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On the ratio [N II]/Hα in the nucleus of Seyfert 2 and LINER galaxies

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SUMMARY

The dependence of the [N II]/Hα ratio of 180 Seyfert 2 and LINER nuclei on the aperture used in the observations is investigated and quantified. When the aperture effect is taken into account it can be concluded that the majority of Seyfert 2 and LINER galaxies present [N II]/H$\alpha > 1.5$, which means an overabundance of nitrogen in the nucleus, according to results of previous works. The relationship of [N II]/Hα to nuclear compact radio emission, absolute magnitude and morphological type of parent galaxy are also investigated.

1 INTRODUCTION

In a previous work (Storchi-Bergmann & Pastoriza 1989a) we have studied in detail the spectra of six emission line galaxies with [N II]$_{\lambda\lambda 6548,6584}$ stronger than Hα. We have concluded that, for four of the studied nuclei, the emitting gas presents an overabundance of nitrogen relative to the other heavy elements. In order to determine the frequency of this effect, we have extended the analysis of the emitting gas to a sample of about 150 Seyfert 2 and LINER galaxies (Storchi-Bergmann & Pastoriza 1989b) using emission line data from the literature. The results indicate that only about 1/3 of the nuclei present nitrogen overabundance; 1/3 present solar abundance and 1/3 present an underabundance of nitrogen. Nevertheless, in a subsequent work (Storchi-Bergmann, Bica & Pastoriza 1990), we have verified that the observed emission line ratios, and, in particular, [N II]/Hα, depend on the slit dimensions used in the observations: for the more distant nuclei one is observing not only the nucleus, but also its surroundings, and sometimes disc emission. This can lead to incorrect conclusions about the physical parameters and chemical abundance of the nuclear gas. This fact has been noted before by Rubin & Ford (1986) in their analysis of the nuclear spectrum of M33, showing that if this galaxy were four times more distant, the nuclear Hα emission (much weaker than the [N II] emission) would become stronger than [N II]. The above effect has direct influence on the conclusions about the nitrogen abundance obtained for the 150 Seyfert 2 and LINER galaxies previously analysed. For this reason, in the present work, I have collected information on the distances and slit dimensions for these objects, as well as for some new ones, in order to quantify the effect. The relation of the [N II]/Hα ratio with the radio emission, absolute magnitude and morphological type of the galaxies is also discussed.

2 THE SAMPLE

The sample consists of 90 Seyfert 2 and 87 LINER galaxies, for which I have collected, from the references listed in Table 1, the following information: emission line ratios, distances, magnitudes, dimensions of the slit used in the observations, morphological type and radio luminosity.

3 [N II]/Hα VERSUS SLIT DIMENSION AT THE GALAXY

In order to investigate the dependence of the [N II]/Hα ratio on the distance of the galaxy, I have plotted, in Fig. 1, this ratio against the radial velocity for the galaxies in the sample. However, as the galaxies were observed with different apertures, it is more meaningful to plot [N II]/Hα against the extent of the observed region of the galaxy. I have therefore calculated the area at the galaxy corresponding to the slits used in the observations and have plotted [N II]/Hα against the square root of this area (an effective length of the region observed) in Fig. 2. In order to better quantify the effect, I have also plotted, in Figs 3 and 4, histograms showing the fraction of galaxies with [N II]/H$\alpha > 1.5$ in each interval of radial velocity and effective length, respectively. The limit [N II]/H$\alpha = 1.5$ was selected based on the results of a previous work (Storchi-Bergmann & Pastoriza 1989a) showing that, if the gas has solar abundance, the ratio [N II]/Hα is about this value. The percentage of the galaxies with [N II]/H$\alpha > 1.5$ when the entire sample is considered is 44 per cent. But from the histograms, it can be seen that, for the galaxies with radial velocities smaller than 1000 km s^{-1}, 75 per cent present [N II]/H$\alpha > 1.5$; this percentage drops to about 55 per cent for radial velocities between 1000 and 3000 km s^{-1}, and to less than 30 per cent for higher radial velocities. The transition is more abrupt in the case of the effective length, l:

Table 1. References for data used.

