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ON THE PHYSICAL STATE IN THE NARROW-LINE REGION OF THE CLASSICAL SEYFERT GALAXY NGC 7469

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ABSTRACT

Based on the spectrophotometric data, by decomposition of the observed continuum, the power - law continuum characteristics of the central source are obtained. The behaviour of both electron temperature T_e and density n_e in the Narrow - Line Region (NLR) of NGC 7469 is discused on the thermal and ionization equilibria calculations. T_e in NLR of the Sy1 galaxies are higher than the Sy2 ones, and the possible explanation is the lack of the dense ($n_c \sim 10^{10}$ cm^{-3}) zone close to the central source in the Sy2 galaxies.

KEYWORDS

Active galactic nuclei; Seyfert galaxies; Physical conditions in the NLR.

An investigation of the classical Sy1 galaxy NGC 7469 was carried out, based on the absolute spectrophotometric data (de Bruyn and Sargent, 1978), and on the spectrograms recently obtained. These data in the visible region (λλ 3150-10660) in principle allows to extract some parameters of the ionizing radiation spectrum at the higher than 13.6 eV energies up to more than 175 eV. Following the Shuder's (1981) idea, we decompose the observed galaxy continuum F_{obs} into the sum of an integrated normal galaxy continuum F_{gal}, and a power - law nonthermal continuum F_{NT}, i.e.

$$F_{obs}(\nu) = a.F_{gal}(\nu) + b.F_{NT}(\nu),$$

where F_{gal} is the normalized continuum of M 31 (spectral type G 4), taken from Oke and Sandage (1968), ν_o corresponds to 13,6 eV, and

$$F_{NT}(\nu) = F(\nu_o).(\nu/\nu_o)^{-\alpha}.$$

Here a is the fraction of the total continuum energy due to the stellar continuum, and the power - law fraction results in b. The solution of the above relationship has been carried out by linear regression fitting. The galaxy fraction a was obtained is 0.03 + 0.015 which agrees with Osterbrock's (1978) value. The uncorrected for reddening value of α is 1.59 ± 0.03 in very good agreement as well with Phillips'one (1978), equal to 1.62 ± 0.11. Correction for reddening have been applied following the Adams and Weedman's approach (1975), and corrected value of α is 0.58 ± 0.05. The continuum fluxes in wavelength range λλ 3150 - 4000 A were not included in the determination of the spectral index since excess emission is present at these wavelengths.

The parameter α can be estimated independently from He II λ4686 line and this estimation is about of 1.45. On the other hand, it is possible to evaluate the nonthermal luminosity at the Lyman continuum frequency ν_o from H_β line, assuming only that each ionization leads to a hydrogen recombination. That luminosity is of $1{,}5.10^{28}$ ergs.s^{-1}.Hz^{-1}. Thus we have got an experimental estima-

tion of the central source spectrum.

The available data doesn't allow to determine the density n_e and the temperature T_e in Narrow - Line Region (NLR) independently. It's known that in the region with higher ionization degree the density n_e will be higher also. For the NLR in NGC 7469 we accepted $n_e = 10^5$ cm^{-3}, to be slightly lower than the critical density for the O III ion. There is a number of the observational determinations of the $I(\lambda4363)/I(\lambda4959 + \lambda5007)$ ratio, which is sensitive to both n_e and T_e variations. For NGC 7469 Dibay and Pronik (1967) reported 0.091, from Anderson (1970) we have 0.084, from Wampler (1971) - 0.081, from Osterbrock (1977) - 0.038, from Phillips (1978) - 0.018, and from our observational material we found 0.097. Phillips gave the mean ratio $I(\lambda4363)/I(\lambda4959 + \lambda5007)$ for 11 Sy1 galaxies equal to 0.045. Taking as a basis this value, we accept that the Osterbrock's value is the most reliable one, because NGC 7469 is a typical Sy1 object.

The large scattering of the various autor's estimations comes from the difficult measurements of λ4363 forbidden line, due to its intrinsic weakness and its proximity to the broad H_γ - emission. In addition this line is affected by Fe II emission. With the Osterbrock's value we solve the exact equation governing the behaviour of the $I(\lambda4363)/I(\lambda4959 + \lambda5007)$ ratio as a function of n_e and T_e, and for $n_e \simeq 10^5$ cm^{-3} we found T_e to be ≃ 23000 K for NGC 7469. The mean T_e for Sy1 galaxies is ≃ 26000 K.

This temperature is sufficiently high and by all means is related to the deeper nuclear regions with a higher ionization degree. To asses whether this T_e is a correct one, the thermal and ionization balance equations are solved in the NLR region with a filling factor 10^{-4} and a total density 2.10^5 cm^{-3}. The ionizing radiation spectrum of the central source was defined in power - law form $\sim(\nu/\nu_o)^{-\alpha}$ in region 13.6 - 100 eV and $\sim (\nu_o/\nu_x)^{-\alpha}(\nu_x/\nu)^{-\beta}$ for energies higher than 100 eV. Here ν_x correspond to 100 eV, $\alpha \simeq 0.6$, and $\beta < \alpha$. We adopted a cutoff at 100 eV. In our model the heating of the gas is produced solely by photoionization of He and H, and the cooling results from line emission, that is produced by collisional excitation of O^{++}, Ne^{++} and Ne^{4+}, from free - free and recombinations of He and H. The behaviour of n_e and T_e obtained after calculations and their dependence on the radius are shown in Figure 1. As it's seen there is a good agreement between the model temperature and the one observed from O^{++} forbidden lines.

