Cluster AGN Topography Survey (CATS)

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Allen, Brandt, **Canning**, **Ehlert**, **King**, von der Linden, Luo, Mantz, Morris, Xue + SPT

AGN in the Cluster Environment

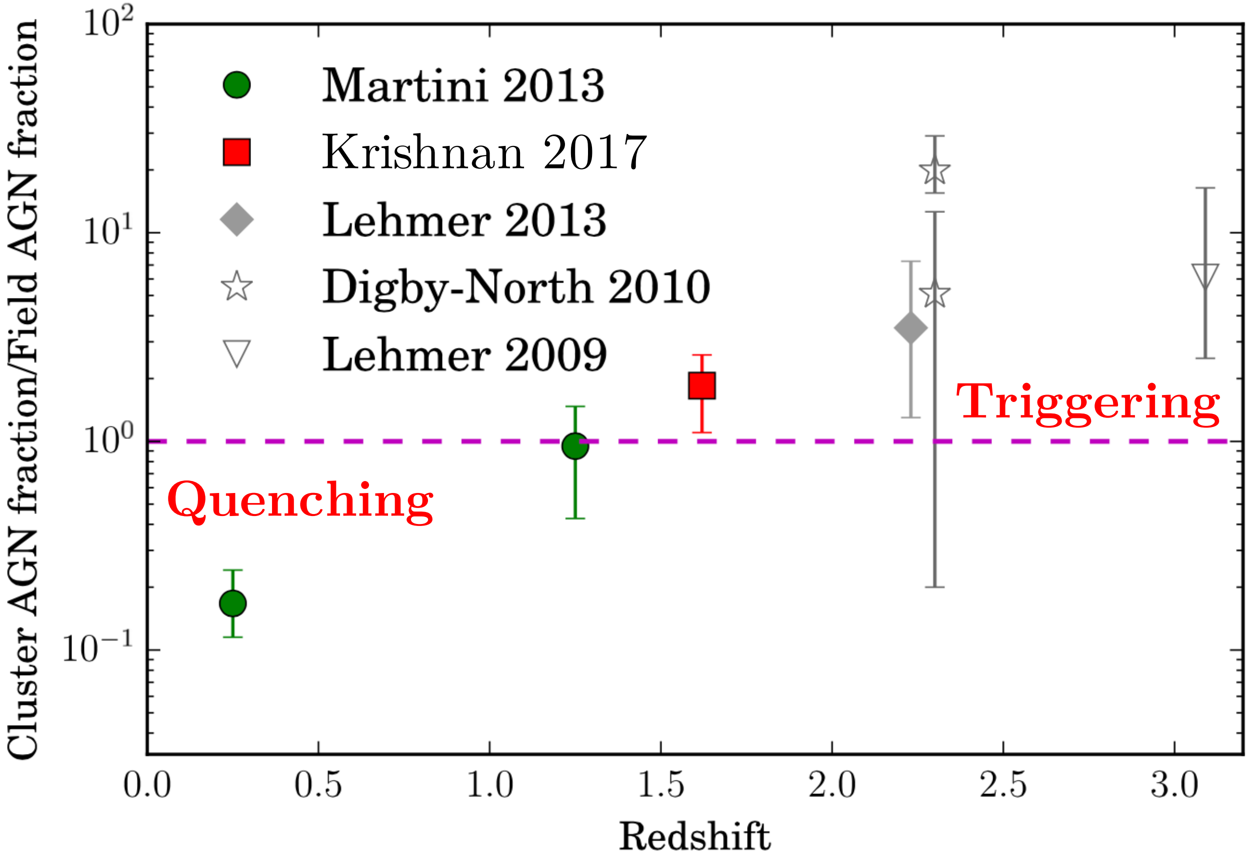
What is the influence of LSS on SMBH activity?

Environmental effects: Ram pressure stripping, starvation, evaporation, tidal effects, mergers and interactions

How does this impact triggering of different modes of AGN activity?

Evidence of quenching **X-ray AGN** at low-z, triggering at high-z but small sample sizes, limited mass coverage!

Adapted from Krishnan+2017



The Survey

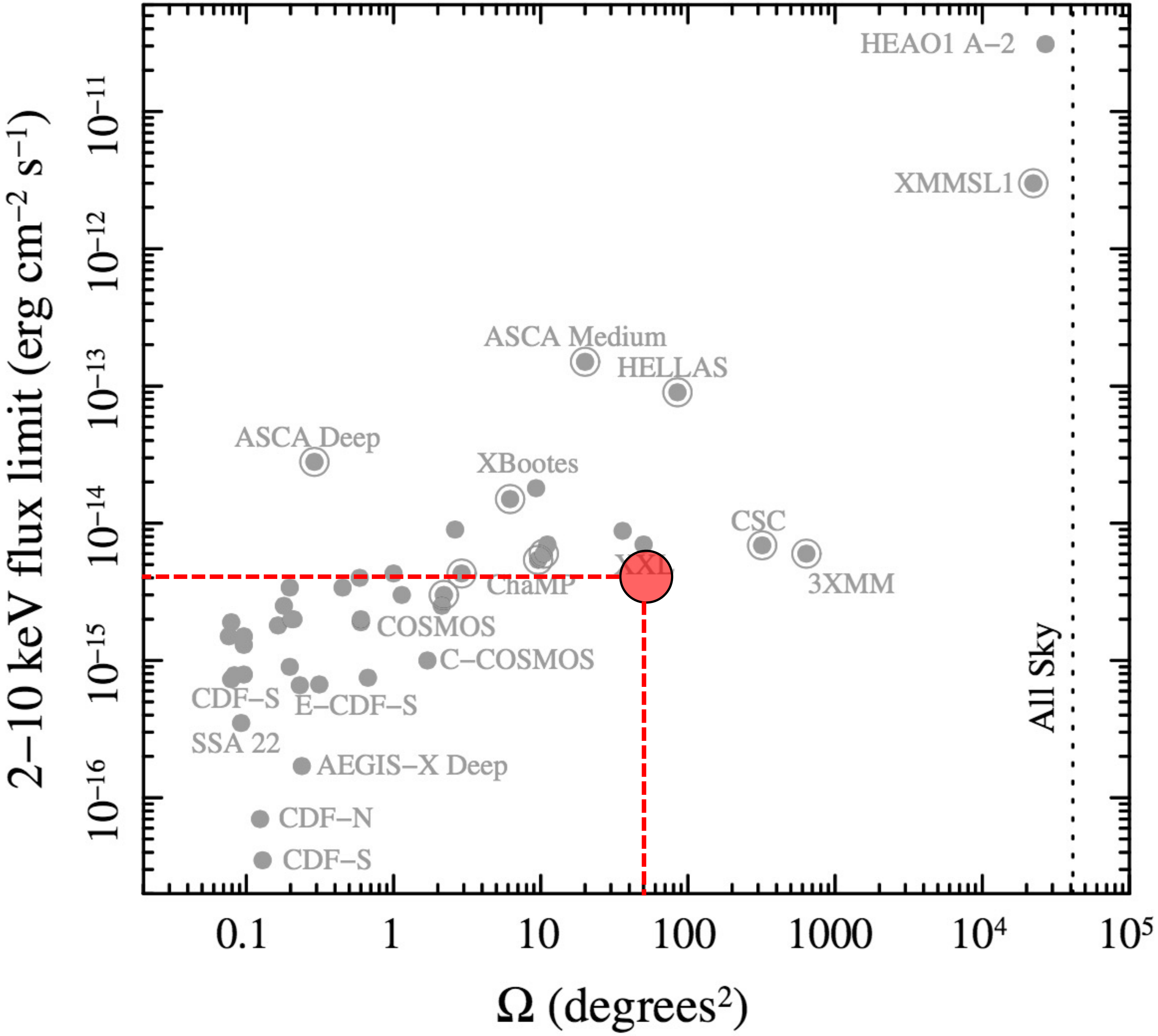
Massive, multi-wavelength survey anchored by Chandra data

Archival, pointed Chandra X-ray observations of **550 clusters**

Cluster AGN are **rare** (<3 per cluster)

Leverage cluster self-similarity

Adapted from Brandt & Alexander 2015



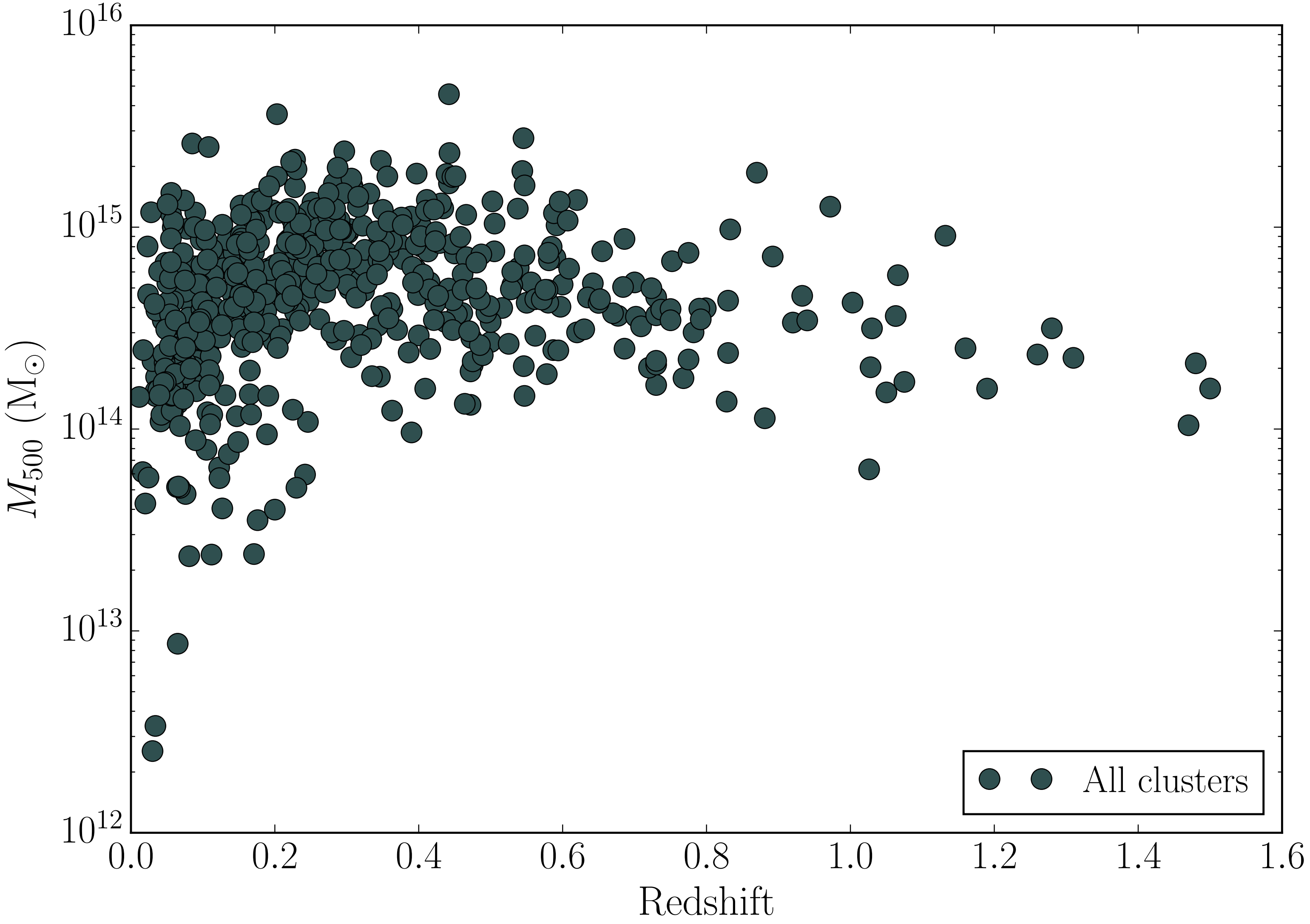
Cluster Sample

550 clusters

All with Chandra data (>10 ks each)

