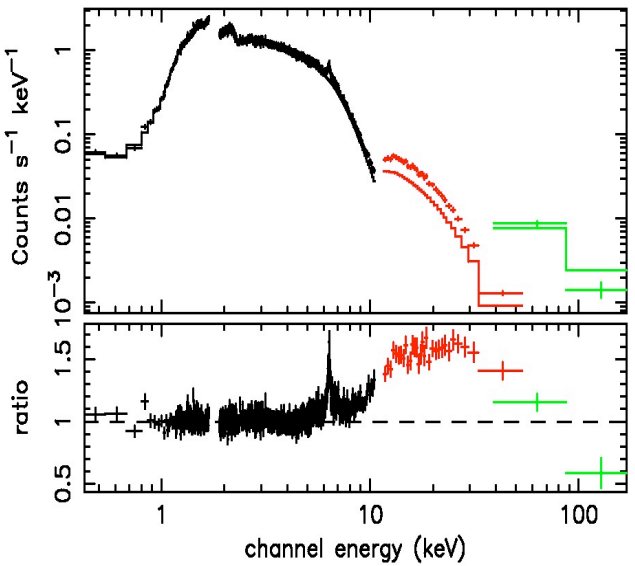
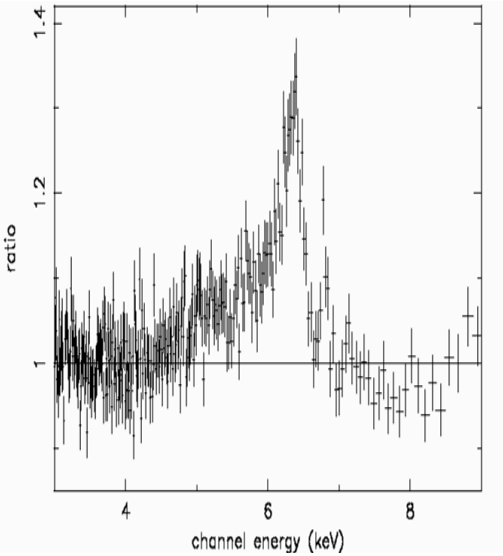
Suzaku Observations of Iron Lines and Reflection in AGN

James Reeves (JHU/GSFC), Richard Mushotzky (GSFC), Alex Markowitz (NRC/GSFC) and Suzaku/SWG team





Suzaku Observations of AGN (GTO Program)

- ***Establish 'reality' of broad Fe K lines-***
  - NGC3516, MCG-5-23-16, MCG-6-30-15, NGC2992….
- ***Determine accurate reflection parameters and comparison of Fe K line to reflection -***
  - NGC2110 (no reflection)
  - MCG-5-23-16,MCG-6-30-15, NGC3516
- ***Precision measurements of Fe line parameters***

Time variability of different Spectral components and their connection

Work is started preliminary results NGC 4051, MCG-5-23-16, MCG-6-30-15

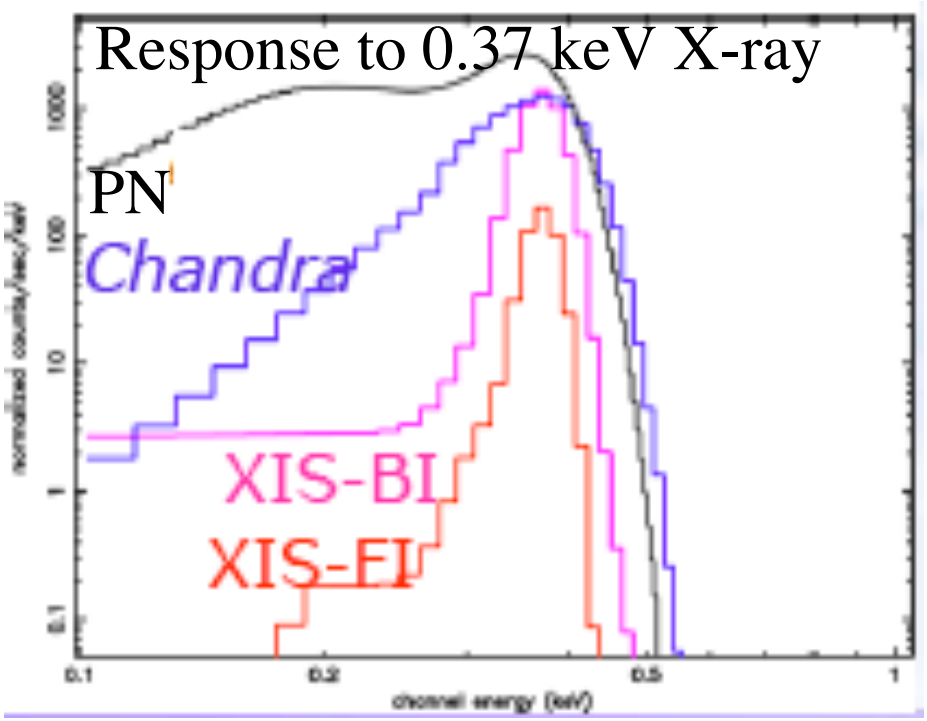
Does the reflection (+Fe line) vary with the continuum?

High energy cutoffs- and connection to x-ray background

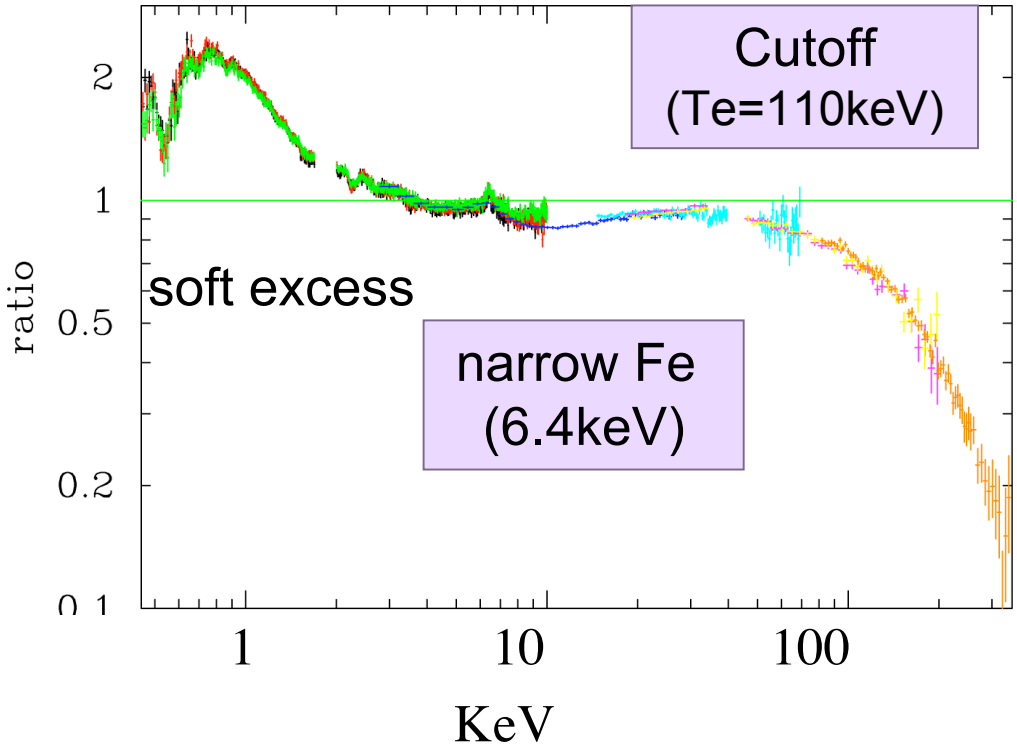
NGC4388, NGC4945, MCG -5-23-16, Cen-A, NGC2110

Important Suzaku Properties for AGN research

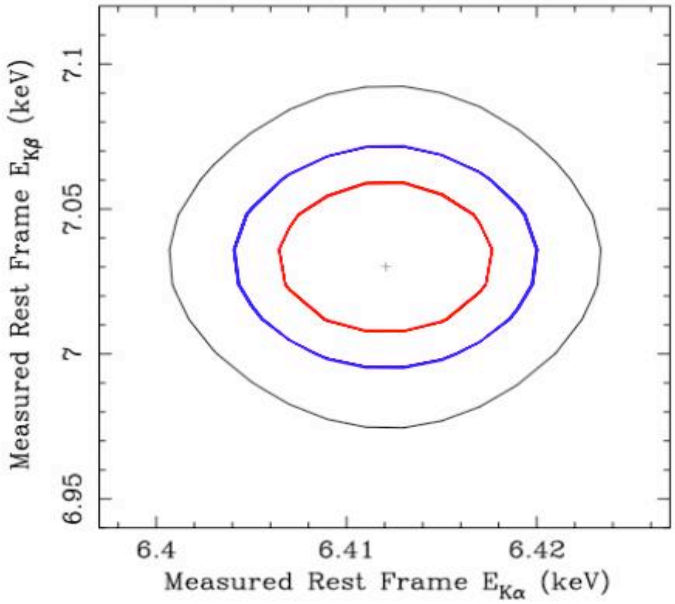
- High signal to noise from 0.3- 50(200) keV
- Well calibrated
- Good energy resolution (better than XMM and Chandra CCDs)



Suzaku data for Cyg X-1

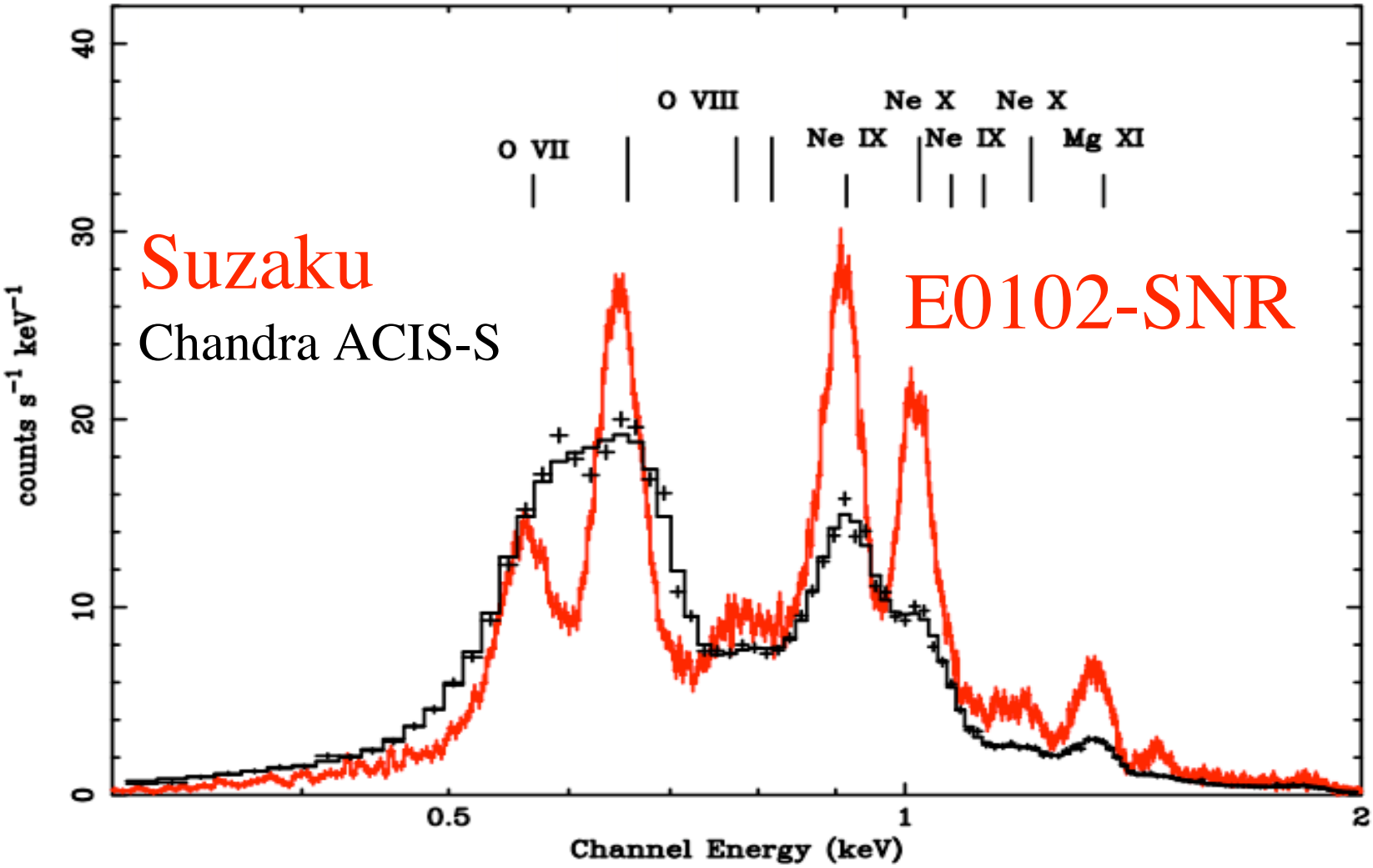


Kα-Kβ line energies in NGC2110



Suzaku XIS: Excellent Spectral Resolution

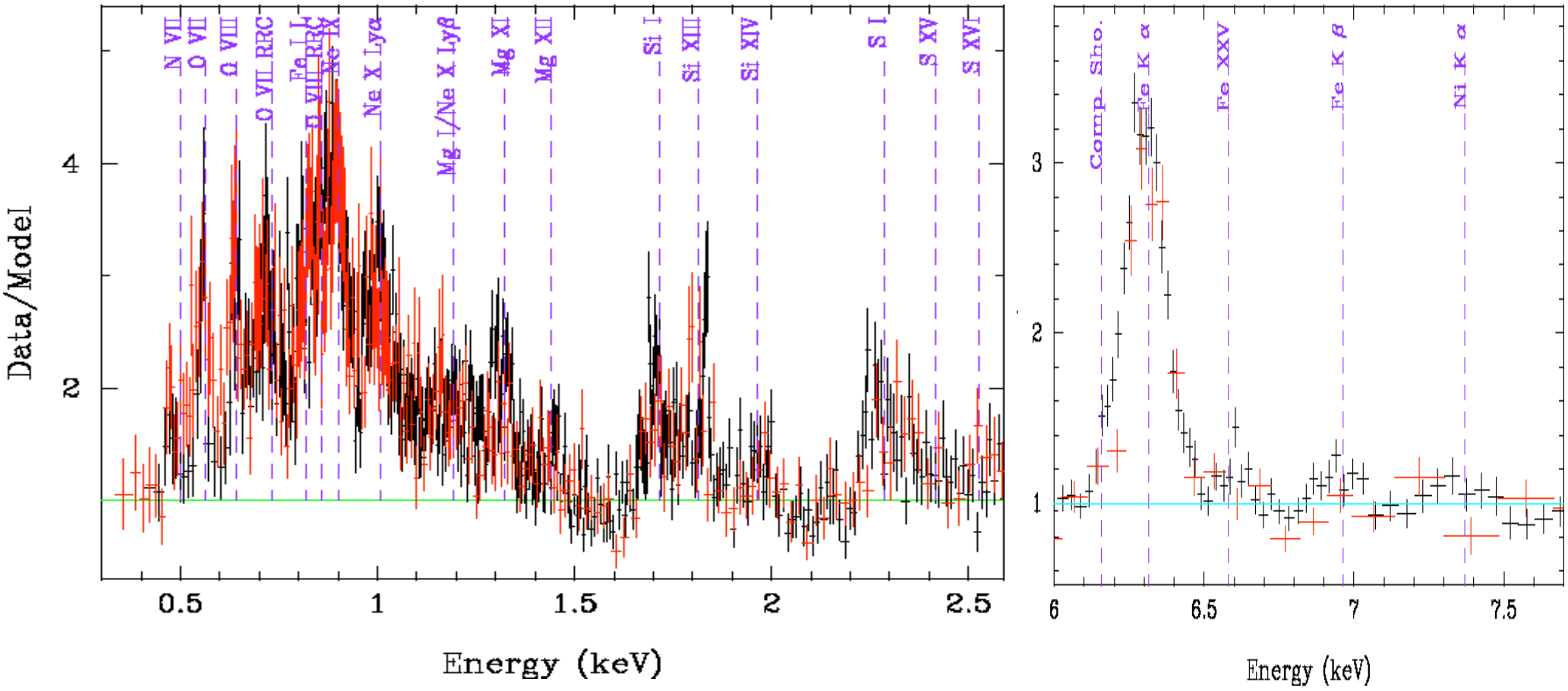
especially at E < 1 keV



Suzaku Observation of Mrk 3 (Awaki et al.)

