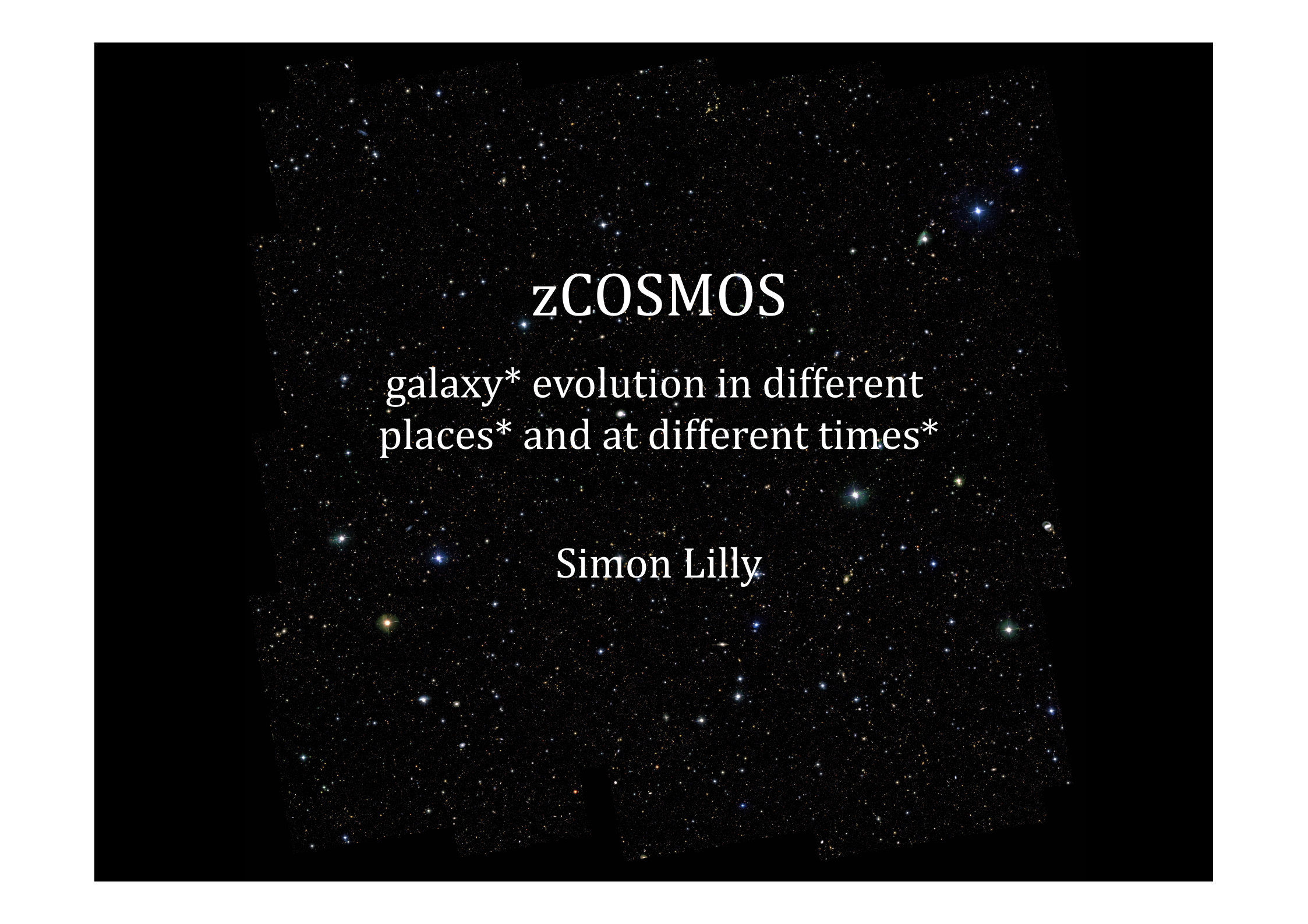


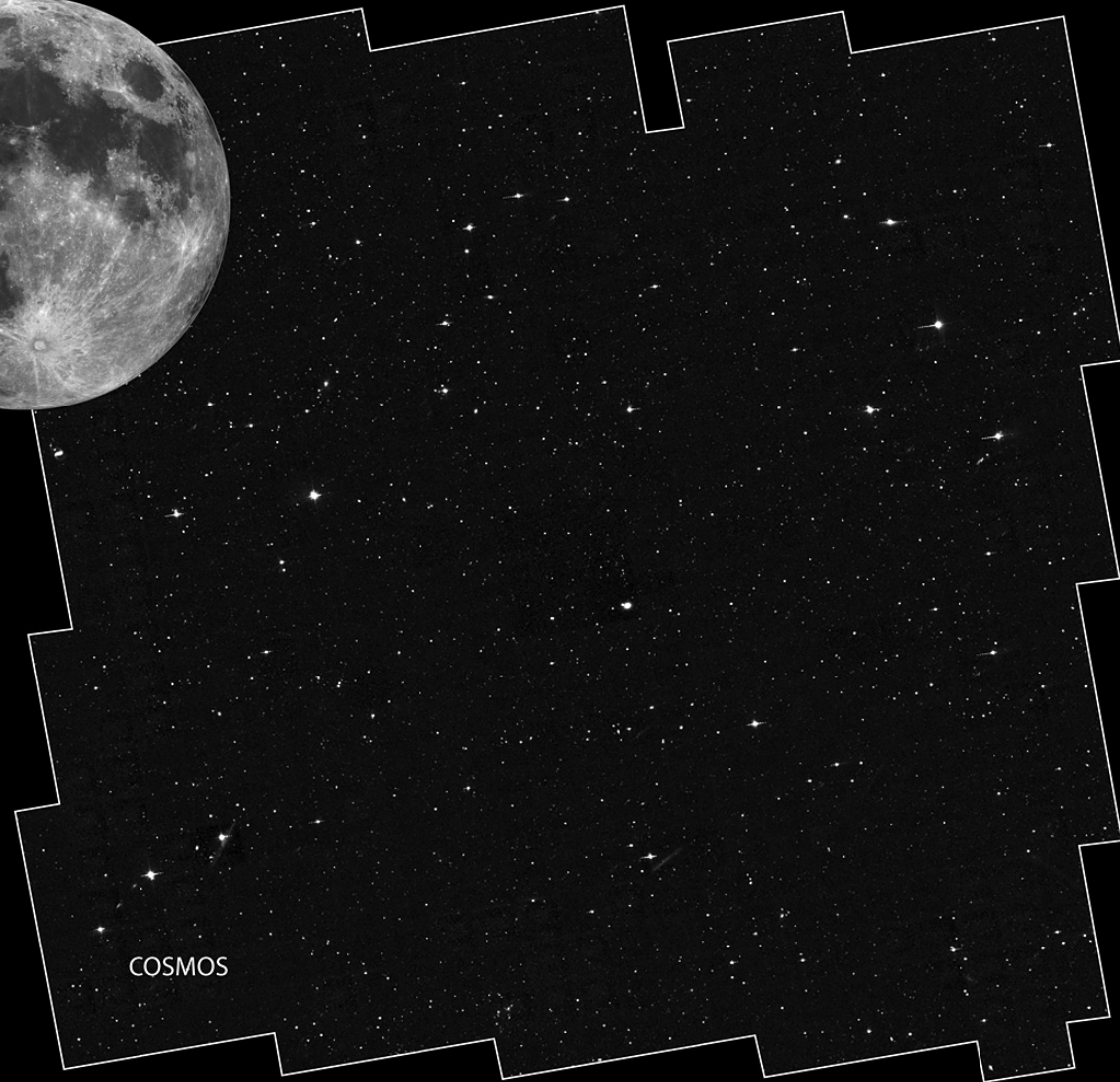
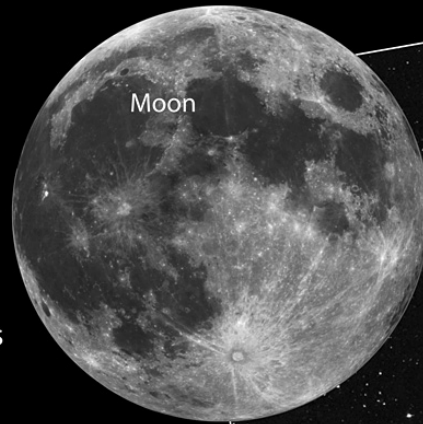
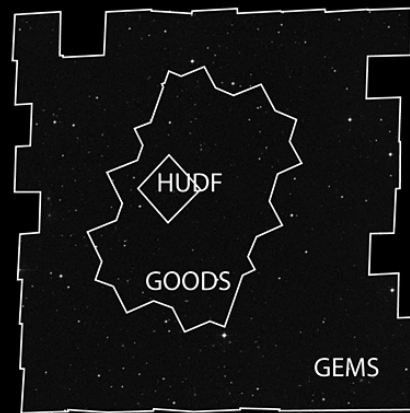


# zCOSMOS

galaxy\* evolution in different  
places\* and at different times\*

Simon Lilly

Relative Sizes of *HST* ACS Surveys



- **80 Mpc transverse at  $z = 1$  & 120 Mpc transverse at  $z = 2$**
- **Deep imaging with XMM-Newton, Chandra, Galex, HST, Subaru/CFHTUKIRT, Spitzer IRAC +MIPS, submm, VLA (e.g. 30-band photo- $z$ ) – mostly publicly released**



**\*\* zCOSMOS Core Spectral Reduction Team:**

**ETH Zurich, INAF Bologna, INAF Milano, LAM Marseille, OAMP Toulouse, MPE/ESO Garching**

Bardelli, S., Bolzonella, M., Bongiorno, A., Caputi, K., Carollo, C. M., Contini, T., Coppa, G., Cucciati, O., de la Torre, S., de Ravel, L., Franzetti, P., Garilli, B., Iovino, A., Kampczyk, P., Kneib, J.-P., Knobel, C., Kovac, K., Lamareille, F., Le Borgne, J.-F., Le Brun, V., Le Fevre, O., Maier, C., Mainieri, V., Mignoli, M., Pello, R., Peng, Y., Perez Montero, E., Ricciardelli, E., Scoddeggio, M., Silverman, J., Tanaka, M., Tasca, L., Tresse, L., Vergani, D., Zamorani, G., Zucca, E.

