Chandra high resolution map of the emitting regions of NGC 7582

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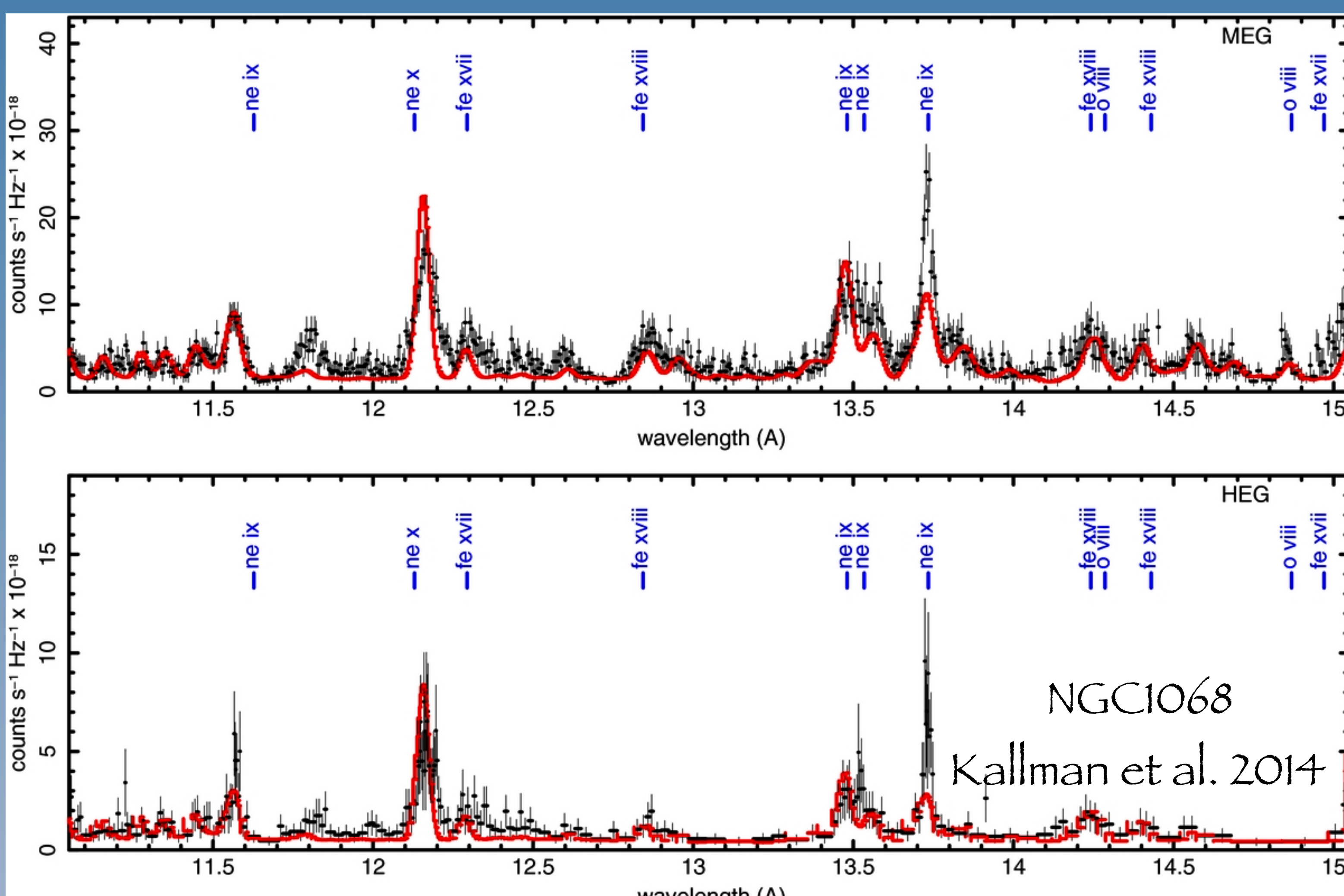
HETG observations of nearby CT-AGN

- Grating spectra are rich in emission lines
  - ➡ Soft excess seen in CCD spectra due blend of bright emission lines (Sako et al. 2000; Kinkhabwala et al. 2002; Ogle et al. 2002).
- Broad range of ions and elements (Kallman et al. 2014 &)
  - ➡ multiple phases with various ionization states.

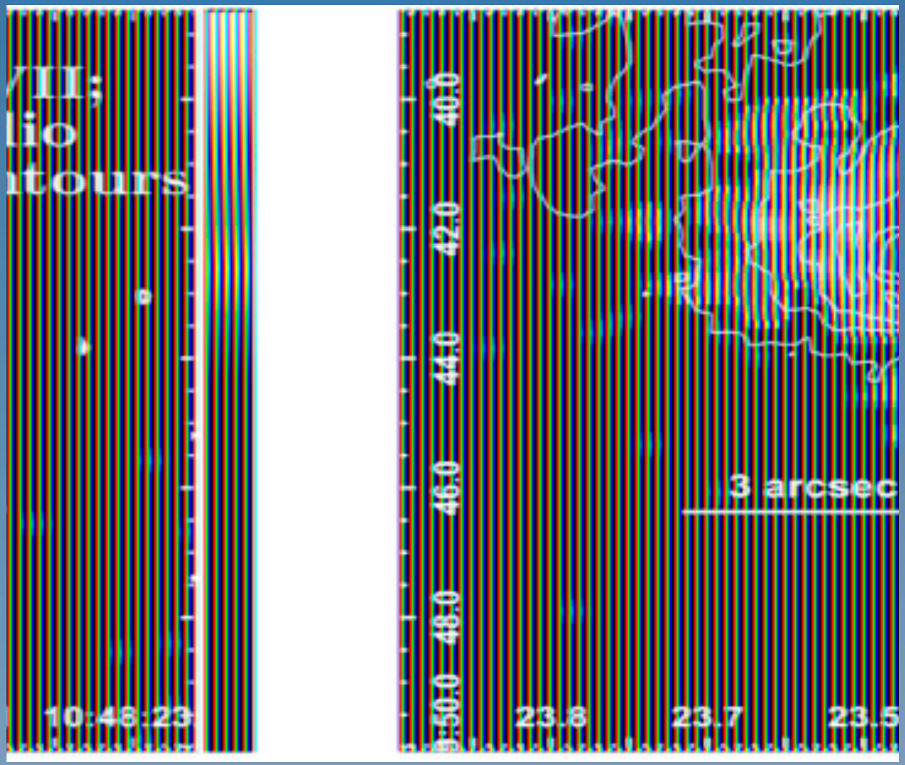


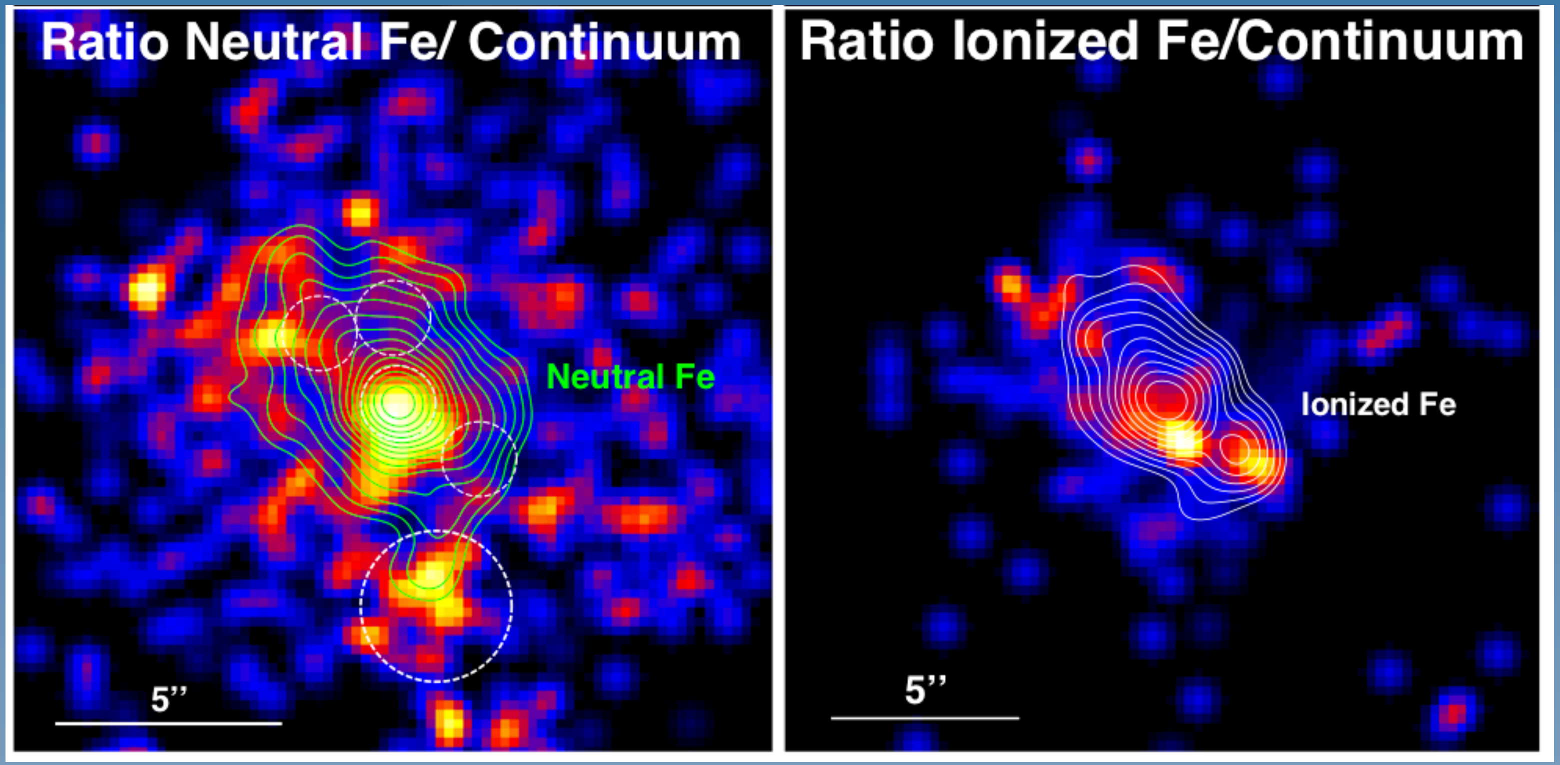
- From ξ & N_H
  - ➡ constrain the location of the emitting gas.
- Line strengths
  - ➡ provide the density and thus amount of emitting gas.
- Line ratios
  - ➡ probe the excitation mechanism: collisional vs photoionized.