Baum *et al.* (1988)
Bonatto, Bica & Alloin (1989)
Condon *et al.* (1982)
Costero & Osterbrock (1977)
Danziger *et al.* (1984)
Diaz, Prieto & Wamsteker (1988)
Durret & Bergeron (1988)
Durret (1989)
Edelson (1986)
Filippenko & Halpern (1984)
Filippenko (1985)
Goodrich & Osterbrock (1983)
Goudfrooji *et al.* (1989)
Heckman (1980)
Heckman, Balick & Crane (1980)
Jones, Sramek & Terzian (1981)
Keel (1983)
Kojoian *et al.* (1976)
Koski (1978)
Mazzarella & Balzano (1986)
Phillips, Charles & Baldwin (1983)
Rose & Searle (1982)
Shuder & Osterbrock (1981)
Stauffer (1982)
Storchi-Bergmann, Bica & Pastoriza (1990)
Ulvestad, Wilson & Srameck (1981)
Ulvestad & Wilson (1984)
Ulvestad & Wilson (1984)
van Breugel *et al.* (1986)

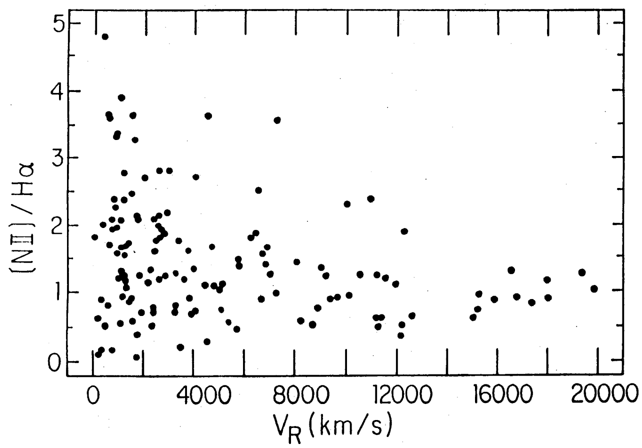

Figure 1. Emission line ratio [N II]/Hα plotted against radial velocity for the sample galaxies.

72 per cent of the galaxies with $l<0.5$ kpc present [N II]/H$\alpha>1.5$; 40 per cent of the ones with $0.5<l<2$ kpc and 18 per cent for $l>2$ kpc. I have also constructed separate histograms, for Seyfert 2s and LINERs, and verified that, although for $l<0.5$ kpc and $l>3$ kpc the percentages are the same as above, for $0.5<l<2$ kpc there is a difference: for the Seyfert 2s, the percentage of the galaxies with [N II]/H$\alpha>1.5$ is 34 per cent, while for the LINERs it is 53 per cent. I interpret this dependence on the slit dimension as being due to the contamination by extranuclear gas when the dimension at the galaxy corresponding to the observational slit is large. Since the probable sources of contamination are its surrounding H II regions, which present small [N II]/Hα ratios, the resulting observed ratio is smaller than the nuclear one. The results also show that this contamination seems to be larger in Seyfert 2s than in LINERs, which present, on average, larger [N II]/Hα ratios for $0.5<l<2$ kpc, probably due to the fact that the morphological types for the LINER galaxies are, on average, earlier than that of the Seyferts and, for this reason, have less disc contamination. This result has important implications in the conclusions of our previous works. First, we verified that for a few galaxies with high [N II]/Hα the most probable explanation was a nitrogen

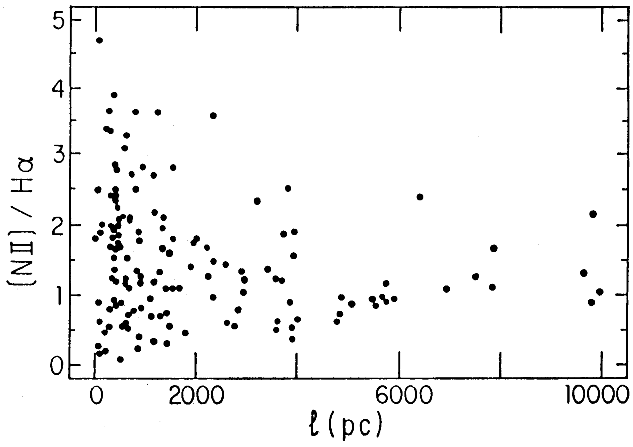

Figure 2. [N II]/Hα plotted against effective length of the region observed at the galaxy (see text).

