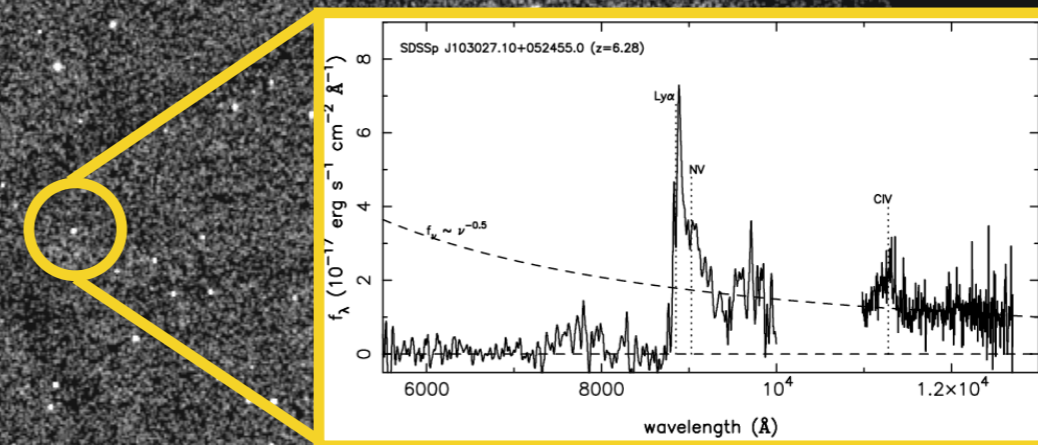




Riccardo Nanni  
INAF - OASBo  
DIFA - Alma Mater Studiorum

# The X-ray properties of $z \sim 6$ quasars

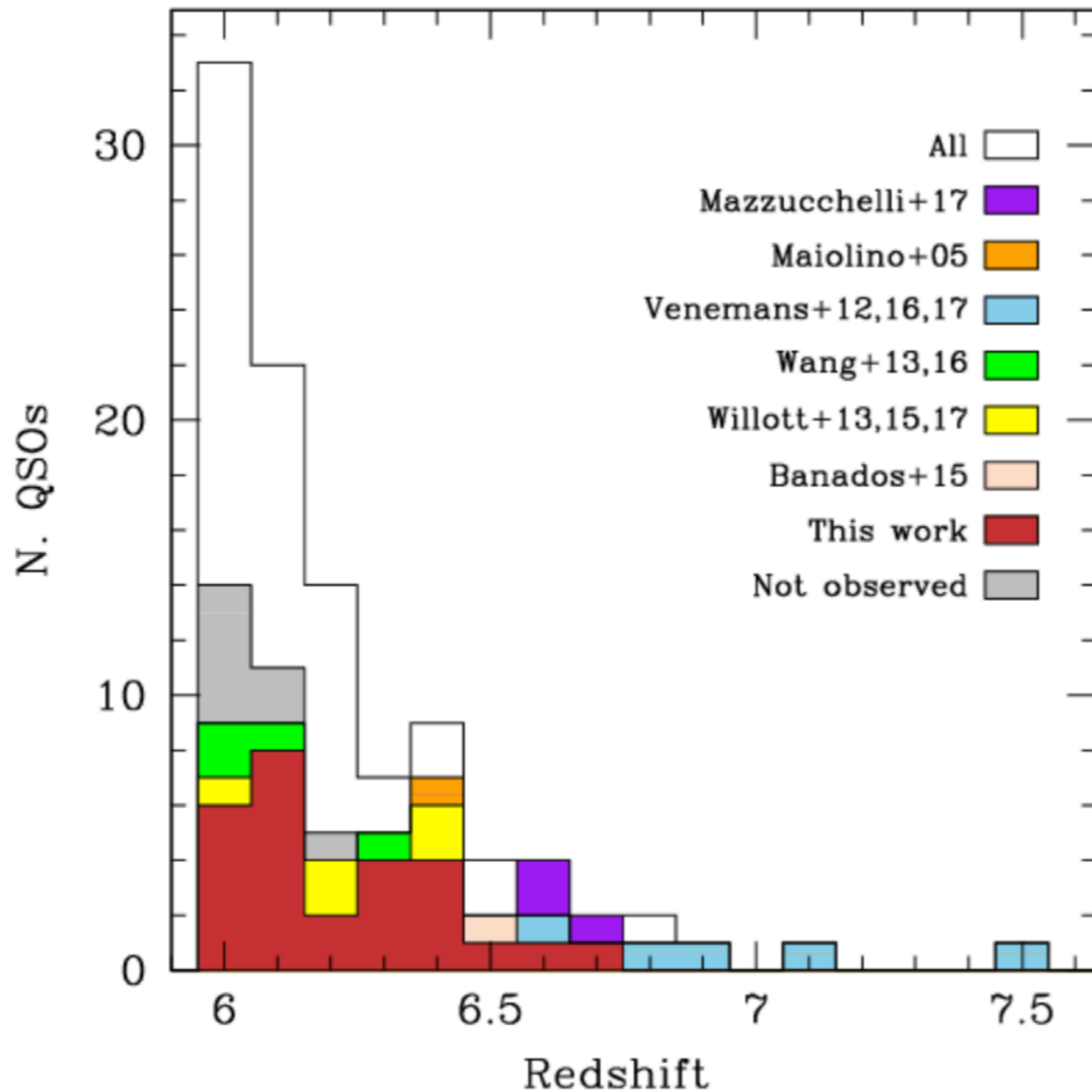


Collaborators: R. Gilli, C. Vignali, M. Mignoli, B. Balmaverde, F. Vito and many others

