ESTIMATING THE SIZE OF X-RAY LAMPPOST CORONAE IN ACTIVE GALACTIC NUCLEI

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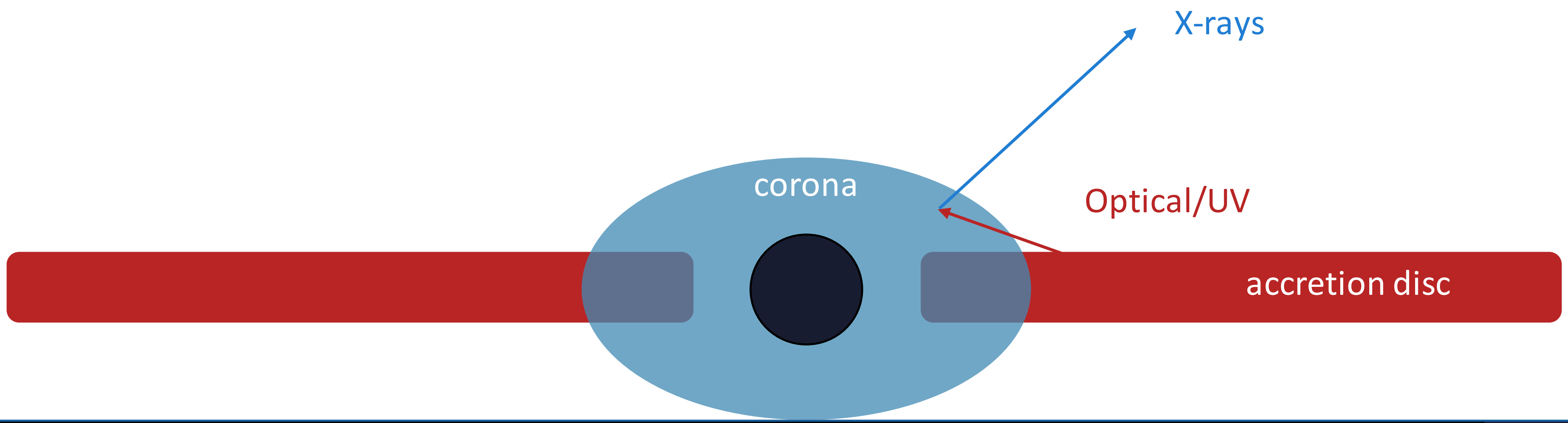
The hot corona

Disc photons are Comptonized in a hot corona



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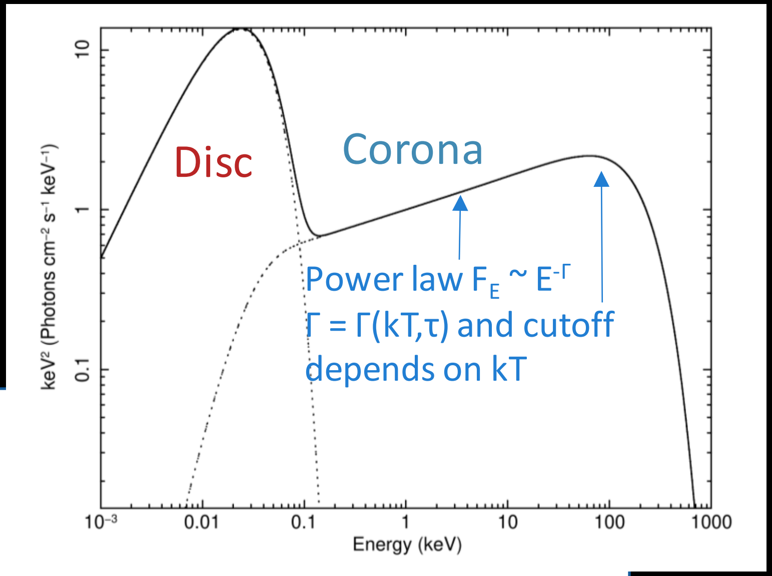
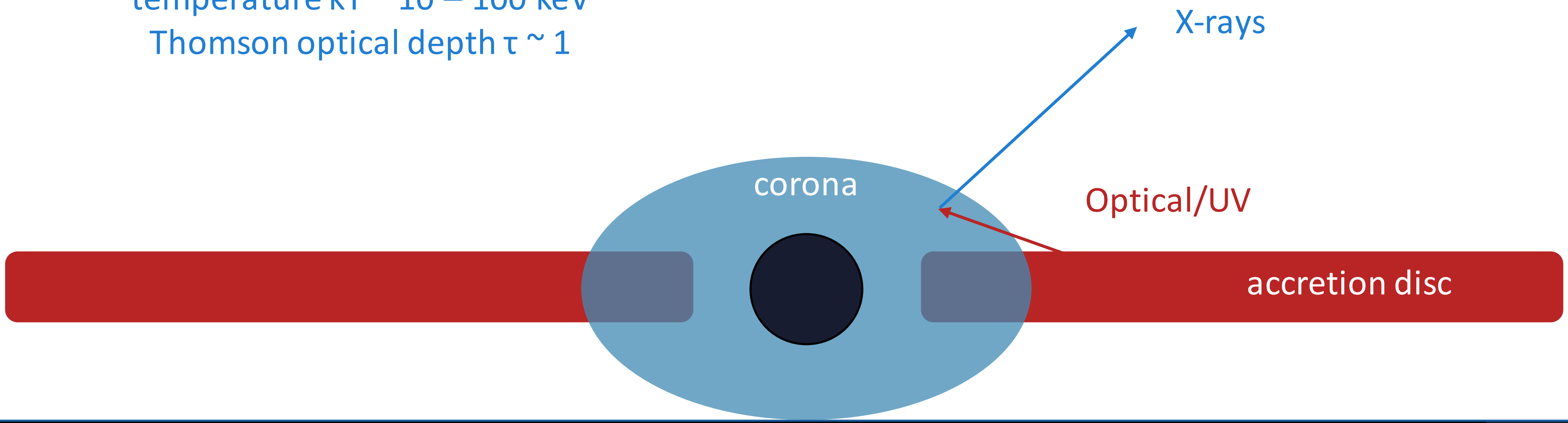


