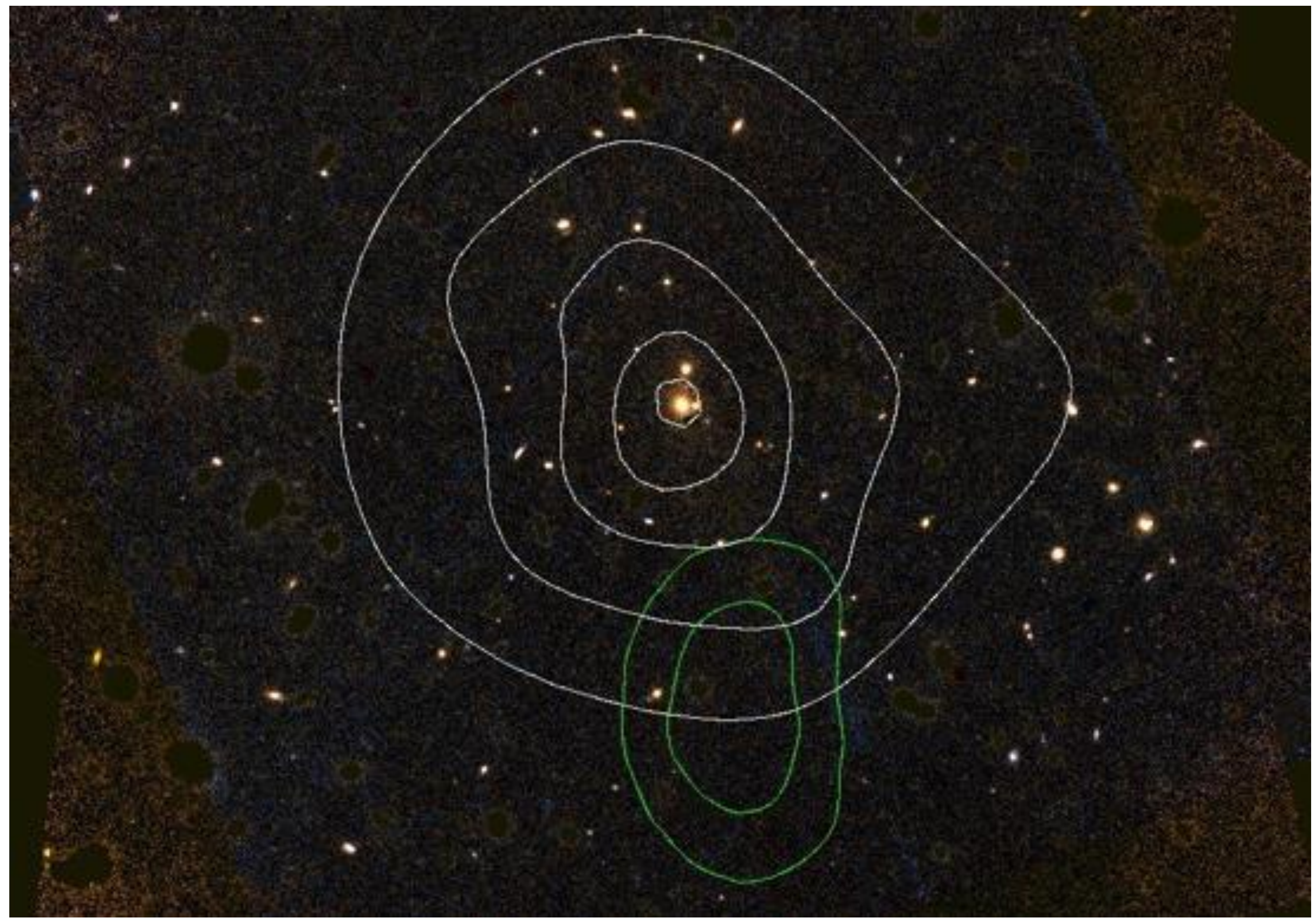
# HST/WFC3 spectroscopic confirmation of XLSSC122: A mature X-ray /SZ detected cluster at z=2?



Jon Willis, Rebecca Canning, Emil Noordeh, Adam Mantz, Adam Stanford

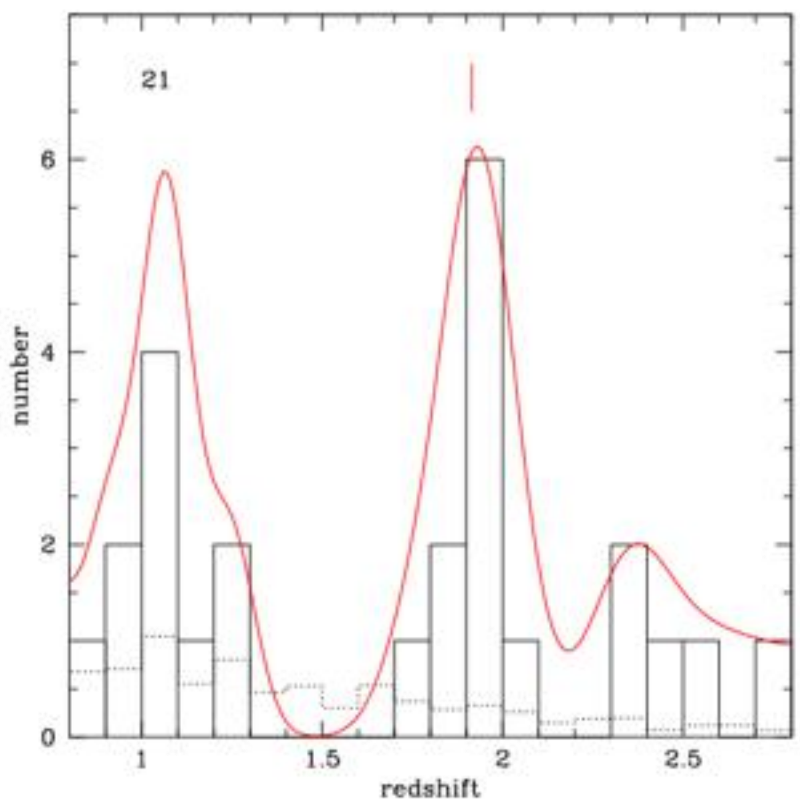
# Motivation:

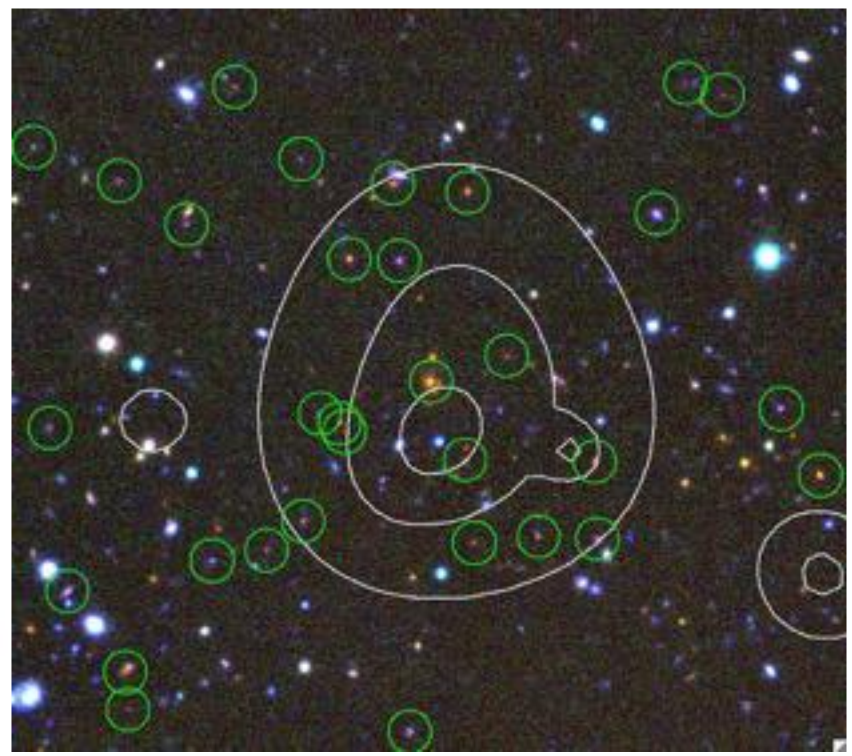
- SF history of cluster galaxies at large look-back time: mass assembly, active SF and quenching.
- AGN triggering in clusters (R. Canning on Thursday).
- Cluster scaling relation evolution.
- Extremal constraints on the mass function.

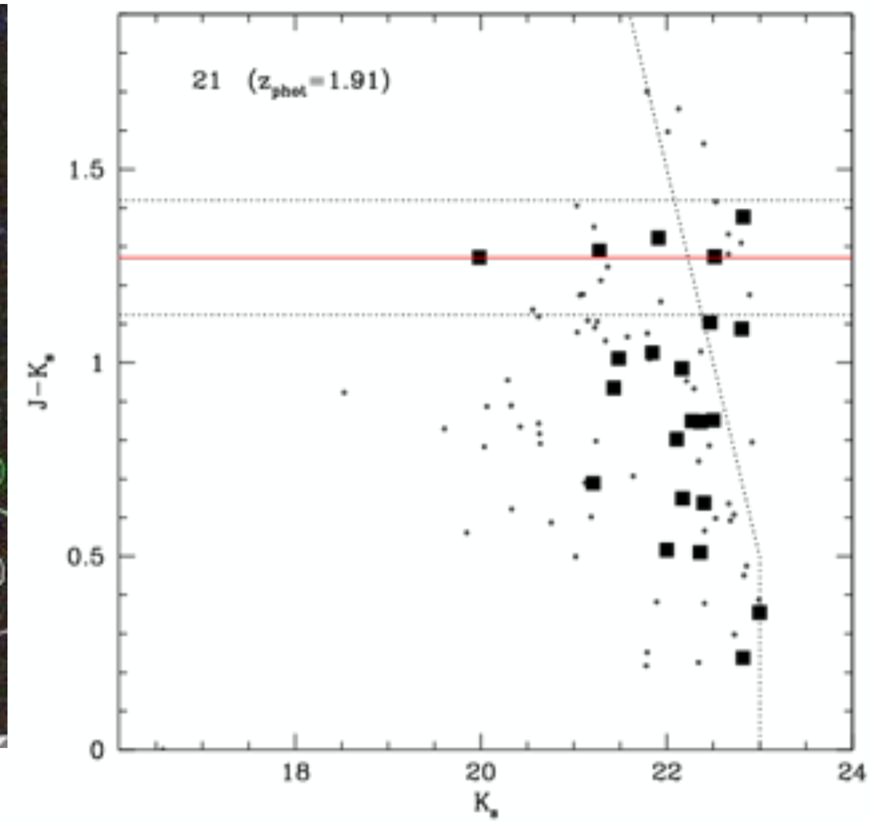
# XLSSC 122: The story so far…

- Selected as a C1 extended X-ray source in the XMM-LSS survey (Willis+2013).
- XLSSC122 = XLSSUJ0217-0345.
- Optical-IR photometric redshift of $z=1.9 \pm 0.2$.
- Detected as a CARMA SZ decrement (Mantz+2014).
- XMM 100 ks image reveals $kT=5$ keV and $z_{X\text{-ray}} = 1.99 \pm 0.06$ (Mantz+2017).
- 12 orbits of HST/WFC G141 grism observations reveal $z_{spec} = 1.98$.

