# Testing the disk-corona interplay in radiatively-efficient broad-line AGN

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Andrea Merloni, Kirpal Nandra, Gabriele Ponti





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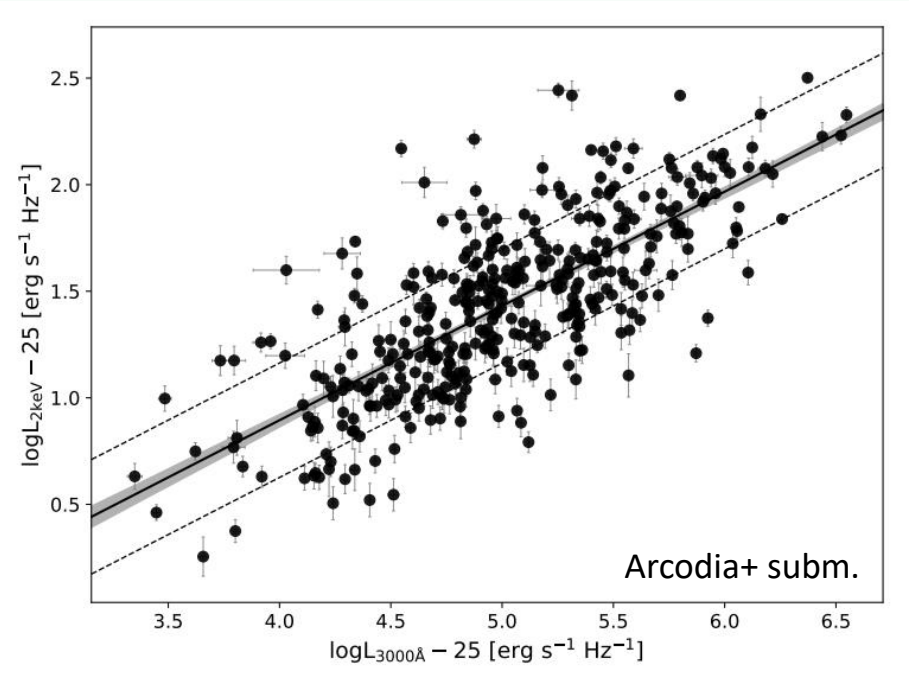
# Outline

- The smoking gun: the $\boldsymbol{L_X - L_{UV}}$
- The **disk-corona model**
- The methodology: an **observational test**
- Results & Conclusions

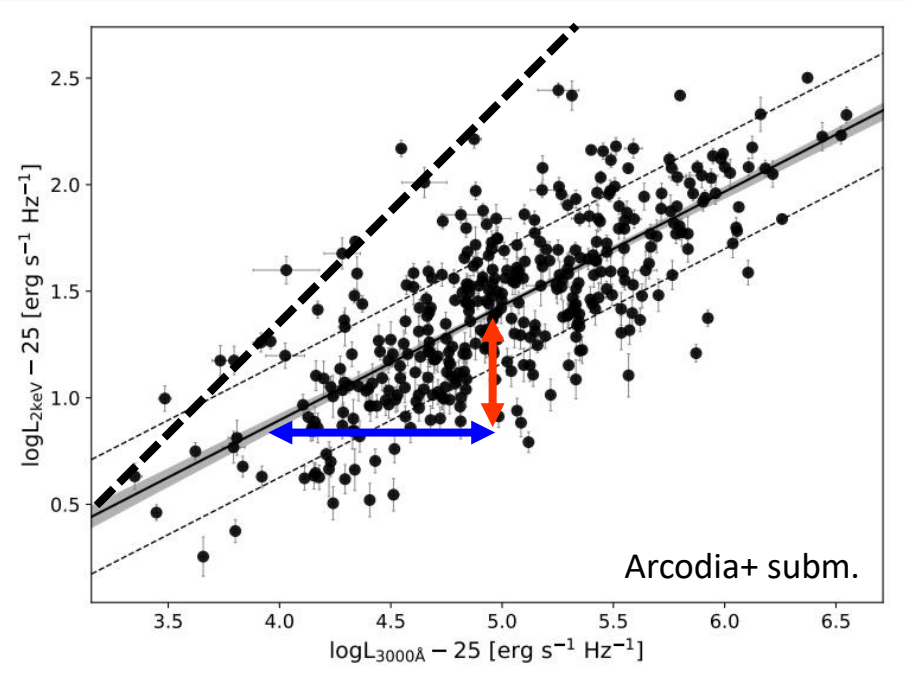
# The smoking gun of the Disk-Corona interplay

Relation between the **Disk** and the **Corona**




- Known for $\sim 40$ yrs, mostly as $\boldsymbol{\alpha_{OX}}$ (Tananbaum+79 and many others)
- Used for **many** applications: CXRB, XLF, $L_{BOL}$, SEDs… (e.g. Marconi+04, Hopkins+07, Lusso+10)
  even for cosmology (e.g. Risaliti & Lusso 15, 18)
- <u>But</u> no conclusive physical explanation yet (but see Lusso & Risaliti 17, Kubota & Done 18)

# The smoking gun of the Disk-Corona interplay

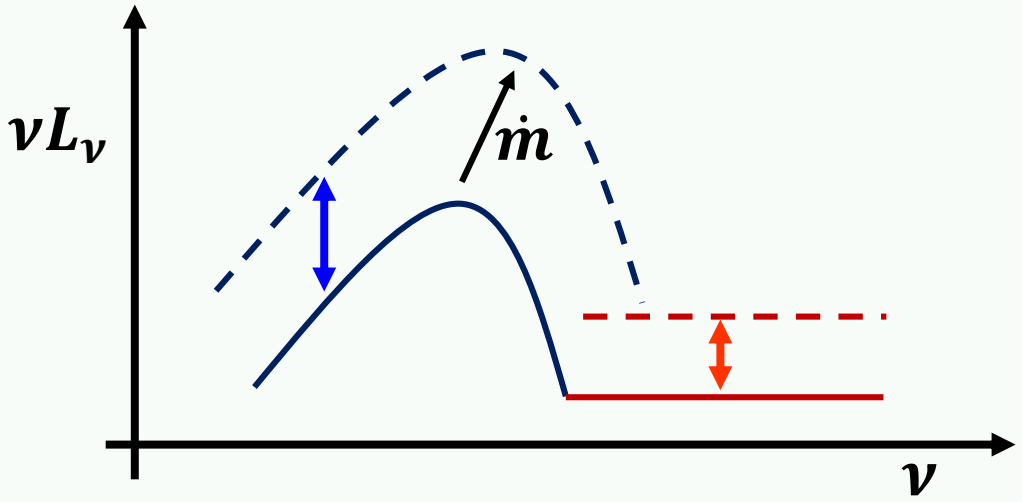



Slope $\approx 0.65$

$\sigma_{phys} \lesssim 0.2$ dex

Lusso & Risaliti 16
Chiaraluce+ 18

The emission from the **Corona** <u>increases less</u> than the **Disk** emission




→ Some mechanism regulates their energetic connection

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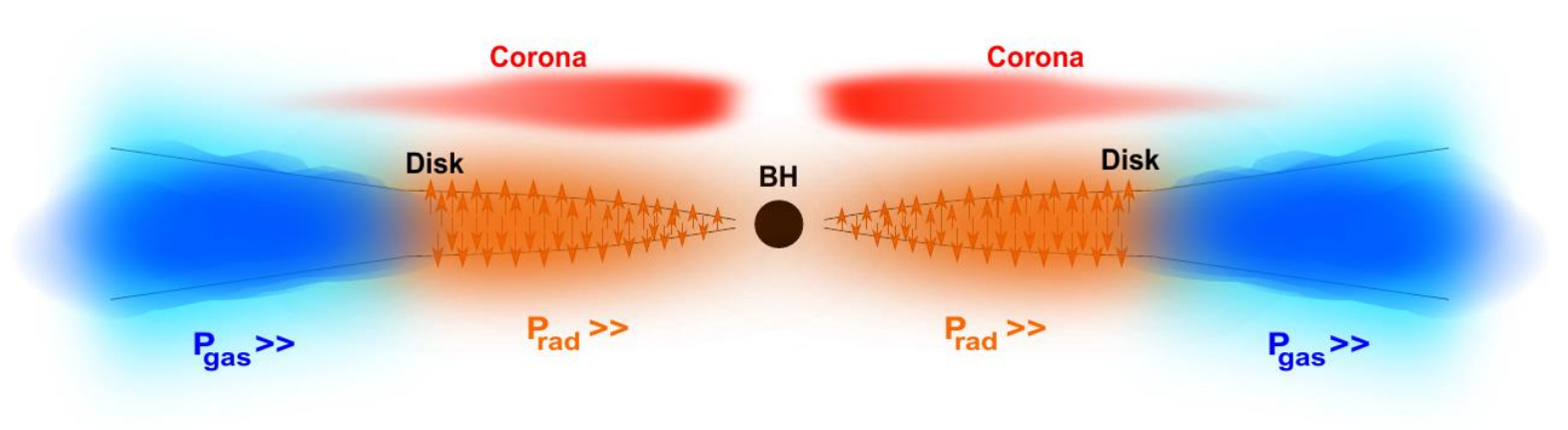
# The disk-corona model