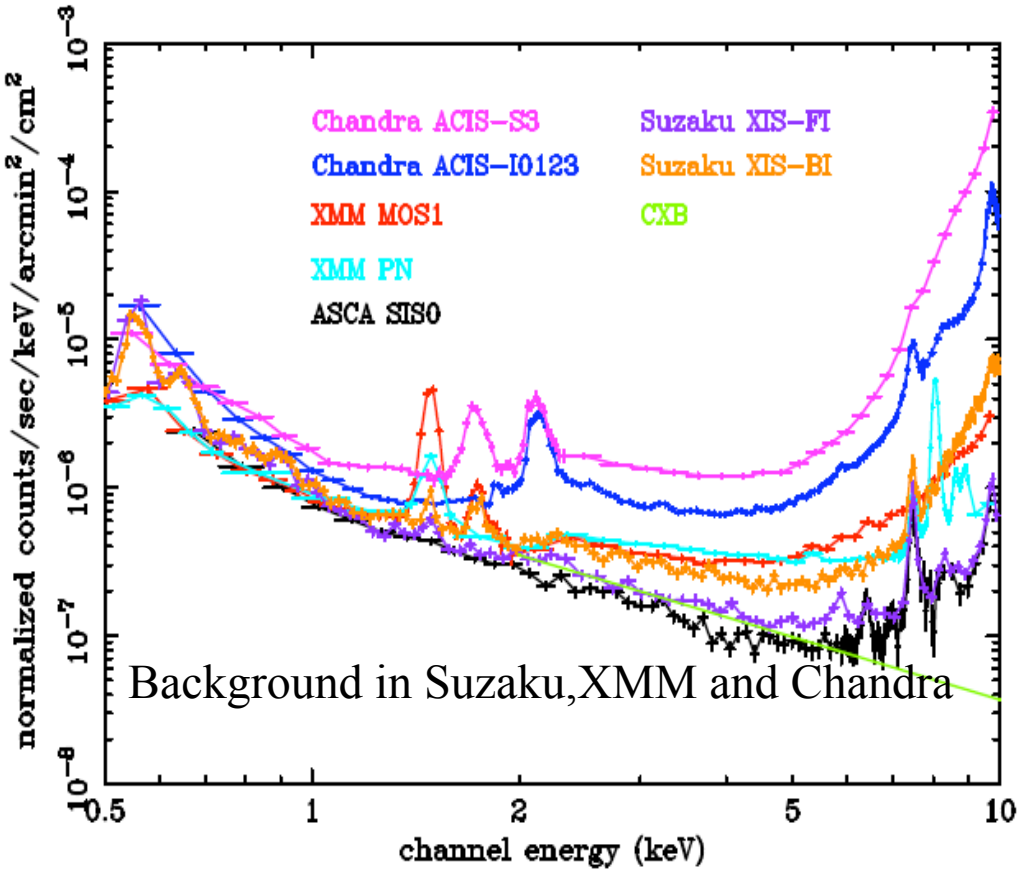
Soft X-ray emission lines

Fe K band

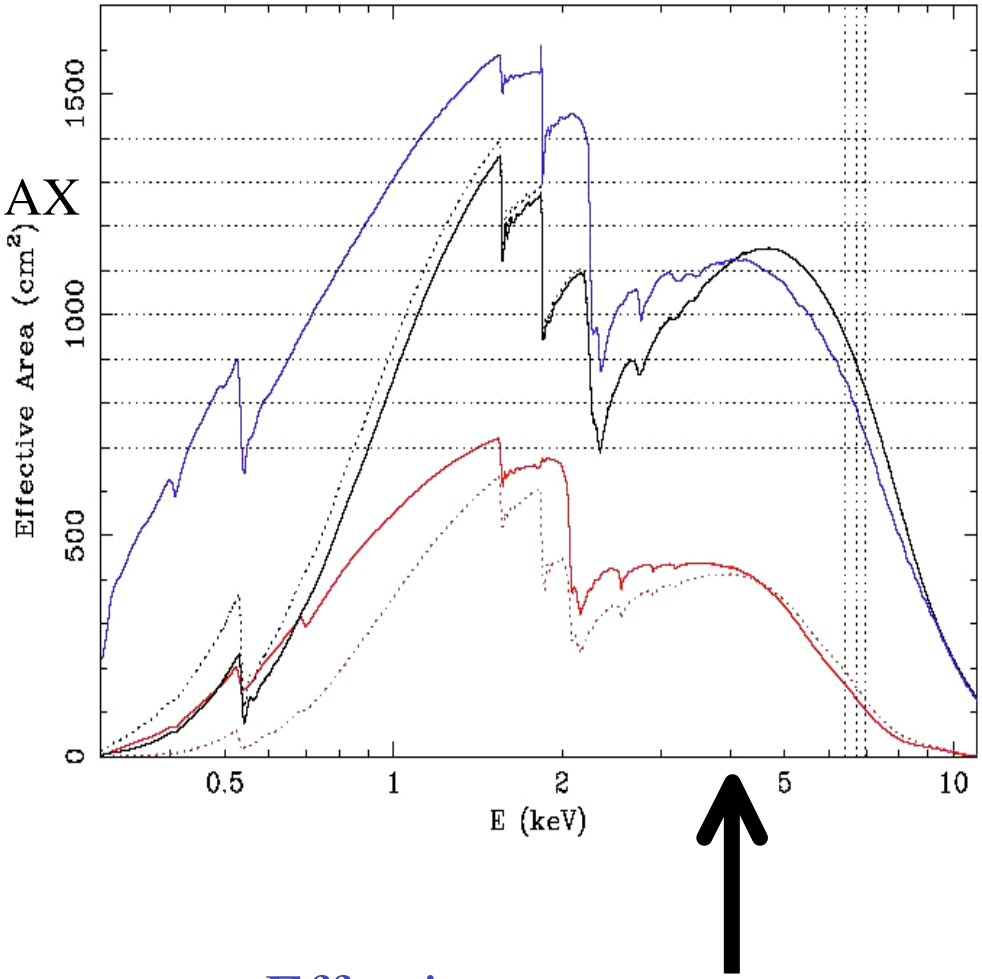


Comparison of Suzaku, XMM and Chandra Background/Areas

For point sources Suzaku is
flux limited- with similar counting
rates for hard sources to XMM EPIC
Hard x-ray detector is more sensitive than SAX
in 10-40 keV band

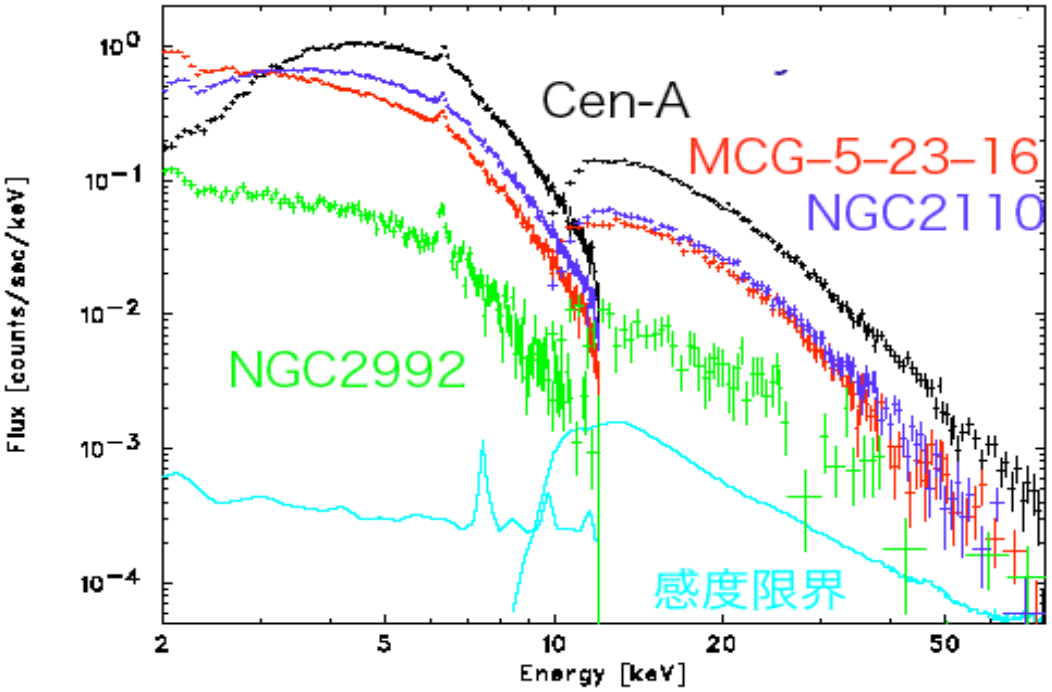


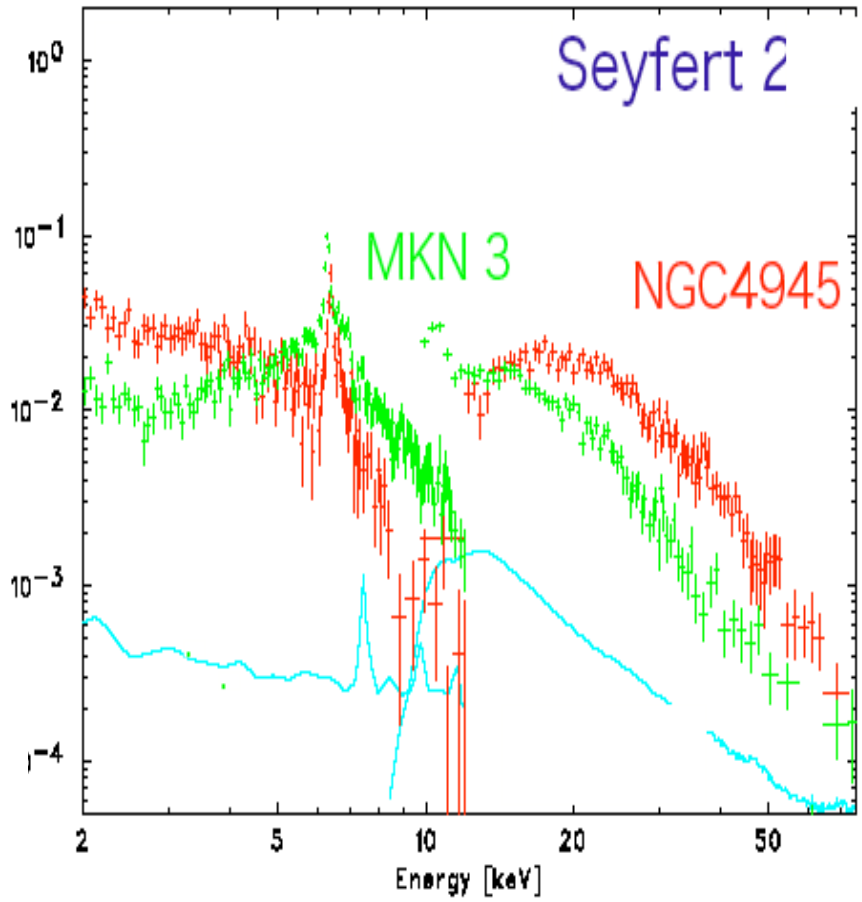
ure 13: Comparison of the background spectra normalized by the effective area and by the FO\

