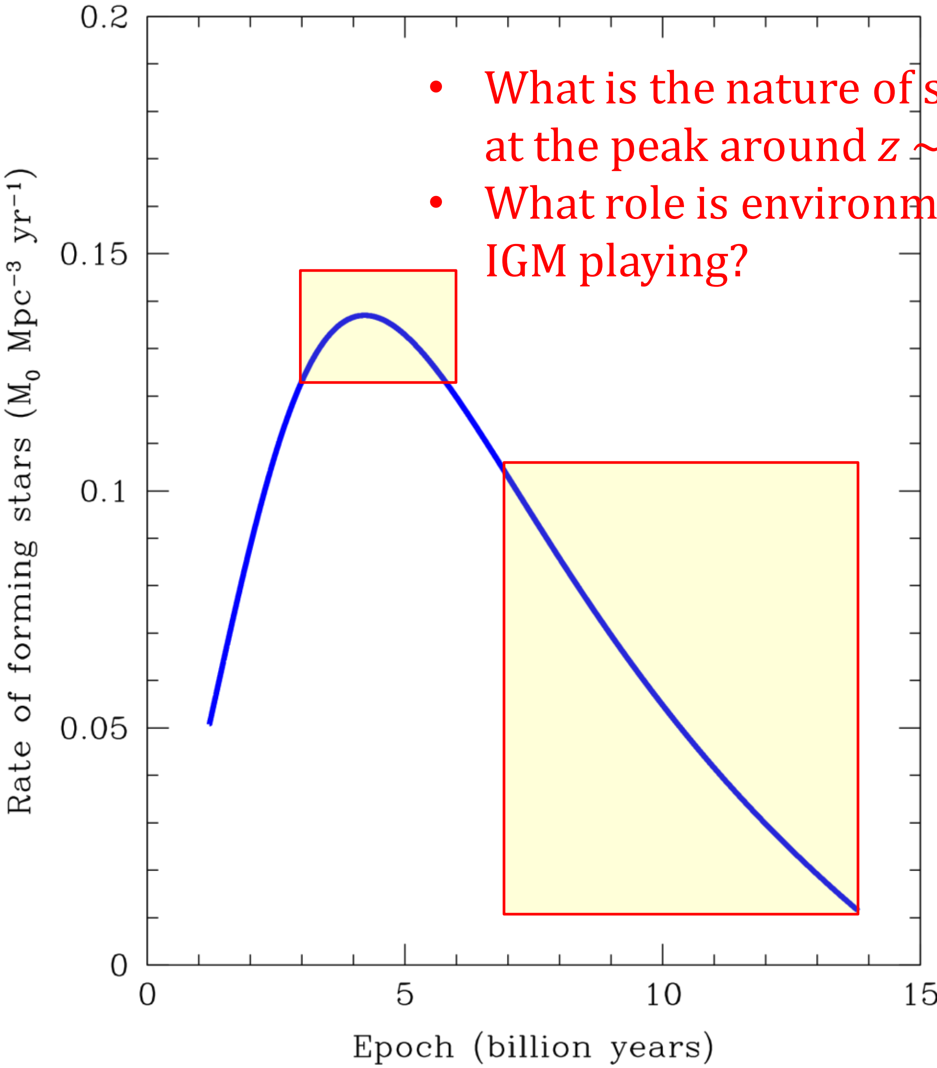
zCOSMOS

galaxy evolution in different places and
at different times

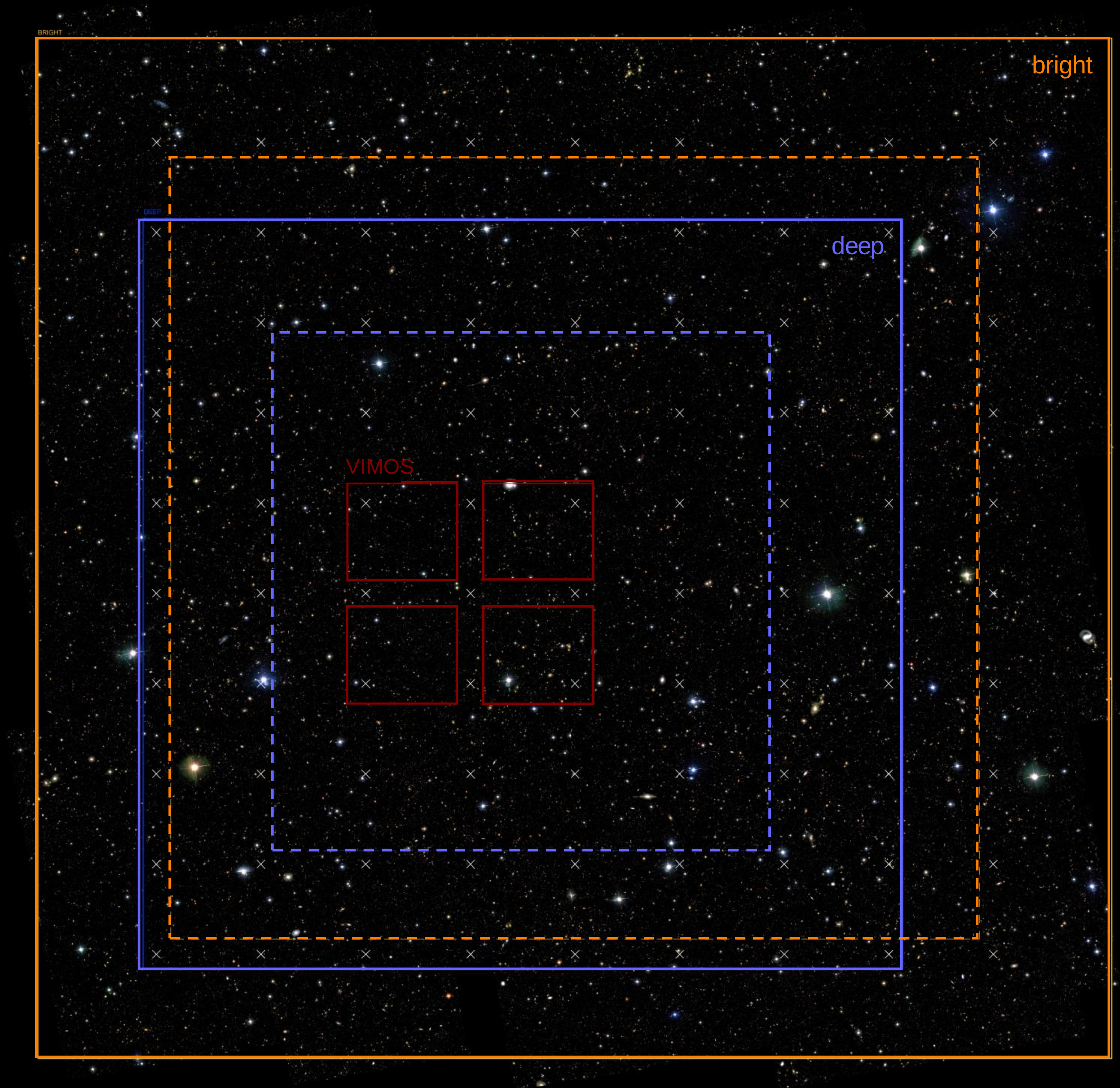
Simon Lilly and zCOSMOS team

Main Science Goals: Environment and evolution



- What is the nature of star-formation at the peak around $z \sim 2$?
- What role is environment and the IGM playing?

- What causes the decline in star-formation at late epochs $z < 1$ (e.g. the "down-sizing")?
- What are the relative roles of mass and environment? *Nature or Nurture?*



zCOSMOS-bright

- $I_{AB} < 22.5$
- MR-Red 1.0 hr
- 90 pointings observed with two masks each giving 8x pass in central area
- 70% sampling
- ~100 kms^{-1} accuracy
- about 20,000 spectra

