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ASTRONOMY AND ASTROPHYSICS

Nitrogen abundance in early B-stars

I. NLTE calculations for γ Pegasi

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Abstract. Based on Kurucz (1992) grid of models the NLTE calculations of nitrogen abundance in γ Peg atmosphere revealed a slight deficiency of this element comparably to solar value ($[N/H] \approx -0.3$). Together with the recent result on carbon abundance in this star atmosphere ($[C/H] = -0.25$; Korotin et al., 1998), the present determination shows that turbulent diffusion in massive main sequence stars (discussed by Maeder, 1987) and connected with it the appearance of the CN-processed material at the stellar surface can hardly be operating in γ Peg.

The list of N II lines that can be used for LTE calculation of nitrogen abundance in hot stars is also presented.

Key words: stars: abundances – stars: early-type – stars: individual: γ Peg

1. Introduction

In our previous work devoted to NLTE analysis of the carbon lines in the spectrum of hot B star γ Peg we have shown that this element is slightly deficient in the atmosphere of program star: $[C/H] = -0.25$. Such a deficiency could be a sign of some dynamical processes involving the upper atmosphere layers and leading to an accumulation in the superficial region of the main sequence star the CN-processed material. In particular, Maeder (1987) discussed a turbulent diffusion induced, for example, by the stellar rotation as such a mechanism.

If the turbulent diffusion is really responsible for observational carbon deficiency, then it is absolutely clear that we should detect the corresponding nitrogen overabundance. This scenario resembles that described by Iben (1966a,b,c) for yellow supergiants. Accordingly to standard evolutionary scenario, an atmospheric carbon abundance for such stars must be slightly reduced after the star passed the red supergiant phase, where so-called first dredge-up occurs, while nitrogen becomes overabundant. In particular, the observations of Cepheids confirm the theory predictions (Luck & Lambert, 1985; Luck & Bond, 1989; Andrievsky et al., 1996, Andrievsky & Kovtyukh, 1996; Kovtyukh et al., 1996).

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It is quite plausible that rapidly rotating B stars of the main sequence can possess some kind of the large-scale mixing that causes the superficial CN anomalies similar to those observed in Cepheids.

In order to check this supposition, we have undertaken an attempt to carry out a detailed NLTE calculations of nitrogen abundance in the main-sequence B star γ Peg (B2 IV). This star possesses the well expressed sharp lines in its spectrum indicating small $v\ sin\ i$ value. It makes this rather bright star a very attractive object for investigation of the NLTE effects in the hot stellar atmospheres.

2. Spectroscopic observations

CCD spectrum of γ Peg has been obtained with an echelle spectrometer GECS on 1-m telescope (Special Astrophysical Observatory of the Russian Academy of Sciences, Russia, Northern Caucasus). The detailed description of the spectrometer is given by Musaev (1993). The resolving power was 24000, S/N ≈ 250. The spectrum consists of 97 spectral orders having total useable length 5000 Å (from 3500 Å to 8500 Å). Observed spectrum has been reduced using DECH20 code (Galazutdinov, 1992). This code includes: (1) spectra extraction from the images, (2) dark and cosmic hits subtraction, (3) flat-field correction, (4) wavelength calibration, (5) equivalent widths measurement, etc.

The internal accuracy of the equivalent widths is of the order of 5%. This estimate is based on the comparison of values derived from the lines present in two overlapping spectral orders. Measured equivalent widths of selected N II lines are presented in Table 1.

3. NLTE calculations

Simultaneous solution of the radiative transfer and statistical equilibrium equations has been realized using MULTI-code (Carlsson, 1986) in the approximation of complete frequency redistribution for all the lines. Taking into account that this code was initially exploited for rather cool stars, it was modified with the aim to apply it for early-type stars' analysis. In particular, we have added the opacity sources from ATLAS9 program (Kurucz, 1992). It enabled us to calculate more precisely a continuum opacity. At the same time, a possibility to take into account

Table 1. Equivalent widths of selected nitrogen lines

λ	I	g_i	J	g_j	f	W obs	W $calc$	W/W^*
3955.85	7	3	15	5	0.055	26.5	25.7	1.16
3994.99	8	3	15	5	0.566	88.0	89.9	1.25
4227.74	15	5	24	3	0.162	19.0	17.4	1.00
4447.03	10	3	18	5	0.579	48.0	47.6	1.20
4601.48	7	3	14	5	0.135	43.0	39.7	1.22
4607.16	7	1	14	3	0.331	36.0	34.9	1.21
4613.87	7	3	14	3	0.081	31.5	28.7	1.19
4621.39	7	3	14	1	0.110	36.0	35.6	1.21
4630.54	7	5	14	5	0.246	74.5	74.2	1.28
4643.09	7	5	14	3	0.081	43.0	41.6	1.21
4788.13	11	5	19	5	0.081	16.0	14.5	1.16
4803.29	11	7	19	7	0.103	26.0	23.2	1.18
4994.36	13	3	20	3	0.297	21.5	21.4	1.15
5005.15	11	7	17	9	0.556	59.0	57.8	1.22
5010.62	7	3	13	3	0.081	28.0	28.3	1.21
5025.66	11	7	17	7	0.048	10.5	11.5	1.11
5045.10	7	5	13	3	0.081	40.0	42.8	1.21
5666.63	7	3	11	5	0.304	53.0	54.3	1.31
5676.02	7	1	11	3	0.407	36.0	33.1	1.26
5679.56	7	5	11	7	0.339	78.0	76.1	1.36
5686.21	7	3	11	3	0.103	27.6	27.5	1.24
5710.76	7	5	11	5	0.061	29.5	28.2	1.23
6482.05	8	3	10	3	0.192	37.0	33.3	1.26

