The mass-SFR relation at z=2: on the role of the SB and steady SF modes

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+ the PEP Team

+ collaboration with H. McCracken and O. Ilbert

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In and Out the Main Sequence of Star-forming Galaxies

The Main Sequence at Low and High Redshift

The Outliers:

- red starbursting galaxies
- red & dead (quenched) galaxies

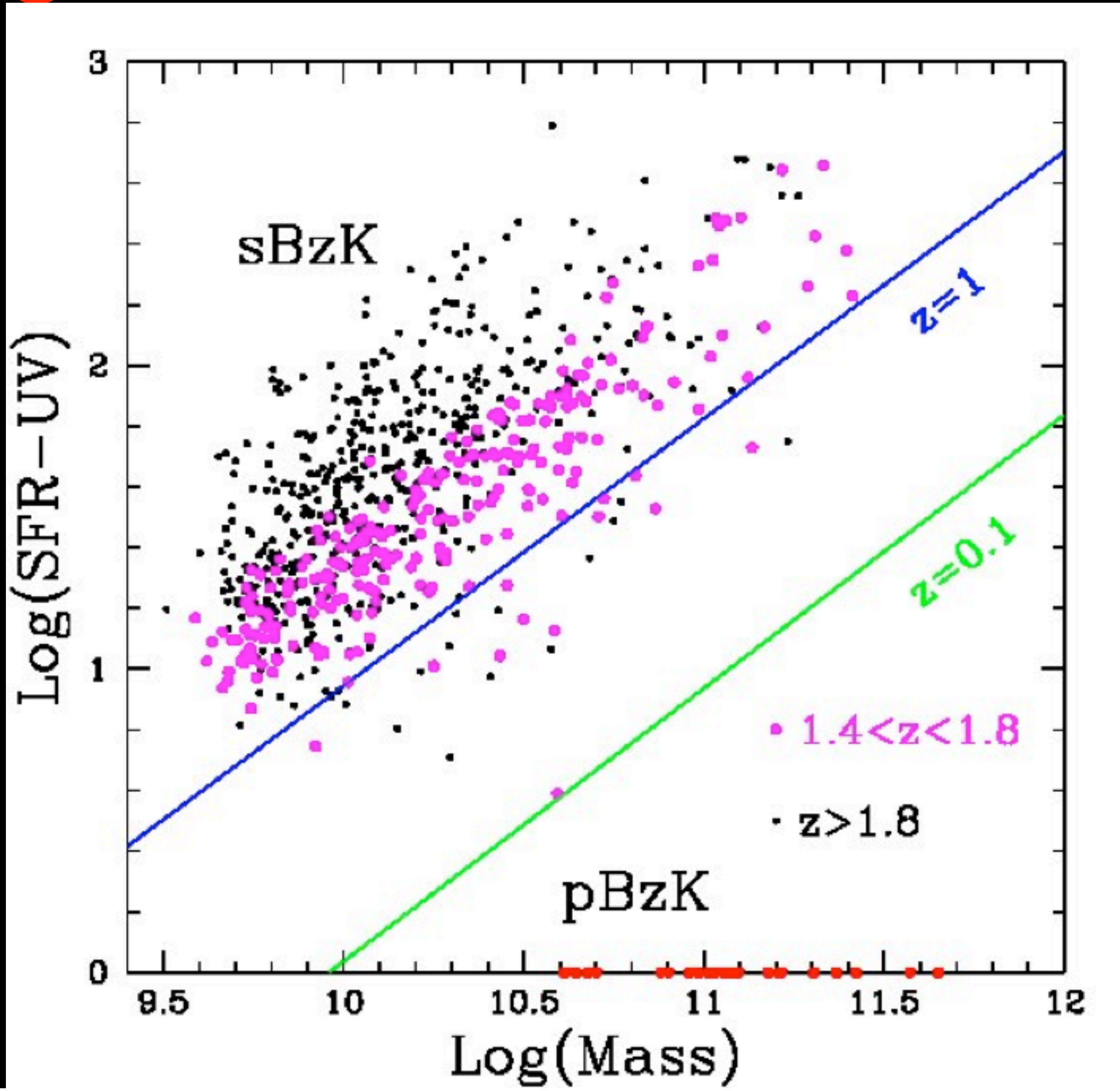
Herschel looking at COSMOS & GOODS fields

The relative role of starbursts and quasi-steady SFR in the mass growth of galaxies

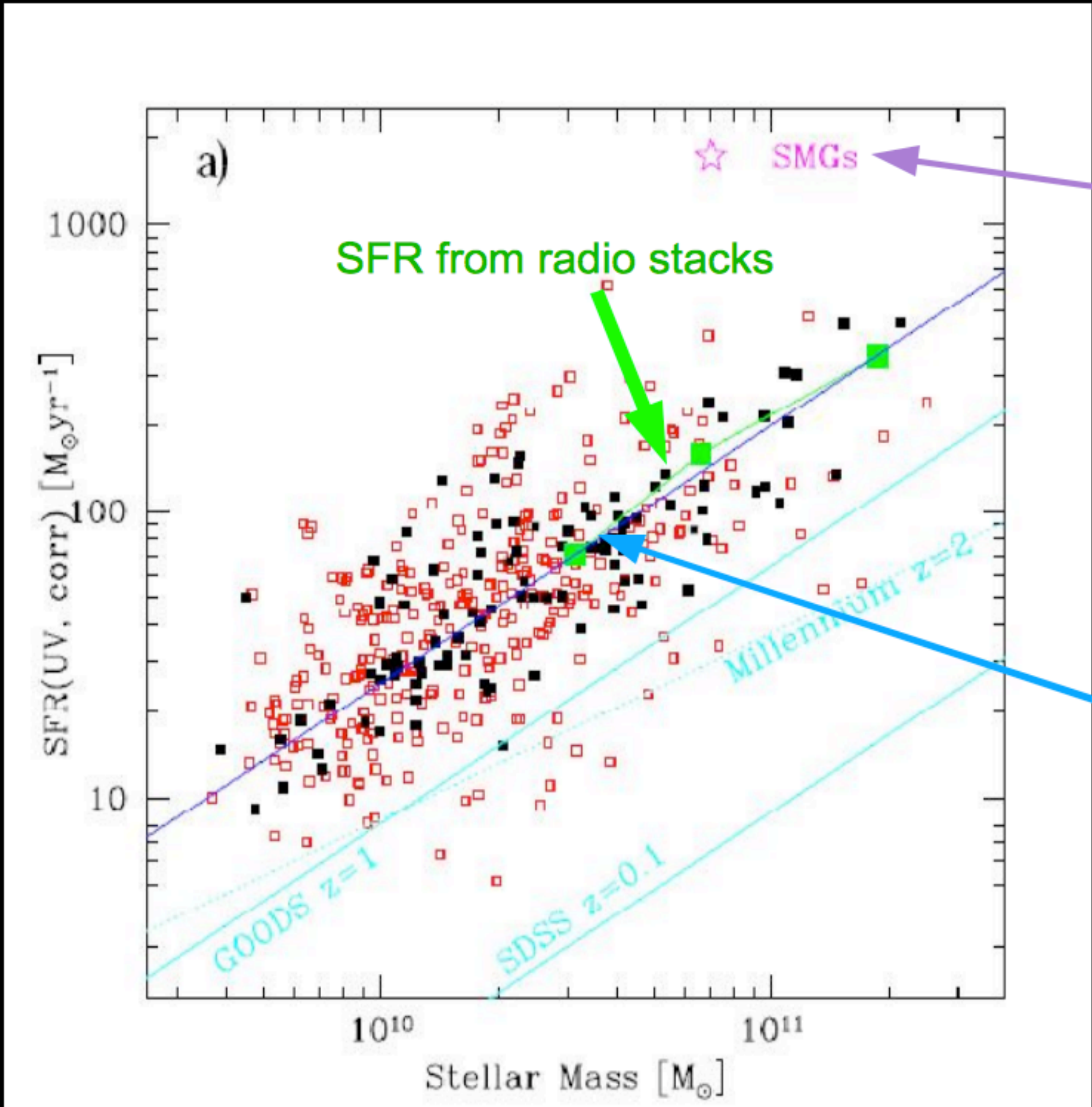
Most recent developments from

Rodighiero et al. 2011, ApJ 739, L40

The Main Sequence of Star-forming galaxies at 1.4 < z < 2.5



Starbursts or just high SFR at z~2?

