Co-evolving AGN activity and star formation within the zCOSMOS density field

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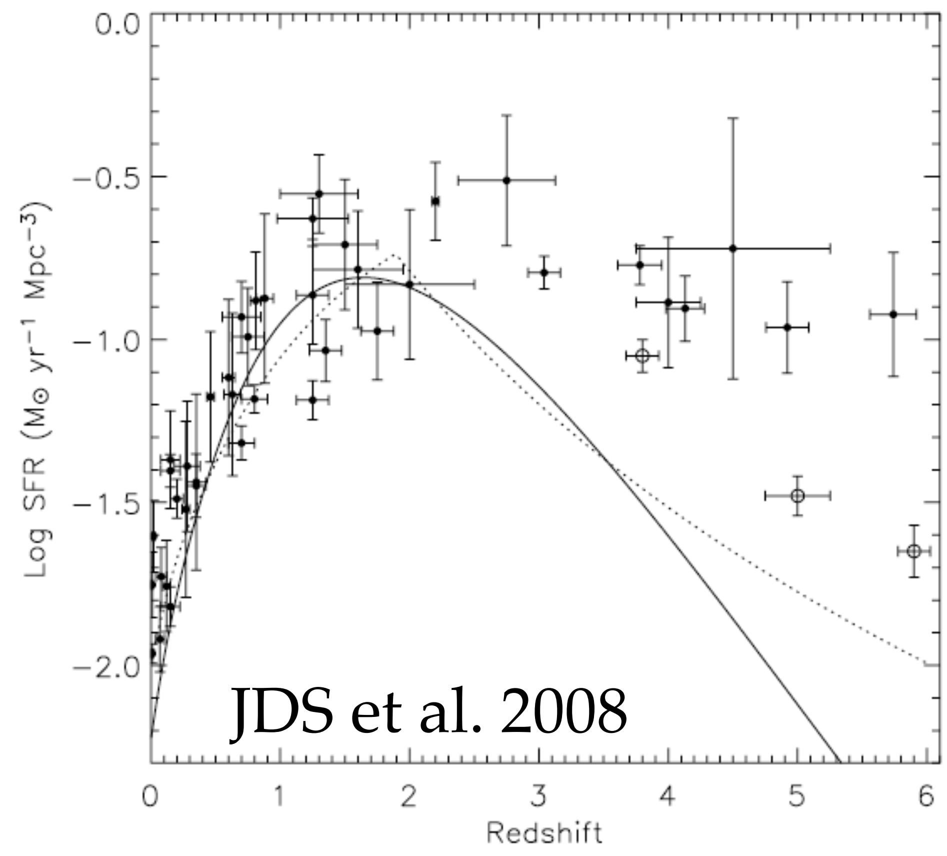
& z/XMM COSMOS teams

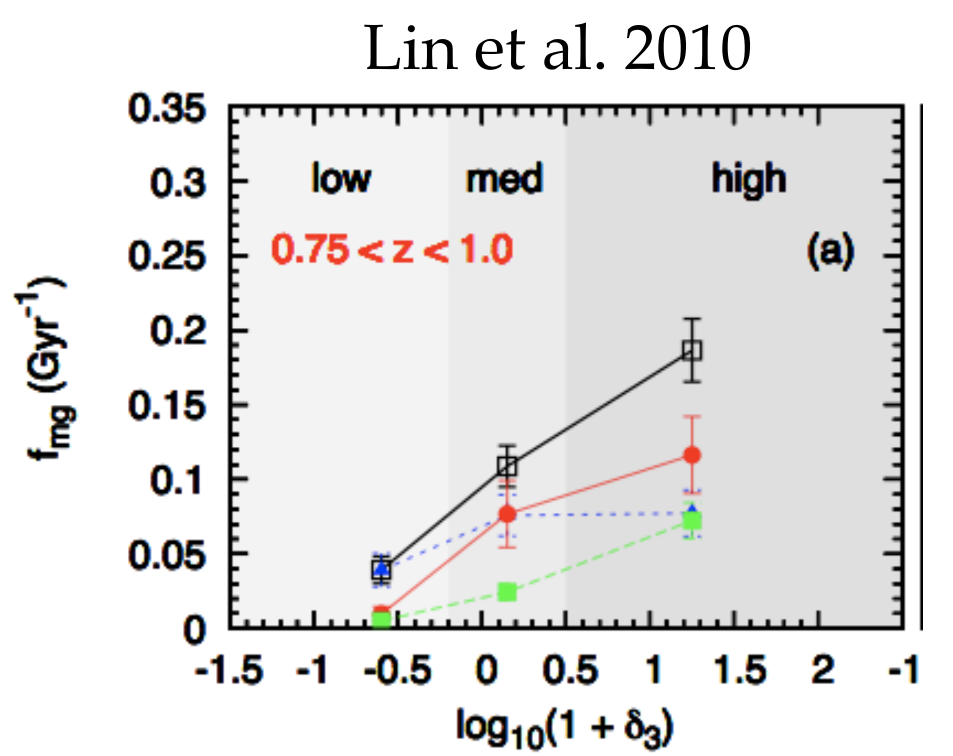
What physical process drives the concurrent growth of SMBHs and their host galaxies?

- **Major mergers of galaxies**
- **Internal processes**
  - ✦ Bar/disk instabilities (Kormendy & Kennicutt 2004)
  - ✦ Stellar ejecta (e.g., Davies et al. 2007; Kauffmann et al. 2009)



✳ **Availability of gas**

✦ Plentiful reservoir of molecular gas on large (kpc) scales (Scoville et al. 2003; Ho et al. 2008)

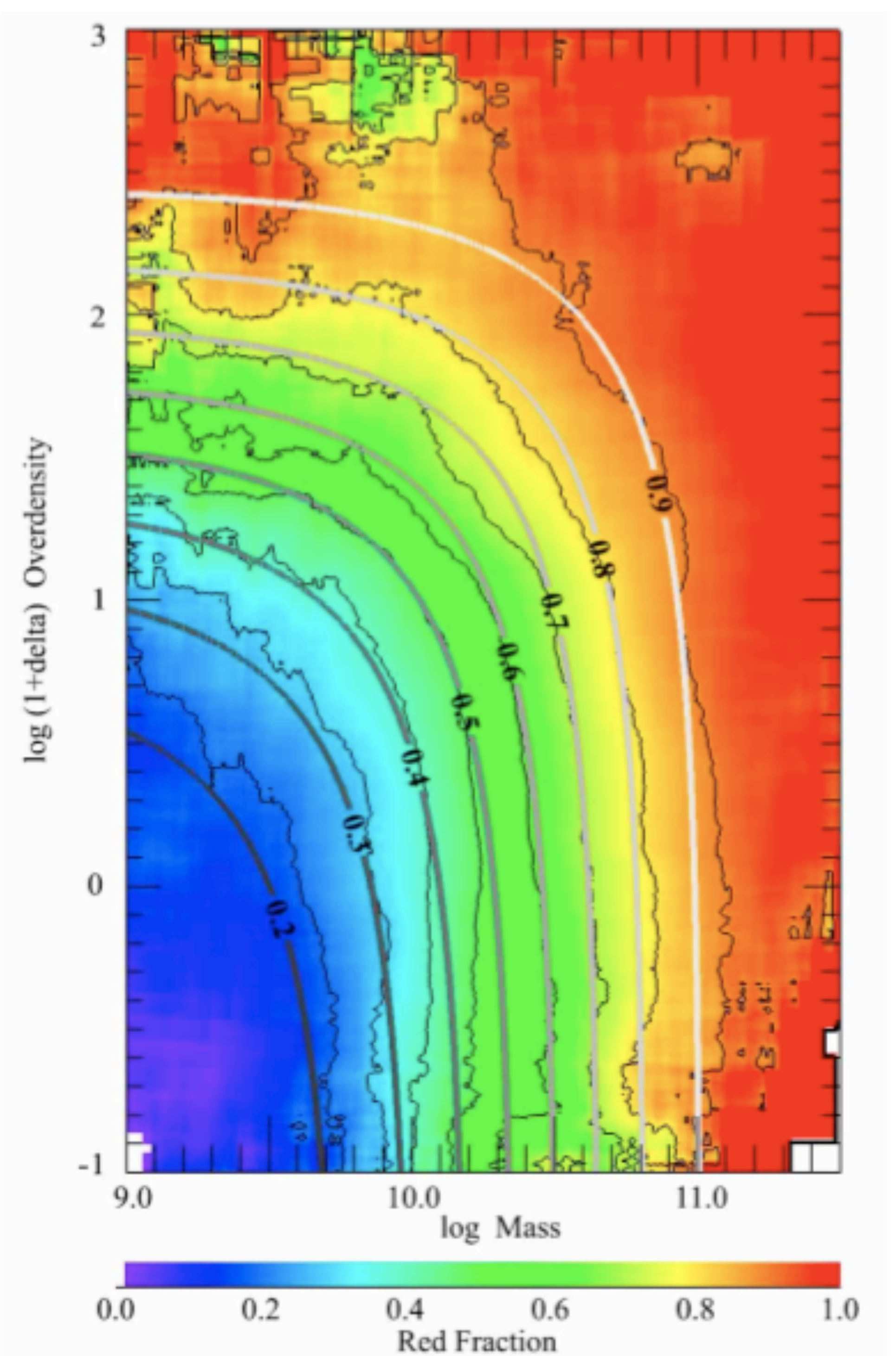


✳ **External processes**

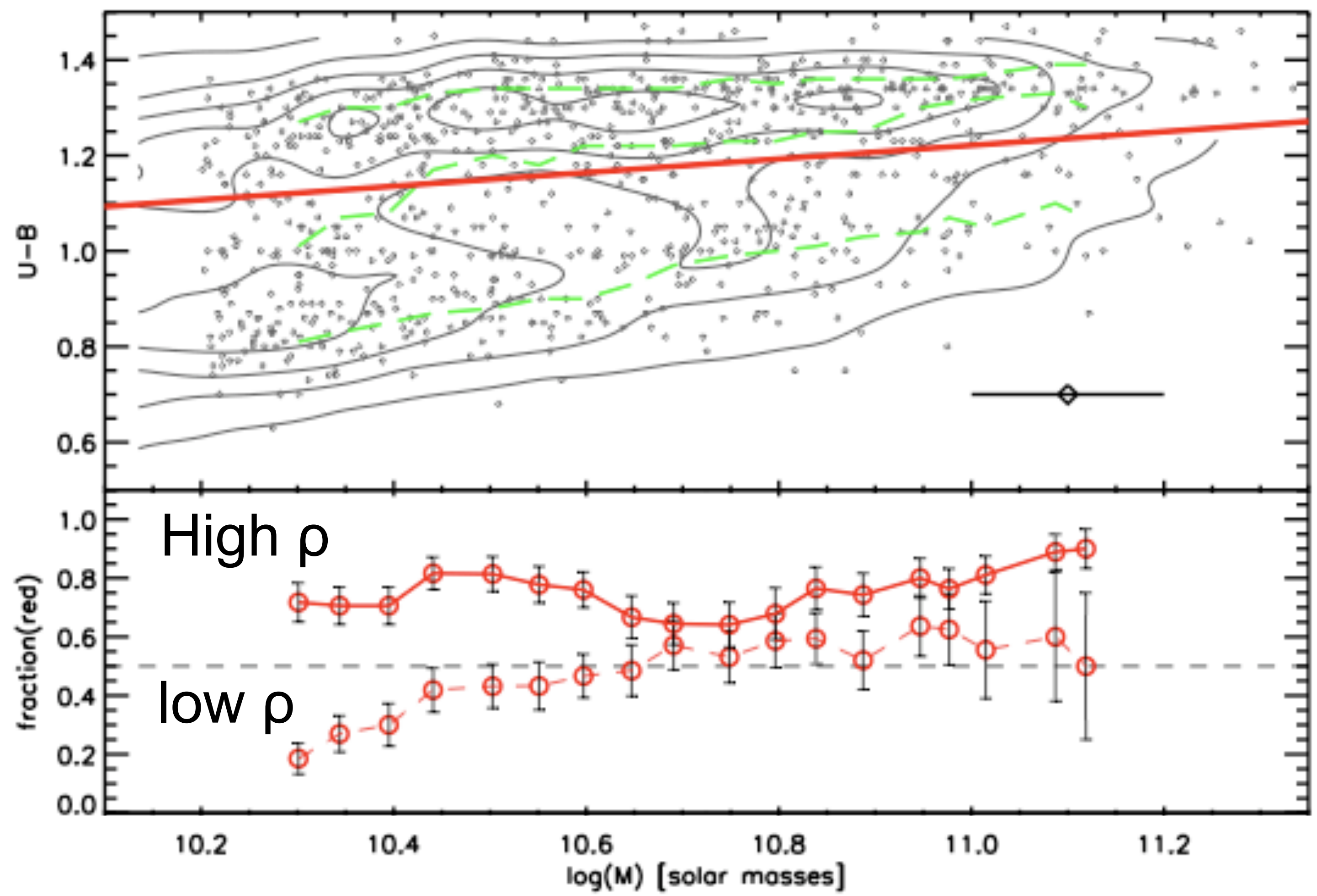
(>100 kpc scales; ram pressure stripping, strangulation, galaxy harrassment)

Galaxy evolution up to z ~ 1

SDSS



zCOSMOS



Cucciatti et al. 2010

Peng, Lilly, zCOSMOS et al. 2010

Mass and environment are fundamental parameters

(e.g.,Baldry et al. 2004; Cooper et al. 2010; Thomas et al. 2009; Peng et al. 2010)

Approach

Establish the relationship between AGNs and their environment

Host galaxy
- stellar mass
- star formation rate (quenching?)

Environment
- large-scale (1-3 Mpc)
- galaxy groups (enhanced merger rates, typical halos of AGN)

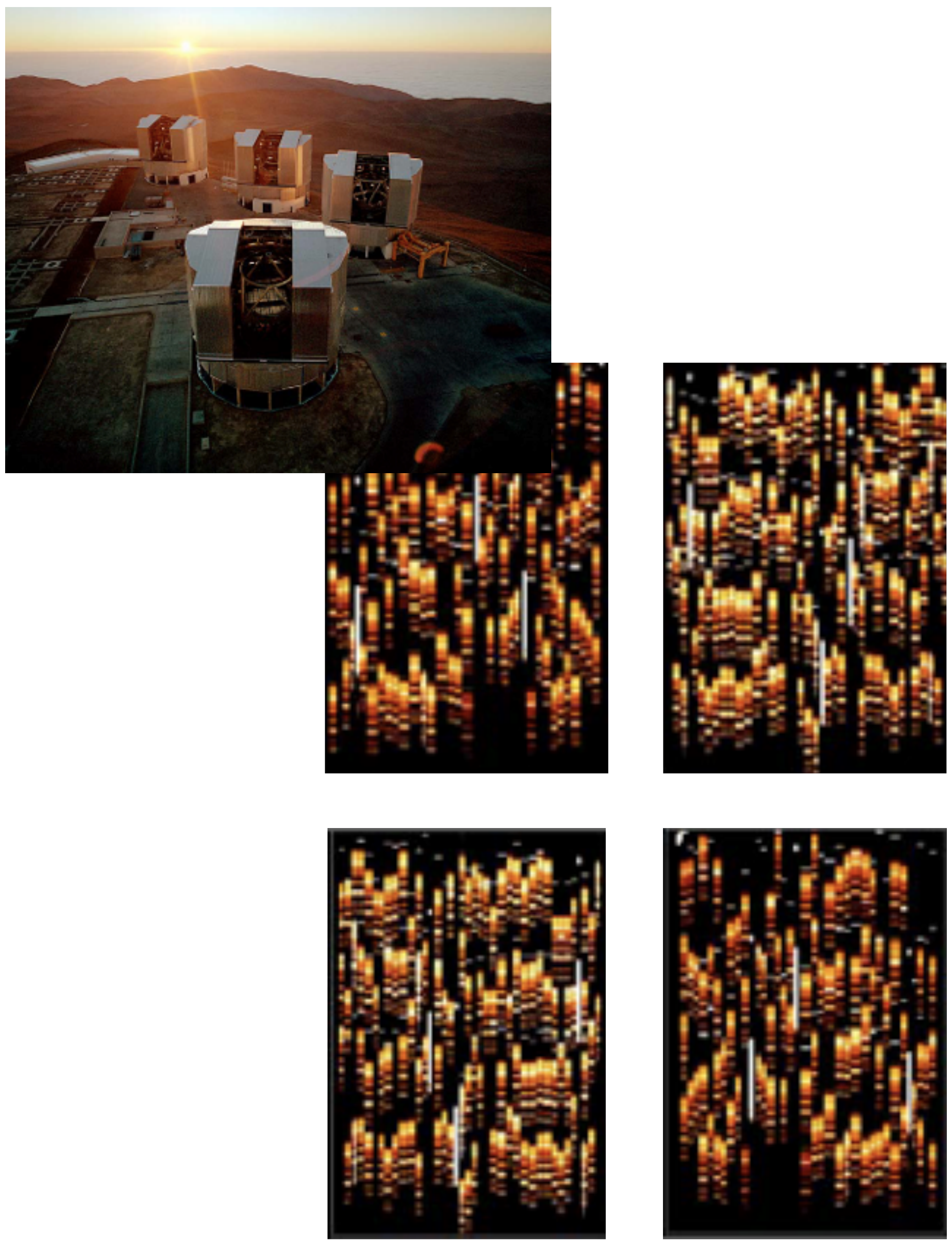
Tools: zCOSMOS 20k spectroscopic redshift survey
X-ray imaging with XMM-Newton