**plus about 15 others in these institutions who are not reducing data**

## **zCOSMOS-bright**

- $I_{AB} < 22.5$
- 70% sampling + high completeness in redshifts 95% @  $0.5 < z < 0.8$
- $\sim 100 \text{ km s}^{-1}$  accuracy
- about 10,000 redshifts in hand (2009: 20,000)

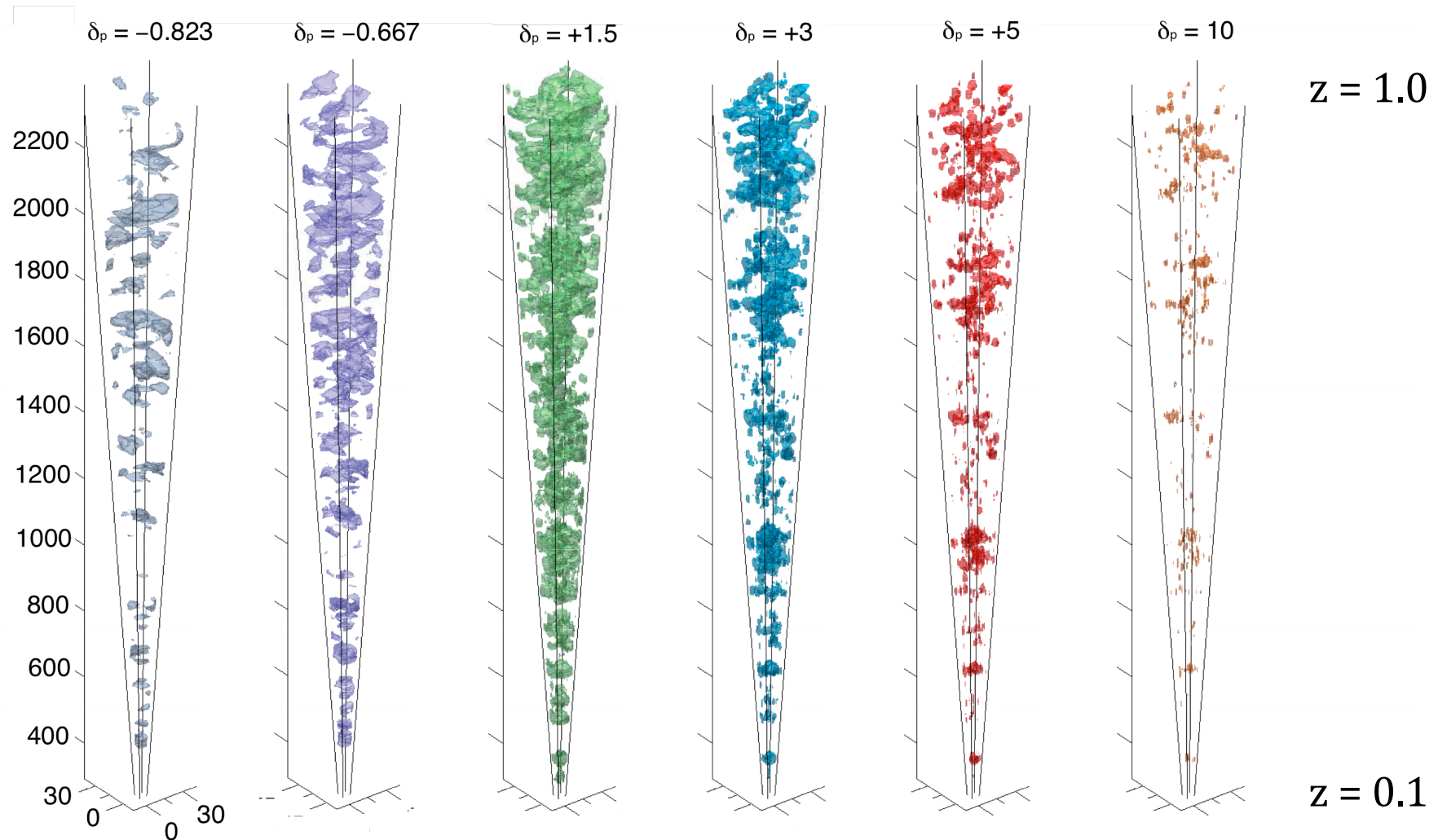
## **zCOSMOS-deep**

- Selected  $1.5 < z < 4$  via *gzK* or *ugr* colours
- 70% sampling
- $B_{AB} < 25.25$  ( $+K_{AB} < 23.5$  for *gzK*)
- about 10,000 spectra by 2010

Together: 600 hours of observation on UT3

**$\sim 30$  person-years of redshift identification**

# Characterizing environment to $z = 1$



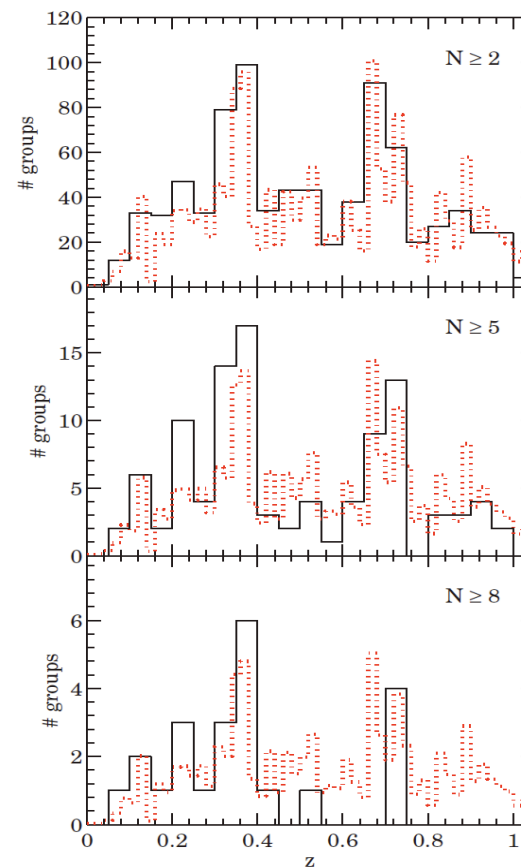
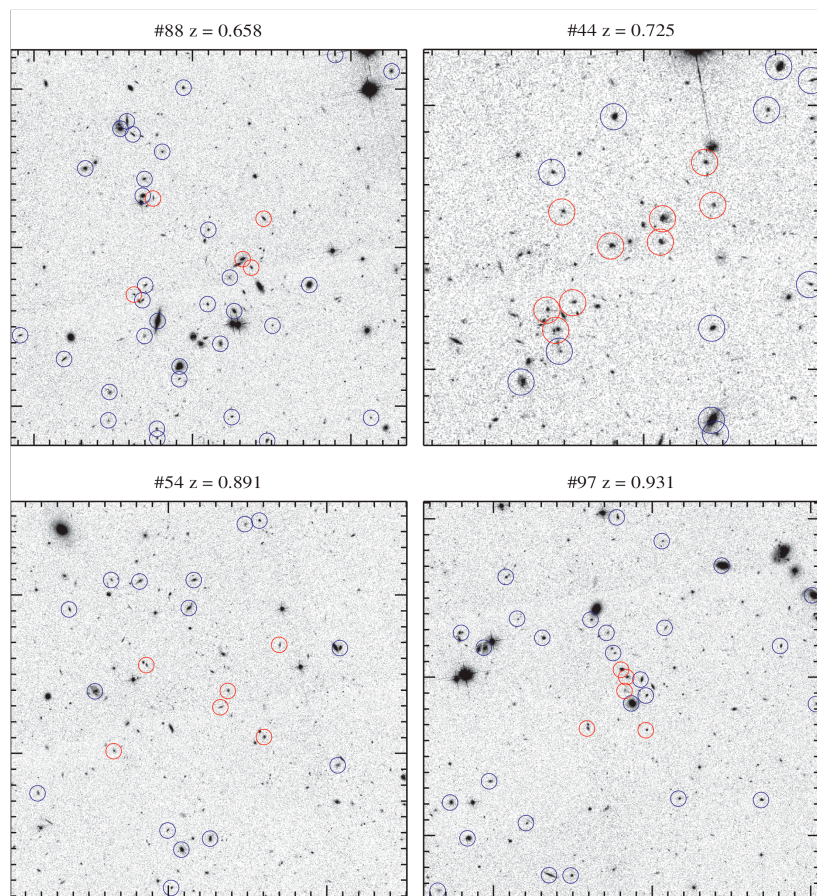
zCOSMOS density field using ZADE approach combining 10,000 spectro-z+30,000 photo-z (Kovac et al 2009, astro-ph last week)