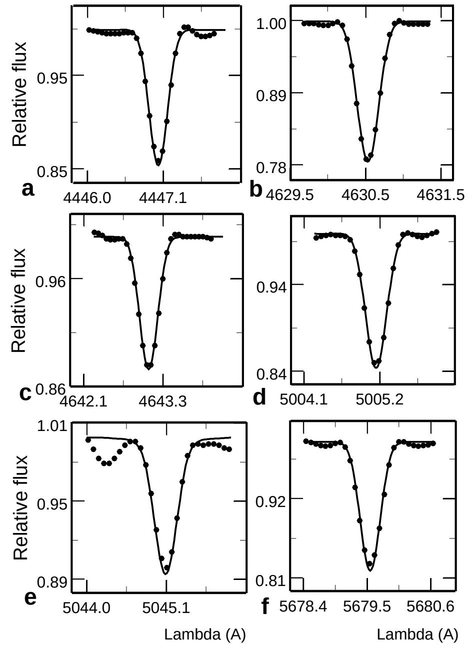

Fig. 1a–f. Calculated (NLTE) and observed in γ Peg spectrum profiles of selected N II lines. Synthetic spectrum – solid line, observed – dots.

an absorption in the great number of spectral lines (especially within the region of the near-UV) allowed to calculate much accurately an intensity distribution in the region 900–1500 Å, that plays a key role in the determination of the radiative rates of $b-f$ transitions. In addition, we changed a code to have a possibility to calculate the combined profile of the blending lines taking into account the star rotation and instrumental profile.

Atmosphere model was selected from the grid calculated with the help of ALTLAS9 (Kurucz, 1992). From the spectrum of program star we have selected N II lines that are formed due to transitions between different levels and situated in the different spectral regions (Table 1).

Such a choice gives a guarantee that an accordance between calculated line profiles and observed ones results from the sufficiently complete description of the nitrogen atom model.

3.1. Parameters of the nitrogen atom

We employed the model of nitrogen atom consisting of 109 levels: 3 ground levels of N I, 93 levels of N II with $L \leq 4$ and $n \leq 6$. A detailed structure of the multiplets was ignored and each LS multiplet was considered as a single term. Next ionization stage includes 12 levels and ground state of N IV. A list of energy levels is given in Table 2. They were selected from compilative catalogue by Hirata & Horaguchi (1995).

Within the described system of the nitrogen atom levels we considered the radiative transitions between the first 43 levels of N II, 5 N III levels and ground level of N IV. Only transitions having $\lambda < 100000$ Å were selected for the analysis. Transitions between the rest levels were not taken into account and they were used only in the equations of particle number conservation. After the numerous test calculations, 92 $b-b$ transitions were included in the linearization procedure. These transitions quite satisfactory describe a formation of the lines of interest. The other transitions were treated as those having fixed radiative rates.

Photoionization cross-sections were mainly taken from the Opacity Project (Yan et al., 1987) keeping a detailed structure of their frequency dependence, including resonances. For some important $b-f$ transitions, the cross-section structure is extremely complicated that makes it difficult to describe it using only simple approximation like $\sim \nu^{-3}$. Other photoionization cross-sections were estimated with the help of quantum defect method.

Oscillator strengths were selected from the extensive compilative catalogue by Hirata & Horaguchi (1995), from survey of the lines which are formed as transitions from the ground level by Verner et al., (1994) and from 23 CD-ROM by Kurucz (1994). Some information was obtained through the Opacity Project. As we ignored a multiple structure of all the levels, the oscillator strengths for each averaged transition were calculated as $f = \frac{\sum g_i f_i}{\sum g_i}$. Results are gathered in Table 3 and Table 4.

After the combined solution of radiative transfer and statistical equilibrium equations, the averaged levels have been splitted with respect to multiplet structure, then level populations were redistributed proportionally to the statistical weights of the corresponding sublevels and finally the lines of the interest were studied.

