Constraining the X-ray reflection in low accretion rate AGN with *XMM-Newton*, *NuSTAR*, and *Swift*

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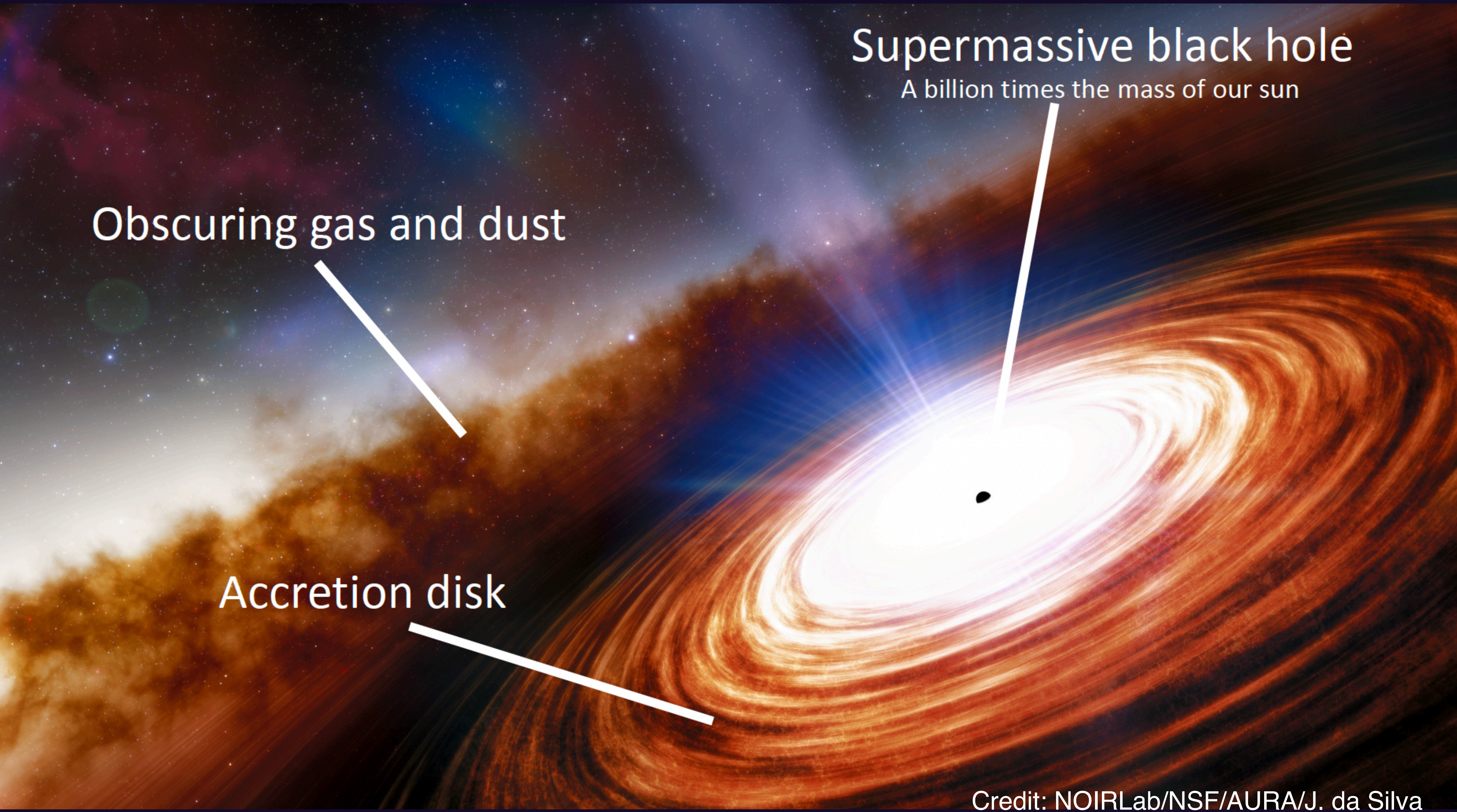
INSTITUTO DE ESTUDIOS ASTROFÍSICOS udp

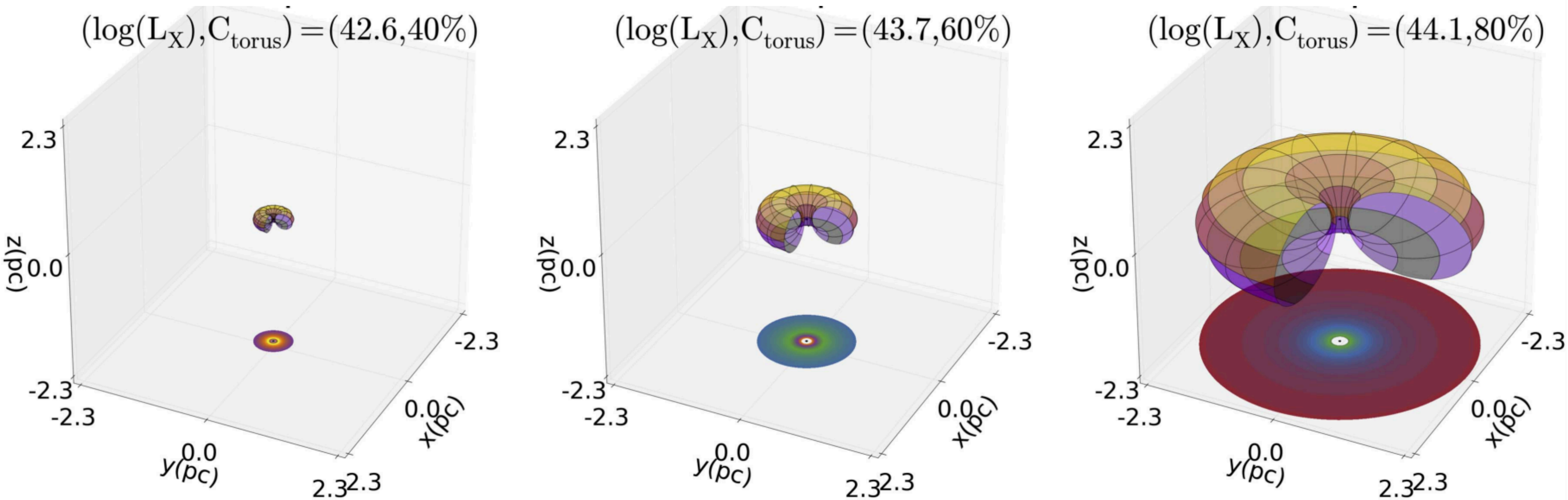
Agencia Nacional de Investigación y Desarrollo
Ministerio de Ciencia, Tecnología, Conocimiento e Innovación
Gobierno de Chile

Universidad de Valparaíso CHILE

Nucleo Milenio TITANS
for Transversal Research and Technology to explore Supermassive Black Holes


Supermassive black hole
A billion times the mass of our sun
Obscuring gas and dust
Accretion disk
Credit: NOIRLab/NSF/AURA/J. da Silva

Torus evolution (Infrared): Dust



$C_{tor} \sim 0\,\%$ → $\log(L_{Bol}) \sim 41$

$C_{tor} \sim 18\,\%$ → $\log(L_{Bol}) \sim 42$

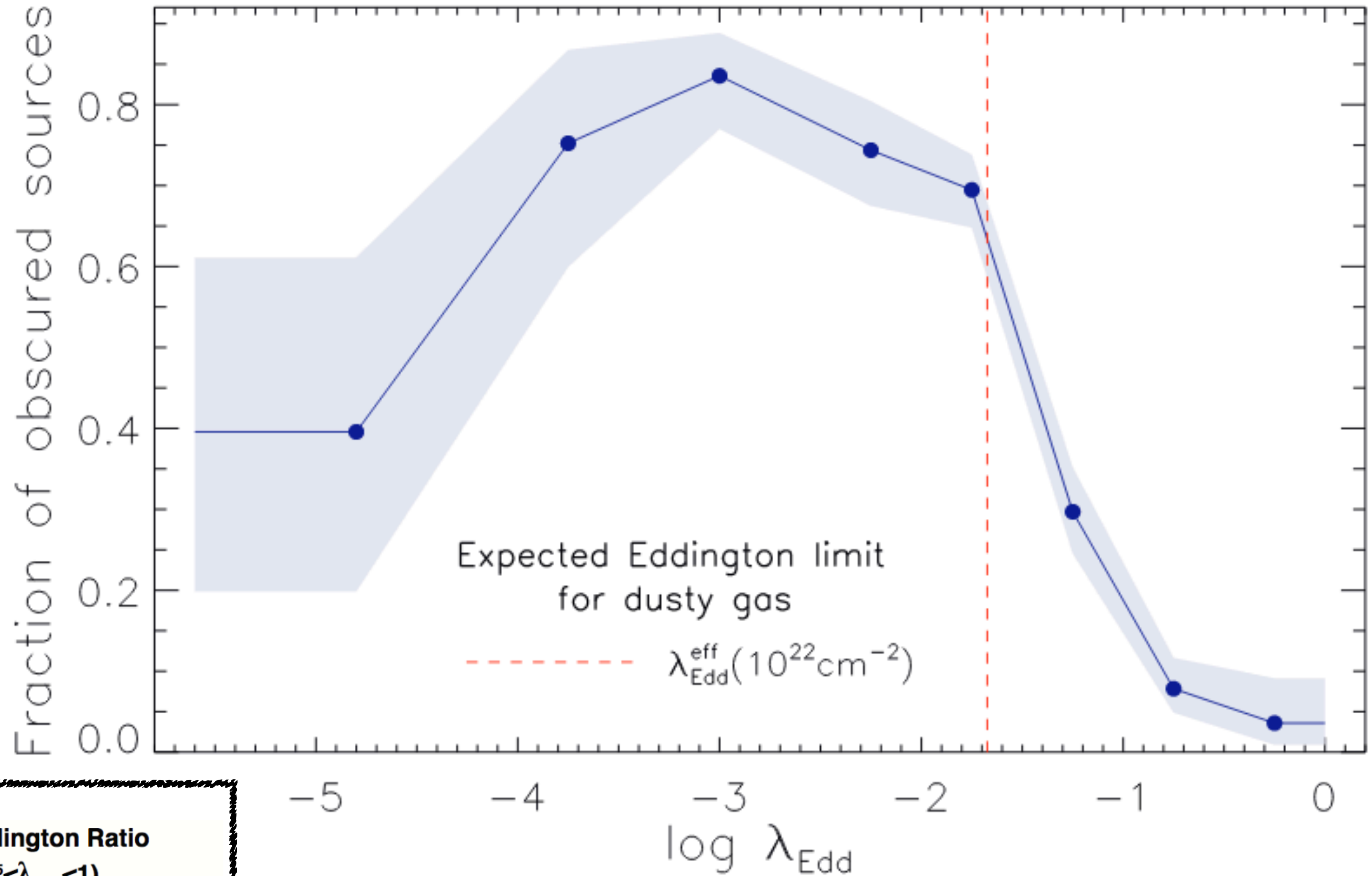
$C_{tor} \sim 40\,\%$ → $\log(L_{Bol}) \sim 42.6$

