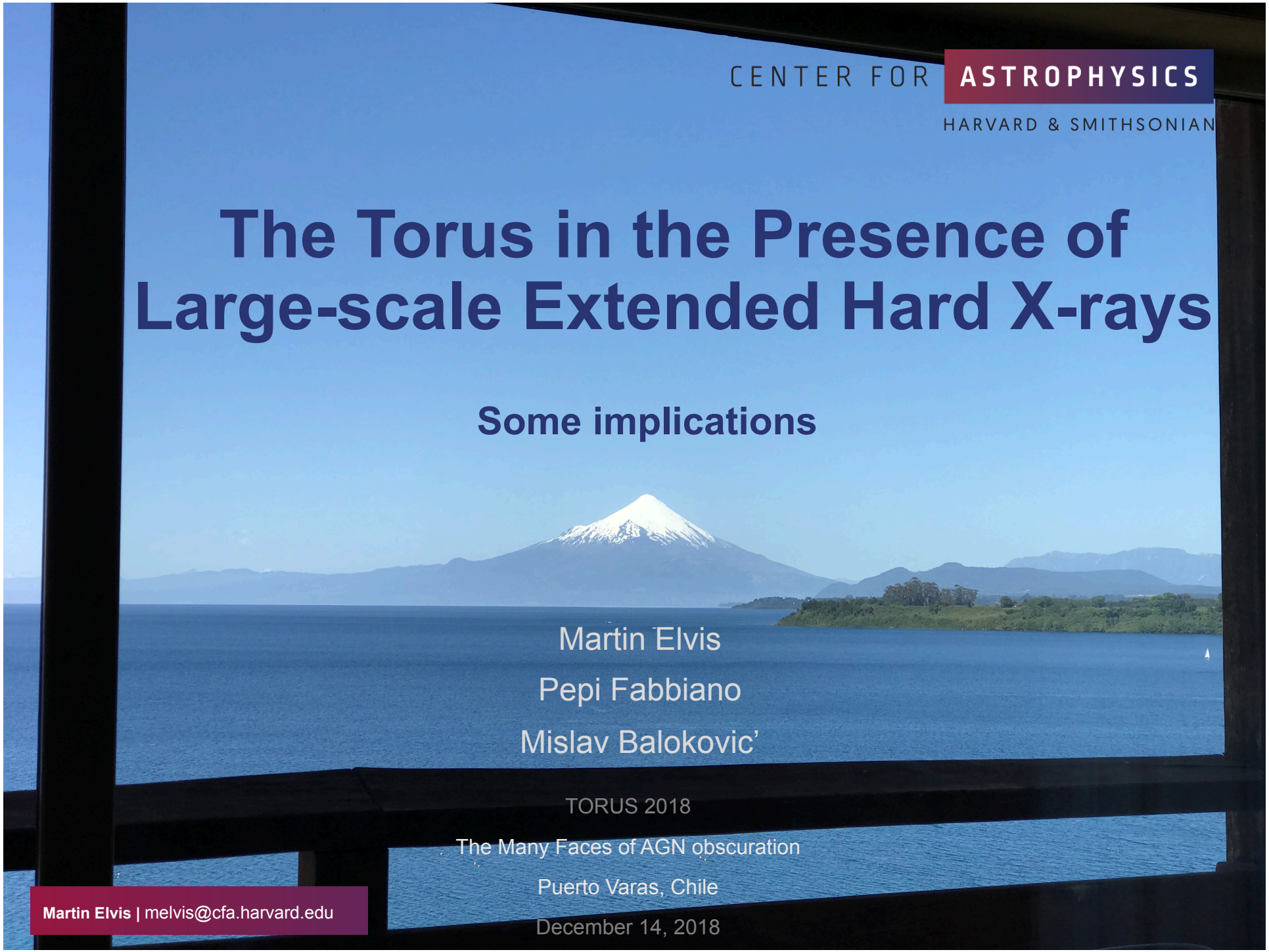


# The Torus in the Presence of Large-scale Extended Hard X-rays

## Some implications

Martin Elvis
Pepi Fabbiano
Mislav Balokovic'

TORUS 2018
The Many Faces of AGN obscuration
Puerto Varas, Chile
December 14, 2018

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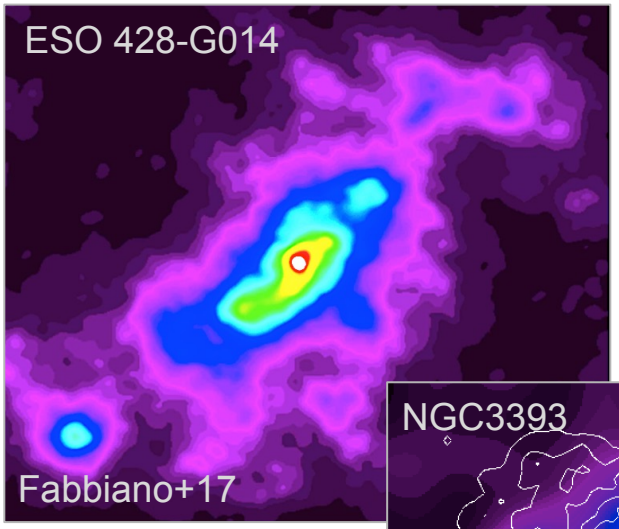