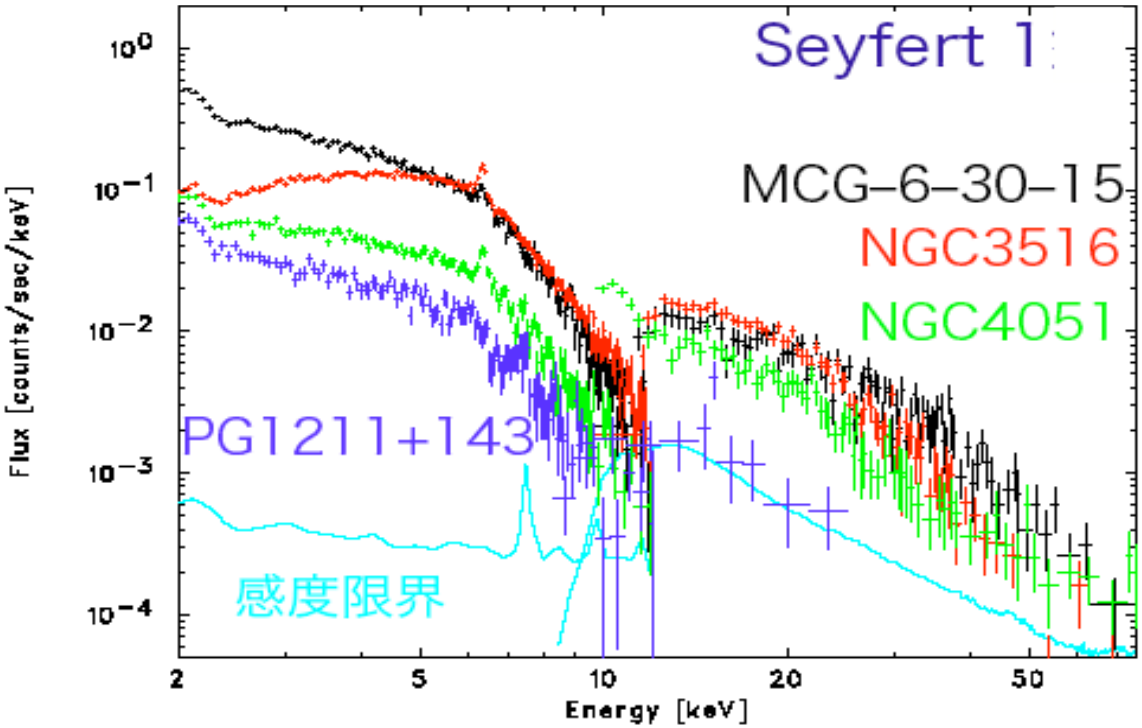


Effective areas

- ***Suzaku in black***
- XMM in blue
- Chandra (ACIS) red



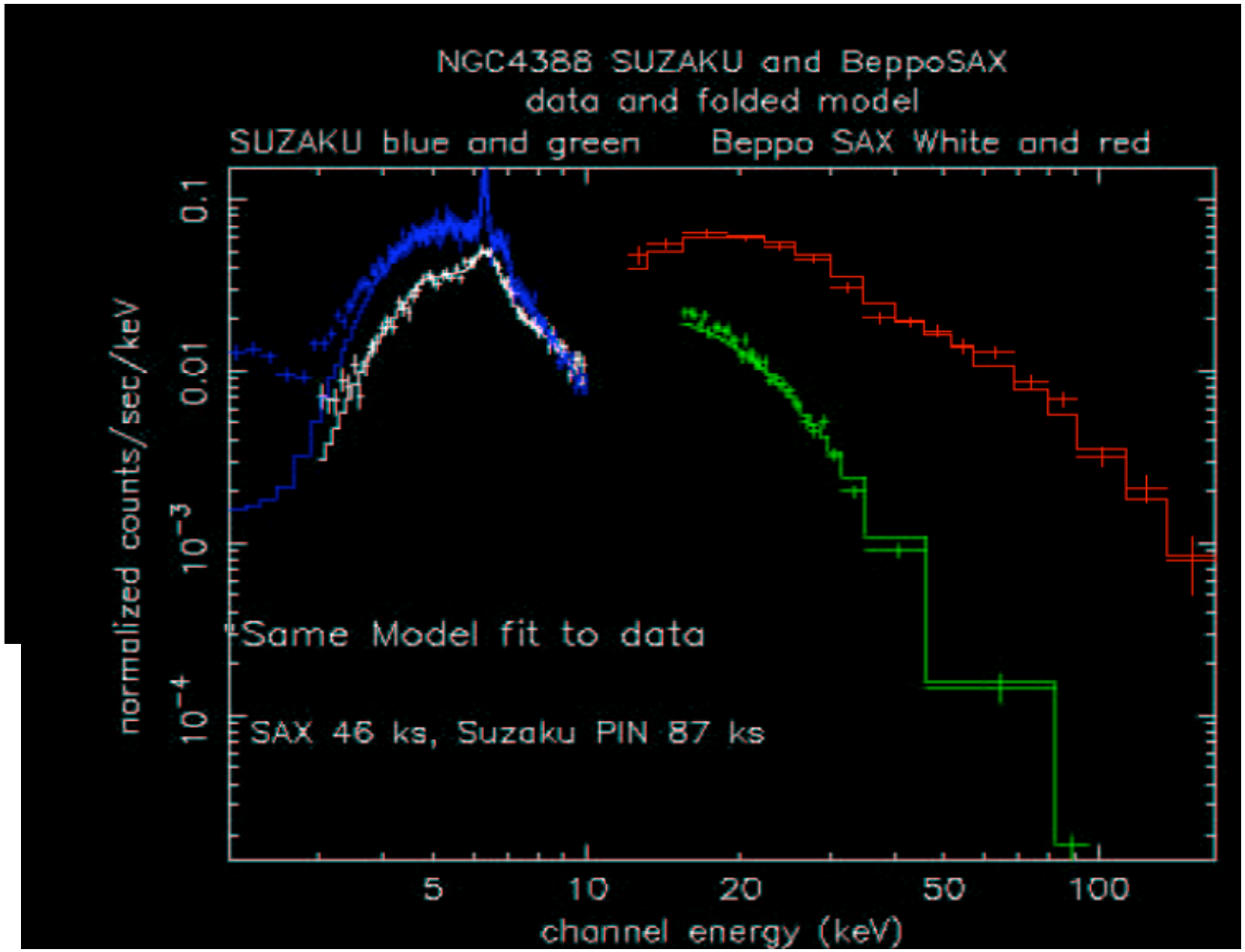


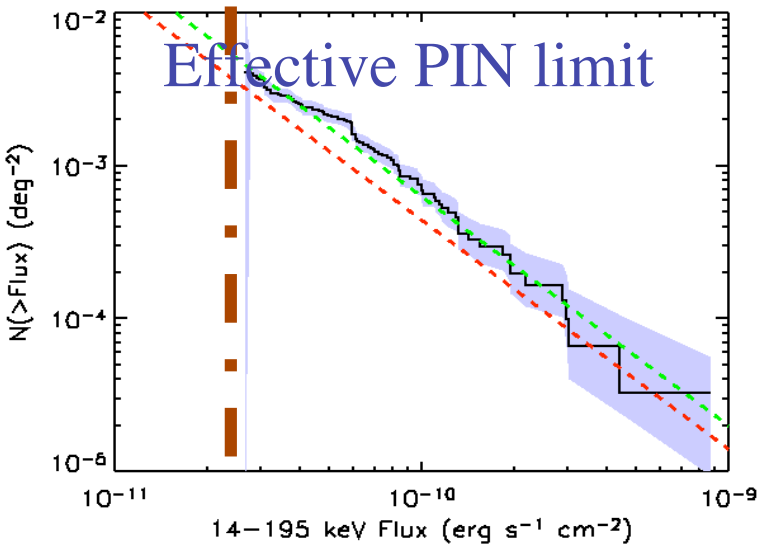


Sample AGN Spectra
Watanabe et al.

NGC4388 Direct Comparison of Suzaku and BeppoSax

- One XIS (Suzaku)- 2 MECS (SAX)
- Flux state very similar
- Same Model fit to data (Suzaku 0.1 steeper PL slope)
- Swift BAT catalog has ~250 AGN above the flux level limits of the PIN and >100 galactic sources

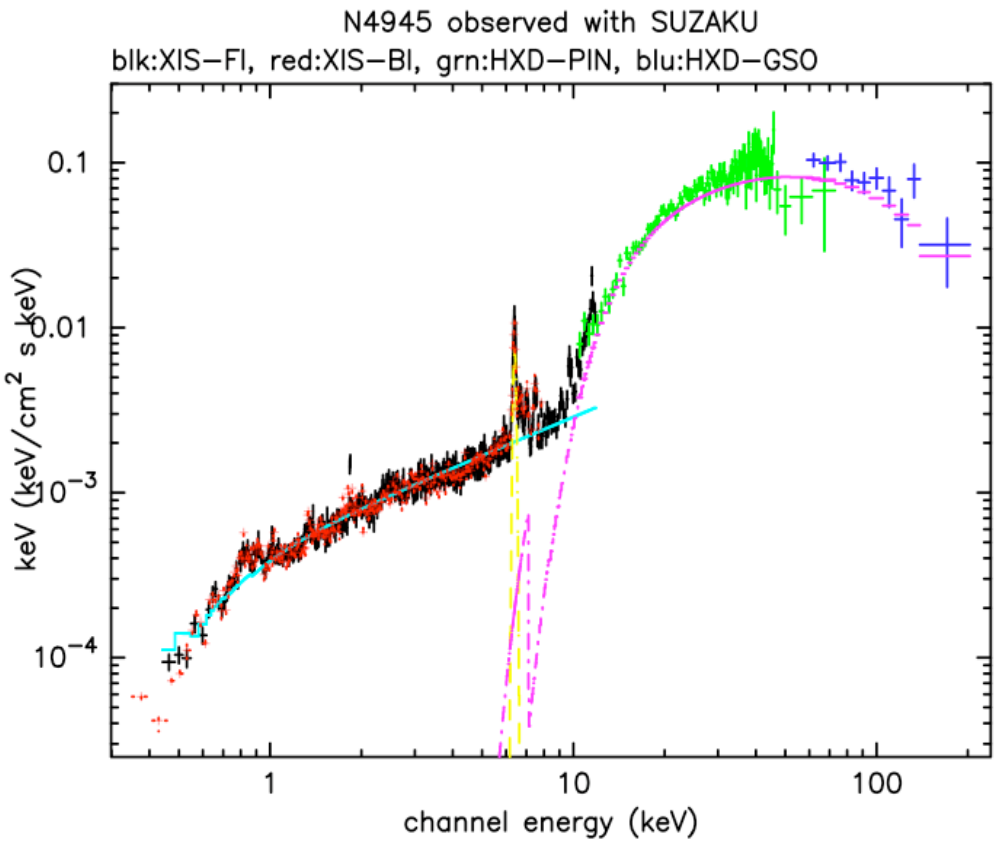


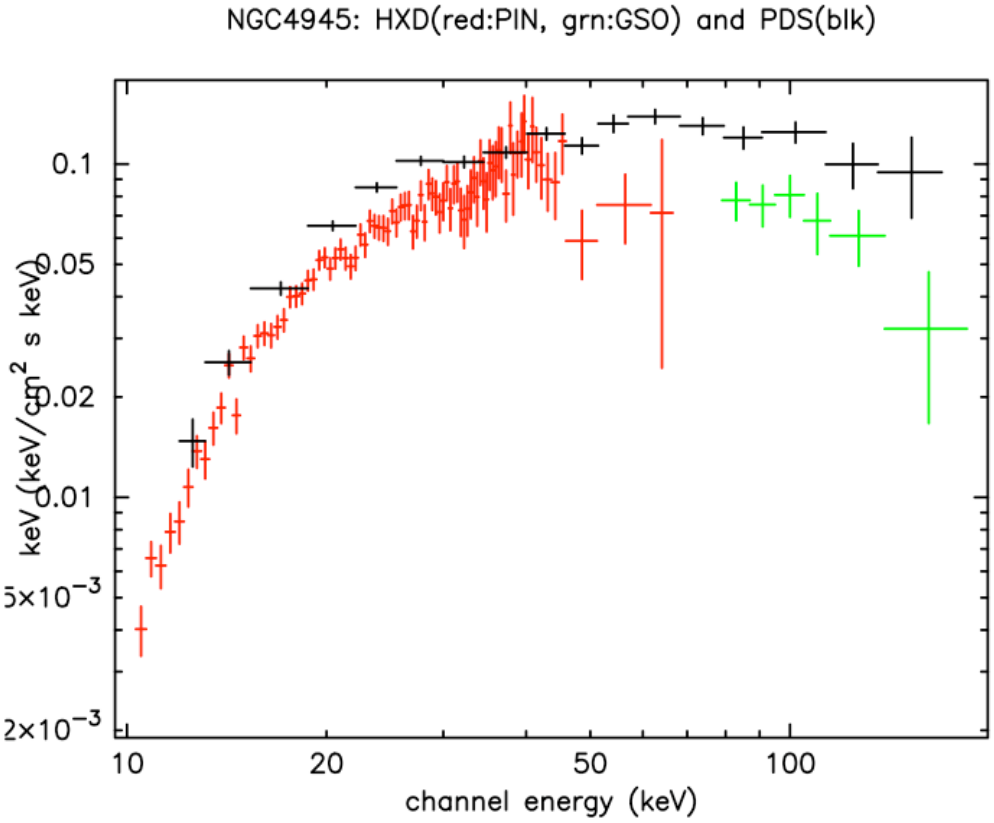


BAT high latitude Log N-Log S (Markward et al 2006)

NGC4945 Direct Comparison of Suzaku and BeppoSax

- ***Complex spectrum of Compton-thick Seyfert 2, with reflection, and transmission, requires broad band to deconvolve.***

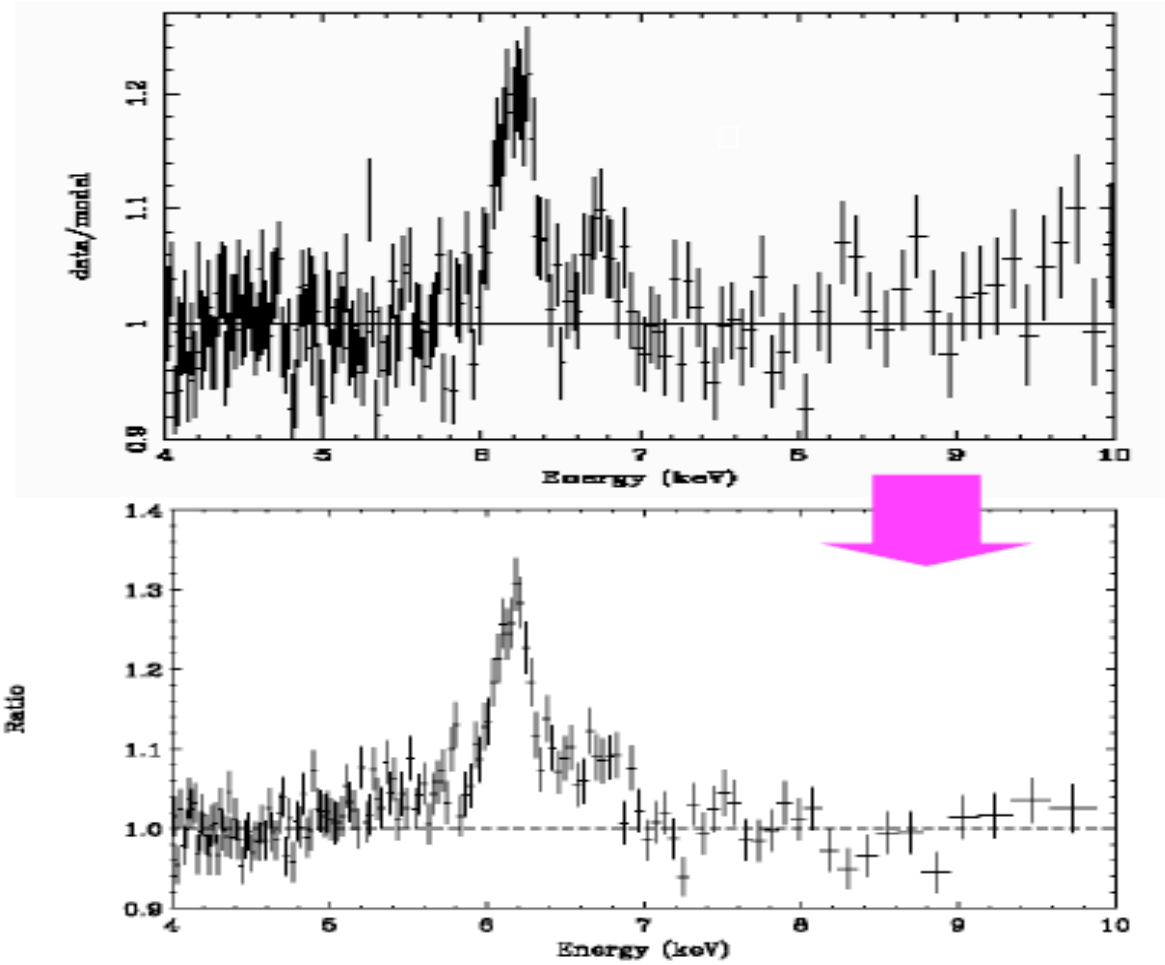




Non-Simultaneous Suzaku and XMM Observation- ***notice the variation of the Fe K line shape***

Iron line Profile of 3C120 (Kataoka et al.)

Comparison with XMM: revisited



XMM (130ksec)

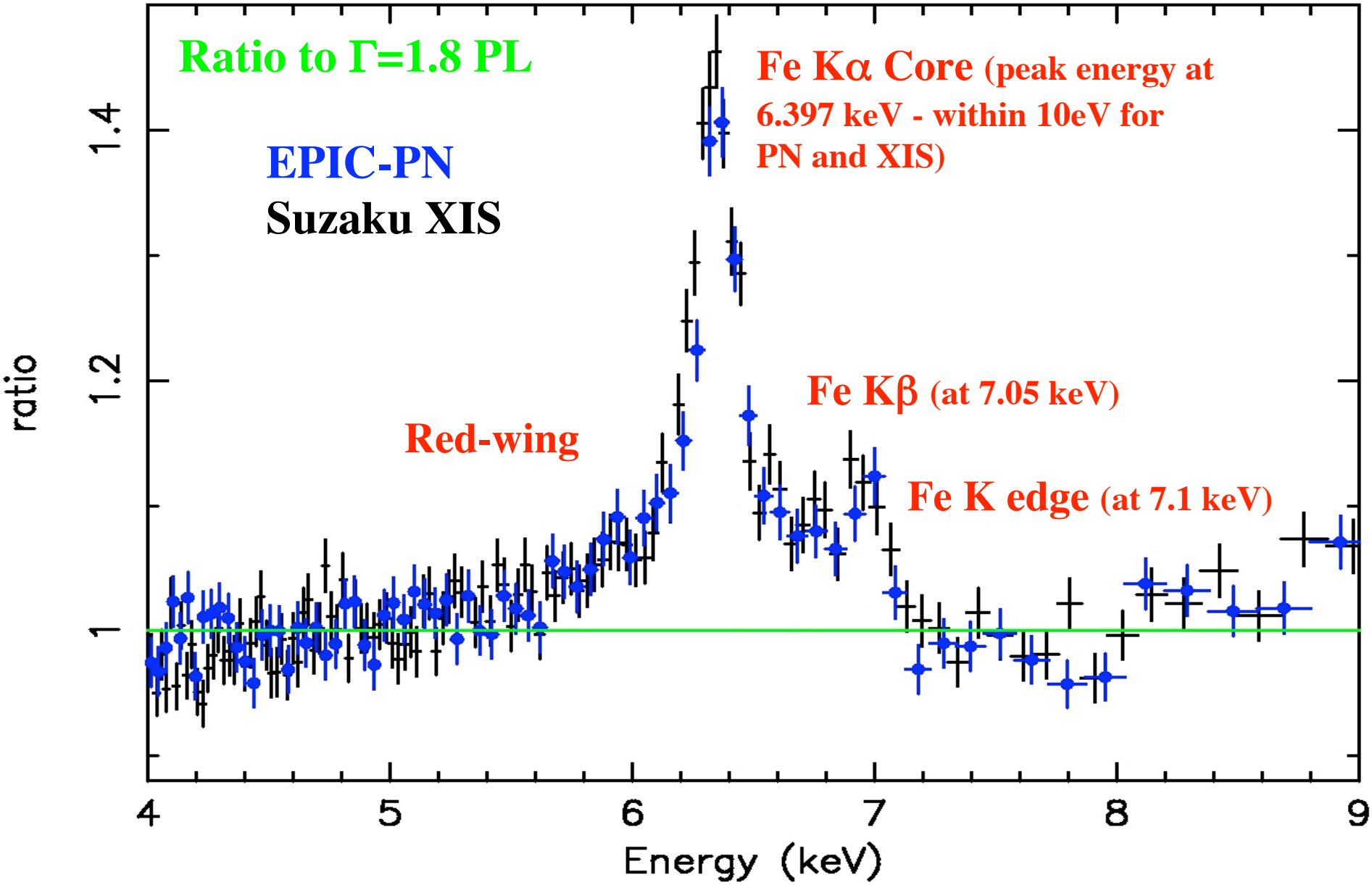
Ballantyne, Fabian & Iwasawa 2004, MNRAS, 354, 839