Exploiting the superb spatial resolution

- The soft X- ray emission strongly correlates with the NLR, gas as mapped by the [O III] HST images (Young et al. 2001; Bianchi et al. 2006; Levenson et al. 2006).
- Narrow band images show all the complexity of the emitting gas even in the Fe K band

➡ Imaging is a key tool to probe the emission processes





NGC3393:

OVII, OVIII & Ne IX trace the [OIII] but differ in morphology

(Maksym et al. 2019)

NGC4945:

Fe Kα extended and varies on scales of tens of pc

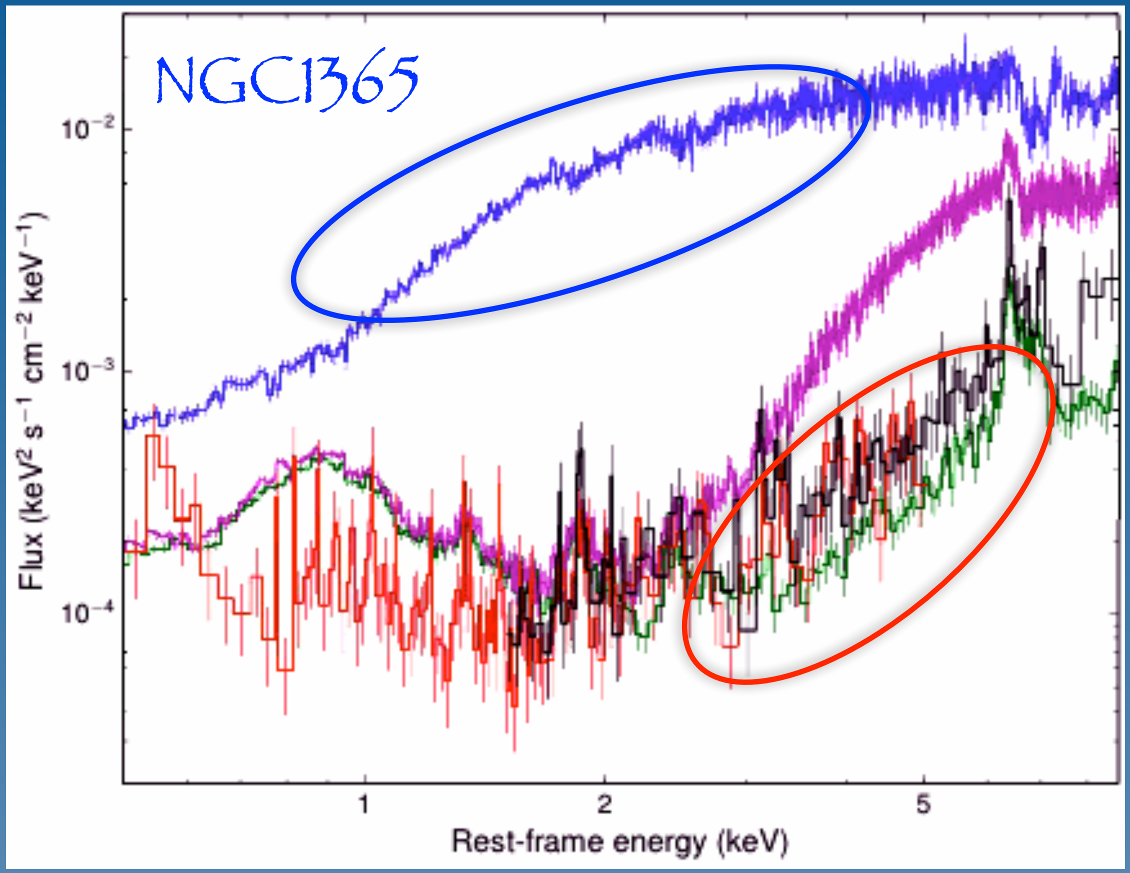
Fexxv detected at 40 pc east to the nucleus

(Marinucci et al. 2017)

What can we learn from changing look AGN?

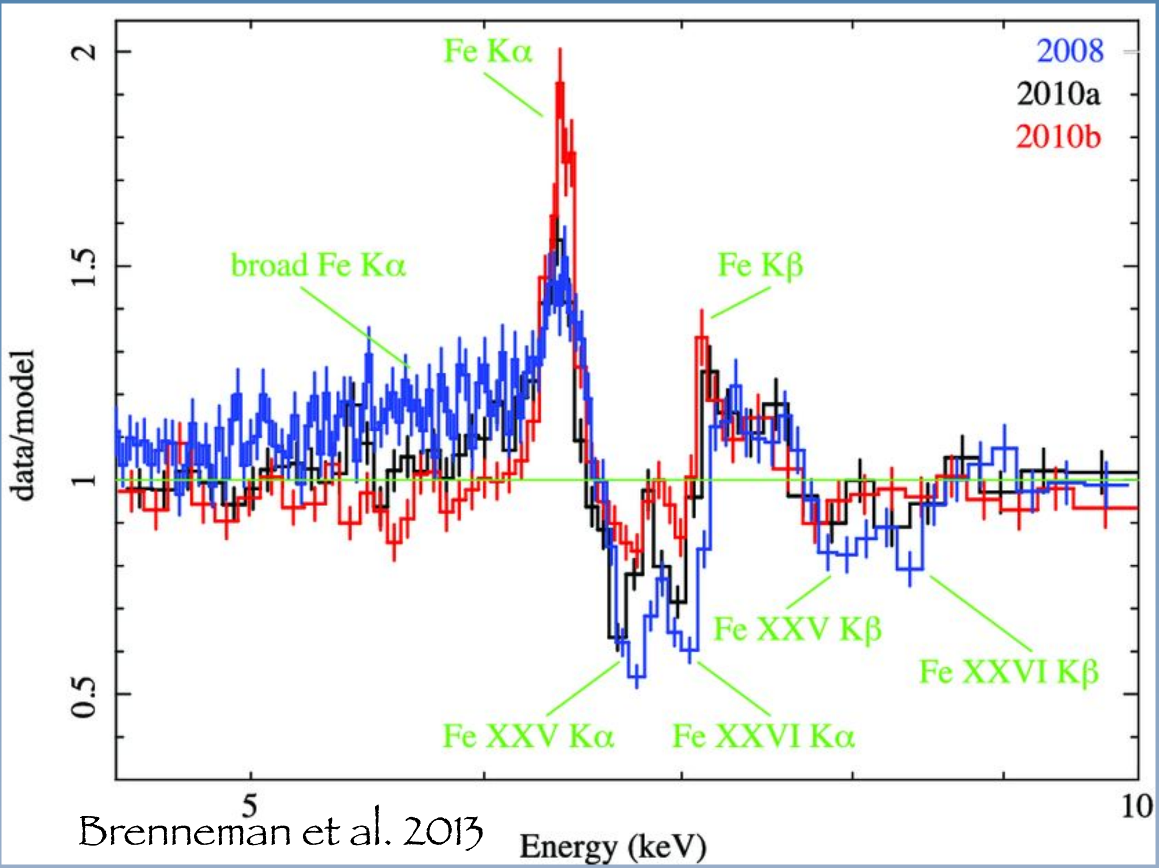
Monitoring the variable N_H:

Clouds with N_H from few $\times 10^{23}$ cm^{-2} up to 10^{24} cm^{-2} and located at the BLR distance (Risaliti et al. 2005)



Emission/absorption line profiles:

location, density, ionisation and outflowing velocities!



