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

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The classical Syl galaxy NGC 7469 was investigated on the basis of absolute spectrophotometric data [1] and on recently obtained spectrograms. The spectral data in the visible region (λλ 3150-10660 Å) allow to extract some parameters of the ionozing radiation spectrum energies above 13.6 eV and up to more than 175 eV. Following Shuder's idea [2], we decomposed the observed galaxy continuum F_{obs} into the sum of an integrated normal galaxy continuum F_{gal}, and a power-law nonthermal continuum $F_{NT} \cdot (\nu) = F(\nu_0)(\nu/\nu_0)^{-\alpha}$, i. e

$$F_{obs}(\nu) = aF_{gal}(\nu) + bF_{NT}(\nu),$$

where F_{gal} is the normalized continuum of M 31 (spectral type G4), taken from [3], and ν_0 corresponds to 13.6 eV. Here a is the fraction of the total continuum energy due to the stellar continuum, and the power-law fraction results in b. The above relation was solved by linear regression fitting. Galaxy fraction a is 0.03±0.015 which agrees with Osterbrock's value [4]. The value of α, uncorrected for reddening 1.59±0.03, is in very good agreement with that of Phillips' [5]: 1.62±0.11. Correction for reddening was applied following the Adams a. Weedman approach [6]; the corrected value of α was 0.58±0.05. The continuum fluxes in a wavelength range of λλ 3150-4000 Å were not included in the determination of the spectral index, because there is excess emission at these wavelengths.

The parameter α can be estimated independently from He II 4686 line; this estimate is about 1.45. On the other hand, it is possible to evaluate the nonthermal luminosity at the Lyman continuum frequency ν_0 from the H_β line, assuming that every ionization leads to a hydrogen recombination. That luminosity of 1.5×10^{28} ergs. s^{-1}. Hz^{-1}. Thus, we have an experimental estimate of the central source spectrum.

The available data does not allow to independently determine the density and temperature T_e in the narrow-line region (NLR). As is known, in a region with a higher ionization degree the n_e will be higher too. For the NLR in NGC 7469 we assumed $n_e = 10^5$ cm^{-3} to be slightly lower than the critical density for the 0 III ion. There are a number of observational determinations of the I(4363)/I(4959+5007) ratio, which are sensitive to both n_e and T_e variations: 0.091 from [7], 0.084 from [8], 0.081 from [9], 0.038 from [10], 0.018 from [5], and from our observational material we found 0.097. Philips gave the mean ratio I(4363)/I(4959+5007) for 11 Syl galaxies: 0.045. Taking this value as a basis, we accept that Osterbrock's value [10] is the most reliable one, because NGC 7469 is a typical Sy1 object.

The considered scattering of the estimates of various authors comes from the difficulty of measurements of the [0 III] 4363 line, due to its intrinsic weak-

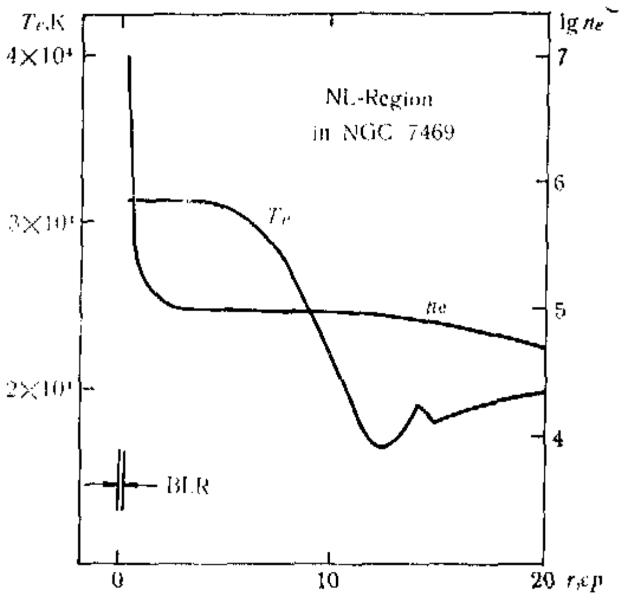

Fig. 1

ness and its proximity to the broad H_γ emission. In addition, this line is affected by the Fe II emission. By means of Osterbrock's value we could to solve the exact equation governing the behaviour of the I(4363)/I(4959+5007) 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 $\simeq$ 23 000 K for NGC 7469. The mean T_e for Sy1 galaxies was $\simeq$ 26000 K.

