The relationship between $[\text{OIII}] \lambda 5007\text{Å}$ equivalent width and obscuration in AGN

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ABSTRACT

In this paper we study the relationship between the equivalent width (EW) of the $[\text{OIII}] \lambda 5007\text{Å}$ narrow emission line in AGN and the level of obscuration. To this end, we combine the results of a systematic spectral analysis, both in the optical and in the X-rays, on a statistically complete sample of $\sim 170$ X-ray selected AGN from the XMM-Newton Bright Serendipitous Source sample (XBS). We find that the observed large range of $[\text{OIII}] \lambda 5007\text{Å}$ equivalent widths observed in the sample (from a few Å up to 500 Å) is well explained as a combination of an intrinsic spread, probably due to the large range of covering factors of the Narrow Line Region, and the effect of absorption. The intrinsic spread is dominant for EW below 40-50 Å while absorption brings the values of EW up to $\sim 100-150$ Å for moderate levels of absorption ($A_V \sim 0.5-2$ mag) or up to $\sim 500$ Å for $A_V > 2$ mag. In this picture, the absorption has a significant impact on the observed EW also in type 1 AGN. Using numerical simulations we find that this model is able to reproduce the $[\text{OIII}] \lambda 5007\text{Å}$ EW distribution observed in the XBS sample and correctly predicts the shape of the EW distribution observed in the optically selected sample of QSO taken from the SDSS survey.

Key words: galaxies: active - galaxies: nuclei - quasars: emission lines

1 INTRODUCTION

The clouds of gas responsible for the narrow line emission in Active galactic Nuclei (AGN), the so-called Narrow Line Region (NLR), are supposed to be placed at large distances from the central source, typically from tens of pc to kpc, where the potential well of the supermassive black-hole (SMBH) is too weak to induce high velocity motion. Nevertheless, even at these large distances, the AGN emission is thought to be the main source of excitation for the NLR clouds (e.g. see Osterbrock 1989). The NLR is often considered as a good indicator of the isotropic emission of the AGN since it should reflect the intensity of the nuclear source independently from its orientation in respect to the line-of-sight. Forbidden emission lines, in particular, like the $[\text{OIII}] \lambda 5007\text{Å}$ are very important as they are not affected by the broad component produced in the Broad Line Region (BLR).

It is well known (e.g. Baskin & Laor 2005) that AGN show a large range of values (more than 2 orders of magnitude) of narrow line equivalent width (EW$^1$). This large spread has been usually interpreted in terms of different physical conditions of the NLR. The NLR covering factor, in particular, has been considered the main driver for the observed EW (Baskin & Laor 2005). However, other factors can affect the EW of the narrow emission lines. For instance, it has been recently proposed that the $[\text{OIII}] \lambda 5007\text{Å}$ EW in type 1 AGN could also be sensitive to the orientation of the accretion disk (Risaliti, Salvati & Marconi 2010). Another potentially important effect that can influence the value of EW is the absorption due to the molecular torus, postulated by the unified model (Antonucci 1993). Indeed, since this kind of absorption affects only the continuum emission and not the narrow emission line intensity, we expect a dependence of the observed EW with the amount of obscuration. The fact that Seyfert 2 galaxies typically have $[\text{OIII}] \lambda 5007\text{Å}$ with very large EW (up to 500 Å) supports this idea. Since moderate levels of absorption are often observed also in type 1 AGN (e.g. De Zotti & Gaskell 1985) it is possible that this effect is important for the global class of AGN and not just for the most absorbed ones.

