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# Deep Surveys

Andrea Comastri

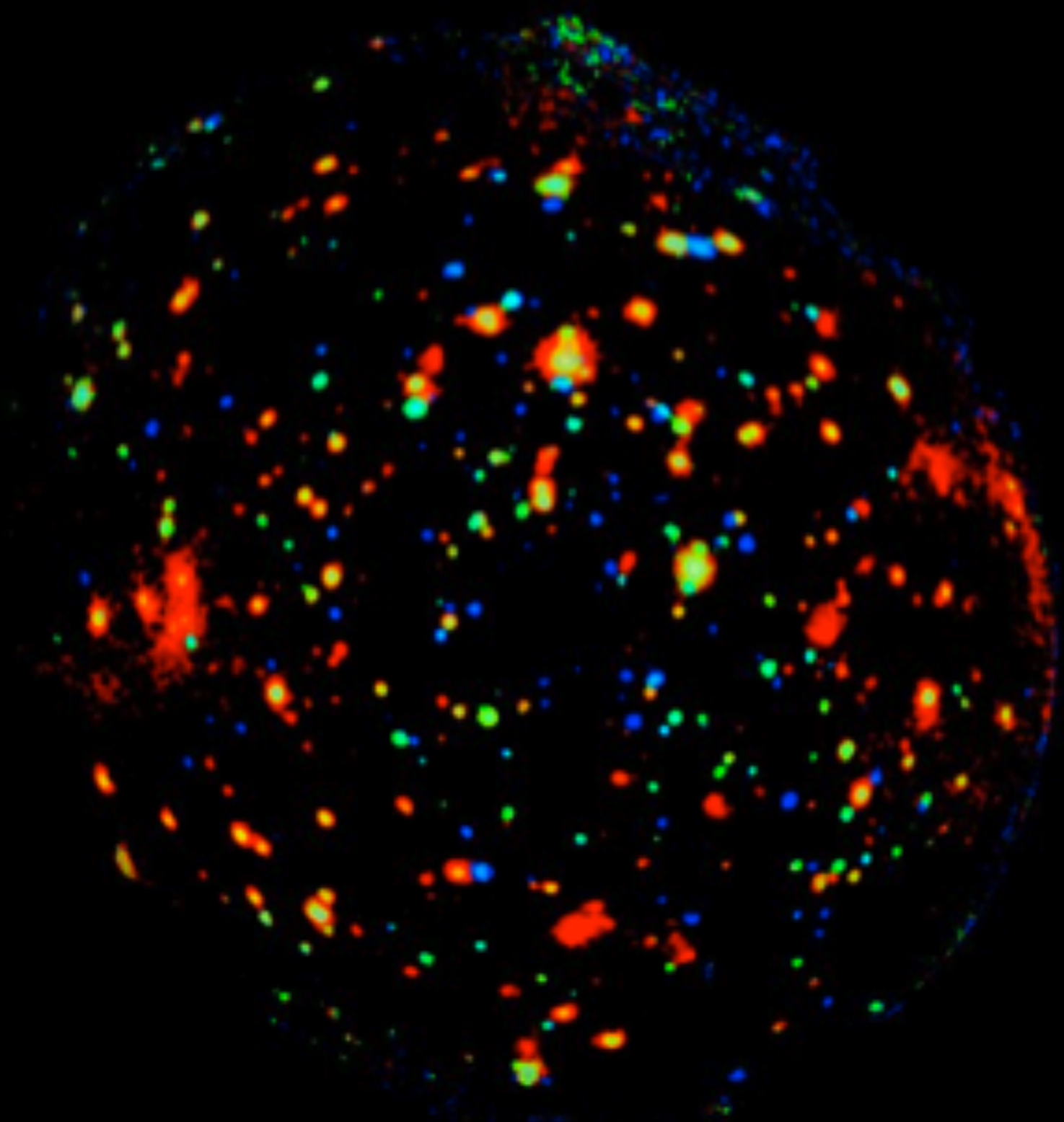
INAF-Osservatorio Astronomico di Bologna



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Lanzuisi, F.J. Carrera, M. Brusa, F. Vito, I. Georgantopoulos,  
E.Rovilos, F.Fiore, F.Civano, W.N. Brandt, P.Tozzi,  
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# ~3 Ms XMM image of the Chandra Deep Field South

~0.3 deg<sup>2</sup>



## Goals:

Resolve the XRB in the 5-10 keV band

Fine spectroscopy of distant heavily obscured AGN

red = 0.4 - 1 keV  
green = 1 - 2 keV  
blue = 2 - 8 keV

# XMM-CDFS deep survey science goals

About 60% of the hard 5-10 keV XRB was resolved

Ranalli+13

Unfortunately the background level was higher than expected

AGN “fine” spectroscopy beyond the local Universe  
evolution, feedback, ...

Census of highly obscured and Compton thick AGN

Iron line properties

Variability

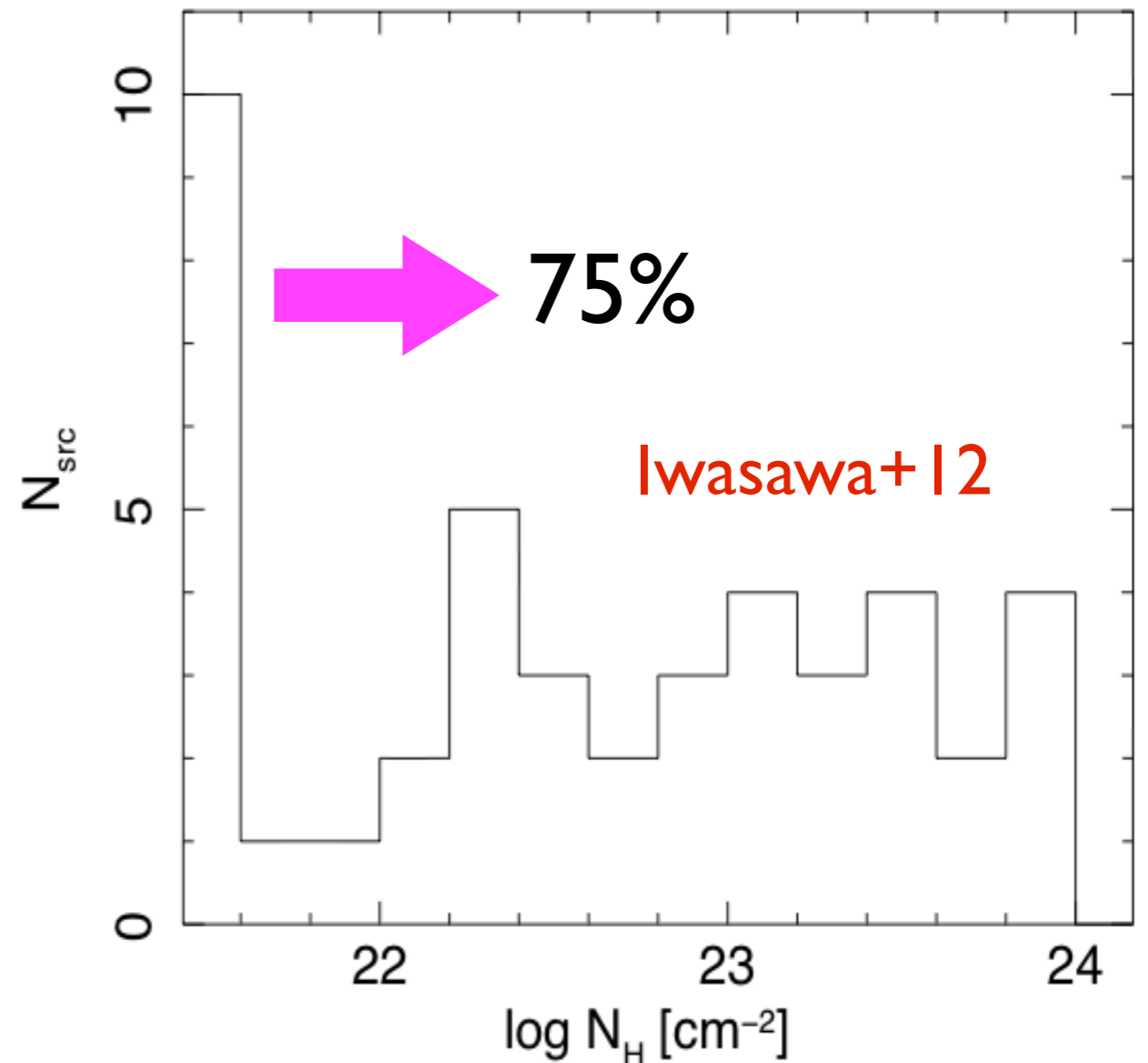
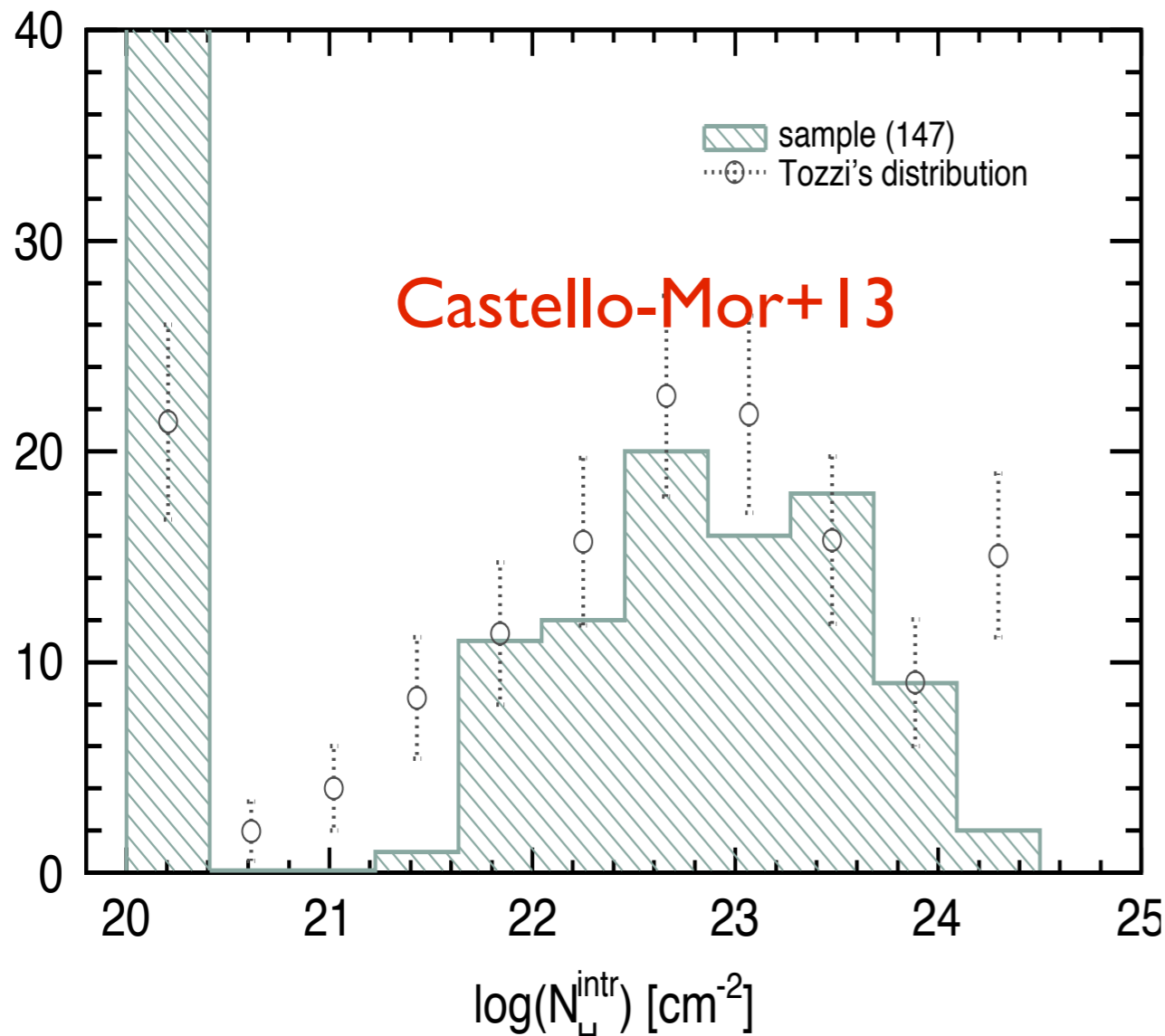
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# The X-ray sample(s)

