First measurement of coronal properties in two luminous high-z QSOs

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E. Piconcelli, C. Vignali, W. N. Brandt, F. Tombesi and M. Gaspari.

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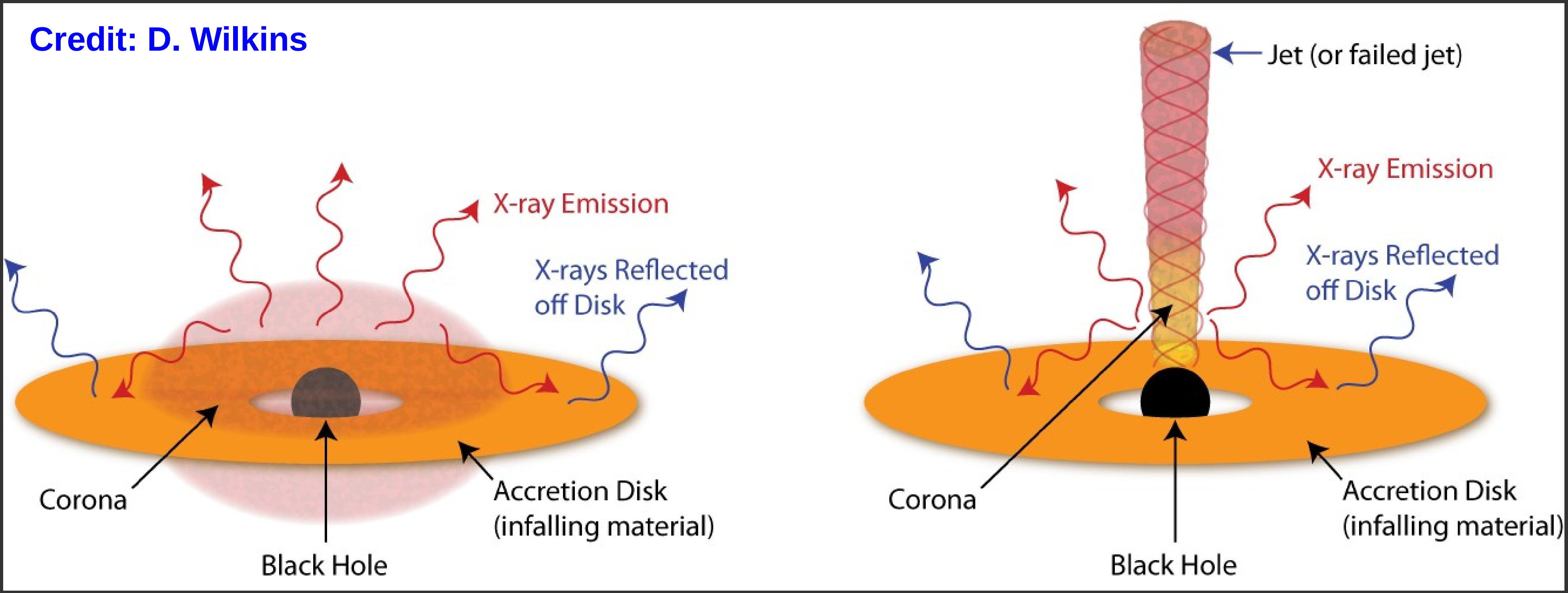
AGN accretion and Coronal properties



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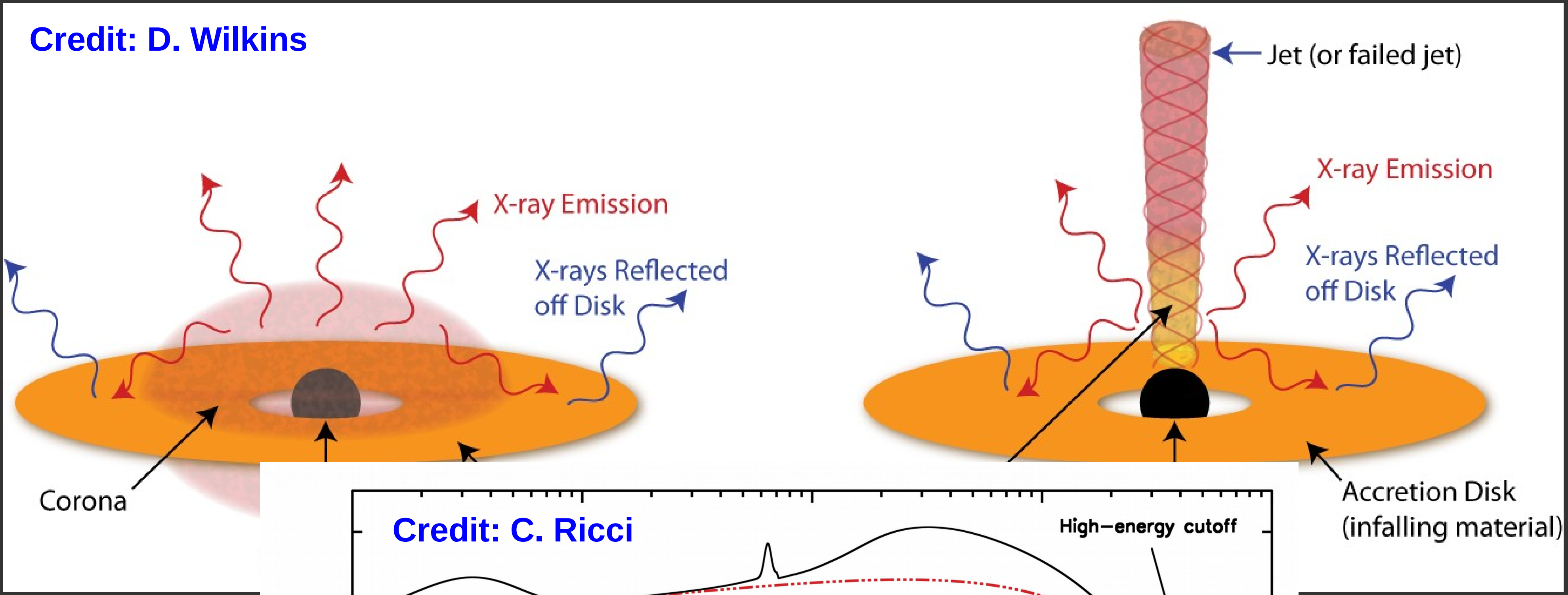
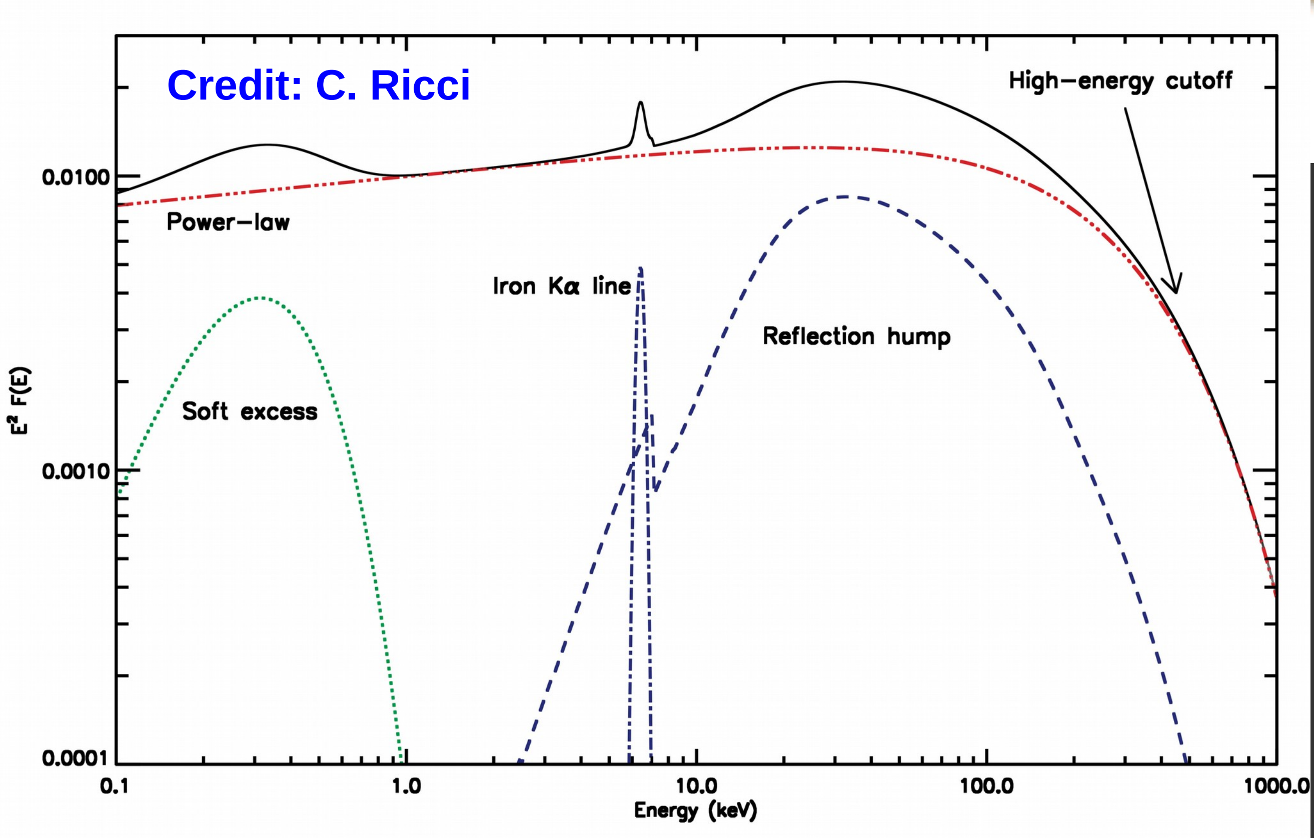




