Environmental impact on the growth of supermassive black holes up to z ~ 1

John Silverman
(Kavli IPMU)
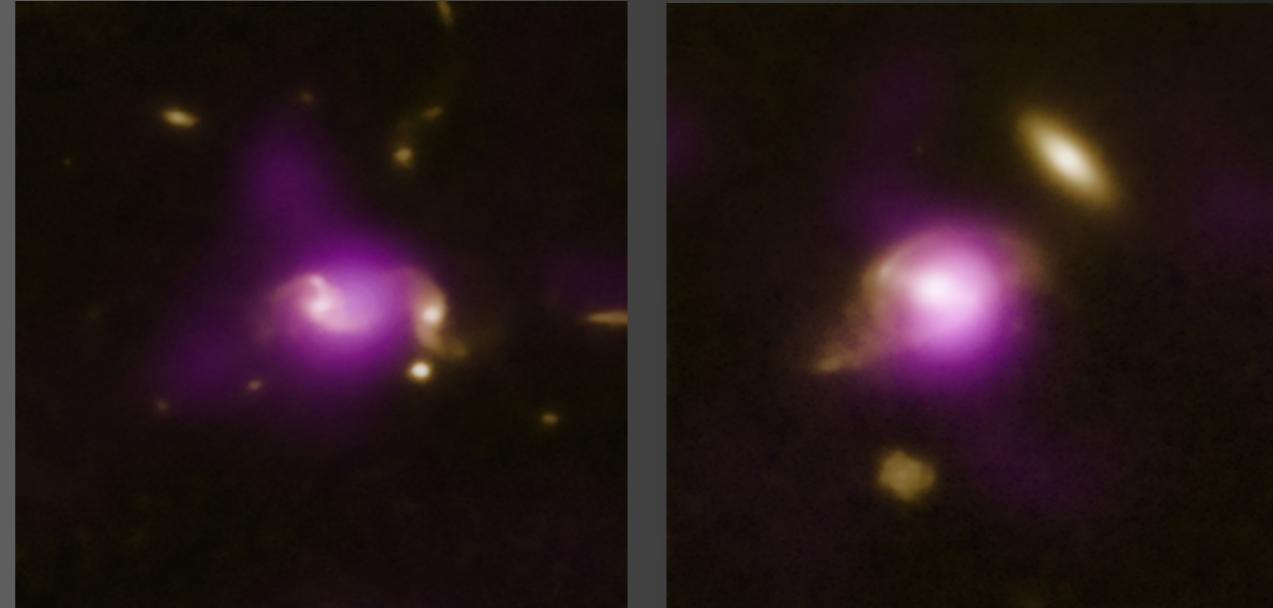
Teams
(z/c/x) COSMOS
Zurich Environmental Study

What environments are most conducive for supermassive black hole growth?

- AGNs prefer massive star-forming (SF) galaxies

Kauffmann et al. 2003; JDS et al. 2009; Jahnke et al. 2004; Mainieri et al. 2011; Mullaney et al. 2011; Rosario et al. 2012; Netzer et al. ; Ammons et al. 2013, etc

- Do AGN exhibit similar environmental trends as SF galaxies?

(e.g. Kauffmann et al. 2003; Arnold, Martini et al. 2009)

- environments: local (mergers) vs. large scale (group-scale halos)

Tools out to z ~ 1

large (spectroscopic) surveys up to z~1
(COSMOS, ZENS, SDSS)

- galaxies (M_*, SFRs)

- AGN/QSOs (M_{BH}, dM_{BH}/dt, M_*, SFR)
[X-ray selection; Chandra and XMM COSMOS]
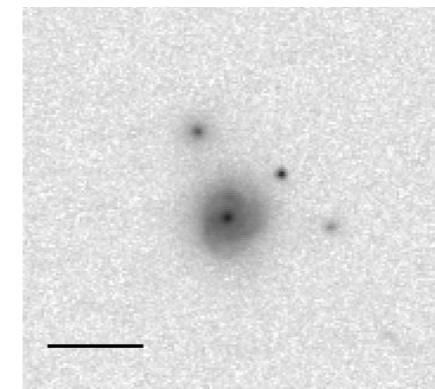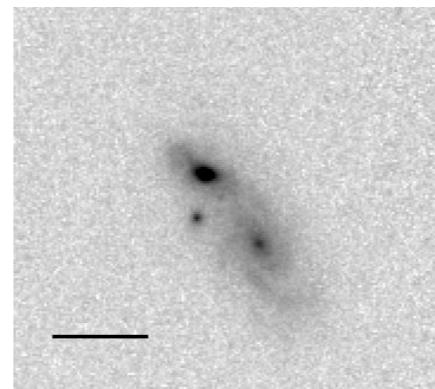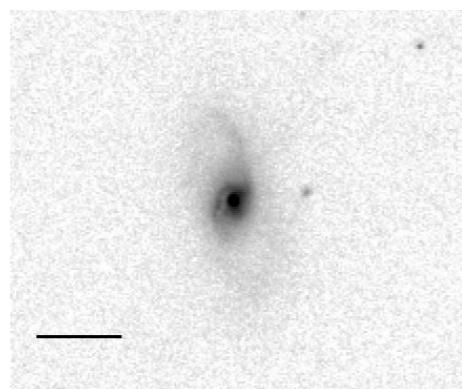
- environments (LSS, groups, pairs)

Large-scale environment of AGNs

AGNs in zCOSMOS 10k spectroscopic catalog

$42.5 < \log Lx < 43.7$

Massive galaxies (M > 10^{11} M$_\odot$) up to z ~1

AGN

All galaxies

AGN

JDS, Kovac, Knobel, Lilly et al. 2009a
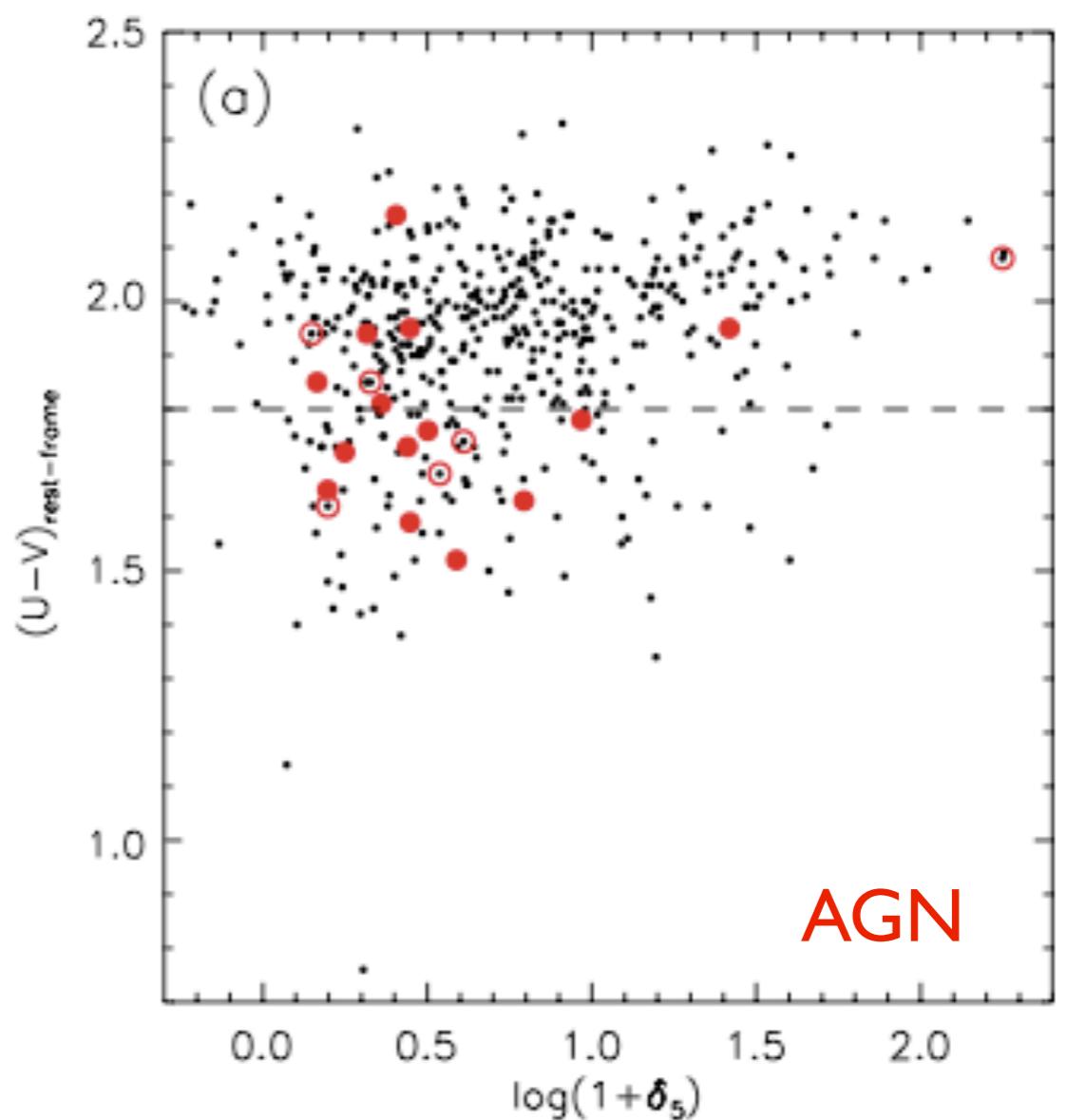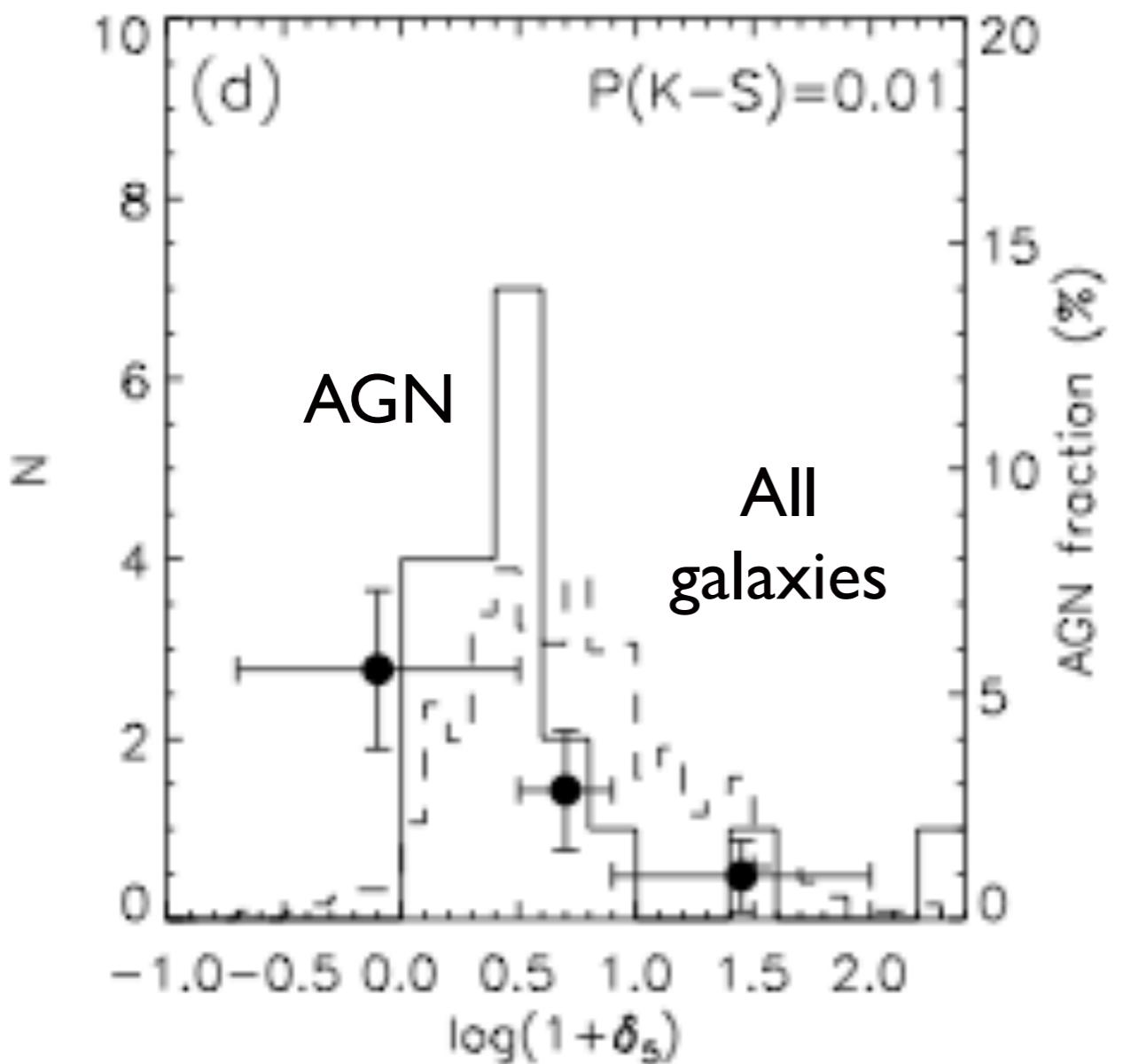
Zurich Environmental Survey (ZENS; PI Carollo)

A detailed study of galaxies groups at z ~ 0.06

- 141 2dFGRS *optically-selected* groups (Eke et al. 2004)

- 1630 galaxies $b_j < 19.45$
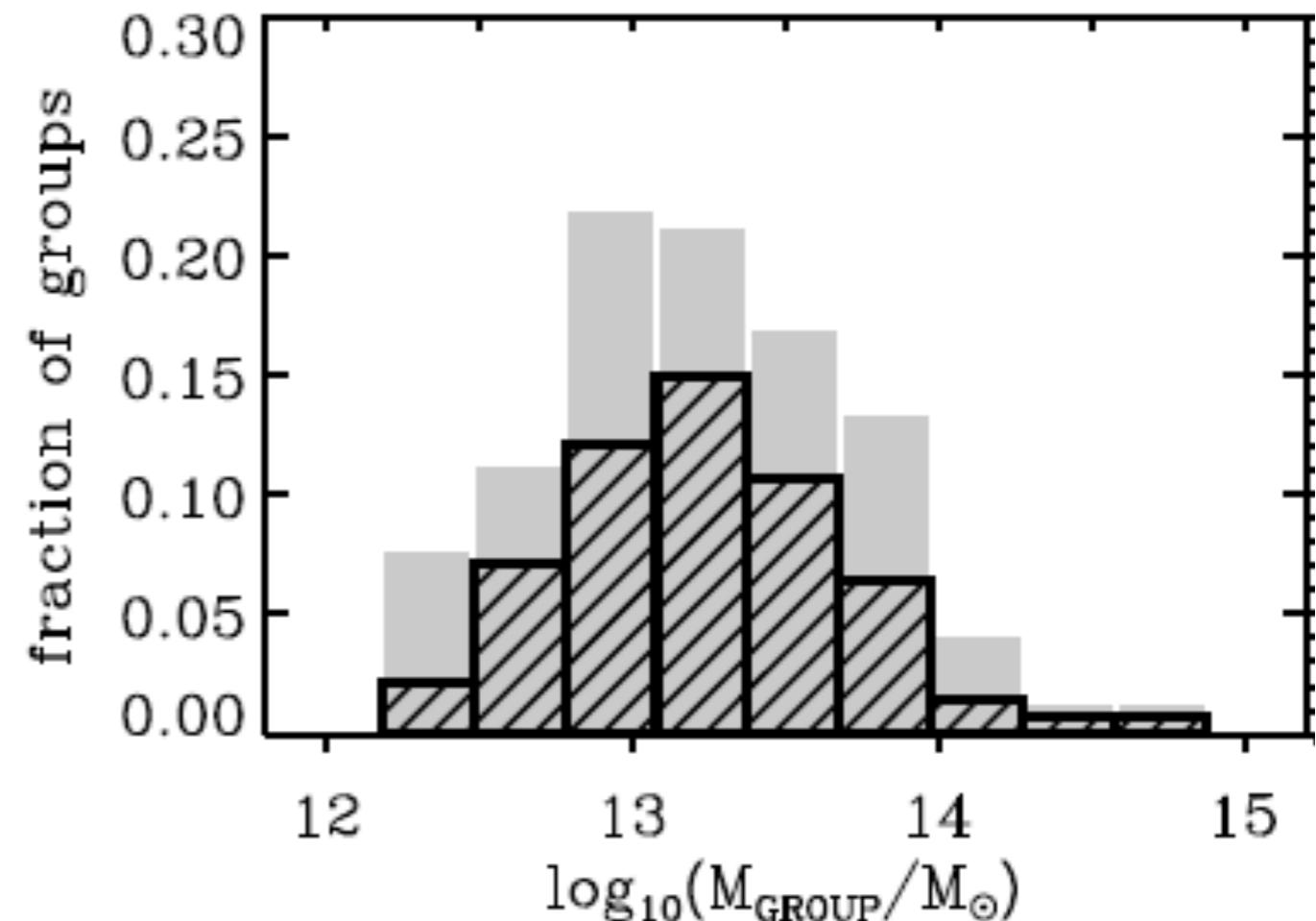
ZENS provides:
- Environmental indicators: (i) Central vs. satellite, (ii) r/r200, (iii) δ_5, (iv) $\delta_{LSS,}$
- Structural characterization of surface brightness distribution (ESO/WFI B,I imaging)
- morphological classification
- stellar masses, SFRs, color gradients, etc

