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Narrow-Line Seyfert 1s: a luminosity dependent definition

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Do sources equivalent to Narrow Line Seyfert 1s in the local Universe exist at high luminosity? The answer is "yes." A fraction of quasars at $z \sim 3$ show rest frame UV spectra that bear a striking resemblance to the one of the NLSy1 prototype I Zw 1. We derive their physical properties, and found them consistent with the ones of I Zw 1. A fixed limit on line FWHM, customarily set to 2000 km s^{-1} on Hβ at low-z is however inadequate to describe high-z luminous NLSy1s. Objects with FWHM < 2000 km s^{-1} become impossible at high luminosity unless they are significantly super-Eddington and the virial assumption is violated. The minimum FWHM of low-ionization lines in NLSy1s-like sources is expected to increase monotonically with luminosity and to become larger than 2000 km s^{-1}, making it necessary to introduce a luminosity-dependent FWHM upper limit for the inclusion of "narrow line" quasars.

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1. Introduction

Narrow Line Seyfert 1s (NLSy1s) were first identified by Osterbrock & Pogge in 1985 who noticed the existence of Seyfert 1 sources with unusually narrow low-ionization lines [18]. Since then the most widely accepted defining criterion of NLSy1s is that the width of the broad component of Balmer lines has to be less than 2000 km s^{-1}. Other typical properties involve an often small [OIII]λ5007/Hβ ratio (< 3), rather strong optical FeII emission, soft X-ray spectra that are very steep and variable (see [8][9][22] for reviews), and unfrequent radio loudness [7]. NLSy1s are neither peculiar low-luminosity nor rare AGNs [22]. They constitute ≈15% of a sample of hard X-ray selected AGNs [20], and may amount to ≈ 30% – 50% of all detected Seyfert 1 sources and in soft X-ray selected samples [5][19]. NLSy1s are well represented among Palomar-Green bright quasars: they account for 27% of the radio-quiet sample of Boroson & Green [1], probably because of the frequent presence of a steeply rising blue continuum [4]. This last result indicate that NLSy1s are not generally low-luminosity sources, and that at low redshift they reach luminosities typical of quasars (in this communication we keep using the term NLSy1 regardless of luminosity). In the so-called optical plane of the Eigenvector 1, NLSy1s are at one end of an elbow-shaped distribution of data points and therefore appear to drive the correlations associated to the 1st eigenvector [2][21].

The original definition of NLSy1s is not void of difficulty since a sharp discontinuity in many properties of type-1 sources is seen at FWHM($H\beta_{BC}$) ≈ 4000 km s^{-1}, and not at FWHM($H\beta_{BC}$) ≈ 2000 km s^{-1}. In other words, in the range 2000 km s^{-1} < FWHM($H\beta_{BC}$) < 4000 km s^{-1} sources still show properties of their optical-UV emission line spectrum that are similar to the ones of NLSy1s, although less extreme. Therefore, they seem to be part of a broader population extending up to FWHM ≈ 4000 km s^{-1} (dubbed "Population A" [3][21] [22]).

2. A revelation of AGN structure

The spectrum of several NLSy1s shows features in the visual band and UV that can be easily recognized: the CIV doublet at λ1549 with a large shift to the blue and/or a blue asymmetric profile, remarkable FeII and FeIII emission (the latter confined to the UV), prominent AlIII emission at λ1860 Å, and weak CIII] λ1909 ([13], Figure 1). The spectrum of a NLSy1 like I Zw 1 reveals important clues to the inner workings of an AGN. Low-ionization lines can be fit by a single function well approximated by a Lorentzian [21]. This component is probably associated to dense, low-ionization gas (contributing especially to FeII, [13]) reputed to be moving under a predominantly virial velocity field. To fit high-ionization lines, both a core and a blueshifted component are needed (Figure 1). The blueshifted component migh be associated to outflowing gas whose receding side is obscured: it could be a high ionization wind originating from an accretion disk [10].

