High-Excitation & Low-Excitation Radio Galaxies: an X-ray comparison

V. Scipione[1,2,3], E. Torresi [2], P. Grandi[2], G.G.C. Palumbo[3]

[1] Leibniz-Institut für Astrophysik, Potsdam, Germany; [2] INAF-IASF Bologna, Italy; [3] Astronomy Department, Bologna University, Italy

ABSTRACT FR II Narrow Line Radio Galaxies (NLRG) can be divided in two optical sub-classes: High Excitation Galaxies (HEGs) and Low Excitation Galaxies (LEGs). The latter category comprises objects with [OIII] EW < 10 Å or [OII]/[OIII] ratio > 1, or both. Although LEGs share the same radio properties of HEGs, they are less bright in the [OIII] line by a factor of 10 at the same total radio luminosity (Buttiglione et al. 2010). The cause of this difference is not well established. It could be due either to a very strong obscuration (that weakens the line) or to different accretion modes. As the [OIII] line luminosity is thought to be a tracer of the accretion power, real intrinsically weak optical [OIII] line would imply low efficient accretion flow. X-ray spectroscopy can play a fundamental role in discriminating between these two scenarios. X-ray photons, able to pass through deep layers of matter, can be used to verify if the nuclear region is strongly obscured. In order to address this point, we studied 14 objects (6 LEGs and 8 HEGs) observed with *Chandra X-ray Observatory*. These sources belong to the 3CR sample and are characterized by $z < 0.1$. We define and compare the average nuclear X-ray properties for each sub-class.

THE SAMPLE

The sample is presented in Table 1. None of these sources is part of the *Chandra* 3CR snapshot survey (PI: Dan Harris) except for 3C 105 and 3C 305 which have been already published (Massaro et al. 2009, 2010).

STRATEGY ADOPTED TO ACHIEVE THE GOAL

A) Measure of the intrinsic neutral hydrogen column densities (N_H) for each source
B) Measure of the unabsorbed X-ray Luminosities (L_X) between 2-10 keV for each source
C) Comparison of the spectral properties (N_H, L_X) between the two sub-classes
D) Search for a correlation between $L_{[OIII]}$ and L_X, expected if the optical emission line flux is not partially obscured by a thick screen.

Table 1: Journal of observations

Name[1]	Class	Telescope Information[2]			T_{exp}[3]	L_{178}[4]	M_H[5]
		Obs ID	Obs. Date	CCD	[ks]		
3C 15	LEG	2178	06Nov00	ACIS-S	28.180	33.30	-25.29
3C 33	HEG	6910	08Nov05	ACIS-S	20.170	33.65	-24.75
		7200	12Nov05	ACIS-S	20.180		
3C 88	LEG	9091	30Jun08	ACIS-I	11.270	32.49	-24.81
		11977	06Oct09	ACIS-S	50.280		
		11751	14Oct09	ACIS-S	20.180		
		12007	15Oct09	ACIS-S	35.080		
3C 98	HEG	10234	24Dec08	ACIS-I	32.130	32.99	-24.38
3C 105	HEG	9299	17Dec07	ACIS-S	8.180	33.54	-24.31
3C 285	HEG	6911	18Mar06	ACIS-S	40.150	33.23	-24.53
		11471	26Mar10	ACIS-S	2.160		
3C 305	HEG	9330	07Apr08	ACIS-S	8.330	32.79	-25.26
		13211	03Jan11	ACIS-S	29.040		
		12797	06Jan11	ACIS-S	29.040		
3C 321	HEG	3138	30Apr02	ACIS-S	47.730	33.49	-25.52
		3338	02Jul02	ACIS-S	4.960		
		3336	25Sep02	ACIS-S	5.170		
		3335	08Oct02	ACIS-S	5.580		
		3337	29Dec02	ACIS-S	4.960		
3C 353	LEG	7886	03Jul07	ACIS-S	71.810	33.60	-24.77
		8565	08Jul07	ACIS-S	18.180		
3C 371	LEG	841	21Mar00	ACIS-S	10.250	32.33	-25.36
		2959	05Aug02	ACIS-S	40.680		
3C 388	LEG	4756	09Jan04	ACIS-I	7.780	33.70	-26.20
		5295	29Jan04	ACIS-I	31.120		
3C 403	HEG	2968	07Dec02	ACIS-S	50.130	33.16	-25.27
3C 442	LEG	5635	27Jul05	ACIS-I	28.570	32.39	-
		6353	28Jul05	ACIS-I	14.170		
		6359	07Oct05	ACIS-I	20.150		
		6392	12Jan06	ACIS-I	33.130		
3C 452	HEG	2195	21Aug01	ACIS-S	80.950	33.94	-24.92

