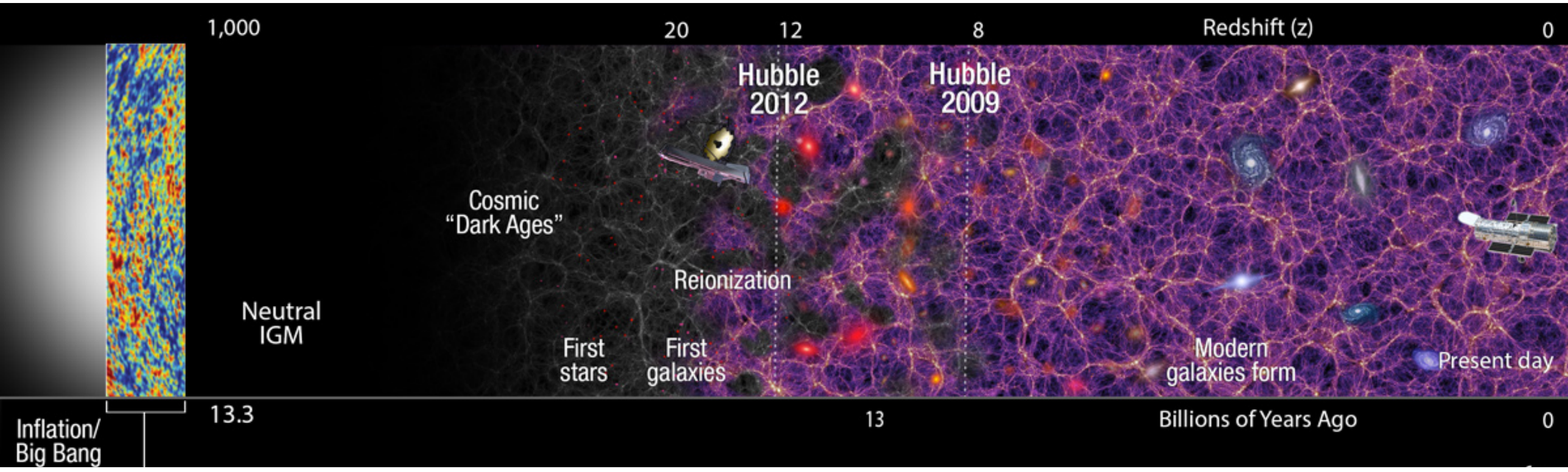
ASTRODEEP

Unveiling the power of the deepest images of the Universe

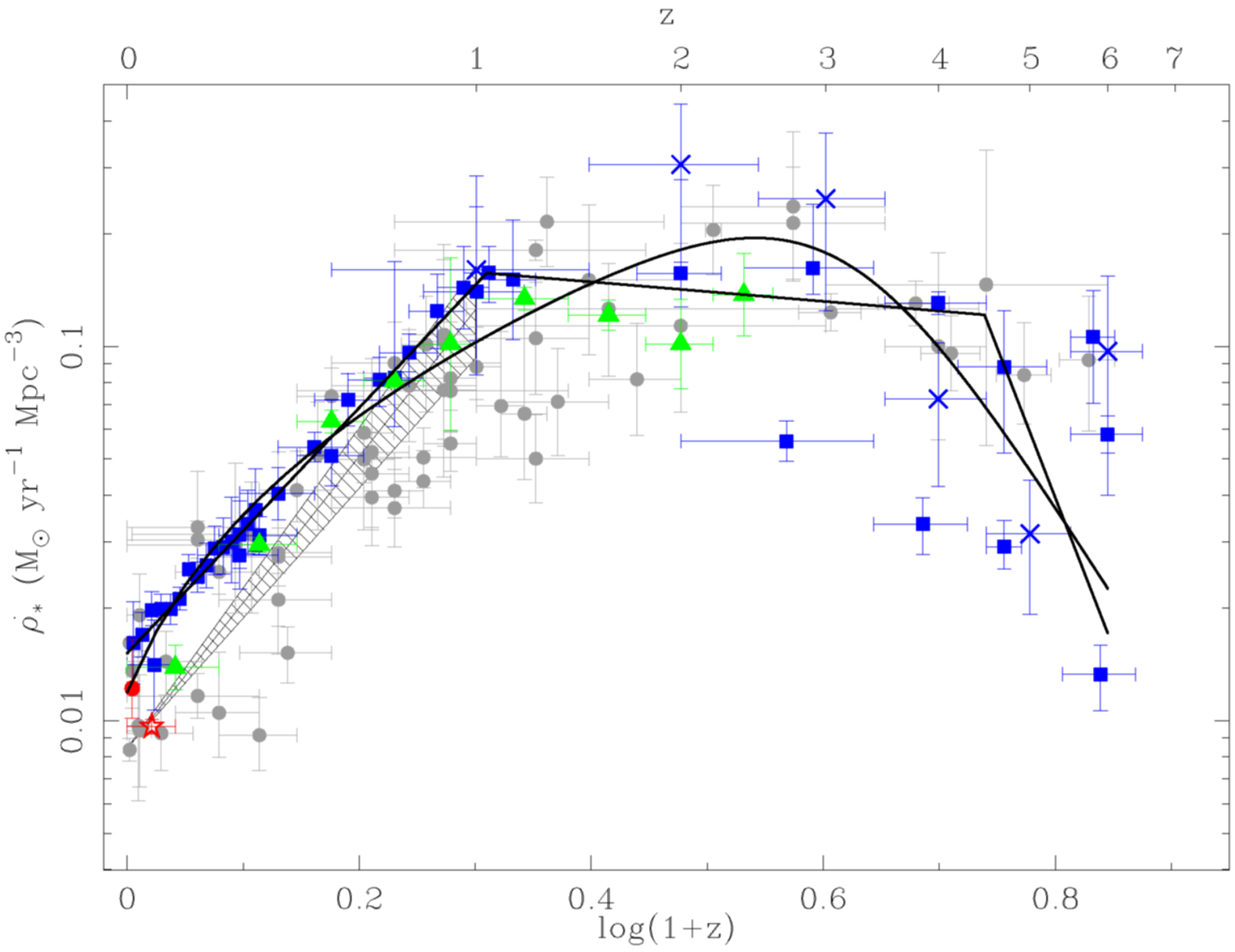
Coordinator: Adriano Fontana (INAF)

James Dunlop (UEDIN)
David Elbaz (CEA)
Sebastien Derriere (CNRS)
+ Team of US collaborators

Cosmic history



Charting the cosmic history of star formation



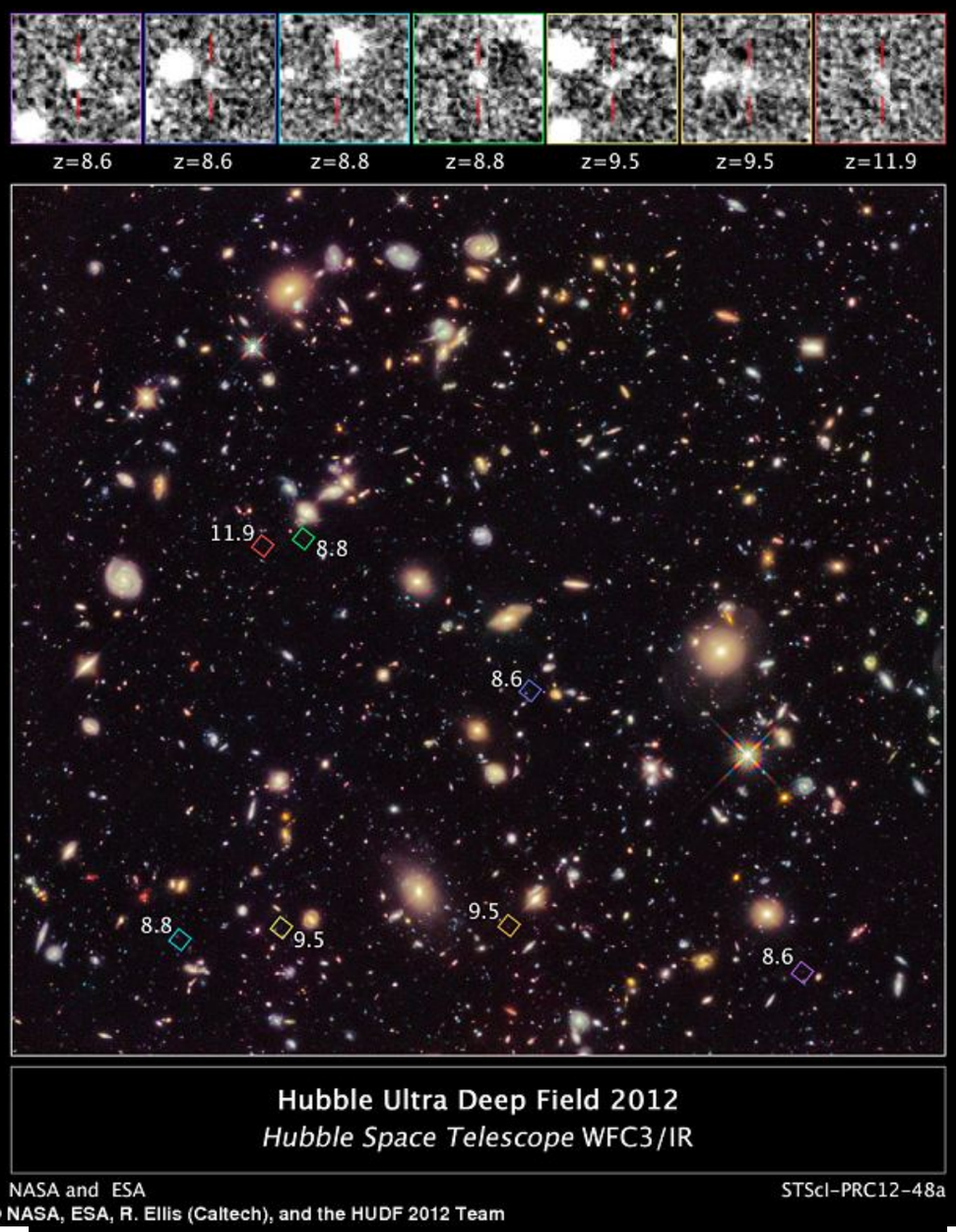
Hopkins & Beacom 2006

ASTRODEEP

SEVENTH FRAMEWORK PROGRAMME

A weddi

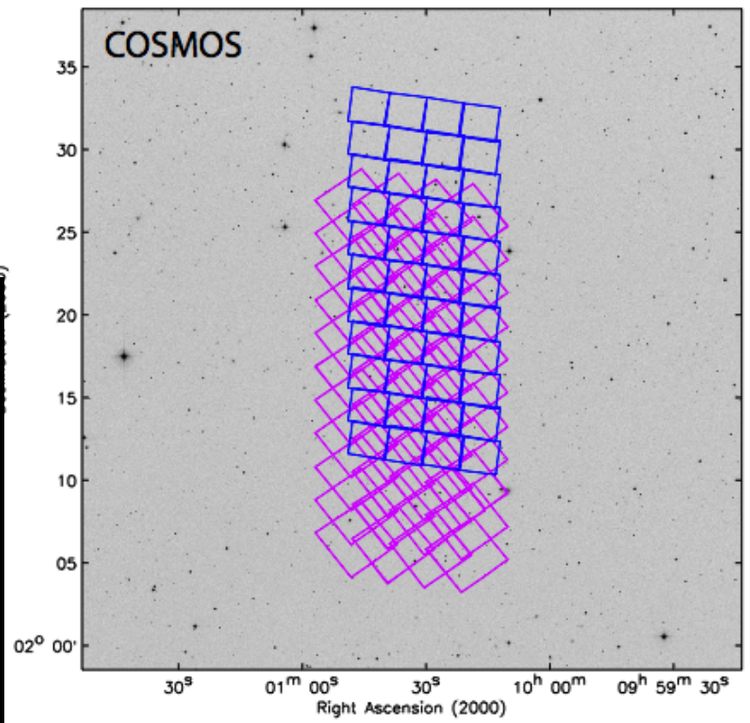


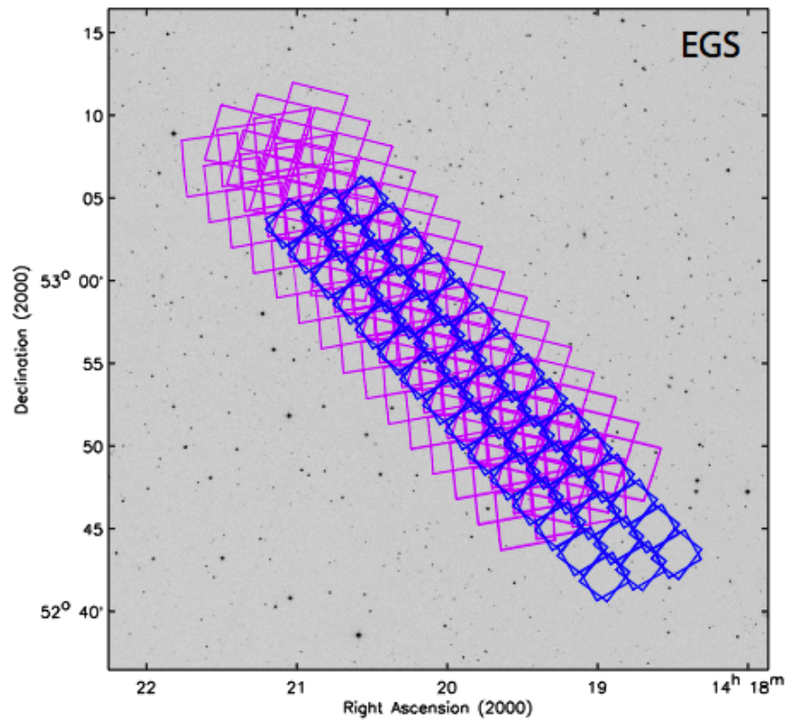


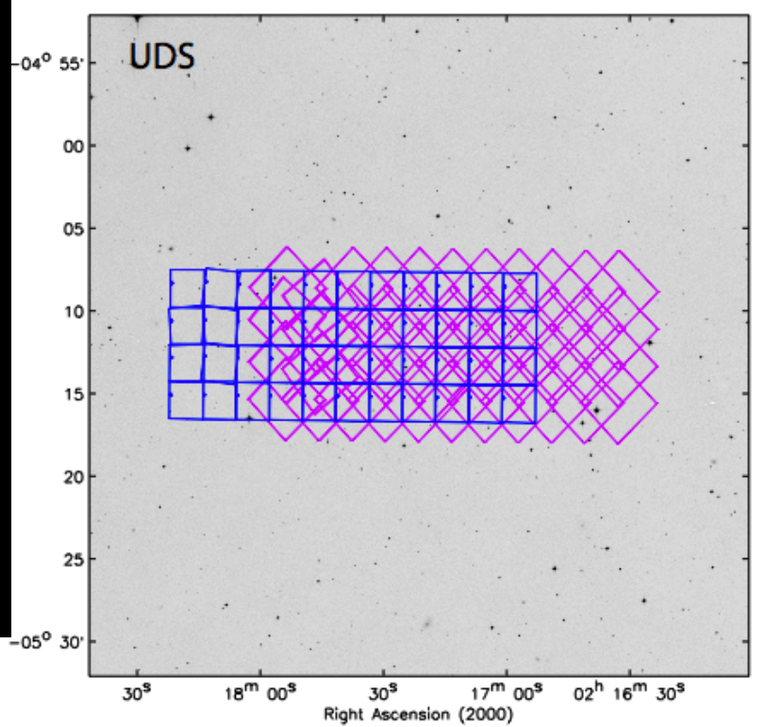
Hubble Ultra Deep Field 2012
Hubble Space Telescope WFC3/IR

