ABOUT PROBABILITY OF RESEARCH OF THE NN Ser SPECTRUM BY MODEL ATMOSPHERES METHOD

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ABSTRACT. The spectrum of close binary system NN Ser is investigated by a models atmospheres method. It is show that the atmosphere near the centrum of a hot spot on surface of red dwarf has powerful chromosphere, arising from heating in Laiman continua. Four models of binary system with various of parameters are constructed and their theoretical spectra are obtained. Temperature of white dwarf $T_{ef} = 62000\,$K, radius of the red dwarf $R_r = 0.20 R_\odot$ and angle inclination of system $i = 82^\circ$ are determined. The spectrum having the good coincidense with data of observation is received.

Key words: Line: formation - Stars: atmospheres

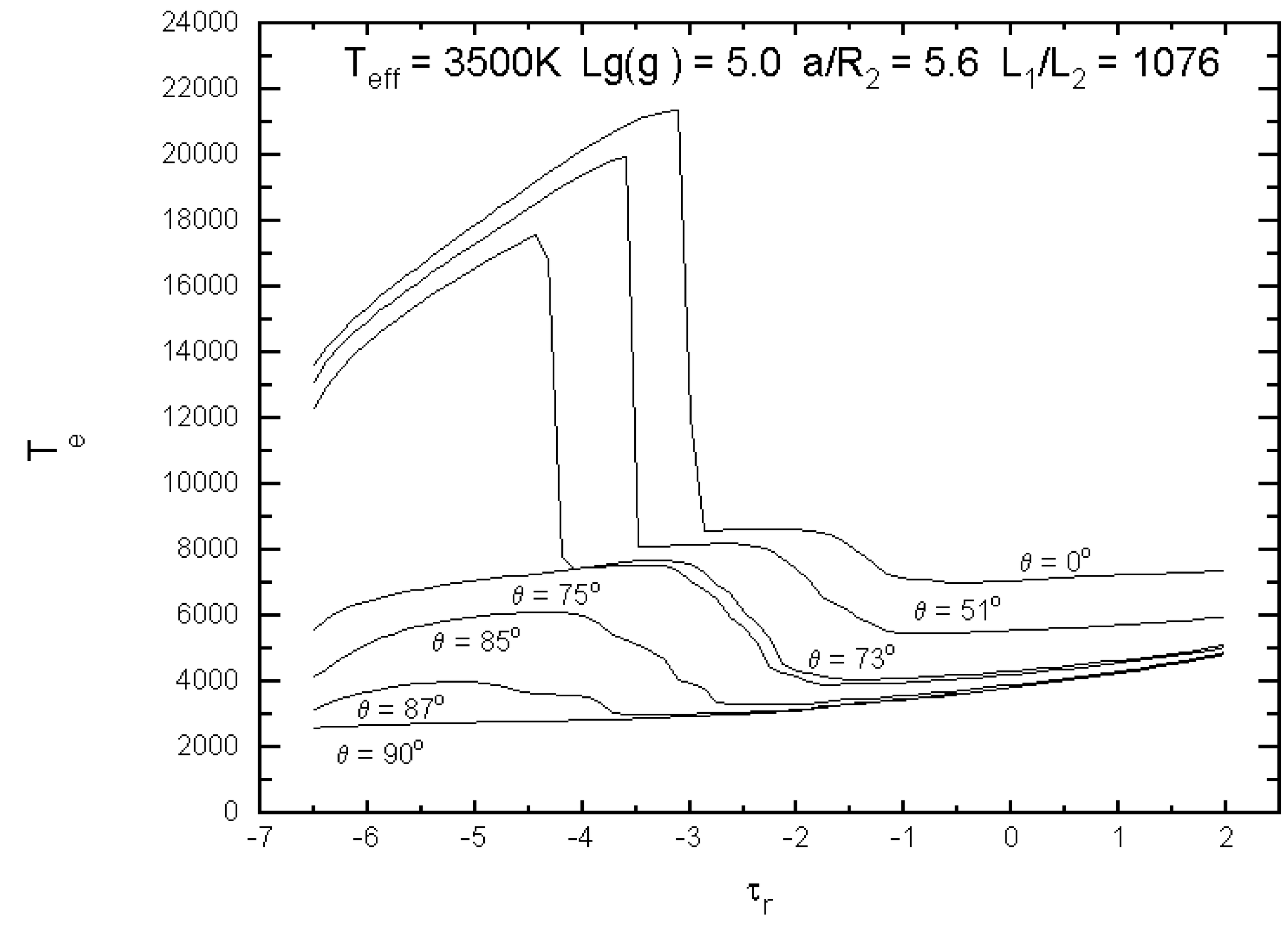

Figure 1. Distributions of temperature in model atmosphere for some angles Θ.

In the several previous work (Sakhibullin and Shimansky, 1996) we have developed a method for account of irradiated stellar atmospheres in half-grey approximation for quantitative description of close binary systems spectra. To test this method in our work we use close binary system, for which there are the high quality observations, several of main parameters were determined and complicating phenomenones (accretion disk and gas envelope) are absent.

We used the results of spectroscopic observations, published in work Catalan et al. (1994). Given observations were made on 4.2-m William Hershel Telescope for several phases and have the average resolution of 5A in studied range. The main accounts were performed by us for average on phases 0.25 - 0.80 spectrum with use of the following parameters, determined in the work Catalan et al. (1994): binary separation $a = 0.95 R_\odot$, red and white dwarfs masses $M_r = 0.12 M_\odot$, $M_w = 0.57 M_\odot$. For other parameters in work Catalan et al. (1994) the limits of changes are given only. We have attempted to obtain the best approximation of observable and theoretical spectra NN Ser and have changed the parameters in available limits. In Table 1 we give these parameters for four various models of the system.

