The Co-Evolution of Black Holes and Galaxies in Clusters

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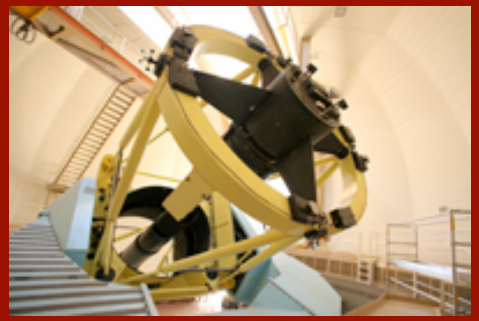
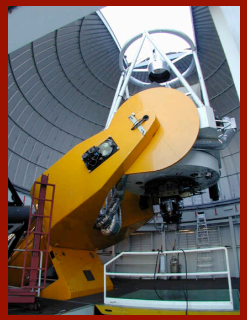
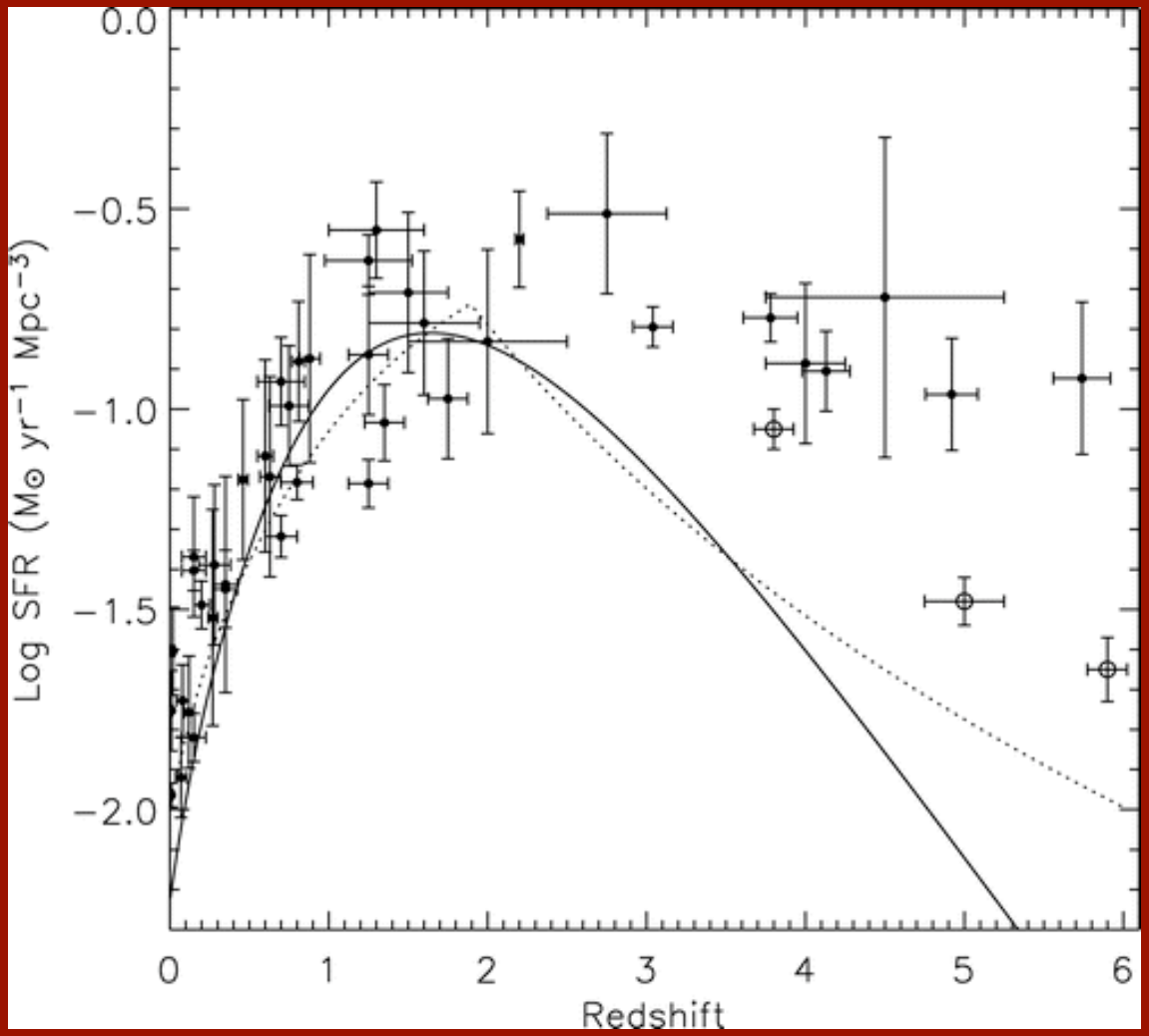





Co-Evolution in Clusters?

