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On the emission lines in active galactic nuclei with relativistic jets

Luigi Foschini

INAF – Osservatorio Astronomico di Brera, Via E. Bianchi 46, 23807, Merate (LC), Italy;
luigi.foschini@brera.inaf.it

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Abstract The effect of the observed continuum emitted from a relativistic jet on the measurement of the full width at half maximum (FWHM) of an emission line is analyzed. If the jet contribution is not properly subtracted, the FWHM of the line could seem narrower than it should. The cases of an emission line detected in BL Lac objects and γ-ray Narrow-Line Seyfert 1 galaxies (γ-NLS1s) are addressed. It is shown that the smallness of the observed FWHM of the Lyα lines detected in three well-known BL Lacs is an effect due to the combined action of both the relativistic jet and a weak accretion disk. Once the Doppler boosting effect of the jet continuum is removed, the intrinsic FWHM values of the lines are found to be in the usual range. By contrast, the narrow permitted lines in γ-NLS1s are really narrow, since the disk and the lines are much more powerful. This also confirms that γ-NLS1 is really a new class of γ-ray emitting AGN, different from blazars and radio galaxies.

Key words: line: profiles — galaxies: jets — BL Lacertae Objects: general — galaxies: Seyfert

1 INTRODUCTION

The recent detection by Stocke et al. (2011) of weak (equivalent width EW < 1 Å) and narrow (full width at half maximum FWHM $\sim 300 - 1000$ km s^{-1}) Lyα lines from three TeV BL Lac Objects (Mkn 421, Mkn 501, and PKS 2005$-$489) poses important questions about their spatial origin and how they are generated. Indeed, the FWHM is not only a measurement of the kinetic conditions of the plasma nearby the central singularity, but it is also an estimator of the black hole mass mainly through the reverberation mapping technique (Blandford & McKee 1982; Peterson et al. 1998; Wandel et al. 1999 and many more). Given the density and temperature conditions inferred from emission line measurements, the broadening due to thermal energy and turbulence does not make a significant impact (e.g. Netzer 1990; see however Foschini 2002). Therefore, the FWHM is mostly dependent on the bulk motion of the plasma and can be used to calculate the mass M of the black hole under the virial assumption

$$M = \frac{R \cdot f \cdot v^2_{\rm FWHM}}{G}\,, \tag{1}$$

where f is an unknown parameter linking the FWHM to the plasma bulk motion speed in the broad-line region (BLR, $v_{\rm BLR} = \sqrt{f} \cdot v_{\rm FWHM}$), R is the radius of the BLR and G is Newton's gravitational constant. In the most general case of a Keplerian motion in a spherical BLR, $f = 3/4$ (Netzer 1990),

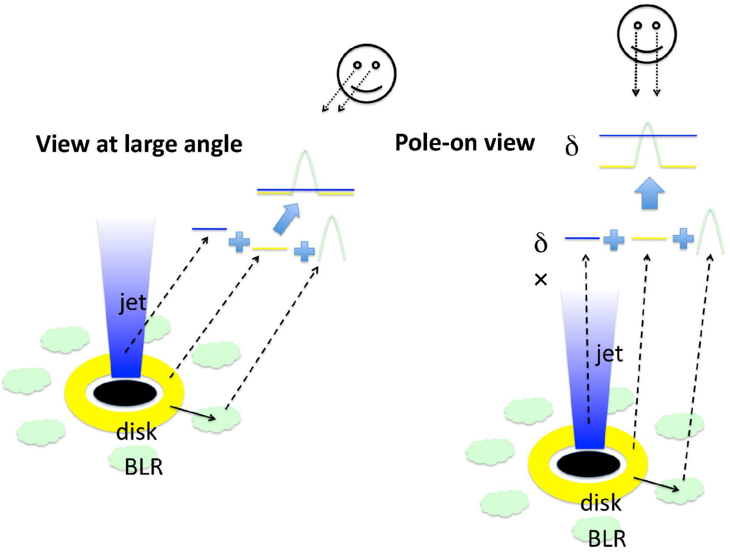

Fig. 1 Sketch (not to scale) of the emission components of AGN with a relativistic jet. (*Left*) View from large angles: the relativistic jet gives a small contribution to the observed continuum, because Doppler boosting is low. (*Right*) View from small angles: the effect of special relativity boosts the intrinsic continuum of the jet, which is now no longer negligible and can overwhelm the emission line, making it very difficult to measure its characteristics. If the observed jet contribution is not properly removed, then the FWHM of the line seems to be narrower than its real value.

while a disk-like BLR viewed with an angle Θ has $f = (4\sin^2\Theta)^{-1}$ (McLure & Dunlop 2002). Other values have been proposed, by taking into account systematic effects (e.g. Collin et al. 2006).

