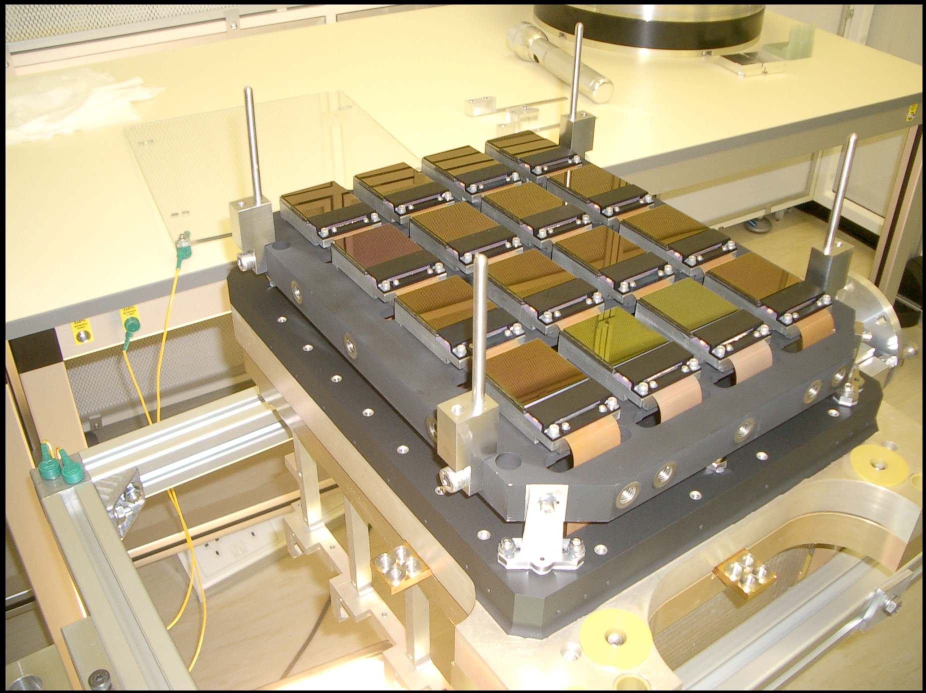
UltraVISTA

James Dunlop University of Edinburgh

Marijn Franx, Olivier Le Fevre, Johan Fynbo, Henry McCracken, Bo Milvang-Jensen

VISTA: Paranal, Chile

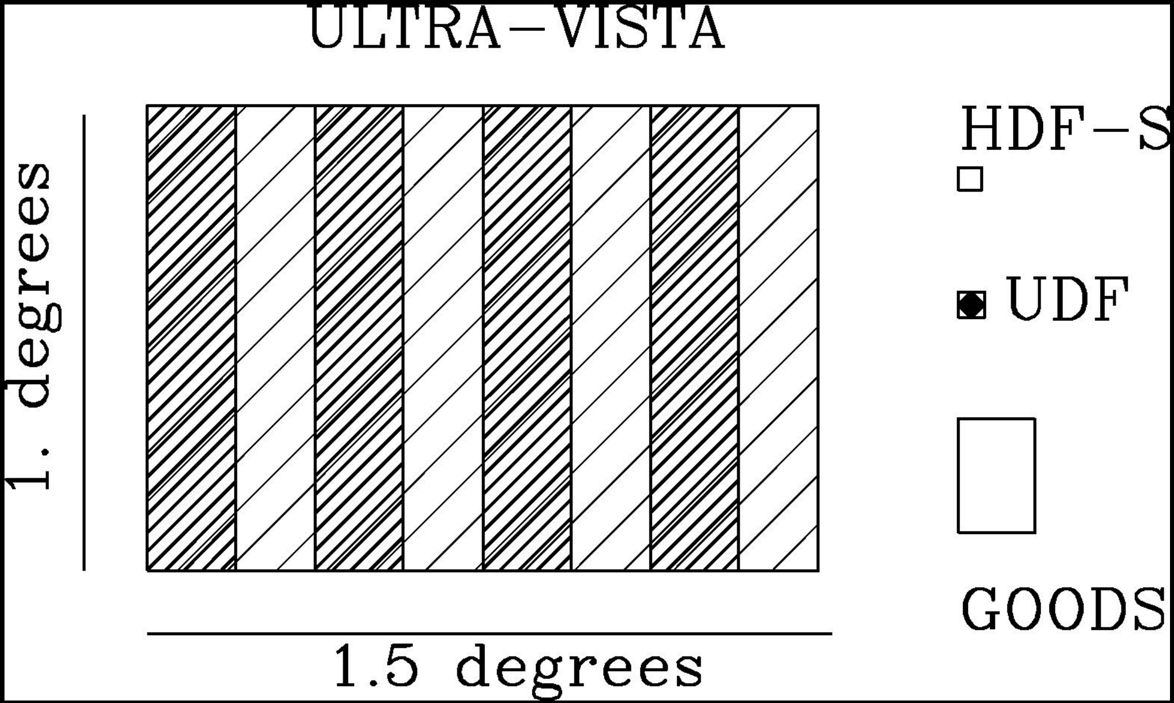


VIRCAM: 67 Mega pixels (1.5 deg^2)

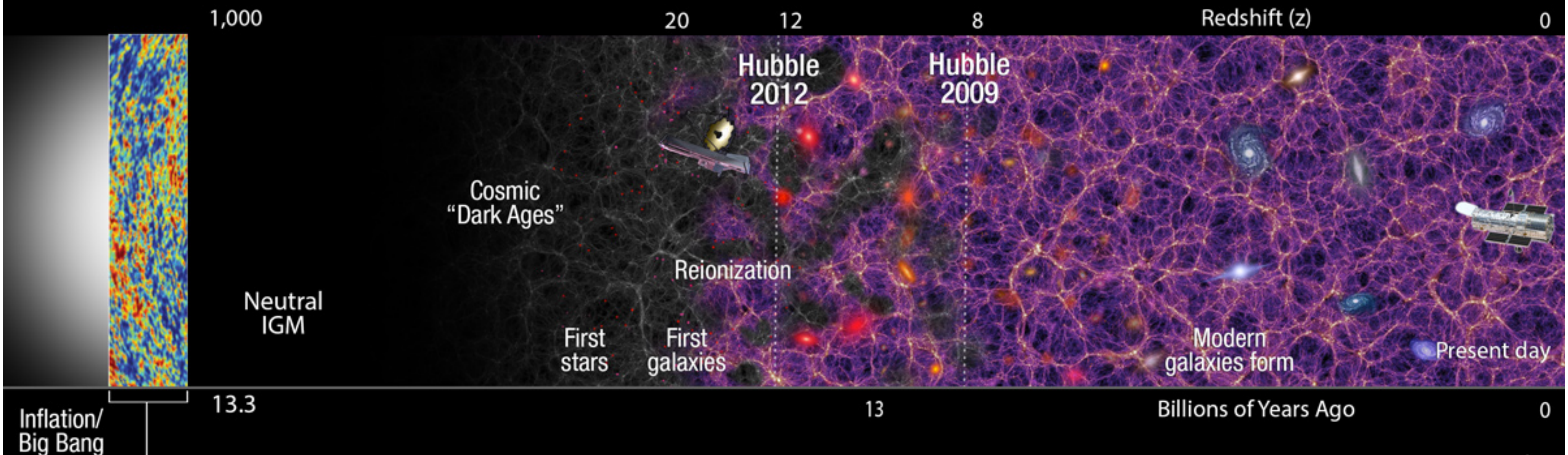
~ 3-4 times more efficient than any other current near-infrared camera

UltraVISTA – planned as deepest public survey with VISTA

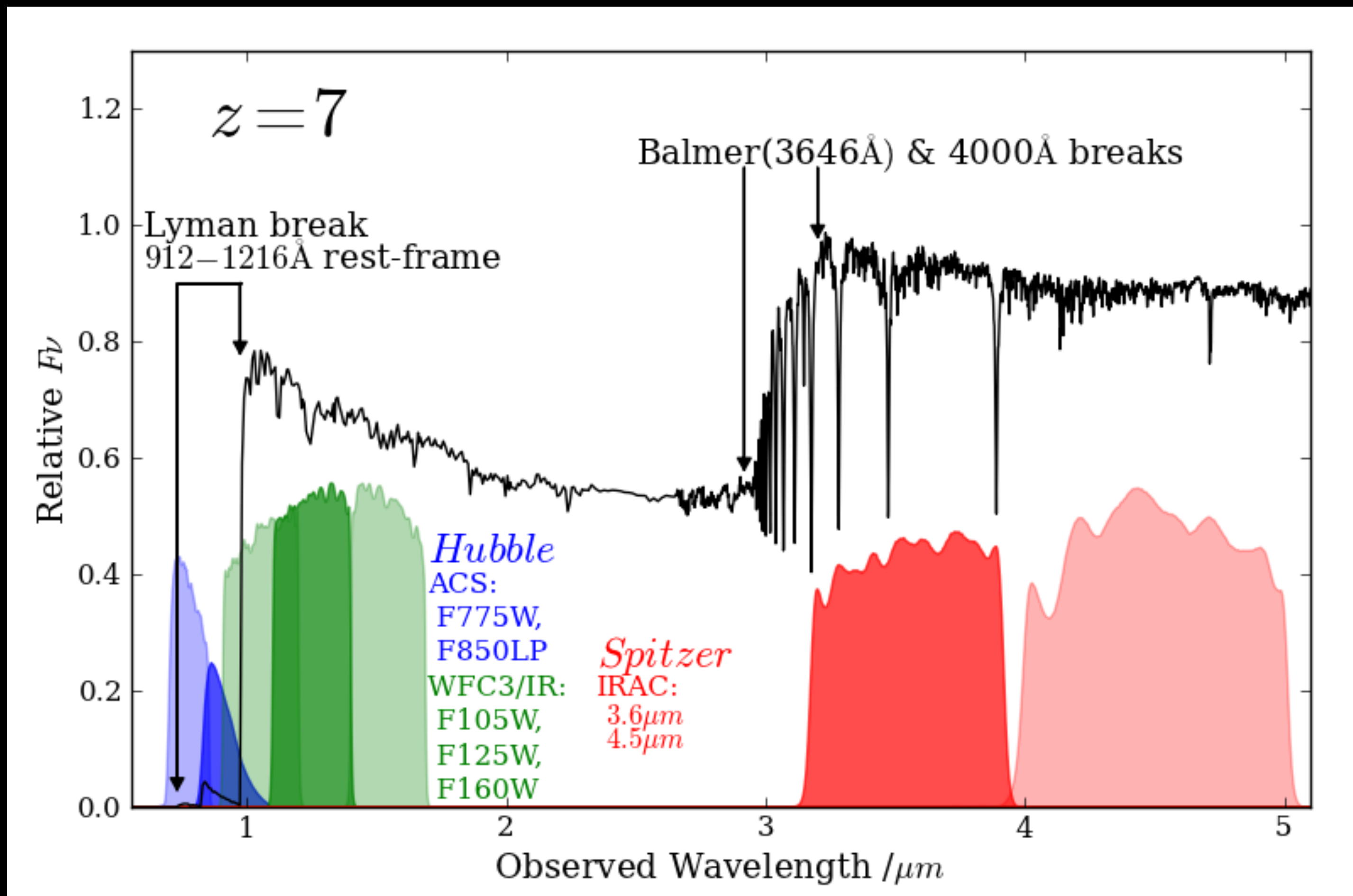
- PIs Dunlop, Franx, Le Fevre, Fynbo
- DEEP - 0.73 sq. deg., Y=26.7, J=26.6, H=26.1, K=25.6 (1408 hr)
- WIDE – 1.50 sq. deg., Y=25.3, J=25.2, H=24.7, K=24.2 (212 hr)
- Narrow-band survey, at 1.185 microns (z = 8.8 for Lyman-alpha) (180 hr)
- 1800 hours over 5 years – started Jan 2010



Primary Motivation – galaxies at z = 7 - 9



Primary Motivation – galaxies at z = 7 - 9



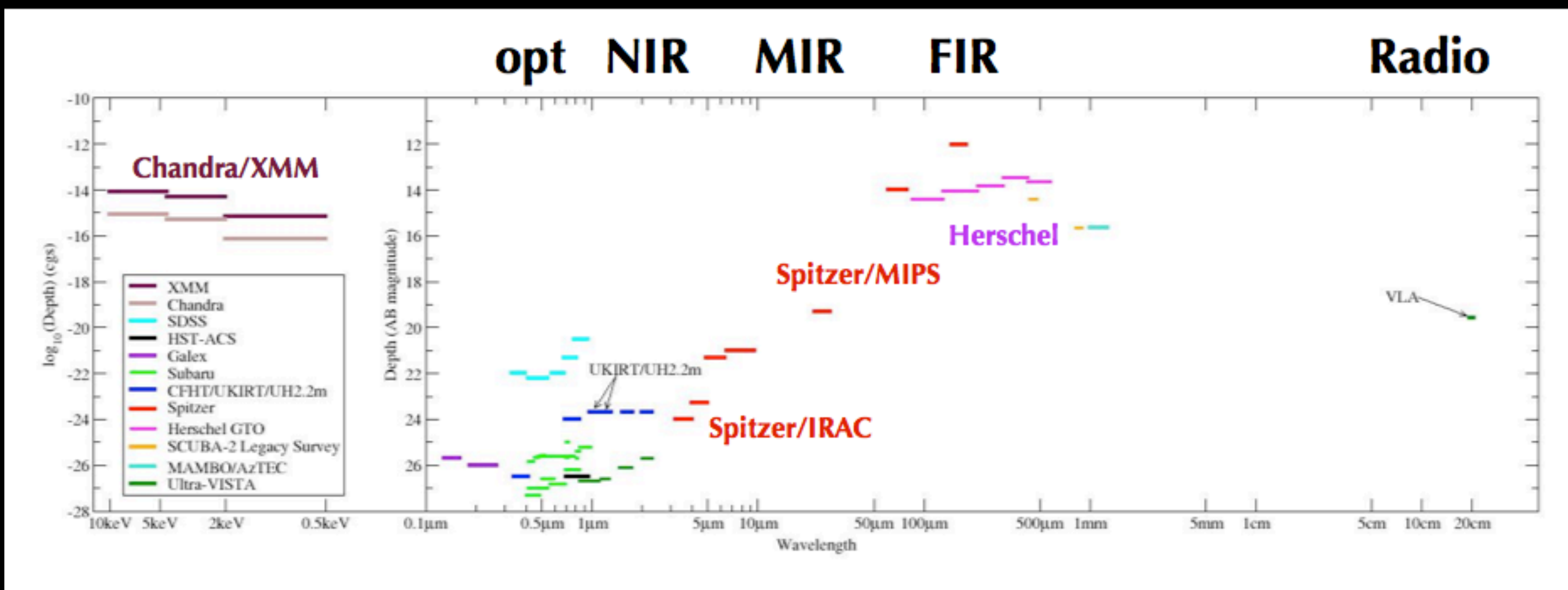
Deep near-infrared imaging is essential for studying rest-frame UV

Deep near-infrared imaging also essential for good photo-zs galaxy stellar mass estimation, and the study of dusty galaxies

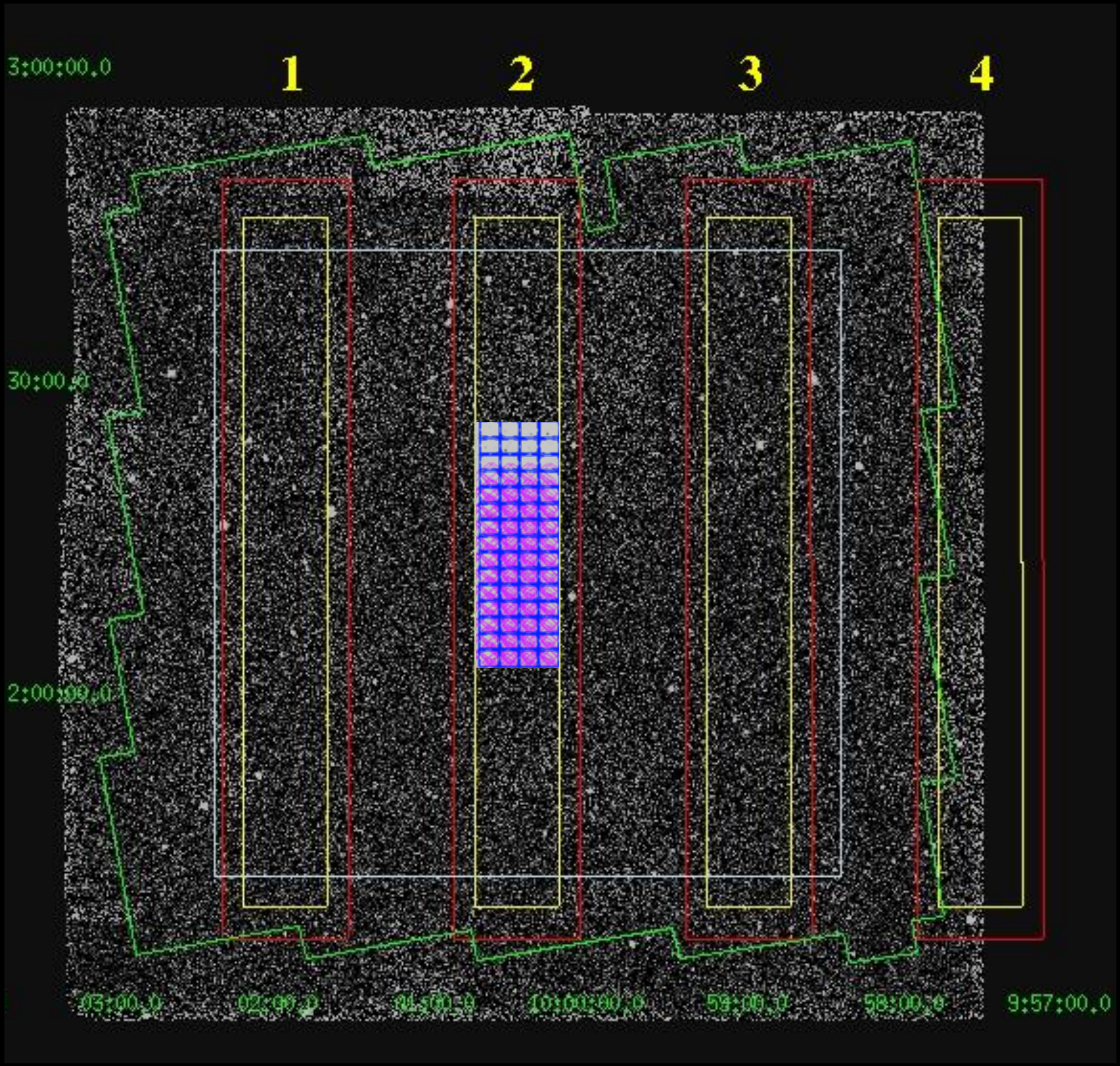
UltraVISTA is located in the COSMOS field, which has become the best degree-scale survey field in which to study galaxy formation and evolution