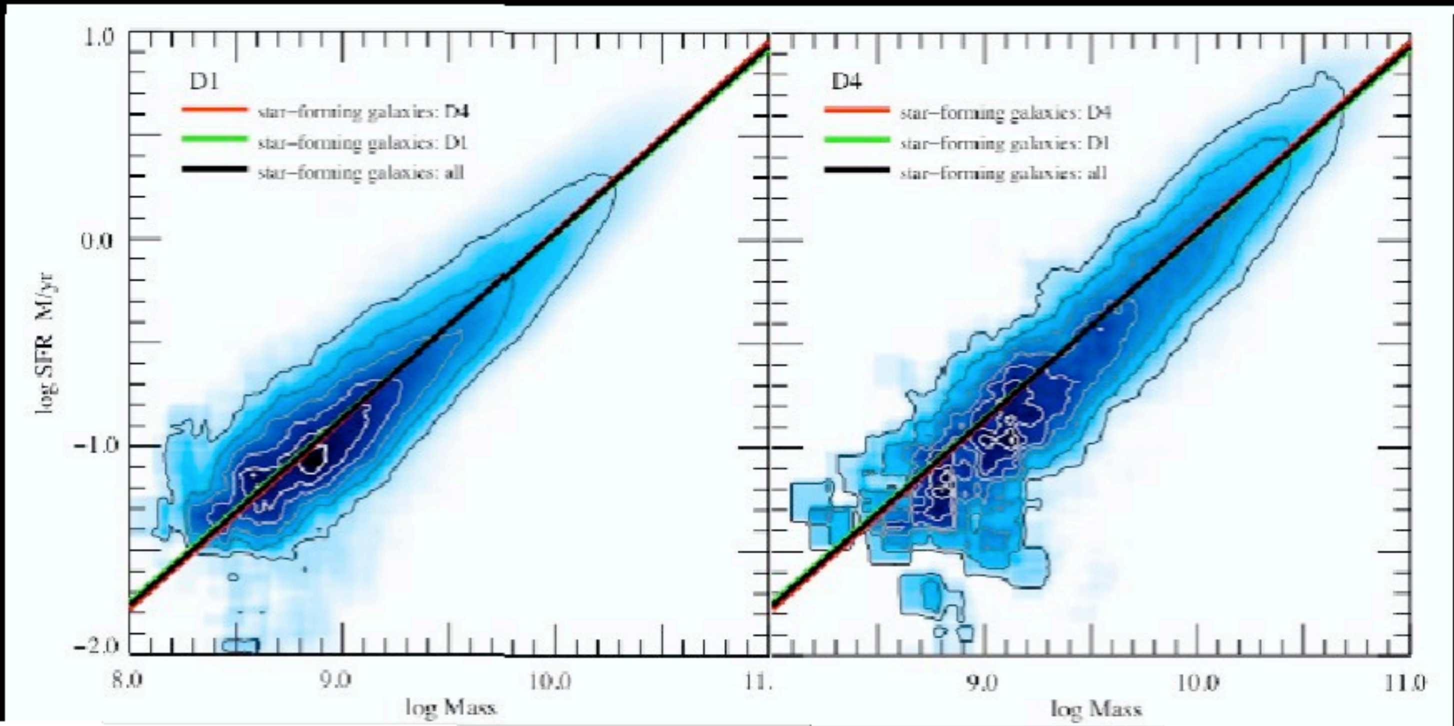


SMGs may be the real, major-merger driven, starburst galaxies

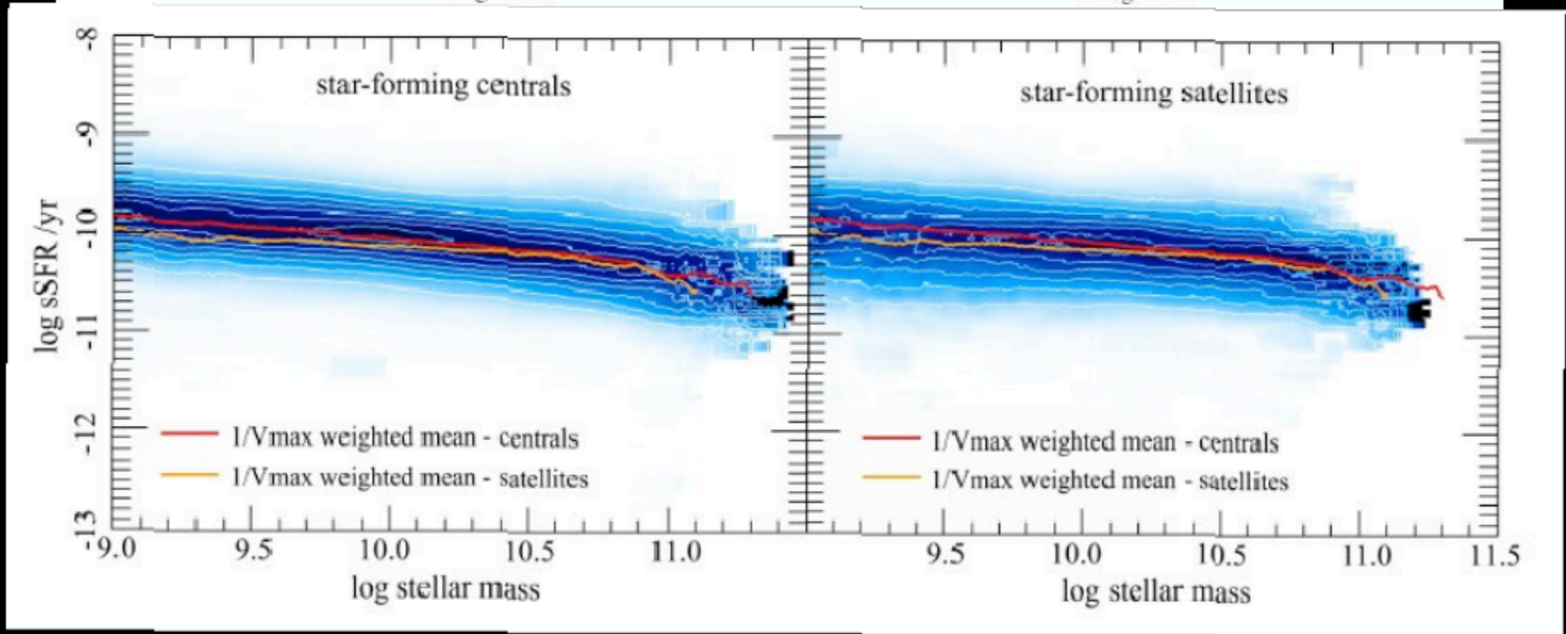
SFR ∝ ~$M^{0.9+/-0.1}$ with very small dispersion!! No starbursting galaxies! just galaxies with high SFR, continuously fed by cold-stream accretion!

GOODS-S Field: Daddi et al. 2007

The SFR-M* relation in the local Universe



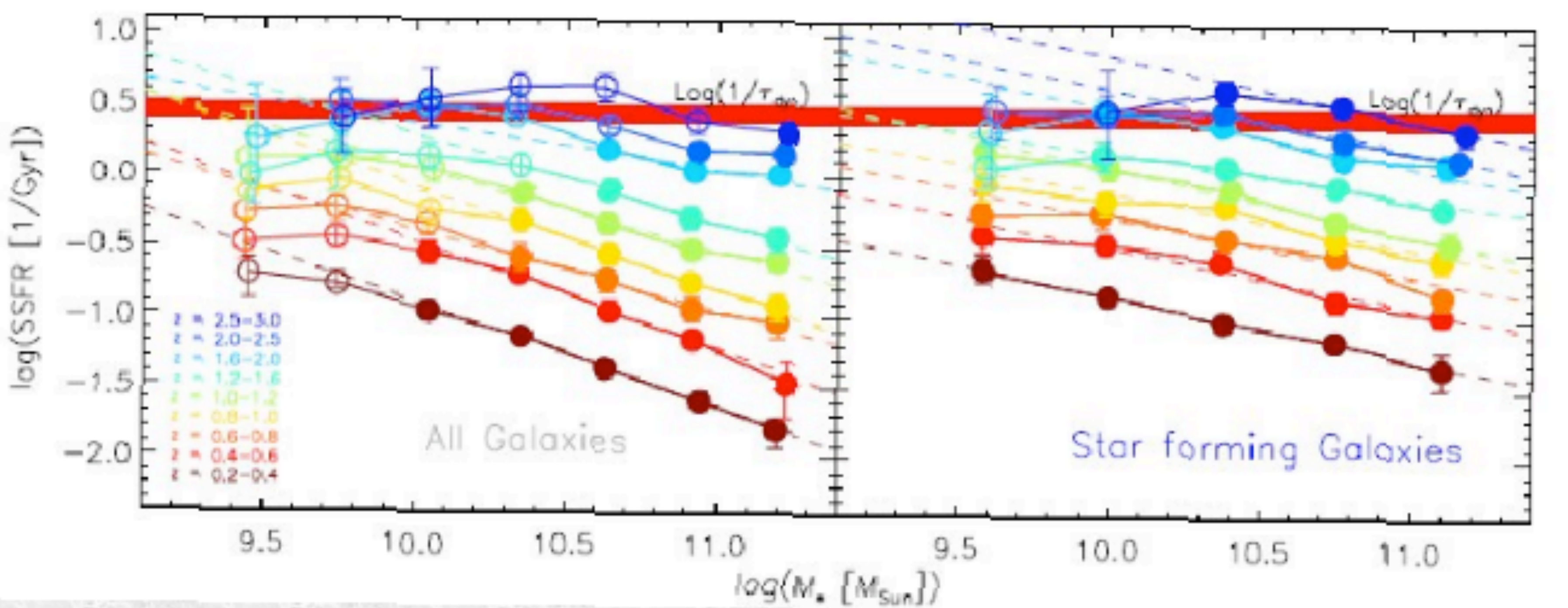
From SDSS data, SFR from Hα, Peng et al (2010)



