Probing the intimate link between Accretion and BLR

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1. Abstract

We propose to observe with XMM-*Newton* a sample of 8 Seyfert 2 (Sy-2) galaxies, with and without Hidden Broad Line Regions (HBLR), extracted from the spectropolarimetric sample of Tran [1, 2], for a total exposure of **162 ks**. These observations (together with those performed or scheduled in "B" priority after our AO4 proposal) will complete the X-ray sample of Sy-2s with published, homogeneous polarimetric spectra down to (uncorrected for extinction) $F_{[OIII]}^{HBLR} \geq 3 \times 10^{-14}$ erg s^{-1} cm^{-2} and $F_{[OIII]}^{non-HBLR} \geq 7 \times 10^{-14}$ erg s^{-1} cm^{-2}. The main goal of this proposal is to measure the 2-10 keV luminosity of these sources and so the accretion rate in Eddington units. This will in turn allow us to verify our 3.2σ findings[3] that Sy-2s with HBLRs all have accretion rate larger than a minimum threshold value ($\dot{m}_{thres} \simeq 10^{-3}$) and much larger than that of Sy-2s without BLRs (non-HBLR sources). This closely relates the existence of the BLR to the physical state of the central engine in AGNs. The proposed observations would allow us to test our hypothesis at a significance $> 10\ \sigma$.

2. Description of the proposed program

A) Scientific Rationale:

A.I) Previous Findings

Despite observations do generally support orientation based unification models for AGNs[4,5], exceptions do exist. Only about 50 % of the brightest Sy-2s show the presence of HBLRs in their polarized optical spectra[1,2], while the remaining half do not. It has now been convincingly shown that the presence or absence of HBLRs in Sy-2s depends on the AGN luminosity, with the HBLR sources having on average larger luminosities[1,2,6,7,8]. Lumsden & Alexander[6] explain this finding still in the framework of an orientation-based Unification model for AGN, while Tran[1,2] proposes the existence of a population of galactic nuclei whose activity is powered by starburst rather than accretion onto a supermassive black hole and in which therefore the BLRs simply do not exist.

Recently we presented evidence[3] that suggests instead that the absence or presence of HBLRs is regulated, in the accretion–powered scenario, by the rate at which matter accretes onto the central supermassive black hole. We used the unabsorbed 2-10 keV luminosities as reliable measures of the level of nuclear activity[1] and estimated the mass of the black hole by using the empirical spectral-type to B_{Bulge}/B_{Tot}[9] and mass to B_{Bulge}[10,11] relations (the tighter, mass versus dispersion velocity, relation was only available for ~ 20 % of the sources of our sample). Finally comparing the black hole mass and the X-ray luminosity, we derived the accretion rate. This is plotted in Fig. 1 against the estimated black hole mass. Open symbols in this plot are HBLR sources, while filled symbols are non-HBLR sources. Circles represent the original sample that we used in [3], and are all sources of the Tran sample for which (a) good quality X-ray spectra and (b) entries in the RC3[12] were available (~ 20 % of the Tran sample). We updated the original plot by using all the available (*Beppo*-SAX and XMM-*Newton*) data of Compton-thin Sy-2s in the Tran sample (squared symbols; of the 6 XMM-*Newton* observations, **only 4 were available to us**, and 2 of them turned out to be Compton thick). The size of our sample then increased up to 13 Sy-2s: eight HBLRs and only five non-HBLRs.

We first note that a very broad range of accretion rates (more than four orders of magnitude) is spanned by the sources of our sample, which are otherwise powered by central black holes with rather homogeneous masses (only a factor of about 15 across the entire sample). Most importantly, Figure 1 clearly shows that HBLR sources are accreting at much faster rates compared to non-HBLR sources. The threshold value of $\dot{m}_{thres} \simeq 10^{-3}$ divides up HBLR from non-HBLR sources in the M_{BH} vs $\dot{m}$ plane (dashed vertical line in

[1][OIII] luminosities of the Sy-2s in Tran[1,2] are $< 10^{42}$ erg s^{-1}. At such low luminosities, stellar light from the galaxy may be a strong contaminant in the optical band. X–ray luminosities, instead, are little or not contaminated by stellar components and so are much more reliable indicators of the nuclear, accretion-powered activity.