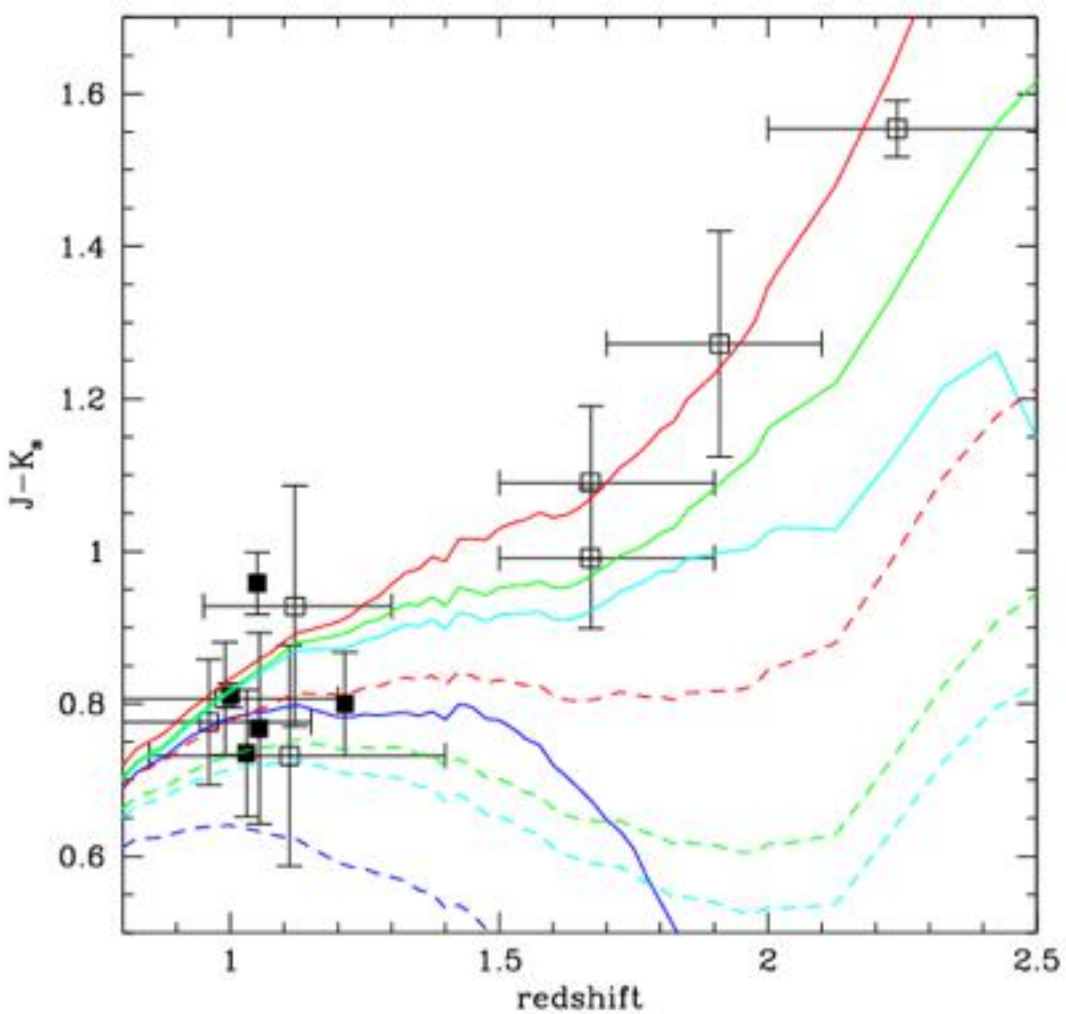
# X-ray detection, optical-IR “confirmation”

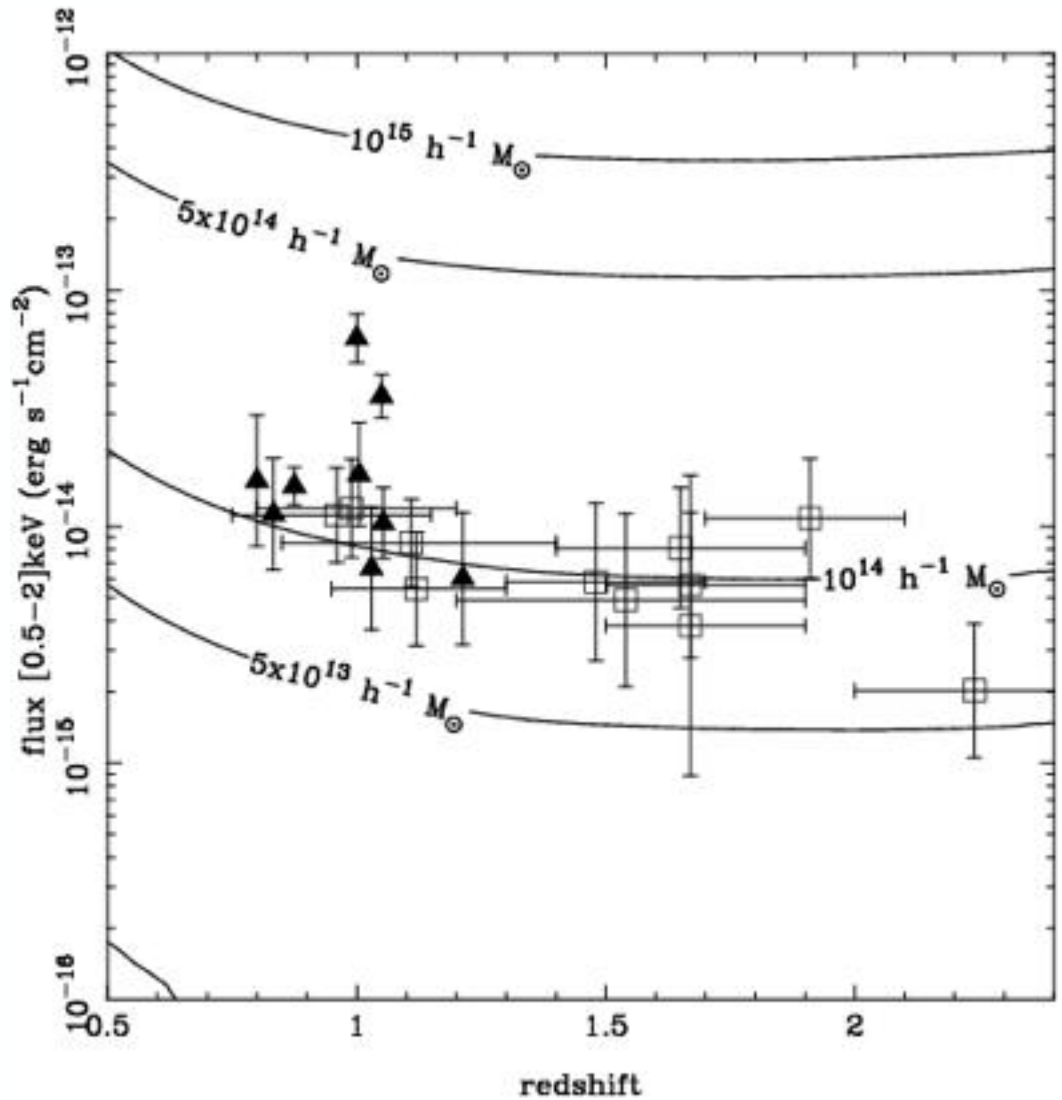




# The XMM-LSS distant cluster sample:




XMM-LSS DCS consists of 22 z>0.8 extended X-ray sources.