See, also Ogle et al., 2005, ApJ, 618, 139

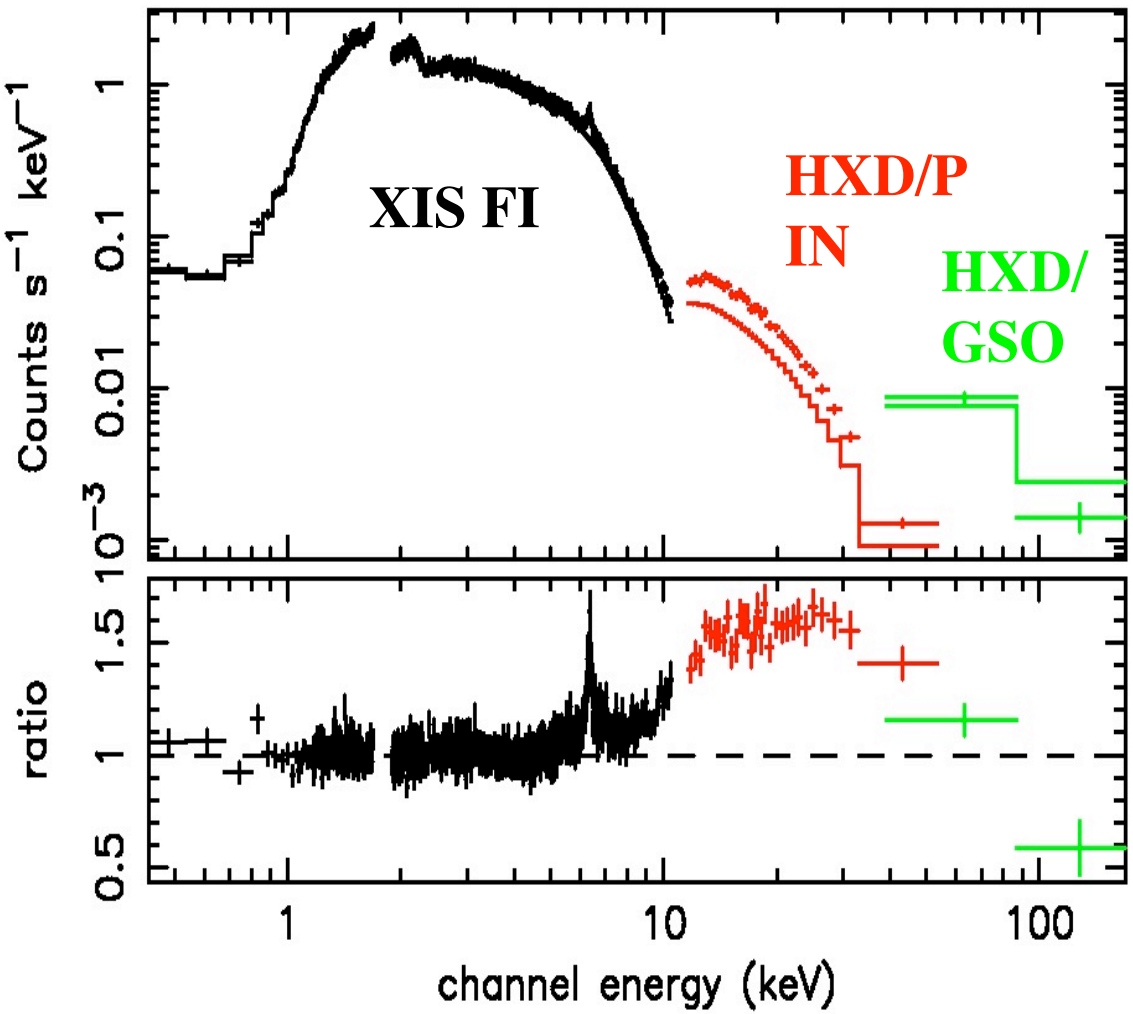
Suzaku (150ksec)

(1) red-wing in 6.4 keV
(2) much better statistics
(3) clear 6.9 keV bump
(4) extremely low BGD

Simultaneous Suzaku and XMM-Newton Observation of MCG -5-23-16 - *notice the excellent agreement on Fe K line shape*



Broad-band Suzaku Spectrum of MCG -5-23-16



Observed Flux 9e-11 cgs (2-10 keV) and 2e-10 cgs (15-100keV).

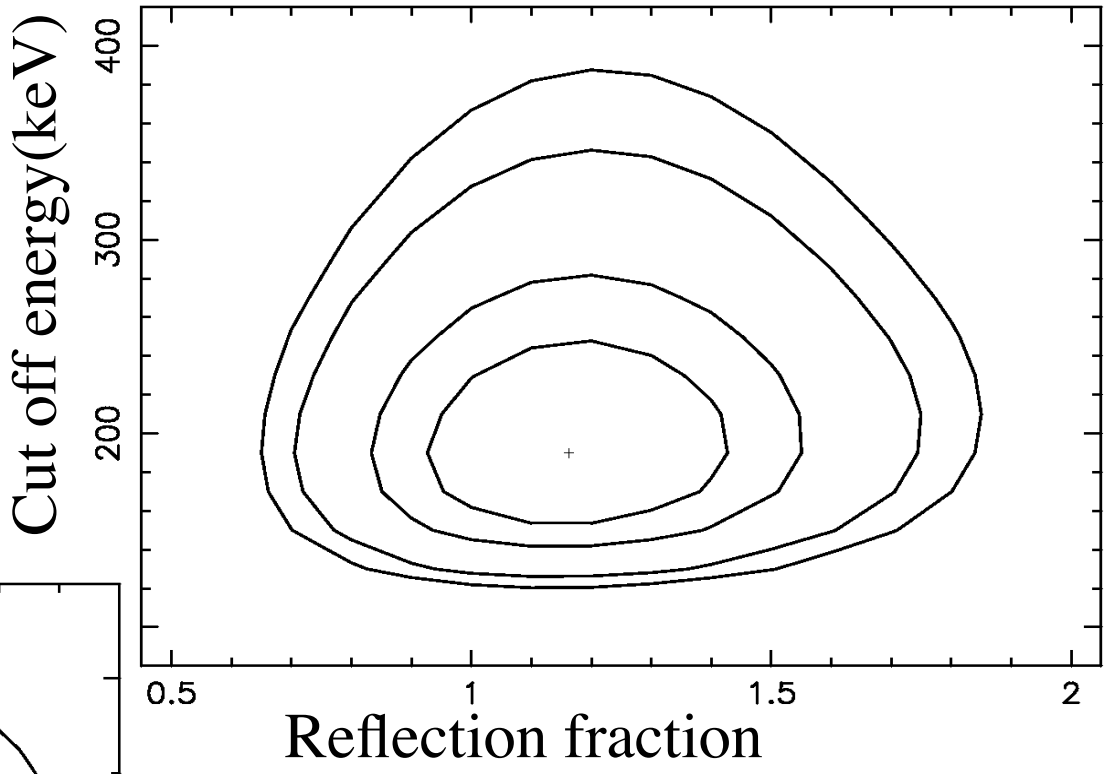
Fe K line present between 6-7 keV and reflection hump clearly detected above 12 keV in HXD.

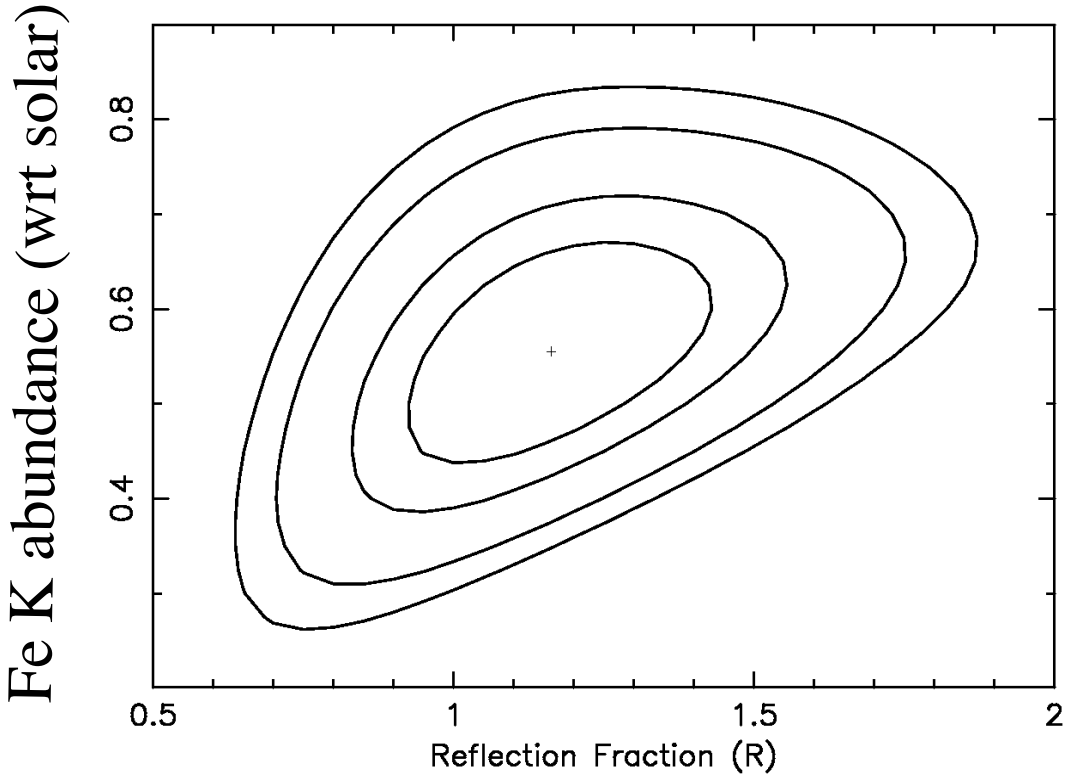
The reflection component is well constrained with R=1.2+/-0.2, with an Fe abundance of 0.6x solar and a cut-off of 200 keV

The edge at 7.1 keV and the Compton hump allows us to determine both parameters.

MCG-5-23-16:Parameters are well determined

- Fe abundance of reflector, cutoff energy and reflection fraction are all well determined and are not highly correlated with each other

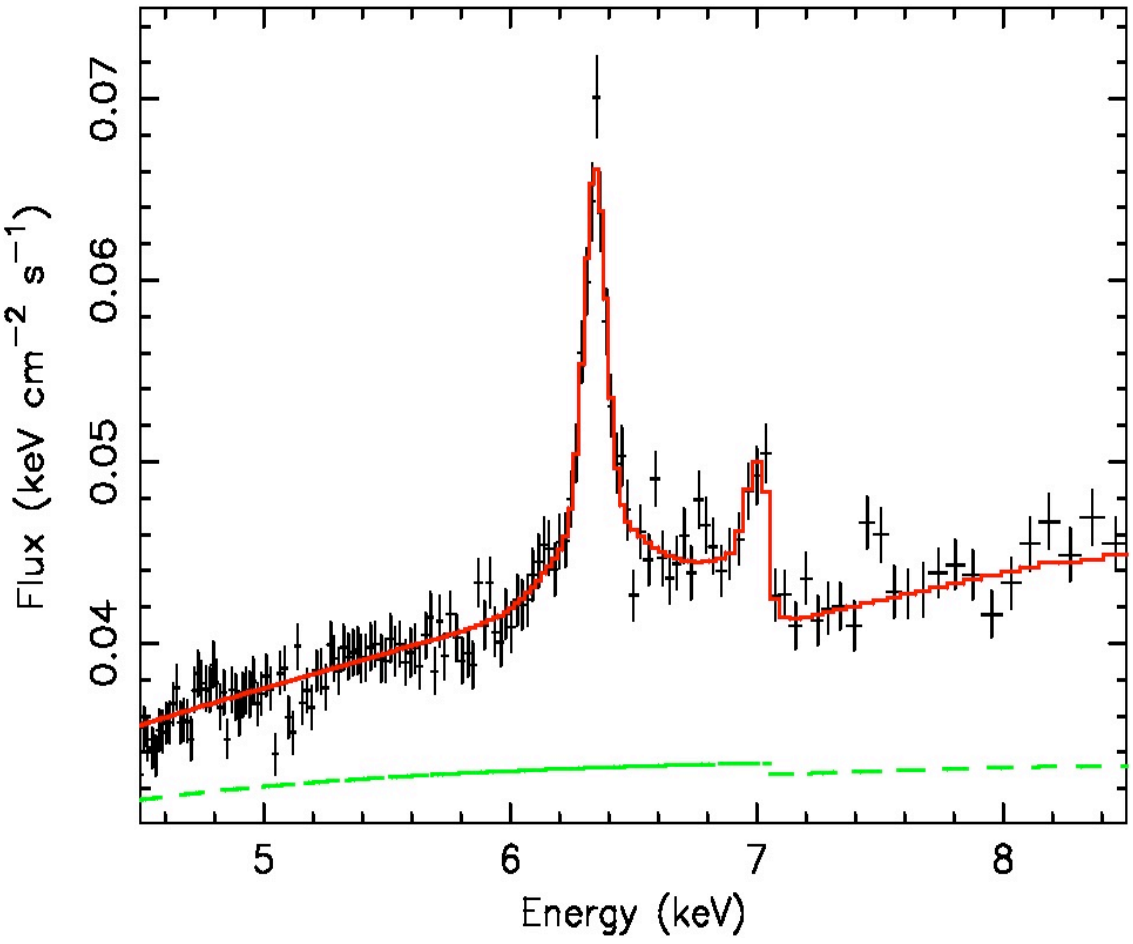




Accurate measurement of the Fe abundance of material near the black hole

Iron K line Models (MCG -5-23-16)

Model = broad + narrow Gaussian (Kα) + Fe Kβ + reflection



Iron line parameters are no longer degenerate with simultaneous measure of reflection component and high energy continuum

Narrow Fe Kα line at 6.40 keV resolved by Chandra/HETG (σ=35 eV or 1600 km/s). EW of 70 eV.

