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CHEMICAL ABUNDANCE PATTERNS FOR SHARP-LINED STARS

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ABSTRACT

In order to increase the completeness of the investigations of stellar abundances, we can use spectrum synthesis method, new atomic data and observation of stellar spectra with resolution comparable to solar spectral atlases. We made a brief review of main problems of these three ways. We present new results of abundance determinations in the atmospheres of four stars. The first is the implementation of new atomic data to well known Przybylski's star. We show that the number of spectral lines, which can be identificated in the spectrum of this star, can be significantly higher. The second example is the investigation of ζ Cyg. We found the abundances of 51 elements in the atmosphere of this mild barium star. The third example is halo star HD221170. Our preliminary abundance pattern consists of 42 elements. The heaviest elements in this pattern are U and Th. The last star is the spectroscopic binary HD153720. The number of elements investigated in the spectra of components of this star is not large, but the results show that the components are Am-stars.

Key words : Line: identification, Stars: abundances, Stars: individual: HD101065, HD153720, HD202109, HD221170

I. INTRODUCTION

In this paper we show the ways of increasing the completeness of the investigations of stellar abundances. If we try to overview the results of determinations of stellar abundances, we find that a lot of elements with Z>30 are omitted. Elements heavier than iron group are synthesized primarily by means of neutron capture processes. According to the work by Burbidge et al. (1957, B2FH hereafter), in order to reconstruct the Galactic evolutionary history of heavy elements, one has to consider two major mechanisms of neutron addition: the s-process and the r-process. Small amount of nuclei can be created in p-process. New process of heavy elements creation was proposed by Woosley & Hoffman (1992) - this is α-process for heavy elements. A review of the developments of the theory of elements creation was made by Wallerstein et al. (1997). This paper was devoted to the 40th anniversary of B2FH work. The theory of element creation needs a detailed abundance pattern for comparison of theoretical predictions with observations. New data on stellar abundance patterns for stars of different types can significantly influence the theory.

The full isotopic pattern is available only for meteoritic matter. The precision of abundance determinations in stars is not so high. The best abundance samples for the stars are:

Sun – 73 elements (Grevesse & Sauval 1998)

Procyon A – 55 elements (Yushchenko & Gopka 1996a,b),

Przybylski's star – 54 elements (Cowley et al. 2000),

χ Lupi – 51 elements (Leckrone et al. 1999),

Gopka (2000) investigated the abundances of several heavy elements in the atmosphere of Sirius A. The abundance pattern of this star consists of 50 elements. In 1988 Reinolds et al. pointed out that the abundance pattern for Canopus (38 elements) is the third after the Sun and Przybylski's star (Wegner & Petford 1974 – 51 elements).

Of course, this review is not full, but it is sufficient to make some conclusions. First of all - detailed abun-

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dance determination is a very long process. In many cases it costs decades of efforts by many scientists. The majority of above cited papers are the review papers or the papers which are the final paper in a long series of articles on abundances in this star. We need the following items for the future progress in our chemical abundance analysis study:

1) the increase of signal/noise ratio and spectral resolution in stellar spectroscopy and the investigation of the chemical abundance using UV spectra;

2) the new atomic data;

3) the use of the spectrum synthesis method not only for limited number of lines in the spectrum, but for majority of lines, taking into account hyperfine and isotopic splitting, magnetic fields, spots, detailed analysis of spectral binaries, individual atmosphere models, etc.

It is difficult to obtain observational data with high quality or best atomic data or best software. Usually the combination of all three items causes poor results.

II. HIGH QUALITY OBSERVATIONS

The majority of cited papers, which give us the most complete stellar abundance samples, deal with the spectra obtained at the best telescopes and spectrographs. During last two decades, when the number of telescopes of 2 meter or larger became near 50, we can see a lot of new results.

The largest telescopes are used mainly for investigations of faint objects. Highest-resolution spectral observations of bright objects are usually obtained with middle class telescopes of 2-4 meter. In the nearest future high resolution spectrograph with resolving power near 100000 will be put in operation at 1.8 m telescope of Bohyunsan optical astronomical observatory (Korea).

A lot of high-quality spectral data are available on the web sites of several observatories (see Prugniel & Soubiran 2001, as an example). A new generation of high dispersion stellar spectral atlases in visual wavelength region started by Arcturus Atlas (Hinkle et al. 2000). In the ultraviolet spectral region it is necessary to point Rogerson's COPERNICUS atlases (see Rogerson 1989, and reference therein), and HST atlases (see Brandt et al. 1998, as an example).

During the last decade observations with Coude-echelle spectrometers started at the 1 meter telescope of SAO RAS and 2 meter telescope of ICAMER. The latter telescope is located at 3124 meters elevation. Echelle spectrometer for this telescope was built as a joint project of four institution: ICAMER, SAO (Russia), Centre for Astronomy of the Nicolaus Copernicus University (Poland), and MAO NASU (Ukraine). The spectrometer was designed tro achieve the maximal resolution up to R=500000 as well as for relatively low resolution observations of faint objects.