# SZ decrement:

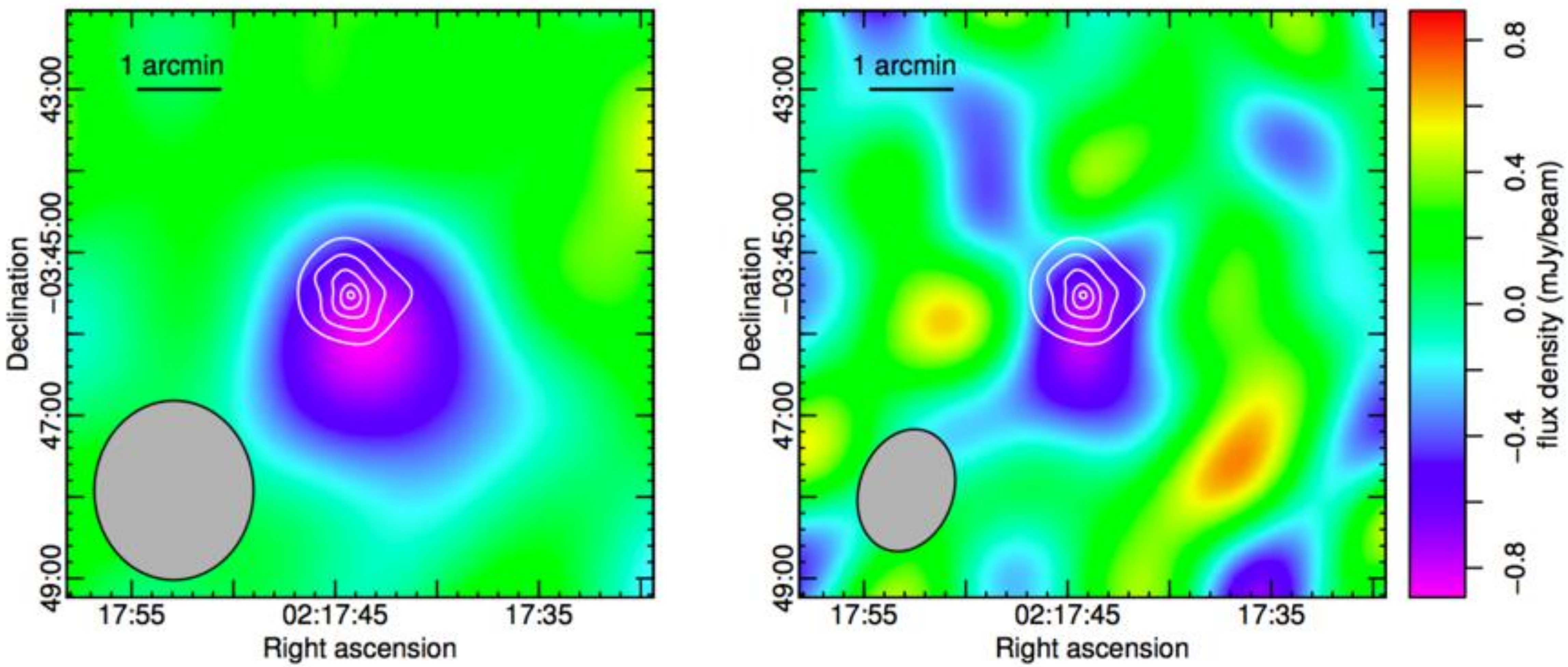
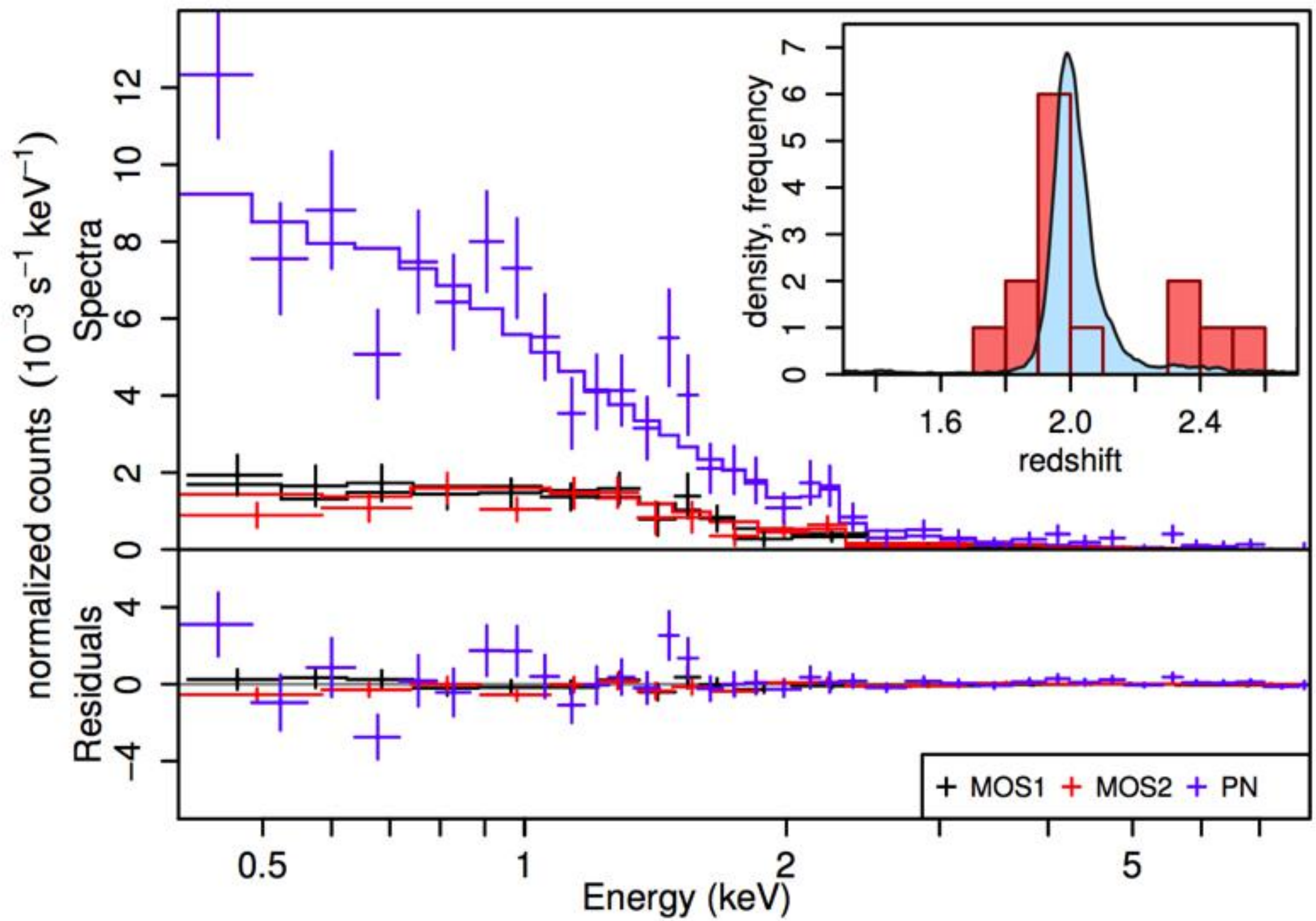
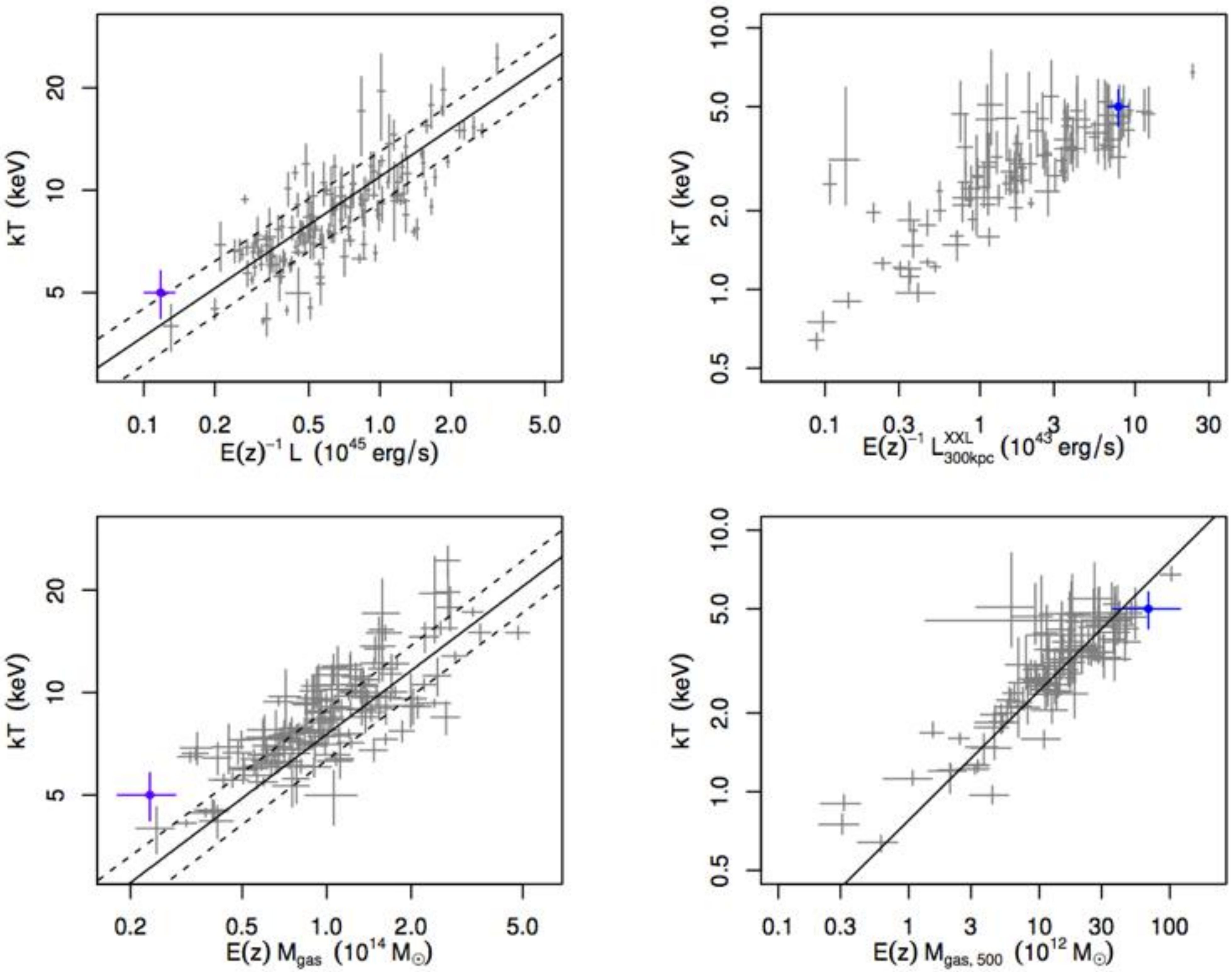



**Fig. 6.** Short-baseline (*uv* radii < 2k$\lambda$) 30 GHz maps of XLSSC 122 from the CARMA-8 (left) and CARMA-23 (WB, right) data, after modeling and subtracting point sources and applying the CLEAN image reconstruction algorithm (Högbom 1974). White contours show the extended X-ray emission, as in Figure 2. Gray ellipses in the lower-left corners show the synthesized beam shapes. Both maps use a common color table.

