The coronal parameters of local Seyfert galaxies

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(Roma Tre)

on behalf of the
NuSTAR AGN Physics WG

From the Dolomites to the event horizon:
Sledging down to the Black Hole Potential Well (3rd edition)
Sesto Val Pusteria
July 13, 2015

Overview

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

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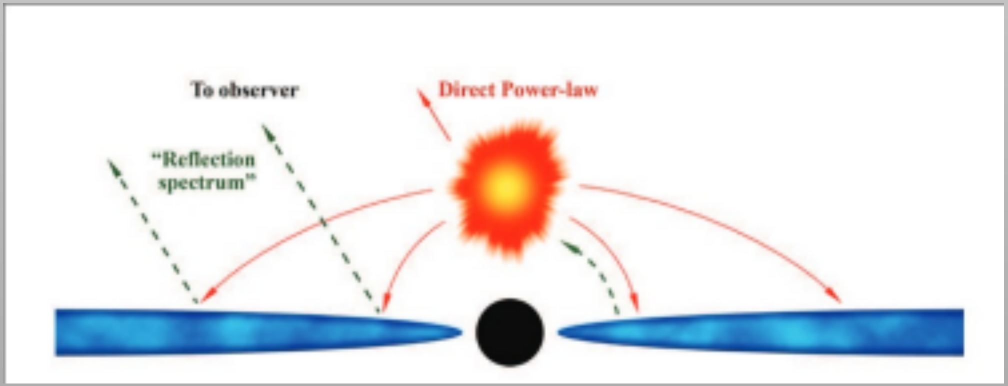
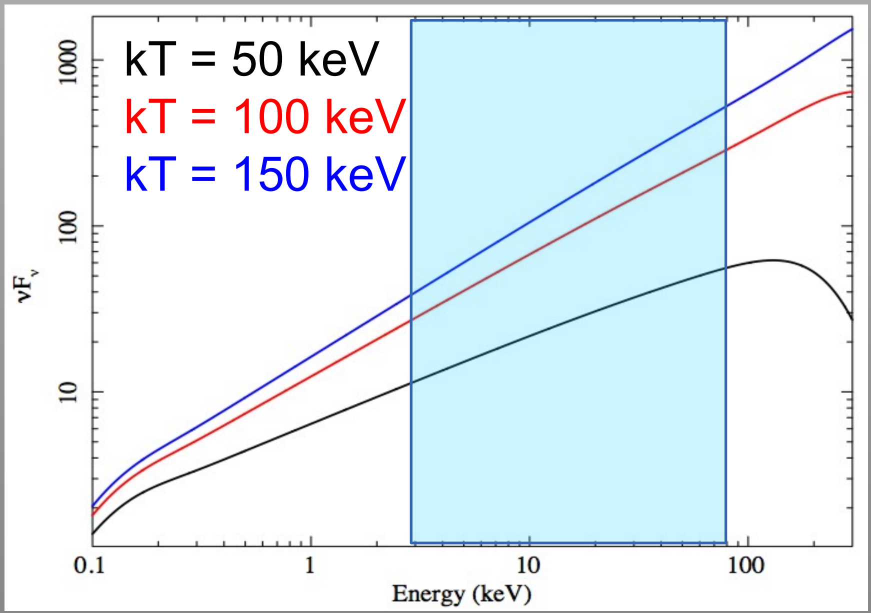
Introduction

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.

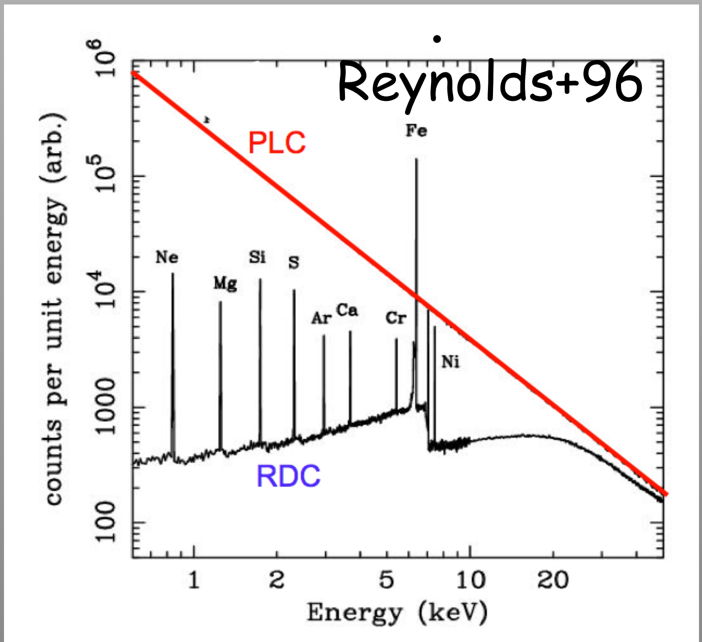


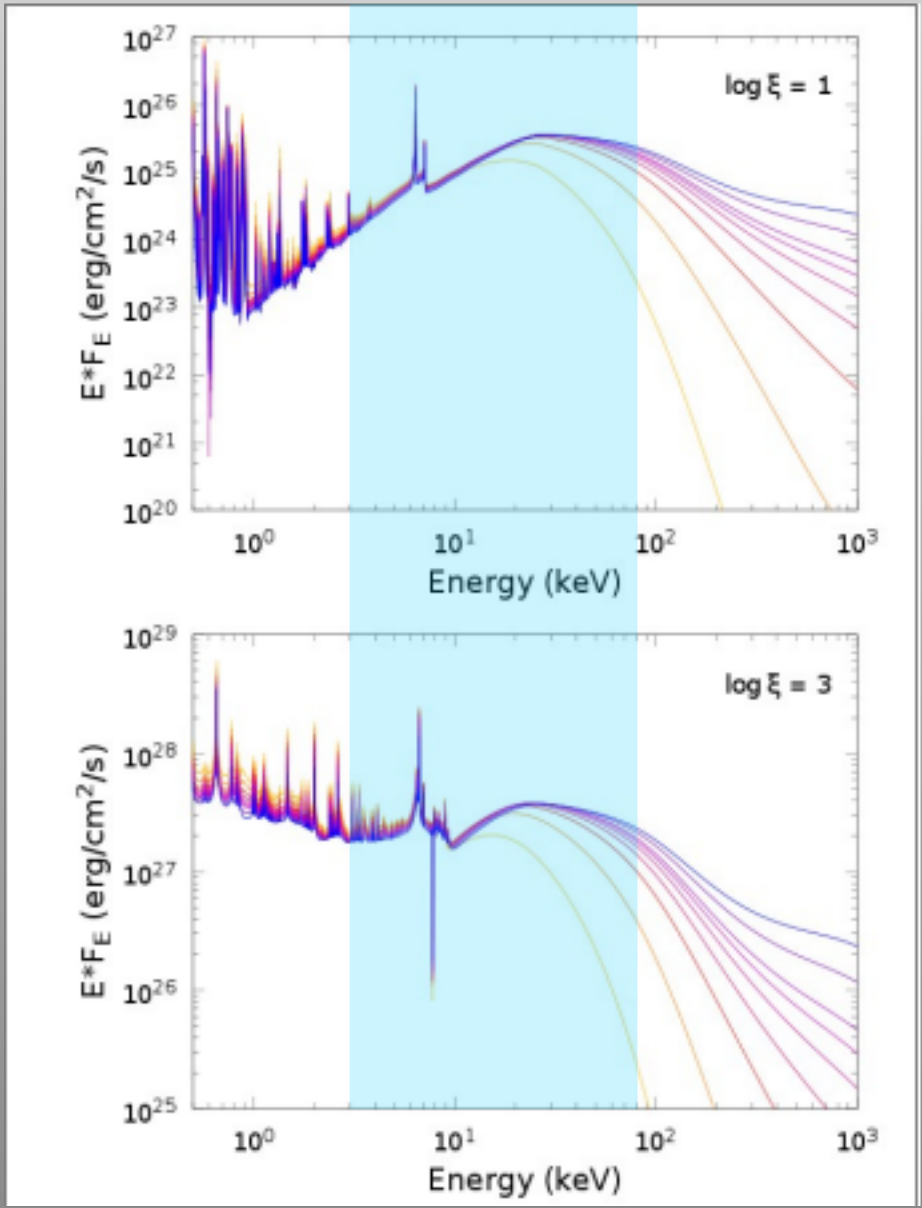


Most popular models imply E_{cut}=2-3x kT_e, so measuring E_{cut} helps constraining Comptonization models.

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: Xillver (Garcia+13), KYreflionx (see Michal's and Jiri's talks) .