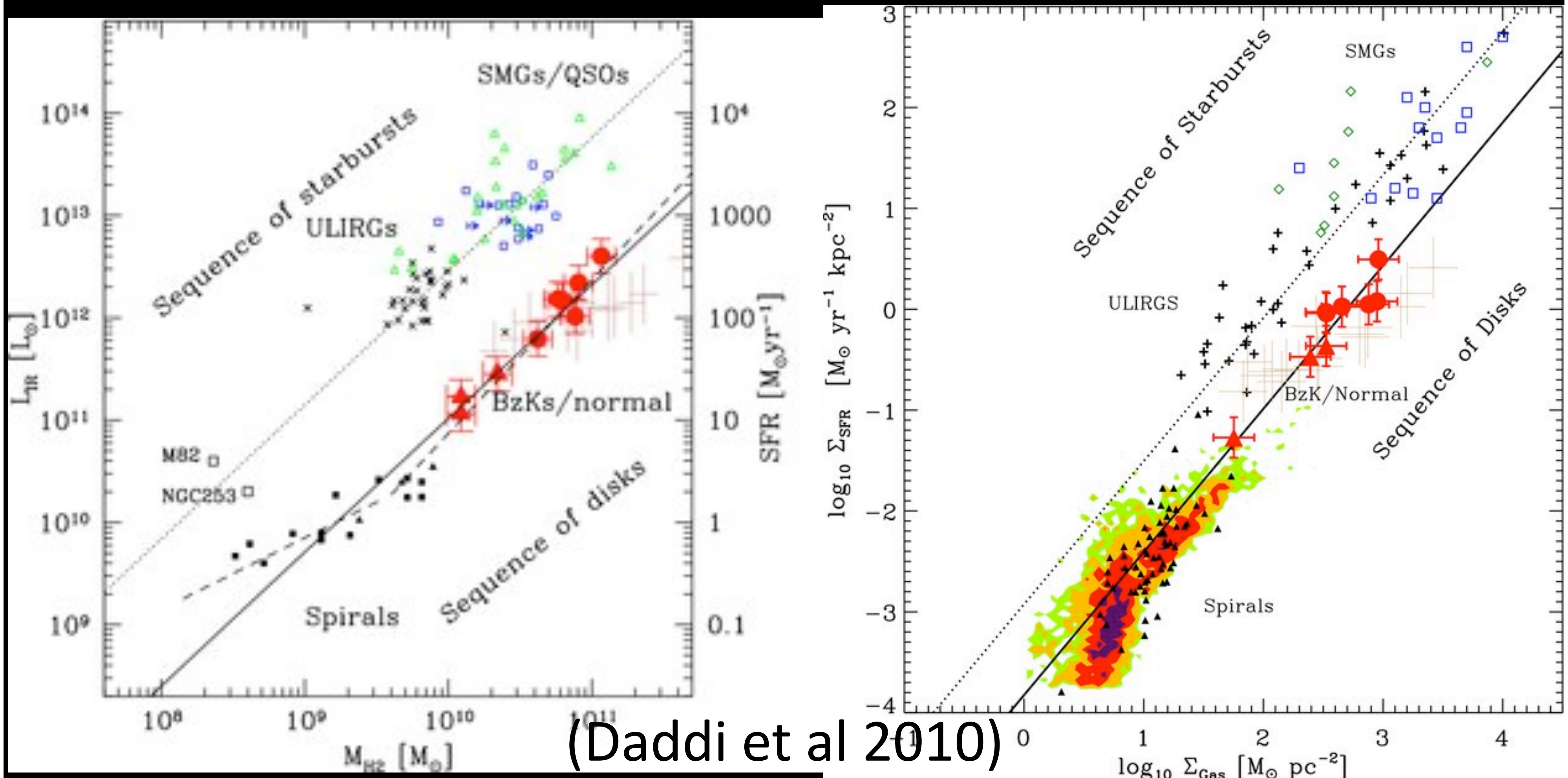
Peng et al. (2011)

A Caveat: not all measurements of the SSFR agree …

Another estimate of the SSFR from stacked radio data, Karim et al. (2011)



Two regimes of star formation: quasi-steady **on** *the main sequence, starbursts* **off** *of it*



(Daddi et al 2010)

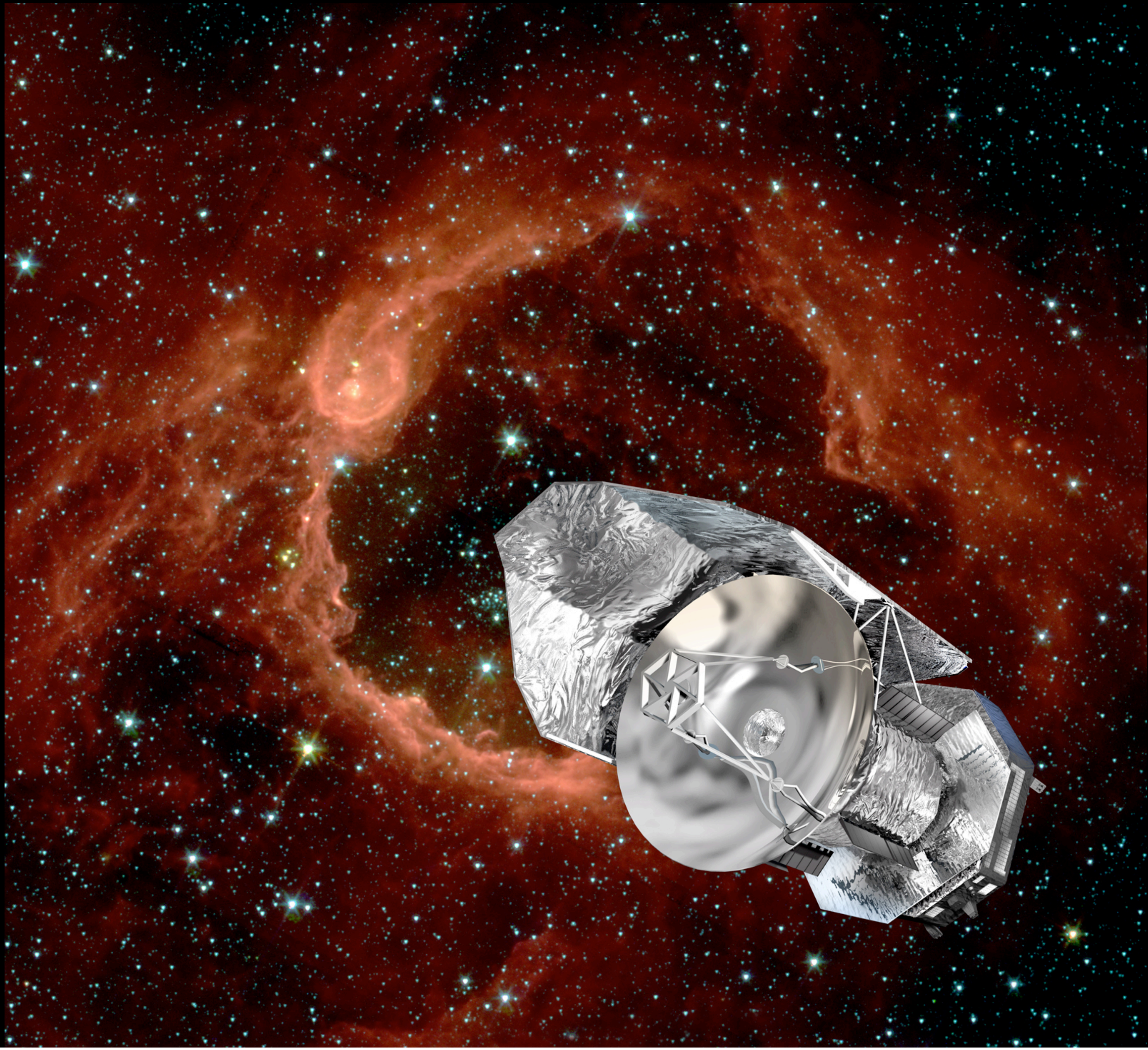
Two regimes of star formation: quasi-steady **on** *the main sequence, starbursts* **off** *of it*

Two Critical Questions:

Q1: what is the relative number of main sequence and starburst galaxies?