“2-10 keV selected” flux limited, widely different spectral quality

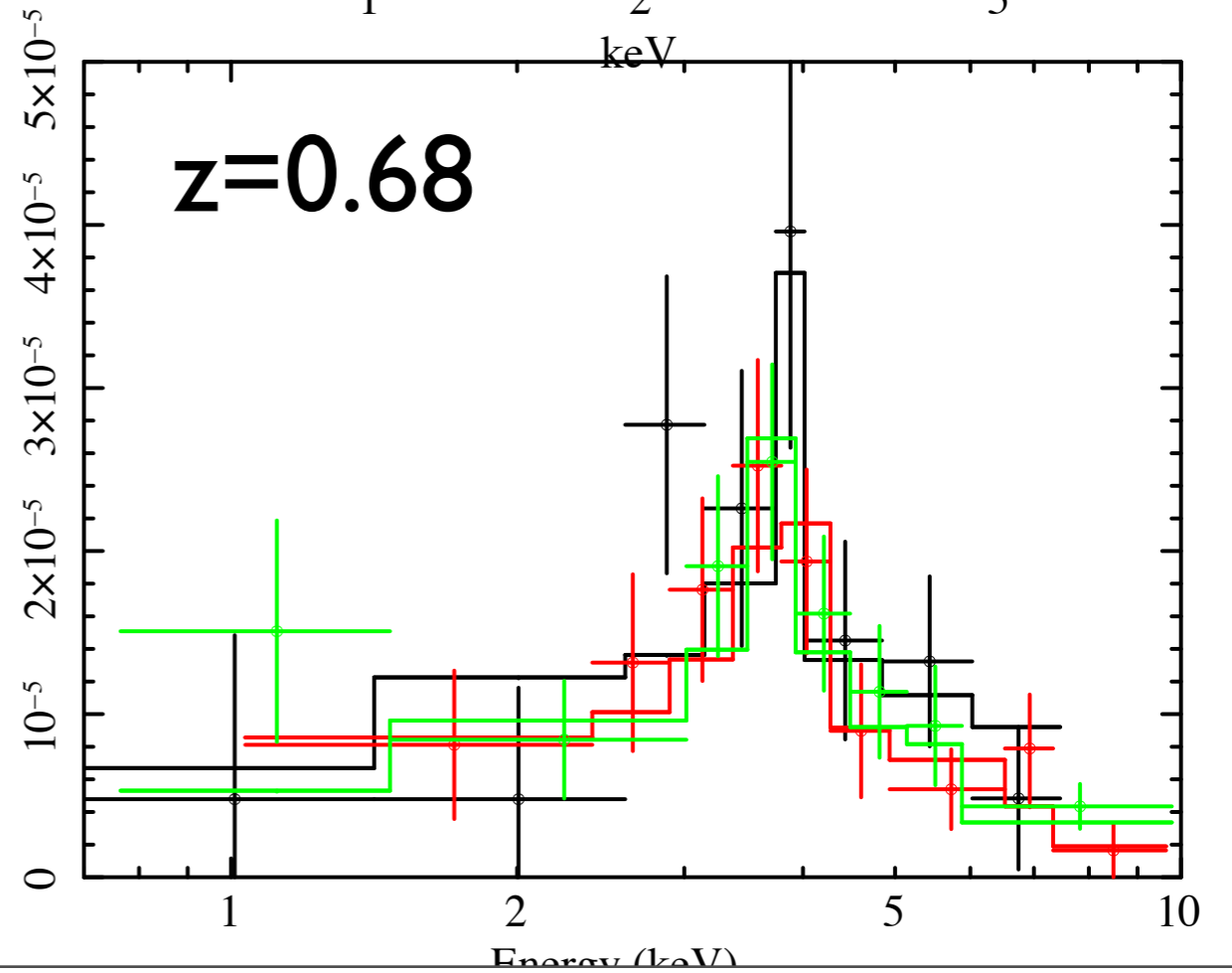
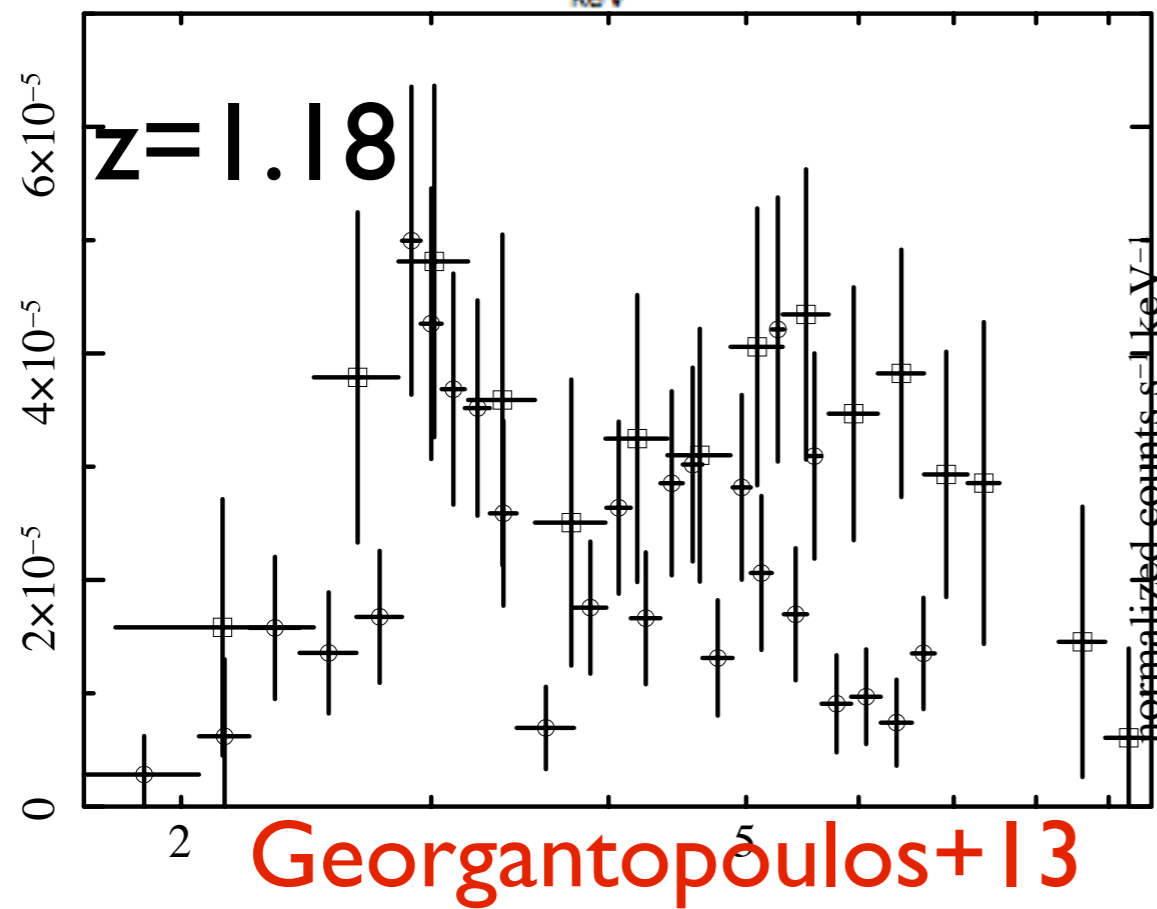
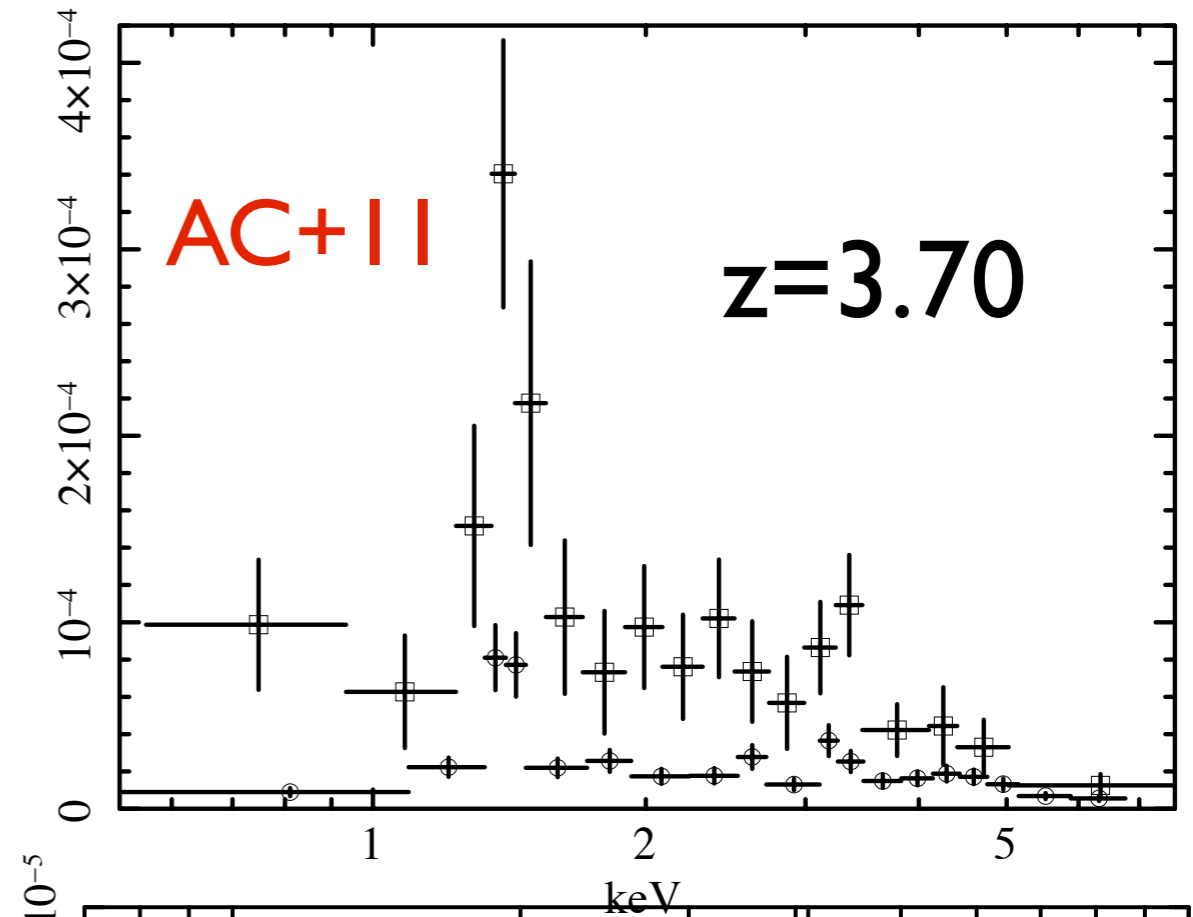
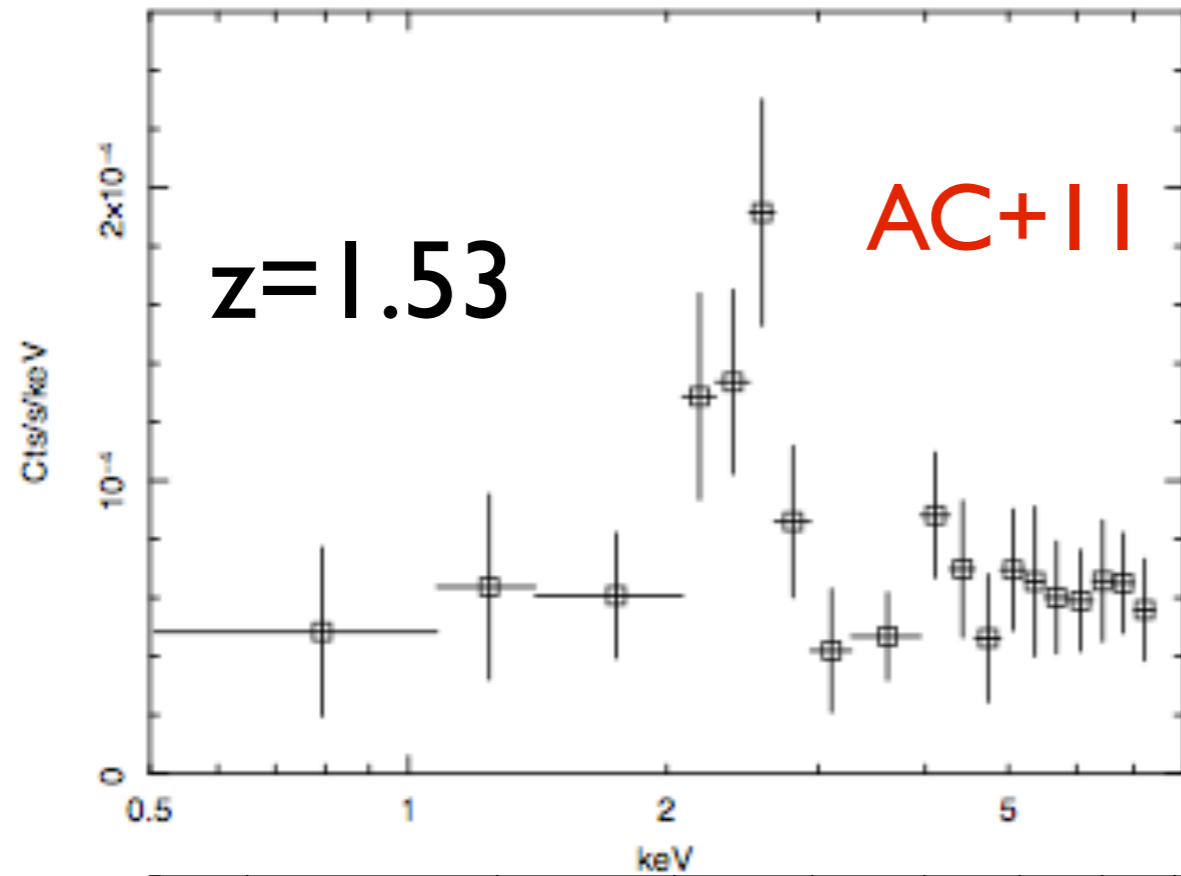
180 sources  $> 1.8 \times 10^{-15}$  cgs