25.7 Ms archival Chandra exposure

>40,000 point sources



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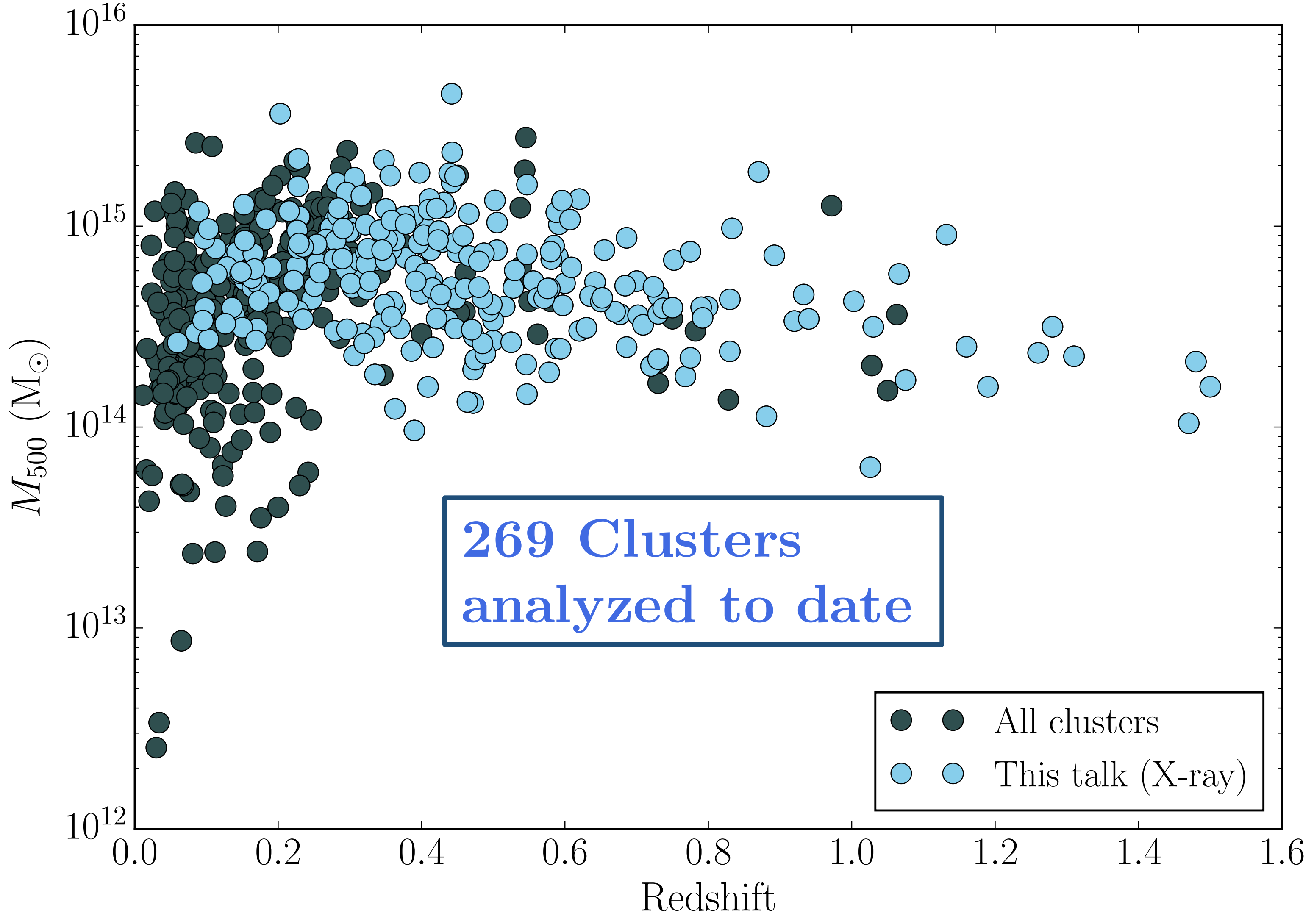
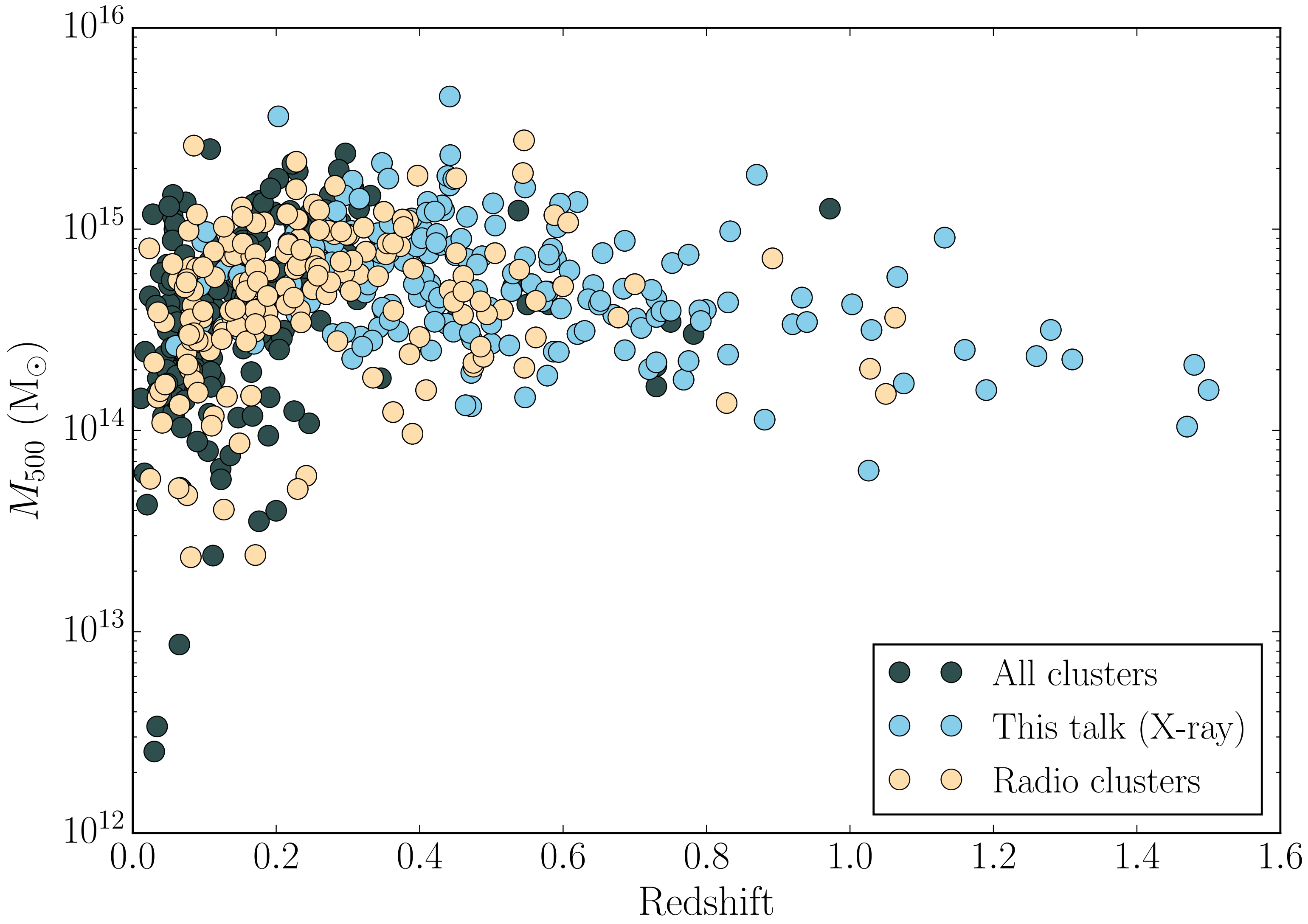


Cluster Sample

183 clusters in VLA FIRST footprint

1.4 Ghz Radio data

3 mJy flux limit



Cluster Sample

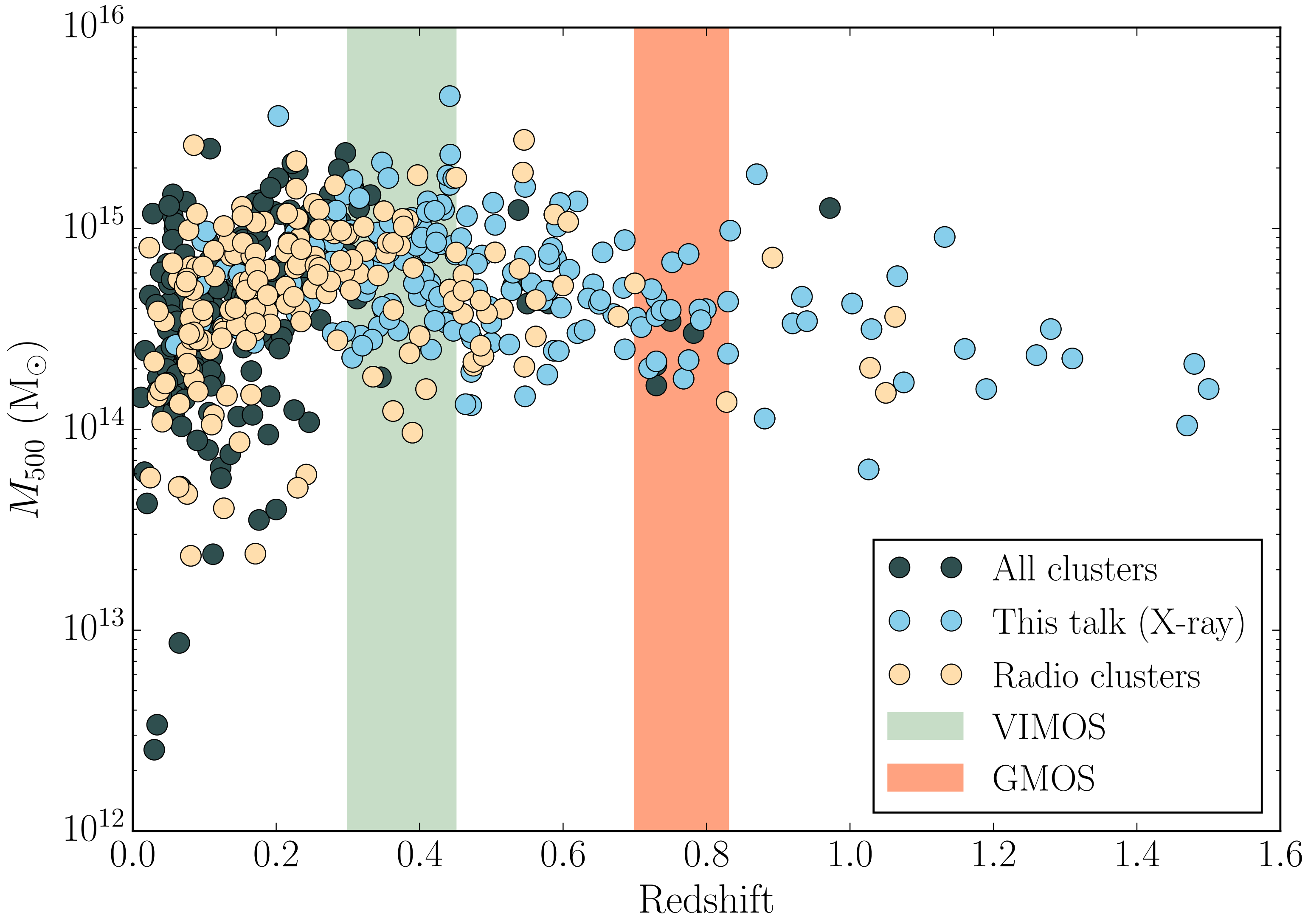
Complete spectroscopic follow up with VIMOS and GMOS

