Profiles of emission lines in AGN – II. Analysis of a sample of [O III] profiles

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Summary. Statistical analysis of a sample of active galactic nuclei (AGN) [O III]λ5007 high-resolution (FWHM ≤ 130 km s⁻¹) line profiles, complemented with other observational information, showed that line kurtosis correlates with narrow-line Balmer decrement, indicating that there is dust inside the narrow-line region. The dust affects preferentially the low-velocity emitting regions. Line kurtosis depends also on radio luminosity and presence of a broad-line region. The analysis shows a correlation between line FWHM and host galaxy inclination, pointing to the planar and aligned nature of the narrow-line region velocity field. Radio-quiet objects showed a good correlation between line FWHM and optical/radio luminosity. No correlation was found on the radio-loud ones, indicating that probably different mechanisms are at play in these two classes of objects. Late-type spirals showed, on the mean, lines with narrower FWHM than early-type ones. The effect is measurable, however, only on the low-velocity emitting regions, indicating that the velocity field in these regions may be shaped by the galaxy-bulge gravitational field. Line asymmetry does not appear to be a good diagnostic tool for probing the velocity field. About 23 per cent of the radio-quiet objects showed lines with red asymmetry.

1 Introduction

In recent years, with the increasing possibility of obtaining high-quality spectroscopic observations of active galactic nuclei (AGN), a growing body of high-resolution spectral data appeared in the literature. In particular, narrow-line region (NLR) studies were of great benefit, providing the possibility to resolve in detail the velocity information coded in emission-line profiles. The role of the NLR as an interface between the nucleus itself and the ambient galactic medium was one main topic of interest in these studies. Issues such as inflow/outflow/circular gas movements, the role of dust and the geometric and ionization structure of the NLR were addressed in several recent studies. However, theoretical modelling of line profiles has shown that (even using simple laws for describing the NLR velocity field) geometry, dust con-

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tent, physical conditions and virtually every observable profile can be reconstructed (e.g. Vrtilek 1985). Obviously, the issue cannot be resolved with just the line profile shape and width; more information from the nuclei being studied must be taken into account.

Two main techniques have been used to analyse AGN narrow-line profiles. One of them is based on the comparison of profile width data between lines coming from regions with different physical conditions, from the same object (e.g. De Robertis & Osterbrock 1984, 1986; Filippenko & Halpern 1984; Whittle 1985c). The analysis benefits of course, when one obtains profile data for the widest ionization conditions in each object being studied. The method can show, for instance, objects with a great degree of ionization structure in the NLR.

The other technique essentially compares profile shape and width data for one specific emission line, between different objects (Heckman et al. 1981, hereafter HMBB; Heckman, Miley & Green 1984, hereafter HMG; Whittle 1985a, hereafter WA; Whittle 1985b, hereafter WB; Vrtilek & Carleton 1985, hereafter VC). The line usually chosen is [O iii] λ5007, because it is normally the most intense forbidden line found in typical AGN spectra, as well as being not contaminated by other strong lines. Studies like these have shown important statistical characteristics of the [O iii] λ5007 line shape, like the well-known tendency to show a blue enhanced wing. Also, important correlations between line shape and width, and other nuclear properties, like luminosity, have been established.

In this paper we present an analysis of AGN [O iii] λ5007 line profiles compiled from the literature and our own measurements. The goal was to examine in detail: (i) all profile parameter distributions, and (ii) all possible correlations between profile parameters and other properties of the objects, using the greatest possible sample. Section 2 describes the dataset; Section 3 describes new results found in the present work, and Section 4 discusses these results.

2 Data

In assembling our dataset, the basic criterion was to include all published [O iii] profiles observed with spectral resolution better than 130 km s⁻¹. As a result, the sample contains every kind of AGN, from bright QSOs to low-luminosity Sy 2 and LINERS. Also, it is not a homogeneous sample, since data were obtained with a variety of instrumental, selection and analysis techniques. The sample size could be somewhat increased by relaxing the basic criterion, but in lower-resolution data the number of resolution elements across a typical profile is so low as to render useless any profile parameter designed to measure line shape. Also, adequate instrumental profile deconvolution becomes increasingly important and difficult as the data have lower spectral resolution.