Disc photons are Comptonized in a hot corona

temperature kT ~ 10 – 100 keV
Thomson optical depth τ ~ 1



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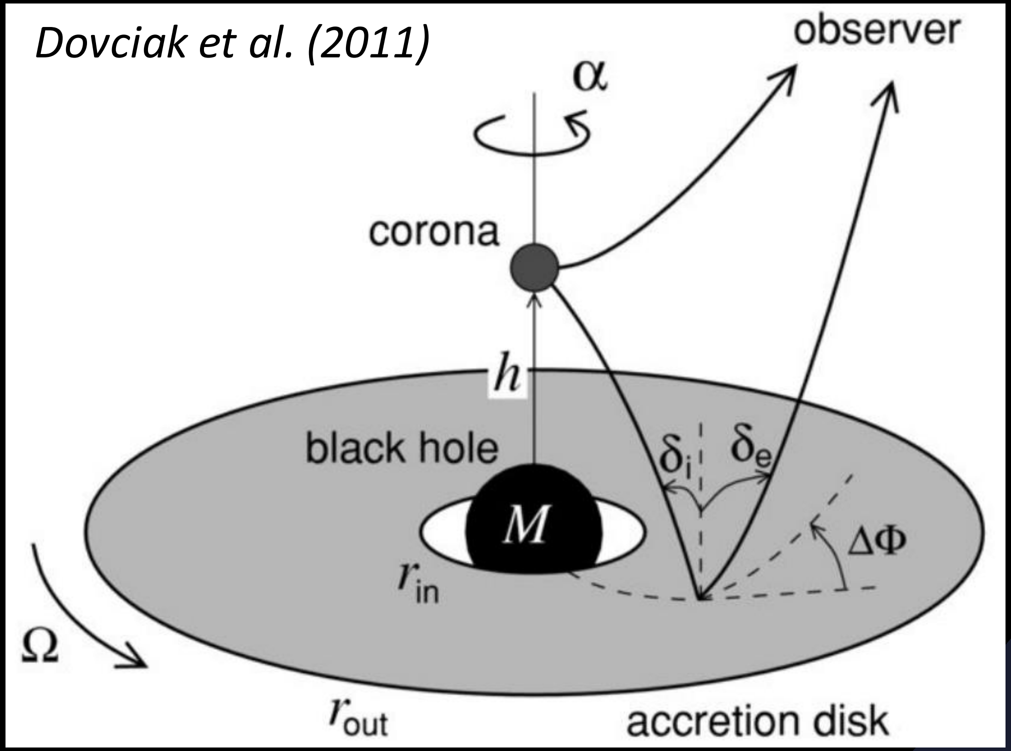
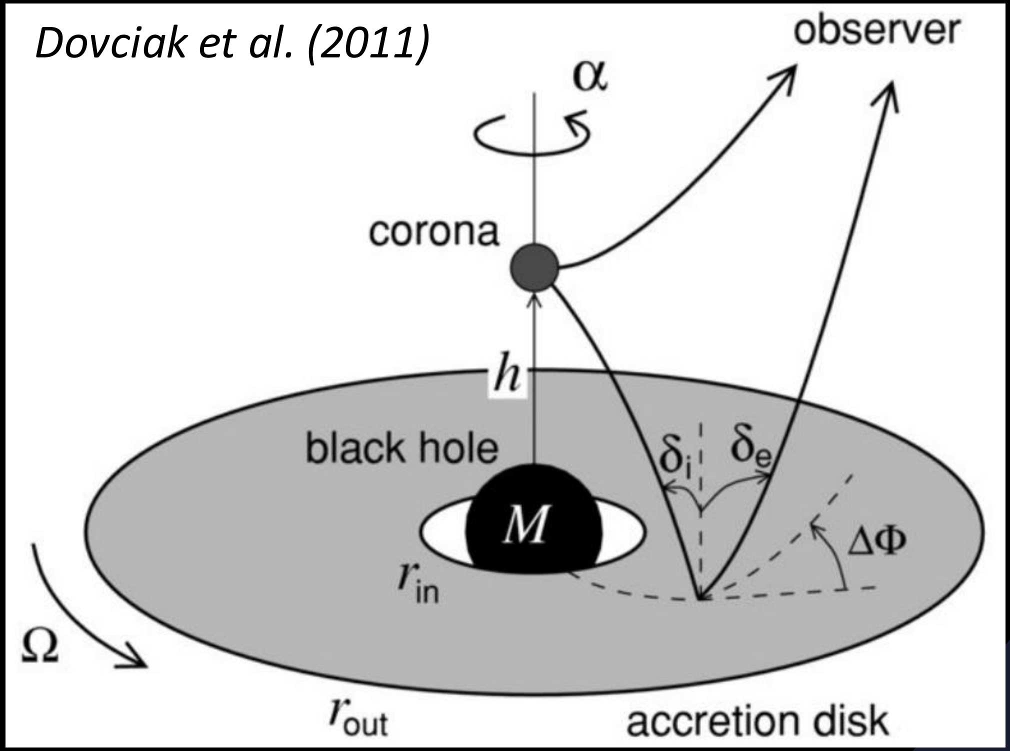
- The ***lamppost*** geometry is a configuration often used to describe the disc–corona system, where the corona is a small source on the symmetry axis of the disc.



What is the size of the corona?

- The lamppost geometry is assumed in models for the calculation of reflection spectra (e.g. Dauser et al. 2013, Garcia et al. 2014) or the effects of X-ray illumination on the disc (e.g. Dovciak et al. 2022).
- The corona is often approximated as a point X-ray source. However, it must intercept enough disc photons to explain the X-ray flux. This constrains the **size** of the corona (Dovciak & Done 2016).



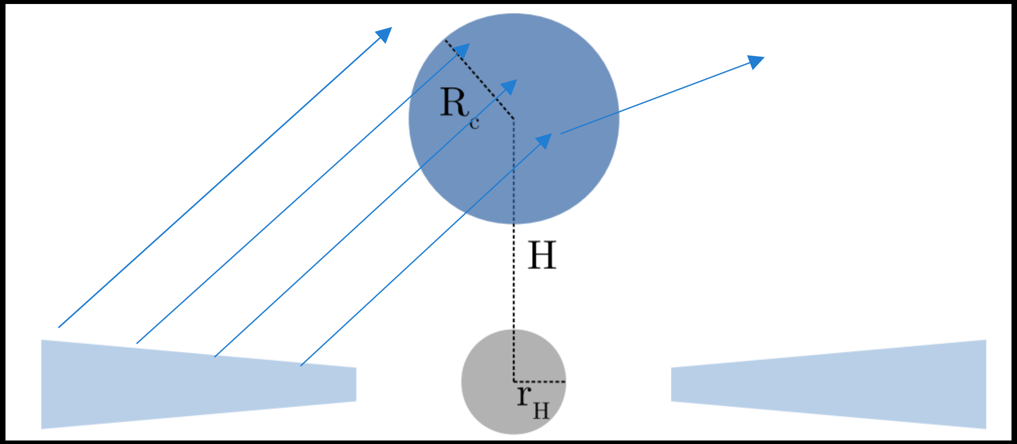
What is the size of the corona?

