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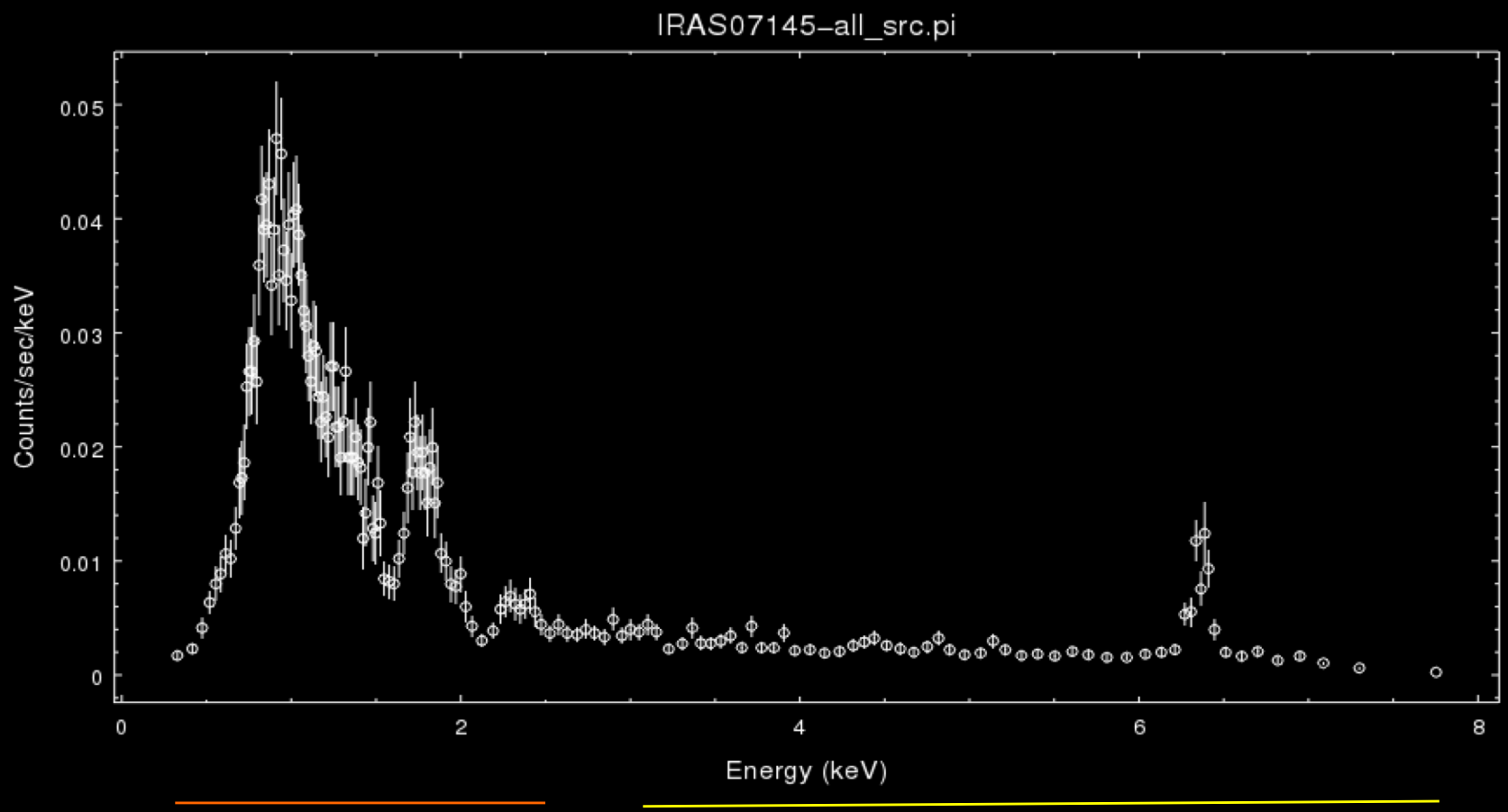
Hard (3-6 keV) Continuum & Fluorescent Fe Kα

In and Beyond the Torus – with *Chandra*'s high-resolution

G. Fabbiano

December 2018

Chandra ACIS X-ray spectrum of CT AGN



Soft line emission
OVII, OVIII, NeIX,
MgXI, SiXIII, etc.

Hard continuum

Fe K lines
Neutral and Fe XXV

Fabbiano et al 2017, 2018a, 2018b, ApJ

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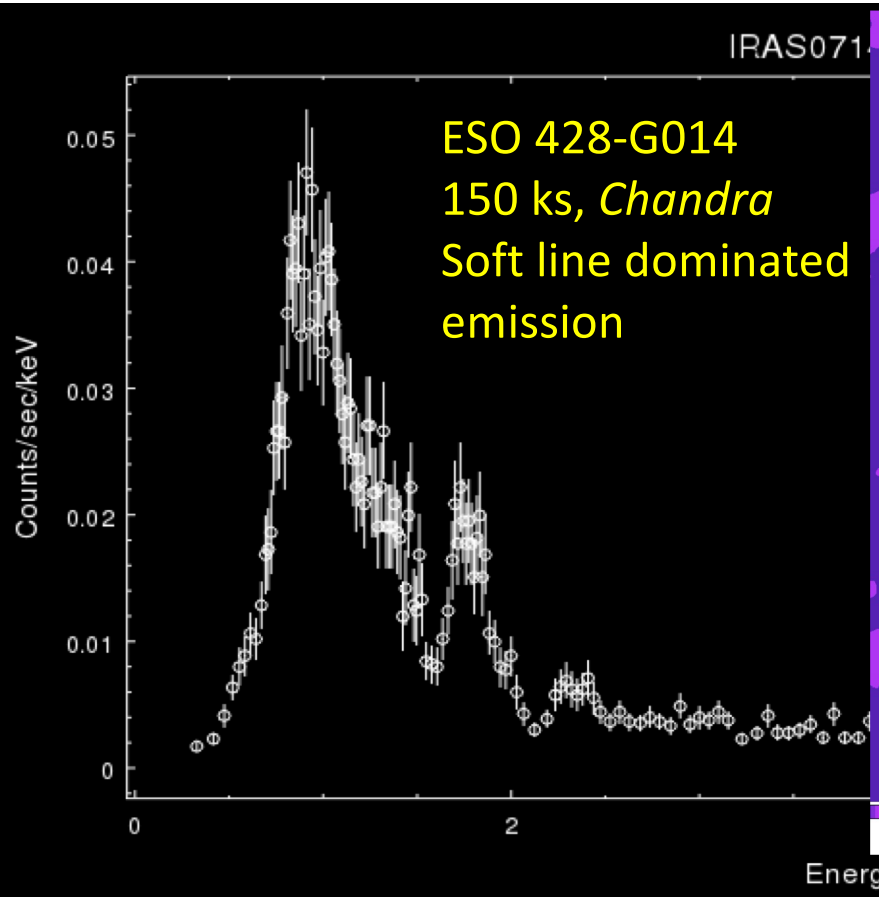

