Estimating coronal parameters using MoCA

a MonteCarlo code for accretion in astrophysic

Riccardo Middei

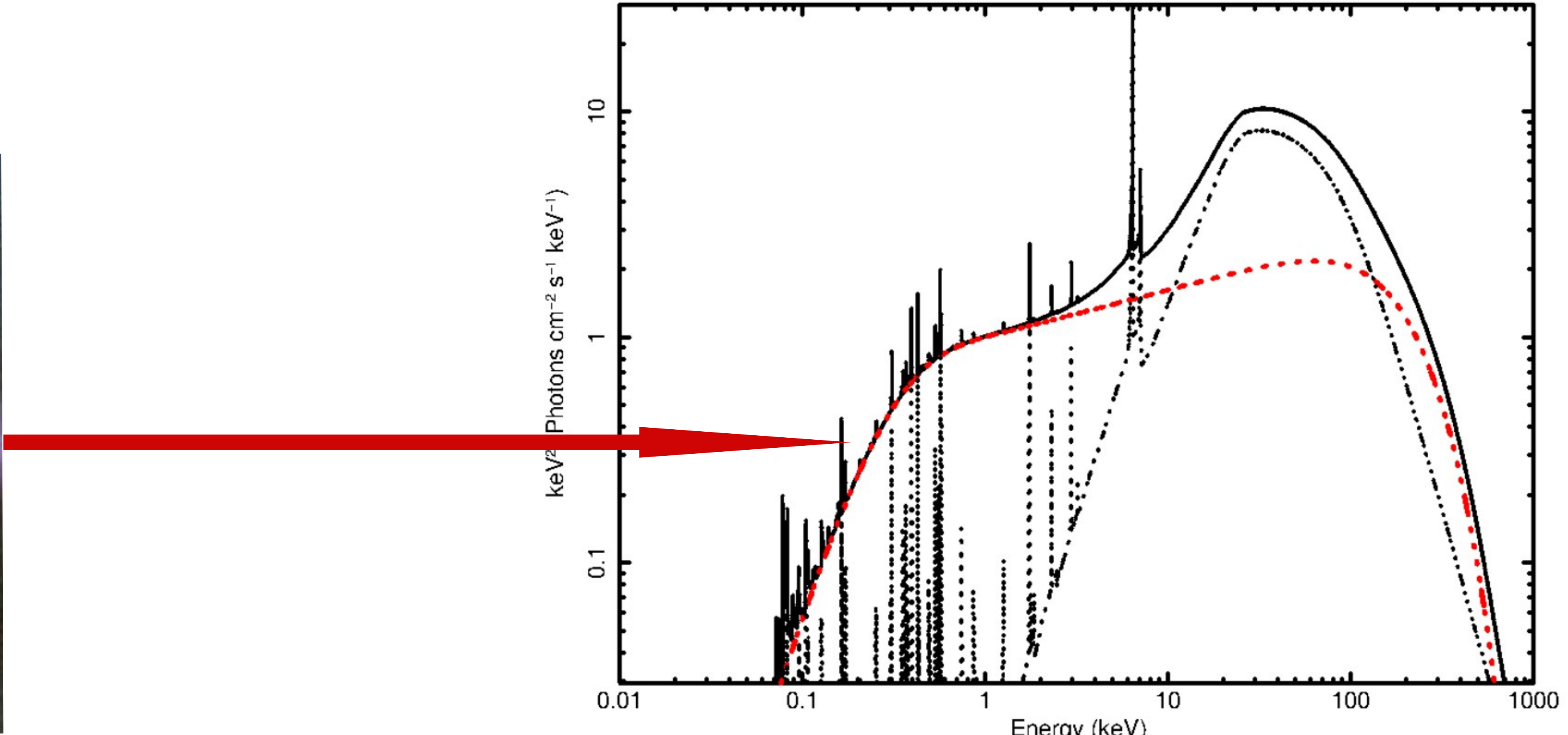
Stefano Bianchi, Giorgio Matt,
Andrea Marinucci, Francesco Tamborra
Alessia Tortosa

AGN13
BEAUTY and the BEAST

ROMA TRE
UNIVERSITÀ DEGLI STUDI

The Complex AGN spectrum:

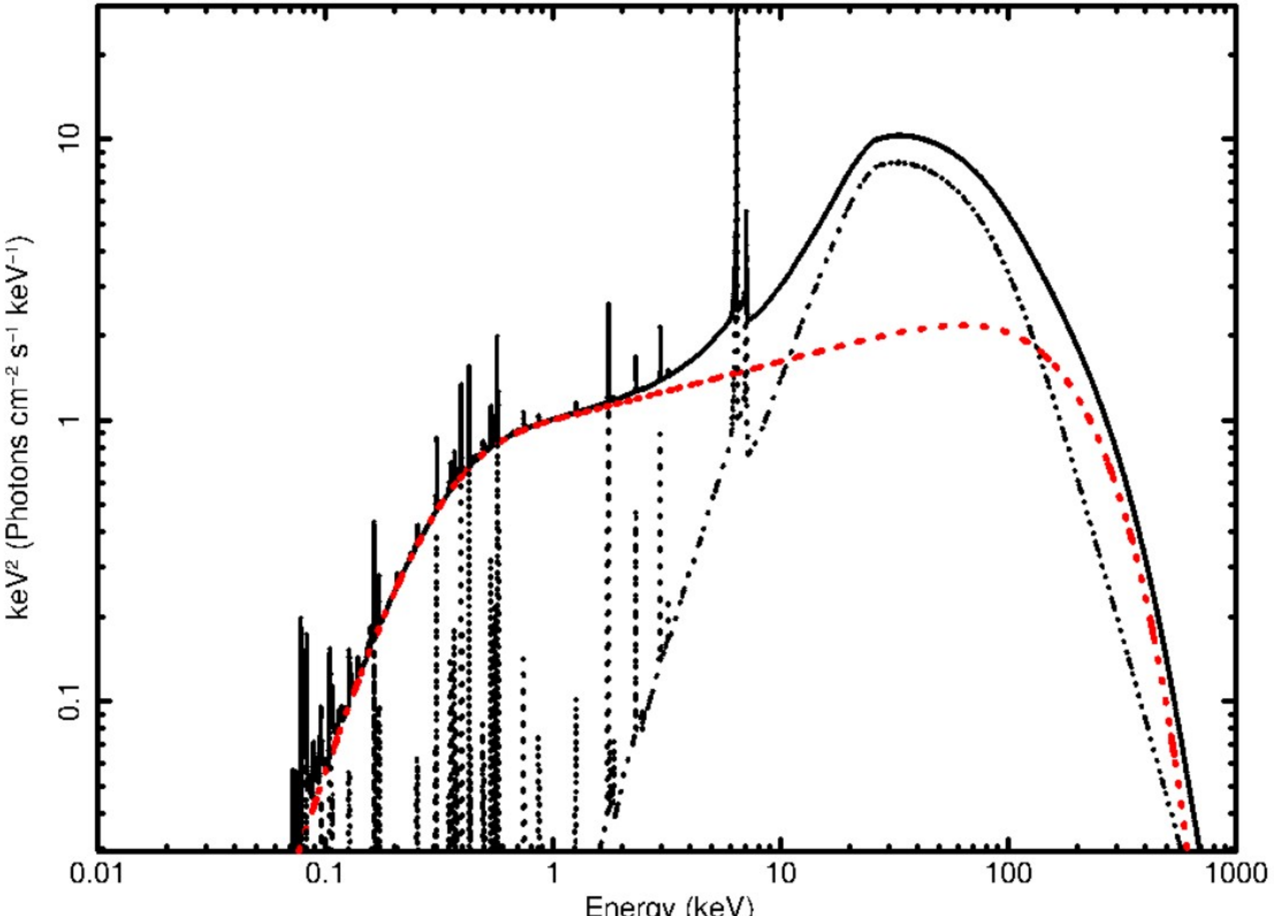
AGN X-ray continuum can be interpreted as the effect of inverse-Compton scattering



The Complex AGN spectrum:

AGN X-ray continuum can be interpreted as the effect of inverse-Compton scattering

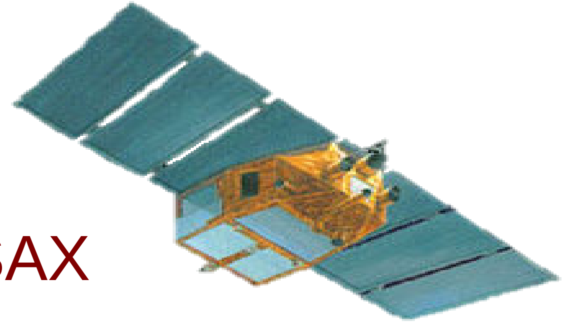
Properties of the emitting corona are largely unknown.



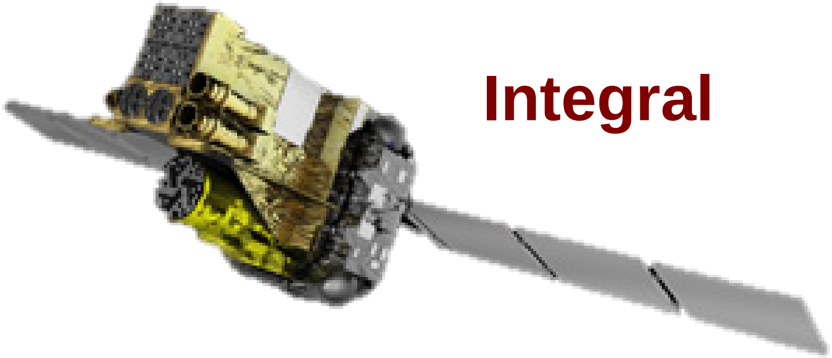
Various high energy cut-off estimates

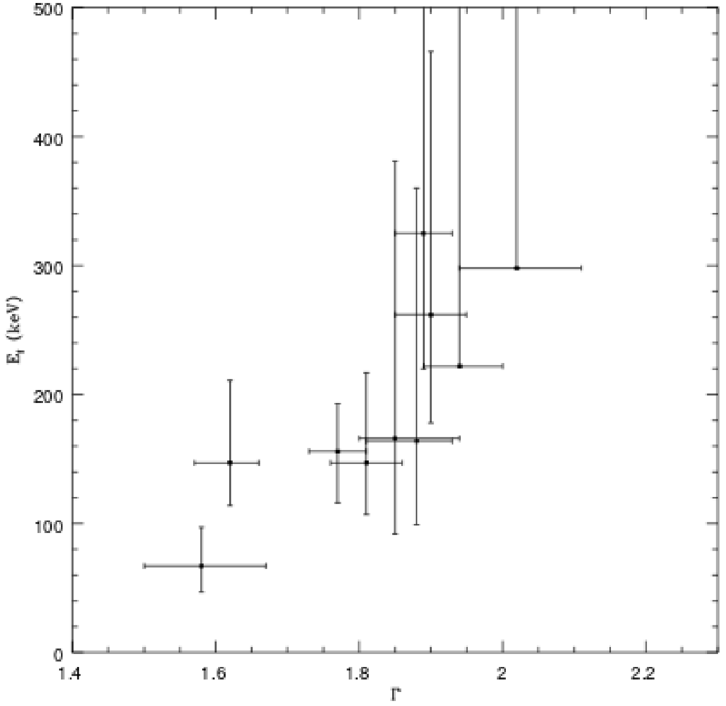
results based on non focusing satellites