We compiled data from WA, VC, HMG, Busko & Steiner (1987, hereafter Paper I) and Véron (1981). We also included in our sample FWHM values taken from the survey at only slightly lower resolution of Feldman et al. (1982; 150 km s⁻¹), but only for objects not already included in the above lists. Also, we included in the sample data for individual objects taken from Iye & Ulrich (1986), Atwood, Baldwin & Carswell (1982), Pelat et al. (1981) and Philips et al. (1983b). These data were obtained by directly measuring the published profile graphs.

In Paper I, we commented on the several methods used to characterize profile shape information of AGN narrow lines. Our main sample was assembled using parameters defined by HMBB, since in this way all objects in the above references could be included in it. The resulting dataset comprises 167 objects. We also assembled a second sample using the 'area parameters' defined by WA. Contrary to HMBB format, which describes profiles in an empirical way, the area parameters convey physically meaningful information about which
fraction of line flux comes from which velocity range. Unfortunately, only 40 objects were measured with this technique.

In the HMBB system, profiles are characterized by: (i) full widths $W_x$ measured at several fractional levels $'x'$ between line peak and continuum, and (ii) asymmetry indices measured at the same levels. The asymmetry at level $'x'$ is defined by $AI_x = (WB_x - WR_x)/(WB_x + WR_x)$, where $WB$ and $WR$ are the semi-widths of the profile to the blue and red, respectively, of the line centre defined at the 80 per cent intensity level. We compiled values of $W_x$ for $x = 80$, 50, 20, 10 and 0 per cent, and values of $AI_x$ for $x = 50$, 20 and 10 per cent. An important derived parameter which was also included in our analysis is a kurtosis-like measure of line peakiness, $R_{x/50} = W_x/W_{50}$ (HMG). We tabulated $R_{x/50}$ for $x = 20$ and 10 per cent. The 10 per cent level parameters from VC were converted to the above format using relations (1) and (2) from Paper I.

Area parameters $IPV$ (width) and $A$ (asymmetry) were taken from WA and Paper I. Their operational definition is more complicated than in the HMBB case, and the reader is referred to WA for the details.

For several objects, two or more observations exist, sometimes with discrepant values (see Paper I). In these cases, we adopted a weighted mean of individual values, with weights proportional to spectral resolution and signal-to-noise ratio.

The final dataset comprises the following number of objects:

<table>
<thead>
<tr>
<th>W50</th>
<th>65</th>
<th>A10</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>W50</td>
<td>167</td>
<td>IPV50</td>
<td>40</td>
</tr>
<tr>
<td>W20</td>
<td>130</td>
<td>IPV20</td>
<td>40</td>
</tr>
<tr>
<td>W10</td>
<td>31</td>
<td>IPV10</td>
<td>40</td>
</tr>
<tr>
<td>W0</td>
<td>38</td>
<td>A50</td>
<td>13</td>
</tr>
<tr>
<td>A150</td>
<td>85</td>
<td>A20</td>
<td>40</td>
</tr>
<tr>
<td>A20</td>
<td>130</td>
<td>A10</td>
<td>40</td>
</tr>
</tbody>
</table>

With regards to error estimates for the parameters, the sample is relatively complete only for the $W_{50}$ and area parameters. For the $A_{20}$ parameter, only about 30 per cent of the objects have an error estimate. No errors are available for the widths at other fractional levels than the 50 per cent one. Due to the very nature of the sample, the $W_{50}$ values are relatively precise, with errors typically in the range 10–20 km s$^{-1}$.

In order to compare line profiles against other object observed properties, we compiled for each object the following data: AGN class; redshift; $\log(L_{H\beta})$; absolute visual nuclear magnitude; $UBV$ colours; Balmer decrement of narrow and broad components; absolute radio flux at 1.4 GHz; radio spectral index; absolute optical flux at 4000 Å; $IRAS$ fluxes; host galaxy morphological type and axial ratio. The data were taken basically from the compilations of Steiner (1981) and Véron-Cetty & Véron (1985). $IRAS$ fluxes came from Lonsdale et al. (1985). Some radio data were taken from Ulvestad & Wilson (1984a, b). Host galaxy type and axial ratio were taken from Kirhakos (1985), and Balmer decrements from the compilation of Andrade (1986). These data are presented also in Appendix I. We adopt $H_0 = 50$ km s$^{-1}$ Mpc$^{-1}$.

