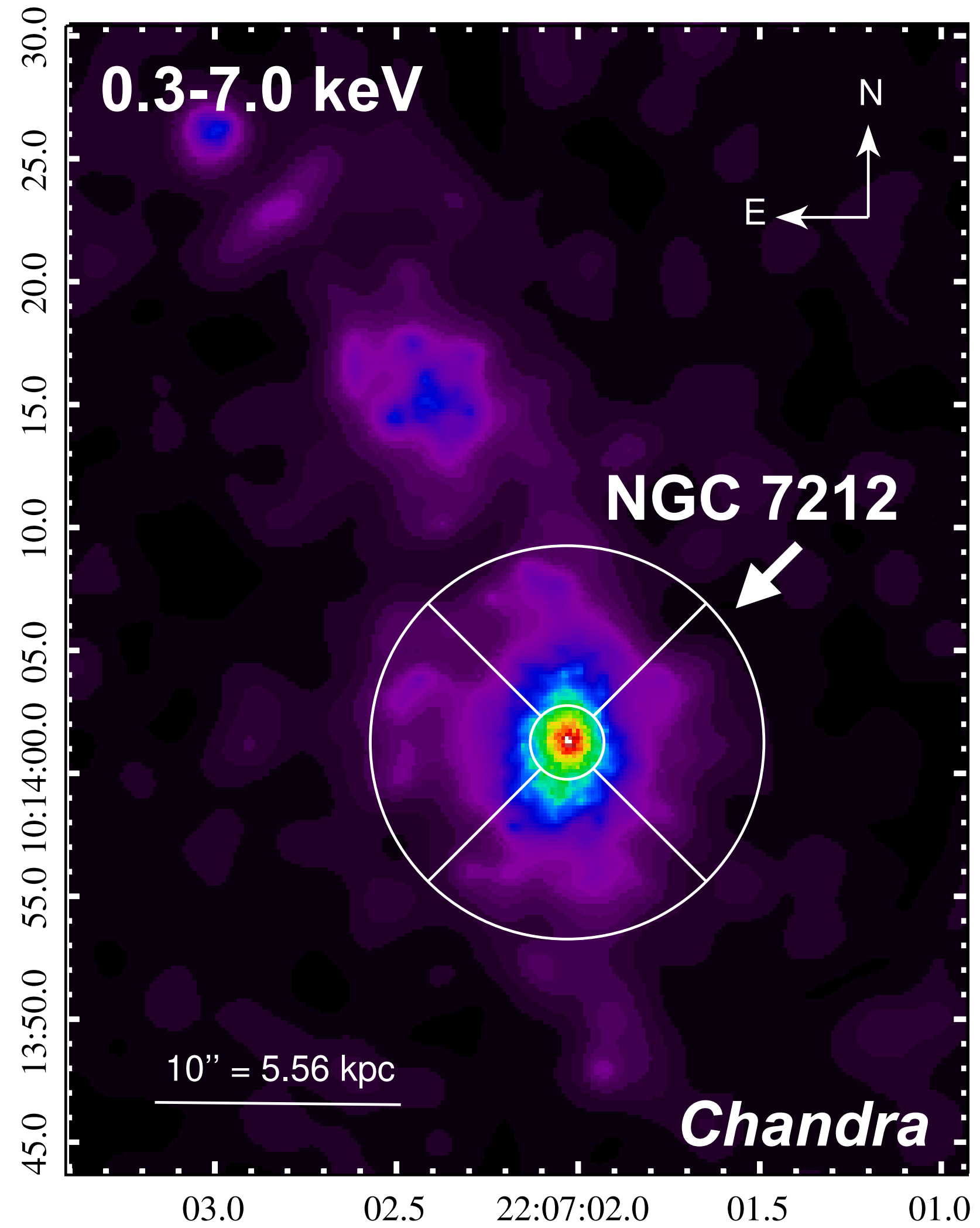
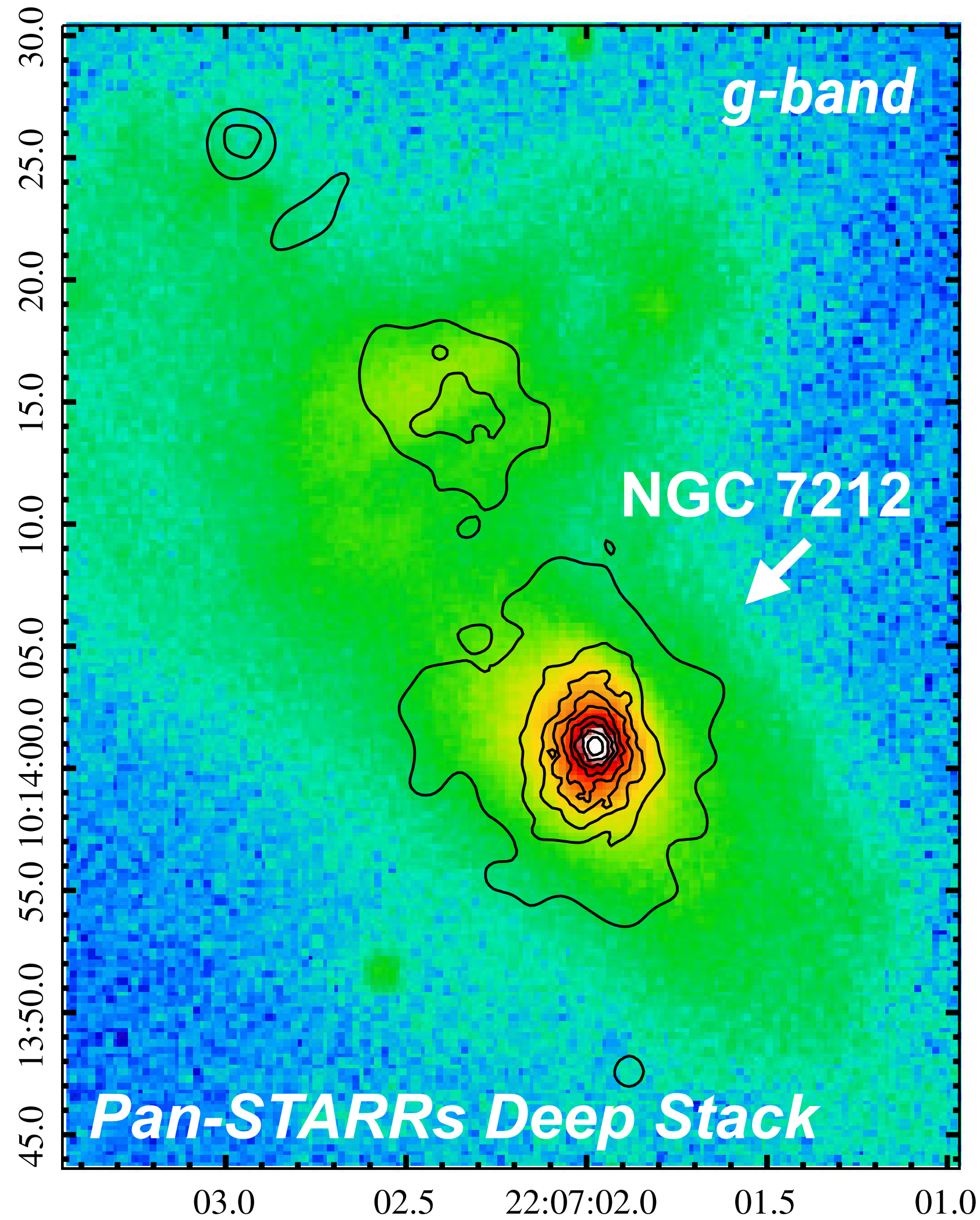
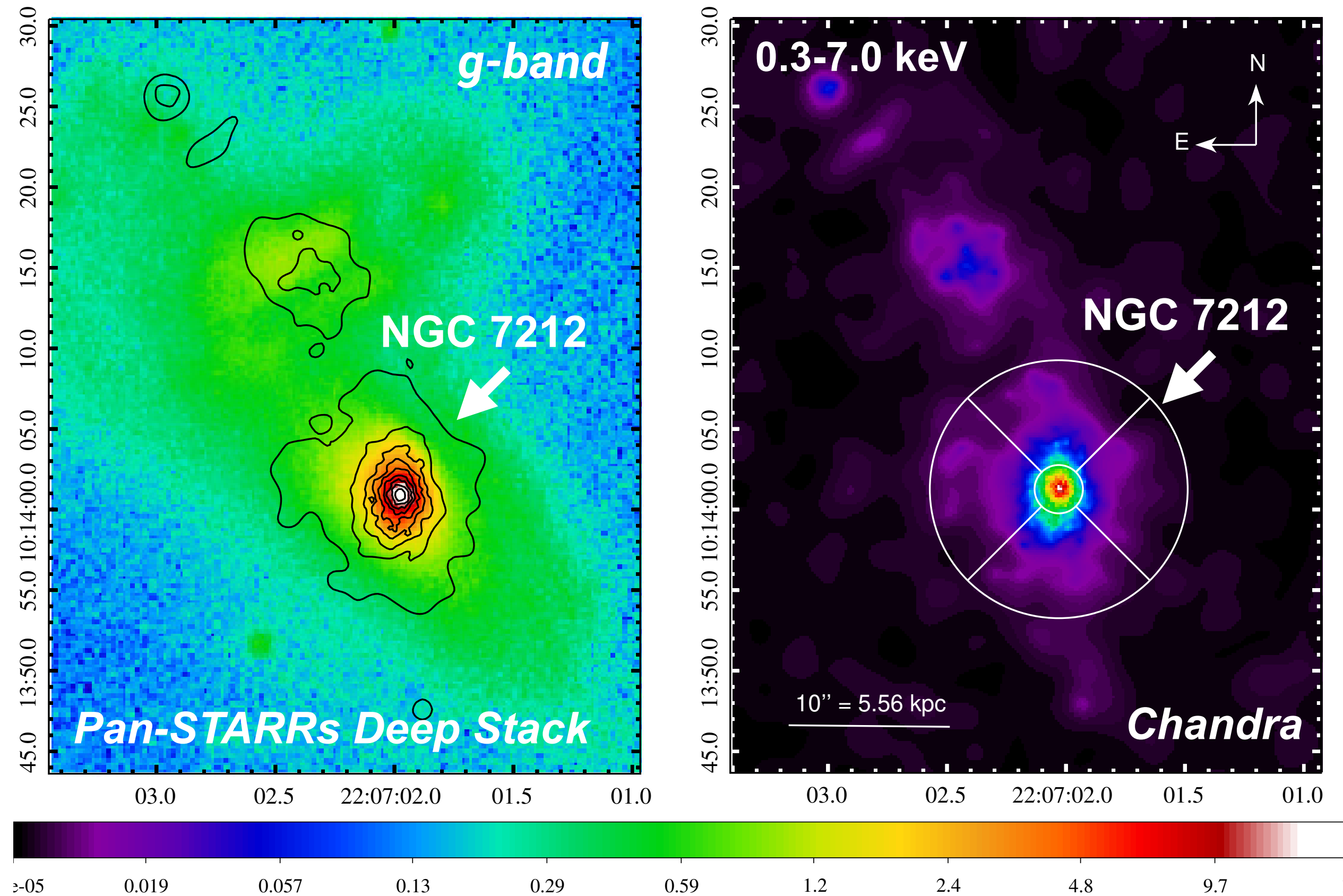


# NGC 7212: Large-scale Extended X-ray Emission

MACKENZIE JONES, G. FABBIANO (PI), MARTIN ELVIS, A. PAGGI, M. KAROVSKA, W. P. MAKSYM, A. SIEMIGINOWSKA, J. RAYMOND

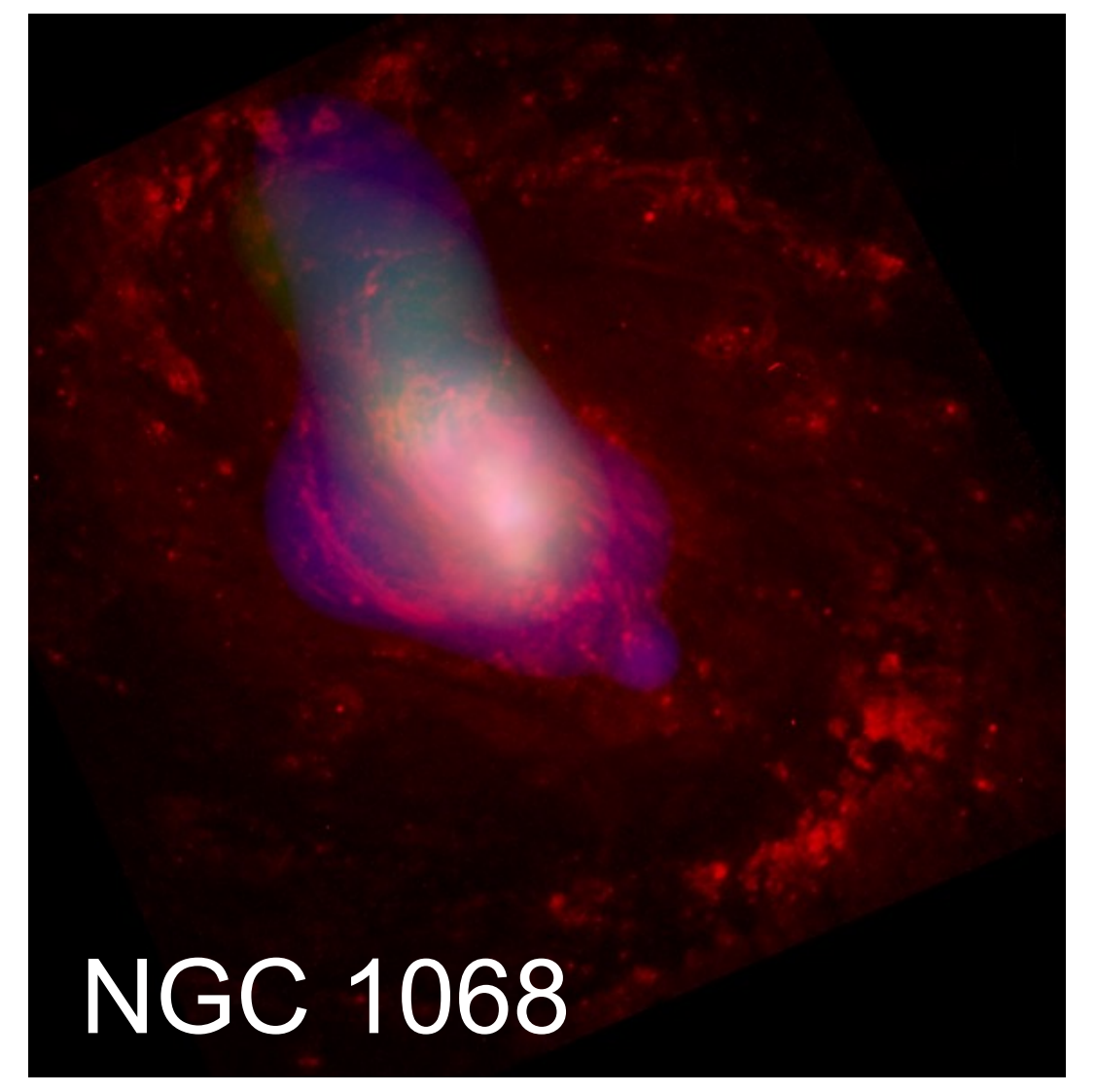
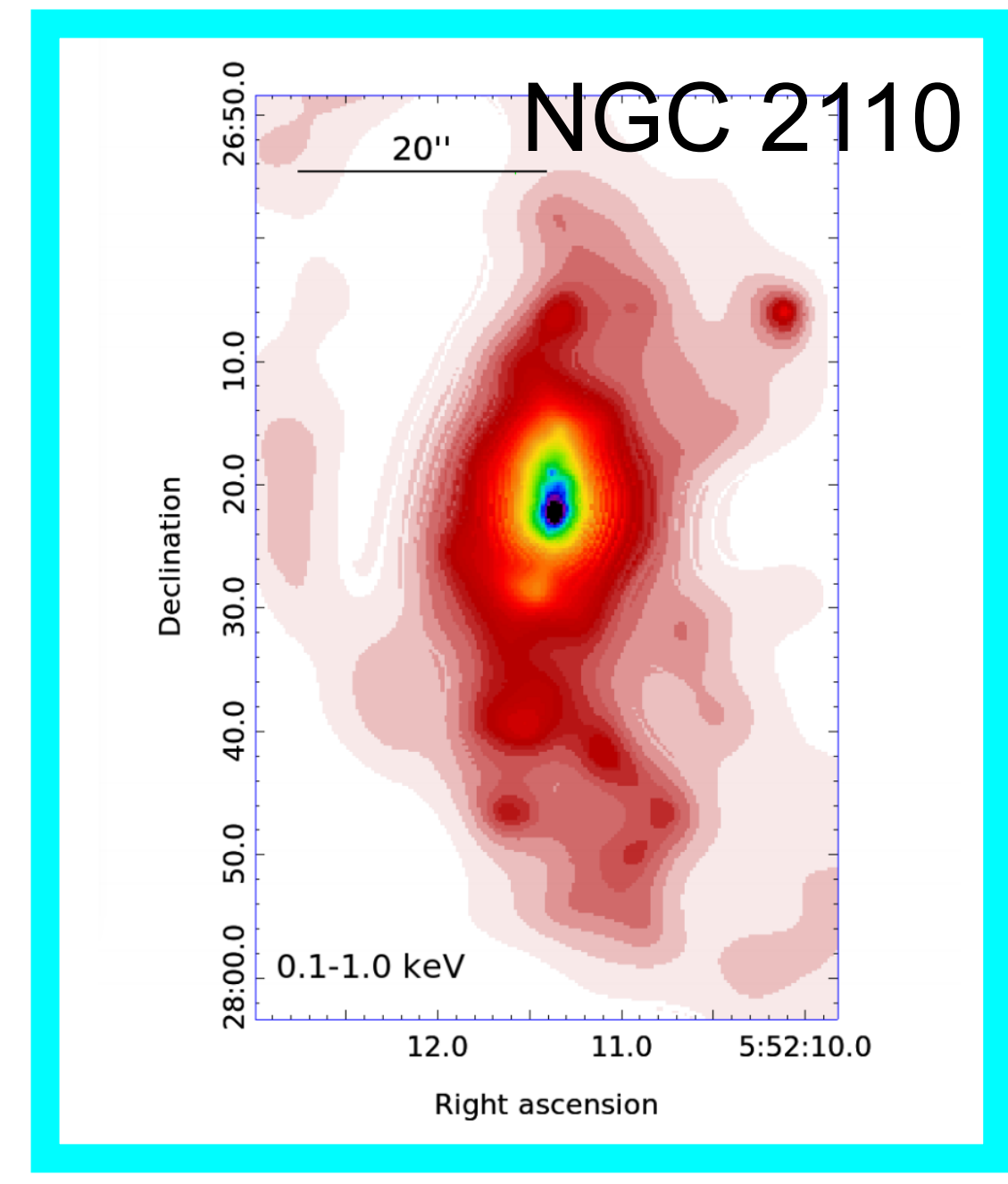
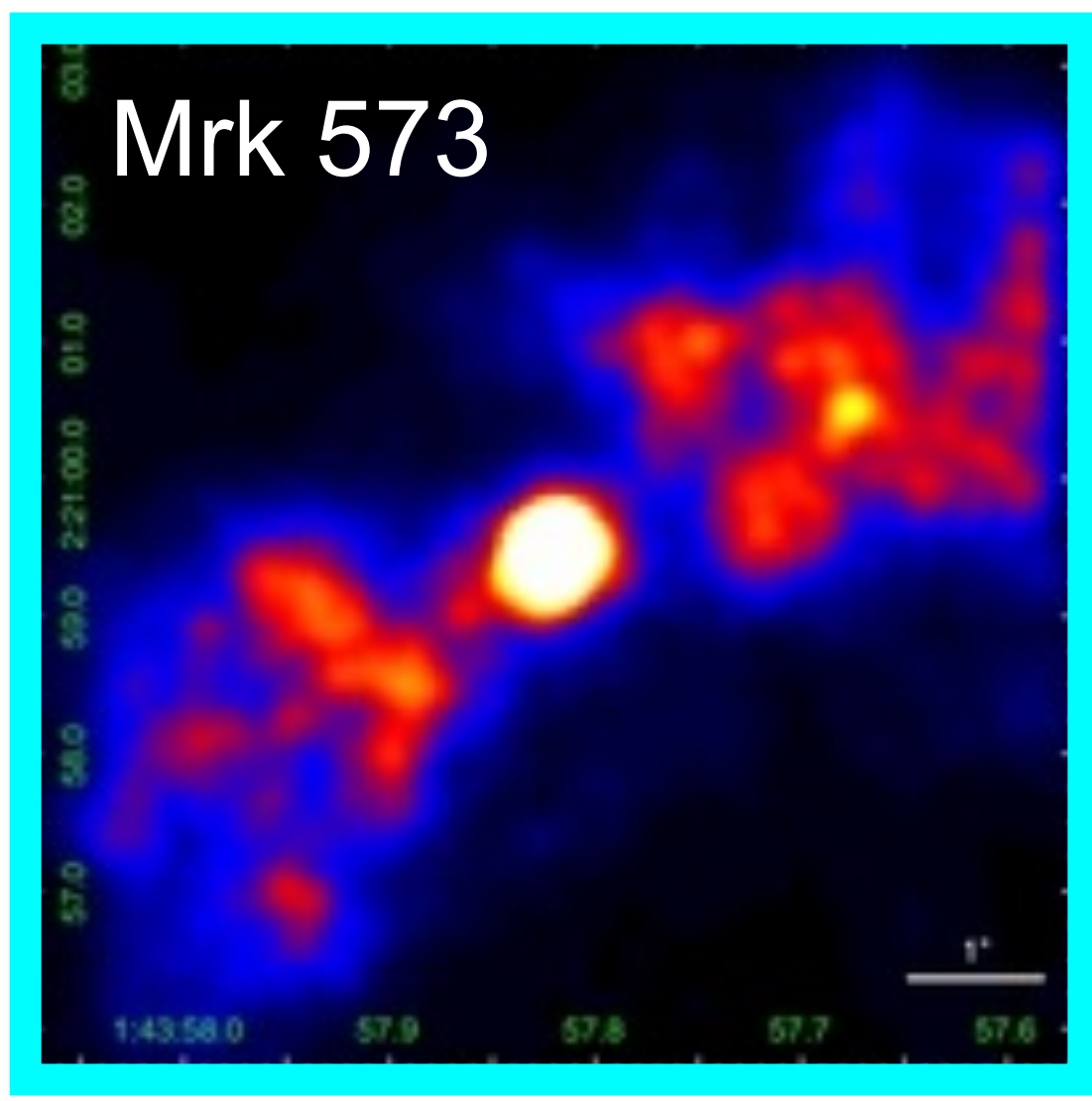
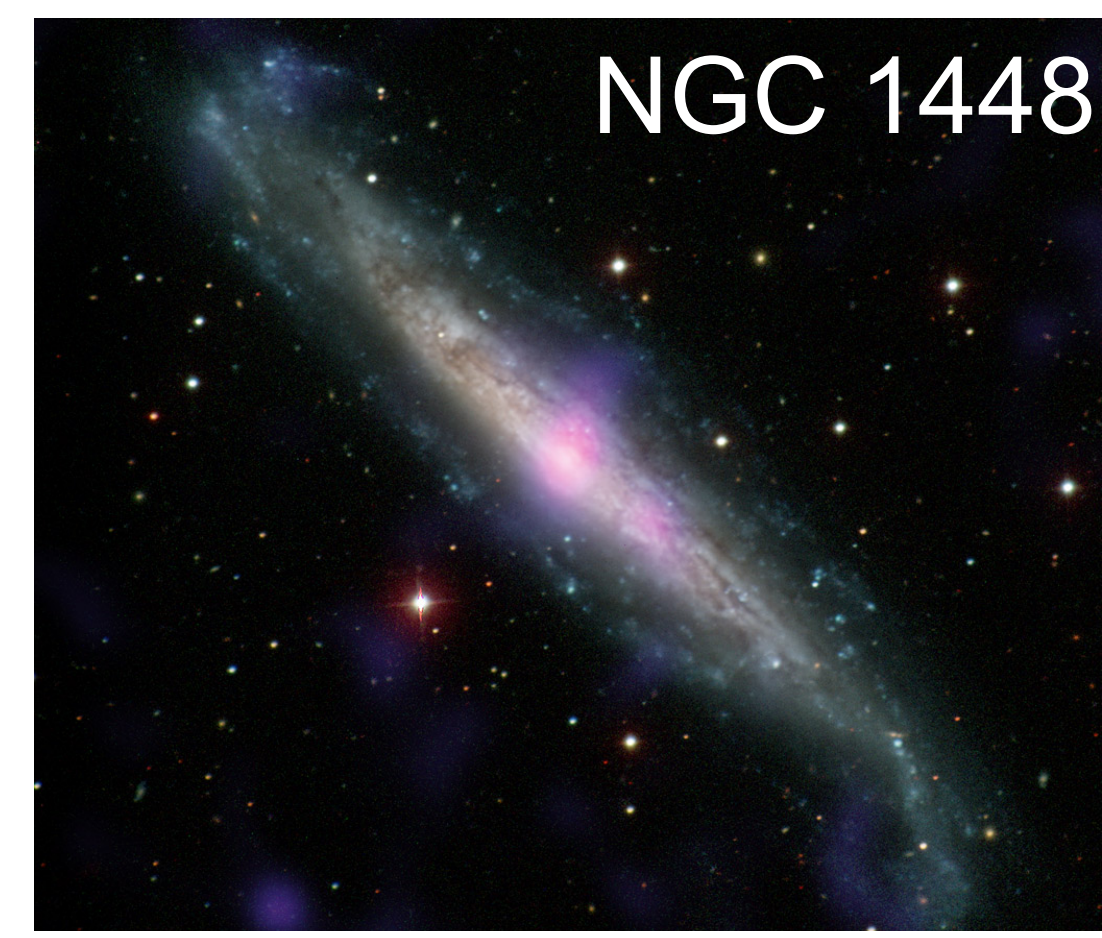
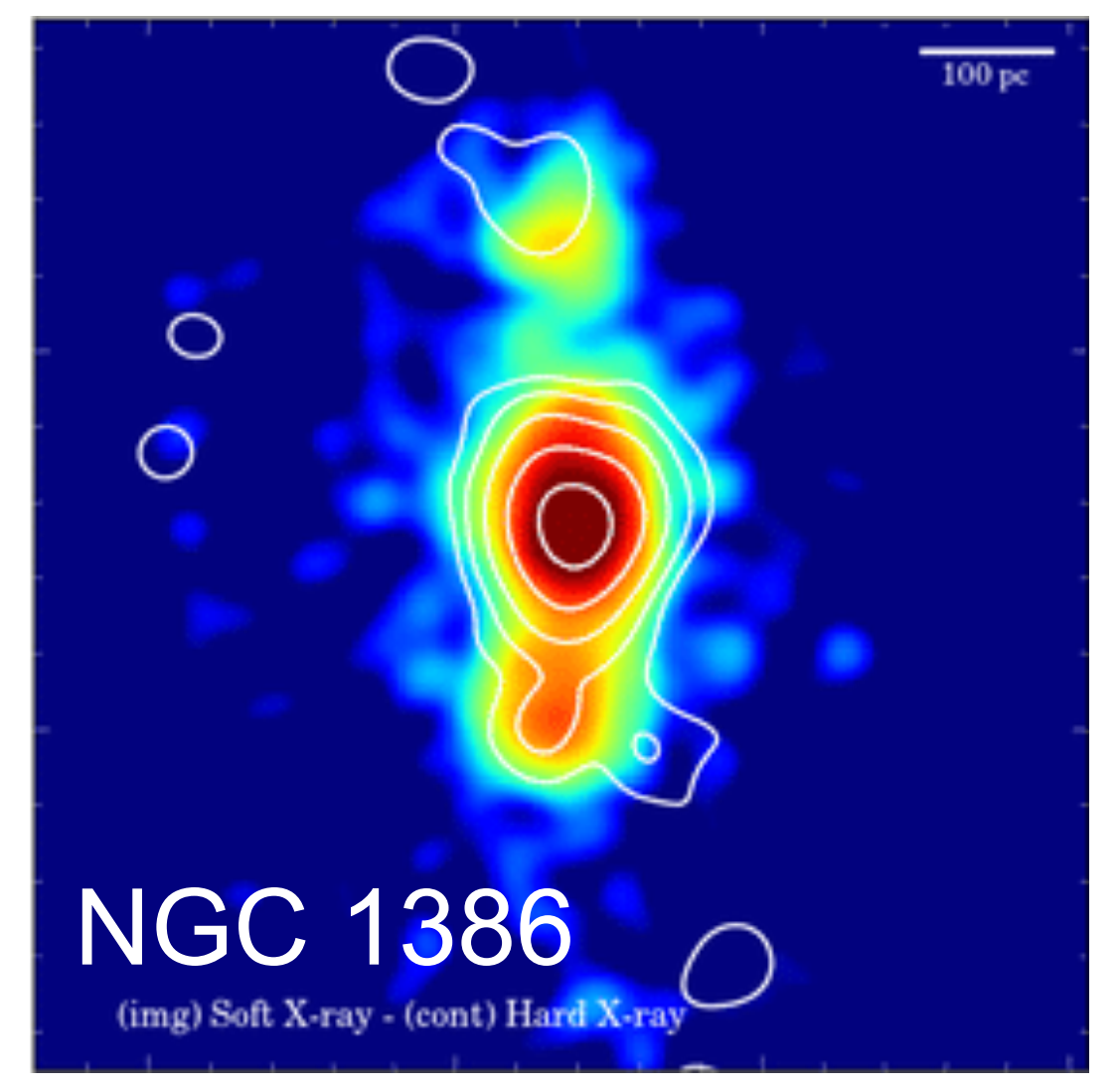
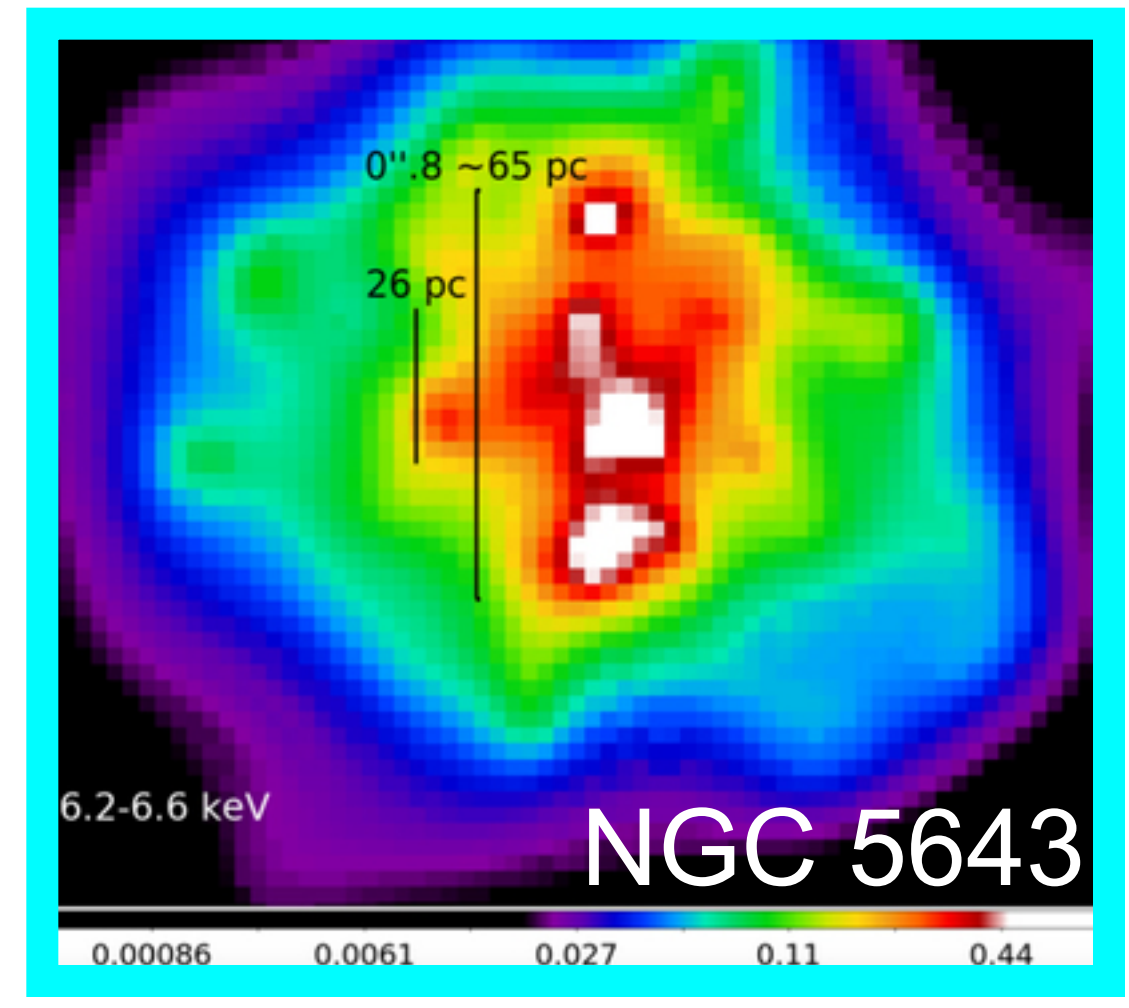
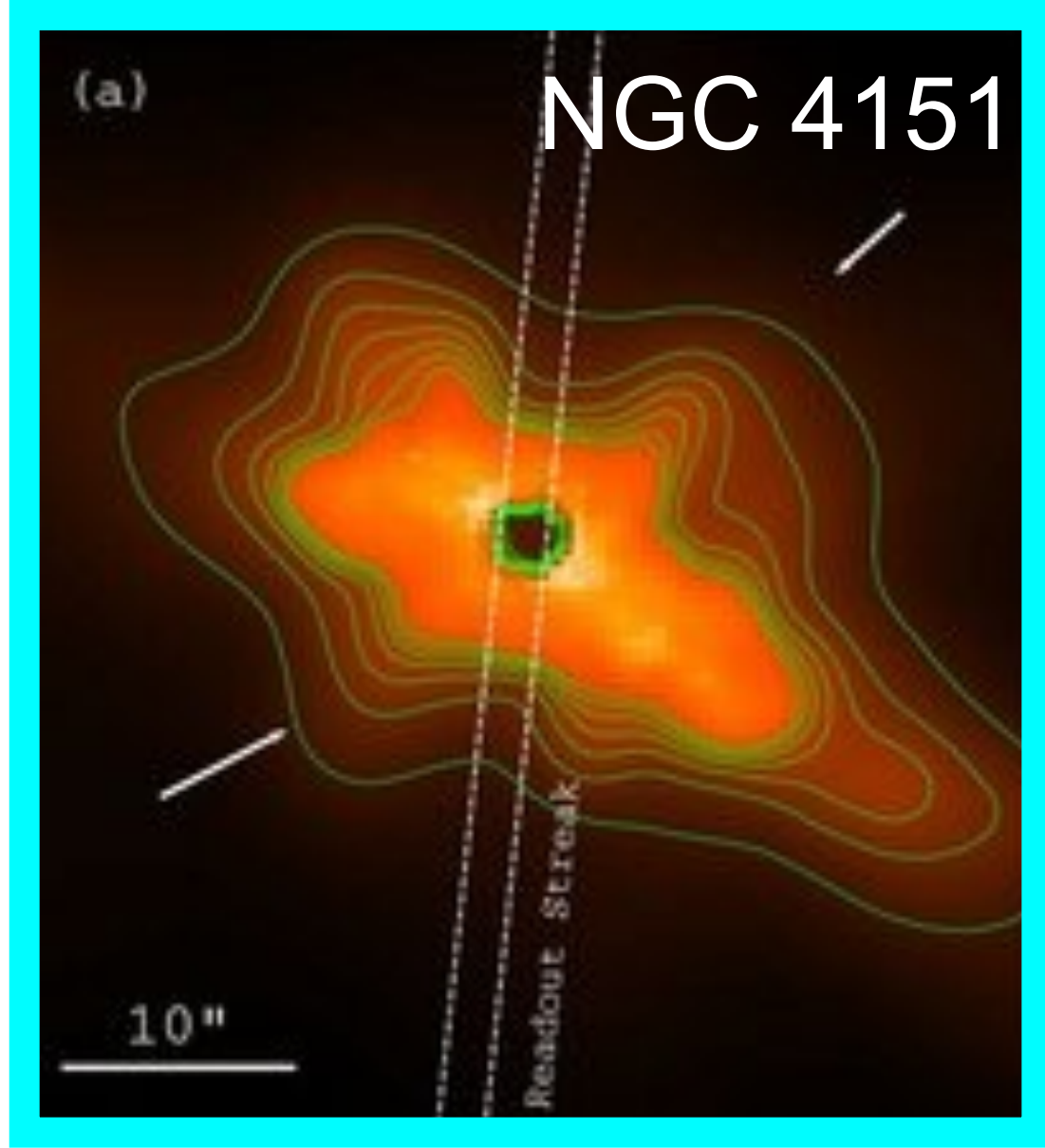
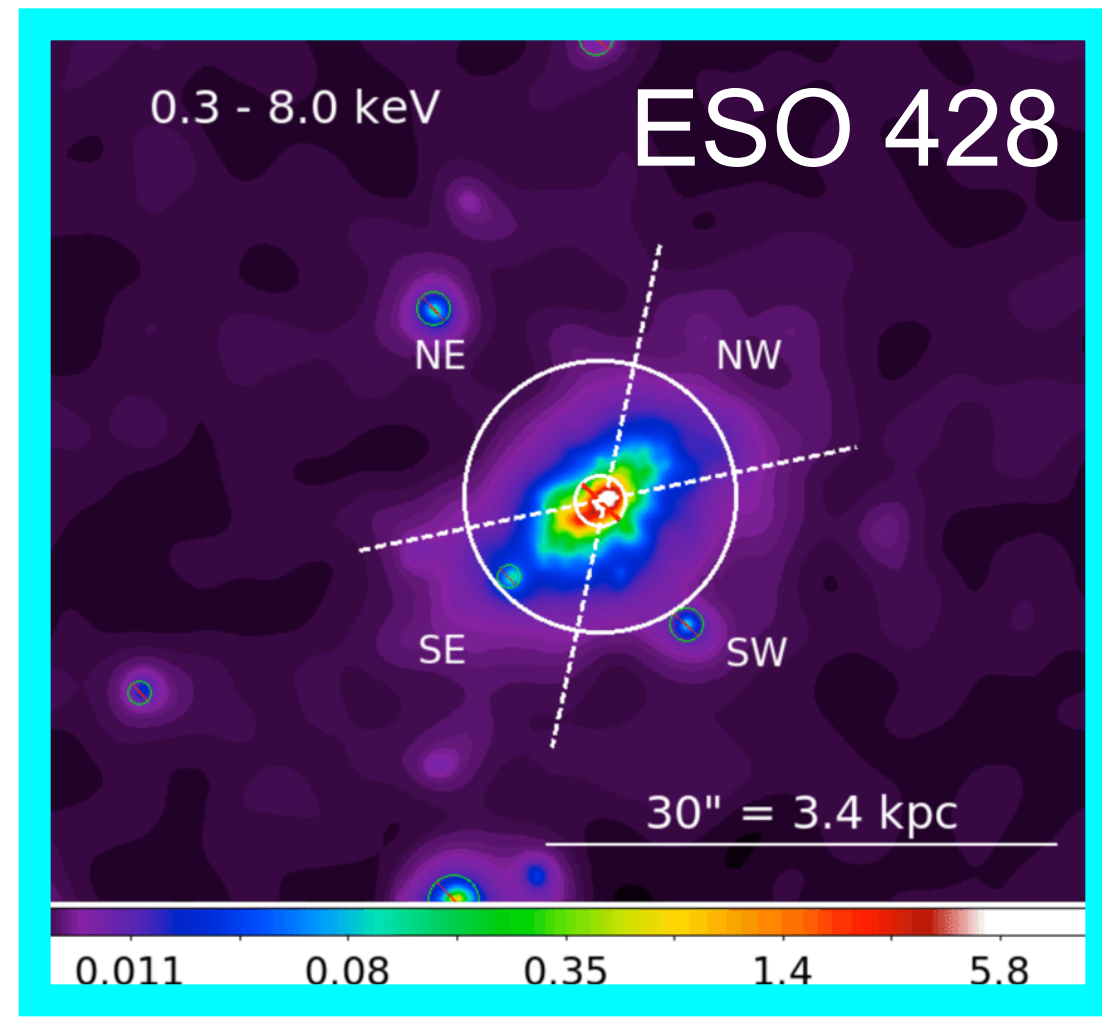