# X-ray spectroscopic confirmation!



# Observations: Gas properties



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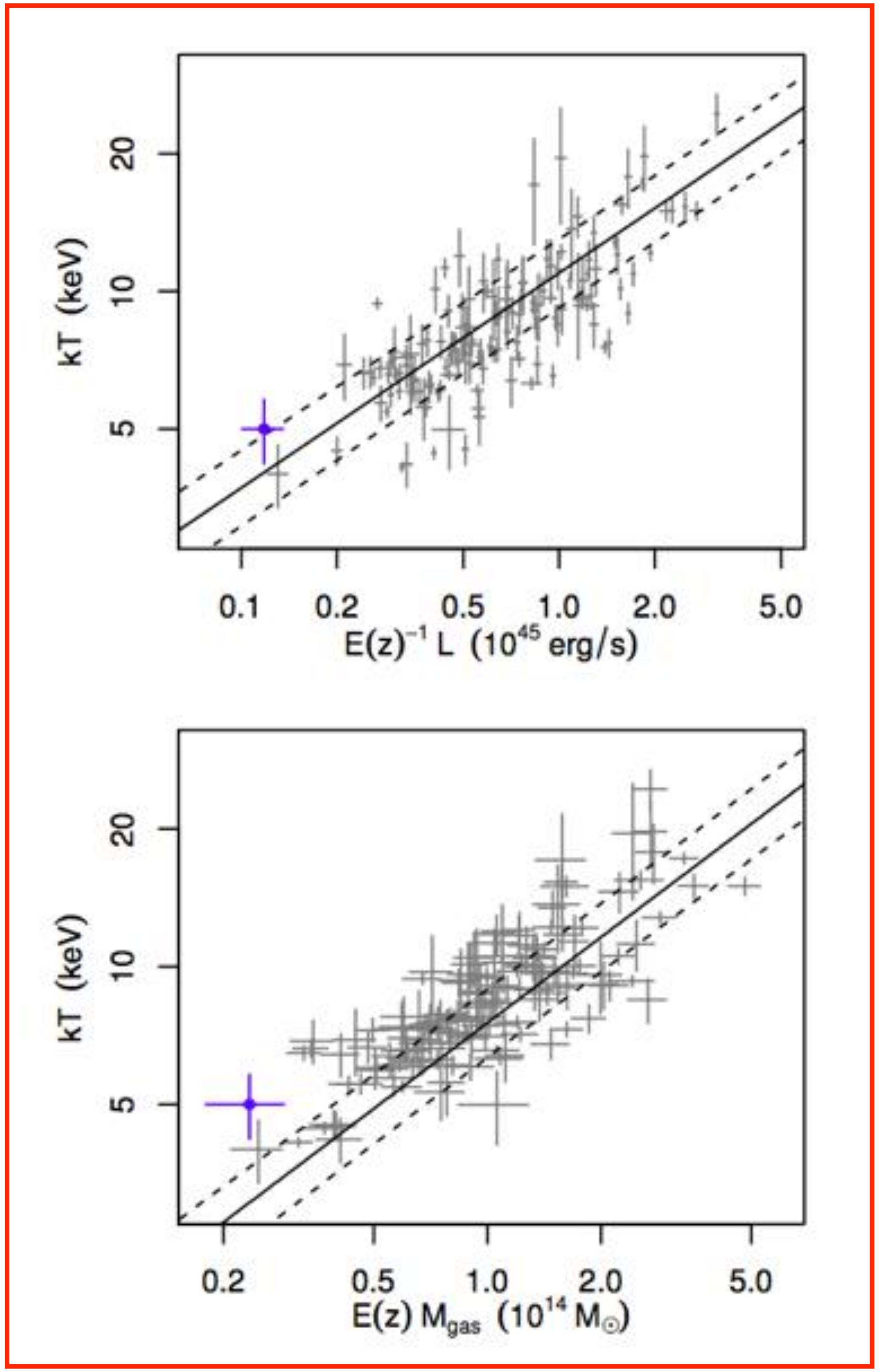


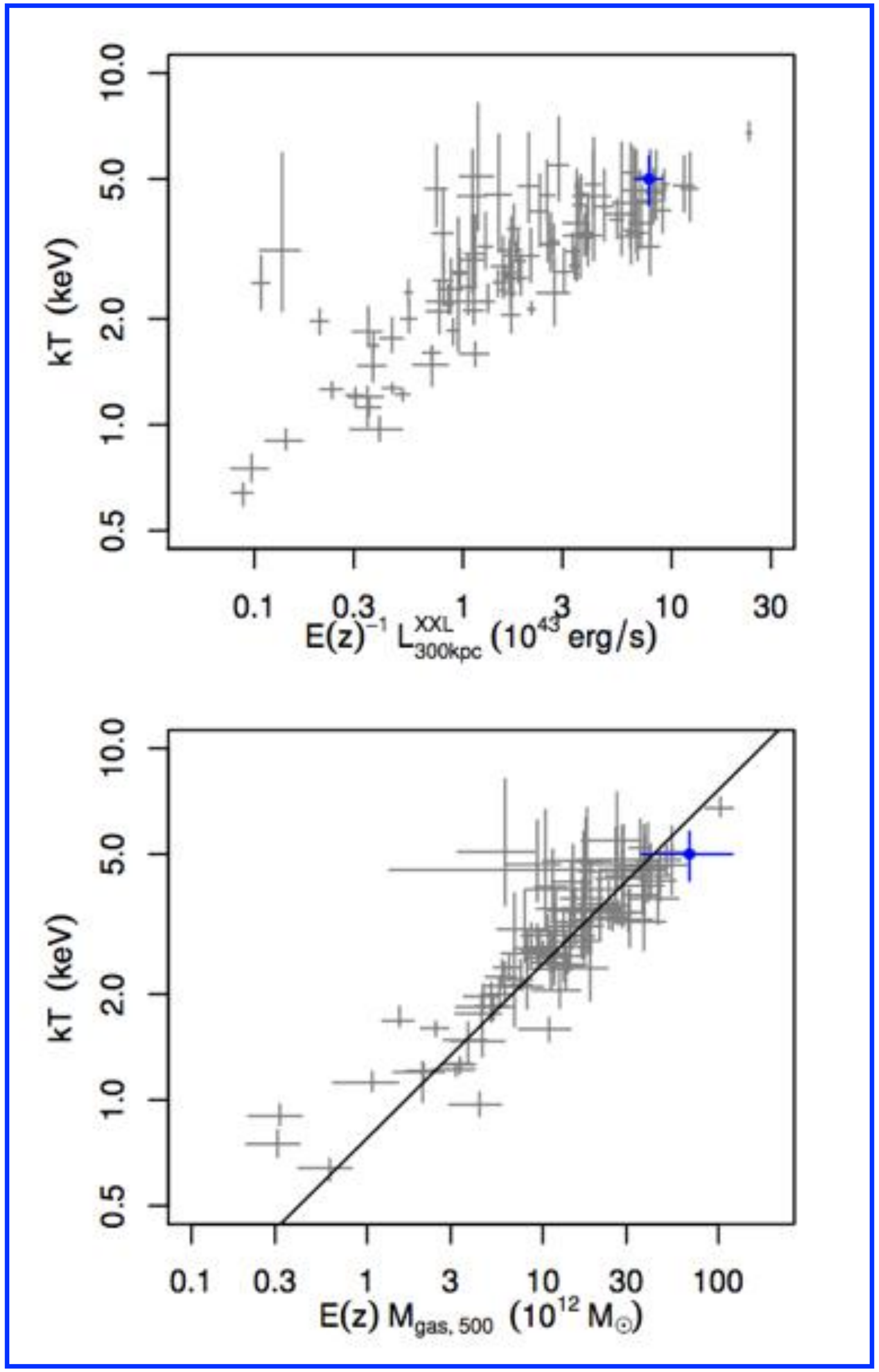

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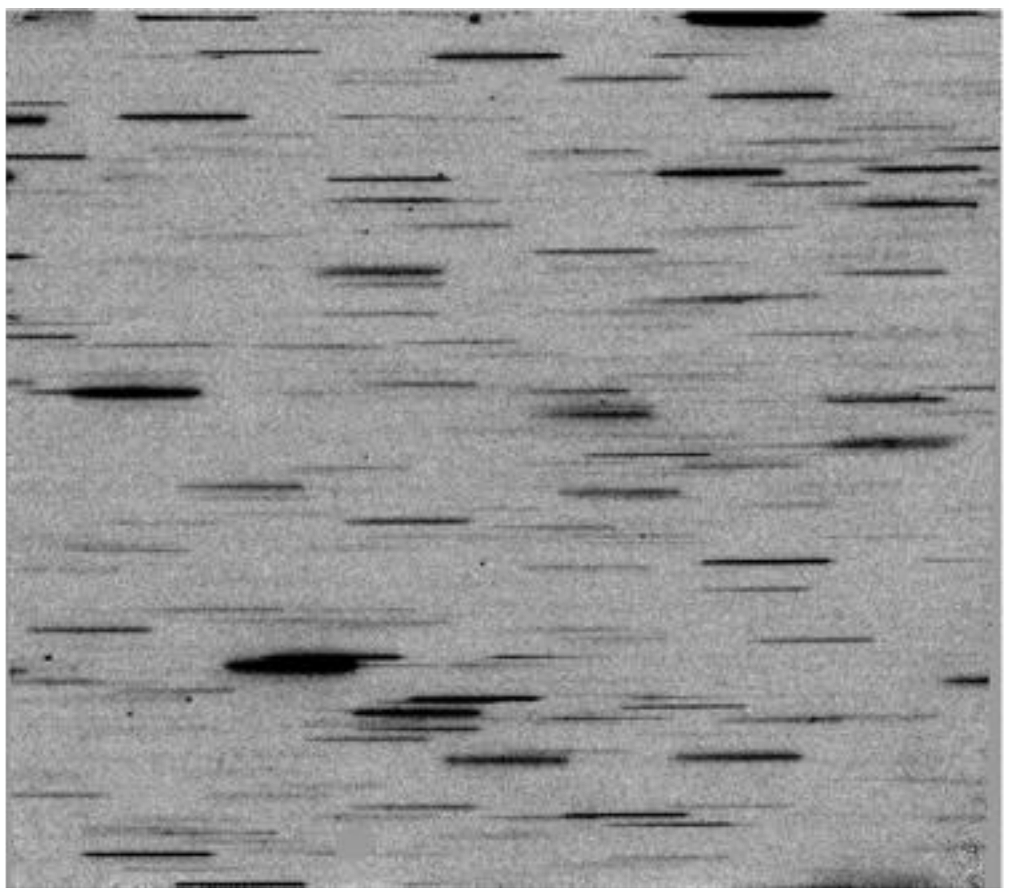