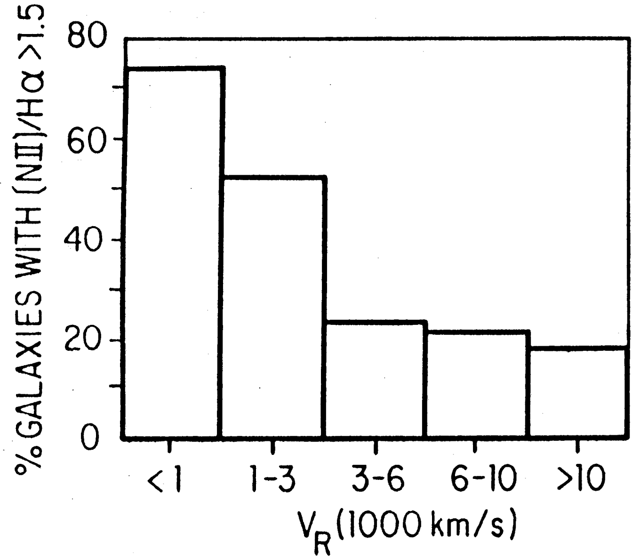

Figure 3. Histogram showing the percentage of galaxies in each radial velocity interval presenting [N II]/H$\alpha>1.5$.

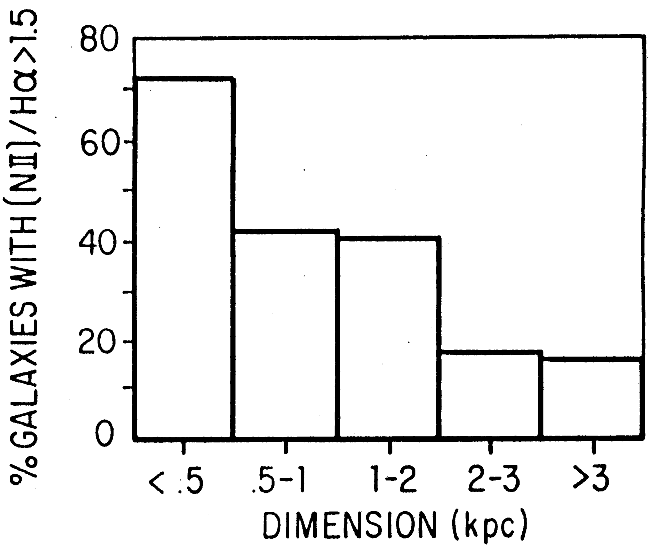

Figure 4. Histogram showing the percentage of galaxies in each effective dimension interval (see text) presenting [N II]/H$\alpha>1.5$.

overabundance. When we tried to check how common this effect was in other Seyfert 2s and LINERs, we concluded that there was an even distribution of nitrogen abundances, from under solar through solar to over solar. The present work shows instead that, when the effect of the different apertures used in the observations is considered, the majority of the Seyfert 2s and LINERs actually present an overabundance of nitrogen in the nucleus. One other point that should be noted is that the overabundance (or high [N II]/Hα) seems to be very localized, being restricted to a maximum distance of about 500 pc from the nucleus.

4 [N II]/Hα VERSUS RADIO EMISSION

In a recent work on models for LINERs, Viegas-Aldrovandi & Gruenwald (1990) argue that the presence of relativistic electrons in an ionized gas cloud enhances the [N II]/Hα ratio. Thus, it might be possible to reproduce high [N II]/Hα ratios without invoking nitrogen overabundances. If this were the case, there would probably be a relation between the [N II]/Hα ratio and the radio luminosity of a possible compact nuclear source. I have collected from the literature radio luminosity data on compact nuclear non-thermal radio sources in the nucleus of the sample galaxies. The total number of objects for which these data could be found was 30. In Fig. 5, I have plotted the ratio [N II]/Hα against the logarithm of the radio luminosity in λ6 cm. No correlation is found, although more points would be necessary before stating a final conclusion. This result does not support the idea that the high [N II]/Hα ratio is due to the presence of relativistic electrons.