The account of a complete spectrum of double system is made with the complex of the codes SPECTR with use the BINARY3 - code for blanketed model atmospheres and the BINARY2 - code for the inclusion of reflection effect. The technique of account of stellar spectrum with external irradiation was developed in previous work (Sakhibullin & Shimansky, 1996). Model atmospheres of white dwarfs with $T_{ef} = 55000\,$K, $60000\,$K, $62000\,$K and $\lg(g) = 7.75$ were obtained by code BINARY3 with blanketing effect in 1500 lines and their spectra were calculated by code BINARY2. We received a complete synthetic spectrum of all system with allowance for the radial velocities of the components, the inclination angle and spectral resolution of $5A$. By this way we have computed intensities for spectral lines at 36 phases of rotation in CBS. The oscillator strengths for lines under investigation were taken from different sources (Kurucz and Peytremann, 1975; Wiese et al., 1969; Radzig and Smirnov, 1985). Line profiles were computed with Doppler broadening, Stark effect, Van der Waals broadening included according to the data by Kurucz (1975) and Unsold (1955).

In Fig. 1 we represent the distributions of electronic temperature T_e versus depth τ_r for some rings with different inclination angle Θ of incident radiation. The atmosphere near to centrum of a hot spot has powerful chromosphere, arising from heating in Laiman continua. On greater depth secondary chromospheres will be formed from heating in continua of the Ca 2, C 1, Si 1 and Fe 1. In peripheral areas of a spot the external radiation is not enough for heating atmosphere down to zone of temperature instability $T_e = 8000 - 14000$ K and "hydrogen" chromosphere will not be formed.

