Suzaku Observations of the Broad-Line Radio Galaxy 3C 382

Rita M. Sambruna[1], James Reeves[2], Valentina Braito[3],
Mike Eracleous[4], Karen Lewis[5]

[1] NASA's GSFC, Code 662, Greenbelt, MD 20771, USA
[2] Astrophysics Group, School of Physical & Geographical Sciences, Keele University, Keele, Staffordshire ST5 5BG, UK
[3] University of Leicester, Department of Physics & Astronomy, University Road, Leicester LE1 7RH, UK
[4] Department of Astronomy and Astrophysics and Center for Gravitational Wave Physics,
The Pennsylvania State University, 525 Davey Lab, University Park, PA 16802, USA
[5] Dickinson College, Dept. of Physics and Astronomy, Carlisle, PA 17013, USA
E-mail(RMS): Rita.M.Sambruna@nasa.gov

Abstract

We describe the results from our 120 ks Suzaku observation of the BLRG 3C 382, together with non-simultaneous Swift BAT data. The 0.4–150 keV spectrum is well described by Seyfert-like emission, with some subtle differences. These reinforce the notion that radio-loud AGN exhibit X-ray properties clustered at one end of the distribution for radio-quiet ones, with significant overlap.

Key words: workshop: proceedings — galaxies: active — galaxies: jets — X-rays: galaxies

1. Introduction and Motivation

Some outstanding open questions in the study of Active Galactic Nuclei are: What is the origin of the powerful, relativistic jets observed in the so-called radio-loud AGN? And why - if all AGN are powered essentially by the same mechanism, accretion onto a supermassive black hole - are they observed only in a fraction of active galaxies? Does that imply special conditions in the accretion regions of these sources? X-rays, being generated in the innermost regions of AGN, can help address these questions.

As part of our ongoing X-ray spectroscopy study of RL AGN (started in 1999 with *ASCA*, Sambruna, Eracleous, & Mushotzky 1999), we acquired *Suzaku* observations of the Broad-Line Radio Galaxy 3C 382. Here we report the preliminary results, while a full account and interpretation of the data will be forthcoming. Another BLRG of our program, 3C 111, is described in these proceedings by Ballo et al., while 3C 390.3 has been published in Sambruna et al. (2009).

2. A brief identikit of 3C 382

3C 382 is a powerful FRII radio galaxy at $z = 0.057$ with a double-lobed structure and a jet in the northern lobe that ends in a hotspot. Optically, the radio source is identified with a disturbed elliptical galaxy dominated by a very bright and unresolved nucleus (Martel et al. 1999), located in a moderately rich environment (Longair & Seldner 1979). The optical spectra show a strong continuum and prominent broad lines resulting from photoionization by a power-law type of spectrum (Tadhunter, Perez, & Fosbury 1986).

In the X-ray band, 3C 382 was extensively studied being bright, $F_{2-10\ \mathrm{keV}} \sim 10^{-11}$ erg cm^{-2} s^{-1}. Previous *ASCA* observations showed that the continuum is fitted with a single power law with a very broad (width $\sigma_G \sim 2$ keV) and strong (Equivalent Width EW ~ 1 keV) Fe Kα emission line, plus a variable soft excess modeled either with a thermal or a blackbody (Sambruna et al. 1999 and references therein). Our 118 ks *Chandra* HETG observation shows the presence of absorption features below 2 keV, indicating a moderate velocity, pc-kpc scale outflow (Reeves et al. 2009).

3. Observations

Suzaku observed 3C 382 on April 27, 2007 for a total exposure time of 120 ks. We used standard cleaning criteria as described in Sambruna et al. (2009) for both the XIS and HXD instruments. The net exposure time after screening was 116 ks. The source is detected with the HXD PIN up to 70 keV.