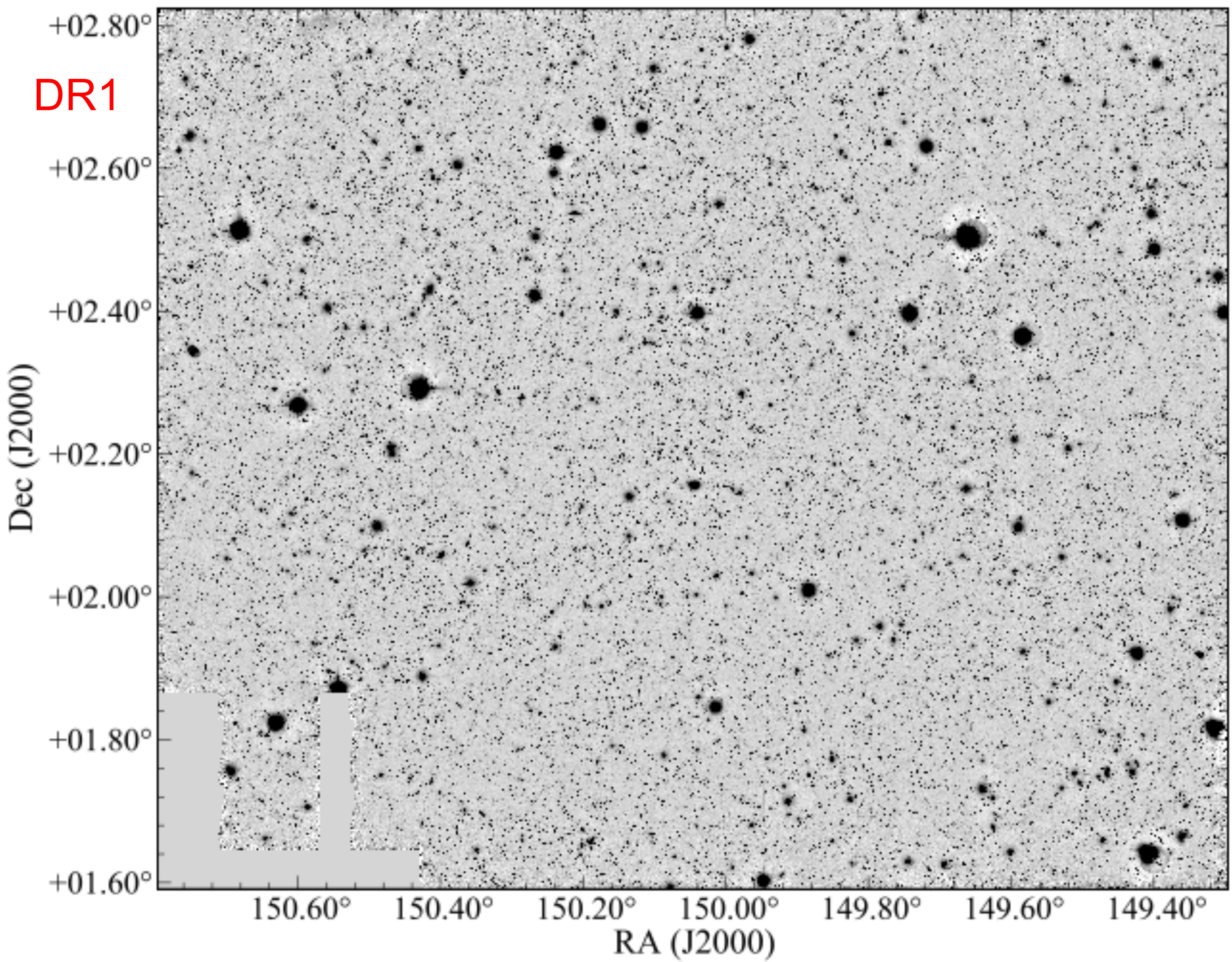
Broad-band and medium-band CFHTLS (D2), Subaru data, VLT, GALEX, Spitzer, Herschel, SCUBA2 (more than 25 imaging bands)

Also a unique and large zCOSMOS spectroscopic sample (the ideal laboratory in which to perfect photometric redshift techniques)



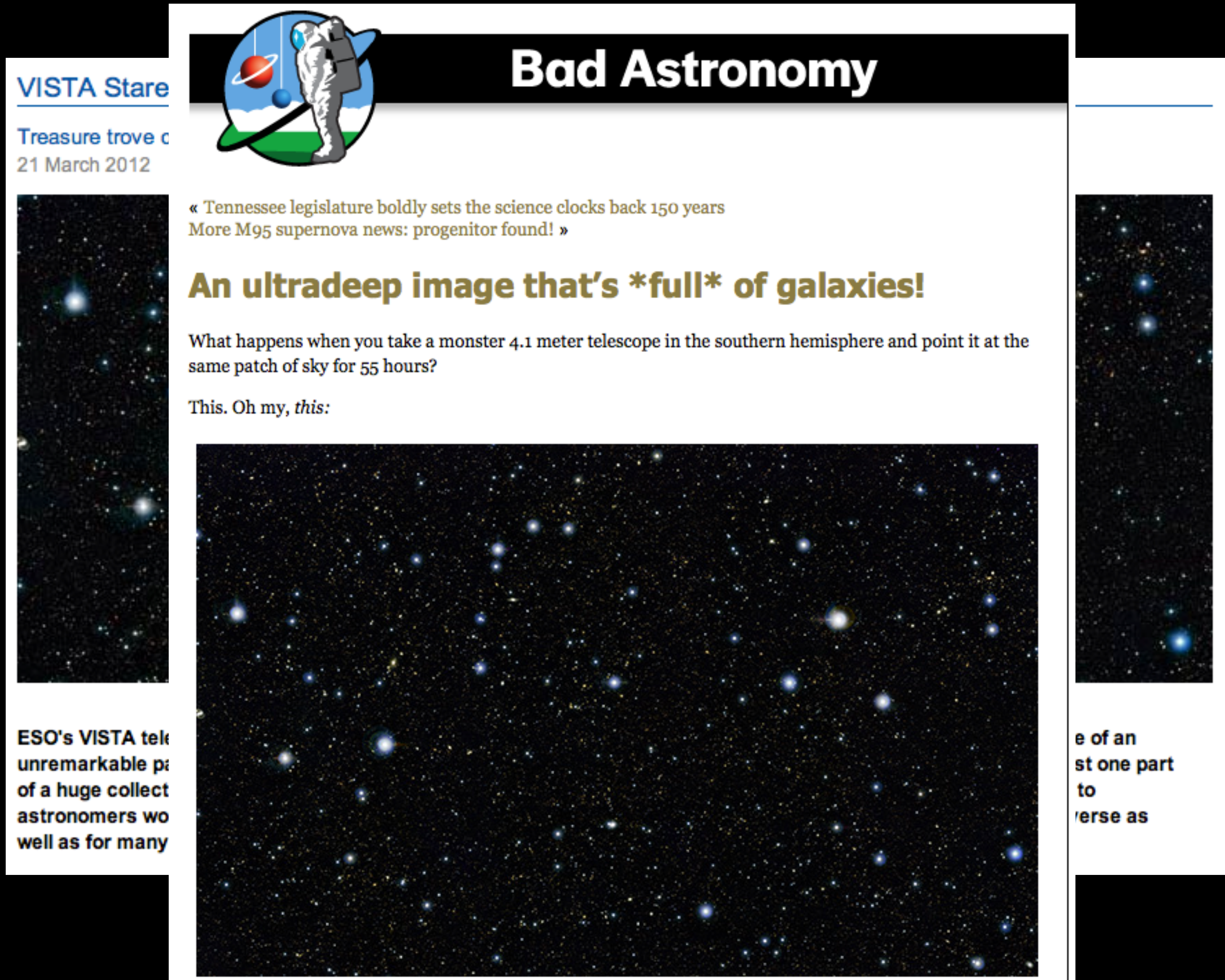
UltraVISTA + CANDELS




DR1
+02.80°
+02.60°
+02.40°
+02.20°
+02.00°
+01.80°
+01.60°
Dec (J2000)
150.60°
150.40°
150.20°
150.00°
149.80°
149.60°
149.40°
RA (J2000)

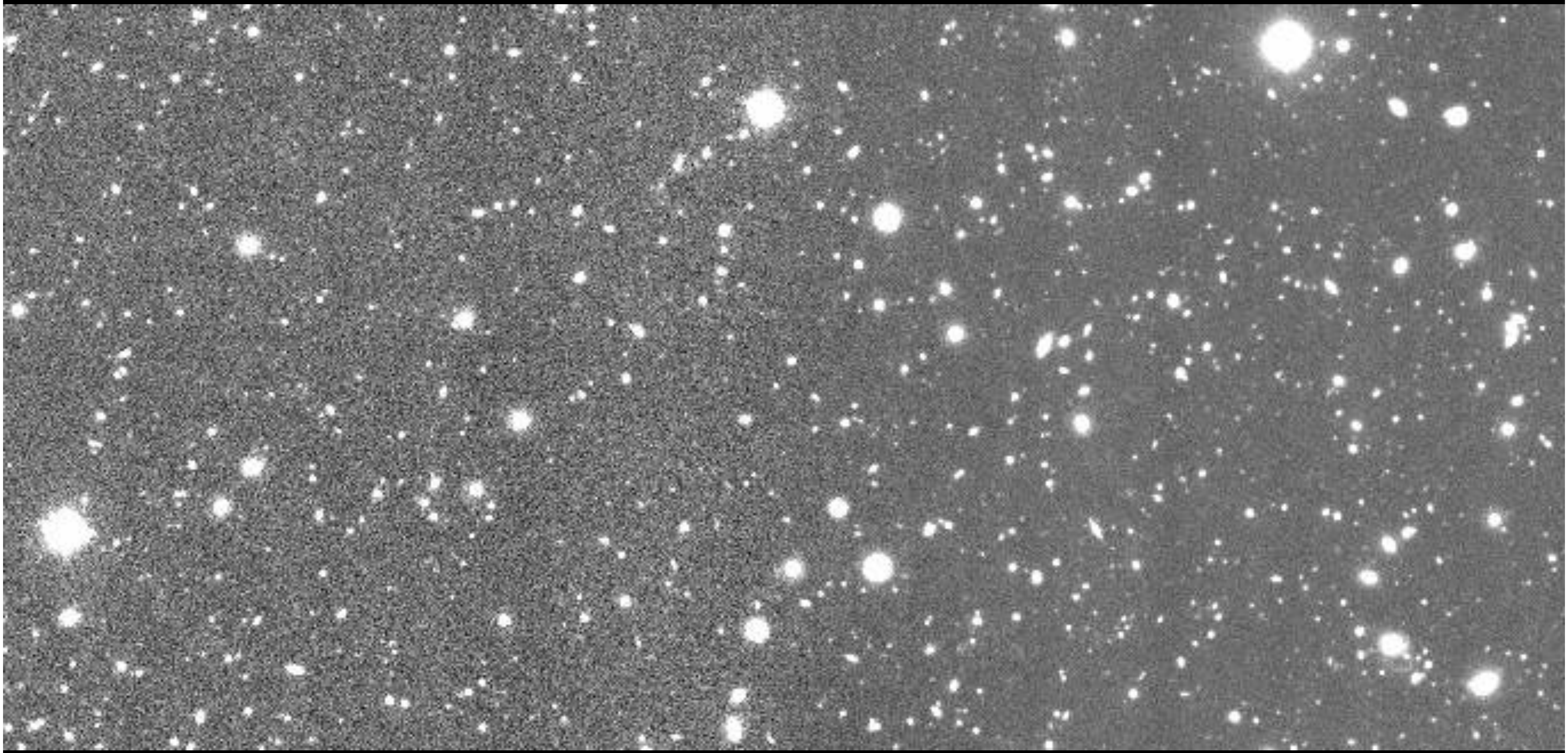
Data Release 1: UltraVISTA survey paper:

McCracken et al. 2012, A&A, 544, 156 (143 citations)

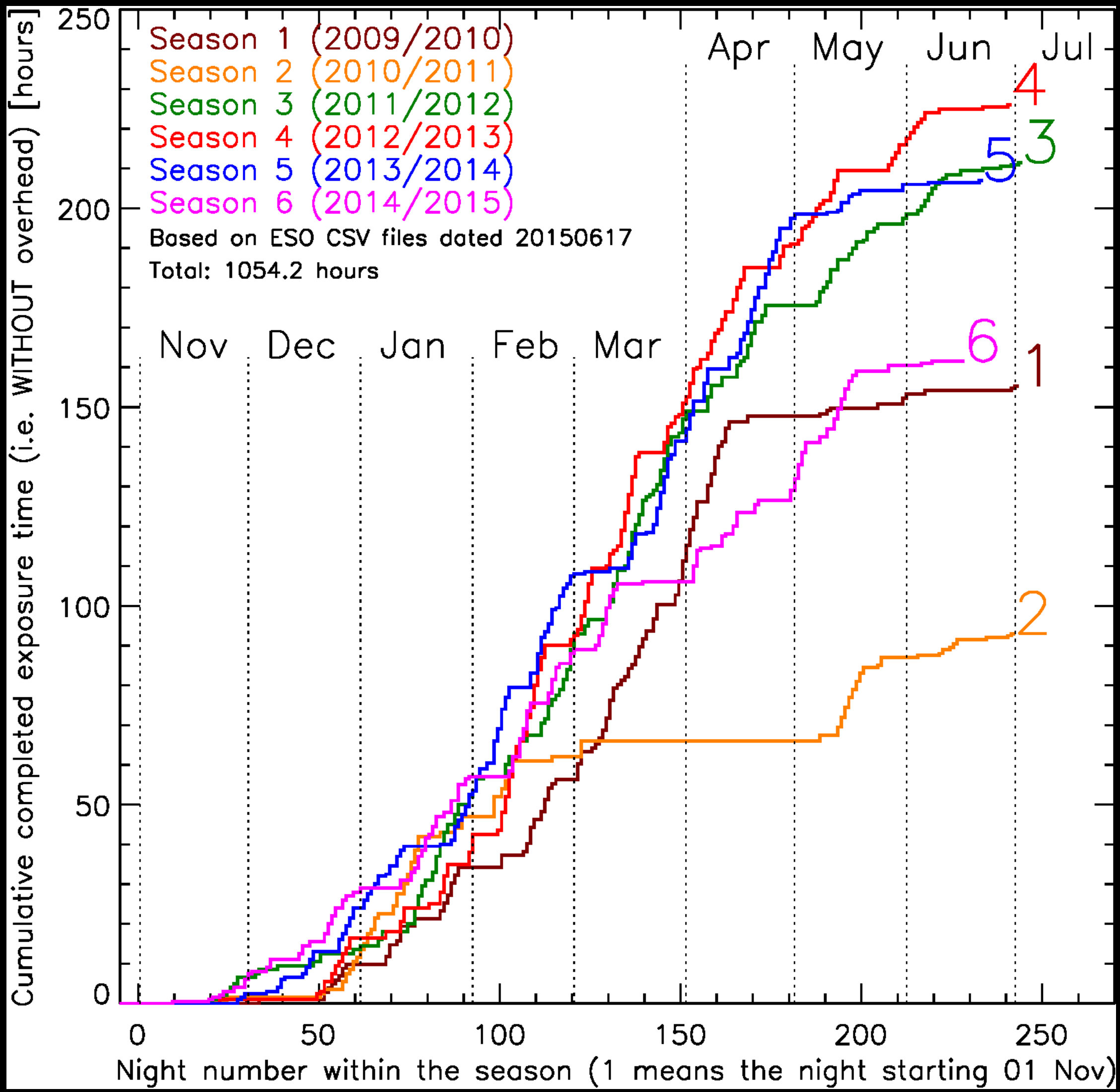


K_s Deep – DR1

K_s Ultra-Deep strip – DR2

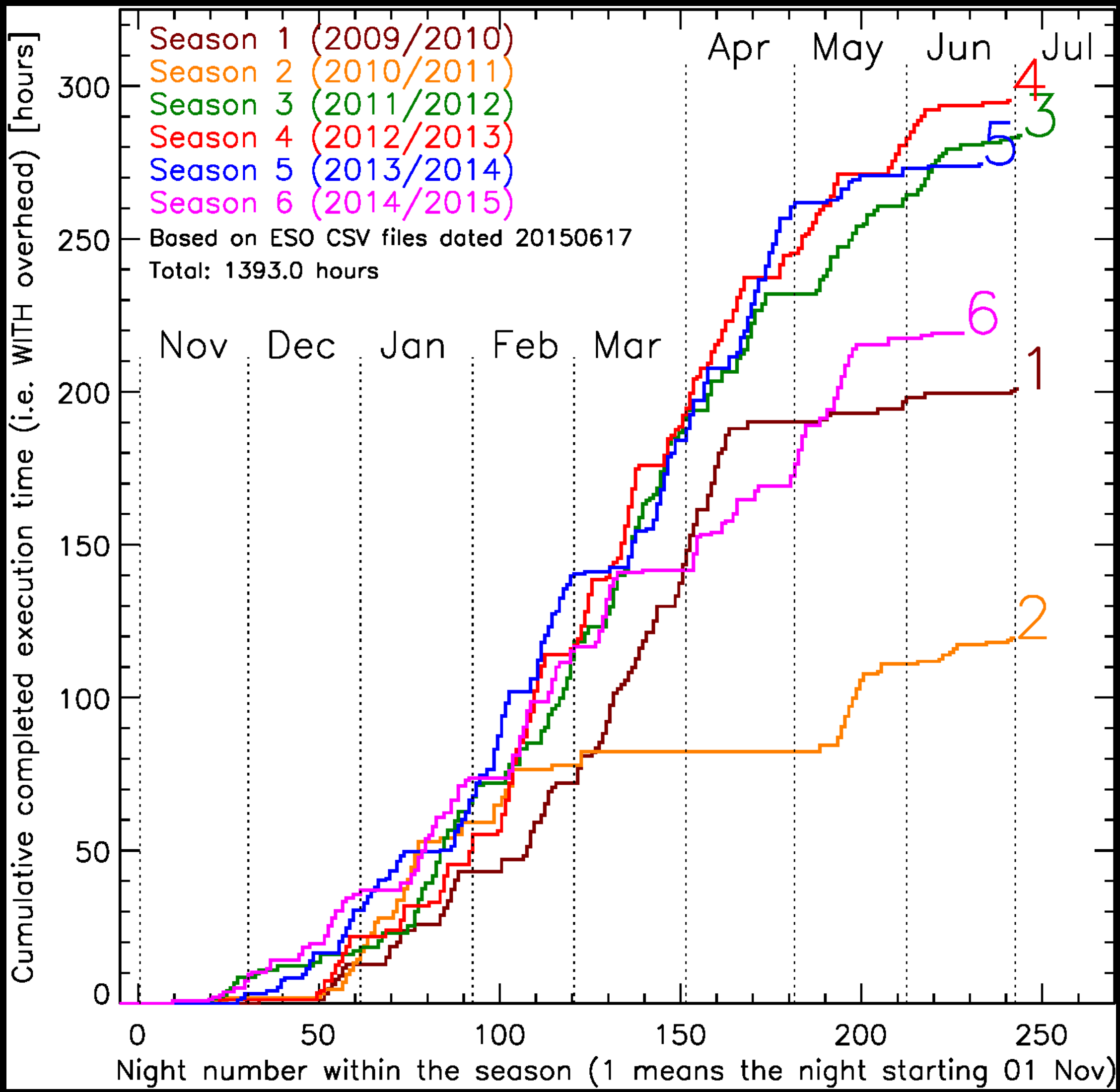


Survey progress: exposure time



1054 hours /1642 awarded

Survey progress: execution time



1393 hours
/1800 awarded

New UltraVISTA Data Release 3 (DR3)

