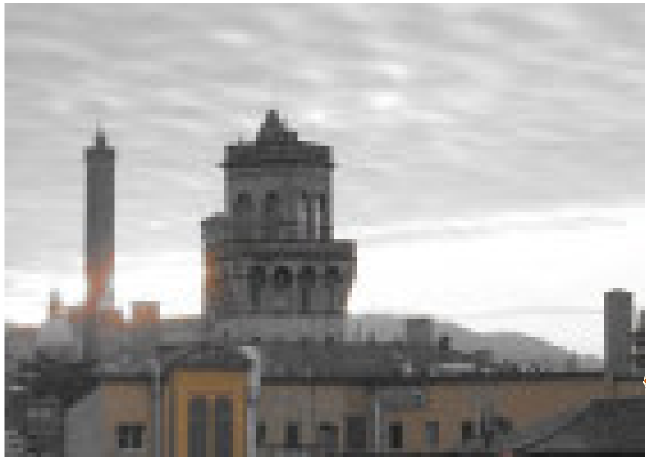
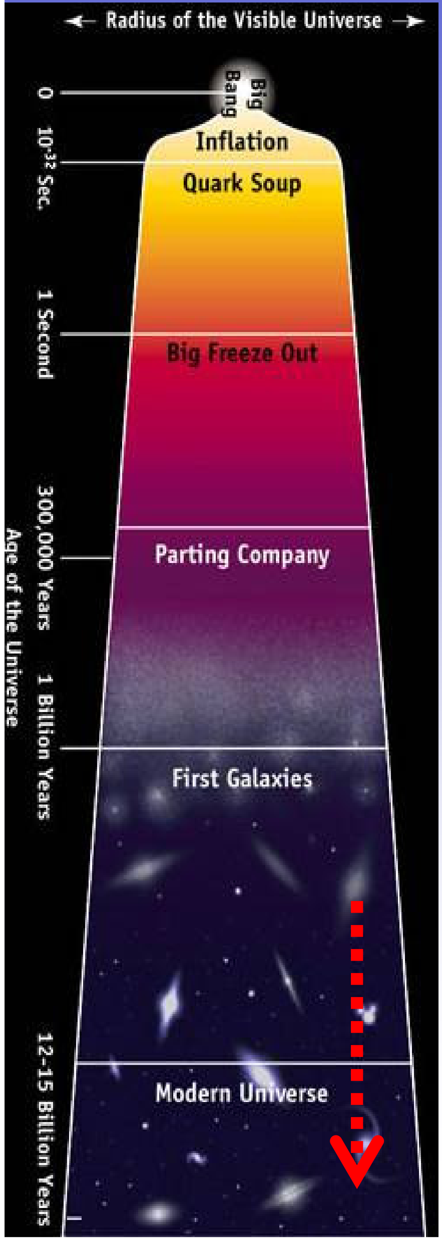


"Observational surveys: the NIR perspective"

Lucia Pozzetti

INAF Osservatorio Astronomico di Bologna

Photometric and redshift surveys: a key tool for cosmology



Follow the evolution of Galaxies from high-z to the local universe to understand their nature:

- how they formed
- how they evolve
- What are the main physical mecanisms at play and the associated timescales

Main steps of a survey:

1. Multi-band photometry
2. magnitude selection (+ colour selection)
3. Spectroscopy --> redshift is derived from the spectrum (from absorption or emission lines)

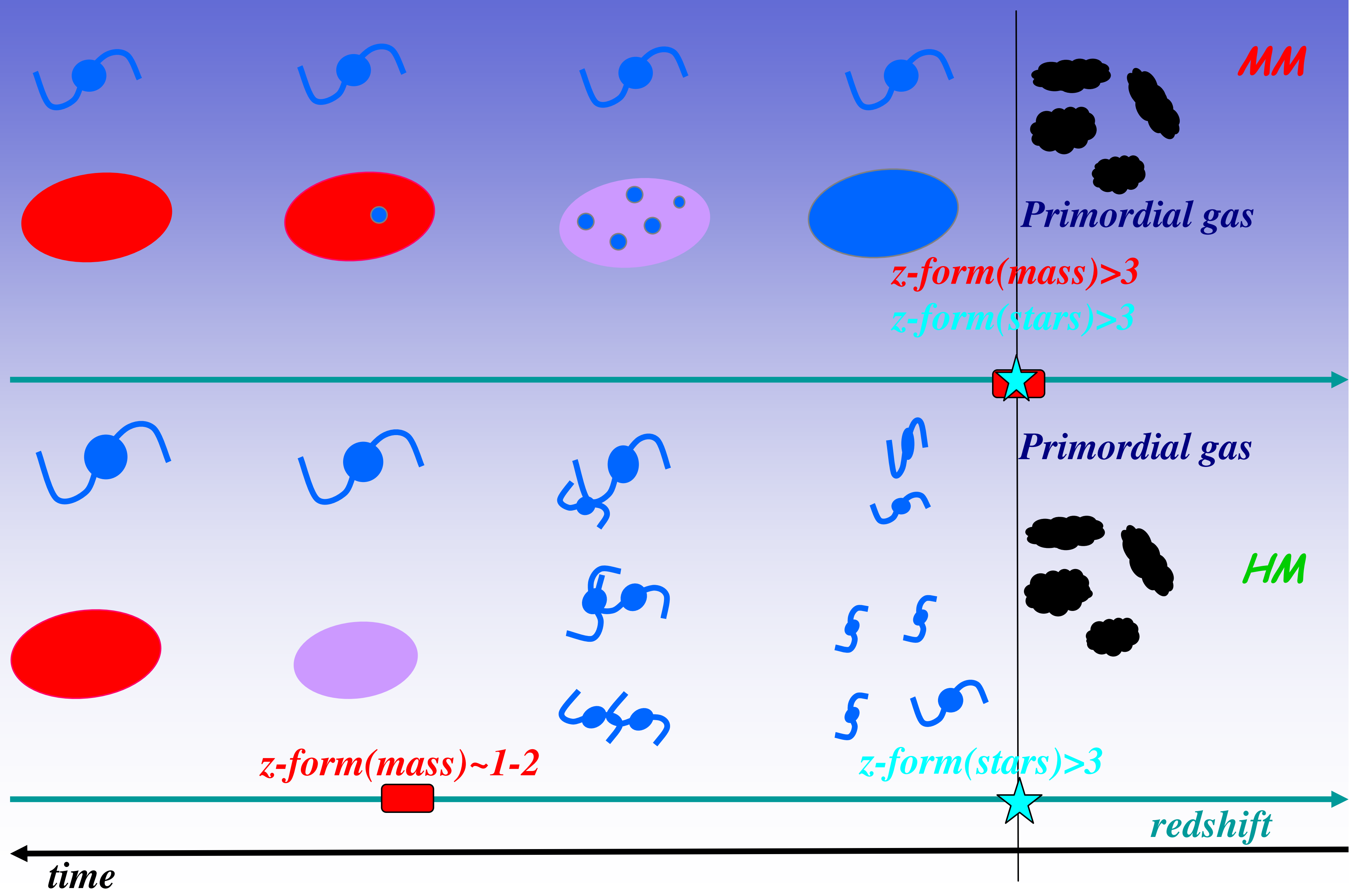
➡ the distance is derived from the redshift and physical properties like Luminosity, Mass, SFR can be determined once the distance is known

