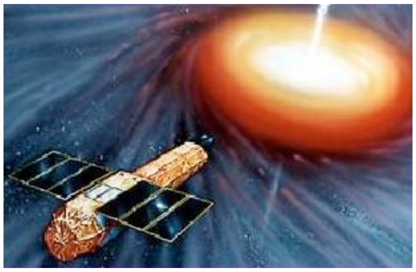

The Suzaku Observation of NGC 3516:

Complex absorption and the Broad & Narrow Fe K Lines

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OVERVIEW OF RESULTS

Suzaku's wide bandpass has enabled us to deconvolve the broadband emitting & absorbing components in the X-ray spectrum of the Seyfert 1 galaxy NGC 3516.

We find complex absorption similar to that found by Turner et al. (2005) in the 2001 XMM observations: a mildly-ionized "UV" absorber whose column density has increased by a factor of 3 since 2001, and a partial covering (35%) mildly-ionized absorber.

We verify the presence of the broad Fe Ka line; its EW is 185^{+130}_{-70} eV. Models that reject either the absorbers or the broad Fe line are rejected.

The XIS's high effective area & low background near 6 keV has resolved the narrow Fe Kα line: FWHM velocity =3800 km/s, commensurate with BLR velocities. Its EW is 46 ± 2 eV.

The Compton reflection hump strength, R=1.4 ± 0.2, suggests it is more likely associated with the broad line than the narrow line.

Controversy in the Sy1 galaxy NGC 3516: Does the Broad Fe Line Really Exist?

The broad, asymmetric Fe K emission line near 6.4 keV is a key tracer of the matter in the innermost accretion disks around accreting black holes. The line profile, sculpted by gravitational redshifting and relativistic Doppler effects (e.g., Fabian et al. 2002), can indicate FWHM velocities near ~0.3c. More recently, XMM-Newton and Chandra observations of Seyfert AGN have shown that a narrow Fe K component (FWHM velocities ~3000 km/s) at 6.4 keV appears to be quite common; a distant origin, such as the BLR or the molecular torus, is likely (e.g., Yaqoob et al. 2001).

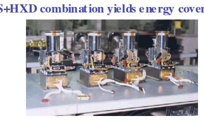
The Seyfert 1 galaxy NGC 3516 (z = 0.0088) was also shown by ASCA to have a broad Fe line (Nandra et al. 1997). Iwasawa et al. (2004) found evidence for rapid line variability near 5.7-6.5 keV, supporting the presence of line emission originating below ~15 R_g. However, NGC 3516 is known to contain a complex and ionized absorber (e.g., Kraemer et al. 2002) which introduces curvature into the continuum near 3-5 keV. Turner et al. (2005) modeled the continuum curvature of two XMM-Newton EPIC spectra taken in 2001 by including a partial covering, mildly-ionized absorber. As a consequence, however, the formal requirement to include the broad line vanished, leading to uncertainty as to whether the broad line really existed in NGC 3516.

Capabilities of the Suzaku Observatory

Suzaku has four **X-ray telescopes** (**XRTs**; Serlemitsos et al. 2006), each with a HPD spatial resolution of 2'; each focused X-rays onto four **X-ray Imaging Spectrometer** (**XIS**; Koyama et al. 2006) CCDs, sensitive to 0.2-12 keV X-rays on a 18' × 18' field of view, and feature an energy resolution of ~140 eV at 6 keV. Three CCDs (XIS 0, 2 and 3) are front-illuminated (FI), the fourth (XIS 1) is back-illuminated (BI) and features an enhanced soft X-ray response. The XRT/XIS combination yields effective areas of roughly 330 cm² (FI) or 370 cm² (BI) at 1.5 keV, and 160 cm² (FI) or 110 cm² (BI) at 8 keV.

Suzaku also features a non-imaging, collimated **Hard X-ray Detector** (**HXD**; Takahashi et al. 2006) sensitive from 12 to >300 keV. Its effective area at 20 keV is 160 cm². Below 100 keV, the f.o.v. is 34' × 34' (FWHM). **The XIS+HXD combination yields energy coverage from 0.3 to >300 keV.**

One of the XRTs



The four XIS sensors

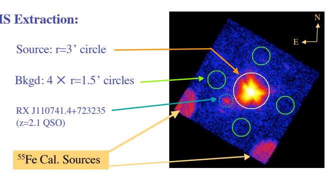
The HXD sensor

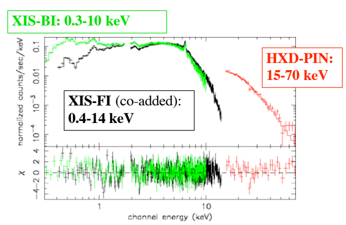
Observational Details

•Observed 2005 Oct 12-15 as part of SWG program.

•Net exposure times after screening: 135 ksec for each XIS; 111 ksec for the HXD-PIN.