By means of statistical studies, several authors have found that broad lines emitted from AGN with relativistic jets have an FWHM a bit smaller than those from AGN with no jets (Wills & Browne 1986; Vestergaard et al. 2000; Jarvis & McLure 2006; Fine et al. 2011). Specifically, quasars whose radio emission is dominated by the core have the narrower lines and this is explained as an orientation effect and geometric shape of the BLR. Taking into account that core-dominated quasars (FSRQs) are viewed pole-on while lobe-dominated quasars are viewed at much larger angles; if the BLR has an equatorial disk-like shape, then the FWHM is smaller than in the case of a spherical BLR or if the source is viewed edge-on, because the kinetic component directed to the observer is missing or negligible.

In addition, Doppler boosting the intrinsic jet continuum can play an important role (see Fig. 1). It is reasonable to expect that there could be cases where the observed jet emission can overwhelm the line emission (blazars: pole-on view → small viewing angles → Doppler boosting), which in turn *seemingly* changes its FWHM. It is known that the functions adopted to fit the line emission profiles are self-similar (e.g. Gaussian), but if the continuum level is too high – and thus the EW is very small – then measurement of the FWHM could really give misleading results if the observed jet contribution is not properly taken into account.

The case of BL Lac reported by Corbett et al. (2000) is exemplary: depending on the observed jet continuum emission, the measured FWHM of the Hα line changed from 5050 km s^{-1} (1997 November 14) to 2030 km s^{-1} (1997 December 7) in about 24 days. The line disappeared at the maximum observed continuum flux on 1997 June 27 (see table 2, figs. 2 and 3 of Corbett et al. 2000).

Although the jet and the line emission are correlated, they are not physically linked, as also stated by Corbett et al. themselves. It is possible to prove this by *reductio ad absurdum*. Let us make the hypothesis that the measured changes in the FWHM are real and not due to measurement problems caused by the high observed continuum. This means that the bulk motion of the BLR is changed. By assuming a mass of the central black hole of BL Lac to be $5 \times 10^8\ M_\odot$ (Ghisellini et al. 2010) and by adopting the virial factor f of McLure & Dunlop (2002) calculated with an angle $\Theta = 3°$, then it is possible to estimate the radius of the BLR to be 2.7×10^{15} cm in the case of FWHM $= 5050$ km s^{-1} and 1.7×10^{16} cm in the case of FWHM $= 2030$ km s^{-1}. This would mean that the BLR size changed by about one order of magnitude in less than one month, which is not reliable, because it requires that the plasma of the whole BLR should have had an outward radial motion on the order of $0.2c$. Such a massive outflow needs a much stronger disk to be produced than that available in BL Lac (cf. Pounds & Page 2004). Therefore, the simplest possibility (*lex parsimoniae*) is to think that the observed changes are not real, but due to the superimposed boosted continuum from the relativistic jet, which was not properly taken into account. It is worth emphasizing that the key issue is the time scale: indeed, significant changes of the FWHM have been observed in AGN without jets and are thought to be due to real dynamical changes (e.g. Wanders & Peterson 1996). However, in the latter case, the time scale is of the order of years and not a few tens of days as for BL Lac.

The main aim of this work is to find a suitable correction to apply to the FWHM when it is not possible to properly subtract the observed jet continuum, because of the weakness of the line. It is shown that when the observed jet contribution is removed, then the real FWHM of these lines is in the usual range expected from broad permitted lines and is no longer correlated with the increase or decrease of the observed jet emission. Therefore, their narrowness is just an observational effect due to the jet's Doppler boosting. The basic concepts are explained in Section 2, while specific application to the case of BL Lac objects and $\gamma-$NLS1s are dealt with in Sections 3 and 4, respectively. Some final remarks in Section 5 conclude the work.

