The evolution of the Galaxy Stellar Mass Function:

towards the high-mass end at high redshifts

Helena Domínguez Sánchez

Jordi Cepa (IAC), Miguel Sánchez Portal (ESAC), Andrea Cimatti (UniBo), Francesca Pozzi (UniBo), Carlotta Gruppioni (INAF-OABO), Marco Mignoli (INAF-OABO)
+ Herschel & Cosmos Teams

24 January 2013, ESAC, Madrid

Outline

- **Introduction**
- **Past research**

  -SFR indicators comparison: L_{IR} vs Hα

  -GSMF evolution of different galaxy types (star-forming, quiescent)
- **Current work**

  -Studying mid-IR drop outs:

  towards the high mass end of the GSMF at high redshifts

  -Preliminary reults:

  zphot, masses, SFR(IR)
- **Conclusions**

Introduction

- **GSMF** key tool to understand galaxy evolution

- Two main parameters constrain the evolution of galaxies:

  -**Mass:** more massive galaxies form earlier (downsizing)

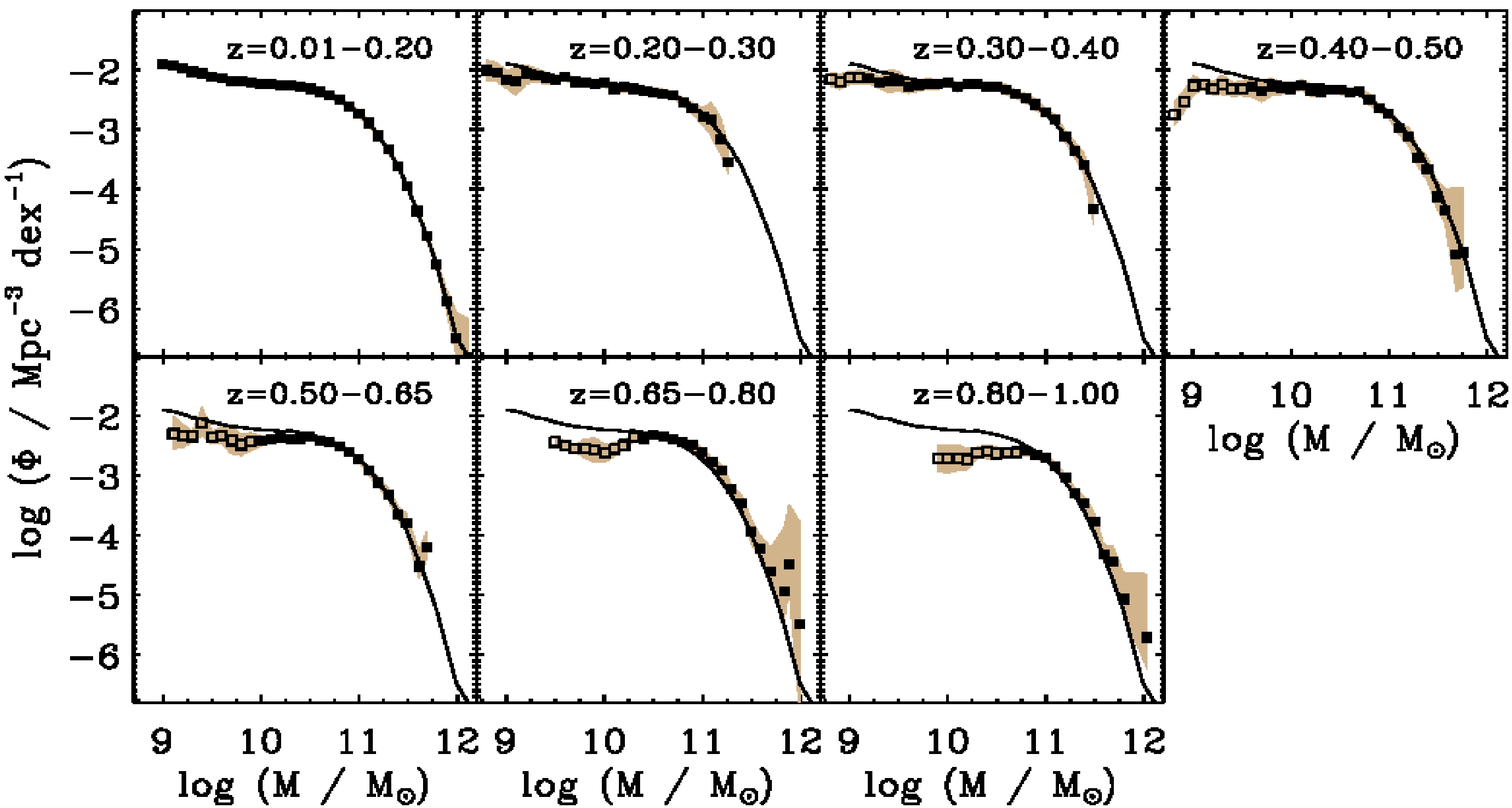
  -**SFR:** quiescent galaxies preferable occupy the high mass end of the GSMF