# Galaxy groups to $z = 1$

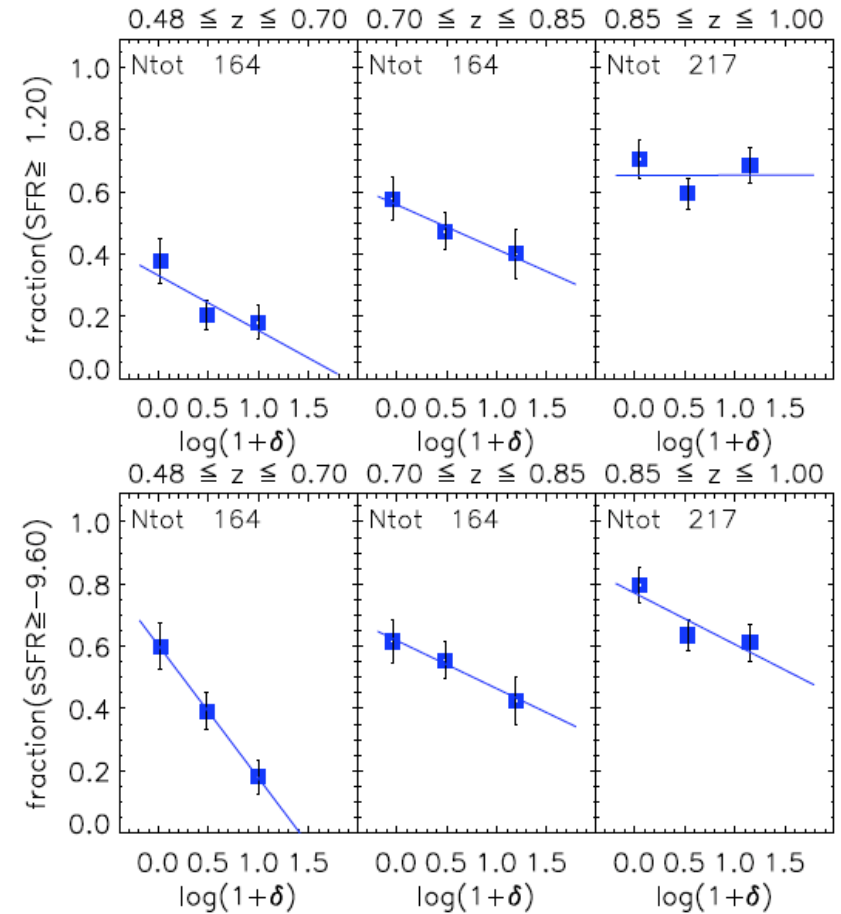
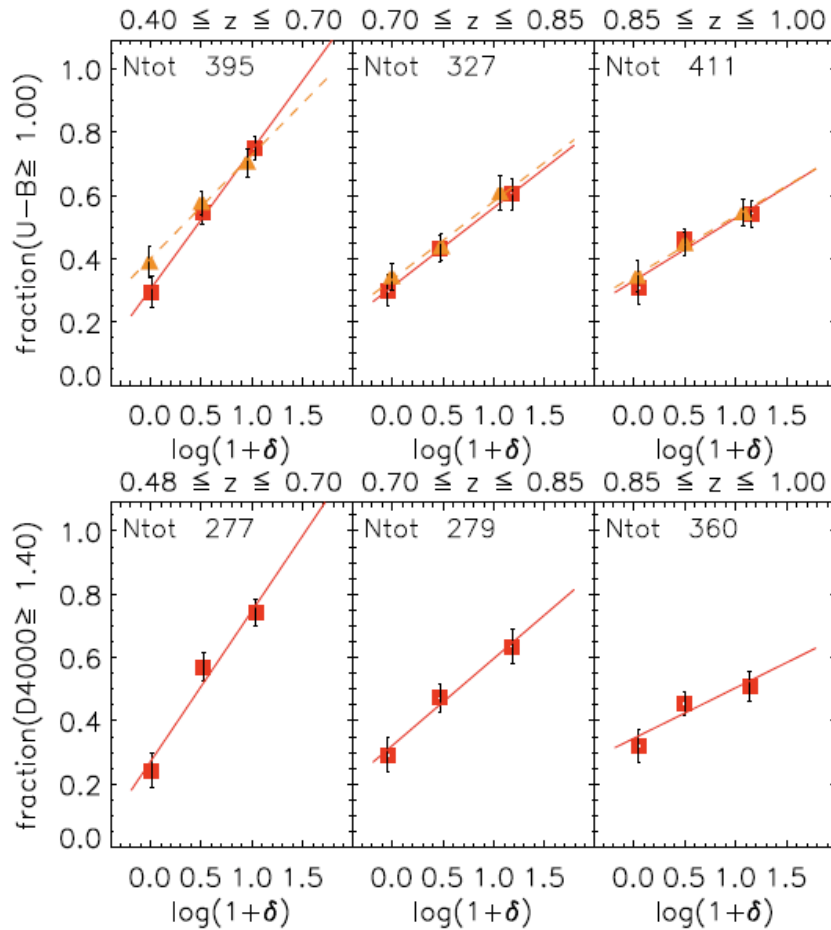
High fidelity groups using optimized "multi-pass" FoF+VDM algorithms  
(Knobel et al 2009, astro-ph last week)

- 151 groups ( $N \geq 4$ )
- plus another 649 ( $4 > N \geq 2$ )
- group membership is 30% of galaxies at  $z = 0.3$  and still 10% at  $z = 0.8$



# Relations with density and (U-B), D4000, SFR, sSFR ...

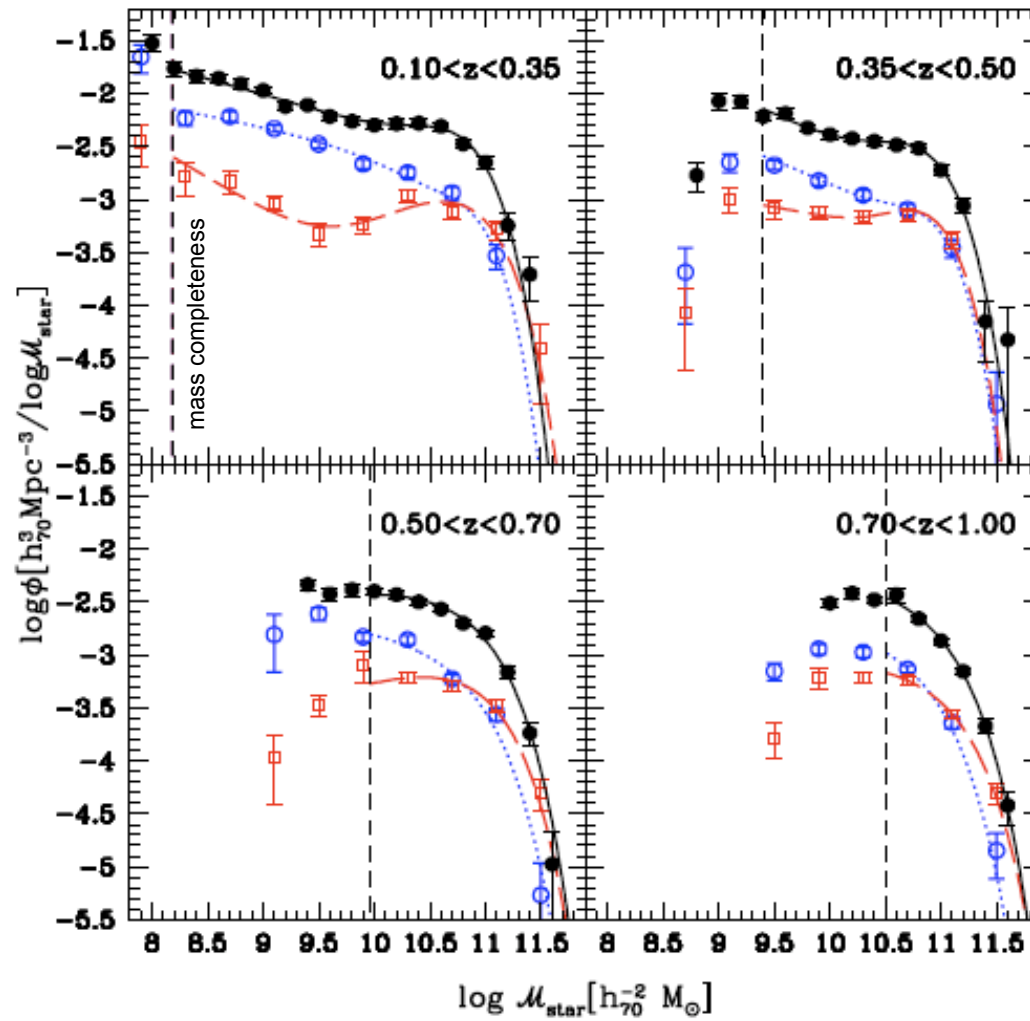
"volume-limited" luminosity-selected sample:  $M_B < -20.5 - z$





# Different galaxy MF in different environments

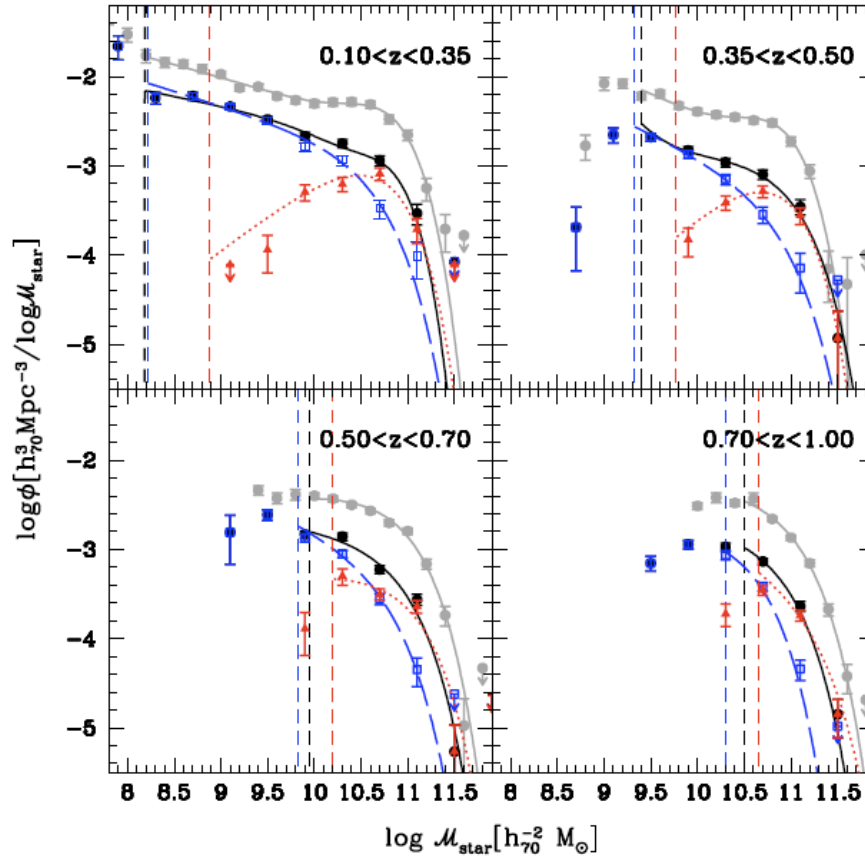
Galactic Stellar Mass Functions in **lowest** and **highest** density quartiles



