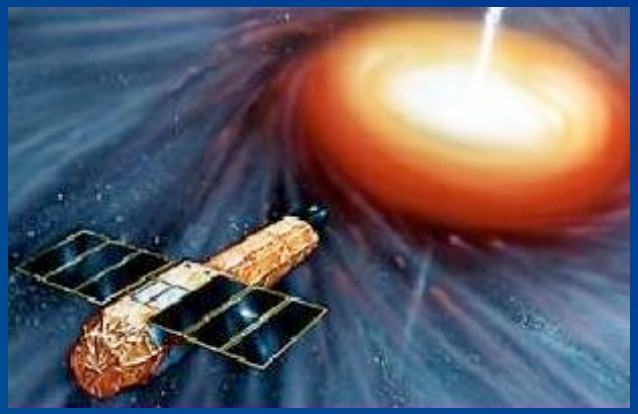
The Suzaku View of Fe Kα Emission Features in Seyferts



Alex Markowitz

(UCSD/CASS)

Including results from: J. Reeves (Keele), T. Yaqoob (JHU), G. Ponti (Bologna), Y. Terashima (Ehime), G. Miniutti (IoA), J. Kataoka (Tokyo Tech), T. Okajima (GSFC), and MANY co-authors ….

Typical Sy 1 X-ray Spectrum

Relativ. Broad Fe Kα lines

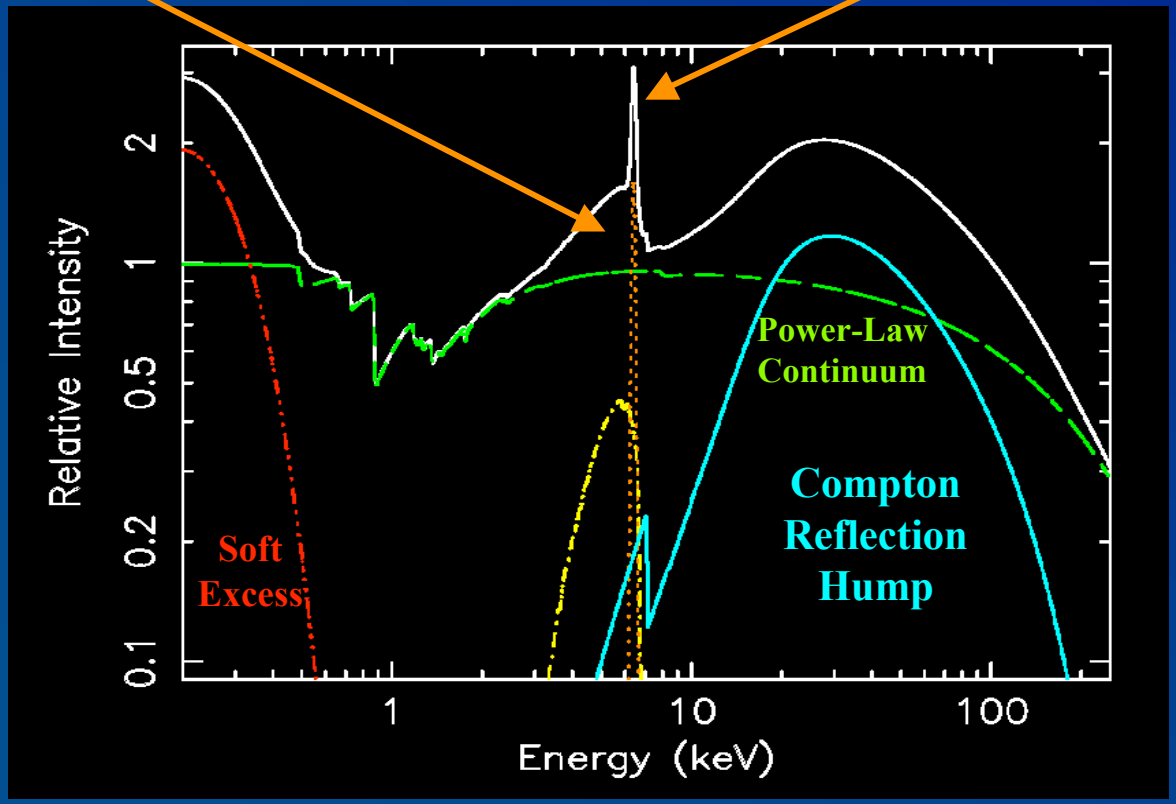
Accretion Disk

FWHM ~ 0.2c

Narrow Fe Kα lines

BLR? Torus?

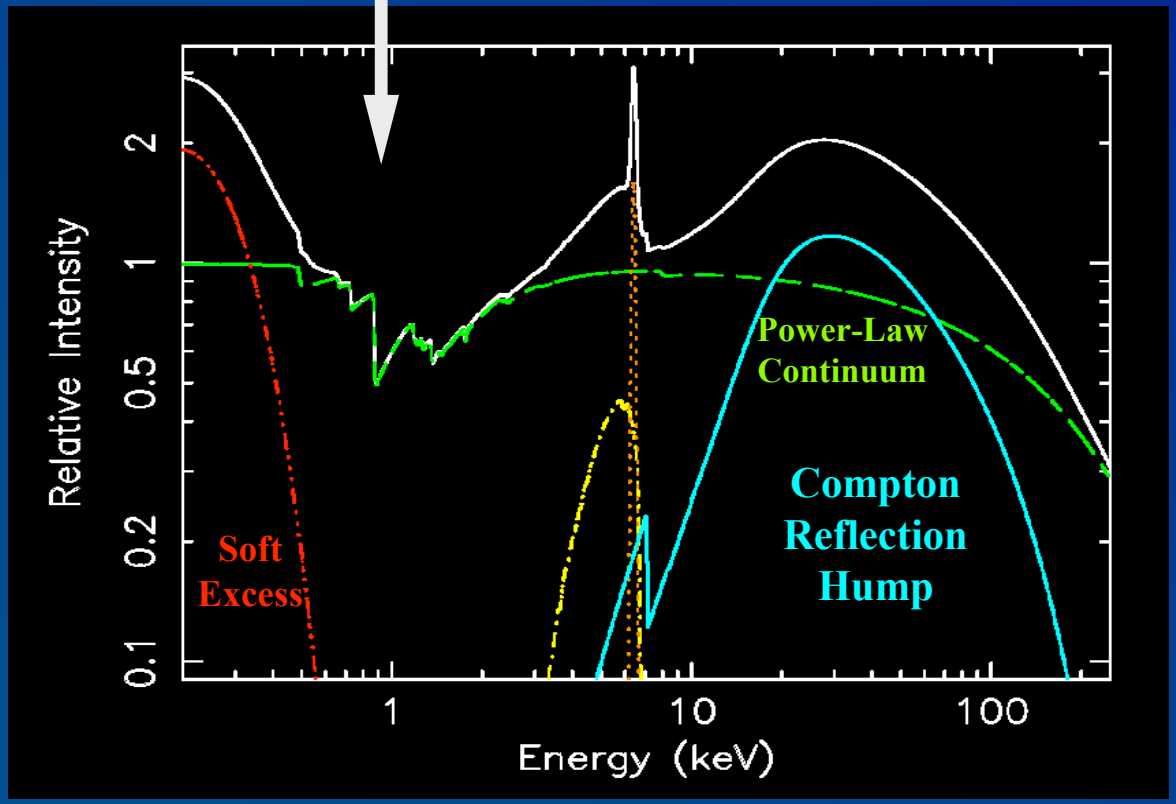
FWHM ~ $10^{3\text{-}4}$ km/s



Typical Sy 1 X-ray Spectrum

Absorbers in Seyfert 1s:
Ionized (warm) absorbers
(e.g., Fe L edges 1-2 keV)

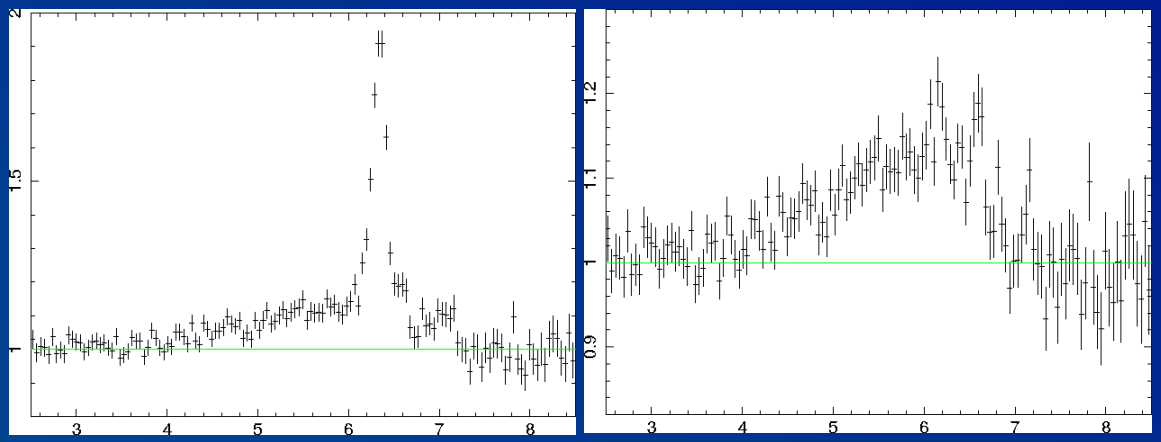
- Solve degeneracy between power-law continuum, Compton hump, broadband absorbing components, disklines
- Completely deconvolve NLs, BLs