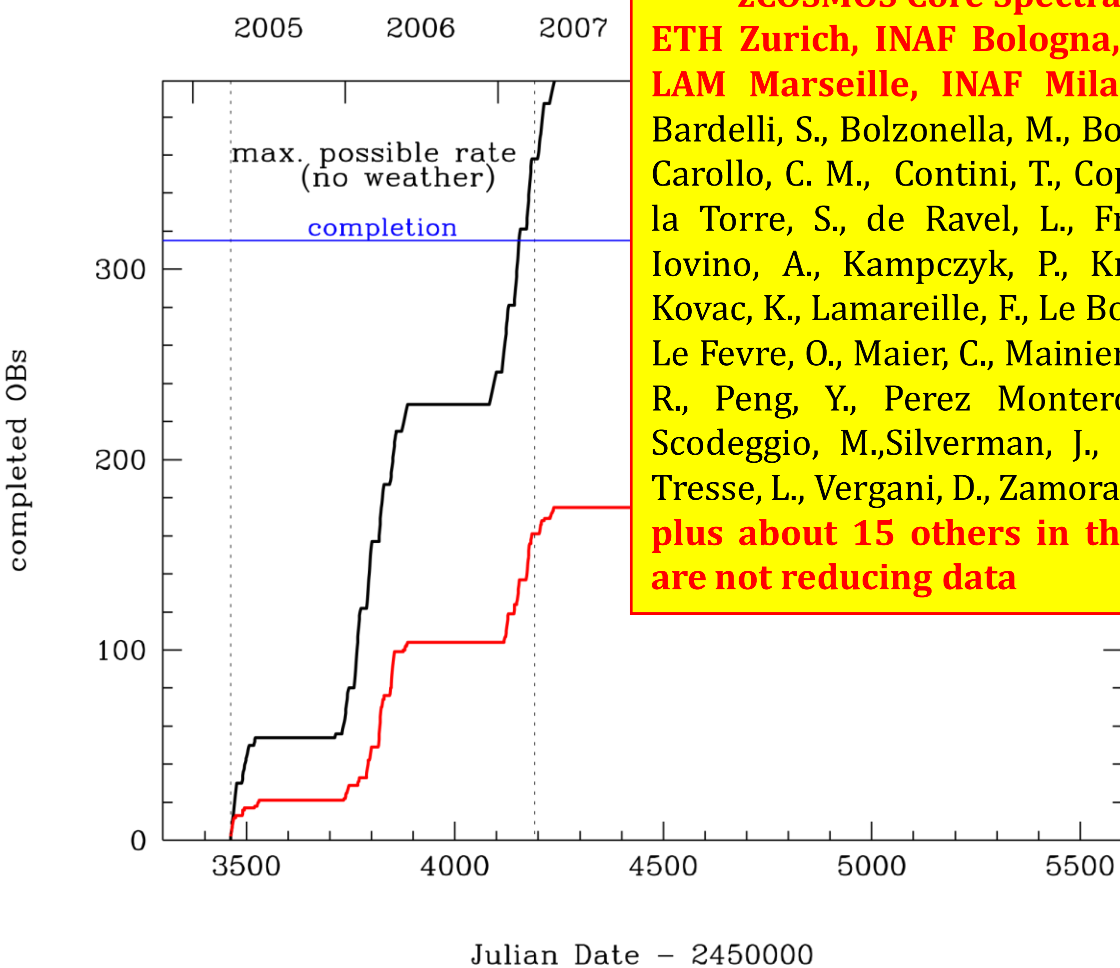
zCOSMOS-deep

- $B_{AB} < 25.25$ colour-selected $1.5 < z < 4$ via *gzK* or *ugr* colours
- LR-blue 4.5 hrs
- 42 pointings in total giving 4x pass in central area
- 70% sampling
- $B_{AB} < 25.25$ $(+K_{AB} < 23.5$ for gzK)
- about 10,000 spectra

Together: 600 hours of observation on UT3

zCOSMOS

- 5-year program at VLT (50% of available time on UT-3)
- At least 30 person-years** of spectral reduction work



**** zCOSMOS Core Spectral Reduction Team:**
ETH Zurich, INAF Bologna, MPE/ESO Garching, LAM Marseille, INAF Milano, OAMP Toulouse
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., Scodeggio, 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

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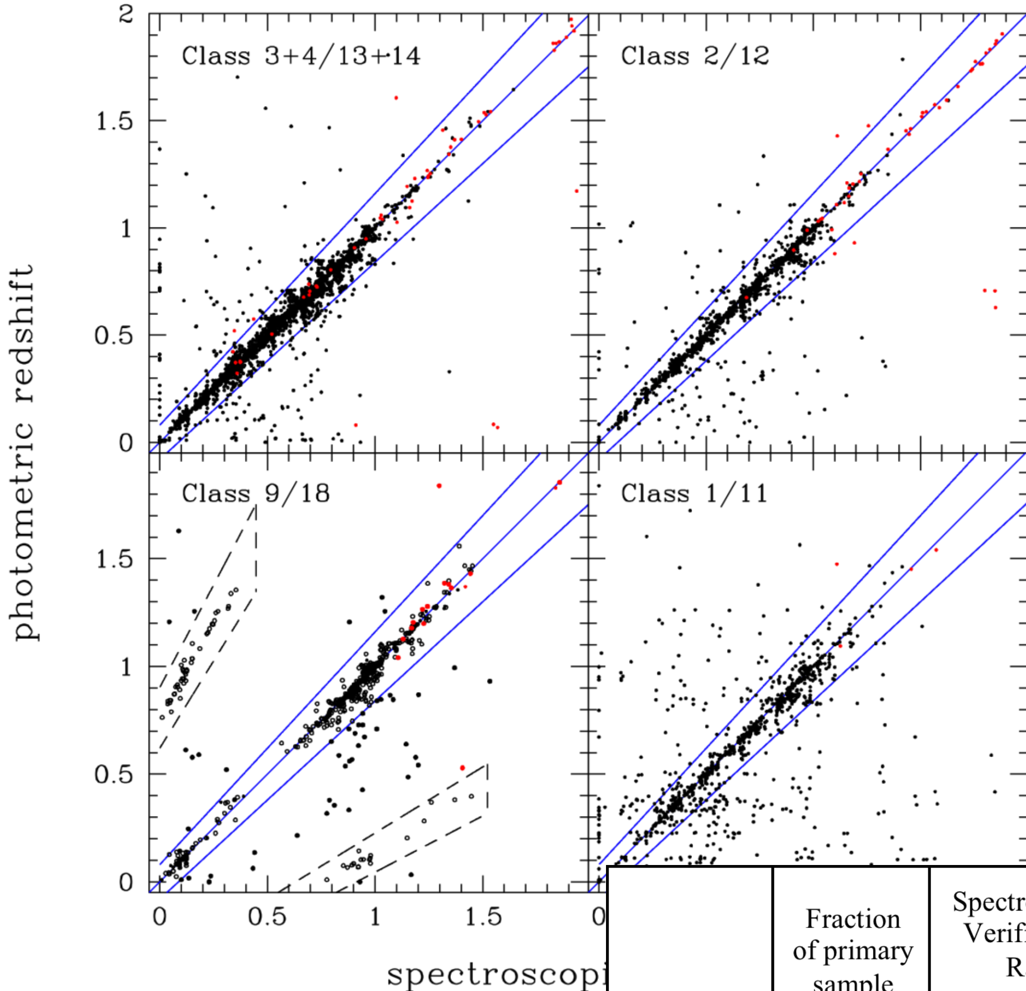
now completed.
k-sample by early

p

•Currently just assembled first 50% of data fom 21/42 masks (4.5k sample).

•Observations of remainder should (just about) complete by the end of the 2009 observing season

zCOSMOS-bright: spectro-z and photo-z

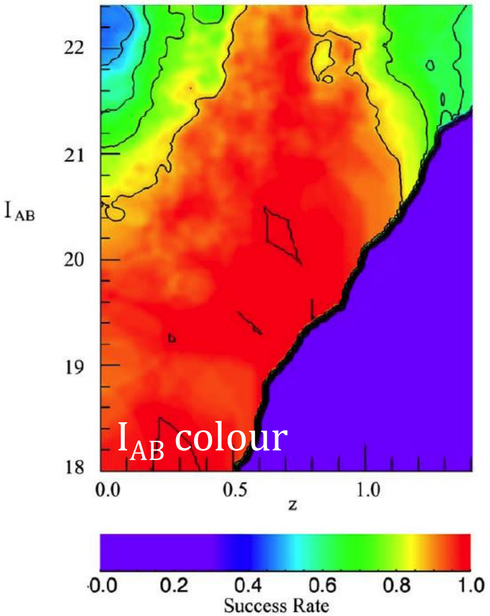


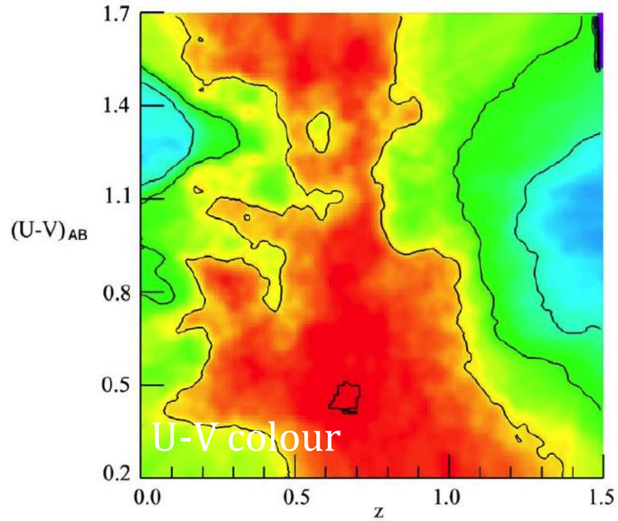
- 30 band photometry
- $\sigma_z < 0.01(1+z)$ with 0.5 – 3% floor of outliers due to photometric "problems" treatable with cleaning Ilbert et al 2009 (also now for AGN Salvato et al 2009)

- 600 repeat spectra: excellent agreement between "spectroscopic repeatability" and "photo-z consistency"