7 clusters at z=0.4

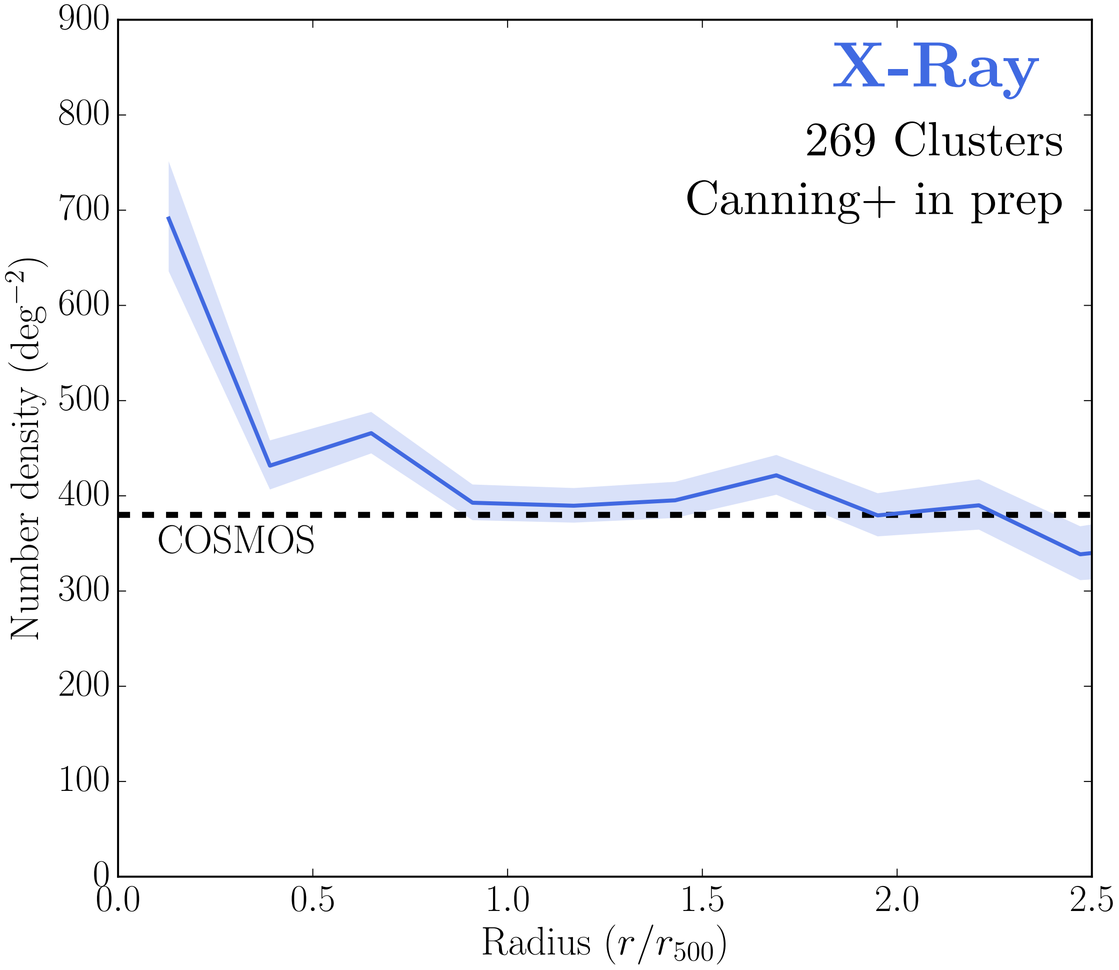
12 clusters at z=0.8

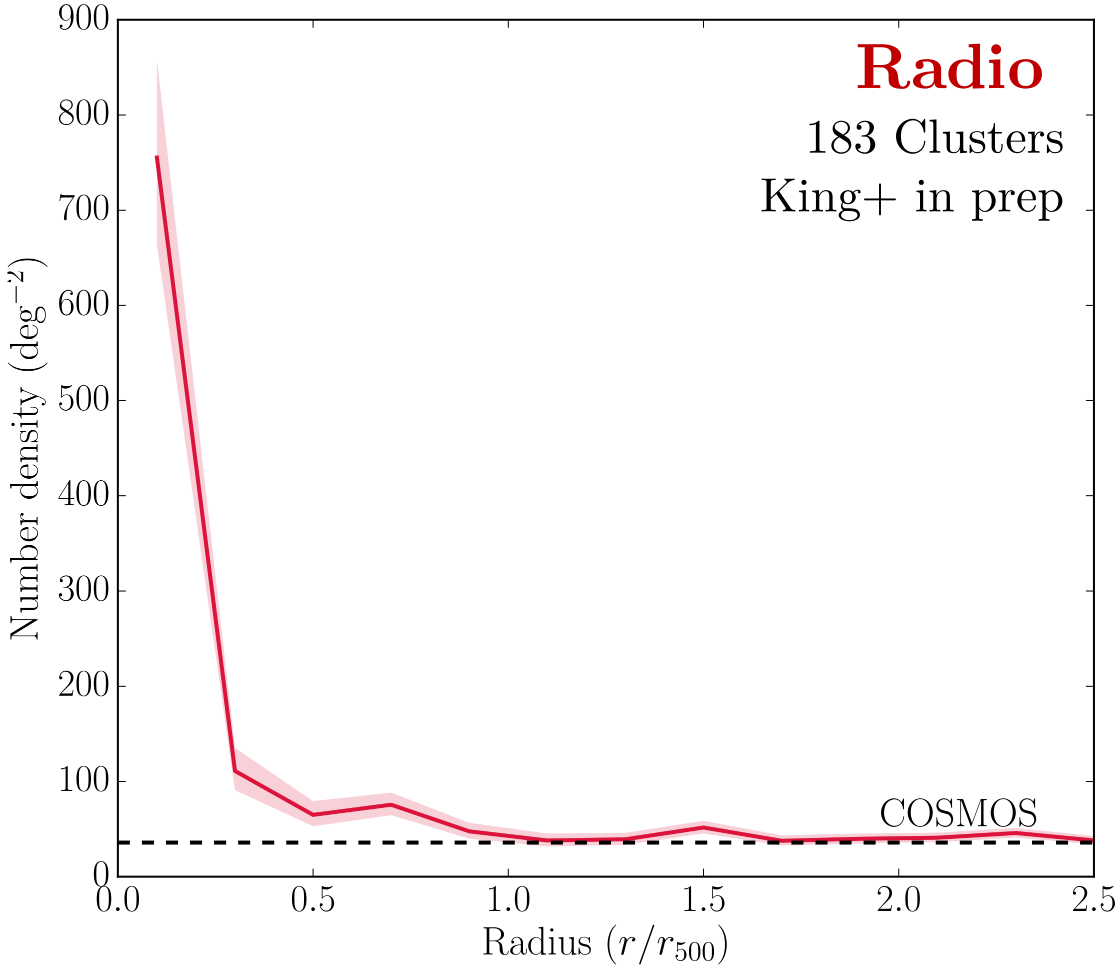
Benefits: Stellar mass, SFR, cluster member confirmation, optical activity