5 [N II]/Hα VERSUS ABSOLUTE MAGNITUDE

It is well established that, when the luminosity of the galaxy increases, there is a strengthening of the absorption lines and reddening of the colours in early-type galaxies, most probably due to an increase in metal content (e.g. Bica 1988). It is reasonable to suppose that this higher metallicity should also be present in the emitting gas. Thus I have investigated the correlation between [N II]/Hα and absolute magnitude of the galaxies. I have found no clear correlation, although the percentage of galaxies with [N II]/Hα > 1.5 does increase with the luminosity of the galaxy, as shown in Fig. 6 for the galaxies with l < 1 kpc. This subsample was selected as a compromise between minimizing the aperture effect and maintaining a good number of galaxies to cover a wide absolute magnitude range. It is also verified that the highest [N II]/Hα ratios occur among the most luminous galaxies. Hence, for the galaxies with the highest [N II]/Hα ratio, the N abundance in the nuclear gas seems to be related to the metallicity of the stellar population.

6 [N II]/Hα VERSUS MORPHOLOGICAL TYPE

Fig. 7 shows a histogram of morphological types for the sample galaxies. These types were obtained from the *Revised Shapley–Ames Catalog of Bright Galaxies* (Sandage & Tammann 1981) for the nearby ones, and from the references

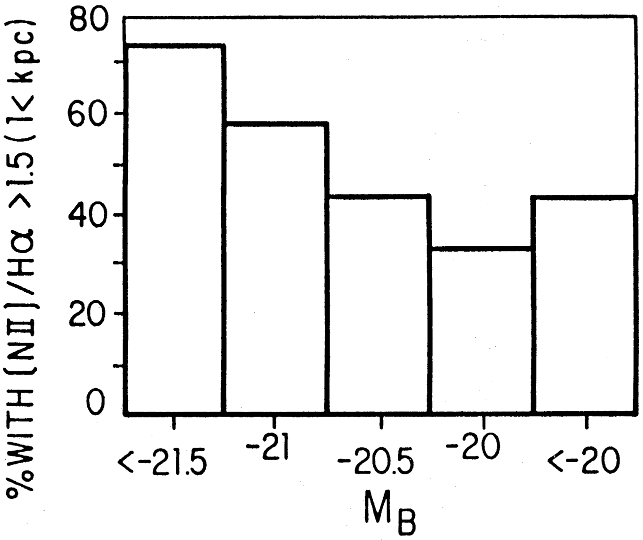

Figure 6. Histogram showing the percentage of galaxies with effective length l < 1 kpc, in each absolute magnitude interval, presenting [N II]/Hα > 1.5.

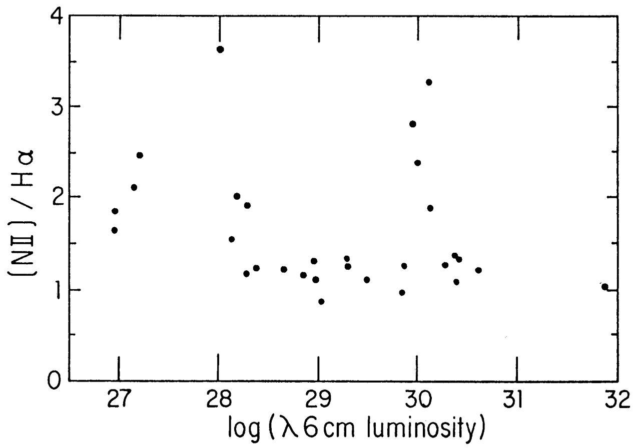

Figure 5. [N II]/Hα plotted against the logarithm of the λ6 cm radio luminosity of a compact nuclear radio source.

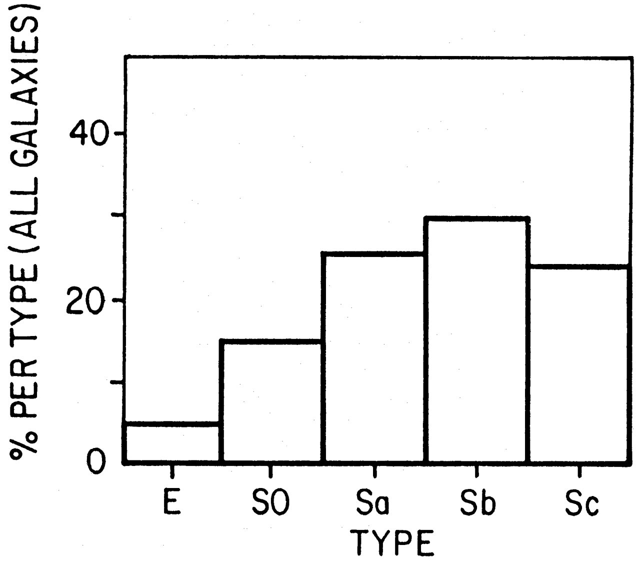

Figure 7. Histogram showing the distribution of all the sample galaxies among the different morphological types.