Brenneman et al. 2013

200 ks HETG obs. of the C-Thick state: several emission lines, from O through to Fe

Velocity widths of FWHM ~ 800-1300 km s^{-1} some requiring an outflow velocity of ~1000 km s^{-1}

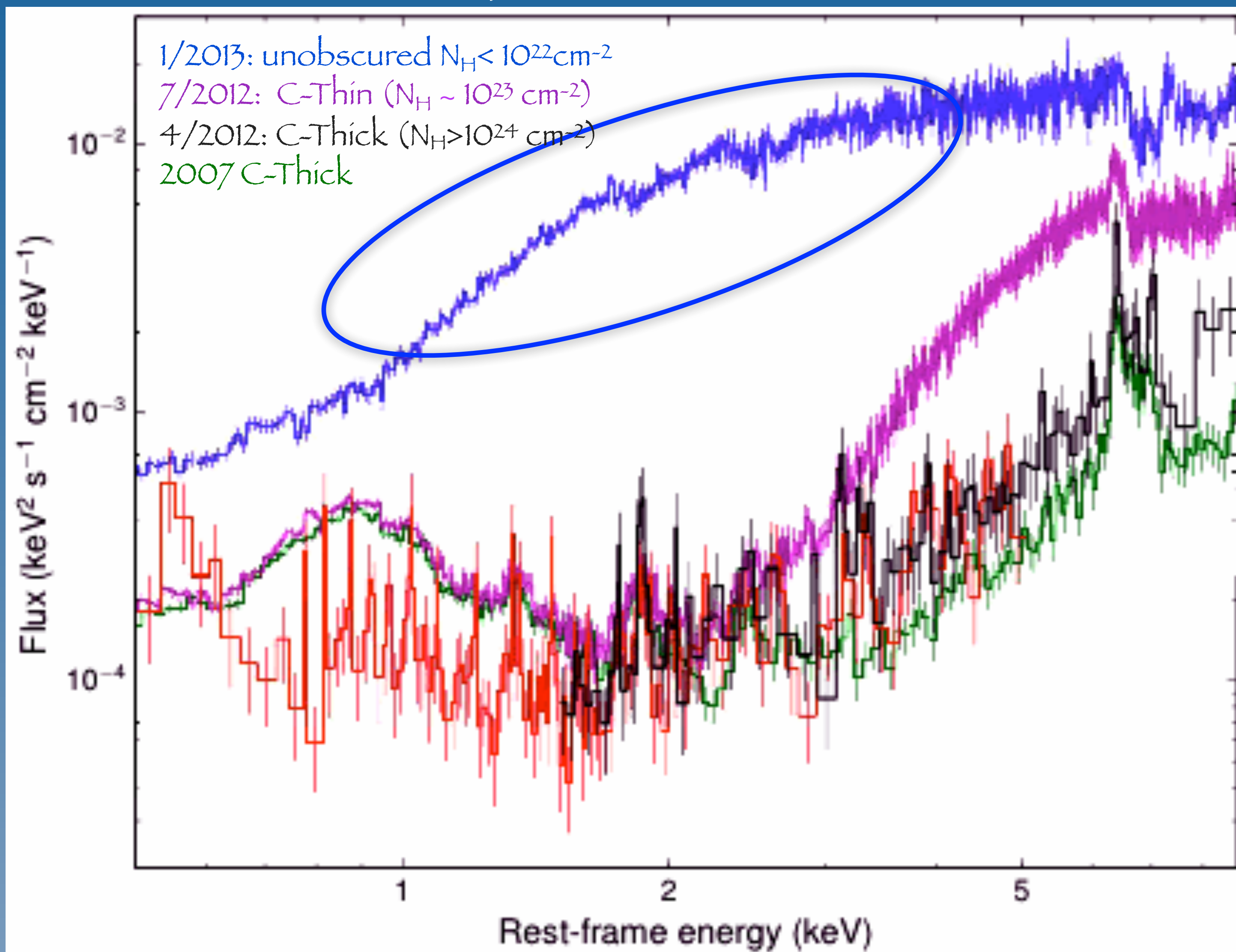
(Nardini et al. 2015)

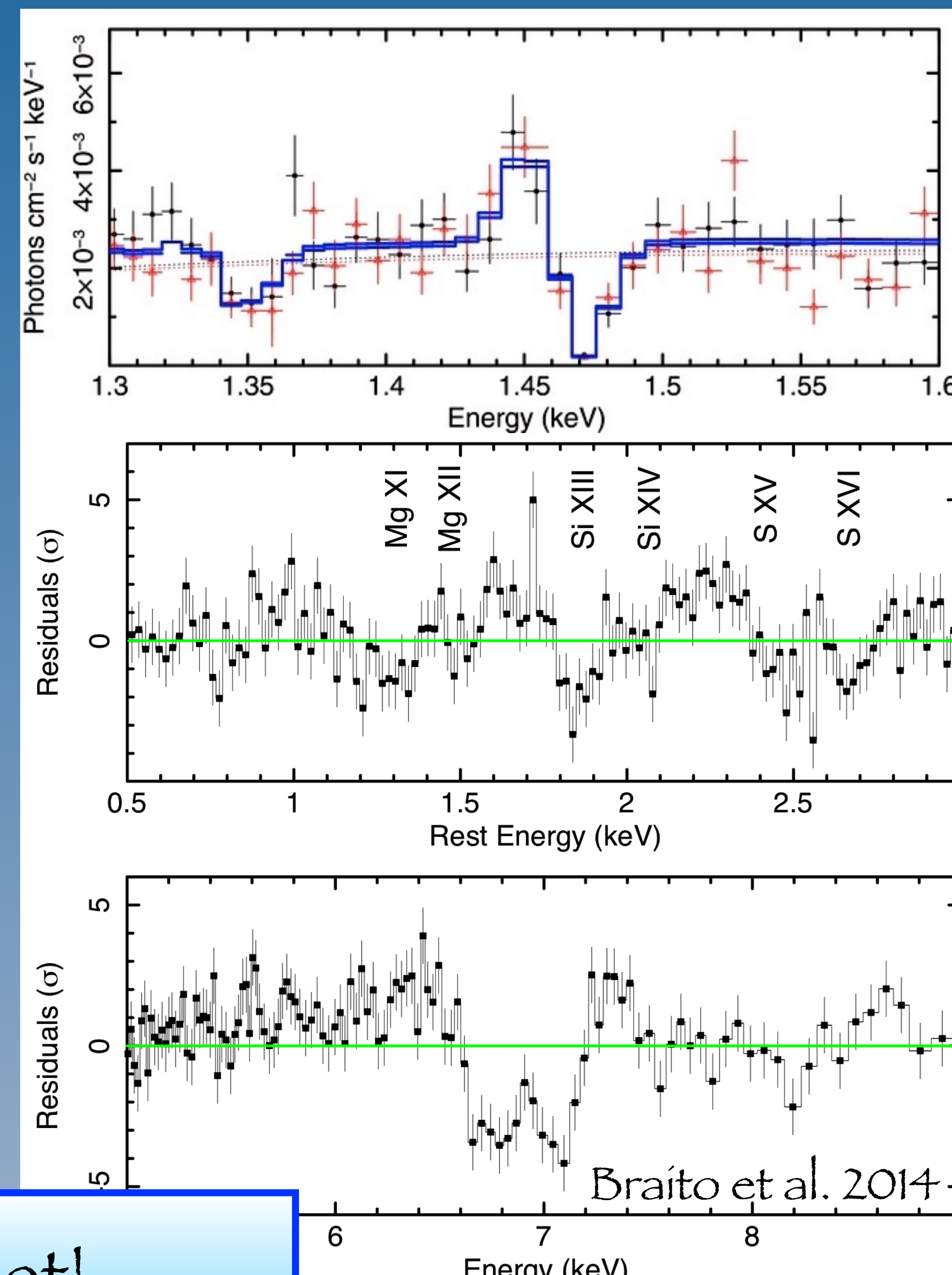
C-Thin state: best example of abs. lines from Fe xxv (He-α & He-β) & Fe xxvi (Ly α & Ly β)

The unobscured state of NGC1365

As the N_H dropped $<10^{22}$ cm^{-2} several abs. features emerged in the RGS & CCD spectra

