The coronal τ-kT_e diagram in AGN

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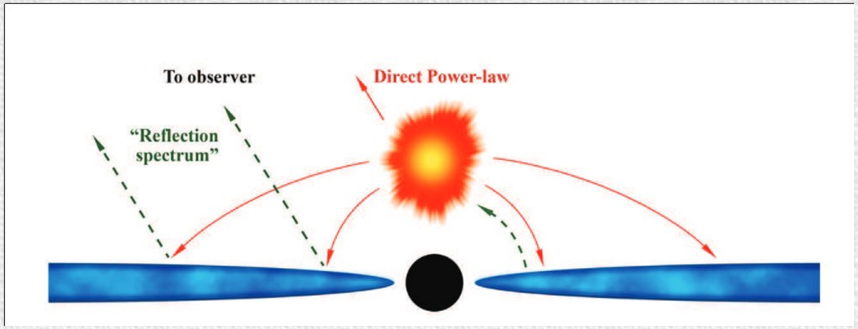
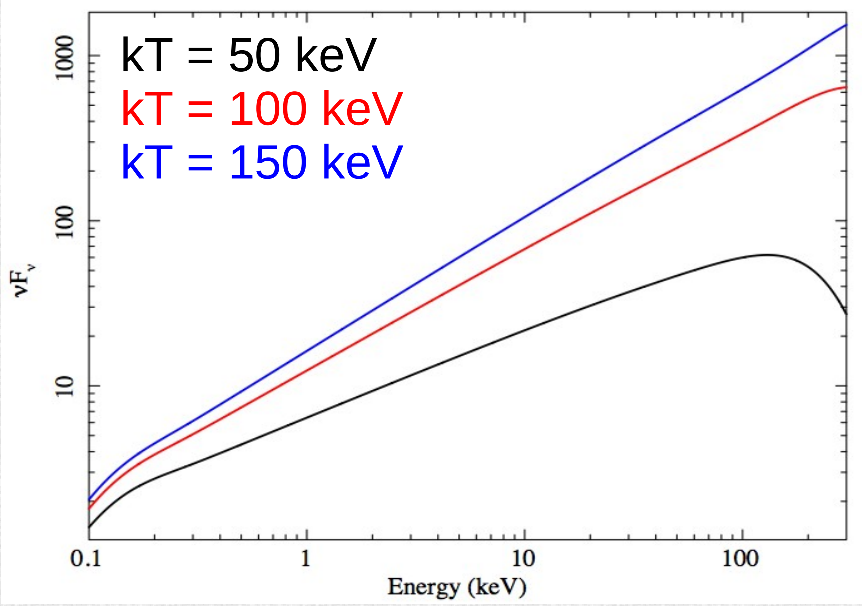
Coronal parameters in local Seyfert galaxies



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

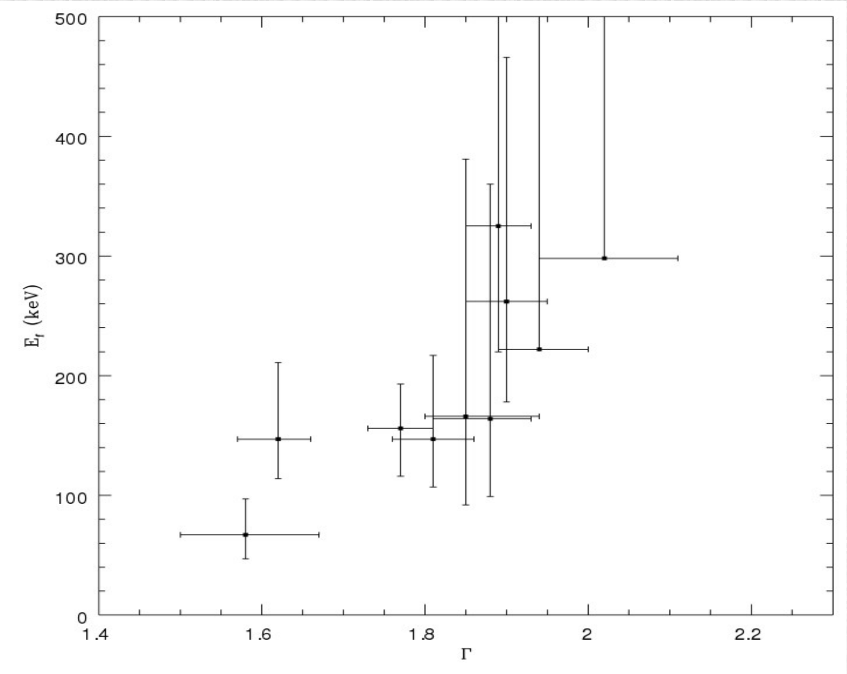
It is due to Comptonization of soft photons, but the geometry, optical depth and temperature of the emitting corona are largely unknown.



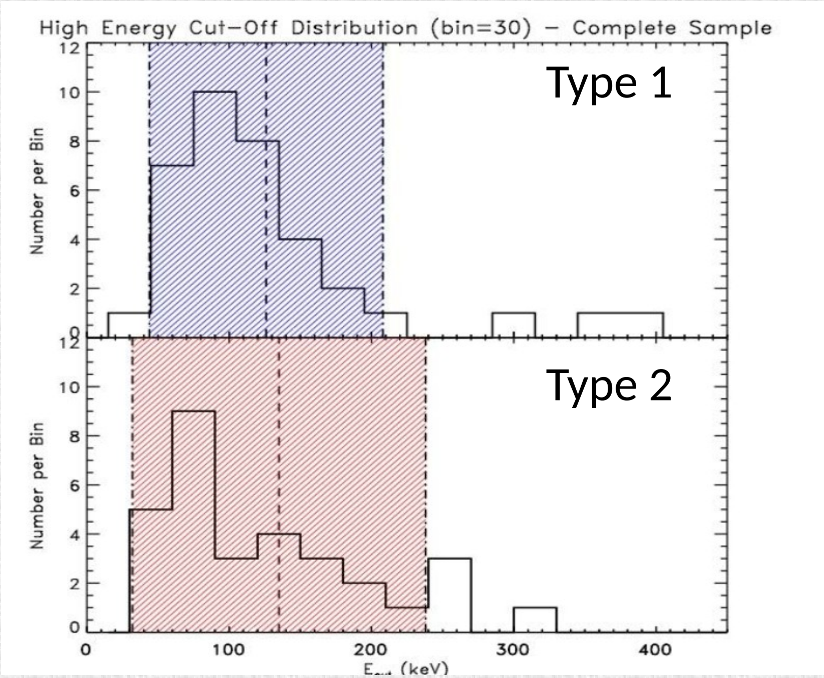
Most popular models imply E_{cut}=2-3x kT_e (Petrucci+00,+01), so measuring E_{cut} helps constraining Comptonization models.