HST snapshot photometry of >200 clusters



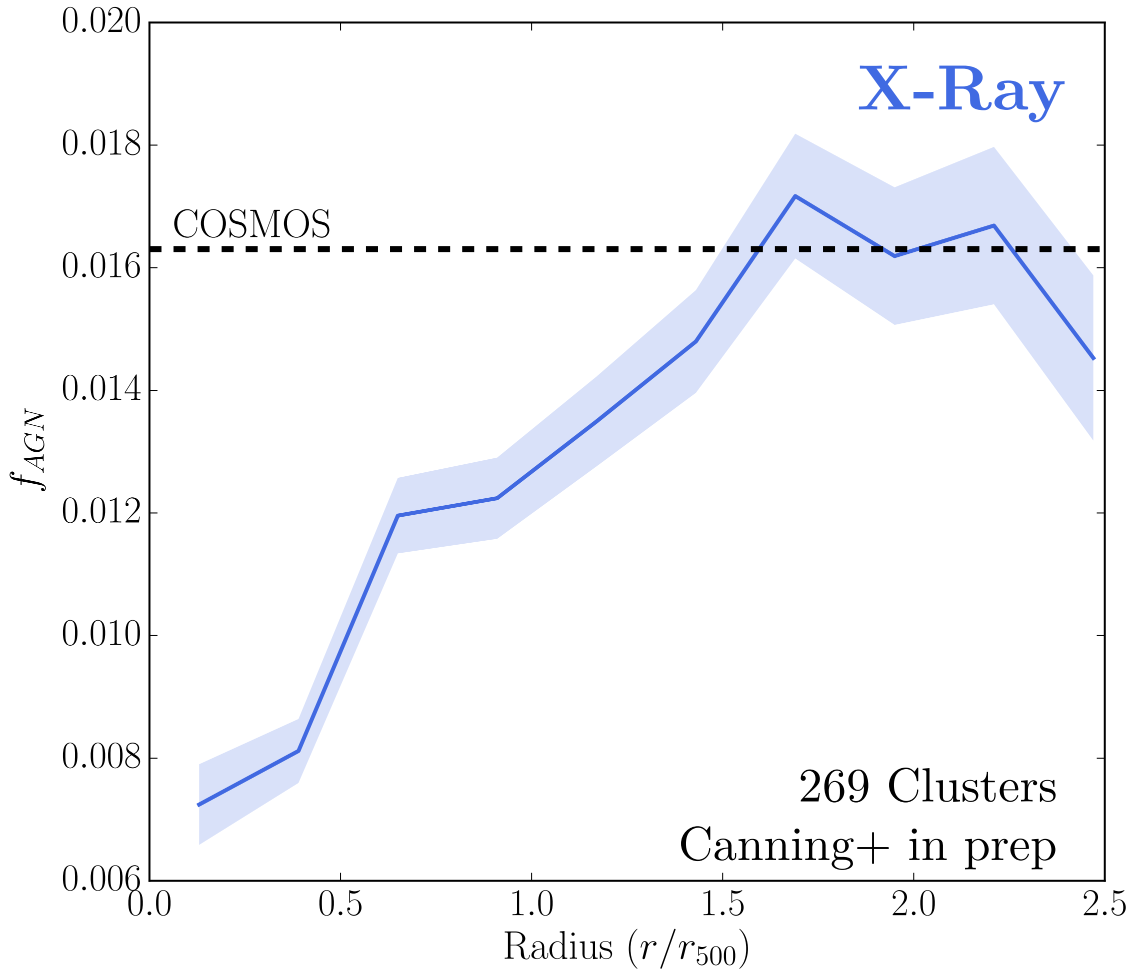
AGN Number Density

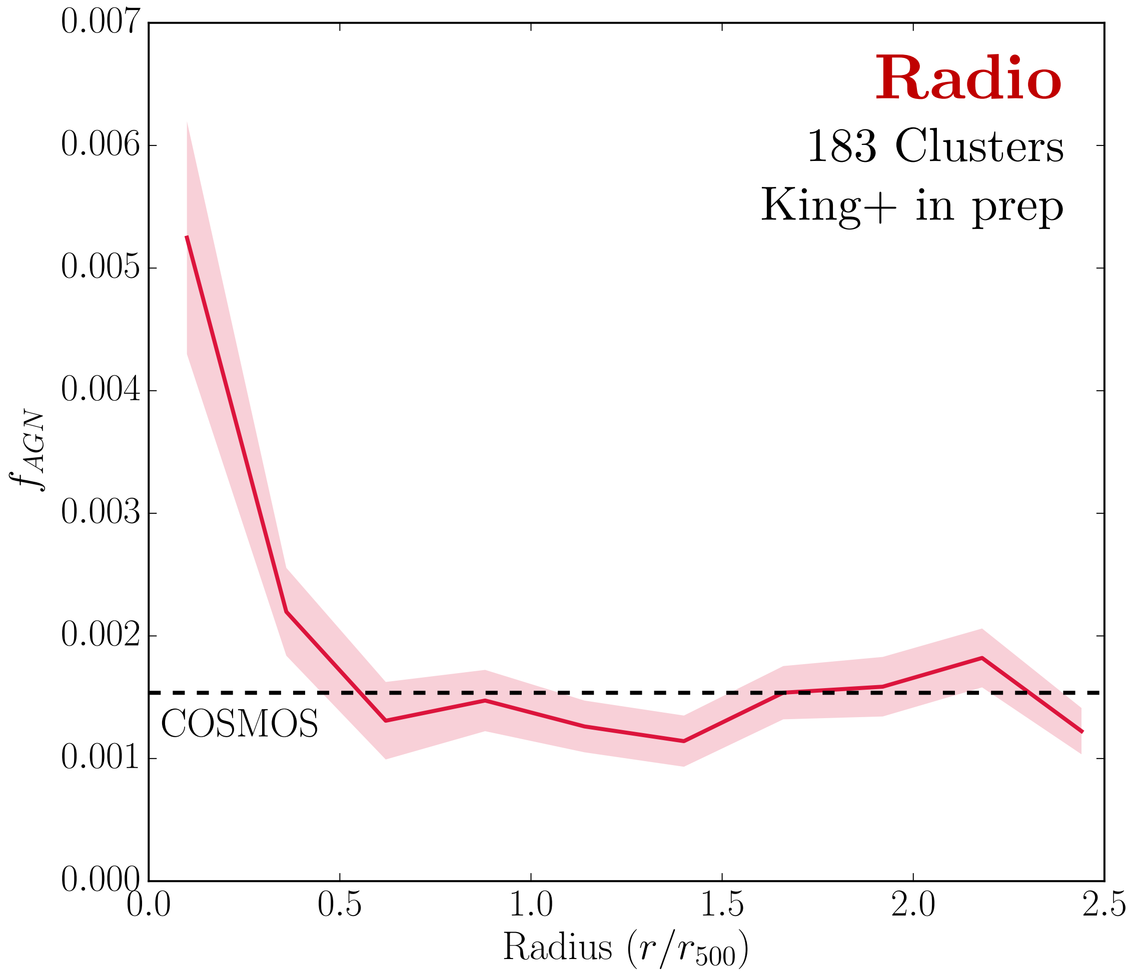




Projected number density of AGN increases towards cluster center

AGN Fraction





X-ray AGN fraction decreases towards cluster center while radio AGN fraction increases

Modelling the Cluster AGN Population

How does the cluster AGN population evolve relative to the field?

$$N_{obs}(> f, r, z) = \underbrace{A D_A^2 r_{500} \Phi(> L, z) \left(\frac{r}{r_{500}}\right)^{\beta}}_{N_{cluster}} + N_{field}$$

$$\boxed{A = A_0 (1+z)^{\eta} \left(\frac{M_{500}}{10^{15}\mathrm{M}_{\odot}}\right)^{\zeta}}$$

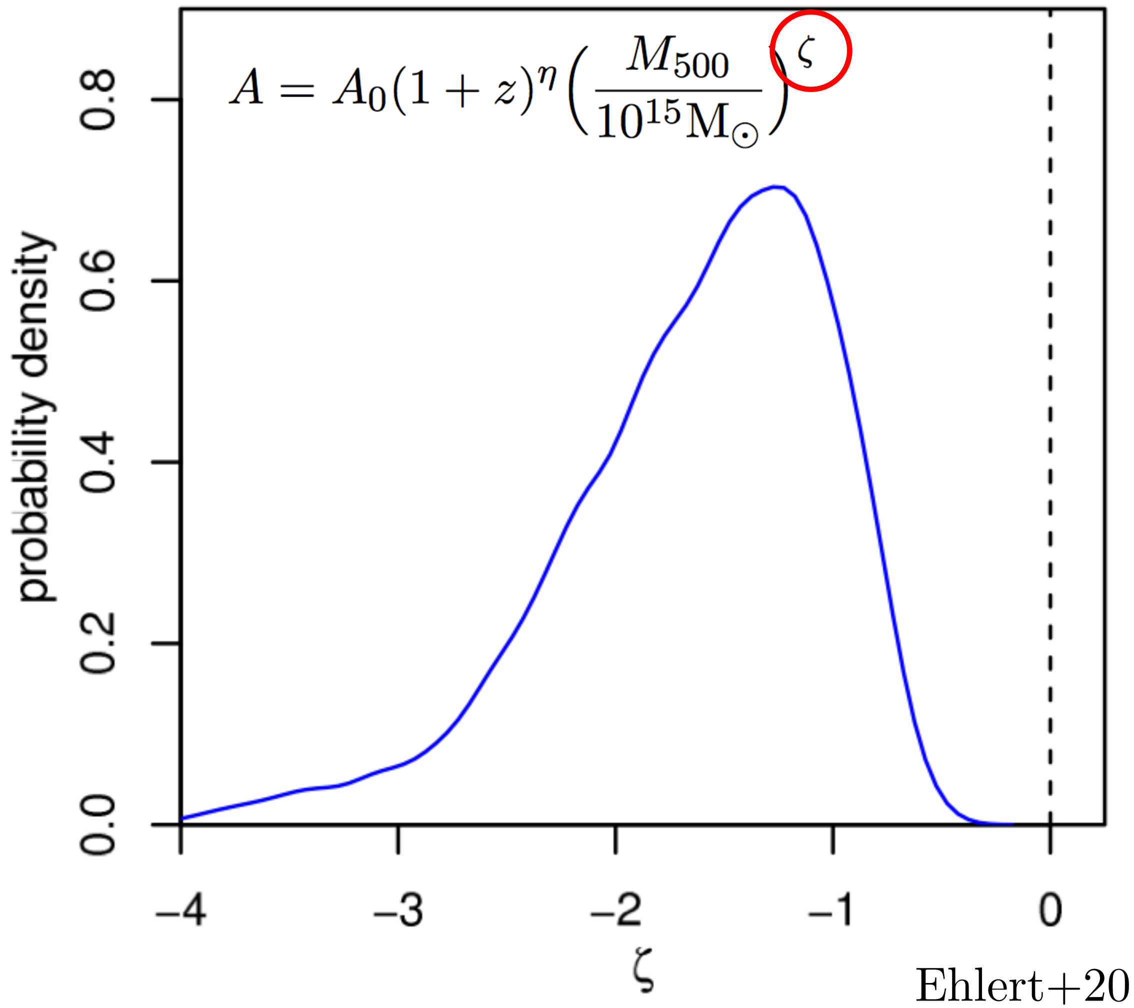
We allow the amplitude of the cluster AGN overdensity to scale with cluster mass and redshift

Modelling the Cluster AGN Population

Model ran on **X-ray** data for **subset of 135 clusters (6.3 Ms)**

Mass dependence of $\zeta = -1.2 \pm 0.7$ with $\zeta = 0$ ruled out at 3 sigma significance

Merger driven AGN triggering? Mergers in massive galaxy clusters scale as $\sim M^{-1}$ (Mamon 1992)



Ehlert+2015

Modelling the Cluster AGN Population

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Mass depende
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X-Ray: Canning+ in prep.
Radio: King+ in prep.

Merger driven AGN triggering?
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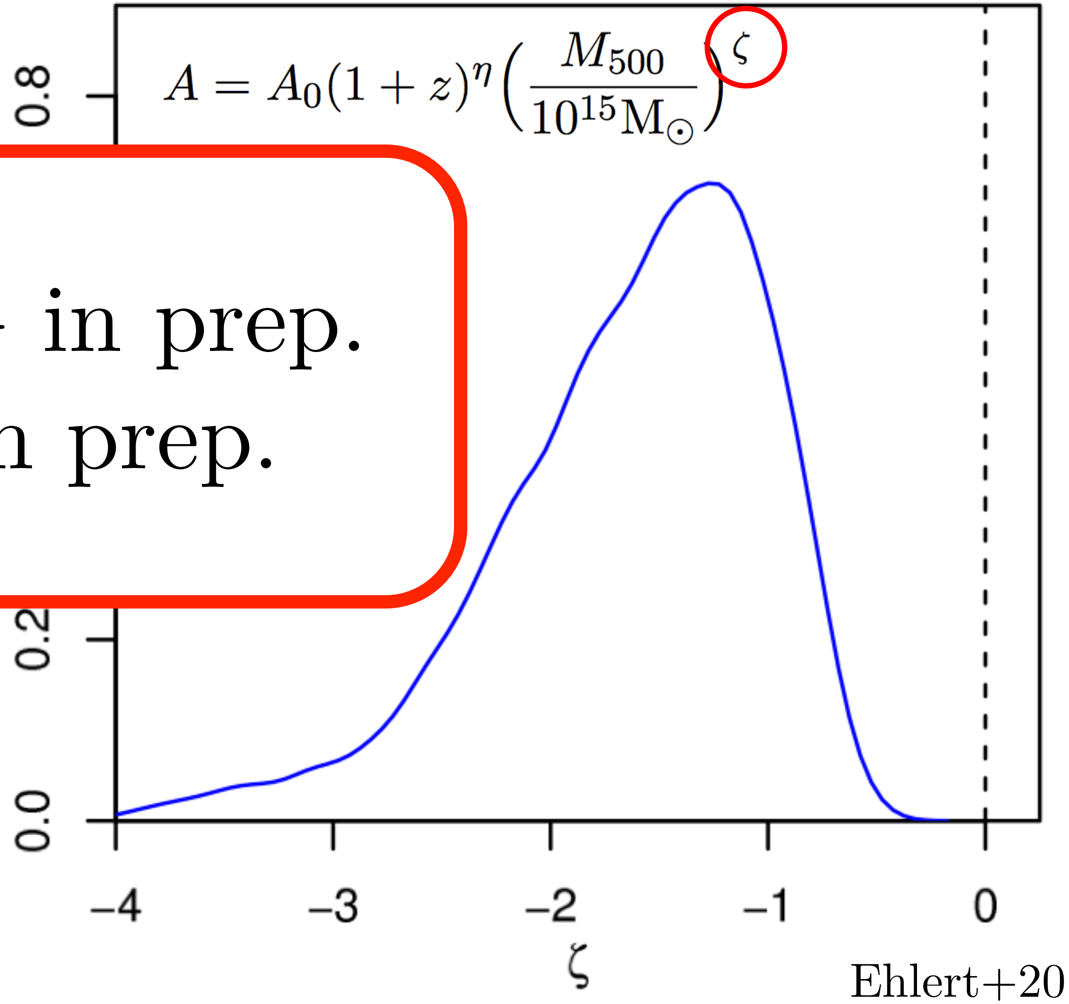
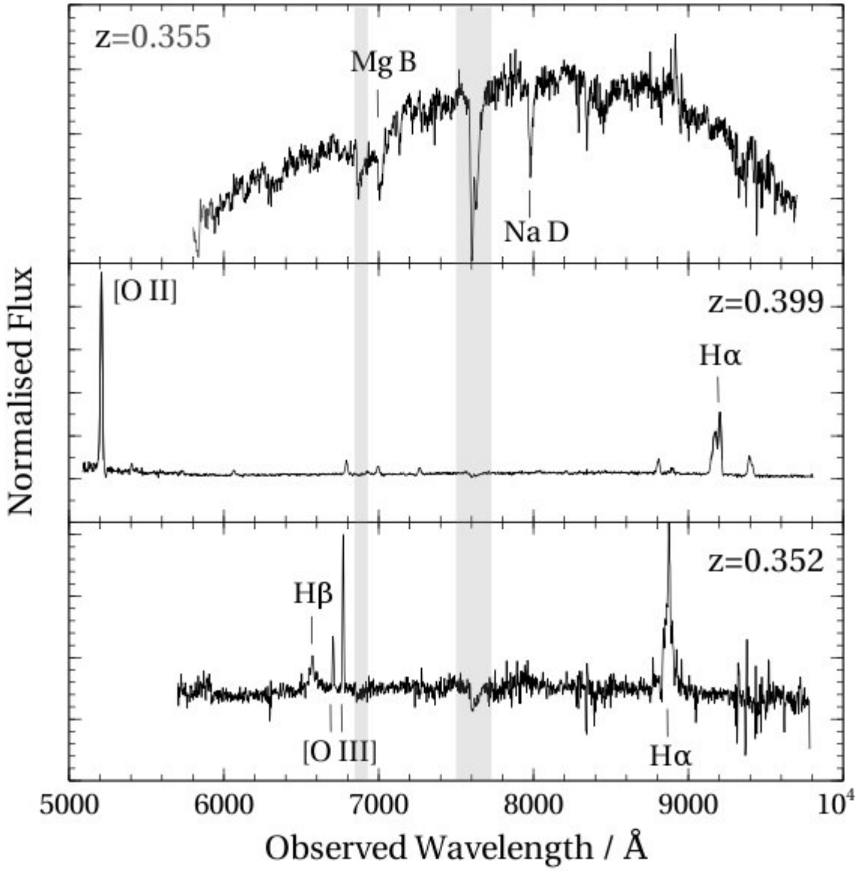