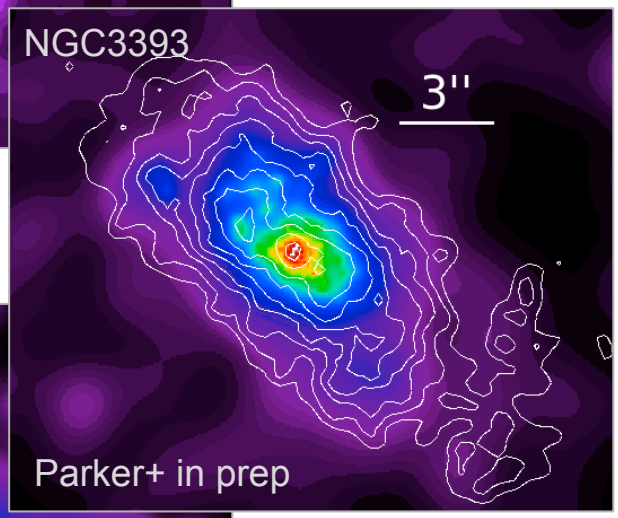


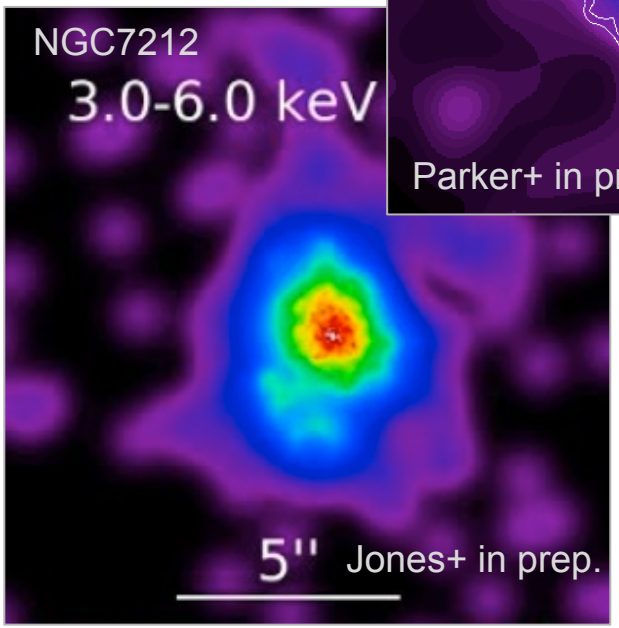


# Kiloparsec extended Hard X-rays are common in CT AGN

See Pepi Fabbiano & Franz Bauer talks

*Chandra* < 0.3" resolution

3 – 6 keV & Fe-K

~50 pc - ~4 kpc radially

Up to 70% of observed flux

In Compton Thick AGN

2 morphologies:

- bi-cone *and/or*
- "torus"

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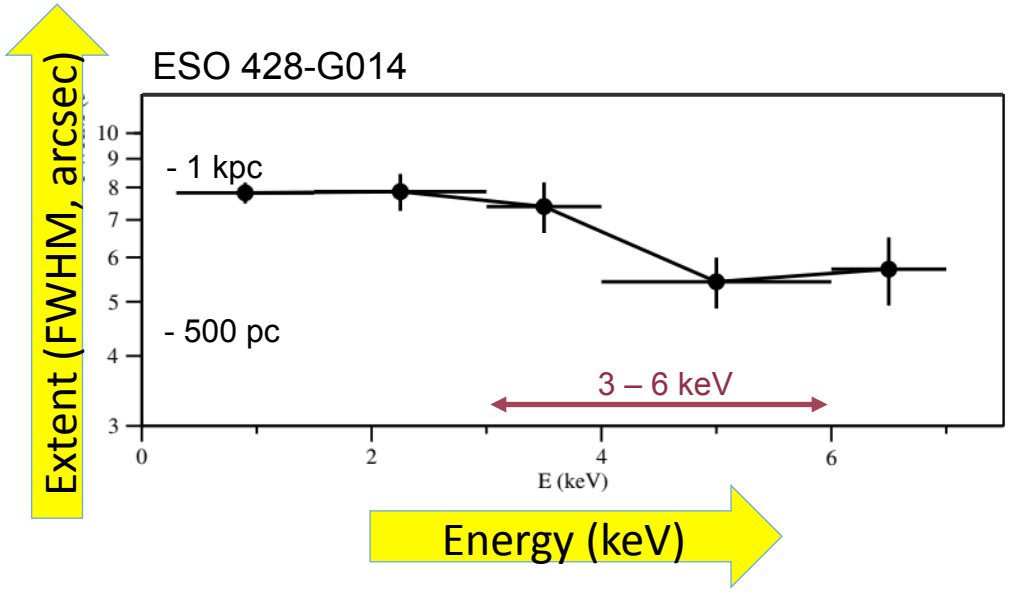
# Bi-cones = ISM Molecular clouds




Fabbiano +2018 II

**FWHM(High E) < FWHM(Low E)**

High $N_H$ material is interior to Low $N_H$

Partial covering by high $N_H$

→ Feedback in action?

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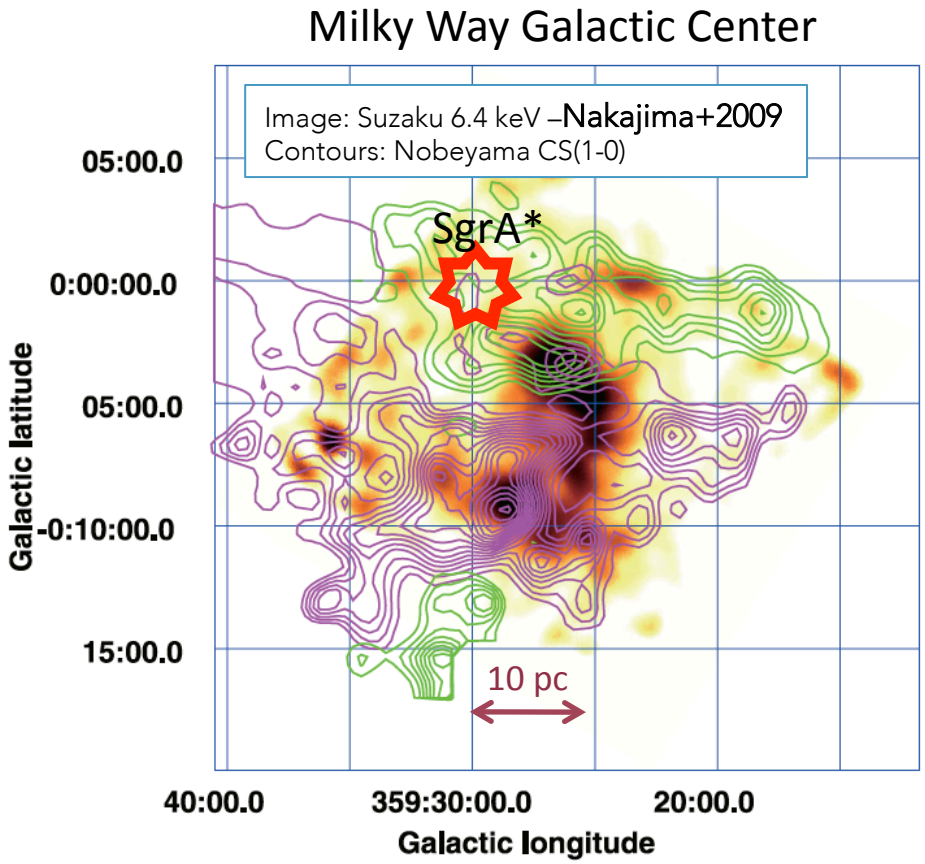


