NonLTE ANALYSIS OF THE Na1 LINES IN THE SOLAR SPECTRUM

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ABSTRACT. Solar spectrum of Na1 lines by method of the nonLTE analysis is investigated. It shown, that in atmosphere of the Sun the Na1 is in moderate "overrecombination". The analysis of influence of atomic data, models of atmospheres and damping constants for nonLTE deviation and sodium abundances is made. Observational solar spectrum of strong lines Na1 has been synthesized in good approximation. On summary data of 15 lines the sodium abundance is determined:-5.78dex.

Key words: line: formation - line: profile - Sun: atmosphere

Use spectrographes of the superhigh resolution at observations of stellar spectra and powerful computers for their theoretical processing has made possible to begin mass determine nonLTE abundances with errors, smaller 0.1 dex. Such researches claim large accuracy for used model atoms and model atmospheres and definition of the base solar abundance. To the purposes of the decision these two problems this work is devoted.

In work the Solar Flux Atlas Kurucz et al, (1984) ($\lambda = 2900 - 13000\mathring{A}$, $\frac{signal}{noise} = 9000$, $\frac{\Delta\lambda}{\lambda} = \frac{1}{522000}$) was used. For selected 16 lines with application of a graphic package Origin 3.0 equivalent width W_λ were defined, the results of research are given in Table 1.

Table 1: The Na1 lines measured in Solar Flux Atlas.

$\lambda\mathring{A}$	W ($m\mathring{A}$)	$\lambda\mathring{A}$	W ($m\mathring{A}$)
5889	830	5895	640
8194	328	8183	254
5688	144	5682	121
6160	61.0	6154	38.1
4982	89.3	4497	35.9
5148	13.5	12679	142
10834	51.4	9961	21.1
10746	22.2	3302	159

For account nonLTE populations and lines a complex of the programs NONLTE3 (Sakhibullin, 1983) which is based on the linearization method proposed by Auer and Heasley with allowance for of all continuous sources of opacity, lines and molecules is used. In applied 21-levels model of atom Na1 [Mashonkina et al., 1993] ($n \leq 7, l \leq 3$), containing 46 transitions in detal and 54 fixed transitions, the energy of levels and ionization cross-sections were redefined according to data by Hofsaess (1979) and Yakovlev et al. (1990). The accounts are carried out for models of atmospheres: by Kurucz (1979, 1993), Holweger and Muller (1974) and Bell (1975) - at various significances of collisional cross-sections with hydrogen (with factor k = 0.0, 0.1, 1.0). At investigation of theoretical line profiles Doppler and Stark broadening, Van der Waals damping with C_6 constants by Unsold (1955), Deridder and Van Rensbergen (1976), radiative damping, microturbulence ($V_{turb} = 1.0, 1.2, 1.4 km/s$) and rotation velosities ($V \sin i = 1.0 - 2.5 km/s$) were taken into account. The sodium abundance is accepted according Anders and Grevesse (1989): [A] = -5.75