2 BASIC CONCEPTS

The BLR is ionized by the ultraviolet photons of the accretion disk and therefore the emission line flux variability is dependent on the accretion disk's power (reverberation mapping, Blandford & McKee 1982). The relativistic jet has a negligible impact on generating lines, and hence on their variability, because its radiation is strongly beamed within a small angle ($\theta \sim \Gamma^{-1}$, where Γ is the bulk Lorentz factor) in a direction almost perpendicular to the disk plane. Although the jet and the disk are believed to be somehow connected (e.g. Ghisellini & Tavecchio 2008), their time scales are different, because the physical mechanisms at work are different. Therefore, the emission lines flux variability is generally unrelated to the changes in the jet emission, as shown by the case of BL Lac (Corbett et al. 2000). This means that – on short time scales – even if the line holds its flux and profile, the observed continuum can increase because of the changes in the jet's Doppler boosting (which in turn does not affect the line), thus reducing the line's EW, but also seemingly its FWHM (Fig. 1).

It is important to stress this point: the line flux is strictly linked to the disk's power (reverberation mapping, Blandford & McKee 1982) and, therefore, a change in the disk continuum results in a change of line flux. The intrinsic FWHM does not change on short time scales, since it is an indication of the Keplerian motion of the BLR plasma[1]. When a relativistic jet is present, we are observing a Doppler-boosted continuum superimposed on the disk continuum (Fig. 1). Its beamed flux can surpass the disk and line fluxes (which are not boosted), resulting in a *seeming change* of the observed FWHM of the line. It is worth noting once again that the intrinsic properties of the line

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[1] Since the thermal broadening is negligible when compared to the bulk motion, a change in disk luminosity has no impact on the line profile. Dynamical changes, implying there are variations of the line profile, occur on much longer time scales (e.g. Wanders & Peterson 1996).

remain stable on the jet time scale, because of their dependence on disk power and the bulk motion of the BLR (see Fig. 1).

To calculate the order of magnitude of the involved effects, let us first consider AGN with a jet viewed at large angles, so that the effects of special relativity are negligible (Fig. 1, left panel). There is the accretion disk generating an ionizing continuum and the emission lines of the BLR, which can be described by a Gaussian profile with width σ. It is well-known that the intrinsic FWHM is related to σ by

$$\mathrm{FWHM}_{\mathrm{int}} = 2\sigma\sqrt{2\cdot\Big(-\ln\frac{1}{2}\Big)} \sim 2.35\sigma\,. \tag{2}$$

Roughly speaking, the ratio between the line luminosity and the continuum is the EW

$$\mathrm{EW} \sim L_{\mathrm{line}}/L_{\mathrm{cont}}\,, \tag{3}$$

where L_{cont} is integrated in a proper frequency range around the line frequency and is composed of a disk and a jet contribution ($L_{\mathrm{cont}} = L_{\mathrm{disk}} + L_{\mathrm{jet}}$). The two contributions could attain their maximum values with the same order of magnitude (Rawlings & Saunders 1991; Ghisellini et al. 2010, particularly see fig. 6).

When the jet viewing angle ϑ is small, then special relativity significantly affects the radiative output (Fig. 1, right panel). Jet luminosity is amplified by a factor of δ^4 in the case of a spherical blob or δ^3 for a steady jet, where $\delta = [\Gamma(1-\beta\cos\vartheta)]^{-1}$ is the Doppler factor and $\beta = v/c$. When compared to the accretion disk luminosity, the latter is overwhelmed. Such “intrusive” presence has the effect of altering the observed characteristics of the emission lines, because the observed continuum is now dominated by the boosted emission of the jet. Obviously, there could be different grades of being overwhelmed, basically depending on two different factors: the strength of the accretion disk and the frequency of the synchrotron peak. FSRQs have strong disks and low peak frequencies (optical/IR): therefore, the jet only overwhelms the disk and the lines during intense outbursts. BL Lac objects have weak disks and the synchrotron emission peaks at UV frequencies; therefore, the jet always dominates the disk and the lines.

