Hot Coronae in local AGN: present status and future perspectives

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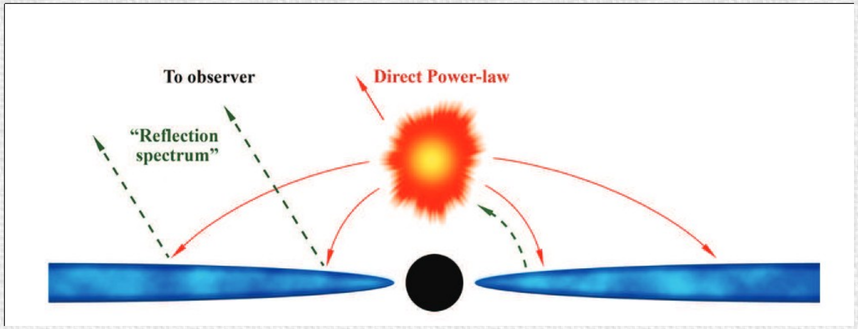
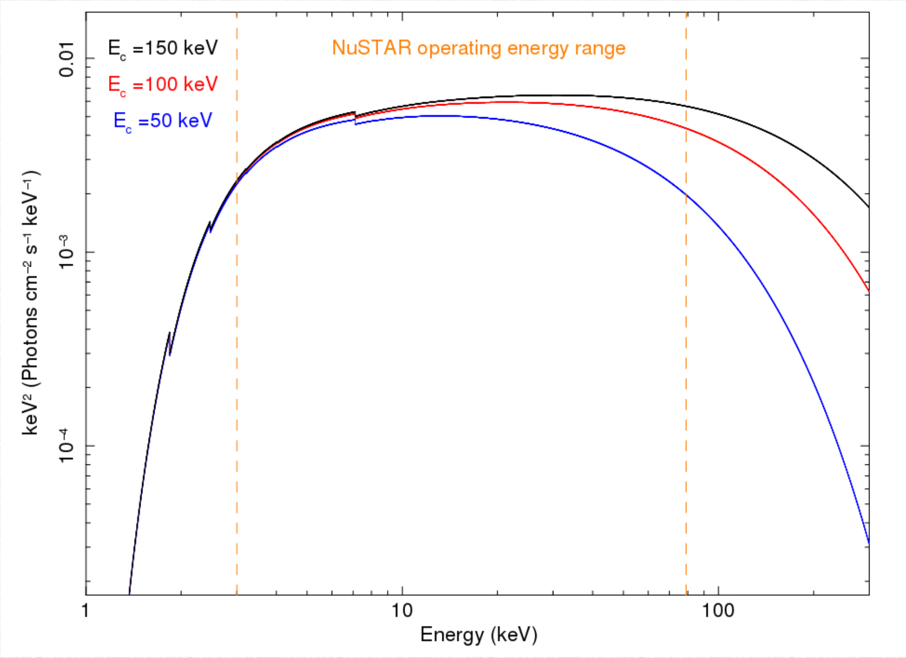
STRONGGRAVITY
EU FP7-SPACE research project 312789
2013 - 2017

Coronal parameters in local Seyfert galaxies



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

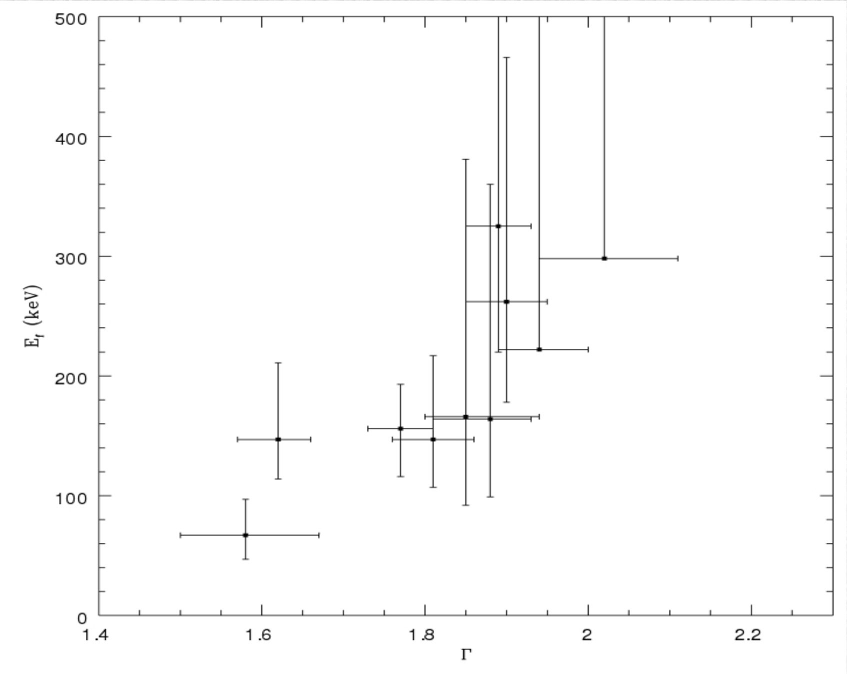
It is due to Comptonization of soft photons, but the geometry, optical depth and temperature of the emitting corona are largely unknown.



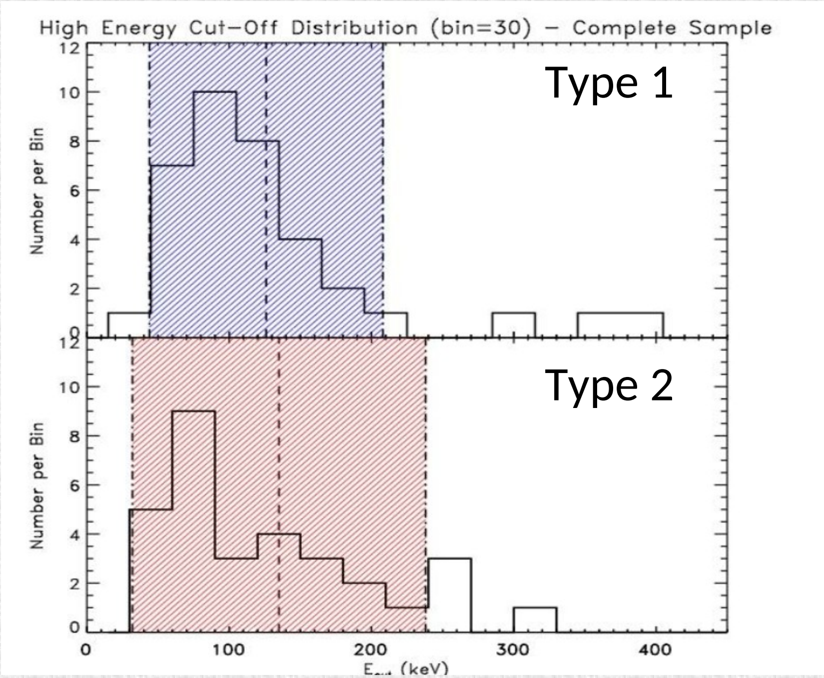
Most popular models imply E_{cut}=2-3x kT_e (Petrucci+00,+01), so measuring E_{cut} helps constraining Comptonization models.