BeppoSAX

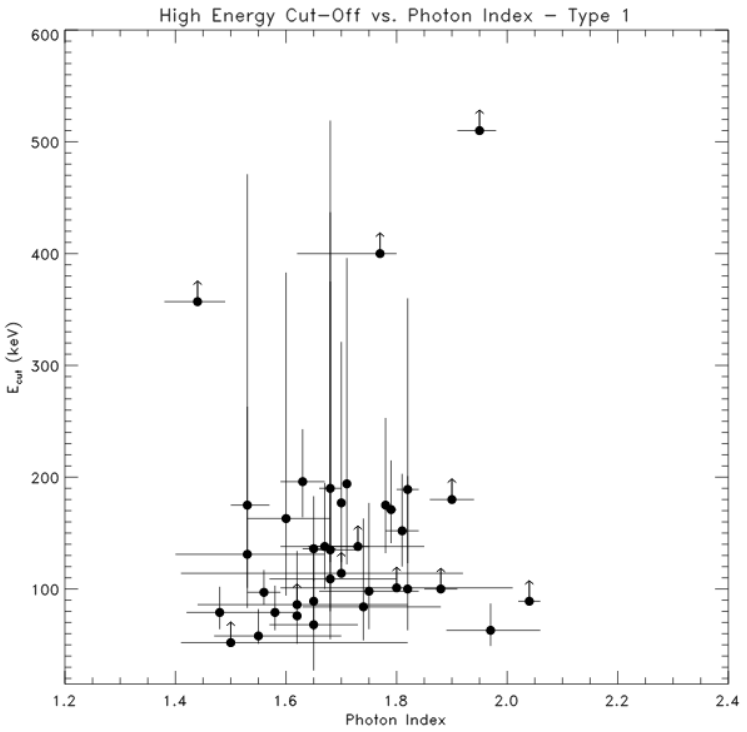


Integral





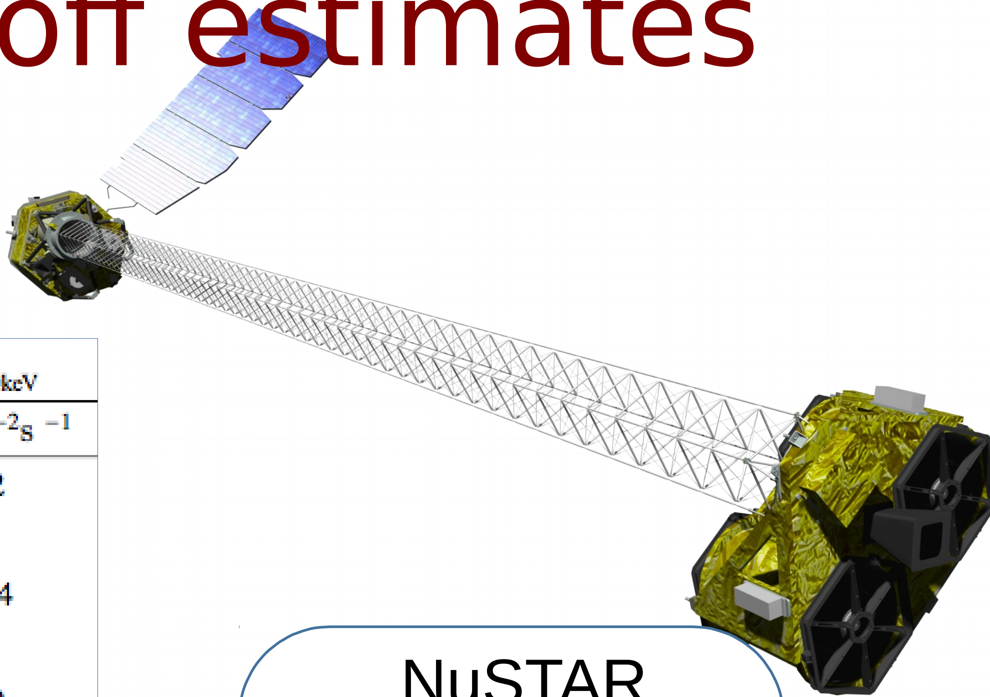
Perola et al., 2002



A. Malizia et al., 2014. see also De Rosa et. al., 2012 Molina et al., 2013

Various high energy cut-off estimates

a number of cut-off measurements in AGN



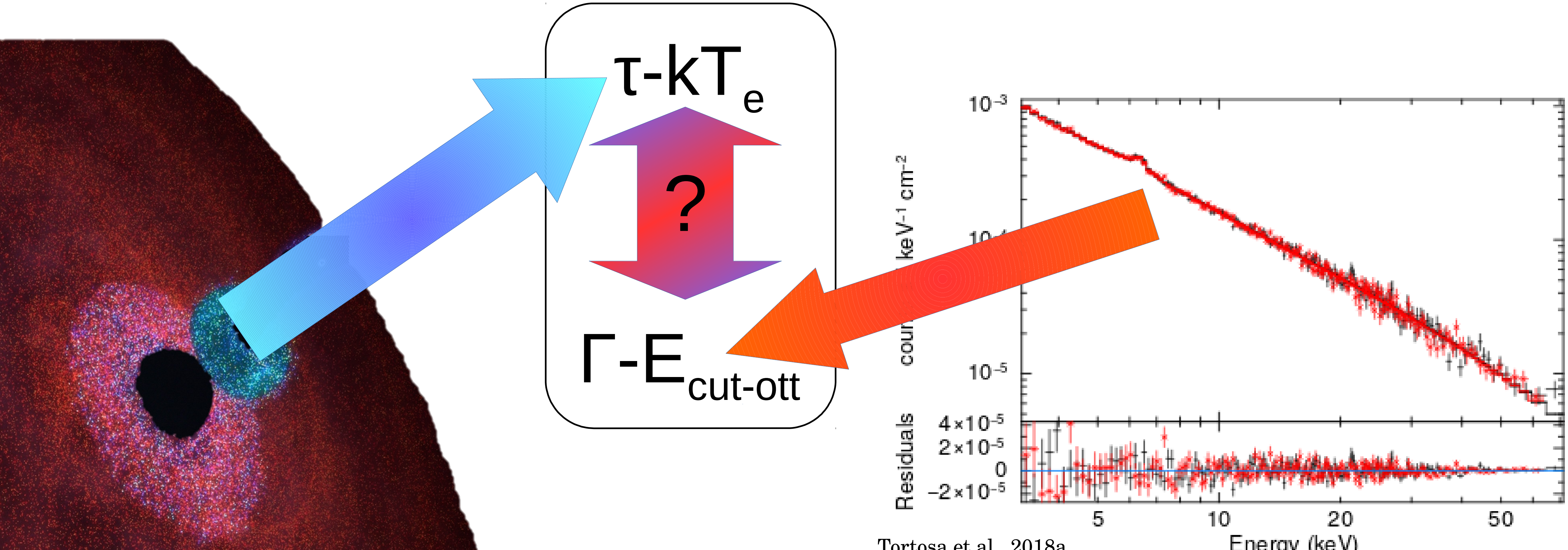
Source	Ref.	Γ	E_c	$\log(M_{bh}/M_\odot)$	Ref.	L_{bol}/L_{Edd}	$L_{2-10keV}$	$F_{2-10keV}$
Adapted from Tortosa et al. 2018			[keV]				ergs s^{-1}	erg $cm^{-2}s^{-1}$
NGC 5506	1	1.91 ± 0.03	720^{+130}_{-190}	8.0 ± 0.2	(A)	0.006	0.053	6.2
MCG -05-23-16	2	1.85 ± 0.01	170 ± 5	7.7 ± 0.2	(B)	0.058	0.18	10.4
SWIFT J2127.4	3-4	2.08 ± 0.01	180^{+75}_{-40}	7.2 ± 0.2	(J)	0.136	0.14	2.9
IC4329A	5-6	1.73 ± 0.01	185 ± 15	8.08 ± 0.3	(N)	0.125	0.56	12.0
3C390.3	7	1.70 ± 0.01	120 ± 20	8.4 ± 0.4	(H)	0.241	1.81	4.03
3C382	8	1.68 ± 0.03	215^{+150}_{-60}	9.2 ± 0.5	(D)	0.072	2.34	2.9
GRS 1734-292	9	1.65 ± 0.05	53 ± 10	8.5 ± 0.1	(L)	0.036	0.056	2.9
NGC 6814	10	1.71 ± 0.04	135^{+70}_{-35}	7.0 ± 0.1	(C)	0.003	0.021	0.2
MCG +8-11-11	10	1.77 ± 0.04	175^{+110}_{-50}	7.2 ± 0.2	(E)	0.754	0.51	5.6
Ark 564	11	2.27 ± 0.08	42 ± 3	6.8 ± 0.5	(H)	1.313	0.39	-
PG 1247+267	12-13	2.35 ± 0.09	90^{+130}_{-35}	8.9 ± 0.2	(M)	0.024	0.79	0.05
Ark 120	14-15	1.87 ± 0.02	180^{+80}_{-40}	8.2 ± 0.1	(H)	0.085	0.92	2.3

NuSTAR
high energy
cut-off

Tortosa et al., 2018

See also
Fabian et al., 2015,2017

Shall we connect phenomenological parameters such as the photon index and the high energy cut-off with the physics of the Comptonising corona?



Adapted from King et al. 2017

Tortosa et al., 2018a

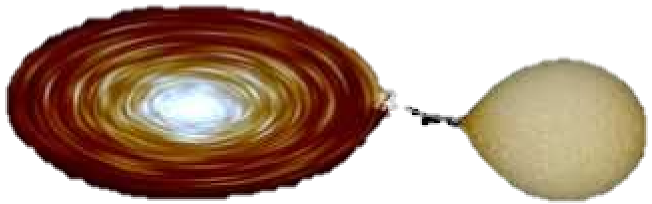
MoCA:
a Monte Carlo code for accretion in Astrophysics

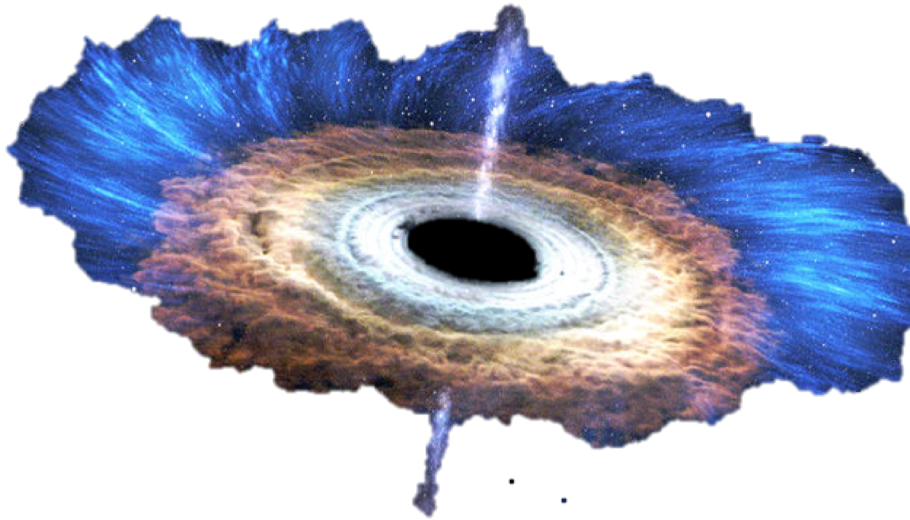
Tamborra et al., 2018

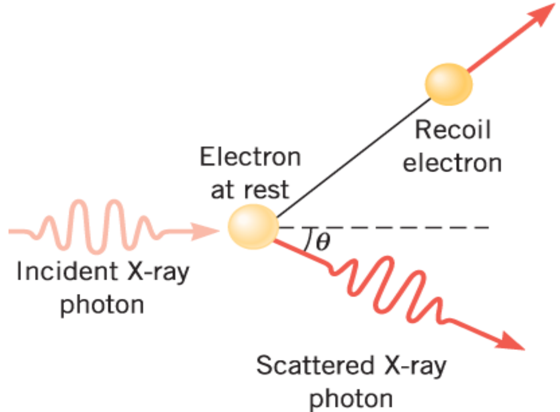
Assumptions:

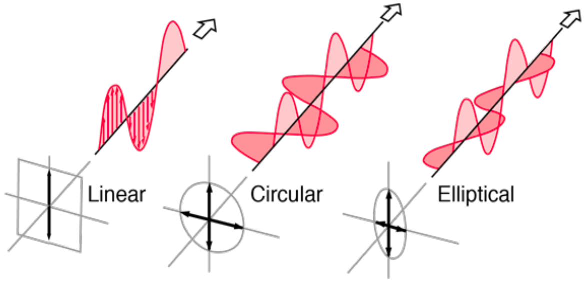
1. Shakura-Sunyaev neutral accretion disc
2. Extended coronae
3. Single photon approach
4. Full special relativity included
5. Polarization signal

Suitable for studying various astrophysical sources

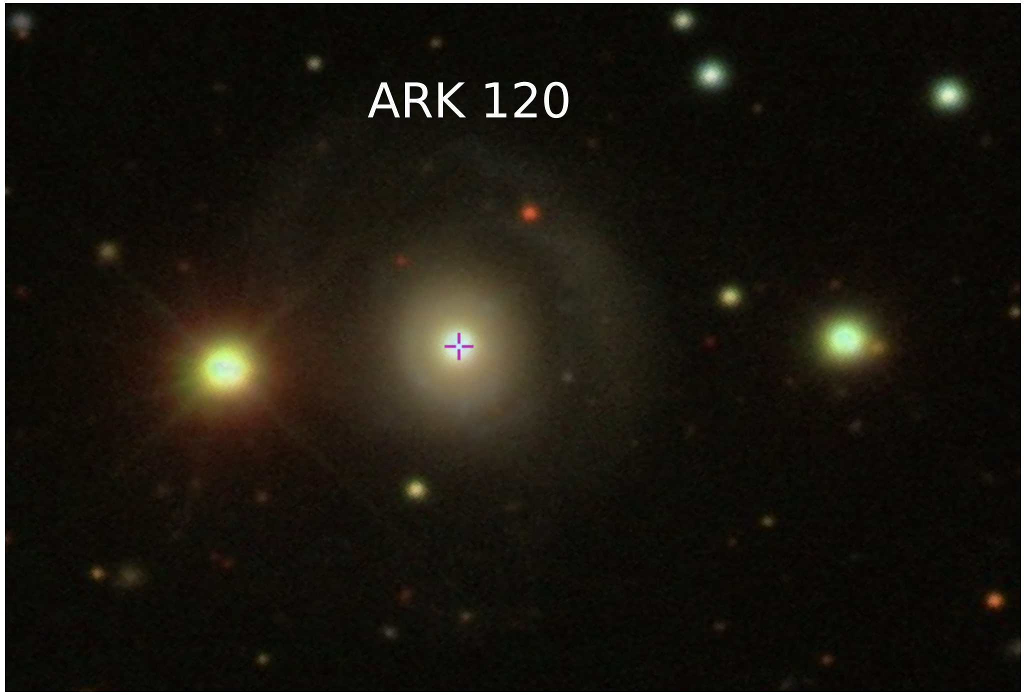








Tuning MoCA:



Step 1: AGN properties

M_{BH}=1.5x10^8 M_O

M=0.01 in units of L/L_{edd}

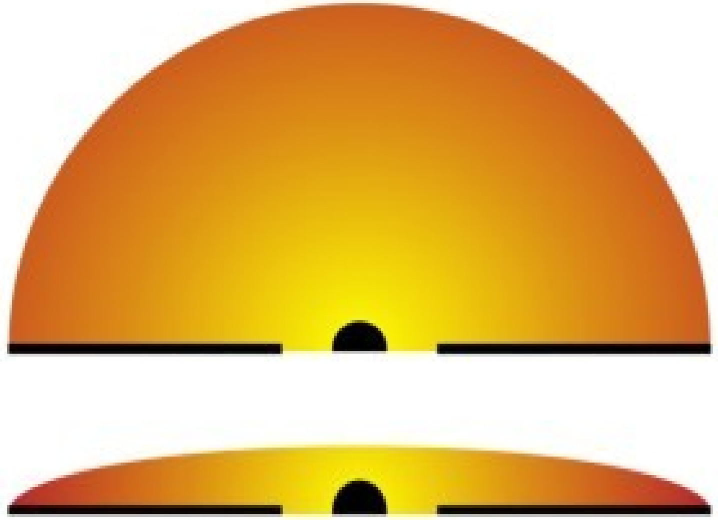
as for Ark120

e.g. Porquet et al., 2018,

Reeves et al., 2016 Nardini et al., 2016

Lobban, et al., 2017

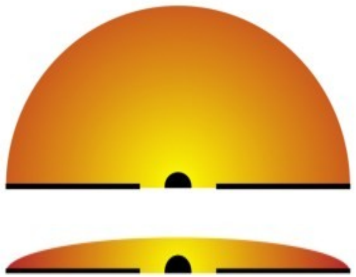
Step 2: Assuming a geometry

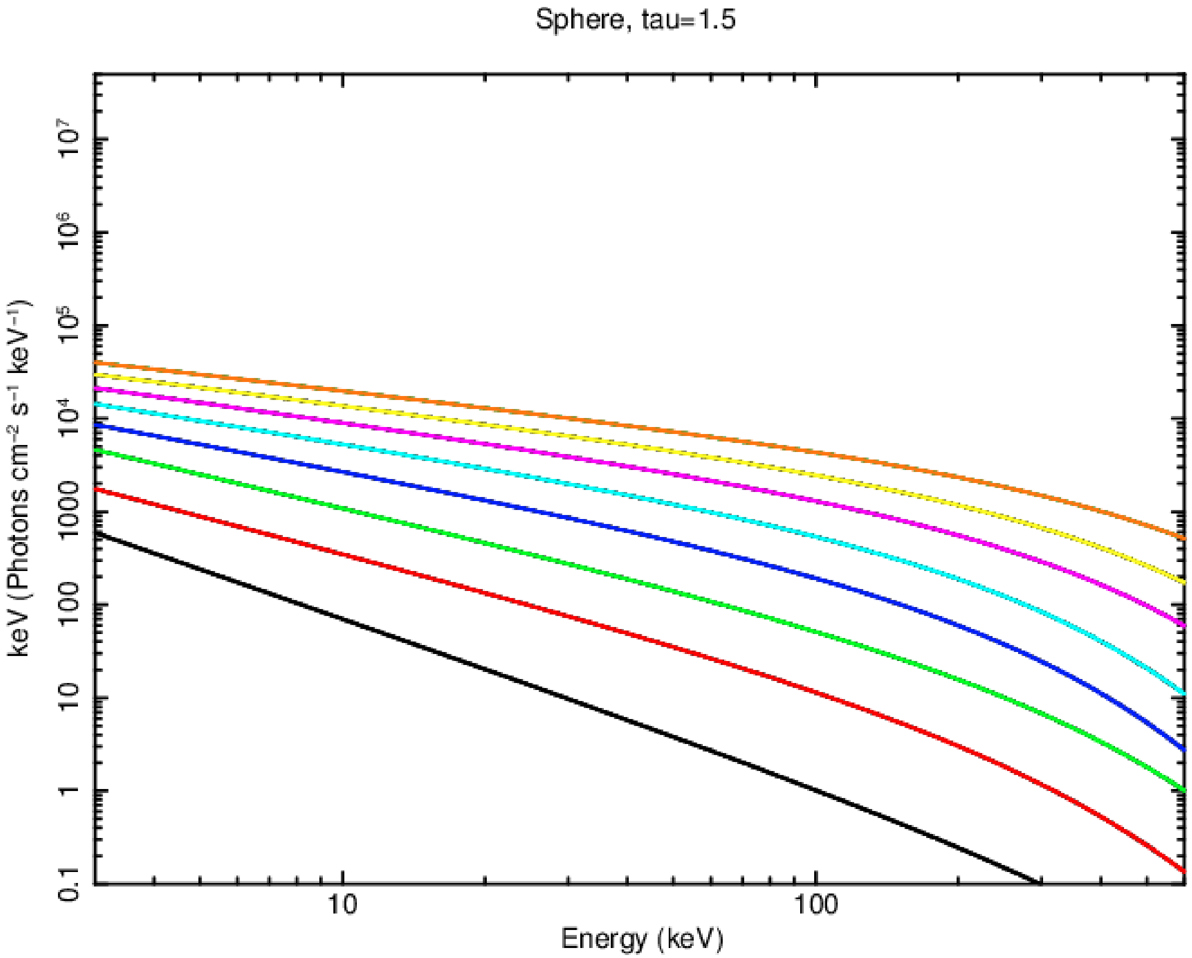


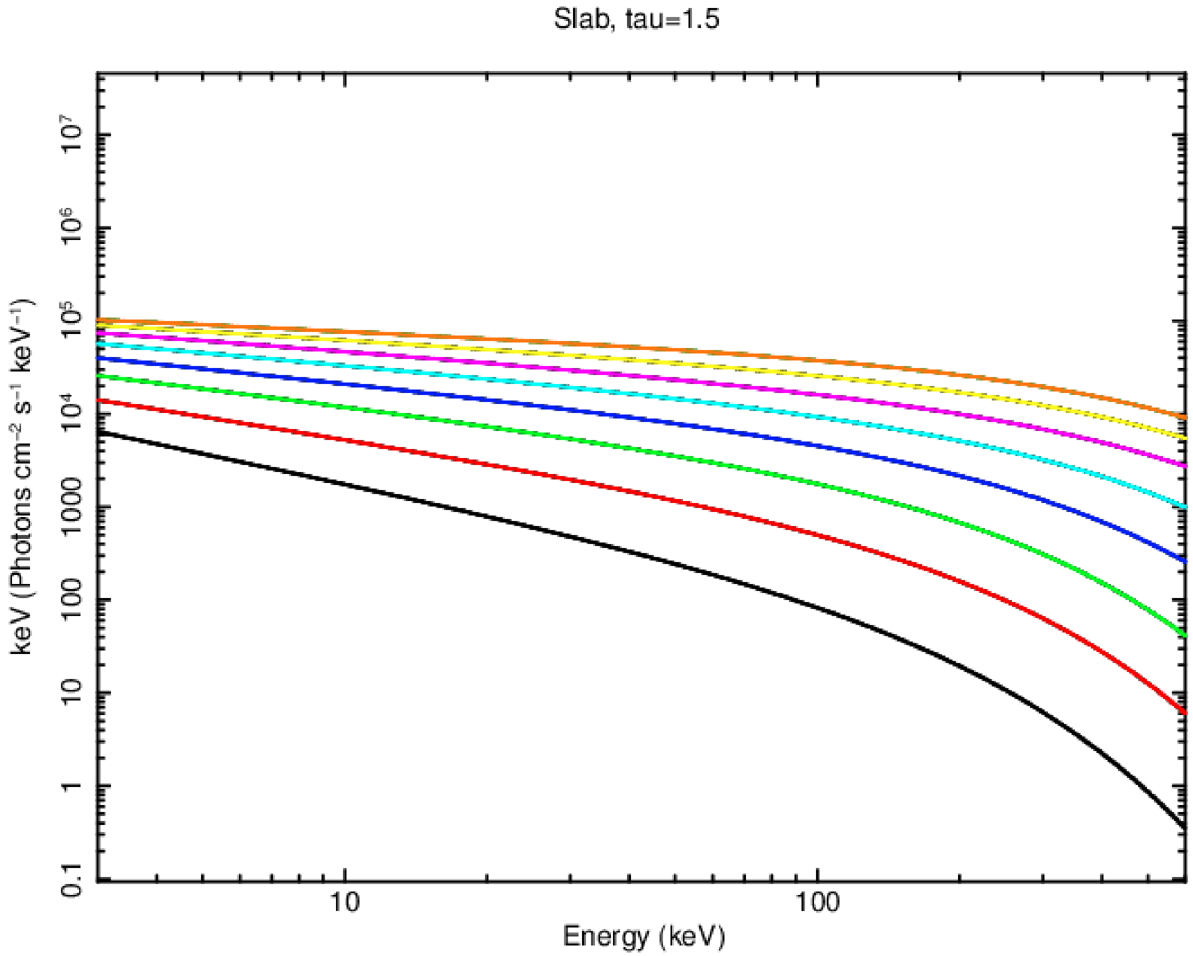
Sphere geometry
$0.5<\tau<7$
10<kT<120 keV
R_{in}=6 R_{grav}
R_{out}=500 R_{grav}

Slab geometry
$0.5<\tau<4.5$
10<kT<120 keV
H=10 R_{grav}
R_{in}=6 R_{grav}
R_{out}=500 R_{grav}

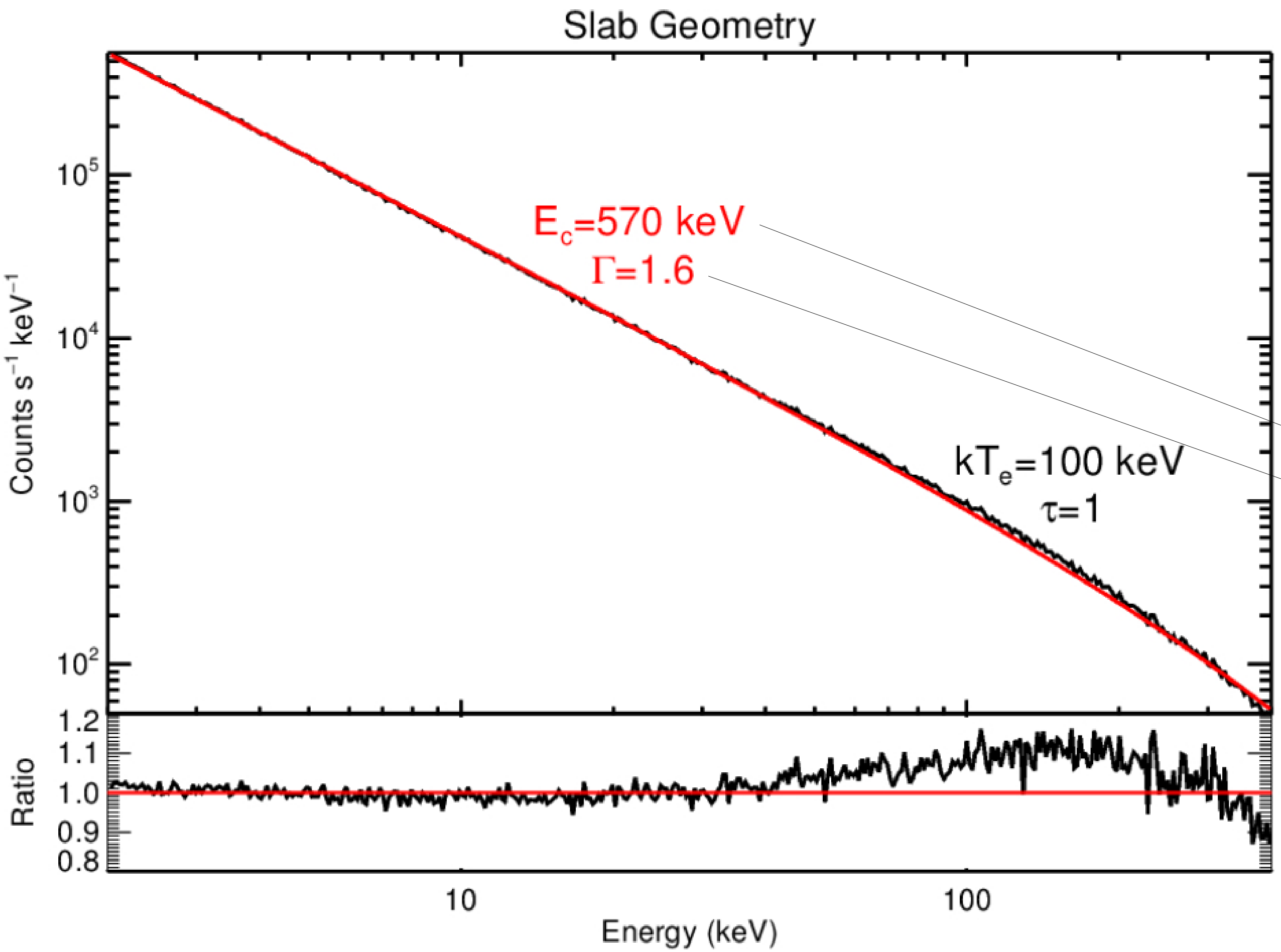
Step 3:Running simulations



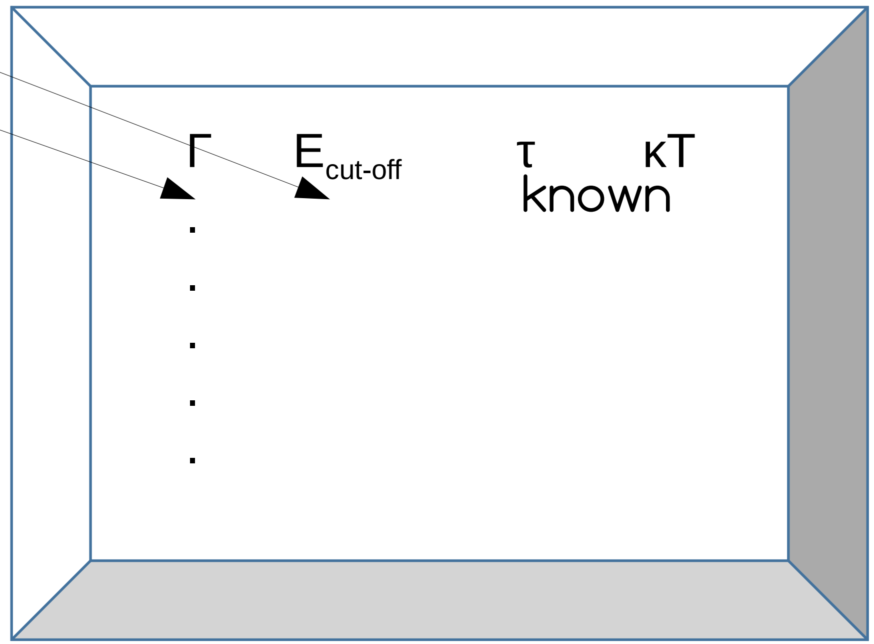




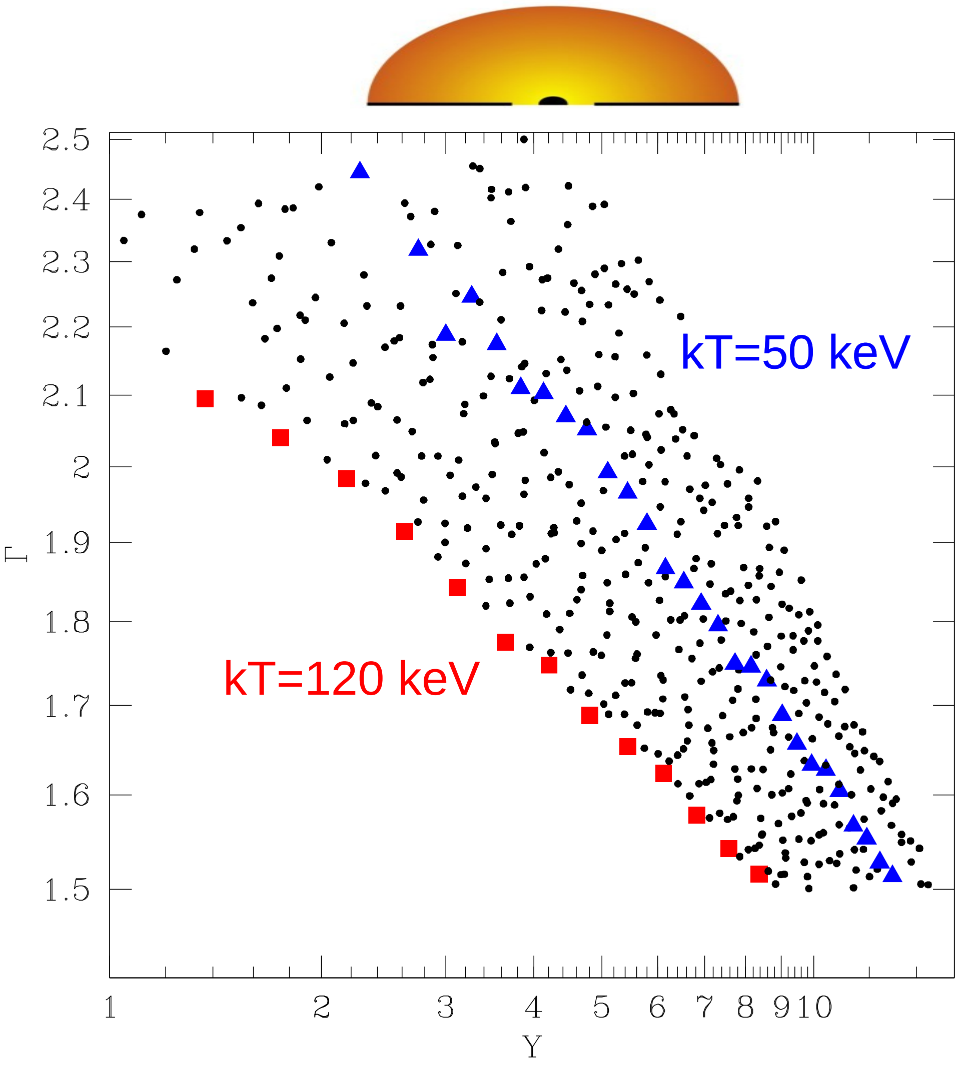
Step 4: fitting synthetic spectra with a cut-off power-law



