CHEMICAL ABUNDANCES IN BINARIES WITH TWIN COMPONENTS

Yu. Lyubchik[1], E. Martin[2], G. Basri[3], Ya. Pavlenko[1]

[1] Main Astronomical Observatory of NASU, Kiev 03680 Ukraine,
lyu@mao.kiev.ua, yp@mao.kiev.ua

[2] Institute for Astronomy, University of Hawaii at Manoa, 2680 Woodlawn Drive, Honolulu HI, 96822, USA,
ege@ifa.hawaii.edu

[3] Astronomy Department, University of California, Berkeley, CA 94720, USA,
basri@soleil.berkeley.edu

ABSTRACT. Procedure and some preliminary results of abundances determination in binaries with twin components from solar neighbourhood are discussed. Numerical analysis were carried out by fits of synthetical spectra and COG to high resolution (R=50000) observed data. To fit the observations we used model atmospheres of Kurucz with different metallicities and (modified) VALD line list.

Key words: Stars: binary stars: chemical abundances.

1. Introduction

Binary stars with twin components from Solar neighbourhood are interesting because they allow to test the validity of stellar evolution models. If all the properties of stars are determined by age, mass and chemical composition, twin componenys should be identical. However, King et.al.(1997) found that in binary 16 Cyg components are nearly identical (T_{eff} =5785 K, log g=4.28; T_{eff} =5747, log g=4.35), but lithium abundances dramatically differ from each other - for component A - log N(Li)=1.25±0.05, but for component B - log N(Li)<0.6. (Lithium abundances are given in the the customary logarithmic scale with log N(H)=12.). Thus, the systematic study of binaries may help us to establish causes of different rates of lithium depletion or any other deviations in chemical abundances in identical stars.

2. Observations.

Observable set of stars was selected from the list of common proper motion pairs compiled by Halbwachs (1986). Spectral type of chosen stars are between F8 and K0. Four stars from our list are given in Table 1.

High resolution (0.05 Å) observations were obtained during several observing runs at Lick and Keck observatories between January 1998 and February 1999 by E.Martin et.al.

3. Analysis.

Since the photometry of our sample of binaries does not come from a single source, and there could be problems with systematic errors, we have preferred to determine the temperatures and chemical abundances of our stars using synthetical spectra fitting to the observed spectra.

We determined the continuum level in the observed echelle spectra using the DECH20 software (Galasutdinov, 1992). Preliminary determination of T_{eff} and log g of observable stars was done using the astrometrical catalogues (Hipparcos was included) from programms and data of Kharchenko N.V. (private communication). Then, these data were compared to Simbad references.

We carried out computations using spectral synthesis program Abel8 (Pavlenko, 2002) Our computations of LTE synthetic spectra were carried out in the frame of classical approaches: a plane-parallel model atmosphere in LTE, with no energy divergence. In our computations we refer to the solar abundances given by Anders & Grevesse (1989).

Kurucz model atmospheres (Castelli et.al.,1997) were used to compute synthetical spectra. In these models convection is treated with overshooting. We compared the results of synthetical spectra computation using different approximations of convection (mixing length theory and overshooting) and concluded that differences are not very strong for temperature range T_{eff} =5250 – 6500 K.