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

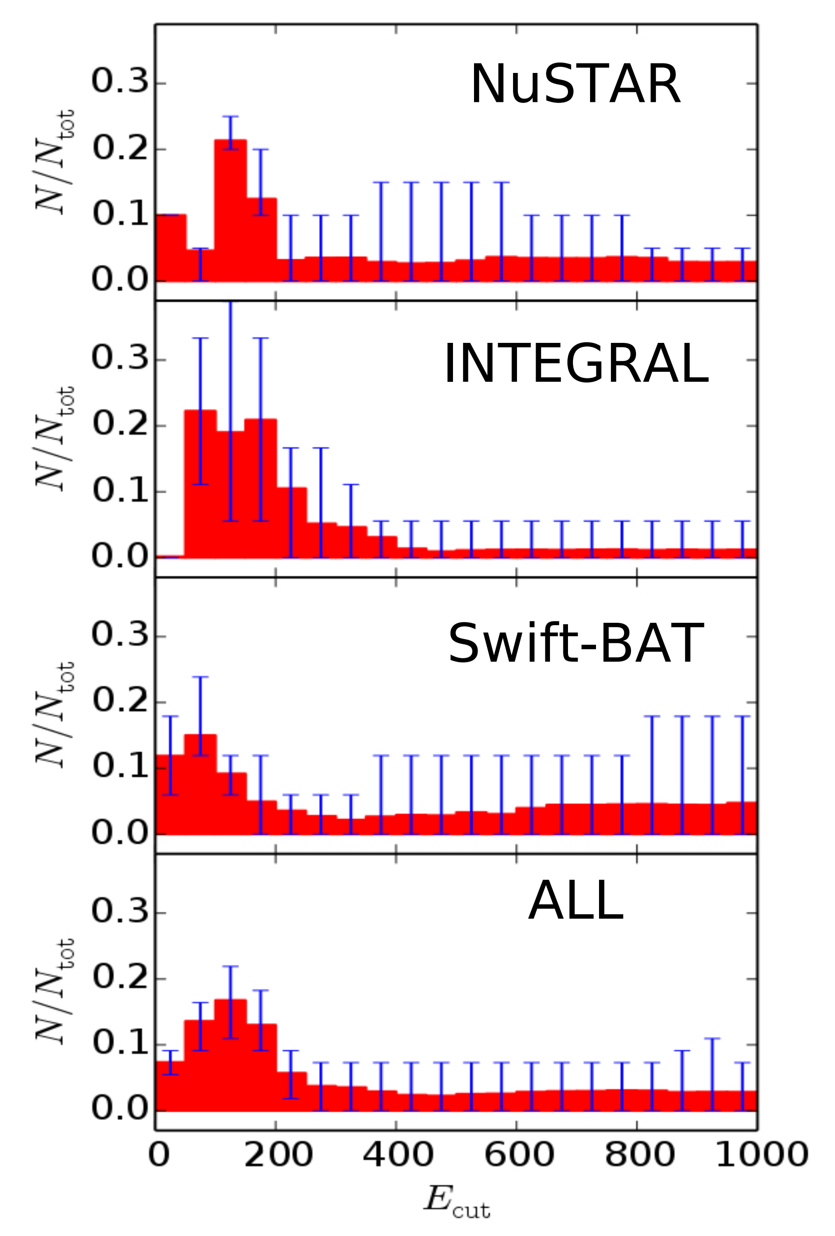
Coronal parameters in local Seyfert galaxies

Source	Ref.	Γ	E_c [keV]	$\log(M_{bh}/M_{\odot})$	Ref.	L_{bol}/L_{Edd}	$L_{2-10keV}$ ergs s^{-1}	$F_{2-10keV}$ erg $cm^{-2} s^{-1}$	kT_e [keV]	τ	geom.	model
NGC 5506	1	1.91 ± 0.03	720^{+130}_{-190}	8.0 ± 0.2	(A)	0.006	0.053	6.2	440^{+230}_{-250}	$0.02^{+0.2}_{-0.01}$	slab	compTT
									440^{+230}_{-250}	$0.09^{+0.2}_{-0.01}$	sphere	compTT
MCG 5-23-16	2	1.85 ± 0.01	170 ± 5	7.7 ± 0.2	(B)	0.058	0.18	10.4	30 ± 2	1.2 ± 0.1	slab	compTT
									25 ± 2	3.5 ± 0.02	sphere	compTT
SWIFT J2127.4	3-4	2.08 ± 0.01	180^{+75}_{-40}	7.2 ± 0.2	(J)	0.136	0.14	2.9	70^{+40}_{-30}	$0.5^{+0.3}_{-0.2}$	slab	compTT
									50^{+30}_{-25}	$1.4^{+1.0}_{-0.7}$	sphere	compTT
IC4329A	5-6	1.73 ± 0.01	185 ± 15	6.99 ± 0.3	(H)	1.291	0.56	12.0	37 ± 7	1.3 ± 0.1	slab	compTT
									33 ± 6	3.4 ± 0.5	sphere	compTT
3C390.3	7	1.70 ± 0.01	120 ± 20	8.4 ± 0.4	(H)	0.241	1.81	4.03	40 ± 20	$3.3^{+1.3}_{-2.8}$	sphere	compTT
3C382	8	1.68 ± 0.03	215^{+150}_{-60}	9.2 ± 0.5	(D)	0.048	2.34	2.9	330 ± 30	0.2 ± 0.02	slab	compTT
GRS 1734-292	9	1.65 ± 0.05	53 ± 10	8.5 ± 0.1	(L)	0.038	0.056	2.9	12 ± 1	2.9 ± 0.2	slab	compTT
									$12^{+1.7}_{-1.2}$	6.3 ± 0.3	sphere	compTT
NGC 6814	10	1.71 ± 0.04	135^{+70}_{-35}	7.0 ± 0.1	(C)	0.003	0.021	0.2	45^{+100}_{-20}	$2.5^{\dagger} \pm 0.5$	sphere	nthcomp
MCG +8-11-11	10	1.77 ± 0.04	175^{+110}_{-50}	7.2 ± 0.2	(E)	0.754	0.51	5.6	60^{+110}_{-30}	$1.9^{\dagger} \pm 0.4$	sphere	nthcomp
Ark 564	11	2.27 ± 0.08	42 ± 3	6.8 ± 0.5	(H)	1.313	0.39	-	15 ± 2	$2.7^{\dagger} \pm 0.2$	sphere	nthcomp
PG 1247+267	12-13	2.35 ± 0.09	90^{+130}_{-35}	8.9 ± 0.2	(M)	0.024	0.79	0.05	46^{+60}_{-20}	$1.4^{\dagger} \pm 0.3$	sphere	nthcomp
Ark 120	14-15	1.87 ± 0.02	180^{+80}_{-40}	8.2 ± 0.1	(H)	0.085	0.92	2.3	-	-	-	-
NGC 7213	16	1.84 ± 0.03	> 140	8.0 ± 0.2	(G)	0.001	0.012	1.3	230^{+70}_{-250}	0.2 ± 0.1	sphere	compPS
MCG 6-30-15	17-18	2.06 ± 0.01	> 110	6.4 ± 0.1	(E)	0.238	0.056	5.5	-	-	-	-
NGC 2110	19	1.65 ± 0.03	> 210	8.3 ± 0.2	(K)	0.035	0.35	12.5	190 ± 130	0.2 ± 0.1	slab	compTT
Mrk 335	21-22	2.14 ± 0.03	> 174	7.2 ± 0.1	(H)	0.284	0.18	1.9	-	-	-	-
Fairall 9	20	1.95 ± 0.02	> 242	8.1 ± 0.7	(H)	0.054	0.60	2.9	-	-	-	-
Mrk 766	17-23-24	2.22 ± 0.03	> 441	6.3 ± 0.1	(I)	1.254	0.046	1.4	-	-	-	-
PG 1211+143	26	2.51 ± 0.2	> 124	8.2 ± 0.2	(H)	0.047	0.35	1.0	-	-	-	-

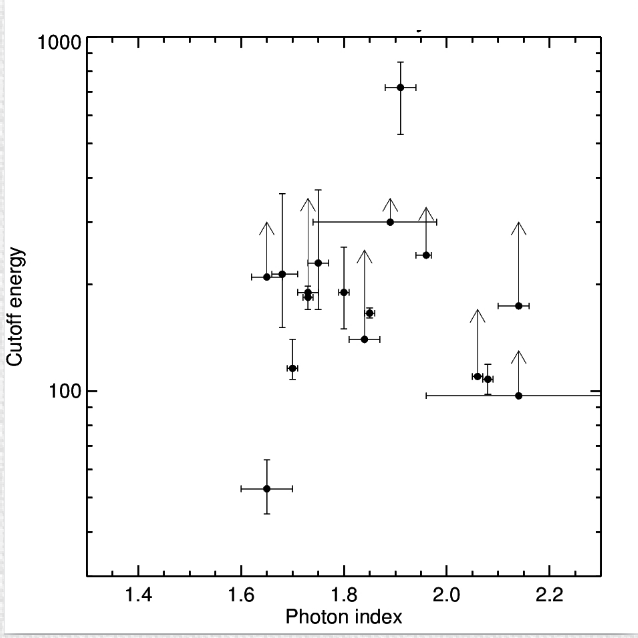
Tortosa+, in prep.

