Revealing the coronal properties of Seyfert galaxies with NuSTAR

Andrea Marinucci
(Roma Tre)

on behalf of the
NuSTAR AGN Physics WG

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Overview

- Brief introduction on high-energy cutoff measurements
- Nearby AGN seen by NuSTAR
- Results
- Conclusions and future perspectives

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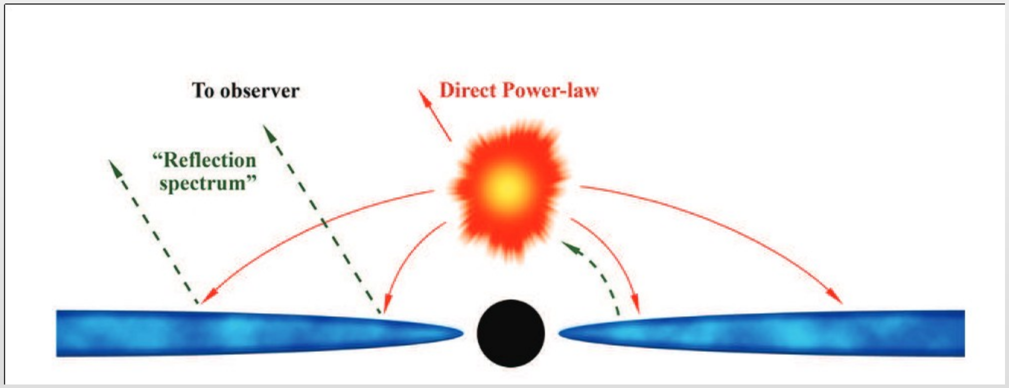
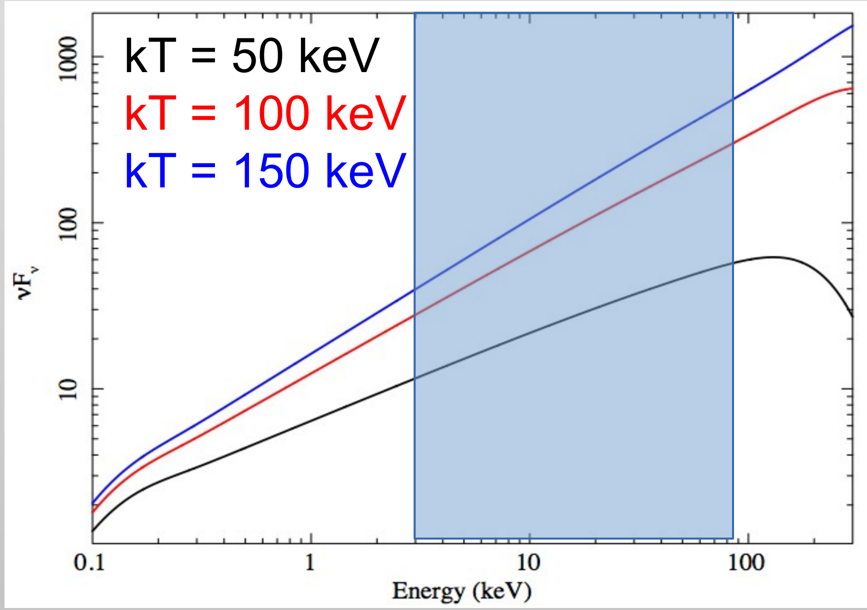
Introduction

One of the main open problem for AGN is the nature of the primary X-ray emission.

It is due to Comptonization of soft photons, but the geometry, optical depth and temperature of the emitting corona are largely unknown.

