LAWS IN BEHAVIOUR OF NonLTE EFFECTS FOR THE NaI AND MgI ATOMS FOR K - A STARS.

L.I. Mashonkina, N.N. Shimanskaya, V.V. Shimansky
Department of Astronomy, Kazan State University,
Kazan, 8, 420008 Russia

ABSTRACT. NonLTE calculations for the NaI and MgI atoms were performed for model atmospheres of T_{ef} = 4000 - 12000K, $\log g$ = 0.0 - 4.5, [M/H] = 0.5 - (-4). Departures from LTE result in strengthening the NaI spectral lines and weakening the MgI ones. For 8 NaI spectral lines and 9 MgI ones used usually in abundances determinations nonLTE abundance corrections were found. They are very individual for each spectral line and for specific parameters of stellar atmosphere. Even for the weakest spectral lines they are not small: they can reach to (-0.15dex) for the NaI $\lambda\lambda615.4, 616.0$nm and 0.17dex for the MgI $\lambda457.1$nm, $\lambda571.1$nm. The errors in abundances will be particularly large in the case of metal deficiency stars because the strong spectral lines are used in abundances determinations: for the NaI resonance lines nonLTE abundance corrections reach to $(-0.8$dex) and for the $\lambda\lambda517.2, 518.3$nm they consist of 0.3dex. We conclude that nonLTE analysis is necessary in each case of sodium or magnesium abundance determination.

Key words: line: formation - Stars: atmospheres - Stars: abundances.

Sodium and magnesium are important elements in consideration of the problems of chemical abundances evolutionary changes in stellar atmospheres and chemical evolution of our Galaxy. For decision of these problems numerous determinations of the sodium and magnesium abundances for various spectral types stars, belonging various Galaxy populations and being at various evolutionary stages are carried out. In majority of cases these determinations are executed within the framework of LTE assumption. The purposes of the present work are the study of the NaI and MgI lines formation for stars in wide range of parameters: T_{ef} = 4000 - 12000K, $\log g$ = 0.0 - 4.5, [M/H] = 0.5 - (-4) on the basis of statistical equilibrium analysis of these atoms and maintenance of a good theoretical basis for any work on sodium and magnesium abundances determination.

A nonLTE method for these atoms, developed by us early (Mashonkina et al. 1993, 1996) is advanced. In the NaI model atom (21 levels) thin splitting of the 3p level is taken into account. More exact photoionization cross sections (Hofsaess, 1979; Yakovlev et al., 1990) are used. In opacity calculations the contribution of numerous spectral lines and molecular absorption with data, kindly given by Pavlenko Ya., were taken into account by the direct method. The calculations were performed with model atmospheres by Kurucz (1994) at V_{turb} = 1.5 km/s.