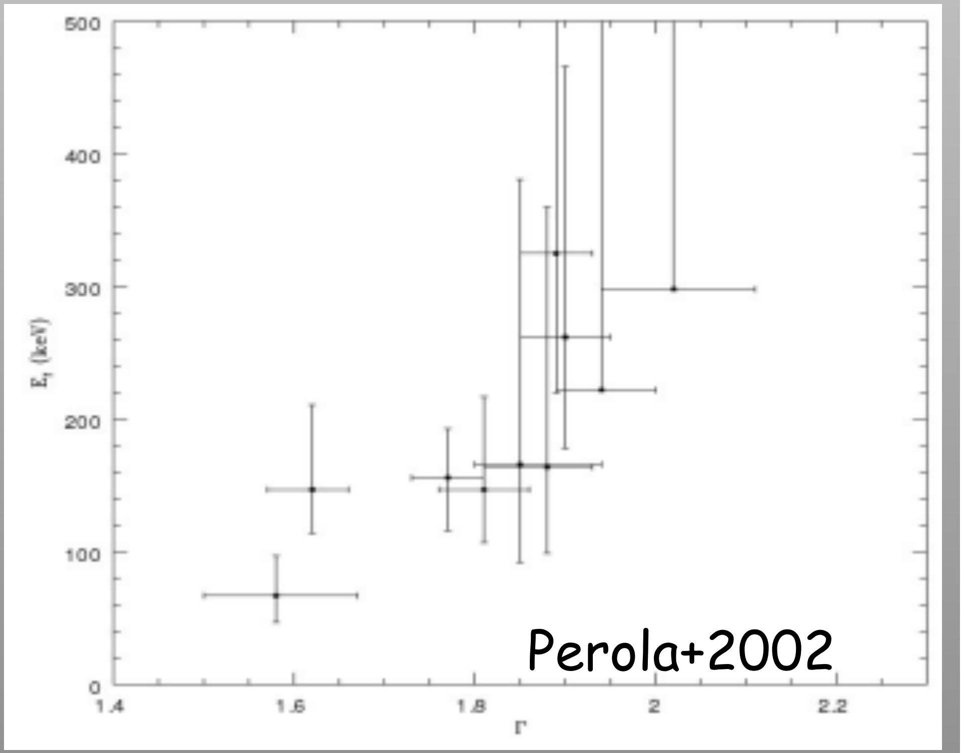


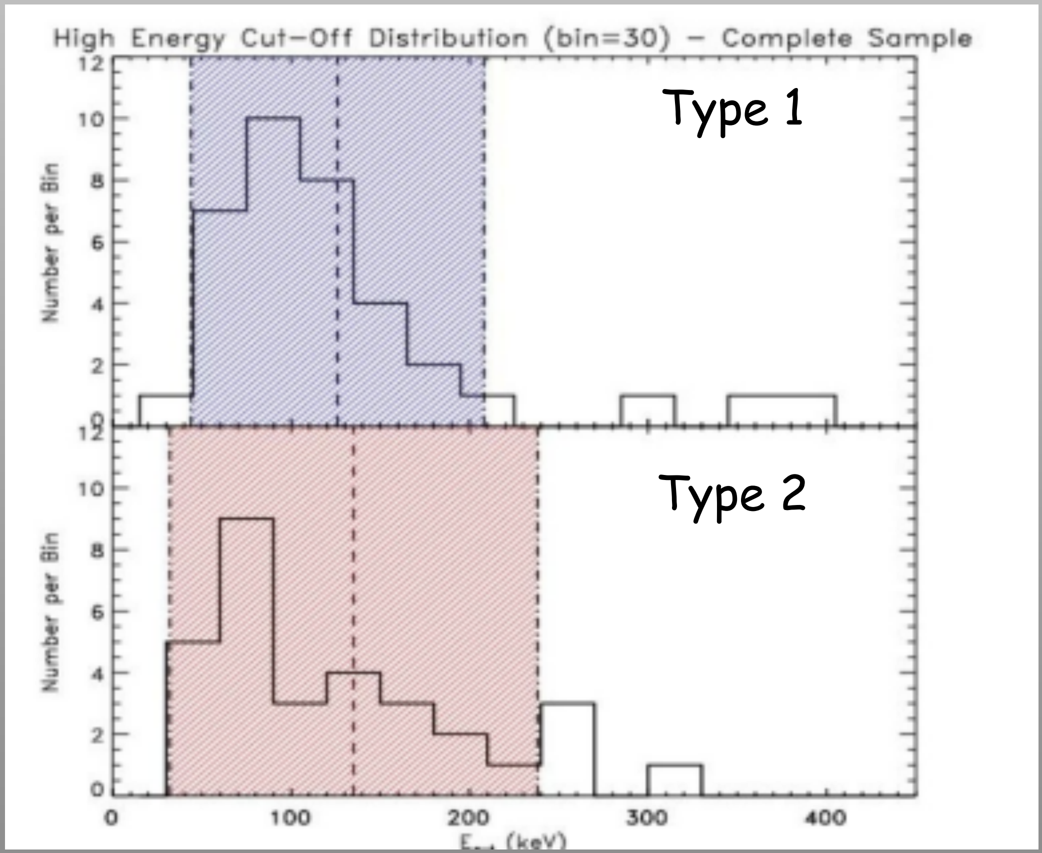


Garcia+15

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)





De Rosa+2012; Molina+2013

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The NuSTAR satellite

Nuclear Spectroscopic Telescope Array

1 Ms Sensitivity

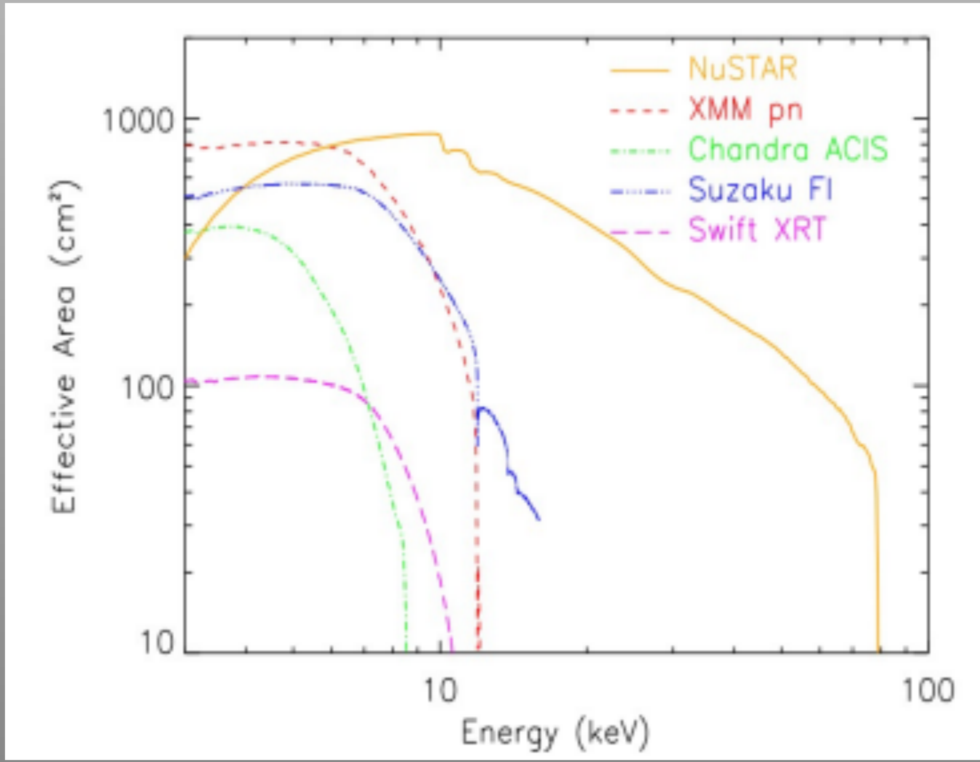
3.2×10^{-15} erg/cm^2/s (6 – 10 keV)

1.4×10^{-14} erg/cm^2/s (10 – 30 keV)