The XIS spectra were extracted from a circular region of 2.9′ radius centered on the source. Background spectra were extracted from four circular regions offset from the main target and avoiding the calibration sources in the field. The XIS response (rmf) and ancillary response (arf) files were produced, using the latest calibration files available, with the *ftools* tasks *xisrmfgen* and *xissimarf-*

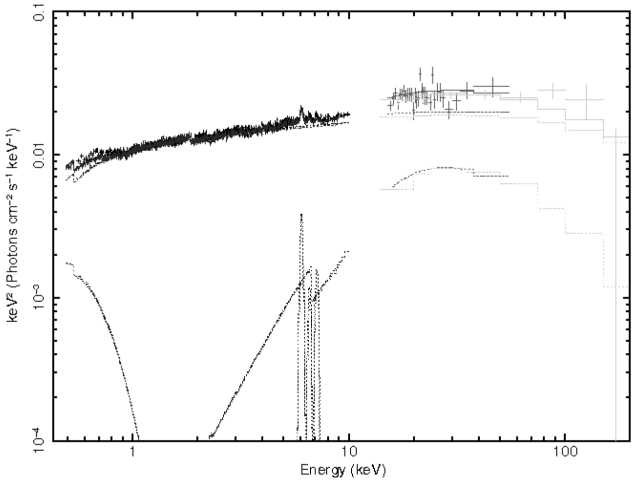

Fig. 1. Broad-band *Suzaku* and *Swift* BAT spectrum of the BLRG 3C 382. Black, blue, and red: XIS1, XIS0+3, and HXD PIN data, respectively. Green: BAT data. The best-fit model is a power law with cold reflection plus three Gaussian lines. A blackbody parameterizes the soft excess.

gen, respectively. The source spectra from the FI CCDs were summed, and fitted jointly with the BI (the XIS1) spectrum. The net XIS source spectra were binned with a minimum of 100 counts per bin.

A *Swift* BAT spectrum was obtained from the 22-month survey archive. The data reduction and extraction procedure of the 8-channel spectrum is described in Tueller et al. (2008). We used the latest calibration response `diagonal.rsp` and background files as of June 2008. The BAT spectrum is consistent with the HXD PIN in the region of overlap and further extend the range of sensitivity for the spectral fits up to 150 keV.

4. Results

The 0.4–150 keV spectrum of 3C 382 is best described by a model including a power law with photon index $\Gamma \sim 1.82$ modified by Galactic absorption ($N_H = 5 \times 10^{20}$ cm^{-2}) at the lower energies, and with a high-energy cutoff at $\sim$ 200 keV; plus a narrow, resolved Fe Kα emission line with width $\sigma_G \sim 100$ eV and EW $\sim$ 57 eV. At low energies a blackbody with $kT \sim 80$ eV parameterizes the soft excess (Reeves et al. 2009). A reflection component from a cold slab (`pexrav` in XSPEC) is also included to fit the HXD and BAT data above 10 keV, yielding an albedo $R \sim 0.5$, for an inclination angle fixed to $\cos\theta = 0.87$. The broad-band spectrum is shown in Figure 1, while Figure 2 shows the confidence contours of the reflection albedo versus the cutoff energy. The continuum flux is $6.5 \times 10^{-11}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ over the 0.6–10 keV band.

In Figure 3 we show the residuals of a single power law fit to the data, zoomed-in in the Fe K region to illustrate its further complexity. Specifically, beside the narrow core of the Fe Kα line, there is evidence for an emission line at observed energies of 6.5 keV (7.0 keV rest-frame) and 7.0 keV (7.5 keV rest-frame). The former is very weak, EW=20 eV, and could be a blend of the weak Fe XXVI Lyalpha (6.97 keV) and Fe I Kbeta (7.06 keV) lines. The 7.5 keV line has EW=30 eV and is highly significant, with $\Delta\chi^2 = 25$ for 3 additional parameters. A Monte Carlo simulation shows that the 7.5 keV line is detected with a probability of 10^{-3}. A deep observation with *Suzaku* or *XMM-Newton* would confirm the existence of the putative blue-shifted emission in 3C 382.

5. Discussion

The *Suzaku* observations of the BLRG 3C 382 reveal that its broad-band X-ray spectrum is dominated up to 200 keV by a Seyfert spectrum. Of all the bright BLRGs studied so far at X-rays, perhaps 3C 382 is the most Seyfert-like in its X-ray properties among classical BLRGs, and yet there are some subtle differences that set it apart from the bulk of its radio-quiet cousins.