Evidence of a multiphases ionized accretion disk wind

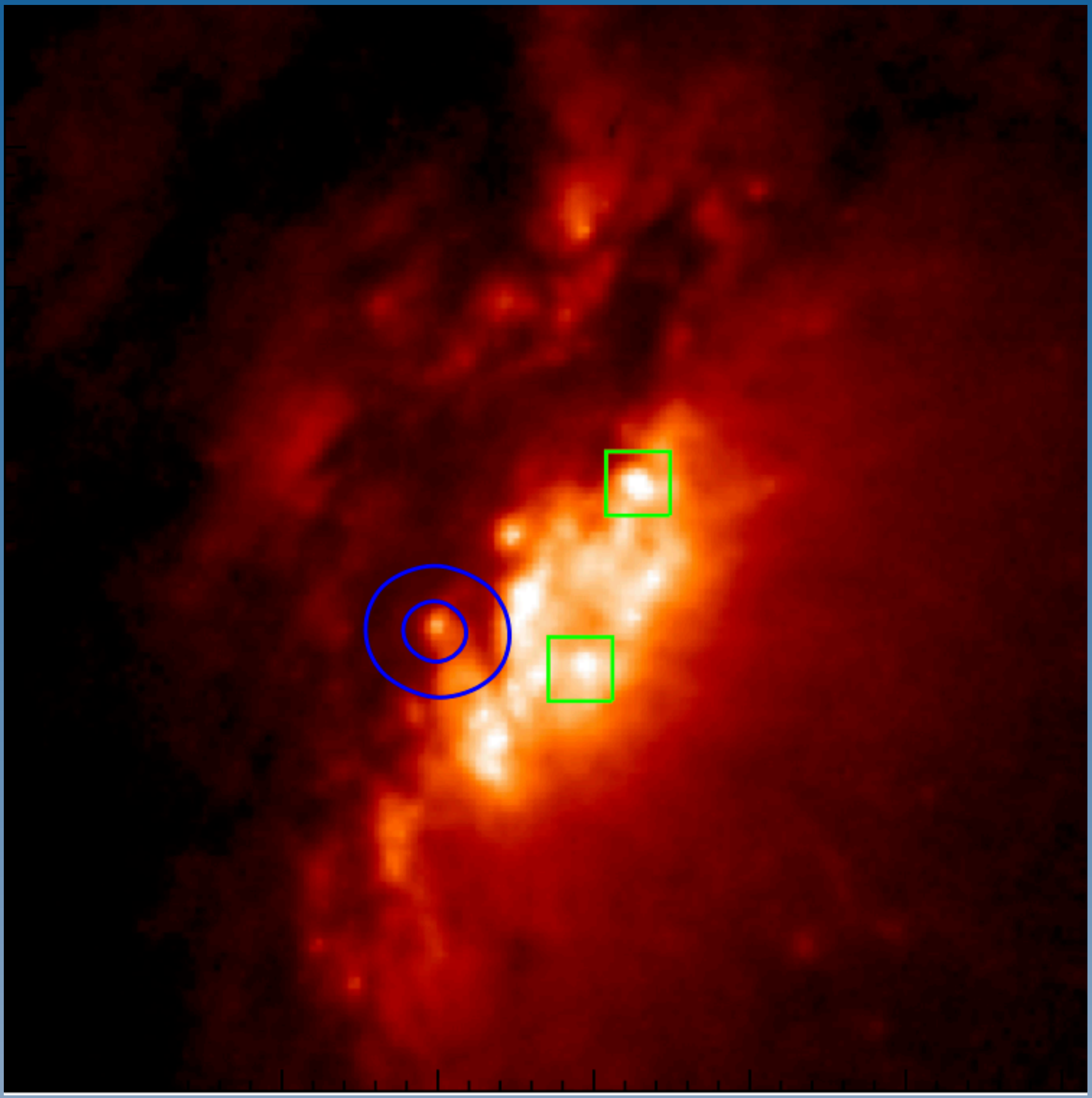




Mapping this ionized gas and its variability can probe the circumnuclear gas in AGN & test the AGN unification model!

NO HETG data for this state yet!

The Changing look NGC7582



HST image of the nuclear region of NGC 7582 (Bianchi et al. 2007).

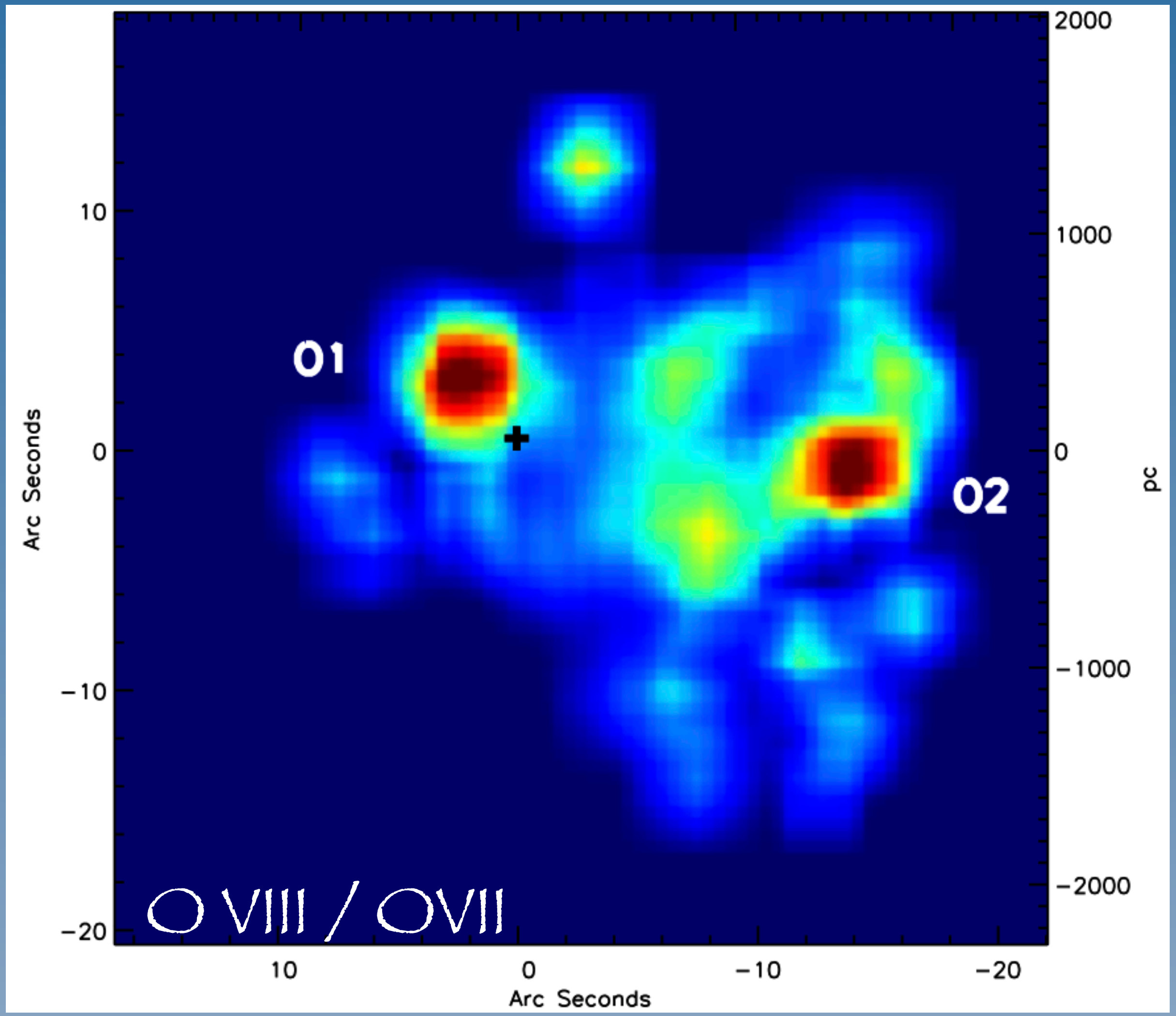
- NGC7582 is one of the prototypes changing look AGN with N_H changes on time scales as short as a day.
- X-ray bright and nearby: z=0.00525 (D ~ 22 Mpc)
  - ➡ 1" corresponds to ~ 100 pc
- XMM-RGS: high-resolution spectrum: low S/N but clearly dominated by several strong emission lines. Possible hybrid plasma with a strong contribution to the emission from a photoionized gas (Piconcelli et al. 2007).

