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On the EUV line diagnostics from N III solar ion*

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Abstract. We present new calculations for N III ion for diagnostics of solar plasma. The atomic model comprising the first 15 energy levels is considered for evaluating the line emissivities as a function of electron density and temperature, taking account of various physical processes. EUV line ratios, hitherto unexplored for diagnostic study, from this ion are presented as a function of electron density at its temperature of peak ionic concentration and their diagnostic applications in the solar atmosphere are discussed.

Key words : line diagnostics - EUV emission lines - optically thin plasmas

1. Introduction

Emission lines from the solar and astrophysical plasmas have been the subject of extensive study since the advent of the space research (cf. Dwivedi 1995, Dwivedi and Mohan 1996). N III is a boron-like ion with its maximum fractional ionic concentration at 8.0 x 10^4 K using the ionization equilibrium calculation of Arnaud and Rothenflug (1985). The lines from this ion has been observed in the planetary and gaseous nebulae, e.g., Harrington *et al.* (1982) and the solar atmosphere (Vernazza and Reeves 1978; Nussbaumer and Storey 1979) and have long been recognised as important density and temperature diagnostics in the UV and EUV range (Nussbaumer and Storey 1979, 1982; Keenan *et al.*, 1994). In this paper, we present the new calculations for N III ion and discuss the emission line ratios as a potential candidate for density determination in different solar structures of the chromosphere-corona transition region and the lower corona.

In the following section, line emissivities and the atomic data used are discussed. The results and discussion are presented in section 3. The last section concludes this paper.

* In honour of Prof. P.K. Raju, Indian Institute of Astrophysics, Bangalore, on the completion of his 60 years.

2. Line emissivity and atomic data

The line emissivity per unit volume, per unit time, from optically thin plasmas is given by

$$\in (\lambda_{ij}) = \frac{1}{4\pi} N_j A_{ji} \frac{hc}{\lambda_{ij}} \text{ ergs cm}^{-3} \text{ s}^{-1} \text{ sr}^{-1} \quad (1)$$

where A_{ji} is the spontaneous transition probability and Nj is the number density of the upper level j which can be parametrised as

$$N_j (X^{+P}) = \frac{N_j (X^{+P})}{N (X^{+P})} \frac{N (X^{+P})}{N (X)} \frac{N (X)}{N (H)} \frac{N (H)}{N_e} N_e$$

Here, X^{+P} is the pth ionisation stage of the element X; $N (X^{+P}) / N (X)$ the ionisation ratio of the ion X^{+P} relative to the total number density of the element; N (X) / N (H) is the abundance of the element X relative to the hydrogen, which may or may not be constant in the solar atmosphere; $N (H) / N_e$ is the hydrogen abundance which is usually assumed to be 0.8 for a fully ionised plasma, and $N_j (X^{+P}) / N (X^{+P})$ is the population of level j relative to the total number density of the ion X^{+P} and is determined by solving the statistical equilibrium equations for each energy level in the atomic model adopted. The line emissivity ratio of the two lines emitted from the same ion can, therefore, be expressed as

$$R = \frac{\in (\lambda_{ij})}{\in (\lambda_{kl})} = \frac{A_{ji}}{A_{lk}} \frac{\lambda_{kl}}{\lambda_{ij}} \frac{N_j (X^{+P})}{N_l (X^{+P})} \quad (2)$$

The schematic energy level atomic model comprising the first 15 levels of the N III ion is shown in Figure 1. The ground configuration consists of a $2s^2\ 2p\ ^2p^0$ term. The higher configuration includes $2s\ 2p^2$ and $2p^3$ states. The collisional processes are shown by solid lines and the radiative processes by broken lines. The atomic data needed to compute the line emissivities are the following: (i) wavelengths, (ii) radiative transition probabilities and (iii) collision strengths. The transition probabilities and the wavelengths for the spectral lines of N III ion have been taken from Stafford, Hibbert and Bell (1993). The collision strengths have been taken from Stafford, Bell and Hibbert (1994). We have also taken account of proton excitation rates for transitions $2s^2\ 2p\ ^2p^0_{1/2\text{-}3/2}$; $2s\ 2p^2\ ^4p_{1/2\text{-}3/2,\ 5/2}$, $^4p_{3/2\text{-}5/2}$ and for $^2p^0 - {}^4p$ transitions (cf. Figure 1). The photo excitation for the transition $2s^2\ 2p\ ^2p^0_{1/2\text{-}3/2}$ has also been considered. The proton excitation rates have been taken from the calculation of Nussbaumer and Storey (1979). The photo excitation value is obtained from the expression (De Boer *et al.* (1972)):

$$R_{ij} = \frac{g_j}{g_i} A_{ji} \left(e^{h\nu_{ij} / KT_r} - 1\right)^{-1} d, \quad (3)$$

where g_j and g_i are the statistical weights of the levels j and i respectively. A_{ji} is the spontaneous transition probability, d is the dilution factor and is assumed to be 0.5 for the sake of simplicity. T_r is the radiation temperature and is obtained from the solar black body emission formula, using the continuum flux at a given wavelength.