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The UV features revealed in sources like I Zw 1 at low redshift are found also in high-luminosity objects. If we perform a search on the SDSS DR7 spectra of quasars in the redshift range where both CIV λ1549 and the λ1900 blend are recorded in optical spectra ($z > 1.5$), we find more than 200 sources out of 5000 with a spectrum resembling the one of I Zw 1. The lower panels of Fig. 1 show fits of the CIV λ1549 line and the λ1900 blend for one of these sources, SDSS J1201+0116 ($z \approx 3.2$). The width of the lines is ≈ 4000 km s^{-1}. The spectrum of SDSS J1201+0116 shows lines that are broader than the 2000 km s^{-1} limit, so nominally SDSS J1201+0116 should not be considered a NLSy1. However, the emission line ratios (and hence the physical conditions) are very close to the ones of I Zw 1 [16].

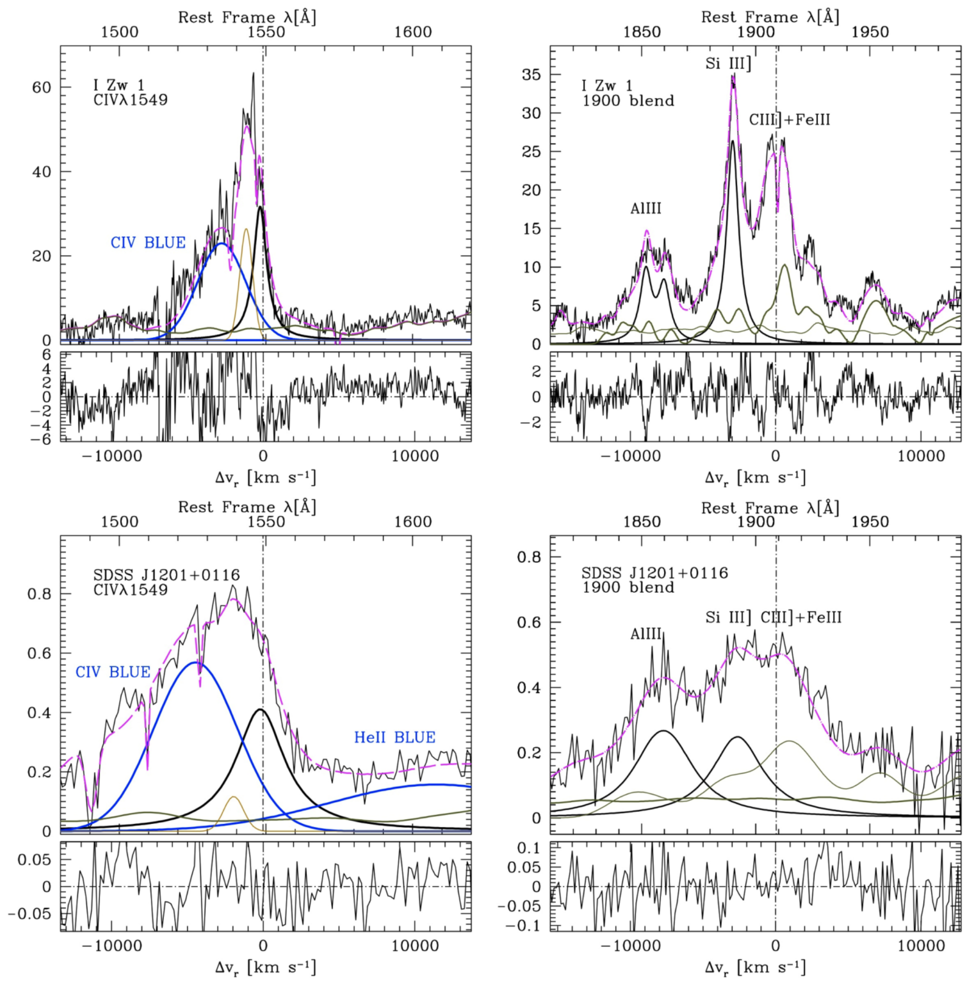

Figure 1 Multicomponents fits of the CIV l549 line and of the 1900 Å spectral region for I Zw1 (upper panels) and SDSS J1201+0116 (lower panels). The ordinate is specific flux at rest frame in units of 10^{-15} erg s^{-1} cm^{-2} A^{-1}. The lower part of each panel shows residuals as a function of radial velocity. Thin black line: continuum-subtracted rest-frame spectrum; thick dashed (magenta) line: multicomponents fit results. Thick continuous lines: blueshifted component (blue) and Lorentzian core component (black). Thin orange line: narrow-line components; thin dark green line: Fe II template emission. In the λ1900 Å blend panels, the thick dark green line shows the adopted Fe III template. In these panels the expected contribution of CIII] λ1909 is not shown (although considered in the multi-component fit); this line is expected to be severely blended with Fe III λ1914, a feature that is affected by Lyα resonance and whose intensity can be significantly larger than the one assumed in the template.

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3.The increase in minimum FWHM

If quasar emission lines are broadened because of Doppler effect and the velocity distribution of the emitting gas follows a virial law, the FWHM of any emission line has a minimum value for a given bolometric luminosity if quasars do not radiate above the Eddington limit. A minimum FWHM can be computed from the virial relationship under the assumption that the distance of the line emitting gas increases following a power-law: $r_{BLR} \propto L^{a}$, with a = 0.52 – 0.67 [1][6]. The virial mass can be written as: $M_{BH} = f\, r_{BLR} \mathrm{FWHM}^2/G$ where G is the gravitational constant and f is a factor parameterizing the (unknown) effect of the broad line region geometry and dynamics. The FWHM then becomes $\mathrm{FWHM}^2 \propto f^{-1} L^{1-a} M_{BH} / L$. Since $M_{BH} /L \propto (L/L_{Edd})^{-1}$. FWHM will be minimum if $L/L_{Edd} = 1$ (if super-Eddington sources are not allowed), yielding $\mathrm{FWHM} \propto L^{(1-a)/2}$.