# NGC 7212: Large-scale Extended X-ray Emission



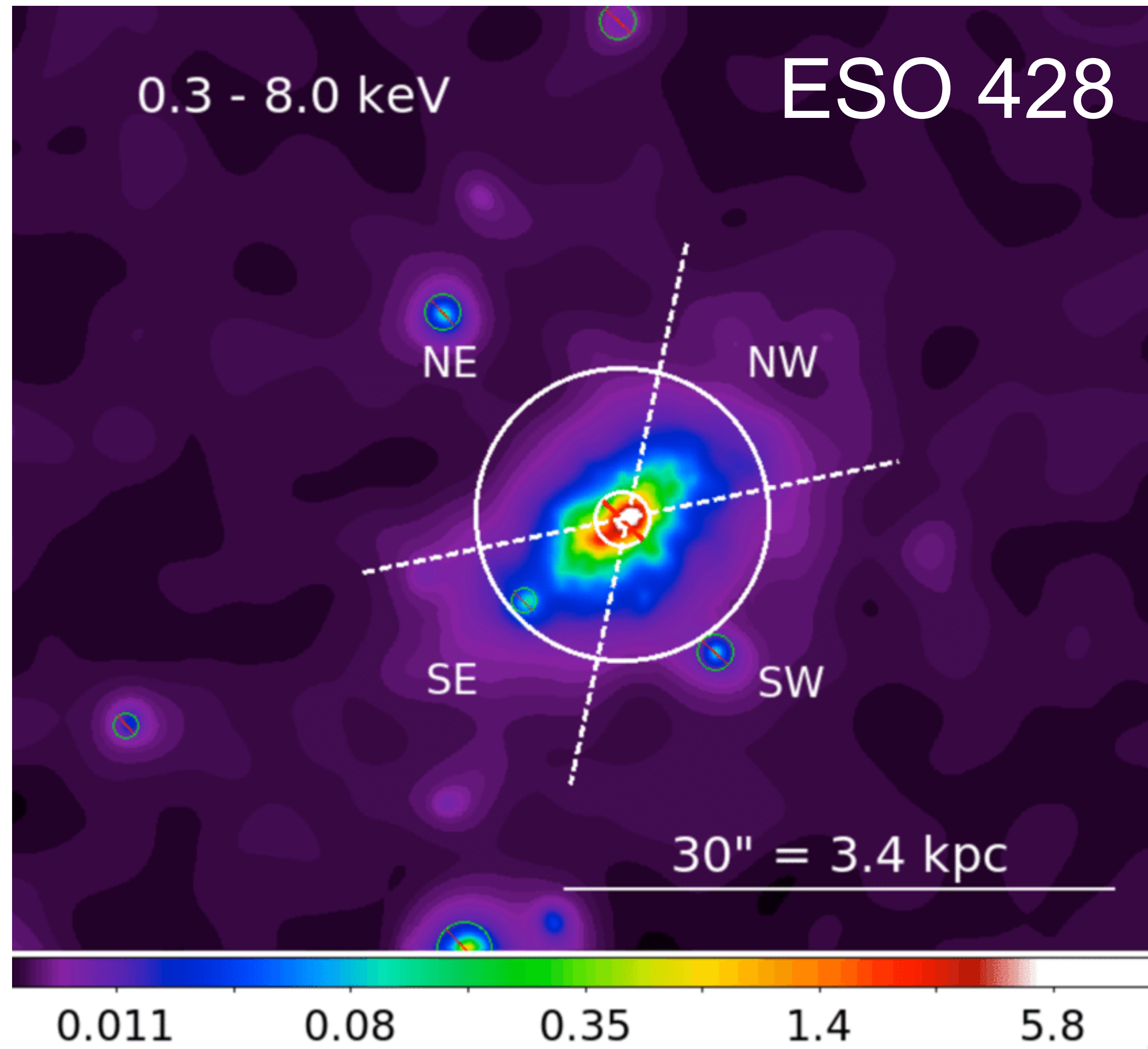
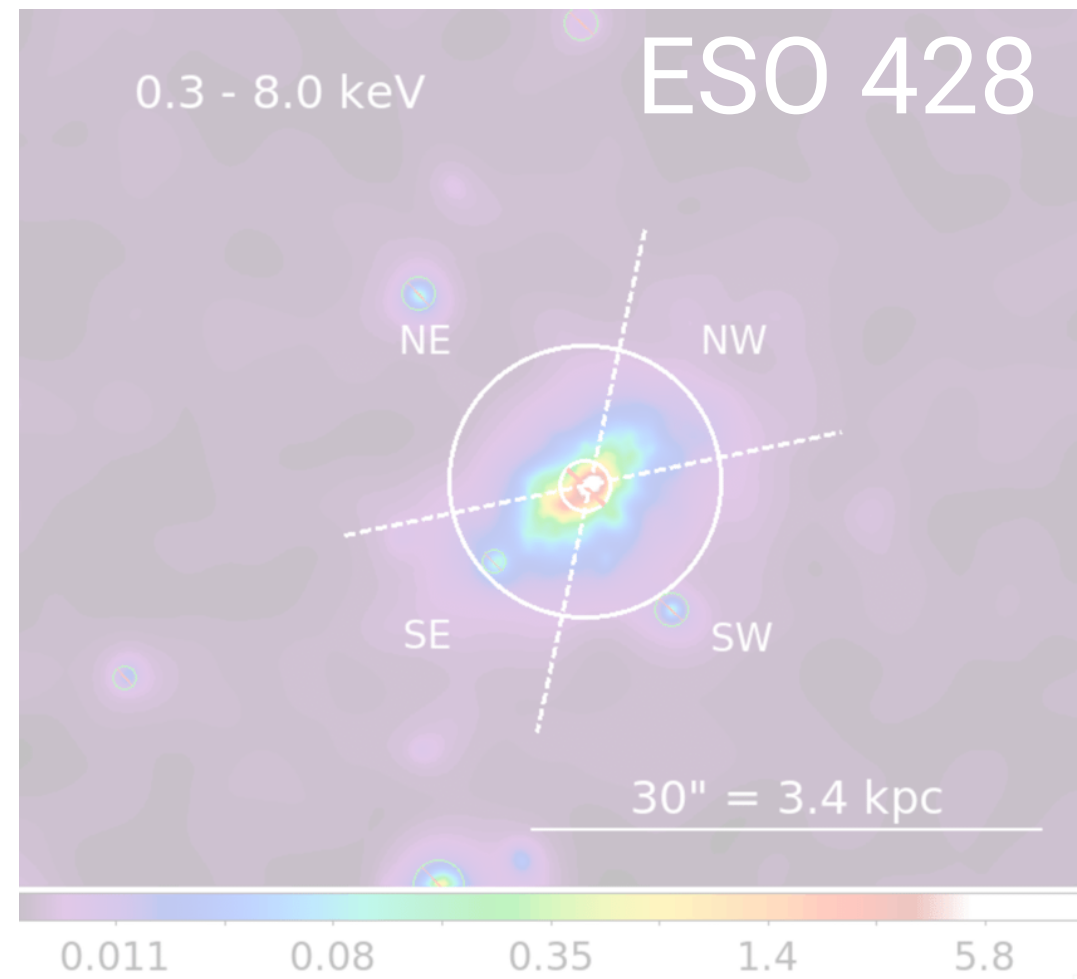
- 1 NGC 7212 & the AGN unified model**  
What does it mean to have Compton thick obscuration AND extended emission?
- 2 Measuring the extended emission**  
Radial profiles outside of the central nucleus  
FWHM as a function of energy
- 3 Spectral Fitting**  
Best fit emission line models  
Best fit photoionization and thermal models

# 1 Extended CTAGN



e.g., Wang+ 2011, Paggi+ 2012, Bauer+ 2015, Annuar+ 2017, Gómez-Guijarro+ 2017, Fabbiano+ 2017, Fabbiano+ 2018a, Fabbiano+ 2018b, Fabbiano 2019

# 1 Extended *CTAGN*



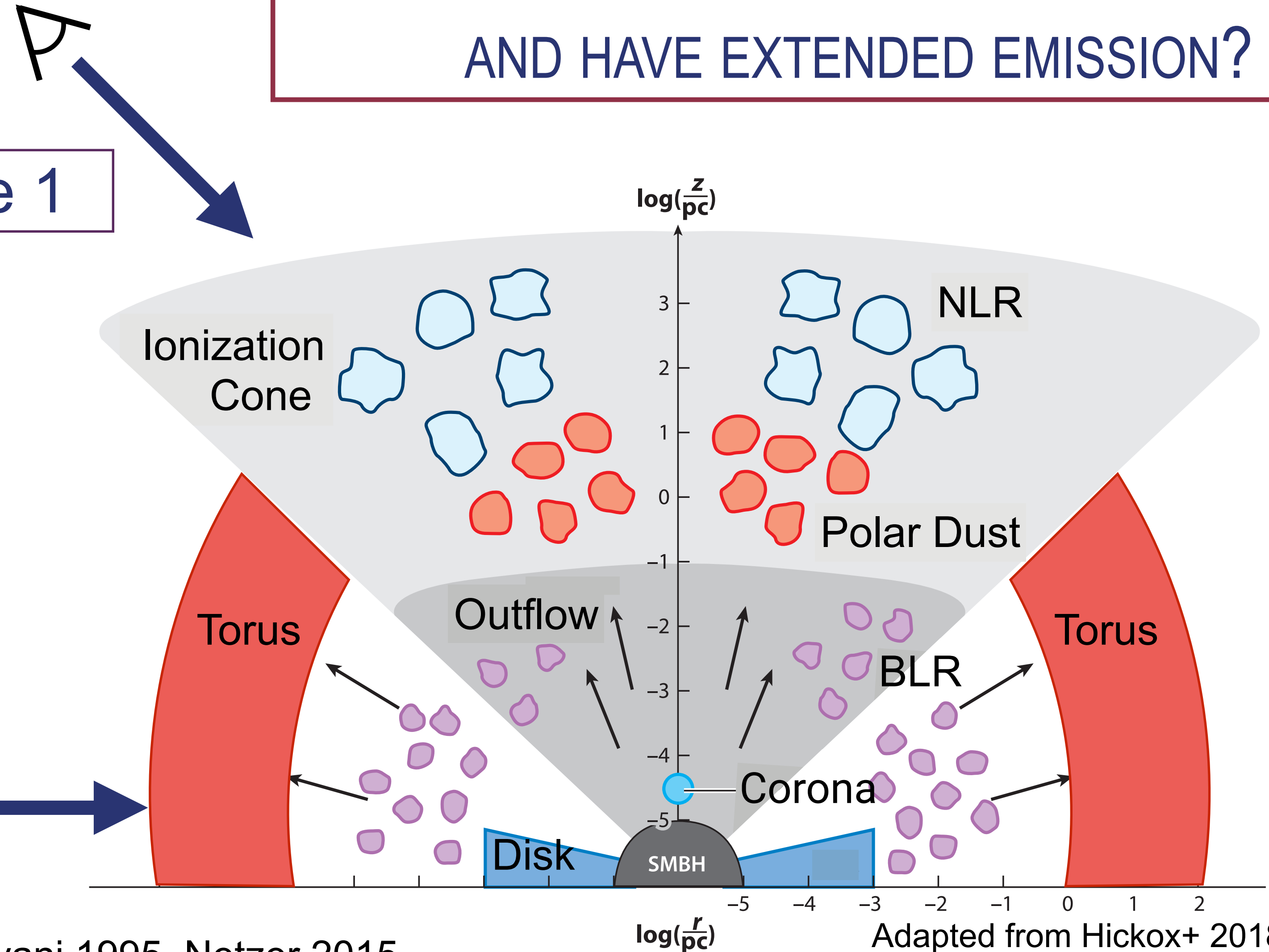
Fabbiano+ 2017, Fabbiano+ 2018a, Fabbiano+ 2018b, Fabbiano 2019

# 1 The AGN UNIFIED MODEL

HOW CAN AN AGN BE BOTH COMPTON THICK AND HAVE EXTENDED EMISSION?

Type 1

Type 2

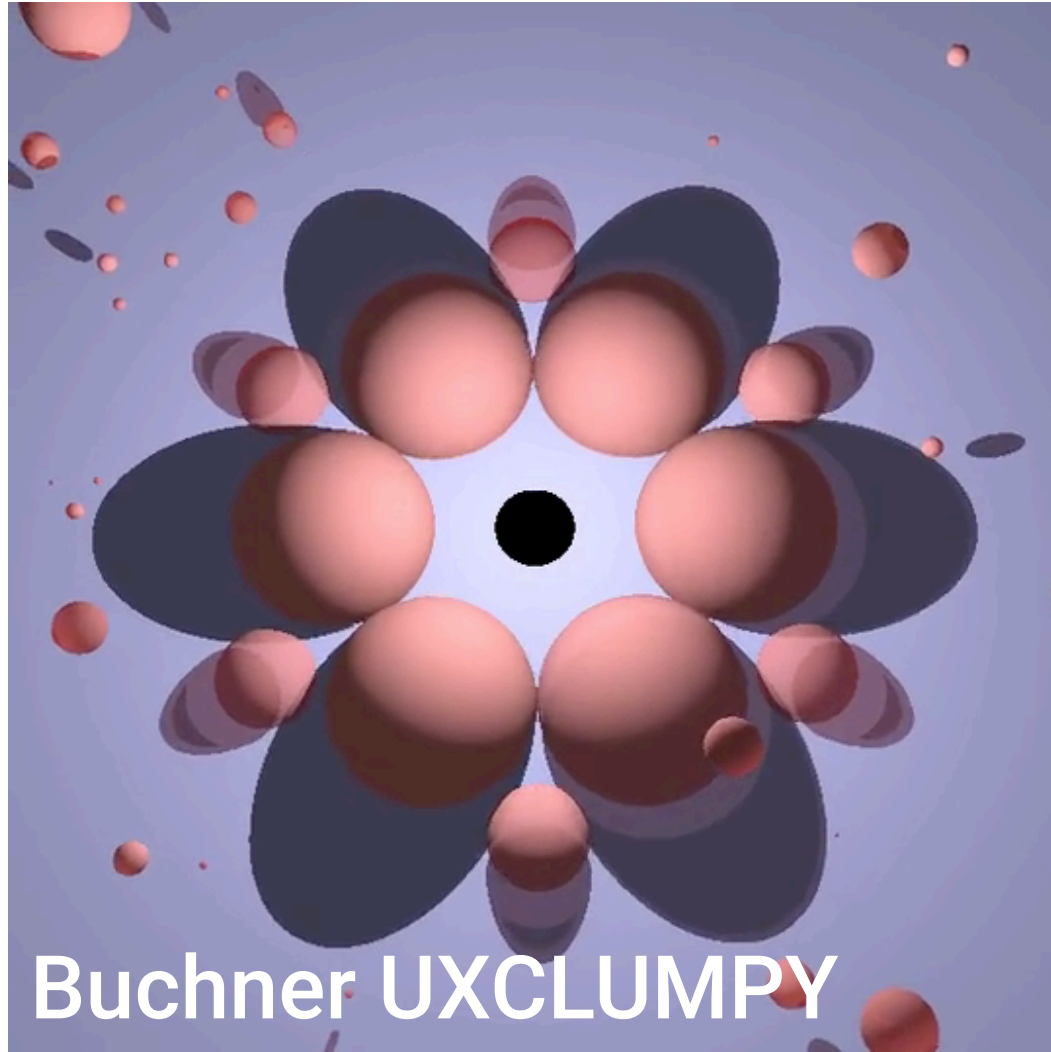


e.g., Antonucci 1993, Urry & Padovani 1995, Netzer 2015

Adapted from Hickox+ 2018

# 1 The AGN UNIFIED MODEL

HOW CAN AN AGN BE BOTH COMPTON THICK AND HAVE EXTENDED EMISSION?



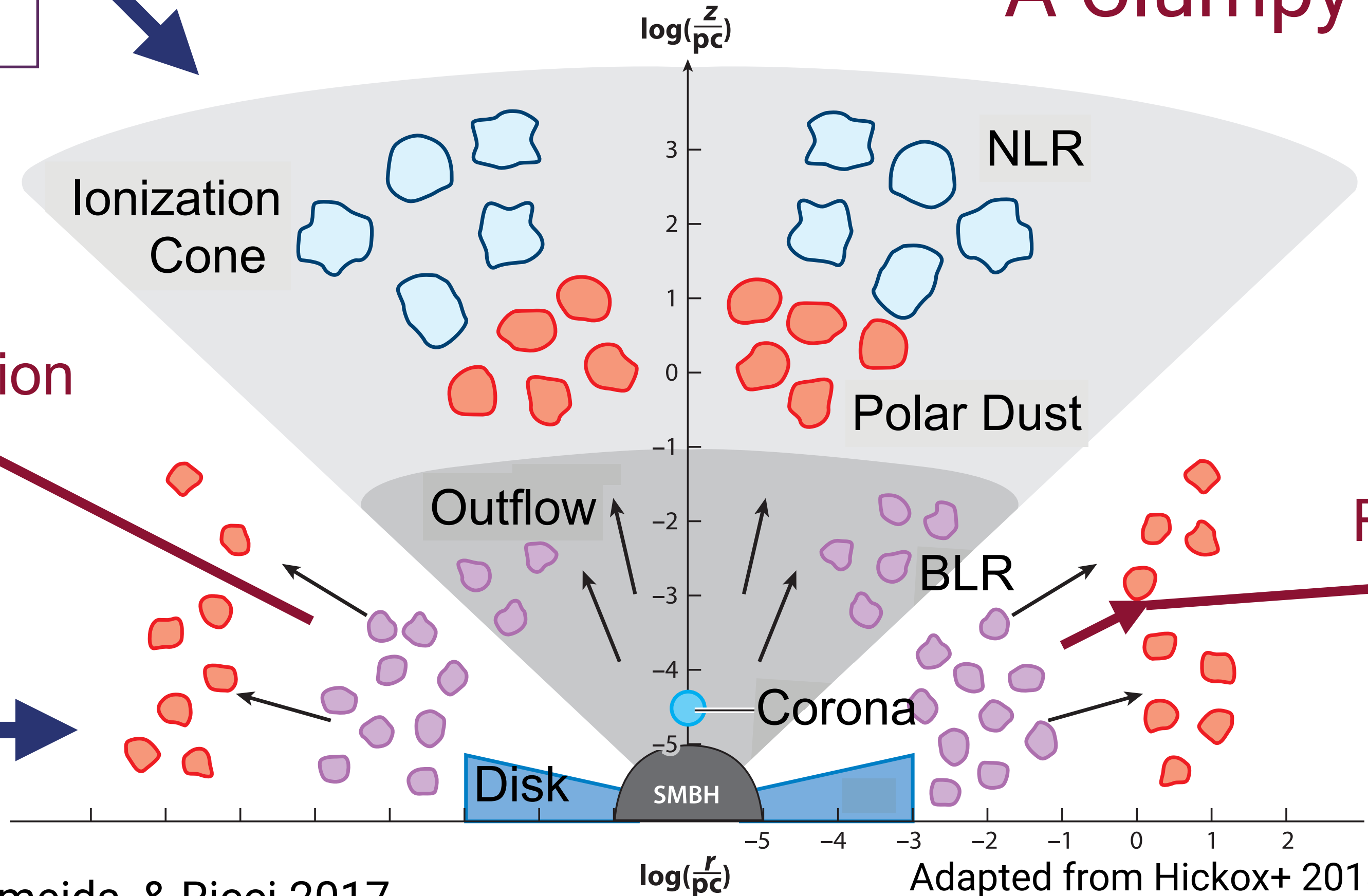
Type 1

A Clumpy Torus?

Transmission

Type 2

Reflection



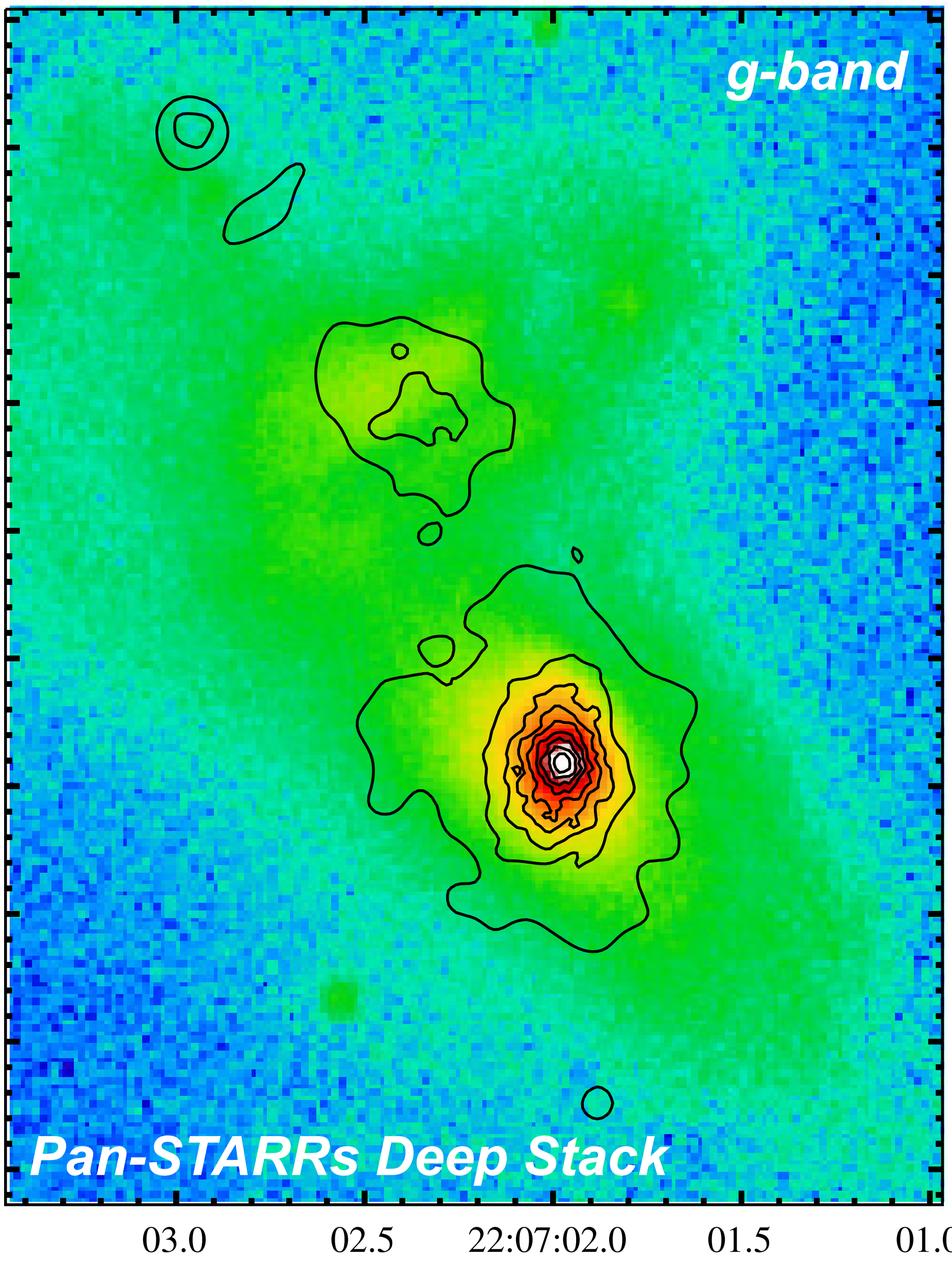
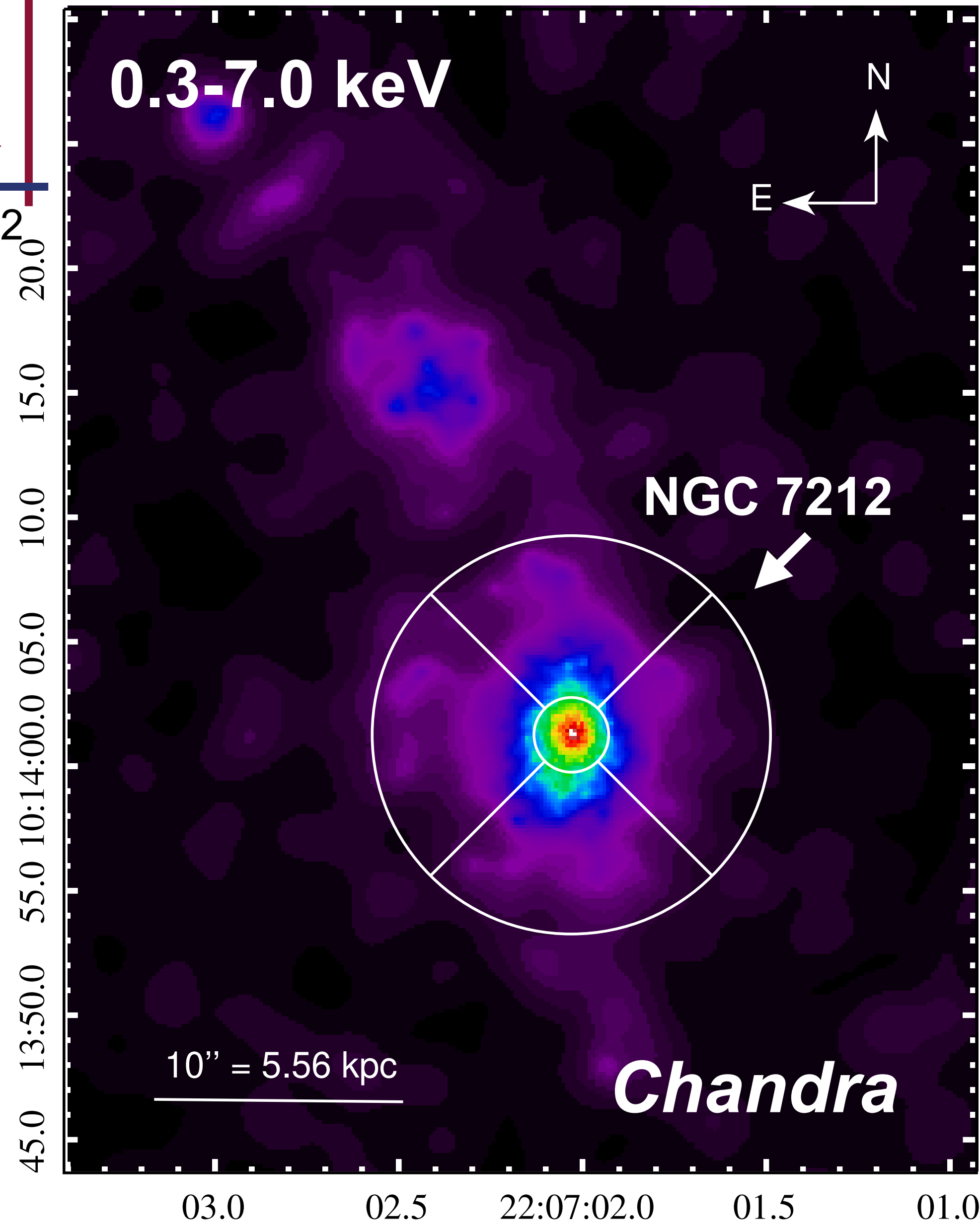
e.g., Hickox+ 2018, See also Ramos, Almeida, & Ricci 2017