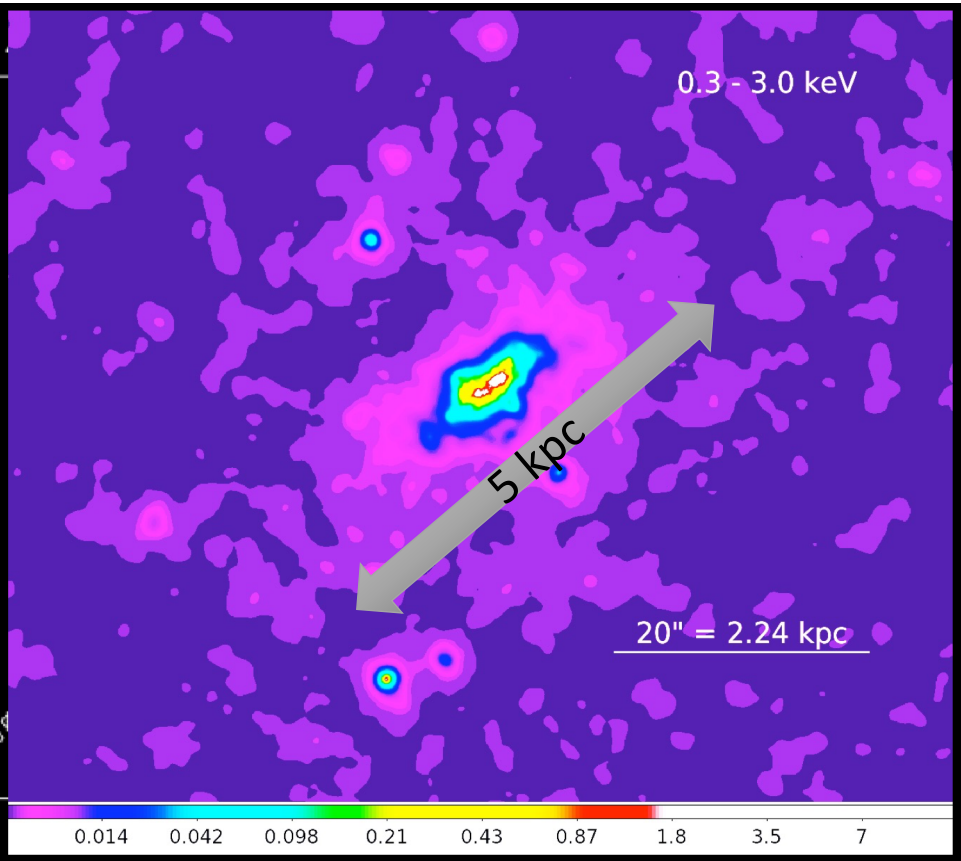

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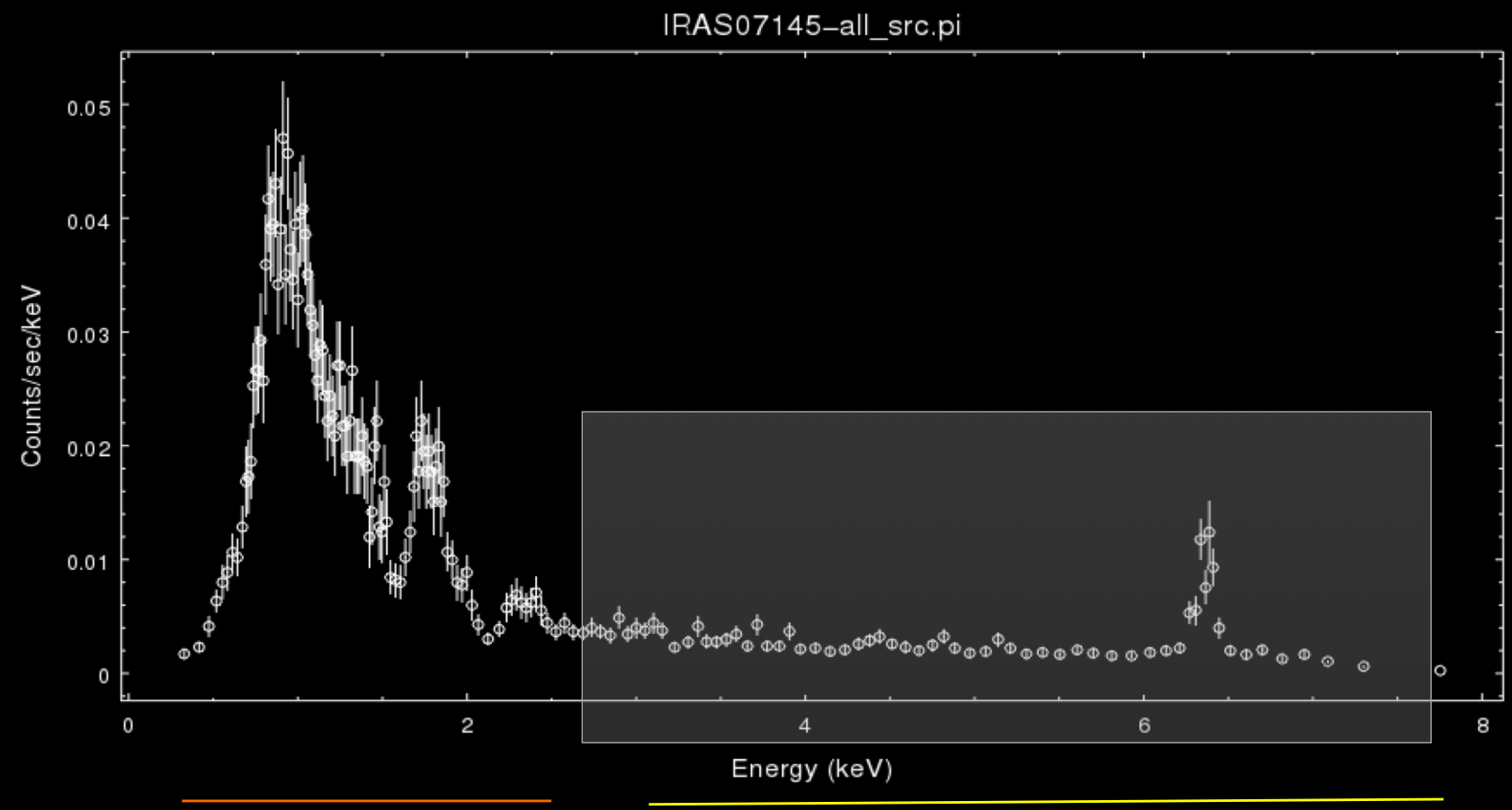

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Beyond the Torus

Kpc-size extended 3-6 keV continuum and often Fe Kα

Deep Chandra observations of CT AGNs

CT AGNs

- ESO 428-G014
- NGC 3393
- NGC 1386
- NGC 7212
- NGC 5643
- NGC 1125
- IC 5063 (to be observed)
- ……

Collaborators

Postdocs - W. P. Maksym, M. Jones

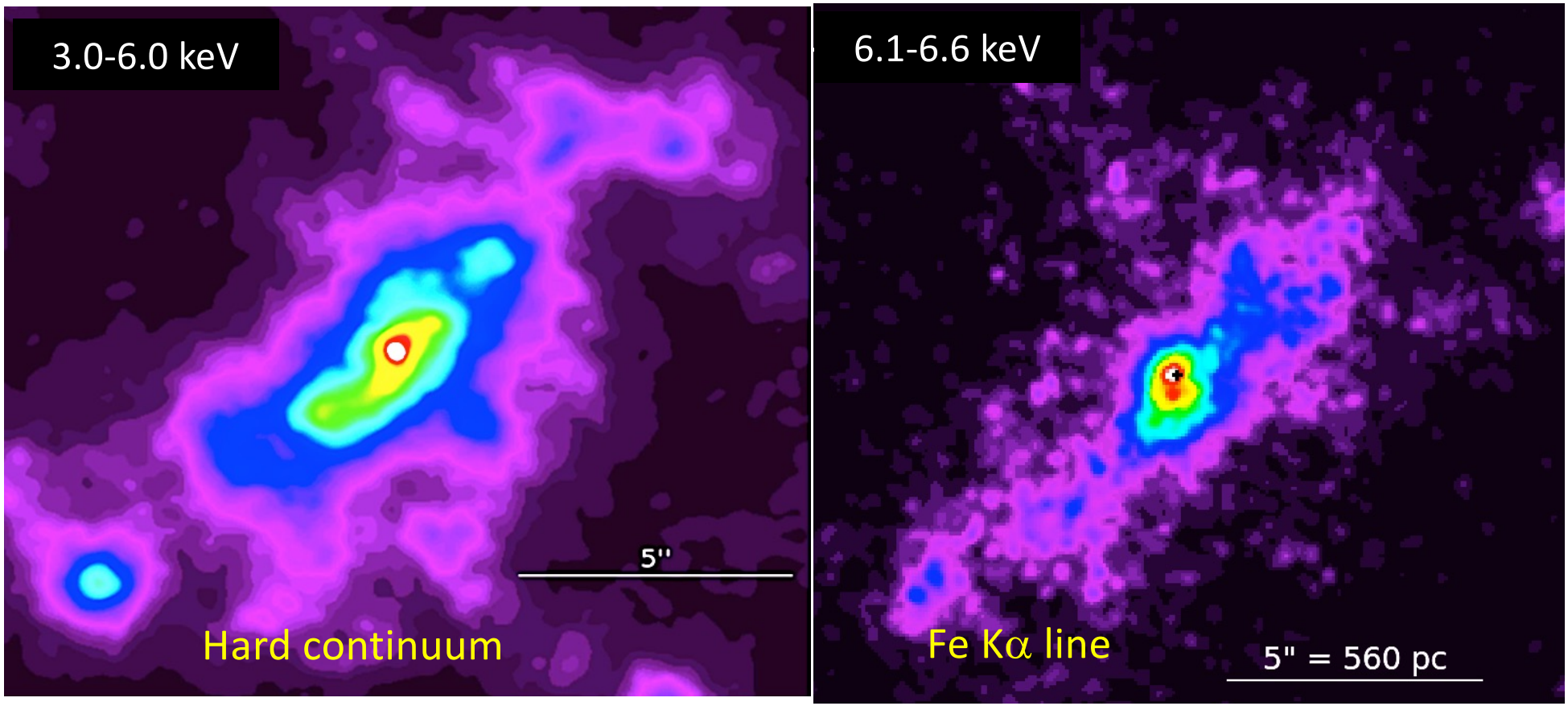
Student - K. Parker

M. Elvis, A. Paggi, Junfeng Wang, G. Risaliti, M. Karovska, A. Siemiginowska, T. Oosterloo, R. Morganti

ESO 428-G014

Chandra ACIS S
T_{exp} ~154 ks

>2 kpc-scale hard continuum and ~ 1 kpc Fe Kα line emission
Counts in extended component (1".5 – 8" annulus) are 30 % of counts in r < 1".5 (Fabbiano et al 2017, 2018a, b)