Suzaku: Deconvolving Broad & Narrow Fe Lines

NGC 3516

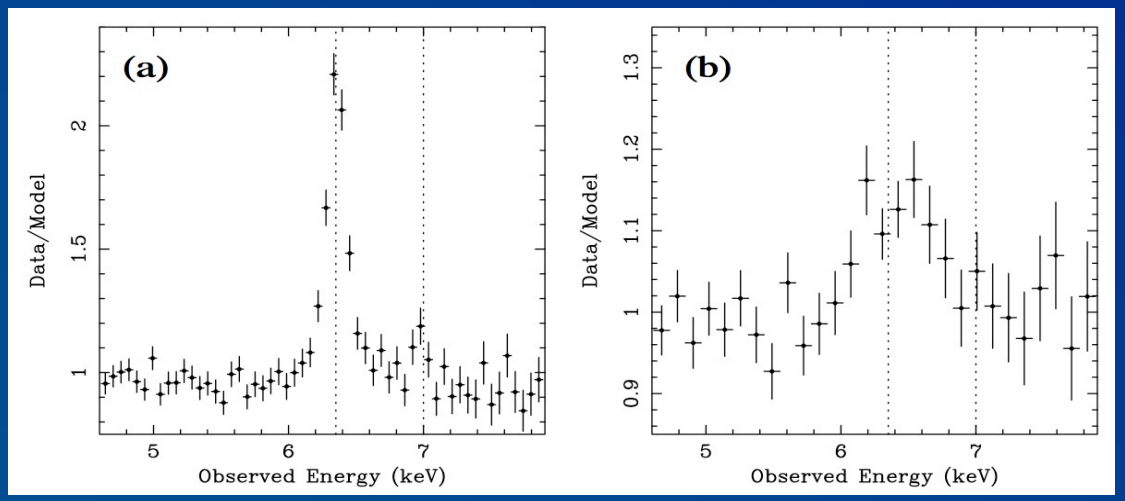
150 ksec obsn., 2005
(Markowitz+ 08)
$R_{in} < 5\ R_g$
$i = 25 \pm 8^o$



Fe line still required in model even after 2 WA's and PC low-ξ absorber taken into account!

NGC 2992

110 ksec obsn., 2005
(Yaqoob+ 07)
$R_{in} = 6\ R_g$ $\quad i > 31^o$



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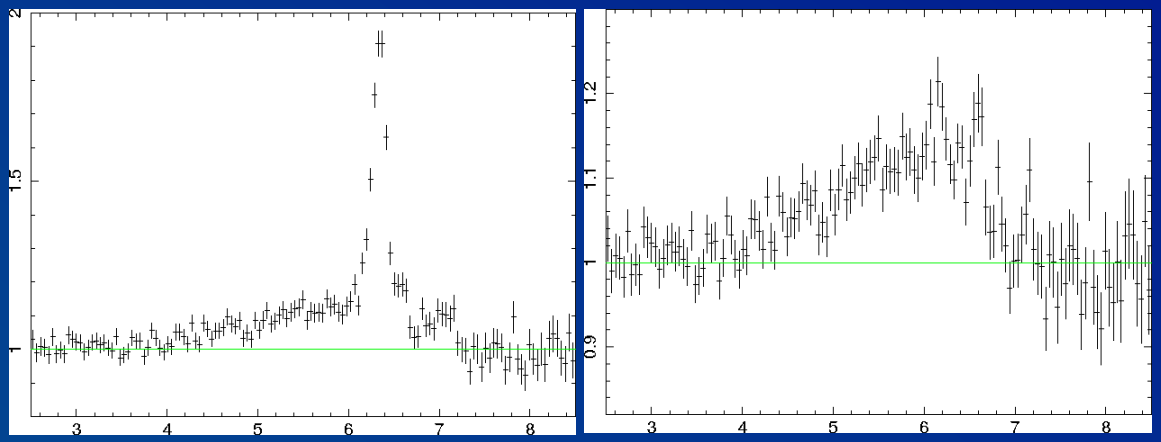

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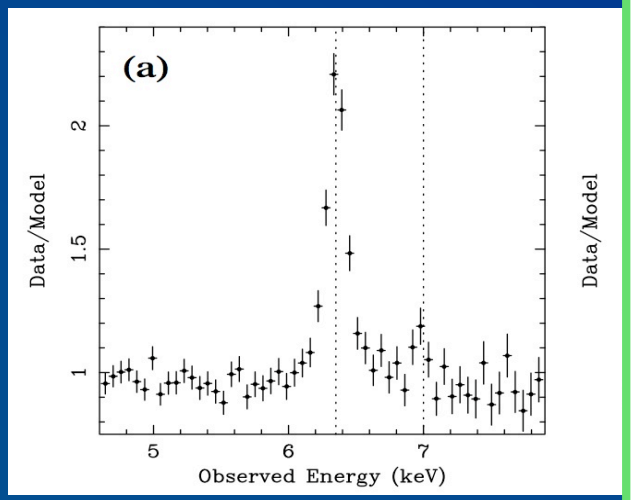
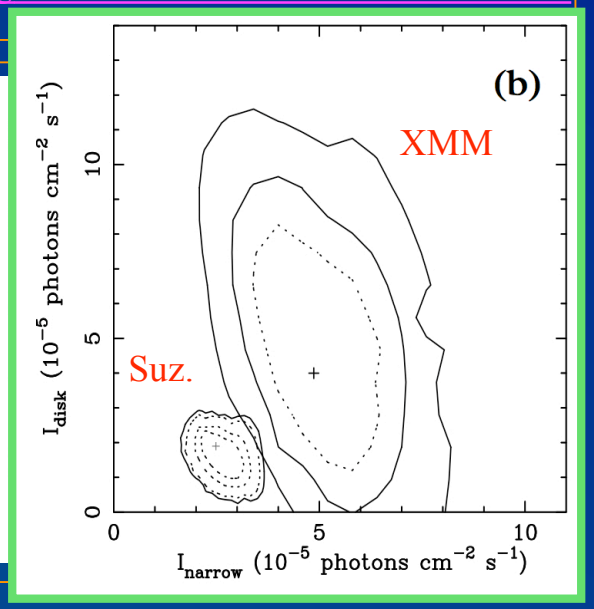


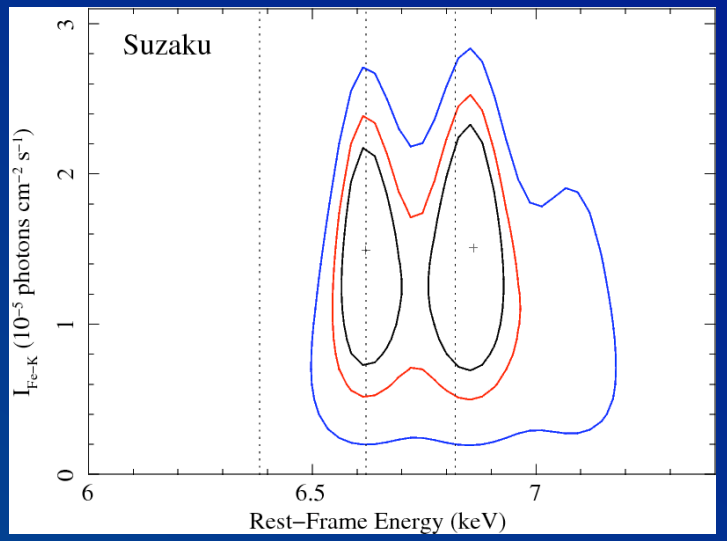


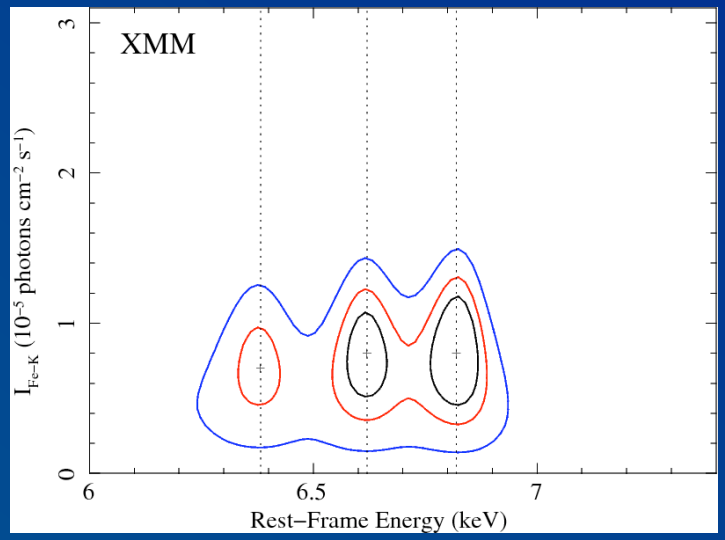
Suzaku-XIS: Narrow Emission Lines in 3C 273

Yaqoob et al., in prep:

Suzaku: 47 ksec obsn., 2007: Narrow emission lines due to Fe XXV+Fe XXV.