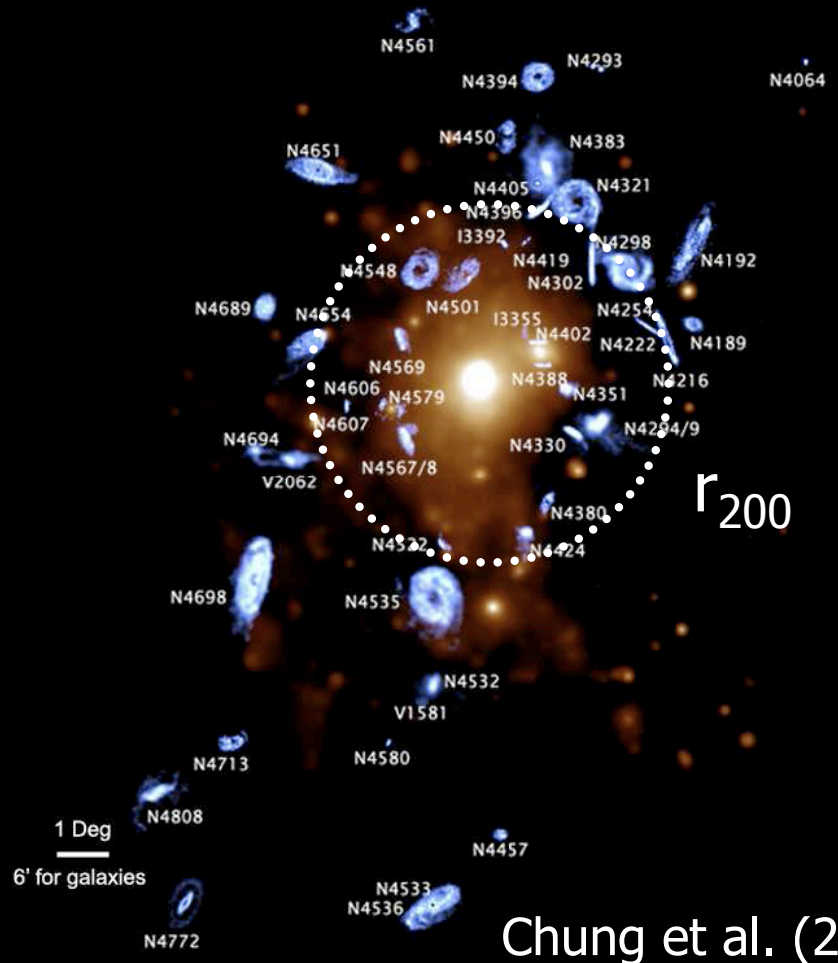


Is there co-evolution between galaxies and black holes in dense environments?

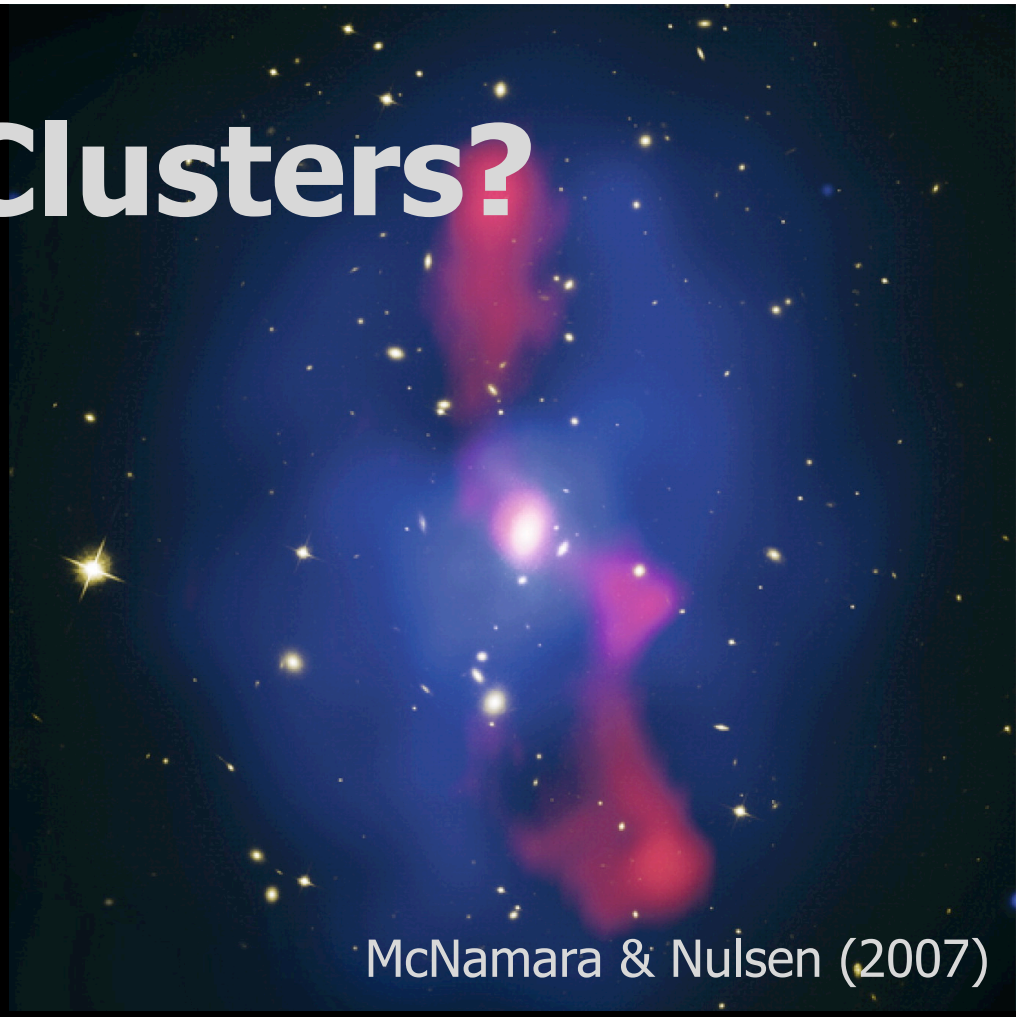
Do cluster black holes grow before those in the field?