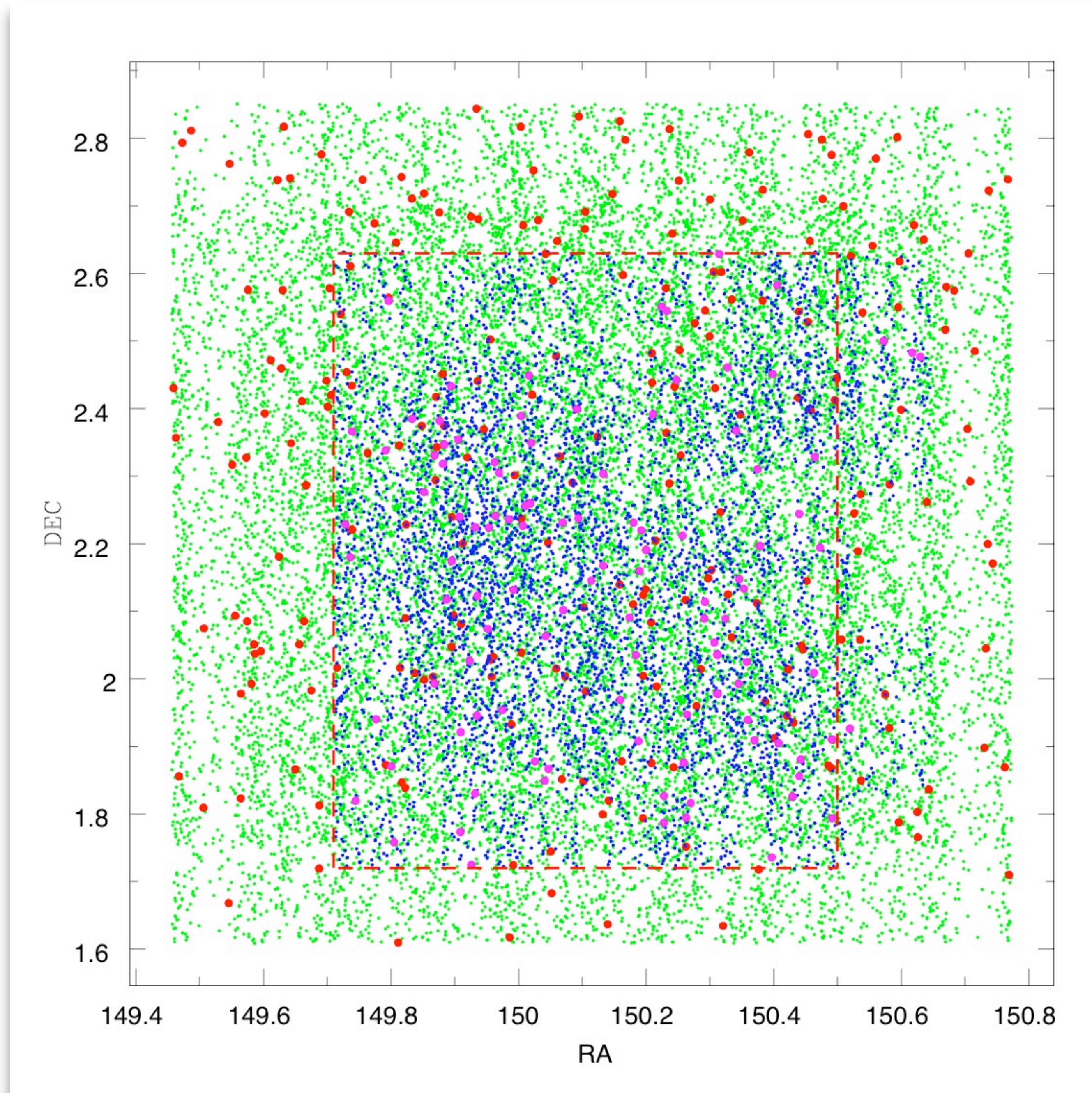
zCOSMOS: spectroscopic redshift survey with VLT

PI: Simon Lilly (ETH-Zurich)

6(+1) primary groups: Zurich, Marseille, Toulouse, Milan, Bologna, MPE/ESO, + Tokyo