XMM-Newton: 10 obsns (130 ksec), 2000-3





Summary (so far): Relativistic Fe Lines from Suzaku

Broad Lines /reflection

- **NGC 3783**: Weak broad line, weak refl. (R~0.3) (Markowitz+, in prep.)
- **MCG -6-30-15*:** Strong broad line, (EW=200 eV) + reflection (R~3) (Miniutti+ 07)
- **MCG -5-23-16**: R_{in}=20-30 R_g. Moderate refl. (R=1.2) (Reeves+ 07)
- **NGC 2992**: Narrow+broad deconvolved (Yaqoob+ 07)
- **NGC 3516**: Broad line + reflection robust to complex absorber. (Markowitz+ 08)
- **3C 120**: Mod. strong broad line, R_{in}=10R_g. Weak reflection (R=0.6) (Kataoka+ 07)

No Broad Lines

- **NGC 4051:** Narrow line only (Terashima+, submitted to PASJ)
- **NGC 2110**: No broad line and no reflection (Okajima+ in prep)
- **3C273:** Narrow Fe XXV & XXVI lines detected (Yaqoob+, in prep.)
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- **NGC 5548:** Narrow line only (Elvis/Reeves+, in prep.).
- **Cen A**: No broad line nor reflection (Markowitz+ 2007)

Publications on additional observed AGN forthcoming…

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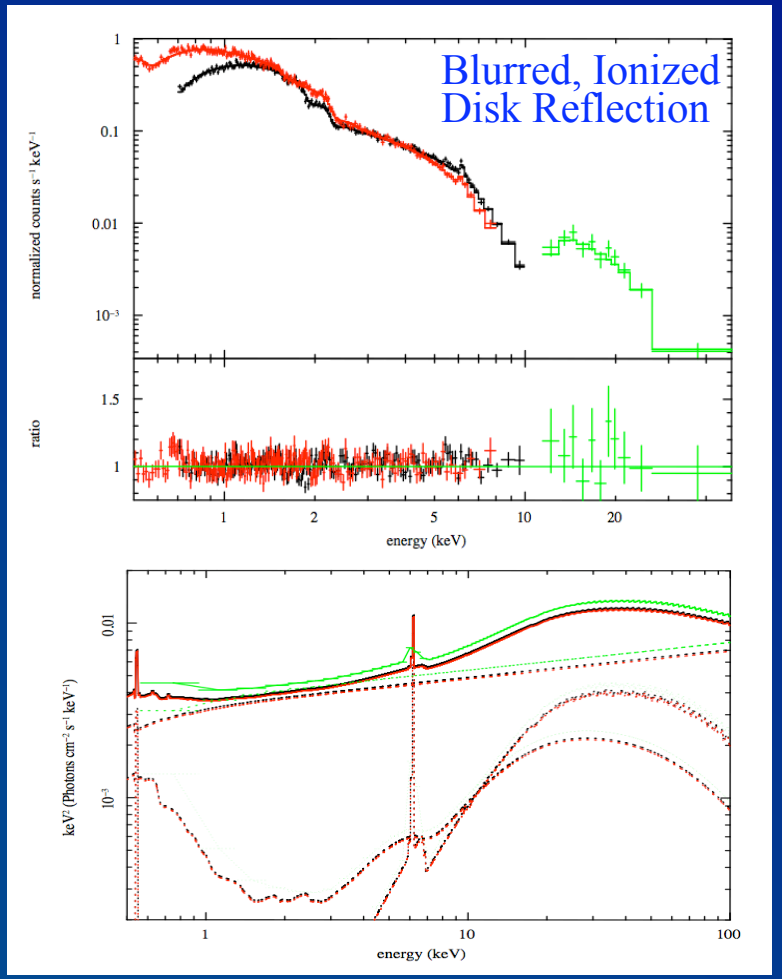
Suzaku broadband modeling: Blurred, Ionized Disk Reflection

Suzaku HXD/PIN is crucial in constraining the amount of Compton reflection > 10 keV!

Broadband modeling (XIS + HXD): constrain relative strengths of reflection components, remove ambiguity due to variability

G. Ponti+ (in prep.): Suz obsn of Mkn 841: ionized disk reflection model fits well (better than smeared absorption.)



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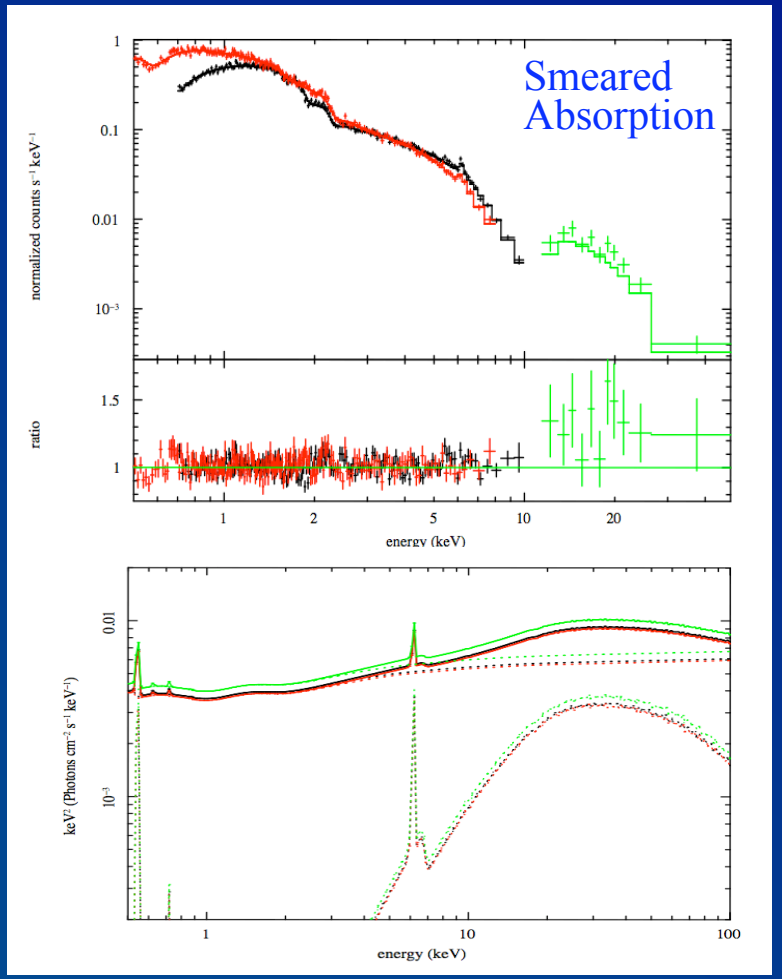

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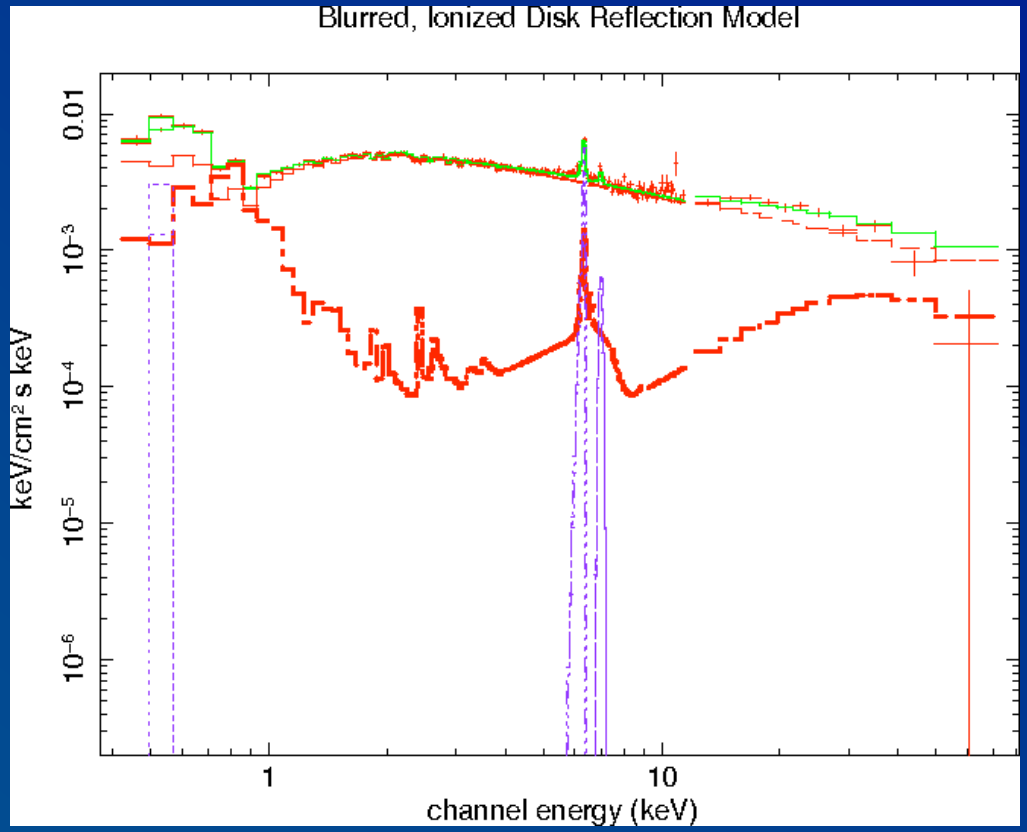
75 ksec Suzaku observation of NGC 3783 in 2006 (Markowitz+ in prep.)

