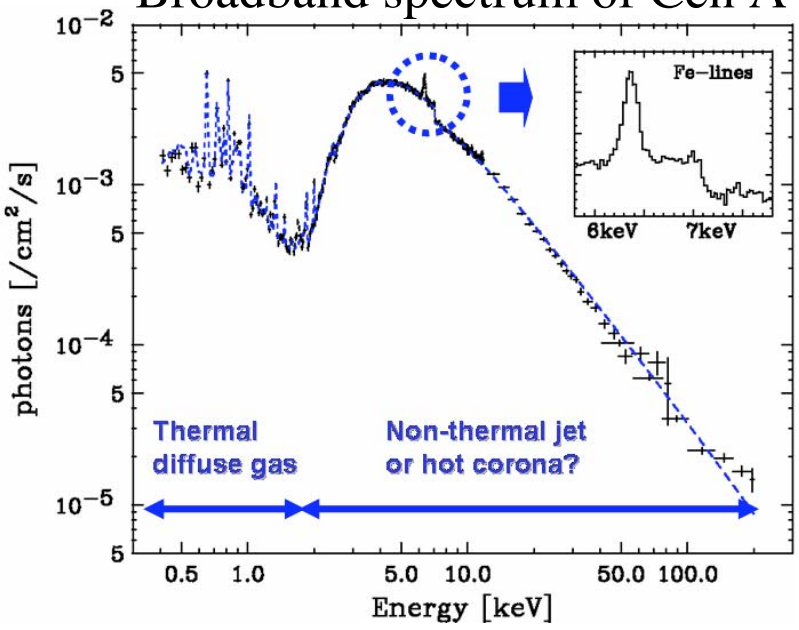
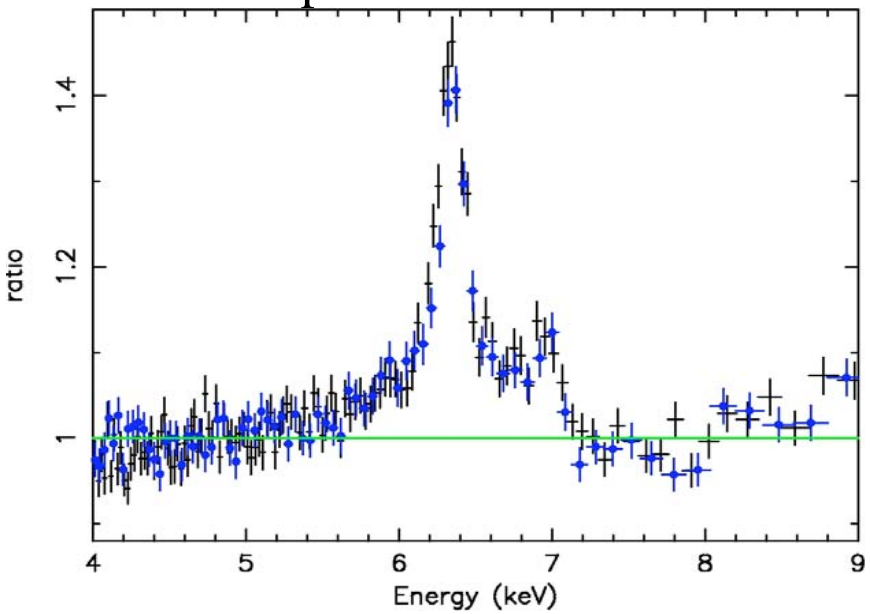
Recent Suzaku Results on AGNs (Initial)

Ryuichi Fujimoto (ISAS/JAXA) on behalf of Suzaku team

Broadband spectrum of Cen A



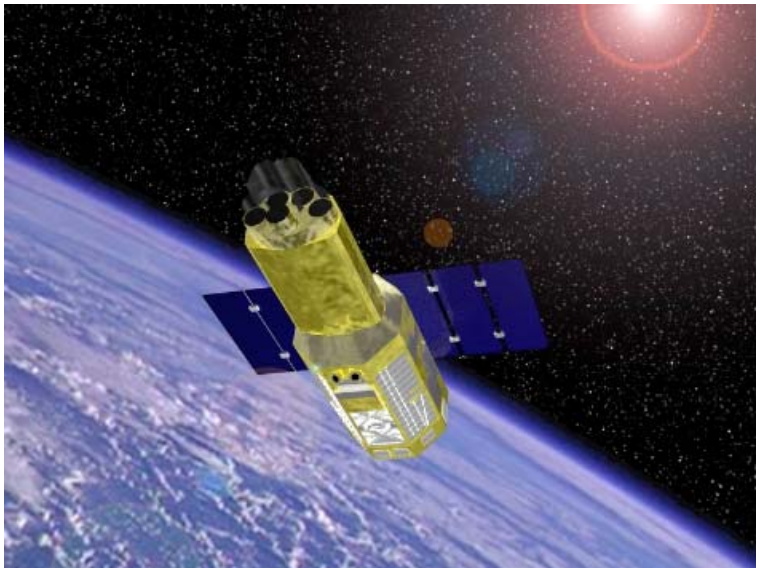
Fe line profile of MCG-5-23-16



Special thanks to R.Mushotzky, J.N.Reeves, K.Mitsuda, T.Takahashi and the Suzaku team.

Outline

- About Suzaku
  - payloads
  - advantages
    - broadband, low background, good energy response
  - story of XRS
  - See http://www.astro.isas.jaxa.jp/suzaku/.
- Initial Suzaku observations of AGNs (SWG program)
  - Science goals
  - Preliminary results
    - broadband spectrum
    - Fe K line profile
    - spectral variation
- Summary



Suzaku satellite

- Investigations of
  - structure-formation of the universe
  - environment very close to black holes

  Using
  - high-resolution X-ray spectroscopy
  - wide-band X-ray spectroscopy

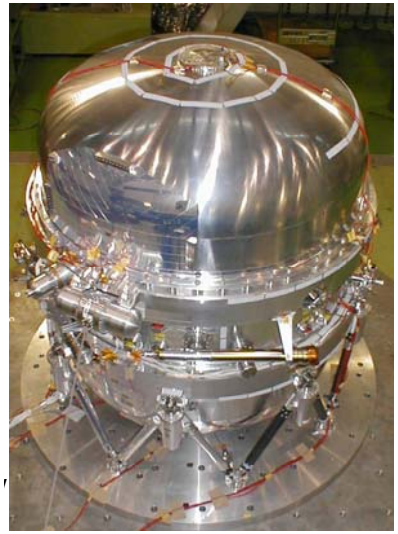
  Highly complementary to Chandra and XMM-Newton
- Japan-US international collaborations
- Launched on July 10, 2005, with JAXA's M-V rocket

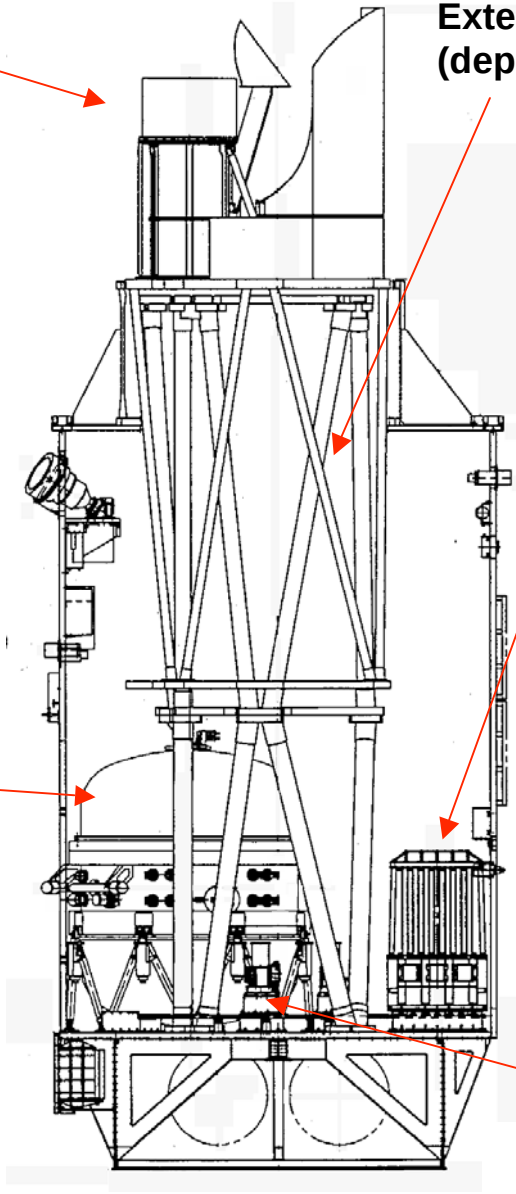
Suzaku during ground testing

Science Payloads of Suzaku

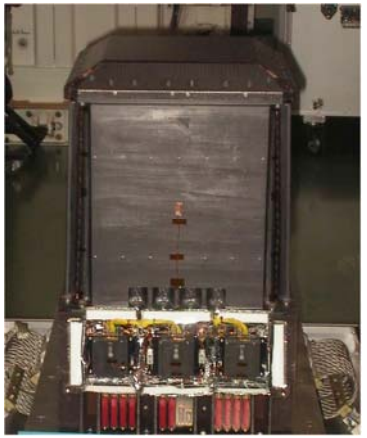
X-ray telescope [XRT]
GSFC, Nagoya, ISAS/ISAS, TMU

X-ray spectrometer [XRS]
GSFC, Wisconsin, ISAS/ISAS, TMU





Extensible optical bench
(deployed in orbit, f=4.5-4.75m)



Hard X-ray Detector [HXD]
Tokyo, ISAS/JAXA, RIKEN,
Saitama, Hiroshima, Kanazawa, ...

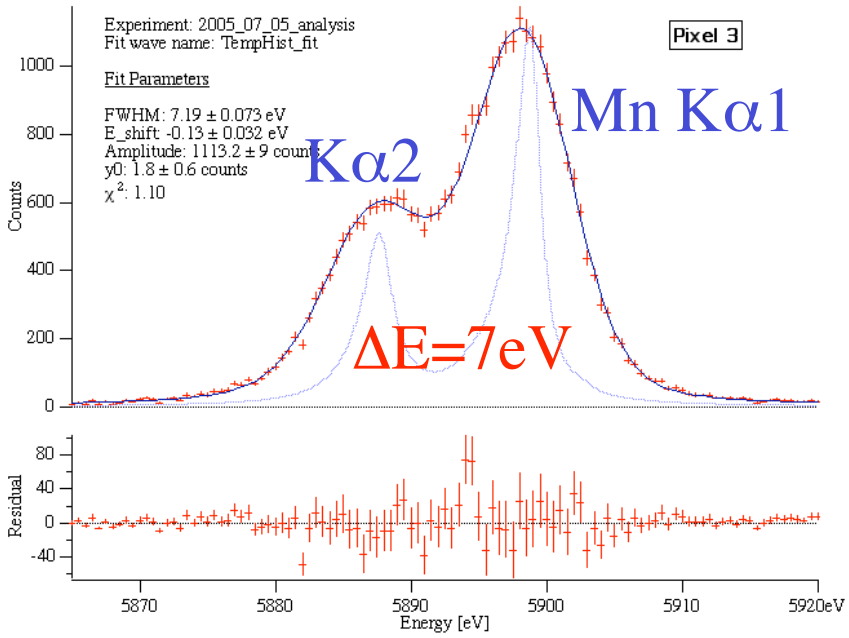
X-ray Imaging Spectrometer [XIS]
Kyoto, Osaka, ISAS/JAXA, MIT, ...

XRS: High resolution spectroscopy

- First X-ray microcalorimeter in orbit
- Detector was operated at 60mK, and energy resolution of 7eV (FWHM) at 6keV was obtained in orbit.
- However, the functionality was lost due to loss of liquid helium after ~1 month in orbit.
  - Independent investigations by the JAXA and NASA investigation boards. JAXA board report issued in Jan 2005. NASA board report will be submitted soon.
  - It was a design problem,

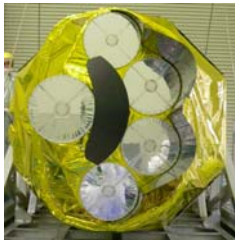
    not a technical problem with the dewar.