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**Milky Way example**

Fluorescent Fe-K-I coincident with Molecular Clouds

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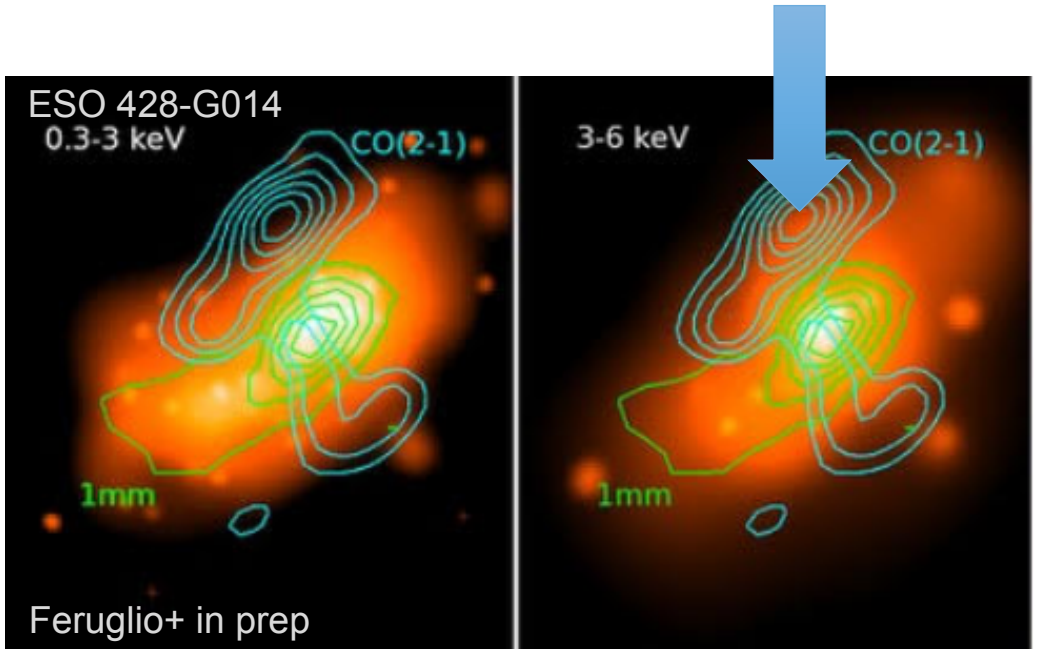


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**CO maps Compton Thin $N_H$**

C-Thin $N_H$ arises in host disk.

[Lawrence & Elvis (1982!) & many others]

→ 2 absorbers. (Prieto talk)

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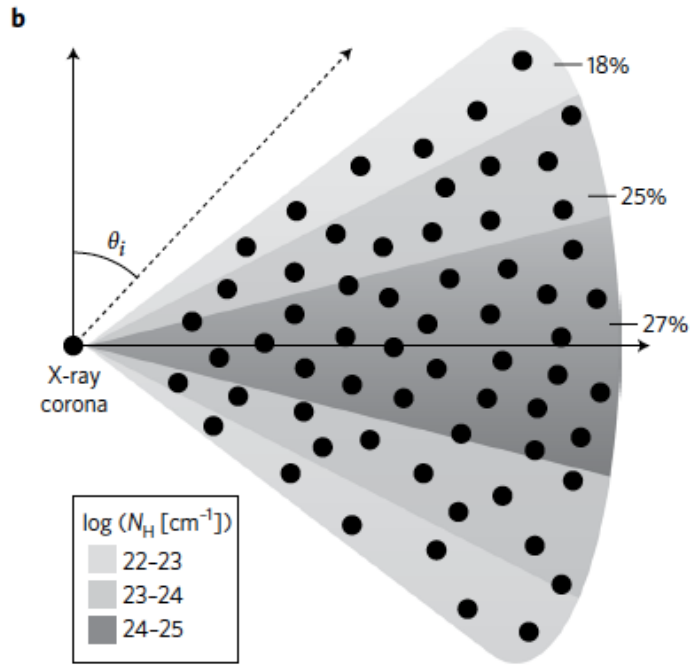


Ramos Almeida & Ricci 2017

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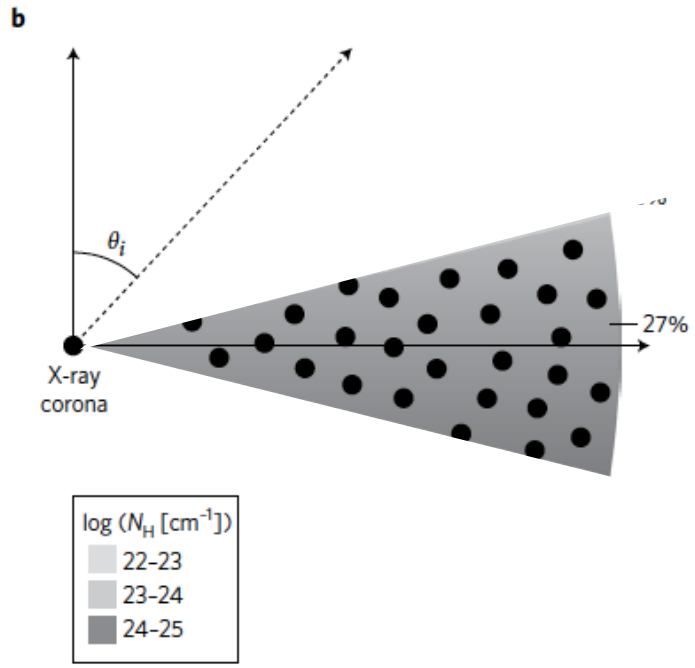


