The Suzaku view of the BLRG 3C 111

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Abstract

Here we report on a *Suzaku* observation of the nearby BLRG 3C 111, a bright FR II with a single-sided jet exhibiting superluminal motion. Preliminary results indicate that the $0.5-200$ keV spectrum is dominated by a disklike component, with a power law with photon index ~ 1.6 cutting off around 100 keV, and a reflection $R \sim 0.04$. The *Suzaku* data do not indicate the presence of a hard X-ray component associated with the jet emission, that should become dominant at GeV energies (i.e. in the range covered by *FERMI*).

Key words: workshop: proceedings — galaxies: active — galaxies: individual: 3C 111 — galaxies: nuclei — X-rays: galaxies

1. Introduction

AGN unification schemes assume that radio-loud AGN contain an accretion disk and a relativistic jet perpendicular to the disk, and an obscuring molecular torus. According to this scheme, the jet dominance decreases with larger viewing angles from blazars to Broad and Narrow line radio galaxies. Broad line radio galaxies (BLRGs) are a rare type of radio-loud AGN, in which the broad optical permitted emission lines have been detected in addition to the extended jet emission.

A fundamental question is how accretion and ejecta are related. In this framework BLRGs are an ideal laboratory since our line of sight is not close to the radio jet axis but it is not obscured by the putative obscuring torus. The study of the disk/jet connection and the identification of the physical parameters determining the AGN radio loudness are amongst the most important topics in the AGNs search. One of the open questions is if the RL/RQ dichotomy reflects fundamental differences in the central engine structure. If this is the case, we would expect these differences to be more evident in the X-ray band, directly probing the structure of the central engine.

Broad Line Radio Galaxies (BLRGs) are a key class to investigate the inner region of RL AGN since seen at intermediate angles with respect to the jets, minimizing the jet contribution and avoiding the torus obscuration.

Previous X-ray observations suggested that reprocessing features observed in Seyfert 1s (i.e. Compton reflection bump and Fe Kα line) are weaker in BLRG spectra. Several scenarios can explain this finding: *a)* radiatively inefficient accretion flow (Rees et al. 1982; e.g., Eracleous et al. 2000); *b)* dilution by non-thermal jet emission (Grandi et al. 2002); *c)* highly ionized accretion disk (Ballantyne et al. 2002).

Moreover, in most of BLRGs the soft X-ray spectra don't show strong signatures of warm absorber, rather common in Seyferts: the only exception, a modest 1000 km/s outflow has been detected in *Chandra* HETG observations of 3C 382 (see Reeves et al. 2009), while 3C 445 shows signatures of soft X-ray photoionized gas only in emission (see Sambruna et al. 2007). The suggestion seems a BLRGs central engine generally devoid of warm gas. This scenario is in contrast with the presence of relativistic jets (Blandford & Payne 1982), and with the Unification Models.

2. The BLRG 3C 111

One of the best targets to probe the central regions of BLRGs is 3C 111. This source is a *nearby* ($z = 0.0485$) radio galaxy, bright in the X-ray band: $F_{2\text{-}10\,\mathrm{keV}} \sim 2.5 \times 10^{-11}$ergs cm^{-2} s^{-1} and $F_{20\text{-}100\,\mathrm{keV}} \sim 4.4 \times 10^{-11}$ergs cm^{-2} s^{-1}. 3C 111 presents a FR II morphology with a single-sided jet (Linfield & Perley 1984) showing superluminal motion (Vermeulen & Cohen 1994); the inclination angle has been estimated to be $i \sim 21^\circ - 26^\circ$ ($> 10^\circ$; Lewis et al. 2007).

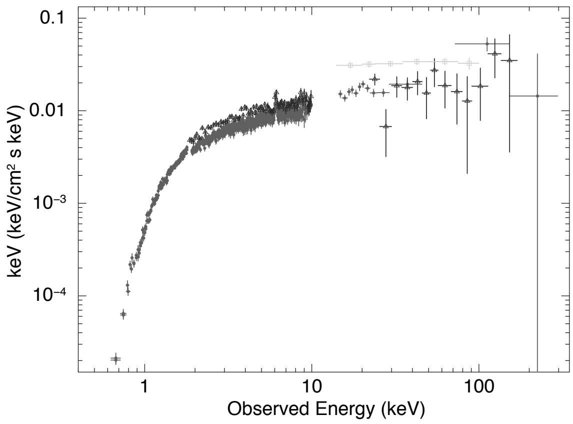

Fig. 1. X-ray spectra unfolded with the best-fit *Suzaku* model. Blue open triangles: *Beppo*SAX MECS and PDS spectra (1998); green open squares: *SWIFT* BAT 22−months spectrum; red filled circles: *Suzaku* XIS, PIN, and GSO data (2008). Cross-normalizations constrained to be in the expected range. The strong variability of 3C 111 at hard X-rays is clearly evident by comparing *SWIFT* and *Suzaku* or *Beppo*SAX spectra.