Adapted from Hickox+ 2018

2

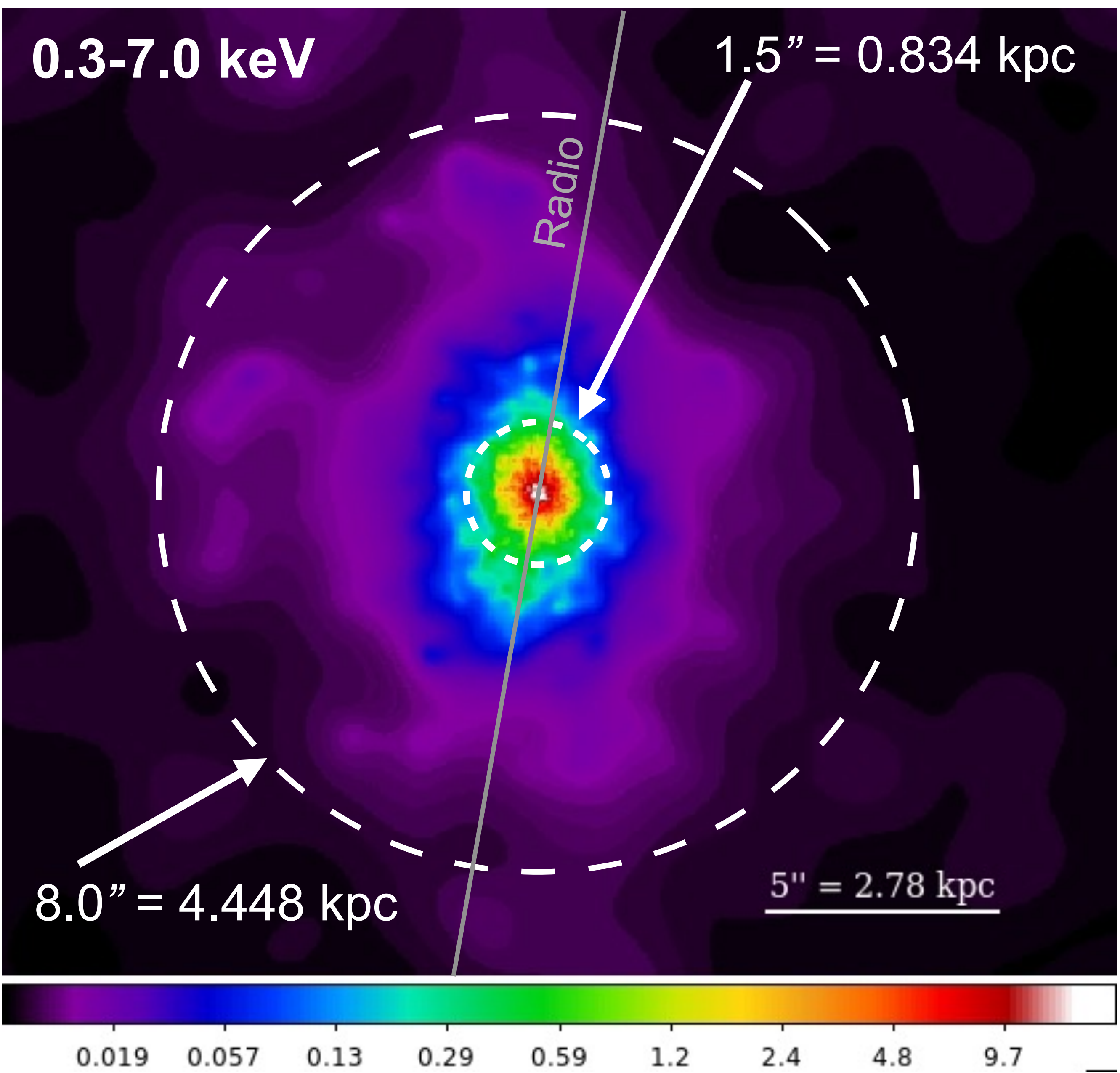
# NGC 7212 WITH CHANDRA

Extended Emission in NGC 7212  
Submitted



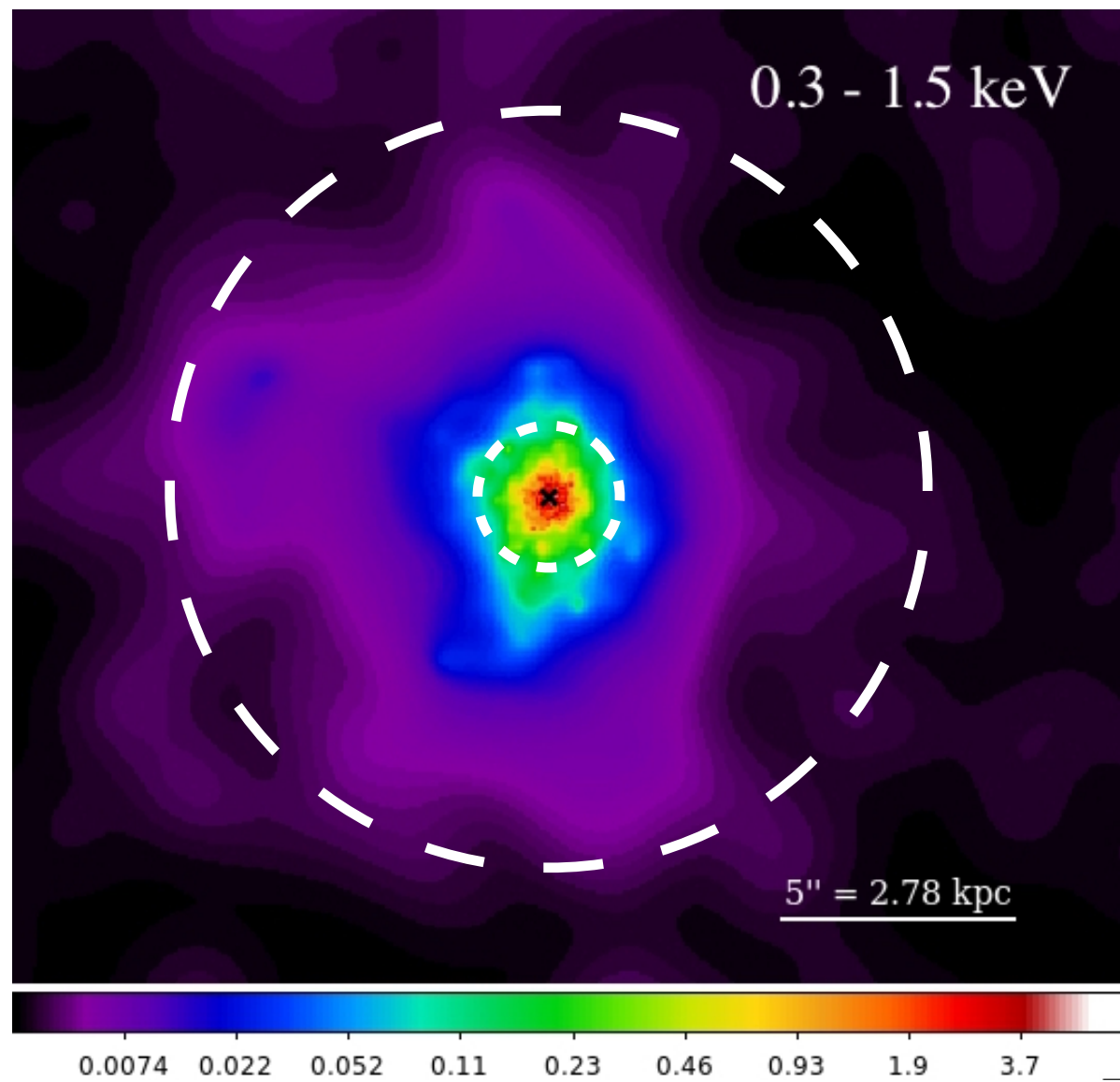
# 2 NGC 7212 WITH CHANDRA

Extended Emission in NGC 7212  
Submitted

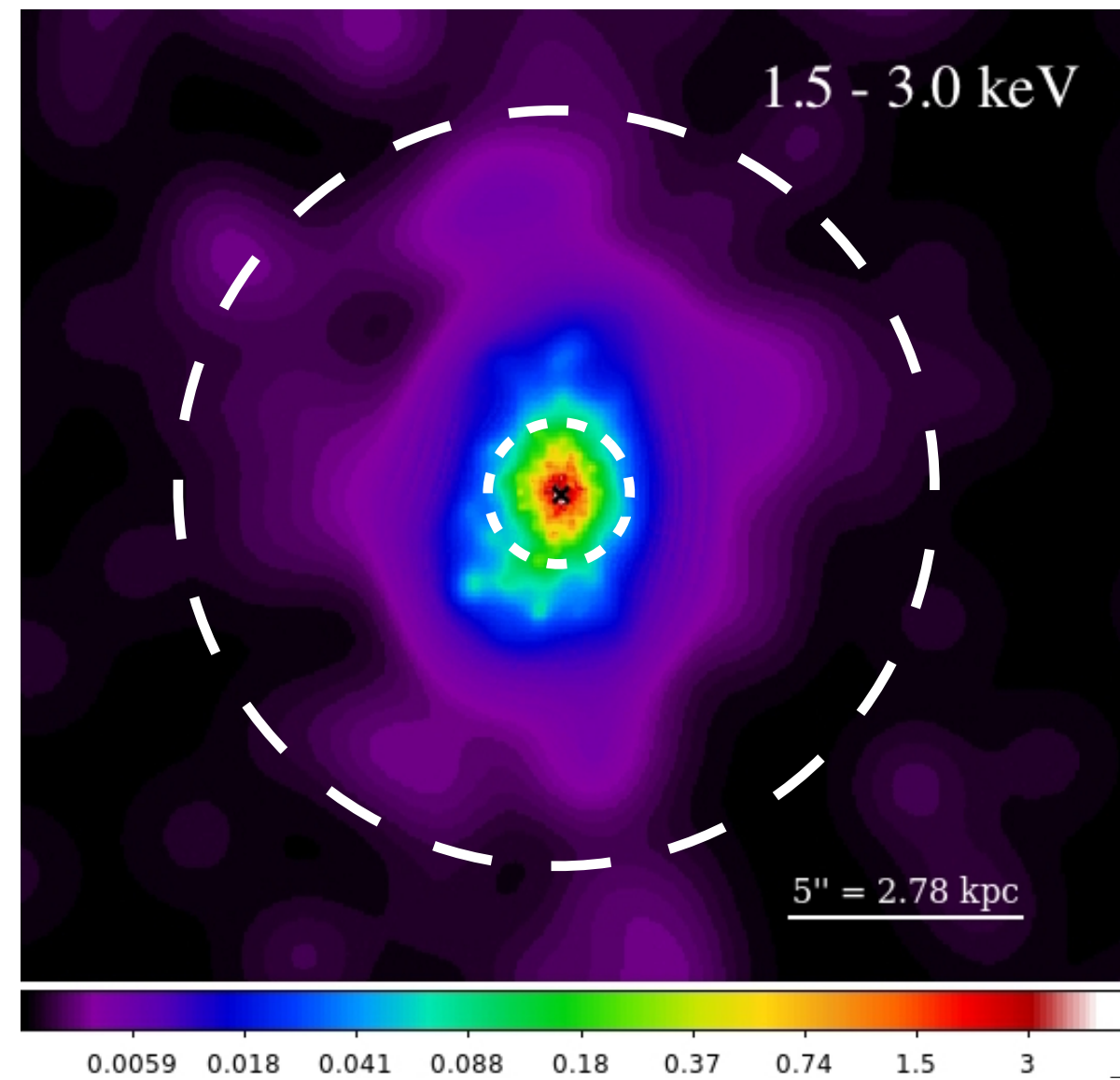




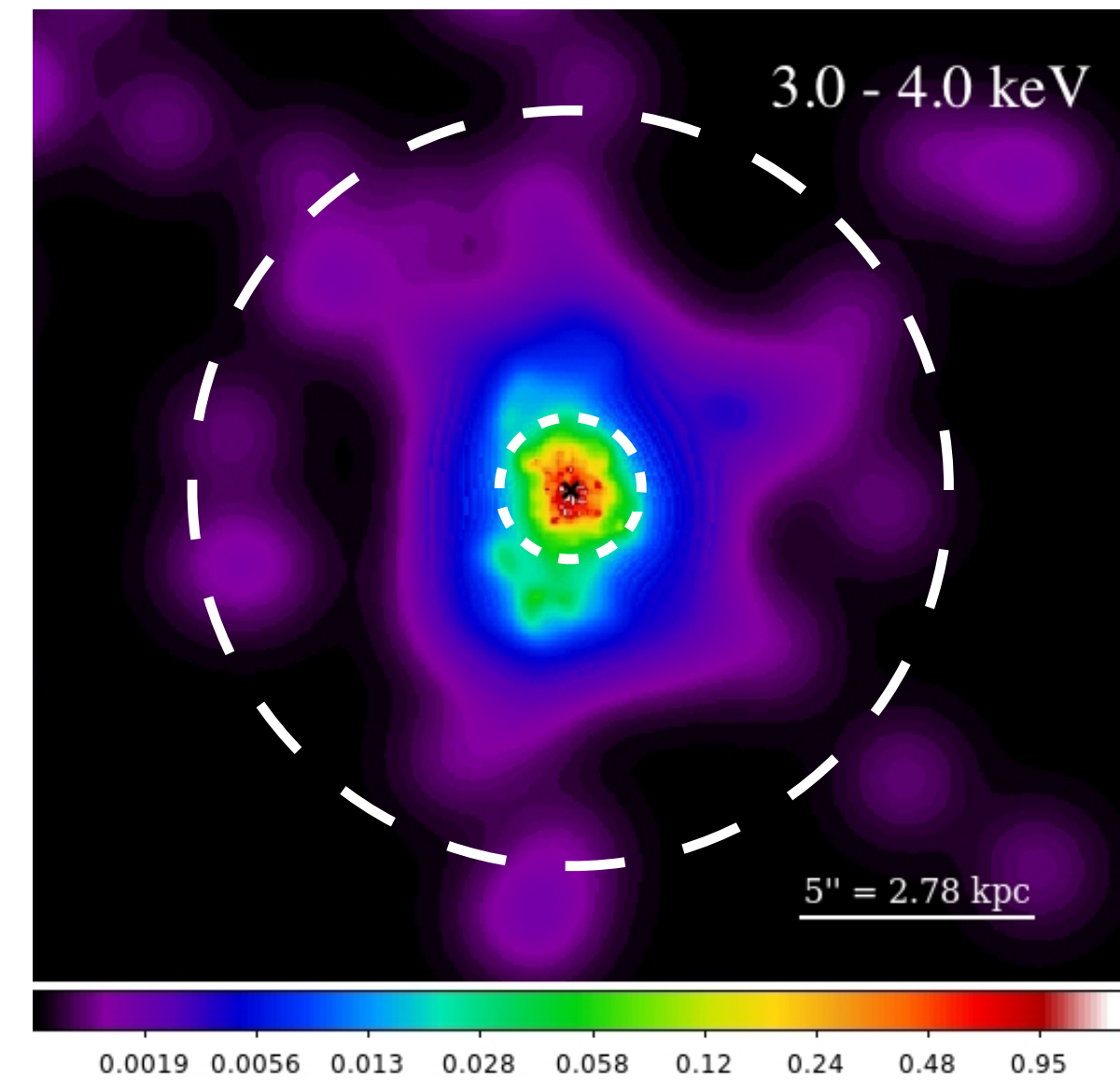
**0.3 - 1.5 keV**



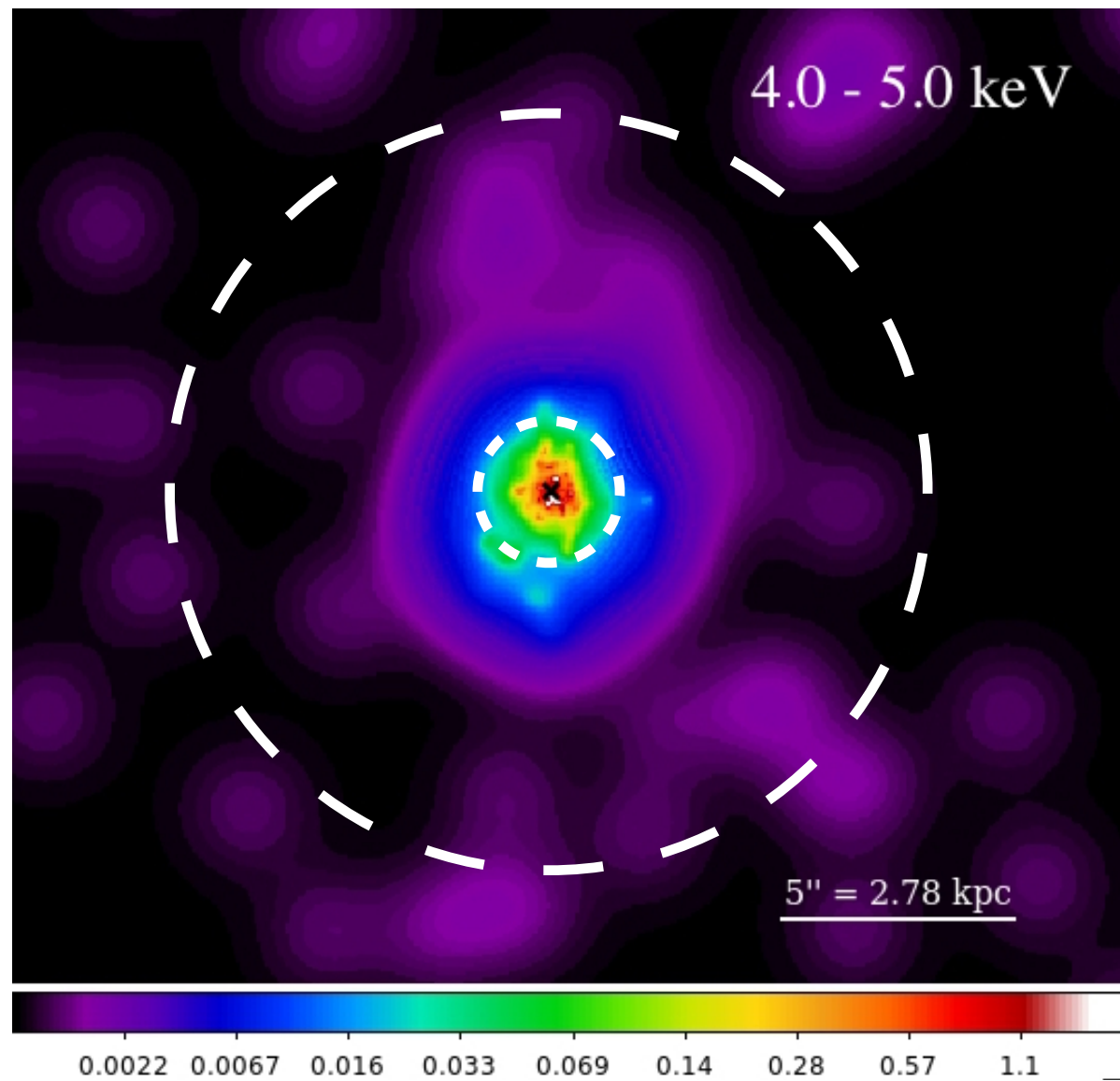
**1.5 - 3.0 keV**



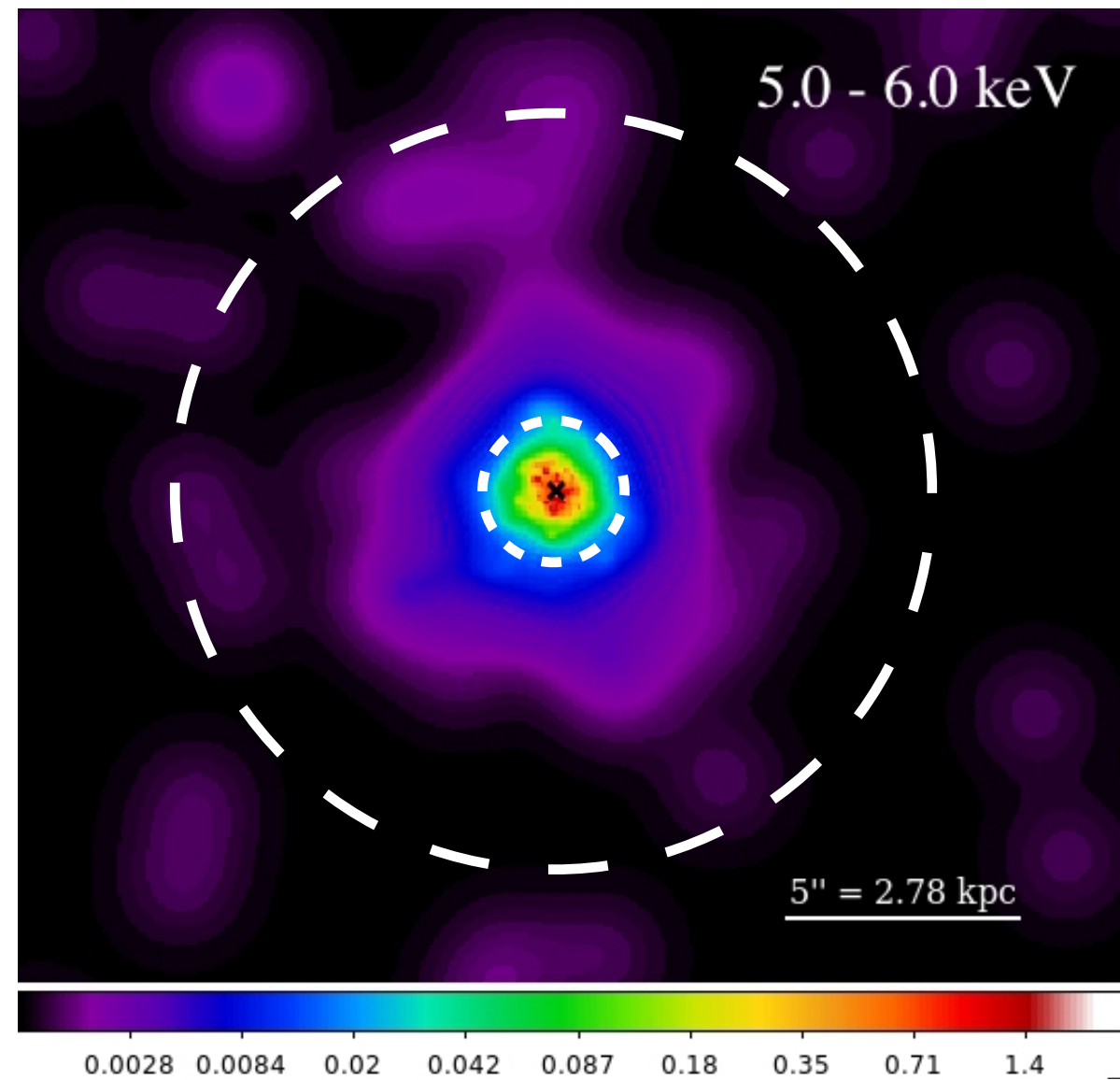
**3.0 - 4.0 keV**



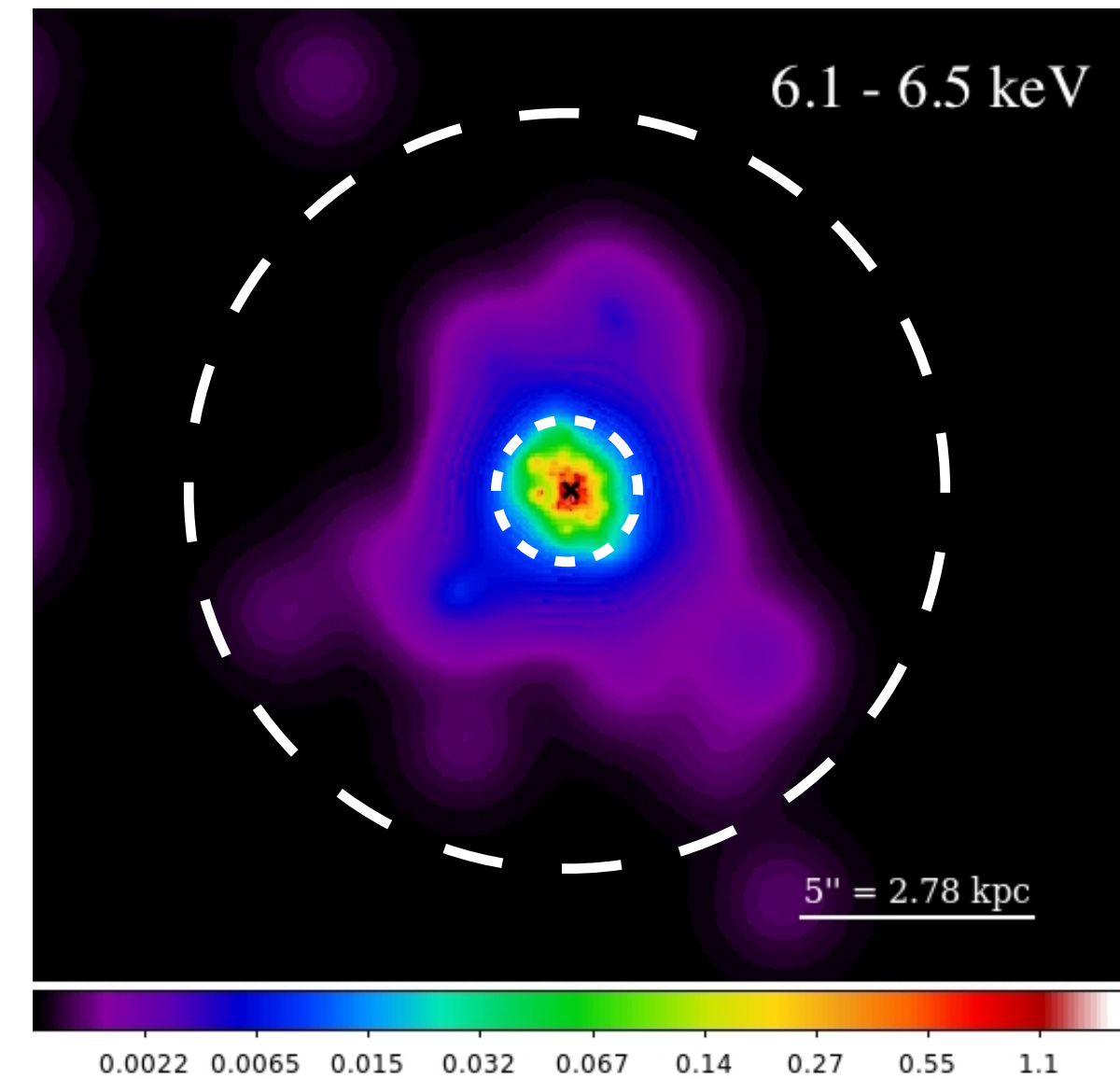
**4.0 - 5.0 keV**

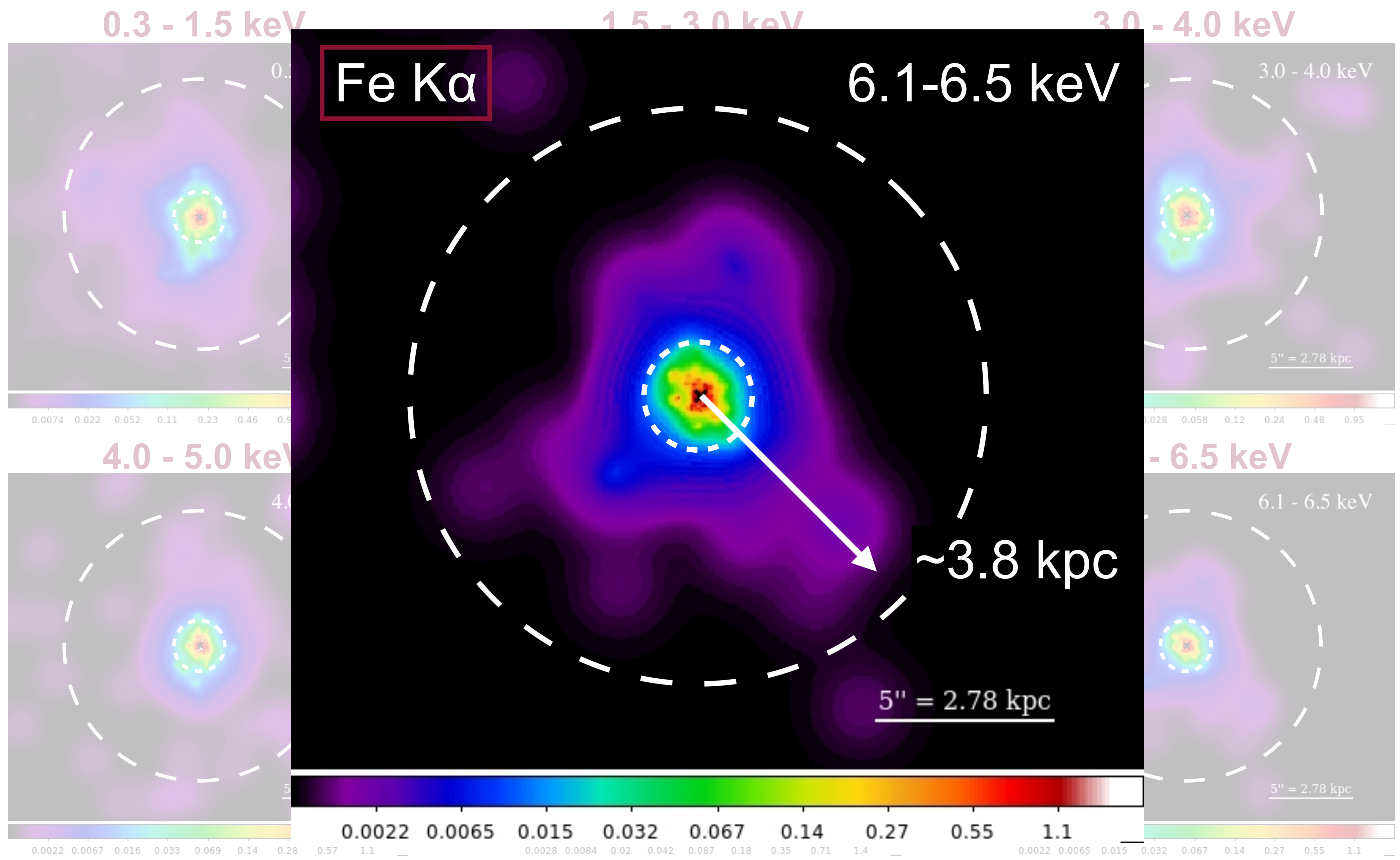


**5.0 - 6.0 keV**



**6.1 - 6.5 keV**

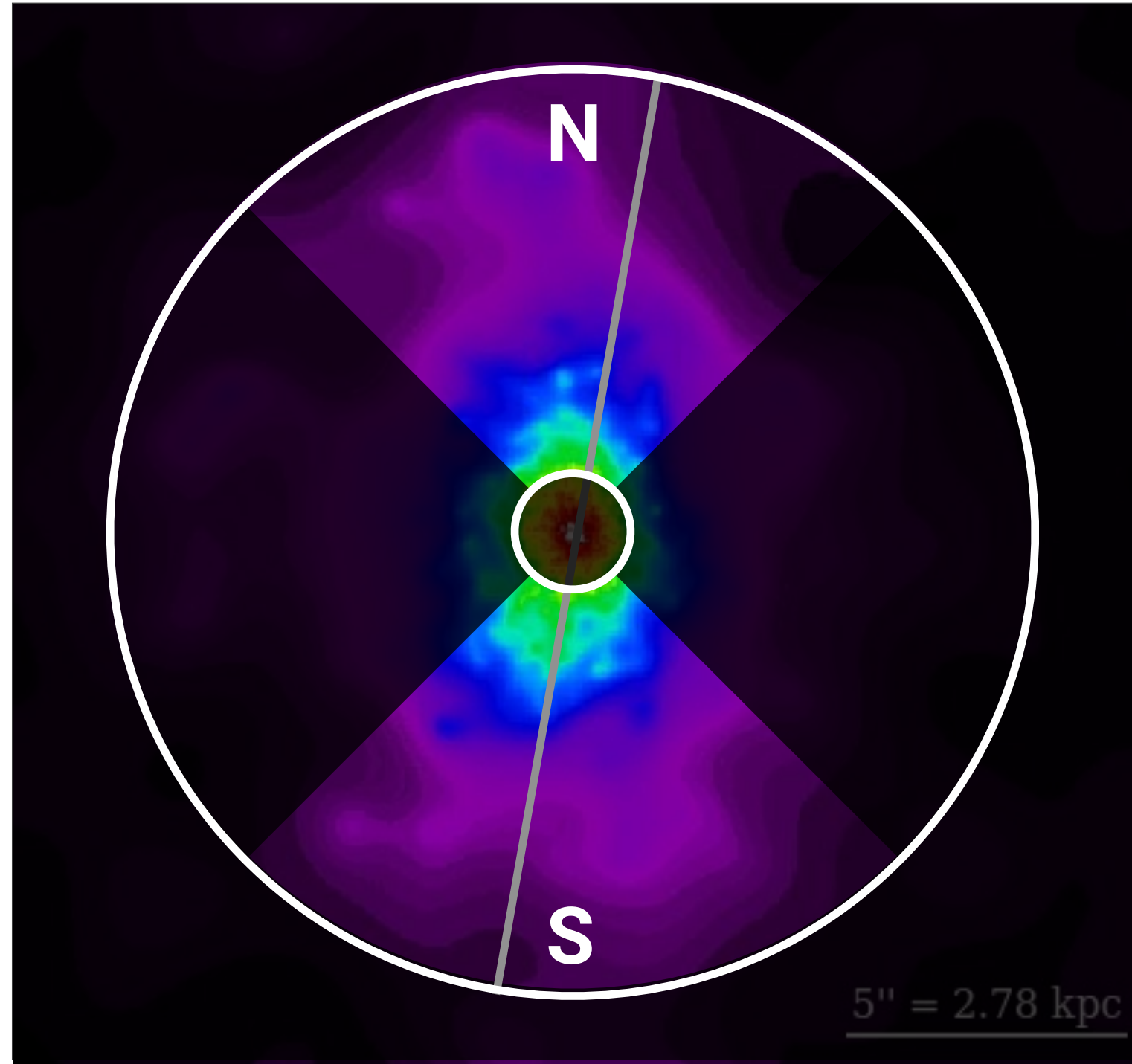




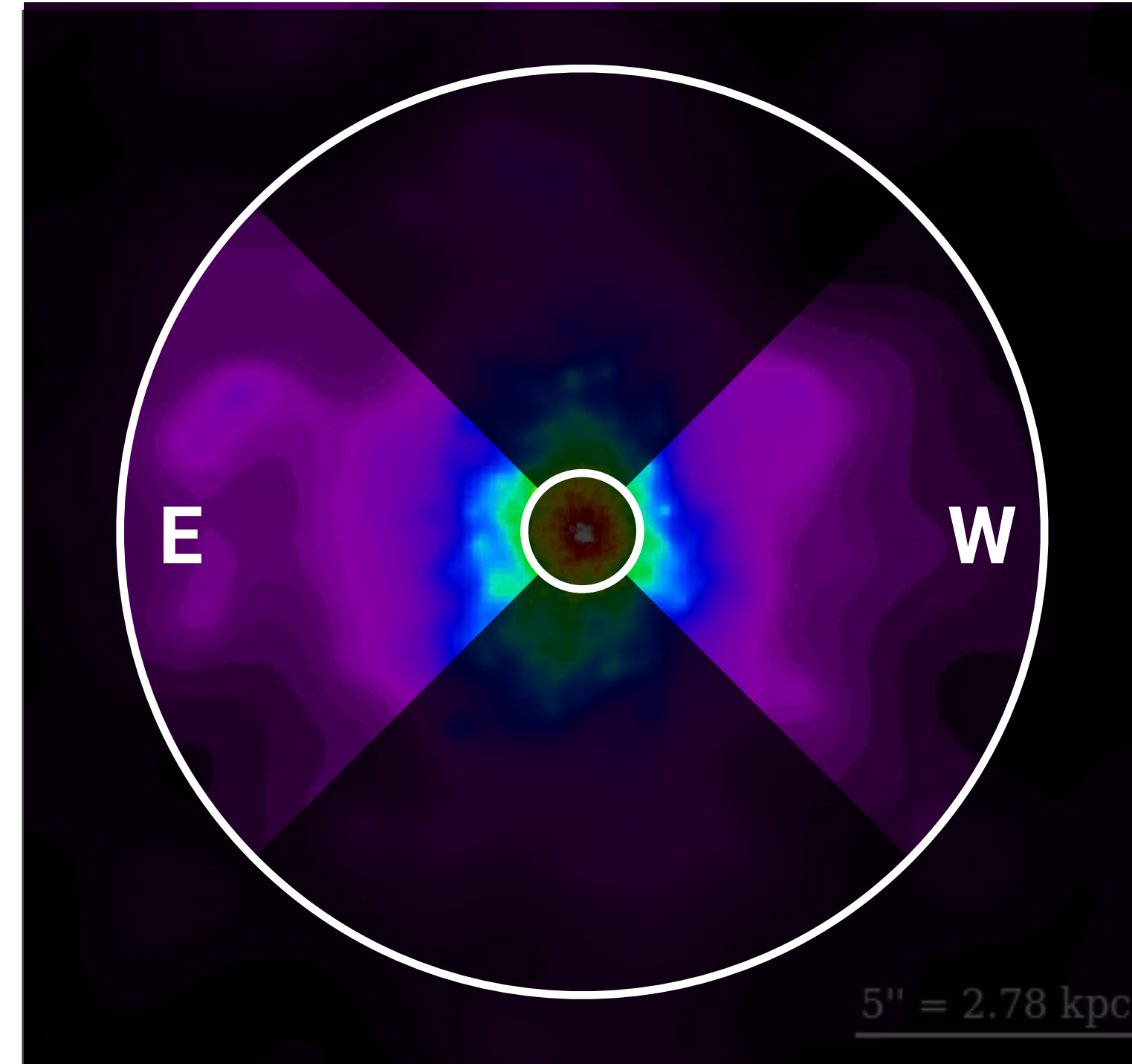
# 2 NGC 7212 *RADIAL PROFILES*

## Two Extraction Regions

Extended Emission in NGC 7212  