Parameters are accepted and stored



Connecting the spectral Γ with τ and y

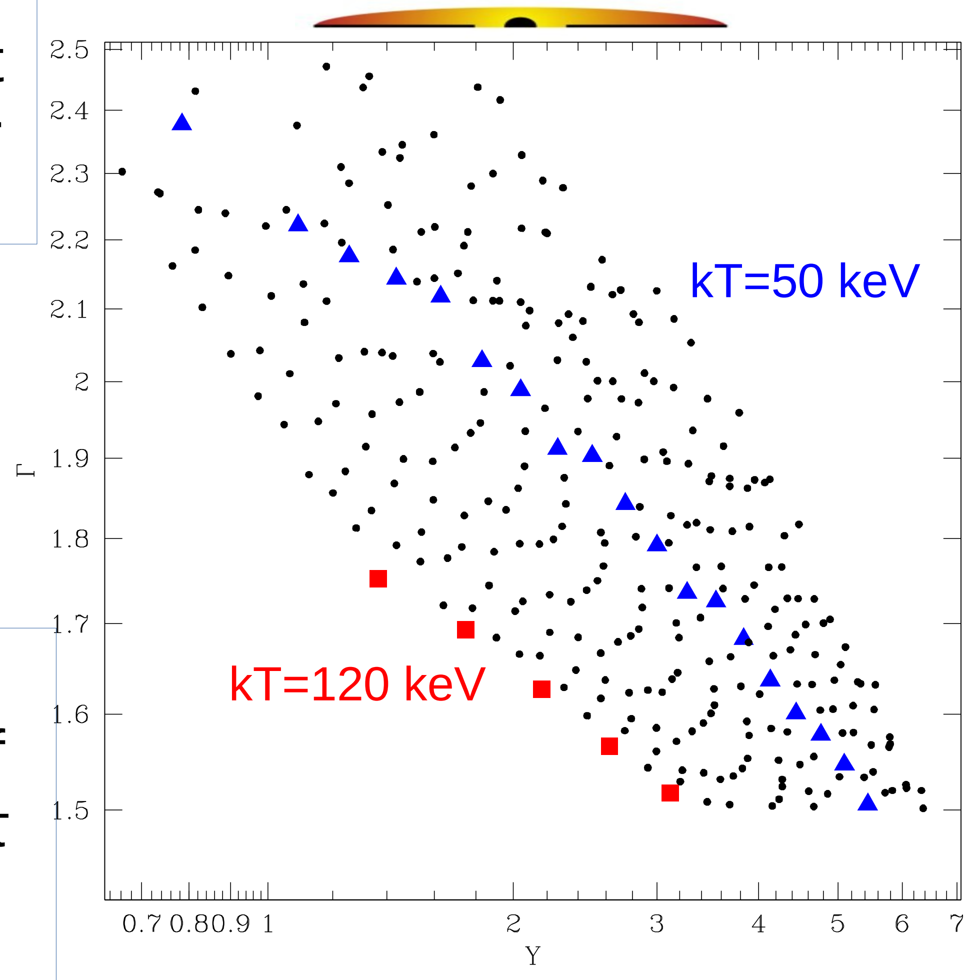


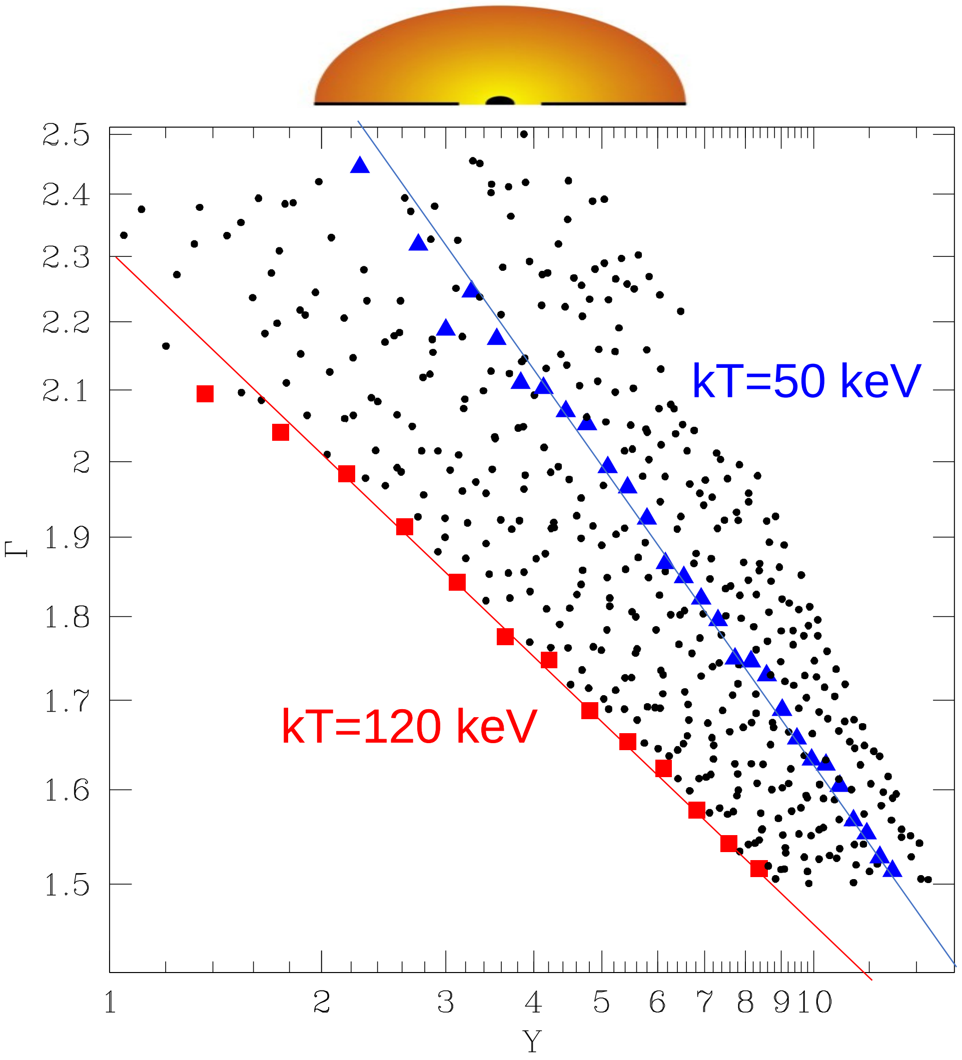
For each $E_{cut\text{-}off}$ -Γ couple, we computed y.
Then fixing kT, we plot Γ as a function of y for various τ

We performed fits of Γ-y as a function of τ for all the kT

$$y = 4(\theta_e + 4\,\theta_e^2)\tau_T(\tau_T + 1)$$

from Beloborodov, 1999

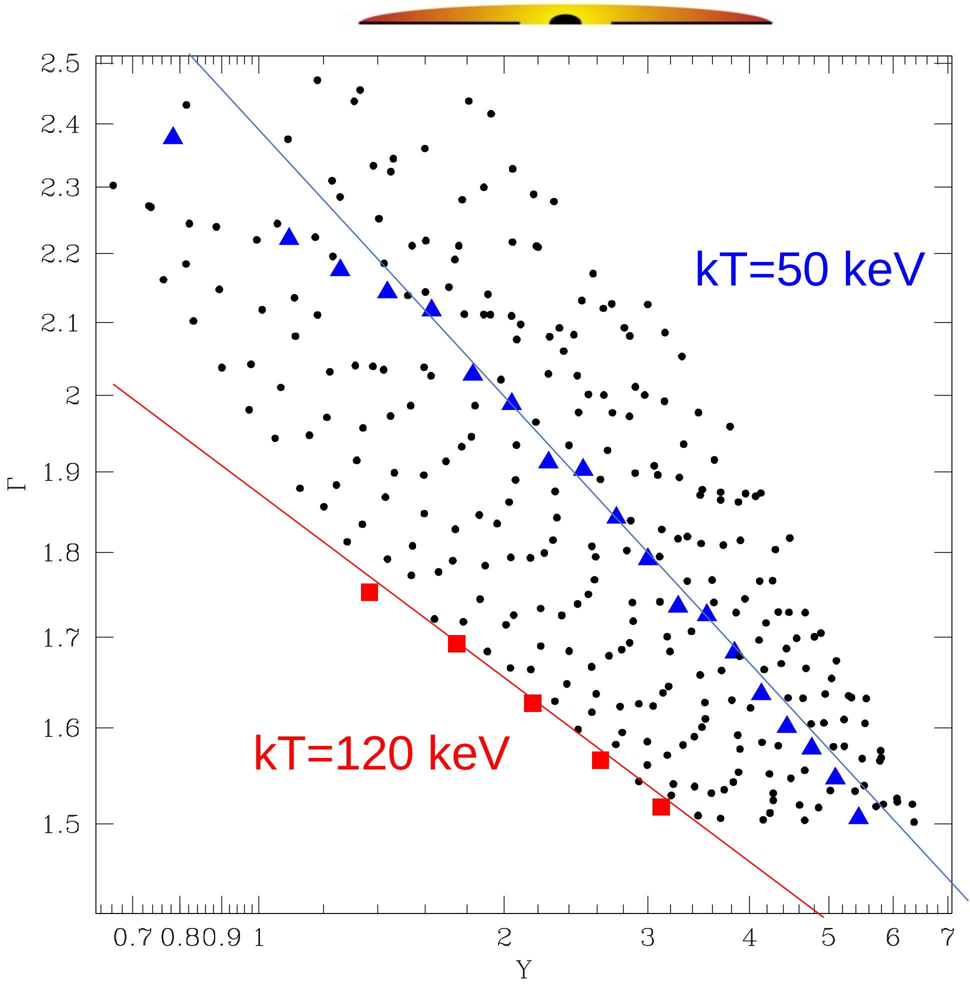




$$log\Gamma(\tau, kT) = a(kT)logY(\tau, kT) + b(kT)$$
$$a(kT) = 0.00169 \pm 0.0002 \times kT - 0.368 \pm 0.012$$
$$b(kT) = -0.0026 \pm 0.0001 \times kT + 0.633 \pm 0.015$$