Carollo et al. 2012; Cibinel et al. 2012a,b

X-ZENS: X-ray AGN study of nearby galaxy groups


-19 2df groups

(> 6 spectroscopic members)

-Chandra and XMM imaging

- 22 X-ray detections out of 177 galaxies

$$40 \lesssim \log L_x \lesssim 42$$

JDS, Miniati, Finoguenov, Carollo et al. 2014

X-ZENS: X-ray AGN study of nearby galaxy groups

2PIGG-s1520

1'
(63.4 kpc @ z = 0.0534)

2PIGG-n1606

1'
(65.4 kpc @ z = 0.0562)

2PIGG-s1571

1'
(66.1 kpc @ z=0.057)
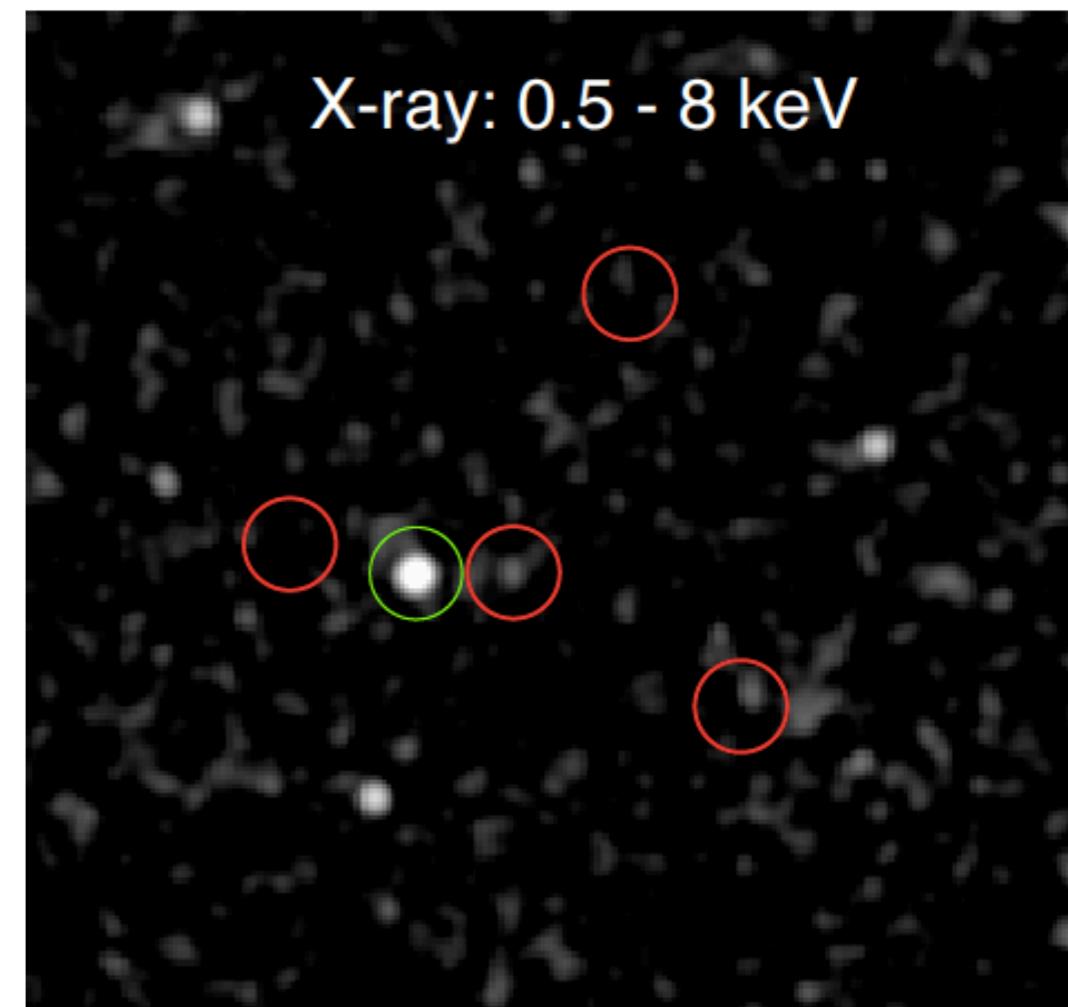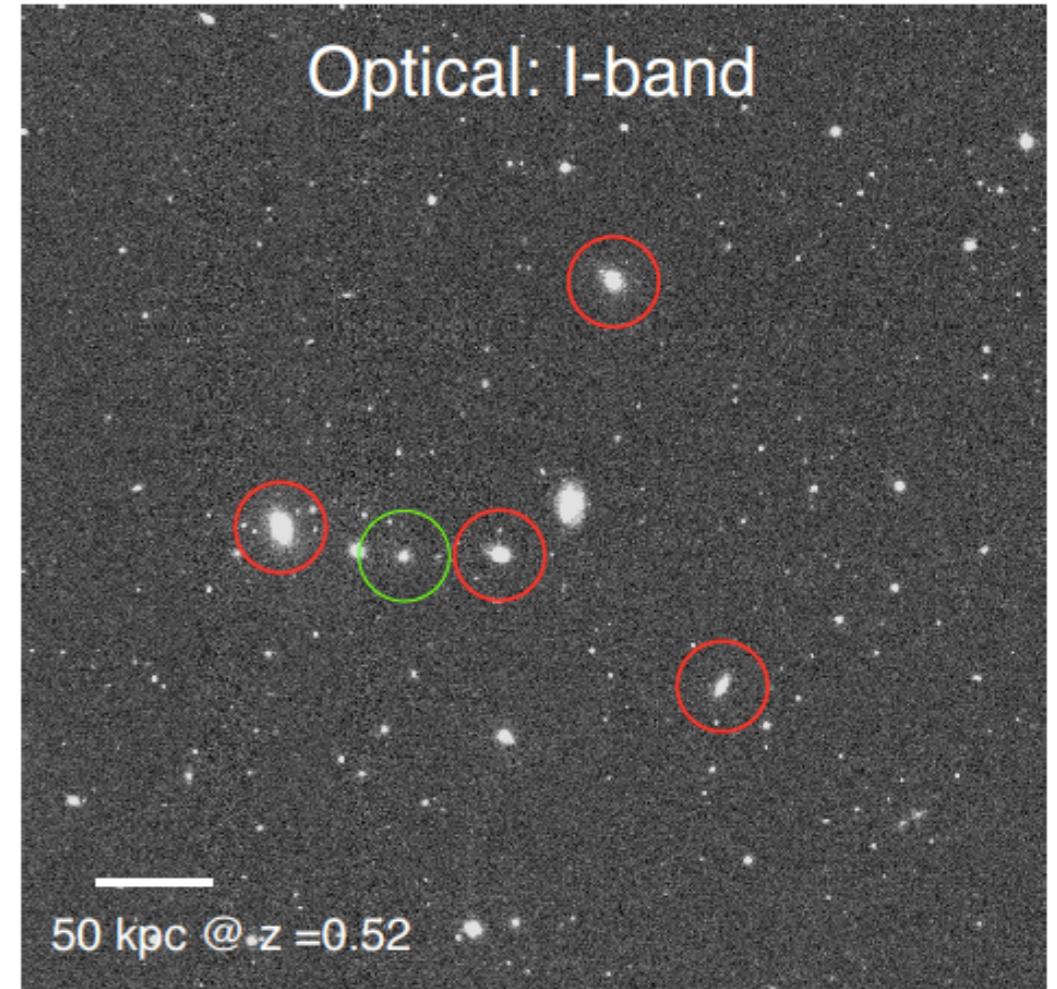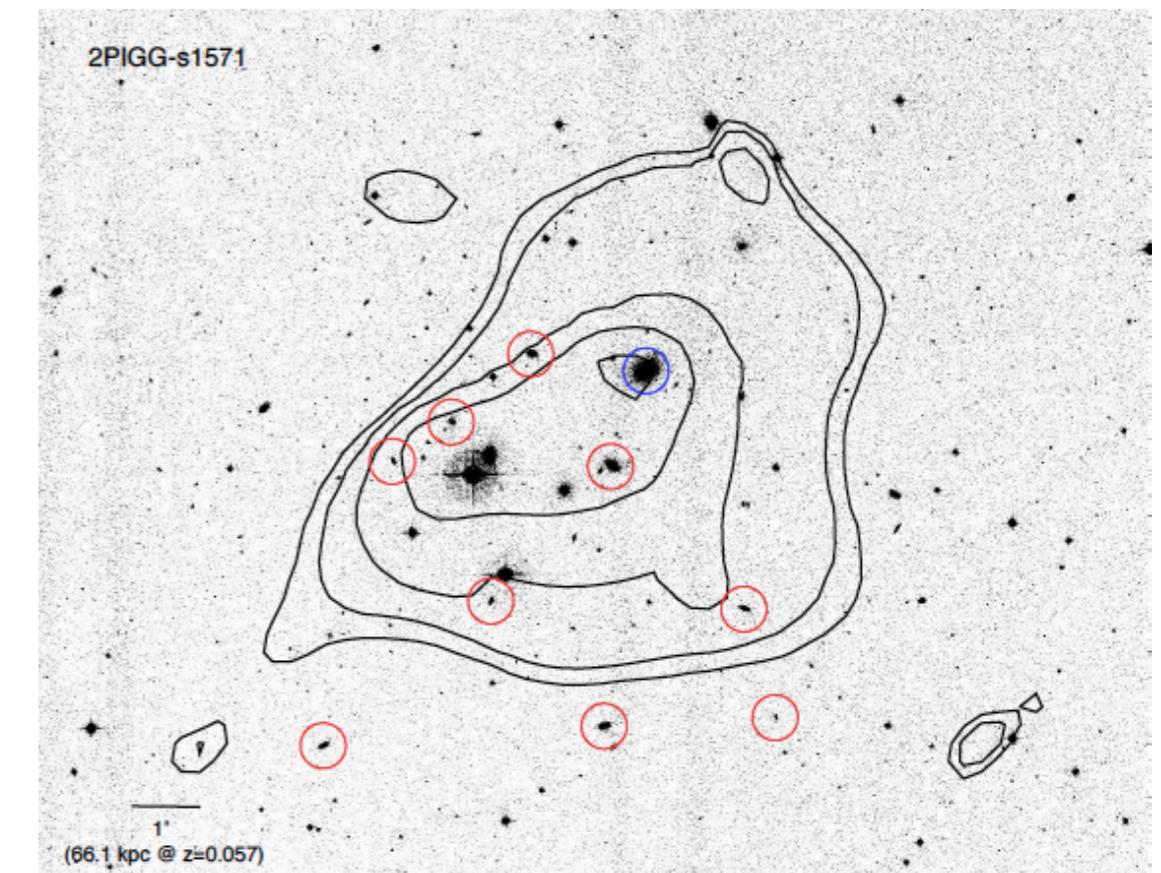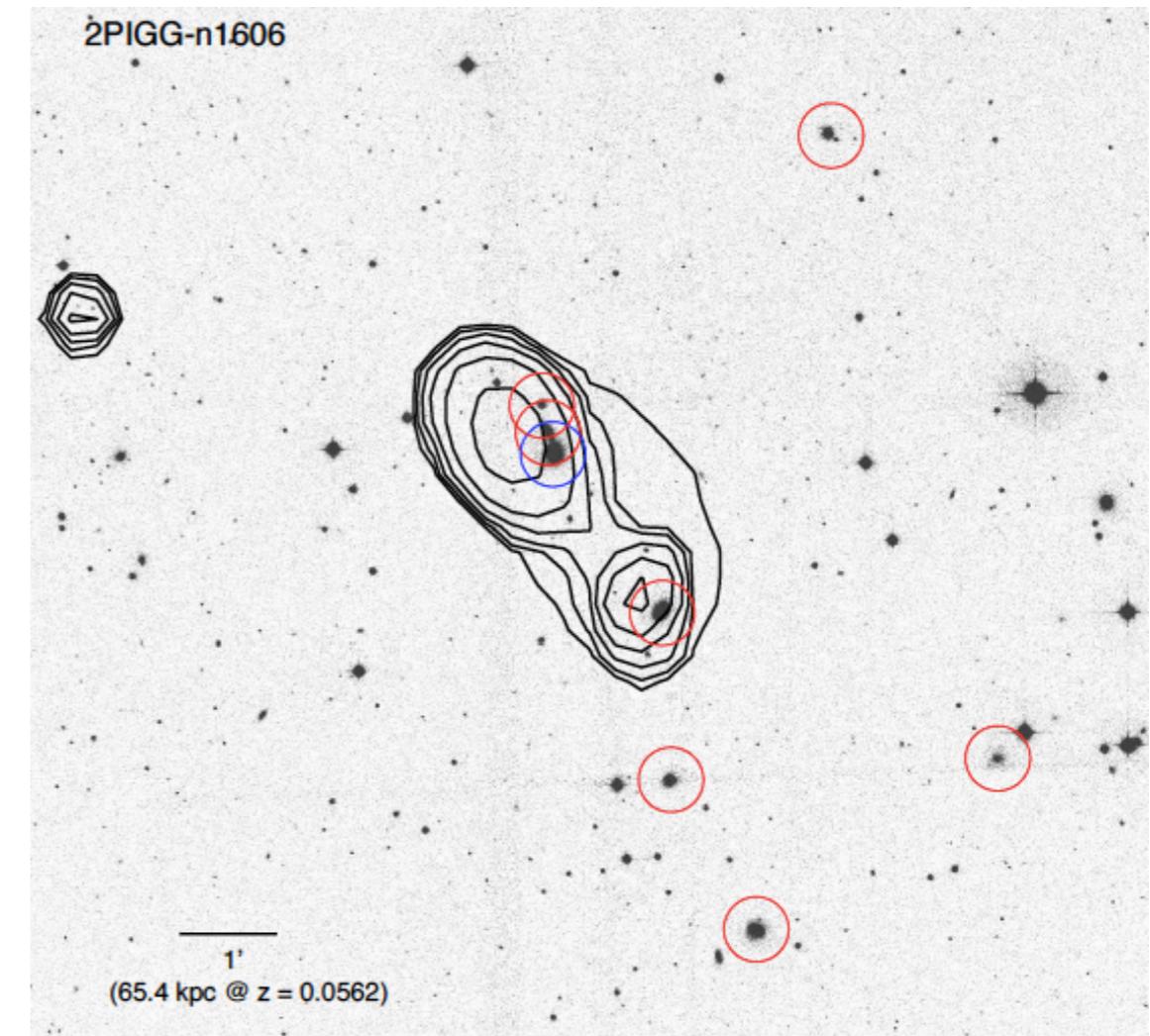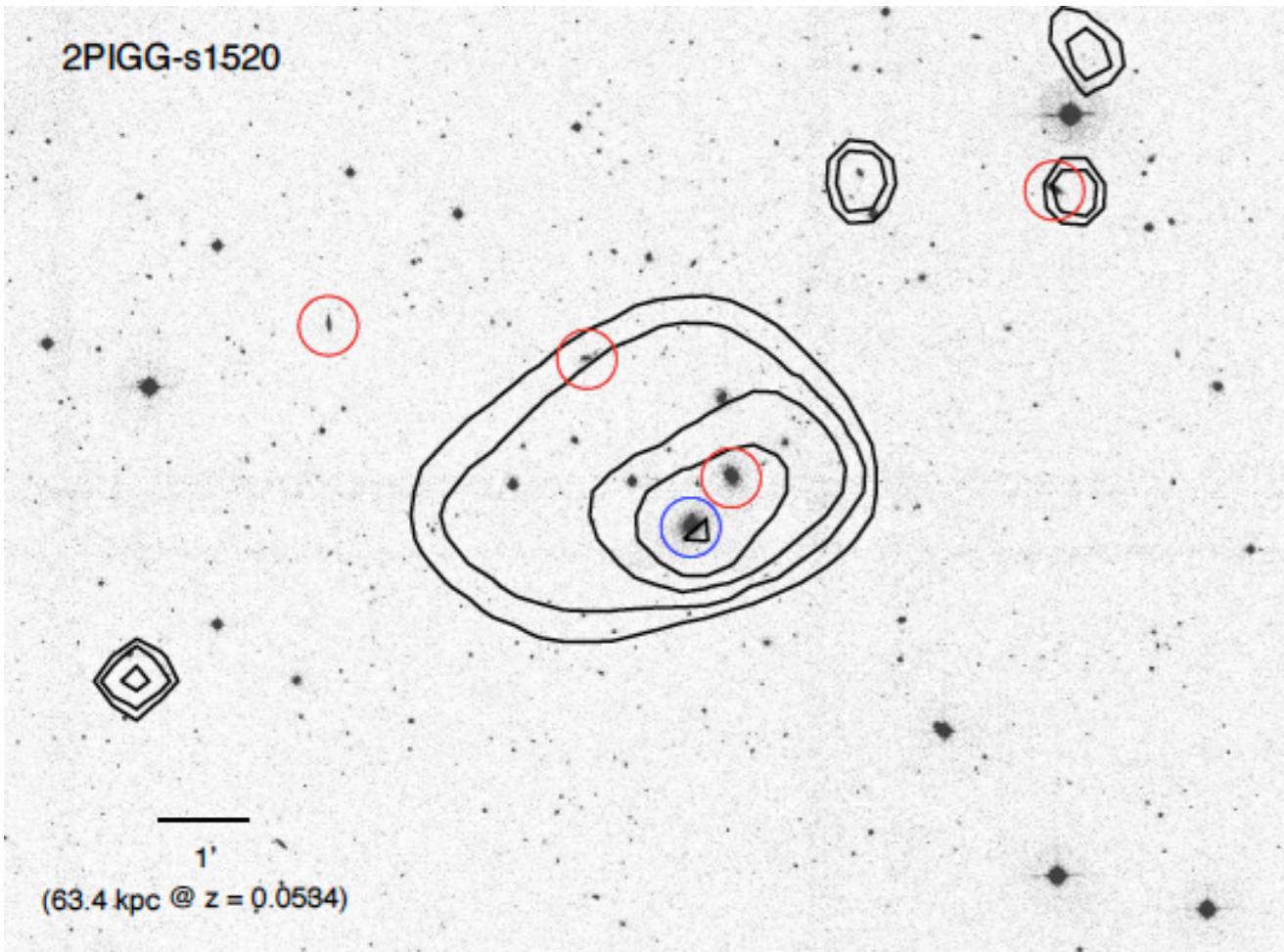
Miniati, Finoguenov, JDS,
Carollo et al. 2014