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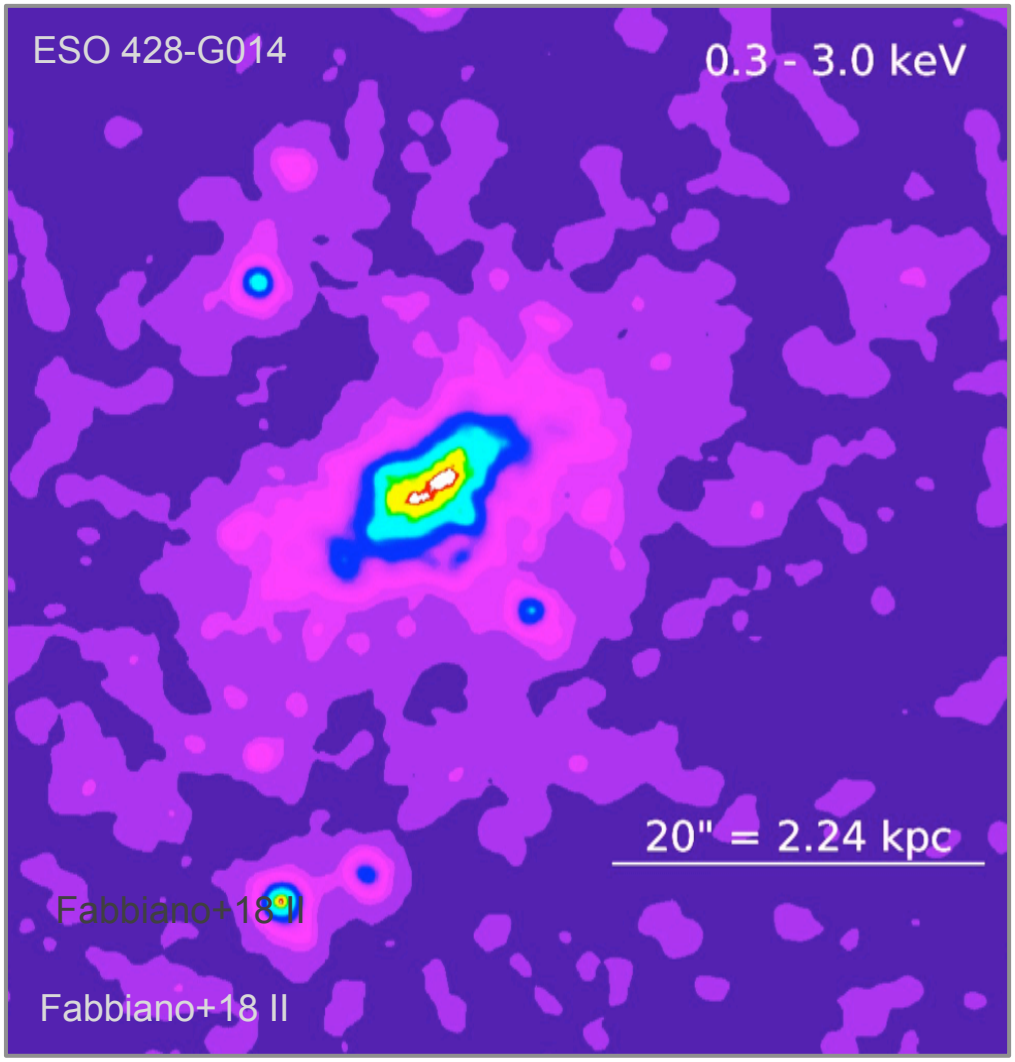
# Cross-cone extent = a Porous Torus?




**Clear extent perpendicular to bi-cone**

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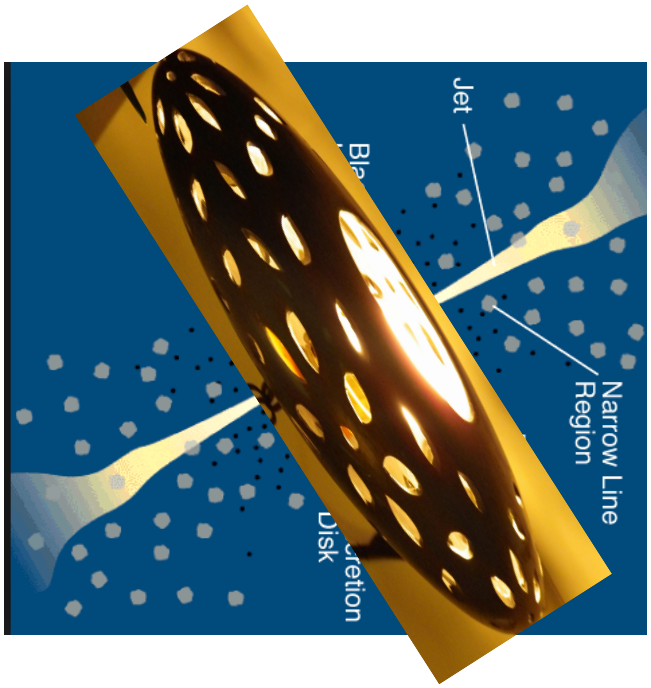


Fabbiano+18 II

## Clear extent perpendicular to bi-cone

Follows bi-cone extent vs Energy

Holes in the Torus? ~10% transmission

Fabbiano+18 II

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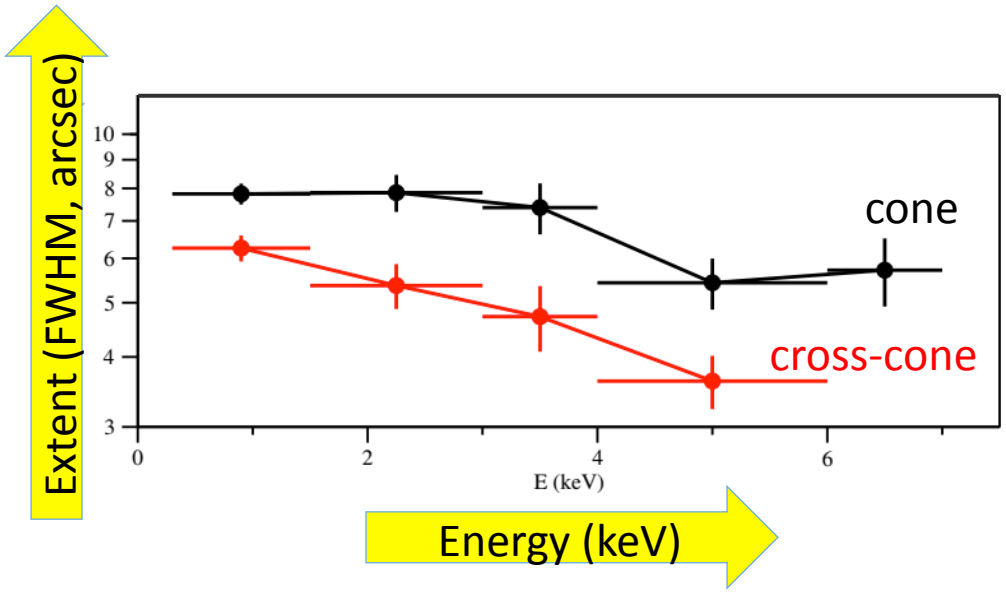