46 sources @  $z > 1.7$

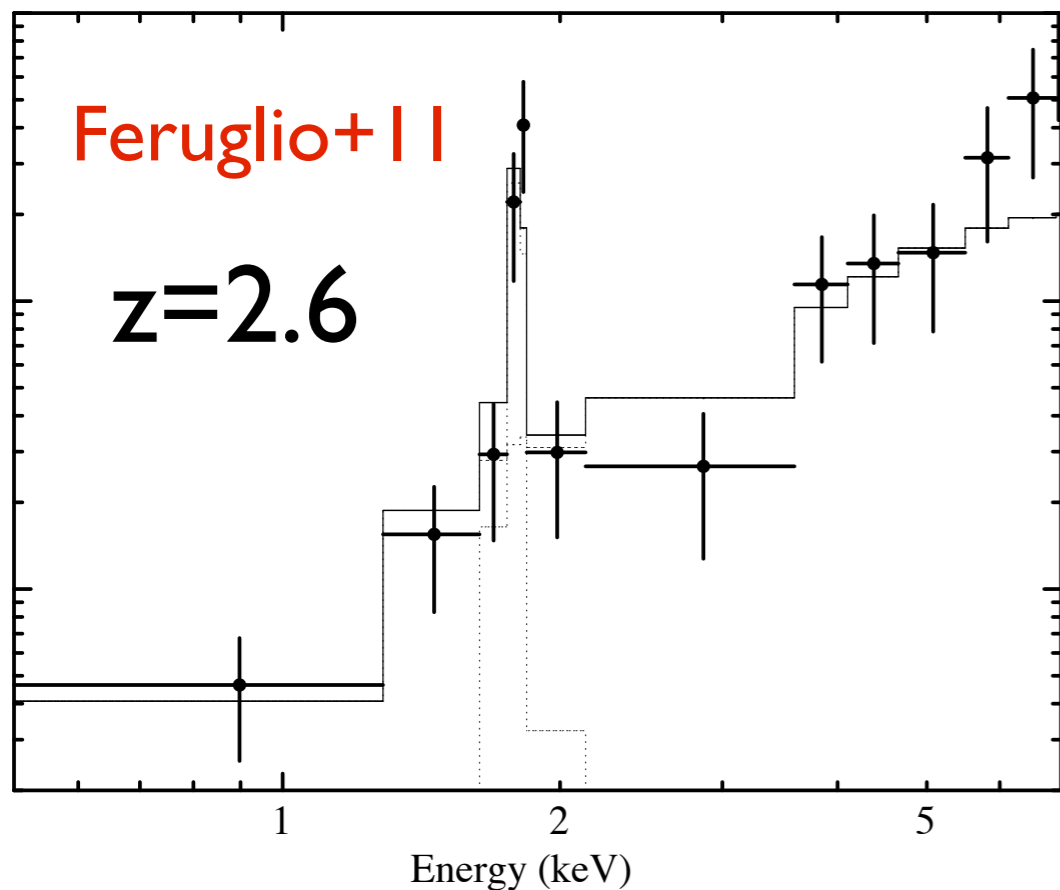
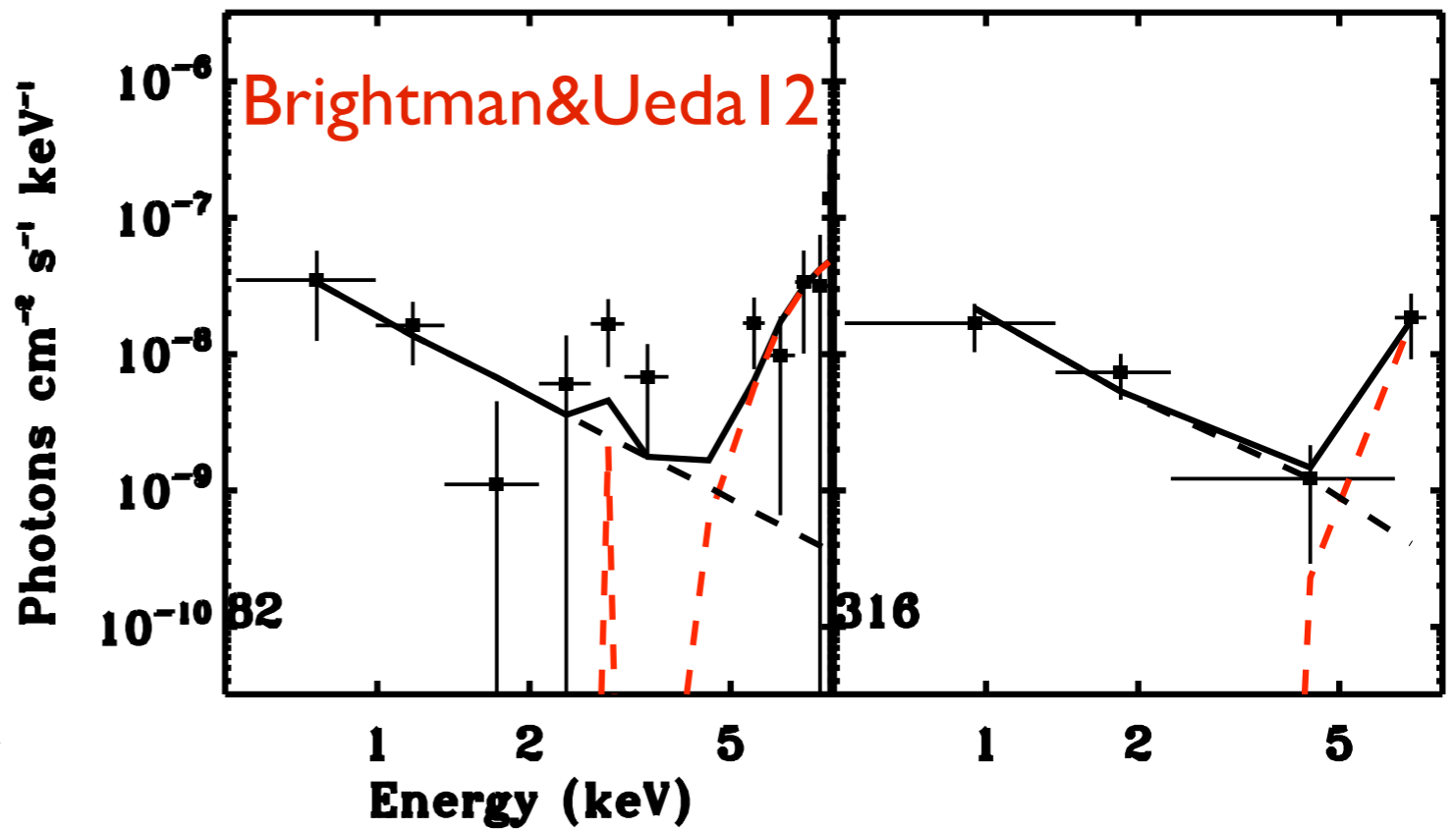
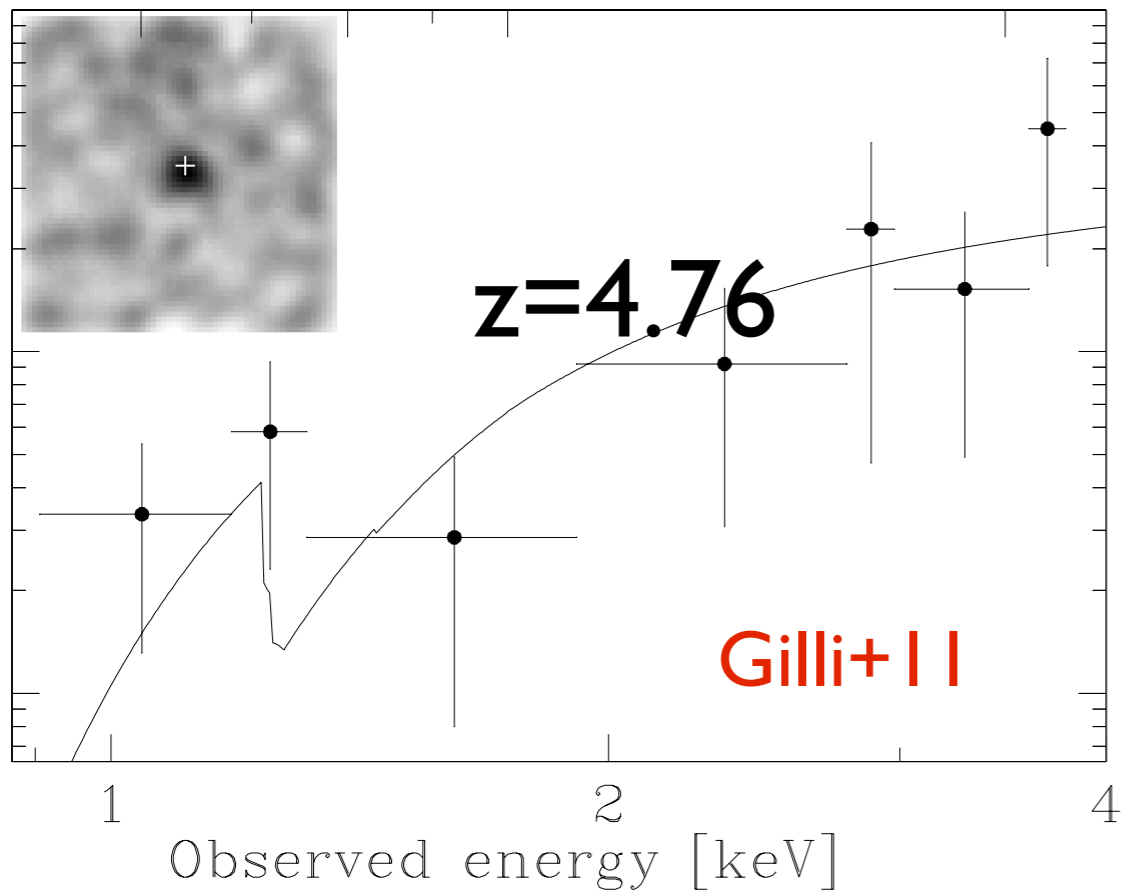