AGN accretion and Coronal properties

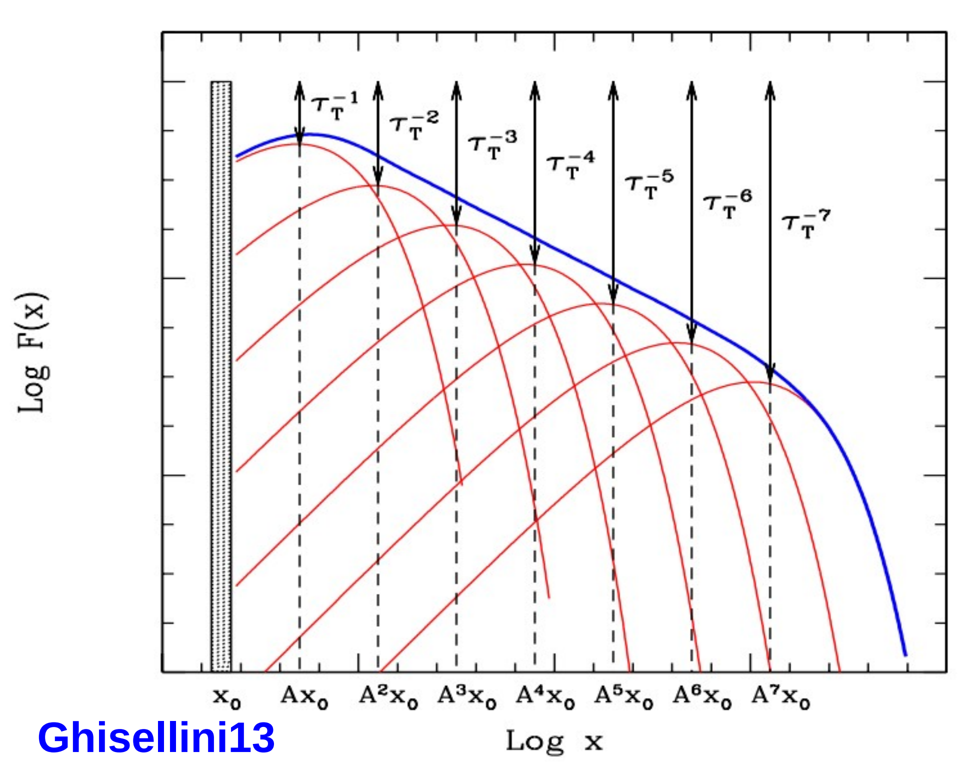
Main coronal parameters:

Optical depth τ_T → drives the number of C. scattering
Electron temperature kT_e → set the energy gain per scattering

$$A \equiv \left(\frac{4k_B T_e}{m_e c^2}\right)^2$$

$$\alpha = -\frac{\log \tau_T}{\log A}$$

$$E_c = 2 - 3 \times kT_e$$



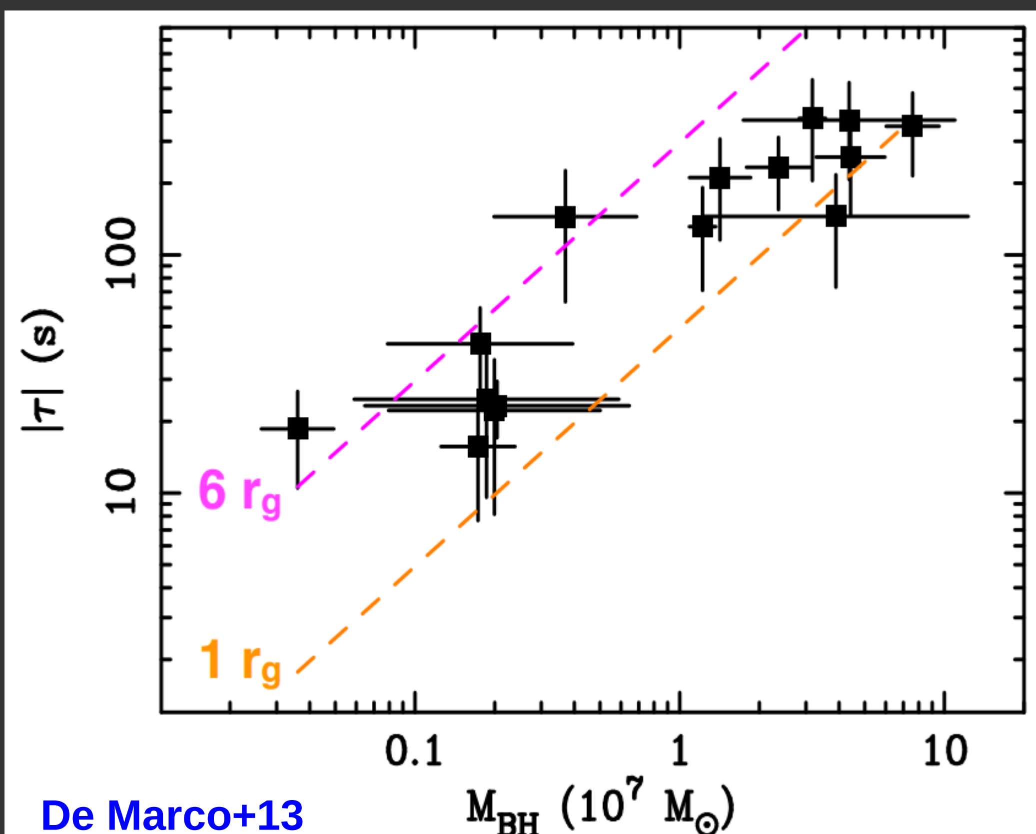
see e.g. Fabian+89, Haardt&Maraschi 91,93, Petrucci+01...

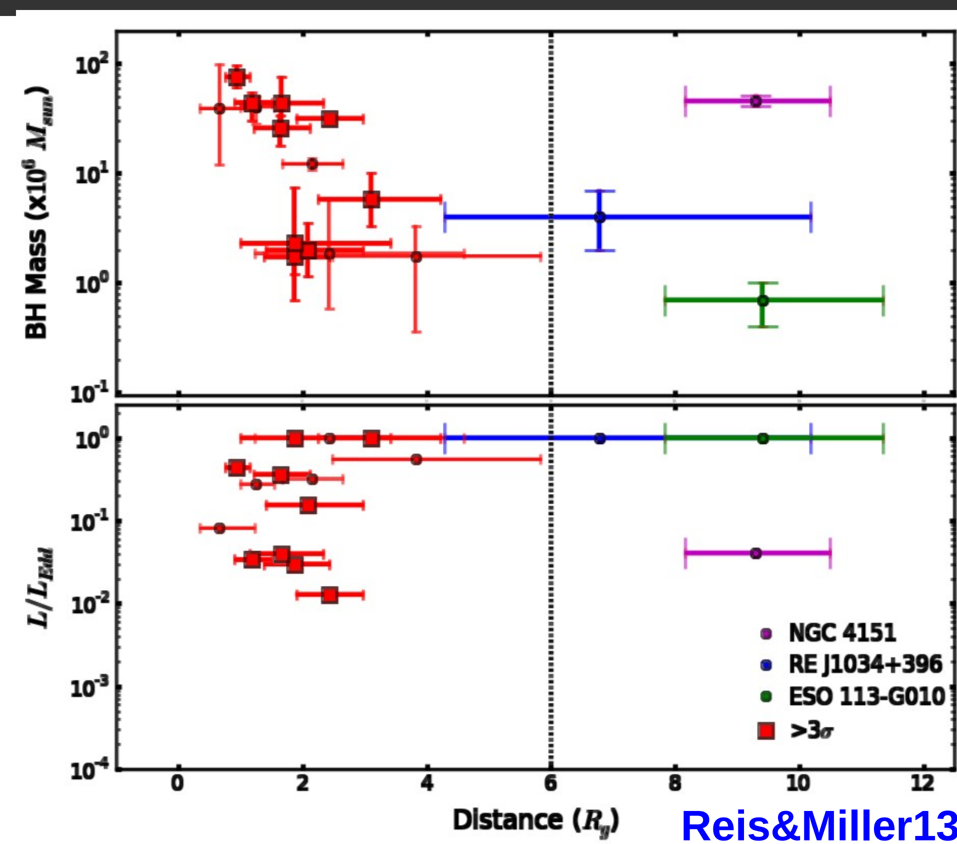
Compactness and pair production

X-ray spectral timing, reverberation and microlensing show that the corona is compact:

$R=3\text{-}10r_g$

e.g. De Marco+11,13, Fabian+09,12, Uttley+14, Chartas+16, King, Lohfink & Kara17, Kara+19...