We will do our best to recover the science of the XRS as soon as possible, implementing the lessons learned and recommendations.
"NeXT" project (target: 2012-3)



Properties of Suzaku now

- Instruments
  - 4XRT & XIS (X-ray CCD): 3 front side (FI) CCD and 1 back side (BI) CCD
  - HXD (Well-type phoswitch counter): PIN and GSO, and active shields as GRB monitor (WAM=Wide-band All-sky Monitor)



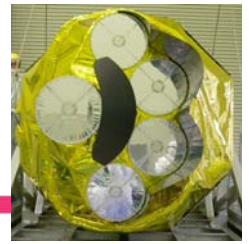
☺ high signal to noise from 0.3 to 50(200) keV
  - ~1000 cm^2 effective area in 1-6 keV band (XIS)
  - extremely low background (XIS, HXD)

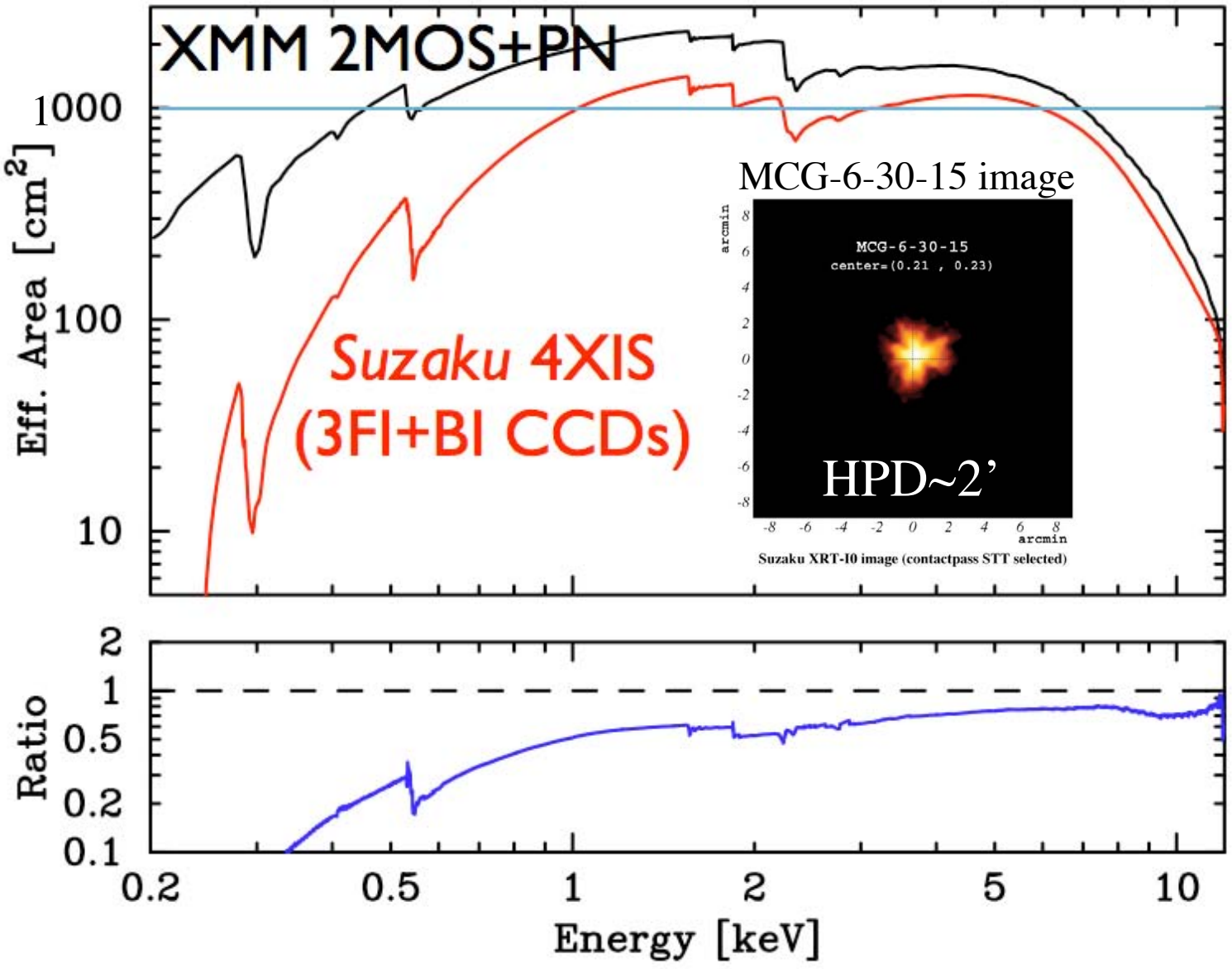
☺ excellent spectral resolution, especially at E<1 keV
  - improved line spread function on low energy side (XIS)

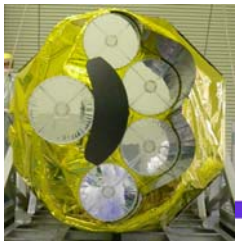
➪ Both of these are important properties for AGN research.
And very powerful for extended source.

☹ moderate spatial resolution (HPD~2')

Large effective area (XRT+XIS)

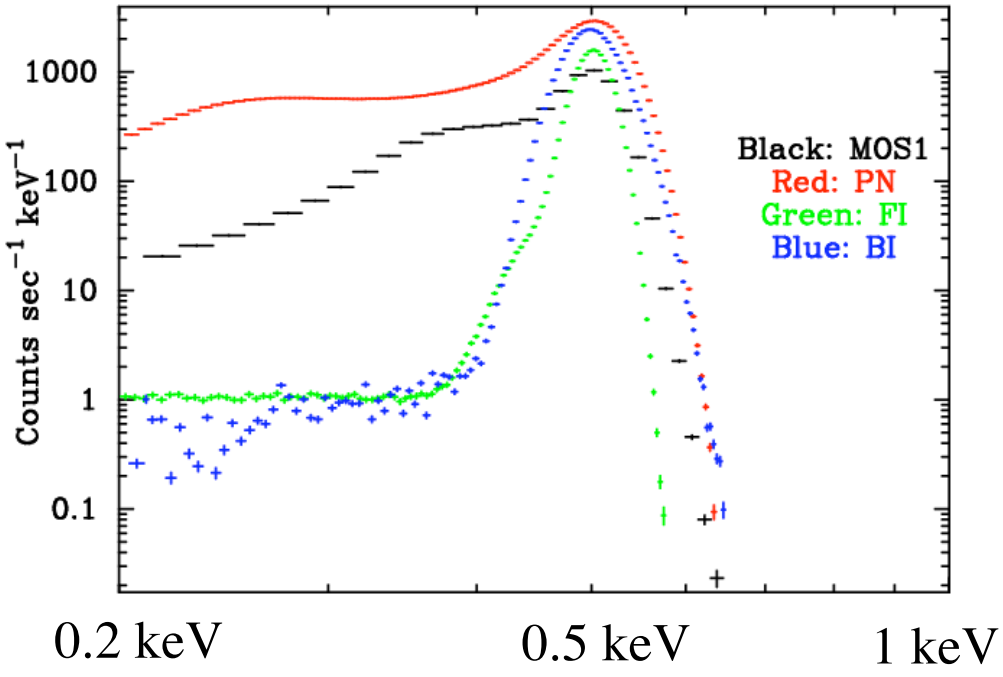




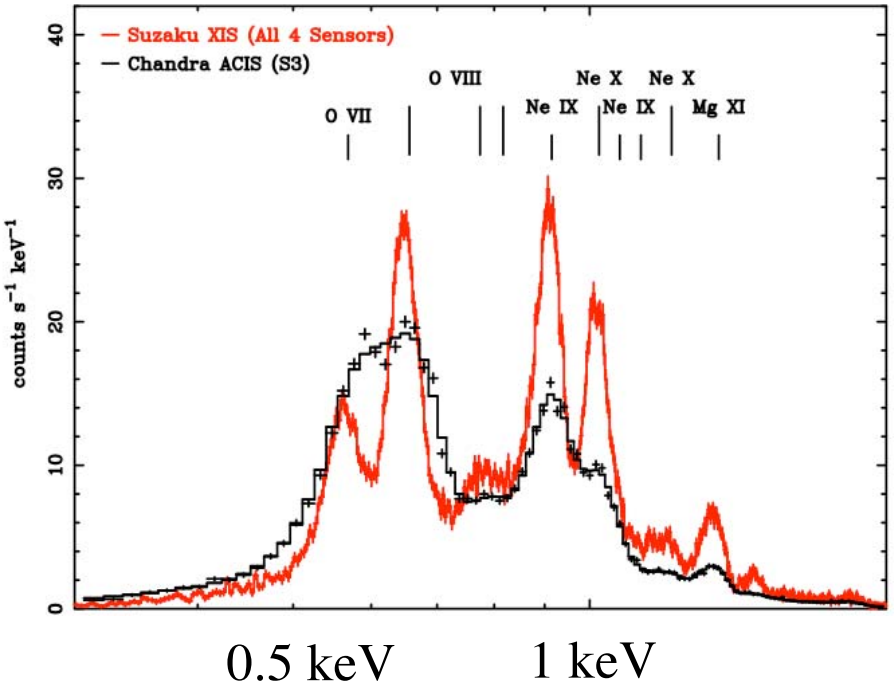


Excellent energy response (XIS)

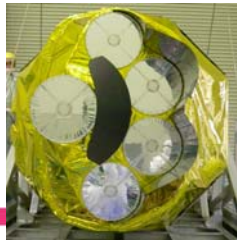
response to 0.5 keV
monochromatic X-ray



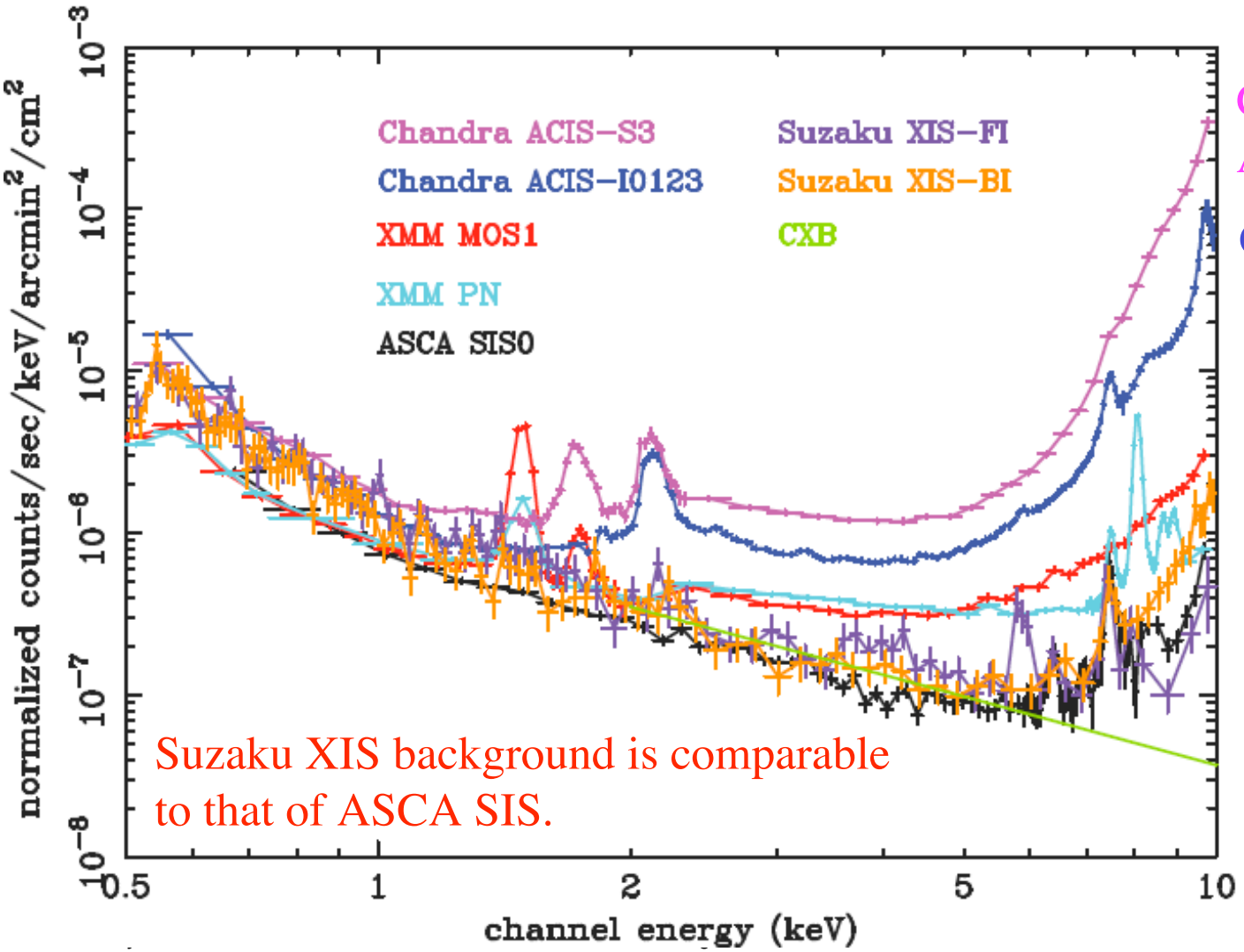
Observed energy spectrum
of SNR E0102.2-729



Low background (XIS, 0.3-10 keV)



background normalized by effective area and FOV



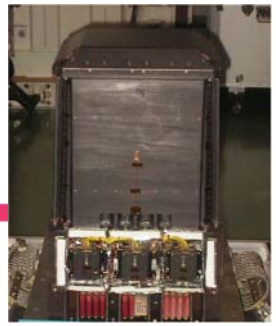
Suzaku XIS background is comparable to that of ASCA SIS.