- Important to study the **separate evolution of different galaxy types**

- Need of **accurate SFR** indicators at high redshift

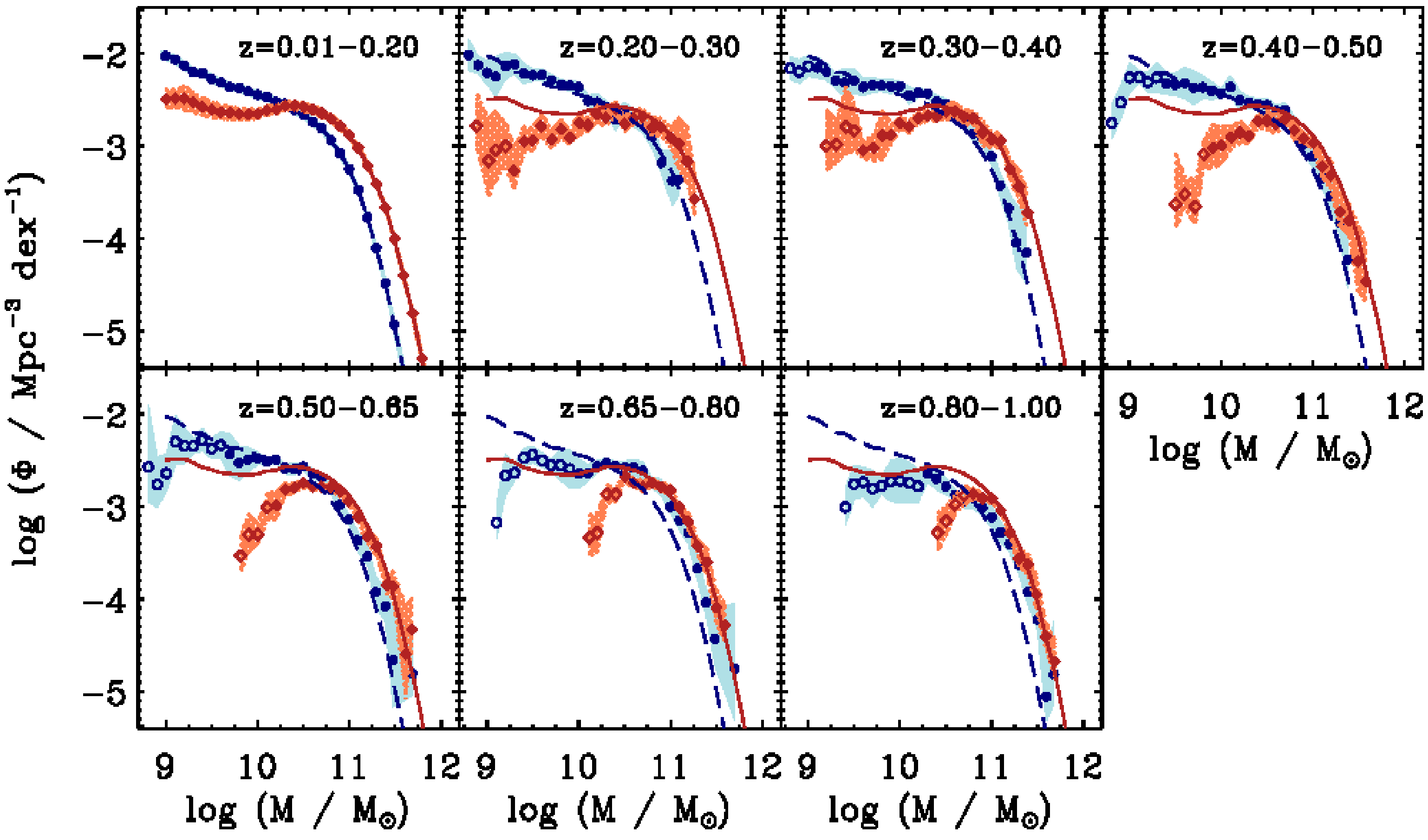
- **High-mass end** of GSMF important to constrain theoretical models: hierarchical vs monolithic

Introduction



GSMF evolution (0.>z>1.0) *Moustakas+2013*
-Massive galaxies form earlier (Downsizing)
-Little evolution of the total GSMF

Introduction



Quiescent and Star Forming galaxies separately show a much dramatic evolution!
-Massive galaxies become quiescent first,
-Less massive galaxies form stars at later times.

Introduction

- **GSMF** key tool to understand galaxy evolution

- Two main parameters constrain the evolution of galaxies:

  -**Mass:** more massive galaxies form earlier (downsizing)

  -**SFR:** quiescent galaxies preferable occupy the high mass end of the GSMF at high-z

- Important to study the **separate evolution of different galaxy types**

- Need of **accurate SFR** indicators at high-z

- **High-mass end** of GSMF important to constrain theoretical models: hierarchical merger vs monolithic collapse scenario

SFR indicators comparison

Infrared luminosity (L_{IR})

- Dust absorbes light emitted by young stars and re-emitts in the IR.
- Commonly used Kennicutt (1998)
- Theoretical derivation: Leitherer & Heckman (1995), continuos burst, Salpeter IMF, solar abundances.
- Valid only for young (10^8 yr) starbursts

$$\mathrm{SFR}\,(M_\odot\,yr^{-1}) = 4.5 \times 10^{-44}\,L_{FIR}\,(\mathrm{ergs\,s^{-1}})$$

Hα emission line luminosity

- Young (< 20 Myr) massive (> 10 $M_\odot$) OB stars ionize the molecular gas??
- Commonly used Kennicutt et al. (1994), Madau et al. (1998)
- Direct probe of the young population.
- Must correct from dust extinction.

$$\mathrm{SFR}\,(M_\odot\,yr^{-1}) = 7.9 \times 10^{-42}\,L(H\alpha)\,(\mathrm{ergs\,s^{-1}})$$

Sample:

474 galaxies COSMOS field:

PEP (100,170 μm Herschel)+**Hα** (20k, zCOSMOS survey,0.06<z<0.46)