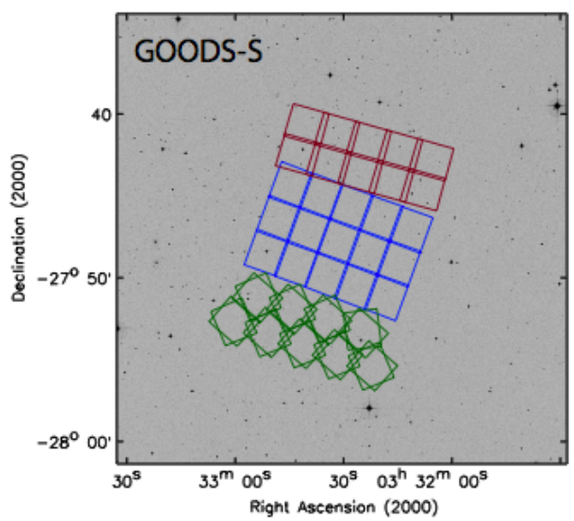
NASA and ESA STScI-PRC12-48a

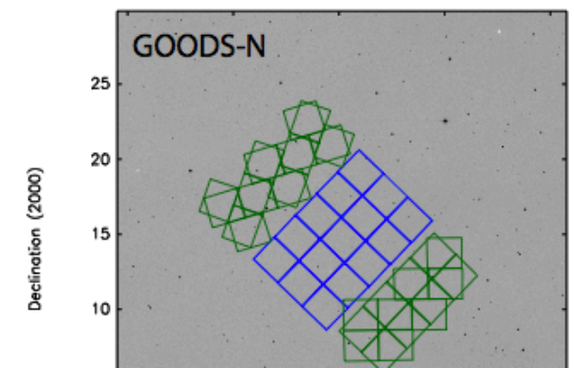
© NASA, ESA, R. Ellis (Caltech), and the HUDF 2012 Team







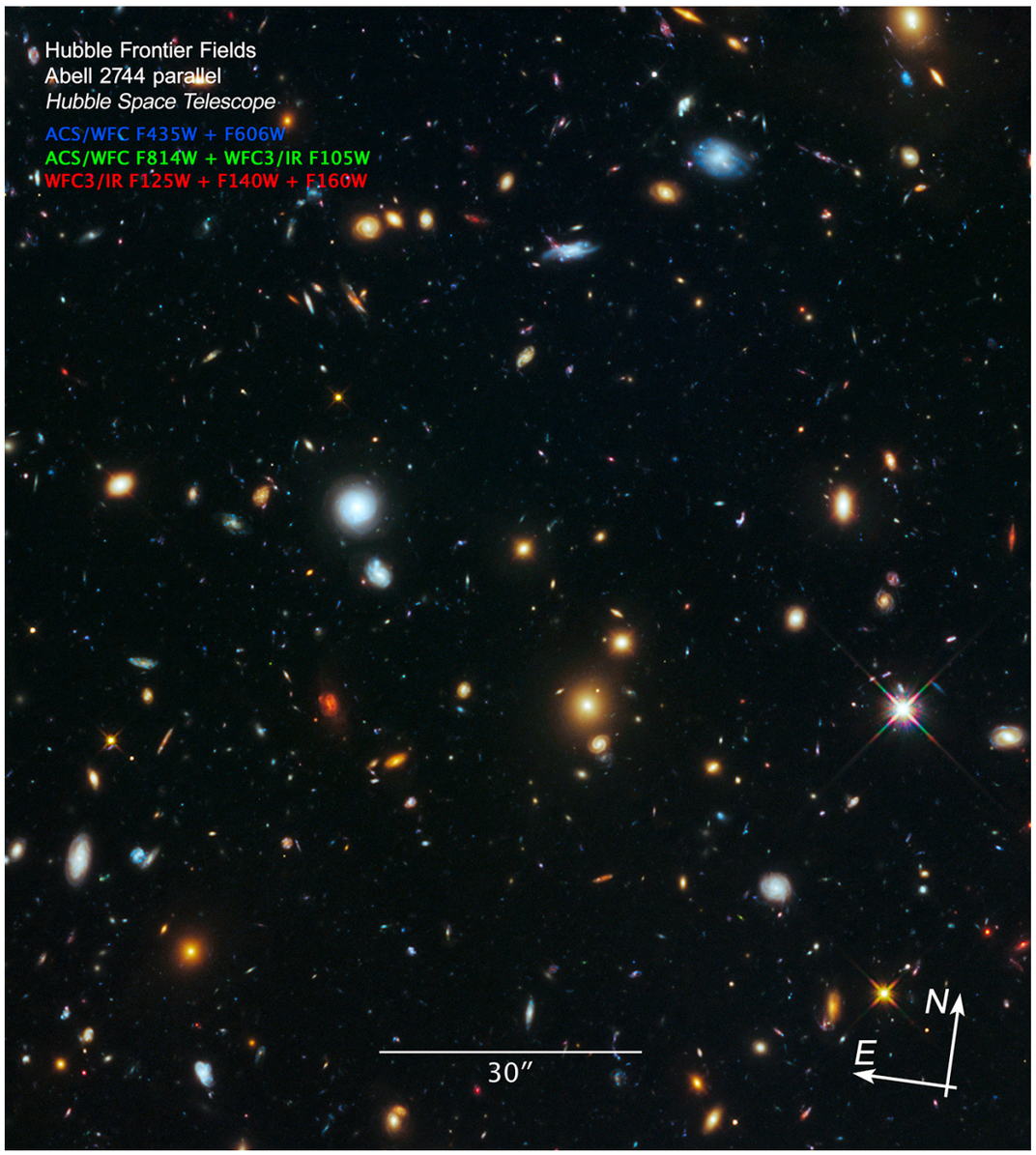




Deep pointings now augmented with the Hubble Frontier Fields

e.g. Abell 2744





ASTRODEEP Science in 2014

- 29 papers explicitly acknowledging AstroDEEP in year 2 (see D5.2)

- This work has helped us further refine and augment the key datasets

- Have also tested existing and new algorithms

- Papers now being produced using new AstroDEEP tools such as TPHOT

ASTRODEEP Science Highlights

5 main areas as highlighted in scientific report

1. High-redshift galaxy evolution from degree-scale surveys

2. Galaxy mass function from CANDELS+HUGS

3. Studies of the first galaxies & reionization from deepest Hubble fields

4. Dust obscured star formation from Herschel and SCUBA-2 data

5. Evolution of galaxy size and morphology from deep HST imaging

The evolution of bright galaxies from z = 5 to z = 7

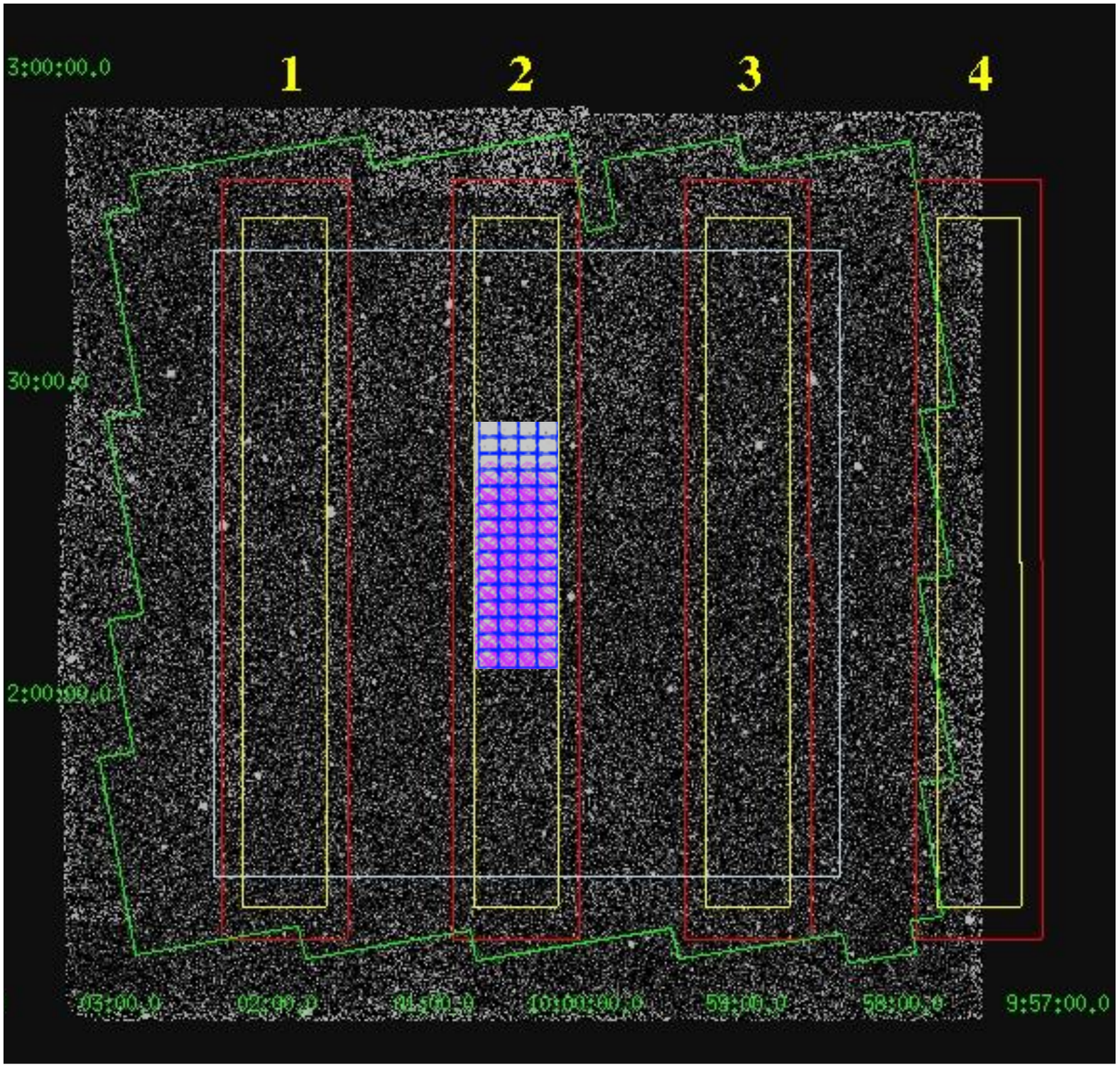
Bowler, Dunlop et al. 2014, 2015

The DATA: widest fields being studied with AstroDEEP

- COSMOS/UltraVISTA field
- UKIDSS Ultra Deep Survey (UDS) field

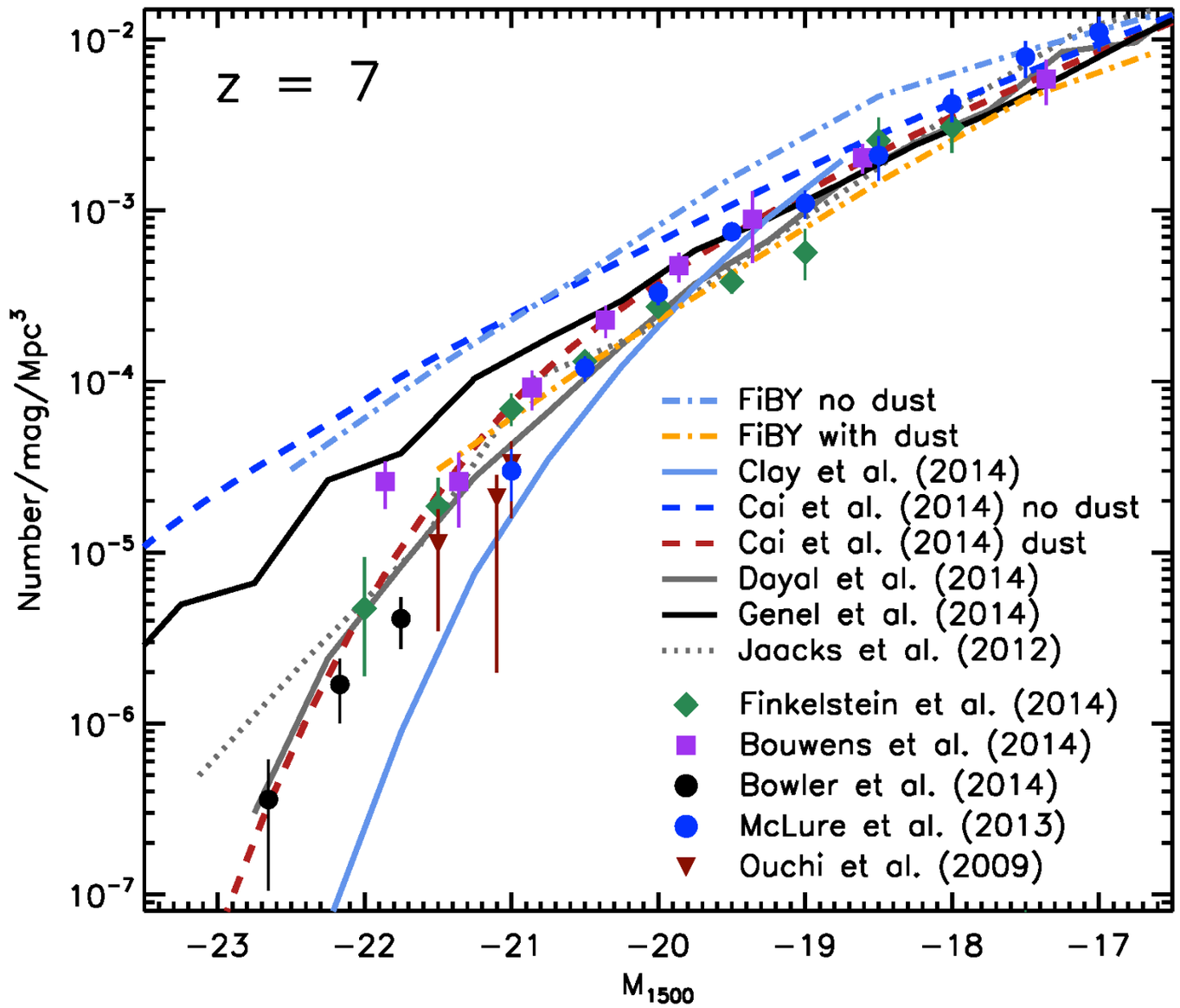
Both ~ 1 square degree fields need careful combination of resolution-matched optical, near-IR and mid-IR imaging