Presently, it is important to focus on the basic concept: when the boosted jet continuum is superimposed, the observed FWHM could not match the intrinsic one. More generally, the observed FWHM will be equivalent to that measured at some fraction q of the flux

$$\mathrm{FWHM}_{\mathrm{obs}} = 2\sigma\sqrt{2\cdot(-\ln q)}, \tag{4}$$

with $1/2 < q < 1$. The ratio between FWHM$_{\mathrm{int}}$ and FWHM$_{\mathrm{obs}}$ can be evaluated by imposing the equivalence of σ (i.e. the line is the same and is constant) in Equations (2)–(4)

$$\frac{\mathrm{FWHM}_{\mathrm{int}}}{\mathrm{FWHM}_{\mathrm{obs}}} = \frac{\sqrt{\ln 2}}{\sqrt{-\ln q}}\,. \tag{5}$$

It is necessary to find a suitable expression of q that indicates the level of the observed jet contribution with respect to the line peak flux (fraction of the maximum flux). If one knows the Doppler factor δ from other methods (e.g. by modeling the spectral energy distribution – SED), then it is sufficient to perform a correction of the continuum. Instead, in this work, I would like to study the possibility of using the equivalent width (EW) of the line.

Indeed, the boosted jet continuum also alters the EW; the intrinsic jet continuum is boosted by δ^4, if the jet can be modeled as a spherical blob, while the disk luminosity – not boosted – is overwhelmed by the jet and therefore it can be neglected. The observed continuum is dominated by the jet: $L_{\mathrm{cont}} = L_{\mathrm{disk}} + \delta^4 L_{\mathrm{jet}} \sim \delta^4 L_{\mathrm{jet}}$. Compared to the unbeamed case above, it is evident that the ratio of the two continua is dominated by the Doppler factor

$$\frac{\mathrm{EW}_{\mathrm{obs}}}{\mathrm{EW}_{\mathrm{exp}}} = \frac{L_{\mathrm{line}}}{(L_{\mathrm{disk}} + \delta^4 L_{\mathrm{jet}})}\frac{(L_{\mathrm{disk}} + L_{\mathrm{jet}})}{L_{\mathrm{line}}} \sim \frac{1}{\delta^4} \tag{6}$$

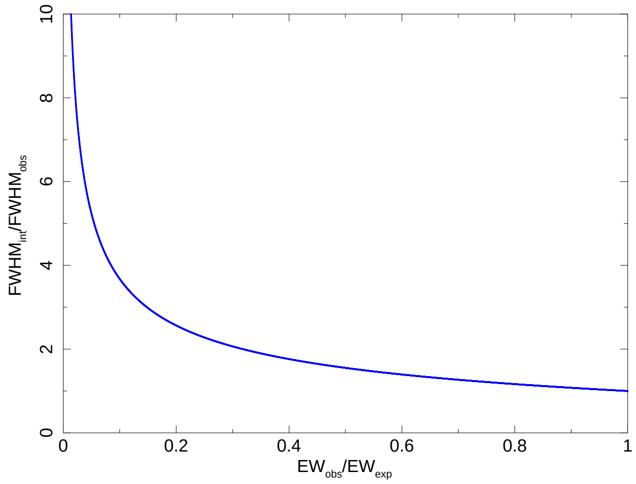

Fig. 2 $\mathrm{FWHM_{int}/FWHM_{obs}}$ ratio as a function of the $\mathrm{EW_{obs}/EW_{exp}}$ ratio.

and, consequently, the observed EW is reduced by a factor of δ^4. Therefore, it is possible to use the ratio between the observed EW ($\mathrm{EW_{obs}}$) and the expected value in the case of absent or negligible jet contribution ($\mathrm{EW_{exp}}$) to bypass the direct knowledge of δ.

We can summarize a few words on the factor δ^4: As is known, this is for the case of a spherical blob. In the case of a steady jet, the factor is δ^3. This has no impact either on the above assumptions or on the calculation of the correction factor for the FWHM (see below), because it is just based on the ratio between the observed and expected EW; it has an impact on the value of δ that can be calculated from this ratio.