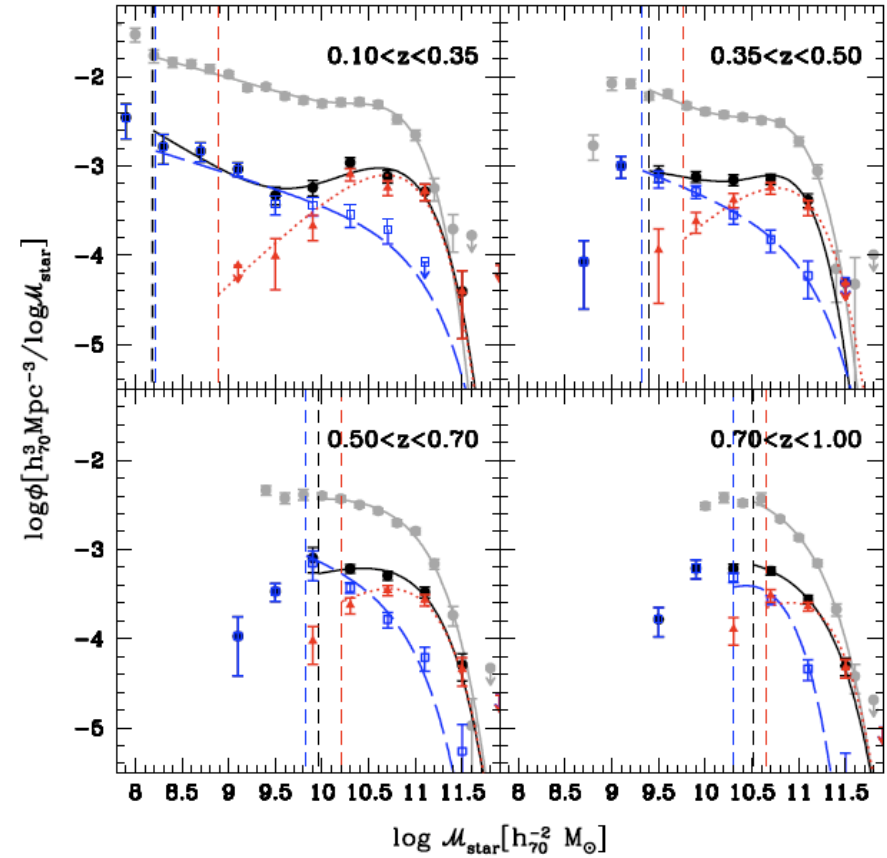
Bolzonella et al (2009)

# Different galaxy MF in different environments

Q1 low density, blue and red galaxies



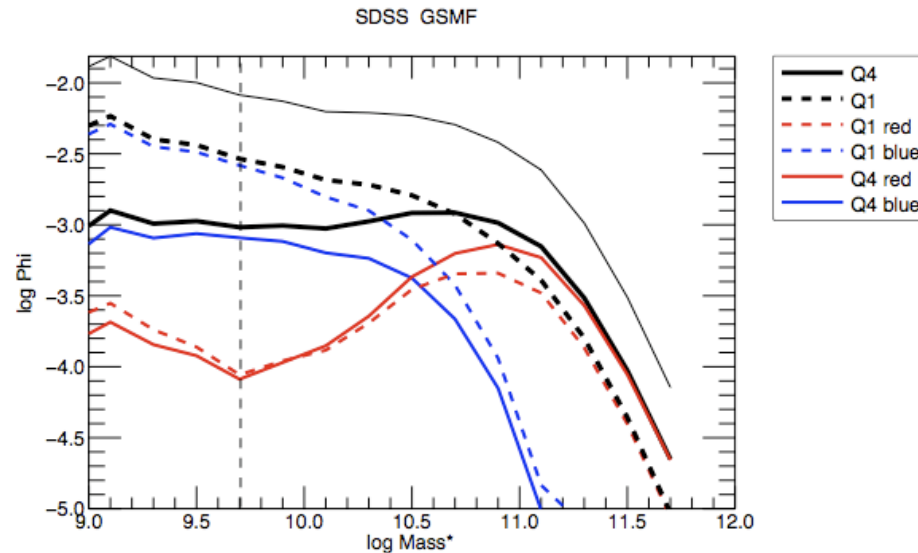
Q4 high density, blue and red galaxies



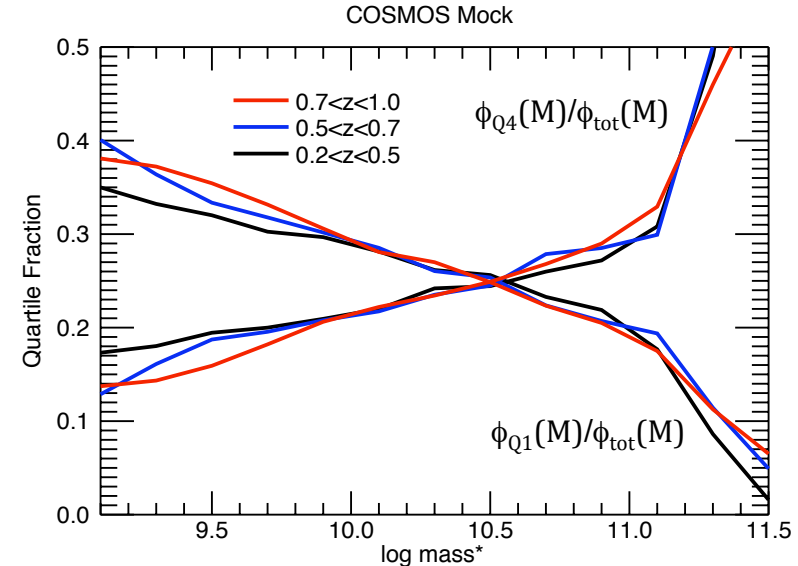
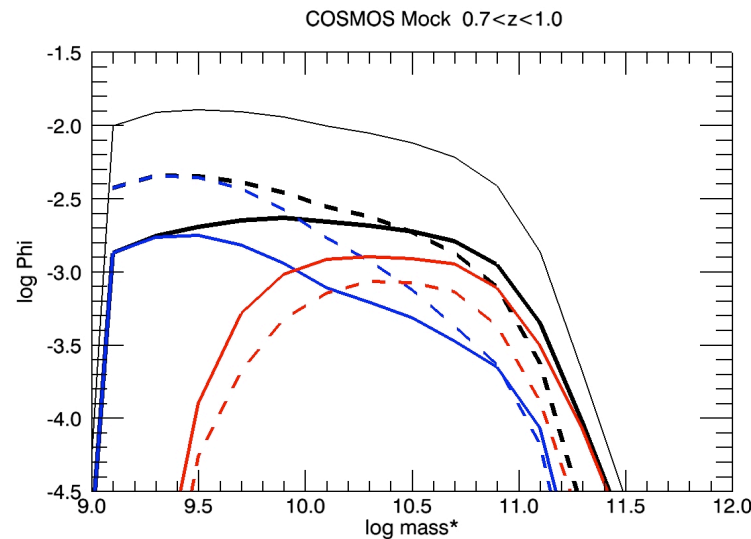
Bolzonella et al (2009)