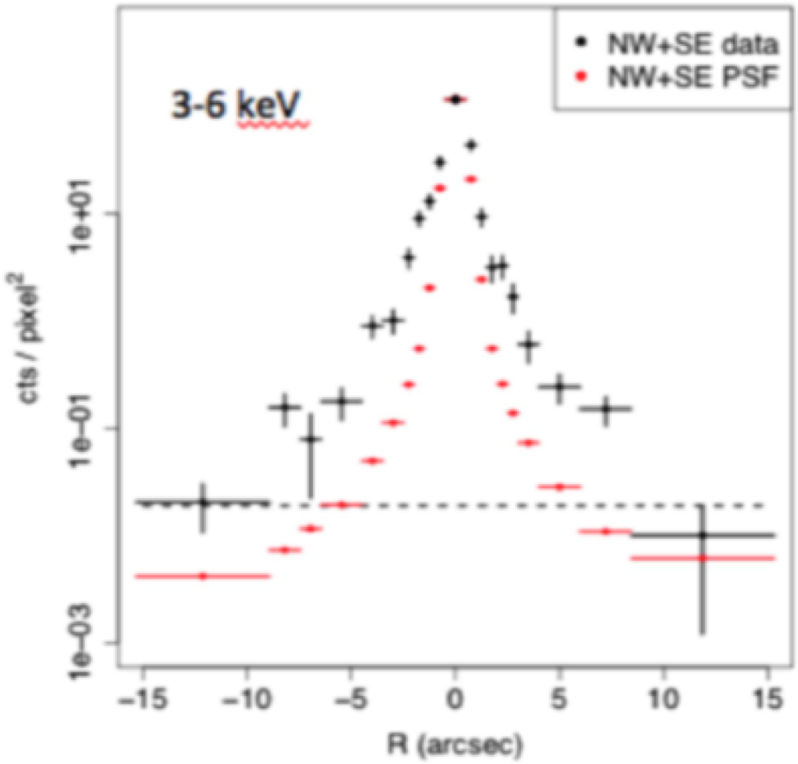
ESO 428-G014

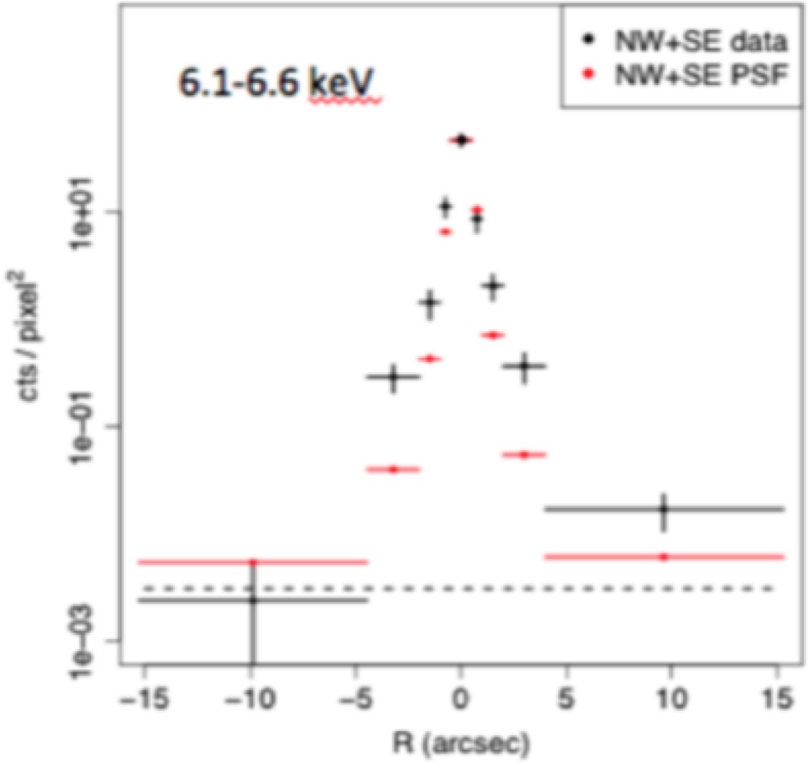
>2 kpc-scale hard continuum and ~1 kpc Fe Kα line emission

Radial profiles (Fabbiano et al 2018a)

X-ray extent is smaller at higher energies

- More centrally concentrated optically thick molecular clouds as in MW?





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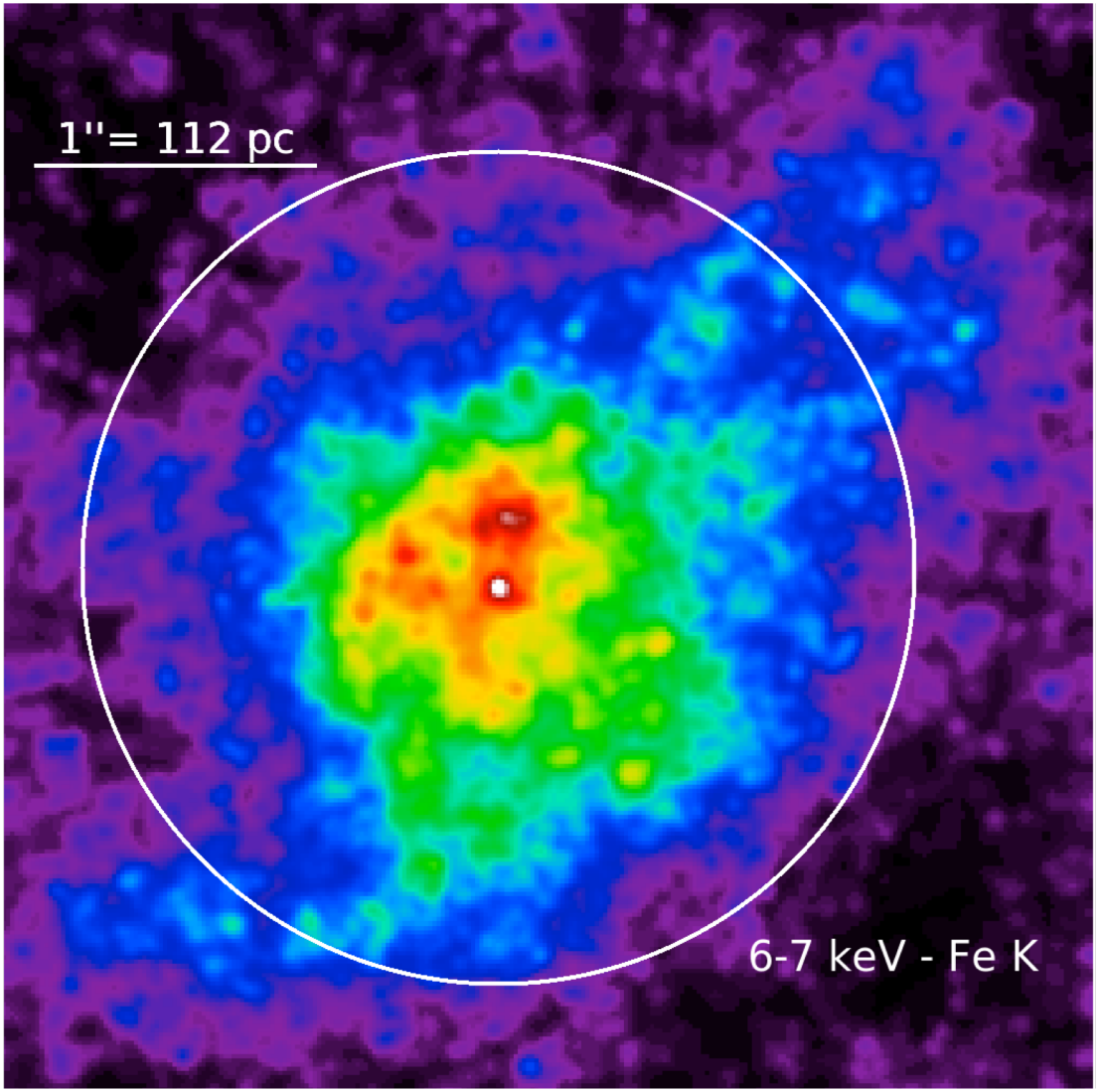
ESO 428-G014