Submitted



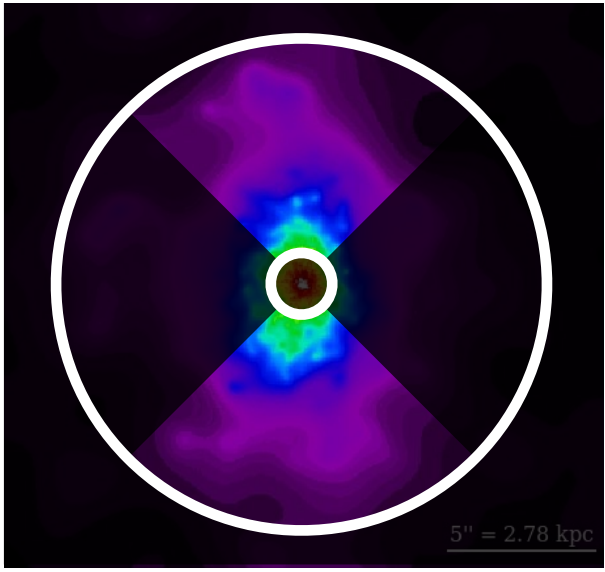
➤ | **S-N Cone Region**



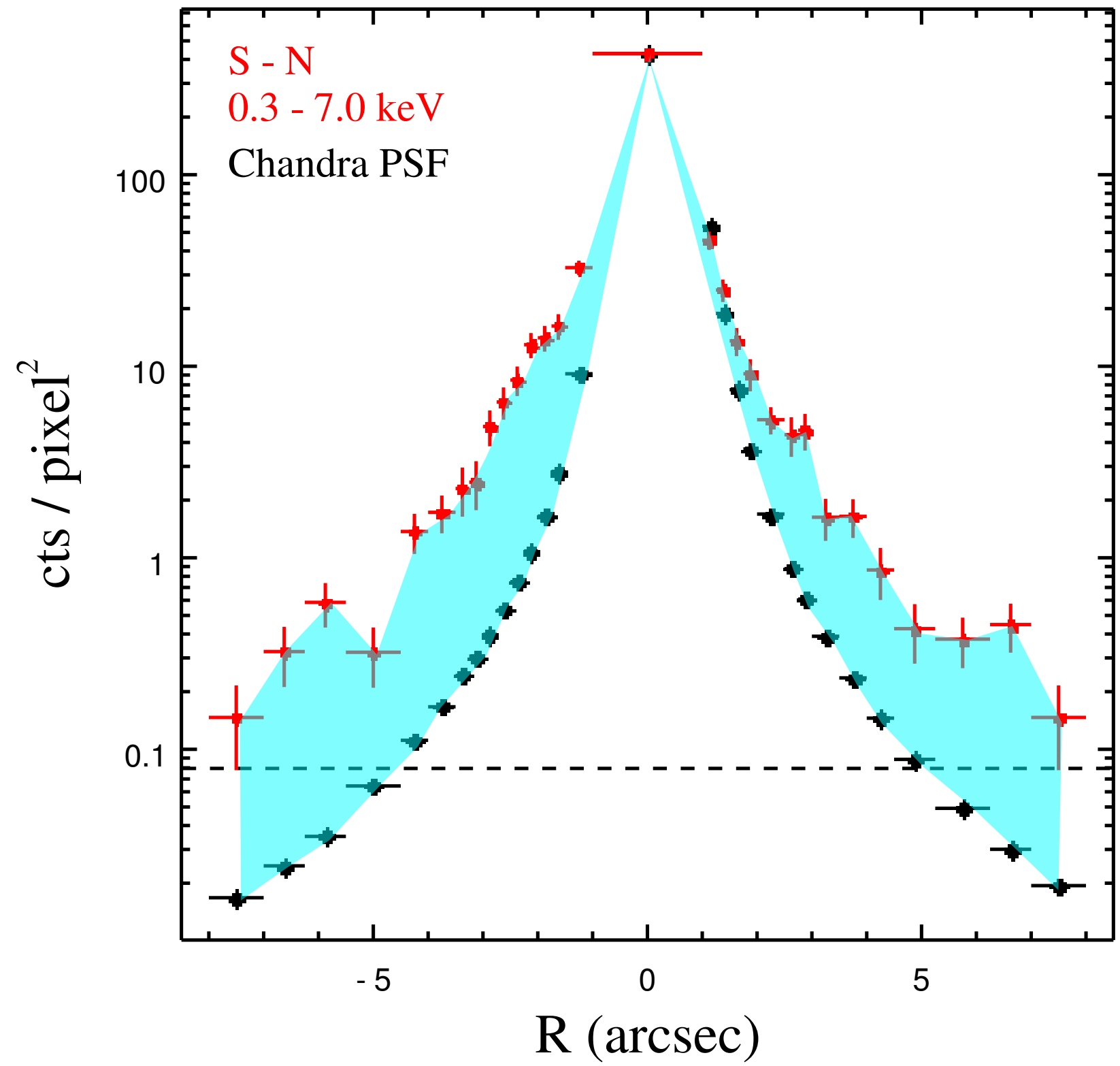
➤ | **W-E Cross-Cone Region**

# 2 NGC 7212 RADIAL PROFILES

## S-N Cone Region

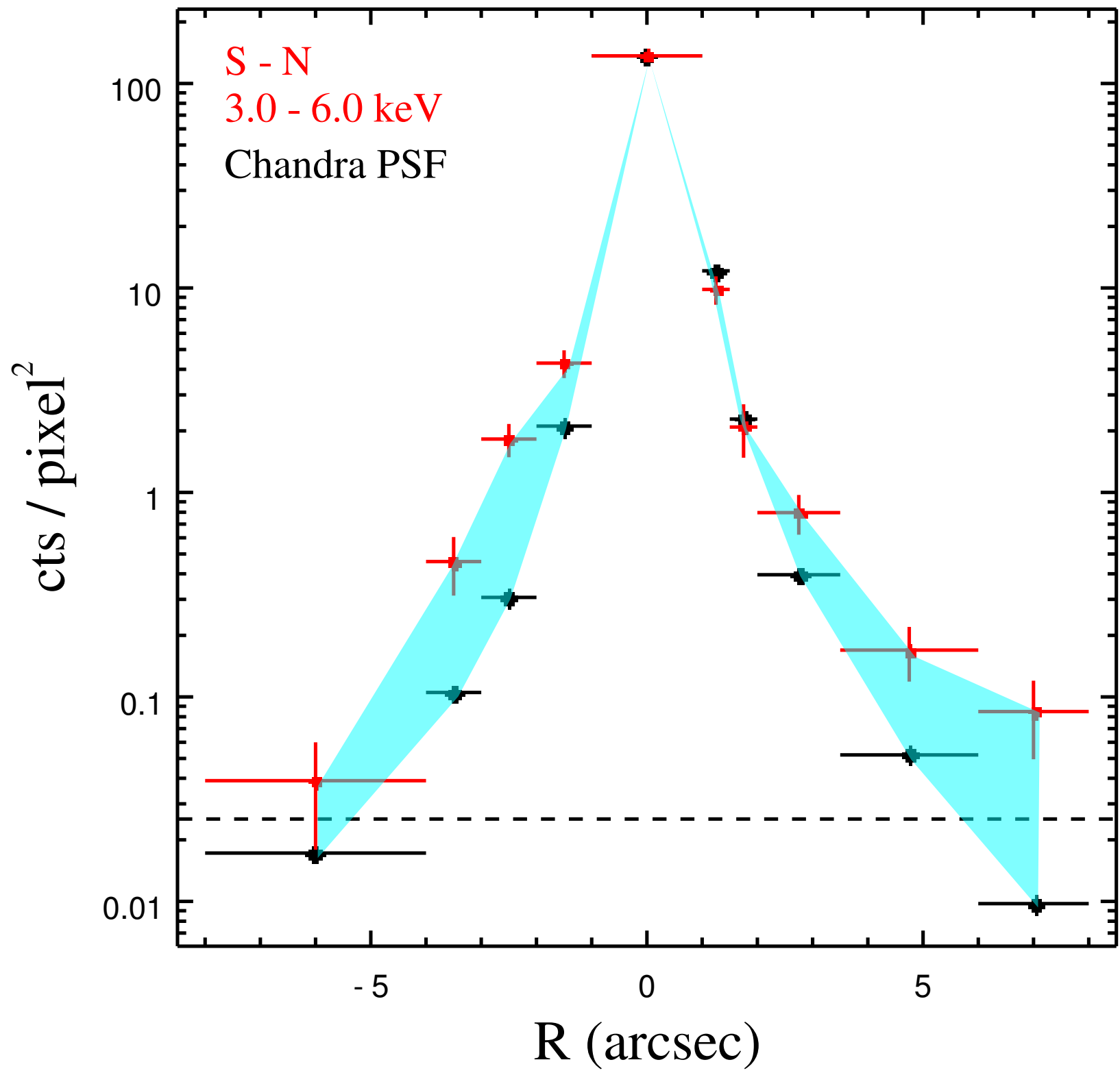


0.3 - 7.0 keV



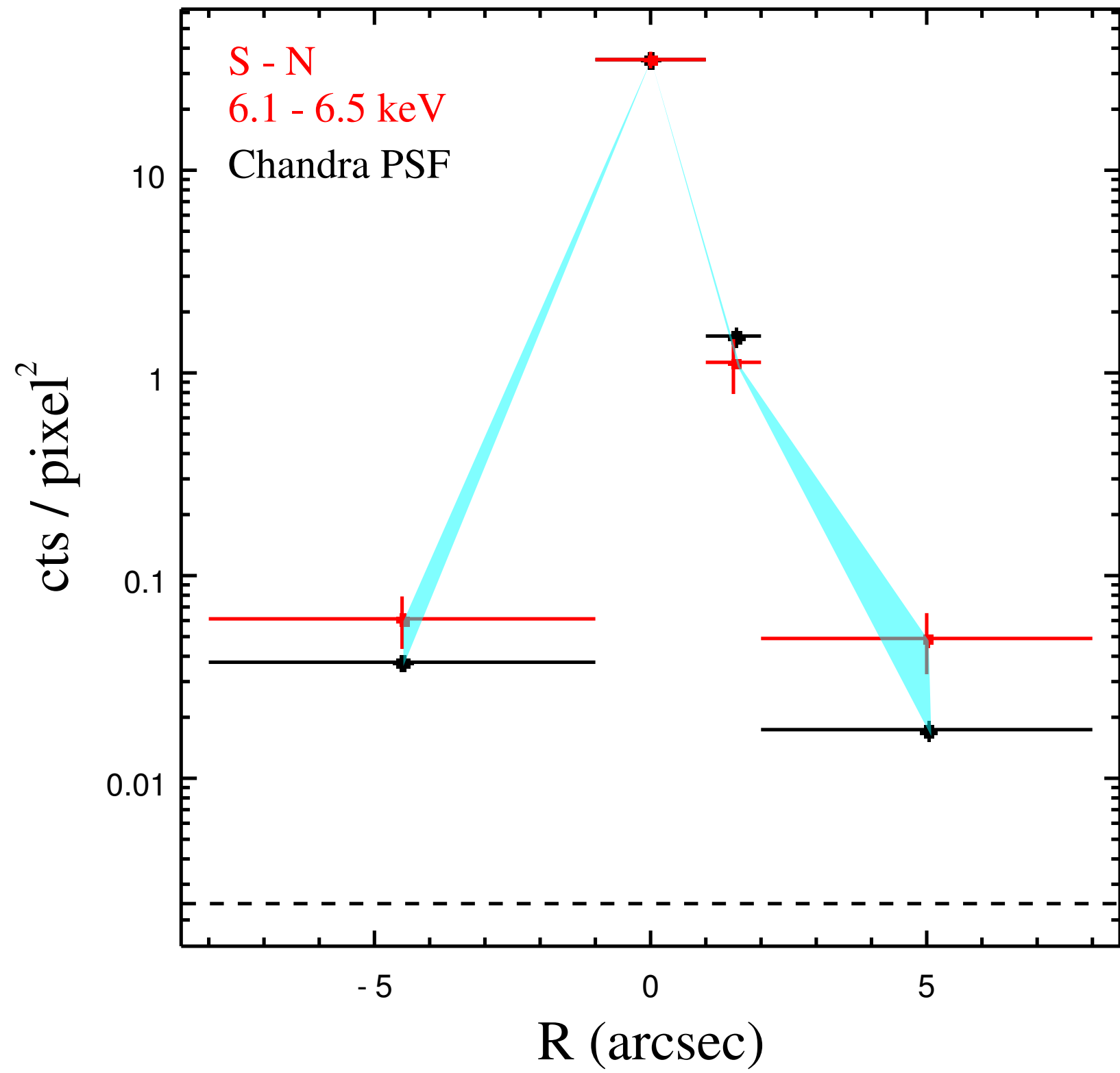
**570 ± 24 counts over Chandra PSF**

3.0 - 6.0 keV



**83 ± 9 counts**

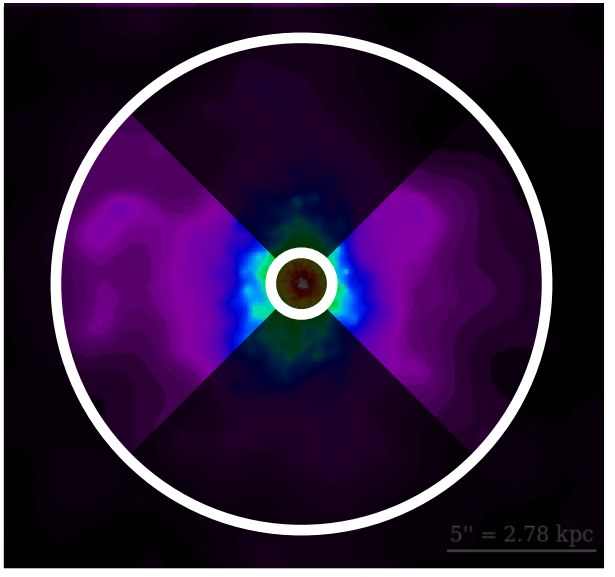
(Fe K $\alpha$ ) 6.1 - 6.5 keV



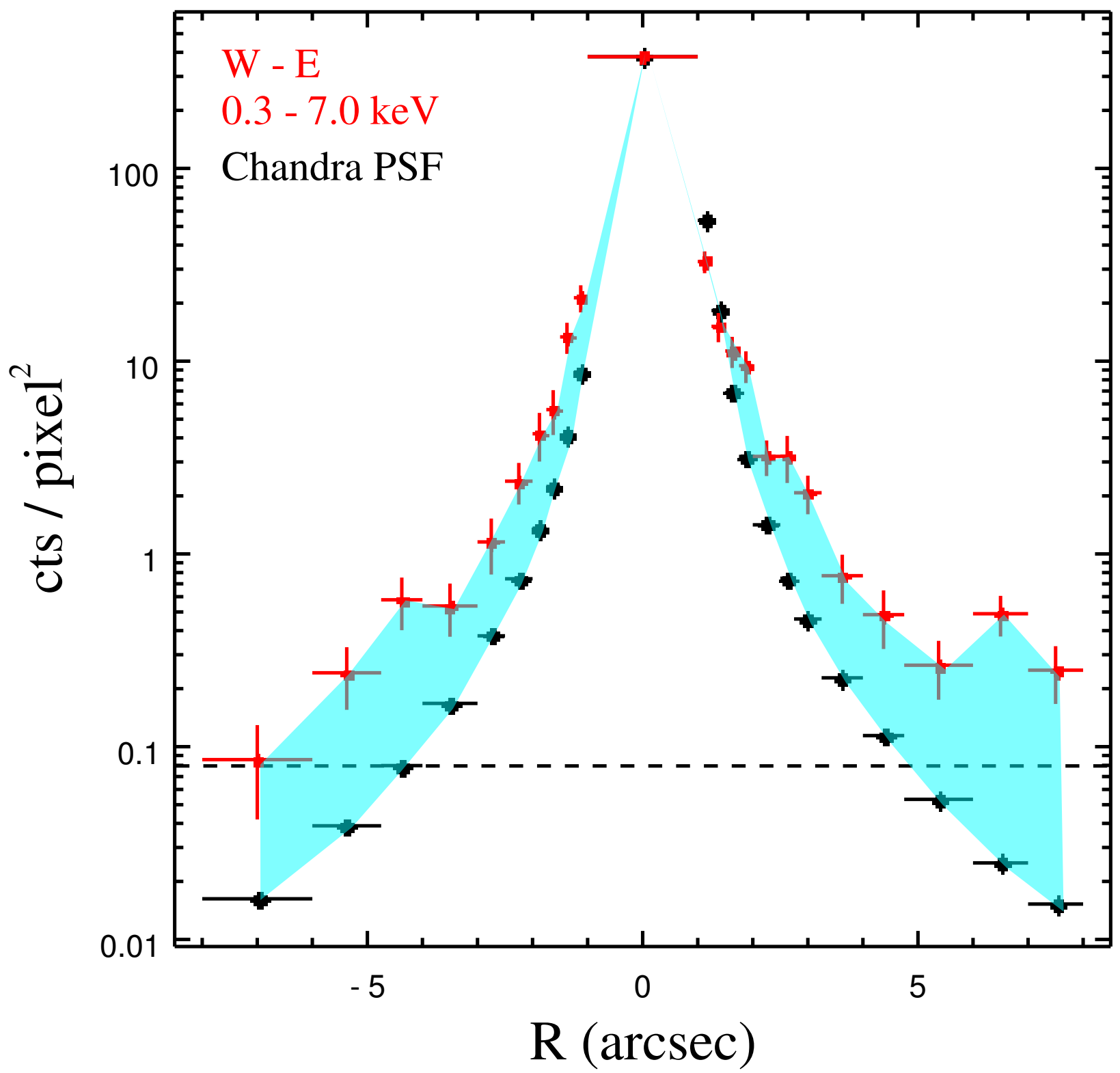
**11 ± 3 counts**

# 2 NGC 7212 RADIAL PROFILES

## W-E Cross-Cone Region

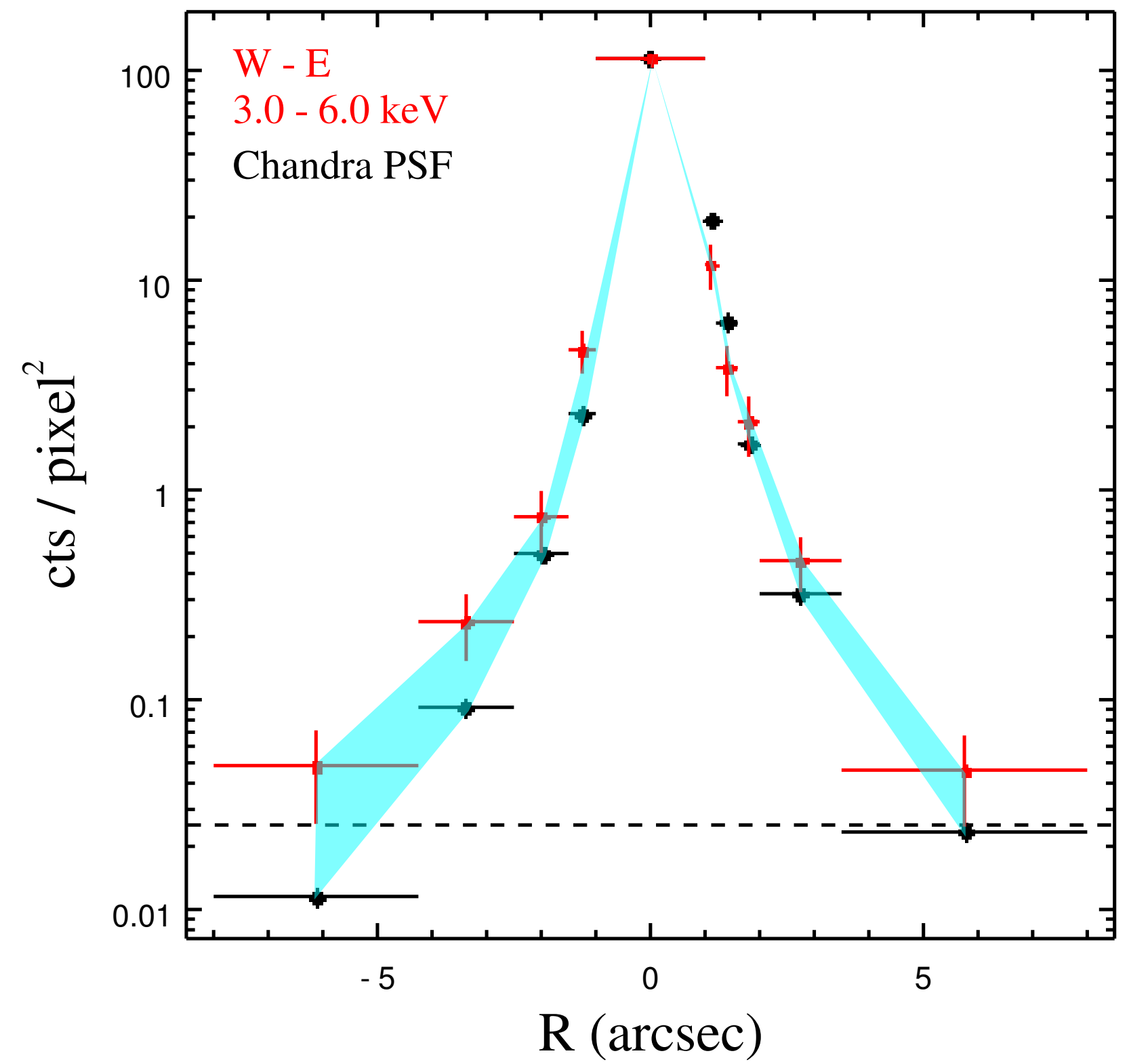


**0.3 - 7.0 keV**



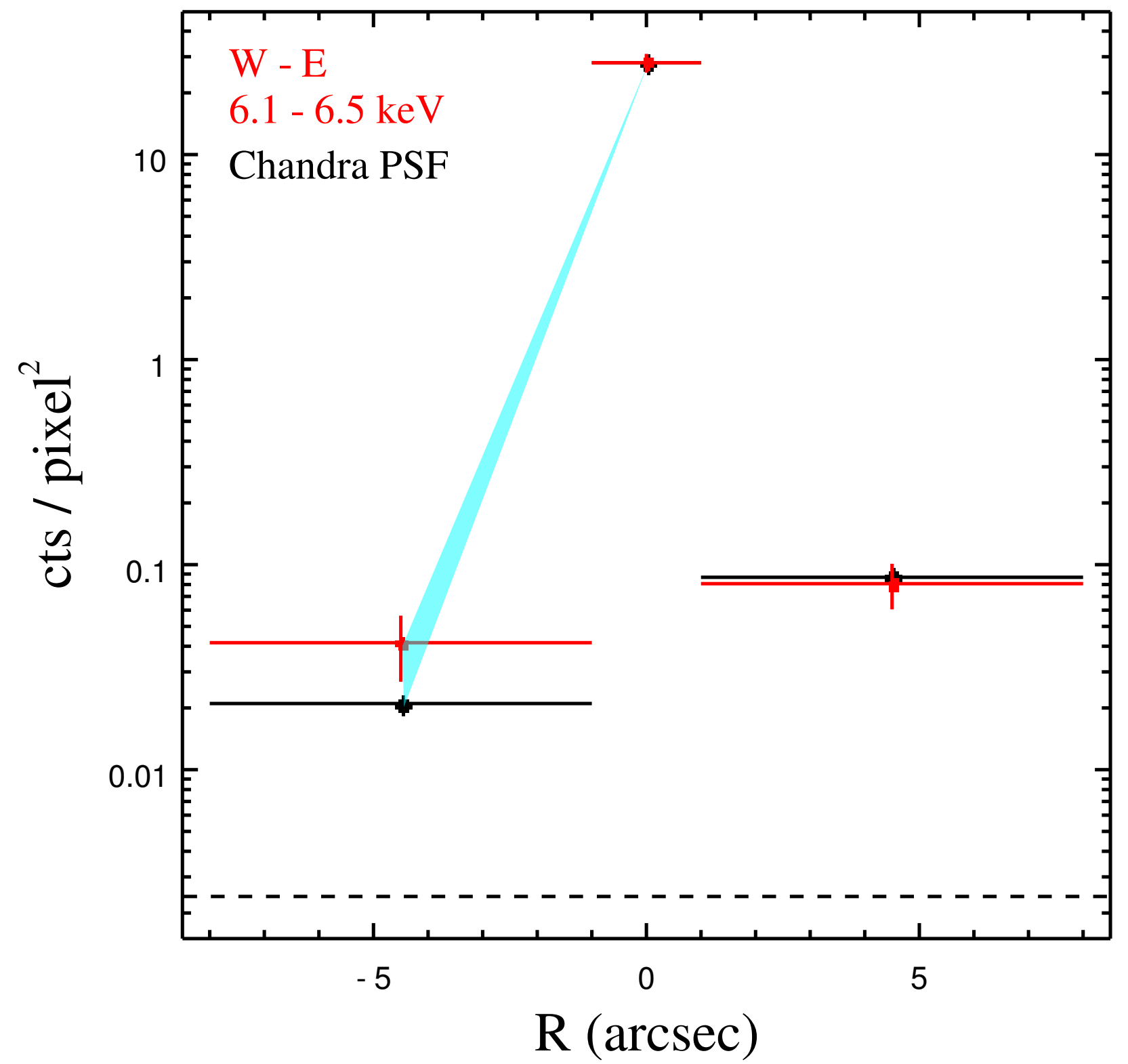
**242 ± 15 counts over Chandra PSF**

**3.0 - 6.0 keV**



**39 ± 6 counts**

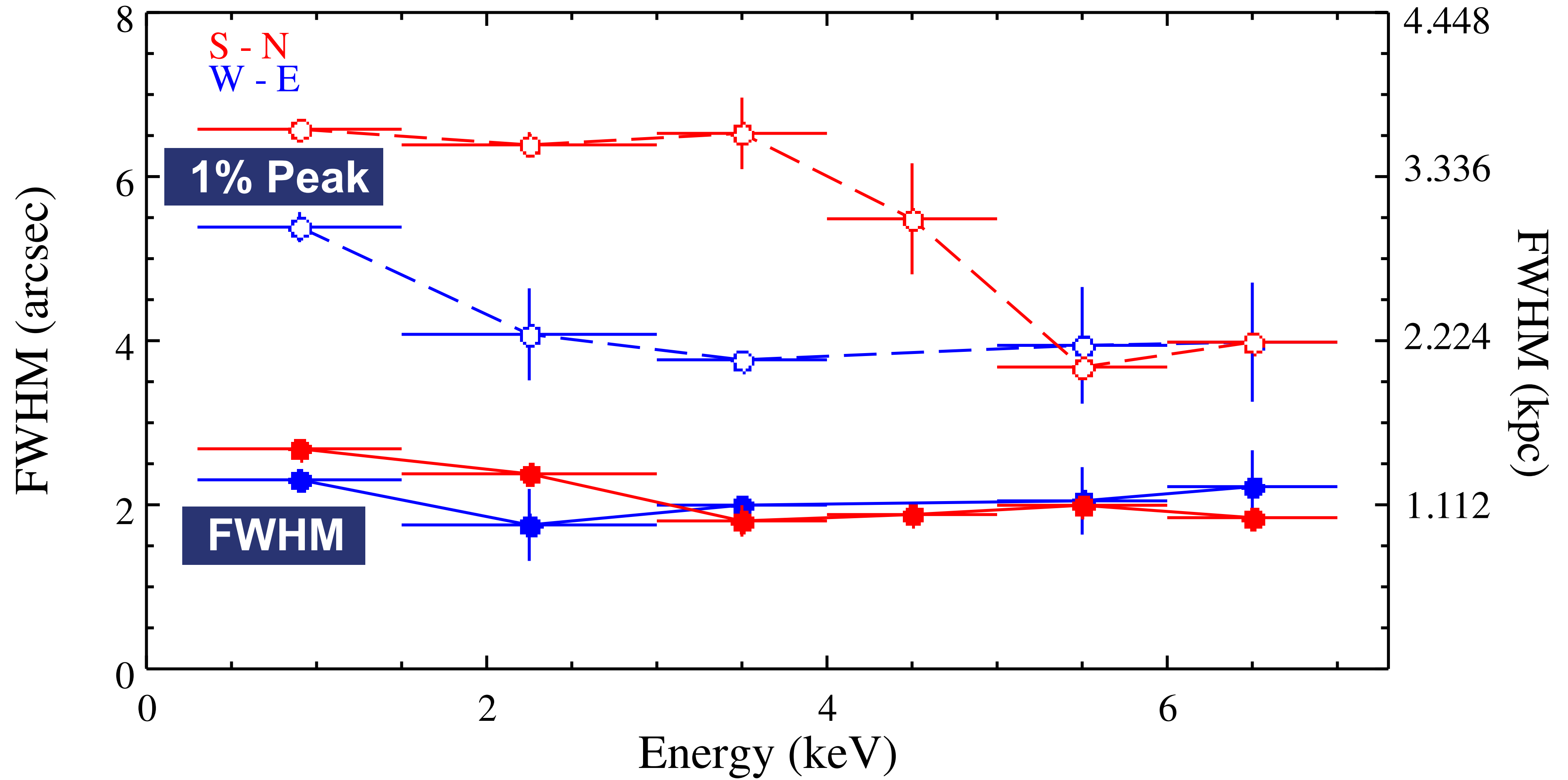
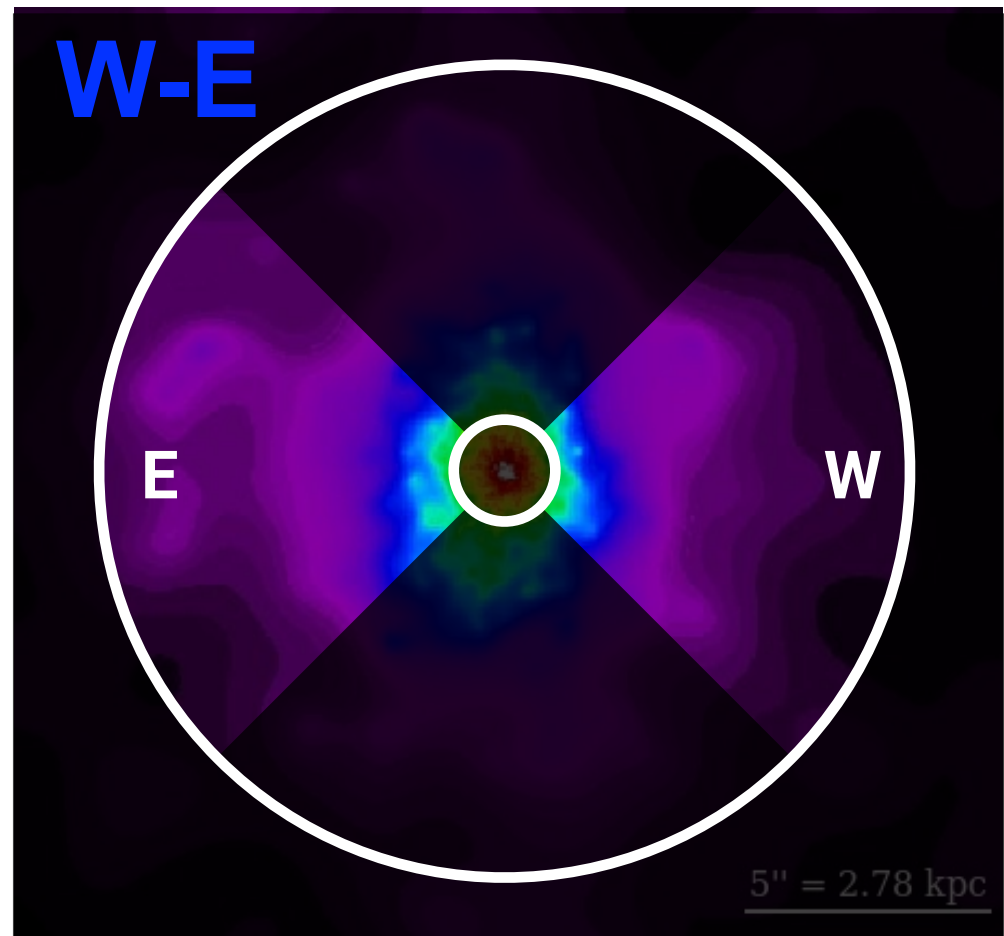