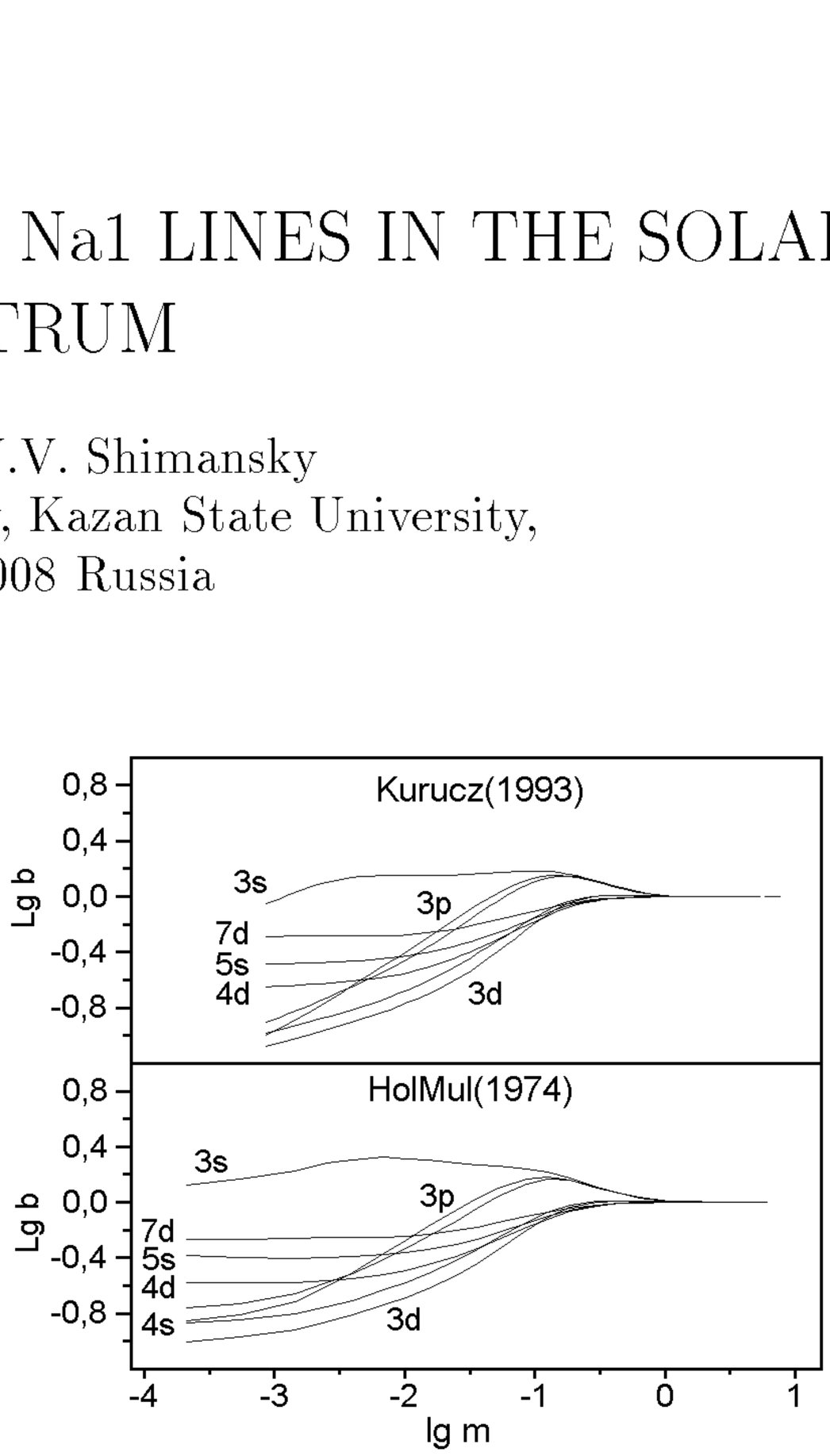

Figure 1. Departures from LTE for populations of Na1 levels in $b = n_{nonLTE}/n_{LTE}$.

At analysis of nonLTE-populations of Na1 levels moderate "overrecombination" for ground state $3s$ and level $3p$ is confirmed (Figure 1). "Overrecombination" is determined by small ionization cross-section and strong scattering in lines of resonance transition $3s - 3p$. The

"overrecombination" effects are maximum for models by Kurucz (1979) and by Bell and minimum for model by Kurucz (1993), and tend to strengthening and shifting in higher layers at increase of collisional processes.

The results of the LTE and nonLTE abundances definition on 15 lines (except $\lambda = 3302\AA$) are resulted in Table 2. Deviations from LTE are large for $\lambda = 8194$, 8183 Å (ΔX = -0.17 dex), essential for $\lambda = 5688$, 5682 Å (ΔX = -0.07 dex) and insignificant for other lines (ΔX < 0.05 dex). The minimum deviations for all lines are reached in model by Kurucz (1993), maximum ones - in models by Kurucz (1979) and by Bell and considerably decrease with growth of collisional processes at $k = 1.0$ Microturbulence velosity does not practically influence deviations from LTE.

Table 2: Solar sodium abundances and dispersions in dex.

Model	K	V_{turb}	nonLTE	LTE
		km/s	$\Delta X \pm \sigma$	$\Delta X \pm \sigma$
Kurucz n.	0.1	1.0	-0.012 0.045	0.032 0.048
		1.2	-0.020 0.046	0.024 0.045
		1.4	-0.028 0.049	0.017 0.041
	0.0	1.2	-0.017 0.047	
	1.0	1.2	-0.001 0.043	
Profiles	1.0	1.2	-0.034 0.023	
Deridder	1.0	1.2	-0.001 0.047	
Kurucz o.	0.1	1.0	-0.075 0.057	0.023 0.052
HolMul	0.1	1.0	0.047 0.046	0.105 0.059
Bell	0.1	1.0	-0.075 0.060	0.016 0.054

The heaviest abundances are received for model HolMul, the least ones - for models by Kurucz (1979). At V_{turb} increase of 0.2 km/s Δ X decreases on 0.008 dex. Dispersions of the abundances, received on 15 lines are minimum for models by Kurucz (1993) and HolMul, and poorly depends from V_{turb} and k.