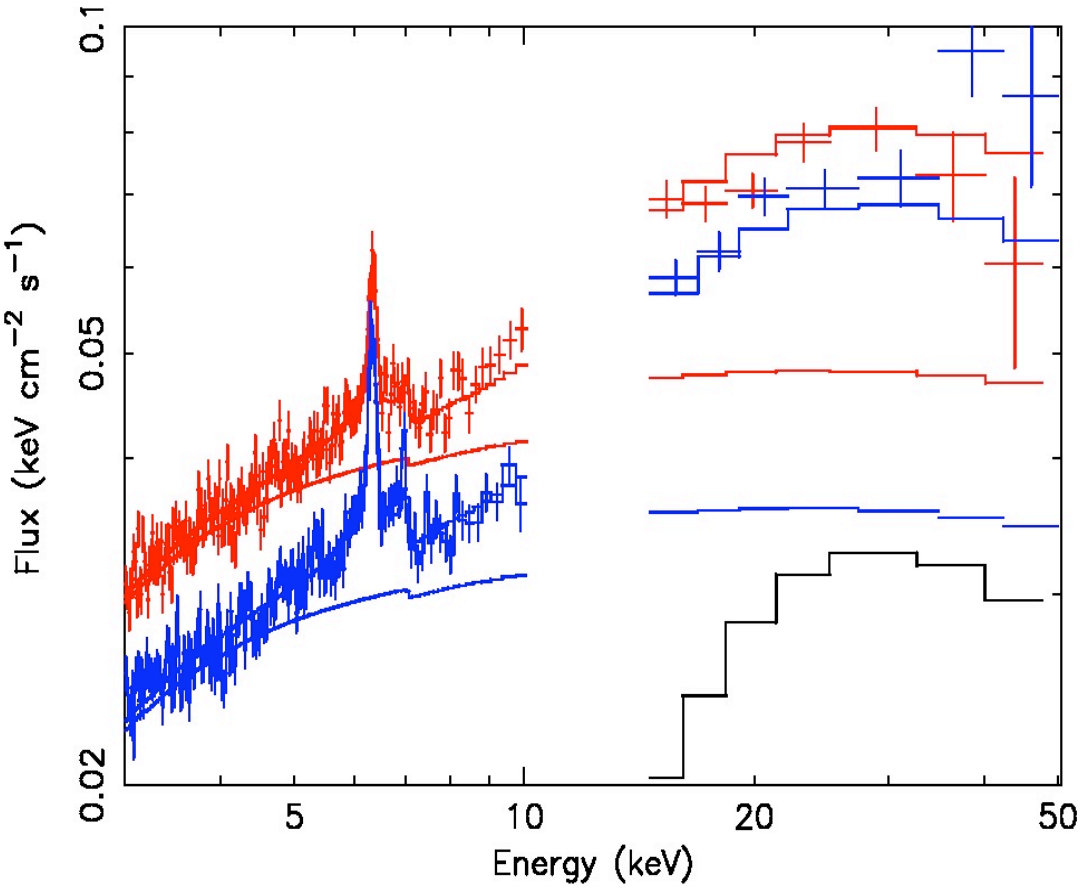
Fe Kβ line of 10 eV EW.

Weak, but v.significant broad Fe component, resolved by XIS (σ =400 eV or 20000 km/s). EW of 70 eV. Modeled by a diskline, 45 deg inclination, Rin=50Rg.

Reflection component with R=1.2. Fe abundance determined (by ratio of Compton hump to Fe K edge) to be x0.6 solar.

Variations in the iron K line and Reflection Component (MCG -5-23-16)

High flux = Red; Low flux = Blue;
Reflection:Black



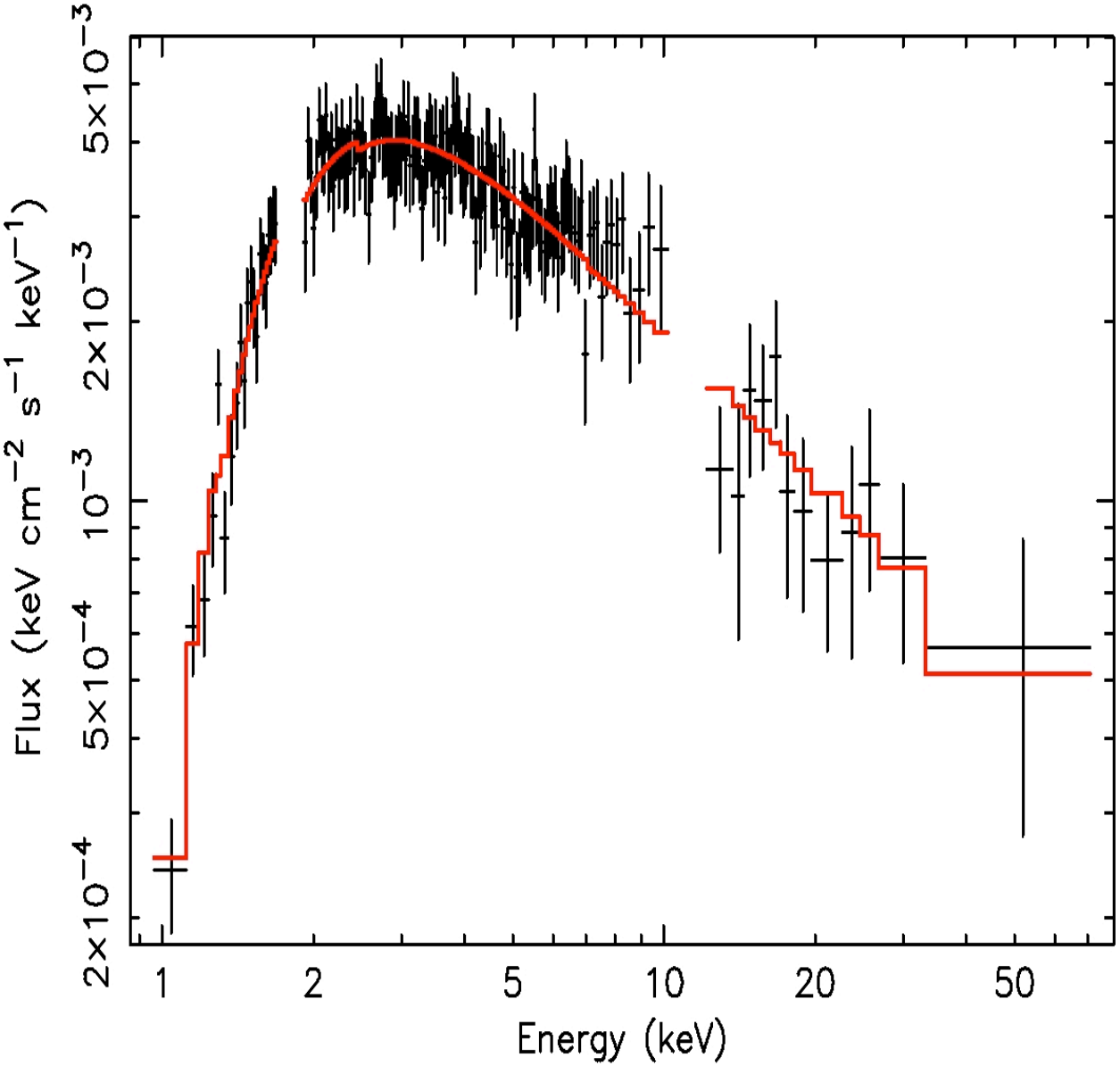
Observation split into high and low flux states

Iron K line and reflection component do not appear to vary during observation.

Spectra can be fit with a superposition of a variable power-law and constant Fe line + reflection hump.

Weak variations in broad Fe line cannot be statistically excluded though.

High - Low Difference Spectrum (MCG -5-23-16)



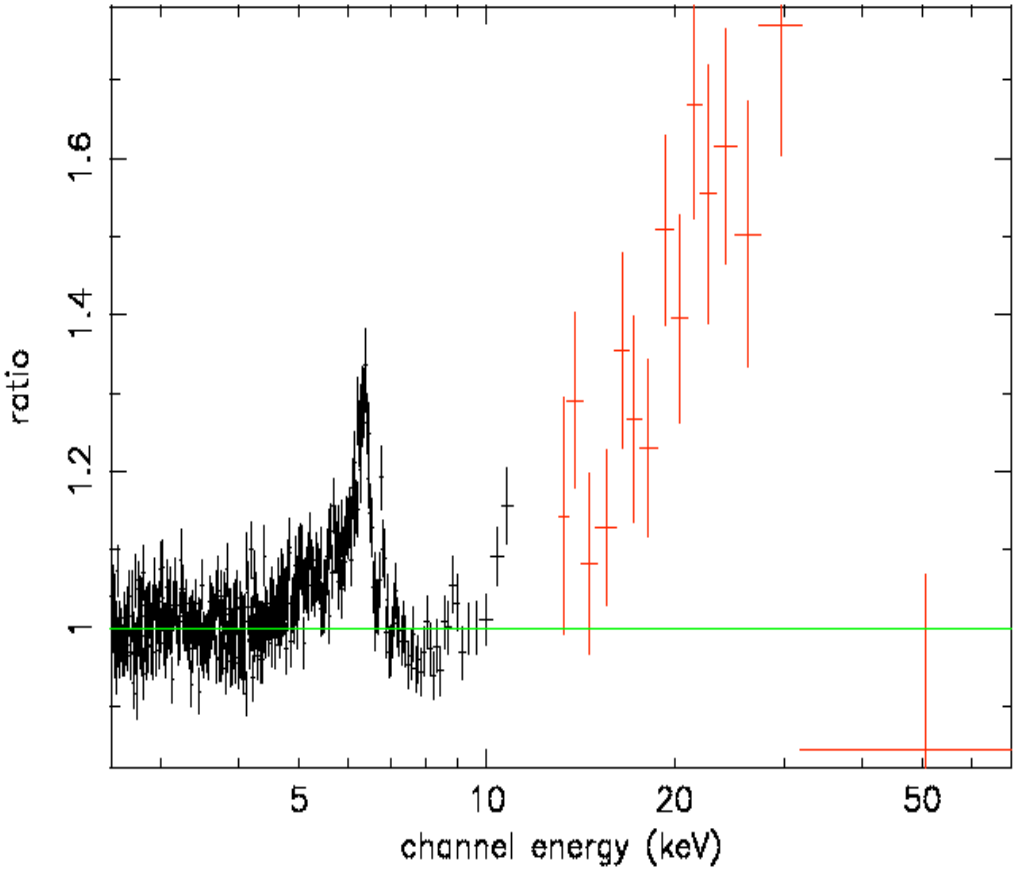
Source continuum varies by about 40% over Suzaku observation (220ks duration).

High - low spectrum shows that the variable component is just a power-law (Γ =1.9), modified by absorption.

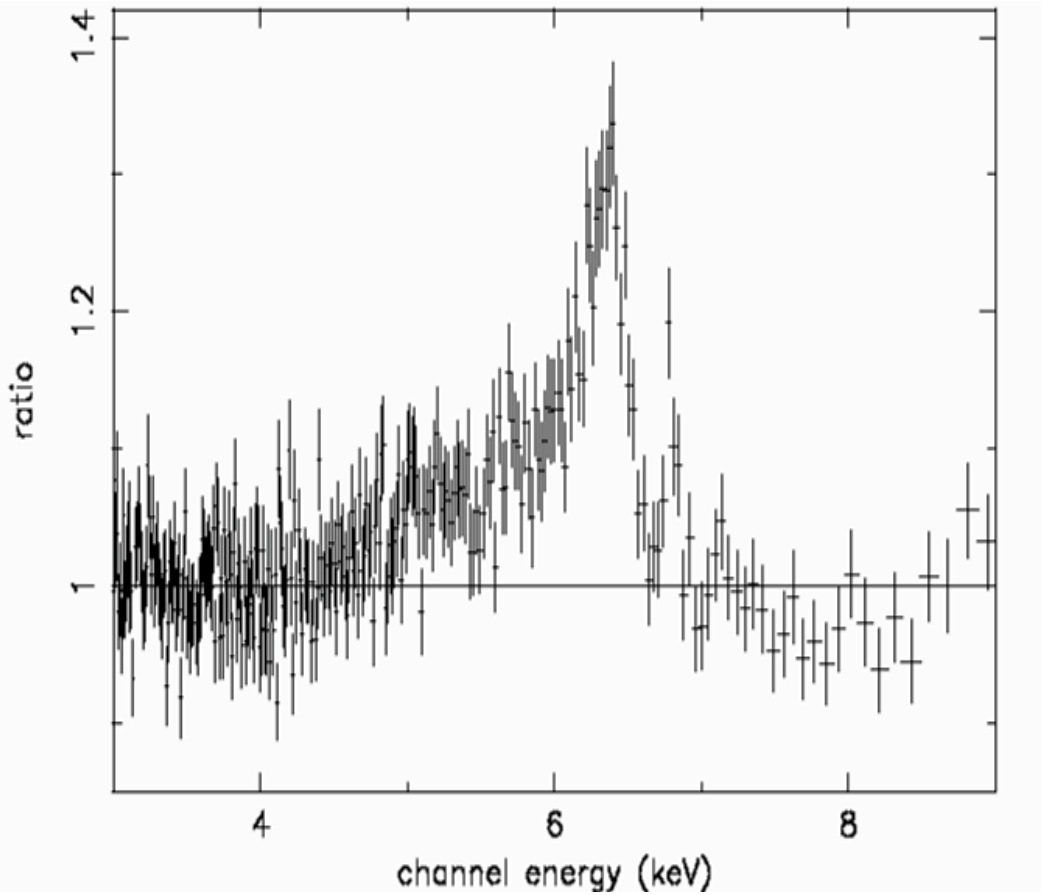
Line and reflection hump appear constant.

Suzaku Observation of MCG -6-30-15 (Jan 06, 300ks, Fabian et al.)

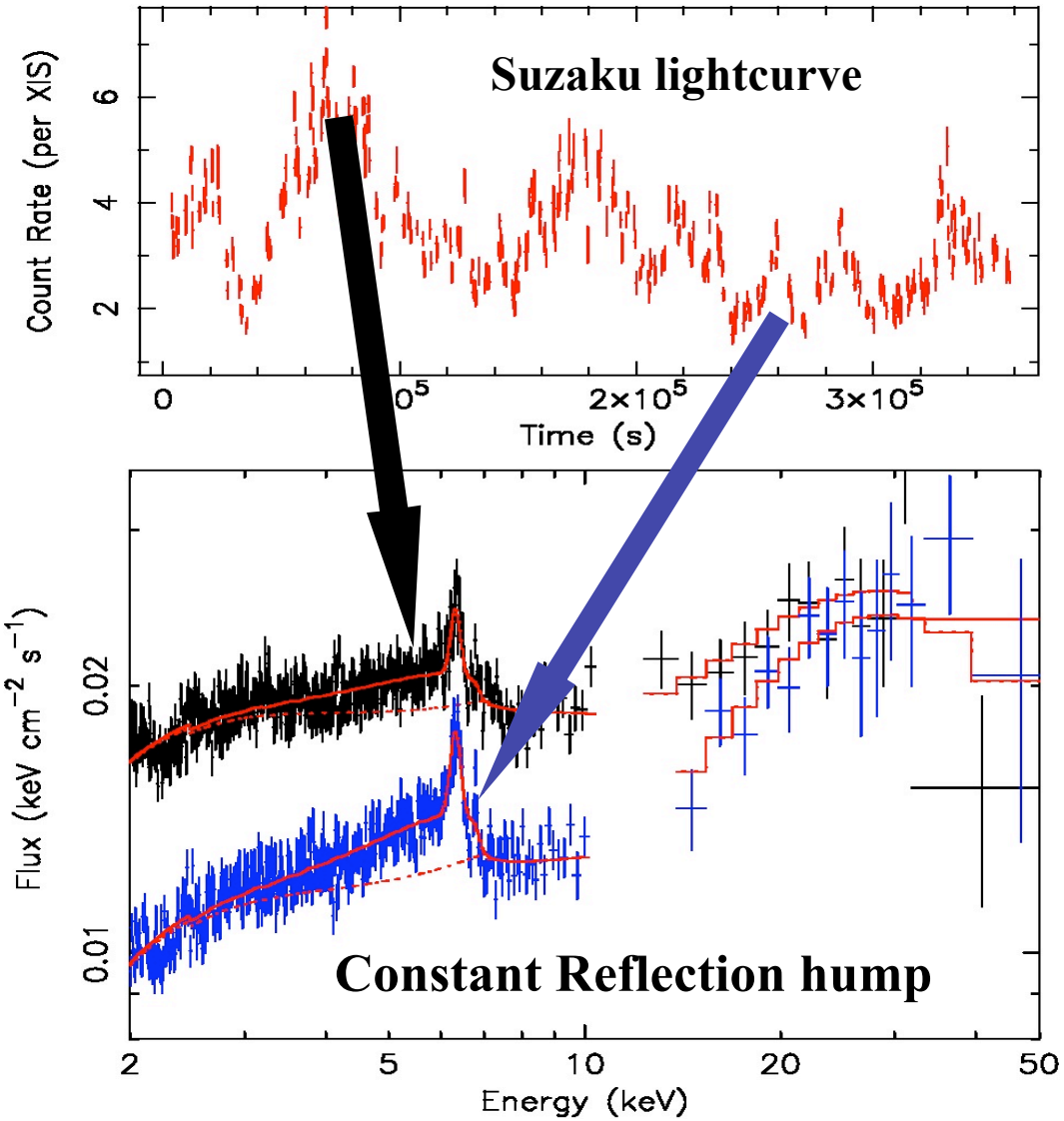
Ratio of XIS + PIN data to a power-law, note broad iron line and reflection hump