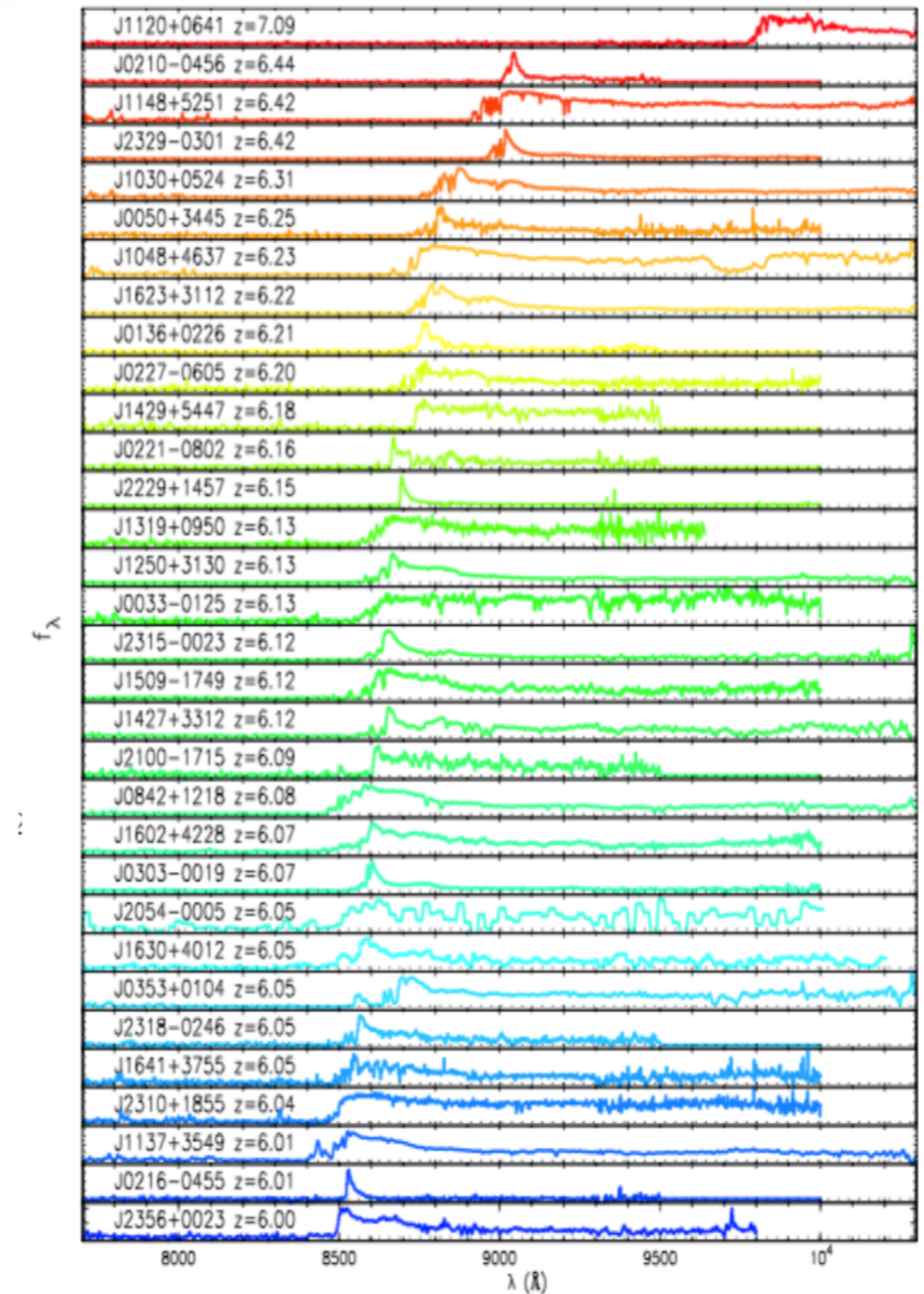
12/10/2018

# High-z QSOs: how many?

**259** detected QSOs at  $z \geq 5.5$



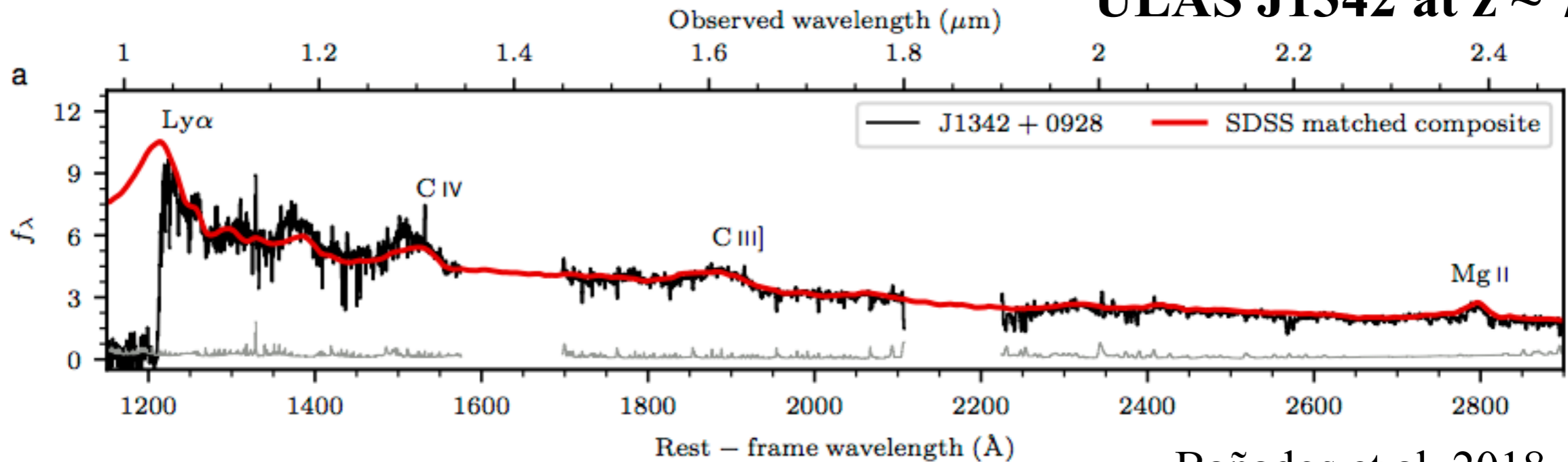
Decarli et al. 2018



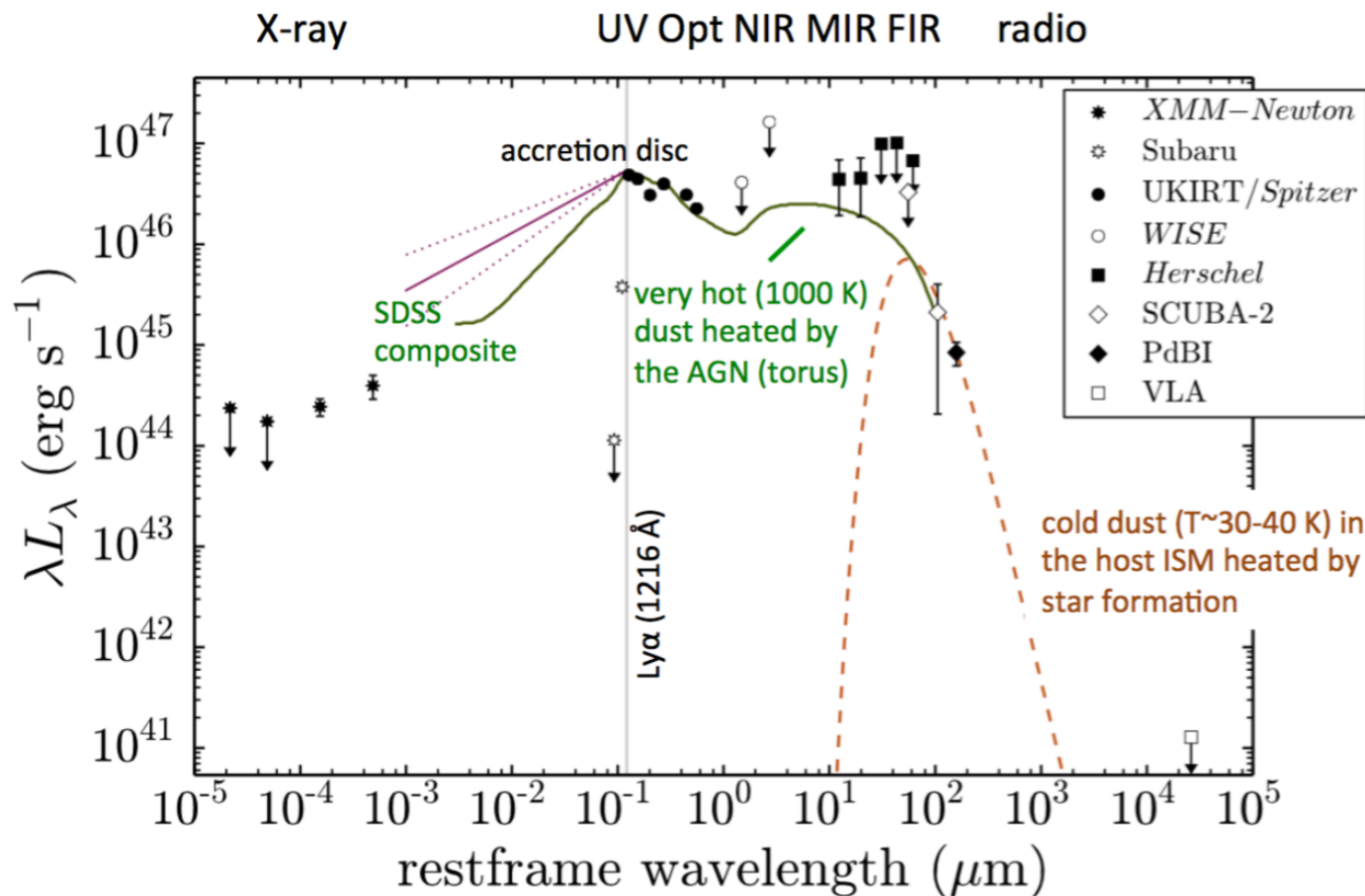
Fan et al. 2012

# Optical/NIR spectral properties

## ULAS J1342 at $z \sim 7.5$



Bañados et al. 2018



## ULAS J1120 at $z \sim 7.1$

Barnett et al. 2015

# X-ray QSOs

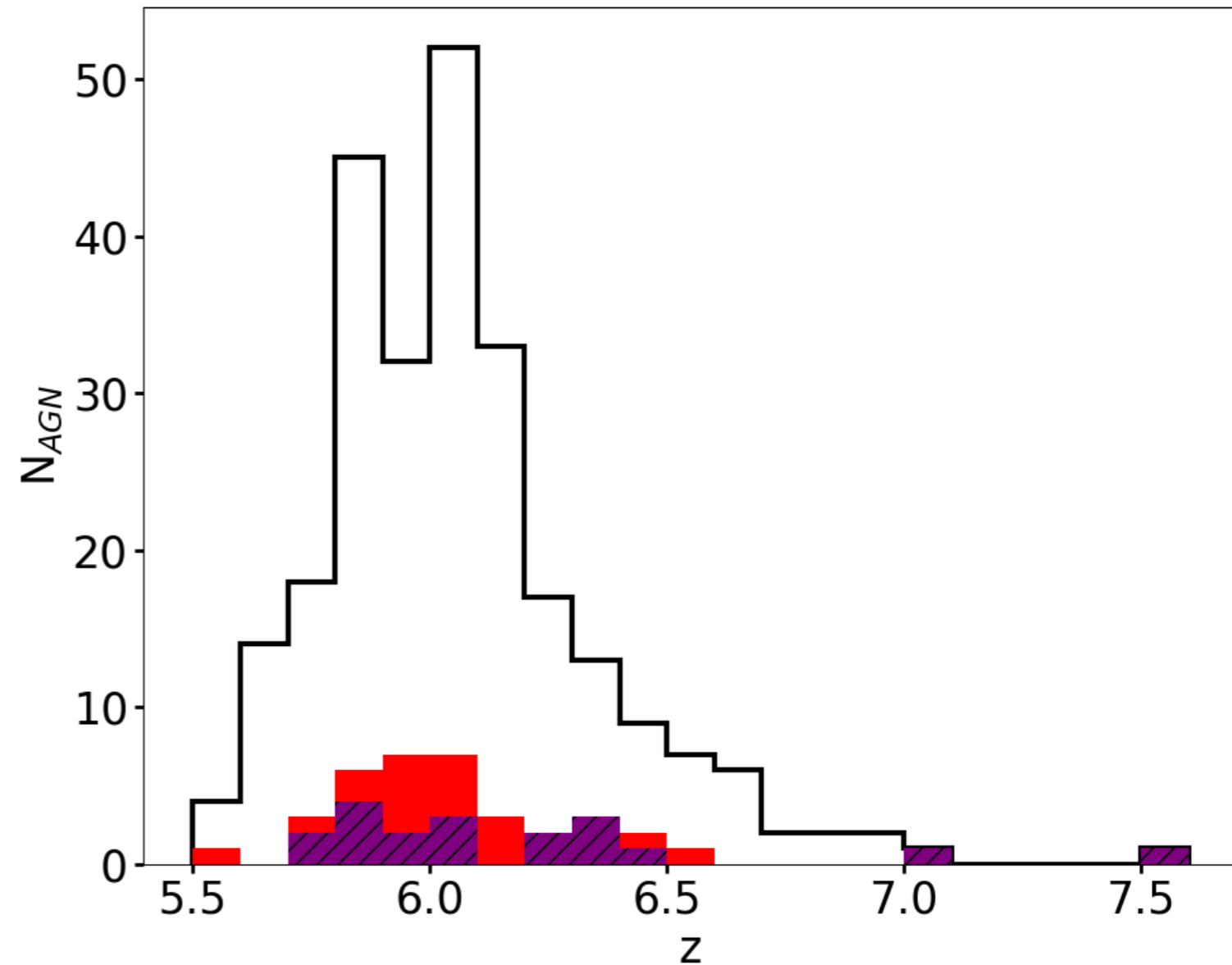