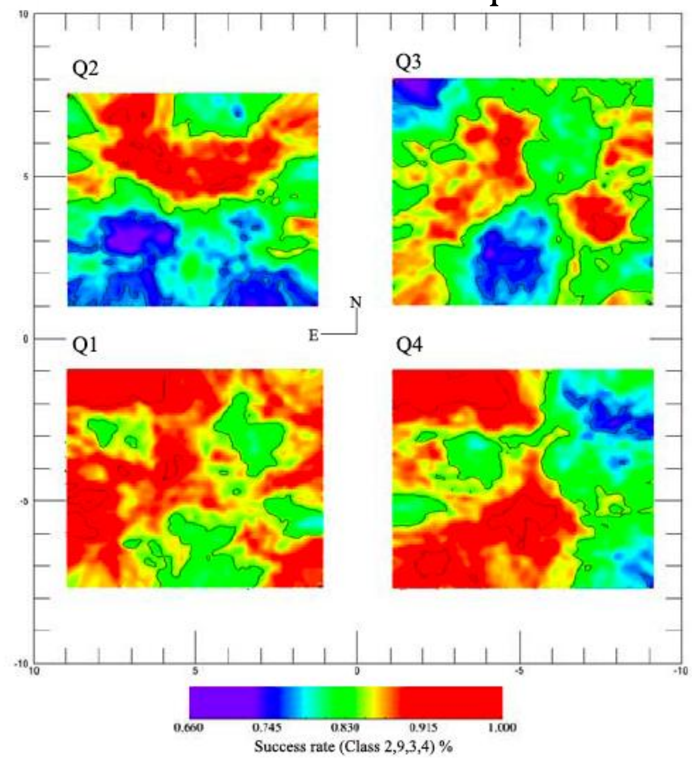
	Fraction of primary sample	Spectroscopic Verification Rate p_i	Photo-z consistency within $\Delta z = 0.08(1+z)$		
			ZEBRA v3.4	Ilbert et al (2009) v3.5	
			All	All objects	Not photometrically masked[b]
Classes 3 and 4	61%	99.8%	95%	96%	98.5%
Class 9	6%	86-96%[a]	94%	94%	95%
Class 2	15%	92%	93%	93%	94%
Class 1	10%	70%	72%	72%	72%
Class 0	8%	-	-	-	-

Good characterization of survey performance



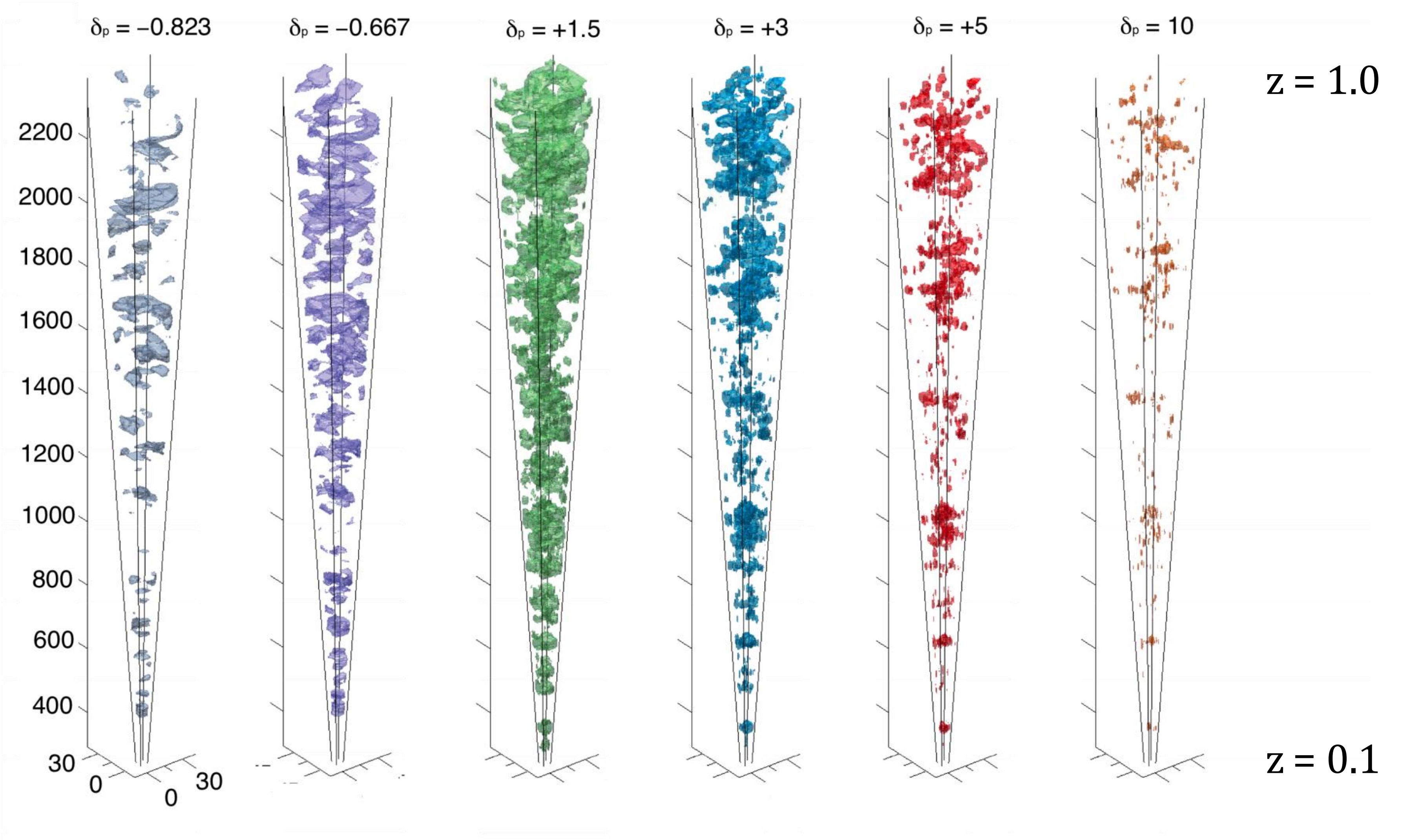


VIMOS quadrants



- Sample at $0.5 < z < 0.8$ is >95% complete at > 99% redshift reliability
- Final sampling rate will be 70% of targets
- Velocity accuracy 110 kms^{-1}
- Non-trivial spatial sampling

Characterizing environment to *z* = 1



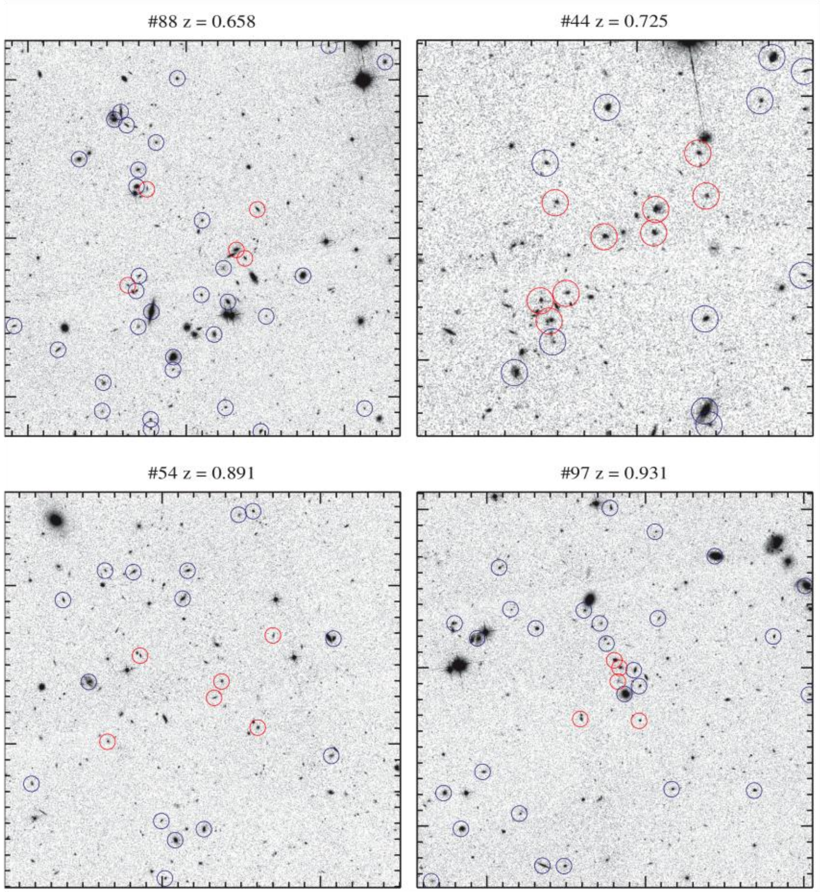
zCOSMOS density field using ZADE approach combining spectro-z+photo-z (Kovac et al 2009)

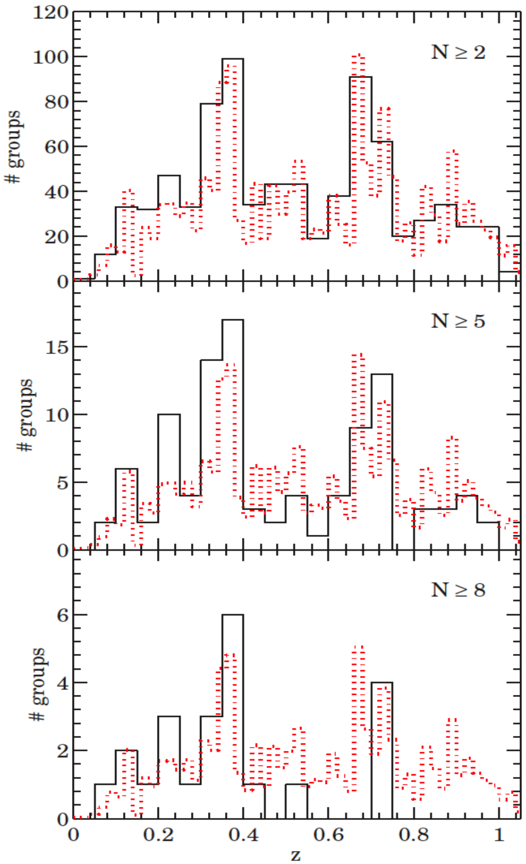
Galaxy groups to $z = 1$

High fidelity groups using optimized FoF+VDM algorithms (Knobel et al 2009)