+multiwavelenght data (NUV-MIPS, Ilbert+2010), no AGN

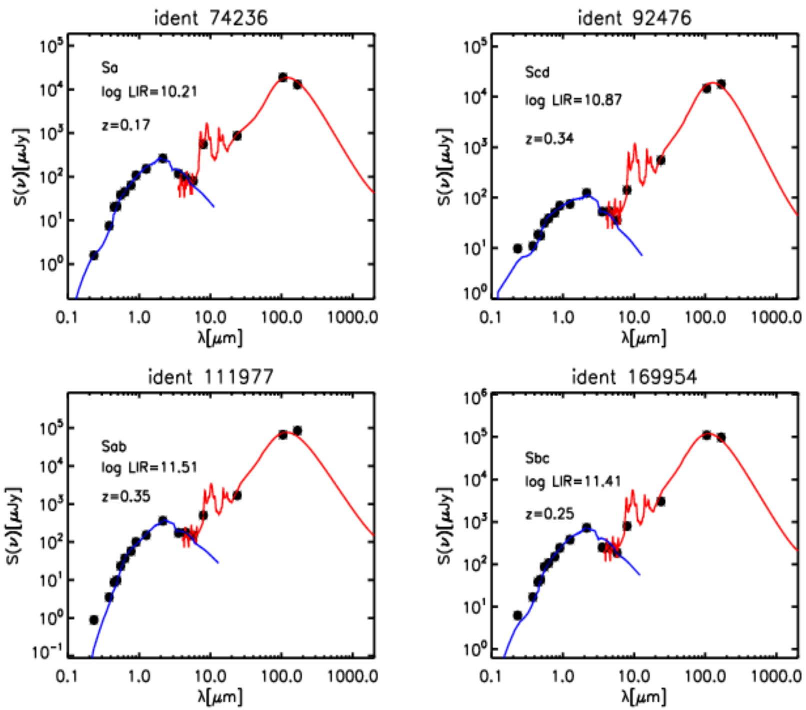
Domínguez Sánchez +2012

SFR indicators comparison

- **L_{IR}: 8-1000μm**

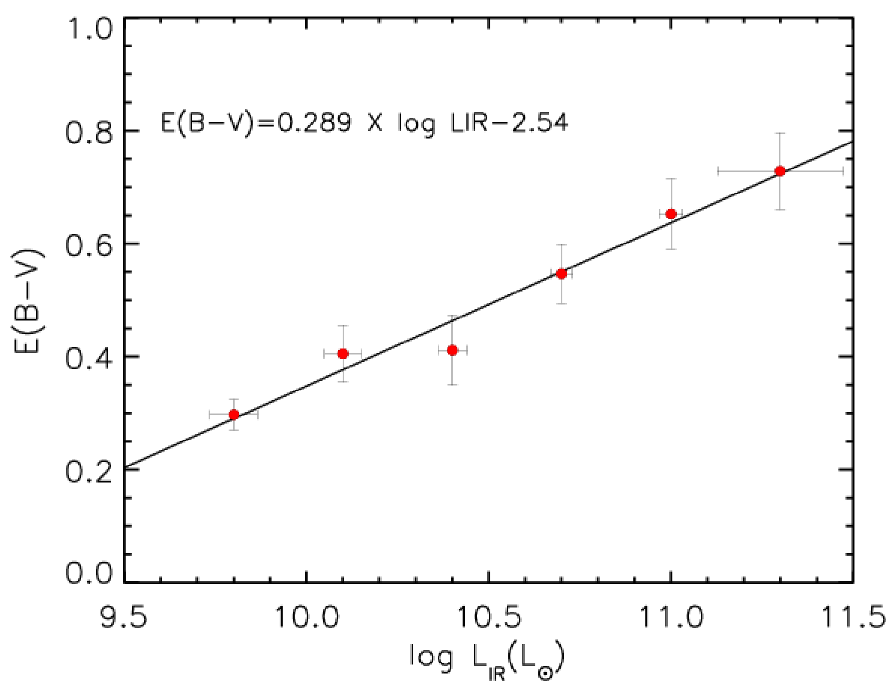
  Lephare code+ IR libraries

  (Dale, Lagache, Chary-Elbaz)