We had to use metallicities in the range [m/H]=0 ÷

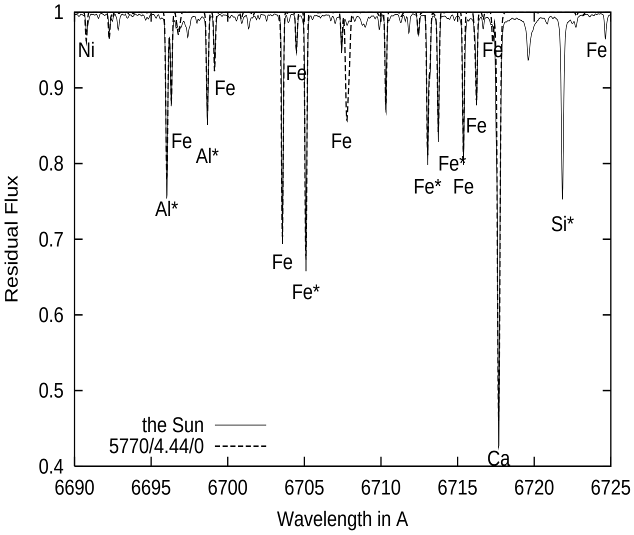

Figure 1: The fit of synthetical spectra 5770/4.44/0 (dashed line) to observed solar spectra (solid line). Identefied lines are labeled, asterisks marked lines with changed gf.

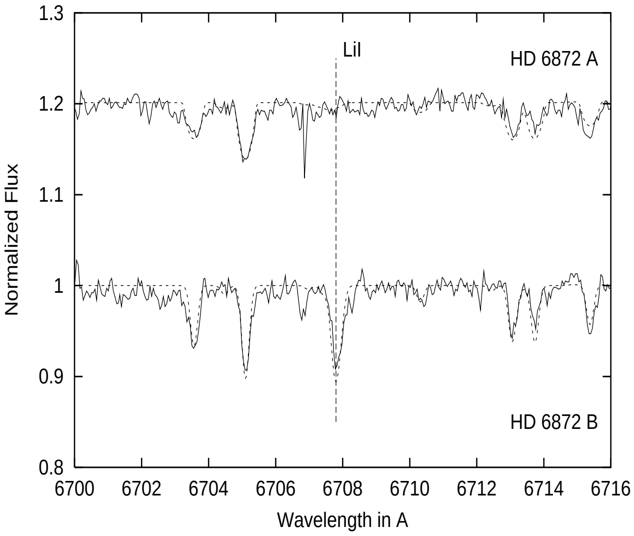

Figure 2: Solid lines: Lick Hamilton echelle spectra of HD 6872 A and B. Dashed lines: Synthetic spectra for T_{eff}=6250 K, [m/H]=-0.2, and log N(Li)=1.8 (above), and for T_{eff}=6250 K, [m/H]=-0.2, and log N(Li)=2.6 (below). Synthetical spectra is convolved with rotatin profile, vsini = 14km/s.

-0.2 for fitting the observed spectra. Chemical equilibrium was computed for the mix of ≈100 molecular species. Data for the computations were taken from Tsuji (1973). ATLAS9 (Kurucz, 1993) grid of continuum opacity sources are used in our computations. We used atomic line list and damping constants from VALD (Piskunov et.al., 1995). We had to change *log gf* for some elements to find good fits to the observed spectra. New *log gf* were taken from Gurtovenko & Kostyk(1989), all changes are listed in Table 2. The fit of synthetical spectrum (5770/4.44/0), for a model atmosphere computed with adjasted *log gf* of some elements, to solar spectrum is given in fig. 1.

Computations were carried out with step 0.02 Åfor microturbulent velocity V_t=2 km/s and Voigt profile for absorption lines.

Instrumental profile and macroturbulence broadening effects were modelled by convolution with a gaussian of half-width (~0.1 Å). For two stars rotational broadening was taken into account with vsin$i$=14 km/s. Abundances of five elements were found by Abel8 using the algorithm of minimization of differences between observed and computed spectra (Pavlenko,2002). For each LTE lithium abundances we determined NLTE abundance corrections using the LTE and NLTE grid of curves of growth of Pavlenko & Magazzu (1996).

4. Results.

In Table 1 we present the results for two pairs from the list of programm stars. Here we give the temperatures, metallicities that we used to get the best fits to the observed spectra and abundances of five elements: Si, Al, Ca, Fe, Li. We have found that abundances of Si, Al, Ca, Fe differ from solar ones not dramatically (< 0.1–0.2dex).

Next, we have found three binaries with large differences in the lithium abundances of their stars (see Martin, 2001). The pair HD 6872 A, B is shown in fig. 2. Ryan (2000) claimed that the difference in lithium abundance in 16 Cyg, mentioned above, can be explained by the normal mass-dependent lithium depletion mechanism in main-sequence stars, because the star with the lower abundance also has slightly lower mass.