NIR surveys (1-5 μm):

- **Evolution of early-type (red & old) galaxies**
- **Galaxy stellar mass assembly history**

- **compare with models of galaxy formation and evolution**

Monolithic vs. Hierarchical



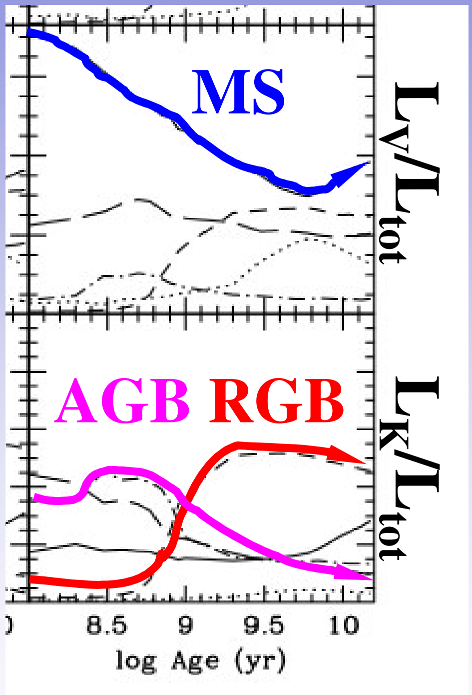
The near-infrared (near-IR)

near-IR (1-5 μm) :

Broad-bands:

z (0.9 μm), J (1.1 μm), H (1.6 μm), Ks (2.1 μm) from ground & space

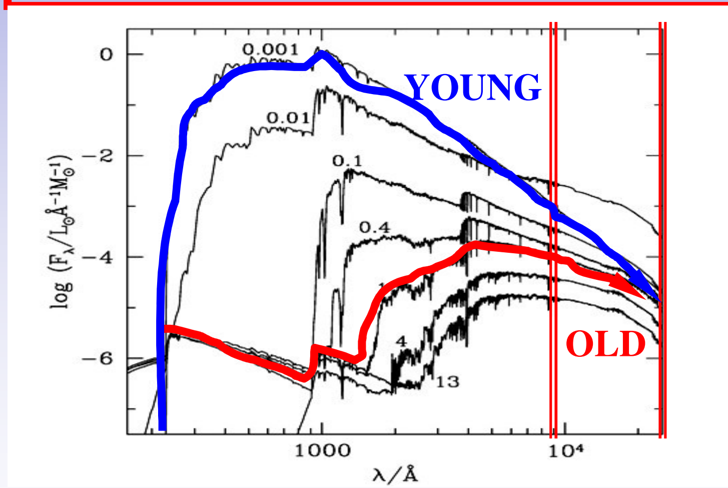
3.6, 4.5, 5.8, 8 μm micron from space (SPITZER +IRAC)

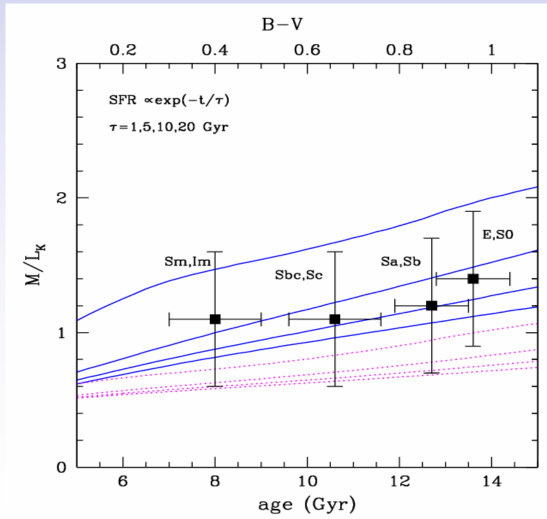


Emission:

From intermediate-low mass stars RGB (+AGB)

Dominate bolometric emission at old ages (> 1 Gyr)





(Madau, Pozzetti, Dickinson 1998)

Advantages:

- *M/L_K mildly depends on colours and galaxy SED and SFH*
- *Less affected than optical by dust extinction*

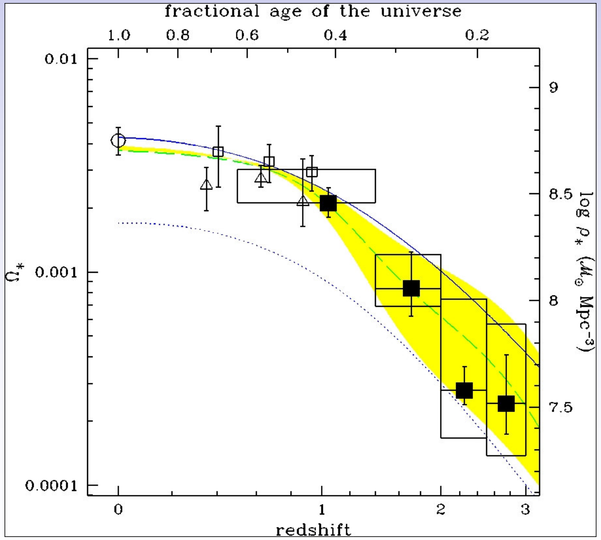
Surveys: near-IR vs. UV/optical

Advantages of a near-IR-selected sample (1-5 mm):

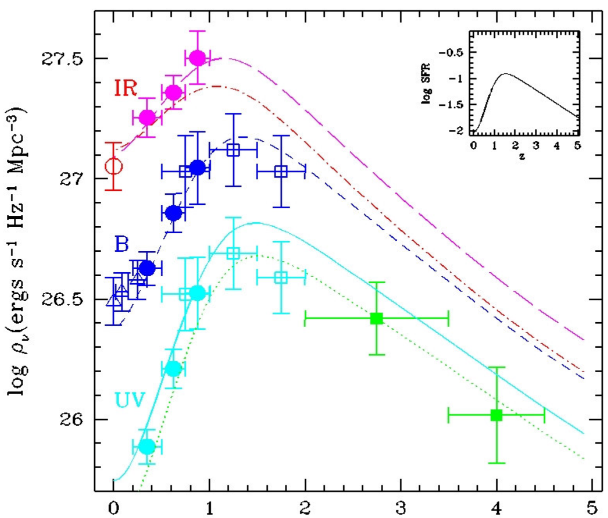
- o *Less affected by dust extinction*
- o *More sensitive to the stellar mass / old stellar populations*
- ➢ *To search massive old high-z (z>1) ellipticals (EROs, BzK)*
- ➢ *To follow the history of mass assembly z~2*
- ➢ ***Surveys: 2MASS, UKIDSS, K20, MUNICS, GDDS, GMASS, ..***

Advantages of a UV/optical-selected sample (1500-9000Å):