UltraVISTA + CANDELS



New results show 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)



More evidence for dust, and implications for mass quenching etc

2. Galaxy Growth

Exploiting CANDELS & associated deep ground-based and Spitzer data

HUGS (Hawk-I UDS and GOODS Survey):

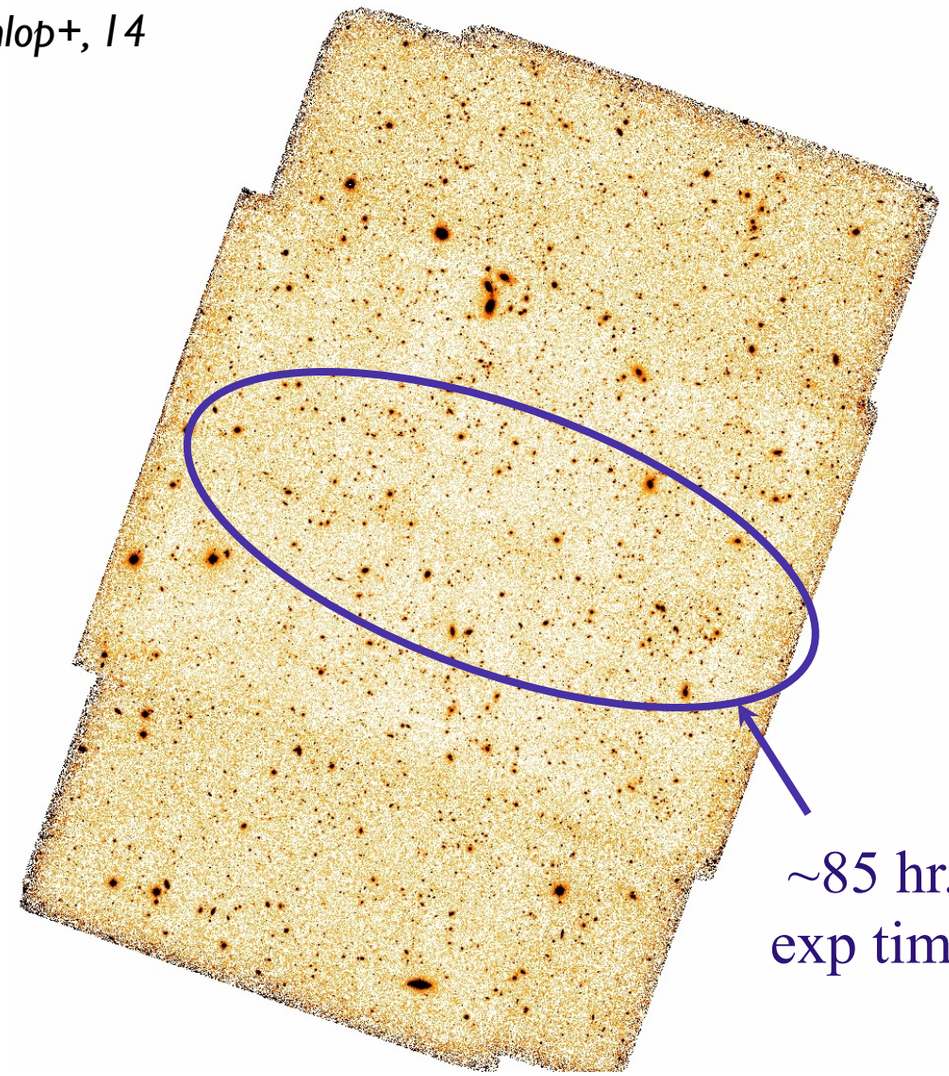
A Rome-Edinburgh+ CANDELS program

A.Fontana (PI), J. Dunlop, Faber, Ferguson et al...

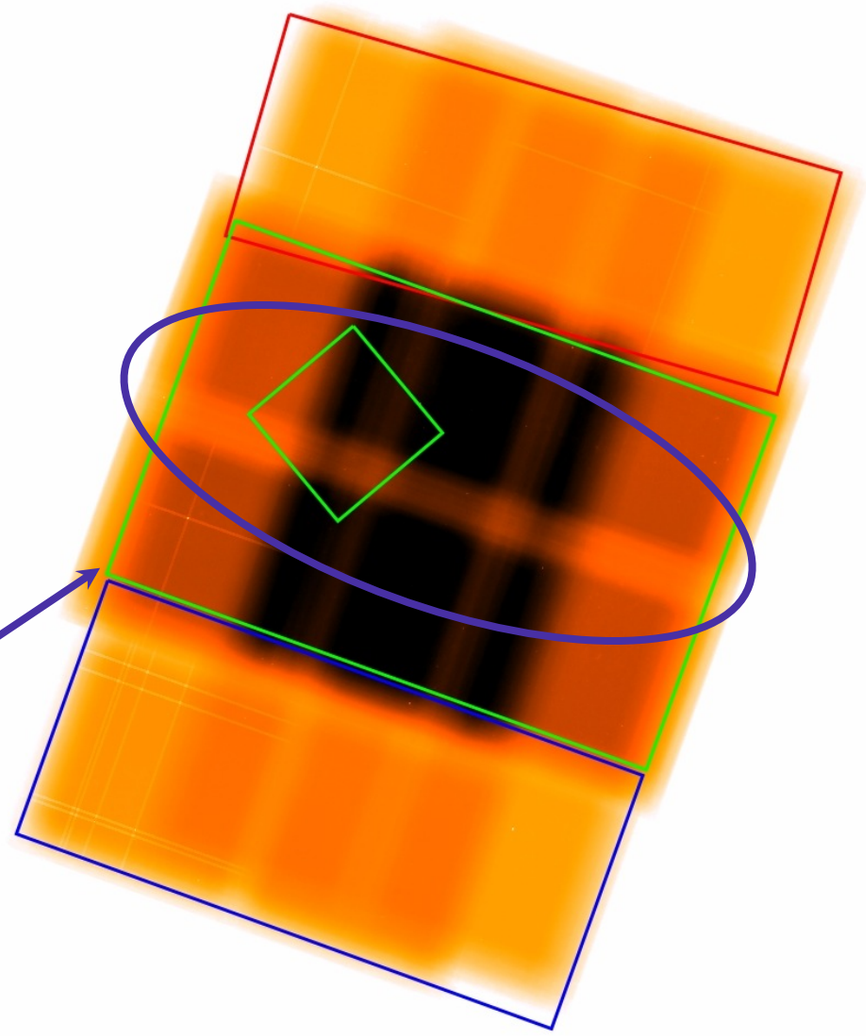
Large Hawk-I@VLT program (250hr)