Fe Kα near the nucleus

R < 1”.5: C (extended)
~ 0.4 C (nuclear PSF)
R < 8”: Total counts
~ 1.8 C (nuclear PSF)

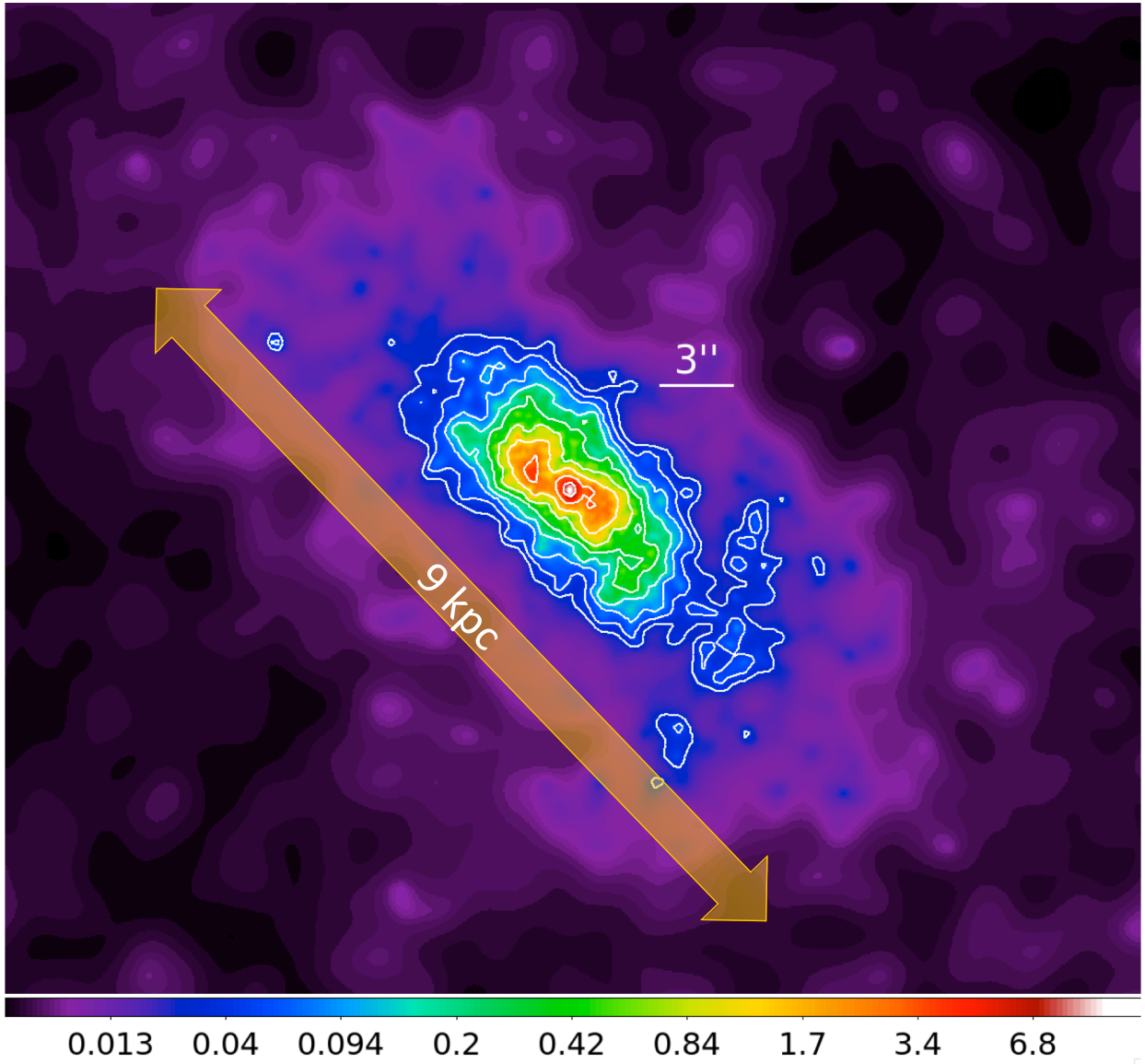
In a “typical” non-Chandra spectral extraction region the large Fe K component contributes almost as much as the nuclear source
i.e. XMM-Newton, NuStar, Athena



NGC 3393 – Soft (0.3-2.5 keV)