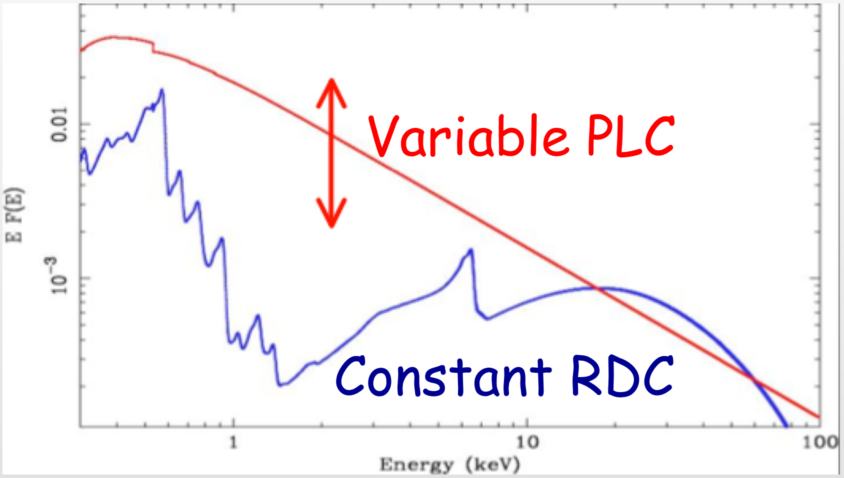


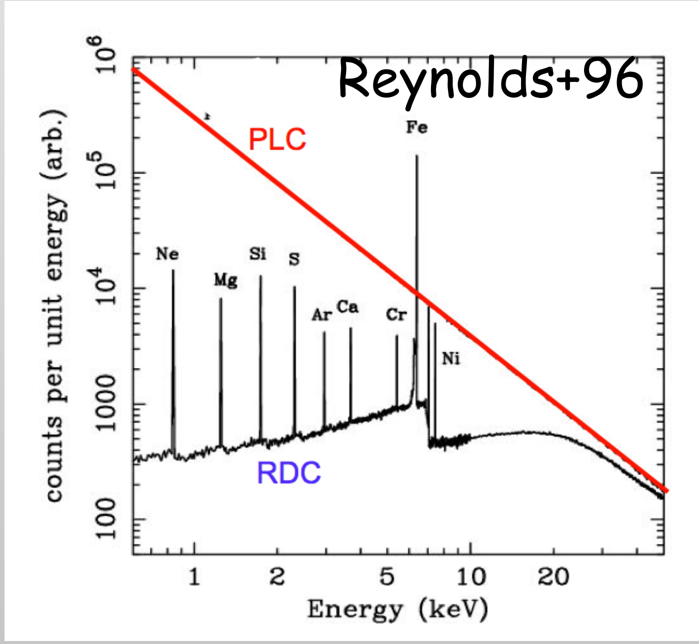


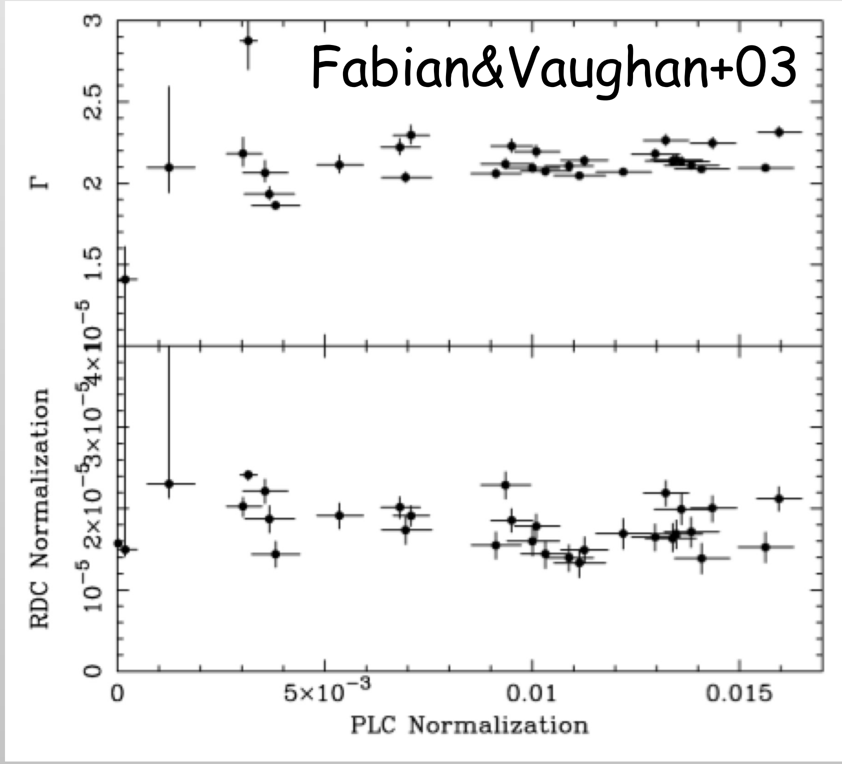
Most popular models imply E_{cut}=2-3x kT_e, so measuring E_{cut} helps constraining Comptonization models.

Introduction

Since the primary X-ray radiation illuminates the disc and is partly reflected towards the observer's line of sight it is fundamental to properly take it into account.

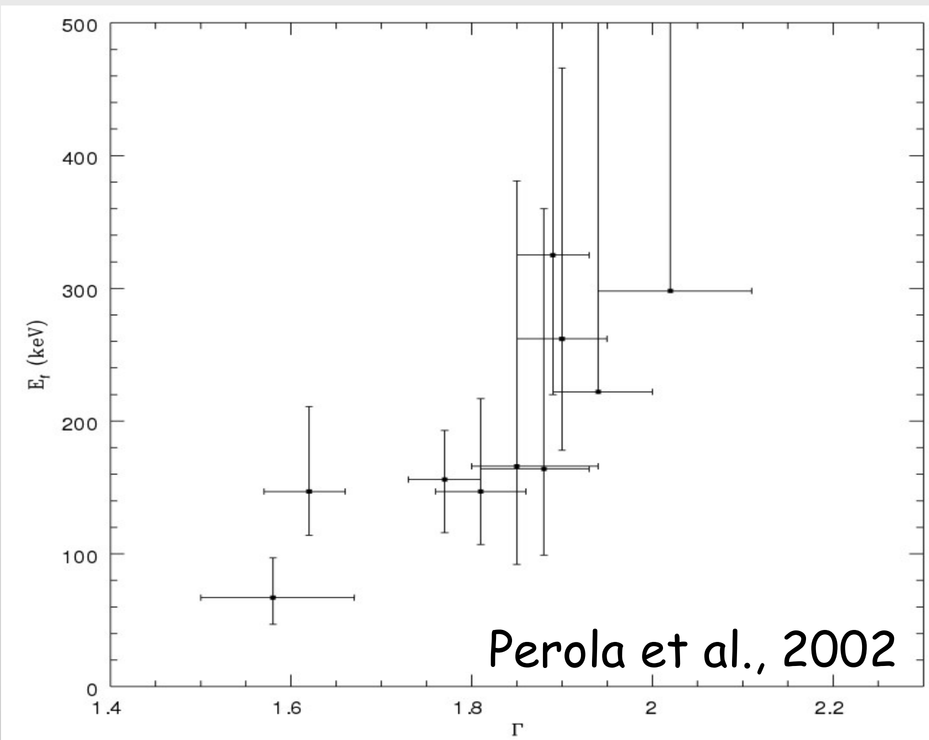




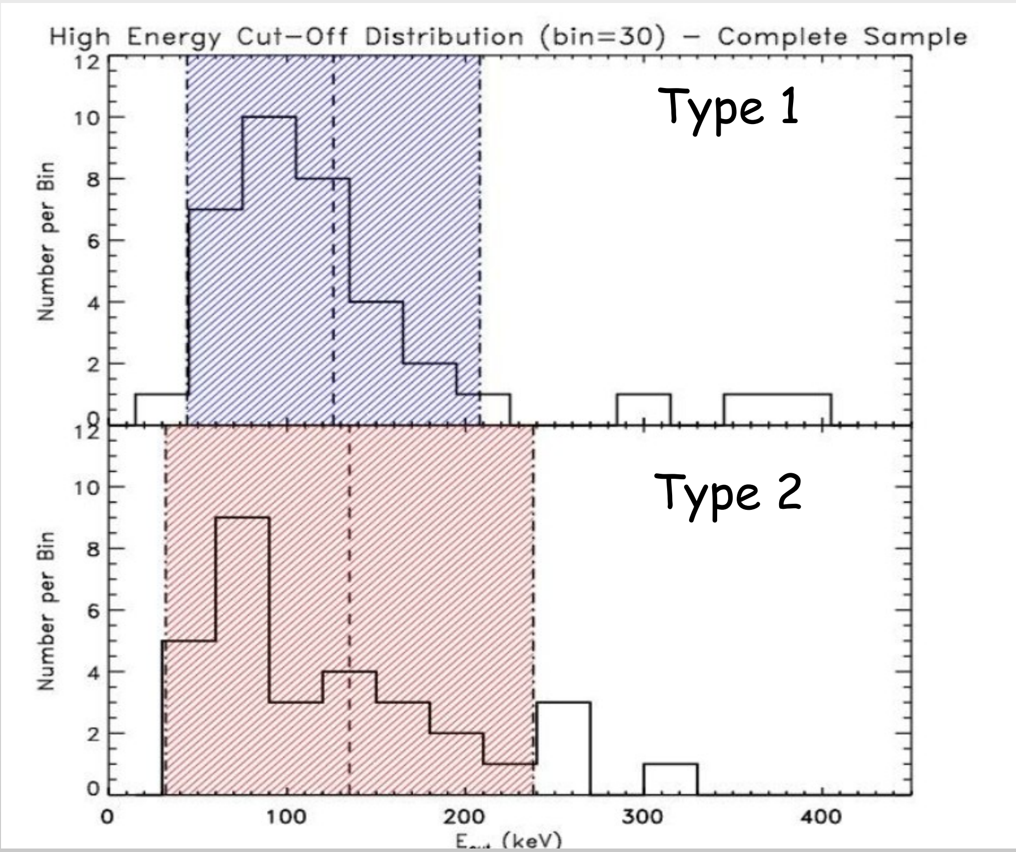


Introduction

So far, we have only a handful of results based on non focusing, and therefore strongly background-dominated, satellites (BeppoSAX-PDS, Suzaku HXD-PIN, INTEGRAL, Swift-BAT)