Ehlert+2015

Optical Photometry & Spectroscopy

Optical spectra of our X-ray AGN

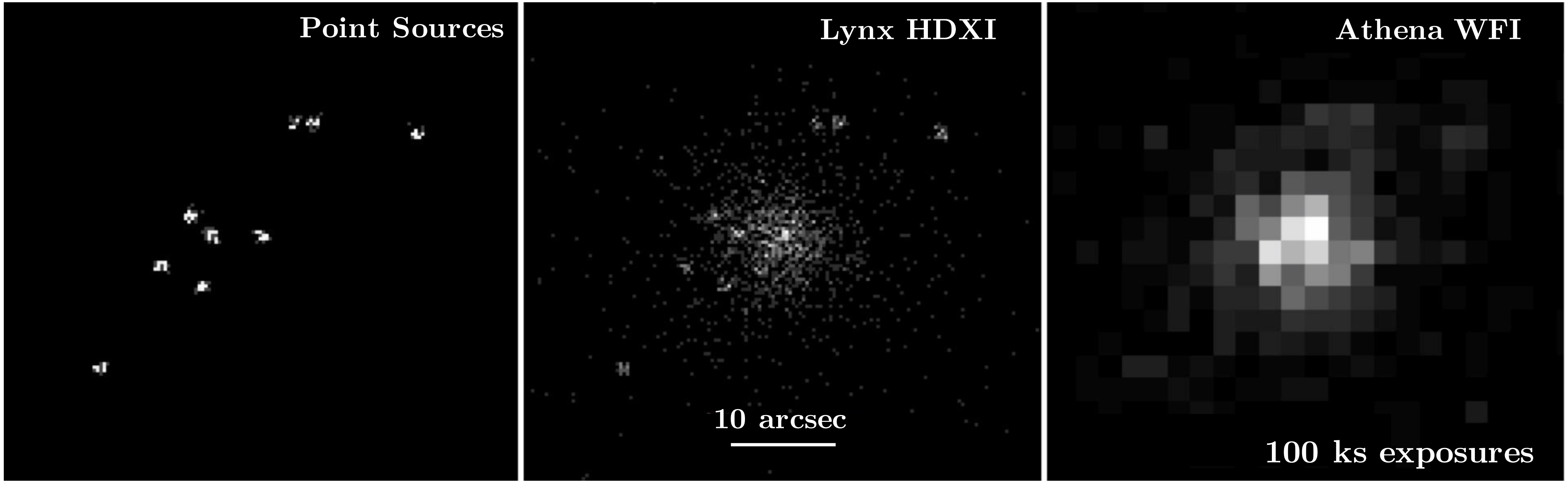


Correlate merger activity with AGN activity

Control for diverse host galaxy properties to isolate environmental impact on AGN triggering

Clean, background free analysis as a function of stellar mass and SFR

Looking to the Future with Lynx



2 keV, $\boxed{z = 3 \text{ cluster}}$ + AGN (5×10^{-17} erg/cm^2/s)

Identifying AGN in clusters:

- PSF critical to separate cluster and AGN emission at high-z
- Sub-arcsec resolution required over wide FOV
- Lynx uniquely allows extension through the peaks of AGN and SF activity

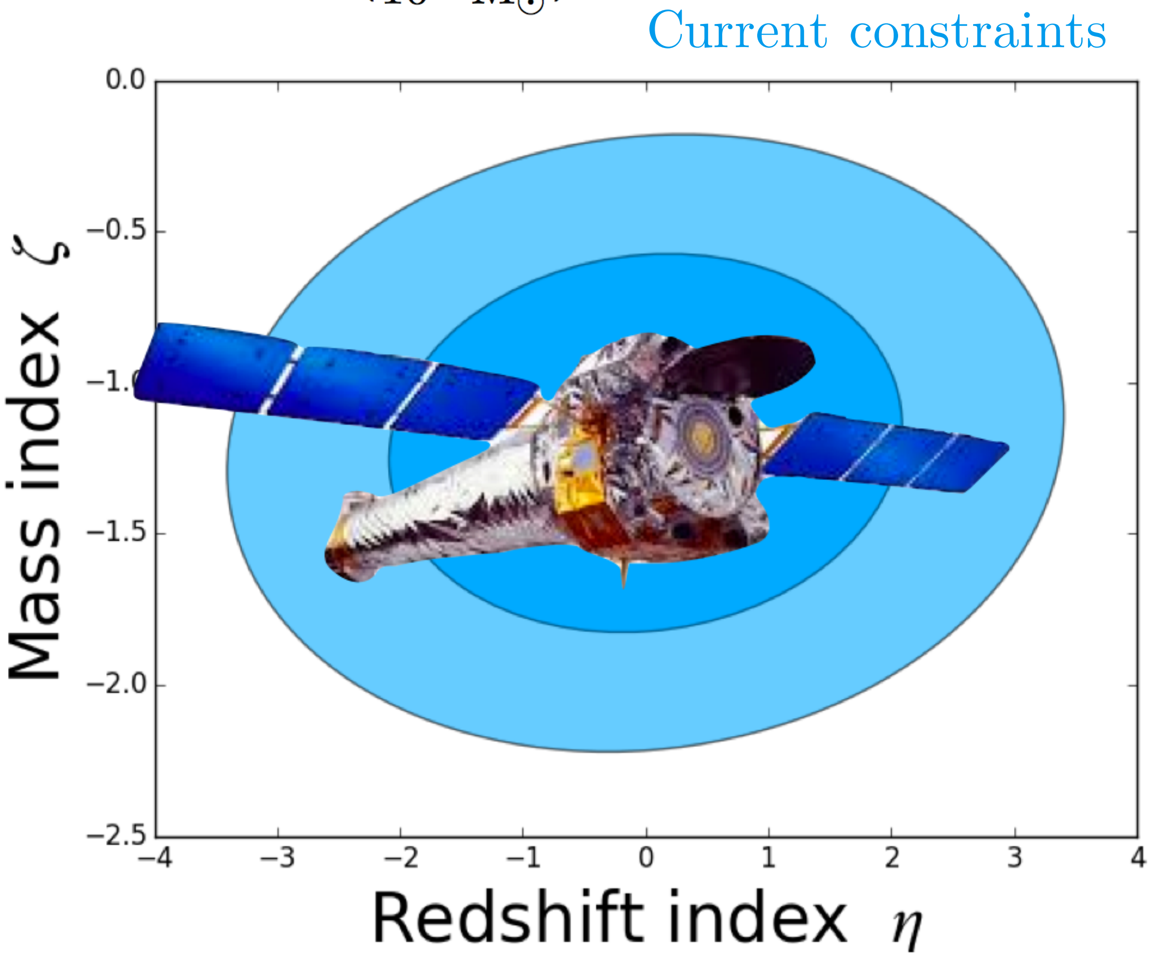
Looking to the Future with Lynx

How well will Lynx do?

$$A = A_0(1+z)^{\eta}\left(\frac{M_{500}}{10^{15}\mathrm{M}_\odot}\right)^{\zeta}$$

Assuming:

- Same exposure as current model results (6.3 Ms)
- 10 ks exposure per cluster (630 clusters)
- Flux limit of 5×10^{-15} erg/cm^2/s (conservative)
- Cluster $M_{500} > 10^{14}\mathrm{M}_\odot$ and $z < 2$



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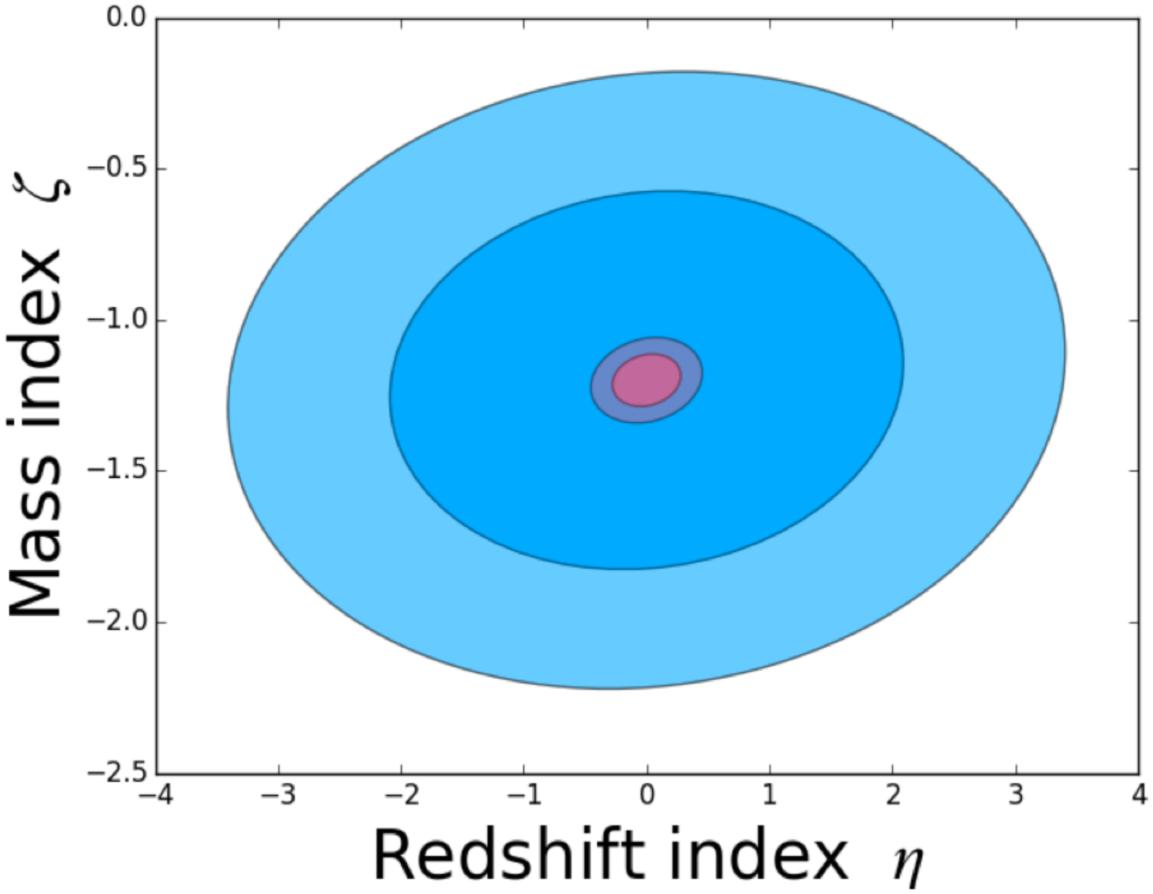
Factor of ~10 better constraints!