259 QSOs at  $z > 5.5$



37 QSOs observed in X-ray  
(20 by Chandra, 10 by XMM-Newton, 6 by both, 1 by Swift)



19 QSOs X-ray detected



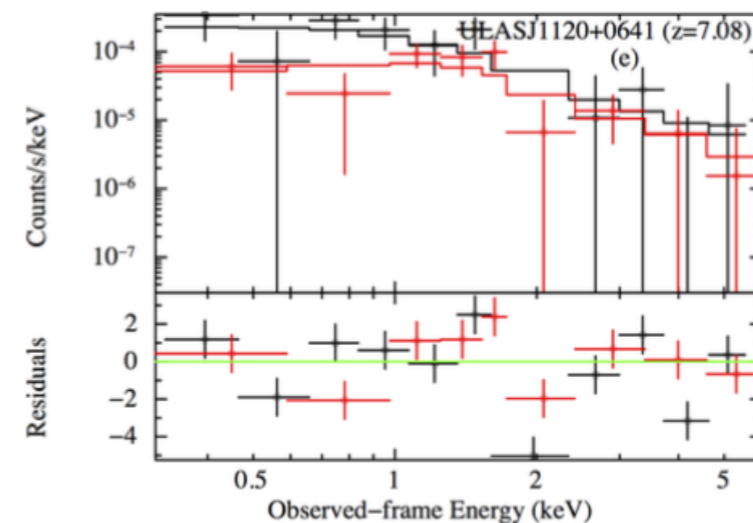
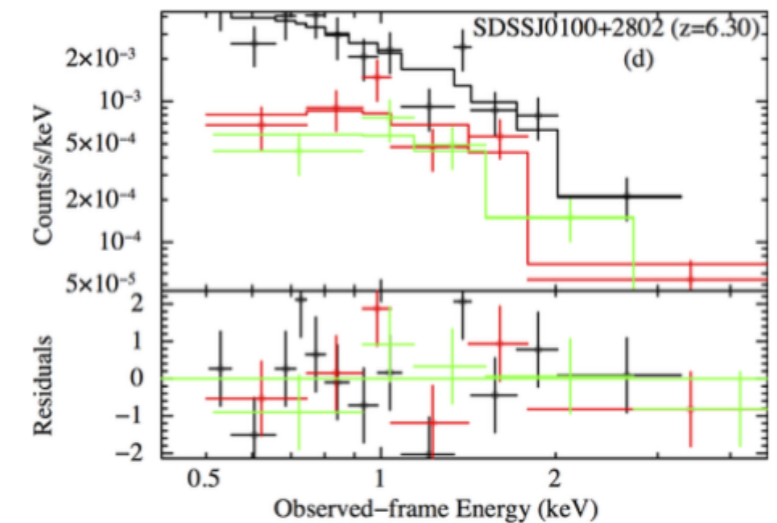
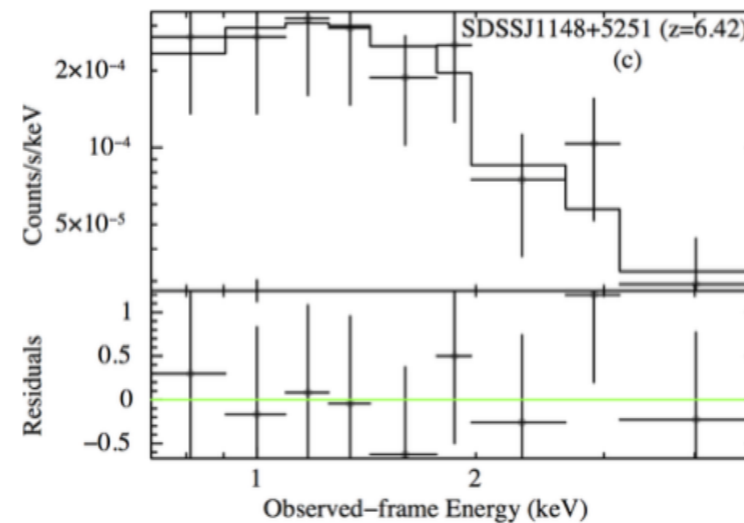
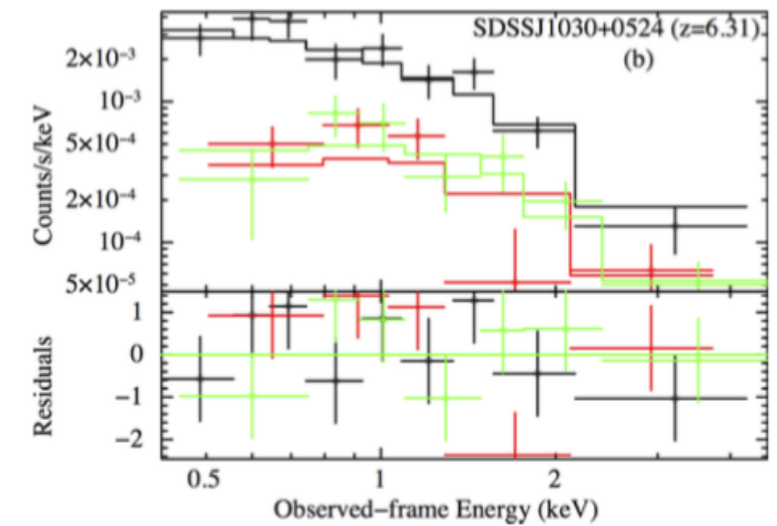
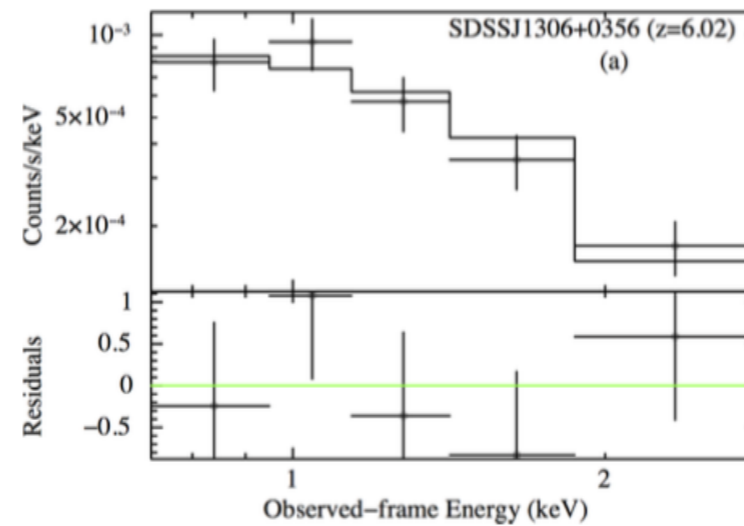
Known QSOs  
X-ray observed  
X-ray detected