Q2: what is their relative contribution to the global, cosmic star formation rate density?

Answering with HERSCHEL/PACS observations over the GOODS & COSMOS fields



HERSCHEL/PACS observations over the GOODS & COSMOS FIELDS

Rodighiero et al. (2011)

Data-set required to fully sample the stellar mass – SFR plane:

1. PACS 100µm and 160µm shallow source catalogs with extraction based on 24µm prior positions + IRAC-selected source catalog from Ilbert et al. (2010)

2. PACS 70, 100 and 160µm deep catalog in GOODS-S + multiwavelength photometry, spec & photo-z

3. BzK COSMOS catalog (Daddi/McCracken)

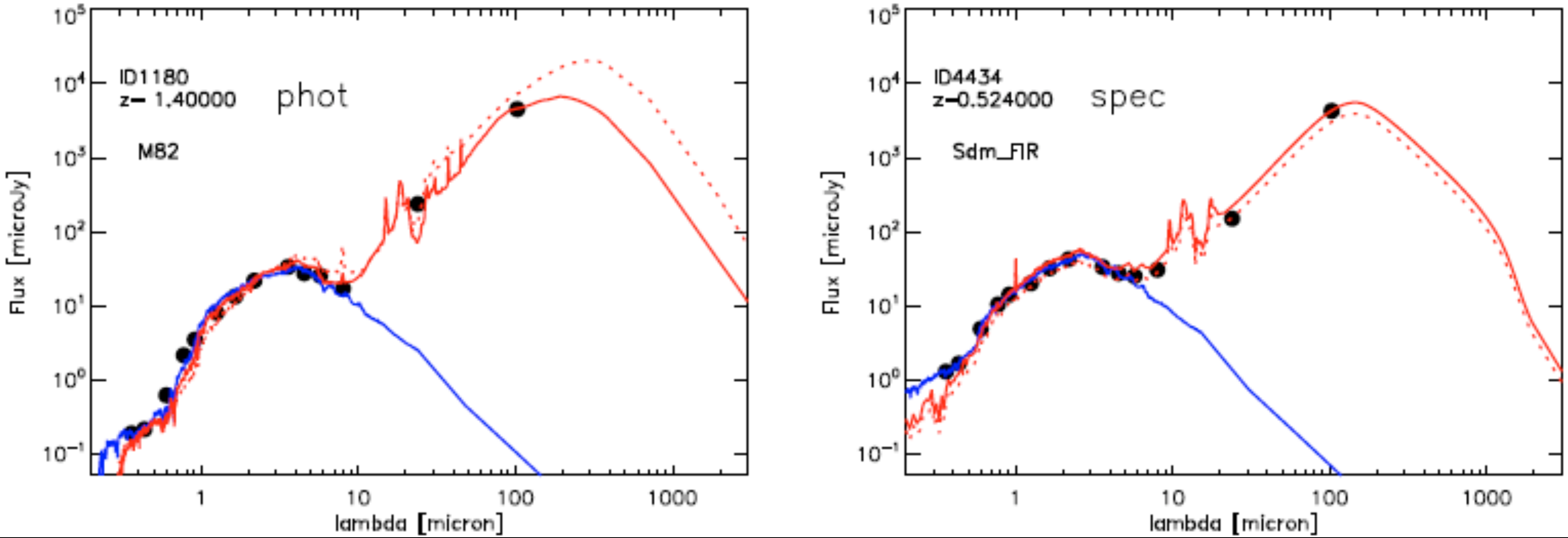
4. BzK GOODS-S catalog (Daddi et al. 2007)

SFR:

derived from SED fitting to the complete UV-to-PACS observed photometry and converting the bolometric emission ([8-1000]μm) with the Kennicutt et al. (1998) relation (inclusion of unobscured SF does not affect the results).

STELLAR MASSES:

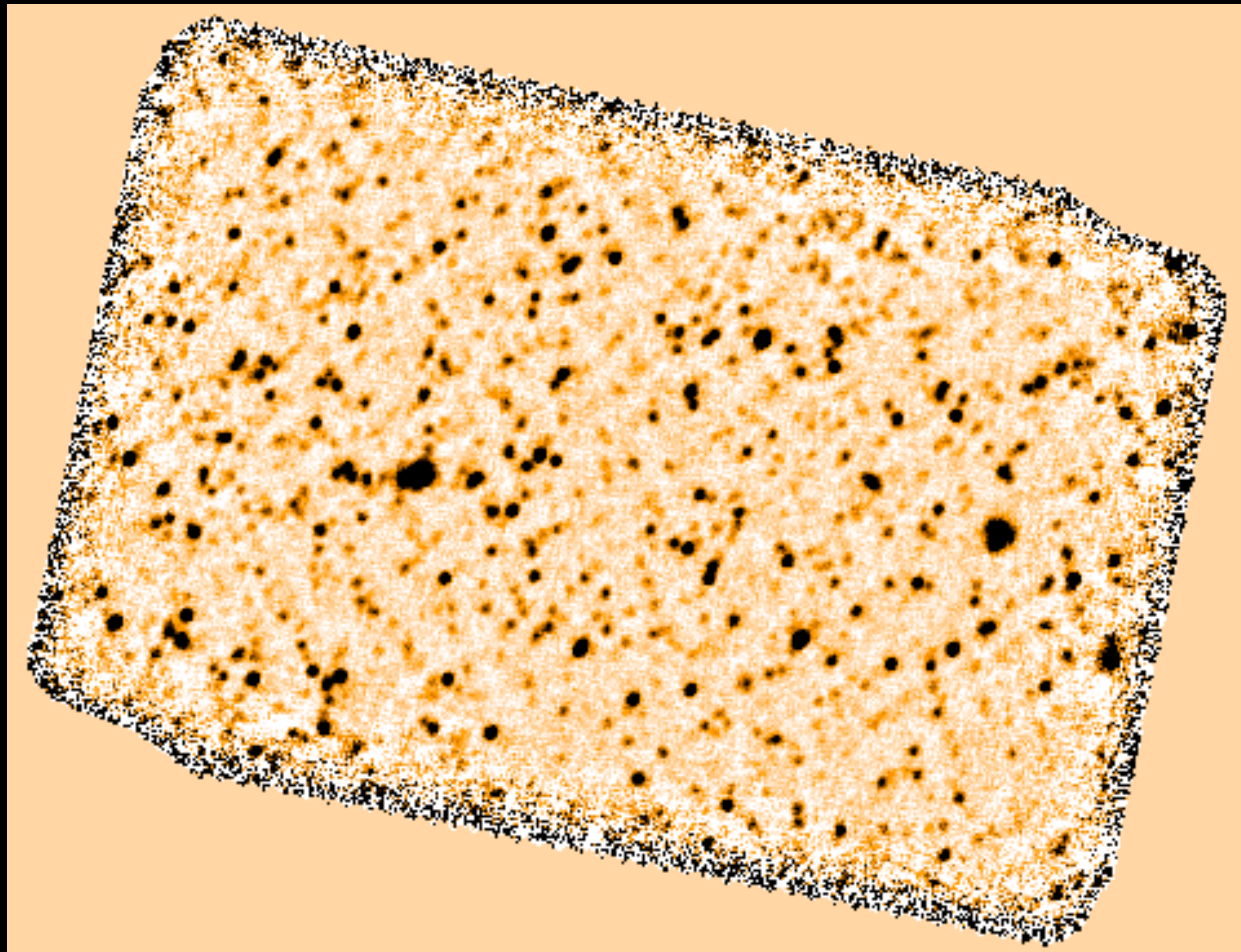
classical SED fitting to the UV-to-IRAC (5.8μm) with Bruzual & Charlot models



The PEP- GOODS South

(Lutz et al. 2011)

~21'x14'

