Probing the assembly of massive galaxies through the evolution of their Specific Star Formation rate up to z=2

i.e.

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Letter to the Editor

The first Herschel view of the mass-SFR link in high-z galaxies ⋆

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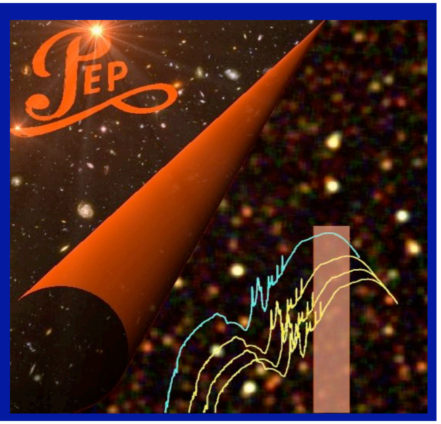
Giulia Rodighiero on behalf of the PEP consortium



Why study the evolution of the specific SFR?

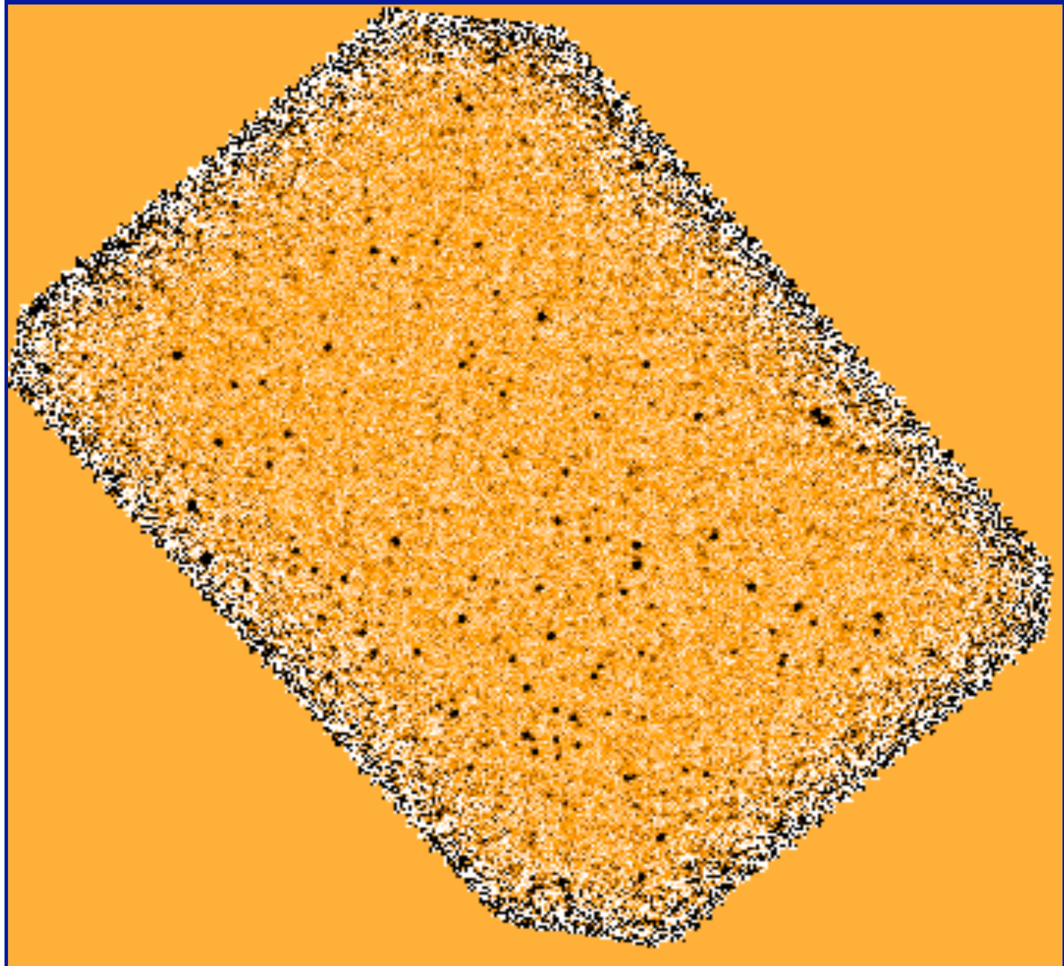
The Specific SFR (SSFR) is often used as a measure of the star formation efficiency of a galaxy, since it provides information about the fraction of a galaxy's mass which could be converted into stars in a given time.

A higher SSFR means a galaxy will increase its mass by a greater fraction in a given time than a lower SSFR.

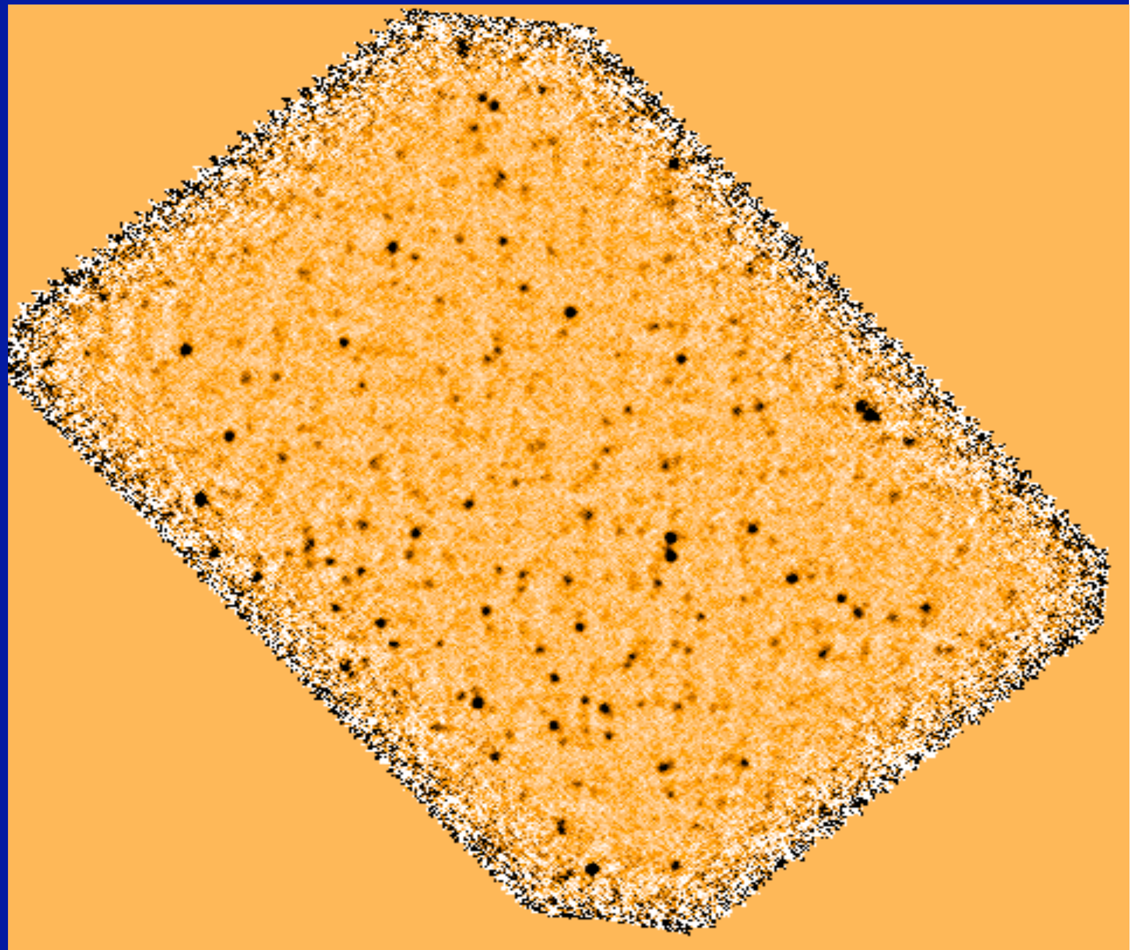
Dunne et al. (2009)