# X-ray spectral properties

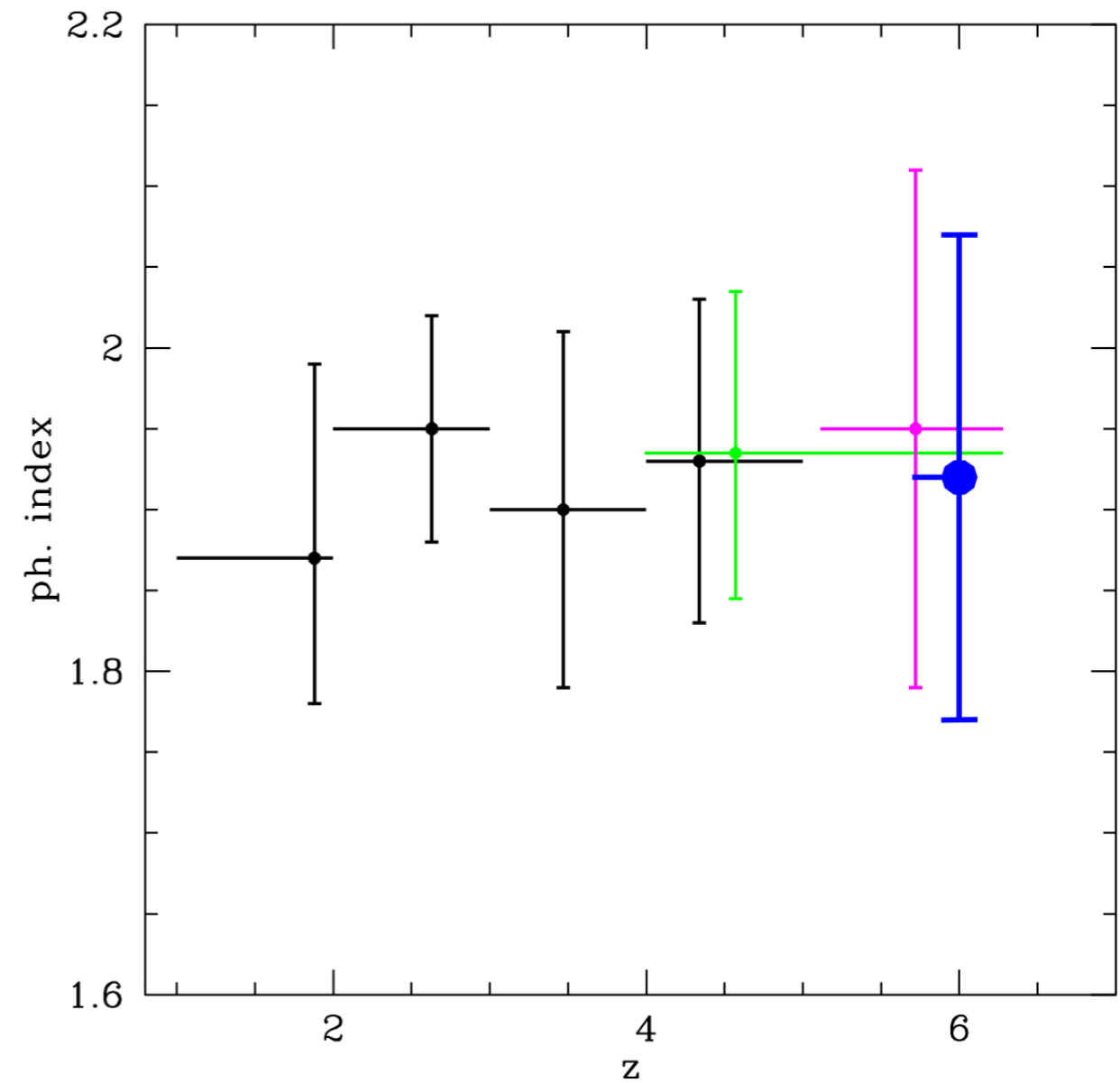
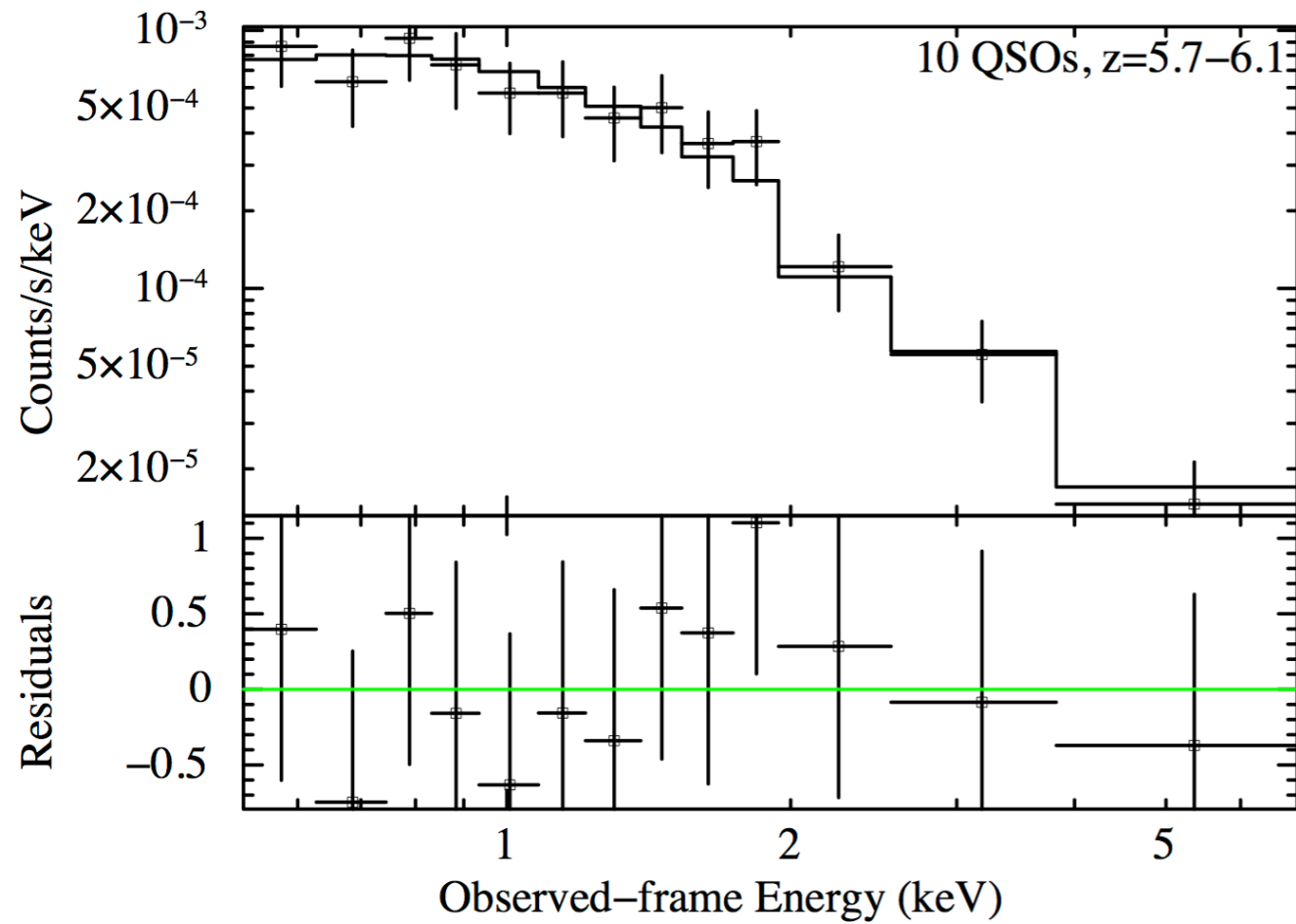
Few X-ray spectra measured:  
similar to lower-z objects

$$N(E) \propto E^{-\Gamma}$$
$$1.6 < \Gamma < 2.4$$

(see also Farrah et al. 2004; Moretti et al 2014; Page et al. 2014; Gallerani et al. 2016)



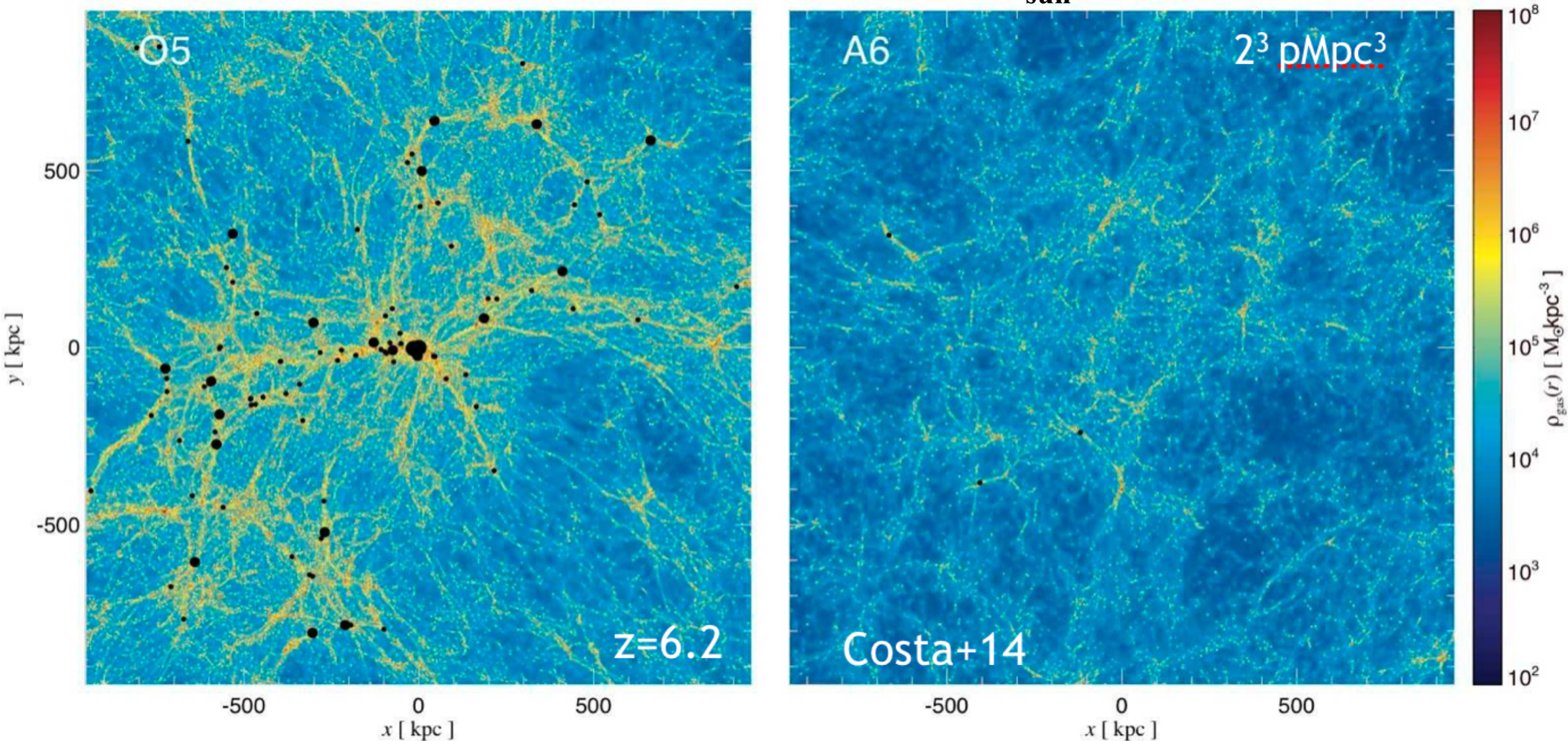
# X-ray spectral properties



- Just et al. 2007
- Vignali et al. 2005
- Shemmer et al. 2006
- Nanni et al. 2017