O. Le Fevre, G. Zamorani, M. Scodeggio, V. Mainieri, T. Contini, A. Iovino & full zCOSMOS

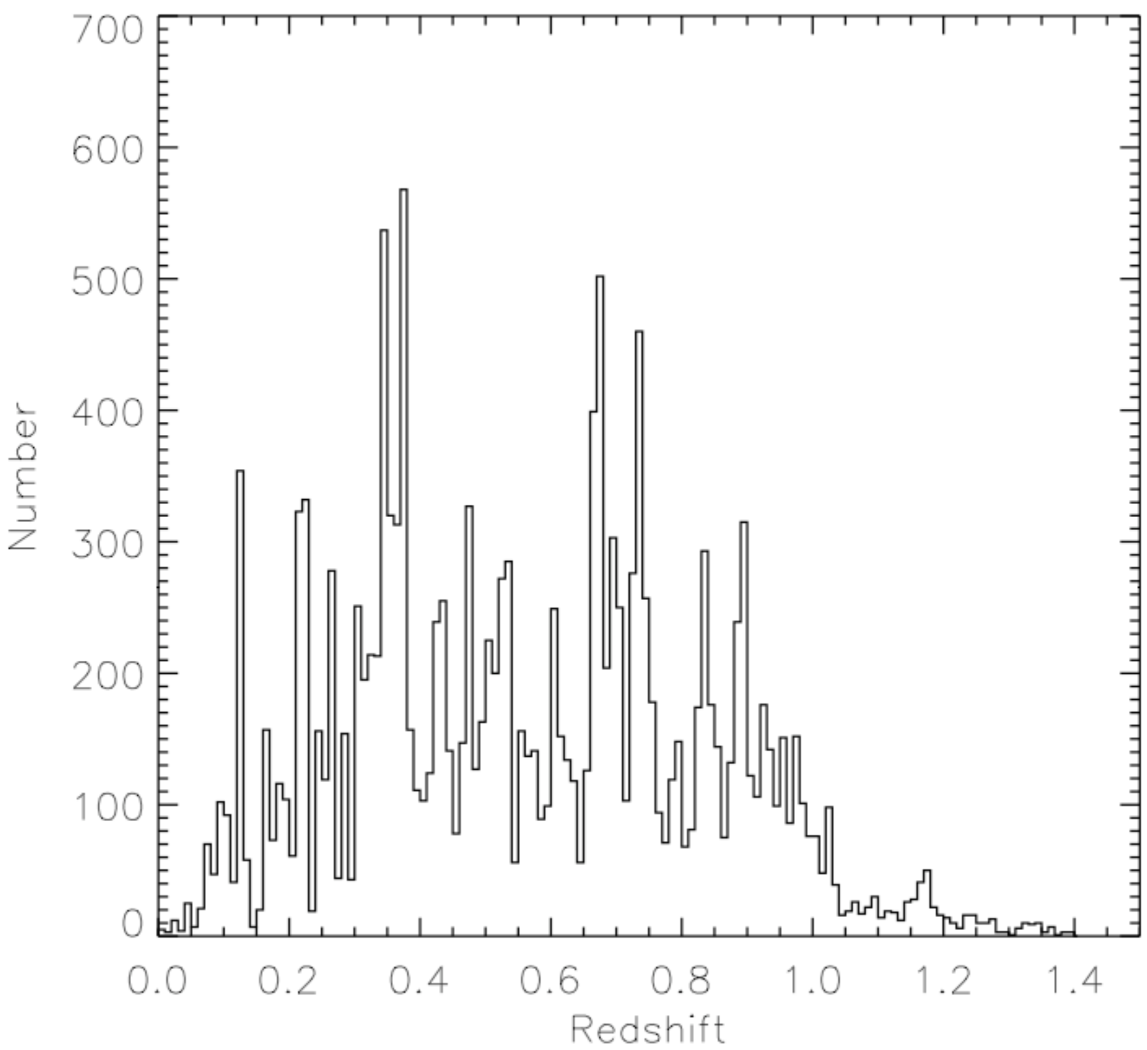


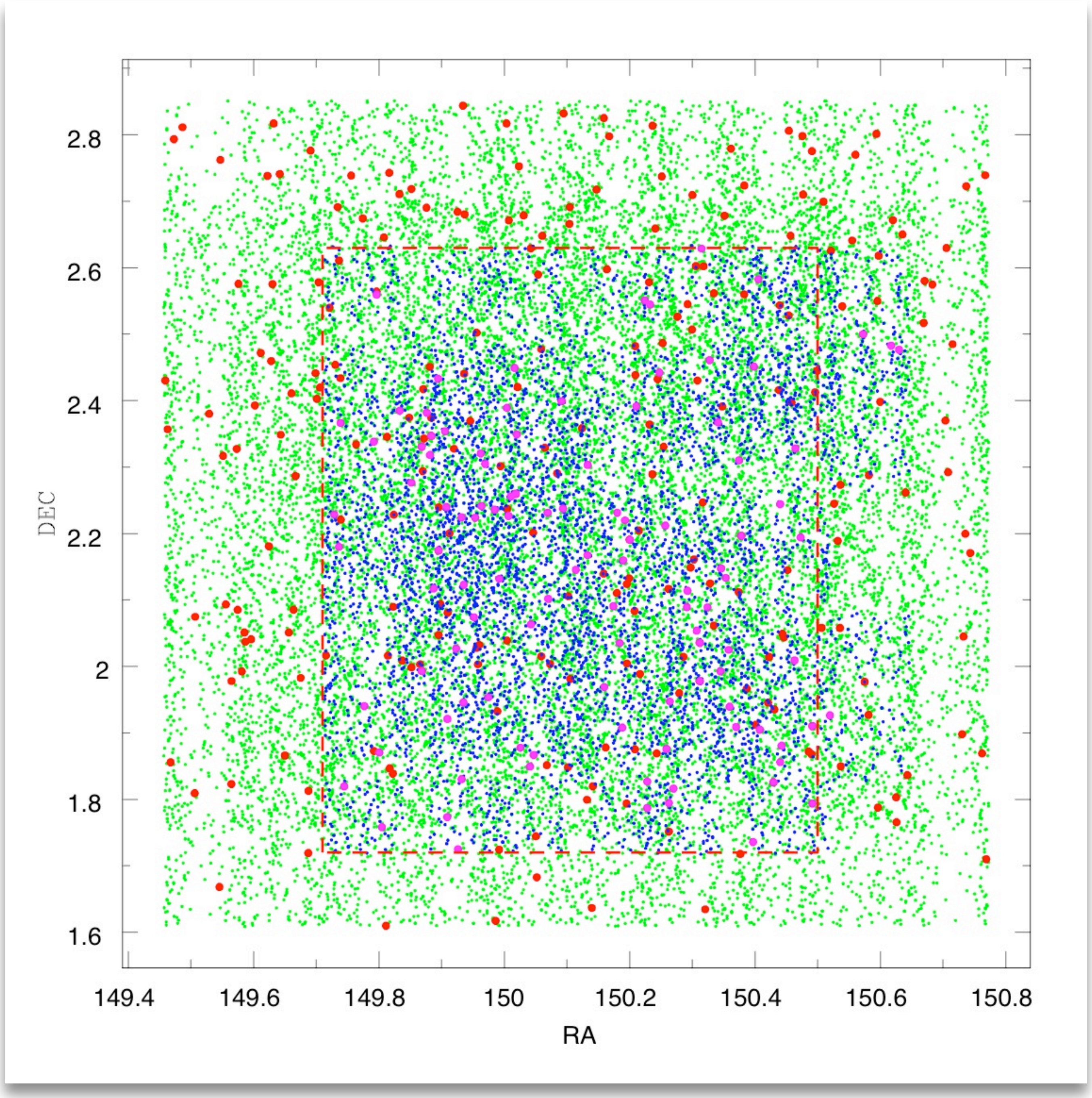


zCOSMOS: bright program

- 20k spectra
- 1.7 sq. deg.
- flux-limited (i < 22.5)
- 5500-9700 Å

- random sampling (70%)
- 90% redshift success rate
- 0.1 < z < 1.2

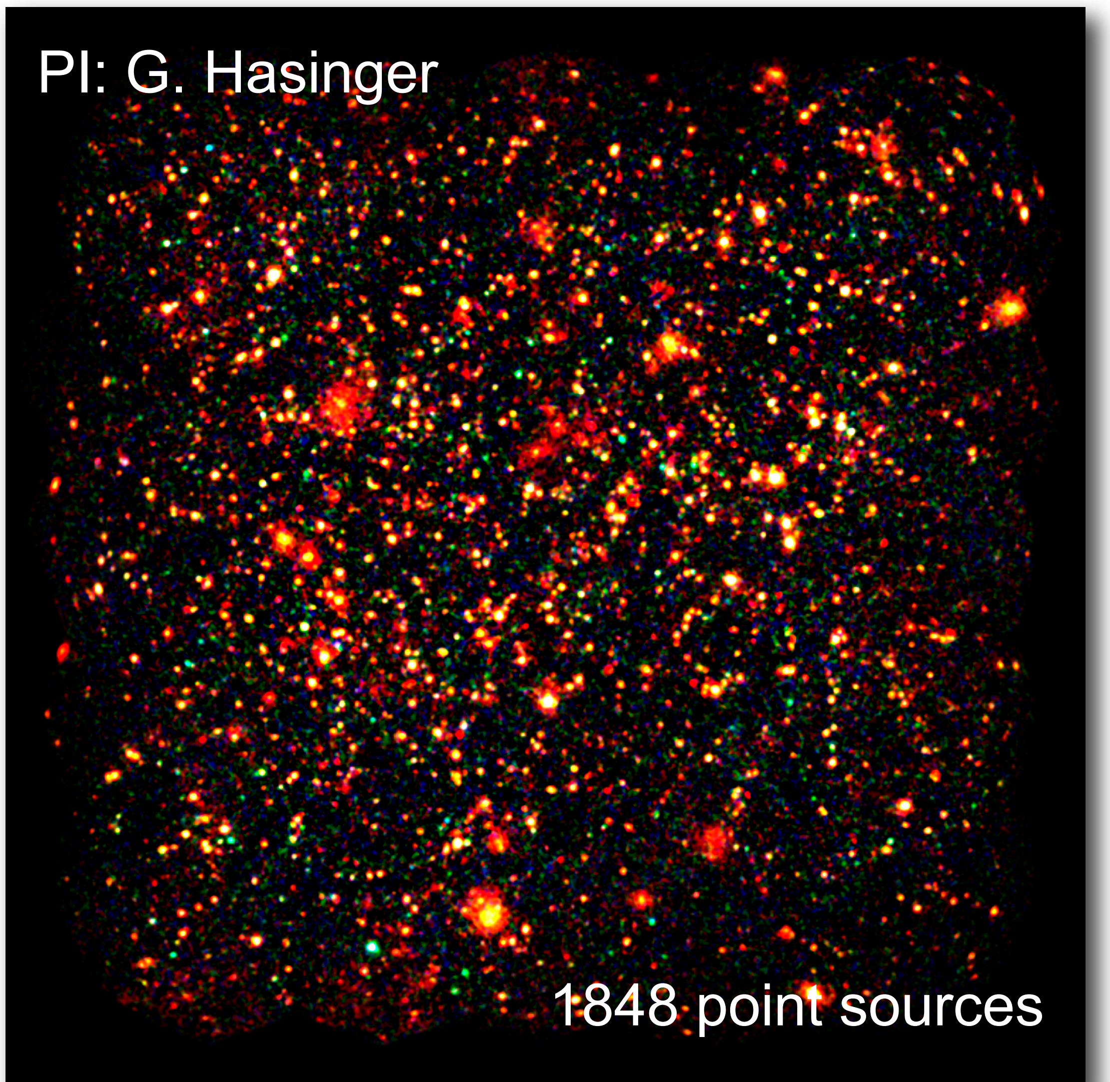




XMM / COSMOS

PI: G. Hasinger

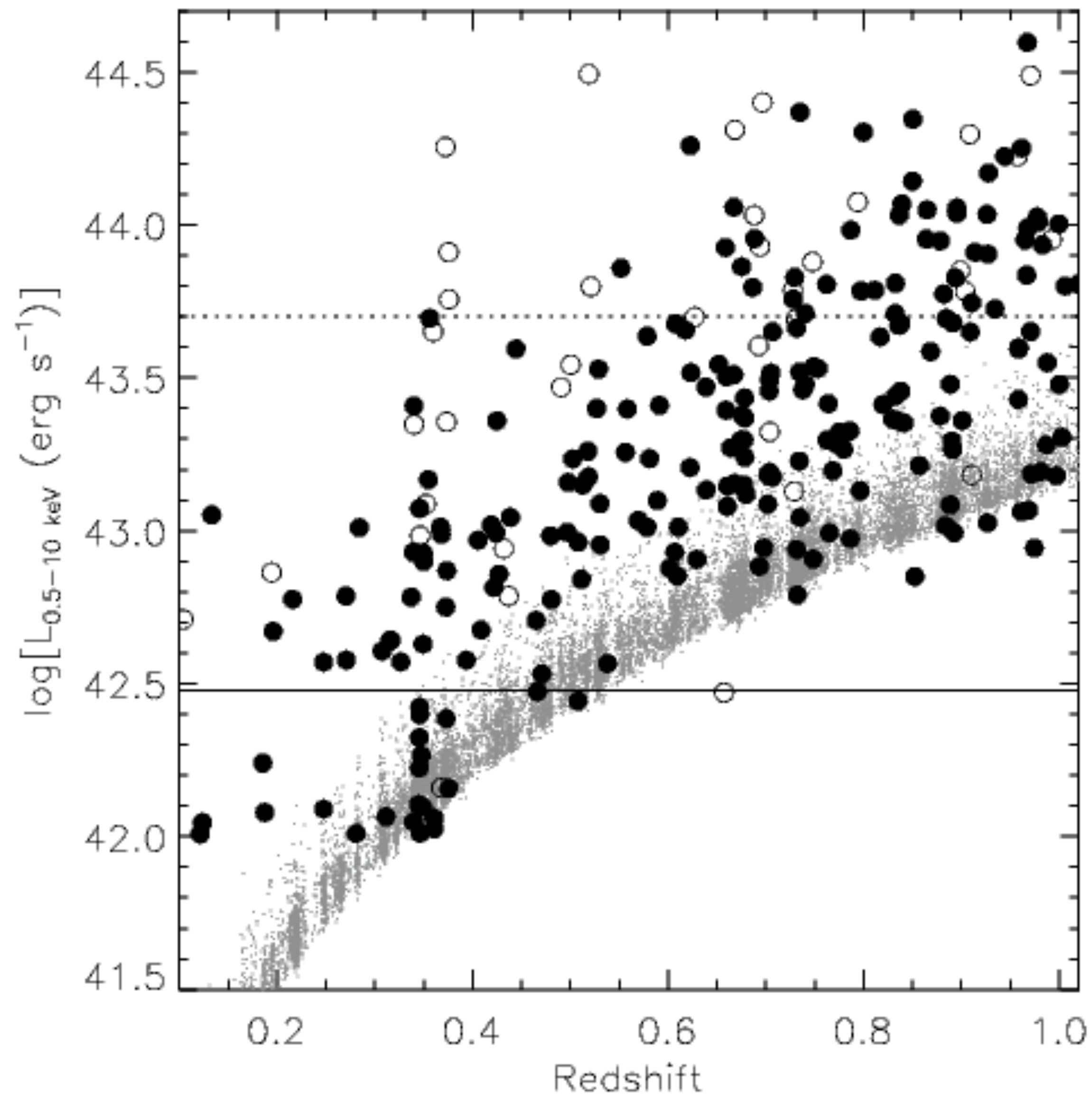
M. Brusa N. Cappelluti, A. Finoguenov (MPE), A. Comastri, R. Gilli (INAF-Bologna), V. Mainieri (ESO) and the entire XMM and Chandra COSMOS team



Hasinger et al. 2007; Cappelluti et al. 2009

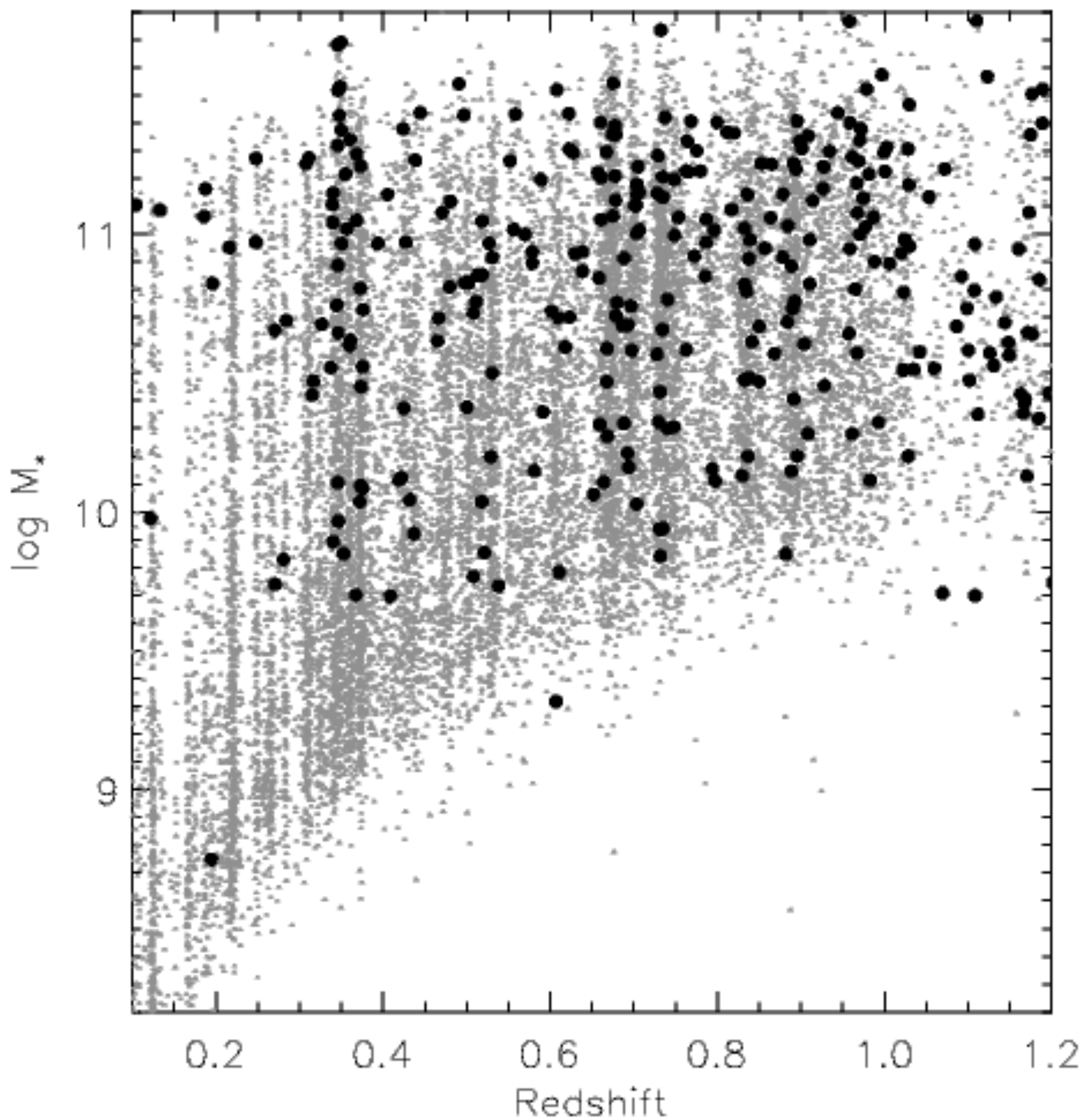
$f_{0.5\text{-}2.0\ keV}$ > 5 x 10^{-16} erg cm^{-2} s^{-1} (Soft band)

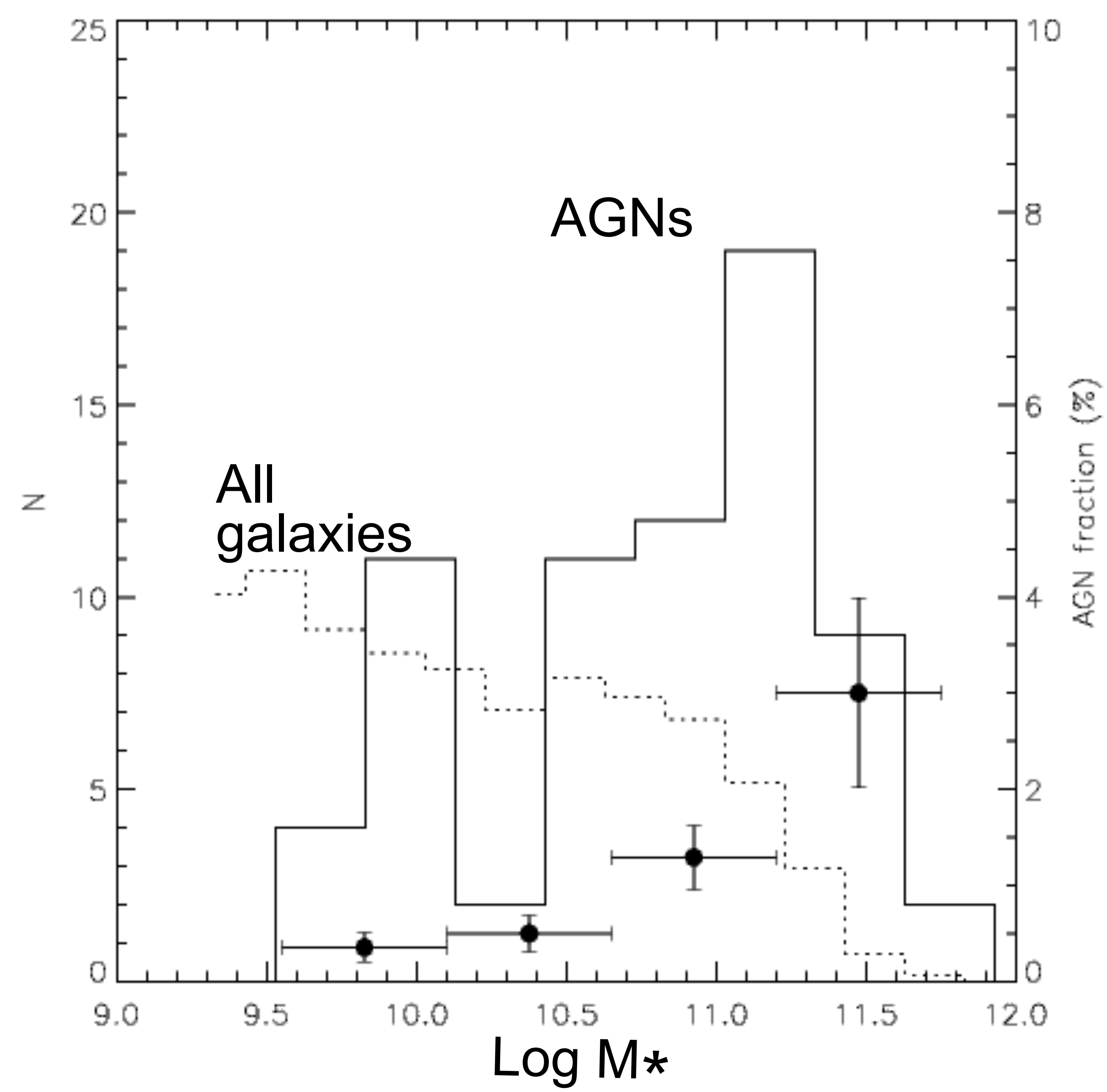
$f_{2.0\text{-}10\ keV}$ > 2 x10^{-15} " " (Hard bard)



261 AGNs (0.1 < z <1) identified by zCOSMOS/10k having L_X > 10^{42} erg s^{-1}

Host galaxy stellar masses





JDS et al. 2009b

In agreement with clustering analyses (e.g. Gilli et al. 2009) local SDSS studies (Kauffmann et al. 2003; Best et al. 2005)

Star formation rates

[OII]λ3727 as a SFR indicator (Ho et al. 2005)

- [OII] mainly attributed to host galaxy (see Croom et al. 2002)
- Quasars exhibit low SFRs (a few $M_\odot$ yr^{-1}). Quenching at low redshift?

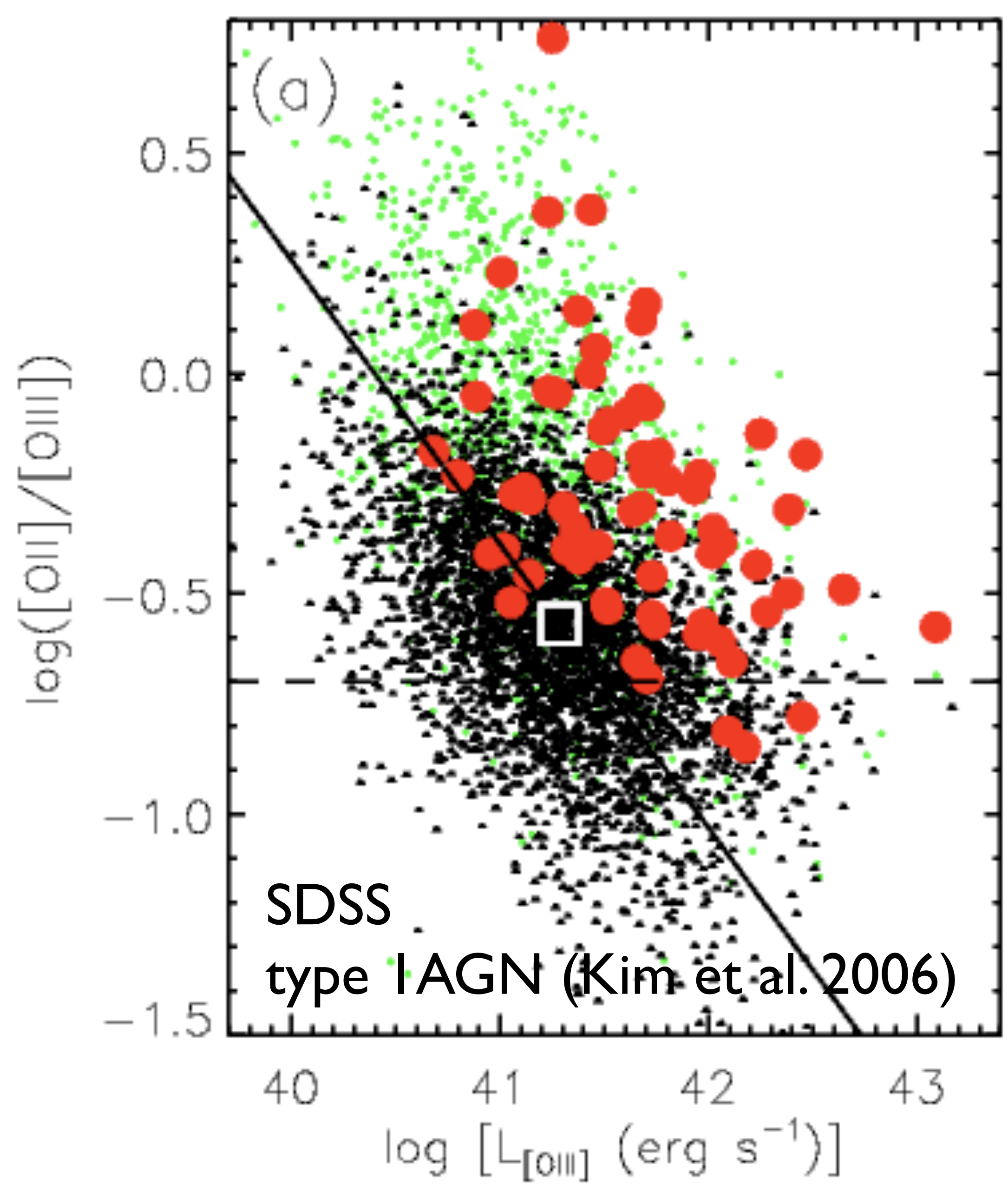
Method:

I. Measure line fluxes [OII]λ3727, [OIII]λ5007

II. Removal of AGN contribution; assume
- [OIII]λ5007 purely AGN dominated
- $[OII]_{AGN}/[OIII]_{AGN}=0.2$ (Kim, Ho et al. 2006)
- Consider extinction
- At z>0.85, infer $L_{[OIII]}$ from $L_{2\text{-}10\ keV}$ (Heckman et al. 2005)

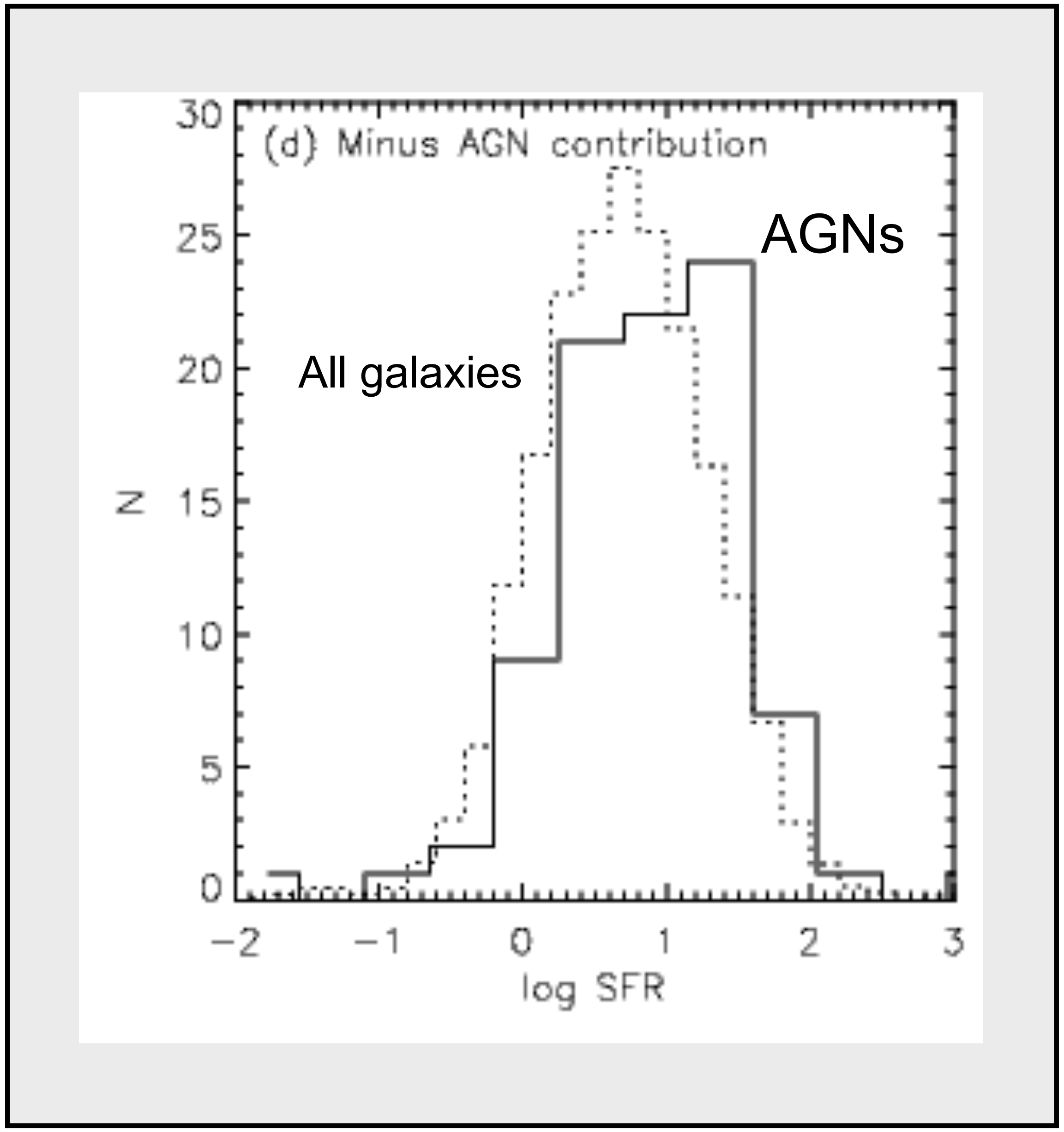
III. SFR = $f(L_{[OII]})$ (Moustakis et al. 2006)