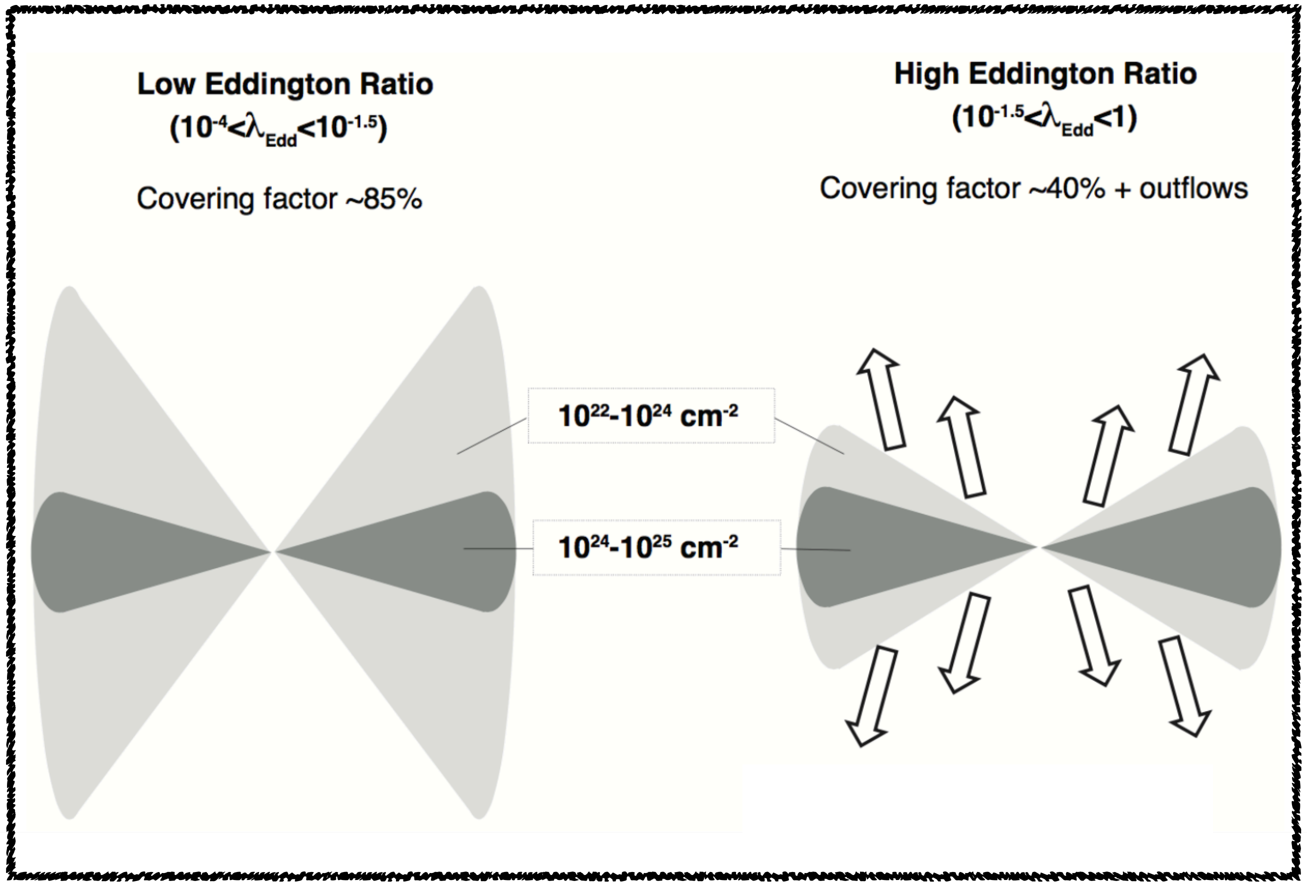
$C_{tor} \sim 60\,\%$ → $\log(L_{Bol}) \sim 43.7$

$C_{tor} \sim 80\,\%$ → $\log(L_{Bol}) \sim 44$

From: Gonzalez-Martin et al., 2017

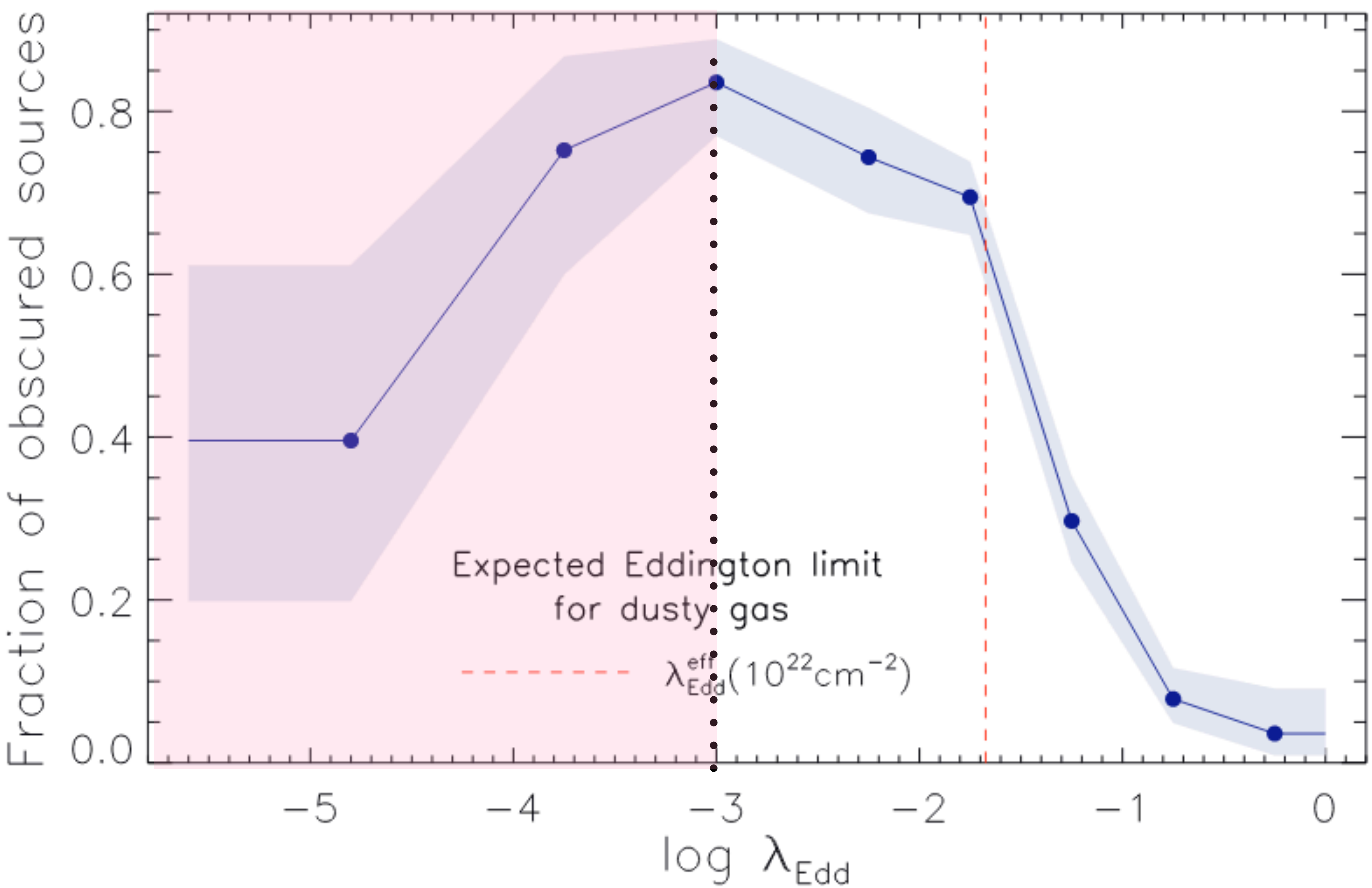
Obscuration is a function of the accretion rate!