Coronal parameters in local Seyfert galaxies

Before the launch of NuSTAR, we only had a handful of results based on non-focusing, and therefore strongly background-dominated, satellites (BeppoSAX-PDS, Suzaku HXD-PIN, INTEGRAL, Swift-BAT)



Perola+02



De Rosa+12; Molina+13

Coronal parameters in local Seyfert galaxies

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}.

References: 1 Guainazzi et al. (2010), 2 Matt et al. (2015), 3 Ursini et al. (2015b), 4 Blank, Harnett & Jones (2005), 5 Emmanoulopoulos et al. (2014), 6 Marinucci et al. (2014c), 7 Moran et al. (2007), 8 Marinucci et al. (2014a), 9 Ponti et al. (2012), 10 Zoghbi et al. (2014), 11 Baloković et al. (2015), 12 Malizia et al. (2008), 13 Marinucci et al. (2014b), 14 Bianchi et al. (2009), 15 Brenneman et al. (2014), 16 Pancoast et al. (2014), 17 Ursini et al. (2015a), 18 Grier et al. (2012), 19 Parker et al. (2014), 20 Peterson et al. (2004), 21 Matt et al. (2014), 22 Bian & Zhao (2003), 23 Kara et al. (2015), 24 Lohfink & Reynolds (2015), 25 Grier et al. (2013), 26 Lohfink & Tombesi (2015), 27 Tadhunter et al. (2003), 28 Reynolds et al. (2015), 29 Winter et al. (2009), 30 Ballantyne et al. (2014)

Fabian+15

More observations are under scrutiny..