Broad iron line
Note He-like and H-like Fe absorption lines in blue wing



Variability of Iron line and Reflection in MCG-6-30-15

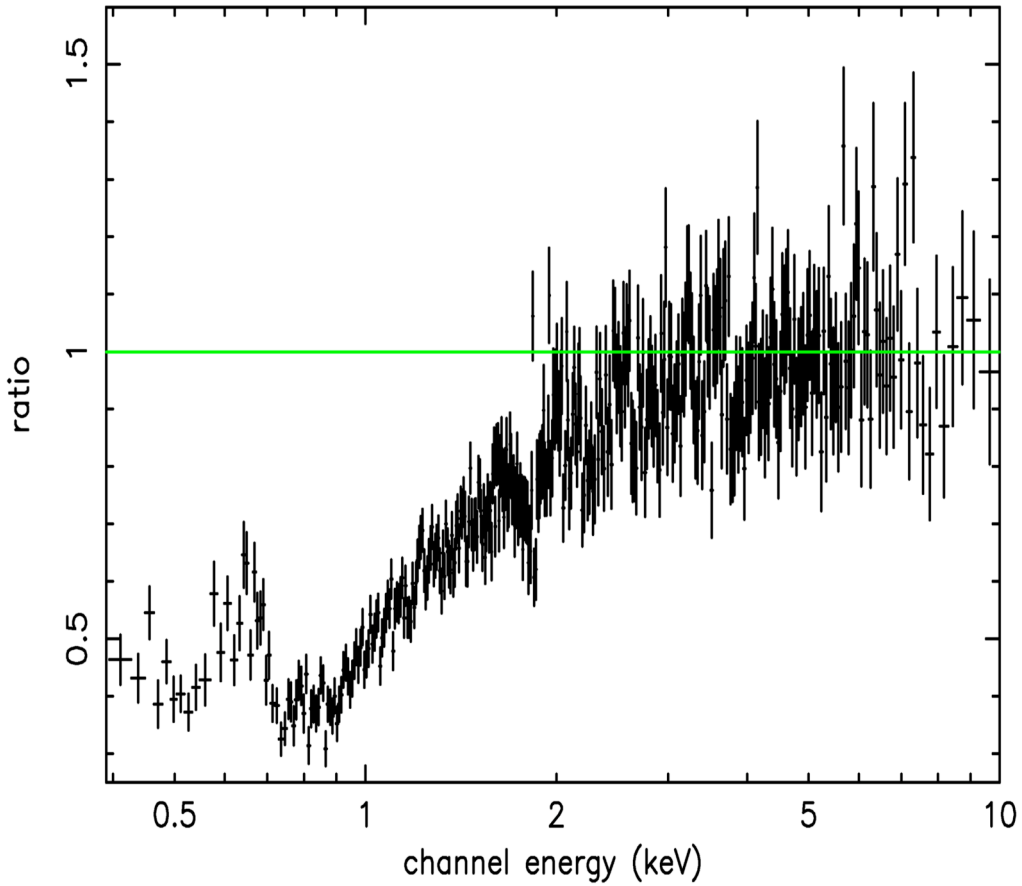


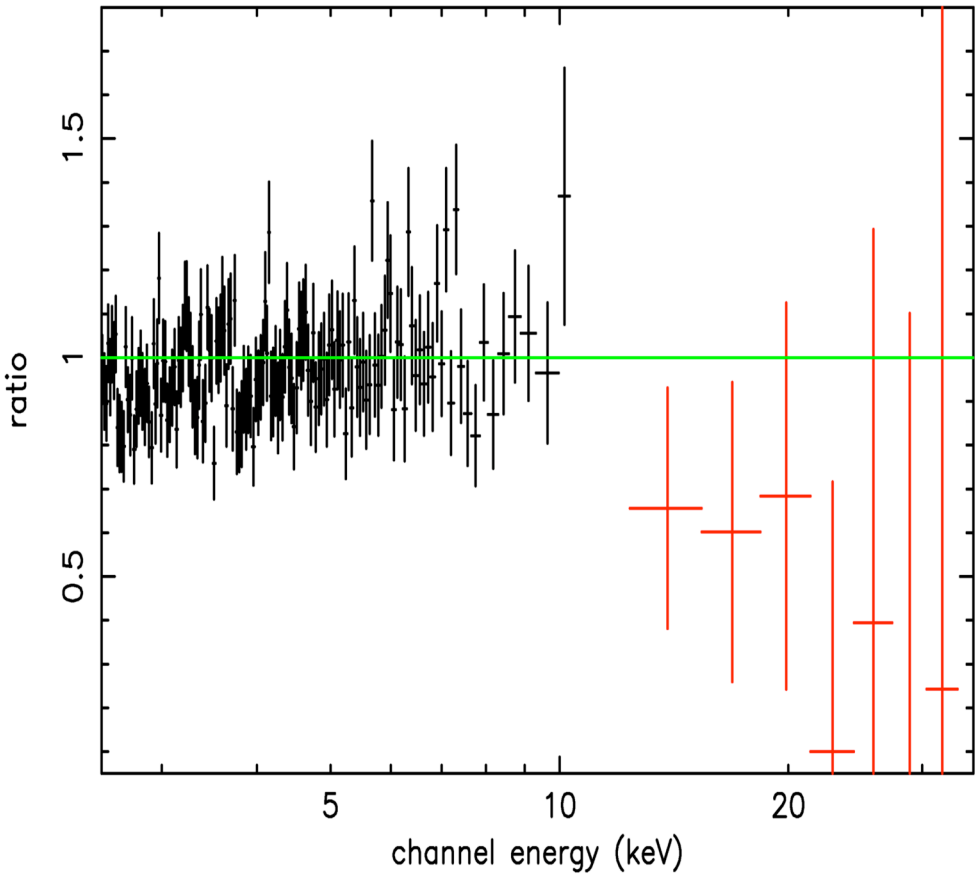
Strong iron K line and disk reflection from around a Kerr (spinning) black hole

No variations in Fe line/reflection - gravitational light bending around a Kerr BH? (Miniutti & Fabian 2004)

MCG -6-30-15 High-Low Difference spectrum

Ratio to a Gamma=2.2 power-law. This clearly indicates that the main variable component is an absorbed power-law. The reflection component varies little.

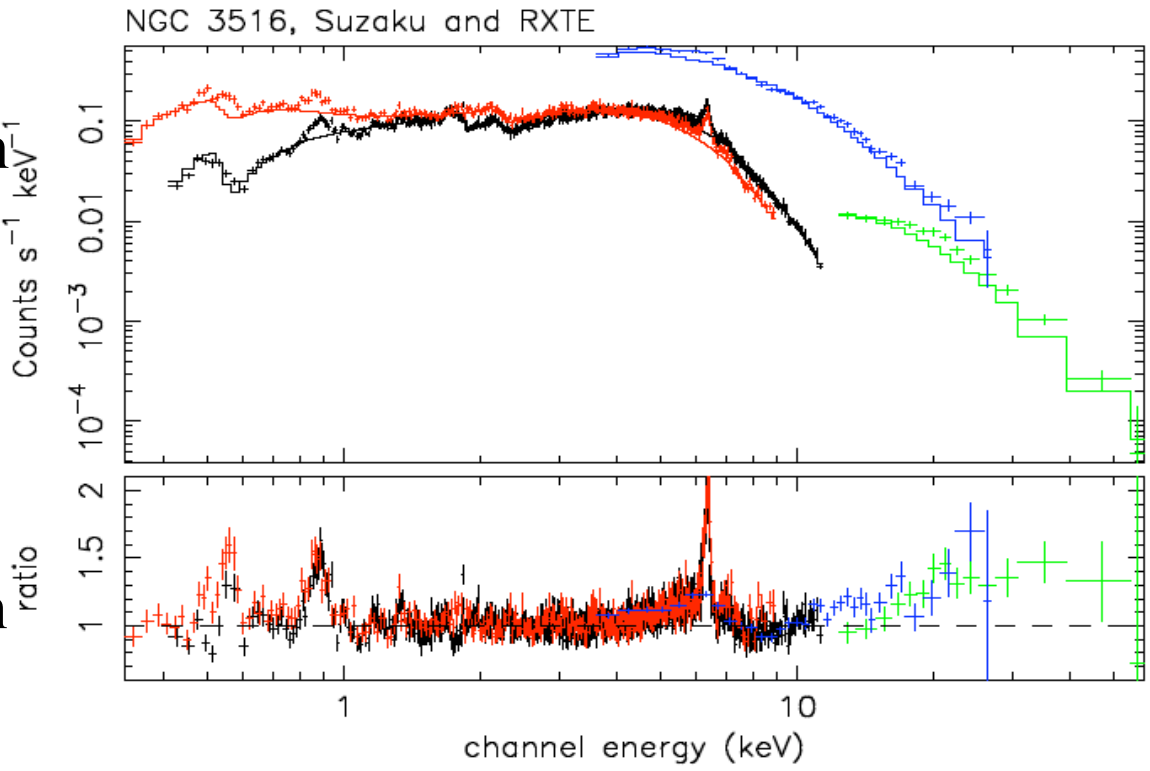




NGC3516 (see Alex Markowitz talk next)

• Both broad (redshifted) and narrow components of the Fe line are required and reflection is seen in HXD,

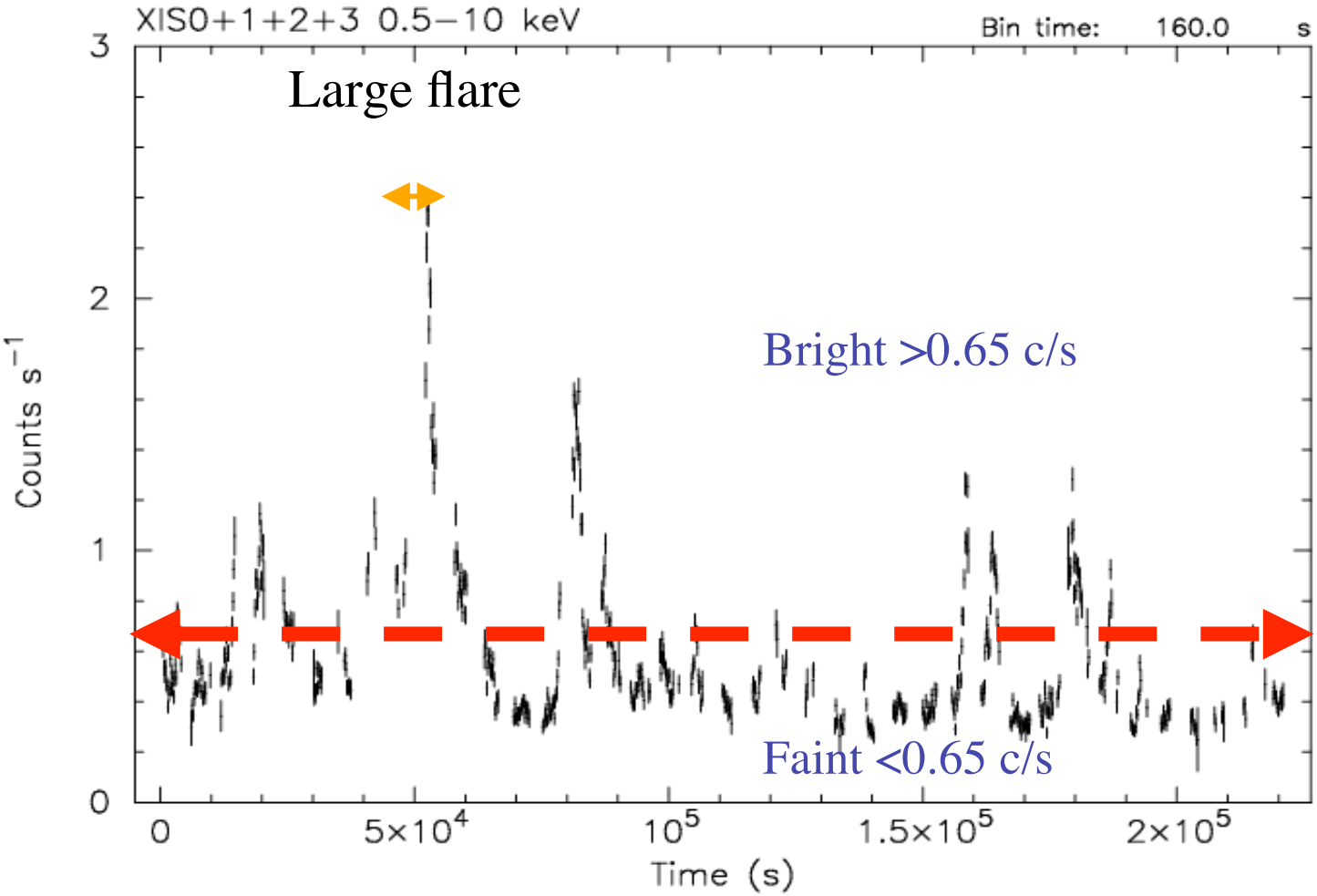
•several soft X-ray lines are also detected.
A new feature is also observed, due to an absorption edge near 7.3 keV in the rest frame, which
is detected in XIS. This could be due to an ionized reflector.



1 10 50

Energy (keV)

NGC 4051 Light curve (Terashima et al.)