DR3 contains all data taken between 5 December 2009 and July 2014, i.e. seasons 1 through 5

39944 images, 1147 Obs, 890 hours of exposure

DR3 now goes much deeper on the ultra-deep strips:

Y	J	H	K_s	NB
26.1	25.8	25.5	25.3	24.5

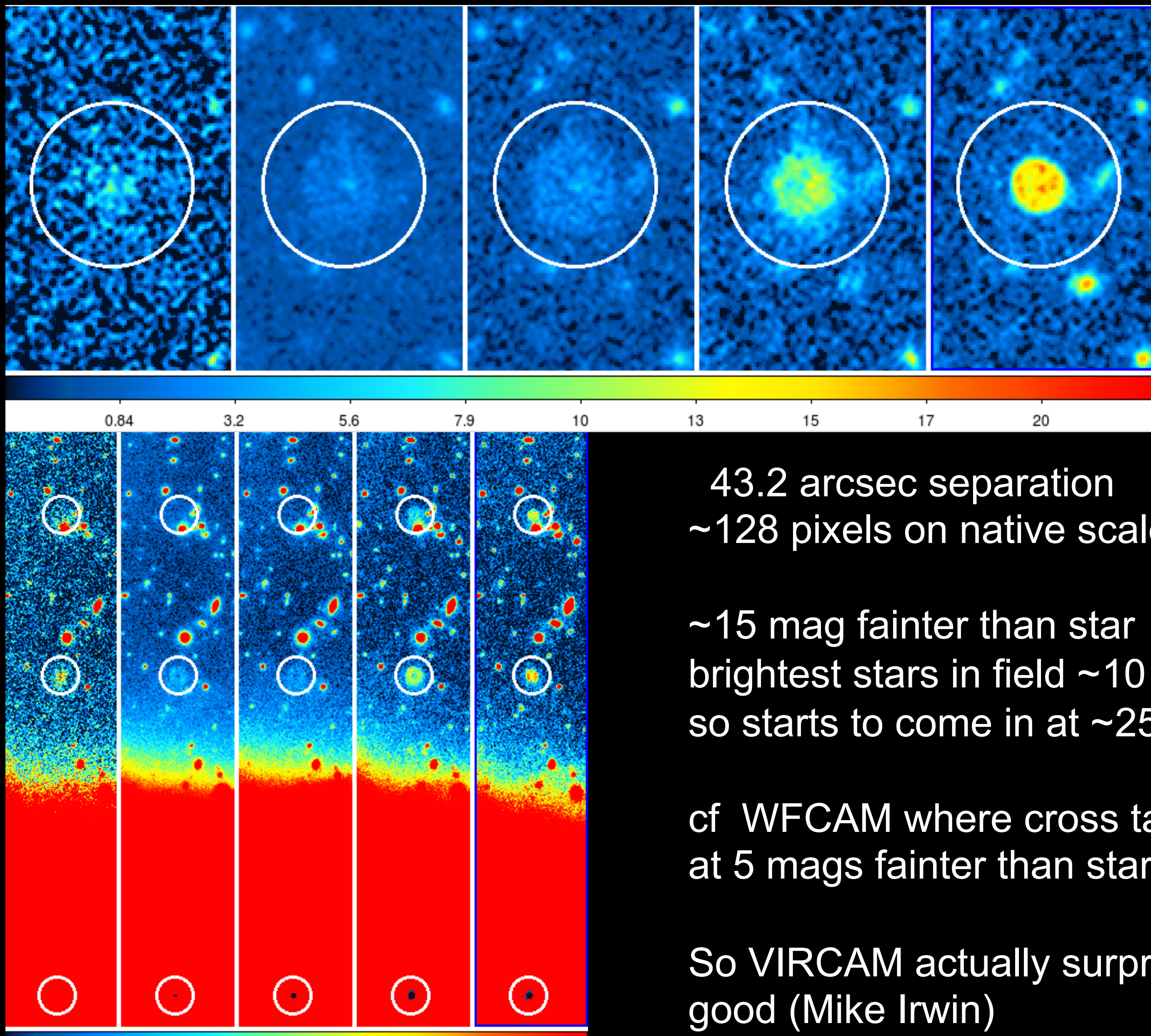
Over 0.73 deg^2

AB mag, 1.8 arcsec diameter apertures, 5-sigma

Seeing FWHM ~ 0.75 arcsec

Y+J+K colour zoom in a DR3 deep strip

Cross talk……



43.2 arcsec separation
~128 pixels on native scale

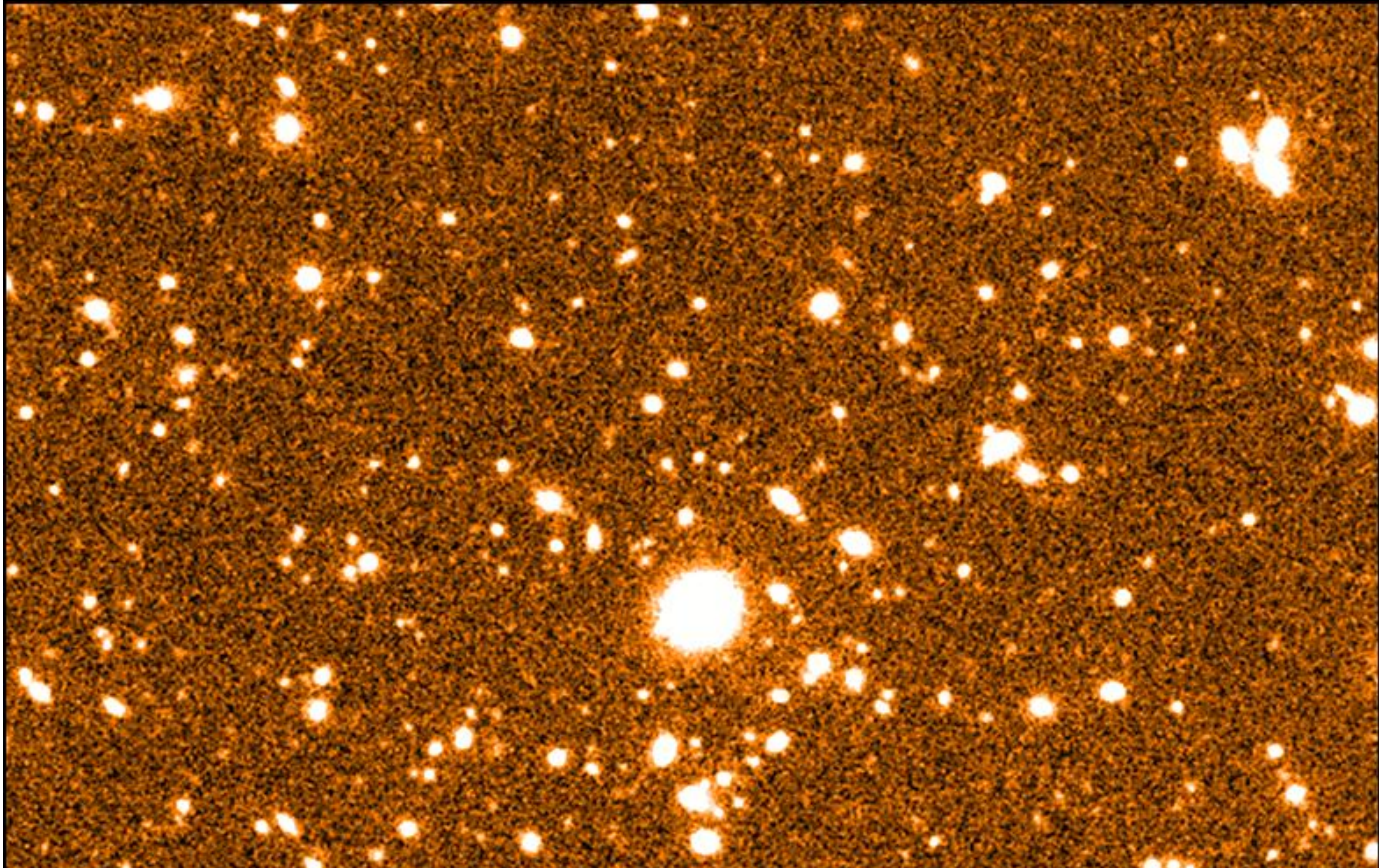
~15 mag fainter than star
brightest stars in field ~10 mag,
so starts to come in at ~25 mag !

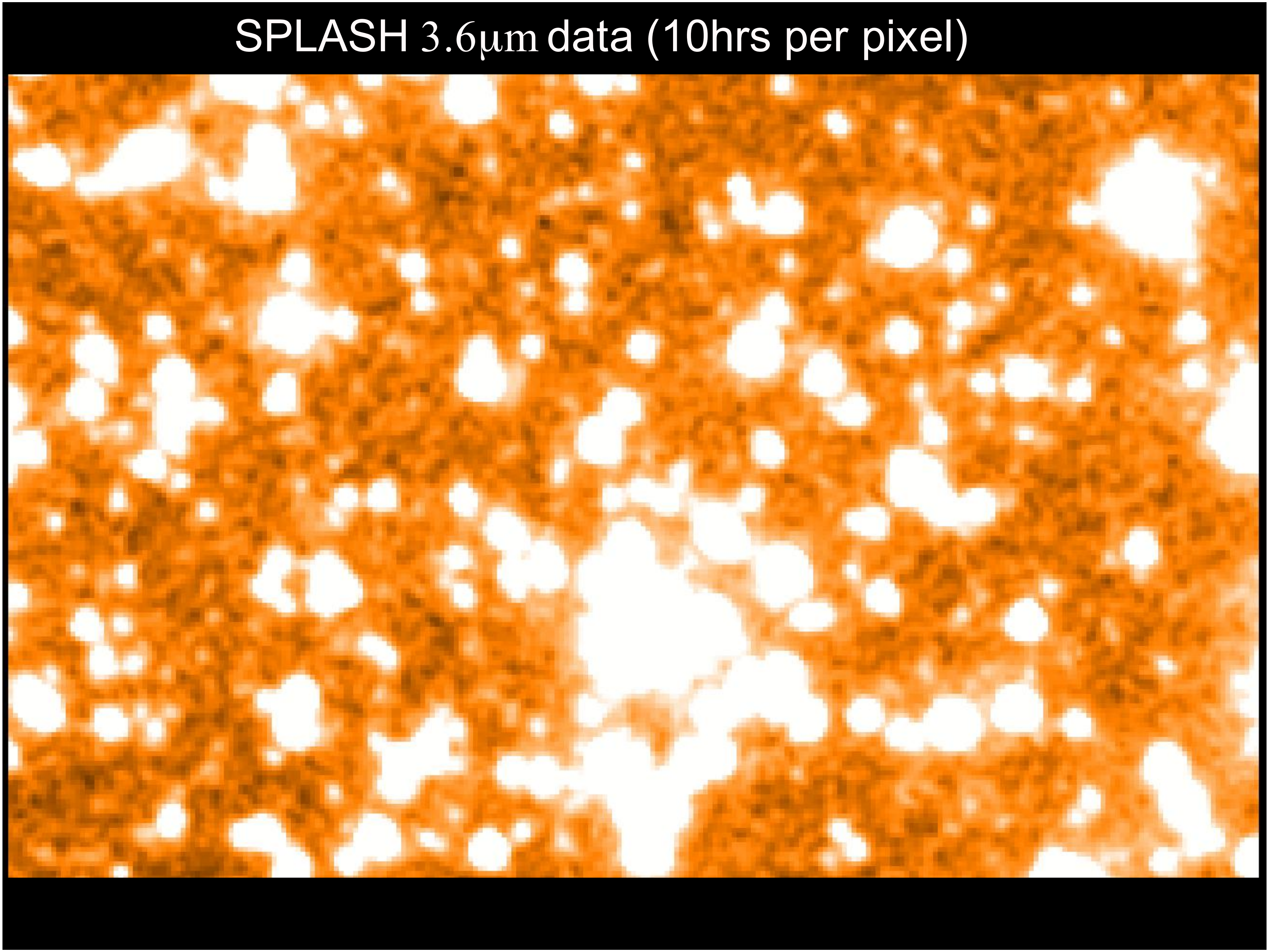
cf WFCAM where cross talk was
at 5 mags fainter than star

So VIRCAM actually surprisingly
good (Mike Irwin)

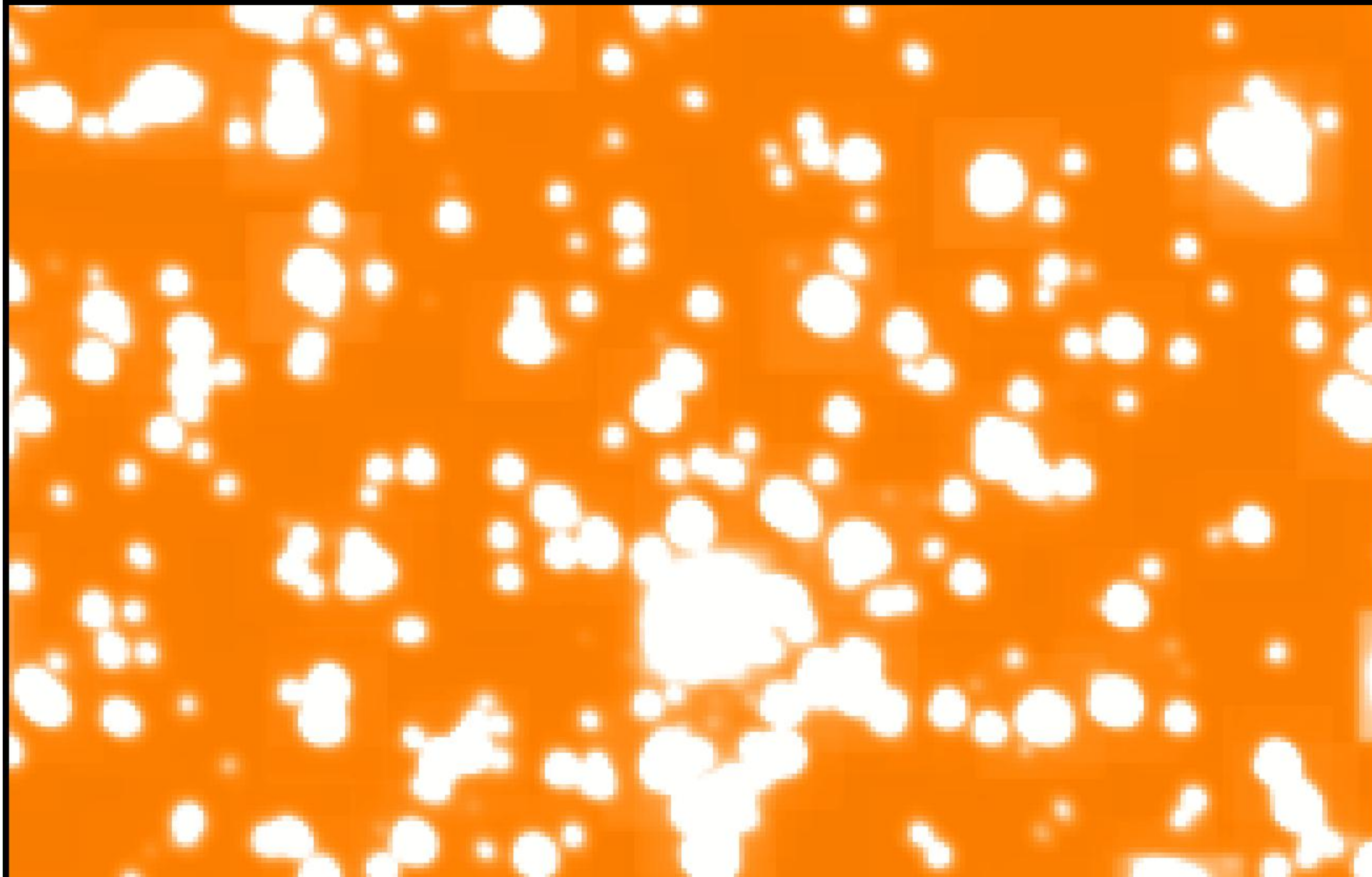
Seasons 6 and 7 – complementing SPLASH

UVISTA DR2 K_s-band

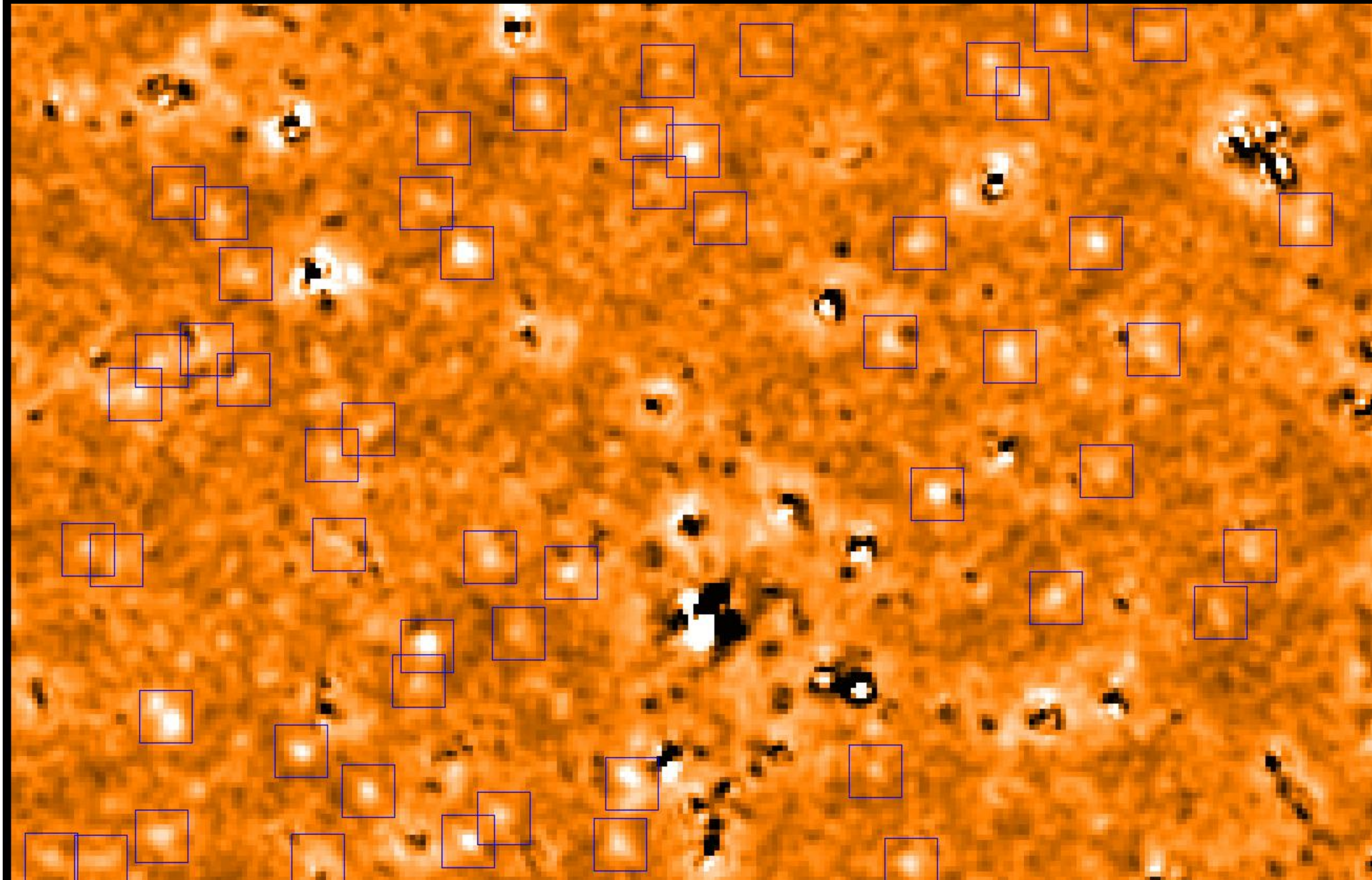



SPLASH 3.6μm data (10hrs per pixel)