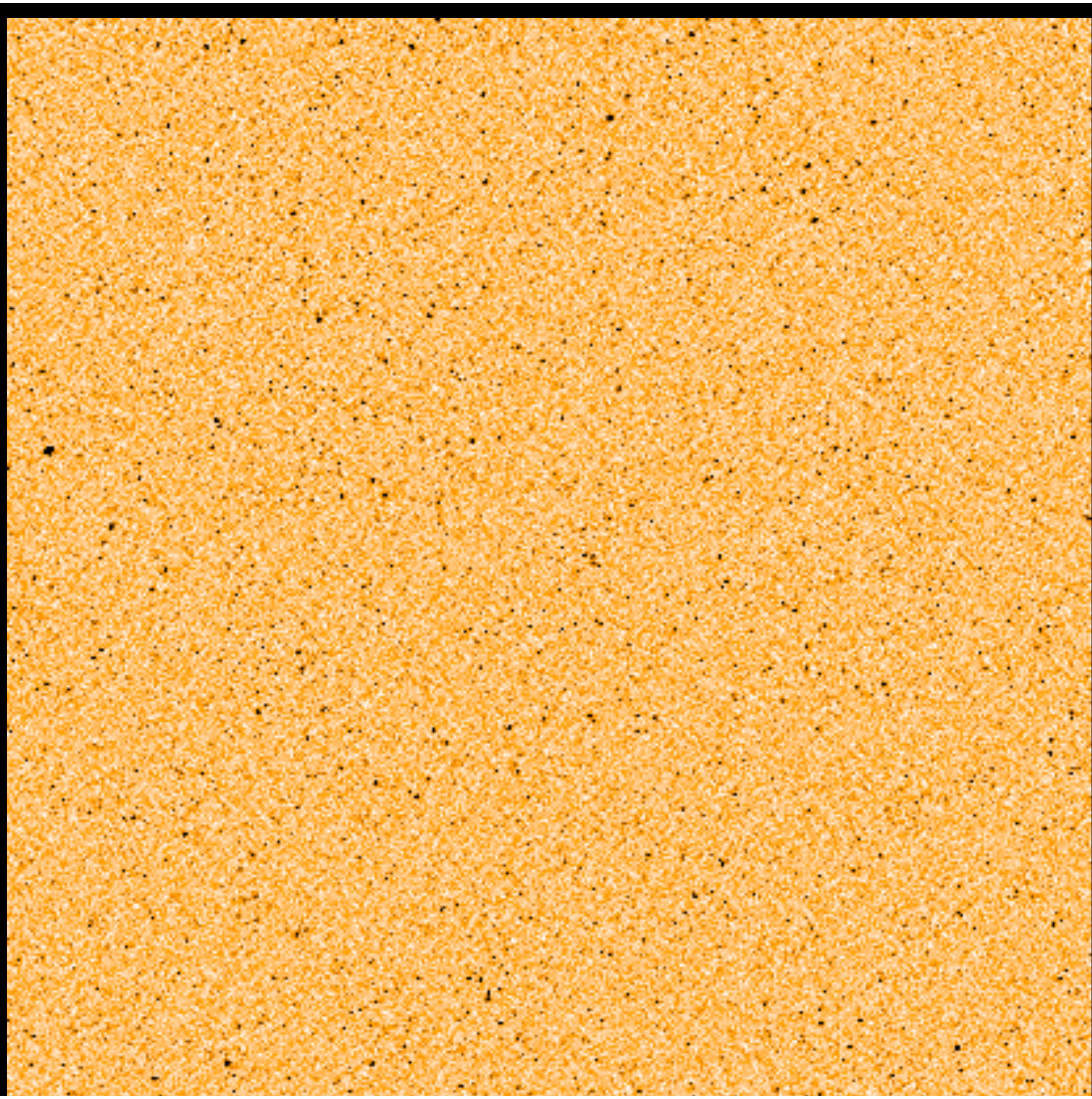


Field & band	F(3σ) mJy	$N \geq 3\sigma$	F(5σ) mJy	$N \geq 5\sigma$	Completeness 3σ	f(spur) 3σ	Completeness 5σ	f(spur) 5σ
GOODS-S 70	~ 1.0	361	~ 1.8	189	0.32	0.21	0.84	0.00
GOODS-S 100	~ 1.1	787	~ 1.9	424	0.21	0.28	0.64	0.04
GOODS-S 160	~ 2.0	874	~ 3.3	531	0.14	0.51	0.52	0.10

Table 4: Statistics of GOODS-S catalogs extracted using position priors at 24μm.

The PEP-COSMOS

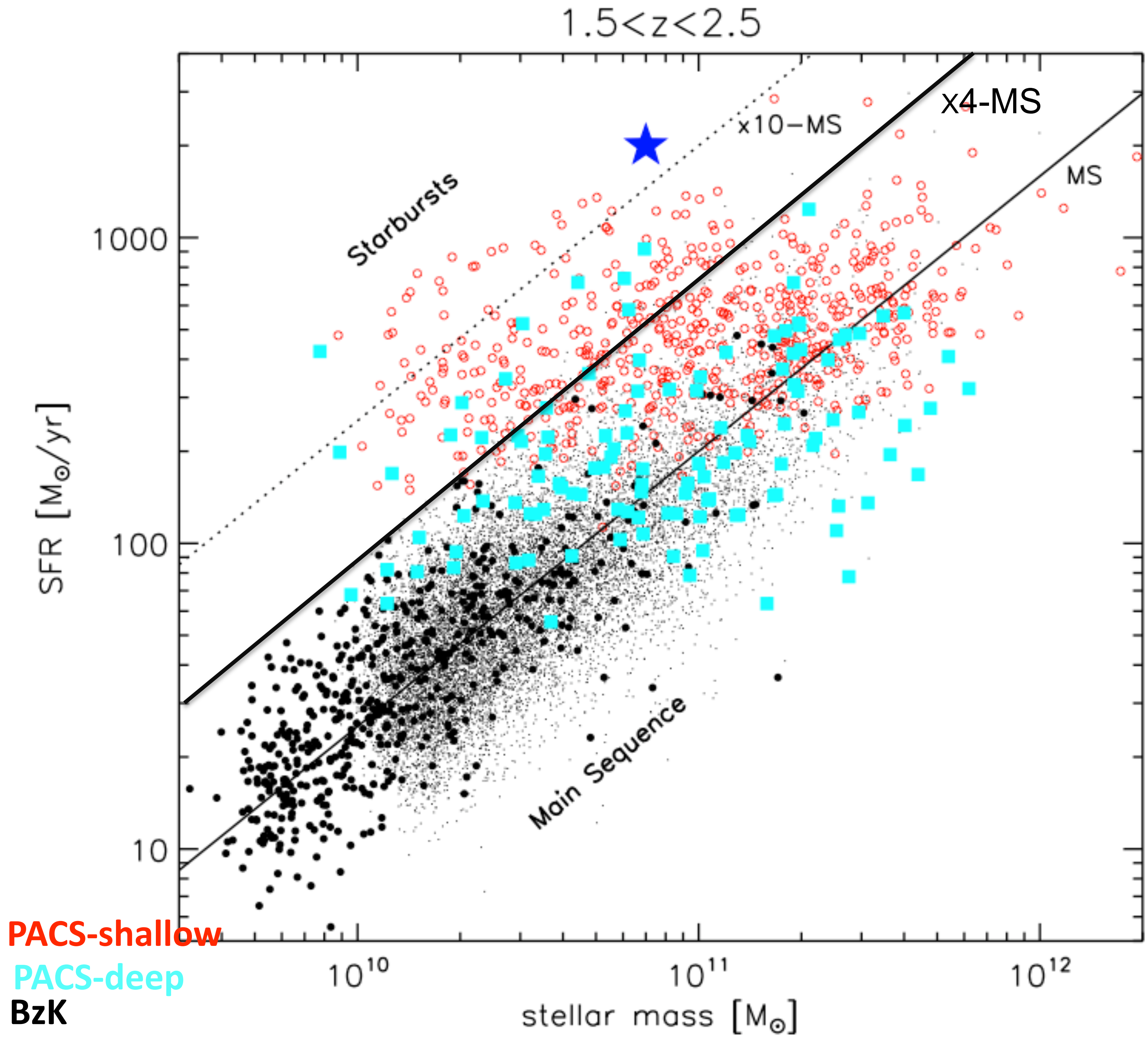
~2 square degrees



Field & band	F(3σ) mJy	$N \geq 3\sigma$	F(5σ) mJy	$N \geq 5\sigma$	Completeness 3σ	f(spur) 3σ	Completeness 5σ	f(spur) 5σ
COSMOS 100	~ 5.0	5368	~ 8.0	2999	0.43	0.58	0.90	0.09
COSMOS 160	~ 11.0	4649	~ 18.0	2159	0.29	0.48	0.84	0.09