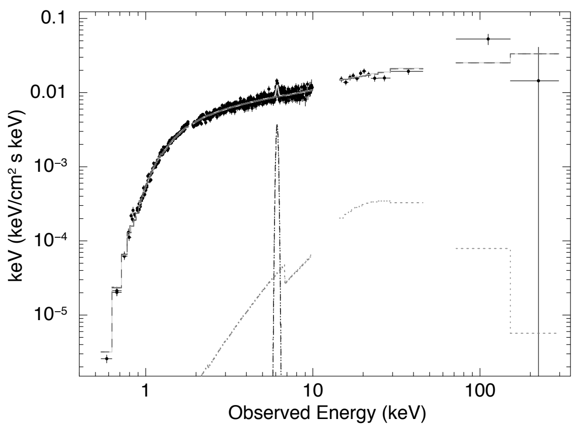

Fig. 2. Unfolded *Suzaku* spectra (black filled circles). The best fit model (green continuous line) consists of: an absorbed power law (long-dashed red line), a Fe Kα line (dotted blue line), and a reflection component (dashed orange line).

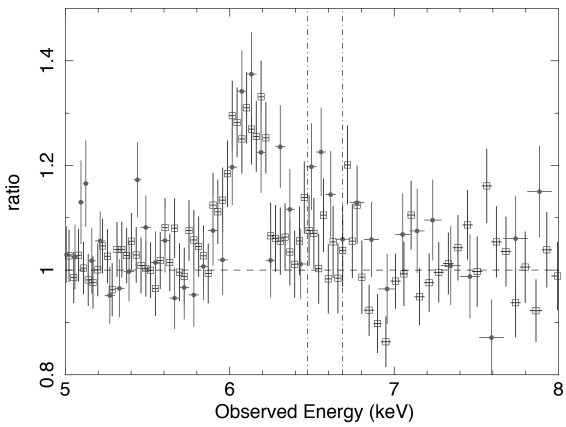

Fig. 3. XIS FI (blue open squares) and XIS BI (red filled circles) data-to-model ratio. Vertical lines mark the centroids of the features possibly responsible of the observed residuals (at *rest-frame* energies of 6.78 and 7.02 keV).

2.1. Previous high-energy observations

Several high-energy observatories targeted 3C 111, highlighting its long time-scale variability (see Fig. 1). *Beppo*SAX detected 3C 111 in all the instruments with high S/N, showing a flat continuum, without intrinsic absorption and with weak reprocessed features (i.e., reflection and Fe Kα line; Grandi et al. 2006; Dadina 2007). A 3σ *EGRET* detection was reported for this source, implying a broad-band SED reminiscent of a de-beamed blazar (Hartman et al. 2008). Finally, XMM-*Newton* spectra showed a weak Compton reflection component, with broad residuals at Fe Kα energy (possibly a feature produced in the accretion disk) and an unresolved Fe Kα line (Lewis et al. 2007).

3. The *Suzaku* observation

Suzaku observed 3C 111 in August 2008, for a nominal exposure of 122 ksec. The source is detected up to 200 keV with the GSO (see Fig. 2). The underlying continuum is well described by an absorbed power law and a weak reflection component, with $\Gamma \sim 1.6$, $N_{\rm H} \sim 9 \times 10^{21}\,{\rm cm}^{-2}$, and $R \sim 0.04$. The addition of a second, jet-related power law is not significant: *observations in the GeV energy range are needed to detect the jet at the highest energies.*

An unresolved iron line is detected at ~ 6.4 keV, with $\sigma \sim 90$ eV and EW~ 90 eV (see Fig. 3). Residuals in the Fe-K band can be due to two unresolved lines at 6.7 keV and 6.97 keV. Below 1 keV, a narrow line at ~ 0.89 keV rest frame is suggested by residuals ($\Delta\chi^2 = 30$), especially in XIS BI data.

For a summary of what *Suzaku* tell us about the BLRGs, and a discussion of the possible interpretations, see Sambruna et al. (these proceedings).

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