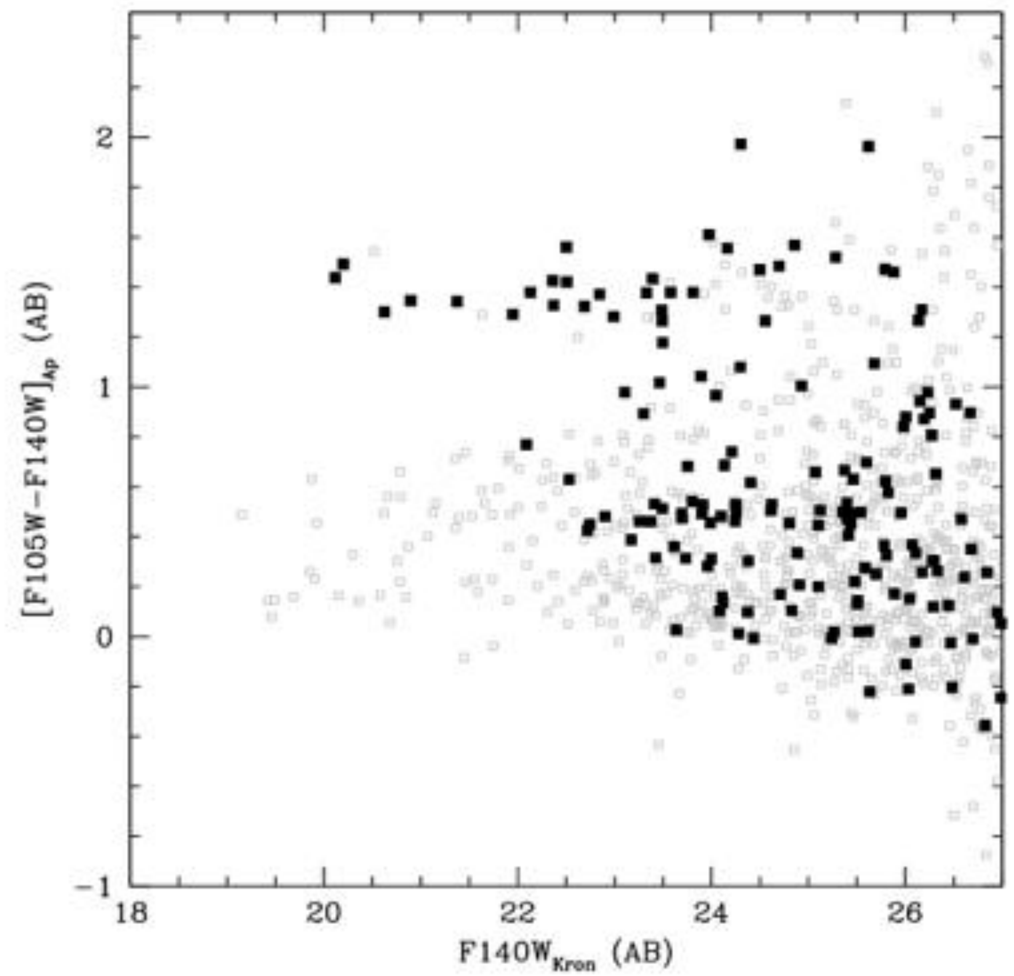


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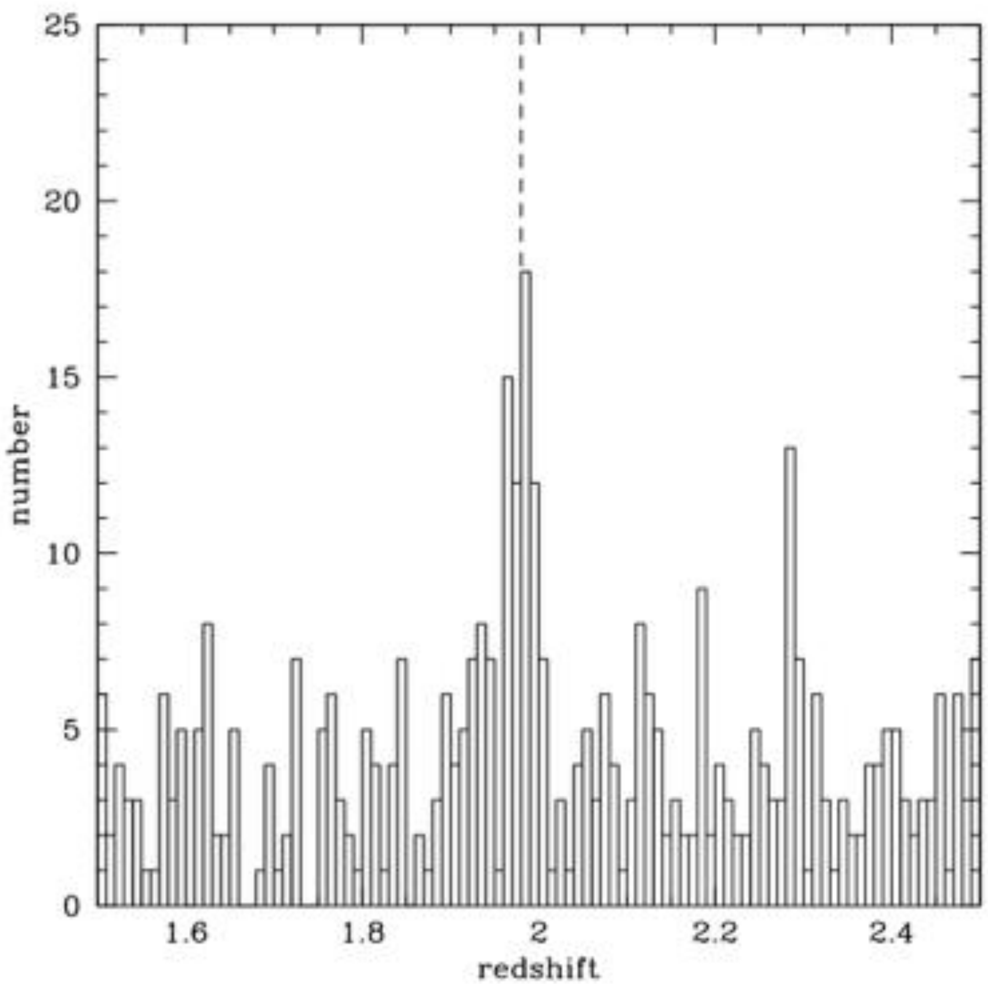


