Big Data applications for Black hole Evolution Studies

A multiwavelength motivated X-ray model for the Circinus Galaxy

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The Circinus Galaxy

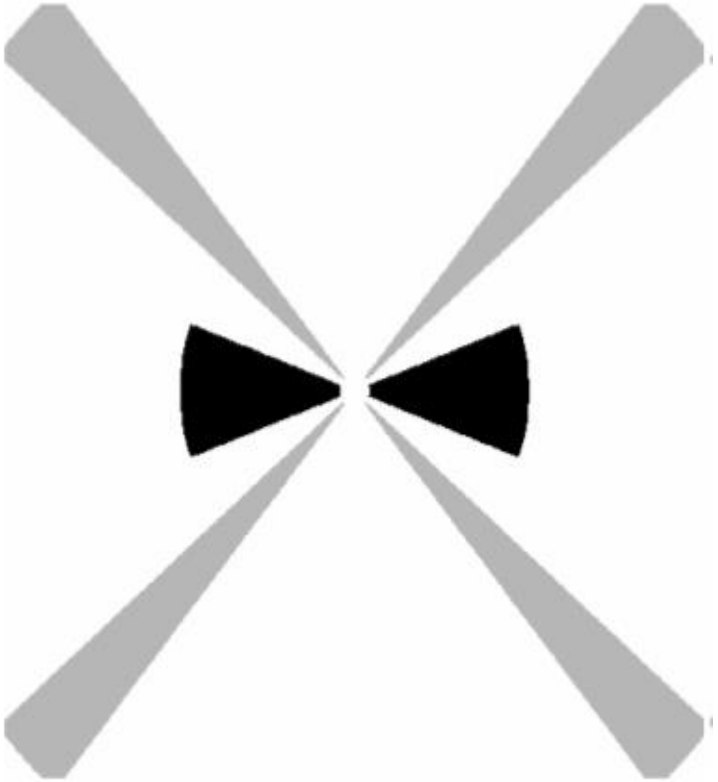
- Seyfert 2, Compton-thick AGN ($N_H > 10^{24}$ cm^{-2})
- d = 4.2 Mpc

Credits: HST

The Circinus Galaxy

Stalevski et al. (2017,2019) proposed for the dusty emitting regions:

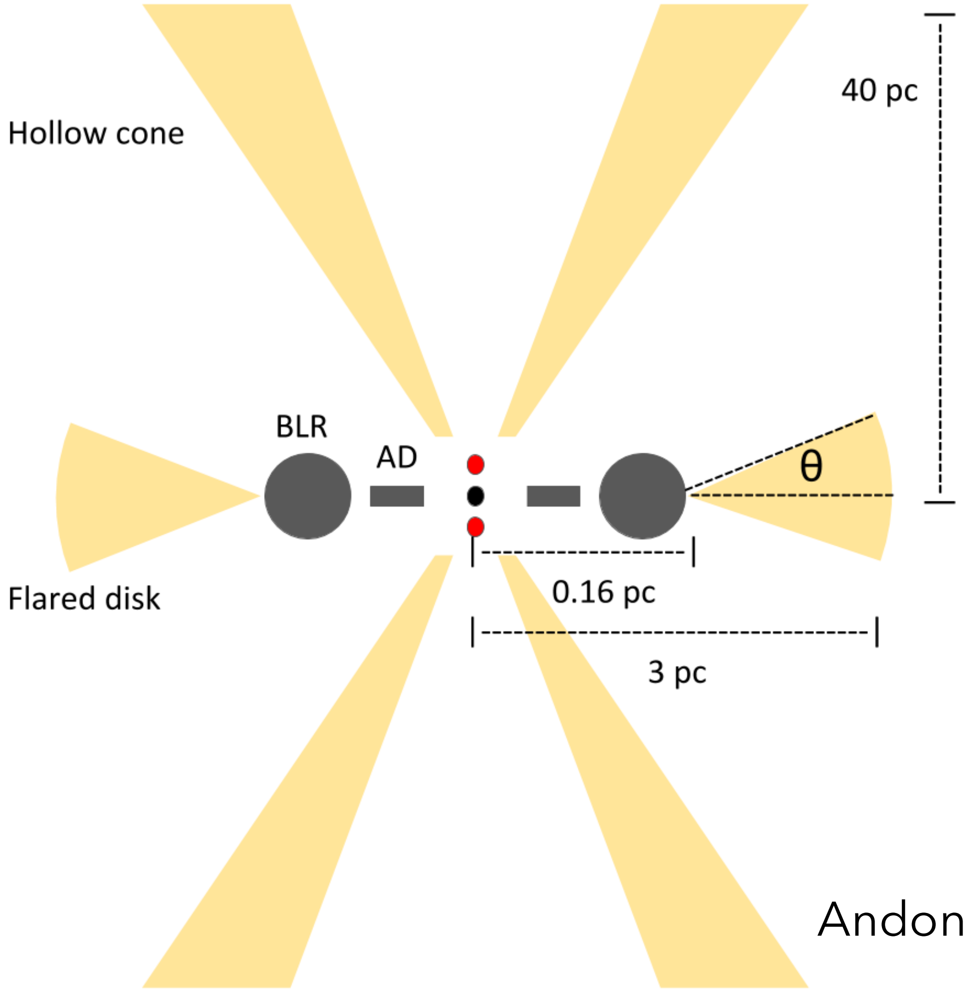
- A flared disk for the disk like component
- A cone/hyperboloid shell for the elongated emission