X-ZENS: X-ray AGN study of nearby galaxy groups

Possibly AGN suppression in satellite galaxies

JDS, Miniati, Finoguenov, Carollo et al. 2014
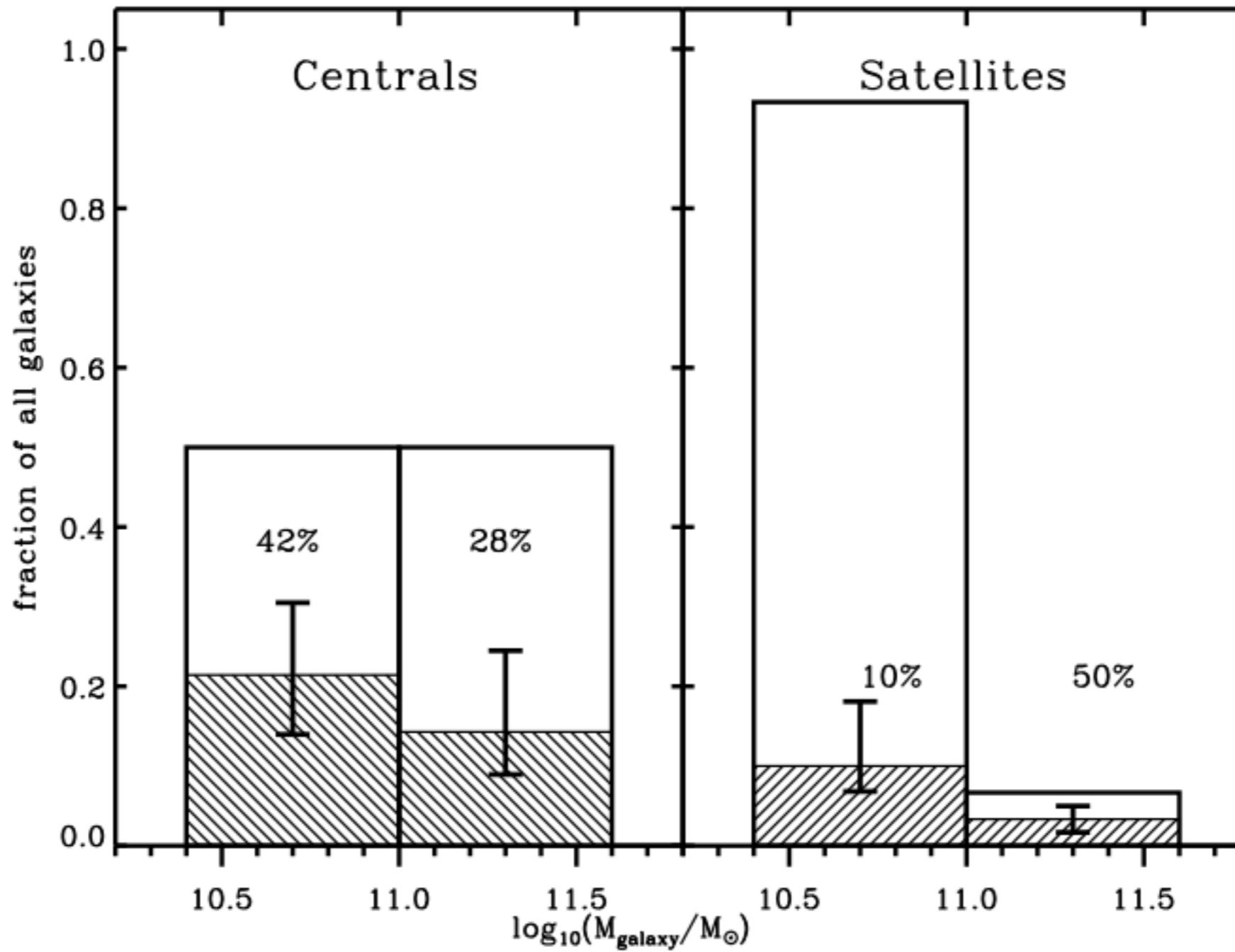
(see Li, Kauffmann et al. 2006;
Martini et al. 2007; Fassbender et al.
2012; Richardson et al. 2013)

# AGNs in galaxy mergers: X-ray selected

Chandra Deep Fields
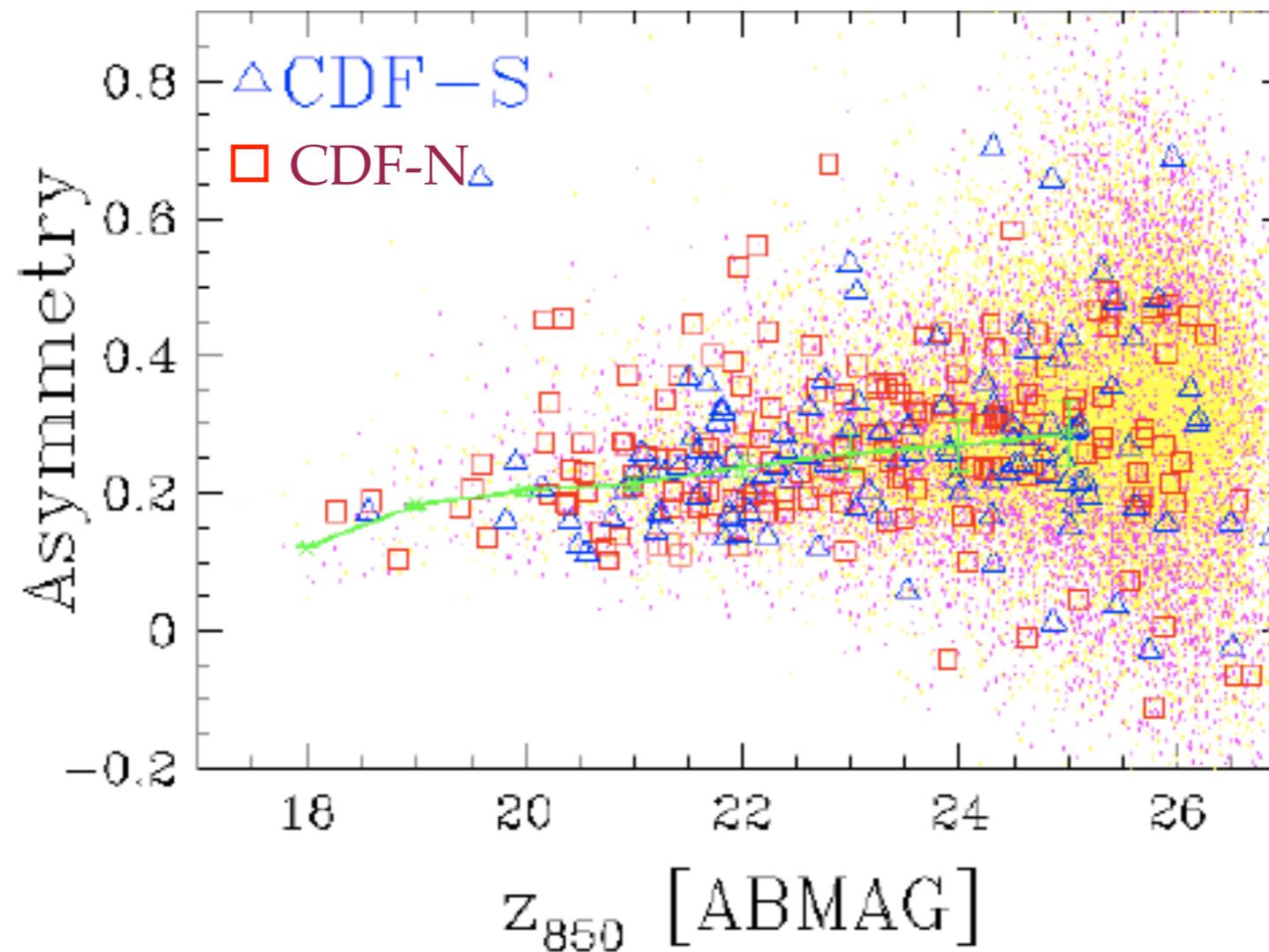
Grogin et al. 2005

No AGN - merger connection

Gabor et al. 2009; Cisternas et al. 2010; Kocevski et al 2011

Local environmental factors (Galaxy mergers)

Kinematic pairs (zCOSMOS)
(~25-150 kpc separations)

Double nuclei (COSMOS)
(2.5-8 kpc separations)
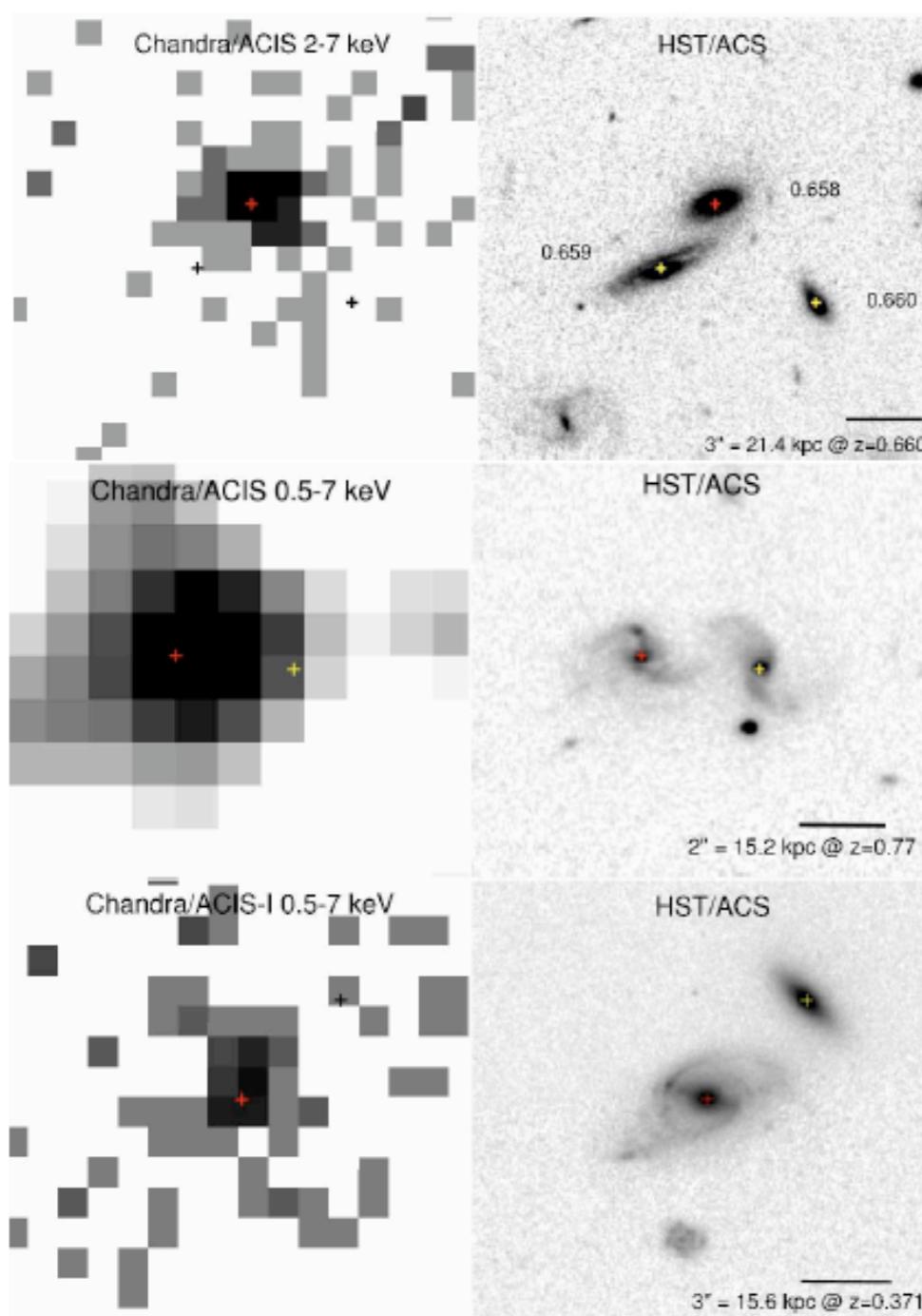
38/562 AGN/Control