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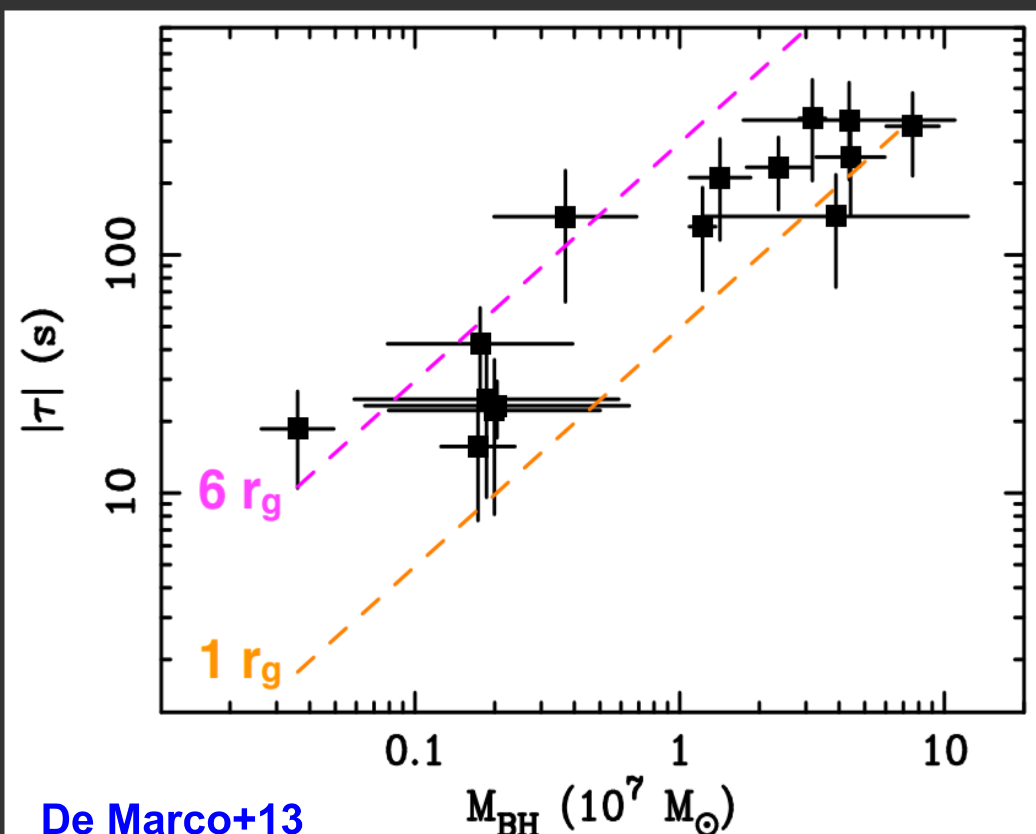
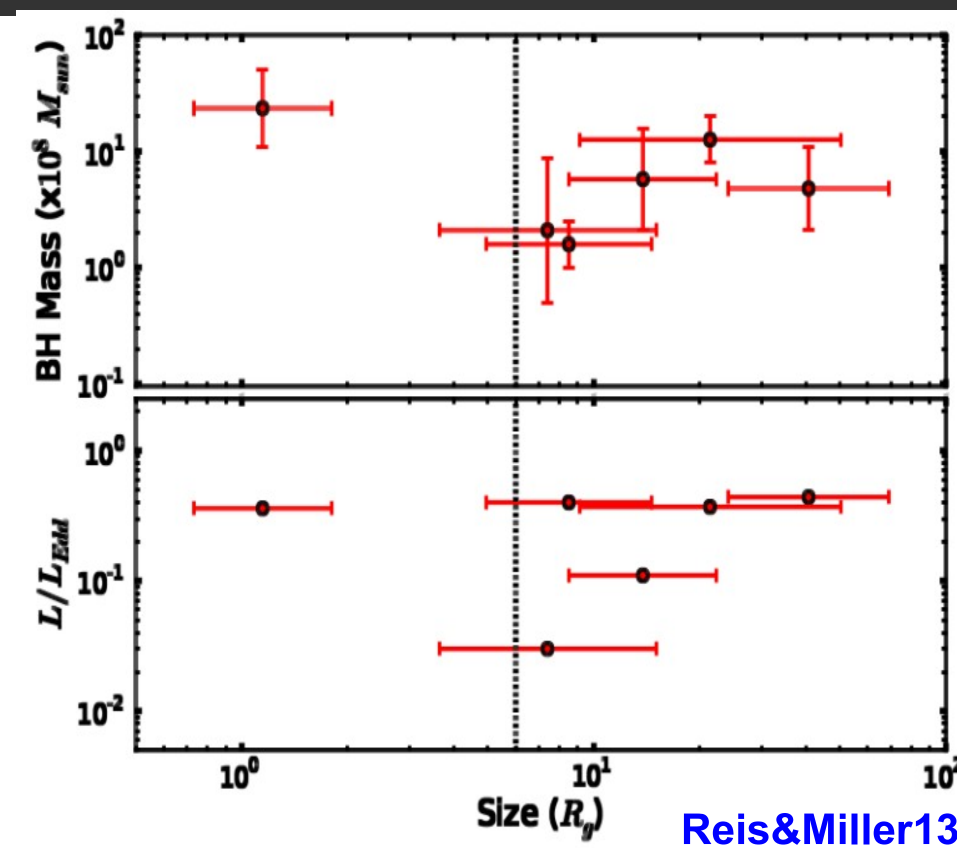




Compactness and pair production

Energetic photons in a “compact” source → electron-positron pair production

$$\ell = \frac{L}{R}\frac{\sigma_T}{m_e c^3}$$

$$\Theta = \frac{k_B T}{m_e c^2}$$

If ℓ >∼1, a particle loses a significant fraction of its energy crossing the system

When the energy exceeds $\sim 2m_e c^2$ (∼1MeV) photon-photon collisions create electron-positron pairs

At equilibrium pair production/annihilation occur at the same rate

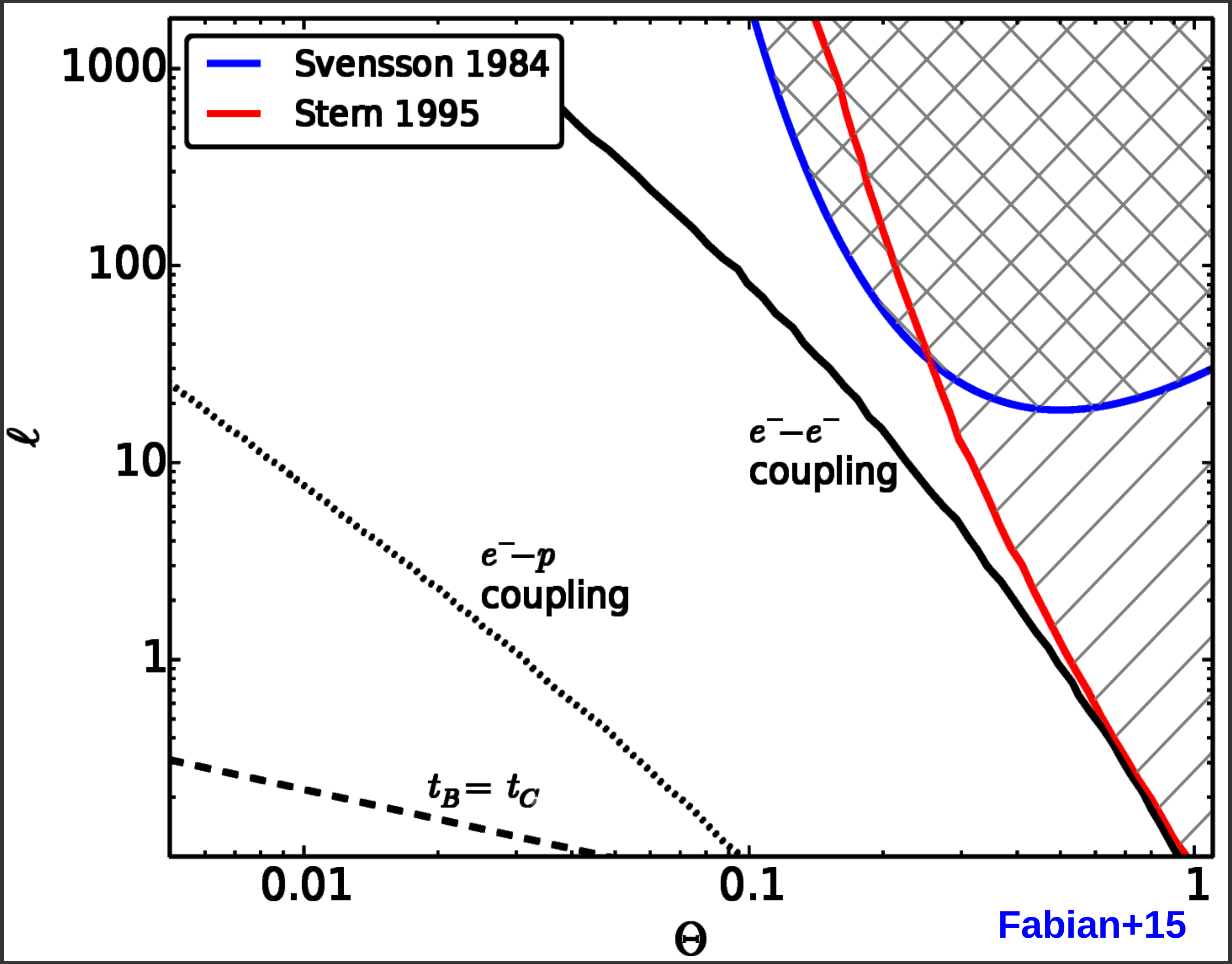
Any increase in energy input goes into producing more pairs rather than increasing temperature