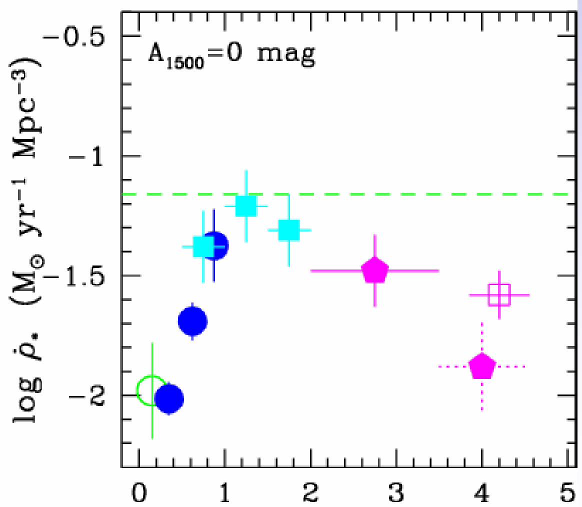
- o *Sensitive to the Star Formation / young stellar populations*
- ➢ *To search star forming objects at low and high-z (LBGs)*
- ➢ *To probe the star formation history*
- ➢ ***Surveys: SDSS, 2dFGRS, HDF, FDF, VVDS, DEEP2, zCOSMOS, …***



Stellar Mass Density
(Dickinson et al. 2003)

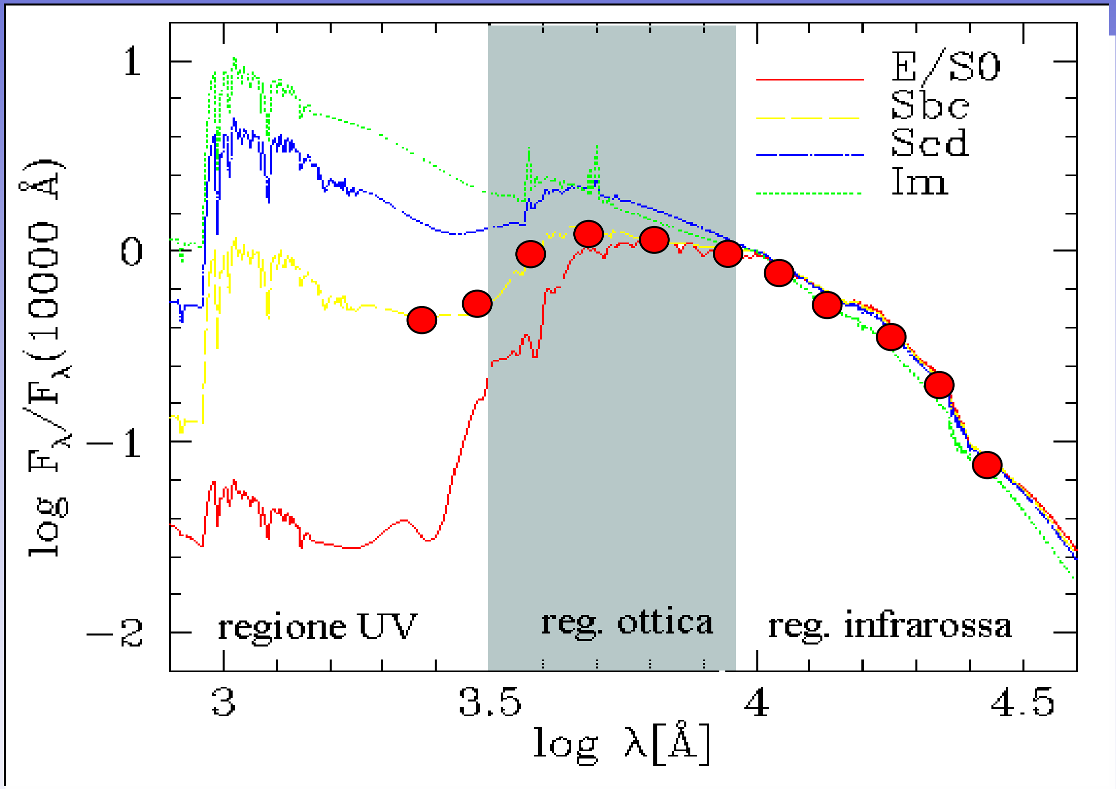


LD + SFH
(Madau, Pozzetti, Dickinson 1998)



Star Formation History
(Madau, et al. 1996)

HyperZ Mass



Estimate of the **Stellar Mass content** from multi-band photometry

(χ^2 SED fitting technique)

$$Mass-processed(t) = \int SFR(t) * dt$$

$$Mass-star(t) = \int SFR(t) * dt * (1-R(t))$$

Assuming a population synthesis model (Bruzual & Charlot 2003, Maraston 2005, Pegase ….)

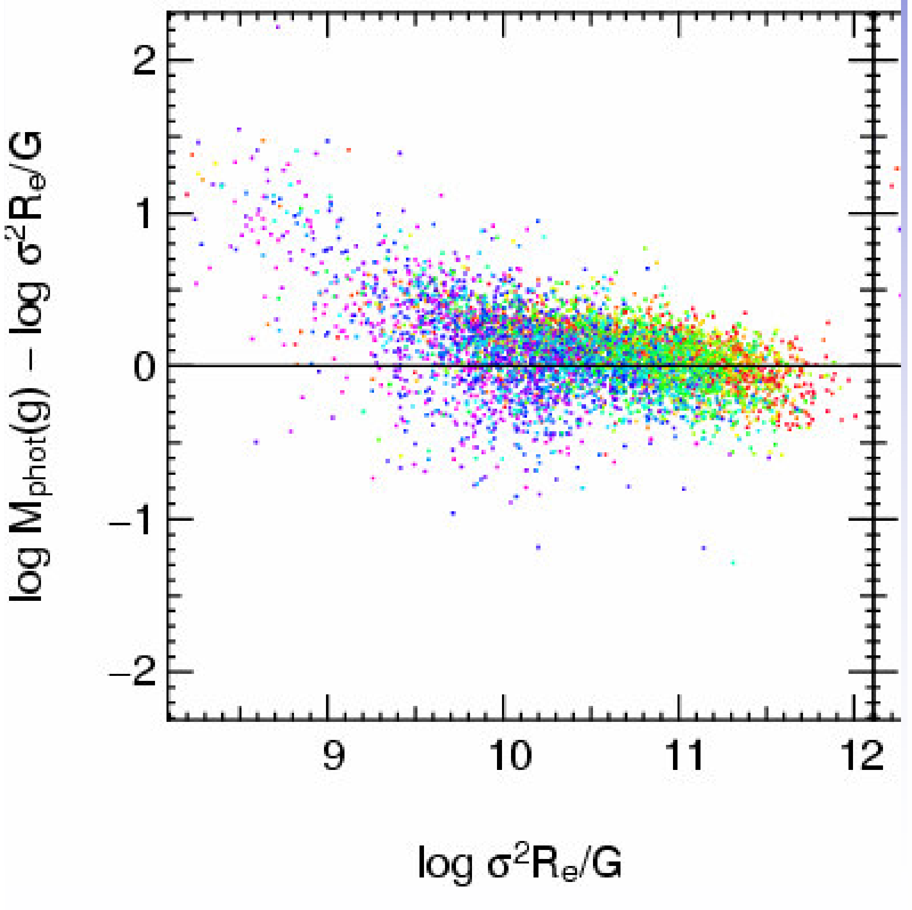
Assuming a Star Formation History (e.g. exponential: $SFR(t) = \frac{M_{gal}}{\tau} e^{-(t/\tau)}$)