Obtained by us theoretical fluxes in continua for four

Table 1: Red and white dwarfs parameters for four models NN Ser, theoretical and observable fluxes: F^1 - average on phases 0.25 - 0.80, F^2 near to phase 0.00

Model	**I**	**II**	**III**	**IV**	
$T_w(K)$	55000	60000	62000	62000	
$R_w(R_\odot)$	0.019	0.019	0.019	0.019	
$T_r(K)$	3500	3500	3500	3500	
$R_r(R_\odot)$	0.20	0.20	0.17	0.20	
$\lambda(A)$	$\frac{F^1_{the}}{F^2_{the}}$	$\frac{F^1_{the}}{F^2_{the}}$	$\frac{F^1_{the}}{F^2_{the}}$	$\frac{F^1_{the}}{F^2_{the}}$	$\frac{F^1_{obs}}{F^2_{obs}}$
5500	$\frac{1.54}{1.04}$	$\frac{1.72}{1.06}$	$\frac{1.47}{1.02}$	$\frac{1.64}{1.04}$	$\frac{1.65}{1.06}$
5200	$\frac{1.62}{1.16}$	$\frac{1.77}{1.14}$	$\frac{1.55}{1.12}$	$\frac{1.71}{1.13}$	$\frac{1.72}{1.16}$
5000	$\frac{1.65}{1.19}$	$\frac{1.80}{1.19}$	$\frac{1.61}{1.19}$	$\frac{1.76}{1.19}$	$\frac{1.75}{1.19}$
4800	$\frac{1.70}{1.26}$	$\frac{1.84}{1.26}$	$\frac{1.66}{1.26}$	$\frac{1.80}{1.26}$	$\frac{1.78}{1.26}$
4700	$\frac{1.73}{1.32}$	$\frac{1.87}{1.32}$	$\frac{1.69}{1.31}$	$\frac{1.82}{1.32}$	$\frac{1.80}{1.32}$
4600	$\frac{1.77}{1.37}$	$\frac{1.92}{1.37}$	$\frac{1.74}{1.37}$	$\frac{1.86}{1.37}$	$\frac{1.85}{1.37}$
4200	$\frac{1.94}{1.61}$	$\frac{2.07}{1.61}$	$\frac{1.93}{1.61}$	$\frac{2.04}{1.62}$	$\frac{2.12}{1.64}$
4050	$\frac{2.01}{1.70}$	$\frac{2.13}{1.70}$	$\frac{2.01}{1.71}$	$\frac{2.11}{1.70}$	$\frac{2.17}{1.70}$
3700	$\frac{2.44}{1.93}$	$\frac{2.60}{1.93}$	$\frac{2.39}{1.95}$	$\frac{2.54}{1.94}$	$\frac{2.52}{1.92}$
3640	$\frac{2.38}{1.97}$	$\frac{2.53}{1.98}$	$\frac{2.37}{2.01}$	$\frac{2.48}{2.00}$	$\frac{2.60}{2.00}$

models and observable ones are submitted in table 1 for several frequencies. Results show, that the best exists at increase of red dwarf radius over established limit in $0.18R_\odot$ up to $0.20R_\odot$. White dwarf temperature is defined correctly only on observations of a hot spot. We assume, that true white dwarf temperature is about $T_{ef} = 62000K$. The inclination angle of system equal to 82° can be appreciated from red dwarf radius.

On Figure 2 the final spectra are given for the model **IV**. The best coincidense with observable spectrum is present for lines H_β, H_γ and H_δ and for lines of Paschen series of the hydrogen. Theoretical intensities of the line H_α and the lines after H_δ are less than observable ones. The He 1 emmision theoretical lines also are a little bit more weak than observable ones, that it shows on probable "overionization" for He 1. Absorption part of lines have the good theoretical description, except for the wings of the line H_γ. The existence " overrecombination" in irradiated atmospheres was shown early (Sakhibullin & Shimansky, 1995) for "cool" lines of a type Ca 2. Therefore the accounts with allowance for of departures from LTE are especially important for line Ca 2 λ3933Å. As a whole we ascertain the good consent with observations as for continua and for lines.