Runaway pair production removes energy and limits any rise in temperature

→ electron-positron pair production act as an ℓ-dependent thermostat

e.g. Cavaliere & Morrison 1980, Svensson82,84, Zdziarski85, Ghisellini&Haardt94…

The Compactness-Temperature plane



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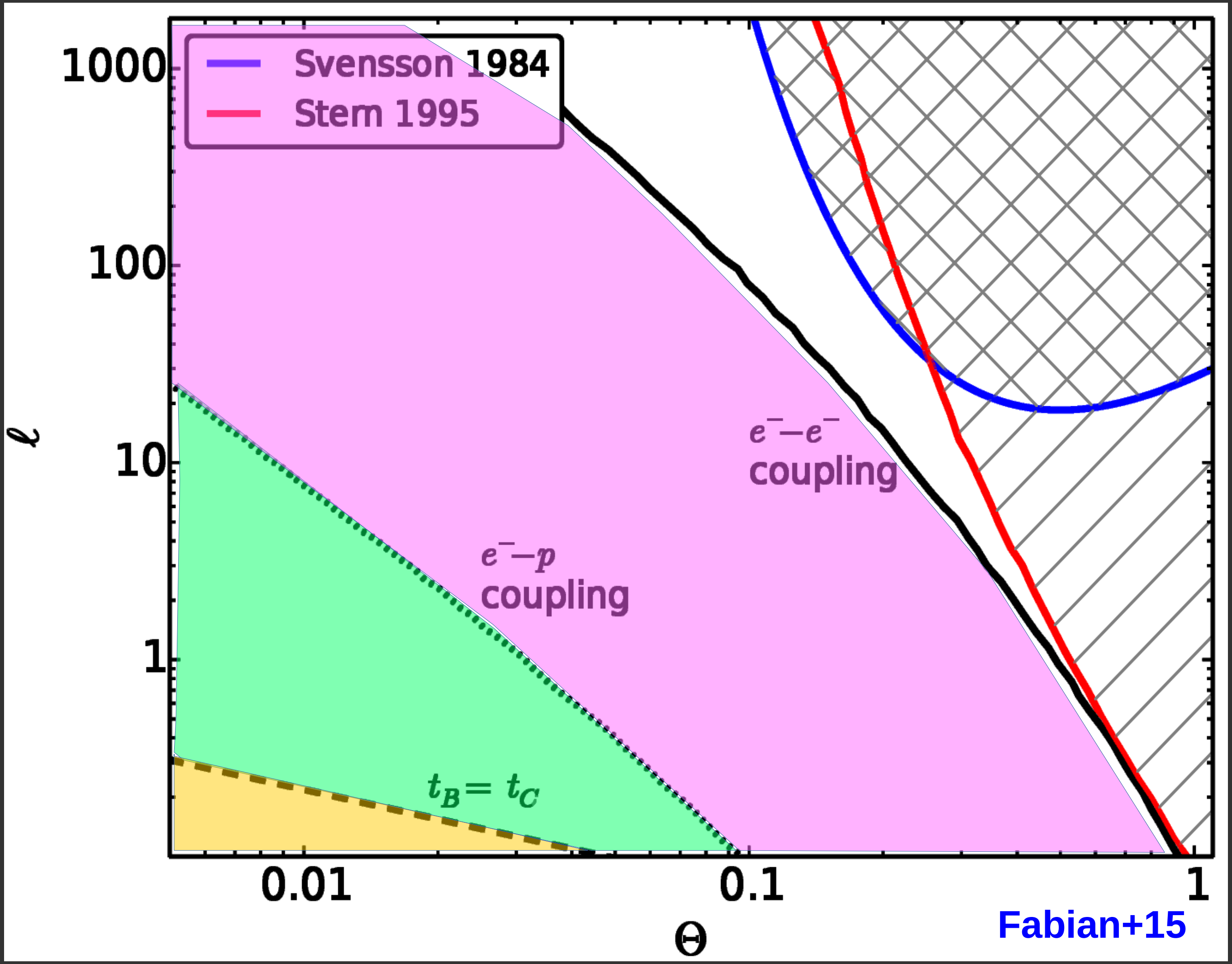
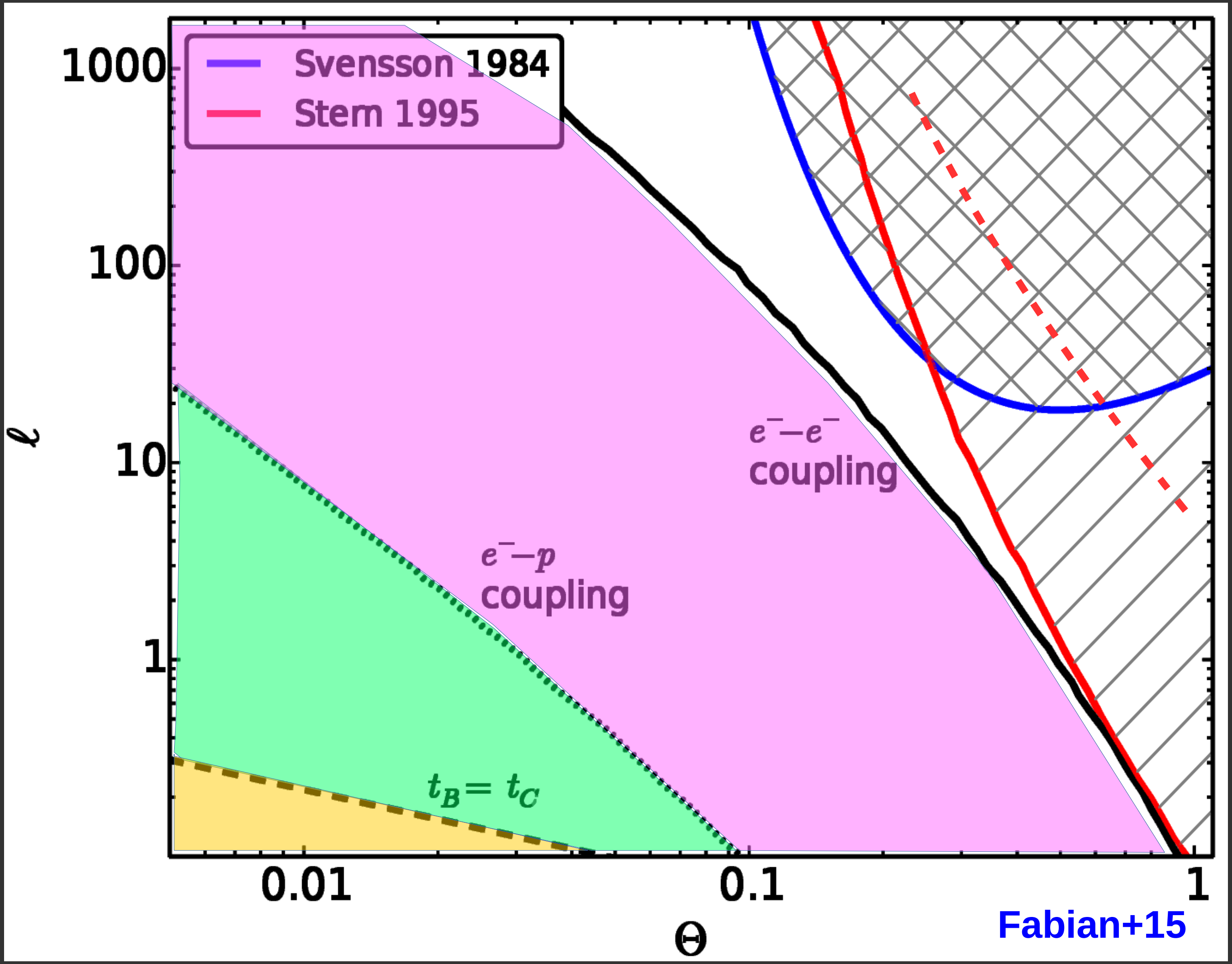


The Compactness-Temperature plane



Runaway pair production regions computed for:
- a spherical corona Svensson84
- a slab (hemisphere) Stern95