(X-ray photon rate)

= (disc photon rate at the corona)

× (fraction of scattered photons)

× (cross section of the corona)



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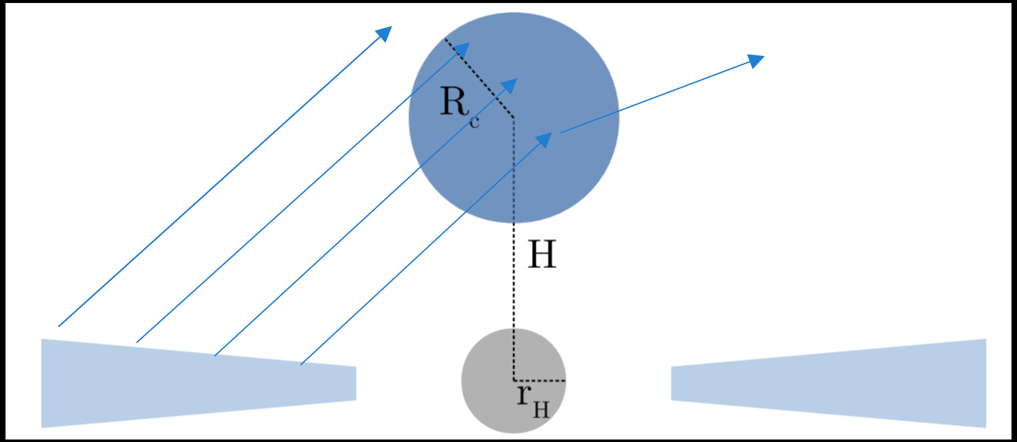
Dovciak & Done (2016): relativistic ray-tracing code to compute the coronal size

Zhang et al. (2019): Monte-Carlo radiative transfer code for Comptonization in Kerr spacetime (MONK)



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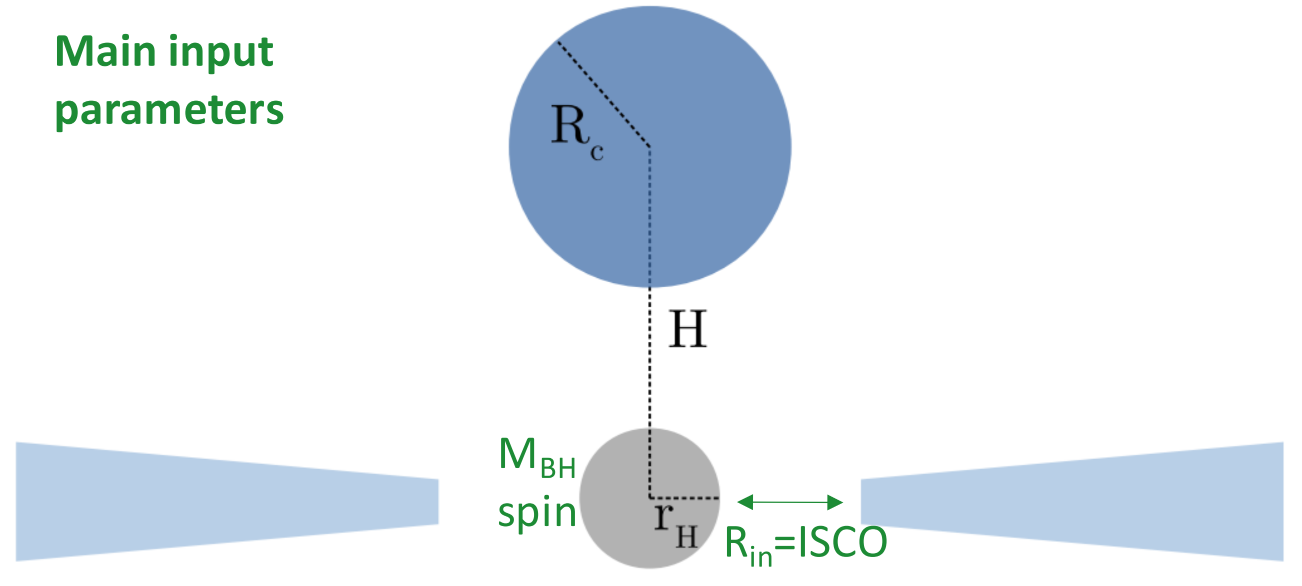

Fig. 1. Sketch of the lamppost configuration. The corona has a radius R_c and is located at a height of $H - r_H$ above the event horizon.

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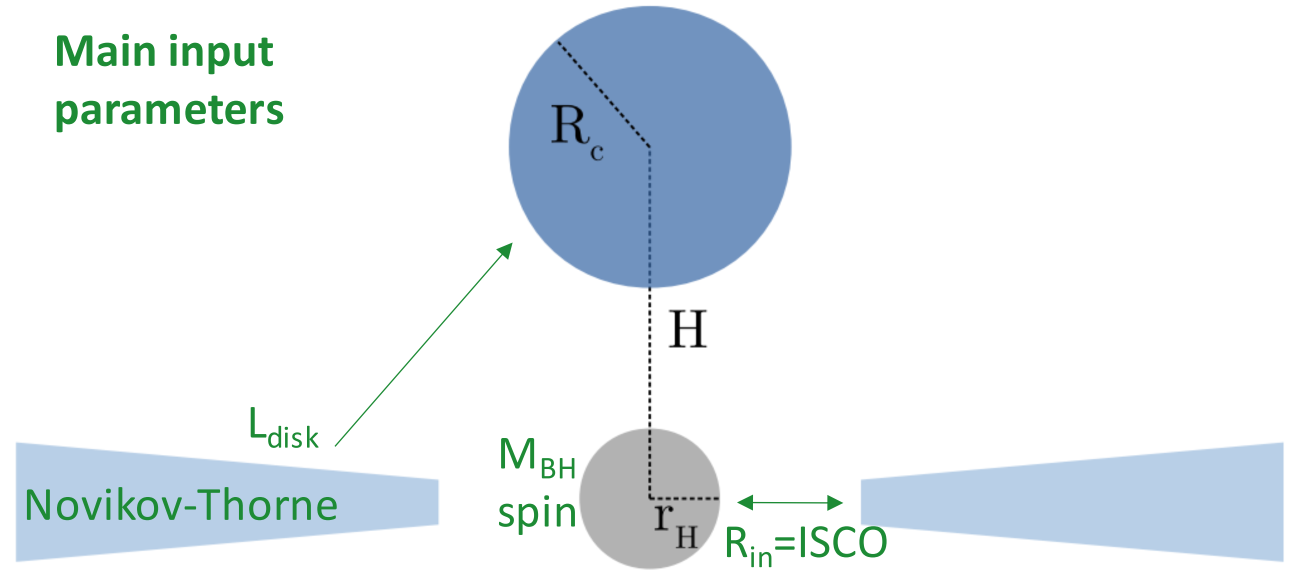