When inserting the EW ratio in q, it is necessary to take into account that $q = 1/2$ if $\mathrm{EW_{obs}} = \mathrm{EW_{exp}}$ (i.e. $\mathrm{FWHM_{int}} = \mathrm{FWHM_{obs}}$) and $q \to 1$ when $\mathrm{EW_{obs}} \ll \mathrm{EW_{exp}}$. One possible function satisfying the necessary constraints is (though other functions cannot be excluded)

$$q = 1 - \frac{\mathrm{EW_{obs}}}{2\mathrm{EW_{exp}}} \,. \tag{7}$$

Therefore, by substituting Equation (7) in Equation (5), it gives

$$\mathrm{FWHM_{int}} = \mathrm{FWHM_{obs}} \frac{\sqrt{\ln 2}}{\sqrt{-\ln(1 - \frac{\mathrm{EW_{obs}}}{2\mathrm{EW_{exp}}})}} \,. \tag{8}$$

As displayed in Figure 2, when $\mathrm{EW_{obs}} \to \mathrm{EW_{exp}}$ the correction is progressively more negligible and unnecessary, since the direct measurement already gives a value consistent with the intrinsic one. The correction is roughly a factor of 2 when $\mathrm{EW_{obs}}$ is about 30% of $\mathrm{EW_{exp}}$. The smaller the ratio is, the larger the correction will be.

To make an immediate example, I apply this correction to the measurements of the Hα line of BL Lac reported by Corbett et al. (2000). The authors themselves noted that the measured changes in the FWHM are biased by the high level of continuum due to the jet, and the intrinsic profile of the line should remain almost constant. However, they did not attempt any correction and the fit of the original $\mathrm{FWHM_{obs}}$ measured by Corbett et al. (2000) to a constant value of FWHM gives a reduced χ^2 equal to 20.1 (i.e. not consistent with a constant value). To apply Equation (8), I adopt $\mathrm{EW_{exp}}$ =18 Å, which only refers to the Hα broad component (Constantin & Shields 2003). It results

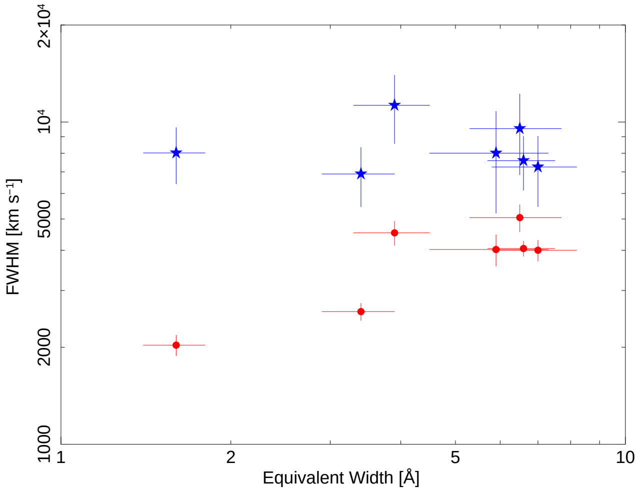

Fig. 3 FWHM vs. EW of BL Lac. The red circles are the measurements ($\mathrm{FWHM_{obs}}$) by Corbett et al. (2000), while the blue stars are the measurements corrected for the jet contribution ($\mathrm{FWHM_{int}}$) (*color online*). It is immediately evident that the red circles indicate a narrower $\mathrm{FWHM_{obs}}$ as the EW decreases (i.e. the observed jet contribution increases), while the corrected values ($\mathrm{FWHM_{int}}$) are no longer dependent on the EW.

immediately in a *broader* and *constant* $\mathrm{FWHM_{int}}$ (Fig. 3). The intrinsic FWHM, calculated as the weighted average of the corrected values, is 7857 ± 1208 km s^{-1} and the reduced χ^2 test for the variability of the $\mathrm{FWHM_{int}}$ vs. EW now gives 0.43 (i.e. it is consistent with a constant value).