This temperature is sufficiently high and 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 were solved in the NLR region with a filling factor 10^{-4} and a total density $2\times10^5\,cm^{-3}$. The ionization radiation spectrum of the central source was defined in power-law form $\sim(\nu/\nu_0)^{-\alpha}$ in region 13.6÷100 eV and $\sim(\nu_0/\nu_x)^{-\alpha}(\nu_x/\nu)^{-\beta}$ for energies higher than 100 eV. Here ν_x correspond to 100 eV, $\alpha \simeq 0.6$ and $\beta<\alpha$. We adopte a cut-off at 100 eV. In our model the heating of the gas is due solely to be photo-ionization of He and H. The cooling results from line emissions produced by collisional excitation of O^{2+}, Ne^{2+} and Ne^{4+}, as well as by free-free transitions 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 Fig. 1. As can be seen, there is a good agreement between the model temperature and the one obtained from the [0 III] lines.

It is worthwhile to compare the T_e values in the NLR of Sy1 with those of Sy2. From Koski's data [11] we averaged the ratio I(4363)/I(4959+5007) on the 40 Sy2 galaxies. The mean value obtained was 0.016. Then the mean T_e in NLR of Sy2 galaxies is $\simeq$ 14000 K for $n_e = 10^5\,cm^{-3}$. The relations with lg n_e—lg T_e, shown in Fig. 2, are based on the [0 III] lines mean ratios for the Sy1 and Sy2 galaxies and for NGC 7469.

The differences in the mean T_e for both SyG classes are probably due to the small ($\sim$ 0.1 pc) dense ($n_e \sim 10^{10}\,cm^{-3}$) region existing in Sy1, which causes full absorption of the low-energy quanta. The gas is heated mainly by X-ray radiation (the so-called Broad Line Region), whereas in Sy2 the absence of such region permits the low-energy quanta to penetrate the NLR and to heat the gas effectively. Thus, Osterbrock's idea (Astron. J. **84**, 1979,

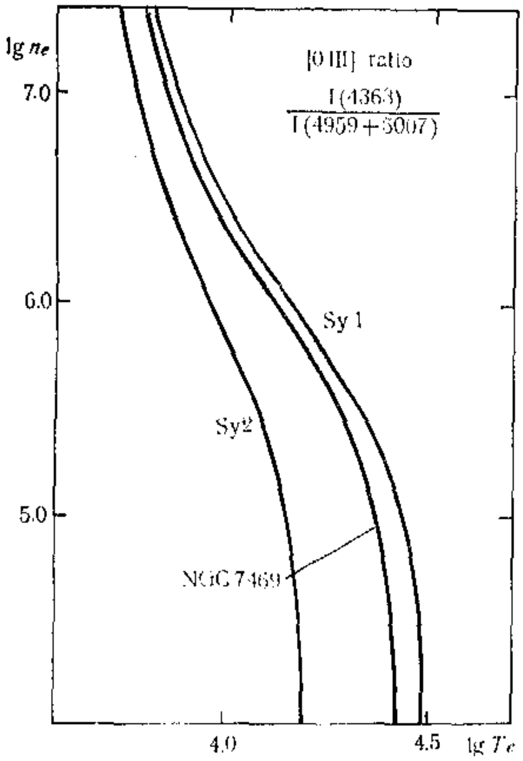

Fig. 2

.J01) about the geometrical differences in the nuclear regions of Sy1 and Sy2 is borne out.

It should be noted that recent observations of the Sy1 nuclei in the UV region show that the UV continuum varies both in shape and intensity (Boisson a. Ulrich, ESO Messenger, **30**, 1982, 4). This behaviour has been observed in NGC 7469 too. The variability of the power-law index remains a moot question and provides grounds for further investigations.

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