- 151 groups (N ≥ 4)
- plus another 649 (4 > N ≥ 2)

•group membership is 30% of galaxies at $z = 0.3$ and still 10% at $z = 0.8$



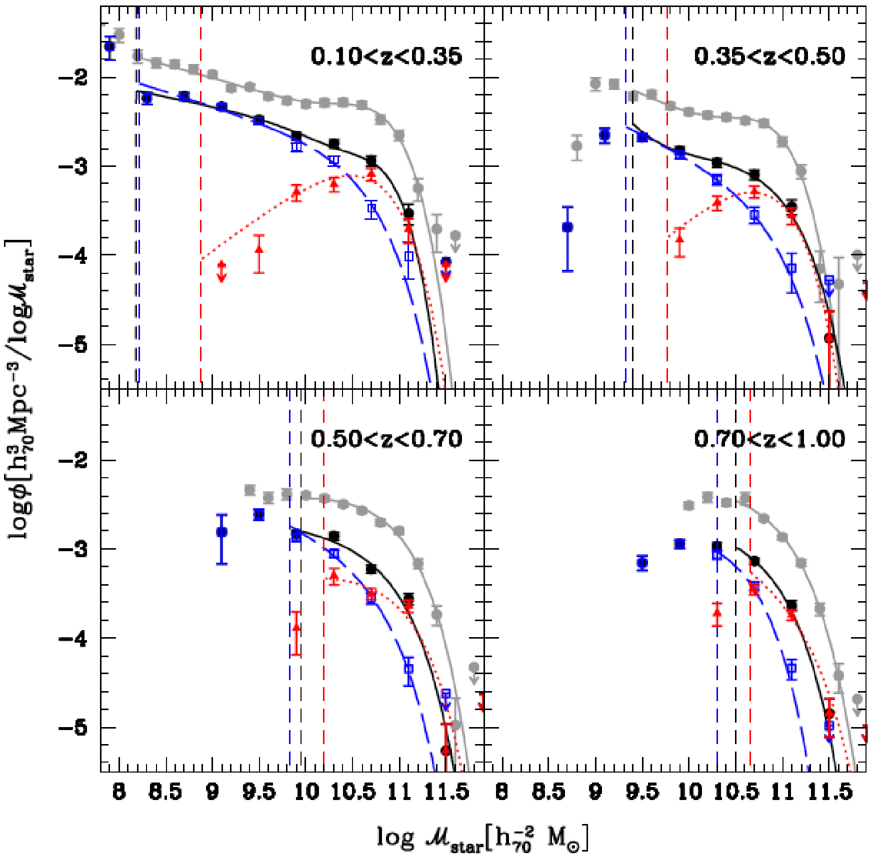


Recent 2008/9 zCOSMOS results 0 > z < 1 based on galaxy mass and environment:

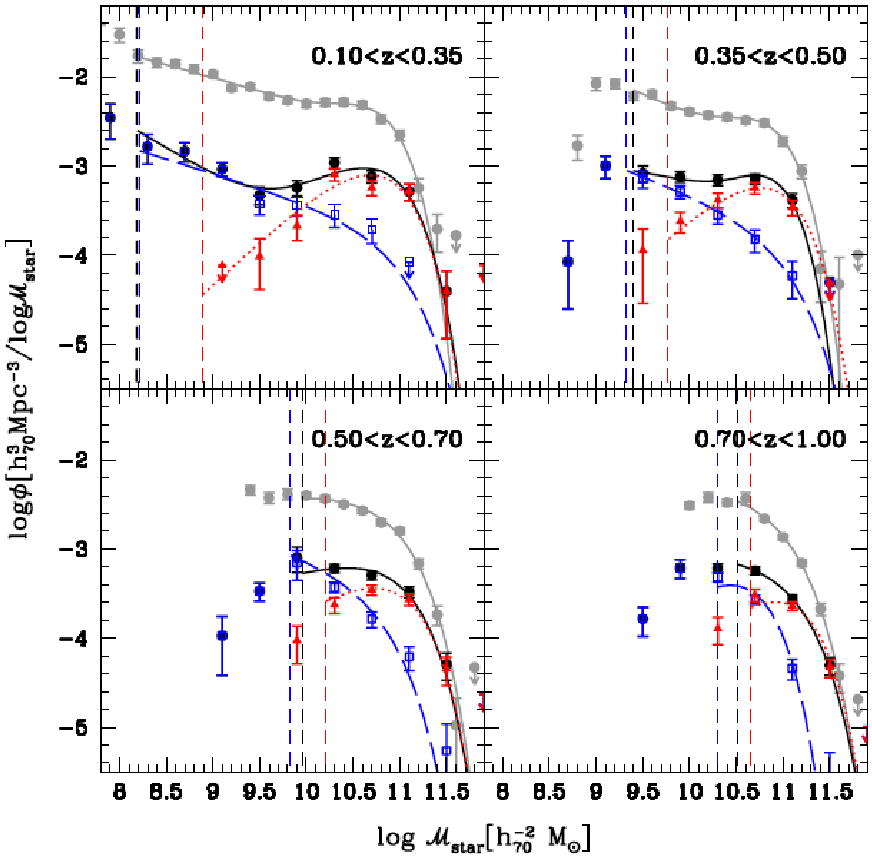
1. GSMF depends on environment, complicating Nature vs. Nurture question (Bolzonella et al., Pozzetti et al.)
2. Shape of GSMF of star-forming and quiescent galaxies varies little with redshift
2. The quite strong relations with density in morphology and colours seen at $z \leq 1$(Tasca et al., Cucciati et al.) are largely but not entirely "selection effects" driven by (1). Also seen in groups vs. field vs. isolated (Iovino et al., Kovac et al.).
3. Rate of colour/morphological transformation is somewhat faster in denser environments. Some evidence that colour may "lead" morphological transformation.
4. Fraction of galaxies hosting X-ray AGN is a simple step-function with star-formation and not a peak in the green-valley (Silverman et al.)
5. Environments of 24 mm sources at $z \sim 0.7$ varies across the LIRG/ULIRG boundary (Caputi et al.).