Table 2. Energy levels included in nitrogen atom model

n	E, cm^{-1}	G	$Configuration$	n	$E, cm{-}1$	G	$Configuration$	n	$E, cm{-}1$	G	$Configuration$
1	0.00	9	$2p^2\ ^3P\ NII$	37	211103.43	7	$4d\ ^1F^0$	73	224491.00	15	$6p\ ^3D$
2	15316.19	5	$2p^2\ ^1D$	38	211300.00	27	$4f\ ^3G$	74	224653.00	3	$6p\ ^3S$
3	32513.84	1	$2p^2\ ^1S$	39	211335.93	3	$4d\ ^1P^0$	75	225158.00	5	$6p\ ^1D$
4	92245.00	15	$2p^3\ ^3D^0$	40	211401.83	9	$4f\ ^1G$	76	225599.00	1	$6p\ ^1S$
5	109216.40	9	$2p^3\ ^3P^0$	41	211410.00	15	$4f\ ^3D$	77	226299.00	21	$6d\ ^3F^0$
6	144187.74	5	$2p^3\ ^1D^0$	42	211490.10	5	$4f\ ^1D$	78	226365.00	5	$6d\ ^1D^0$
7	148940.00	9	$3s\ ^3P^0$	43	211800.00	9	$3s^{'}\ ^3P$	79	226399.00	15	$6d\ ^3D^0$
8	149187.60	3	$3s\ ^1P^0$	44	213669.22	9	$5s\ ^3P^0$	80	226703.00	7	$6f\ ^1F$
9	155126.56	3	$2p^3\ ^3S^0$	45	214174.22	3	$5s\ ^1P^0$	81	226707.00	21	$6f\ ^3F$
10	164610.56	3	$3p\ ^1P$	46	216202.40	3	$5p\ ^1P$	82	226734.00	7	$6d\ ^1F^0$
11	166600.00	15	$3p\ ^3D$	47	216497.99	15	$5p\ ^3D$	83	226768.00	27	$6f\ ^3G$
12	166765.46	3	$2p^3\ ^1P^0$	48	217606.00	3	$5p\ ^3S$	84	226782.00	9	$6f\ ^1G$
13	168892.01	3	$3p\ ^3S$	49	218351.00	9	$5p\ ^3P$	85	226784.00	9	$6g\ ^1G^0$
14	170607.00	9	$3p\ ^3P$	50	218540.00	5	$5p\ ^1D$	86	226784.00	27	$6g\ ^3G^0$
15	174211.83	5	$3p\ ^1D$	51	219314.00	1	$5p\ ^1S$	87	226793.00	27	$6h\ ^3G$
16	178273.18	1	$3p\ ^1S$	52	219514.34	9	$2p^2(^2D)2p\ ^3P^0$	88	226794.00	9	$6h\ ^1G$
17	186570.00	21	$3d\ ^3F^0$	53	219744.30	21	$5d\ ^3F^0$	89	226794.00	21	$6g\ ^3F^0$
18	187091.17	5	$3d\ ^1D^0$	54	219825.33	5	$5d\ ^1D^0$	90	226797.00	7	$6g\ ^1F^0$
19	187460.00	15	$3d\ ^3D^0$	55	220015.31	15	$5d\ ^3D^0$	91	226801.00	5	$6f\ ^1D$
20	188900.00	9	$3d\ ^3P^0$	56	220237.08	9	$5p\ ^3P^0$	92	228536.00	3	$7p\ ^1P$
21	189334.96	7	$3d\ ^1F^0$	57	220383.13	7	$5f\ ^1F$	93	228648.91	15	$3P\ ^3D^0$
22	190120.04	3	$3d\ ^1P^0$	58	220396.67	21	$5f\ ^3F$				$NIII$
23	196600.00	9	$4s\ ^3P^0$	59	220469.93	7	$5d\ ^1F^0$	94	238750.00	6	$2p\ ^2P^0$
24	197858.49	3	$4s\ ^1P^0$	60	220492.05	9	$5g\ ^1G^0$	95	295912.00	12	$2p^2\ ^4P$
25	202170.43	3	$4p\ ^1P$	61	220494.84	27	$5g\ ^3G^0$	96	339780.00	10	$2p^2\ ^2D$
26	202766.00	15	$4p\ ^3D$	62	220574.29	3	$5d\ ^1P^0$	97	369754.00	2	$2p^2\ ^2S$
27	203188.00	9	$4p\ ^3P$	63	220586.83	27	$5f\ ^3G$	98	384735.00	6	$2p^2\ ^2P$
28	203537.46	3	$4p\ ^3S$	64	220633.45	15	$5f\ ^3D$	99	425547.00	4	$2p^3\ ^4S^0$
29	205349.98	5	$4p\ ^1D$	65	220639.06	9	$5f\ ^1G$	100	441830.00	10	$2p^3\ ^2D^0$
30	206910.04	1	$4p\ ^1S$	66	220670.68	7	$5g\ ^1F^0$	101	460052.00	2	$3s\ ^2S$
31	209700.00	21	$4d\ ^3F^0$	67	220670.87	21	$5g\ ^3F^0$	102	469155.00	6	$2p^3\ ^2P^0$
32	209925.56	5	$4d\ ^1D^0$	68	220682.31	5	$5f\ ^1D$	103	484420.00	6	$3p\ ^2P^0$
33	210265.00	15	$4d\ ^3D^0$	69	220712.00	9	$2p^4\ 3P$	104	505990.00	20	$3d\ ^2D$
34	210750.00	9	$4d\ ^3P^0$	70	222392.34	3	$3p'\ ^3S^0$	105	526350.00	10	$3s'\ ^4P^0$
35	211029.87	7	$4f\ ^1F$	71	223256.00	3	$6s\ ^1P^0$				NIV
36	211050.00	21	$4f\ ^3F$	72	224365.00	3	$6p\ ^1P$	106	621454.00	1	$2s^2\ ^1S$

A certain problem is linked with a correct accounting of the line broadening due to a quadratic Stark effect. Some estimates of the broadening constants were taken from Kuruczs CD-ROM 23. For the rest transitions we used a classic expression for radiative broadening constant and Stark broadening constant was adopted to be equal to 10^{-6}.