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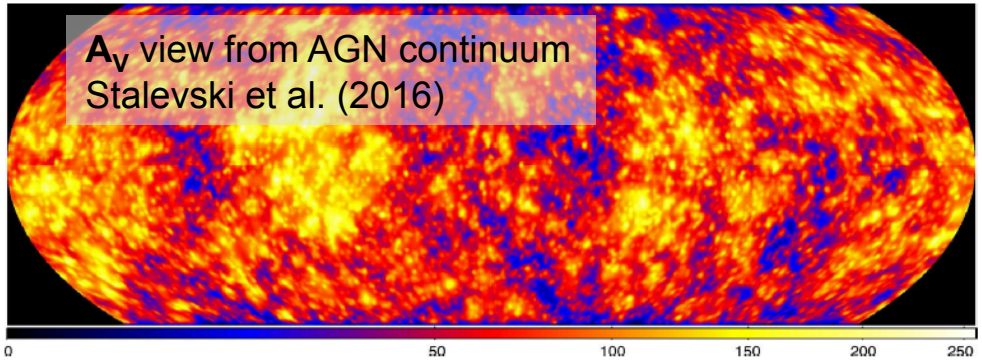


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Holes in the Torus? ~10% transmission

Inter-clump medium: $N_H(\text{cold})<10^{21}$ cm$^{-2}$

<< $N_H$ in e.g. Stalevski et al. 2016 model

(also Baskin & Laor 2018?)

OK with eclipse events (e.g. Markowitz+14)

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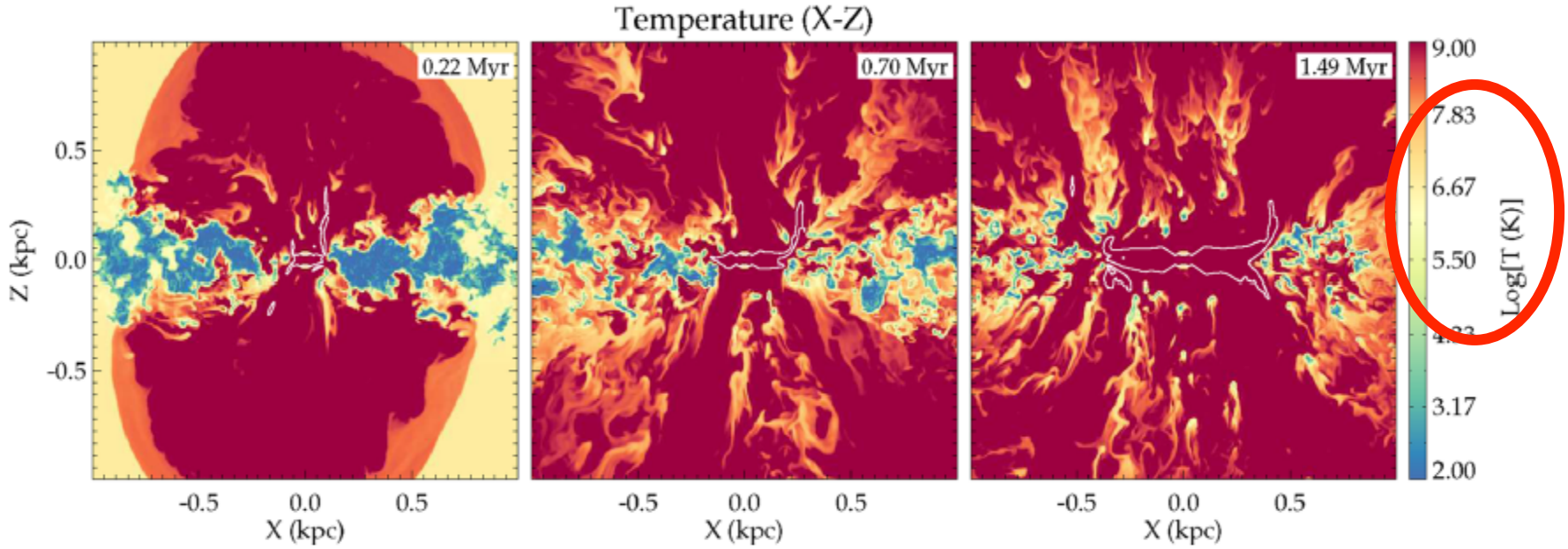
# Cross-cone extent = Jet blowback?

## Hot Cocoon from Jet interaction with Molecular Clouds

E.g. Mukherjee et al. (2018) simulations; Morganti talk

Co-extensive X-ray – Radio

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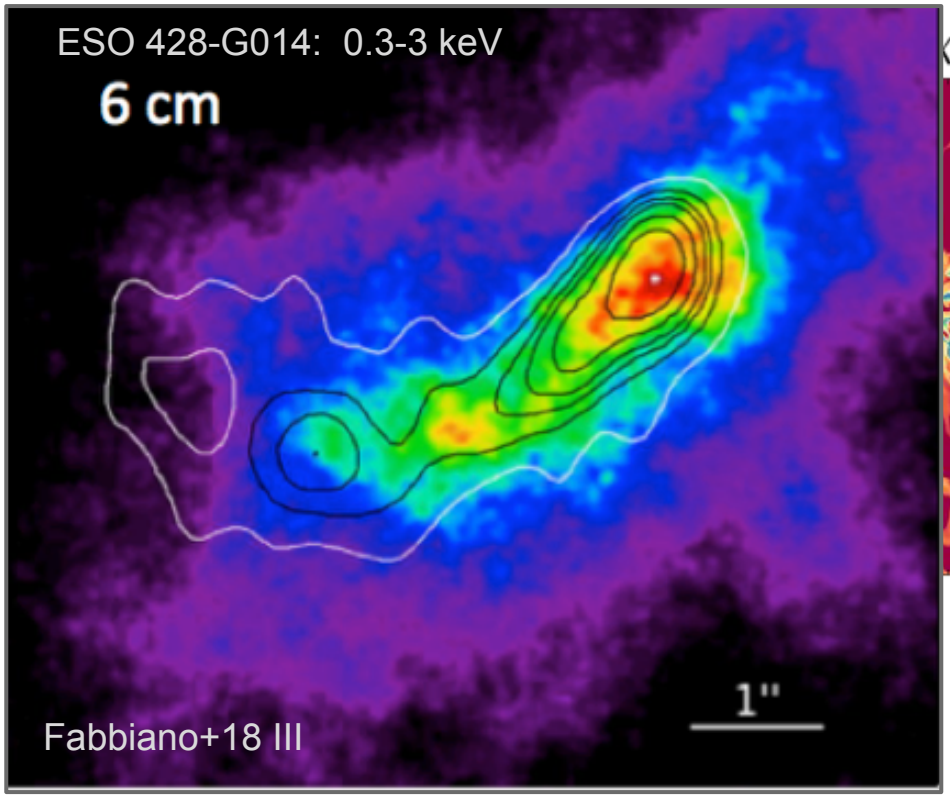