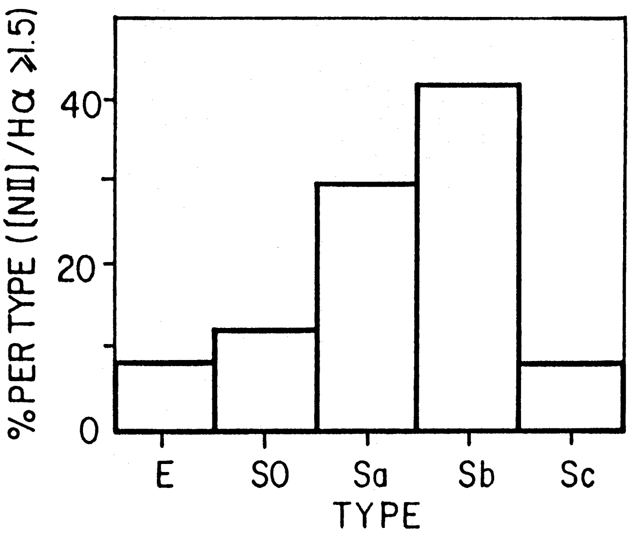

Figure 8. Histogram showing the distribution of the galaxies with [N II]/Hα > 1.5 among the different morphological types.

listed in Table 1 for the rest. It can be seen that the majority of galaxies have types Sa, Sb and Sc. The intermediate classes Sab and Sbc are included in the previous classes Sa and Sb, respectively. Barred spirals are 25 per cent of the sample spirals (the same proportion as in the *Shapley–Ames Catalog*, for example). The number of ellipticals and S0s should be somewhat higher due to the fact that for several galaxies the morphological types where not given in the literature and most of these are radio galaxies, whose types are probably E or S0. Fig. 8 shows the histogram for the galaxies with [N II]/H$\alpha \geq 1.5$. As compared with the histogram for all the galaxies, the percentage of Scs is considerably smaller, the percentage of S0s is slightly smaller, and the percentage of Sas and mainly of Sbs is larger. The proportion of barred galaxies decreased from 25 to 20 per cent. Thus, in this sample, the majority of galaxies with [N II]/Hα > 1.5 are non-barred Sa and Sb spirals.

7 CONCLUSIONS

The main conclusion of this paper is that for Seyfert 2 and LINER galaxies the observed [N II]/Hα ratio is dependent on the size of the region at the galaxy corresponding to the observing apertures, due to extranuclear contamination when these apertures are large. It is concluded that if this effect is taken into account, the majority of Seyfert 2s and LINERs present a nuclear [N II]/Hα ratio higher than 1.5. It is also verified that this high ratio is very concentrated around the nucleus, within a typical radius of less than 500 pc. From results of previous works, [N II]/Hα > 1.5 indicates overabundance of nitrogen relative to other elements. Thus, on the basis of these results, it can be concluded that the majority of Seyfert 2s and LINERs present a nitrogen overabundance in the nuclear gas, which is confined to a small region around the nucleus. This conclusion sets important constraints to the history of the nuclear gas. No correlation was found between the [N II]/Hα ratio and the luminosity of the compact nuclear radio source on the basis of existing data for 30 galaxies, giving no support to the idea that the high [N II]/Hα could be due to the presence of relativistic electrons. The observation that the largest [N II]/Hα ratios are presented by the most luminous galaxies, together with the overabundance of nitrogen in the gas, indicates a possible link between high metal abundance and nuclear activity in galaxies. This link is suggested, for example, by the 'Warmers' theory for Seyfert 2s and LINERs (Terlevich & Melnick 1985). Nevertheless, several luminous galaxies present low [N II]/Hα ratios. One speculative possibility for these cases could be that the gas has an extranuclear origin in these galaxies. The morphological types corresponding to most galaxies with [N II]/Hα > 1.5 are non-barred Sas and Sbs.

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