Stalevski et al. 2017

See also the talks of Jeffrey McKaig and Claudio Ricci

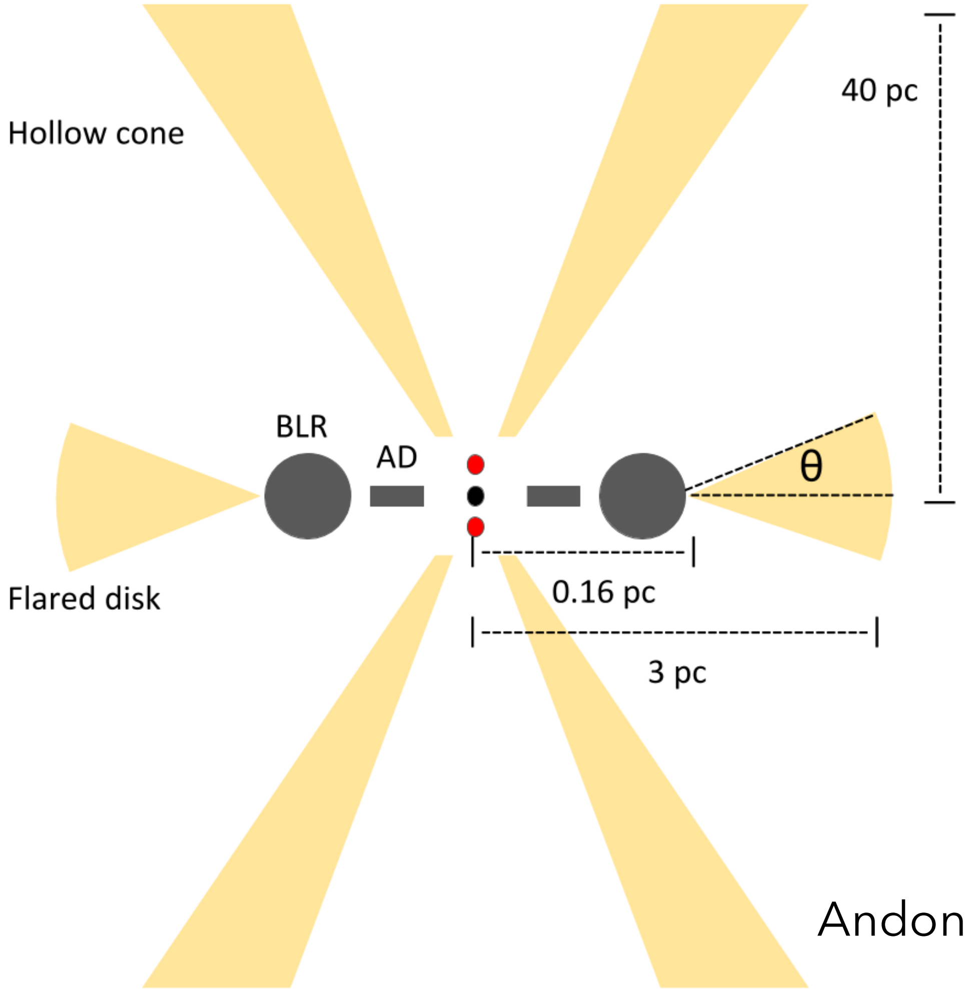
X-ray model built with RefleX (Paltani & Ricci 2017)



Andonie, in prep

Flared disc	
Covering factor (CF^*)	[0.1; 0.7]
Inner radius	0.16 pc
Outer radius	3 pc
Column density flared disk $N^*_{\rm H,d}$	$[10^{24}; 10^{25.5}]$ cm^{-2}
Shell cone	
Half opening angle	40°
Angular full width	10°
Inner height	0.16 pc
Radial extension	40 pc
Column density cone $N^*_{\rm H,c}$	$[10^{21}; 10^{23}]$ cm^{-2}
Broad Line Region	
Inner radius ($R_{\rm BLR}$)	0.0038 pc
Covering factor ($CF_{\rm BLR}$)	0.4
Volumetric density	10^9 cm^{-3}
Accretion Disk	
Inner radius	10^{-8} pc
Outer radius	6.7×10^{-7} pc
Volumetric density	10^{15} cm^{-3}
X-ray Corona	
Radius	10^{-8} pc
Height	1.67×10^{-8} pc
Photon index (Γ^*)	[1.5; 2.4]
High-energy cut-off ($E_{\rm c}$)	200 keV

X-ray model built with RefleX (Paltani & Ricci 2017)



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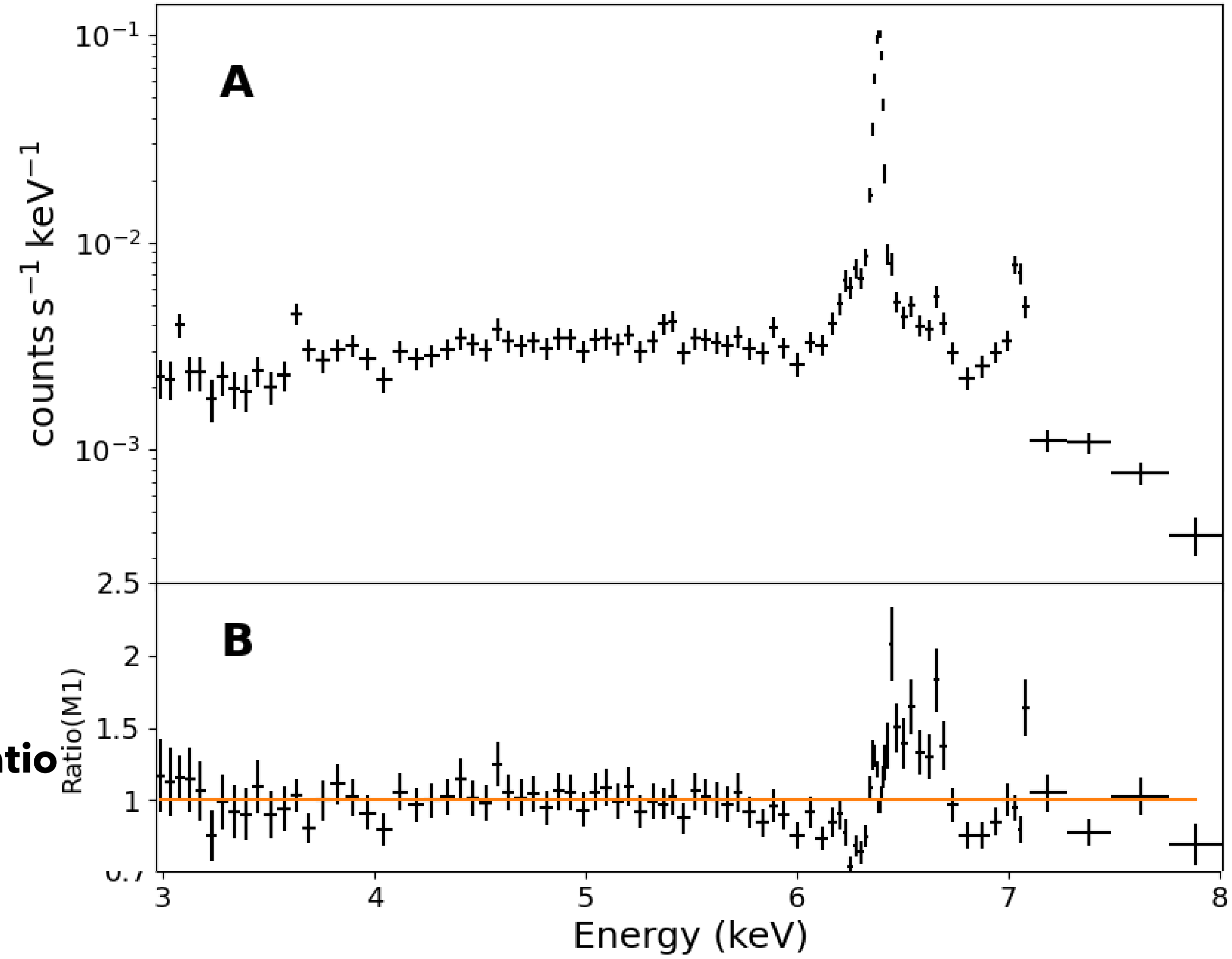
X-ray spectral fitting: *Chandra*/HEG