Silverman et al. (2008)

Why search in Clusters?



Chung et al. (2009)



McNamara & Nulsen (2007)

1. Less cold gas
2. Cluster-specific catalysts
3. Pre-heating the ICM

See also posters 2.15 Raychaudhury, 2.16 Siemiginowska, 3.6 Lietzen

AGN Demographics

One way to characterize the AGN population is the AGN fraction:

$$f_A = \frac{N_{AGN}\,(L_{X,H} > 10^{43}\ \mathrm{erg/s})}{N_{galaxies}\,(M_R < M_R^*(z)+1)}$$

Advantages are:

- Relatively simple to compare different environments
- Evolution is measured relative to the galaxy population

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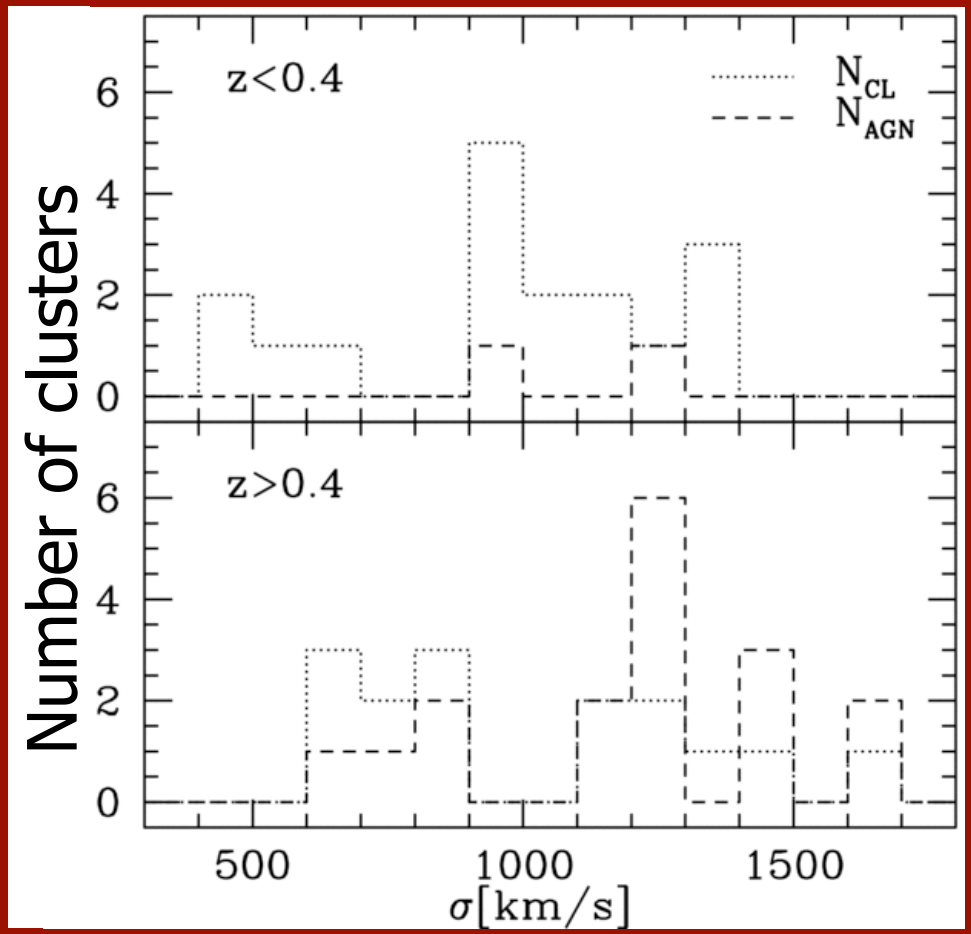
Cluster Samples