Chandra ACIS S

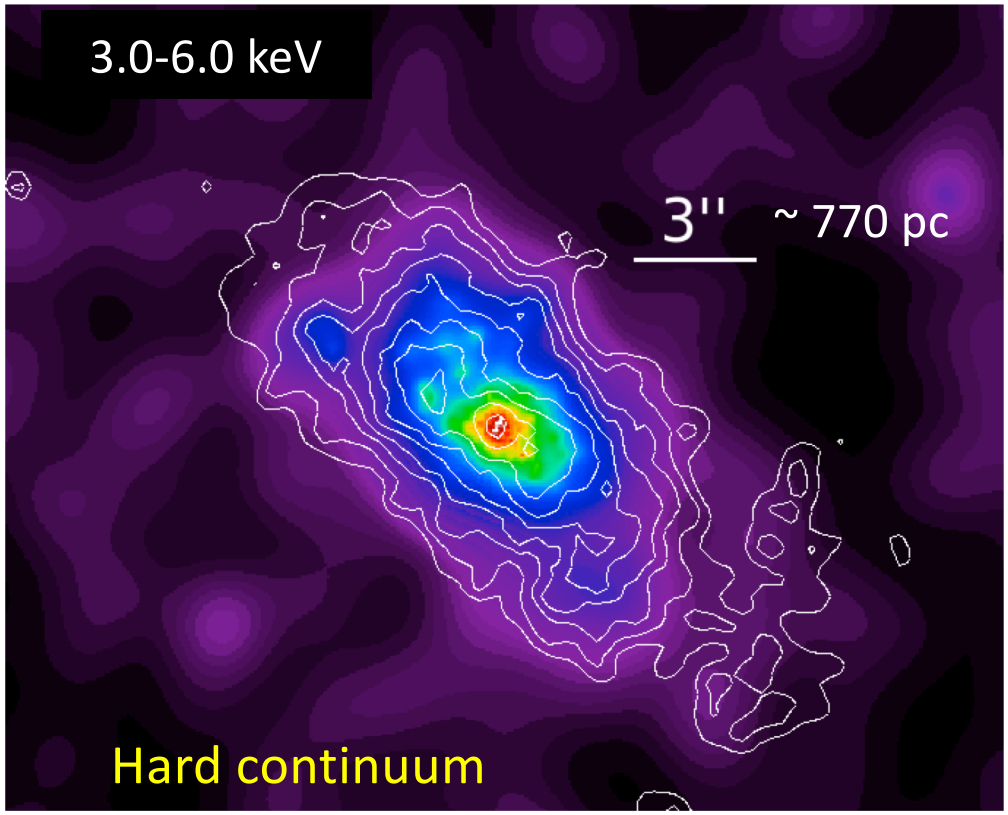
T_{exp} ~315 ks

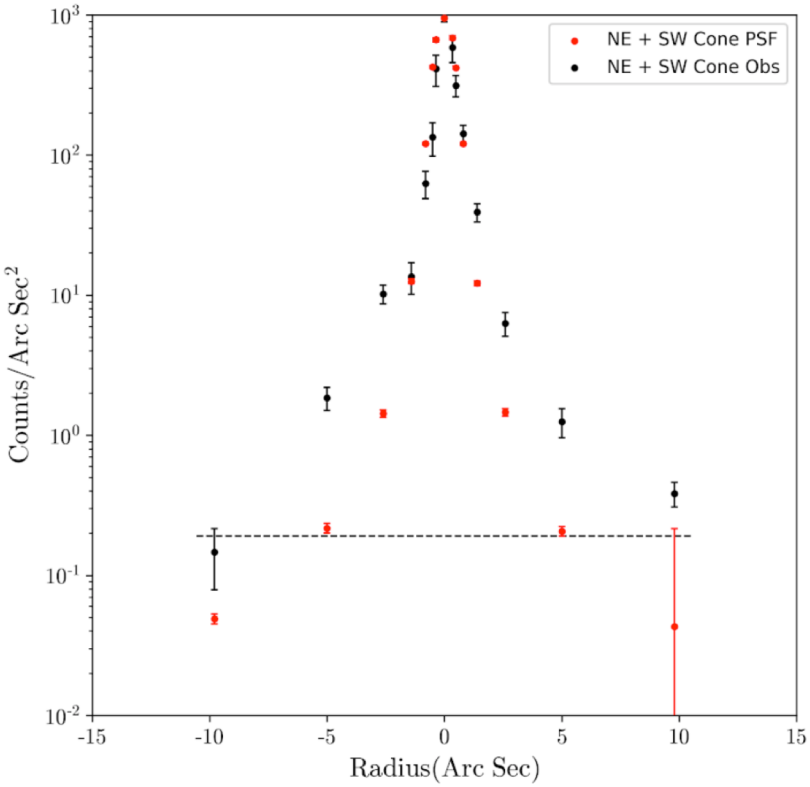


NGC 3393

~ 3 kpc-scale hard continuum emission

Contours are from soft (0.3-2.5 keV) line-dominated bicone emission (Parker et al 2019 Master Thesis)





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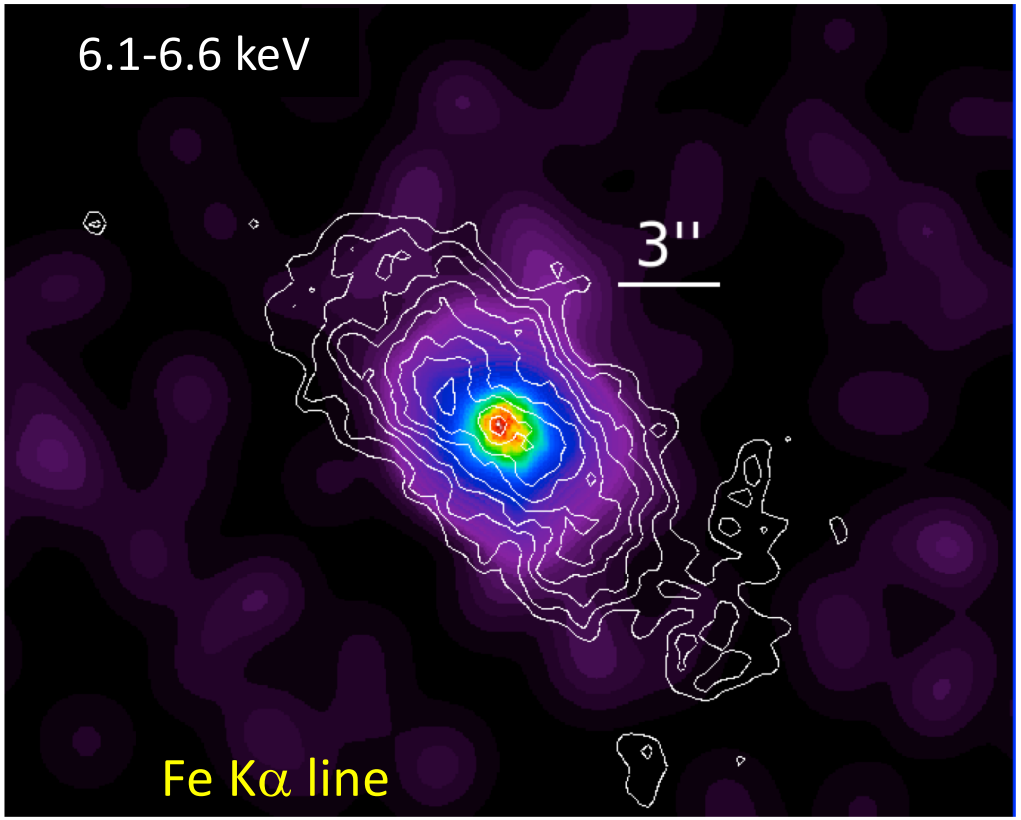
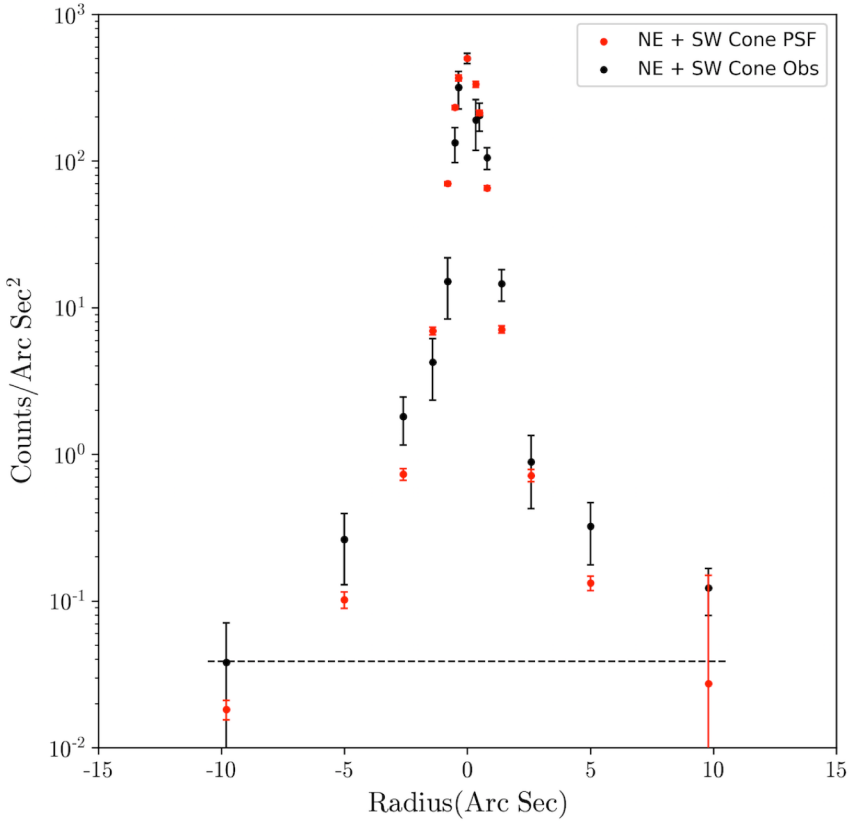
NGC 3393

Fe Kα line emission - consistent with PSF?

Contours are from soft (0.3-2.5 keV) line-dominated bicone emission (Parker et al 2019 Master Thesis)