Also seen locally in SDSS and in COSMOS SAM-based mocks

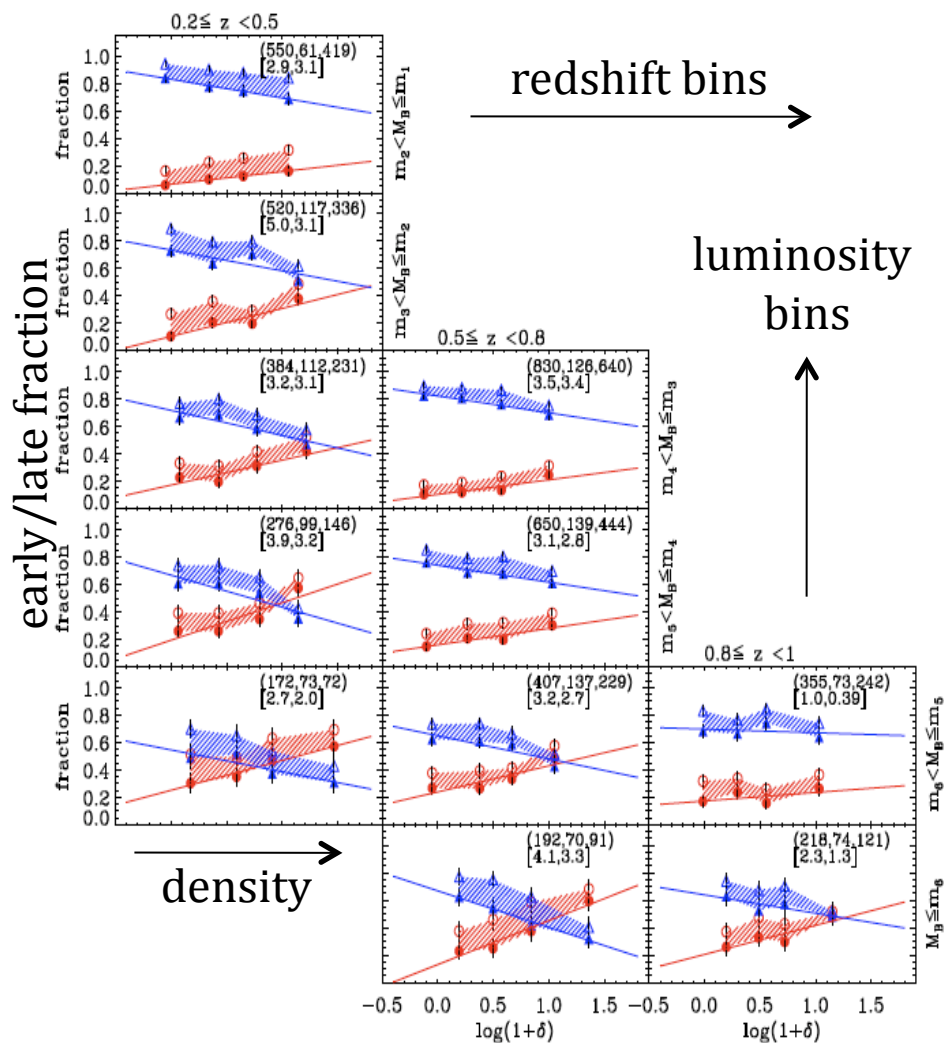


- Given that GSMF is  $f$  (density), the density effects seen in luminosity-selected samples (and broad mass bins) may be due to the underlying mass effect plus different relative numbers of high and low mass galaxies in different environments
- Disentangling "Nature" vs. "nurture" issue will be more complicated if mass anyway varies with environment.

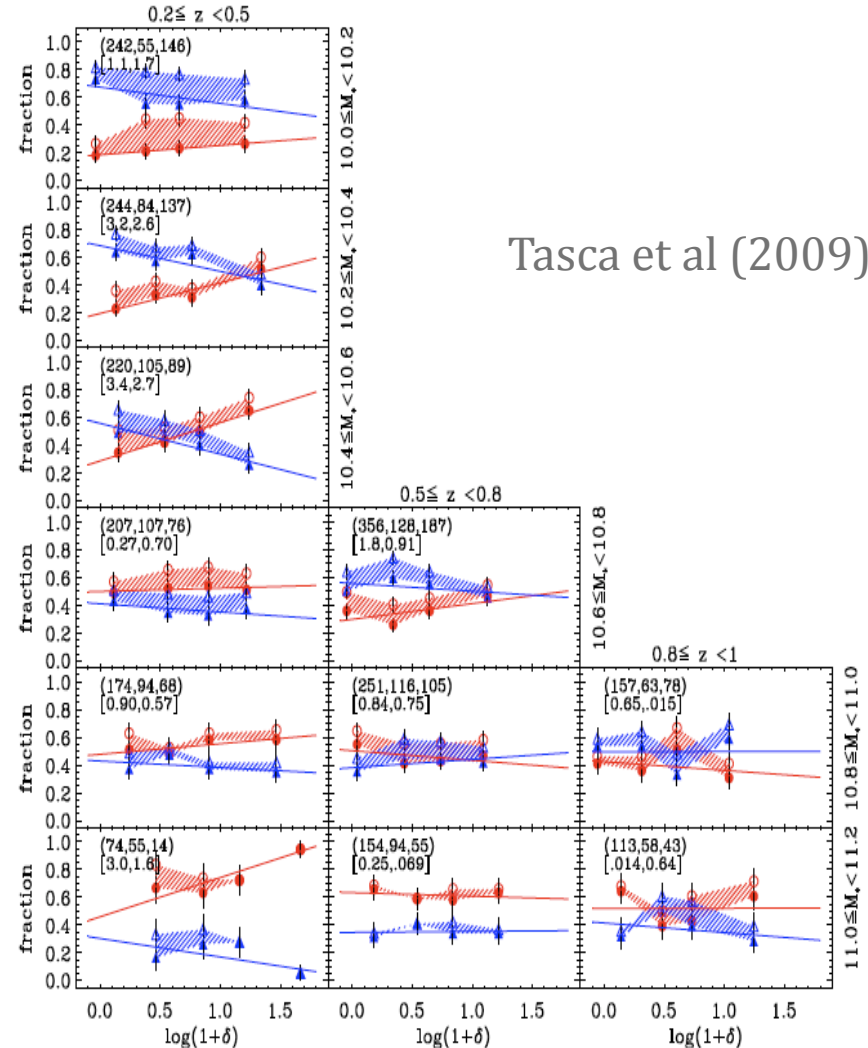


Modest decrease in mass segregation with epoch in mocks

# From luminosity-bins to mass-bins



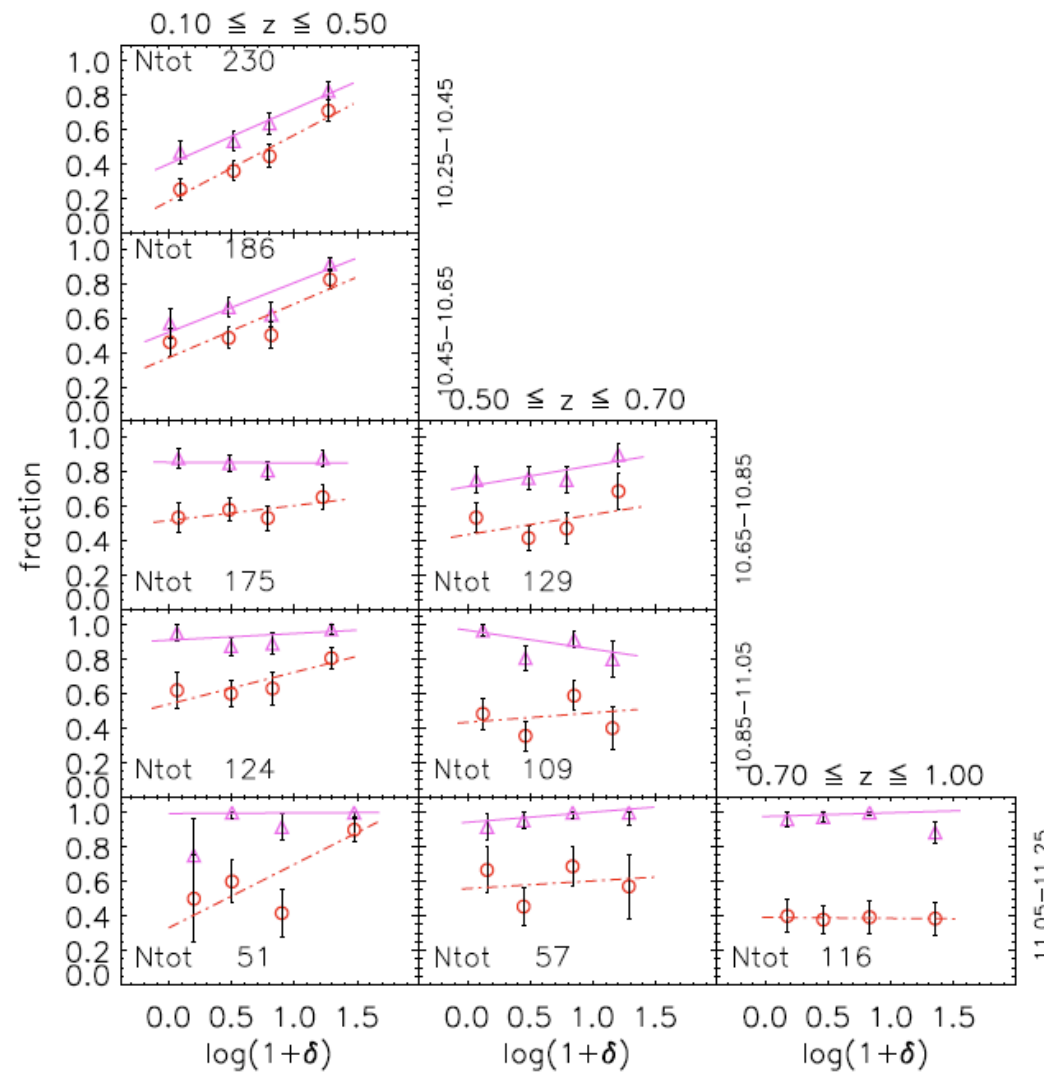
## Strong morphology-density relation in luminosity-binned samples....