3 APPLICATION TO BL LAC OBJECTS

Stocke et al. (2011) recently reported the detection of very weak (EW < 1 Å) Lyα emission lines from three well-known TeV BL Lac objects: Mkn 421 ($z = 0.030$), PKS 2005−489 ($z = 0.071$) and Mkn 501 ($z = 0.0337$). Since Lyα lines are thought to be produced in the BLR, FWHM values of several thousands of km s^{-1} are expected (masses of BL Lacs are $\sim 10^8 - 10^9\ M_\odot$). Instead, Stocke et al. (2011) found values for the Lyα FWHM of 300, 1050, and 820 km s^{-1} respectively, for the three blazars. They suggested different possible explanations based on the covering factor of the BLR, the ionization power, or that the emitting plasma is located far away from the black hole, at distances in excess of 10 pc (i.e. in the narrow line region). Another possible explanation is that if these FWHMs are indeed small and produced in the BLR, this would imply small masses for these BL Lacs, with many important consequences. Or – this is indeed what I am going to prove – the lines are broad, with FWHM values within the usual range, but they are observed to be narrow because of the presence of the jet emission. This is something similar to the case of the BL Lac analyzed in Section 2, although more extreme.

The values of the EW measured by Stocke et al. (2011) in the case of the three BL Lacs are on the order of tens/hundreds of mÅ, much lower than the average values of $40 - 100$ Å, found in other types of AGN (Vanden Berk et al. 2001; Telfer et al. 2002; Constantin & Shields 2003; Bachev et al. 2004; Pian et al. 2005; Gavignaud et al. 2006). Stocke et al. (2011) made the hypothesis that the ionizing radiation generating the Lyα is provided by the jet, because it is commonly thought that the disk of BL Lac Objects is inefficient, an advection-dominated accretion flow. However, although the disk could have low luminosity, it is likely *not* in an advection-dominated regime yet. Elitzur

Table 1 Summary of the observed quantities of the Lyman α line: $L_{\mathrm{Ly}\alpha}$ [10^{41} erg s^{-1}], EW$_{\mathrm{obs}}$ [Å] and FWHM$_{\mathrm{obs}}$ [km s^{-1}] from Stocke et al. (2011), with the corresponding calculated FWHM$_{\mathrm{int}}$ [km s^{-1}] and Doppler factors for beaming, according to the procedure outlined in this work and having considered EW$_{\mathrm{exp}} = 40 - 100$ Å. The size of the BLR is in units of [10^{15} cm]. The mass M is calculated with f proposed by McLure & Dunlop (2002) and assuming a viewing angle of 3°.

Source	$L_{\mathrm{Ly}\alpha}$	EW$_{\mathrm{obs}}$	FWHM$_{\mathrm{obs}}$	FWHM$_{\mathrm{int}}$	δ	R_{BLR}	log $M/M_{\odot}$
Mkn 421	0.24	0.076	300	8122–12812	4.8–6.0	1.5	8.8–9.2
Mkn 501	0.52	0.830	820	6702–10586	2.6–3.3	2.3	8.8–9.2
2005$-$489	2.49	0.467	1050	11453–18080	3.0–3.8	5.0	9.6–10.0

& Ho (2009) suggested that the BLR vanishes (which in turn occurs when the disk is radiatively inefficient) when the disk power is below a critical value

$$L_{\mathrm{crit}} = 5 \times 10^{39} \left(\frac{M}{10^{7} M_{\odot}} \right)^{2/3} \mathrm{erg\ s^{-1}} \, . \tag{9}$$

By considering masses for Mkn 421, Mkn 501, and PKS 2005$-$489 with values of 4×10^{8}, 10^{9}, and 4×10^{8} $M_{\odot}$, respectively (from Wagner 2008), then the critical disk luminosities for the disappearance of the BLR are 6×10^{40}, 10^{41}, and 6×10^{40} erg s^{-1}, respectively. These values are comparable with the luminosities of the Lyα lines observed by Stocke et al. (2011), which are: 2.4×10^{40}, 5.2×10^{40}, and 2.5×10^{41} erg s^{-1} for Mkn 421, Mkn 501, and PKS 2005$-$489, respectively. Therefore, since the disk must have a greater luminosity – say at least one order of magnitude greater taking into account the covering factor (e.g. Netzer 1990) – to generate such lines, it results that the disks of these three BL Lac objects are still powerful enough to be considered in the standard regime.