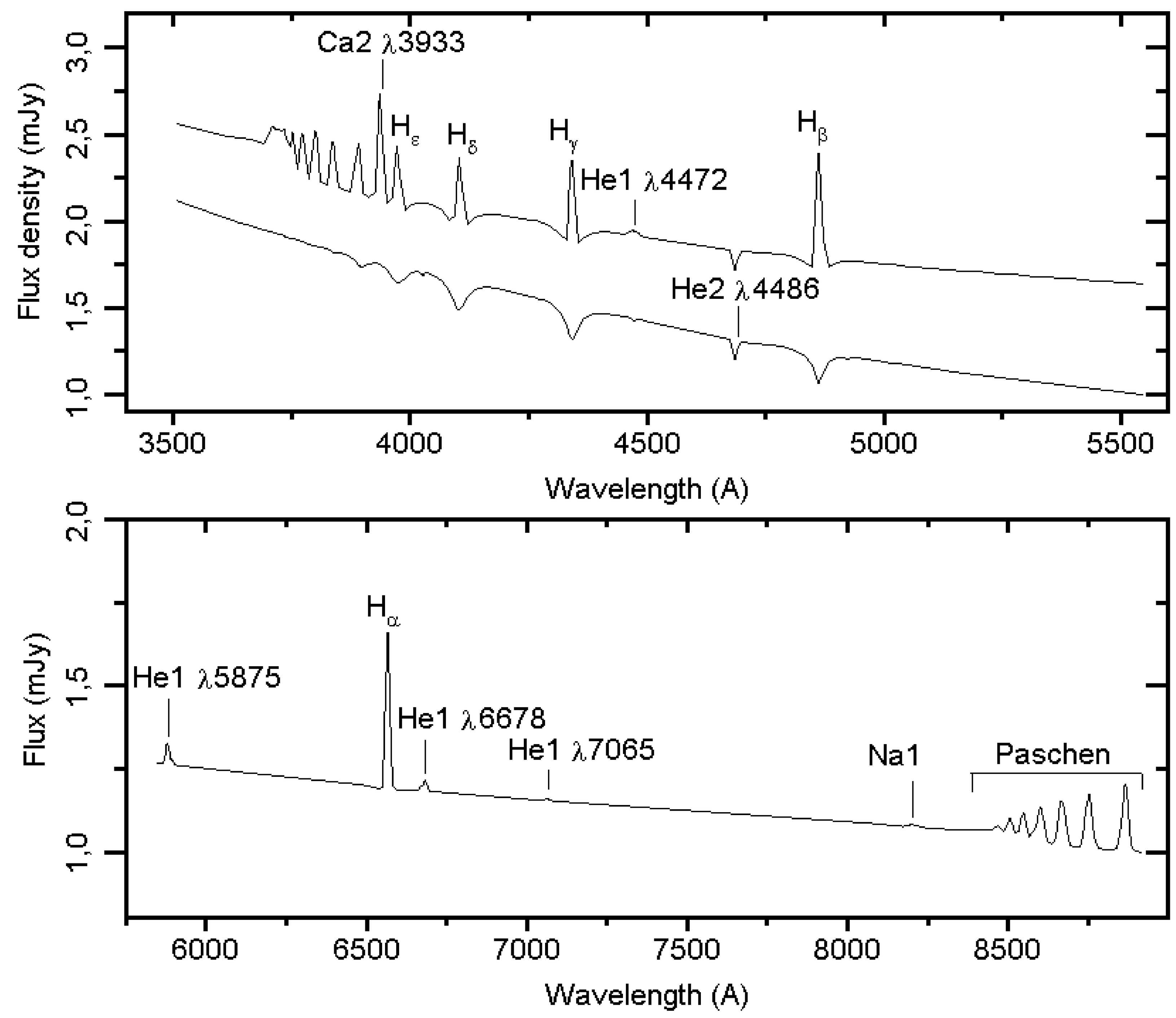

Figure 2. An average spectrum NN Ser for phases 0.25 - 0.75 and spectrum near to phase 0.00 for parameters of system $a = 0.95$, $i = 82°$, $T_w = 62000\,\mathrm{K}$, $T_r = 3500\,\mathrm{K}$, $R_w = 0.019$, $R_r = 0.20$.

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