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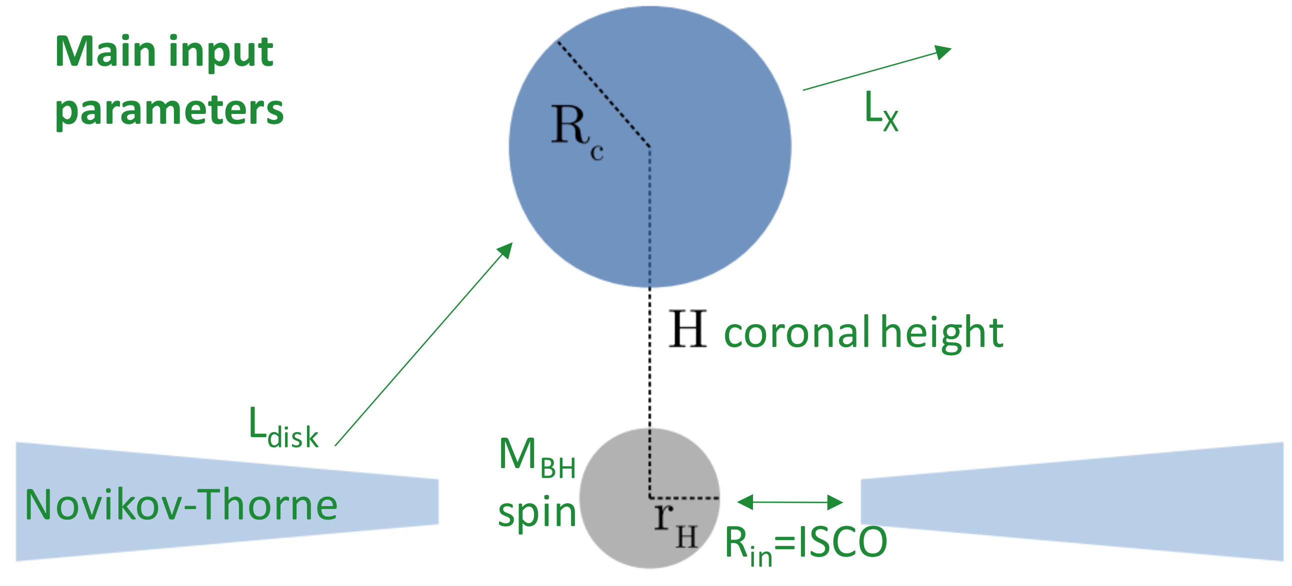

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The sample

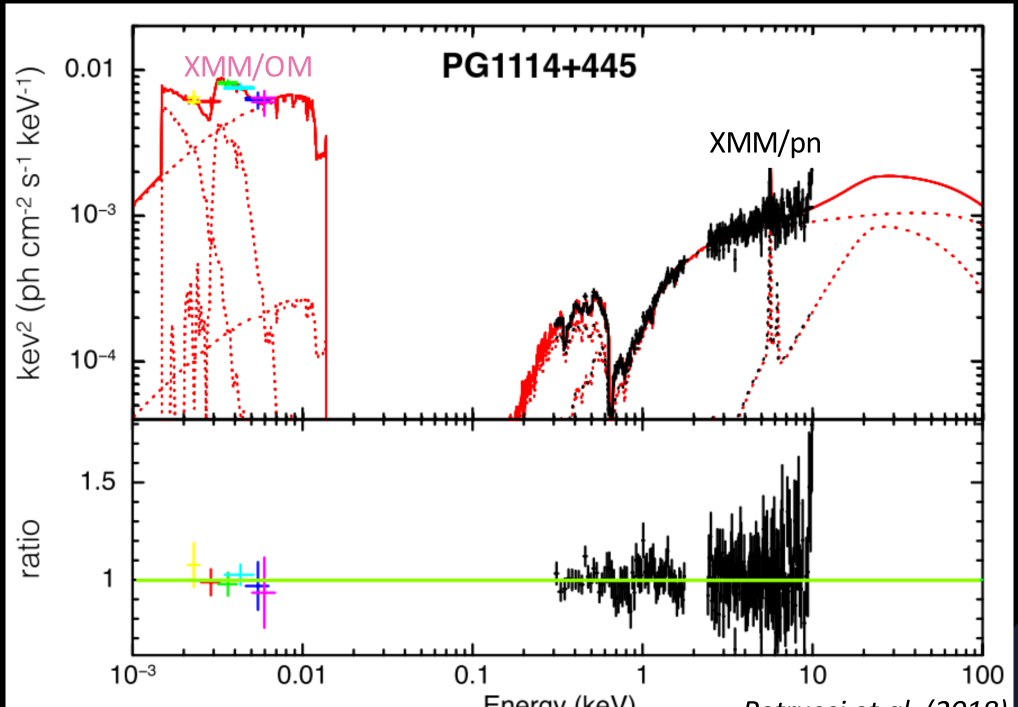
- 20 Seyfert 1s selected with the criteria of the CAIXA catalog (Bianchi et al. 2009): radio-quiet, unabsorbed, observed by *XMM* and with estimates of the black hole mass (see also Petrucci et al. 2018).

Name	Redshift	log M_{BH}	Obs.
1H 0419-577	0.1040	8.58	8
ESO 198-G24	0.0455	8.48	3
HE 1029-1401	0.0858	8.73	2
IRASF 12397+3333	0.0435	6.66	2
MRK 279	0.0304	7.54	3
MRK 335	0.0257	7.15	3
MRK 509	0.0343	8.16	16
MRK 590	0.0263	7.68	2
MRK 883	0.0374	7.28	4
NGC 4593	0.0090	6.73	7
PG 0804+761	0.1000	8.24	2
PG 0844+349	0.0640	7.97	2
PG 1114+445	0.1438	8.59	12
PG 1116+215	0.1765	8.53	5
PG 1351+640	0.0882	7.66	3
PG 1402+261	0.1640	7.94	2
PG 1440+356	0.0790	7.47	4
Q0056-363	0.1641	8.95	3
RE 1034+396	0.0424	6.41	8
UGC 3973	0.0221	7.72	5