186.A- 0898 + 181.A- 0717 AND HAWK-I SV

Fontana, Dunlop+, 14

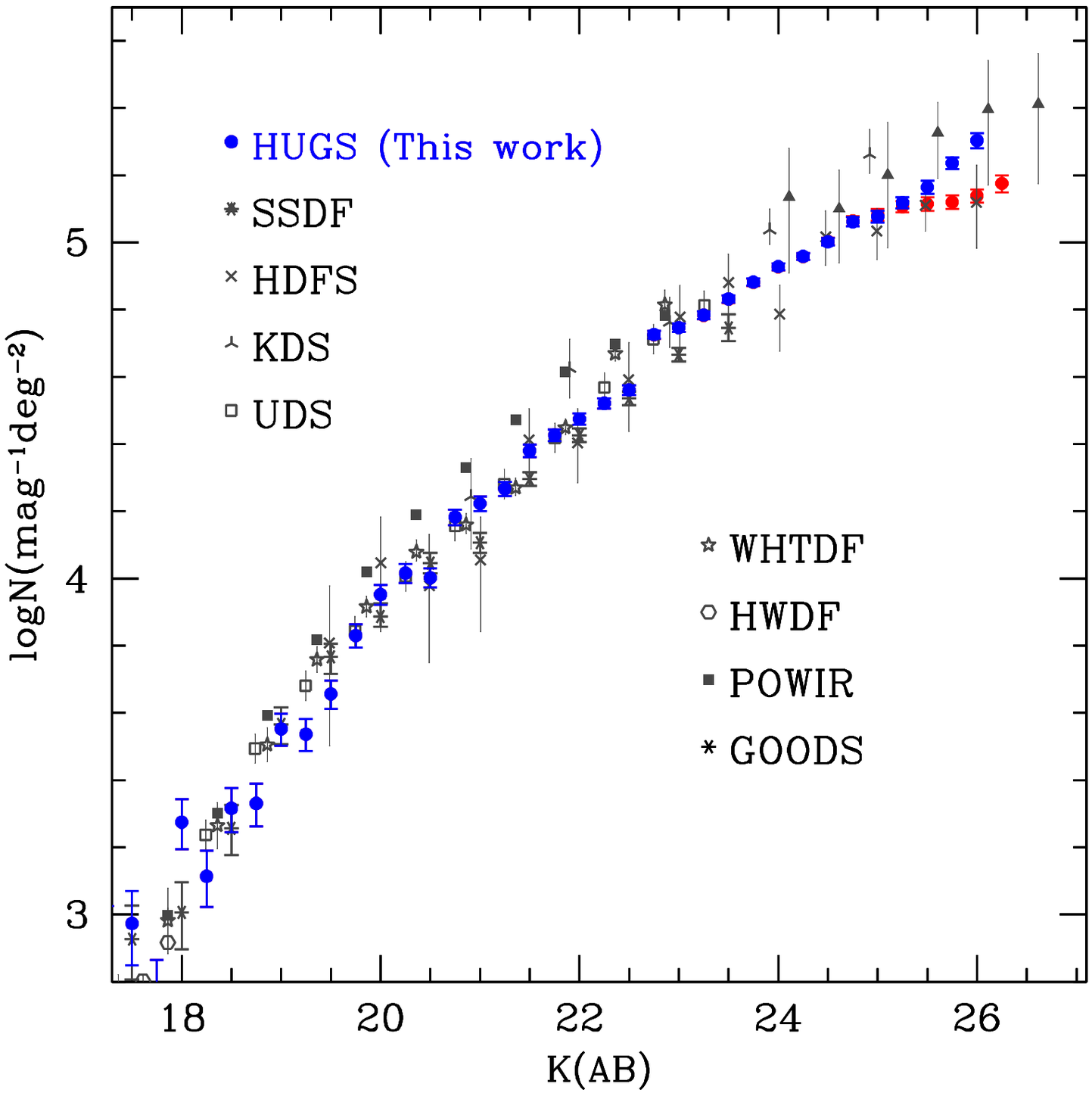


~85 hr.
exp time



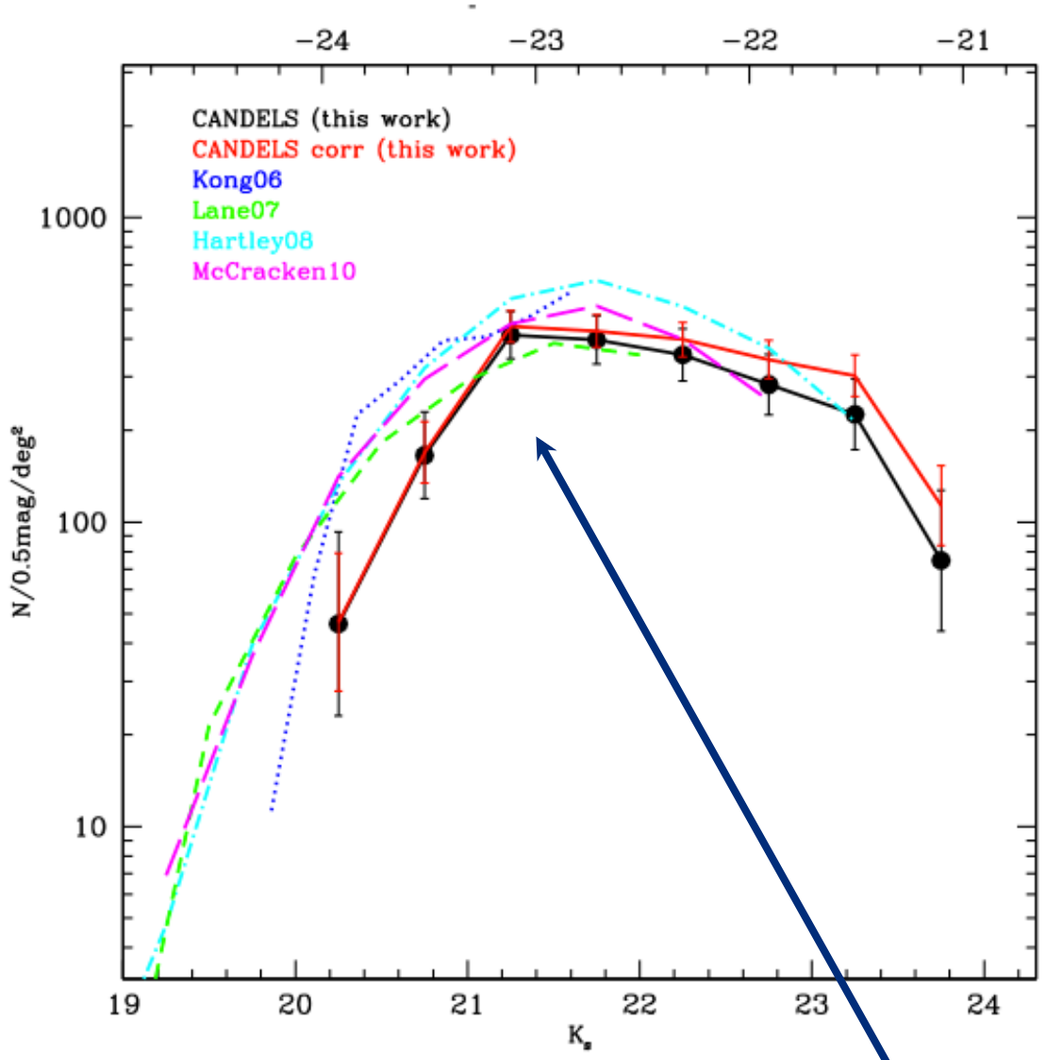
Deep K-band number counts

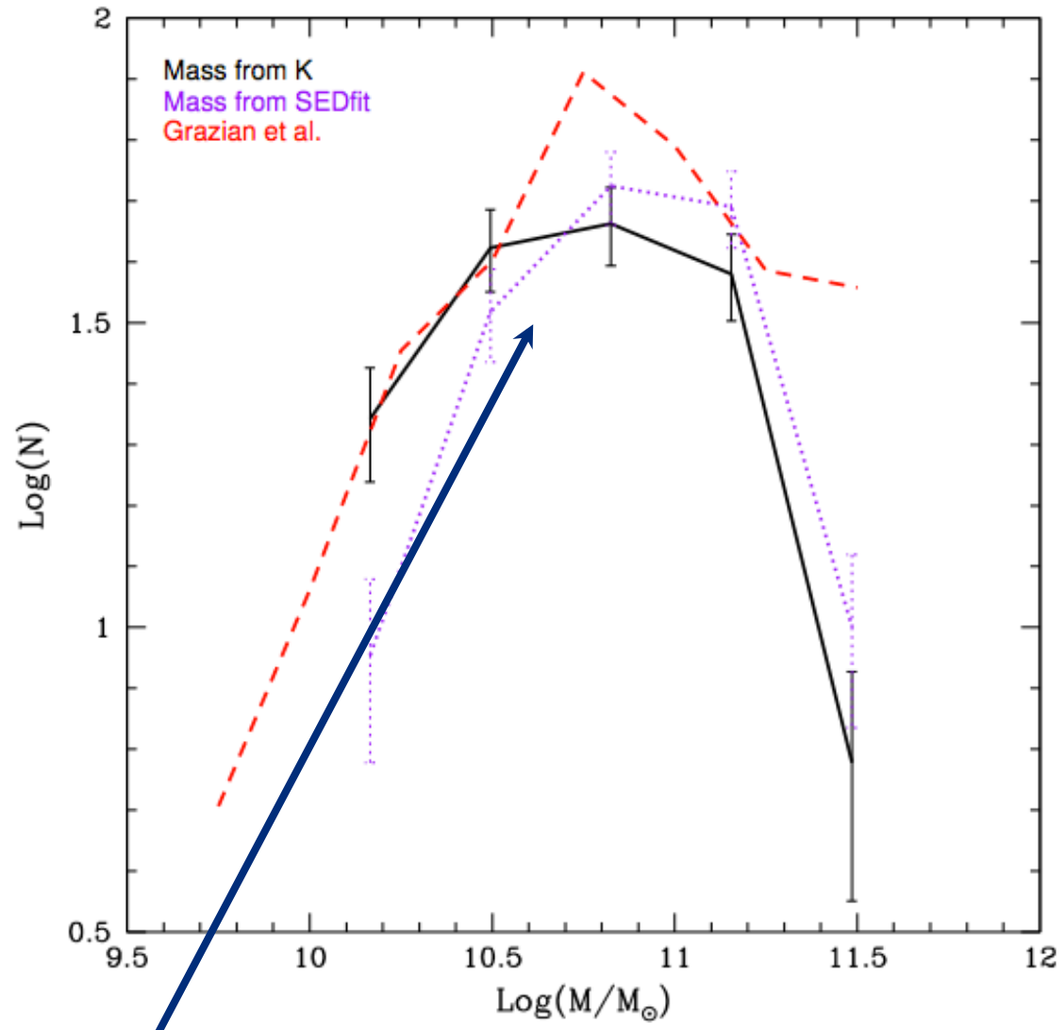
Fontana, Dunlop et al. 2014



A mass threshold in the number density of passive galaxies at z ~ 2

Sommariva et al. 2014

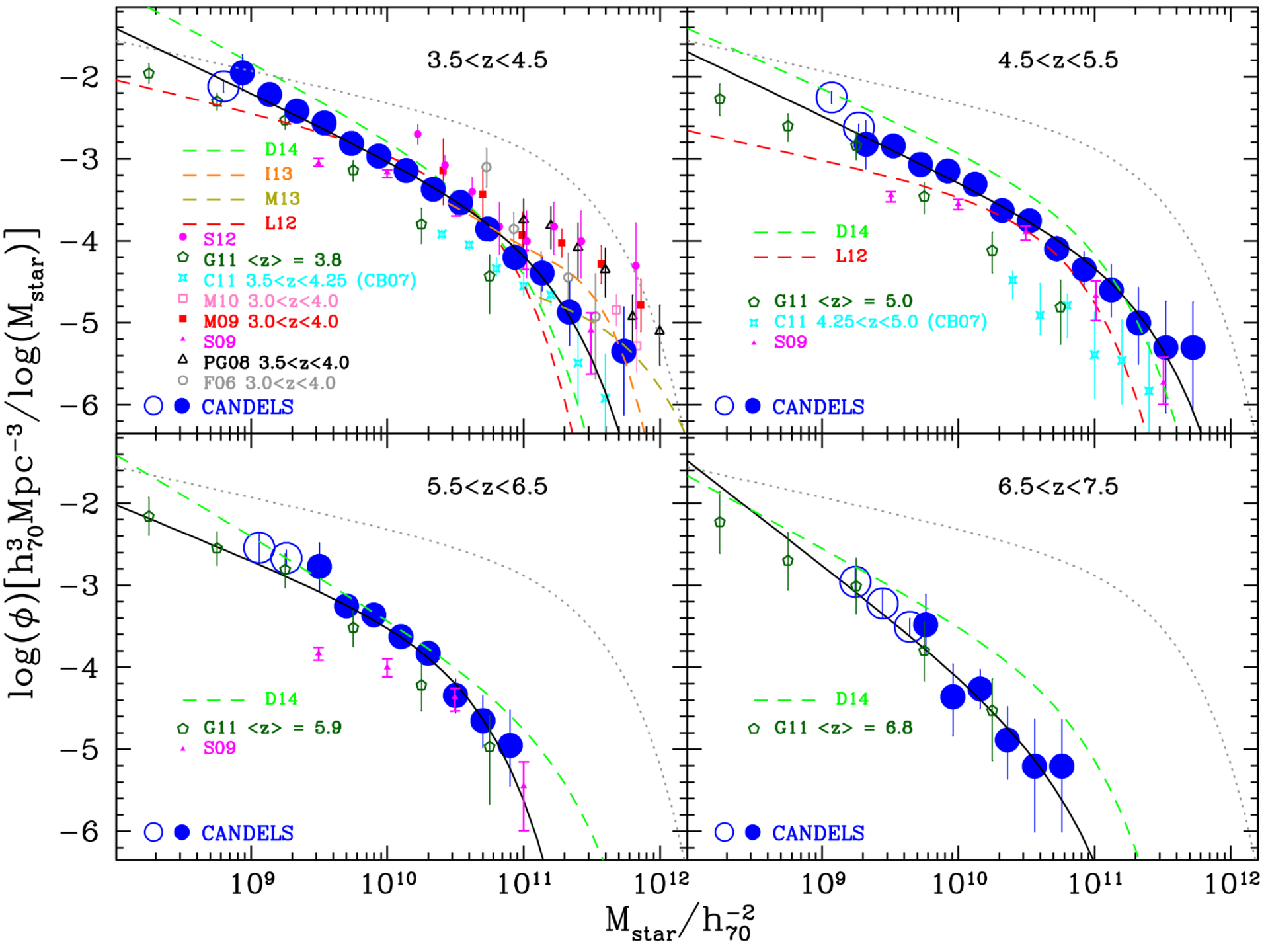




A mass threshold for quenching?

The galaxy stellar mass function at 3.5 <z < 7.5 in The CANDELS/UDS, GOODS-S, & HUDF fields.

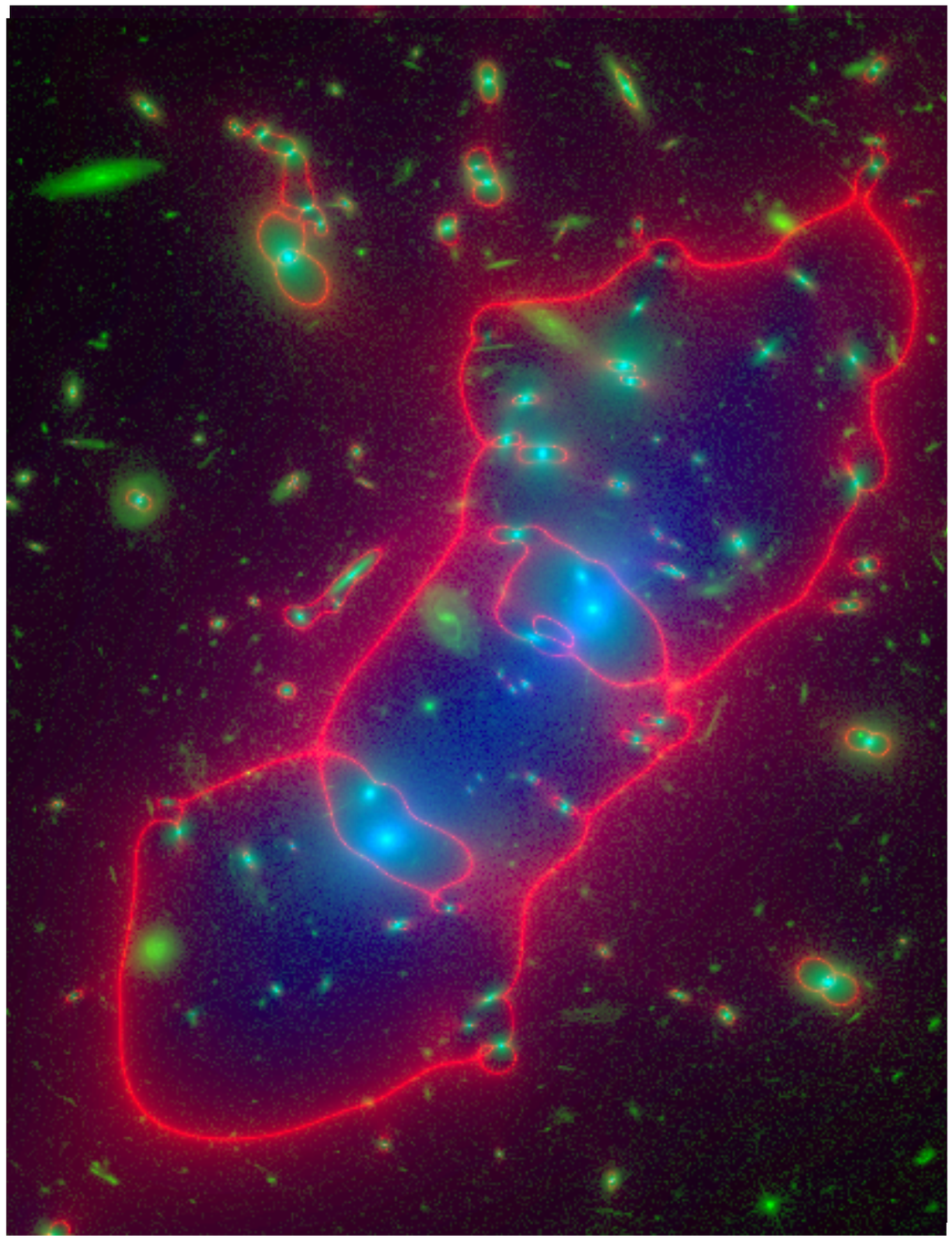
Grazian et al. 2015



3. Very early galaxy evolution

Exploiting the very deepest data:
Hubble Ultra Deep Field and Frontier Fields.