Z, IMF, dust (Calzetti/SMC): A_V

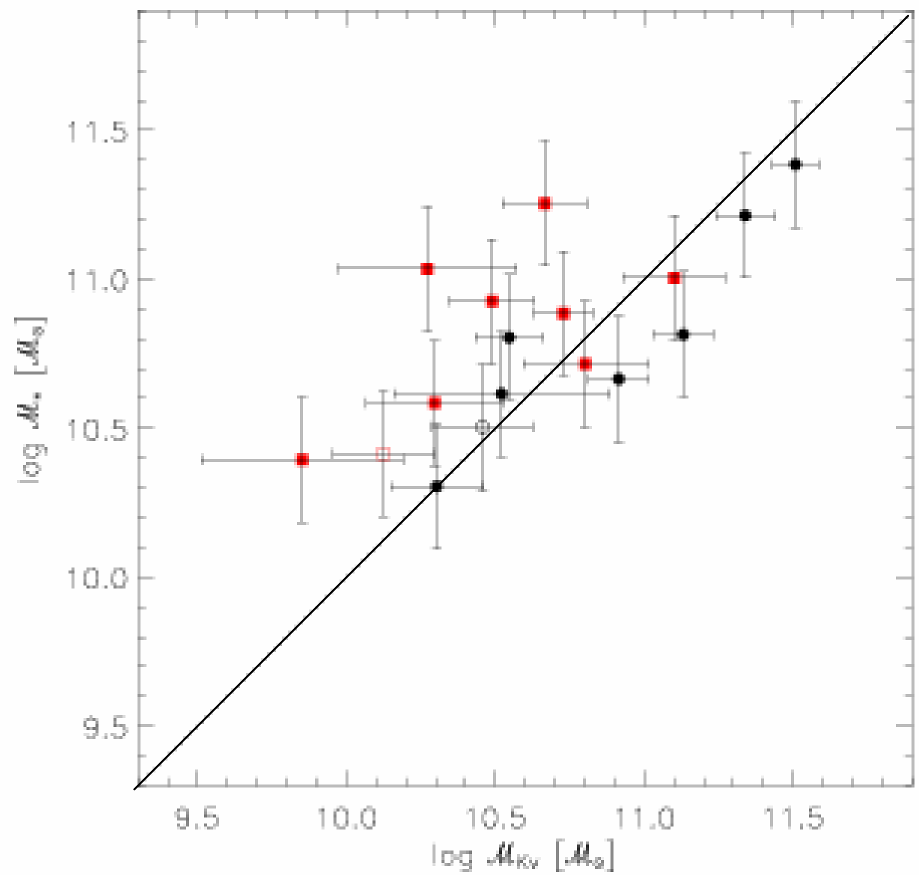
Stellar Mass vs. Dynamical Mass

Roughly consistent with dynamical Masses derived using velocity-dispersion in HR spectra

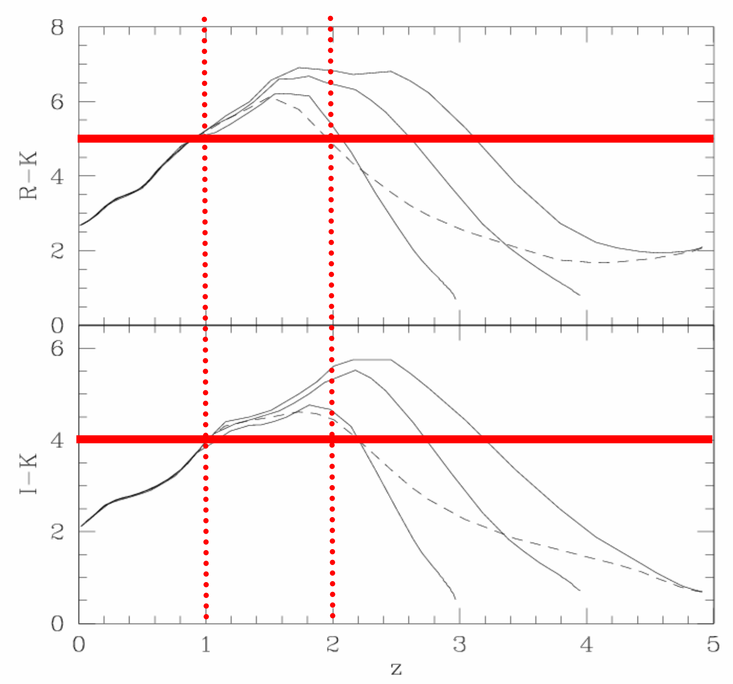
Drory et al. 04



Di Serego et al. 05



EROs & BzK colour selection



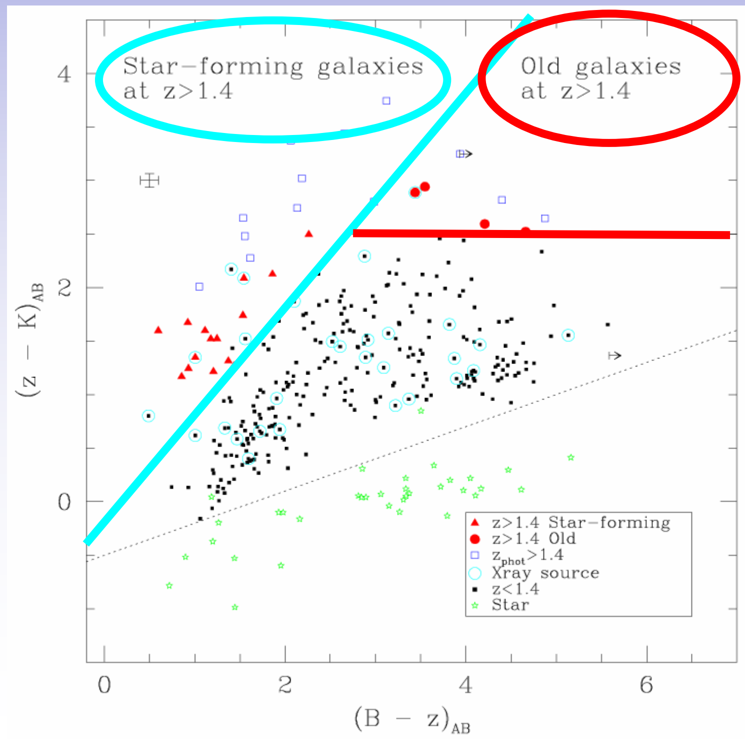
EROs: *Objects selected with extremely red colors:*

R-K>5 o I-K>4 (Hu & Ridgway 1994). Candidate to be:

1-Ellipticals at 1<z<2 BUT also

2-dusty SB at z>1 or

3-absorbed AGN

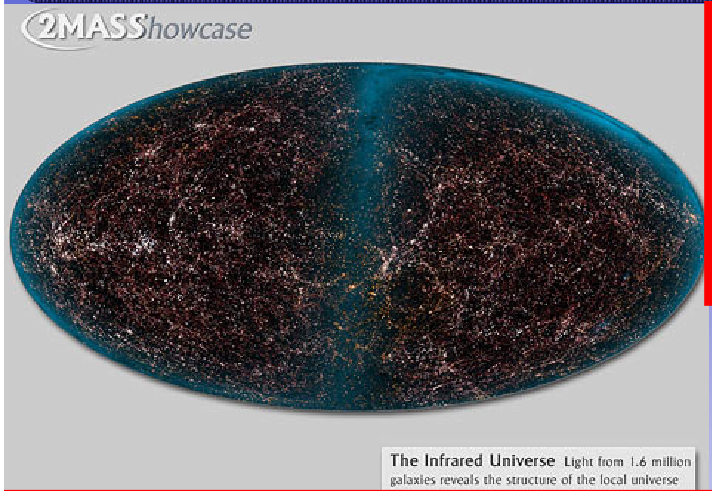


BzK (Daddi et al. 2004):