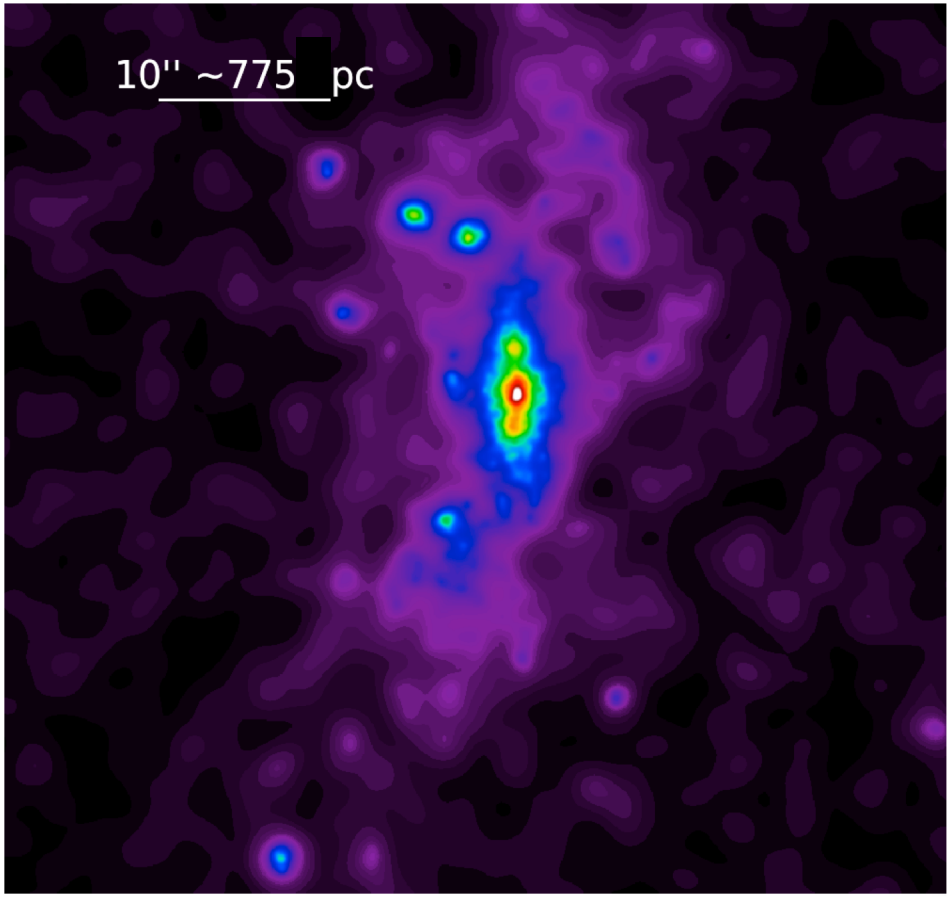


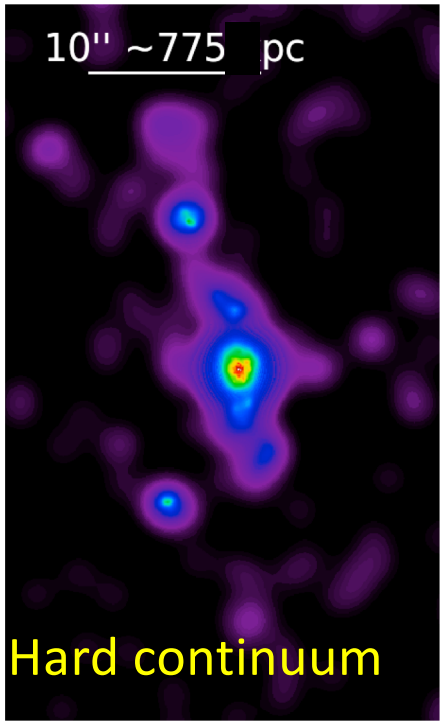


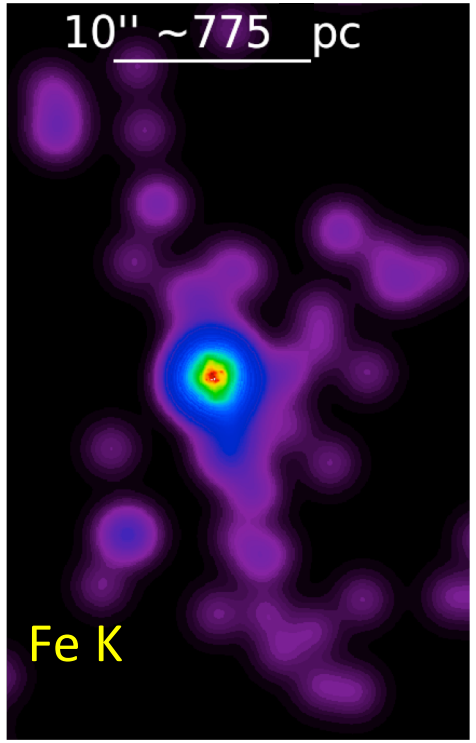
NGC 1386

Chandra ACIS S
T_{exp} ~100 ks

~1.5 kpc-scale hard continuum and possibly Fe K
(Parker, Thesis)





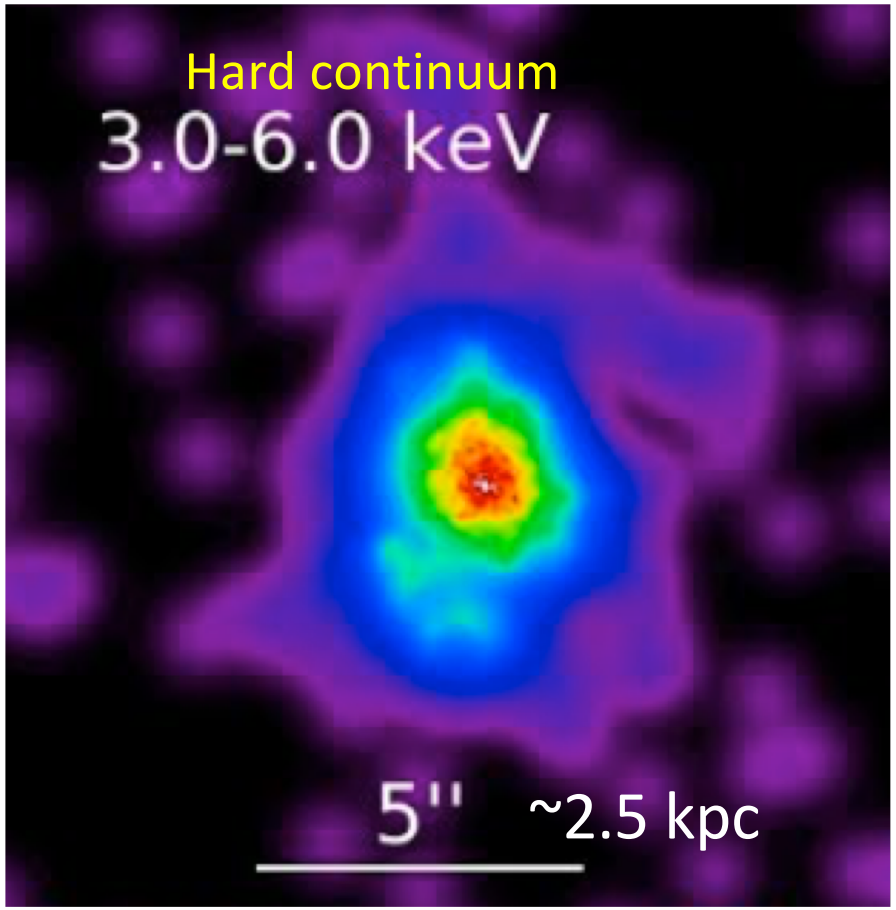


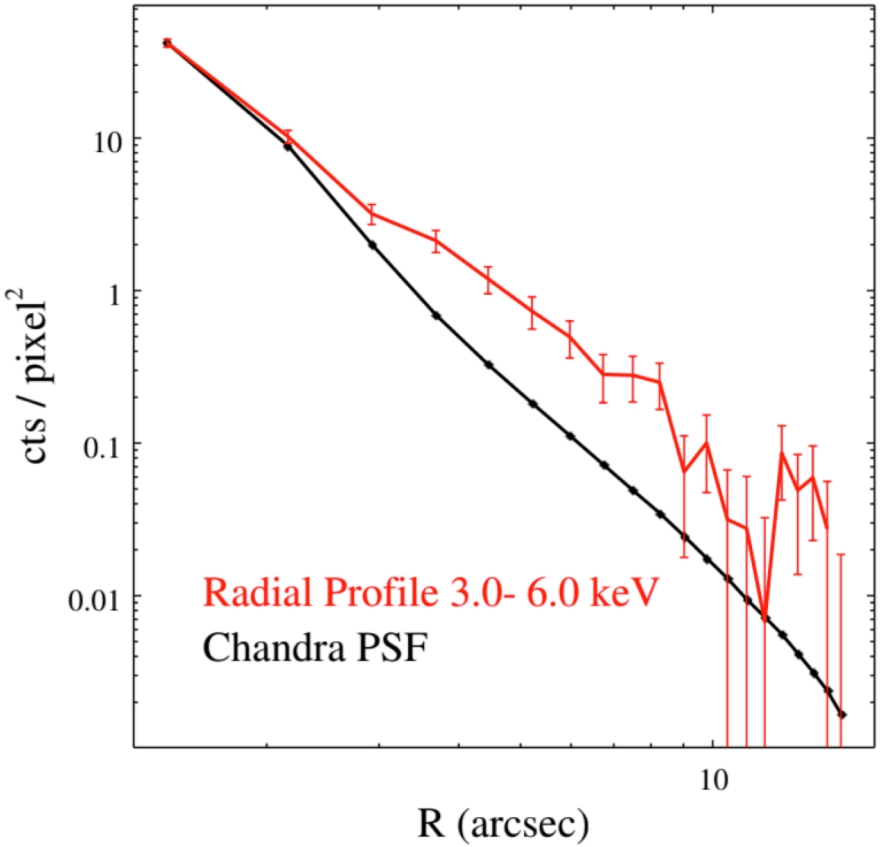
NGC 7212

Chandra ACIS S
T_{exp} ~128 ks

~8 kpc-scale hard continuum

The largest scale so far (Mackenzie Jones et al 2019, in preparation)