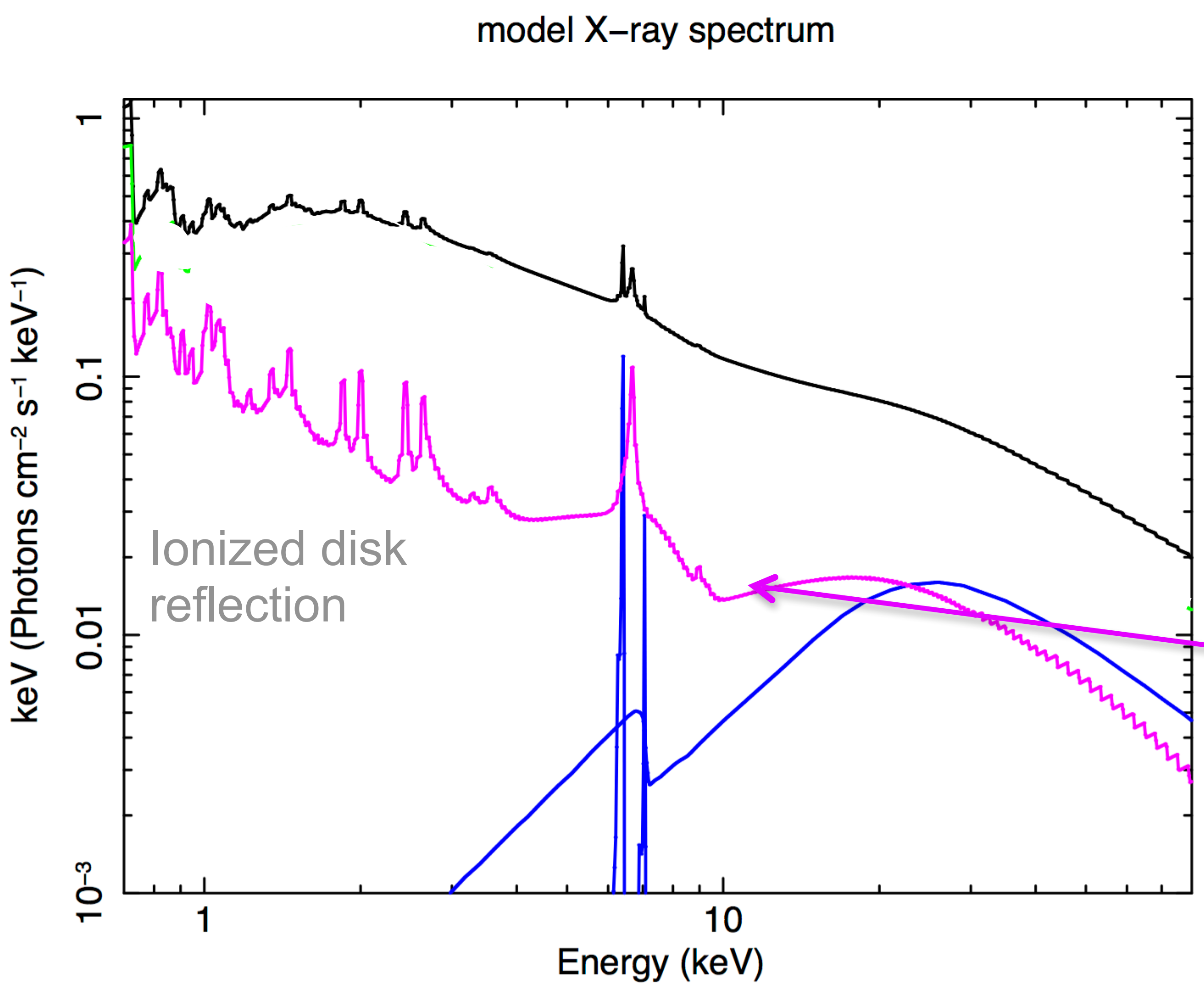
From: Ricci et al. 2017

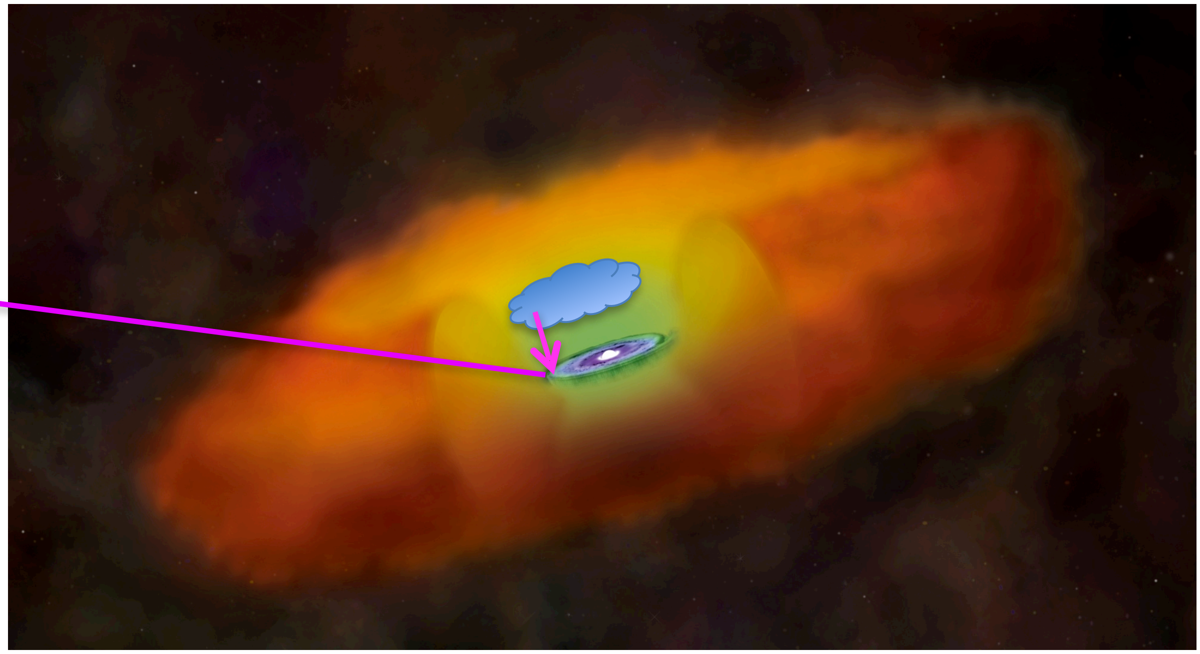
Obscuration is a function of the accretion rate!



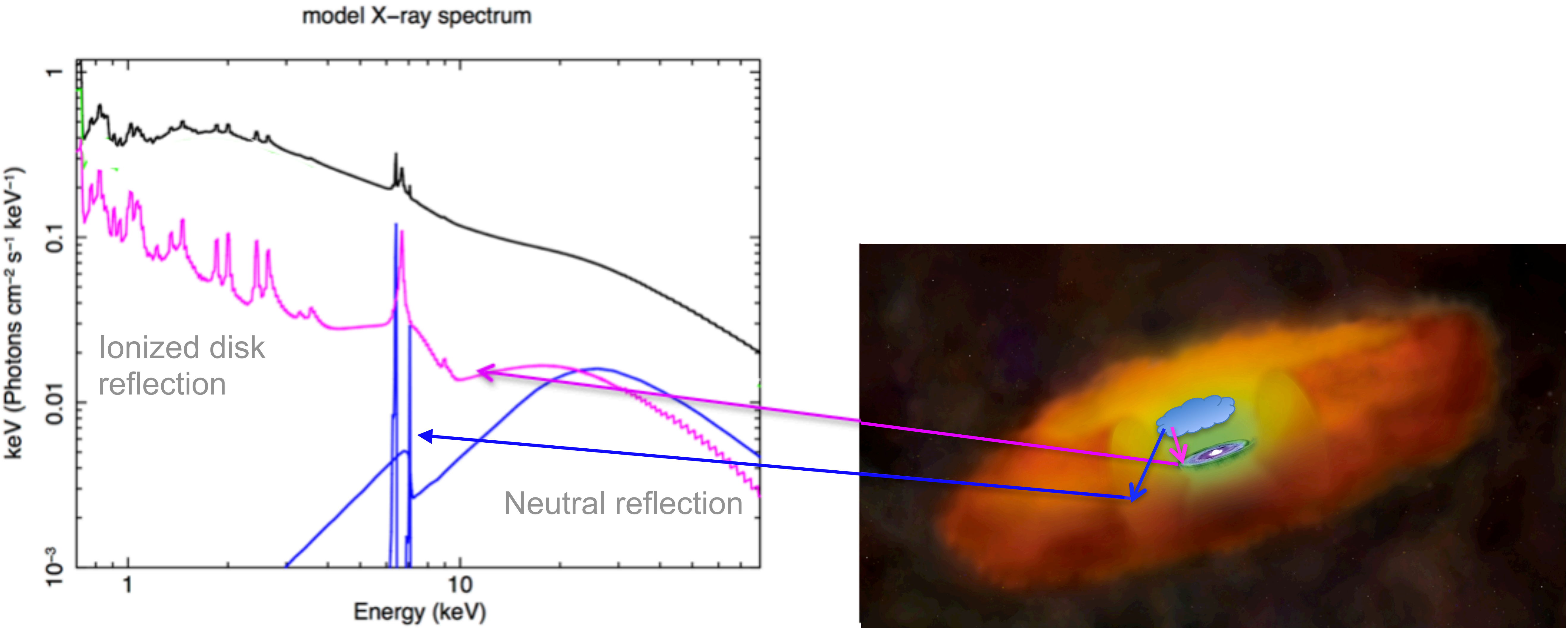
From: Ricci et al. 2017

Reflection


model X–ray spectrum
keV (Photons cm^{-2} s^{-1} keV^{-1})
1
0.1
0.01
10^{-3}
1
10
Energy (keV)
Ionized disk
reflection

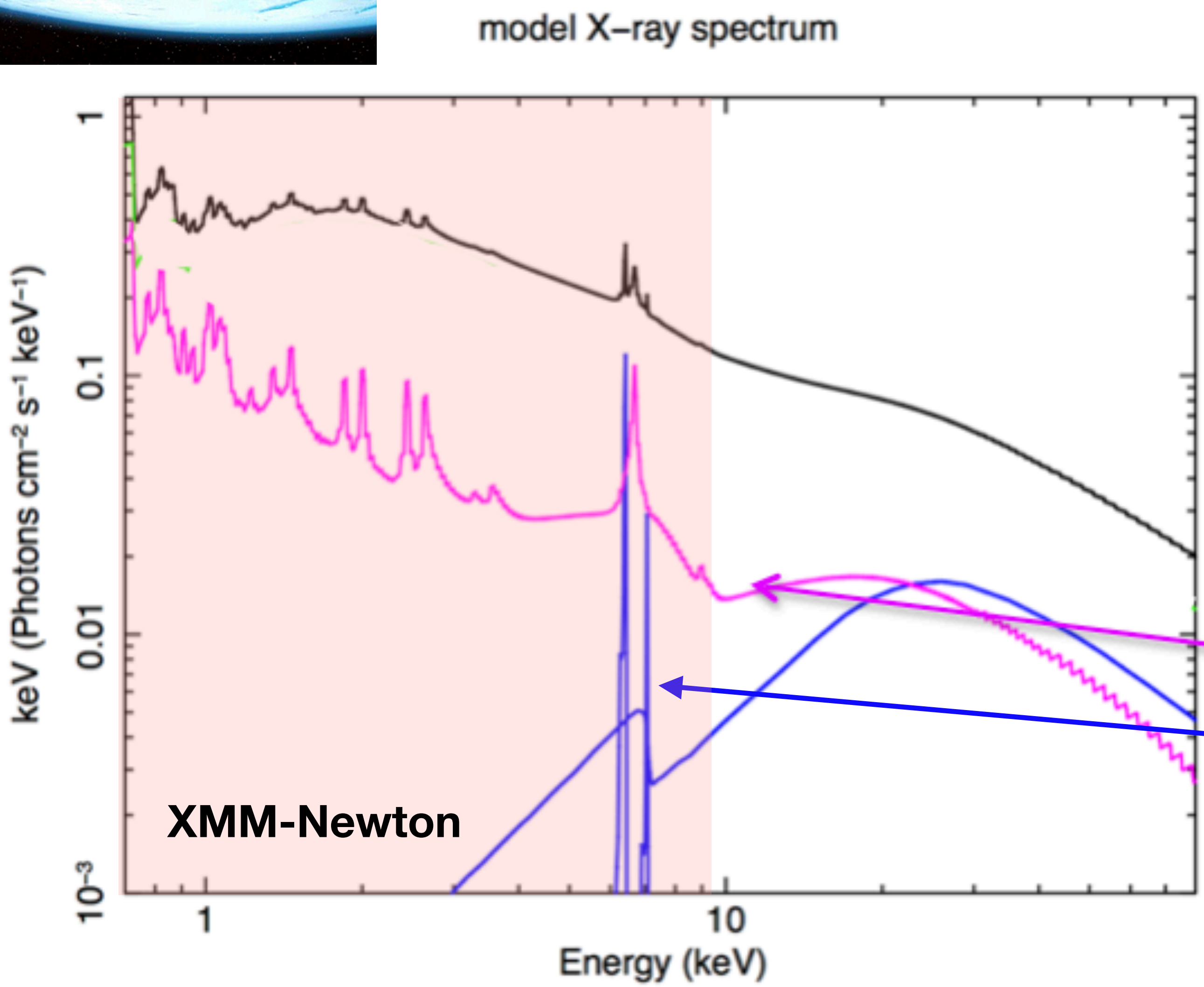


Reflection

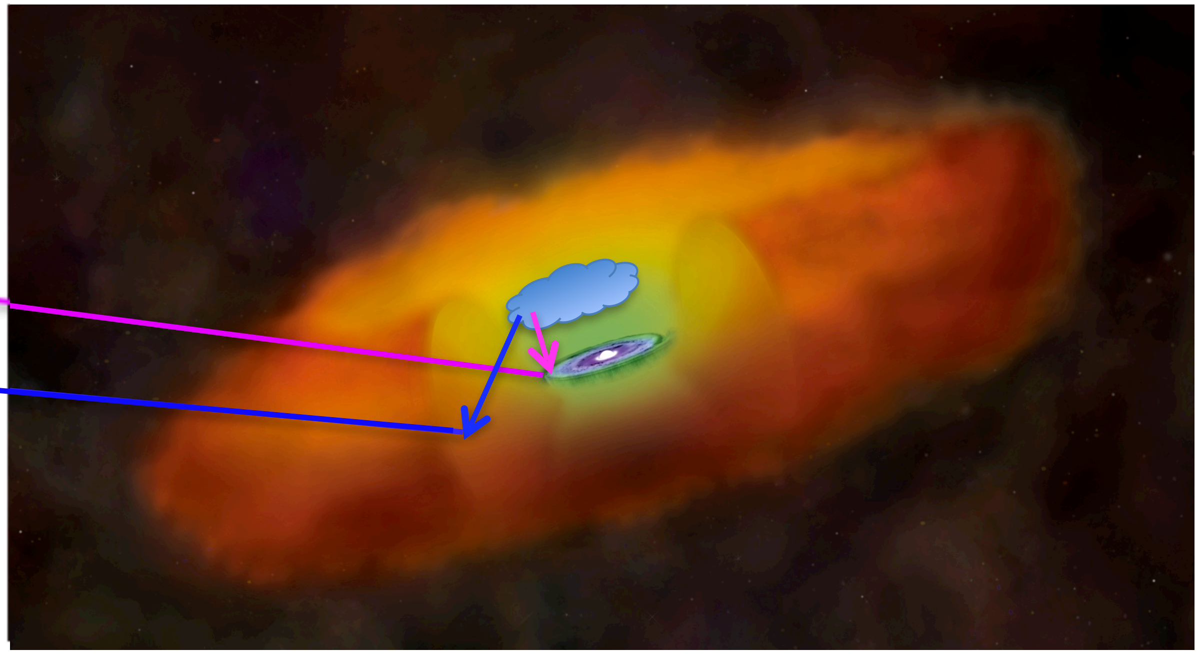


model X–ray spectrum
keV (Photons cm⁻² s⁻¹ keV⁻¹)
1
0.1
0.01
10⁻³
1
10
Energy (keV)
Ionized disk reflection
Neutral reflection