Perola et al., 2002



De Rosa et al., 2012; Molina et al., 2013

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The NuSTAR satellite

1 Ms Sensitivity
- 3.2×10^{-15} erg/cm²/s (6 – 10 keV)
- 1.4×10^{-14} erg/cm²/s (10 – 30 keV)

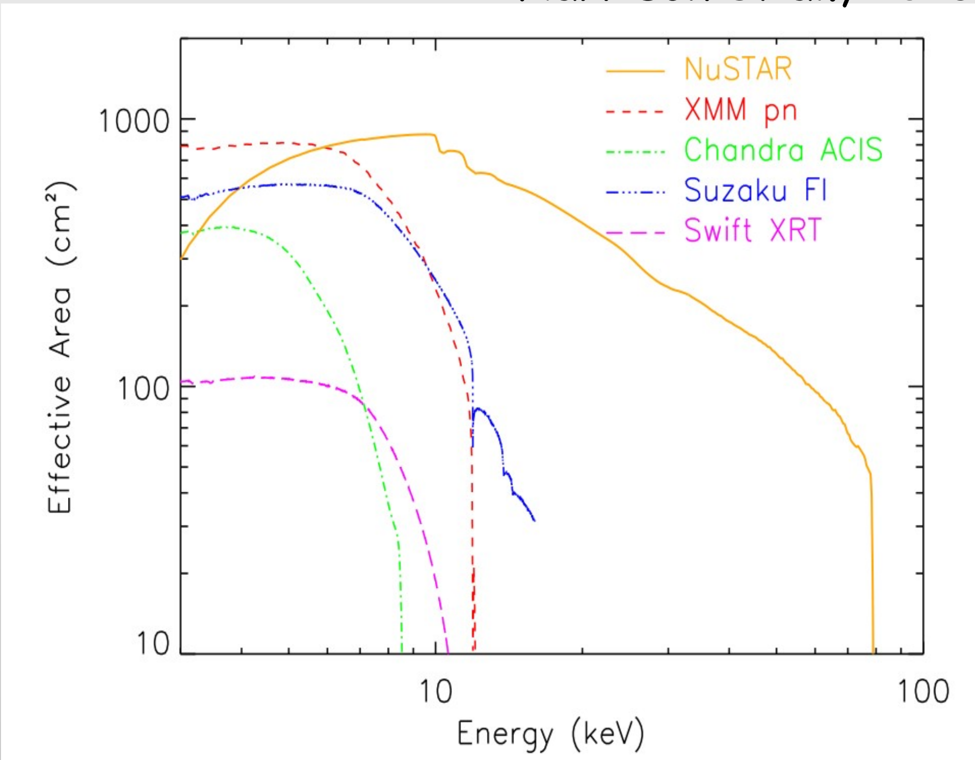
Imaging

HPD	58"
FWHM	18"
Localization	2" (1-sigma)

Spectral response
- energy range: 3-79 keV

ΔE @ 6 keV	0.4 keV FWHM
ΔE @ 60 keV	1.0 keV FWHM

Harrison et al., 2013

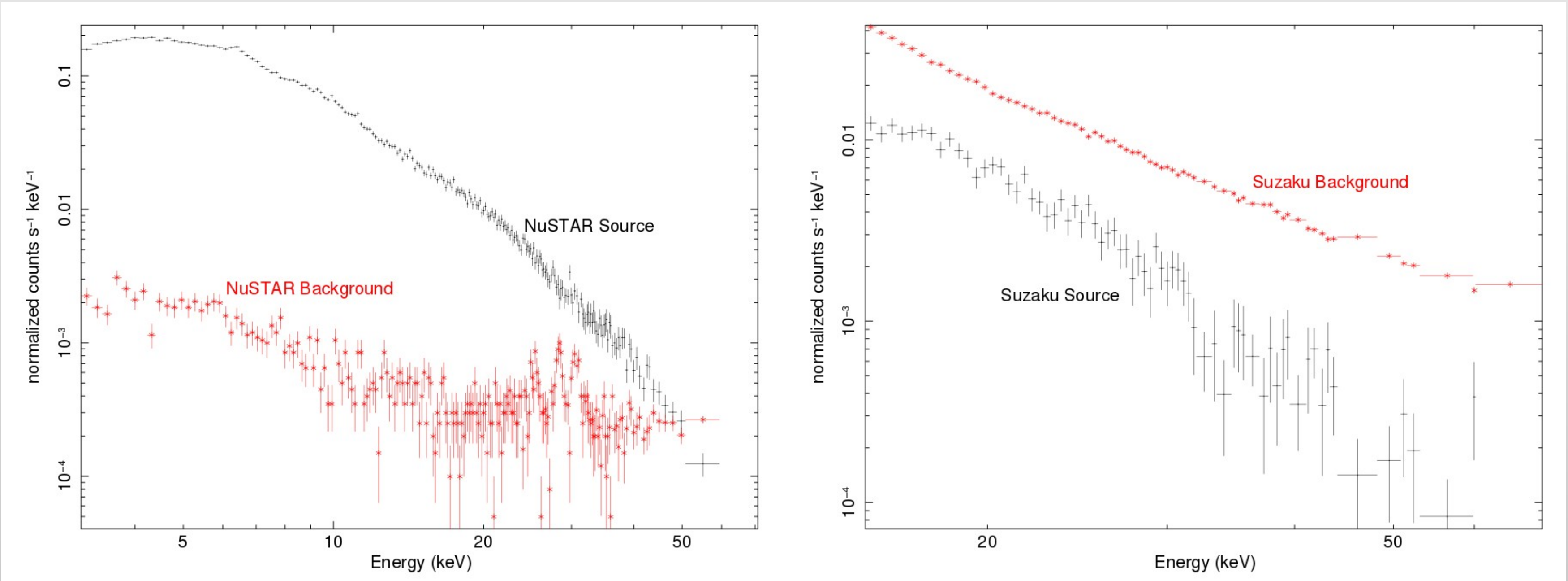


Target of Opportunity
- response <24 hr
- typical 6-8 hours
- 80% sky accessibility

The NuSTAR satellite

The combination of NuSTAR high effective area and low background yelds ~100x better S/N versus Suzaku HXD-PIN

MCG-6-30-15: 125 ks net exposure time and same 15-70 keV flux (6.5×10^{-11} erg/cm^2/s)



Marinucci et al., 2014a

AGN observed by NuSTAR

AGN Physics WG:

Target	R.A.	Dec.	T_observd	ObsDate
3C273	187.277917	2.052500	371.5 ks	2012 Jul
MCG-5-23-16	146.917319	-30.948734	243.5 ks	2012 Jul+
IC4329A	207.330000	-30.309444	185.2 ks	2012 Aug
SwiftJ2127d4p5654	321.937083	56.944444	212.4 ks	2012 Nov
NGC4151	182.635833	39.405833	151.2 ks	2012 Nov
MCG-6-30-15	203.974167	-34.295556	209.3 ks	2013 Jan+
Cyg_A	299.868153	40.733916	67.1 ks	2013 Feb+
Ark120	79.047500	-0.149722	93.2 ks	2013 Feb
3C120	68.296250	5.354444	181.4 ks	2013 Feb
3C390.3	280.537458	79.771424	104.7 ks	2013 May
Mkn335	1.581339	20.202914	146.9 ks	2013 Jun
NGC4051	180.790060	44.531334	185.4 ks	2013 Jun
NGC5548	214.497958	25.136806	219.0 ks	2013 Jul+
Cen A	201.365063	-43.019112	58.6 ks	2013 Aug
PDS 456	262.082483	-14.265519	376.0 ks	2013 Aug
NGC3783	174.757339	0.000000	...... ks	....