PEP: PACS Evolutionary Probe (Lutz talk!)
SDP data in the GOODS-North

100 micron



160 micron



SAMPLE SELECTION:

From internal PEP multiwavelength catalog

Spitzer-IRAC 4.5 mag < 23: 4459 sources

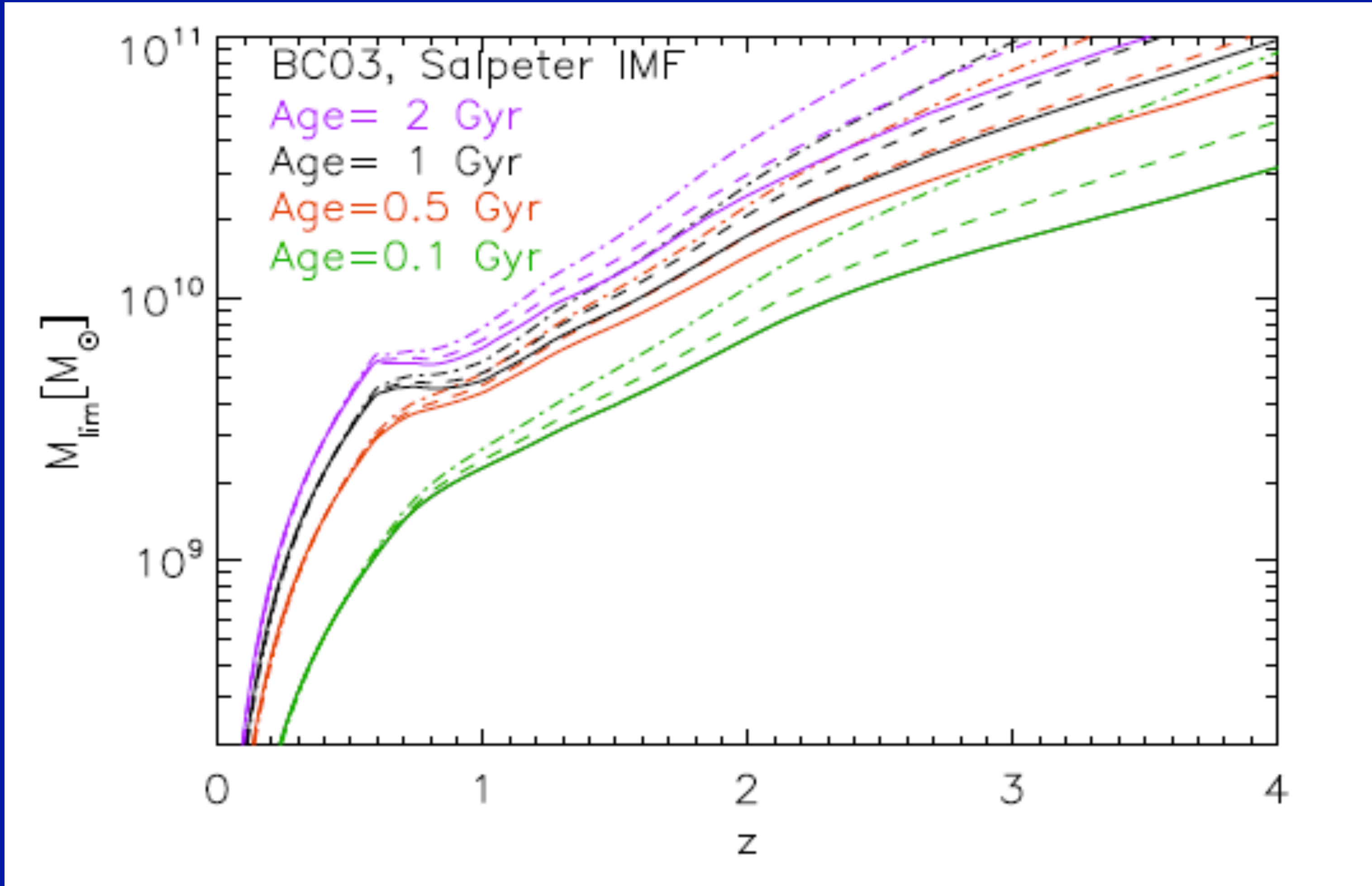
1887 with MIPS 24 µm SNR>3 and PSF-fitted photometry

351 with a PACS 100 µm and/or 160 µm SNR>3 and PSF-fitted photometry

MAIN INGREDIENTS:

1) Masses from stellar SED fitting to the UV-5.8µm range (Bruzual & Charlot 2003 and Maraston 05)
2) SFR ⇔ L(IR) from fitting to the whole observed multivelength SEDs

Mass completeness as a function of redshift for a flux limited sample at [4.5]<23.0, derived from synthetic stellar population models