JDS, Kampczyk et al. 2011
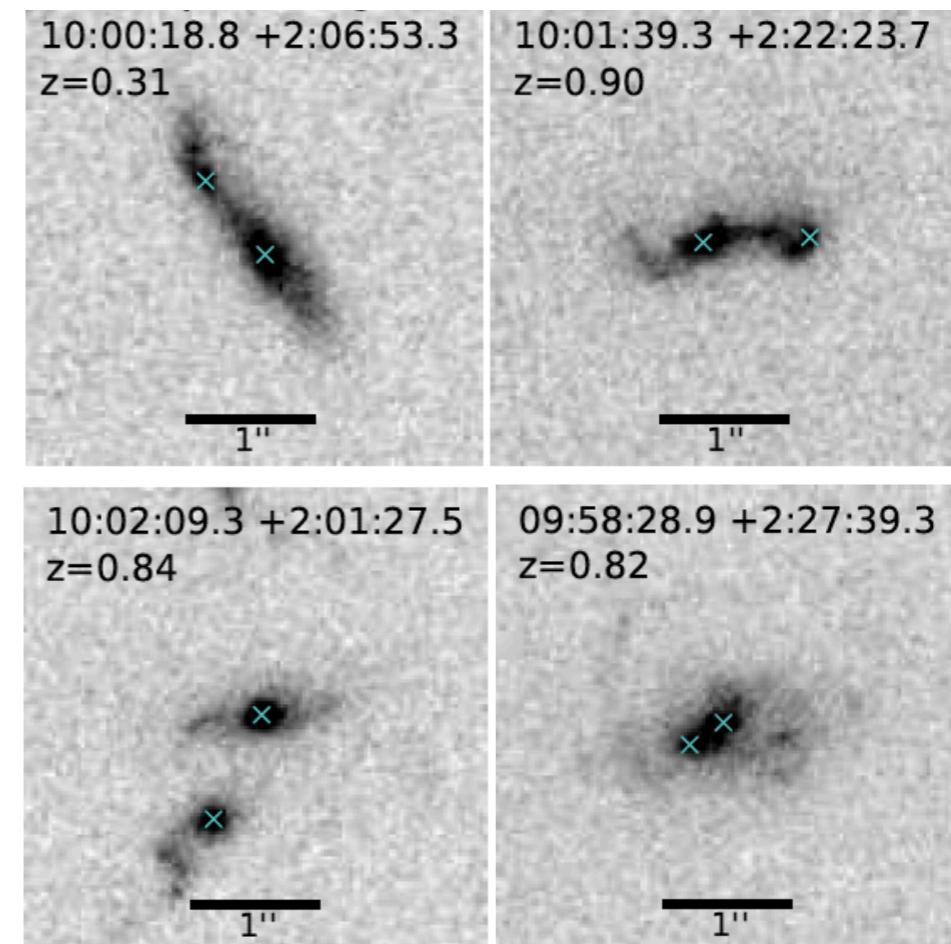
2047/44164 (4.6%) galaxies with double nuclei
(i < 23)

Lackner C. (IPMU) , JDS et al. 2014

Double nuclei: merger rates and evolution
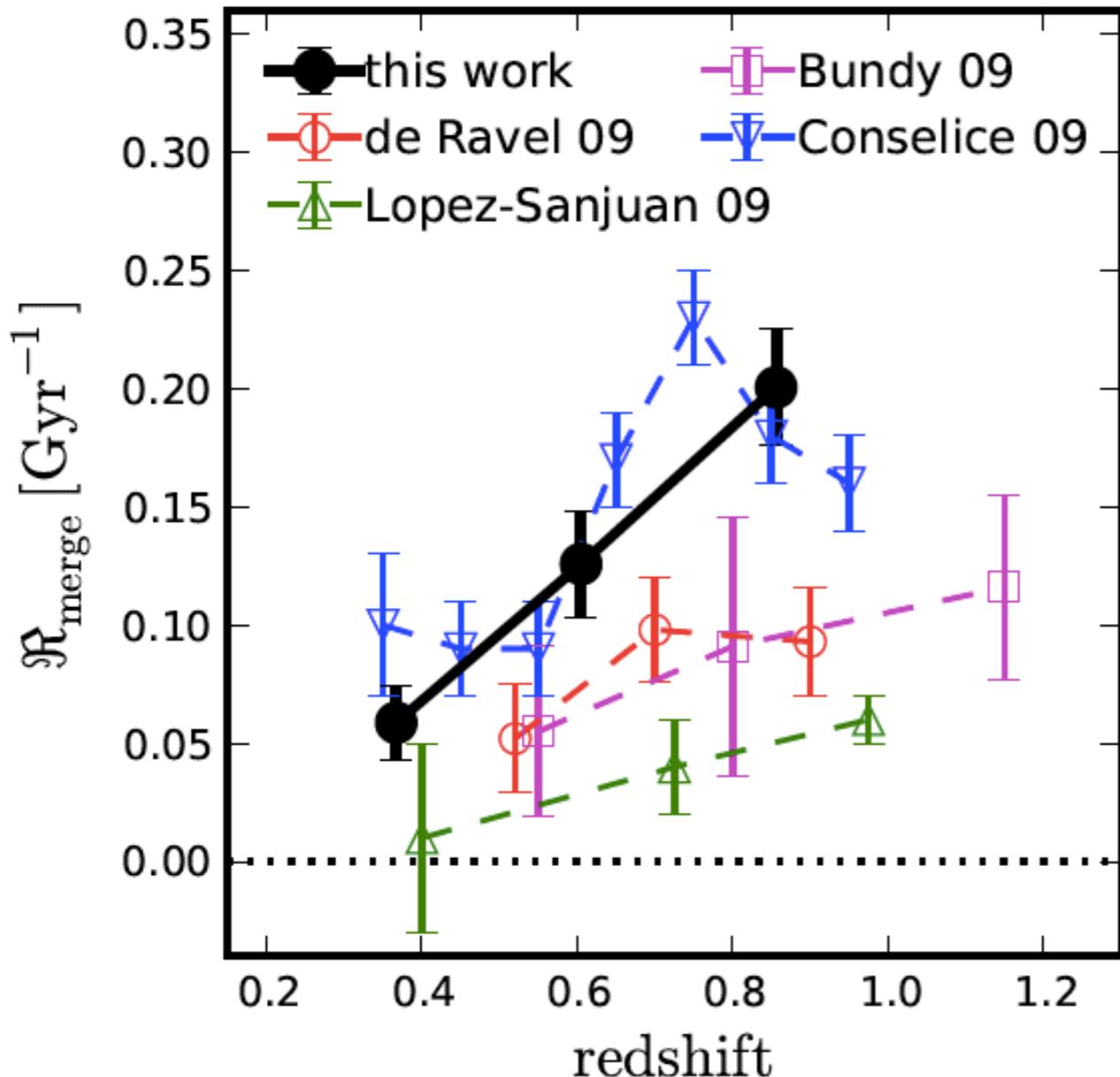
$$\Re_{merge} = f_{merge}\langle\frac{1}{T_{obs}}\rangle \sim (1+z)^{3.8\pm0.9}$$

Consistent with dark matter simulations
(e.g., Fakhouri et al. 2010; Guo & White 2008)
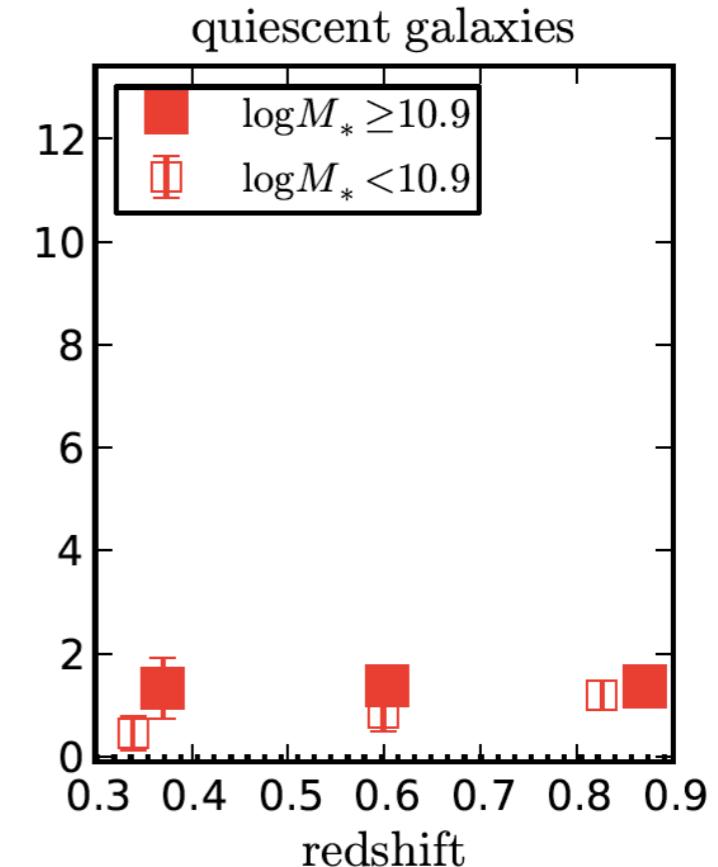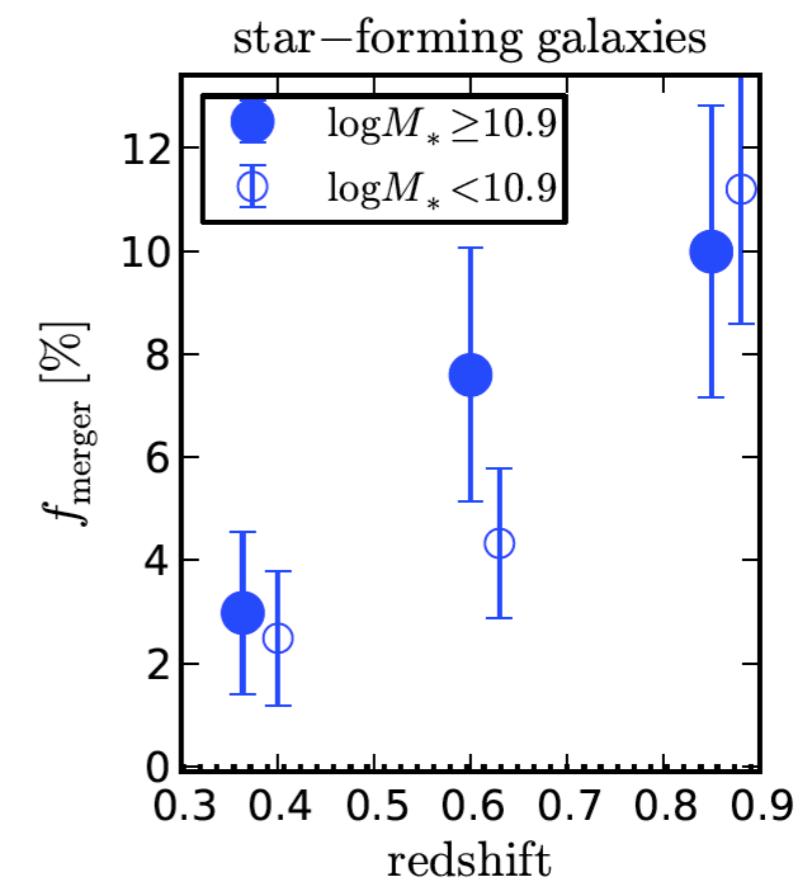
Lackner, JDS et al. 2014

# AGN fraction in merging and interacting galaxies
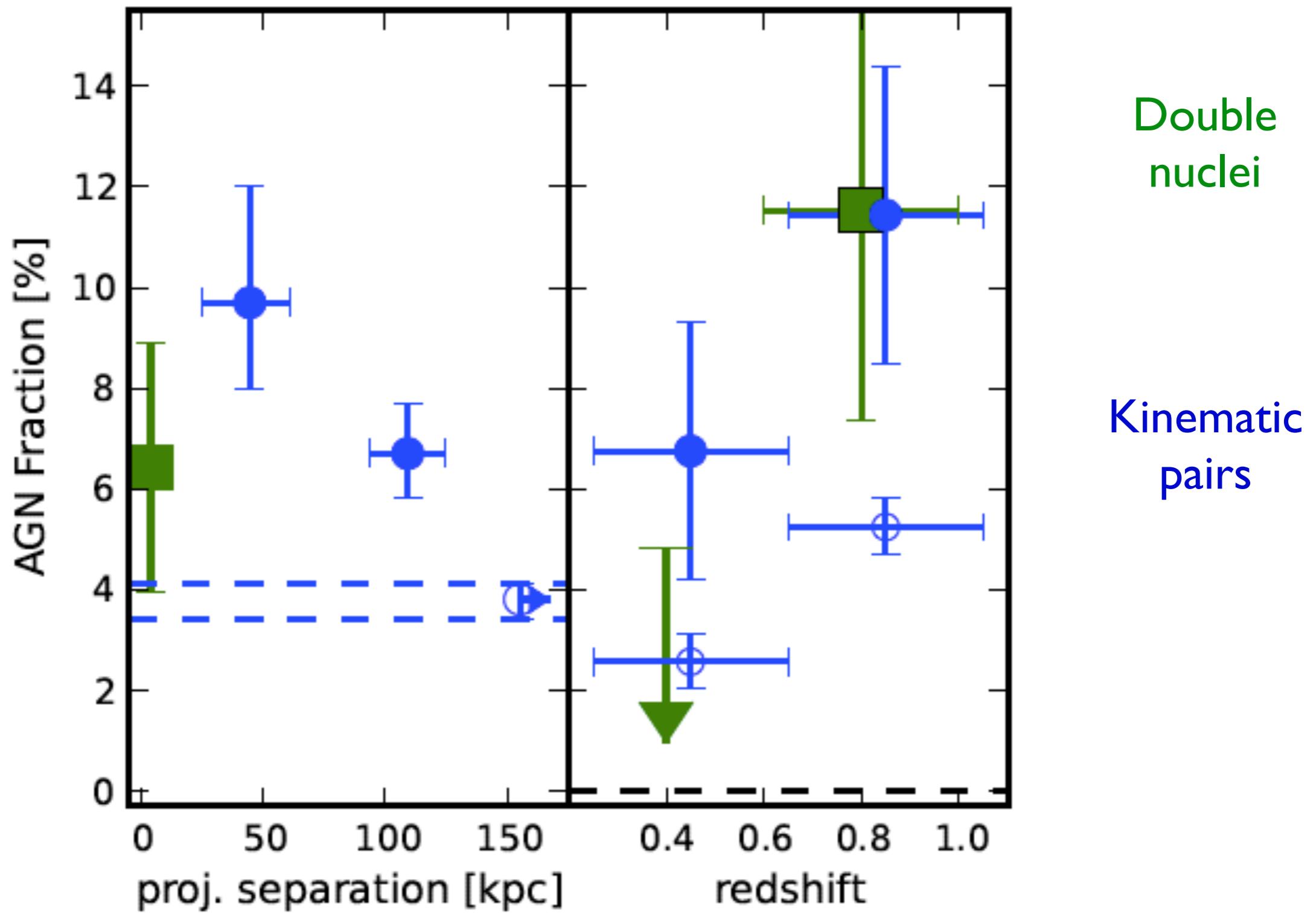
~2x boost in both SFR and AGN activity
(similar to kinematic pairs; See Kampczyk et al. 2013; JDS et al. 2011)

Disentangling local and large-scale influences on SDSS AGN

Emil Khabiboulline (undergrad @ Cal Tech), Charles Steinhardt (SSC, Caltech),
JDS, Sara Ellison & Trevor Mendel
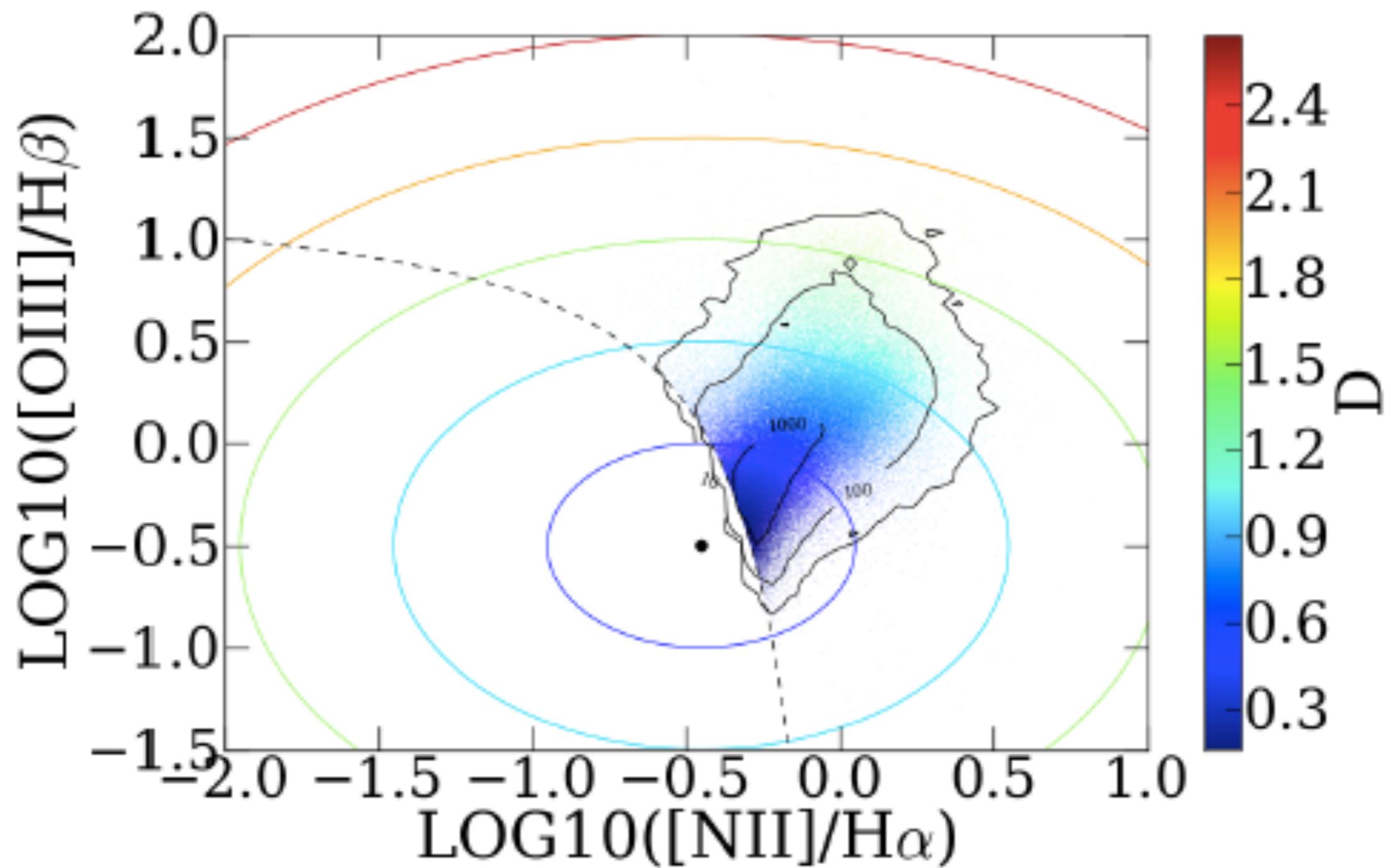
Kauffmann et al. 2003; LaMassa et al. 2012