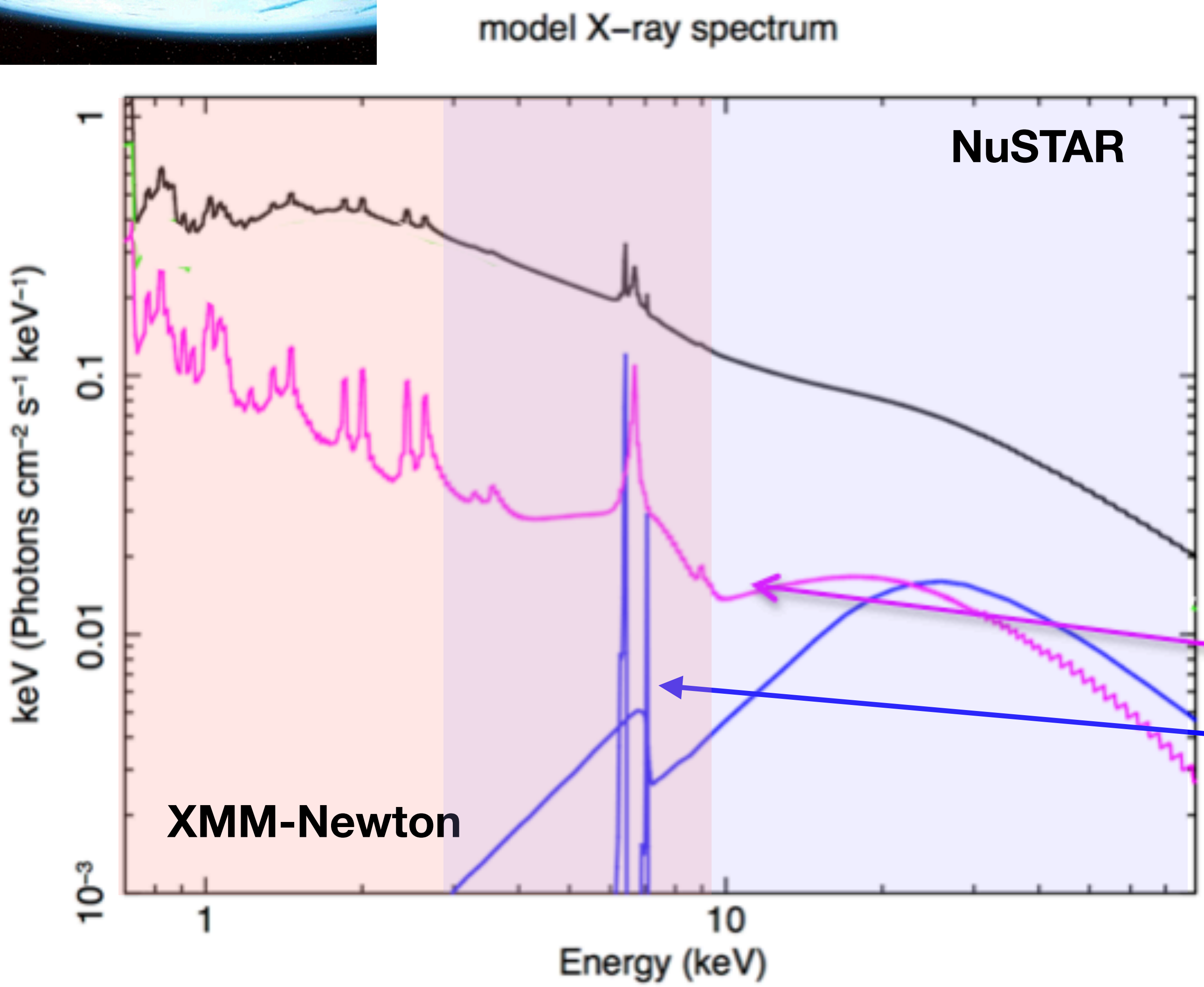
Reflection

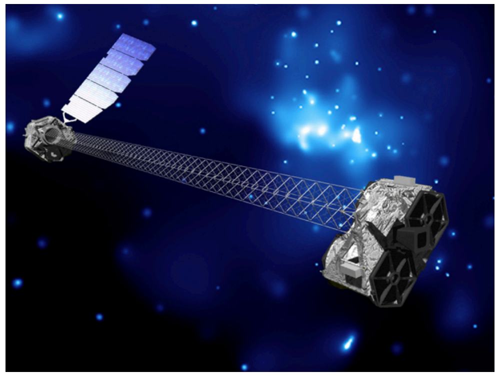


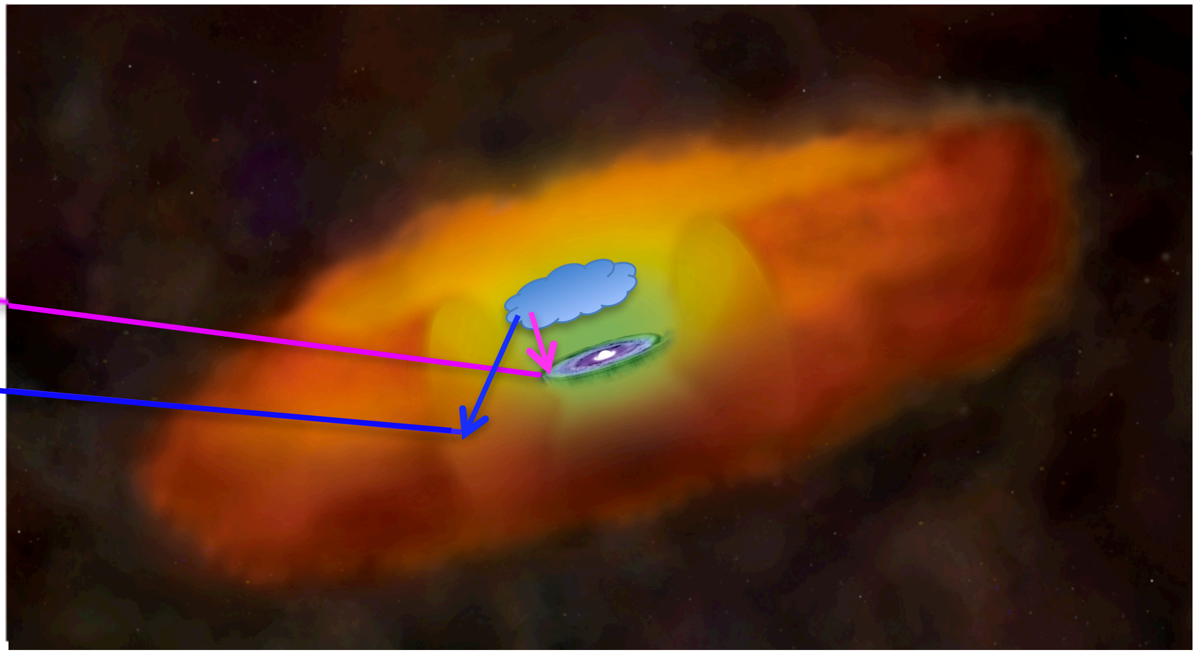
model X–ray spectrum
keV (Photons cm^{-2} s^{-1} keV^{-1})
1
0.1
0.01
10^{-3}
1
10
Energy (keV)
XMM-Newton



Reflection

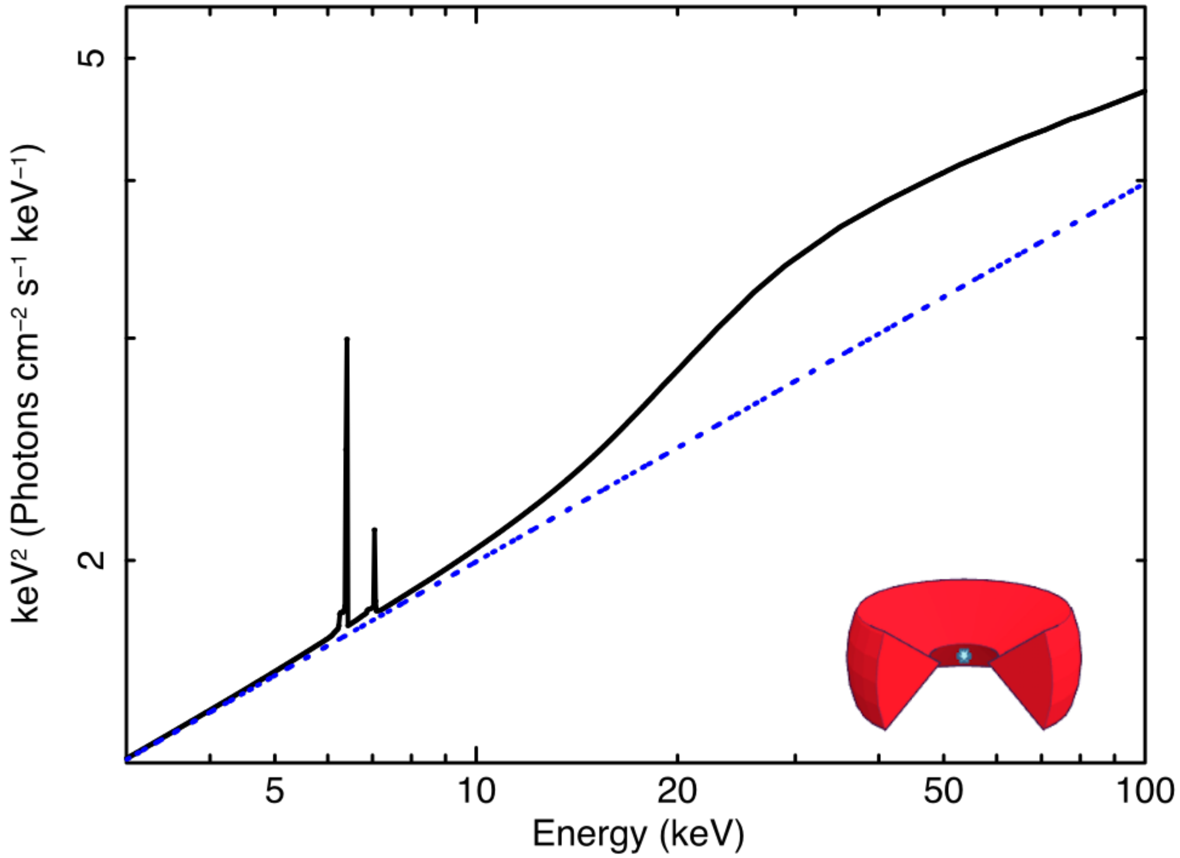

model X–ray spectrum
NuSTAR
XMM-Newton
keV (Photons cm⁻² s⁻¹ keV⁻¹)
Energy (keV)
1
0.1
0.01
10⁻³
1
10