Together with the broadening constants, we have also taken into account the microturbulence parameter. It is important to note that all the broadening mechanisms were included in both the statistical equilibrium and line formation calculations.

Table 3. Linearized transitions

I	J	λ	f	I	J	λ	f	I	J	λ	f	I	J	λ	f
1	2	6527.23	2.81E-06	2	18	582.15	1.48E-01	7	14	4614.02	3.28E-01	14	23	3846.09	2.06E-01
1	4	1084.07	1.02E-01	2	19	580.91	3.66E-02	7	15	3955.85	1.85E-02	15	21	6610.56	5.77E-01
1	5	915.61	1.45E-01	2	21	574.65	2.58E-01	7	26	1857.83	2.38E-02	15	24	4227.73	1.63E-01
1	7	671.41	7.69E-02	2	22	572.07	3.03E-04	7	27	1843.38	6.08E-03	16	22	8438.72	7.08E-01
1	8	670.29	3.21E-03	2	23	551.62	2.64E-04	8	10	6482.04	1.92E-01	17	26	6172.65	1.27E-01
1	9	644.63	2.20E-01	2	24	547.81	5.38E-03	8	11	5741.43	5.44E-02	17	36	4083.81	6.96E-01
1	12	599.64	6.62E-04	2	31	514.44	1.40E-03	8	14	4667.35	2.76E-02	17	38	4042.53	7.89E-01
1	17	535.99	1.13E-03	2	32	513.85	4.91E-02	8	15	3994.99	5.66E-01	17	40	4025.95	9.69E-02
1	18	534.49	2.61E-02	2	33	512.95	1.40E-03	8	16	3437.14	1.27E-01	18	35	4176.15	7.96E-01
1	19	533.44	3.00E-01	2	34	511.68	4.00E-04	8	25	1887.40	2.47E-02	18	36	4172.65	3.94E-01
1	20	529.38	1.03E-01	2	37	510.75	1.03E-01	8	30	1732.42	3.04E-03	19	35	4241.50	1.09E-01
1	21	528.16	2.00E-04	2	39	510.15	1.03E-03	9	43	1764.49	6.01E-02	19	36	4237.89	8.35E-01
1	22	525.98	2.04E-04	3	4	1674.16	1.00E-05	10	18	4447.02	5.79E-01	19	38	4193.44	1.11E-01
1	23	508.64	1.12E-02	3	8	857.09	1.55E-02	10	22	3919.00	1.52E-01	19	41	4174.18	1.01E-01
1	33	475.59	1.19E-01	3	12	744.87	2.51E-01	10	24	3006.83	1.30E-01	20	41	4441.22	9.46E-01
1	34	474.49	4.30E-02	3	22	634.49	4.17E-01	11	17	5006.11	6.06E-01	20	42	4425.47	1.59E-01
2	4	1299.90	9.02E-06	3	24	604.79	6.17E-02	11	19	4792.52	1.17E-01	21	38	4551.41	2.38E-01
2	5	1064.96	2.63E-05	3	39	559.21	1.59E-01	11	20	4483.04	1.96E-02	21	40	4530.41	9.01E-01
2	6	775.96	3.17E-01	5	43	974.81	2.86E-02	11	23	3332.37	1.19E-01	22	41	4695.73	4.20E-01
2	7	748.37	1.00E-02	6	43	1479.02	3.03E-06	11	31	2319.47	2.20E-02	22	42	4678.13	9.84E-01
2	8	746.98	1.95E-01	7	10	6379.63	1.35E-02	13	20	4996.61	8.88E-01	44	47	763.33	8.12E-02
2	9	715.25	4.00E-04	7	11	5660.94	4.06E-01	14	19	5932.01	4.93E-01	44	48	685.00	4.01E-01
2	12	660.28	1.55E-01	7	13	5010.62	8.16E-02	14	20	5465.05	1.34E-01	44	46	989.80	1.22E-01

Collisional ionization was described using Seaton's formula (Seaton, 1962):

$$C_{ik} = 1.55 \cdot 10^{13} \frac{\alpha(\nu_0)\overline{g} N_e e^{-u_0}}{\sqrt{T_e} u_0},$$

were $\alpha(\nu_0)$ – threshold value of the cross-section, $u_0 = \frac{E_0}{kT_e}$, E_0 – energy of ionization, N_e and T_e-electron concentration and temperature respectively. For Gaunt factor we adopted value of 0.3. For all allowed $b-b$ transitions we used van Regemorter (1962) formula:

$$C_{ij} = 5.465 \cdot 10^{-11} N_e \sqrt{T_e} \cdot 14.5 f_{ij} \left(\frac{I_H}{E_0}\right)^2 u_0 e^{-u_0} \times \max\left[\overline{g}; 0.276 e^{u_0} E_1(u_0)\right],$$

where I_H – hydrogen ionization potential, $E_1(u_0)$ – first-order integral exponential function. Collisional rates for the forbidden transitions were calculated with the help of semiempirical formula (Allen, 1973):

$$C_{ij} = 8.63 \cdot 10^{-6} \frac{N_e e^{-u_0}}{g_i \sqrt{T_e}},$$

with collisional force of 1.