Four other binaries have components with undistinguishable lithium abundances. We cannot say much about the remaining 7 binaries because we did not detect the lithium line in any of their stars, and hence we only have upper limits to their lithium abundances (Martin, 2001).

These results indicate that twin stars in binaries often do not share the same lithium abundances and that lithium depletion in solar-type stars does not only depend on age, mass and metallicity. And it is clear, that

Table 1: Characteristics and element abundances of program stars.

HD/BD	Sp.T.	T_{eff} (K)	[m/H]	log N(Li)	logN(Si)	logN(Al)	logN(Ca)	logN(Fe)
SUN:					7.51	6.43	6.32	7.63
HD 6872 A	F8	6250	-0.2	<1.8	7.5	6.05	6.24	7.4
HD 6872 B	F8	6250	-0.2	2.6	7.4	6.15	6.14	7.4
HD 224984	F8	6000	-0.1	2.3	7.5	6.25	6.24	7.5
HD 224994	G0	6000	-0.1	2.3	7.4	6.25	6.24	7.5

Table 2: List of identified lines and changes in *gf*'s.

Chemical element	λ, Å	*gf*, VALD	*gf*, Gurtovenko& Kostyk, 1989
Si	6696.044	1.479e-02	—
	6721.848	3.236e-02	7.079e-02
Ni	6690.770	5.620e-03	—
Al	6696.023	4.170e-02	2.630e-02
	6698.673	1.780e-02	1.259e-02
Ca	6717.681	2.535e-01	—
Fe	6696.320	2.138e-02	—
	6699.142	7.925e-03	—
	6704.481	2.188e-03	—
	6705.101	3.190e-02	6.400e-02
	6707.432	4.470e-03	—
	6713.046	3.090e-02	2.511e-02
	6713.195	2.754e-03	—
	6713.745	5.010e-02	2.951e-02
	6715.383	2.291e-02	—
	6716.237	1.202e-02	—
	6717.298	1.107e-02	—
	6724.082	3.013e-02	—

more observations are necessary to establish the fraction of binary twins that show similar lithium abundance anomalies and to establish the causes of these anomalies.

Acknowledgements. Yu.Lyubchik and Ya.Pavlenko are thankful to LOC of VS-2001 for partial financial support to paticipate in this conference.

References

Anders E., Grevesse N.: 1989, *Geochim. et Cosmoch. Acta,* **53**, 197.

Castelli F., Gratton R.G., Kurucz R.L.: 1997, *As.Ap.*, **318**, 841.

Galazutdiniv G.A.: 1992, *"Stellar echelle-spectra processing system. I.Image processing. II. Spectra processing.* **Prepr.92**, SAO RAN, Nizhnii Arhyz.

Gurtovenko E.A., Kostyk R.I.: 1989, *Fraungher spectrum and solar lines oscillator strengths.*, Naukova Dumka, Kyiv.

Halbwachs J.L.: 1986, *As.Ap.Suppl.*, **66**, 131.

King J.R., Deliyannis C.P., Hiltgen D.D., et al.: 1997, *Astron. J.*, **113**, 1871.

Kurucz R.L.: 1993, CD ROM No. 15.

Martin E., Basri G., Pavlenko Ya., Lyubchik Yu.: 2001, *Astron. J.*, in preparation.

Pavlenko Ya.V.: 2002, *Kinemat. and Physics of Celest. Bodies*, submitted.

Pavlenko Ya.V., Magazzù A.: 1996, *As.Ap.*, **311**, 961.

Piskunov N.E., Kupka F., Ryabchikova T.A. et.al.: 1995, *As.Ap.Suppl.*, **112**, 525.

Ryan S.G.: 2000, *Mon. Not. of Roy. Astron. Soc.*, **316**, L35.

Tsuji T.: 1973, *As.Ap.*, **23**, 411.