We searched systematically almost all possible correlations in between line parameters and between them and other properties of the objects. Results are expressed in terms of probability of the data being correlated, given by the one-sided correlation coefficient $t$-distribution. We also examined quantitatively the parameter distributions, using the non-parametric
Kolmogorov–Smirnov two-sample one-sided test to check for intrinsic differences in underlying populations of two distributions.

Table 1 summarizes the searched correlations. We have done this analysis for the dataset as a whole, and also for subsamples selected on the basis of AGN class, luminosity and radio power. Also, in some cases we have taken into account the morphological type of the host galaxy. For the AGN class, we divided the sample into Broad Line Objects (BLO) and Narrow Line Objects (NLO). Objects brighter than \( M_V = -23 \) were classified as QSOs, and fainter ones as galaxies. Radio-loud objects were taken as the ones with continuum radio power at 1.4 GHz greater than \( 3.0 \times 10^{24} \text{ W Hz}^{-1} \). Normally they are steep-spectrum sources, but a small fraction of them (8 objects) has a flat radio spectrum. Unfortunately, the available data do not allow discrimination between 'steep-spectrum core' and extended sources.

3 Results

Previous work has revealed several aspects of the \([\text{OIII}]\) profile shape and width distributions and correlations among AGN, and a review of the present status of the subject can be found in Wilson & Heckman (1985). Our results are in general in good agreement with those reported there. In the following, we will comment only on the new results that appeared in our analysis.

3.1 Optical luminosity and radio properties

3.1.1 Linewidths

A correlation between \([\text{OIII}]\) linewidth \((W50)\) and \([\text{OIII}]\) luminosity was already well established (WB). However, there were indications that this correlation 'saturates' in the bright end of the luminosity scale. Also, it was not clear whether this situation was in fact a consequence of powerful radio emission, and not of optical luminosity only. In Fig. 1(a) and (b) the log\((W50)\) parameter is plotted against nuclear absolute visual magnitude, separately for the radio-loud and radio-quiet subsamples. Two different behaviours are apparent: (i) radio-quiet
objects show the same kind of correlation between log(W50) and \( M_v \) as between log(W50) and [O iii] line luminosity \( (p_{1 - \text{tail}} > 99.99 \text{ per cent, 105 objects}) \); (ii) radio-loud objects do not show any correlation between linewidth and optical luminosity \( (p_{1 - \text{tail}} \approx 30 \text{ per cent, 48 objects}) \). Even neglecting the presence of a clear correlation in only one of the subsamples, the W50 distributions of the two subsamples differ in a significant way \( (p_{1 - \text{tail}} = 98.2 \text{ per cent}) \). No dependencies on the presence of a broad-line region were found.

Fig. 2 shows W50 against radio luminosity for the two subsamples. Radio-quiet objects also show a good correlation between linewidth and radio luminosity \( (p_{1 - \text{tail}} = 99.9 \text{ per cent, 61 objects}) \).

This result suggests that at least two line-broadening mechanisms must exist in the NLR: one of them dominates in the radio-quiet objects, and is directly linked to the nuclear ‘bolometric’ output (at least in the radio–optical band). The other takes over when the energy output in the radio band exceeds some limit, and dominates in the radio-loud nuclei. None of these mechanisms seem to depend on the presence of a (visible) BLR.

The scatter in the correlations for both radio-quiet and radio-loud objects does not allow a firm conclusion, but a luminosity saturation effect may still remain.

The same general trend as discussed above is found when one plots line core (W80) and base (W20 and W10) widths, as well as area parameters IPV, against nuclear luminosity. However, the smaller number of objects coupled with the intrinsic scatter of the correlation does not allow any additional conclusions.
3.1.2 Line kurtosis