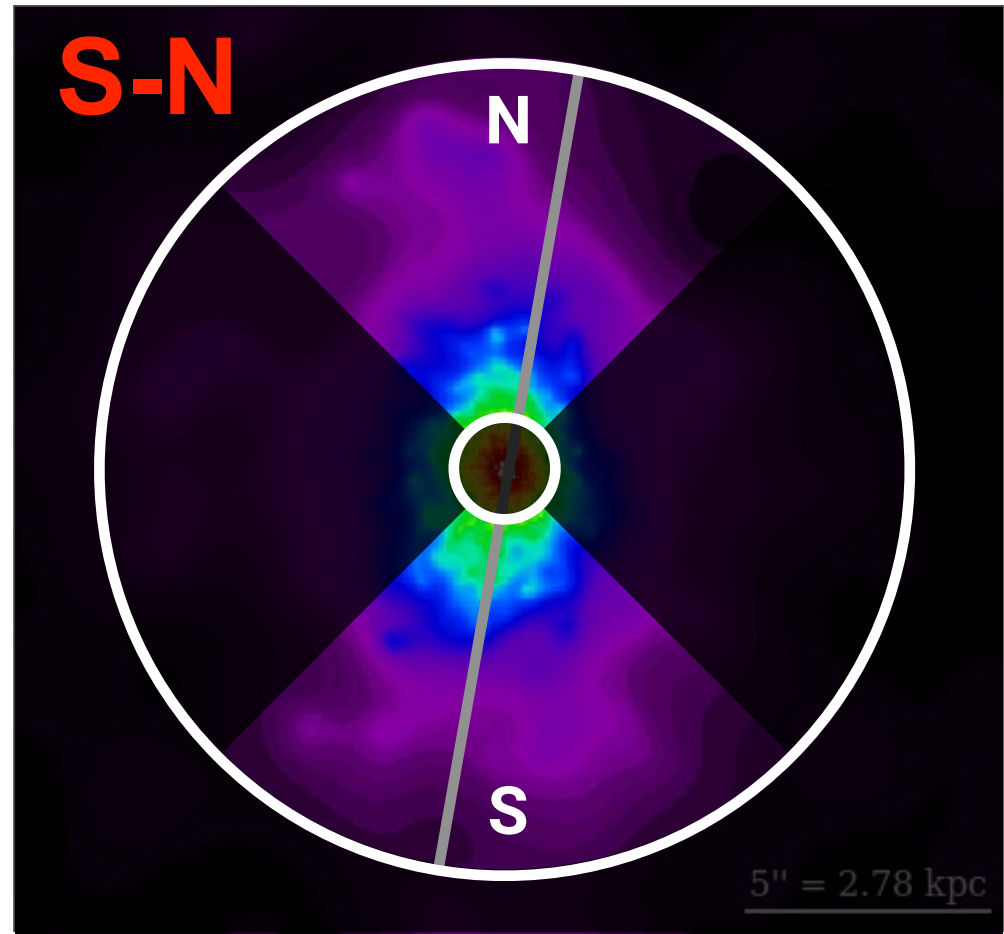
**(Fe K $\alpha$ ) 6.1 - 6.5 keV**



**4 ± 2 counts**

# 2 NGC 7212 RADIAL PROFILES

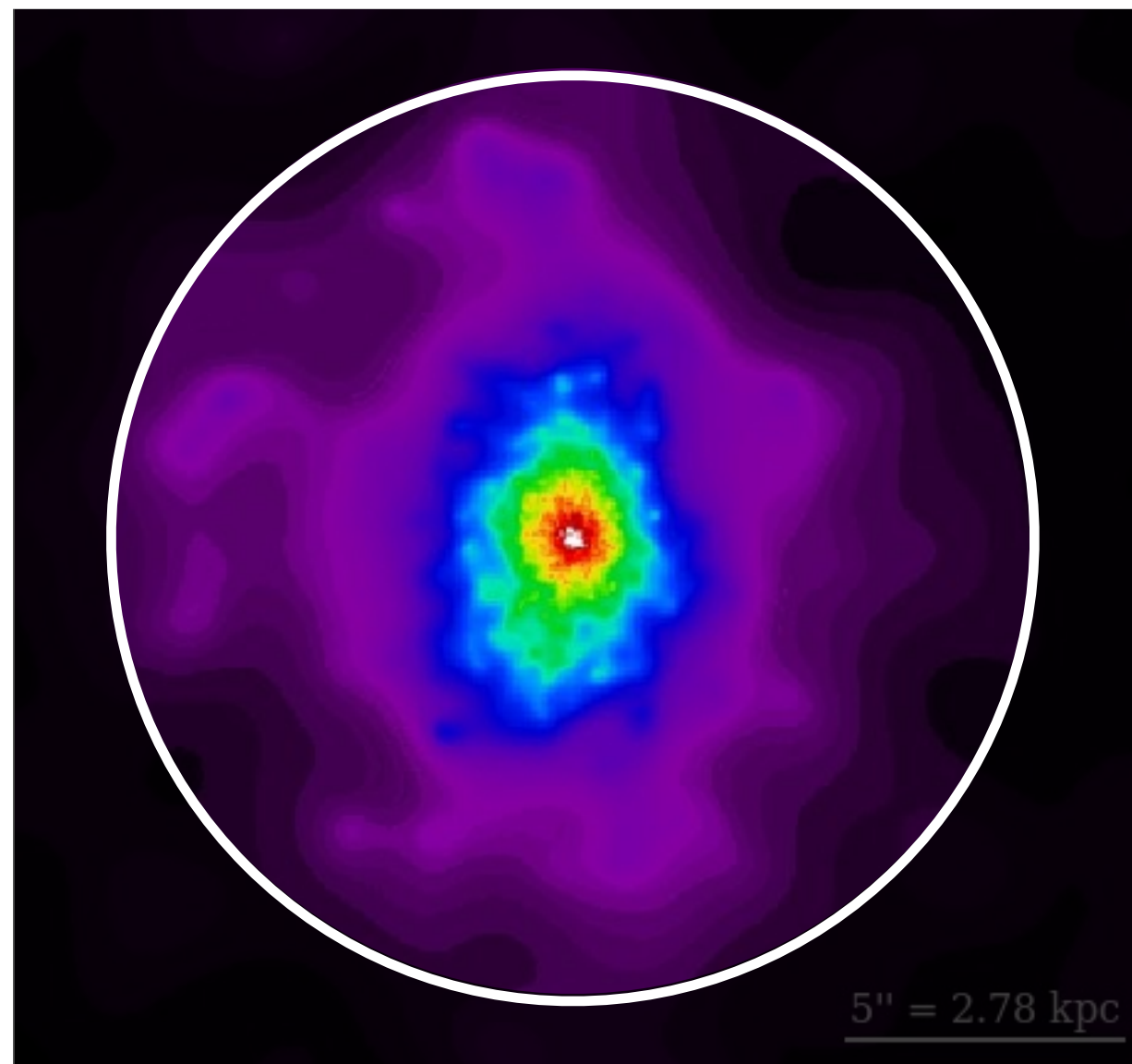
## Measuring the Extended X-rays



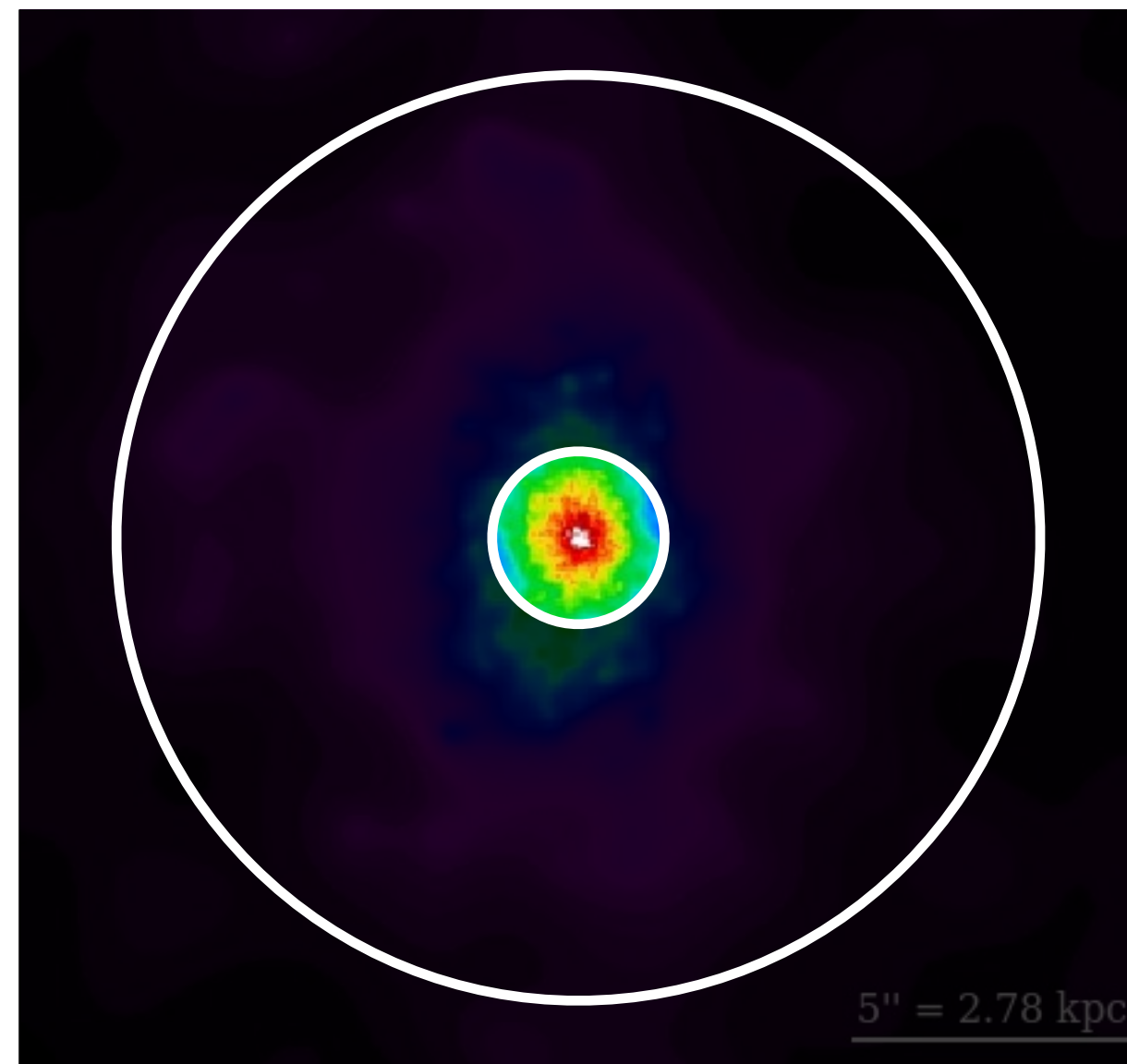
# 3 NGC 7212 *SPECTRAL FITS*

Extended Emission in NGC 7212  
Submitted

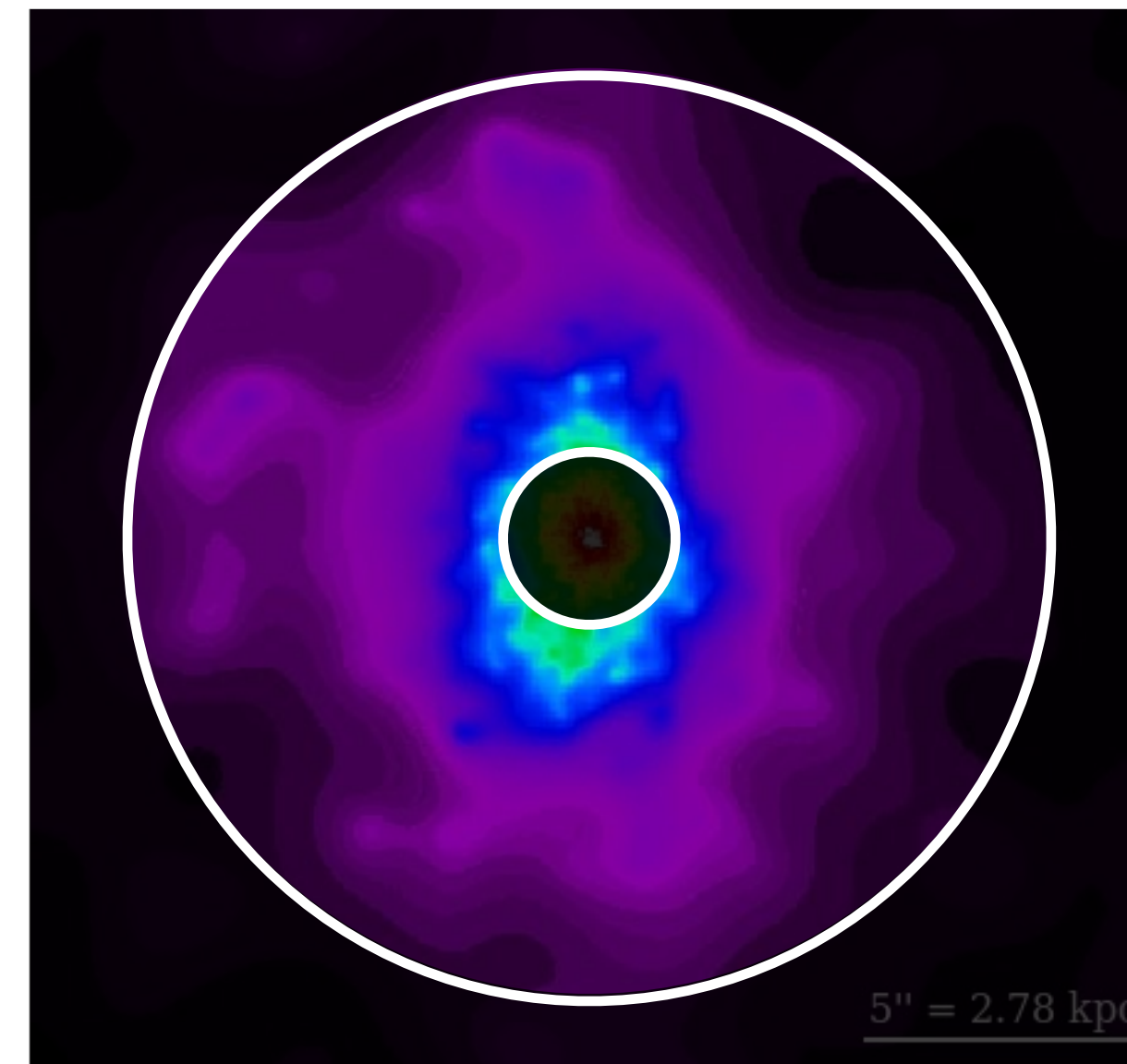
## Three Extraction Regions



➤ | **8.0" Circular Region**  
(4.448 kpc)

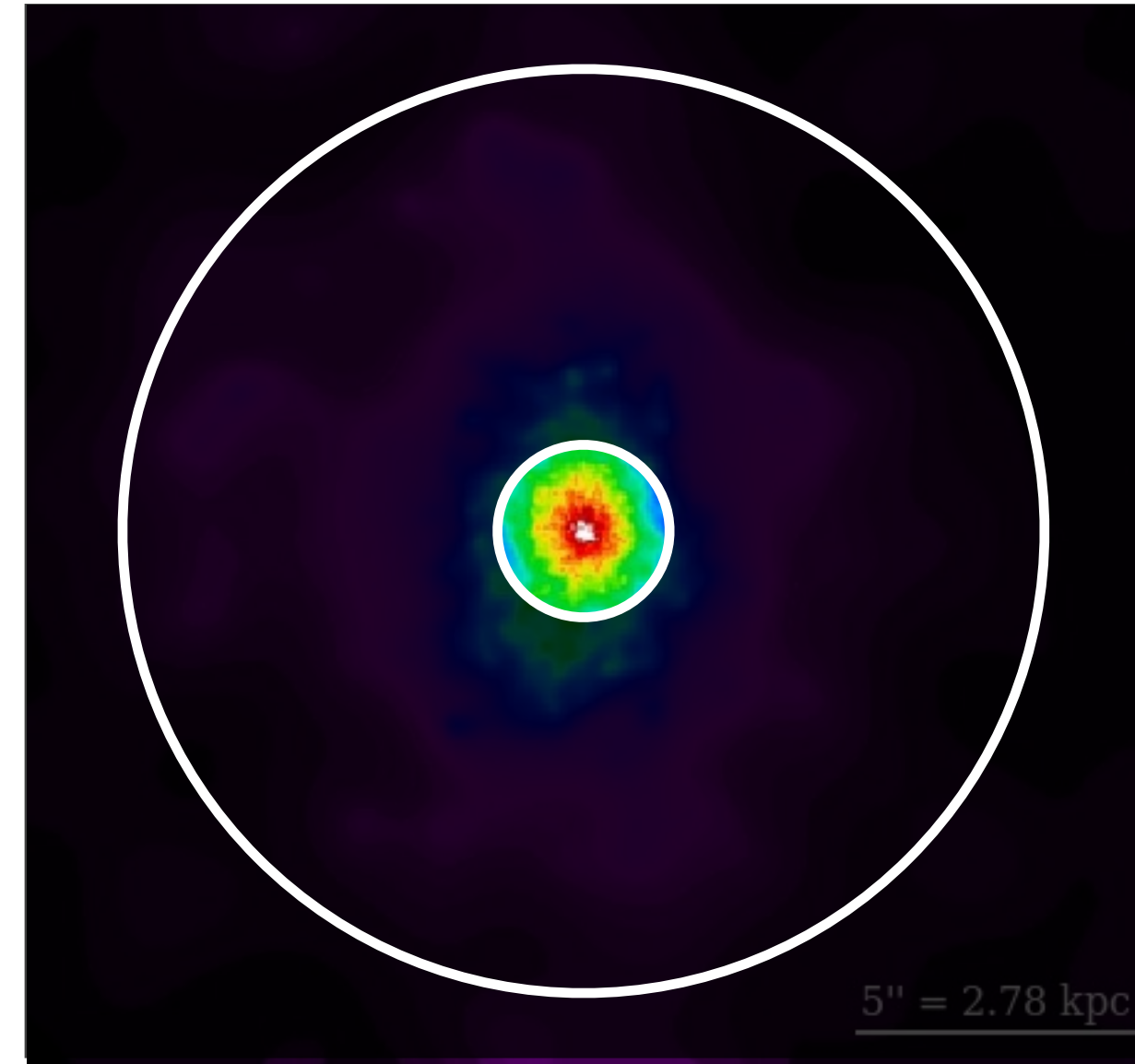


➤ | **1.5" Nuclear Region**  
(0.834 kpc)



➤ | **1.5-8.0" Annular Region**

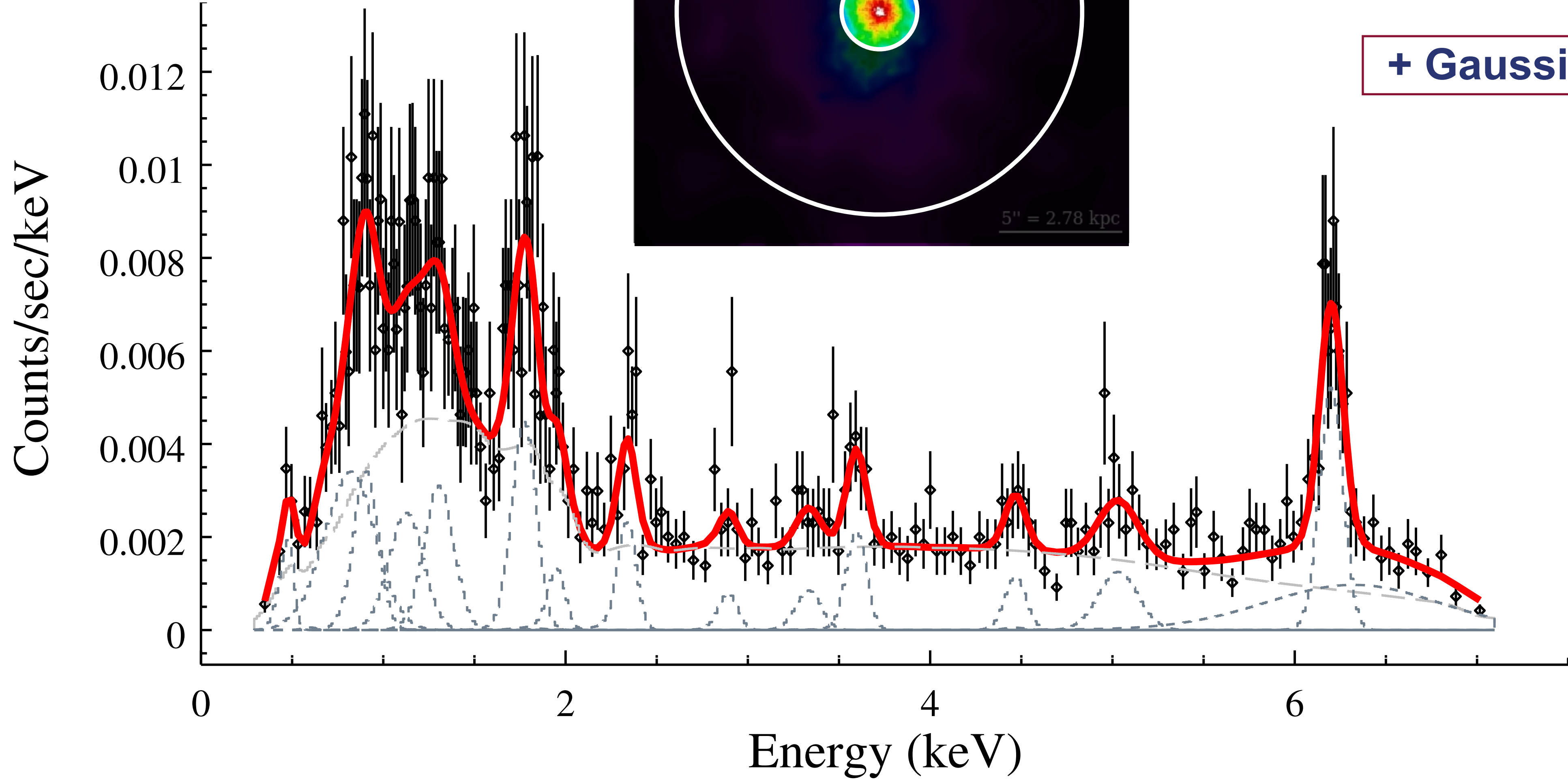
# 3 NGC 7212 *SPECTRAL FITS*



## The Nuclear Region

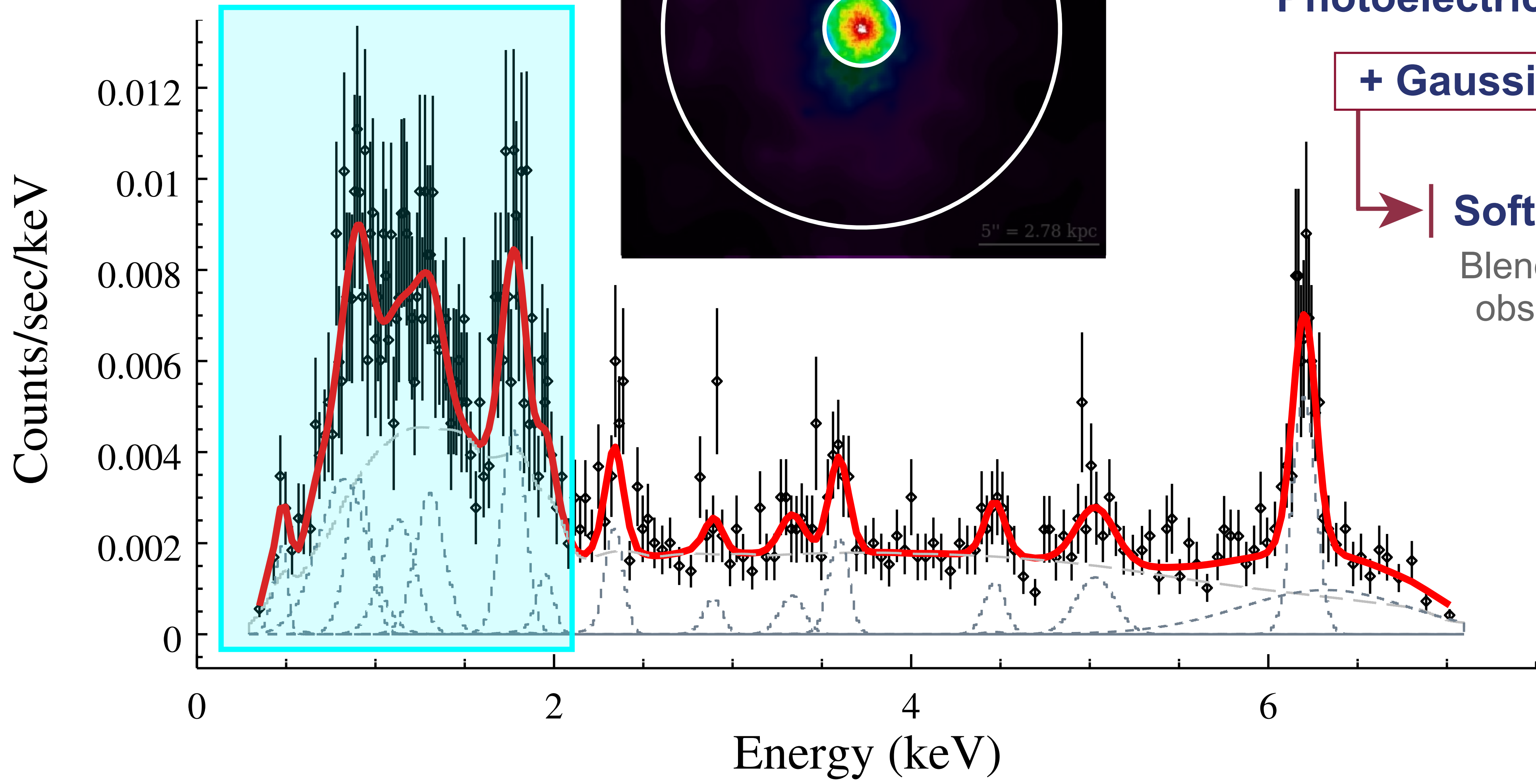
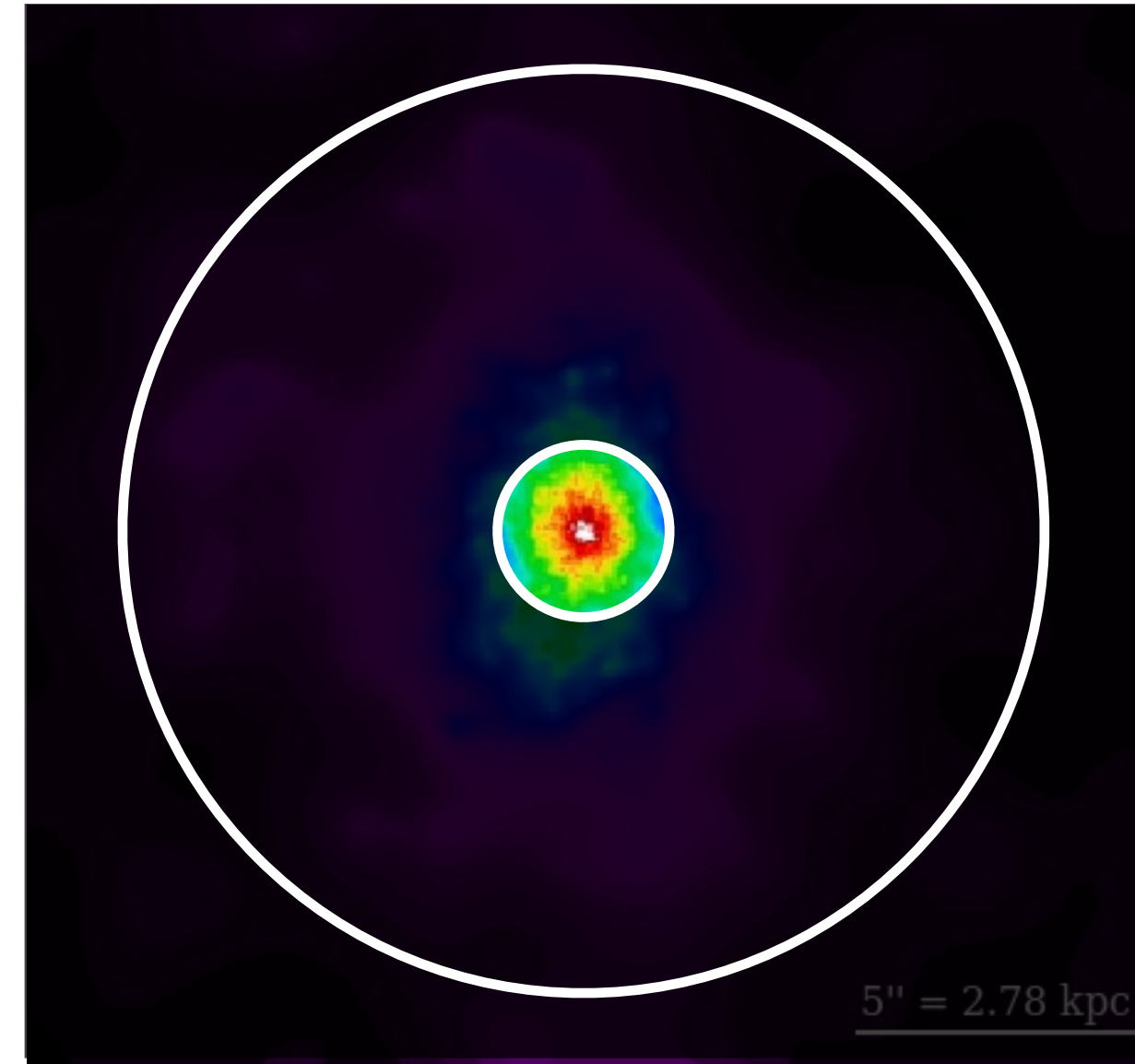
➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

