Galaxy evolution at high z from mass selected samples.
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Thanks to:
High-z@Rome: E. Giallongo, N. Menci, A. Cavaliere, Donnarumma, I., A. Grazian, S. Salimbeni, C. De Santis, S. Gallozzi


M. Dickinson (HDFN-Nicmos data)
HDFS: $K_{AB} < 25$

Data in common with FIRES (P. van Dokkum’s talk)

$4 \text{arcmin}^2$

$\sim 100 \text{hr ISAAC JHK+WFPC-2}$

302 galaxies $K_{AB} \leq 25$

730 galaxies $I_{AB} \leq 27.2$

60 spectr. redshift

$60 \text{spectr. redshift}$

"photometric" redshift

$z=1$

$M(\text{star})$, SFR, Dust, Z

$202 \text{galaxies}$

$250 \text{galaxies}$

$443 \text{spectr. redshift}$
Galaxy Stellar Masses at high $z$: dealing with incompleteness

"Strict" selection limit

Correction for incompleteness

$$f_{\text{obs}}(z, M) = \frac{\int_{k_{\text{min}}}^{k_{\text{max}}} k^{-n-2} e^{-\frac{k(z)}{\mu(z)d_L(z)} \frac{dL(z)}{dz}} \, dk}{\int_{k_{\text{min}}}^{k_{\text{max}}} k^{-n-2} e^{-\frac{k(z)}{\mu(z)d_L(z)} \frac{dL(z)}{dz}} \, dk}$$

$$= \frac{\Gamma(n + 1, \frac{D_L^2(z)}{\mu(z)d_L(z)} \frac{M}{k_{\text{min}}}) - \Gamma(n + 1, \frac{D_L^2(z)}{\mu(z)d_L(z)} \frac{M}{k_{\text{max}}})}{\Gamma(n + 1, \frac{D_L^2(z)}{\mu(z)d_L(z)} \frac{M}{k_{\text{min}}}) - \Gamma(n + 1, \frac{D_L^2(z)}{\mu(z)d_L(z)} \frac{M}{k_{\text{max}}})}$$

$z=0.7$
Galaxy Stellar Masses at high $z$: dealing with incompleteness
The evolution of the stellar mass: the HDFS + K20 survey view
The evolution of the Stellar Mass Density
The evolution of the Stellar Mass Density

- ~80% at $z=1$
- ~40% at $z=2$
- ~10-40% at $z=3$

Data from:
- Brinchmann & Ellis 00
- Dickinson +03
- Fontana +03
- Drory +04
- Fontana +04
- Glazebrook +04
- Consistency with integrated cosmic SFR
The Galaxy Stellar Mass Function: the K20 survey data
A comparison between K20 and MUNICS Mass Functions:

1) Astronomy

MUNICS (Drory+ 04):
- Mostly photo-z
- $K<18.7$
- 3600 arcmin
- 5000 objects

K20 (A.F.+04):
- 95% spec. Complete
- $K<20$
- 470 objects
A comparison between K20 and MUNICS Mass Functions:

2) Anthropology

**MUNICS**

The total normalization decreases by a factor of 2, the characteristic mass (the knee) shifts toward lower masses, and the bright end therefore steepens with redshift.

The amount of number density evolution is a strong function of stellar mass, with more massive systems showing faster evolution than less massive systems.

**K20**

Up to $z \sim 1$, we observe only a mild evolution of the GSMF and of the corresponding global stellar mass density. .. indicate a decrease by 20-30% of the number density of objects around $M=10^{11} M_{\odot}$ ..

We suggest that more massive galaxies appear to reach near completion first, while less massive ones keep growing in mass till later times.
MUNICS: number density: \( N(M>10^{11} M_{\odot}) \)

K20: stellar mass density: \( N(M>10^{11} M_{\odot}) \)
??? #2: Trend with Mass

![Graph showing trend with mass](image)

- **K20 0.2 ≤ z < 0.7**
  - MUNICS z = 0.5

- **K20 0.7 ≤ z < 1.0**
  - MUNICS z = 0.9

- **K20 1.0 ≤ z < 1.5**
  - MUNICS z = 1.1
Mass/Light in “spectral” Early Type
Massive galaxies originate from the merging of clumps which have collapsed in biased, high-density regions of the density field, hence at higher redshift.