Brenneman et al. 2014a

Brenneman et al. 2014b

Marinucci et al. 2014b

Matt et al. 2014

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NuSTAR cutoff measurements

So far, NuSTAR has provided a number of cutoff measurements in AGN with different spectral characteristics:

Relativistic reflection

SWIFT J2127.4+5654 (E_c=108±10 keV), $L_{2-10\ keV}$=1.5x10^{43} erg/s

Cold, distant reflection

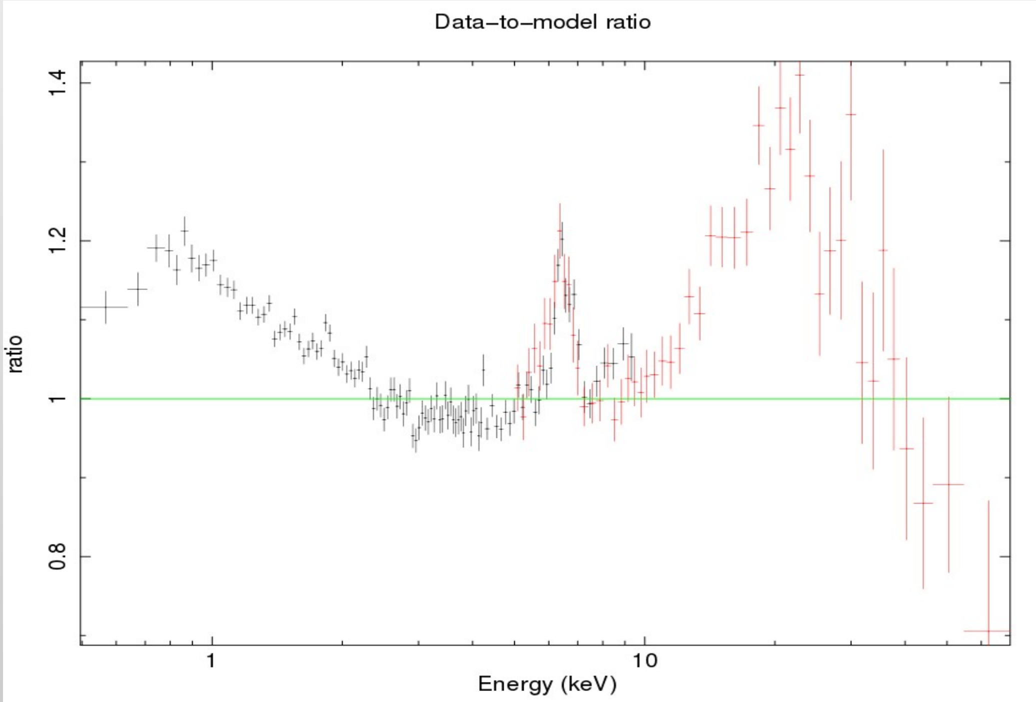
IC 4329A (E_c=186±14 keV), $L_{2-10\ keV}$=6.3x10^{43} erg/s

Ark 120 (E_c>190 keV), $L_{2-10\ keV}$=5.6x10^{43} erg/s

Swift J2127.4+5654

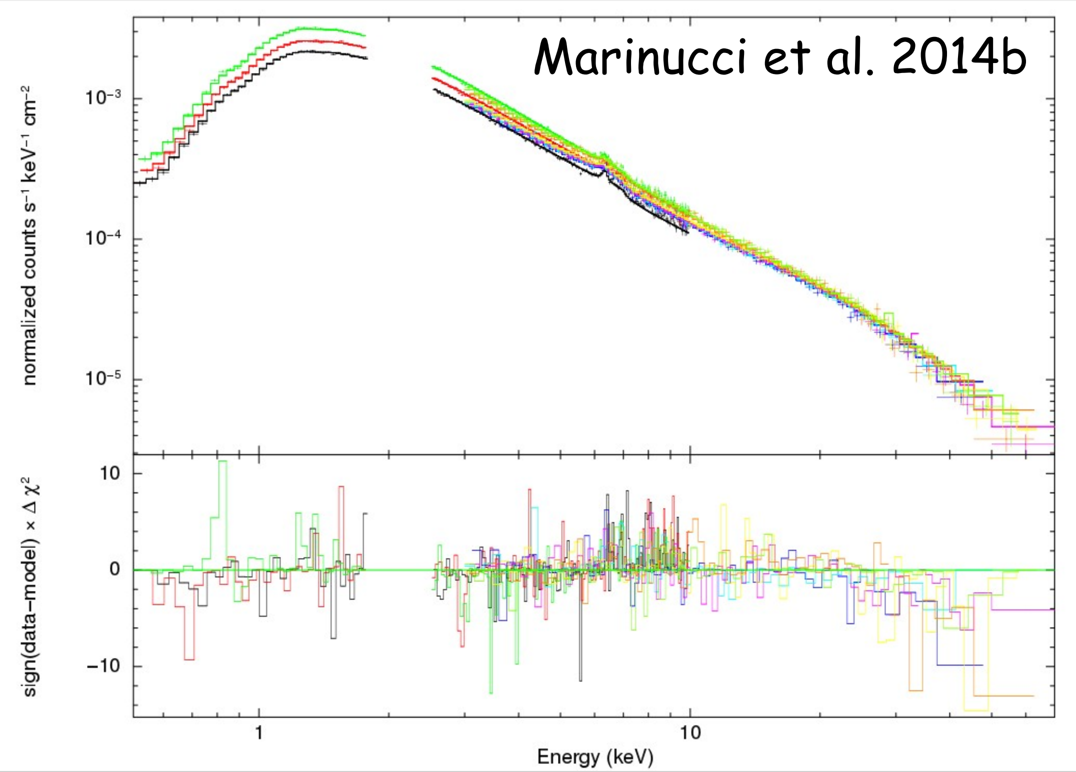
NLS1 with a relativistically broadened Fe Kα emission line (a=0.6±0.2), a steep continuum (Γ=2-2.4), E_c=30-90 keV, L_{bol}/L_{Edd}~0.18 (Miniutti+09, Malizia+08, Panessa+11, Sanfrutos+13)

It was observed simultaneously with XMM-Newton for ~300 ks and both a strong Compton Hump and a broad Fe Kα line are present



Swift J2127.4+5654

When a model composed of a primary continuum, relativistic and distant reflection components is applied to the data the only residuals are above ~25 keV