AGN: $L_{X,H}>10^{43}$ erg/s



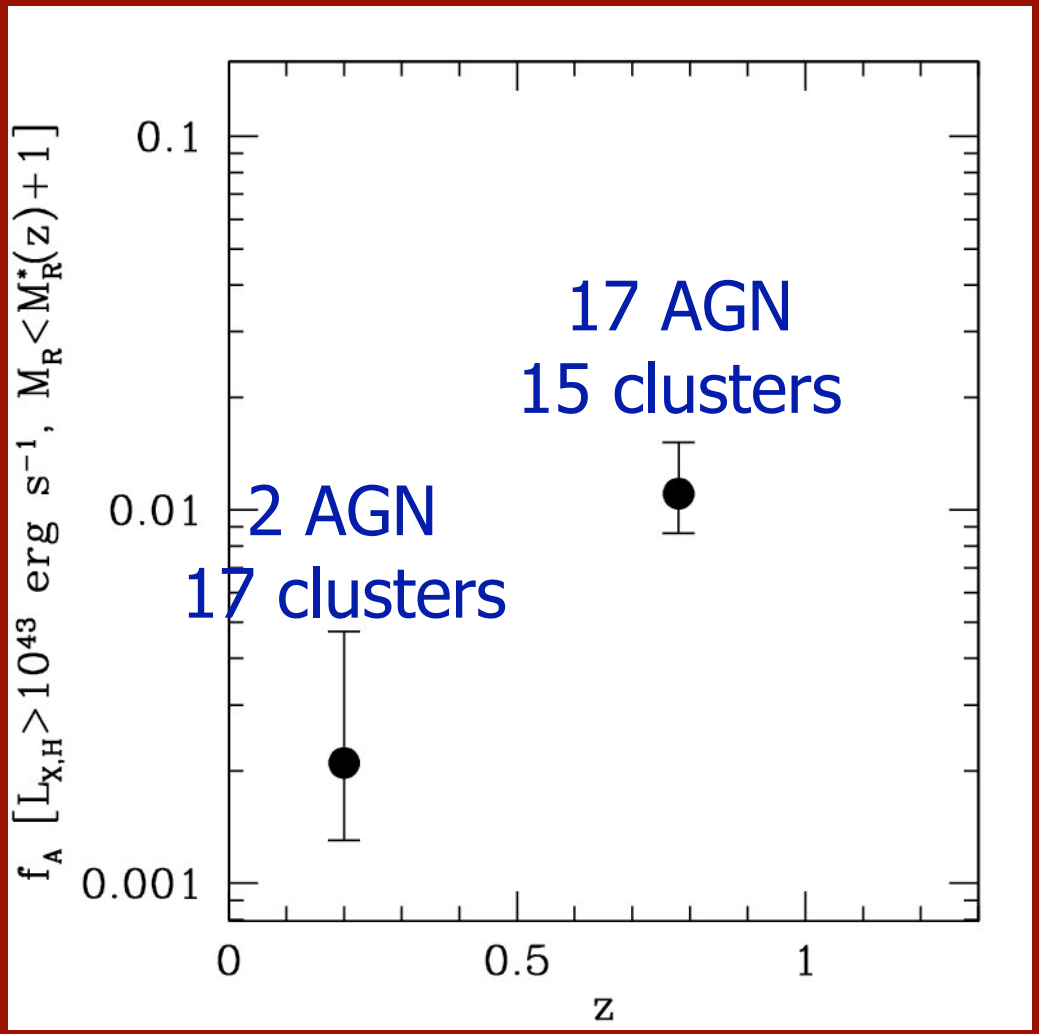
17 z<0.4 clusters
2 AGN

15 z>0.4 clusters
17 AGN

Comparable median velocity dispersions

Martini et al. (2009)