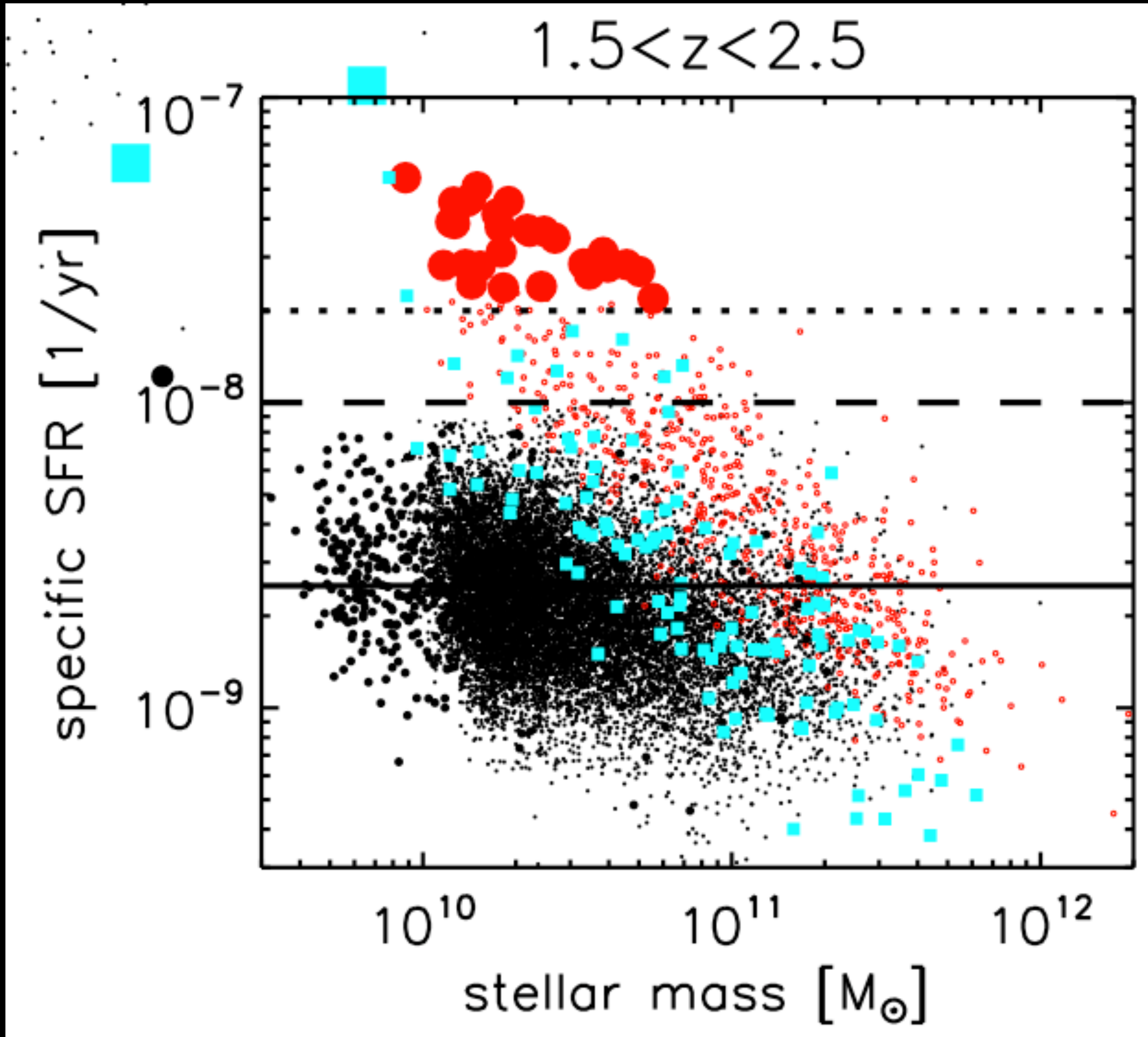
Table 3: Statistics of COSMOS catalogs extracted using position priors at 24μm.

Populating the mass-SFR plane

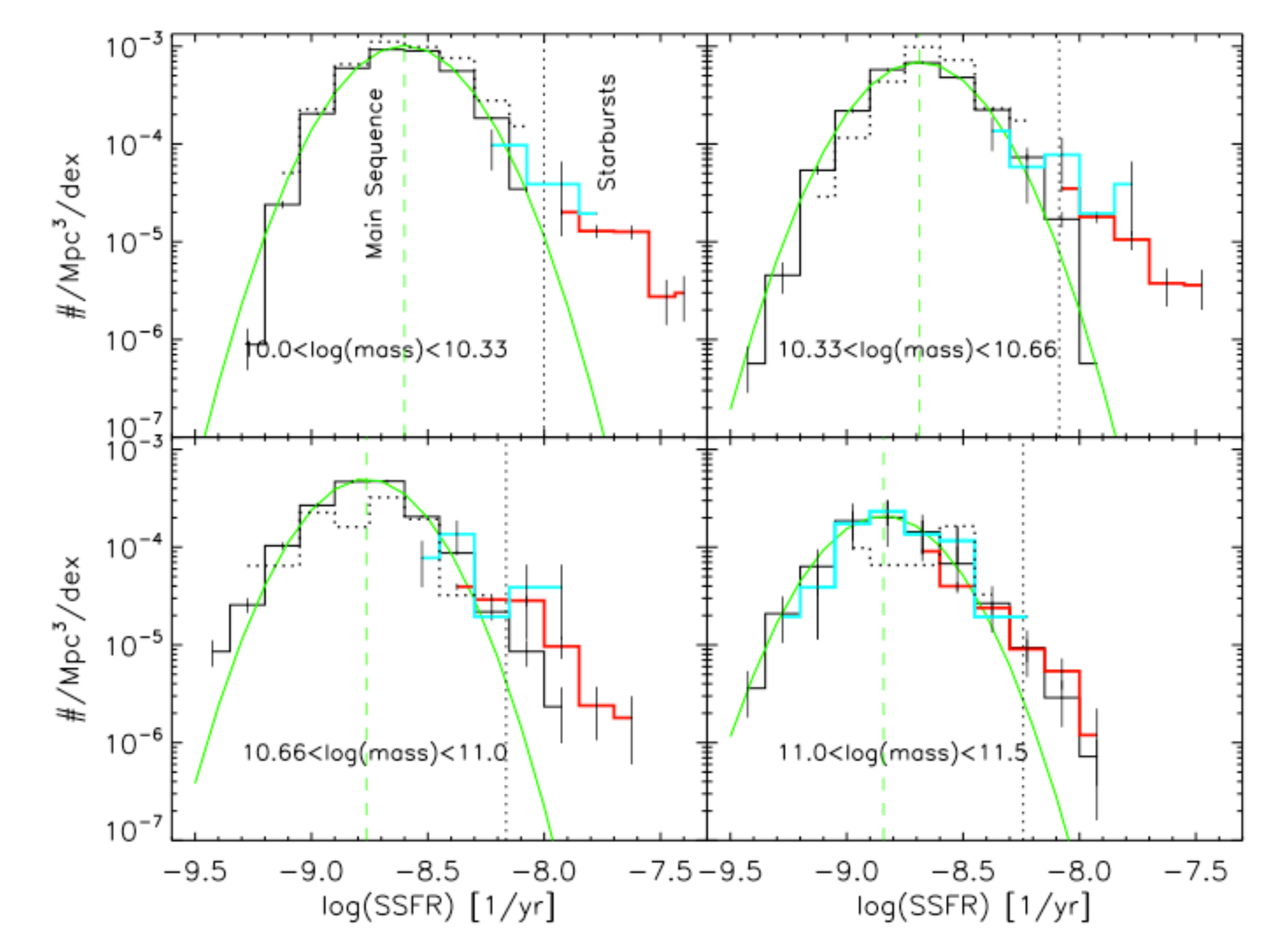


1.5<z<2.5
x4-MS
x10−MS
MS
Starbursts
Main Sequence
SFR [M☉/yr]
1000
100
10
stellar mass [M☉]
10^{10}
10^{11}
10^{12}
PACS-shallow
PACS-deep
BzK