The high spectral resolutions achieved by means of three Schmidt cameras with focal lengths 450 mm, 875 mm, and 1960 mm are 45000 or 120000, 210000, and 500000, respectively. Now we made first test observations of bright stars in the highest resolution mode. The detailed information about this instrument can be found in the paper by Mysaev et al. (1999)

In the next sections of this paper we will review the preliminary results of several detailed investigations of stellar abundances with this and other spectrographs on two meter class telescopes. The mild barium star ζ Cyg was observed at ICAMER 2 meter telescope. Spectra obtained with this telescope, and 1.93 meter telescope of Haute-Provence observatory (France) are used for investigation of halo star HD221170. The spectrum from 2.7 meter telescope of Mac-Donald observatory (USA) is used for investigation of spectroscopic binary HD153720. The spectrum of Przybylsky's star was obtained with ESO Coudé Auxiliary Telescope.

III. NEW ATOMIC DATA

High signal to noise spectral observations obtained with high resolution in the wavelength region from UV to IR are very tentative tool for determinations of stellar abundances. Unfortunately the progress in expanding the atomic data is not so fast. Now it is possible to investigate very faint lines. Atomic data for these lines (transition probabilities, hyperfine and/or isotopic splitting constants, partition functions) in many cases are unavailable.

The biggest data base of atomic and molecular lines data was created by Kurucz (1995). In the recent years several CDs were added to this data base. These are the lines of TiO (Kurucz 1999a) and H_2O (Kurucz 1999b, 1999c). VALD data base (Piskunov et al. 1995) is one of the best atomic line databases. New data are continuously added to this database. The list of the strongest lines of all elements with atomic number $Z \geq 32$ was published by Morton (2000). In the recent years success was achieved in campaigns of upgrading the atomic data for the first three ionization stages of many rare-earth elements (see Zhang et al. 2002 as an example) and for many other elements from lithium (Guan & Li 2001) to uranium (Nilsson et al. 2002a,b).

In many cases we can find only wavelengths for lines of some element. This information can be obtained from the list of energy levels. These lists are accessible, for example, at NIST database (*www.nist.gov*). Of course in this case we can not estimate the strengths of the line, but it helps to avoid misidentifications in crowded spectral regions. It should be noted that the precision of wavelength measurements now is higher, than the precision of old laboratory wavelengths even for part of the lines of iron group elements. The energy levels for several species are based on papers, published more than 60 years ago. The accuracy of these levels is less than 0.1 cm^{-1}.

The other problem is very limited data on hyperfine and isotopic splitting of the lines. The spectroscopic method for the determination of the isotopic compositions is not so precise, as methods used in laboratories for investigations of meteoritic matter. There is no database containing the information on the line splitting of all elements. We can point the list of elements, with large isotopic splitting, measurable in stellar spectra. These are He, Li, C, N, O, Mg, K, Cu, Rb, Zr, Ba, Eu, Pt, Hg, Pb, Tl. Very uncertain results can be obtained for La, Ce, Pr, Nd, Sm.

Kurucz database (1995) contains isotopic and hyperfine splitting for part of iron group elements and several other elements. For Mn and Co, these splittings are large enough to be easily detectable in the visual wavelength region. In our calculation we always take into account hyperfine and isotopic splitting for Mn, Co, Cu, Ba, Eu. We try to expand this list.

Data on broadening coefficients help us to obtain the approximation of profiles of spectral lines. Without these data the exact determination of stellar abundances is impossible. BELDATA database (Milovanovic et al. 2000) contains all papers on Stark broadening of lines of different elements published by Dimitrijevic and coworkers. But all these data permit us to identify only half of the lines in the Solar spectrum (Kurucz 2002).

Table 1. Number of lines of different elements in DREAM database

Element	Number of lines	
	DREAM	Common in DREAM and in our old line list
La III	137	9
Ce II	14970	1663
Pr III	18401	
Nd III	51	51
Tb III	923	
Ho III	1324	
Er III	1307	304
Tm II	7954	474
Tm III	1478	
Yb II	5484	311
Yb III	278	
Yb IV	2769	
Lu II	106	74
Lu III	58	3
Th III	901	

IV. SPECTRUM SYNTHESIS METHOD

It should be noted that in many cases new information can be obtained from the observations of very crowded spectral regions. Usual model atmosphere technique is not available in this case. It is necessary to use spectrum synthesis and automatic spectrum synthesis. The programs for automatic spectrum synthesis are described by Cowley (1995) and Tsymbal & Cowley (2000) – MERSEN code, Valenty and Piskunov (1995) – SME, Yushchenko (1998) – URAN, Erspamer & North (2002). These programs are very different, but all of them can help us to obtain detailed abundance samples for different stellar types.

To obtain realistic abundances it is necessary to take into account stratification of the elements in the stellar atmospheres, the spots, the magnetic fields, differential rotation, effects of convection and turbulence, 3-dimensional atmosphere models, non-LTE effects, individual model atmospheres and the variations of physical conditions in the atmospheres due to pulsations and other effects. Our URAN code and Tsymbal's (1996) code STARSP were designed to process the observations of spectroscopic binaries.

The power of modern computers is sufficient for using the automatic fitting of observations by synthetic spectra at all stages of processing of the observed spectra – from wavelength scale and continuum placement through the determination of parameters of used atmosphere model to the final calculations of stellar abundances.

In reality the large number of free parameters and the uncertainties in atomic parameters do not permit us to control each stage of the calculations. It is impossible to create the software for fully automatic spectra processing with the inclusion of all above mentioned effects. The individual calculations for every line are desirable. That is why we use our URAN code in semiautomatic mode.