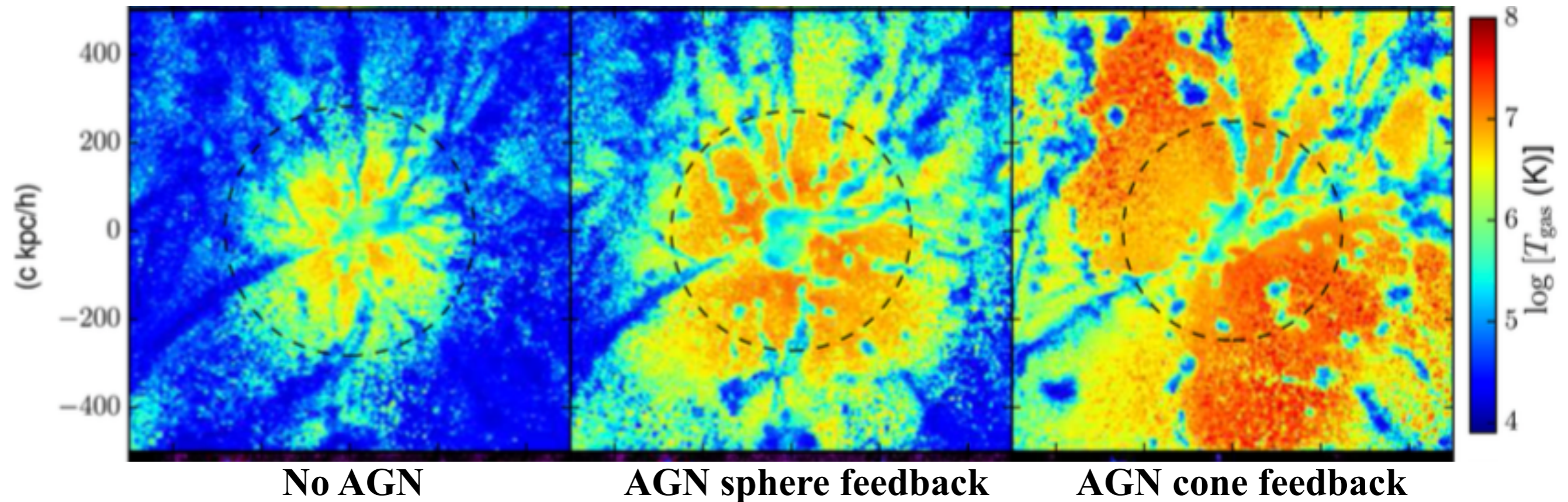
# BH formation: simulations

Masses from  $10^8$  to  $10^{10} M_{\text{sun}}$



Early SMBHs most likely form in the most overdense regions with extension up to  $10 \text{ pMpc}$  (e.g., Overzier et al. 2009; Costa et al. 2014; Barai et al. 2017)

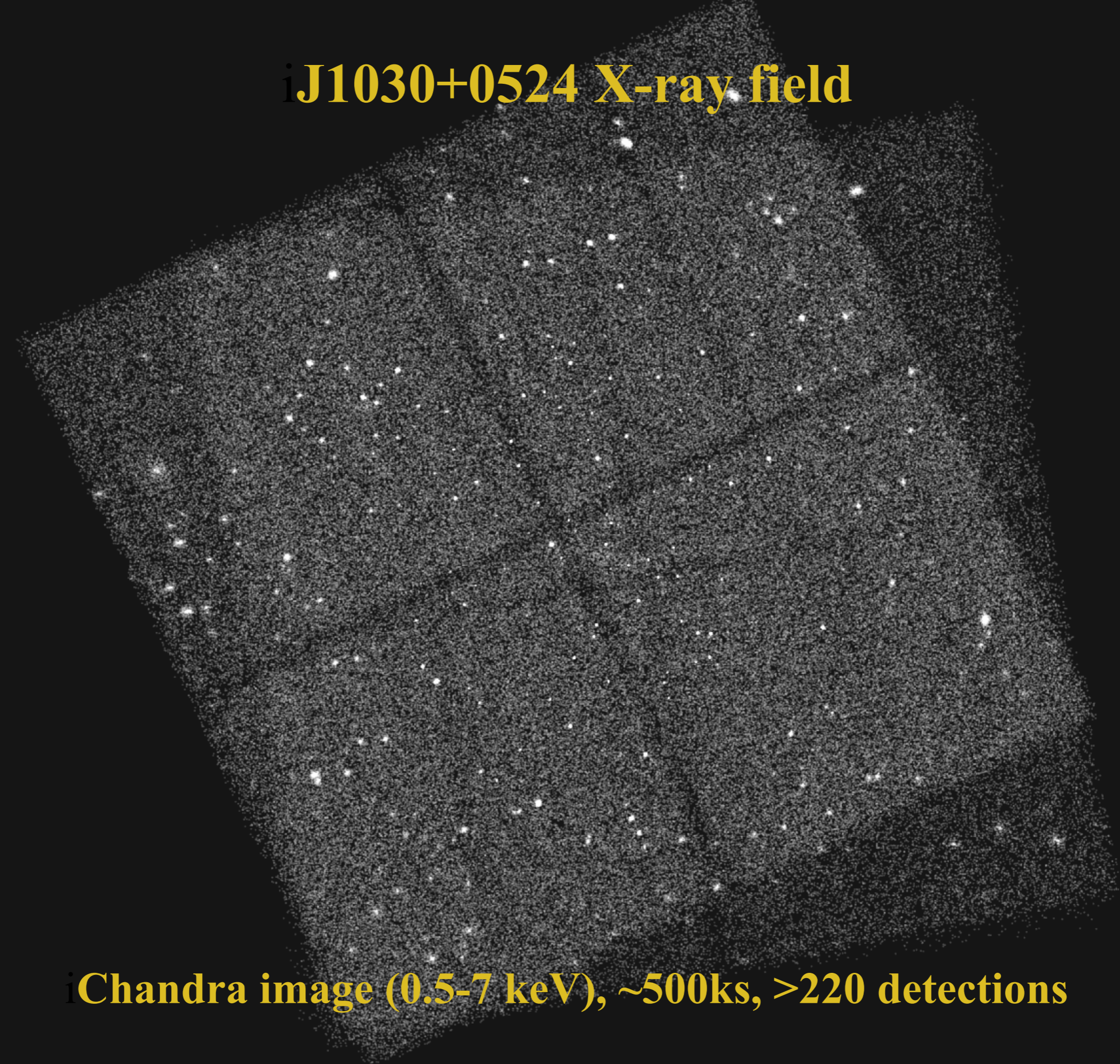
# BH formation: simulations



The evidence of overdense regions around  $z \sim 6$  QSOs is unclear.  
(e.g., Stiavelli et al. 2005; Willott et al. 2005; Kim et al. 2009; Mazzucchelli et al. 2017)  
Problem related to **small scale** observations? AGN **feedback**?