Colour criteria to select star forming (sBzK) and old-passive (pBzK) galaxies at 1.4<z<2.5

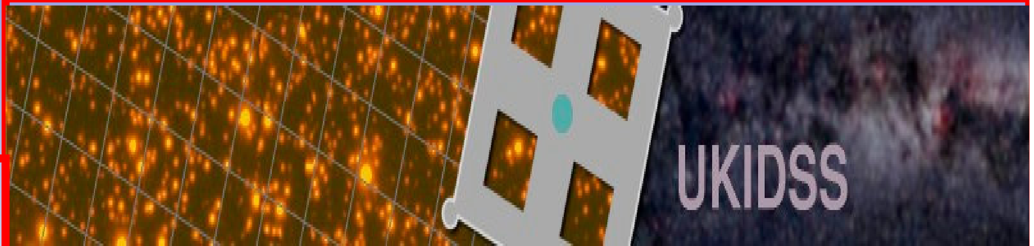
➔ ellipticals & their progenitors

Local photometric surveys in the NIR



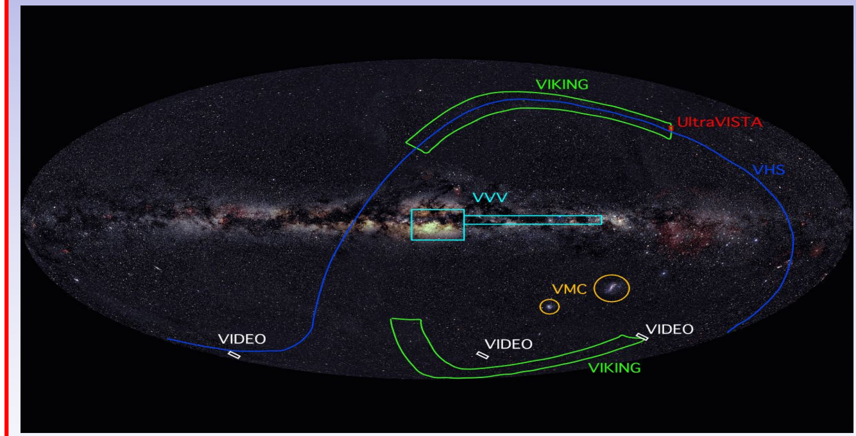
Two Micron All Sky Survey (2MASS)

(2 highly-automated 1.3-m tel.)
The first all-sky (~95%: > 200 square degrees contiguos) photometric census (J,H,Ks bands) of 1,000,000 galaxies brighter than K_s=13.5 mag



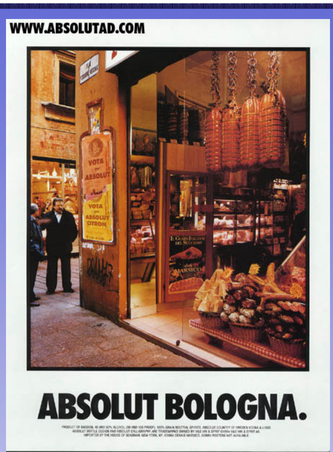
UKIDSS (in progress)

The survey instrument is WFCAM on the UK Infrared Telescope **(UKIRT)** in Hawaii.
five surveys: 7500 square degrees in JHK to K_{AB}=18.3
+ two deep: 35 square degrees to K_{AB}=21,
0.77 square degrees. K_{AB}=23



VISTA is the next generation near-IR sky survey
The survey instrument is **VISTA** on VLT
6 surveys: K_{AB}<18-23.5 (20K-15deg^2)
+ **ULTRA-VISTA** (0.73 deg^2 K_{AB}<25.6)

Deep spectroscopic surveys in the NIR



K20 (PI Cimatti) K_s<20

17 nights VLT + FORS1 & FORS2

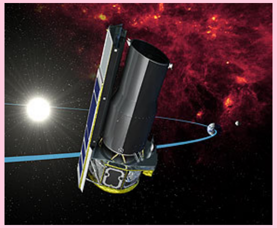
52 arcmin^2 (CDFS+Q0055)

~500 galaxies (0<z<2, mean z =0.7)

U-Ks multi-band photometry

> 95% redshift completeness

Galaxy **M**ass **A**ssembly ultradeep **S**pectroscopic **S**urvey ***(GMASS)***



(PI Cimatti)

m(4.5 μ m) < 23 (AB) + z(phot) > 1.4

VLT+FORS2 LP (145h) 50 arcmin^2 in the GOODS-South/HUDF

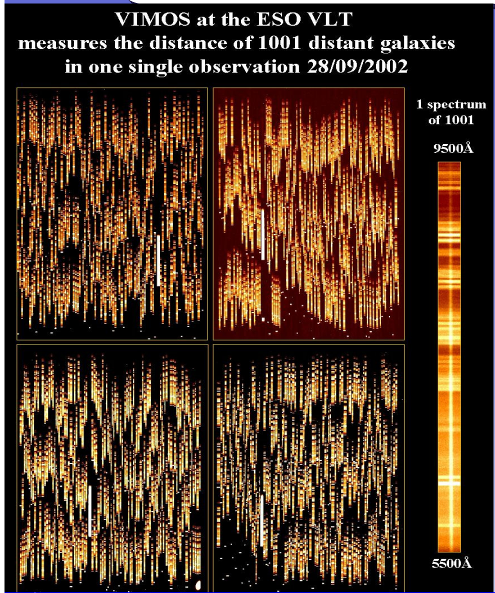
Ultradeep spectroscopy of ~200 gal. to B=27, I=26, 11h-30h

MUNICS: (PI. Bender)

5000 gal (600 zsp) K<19.5, 0.4 deg^2

COMBO 17 (PI. Wolf) 796 gal. HAB<26.5, 1<zph<6

Optical Surveys



VVDS:

(PI Le Fevre)
purely OPTICAL magnitude selected

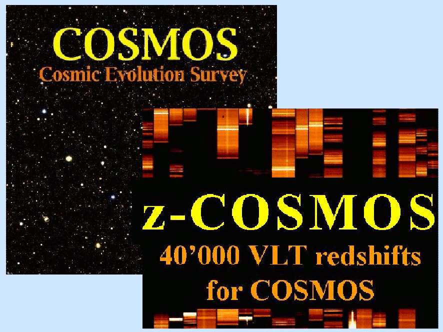
DEEP: $17.5<I_{AB}<24$, 0.5 deg²(10k zspec)
WIDE: $17.5<I_{AB}<22.5$, 10deg²
Ultra-Deep: $22.5<I_{AB}<24.75$, 600 arcmin²
multi-band photometry: GALEX to SPITZER
+ VLA (>80 μJy)