V. CHEMICAL ABUNDANCE PATTERNS IN DIFFERENT STARS

In this section we will overview the new results of abundance determinations in the atmospheres of four stars using the described methods. In all cases URAN code was used for processing the data and abundance determinations. The telescopes used for this study are listed in the second section of this paper.

(a) Line identification in Przybylski's star

We used spectra in two short regions. Wavelength coverage was 6123-6175 ÅÅ and 6676-6732 ÅÅ – 108 Å. Spectral resolution was R=100000, and signal to noise ratio was S/N>100. In our calculations we used new lanthanides lines from DREAM database (Biemont et al. 2002).

We calculated individual atmosphere model with parameters T_{eff}=6600 K, log g=4.2, and real chemical composition. We used the values 1.45 km/s, 3-3.5 km/s for micro and macroturbulent velocities.

Identification of lines and calculation of abundances were made using spectrum synthesis method. We used Kurucz's (1995) SYNTHE program for the calculation of synthetic spectra and Yushchenko's (1998) URAN

Table 2. Abundances in Przybylski's star

Elem.	Results with DREAM		Cowley et al. 2000		
	logN	N1	logN	N2	N2/N1
O I	-3.74	1	-3.75±0.25	2	2
Na I	-5.86±0.06	2	-5.86±0.22	4	2
Si I	-4.32±0.34	4	-4.42±0.26	7	1.7
Ca I	-6.37±0.07	4	-6.72±0.36	5	1.2
Fe I	-5.50±0.35	2	-5.51±0.30	35	18
Fe II	-5.12	1	-5.17±0.23	9	9
La II	-8.32±0.25	4	-8.17±0.29	28	7
Ce II	-7.58±0.06	28	-7.60±0.26	46	1.6
Pr I			-6.40±0.21	4	
Pr II	-9.45±0.13	3	-8.80±0.21	31	10
Pr III	-8.25±0.52	3	-7.46±0.16	12	4
Nd I			-6.39±0.35	6	
Nd II	-7.62±0.09	10	-7.65±0.28	71	7
Nd III	-6.89	1	-7.31±0.30	7	7
Sm II	-7.65±0.07	10	-7.75±0.29	41	4
Eu II	-9.15	1	-8.58±0.19	5	5
Gd II	-7.61	2	-7.62±0.25	35	18
Tb II	-8.84	1	-8.89±0.16	3	3
Dy II	-7.68	2	-7.88±0.23	16	8
Ho I			-6.60	1	
Er I	-6.24	1			
Er II	-8.17	2	-8.09±0.22	18	9
Er III			-6.83±0.04	4	
Tm II			-8.20±0.28	15	
Yb II			-8.99±0.33	9	
Lu II	-8.80	1	-8.65±0.14	6	6
Re I	-7.44	1	-7.39±0.02	2	2
Os I	-6.89	1	-7.40		
Ir I	-7.29	1	-7.16±0.07	2	2

program for line identification and spectrum synthesis in automatic mode. The values of abundances for all identified lines were found with spectrum synthesis method.

In Tables 1 and 2 we give the summary of results. In Table 1 one can find the total number of lines of different elements and ions in DREAM database. The numbers in the last column of this table - the part of these lines, are those present in our previous line list. The total number of lanthanides and thorium lines in DREAM database is 56150.

We tried to use these lines to find the abundances in Przybylski's star. We used 108 Å wavelength interval in red part of the spectrum. In Table 2 we show our mean abundances (in the scale of log N(H)=12.00), errors and number of lines from 108 Å interval in red region of the spectrum and the corresponding values from 2693 Å interval in blue-red parts of the spectrum according to Cowley et al. (2000).

The brief inspection of the abundances shows, that the results are similar in the range of uncertainties. In the last column of this table we give the ratio of lines, identified in the work of Cowley et al (2000) and in this work.

From the ratio of wavelengths coverage in two studies we can expect that the ratio of numbers of identified lines will be near 25 or more, if we take into account, that the majority of lanthanides lines are located in the blue part of the spectrum. But only one value in the last column of the table exceeds 10.

It means that the lanthanides lines from DREAM database give us a powerful instrument for examination of the atmospheres of peculiar stars.

On Figure 1 we show the example of the spectrum of Przybylski's star near the Ni I 6163.418 Å line. One can see that the use of lines from DREAM database permit us to find the identification of several lines on this plot. But not all lines can be identificated.

It should be noticed, that the inclusion of new lanthanides lines made no significant effect on the synthetic spectra of normal stars, without big excess of lanthanides - new lanthanides lines are relatively weak.