Chandra ACIS-S3

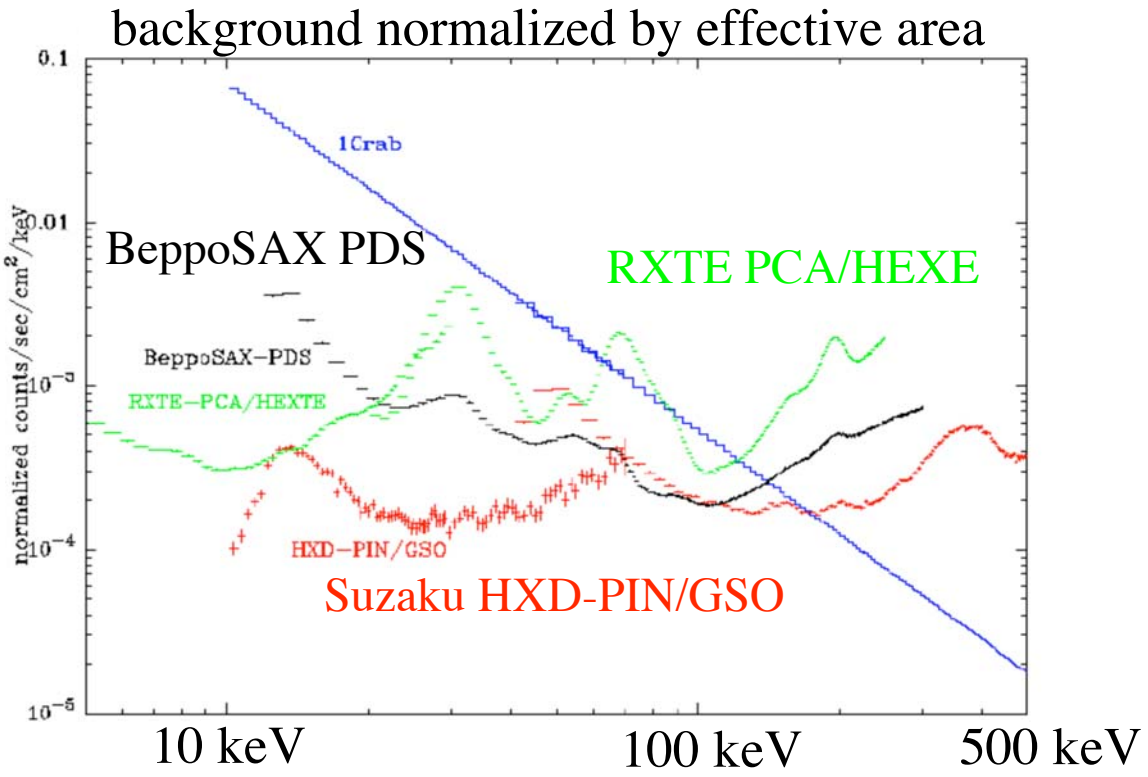
Chandra ACIS-I

XMM MOS1
XMM PN
Suzaku BI
Suzaku FI
ASCA SIS

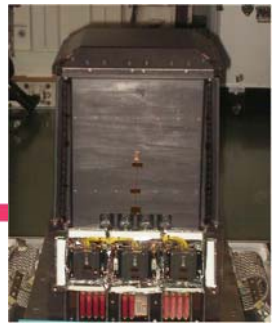
Low background (HXD, >10 keV)



- Focusing optics is not available above 10 keV.
- HXD is designed to achieve low background and high sensitivity utilizing well-type phoswitch technique.
- Passive collimator for PIN; 30'x30' FOV
- Presently, background can be estimated with an accuracy of 5%. Goal: 1%.

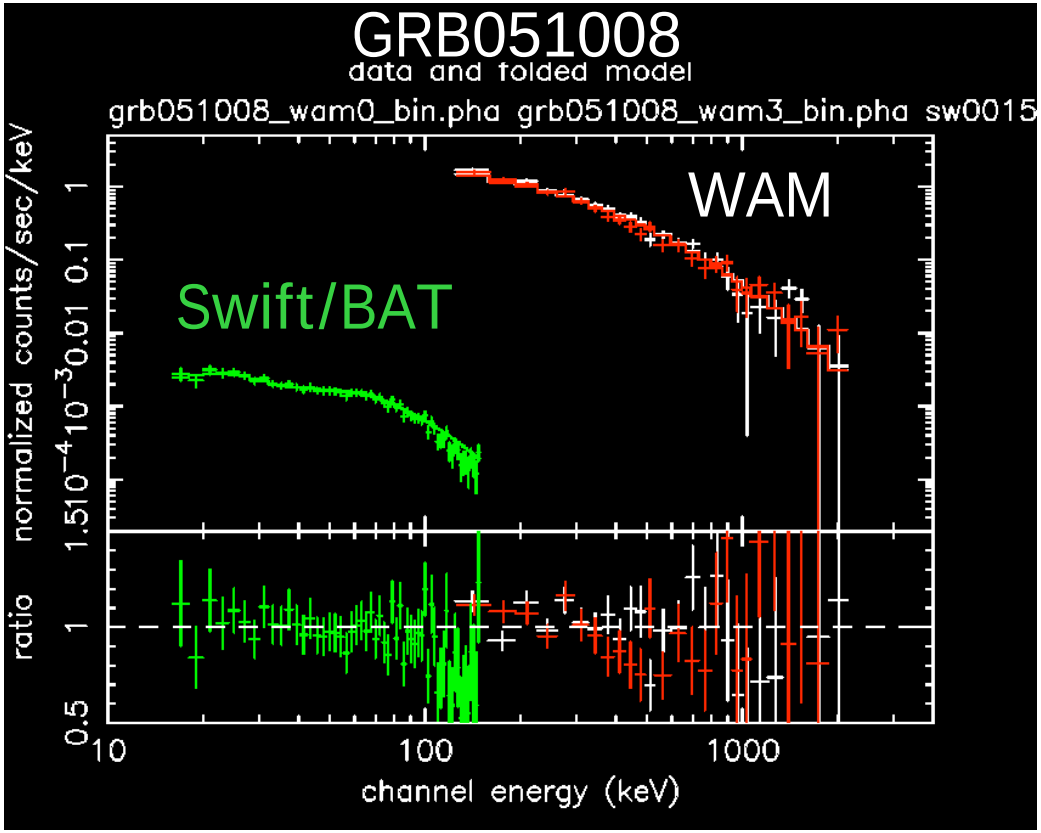


WAM (Wide-band All-sky Monitor)



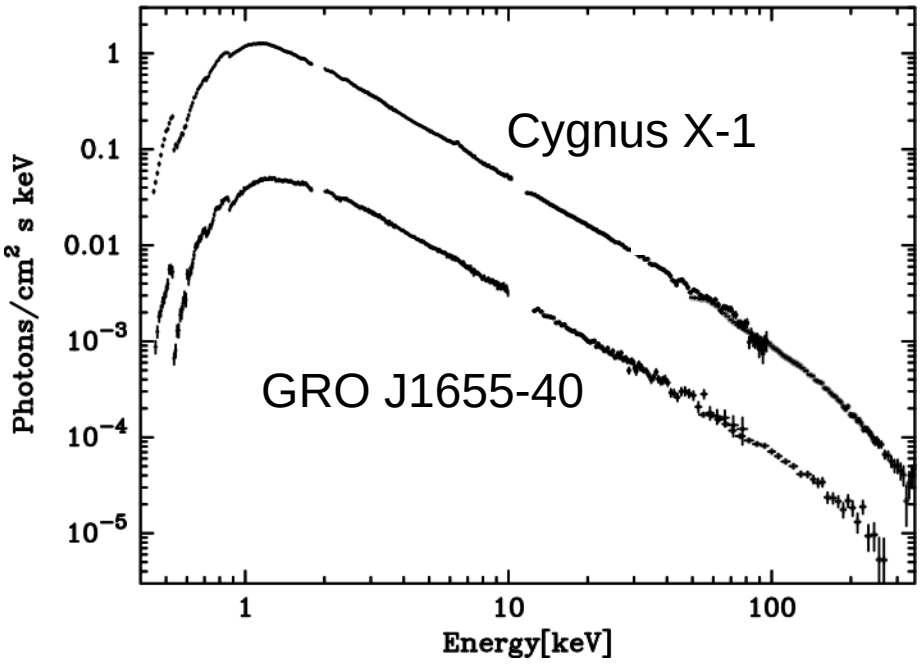
- GRB monitor using HXD anticounters.
- Covers 100-2000 keV, complementary to Swift/BAT.
- WAM data (GRB light curve, etc.) are available at

  http: //www.astro.isas.jaxa.jp/suzaku/research/HXD-WAM/WAM-GRB/.

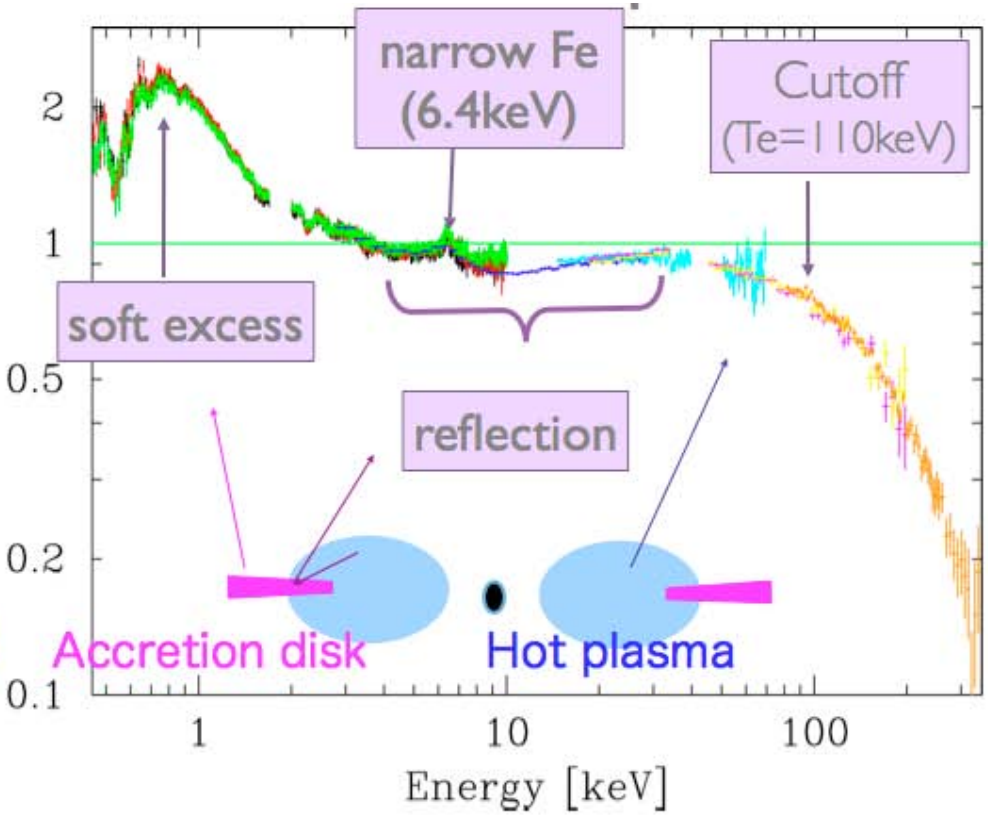


Broadband spectrum of BHC

Suzaku spectrum in 0.4-300 keV

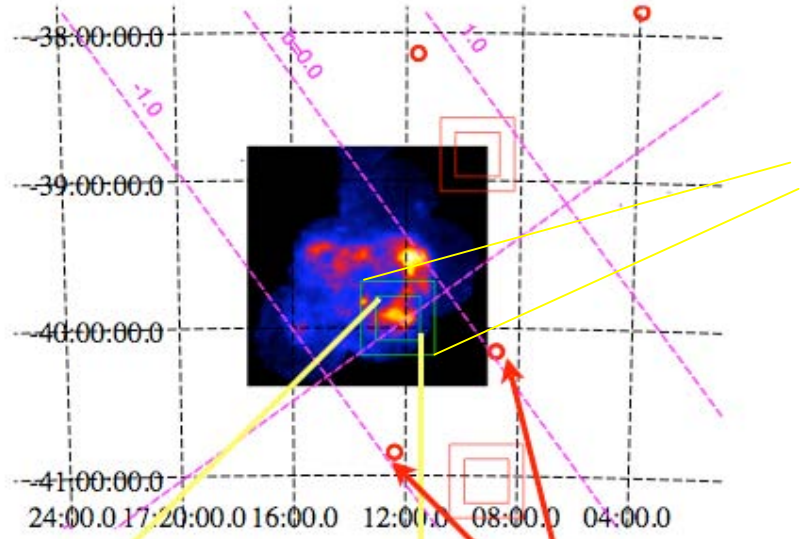


Cyg X-1 ratio to powerlaw model

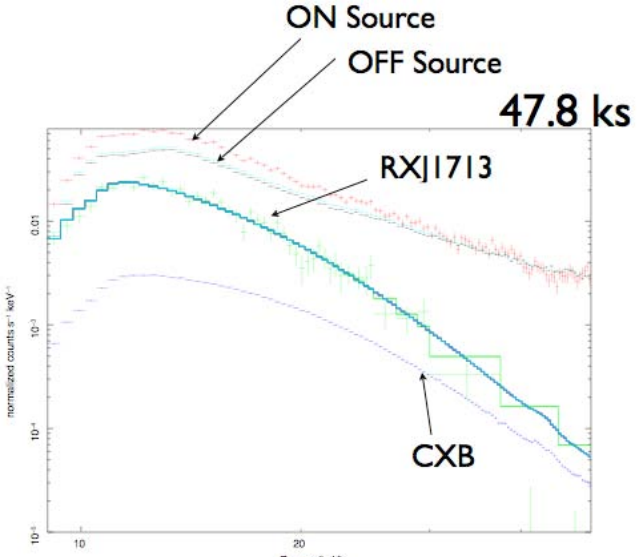


Kubota et al. (preliminary)