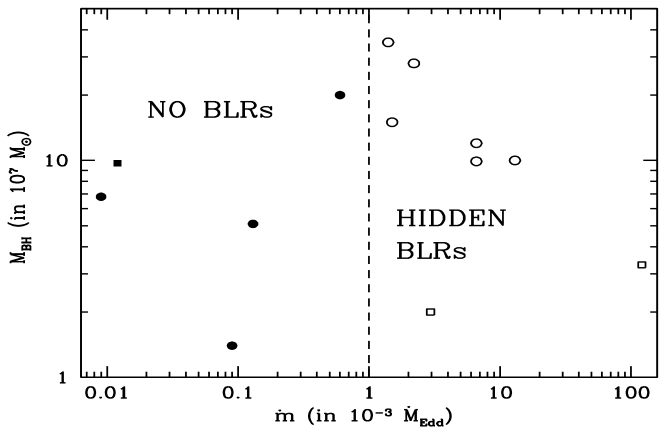

Figure 1: Black hole masses vs accretion rates. Open and filled symbols refer to HBLRs and non-HBLRs.

Fig. 1). Although the two distributions appear clearly disjointed in the M_{BH} vs $\dot{m}$ plane, due to the small number statistics (13 sources of which only 5 non-HBLRs) the significance of our result is only of 3.2σ (i.e. a K-S test probability of P=0.11 % that the two distributions are drawn by the same parent population).

A.II) The Proposed Model

Our findings fit nicely with predictions of the model by Nicastro[13], in which the BLRs originate from the accretion disk at a distance related to the transition radius between the gas pressure and radiation pressure dominated regions. This radius diminishes with decreasing $\dot{m}$; for low enough accretion rates (and therefore luminosities), the critical radius becomes smaller than the innermost stable orbit, and BLRs cannot form. It is remarkable that the threshold value of $\dot{m}_{thres} \simeq 10^{-3}$ that we find is so close to what predicted in the framework of the Nicastro model (i.e. about 4×10^{-3} for a black hole mass of 10^8M$_\odot$).

B) Immediate Objective:

Clearly, a larger number of sources, extended towards the low [OIII] (and X-ray) luminosity end and thus populating the non-HBLR subsample, is strongly needed to definitely confirm or reject our findings. **After our AO4 observation proposal, 4 further Sy-2s were given "B" priority for being observed by XMM-*Newton*: two HBLR Sy-2s (MCG–3-58-7 and NGC 7682, both observed already) and two non-HBLR Sy-2s (NGC 6890 and UGC 6100, not yet observed but to be possibly transferred into the following AO). Of the observed ones, the first is being analyzed by us, while the second (NGC 7682) turned out to be Compton-thick, thus not useful to our aims.** We now propose to observe 8 more low luminosity ($L_{[OIII]} = (0.1 - 5.5) \times 10^{41}$ erg s^{-1}) Sy-2s of the spectropolarimetric sample of Tran[1,2], in order to (a) complete the X-ray sample of Sy-2s with homogeneous spectropolarimetric information, down to

$$F^{HBLR}_{[OIII]} \geq 3 \times 10^{-14} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ and } F^{non-HBLR}_{[OIII]} \geq 7 \times 10^{-14} \text{ erg s}^{-1} \text{ cm}^{-2}$$

(see footnote 2 below); (b) measure 2-10 keV luminosities for all the objects of the proposed sample that will turn out to be Compton-thin (an estimated fraction of $> 50 - 80$ %: Panessa, 2004, PhD Thesis), and so derive an estimate of the accretion rate for these sources. With these 8 sources - the ones which were accepted in priority "C" in the past AO - we will double the current sample of Sy-2s with good optical polarimetric and X-ray spectra, and more than double the subsample of non-HBLR sources, thus providing two sizeable subsamples (HBLR and non-HBLR) with roughly equal number of members. This, in turn, will allow us to verify unambiguously (if the samples remain disjointed we estimate that the significance of the result would raise from the current 3.2σ to $> 10\sigma$: see feasibility below) the evidence that non-HBLR sources are accreting at a much lower rate than HBLR ones, and so to test models that link the accretion to the formation and thus the existence of ubiquitous gaseous components of AGNs.