X-ray model ratio



Andonie, in prep

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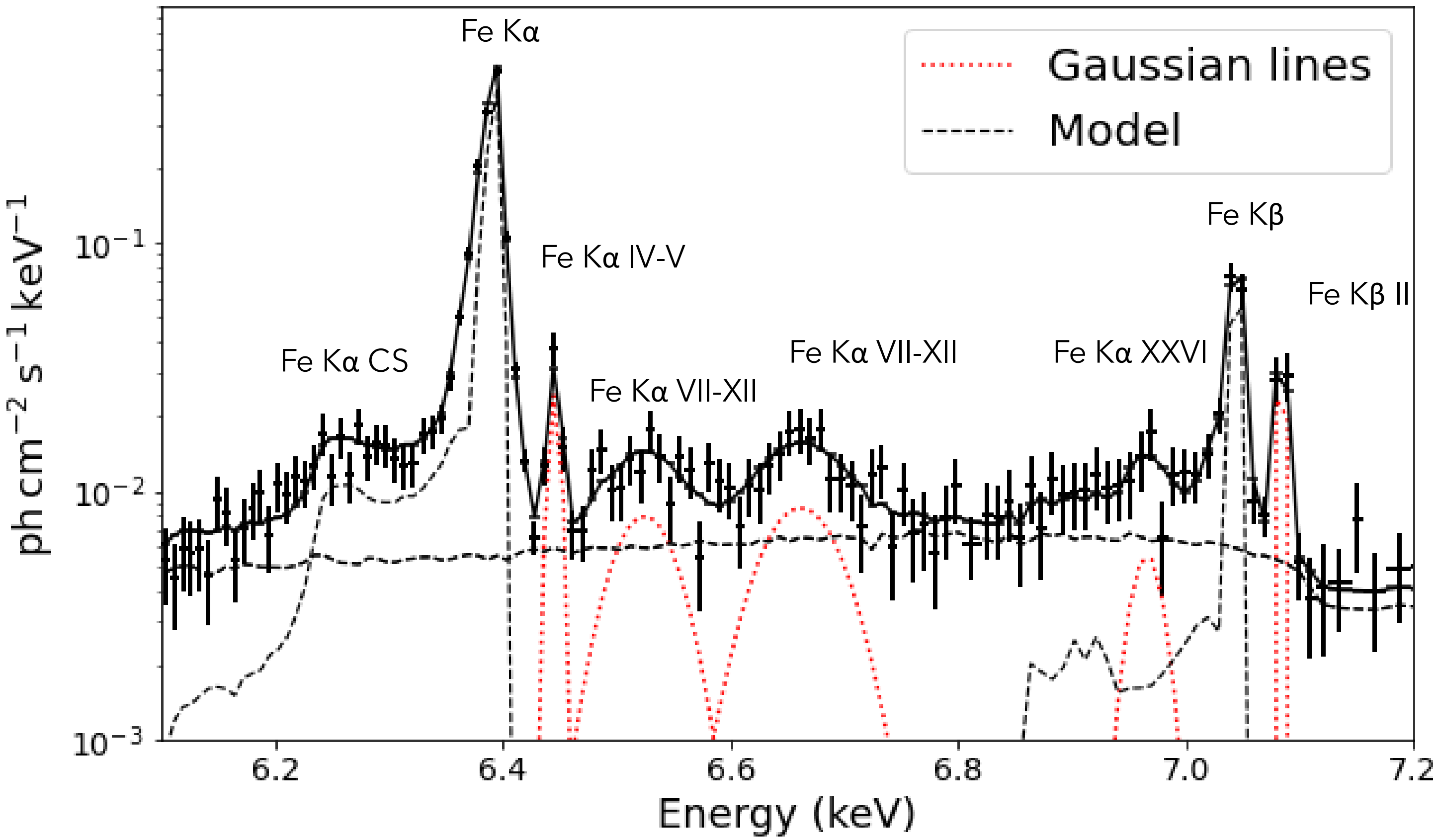