Observations: the Nustar era

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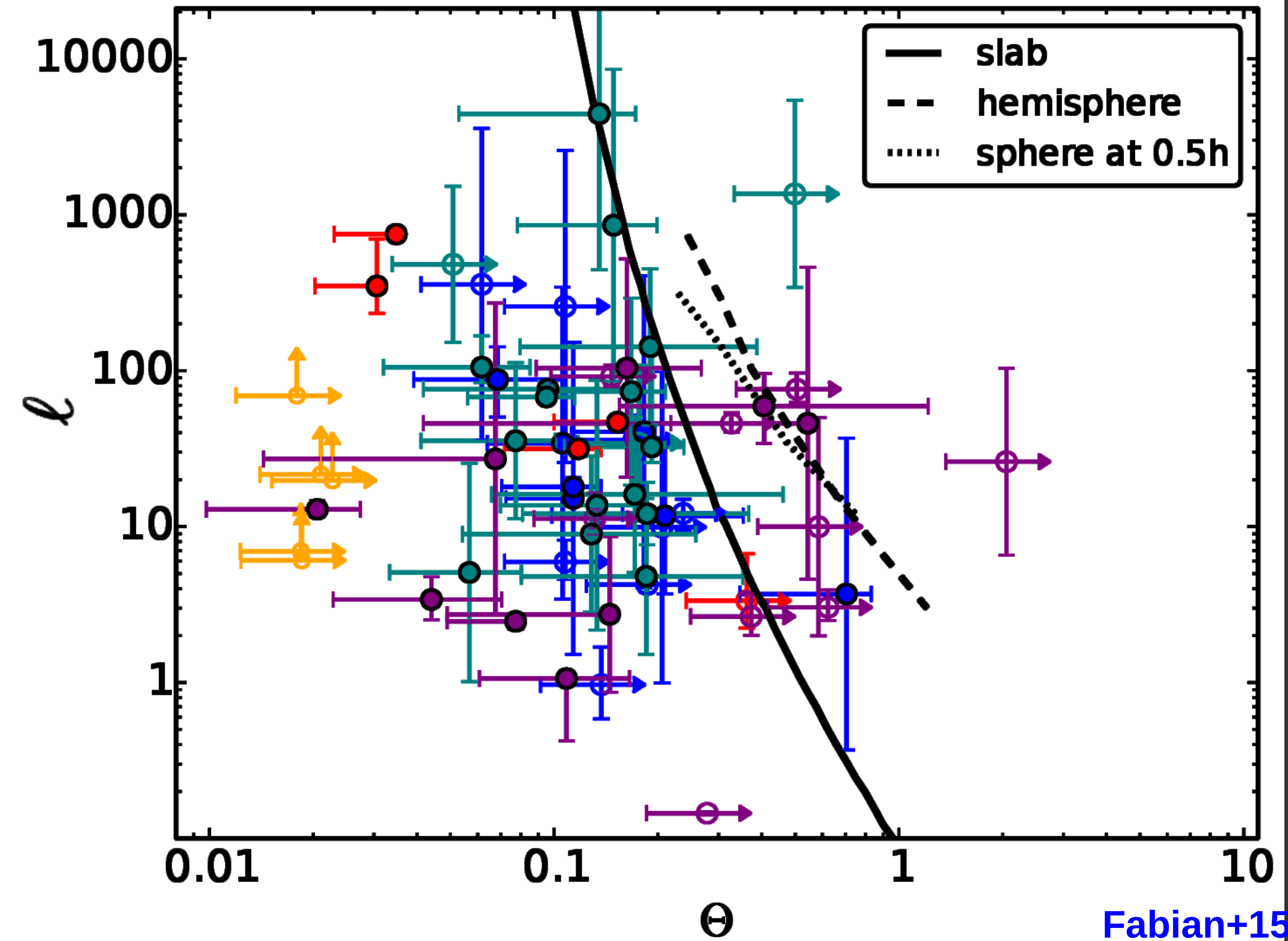


Fabian+15

$$\ell = 4\pi \frac{m_p}{m_e} \frac{R_g}{R} \frac{L}{L_E}$$

***R* = 10 R_g**

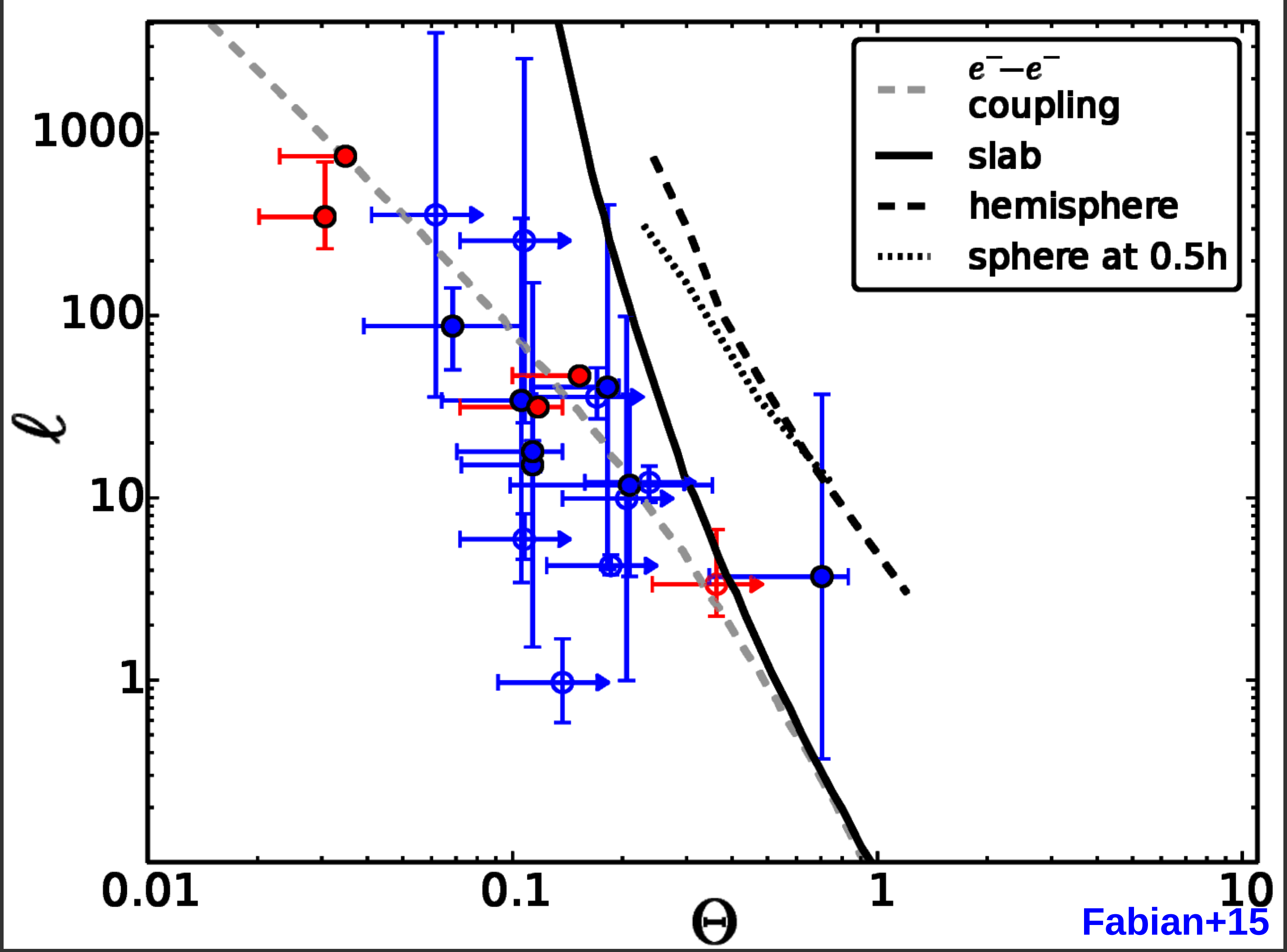
$$kT_e = E_{cut}/2$$

Nustar+non focusing X-ray telescopes (Integral, Swift-BAT…)

Vasudevan+13, Malizia+14

Mostly upperlimits!

Observations: the Nustar era



$$\ell = 4\pi \frac{m_{\rm p}}{m_{\rm e}} \frac{R_{\rm g}}{R} \frac{L}{L_{\rm E}}$$

$R = 10\, R_g$

$$kT_{\rm e} = E_{\rm cut}/2$$

Only Nustar (+ soft X-rays)

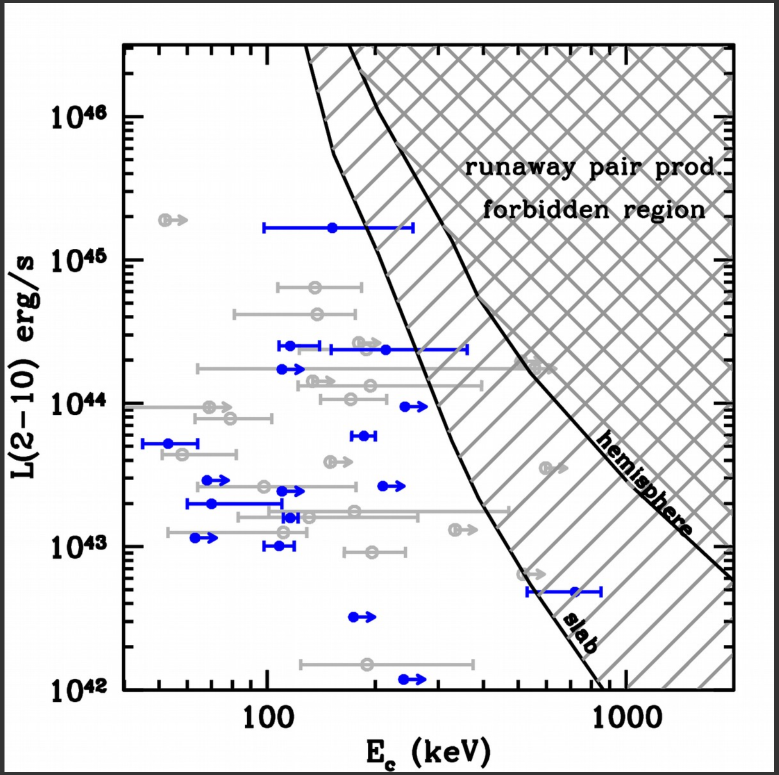
z<0.06, L_X<~10^{44} erg/s

QSOs at high z with Nustar

Can we extend to higher luminosities (QSO regime) and high z?