The obscured fraction increases toward high- $z$  for luminous ( $> 10^{44}$  erg s<sup>-1</sup>) AGN (cfr. ~20-30% at  $z \sim 0$  Burlon+11)

# Distant Compton thick in the CDFS



# Chandra Results



Chandra is/will reach higher redshifts especially with the 7 Ms

Spectral Quality is not good enough for accurate  $N_{\text{H}}$  measurements in the Compton thick regime

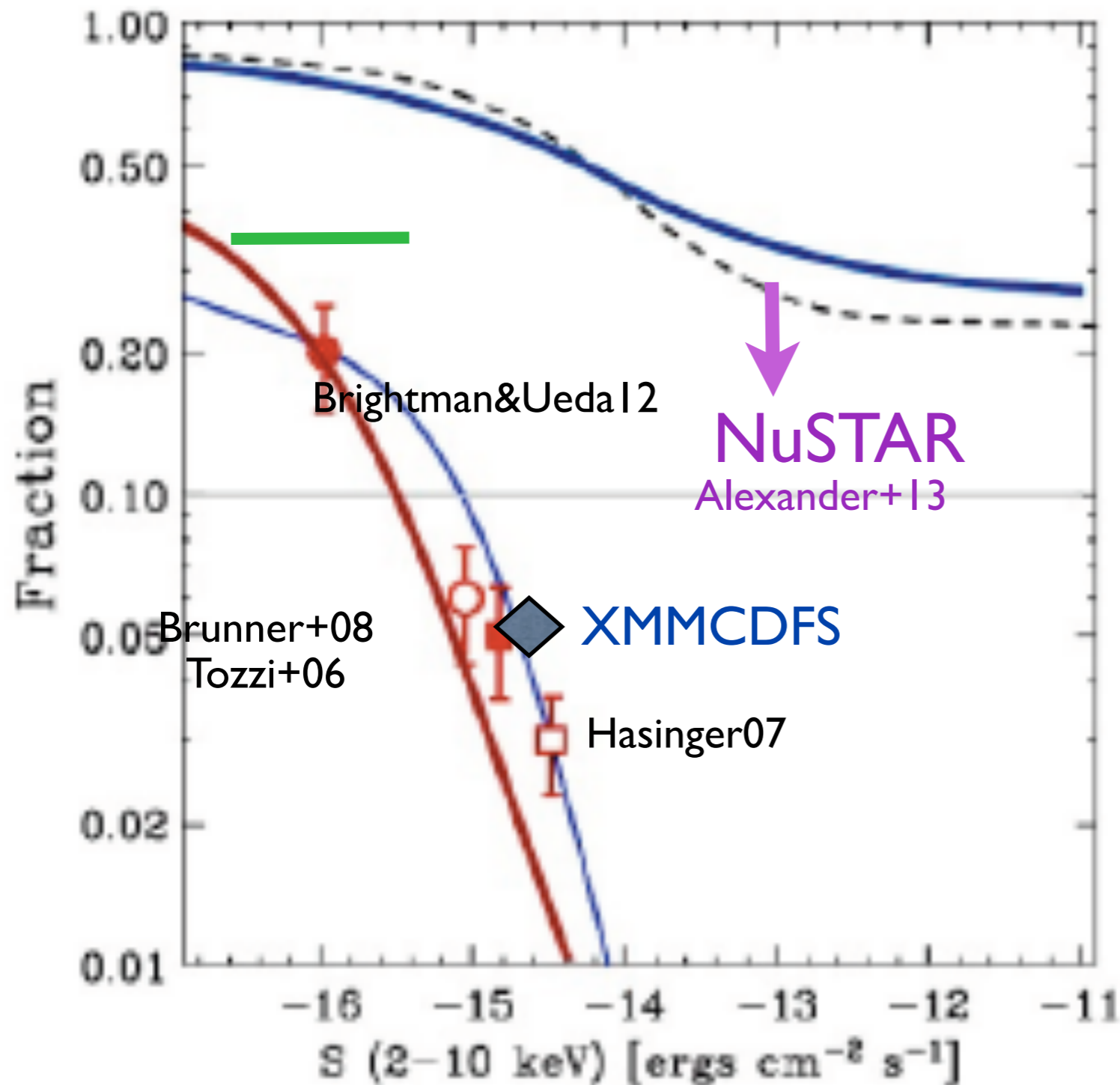
# Comparisons

ID210	us	T06	C11	B12	I12	G13	
30	heavily	–	–	–	heavily	–	FLAT
44	unabsorbed	CThick	–	heavily	–	–	< 5 × 10 <sup>-15</sup>
48	moderately	–	–	–	–	heavily	Moderate
64	heavily	–	–	–	heavily	–	
66	heavily	–	–	–	–	secure-CThick	
106	moderately	CThick	–	heavily	–	–	< 5 × 10 <sup>-15</sup>
114	heavily	–	–	–	heavily	–	< 5 × 10 <sup>-15</sup>
144	heavily	CThick	CThick	heavily	heavily	secure-CThick	< 5 × 10 <sup>-15</sup>
147	heavily	CThick	CThick	heavily	–	secure-CThick	
155	moderately	CThick	–	heavily	–	< 5 × 10 <sup>-15</sup>	Reflection Dominated
180	heavily	–	–	–	heavily	heavily	
214	heavily	–	–	–	–	heavily	NuSTAR Heavily
222	unabsorbed	–	–	–	–	heavily	FLAT
245	heavily	–	–	–	heavily	heavily	< 5 × 10 <sup>-15</sup>
289	moderately	–	–	–	–	heavily	Reflection Dominated
324	unabsorbed	–	–	–	–	secure-CThick	

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**Reflection Dominated**

# Compton thick Fraction



At the limiting fluxes of the XMM and Chandra spectral surveys the number of Compton Thick (CT) AGN is in fairly good agreement with the XRB model expectations.