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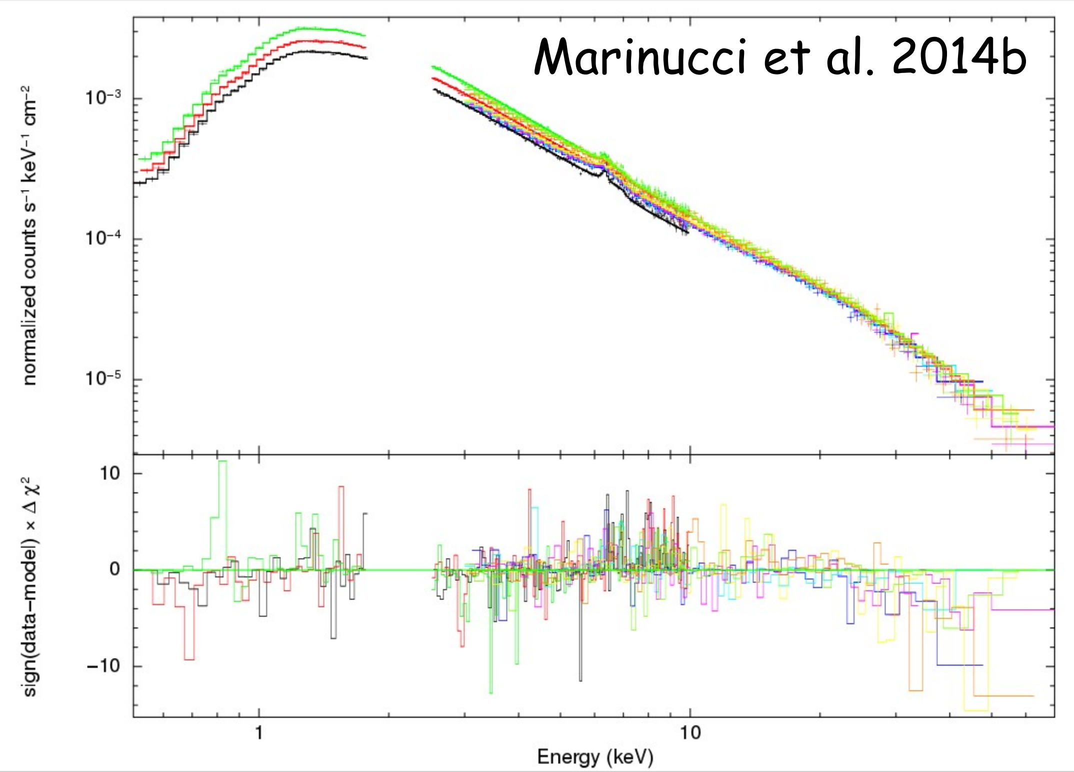
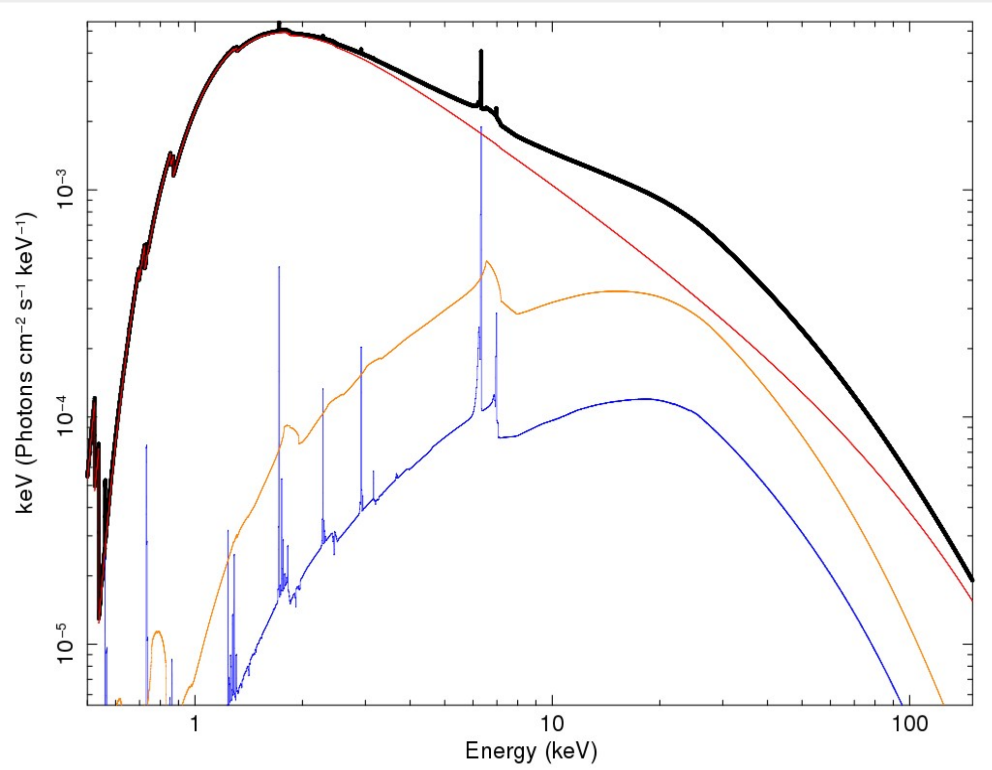
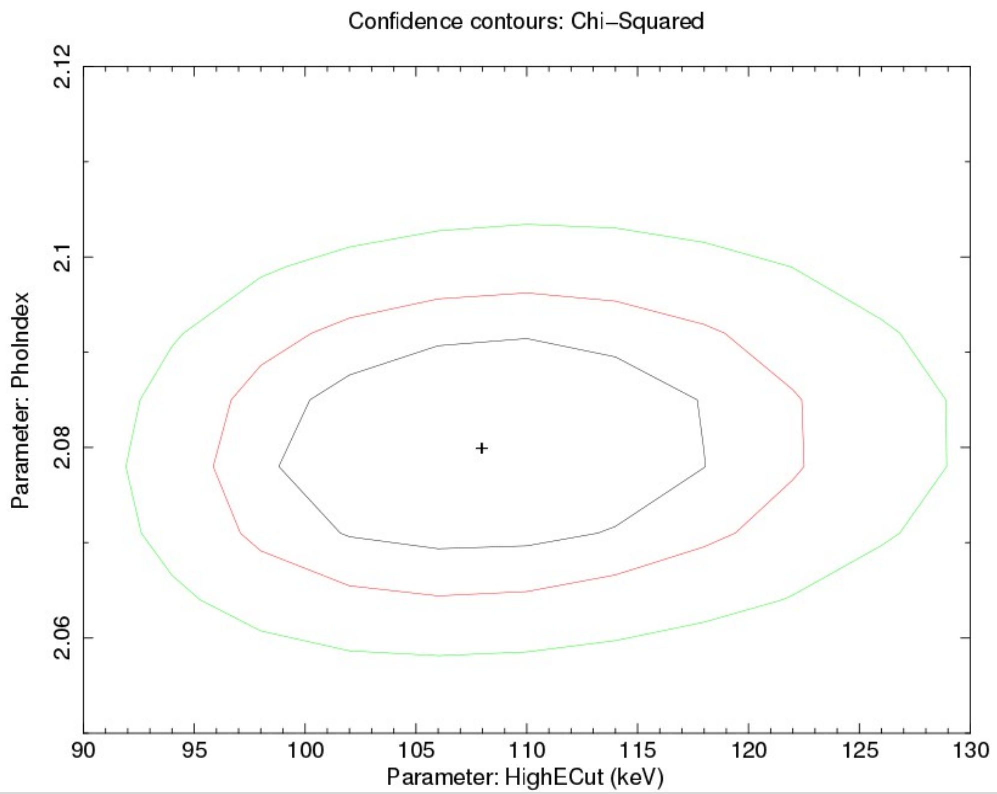
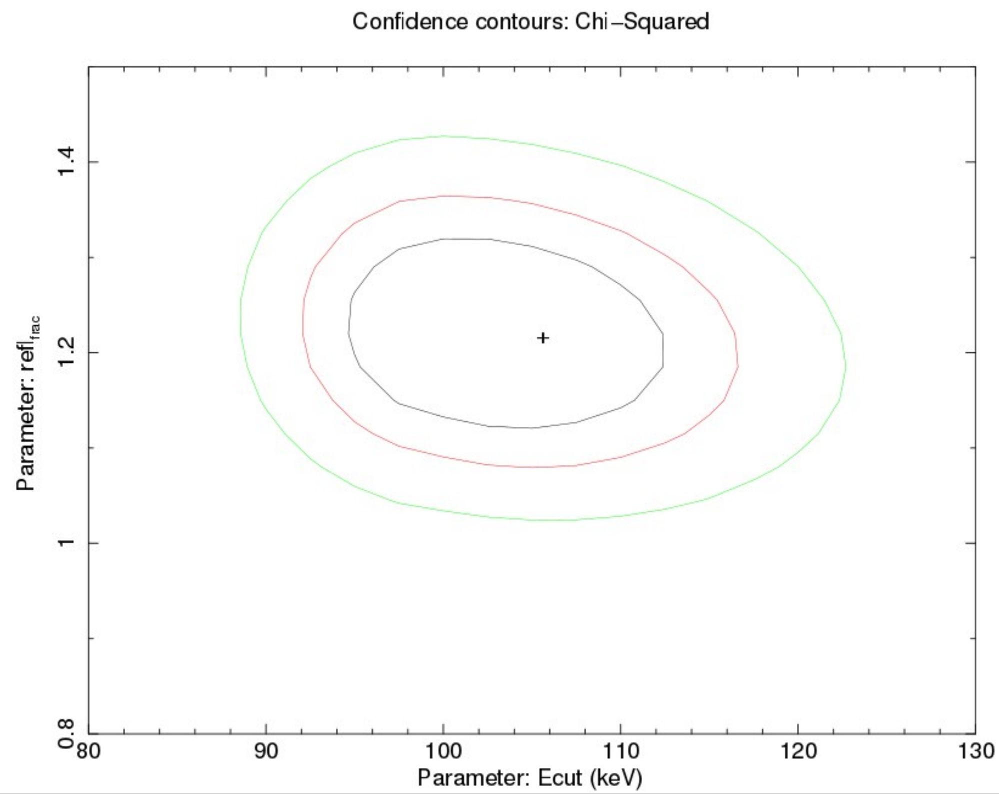