Disentangling local and large-scale influences on SDSS AGN

Emil Khabiboulline (undergrad @ Cal Tech), Charles Steinhardt (SSC, Caltech),
JDS, Sara Ellison & Trevor Mendel

Galaxy pairs

Clusters/groups
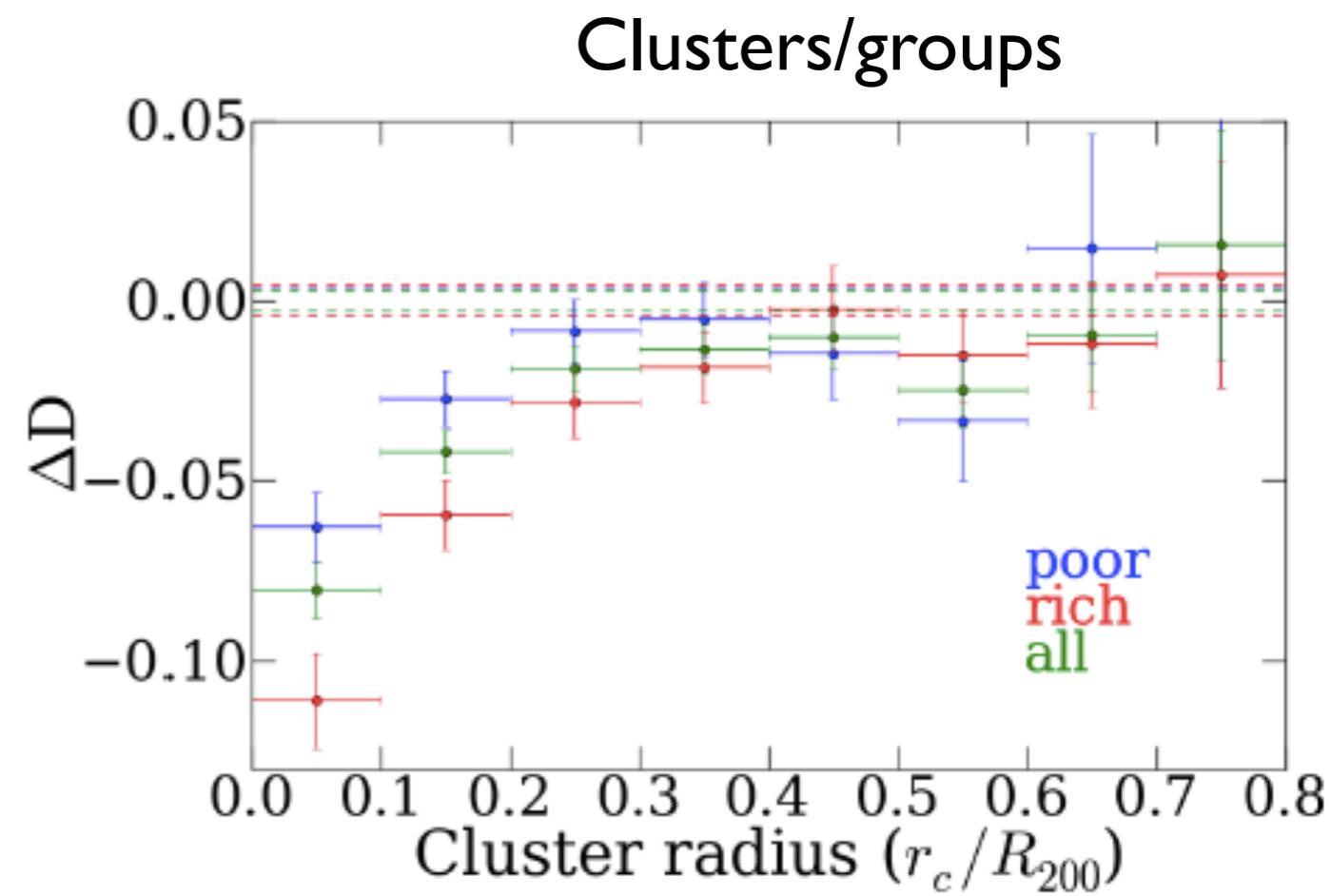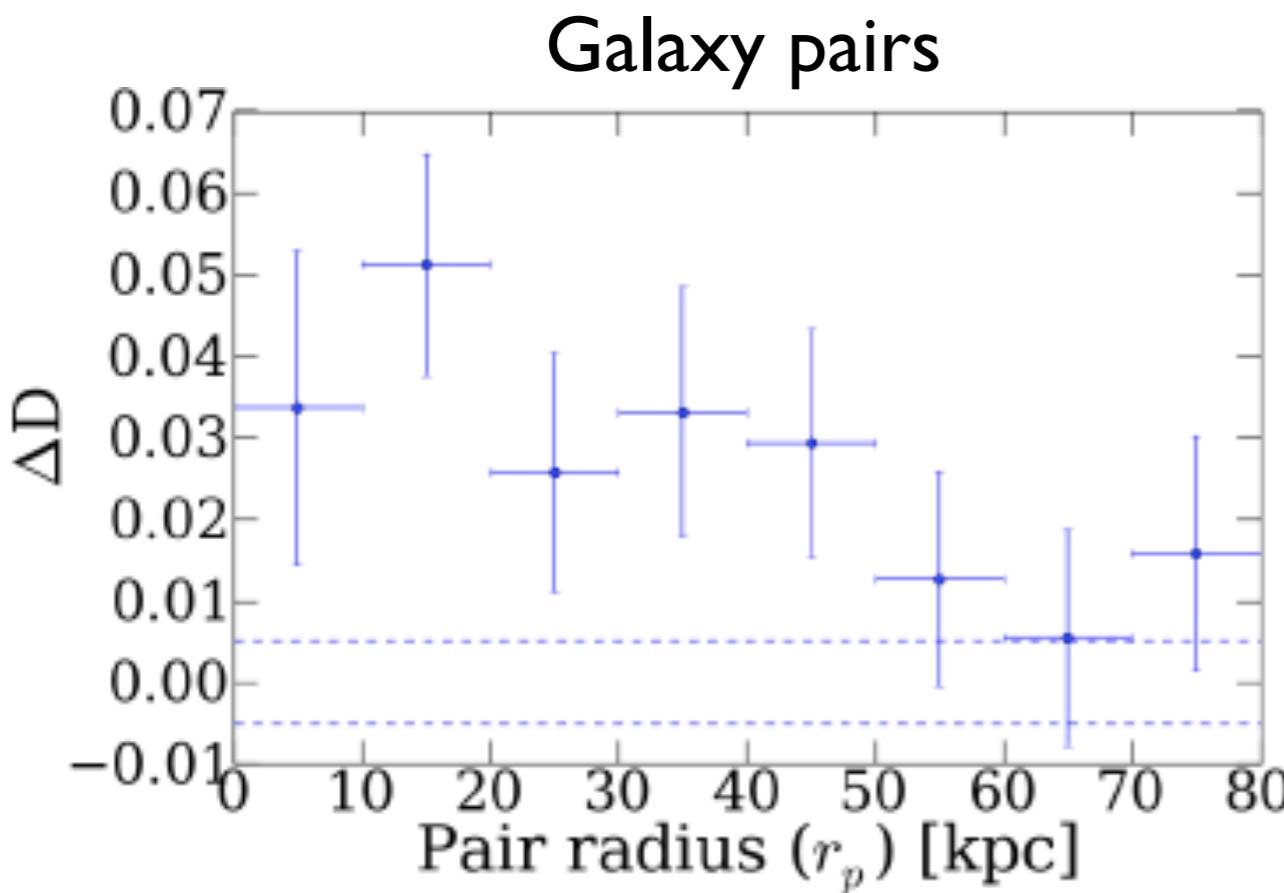
see Sabater et al. 2013 for a similar study

Disentangling local and large-scale influences on SDSS AGN

Emil Khabiboulline (undergrad @ Cal Tech), Charles Steinhardt (SSC, Caltech),
JDS, Sara Ellison & Trevor Mendel
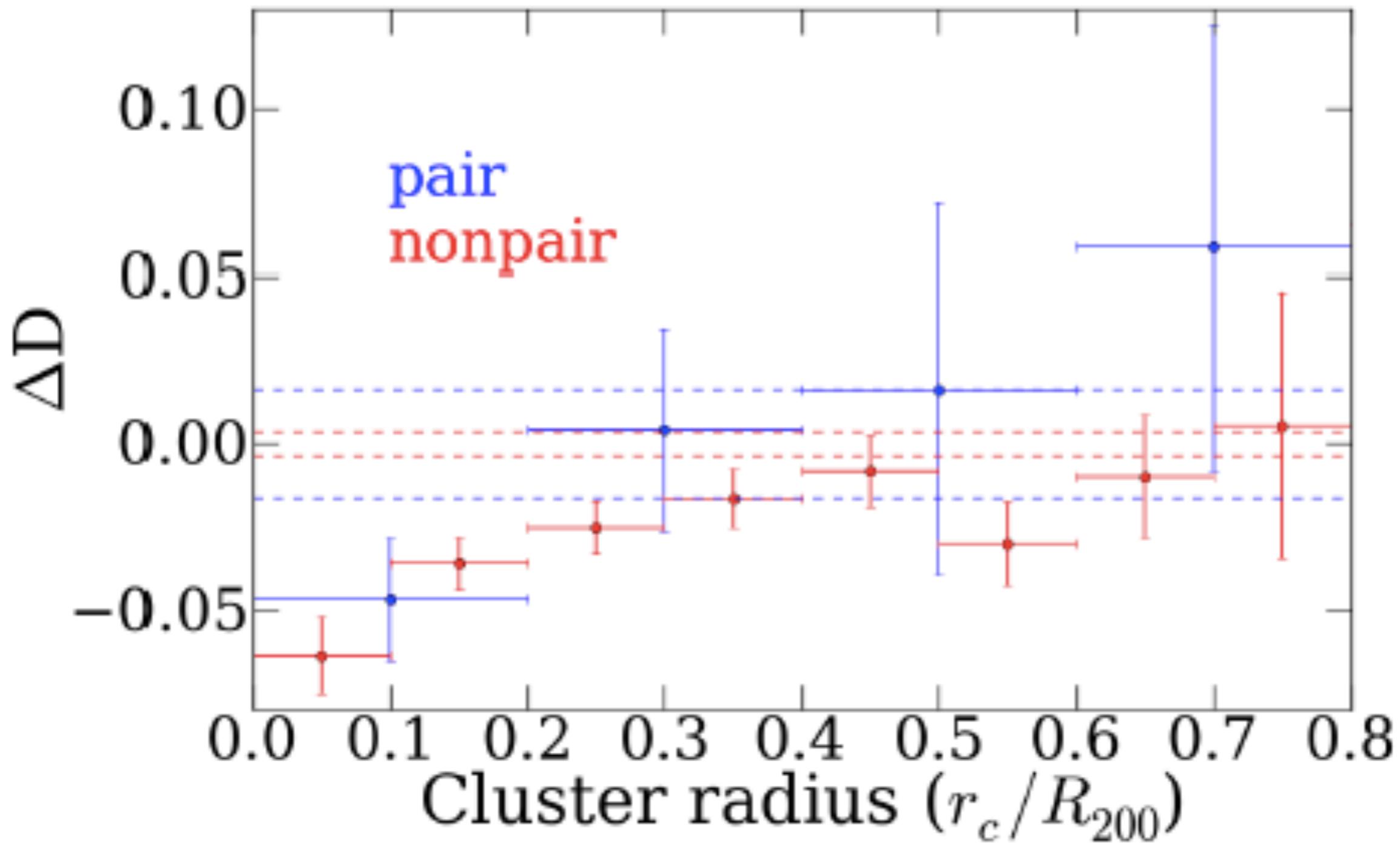
Conclusions

## Scale-dependent modulation of AGN activity

Local influences

- Major mergers account for ~22% of all AGN activity
- Early encounters (kinematic pairs) generate gas inflow to the black hole
- Late-stage mergers sustain black hole growth

Large-scale factors

- Suppression of AGN activity in group-sized halos (likely in the satellite population); maybe similar to environmental quenching mode for galaxies (e.g., Peng et al. 2012)
- Higher suppression in the cluster center that overcomes any merger-enhanced activity

X-ZENS: X-ray AGN study of nearby galaxy groups

$$R/R_{200} \text{ vs } \log_{10}(M_{galaxy}/M_\odot)$$

JDS, Miniati, Finoguenov, Carollo et al. 2014
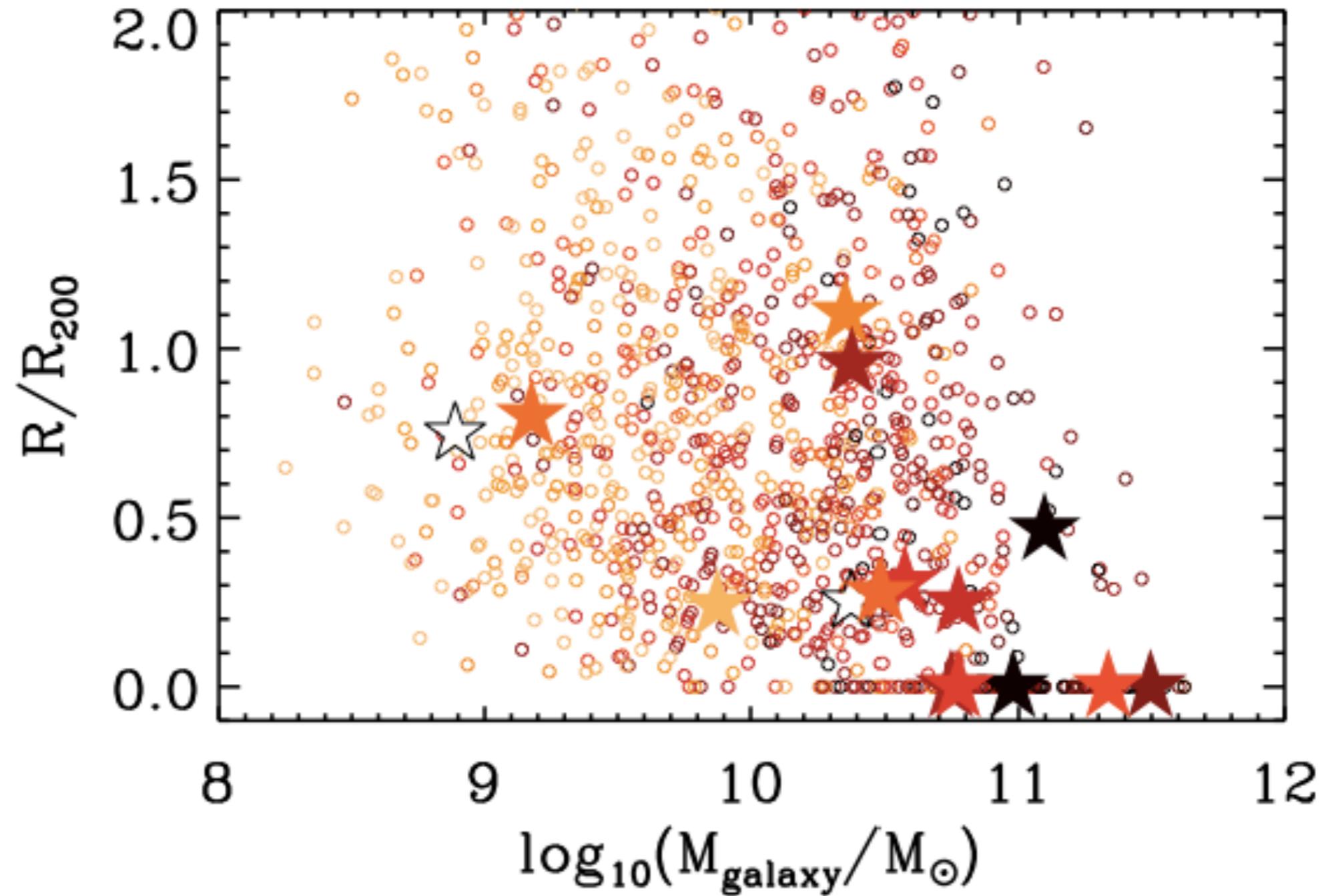
(see Li, Kauffmann et al. 2006;
Martini et al. 2007; Fassbender et al.
2012; Richardson et al. 2013)