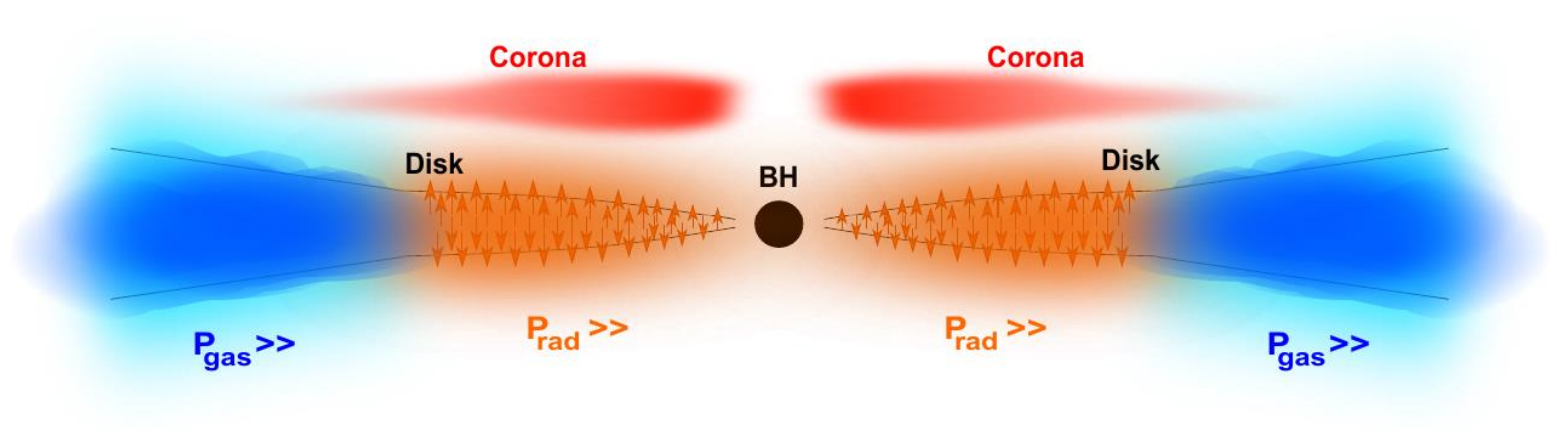

AGN in a sweet spot of accretion
$\dot{m} \approx$ **(0.0x – 1)**

- Prescriptions from the standard accretion theory (Shakura&Sunyaev73, Pringle81)
- Modified with:

→ Generalised **viscosity law**: $\tau_{r\varphi} \propto P_{gas}^{\mu} P_{tot}^{1-\mu}$

$\mu =$ **DISK PHYSICS PRESCRIPTION**

# The disk-corona model

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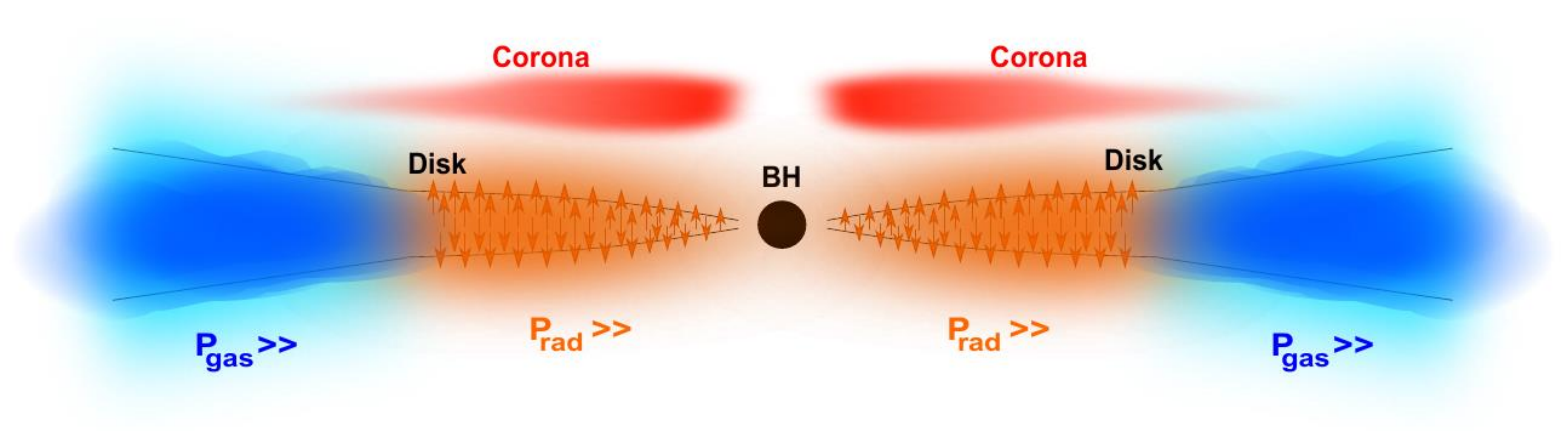
→ Generalised **viscosity law**: $\tau_{r\varphi} \propto P_{gas}^{\mu} P_{tot}^{1-\mu}$ $\quad \mu =$ **DISK PHYSICS PRESCRIPTION**

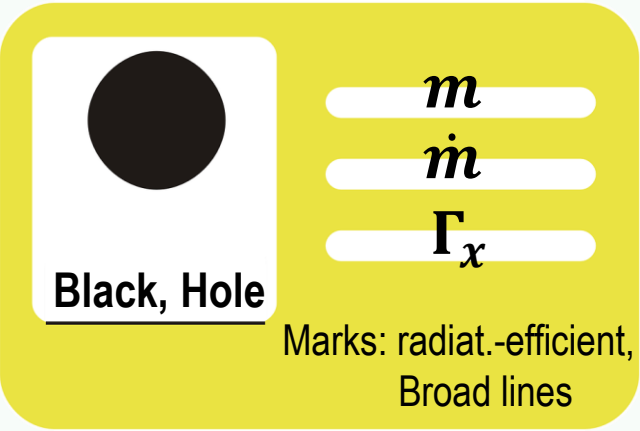
→ **X-ray corona**: $f = \frac{Q_{cor}}{Q_{accr}} = f_{max}\left(1 + \frac{P_{rad}}{P_{gas}}\right)^{-\mu/2}$ $\quad f_{max} =$ **MAX CORONAL STRENGTH**

(Haardt & Maraschi 91,93)
(Svensson & Zdziarski 94)

(Merloni & Fabian 02; Merloni 03)

# The disk-corona model

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$f_{max} =$ MAX CORONAL STRENGTH

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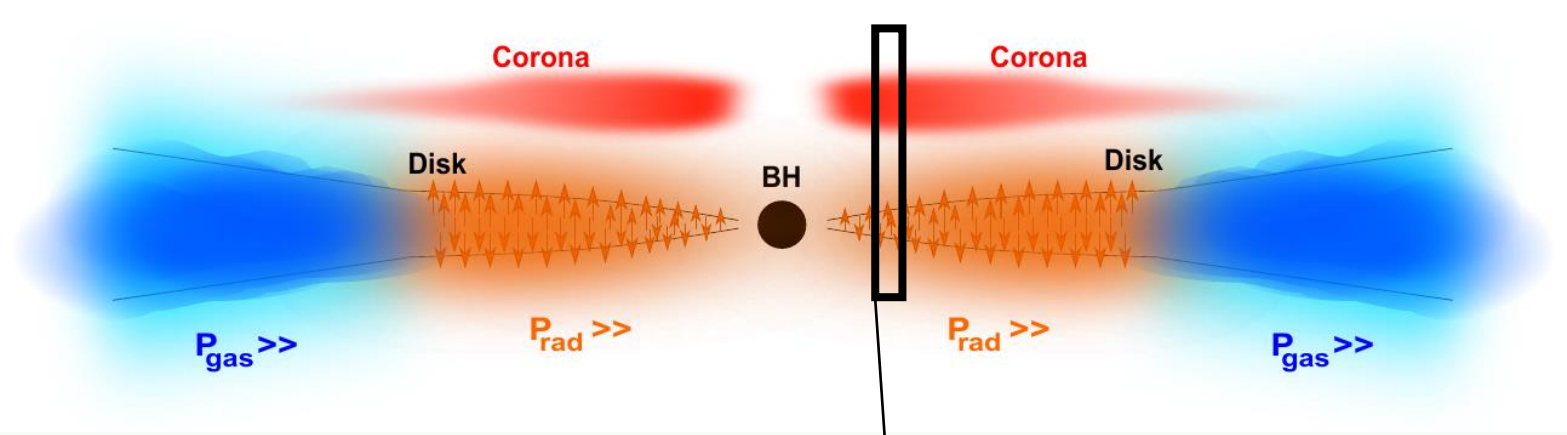


Black, Hole

$m$

$\dot{m}$

$\Gamma_x$

Marks: radiat.-efficient, Broad lines

→

Radial profiles:

$P, \rho, T, h, f$

→

$L_X \propto f Q_{accr}$

$L_{UV}$ multicolor BB

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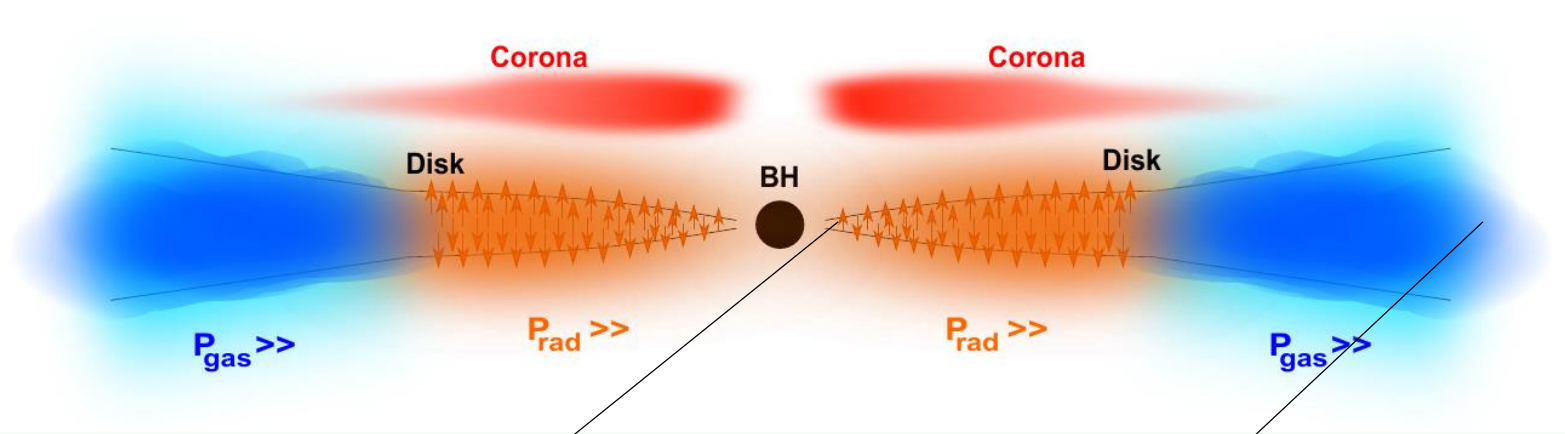


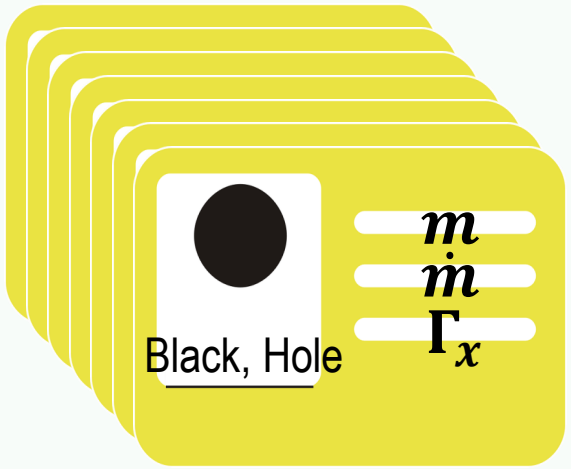


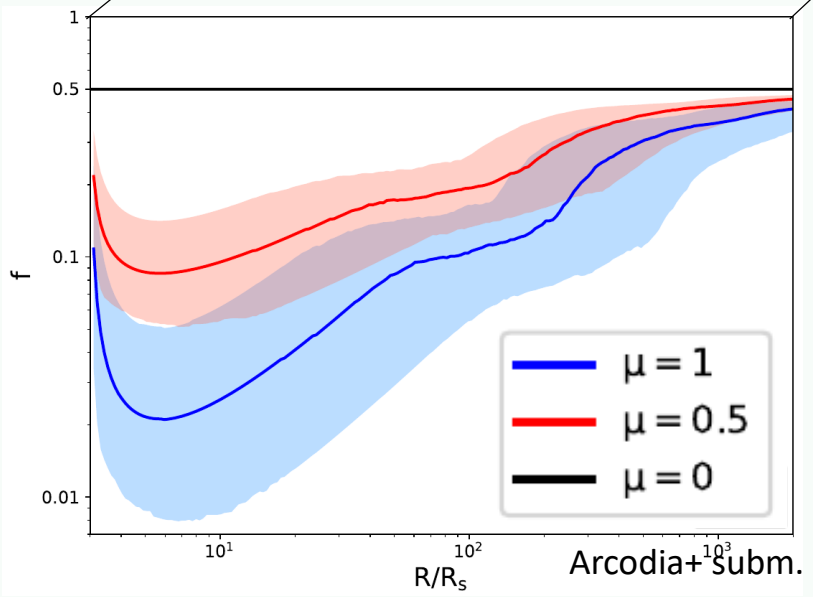


$\mu$ = DISK PHYSICS

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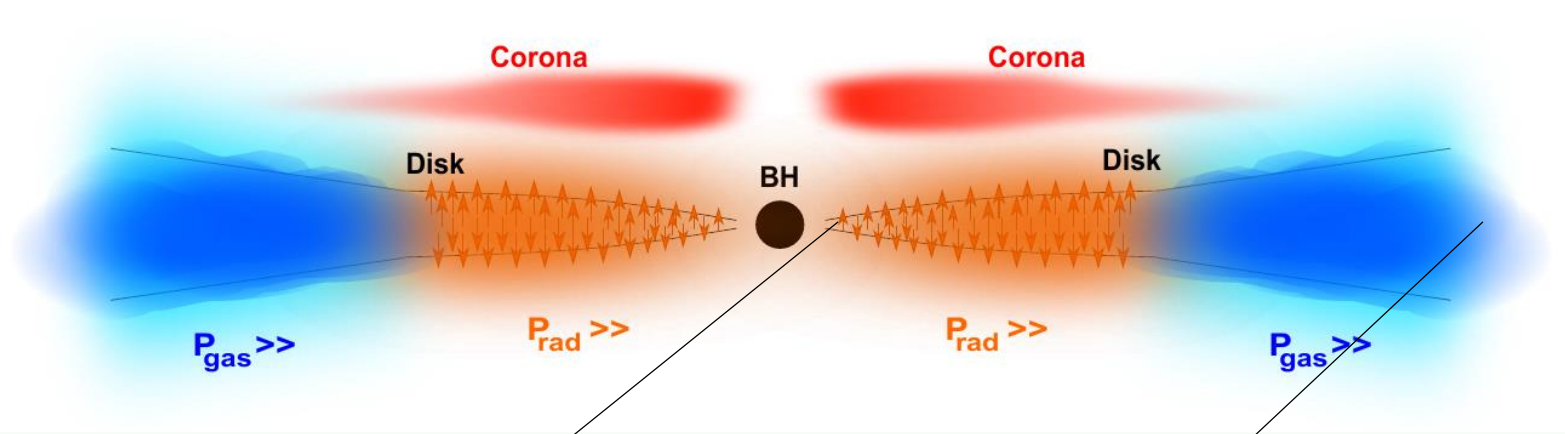