- at high L_X (high ℓ) pair production predicts low E_{cut}
- at high z hard X-rays (>100keV) enter the Nustar band

→ possible to test pair production models



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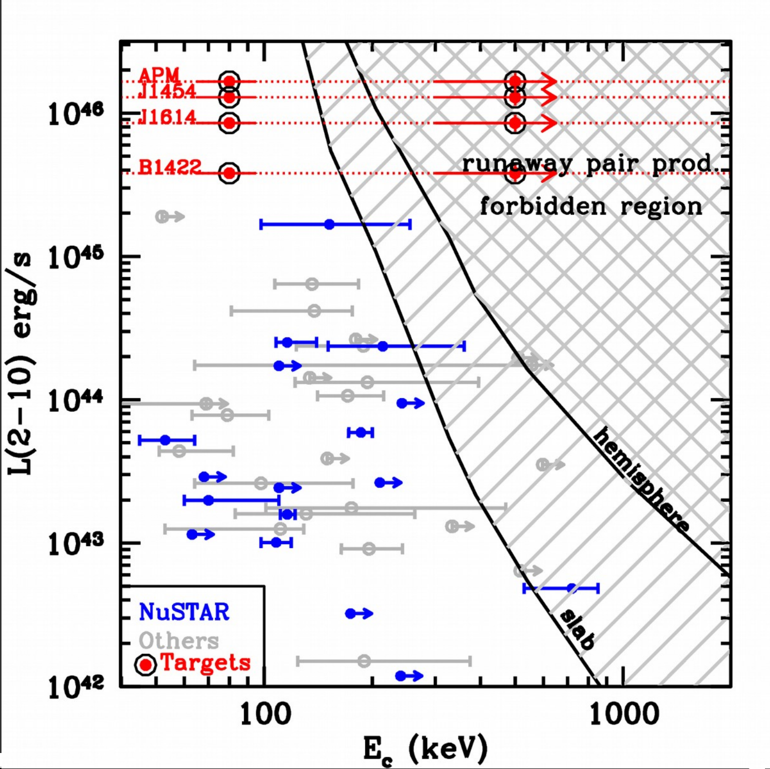
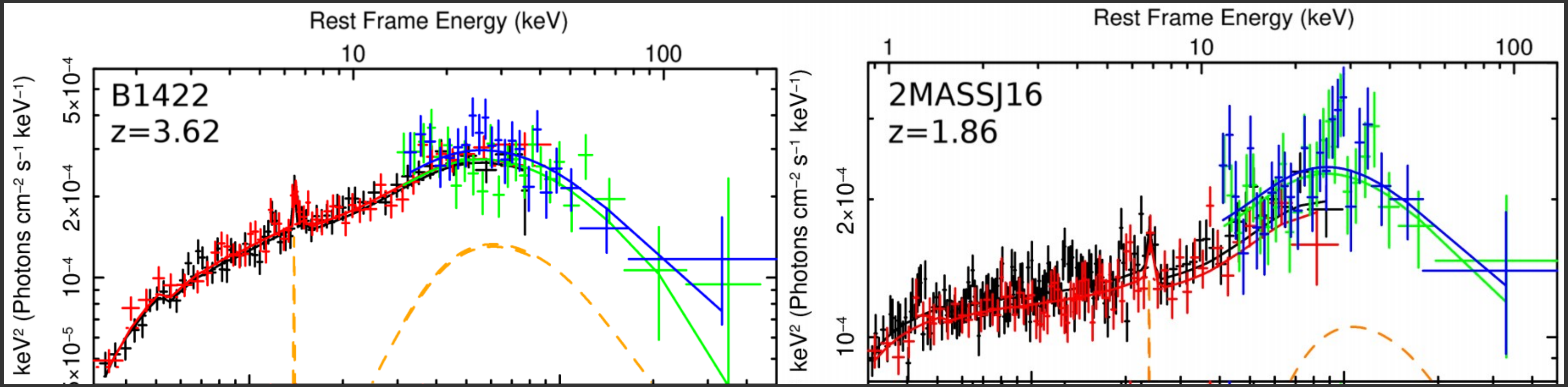
Building on the experties on high-z/lensed QSOs
Lanzuisi+12,+16, Dadina+16, Chartas+14,16
based on several XMM/Chandra/Nustar obs.
and one XMM LP in AO16 PI Cappi

→ 4 targets (2 lensed) 2 of which approved in Nustar Cycle 3 (+ *quasi*-simultaneous XMM)



Target	z_{spec}	$f_{0.5-10}$ (10^{-13} cgs)	Lens?	XMM LP (ks)	$\log L_{2-10}$ (erg/s)	Req. Expo. (ks) *NuSTAR*	XMM
B1422+231	3.62	10	Y	-	45.58	100	30
2MASSJ1614346+470420	1.83	6.7	N	92	45.97	150	-
APM08279+5255	3.91	5.3	Y	-	45.11	-	-
SDSSJ145453.53+032456.8	2.37	5.2	N	117	46.11	-	-

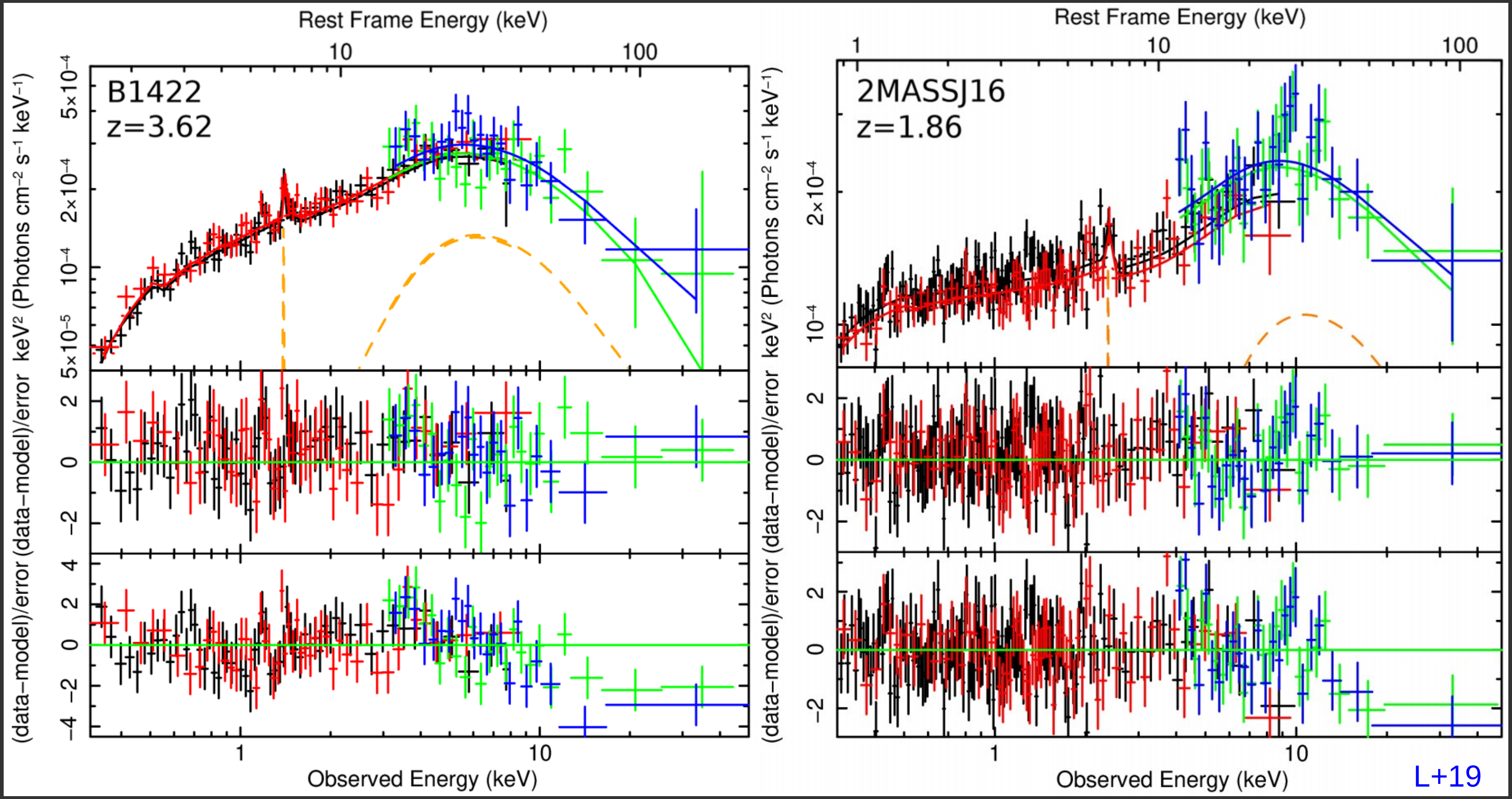
The data



Phenomenological model: power-law + cold reflection (+lines) + E_{cut}
***Pexmon*, Nandra+07**