RX J1713.7-3946: Brightest non-thermal SNR (X/TeV)

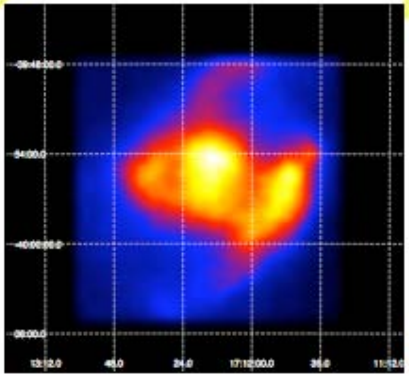


HXD-PIN FOV
(30'x30')

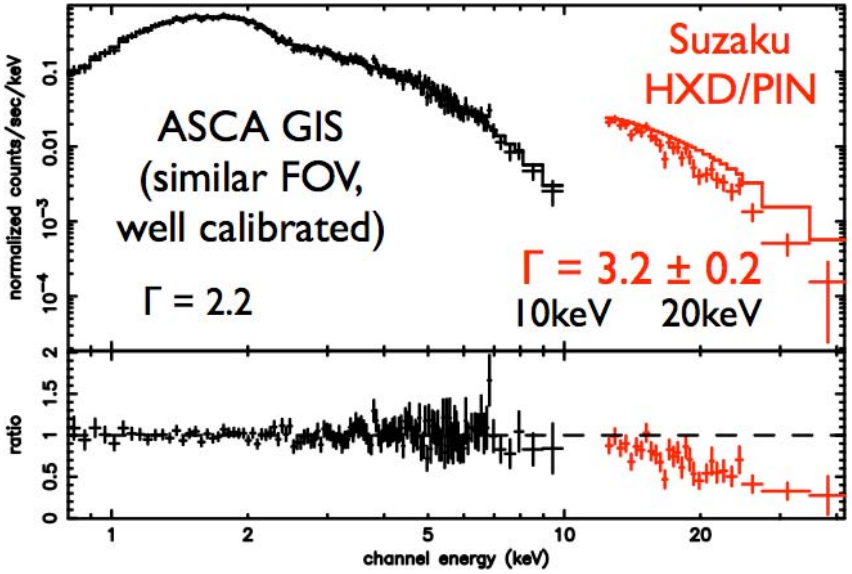


signature of break at ~15 keV

hard X-ray sources



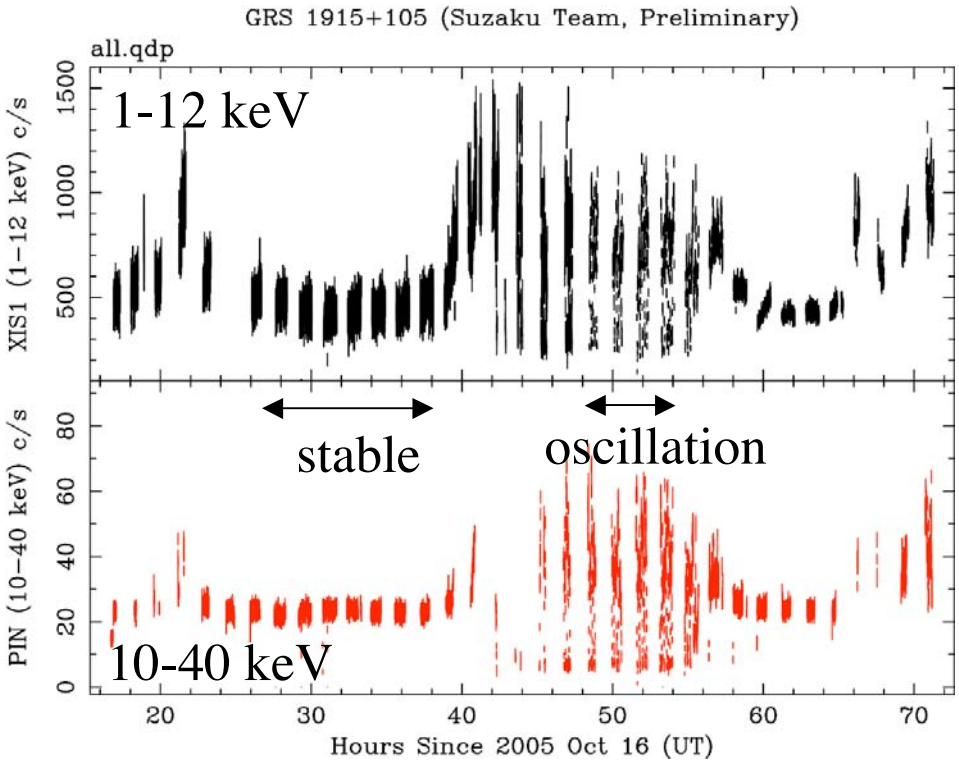
XIS Image



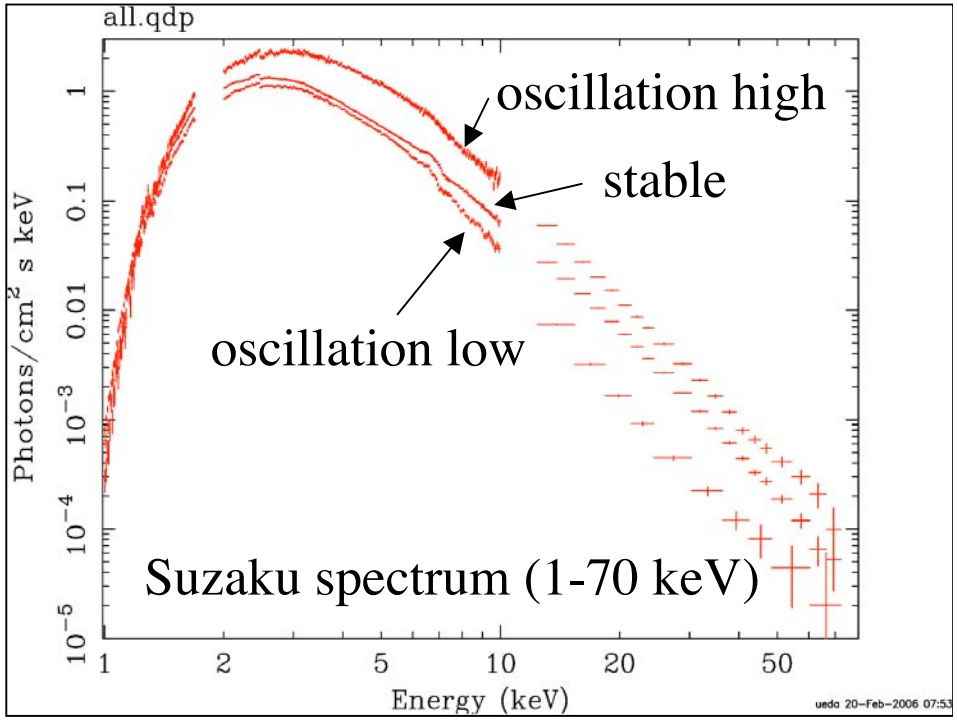
Takahashi et al. (preliminary)

Campaign of microquasar GRS1915+105

- 2005 Oct 17-18
- Suzaku, Integral, RXTE, Swift, radio, NIR (Spitzer, ground)



Ueda et al. (preliminary)



Absorption by highly ionized gas.
Reflection by moderately ionized mattrer.
Analysis is underway.

Main science goals of Suzaku AGN SWG 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
- *Precise measurements of Fe line parameters*

Time variability of different spectral components and their connection

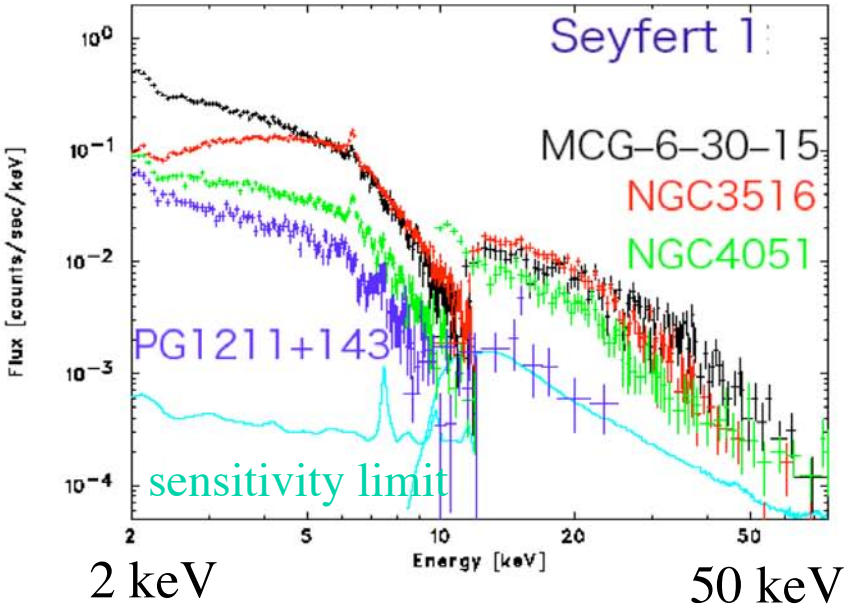
Work is started preliminary results NGC 4051, MCG-5-23-16, MCG-6-30-15

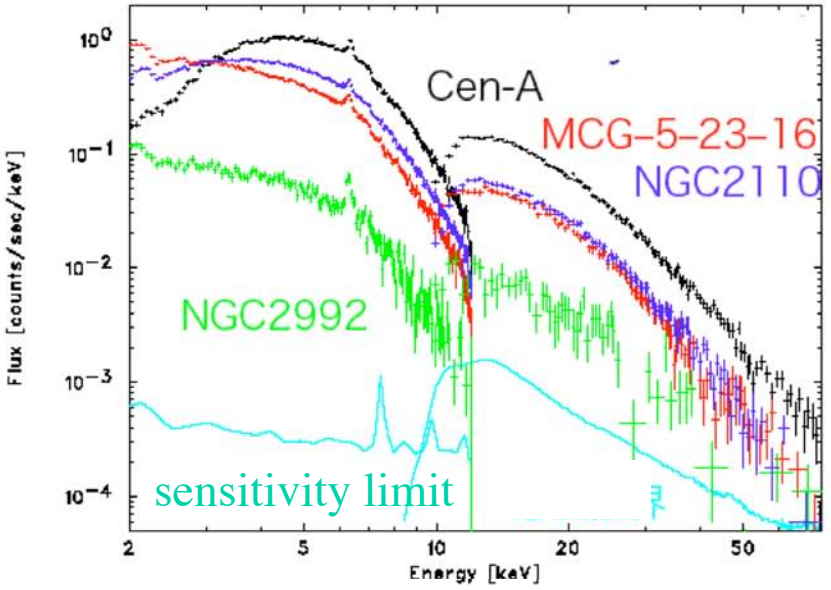
Does the reflection (+Fe line) vary with the continuum?