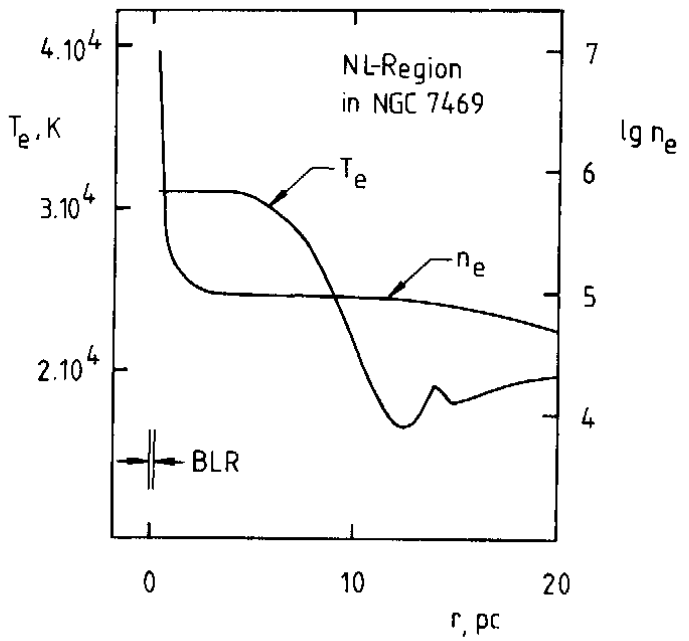

Fig. 1. Dependence of n_e and T_e on the distance from the central source for NLR of the NGC 7469.

A matter of interest is to compare the T_e values in the NLR of Sy1 to the Sy2 ones. From the Koski's data(1978) we averaged the ratios $I(\lambda4363)/I(\lambda4959 + \lambda5007)$ on the 40 Sy2 galaxies. The mean value as obtained is 0.016. Then the

mean T_e in NLR of Sy2 galaxies is ≈ 14000 K for $n_e = 10^5$ cm^{-3}. The relationships lg n_e - lg T_e shown in Figure 2 are based on the O^{++} forbidden lines mean intensity ratios for Sy1 and Sy2 galaxies and for NGC 7469.

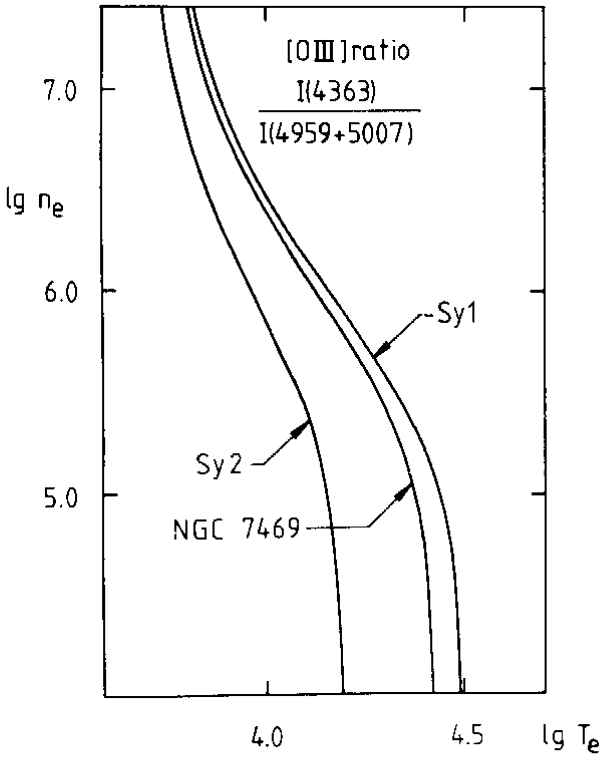

Fig. 2. Relationships lg n_e - lg T_e for Sy1 and Sy2 galaxies and for NGC 7469.

The differences in the mean T_e for both SyG classes probably are due to that in Sy1 exists a small (∼ 0.1 pc), dense ($n_e \sim 10^{10}$ cm^{-3}) region which causes the full absorption of the low - energetic quanta and the gas is heated mainly by X - ray radiation (this is the well known Broad - Line Region), whereas in Sy2 the lack of such region permits to the low - energetic quanta to penetrate into the NLR and to heat effectively the gas. Thus the Osterbrock's idea (1979) about the geometrical diferences in the nuclear regions of Sy1 and Sy2 is supported.

It should be stated that the recent observations of the Sy1 nuclei in UV region exibit the UV continuum varies both in shape and intensity (Boisson and Ulrich, 1982). This behaviour was seen in NGC 7469 too. The variability of the power - law index remains an open question for other investigations.

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