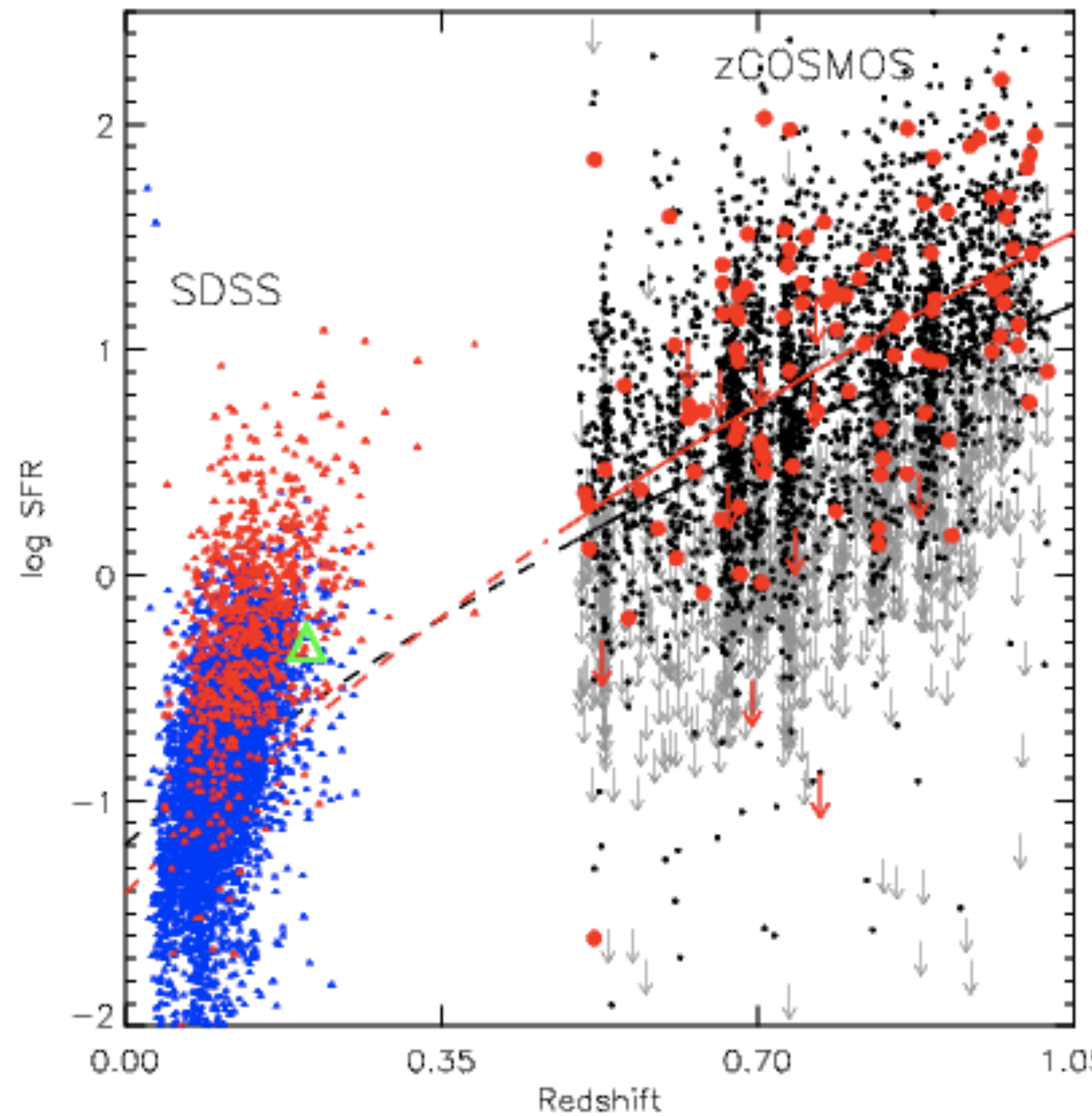
zCOSMOS AGNs ●



JDS et al. 2009b

Star formation rates



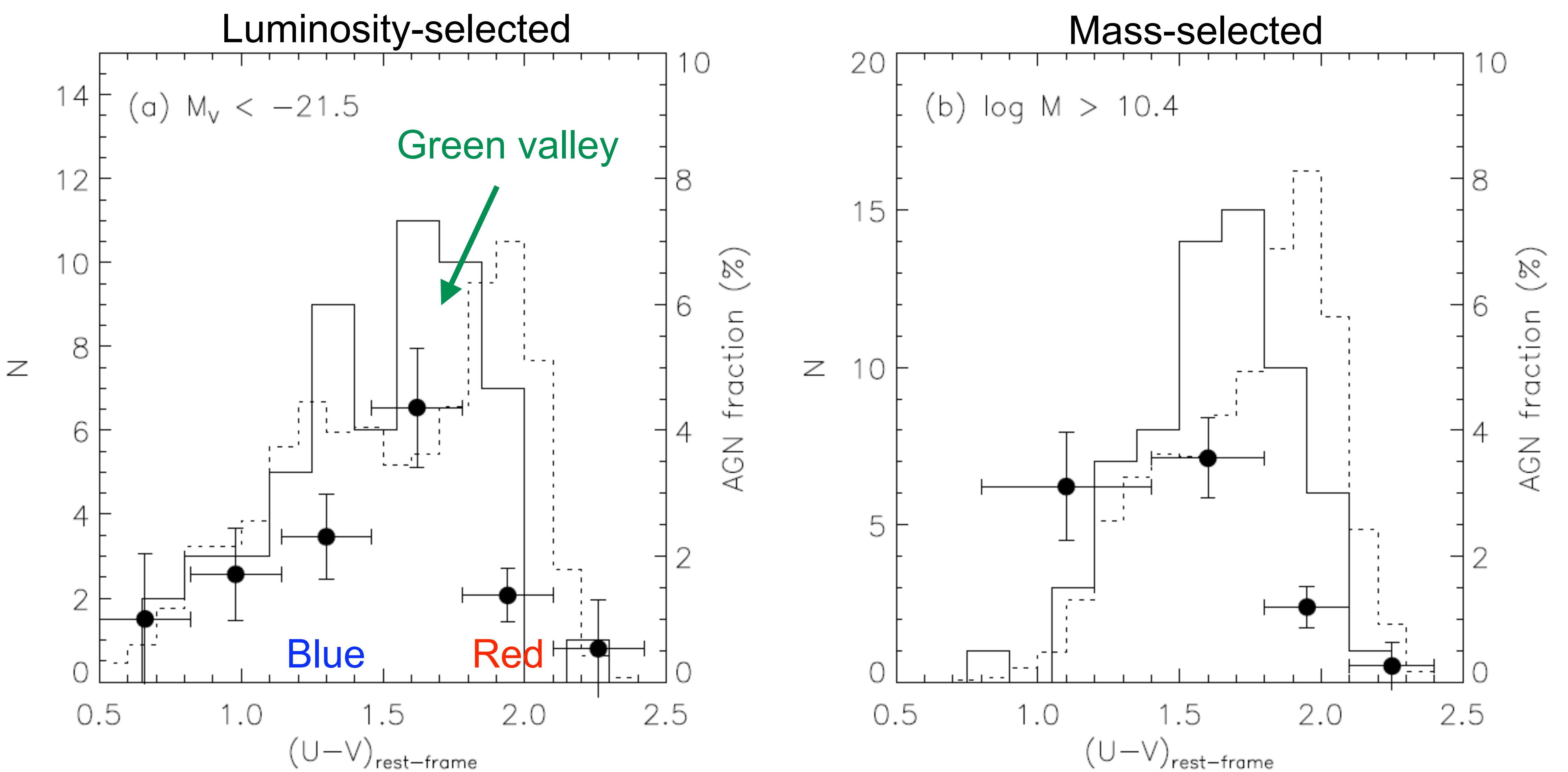


JDS et al. 2009b

Significant levels of star formation: ~1< SFRs < 100 M⊙ yr^{-1}

Similar to studies covering a wide range of redshift (e.g., Kauffmann et al. 2003; Jahnke et al. 2004)

Are AGNs associated with transitional galaxies?



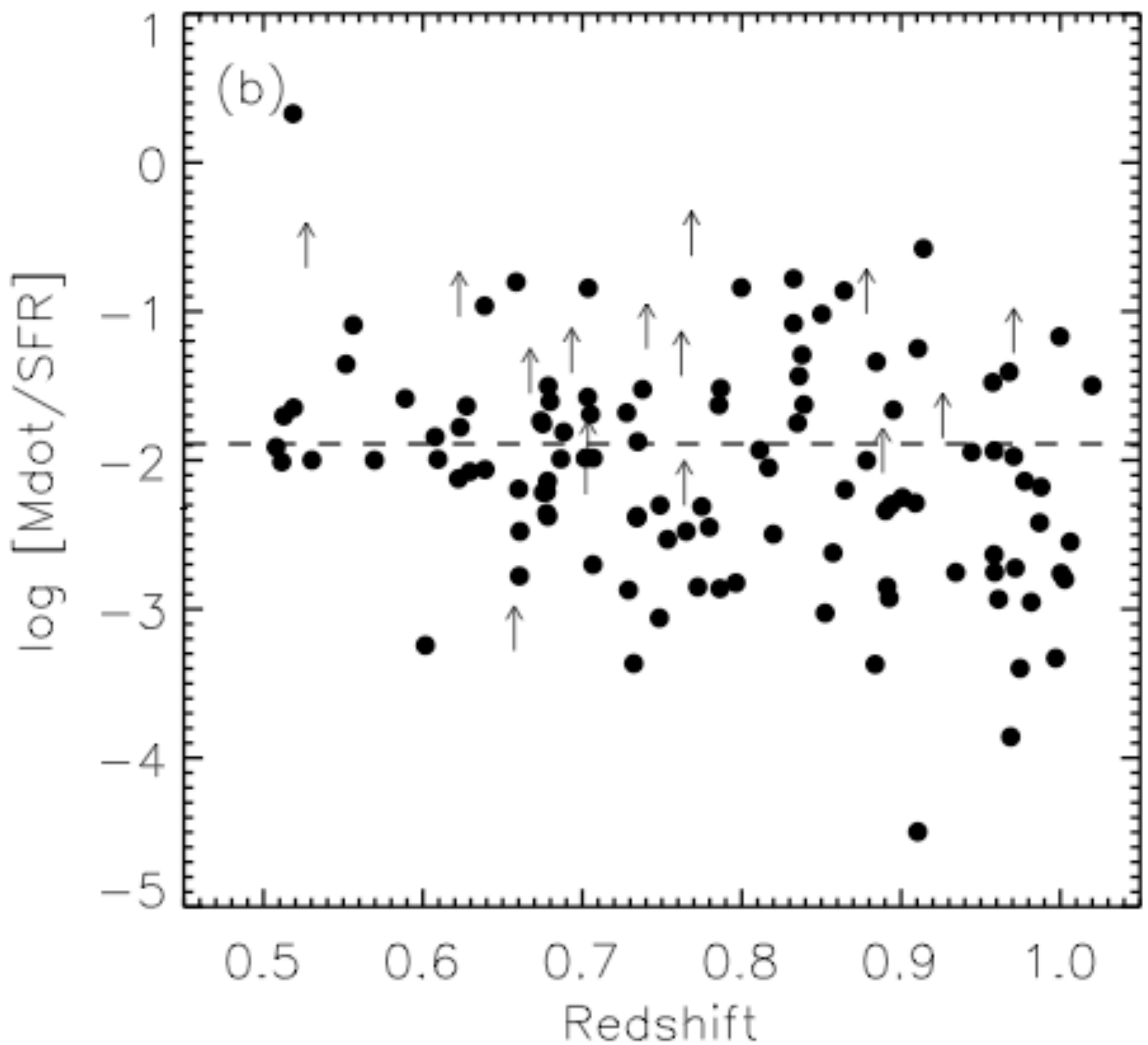
SDSS: Martin et al. 2007; Salim et al. 2007; Schawinski et al. 2007; Westoby et al. 2007

X-ray surveys: see Nandra et al. 2007; Silverman et al. 2008; Georgakakis et al. 2008; Schawinski et al. 2009

Must account for the low mass-to-light ratio of 'blue cloud' galaxies

JDS et al. 2009b; Xue et al. 2010

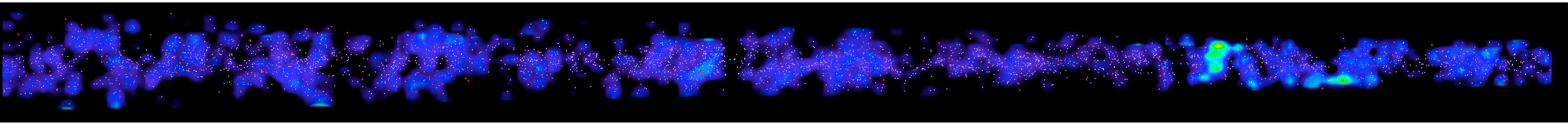
Co-evolution



- Constant ratio with redshift
- $<\dot{M}_{accr}/SFR> \sim 10^{-2}$ [A factor of 10x higher than M_{BH}-M_{bulge} relation]
- Intermittant scenario with an AGN duty cycle 10x shorter than star formation