B.I) Sample Selection

Table 1: **Selected Sample**

Source	z	$F_{[OIII]}{}^{a}$	HBLR	Requested Exp^{b}
F 00521-7054	0.0689	0.0052	Y	12
F 02581-1136	0.02998	0.0014	Y	18
NGC 513	0.01954	0.0035	Y	15
NGC 1144	0.02885	0.010	N	20
NGC 1320	0.0094	0.014	N	15
NGC 3362	0.0276	0.007	N	30
NGC 5695	0.014	0.007	N	30
NGC 5929	0.00831	0.010	N	22

^{a} In 10^{-11} erg s^{-1} cm^{-2}. ^{b} In ks.

We selected all HBLR and non-HBLR Sy-2s of the Tran[1,2] sample, that have never been observed with imaging-spectroscopy X-ray satellites (to minimize confusions problems, which, at the typical flux level of our sample may be important: e.g. [14]), down to:[2]

$$F_{[OIII]}^{HBLR} \geq 3 \times 10^{-14} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ and } F_{[OIII]}^{non-HBLR} \geq 7 \times 10^{-14} \text{ erg s}^{-1} \text{ cm}^{-2}.$$

Our sample also includes sources that have been observed with *ASCA* once but with exposure too short to either detect them (NGC 5695) or get sufficiently good quality spectra to disentangle the continuum from the absorption component (NGC 5929). This selection yields a sample of 8 sources: 3 HBLR and 5 non-HBLR ones (see Table 1). For all these sources, corrected for extinction B-magnitudes and spectral types of the host galaxy are available, either in the RC3[12] or from individual works. These are needed to estimate the bulge B magnitude (applying the empirical relationship in [9]) and thus the mass of the central accretor (using the Ferrarese & Merrit[11] correlation: details in [3]).

3. Justification of requested observing time, feasibility and visibility

3.I Technical Feasibility

To assess the feasibility of our proposed observations, and so derive the requested exposure times (listed in Table 1, last column), we first simulated 100 net counts 2-10 keV EPIC-PN spectra using a source model consisting of power law with photon index of $\Gamma = 1.8$, absorbed by an equivalent H column of neutral gas, of $N_H = 10^{23}$ cm^{-2}, and verified that with such a number of counts we would be able to measure the unabsorbed luminosity of the source to better than 20 % (at 1-σ). For sources that are not too heavily absorbed, the intrinsic continuum parameters, even at the lowest fluxes, will be determined better than the above level.

We then estimated the average $< F_{[OIII]}/F_{2-10keV} >$ ratios for the HBLR and non-HBLR Seyfert 2s in the Tran sample, for which measures of both factors are known. We used this value to compute, for each source, the minimum exposure needed to collect 100 net counts in the 2-10 keV EPIC-PN band. We then request twice the minimum exposure that would guarrantee 100 net counts, based on the evidence that individual values of $F_{[OIII]}/F_{2-10keV}$ fluctuate around the mean by less than a factor of 1.8 (1σ), both positively and negatively. The requested exposure times are listed in Table 1, Col. 6, and add up to a total exposure of **162 ks**.

3.II Science Feasibility

With the currently available data, the significance of the accretion-rate versus existence of BLR correlation (Fig. 1) is only of 3.2σ. **This is mostly due to the limited number of objects available, and the small size of the non-HBLR sub-sample**. The proposed observations will enable us to verify the Nicastro, Martocchia & Matt (2003) result at a much larger significance level. With these observations we will almost triple the non-HBLR sample, and almost double the HBLR one to end up with two sizeable

[2]This cut in [OIII] flux leaves with no-X-ray data only 3 of the 49 Sy-2s of the original Tran compilation: 1 HBLR and 2 non-HBLRs. These sources have extremely low [OIII] fluxes and so would require very large exposures (> 160 ks each) to obtain XMM-*Newton* spectra with $\sim$ 100 counts (based on the average known $F_{[OIII]}/F_{2-10keV}$ values for HBLR and non-HBLR sources in the Tran sample.)