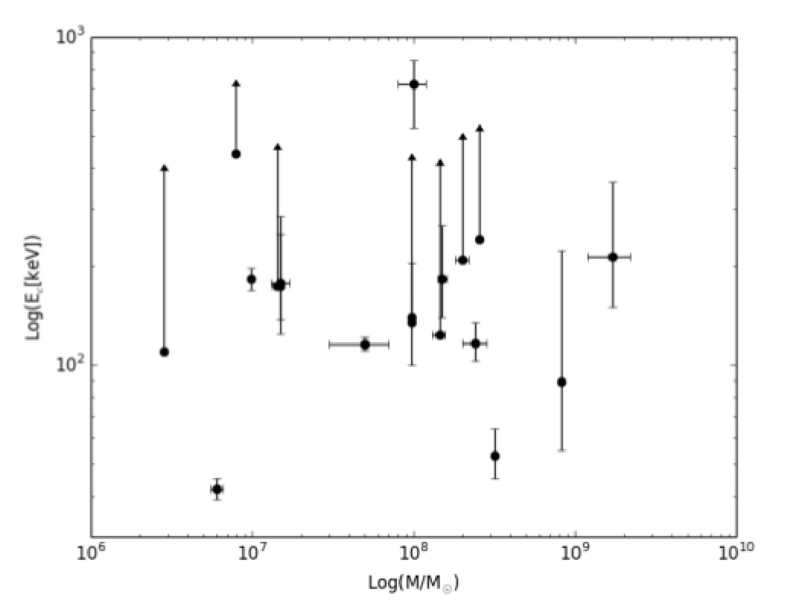
So far, about twenty sources have been observed and their primary continua investigated.

Coronal parameters in local Seyfert galaxies



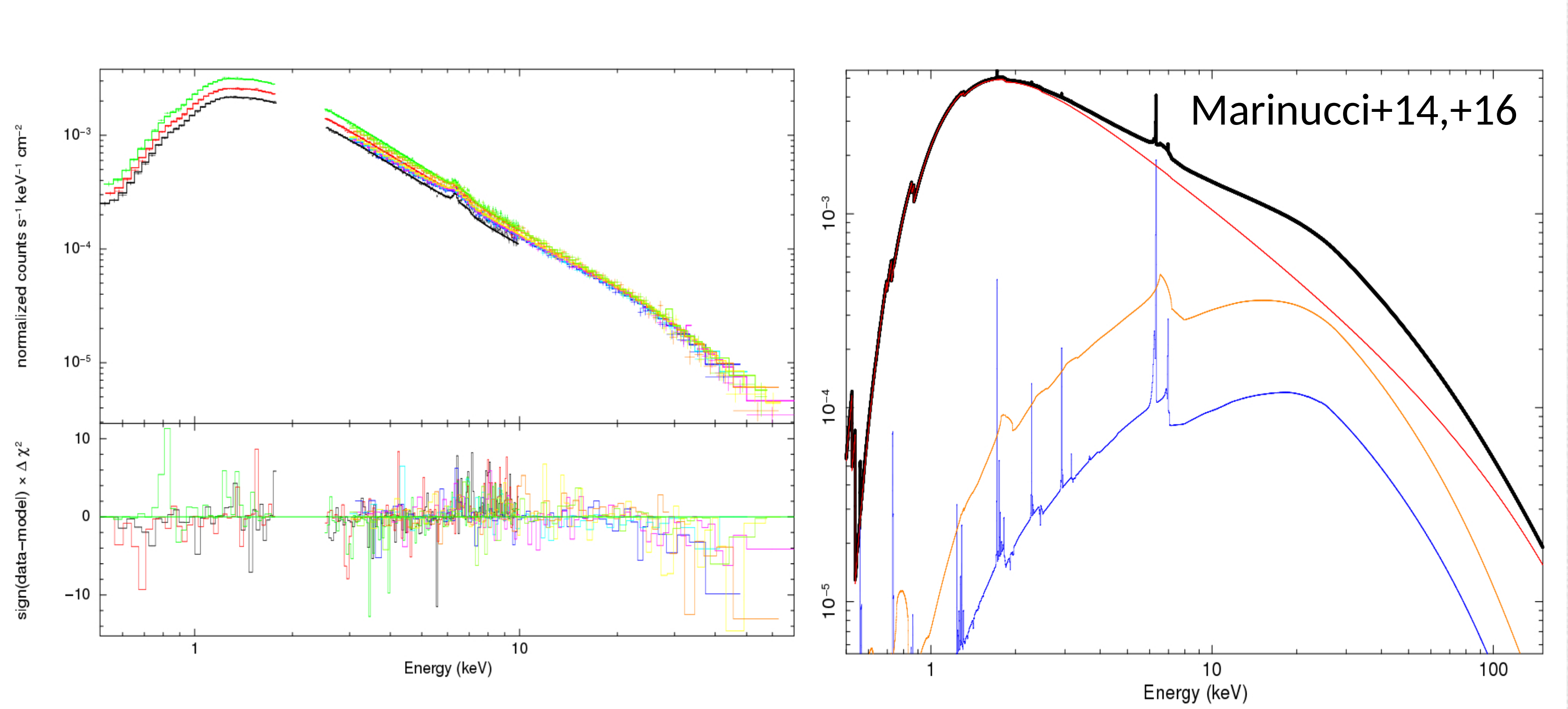
Fabian+15





(Middei+; Tortosa+, in prep.)

Coronal parameters (Swift J2127.4+5654)



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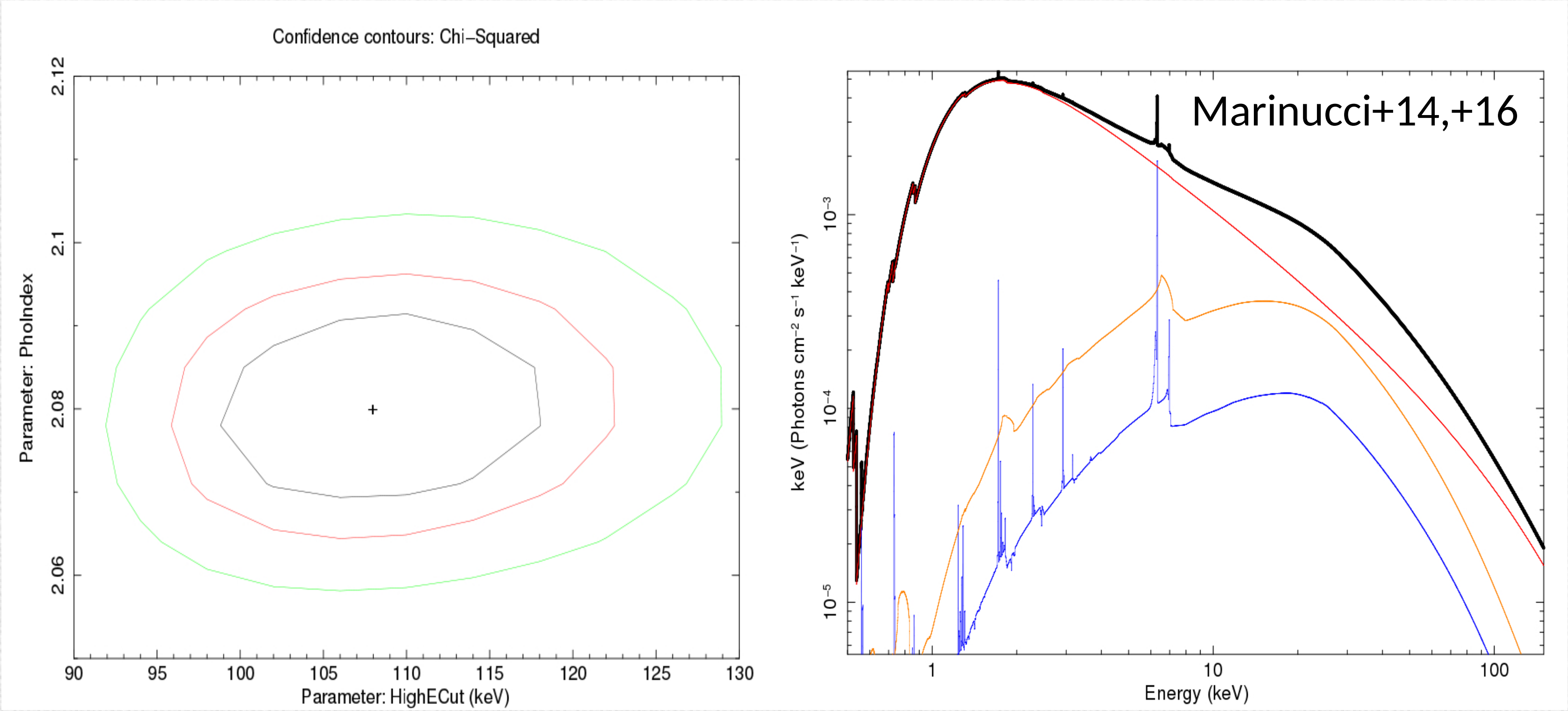