4. Results of calculations

In Table 1 we give the equivalent widths W of selected N II lines calculated in the NLTE approximation, as well as W^* – values found under LTE approach. Measured equivalent widths in γ Peg spectrum are also given in Table 1.

Calculations were performed for temperature and gravity that are close to γ Peg atmosphere parameters: $T_{eff} = 22600K$ and $\log g = 4.0$, (Gies & Lambert [1992] give the following parameters: $T_{eff} = 22670K$ and $\log g = 4.02$), with microturbulent velocity $V_t = 2\,km\,s^{-1}$. Adopted absolute nitrogen abundance was $\log A(N) = 7.65$. Calculated line profiles were convolved using $v\ sin\ i\ = 9\ km\ s^{-1}$ (Slettebak et al. (1975) give $v\ sin\ i$ for $\gamma\ Peg < 10\ km\ s^{-1}$). A comparison of the calculated and observed profiles is given in Fig. 1a–f. From this figure and from Table 1 one can conclude that calculated profiles and equivalent widths of N II lines agree very well with the observational data.

5. Discussion, conclusion and future plans

A grid of equivalent widths for 23 N II lines in the region 3950 Å–6500 Å was calculated in both NLTE and LTE approaches. Calculations were performed for the temperature spanning the interval from 16000 K to 31000 K.

Let us briefly discuss the results of these calculations. Note, that similar study of the behaviour with a temperature of the nitrogen lines was carried out by BB (Becker & Butler, 1989). They investigated trends in the equivalent width as a function of T_{eff}, microturbulent velocity and initial nitrogen abundance. Atmosphere models, used for analysis, were those of Gold (1984). Some of the investigated lines showed a strong NLTE effects, while for line 4432.66 Å the difference between LTE and NLTE predictions was negligible.

We decided to undertake the similar study of the line equivalent width behaviour with a temperature, but based on Kurucz