The sample

- L_{UV} (5—7 eV) and black hole mass --> L_{disk}
- L_x (2—10 keV) and X-ray spectral shape

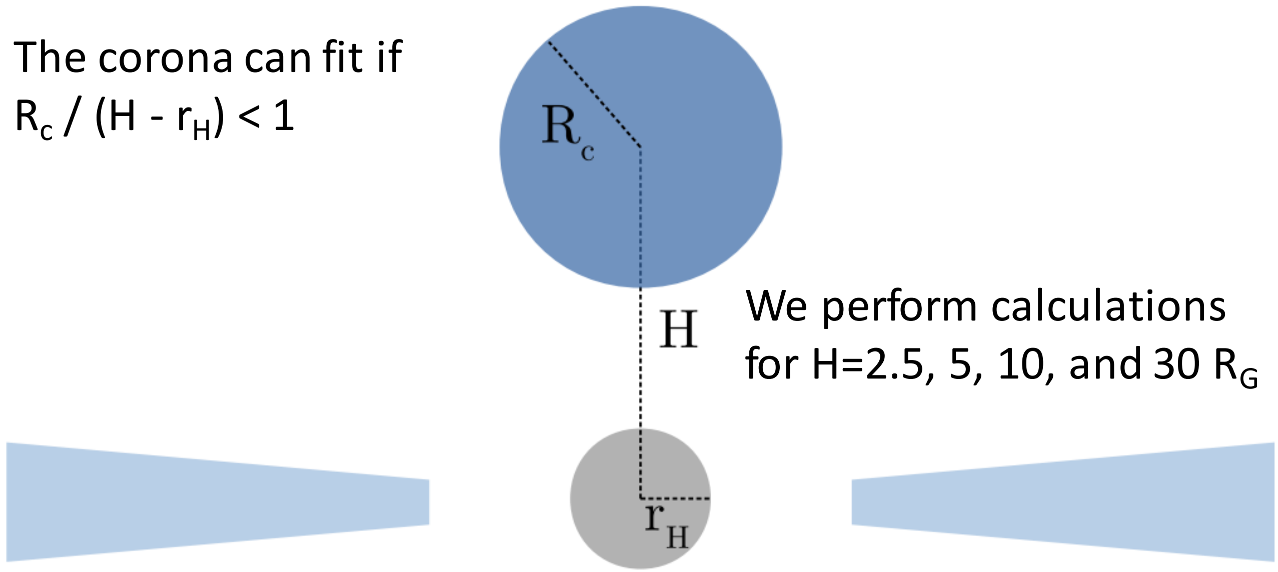
  --> L_x (tot)



Petrucci et al. (2018)

Can the corona fit?

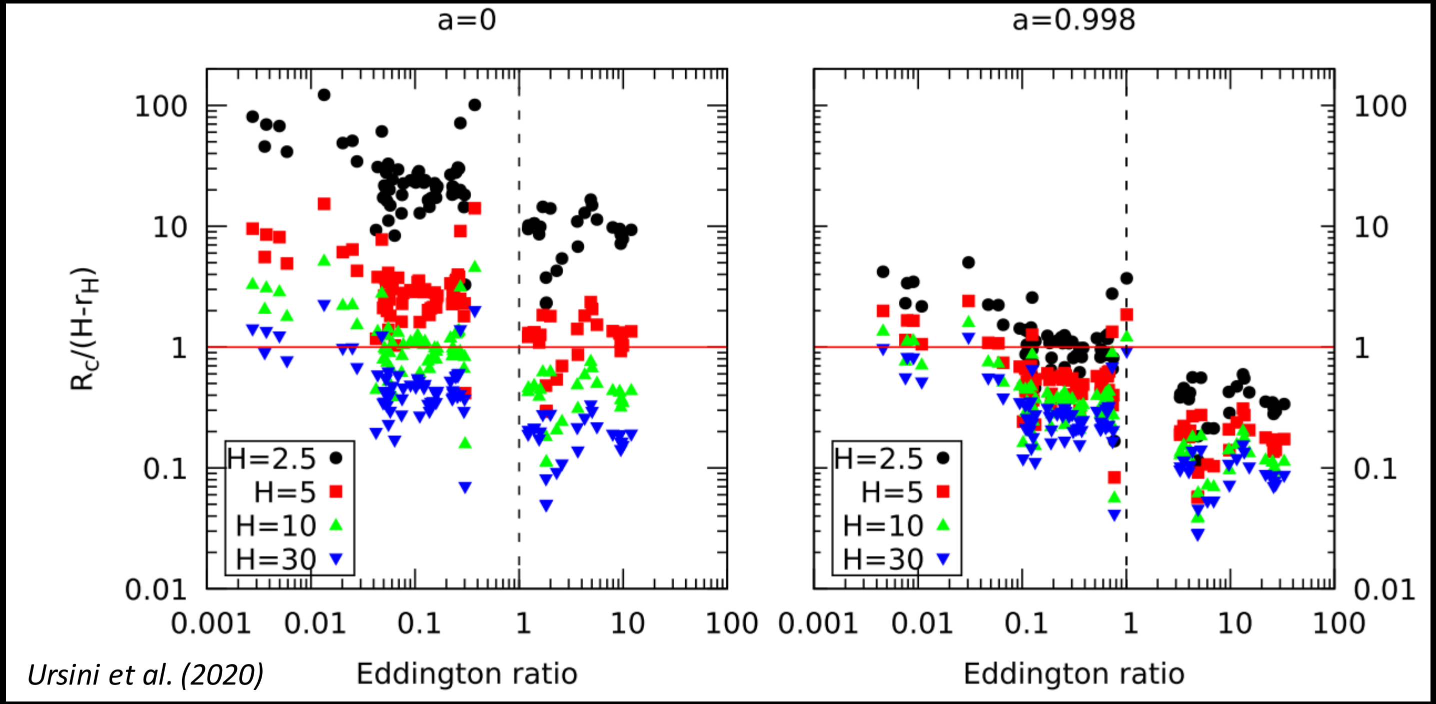
The corona can fit if
$R_c / (H - r_H) < 1$



We perform calculations for H=2.5, 5, 10, and 30 R_G

Fig. 1. Sketch of the lamppost configuration. The corona has a radius R_c and is located at a height of $H - r_H$ above the event horizon.