Blurred, ionized reflection describes soft excess (and full spectrum) well!



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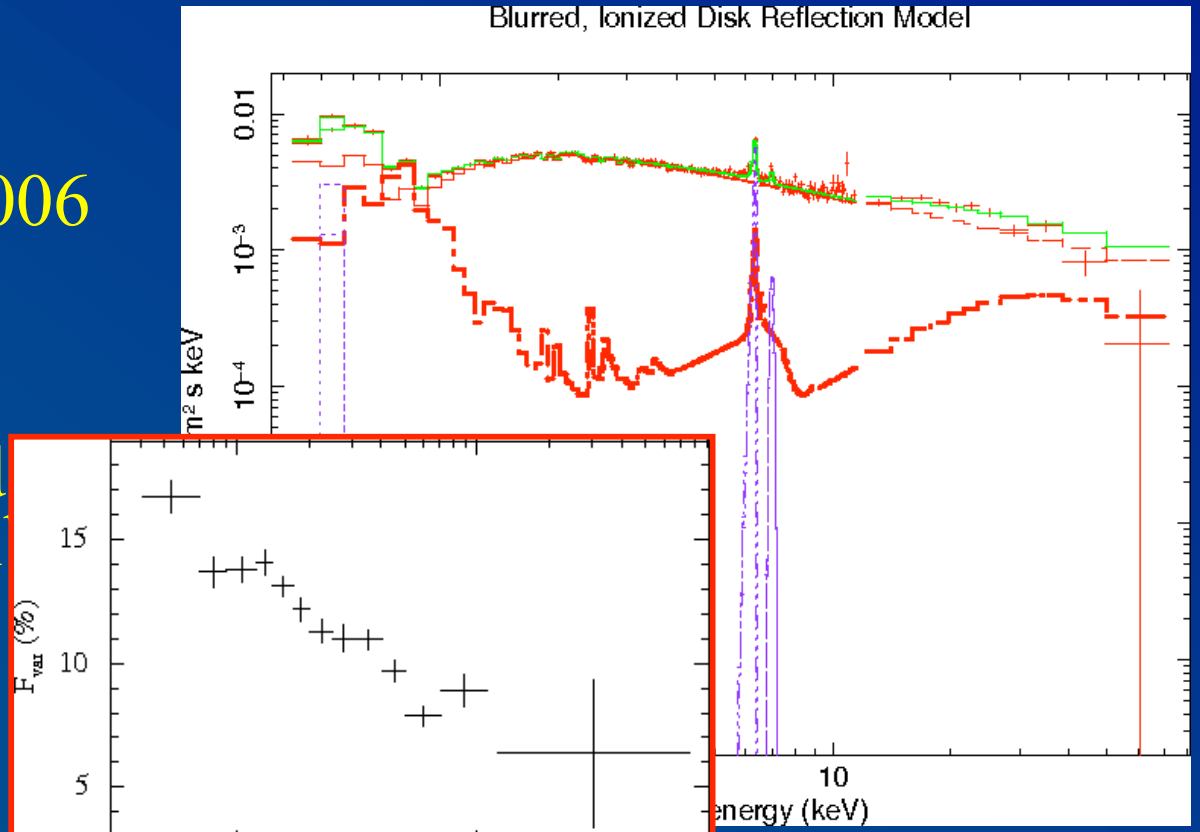
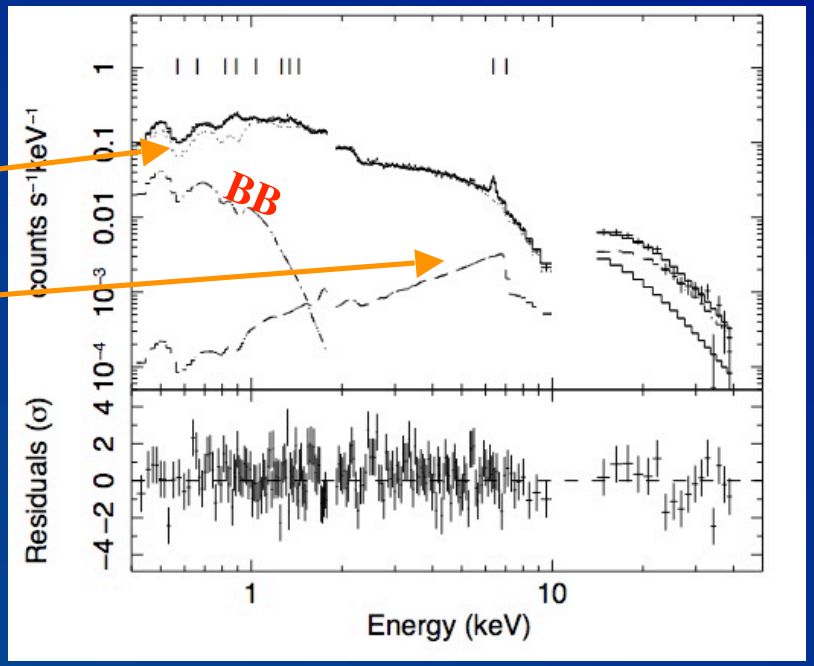
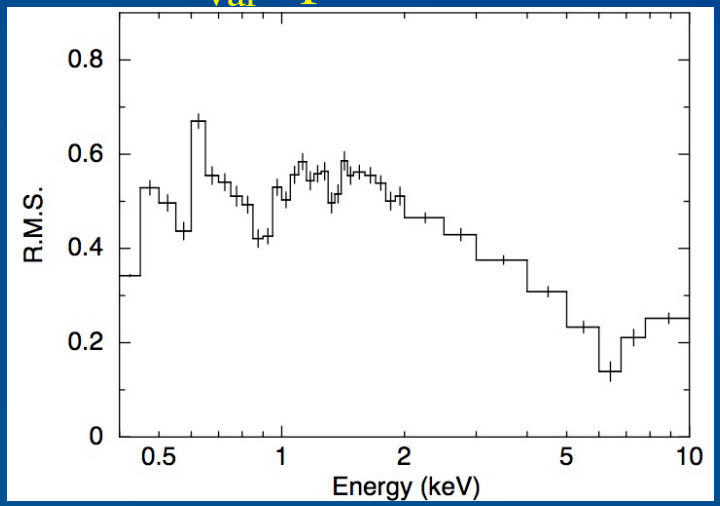


Partial-Covering Absorption Explains Spectral Variability in NGC 4051 (Terashima et al., PASJ subm.)

Spectral variability during Suzaku obsn. explained via modeling a partially-covered (10^{23} cm^{-2}) PL + independent partial covering (10^{24} cm^{-2}) for the Compton reflector



F_{var} spectrum:



PL norm varies (Γ constant) **AND** covering fraction of PC absorber varies (yielding extra spectral variability < 3 keV)

Summary

•Suzaku's broad X-ray bandpass & narrow CCD response are allowing us to deconvolve broad & narrow Fe Kα lines and (ionized + neutral) absorbing components

•The community is critically testing for the presence of broad Fe disklines on a per-object basis, as well as testing models incorporating blurred (disk), ionized reflection

•The sample of Seyferts observed with Suzaku is gradually accumulating; Suzaku will accurately gauge frequency of occurrence of broad Fe lines and applicability of blurred ionization reflection models.