Imaging

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

Harrison+13



Spectral response

energy range: 3-79 keV

ΔE @ 6 keV 0.4 keV FWHM

ΔE @ 60 keV 1.0 keV FWHM

Target of Opportunity

response <24 hr

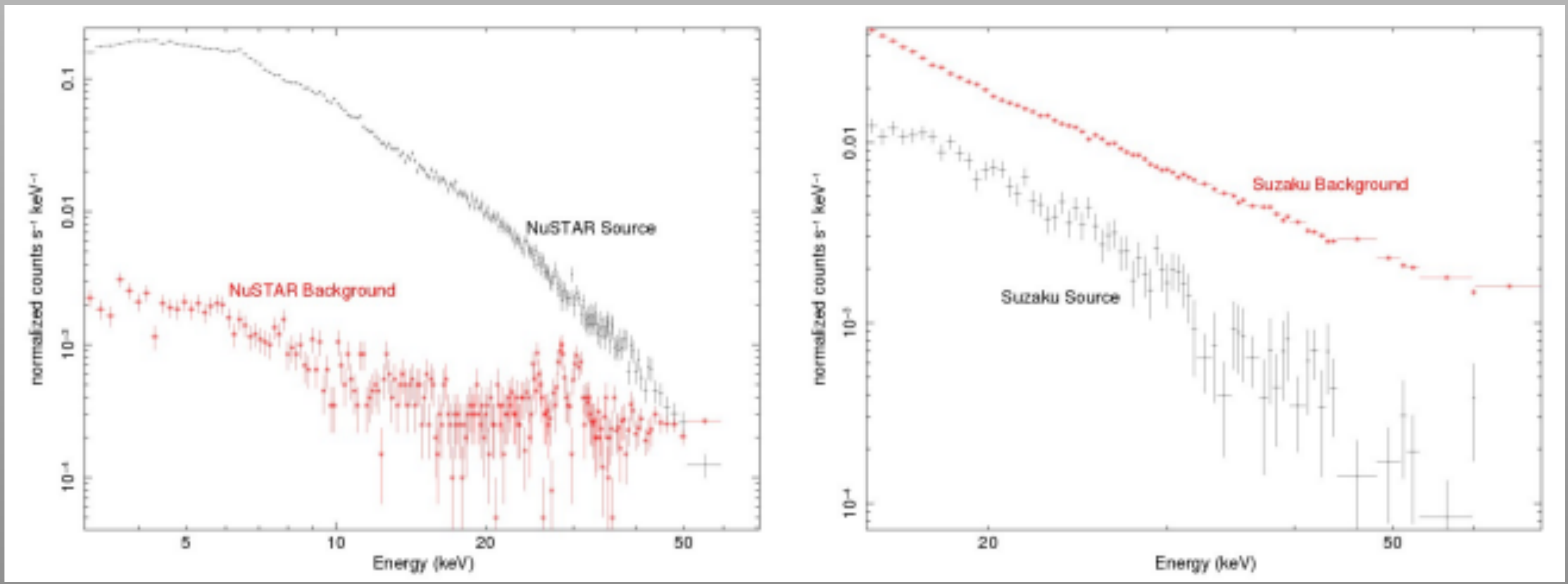
typical 6-8 hours

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 ($6.5x10^{-11}$ $erg/cm^2/s$)



Marinucci+14

Nearby AGN seen by NuSTAR

Source	z	$\log(M)$ $[M_\odot]$	r_{co} $[r_G]$	F_x	E_{cut} [keV]	Γ	Θ	ℓ	Data	References
NGC 5506	0.006	8 ± 1	10	2.9	720^{+130}_{-190}	$1.91^{+0.03}_{-0.03}$	$0.71^{+0.13}_{-0.36}$	4^{+33}_{-3}	SWIFT/NU	$1-2$
NGC7213	0.006	$7.98^{+0.22}_{-0.24}$	10	0.71	>240	$1.84^{+0.03}_{-0.03}$	>0.05	$1.0^{+0.7}_{-0.4}$	NU	$3-4$
MCG-6-30-15	0.008	6.7 ± 1	2.9	8.2	>110	$2.061^{+0.005}_{-0.005}$	>0.04	258^{+2323}_{-232}	XMM/NU	$5-6$
NGC 2110	0.008	8.3 ± 1	10	8.9	>210	$1.64^{+0.03}_{-0.03}$	>0.07	10^{+89}_{-9}	SWIFT/NU	$7-8$
MCG 5-23-16	0.009	7.85 ± 1	10	4.2	116^{+6}_{-5}	$1.85^{+0.01}_{-0.01}$	$0.11^{+0.01}_{-0.04}$	15^{+136}_{-14}	NU	$9-11$
SWIFT J2127.4+5654	0.014	7.18 ± 1	13	1.1	108^{+11}_{-10}	$2.08^{+0.01}_{-0.01}$	$0.11^{+0.01}_{-0.04}$	34^{+308}_{-31}	XMM/NU	$12-13$
IC4329A	0.016	8.1 ± 1	10	4.9	186^{+14}_{-14}	$1.73^{+0.01}_{-0.01}$	$0.18^{+0.01}_{-0.07}$	41^{+365}_{-37}	SU/NU	$14-15$
NGC 5548	0.018	$7.59^{+0.24}_{-0.21}$	4.5	1.3	70^{+40}_{-10}	$1.49^{+0.05}_{-0.05}$	$0.07^{+0.04}_{-0.03}$	88^{+55}_{-37}	XMM/NU	$5, 16-17$
Mrk 335	0.026	$7.42^{+0.12}_{-0.16}$	3	0.10	>174	$2.14^{+0.02}_{-0.04}$	>0.06	36^{+16}_{-9}	SWIFT/NU	$18-19$
Ark 120	0.033	$7.66^{+0.05}_{-0.06}$	4.4	0.55	>68	$1.73^{+0.02}_{-0.02}$	>0.06	4^{+1}_{-1}	XMM/NU	$20-21$
1H0707-495	0.041	6.31 ± 1	2	0.14	>63	$3.2^{+0.2}_{-0.2}$	>0.02	358^{+3219}_{-322}	SWIFT/NU	$22-23$
Fairall 9	0.047	$8.41^{+0.11}_{-0.09}$	21	0.87	>242	$1.96^{+0.01}_{-0.02}$	>0.08	12^{+3}_{-3}	XMM/NU	$20, 24$
3C390.3	0.056	$9.40^{+0.05}_{-0.06}$	10	1.6	116^{+24}_{-8}	$1.70^{+0.01}_{-0.01}$	$0.11^{+0.02}_{-0.04}$	18^{+3}_{-2}	SU/NU	$25-26$
Cyg A	0.056	$9.40^{+0.11}_{-0.14}$	10	1.1	>110	$1.47^{+0.13}_{-0.06}$	>0.04	6^{+2}_{-1}	NU	$27-28$
3C382	0.058	9.2 ± 0.5	10	1.4	214^{+147}_{-63}	$1.68^{+0.03}_{-0.02}$	$0.21^{+0.14}_{-0.11}$	12^{+25}_{-8}	SWIFT/NU	$29-30$

F_x is the 0.1-200 keV X-ray flux in 10^{-10} erg cm^{-2} s^{-1}.

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Fabian+15

Nearby AGN seen by NuSTAR

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Fabian+15

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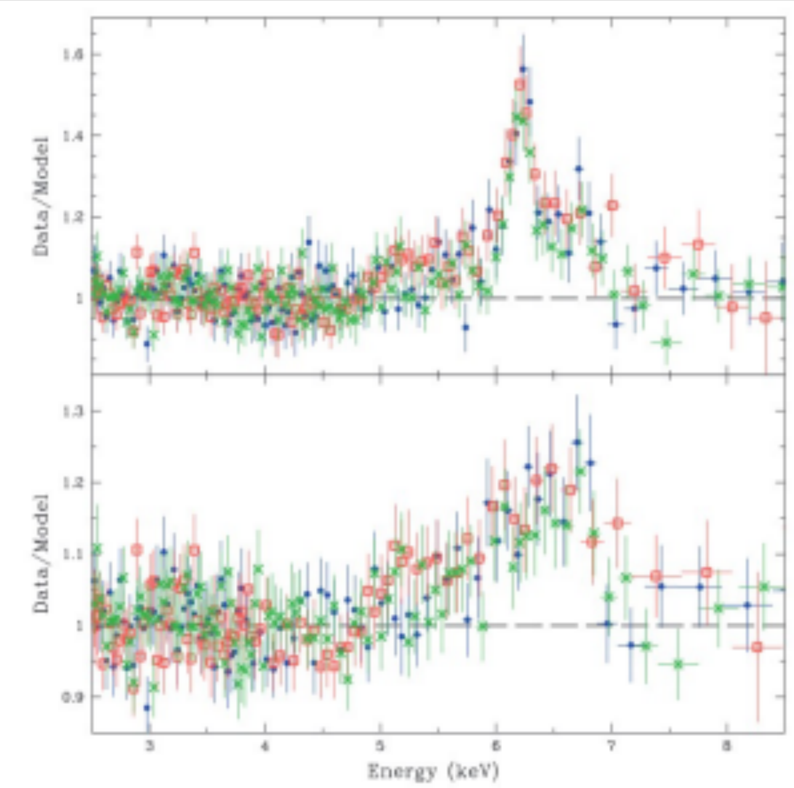
Ark 120

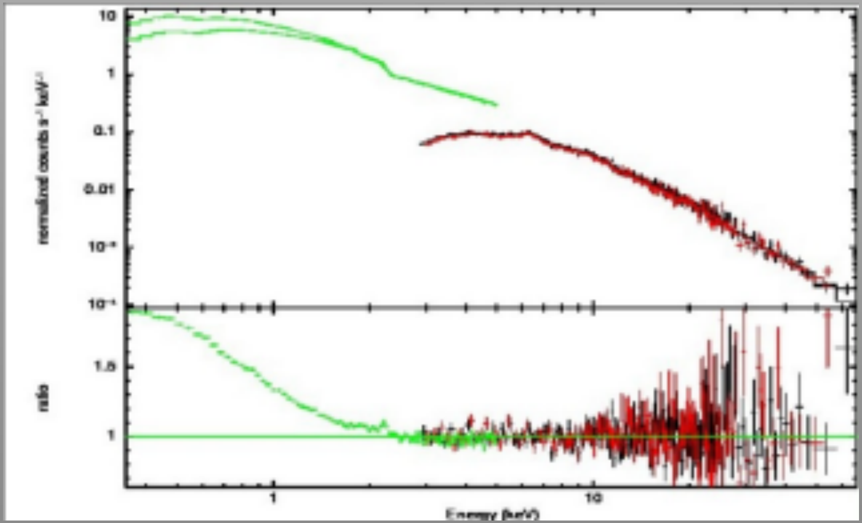


Nardini+11

- "Bare" Seyfert 1 galaxy, $F_{2\text{-}10\ keV} \sim 2\text{-}4 \times 10^{-11}\ erg/cm^2/s$
- Relativistic Iron line (Suzaku, Nardini+11)
- Prominent soft excess (XMM, Vaughan+04)