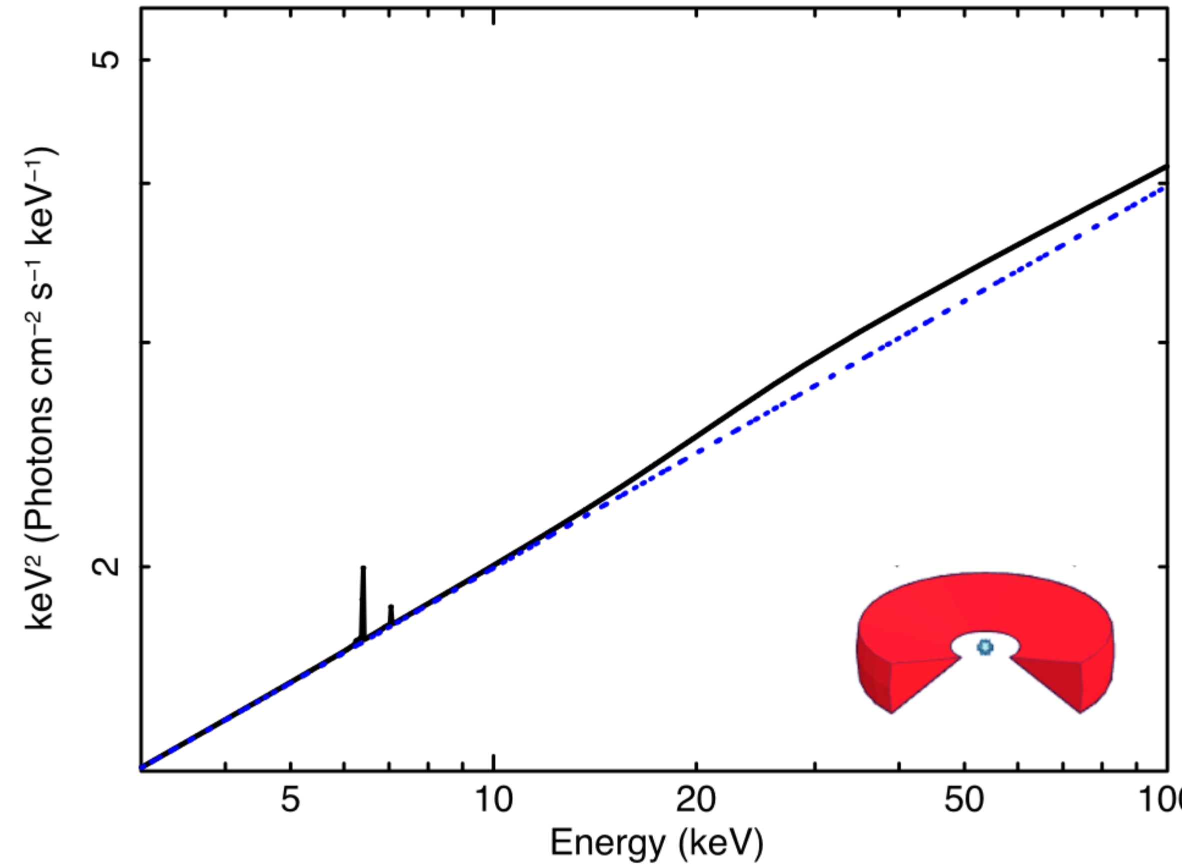


decreasing covering fraction

$N_H=10^{25}$, C=0.25

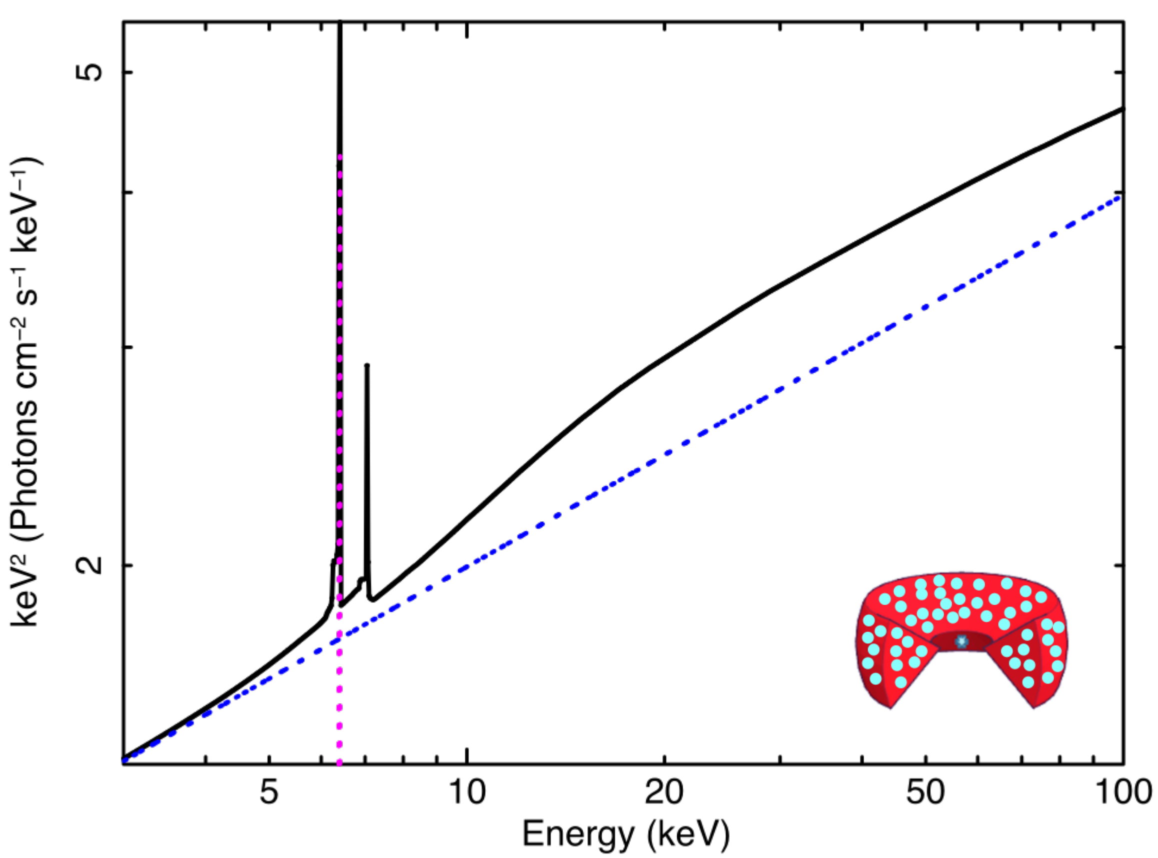


$N_H=10^{25}$, C=0.05

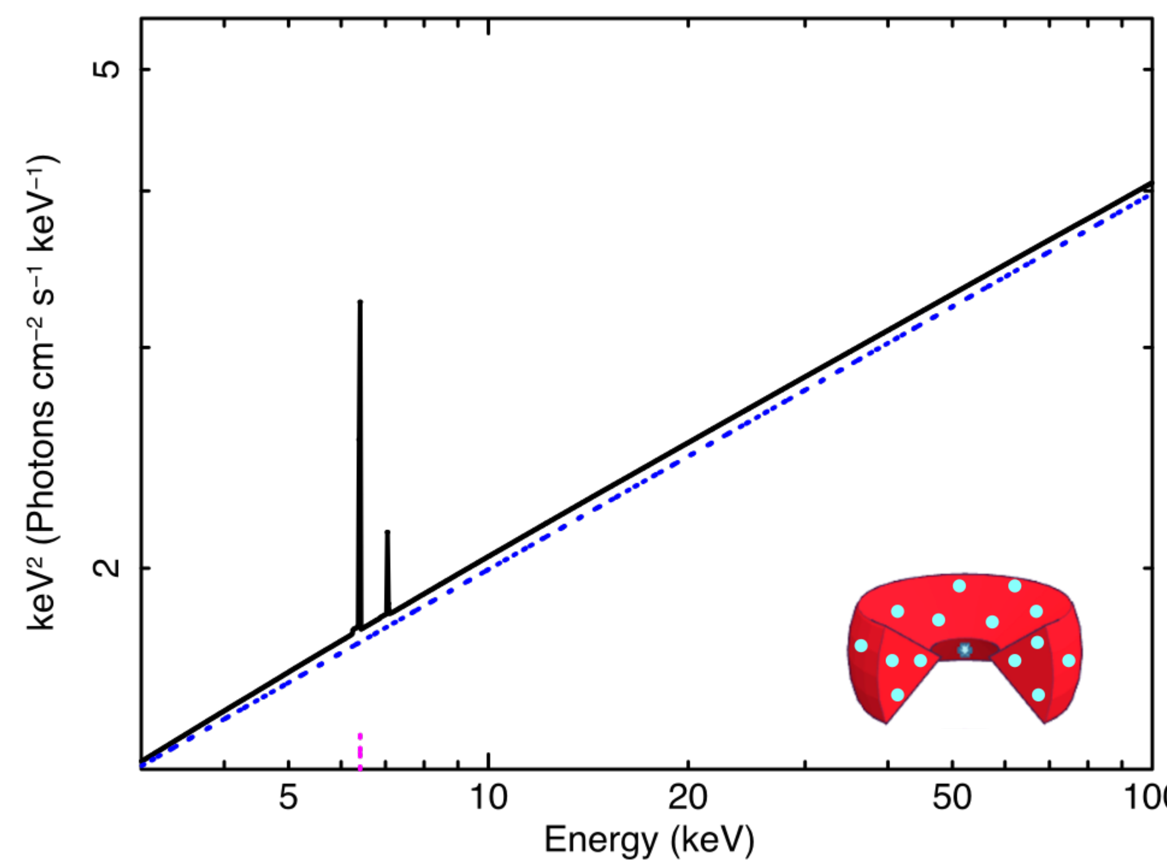


decreasing column density

$N_H=10^{24}$, C=0.5



$N_H=10^{23}$, C=0.5



Methodology

BASS
BAT AGN Spectroscopic Survey
Logo by: K. Oh (Kyoto U.)