For lines with $W_\lambda > 20m\AA$ synthesis of observable profiles was performed, the results for some lines are shown on Figure 2. The resonance spectral lines ($\lambda =$ 5889, 5895 Å) and subordinate ones $\lambda = 8194\AA$ have the good theoretical description. There is the difficulty in description of observable wings of more weak lines $\lambda = 8183, 6160, 6154, 4982, 5682\AA$. Such wings, increased with reduction of equivalent width of a line, are not described theoretically with change $V_{turb}k$, and damping constants. At research of lines profiles of md-nf transitions a necessity of C_6 constants by Unsold increase (with factor 5 for $\lambda = 12679$ and with factor 30 for $\lambda = 9961$) and efficiency of C_6 constants by Deridder is shown. Simultaneously the constants by Deridder are not suit for lines of ms-np transitions. The line

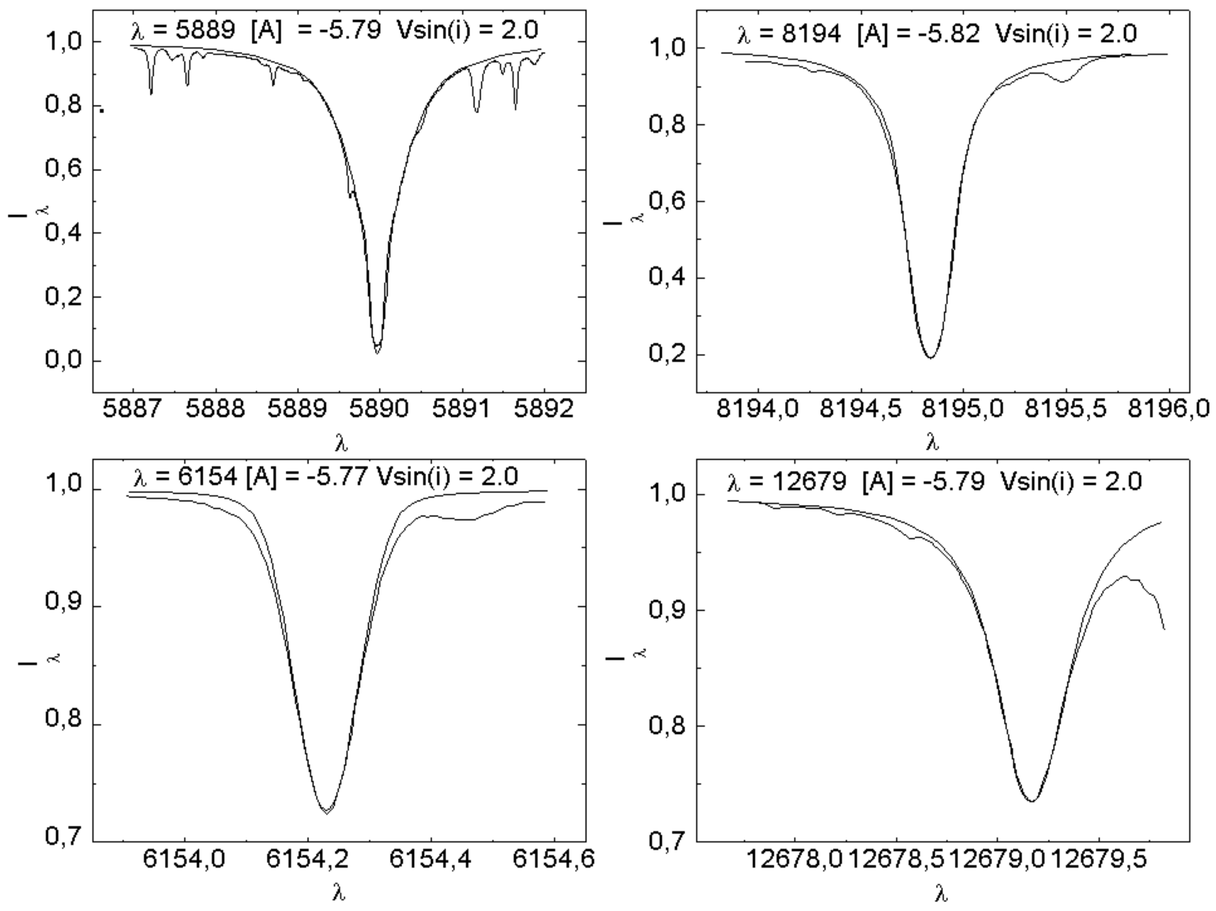

Figure 2. Profiles of some lines Na1.

$\lambda = 3302\AA$ does not yield to adequate theoretical synthesis.

At investigation of profiles and equivalent width of all lines the following best significances are received: $[A] = -5.779 \pm 0.023 dex, k = 1.0, V_{turb} = 1.0 km/s, V \sin i = 2.0 km/s$.

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