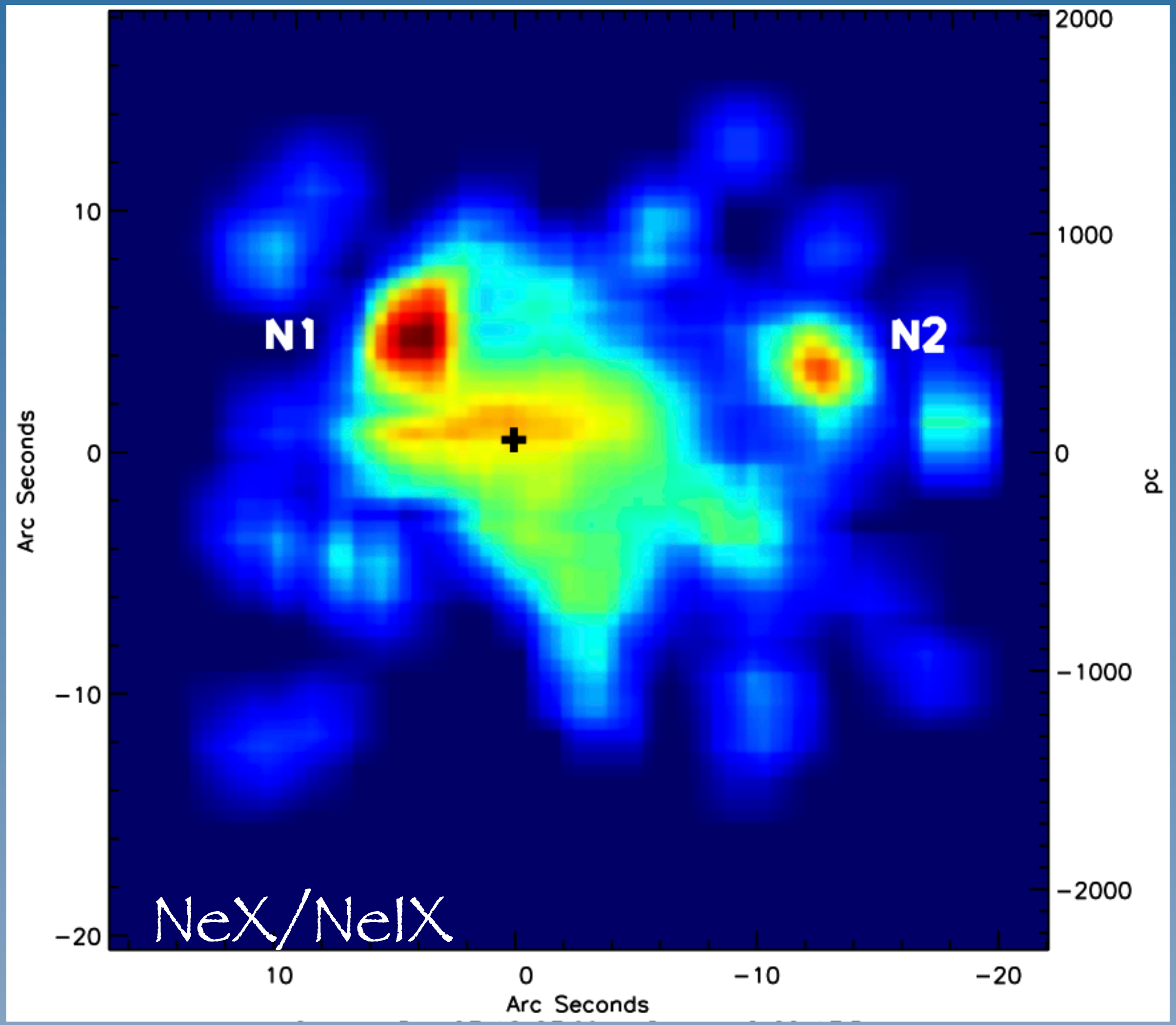
NGC7582

Short 20 ksec ACIS-S observation performed in 2000:

✦Soft X-ray emission extends over 20" with a highly complex morphology

✦Maps of the O VIII to O VII & Ne X and Ne XI ratios: reveals two "hot spots" where higher ionization phase dominates





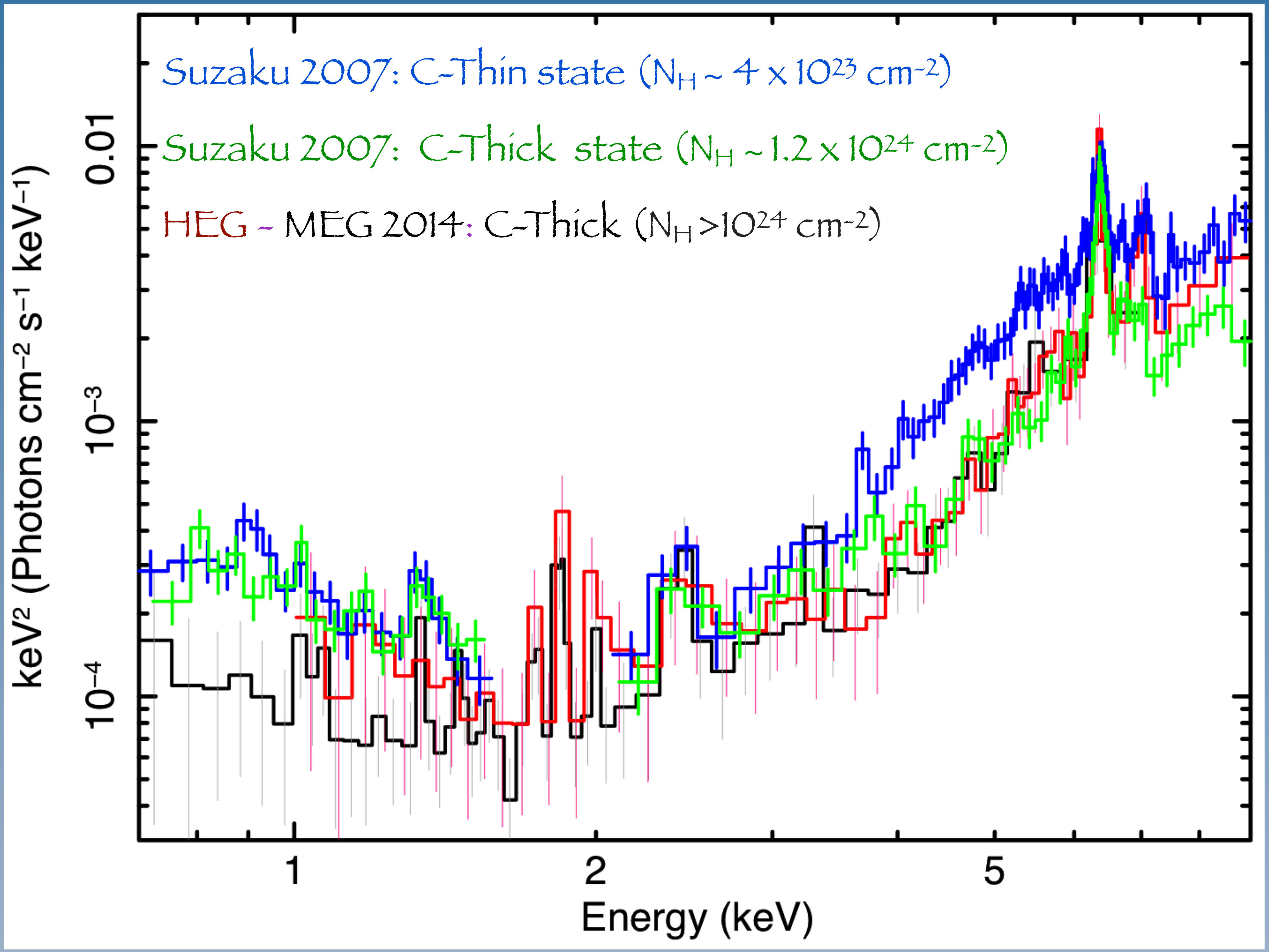
Inhomogeneity seen in the X-ray images can be in part explained as:

- absorption by the dust lane
- the emitting regions differ in ionization and/or density (Bianchi et al. 2007)

The C-Thick state seen with the HETG

200 ks HETG obs. of the C-thick state: spectrum is dominated by emission lines with an extremely low continuum

✦reveals all the stratification of the pc-scale emitter.



The C-Thick state similar to the past Suzaku observation.

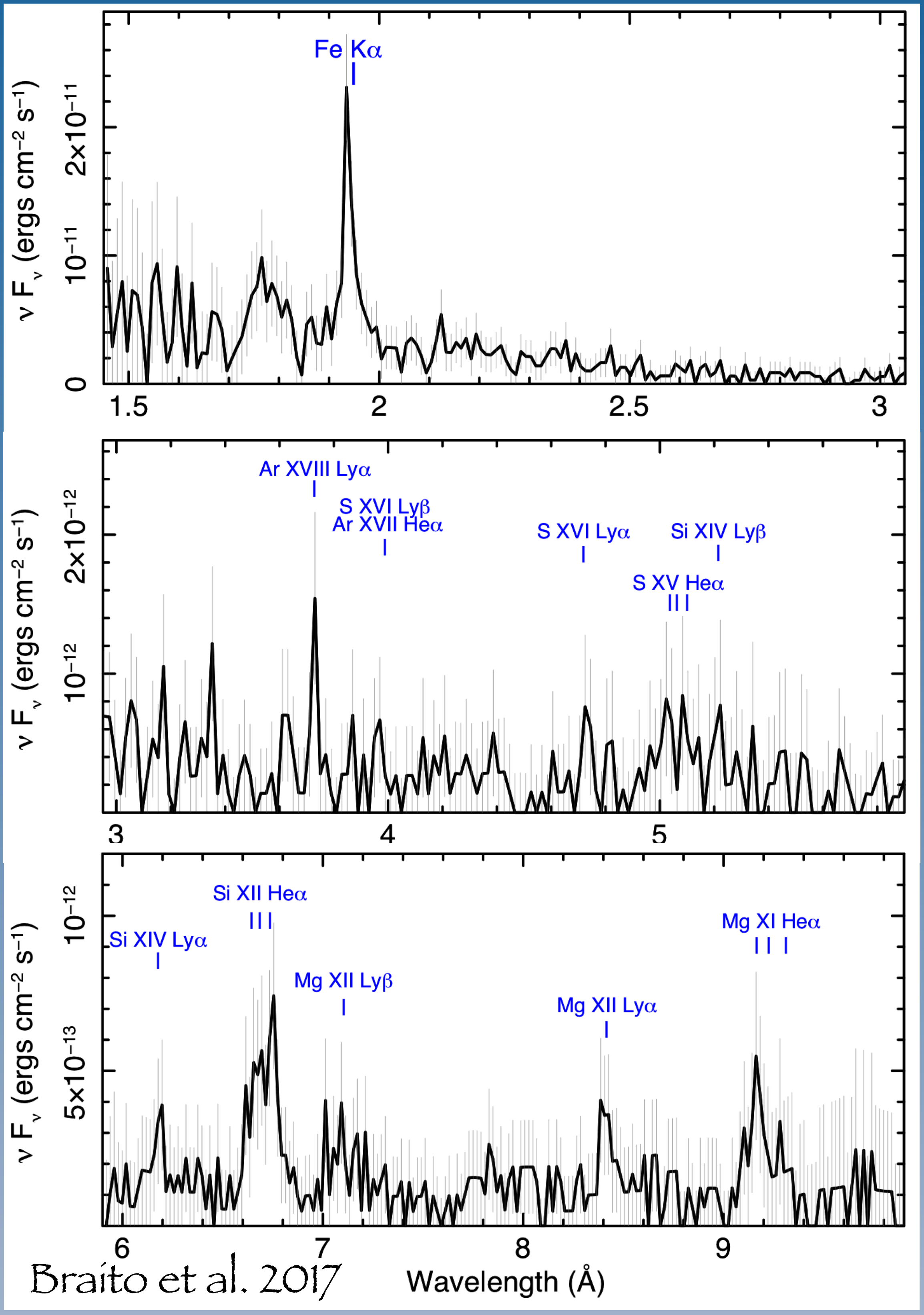
Simultaneous fit provides a model for the underlying continuum:

$\Gamma = 1.7 \pm 0.2$

$N_H = 1.2 \pm 0.2 \times 10^{24}$ cm^{-2}

The pc-scale emitting gas

Thanks to the HETG we can probe all the stratification of the pc-scale emitter



Braito et al. 2017

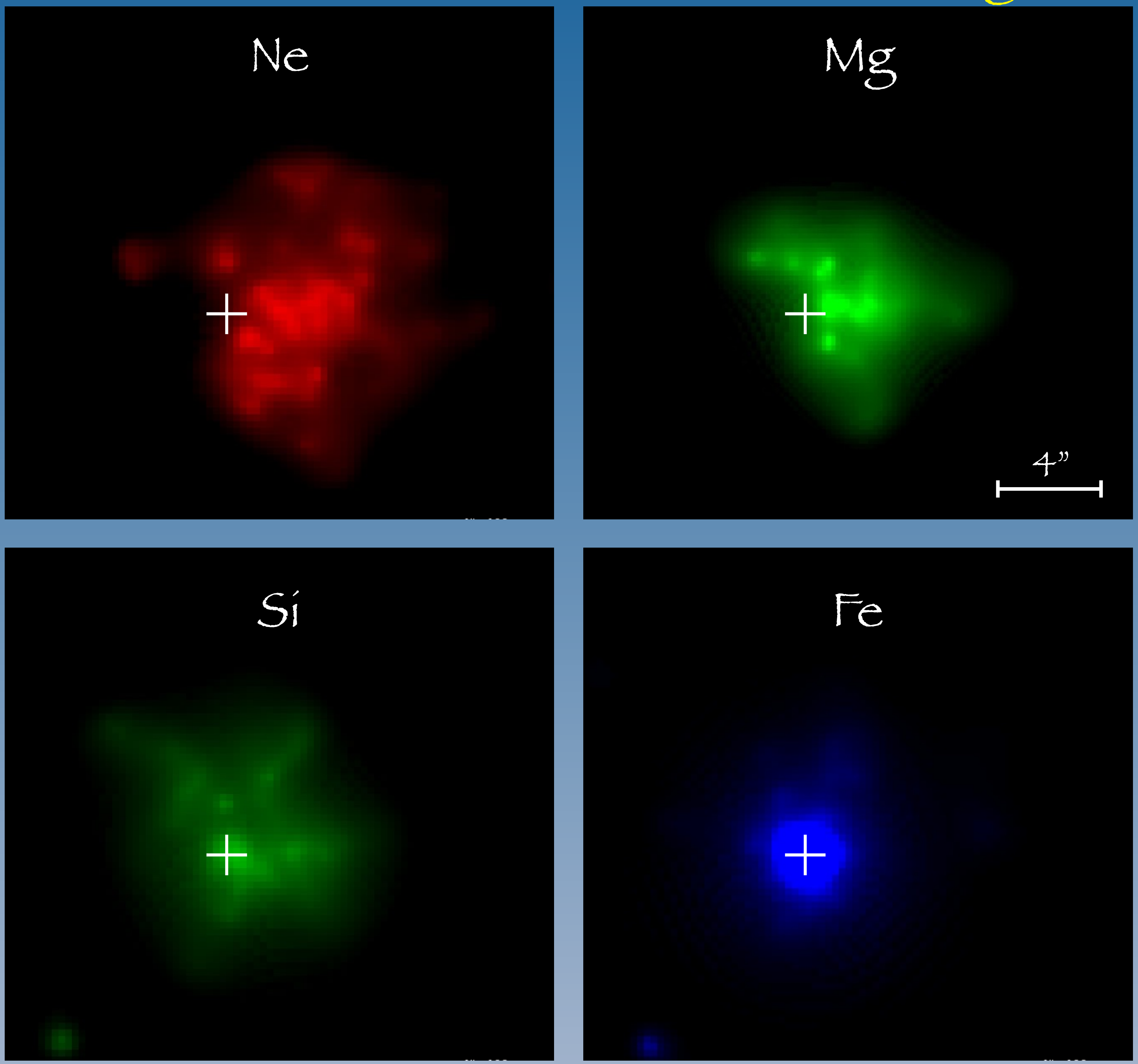
As for NGC1365 in the obscured state the spectrum is rich of emission lines (Mg, Si, S and Fe)

BUT

- Strong resonance components + Mg XI He-α triplet lacks the forbidden component
  - ➡ suggestive of an hybrid plasma ionised by the AGN and by the strong star forming activity
- Unusually broad profiles with FWHM=2000-3000 km/s

Narrow band images

Chandra images unveil the inhomogeneity and spatial extent of the circumnuclear gas



The Ne region is mainly distributed on the west side

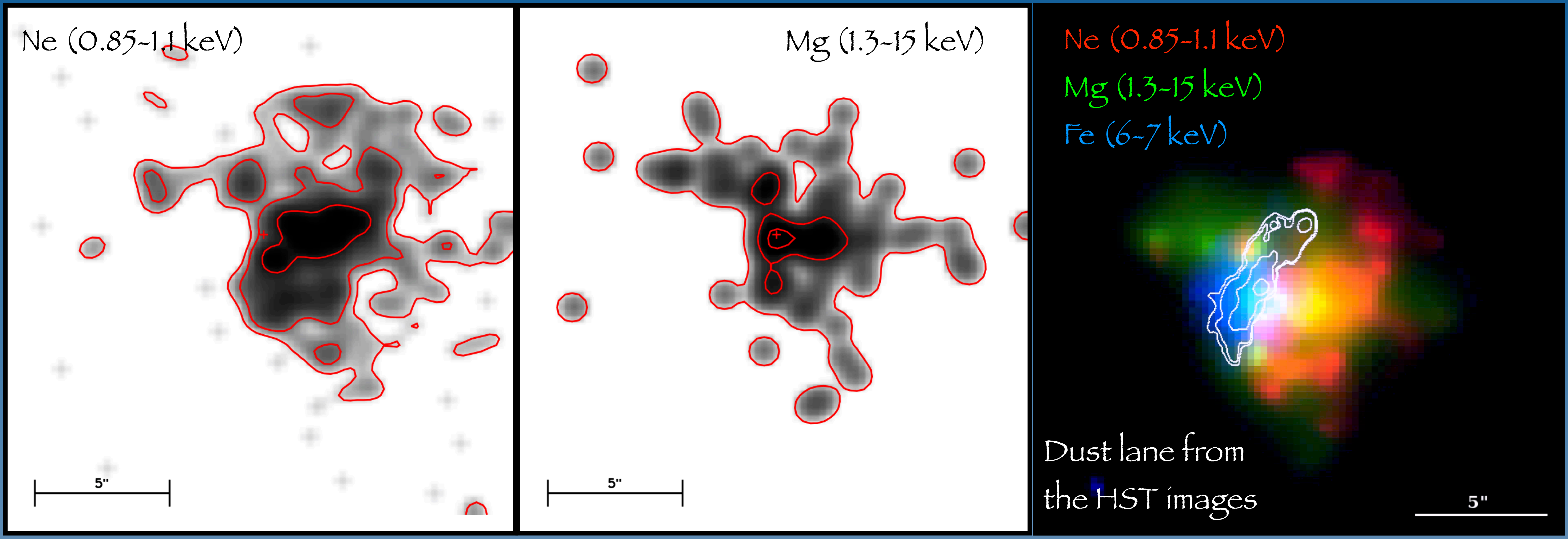
No Ne emission coincident with the nucleus!