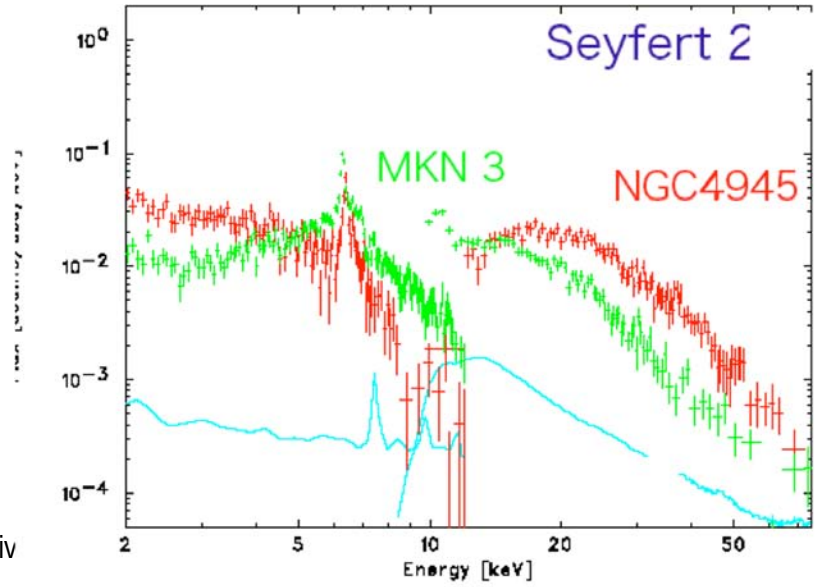
High energy cutoffs- and connection to x-ray background

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

Sample AGN spectra

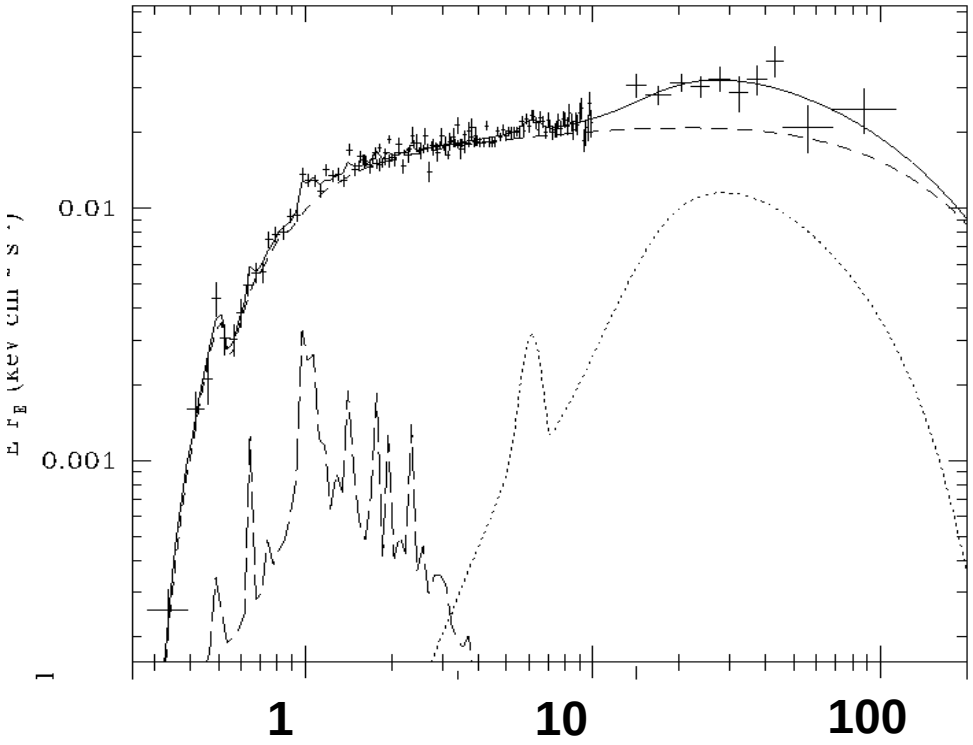






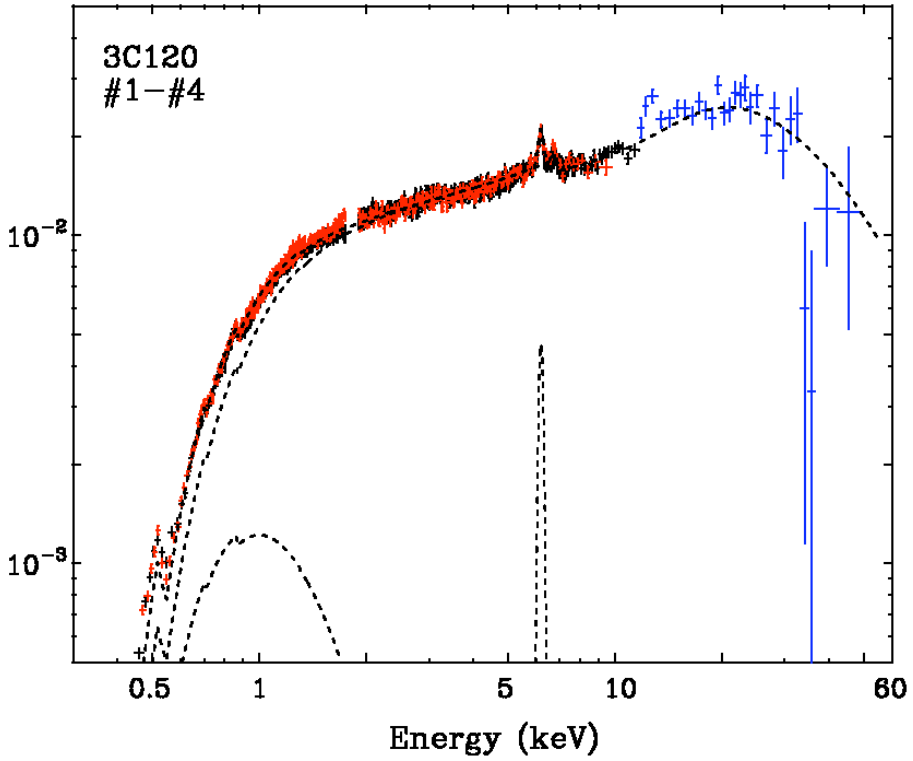
Watanabe et al. (preliminary)

3C120: Direct comparison with BeppoSAX



Beppo SAX (160ksec)

Zdziarski & Grandi 2001, ApJ 551, 186



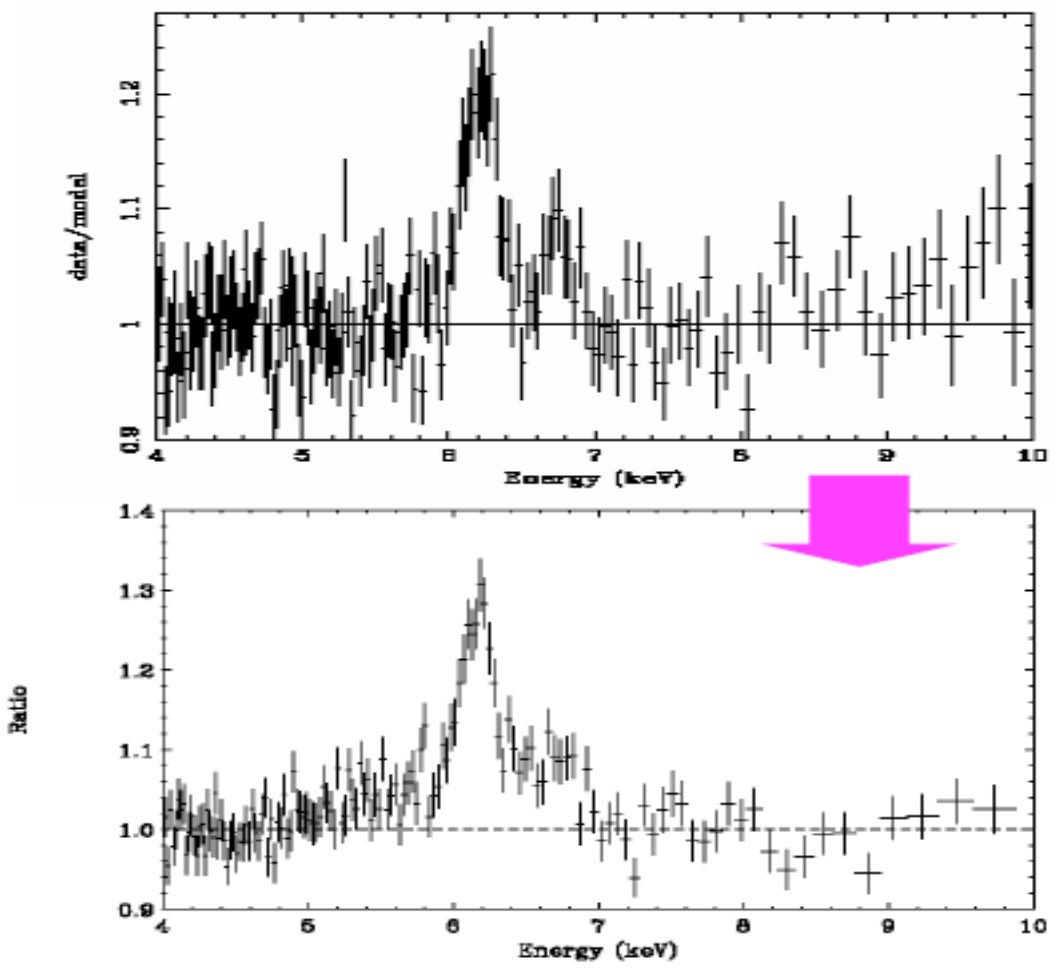
Suzaku (150ksec)

Kataoka et al. (preliminary)

NOTE! (1) Much better statistics
(2) Good energy resolution
(3) clear reflection hump

3C120: Fe K line profile

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



XMM (130ksec)

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

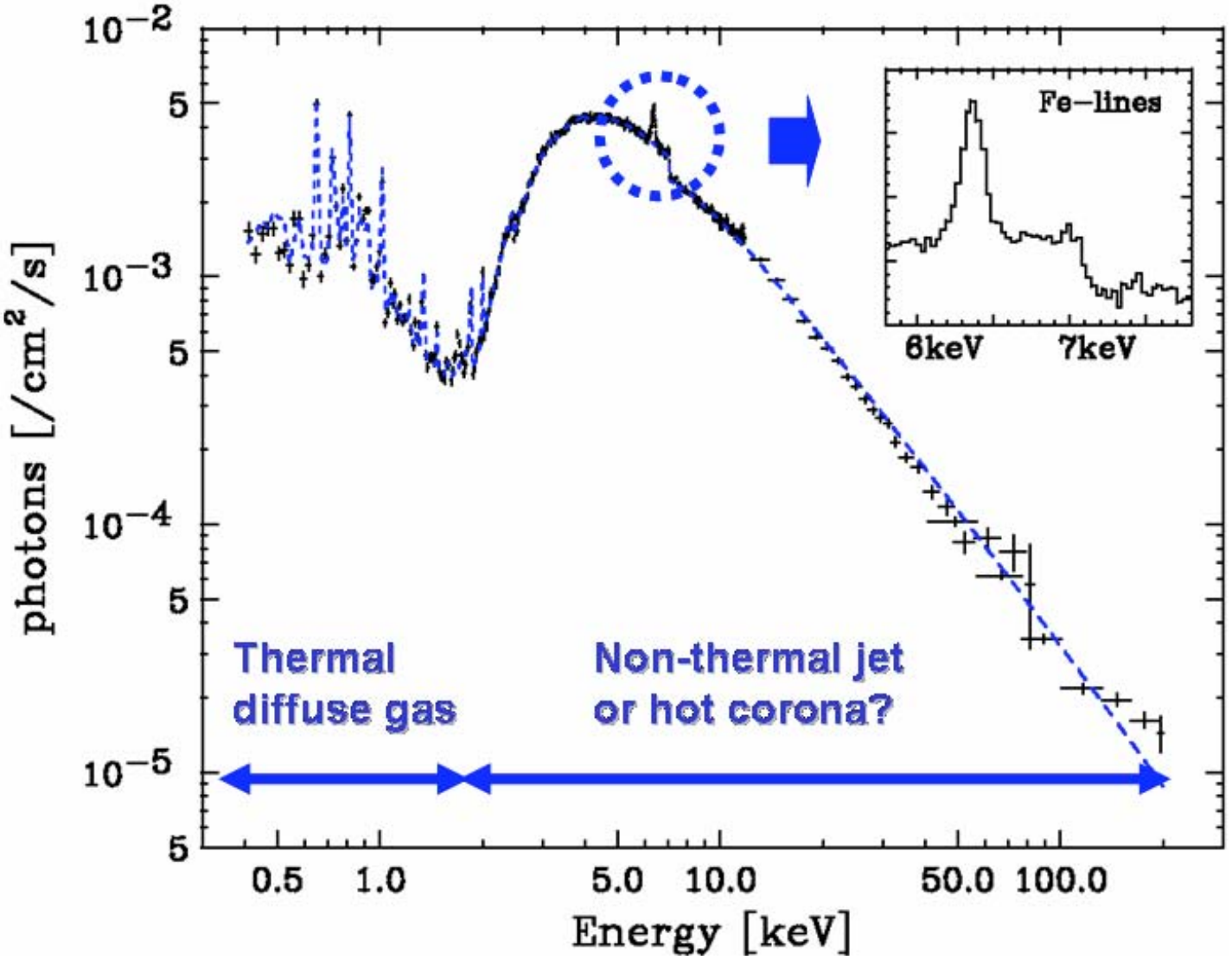
See, also Ogle et al., 2005, ApJ, 618, 139

Suzaku (150ksec)

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

Kataoka et al. (preliminary)

