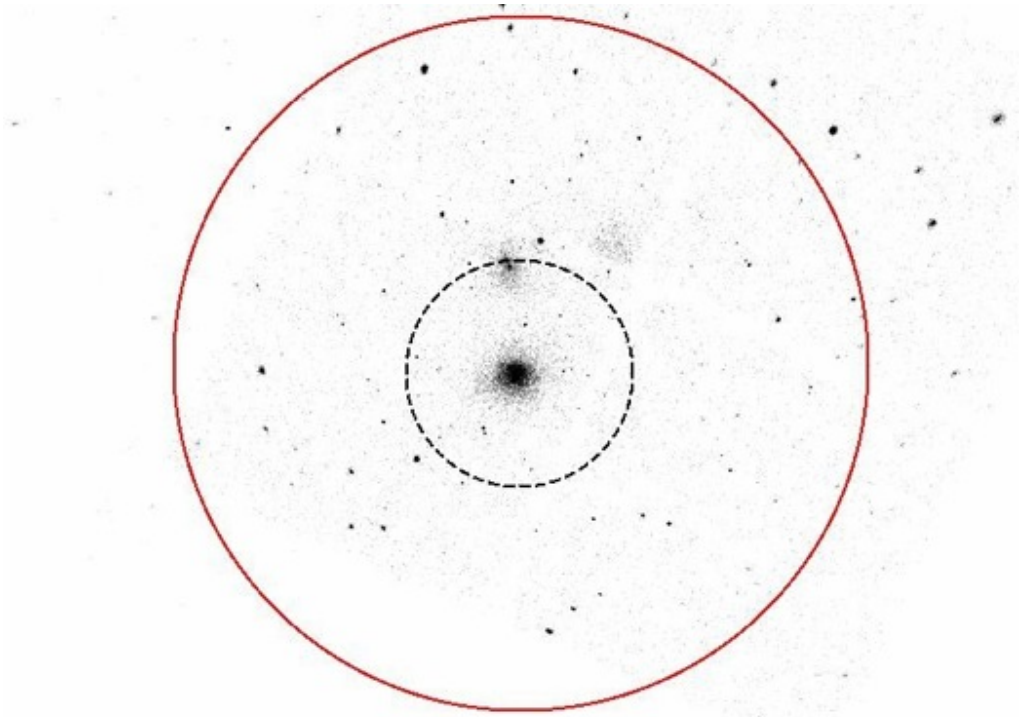
X-ray AGN in massive galaxy clusters



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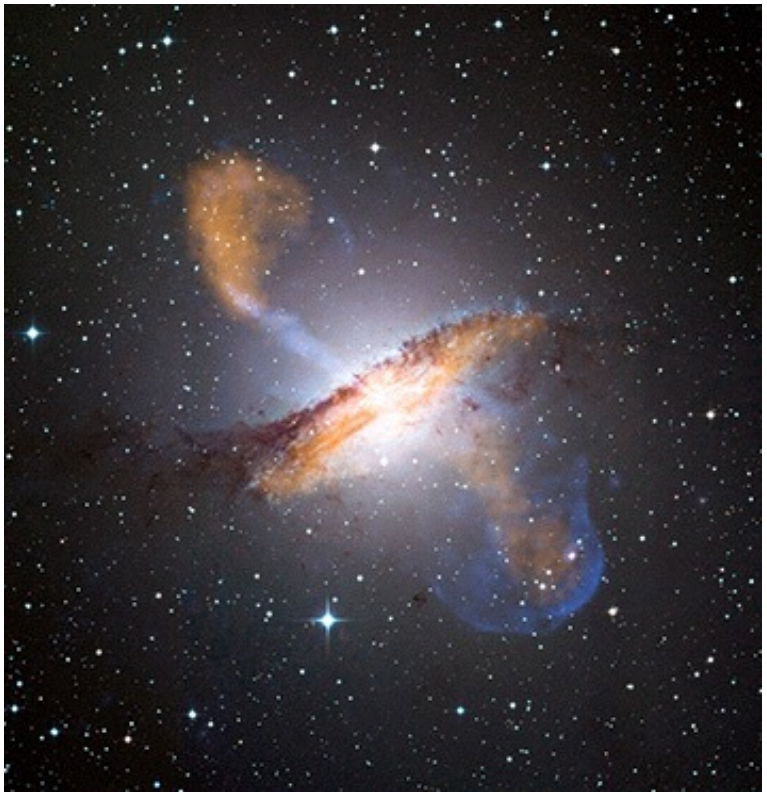
Motivation