Looking forward for NuSTAR deep surveys spectral analysis (Zappacosta+; Del Moro+ in preparation) to understand the evolution of the CT obscuring gas and implications for models

Ueda+14, GCH07, Buchner+15

# XMM deep X-ray spectrum

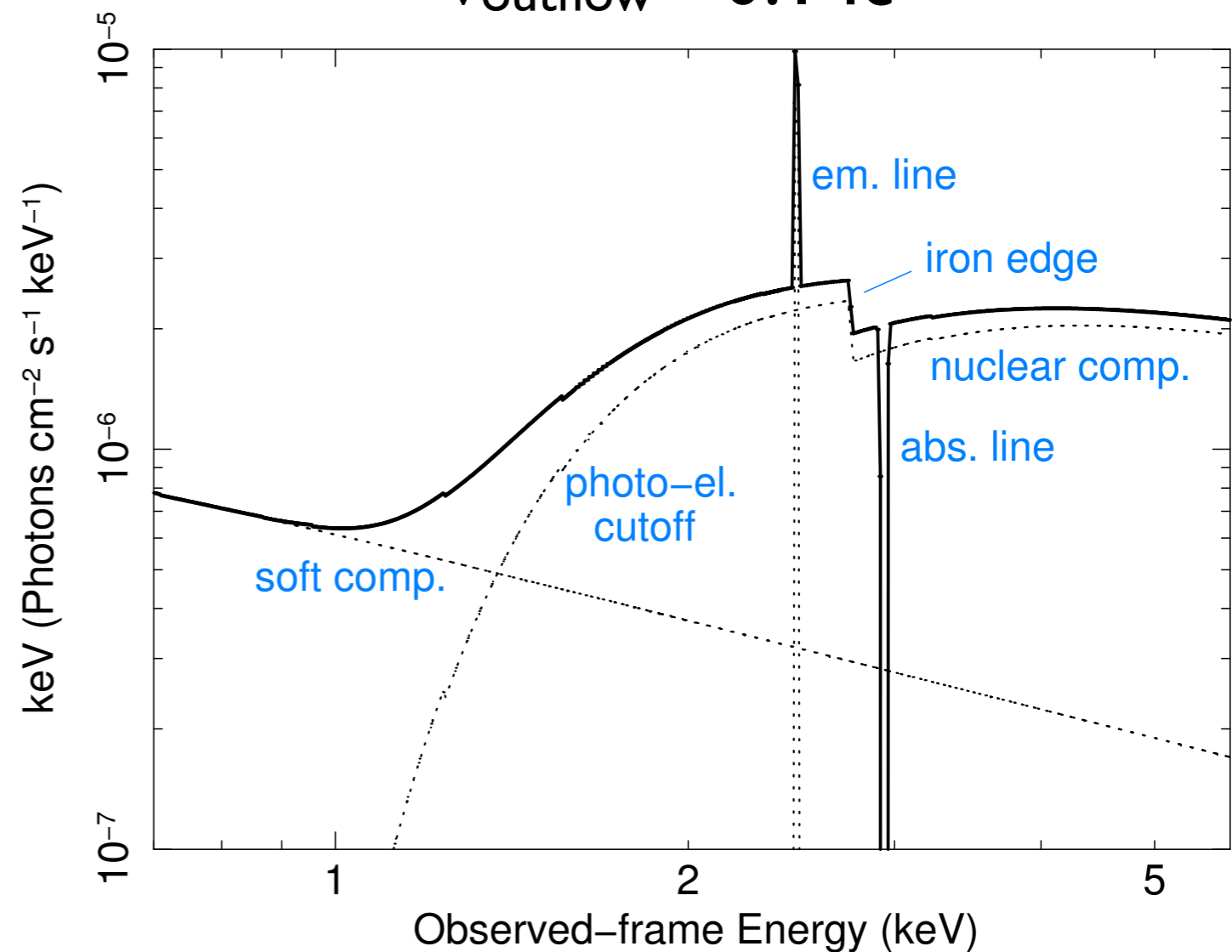
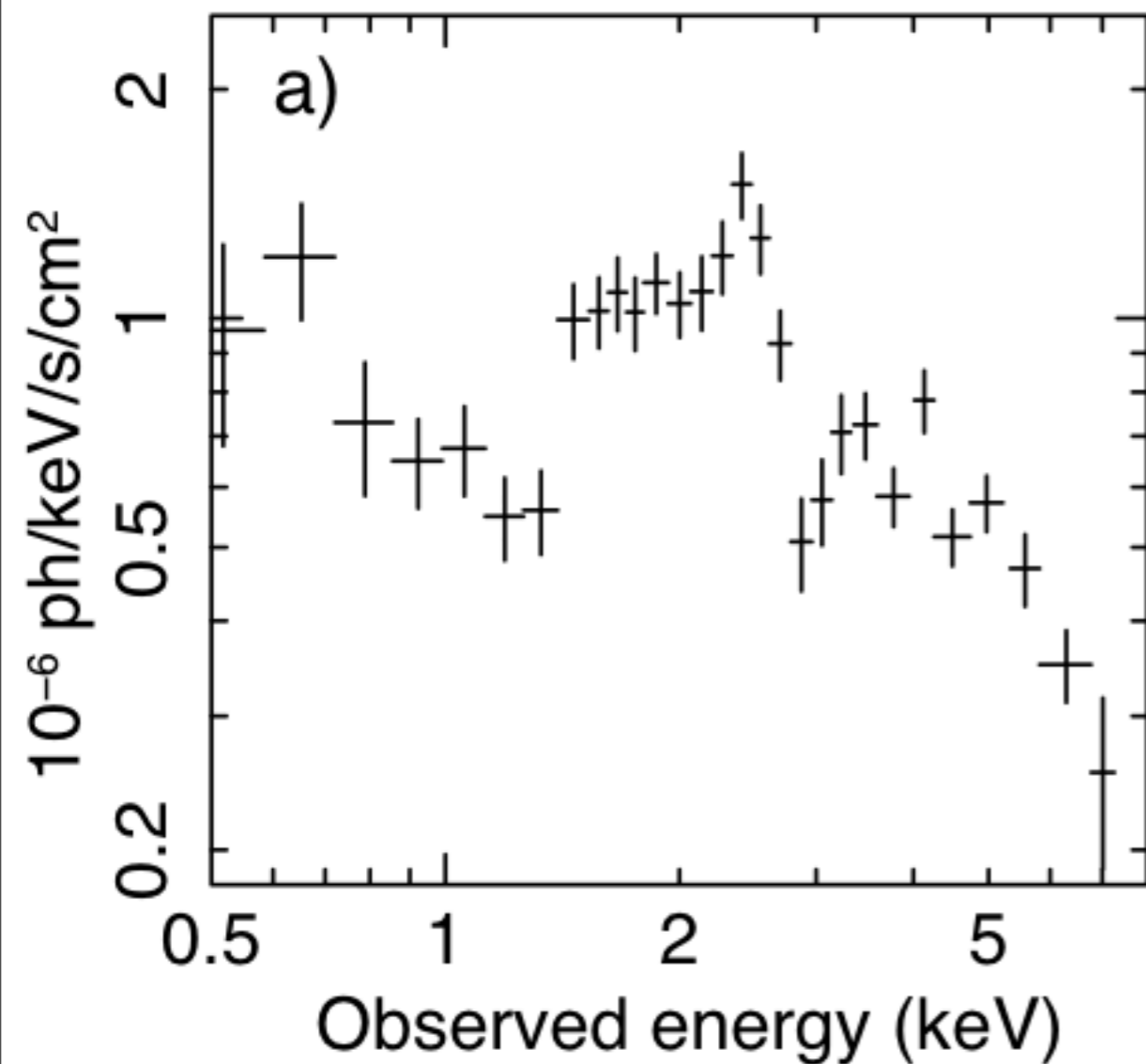
$$F_X \sim 3 \times 10^{-14} \quad L_X \sim 2 \times 10^{44} \quad N_H \sim 2-3 \times 10^{23} \text{cm}^{-2}$$