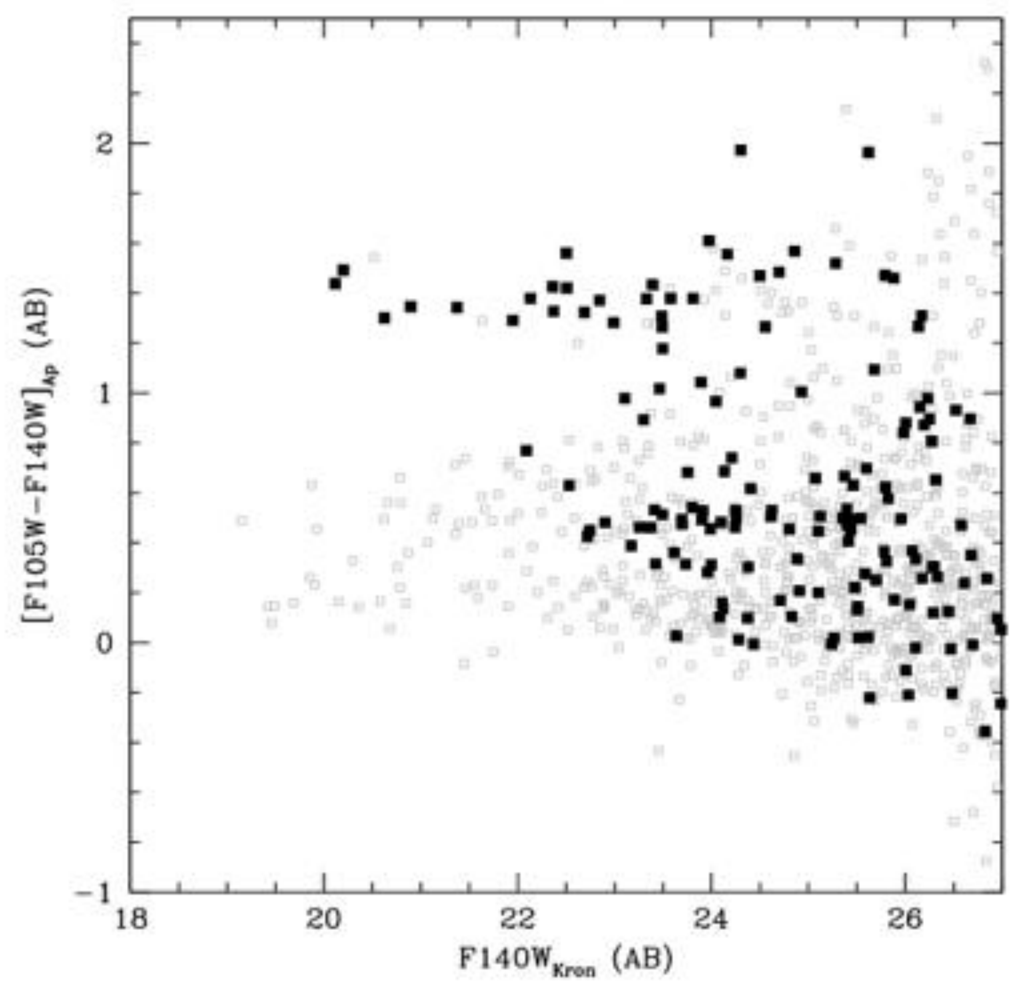


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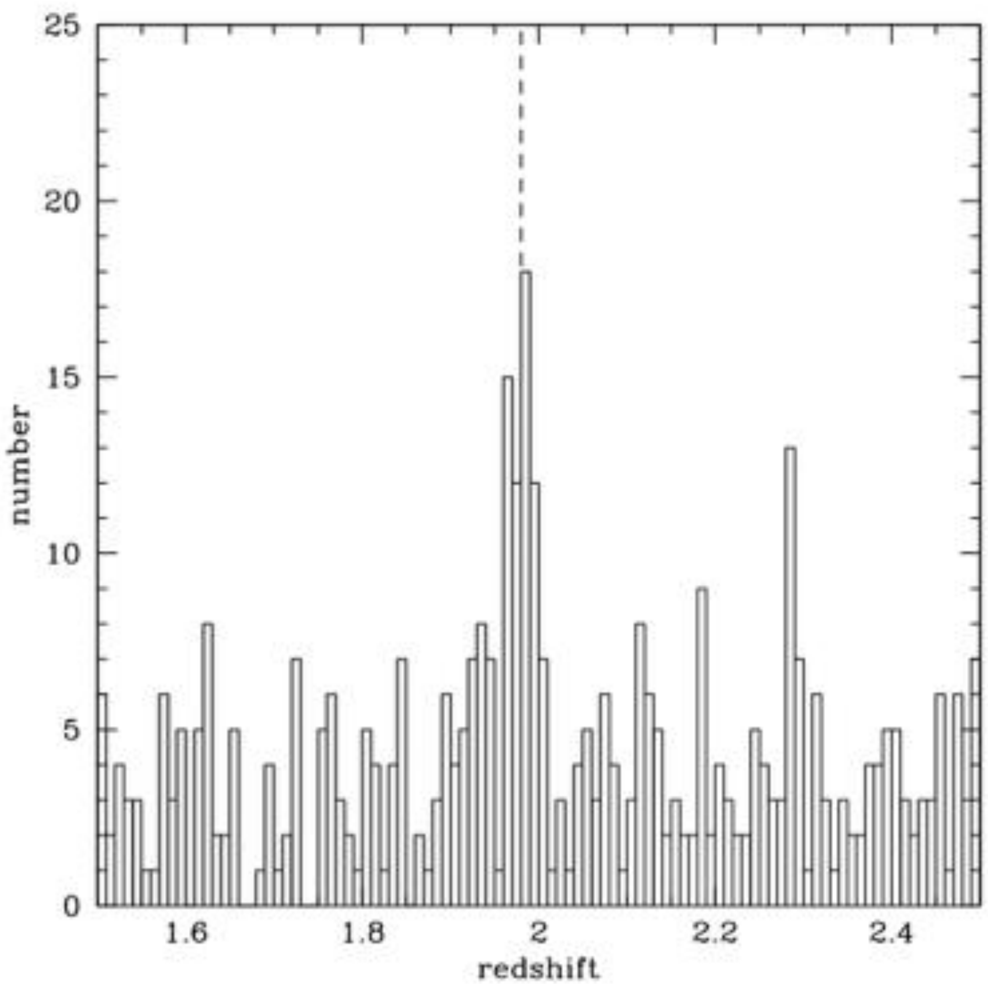