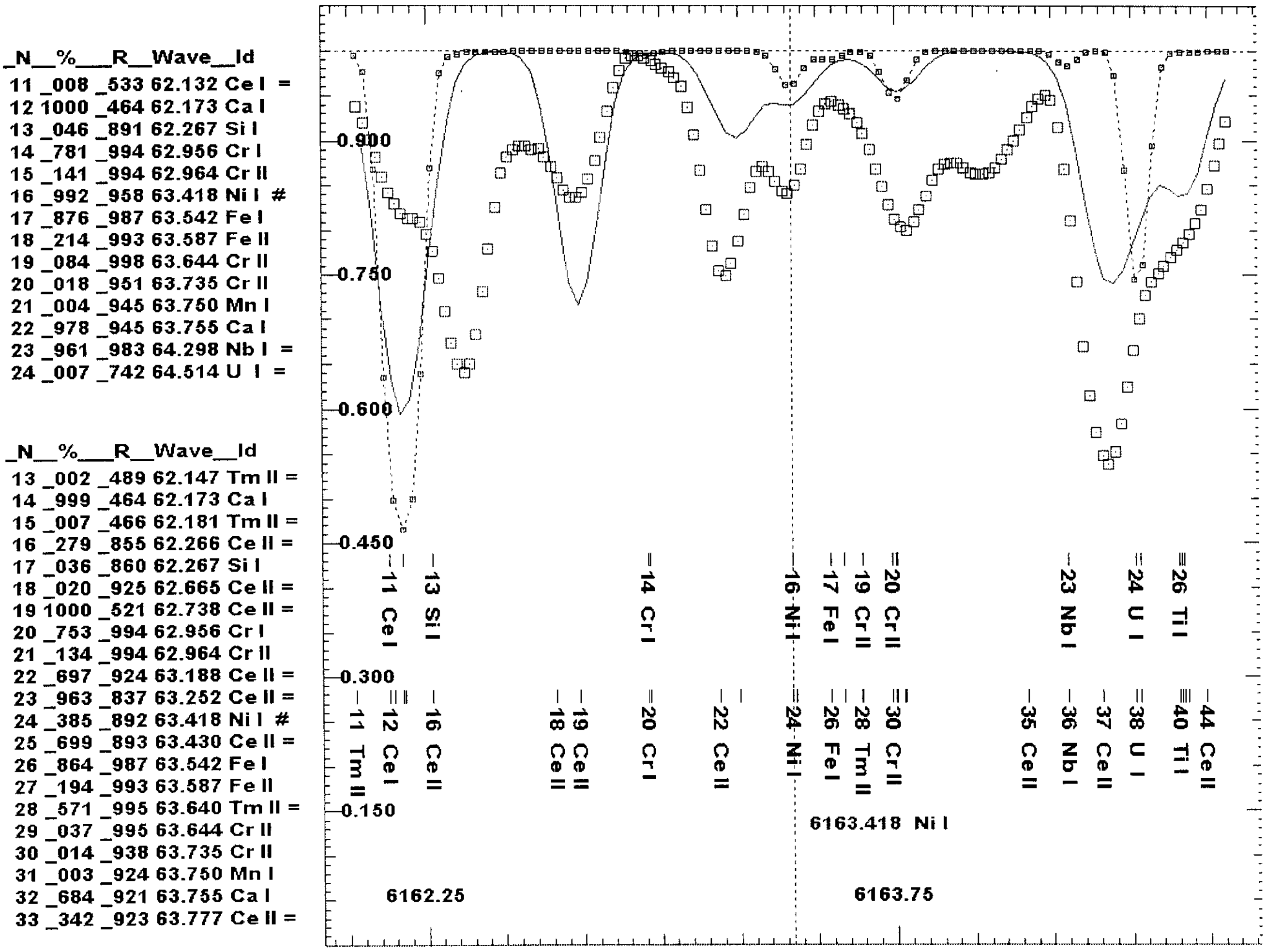
Not only lanthanides show the overabundance in the atmosphere of Przybylski's star, but all heavy elements. Unidentified lines can be the lines of other heavy elements. That is why the calculations or laboratory measurements of oscillator strengths for weak lines of other elements will be very important for identification of lines in chemically peculiar stars.

(b) Chemical composition of ζ Cyg

ζ Cyg is one of the brightest middle barium star. The spectrum was obtained with resolving power R=80000 in the wavelength range 3495-10000 ÅÅ with signal to noise ratio in visual and infrared region more than 100. As a first step we tried to find atmosphere parameters. We tested the parameters used by Zacs (1994) and Boyarchyk et al. (2001). We used the depth ratios of iron lines (Kovtyukh & Gorlova 2000) and other methodics and found that following atmosphere parameters are valid:
T_{eff}=5050 K, $log\ g$=2.8, v_{micro}=1.45 km/s, v_{macro}=3-3.5 km/s

We interpolated Kurucz (1995) atmosphere model with these parameters and calculated synthetic spectrum with increased abundances of heavy elements for all observed region. This spectrum was used for identification of spectral lines. Abundance calculations for all elements except iron were made with spectrum synthesis method. We used Kurucz (1995) SYNTHE program for calculation of synthetic spectra and Yushchenko (1998) URAN program for approximation of the observed program by calculated one in automatic mode.