Andonie, in prep

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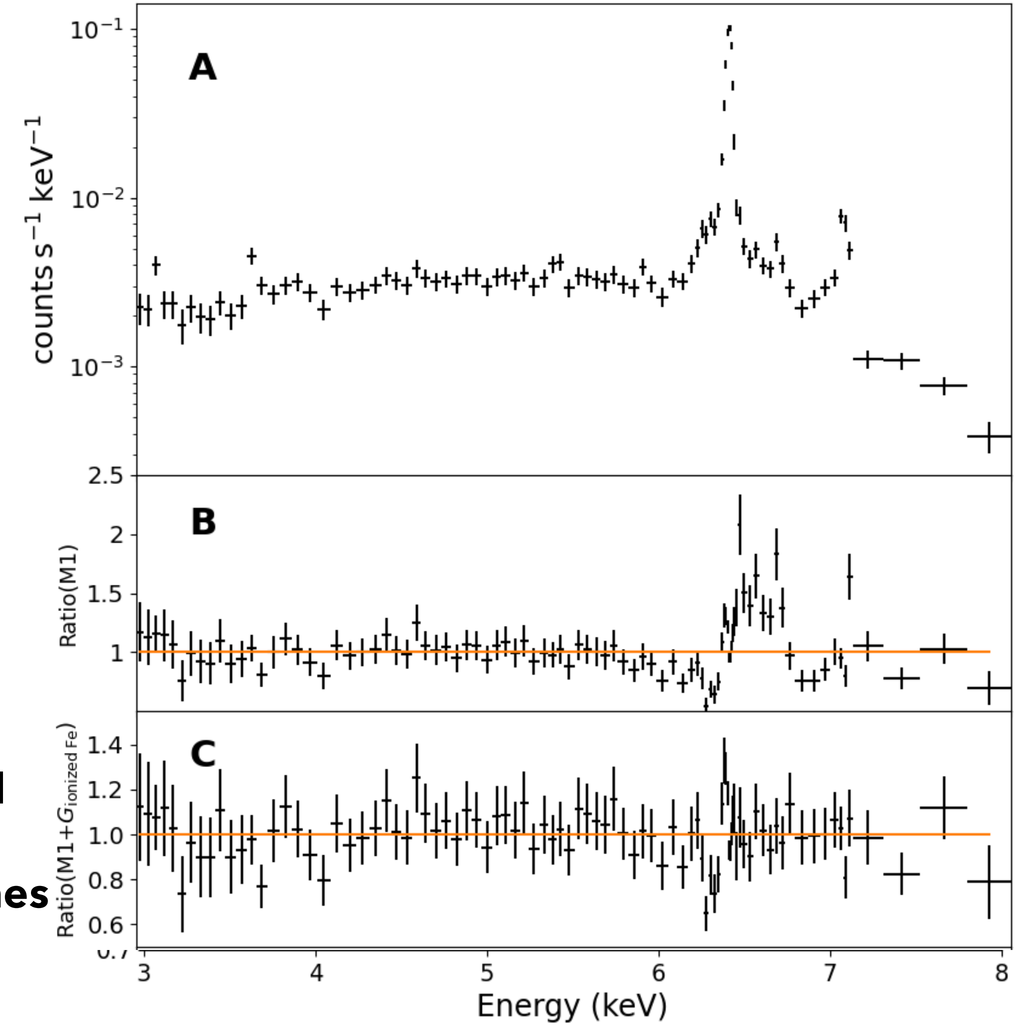
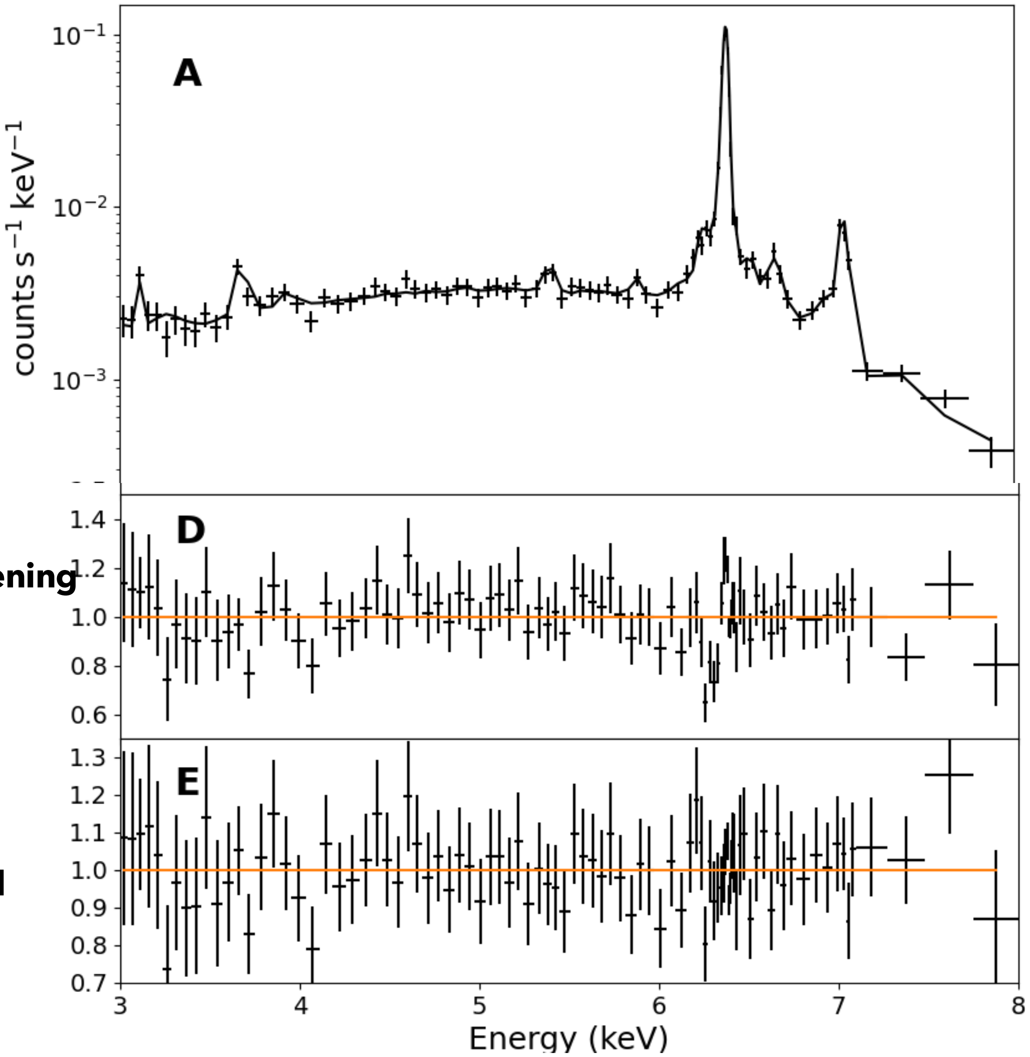


X-ray model

X-ray model +ionized Fe Gaussian lines

Andonie, in prep

X-ray spectral fitting: *Chandra*/HEG



Considering gravitational broadening in BLR ⟶ does not substantially improve the fit

Extended emission along grating arms ⟶ Gaussian lines at 6.4 and 7.05 keV (Arevalo et al 2014)