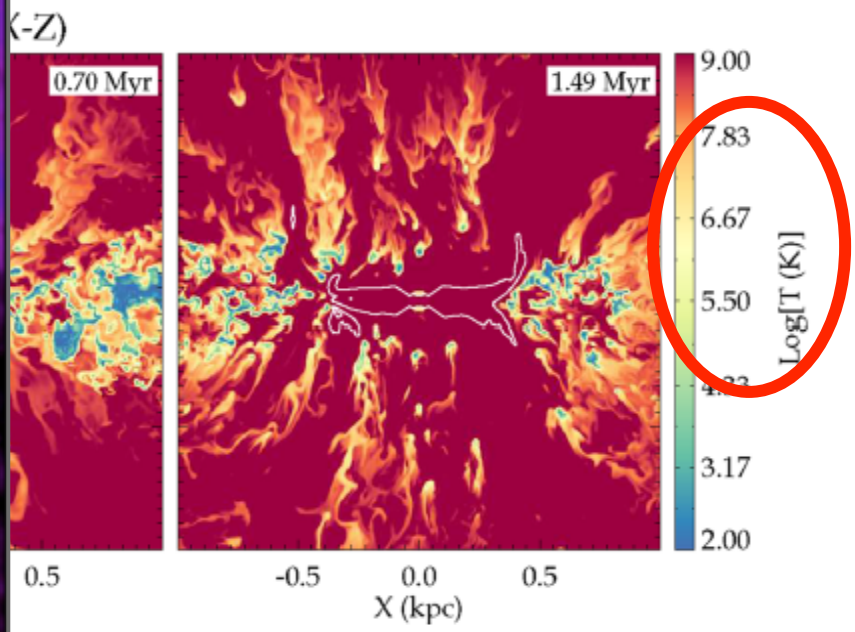


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# Hard X-ray Extent Perpendicular to bi-cones =Torus?

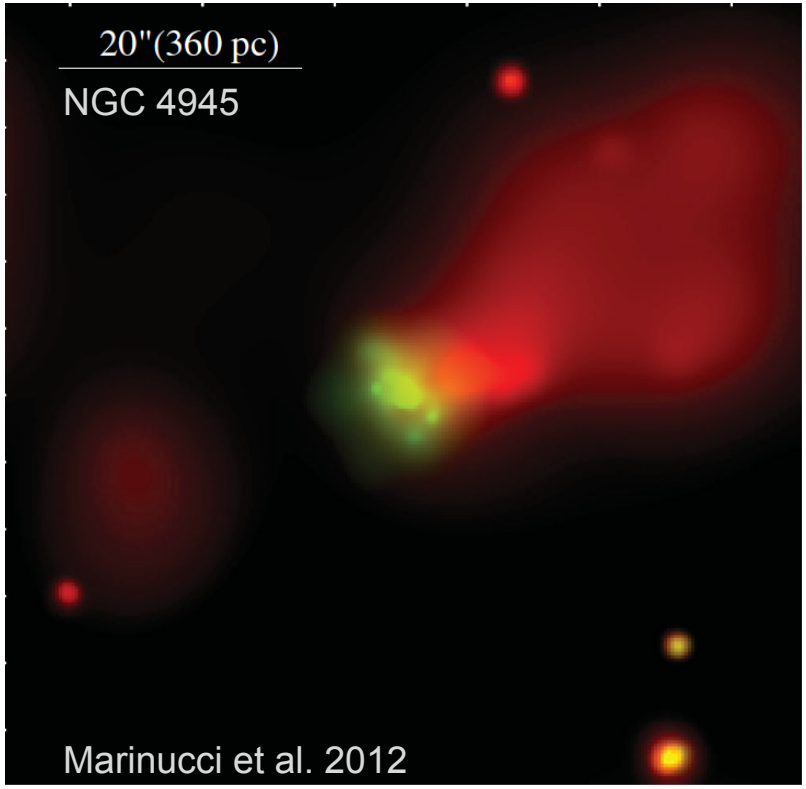


**Figure 2.** Two-colour (red: 0.3–2 keV; green: 2–10 keV) *Chandra* image of the 1 × 1 arcmin$^2$ central region of NGC 4945.

* a=0.05μm, Graphite

## NGC4945 90 x 180 pc

c.f. dust sublimation radius*
$r_{1500K}$ ~0.014 pc; **$r_{150K}$ ~ 8 pc**

→Not the torus (as Marinucci+ say)

Larger X-ray structure: molecular/dust ring in host. (CND) (Curran+ 2001)

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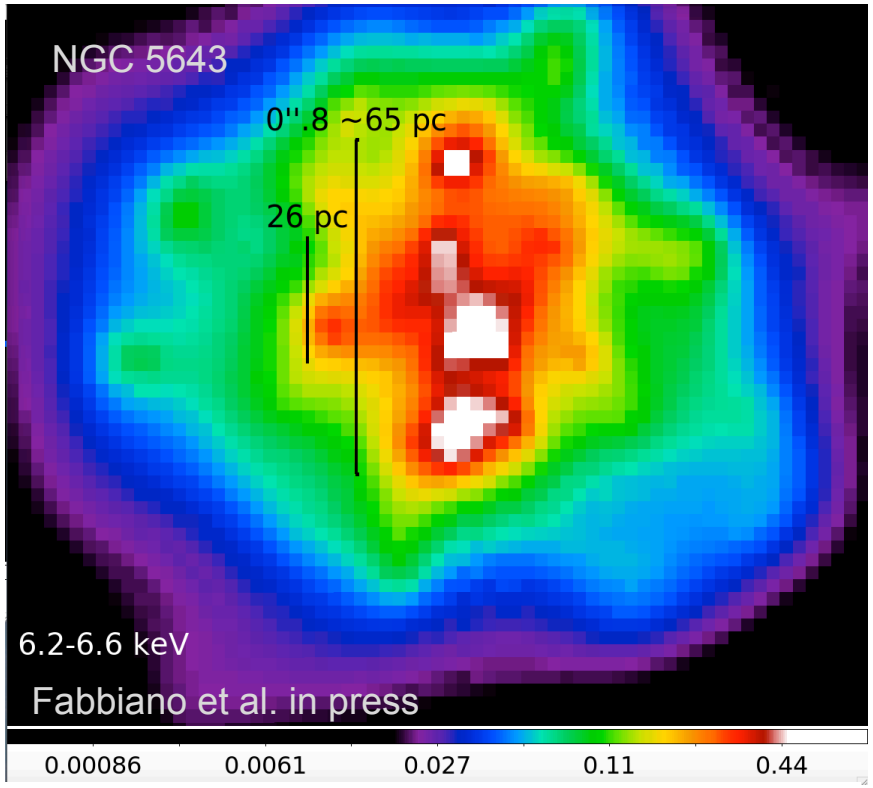