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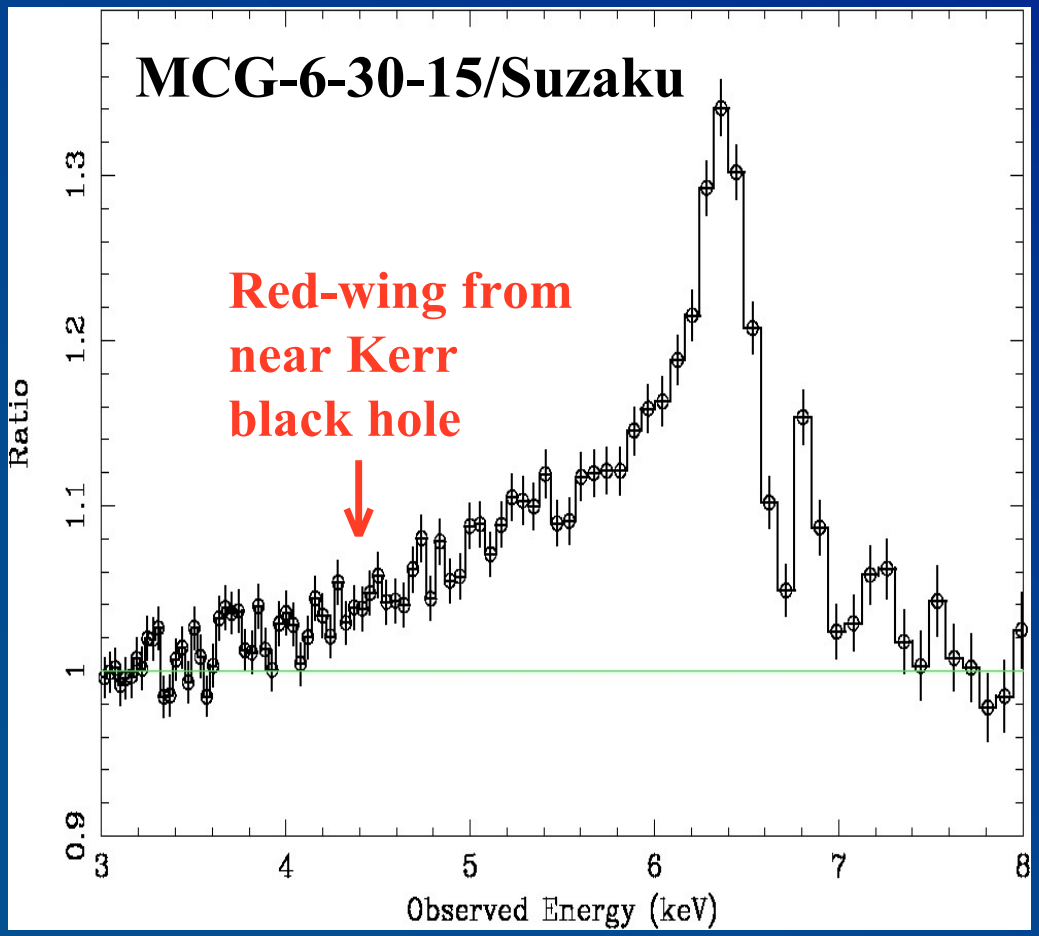
Probing effects of strong gravity



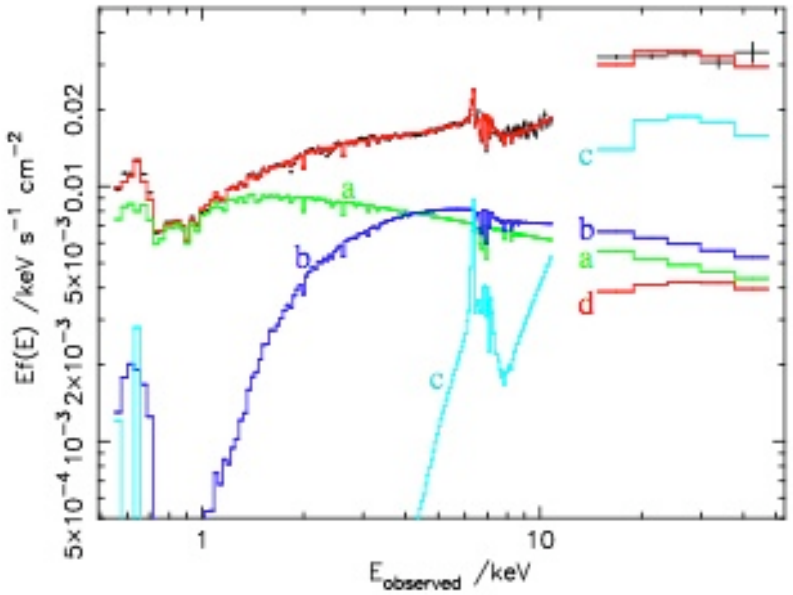
300 ksec observation of MCG–6-30-15 (Miniutti et al. 2007)

$R_{in} < 2.2\ R_g$

Spin parameter
$a_* > 0.917$

*But see also paper by L. Miller et al., arXiv/0803.2680

L. Miller+ 2008: Principle Component Analysis of MCG-6-30-15 (Suzaku + XMM-EPIC + Chandra-HETGS) -- arXiv:0803.2680



Eigenvector 1 (variable) =
PL * Z1 * Z2

Eigenvector 0 (constant) =
(PartialCov.Powerlaw*Z1*Z2*Z3*Z5)
+ (Distant Reflection *Z1*Z2*Z3*Z4)

Zone 1: logξ=2, N_H=3e21/cm^2 (Chandra HETGS, Lee+01)

Zone 2: logξ=0.5, N_H=3e20/cm^2 (Chandra HETGS, Lee+01)

Zone 3:logξ>3.5, N_H=2e22/cm^2 (Chandra HETGS, Young+05)

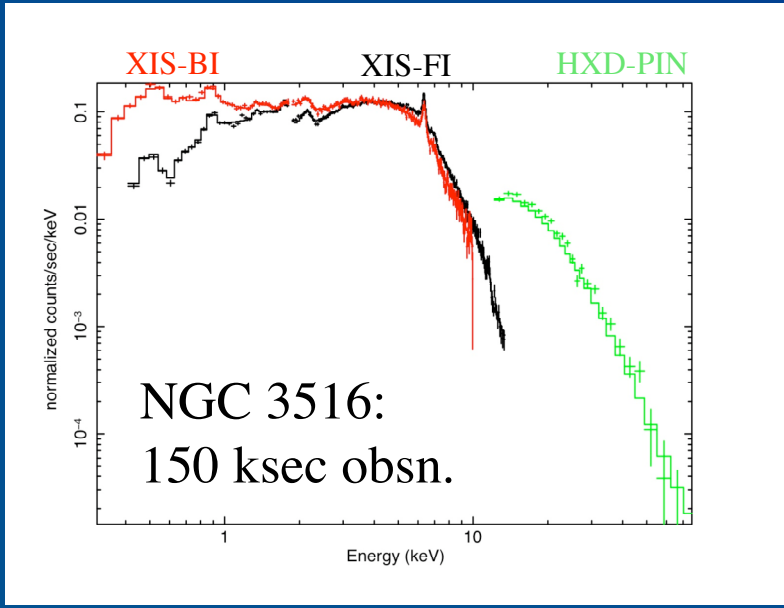
Zone 4: Absn which hardens the reflection spectrum: logξ=1.5, N_H=3e23/cm^2

Zone 5: logξ=1.5, N_H=5e22/cm^2 (partial-covering only)

Suzaku

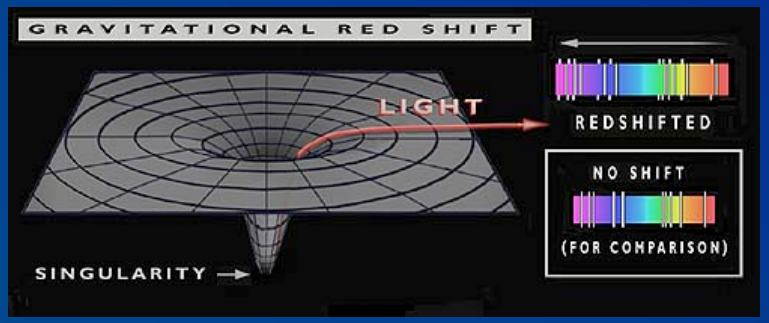
(JAXA/ISAS)

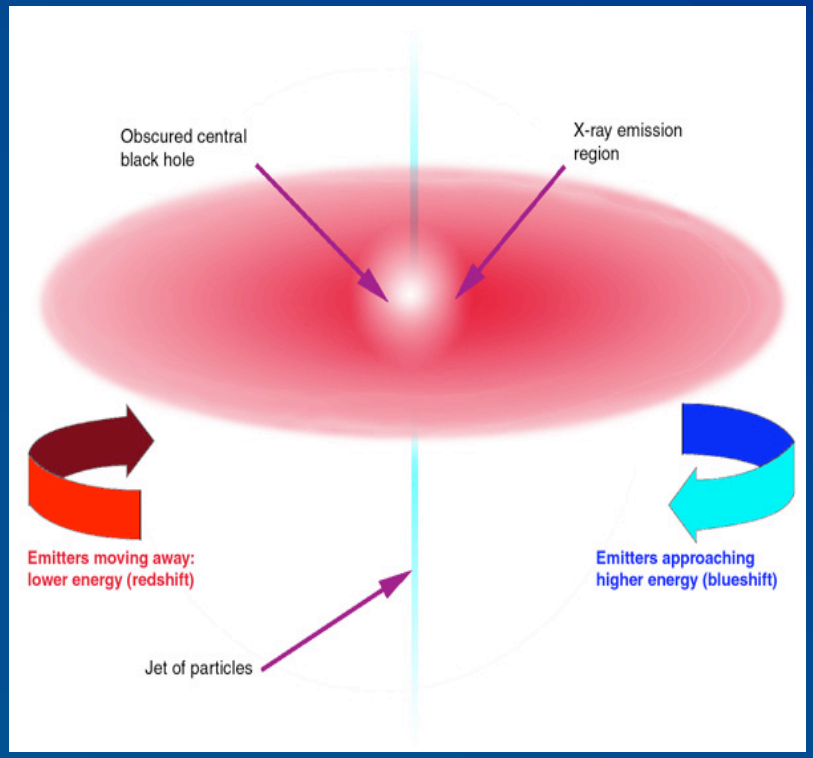
- Launched 2005 July 10; AO3 observations start April '08
- **X-ray Imaging Spectrometer (XIS) CCDs:** 0.3 to 12 keV
- **Hard X-ray Detector (HXD):** 12 to >300 keV