In this paper, we want to quantify the importance of the absorption on the $[\text{OIII}] \lambda 5007\text{Å}$ EW in all classes of AGNs, including type 1 sources. To this end, we study the prop-

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$^1$ We define equivalent width as: $\text{EW} = \int \left( F_{\lambda}/F_C - 1 \right) d\lambda$ where $F_C$ and $F_\lambda$ are the continuum and total flux respectively. Please note that the continuum flux includes both the AGN and the host-galaxy flux.
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properties of the [OIII]λ5007Å emission line in a well-defined flux-limited sample of X-ray selected AGN extracted from the XMM-Newton Bright Serendipitous Sample (XBS, Della Ceca et al. 2004). The peculiarity of this sample is that, thanks to its relatively bright flux limit, the identification level is very high (>90%) thus reducing any possible bias related to the lack of some identifications. Furthermore, for all the AGN in the sample XMM-Newton X-ray data of medium/good quality are available and a complete and systematic spectral analysis has been already carried out (Coral et al. 2011), providing important pieces of information like the intrinsic hydrogen column density (N_H) and the de-absorbed X-ray luminosity. We are thus in the position of combining the [OIII]λ5007Å properties (EW, luminosity) with a measure (or an upper limit) of the level of absorption, from the X-ray data.

In Section 2 we describe the sample while in Section 3 we test whether the large spread of EW observed in the AGN of the XBS sample can be due to the intrinsic strength of the NLR. In Section 4 we study the impact of the obscuration on the observed [OIII]λ5007Å EW. In Section 5 we use numerical simulations to test in a quantitative way the hypothesis that the absorption has an important role on the observed EW of the [OIII]λ5007Å also in type 1 AGN. In Section 6 we compare the predictions of our models with those of the disk-orientation model. The conclusions are summarized in Section 7.

Throughout the paper we assume H_0=65 km s^{-1} Mpc^{-1}, Ω_Λ=0.7 and Ω_M=0.3.

2 THE XBS SAMPLE

The XMM-Newton Bright Serendipitous Survey (XBS survey, Della Ceca et al. 2004) is a wide-angle (∼28 sq. deg.) high Galactic latitude (|b| >20 deg) survey based on the XMM-Newton archival data. It is composed of two samples both flux-limited (∼7×10^{-14} erg cm^{-2} s^{-1}) in two separate energy bands: the "soft" 0.5-4.5 keV band (the BSS sample) and the hard 4.5-7.5 keV band (the HBSS sample). A total of 237 (211 for the HBSS sample) independent fields have been used to select 400 sources, 389 belonging to the BSS sample and 67 to the HBSS sample (56 sources are in common). The details on the fields selection strategy, the source selection criteria and the general properties of the 400 objects are discussed in Della Ceca et al. (2004).

One of the main goals of the survey is to provide a well-defined and statistically complete census of the AGN population with particular attention to the problem of obscuration. To this end, the possibility of comparing X-ray and optical spectra of good quality for all the sources present in the two complete samples offers a unique and fundamental tool to statistically study the effect of absorption in the AGN population in an unbiased way. Indeed, most of the X-ray sources of the XBS survey have been detected with enough counts to allow a reliable X-ray spectral analysis. The systematic analysis of the X-ray spectra of all the extragalactic sources is presented in Coral et al. (2011). At the same time, most of the sources have a relatively bright (R<22 mag) optical counterpart and they have been spectroscopically characterized using 4-meters-class telescopes. To date, the spectroscopic identification level has reached 92%.

The results of the spectroscopic campaigns are discussed in Caccianiga et al. (2007, 2008). In total, the XBS sample contains about 300 AGN out of which 169 have a redshift low enough (below ~0.7) to allow the sampling of the [OIII]λ5007Å emission line in the optical spectrum. This is the sample that we will analyse in the following sections. In Sections 3 and 4 we will use AGNs from both BSS and HBSS sample while, for the numerical simulations (Section 5) we will use only the AGN in the BSS in order to have a simple and clear selection method that is an important requirement for this type of analysis.

3 THE EFFECT OF THE INTRINSIC STRENGTH OF THE NLR

Consistently with what is observed in other AGN samples, among the XBS AGN we find a very wide range of [OIII]λ5007Å EW. Considering all types of AGN the observed values of EW range from a few Å up to ∼500Å. If we restrict the analysis just to the type 1 AGN the range is somewhat smaller (from a few Å up to ∼150Å) but still very broad. An intrinsic dispersion on the values of [OIII]λ5007Å EW is expected due to the variety of properties of the Narrow Line Region. For instance the NLR covering factor is a parameter that is expected to influence the strength of the narrow emission lines in respect to the AGN continuum emission, and therefore their equivalent widths (e.g. Osterbrock 1989; Baskin & Laor 2005).