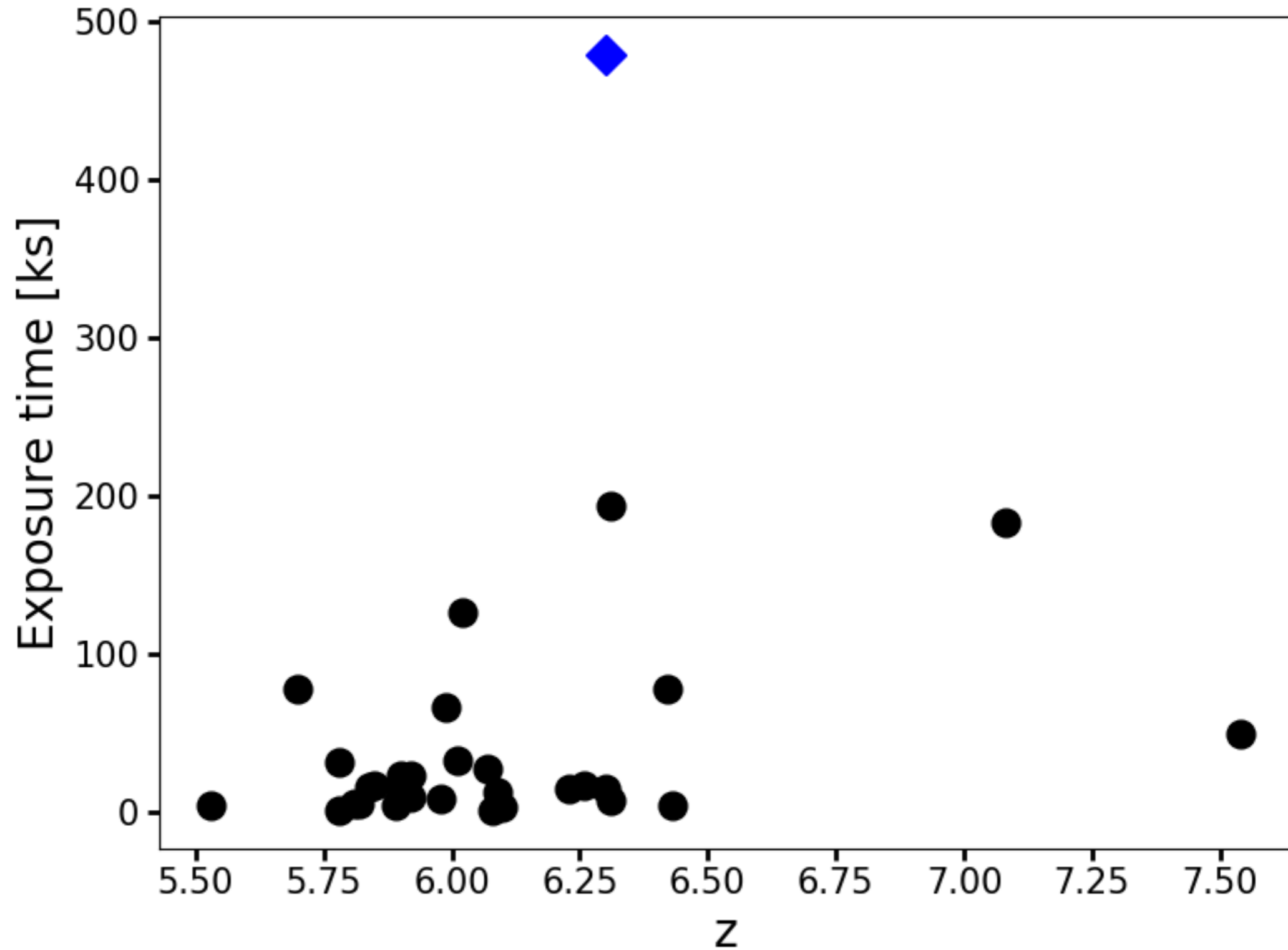
**iJ1030+0524 X-ray field**

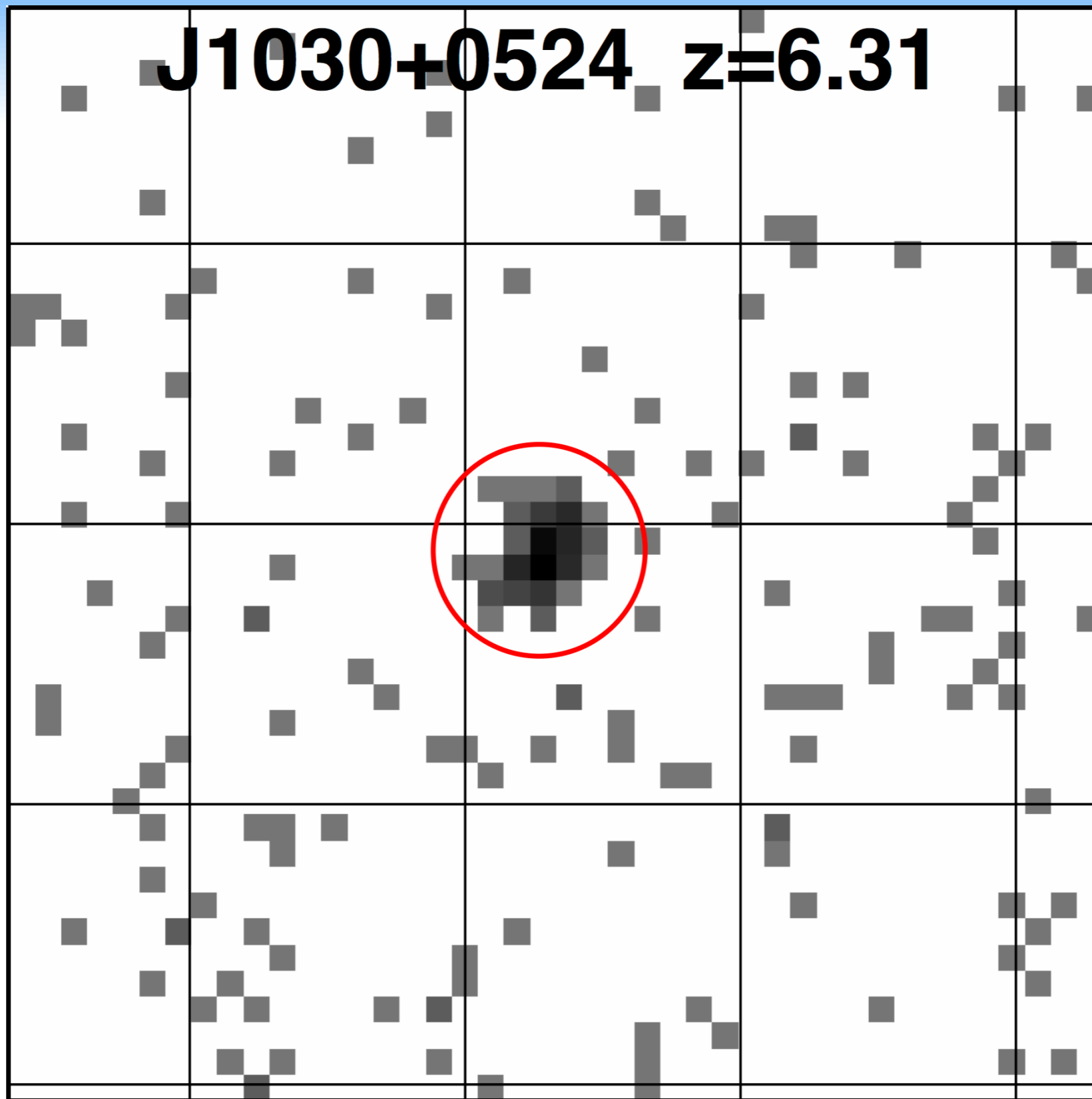


**iChandra image (0.5-7 keV), ~500ks, >220 detections**

# Chandra observation

Jan-May 2017, Cycle 17





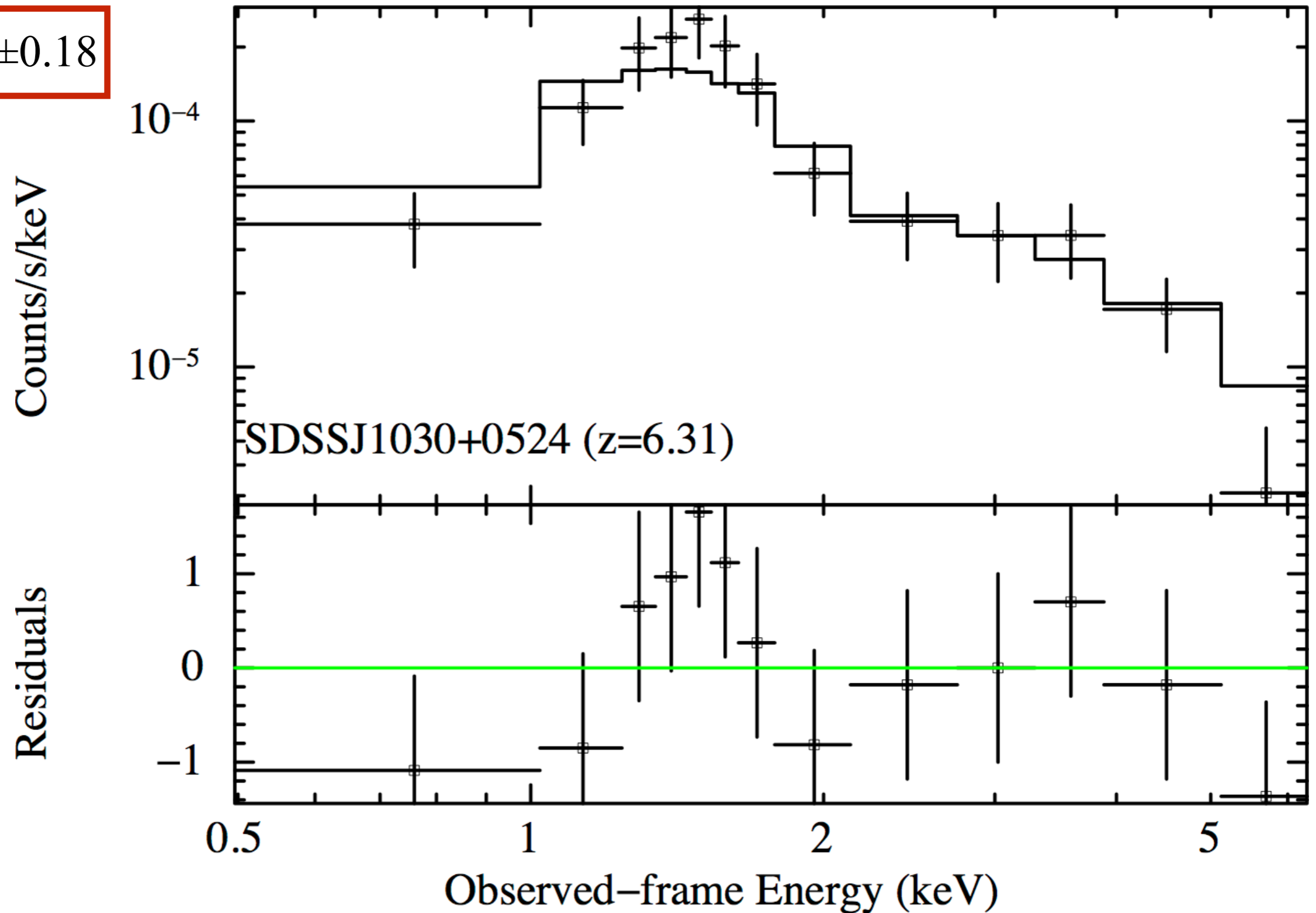
20''x20''