It is a well-known fact that AGN [O iii] lines show a wide range of the ‘kurtosis’ parameter $R_{20/50}$, and also have a strong tendency to be more peaky than a Gaussian ($R_{20/50} > 1.524$). No dependencies on AGN class, radio or optical power were known. However, a difference was found between ‘linear’ and ‘non-linear’ radio sources, in the sense that the linear ones have stubbier profiles. This may be interpreted as optical Doppler-shifted radiation coming from the two opposite sides of a double jet (WB). Fig. 3 shows the distribution of the $R_{20/50}$ parameter separately for BLOs and NLOs, taking account also of the emitted radio power. BLOs, both radio and non-radio, show the expected distribution (as shown, for instance, in Wilson &
Heckman 1985), but NLOs have a surprising behaviour: radio-quiet ones have a marginal tendency to show peakier lines than BLOs \( p_{1-\text{tail}} = 94 \) per cent between BLO-Q and NLO-Q), but radio-loud NLOs have Gaussian or even stubbier lines. Comparison of this subsample with the BLO one rejects the null hypothesis with 99.7 per cent confidence. Differences in kurtosis distribution between radio-loud and quiet subsamples should be expected from the present data, since most of the radio-loud objects show steep radio spectra, and the fraction of 'linear' sources among the data should be large. However, the data also points to an important difference between the NLR of broad- and narrow-line objects.

3.1.3 Line asymmetry

Analysing a smaller sample than the present one, HMG showed that radio-quiet AGN (and perhaps flat-spectrum radio sources as well) have a marked tendency to have the [O iii] \( \lambda 5007 \) line with an enhanced blue wing (positive \( A1x \) or \( Ax \) parameter). The same is not true for steep-spectrum radio-loud objects, in which no significant excess of blue-asymmetric lines is found. The two HMG subsamples differ at the 99 per cent confidence level.

![Figure 4. Asymmetry index \( A120 \) of [O iii] \( \lambda 5007 \) distributions. Q designates radio-quiet objects; S designates steep-spectrum radio-loud ones; F designates flat-spectrum ones.](image)

Fig. 4 shows the distribution of the asymmetry index \( A120 \) found in our sample. Although there still exists a greater number of radio-quiet objects with blue asymmetric lines, a significant number of them shows symmetric or red-asymmetric lines (60 against 18 objects). The hypothesis that both radio-loud and radio-quiet subsamples came from the same underlying population can be rejected, in this case, with only 90 per cent confidence.

The small subsample of flat-spectrum objects in the present work is the same as that used by HMG, so no new results were drawn for it. The \( A120 \) distribution was investigated also in terms of luminosity and AGN class, but no dependencies were found, in accordance with HMG.
3.2 HOST GALAXY INCLINATION

If some orientation with respect to a preferential axis exists in the geometric/dynamic configuration of the NLR, a question arises naturally: is there any tendency for this axis to be aligned with the host galaxy disc axis? This question was tackled firstly by HMBB and, using a greater number of objects, by WB. They searched for correlations between profile parameters and galaxy disc axial ratio \((b/a)\), with null results. Only a marginal correlation between line core width and \(b/a\) was found by WB. He interprets these results as an indication of one out of two possible cases: (i) if disc motion is important in the NLR, it is not aligned with the galaxy disc, or (ii) if an NLR disc is aligned with the galaxy plane, its contribution to the NLR velocity field must be small (50 per cent or less).

However, both of these studies relied on \(b/a\) values published by Keel (1980). A morphological study done by Kirhakos (1985) showed that only 43 out of the 93 objects in Keel's list can be unambiguously classified as unperturbed disc galaxies. Eight show only marginal evidence of discs, 20 have compact/stellar appearance or show signs of strong interaction, and 22 are indeterminate. Even considering that this last class might contain only distant or weak disc systems, at least 22 per cent of non-disc objects contaminate the sample. A more conservative figure, for the purposes of the present analysis, should count only the unambiguous and unperturbed disc systems, and these are only 46 per cent of the sample (55 per cent if including the marginal objects). A weak correlation, if existent, can be completely masked out by a contamination of this order.

Our profile sample contains 59 clearly discernible and undistorted, non-interacting disc galaxies, and also 6 systems probably pertaining to this class.* Since \(b/a\) measurement is strongly influenced by the presence of distortions on the galaxy disc, and also is more difficult in systems with smaller angular size and/or compact appearance, in which the presence of a disc might be questioned, we assume that only \(b/a\) values for those 65 systems in our sample are reliable, and the following results were obtained from them only. This could, however, lead to some bias, since there are indications that nuclear activity is related to galaxy interactions.