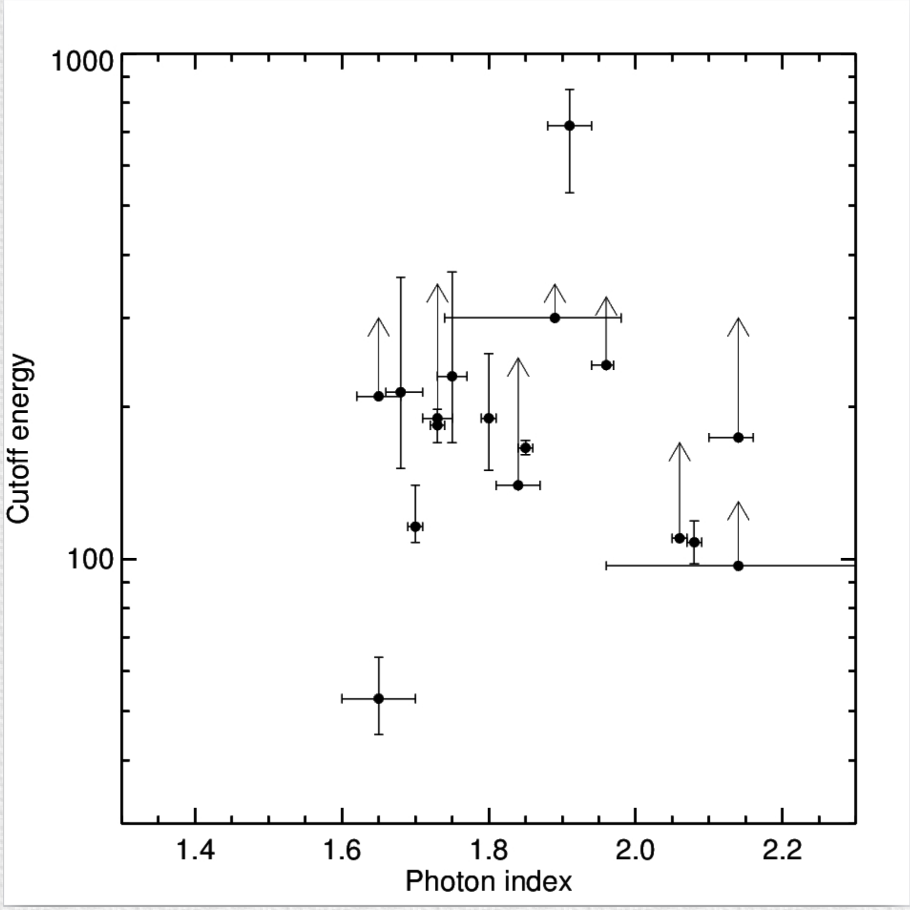
Using compTT (Titarchuk+94) with two different geometries we get:

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

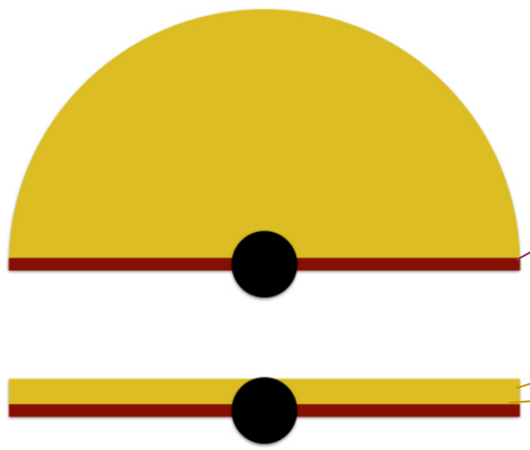
The τ-kT_e diagram (in a slab geometry)

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?



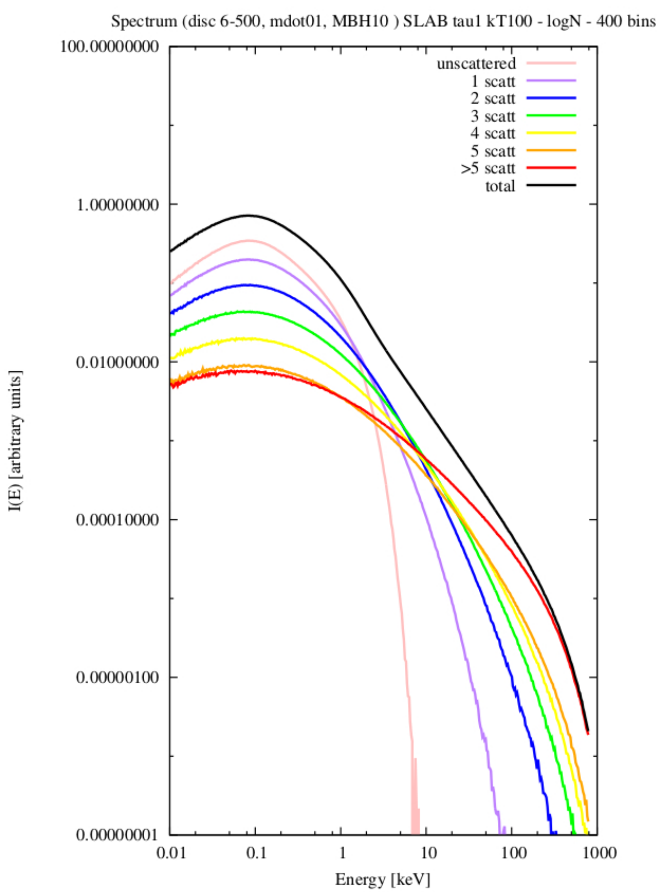
A MC code for Comptonization in Astrophysics (MoCA)