Different GSMF in different environments

Low density, blue and red galaxies

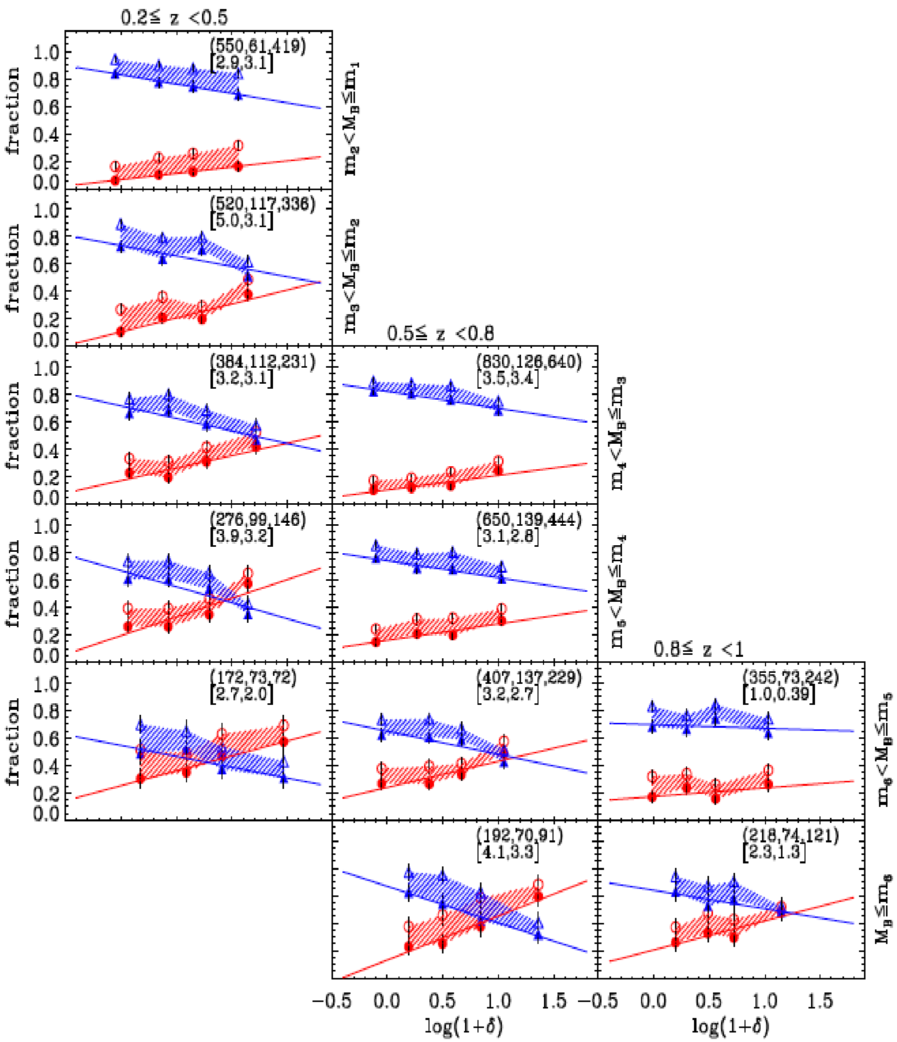


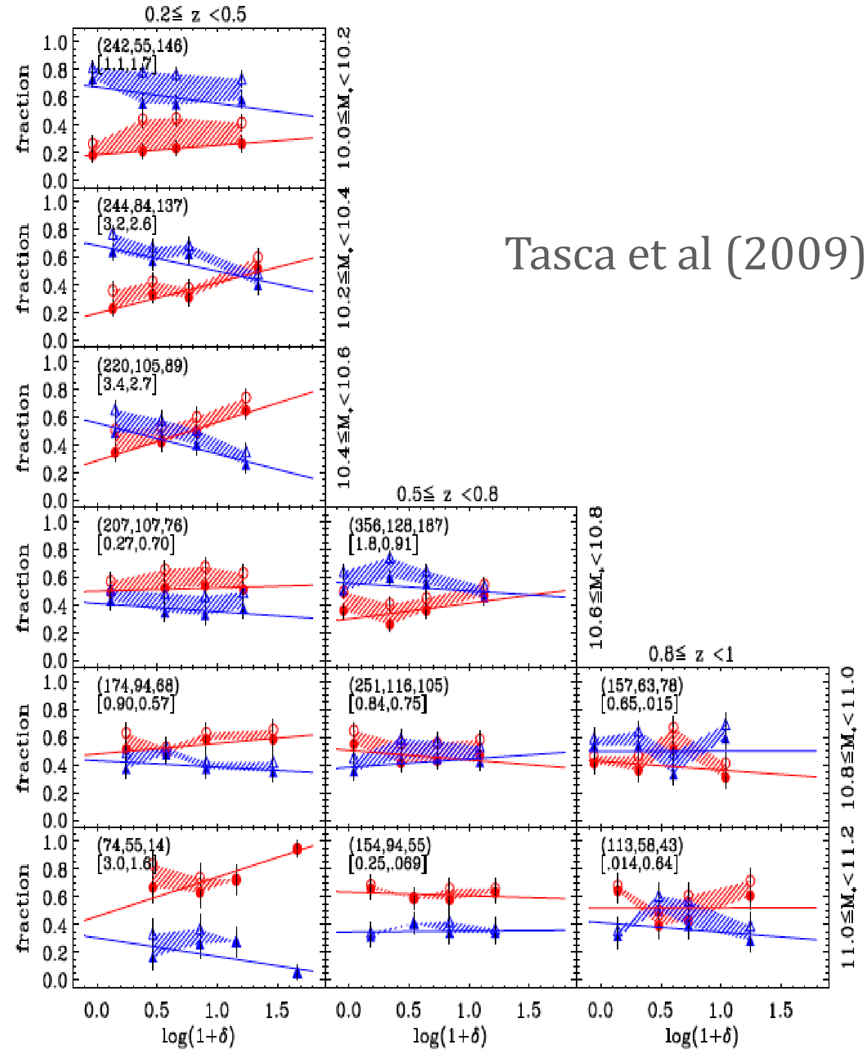
High density, blue and red galaxies



Bolzonella et al (2009)

Relative role of mass and environment



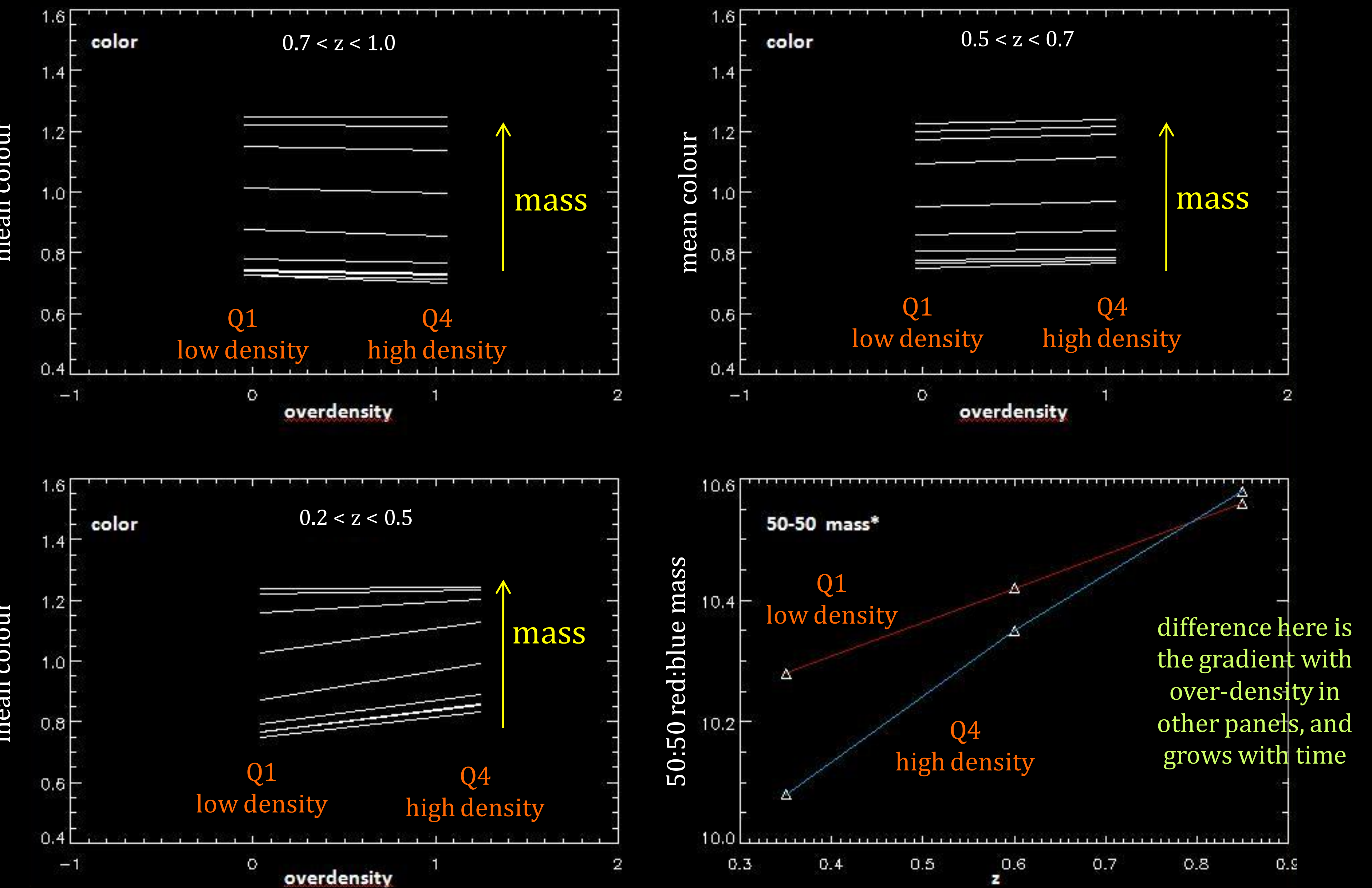


Tasca et al (2009)

Strong morphology-density relation in <u>luminosity</u>-binned samples....

.... largely disappears in constant <u>mass</u> bins (at least for log M > 10.6)

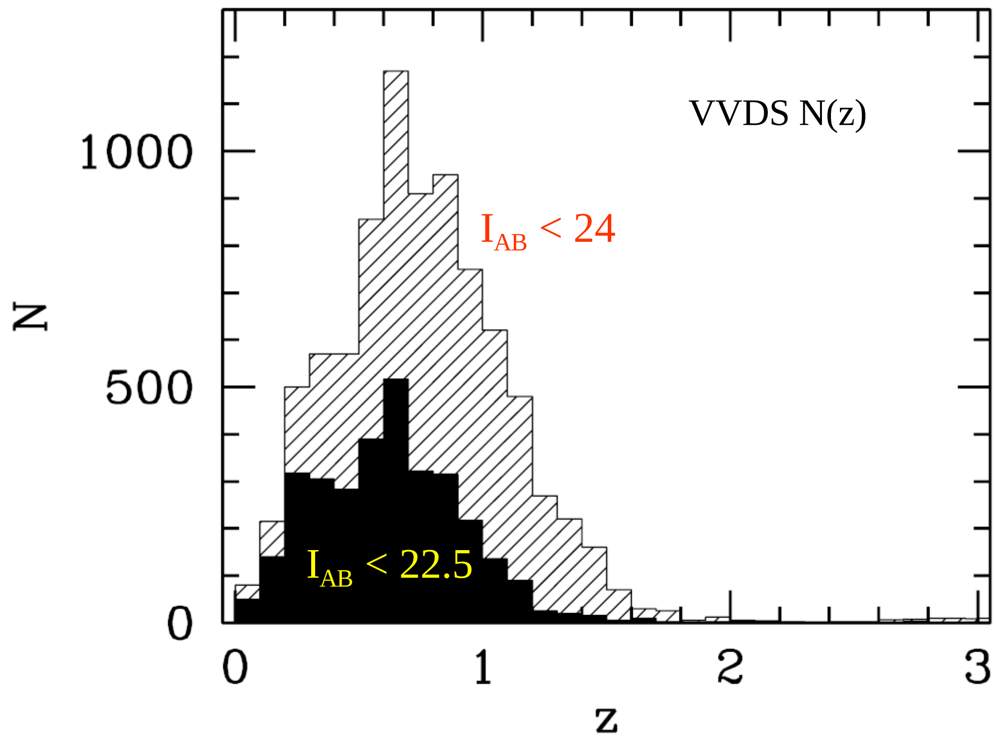
Summary – the build-up of the density – colour relation