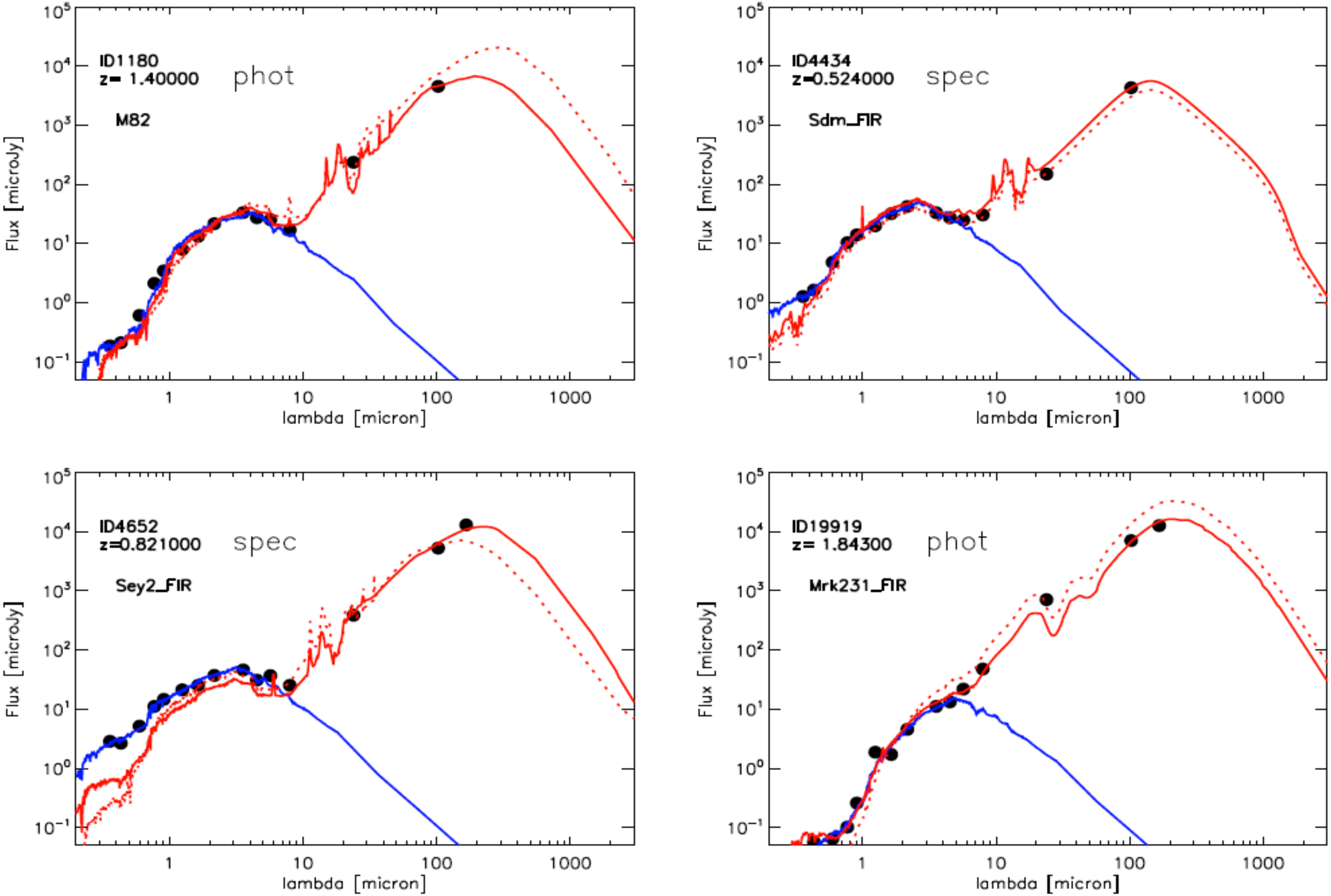


We use the constant SFR templates of BC03, different ages, and dust extinction parameters (E(B-V)=0.3, 0.5,0.8).

In our analysis we adopt the most conservative mass-completeness limit (dot-dashed magenta line), above which even the oldest (2 Gyr) and highly extincted star-forming galaxy population would be entirely recovered.

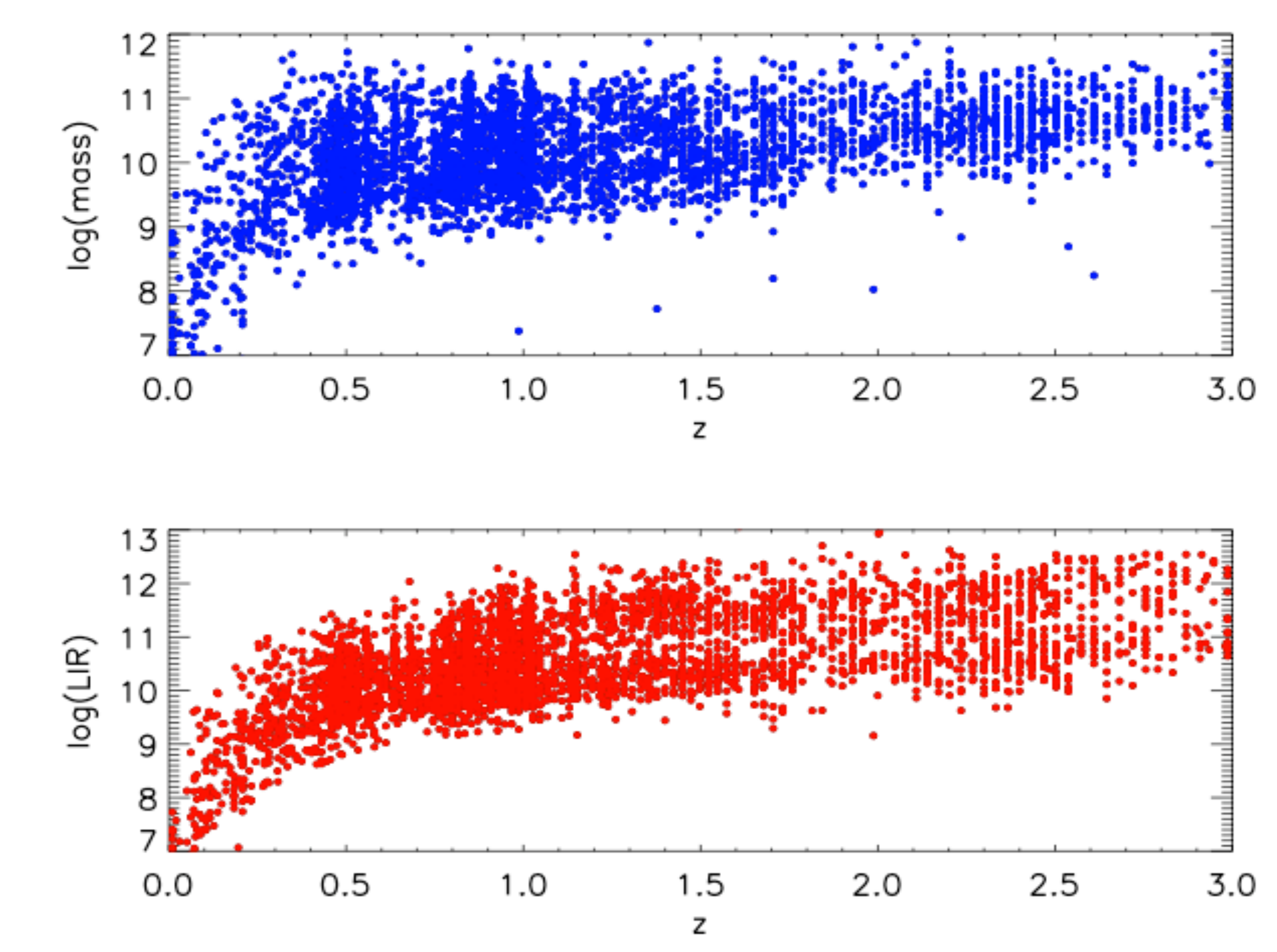
(Mancini C. et al. 2009)