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

kT_e

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



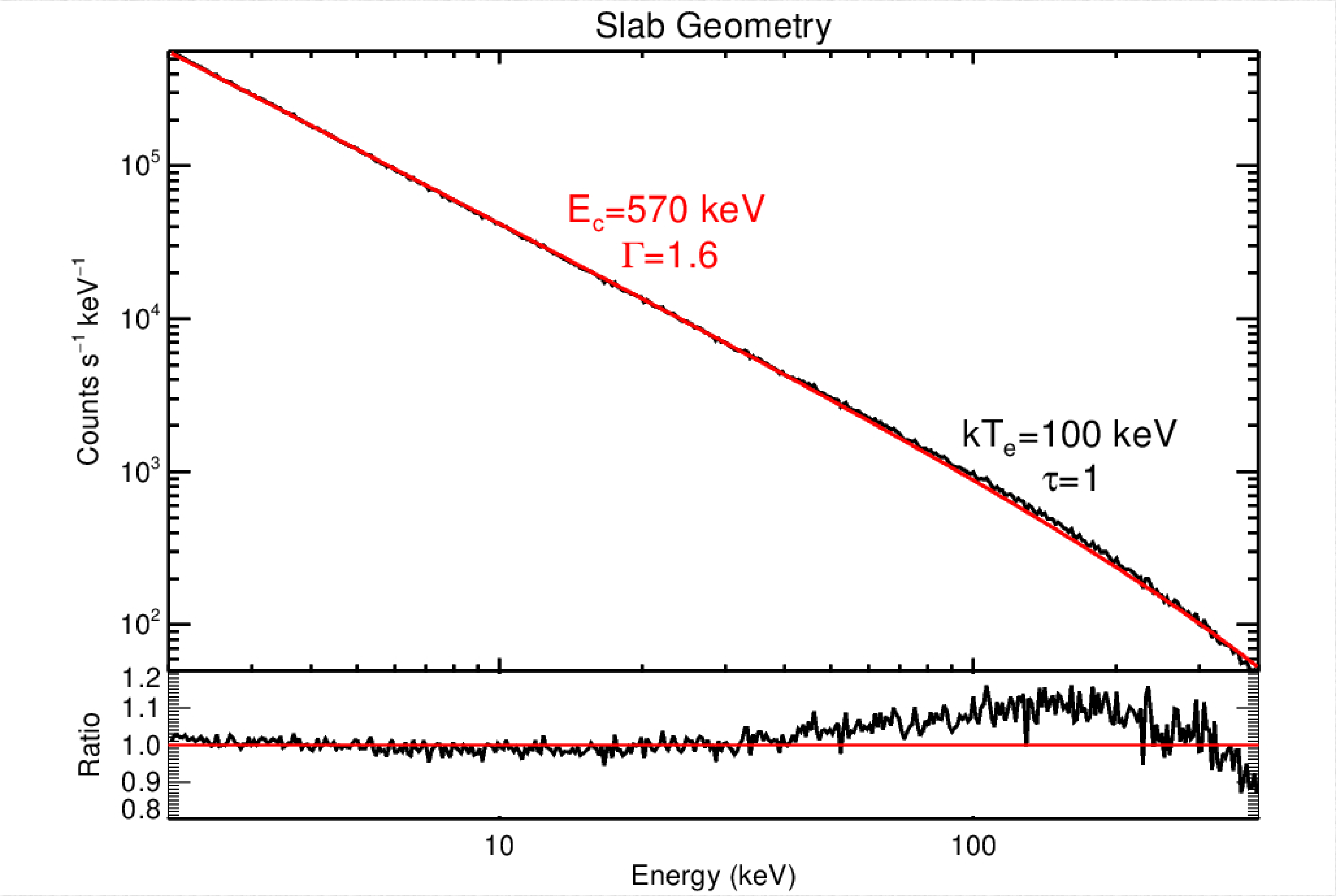
Assumptions and advantages:

1. Shakura-Sunyaev neutral accretion disc
2. Extended coronae
3. Single photon approach
4. Polarization signal

Tamborra+, submitted

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; $\tau=1$

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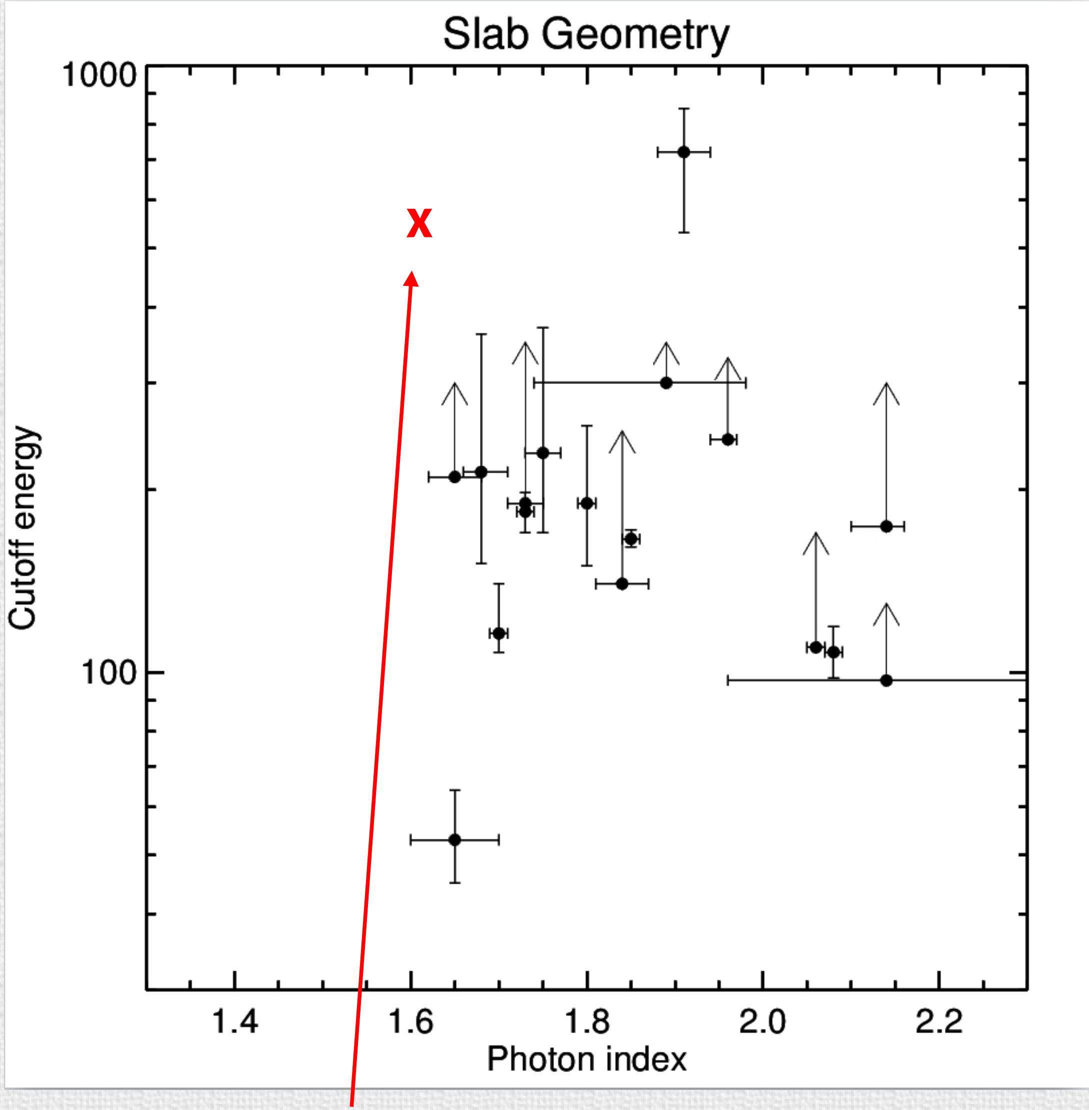