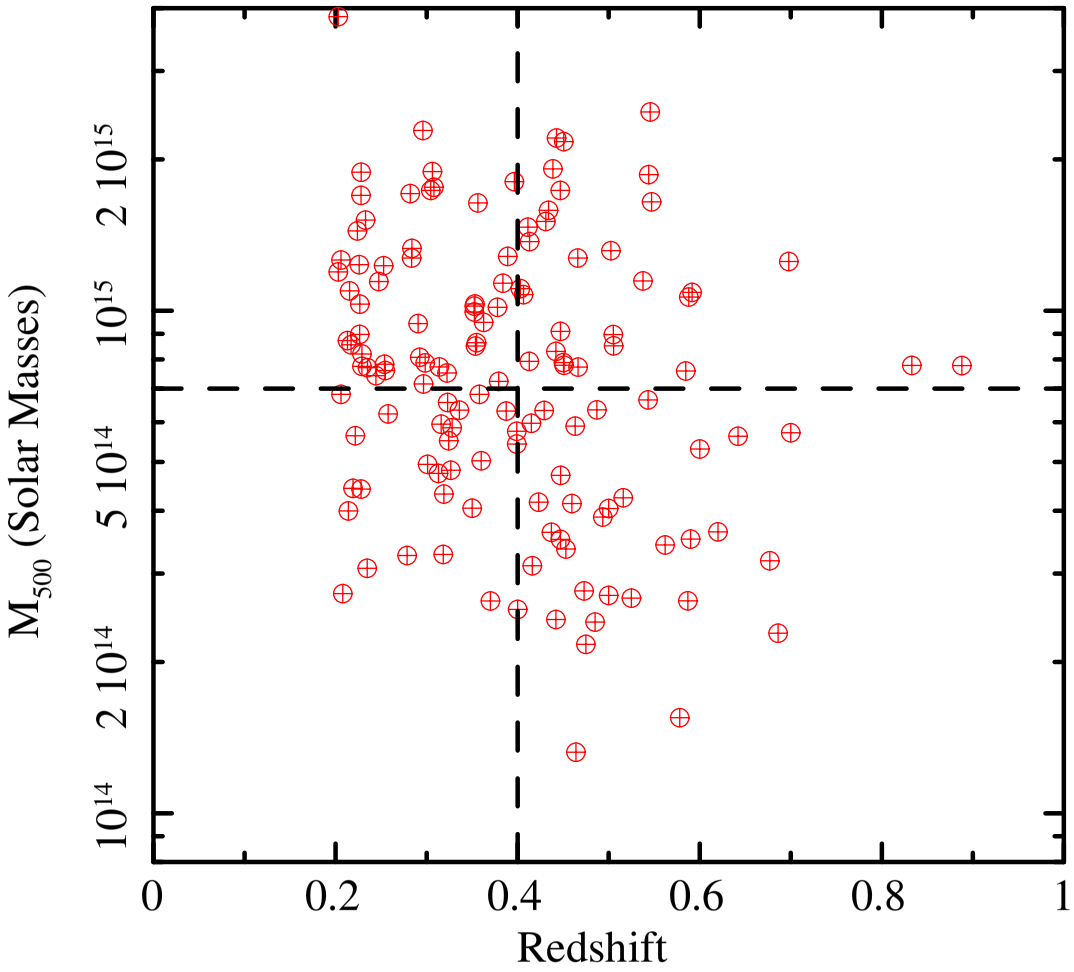
AGN feedback can have a significant effect on the evolution of galaxies

Triggering of AGN still an open question

Some previous studies have shown differences in field and cluster AGN with AGN fraction lower in clusters (e.g. Gisler 1978, Dressler 1985, Kauffman+2004, Rines +2005 and many more) but not all (e.g. Miller+2003, Haines+2007)

Studies of X-ray AGN show general overdensity of X-ray AGN but again lower AGN fraction in clusters than in the field (e.g. Gilmour+2007 ,Cappi+2001, Martini +2006, Silverman+2009 and many more)