3.2.1 Linewidths

Using the sample as a whole, we cannot confirm the weak correlation found by WB between FWHM and \(b/a\). However, we found a significant correlation in the subsample comprised of broad-line objects (BLOs) with nuclear magnitude fainter than \(-22\) (Fig. 5a). The correlation is in the sense that edge-on objects have the broader lines, and have a formal linear correlation significance of 99.4 per cent (1-tail, 27 objects). The magnitude cut-off \(-22\) was chosen through maximization of this correlation probability. There is an indication that the slope is even stronger if we cut-off the sample at fainter magnitudes, but the number of objects becomes too small to draw firm conclusions. As a matter of fact, we cannot exclude the cut-off \(M_V = -23\), widely used as a formal separation criterion between Seyferts and QSOs, as the best value to be adopted. Also, the correlation still remains significant even if we remove the few extreme edge-on objects \((b/a < 0.4)\).

Narrow-line objects (NLOs), however, do not show the same behaviour (Fig. 5b). They may have a weak tendency to show the opposite trend: face-on objects have the broader lines. There are no objects in the NLO subsample brighter than \(M_V = -22.2\). Also, there are no indications that radio power at 1.4 GHz plays any role in this result.

The same trend as above is found for the core linewidth \(W'80\), but with greater scatter.

* Other morphological classes are represented in the sample by the following members: ellipticals - 4; peculiar - 3; stellar - 19; undetermined - 17; interacting - 3; not classified - 56 (usually systems with \(z > 0.05\)).
Figure 5. FWHM (∫ W 50) of [O iii]λ5007 against host galaxy axial radio; (a) broad-line objects, (b) narrow-line objects. Open symbols: objects less luminous than $M_v = -22$. Filled symbols: objects more luminous than $M_v = -22$. Symbol size depicts radio luminosity: small = radio quiet; big = radio loud. Curved line is least-squares fit of equation (1) to the low-luminosity objects. Triangle points to off-scale NGC 1068 (∫ W 50 = 1300 km s⁻¹).

($p_{1 - tail} = 99$ per cent, 23 objects). Greater relative errors introduced by finite spectral resolution and inadequate profile-measuring techniques may be responsible for the increased scatter. NLOs also do not show any correlation between W 80 and b/a.

For the line base width W 20 the correlation is weaker ($p_{1 - tail} = 95$ per cent, 22 objects). However, objects with b/a < 0.4 show a marked tendency to have broader lines.

The number of W 10 measures in our subsample of disc systems is insufficient to derive any conclusions about the extreme base of the lines.

We have searched also for correlations between the area parameters IPV and b/a. The number of objects is small (12 BLOs and 14 NLOs), and we found no correlations. This can be understood, however, if we remember that area parameters are more sensitive to line wings than simple width measures at a constant intensity level. As the correlation between width and b/a weakens with decreasing intensity level we should expect absence of correlation between b/a and parameters more sensitive to the profile wings.

Galaxy rotation may distort these results, however, if in a highly inclined system the spectrograph slit is put parallel to the galaxy major axis. H I regions in the galaxy inner disc, coupled with the disc rotation, could contaminate the emission line profile. In order to check this, we examined slit position angles relative to major axis position angles for all highly inclined systems in our sample (b/a < 0.5). In all of them the relative position difference is around
90° (± 10°), which shows that the data are relatively free of contamination by traditional galaxy rotation.

If we assume that the NLR velocity field (in BLOs) can be decomposed in turbulent and planar components, the observed line width can be expressed by (relation B2 of WA):
\[ V_0^2 = V_t^2 + (V_p \sin i)^2 \]  
(1)

where \( V_t \) and \( V_p \) measure the relative importance of the two components. A least-squares fit to the low-luminosity data (open symbols in Fig. 5a) gives values for \( V_p = 420 \ (± 10) \text{ km s}^{-1} \) and \( V_t = 50 \ (± 30) \text{ km s}^{-1} \). The curved line in Fig. 5(a) shows this fit. Even removing objects with \( b/a < 0.4 \) from the sample, we obtain \( V_p = 350 \text{ km s}^{-1} \) and \( V_t = 120 \text{ km s}^{-1} \).