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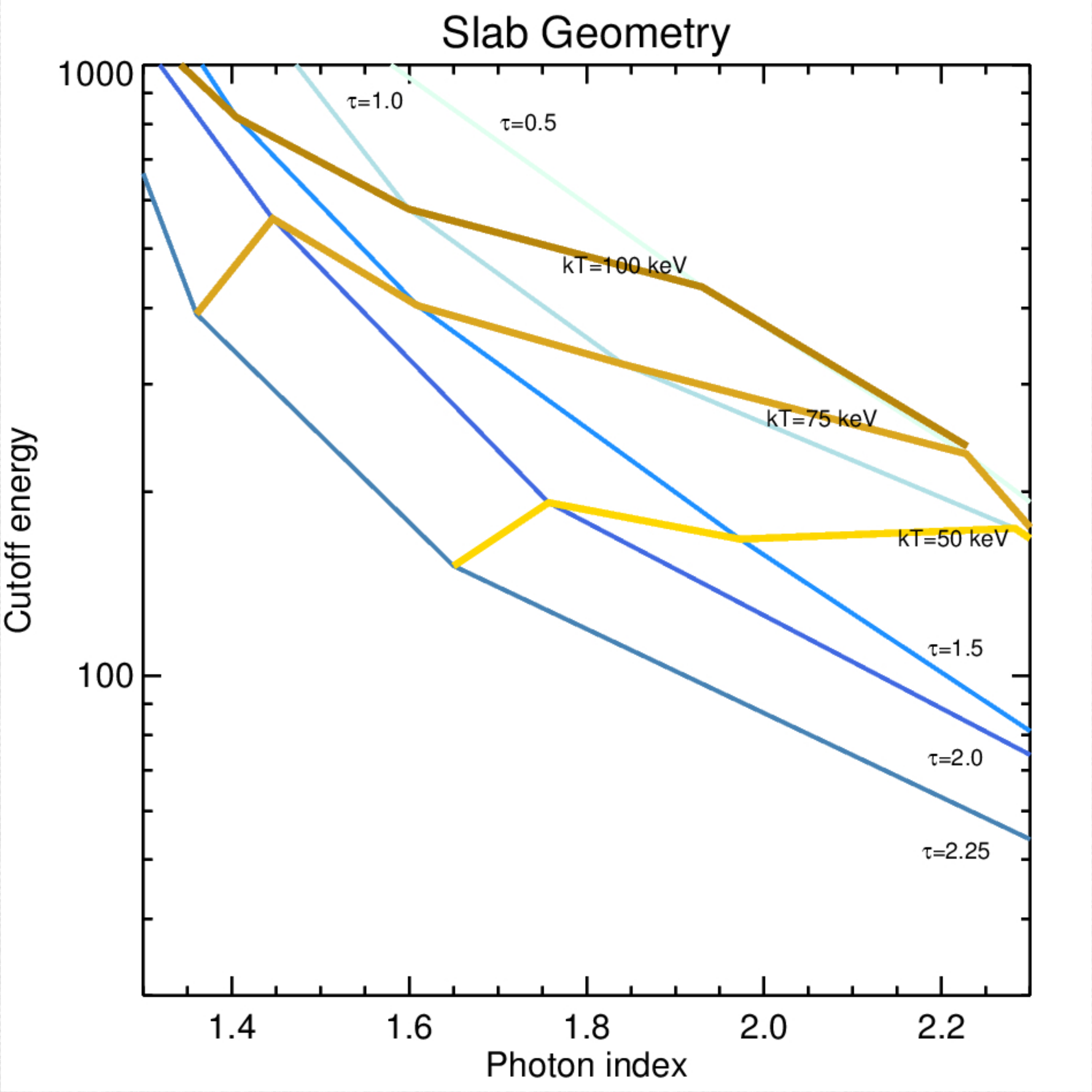
The τ-kT_e diagram in AGN

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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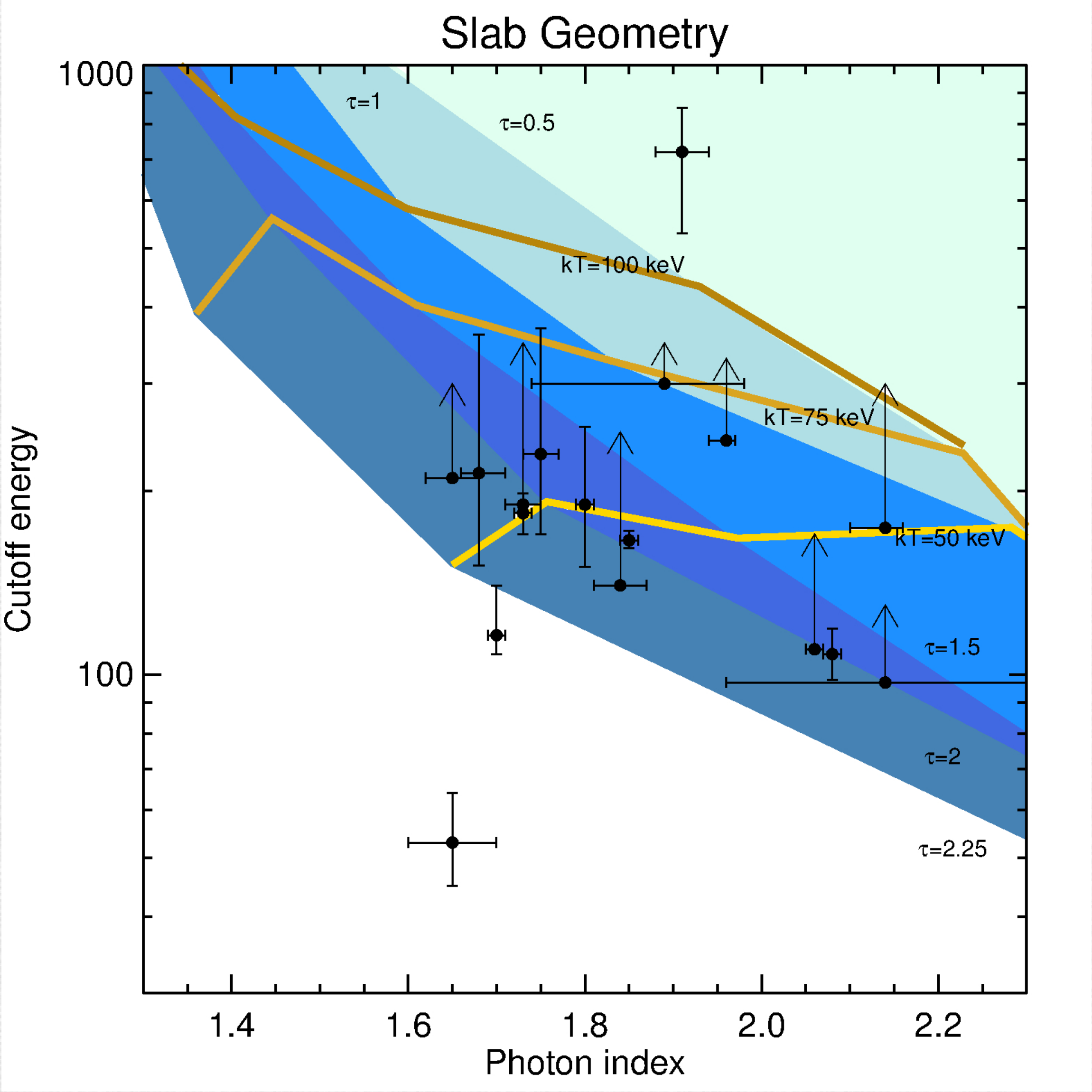
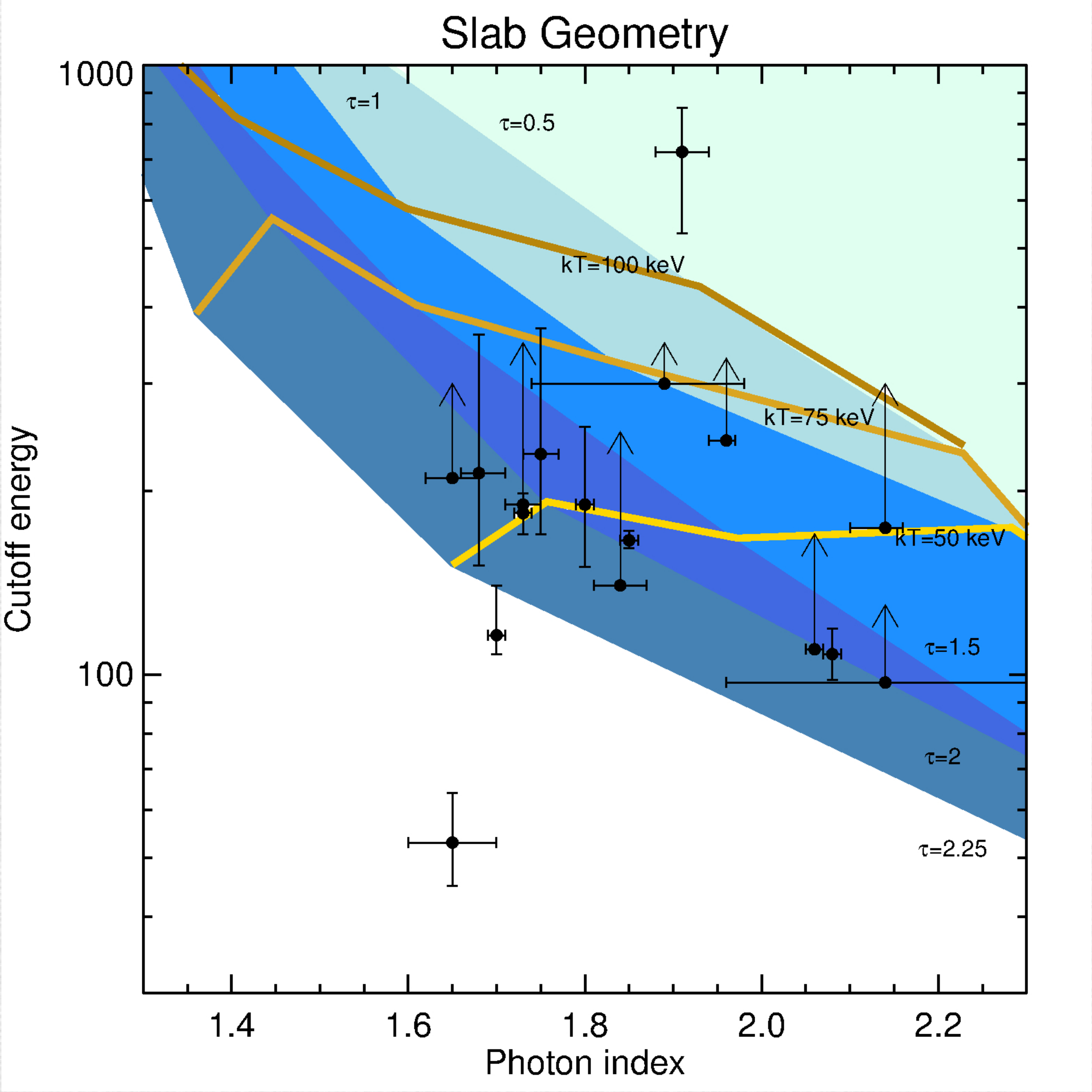