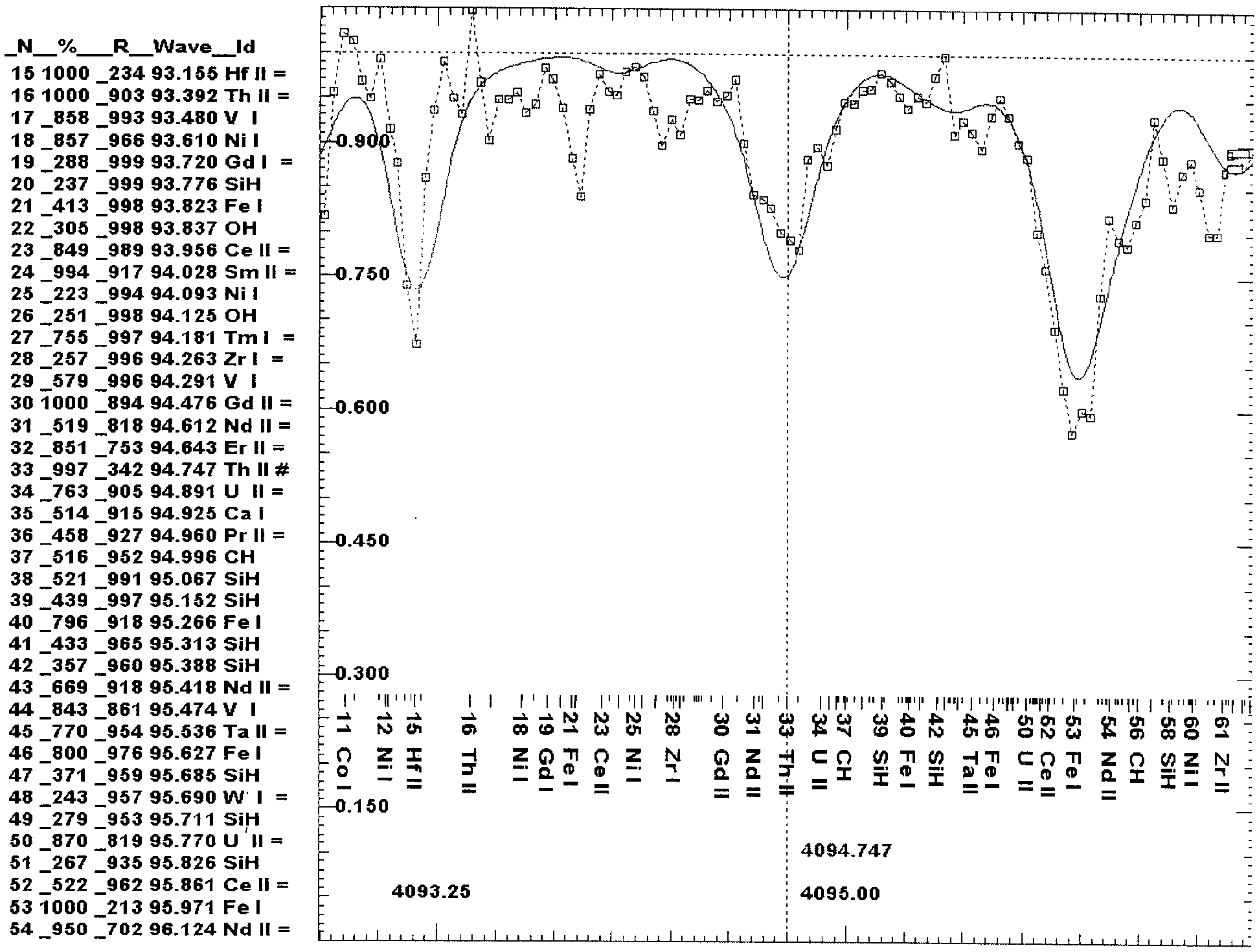
We tried to obtain abundances by direct comparison with the solar spectrum. We found solar oscillator strengths for majority of the used lines. We used Liege Solar atlas (Delbouille et al. 1974), Holweger-Muller (1974) atmosphere model, microturbulent velocity 1.0



```
_N__%___R__Wave__Id
 11 _008 _533 62.132 Ce I  =
 12 1000 _464 62.173 Ca I
 13 _046 _891 62.267 Si I
 14 _781 _994 62.956 Cr I
 15 _141 _994 62.964 Cr II
 16 _992 _958 63.418 Ni I  #
 17 _876 _987 63.542 Fe I
 18 _214 _993 63.587 Fe II
 19 _084 _998 63.644 Cr II
 20 _018 _951 63.735 Cr II
 21 _004 _945 63.750 Mn I
 22 _978 _945 63.755 Ca I
 23 _961 _983 64.298 Nb I  =
 24 _007 _742 64.514 U  I  =
```

```
_N__%___R__Wave__Id
 13 _002 _489 62.147 Tm II =
 14 _999 _464 62.173 Ca I
 15 _007 _466 62.181 Tm II =
 16 _279 _855 62.266 Ce II =
 17 _036 _860 62.267 Si I
 18 _020 _925 62.665 Ce II =
 19 1000 _521 62.738 Ce II =
 20 _753 _994 62.956 Cr I
 21 _134 _994 62.964 Cr II
 22 _697 _924 63.188 Ce II =
 23 _963 _837 63.252 Ce II =
 24 _385 _892 63.418 Ni I  #
 25 _699 _893 63.430 Ce II =
 26 _864 _987 63.542 Fe I
 27 _194 _993 63.587 Fe II
 28 _571 _995 63.640 Tm II =
 29 _037 _995 63.644 Cr II
 30 _014 _938 63.735 Cr II
 31 _003 _924 63.750 Mn I
 32 _684 _921 63.755 Ca I
 33 _342 _923 63.777 Ce II =
```