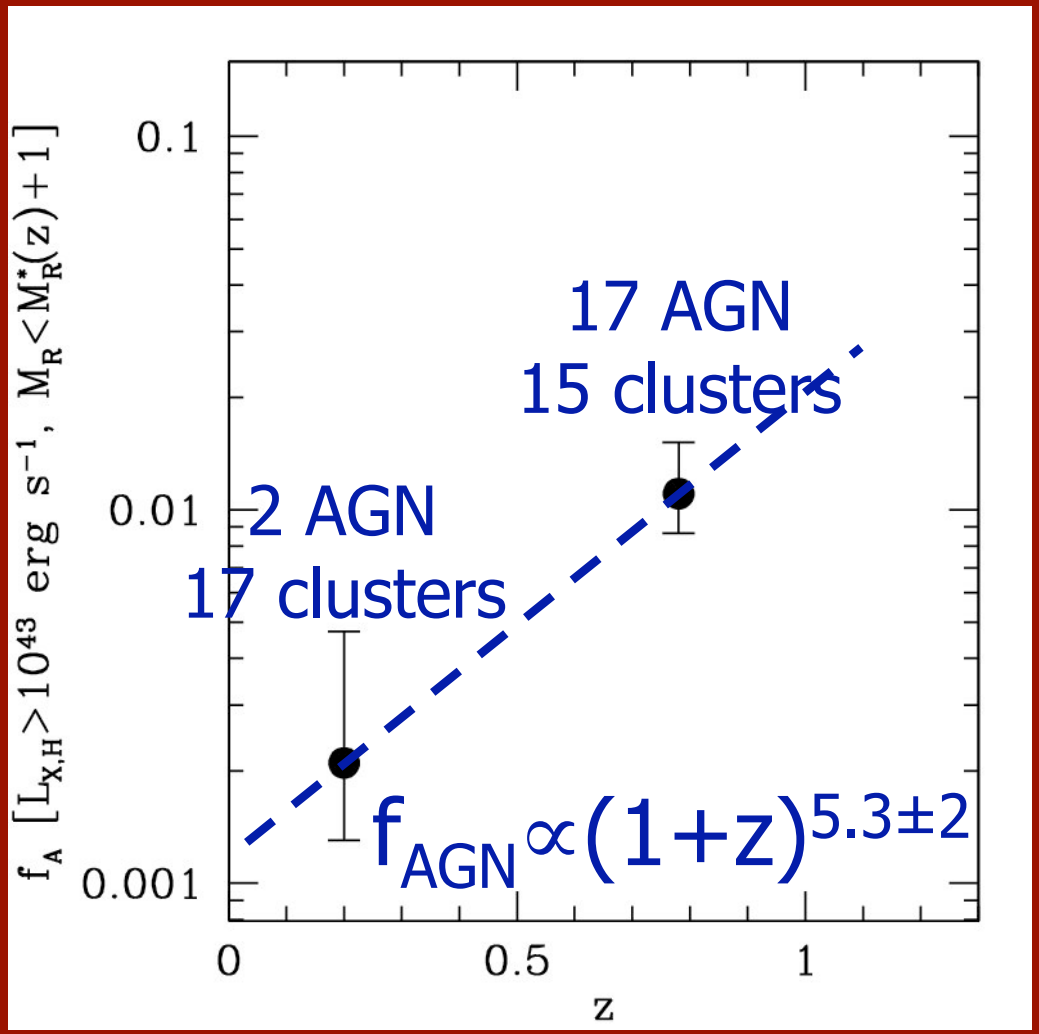
Evolution of the AGN Fraction



Factor of ~8 evolution

Martini et al. (2009)