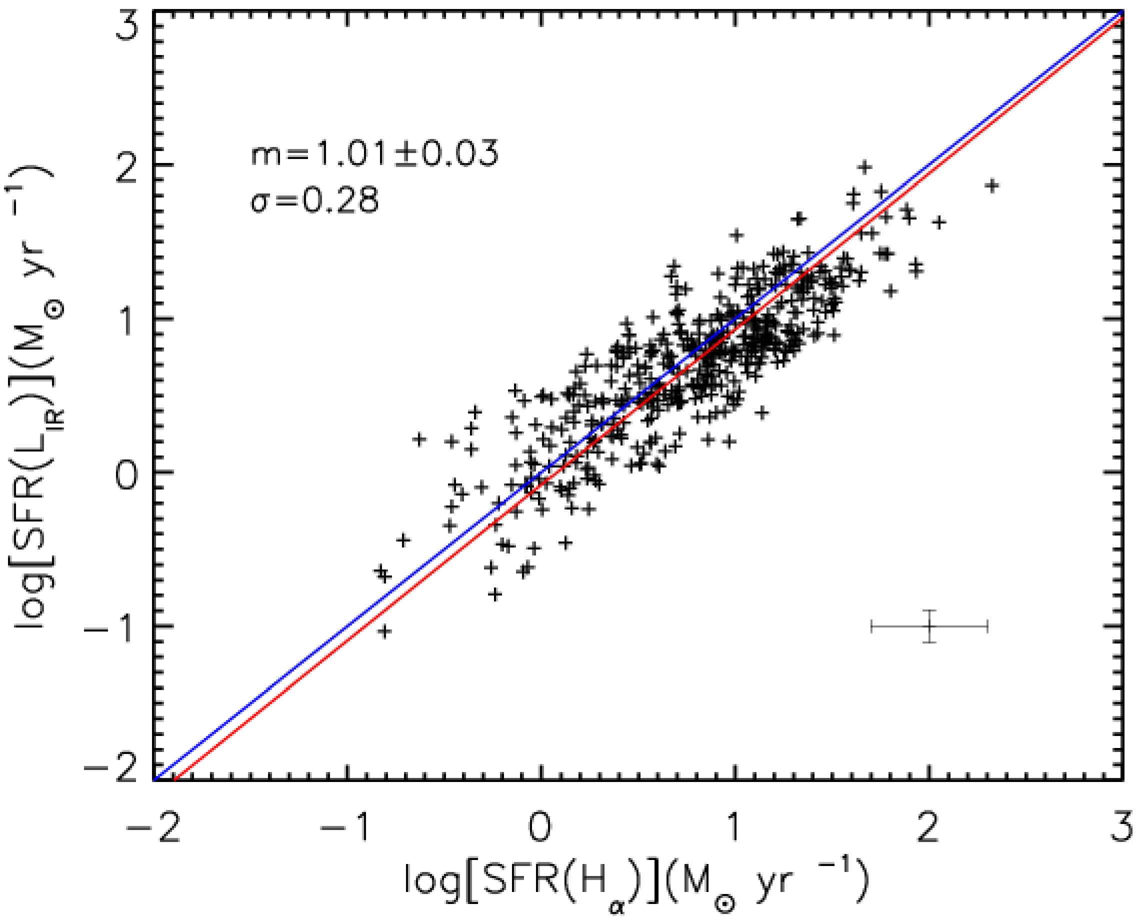
- **Hα: Dust extinction correction**

  Correlation between LIR and E(B-V)



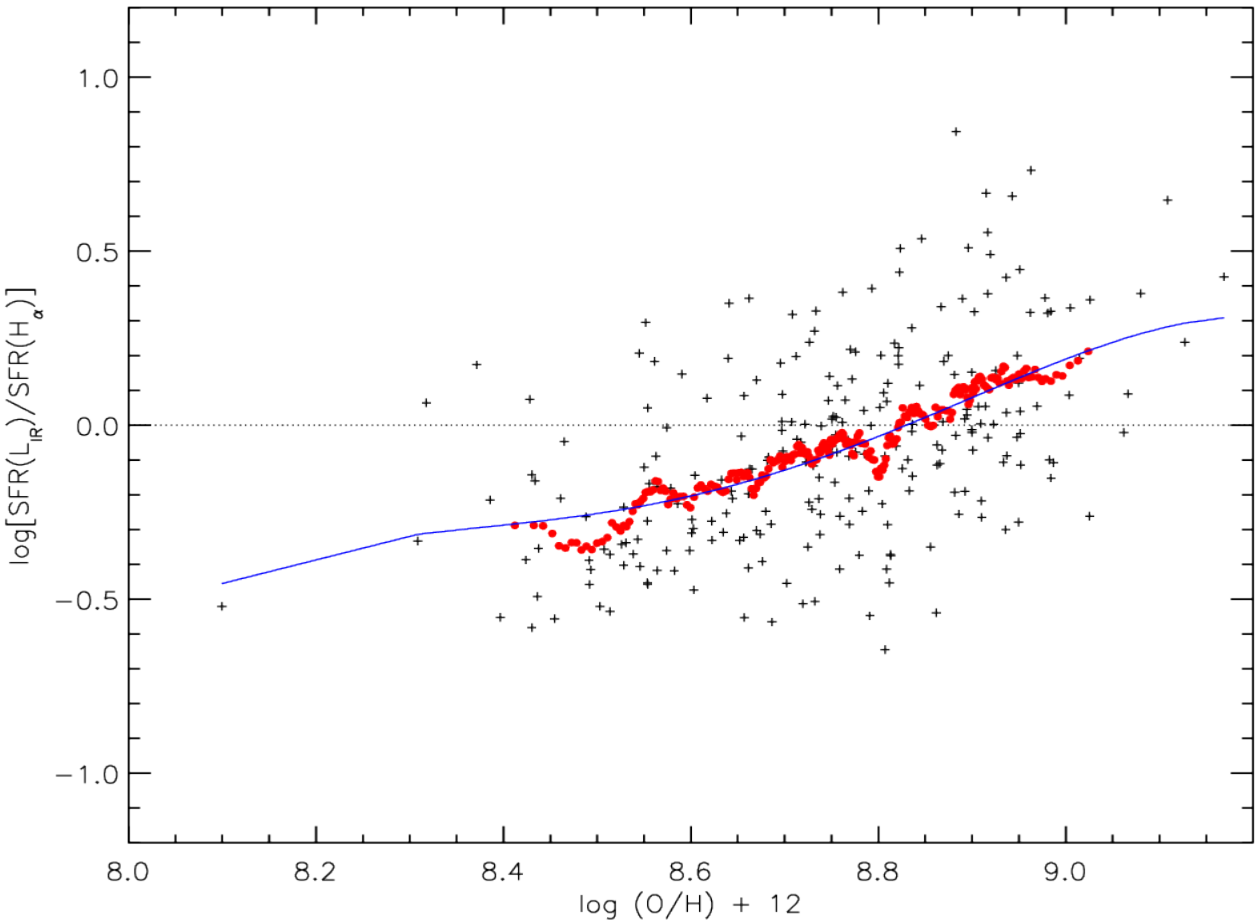
SFR indicators comparison

Excellent agreement between the two SFR indicators for the bulk of galaxies!



SFR indicators comparison

Studied main galaxy properties that could affect the SFR indicators comparison: redshift, mass, sSFR (SFR/Mass), morphological type, **metallicity**.



GSMF evolution

<u>Sample</u> :

IRAC selected ($mag_{3.6}$ < 22 mag, 95% complete)

COSMOS field: multiwavelength coverage, 2 deg^2 multiwavelength catalog:

Likelihood Ratio Technique (Sutherland & Sanders 1992)

-**IRAC** (3.6,4.5,5.8,8.0 µm, Sanders et al. 2007): **78649**, 353 only IRAC, 0.5 %

-**MIPS** 24 µm (mag_{lim} =18.5 mag, Le Floc' h et al. 2009): 11352 sources, 7%

-**Optical** (i < 26.5 mag; u^*, B_J, g^+, v_J, r^+, i^+, z^+, J, K; Capak et al. 2007): 74742 sources, 95%