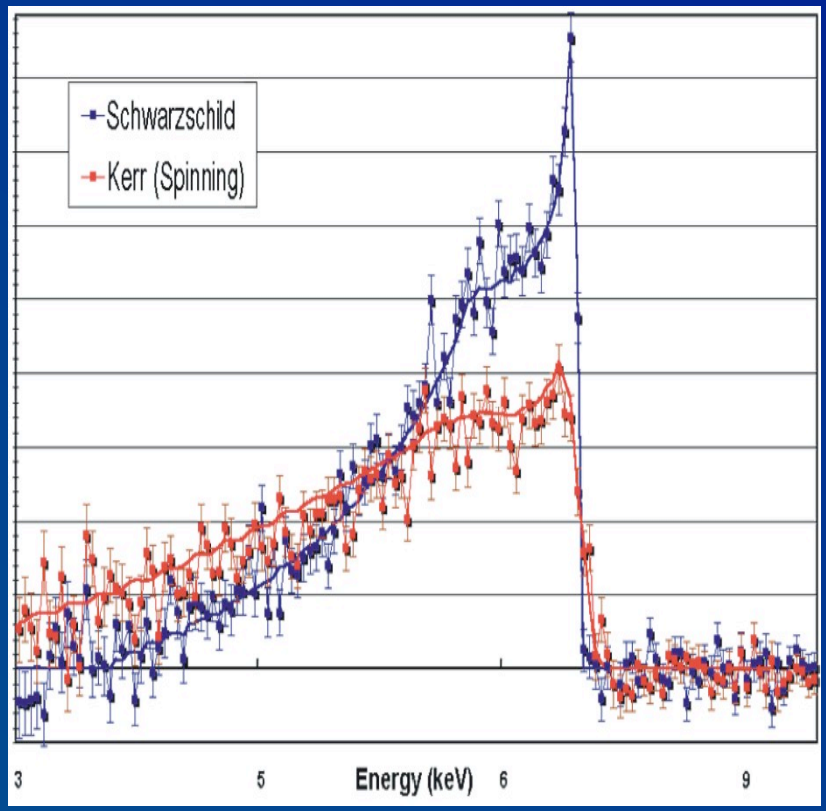
- Broad bandpass: deconvolve broadband components (power-law, WA's, Partial Coverers, broad Fe lines)
- > 10 keV coverage (Compton reflection hump)
- Narrow CCD response: ~150 eV FWHM

Broad Line Profiles: Gravitational and Tranverse Doppler Shifts

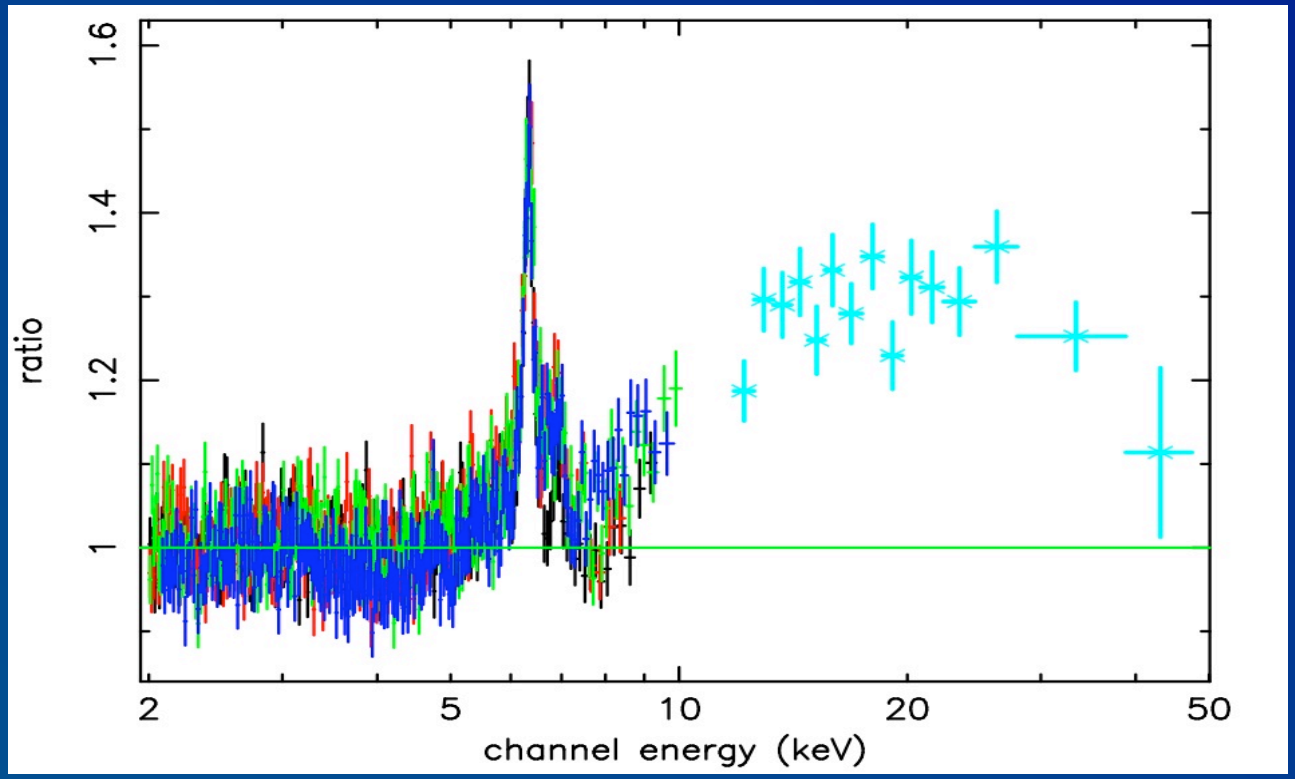




Predicted Iron Line Profiles

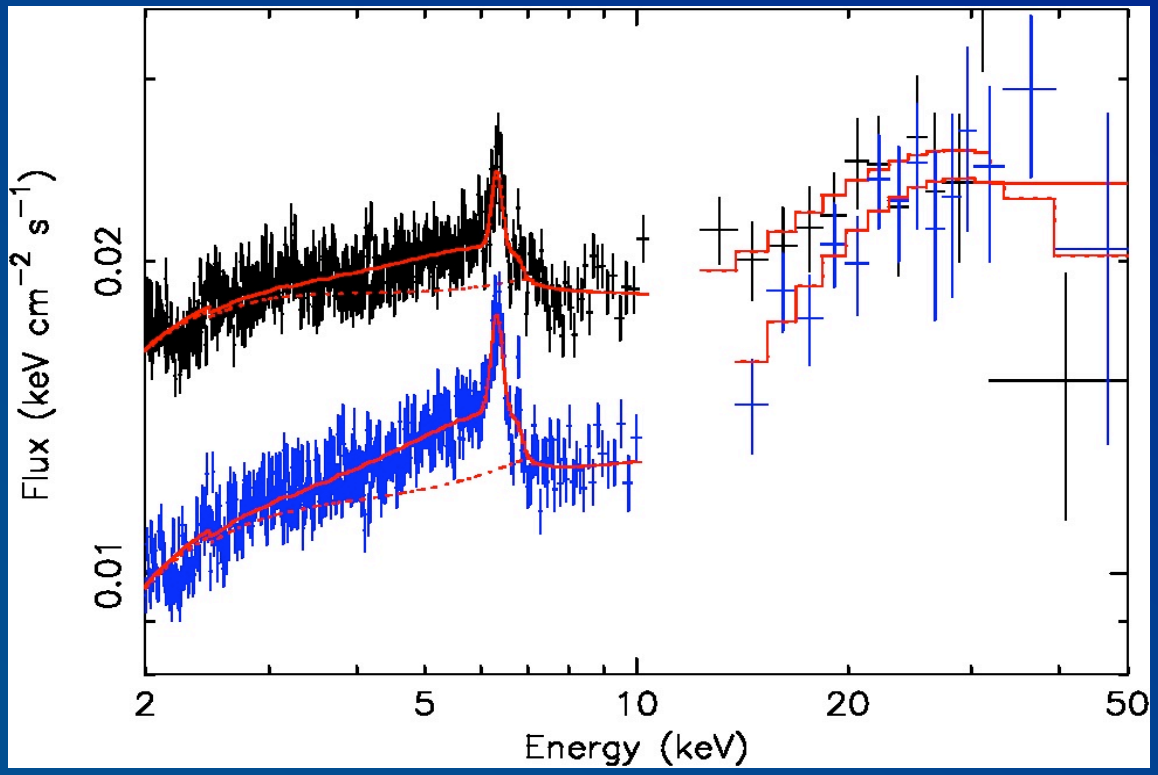


Reflection Components



MCG–5-23-16 (Reeves et al. 2007)