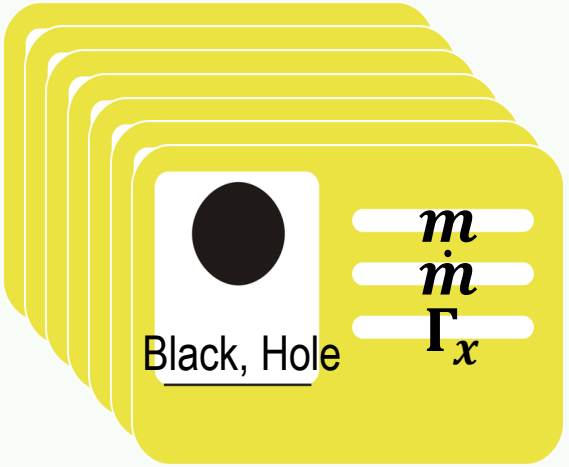


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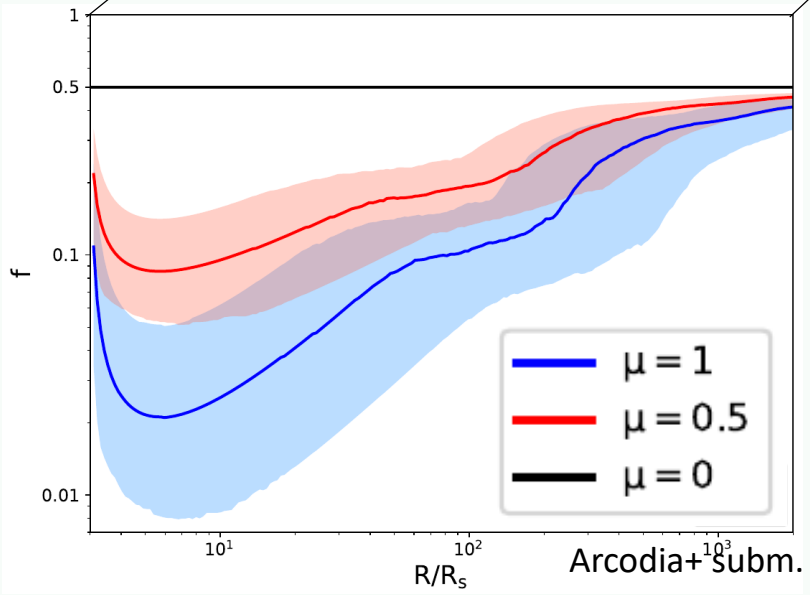
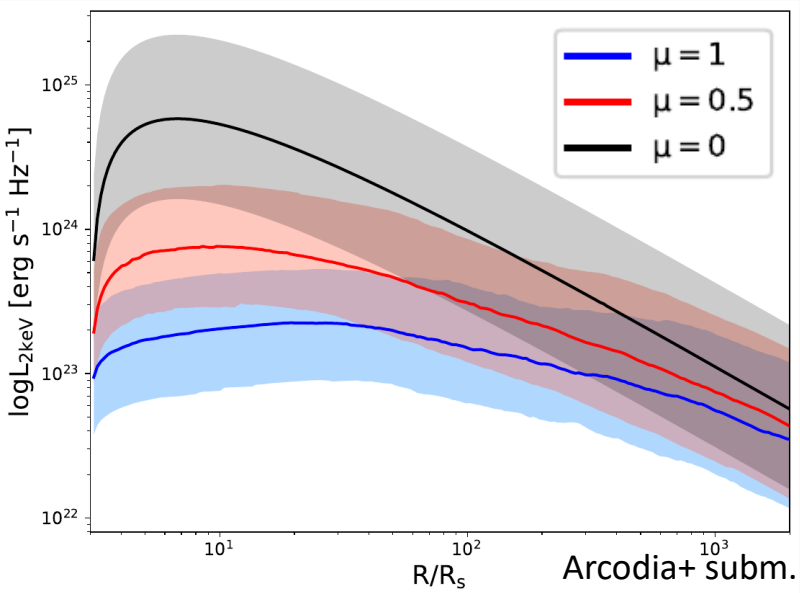
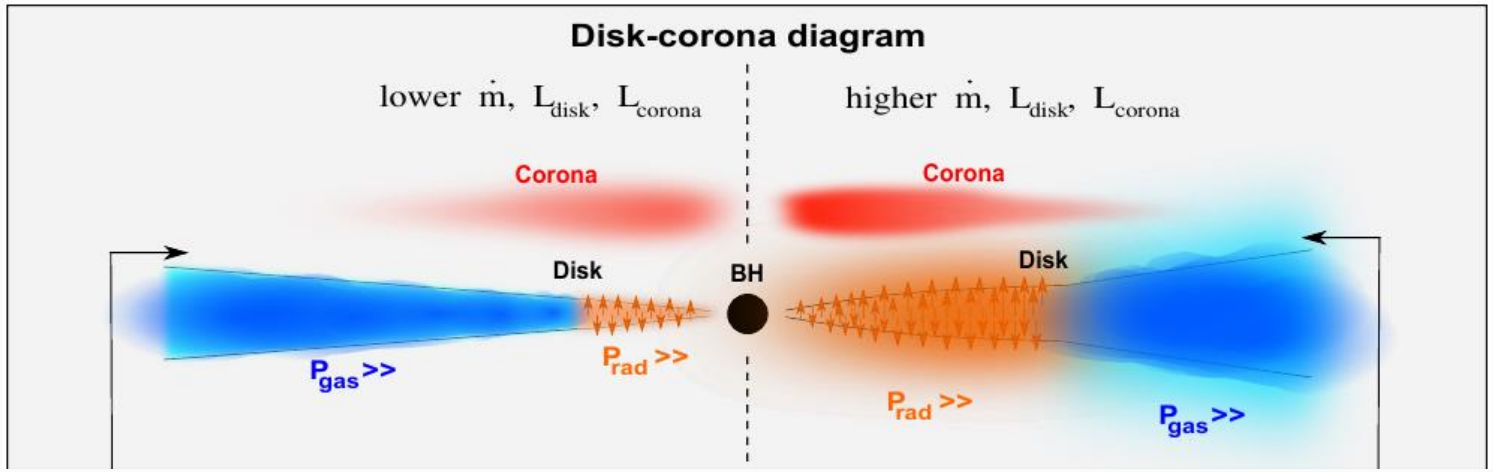



$L_X \propto f Q_{accr}$

# Qualitative prediction: $L_X - L_{UV}$ slope < 1



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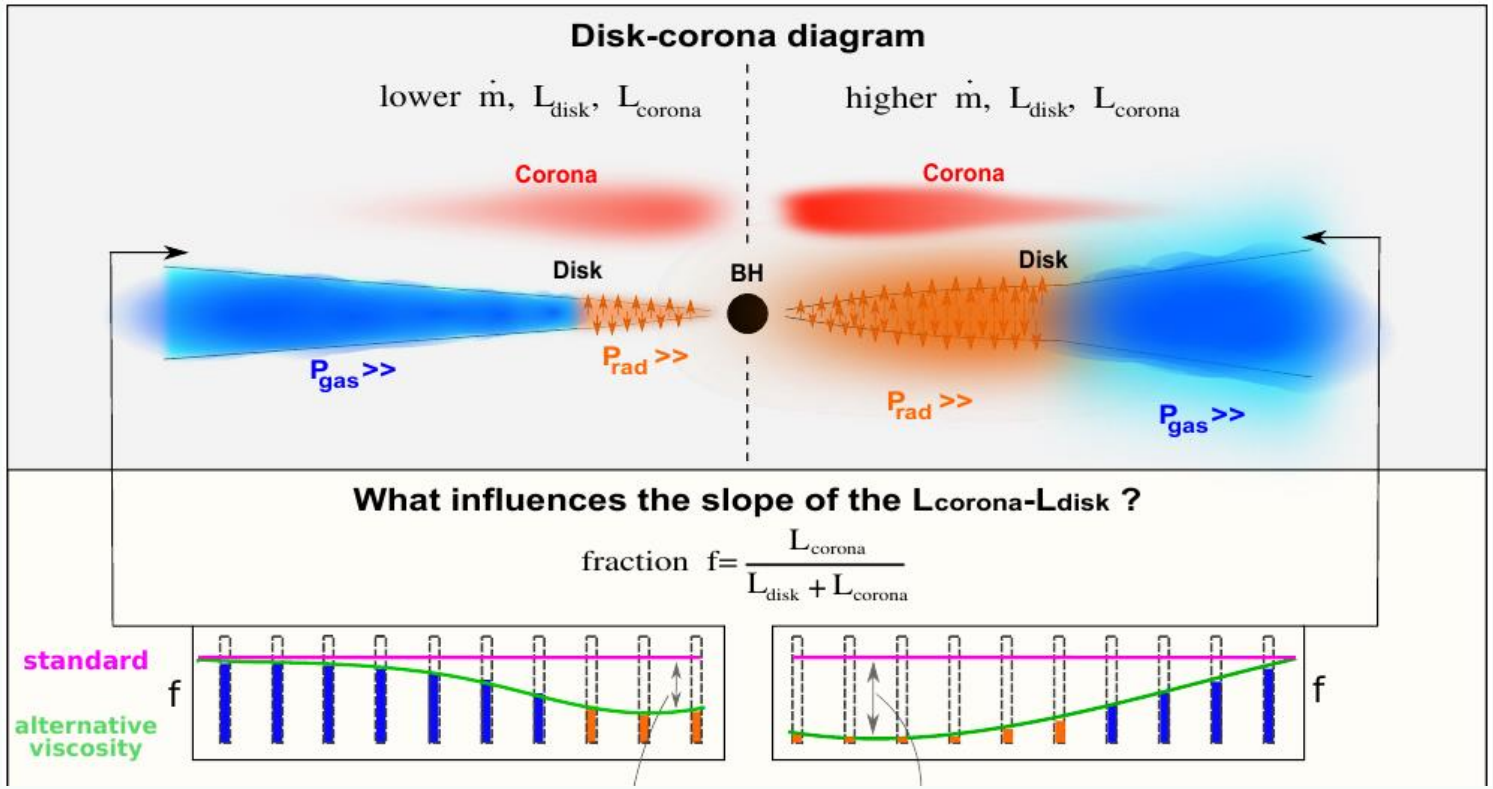
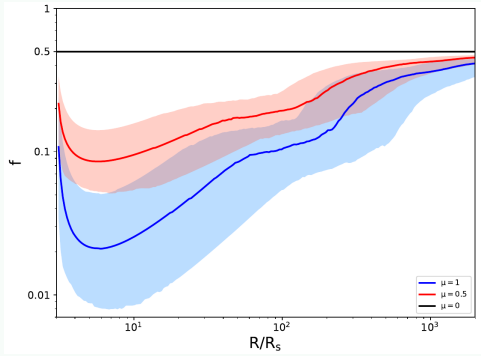
$$f = f_{max}\left(1 + \frac{P_{rad}}{P_{gas}}\right)^{-\mu/2}$$