e.g. MCG+8-11-11 and NGC 6814: A. Tortosa's poster

NGC 7469: R. Middei's poster

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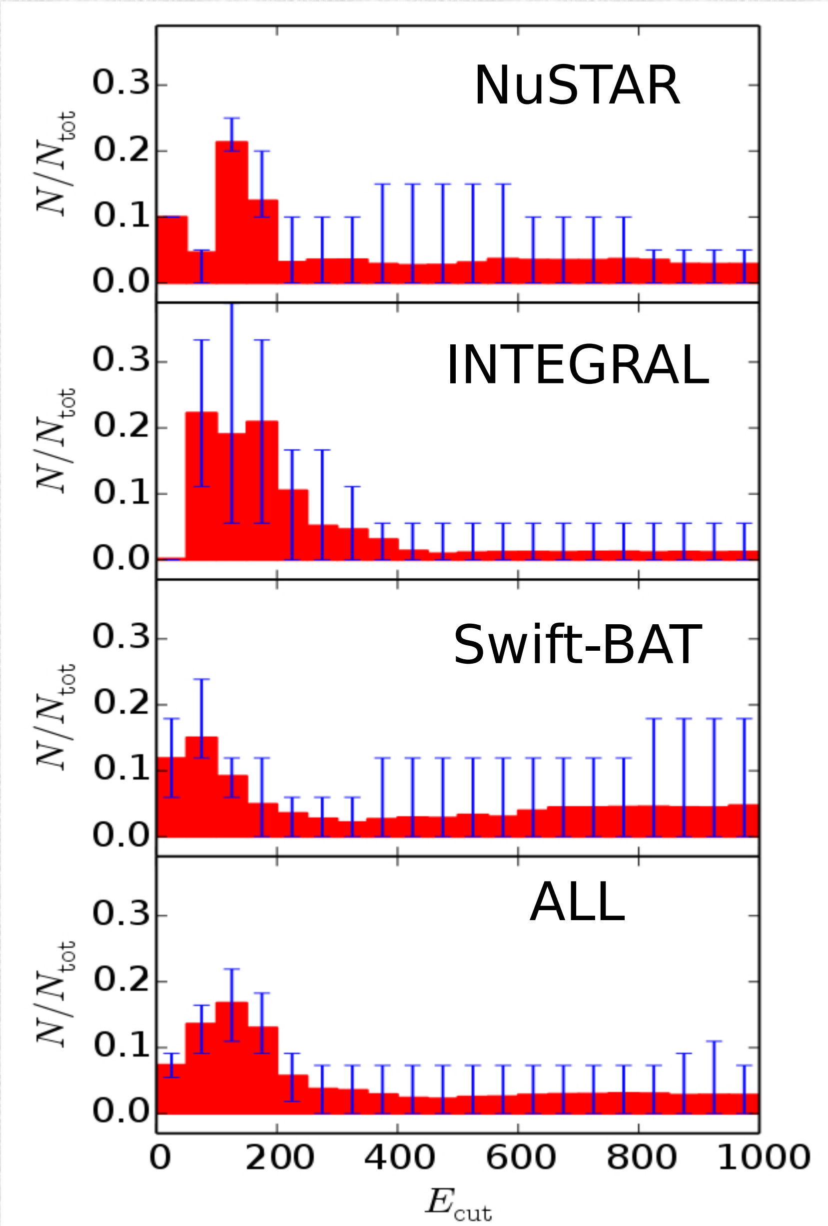
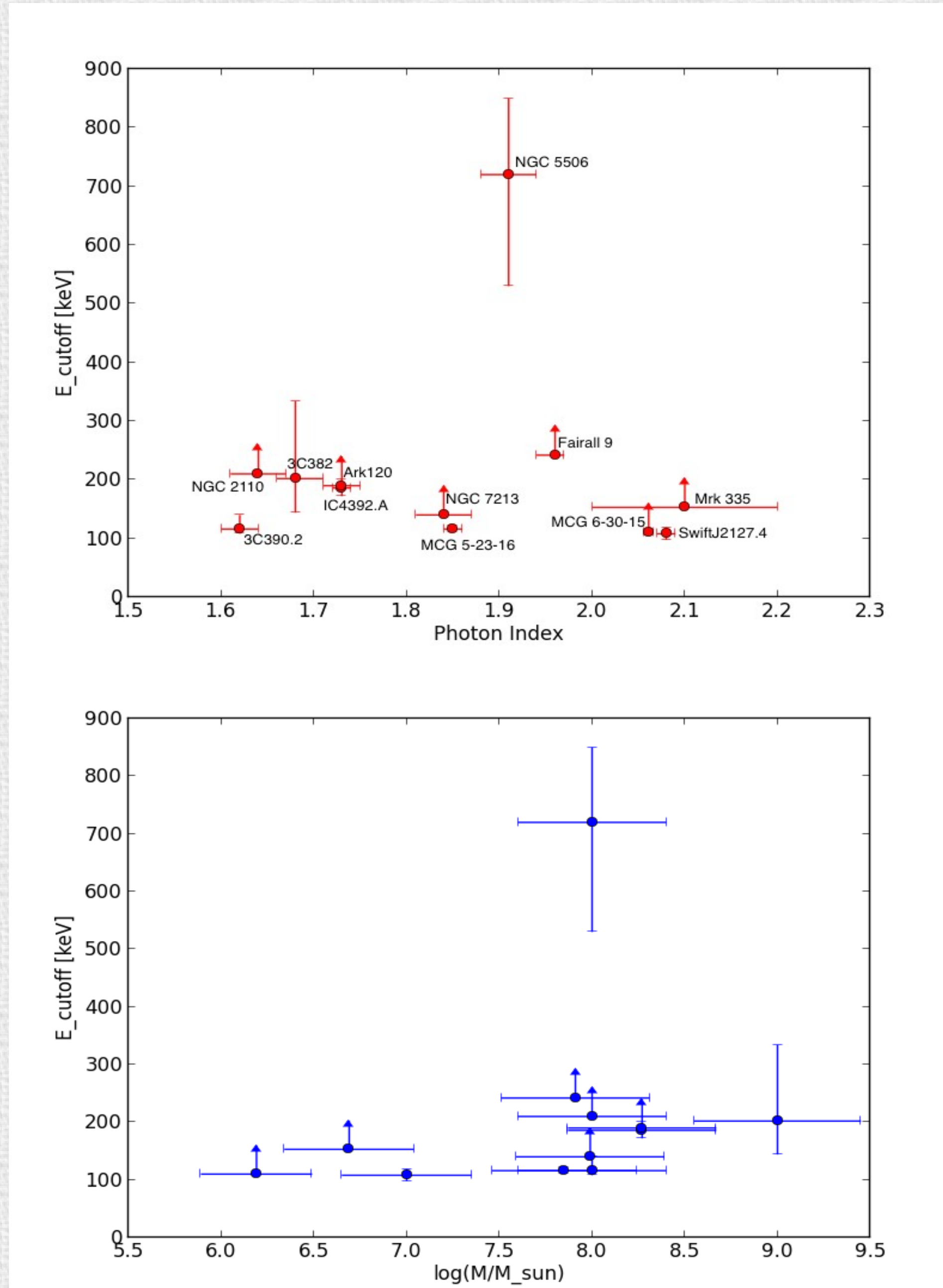
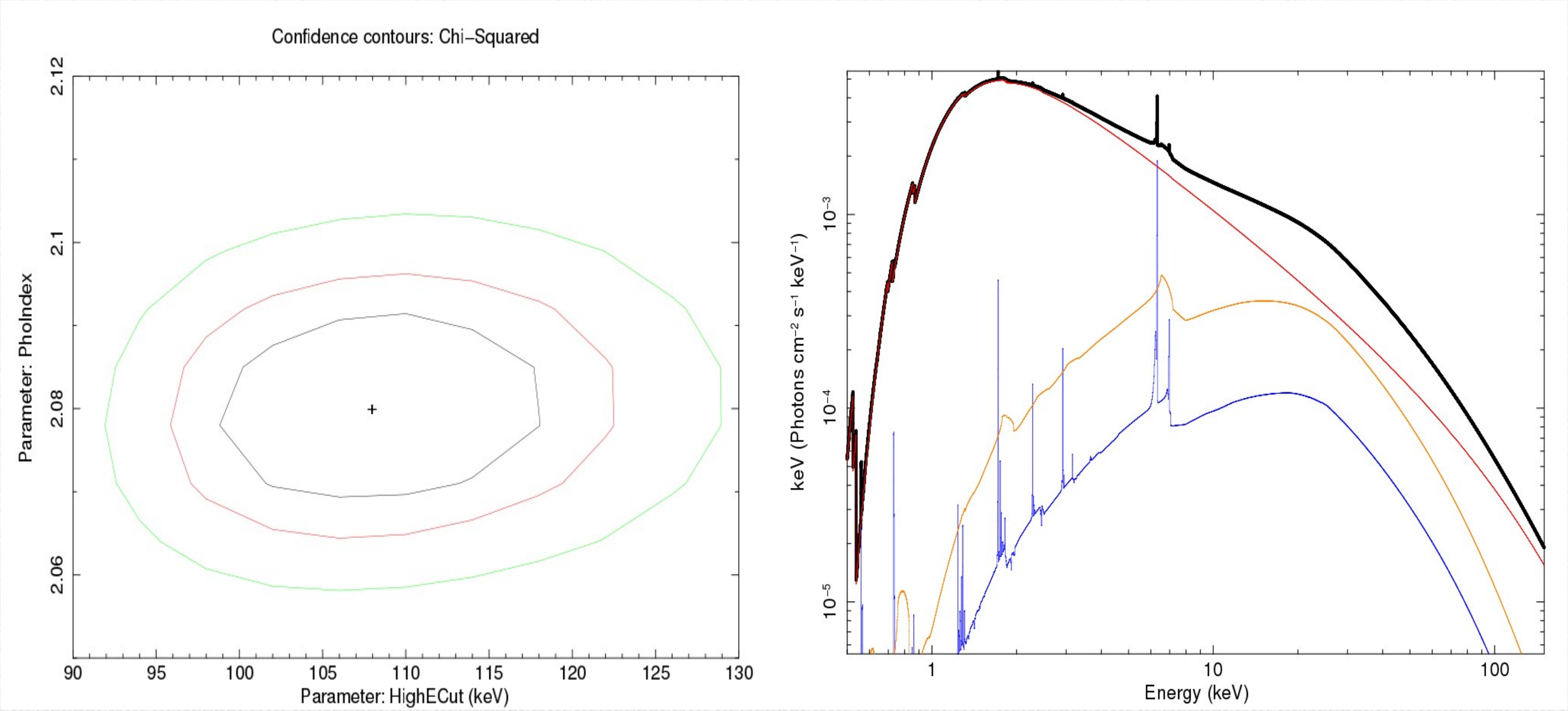