- Observed simultaneously by NuSTAR and XMM for 90 ks in 2013

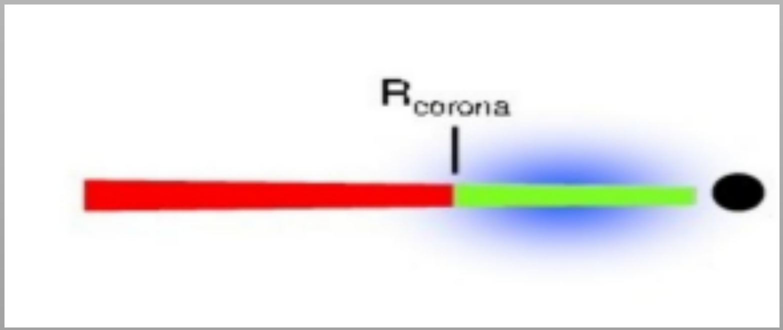
(and then again in 2014, see Delphine's talk)



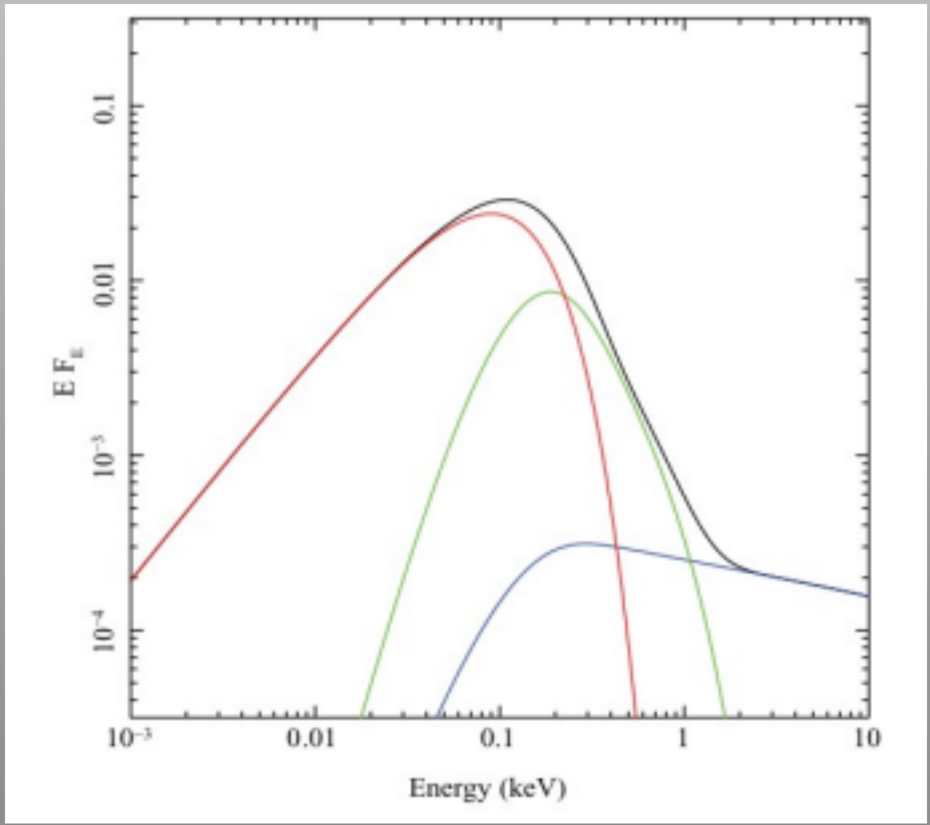
Matt+2014

Ark 120

The broad-band best fit is with a Comptonization model for the soft excess. Optxagnf (Done+2012) is a disk/corona emission model which assumes a thermal disk emission outside the coronal radius, and soft and hard Comptonization inside.



Done+12

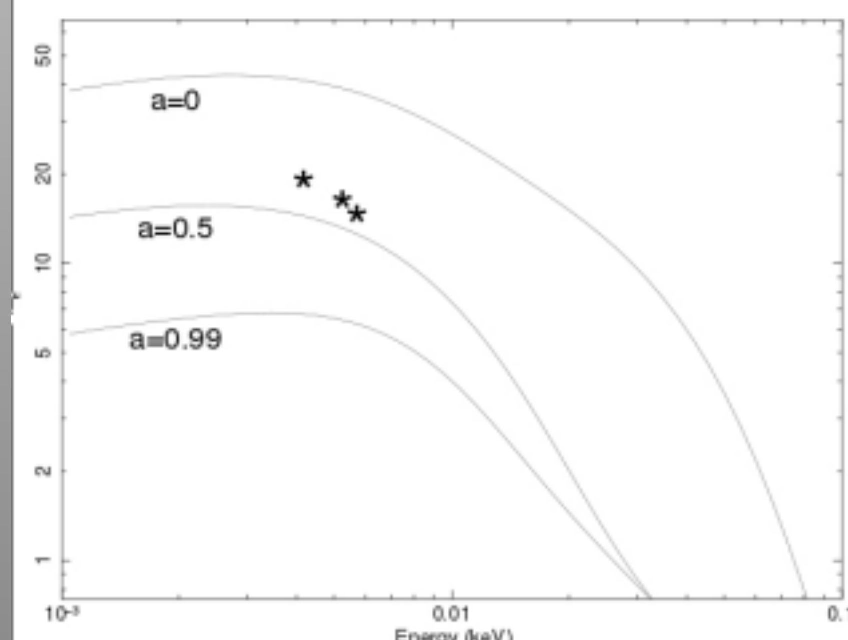


Ark 120

Fluxes from the Optical Monitor on board on XMM-Newton support an intermediate value for the black hole spin.

Matt+2014

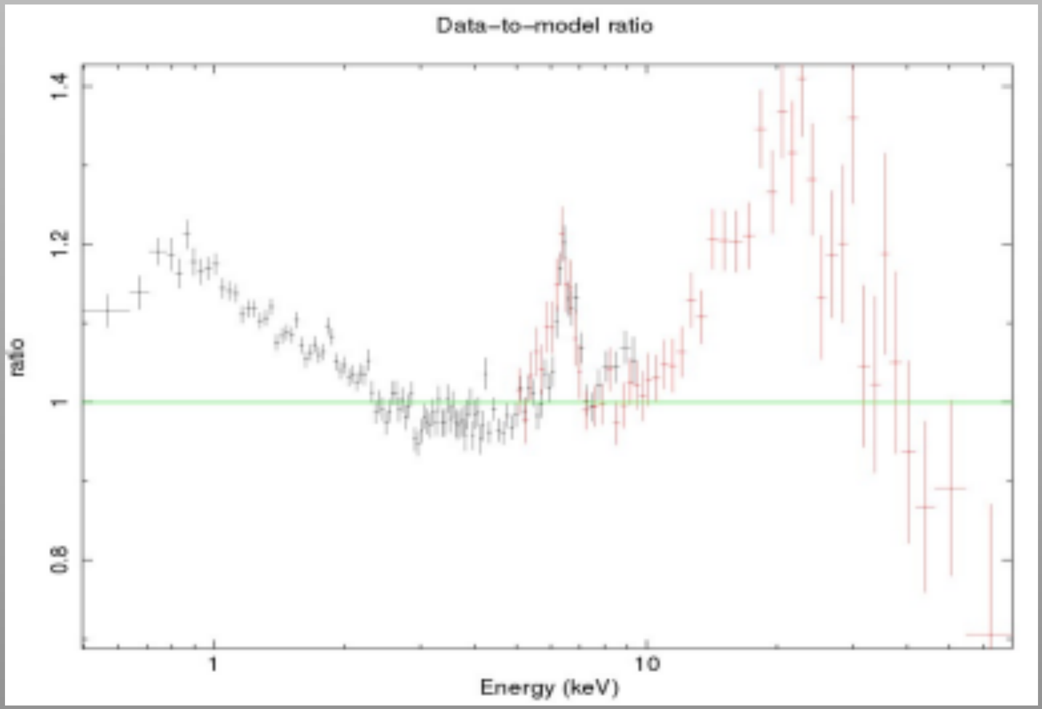
a	0	0.50	0.99
L/L_{Edd}	$0.16^{+0.16}_{-0.08}$	$0.05^{+0.01}_{-0.01}$	$0.04^{+0.03}_{-0.01}$
R_c (R_G)	$11.5^{+0.1}_{-3.4}$	$31.3^{+39.2}_{-16.6}$	$24.9^{+16.0}_{-15.2}$
kT (keV)	$0.33^{+0.02}_{-0.02}$	$0.32^{+0.01}_{-0.01}$	$0.32^{+0.02}_{-0.01}$
τ	$12.9^{+1.1}_{-0.9}$	$13.6^{+0.6}_{-0.2}$	$13.6^{+0.4}_{-0.7}$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