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‘Torus’ & Near-Torus

30-100 pc morphology

CT AGNs

- NGC 4945
- ESO 428-G014
- NGC 5643
- ……

Collaborators

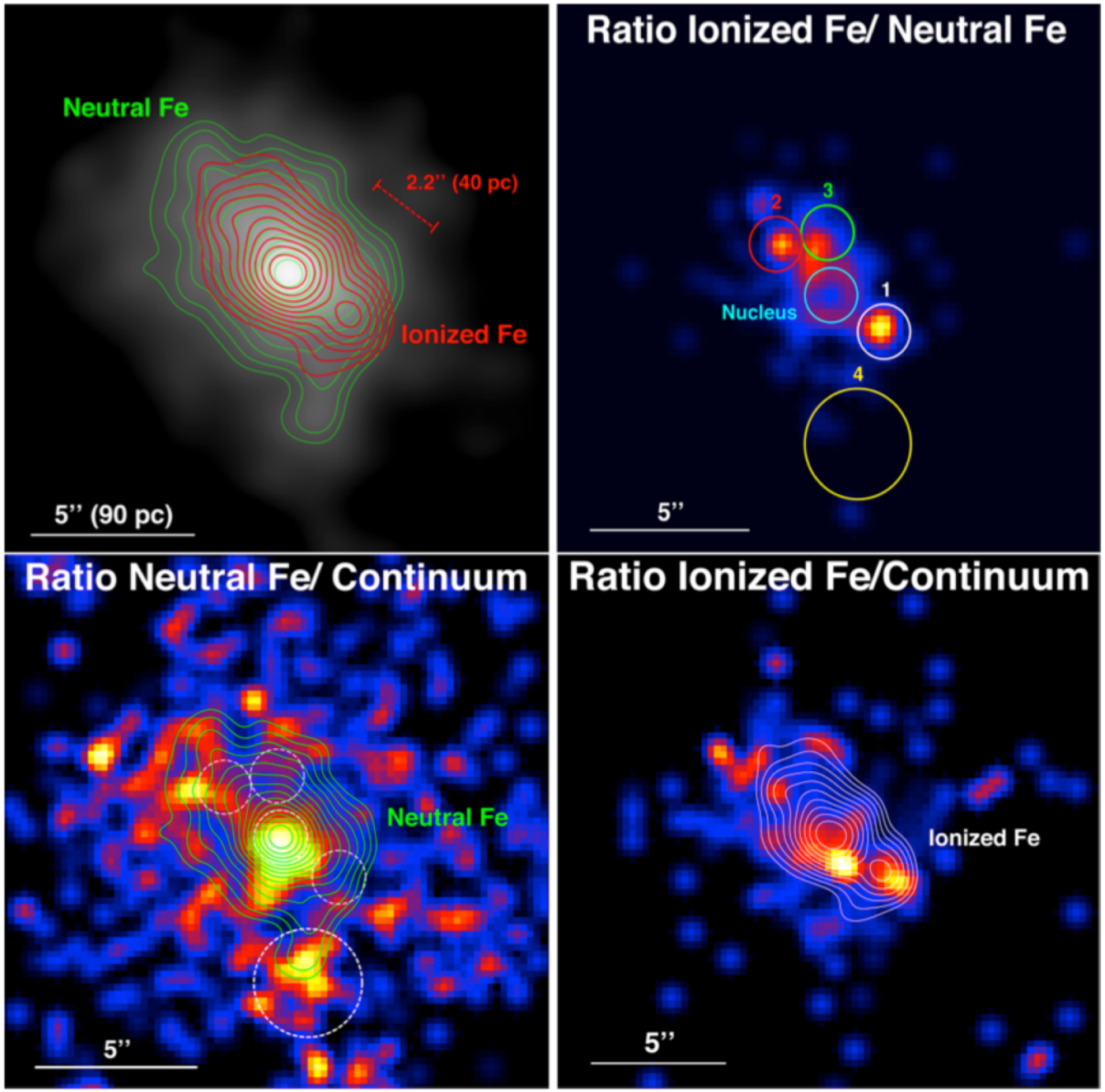
A. Marinucci, M. Elvis, A. Paggi, Junfeng Wang, G. Risaliti, M. Karovska, A. Siemiginowska, W. P. Maksym, M. Volonteri, L. Mayer

NGC 4945

~200 pc-scale flattened hard continuum and FeKα emission in the cross-cone direction.

Clumpy Fe Kα neutral and ionized (Fe XXV) structure (Marinucci et al 2012, 2017).

Torus?



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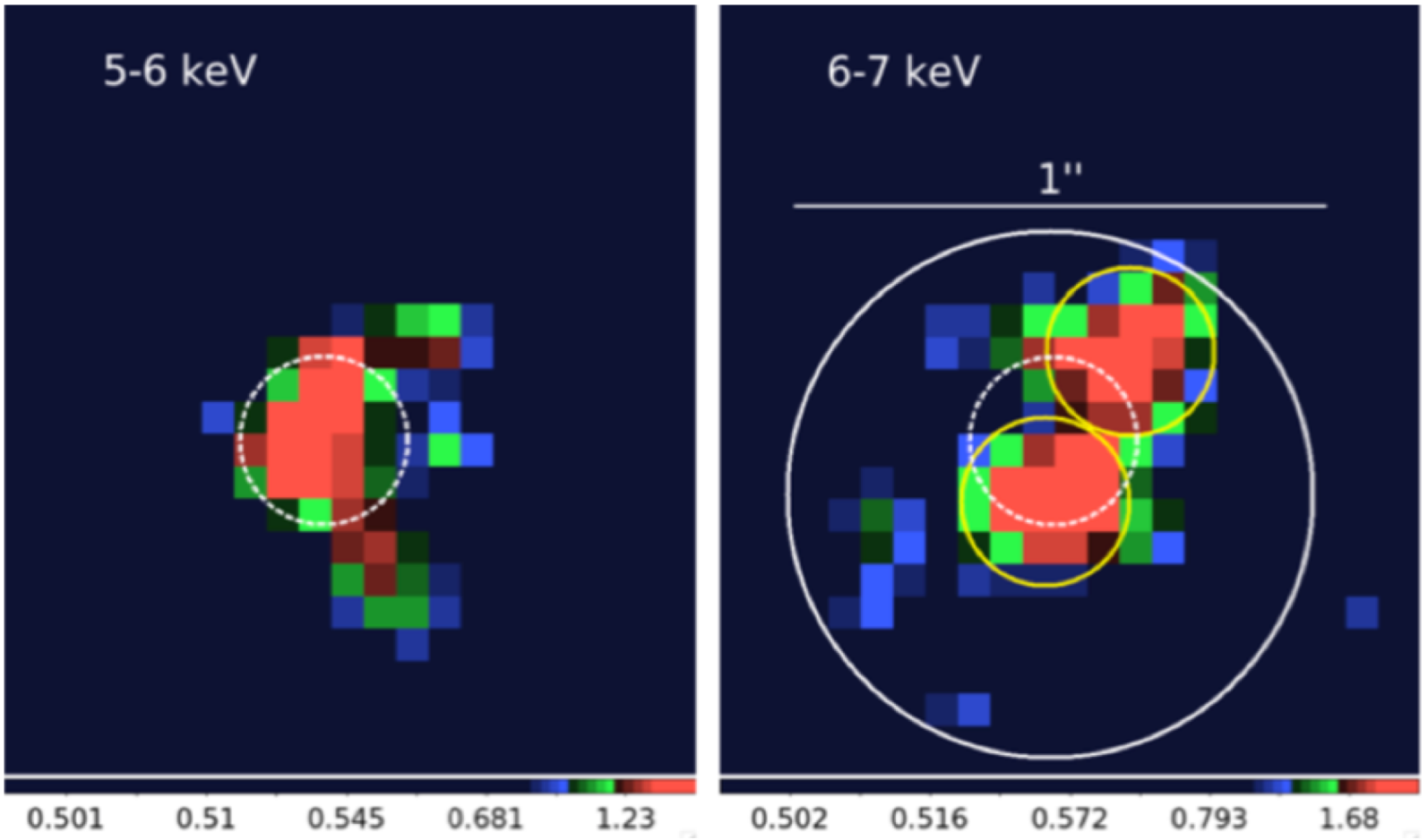
ESO 428-G014

~30 pc separation double clump in FeKα emission, single source in continuum (Fabbiano et al 2018, ApJ, in press).