In order to test the hypothesis that the observed EW spread is related to an intrinsically high luminosity of the NLR (in respect to the luminosity of the central source) we have searched for correlation between the [OIII]λ5007Å EW of the AGN and the [OIII]λ5007Å luminosity, normalized to the X-ray (de-absorbed) luminosity. The reason for using the de-absorbed X-ray luminosity as a reference is to have an independent indicator of the AGN luminosity, already corrected for the absorption2. As shown in Fig. 1 the [OIII]λ5007Å EW in type 1 AGN appears to be well correlated with the L[OIII]/L[2-10keV] ratio, at least up to EW∼50-60Å. This correlation is confirmed by a Spearman's rank correlation analysis (see Tab. 1). In principle, the observed correlation could be - at least in part - induced by the fact that both [OIII]λ5007Å EW and L[OIII]/L[2-10keV] ratio depend on the same quantity (L[OIII]). In order to test this possibility we have applied the partial correlation analysis (Kendall & Stuart 1979) that estimates the level of correlation between two variables excluding the effect of a third variable. We find that the correlation between [OIII]λ5007Å EW and L[OIII]/L[2-10keV] is still present although with a smaller significance (see Tab. 1).

On the contrary, if we consider only the type 2 AGN we do not observe any significant correlation.

These findings support the idea that the spread on the

2 We note that, in case of large column densities, N_H >10^{24} cm^{-2}, i.e. for the so-called Compton-thick AGNs, the computed X-ray luminosity could be strongly underestimated (of two orders of magnitude or more) since the absorption cut-off cannot be recognized in a 0.5-10 keV spectrum. However, using the available diagnostics we have shown in Coral et al. (2011) that no Compton-thick AGN candidate are present in the XBS sample.
In this section we want to analyse the dependence of the [OIII]λ5007Å EW with the level of absorption as derived from the X-rays. In Fig. 2, we report the values of [OIII]λ5007Å EW for all the AGN for which this line is covered versus the value of $N_H$ computed through the X-ray spectral analysis described in Corral et al. (2011). We have excluded from the plot the “elusive” AGN, i.e. the AGN whose spectrum is dominated by the light from the host galaxy making their classification difficult or impossible (see Caccianiga et al. 2007 for details). Even if with a great scatter, we observe a clear correlation (see Tab. 1) between the two parameters, with the absorbed [OIII]λ5007Å AGN showing the largest values of $[\text{OIII}]\lambda 5007\,\AA$ EW (from 50 to 500 Å) and the unabsorbed/“weakly” absorbed ($N_H < 4 \times 10^{21} \, \text{cm}^{-2}$) AGNs covering the lowest values (between a few Å up to ∼100Å). The two groups overlap mostly in the intermediate range of $N_H$ ($10^{21} \, \text{cm}^{-2}$ - $10^{22} \, \text{cm}^{-2}$). In agreement with what is expected from the unified schemes, the correlation also holds using the optical classification (see Caccianiga et al. 2008 for details) instead of $N_H$, i.e. the type 2 AGN show the largest values of $[\text{OIII}]\lambda 5007\,\AA$ EW while type 1 AGN show the lowest values. The good agreement between optical and X-ray “classification” observed in the XBS has been reported also previously (Corral et al. 2011; Caccianiga et al. 2004). Notably, the correlation between $[\text{OIII}]\lambda 5007\,\AA$ EW and $N_H$ still holds (although marginally) when considering separately type 1 and type 2 AGN while it disappears when we consider only the type 1 AGN without a significant absorption. This suggests that the effect of absorption could be relevant also within a single class of AGN.