Real strength is pushing to high *z*, low mass clusters

$$A = A_0 (1+z)^{\eta} \left(\frac{M_{500}}{10^{15} \mathrm{M}_\odot} \right)^{\zeta}$$

Current constraints
Lynx constraints



Summary

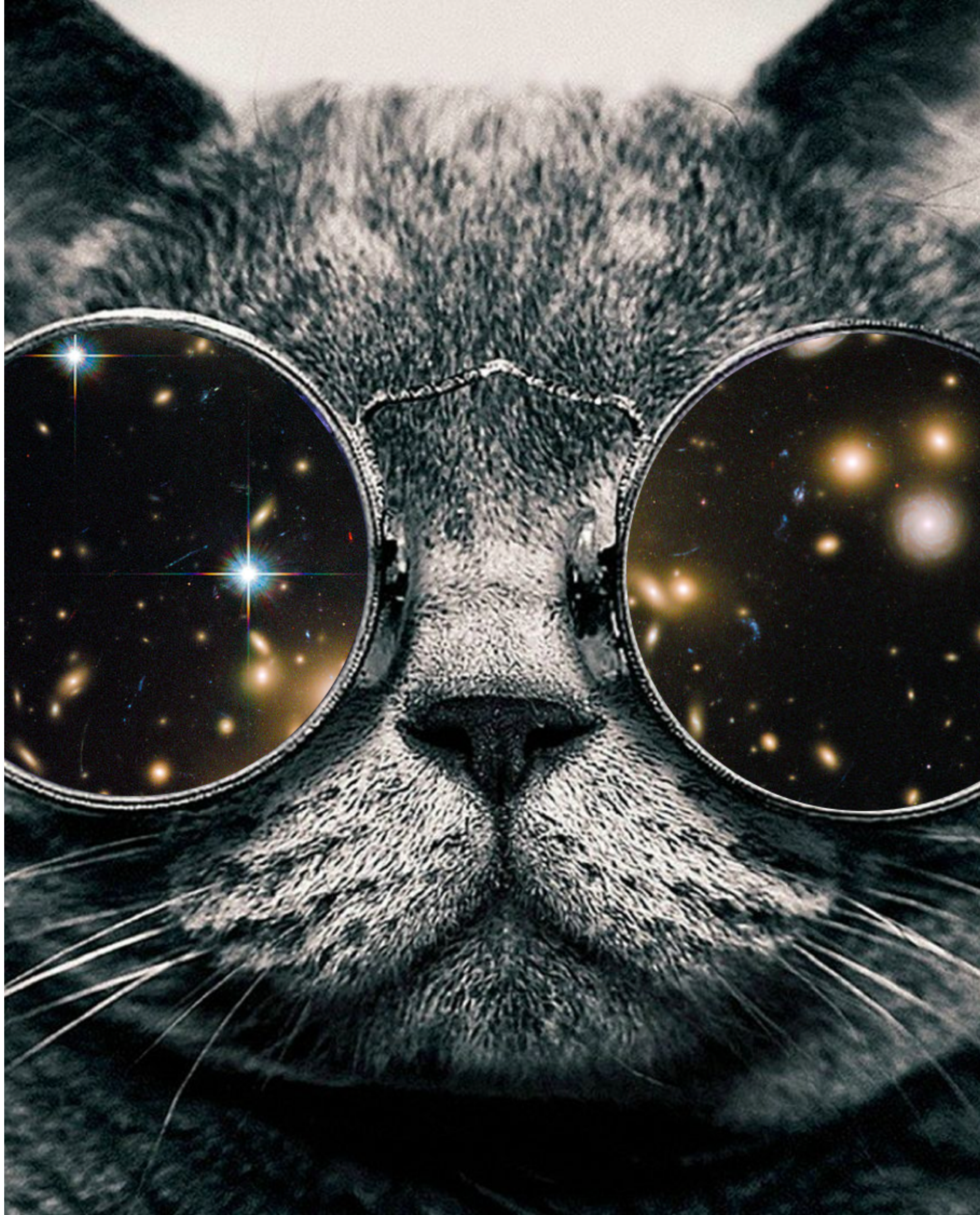
CATS: Multi-wavelength survey of 550 galaxy clusters anchored by Chandra data

Observed decrease in the X-ray AGN fraction towards cluster center and increase in the radio AGN fraction

Pathfinder study: inverse mass dependence of cluster X-ray AGN overdensity suggestive of **merger driven triggering**

Analysis of full sample ongoing with results coming soon!

Lynx's *uniquely* enables us to complete the story of cluster AGN evolution through the peaks of AGN and star formation activity



Extra Slides

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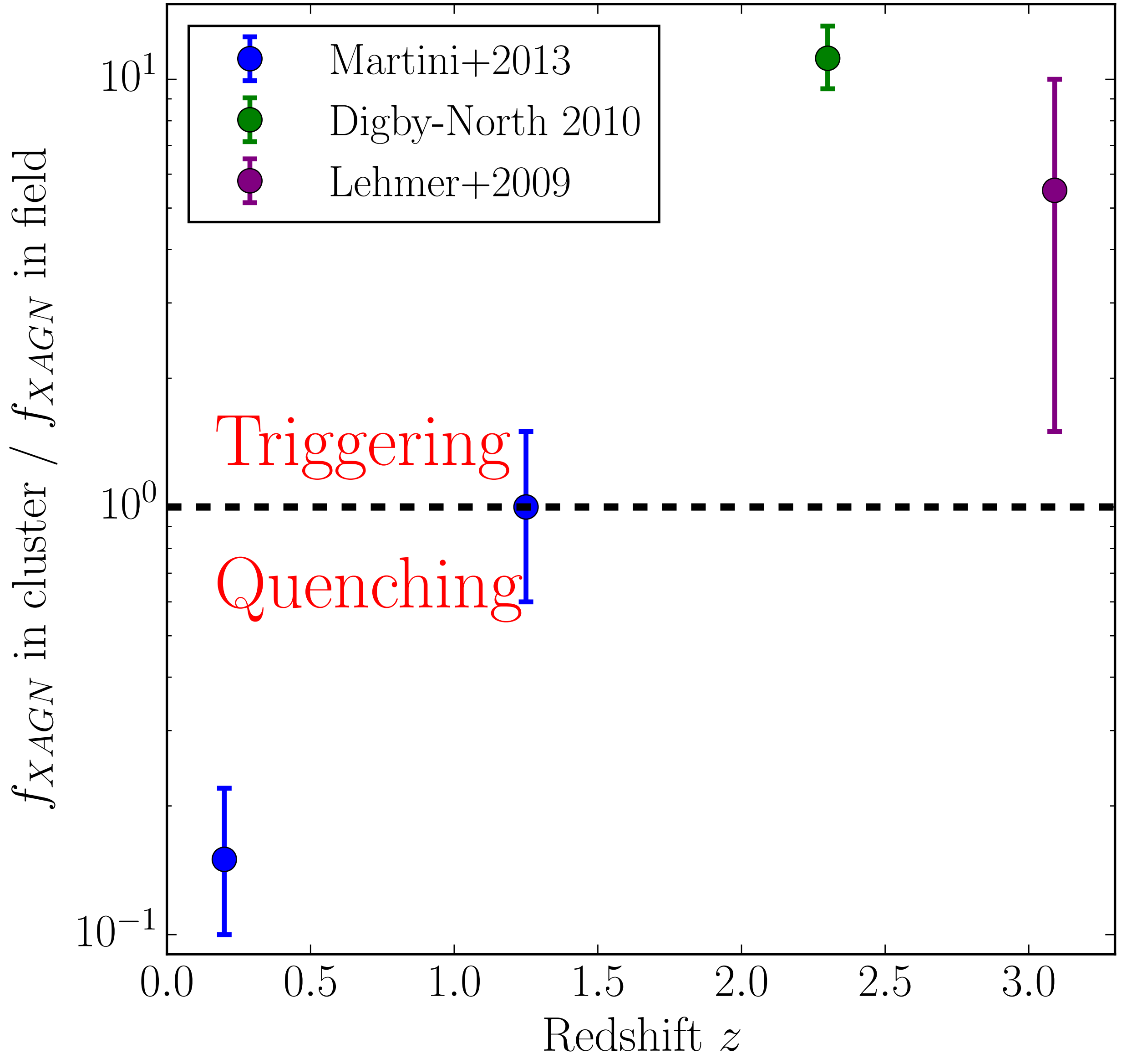

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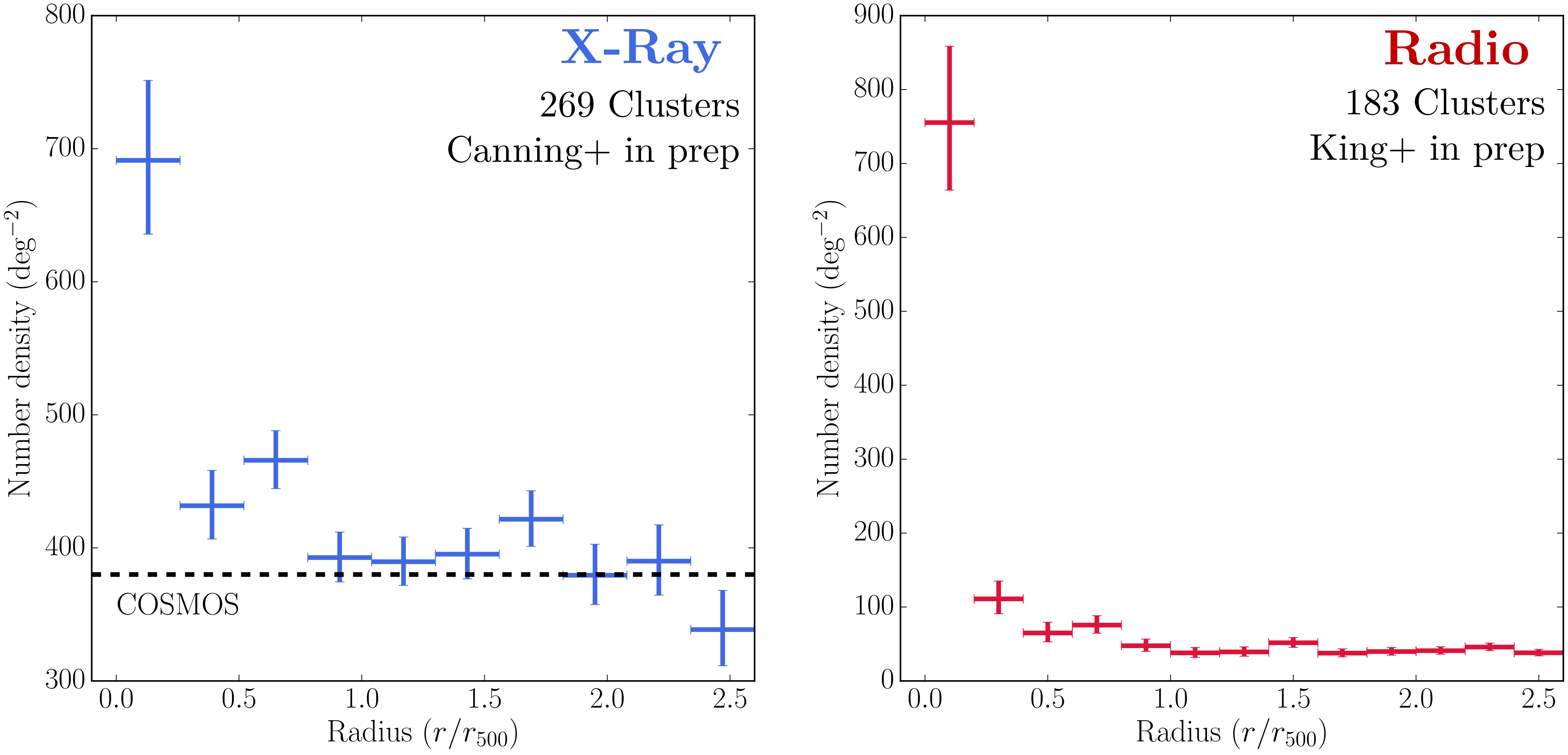