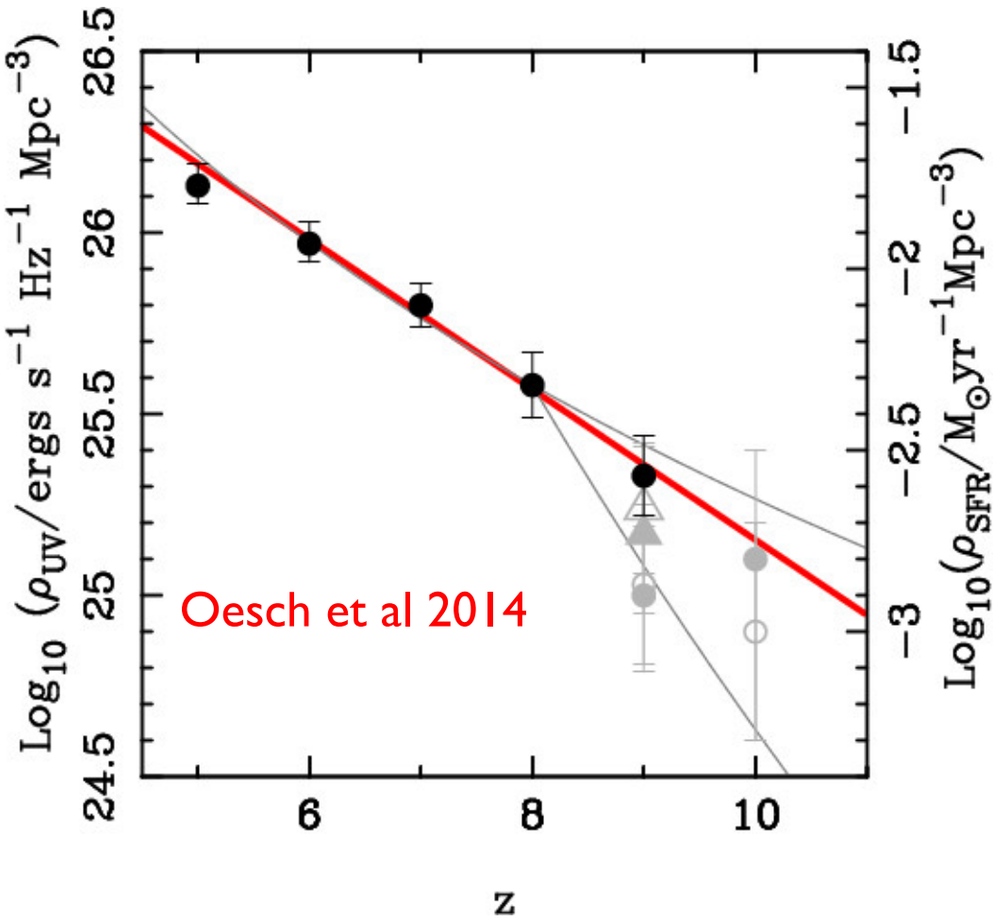
Exploiting Hubble Frontier Fields

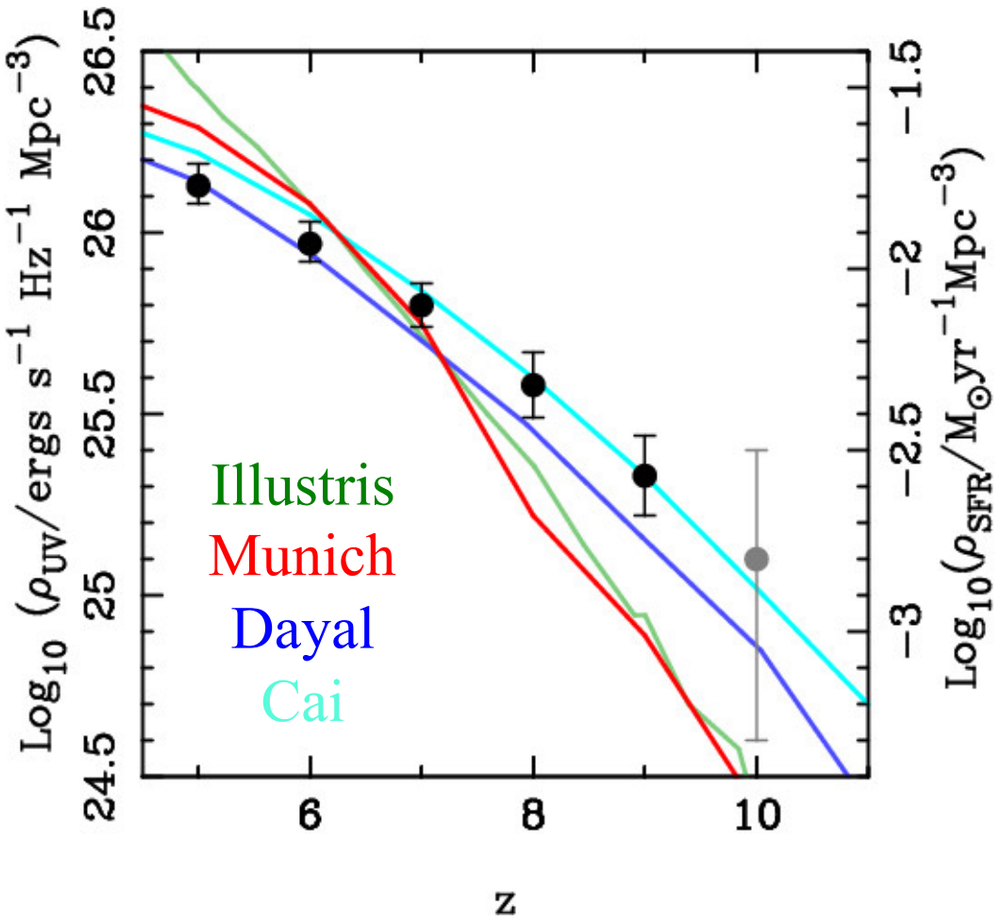


Alternative magnification maps for Abell 2477

High-redshift decline of UV luminosity/star-formation rate density

McLeod, McLure, Dunlop et al. 2015



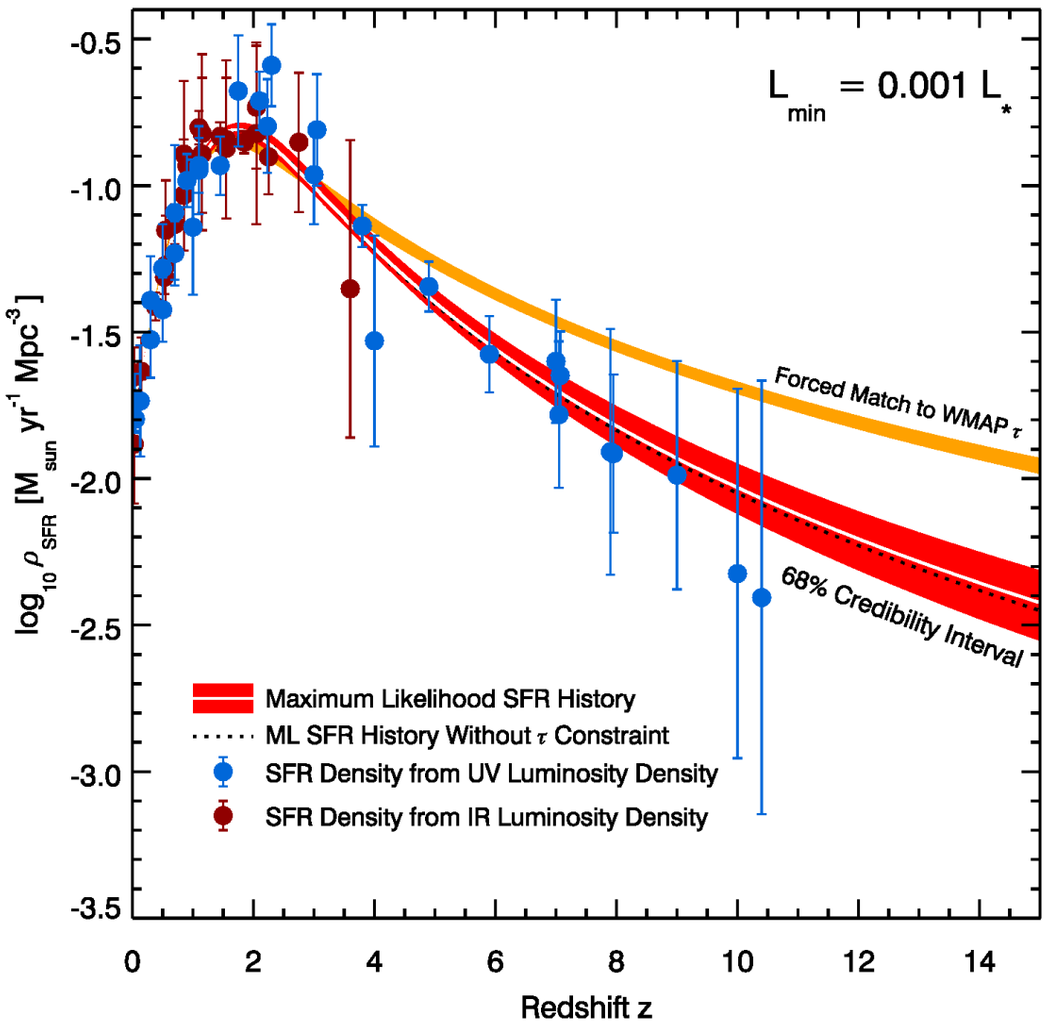


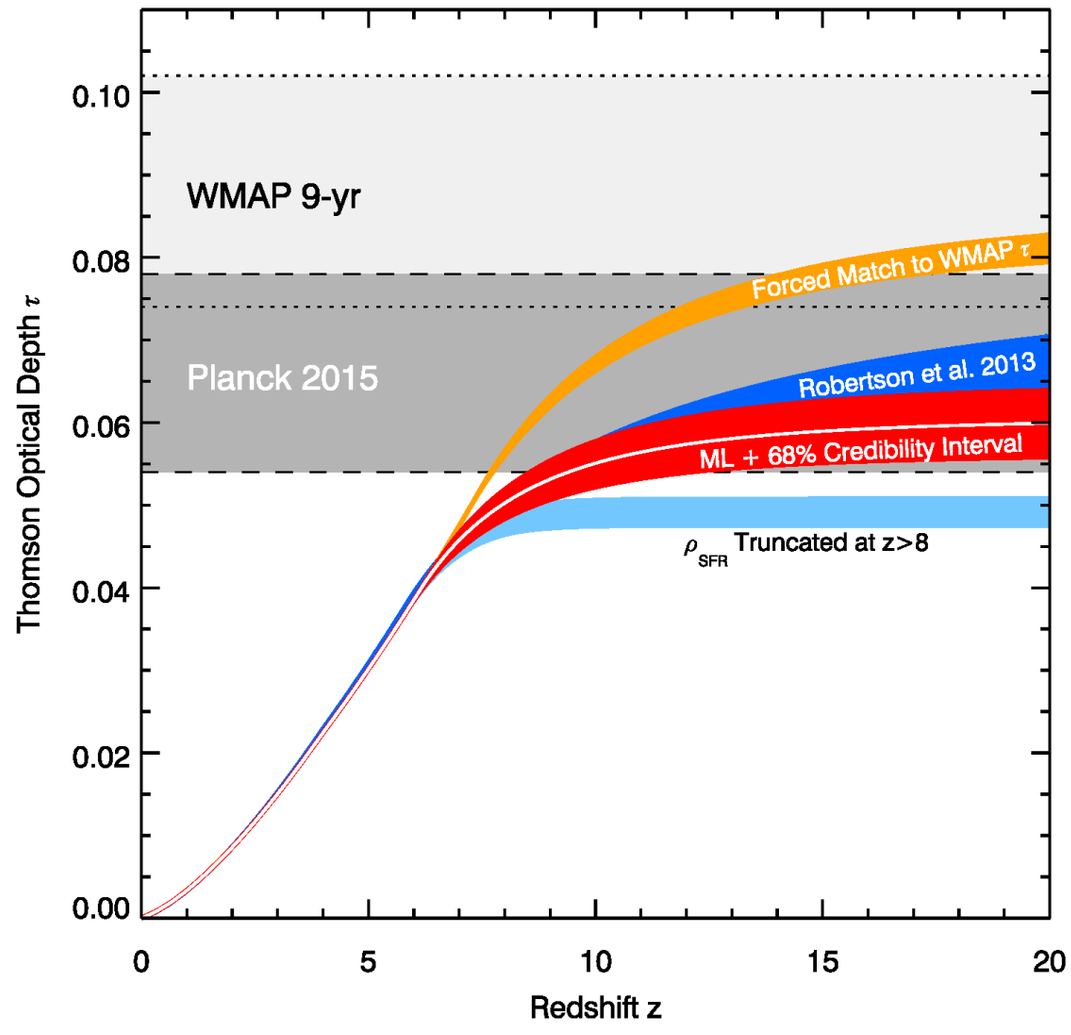
Confirms continued smooth decline in star-formation density out to z ~ 9

At least some models struggle to drop off so gradually

Reconciliation of early galaxy evolution with cosmic reionization

Robertson et al. inc Dunlop, 2015





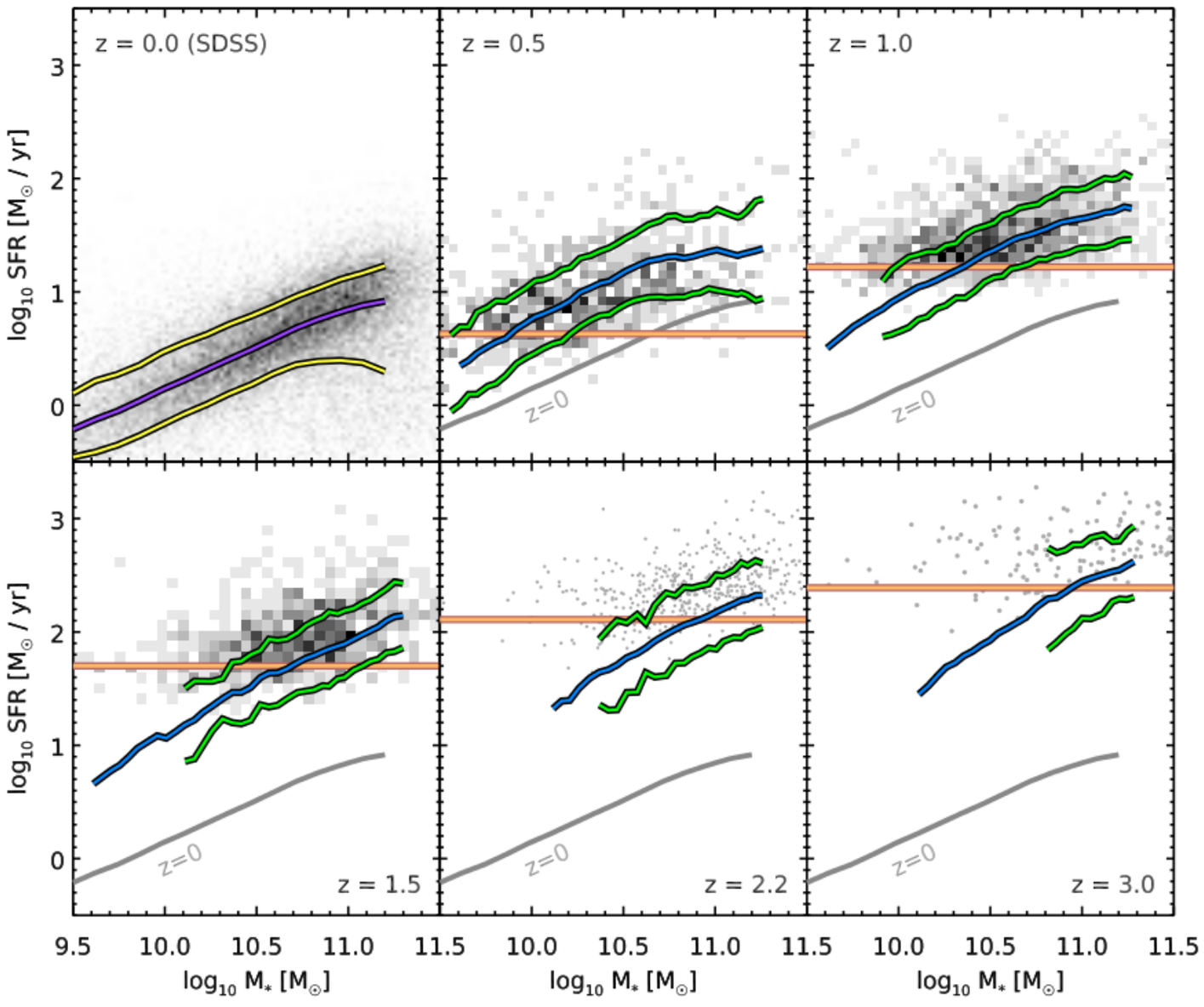
4. Dust-enshrouded star-formation

Broadening the wavelength range to include Herschel (far-IR) and JCMT SCUBA-2 (sub-mm) data

The Herschel view of the dominant mode of galaxy growth since z = 4

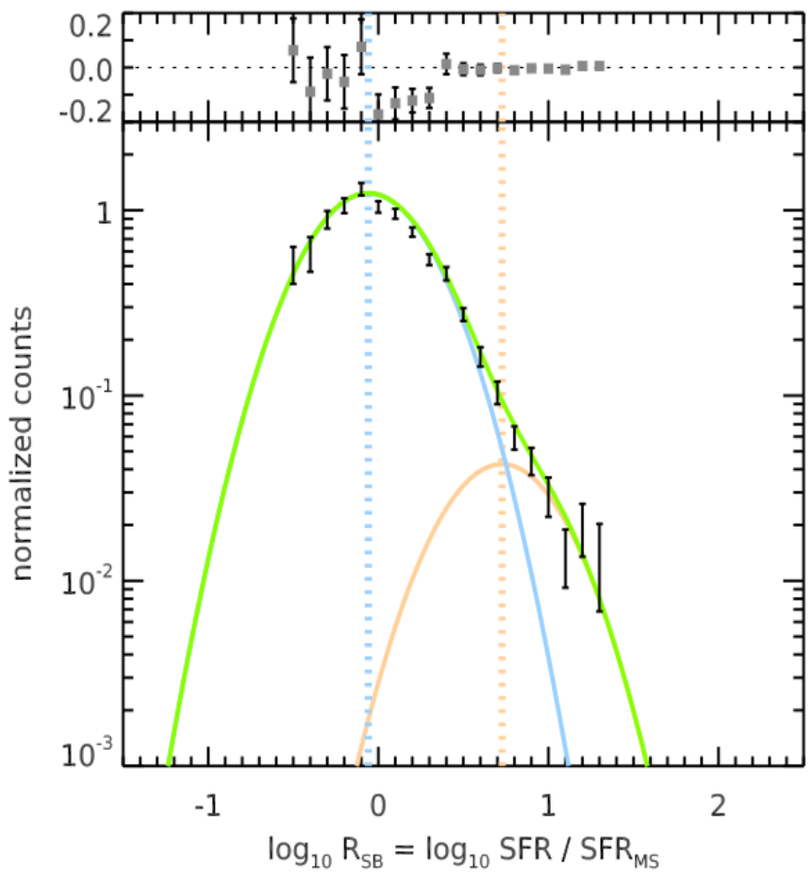
Schreiber et al. 2015

The *Main Sequence* of star-forming galaxies constrained with Herschel through stacking