+ Gaussian Emission Lines





# 3 NGC 7212 SPECTRAL FITS



## The Nuclear Region

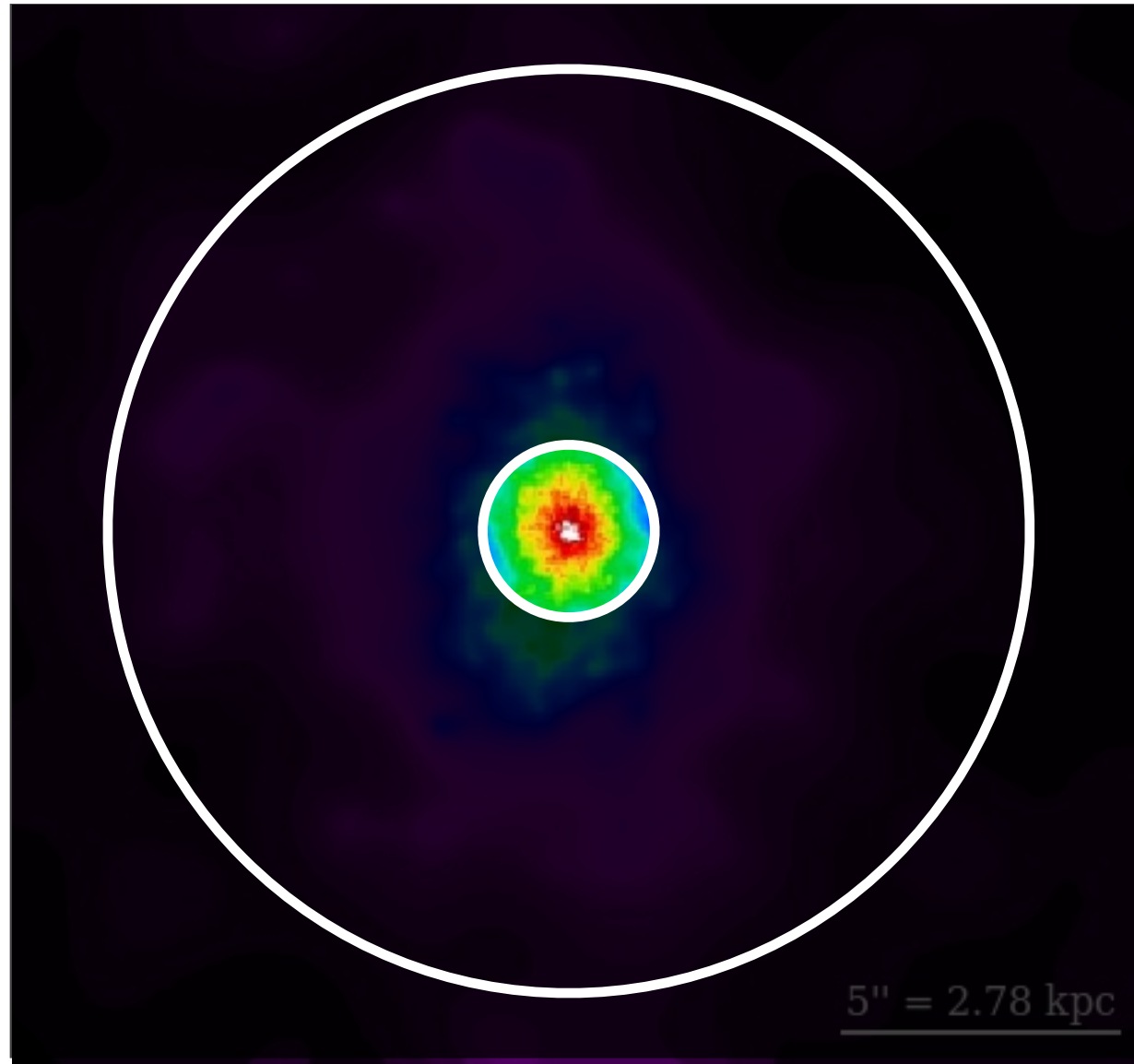
➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

+ Gaussian Emission Lines

➤ Soft X-ray Emission  
Blended emission typically observed in nearby AGN

- ▶ N VII Ly $\alpha$ , O VII
- ▶ Fe XVII
- ▶ Ne IX, Fe XIX
- ▶ Fe XX, Fe XXIV
- ▶ Mg XI, Mg XII
- ▶ Si XIII

# 3 NGC 7212 SPECTRAL FITS



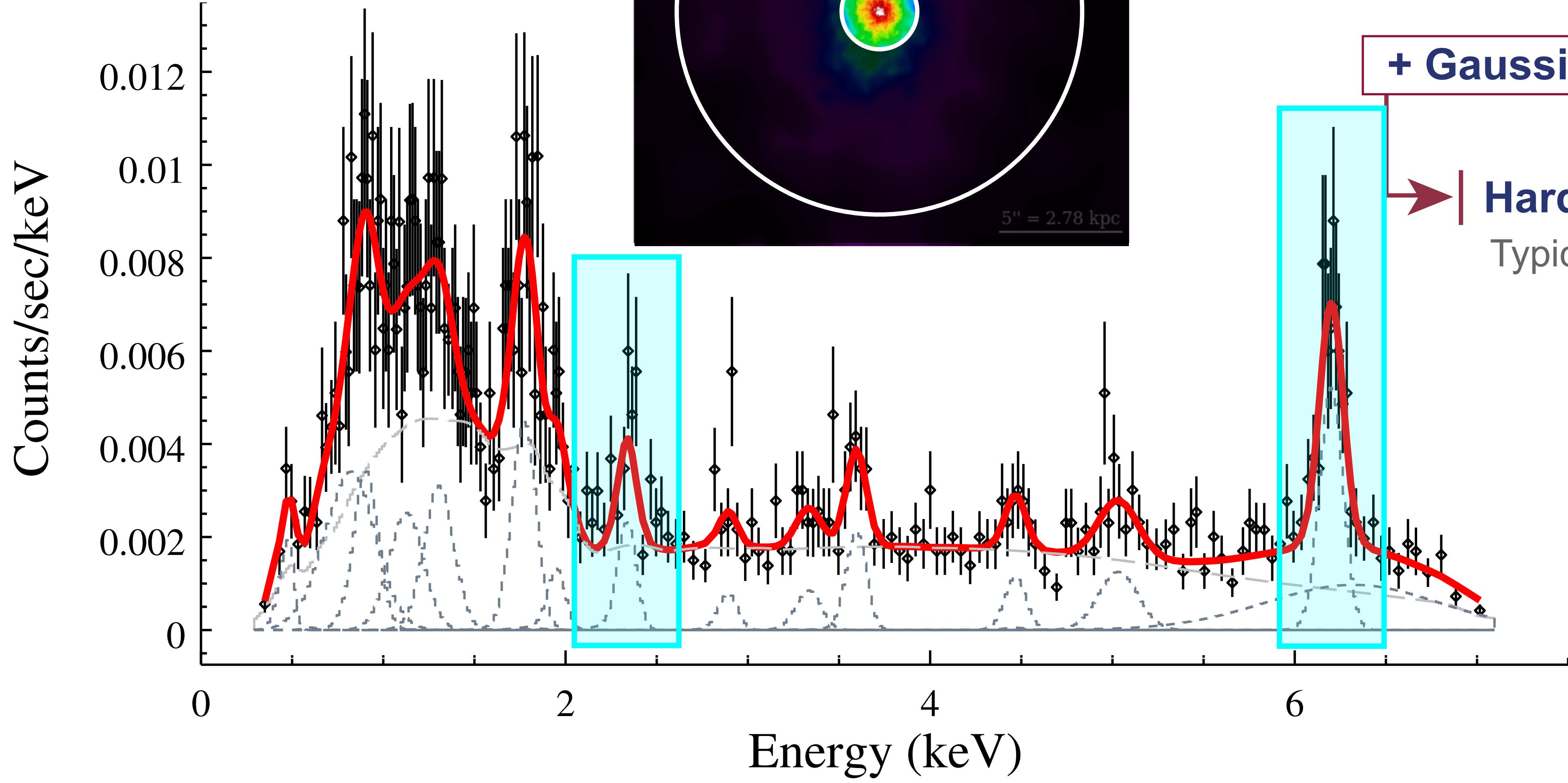
## The Nuclear Region

➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

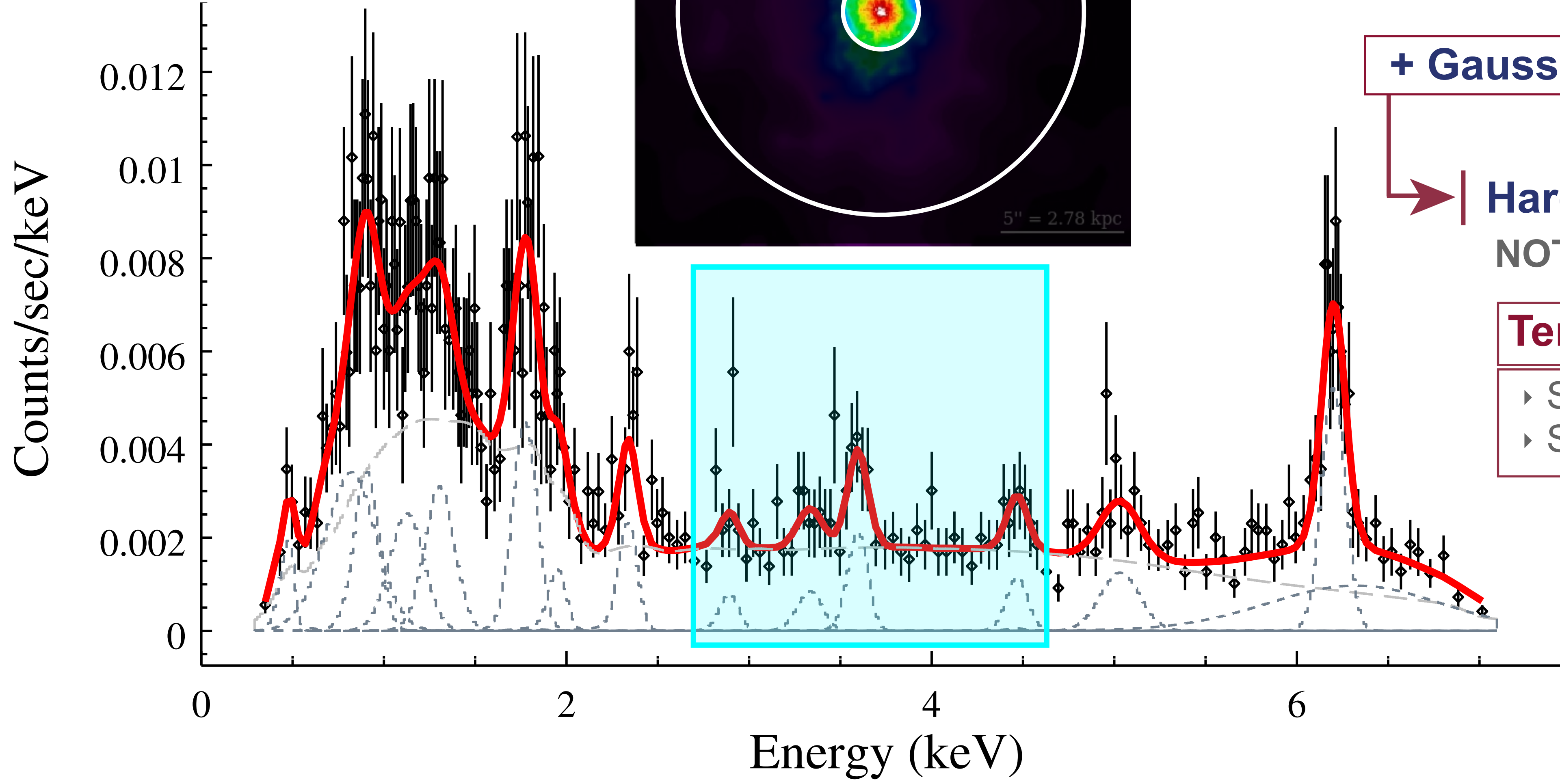
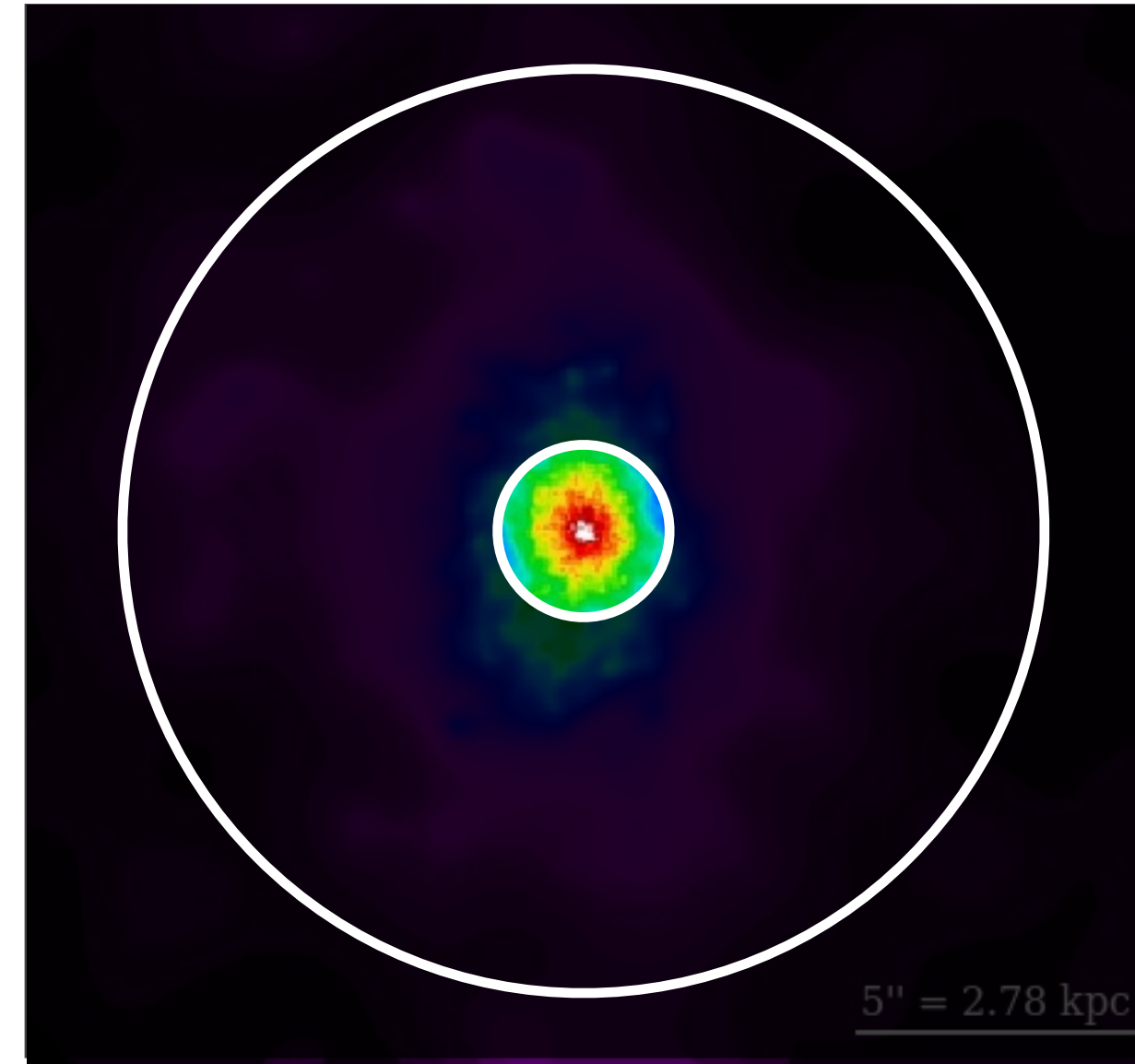
+ Gaussian Emission Lines

➤ Hard X-ray Emission  
Typical emission observed  
in nearby AGN

- S K $\alpha$ , S XV
- Fe K $\alpha$
- Fe K $\alpha$  wings, Fe



# 3 NGC 7212 SPECTRAL FITS



## The Nuclear Region

➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

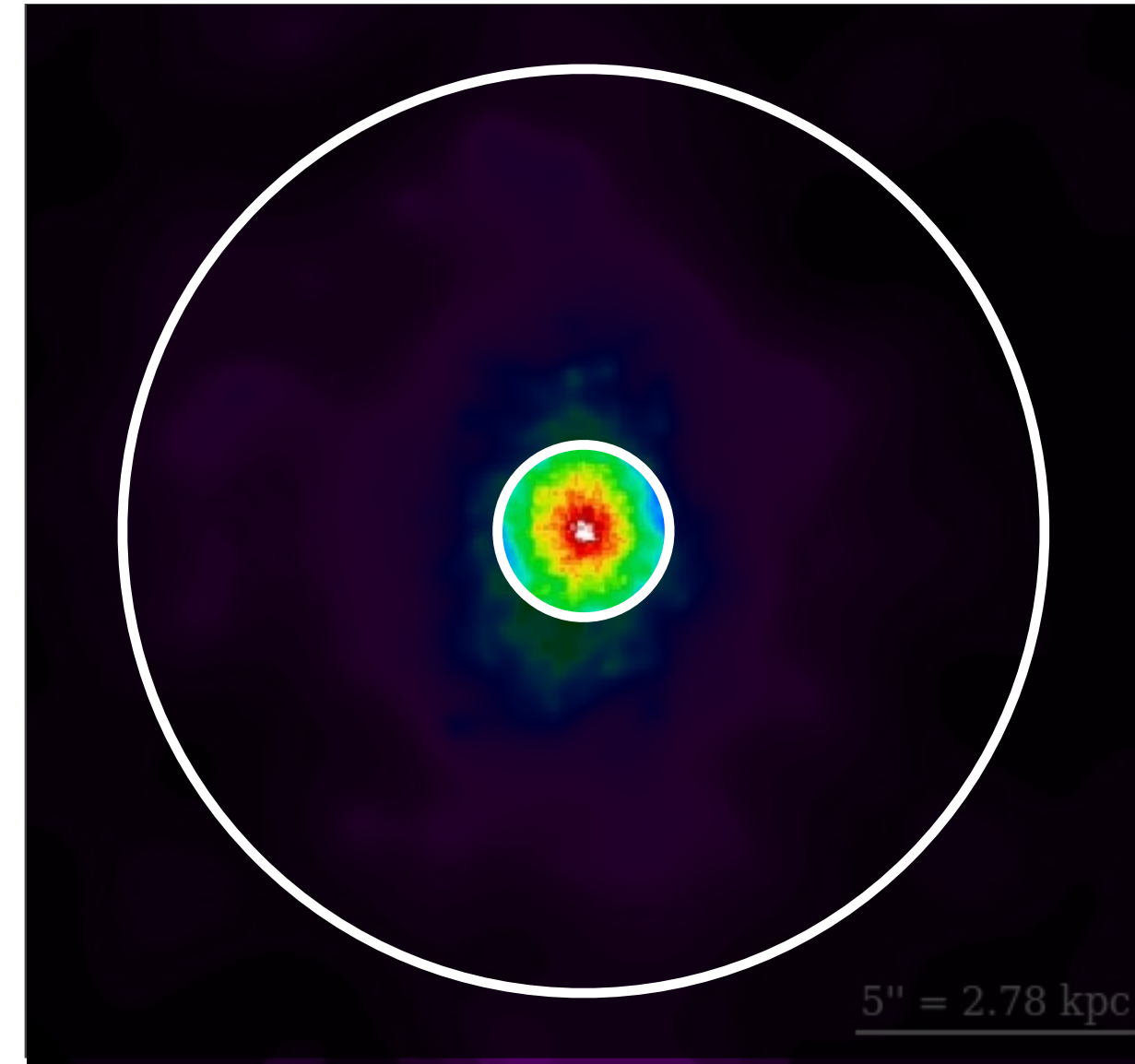
+ Gaussian Emission Lines

➤ Hard X-ray Emission  
NOT typical AGN emission lines

### Tentative Identifications

- Species of Argon
- Species of Calcium

# 3 NGC 7212 SPECTRAL FITS



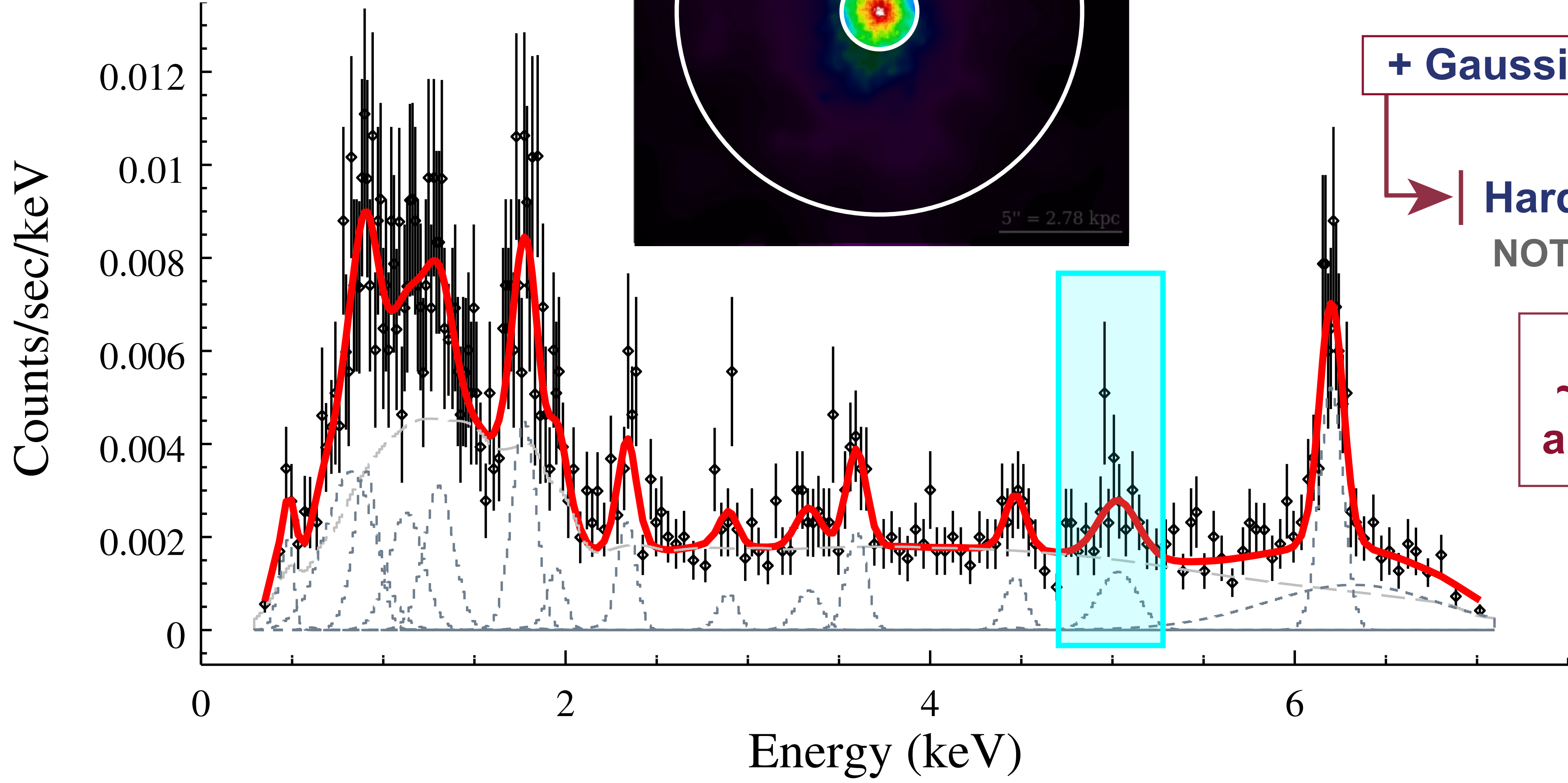
## The Nuclear Region

➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

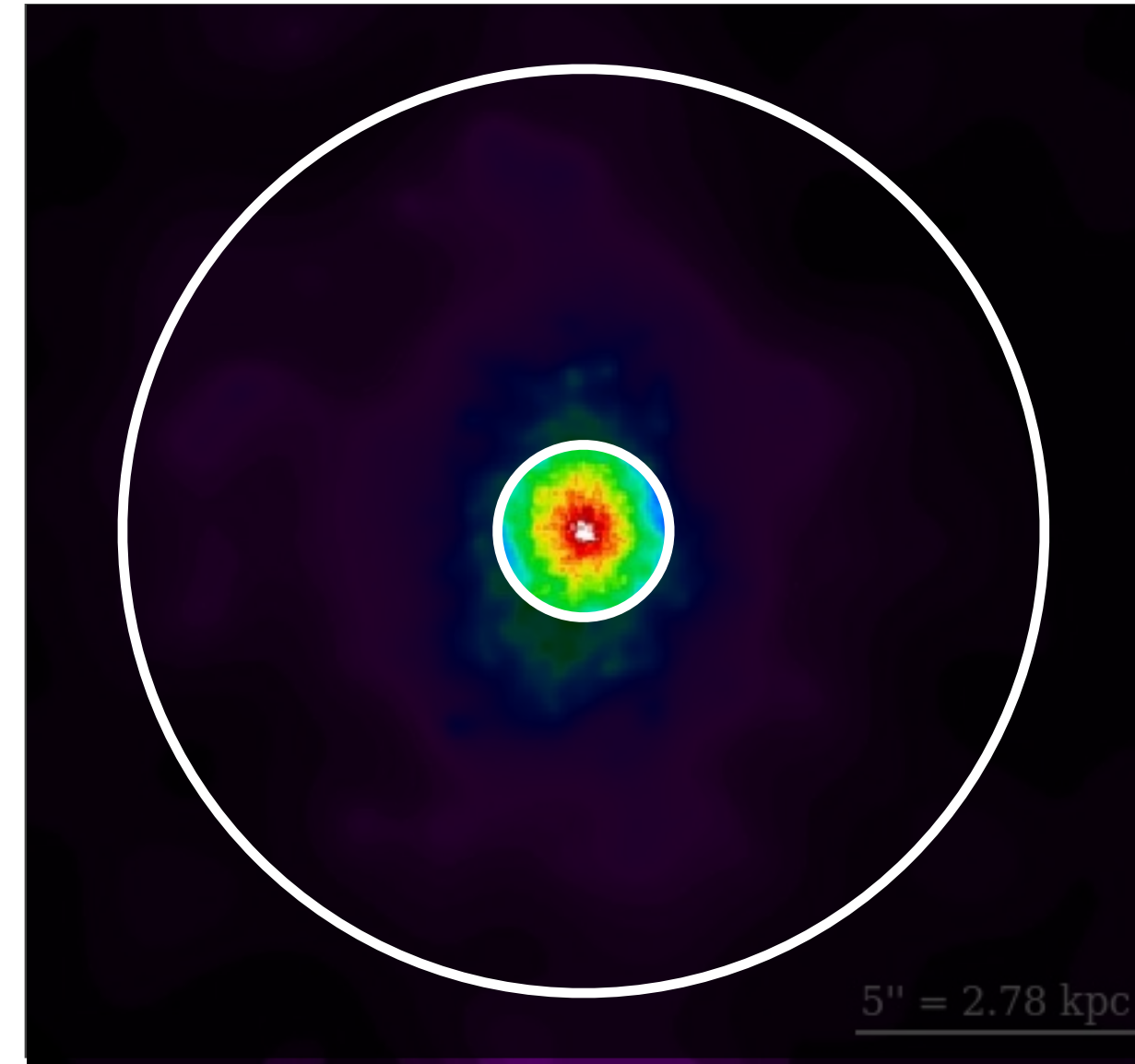
+ Gaussian Emission Lines

➤ Hard X-ray Emission  
NOT typical AGN emission lines

The emission at  
~5.2 keV is puzzling  
and not yet identified

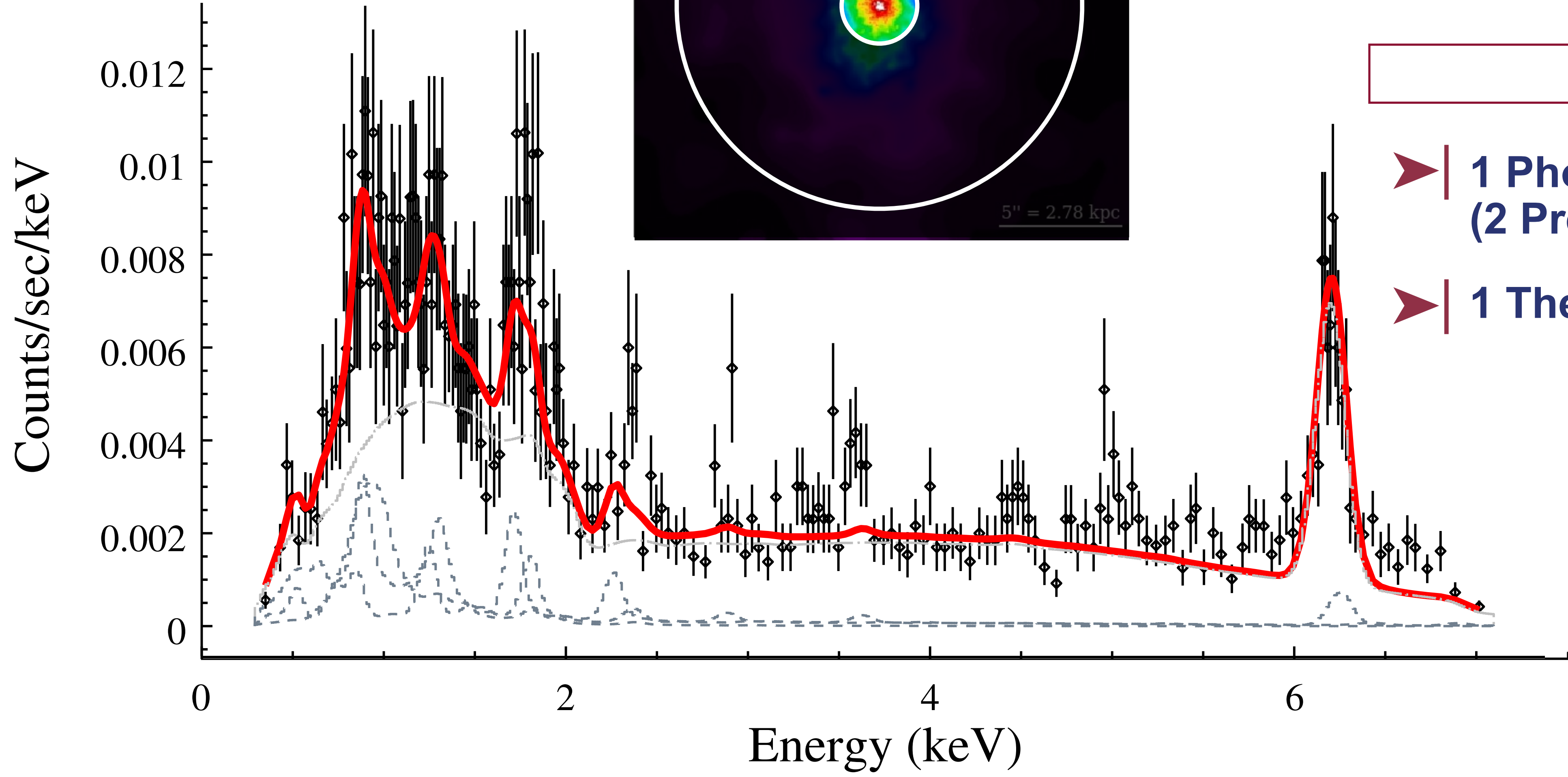


# 3 NGC 7212 *SPECTRAL FITS*



## The Nuclear Region

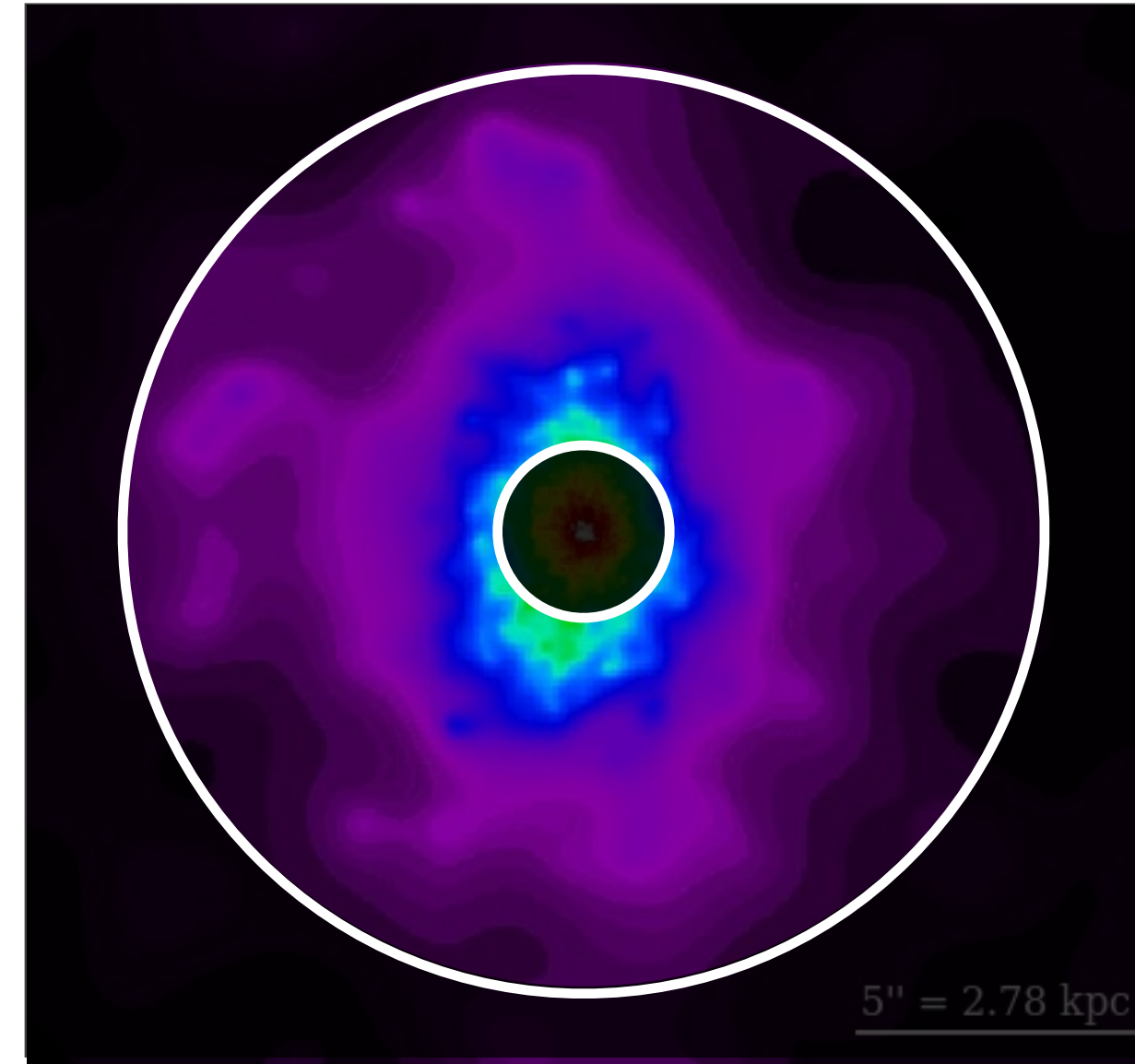
➤ Physical Spectral Model:  
Photoelectric Absorption \* PEXRAV