X-ray redshift from emission line + edge  $z \sim 1.6$

Resonant FeXXV-XXVI absorption  $\rightarrow$  **outflow**

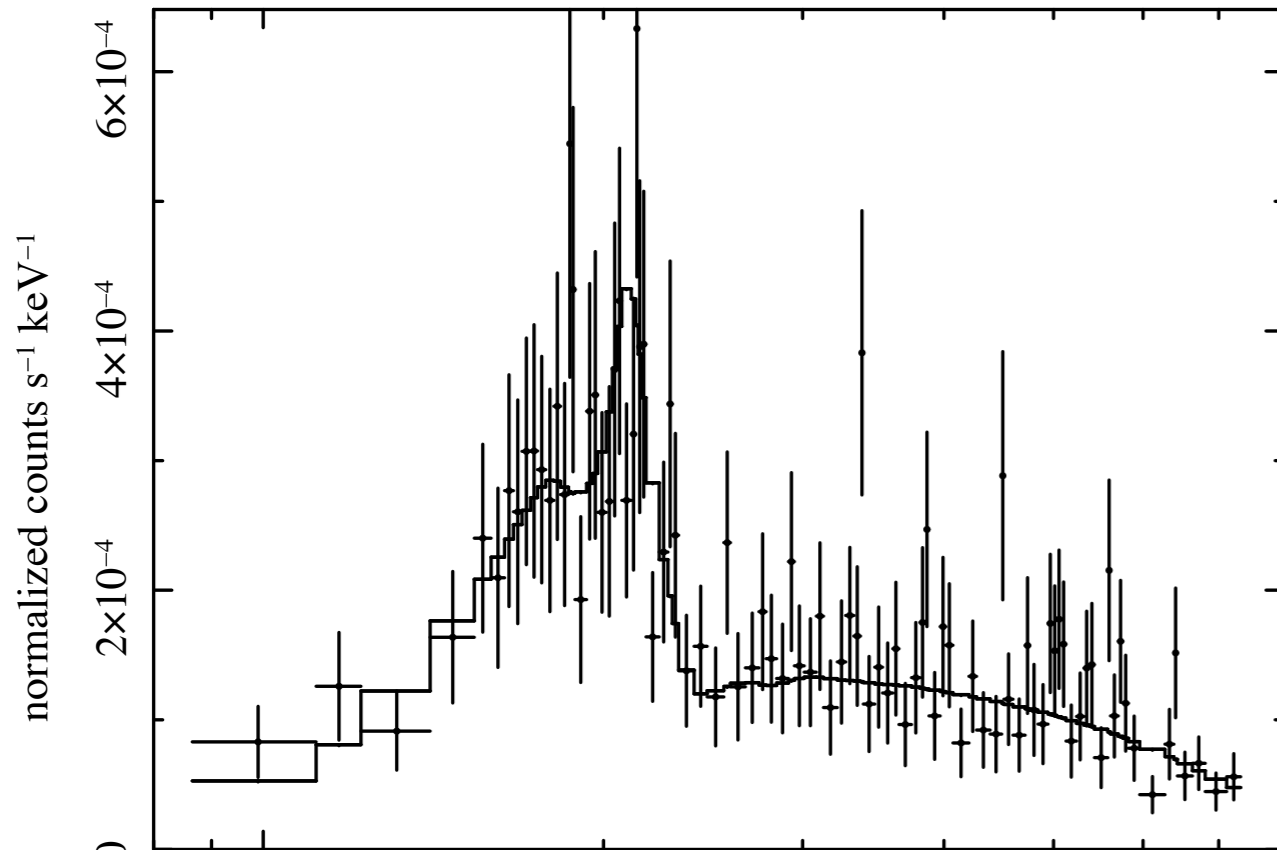
$\sim 700$  ksec

$v_{\text{outflow}} \sim 0.14c$



**Vignali+15**

# Redshift from the X-ray spectrum



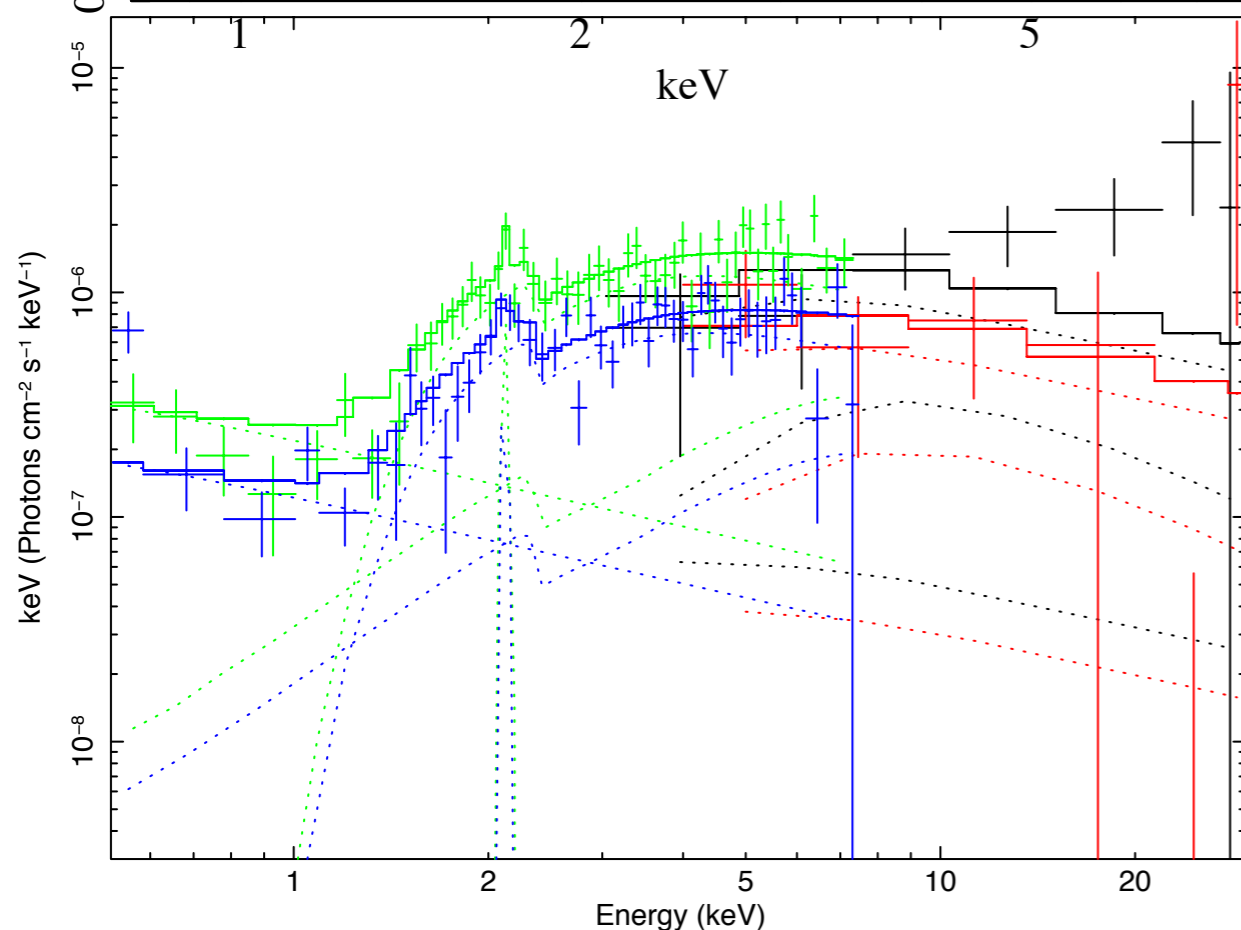
X-ray redshift from the K $\alpha$  Iron Edge (7.11 keV)

$$z = 2.03 \pm 0.04$$

Georgantopoulos+13

$$F_X \sim 1.5 \times 10^{-14} \quad L_X \sim 4 \times 10^{44}$$

$$N_H \sim 5-6 \times 10^{23} \text{ cm}^{-2}$$

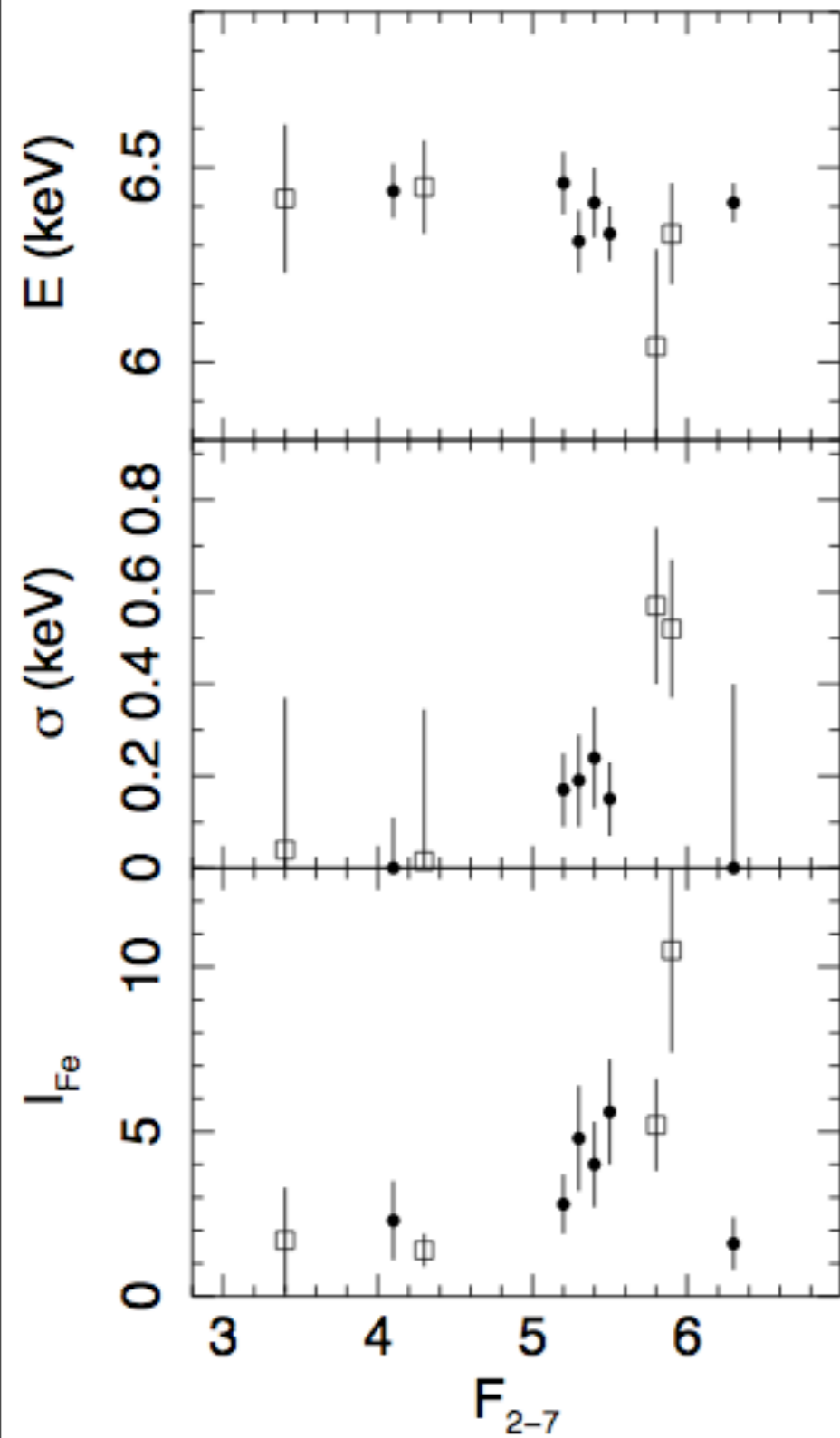


Detected by NuSTAR  
in the 8-24 keV band  
(but not < 8 keV)

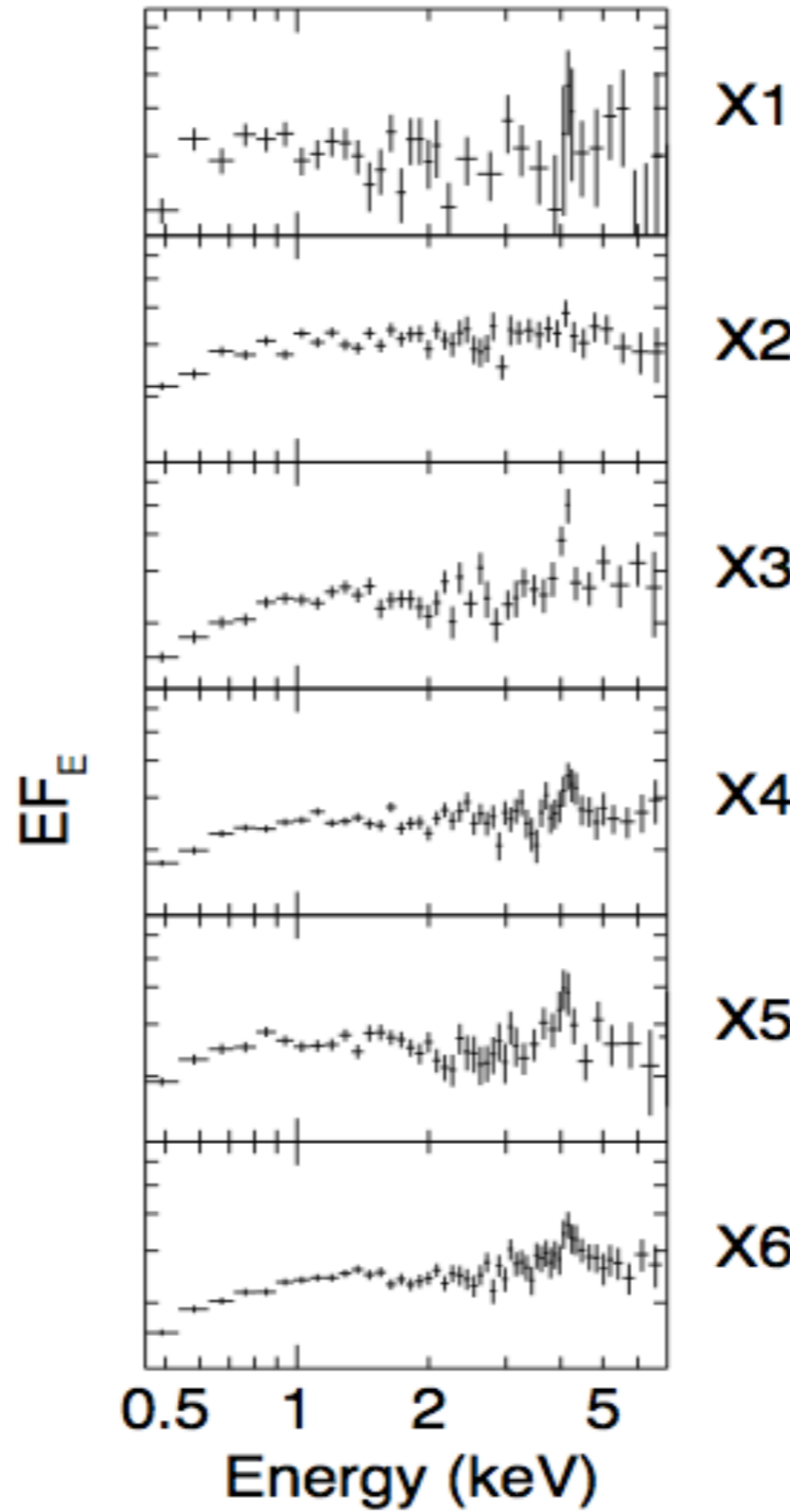
The most distant AGN  
detected above 10 keV