Time Variability of Reflection Components

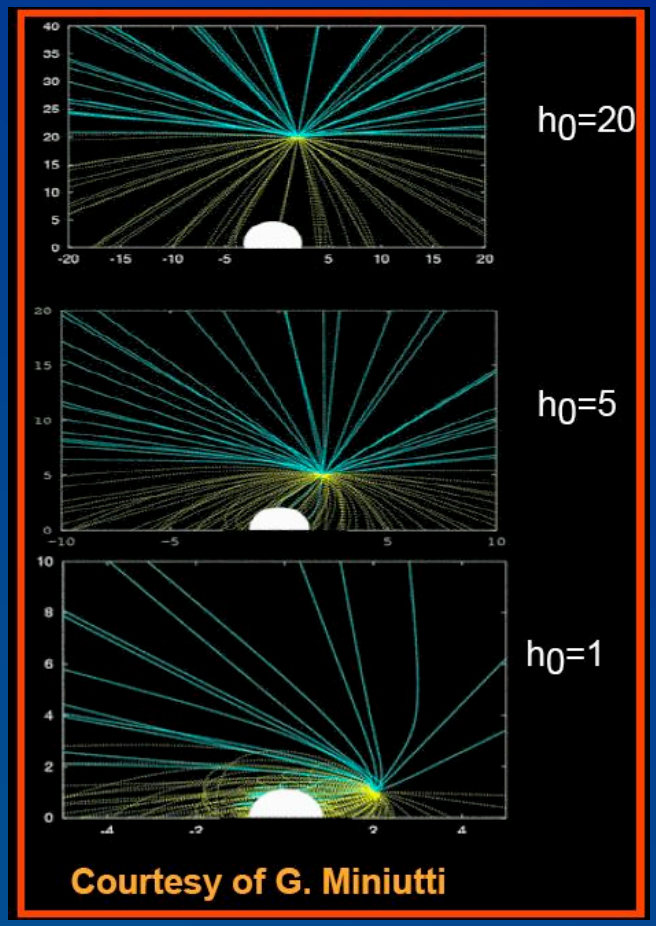


MCG–6-30-15 HIGH & LOW flux levels
(Miniutti et al. 2007)

- Broad Line & Compton Reflection Hump both vary less than continuum.
- Effects of light-bending near BH?

Light-bending in Region of Strong Gravity

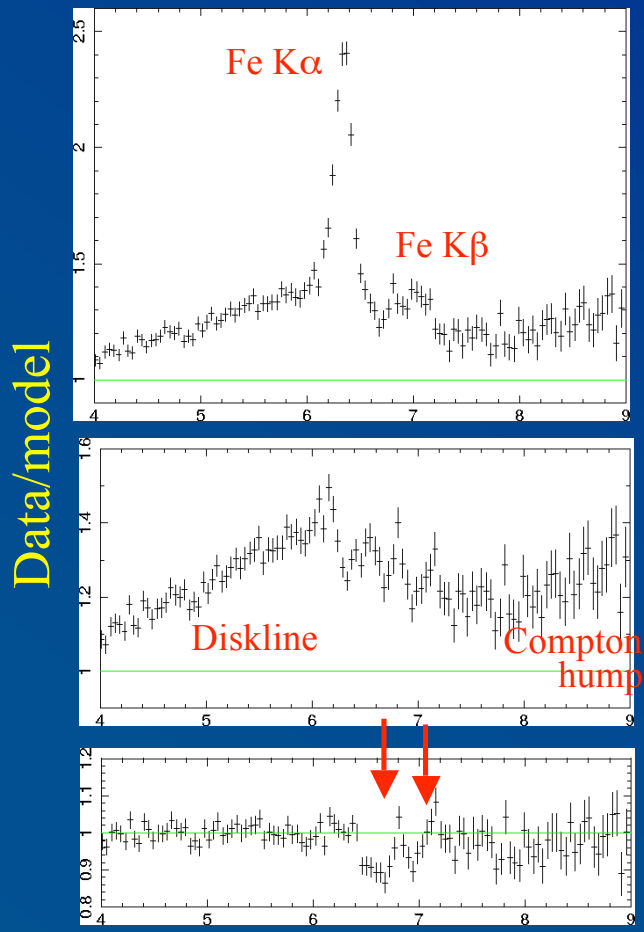
Higher power-law flux



See Miniutti & Fabian (2004) for more details….

Ionized Fe K absorption features

NGC 3516/Suzaku
(Markowitz+ 2007)

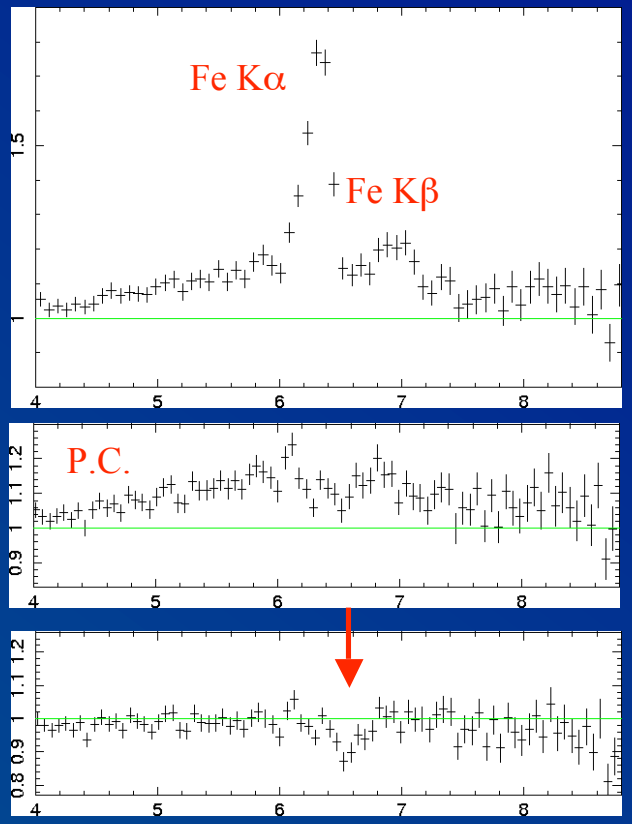


Both cases: consistent with systemic veloc.

Fe XXVI & XXV ($\log\xi = 3.7^{+0.3}_{-0.7}$ erg cm/s)

Fe XXV ($\log\xi \sim 3$ erg cm/s)

NGC 3783/Suzaku
(Markowitz+, in prep.)



Relativistic, highly-ionized outflows

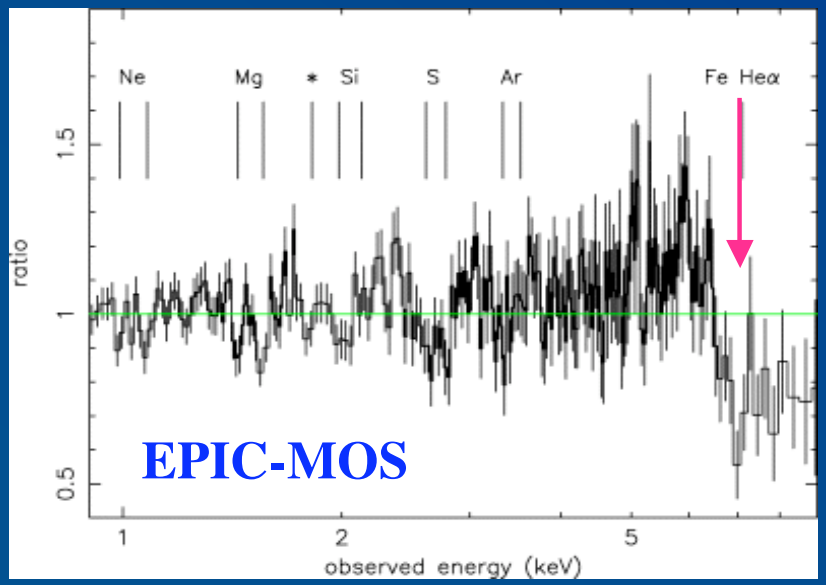
Outflows of ~0.1-0.3c claimed from X-ray spectra of several AGN

Mainly via absorption features in the Fe K band.