JDS et al. 2009b

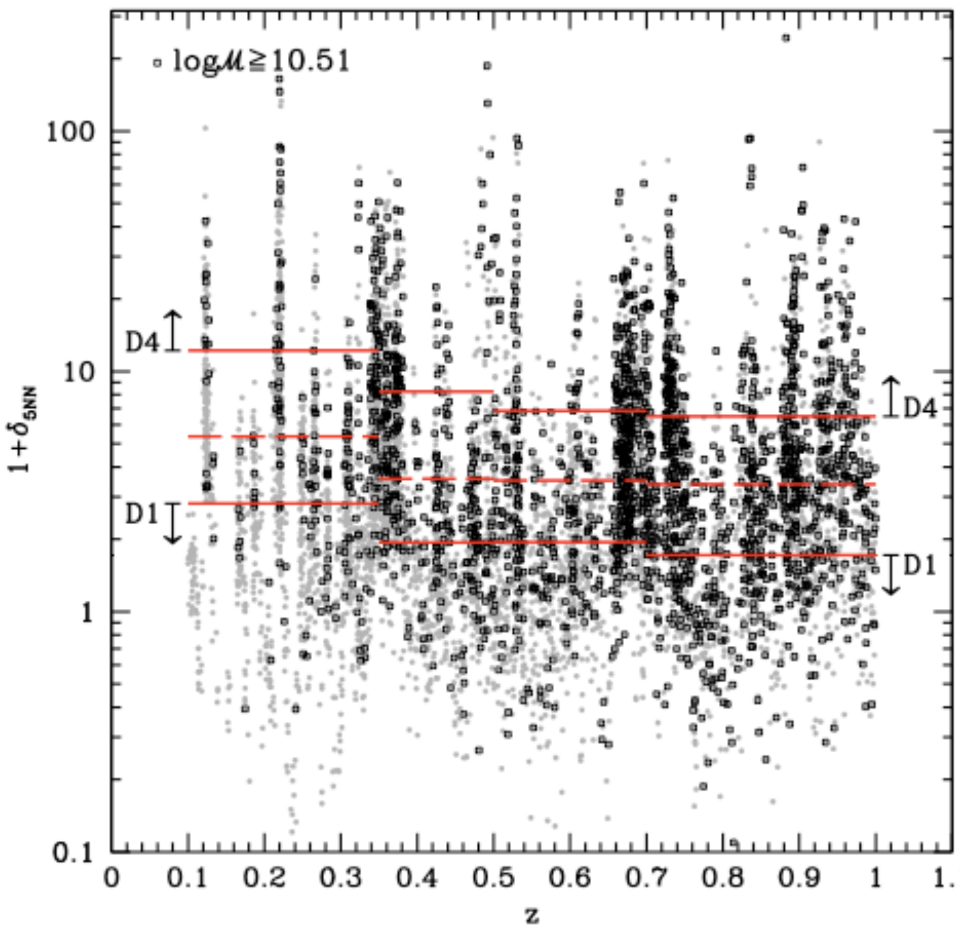
Large-scale environment

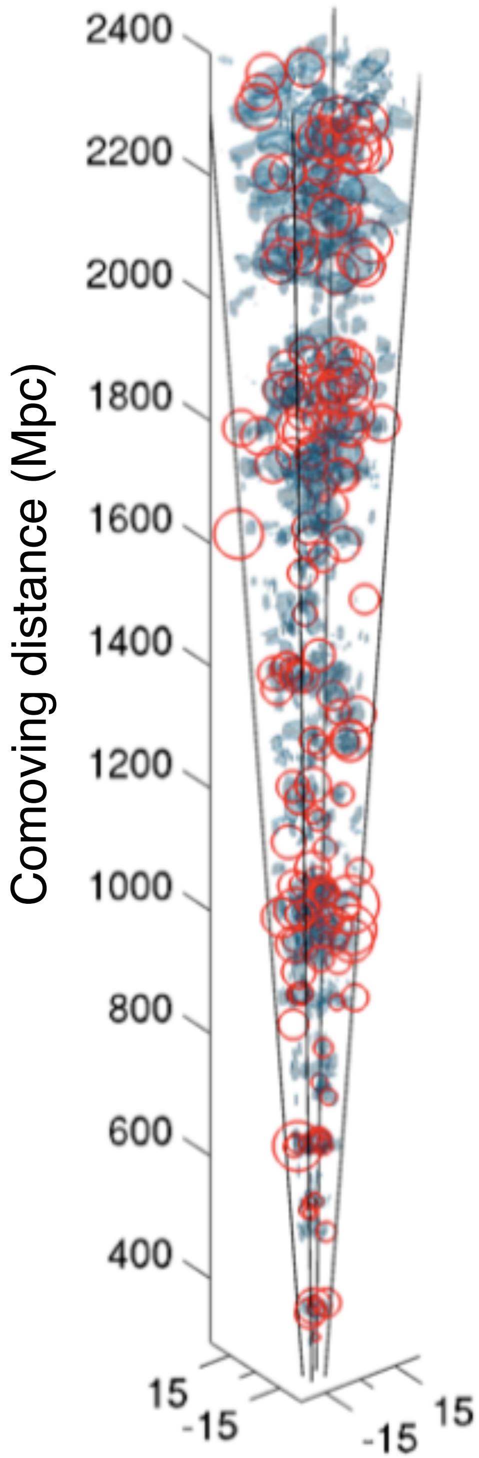


Zurich-developed density estimator

Kovac et al. 2009

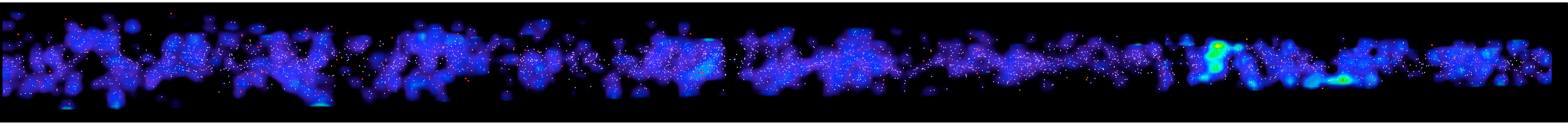
- Nearest neighbor approach (e.g., 5th,10th)
- spectroscopic (10k) + photometric (30k) redshifts
- flux and volume limited tracers





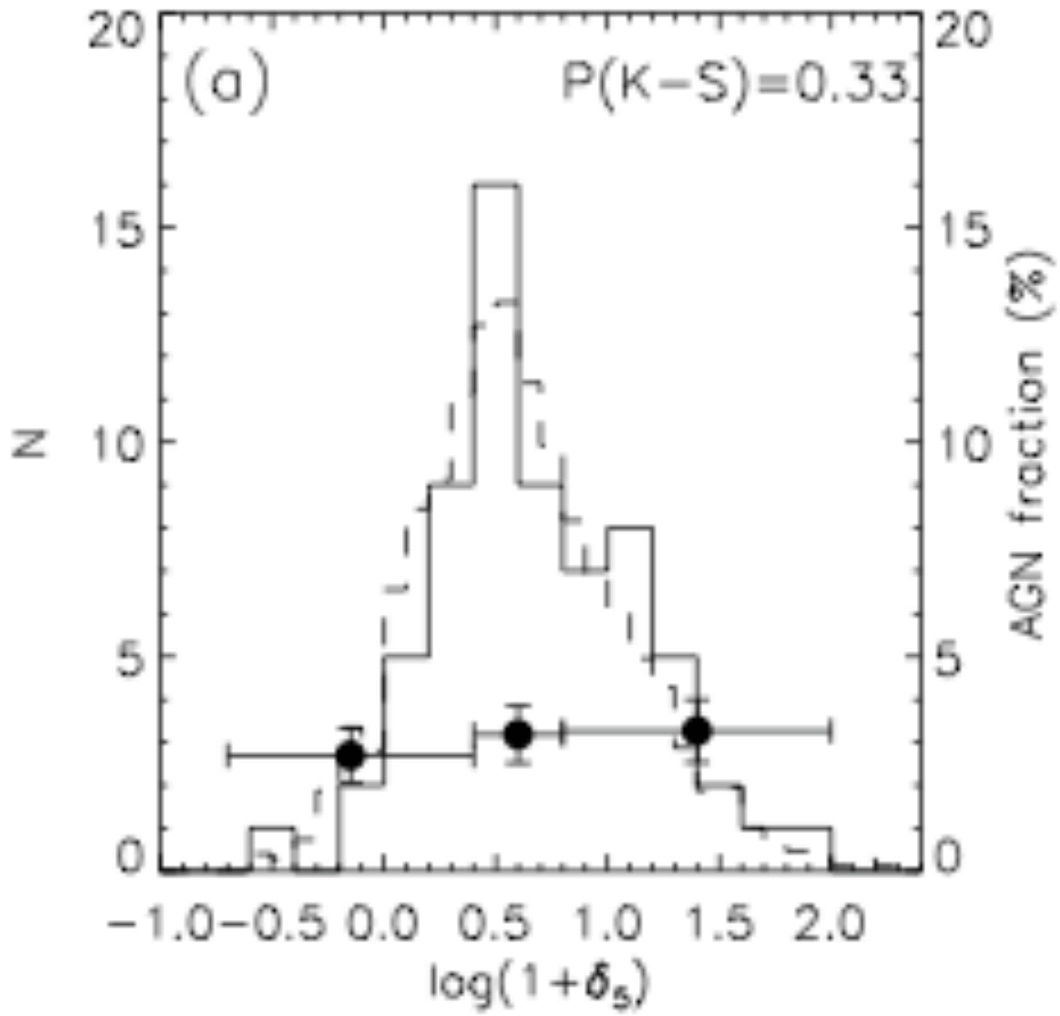
- Projected-density (± 1000 km s^{-1})
- Overdensity (δ): $1 + \delta = \rho/<\rho>$
- Physical scale: 1-3 Mpc

Large-scale environment

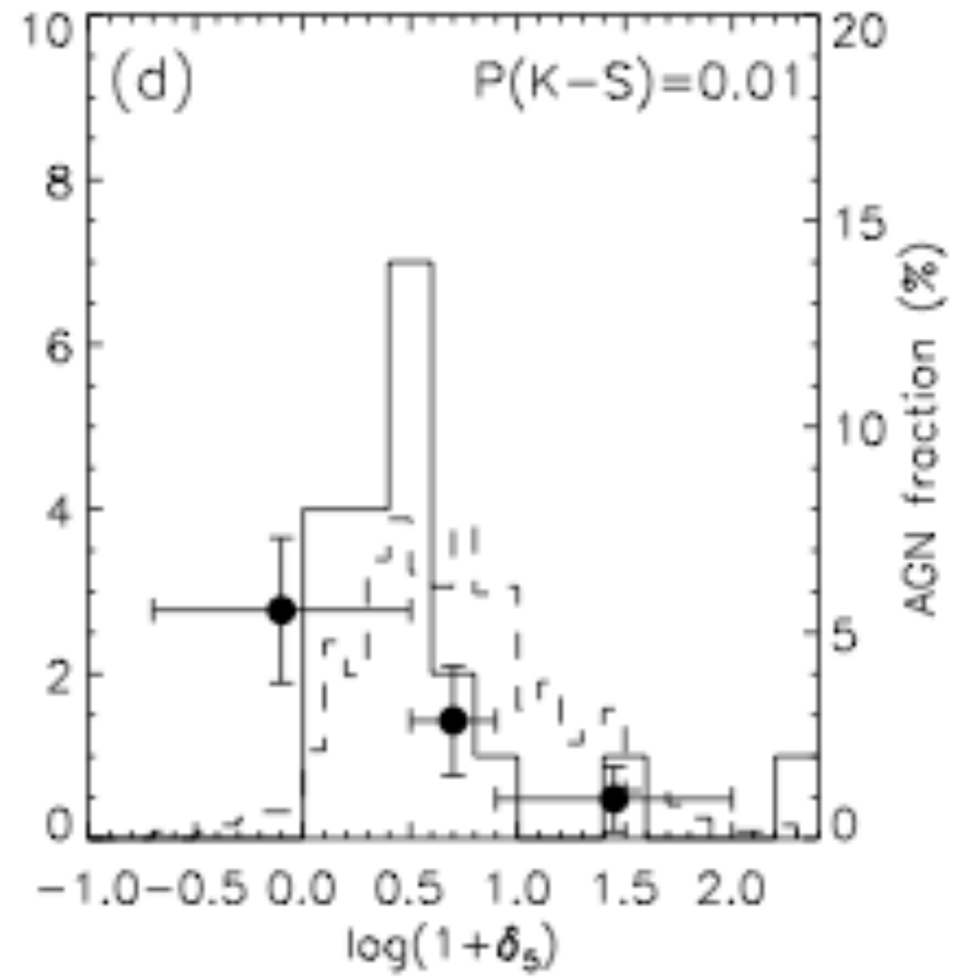


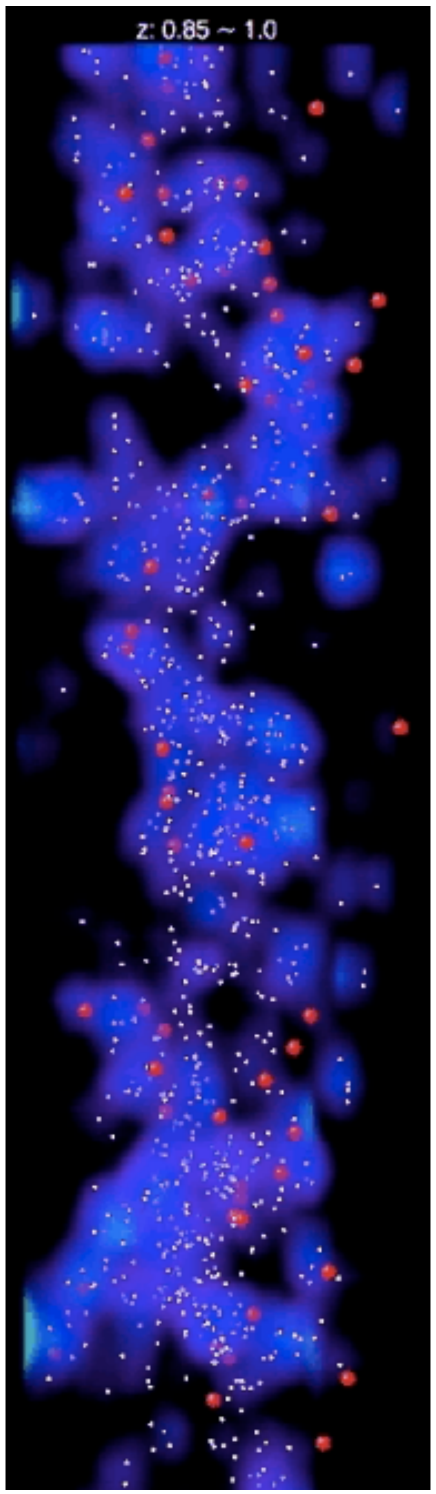
AGNs in zCOSMOS 10k spectroscopic catalog
42.5 < log Lx < 43.7

10.4 < log M < 11



log M > 11





JDS, Kovac, Knobel, Lilly et al. 2009a

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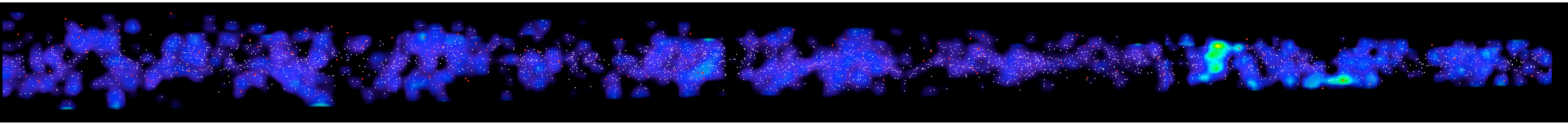

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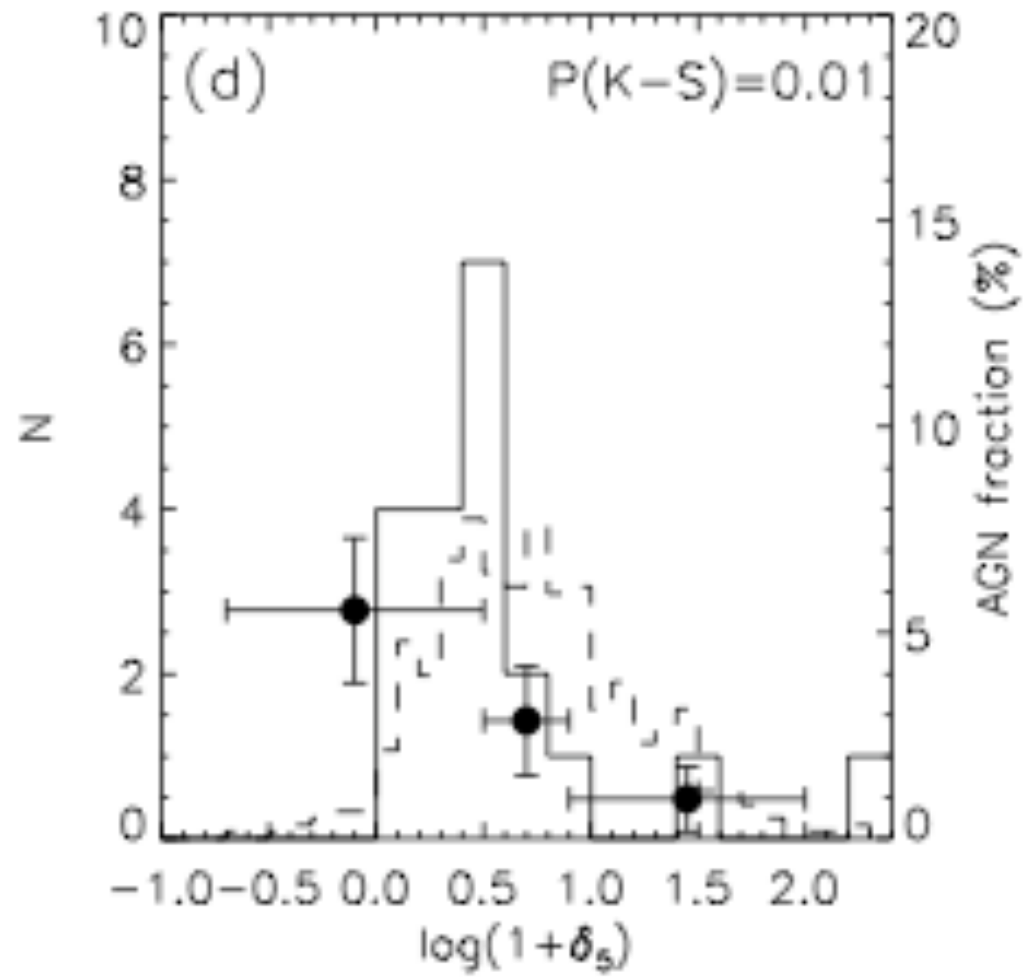