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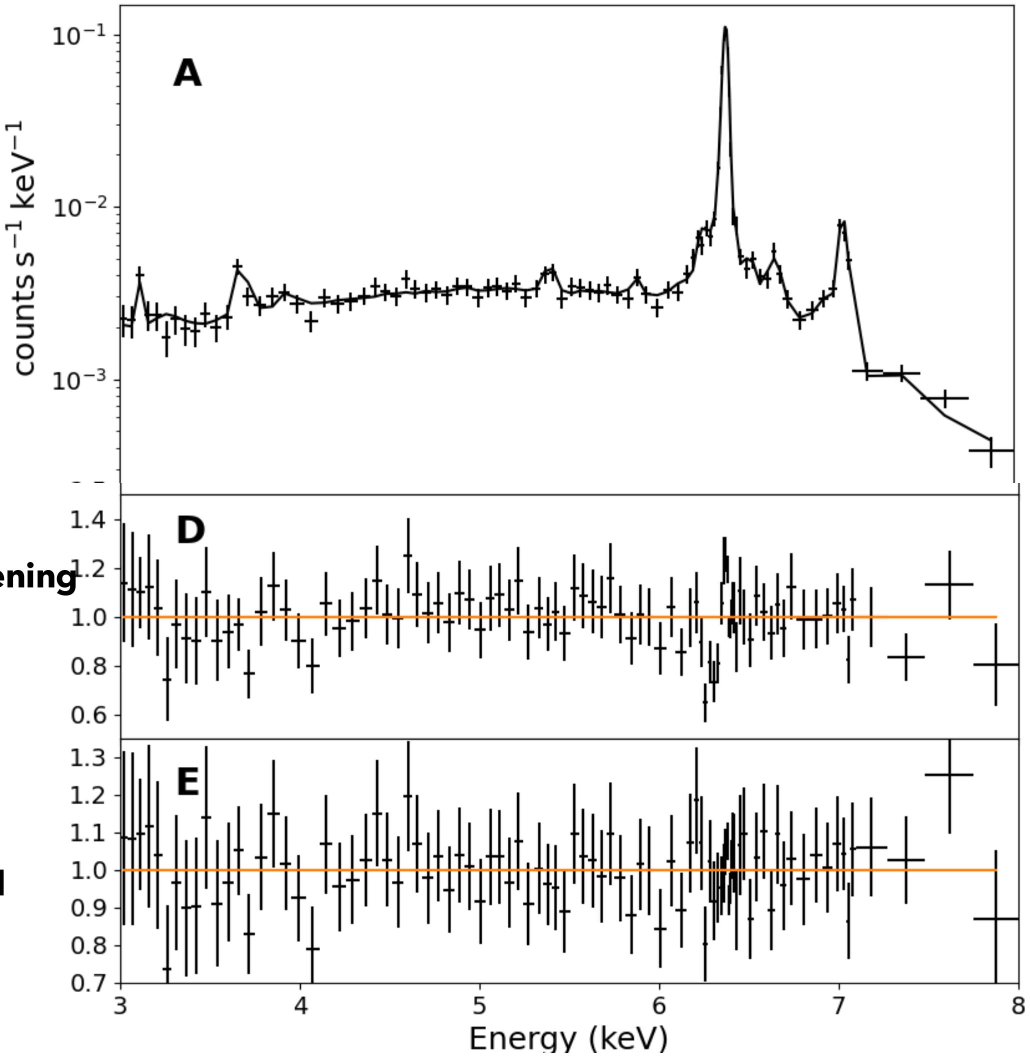

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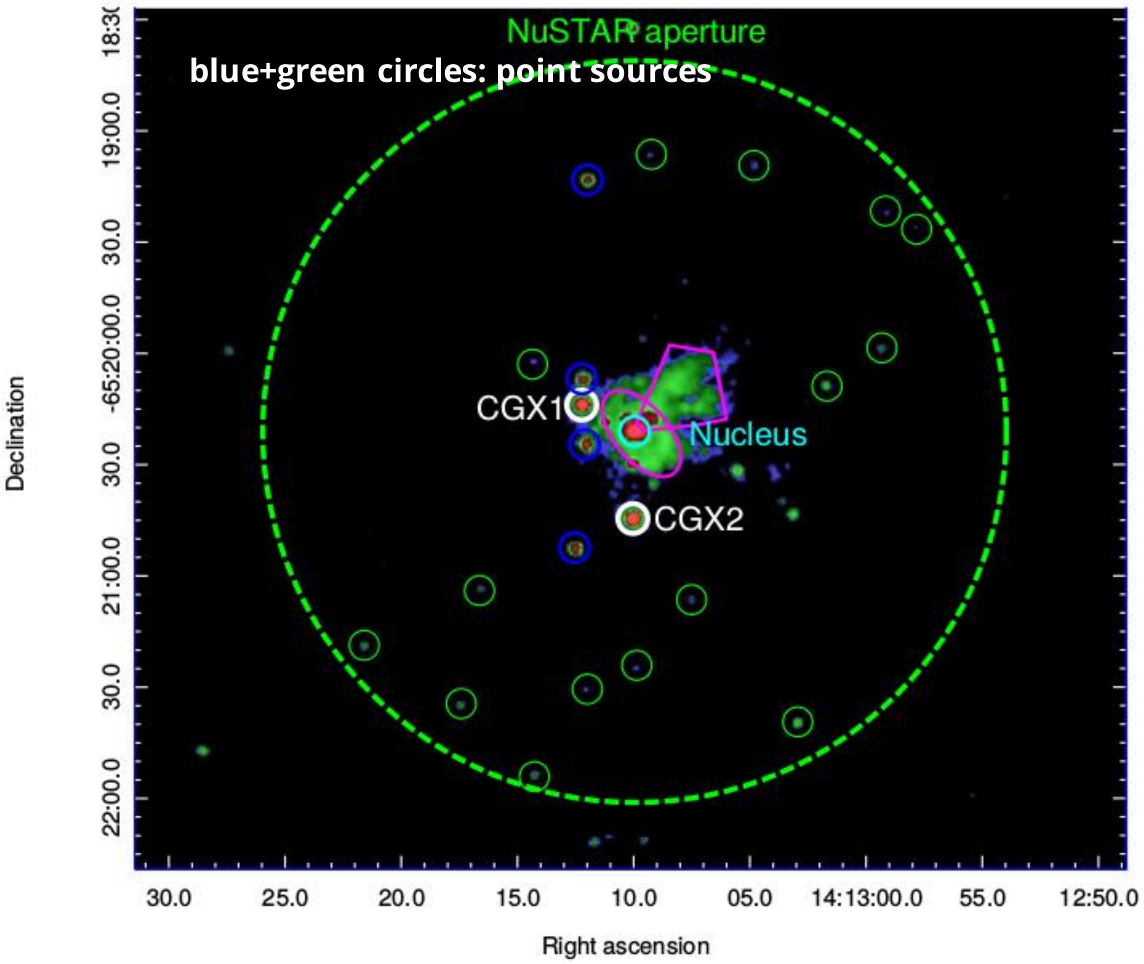
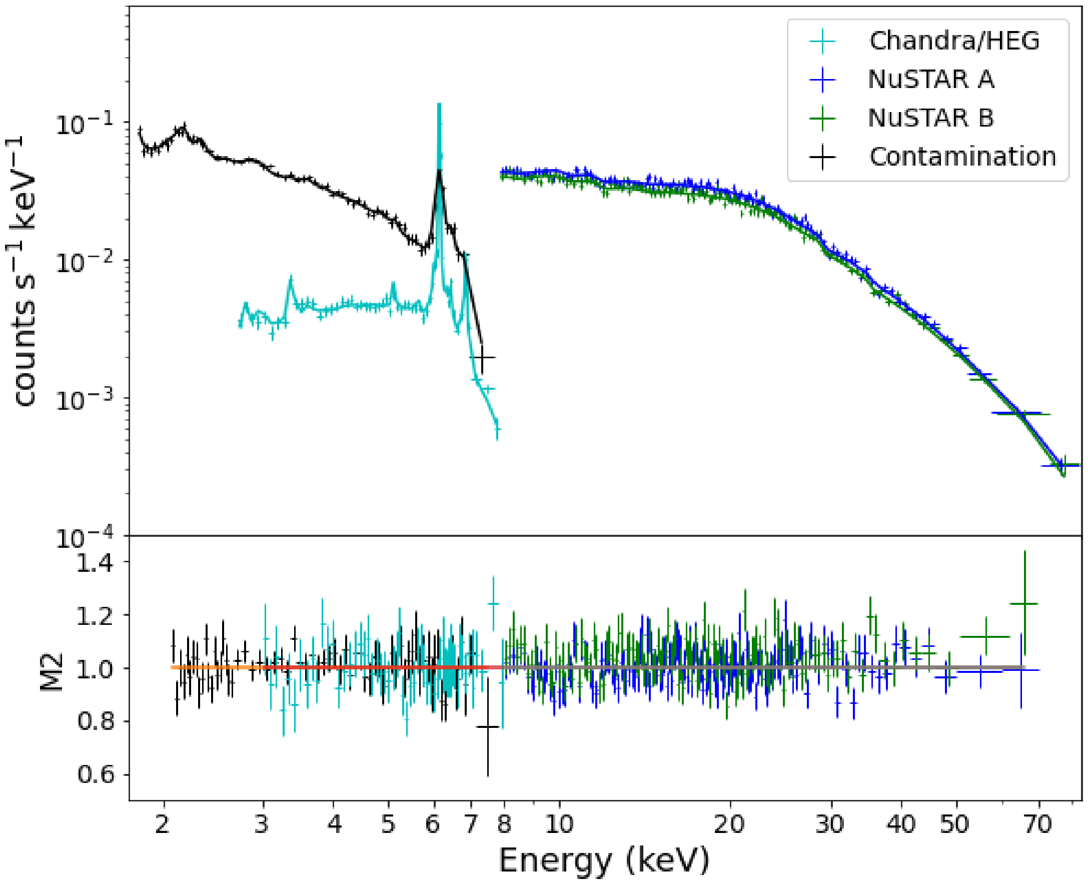
With facilities such as XRISM, iron extended emission will not be a problem