SED fitting examples: BC03 + Polletta '07

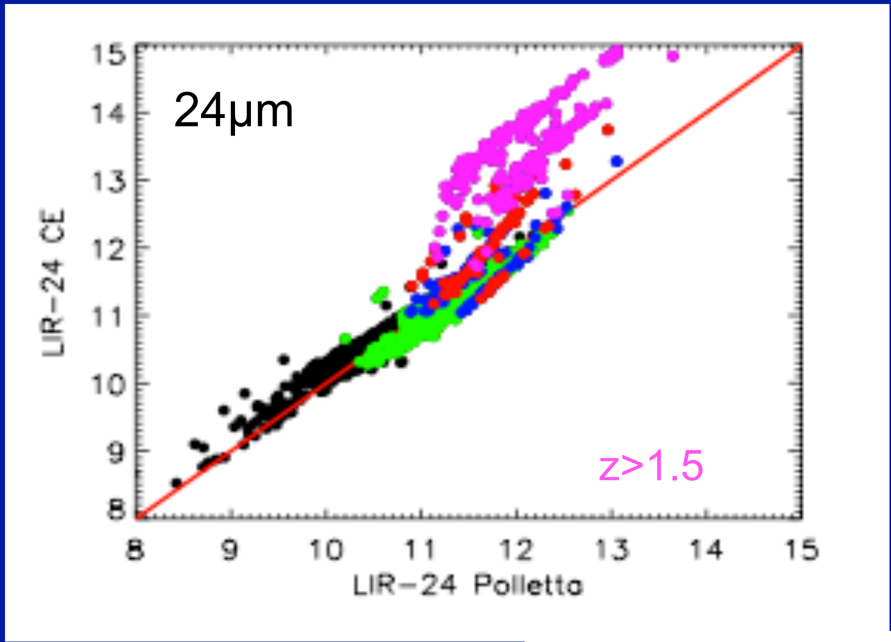


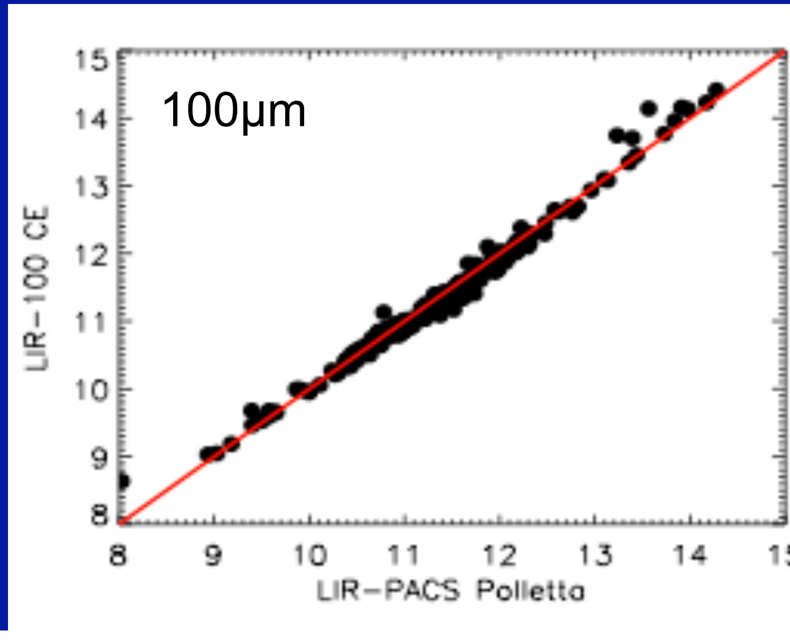
(See also C. Gruppioni's Poster, P1.66)

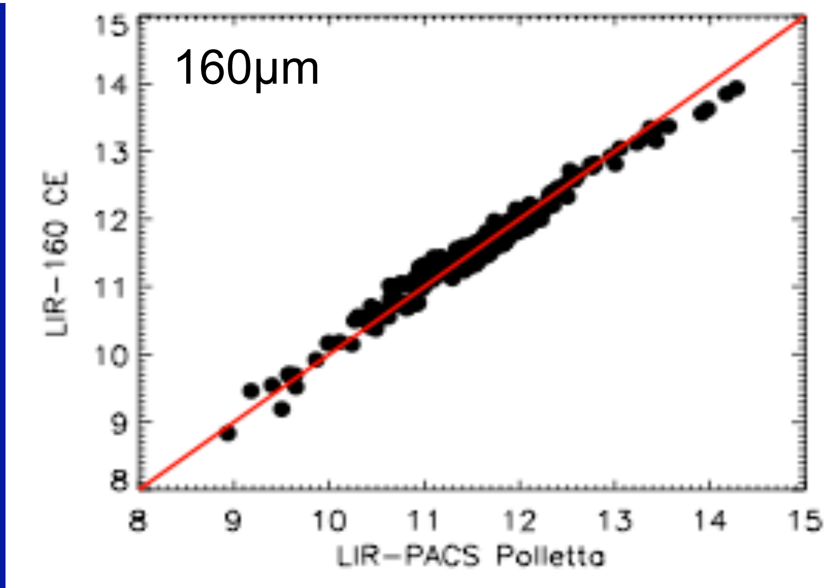
The redshift – mass – IR luminosity space of the IRAC [4.5]<23.00 sample