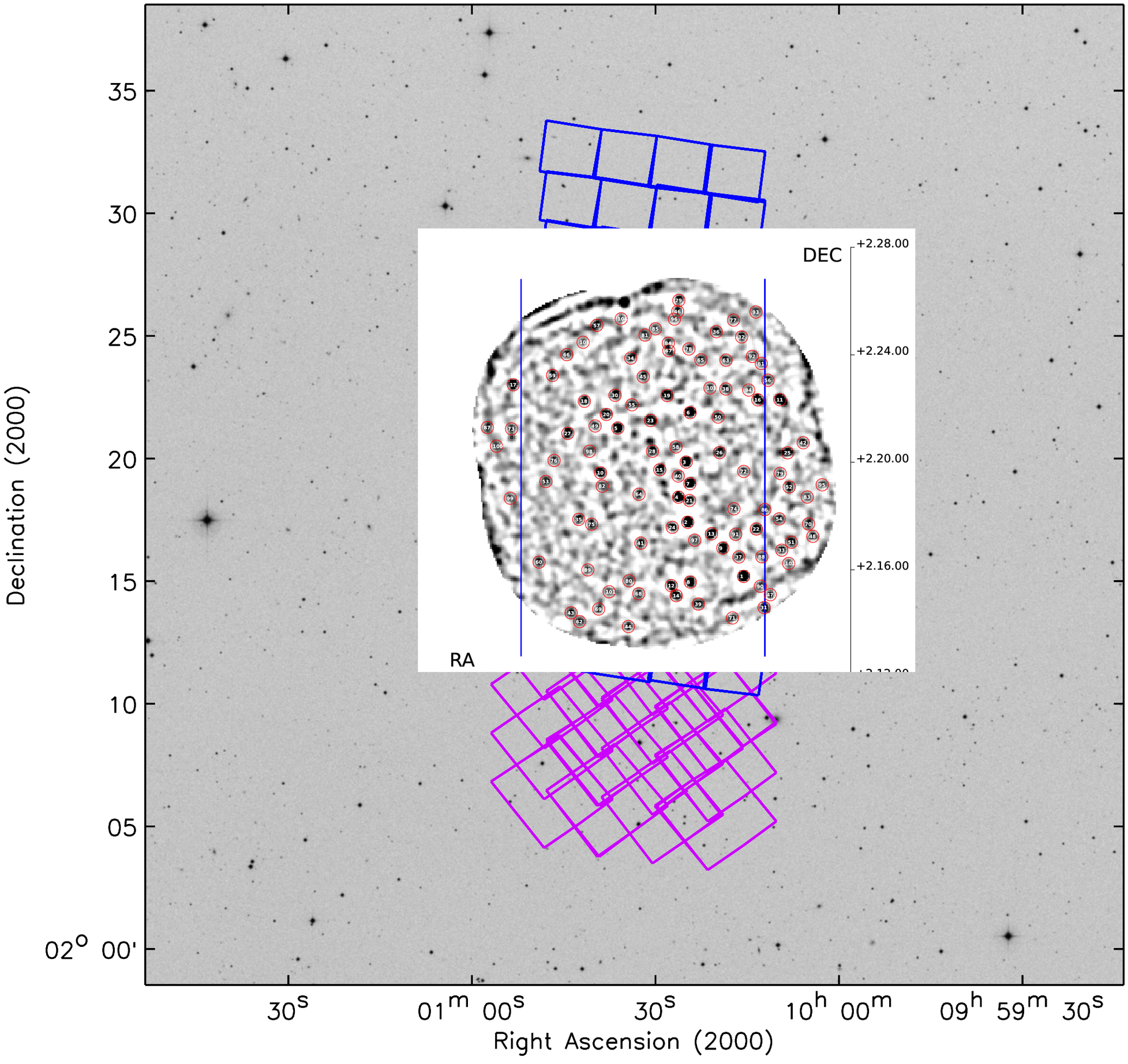
Main Sequence galaxies formed more than 2/3 of present-day stars.

Found a population of starburst galaxies at all redshifts/masses



% of starbursts does not evolve

Constraints on star formation triggered by galaxy mergers

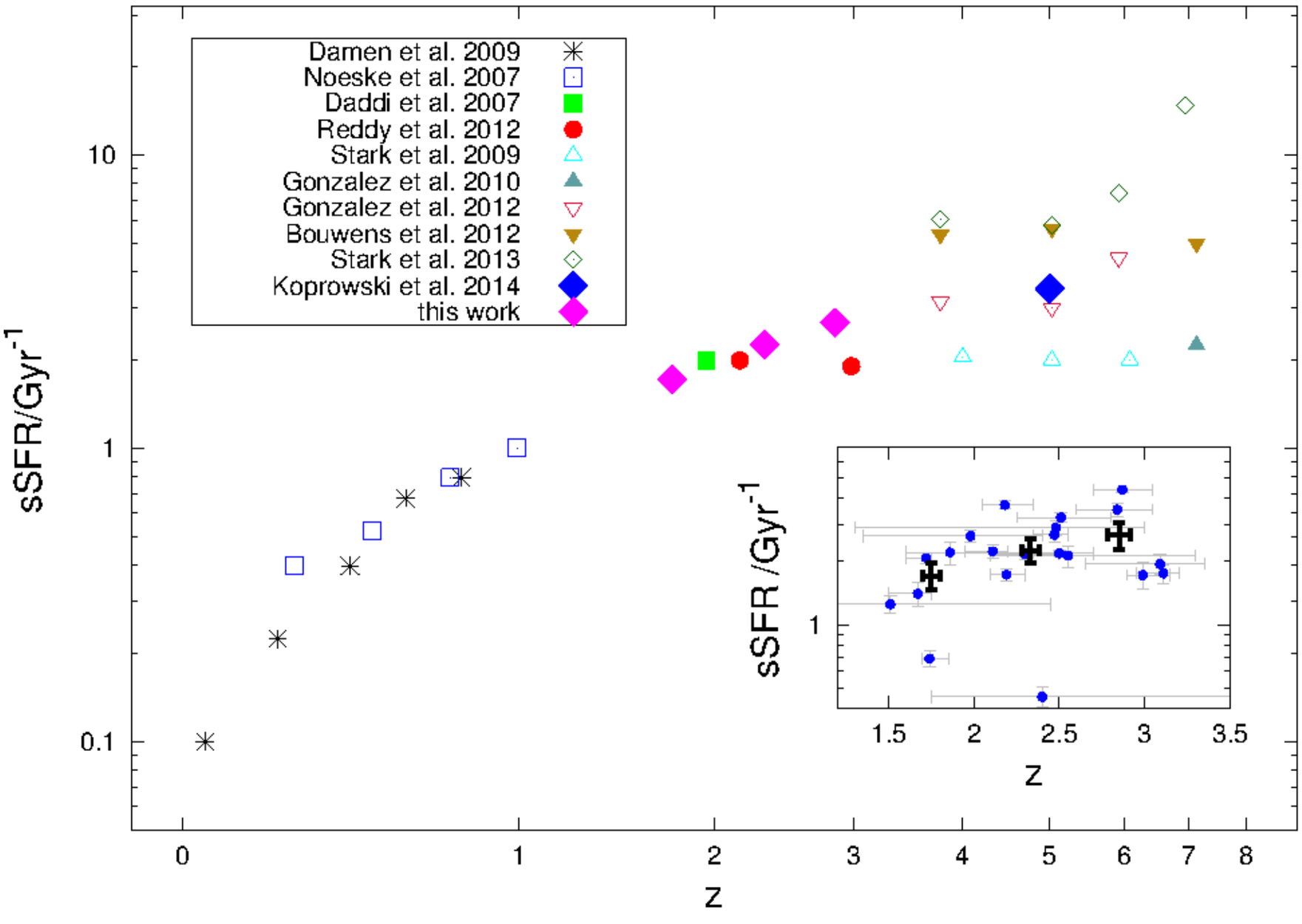


HST CANDELS
COSMOS field

SCUBA-2 Map

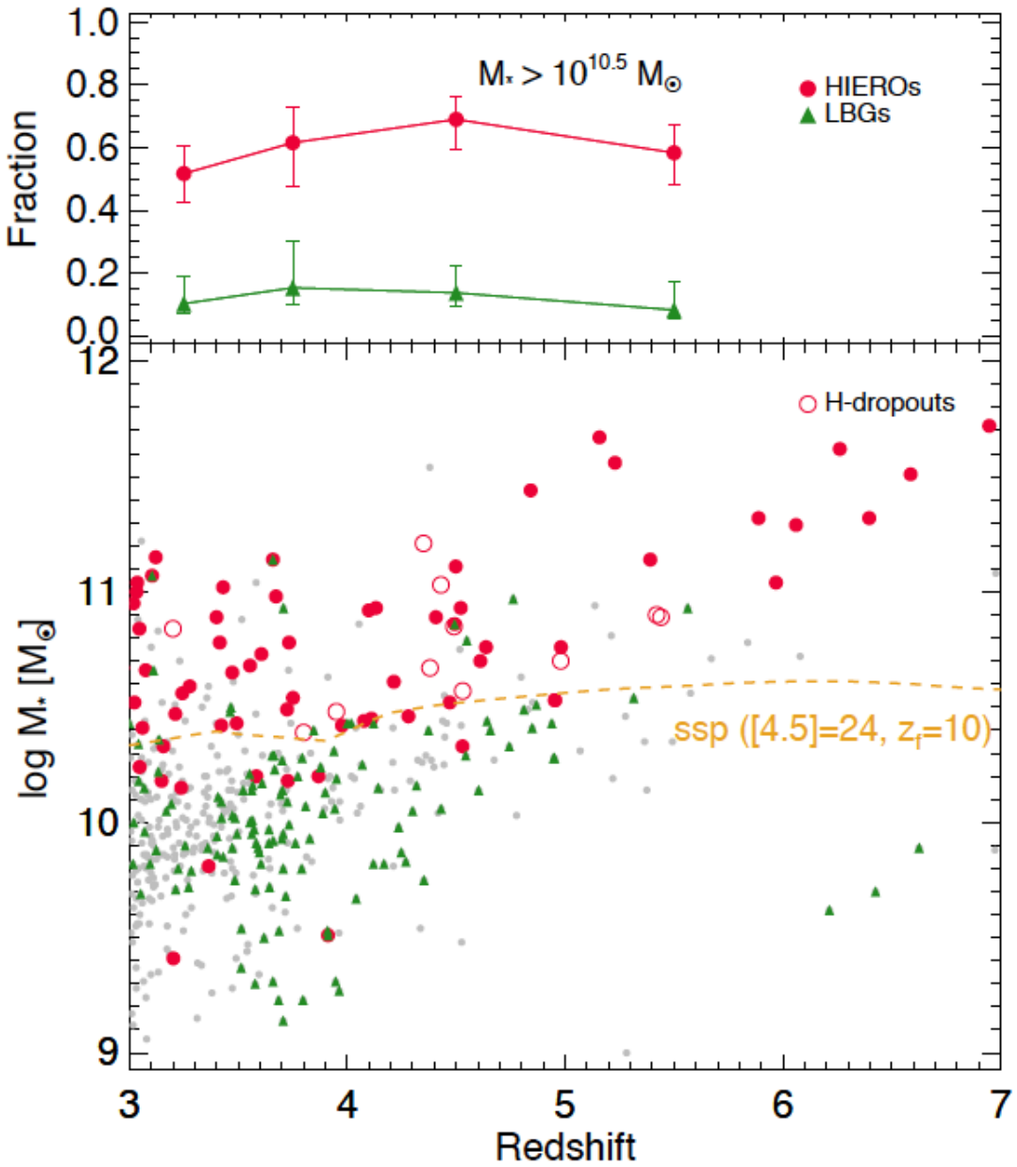
The role of sub-mm galaxies in cosmic star-formation history