Fig. 1.— The example of the screen of URAN program - the spectrum of Przybylski's star near the Ni I 6163.418 Å line. The big squares are observed spectrum. The dashed line with small squares and the solid line are the synthetic spectrum calculated without and with DREAM lines, respectively. Identified lines are presented in the bottom part of the figure. In the left part we place a result of calculations of synthetic spectrum without and with DREAM lines. In the tables first column is the line number and second column is the portion of each line with respect to the line absorption coefficient at the wavelength at the center of the line in the synthetic spectrum. For clean line the value in this column must be 1000. In the next column one can find the value of synthetic spectrum at the center of the line. The continuum value is 1000. The values of intensities of synthetic spectrum in the tables are not smoothed by instrumental, rotational and macroturbulence profiles. In the last two columns we can see the wavelengths of these lines and the identifications. Lines of r- and s-processes elements are marked by equal sign, The central line of the plot is nickel line which is marked by # sign in the table.



```
_N__%___R__Wave__Id
 15 1000 _234 93.155 Hf II =
 16 1000 _903 93.392 Th II =
 17 _858 _993 93.480 V  I
 18 _857 _966 93.610 Ni I
 19 _288 _999 93.720 Gd I  =
 20 _237 _999 93.776 SiH
 21 _413 _998 93.823 Fe I
 22 _305 _998 93.837 OH
 23 _849 _989 93.956 Ce II =
 24 _994 _917 94.028 Sm II =
 25 _223 _994 94.093 Ni I
 26 _251 _998 94.125 OH
 27 _755 _997 94.181 Tm I  =
 28 _257 _996 94.263 Zr I  =
 29 _579 _996 94.291 V  I
 30 1000 _894 94.476 Gd II =
 31 _519 _818 94.612 Nd II =
 32 _851 _753 94.643 Er II =
 33 _997 _342 94.747 Th II #
 34 _763 _905 94.891 U  II =
 35 _514 _915 94.925 Ca I
 36 _458 _927 94.960 Pr II =
 37 _516 _952 94.996 CH
 38 _521 _991 95.067 SiH
 39 _439 _997 95.152 SiH
 40 _796 _918 95.266 Fe I
 41 _433 _965 95.313 SiH
 42 _357 _960 95.388 SiH
 43 _669 _918 95.418 Nd II =
 44 _843 _861 95.474 V  I
 45 _770 _954 95.536 Ta II =
 46 _800 _976 95.627 Fe I
 47 _371 _959 95.685 SiH
 48 _243 _957 95.690 W  I  =
 49 _279 _953 95.711 SiH
 50 _870 _819 95.770 U  II =
 51 _267 _935 95.826 SiH
 52 _522 _962 95.861 Ce II =
 53 1000 _213 95.971 Fe I
 54 _950 _702 96.124 Nd II =
```

Fig. 2.— The example of the spectrum of HD221170 in the vicinity of thorium line λ 4094.747 Å. Squares are observed spectrum, solid line - the calculated one.

Table 3. Chemical composition of ζ Cyg

n	Z	Boyar-chuk et al. 2001	Zacs, 1994 ∗ - ⊙	N	Gratton 1985 ∗ - ⊙	This work ∗ - ⊙	N	Element
1	3		-0.14	1				Li I
2	6				-0.09	-0.00±0.21	4	C I
3	7				-0.62			N I
4	8				-0.33	-0.46	1	O I
5	11	+0.19	-0.35	2		-0.37±0.16	5	Na I
6	12		-0.51	2		+0.22±0.22	6	Mg I
						+0.26	2	Mg II
7	13	+0.16				-0.11±0.06	8	Al I
8	14	+0.09	+0.14±0.13	3		-0.05±0.13	52	Si I
9	15					+0.10	1	P I
10	16					+0.20±0.26	5	S I
11	19					+0.00±0.26	3	K I
12	20	-0.03	+0.08±0.19	4		+0.02±0.09	5	Ca I
13	21	-0.02	+0.04±0.30	4		+0.06±0.11	4	Sc I
						+0.08±0.15	10	Sc II
14	22	-0.11	-0.17±0.22	21		-0.07±0.06	23	Ti I
						+0.00±0.11	31	Ti II
15	23	-0.04	-0.13±0.18	16		-0.01±0.12	40	V I
16	24	-0.08	-0.06±0.18	11		-0.11±0.06	26	Cr I
						+0.14±0.06	14	Cr II
17	25		-0.30±0.13	5		-0.26±0.15	21	Mn I
18	26	-0.03	+0.12±0.23	51		+0.02±0.10	92	Fe I
						+0.06±0.08	6	Fe II
19	27	-0.13	-0.22±0.12	6		-0.02±0.09	11	Co I
20	28	-0.09	-0.05±0.25	10		+0.04±0.07	28	Ni I
21	29					+0.44±0.45	3	Cu I
22	30					+0.00±0.24	4	Zn I
23	32					+0.28	1	Ge I
24	37					-0.12	1	Rb I
25	38					+0.22±0.10	3	Sr I
26	39	+0.30	+0.37±0.24	3		+0.15±0.15	3	Y I
						+0.48±0.16	22	Y II
27	40		-0.08±0.20	5		+0.24±0.04	8	Zr I
						+0.61±0.11	7	Zr II
28	41					+0.13	1	Nb I *
29	42					+0.13±0.12	3	Mo I
30	44					-0.02	2	Ru I
31	45					<+0.2	2	Rh I *
32	46					+0.36	1	Pd I *
33	49					-0.12	1	In I
34	56	+0.54	+0.41 0.13	3				Ba II
35	57	+0.45	+0.38 0.15	3		+0.51±0.20	12	La II
36	58	+0.33	+0.55	1		+0.36±0.16	43	Ce II
37	59	+0.43	+0.32 0.13	3		+0.19±0.19	6	Pr II
38	60	+0.23				+0.42±0.17	70	Nd II
39	62					+0.31±0.15	14	Sm II
40	63	+0.22	-0.05	2		+0.45±0.05	4	Eu II
41	64					+0.27±0.19	4	Gd II
42	65					+0.12	1	Tb II *
43	66					+0.28±0.19	5	Dy II
44	68					+0.35	1	Er II
45	69					<+0.2	1	Tm II
46	72					+0.45	1	Hf II *
47	76					+0.30	2	Os I *
48	77					<+0.5	2	Ir I *
49	78					<+0.5	1	Pt I *
50	81					<+0.5	1	Tl I *