Middei+, in prep.

The τ-kT_e diagram in AGN

We can define the most populated region in both slab and spherical geometries but we cannot discriminate between the two.



Middei+, in prep.

A fresh pair of eyes: X-ray polarimetry

Polarisation sensitivity	1.8 % MDP for $2x10^{-10}$ erg/s cm^2 (10 mCrab) in 300 ks (CBE)
Spurious polarization	<0.3 %
Number of Telescopes	3
Angular resolution	28'' (CBE)
Field of View	12.9x12.9 $arcmin^2$
Focal Length	4 meters
Total Shell length	600 mm
Range Shell Diameter	24 shells, 272-162 mm
Range of thickness	0.16-0.26 mm
Effective area at 3 keV	854 cm^2 (three telescopes)
Spectral resolution	16% @ 5.9 keV (point source)
Timing	Resolution <8 μs
	Accuracy 150 μs
Operational phase	2 yr
Energy range	2-8 keV
Background (req)	$5x10^{-3}$ c/s/cm2/keV/det
Sky coverage, Orbit	50 %, 540 (0^o)

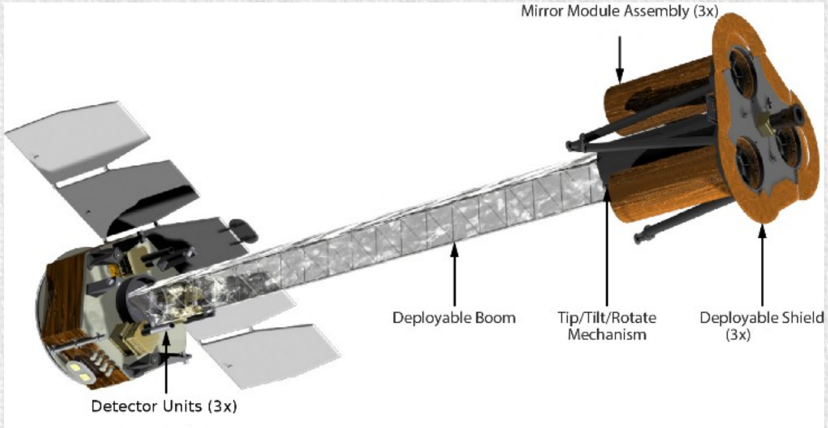
IXPE

(Imaging X-ray Polarimetry Explorer)

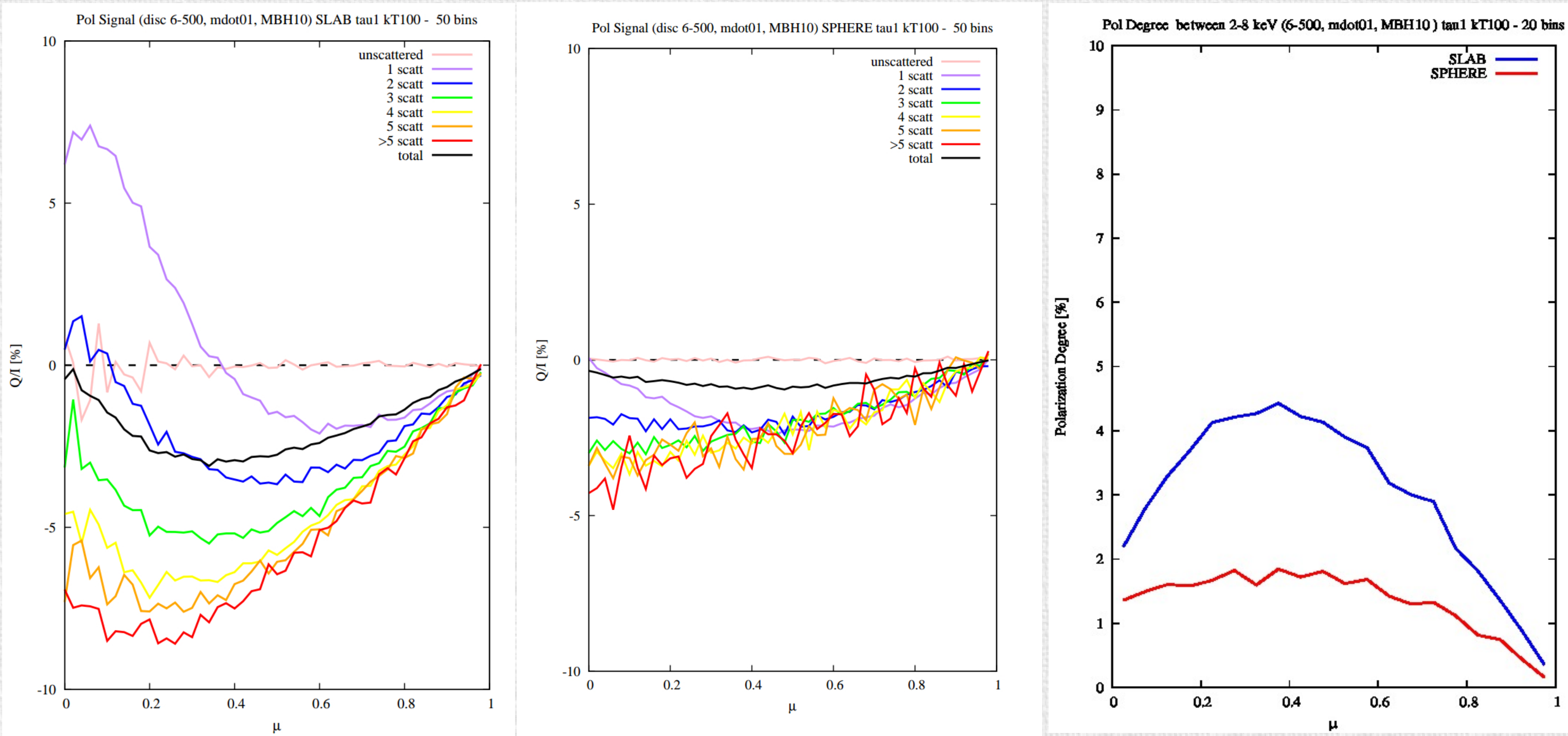
Selected by NASA (SMEX) for a launch in early 2021

P.I.: Martin Weisskopf (MSFC)

It will re-open the X-ray polarimetry window!