The sample

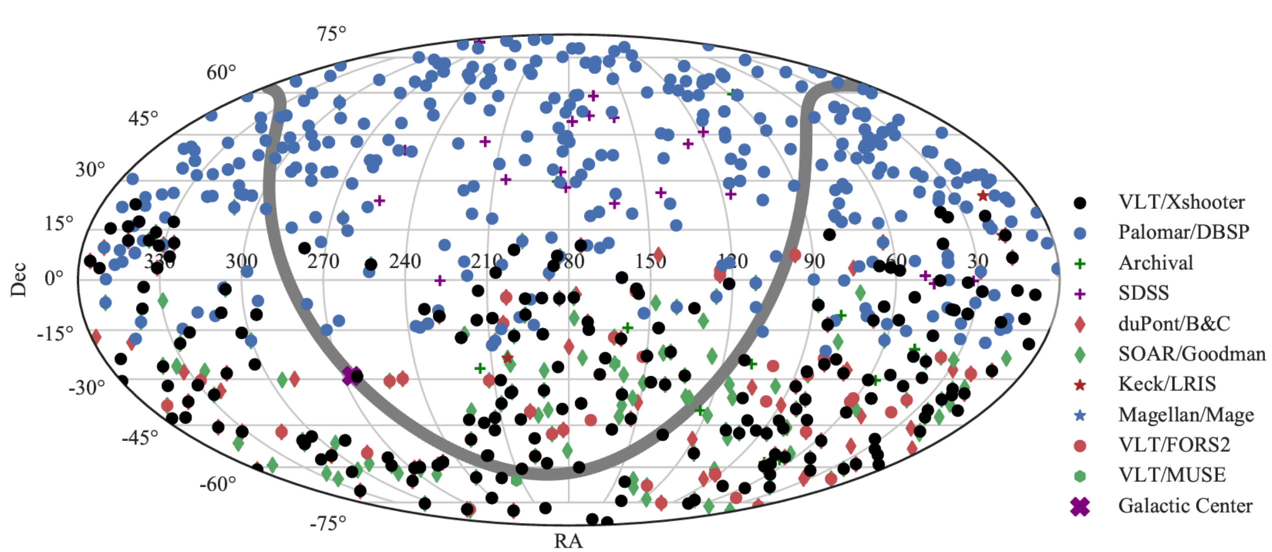
∼1000 hard X-ray selected AGN

Swift/Burst Alert Telescope (BAT)

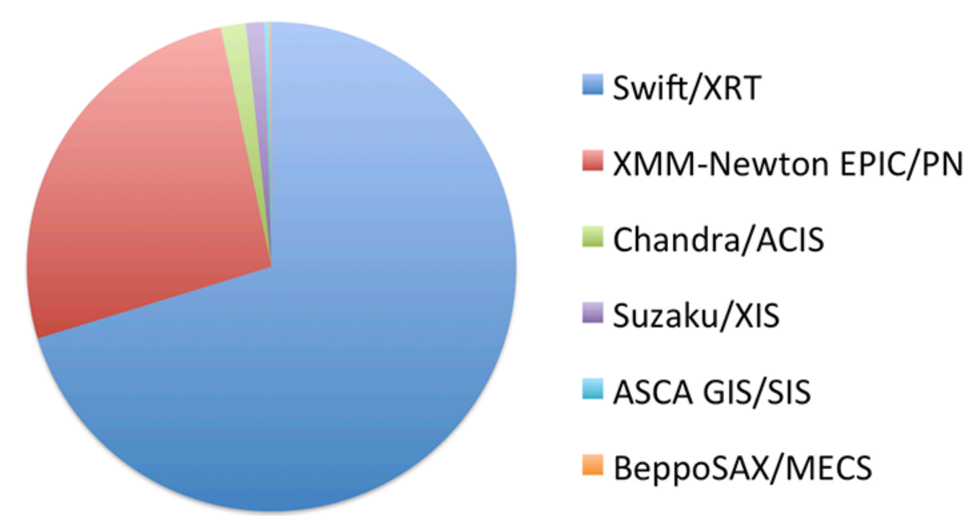
Covers a wide range of AGN properties

Combines optical, IR, and X-ray spectral analyses.

$$10^6 M_\odot < M_{BH} < 10^{10} M_\odot$$



From: Koss et al. 2022



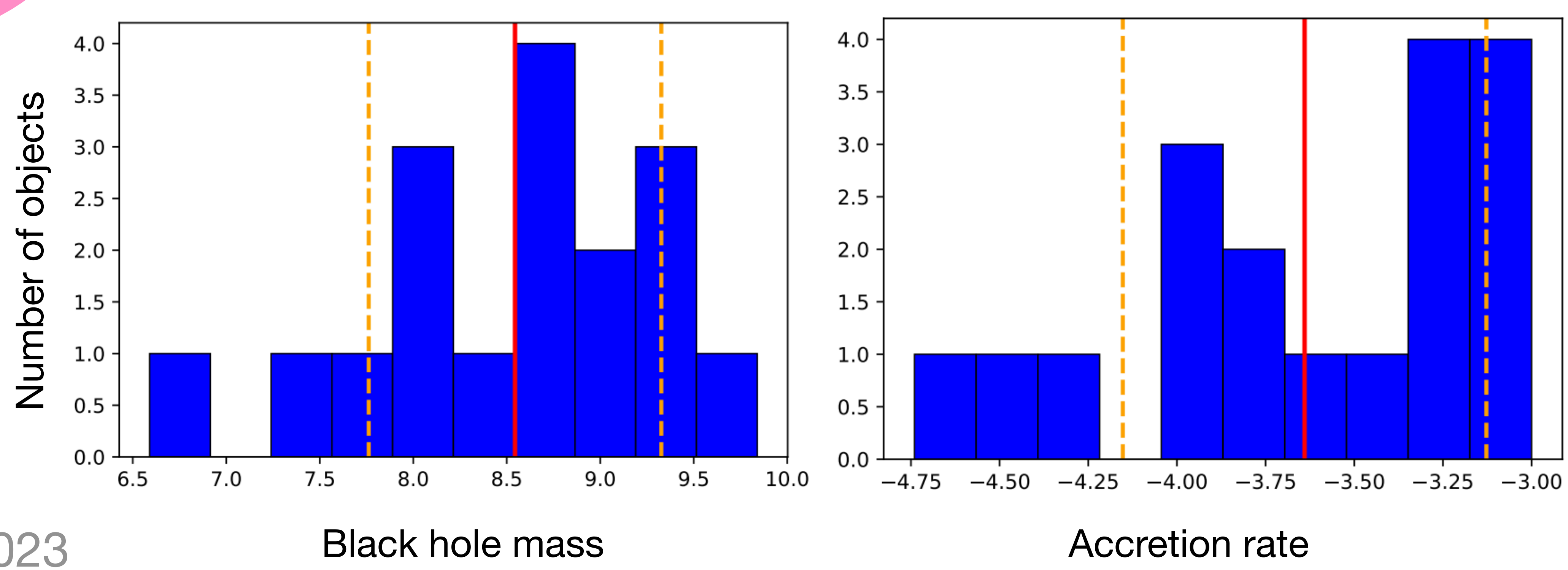
From: Ricci et al. 2017

Methodology

BASS
BAT AGN Spectroscopic Survey
Logo by: K. Oh (Kyoto U.)

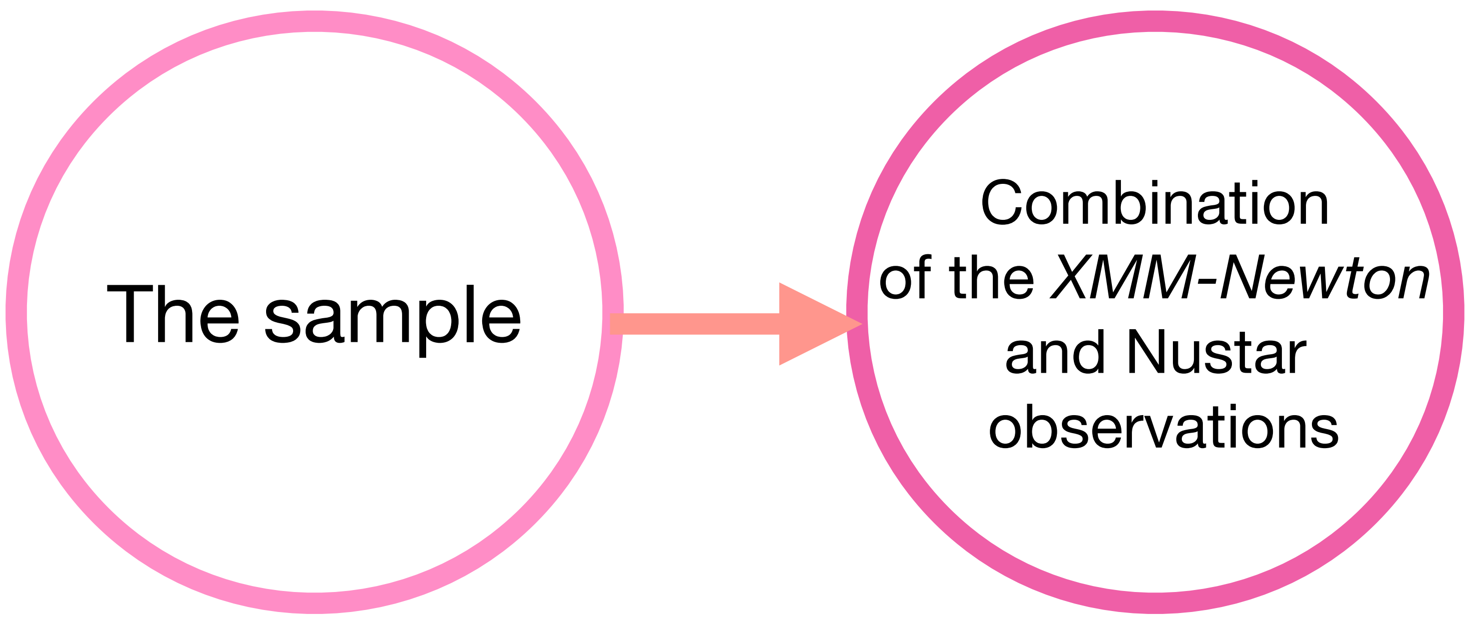
The sample

- AGNs with accretion rate below to 10^{-3}
- 16 AGN public data and 1 AGN (NGC 5033) proprietary data (*XMM-Newton + NuSTAR*)