Table 4. Chemical composition of HD221170

n	Z	Elem.	$* - \odot$	N	n	Z	Elem.	$* - \odot$	N
1	6	C	-3.0	(CH)	21	41	Nb I	-1.99	1
2	8	O I	-1.61±0.13	2	22	42	Mo I	-1.61	1
3	11	Na I	-2.31±0.21	5	23	44	Ru I	-2.17±0.19	2
4	12	Mg I	-1.92±0.26	5	24	56	Ba I	-1.97	1
5	13	Al I	-1.67	1	25	56	Ba II	-2.06±0.11	5
6	14	Si I	-2.06±0.19	11	26	57	La II	-1.93±0.09	21
7	20	Ca I	-1.96±0.11	26	27	58	Ce II	-1.93±0.12	10
8	21	Sc II	-2.20±0.12	11	28	59	Pr II	-1.90±0.11	7
9	22	Ti I	-2.16±0.19	68	29	60	Nd II	-2.71±0.18	125
		Ti II	-2.11±0.14	38	30	62	Sm II	-1.72±0.11	13
10	23	V I	-2.29±0.17	19	31	63	Eu II	-1.69±0.02	2
11	24	Cr I	-2.26±0.25	15	32	64	Gd II	-1.50±0.08	4
		Cr II	-2.17±0.20	9	33	65	Tb II	-1.58	1
12	25	Mn I	-2.61±0.16	14	34	66	Dy II	-1.69±0.33	5
13	26	Fe I	-2.18±0.23	215	35	68	Er II	-1.29±0.15	3
		Fe II	-2.23±0.18	26	36	71	Lu II	-0.93	1
14	27	Co I	-2.10±0.17	17	37	72	Hf II	-0.99	1
15	28	Ni I	-2.16±0.18	79	38	74	W II	-0.87	1
16	29	Cu I	-2.82±0.12	2	39	76	Os I	-0.55±0.06	2
17	30	Zn I	-2.20±0.04	3	40	77	Ir I	-0.50	1
18	38	Sr I	-2.66	1	41	90	Th II	-1.12±0.28	2
19	39	Y II	-2.43±0.11	16	42	92	U II	-0.69±0.11	2
20	40	Zr I	-2.17	1					
		Zr II	-2.08±0.05	3					

km/s, macroturbulent velocity 1.8 km/s. SYNTHE and URAN codes were used for approximation of observed solar spectrum by synthetic one.

In Table 3 we show the results of abundance determinations. The results of Gratton (1985), Zacs (1994), Boyarchuk et al. (2001) are displayed for comparison. The abundances are given with respect to solar values. The chemical elements with lines, that have no counterparts in the solar spectrum are marked by asterisk.

We found the abundances of 48 elements in the atmosphere of ζ Cyg. The abundances of Li, N, Ba were known from the previous investigations of this star. The total abundance sample consist of 51 elements. Among these elements, *s*-process elements show overabundances in the atmosphere of this star. The relative abundances of heaviest *s*-process elements are not higher than 0.5 dex.

(c) Chemical composition of HD221170

HD221170 is a well known halo star. But previously only elements with $Z\leq66$ were investigated in it's spectrum. We used two spectra of the star. The first was observed at 1.93 m Haute-Provence telescope, the second at 2 m ICAMER telescope. The resolving power of the spectra were 42000 and 35000, wavelength coverage 4478-6820 ÅÅ and 3812-7753 ÅÅ respectively. Signal to noise was near 100 in both cases. The adopted atmospheric parameters were:

T_{eff}=4500 K, log g=1.0, v_{micro}=1.5 km/s, v_{macro}=3.5-4 km/s.

We have used the same method as for ζ Cyg, with only one exception: we did not make the direct comparison with the Sun. The abundances of elements from sodium to samarium (except praseodymium) were found using model atmospheres method. The values of abundances for other elements were found with SYNTHE and URAN codes. The results are given in Table 4.

The total abundance sample consists of 42 elements. The heaviest elements in the sample are thorium and uranium. These elements and other *r*-process elements show overabundances in the atmosphere of this star up to 1.5 dex with respect to iron. The relative abundance of uranium is larger than that of thorium. It should be noted that we used only several lines of these two elements with new experimental values of oscillator strengths, published by Nillson et al. (2002ab). Fig. 2 shows the example of the spectrum of HD221170 near the thorium line.

(d) Chemical composition of HD153720

HD153720 is a spectral binary with very similar components (M_A/M_B=1.0). We used one spectrum with resolution 60000, S/N>100 in the wavelength region 3595-10260 ÅÅ. The chemical composition of the star was not investigated earlier and it was used as a normal standard star in the papers devoted to Am stars.