These results are evidence that, at least in BLOs with low luminosity, a substantial component of the NLR velocity field may be co-aligned with the host galaxy plane.

3.2.2 Line asymmetry kurtosis

Figs 6 and 7 show the distribution of \( A120 \) and \( R_{20/50} \) as a function of host galaxy axial ratio. Although not showing any statistically significant relationship between the parameters, it is not yet possible to discard the hypothesis that edge-on BLOs (but not NLOs) may show a tendency for displaying more symmetric and Gaussian-like lines.

This result must be taken with caution, since so few edge-on objects have measured [O III] profiles. However, it is compatible with the facts pointed out in Section 3.2.1 if we assume that

![Figure 6](image-url)  
**Figure 6.** Profile asymmetry \( A120 \) of [O III] λ5007 against host galaxy axial ratio; (a) broad-line objects, (b) narrow-line objects. Open symbols: objects less luminous than \( M_r = -22 \). Filled symbols: objects more luminous than \( M_r = -22 \). Symbol size depicts radio luminosity: small - radio quiet; big - radio loud.
the nature of the planar velocity field in the NLR of BLOs is mainly rotational. More high-resolution data on edge-on Seyfert are needed to confirm this point.

3.3 Balmer Decrement

The idea that dust is an important ingredient in generating a typical AGN narrow-line region is an old one, and was initially proposed in order to explain anomalous (different from Case B recombination) Balmer decrements found in many AGN narrow-line regions. The discovery that [O iii]λ 5007 has a strong tendency to be asymmetric led HMBB to propose selective dust absorption coupled with radial motion as the mechanism to produce the observed asymmetries, in analogy with the BLR (Capriotti, Foltz & Byard 1979). Unfortunately, a possible correlation between the degree of line asymmetry and Balmer decrement (HMBB) was found to be a small-sample effect (WB), and the two parameters in fact do not correlate. On the other hand, the issue remains controversial, as Dahari & De Robertis (1988) found a correlation between asymmetry index and dust content. Since there is no other satisfactory explanation for the presence of strong asymmetries in the [O iii] line, the dust explanation was retained, despite the lack of unambiguous evidence for it.

We searched extensively in our sample for any correlation with narrow-line Balmer decrement. We found no correlation as regards linewidths (Wx and IPVx) and asymmetries
(AIX and AX), but the kurtosis parameter $R_{20/50}$ shows a good degree of correlation with Hα/Hβ (Fig. 8; Balmer decrements taken from Andrade 1986; see also Appendix A). Two objects in this sample have probably abnormally high Balmer decrements (NGC 2992 and NGC 5506) and are usually avoided in analysis of this kind (WB). Apart from the main trend, shared by 32 objects ($p_{-\text{tail}} = 99.6\,\text{per cent}$), there seems to be a small subset of high-kurtosis objects ($R_{20/50} > 2.4$): Mkn 279; Pic A; NGC 6890; Mkn 6; IC 5135, and NGC 5135. All of them share the same multi-component basic profile: a narrow core superimposed on a broad and intense base, sometimes shifted to the blue.

Fig. 8 also shows the importance of radio emission in NLOs, as regards the line kurtosis. Radio-loud NLOs effectively define the lower envelope of the correlation, suggesting that radio emission and dust are both involved in affecting the [O III] line in NLOs. In this case maybe it would be more reasonable to take into account only the correlation defined by the radio-quiet objects alone ($p_{-\text{tail}} = 99.97\,\text{per cent}, 21\,\text{objects}$).

A least-squares fit to the radio-quiet data in Fig. 8 (dot–dash line) predicts that an NLR without dust (Hα/Hβ ≈ 3) must show a Gaussian [O III] line profile.

Since the line shape can be changed, in the case of dust absorption, only by dust inside the emitting region, the above result shows unambiguously that there is dust associated with the NLR, and that the dust is affecting preferentially regions of low velocity (200–400 km s$^{-1}$ in ‘typical’ AGN). This is because the effect of dust on $R_{20/50}$ must be through absorption of low-velocity emission (W50), without affecting high-velocity emission (W20). Also, considering that the correlation is dominated by narrow-line objects, we see that in these ones the amount of NLR dust must be greater, on the mean, than in broad-line objects.