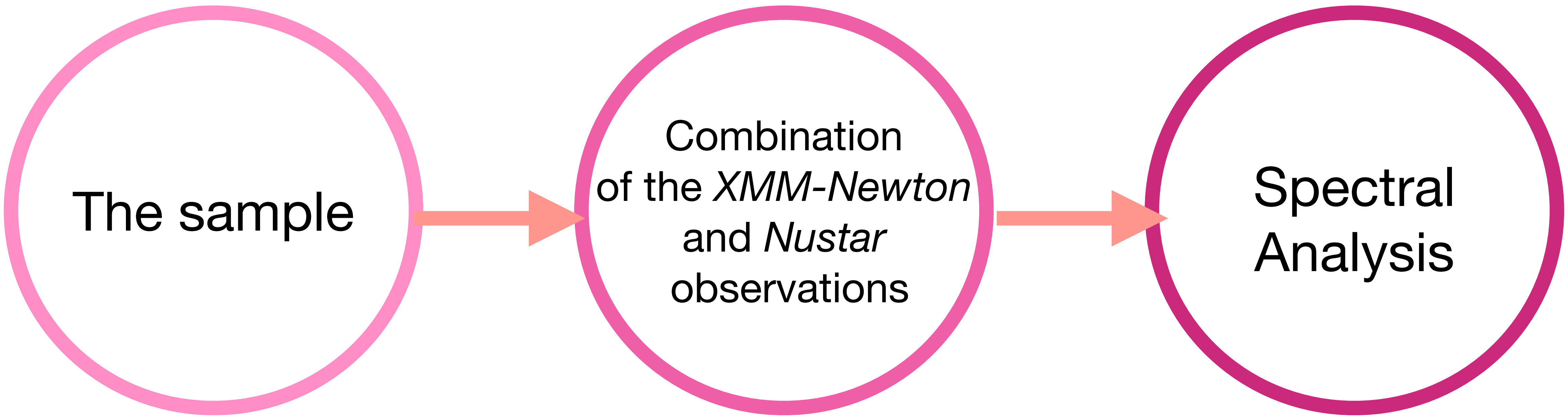


From: Diaz et al. 2023

Methodology



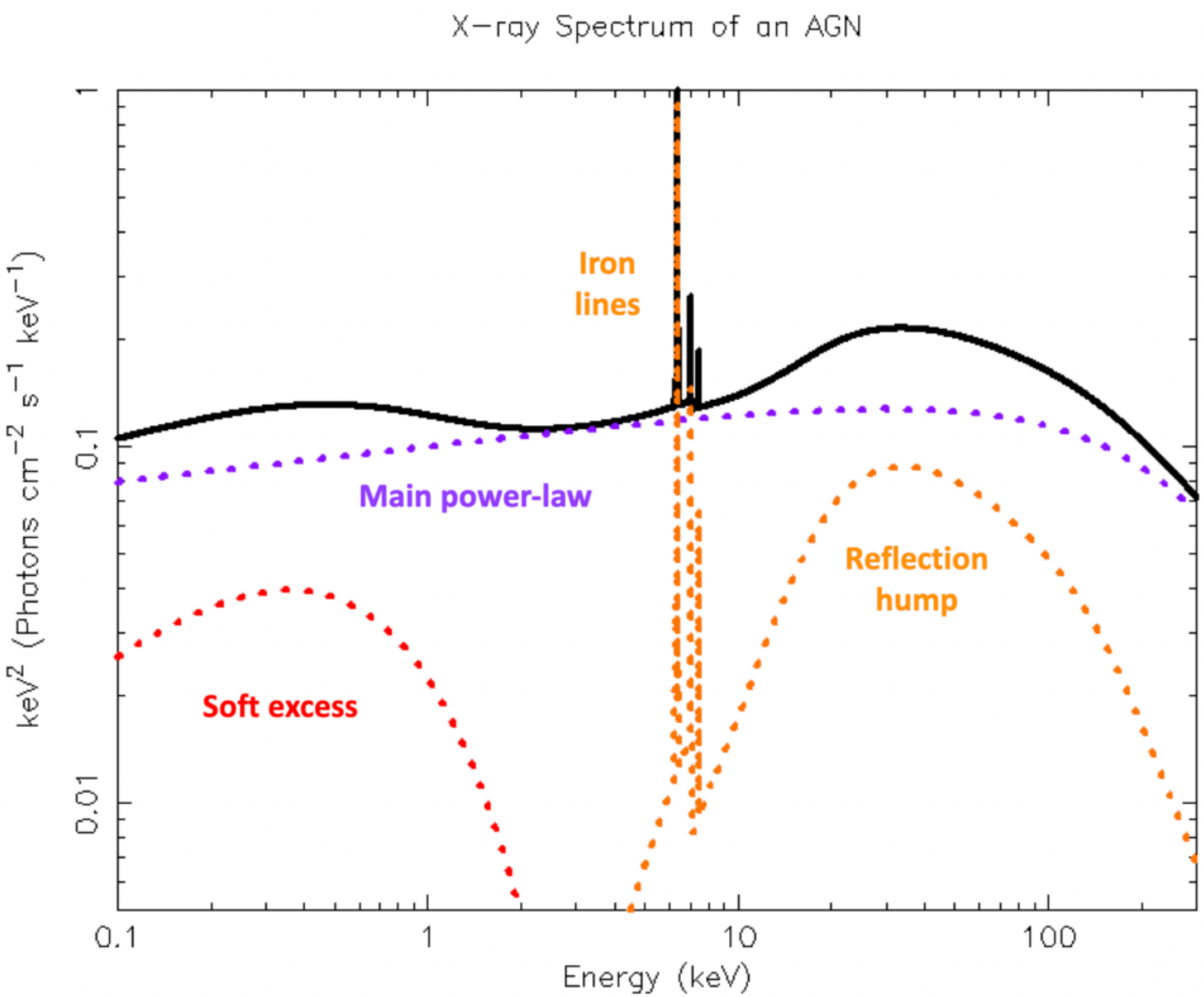
Methodology



Methodology

Cut off Power-law model: Coronal emission

Reflection models: pexmon, borus02 and xillver

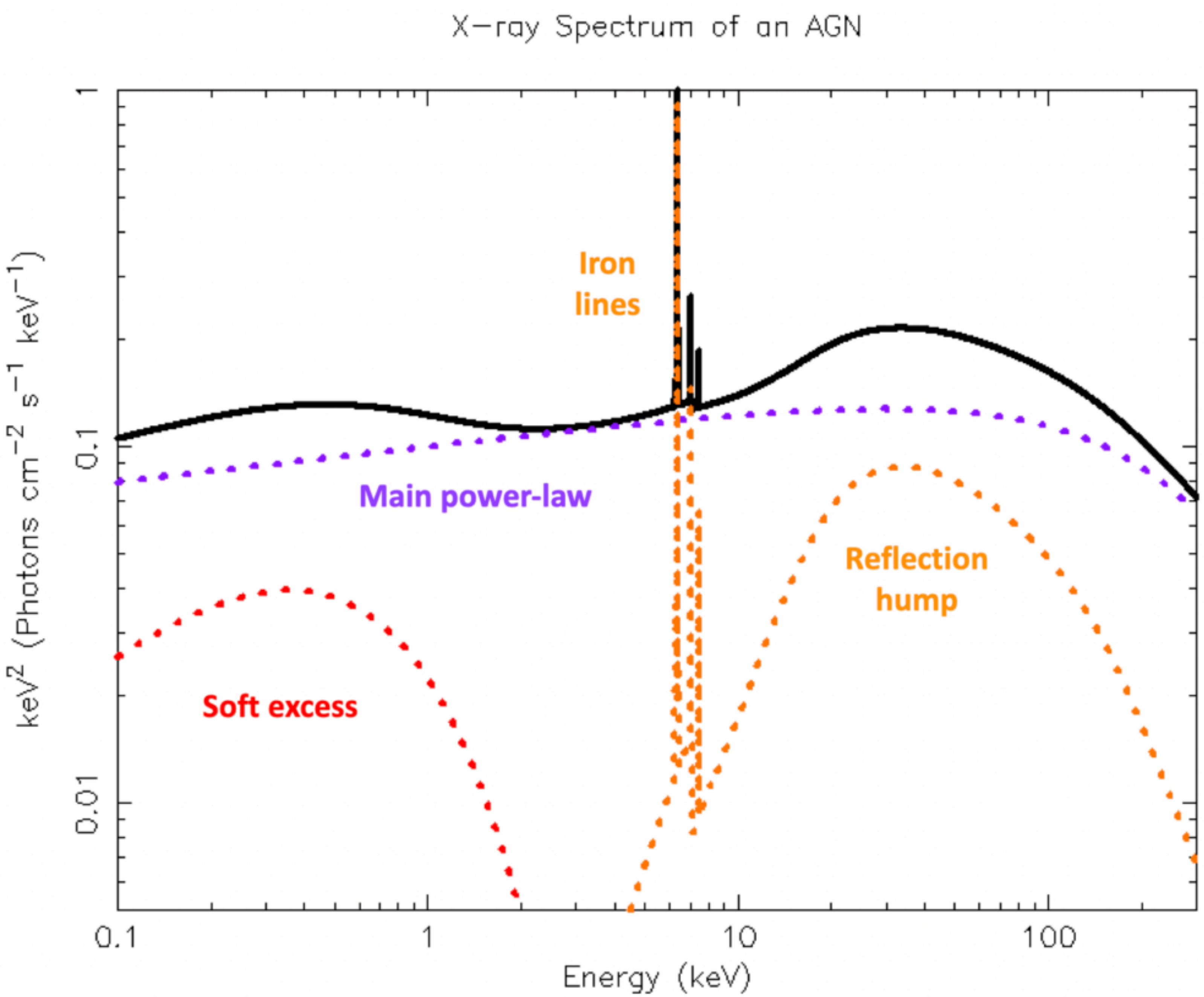


From: https://science.clemson.edu/ctagn/project/

Methodology

Cut off Power-law model: Coronal emission

Reflection models: pexmon, borus02 and xillver



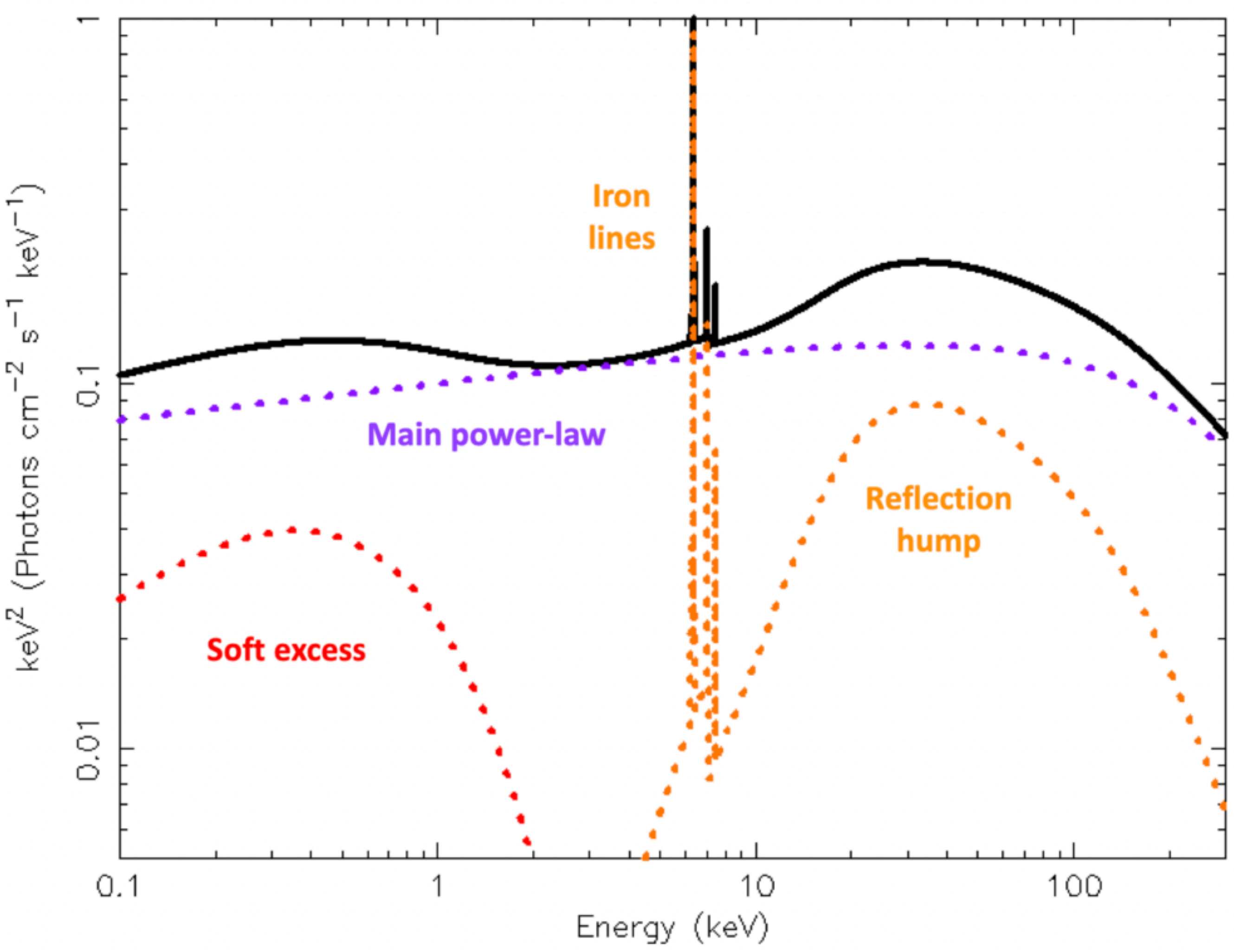
From: https://science.clemson.edu/ctagn/project/

Methodology

Cut off Power-law model: Coronal emission

Reflection models: pexmon, borus02 and xillver

Soft Emission: scattered power-law, thermal emission (mekal) and an ionized absorber (zxipcf).