~125 photons detected in 0.5-7 keV band

# J1030 X-ray spectrum

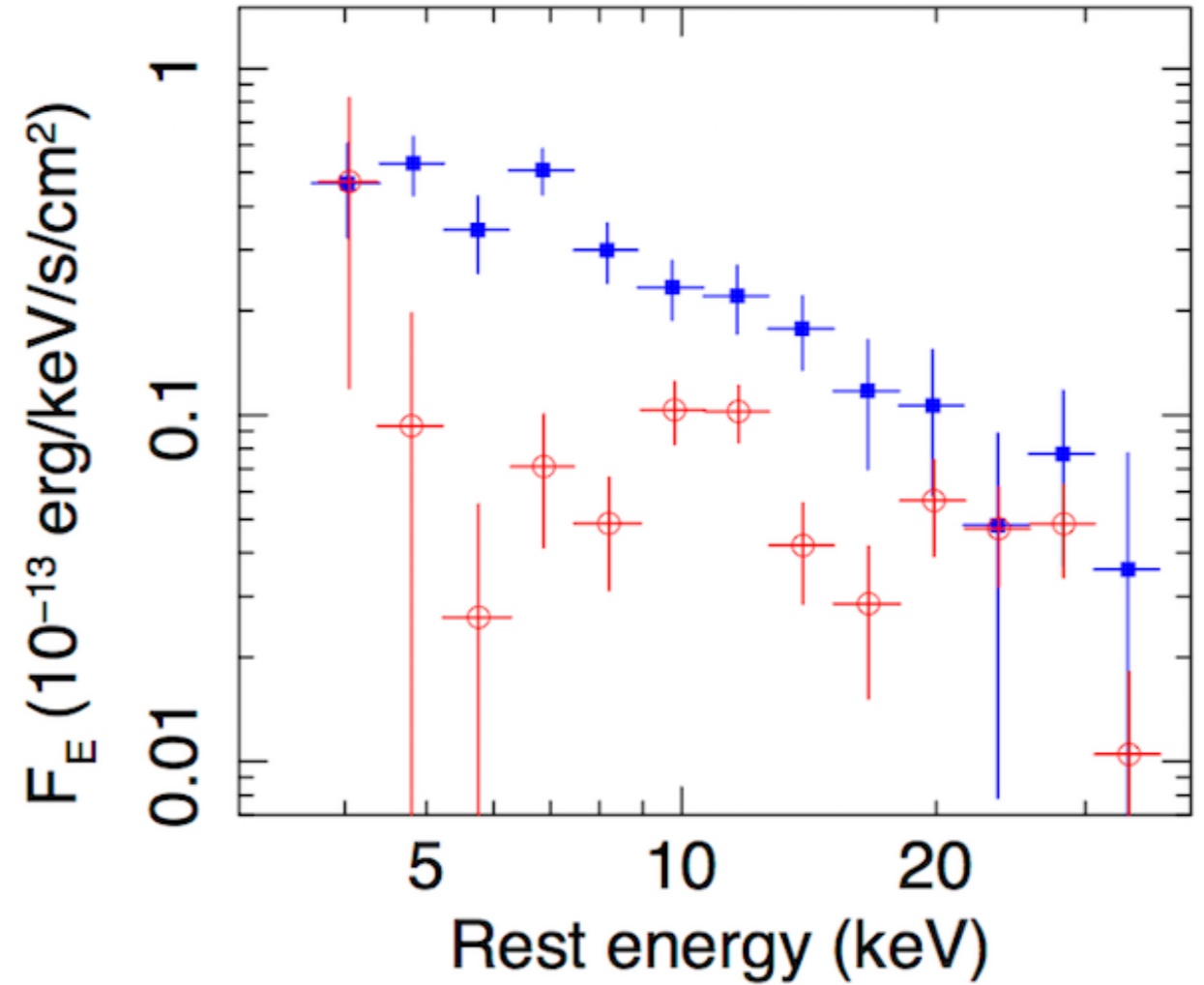
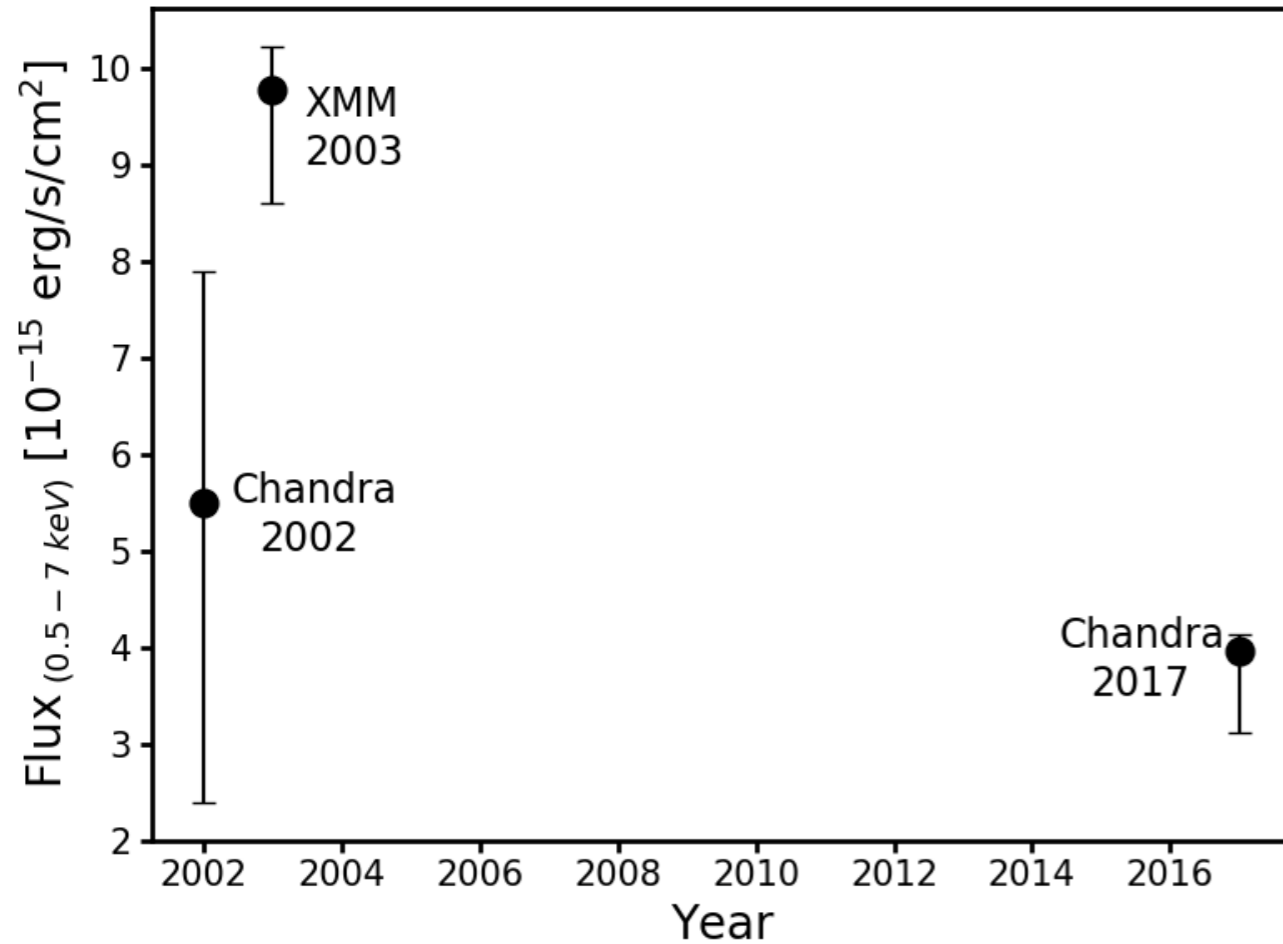
Nanni et al. 2018

$$\Gamma = 1.81 \pm 0.18$$



# J1030 X-ray variability

Nanni et al. 2018



$$f_{0.5-7keV} = (9.8^{+0.4}_{-1.2}) \cdot 10^{-15} \text{ erg/s/cm}^2$$

**XMM**

$$\Gamma = 2.37 \pm 0.16$$

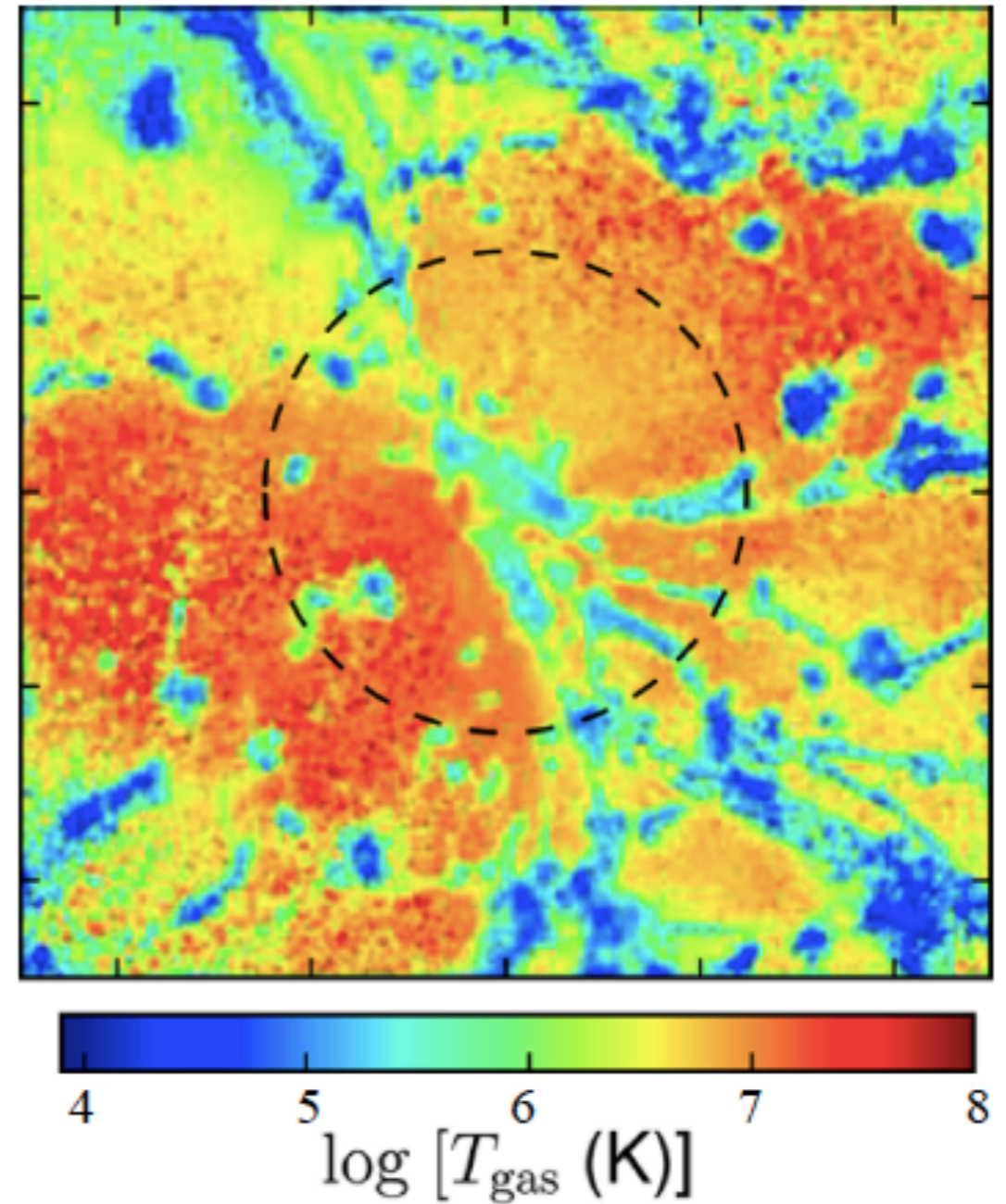
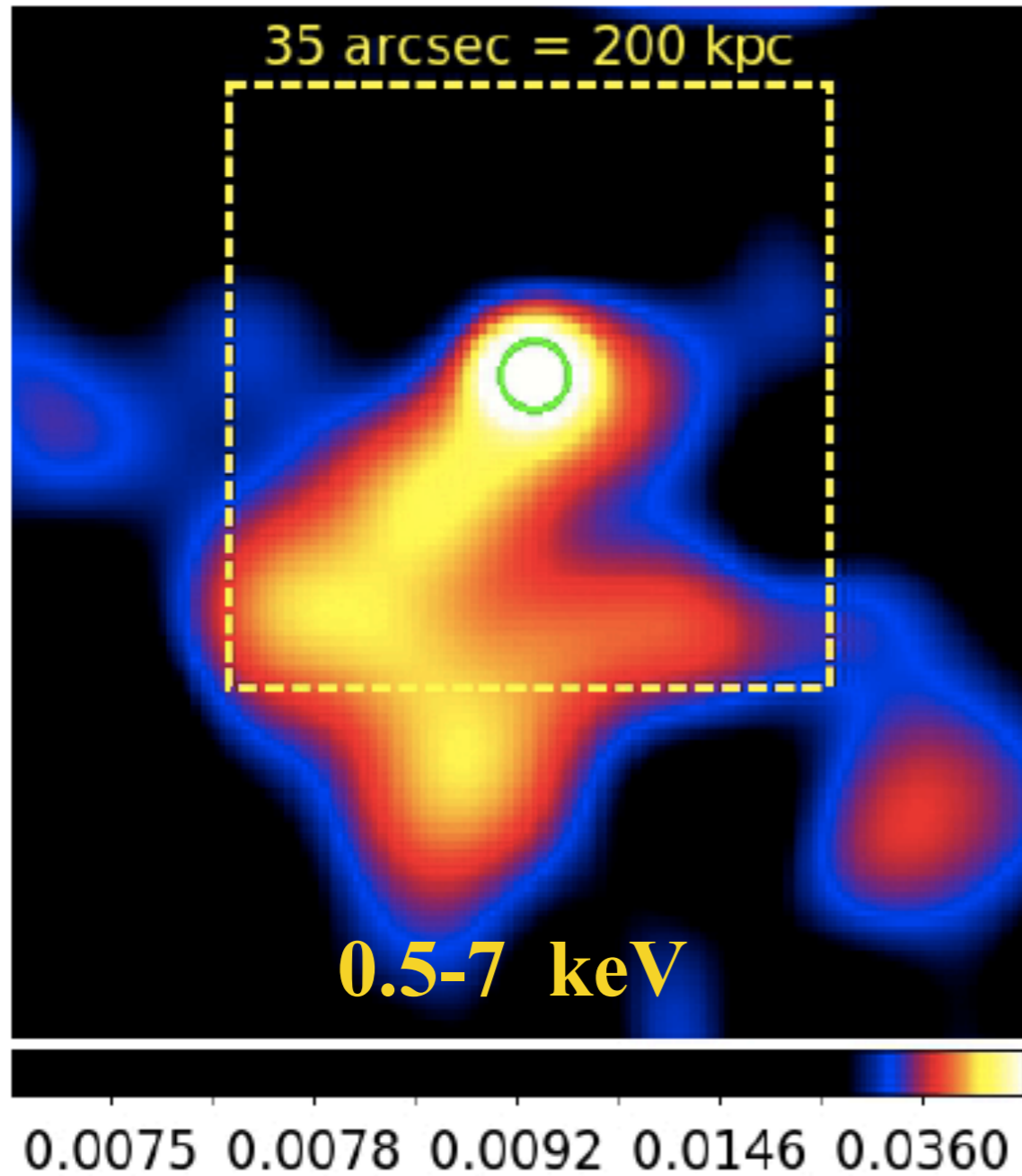
$$f_{0.5-7keV} = (4.0^{+0.2}_{-0.8}) \cdot 10^{-15} \text{ erg/s/cm}^2$$