The correlation observed between the $[\text{OIII}]\lambda 5007\,\AA$ EW and $N_H$/optical classification suggests a possible use of the $[\text{OIII}]\lambda 5007\,\AA$ EW as a simple proxy to classify a source as type 1/type 2 or unabsorbed/absorbed AGN. This may be very useful for the identification of faint sources in deep surveys. For instance, by adopting a limit on the EW of 100 Å type 1 and type 2 AGN, as well as unabsorbed/absorbed AGN, can be distinguished in our sample with a good level of reliability (>70%). The completeness, i.e. the capability of including most of the sources of a given class, is very high (80-90%) for type 1 and unabsorbed AGN while it is around 60% for type 2 and absorbed AGN. Moreover, if we include in the computation also the “elusive” AGN, i.e. sources whose optical spectrum is dominated by the host-galaxy, the capability of detecting type 2/absorbed AGN just using the $[\text{OIII}]\lambda 5007\,\AA$ EW decreases dramatically and the completeness falls down to ∼40%. Therefore, caution must be taken when using only the $[\text{OIII}]\lambda 5007\,\AA$ EW for the AGN classification.

4.1 The model

In order to better understand the trend observed in Fig. 2 we have adopted a simple spectral model, described in Sev-

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**Table 1.** Values of probability for two uncorrelated variables to give Spearman’s rank correlation coefficient greater than the observed one.

|                      | all    | Type 1 | Type 1 (low $N_H$) | Type 2 |
|----------------------|--------|--------|---------------------|--------|
| EW vs $L_{\text{OIII}}$/LX | <0.1%  | <0.1%  | <0.1%               | 25%    |
| EW vs $L_{\text{OIII}}$/LX (excluding $L_{\text{OIII}}$) | 0.6%   | 0.5%   | 0.5%               | 70%    |
| EW vs $N_H$          | <0.1%  | 8%     | 15%                | 3%     |

1 $N_H <10^{21} \, \text{cm}^{-2}$

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**Figure 1.** [OIII]λ5007Å equivalent widths of the type 1 AGN (filled points - blue in the electronic version) and type 2 AGN (triangles - red in the electronic version) in the XBS versus the [OIII]λ5007Å to X-rays luminosity ratio.

[OIII]λ5007Å EW in type 1 AGN is mainly due to the NLR that can have a large range of luminosities (up to 2 orders of magnitude) for a given AGN luminosity. The most obvious interpretation of this effect is that the covering factor of the NLR can vary significantly from source to source, as suggested by other authors (e.g. Baskin & Laor 2005; Risaliti, Salvati & Marconi 2010).

At the same time, the fact that the correlation is not found for type 2 AGN indicates that other effects are regulating the values of EW. In the case of type 2 AGN the most obvious explanation is the absorption that affects the intensity of the continuum. The fact that also in type 1 AGN the correlation seems to break down for EW larger than 40-50Å suggests that a similar mechanism could be at work also in this class of sources. In the next section we analyse in detail this hypothesis.

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3 In Caccianiga et al (2008) we have shown that the threshold $A_V=2$ mag, corresponding to $N_H=4 \times 10^{21} \, \text{cm}^{-2}$ for a Galactic gas-to-dust ratio, well matches the optical separation between type 1 and type 2 AGN.
This model uses an AGN template composed of two parts: a) the continuum with the broad emission lines and b) the narrow emission lines. According to the basic version of the AGN unified model, the first part can be absorbed while the second one is not affected by the presence of an obscuring medium. The AGN template is based on the data taken from Francis et al. (1991) and Elvis et al. (1994) while the extinction curve is taken from Cardelli, Clayton & Mathis (1989). The EW of the [OIII]λ5007Å emission line in the template is 15Å. Besides the AGN template, the spectral model includes also a galaxy template, produced on the basis of the Bruzual & Charlot (2003) models. In order to set an average relative intensity of the AGN in respect to the host galaxy we have computed the average value of the absolute magnitudes observed for the type 1 AGN considered here (<M_R>∼22.7) and assumed an average host-galaxy absolute magnitude equal to M_R(∼−21, Brown et al. 2001). Two values yield an expected average AGN/galaxy ratio at 4050Å (rest-frame) (η_{4050}) of ∼15. This parameter is expected to be very different, source by source, spanning more than 2 orders of magnitude (see discussion in Caccianiga et al. 2007). With the purpose of understanding the observed trend of Fig 2 we have fixed the AGN-to-host galaxy ratio to the expected average value. In principle, the value of η in the average optical spectrum should be higher than that estimated above because the spectrograph slit limits the amount of starlight from the host galaxy. However, at the average redshift of the sources considered here (<z>∼0.7) the slit width adopted for the observations (typically 1.5") corresponds to ∼10 kpc and, therefore, most of the starlight is probably falling into the aperture making this correction, on average, negligible.