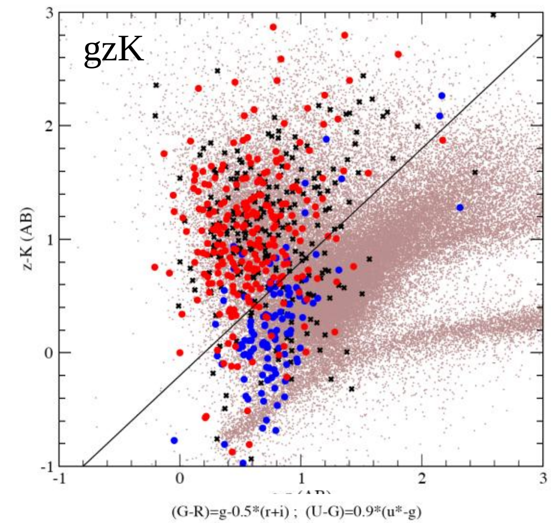


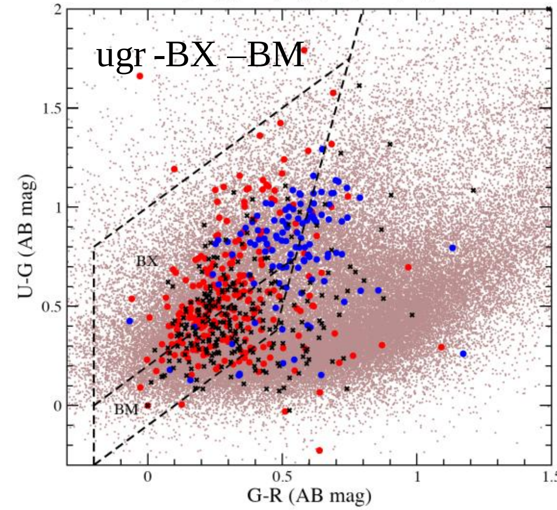
zCOSMOS-deep

To get large samples of $z \sim 2$ galaxies, you must apply colour-selection. You probably also want to do spectroscopy in the blue, i.e. $B_{AB} < 25.25$, implying these are (vigourously) star-forming galaxies.

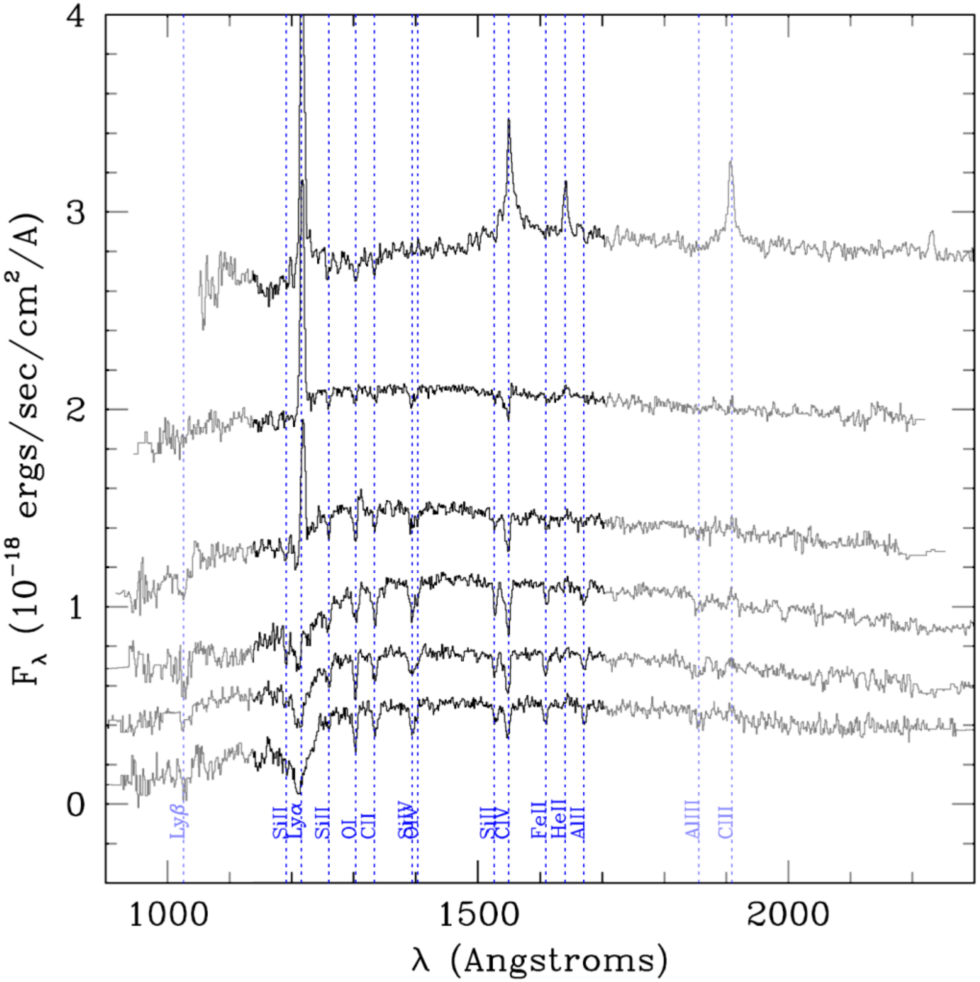
Currently working with first 4500 spectra (21/42 masks). Remainder should be observed in 2009.





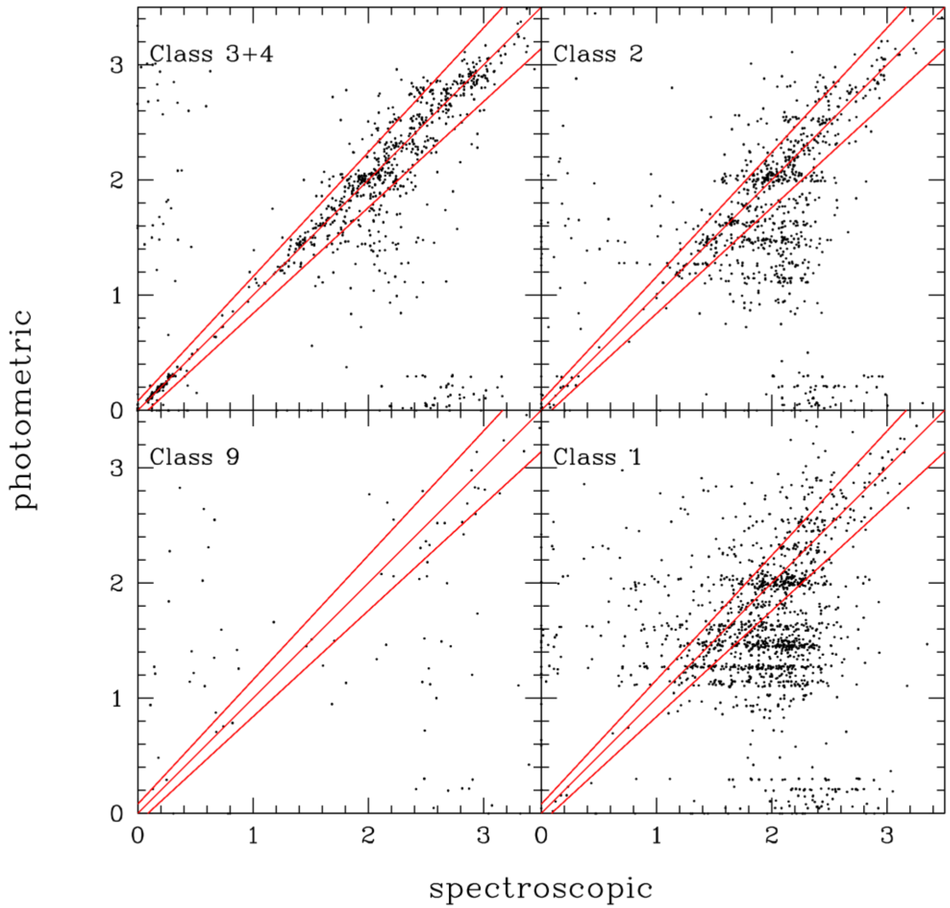


Spectral features



- LR-blue R ~ 200
  3700 > λ > 6700 A
  16200s exposure
- Redshifts based mostly on uv absorption lines at l < 1700 A, and therefore easiest for z > 1.9.