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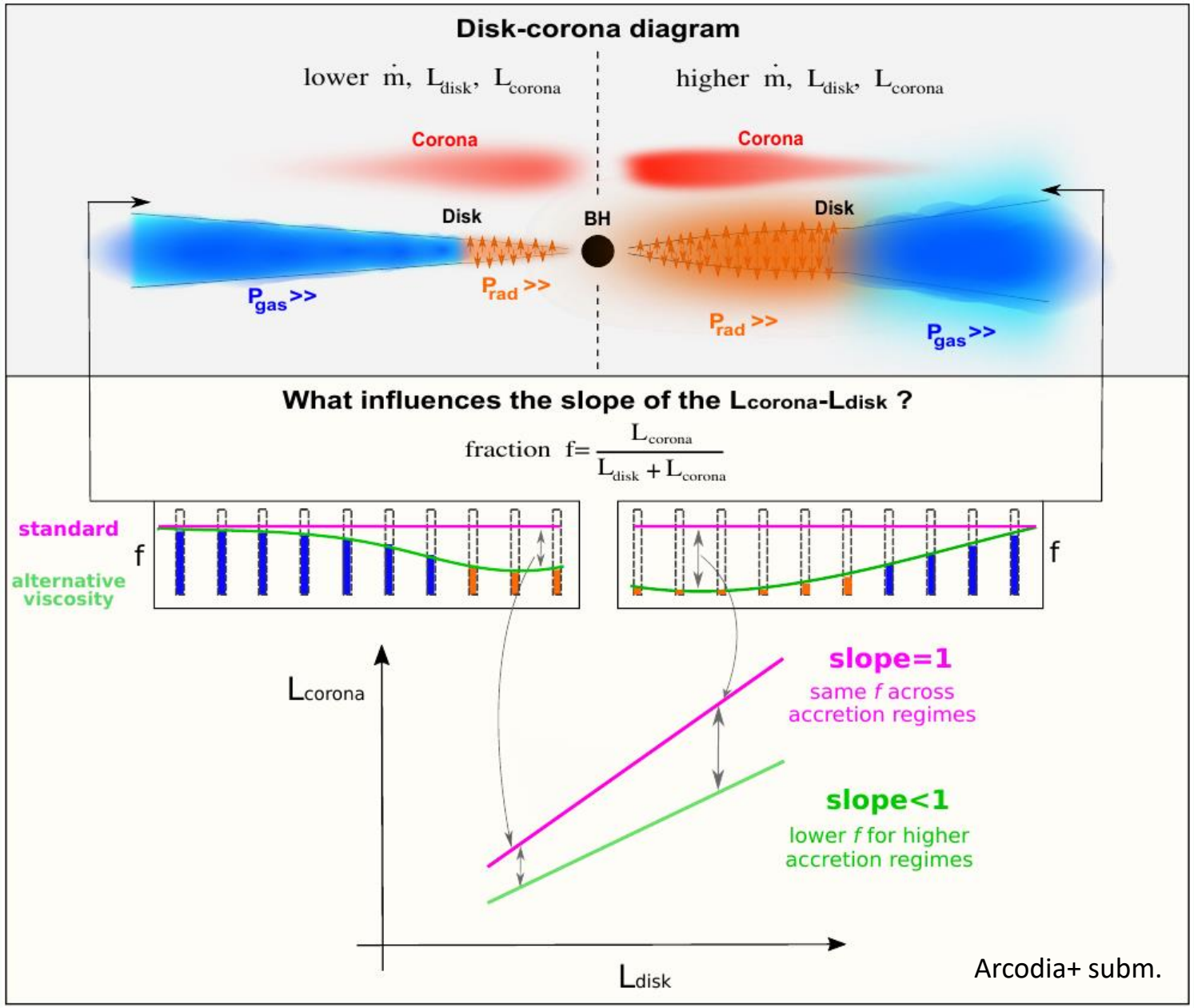


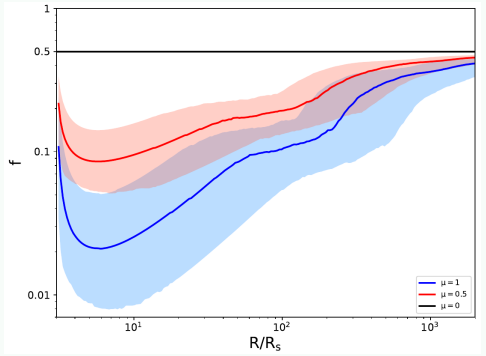


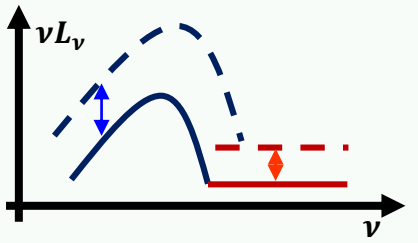

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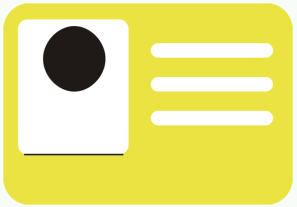
# Observational test: methodology

- Mock $\boldsymbol{L_X}, \boldsymbol{L_{UV}}$ values depend on the BH ID card $(m, \dot{m}, \Gamma_x)$

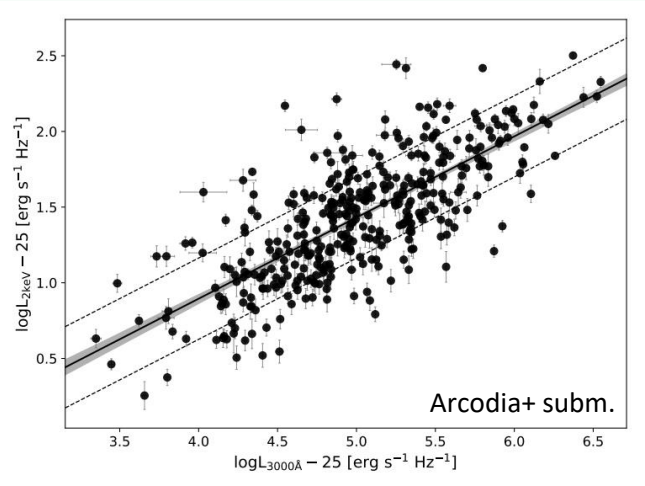


# Observational test: methodology

- Mock $L_X, L_{UV}$ values depend on the BH ID card $(m, \dot{m}, \Gamma_x)$

- We build a sample of radiatively-efficient BL AGN

  - Starting from 1787 BL AGN in **XMM-XXL** (Liu+16, Menzel+16)
  - Minimizing contamination from extinction, X-ray absorption, X-ray reflection
  - $\boldsymbol{N = 379}$ (referred to as XMM-XXL)



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- Mock $L_X, L_{UV}$ values depend on the BH ID card $(m, \dot{m}, \Gamma_x)$

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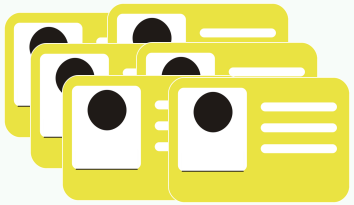
- We take all the BH IDs of XMM-XXL $(m, \dot{m}, \Gamma_x)$



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- Mock $L_X - L_{UV}$ for every $\mu, f_{max}$ ⟶

Match in **normalization**, **slope** and **scatter**

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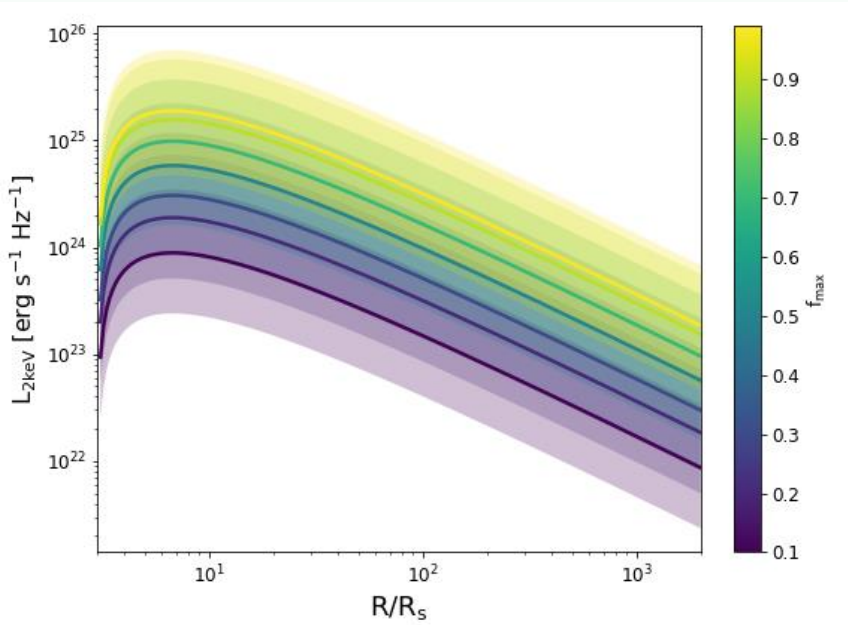
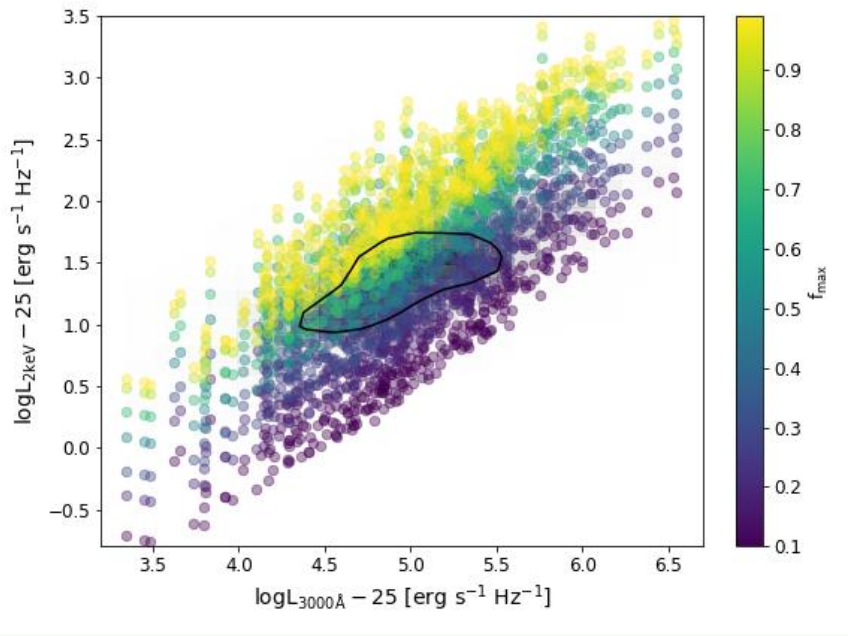
# Results: $L_X - L_{UV}$ normalization