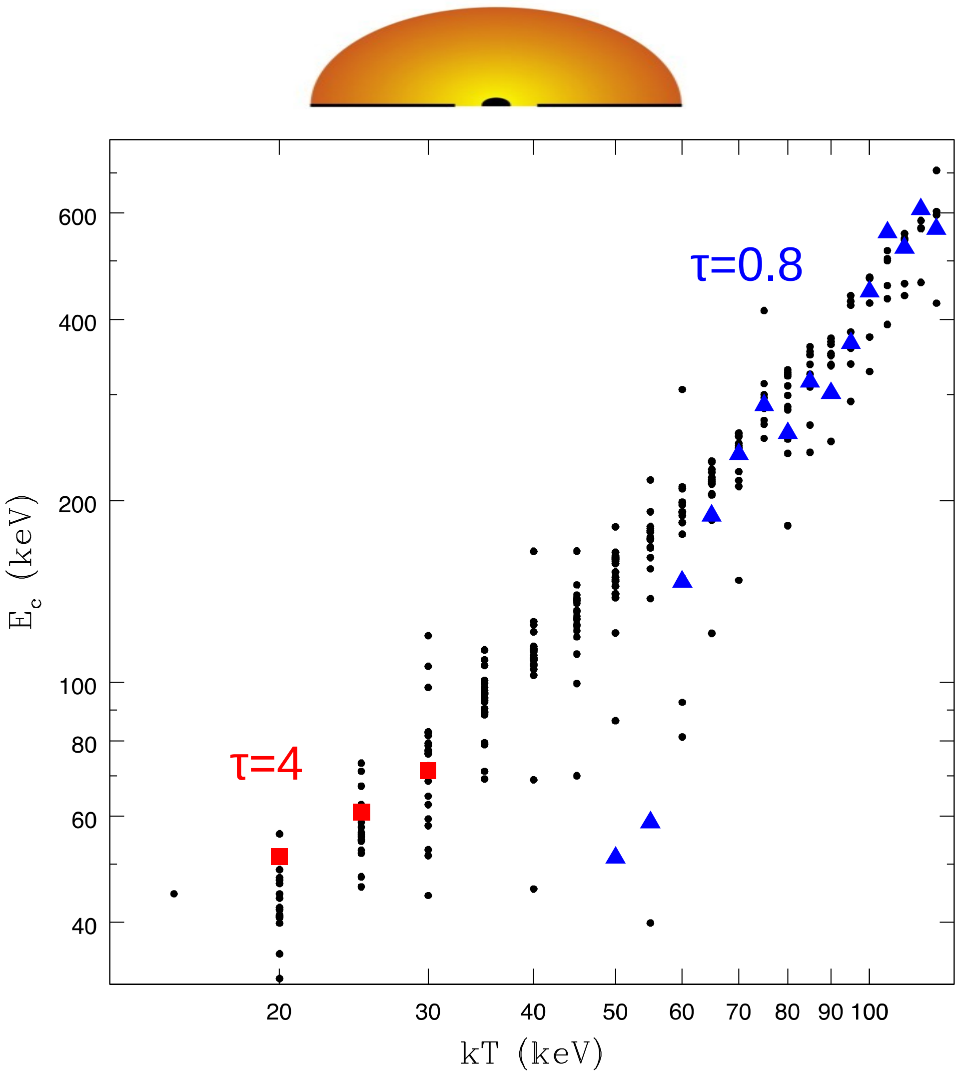
We find a further dependence of the slopes and normalizations on kT

$\Gamma_{MoCA}(\tau,kT)$ reproduces the photon index distribution within $\Delta\Gamma$ ~0.05



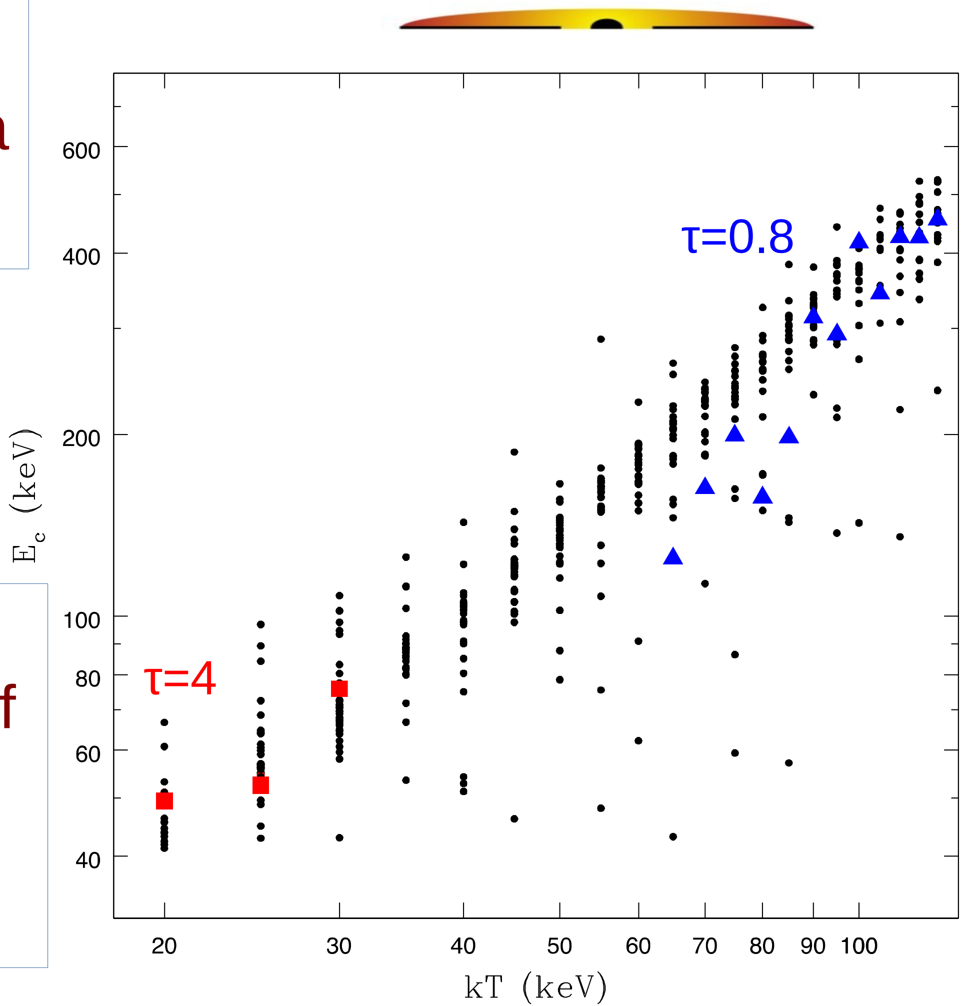
$$log\Gamma(\tau, kT) = a(kT)logY(\tau, kT) + b(kT)$$
$$a(kT) = 0.0010 \pm 0.0001 \times kT - 0.324 \pm 0.008$$
$$b(kT) = -0.0017 \pm 0.0001 \times kT + 0.468 \pm 0.008$$

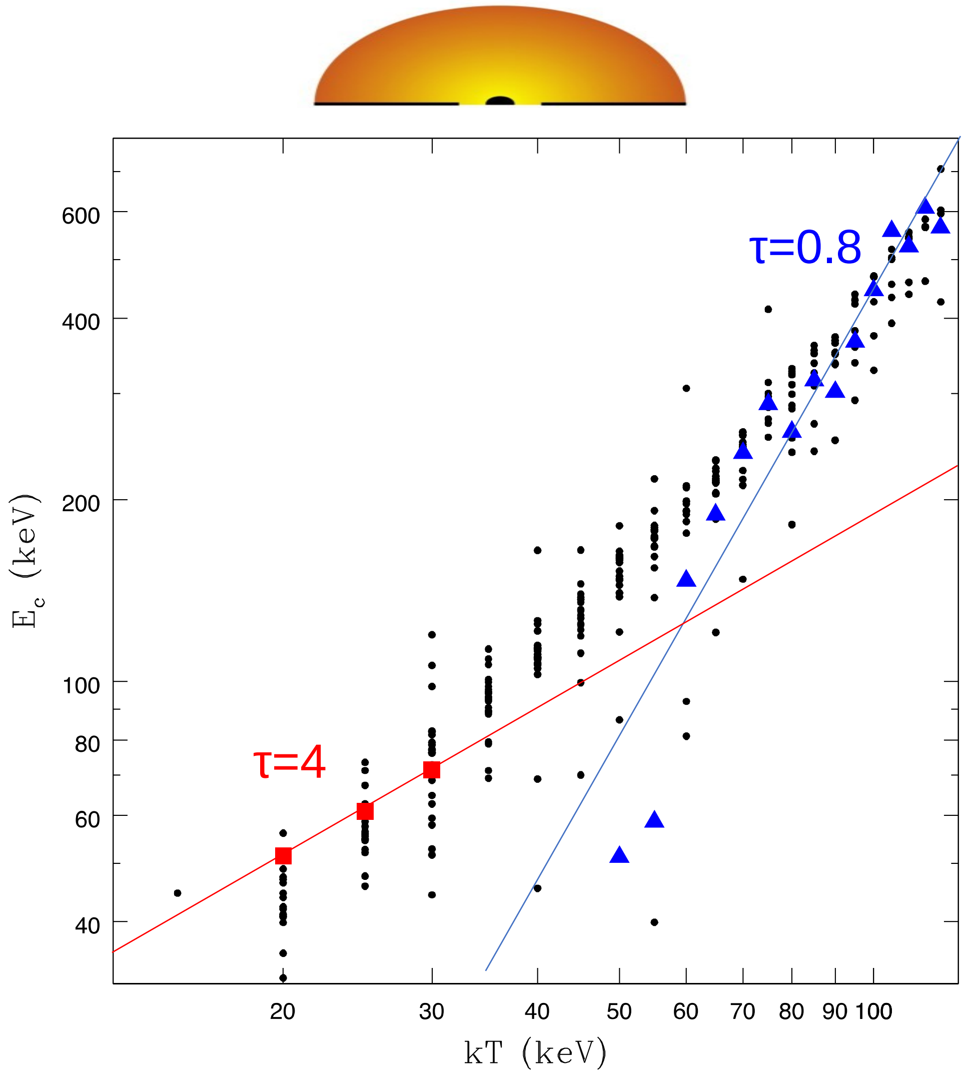
Connecting the spectral $E_{cut\text{-}off}$ with τ and kT



For each $E_{cut\text{-}off}$-κT couple, we fix τ and plot $E_{cut\text{-}off}$ as a function of kT

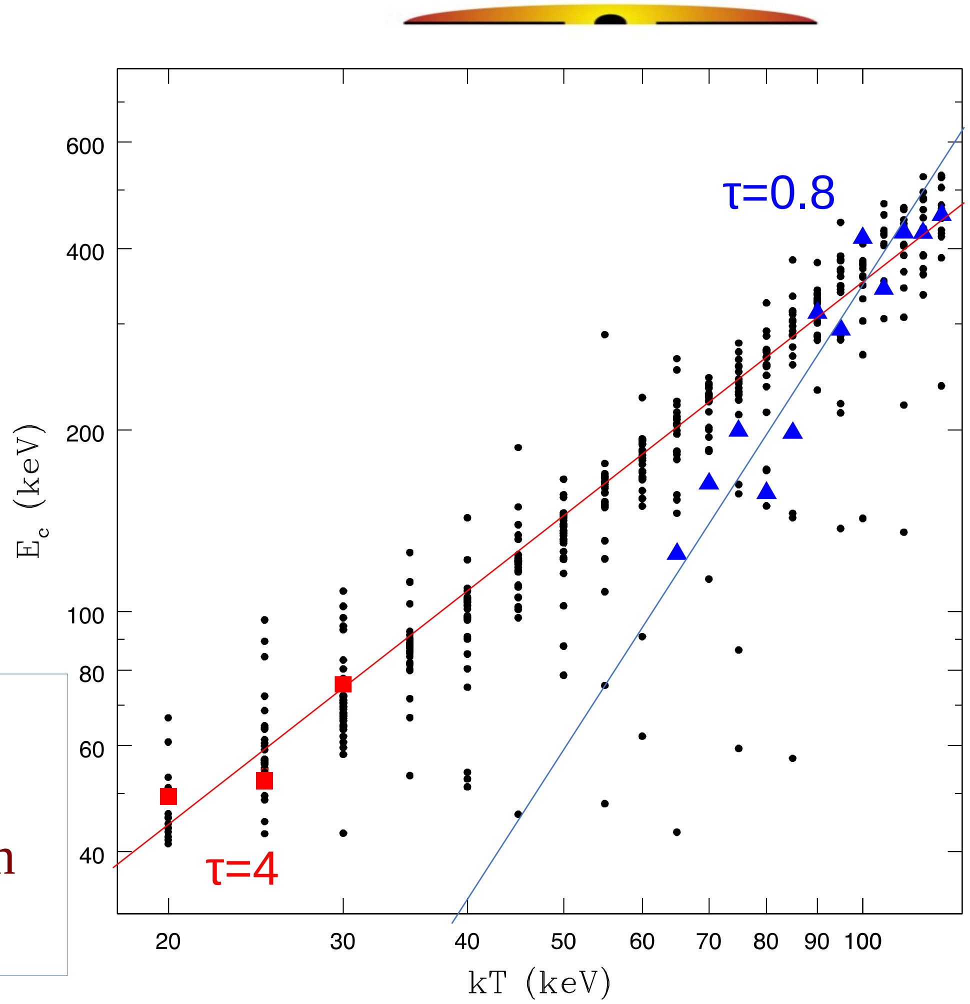
We performed fits of E_c-kT as a function of kT for all the τ