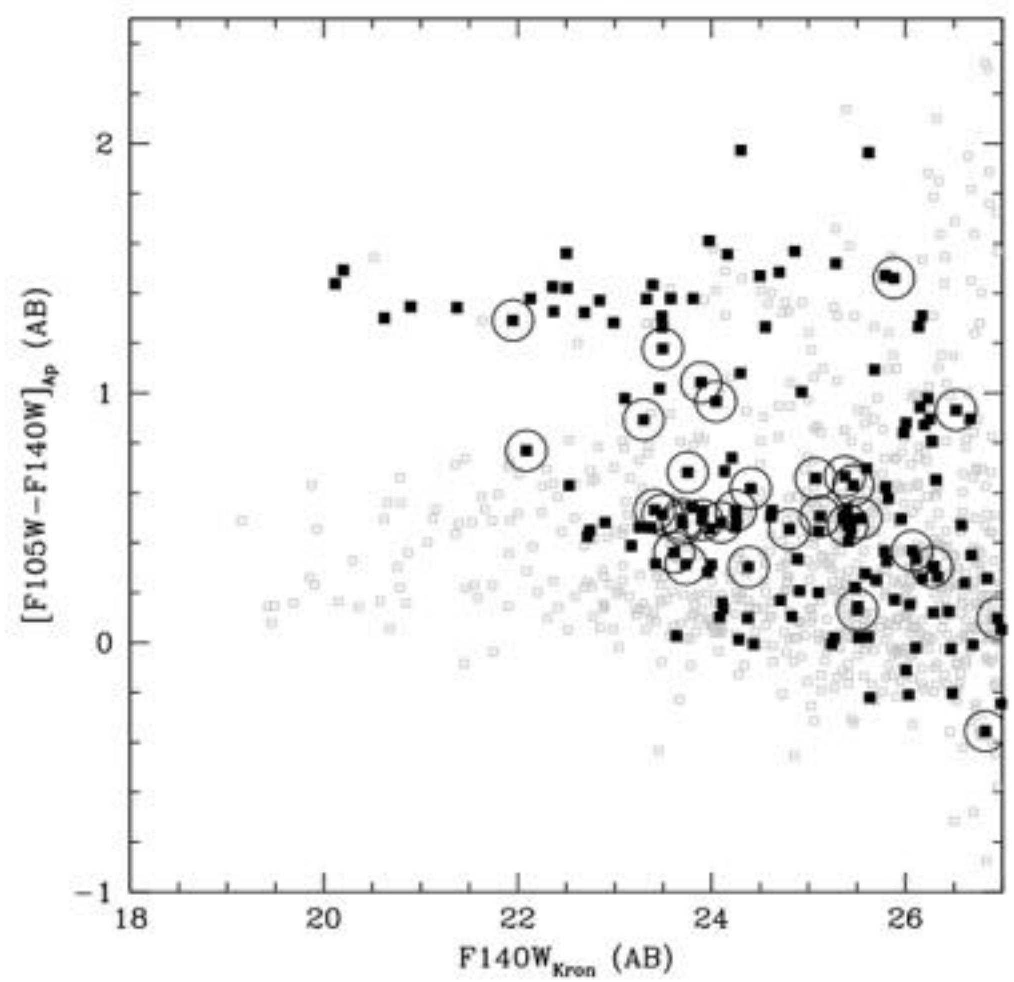


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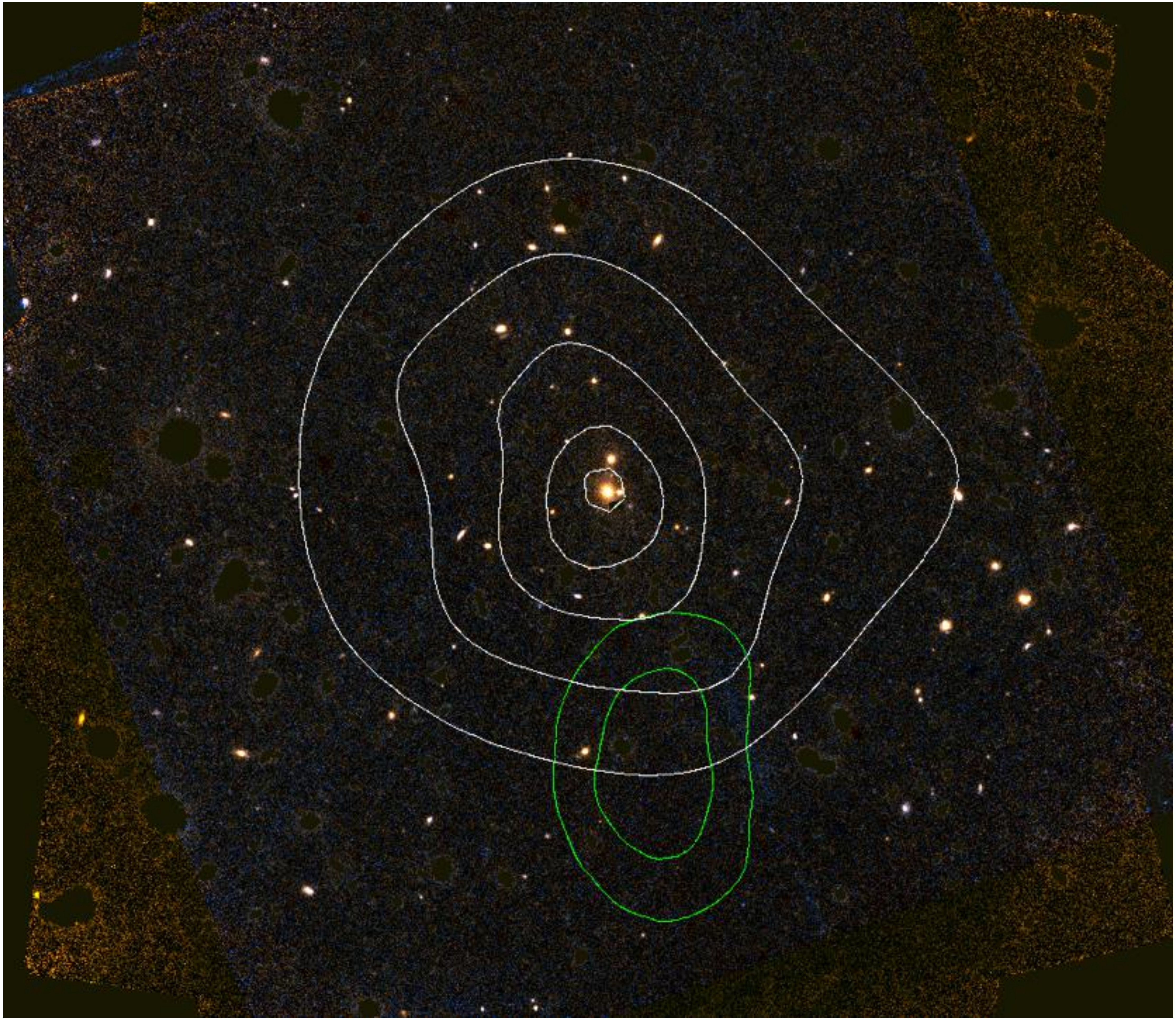
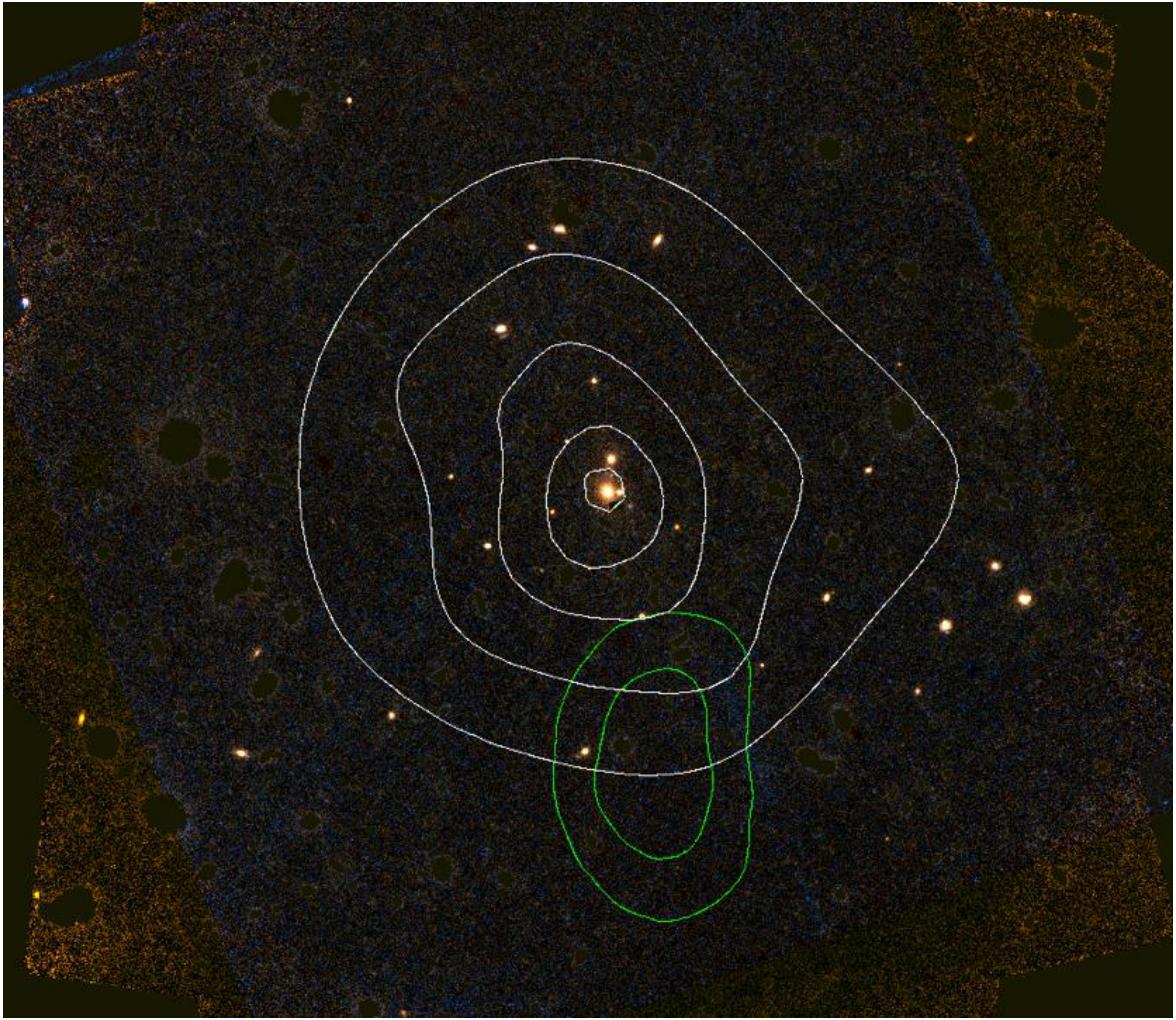
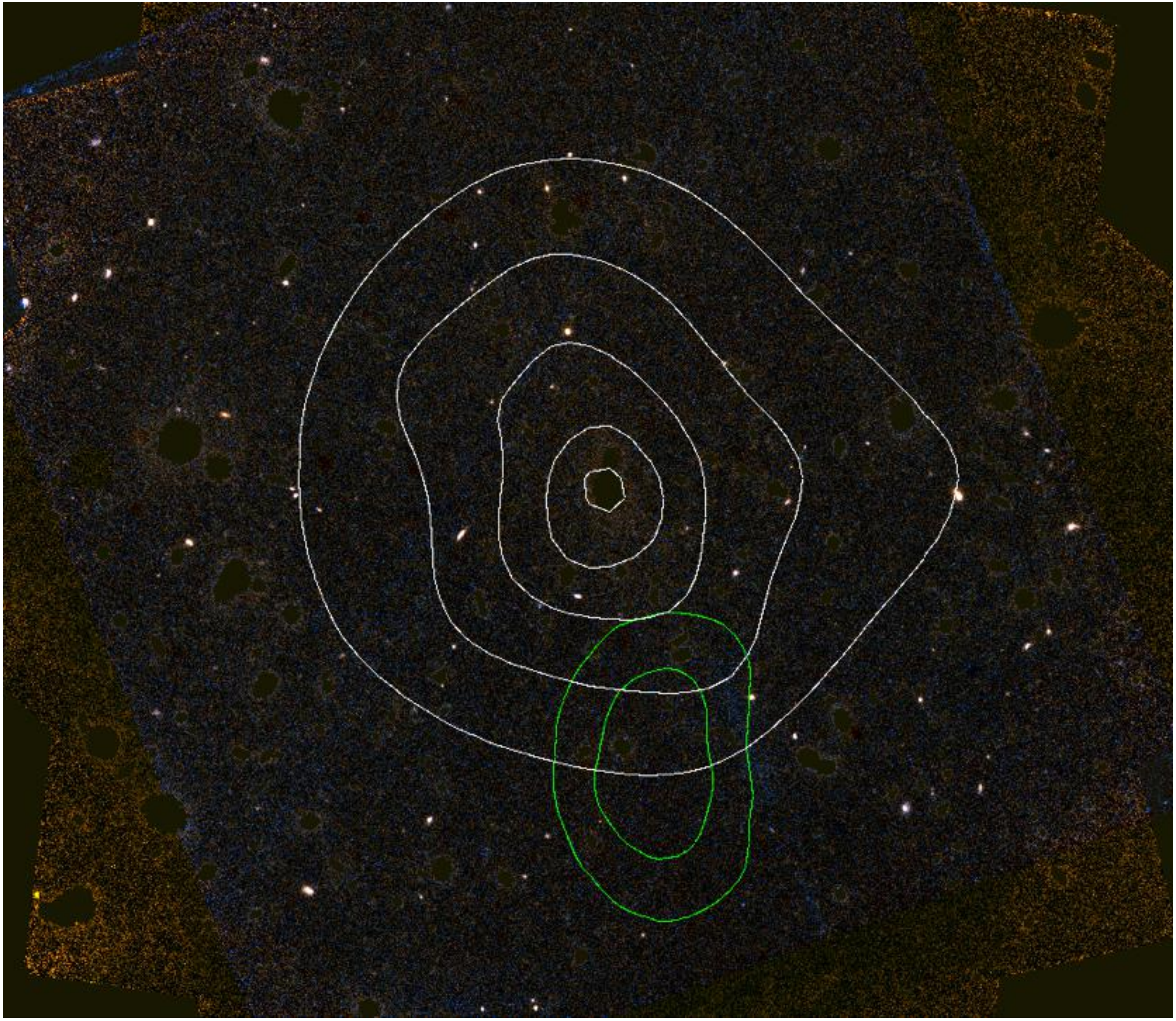


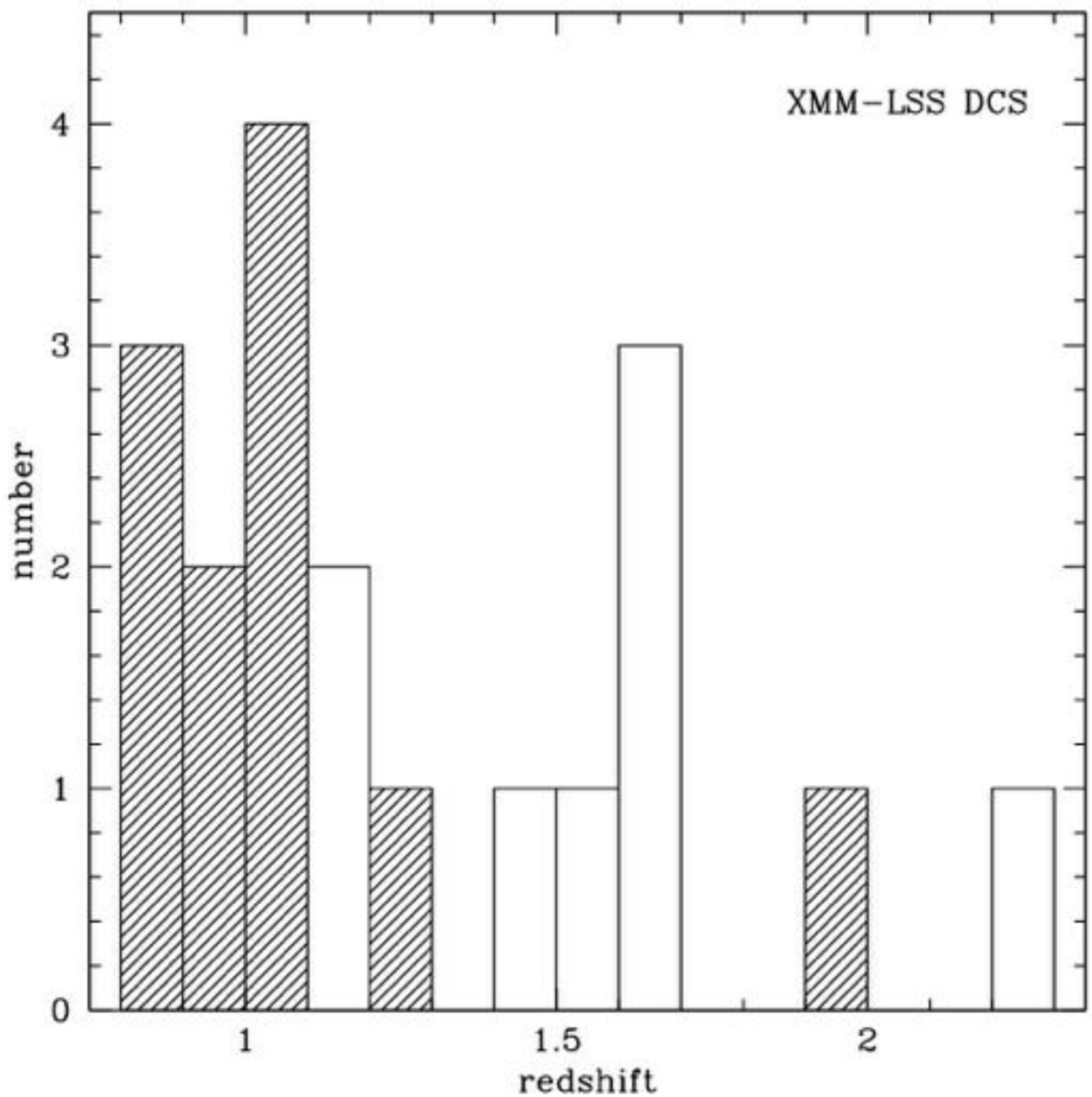




# Does XLSSC122 represent a "mature" cluster at z=2?

- Among the lowest mass of known z>1.5 clusters ($M_{500}=6.3 \times 10^{13}\ M_{\odot}$).
- The X-ray gas is already enriched to 30% solar.
- The cluster CMD is strongly bi-modal.
- How does it compare to its peers?
- Consider that, at z<1, large samples of uniformly selected clusters were required to disentangle the effects of mass, redshift, relaxation state and selection bias.