Results: the coronal size



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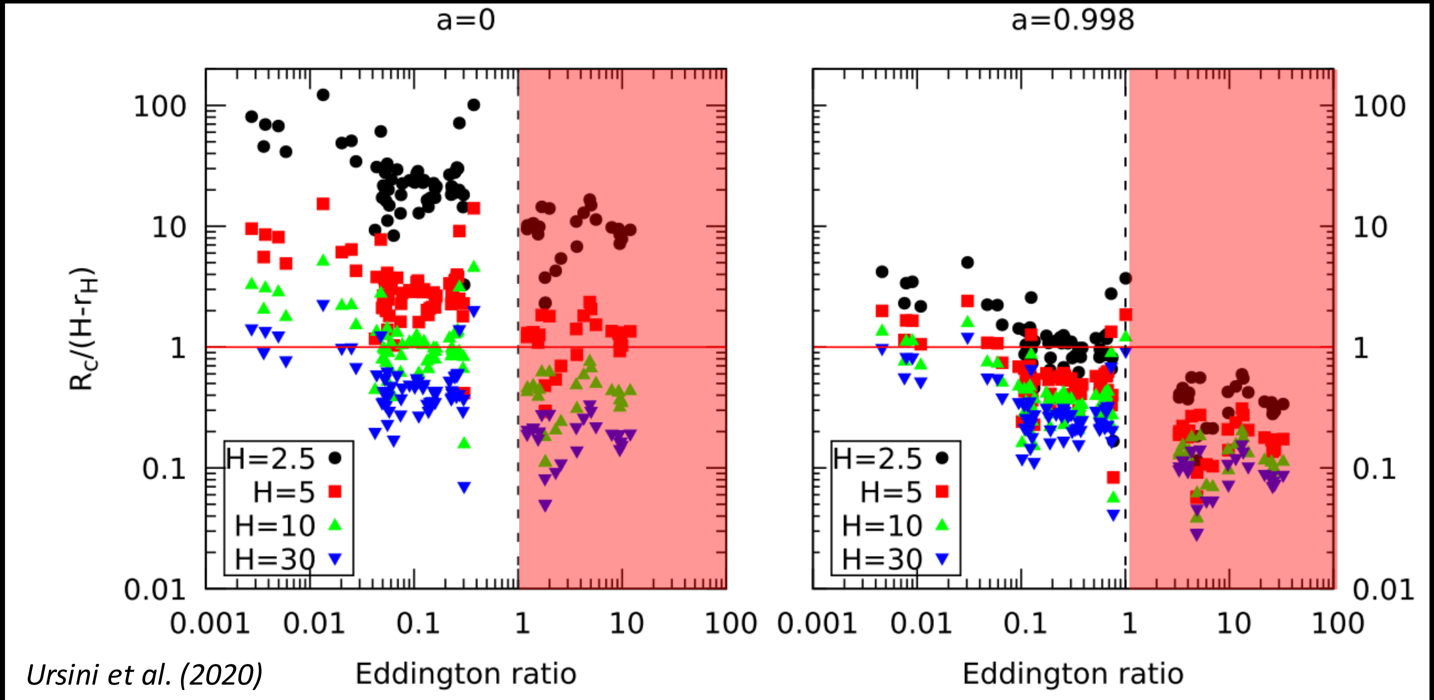

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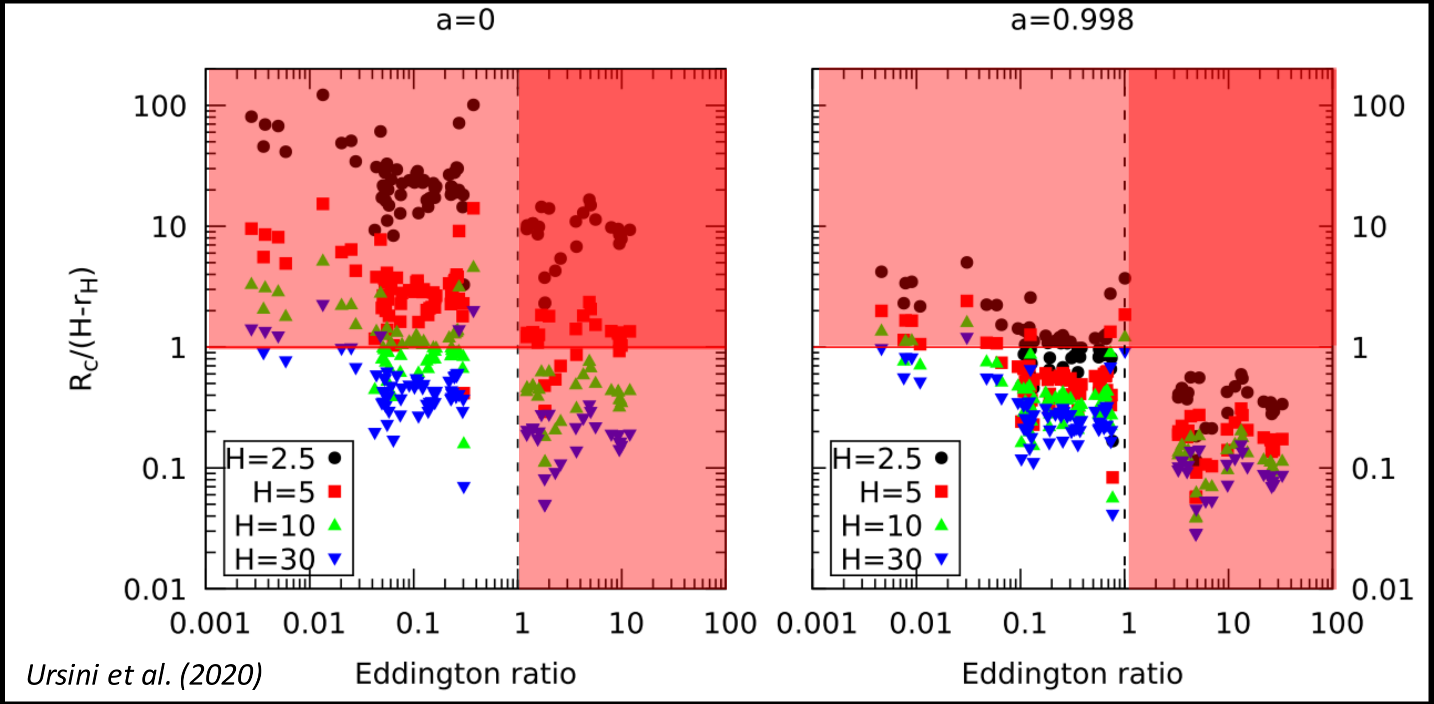