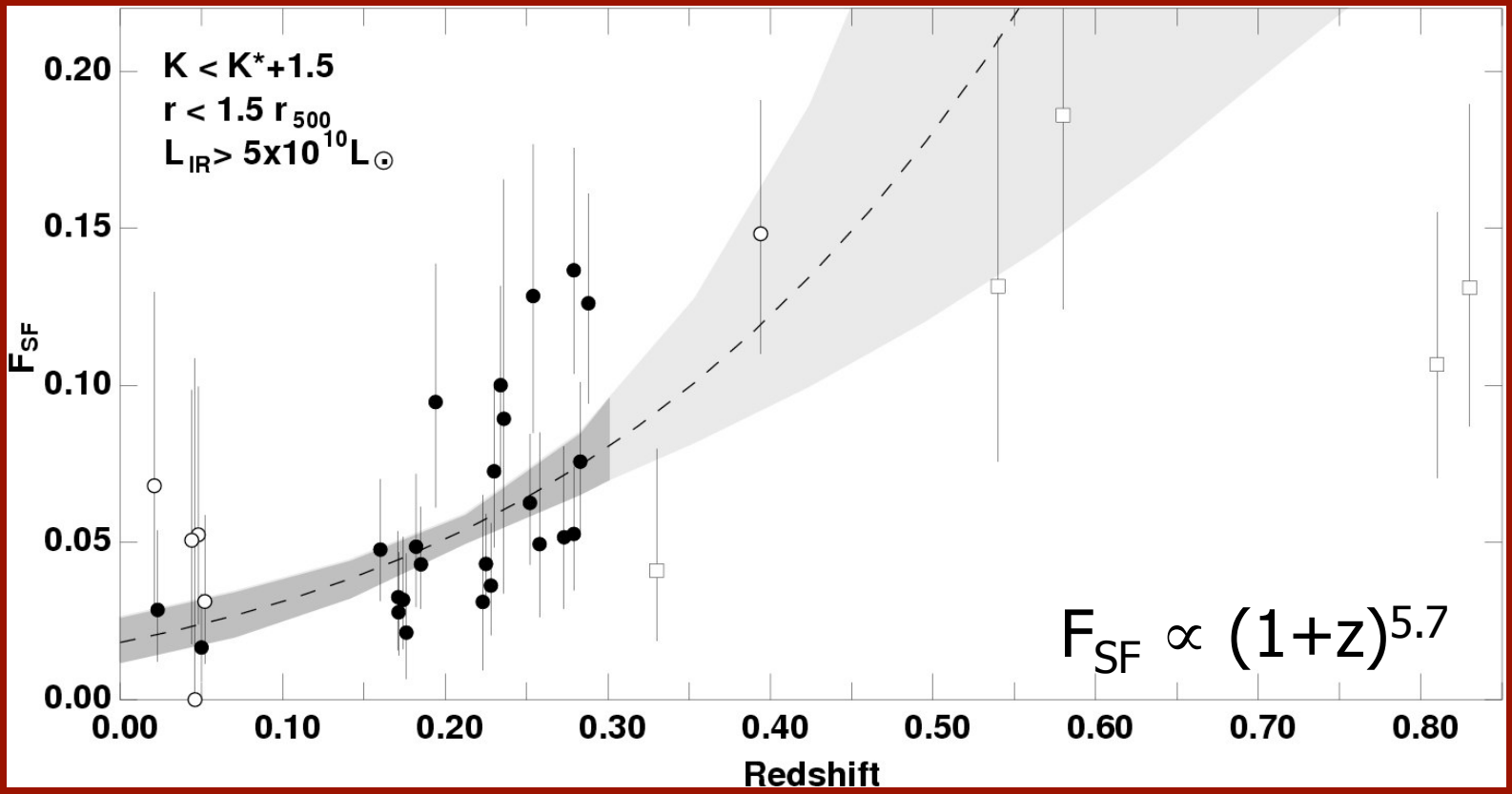
Evolution of the AGN Fraction



Factor of ~8 evolution

Martini et al. (2009)

MIR Butcher-Oemler Effect

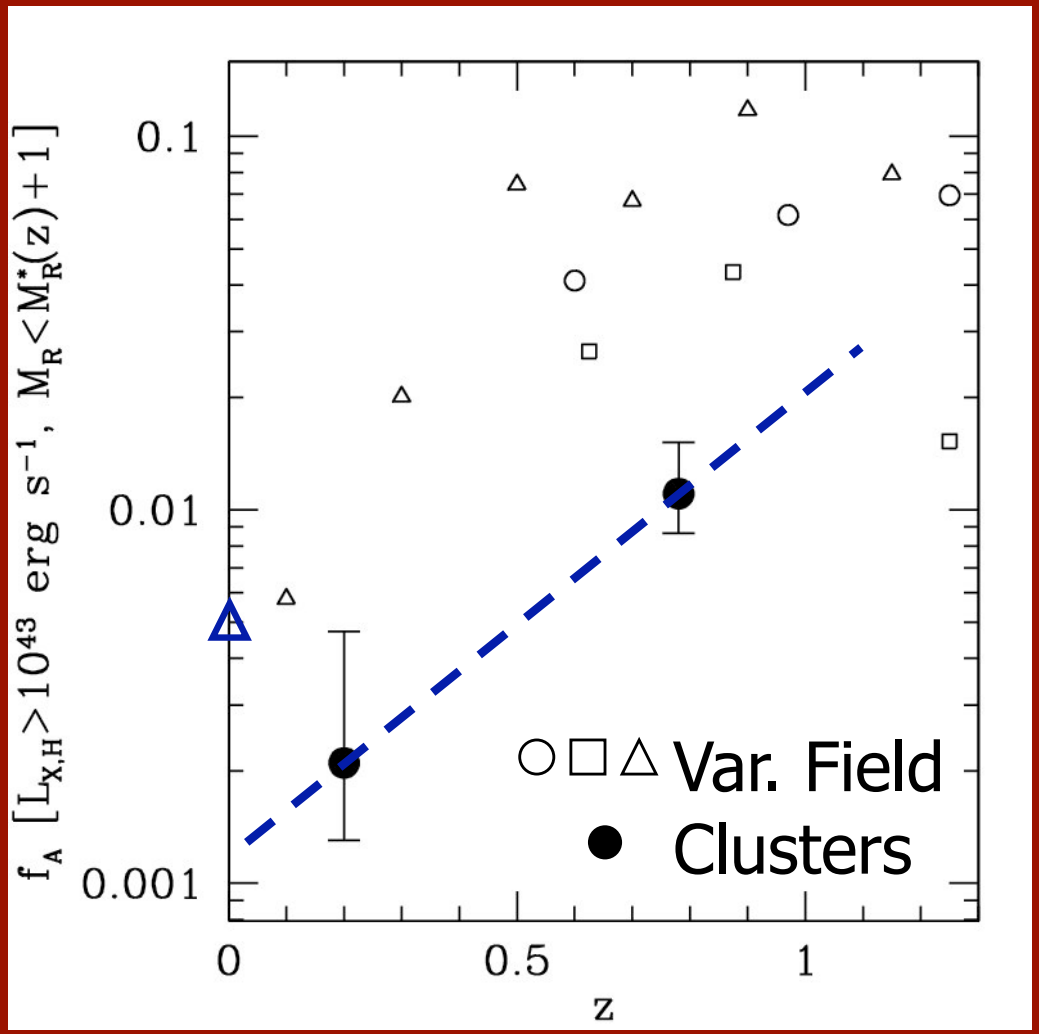


Haines et al. (2009)