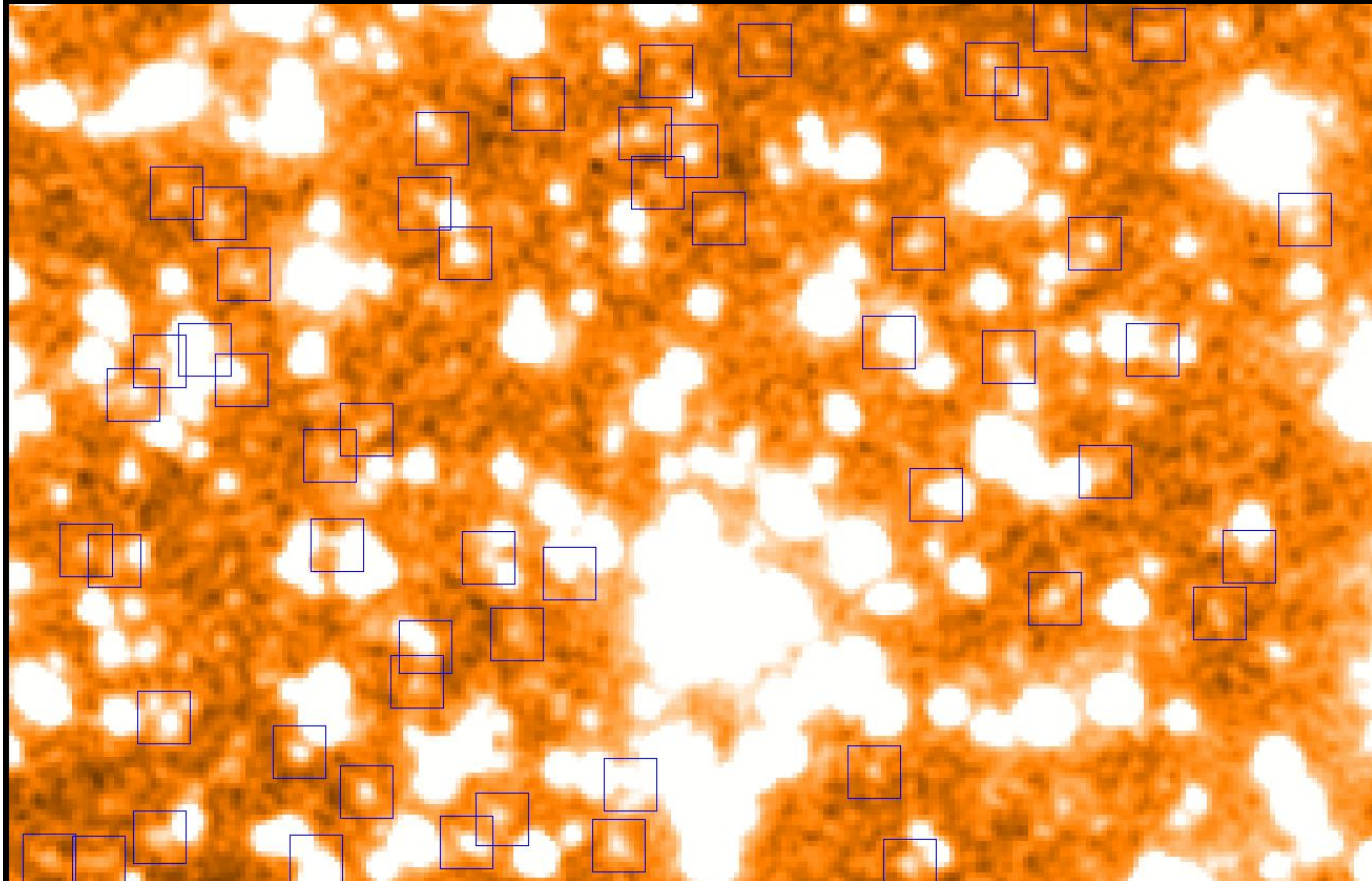
3.6μm model image, based on 5σ K_s-band templates



3.6μm residual image, objects missed in K_s model highlighted



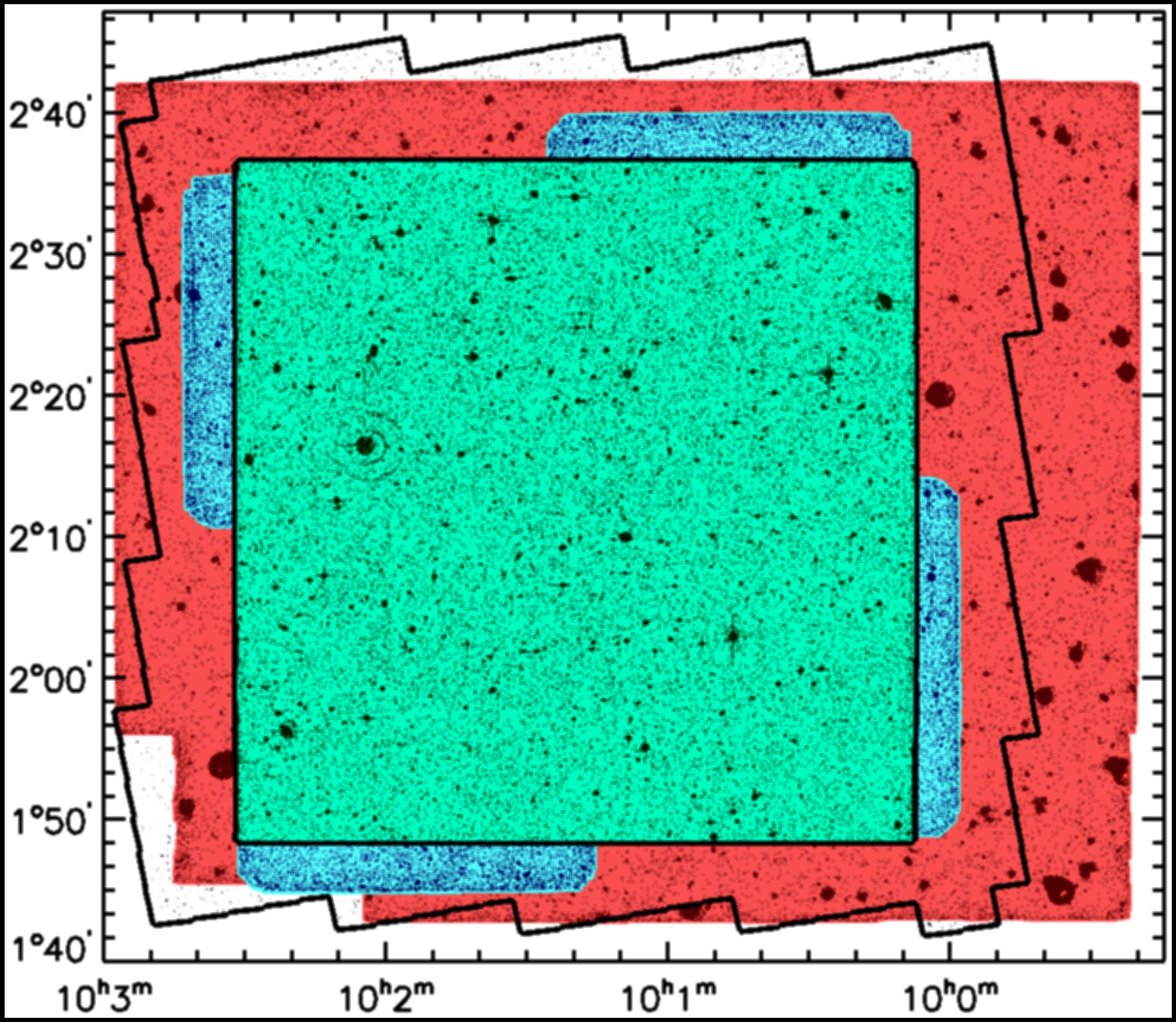
3.6μm SPLASH data, objects missed in K_s model highlighted



Science: UV-selected Galaxies at high z

Bowler, Dunlop et al., 2012, MNRAS, 426, 2772
Bowler, Dunlop et al., 2014, MNRAS, 445, 359
Bowler, Dunlop et al., 2015, MNRAS, 452, 1817
Parsa, Dunlop et al., 2015, arXiv:1507.05629

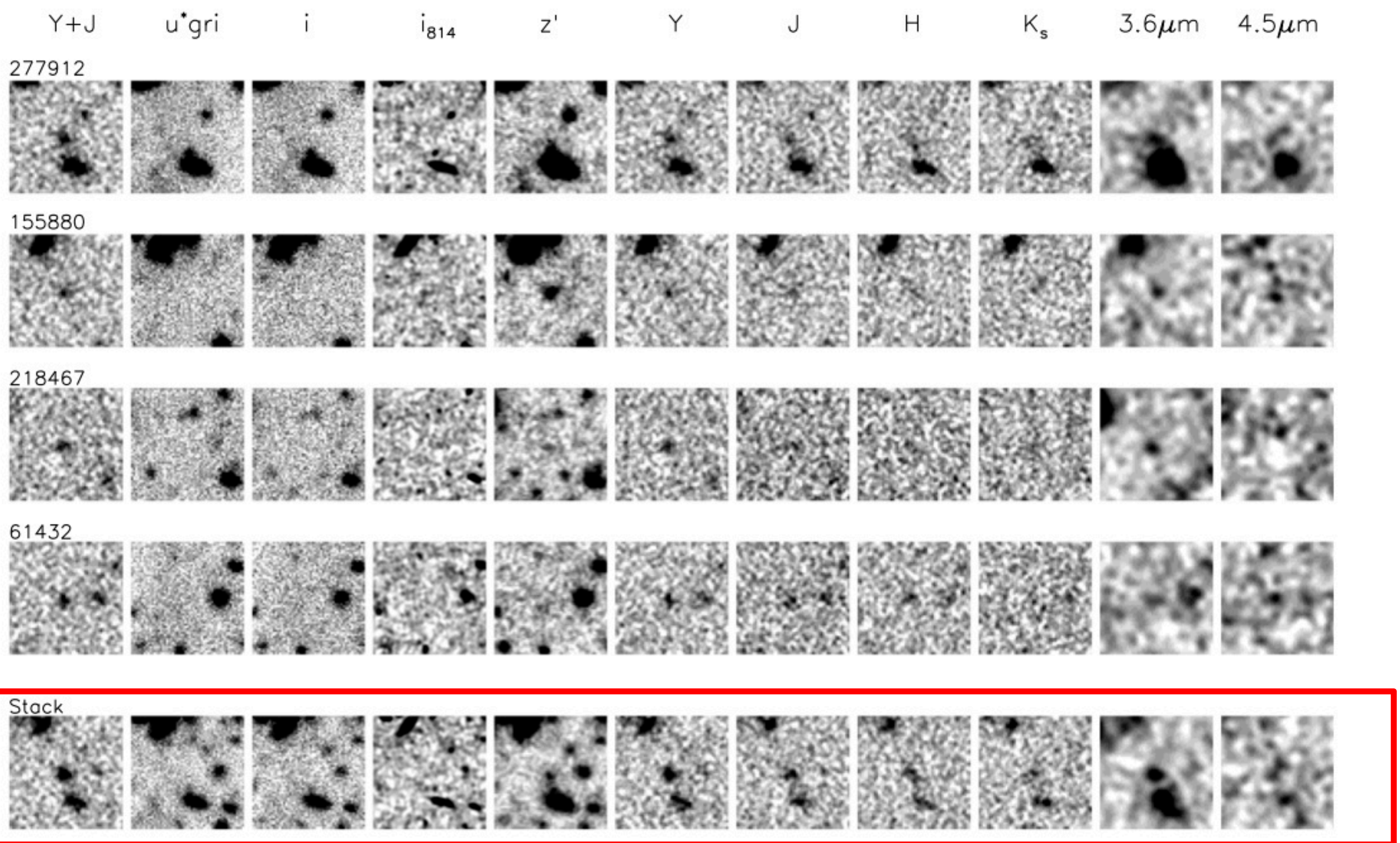
Combine UltraVISTA with deep CFHT/Subaru/HST optical imaging



Objects selected on Y+J catalogue

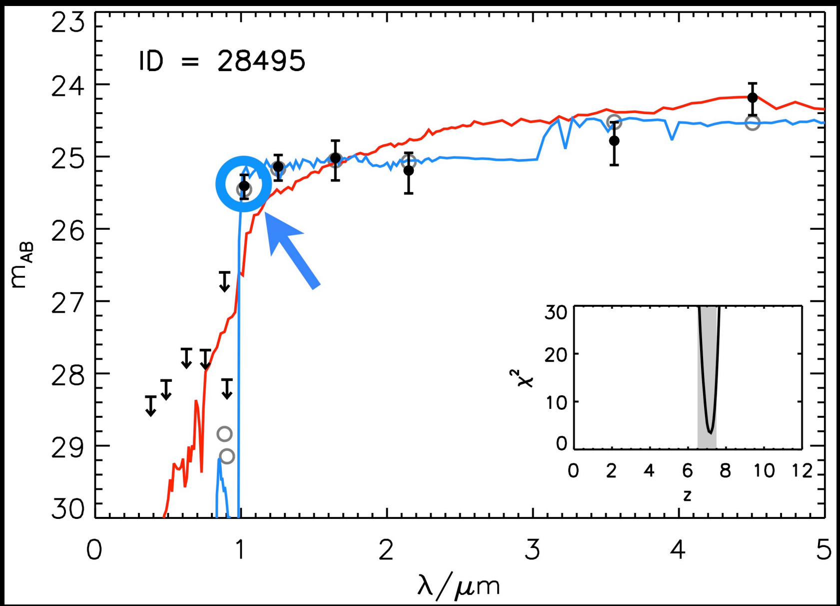
UltraVISTA robust z ~ 7 galaxies

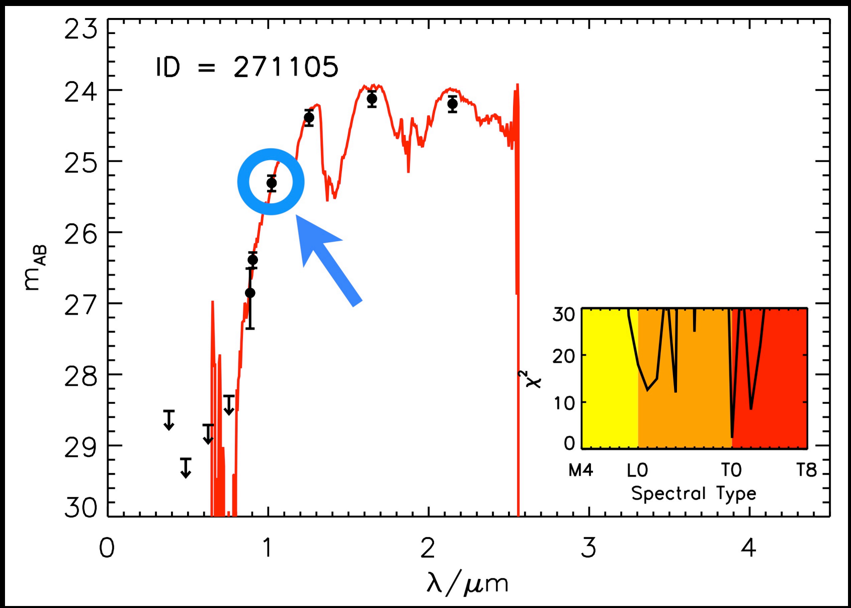
Bowler, Dunlop et al. (2012)