Free parameters: Γ, R, Ecut, plus cross-calibrations and cold absorption

The data



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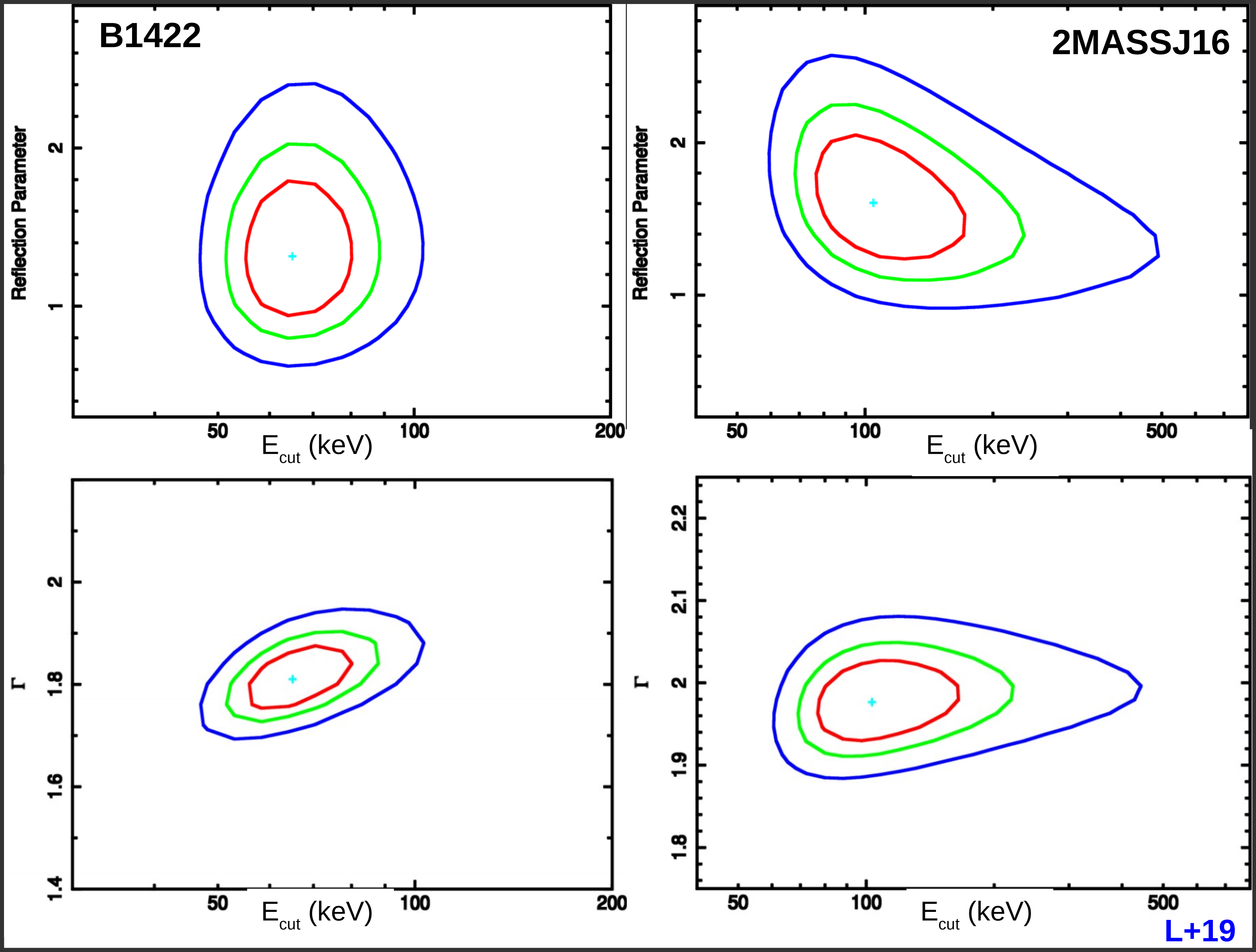
Results



B1422
2MASSJ16
Reflection Parameter
Γ
E_{cut} (keV)
50
100
200
500
1
2
1.4
1.6
1.8
2
1.9
2.1
2.2
L+19

Results

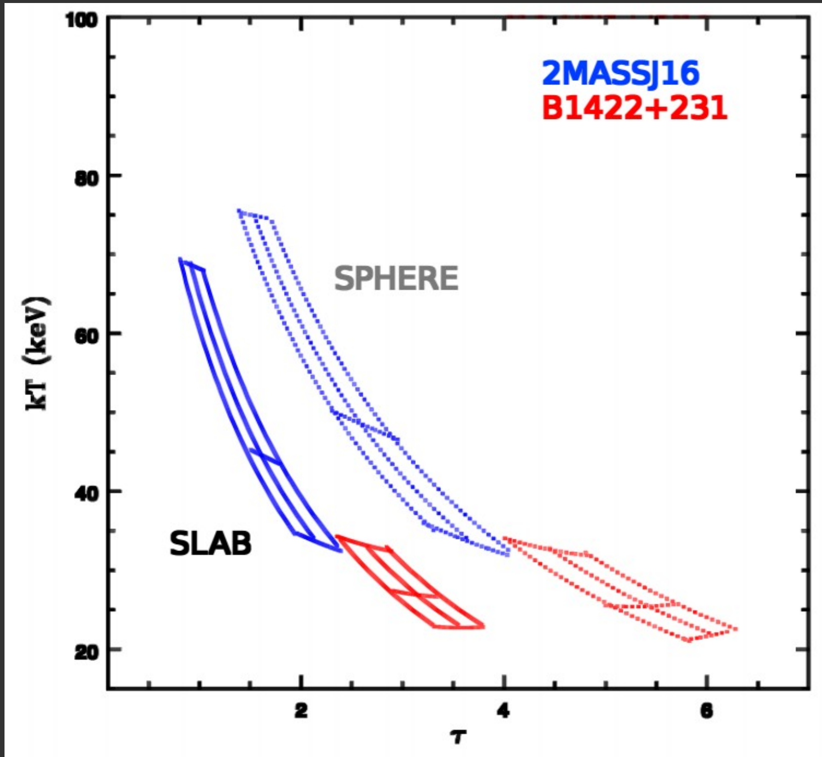
- Phenomenological model: *Pexmon*

Target	Γ	E_{cut} keV	R
(1)	(2)	(3)	(4)
B1422	$1.81^{+0.07}_{-0.06}$	66^{+17}_{-12}	$1.3^{+0.5}_{-0.4}$
2MASSJ16	$1.98^{+0.11}_{-0.05}$	106^{+102}_{-37}	$1.6^{+0.7}_{-0.5}$

- Comptonization model: *Nthcomp* (Zycki+99)

	kT_e	τ
B1422	22^{+7}_{-2}	$3.6^{+0.6}_{-0.4}$
2MASSJ16	42^{+10}_{-11}	$2.0^{+0.3}_{-0.2}$

- Consistent results using the MonteCarlo Comptonization model *MoCa*
Tamborra+18, Marinucci+18