Extremely close pairs in (z)COSMOS
## Claire Lackner (IPMU)


09:58:22.7 +2:49:24.5
z=0.38

1"
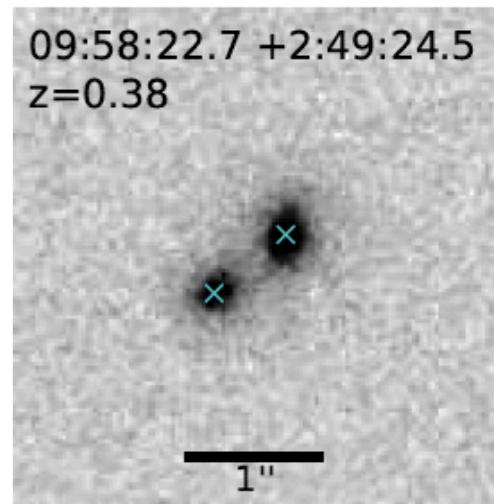
- Automated detection algorithm for galaxies with double nuclei
    - two bright, concentrated nuclei of each galaxy within a merger

- HST i' band (0.03"/pixel)

- Median ring filter

- flux ratio > 0.25; each peak contains > 10% total galaxy light

- COSMOS galaxies with $0.2 < z < 1$
    - i < 23
    - $\Delta r \sim 2.5\text{-}8$ kpc (upper bound limit help remove contaminants)

- Science: star formation rates, AGN fraction, merger rates

Extremely close pairs in (z)COSMOS

Original Image

10:01:33.6 +01:38:07.5
z=0.58

Median Filtered Image

Detected Peaks

1"
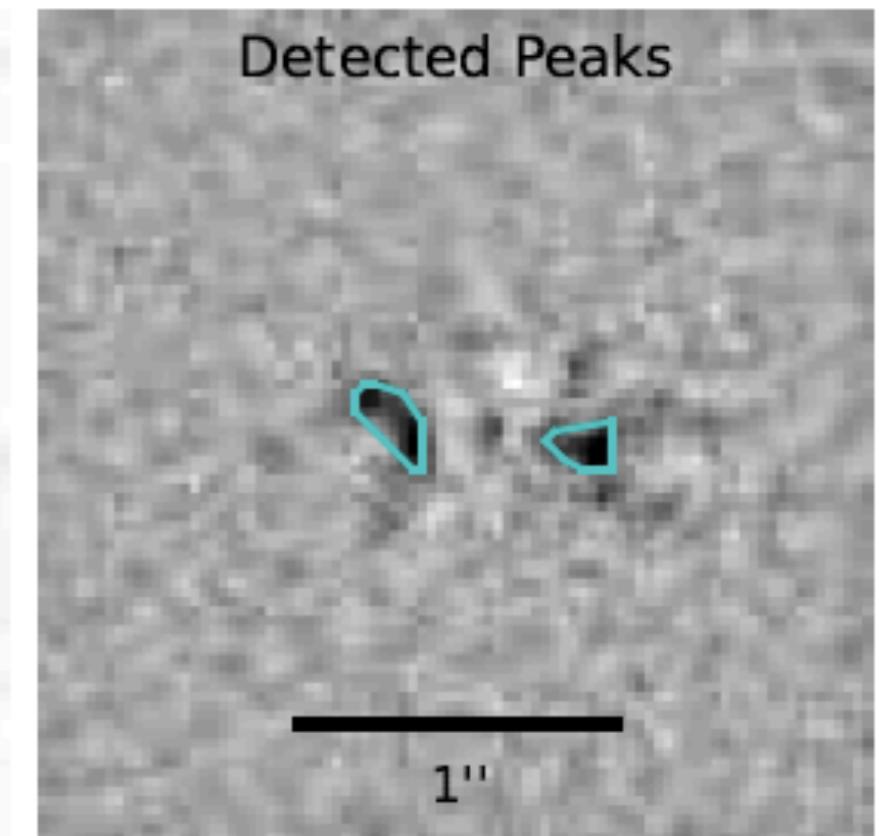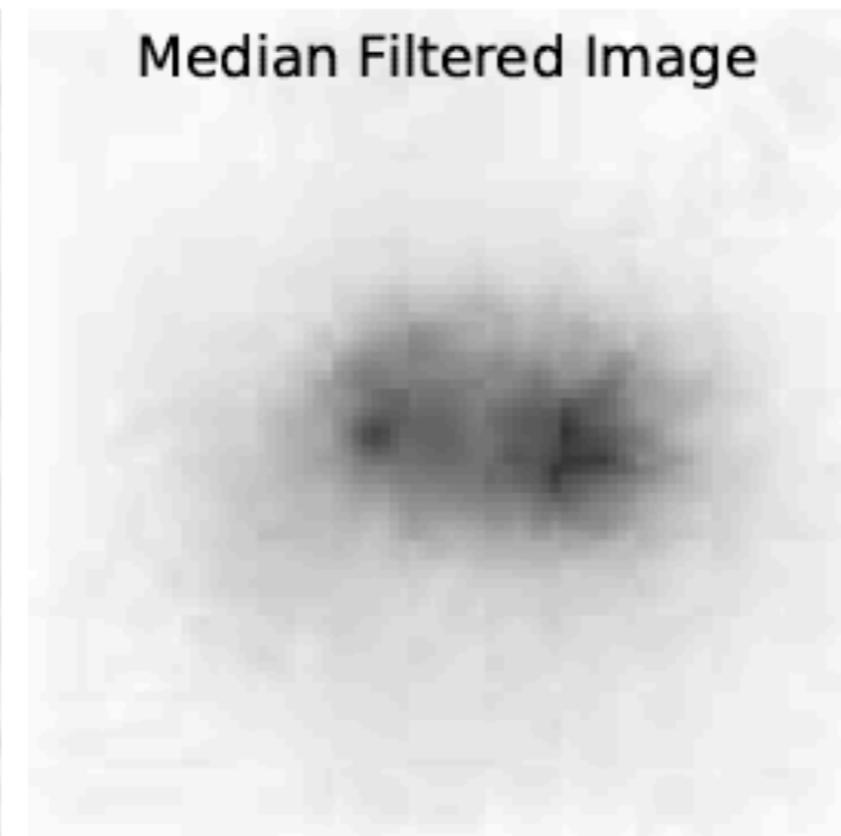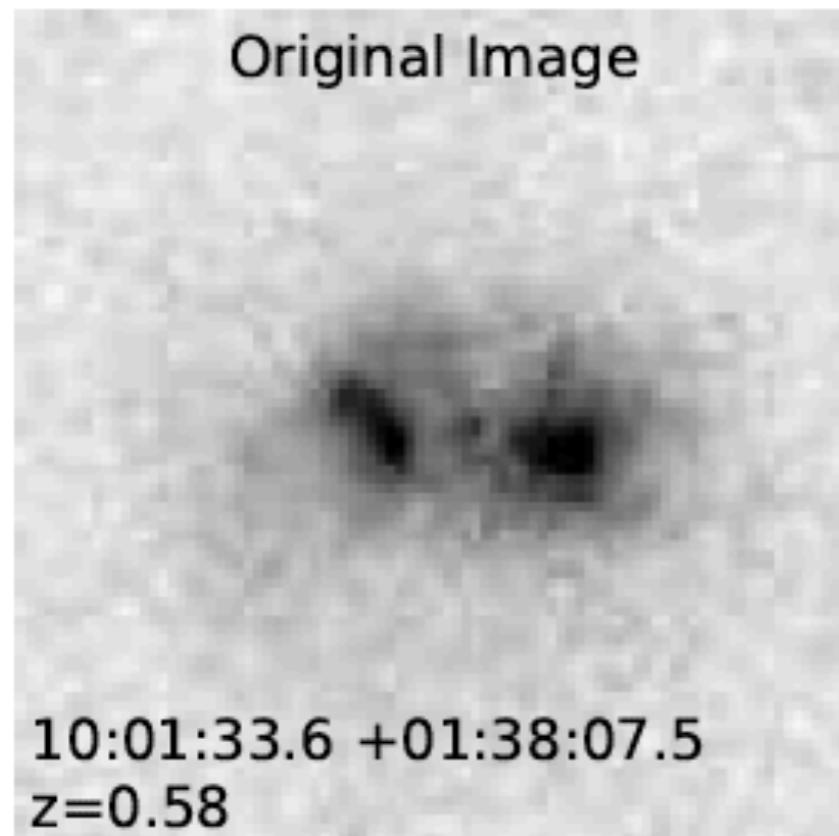
2047/44164 (4.6%) galaxies with double nuclei (i < 23)