Major challenge is distinguishing z = 7 galaxies from T dwarfs

Big problem for ground-based surveys at J ~ 25

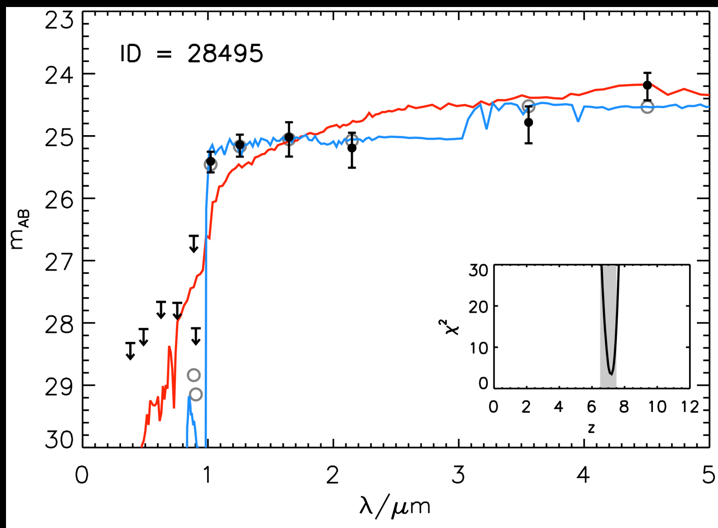


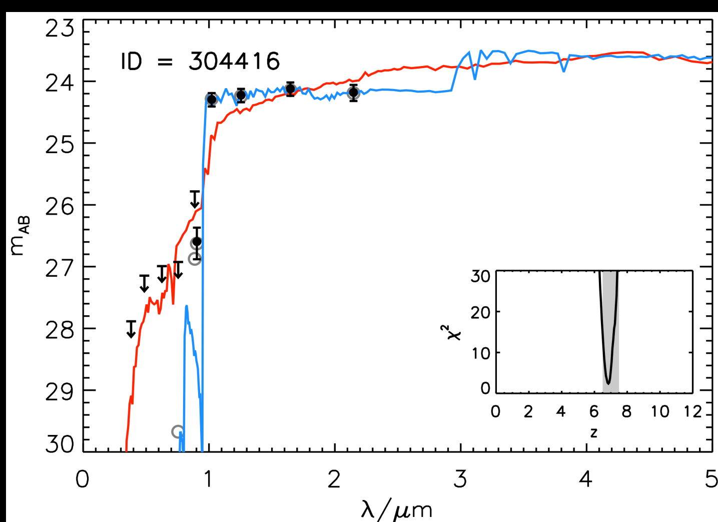


Crucial importance of deep Y-band, and deep z-band

UltraVISTA robust z ~ 7 galaxies

Bowler, Dunlop et al. (2012, 2014)





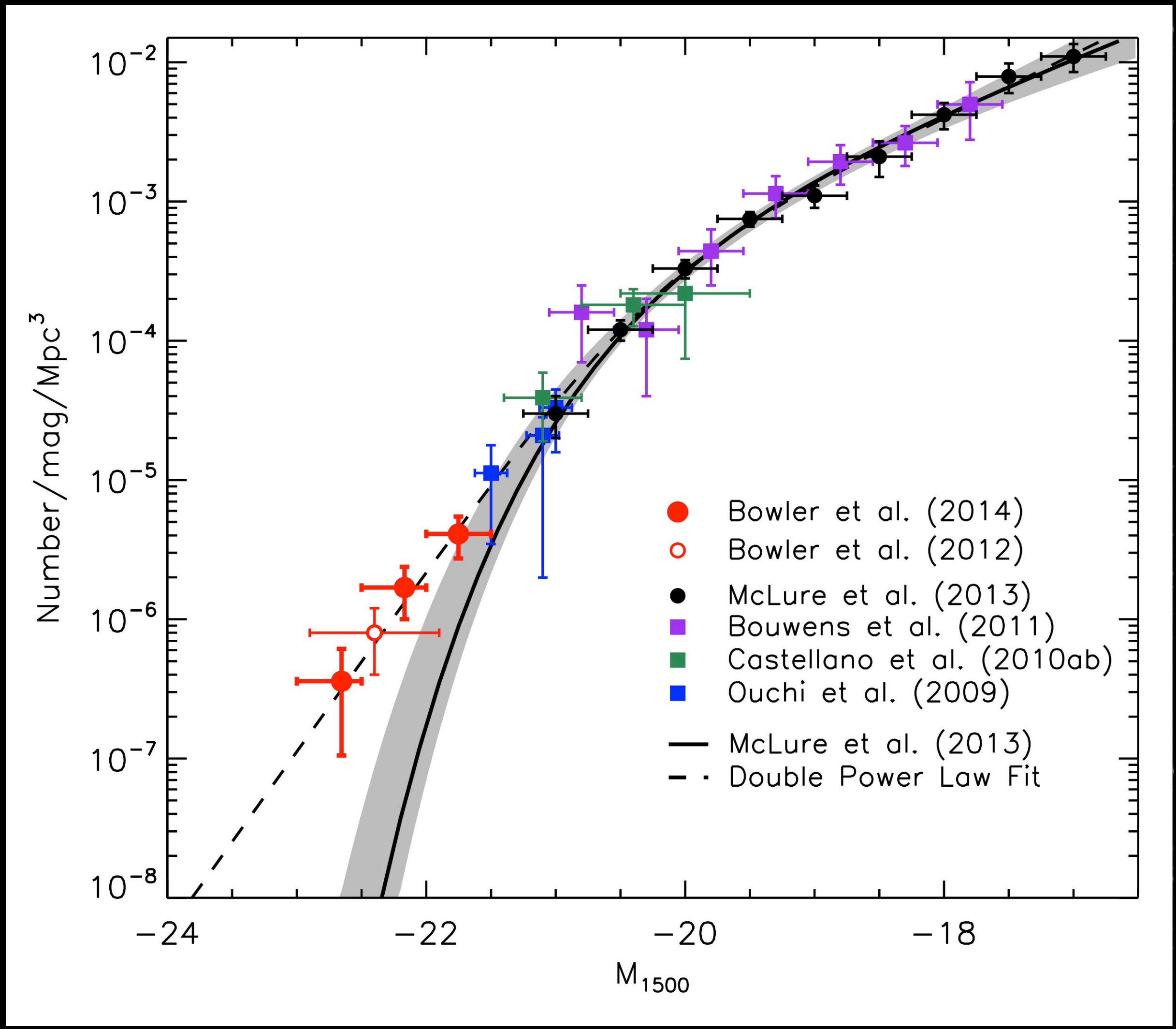
Sample includes most massive z = 7 galaxies with M* = ~ 10^{10} M_{sun}

SFR ~ 10 – 40 M_{sun}/yr

Median rest-frame UV slope β = -2.0

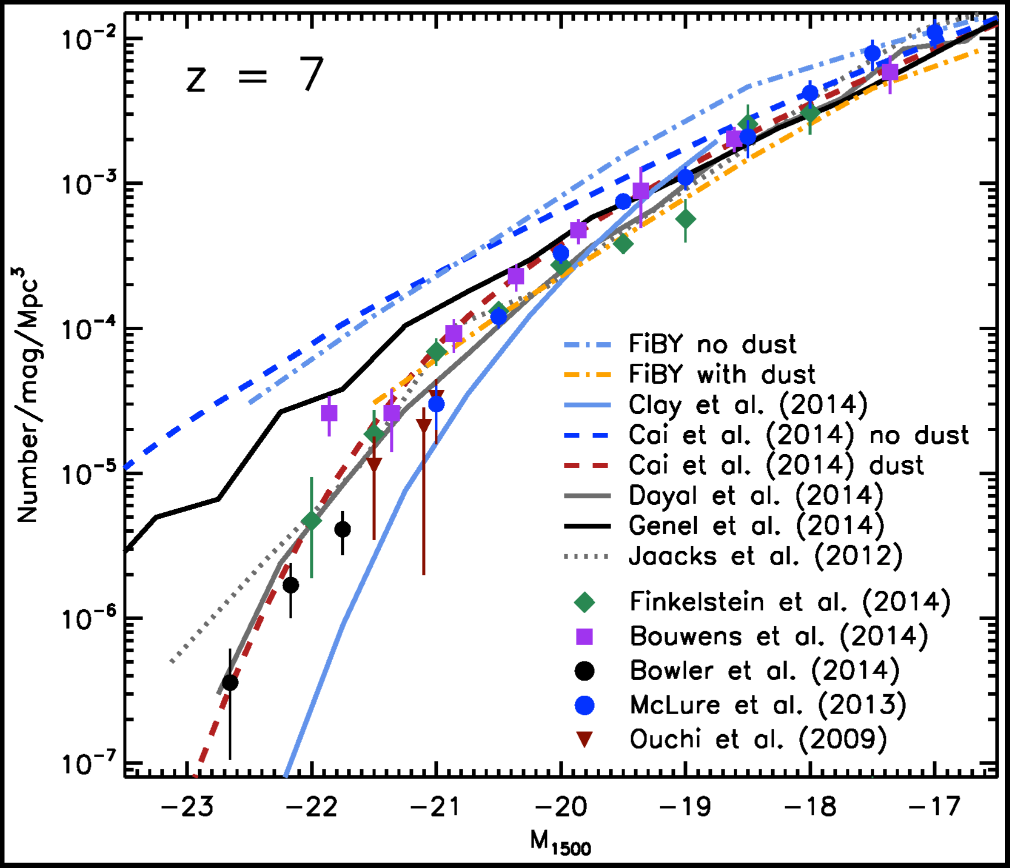
Bright end of z = 7 Luminosity Function

Bowler, Dunlop et al. (2012, 2014)



Evidence for dust at z ~ 7 ?

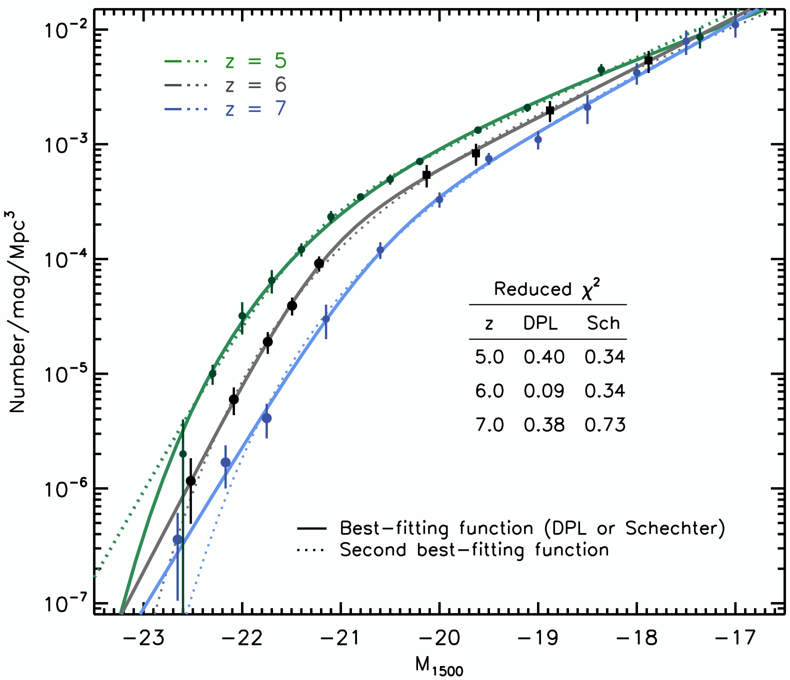
New results from UltraVISTA indicate bright end of LF at z = 7 flatter than Schechter function, but steeper than most model predictions without dust
Bowler, Dunlop et al. (2014, 2015)

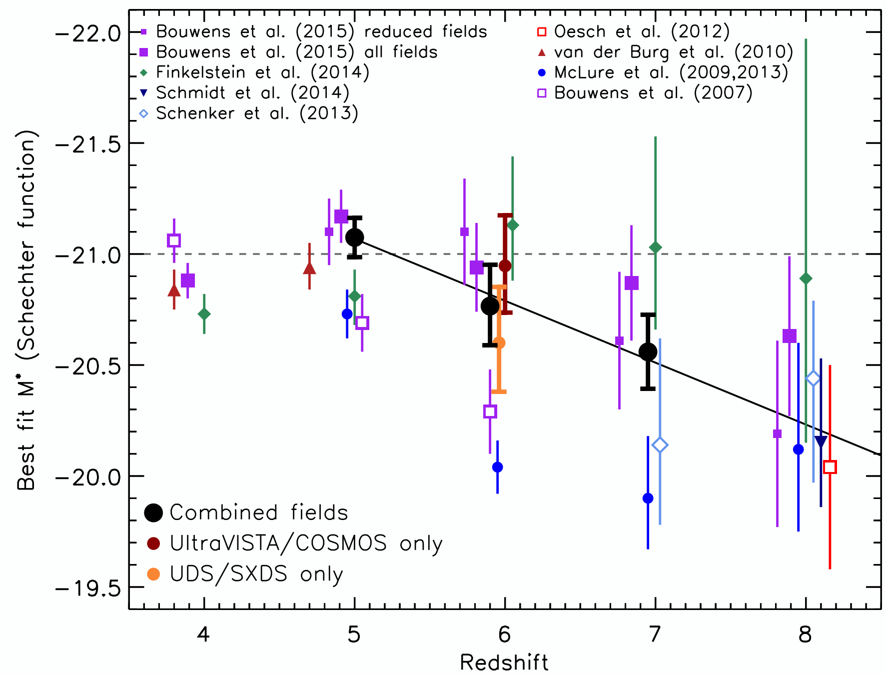


Evidence for dust,
+ implications for mass quenching etc

UV Galaxy LFs at z = 5,6,7:

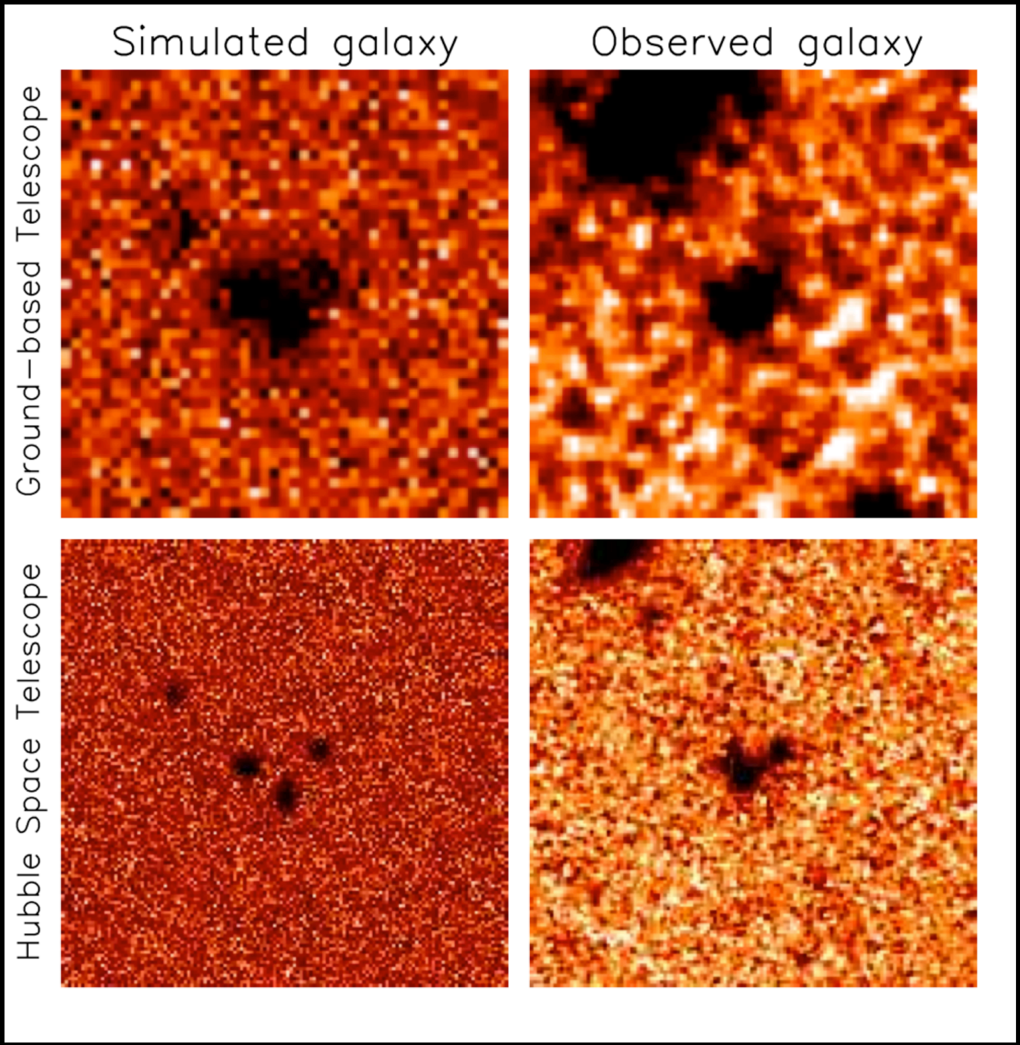
Evidence for transition from double power-law to Schechter
Evolution is primarily luminosity evolution