Fabian+15



Marinucci et al, in prep.

Coronal parameters (Swift J2127.4+5654)



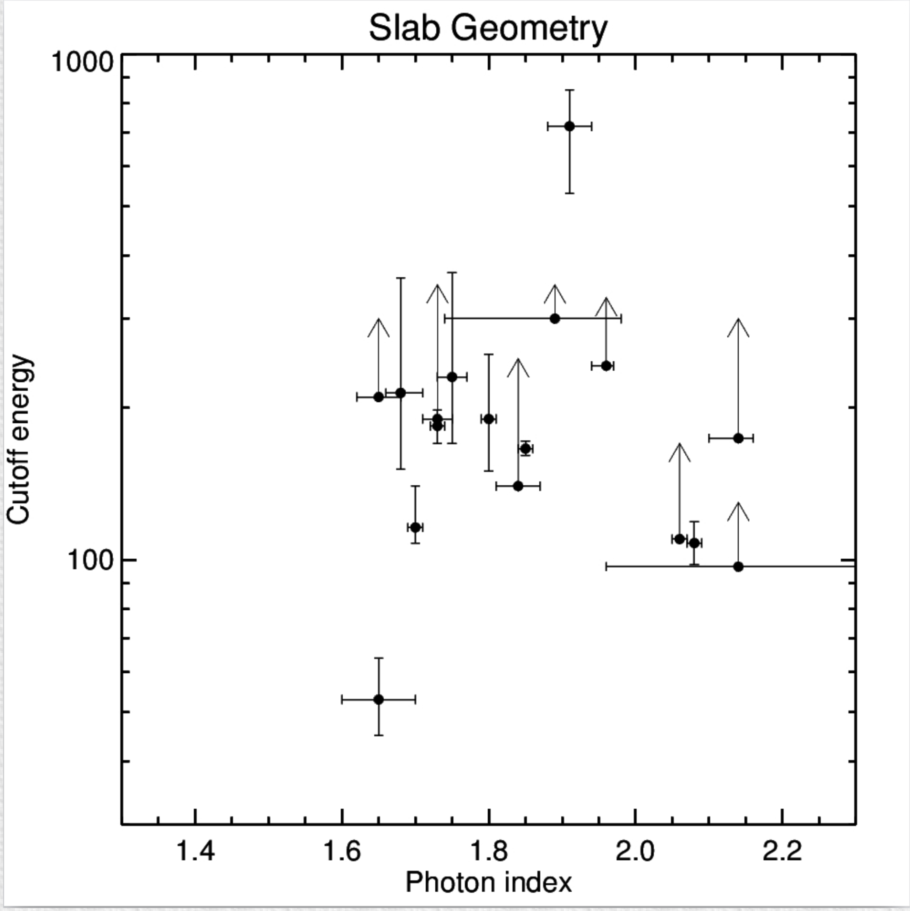
Using compTT (Titarchuk+94) with two different geometries we get:

SLAB	SPHERE
kT_e=70±35 keV	kT_e=50±25 keV
$\tau=0.35^{+0.35}_{-0.20}$	$\tau=1.3^{+1.0}_{-0.7}$

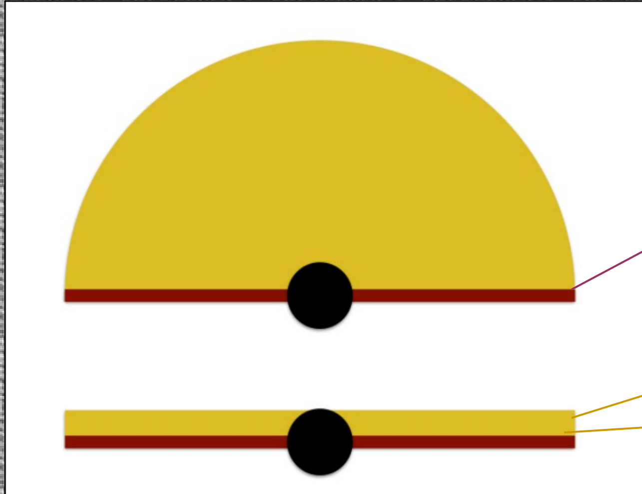
The τ-kT_e diagram (in a slab geometry)

1. How can we translate the commonly derived photon indices and high-energy cutoff values into optical depths and electronic temperatures?