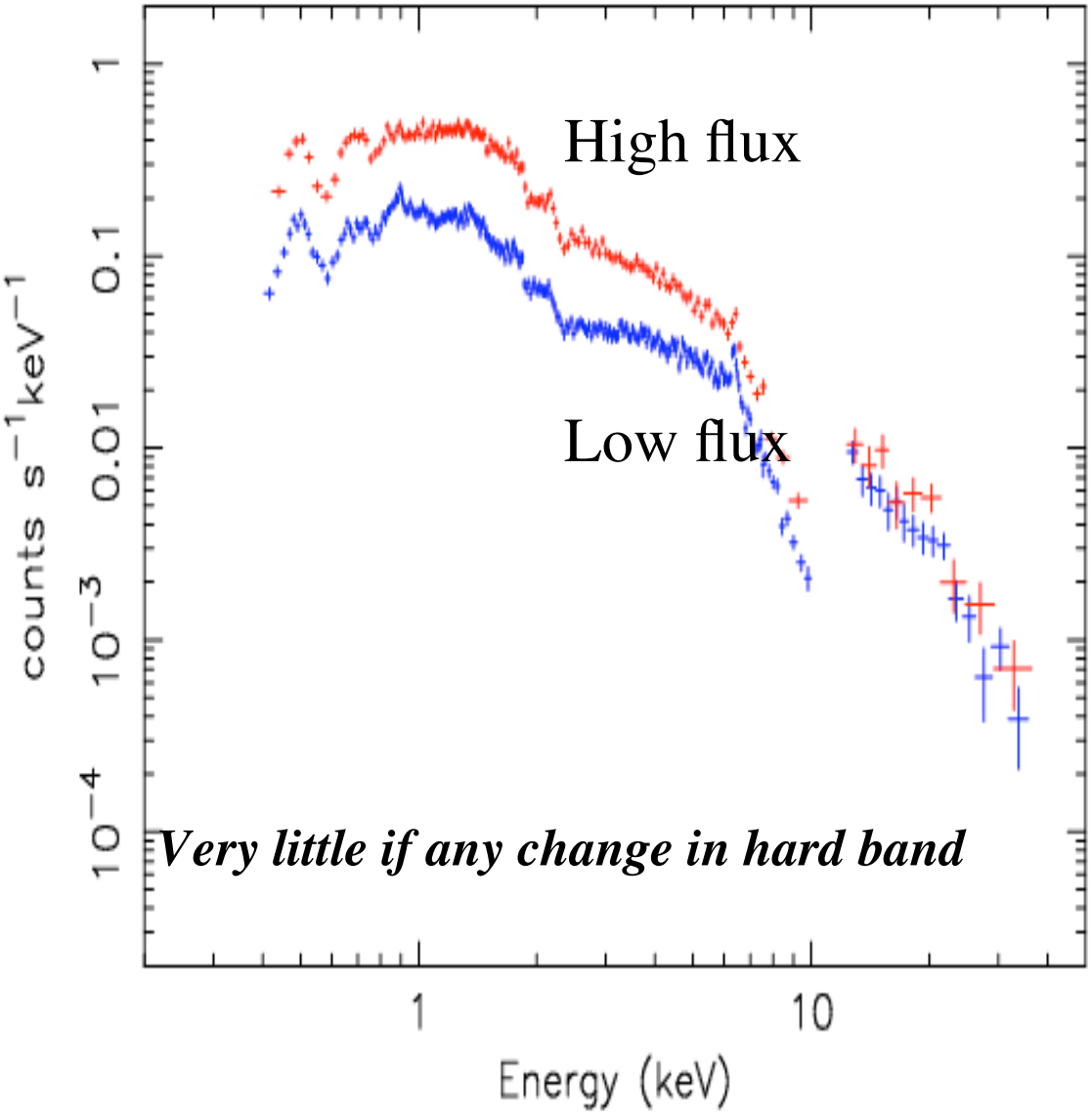


86 ksec XIS+HXD simultaneous exposure

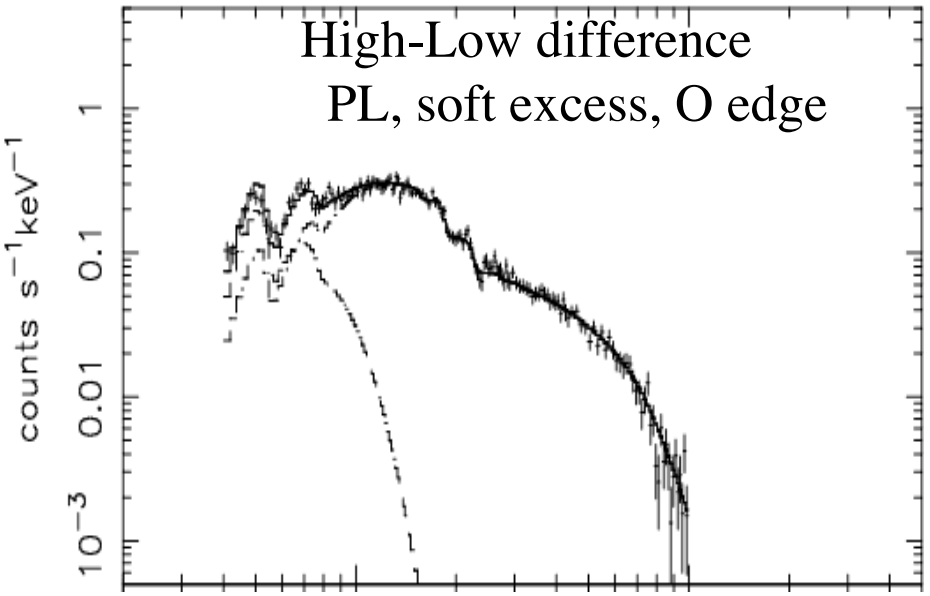
Average flux in 2-10 keV

9×10^{-12} erg/s/cm^2

NGC 4051- Spectral Variability

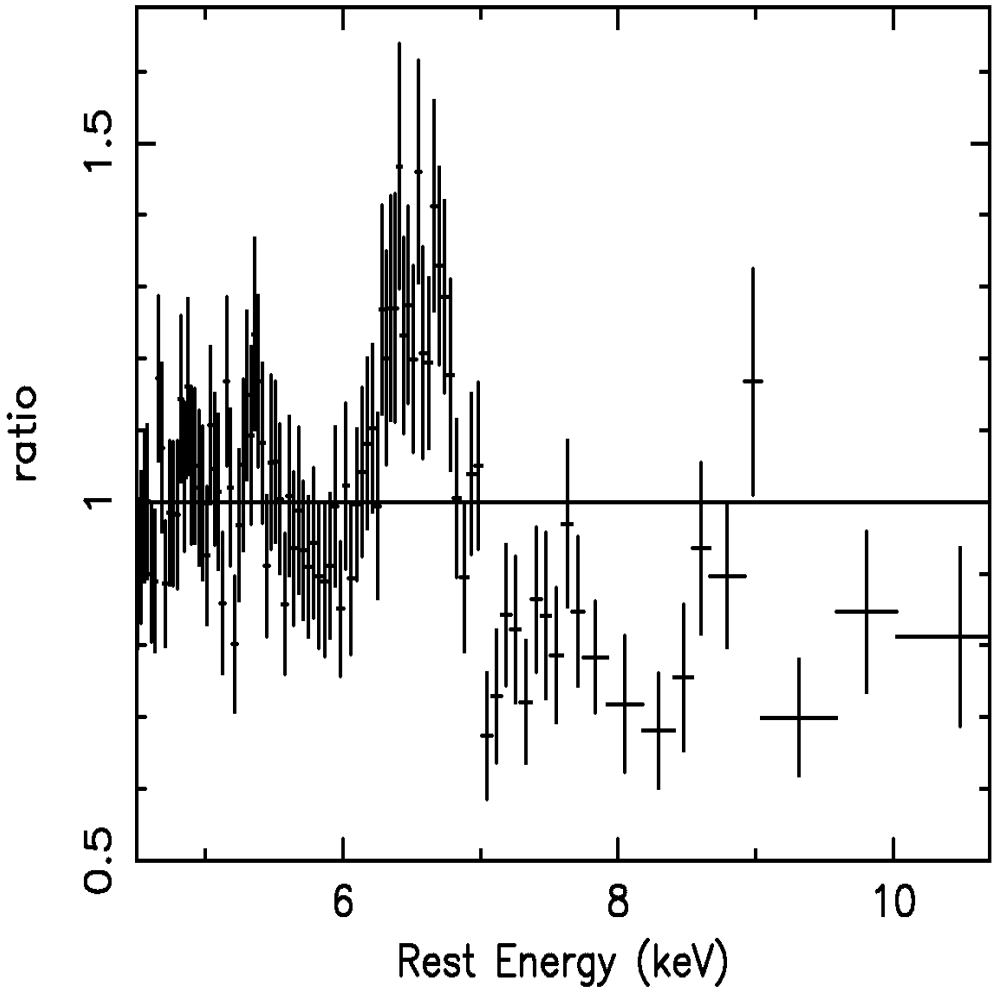


NGC4051(Terashima et al) - spectral variability breaks into two components (constant + variable power law) ; E> 10 keV spectrum varies very little.

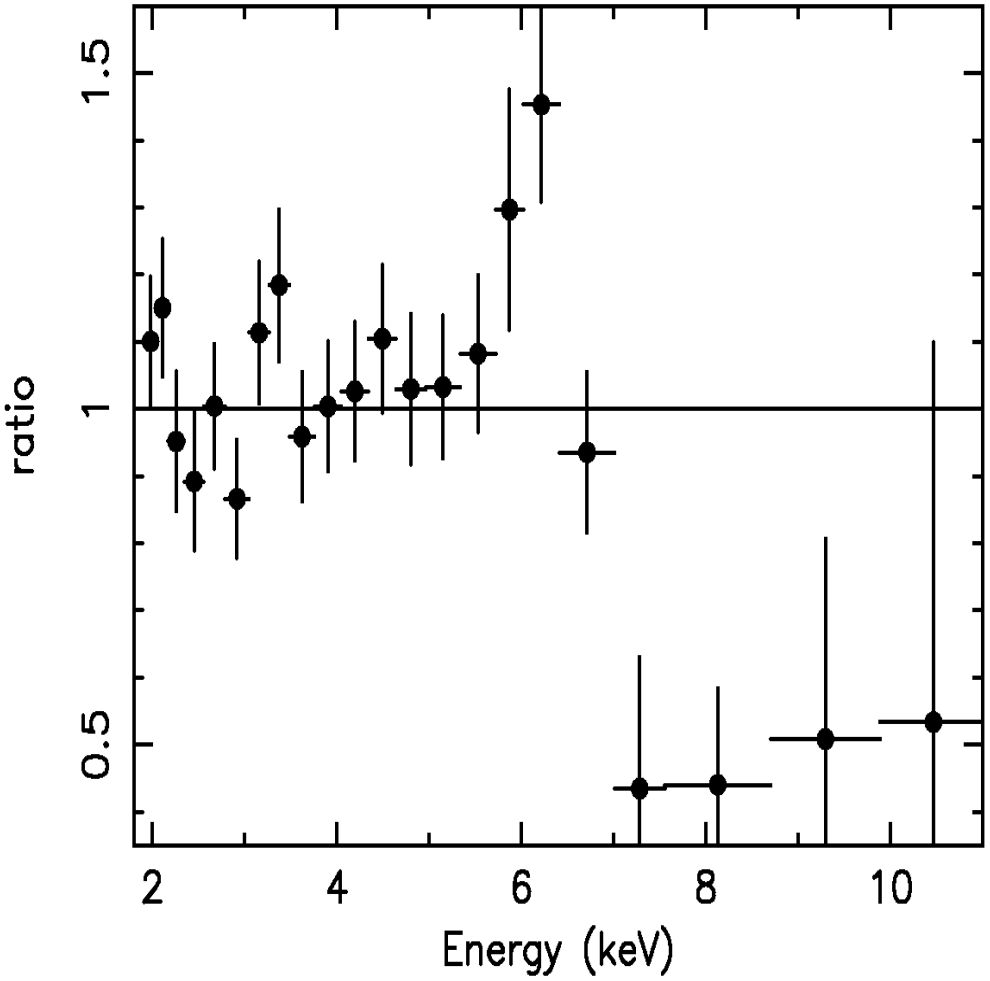


Suzaku Fe K band "Absorption" Features - PG 1211+143, 1H 0707-495 (but also NGC 4388, MCG -6-30-15)

PG 1211+143; Reeves et al.



1H0707-495; Hayashida et al.



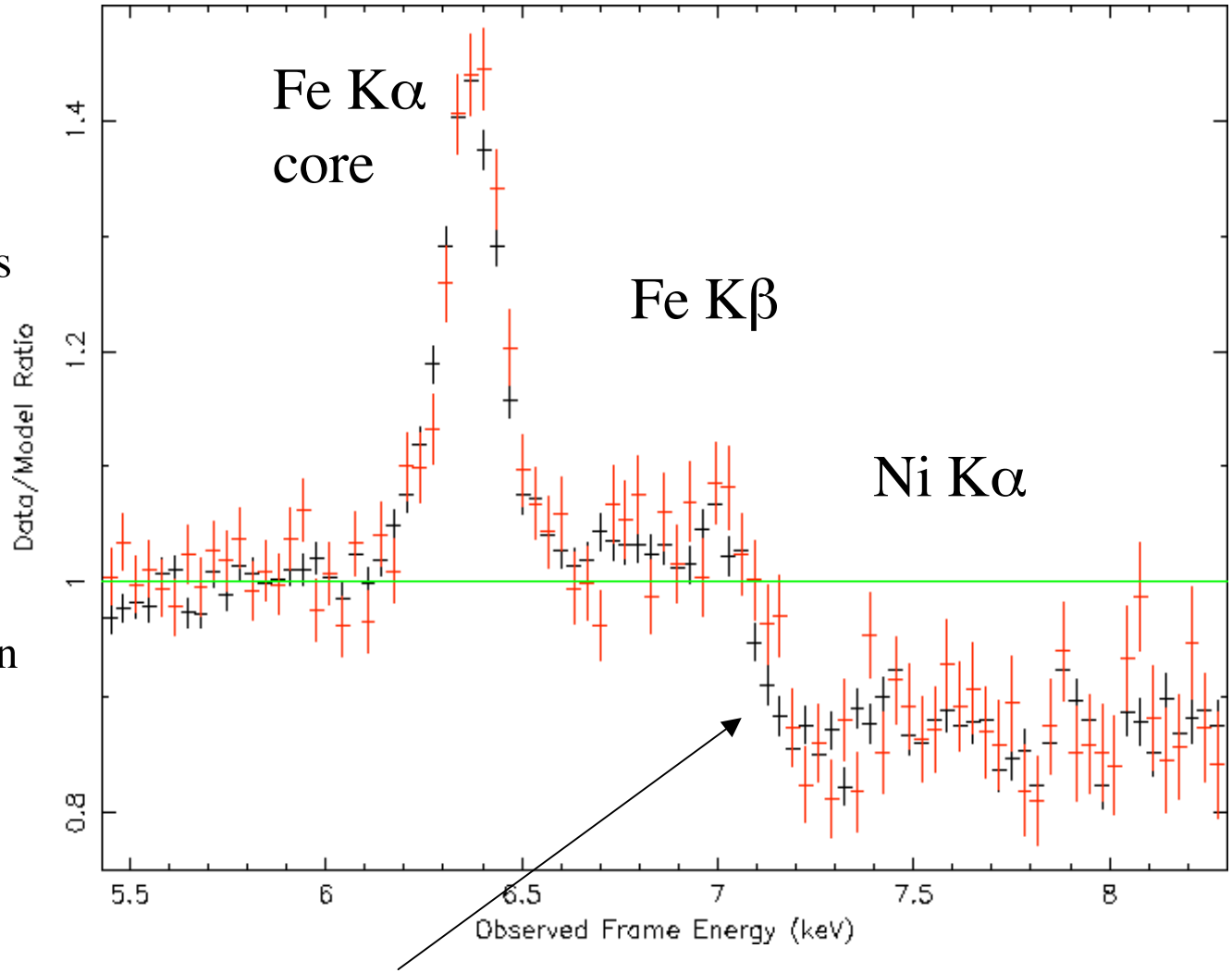
Cen -A Fe K bandpass emission- Markowitz et al

Line width of emission lines: σ= 29 (+6,-22) eV, v= 3100 (+600,-2500) km/s, suggesting $R_{Fe} > 6600\ R_{\_Sch}$.

for a 1.8 10^8 M_{sun} black hole, this is ~120 light-days from the nucleus.

The absorbing material is consistent with
also being the origin for the Fe K α line, consistent with an origin in uniform-density gas.