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## NGC5643 ~25 x 65 pc

c.f. dust sublimation radius
$r_{1500K}$ ~0.1 pc; **$r_{150K}$ ~ 50 pc**

→ Good torus candidate

Clumpy

& molecular ring in CO (CND)
(Alonso-Herrera +2018)

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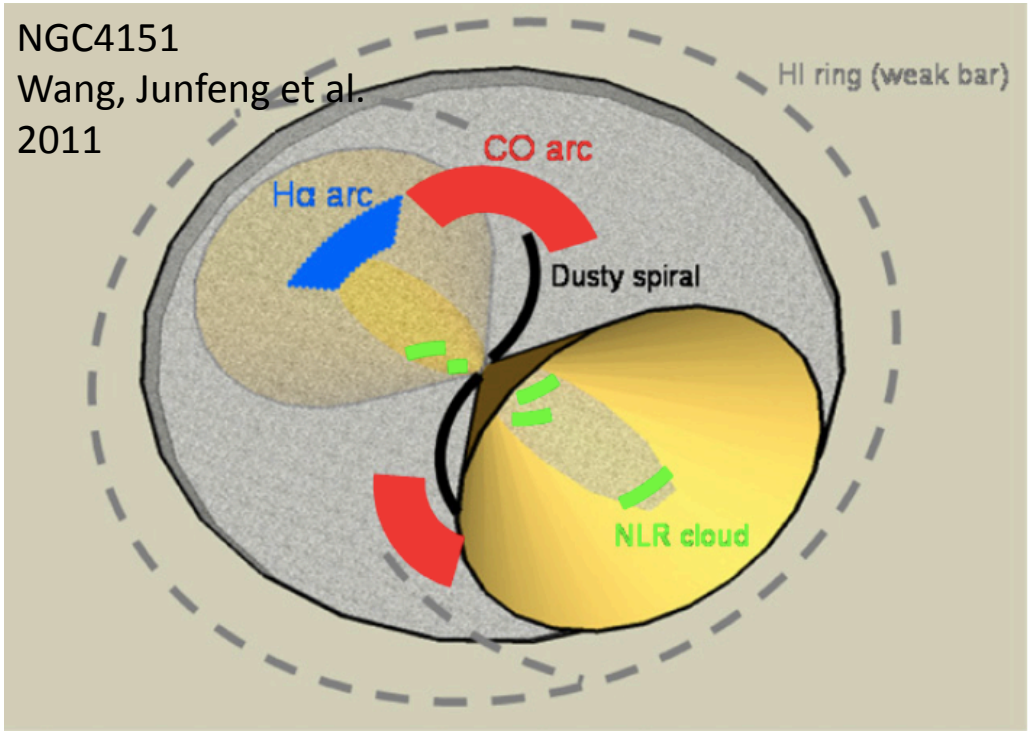


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(Alonso-Herrera +2018)

Connection? (Prieto, Storchi-Bergman talks)

*Need all temperatures @ hi resolution*

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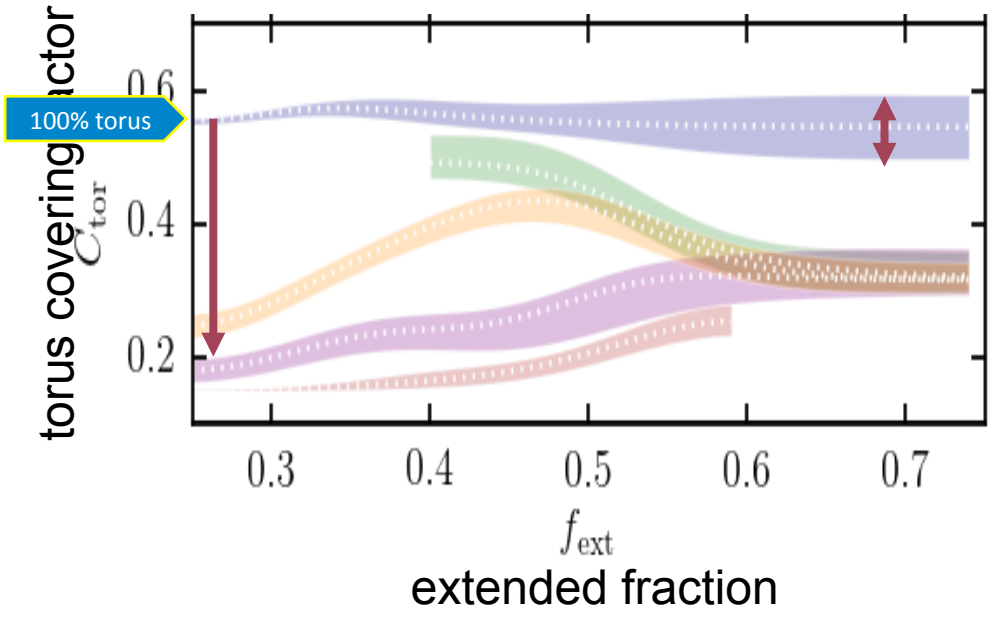
# Extended Hard X-rays
# Effect on Torus parameters?




Balokovic'+ in prep

## Much of Hard X-rays/Fe-K is not from the Torus

Ignoring this means overestimating Torus reflection/fluorescence. I.e. $C_{tor}$ x e $^{-N_H\sigma}$

E.g. **borus02** model (Balokovic' et al. 2018)

Error bars increase to +/- 10%

For some model choices torus covering factor drops to ~20%, 1/2 - 1/3 previous value.

→ Models need adapting

→ Better data: >50 keV, E/ΔE, ang.res.