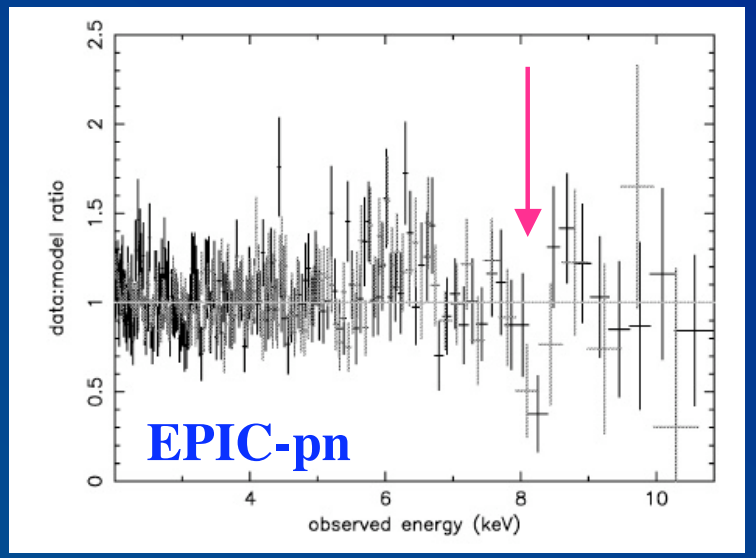
Large column densities (>~ 10^{23} /cm^2) required

High N_H + high velocity → outflow is both massive and energetic (unless very highly collimated)

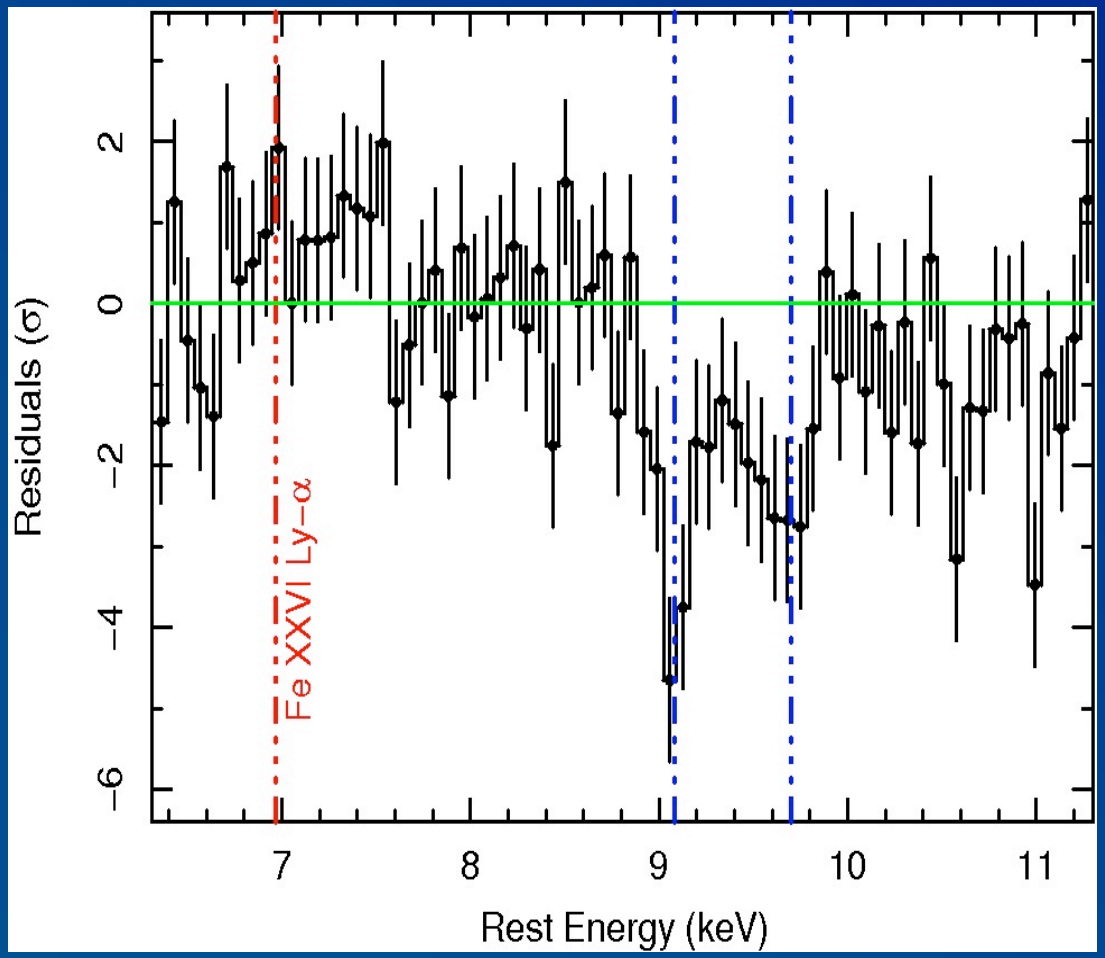
PG 1211+143, z=0.081
(Pounds+ '03, '06, '07)



PG 0844+349
(Pounds+ '03)



Relativistic Outflow in PDS 456

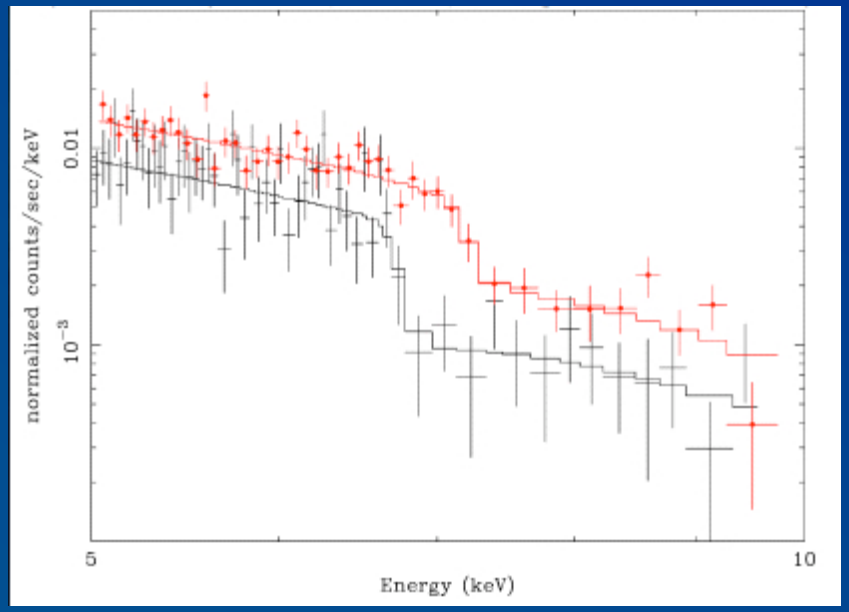


Deep Suzaku Observation, 190ks, Feb 07

Reeves+, in prep.

More Ionized Fe K absorption features

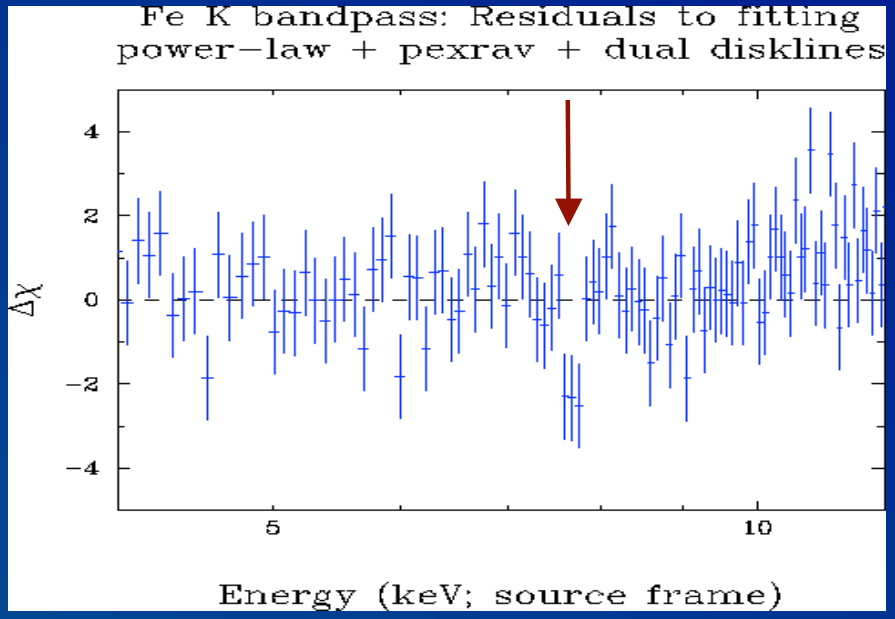
1H0707-495/XMM:
Fe K edge variations
(Gallo et al. 2004)



Evolution in outflowing, partial-covering absorber over 2 years

(Prelim. Suzaku result: edge is VERY DEEP!)

IC 4329a/XMM
(Markowitz et al. 2006)



Fe XXVI, outflowing at 0.1c

Ionized Disk Wind?

These winds represent large fractions of the AGN's total kinetic energy!

Blurred + Ionized Disk Reflection in NGC 3783

Fvar.ps with new models?

Fits + resids to difference spectrum?

- Blurred+ionized disk reflection fits soft excess well in both time-averaged spectrum and hi-lo difference spectrum
- F_{var} spectrum: soft excess more variable than PL.
- Consistent with ξ responding linearly to continuum flux!