Table 4. Fixed transitions

I	J	λ	f	I	J	λ	f	I	J	λ	f	I	J	λ	f
1	24	505.41	8.88E-05	13	33	2417.03	4.54E-04	19	25	6797.89	8.31E-04	25	32	12894.70	8.77E-01
1	31	476.87	6.65E-04	13	34	2389.03	8.10E-03	19	26	6533.38	3.45E-02	25	33	12353.96	1.56E-02
1	32	476.35	9.95E-04	14	17	6264.48	4.66E-03	19	27	6358.08	9.45E-02	25	34	11655.60	7.75E-03
1	37	473.70	2.00E-04	14	18	6066.42	2.56E-04	19	28	6219.88	2.66E-03	25	39	10910.48	2.30E-01
1	39	473.18	1.17E-04	14	21	5339.60	1.89E-05	19	29	5589.71	5.63E-05	26	31	14421.67	9.33E-01
2	17	583.92	2.04E-04	14	22	5124.77	2.33E-04	19	30	5141.37	2.84E-06	26	32	13967.33	2.17E-01
2	20	576.09	2.05E-04	14	24	3669.52	1.01E-04	19	40	4176.79	3.26E-03	26	33	13335.10	1.77E-01
3	7	858.91	5.01E-03	14	31	2558.00	1.19E-05	19	42	4161.44	1.55E-02	26	34	12525.04	2.10E-02
3	9	815.57	1.74E-03	14	33	2521.55	3.60E-02	20	25	7535.54	4.18E-04	26	37	11994.08	1.19E-03
3	19	645.38	7.94E-04	14	34	2491.09	9.20E-03	20	26	7211.88	3.14E-02	26	39	11668.70	3.28E-03
3	20	639.44	9.12E-04	14	37	2469.35	1.50E-05	20	27	6998.87	2.78E-02	27	31	15356.26	7.17E-03
3	23	609.43	3.09E-04	14	39	2455.25	4.00E-06	20	28	6831.78	1.08E-01	27	32	14842.17	3.37E-03
3	33	562.58	1.00E-03	15	17	8091.81	3.11E-03	20	29	6079.03	1.61E-04	27	33	14130.28	7.34E-01
3	34	561.05	2.19E-05	15	18	7764.37	8.15E-02	20	30	5552.45	2.17E-05	27	34	13224.01	1.92E-01
4	43	836.43	8.74E-02	15	19	7548.21	2.22E-04	20	35	4518.77	7.51E-03	27	37	12633.54	2.17E-02
7	16	3409.10	4.32E-03	15	20	6808.20	6.32E-04	20	36	4514.67	1.84E-03	27	39	12273.05	1.54E-03
7	28	1831.58	2.58E-03	15	22	6286.06	2.76E-02	20	38	4464.28	1.34E-04	28	31	16227.06	7.46E-04
8	13	5075.00	1.75E-02	15	23	4466.64	2.29E-04	21	26	7445.43	2.29E-05	28	32	15654.10	1.83E-04
8	29	1780.55	3.41E-04	15	31	2817.84	1.62E-02	21	27	7218.62	1.64E-05	28	33	14864.27	1.09E-01
10	17	4553.84	3.65E-03	15	32	2800.04	1.82E-02	21	29	6244.13	1.22E-01	28	34	13864.73	1.31E00
10	19	4376.47	4.97E-03	15	33	2773.68	1.20E-05	21	35	4609.37	8.03E-02	28	39	12823.01	7.46E-04
10	20	4117.01	5.15E-04	15	34	2736.86	1.12E-05	21	36	4605.10	5.33E-02	29	32	21855.14	1.26E-01
10	23	3126.03	2.60E-03	15	37	2710.64	4.00E-02	21	41	4530.00	3.67E-03	29	33	20345.78	1.05E-03
10	31	2217.81	4.10E-03	15	39	2693.66	2.89E-04	21	42	4513.62	2.11E-03	29	34	18518.44	6.39E-04
10	32	2206.77	8.57E-03	16	19	10885.17	5.13E-04	22	25	8298.48	2.47E-02	29	37	17380.83	8.93E-01
10	33	2190.36	1.46E-05	16	20	9410.15	1.12E-03	22	26	7907.66	4.82E-03	29	39	16705.76	3.72E-02
10	34	2167.34	5.41E-06	16	23	5456.48	4.07E-04	22	27	7652.30	1.74E-03	30	33	29806.57	1.51E-04
10	39	2140.16	1.00E-06	16	24	5105.87	1.02E-01	22	28	7453.00	5.93E-04	30	39	22594.28	1.07E00
11	18	4880.15	2.52E-03	16	39	3024.55	9.12E-02	22	29	6566.01	4.60E-03	31	35	75195.16	2.03E-03
11	21	4398.51	5.23E-05	17	25	6410.07	4.55E-05	22	30	5955.92	8.77E-02	31	36	74074.38	2.54E-02
11	22	4251.69	7.83E-04	17	27	6017.57	8.37E-06	22	36	4777.84	1.39E-02	31	38	62500.21	1.64E-01
11	24	3199.13	3.08E-04	17	28	5893.63	4.05E-06	23	25	17951.94	1.14E-02	31	40	58760.65	2.05E-02
11	32	2308.10	4.14E-03	17	29	5324.82	2.69E-04	23	26	16217.99	6.41E-01	31	41	58479.94	2.81E-04
11	33	2290.16	1.66E-03	17	35	4088.32	2.22E-02	23	27	15179.12	3.94E-01	31	42	55863.09	2.40E-03
11	34	2265.00	1.32E-05	17	41	4025.76	2.02E-02	23	28	14414.51	1.17E-01	32	35	90553.69	1.05E-01
11	37	2247.01	5.17E-06	17	42	4012.82	1.47E-03	23	29	11428.61	5.97E-05	32	36	88933.23	2.84E-02
11	39	2235.34	1.39E-06	18	25	6631.62	1.10E-01	23	30	9699.29	4.53E-05	32	38	72756.95	1.18E-01
12	43	2220.51	5.97E-05	18	26	6379.65	1.77E-03	24	25	23191.35	3.26E-01	32	41	67365.81	9.45E-04
13	17	5656.75	1.71E-04	18	27	6212.40	2.13E-04	24	26	20376.91	2.15E-02	32	42	63916.74	1.95E-02
13	18	5494.76	8.18E-05	18	28	6080.39	3.90E-05	24	27	18763.41	9.18E-03	33	38	96618.51	2.16E-03
13	19	5385.61	2.62E-02	18	29	5476.80	2.14E-02	24	28	17608.81	1.21E-03	33	41	87336.88	1.40E-02
13	22	4710.75	2.25E-03	18	38	4130.72	7.60E-03	24	29	13348.47	7.81E-01	33	42	81626.36	2.95E-03
13	23	3609.06	7.50E-02	18	41	4112.04	6.34E-02	24	30	11047.83	1.36E-01				
13	24	3452.26	5.66E-04	18	42	4098.54	9.57E-02	25	31	13280.97	8.18E-01				

(1992) grid of models. To have the possibility to compare our results with those of BB, we used the same initial parameters ($V_t = 5\,km\,s^{-1}, \log g = 4.0, \log A(N) = 7.95$) as above mentioned authors did. Note that adopted for this step of the analysis V_t value ($5\,km\,s^{-1}$) differs from that used for γ Peg, but it can be considered as a more typical for B stars value.