Both Ne and Mg emitting regions are extended & asymmetric

The Si emission is extended but more symmetric and centered at the nucleus

The Fe emission originate from the central nucleus

Chandra narrow band images

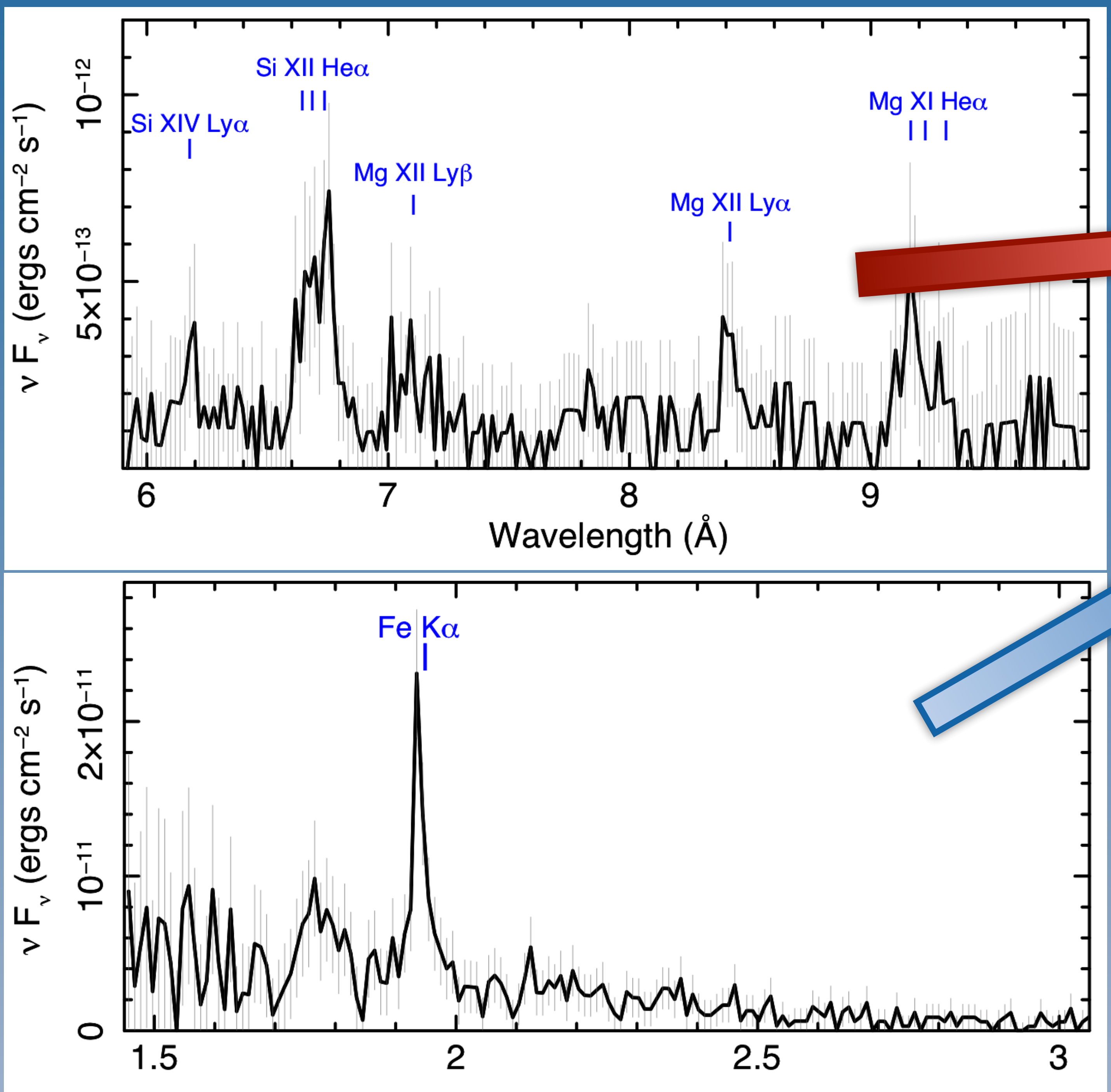


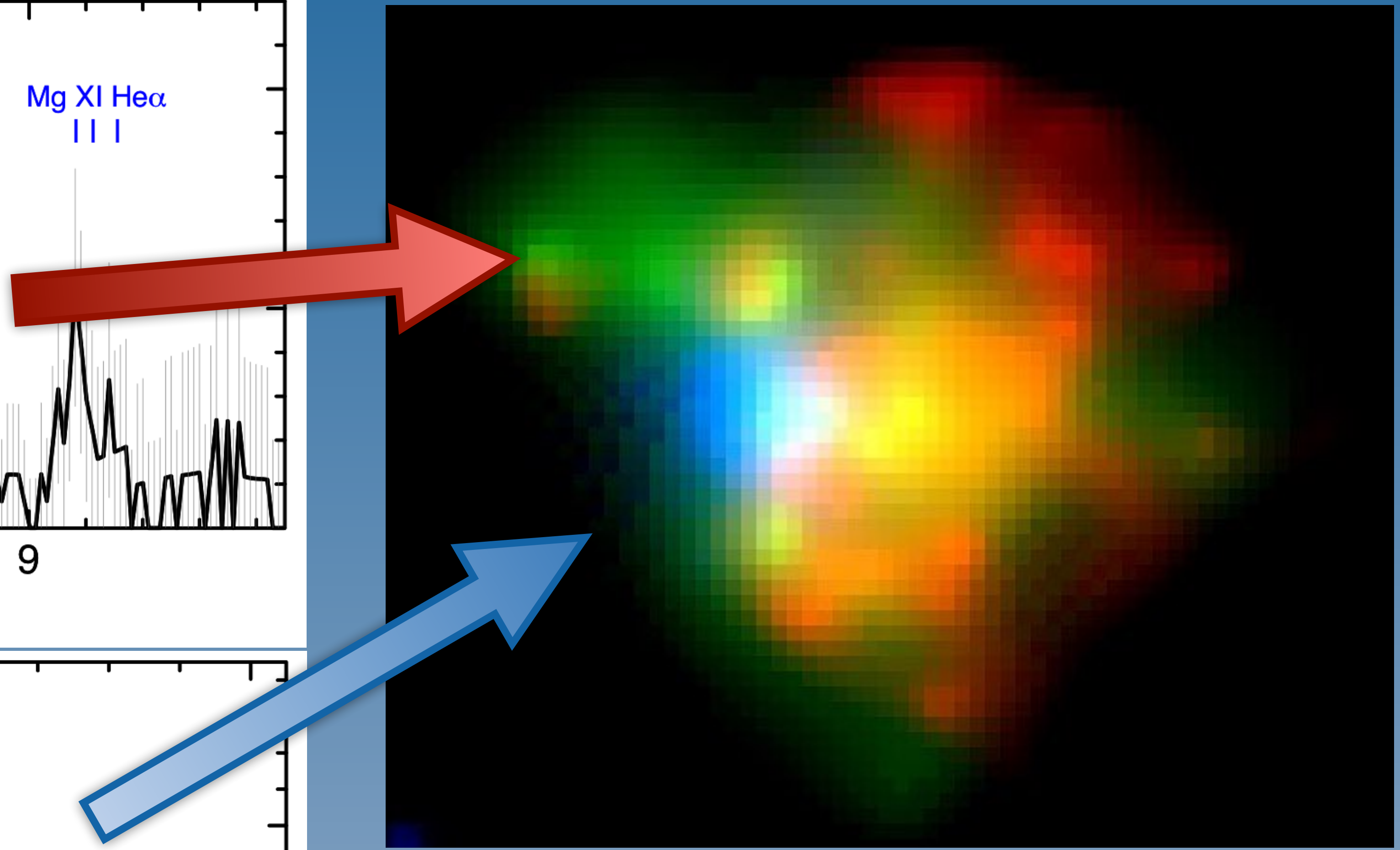
- The emission is spatially extended up to 6" in the Ne and Mg band.
- Different morphologies depending on the energy and progressively less extended with increasing energy.
- Only the Fe Kα emission line image consistent with a point-like source.
- The lack of Ne emission on the east side of the nucleus due to the effect of obscuration by the dust lane present in NGC7582.

The pc-scale emitting gas

Imaging can inform the spectral modelling

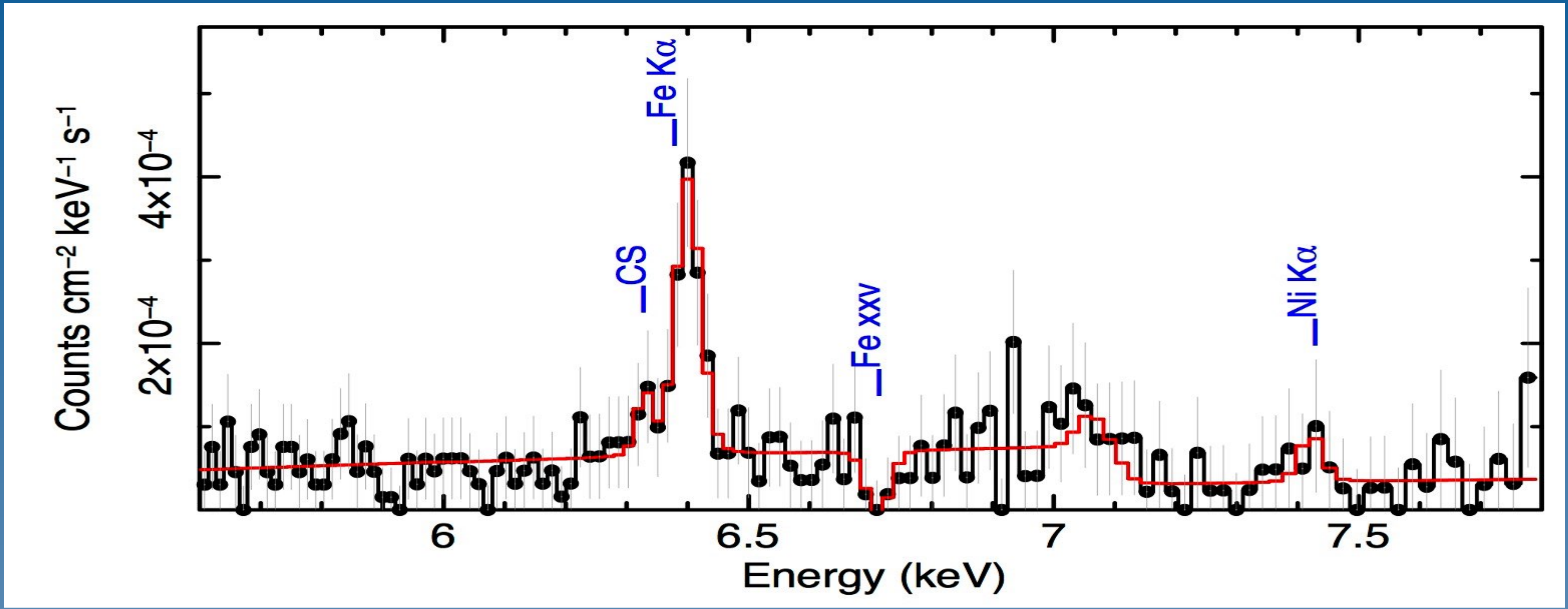
Both the Si and Mg images reveal that the emitting regions are extended this causes an artificial broadening of the soft X-ray line profiles





Strong nuclear Fe Kα emission consistent with the presence of a circumnuclear optically thick absorber. Point like: broadening is intrinsic.