We have then assumed different levels of N_H and, adopting the Galactic dust-to-gas ratio, we have derived the correspondent value of optical absorption, A_V, and applied it to the template. In Fig. 2, we plot the expected values of EW as a function of N_H. In the same figure we have also plotted the regions where we expect to find sources if the starting template has an intrinsic [OIII]λ5007Å EW within a factor 3 in respect to the adopted AGN template. The width of this region is based on the intrinsic distribution derived in the previous section and represents the expected range of EW before the effect of absorption. For clarity we have also plotted the binned version of Fig. 2 together with the model in a separate figure (Fig B).

Clearly, the “S-shaped” trend observed in the data points can be qualitatively reproduced by the model: for low values of N_H (<10^{21} cm^{-2}) the [OIII]λ5007Å EW is almost insensitive to the absorption and roughly equals the value adopted in the starting template; as the value of absorption increases, the [OIII]λ5007Å EW increases and “saturates” at high values (N_H >5×10^{22}-10^{23} cm^{-2}) due to the presence of the emission from the host-galaxy which becomes important as the absorbed AGN continuum gets weaker and weaker. In this case, the value of EW converges to the limit value set by the adopted AGN-to-host galaxy luminosity ratio and by the starting value of EW.

The evidences presented so far support a picture in which the [OIII]λ5007Å equivalent width is determined by a combination of intrinsic intensity of the NLR in respect to the continuum (for EW<40-50Å) and the effect of absorption (for EW>40-50Å). Notably, the effect of absorption is not important just for type 2 AGN but it seems to have an important role also for type 1 AGN. However, due to the limited sensitivity of the X-ray data to column densities of a few 10^{21} cm^{-2} or below (as shown by the range of upper limits in Fig. 2) it is difficult to test more quantitatively this picture through a direct comparison of the values of N_H. Besides, it is reasonable to expect that the relationship between optical and X-ray absorption has an intrinsic dispersion (see, for instance, Maiolino et al. 2001 and Maiolino, Marconi, & Oliva 2001) and, as a consequence, that the value of N_H can be used as an indicator of the optical absorption only in a statistical sense. If we split the sample of type 1 AGN in two groups with [OIII]λ5007Å EW larger or lower than 40Å and compute the average values of N_H (considering just the detections and excluding the source with very high column densities, >5×10^{22} cm^{-2}) we obtain a marginal (∼1.4σ) evidence that the type 1 AGN with large EW have also larger (< N_H >≈2.0±0.8×10^{21} cm^{-2}) column densities when compared to low-EW type 1 AGN (< N_H >≈0.9±0.2×10^{21} cm^{-2}).

In order to test more quantitatively this picture we have used a simple numerical simulation that we describe in the following section.