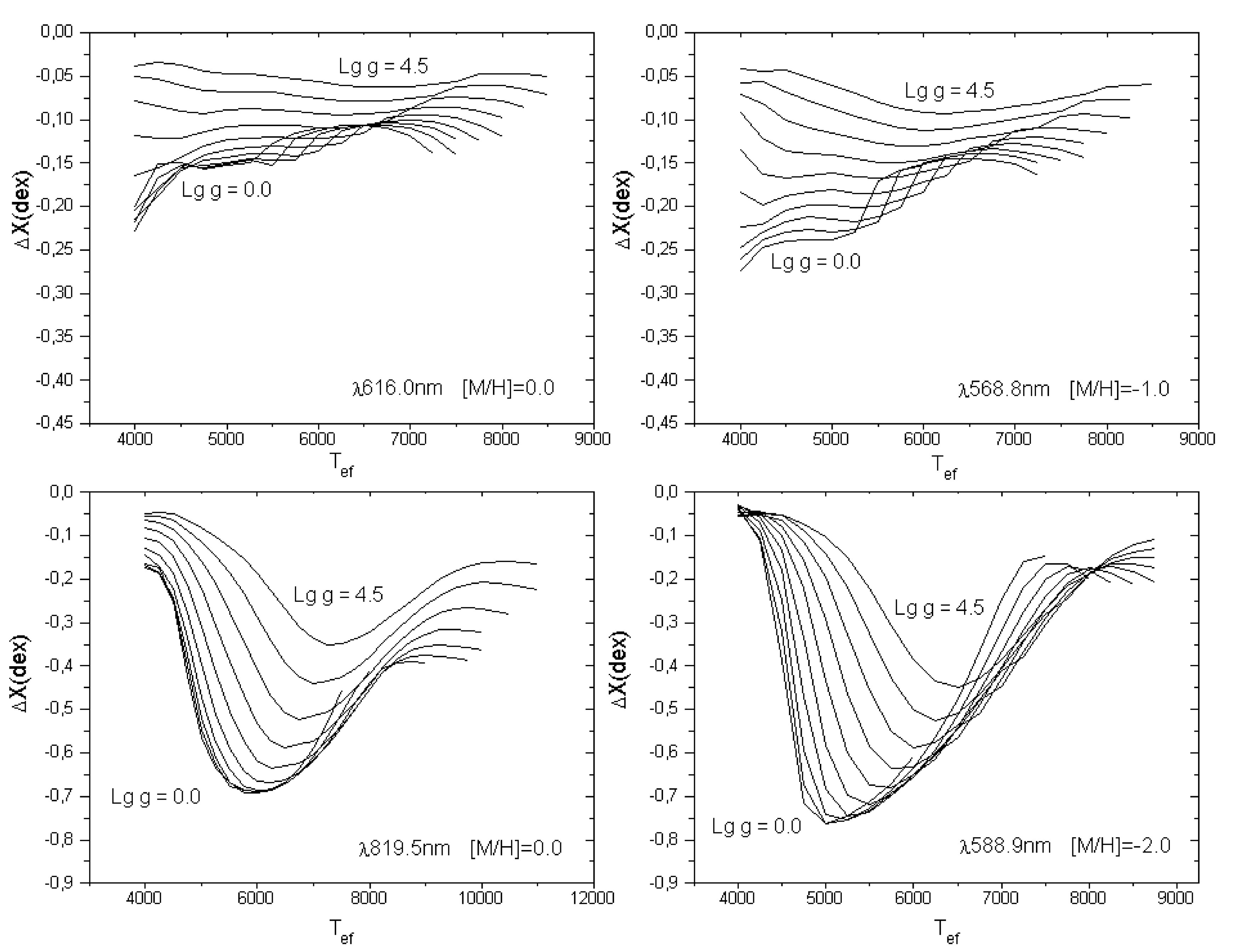

Figure 1. NonLTE abundance corrections ΔX versus T_{ef} at various $\log g$ for some NaI spectral lines.

For the NaI "overrecombination" effect, found out early by us (Mashonkina et al., 1993) and other authors for solar type stars, exists in whole range of parameters, and it intensifies with T_{ef} increasing and with $\log g$ decreasing. It results in amplification of the NaI spectral lines and reduction of the abundances determined on them. For the MgI there is the opposite effect of "overionization" in atmospheres of stars with $T_{ef} > 5500K$, where the MgI stage of ionization does not dominate. Alongside with it an influence of radiative b-b transitions on the populations of bottom levels, between which investigated lines are formed, is great. As it was shown by Mashonkina et al. (1996), their W_λ can be as more, and less of the LTE - magnitudes.