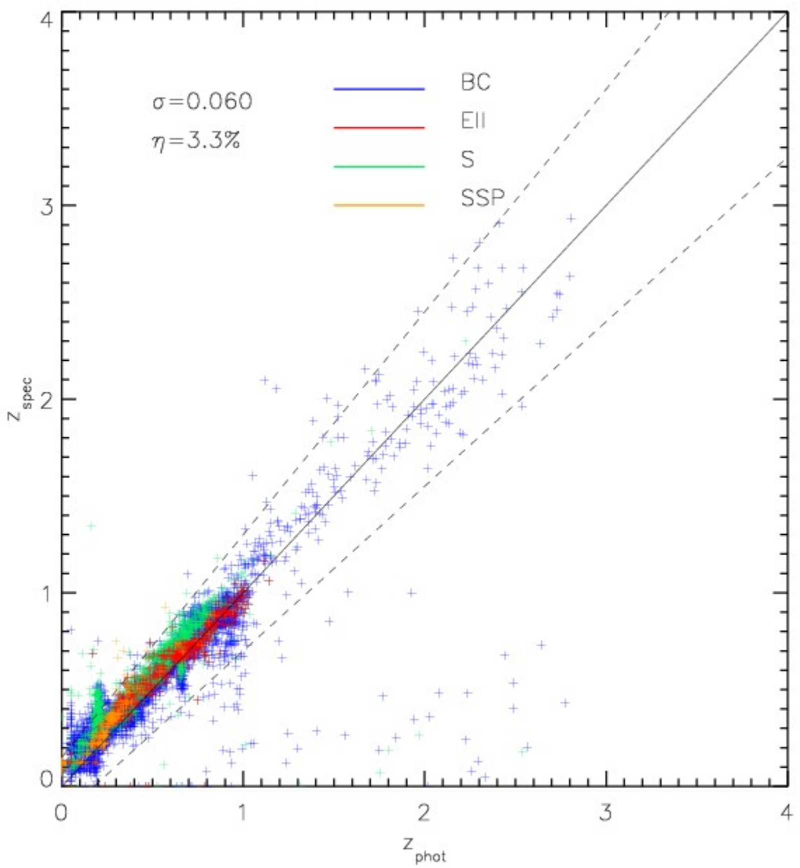
-$\mathbf{K_s}$: (B_J, i^+, z^+ , J ; 23 mag, McCracken et al. 2010): 3554 sources, 4.5%

High-z (z > 1.4) sample ~ 20000 galaxies

Domínguez Sánchez+2011

GSMF evolution

Redshift accuracy



Classification:

- **Star Forming:**

  $\log(sSFR[Gyr^{-1}]) > -0.5$

- **Intermediate:**

  $-2.0 < \log(sSFR[Gyr^{-1}]) < -0.5$

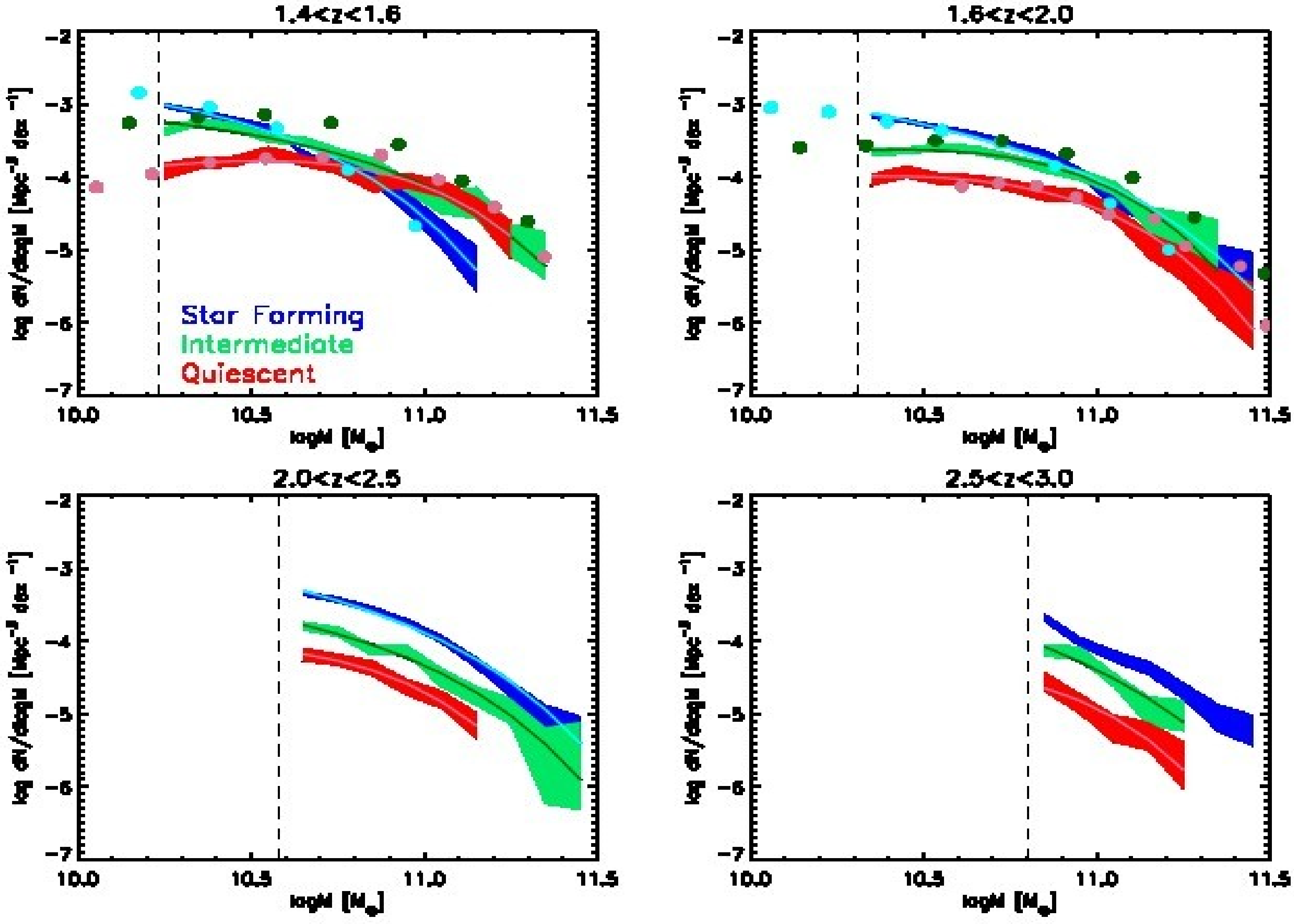
- **Quiescent:**

  $\log(sSFR[Gyr^{-1}]) < -2.0$ (no MIPS)

sSFR=SFR/Mass

Main physical parameters with **SED-fitting** method (z,mass, SFR, age, E(B-V),...)