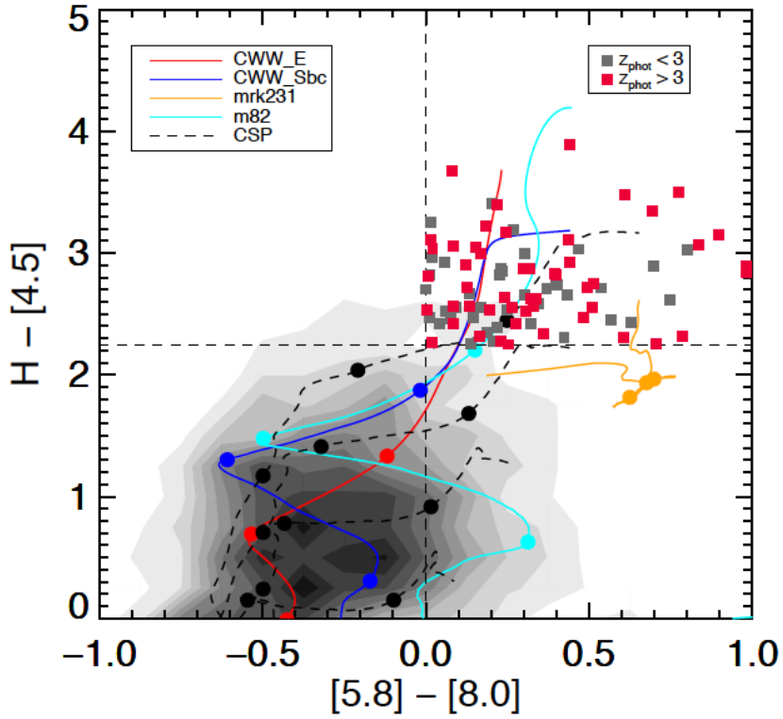
Koprowski, Dunlop et al. 2015



Towards a complete census of star formation in massive galaxies at z > 3

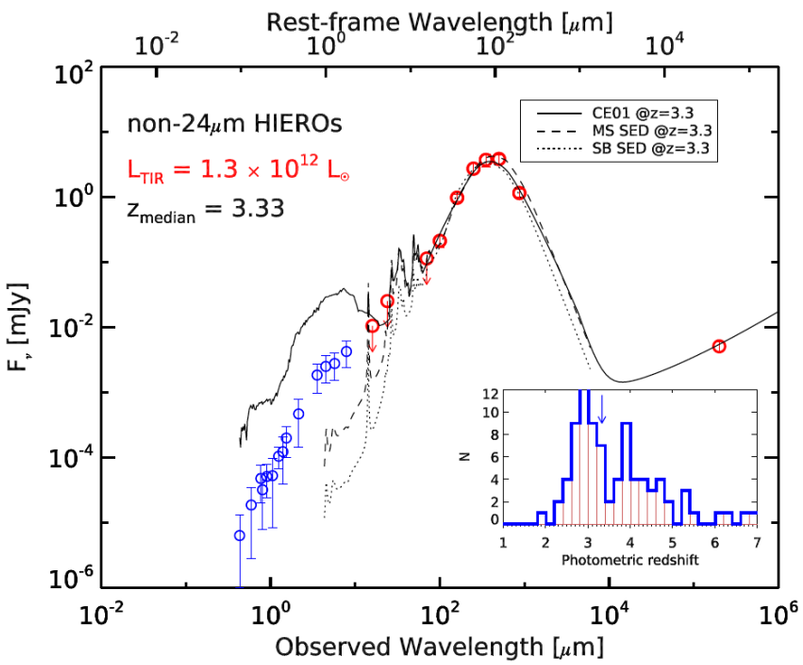
Wang et al. 2015





H and IRAC selected extremely red objects:
H - [4.5] > 2.25
&
[5.8] - [8.0] > 0

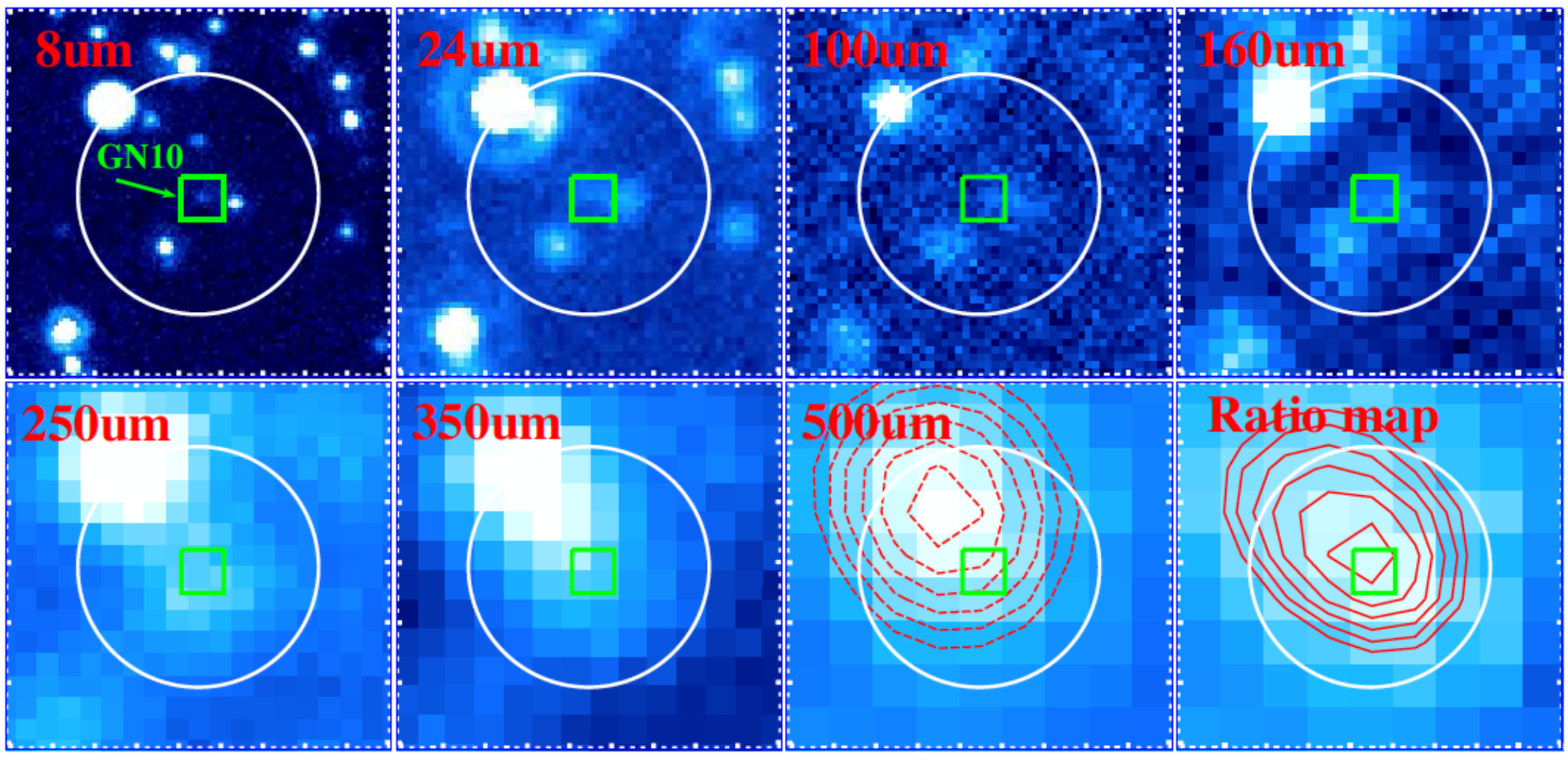
We reveal a significant population of massive galaxies at z > 3 that are systematically missed by the Lyman-break selection technique. These galaxies dominate the massive end of the stellar mass function, and are key to understanding massive galaxy evolution at high-z.



Stacked UV-to-FIR SEDs

Identification of high-z Herschel 500-micron sources using colour deconfusion

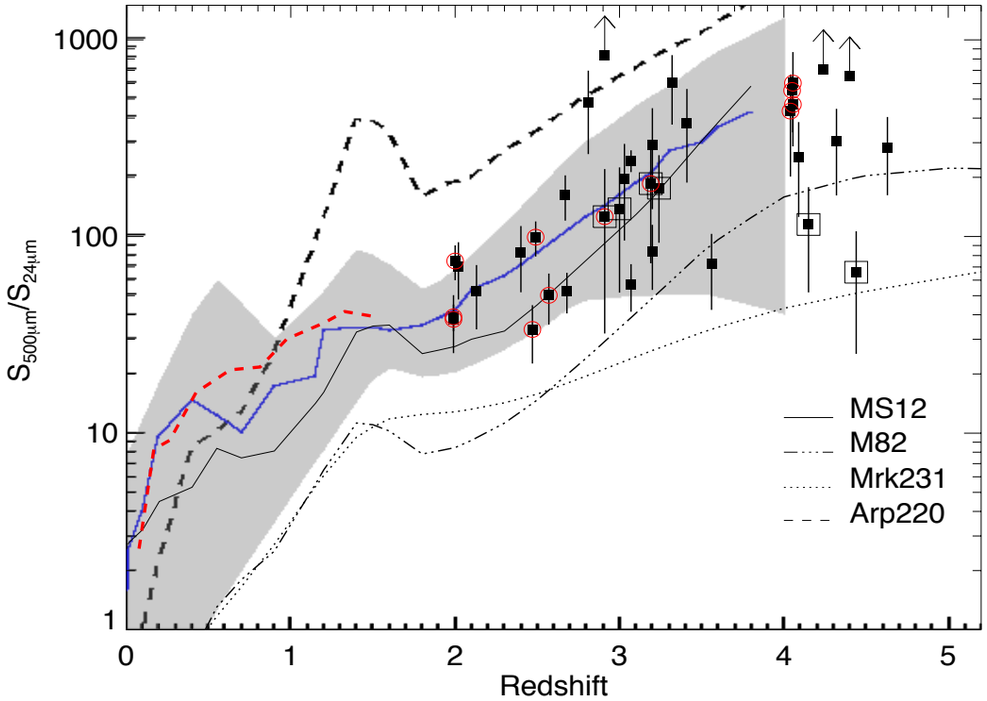
Shu et al. 2015

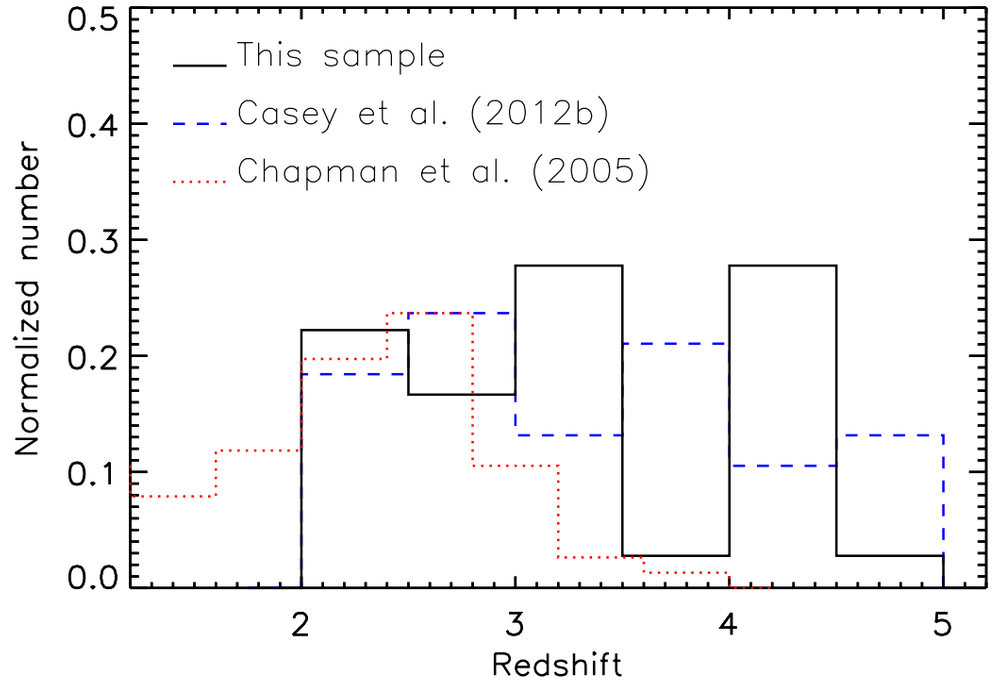


A spectroscopically-confirmed z = 4.04 sub-mm galaxy recovered in the 500/24 micron ratio map (confusion substantially reduced)