X-ray survey



135 X-ray selected galaxy clusters
Mantz et al. 2010

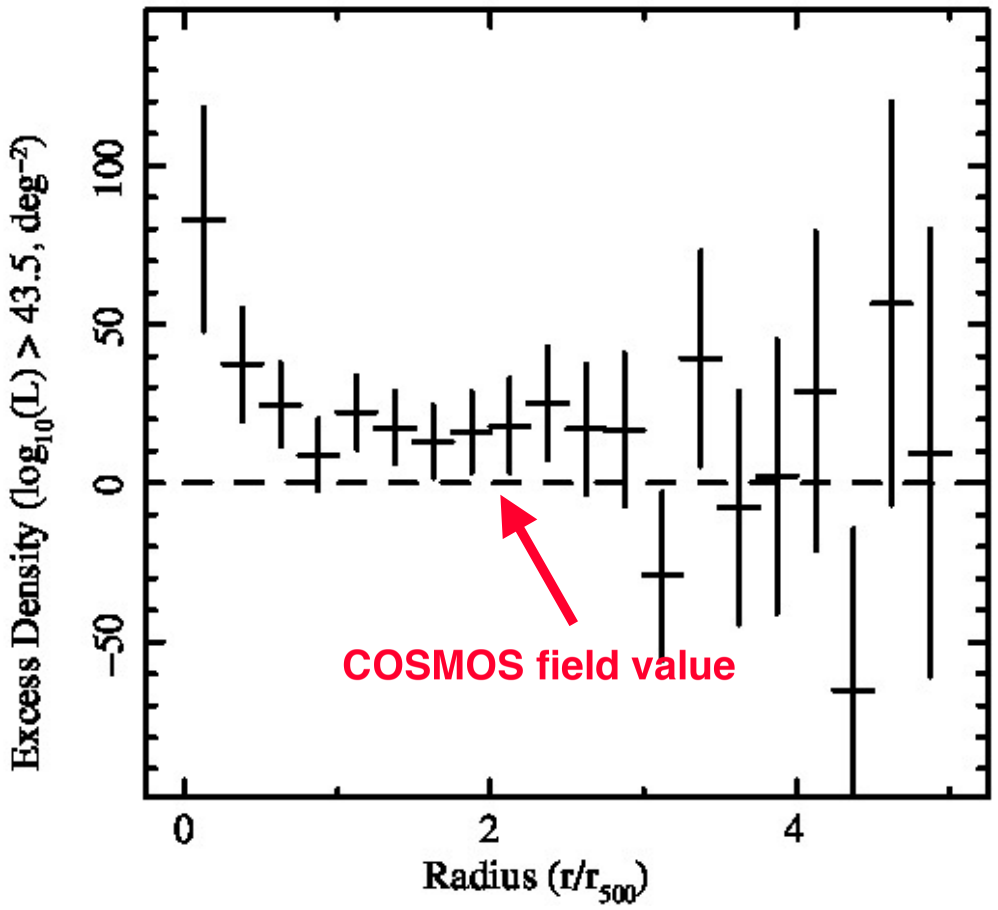
11,671 X-ray AGN in cluster fields

cluster fields cover ~12 sq degree area

3x larger than previous surveys

Ehlert et al. 2014

X-ray AGN number densities



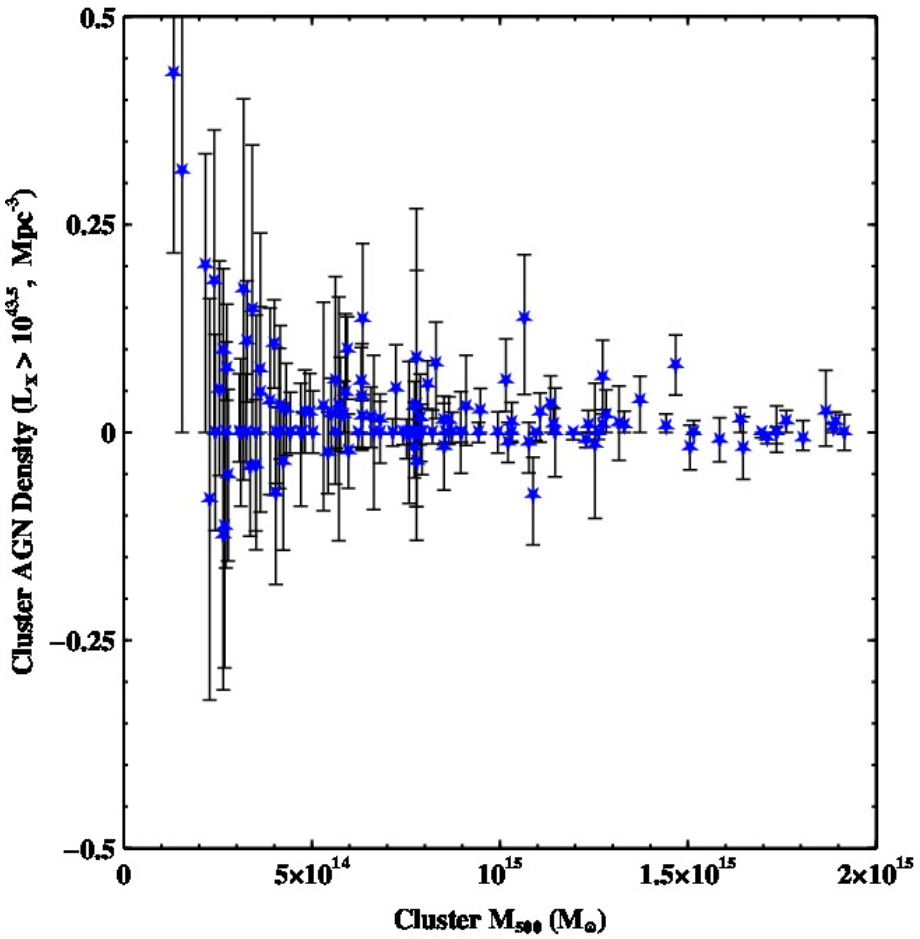
Projected number density of X-ray AGN *per square degree* shows excess above field value (L_X>3x10^{43} ergs^{-1}, 12' from aim point)