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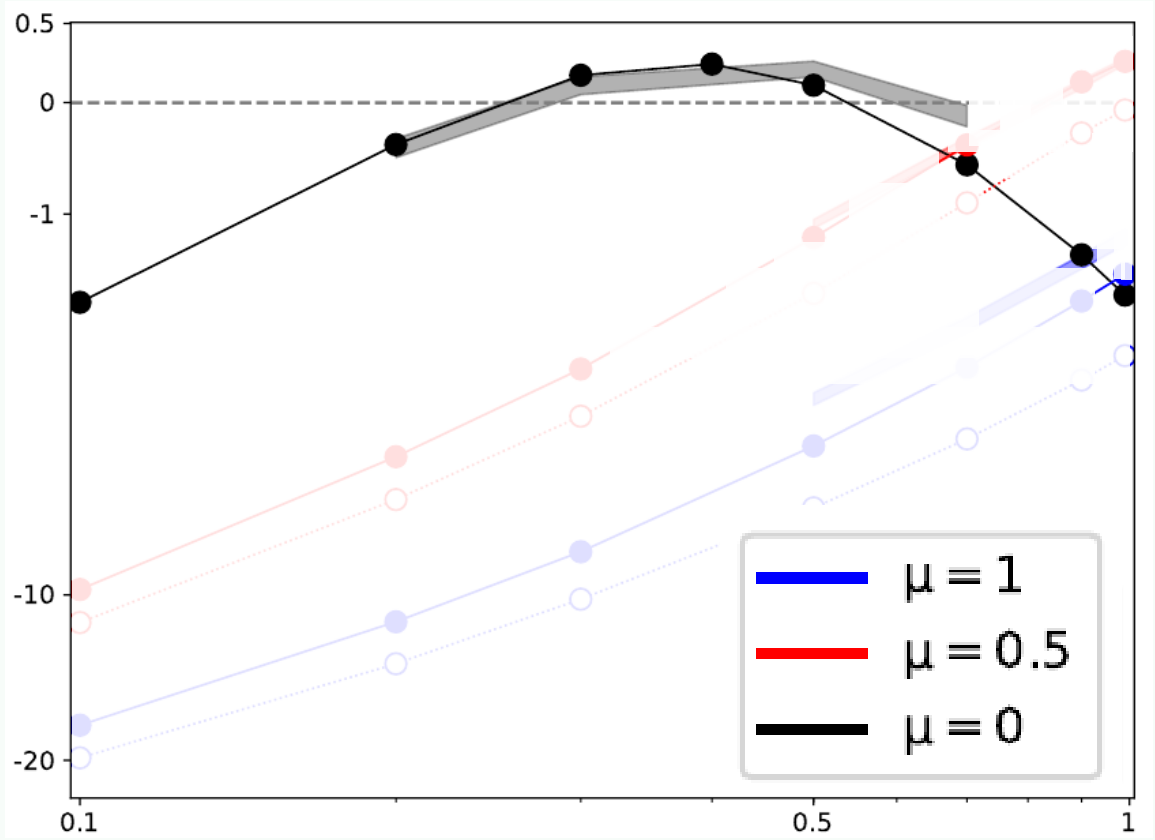
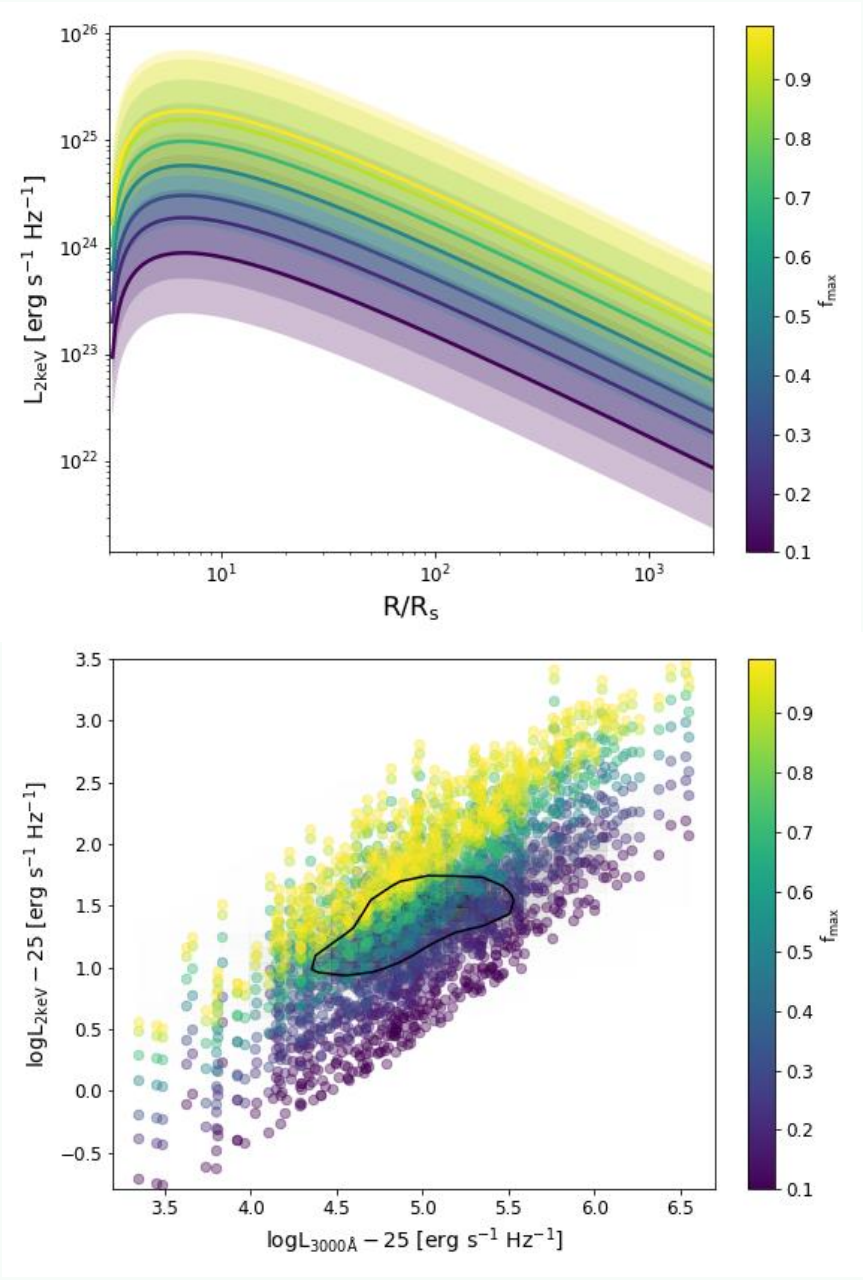