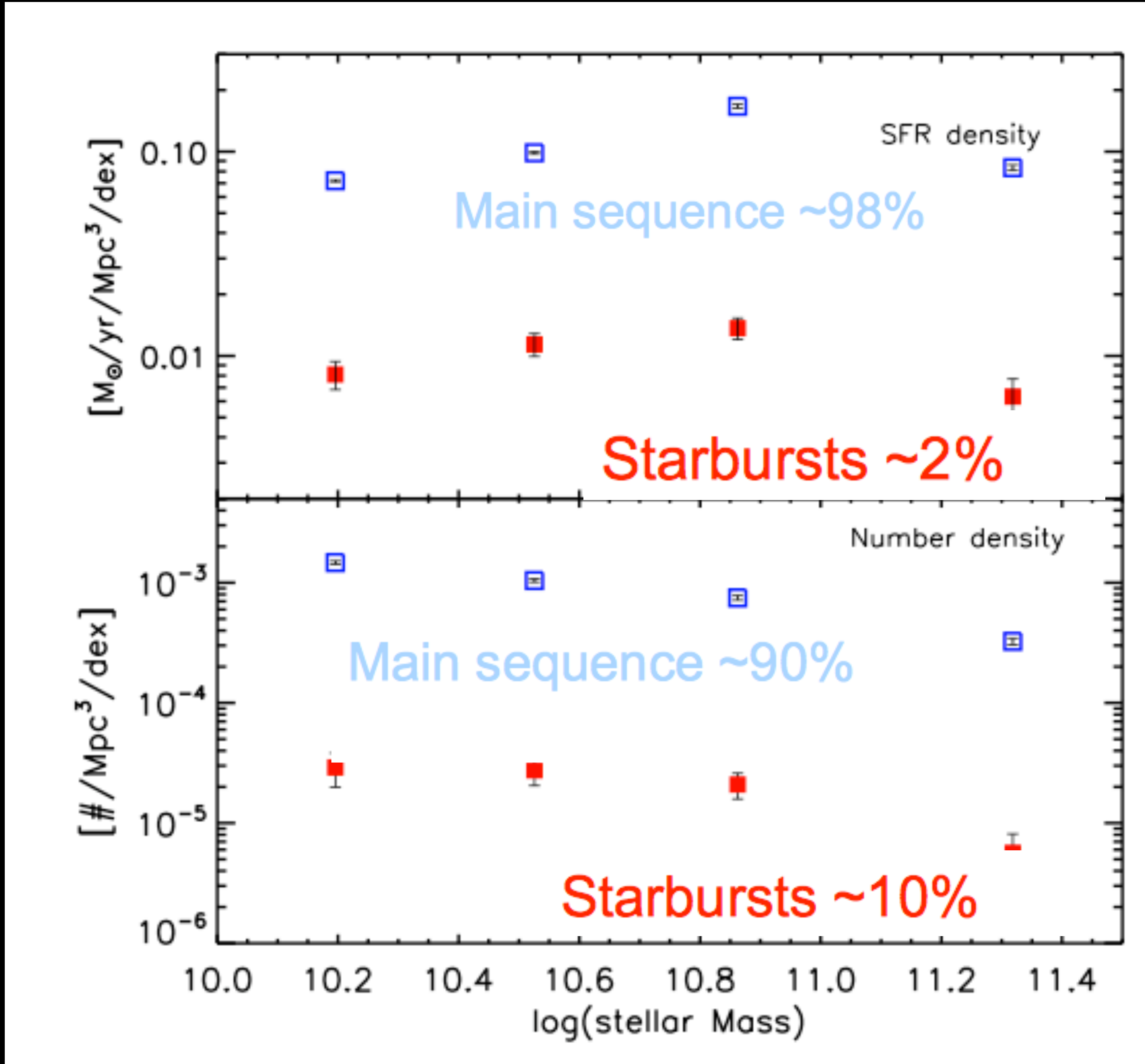
Same but in Specific-SFR



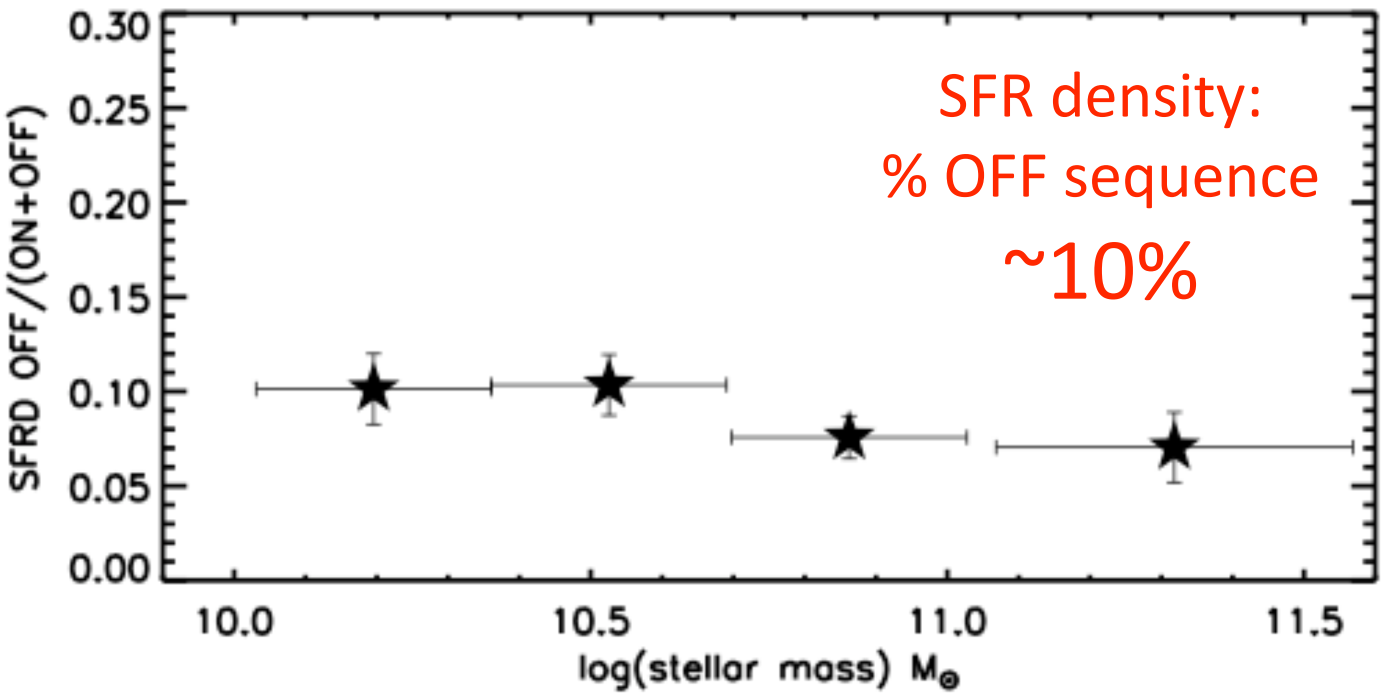
Number densities as a function of mass and SSFR bins:



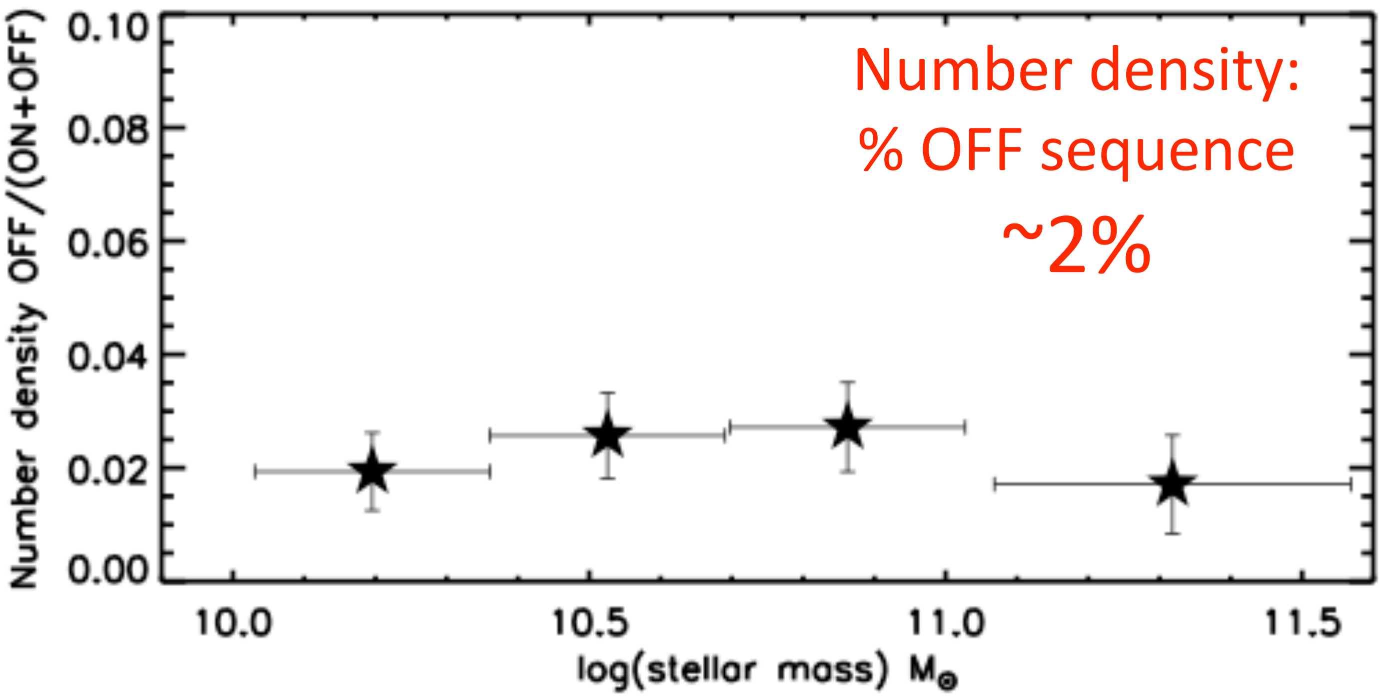
SFR density & Number density: ON and OFF sequence



SFR density



Number density



DUTY CYCLE ON/OFF the MAIN SEQUENCE

The cosmic time elapsed within the $1.5 < z < 2.5$ redshift interval is ~2 Gyr, thus observed galaxies within this interval have spent on average ~1 Gyr within it.