**Chandra**

$$\Gamma = 1.81 \pm 0.18$$

# The southward diffuse emission: QSO feedback?

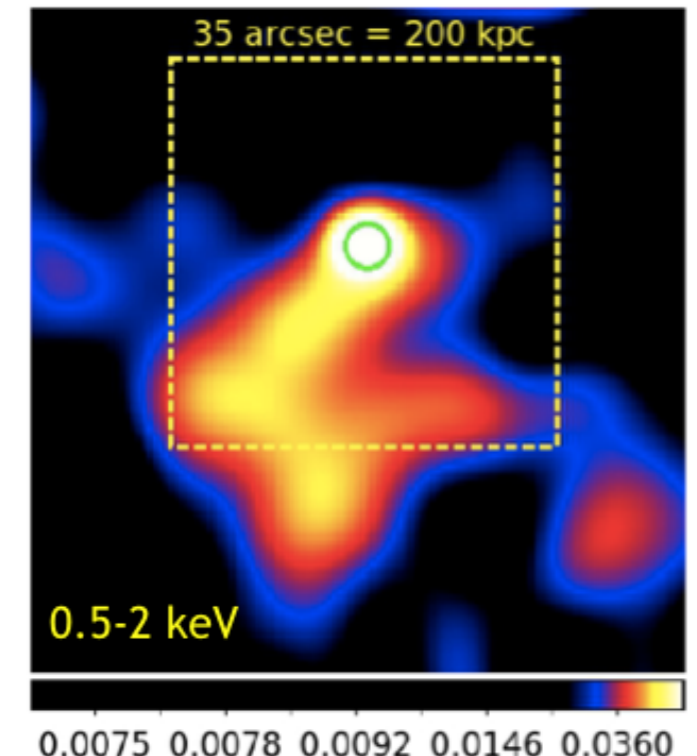
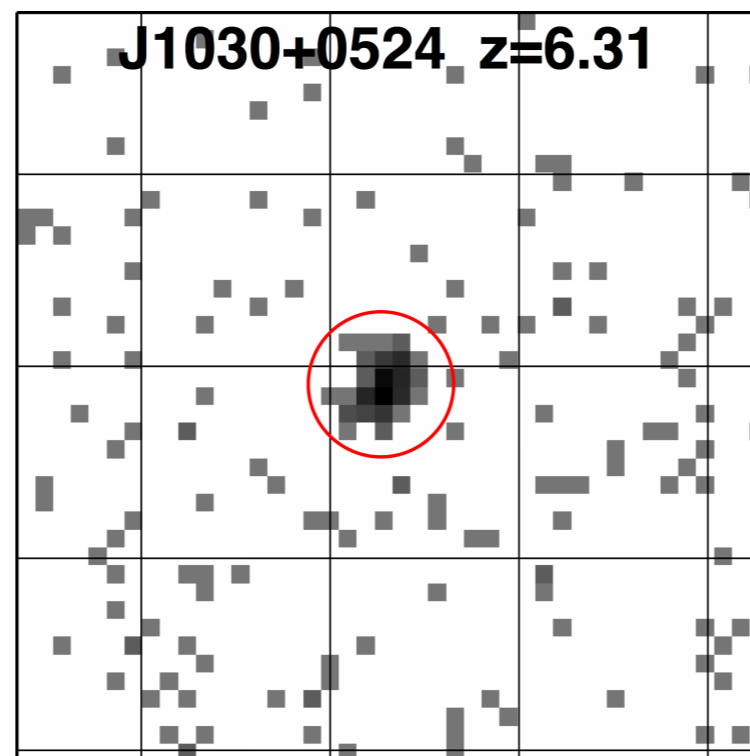
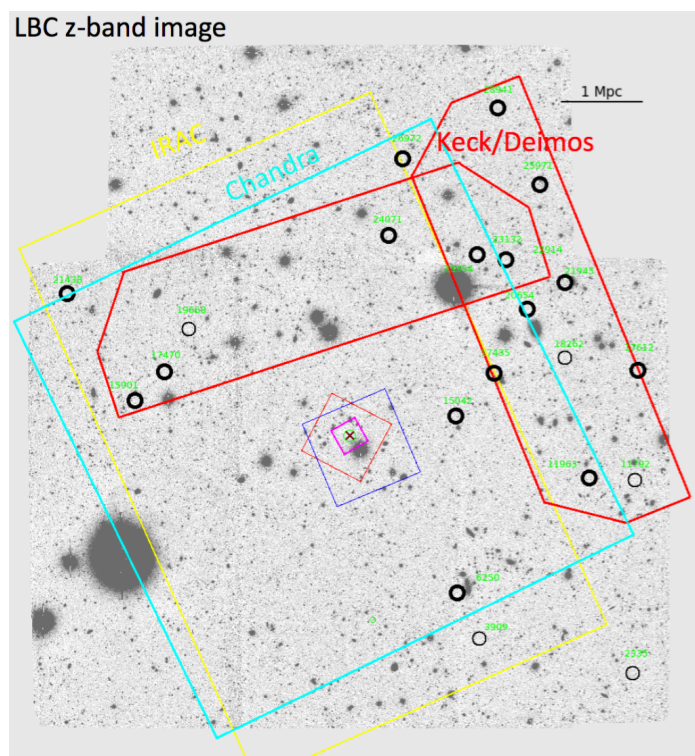
Nanni et al. 2018



**SNR  $\sim$  6,  $L_{2-10 \text{ keV}} = 5 \times 10^{44} \text{ erg s}^{-1}$**

# Conclusions

- 1) X-ray/optical/NIR properties do not significantly evolve through the passing of time, so the interplay between the disk and hot corona is already in place at  $z \sim 6$
- 2) J1030 is the first evidence of a variable AGN in the primordial Universe
- 3) Evidence of diffuse emission southward the QSO: AGN feedback?
- 4) The J1030 deep-field is likely the best place to study the properties and environment of  $z \sim 6$  SMBHs



**Do you want to collaborate with us or just be updated on this work?**

**Visit: <http://www.oabo.inaf.it/~LBTz6/1030/>**



**Thanks for the attention!**