The star formation histories of the population contained (today) in massive galaxies peaks at higher redshift compared to that of smaller galaxies.
The Galaxy Stellar Mass Function: dependence of the spectral type

- Up to $z \sim 1$, dominated by early spectral types
- At $z > 1$, at least 30% due to star-forming galaxies
Physical properties of $z>2$ galaxies in the HDFS: Ages & Specific Star-Formation rates

$\frac{\text{SFR}}{\text{MASS(star)}} \geq 3x$ higher than local: mass-doubling time 2.5 Gyr

$\sim 70\%$ star—forming

$\leq 30\%$ passively evolving

$z=0.5, z=1$
What sources dominate the bright side of the B-band Luminosity Function?
The Luminosity Function of red galaxies at high $z$
(Giallongo +04, ApJ subm)

Composite sample (K20 area+HDFS+HDFN): I-selected + HKselected: 1434 gals

Criteria #1:
Color selection
$S0$ evolutionary tracks
Criteria #2: Color by-modality
Criteria #3: Selecting passive objects from spectral fitting
**Luminosity Functions**

**Criteria #1:**

**Color selection**

**S0 evolutionary tracks**

**Global (all-z) Maximum Likelihood**

Parametrized evolution:

\[ M^*(z) = M^*(0) - \delta \lg(1+z) \]

\[ \phi(z) = \phi(0) (1+z)^\gamma \]

\[ \phi(z) \rightarrow \gamma = -2.23 \pm 0.34 \]

\[ M^*(z) \rightarrow \delta = 2.72 \pm 0.66 \]

\[ z = 0.5 \rightarrow 2 \]

\[ \Delta M^* = 0.8 \text{ mags} \]

\[ \Delta M(S0) = 1.3 \text{ mags} \]
Criteria #3: Selecting passive objects from spectral fitting

\[ \phi(z) \rightarrow \gamma = -3.40 \pm 0.45 \]
\[ M^*(z) \rightarrow \delta = 3.20 \pm 0.9 \]
\[ z = 0.5 \rightarrow 2 \]
\[ \Delta M^* = 0.8 \text{ mags} \]
\[ \Delta M(S0) = 1.3 \text{ mags} \]
Number density of red galaxies

PLE is ruled out

O: “bright” (-23<M<-22)
Δ: “faint” (-21.5<-20.6)
What is the picture?

- GSMF mild evolution up to $z=1$, then much faster
- GSMF: less evolution in more massive

- Fraction of SF galaxies in massive sample increase with redshift
- SFR/M 3x higher than at $z=1$: not much more
- LF of red galaxies anti-evolves with $z$

- PLE ruled out at $z=1.5$ in lumden, not in stellar mass $\Rightarrow$ change of physical properties
- Rise of the stellar mass density is consistent with integrated cosmic SFR
Menci et al. 2002
Menci et al. 2004
PLE (Pozzetti et al. 2003)

Nagamine, Cen & Ostriker 01

Granato et al. 2004
Cole et al. 2000
Somerville et al. 04
Somerville et al. 04
Lessons learned....I

1) Models differ by a significative amount.

↓ “Robust predictions” of CDM models are not robust

↑ Observations $z>2$ are crucial!

PLE is not ruled out
Lessons learned...II

2) “THINGS MAKE SENSE”:
i.e., differences among the
models are due to the
differences in the treatment of
physical processes:

“quiescent” models do not
produce enough stars:
starburst due to interactions &
merging seem to be required

Treatment of dynamical friction:
S03 Standard DF
S03b “reduced merging” DF
Galaxy encounters in hierarchical structures: “fly-by” starburst

Cavaliere & Vittorini 2000, Menci+ 2003, Menci+ 2004a, Menci et al 2004b:

The gravitational torques in fly-by encounters destabilizes a fraction $f_g$ of cool gas

$f_g$ from kinematical parameters:

$$f_g \propto \Delta j / j$$

- $1/8 \ f_g$ feeds BH activity $\rightarrow$ QSO
- $3/8 \ f_g$ provides a starburst with short timescale $\rightarrow$ starburst
- well-motivated physical mechanism
- no new free parameters
- keep consistent with as many observables as possible
- minimizes changes to other features of the models
$-1/8 \ fg$ feeds BH activity $\rightarrow$ QSO matches QSO activity:

In the optical (Menci +03, ApJL 587, 63)

Galaxy encounters in hierarchical structures: the effect on the K20 redshift distribution

\[ \langle z \rangle = 1.5 \]
Galaxy encounters in hierarchical structures: “fly-by” starburst

Cavaliere & Vittorini 2000, Menci+ 2003, Menci+ 2004:

- well-motivated physical mechanism
- no new free parameters
- keep consistent with as many observables as possible
- minimizes changes to other features of the models

- suggests connection between AGN & massive galaxies
Galaxy Stellar Masses at high $z$: uncertainties
Galaxy Stellar Masses at high z: uncertainties (systematic)
Galaxy Stellar Masses at high $z$: uncertainties (statistical)
The K20 Galaxy Stellar Mass Function: evolution with respect to local
Gravitational instability scenario

CDM “mantra” : ‘in this theory primordial density fluctuations collapse and merge continuously under the effect of gravitational instability to form more and more massive objects’.

F. Governato et al, astro-ph 01005443