Best Fit

- 1 Photoionization Model (2 Preferred)
- 1 Thermal Model

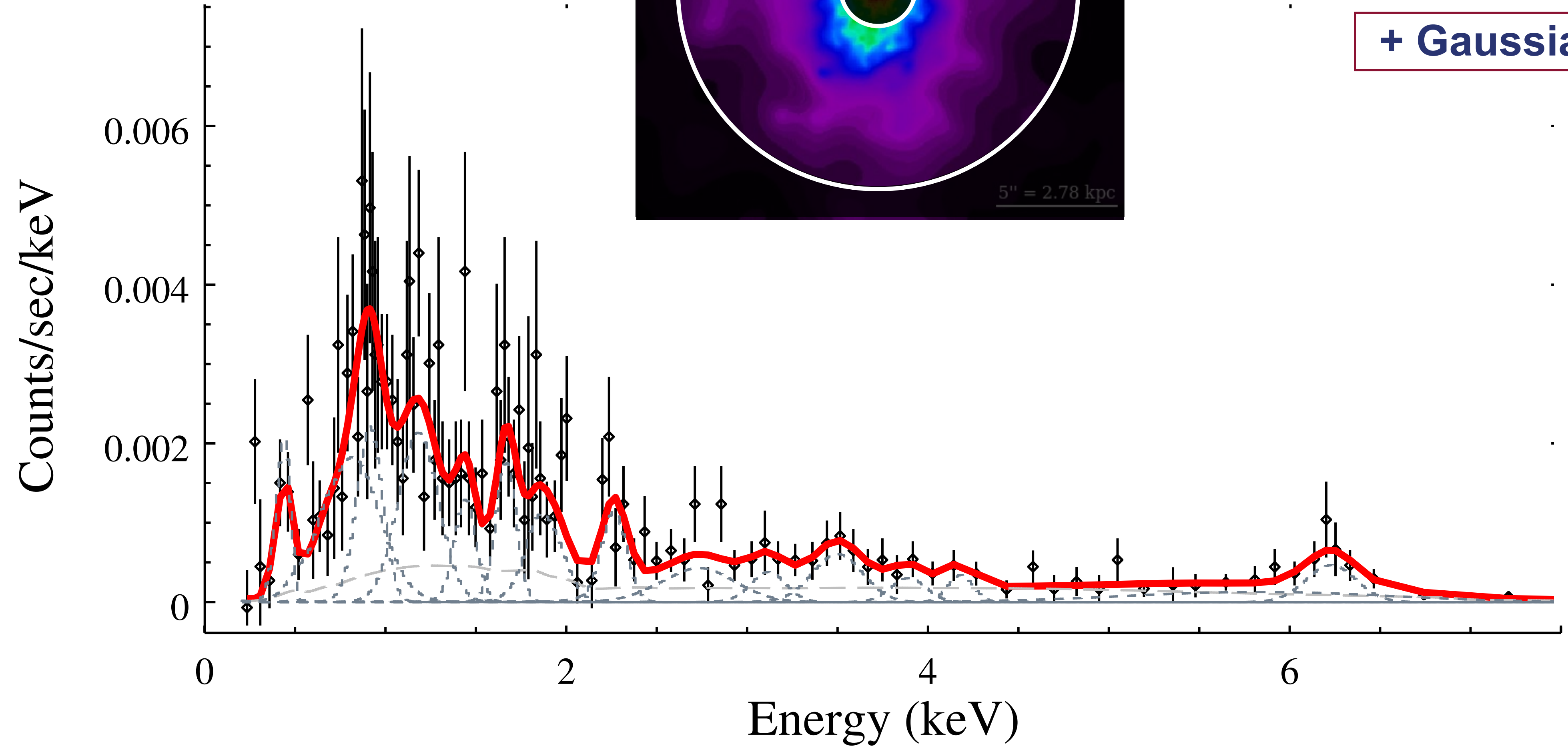
# 3 NGC 7212 *SPECTRAL FITS*



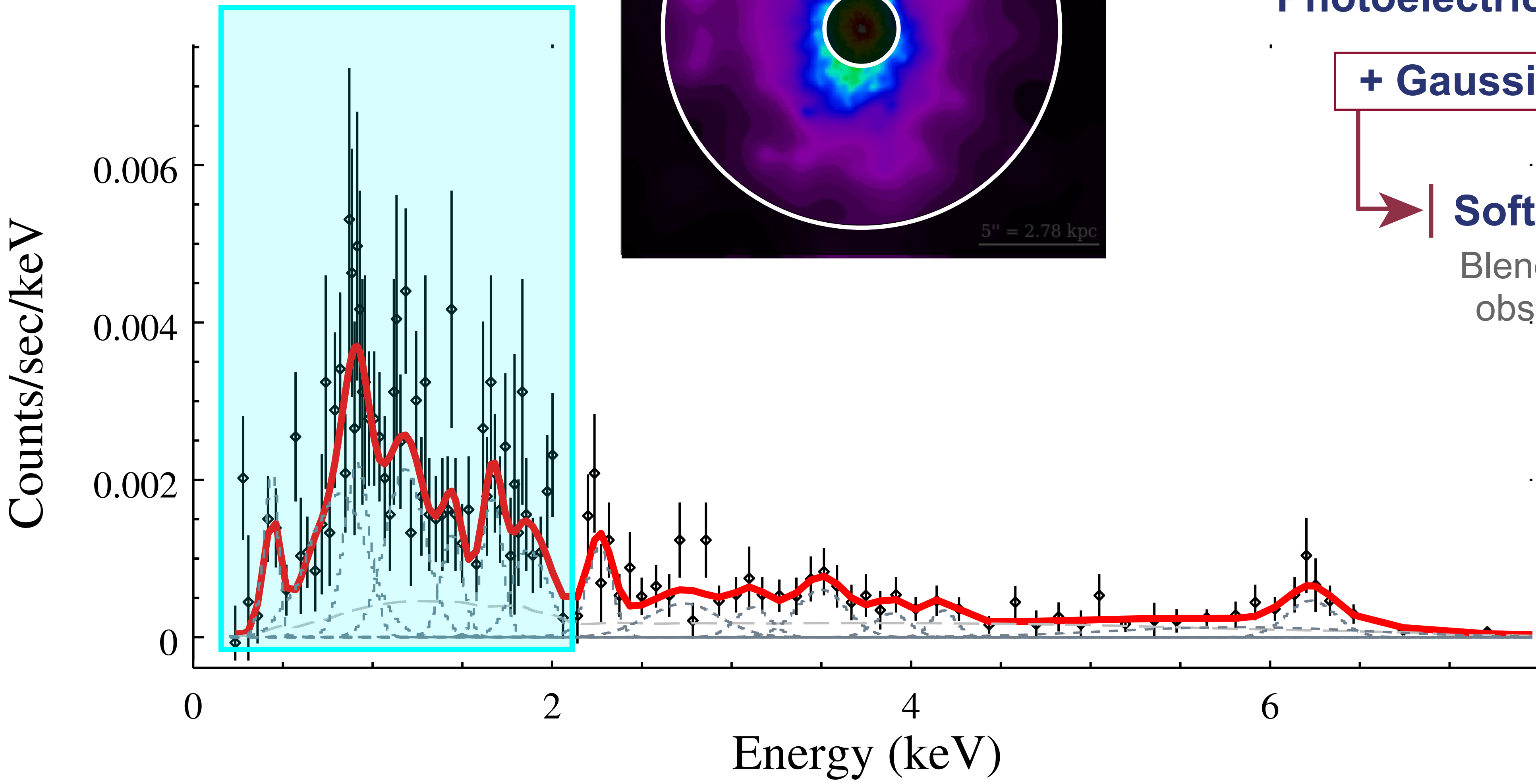
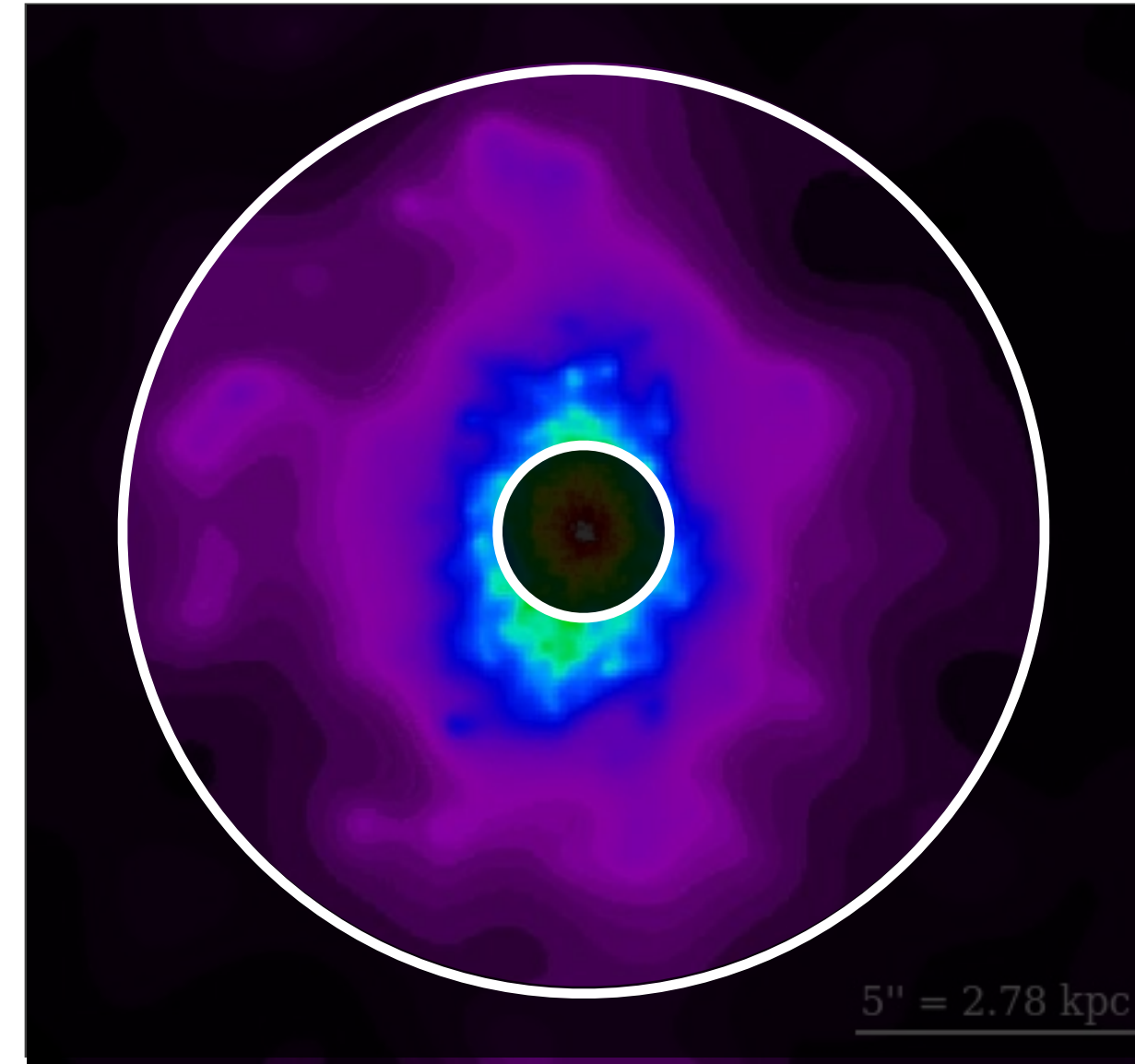
## The Annular Region

➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

+ Gaussian Emission Lines



# 3 NGC 7212 *SPECTRAL FITS*



## The Annular Region

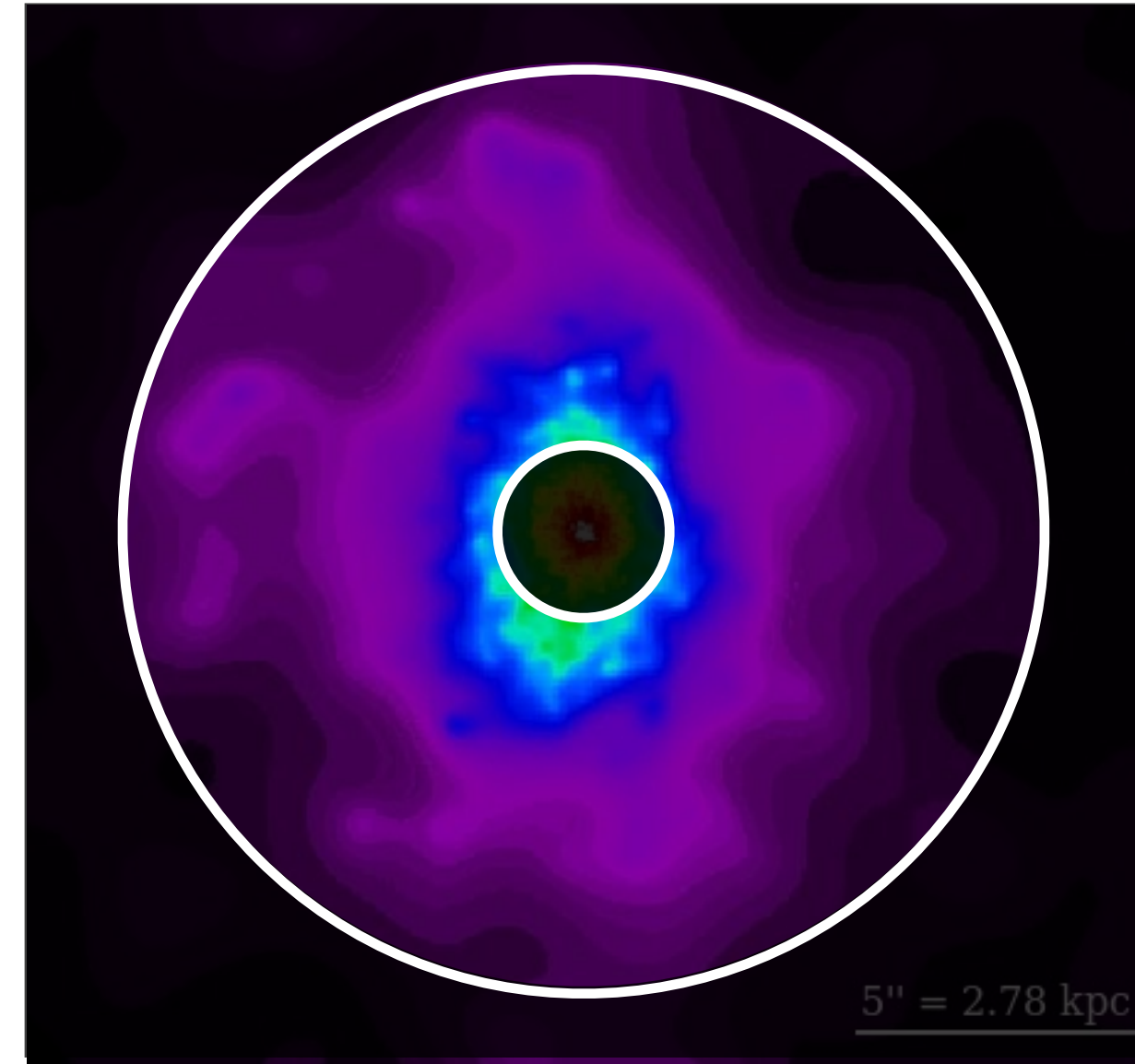
➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

+ Gaussian Emission Lines

➤ Soft X-ray Emission  
Blended emission typically  
observed in nearby AGN

- ▶ N VII Ly $\alpha$ , O VII
- ▶ Fe XVII
- ▶ Ne IX, Fe XIX
- ▶ Fe XX, Fe XXIV
- ▶ Mg XI, Mg XII

# 3 NGC 7212 *SPECTRAL FITS*



## The Annular Region

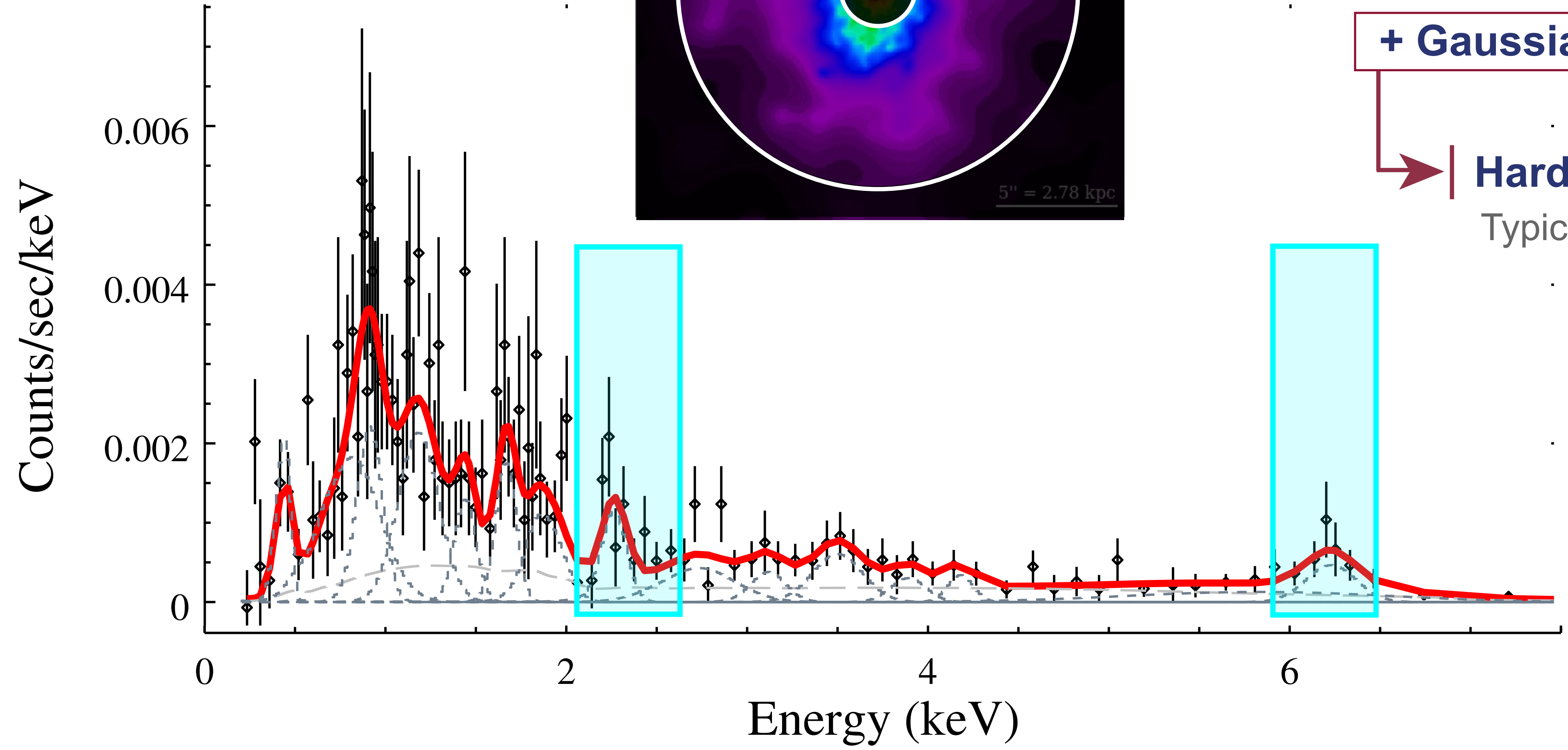
➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

+ Gaussian Emission Lines

➤ Hard X-ray Emission

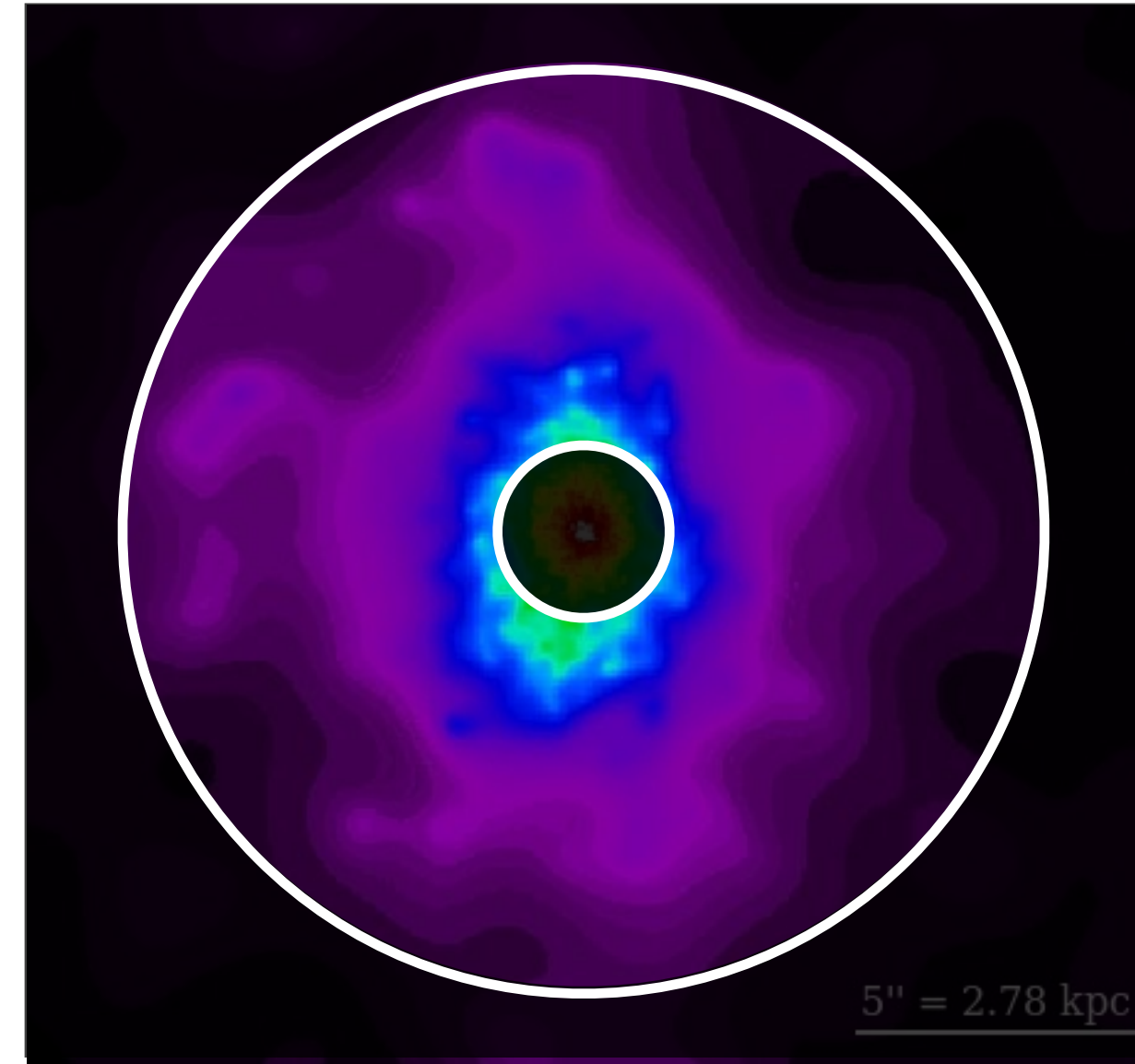
Typical emission observed  
in nearby AGN

- S K $\alpha$ , S XV
- Fe K $\alpha$
- Fe K $\alpha$  wings, Fe





# 3 NGC 7212 *SPECTRAL FITS*



## The Annular Region

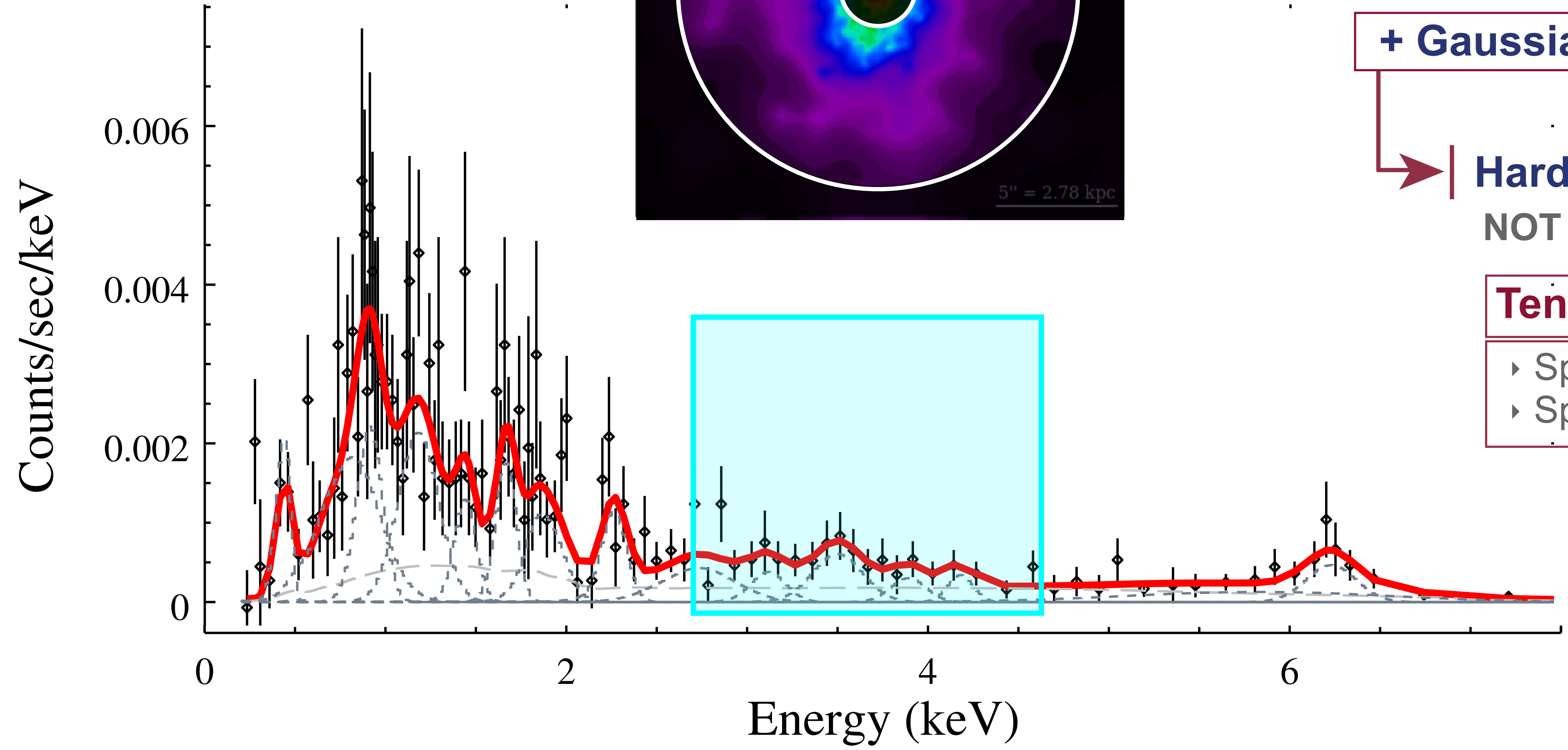
➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

+ Gaussian Emission Lines

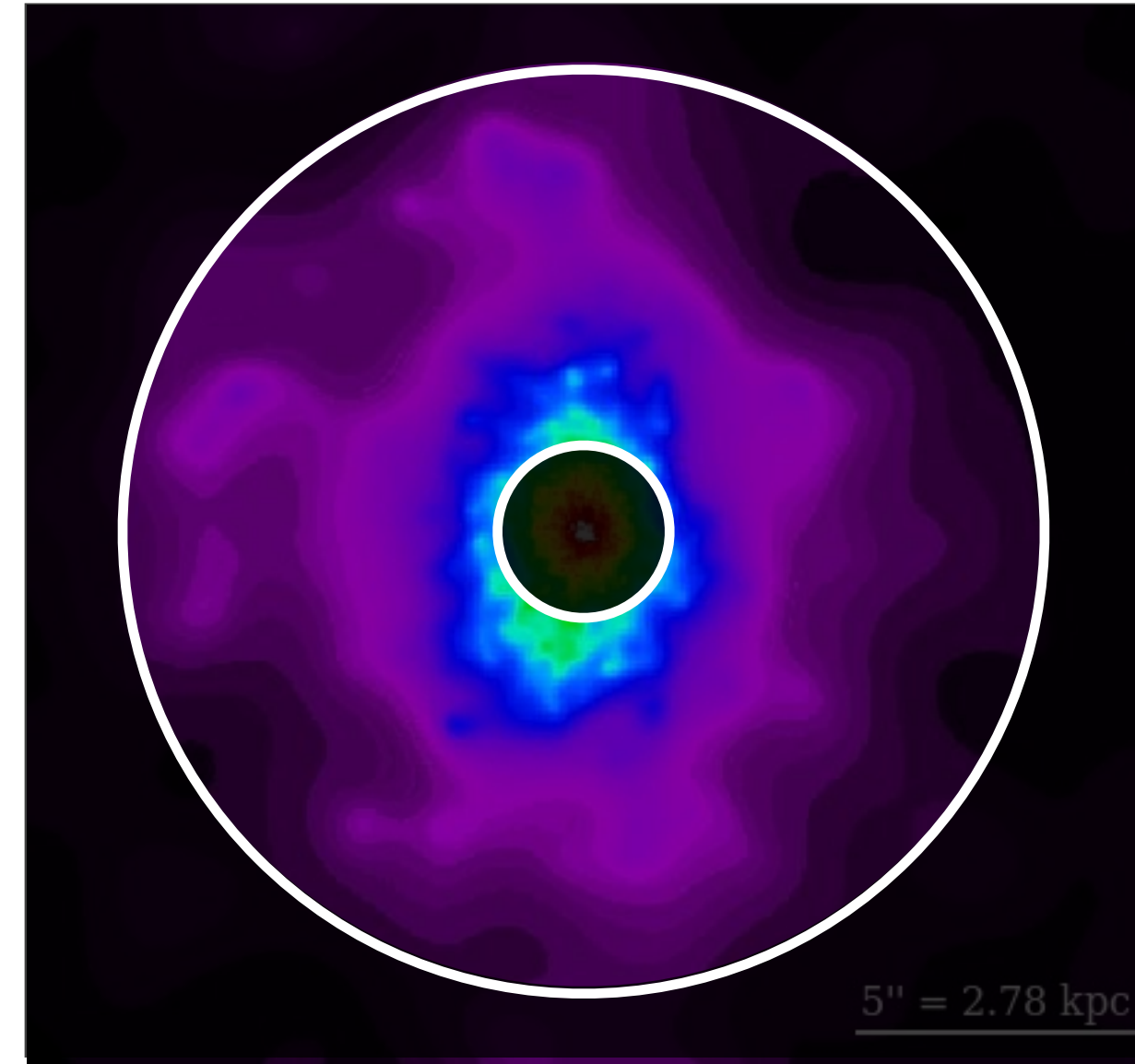
➤ Hard X-ray Emission  
NOT typical AGN emission lines