A fresh pair of eyes: X-ray polarimetry

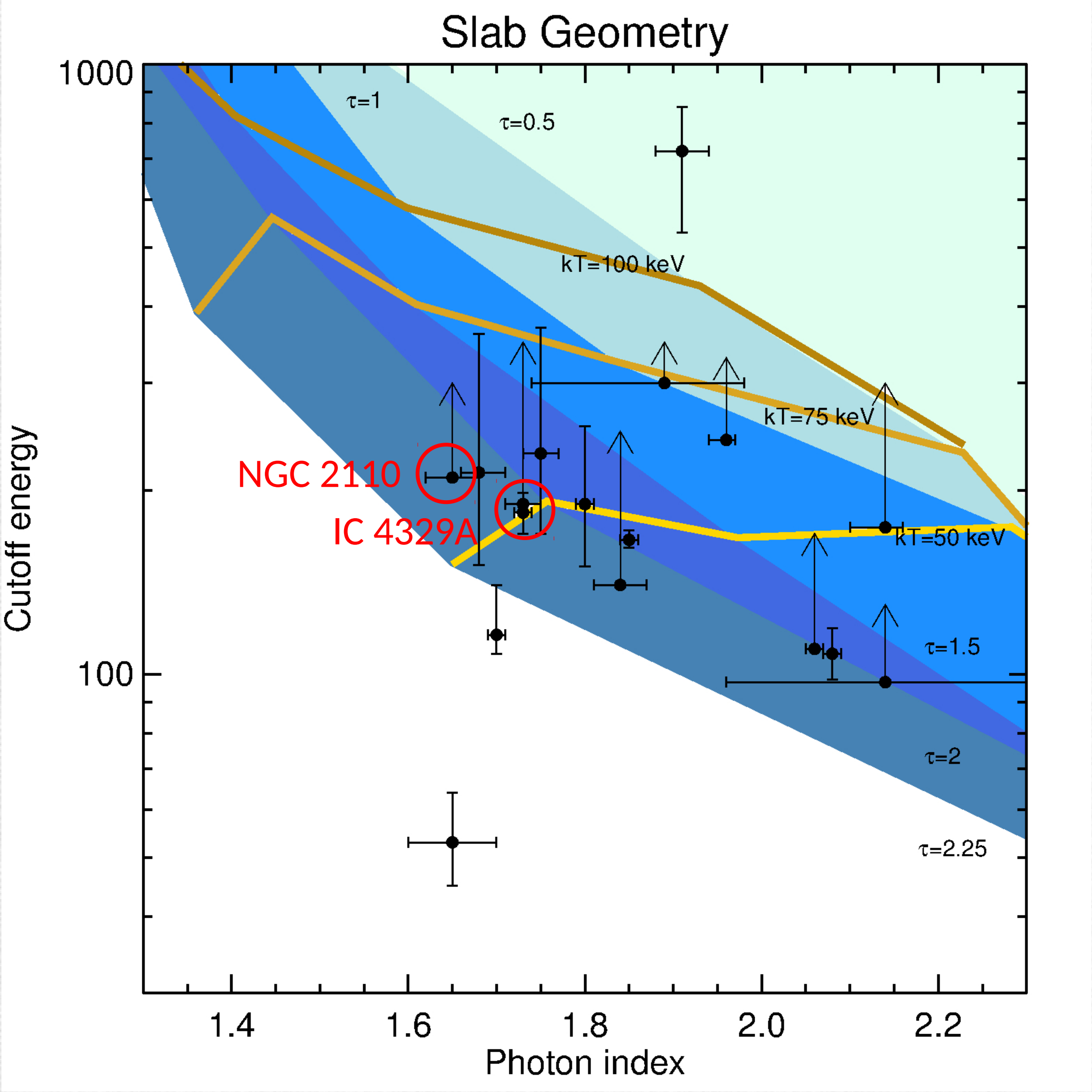


Tamborra+, subm.

Since I is proportional to the intensity of the polarized component and Q is related to the angle of polarization their ratio contains information about the polarized signal after each scattering.

A fresh pair of eyes: X-ray polarimetry

We focus on the brightest Seyfert 1 and 2 objects of the sample (NGC 2110 and IC 4329A):

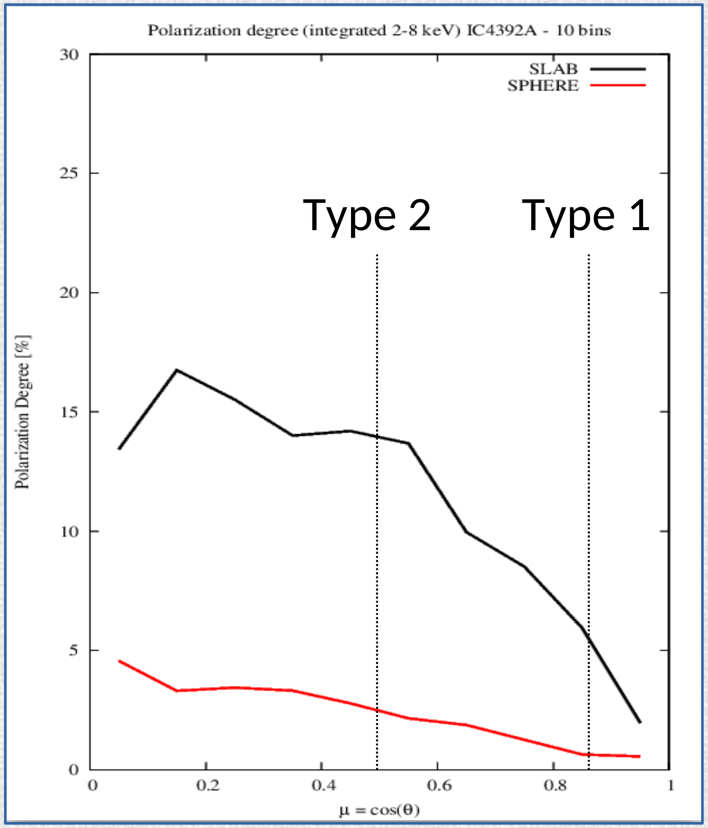


Middei+, in prep.

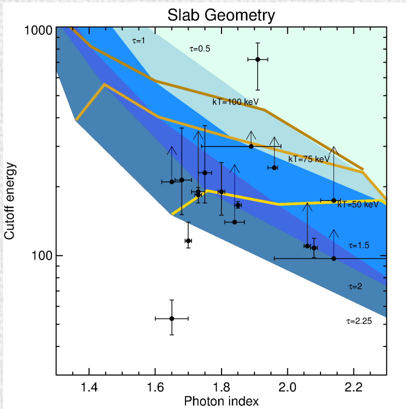
A fresh pair of eyes: X-ray polarimetry

We focus on the brightest Seyfert 1 and 2 objects of the sample (NGC 2110 and IC 4329A) and retrieve observing times to obtain an MDP=2%: this should suffice in distinguishing between the two models.

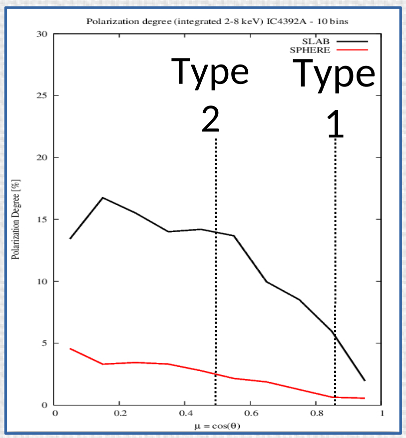
Source	Γ	E_c [keV]	F_{2-8keV} (erg cm^{-2} s^{-1})	Exposure time (ks)
NGC 2110	1.65 ± 0.03	> 210	1.04×10^{-10}	450
IC 4329A	1.73 ± 0.01	184 ± 14	1.00×10^{-10}	450



Conclusions



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



X-ray polarimetry will be the next tool to reveal the geometry of the coronae in AGN

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