Total IR luminosities: Polletta vs Chary&Elbaz



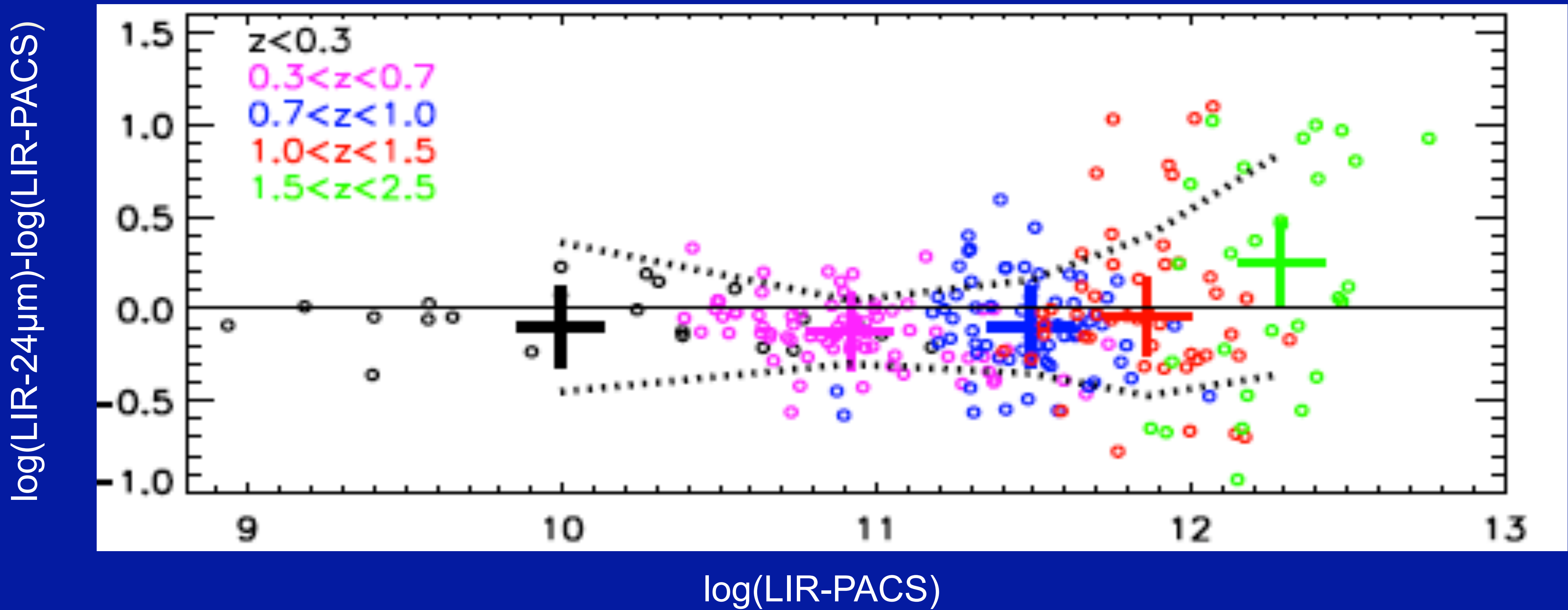




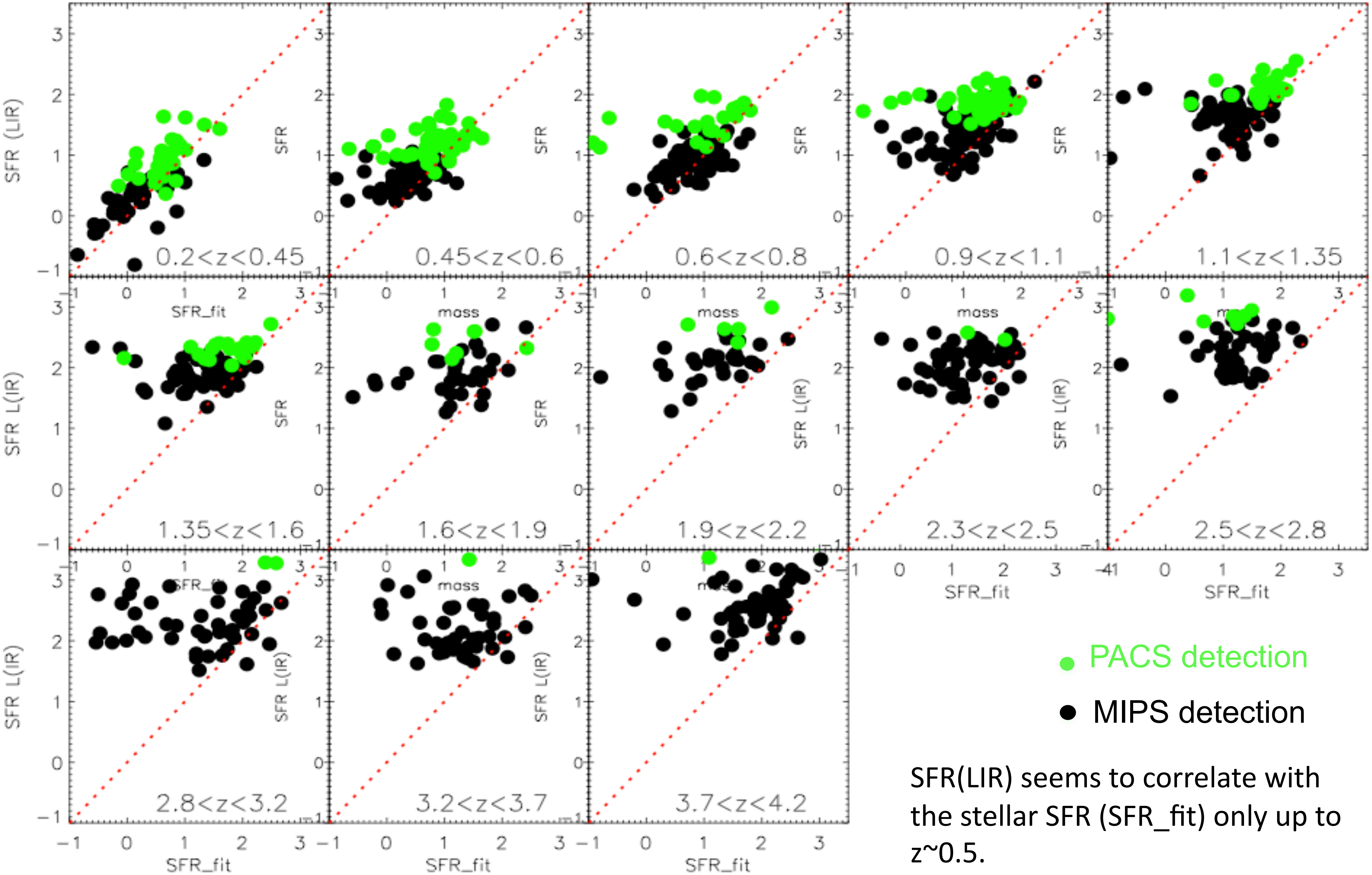
IR luminosities: Spitzer versus Herschel

@z-2.0 : MIPS overestimates LIR by a factor ~2

(when including PACS upper limits in the analysis, i.e. by stacking, this factor increases up to ~4! Nordon et al. 2010 A&A special issue, see Poster P2.58 + Elbaz's talk)

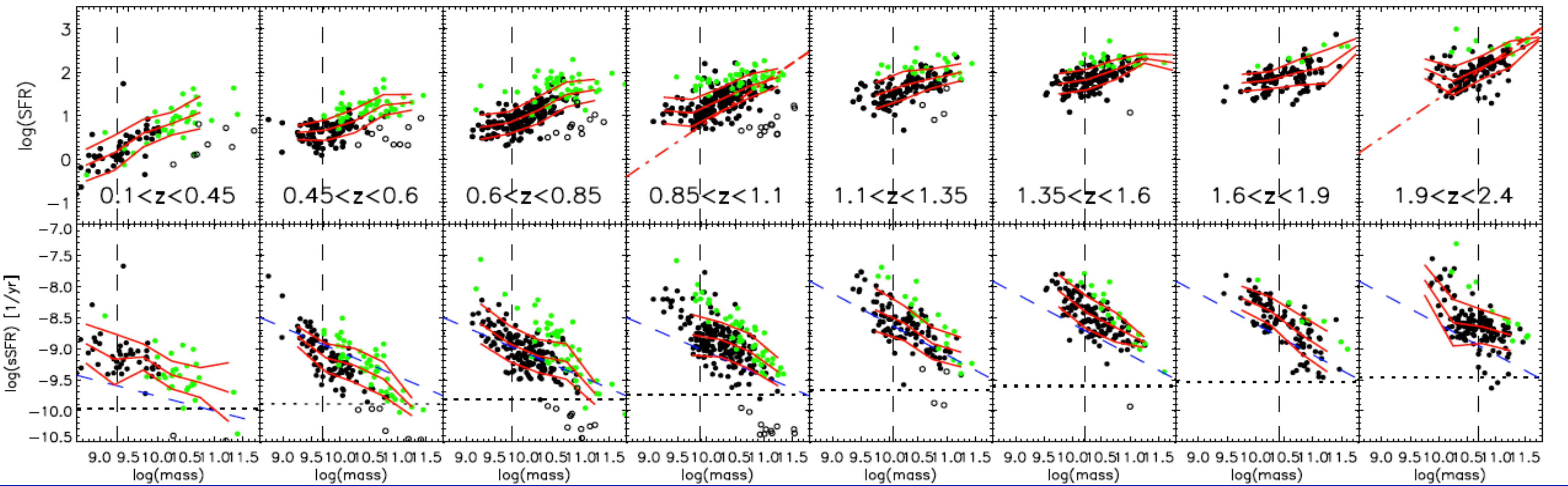


SFR from stellar fit vs SFR from L(IR) SED fitting



SFR(LIR) seems to correlate with the stellar SFR (SFR_fit) only up to z~0.5.

Stellar Mass vs SFR (LIR SED fitting) for PACS & MIPS sources



-We observe the existence of a (rather scattered) positive correlations between the SFR and stellar mass at all redshifts.

-The comparison with Elbaz et al. (2007) at z~1 and Daddi et al. (2007) at z~2 shows that their observed slope of the SFR-mass relation is not inconsistent with our results.

-A negative trend of SSFR with mass is evident at all redshifts, although the scatter is quite large.

- The bulk of PACS and/or MIPS sources is located above the horizontal dotted line (the inverse of the age of the Universe), indicating that these systems are experiencing a major episode of star formation, forming stars more actively than in their recent past and building up a substantial fraction of their final stellar mass.

Herschel: constraining tighter high-z relations?

PACS detects only the brightest objects and we cannot than verify that the scatter is intrinsically lower. However, the fact that at least at high luminosities, at z~2, PACS produces a smaller scatter (because it provides a more accurate SFR), might suggest that a similar trend should happen also at low luminosities.