2. Is there a more populated region in the τ-kT parameter space?



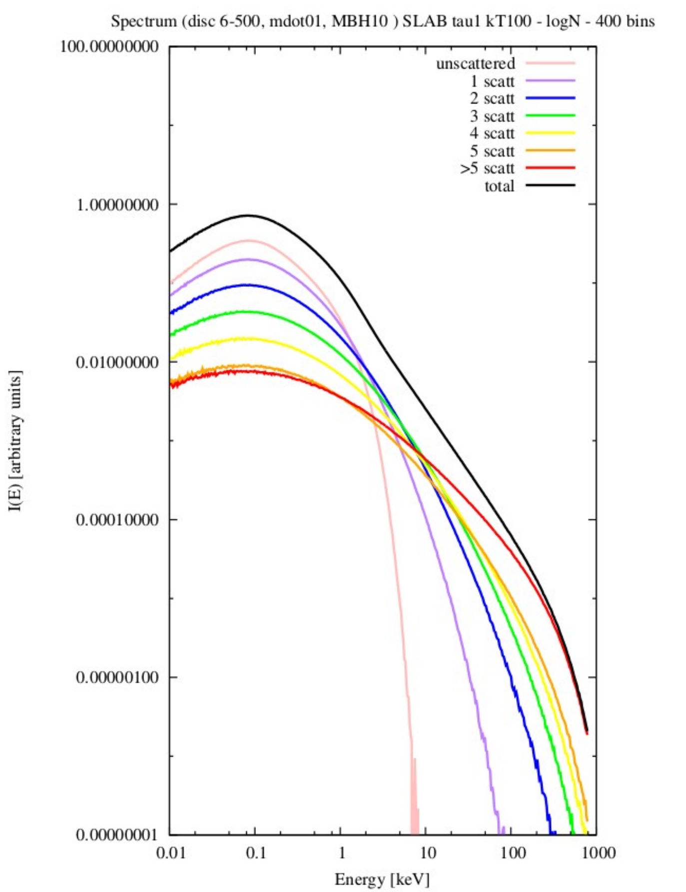
A MC code for Comptonization in Astrophysics (MoCA)



$$T(R) = \left[\frac{3GM\dot{m}}{8\pi R^3 \sigma_{SB}}\left(1 - \sqrt{\frac{R_{in}}{R}}\right)\right]^{\frac{1}{4}}$$

kT_e

$d\tau = n_e \sigma_{kn}\, dx$



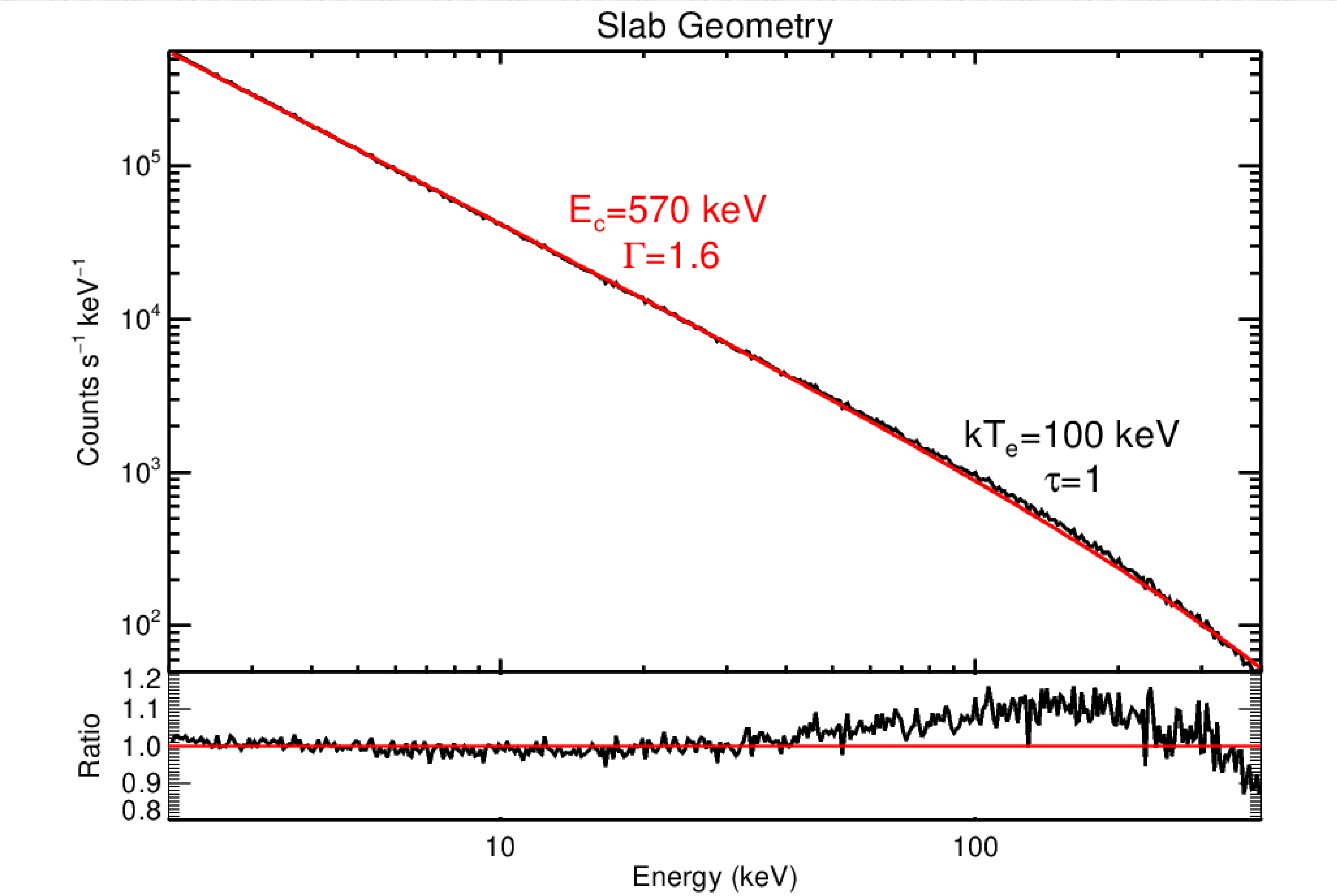
Assumptions and advantages:

1. Shakura-Sunyaev neutral accretion disc
2. Extended coronae
3. Single photon approach
4. Full special relativity included
5. Polarization signal (!)