sub-samples of 12 and 13 sources. For optical and X-ray (i.e. absorbed) classified type 2 Seyferts, the maximum estimated fraction of Compton thick objects is 50 % (Panessa, 2004, PhD Thesis). In our sample, at least for the non-HBLR sources (some of which may very well be a type 1 AGN in X-ray, i.e. unabsorbed), this fraction is likely to be lower. However, once all observations have been performed, even if 50 % of all the sources would turn out to be Compton-thick, we would still end up with a total of 8 non-HBLR and 9 HBLR. If the two sub-samples will still be completely disjointed after the addition of the new data-points, we estimate a K-S test probability of 0.015 % that the two subsample are randomly drawn from the same parent population, making the significance of the bimodality of the accretion rate distribution of Sy-2s larger than 10σ.
In case scheduling observations for all of the proposed objects will not be possible, we recommend to give priority to non-HBLR sources (rows 4 to 8 in Table 1), i.e. to the class which has the poorer statistics at present.

References

[1]: Tran, H.D. 2001, ApJ, 554, L19. [2]: Tran, H.D. 2003, ApJ, 583, 632. [3]: Nicastro, F., Martocchia, A., & Matt, G., 2003, ApJ, 589, L13. [4]: Antonucci, R., 1993, ARA&A 31, 473. [5]: Elvis, M., 2000, ApJ, 545, 63. [6]: Lumsden, S.L. & Alexander, D.M. 2001, MNRAS, 328, L32. [7]: Gu, Q. & Huang, J. 2002, ApJ, 579, 205. [8]: Martocchia, A. & Matt, G. 2002, Proceedings of the 5th Italian AGN Meeting, (astro–ph/0210332). [9]: Simien, F. & de Vaucouleurs, G. 1986, ApJ, 302, 564. [10]: Magorrian, J., et al. 1998, AJ, 115, 2285. [11]: Ferrarese, L. & Merritt, D. 2000, ApJ, 539, L9. [12] de Vaucouleurs, et al., 1991, 3rd Reference Catalogue of Bright Galaxies (New York: Springer). [13]: Nicastro, F., 2000, ApJ, 530, L65. [14]: Georgantopoulos, I. & Zezas, A., 2003, ApJ, 594, 704.

4. Report on the last use of XMM-Newton data

The present proposal is a re-submission of AO4 proposal no. 030115, which was accepted but with most sources in priority "C".
The PI of this proposal is also PI of two accepted XMM-*Newton* TOO proposals in AO2 and AO3, to observe WHIM filament against blazars in outburst. Only one of these two TOO has been triggered and performed (80 ks); unfortunately the target was not as bright as at the time of the trigger, and we could not detect any significant intervening absorption line in this spectrum. The data are now being used in the context of a summary work on the detection and upper limits of OVII WHIM lines in the available high resolution X-ray spectra of bright extragalactic sources (Nicastro et al., 2005, in preparation). The second, much longer (250 ks) TOO (AO3 program) has not been triggered yet.
The CoIs of this proposal have been PIs of several succesful proposals in the previous XMM AOs, and results from these observations have been published in a number of recent MNRAS, A&A and ApJ papers and conference proceedings.

5. Most relevant applicant's publications (related to the subject of this proposal and especially publications resulting from accepted XMM-Newton proposals during the past two years)

Nicastro, F., Martocchia, A., & Matt, G., 2003, ApJ, 589, L13: The Lack of Broad-Line Regions in Low Accretion Rate Active Galactic Nuclei as Evidence of Their Origin in the Accretion Disk.

Martocchia, A. & Matt, G., 2002, Proceedings of the 5th Italian AGN Meeting, (astro–ph/0210332): On the Nature of Hidden Broad Line Regions in Seyfert 2 Galaxies.

Nicastro, F., 2000, ApJ, 530, L65: Broad Emission Line Regions in Active Galactic Nuclei: The Link with the Accretion Power.