We have obtained nonLTE abundance corrections

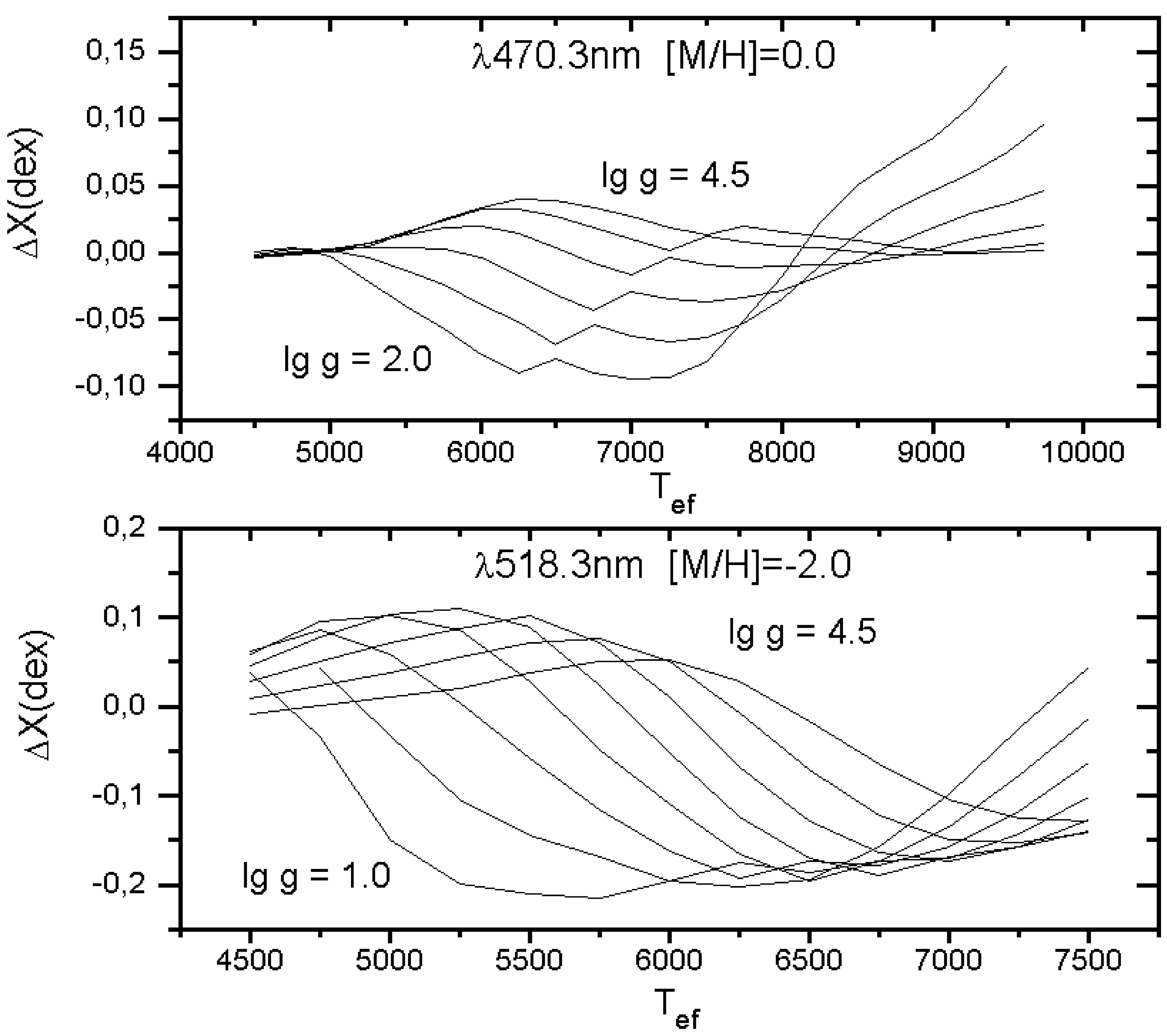

Figure 2. NonLTE abundance corrections ΔX versus T_{ef} at various $\log g$ for some MgI spectral lines.

ΔX as logarithmic displacements of nonLTE and LTE curves of growth at W_λ, calculated by LTE method with normal for given model atmosphere abundance. The part of results in kind of dependences ΔX - T_{ef} is presented on fig. 1, 2.

At analysis of sodium abundances the preference is usually given back the NaI doublets $\lambda\lambda 615.4, 616.0$nm and $\lambda\lambda 568.2, 568.8$nm. The calculations show, that only for the first of them deviations from LTE are small in whole range of parameters: (-ΔX) $\leq$ 0.08dex for main sequence (MS) stars and $\leq$0.15dex for supergiants. For $\lambda\lambda 568.2, 568.8$nm (-$\Delta X$) are small for MS stars (<0.11dex), but can reach to 0.32dex for supergiants.

The NaI resonance lines $\lambda\lambda 588.9, 589.5$nm are used in abundance determinations basically for stars with metals deficiency. Despite significant weakening of lines in this case, the deviations from LTE appear rather large, as for stars with normal metallisity. (fig. 1). Even for MS stars nonLTE abundance corrections can reach to 0.5dex at T_{ef} = 6000 - 6500K.

Due to progress in infrared detectors there was the possibility to use at abundance analysis the NaI doublet $\lambda\lambda 818.3, 819.5$nm, which can be measured up to T_{ef} = 10000K. But it is necessary to mean, that for stars with [M/H] $\geq$ -1 the deviations from LTE for these lines are the same, as for resonance lines. For stars with more essential heavy elements deficiency they are less, but in whole range of parameters $(-\Delta X) \geq 0.1$dex.

For all the MgI spectral lines the absolute magnitudes of nonLTE abundance corrections do not exceed 0.25dex in whole range of investigated stellar parameters. For the λ457.1nm, λ571.1nm ΔX are positive and do not exceed 0.17dex. For the λ470.3nm, λ552.8nm $\Delta X < 0.04 dex$ for MS stars. For stellar atmospheres with $\log g$ $\leq$3.0 there is the strong dependence of nonLTE abundance corrections from T_{ef} (fig. 2b) and they can have a different sign for stars with T_{ef}, distinguishing in limits 1000K.

For metal deficiency stars the $\lambda\lambda 517.2, 518.3$nm and $\lambda\lambda 382.9, 383.2, 383.8$nm are used at magnesium abundance determinations. If deviations from LTE are not taken into consideration the dispersion of abundances for them can reach to 0.3dex.

So, both for the NaI and for the MgI the nonLTE abundance corrections are very individual for each spectral line and for specific parameters of stellar atmosphere, and without realization of nonLTE calculations even the sign of these corrections cannot be predicted beforehand.

Astrophysicists interested in the results of nonLTE calculations for the NaI and MgI for the specific stars may address by e-mail to Mashonkina L.I. (Lyudmila.Mashonkina@ksu.ru) or Shimansky V.V. (Slava.Shimansky@ksu.ru).

Acknowledgements. The authors are very gratefull to Russian fund of fundamental researches (grant 96-02-16306-a) for partial financial support of this research.

References

Mashonkina L.I., Sakhibullin N.A., Shimansky V.V.: 1993, *Astron. Rep.*, **37**, 192.

Mashonkina L.I., Shimanskaya N.N., Sakhibullin N.A.: 1996, *Astron. Rep.*, **40**, 187.

Hofsaess D.: 1979, *Atomic Data and Nuclear Data Tables*, **24**, 285

Yakovlev D.G., Band I.M., Trzhaskovskaya M.B., Verner D.A.: 1990, *Astron. Aph.*, **237**, 267.

Kurucz R.L.: 1994, *CD-Roms N18.*