These BL Lacs have line and disk luminosities that are $3-4$ orders of magnitude smaller than the average among powerful blazars ($\langle L_{\mathrm{Ly}\alpha} \rangle = 10^{44} - 10^{45}$ erg s^{-1}, see Pian et al. 2005), but are still similar to the latter, i.e. the disk is still standard and not dominated by the advection. This is in agreement with the findings of Maoz (2007) and Pian et al. (2010), according to which the low luminosity AGN have accretion disks similar to their more luminous Seyfert cousins and therefore replicate the same patterns, but at lower fluxes. This also supports the use of the EW in calculating the real FWHM of BL Lacs: the disk and line are the same as those in powerful blazars, but scaled down to low luminosities, although still in a standard disk regime. It is reasonable to think that the EW remains more or less the same along several orders of magnitude of disk and line luminosities.

Therefore, from the ratio of EW$_{\mathrm{obs}}$/EW$_{\mathrm{exp}}$, it is possible to estimate the real FWHM$_{\mathrm{int}}$ and the Doppler factor δ necessary to increase the continuum in order to reach the observed EW, under the hypothesis that the line remains almost constant during the changes of the jet emission. The results are summarized in Table 1. The FWHM$_{\mathrm{int}}$ values are now typical of lines from a BLR and the Doppler factors, although lower than the values obtained by Stocke et al. (2011), are more consistent with the relatively low activity of the jet during observations. Indeed, no outbursts have been reported in the days of the measurements and, perhaps, this is the reason for which it was possible to detect these weak lines. The SEDs of these three blazars reported by Tavecchio et al. (2010) indicate that when the jet is active, its ultraviolet luminosity can even surpass the observed Lyα power, resulting in an observed featureless spectrum.

As for an additional check, it is now possible to calculate the masses of the central black holes. The radius of the BLR can be estimated by the relationship (Ghisellini & Tavecchio 2008)

$$R_{\mathrm{BLR}} = 10^{17} \sqrt{\frac{L_{\mathrm{disk}}}{10^{45}\,\mathrm{erg\ s^{-1}}}}\,\mathrm{cm} \tag{10}$$

and by assuming a disk luminosity of about one order of magnitude greater than the Lyα power (e.g. Netzer 1990). Given the low luminosity of the disk, the radius of the BLR is much smaller than in powerful blazars and, despite the correction on the FWHM, the mass calculated by Equation (1) and $f = 1$ resulted in a value two orders of magnitude smaller than the quantities measured using other methods (cf. Wagner 2008). By considering a disk-like BLR and an almost pole-on orientation ($\Theta = 3^\circ$, see Ghisellini et al. 2010), the value of f as proposed by McLure & Dunlop (2002) results in a factor $f = (4\sin^2\Theta)^{-1} \sim 90$. The masses are now consistent with the other values reported by Wagner (2008). The results are summarized in Table 1.

4 THE CASE OF NARROW-LINE SEYFERT 1 GALAXIES

In light of the considerations exposed above, one could ask if the narrow permitted lines of γ-NLS1 (see Foschini 2011 for a review) are really narrow or if they are an effect of the presence of the jet, as in the case of BL Lacs mentioned above. The latter option is likely to be easily discarded, as the disk of γ-NLS1 is much more powerful than that of BL Lacs, similar to FSRQs, and hence the lines are more prominent and easier to measure. However, it is a case worth checking, because if there is a possibility that the lines are only seemingly narrow, then this new class of γ-ray emitting AGN would be reconciled with the common knowledge on blazars and radio galaxies (and therefore would no longer be a new class of γ-ray AGN).

There are a few data available on these γ-NLS1s, but one of them – PMN J0948+0022 – has been the target of two multiwavelength campaigns in 2009 (Abdo et al. 2009a) and 2010 (Foschini et al. 2011). Therefore, I will study this case as an archetypical example of this new class.

PMN J0948+0022 ($z = 0.585$) was recognized as an anomalous NLS1 by Zhou et al. (2003), who discovered its characteristics together with a strong radio emission and a flat spectrum, which in turn suggested the presence of a relativistic jet viewed at small angles (see also Yuan et al. 2008). This specific source was the first of this class to be detected by high-energy γ rays by means of *Fermi*/LAT (Abdo et al. 2009b; Foschini et al. 2010).