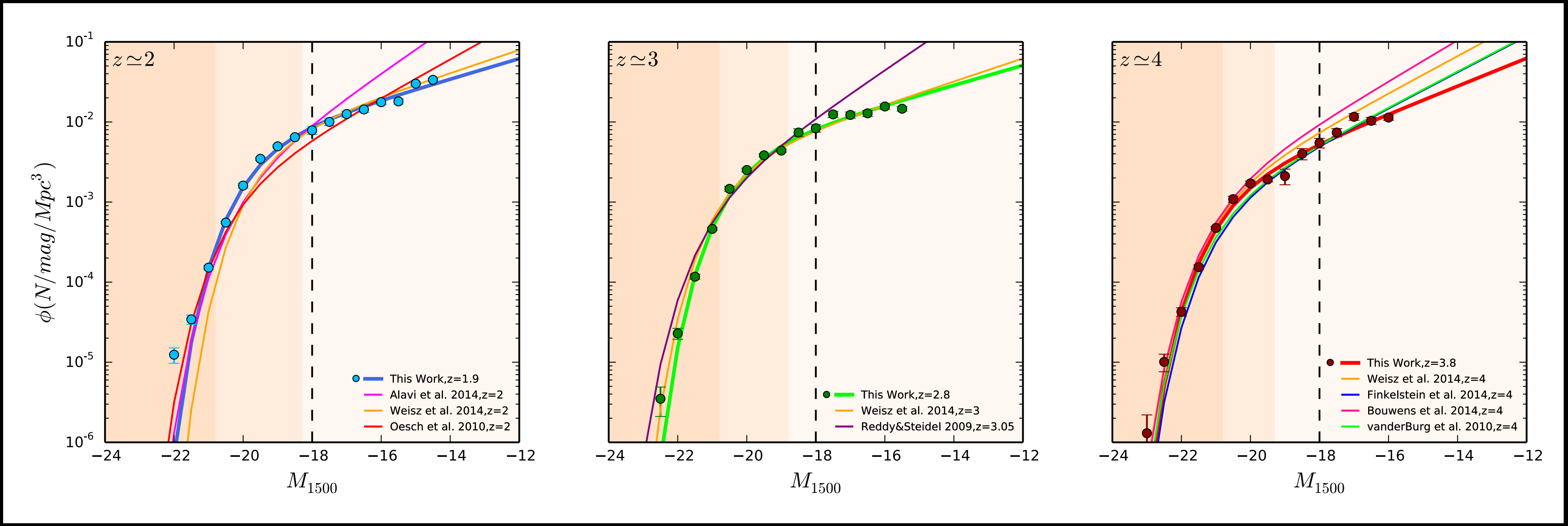
Bowler, Dunlop, McLure et al. 2015

Currently receiving HST WFC3 imaging of brightest z = 7 sources



+ Cycle 3 ALMA observations approved

New measurements of the UV galaxy luminosity function at z = 2, 3, 4

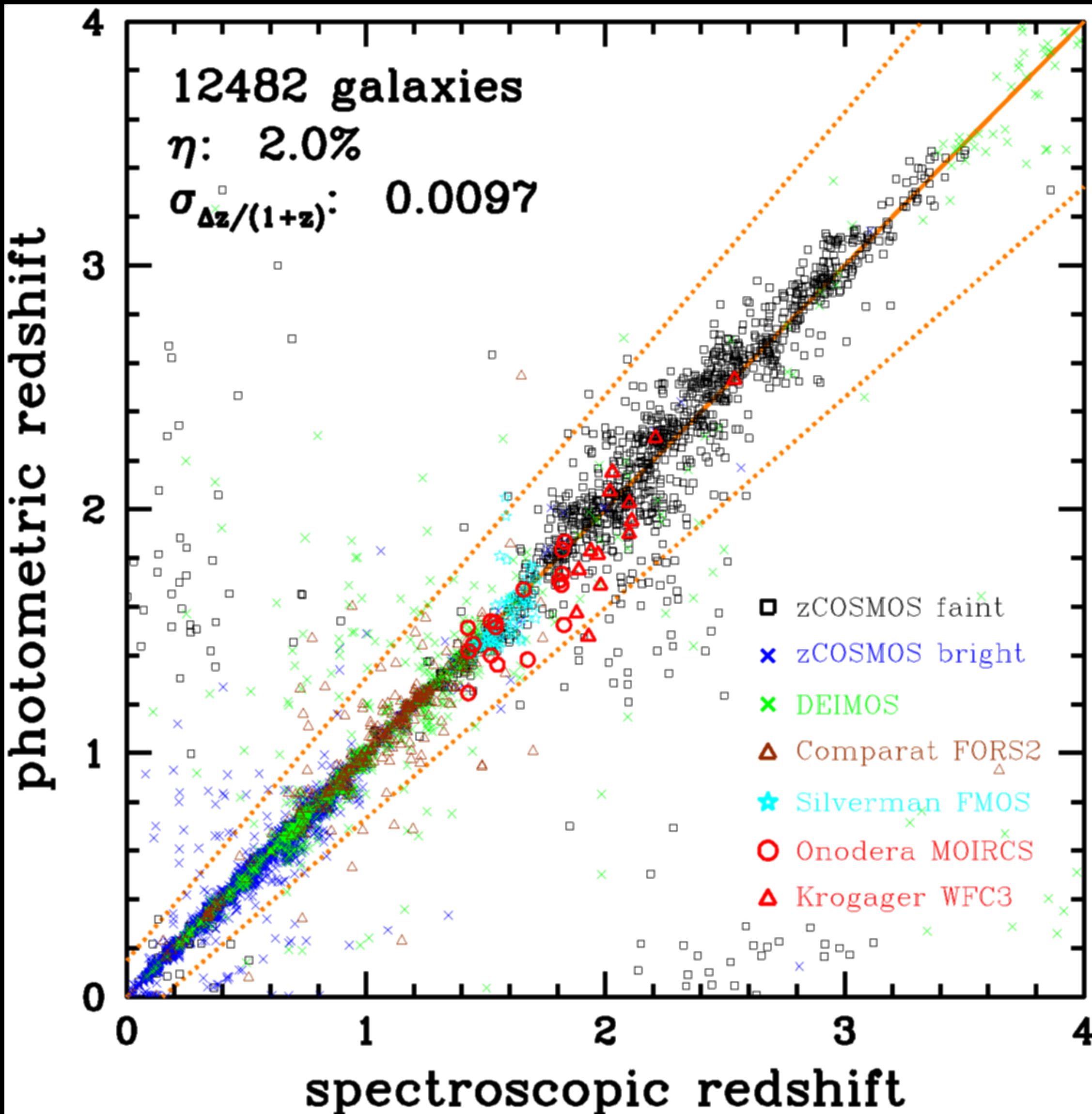


UltraVISTA combined with HST GOODS/CANDELS and HUDF12

Parsa, Dunlop et al. 2015

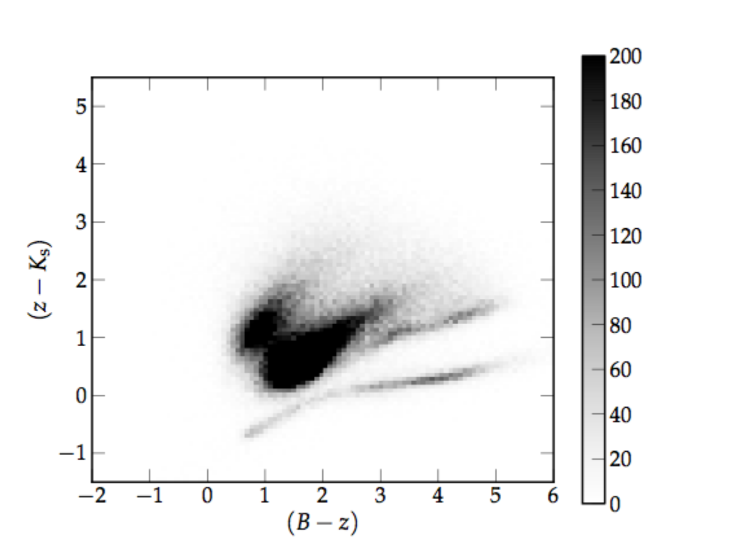
Science: Galaxy Mass Functions

Muzzin et al. 2013, ApJ, 777, 18
Ilbert et al. 2013, A&A, 556, 55
Mortlock, McLure et al., 2015



Deep, high quality photometry now **enables new science** at z~2 (mass function, clustering), pushing further down in mass to allow us to see M* galaxies out to z~2

addition of Y helps a lot at $1 < z_{phot} < 2$



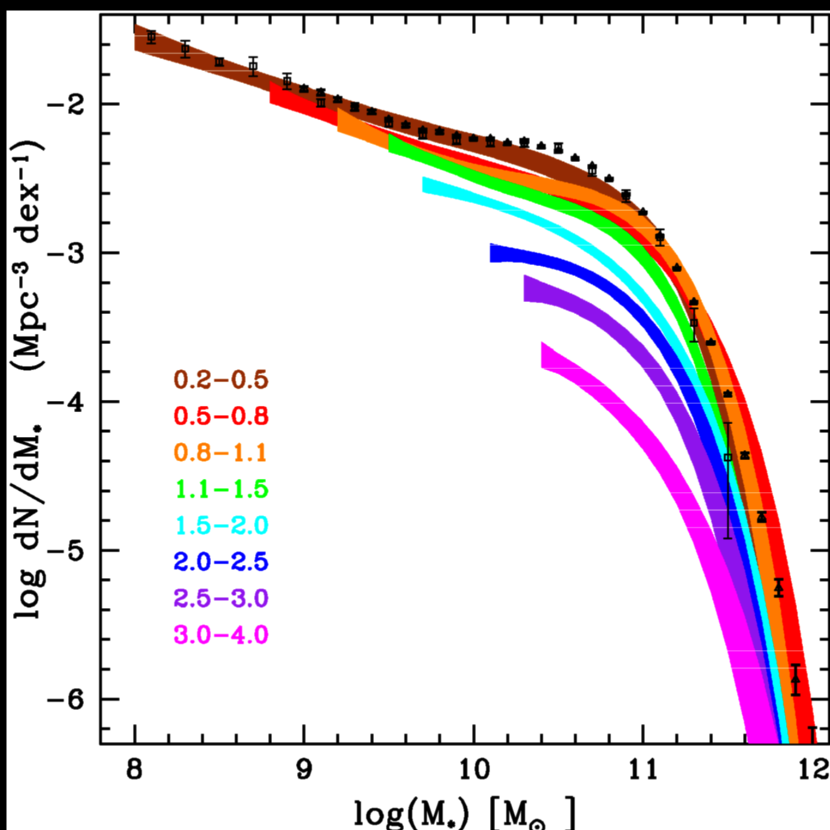
UltraVISTA + COSMOS (25-band) means we can now compute **reliable bias-free** photometric redshifts at 1 < z < 3 (O. Ilbert et al + FMOS +zCOSMOS + DEEP2 spectra)

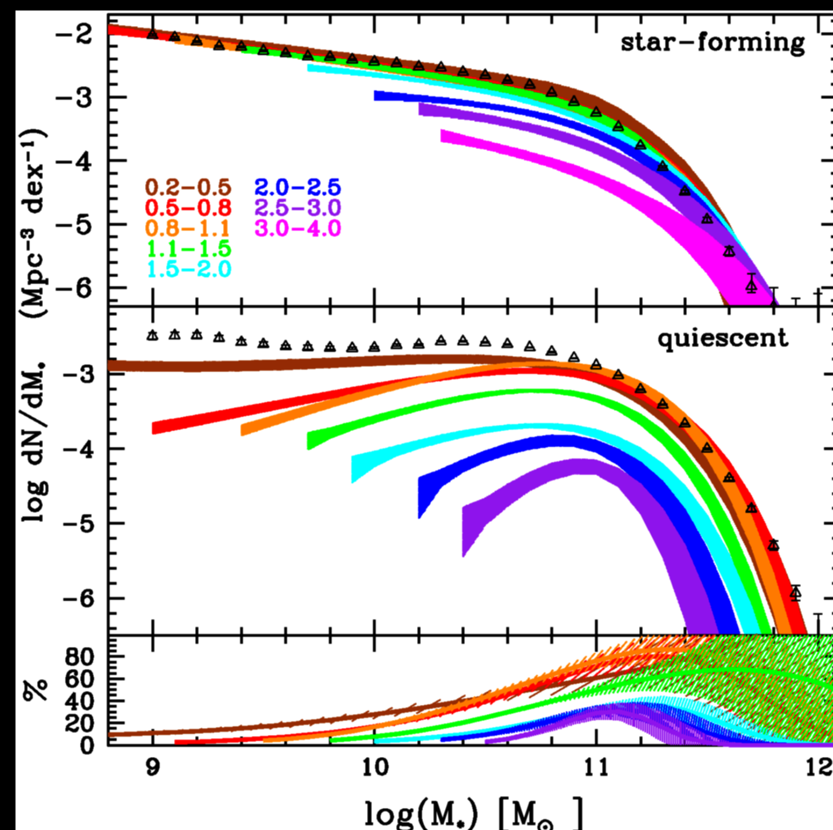
Ilbert et al. 2013

Growth of galaxy stellar mass function since z ~ 4

220,000 galaxies with K_s < 24 from UltraVISTA DR1

10,800 spectroscopic redshifts

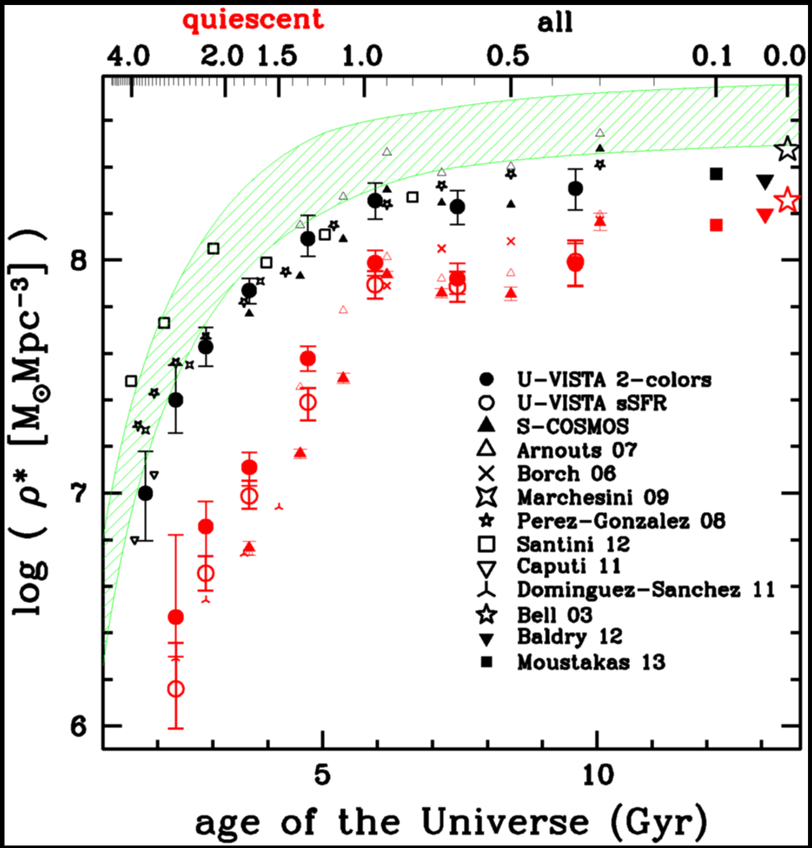


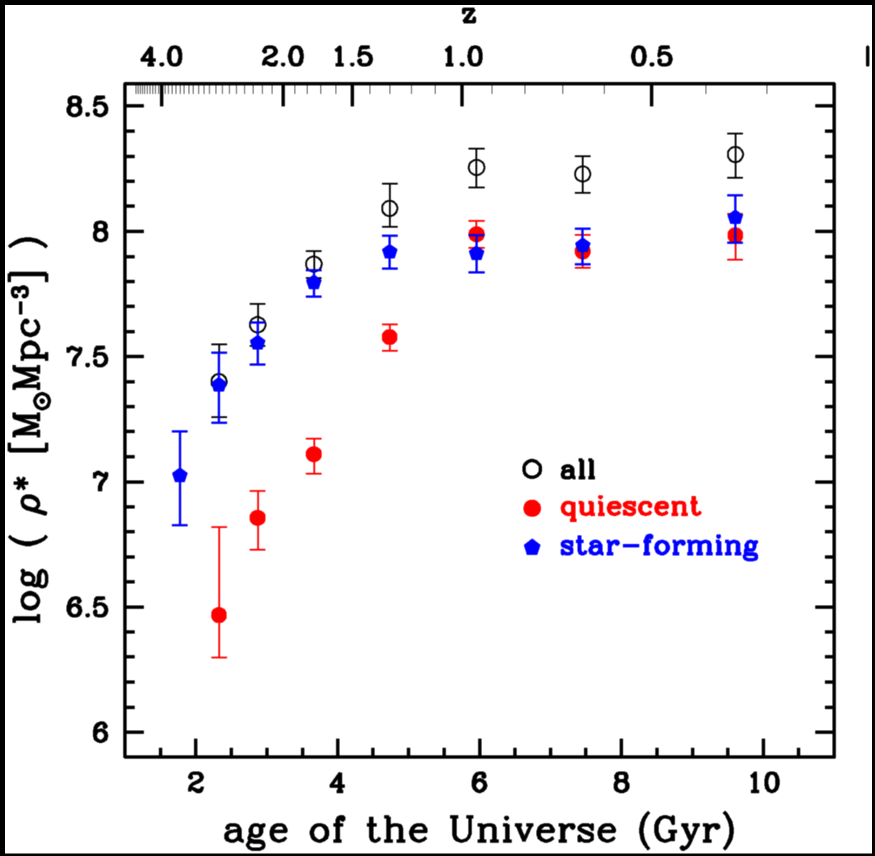


Ilbert et al. 2013

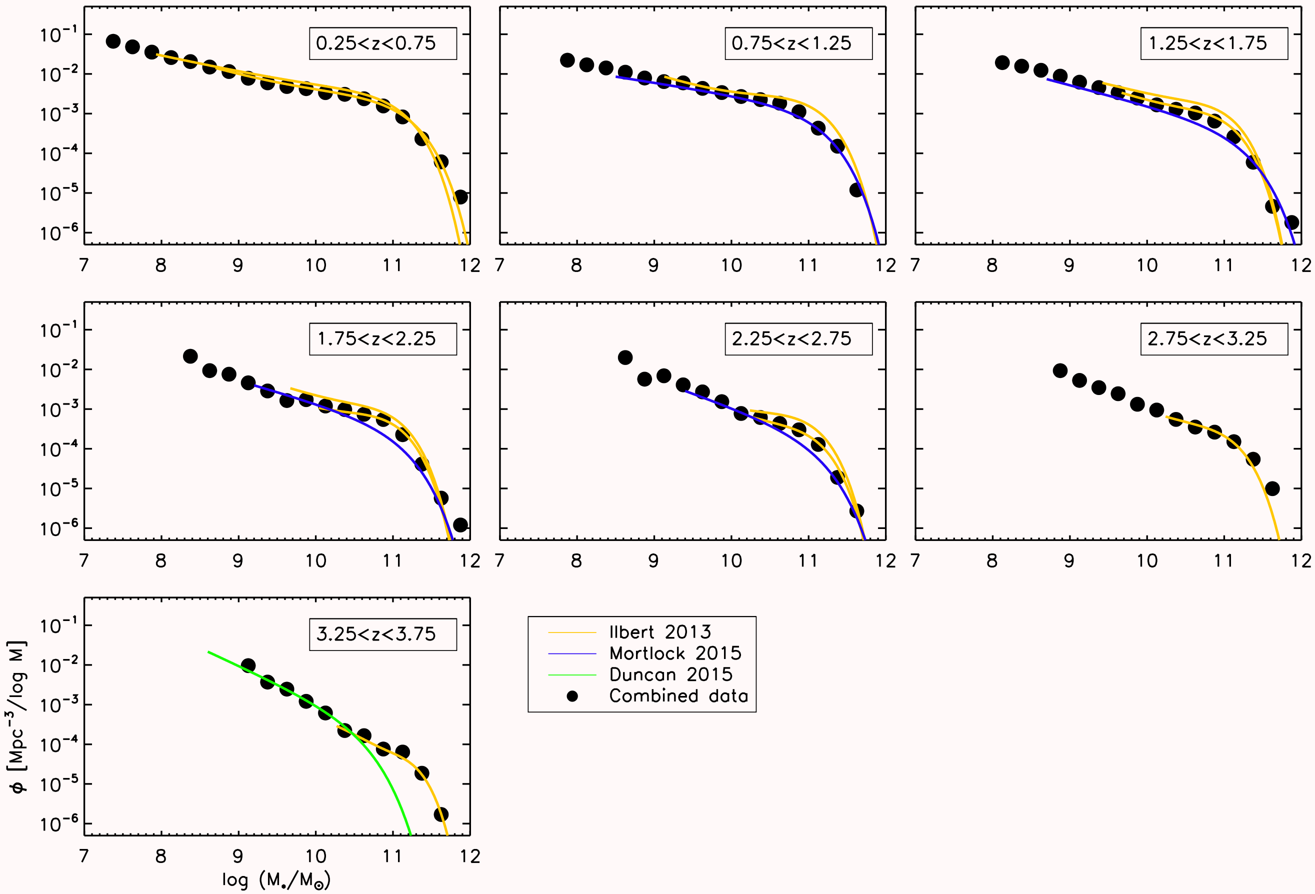
Growth of galaxy stellar mass function since z ~ 4