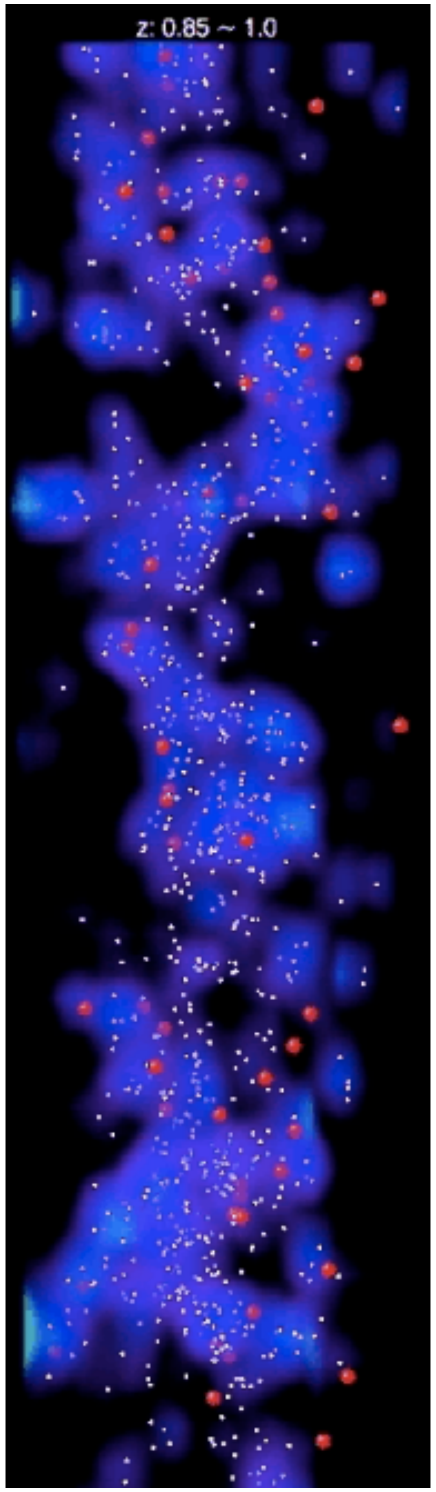

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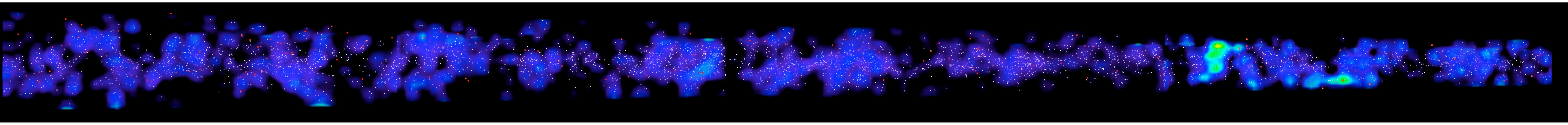

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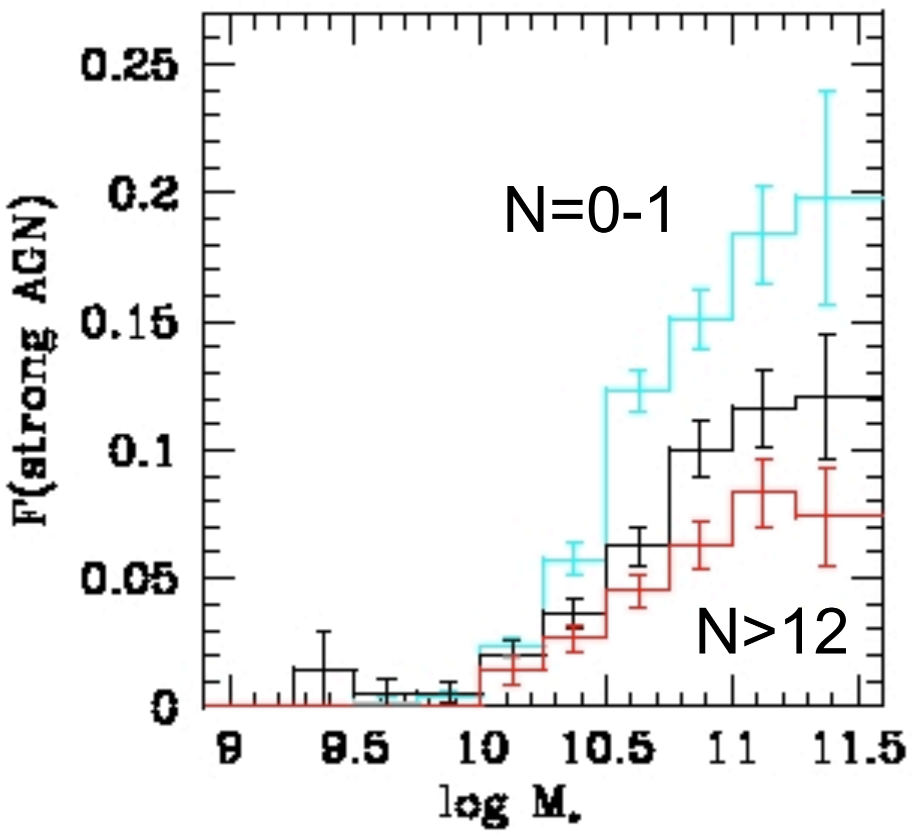

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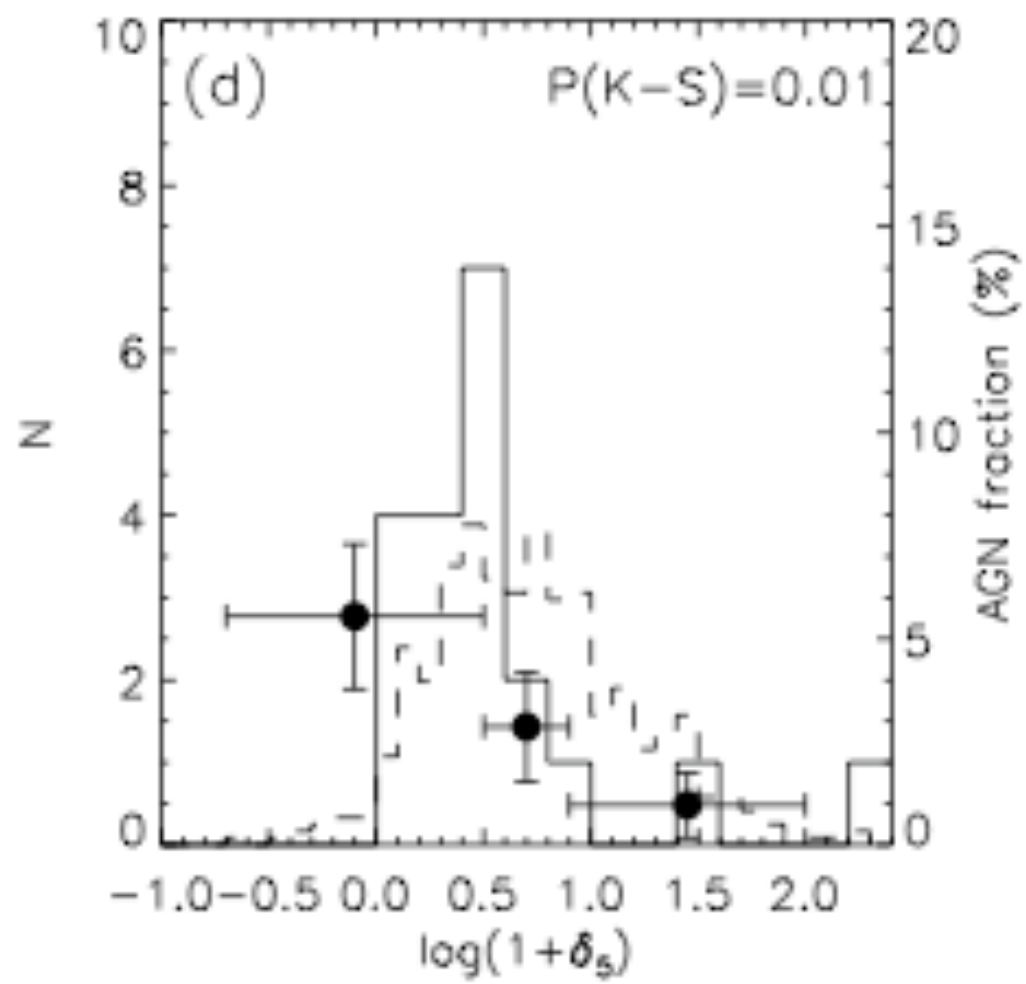

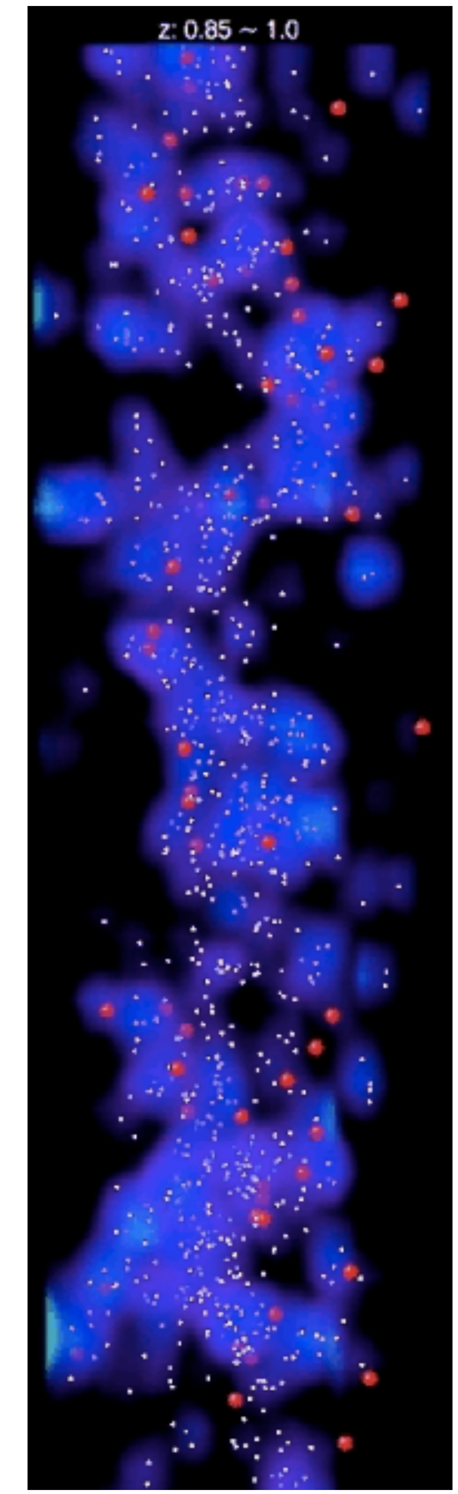

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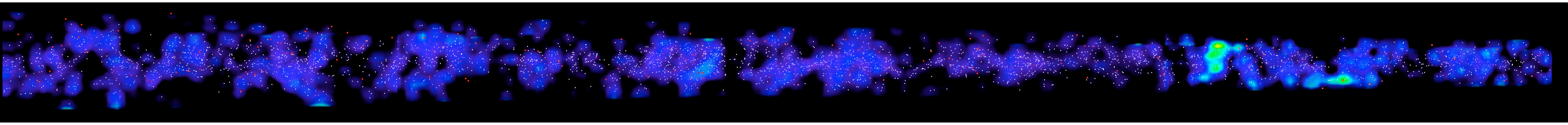

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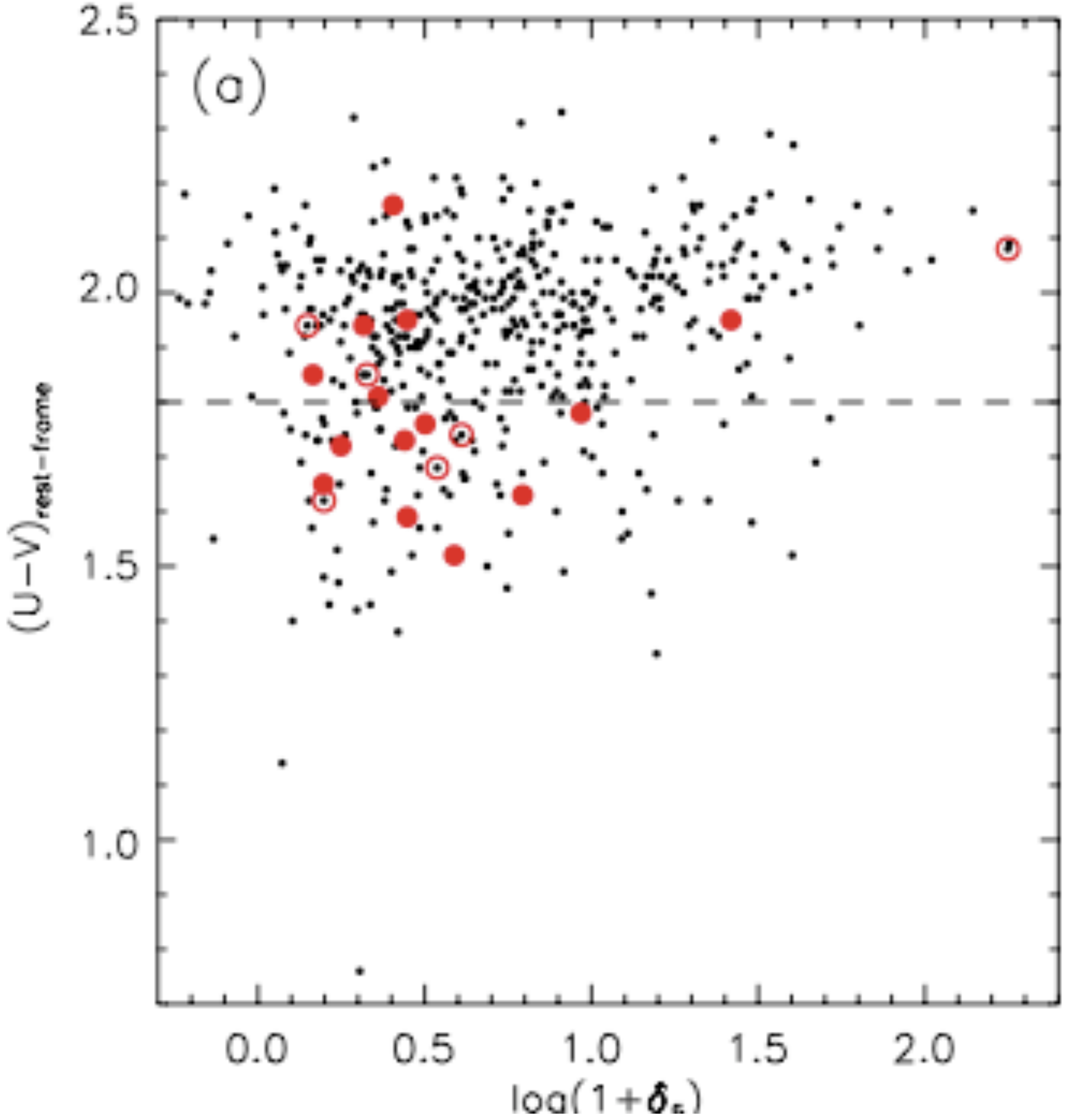

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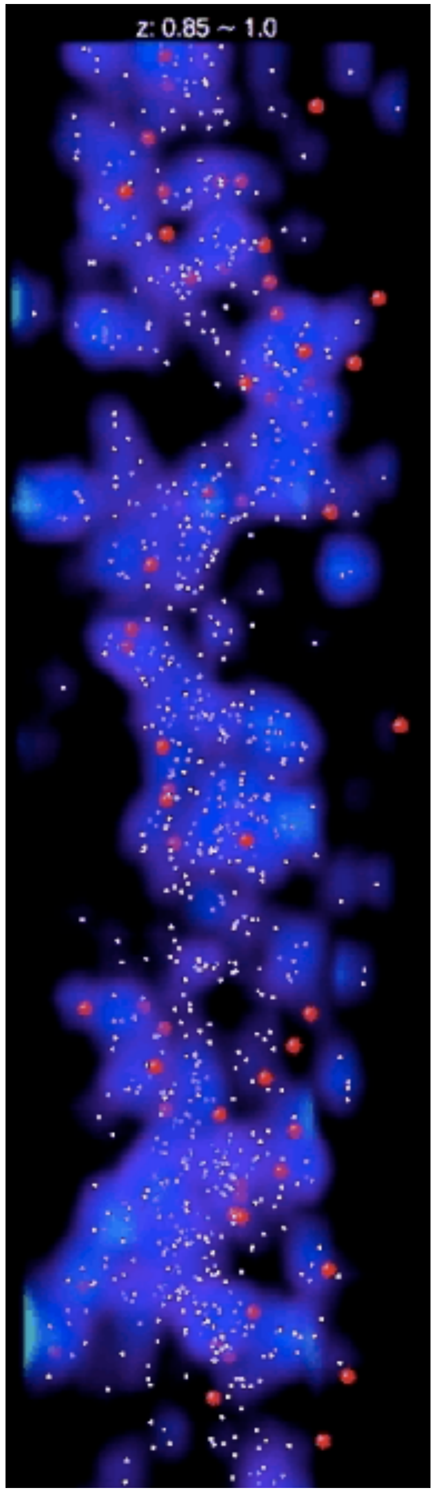

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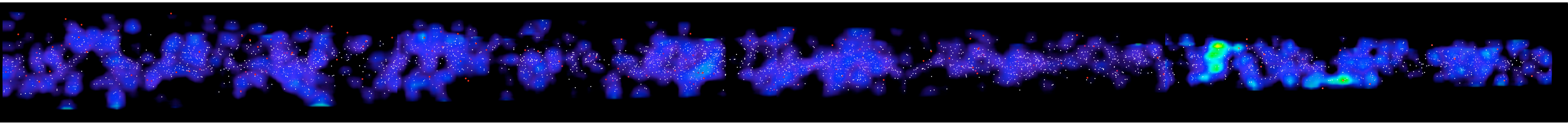