Our results generally agree with those of BB (see Figs. 2a–4a and Table 5 for selected lines. Some dependence of the equivalent width upon the nitrogen abundance for $T_{eff} = 22600K$, $\log g = 4.0$ and $V_t = 5\,km\,s^{-1}$ are also shown on Figs. 2b–4b). Nevertheless, there are some important supplements, which should be mentioned.

Firstly, at low temperatures the differences between LTE and NLTE equivalent widths are smaller than at higher temperatures. Secondly, the maximal discrepancy between equivalent widths calculated in LTE and NLTE approach slightly greater than derived by BB. And finally, maximum of the calculated equivalent width for all investigated N II lines is slightly shifted towards the lower temperatures comparably to BB maximum. The difference in temperature achieves 2000–2500 K. To our

Table 5. Equivalent widths of selected nitrogen lines calculated with $V_t = 5\,km\,s^{-1}$, $\log g = 4.0$ and $\log A(N) = 7.95$.

λ	W	W/W^*	W	W/W^*	W	W/W^*	W	W/W^*	W	W/W^*	W	W/W^*	W	W/W^*	W	W/W^*
$T_{eff} in 10^3$	16	16	18	18	20	20	22	22	24	24	26	26	28	28	30	30
3955.85	8.3	1.10	17.6	1.12	29.9	1.14	37.4	1.14	46.4	1.14	39.3	1.13	27.6	1.19	17.0	1.27
3994.99	36.7	1.15	64.8	1.18	98.0	1.22	107.8	1.25	147.8	1.28	139.6	1.26	113.3	1.22	79.3	1.14
4227.74	3.6	0.97	9.4	1.00	18.5	1.02	26.9	1.04	34.4	1.01	31.0	0.98	22.9	0.98	13.9	0.91
4447.03	11.0	1.10	25.3	1.14	46.4	1.17	60.5	1.20	86.4	1.22	83.3	1.21	67.6	1.20	48.3	1.20
4601.48	9.4	1.14	21.6	1.17	39.9	1.20	52.5	1.21	72.1	1.20	65.0	1.18	48.1	1.18	30.8	1.20
4607.16	8.1	1.14	18.9	1.16	35.3	1.19	47.1	1.20	64.1	1.19	57.2	1.17	41.6	1.17	26.1	1.19
4613.87	6.4	1.13	15.4	1.15	29.3	1.17	40.0	1.18	53.5	1.17	46.9	1.15	33.2	1.15	20.4	1.18
4621.39	8.3	1.13	19.3	1.16	36.0	1.18	47.9	1.19	65.2	1.18	58.1	1.16	42.4	1.16	26.7	1.19
4630.54	21.7	1.17	44.4	1.20	75.1	1.24	89.5	1.27	126.3	1.27	119.6	1.25	97.4	1.23	70.6	1.23
4643.09	10.2	1.13	23.0	1.16	42.1	1.18	54.8	1.20	75.2	1.19	67.9	1.17	50.5	1.17	32.6	1.19
4788.13	2.1	1.07	6.1	1.10	13.6	1.13	21.6	1.15	29.8	1.16	27.4	1.15	20.4	1.19	13.6	1.25
4803.29	3.6	1.08	10.1	1.11	21.5	1.14	32.7	1.17	46.4	1.18	43.5	1.17	33.6	1.19	23.0	1.25
4994.36	2.9	1.07	8.5	1.10	19.0	1.13	30.1	1.15	43.4	1.14	40.9	1.12	31.4	1.12	21.3	1.14
5005.15	11.2	1.13	27.2	1.16	52.7	1.19	70.2	1.22	104.3	1.21	103.0	1.20	88.1	1.18	68.9	1.20
5010.62	4.9	1.12	13.1	1.15	27.5	1.19	41.7	1.20	54.6	1.20	47.6	1.18	33.4	1.18	20.6	1.23
5025.66	1.5	1.07	4.6	1.09	10.6	1.10	17.4	1.11	24.0	1.09	21.8	1.07	16.1	1.09	10.6	1.14
5045.10	8.1	1.12	20.7	1.15	41.5	1.19	60.1	1.21	79.3	1.21	70.7	1.19	51.8	1.18	33.3	1.22
5666.63	9.0	1.19	23.4	1.24	48.3	1.29	68.1	1.31	100.6	1.28	94.6	1.24	72.4	1.17	47.0	1.10
5676.02	4.6	1.17	13.1	1.20	28.9	1.24	44.2	1.25	64.5	1.21	58.7	1.17	42.1	1.12	25.3	1.06
5679.56	14.7	1.20	35.8	1.26	69.6	1.32	91.7	1.36	135.5	1.33	129.5	1.29	103.7	1.22	71.9	1.14
5686.21	3.7	1.16	10.7	1.19	24.0	1.22	37.7	1.23	54.6	1.19	49.0	1.15	34.4	1.10	20.2	1.05
5710.76	3.9	1.15	11.0	1.18	24.7	1.21	38.7	1.22	56.0	1.18	50.3	1.15	35.4	1.10	20.9	1.05
6482.05	3.2	1.10	10.4	1.16	26.0	1.23	45.9	1.32	73.1	1.31	67.8	1.24	44.3	1.04	19.2	0.69