Star forming fraction and AGN fraction evolve at similar rates

Comparison to Field Evolution

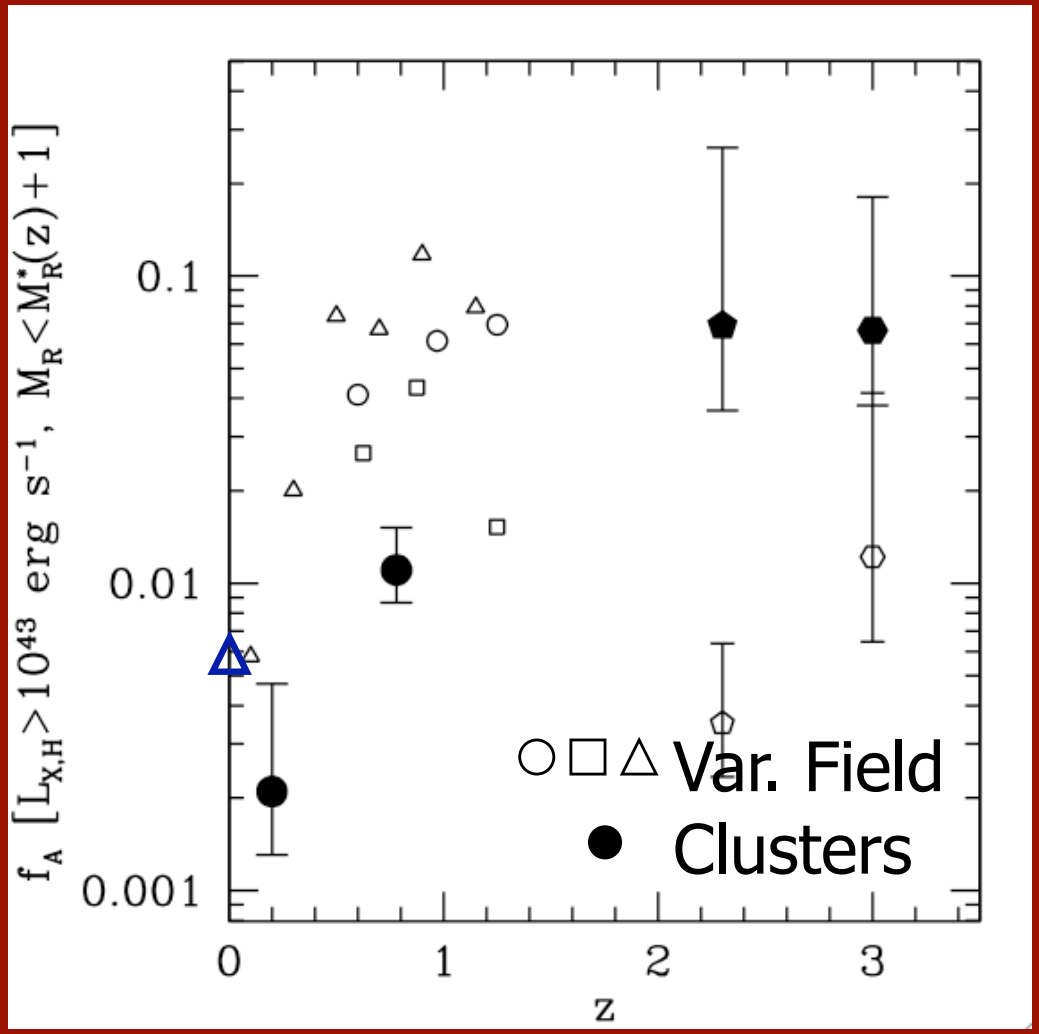
AGN Fraction



Martini et al. (2009)

Evolution to z=3

AGN Fraction

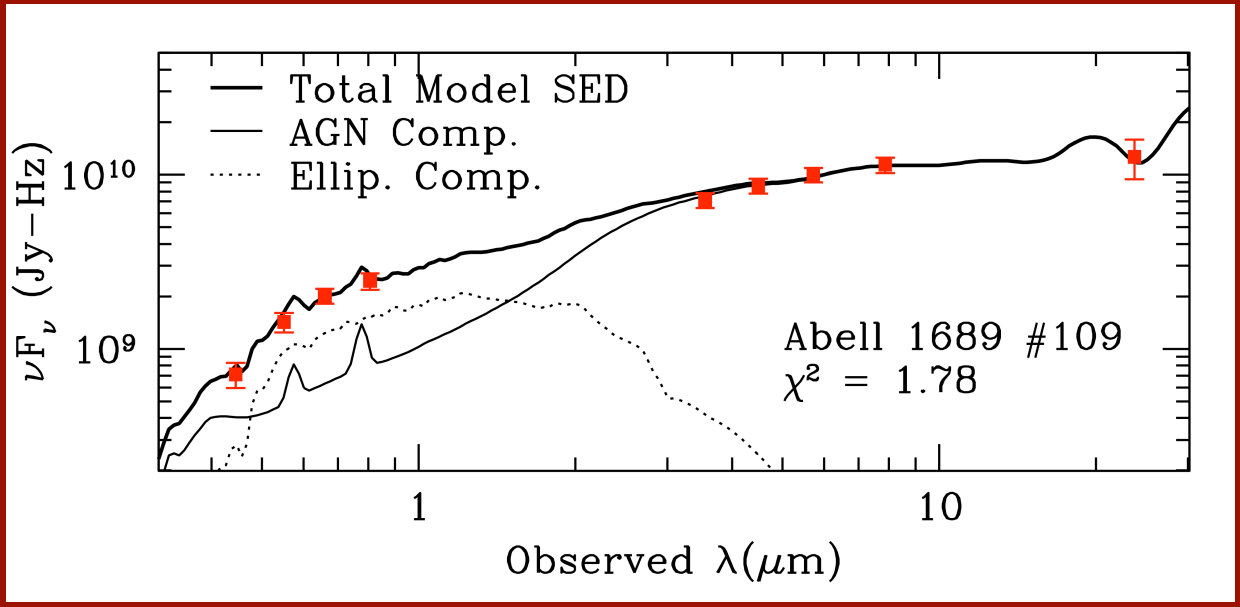


Data from Martini et al. (2009); Lehmer et al. (2009); Digby-North et al. (2010)