Cen A: Broadband spectrum

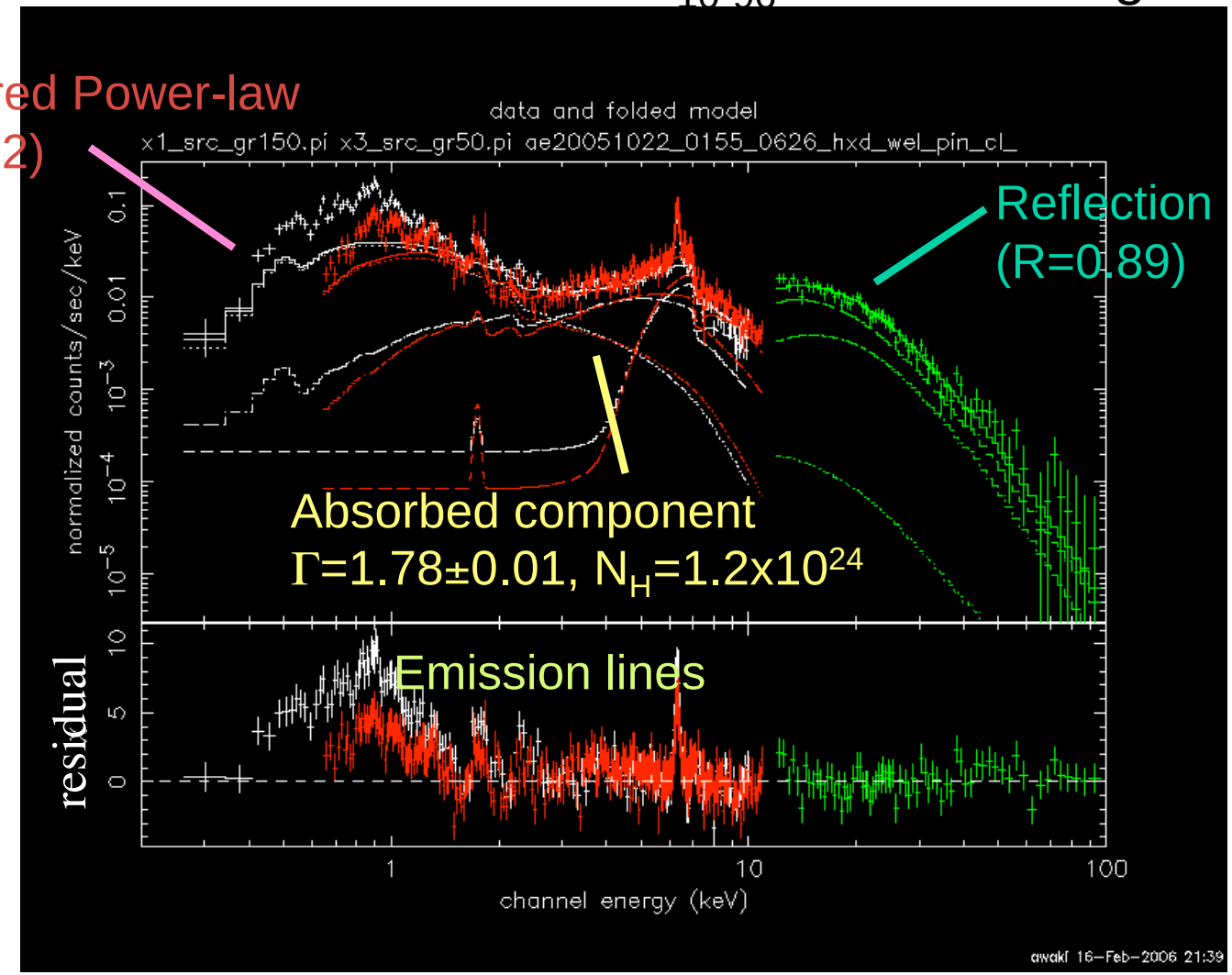


Mrk 3: Broadband spectrum

Continuum emission (soft lines + scattered + absorbed + reflection)

$F_{2\text{-}10} = 5.8 \times 10^{-12}$ erg/s/cm^2

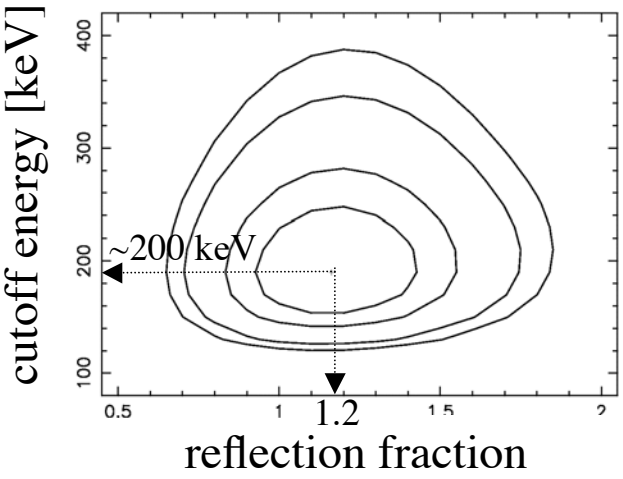
$F_{10\text{-}96} = 1.1 \times 10^{-10}$ erg/s/cm^2



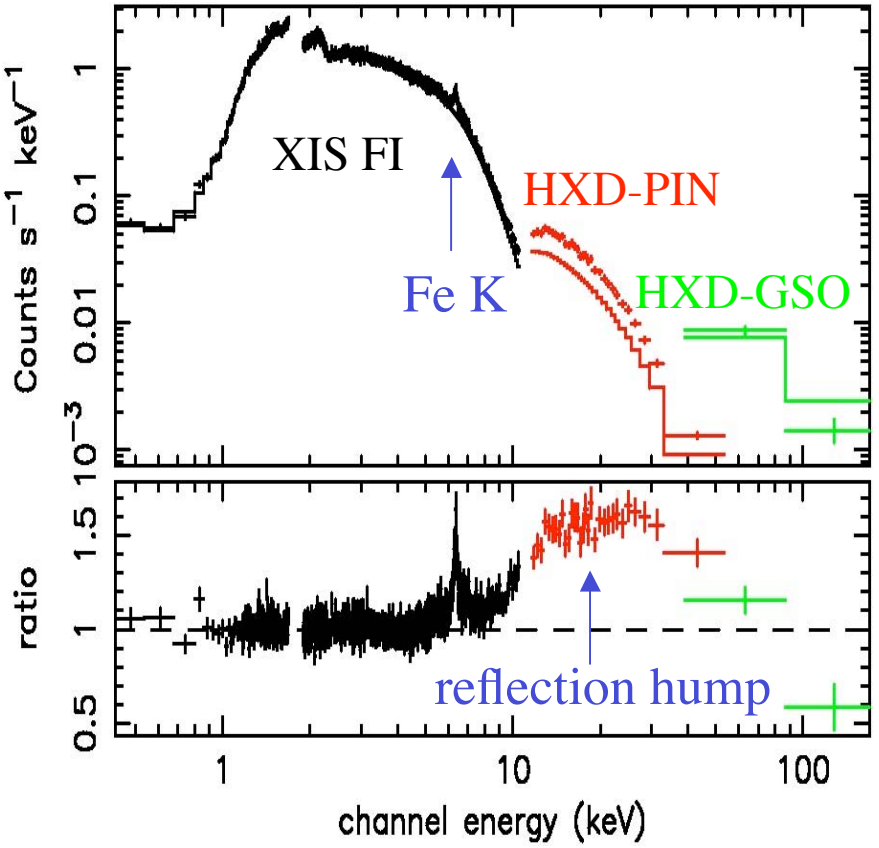
Awaki et al. (preliminary)

MCG -5-23-16: Broadband spectrum

- Observed Flux 9×10^{-11} cgs (2-10 keV) and 2×10^{-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.



Reeves et al. (preliminary)

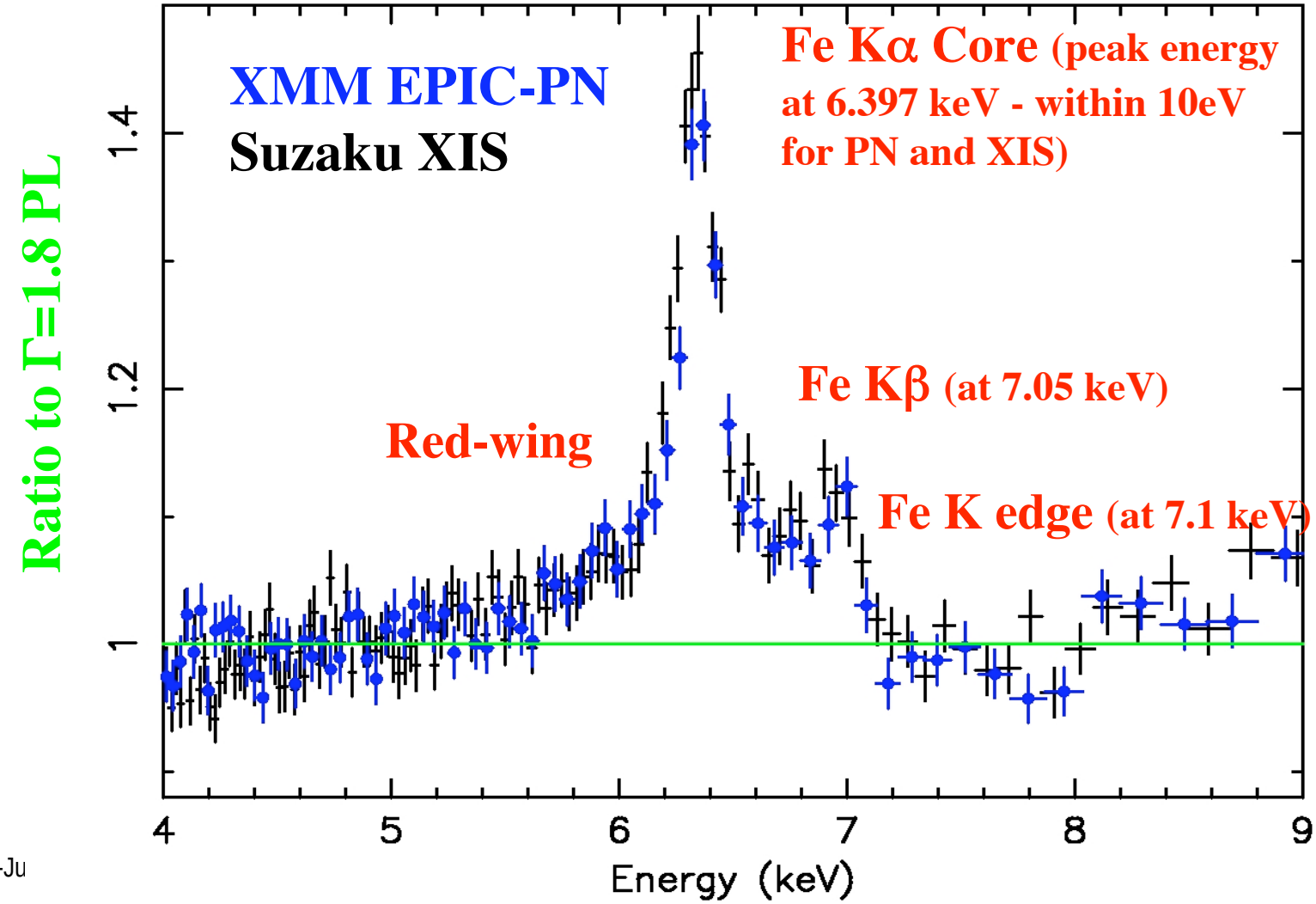


Iron line parameters are no longer degenerate with simultaneous measure of reflection component and high energy continuum

MCG -5-23-16: Fe K line profile

Simultaneous Suzaku and XMM-Newton observation

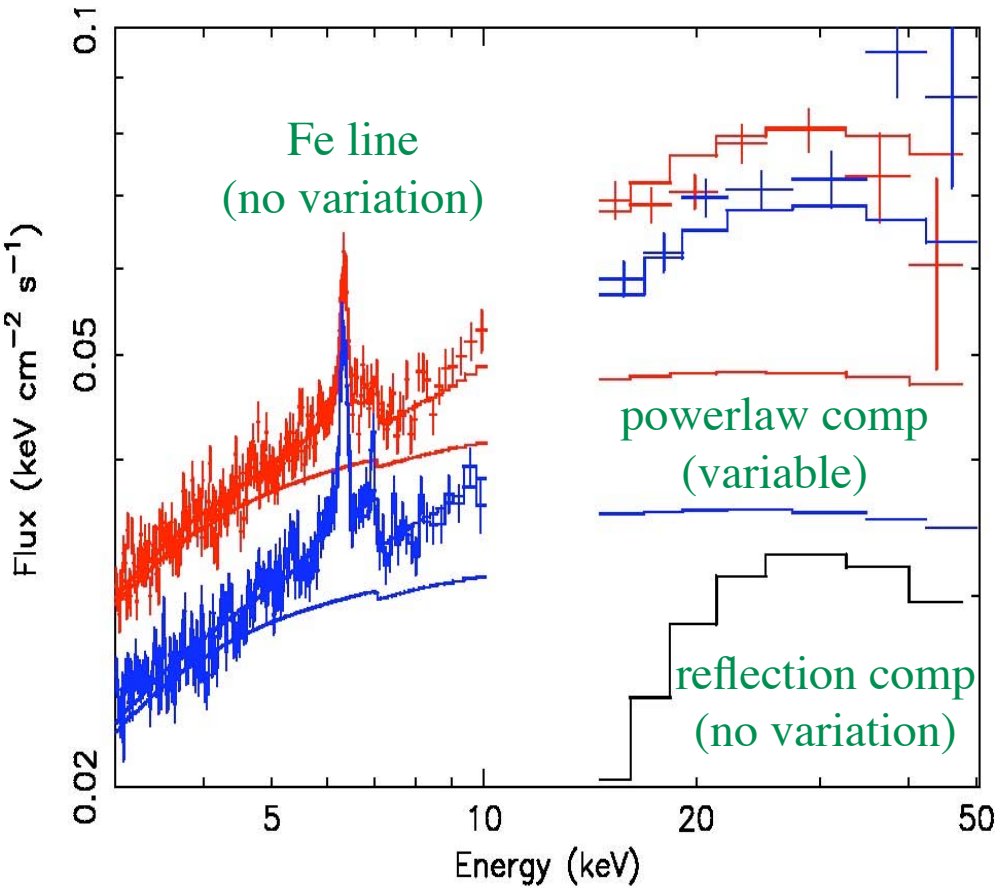
- notice the excellent agreement on Fe K line shape



MCG -5-23-16: Spectral variation

- Observation split into high and low flux states
- Spectra can be fit with a superposition of a variable power-law and constant Fe line + reflection hump.
- Iron K line and reflection component do not appear to vary during observation.
- Though weak variations in broad Fe line cannot be statistically excluded.