The optical spectrum was measured by the Sloan Digital Sky Survey (SDSS[2]) on two different days (2000 February 28 – MJD 51602; 2000 March 27 – MJD 51630). Both observations resulted in faint $ugriz$ magnitudes ($\sim 18-19$). The Hβ line has an almost constant σ: 12.9 ± 0.8 Å on MJD 51602 and 12.8 ± 0.5 Å on MJD 51630, while the EW changes slightly, from 16.1 ± 0.8 Å (MJD 51602) to 21.5 ± 0.7 Å (MJD 51630).

During the 2009 MW Campaign, the optical flux dropped in the period 2009 May $5-15$ and also changed the slope (see fig. 12 in Abdo et al. 2009a), indicating changes in synchrotron emission. Given the redshift of $z = 0.585$, the Hβ line is at ~ 7705 Å, which is between the R and I filters. Therefore, I calculated the flux densities of these two filters from the SDSS (2000), from the continuum below the Hβ line and in 2009 early/mid May (MW Campaign). The results are displayed in Table 2.

It is evident that the measurement of the FWHM (Zhou et al. 2003; Yuan et al. 2008) has been done in a period of low continuum flux, i.e. with low jet activity. The period of relatively low jet flux measured during the 2009 MW Campaign is slightly greater and, during high flux, the values are greater by a factor of $3-4$. As given in Section 2, the FWHM of the line becomes narrower when the jet continuum increases, but in this case the measurement has been done with the lowest contribution from the jet. Therefore, this is really an NLS1 and the jet activity can only make the line narrower.

In addition, it is worth noting that the disk power of NLS1s is much greater than that of BL Lac objects and, hence, the lines are also much more luminous: a situation similar to that of BL Lacs could only occur during exceptional outbursts. The flux density of the line as measured by SDSS is $\sim 1.8 \times 10^{-16}$ erg cm^{-2} s^{-1} Å^{-1}. By comparing this value with f_I and f_R in the period of high flux (MJD 54956), it is clear that the jet activity literally surpassed the Hβ emission line flux by a factor

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[2] *http://www.sdss.org/*

Table 2 PMN J0948+0022: comparison of flux densities [in units of 10^{-16} erg cm^{-2} s^{-1} Å^{-1}] as measured in 2000 by the SDSS (MJD 51602/51630) and in 2009 during the MW Campaign. Here $f_{\rm cont}$ indicates the continuum at 7705 Å as measured from the SDSS spectrum (average of the two observations), and f_I and f_R are the flux densities in the I and R bands, respectively. In the case of SDSS, the conversion from $ugriz$ to $UBVRI$ has been done according to Chonis & Gaskell (2008). In the case of the 2009 MW Campaign the f_I has been extrapolated from B and R fluxes. All the fluxes have been dereddened by using $N_{\rm H} = 5.22 \times 10^{20}$ cm^{-2} (Kalberla et al. 2005) and standard extinction laws (Cardelli et al. 1989).

Period	$f_{\rm cont}$	f_I	f_R
51602/51630	1.1	0.8	1.1
54956		2.9	4.0
54966		1.2	1.8

of ~ 2. During the 2009 MW Campaign, the source displayed some activity, but is negligible when compared with the more prominent outburst observed in 2010 (Foschini et al. 2011). It is therefore reasonable to think that when the jet is very active, the optical spectrum of PMN J0948+0022 could become featureless. This could be verified with an MW campaign, but with optical instruments set to acquire spectra instead of photometry.

5 CONCLUSIONS

In this work, I have studied the effect of a relativistic jet on the emission line profiles in the cases of BL Lac objects and γ-ray Narrow-Line Seyfert 1 galaxies. In the former case, it is shown that the smallness of the observed FWHM of the Lyα lines, detected by Stocke et al. (2011) in three BL Lacs, is an effect due to the combined action of both the relativistic jet and a low luminosity accretion disk. Once the Doppler boosting of the jet continuum is removed, the intrinsic FWHM values of the lines are found to be in the range expected in a BLR.

By contrast, in the latter case – narrow permitted lines in γ-NLS1s – it is shown that these lines are really narrow, since the disk and the lines are much more powerful and the measurements of their FWHM values were done during periods of low jet activity. Therefore, it is confirmed that γ-NLS1 is really a new class of γ-ray emitting AGN, different from blazars and radio galaxies.

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