Chandra & ALMA

Complementary views of the scattering clouds and scattered radiation

CT AGNs

- NGC 5643
- ESO 428-G014
- ……

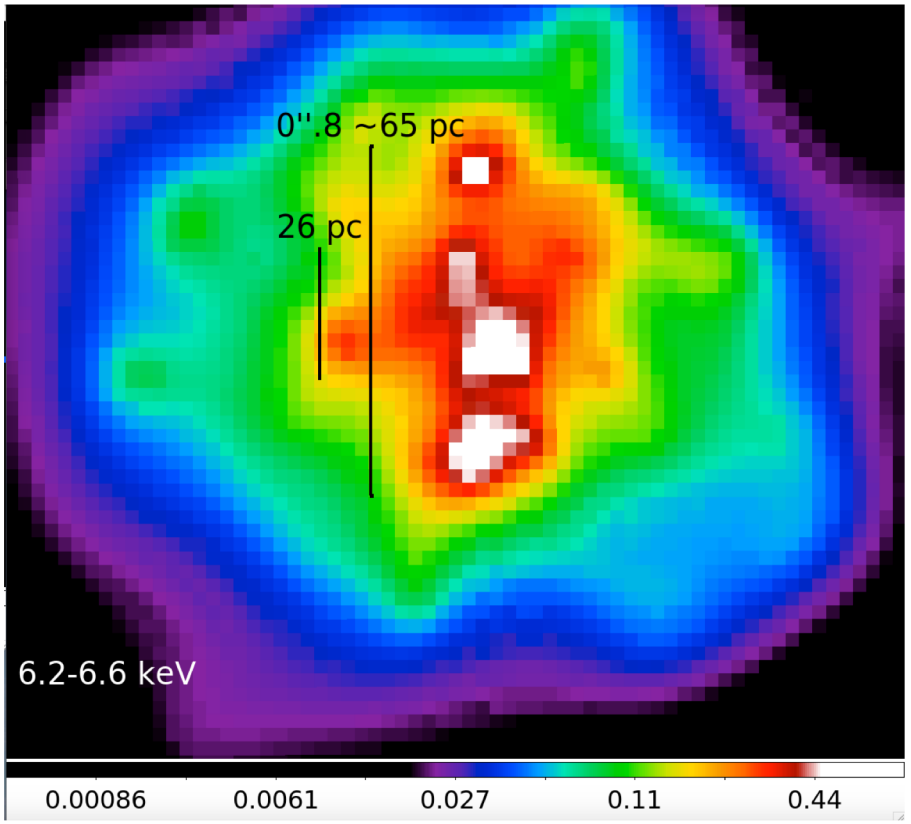
Collaborators

M. Elvis, A. Paggi, Siemiginowska, C. Feruglio

NGC 5643

N-S ~65 pc Fe Kα nuclear feature found in deep on-axis Chandra ACIS data (Fabbiano et al 2018, ApJ Letters, in press).

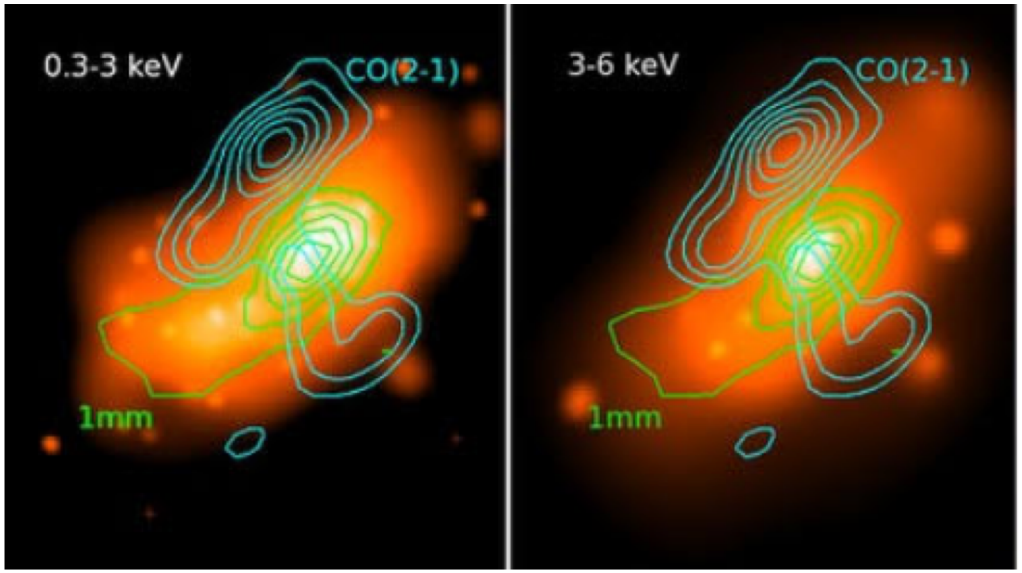
The Fe Kα feature is spatially consistent with the N-S elongation found in the ALMA high resolution imaging (Alonso-Herrero et al 2018), but slightly more extended than the rotating molecular disk of r=26 pc indicated by the kinematics of the CO(2-1) line.



T_{exp} ~113 ks

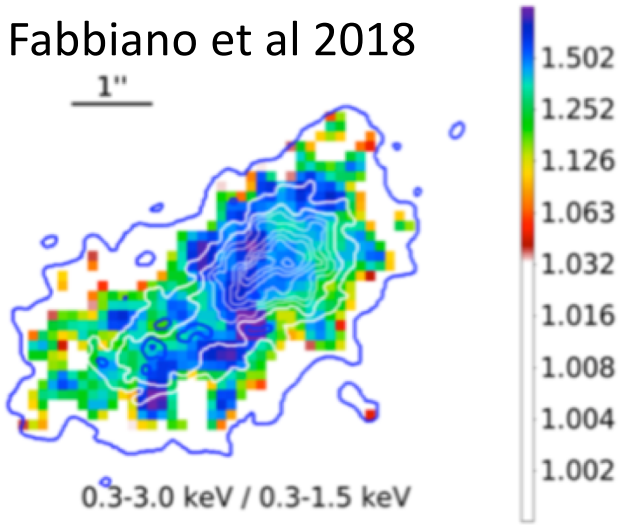
ESO 428-G014

ALMA 1 mm continuum follows hard Chandra 3-6 keV X-ray continuum (Feruglio et al in preparation)



ALMA CO(2-1) in nuclear region and ‘hard excess’ areas N and S of nucleus (Feruglio et al in preparation)

Fabbiano et al 2018



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Summary

Not all the hard continuum and Fe K emission of CT AGNs come from the obscuring circumnuclear torus

In ESO 420-G014 the luminosity of extended hard (3-6 keV) and Fe K 6.4 keV line emission is comparable to that of the nuclear point source

At high sub-arcsecond resolution, clumpy circumnuclear Fe K emission

Chandra and ALMA provide complementary views

- In NGC 5643, N-S X-ray structure follows the N-S rotating CO(2-1) disk
- In ESO 420–G014 CO(2-1) emission correlated with localized hard X-ray excess.
- 1 mm continuum follows the hard X-ray emission (scattered AGN photons)

Food for thought

See Martin Elvis' talk

Possible uncertainties in spectral modeling of torus in CT AGNs

We must consider the full AGN – galaxy interaction to understand AGN emission

Observationally, deep high-resolution Chandra ACIS images are needed to find and characterize extended and complex torus and AGN-galaxy interaction emission

➔ **Lynx: Large, Chandra resolution telescope with IFU capability**

Food

See Martin

- Possible ur AGNs
- We must c derstand AGN emission
- Observatio es are needed to find and AGN-galaxy interaction
- ➔ Lynx: capability