The relation between the observed E_{cut} and kT is a function of both τ and the κT

$E_{cut\text{-}MoCA}(\tau,kT)$ reproduces the $E_{cut\text{-}off}$ distribution within ΔE_{cut} <50 keV

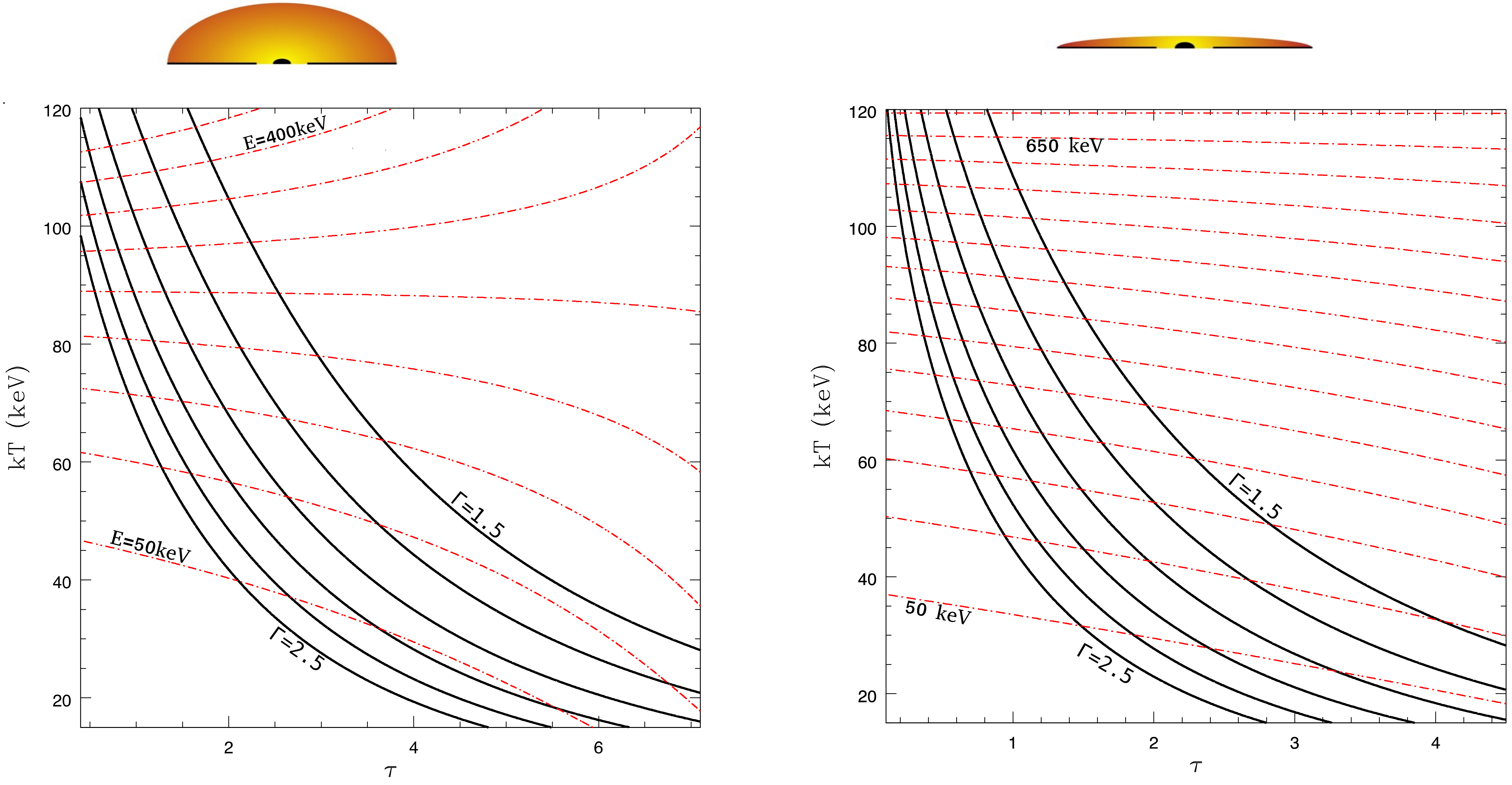


$$\log E_c(\tau, kT) = \alpha(\tau)\log kT + \beta(\tau)$$
$$\alpha(\tau) = -0.285 \pm 0.04 \times \tau + 2.61 \pm 0.2$$
$$\beta(\tau) = 0.558 \pm 0.08 \times \tau - 2.69 \pm 0.34$$

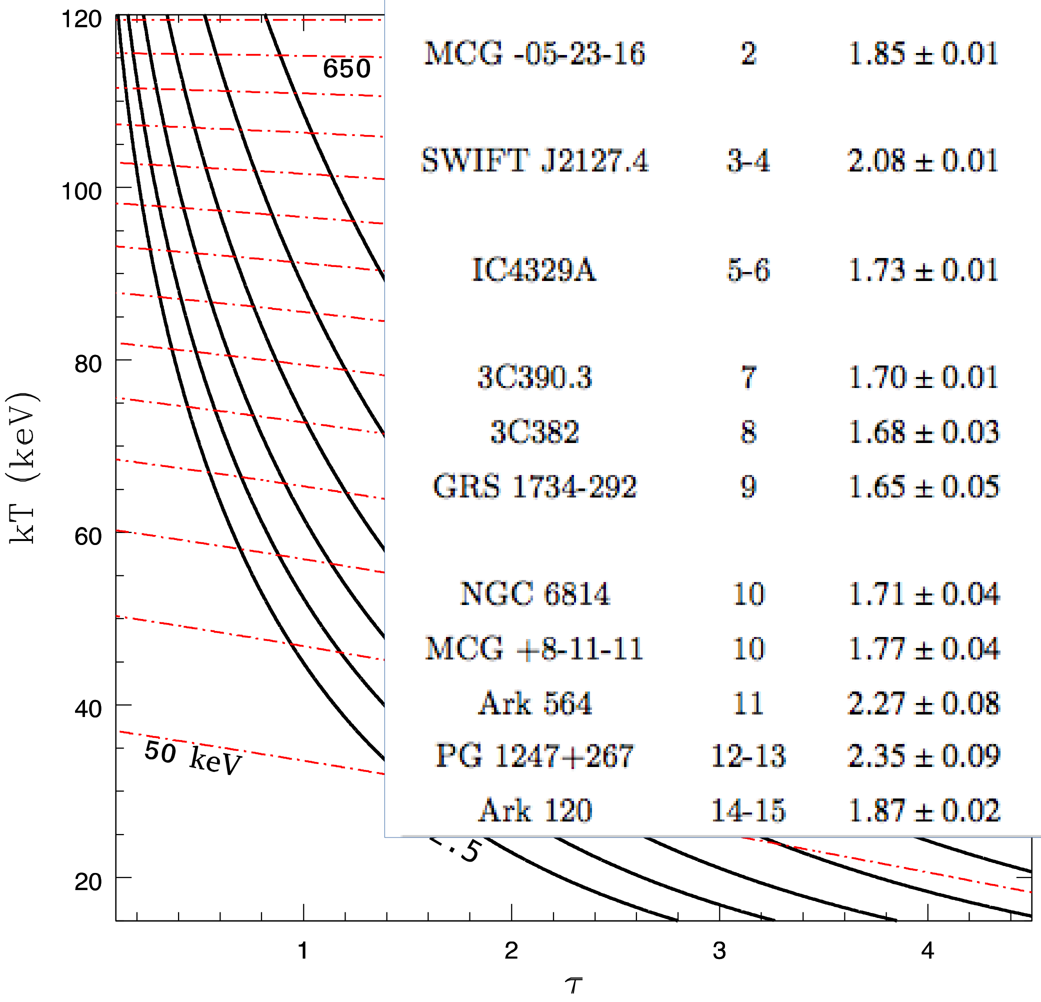
Most popular models implying E_{cut} =2-3x kT_e (Petrucci et al., 2000,2001) not always working

$$\log E_c(\tau, kT) = \alpha(\tau)\log kT + \beta(\tau)$$
$$\alpha(\tau) = -0.19 \pm 0.04 \times \tau + 2.26 \pm 0.13$$
$$\beta(\tau) = 0.398 \pm 0.08 \times \tau - 1.87 \pm 0.23$$

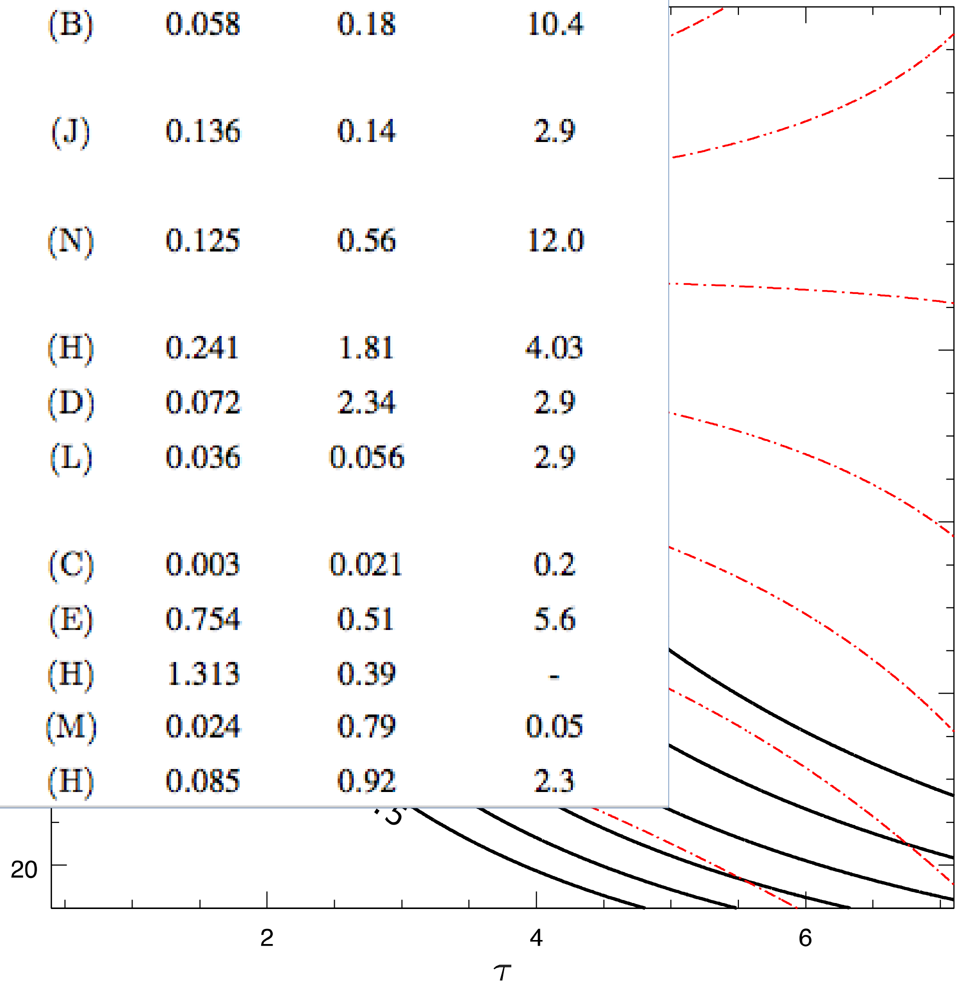
Connecting the physics of the corona with the phenomenological spectral properties