Swift J2127.4+5654

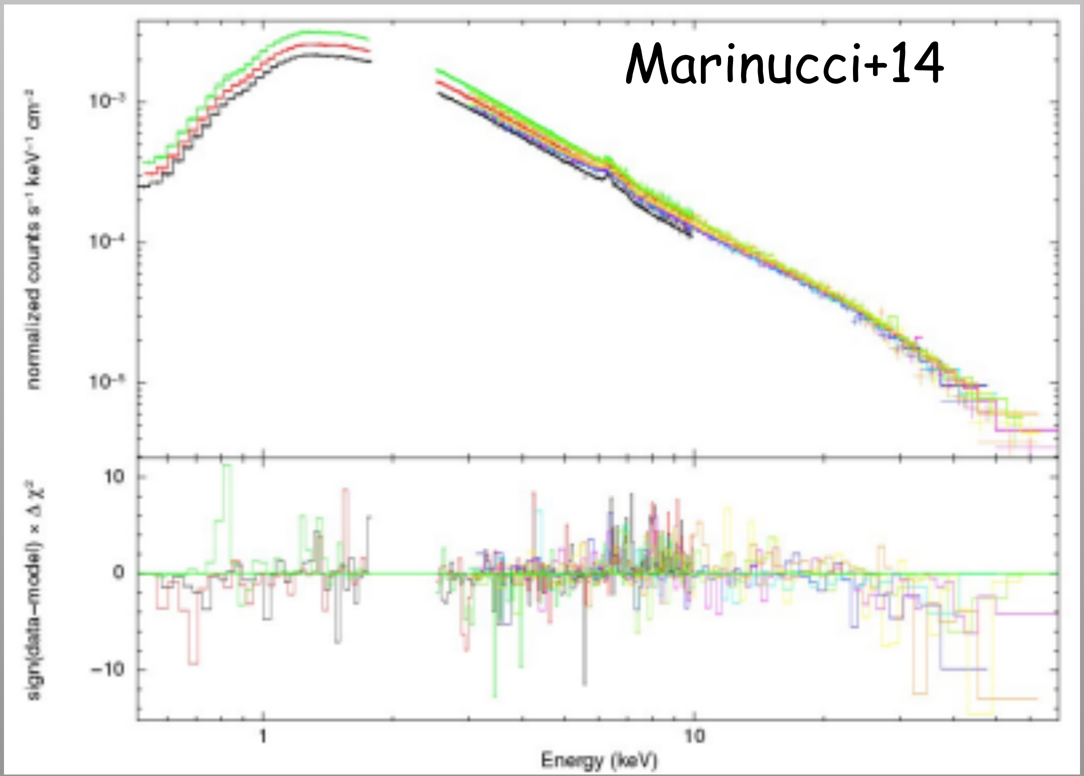
NLS1 with a relativistically broadened Fe Kα emission line (a=0.6±0.2), a steep continuum (Γ=2-2.4), E_c=30-90 keV, L_{bol}/L_{Edd}~0.18 (Miniutti+09, Malizia+08, Panessa+11, Sanfrutos+13)

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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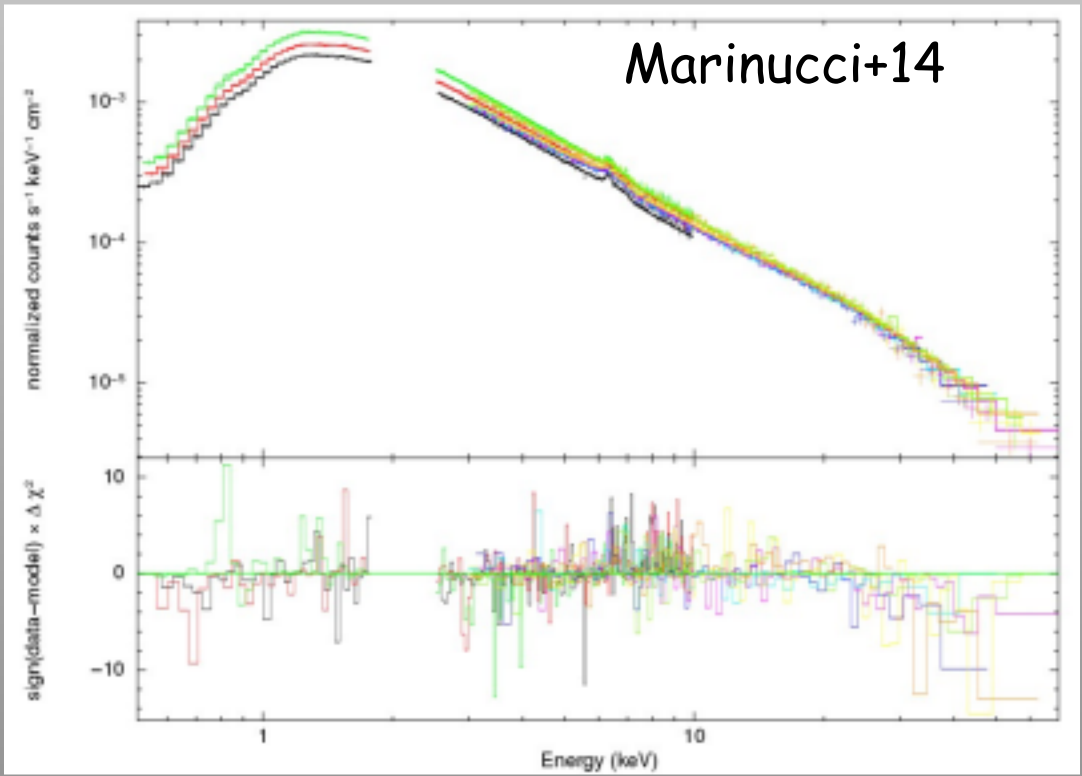
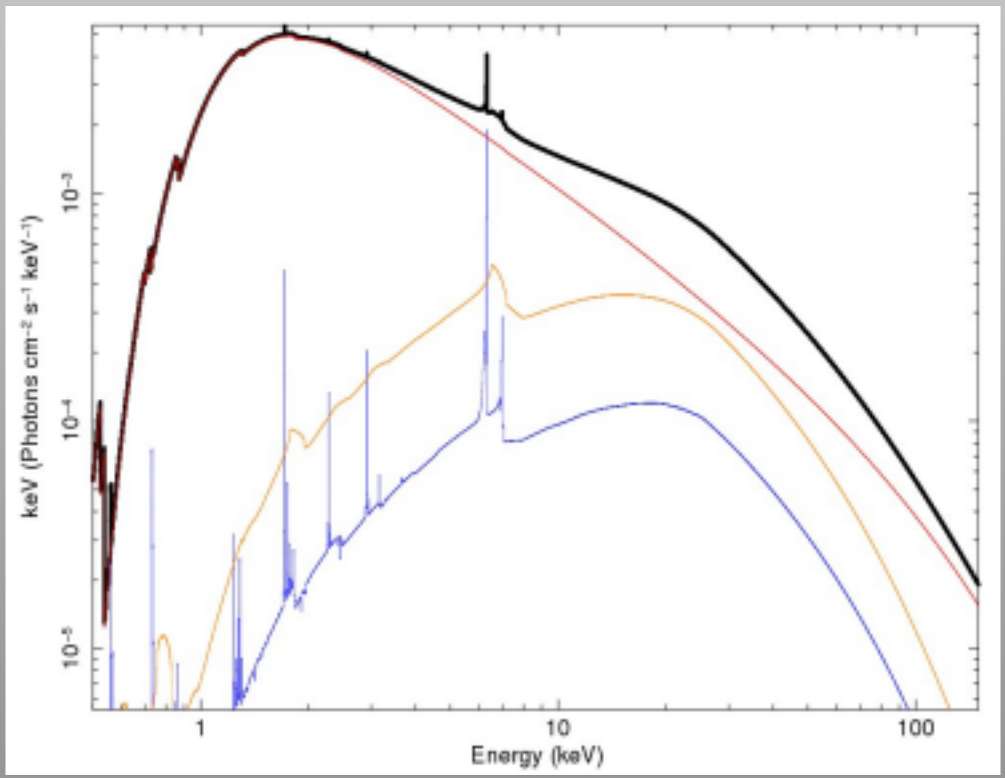
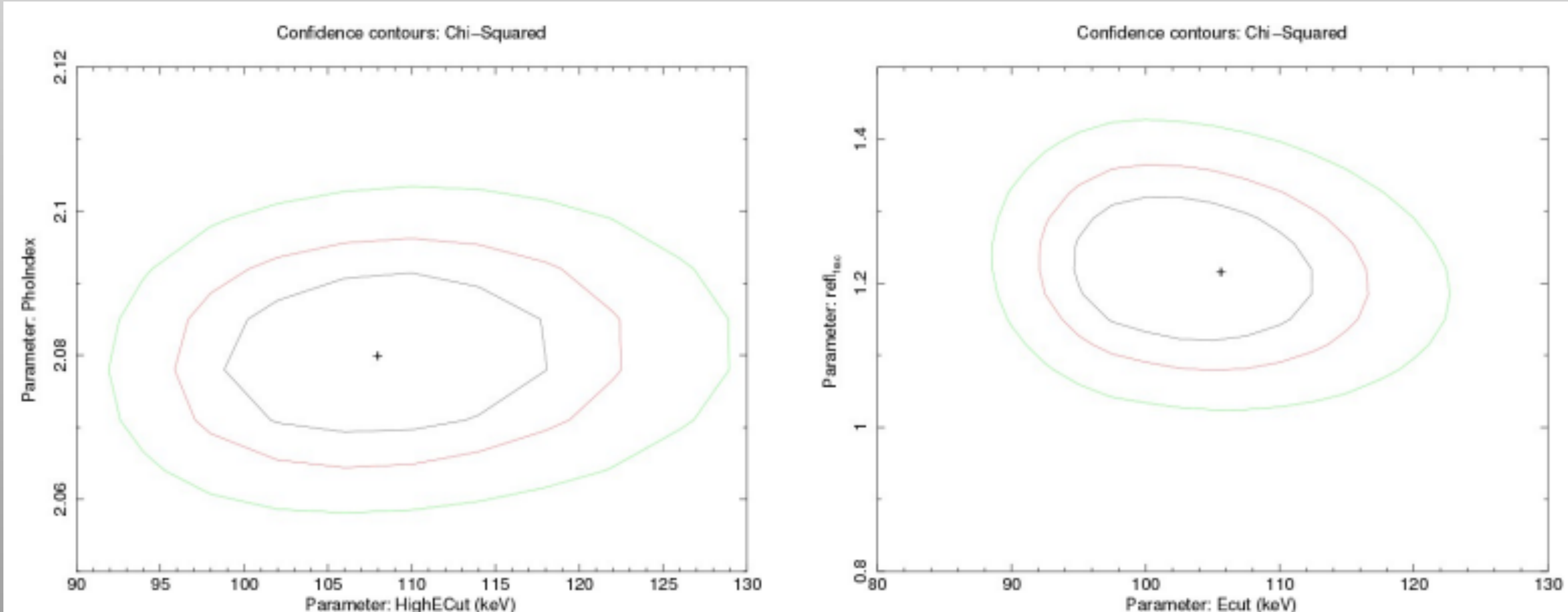