Photometric redshifts and colour-selection in zCOSMOS-deep



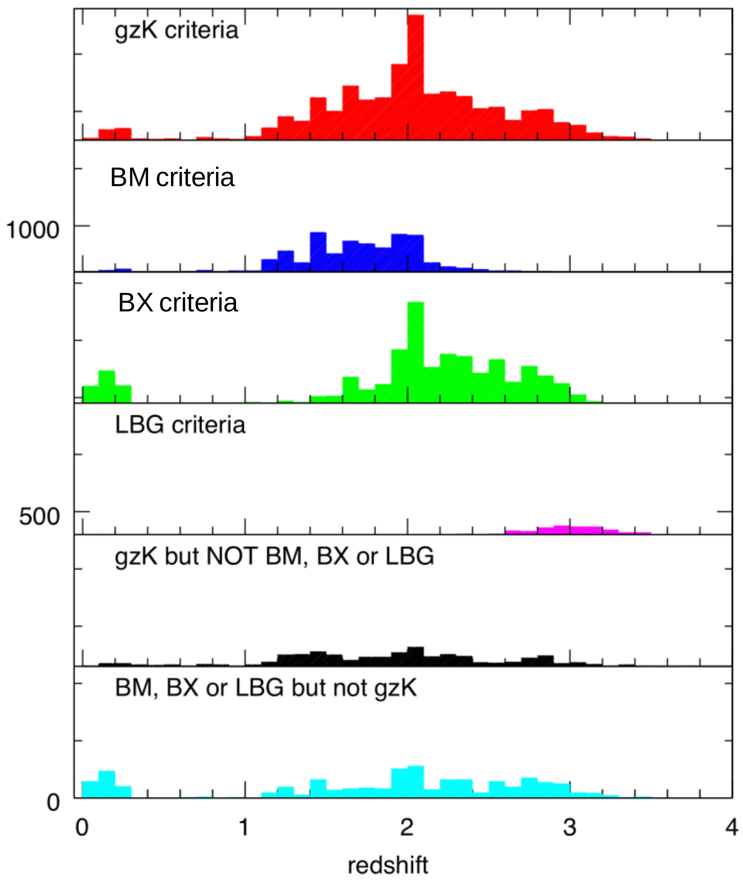
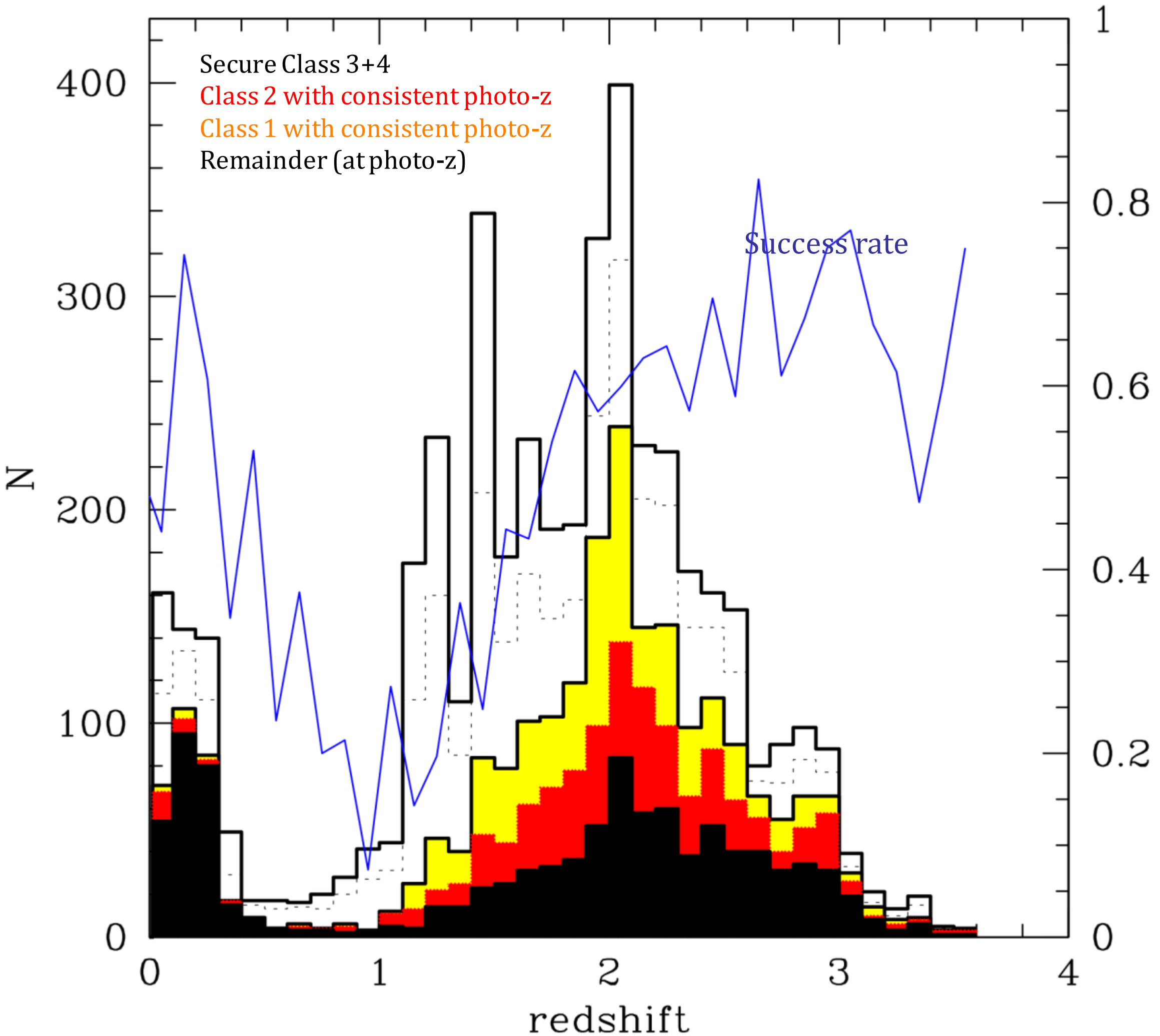


Photo-z probably will improve only with UltraVISTA

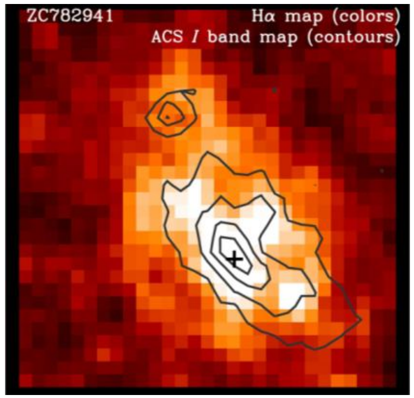
Overall redshift distribution and success rate



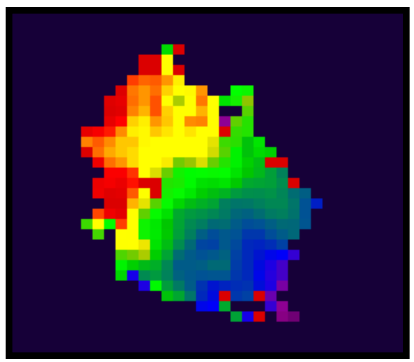
- Success rate varies with redshift and is about 66% at $z > 1.9$. Do not (yet) well understand why we fail on the reminder in this redshift range
- Already 2000 reasonably reliable redshifts at 1.0 < z < 3.5 (should get to 4000 by end of program)

(De-)constructing galaxies in the early Universe with SINFONI (collaboration with SINS team at MPE)