In 3C 382, the Fe Kα velocity width of $\sim 10000\,\mathrm{km\,s^{-1}}$ implies an origin at about 1000 gravitational radii, consistent with the outer accretion disk or Broad Line Region, in agreement with other BLRGs (Sambruna et al. 2009), and weaker than in Seyferts. The width of the Fe Kα line is similar to the width of the double-peaked optical emission lines (Eracleous & Halpern 1994), supporting an origin in the BLR. Cold reflection is clearly detected (Figure 2), albeit weaker than in most Seyferts,

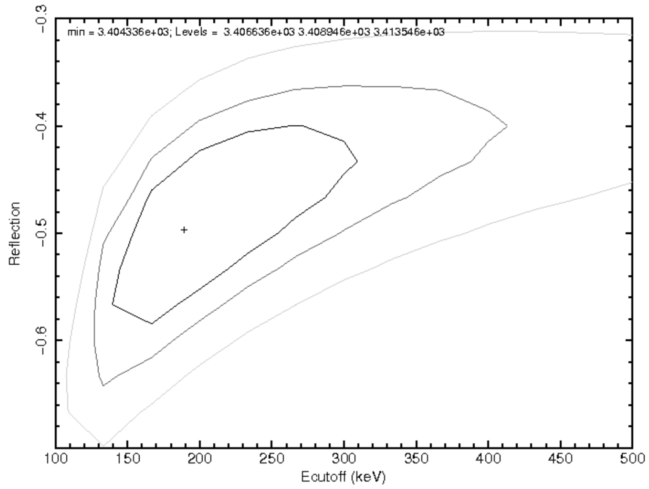

Fig. 2. Confidence contours at 68, 90, and 99% level for the reflection albedo versus the power law energy cutoff.

where $R = 0.63 - 1.35$ (Nandra et al. 2007). The photon index, $\Gamma \sim 1.8$, is typical of radio-quiet sources where the X-rays are produced by Comptonization processes in a disk-corona system.

In conclusion, 3C 382 exemplifies the trend unearthed by *Suzaku* and *XMM-Newton* for radio-loud vs. radio-quiet AGN. Indeed, the current evidence suggests that the range of Compton reflection albedoes and Fe Kα widths in radio-quiet Seyferts is much larger than in the *ASCA* era, with some sources having little or negligible reflection humps and broad emission lines, similar to some BLRGs (Sambruna et al. 2009, and references therein). It seems, then, that BLRGs are clustered at one end of the distribution of X-ray spectral parameters for Seyferts, with significant overlap. This may indicate a substantial similarity of accretion conditions in the central engines, with only one or two parameters responsible for the radio-loud or radio-quiet flavor, e.g., the black hole spin and accretion rate (e.g., Garofalo, Evans, & Sambruna 2009, submitted).

With their broad-band coverage and improved sensitivity *Suzaku* and *XMM-Newton* have opened a new era in the study of AGN at X-rays. Together with exciting new developments from the theoretical side, perhaps we are finally at the verge of cracking the radio-loud/radio-quiet mystery.

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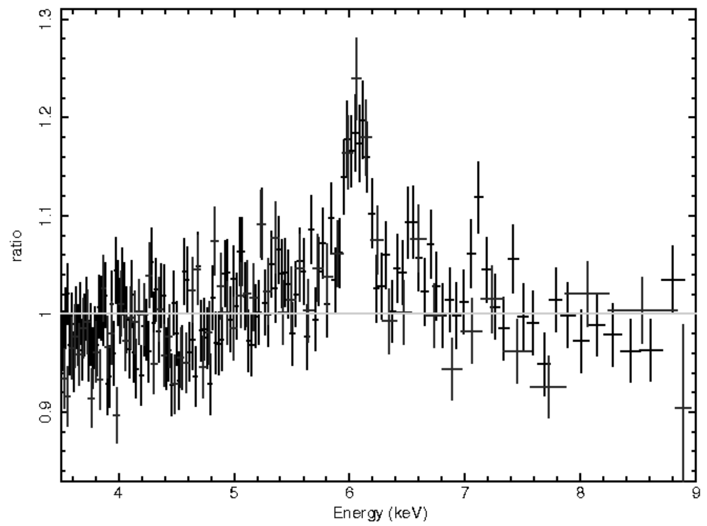

Fig. 3. Zoom-in of the Fe K line region in the Suzaku XIS spectrum of 3C 382. Blue: XIS1, Black: XIS0+3. The narrow core of the Fe Kα line, plus two additional emission lines at 6.5 and 7.5 keV can be easily seen.