3.4 Host Galaxy Bulge

Wilson & Heckman (1985) showed a correlation between nuclear [O III] linewidth and velocity dispersion $\sigma$ of galaxy bulge stars. Also, Meurs & Wilson (1984) pointed out that radio emission may be correlated with bulge mass. These facts may indicate that the relationship linking linewidth and radio power, discussed in Section 3.1.1, is in fact a secondary one, being produced by a more fundamental relationship between the NLR gas velocity field and bulge gravitational field.

In order to gain some insight on this problem, we selected from our sample all spiral galaxies
with known Hubble-type subclassification. There are 24 objects with W50 measurements, 23 with W20 and 9 with W10, all of them distributed in classes Sa, Sab, Sb, Sbc and Sc. Since inclination may play a role in defining linewidth and shape, we do not take into account objects with $b/a < 0.4$.

Fig. 9 shows the dependency of the [O III] linewidth with host galaxy Hubble type, which is also a discriminant of relative bulge importance. As expected from the Wilson & Heckman (1985) results, more prominent bulges imply greater NLR gas velocities, at least in regions of low velocity (W50). The trend is remarkably smooth, if we disregard the only object classified as Sa-b (Mkn 766). A comparison between the W50 distributions of classes Sa-Sab and Sbc-Sc gives a 98.5 per cent confidence level (1-tail, 14 objects) for rejecting the hypothesis that W50 does not depend on spiral type. The base linewidth W20 does show the same general trend, but with less confidence (92 per cent), and the extreme base width W10 shows, if any, the inverse dependency.

This result shows that, if in fact the bulge gravitational field plays a role in defining the NLR velocity field, it influences only regions of low velocity. We cannot say anything definite, however, about the fundamental cause of line broadening (bulge mass or radio emission, see Section 3.1.1), since our data shows also a very marginal correlation between radio luminosity and Hubble type ($p_{1-tail} \sim 80$ per cent, 12 objects).

An alternative view, which must be taken into account when considering the present dataset, is to interpret the dependency between linewidth and Hubble type as a contamination effect. Since later-type spirals have more prominent H II regions, narrower lines in these types can be an effect of superposition, on the spectrograph slit, of a typical AGN profile with a narrow one
coming from H II regions. Long-slit resolved spectroscopy, and/or high-resolution profiles of other emission lines could help solve the problem.

If in fact bulge mass is the fundamental property governing the correlation, we can conclude that regions of high velocity (which define the line base width) are probably closer to the central source, and so relatively less influenced by the galaxy gravitational field, than regions of low velocity.

3.5 IRAS Fluxes

We searched for any possible correlation between [O III] $\lambda$5007 profile parameters and IRAS fluxes and colours. No correlations were found. This is not surprising, since at least in the Seyfert galaxies (which dominate the sample) disc dust and stars must make a significant contribution to the total IR emission, as compared with a non-thermal nuclear component. Also, the great difference in spatial sampling between IRAS and optical spectroscopy must play an important role in this context.

4 Discussion

The [O III] $\lambda$5007 linewidth, which is a measure of the overall high-ionization NLR velocity field, depends significantly on the nuclear radio and optical luminosities. Radio-loud nuclei have, on the mean, broader lines than radio-quiet ones. However, in the radio-loud nuclei the [O III] linewidth does not correlate with luminosity (optical and radio), whereas in radio-quiet nuclei there is a good correlation. This means that at least two independent mechanisms are responsible for broadening the NLR lines. One is dominant in radio-quiet objects, and the other takes over as radio emission becomes stronger. We note that cloud-accelerating mechanisms driven by radiation pressure, as proposed for the BLR clouds (e.g. Blumenthal & Mathews 1975), predict a $v \propto L^{1/2}$ dependency, much stronger than the one obtained for the data in Figs 1(b) and 2 ($v \propto L^{0.15}$). Other mechanisms, such as gravitational infall (Carroll & Kwan 1983) and wind entrainment (Krolik & Vrtilek 1984; Schiano 1986; Smith 1984; Mardaljevic, Raine & Smith 1986) also do not predict the dependency found in the present work. On the other hand, for radio-loud nuclei a mechanism that in some way decouples gas velocity from radio-emission processes is needed. Such a mechanism was already proposed for radio-quiet objects by Pedlar, Dyson & Unger (1985).