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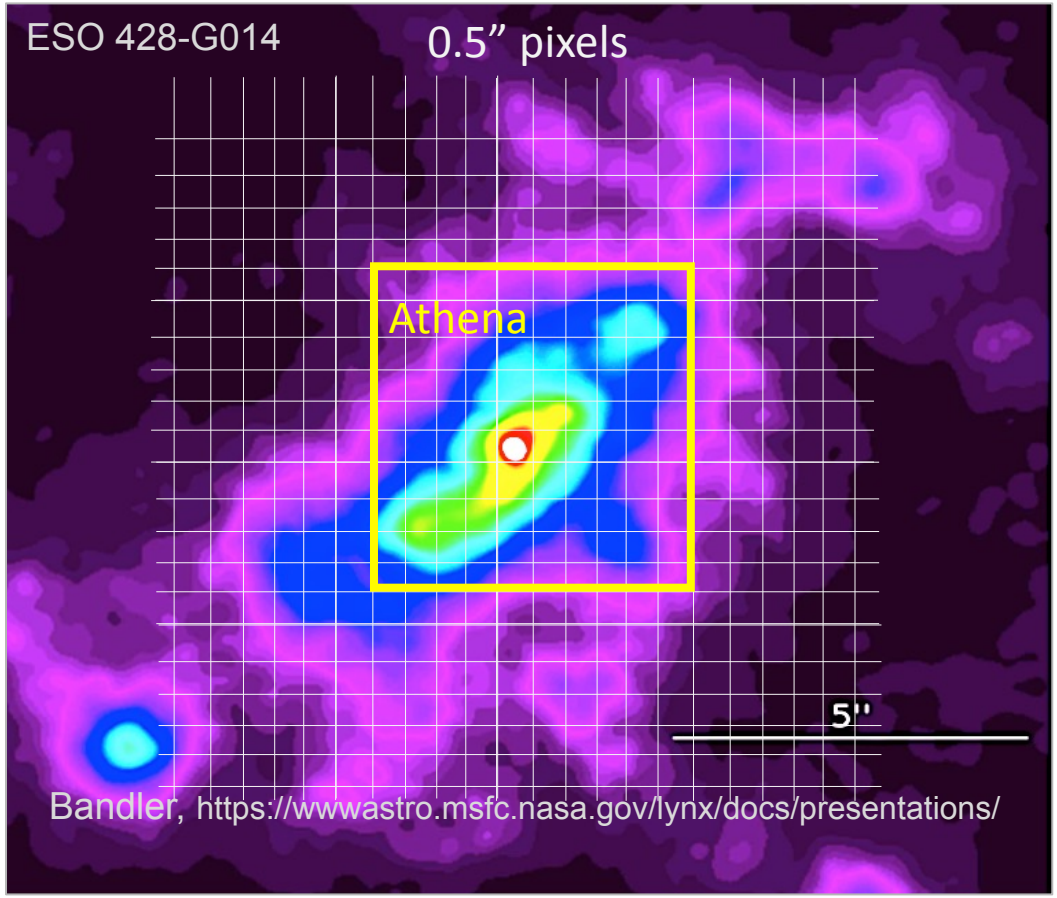
# The Way forward

X-RAY OBSERVATORY
LYNX




**Need high spatial resolution + high spectral resolution**

= Lynx + microcalorimeter array

**50X Chandra area; 0.5 arcsec**

Resolving power:

R = 3000 = **100 km s$^{-1}$ @ 6 keV**

R = 500 = 600 km s$^{-1}$ @ 1 keV

“IFU” with lots of photons

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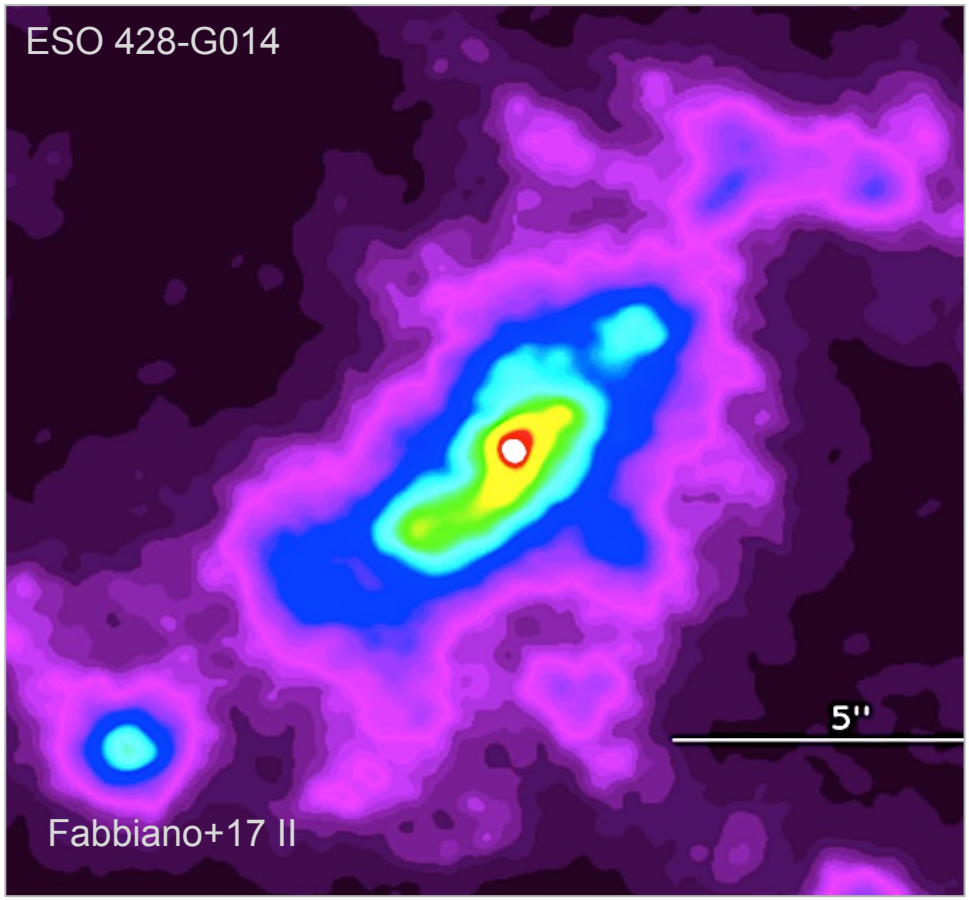
# Extended Hard X-rays in CT AGN

## Summary of Implications

Much of the Hard X-rays/Fe-K in CT AGN is not from the Torus




**Reflection off ISM molecular clouds**

→ feedback in action

= Compton Thin $N_H$ → 2 absorbers

**Cross-cone emission:**

- Porous Torus?
  - Inter-clump medium: cold $N_H < 10^{21}$ cm$^{-2}$
- Jet Blowback? radio-hard X-ray

**Changes Torus parameters**

- needs adapting models, more data

**We need** X-RAY OBSERVATORY LYNX

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