$data - model$ distance

$f_{max}$ = MAX CORONAL STRENGTH



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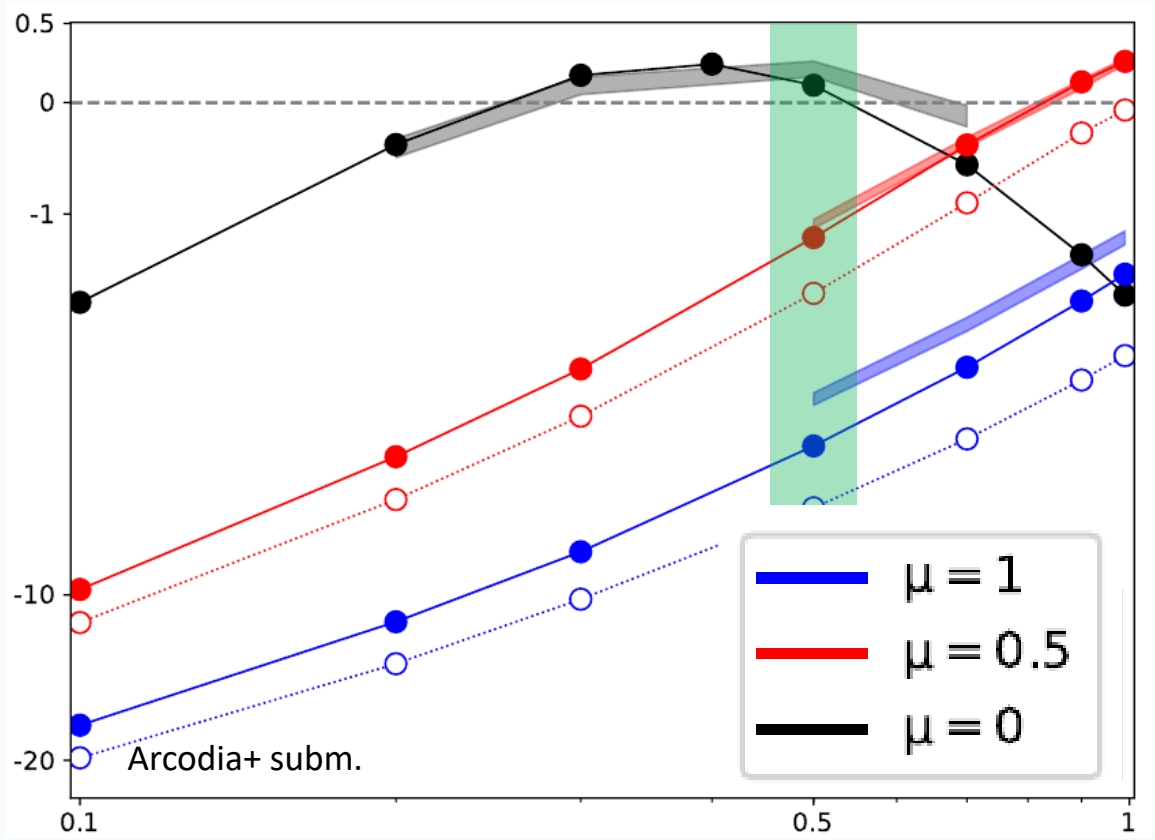
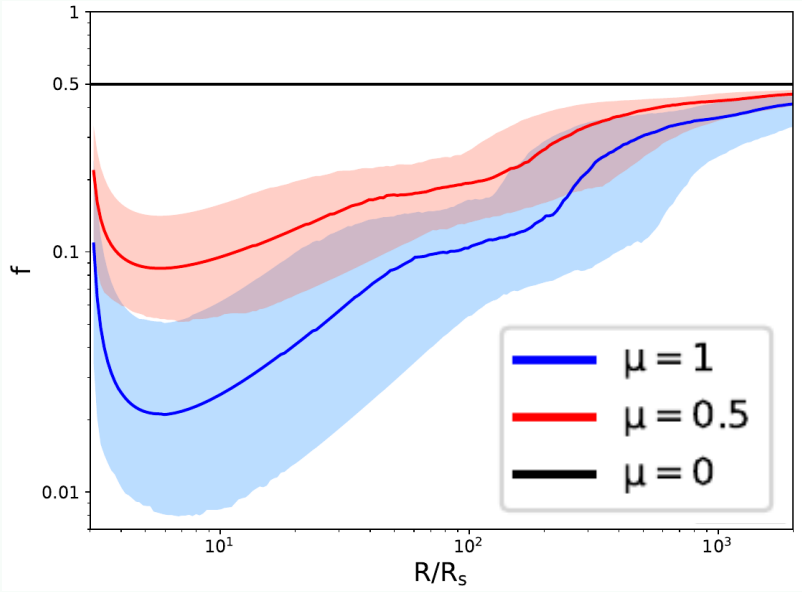
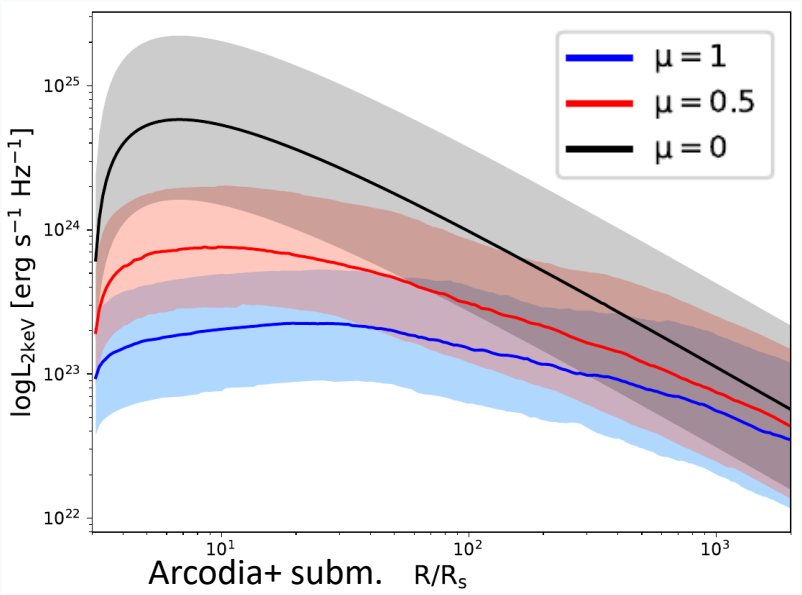
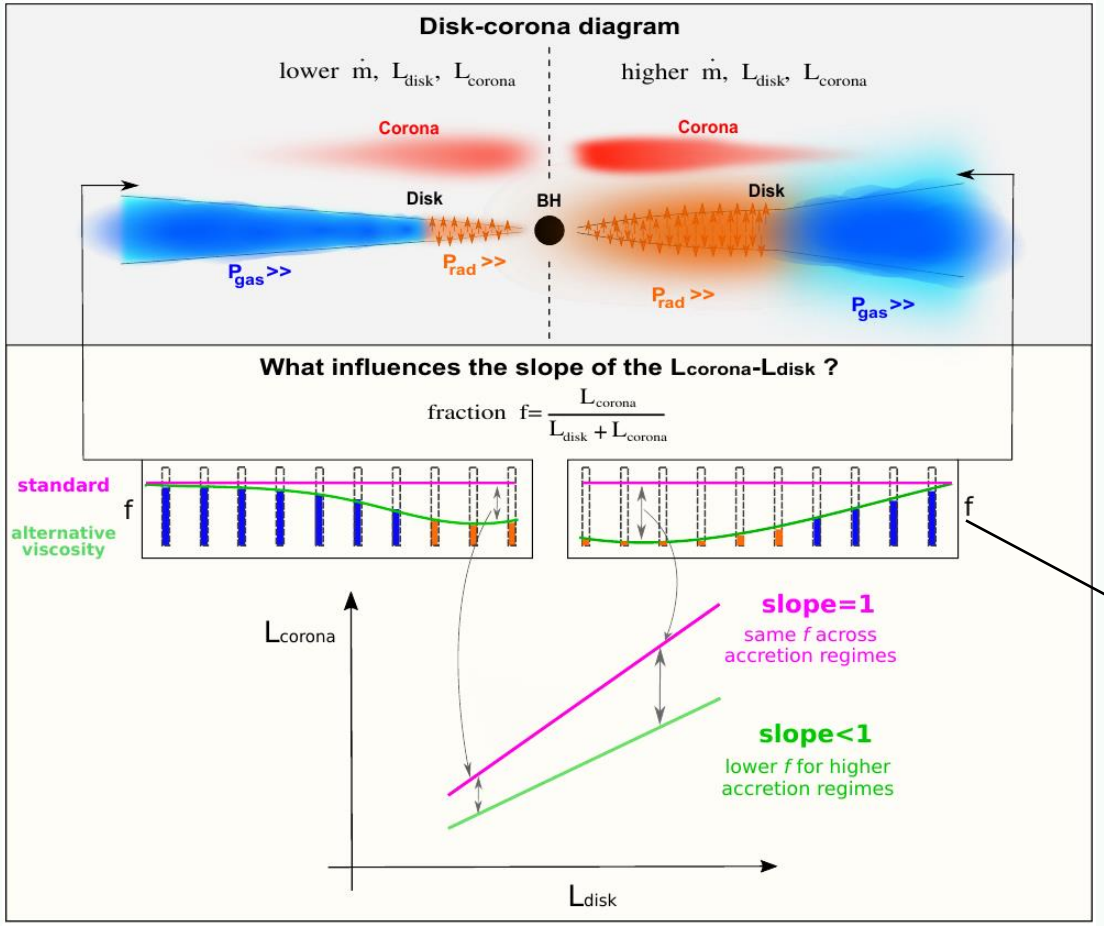