Table 5. Chemical composition of HD153720

n	Z	Elem.	A - ⊙	N	B - ⊙	N
1	6	C I	-0.31±0.09	6	-0.34±0.11	6
2	7	N I	-0.46±0.03	2	-0.44±0.10	2
3	8	O I	-0.35	1	-0.59±0.07	2
4	11	Na I	+0.02±0.07	2	+0.25±0.10	3
5	12	Mg I	-0.13±0.17	2	-0.32±0.13	4
		Mg II			-0.22:	1
6	13	Al I	-0.07±0.03	2	-0.08±0.04	3
7	14	Si I	-0.09±0.13	9	-0.13±0.10	9
		Si II	-0.13	1	-0.14	1
8	16	S I	+0.06±0.09	7	+0.02±0.11	7
9	19	K I	+0.09±0.10	2	+0.17	1
10	20	Ca I	-0.17±0.12	12	-0.52±0.09	10
		Ca II	-0.20	1	-0.67±0.18	2
11	21	Sc II	+0.18±0.04	3	-0.16±0.16	4
12	22	Ti I	+0.15±0.13	3	-0.13±0.16	3
		Ti II	-0.12±0.33	4	-0.08±0.23	2
13	24	Cr I	-0.06±0.19	6	-0.01±0.25	7
		Cr II	+0.03±0.12	6	+0.13±0.18	9
14	25	Mn I	+0.17±0.15	4	-0.05±0.11	3
15	26	Fe I	+0.01±0.16	55	+0.08±0.15	44
		Fe II	+0.03±0.13	8	+0.13±0.10	10
16	28	Ni I	+0.21±0.16	21	+0.38±0.20	25
17	29	Cu I			+0.47±0.18	2
18	30	Zn I	+0.13±0.11	2	+0.20	1
19	38	Sr II	+0.80	1	+0.84	1
20	39	Y II	+0.69±0.24	5	+0.98±0.26	4
21	40	Zr II	+0.72±0.06	2	+0.65	1
22	56	Ba II	+0.85±0.27	3	+1.17±0.20	2
23	58	Ce II	+0.67	1		

We found atmospheric parameters of the components on the basis of analysis of all available photometric and spectrophotometric data and equivalent widths of iron lines. The large IR excess is observed at the wavelengths longer than 25 micron. We found the values of atmospheric parameters of components: effective temperature T_{eff}=7450 K and 7125 K, surface gravity log g=4.0 and 3.9, microturbulent velocity v_{micro}=2.7 km/s and $v \sin i$=15 km/s for both components. We used the methods of determination the physical parameters of components, described by Yushchenko et al. (1999)

The identification of spectral lines was made on the basis of comparison of observed spectra with synthetic spectra of the components, calculated for the whole observed region. The lines of 22 chemical elements were identified in the spectra of the components - the relatively big value of $v \sin i$ does not permit us to identify faint lines. The abundances of elements were determined with the method of spectrum synthesis. For majority of the lines oscillator strengths were determined from solar spectrum synthesis using all atomic and molecular lines of Kurucz data base. The results for both components are given in Table 5.

The CNO elements show an underabundances relative to the solar values (0.3-0.5 dex). The underabundant are also Mg, Ca. The abundances of Na, Al, Si, S, K, Sc, Ti, Cr, Mn, Fe are near solar values. The abundances of Ni, Cu, Zn, Sr, Y, Zr, Ba, Ce show an overabundances which increase with atomic number from 0.2 dex for Ni to 1 dex for Ba. The largest differences in chemical compositions of the components is observed for Ca (0.4 dex). The abundances of other elements in the atmospheres of components differ no more than by 0.3 dex. It permit us to claim that both components of this binary are Am stars.

VI. CONCLUSION

We show that the abundances of 50-55 elements are the best results for stellar abundance samples in sharp-lined stars. We can point out some ways to increase these number for several types of the stars. First of all for F stars of main sequence. The detailed chemical composition of Procyon is a summary of many papers, and significant part of these papers used Griffin's (1979) atlas of this star. New atlas of the star observed with higher signal to noise ratio and spectral resolution will help us to find several new elements.

The other way is the observations of UV spectrum of Procyon or Procyon type stars. We have no determinations of chemical composition of Procyon from UV spectral data, with wavelengths shorter than 3100 Å.

For barium stars additional abundances can be obtained from observations in the near UV wavelengths region - 3100-3500 Å.

And we must mention about the Sun. There are a dozen of chemical elements with unknown abundances in the solar atmosphere. For example Gopka et al. (2001) found the abundance of arsenic in the Sun. The spectral atlases of solar spots (Wallace et al. 2002ab) can be used for abundance determinations, if the good model of the spot is made. It should be noted that we have no high resolution UV solar atlas. The works of Samain (1995) and Tartag et al. (2001) are only next steps in this direction.

Here we have showed the significance of new atomic data for lanthanides. But it should be noted that Corliss & Bozman (1961) oscillator strengths are still in use for several elements. We have very limited information about the abundances of elements with Z=50-55, 33-36. One of the peaks of solar system abundances is near Z=50-55. And we have almost no information about this peak in the Sun and in other stars. One of the first attempts to find the abundance of tellurium (Z=52) (Yushchenko & Gopka 1996ab) lead us to possible overabundance of this element in Procyon.

Maybe a decade later, when 50-70 elements will be a common number of elements in every paper on chemical abundance in sharp-lined stars, we will be able to resolve a lot of modern problems in this field and to ask new questions.

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