, Mn is also overabundant by a factor 100, and Fe is 6 times solar. The iron peak abundances are similar to the ones calculated for α Scl. Sr is of order 100 solar and Y and Zr are about 100 solar in all stars. The rare earths are 1000 or more times overabundant. Elements heavier than Fe were not identified in α Scl.

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