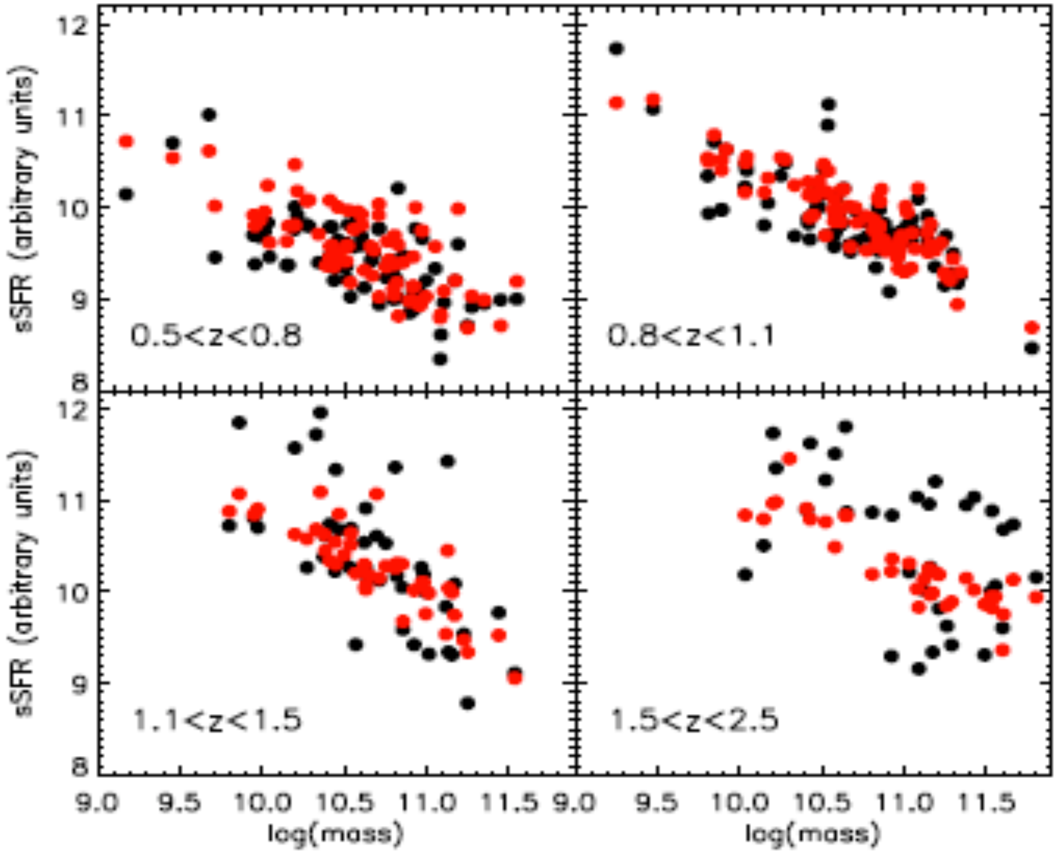


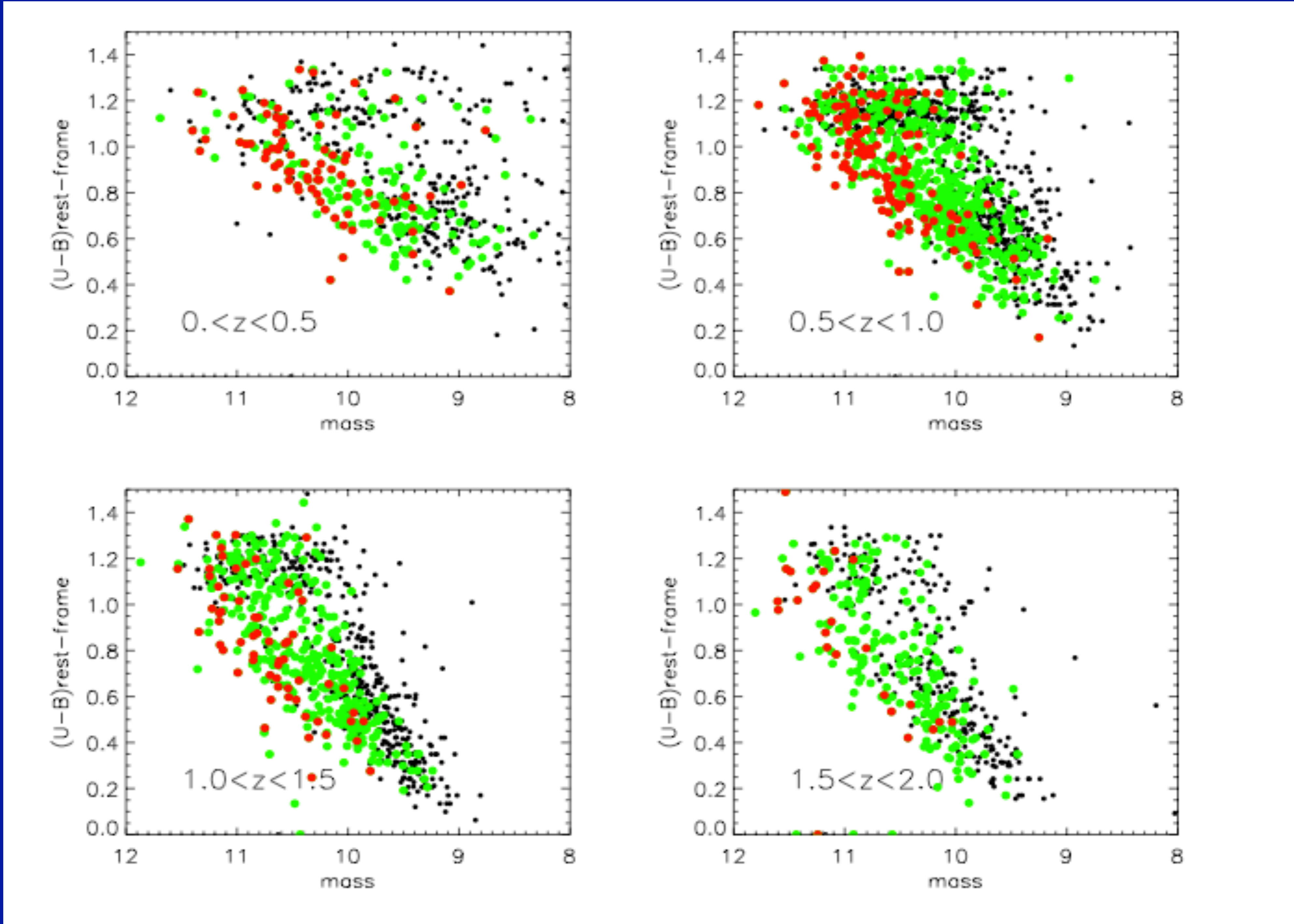
Fig. 3. Relation of the stellar mass as a function of the SSFR for PACS detected sources in various redshift bins: the SFR for red points has been computed from PACS fluxes, while for black points it has been extrapolated from the SED fitting from the 24μm data.