GSMF evolution



Current work: high-mass end GSMF

Sample :

IRAC selected ($mag_{3.6}$ < 22 mag, 95% complete)

COSMOS field: multiwavelength coverage, 2 deg^2 multiwavelength catalog:

Likelihood Ratio Technique (Sutherland & Sanders 1992)

- -**IRAC** (3.6,4.5,5.8,8.0 µm,   Sanders et al. 2007): 78649, 353 only IRAC, 0.5 %
- -**MIPS** 24 µm (${mag}_{lim}$ =18.5 mag, Le Floc' h et al. 2009): 11352 sources, 7%
- -**Optical** (i < 26.5 mag; u^*, B_J, g^+, v_J, r^+, i^+, z^+, J, K; Capak et al. 2007): 74742 sources, 95%
- **-K_s**: (B_J, i^+, z^+ , J ; 23 mag, McCracken et al. 2010): 3554 sources, 4.5%

IRAC drop-out sample: Massive high-z galaxies??

Current work: high-mass end GSMF

Sample :

353 only-IRAC

+**ULTRA-VISTA** (nIR: YJHK; McCracken+2012)

+ opt. Bands (ubvriz; Ilbert+2010)

+**Herschel** (FIR : 100-500 μm)

↓

-**143** ULTRA-VISTA (49 flag Sextractor=0) → 34 in common!

-**62** Herschel (S/N >3.0 in at least one band)

Current work: high-mass end GSMF

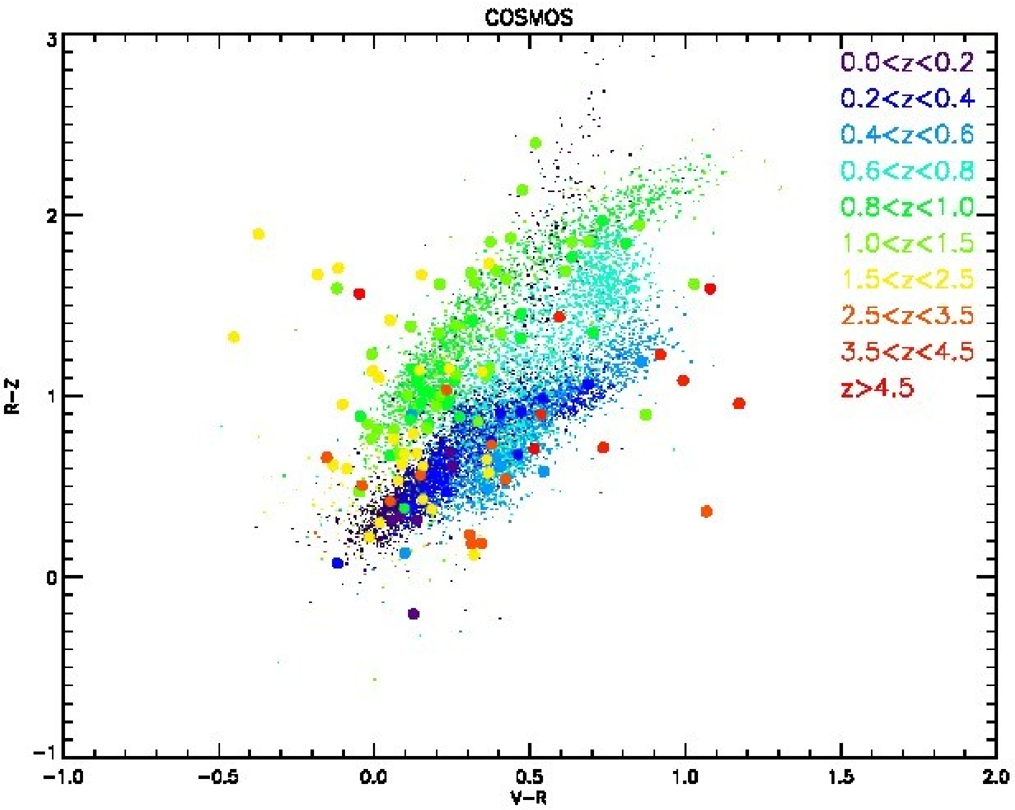
SED-fitting +*Lephare* code

- **Photometric redshifts:**
  COSMOS_SED
  (Domínguez Sánchez+2011)