Figure 2. The [OIII]λ5007Å equivalent width of the AGN in the XBS sample versus the column densities derived from the X-ray data. Points (blue in the electronic version) and triangles (red in the electronic version) indicate, respectively, the AGN optically classified as type 1 and type 2. The dashed line represents the expected values of EW as a function of N_H according to the model described in the text assuming an AGN/galaxy luminosity ratio (at 4050Å) of 15 and an AGN template with [OIII]λ5007Å EW equal to 15Å. The grey area represents the expected value of EW when the starting value of [OIII]λ5007Å EW is within a factor 3 in respect to the value in the adopted AGN template.
5 NUMERICAL SIMULATIONS

The fact of that we measure the level of absorption from the X-rays and that there is an intrinsic dispersion between optical and X-ray absorption, prevents us to directly test, source by source, the idea that the absorption is relevant also in type 1 AGNs. We thus decide to approach the problem in a statistical way. If \( A_V \) and \( N_H \) are linearly correlated (although with an intrinsic dispersion) we expect that the \( A_V \) distribution statistically follows the distribution of \( N_H \). Therefore, even if we are not able to determine univocally the value of \( A_V \) of a single source, we can reasonably assume to know the distribution of \( A_V \) if we know the distribution of \( N_H \). Using this distribution, we now want to assess whether we are able to reproduce the observed distribution of EW.

As starting point we need a form for the intrinsic dispersion that, as explained in the previous sections, is likely to dominate the low tail of the EW distribution (<40\AA). To this end we have fitted the low tail of the observed EW distribution with a Gaussian profile peaked around EW=12\AA (a value very close to the one measured in the AGN template by Francis et al. 1991) and derived a sigma of ∼8\AA.

We then use the distribution of \( N_H \) observed in type 1 AGNs of the BSS sample (i.e. the one selected in the 0.5-4.5 keV band). Since, as said before, we have many upper limits on \( N_H \) in our sample we have used the method described in Avni et al. (1980) to derive the “real” \( N_H \) distribution. We have found that the distribution (in Log \( N_H \)) is best represented by two Gaussian, one peaked at Log \( N_H \)=20.15 cm\(^{-2}\) and \( \sigma=0.5 \) and one peaked at Log \( N_H \)=21.2 cm\(^{-2}\) and \( \sigma=0.35 \). The second Gaussian has a relative normalization of 0.44 times in respect the first one. As explained above, we assume that this distribution coincides with the distribution of \( A_V \), once converted using the Galactic dust-to-gas ratio. We then extract randomly one EW from the intrinsic distribution and one value of \( A_V \) from the \( A_V \) distribution and “absorb” the continuum below the line accordingly. Following our classification criteria, in the simulation we consider an AGN as type 1 only if the value of Log \( N_H \) is below 21.6.

In Fig. 4 we compare the simulated EW distribution for type 1 AGN with the one observed in the BSS sample. The good agreement is confirmed by an independent K-S test (probability >10\%).

It could be questioned that the (low) absorptions observed in type 1 AGN may be related (at least in part) to the host-galaxy and not to the molecular torus. This is a concrete possibility for values below 10\(^{21}\) cm\(^{-2}\). In this case, the effect of the absorption on the \([\text{OIII}]\lambda5007\) Å EW is less obvious. If the dust from the host galaxy influences equally both the continuum and the NLR emission then we expect that the net effect on the equivalent width of \([\text{OIII}]\lambda5007\) Å is null. Under this condition the model described here, that assumes a different effect of the absorption on the continuum and the emission line flux, cannot be applied. If, on the contrary, the host galaxy is not able to completely hide the NLR, as suggested by some studies (e.g. Keel 1980; De Zotti and Gaskell 1985), then we must expect a net effect on the \([\text{OIII}]\lambda5007\) Å EW similar to that predicted from the dusty torus.

As described above, the observed distribution of \( N_H \) in the type 1 AGN of the BSS sample is well described by two gaussians centered respectively to Log \( N_H \)=20.15 and 21.2 cm\(^{-2}\) and a relative normalization of ∼2:1. It is therefore possible that the first Gaussian is (mainly) due to the host-galaxy and that only the second one is produced by...
the torus. We have thus modified the simulations by assuming that only the second Gaussian has the effect on the [OIII] λ5007Å EW. We find that the results of the simulation do not change since only the high part of the \( N_H \) distribution (\( >10^{21} \text{ cm}^{-2} \)) has a relevant effect on the distribution of [OIII] λ5007Å EW.