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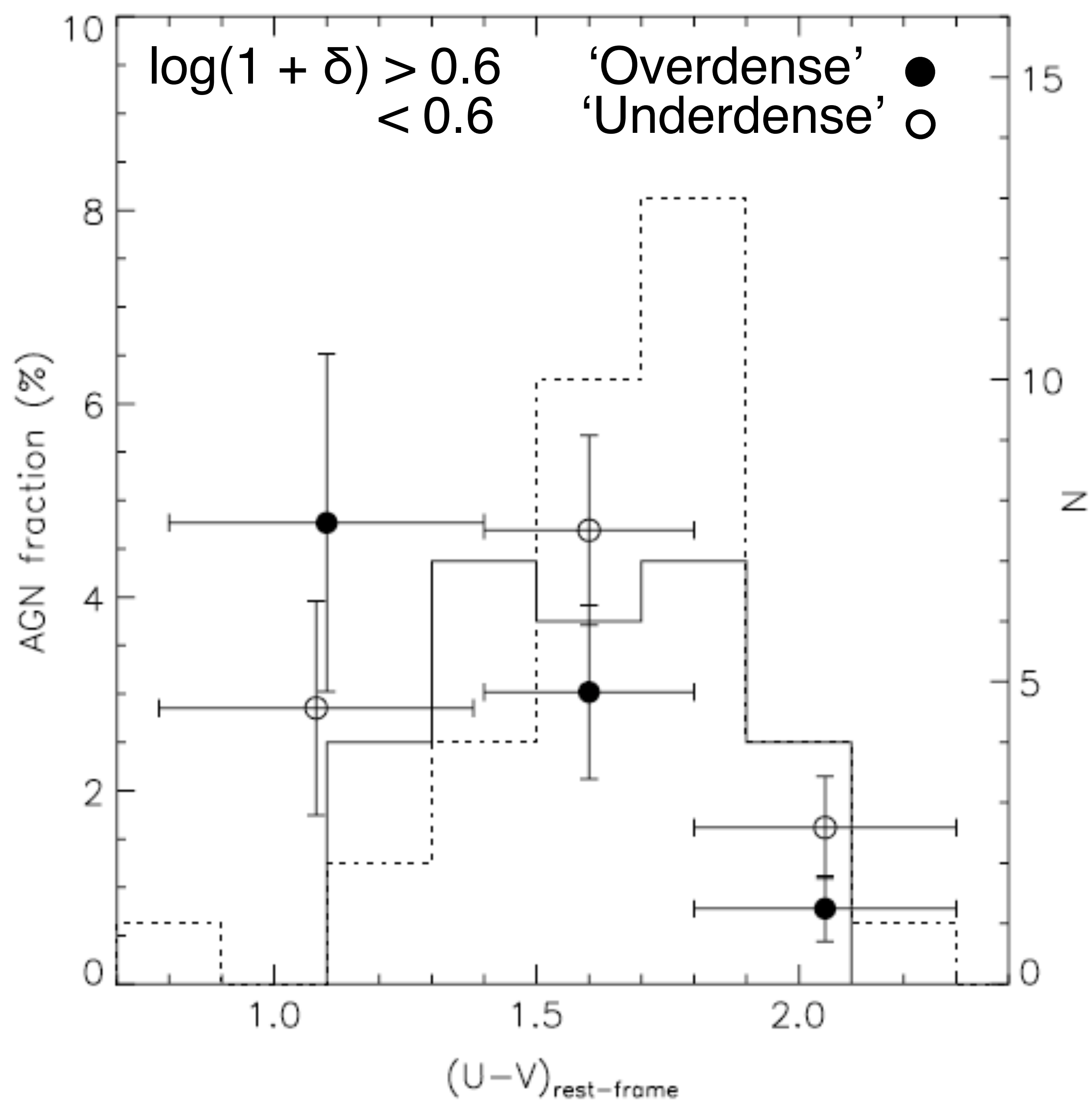
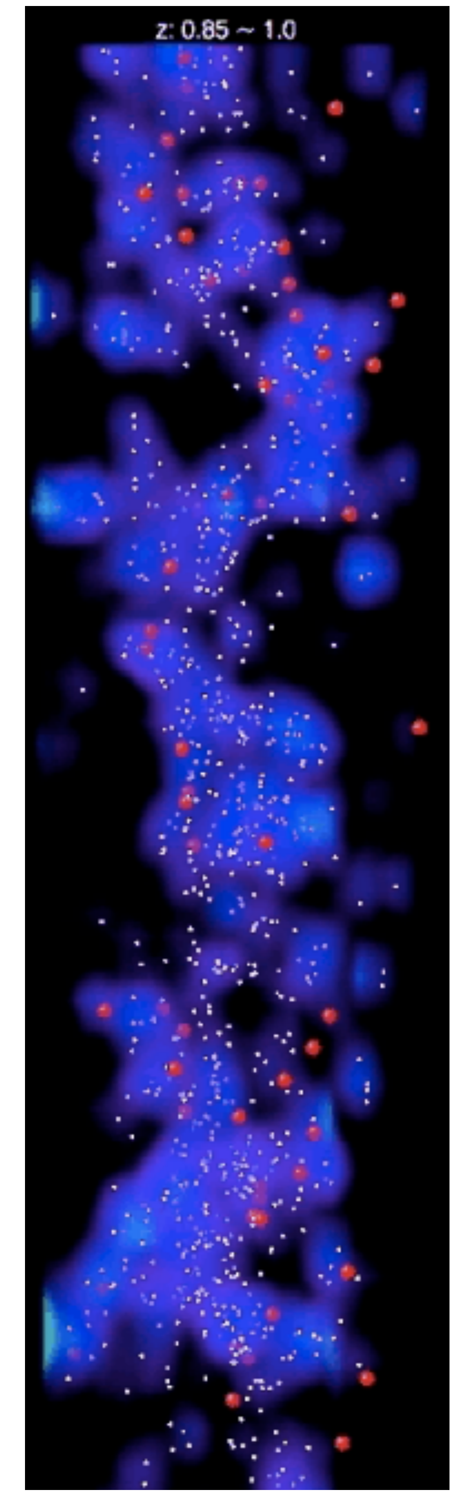


JDS, Kovac, Knobel, Lilly et al. 2009a

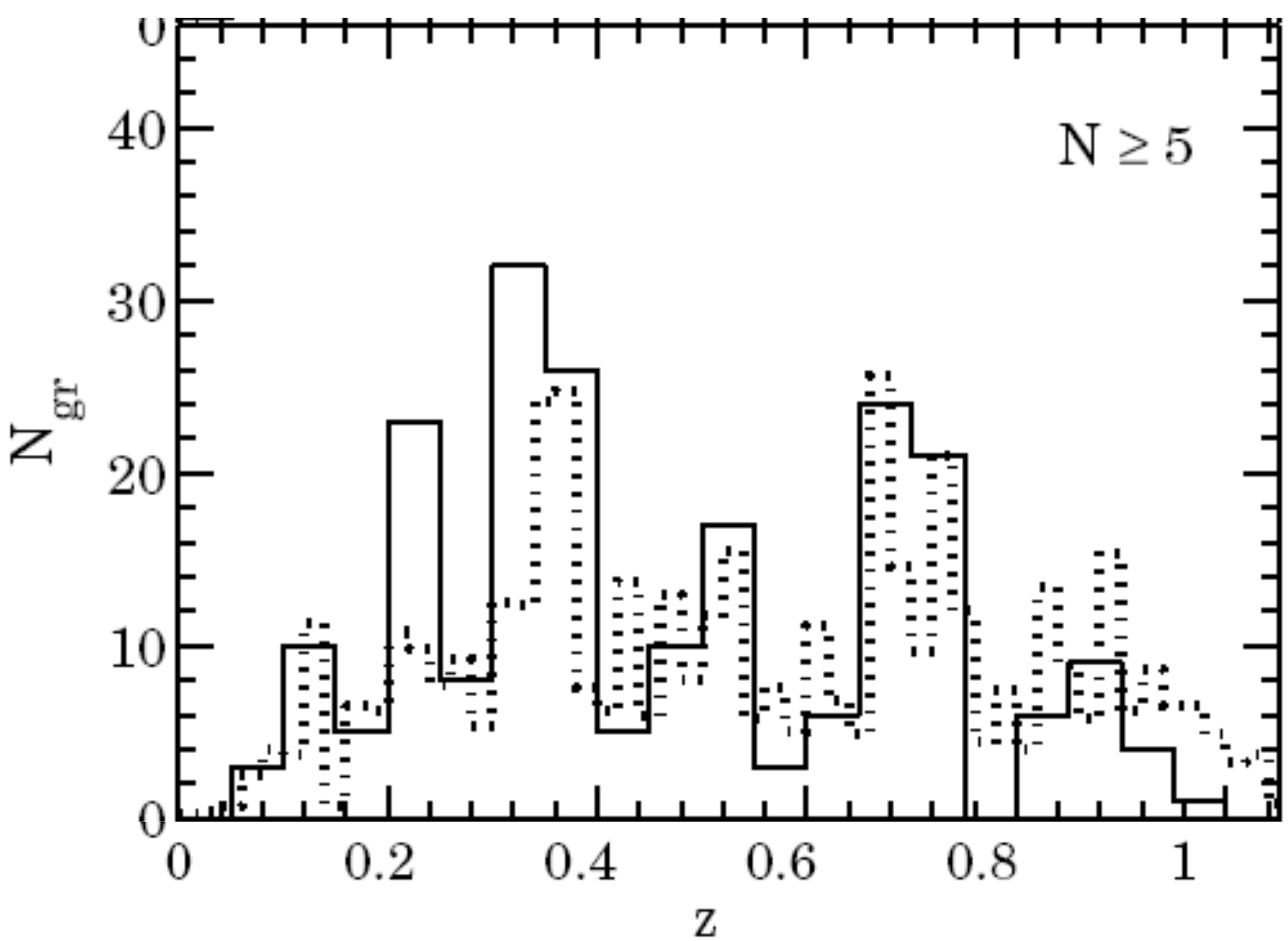


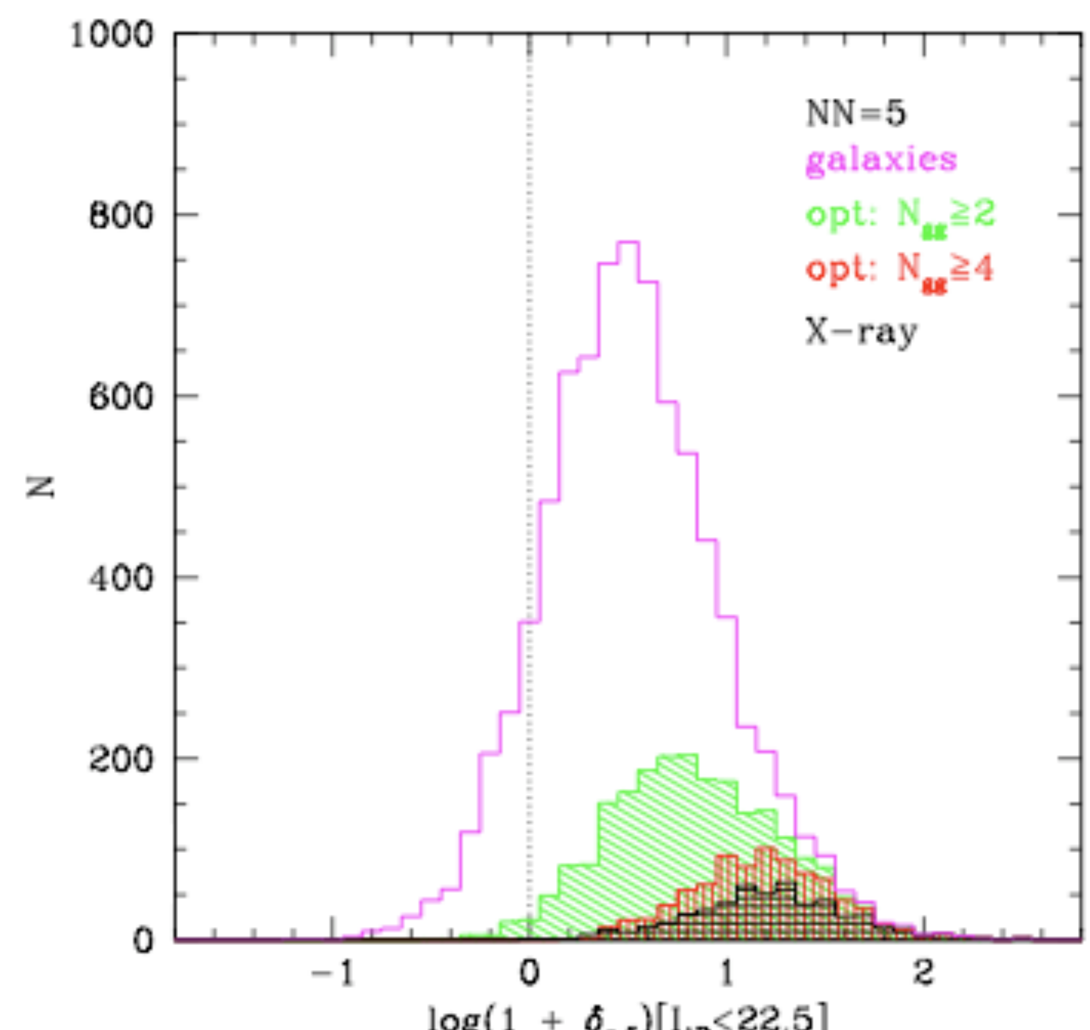
Galaxy groups

Identification using both **friends-of-friends** and **Voronoi-Delaunay-method**

Knobel et al. 2009

- 1681 groups with 5102 members
- 577 groups with 3 or more members (> 85% completeness; >80% purity)
- $10^{12} < M_{halo} < 10^{14} M_\odot$
  (see also Finoguenov et al. 2007; Leauthaud et al. 2010)