Tasca et al (2009)

.... largely disappears in constant mass  
bins (@ log M > 10.6 and higher z)

# From luminosity-bins to mass-bins



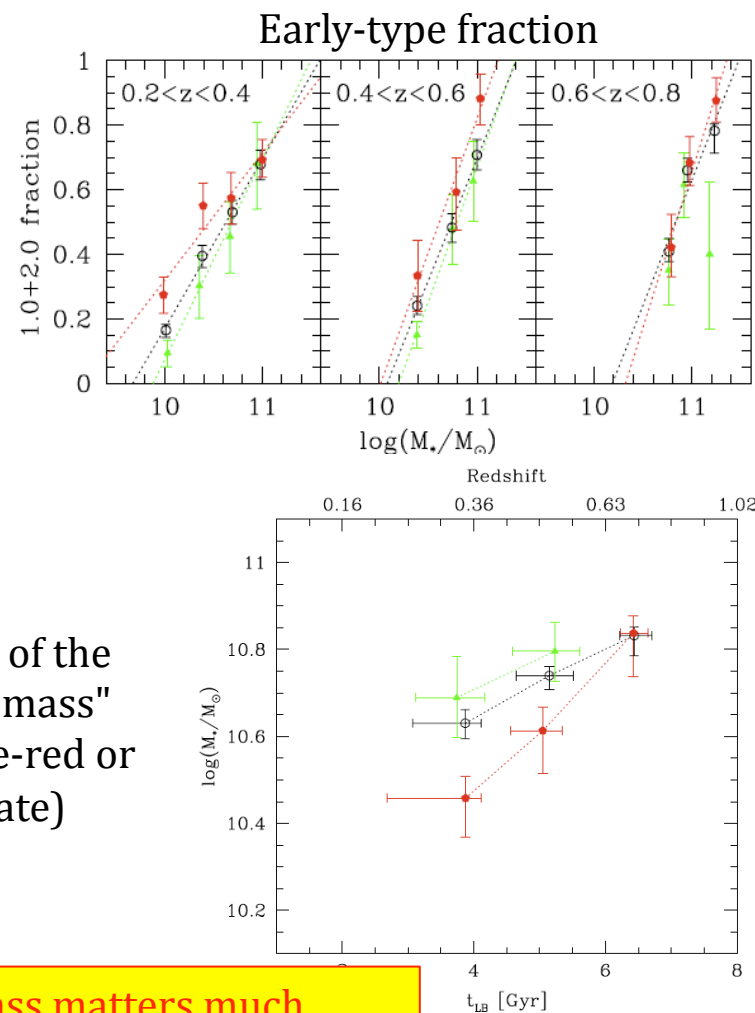
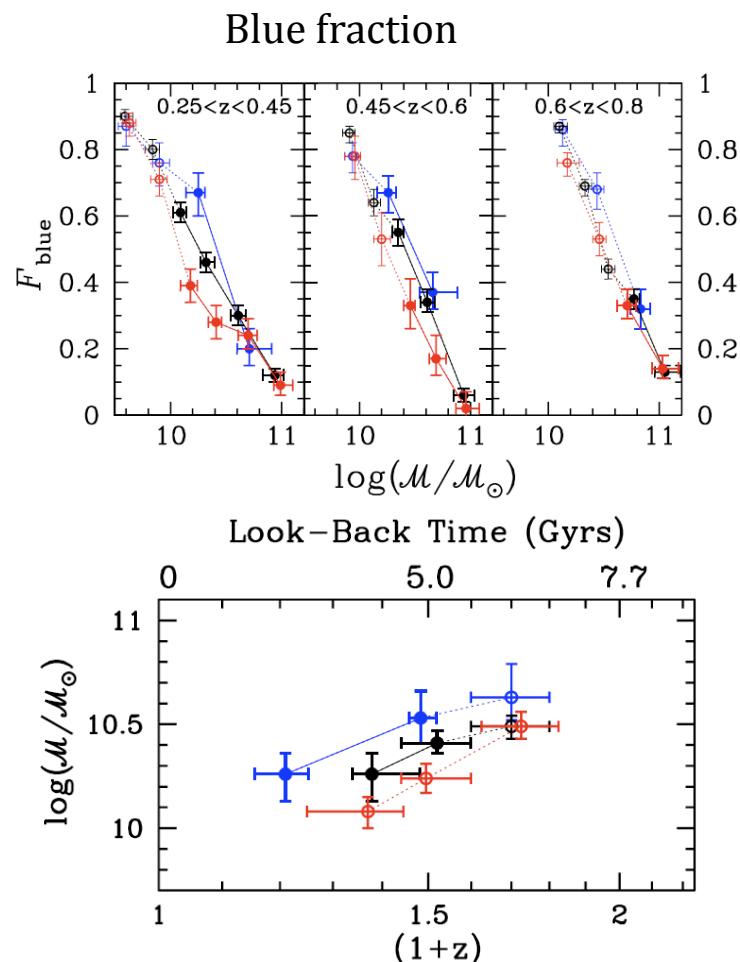
Cucciatti et al (2009)

cut at  $(U-B)_{AB} = 1.0$   
cut in green valley



# Roles of mass, environment in groups, field and isolated galaxies

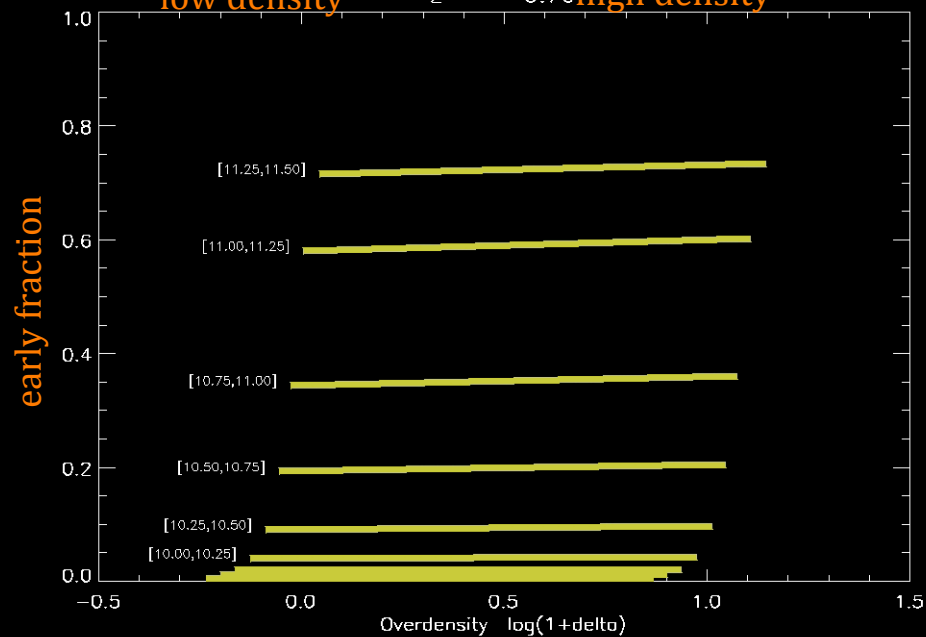
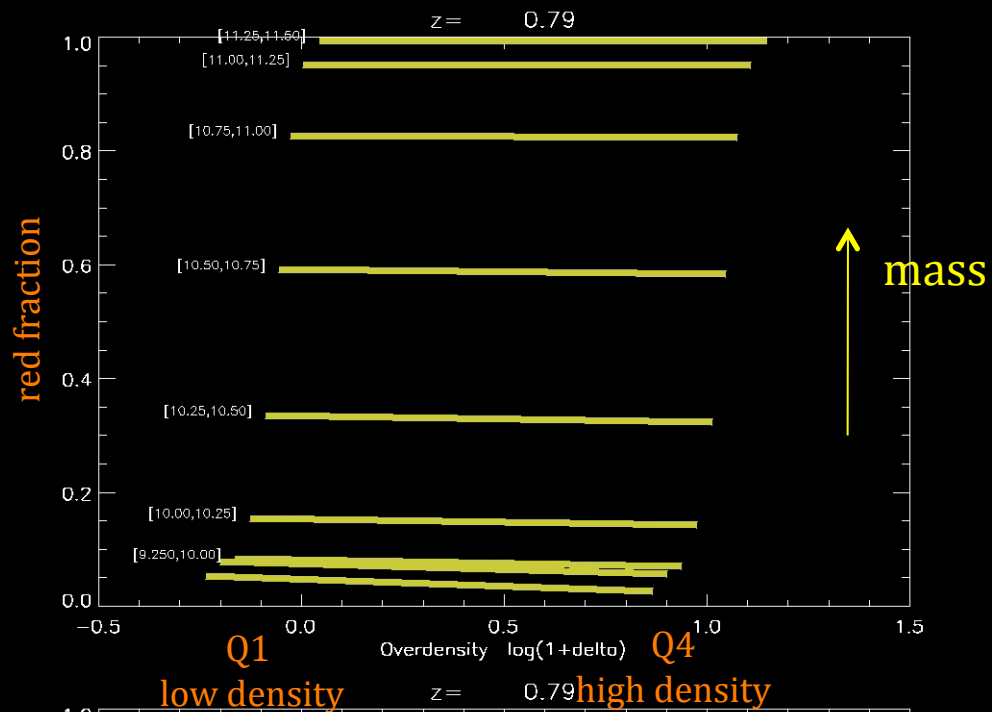
As best we can, select the same galaxies in the same groups (in red)



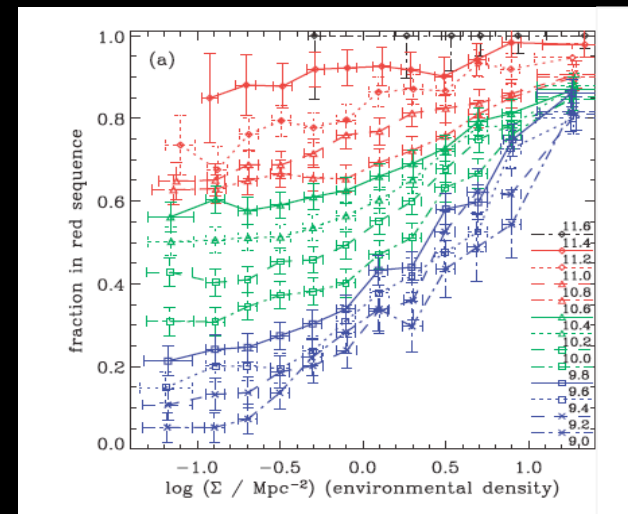
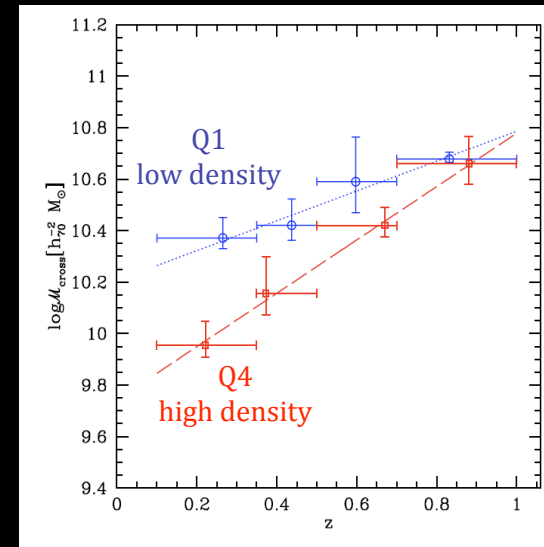
Evolution of the  
"crossing mass"  
(50:50 blue-red or  
early-late)