VVDS-Deep: Mass Function from I- or K-selected sample

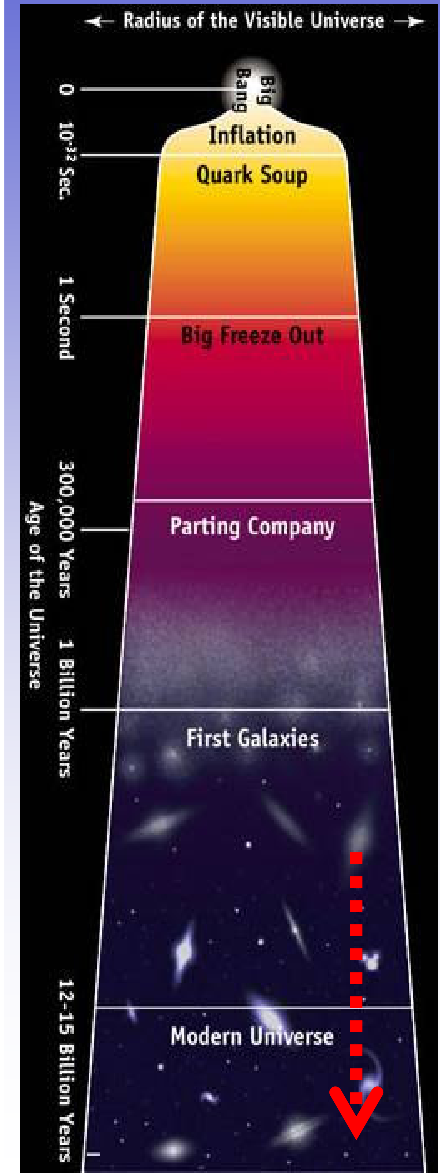
COSMOS (PI Scoville) ~ 2 deg^2

HST (640 orbits) + **zCOSMOS** (PI. S.Lilly: 40k redshift) + **S-COSMOS** (Spitzer) + **VLA-COSMOS** + **X-COSMOS** (XMM) + **C-COSMOS** (Chandra)

zCOSMOS Bright: $I_{AB}<22.5$ (10k redshifts) Mass Function



Main Results



NIR Galaxy Surveys @ OABo

K20 + GMASS +VVDS

Highlights

Evolution of early-type galaxies at z>=1

Evolution of the NIR Luminosity Function & Stellar Mass Function and Mass density up to z=2

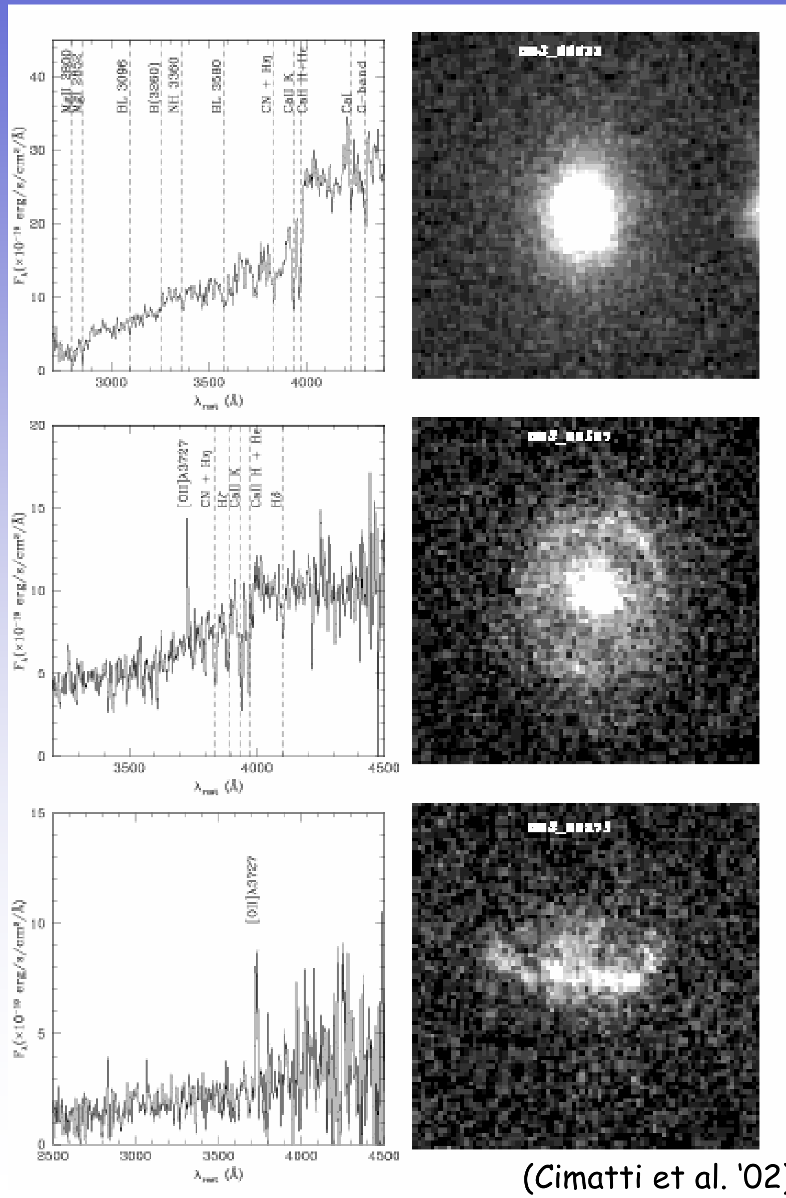
Old massive galaxies @ z>1

K20

First spectroscopic sample of **EROs** (R-K>5)
(Cimatti, Daddi, Mignoli, **Pozzetti** et al. 02)

~1/2 old ellipticals @ z=1
=> age>=3 Gyrs,
zform>2
~1/2 dusty starbursts (disc or irregulars)
=> 20%of SFD@z=1

Densities:
N(z~1) >> N(predicted in hierarchical models)
Clustering: Strongly clustered (r_0 ~ 10 Mpc)



(Cimatti et al. '02)