Number density of X-ray AGN has a radial dependence

Radial dependence is well fit by a power-law:

$$\sim \left(\frac{r}{r_{500}}\right)^{\beta} + C$$

X-ray AGN number densities

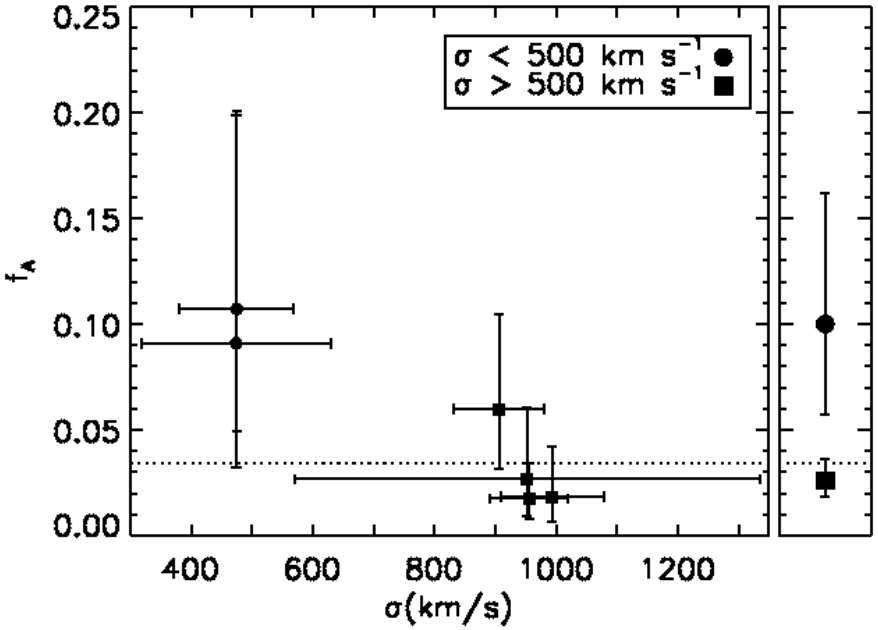


Some (very weak) evidence for evolution of the comoving number density of X-ray AGN with cluster mass (binned within $2r_{500}$)

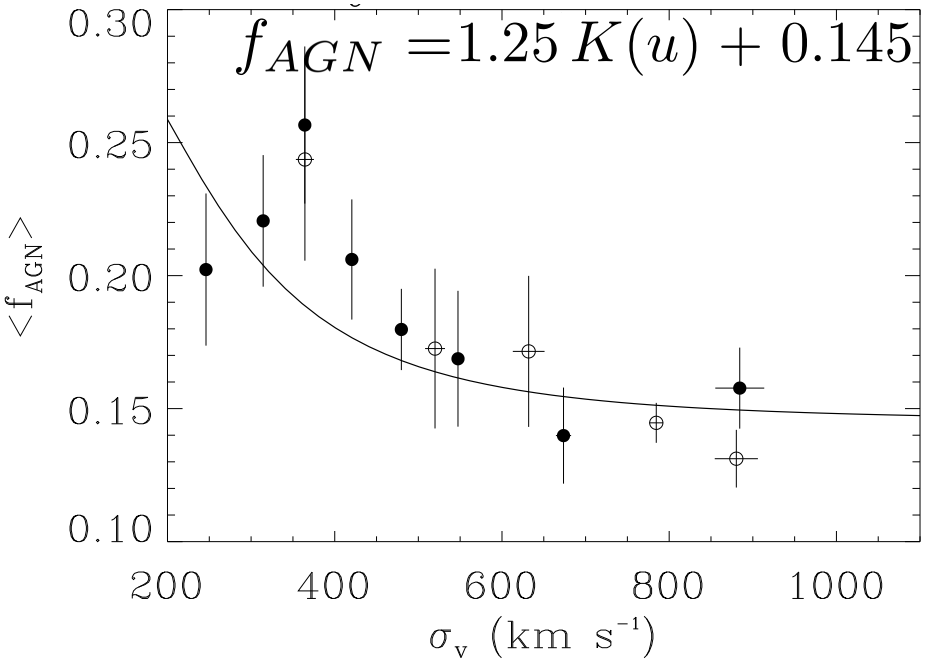
Lower mass clusters host larger AGN number densities?