The black solid line in Figure 2 presents this behavior for the broad component of the Hβ line. The two horizontal dot-dashed lines represent the constant upper limits for NLSy1s (at 2000 km s^{-1}; blue) and for Pop. A (at 4000 km s^{-1}; magenta) defined from relatively low-luminosity samples. The magenta and blue curves show the luminosity-dependent behavior of the NLSy1 and Pop. boundary, respectively (a = 0.67 is assumed).

The shaded area below the curve with a = 0.67 is an apparent zone of avoidance for broad-line AGNs. We remark that the zone of avoidance is not due to a photometric limit hampering discovery of quasars; objects located there should not happen at all under the assumptions made. Of course the existence of high-L NLSy1-like sources does not imply that smaller black hole mass sources like 1 Zw 1 do not exist at high z. Those sources might be lost in a survey because of limits in discovery magnitude; however their FWHM should be consistent with the L-dependent limit shown in the Figure. The normalization adopted assumes $f \approx 2.1$. This value is believed appropriate for the narrowest sources [3]. If a ≈ 0.52, at high L there are sources lying below the minimum limit. A possible interpretation is that their FWHM is underestimated because the symmetry axis of their accretion disk is close to the observer's line of sight. Orientation effects and dynamical factors like radiation pressure can strongly influence the value of f [3] [17].

4. Conclusion

NLSy1s are believed to radiate at high Eddington ratio, be intrinsically young or rejuvenated by newly available accretion material [14][15][22]. They are even expected to become more frequent at high-z where they could well constitute a population of very luminous quasars. Apart from the larger FWHM, properties of typical NLSy1s like I Zw 1 seem to be preserved also in high luminosity sources found at high redshift, with the detection of low-EW, blueshifted CIV emission and the revelation of Lorentz-like profiles for Hβ.

Considering the trend of FWHM and luminosity, a luminosity-dependent definition of NLSy1s (and of NLSy1-like Population A quasars, defined by a limiting FWHM ≈ 4000 km s^{-1} at low-luminosity) seems appropriate.