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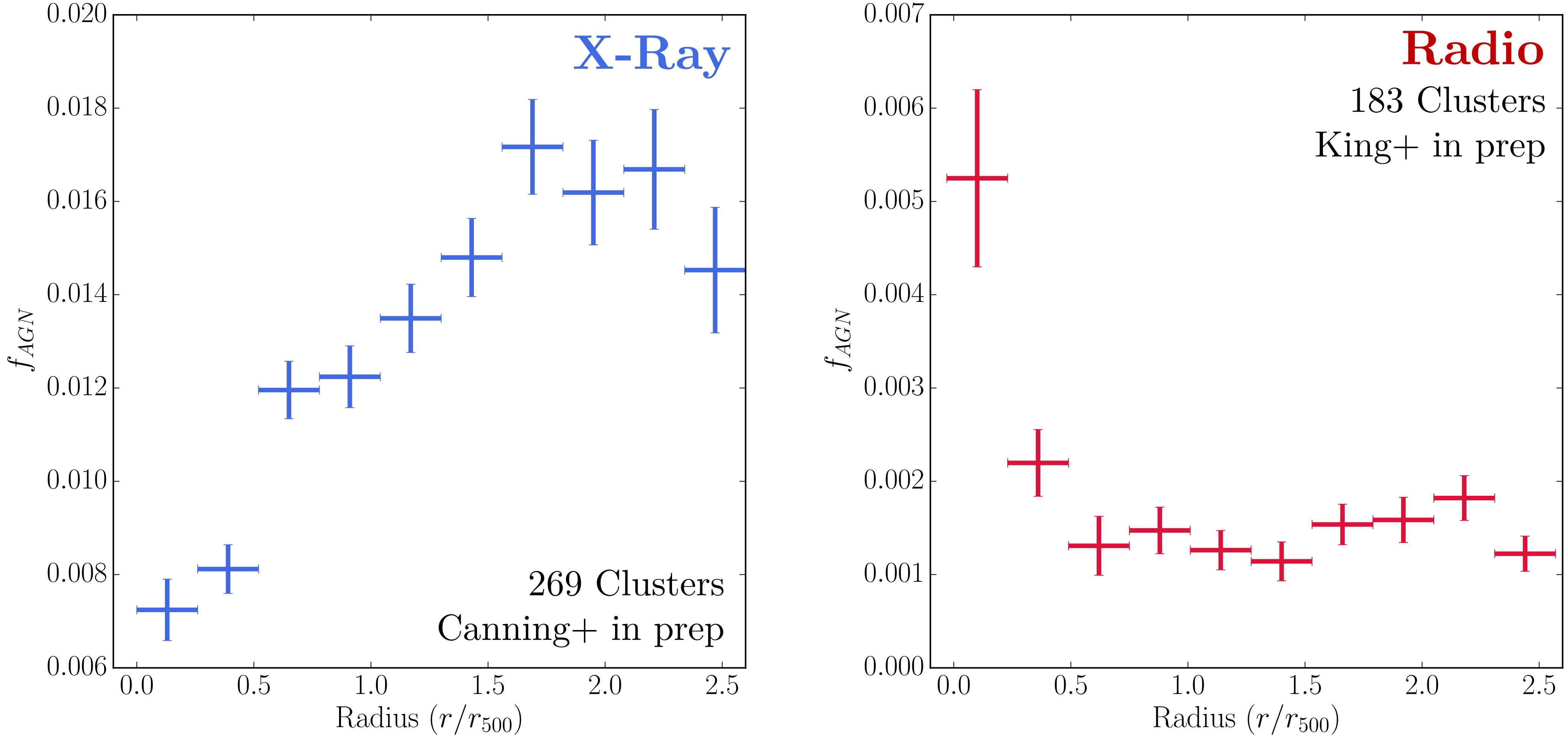