Mass dependence of X-ray AGN fraction?

Higher AGN fraction in low velocity dispersion clusters?



Sivakoff et al. 2008



Popesso & Biviano 2006

Poggianti et al. 2006 $f_{EW[O\ II]<-3}$ decreases with v_{cl}

Mass or redshift evolution?

So far results have involved binning and as such have very stringent limits on luminosity ($L_X > 3 \times 10^{43}$ $ergs^{-1}$) to be complete at all redshifts

Ideally form model without binning and that accounts properly for the complicated selection function - can look for mass, redshift and radial dependence

Mass or redshift evolution?

$$N_{\rm obs}(>f,r,z) = N \times D_{\rm A}(z)^2 \times r_{500} \times \Phi(>L_{\rm cut},z) \times \left(\frac{r}{r_{500}}\right)^{\beta} + C$$

Projected number density of observed X-ray AGN in a cluster field at a given cluster z, r and above flux limit f = **Projected number density of X-ray AGN expected in cluster** above flux limit + **Projected number density of all field AGN** above flux limit

'Scale factor' which allows number density to exceed co-moving field AGN X Scaled by radius X Co-moving field AGN number density at z and above luminosity related to flux limit X Some radial dependence

Luminosity function from Ueda et al. (2014) converted to our energy band 0.5-8.0 keV and priors allowed factor of 2 greater freedom

Mass or redshift evolution?

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Allow a mass and redshift dependence for scale factor (normalisation) and radial scaling

$$N \rightarrow N_0(1+z)^{\eta}\left(\frac{M_{500}}{10^{15}M_{\odot}}\right)^{\zeta} \qquad \beta \rightarrow \beta_0 + \beta_{\rm z}(1+z) + \beta_{\rm m}\left(\frac{M_{500}}{10^{15}M_{\odot}}\right)$$

Mass or redshift evolution?

Null hypothesis: No difference between field and cluster

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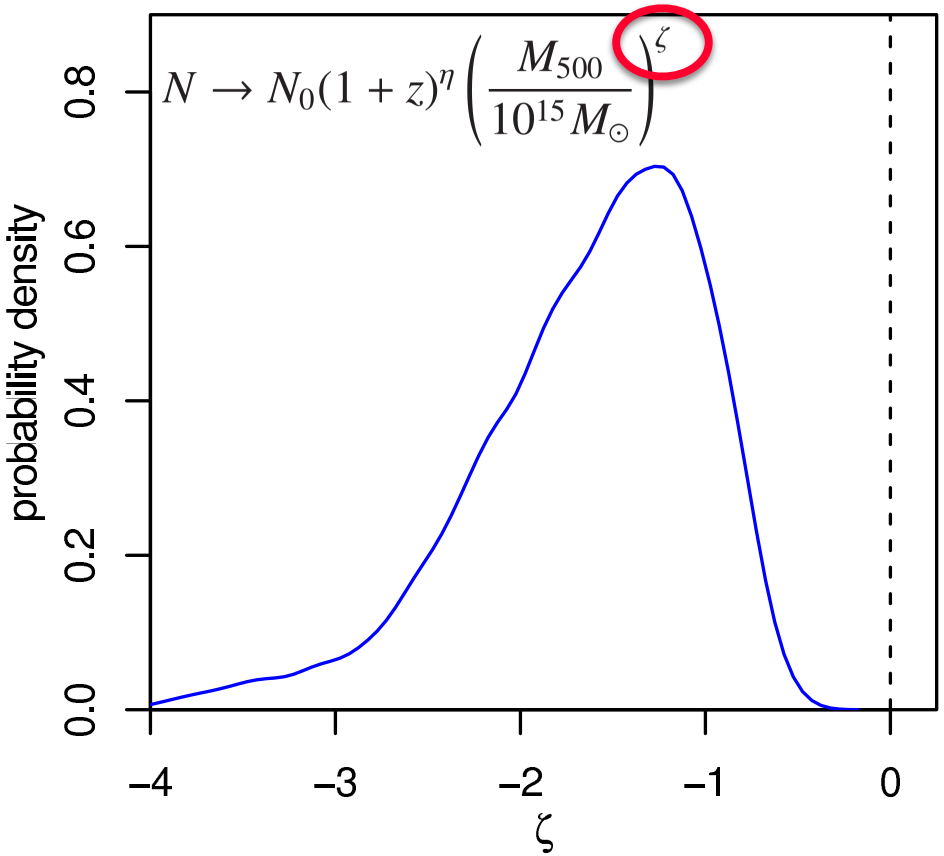
Null hypothesis: No difference between field and cluster