The inclusion of relxill model (Garcia & Dauser +14) allows us to measure a cutoff energy E_c=108±10 keV and to infer the contribution of the disk to the Compton hump.

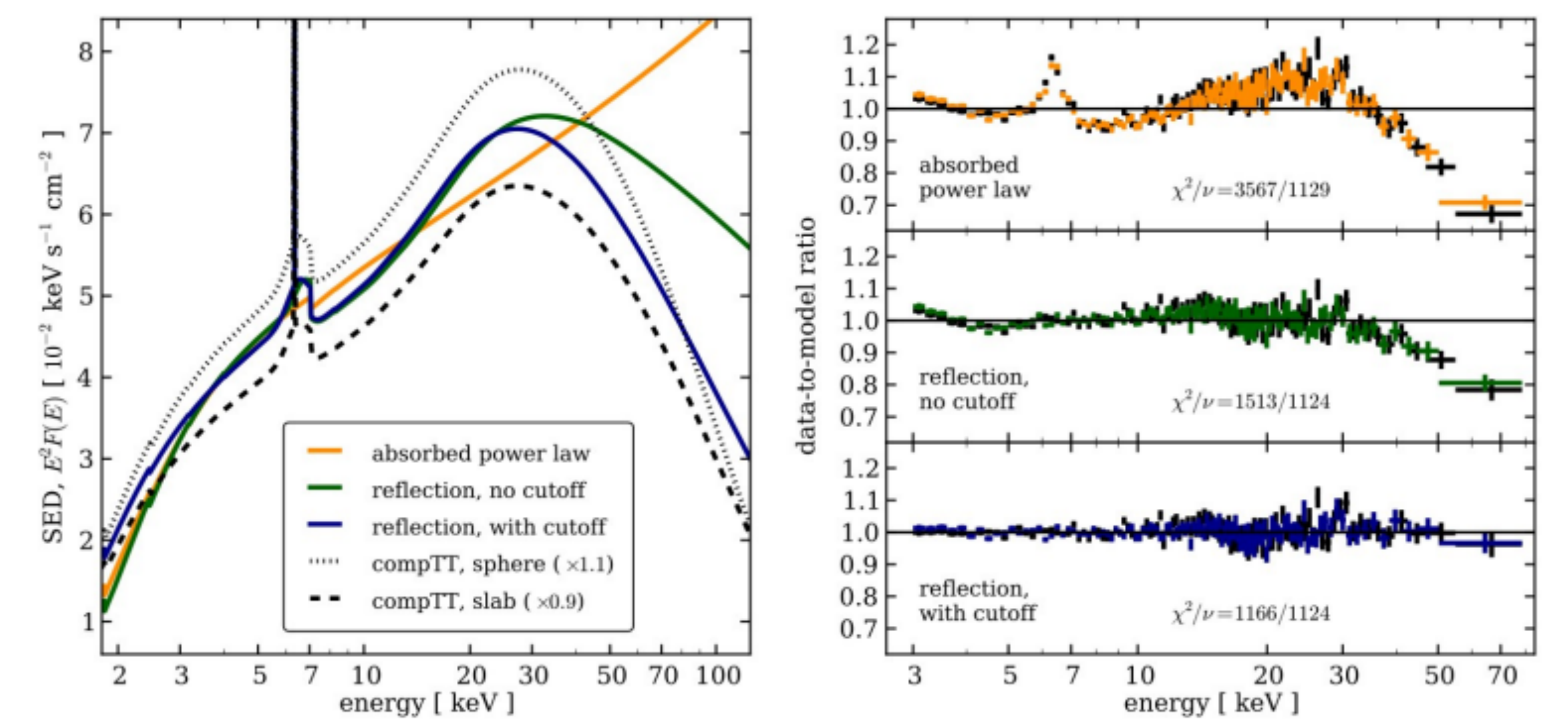
Swift J2127.4+5654



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

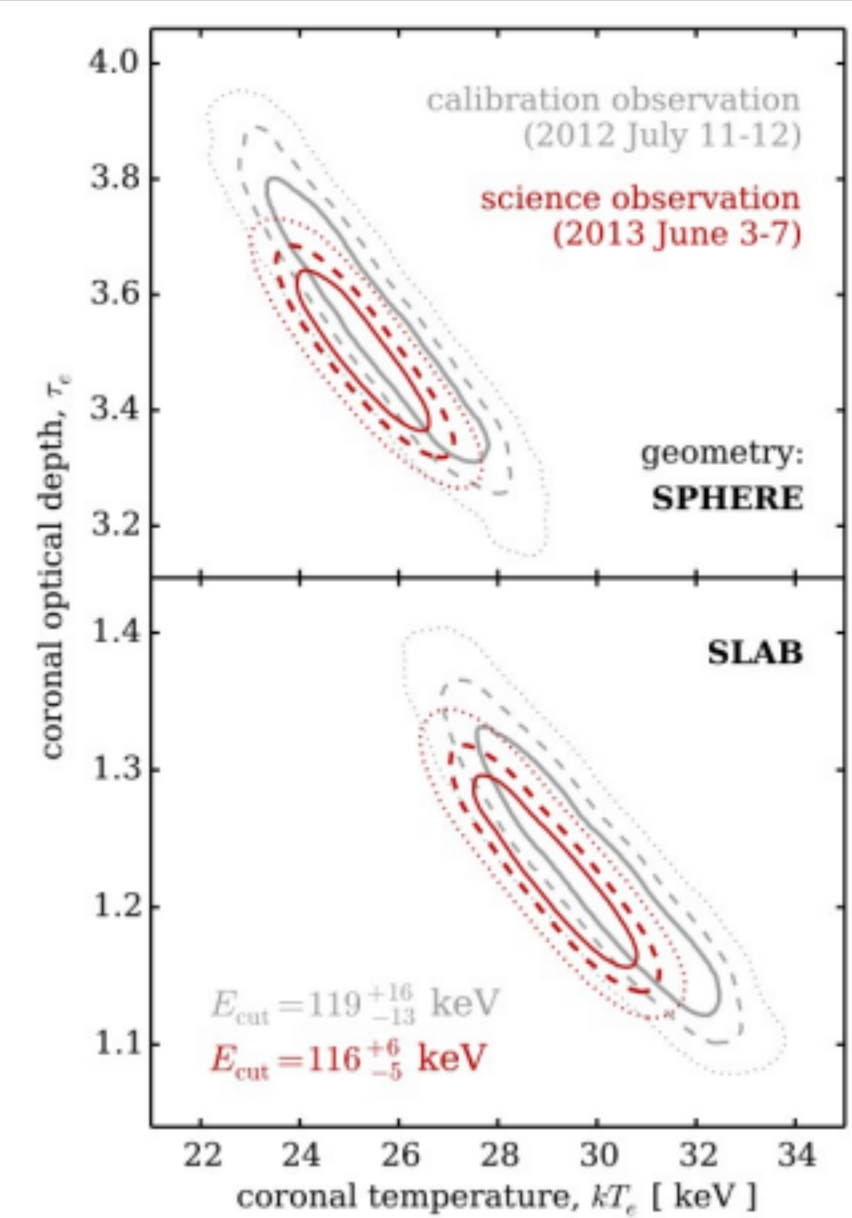
SLAB	SPHERE
$kT_e = 68^{+37}_{-32}$ keV	$kT_e = 53^{+28}_{-26}$ keV
$\tau = 0.35^{+0.35}_{-0.19}$	$\tau = 1.35^{+1.03}_{-0.67}$

