The evolution of the Galaxy: Stellar Mass Function
towards the high-mass end at high redshifts

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Outline

- Introduction
- Past research
  - SFR indicators comparison: $L_{IR}$ vs $H\alpha$
  - 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 results:
    - $z_{phot}$, 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 preferably 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
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

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- Two main parameters constrain the evolution of galaxies:
  - **Mass**: more massive galaxies form earlier (downsizing)
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- Important to study the *separate evolution of different galaxy types*

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

Infrared luminosity ($L_{\text{IR}}$)

- Dust absorbs light emitted by young stars and re-emits in the IR.
- Commonly used Kennicutt (1998)
- Valid only for young ($10^8$ yr) starbursts

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

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.

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

Sample:

474 galaxies  COSMOS field:
PEP (100,170 μm Herschel)+Hα (20k, zCOSMOS survey,0.06<z<0.46)
+multiwavelength data (NUV-MIPS, Ilbert+2010), no AGN

Domínguez Sánchez +2012
SFR indicators comparison

- $L_{IR} : 8\text{-}1000\mu m$

*Lephare* code+ IR libraries

(Dale, Lagache, Chary-Elbaz)

- $H\alpha$: Dust extinction correction

Correlation between LIR and $E(B-V)$

$$E(B-V) = 0.289 \times \log L_{IR} - 2.54$$
SFR indicators comparison

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

\[ m = 1.01 \pm 0.03 \]
\[ \sigma = 0.28 \]
SFR indicators comparison

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

Sample:

IRAC selected \((\text{mag}_{3.6} < 22 \text{ mag, 95\% complete})\)

COSMOS field: multiwavelength coverage, 2 deg\(^2\) multiwavelength catalog:

Likelihood Ratio Technique (Sutherland & Sanders 1992)

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

High-z \((z > 1.4)\) sample \(\sim 20000 \text{ galaxies}\)

Domínguez Sánchez+2011
GSMF evolution

Redshift accuracy

Classification:

- **Star Forming:**
  \[ \log(\text{sSFR[Gyr}^{-1}]) > -0.5 \]

- **Intermediate:**
  \[ -2.0 < \log(\text{sSFR[Gyr}^{-1}]) < -0.5 \]

- **Quiescent:**
  \[ \log(\text{sSFR[Gyr}^{-1}]) < -2.0 \text{ (no MIPS)} \]

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

\[ \text{sSFR=}\frac{\text{SFR}}{\text{Mass}} \]
GSMF evolution
Current work: high-mass end GSMF

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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
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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 your attention!
Comments/Suggestions/Questions