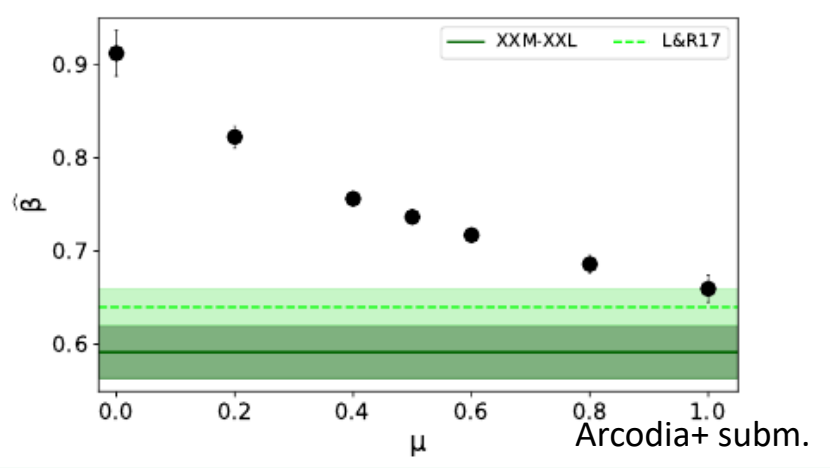

$f_{max} =$ **MAX CORONAL STRENGTH**



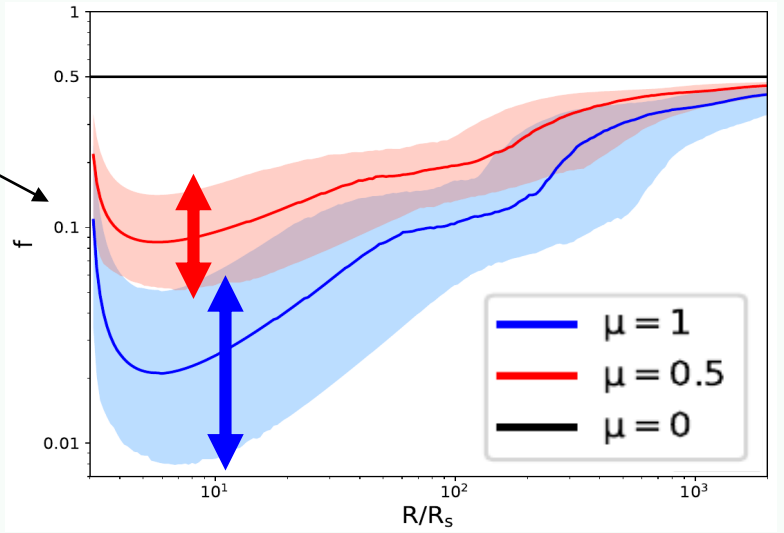



# Results: $L_X - L_{UV}$ slope

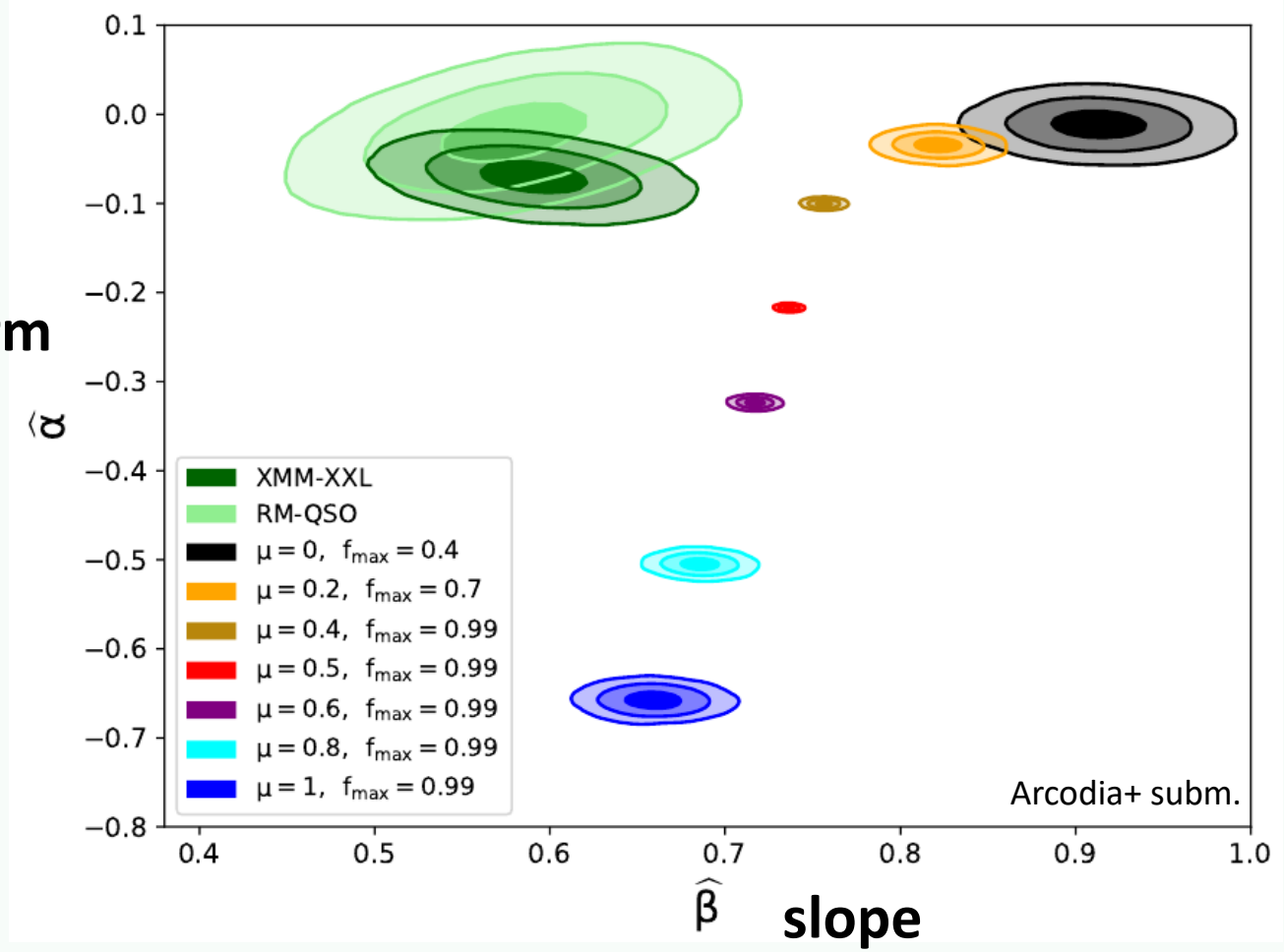



Arcodia+ subm.

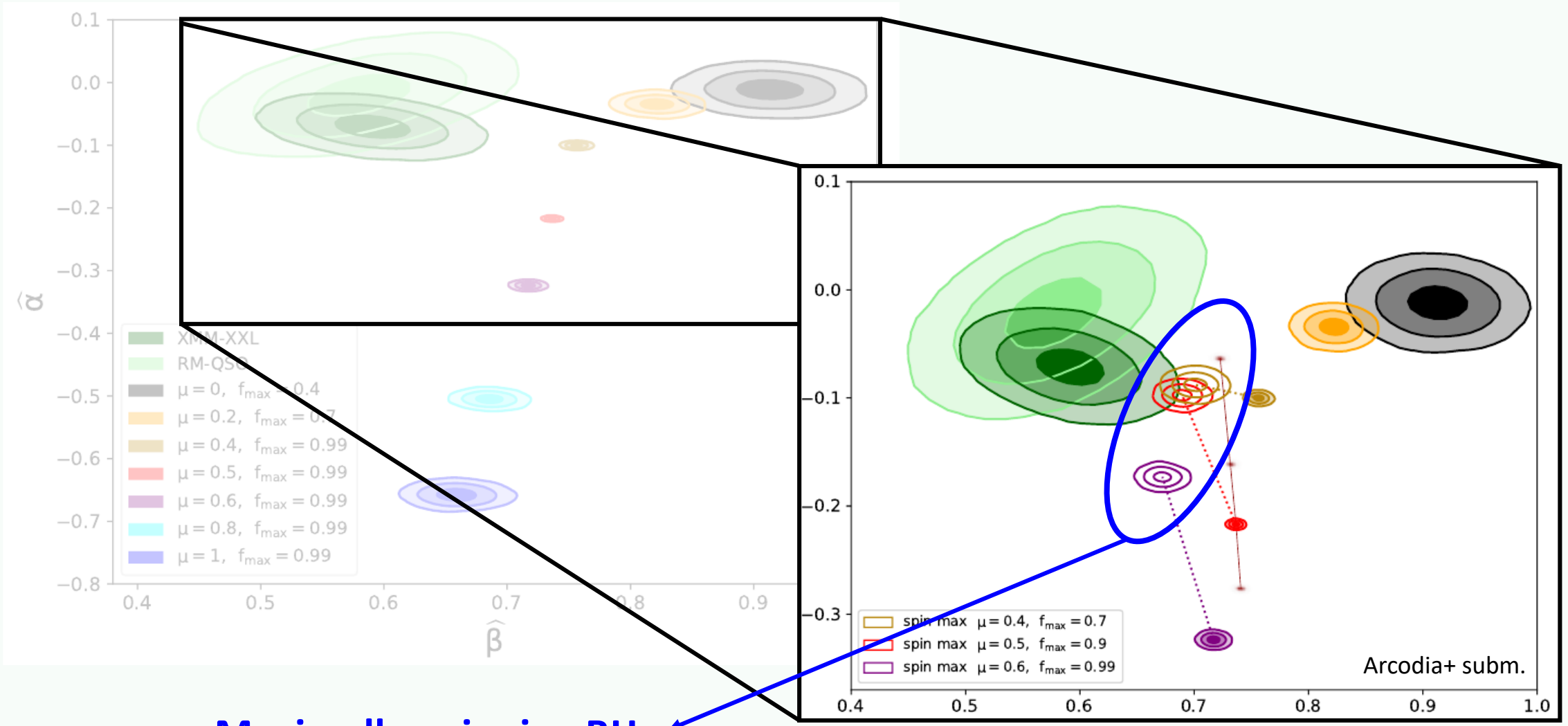


# Results: a complete picture




$$logL_X = \hat{\alpha} + \hat{\beta}\, logL_{UV}$$

# Results: the role of BH spin




**Maximally-spinning BHs**

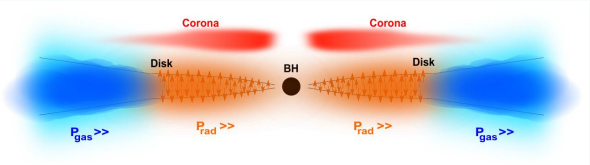
Flux-limited samples are biased in detecting high-spin sources preferentially!

(Brenneman+11; Vasudevan+16; Baronchelli+18; Reynolds19)

# Conclusions

- The gap between simulations and observations needs to be reduced

  ⟶ Simplified but motivated analytic prescriptions are still a powerful tool



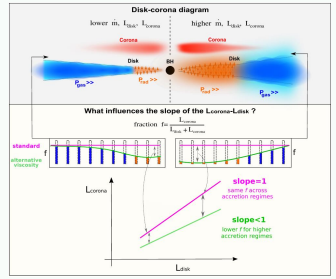

- Disk-corona models should be tested against the observed $\boldsymbol{L_X - L_{UV}}$ (and others..)

  ⟶ We modeled the observed sample sources $(m, \dot{m}, \Gamma_x)$ one by one

  ⟶ Match in normalization, slope and scatter of the $\boldsymbol{L_X - L_{UV}}$

- Why is the slope of the $\boldsymbol{L_X - L_{UV}} < 1$?

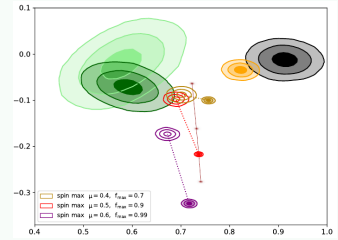
  ⟶ Our model can explain it in terms of modified accretion prescriptions




- Is the observed $\boldsymbol{L_X - L_{UV}}$ recovered?

  ⟶ In a spin=0 case, models that get the slope right show too weak coronae

  ⟶ More realistic spin distributions can relax the tension



# Thank you!