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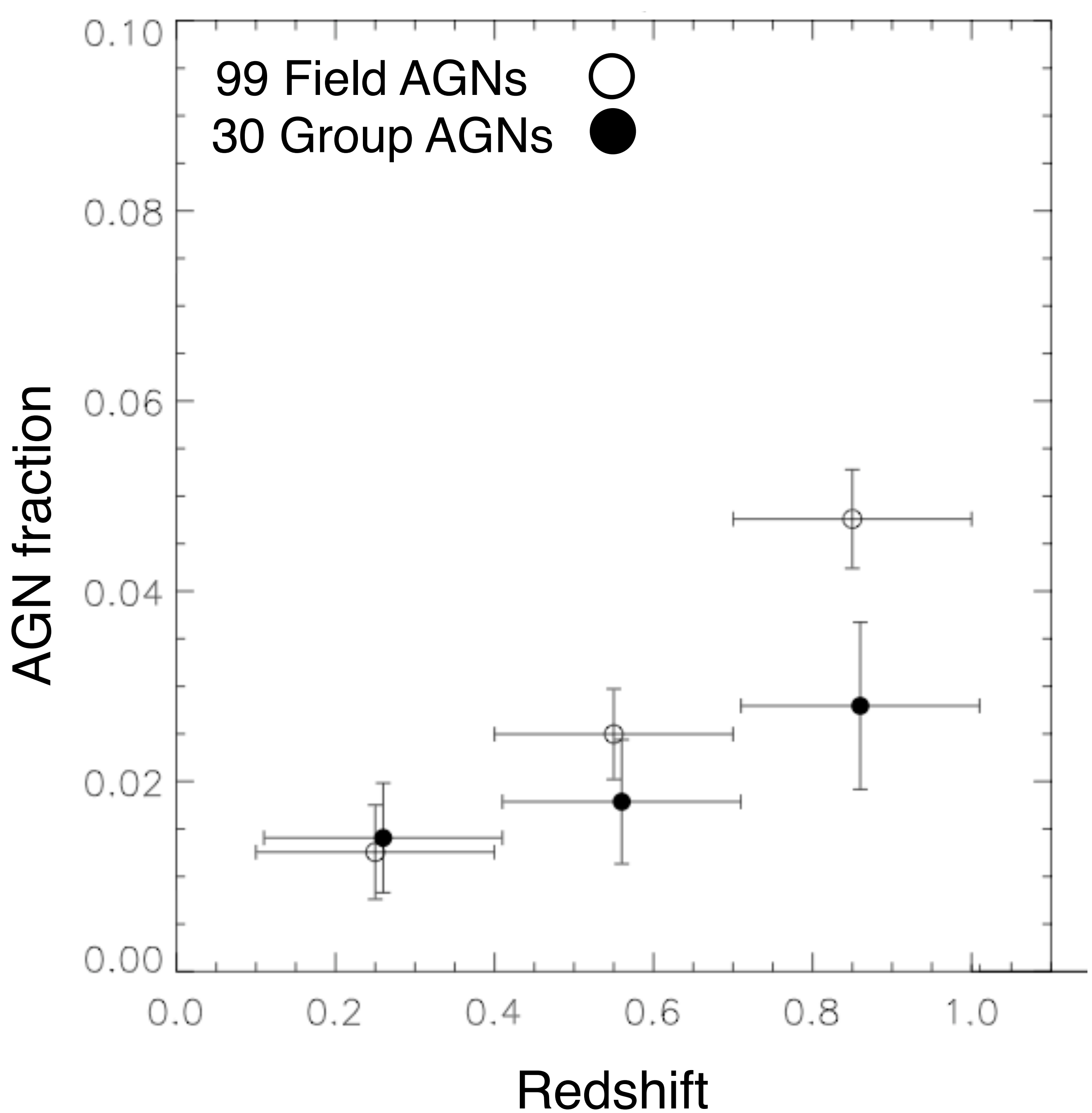
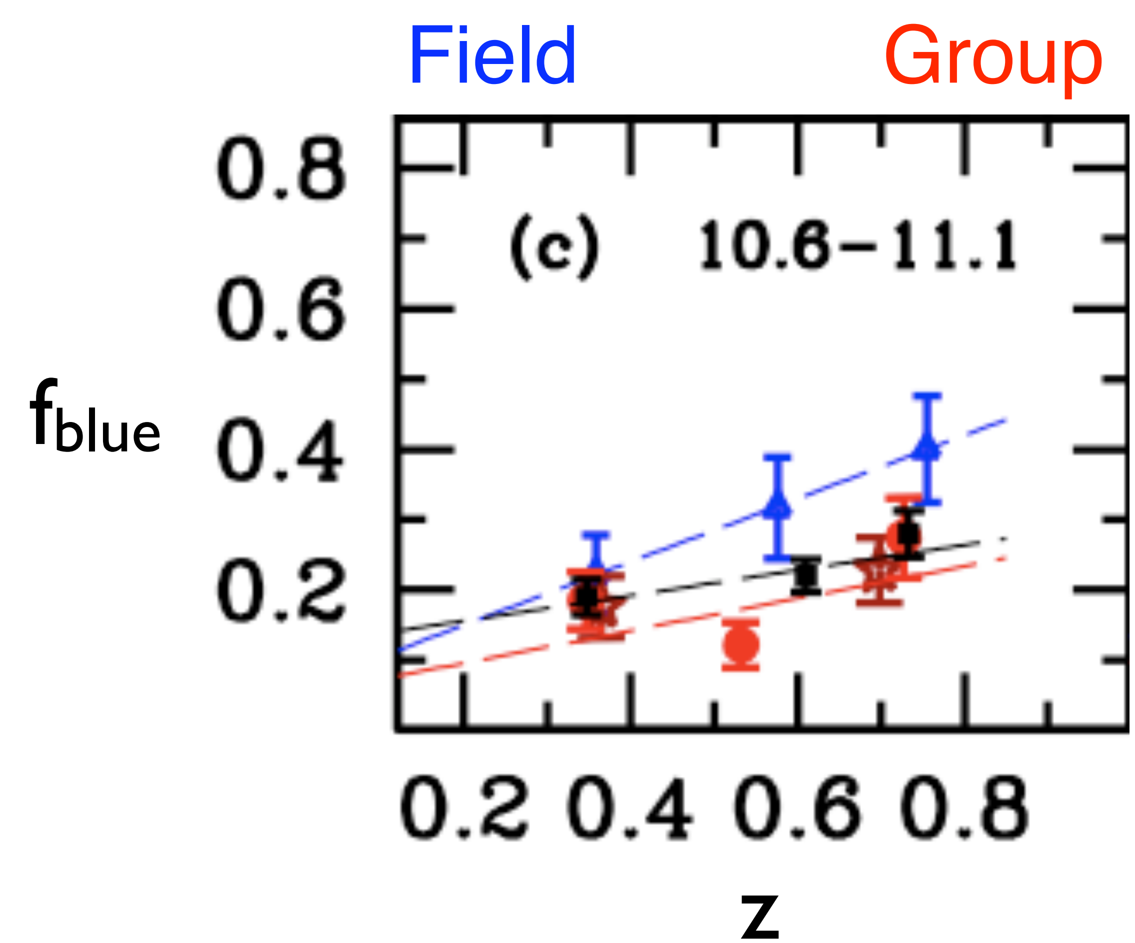




Iovino et al. 2009

Stay tuned for an extension to massive clusters (P. Martini's talk)

Summary

- **Massive, star forming galaxies are more likely to host AGN**

- **Mutual decline in star formation and supermassive black hole accretion**
  - ✦ shifts the evidence for co-evolution scenario to smaller physical scales (i.e., within the same galaxies)

- **Environmental quenching in denser environments**
  - ✦ similar to the impact on star formation
  - ✦ lower levels of AGN activity in galaxy groups
  - ✦ black hole growth may be suppressed in satellite galaxies

Open issues: role of galaxy mergers, luminous quasars, relation to the radio-loud population

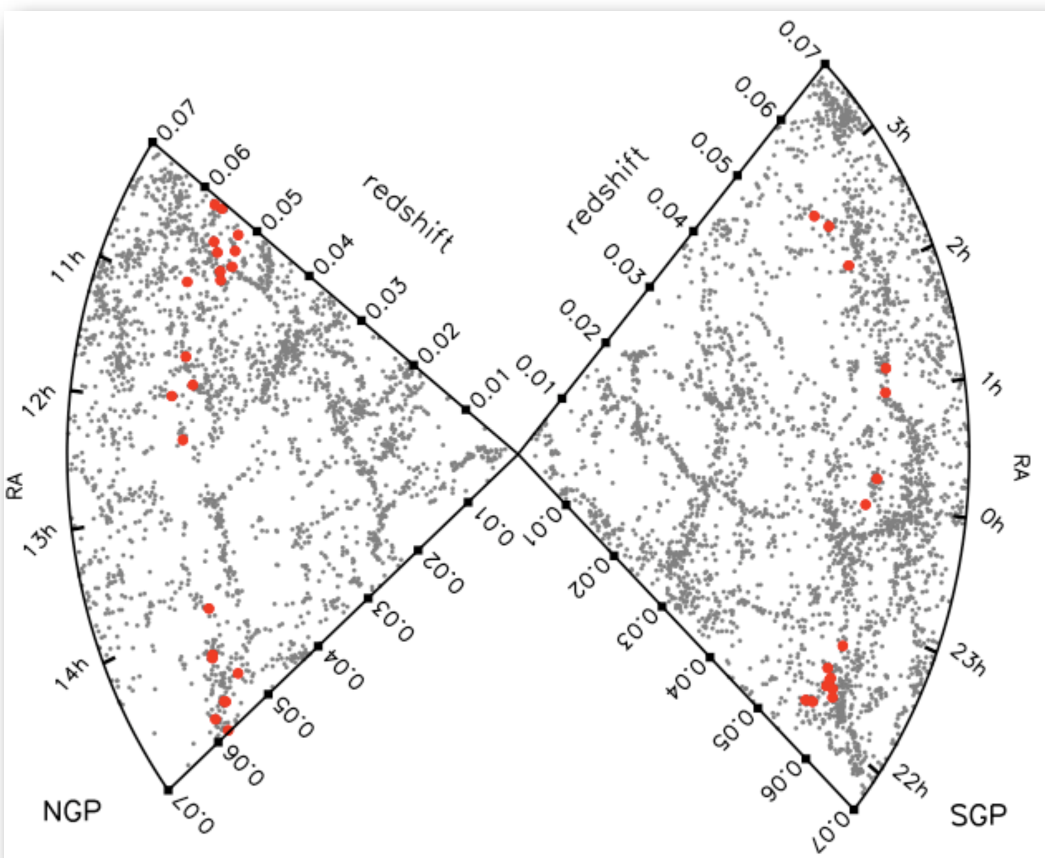
cZENS: a local benchmark of AGN activity in galaxy groups

Chandra imaging of galaxy groups in Zurich ENvironmental Survey

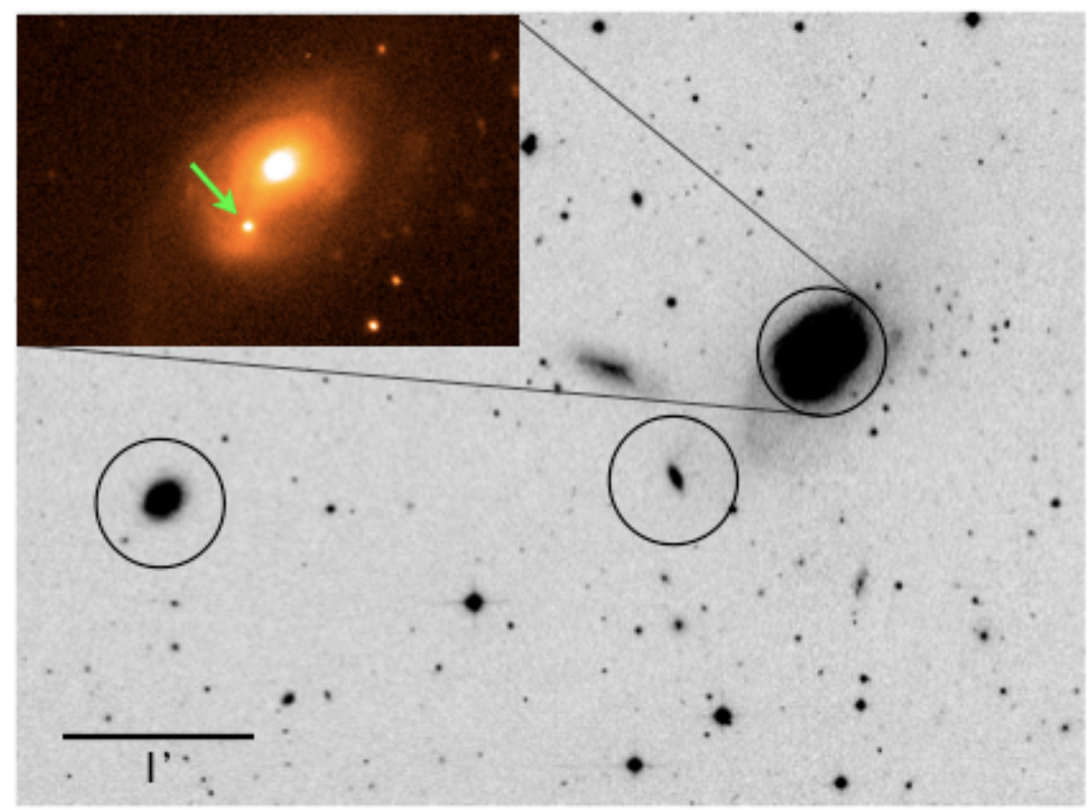
<u>ZENS (PI M. Carollo, A. Cibinel, F. Miniati: ETH-Zurich):</u>

Study of galaxy evolution in 2dF groups (Eke et al. 2004)

- ESO large program: optical imaging of 185 groups @ z~0.05
- $10^{12} < M_{halo} < 10^{14}\ M_{\odot}$
- Chandra imaging (Cycle 11; PI: JDS) of 12 groups w/ >6 members
- AGNs with Lx>10^{41} erg s^{-1} (10 ks per group)
- Radio coverage (NVSS and FIRST)



XMM-Newton followup (PI: F. Miniati-ETH)



Carollo et al. 2010, Cibinel et al. 2010, in preparation

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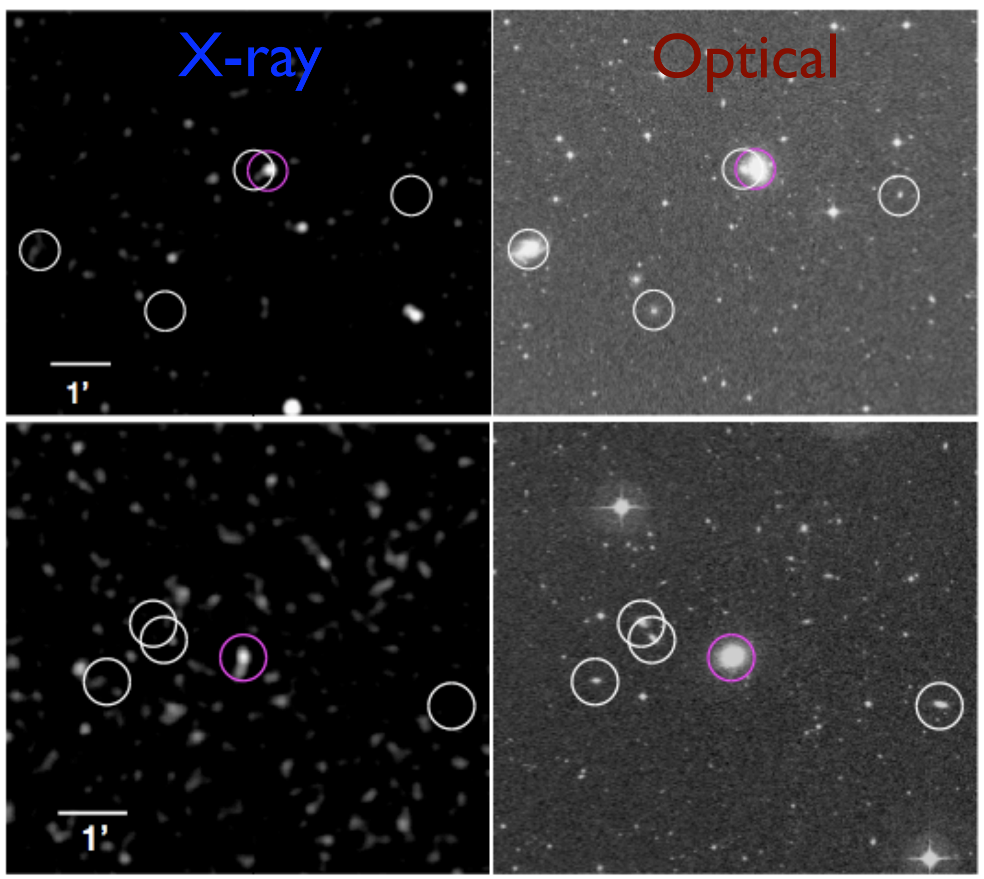

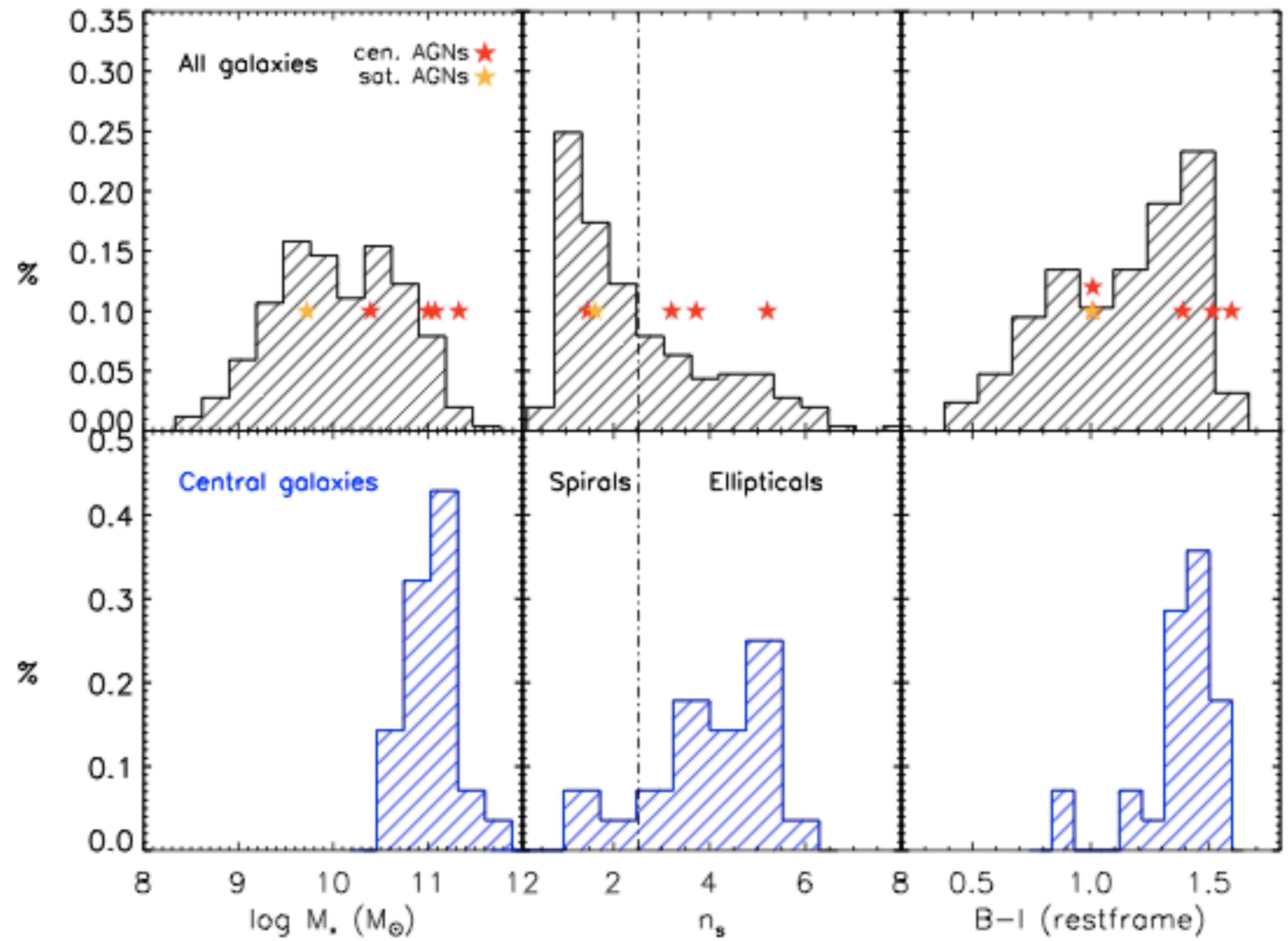

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