### Tentative Identifications

- Species of Argon
- Species of Calcium



# 3 NGC 7212 *SPECTRAL FITS*



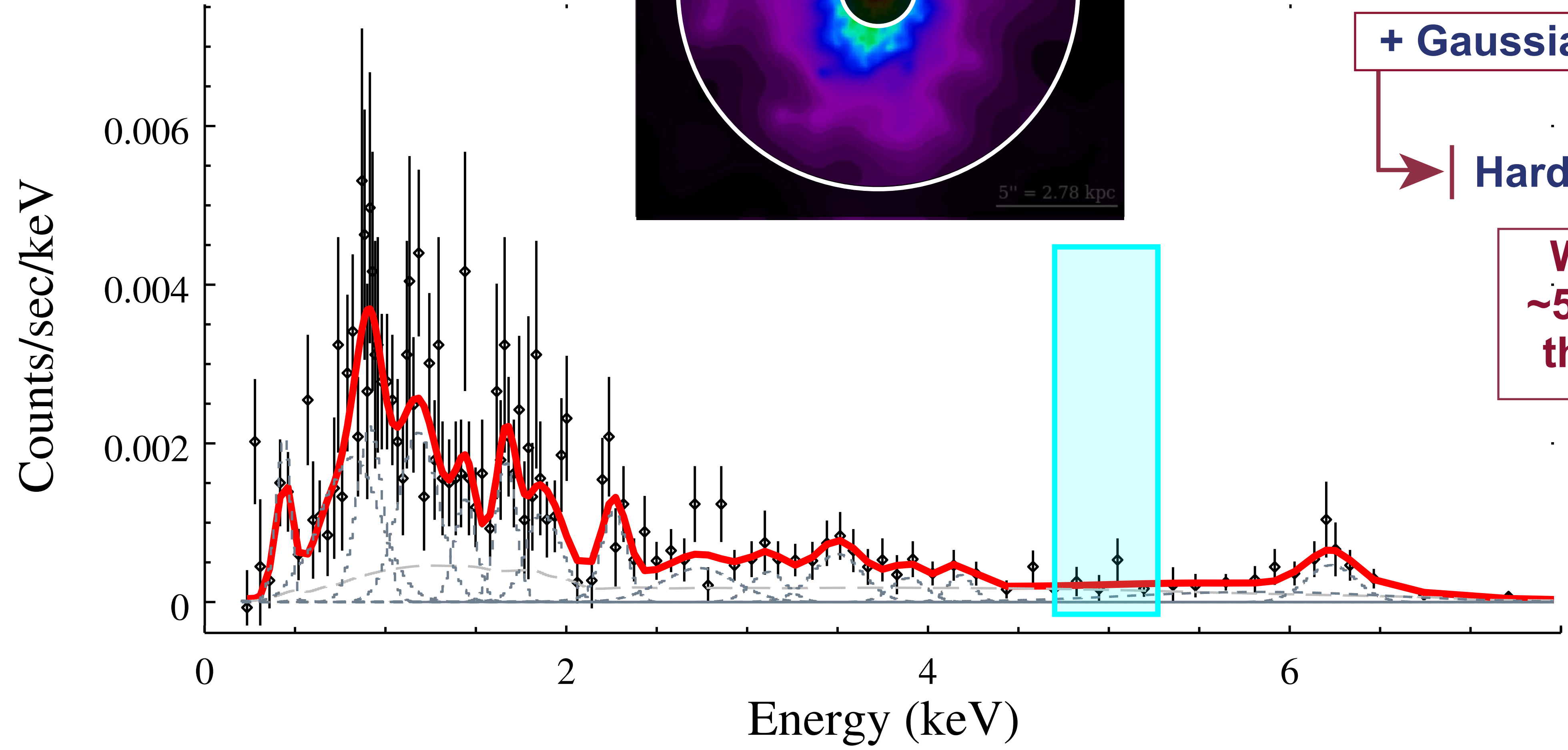
## The Annular Region

➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

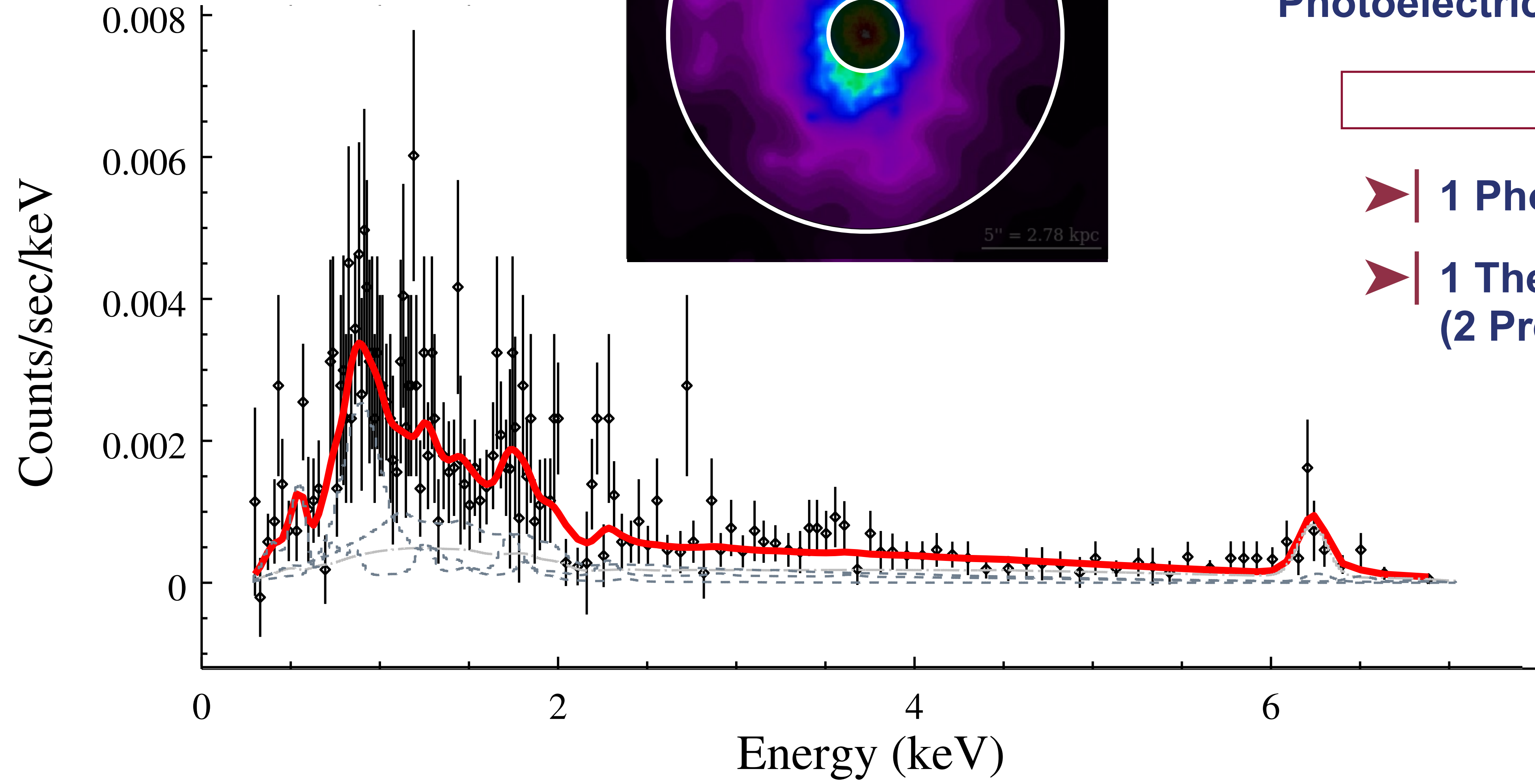
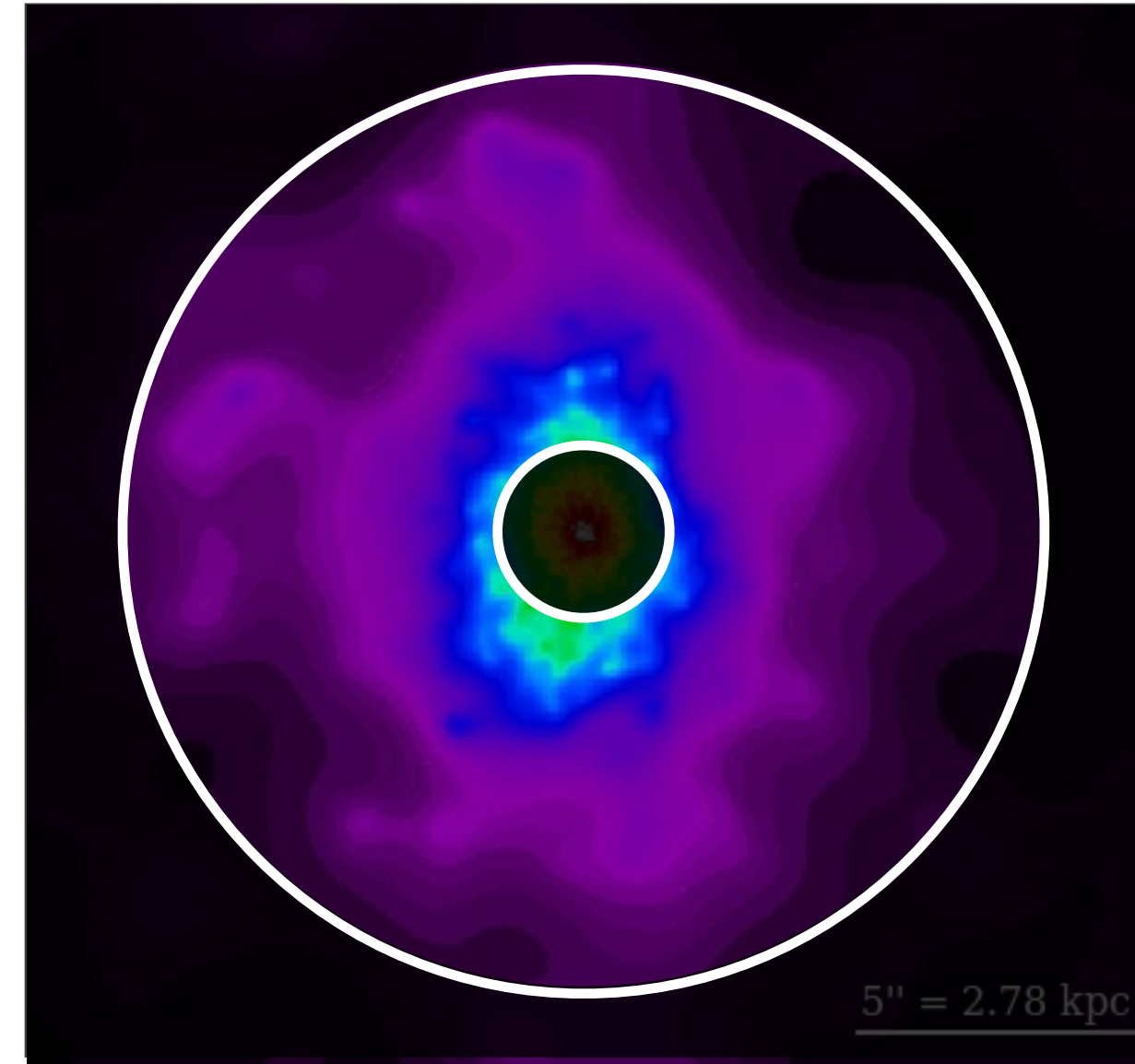
+ Gaussian Emission Lines

➤ Hard X-ray Emission

**We do not find the  
~5.2 keV emission in  
the annular region!**



# 3 NGC 7212 *SPECTRAL FITS*



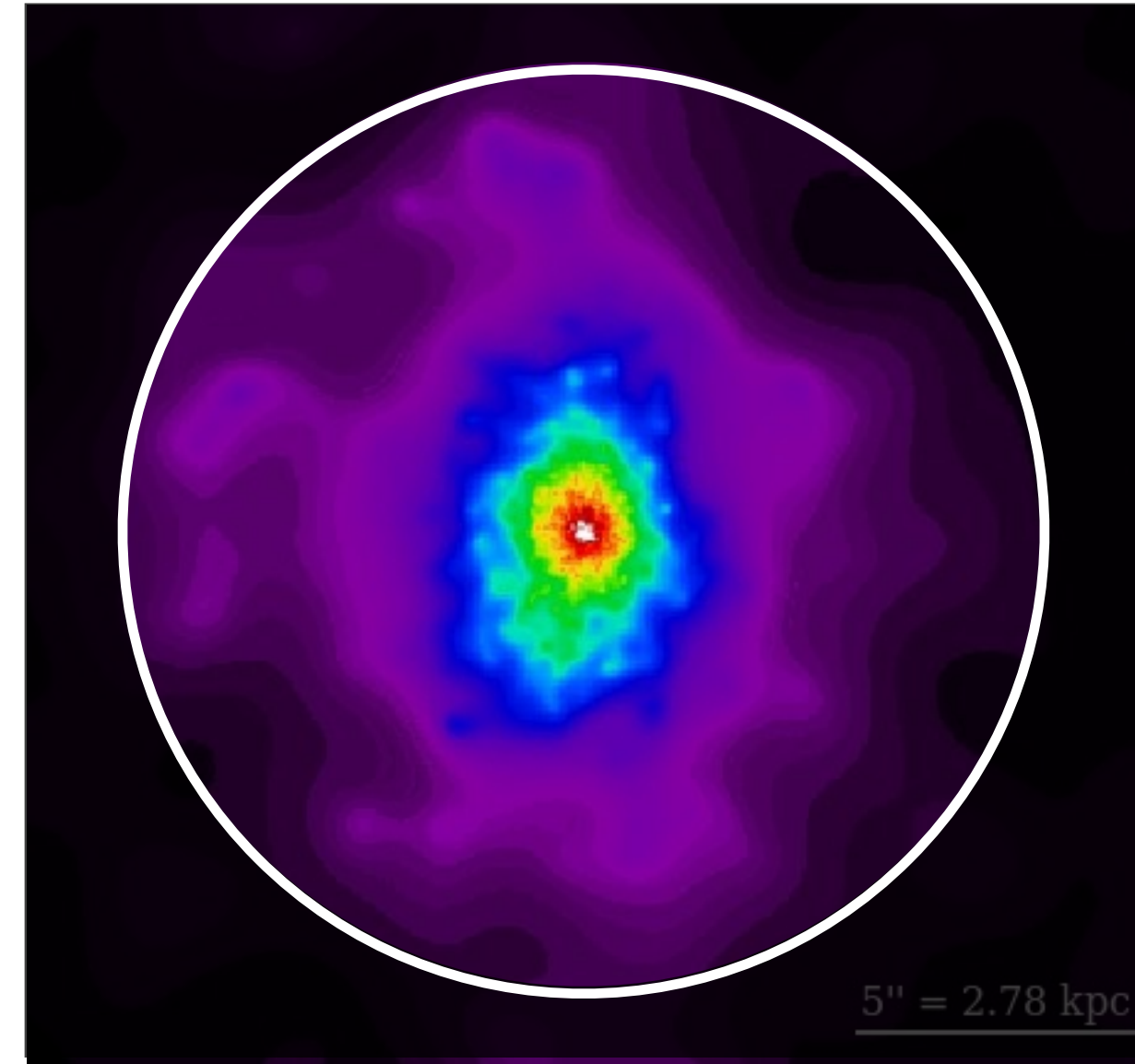
## The Annular Region

➤ Physical Spectral Model:  
Photoelectric Absorption \* PEXRAV

Best Fit

- 1 Photoionization Model
- 1 Thermal Model (2 Preferred)

# 3 NGC 7212 *SPECTRAL FITS*

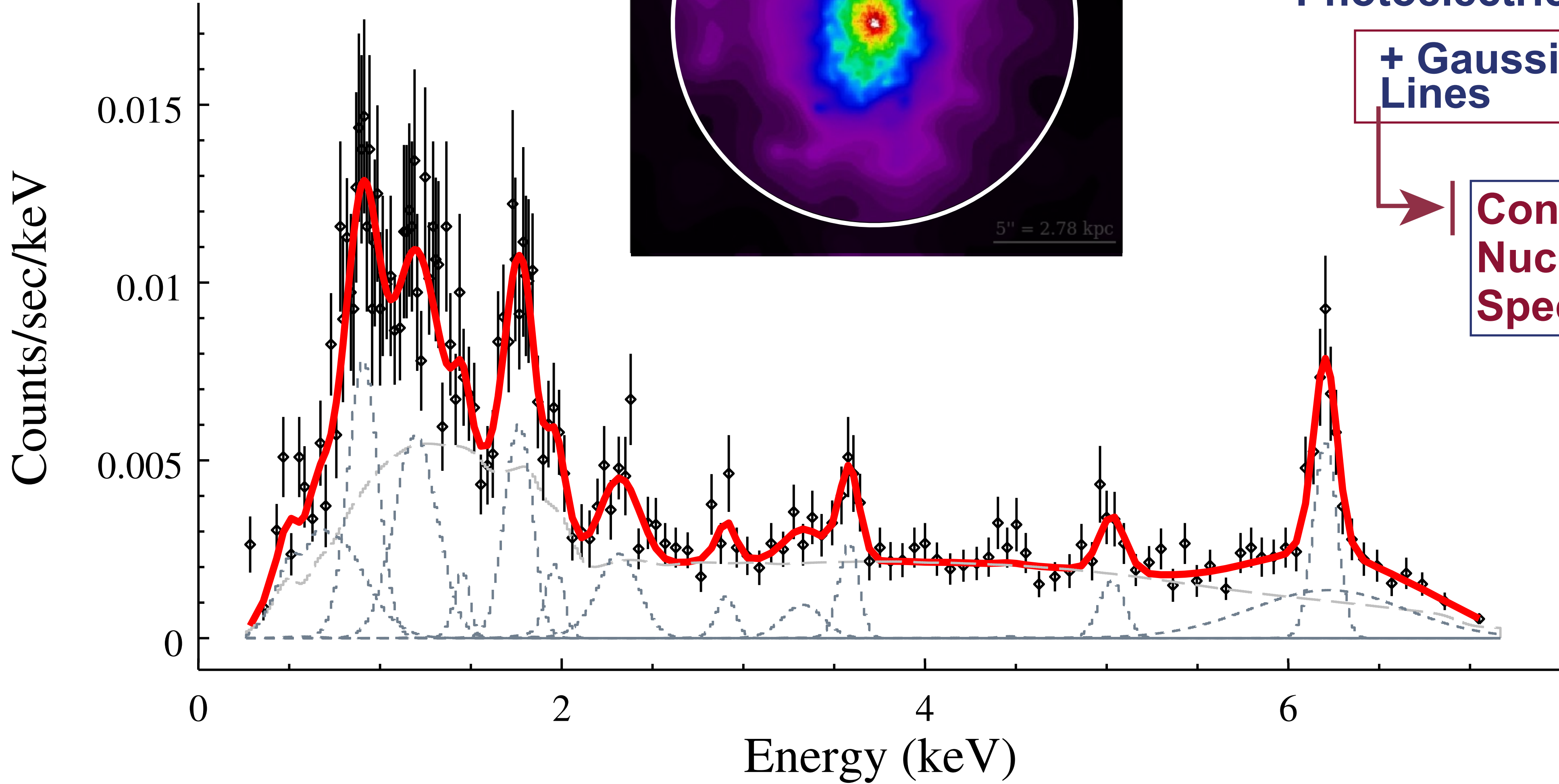


## The Circular Region

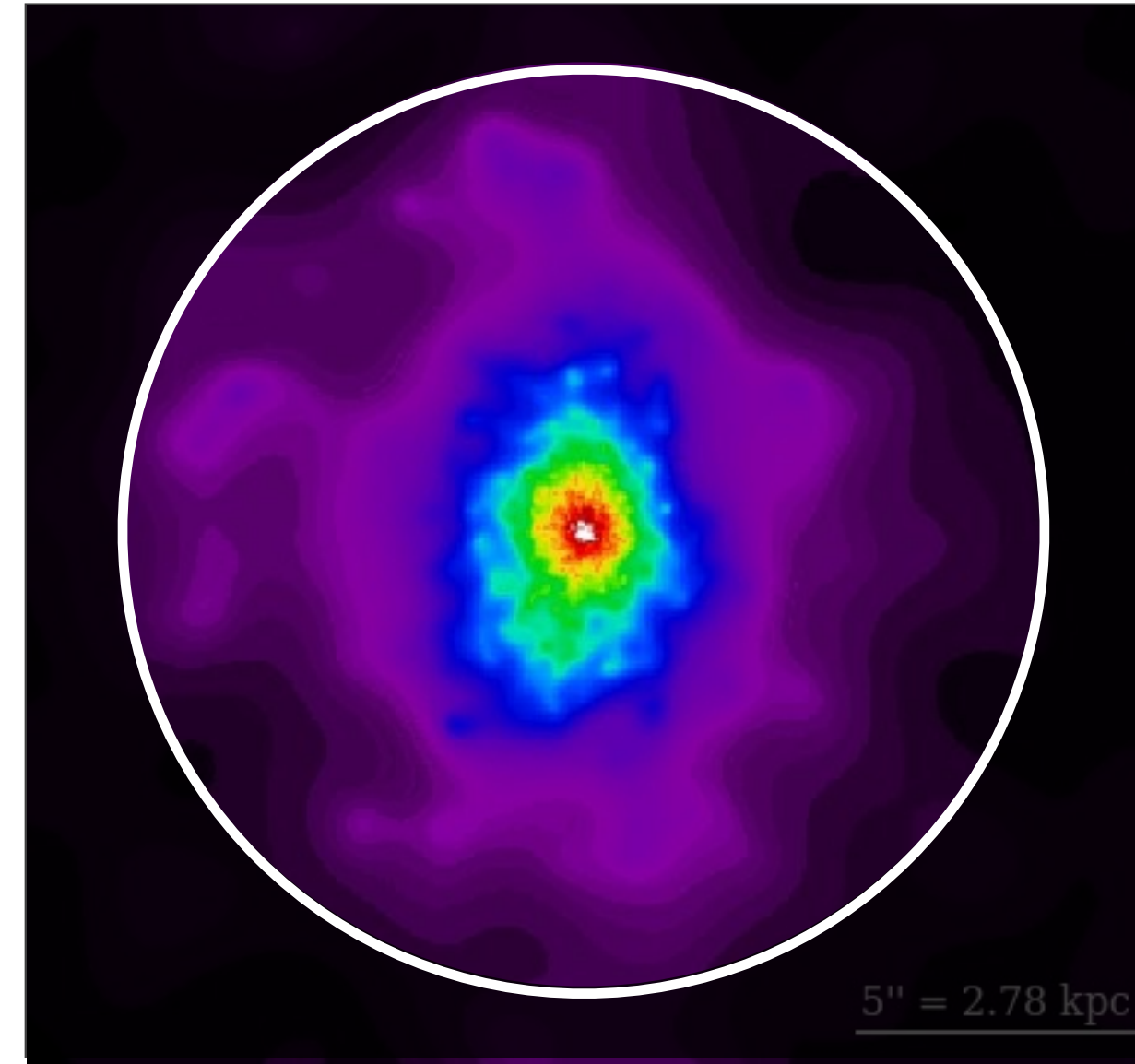
➤ Emission Line Spectra:  
Photoelectric Absorption \* PEXRAV

+ Gaussian Emission Lines

Consistent with the Nuclear and Annular Spectral Fits

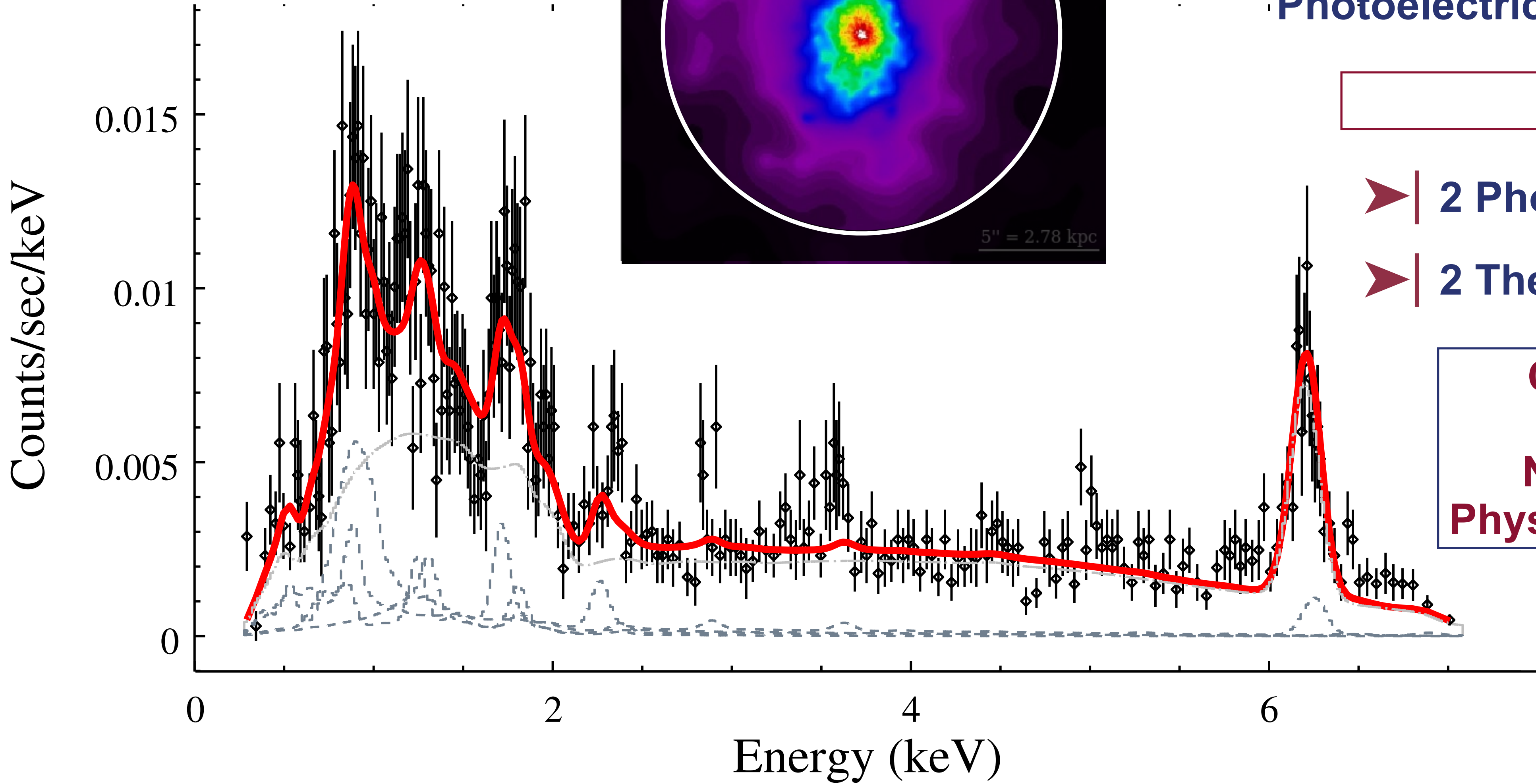


# 3 NGC 7212 *SPECTRAL FITS*



## The Circular Region

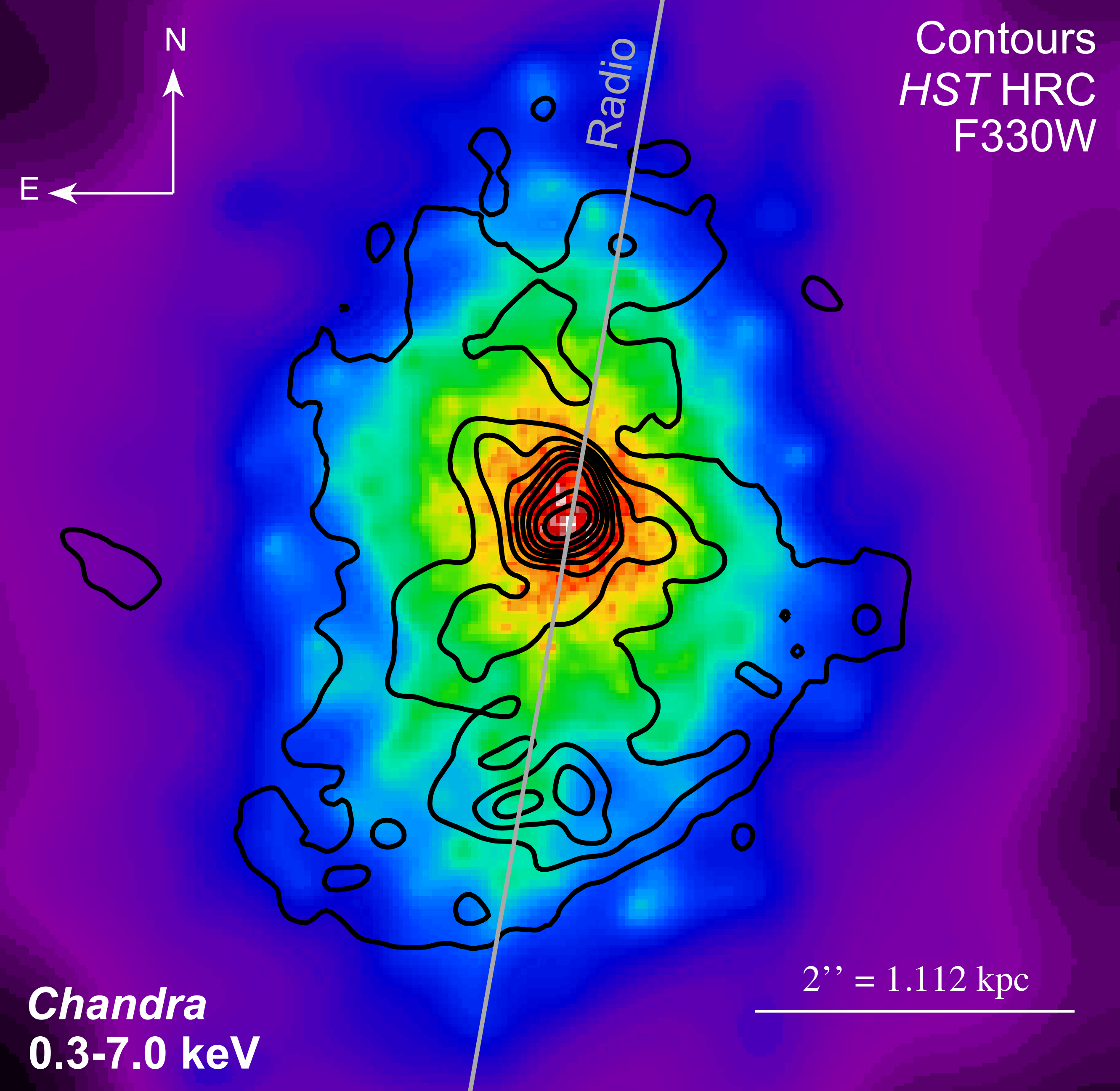
➤ Physical Spectral Model:  
Photoelectric Absorption \* PEXRAV



Best Fit

- 2 Photoionization Models
- 2 Thermal Models

Consistent with a combination of Nuclear + Annular Physical Spectral Models



## Summary

- We observe extended X-ray emission
  - 0.3-3.0 keV: ~3.7 kpc
  - 3.0-6.0 keV: ~2.7 kpc
  - FeKa: ~2.7 kpc
- We observe emission in the cone and cross-cone regions
- We find three emission lines NOT consistent with AGN observations around 2.9 keV, 3.6 keV, 5.2 keV
- NGC 7212 requires a complex combination of photoionization and thermal spectral models