Mass dependence of scale factor

ζ ~ -1.2

Scale factor has a $M^{-1.2}$ dependence

ζ = 0 rejected at >99.9%

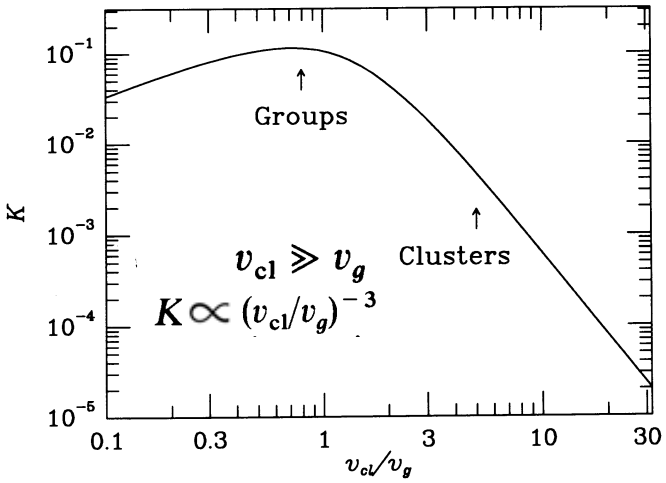
No other parameters are significantly different from zero

Triggering mechanism?

1. Projected number density of X-ray AGN in galaxy clusters scales with galaxy mass as ~ $M^{-1.2}$
2. No evidence for evolution of radial scaling - so process occurs on same length scales irrespective of mass

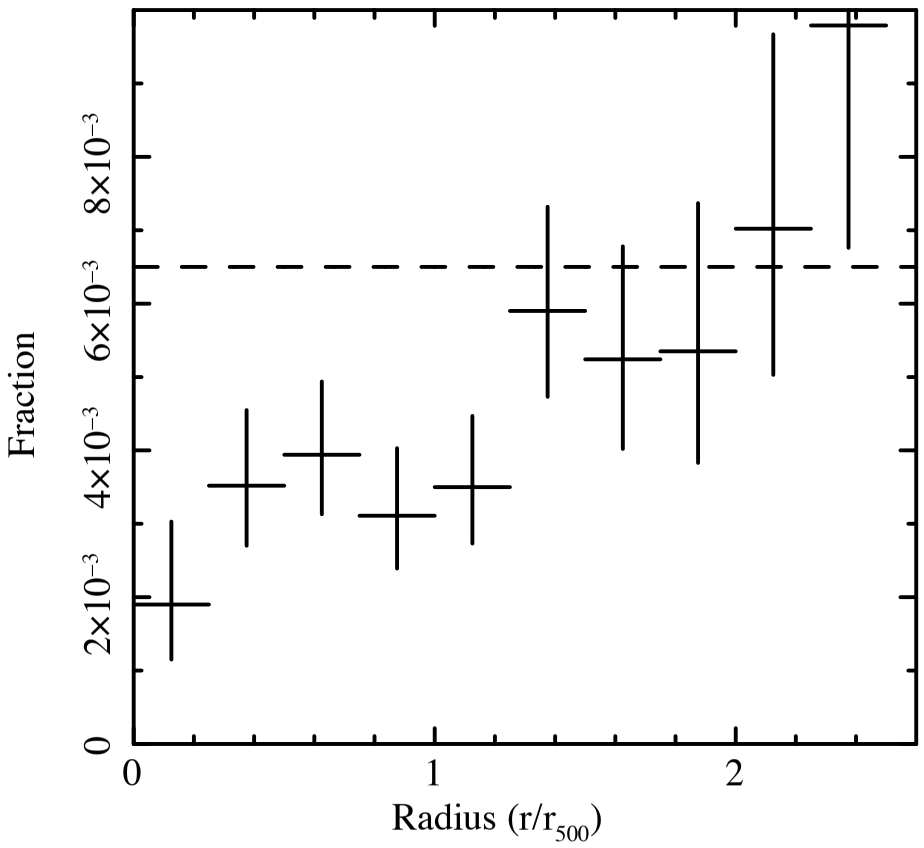
Environmental effects:
Ram pressure? Harassment? Strangulation? May lead to different radial profiles (e.g. Treu et al. 2003).
Mergers?