MCG-05-23-16



Balokovic+15

MCG-05-23-16

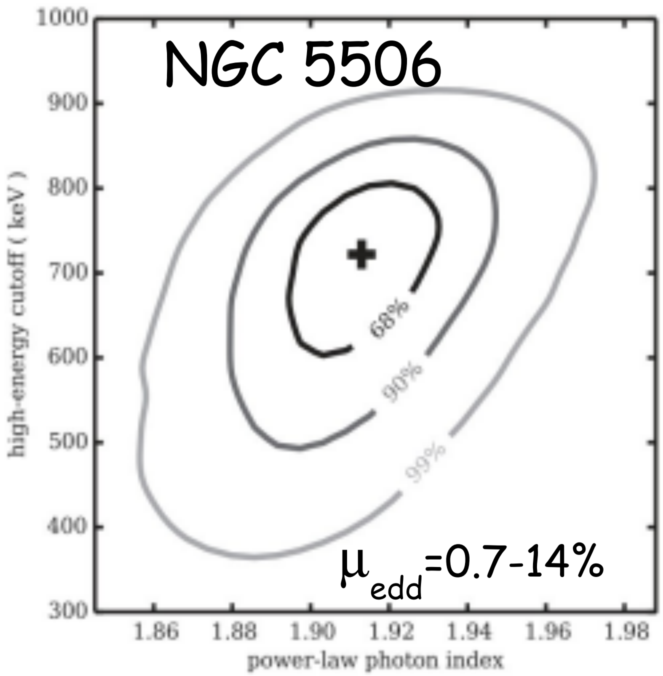


Balokovic+15

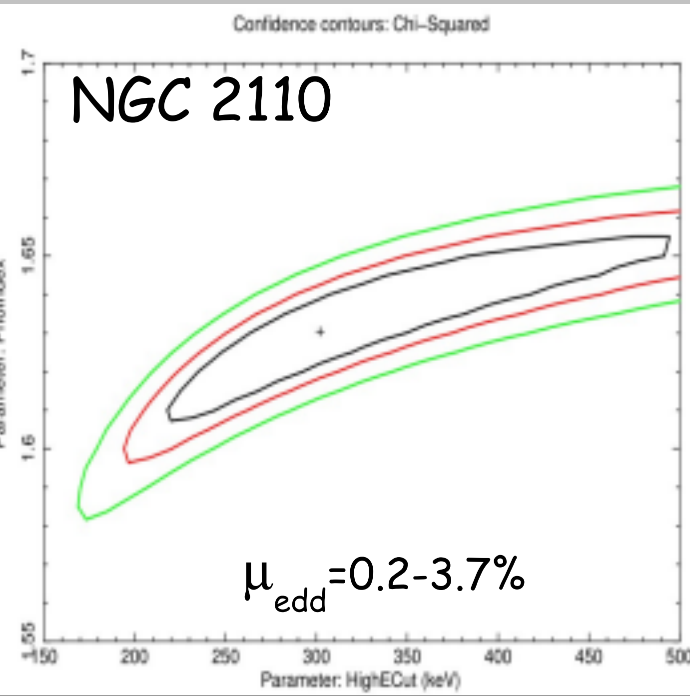
independent of the continuum model			
C_{FPMB} [c]		1.032 ± 0.002	1.045 ± 0.005
$E_{line\,1}$	[keV]	6.43 ± 0.05	$6.5^{+0.2}_{-0.1}$
$\sigma_{line\,1}$	[keV]	0.46 ± 0.06	0.5 ± 0.2
$EW_{line\,1}$	[eV]	80 ± 10	80 ± 20
$EW_{line\,2}$	[eV]	40 ± 10	50 ± 20
phenomenological continuum model: pexrav			
χ^2		1163	687
Γ		1.85 ± 0.01	1.83 ± 0.02
R		0.87 ± 0.04	1.1 ± 0.1
E_{cut}	[keV]	116^{+6}_{-5}	119^{+16}_{-13}
Comptonized continuum model: refl(compTT)			
assumed corona geometry: slab			
χ^2		1163	688
R		0.84 ± 0.04	1.1 ± 0.1
kT_e	[keV]	29 ± 2	30 ± 3
τ_e		1.23 ± 0.08	1.2 ± 0.1
assumed corona geometry: sphere			
χ^2		1161	688
R		0.82 ± 0.04	1.0 ± 0.1
kT_e	[keV]	25 ± 2	26 ± 3
τ_e		3.5 ± 0.2	3.5 ± 0.3

High values/lower limits

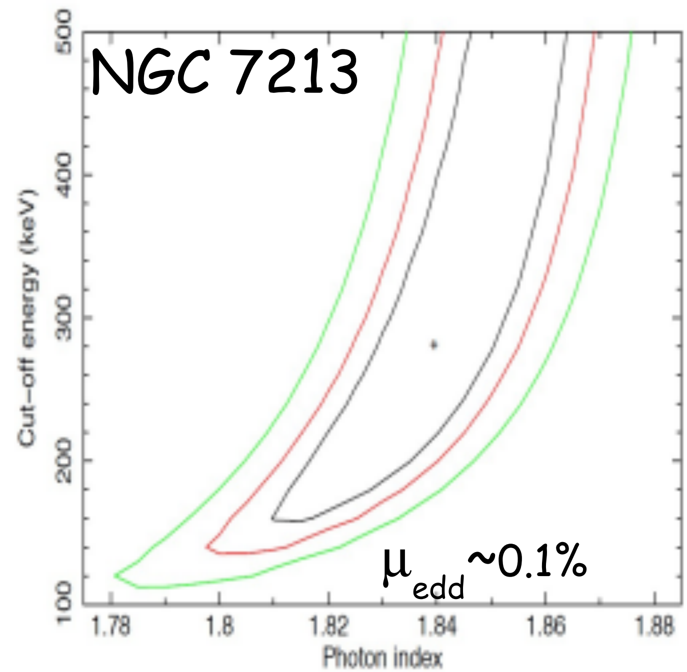
In other bright sources, high values or lower limits to the cutoff energy have been found, suggesting the presence of a very hot corona surrounding the accretion disc.