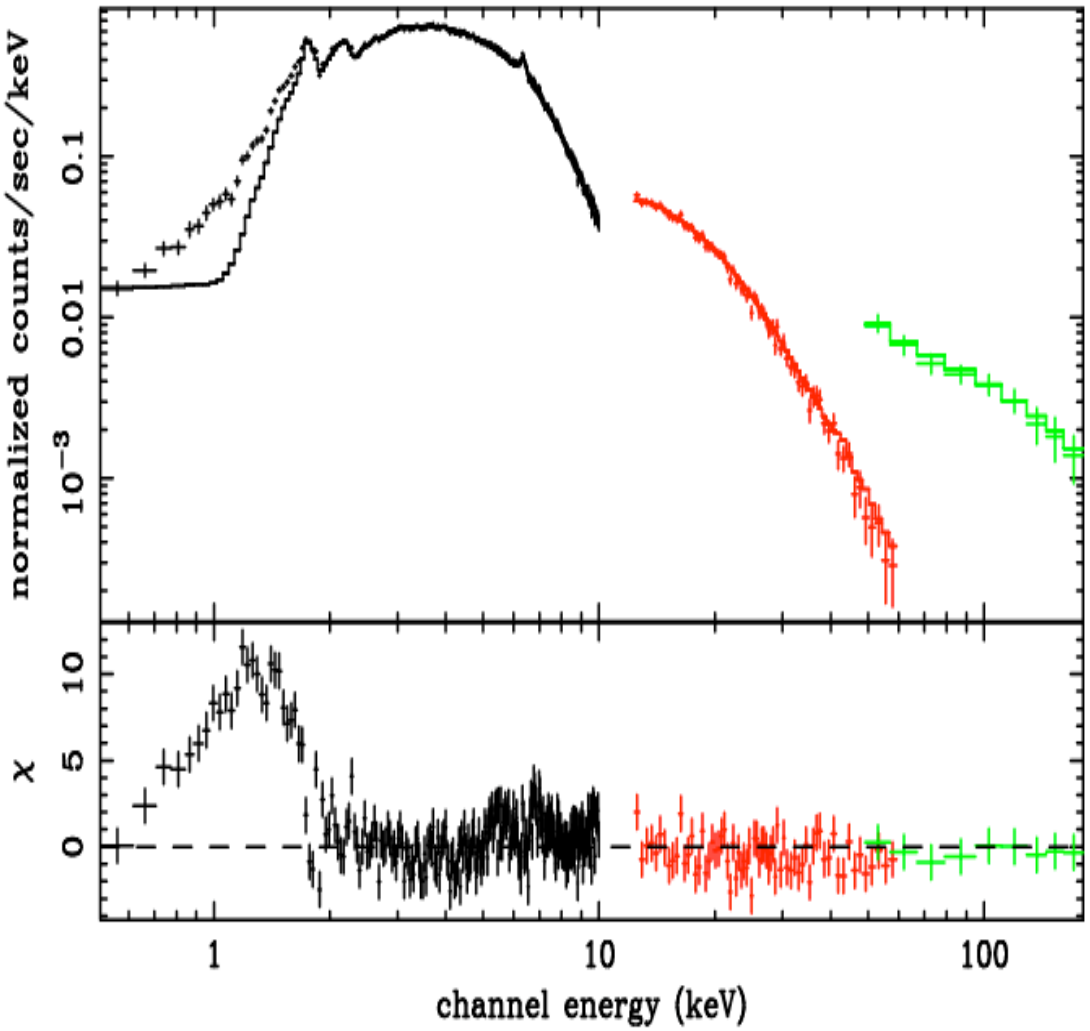
No Compton hump seen: ***Fe K line originates in Compton-thin absorbing material***

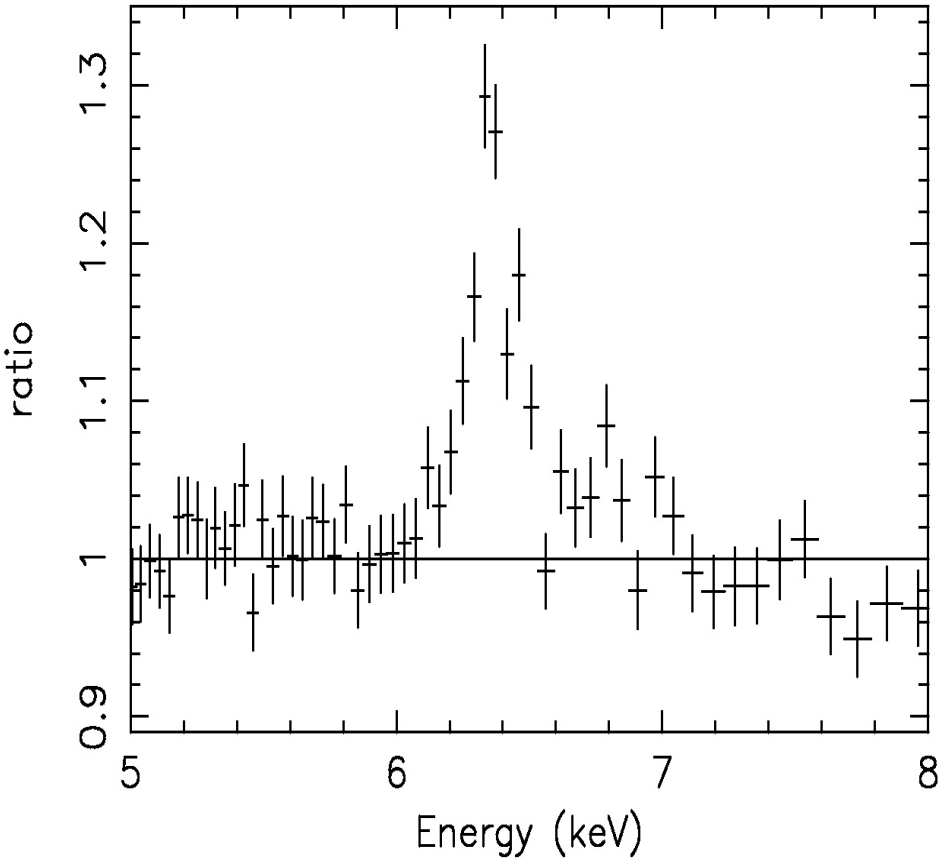


Edge at 7.15 ± 0.01 keV corresponds to optical depth τ = 0.20 ± 0.01

NGC2110-Okajima et al

- Detection to E>150 keV
- Best fit puts strong upper limit on reflection (R<0.1), yet Fe line is 70-80 eV.
- Compton-thin matter (BLR?)



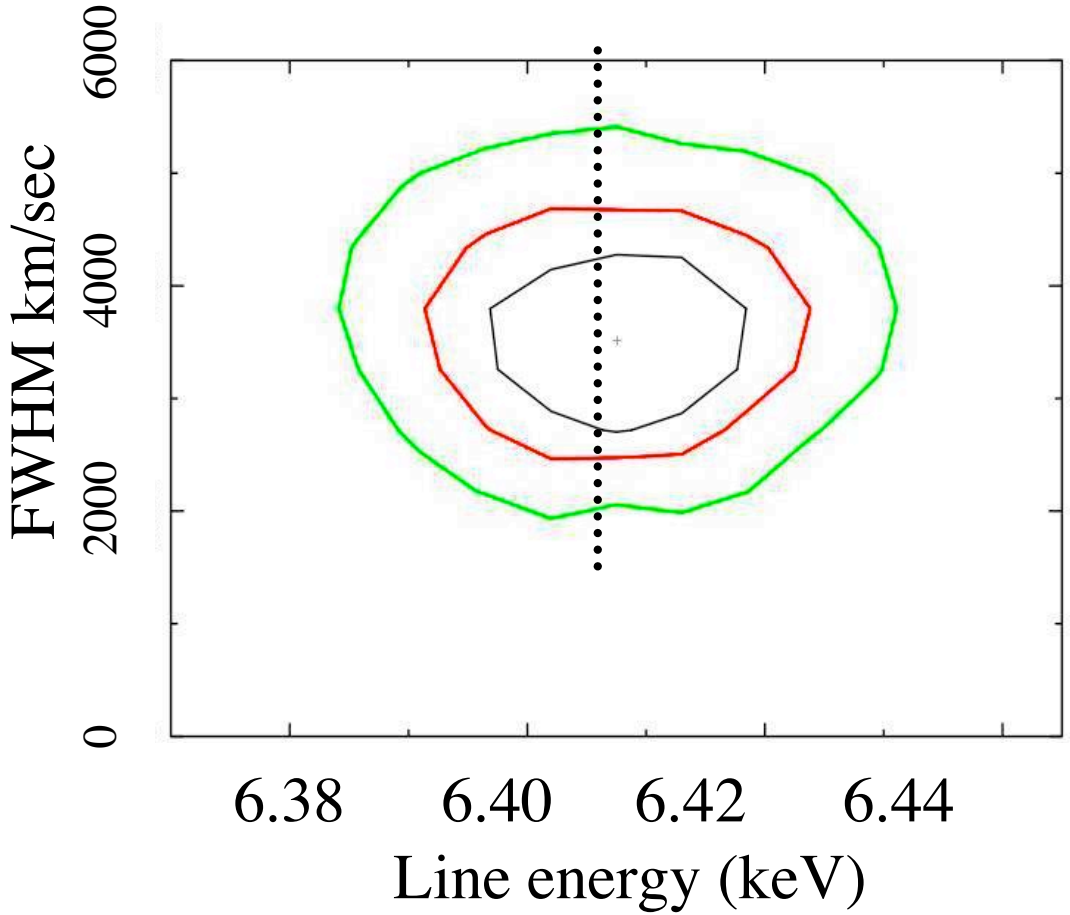


NGC2110- narrow line resolved

- Suzaku data have allowed the resolution of several of the ‘narrow’ Fe K lines with errors similar to that of the Chandra HETG

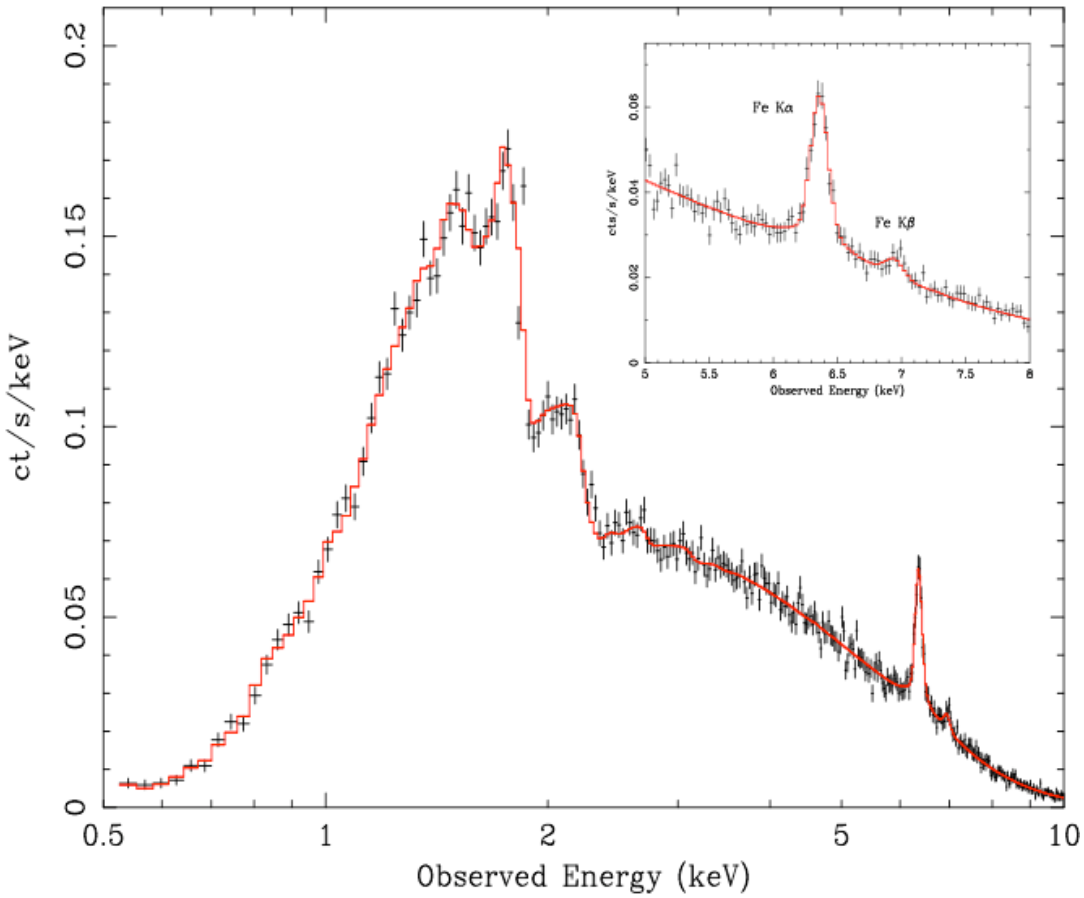
- Fe55 calibration source on XIS allows for very accurate constraints on Fe line width and energy

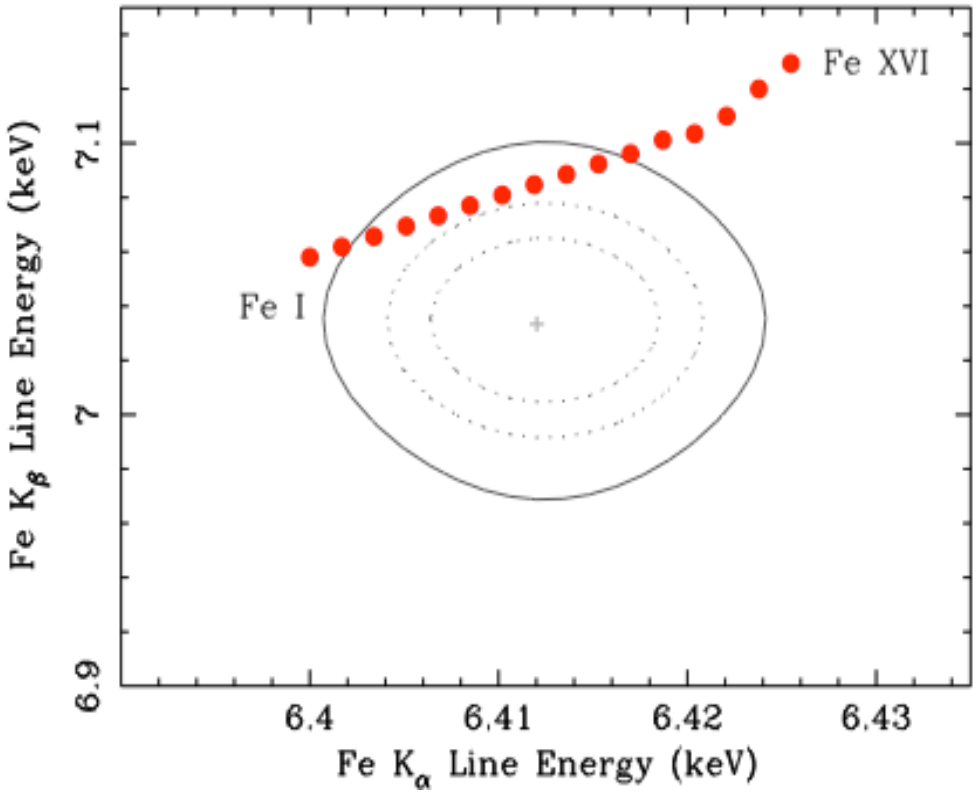
- The ionization state of the Fe can be determined from the ratio of Ka/Kb and the energy of the Fe K line



Observations of NGC2992 - Yaqoob et al.

- ***By combining the energy and line ratio information from K-alpha and K-beta, one can get a tight constraint on the ionization state of Fe.***





Conclusions

- The broad bandpass of Suzaku enables us to break the degeneracies in modeling the broad iron line. Uncertainties in the modeling of continuum shape, absorption and reflection component are removed.
- Broad Fe lines are confirmed in a number of sources - MCG -6-30-15, MCG -5-23-16, NGC 3516 (possibly NGC 4051).
- Narrow line origin not ubiquitous. Some (e.g. MCG -5-23-16) originate from Compton-thick matter (torus?). In others (Cen A, NGC 2110), no reflection is present (Fe line from BLR?). Line widths can be constrained (e.g. NGC 2110).
- A constant hard component appears to be present in a number of spectra (MCG -6-30-15, NGC 4051, MCG -5-23-16). Fe line and reflection component do not respond to continuum.
- In the future, a large sample of AGN (>200 from Swift/BAT survey) can be studied with XIS+HXD.