Example Mergers

10:02:09.3 +2:01:27.5
z=0.84

10:00:18.8 +2:06:53.3
z=0.31

10:01:39.3 +2:22:23.7
z=0.90

09:58:28.9 +2:27:39.3
z=0.82

09:59:55.7 +2:33:30.9
z=0.73

09:58:22.7 +2:49:24.5
z=0.38

Not selected as mergers

09:58:49.7 +1:57:29.2
z=0.29

09:58:57.0 +1:58:06.7
z=0.66

10:02:10.6 +2:34:59.4
z=0.81
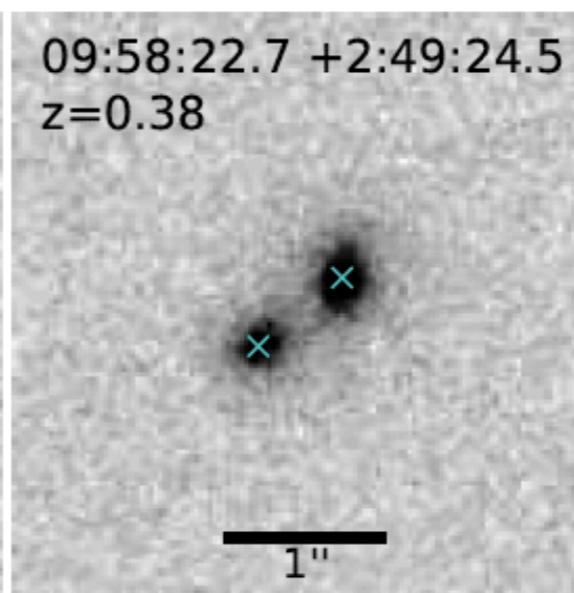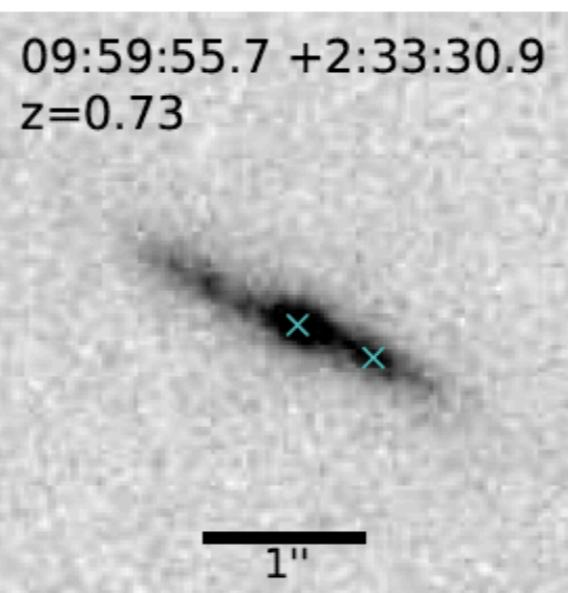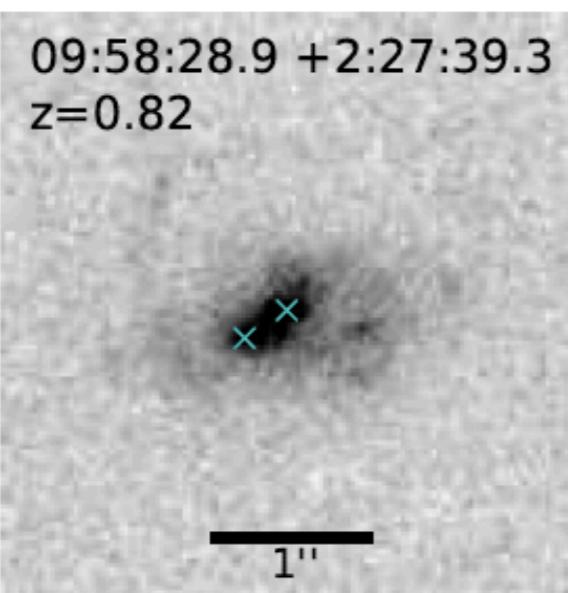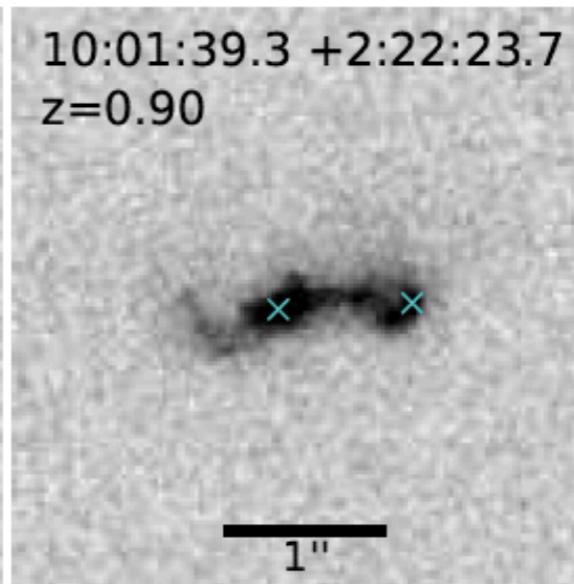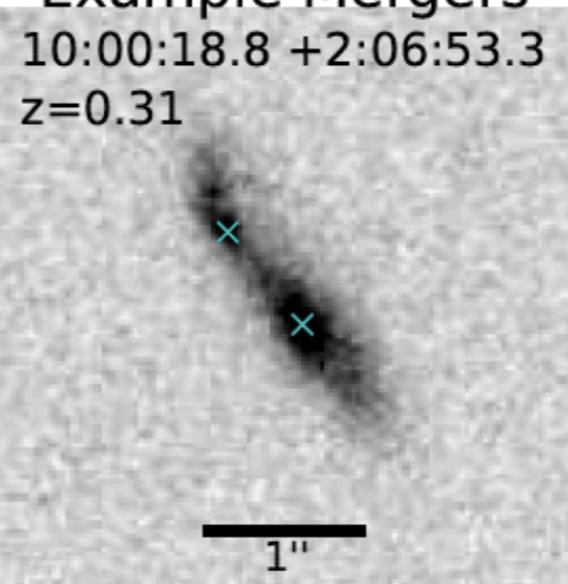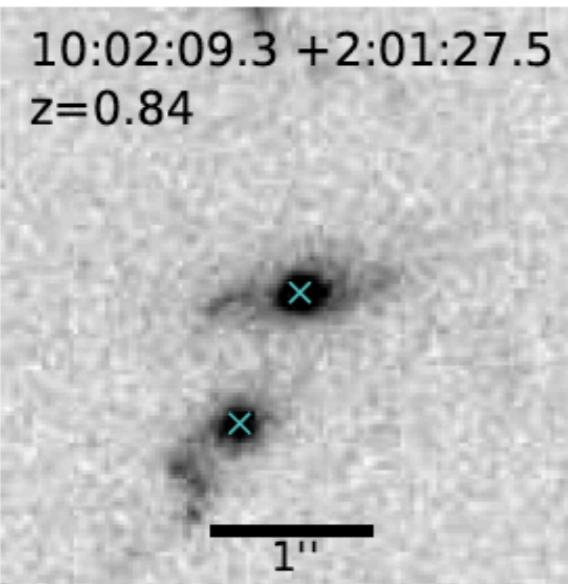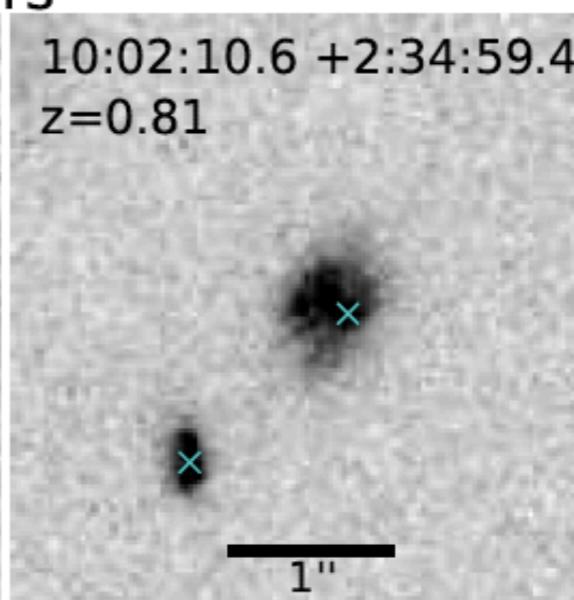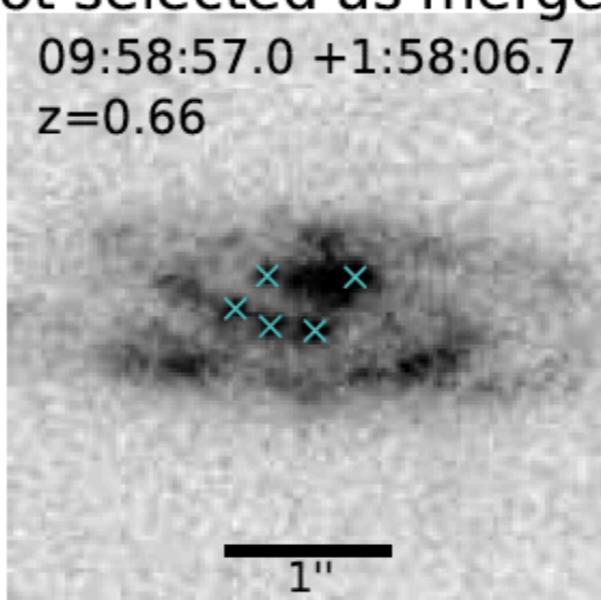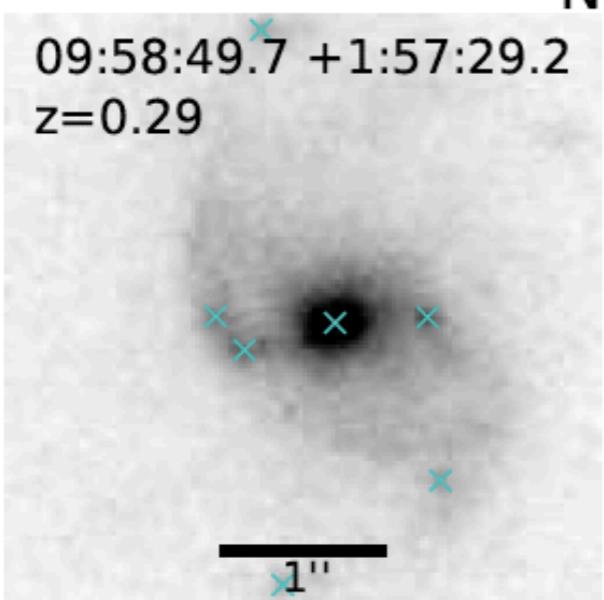
X-ray detected AGNs
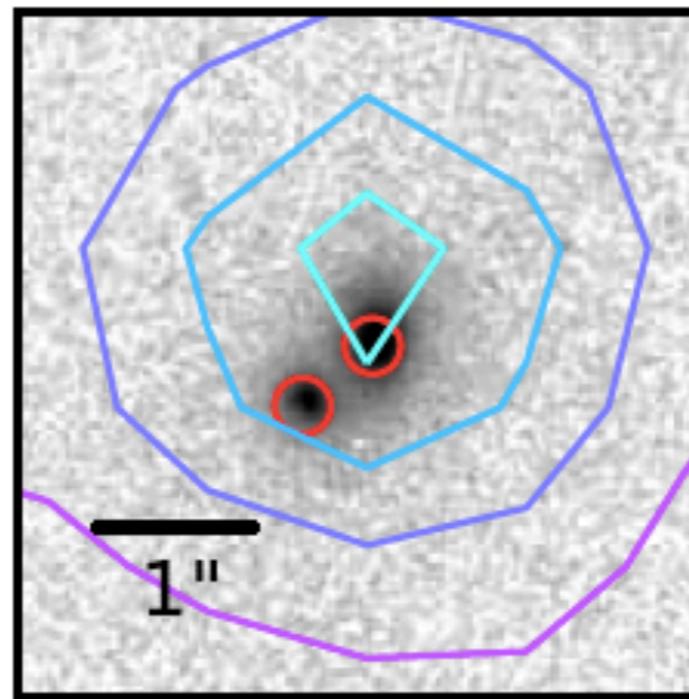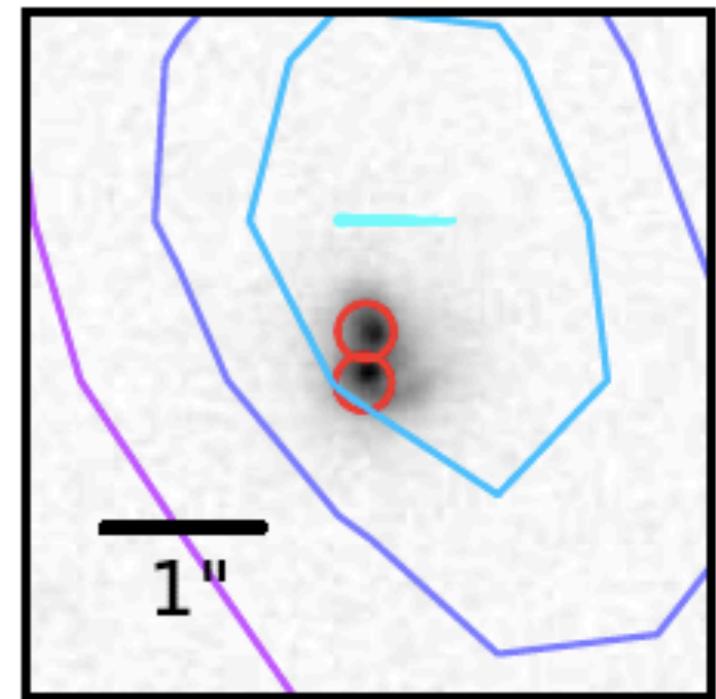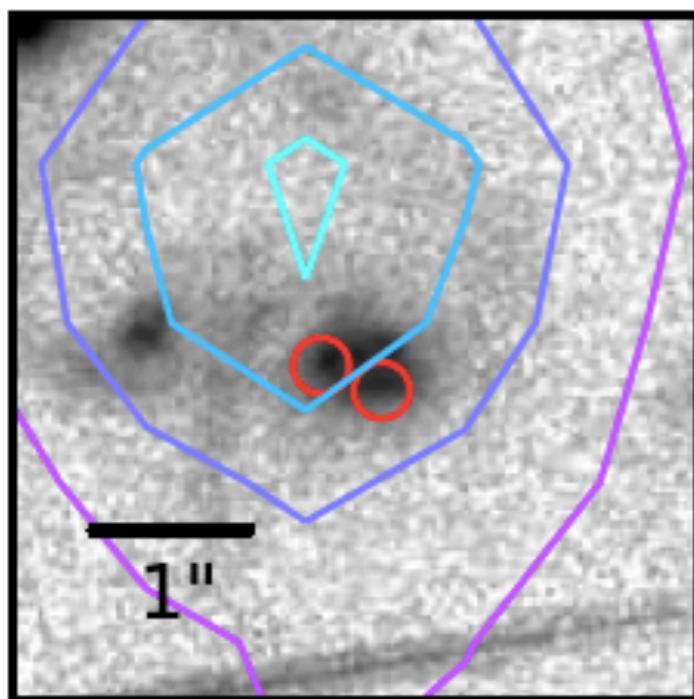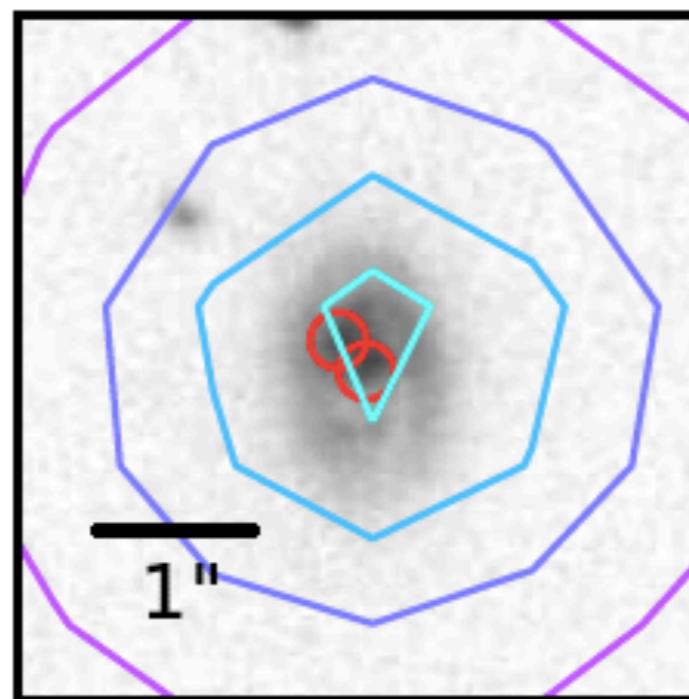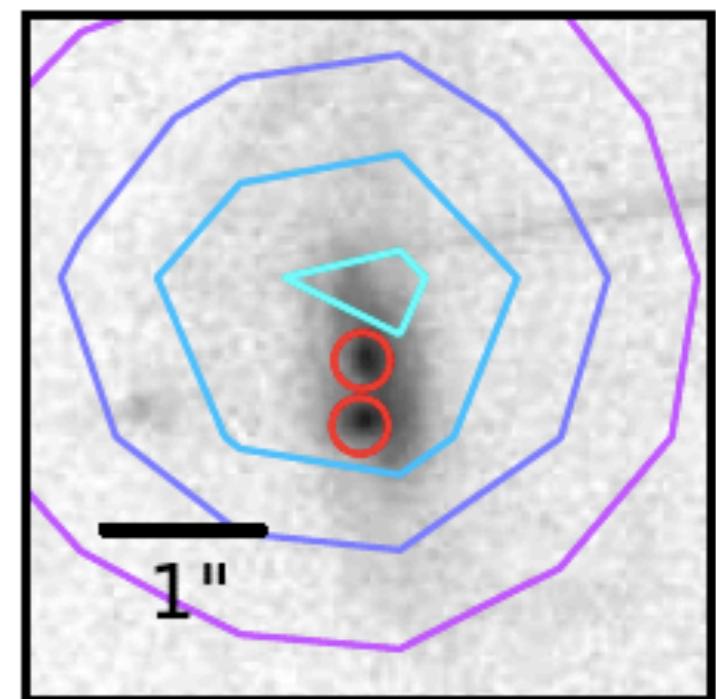
AGN enhancement in kinematic pairs in SDSS (z ≲ 0.1)

Ellison et al. 2011
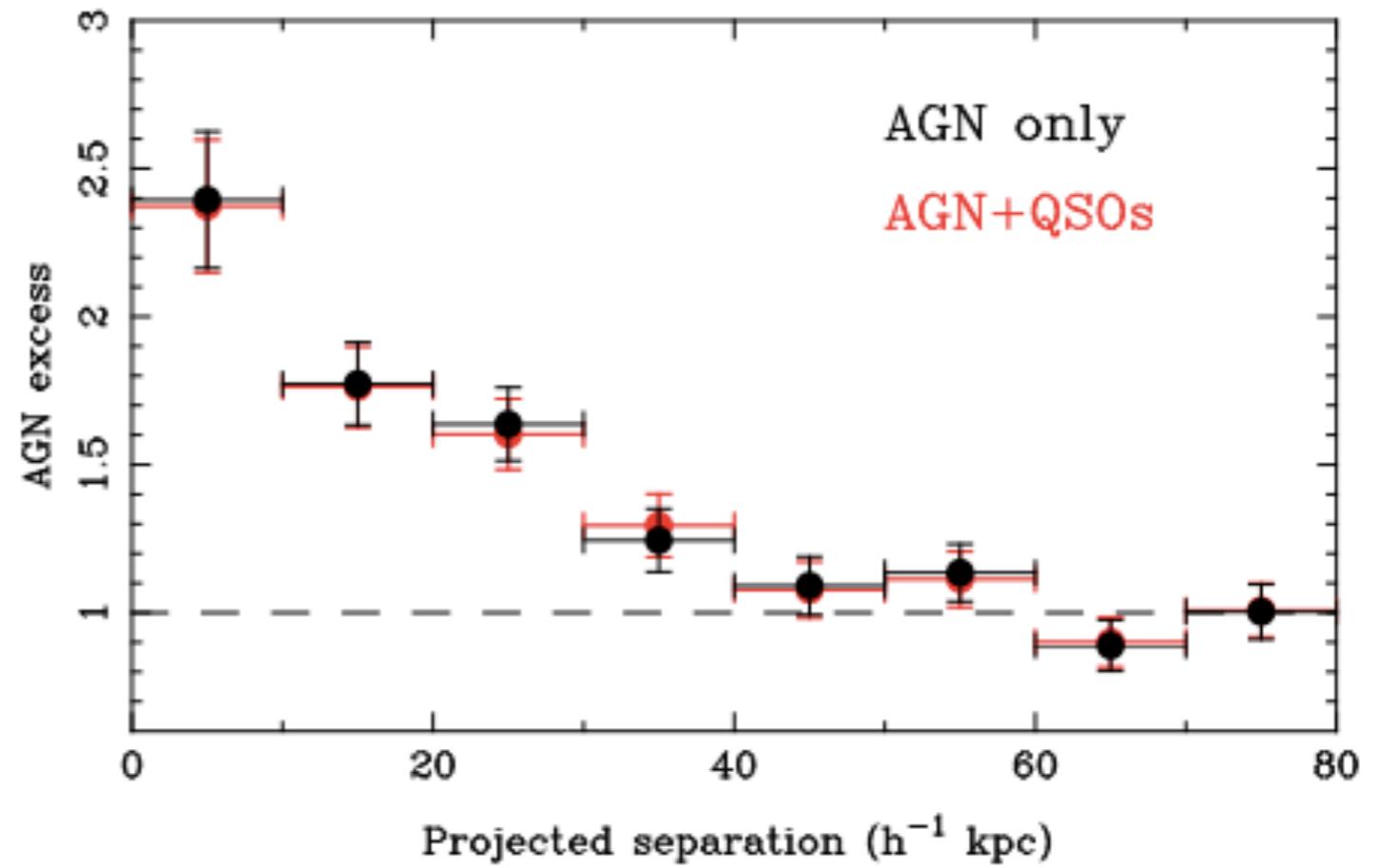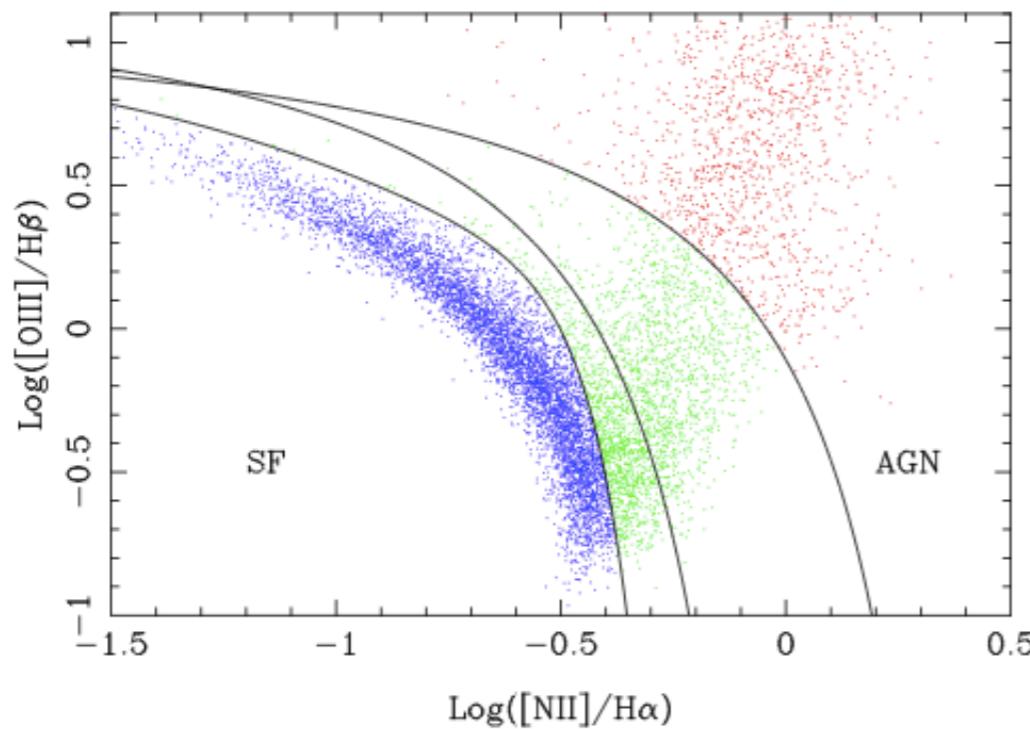
see Woods et al. 2010, Koss et al. 2010 on low-z galaxies