From: https://science.clemson.edu/ctagn/project/

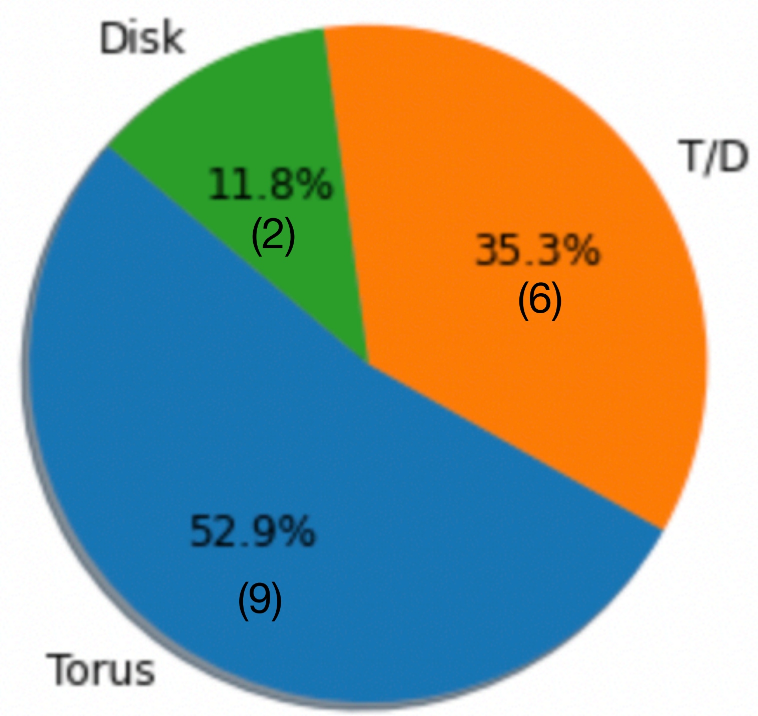
BASS/DR2 - Best model

Evidence ratio (ϵ) using the Akaike information criterion (AIC, Emmanoulopoulos et al. 2016)

The evidence ratio is a measure of the relative likelihood of the torus versus the disk model.

The torus model is 200 times more likely than the disk model when $\epsilon \leq 0.0067$

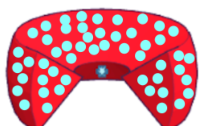
The disk model is 200 times more likely than the torus model when $\epsilon \geq 150$

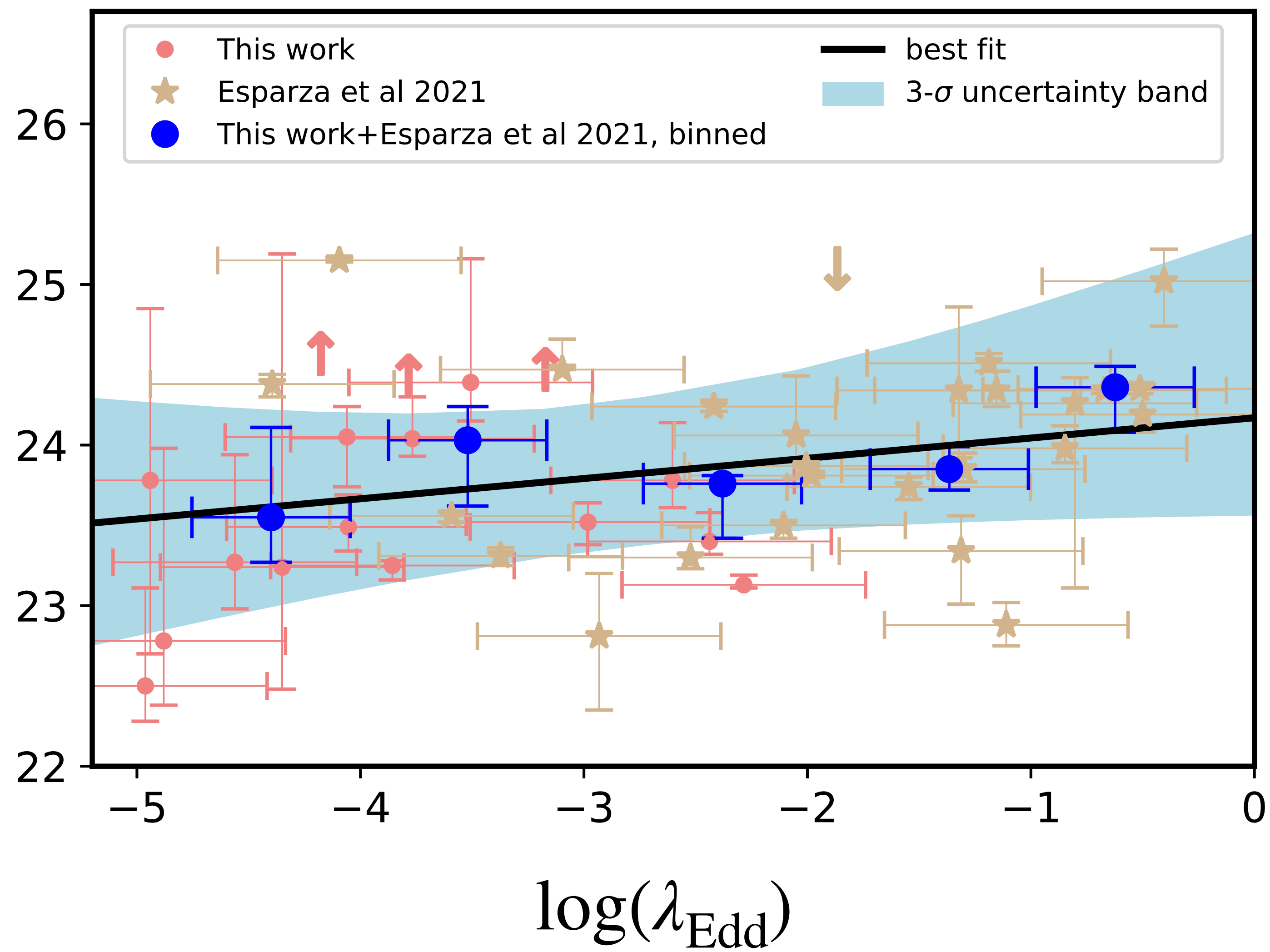


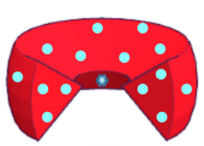
From: Diaz et al. 2023

BASS/DR2 - Torus column density versus accretion rate

Column density of the torus like reflector is a function of the accretion rate?







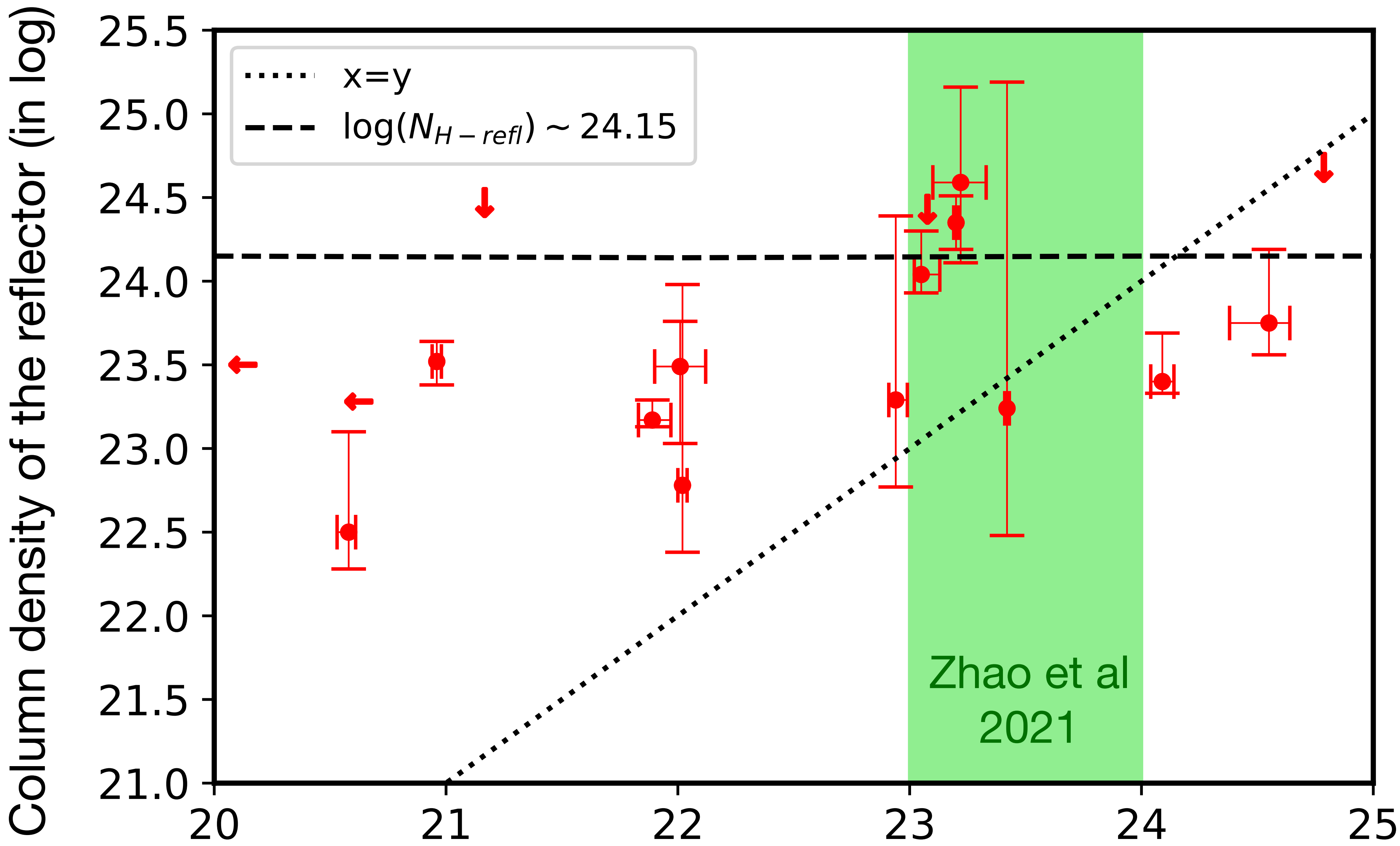
Low luminosity AGN

↓

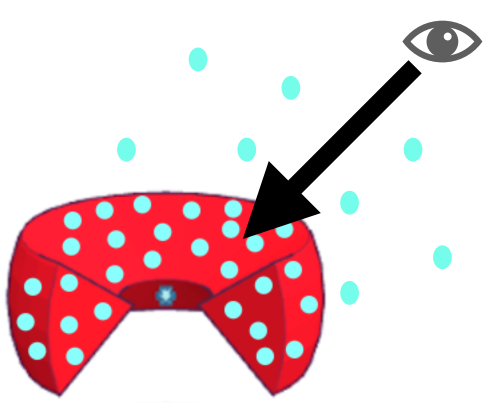
Torus with low column density

From: Diaz et al. 2023

BASS/DR2 - Torus column density versus column density in the line of sight



Column density in the line of sight (in log)



From: Diaz et al. 2023

Summary

Summary

We study the reflection of LLAGN by analyzing the X-ray spectra of a BASS/DR2 sample with $\log(\lambda_{Edd}) < -3$ (17 objects) using *XMM-Newton*+*NuSTAR*+Swift observations and characterizing the reflection features using the borus02 model to represent torus reflection and xillver to model accretion disk emission.

17 objects:
- Nine objects are better fitted with a torus
- Six objects are equally well fitted with a torus or a disk
- Two objects are better fitted with a disk like reflector

- AGN at $\log(\lambda_{Edd}) < -3$ has a torus with lower column density (not dependent of the covering factor) compared to more luminous AGN (with large scatter).
- In all AGN in our sample with a column density in the line of sight below $10^{23} cm^{-2}$, the torus could be observed through an underdense region.