We conclude that the observed high values of [OIII] λ5007Å EW (\( >40\AA \)) in type 1 AGN can be consistently explained as the result of the effect of a mild obscuration (\( 10^{21} \text{ cm}^{-2} < N_H < 4 \times 10^{21} \text{ cm}^{-2} \)) probably due to the molecular torus.

6 THE EFFECT OF DISK-ORIENTATION

In a recent paper, Risaliti, Salvati & Marconi (2010) have suggested that the distribution of [OIII] λ5007Å EW in type 1 AGN contains information on the orientation of the accretion disk in respect to the line-of-sight. Indeed, since the emission from a disk is not isotropic, the observed optical continuum is expected to decrease for large observing angles (in respect to the normal) while the line flux is supposed not to vary with the inclination. As a consequence, we expect a variation of the [OIII] λ5007Å EW with the accretion disk orientation. By means of a comparison between the [OIII] λ5007Å EW observed in a sample of \( \sim 6000 \) type 1 AGN of the SDSS and the results of numerical simulation, these authors have concluded that the values of EW between 40Å and \( \sim 100\AA \) are likely the consequence of disk-inclination effect while the values below 40Å are probably due to the intrinsic scatter related to the NLR geometry/covering factor. This result, if confirmed, would imply that the orientations of the molecular torus and of the disk are not coupled or that the torus opening angle is very large otherwise it would not be possible to observe high disk inclinations because of the presence of the obscuring medium. According to Risaliti, Salvati & Marconi (2010), the strong evidence for the disk-inclination model is the slope (\( \sim -3.5 \)) observed in the EW distribution above 40-50Å. This characteristic slope can be well reproduced by their numerical simulation if the effect of the presence of a flux/luminosity limit is taken into account.

In the previous sections we have presented evidences that the “tail” above 40Å of the [OIII] λ5007Å EW distribution in the type 1 AGN of the BSS sample could be due to the effect of the absorption (likely related to the molecular torus). It is thus interesting to evaluate if this effect can be important also for the SDSS sample. As explained in the previous section, the critical values of \( N_H \) are those above \( 10^{21} \text{ cm}^{-2} \). In principle it is not clear whether the selection criteria adopted in the SDSS sample have an impact on the \( N_H \) distribution, for type 1 AGN. Therefore, it is important first of all to check whether in the SDSS sample used by Risaliti, Salvati & Marconi (2010) there are sources with \( N_H > 10^{21} \text{ cm}^{-2} \). In Young, Elvis & Risaliti (2009) it is presented the X-ray analysis of a subsample of the SDSS quasar sample containing the sources falling serendipitously in XMM-Newton fields. Considering only the \( \sim 120 \) sources with redshift below 0.8 (to match the sample used by Risaliti, Salvati & Marconi 2010) we count 10 sources with a detected value of \( N_H > 10^{21} \text{ cm}^{-2} \) plus 26 sources with an upper limit on \( N_H \) above \( 10^{21} \text{ cm}^{-2} \). Therefore, the percentage of AGNs in the SDSS with \( N_H > 10^{21} \text{ cm}^{-2} \) ranges from 8% up to 30%. In the BSS sample we have estimated that the fraction of type 1 AGN with \( N_H > 10^{21} \text{ cm}^{-2} \) is similar (about 20%, taking into account the upper limits through the survival analysis). We thus expect that also in the SDSS sample the impact of the absorption on the [OIII] λ5007Å EW distribution is important. We now want to quantify this statement by using the numerical simulations described in the previous section. In particular, we want to see whether the slope of -3.5 observed in the SDSS sample can be similarly reproduced also by a model where the absorption, and not the disk-orientation, is the principal driver for the observed EW distribution.