X-ray spectral fitting: *Chandra*/HEG + *NuSTAR*

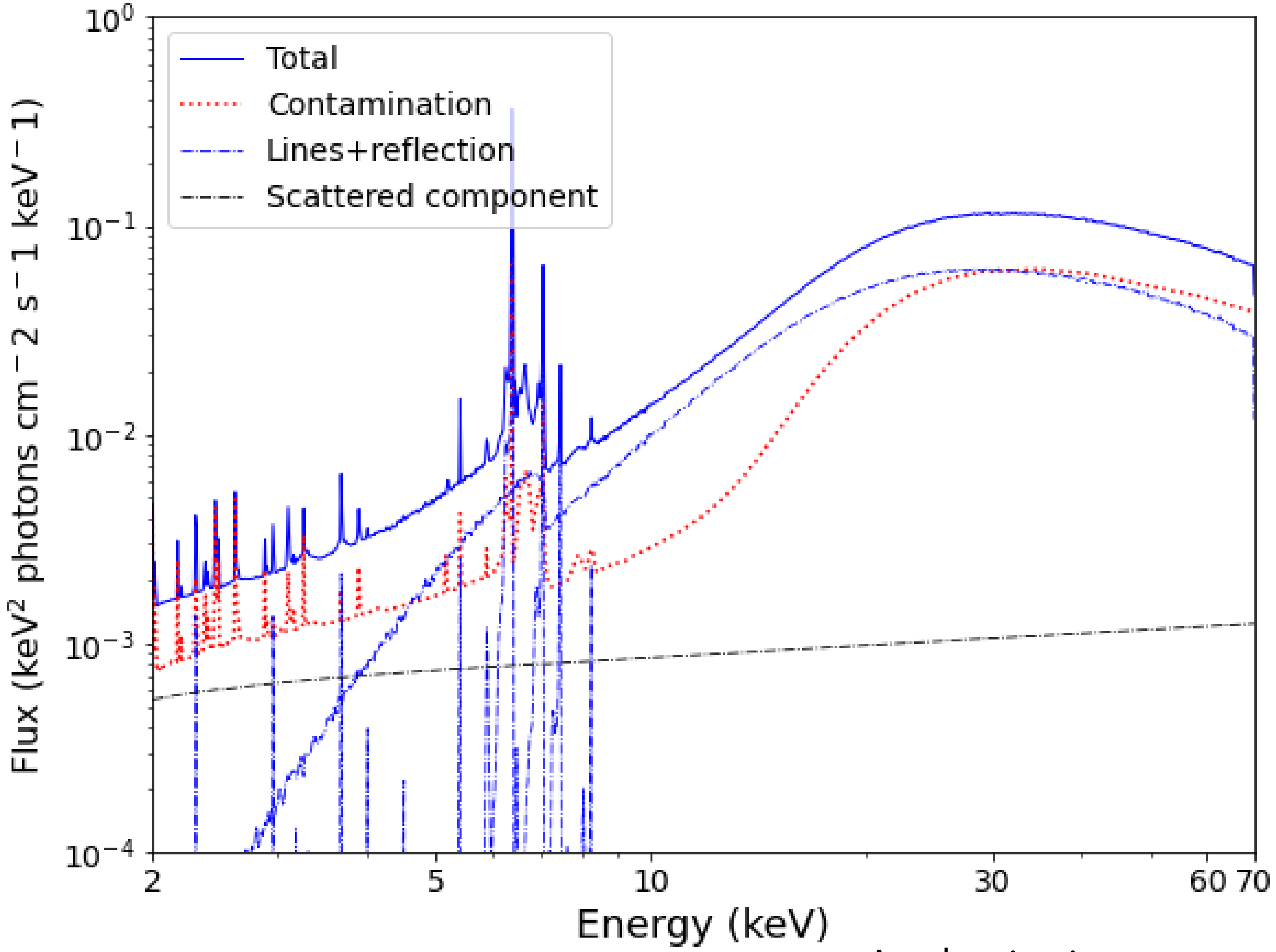


Arevalo et al. 2014



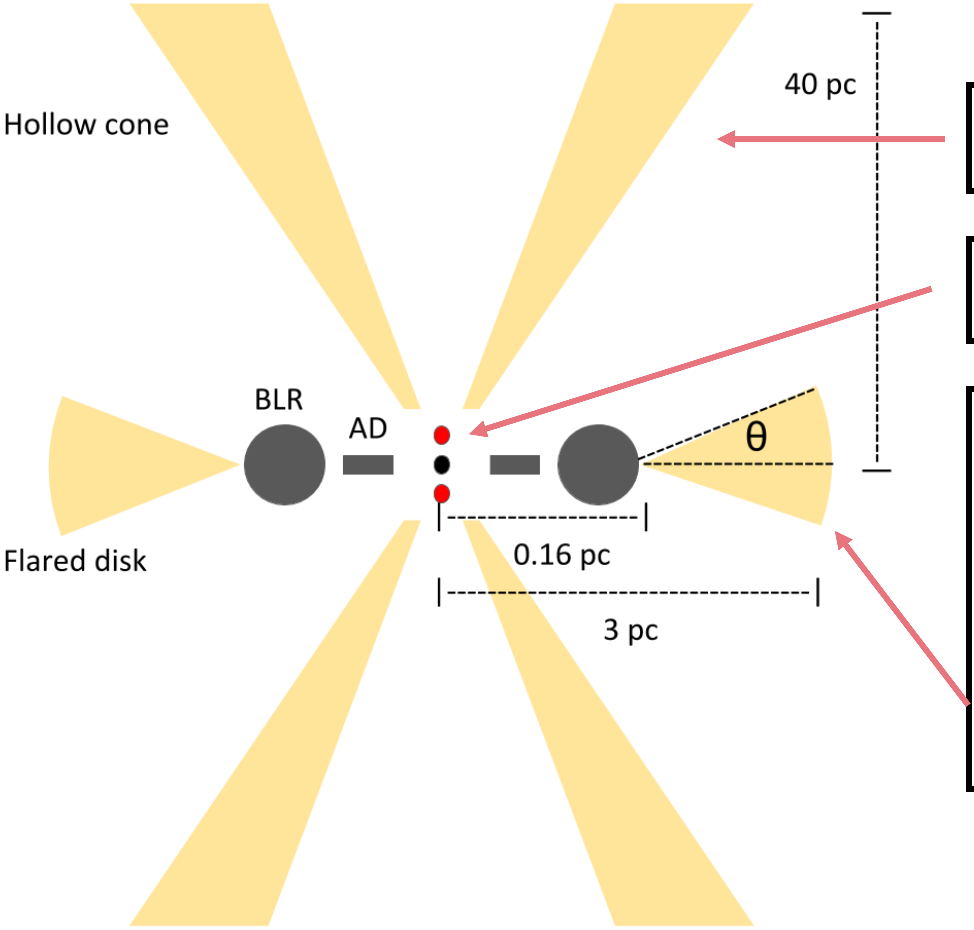
Andonie, in prep

X-ray spectral fitting: *Chandra*/HEG + *NuSTAR*



Andonie, in prep