Integrate - Growth of stellar mass density





New measurement of evolving galaxy stellar mass function combining CANDELS and UltraVISTA DR3



Mortlock, McLure et al., in prep

Science: Dusty star-forming galaxies

e.g. from Spitzer

Steinhardt et al. 2014, ApJ, 791, L25

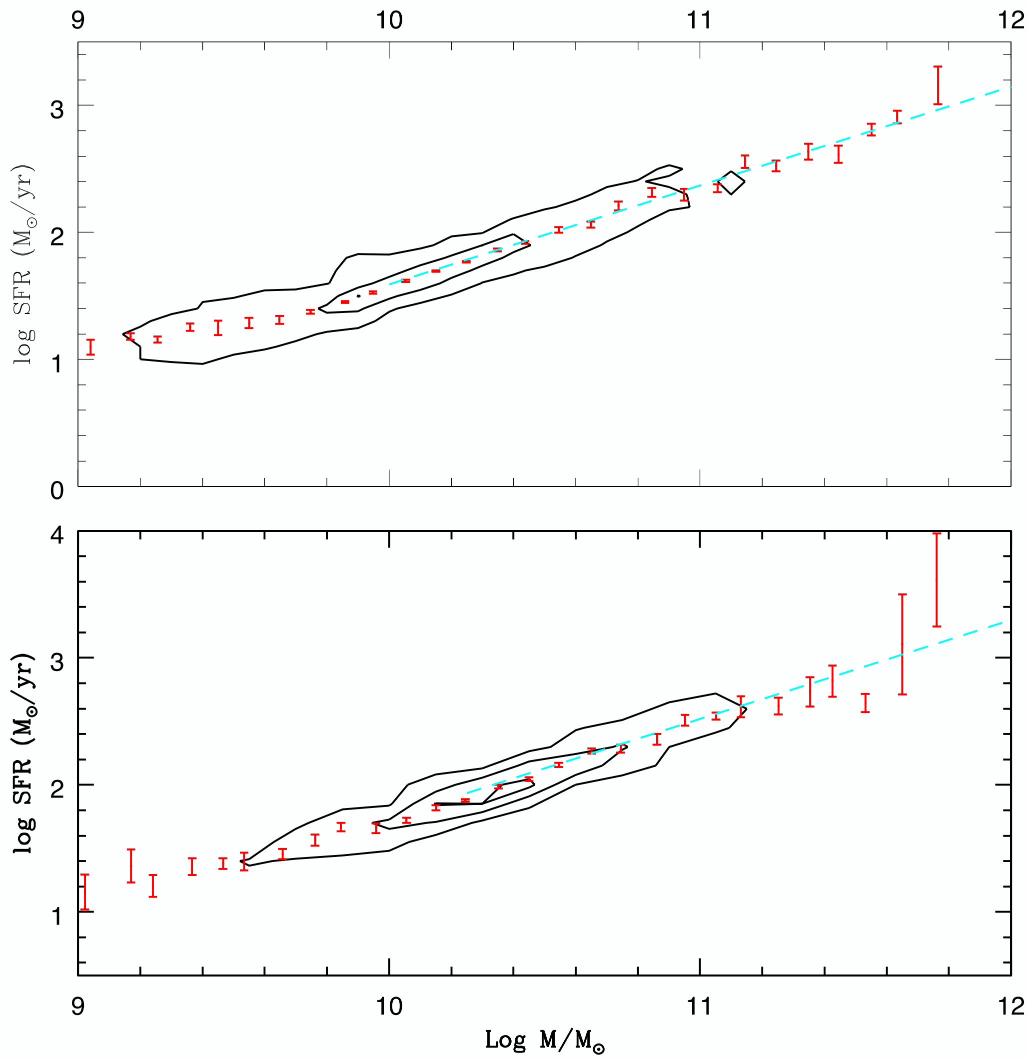
e.g. fom sub-mm/mm surveys

Smolcic et al. 2012, A&A, 548, 4

Koprowski et al. 2014, MNRAS, 444, 117

Scoville et al. 2015, arXiv:1505.02159

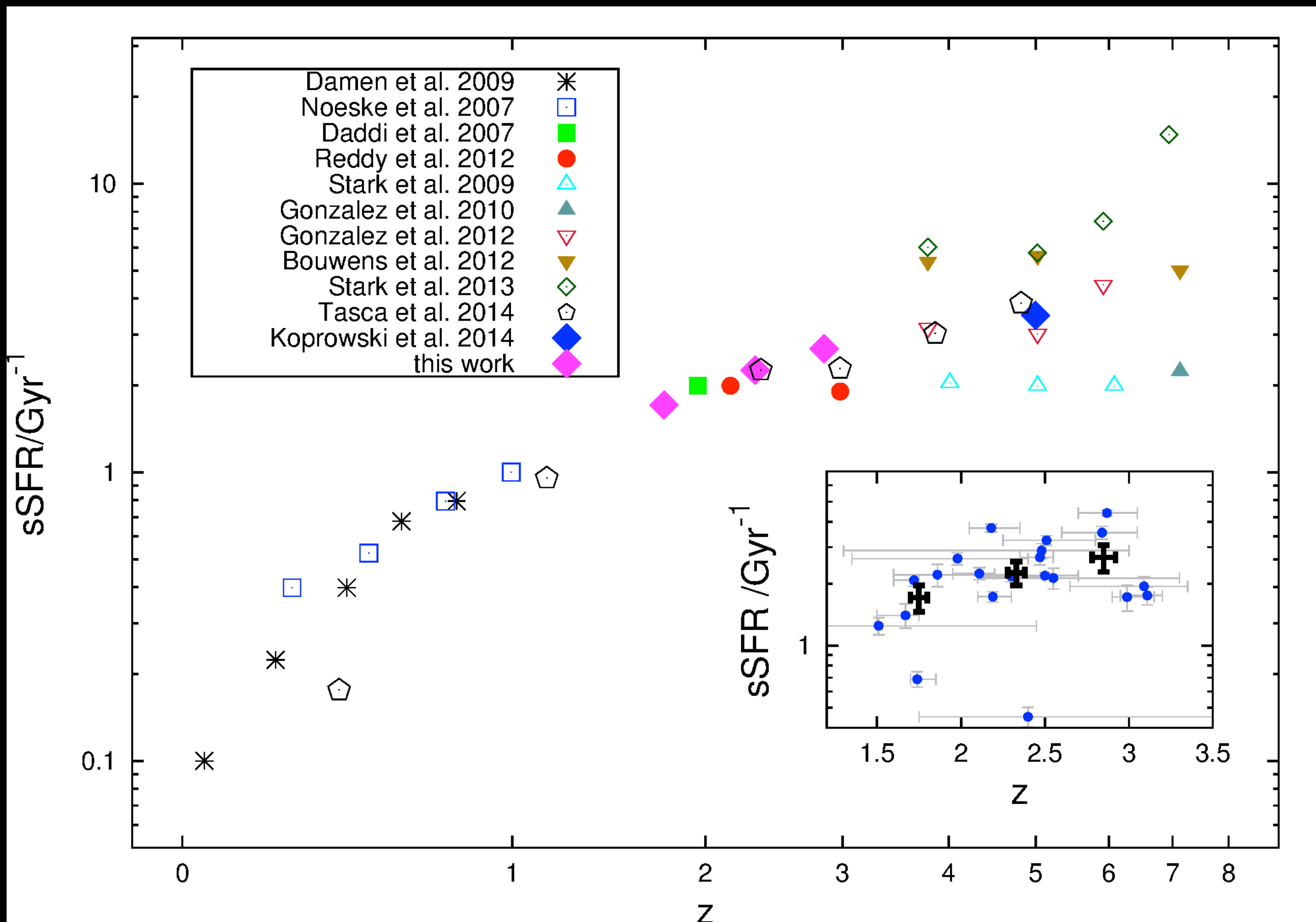
Koprowski et al. 2015, arXiv:1509.07144



Star-forming galaxy "main sequence" at 4 < z < 4.8 and 4.6 < z < 6

Steinhardt et al. 2014

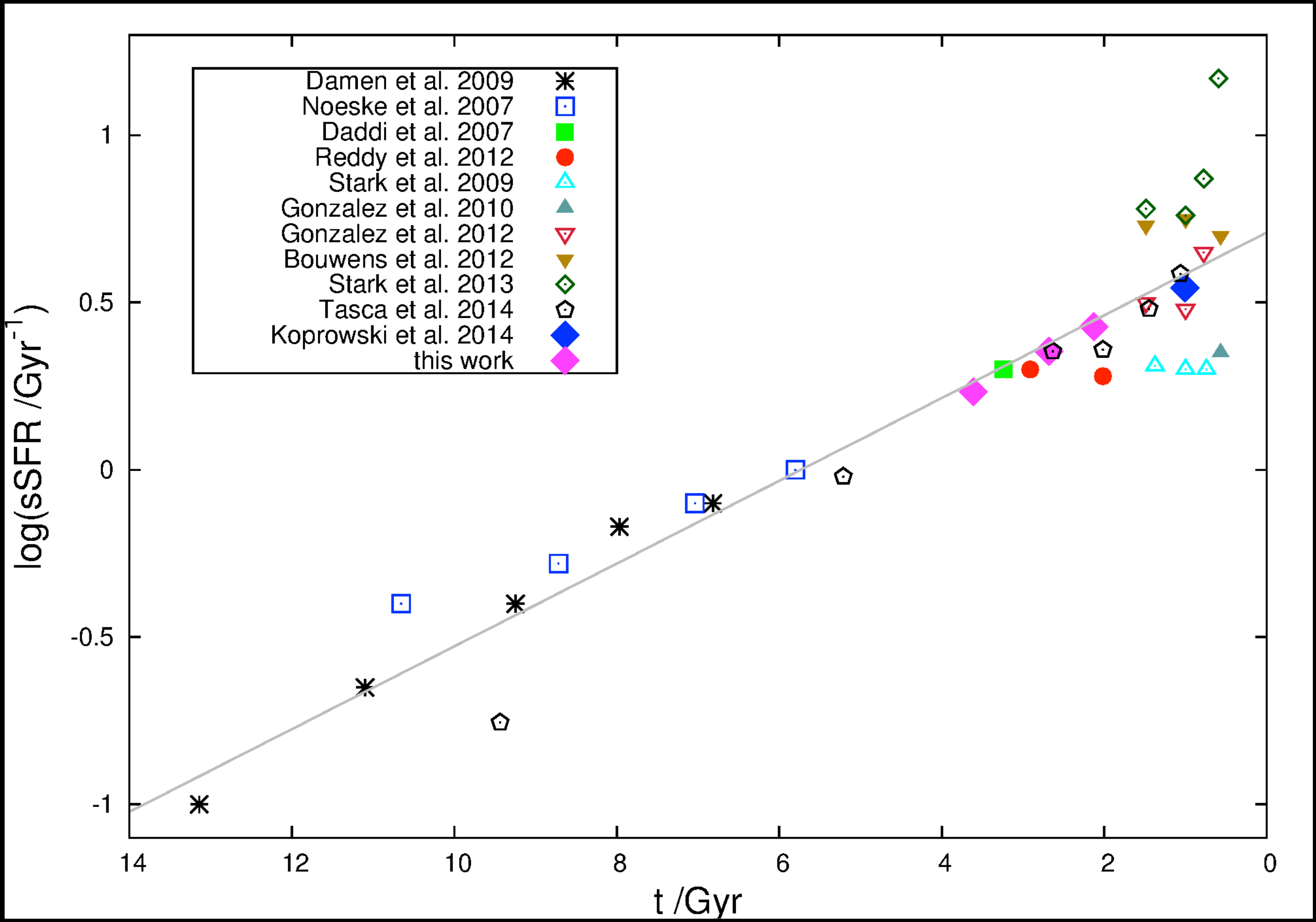
Evolution of specific star-formation rate