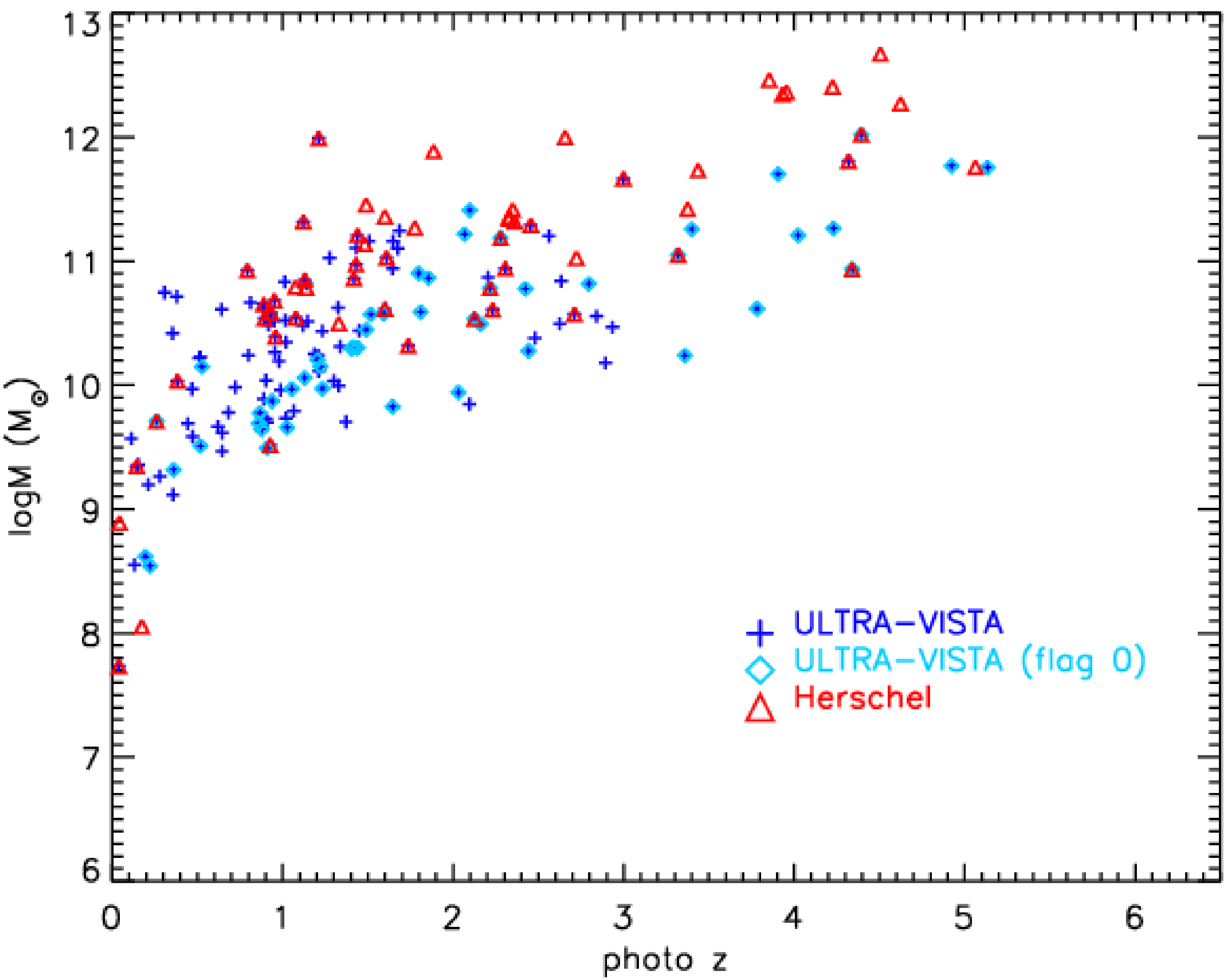
  No z_spec to compare,
  color-color plots

- **Stellar masses:**
  BC03 library

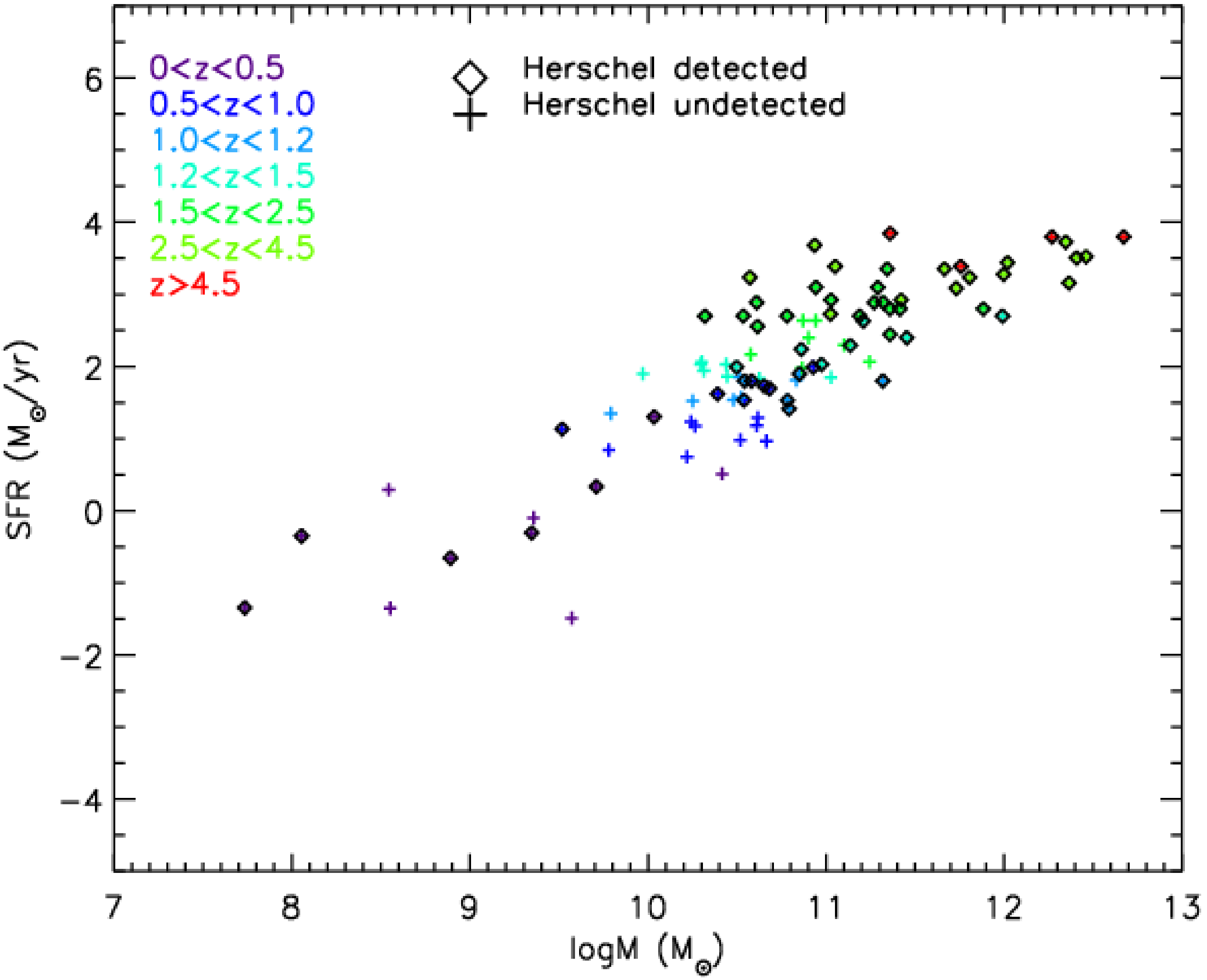
- **SFR(IR):**
  Chary Elbaz library
  (DS+2012)