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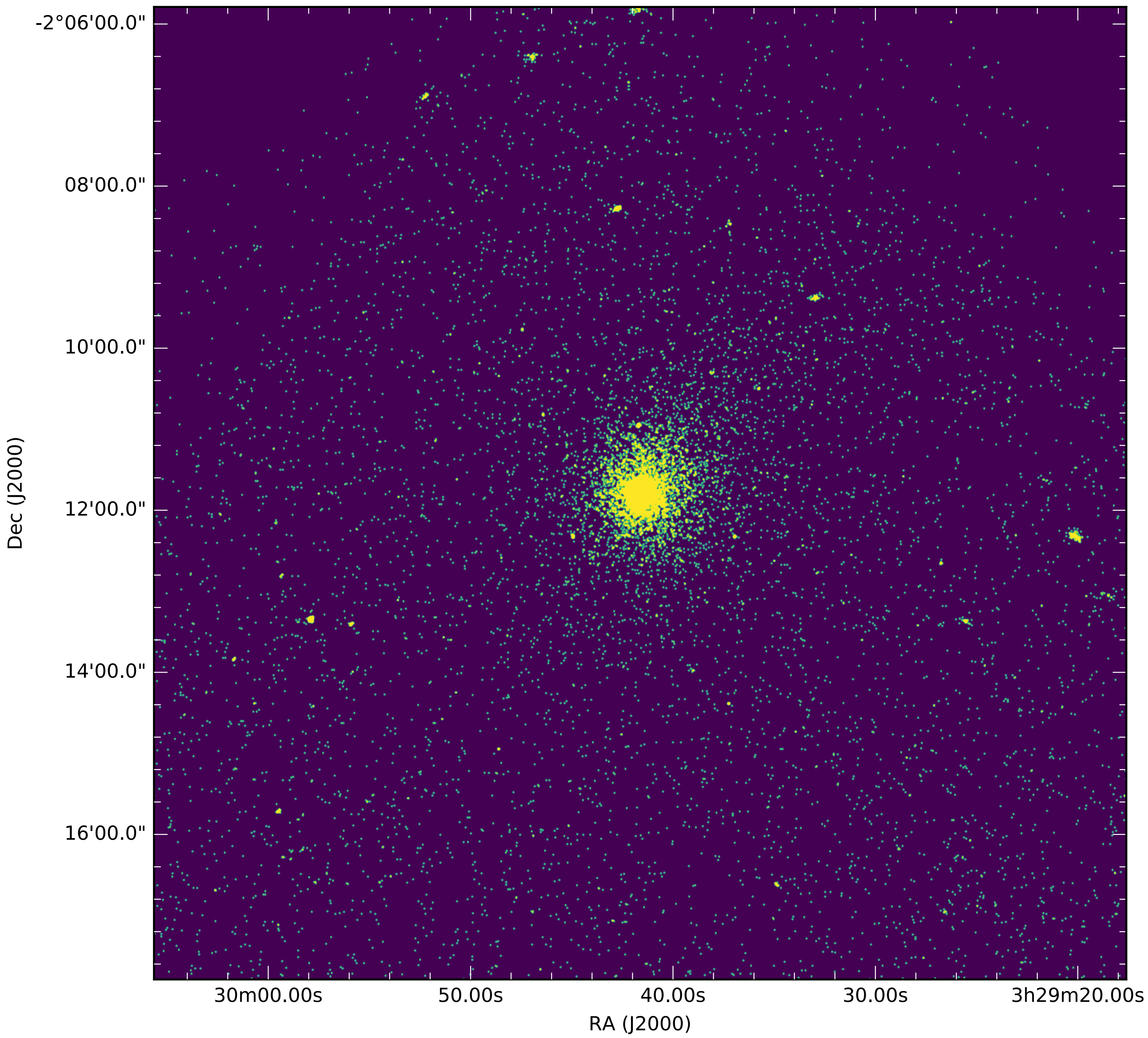
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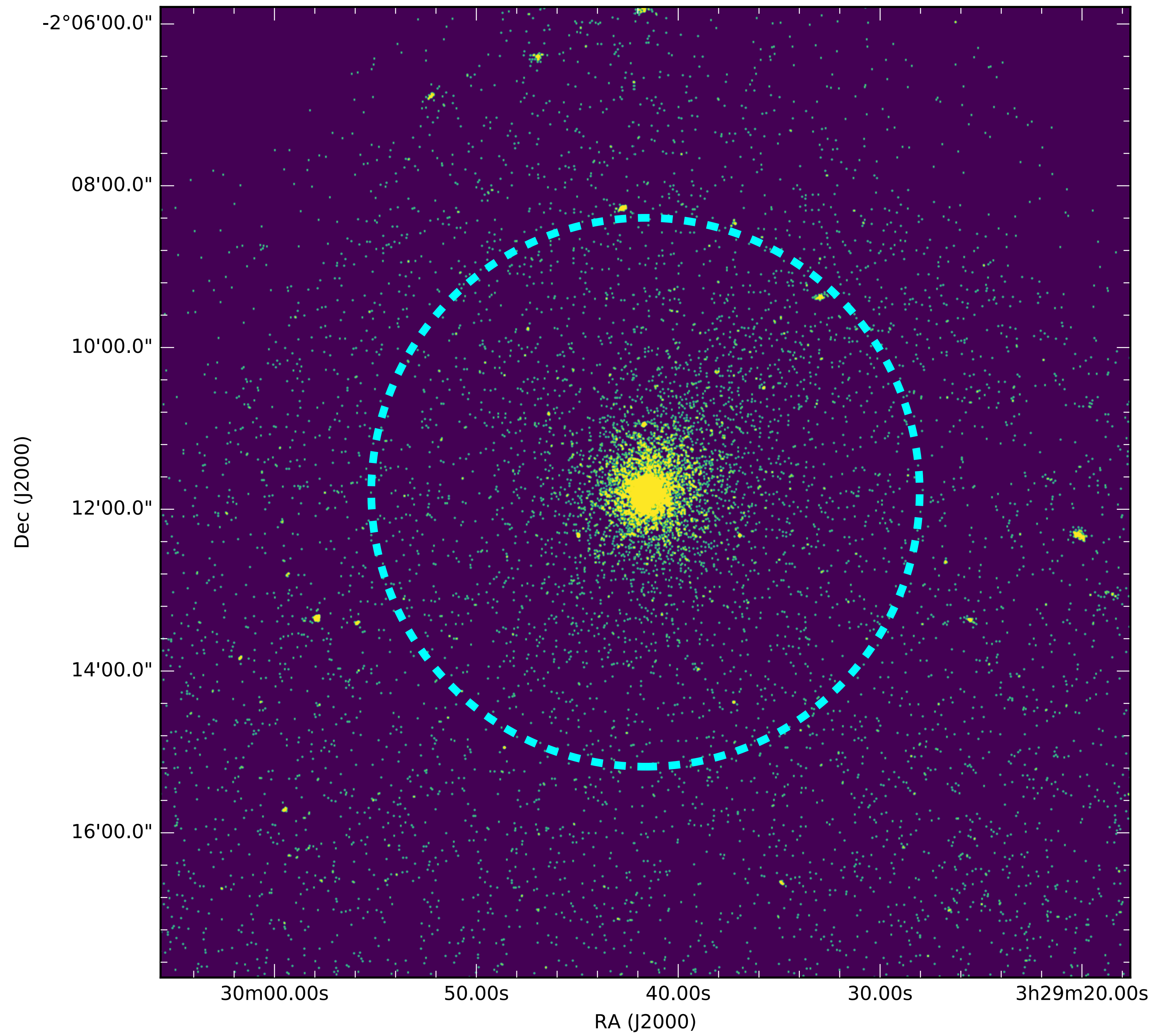
RA (J2000)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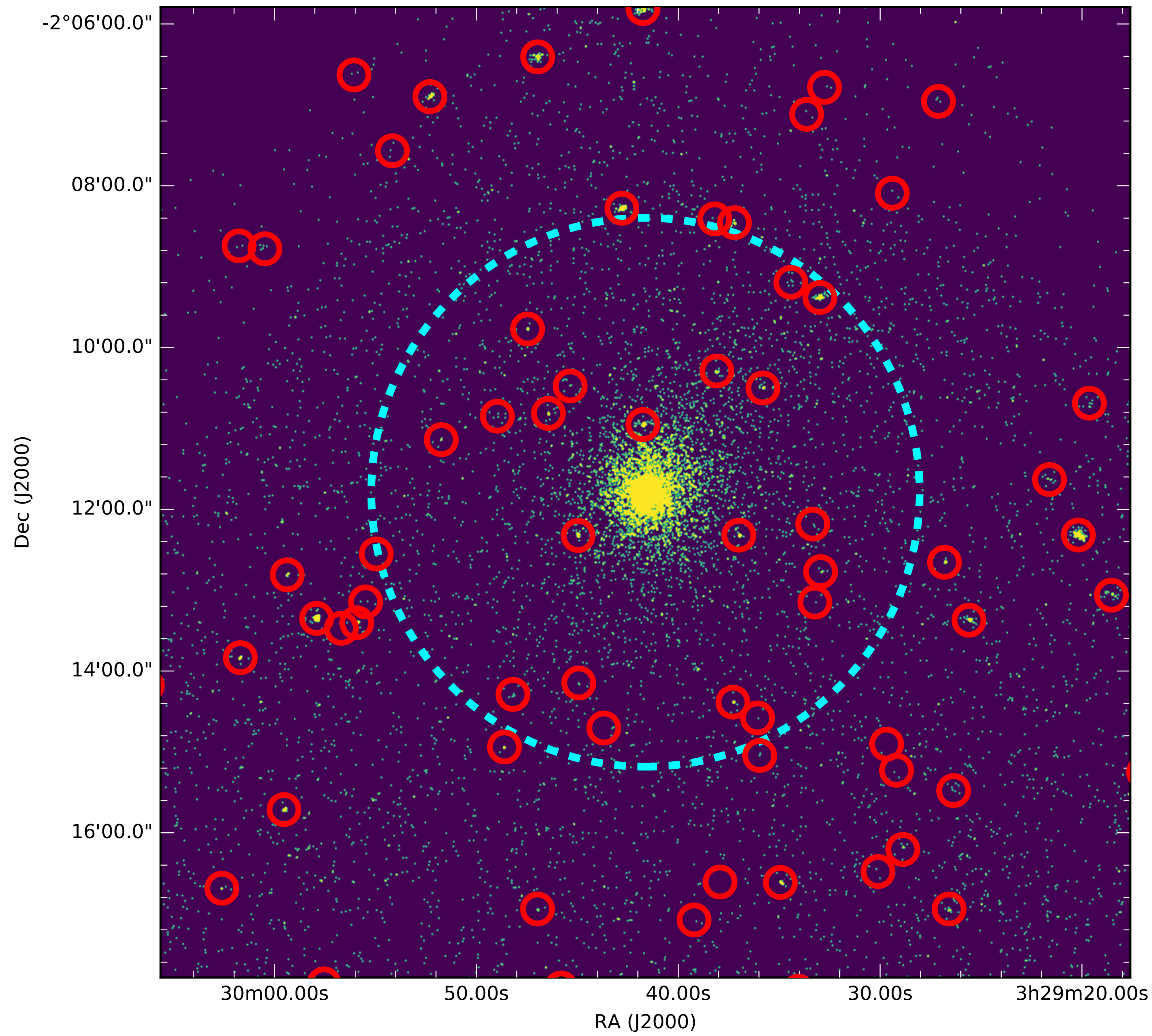
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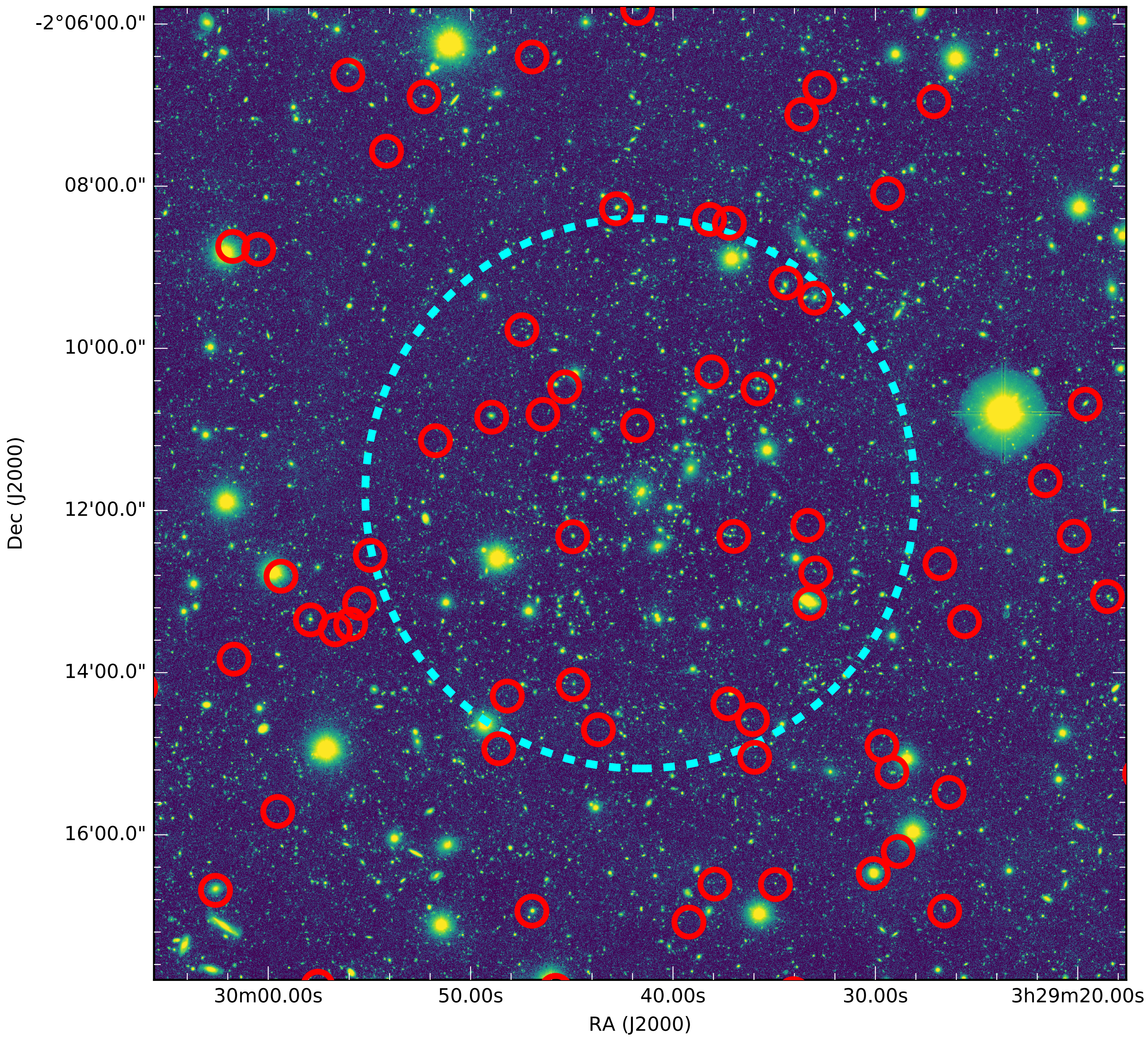

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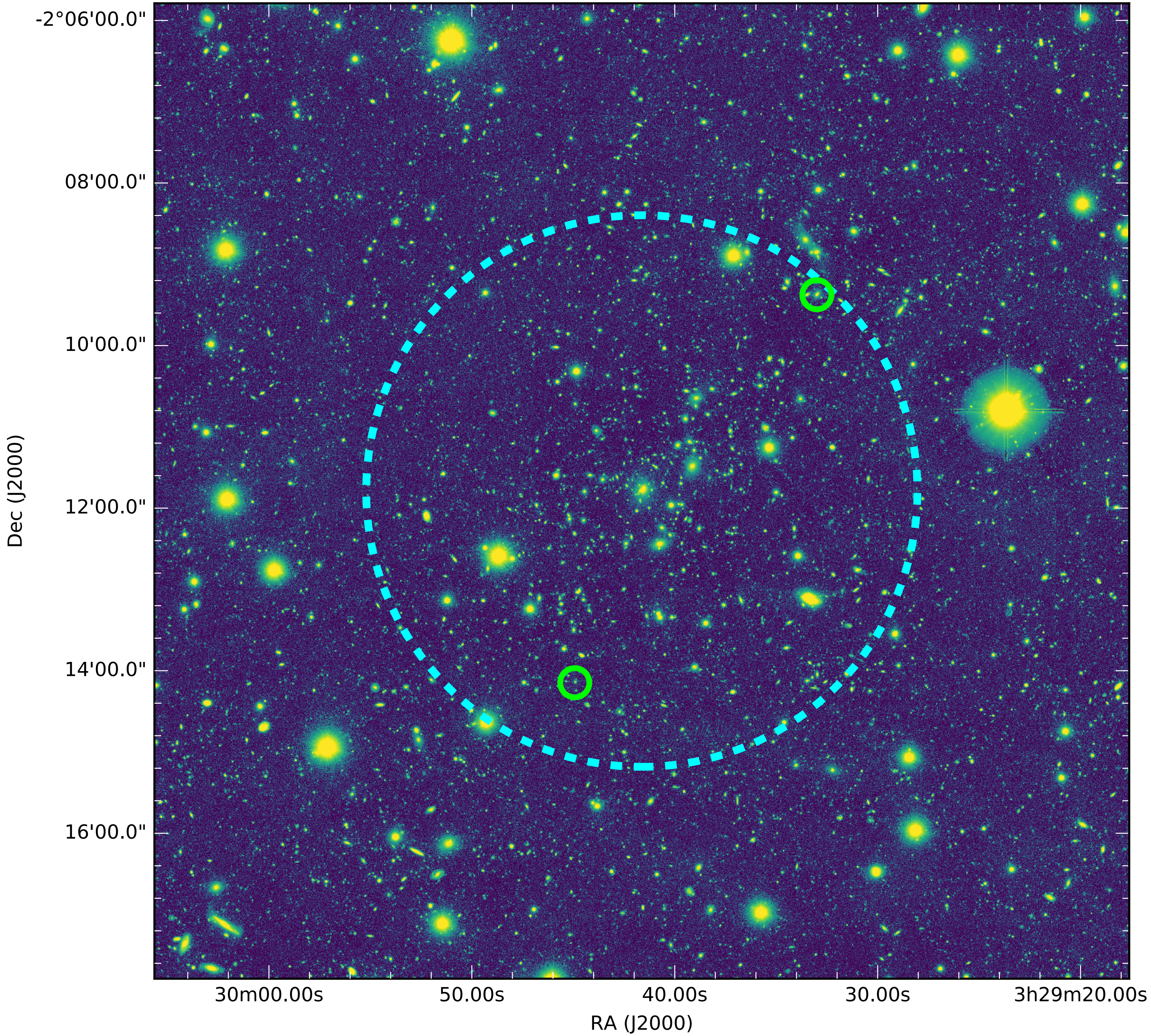

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