- Rate of mergers in massive clusters scales as $\sim \sigma^{-3} \sim \bar{M}^{-1}$ (e.g. Mamon 1992)



No evidence as yet for redshift evolution in number density, but not well constrained, will include SPT clusters to increase redshift lever arm

X-ray AGN fraction



Projected AGN fraction rises with increasing cluster centric radius

X-ray AGN suppressed by ~3 times in cluster centres compared with outskirts

Similar to star-forming galaxies and optical AGN

But: This is projected AGN fraction and based on magnitudes

Need spectroscopic confirmation of X-ray AGN and matched optical galaxies to reliably determine AGN fractions

Optical follow-up

Next step: Need spectroscopic confirmation

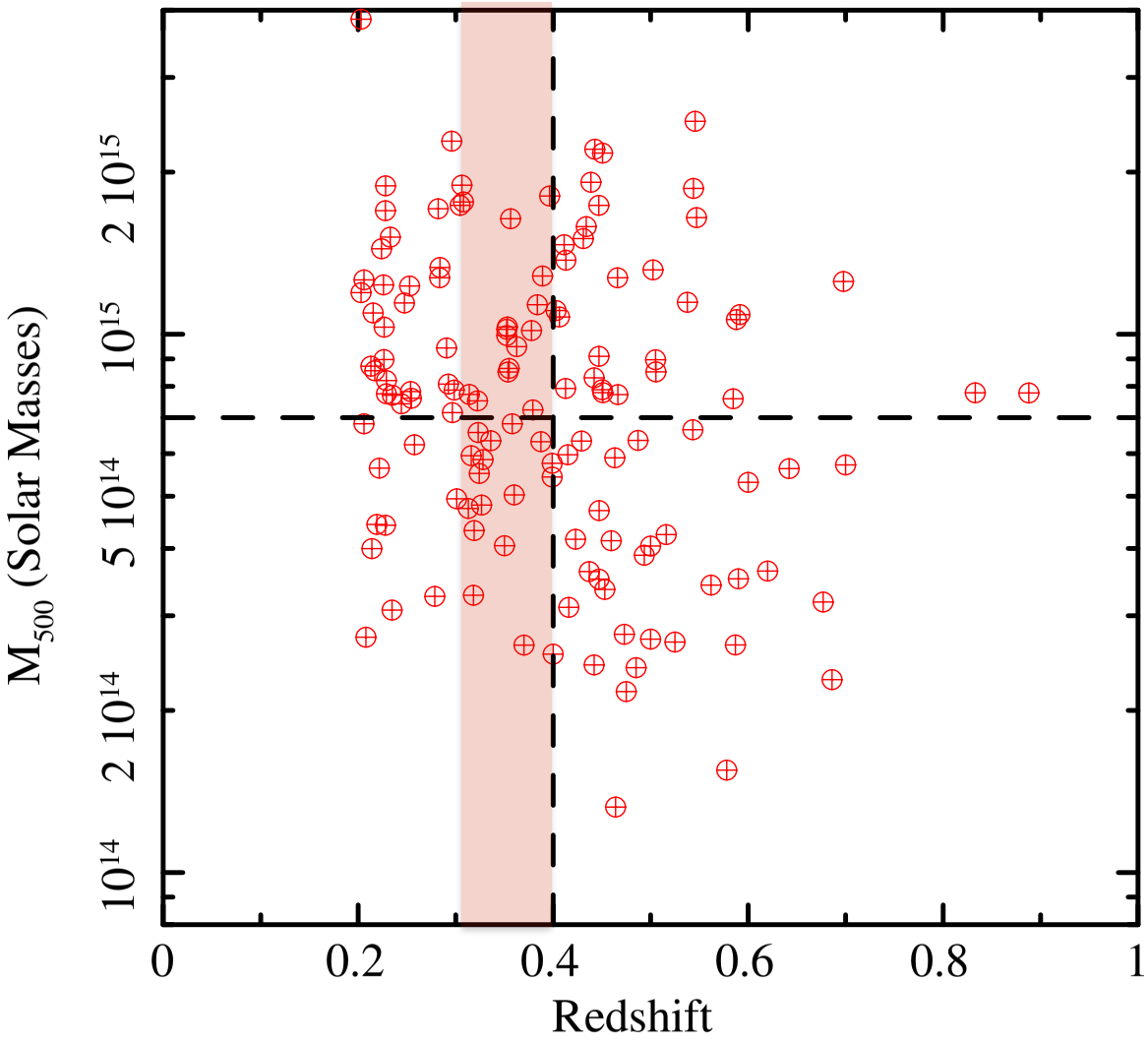
SDSS: NOTE - Sample not at all well defined!