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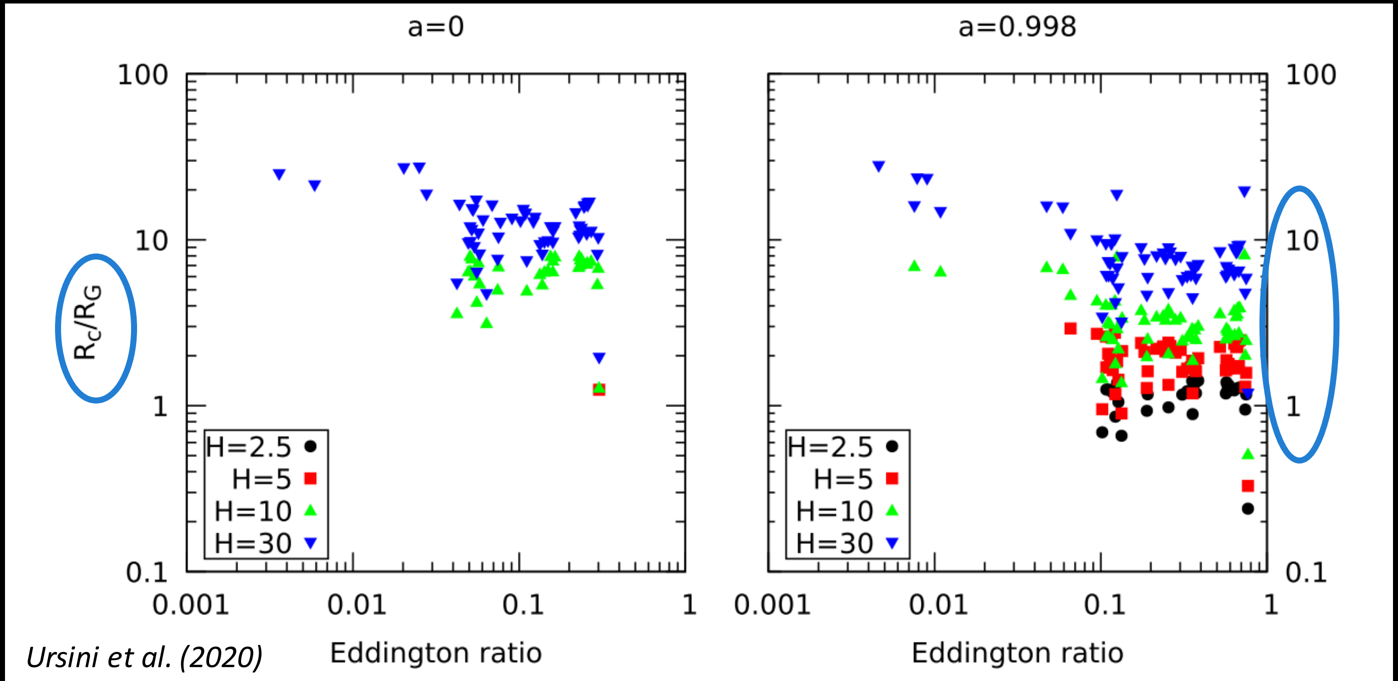


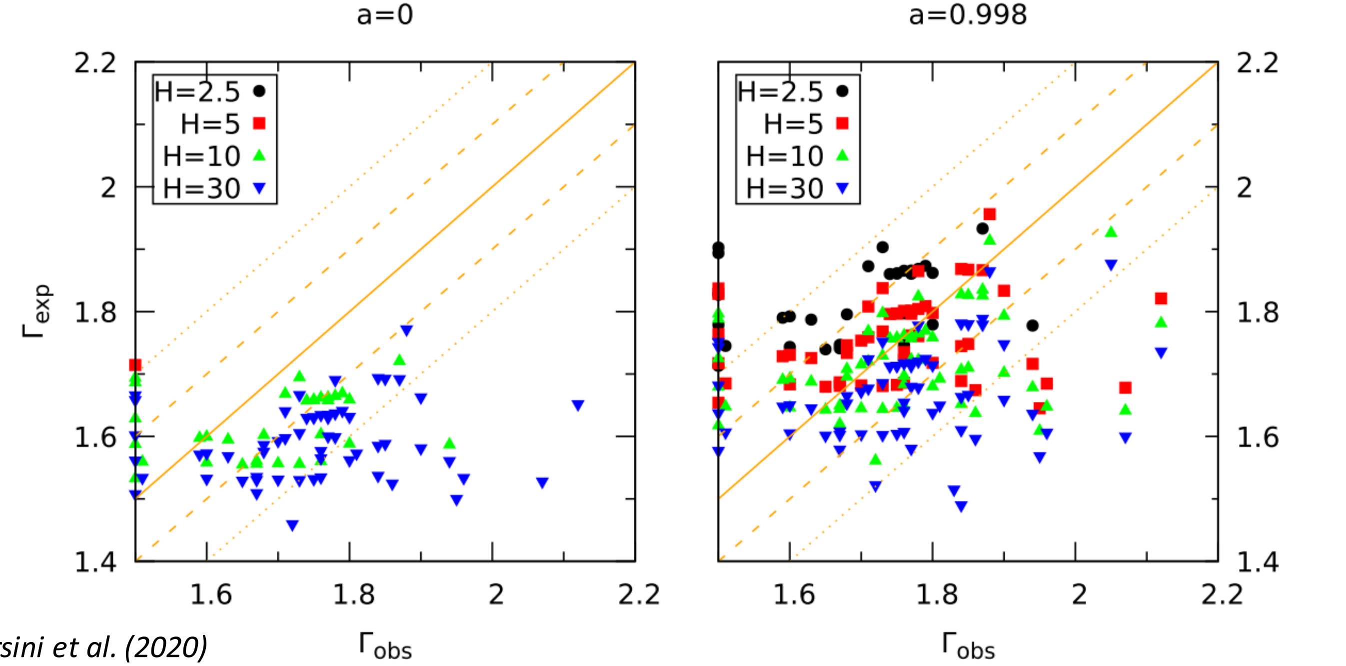
Results: the spectral shape

- For a given luminosity, the coronal radius is inversely related to the Compton amplification factor ($A = L_X / L_{seed}$ --> computed by the code)
- Numerical simulations (Beloborodov 1999, Malzac et al. 2001) show that the photon index depends on the Compton amplification factor:

$$\Gamma_{exp} \simeq 2(A-1)^{-0.1}$$

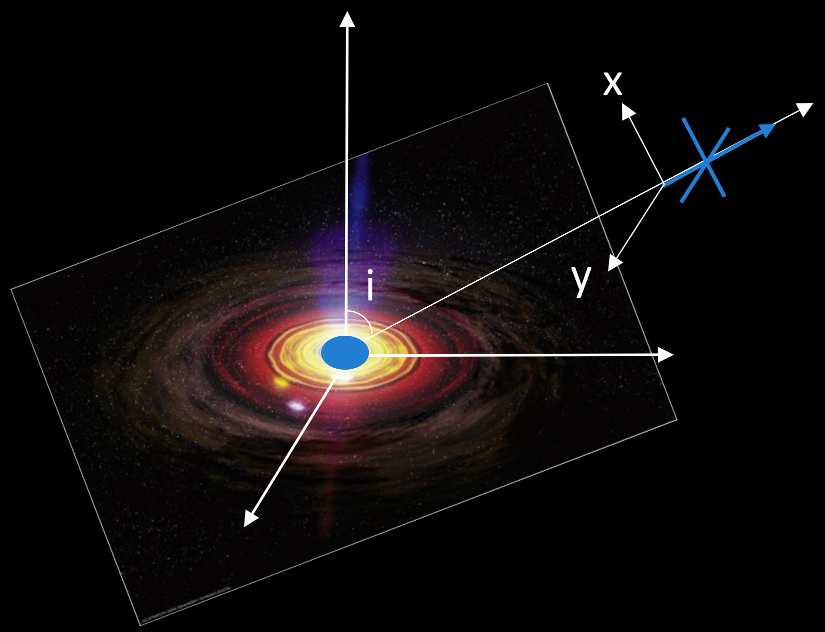
- We can compare the **expected** photon index $\boldsymbol{\Gamma_{exp}}$ with the **observed** one $\boldsymbol{\Gamma_{obs}}$

Results: the spectral shape



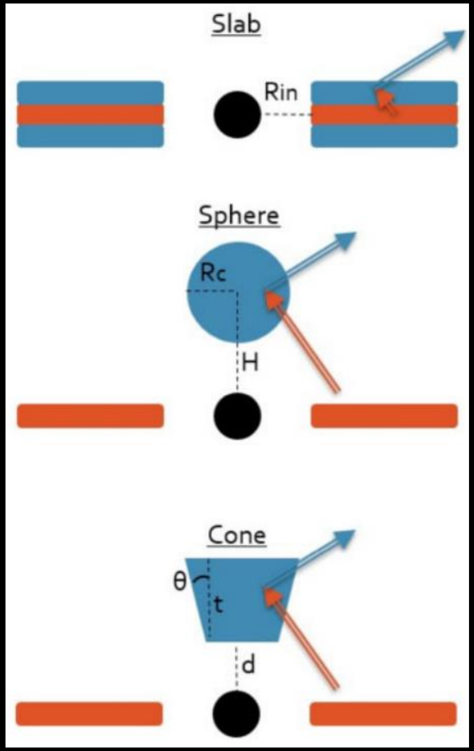
Ursini et al. (2020)

Future: polarimetry



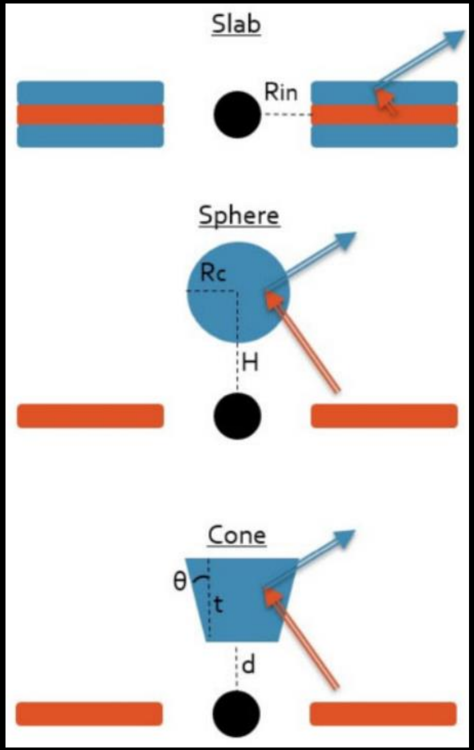
IXPE will measure the X-ray polarization in AGN for the first time

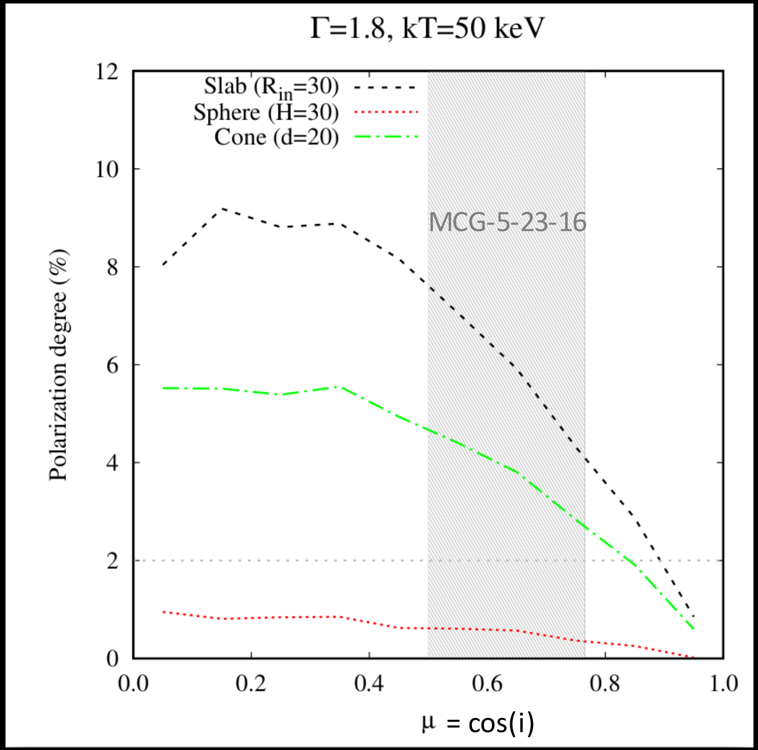
Future: polarimetry



- Polarization depends on geometry (deviation from spherical symmetry).
- Numerical simulations with the MONK code show that by measuring polarization we will be able to constrain the shape of the corona (Ursini et al. 2022).

Future: polarimetry





Conclusions

- For a maximally spinning black hole, a lamppost corona can be located down to a height of H = 2.5 R_G, having a radius of order 1 R_G. A coronal height of 5 R_G is a physically consistent value for almost all sources of our sample.
- For a non- spinning black hole, the corona cannot fit within 5 R_G.
- The maximal spin solution is favored, because it predicts a spectral shape in better agreement with that observed.
- Upcoming X-ray polarimetric measurements will crucially help us to constrain the geometry of the corona, and thus its physical origin.