The inclusion of relxill model (Garcia & Dauser +14) allows us to measure a cutoff energy E_c=108±10 keV and to infer the contribution of the disk to the Compton hump.

Swift J2127.4+5654





Using compTT (Titarchuk+94) with two different geometries we get:

SLAB	SPHERE
$kT_e = 68^{+37}_{-32}$ keV	$kT_e = 53^{+28}_{-26}$ keV
$\tau = 0.35^{+0.35}_{-0.19}$	$\tau = 1.35^{+1.03}_{-0.67}$

IC 4329A

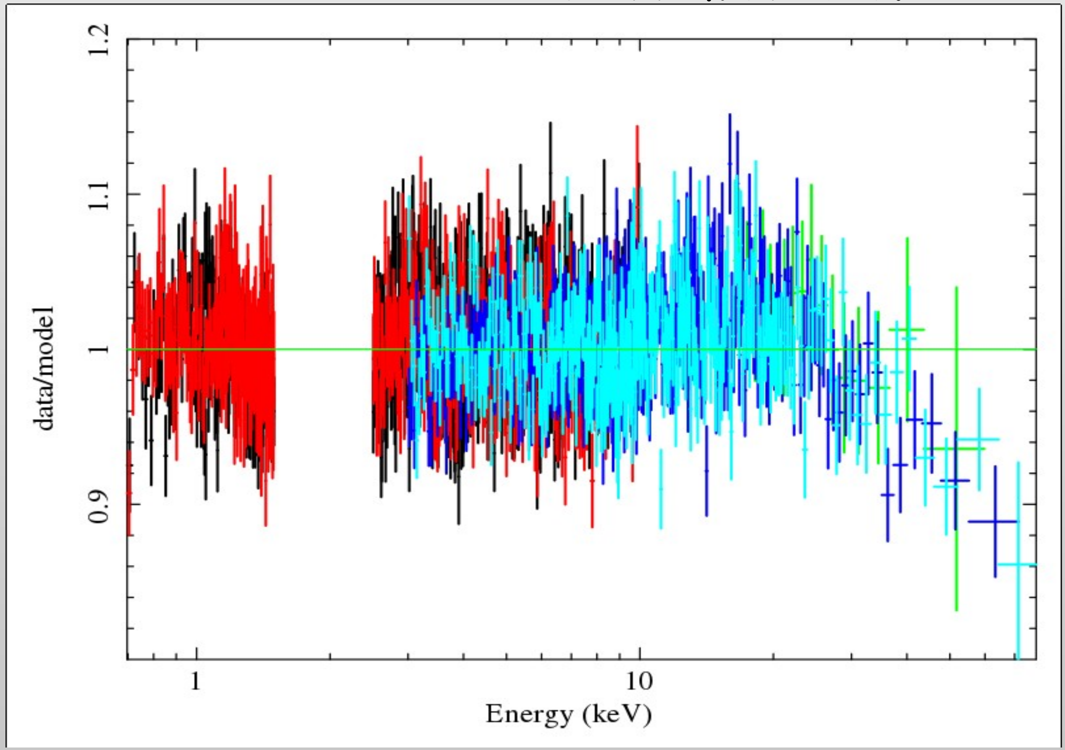
-Bright Sy1 galaxy, $F_{2\text{-}10\ keV}$ ~ 0.1-1.8 $\times 10^{-10}$ erg/cm^2/s

- $E_c=100^{+200}_{-40}$ keV (INTEGRAL+XMM, Molina+13)