Koprowski, Dunlop et al. 2015

See also Lidia Tasca's talk tomorrow

Evolution of specific star-formation rate



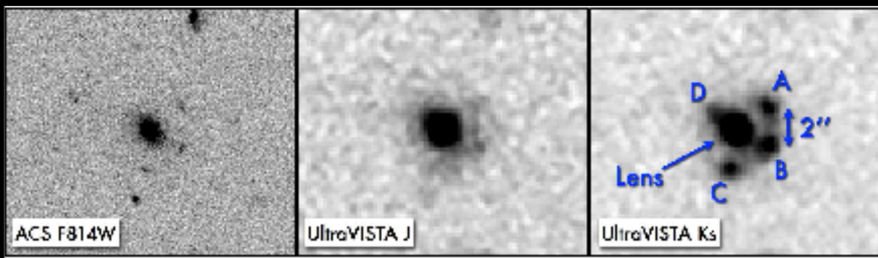
Koprowski, Dunlop et al. 2015

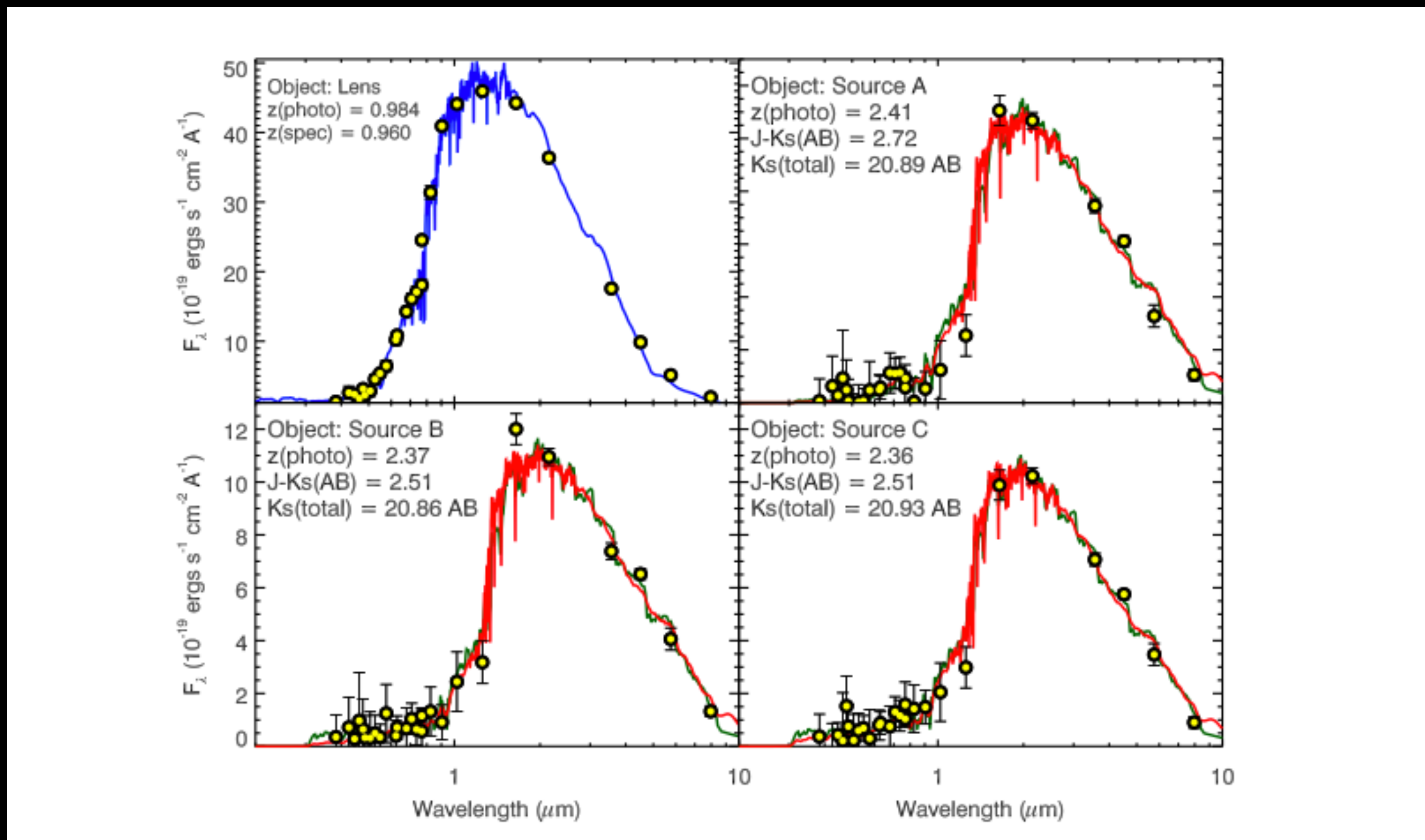
Science: other

> 100 studies have utilised UltraVISTA data over last 3 years

Triply-lensed background z~2 galaxy, lensed by foreground elliptical

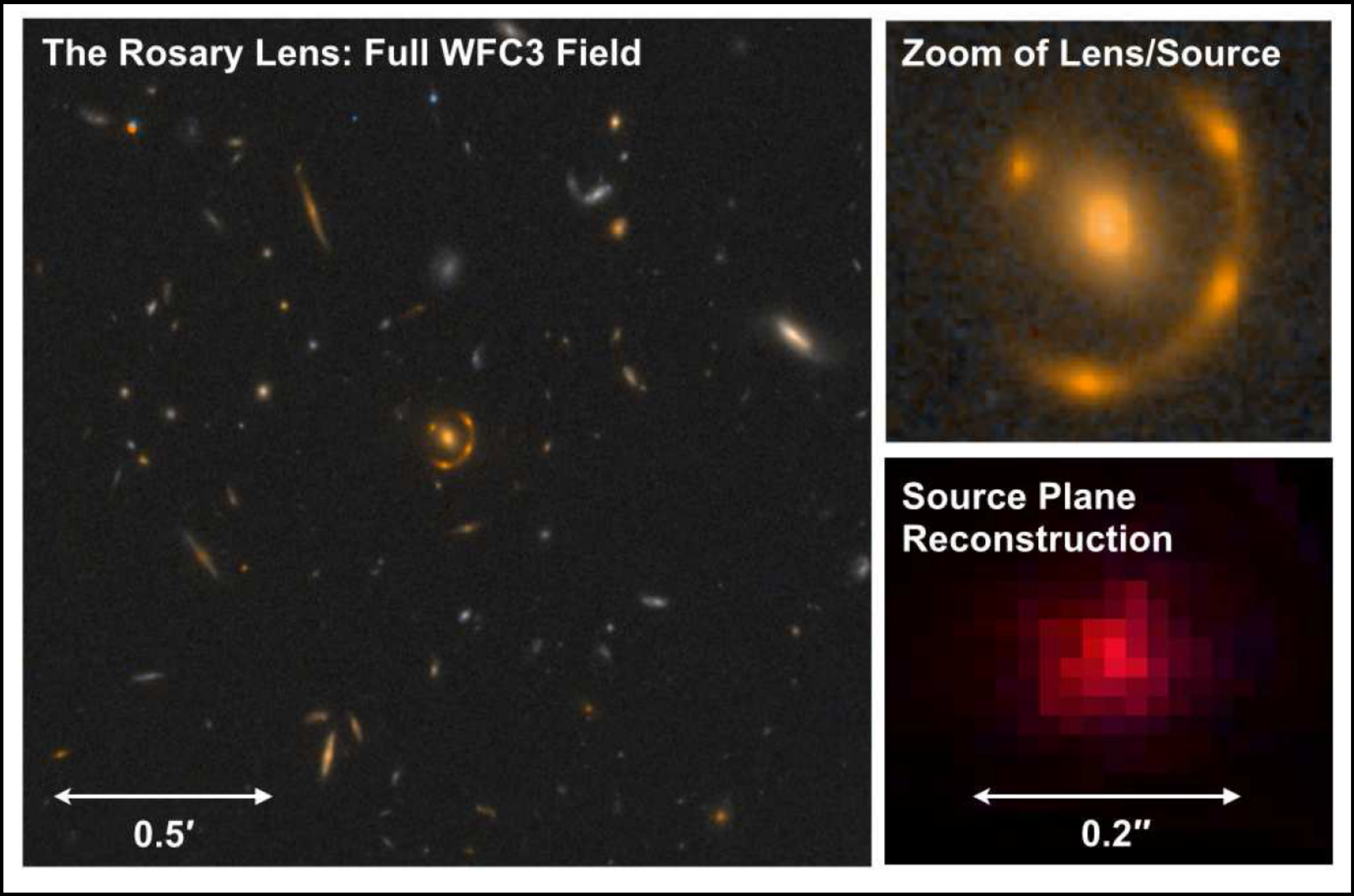
Muzzin et al. 2012, ApJ, 761, 142





HST follow-up of this lens: n = 4, so small bulge

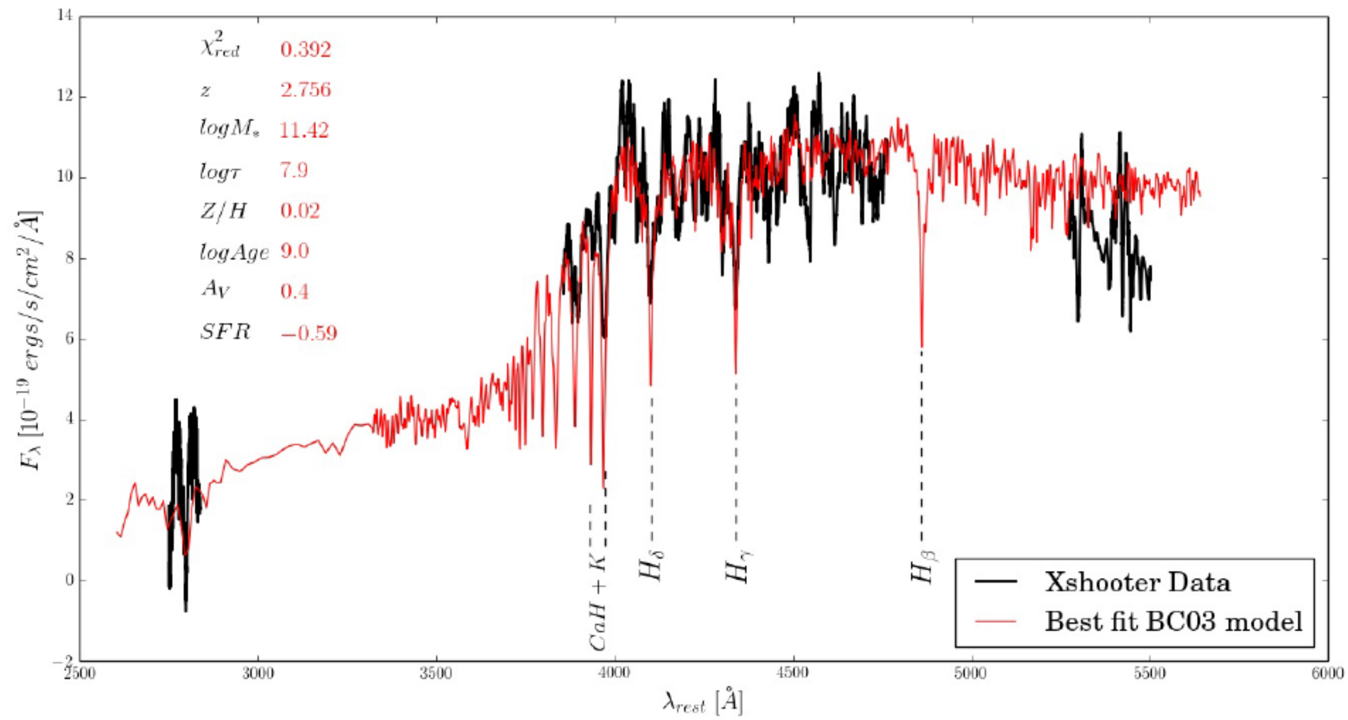
Muzzin et al. in prep



X-shooter follow-up: Hill et al. in prep

z = 2.756, highest redshift quiescent/quenched galaxy with measured velocity dispersion

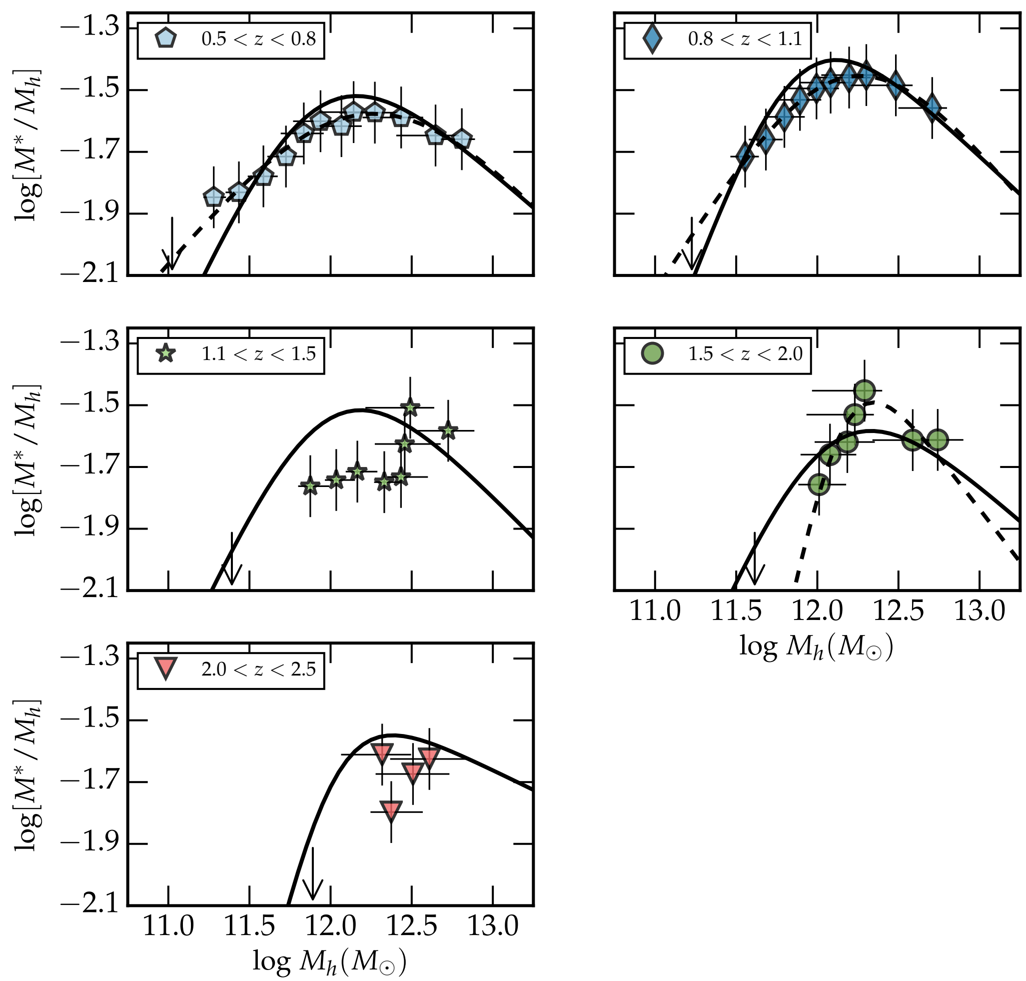
Figure 2: X-SHOOTER spectrum of a strongly-lensed quiescent galaxy at $z = 2.756$ (Hill et al. in prep). This is the highest-redshift quiescent galaxy for which absorption lines have been detected. This galaxy is at similar redshift, and is slightly fainter than the proposed target so is indicative of the quality of spectrum we will obtain. Note the K-blocking filter was used in this observation so most of the data is in the observed H-band.



Dynamical mass = stellar mass

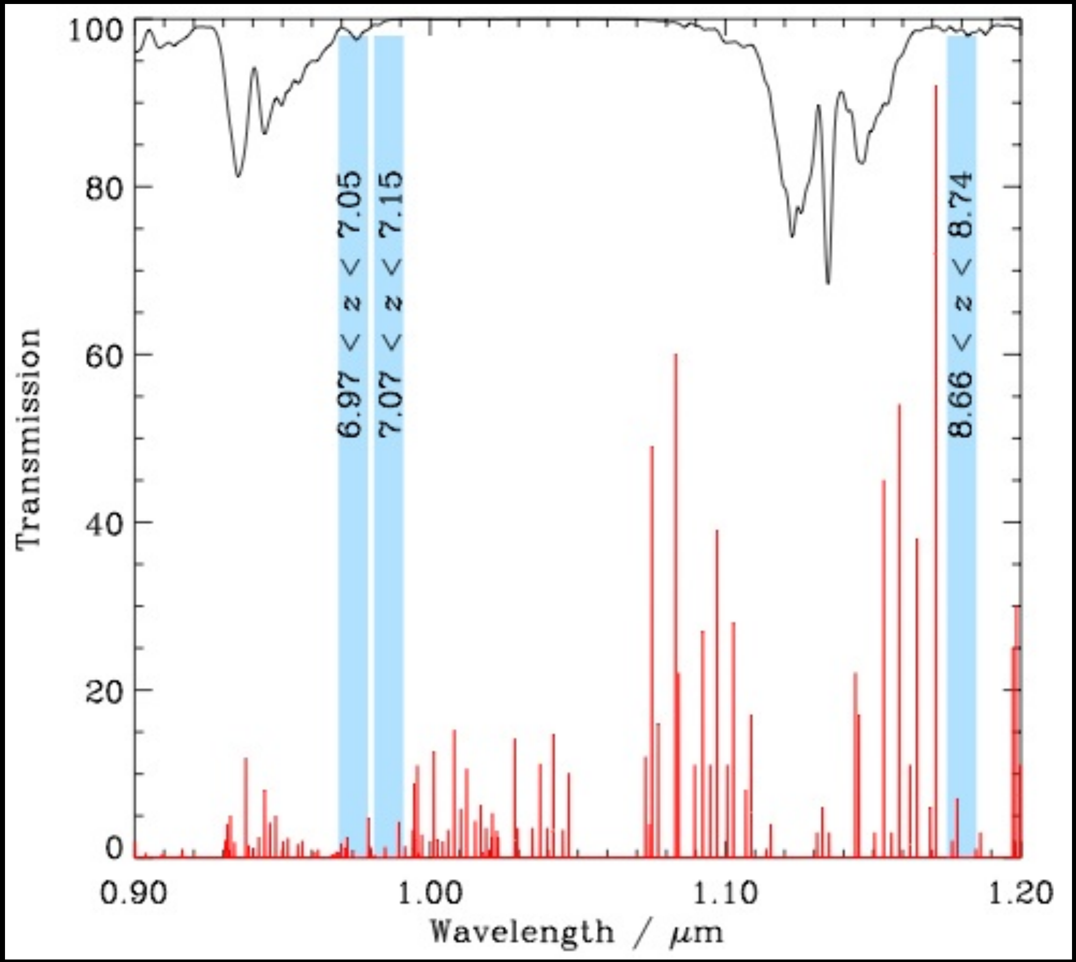
Clustering studies and M^*/M_{halo}: peaks at $\log(M_h) \sim 12.2$

McCracken et al. 2015, MNRAS, 449, 901



Emission-lines at z > 7

VISTA narrow-band imaging



See Bo Milvang-Jensen's talk tomorrow

DR4 - Will contain all data to summer 2016

These new data will deepen the “deep strips” and are expected to deliver imaging reaching
5-sigma, 1.8-arcsec diameter AB mag detection limits:
Y=26.3, J=26.0, H=25.7, K_s=25.3

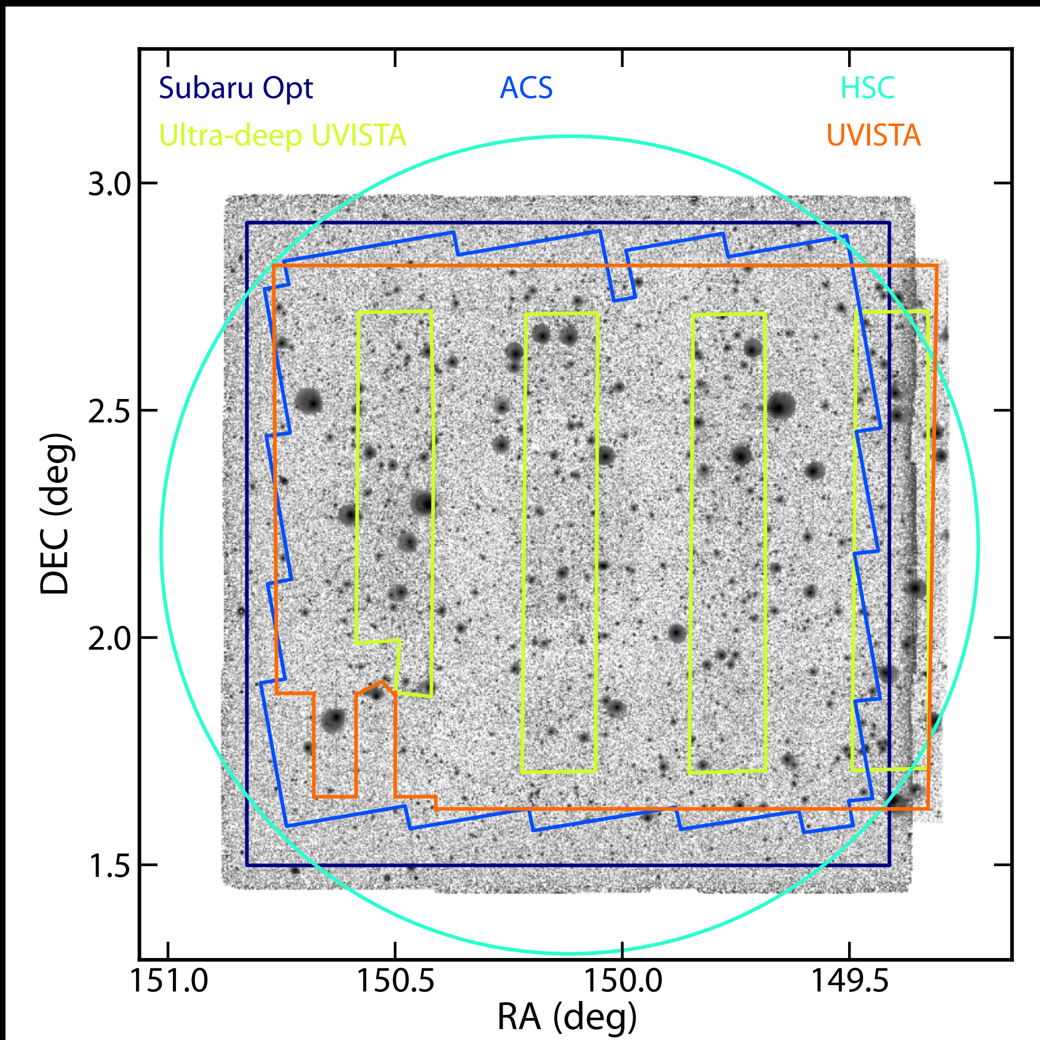
Will also have deepened the complete K_s image to K_s=25.0

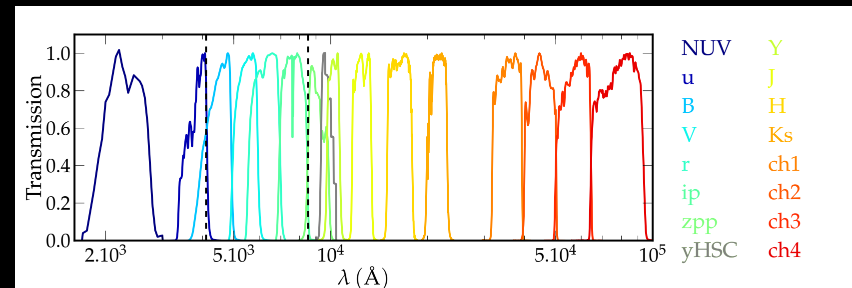
This dataset will be based on ~1300 out of the 1642 hours of exposure time awarded.

Observing overhead: execution/exposure = 1.32

So ~450 hours would need to be awarded starting Dec 2016 to complete originally requested/allocated time

The Future: boosting the legacy value of UltraVISTA





Need to re-appraise in the era of Subaru HyperSuprimeCam

Deep HSC survey proposes to deliver Y-band to 26.5 (5-sigma)

COSMOS2015 catalogue

Laigle, McCracken et al. 2015

Summary

- UltraVISTA has been, and continues to be a powerful/productive public survey
- Now ultilised in essentially all studies of the COSMOS field

- Breakthrough results on bright high-redshift galaxies, into the reionization era at z ~ 7
- State-of-the-art galaxy stellar mass functions out to z ~ 4
- Key role in identifying and studying dusty star-forming galaxies

- Completes λ coverage with CFHT/Subaru/Spitzer/Herschel/SCUBA-2
- Provides crucial boost in dynamic range when combined with HST and Hawk-I surveys
- Proving a powerful lever for HST, ALMA and VLT follow-up

- VIRCAM+VISTA performing to spec, but observing overhead 1.32
- First 5 seasons now released. Seasons 6 and 7, ending July 16, will provide DR4
- Survey needs extra time beyond summer 2016 to provide original planned exposure time

- Now reconsidering strategy in light of SPLASH and Subaru HyperSuprimeCam
- LOI plan for max legacy ~800 hours to complete JHK_s to DR4 depth across whole field