Matt+15



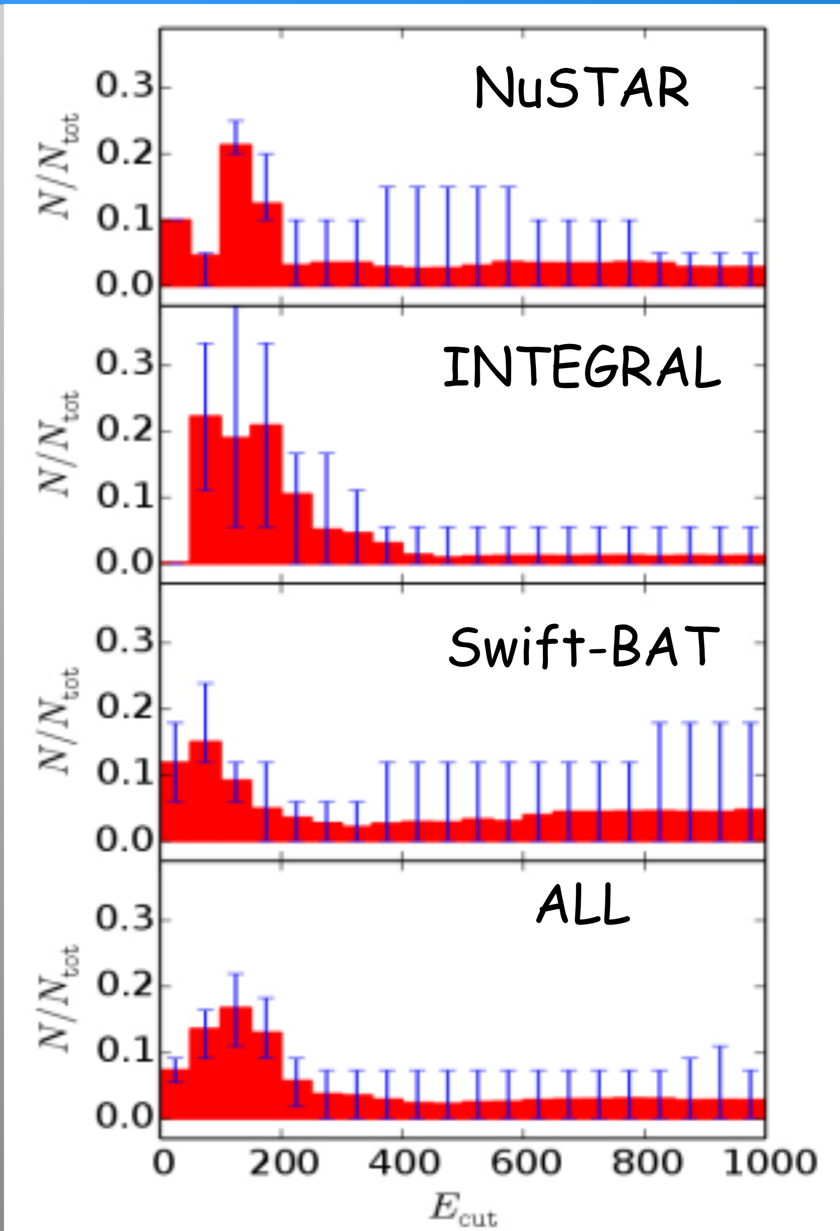
Marinucci+15



Ursini+15

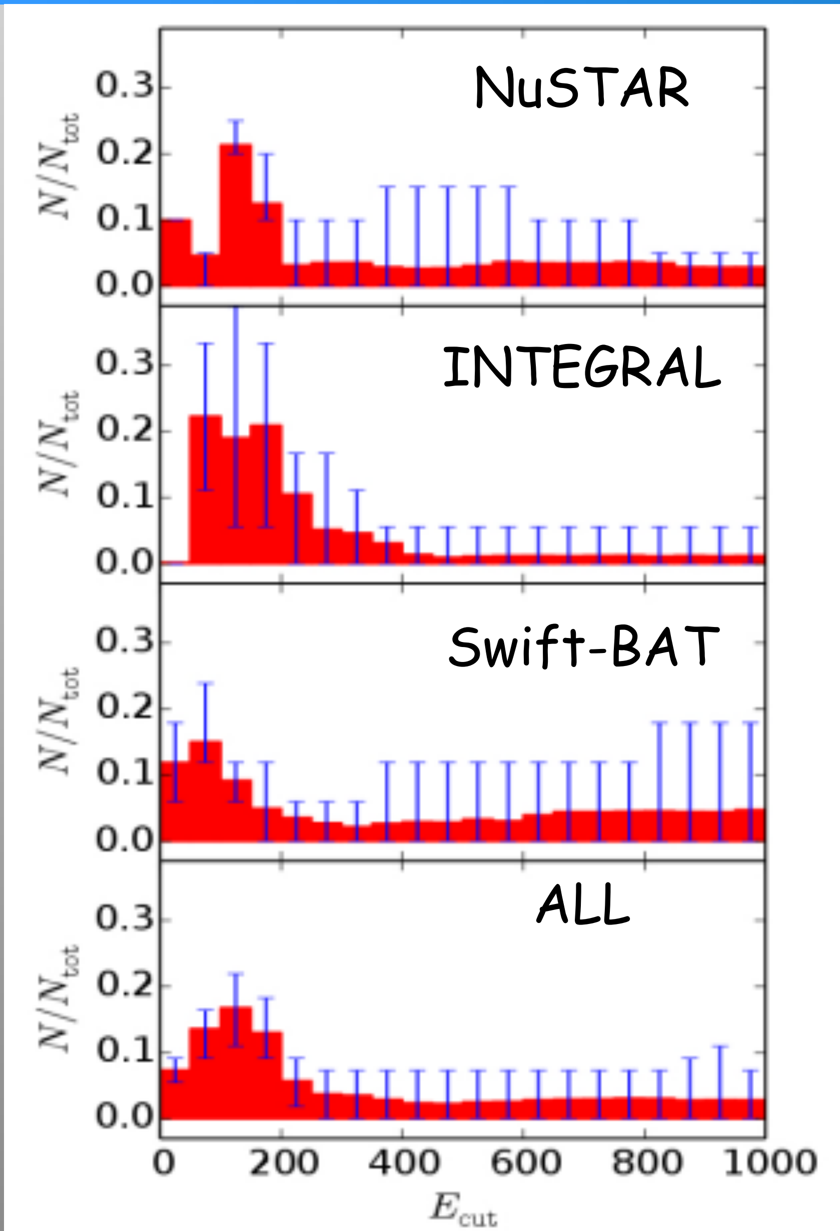
The next step is to build a small catalog and to start looking for correlations between the coronal temperature and other physical properties (e.g. black hole mass, accretion rate).

A larger view

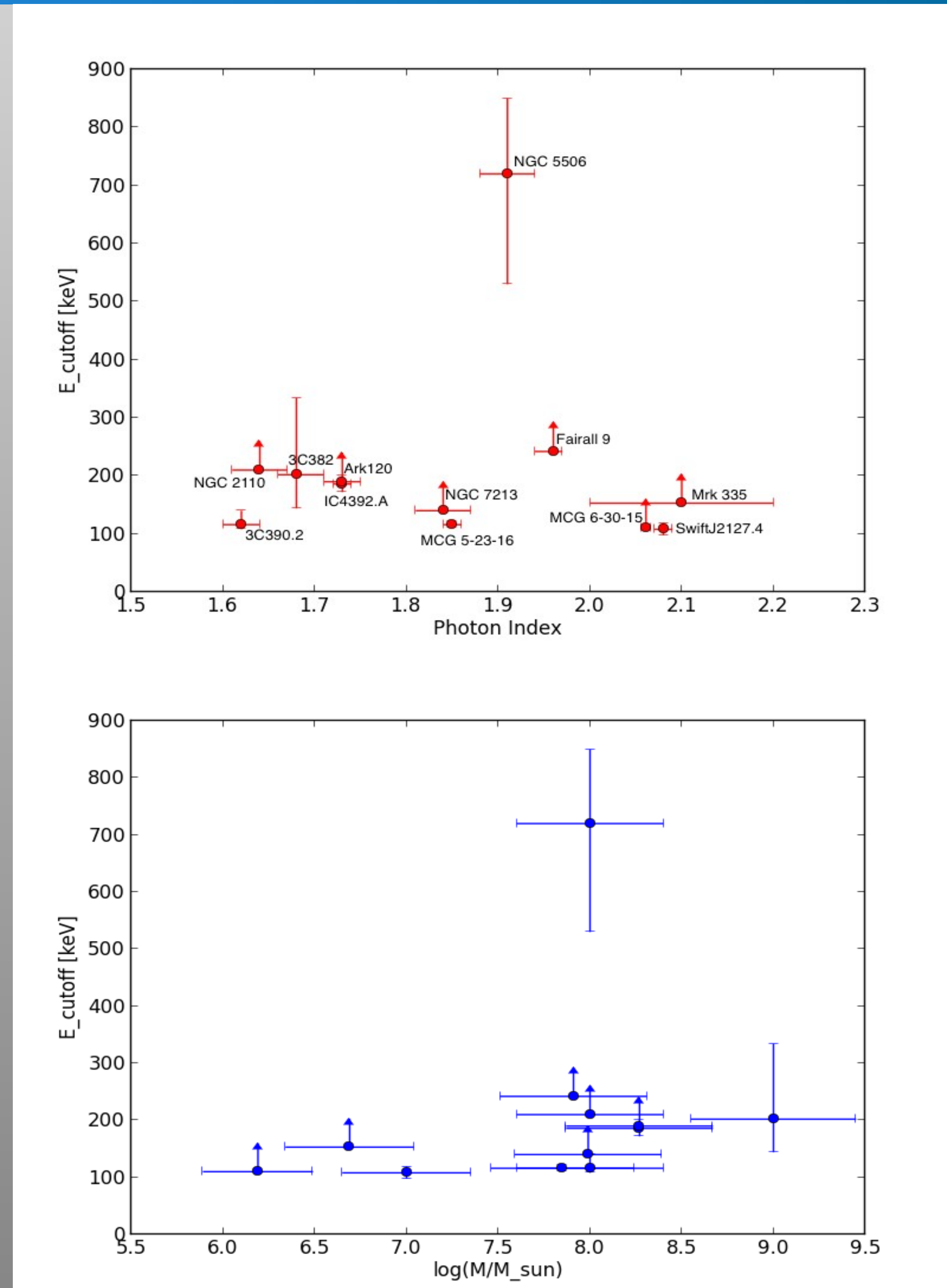


Fabian+15

A larger view



Fabian+15



Tortosa et al., in prep.

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Conclusions

- High energy cut-off have been measured in a number of AGN with NuSTAR (more are yet to come!)
- They are not ubiquitous
- 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.