- Within 2'' of X-ray position find 7753 objects of 11671, 318 have spectra 49/318 have velocities +-5000 kms^{-1}

	Ckuster	Field
Absorption	30/49	44/269
SF-emission	5/49	8/269
AGN-emission	4/49	9/269
QSO	10/49	175/269

Need targeted follow-up

Spectroscopy



VIMOS follow-up program:

Observe 10, z=0.35 - 0.4, relaxed clusters

Aims:

- Examine X-ray AGN host relationship
- Does AGN fraction depend on cluster mass?

Spectroscopy

VIMOS follow-up program:

Expect: 500-700 targets per cluster (~6000 targets)

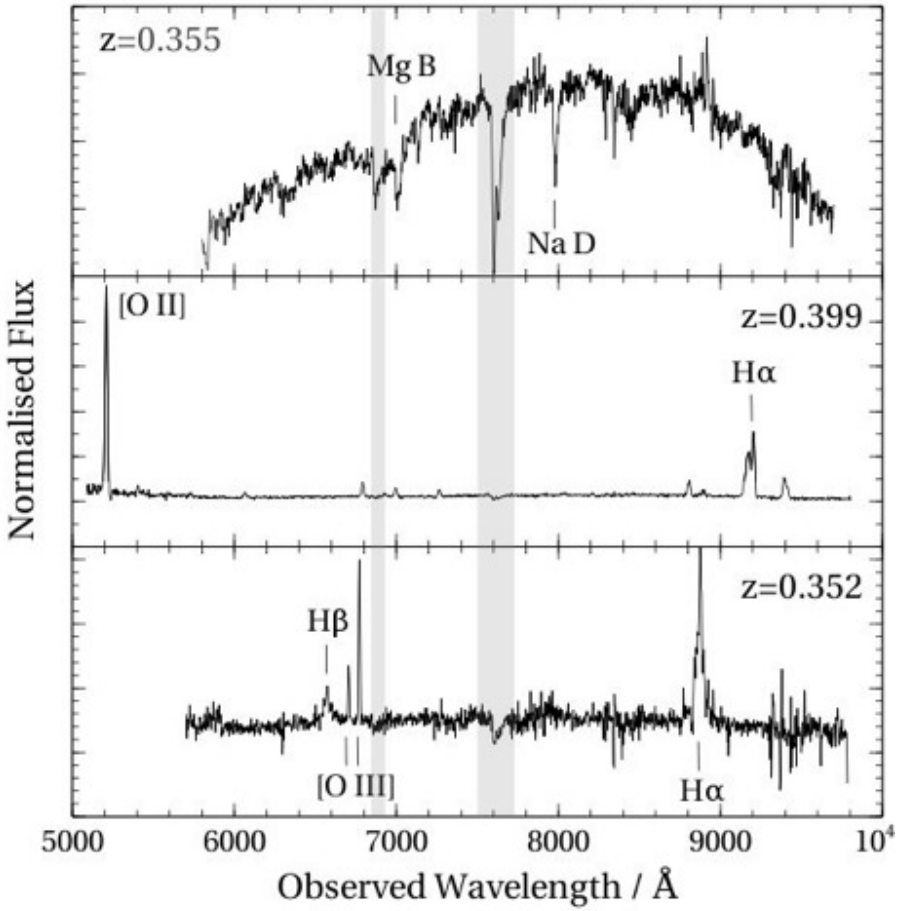
~860 X-ray AGN

>50 within ~2x r_{500},

(15 so far)

Matched by magnitude and cluster centric distance for V<23

2700 seconds on target



Summary

Results:

1. Number density of X-ray AGN in clusters depends on cluster mass

2. No evidence for redshift evolution beyond the field

3. No evidence for radial variations with mass or redshift

Next steps:

SPT clusters to higher redshift.

Add luminosity radial-dependence to the model?

Triggering/Quenching mechanism?

1. Look for asymmetries in optical images and test against simulations of merger rates.

2. Test against simulations of galaxy-ICM interaction.

Ongoing VIMOS program:

1. Fraction of X-ray AGN appears to increase with radius in the cluster - similar to star forming galaxies in clusters?

2. X-ray AGN hosts are diverse, but, is there a dominant population of hosts and where in the cluster are these hosts located?