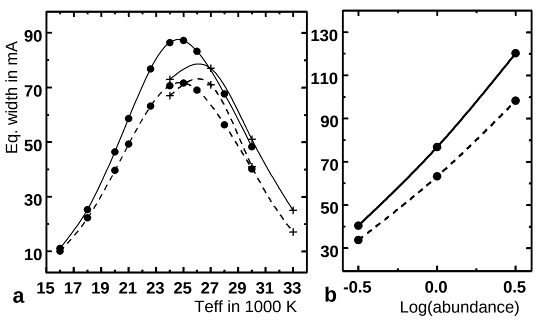

Fig. 2a and b. Equivalent width of 4447.03 Å line versus T_{eff} **a** and $\log A(N)$ **b** for NLTE (solid line) and LTE (dashed line) approach. Our data – filled circles, Becker & Butler (1989) – crosses.

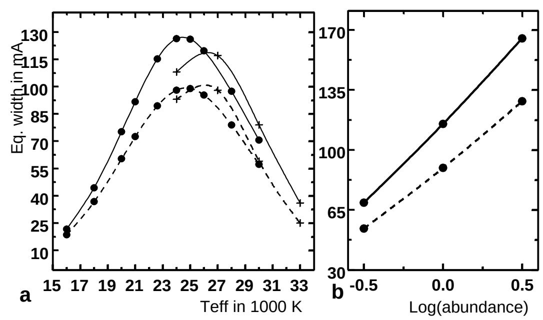

Fig. 4a and b. Equivalent width of 4630.54 Å line versus T_{eff} **a** and $\log A(N)$ **b**. Parameters and symbols are the same as for Fig. 2.

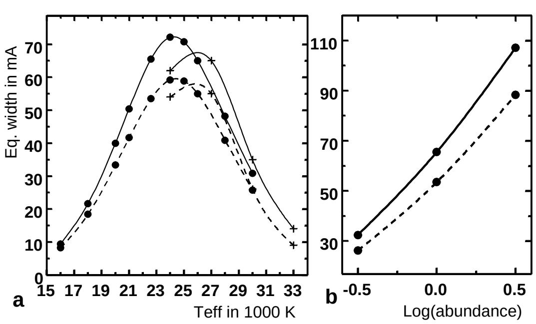

Fig. 3a and b. Equivalent width of 4601.48 Å line versus T_{eff} **a** and $\log A(N)$ **b**. Parameters and symbols are the same as for Fig. 2.

mind, such a discrepancy is caused by the different grids of the atmosphere models used in the analyses. BB used Gold's (1984) grid, while we employed Kurucz (1992) models.

Similar conclusion was recently made by Cunha & Lambert (1994) in their work on chemical evolution of Orion association. In that extremely interesting study of 18 main sequence B stars authors used for determination of the elemental abundances (of the nitrogen, in particular) LTE calculations based on the use of Gold's (1984) and Kurucz's (1979) grids of models. Simultaneously, they took into account the NLTE corrections for investigated lines using the grid of NLTE equivalent widths calculated by BB. Those calculation, as it was already mentioned, were based on the Gold's (1984) grid too. Then, having inspected LTE equivalent widths calculated with both Gold's and Kurucz's grids, the authors made a conclusion that LTE equivalent width of a given line reaches the maximum at higher effective temperatures for lightly blanketed Gold's models and $\approx$ at 3000 K lower temperatures for heavily blanketed models of Kurucz's grid.

After the statement that more heavily blanketed models would be more realistic, Cunha & Lambert (1994) performed a preliminary assessment of NLTE abundances that would result from use of Kurucz's models, assuming that 1) NLTE effects are identical for two considered grids of models and 2) the difference between LTE abundances derived using these grids of the models should produce the same difference between corresponding NLTE abundances. As a result of such supposition, they indirectly obtained the mean value of NLTE nitrogen abundance for sample of 18 early B stars: $log\ A(N)$=7.65 $\pm$ 0.09. The nitrogen abundance determined by us for γ Peg is in excellent agreement with that inferred by Cunha & Lambert (1994) for their sample of the stars.

Our precise NLTE calculation of carbon (Korotin et al., 1998) and nitrogen (present work) abundances in γ Peg show that these elements are both deficient in the atmosphere of this star $log\ A(C)$=8.30 and $log\ A(N)$=7.65, when compared with solar values. It implies that CN-cycled material is not present in the superficial layers of program star. Probably the turbulent diffusion, proposed by Maeder (1987), as a mechanism responsible for CN anomalies in the main sequence stars) is not operating in γ Peg, provided its rotation is slow.

In the next papers we plan to present the results on slowly rotating main sequence B stars and stars with high $v\ sin\ i$ values. We hope that such detailed study can help to understand whether the turbulent diffusion induced by rapid rotation is operating in some main sequence stars and what is the real magnitude of CN anomalies caused by the turbulent diffusion.

Finally note, that Table 1 provides several nitrogen lines with deviation between LTE and NLTE calculated equivalent widths less than 20%. Such lines can be used in LTE analysis of the nitrogen abundance in the hot main sequence B stars.

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