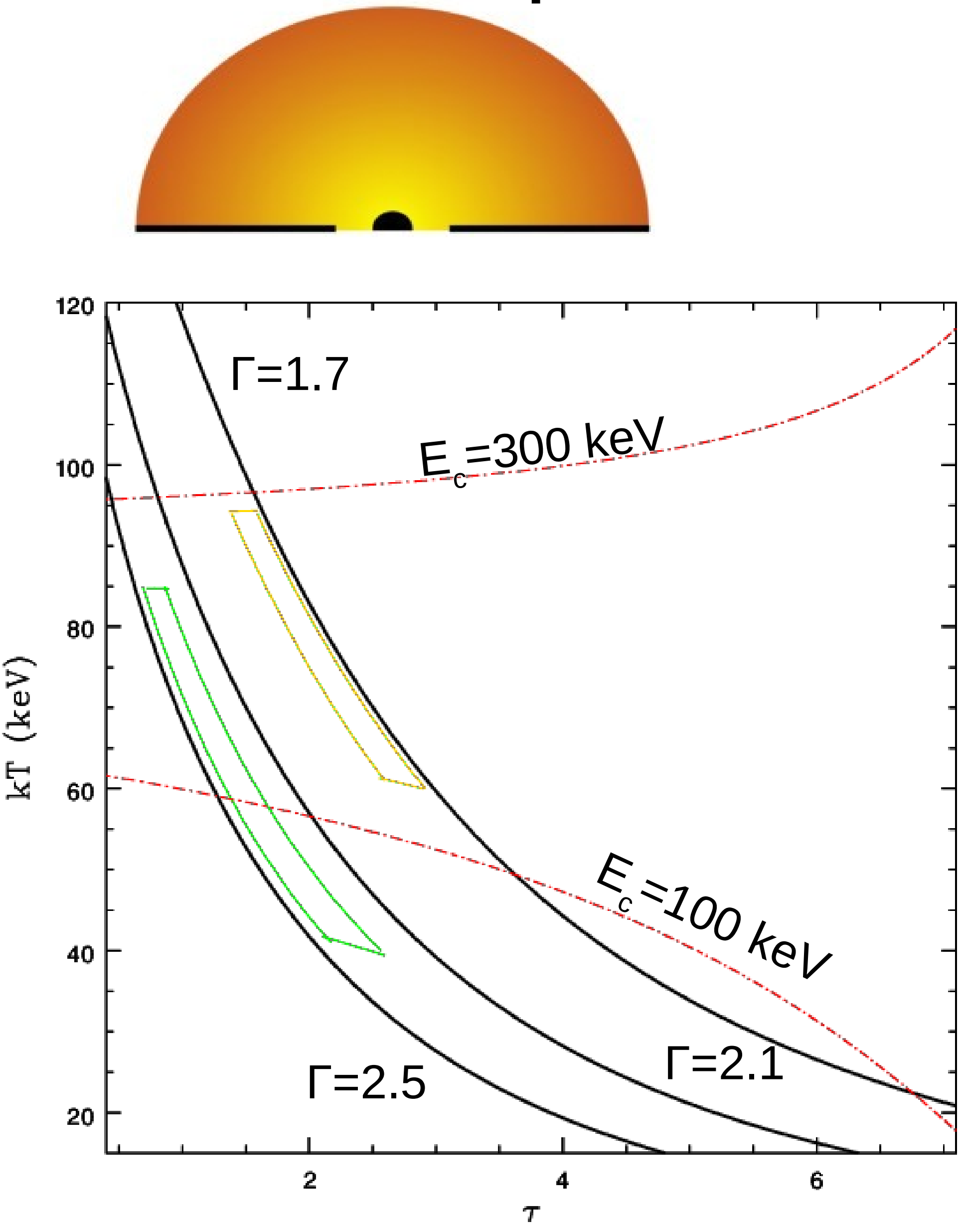
Hands on, from E_{cut} & Γ into kT & τ



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 $cm^{-2}s^{-1}$
NGC 5506	1	1.91 ± 0.03	720^{+130}_{-190}	8.0 ± 0.2	(A)	0.006	0.053	6.2
MCG -05-23-16	2	1.85 ± 0.01	170 ± 5	7.7 ± 0.2	(B)	0.058	0.18	10.4
SWIFT J2127.4	3-4	2.08 ± 0.01	180^{+75}_{-40}	7.2 ± 0.2	(J)	0.136	0.14	2.9
IC4329A	5-6	1.73 ± 0.01	185 ± 15	8.08 ± 0.3	(N)	0.125	0.56	12.0
3C390.3	7	1.70 ± 0.01	120 ± 20	8.4 ± 0.4	(H)	0.241	1.81	4.03
3C382	8	1.68 ± 0.03	215^{+150}_{-60}	9.2 ± 0.5	(D)	0.072	2.34	2.9
GRS 1734-292	9	1.65 ± 0.05	53 ± 10	8.5 ± 0.1	(L)	0.036	0.056	2.9
NGC 6814	10	1.71 ± 0.04	135^{+70}_{-35}	7.0 ± 0.1	(C)	0.003	0.021	0.2
MCG +8-11-11	10	1.77 ± 0.04	175^{+110}_{-50}	7.2 ± 0.2	(E)	0.754	0.51	5.6
Ark 564	11	2.27 ± 0.08	42 ± 3	6.8 ± 0.5	(H)	1.313	0.39	-
PG 1247+267	12-13	2.35 ± 0.09	90^{+130}_{-35}	8.9 ± 0.2	(M)	0.024	0.79	0.05
Ark 120	14-15	1.87 ± 0.02	180^{+80}_{-40}	8.2 ± 0.1	(H)	0.085	0.92	2.3



a few examples...

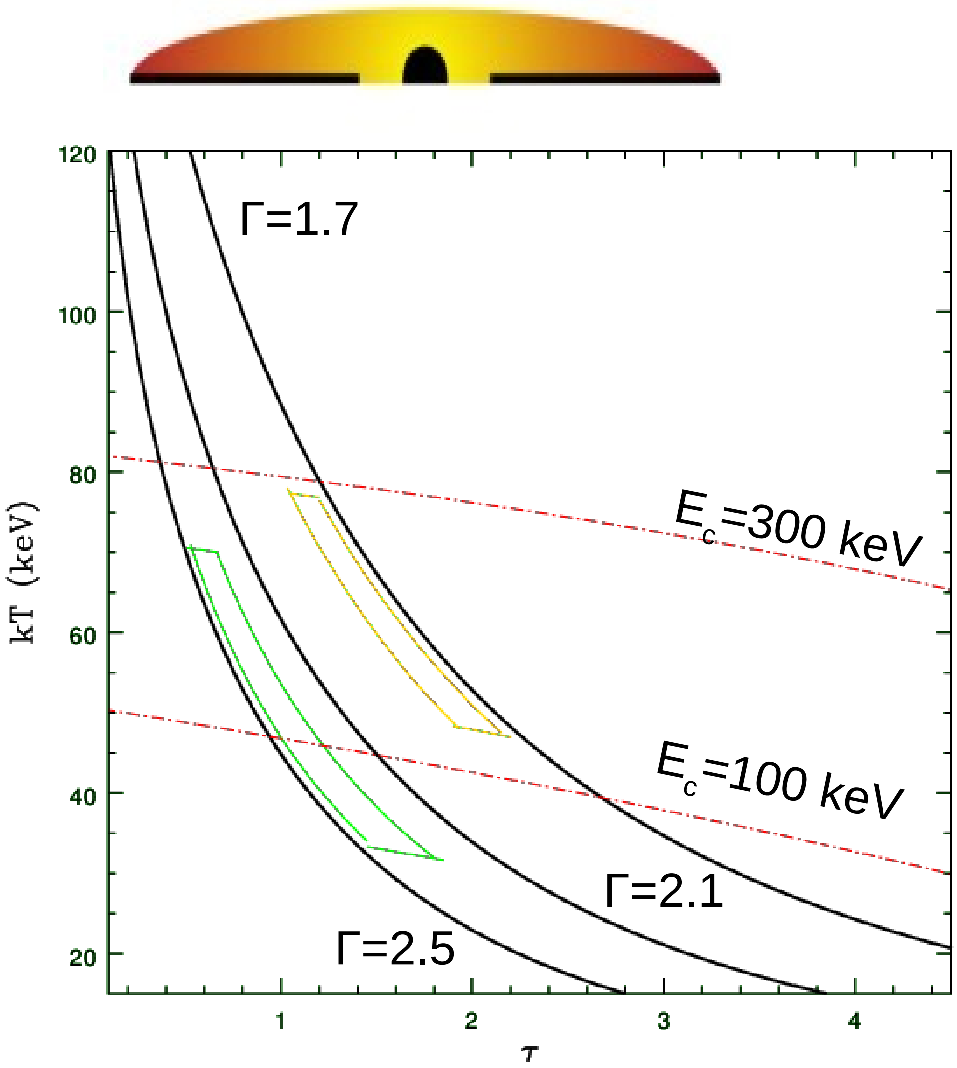


PG 1247+267

E=90+130-25 keV
Γ=2.35+-0.09
Sphere
40<κT<85 keV
1<τ<2.5
Slab
35<kT<70 keV
0.9<τ<1.9

MCG+8-11-11

E=175+110-50 keV
Γ=1.77+-0.04
Sphere
65<κT<95 keV
0.8<τ<3
Slab
50<kT<75 keV
1.5<τ<2.5



take home message

MoCA can be exploited for studying the X-ray AGN emission

It is possible to exclude regions in the τ and kT parameters space

We find that both E_{cut} and Γ are functions of kT and τ

We derive relations connecting the MoCA Γ and E_{cut} with kT and τ for the slab and spherical geometry

more details soon, Middei et al., is in ongoing :)