- Environment (only) buys you a couple of Gyr and mass matters much more. But transformation rate is faster in denser environments, leading to widening of differences which are small at  $z = 1$  and significant at  $z = 0$

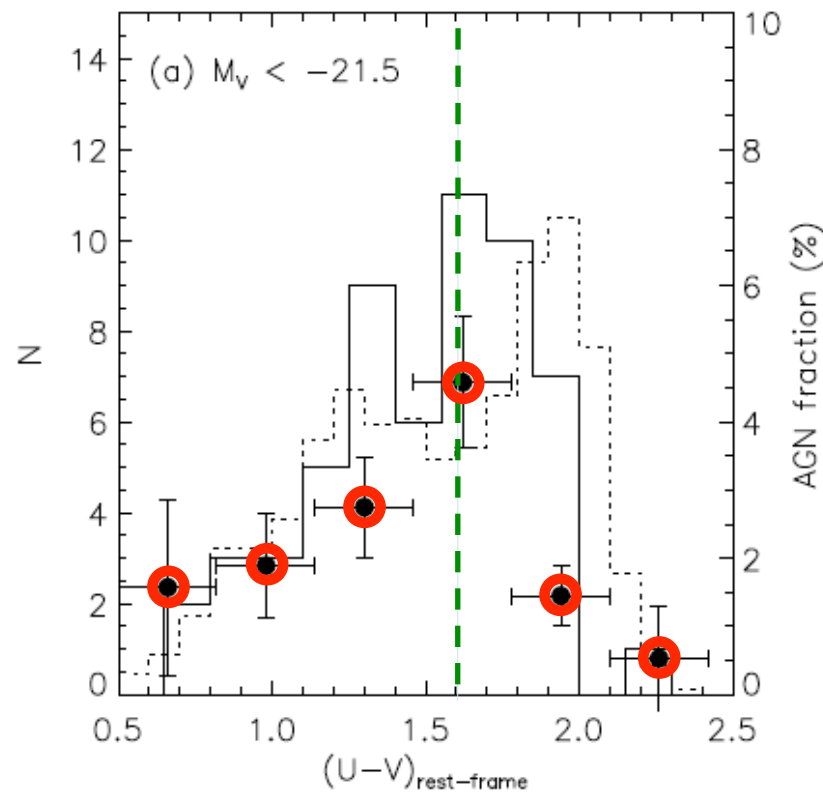
Iovino et al (2009)  
Kovac et al (2009b)



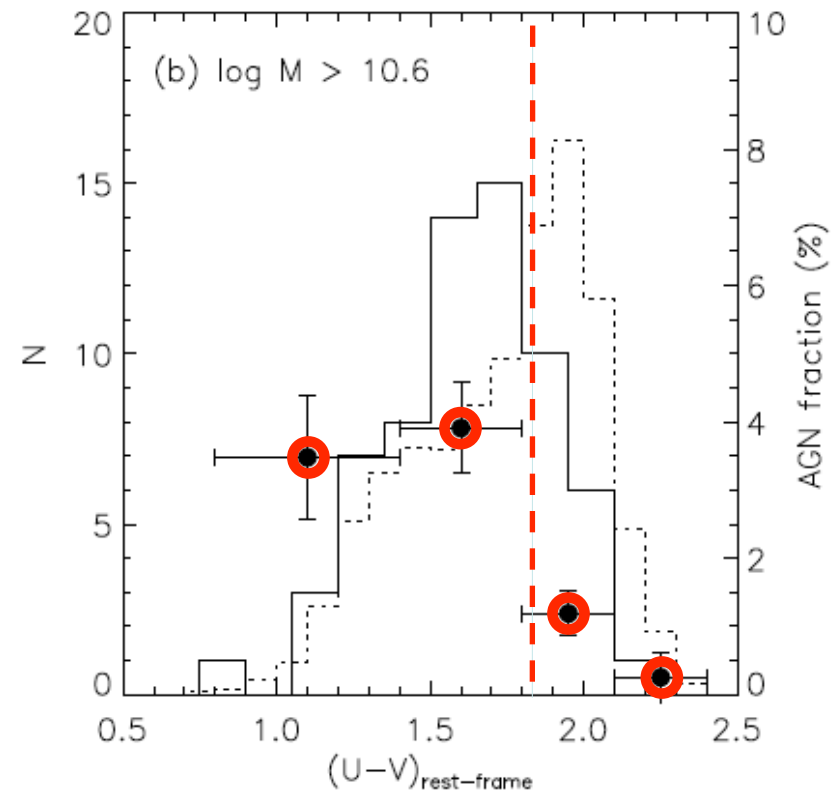
Summary: the build-up of the density-color and -morphology relations at constant mass



## Importance of star-formation and mass in X-ray selected low luminosity AGN



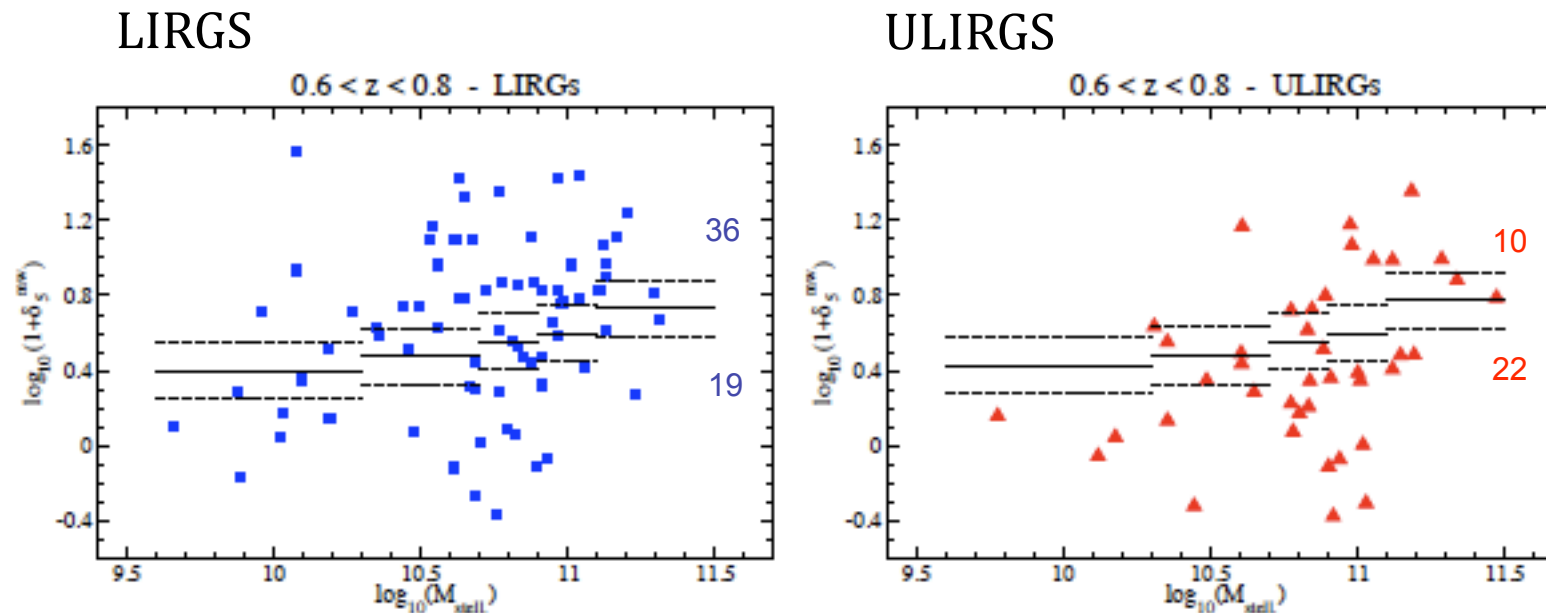
preferentially in green valley?  
(luminosity-selected)



or a step-function with star-formation  
(mass-selected)?