Del Moro+14

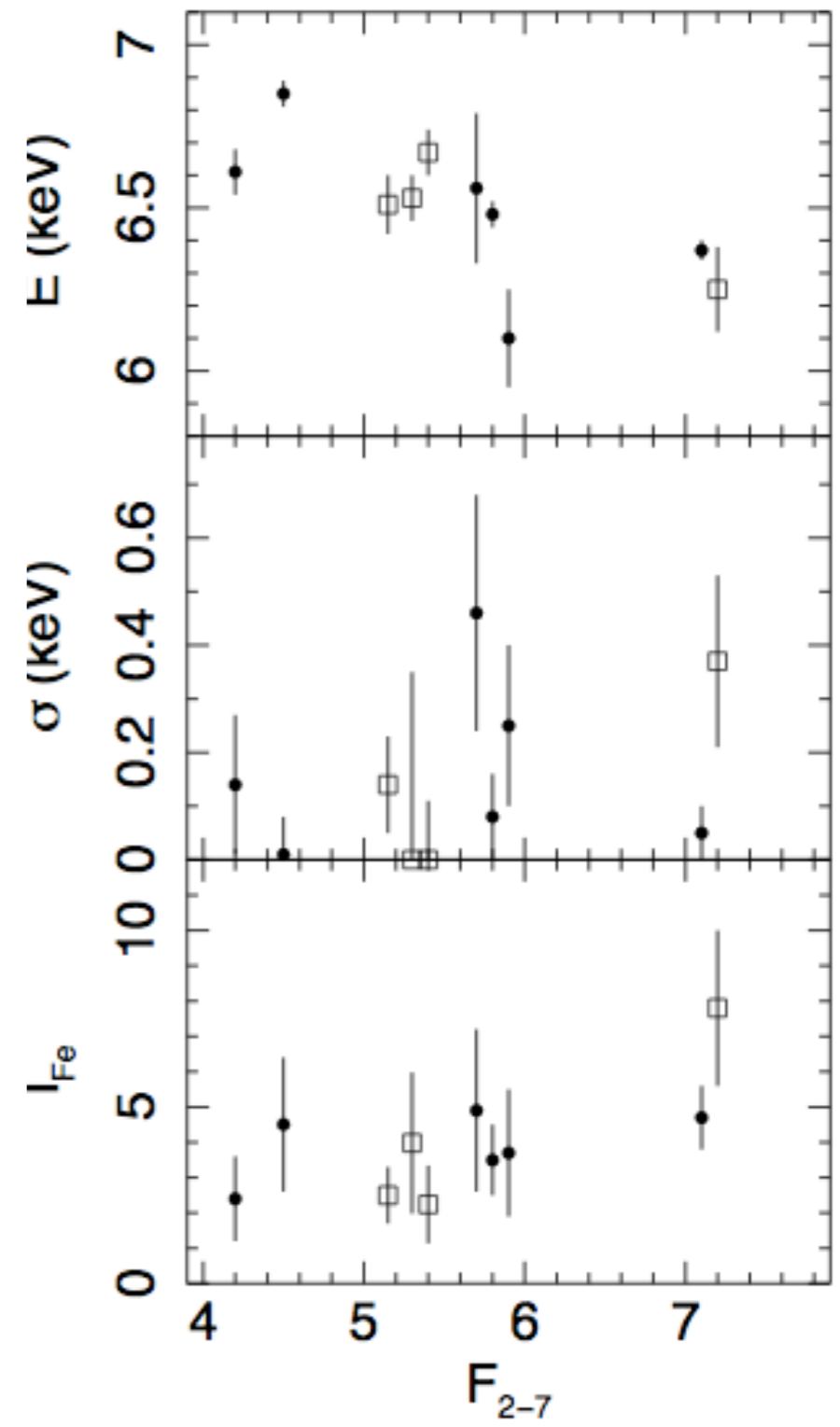
# Brightest sources iron line variability



$z=0.544$

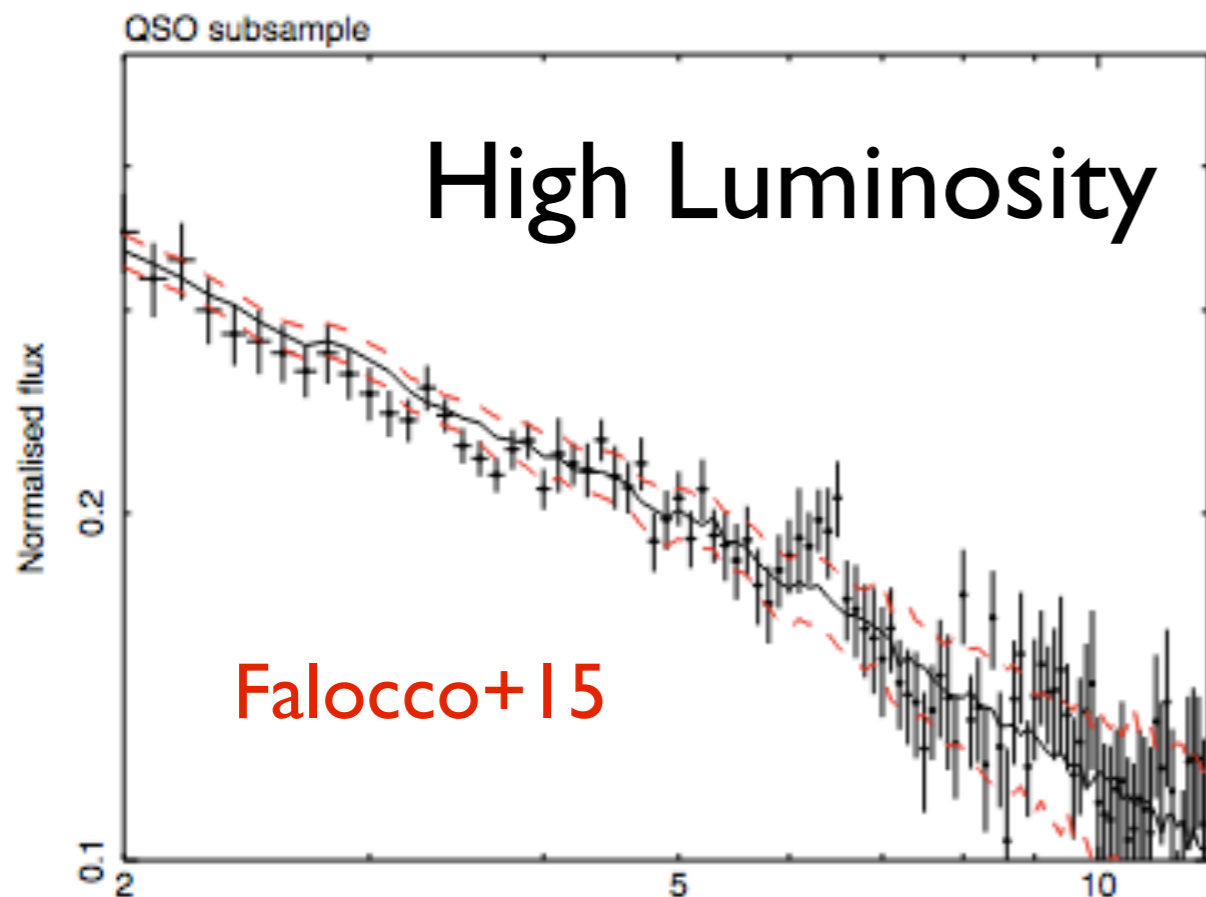
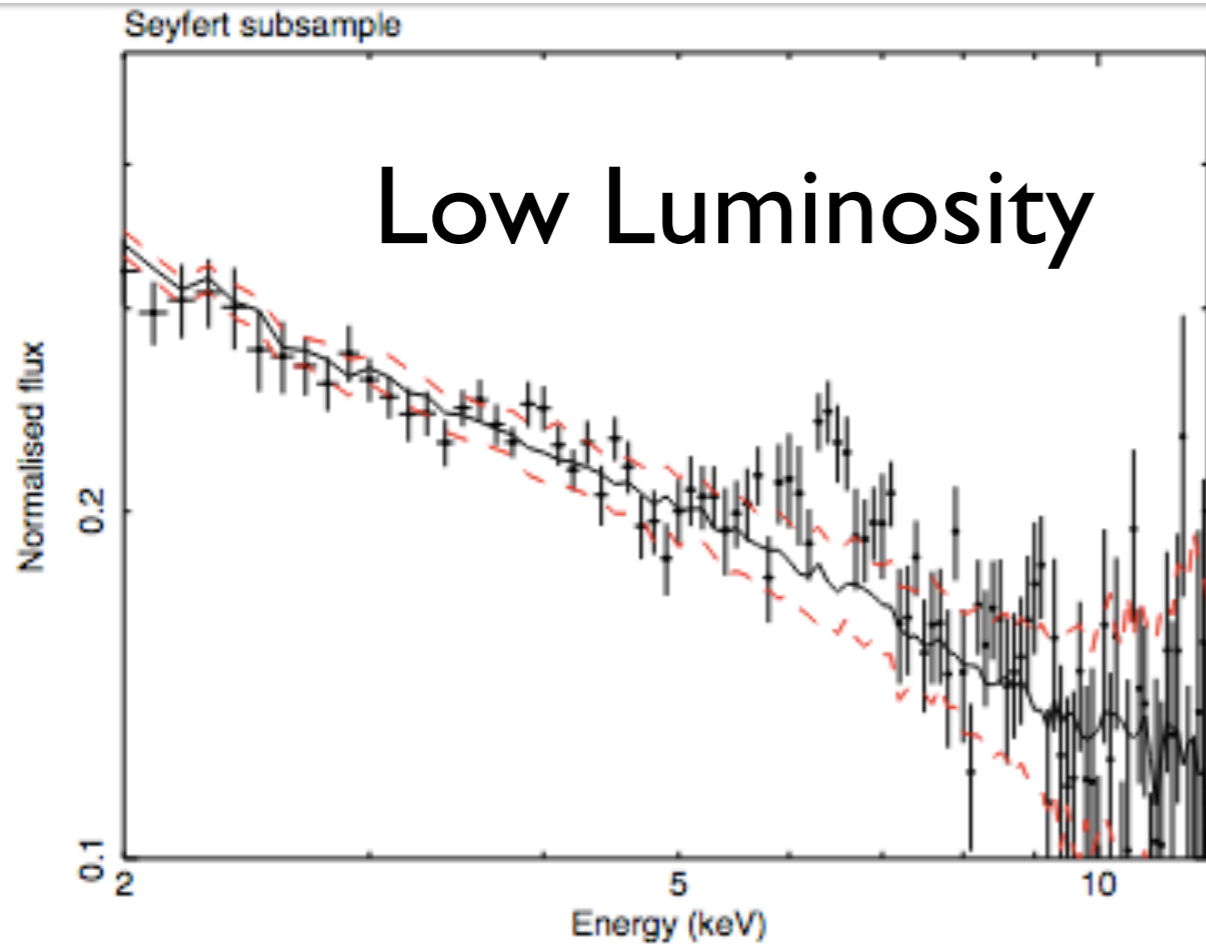