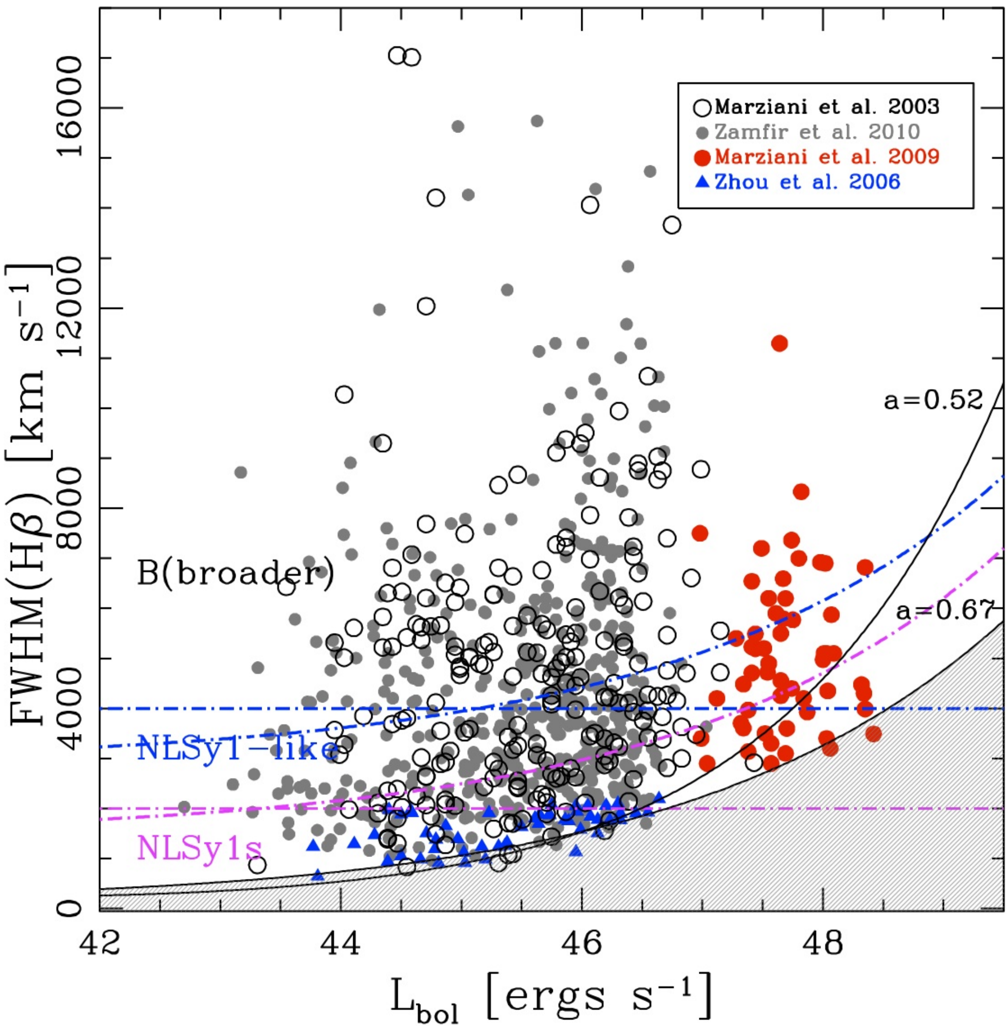

Figure 2 Behavior of FWHM Hβ vs. bolometric luminosity for two samples of bright quasars (from SDSS: grey dots, Zamfir et al. [23]; open circles: Marziani et al. [11], and high luminosity Hamburg-ESO quasars reported in Marziani et al. (red circles, [10]). A sample of very narrow NLSy1s (blue triangles; Zhou et al. [24]) is also shown. The dot-dashed lines indicate the limits for NLSy1s (magenta) and for Pop. A sources (blue).

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