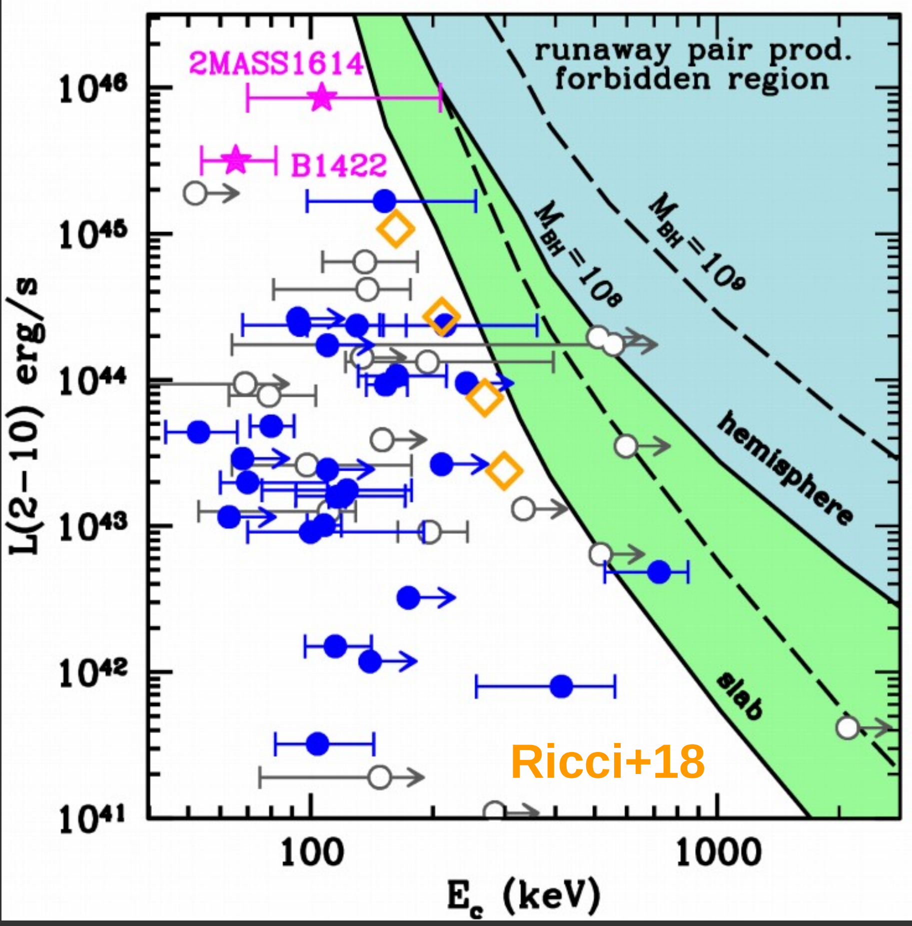


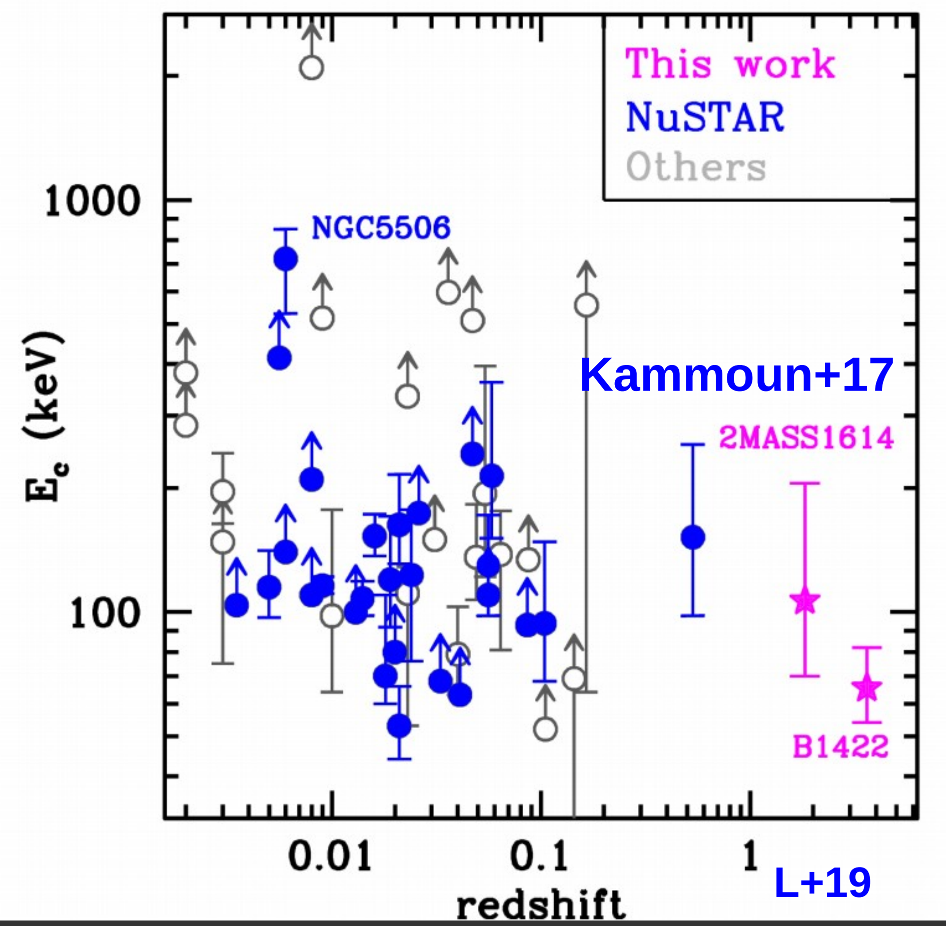
Results

- We can rule out high values of E_{cut}:
<80 keV for B1422 and <200 keV for 2MASSJ16 at 90% c.l.

- We extended for the first time E_{cut} measurements to $L_X=10^{46}$ erg/s

- We extended for the first time coronal studies at z>1
(see Lanzuisi+16 and Dadina+16 for previous attempts)





What's next...

Approved in Cycle 4!

Target	z_{spec}	$f_{0.5-10}$ (10^{-13} cgs)	Lens?	XMM LP (ks)	$\log L_{2-10}$ (erg/s)	Req. Expo. (ks) *NuSTAR*	XMM
APM08279+5255	3.91	6.6	Y	-	46.22	150	30
SDSSJ145453.53+032456.8	2.37	5.2	N	117*	46.11	170	40

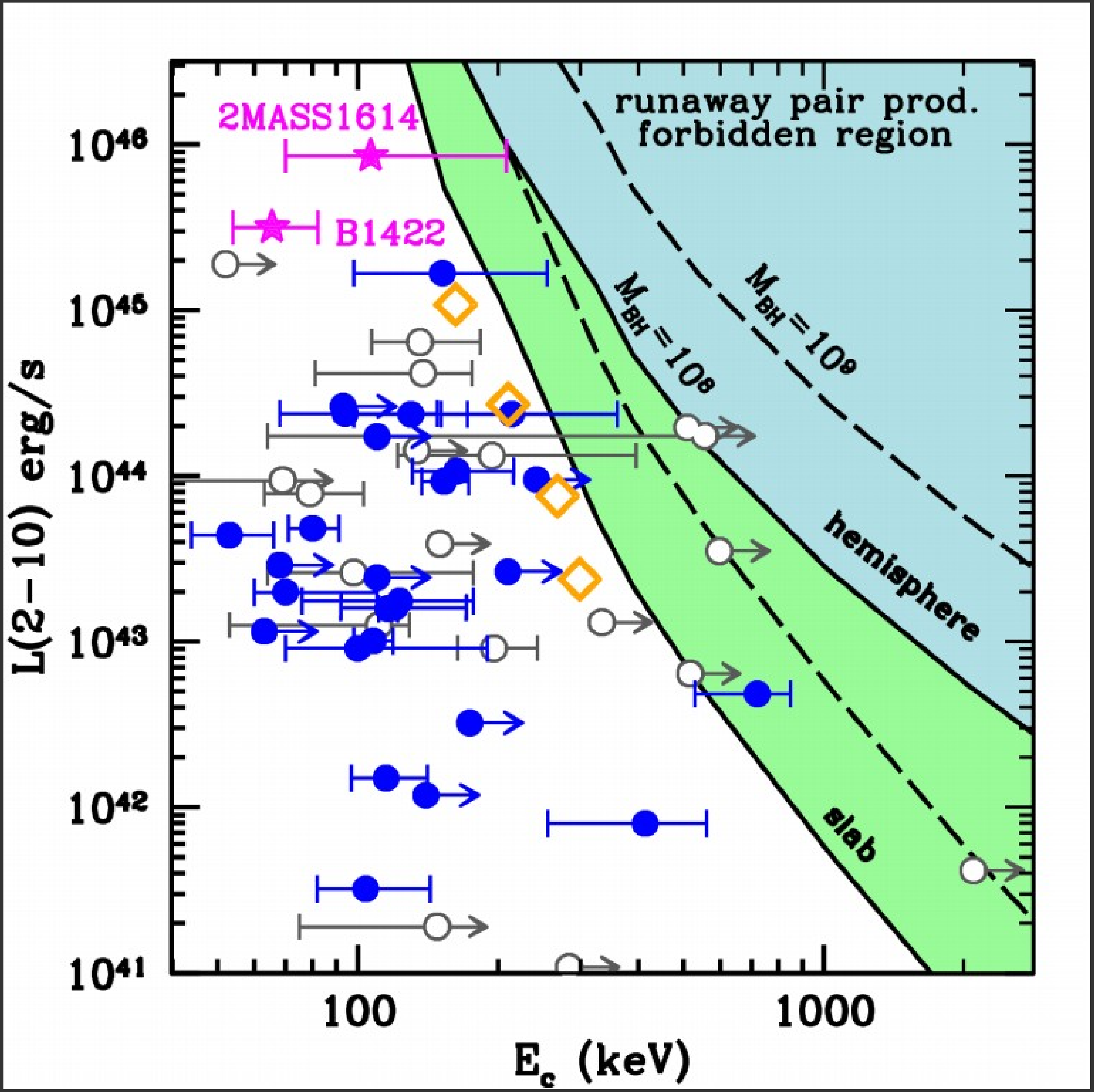
- Observations successfully performed in Jan/Mar 2019

- 8k and 14k counts available respectively

- analysis on going...

Stay tuned!

Conclusion



runaway pair prod.
forbidden region
2MASS1614
B1422
$M_{BH}=10^9$
$M_{BH}=10^8$
hemisphere
slab
10^{46}
10^{45}
10^{44}
10^{43}
10^{42}
10^{41}
L(2–10) erg/s
100
1000
E_c (keV)