A Complete AGN and SF Census

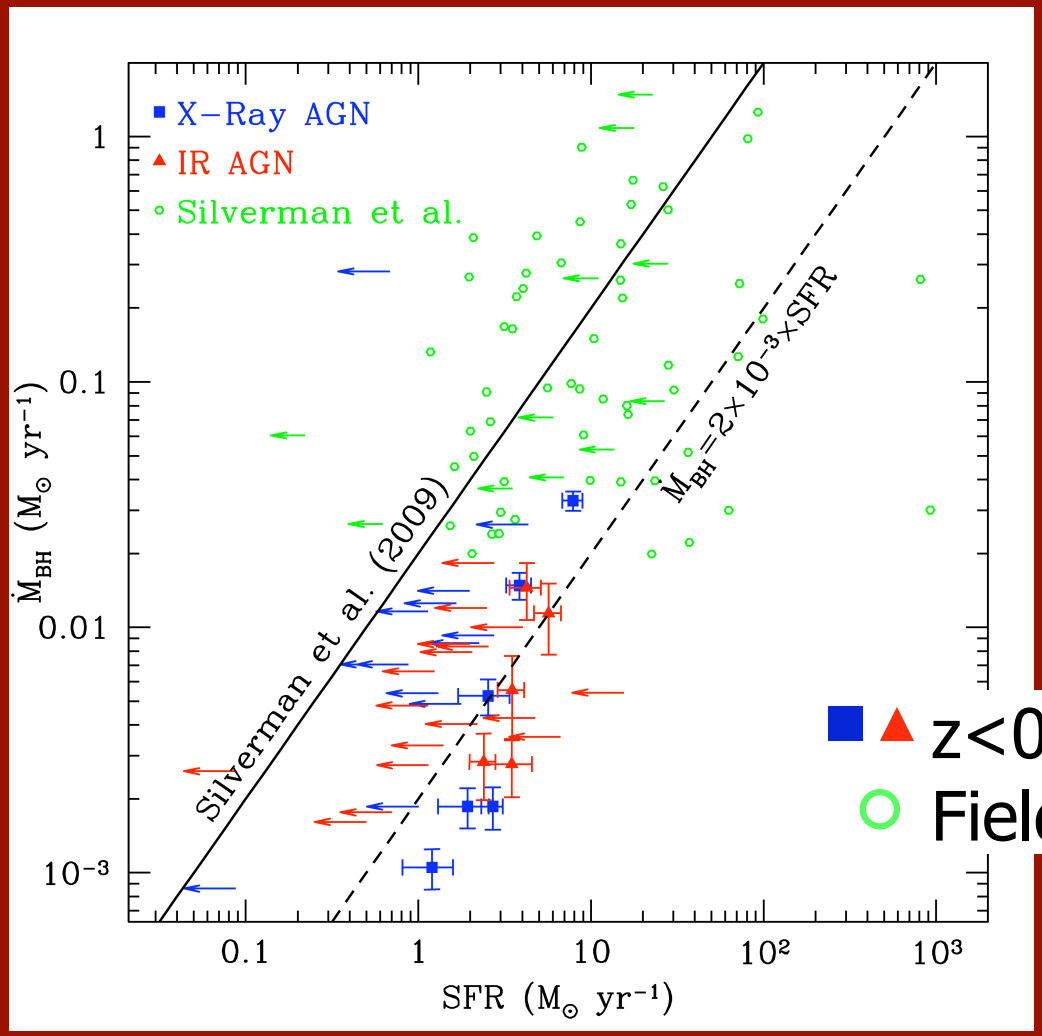
Spitzer photometry reveals many additional AGNs, although mostly at lower luminosities

Significant star formation is present in many AGNs



Atlee et al. (2010)

Co-Evolution in Galaxies



BH Accretion Rate

SFR

■ ▲ z<0.3 Cluster AGN

○ Field AGN

Atlee et al. (2010)

Summary

There is an order of magnitude increase in the cluster AGN fraction from $z=0 \rightarrow 1$

- About one luminous AGN ($L_X > 10^{43}$) per cluster at $z>0.4$

Good evidence for the global co-evolution of star formation and black hole growth in clusters

Some evidence for a higher incidence of AGN in clusters relative to the field at $z>2$, similar to the earlier epoch of star formation for cluster galaxies

- Evidence for an inversion of the activity-density anti-correlation observed for luminous AGN at low redshift
- Substantial population available for pre-heating the ICM