Identification of high-z Herschel 500-micron sources using colour deconfusion

Shu et al. 2015



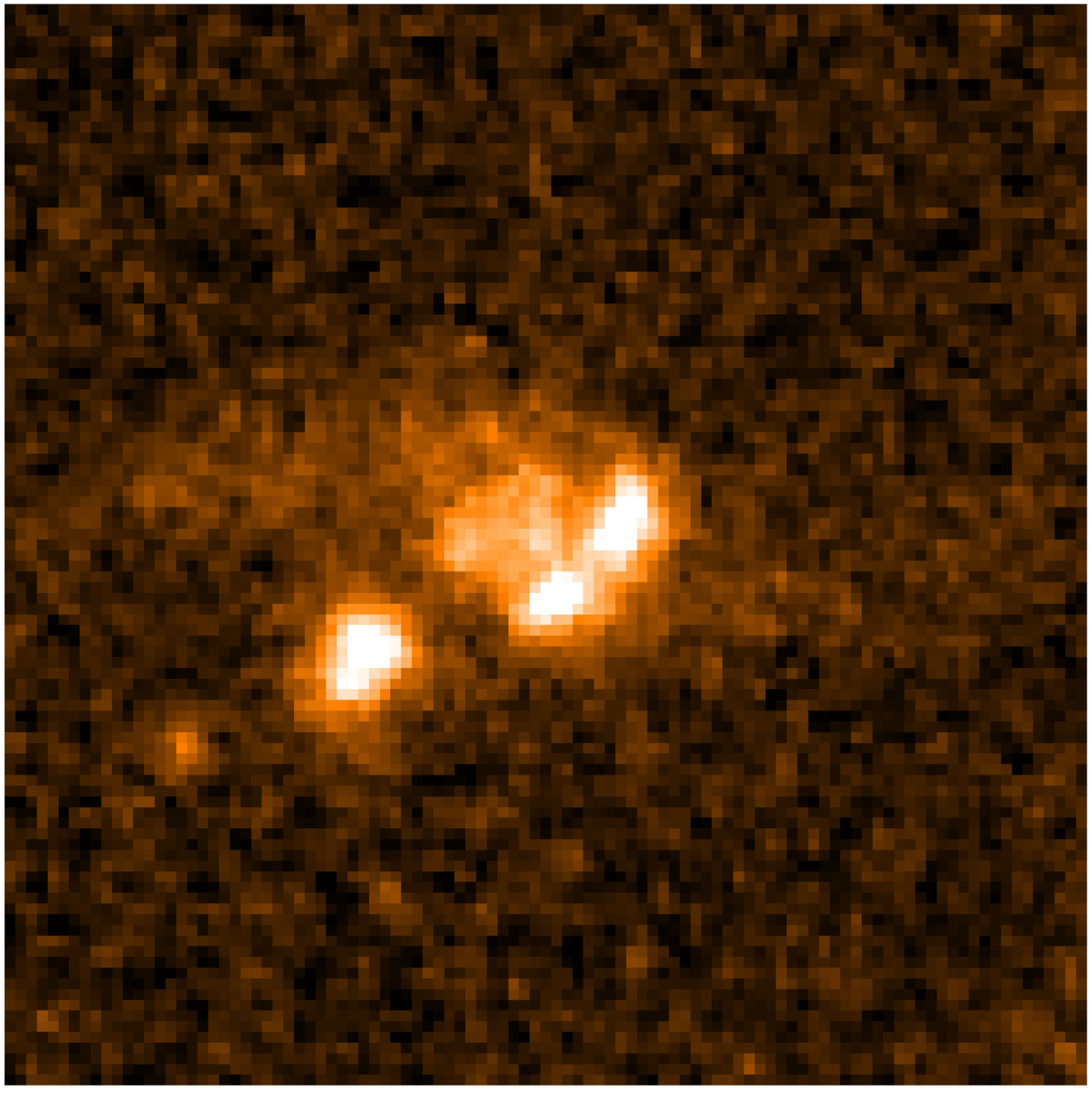


First search yields 36 candidates at z>2 in the GOODS-North field

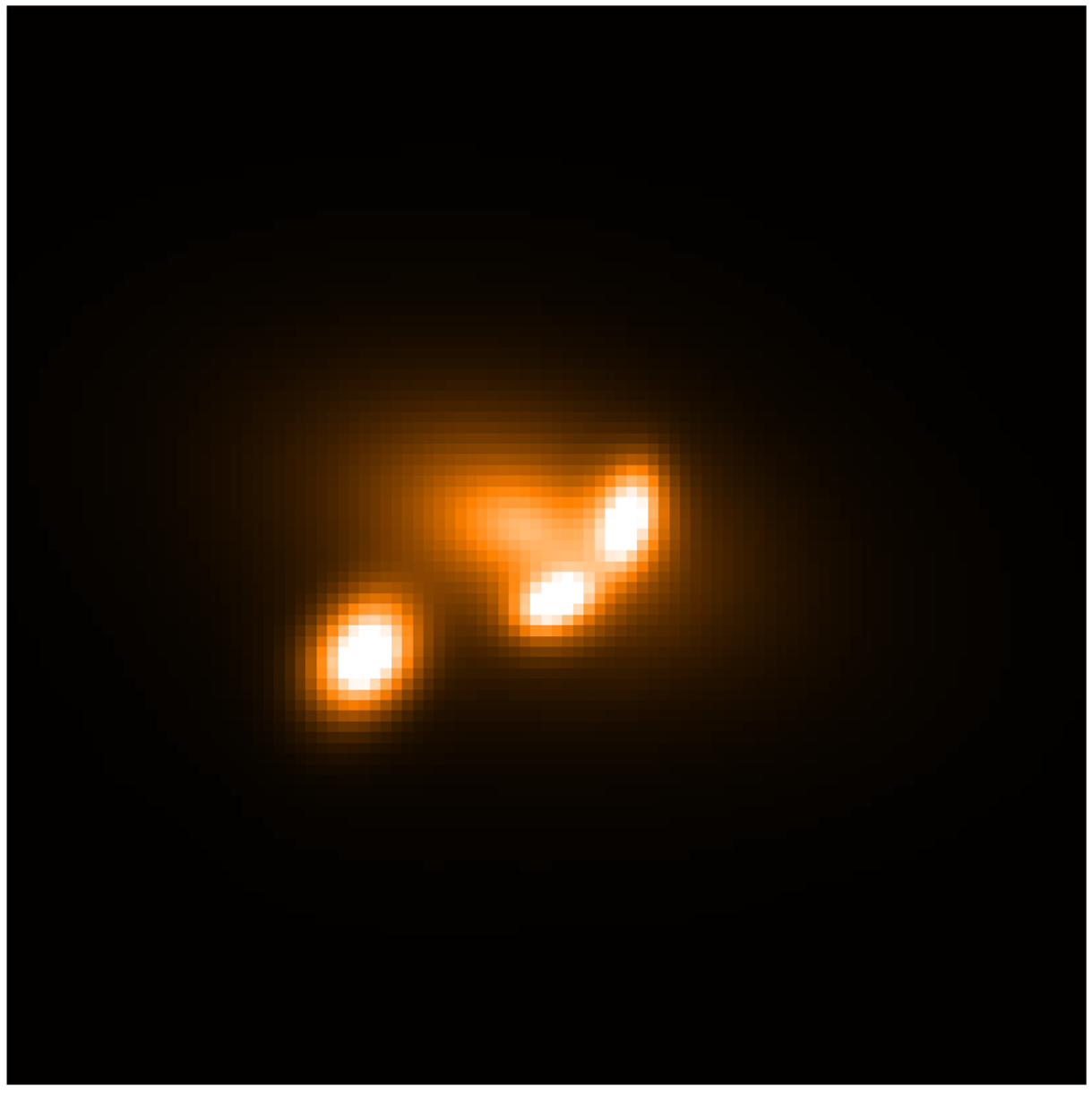
Need to apply to all CANDELS field to quantify number density at z ~ 3

5. Galaxy morphologies

Connecting SED and structural information.



HST H-band image

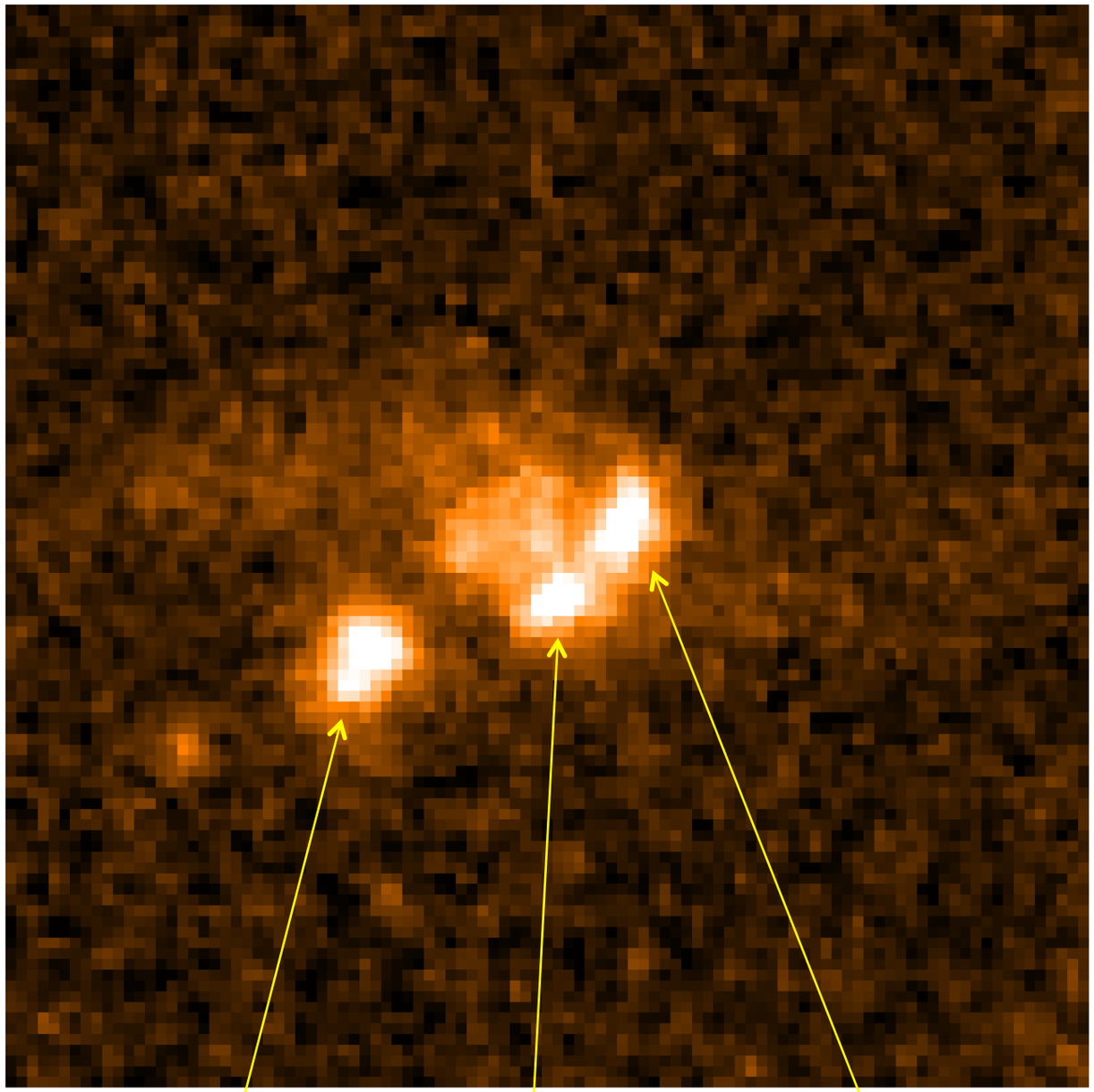


Model

The morphologies of sub-mm galaxies from SCUBA-2+HST imaging

Targett, Dunlop et al. 2014

High surface-brightness clumps

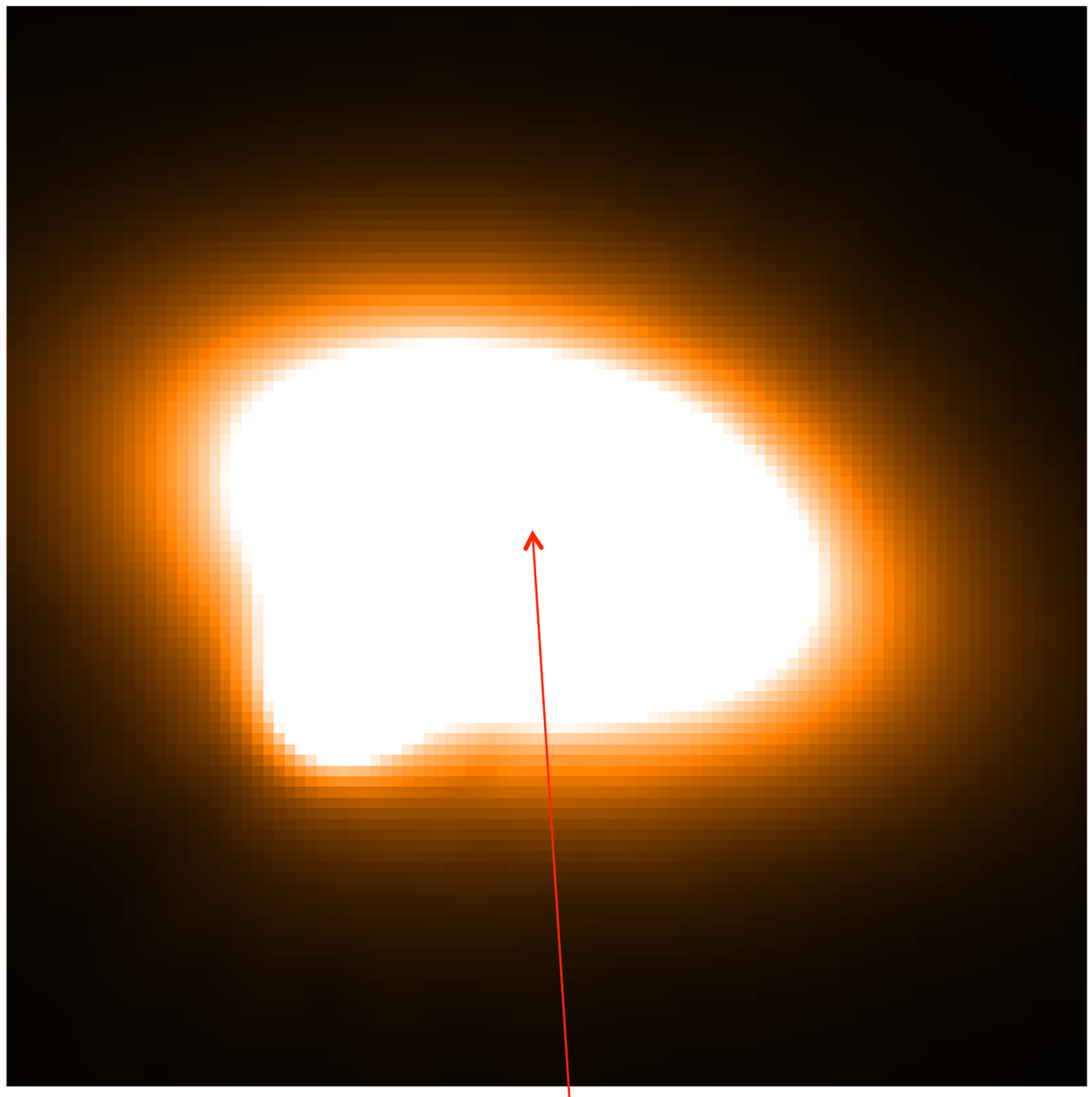


1.5 kpc
n = 0.8

1.1 kpc
n = 0.4

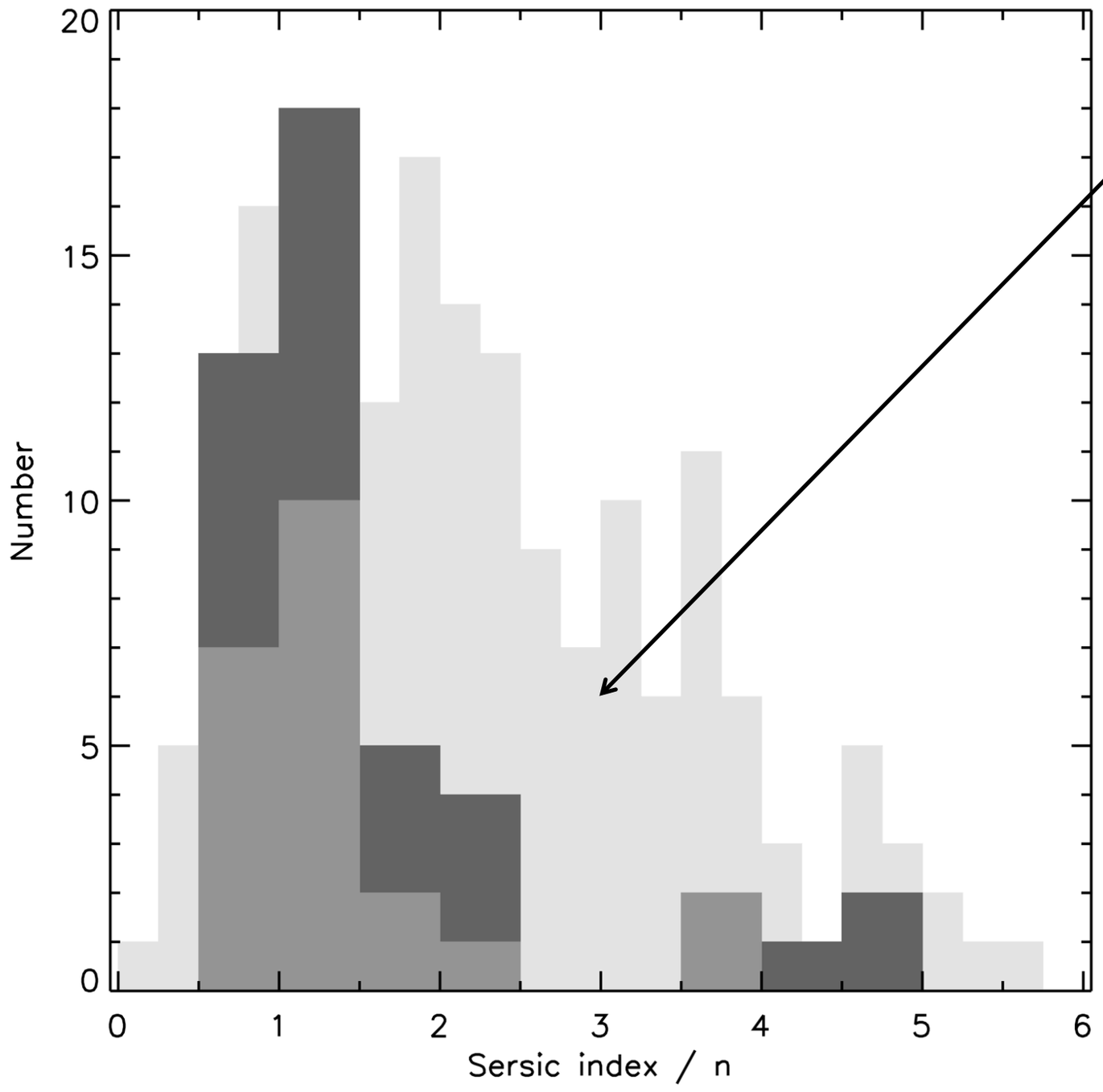
1.4 kpc
n = 0.4

Big underlying disk



7.3 kpc
n = 1.1

Sub-mm galaxies appear to be massive (often clumpy) star-forming discs



All massive galaxies at $1 < z < 3$

Bruce, Dunlop et al. (2012, 2014)

5. Galaxy morphologies

Connecting SED and structural information.

Handover to Victoria Bruce