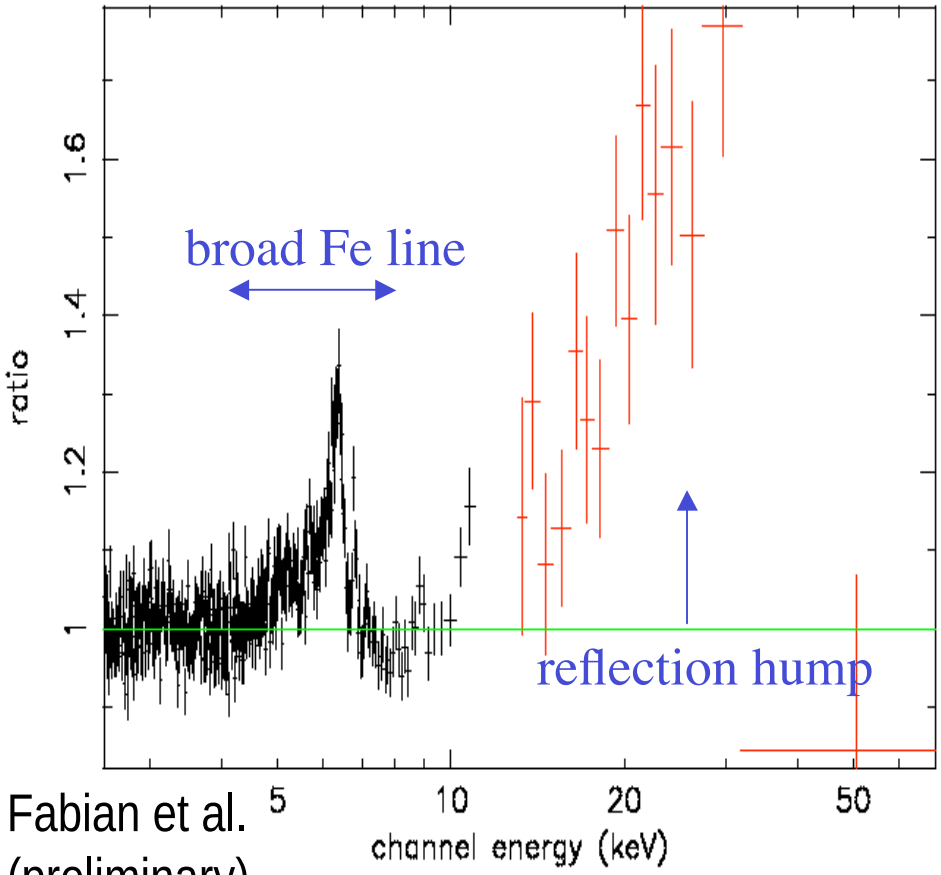
High flux = Red; Low flux = Blue;
Reflection:Black



Reeves et al. (preliminary)

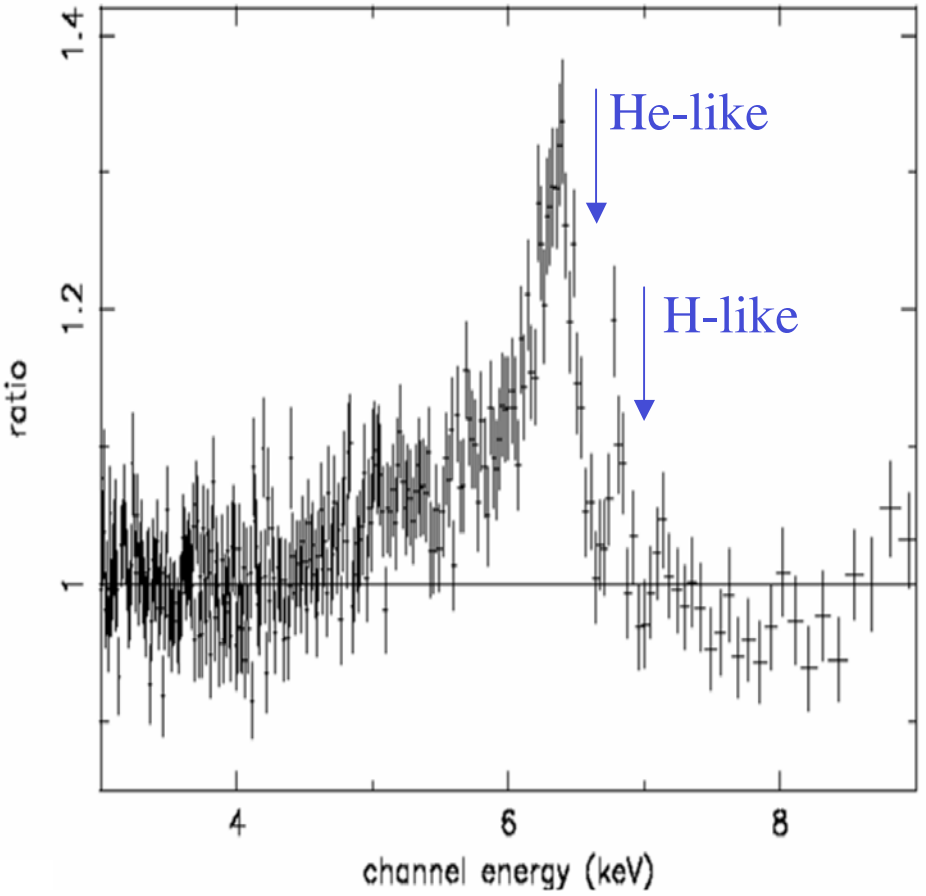
Suzaku long look of MCG -6-30-15 (300ks)

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

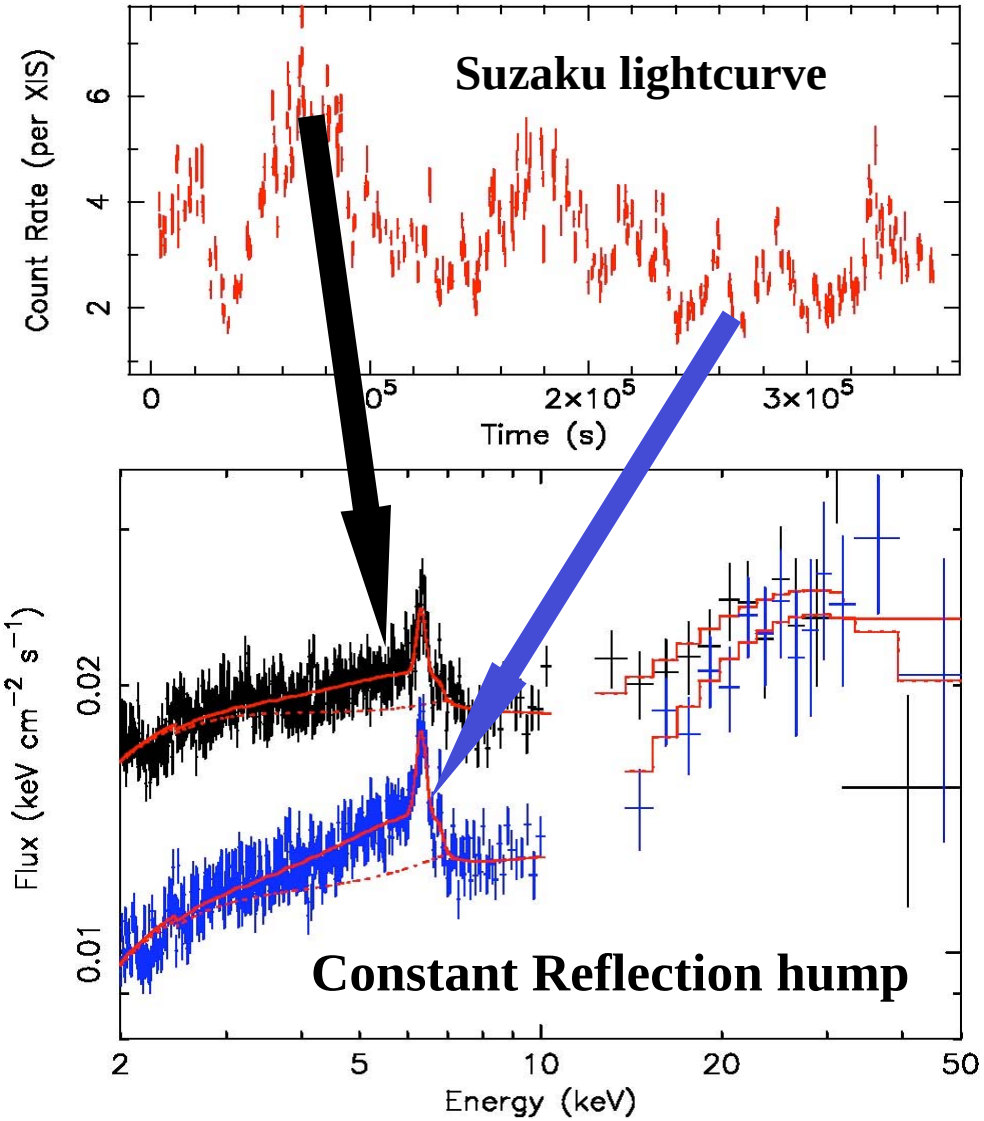


Fabian et al. (preliminary)

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

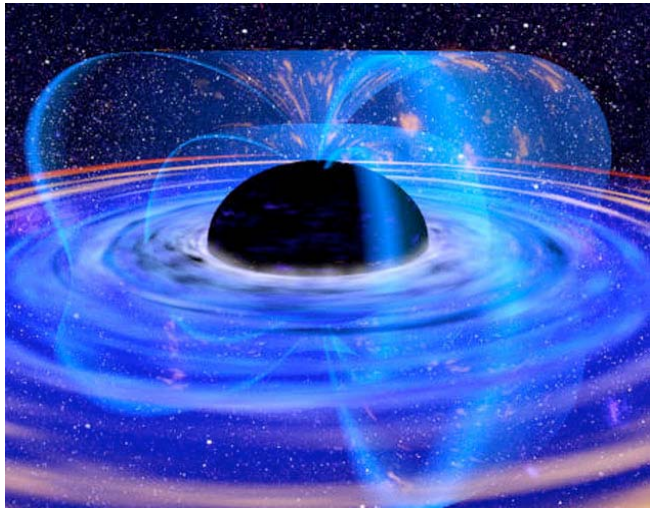


MCG -6-30-15: Spectral variation



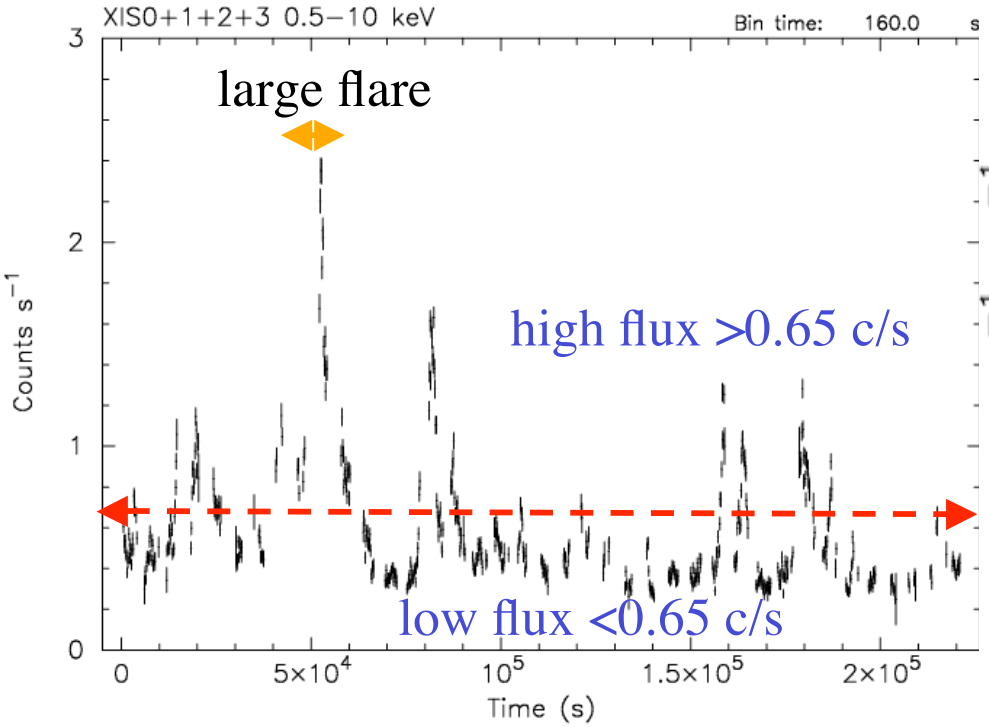
Strong iron K line and disk reflection from around a Kerr (spinning) black hole