•**XIS Extraction:**





$F_{0.4\text{-}14}$ keV = 3.4 × 10^{-11} erg cm^{-2} s^{-1}

$F_{15\text{-}70}$ keV = 8.6 × 10^{-11} erg cm^{-2} s^{-1}

Broadband Spectral Modeling Results

Similar model to Turner et al. (2005) fit to 2001 XMM observations:

•**Power-law continuum** Γ=1.84 ± 0.02 obscured by:

→**Ionized "UV" absorber**, $\log\xi = -1.2 \pm 0.1$ erg cm s^{-1} ; $N_H = 1.92 \pm 0.02 * 10^{22}$ cm^{-2}

→**Partial Covering absorber: f_c = 35%;** $N_H = 1.03 \pm 0.12 * 10^{23}$ cm^{-2}; $\log\xi = -0.3$ erg cm s^{-1}

•**Scattered Emission Power-law:** 5% of nuclear continuum

•**Soft X-ray narrow emission lines** (see Turner et al. 2003 for RGS)

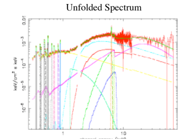
•**Broad + narrow Fe K emission lines**

•**Compton Reflection hump:** R = 1.4 ± 0.2

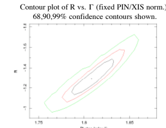
•Models that exclude either the complex absorbers or the broad line are rejected!

•Column density of ionized material along line of sight has increased by ~3 since 2001, consistent with a drop in $F_{0.5\text{-}2.0\ keV}$ from 3-4 × 10^{-12} erg cm^{-2} s^{-1} during the 2001 XMM observations to 1.2 × 10^{-12} erg cm^{-2} s-1 during the Suzaku observation in 2005.

Unfolded Spectrum



Contour plot of R vs. Γ (fixed PIN/XIS norm.). 68,90,99% confidence contours shown.



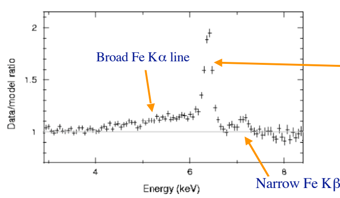
Suzaku Confirms the Broad Fe Kα Line

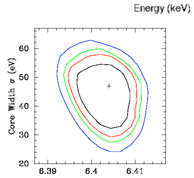
•The broad line is required at >99.99% confidence in an F-test, even with warm absorption parameters left free.

•Assuming that the broadband nuclear continuum is indeed a simple power-law, then with the level of the continuum properly defined, Suzaku can distinguish between the curvature associated with the diskline and the partial-covering absorber.

•We find an equivalent width EW of 185^{+130}_{-70} eV. The inner radius is constrained to be <5.0 R_g. The best-fit inclination is 35 ± 10°.

•A Fe Kβ diskline (centered at 7.06 keV) is also required in the fits (97% confidence in an F-test)





ABOVE: Residuals to power-law continuum when the broad and narrow Fe Kα lines are removed.

LEFT: Contour plot of measured narrow line width σ_{meas} versus rest-frame centroid energy.

Suzaku Resolves the Narrow Fe Kα Line

Narrow Fe Kα:

•E_o = 6.404 ± 0.006 keV

•EW = 46 ± 2 eV

• σ (measured) = 47 ± 11 eV

• σ_{cal} = 30 ± 1 eV: **Narrow Fe Kα line is resolved!**

→ σ (intrinsic) = 36^{+14}_{-18} eV

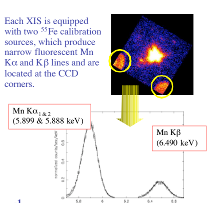
•**FWHM velocity = 3800^{+1500}_{-1900} km s^{-1}**

•Consistent with optical Broad Line Region velocity widths (e.g., Peterson et al. 2004)

•Consistent with Chandra HETGS value (Yaqoob & Padmanabhan 2004)

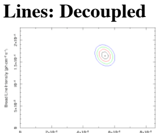
• A narrow Fe Kβ line at 7.06 keV also detected (at 98% confidence in F-test)

Each XIS is equipped with two 55Fe calibration sources, which produce narrow fluorescent Mn Kα and Kβ lines and are located at the CCD corners.



Broad & Narrow Lines: Decoupled

The broad & narrow Fe Kα lines are each detected independently. A contour plot of the broad & narrow line intensities (right) shows this decoupling is significant at >4σ confidence.



This separation, also seen in Suzaku spectra of other Seyferts (NGC 2992, Yaqoob et al. 2006; MCG-5-23-16, Reeves et al. 2006), is due in part to the high signal/noise in the narrow line, thanks to the high effective area and in particular the exceptional narrow response of the XIS.

Connecting the Compton hump & the broad Fe K line: The fact that the EW of the broad line is much larger than that of the narrow line suggests that the Compton reflection hump may be more associated with the broad line. The broad line EW of 185^{+130}_{-70} eV and reflection fraction R = 1.4 ± 0.2 are consistent with the prediction of George & Fabian (1991) that EW/150 eV = R for reflection off neutral material.

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References: Fabian, A. et al. 2002, MNRAS 335, L1; George, I.M. & Fabian, A. 1991, MNRAS 249, 352; Iwasawa, K. et al. 2004, MNRAS 355, 1073; Koyama, K. et al. 2006, PASJ, submitted; Kraemer, S.B. et al. 2002, ApJ 577, 98; Nandra, K. et al. 1997, MNRAS 284, L7; Peterson, B. et al. 2004, ApJ 613, 682; Reeves, J.N. et al. 2006, PASJ, in press; Serlemitsos, P. et al. 2006, PASJ, in press; Takahashi, T. et al. 2006, PASJ, submitted; Turner, T.J. et al. 2003, ApJ 594, 128; Turner, T.J. et al. 2005, ApJ 618, 155; Yaqoob, T. & Padmanabhan, U. 2004, ApJ 604, 63; Yaqoob, T. et al. 2006, PASJ, in press (astro-ph/0906581)