With only ~2% of the massive galaxies being OFF the main sequence, on average each galaxy spends 20 Myr in the starburst mode.

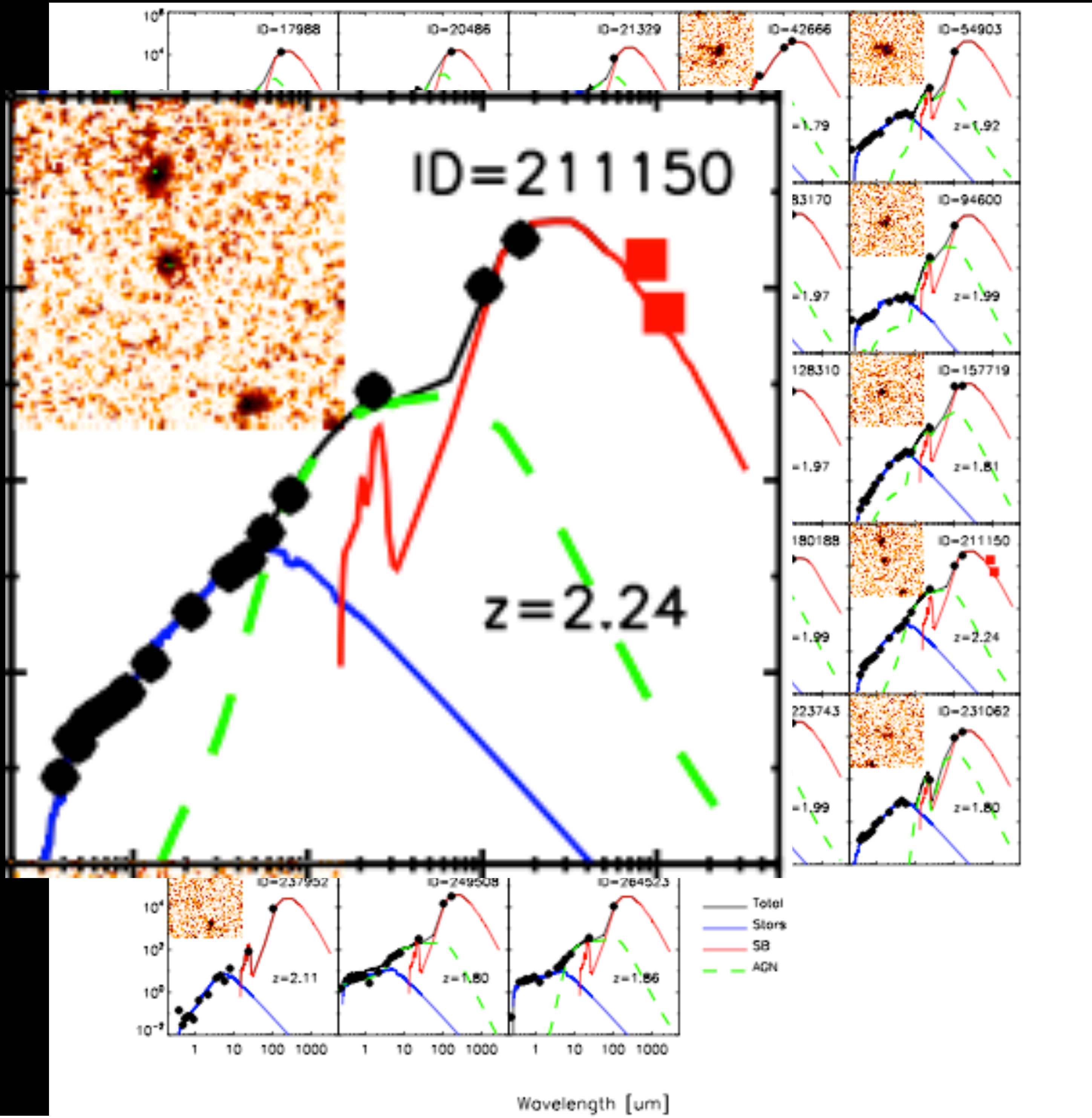
This is actually much shorter than both the gas depletion timescale (~0.5 Gyr) and the dynamical time in starburst galaxies (~50-200 Myr, Daddi et al. 2010; Genzel et al. 2010).

Not all galaxies may experience a (merger-driven) starburst during these ~2 Gyr of cosmic time interval.

The most SB sources:
SMGs brothers

Dominated by SFR

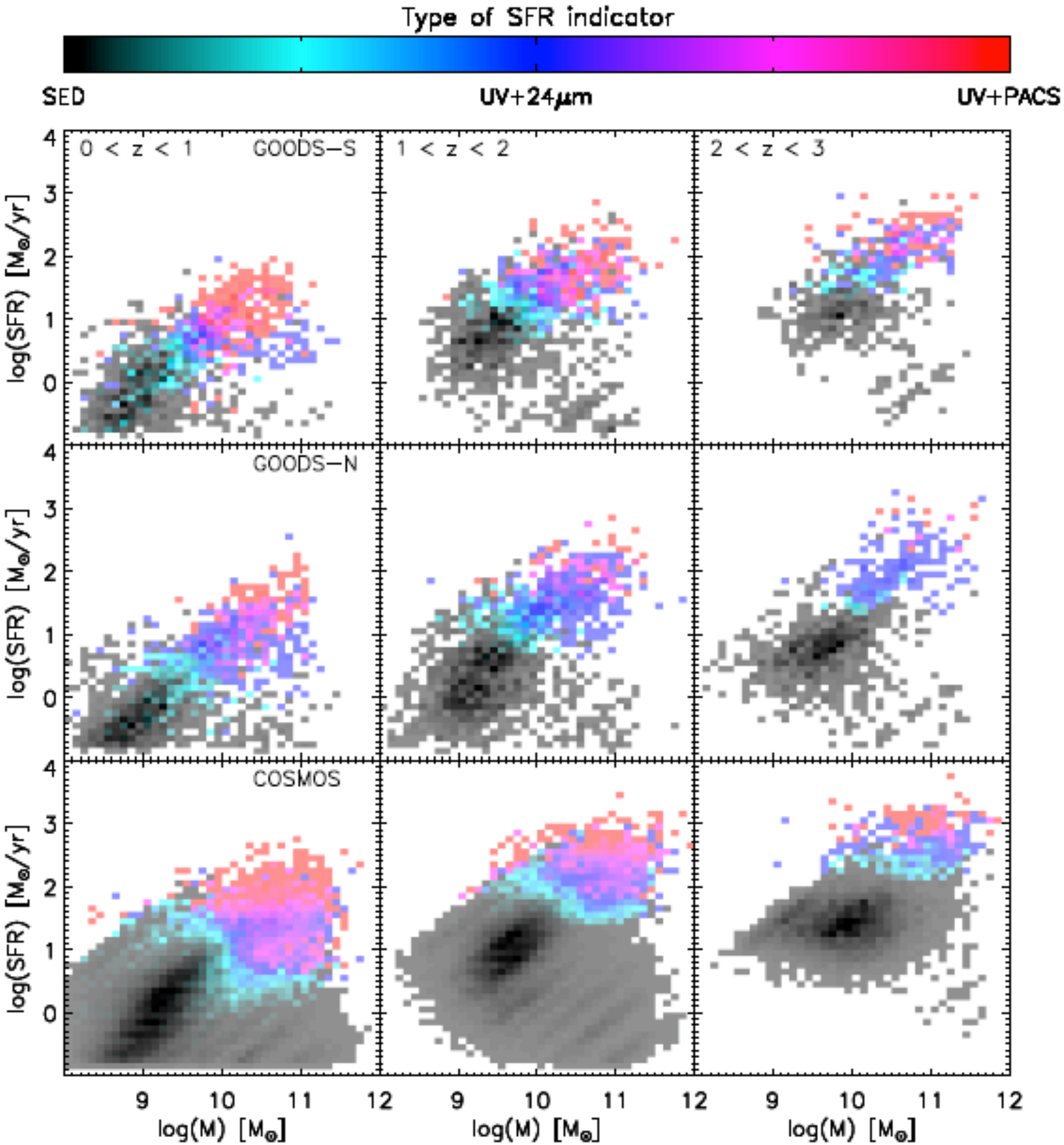
Obscured AGN present
but does never dominate
the bolometric far-IR emission



MAIN CONCLUSION

The merger-enhanced SFR phases are relatively unimportant for the stellar mass growth of z ~ 2 galaxies, and probably so at all redshifts given that z ~ 2 is known to be the 'prime time' for SMGs (Chapman et al. 2005).

Still, going through a merging-driven starburst phase may turn star-forming galaxies into passive ellipticals.



The composite MS at all redshifts

Wuyts et al. 2011