Going deeper: STACKING analysis on PACS maps

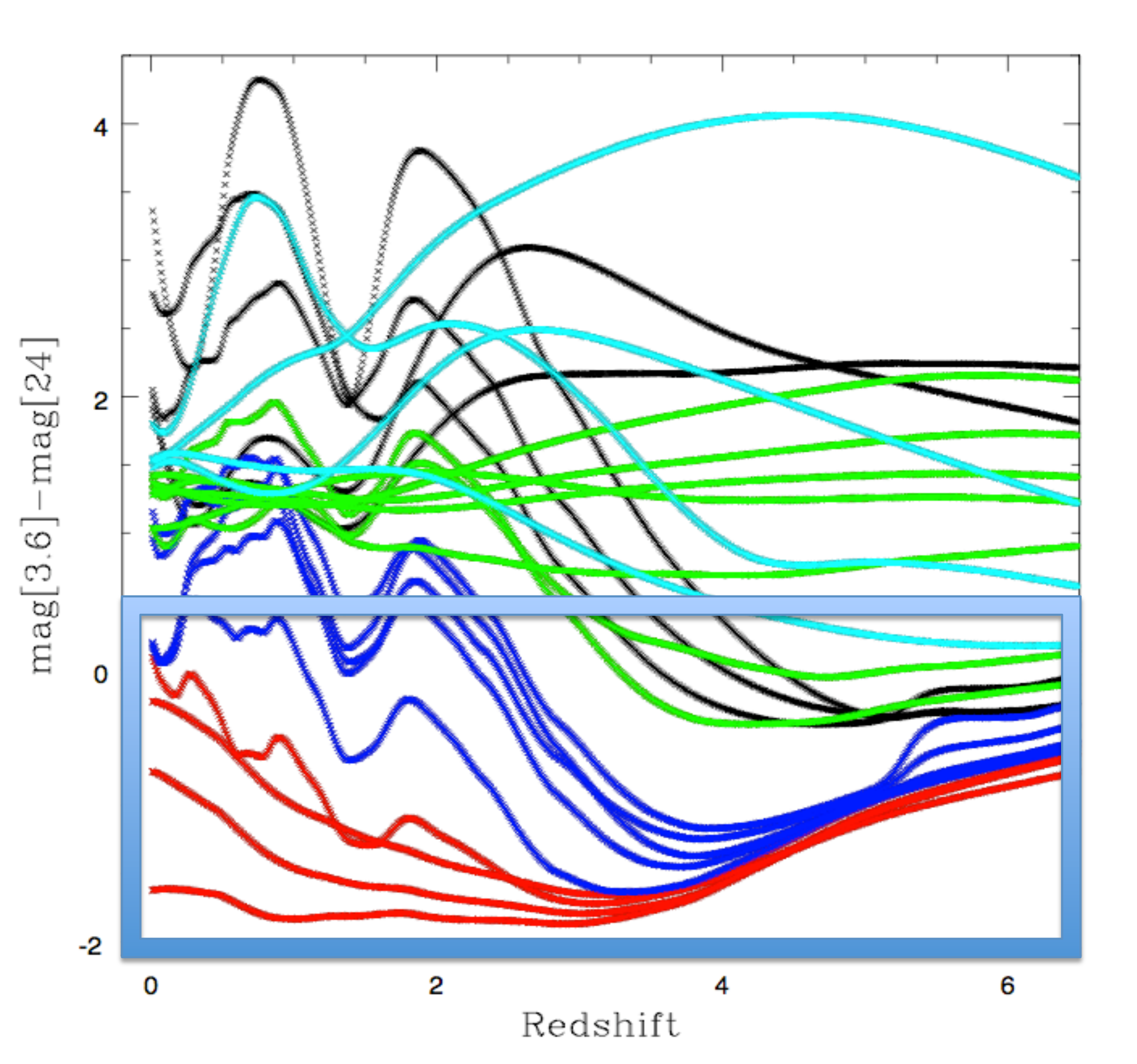
We performed a stacking analysis including all sources of the original IRAC with [4.5]<23.0 sample.
We splitted the sample in bins of mass and redshift, and stacked on a residual 160μm map.

To exclude passive sources we applied an empirical color selection of (U-B)rf<1.1, calibrated from our data, and, to recover massive dusty sources that might fall into the red sequence, we included in the stacking analysis also sources with (U-B)rf>1.1 and mag[24]-mag[3.6]>0.5.

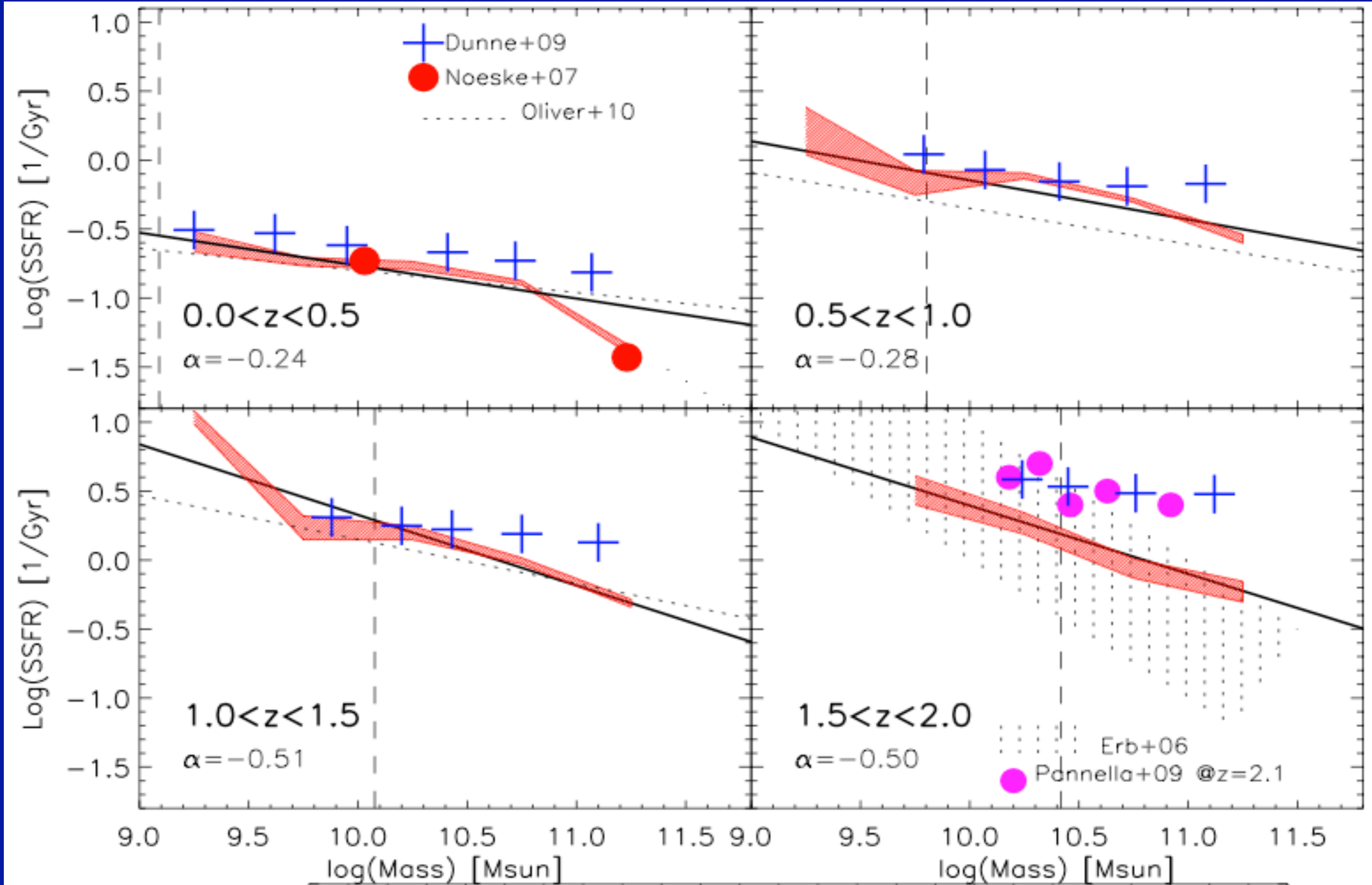
Color bimodality: (U-B)r.f. vs stellar mass