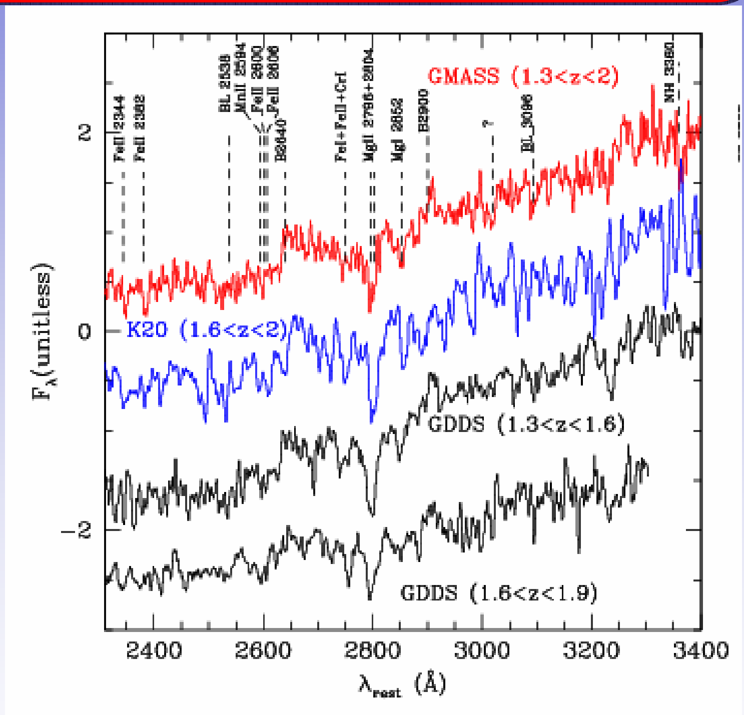
Old massive galaxies up to z=2

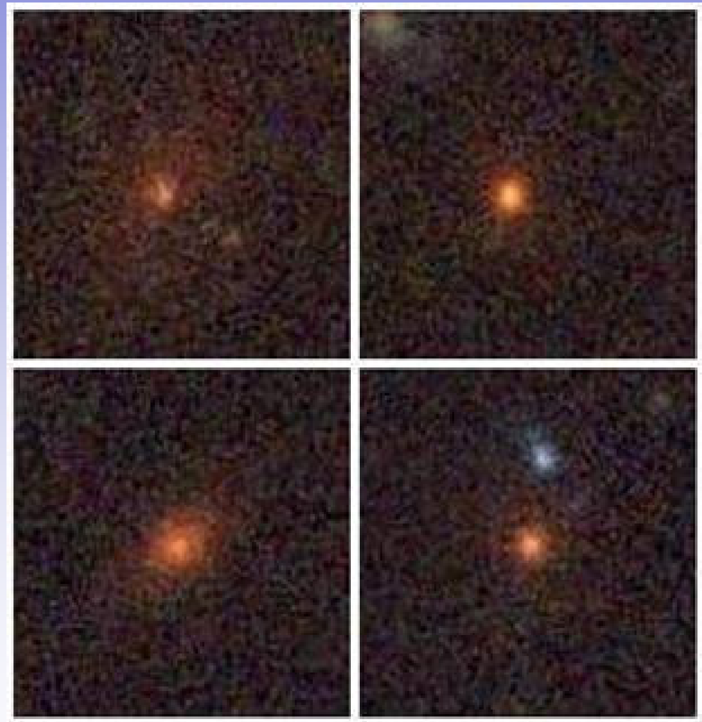
K20 Cimatti et al. 2004

4 massive ETGs at z=1.6-1.9

GMASS Cimatti, Cassata, **LP,** et al. '07

13 massive ETG (10^{10}-10^{11} Msun) at 1.4<z<2.
500 h stacked spectra





consistent with old (1-2 Gyr) stellar population
=> z(form)>2.5-4 & M(stars)>10^{11} Msun

Spheroidal and compact morphology

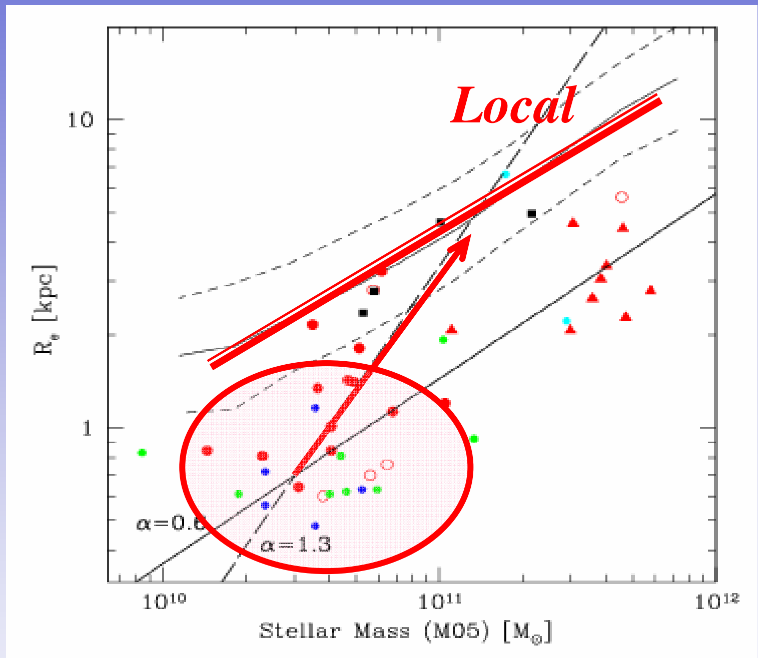
Absent in hierarchical models

Cosmic variance results ? No ! GDDS (McCarthy et al. 2004) + Saracco et al. 2005, Daddi et al. 2005

Superdense early-type at z>1.4

GMASS Cimatti, Cassata, **LP,** et al. '07

13 massive ETG (10^{10}-10^{11} Msun) at 1.4<z<2.



Old massive ETG with Spheroidal and compact morphology
Compact and superdense: size (Re= 1 kpc) 3 times smaller than z=0

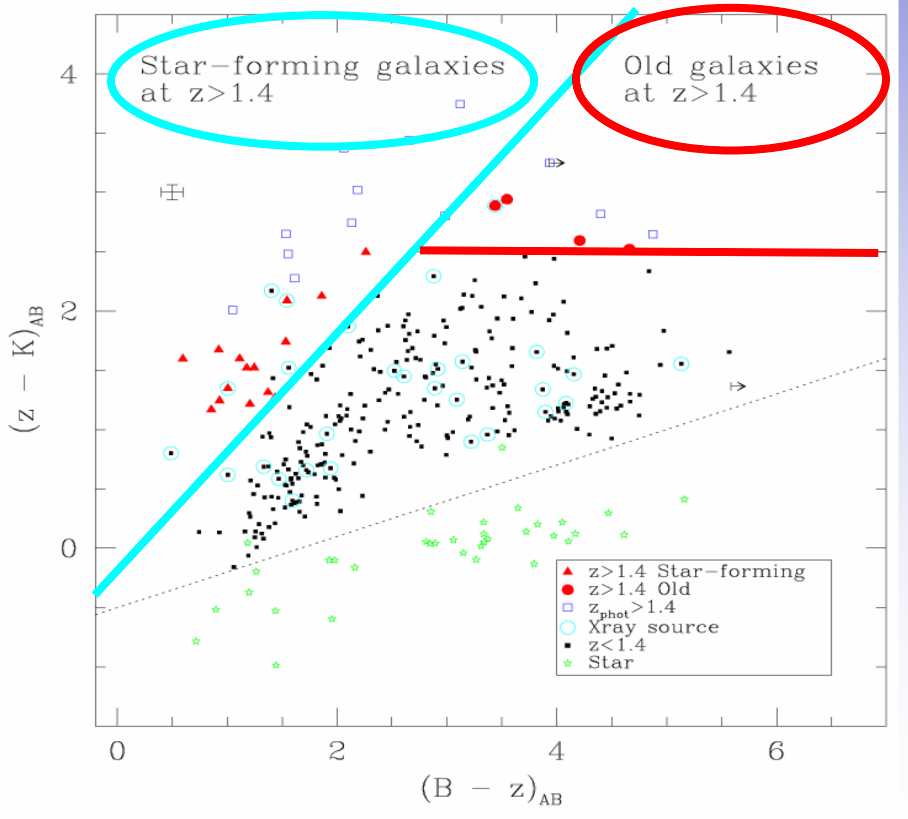
→ Remnants of Submm Galaxies (z>2) ?
→ they evolve in z=0 ETG by dry-merging or envelope stars accretion