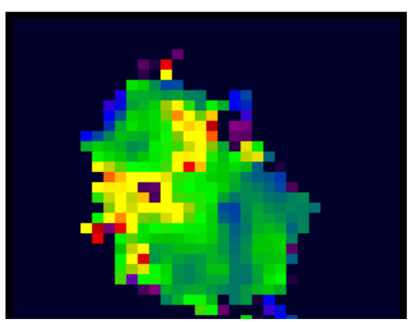
Hα distribution

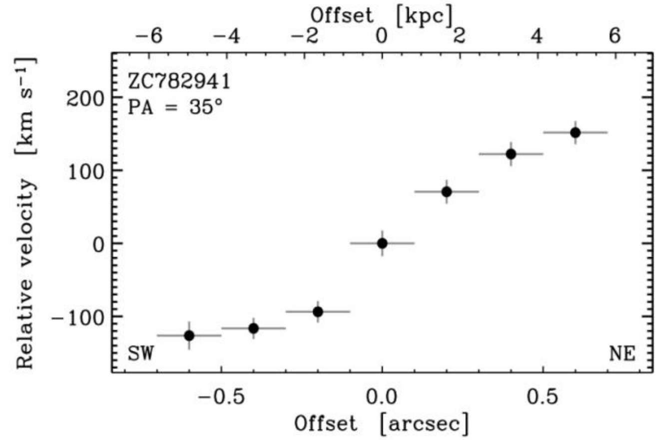


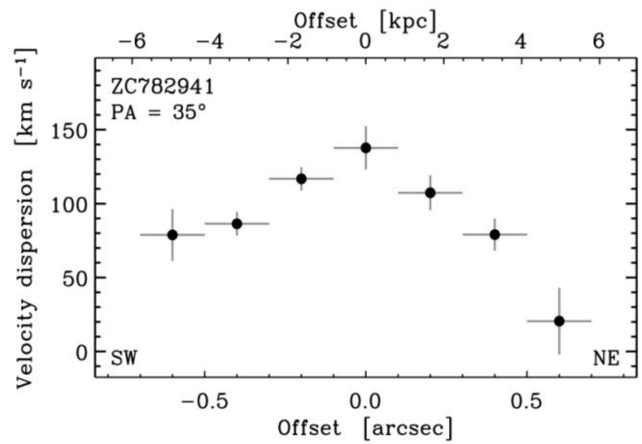
Gas rotation



Gas velocity dispersion



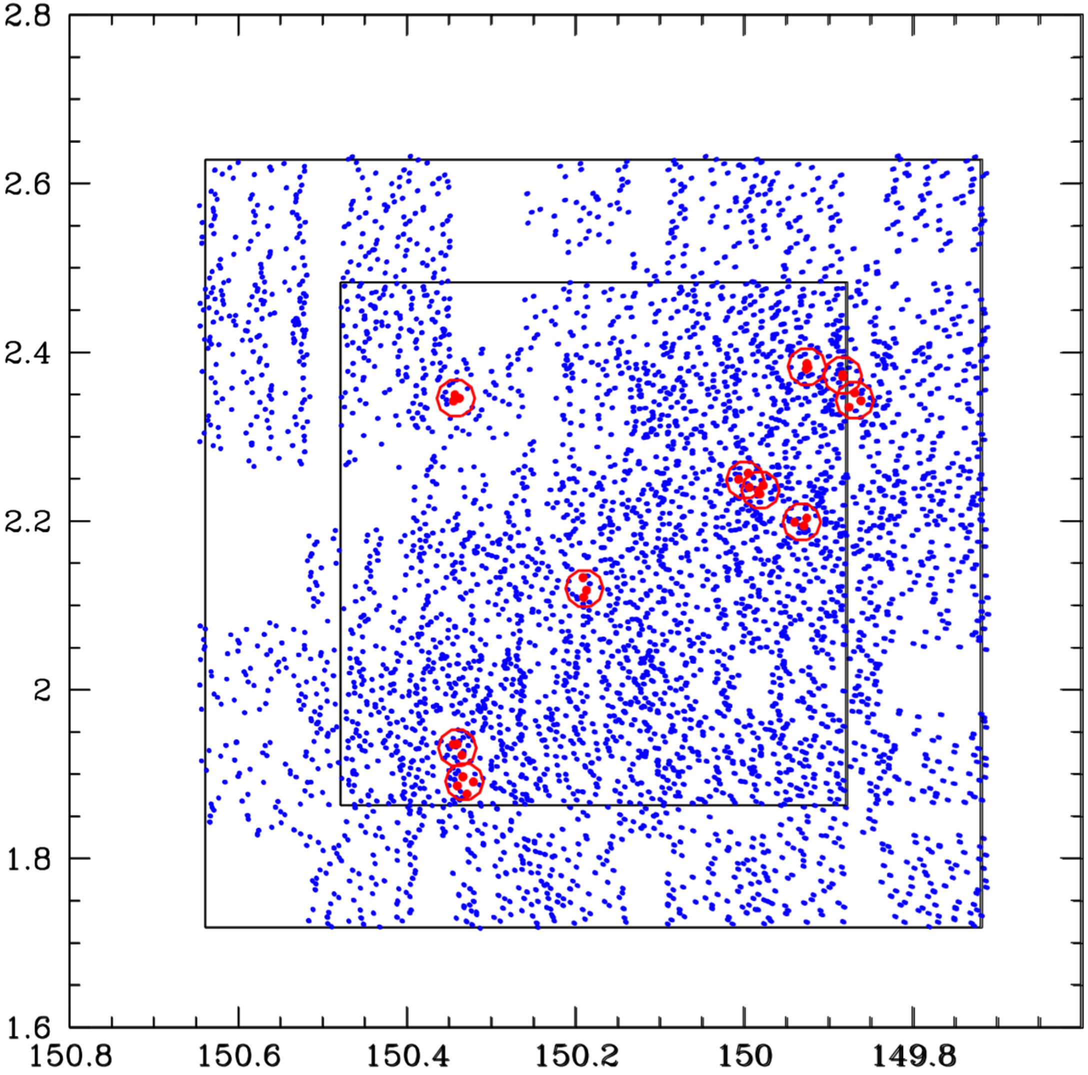




Gas-rich, turbulent, "blobby" disks with high SFR due to high volume cold flows, disk fragmentation and secular evolution? (Genzel et al 2009)

Towards environmental measures in zCOSMOS-deep

Current sampling is inhomogeneous….



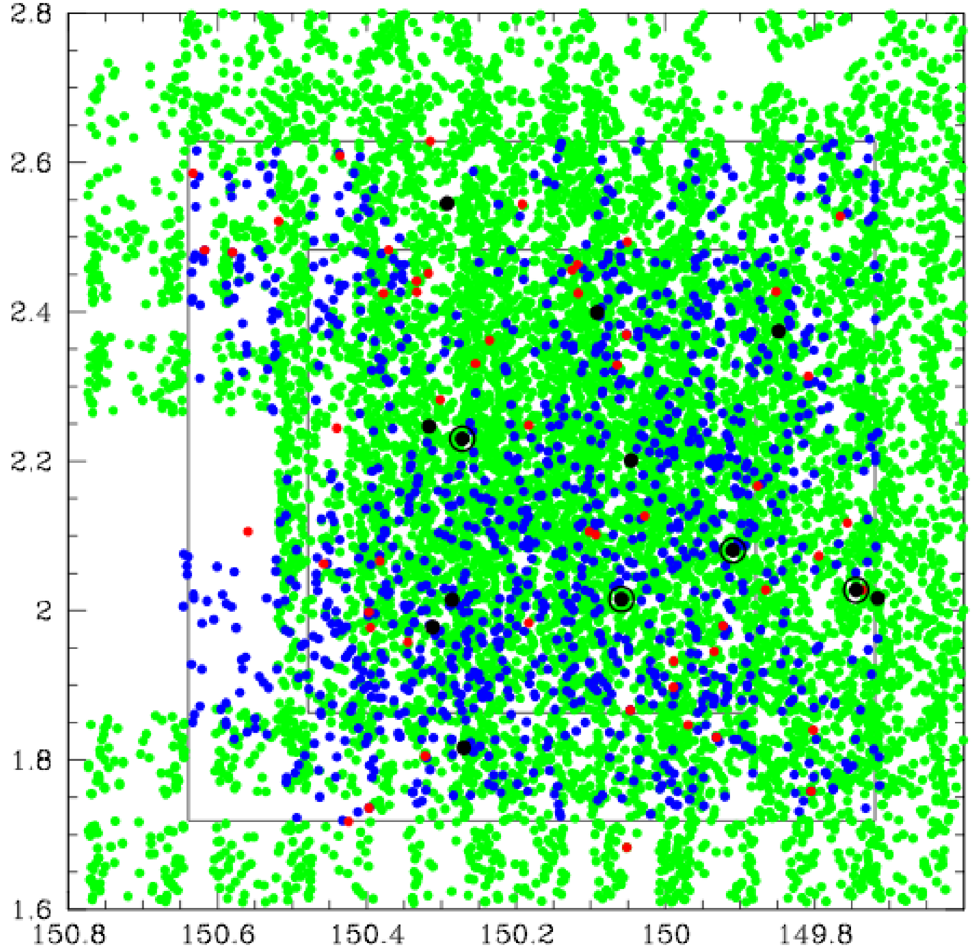
… but we can already apparently find "groups" at $1.5 < z < 3$

- $r < 0.5$ Mpc,
- $\Delta v < 1000$ kms^{-1}
- $N \geq 3$

Redshift	σ_v (kms^{-1})	σ_r (kpc)
1.603	800	270
1.647	1000	180
1.803	430	150
2.140	350	100
2.177	200	350
2.279	270	260
2.444	220	330
2.678	453	100
2.678	250	330
2.960	400	350

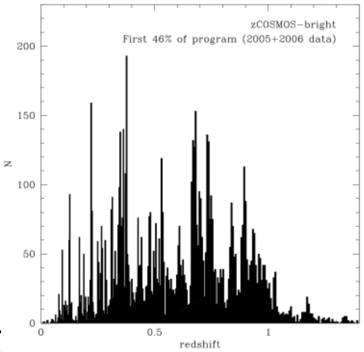
Linking the IGM and galaxies

- Absorption line spectroscopy of $2.4 < z < 2.8$ quasars for HI Lyα forest tomography and metal-enriched winds from identified galaxies



- 1000 galaxies with $1.9 < z < 2.8$ (will double in 2010)
- 4 quasars $2.4 < z < 2.8$ with $g < 21$, 13 with $g < 23$ and ~50 more with photo-z
- 10,000 $z < 1.3$ galaxies (will double in 2009)

Some concluding thoughts:



•COSMOS is CV limited – continuing need.
•Two-way synergy of photo-z and spectro-z.
There are "no fundamental limits to photo-z performan
•Issues with spectroscopic surveys are incompleteness (and spatial sampling) at interesting depth
•Need for high resolution faint multiplexed spectroscopy, and spatially resolved kinematics etc.

Photo-z calibration (EUCLID)

- Nominally requires 10^5 redshifts with <u>very high completeness</u>, <u>uniformity</u> etc. Extremely challenging from the ground at R = 24.5 and $z > 1$ etc. Relatively easy from space.
- As photo-z get better, can relax requirements on spectro-z, number, completeness etc. e.g. use photo-z themselves to define $N_{bin}(z)$ and spectro-z to characterize photo-z.
- Near-IR needed for photo-z at $z > 1$
- Extensive simulations of catastrophic failures, effects of variable A_V, suggest that these are manageable.