# Selection efficiency

Mock images

late-late merger
z=0.69
8 kpc

early-late merger
z=0.34
8 kpc

late-late merger
z=0.85
8 kpc

early-early merger
z=1.04
8 kpc
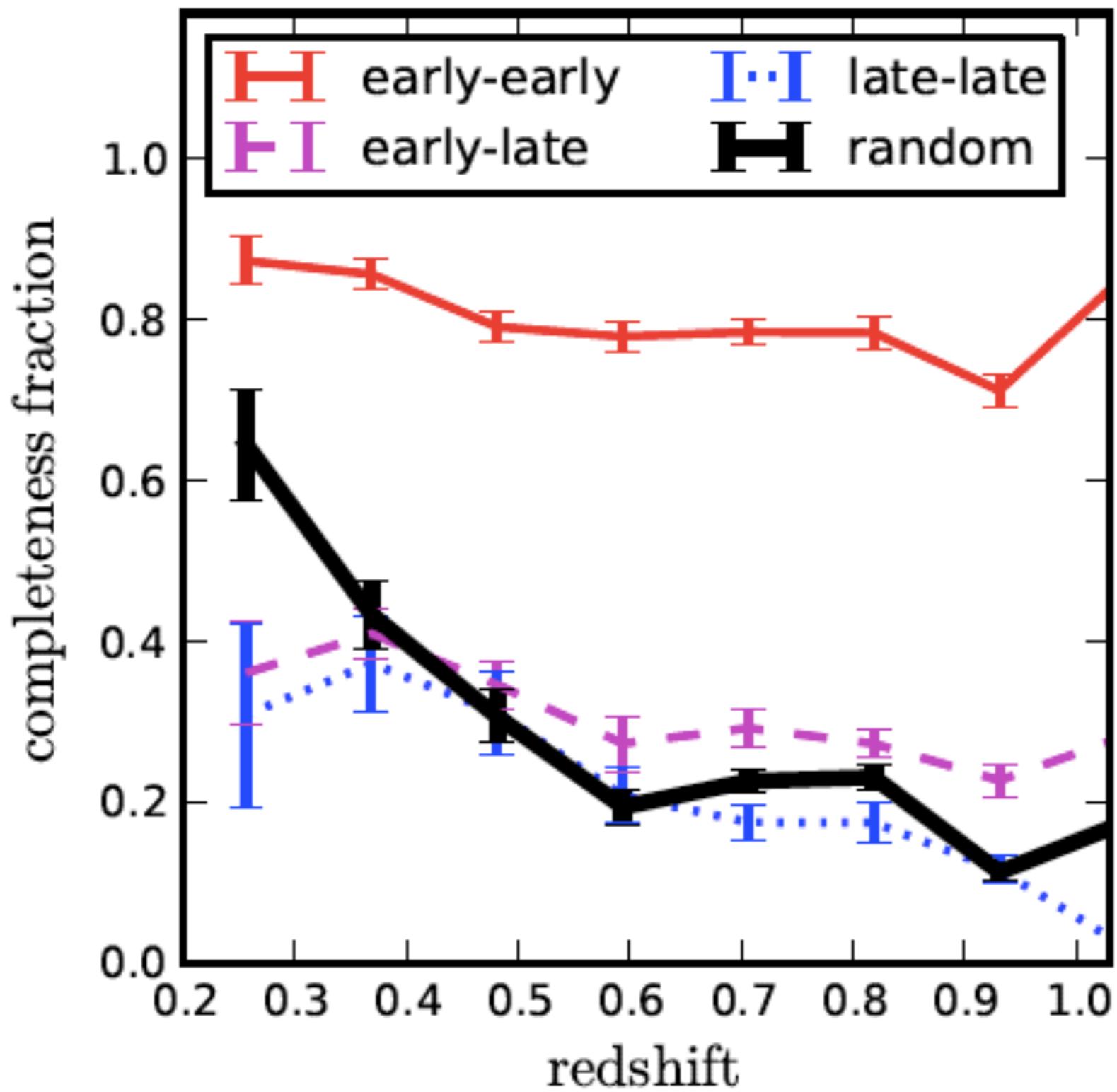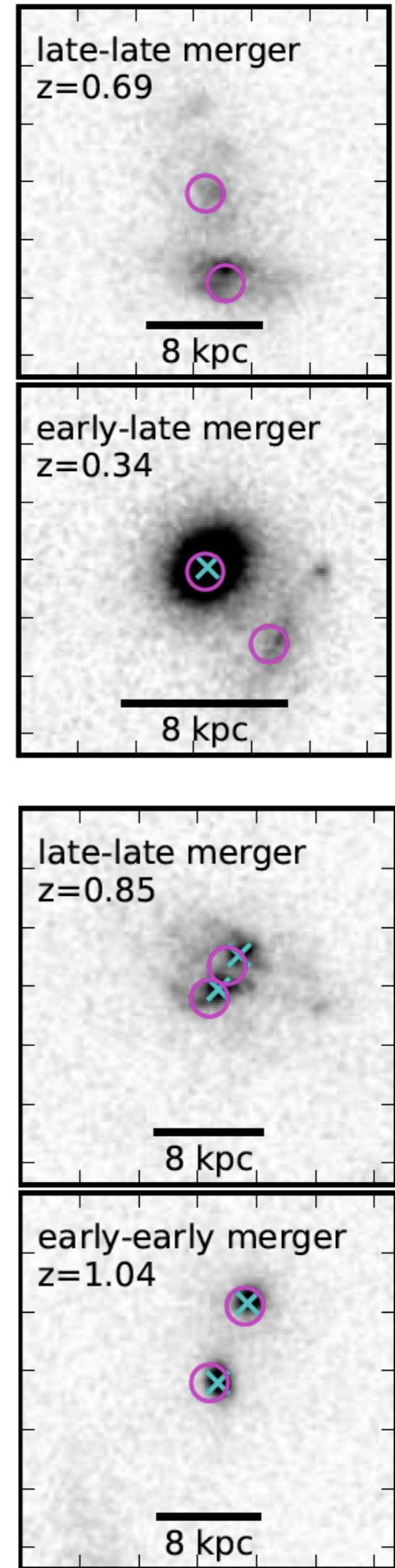
Merger rates for SF and quiescent populations
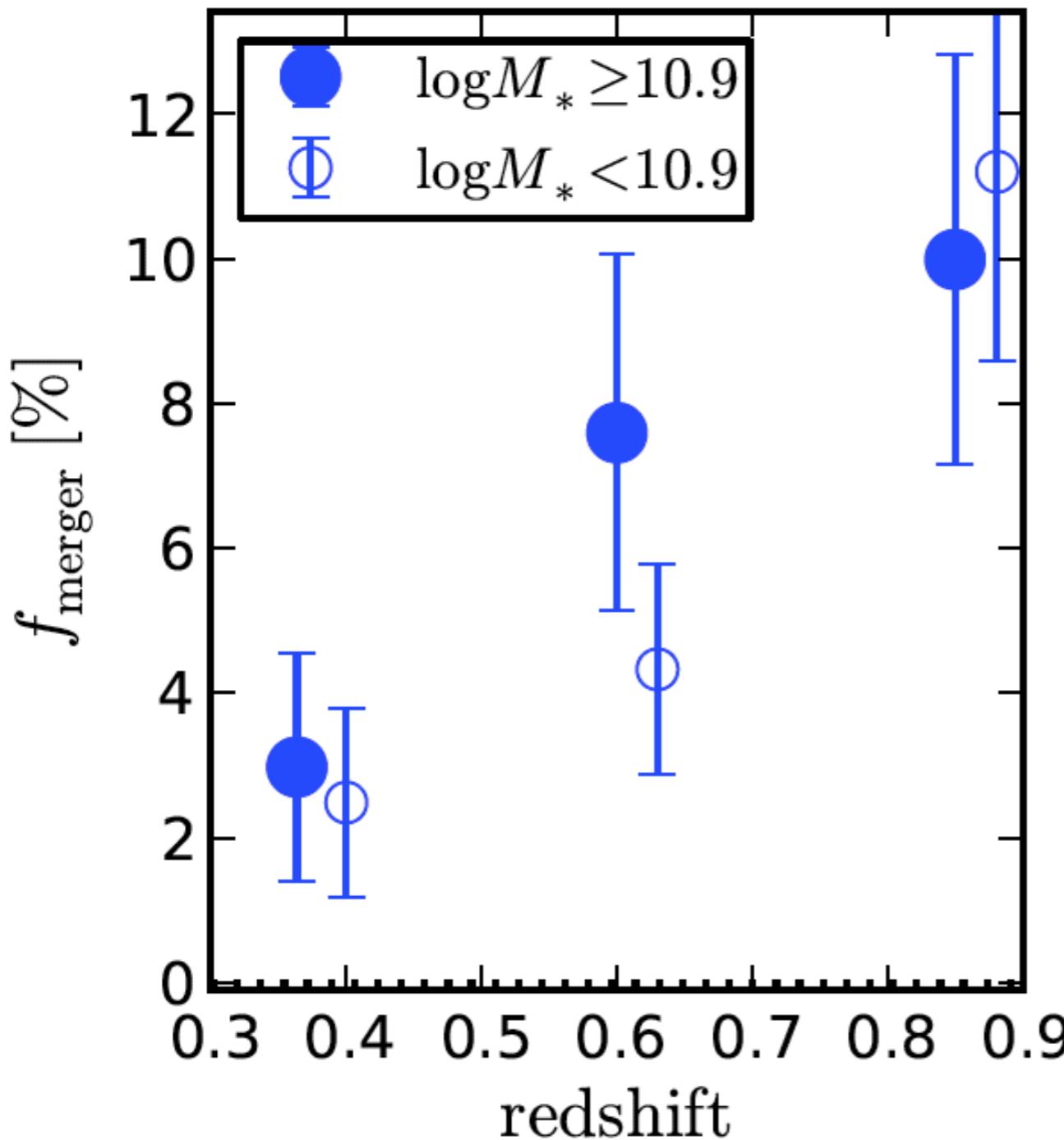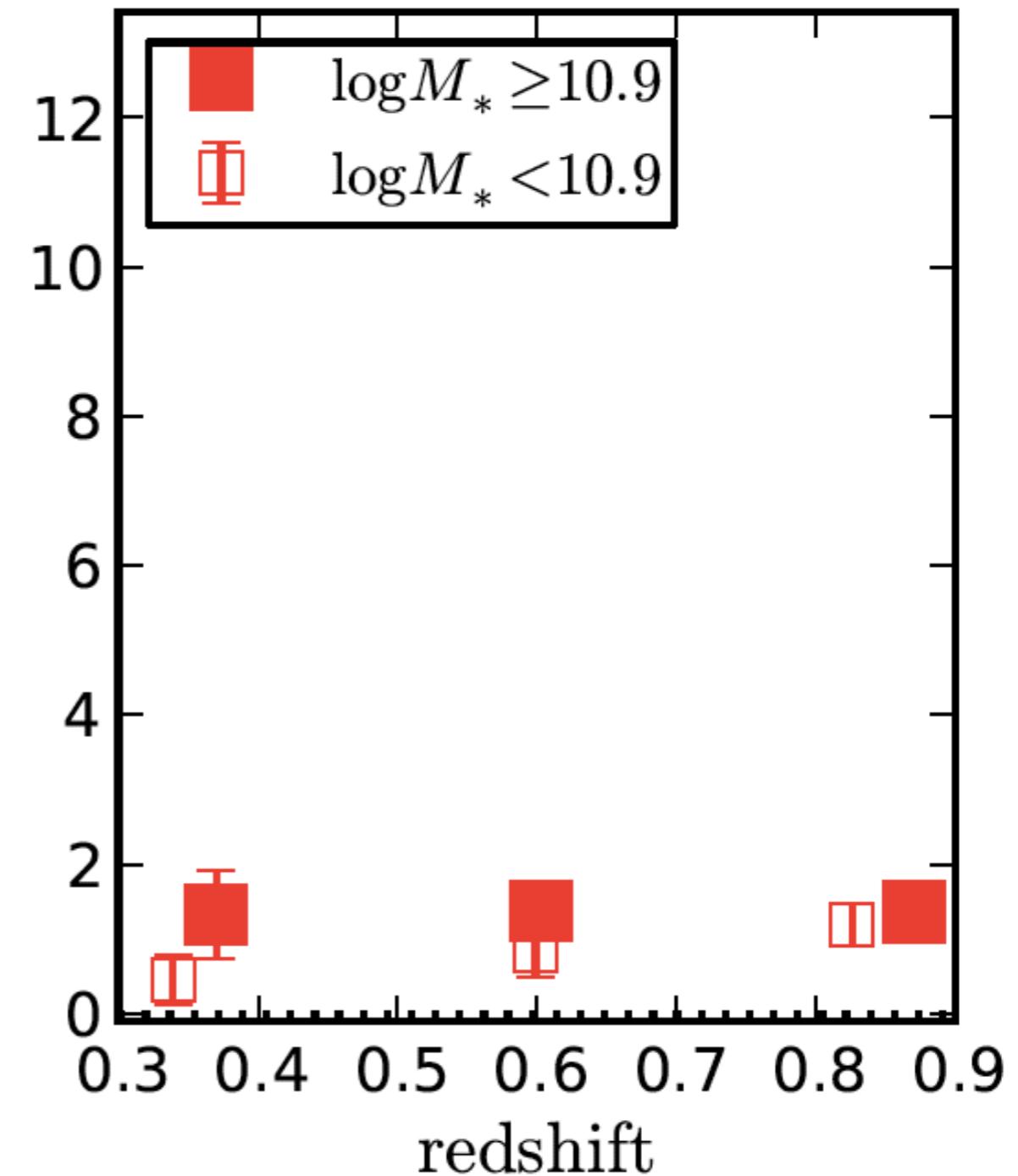
$R_{merge} \sim (1+z)^{4.5 \pm 1.3}$

$R_{merge} \sim (1+z)^{1.1 \pm 1.2}$