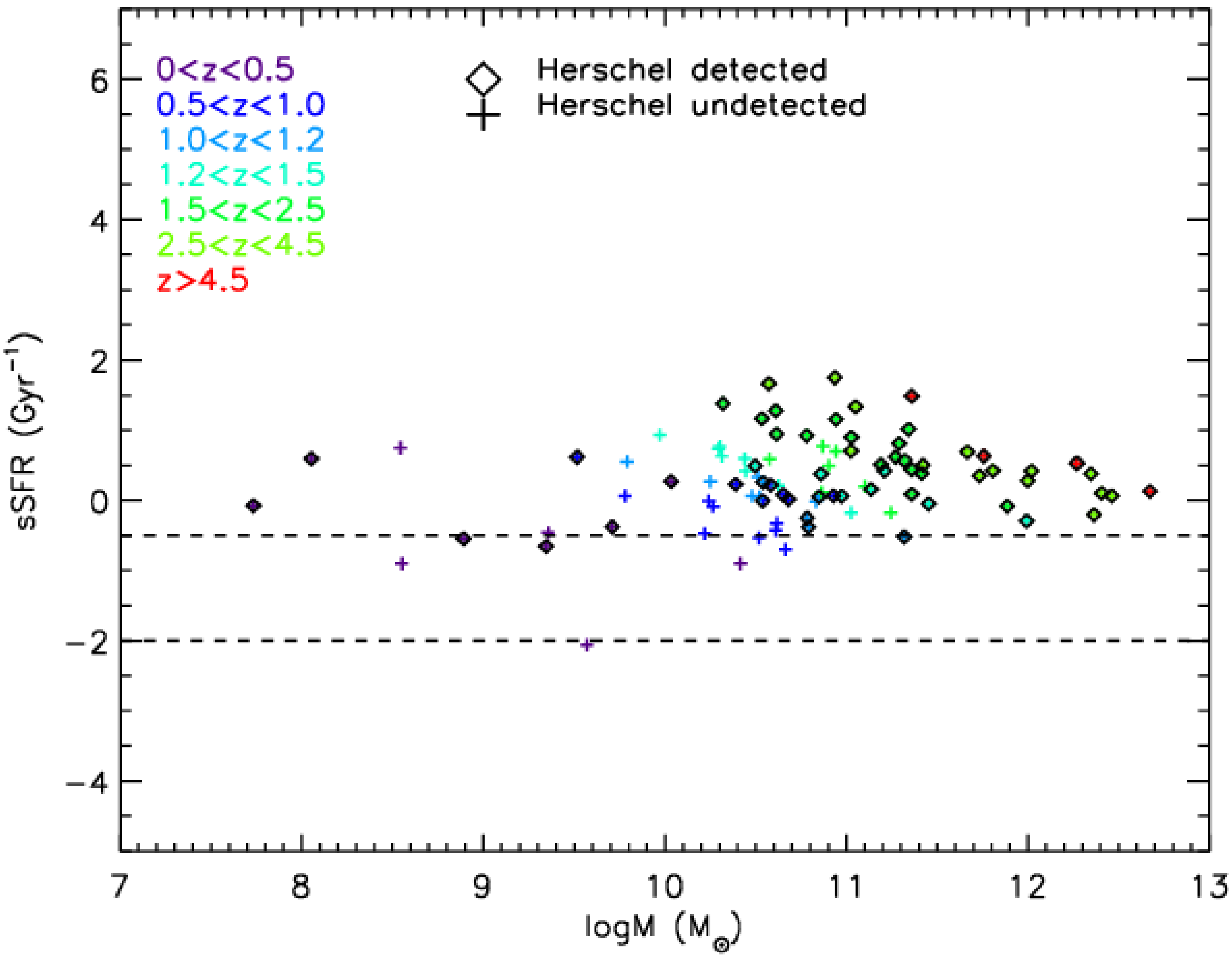
Current work: high-mass end GSMF



Current work: high-mass end GSMF



Current work: high-mass end GSMF



Conclusions

- **SFR** and **mass** are two fundamental parameters to study galaxy evolution
- **LIR accurate SFR indicator** (DS+2012):

  importance of FIR data (Herschel)
- **GSMF evolution** (DS+2011):

  different evolution of galaxies with different sSFR; massive galaxies become quiescent first; downsizing
- Looking for **high-mass galaxies at high-z** (DS in prep.):

  IRAC-drop out+deep nIR (ULTRA-VISTA)&FIR (HERSCHEL) data
- Preliminary results: photo-z, masses, SFR(IR): already massive galaxies at z > 3; no quiescent galaxies (selection effects)
- **On-going:** morphology (CANDELS), focus on high-z sample, spectroscopic follow-up of high-z candidates?

Thank you for you attention!

Comments/Suggestions/Questions