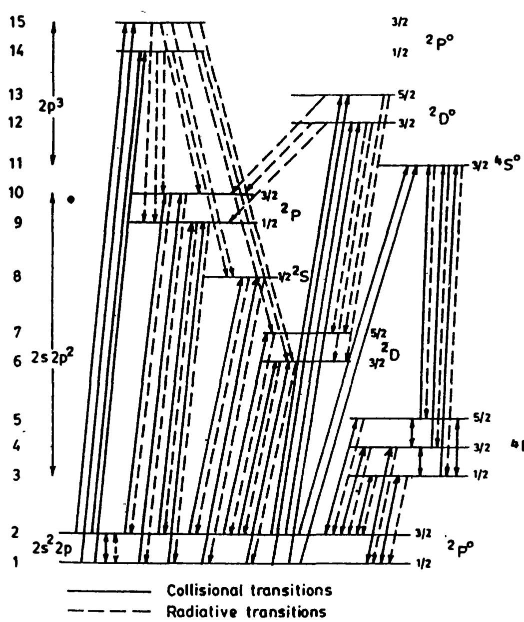

Figure 1. Schematic energy level scheme for our model of N III ion, and population and de-population processes of the levels.

3. Results and Discussion

Dwivedi, Mohan and Gupta (1995) recently studied the emission lines from N III ion using the first eleven energy level atomic model, for measurement of density and temperature in different solar structures in the chromosphere-corona transition region. In this paper, we have extended this study to the first fifteen energy level atomic model to include the emission lines from the higher levels which fall in the SUMER (Solar Ultraviolet Measurements of Emitted Radiation) spectral range (500-1610 Å) for diagnostic study. In Figure 2a and 2b, we have shown the line emissivity ratios as a function of electron density for N III ion at its maximum ionic abundance temperature $T_{max} = 8.0 \times 10^4$ K. We find that, these line ratios are density-sensitive in the density range $10^8 - 10^{11}$ cm^{-3} and will be very effectively used for density measurements in the solar chromosphere-corona transition region and other astrophysical sources, as they are insensitive to temperature variations. The temperature diagnostics of this ion have already been reported by Dwivedi, Mohan and Gupta (1995). The SUMER instrument aboard the Solar and Heliospheric Observatory (SOHO) will provide a wealth of observations with greater spectral, spatial and temporal resolution than previously available to study in detail, the density and temperature structure in the chromosphere-corona transition region and the fine structures in it, from the present investigation.

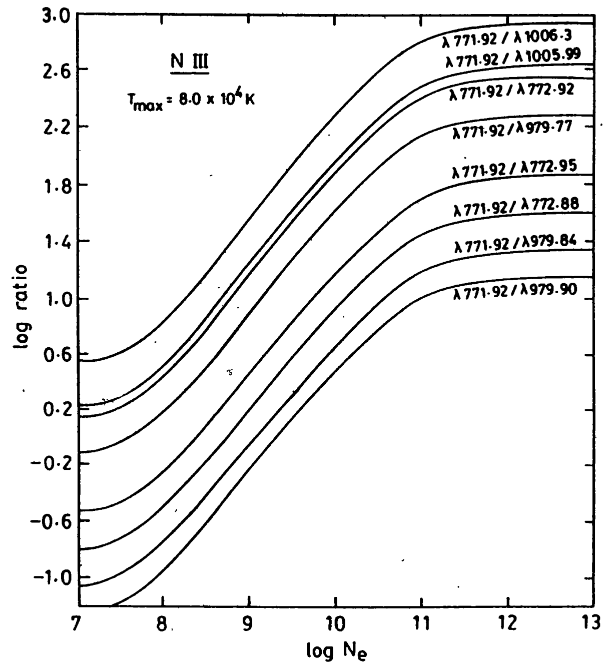

Figure 2a. Line emission ratios as a function of electron density.

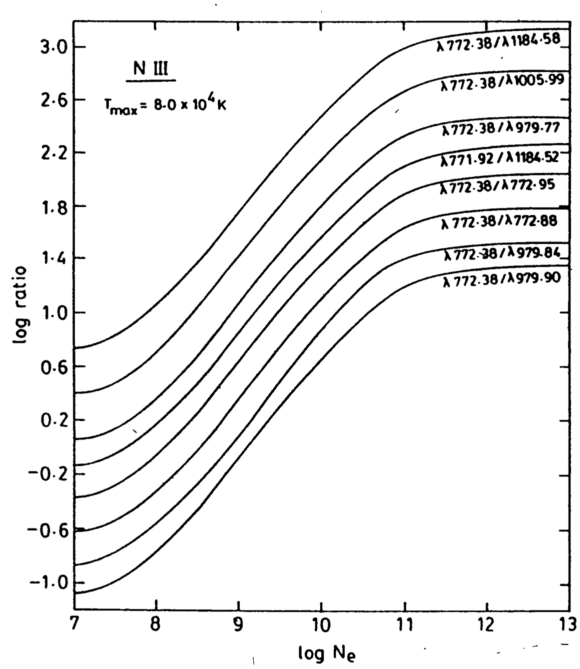

Figure 2b. Line emission ratios as a function of electron density.

4. Conclusion

We have studied in detail the diagnostics of the spectral lines from the N III ion. The line ratio curves show density sensitivity over a wide range of densities and should in principle, be useful to infer densities in different solar structures in the chromosphere-corona transition region and also in planetary nebulae and other astrophysical sources. The present study will be useful in analysing the observations which will become available from the SUMER instrument on board the SOHO mission.

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