- Observed simultaneously by NuSTAR and Suzaku for ~120 ks in 2012

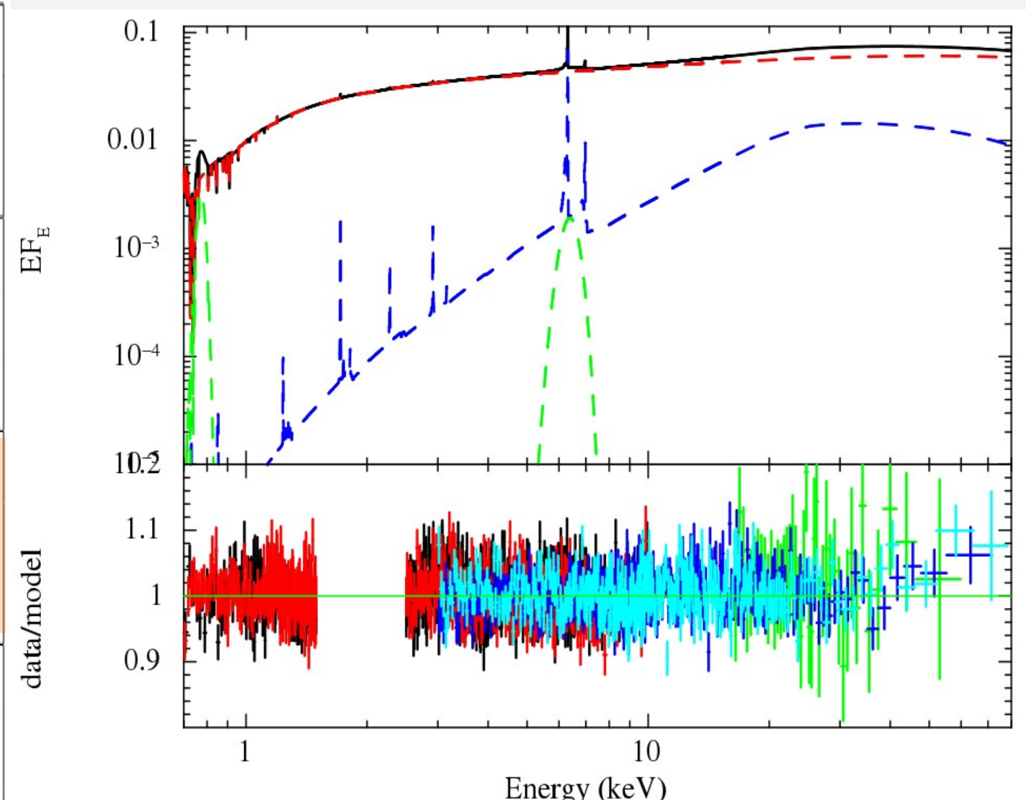
When a model composed of a primary continuum+reflection is applied to the data some residuals at high energies are found.

Brenneman et al. 2014b



IC 4329A

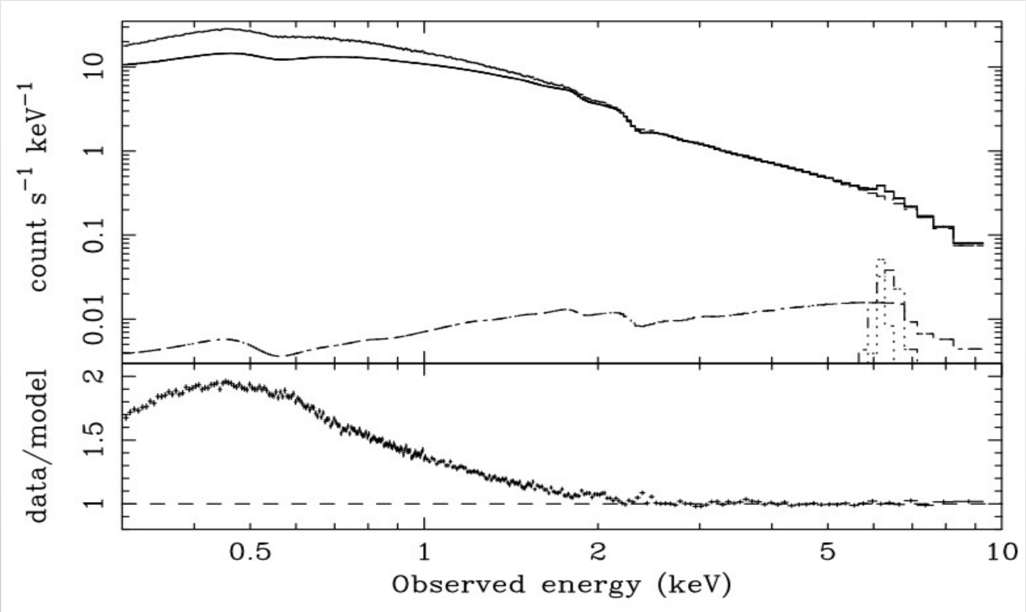
Component	Parameter (units)		SPHERE	SLAB
TBabs	$N_H\,(\mathrm{cm}^{-2})$	$4.61 \times 10^{20}(f)$	$4.61 \times 10^{20}(f)$	$4.61 \times 10^{20}(f)$
XSTAR grid	$N_H\,(\mathrm{cm}^{-2})$	$6.03 \pm 0.13 \times 10^{21}$	$6.02 \pm 0.13 \times 10^{21}$	$6.00^{+0.12}_{-0.13} \times 10^{21}$
	$\log\xi\,(\mathrm{erg\,cm\,s^{-1}})$	0.73 ± 0.02	0.73 ± 0.02	0.73 ± 0.02
zpo	Γ	1.73 ± 0.01	$1.73(f)$	$1.73(f)$
	$E_{cut}\,(\mathrm{keV})$	186^{+14}_{-14}	---	---
	$K_{po}\,(\mathrm{ph\,cm^{-2}\,s^{-1}})$	$2.82 \pm 0.03 \times 10^{-2}$	---	---
compTT	$kT_e\,(\mathrm{keV})$	---	50^{+6}_{-3}	61 ± 1
	τ	---	$2.34^{+0.16}_{-0.21}$	0.68 ± 0.02
	$K_{comptt}\,(\mathrm{ph\,cm^{-2}\,s^{-1}})$	---	$5.46^{+0.38}_{-0.54} \times 10^{-3}$	$4.46 \pm 0.11 \times 10^{-3}$
xillver	Fe/solar	$1.51^{+0.29}_{-0.28}$	$1.51^{+0.28}_{-0.27}$	$1.50^{+0.28}_{-0.27}$
	Γ	$1.73*$	$1.73(f)$	$1.73(f)$
	$K_{refl}\,(\mathrm{ph\,cm^{-2}\,s^{-1}})$	$2.79 \pm 0.20 \times 10^{-4}$	$2.74 \pm 0.18 \times 10^{-4}$	$2.89 \pm 0.18 \times 10^{-4}$