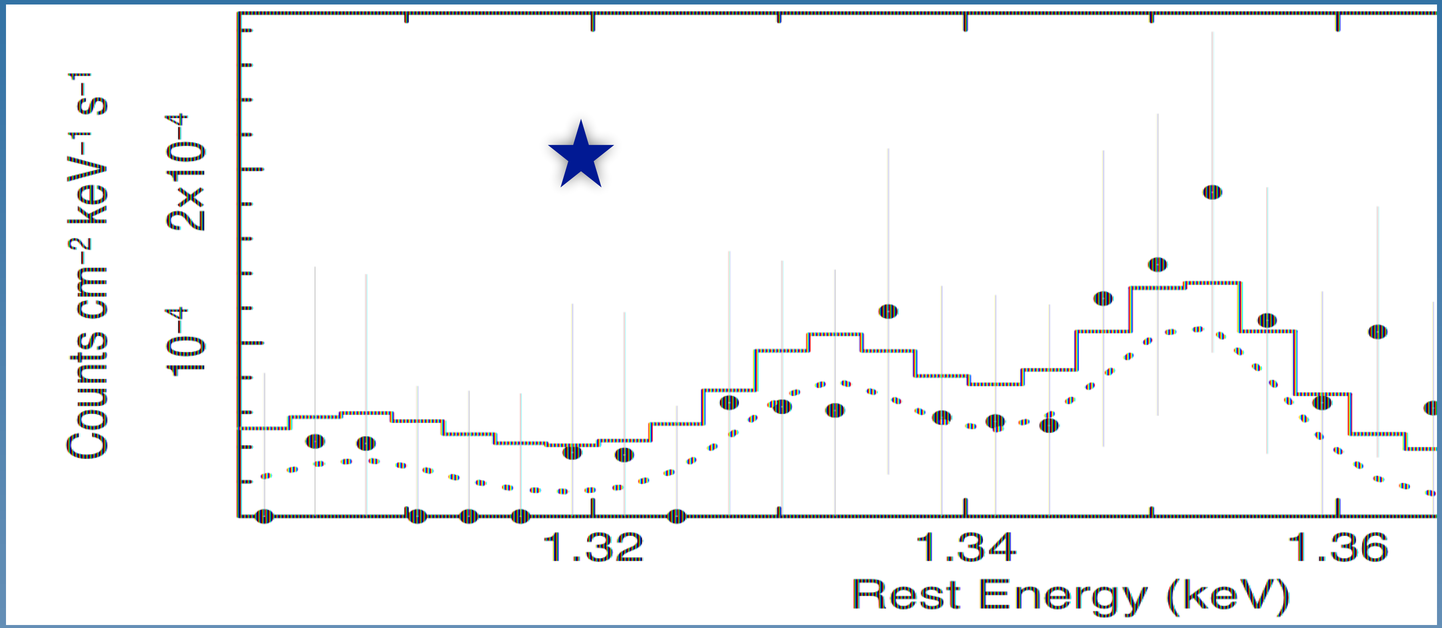
The Fe Kα emitting gas



- The Fe Kα em. line is resolved with a FWHM=1500±900 km s^{-1}
  - ➡ gives a distance of Fe emitter of R ~ 0.05 - 0.7 pc compatible with the outer BLR and the pc-scale torus.
- A clear absorption feature is detected @ 6.7 keV (ΔC = 13.8) consistent with Fe xxv & no blue shift
  - ➡ The absorber has log ξ~2.8 erg cm s^{-1} and N_H~10^{23} cm^{-2} & traces an ionized absorber located at the same scale of the Fe Kα emitting region
    It could be identified with the putative electron scattering region.

The Soft X-ray emitting gas

- Once we account for the artificial broadening introduced by the extension of the emitting region from the spectral analysis we get:



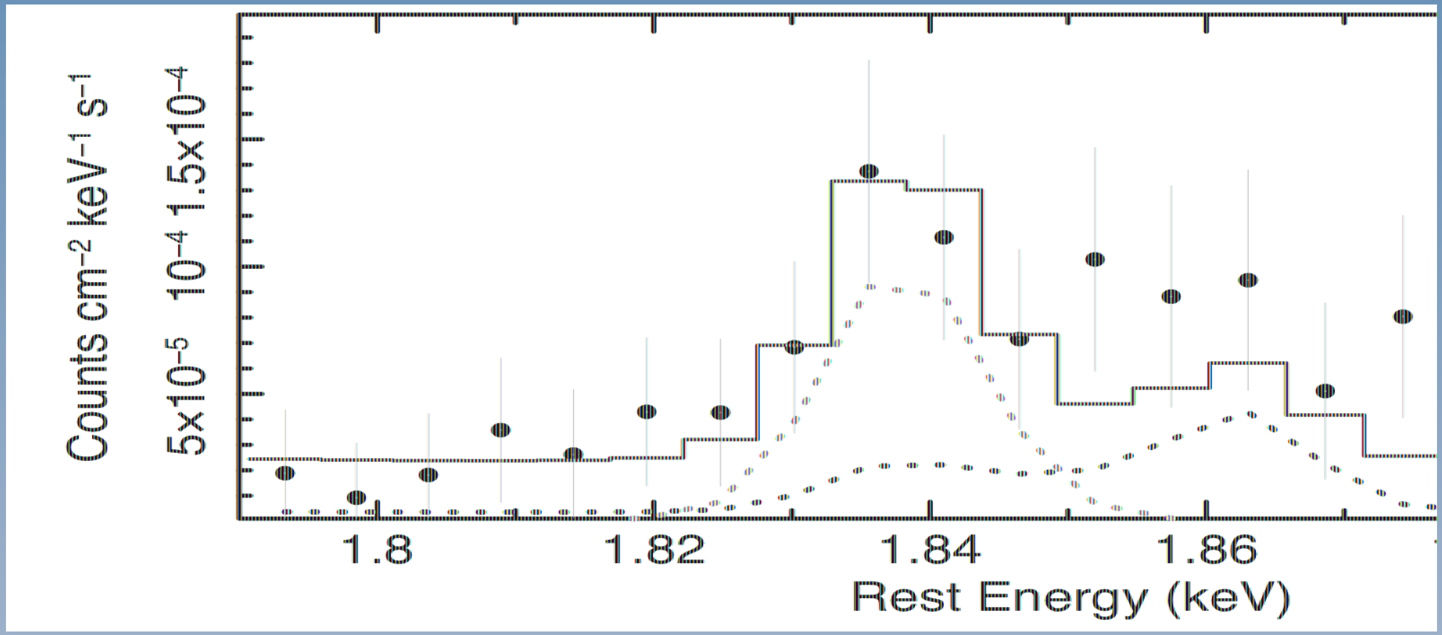
The Mg XI triplet:

No evidence for a forbidden component

Can be modeled with a thermal emission model with:

★ kT~0.6 keV & L_X ~2×10^{40}erg s^{-1}

in agreement with a SFR~4 M_{SUN}/yr



The Si XIII triplet:

Strong forbidden line

★ requires the addition of a photoionised emitter with

Log ξ~2.4 erg cm s^{-1}

Location and density of the soft emitting gas

Combining imaging and spectral informations we can derive the density of the collisionally and photoionized gas.

For the thermal emitter

Normalization of the thermal emission & the extension of R~500 pc gives:

$n_e \sim 0.3\ cm^{-3}$ for a uniform spherically symmetric gas distribution

or $n_e \sim 10\ cm^{-3}$ for an inhomogeneous gas with $F_v \sim 10^{-3}$

For the ionized emitter

XSTAR model: gas has a low $N_H = 2 \times 10^{20}-10^{21}\ cm^{-2}$ & up to 40% covering factor

From the ionization parameter $L_{ion}/\xi = nR^2$ & R~200-300 pc we infer a density of $n_e \sim 0.3-1.4\ cm^{-3}$ consistent with the NLR gas

Summary

The synergy between the high spectral and spatial resolution offered by deep Chandra HETG observations is a unique and key tool to understand AGN emitting regions.

The superb imaging can shed light into the location, extension & clumpiness of the emitting gas and inform the spectral analysis.
But only with the spectral resolution offered by the HETG we can infer its physical nature through emission line diagnostics.

Still only few nearby obscured AGN have been observed in such mode with the exposure that is required to fully exploit the HETG spectral capability and Chandra spatial resolution.