# Completing spectroscopic follow-up of XMM-LSS DCS




- XMM-LSS is pure but incomplete.
- Clusters at $z<1.6$ are within the grasp of ground based 8m-class telescopes.
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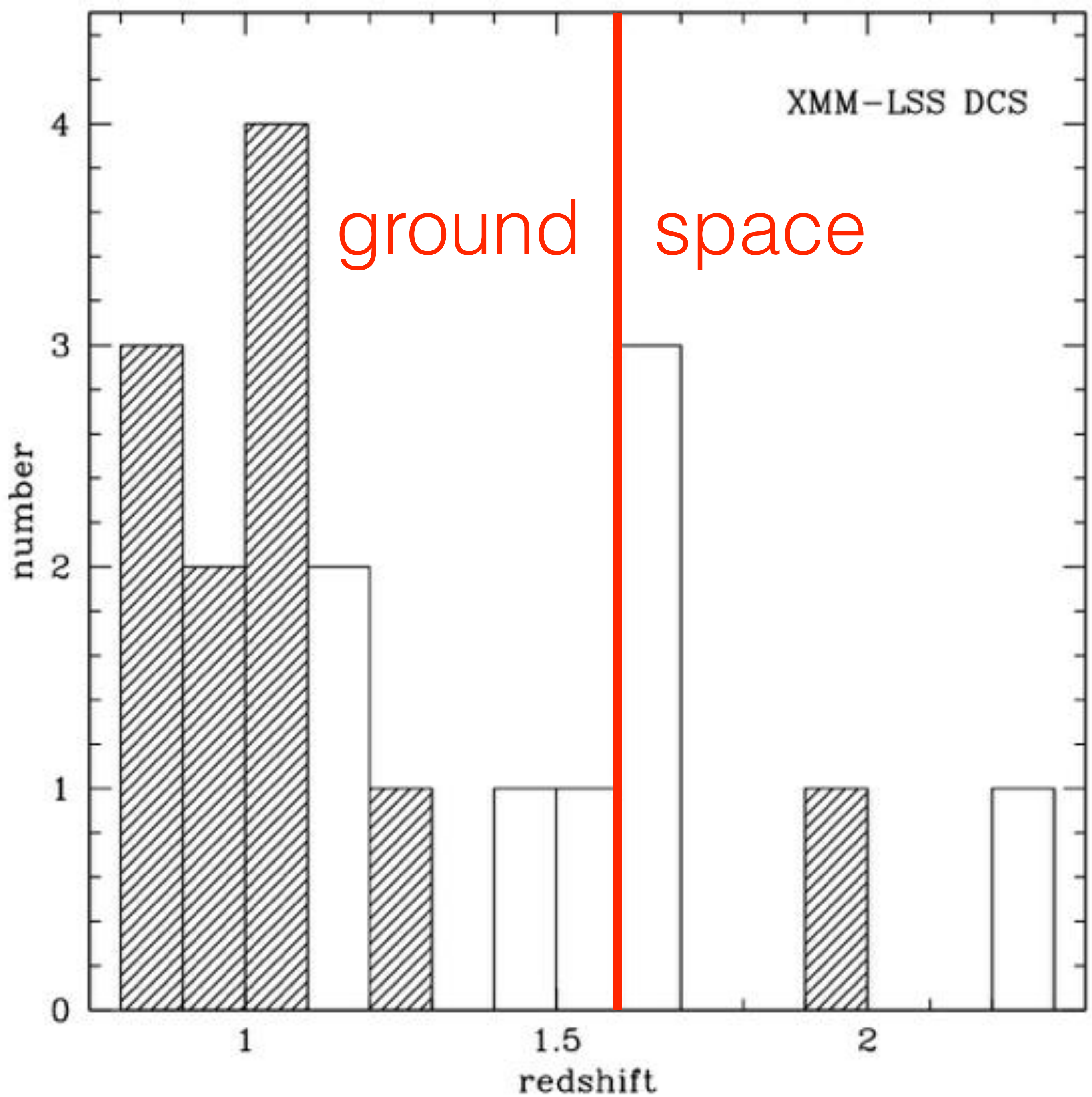


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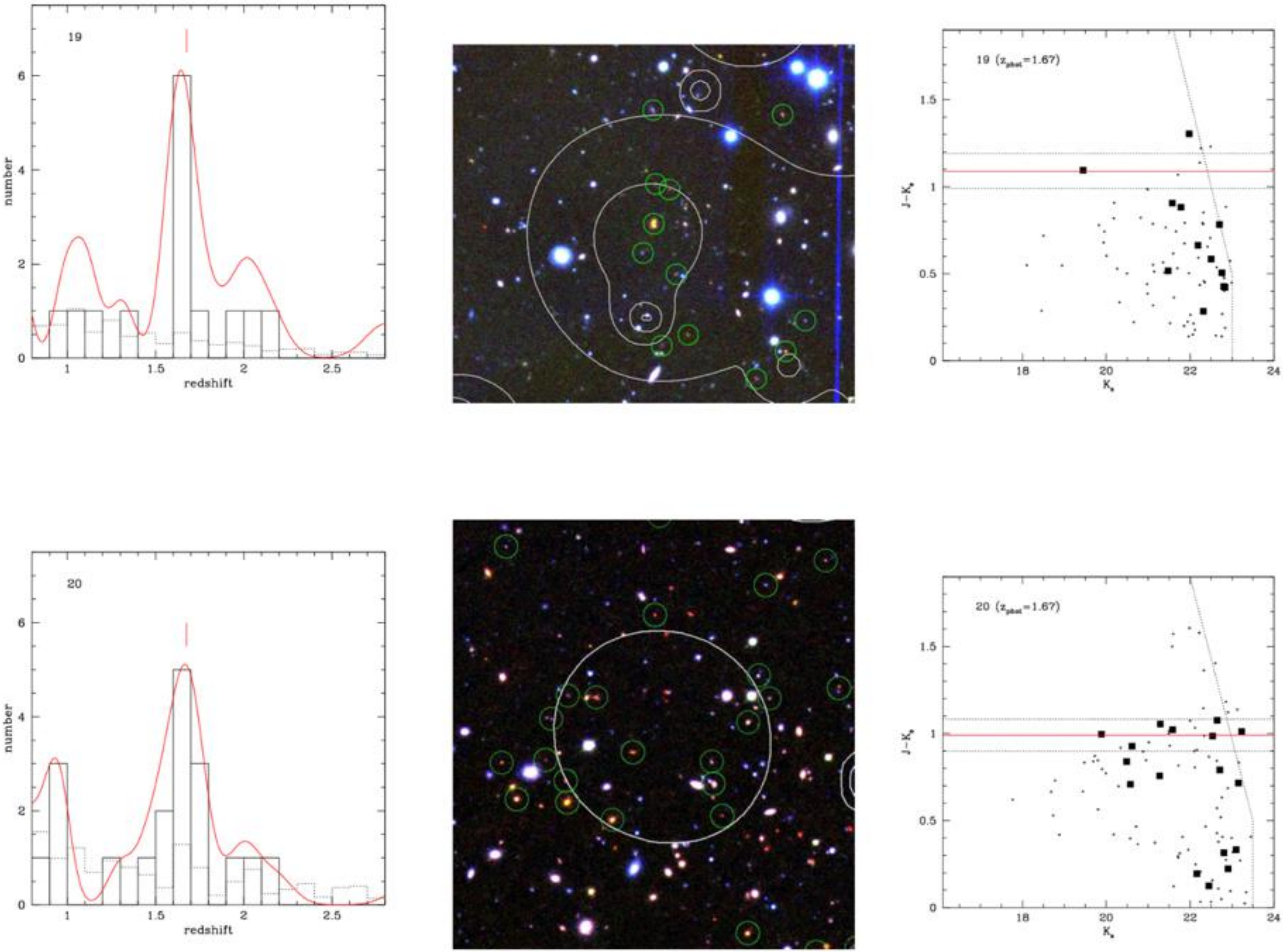
19
number
redshift
19 (z_phot=1.67)
J−K_s
K_s
20
number
redshift
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J−K_s
K_s

# Conclusions:

This relative lack of statistically complete X-ray studies of distant clusters, with few exceptions (e.g., Fassbender et al. 2011, [Willis et al. 2013]), is broadly due to the small number of known high-z clusters and the increased exposure times necessary at such high redshifts. Without such samples, our ability to make general conclusions about cluster evolution is severely limited.

McDonald et al. (2017)

**Table 3.** Global properties of XLSSC 122.

| $z$ | $r_{500}$ (kpc) | $M_{500}$ ($10^{13}\,M_\odot$) | $M_{\rm gas}$ ($10^{12}\,M_\odot$) | $kT$ (keV) | $Z$ ($Z_\odot$) | $L$(0.1–2.4 keV) ($10^{44}$ erg s$^{-1}$) | $L$(0.5–2.0 keV) ($10^{44}$ erg s$^{-1}$) | $Y_{500}$ ($10^{-12}$) | $Y_{500}\,d_{\rm A}^2$ ($10^{-5}$ Mpc$^2$) |
|---|---|---|---|---|---|---|---|---|---|
| $1.99^{+0.07}_{-0.05}$ | $295 \pm 23$ | $6.3 \pm 1.5$ | $7.9 \pm 1.9$ | $5.0 \pm 0.7$ | $0.33^{+0.19}_{-0.17}$ | $3.5 \pm 0.5$ | $2.2 \pm 0.3$ | $3.6 \pm 0.4$ | $1.07 \pm 0.13$ |

**Notes.** Where appropriate, measurements are referenced to the characteristic radius $r_{500}$. A redshift of $z = 1.99$ is assumed in the derivations of mass, gas mass, luminosity and Compton $Y$. The impact of the redshift uncertainty on other quantities (e.g. through the angular diameter distance) is subdominant to statistical uncertainties.