The intrinsic distribution, important for both models below 40Å, has a different shape/parametrization in the BSS and the SDSS sample. As explained above we have used a single Gaussian centered at 12 Å and a \( \sigma=8\AA \) while Risaliti, Salvati & Marconi (2010) used two Gaussians. For consistency with the work by Risaliti, Salvati & Marconi (2010) we have adopted the same intrinsic distribution used in their paper. The second piece of information required to run the simulations is the observed distribution of \( N_H \). Since the fraction of type 1 AGN with \( N_H > 10^{21} \text{ cm}^{-2} \) is similar in the two sample it is reasonable to use the same \( N_H \) distribution derived from the BSS sample.

In Figure 5 we have reported the results of the simulations. As a reference, it is also plotted the slope -3.5 observed in the SDSS sample. It is clear that: 1) the presence...
of sources with large values of $N_H$ is expected to produce a significant tail of EW above 40-50Å and 2) the predicted slope for EW>40-50Å is consistent with the one observed in the SDSS sample. We conclude that the hypothesis that the absorption is the main driver for the observed EW of the [OIII]λ5007Å could be valid also for the SDSS sample of type 1 AGN. It is also possible that both absorption and disk-orientation effects co-exist in the same sample. In this case, in order to infer information on the disk inclination it is necessary to properly take into account the effect of absorption on the [OIII]λ5007Å EW.

7 SUMMARY AND CONCLUSIONS

We have studied the equivalent widths of the [OIII]λ5007Å narrow emission line in a sample of ∼170 X-ray selected AGN taken from the XMM-Newton Bright Survey. We have combined optical and X-ray information in order to understand the origin of the observed large range of [OIII]λ5007Å EW values (from a few Å up to 500Å) and, in particular, to quantify the importance of absorption. The main results can be summarized as follows:

- The values of EW correlate with the luminosity of the [OIII]λ5007Å normalized to the (de-absorbed) X-ray luminosity, at least up to EW∼40-50Å. This suggests that the values of [OIII]λ5007Å from ∼1Å up to 40-50Å are determined by the intrinsic strength of the NLR (related, for instance, to the NLR covering factor). Above EW=40-50Å the correlation does not hold anymore. In this range of EW we have both type 1 and type 2 AGNs.
  - We have found a strong dependence of the [OIII]λ5007Å EW with the absorbing column density, $N_H$, derived from the X-ray spectra. On average, sources with low values of $N_H$ ($<10^{21}$ cm$^{-2}$) present low average values of [OIII]λ5007Å EW (≈20Å) while sources presenting large column densities ($N_H > 10^{22}$ cm$^{-2}$) have the largest values of [OIII]λ5007Å EW (up to ∼500Å). This trend is well explained in the context of the AGN unified model, which postulates a connection between optical and X-ray absorption (due to the putative molecular torus): in this framework the increase of the [OIII]λ5007Å EW with $N_H$ is simply caused by the decrease of the optical continuum beneath the line due to its progressive obscuration. In this sense, the value of [OIII]λ5007Å EW is a rough indicator of the orientation of the AGN (in respect to the torus opening angle) and can be used as simple proxy for the optical/X-ray classification of an AGN (type1/type2 or unobscured/obscured AGN) although not very efficient in identifying all the type 2/absorbed AGNs (completeness level ∼40%).
  - By means of numerical simulations we have demonstrated that the observed distribution of [OIII]λ5007Å EW of type 1 AGN is well reproduced by combining an intrinsic distribution (a symmetric Gaussian centered at EW=12Å and a $\sigma$=8Å) with the distribution of absorption derived from the X-ray analysis. Therefore, we conclude that also in type 1 AGN the effect of absorption is important and produces [OIII]λ5007Å lines with large EW (between 40Å and 100Å).
  - The combination of intrinsic EW distribution and mild ($N_H$ of a few $10^{21}$ cm$^{-2}$) absorption seems to be a valid explanation also for what is observed in the SDSS sample considered by Risaliti, Salvati & Marconi (2010) and thus represents an alternative to the disk-inclination hypothesis, although we cannot exclude that both effects are at work in the sample.

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