[1] 3C name of the source [2] Observation ID, date of observation and CCD used [3] Exposure time (ks) [4] Radio luminosity at 178 MHz [erg s^{-1} Hz^{-1}], from Spinrad et al. (1985) and Buttiglione et al. (2009) [5] Host H magnitude from 2MASS (Skrutsie et al. 2006), from Buttiglione et al. (2009)

TABLE 1

SPECTRAL ANALYSIS RESULTS

✦ HEGs are rich of cold ABSORBING material. On average the column densities are as large as ~ 5×10^{23} cm^{-2}. This obscuring line-of-sight matter is probably related to a toroidal structure as postulated by unification models.
✦ An iron Kα line is observed in 6 HEGs out of 8. The features are prominent (EW ~ 200-300 eV) as expected if reprocessed by a torus. Note that the Kα iron line is considered a signature of an efficent accretion regime.
✦ In LEGs the nucleus is less obscured. The column densities are lower, of the order of ~ 10^{23} cm^{-2}. The iron Kα line is not present in any of the sources.

LEG AND HEG COMPARISON

1) There is a clear separation in the N_H distribution of LEGs and HEGs, with the former peaking around 10^{22} cm^{-2} and the latter around 10^{23} cm^{-2} (Figure 1).
2) On average, LEGs are also less bright than HEGs by a factor of about ten in the X-ray band. As shown in the histogram of the unabsorbed 2-10 keV X-ray luminosity, LEGs prefer to populate regions with $L_X < 10^{43}$ erg s^{-1} (Figure 2).
3) The [OIII] line is a good tracer of the nuclear activity, because well correlated with the unabsorbed X-ray luminosity. The [OIII] line luminosity is therefore unaffected by obscuration, at least in our sample. Figure 3 shows a correlation between the [OIII] line luminosity and the 2-10 keV luminosity. Note in particular that LEGs are located at the bottom part of the plot, i.e. they occupy the low luminosity region.

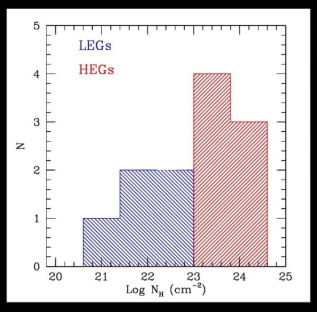

Figure 1 Comparison of intrinsic neutral hydrogen column densities (in cm^{-2}) between LEGs and HEGs. LEGs have values for N_H in the order of 10^{22} cm^{-2}, while HEGs are heavily absorbed ($N_H \approx 10^{23}$ cm^{-2}).

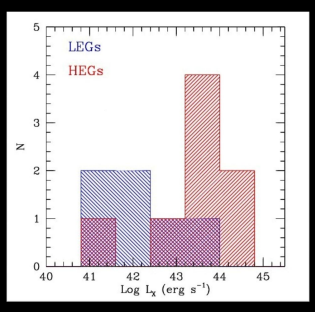

Figure 2 Comparison of the X-ray unabsorbed luminosity in the range 2-10 keV (in erg sec^{-1}) between LEGs and HEGs.

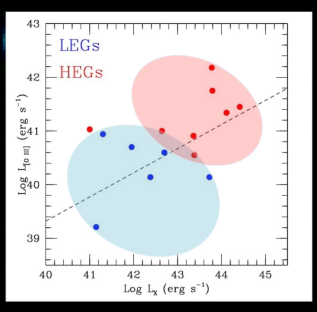

Figure 3 Comparison of the [O III] line luminosity (in erg sec^{-1}) versus the 2-10 keV luminosity (in erg sec^{-1}) for our 3CR sample. The line represent a linear fit to the data.

The results of our analysis suggest that the difference between HEGs and LEGs is intrinsic and not dependent on the circumnuclear neutral hydrogen column density. LEGs are less efficient mass accreting systems and might represent a transition quiescent phase of the radio-loud AGN.

REFERENCES:
(1) Buttiglione et al. 2009, 2010, A&A, 495, 1033-1060; A&A, 509, A6 (2) Massaro et al. 2009, 2010, ApJ, 692, L123; ApJ, 714, 589 (3) Spinrad et al. 1985, PASP, 97, 932; (4) Skrutsie et al. 2006, AJ, 131, 1163.

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