Iwasawa+15



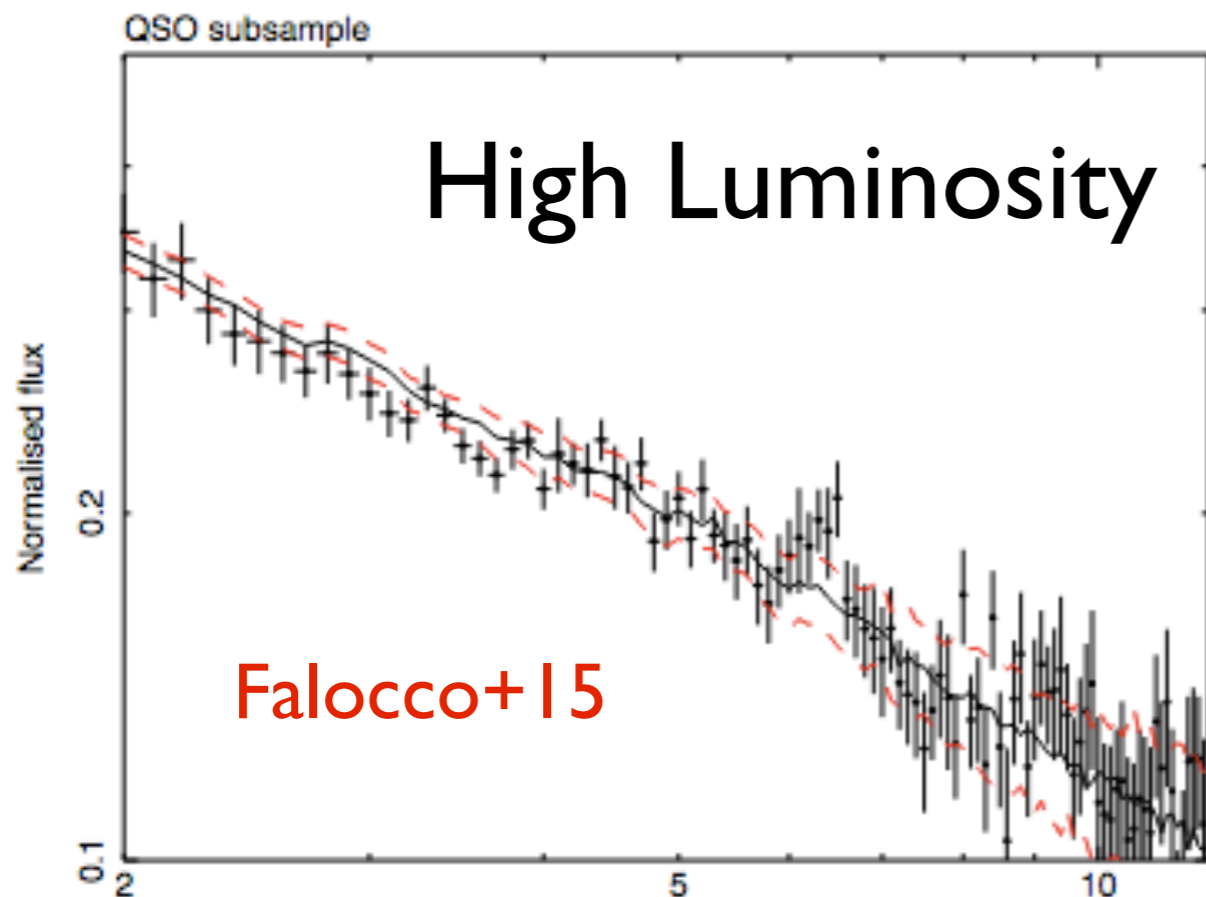
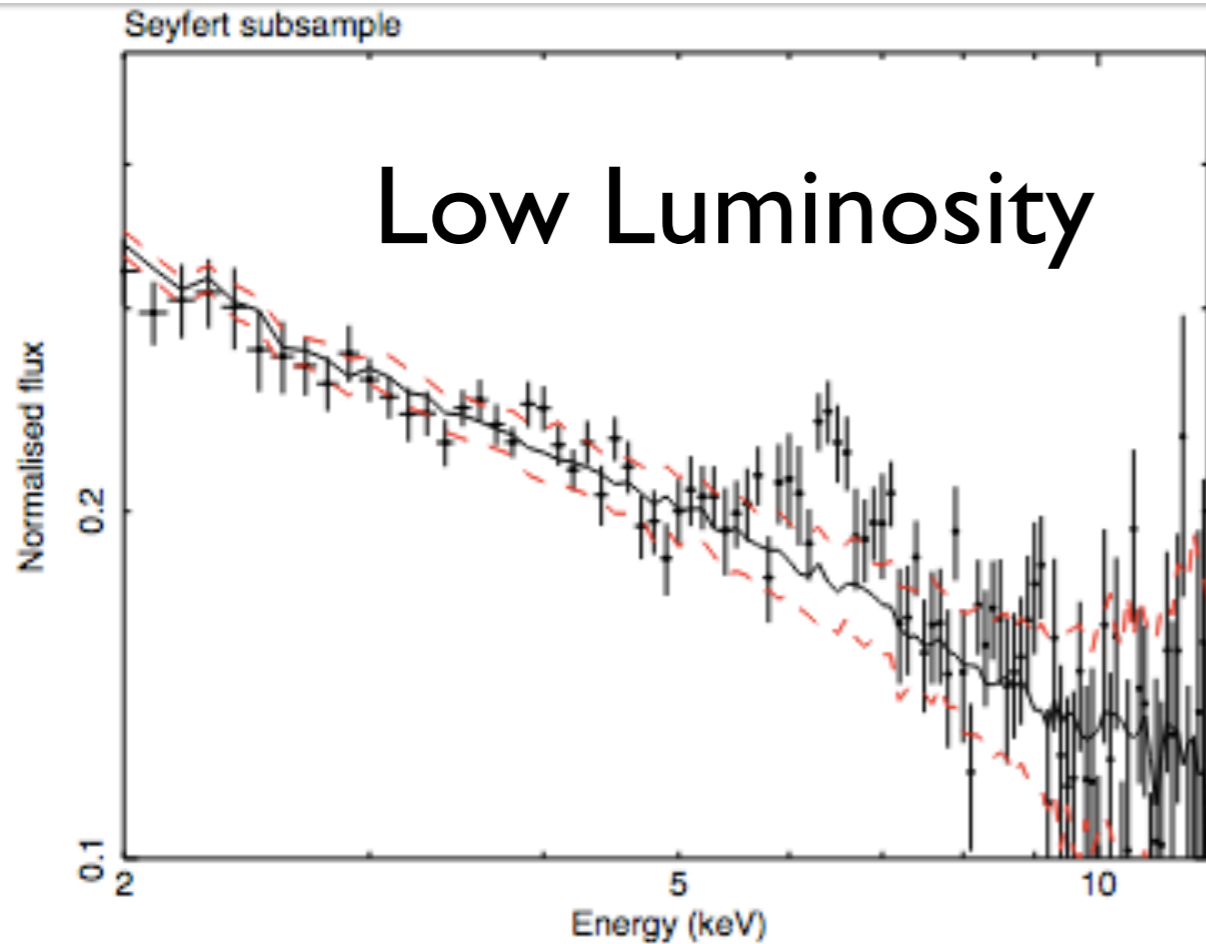
$z=0.742$

# Iron line profile



“Tentative” evidence  
of a broad component  
cfr. Brusa+05  
Chaudary+12  
and many others

# Iron line profile



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# Lessons learned & Perspectives

Pushing even deeper is not rewarding especially with 7 Ms Chandra

Good quality spectra are absolutely needed for many science goals

$N_H$  distribution above  $10^{24}$   $\text{cm}^{-2}$ : relative fraction of reflection dominated vs XRB contributors and their volume emissivity/space density (cfr. Akylas+12; Fabian+16; Esposito&Walter 16, XRB is mostly due to disk reflection rather than CT)

UFO/Outflows at high-z: feedback at work

Iron line, absorption and continuum variability

...

# XMM 2016-2026

If I have 10 - 20 Ms

Identify a well defined sample of molecular outflows and UFO  
only two examples (Tombesi+15;Feruglio+15)  
and/or high-redshift interesting objects (cfr. **Massimo Cappi** review)

Large sample of “representative” heavily obscured AGN,

Iron line intensity and profile distribution beyond the local Universe

COSMOS, (**Lanzuisi**) XSERVS (**Brandt**), XXL(**Pierre**), Stripe82 (**La Massa**) are excellent starting points.