Color selection to clean the star forming catalog from passive MIPS sources



Going deeper: STACKING analysis on PACS maps



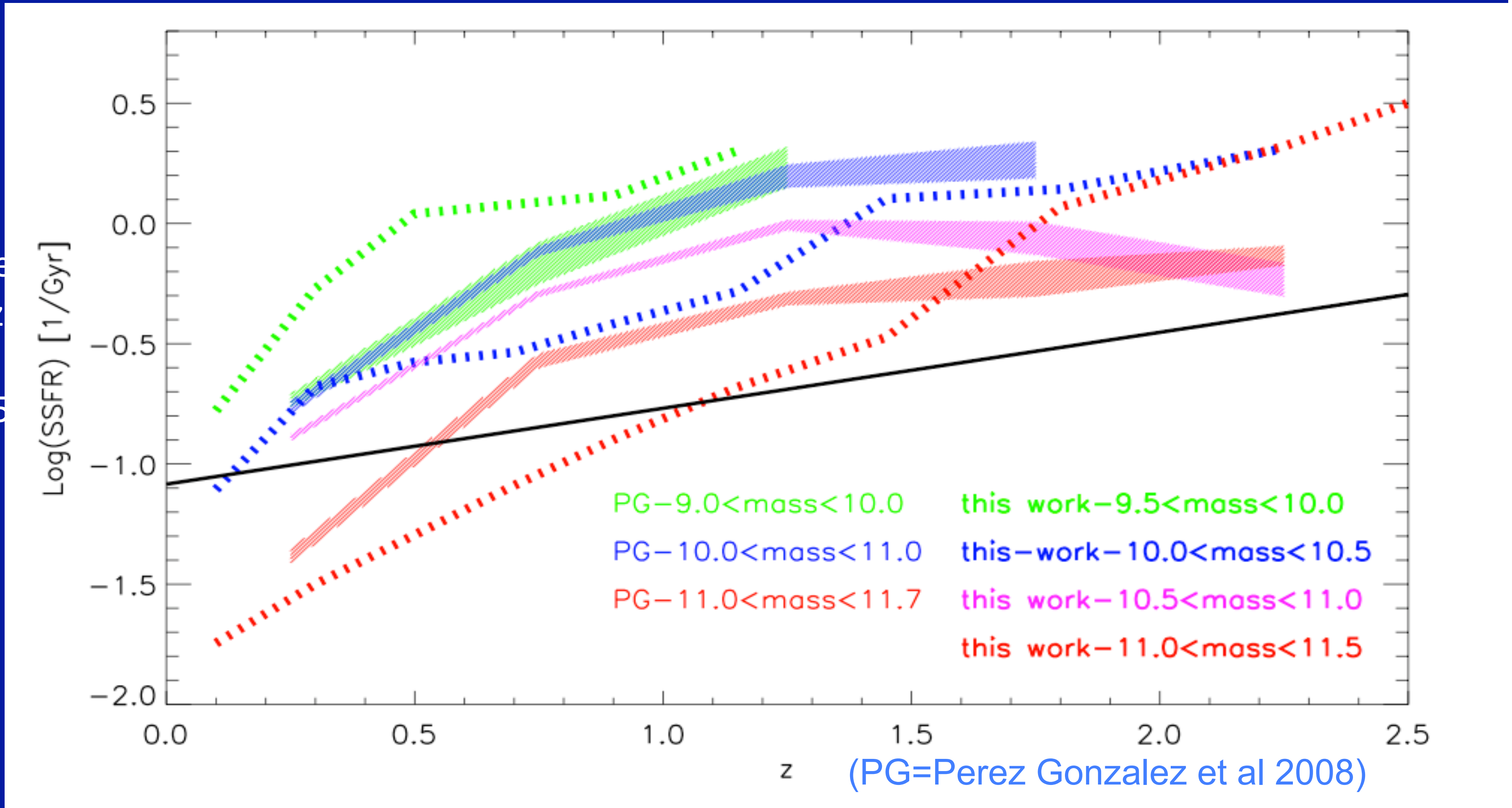
The slope of our SSFR-mass relation becomes steeper with redshift.

At z<1, our results are in broad agreement with those based on radio-stacking that found almost flat relations up to z~2 (Dunne et al. 2009, Pannella et al. 2009) , while at z>1 our relation evolves toward stronger dependencies.

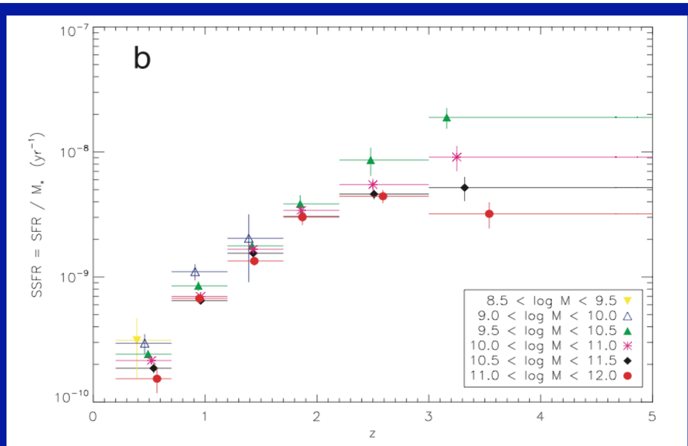
Combining far-IR detection and no-detections: STACKING analysis on PACS maps

Downsizing : the higher the masses, the lower the sSFR at all z

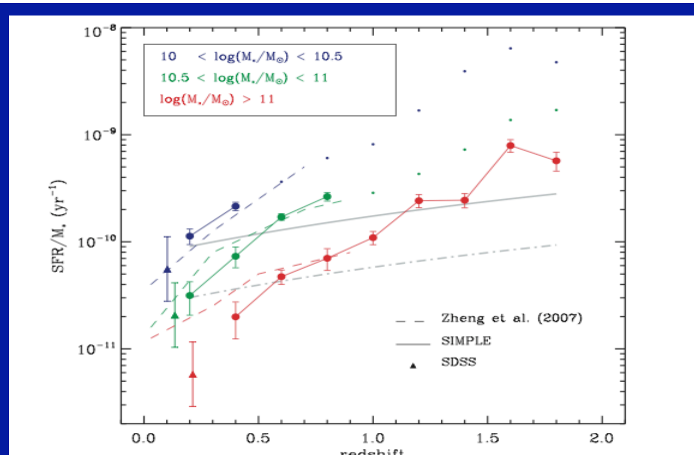
Flattening above z~1.5 for log(mass)>10.5



(PG=Perez Gonzalez et al 2008)



Dunne et al. 2009 – radio stacking



Damen et al. 2009

Main conclusions:

1) Consistently with other Herschel results, we find that L(IR) based only on 24 µm data is overestimated by a median factor ~2 at z~2 (with our approach). We exploited this calibration to correct L(IR) based on the MIPS/Spitzer fluxes.

2) The slope of the SSFR-mass relation becomes steeper with redshift (α=-0.25 at z<1 and α=-0.5 at z~2) at odds with recent works based on radio-stacking analysis at the same redshift at z~2.

3) The mean SSFR of star-forming sources rises with redshift, up to a factor ~15 for the most massive galaxies (log(M)>11), implying that galaxies tend to form their stars more actively at higher redshifts.

4) The mean SSFR seems also to flatten at z>1.5 for log(M)>10.5.

5) The most massive galaxies have the lowest SSFR at any redshift, implying that they have formed their stars earlier and more rapidly than their low mass counterparts (downsizing).