In low-luminosity BLOs, another mechanism to control line broadening seems to be at play: galaxy-disc inclination to the line-of-sight. This means that a planar component dominates effectively the NLR velocity field in these objects, contrary to previous results. The data are not sufficient, however, to distinguish unambiguously between rotational and radial movements. The result can be understood if we take into account the fact that a typical NLR is an object with size in the range $10^2$–$10^3$ pc, comparable at least with the galaxy-disc scale height. Any gas movements in its outer parts can easily be strongly influenced by the potential and angular momentum of the galaxy. This interpretation is consistent with the result that the linewidth dependency on inclination weakens out in the higher-velocity regions. What is more difficult to understand is the absence of this dependency in NLOs.

The correlation between mean linewidth and galaxy Hubble type also adds support to the above ideas.

As regards line asymmetry, we do not find any dependency between it and other nuclear or galactic properties. The line asymmetry, albeit a characteristics of AGN narrow lines, may not be a good diagnostic tool for probing the NLR velocity field. At best it indicates that radial
movements are present. However, models designed to explain line profiles must take into account that, contrary to previous results, a significant fraction (≈23 per cent) of the radio-quiet objects shows red asymmetric lines.

On the other hand, we found that line kurtosis depends strongly on some aspects of the nuclei. Presence of a BLR, radio luminosity and dust absorption, all play a role in defining the peakiness of the [O III] λ5007 line.

A scenario that could explain the kurtosis results can be constructed on the following grounds: a 'normal', dust-free NLR gives rise to a Gaussian profile (in what regards kurtosis only). Inclusion of dust in low-velocity regions produces peakier lines through the selective absorption of radiation coming from these regions. NLOs, being richer in dust, have peakier lines. Radio-emission mechanisms, on the contrary, through the ejection of nuclear matter at high velocities and in bipolar structures or shells, favour optical emission in the form of double-peaked lines, and the resulting convolved line profile becomes stubbier than a Gaussian (but see also remark below).

The interplay between these two mechanisms is sufficient to explain the observed trends, provided that we hypothesize the existence of some mechanism, imposed by the presence of the BLR, which effectively blocks the ejection of nuclear matter. This is necessary in order to explain the kurtosis distribution of radio-loud BLOs, indistinguishable from that of the radio-quiet ones.

A point that must be stressed, which follows from the preceding discussions, is the difference between the NLR velocity field found in BLOs and NLOs. Although some NLOs can be interpreted as obscured BLOs (Snijders, Netzer & Boksenberg 1986; Antonucci & Miller 1985), the results found in the present work are consistent with the idea that a substantial fraction of NLOs are intrinsically different from the BLOs.

5 Conclusions

In this work, we assembled a sample of AGN [O III] λ5007 high-resolution line profiles. Statistical analysis of this sample, complemented with other observational information, in part reproduced early results already obtained by other authors. However, the following new results were found in the present work:

(i) There exists a good correlation between line kurtosis and narrow Balmer decrement, showing unambiguously that there is dust inside the NLR. The dust seems to affect preferentially low-velocity regions, and probably localizes there.

(ii) Line kurtosis also depends strongly on the radio luminosity and presence of a BLR. Lines have a tendency to be more peaked than a Gaussian (a dust effect), but in the radio-loud narrow-line objects the lines are even stubbier than a Gaussian.

(iii) There exists a correlation between the line FWHM and host-galaxy inclination, showing the planar nature of the NLR velocity field. This happens, however, only in the low-luminosity broad-line objects.

(iv) Radio-quiet objects show a good correlation between line FWHM and optical/radio luminosity. This is not the case for the radio-loud ones, which on the mean have broader lines than the radio-quiet objects and show no trend between FWHM and luminosity.

(v) Late-type spirals have, on the mean, lines with narrower FWHM than early-type ones. The effect is absent at the line base, however. The effect could be due to the gas velocity being influenced by the bulge gravitational field.

(vi) About 25 per cent of the radio-quiet objects show lines with red asymmetry.
References

### Appendix A: Adopted narrow Balmer decrements (Andrade 1986) and axial ratios (Kirhakos 1985)

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