X-ray spectral fitting results



$N_{H,c}$ = 2.5±0.45×10^{22} cm^{-2}

Γ = 1.81± 0.05

CF = 0.53 ± 0.02

$N_{H,d}$= 4±0.5×10^{24} cm^{-2}

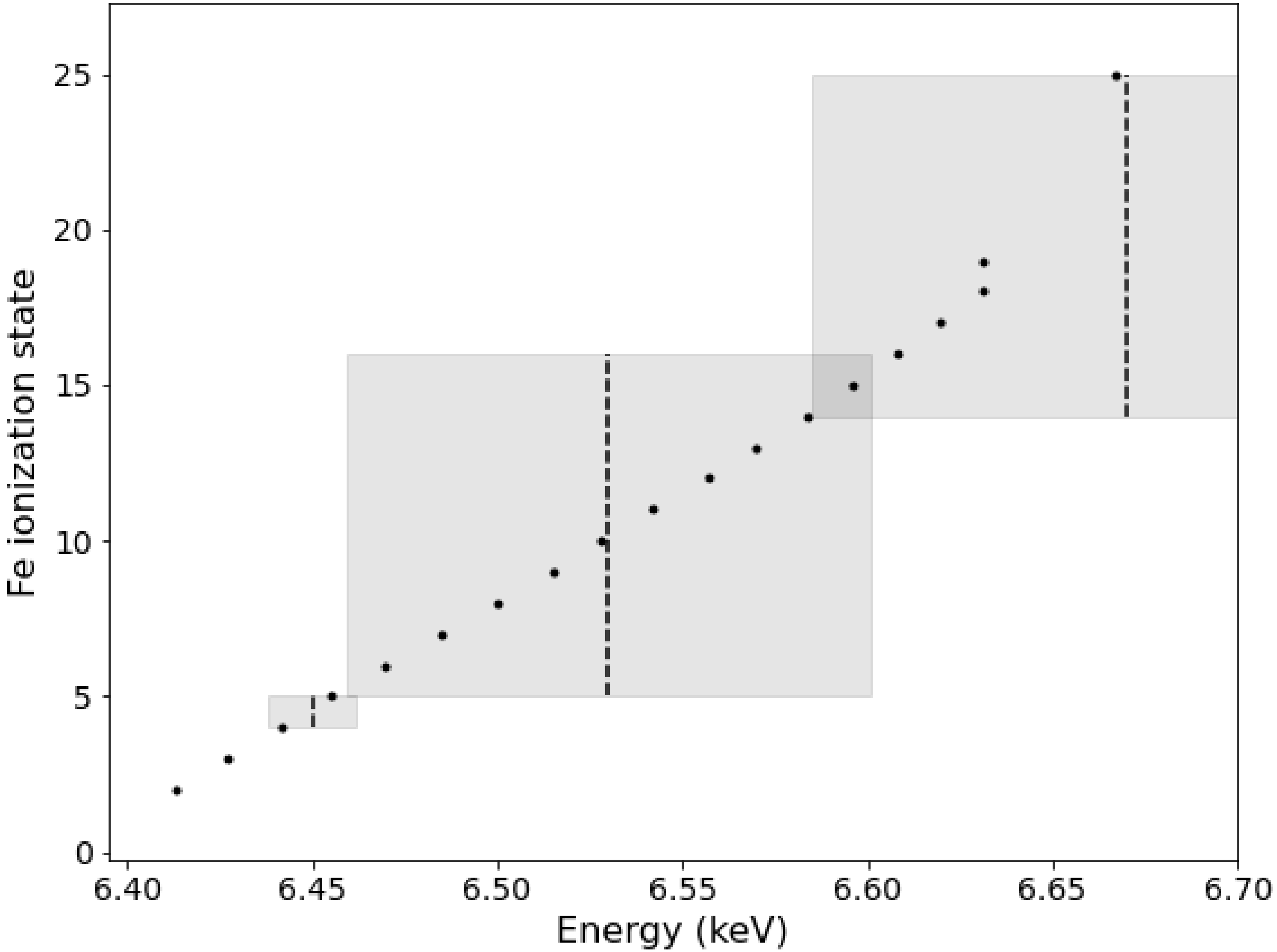
Effective equatorial
N_H =8±0.5 ×10^{24} cm^{-2}