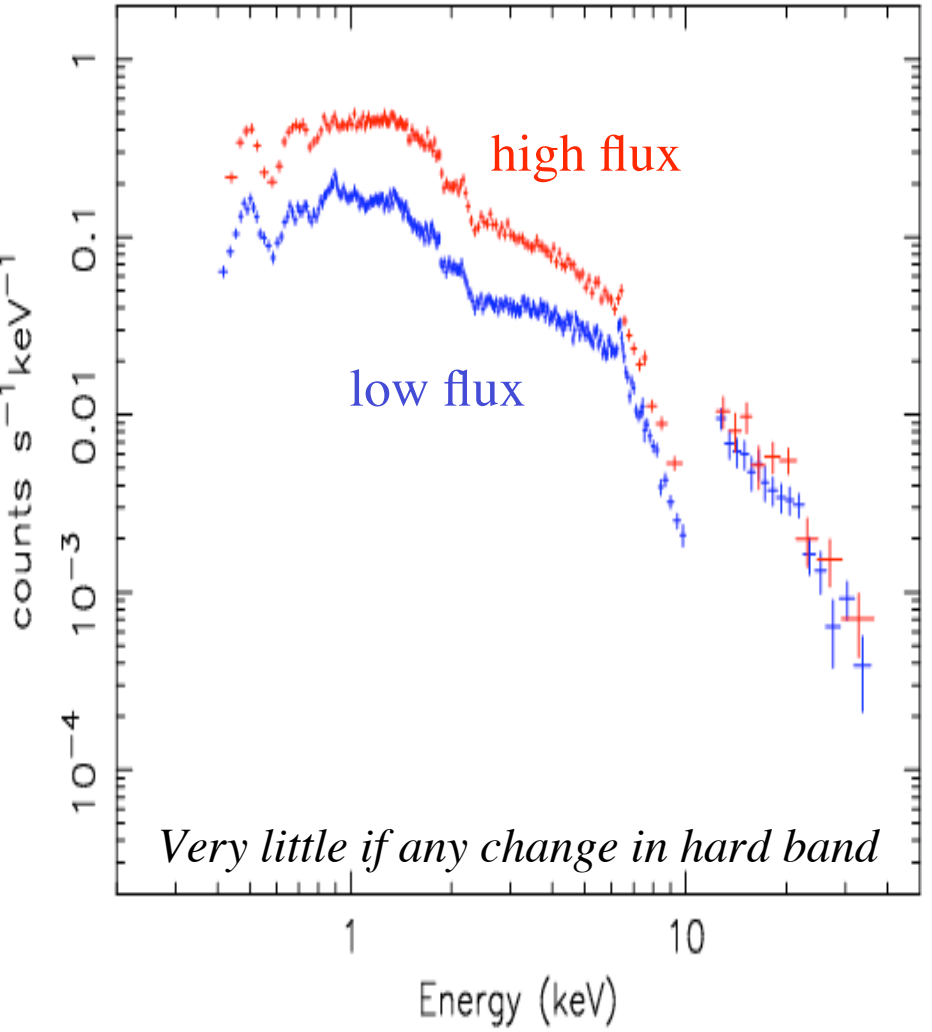
No variations in Fe line/reflection - gravitational light bending around a Kerr BH? (Miniutti & Fabian 2004)



NGC 4051: Spectral variability

- 86 ksec XIS+HXD, average flux in 2-10 keV: 9×10^{-12} erg/s/cm^2
- Spectral variability breaks into two components: constant + variable power law
- E> 10 keV spectrum varies very little.



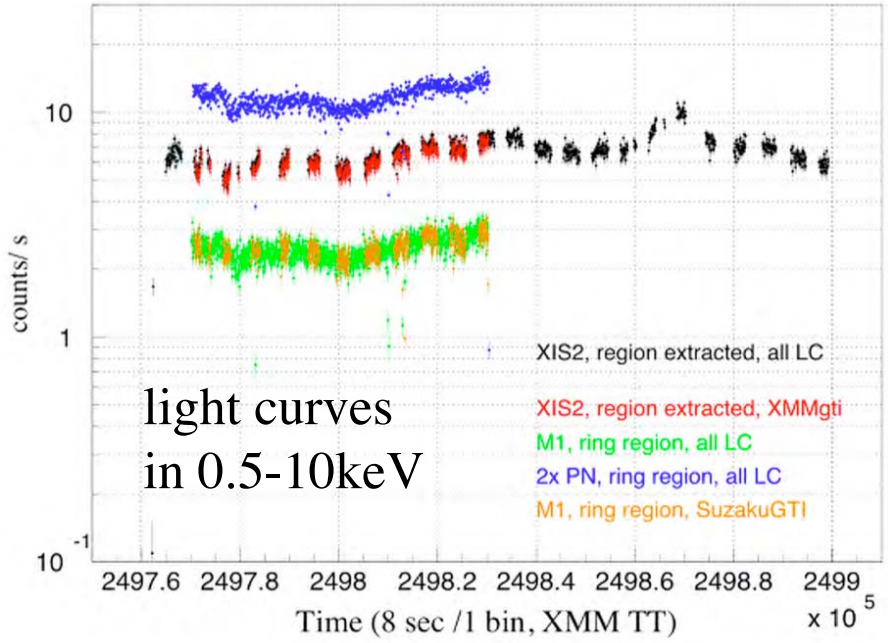


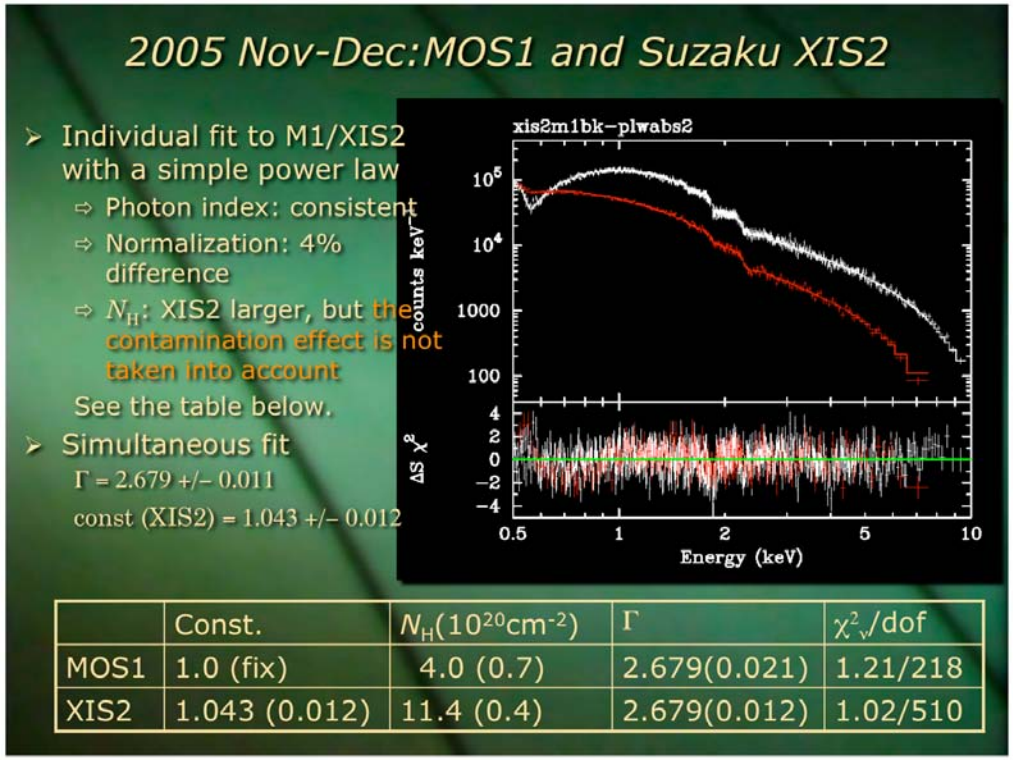
Terashima et al. (preliminary)

PKS2155-304

- Campaigns with Chandra and XMM-Newton (for calibration purpose).
- XIS window mode -> no pile up
- HXD data not yet analyzed.
- More objects in AO-1 phase.

Ishida et al. (preliminary)

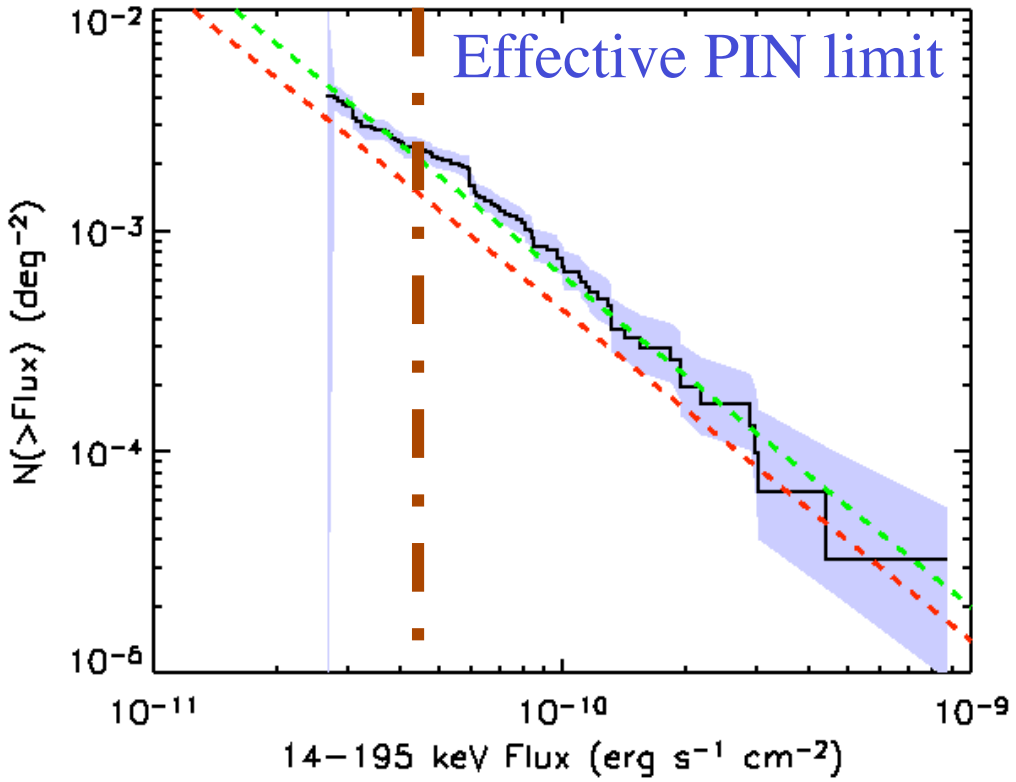




	Const.	$N_H(10^{20}cm^{-2})$	Γ	χ^2_ν/dof
MOS1	1.0 (fix)	4.0 (0.7)	2.679(0.021)	1.21/218
XIS2	1.043 (0.012)	11.4 (0.4)	2.679(0.012)	1.02/510

Number of potential targets for HXD

- 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 (Markwardt et al 2006)

Summary

- Suzaku will add a large sample of very high quality AGN spectra and time series data.
- The broad bandpass and good spectral capability of Suzaku will allow
  - breaking the degeneracies between broad Fe K lines and continuum shape
  - measurement of reflection component
  - connection between soft X-ray excess and reprocessing
  - abundance determinations of the reprocessing material
- Preliminary results of AGNs were shown.
  - Broad Fe lines are confirmed in a number of sources.
  - Narrow Fe line of some objects originates from Compton-thick matter (torus?), while in others, no reflection is present and Fe line comes from Compton thin material (BLR?).
  - A constant hard component appears to be present in a number of spectra. 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.