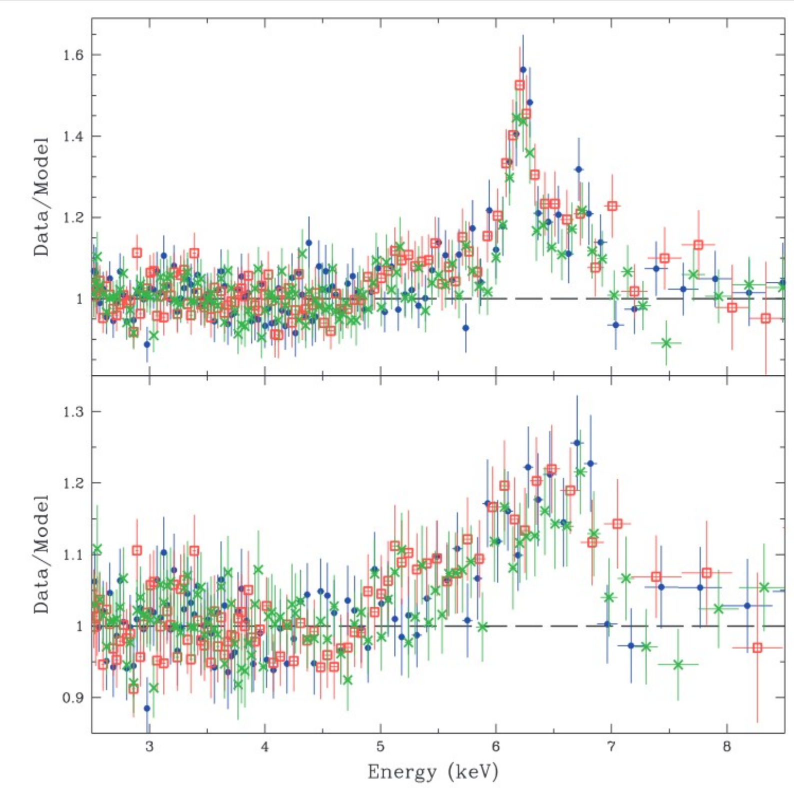
No evidence for relativistic lines.
Iron line and Compton reflection originate from distant material.

Ark 120

- "Bare" Seyfert 1 galaxy, $F_{2\text{-}10\ keV}$ ~ 2-4 x10^{-11} erg/cm^2/s
- Prominent soft excess (XMM, Vaughan et al.+04)
- Relativistic Iron line (Suzaku, Nardini et al.+11)
- Observed simultaneously by NuSTAR and XMM for 90 ks in 2013

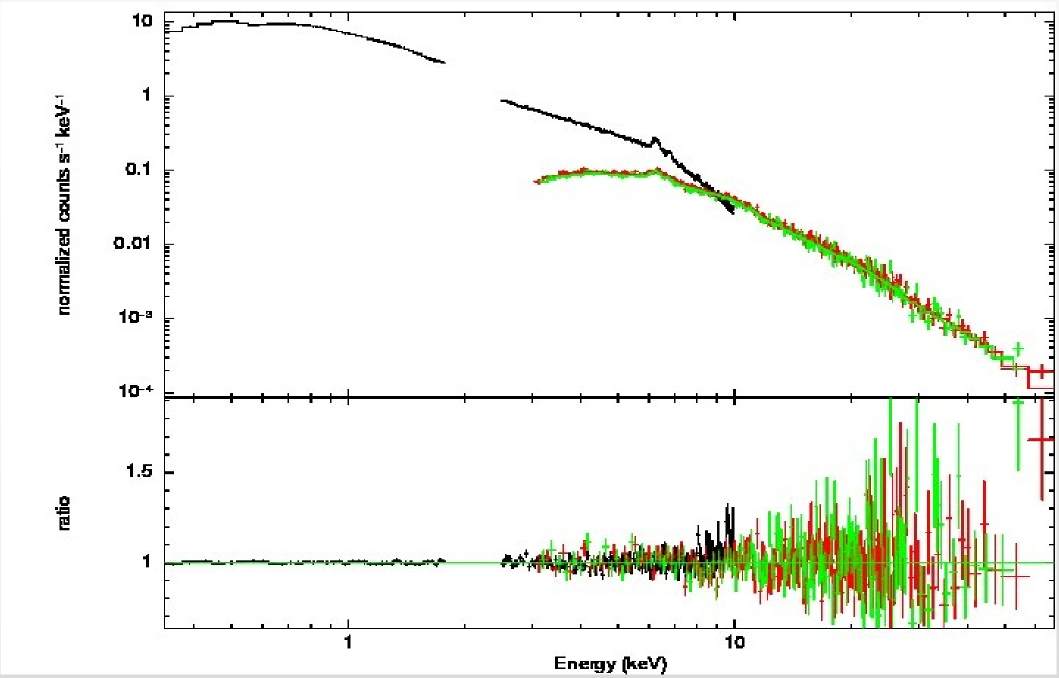


Vaughan et al. 2004

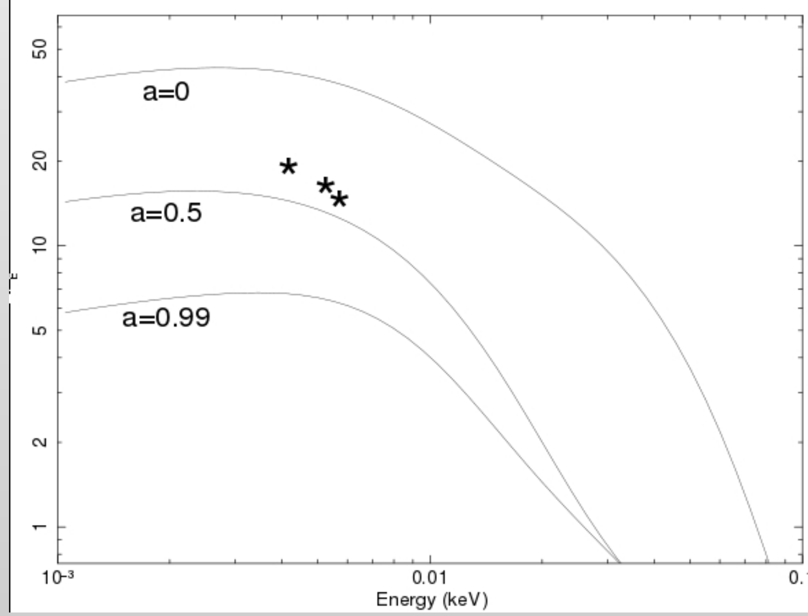


Nardini et al. 2011

Ark 120



a	0	0.50	0.99
L/L_{Edd}	$0.16^{+0.16}_{-0.08}$	$0.05^{+0.01}_{-0.01}$	$0.04^{+0.03}_{-0.01}$
R_c (R_G)	$11.5^{+0.1}_{-3.4}$	$31.3^{+39.2}_{-16.6}$	$24.9^{+16.0}_{-15.2}$
kT (keV)	$0.33^{+0.02}_{-0.02}$	$0.32^{+0.01}_{-0.01}$	$0.32^{+0.02}_{-0.01}$
τ	$12.9^{+1.1}_{-0.9}$	$13.6^{+0.6}_{-0.2}$	$13.6^{+0.4}_{-0.7}$
Γ	$1.73^{+0.02}_{-0.02}$	$1.73^{+0.02}_{-0.02}$	$1.73^{+0.02}_{-0.02}$
E_c (keV)	>190	>190	>190



When 0.5-80 keV data are considered the coronal parameters can be derived, testing the optxagnf model (Done et al., 2012).
The OM fluxes support an intermediate value for the black hole spin.

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Conclusions

- High energy cut-off have been measured in a number of AGN with NuSTAR (more are yet to come!)

- The hard X-ray band (3-80 keV) is fundamental for testing and discriminating between different Comptonization models

- Further observations will help us in understanding the nature of the primary continuum, such as the relation between the accretion rate and the cutoff energy and the link between the disc reflection and the extension of the hot corona.