Conclusions

- The IR geometry is able to properly reproduce the broadband X-ray spectrum of Circinus. However, we need to add several Gaussian lines to reproduce the Fe Kα complex
- We conclude that the spatial extension of the line along the HEG arms needs to be taken into account to accurately reproduce the shape of the Fe Kα complex
- The column density and covering factor of the flared disk and cone are consistent with the values found in the scales IR model

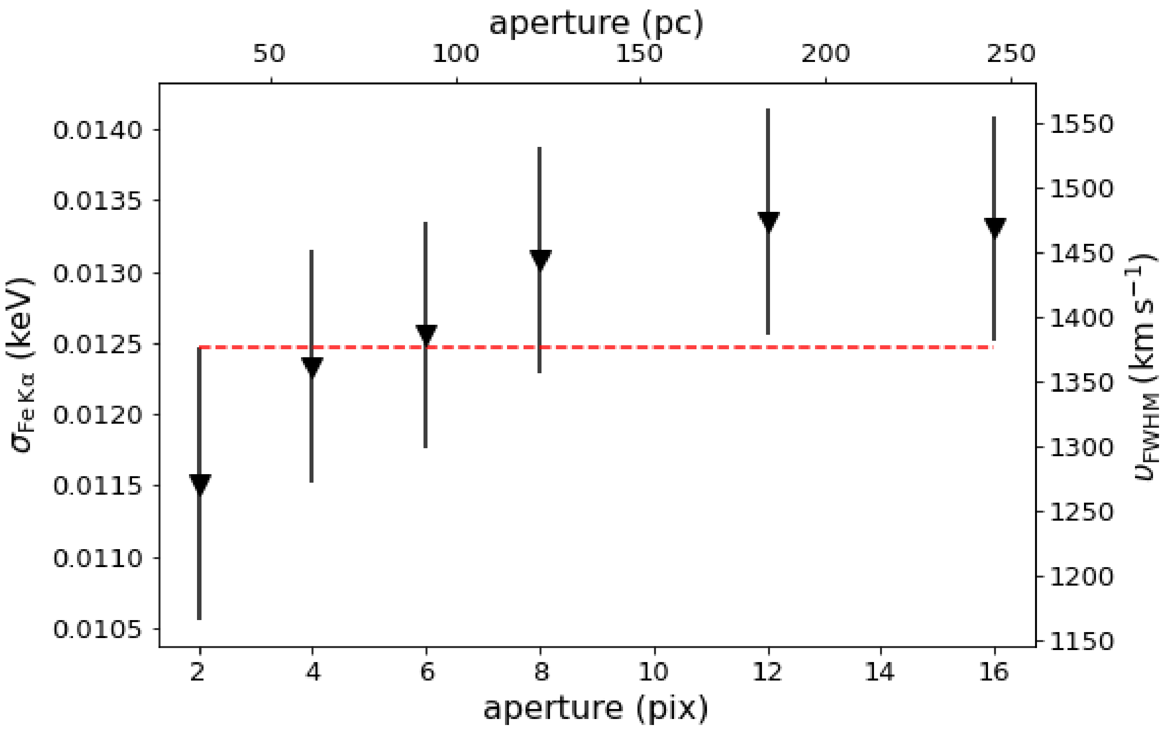
With facilities such as XRISM and Athena, it will be possible to understand what causes the shape of the Fe Kα line and its CS, and also fully constrain the different ionization levels of iron and their contribution to the 6.4-7 keV flux

Thanks!



Fe ionization state
Energy (keV)
0
5
10
15
20
25
6.40
6.45
6.50
6.55
6.60
6.65
6.70

X-ray spectral fitting: *Chandra*/HEG



- Arevalo et al. (2014) found that there is an overall broadening of the Fe Kα and Fe Kβ lines due to Fe spatial extension
- It is unclear what fraction of this broadening might be caused by a spatial extension of the line, or due to Doppler broadening if part of the line originates in the BLR

With facilities as XRISM, it will be possible to understand what causes the shape of the Fe Kα line and its CS!

X-ray spectral fitting: *Chandra*/HEG + *NuSTAR*

Component	Parameters	*Chandra*/HEG	*Chandra*/HEG + *NuSTAR*
Cone model	Γ	2.1 ± 0.11	1.81 ± 0.05
	equatorial $N_{\rm H}$ (cm^{-2})	$6.31^{+0.29}_{-0.16} \times 10^{24}$	$8.7^{+0.4}_{-0.6} \times 10^{24}$
	$N_{\rm H,c}$ (cm^{-2})	$10^{+..}_{-0.67} \times 10^{22}$	$2.46^{+0.47}_{-0.43} \times 10^{22}$
	CF	$0.4^{+0.03}_{-0.07}$	$0.53^{+0.01}_{-0.05}$
	N_l (ph keV^{-2} s^{-1} cm^{-2})	$0.24^{+0.03}_{-0.01}$	0.16 ± 0.16
	N_s (ph keV^{-2} s^{-1} cm^{-2})	0.18 ± 0.14	0.17 ± 0.009
Scattered pl	N/N_c	$3.1 \pm 0.5 \times 10^{-3}$	$3.9 \pm 0.4 \times 10^{-3}$
stats/dof		$1104/1033 = 1.07$	$2368.63/2401 = 0.99$