## Other interesting phenomena to be explored

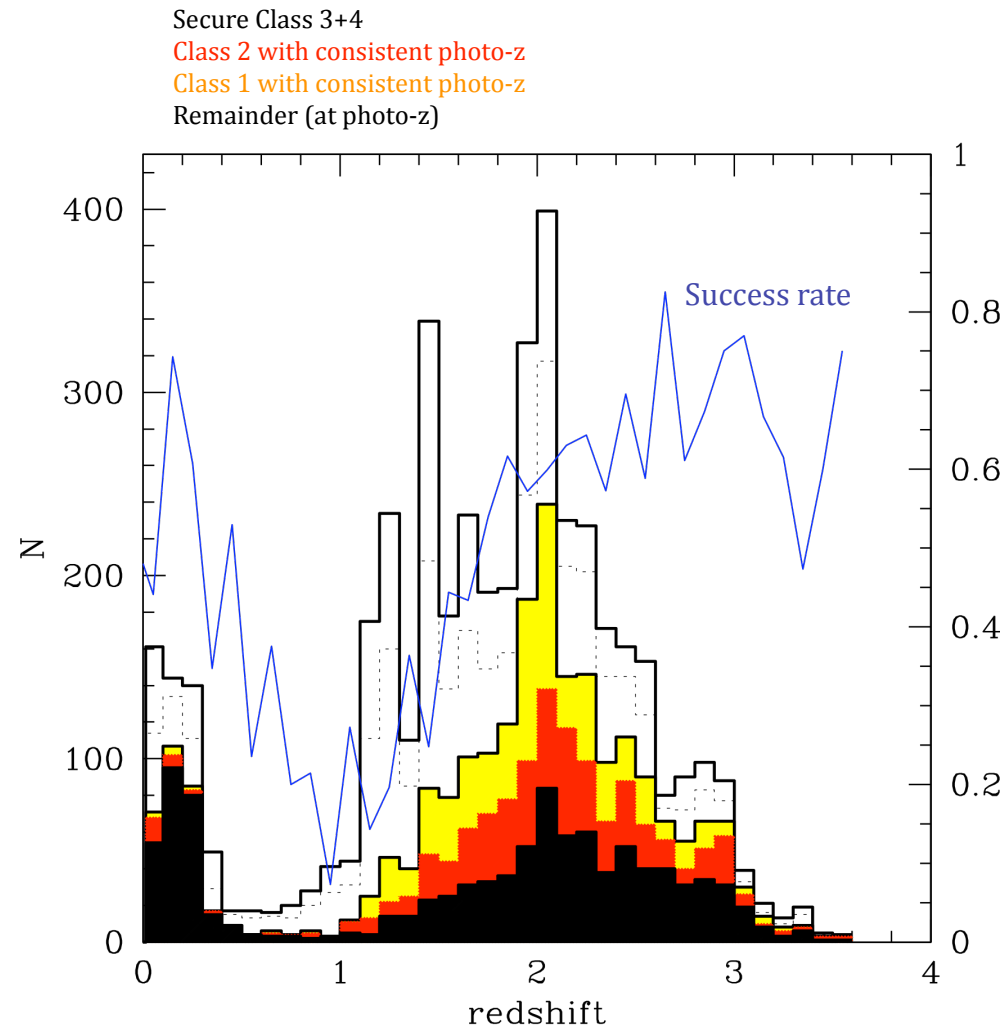
LIRGs ( $10^{11}$ - $10^{12}L_{\text{sun}}$ ) at  $0.6 < z < 0.8$  are in slightly overdense regions with more passive neighbours, relative to control sample of same stellar mass, whereas ULIRGs ( $>10^{12} L_{\text{sun}}$ ) are in somewhat underdense regions with more actively star-forming neighbours

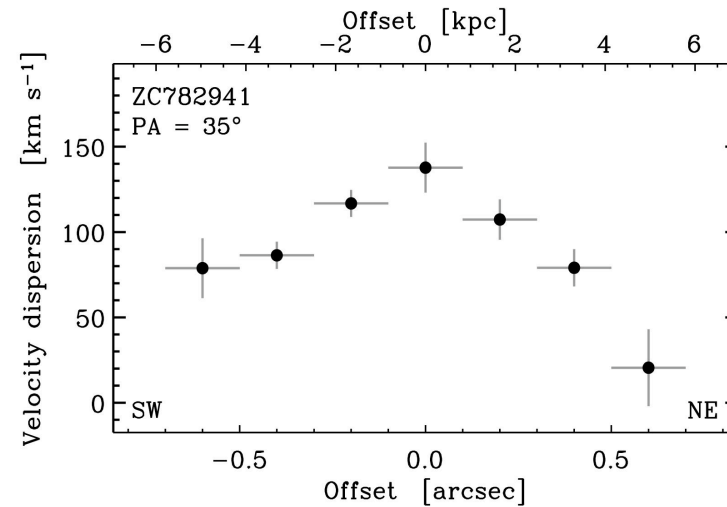
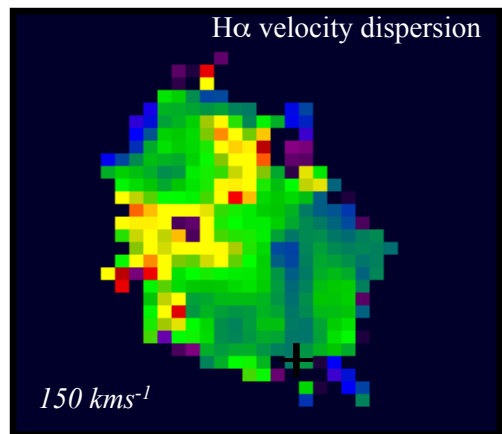
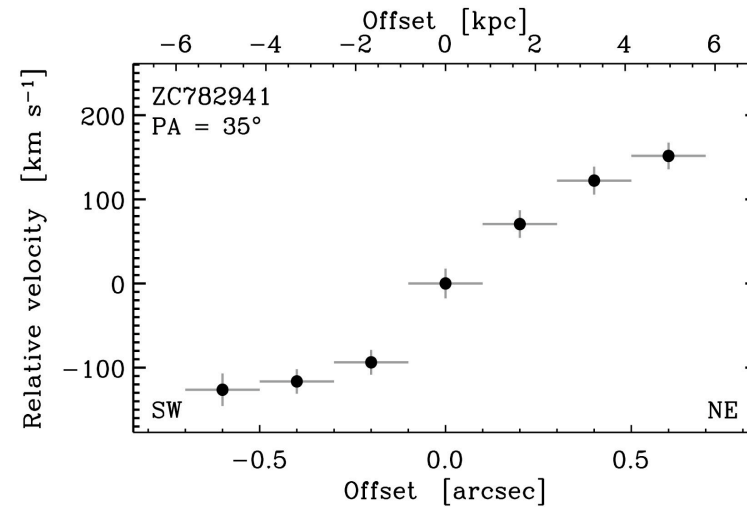
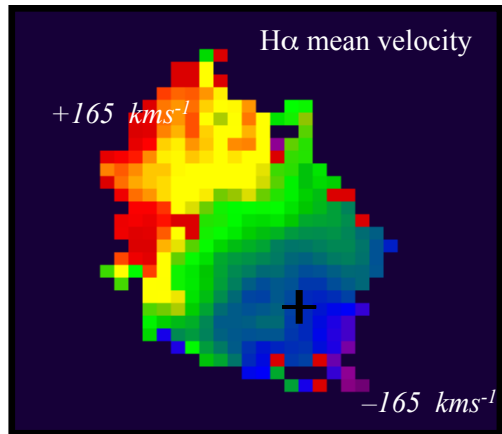




# zCOSMOS-deep (colour-selected at $1.4 < z < 3$ )

Currently 2000 galaxies at  $z > 1$  (will double by end of 2009)





$$v_c = 260 \text{ km s}^{-1}$$

$$\sigma_{1d} = 135 \text{ km s}^{-1}$$

$$r_{1/2} = 3.0 \text{ kpc}$$

$$M_{\text{dyn}} = 5 \times 10^{10} M_\odot$$

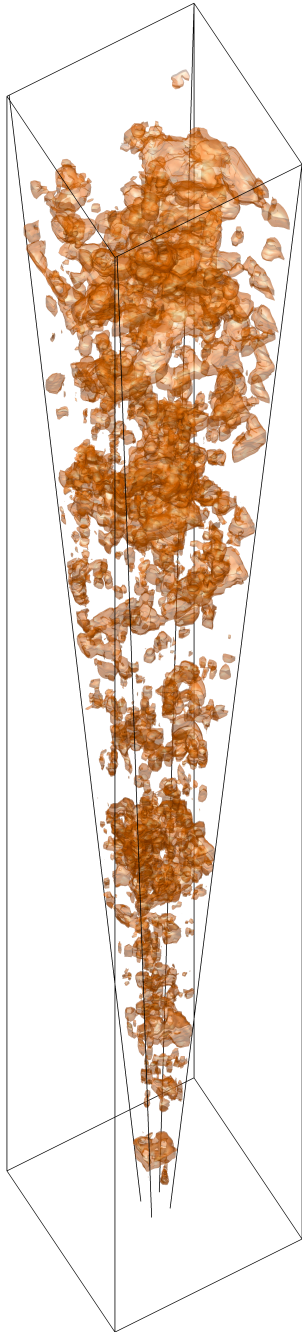
$$j = 800 \text{ km s}^{-1} \text{ kpc}$$

$$\text{SFR (H}\alpha) \sim 60 M_\odot \text{ yr}^{-1} \rightarrow \tau \sim 10^9 \text{ yr}$$

A large  
galactic disk at  
 $z = 2.18$

Gas-rich, turbulent, "blobby" disks with high SFR due to high volume cold flows, disk fragmentation and secular evolution? (Genzel et al 2009)

# Summary of the talk



COSMOS and zCOSMOS in particular are enabling detailed studies of environment and galaxy properties at  $0 < z < 1$ , and increasingly at  $z \sim 2$ .

## At $0 < z < 1$ :

- Galaxy properties and their evolution with time are clearly very dependent on mass.
- The Nature vs. Nurture debate is complicated by the clear dependence of galactic mass on environment, which also produces strong and "artificial" effects with environment in samples that contain a range of masses (e.g. at fixed  $L$ , or above a mass threshold)
- Environment also matters (at fixed  $M$ ) but at a weaker level, equivalent to a couple of Gyr of cosmic time (or 0.25 dex in  $\text{mas}$ ) at  $z \sim 0.5$ , over the full range of environments
- The importance of environment (at fixed  $M$ ) grows with time due to a faster "transition rate" in dense environments at  $z < 1$ . There is little dependence present at  $z = 1$ .

## At $z \sim 2$ :

- Environmental measures at  $z = 2$  will hopefully soon be possible, both in galaxies and the IGM.
- Many rapidly star-forming galaxies appear to be large lumpy rotating turbulent disks (collaboration with SINS program)