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Abstract

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ON ONE POSSIBLE ESTIMATE OF THE TEMPERATURES OF HOT STARS FROM THE CHARACTER OF THE EMISSION SPECTRUM OF N III

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In the spectra of stars of type W–R (1), of some novae (2), and also in the spectra of a number of planetary nebulae (3), emission lines of N III are observed which belong to two groups. One group of lines is due to transitions between levels of the basic configurations $2s^2 + n(s, p, d, f, ...)$, and the second is associated with the levels of configurations $2s2p\ (^3P) + n(s, p, d, ...)$. Characteristic representatives of these groups are the lines $\lambda4640$ ($3\,^2P$—$3\,^2D$) and $\lambda4514.89$ ($3s\,^4P$—$3p\,^4D$), etc.

The appearance of the first group of lines is qualitatively explained by the joint action of the recombination mechanism and Bowen' s fluorescence mechanism; the explanation of the origin of the second group, under the assumption of the recombination character of the spectrum, encounters great difficulties (4). The main difficulty is that, in such a recombination process, the electron must be captured by an N IV ion that is not in the ground $2s^2\,^1S_0$ state but in the excited (excitation potential ~ 8 eV) state $2s2p\,^3P$; although this state is highly metastable, the residence time of an atom in it is limited.

From stationarity considerations, however, it follows that, whatever the mechanism of formation of these lines may be, a necessary condition for its effectiveness must be the comparability of the number of ionizations of the N III atom with ejection of a $2p$-electron and formation of N IV in the state $2s^2\,^1S$ with the number of its ionizations with ejection of a $2s$-electron and formation of N IV in the $2s2p\,^3P$ state. Let us determine under what conditions this comparability will occur.

The absorption coefficient of N III associated with ejection of a $2p$-electron was calculated by us using variational wave functions (5), with a correction for the distortion of electrons not participating in the transition. Its asymptotic expression at the series limit has the form:

$$\alpha_\nu(2s^2 2p\,^2P—2s^2 kd\,^2D\,^2S) \simeq 5 \cdot 10^{-19} \left(\frac{\nu}{\nu}\right)^2 .$$

In calculating α_ν associated with ejection of a $2s$-electron, two possibilities were considered: formation of an N IV ion in the states $2s2p\,^3P$ and $2s2p\,^1P$. This effect was taken into account by means of the genealogical coefficients given in (^{6}), as well as by the corresponding choice of the radial parts of the wave functions (^{5}); the correction due to distortion was also estimated and proved negligibly small.

The asymptotic expression for α_ν in the first case was

$$\alpha_\nu(2s^2 2p\,^2P\text{—}2s2p(^3P)\,kp\,^2SPD) \simeq 2\cdot 10^{-19}\left(\frac{\nu}{\nu}\right)^{0.2}.$$

Approximately one may regard $\alpha_\nu = 2\cdot 10^{-19}$ as constant.

In the second case, the value of α_ν at the series limit was

$$\alpha_\nu\,(2s^2 2p\,^2P - 2s\,2p\,(^3P)\,kp\,^2SPD) \simeq 10^{-19}\left(\frac{\nu_{\text{gr}}}{\nu}\right)^2.$$

Let us suppose that the N III atoms are in a radiation field described by Planck's formula with temperature T. Let us find for what values of T the comparability indicated above of the two ionization processes will occur. From the equality

$$\int_{\nu_1}^{\infty}\frac{\alpha_\nu(1)I_\nu}{h\nu}\,d\nu = \int_{\nu_2}^{\infty}\frac{\alpha_\nu(2)I_\nu}{h\nu}\,d\nu$$

we find the required relation

$$I_1^2 + 2I_1kT + 2(kT)^2 \simeq \alpha I_2 e^{(I_1-I_2)/kT}; \tag{1}$$

$I_2 = 47.4$ eV, $I_1 = 55.8$ eV are the ionization potentials of N III with the ejection, respectively, of $2p$- and $2s$-electrons (in the state ^3P of N IV); $\alpha \sim 2$, as follows from the estimates of α_ν given above. At $T \sim 5\cdot 10^4$ the right-hand side of (1) is substantially greater than the left-hand side—the ionization with the ejection of two s-electrons is small. If T lies between 10^5 and $2\cdot 10^5$, then the number of N III ionizations with the ejection of two s-electrons and the number of ionizations with the ejection of $2p$-electrons are comparable to each other, and therefore in the spectra of stars and nebulae with such a high temperature one should expect the appearance of N III lines of the second group; conversely, the appearance in the spectra of stars of these lines should be an indicator of high temperatures of the objects under consideration.

If we turn to the W–R stars studied in $^{(1)}$, it may be noted that in the spectra of such stars as BD $+37, 3821$, BD $+35, 4001$, to which a high ionization temperature ($\sim 10^5$) is ascribed, the N III lines of the second group are very intense (the total intensity on an arbitrary scale is, respectively, 121 and 88); conversely, in the spectra of BD $+35, 3987$, BD $+38, 4010$, to which lower temperatures are ascribed in (1), the total intensity of the lines of the second group is small (23 and 31).

In the spectrum of Nova Herculis 1934, observations (2) revealed two N III lines of the second group, λ 4510.92 and 4514.89 ($3s\,^4P - 3p\,^4D$), along with lines of the first group. The presence of these lines, together with the lines [Ne V], O IV, indicates a high temperature of the nova shell at that time.

In the spectra of planetary nebulae, such as NGC 2440, 7009, 7662, according to (3), the indicated lines of the second group are also present (the identification, in our opinion, is debatable), and the nuclei of all these nebulae have temperatures $\sim 10^5$. More accurate calculations require more detailed knowledge of the character of the recombination spectrum of N III.

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