Tamborra+, in prep.

MoCA in action

We simulate a coronal configuration and fit it with a cutoff powerlaw, retrieving the corresponding values of E_c and Γ



Middei+, in prep.

$M_{bh}=10^7 M_{sun}$; $\dot{m}$=1, kT_e=100 keV; τ=1

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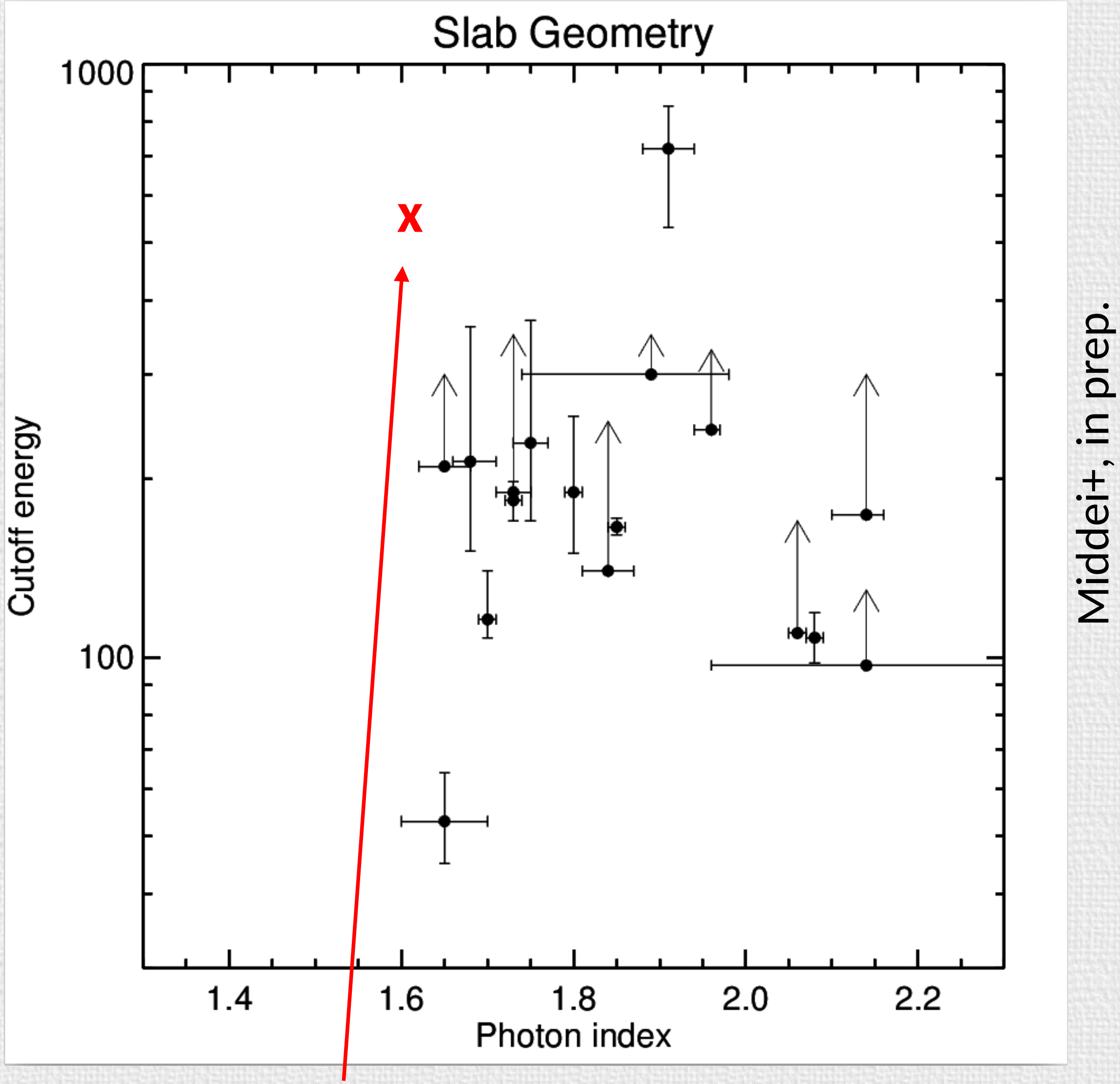
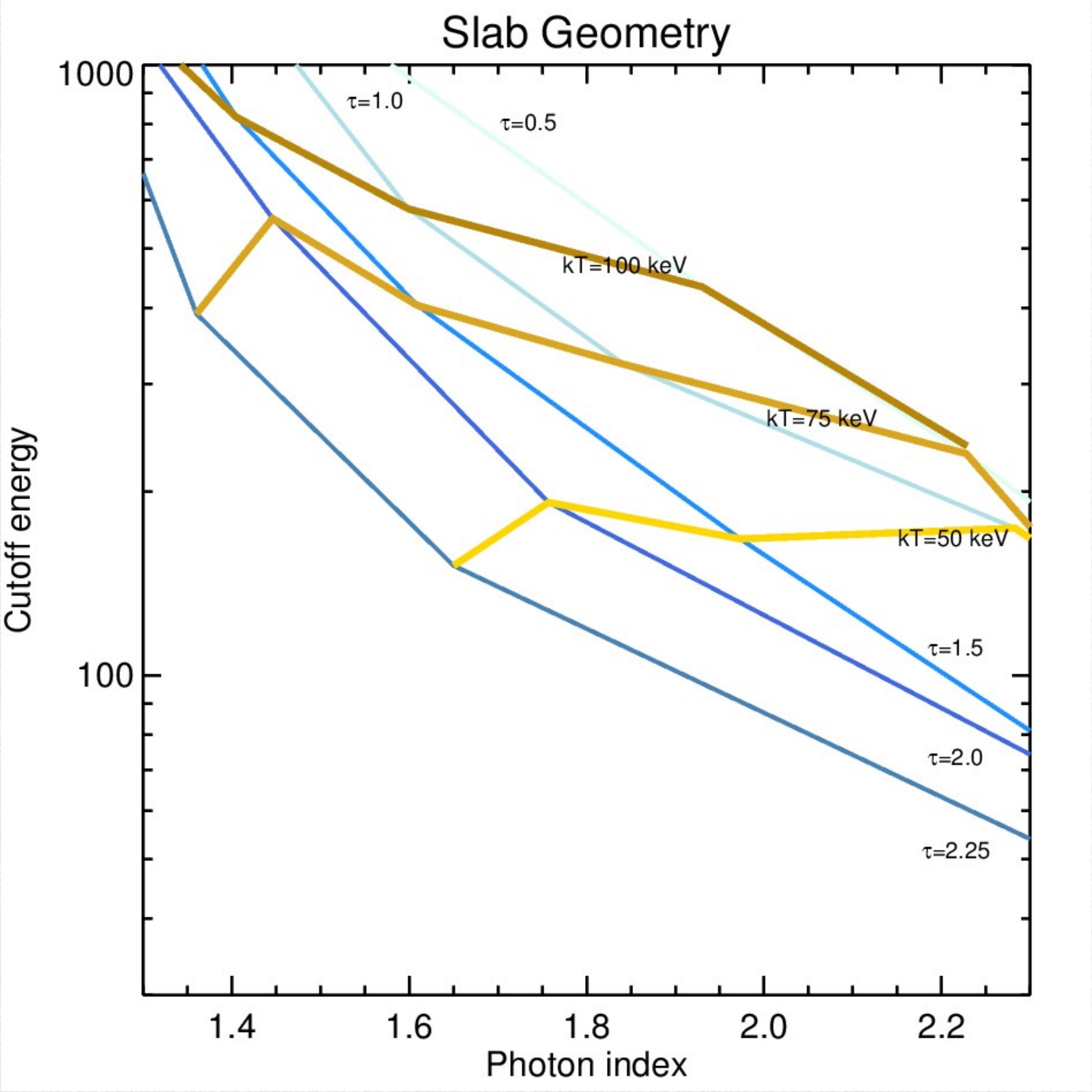


$M_{bh}=10^7 M_{sun}$; $\dot{m}=1$, $kT_e=100$ keV; $\tau=1$

The τ-kT_e diagram in AGN

The region of the observed parameters ranges between kT=50-100 keV and τ=0.5-2.25



Middei+, in prep.

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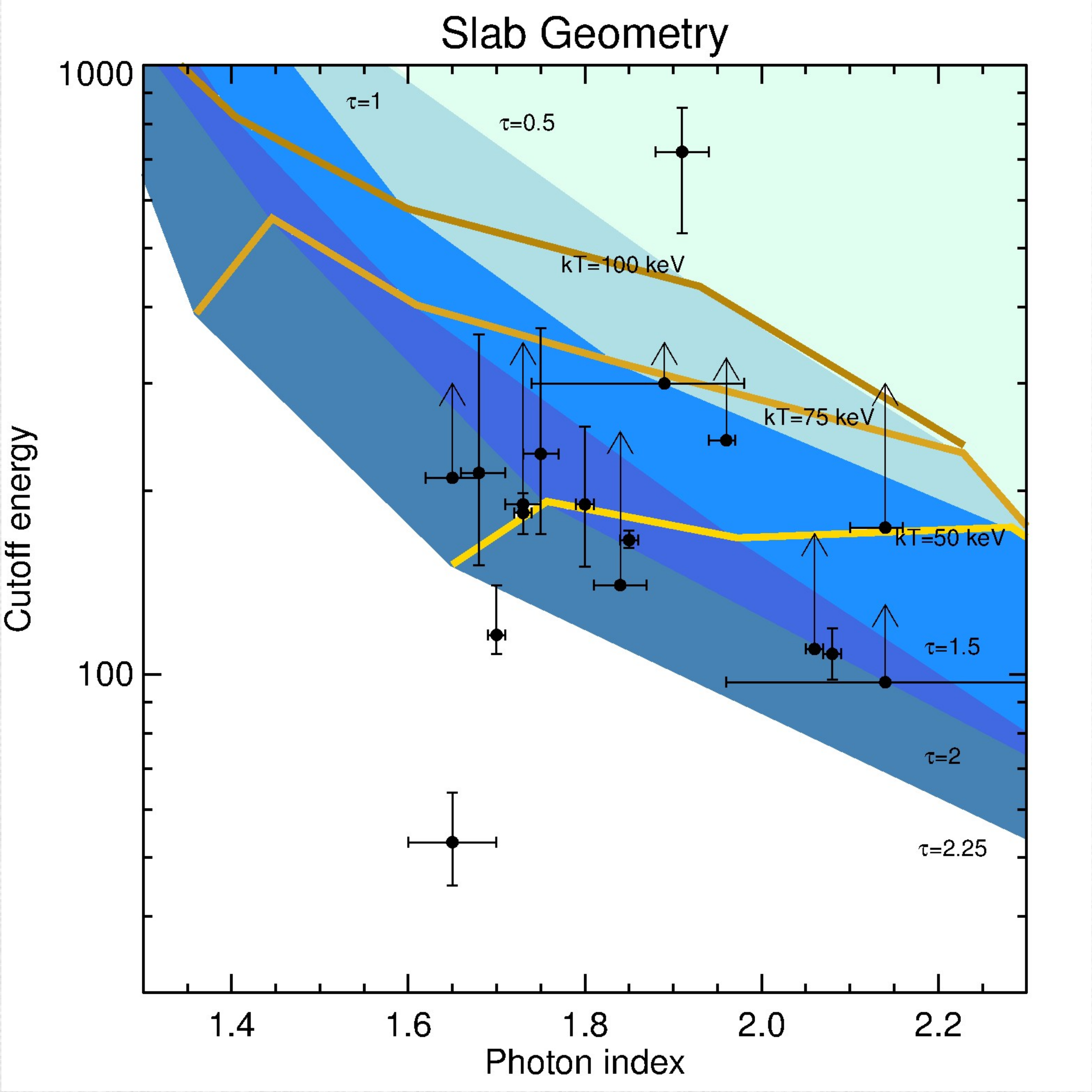
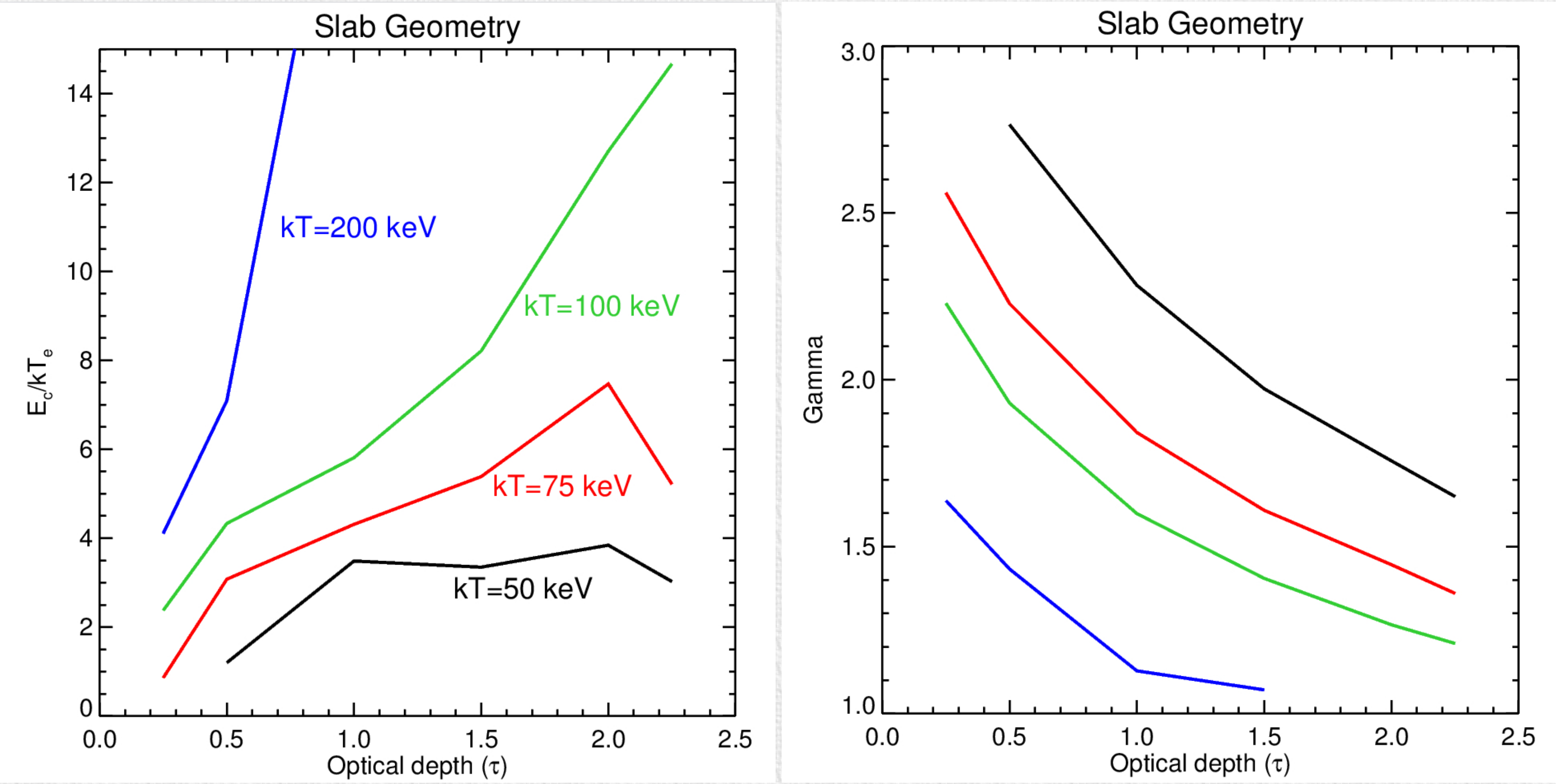


Middei+, in prep.

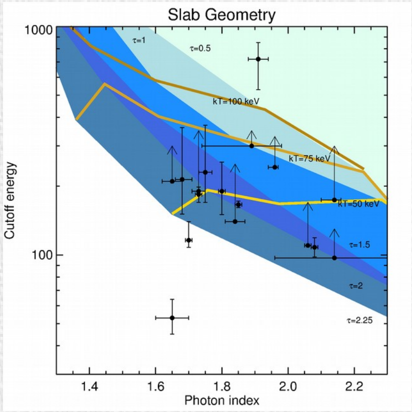
The τ-kT_e diagram in AGN

The trend between the cutoff energy and kT discussed in Petrucci+00,01 is observed only for low values of the optical depth and coronal temperature

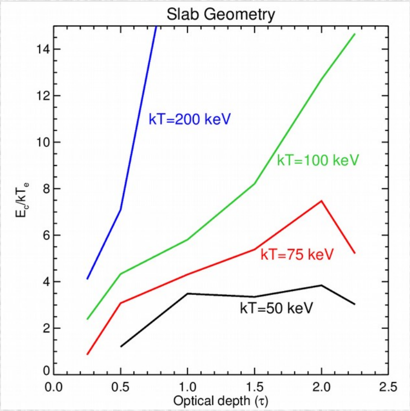


Middei+, in prep.

Conclusions



Simulations with MoCA have shown that the observed cutoff energies and photon indices occupy a well-defined region in the τ-kT diagram



The relation between the observed cutoff energy and kT is a function of both the optical depth and the coronal temperature.

We are currently working on running more simulations and trying different geometries.