sBzK

K20

Daddi et al.'04

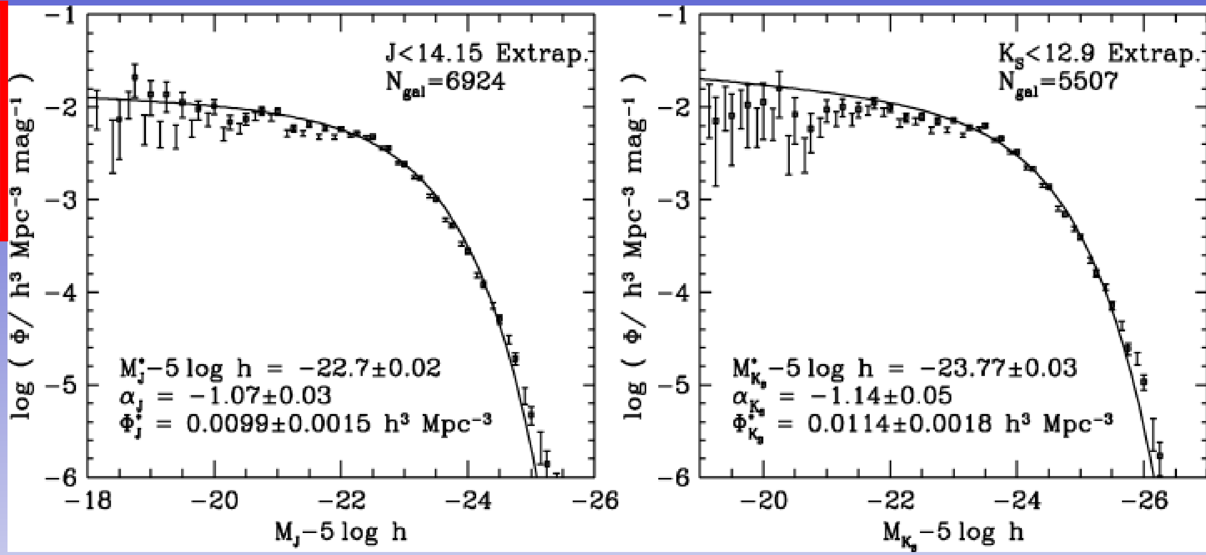
sBzK: Population of massive star forming galaxies at z>1.4 ➔ progenitors of ellipticals

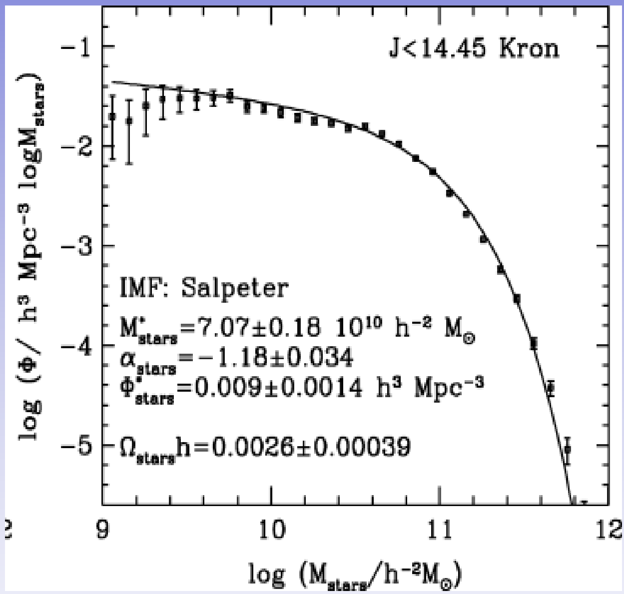


Sinfoni: Massive unstable disks (Genzel et al. '06)

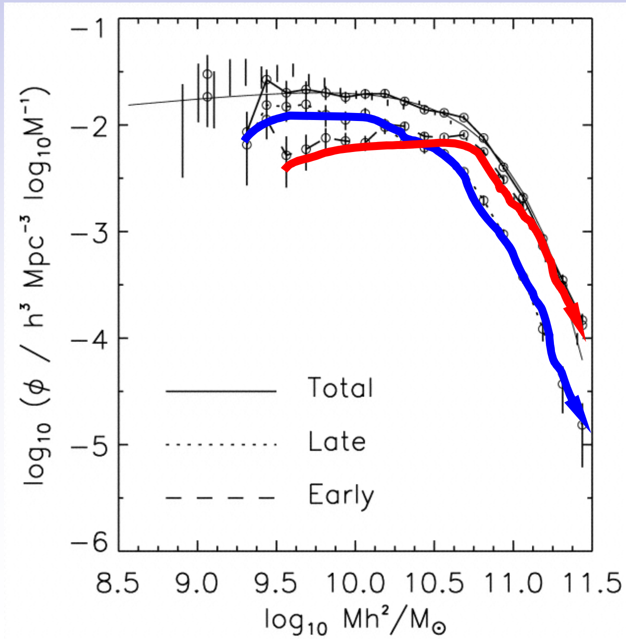
Luminosity and Mass Functions: 2MASS

2MASS + 2dFGRS : Near-infrared LF (J,Ks) (Cole et al. 2001) yielding the stellar mass function of galaxies





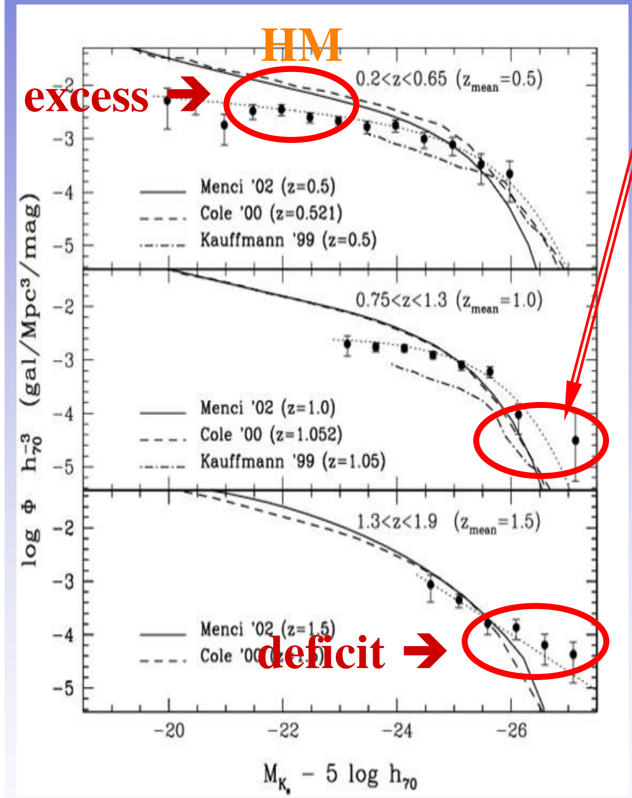
2MASS + SDSS : red/ETGs galaxies dominate the luminous/massive part of LF/MF (Baldry et al. 04, Bell et al. 03)



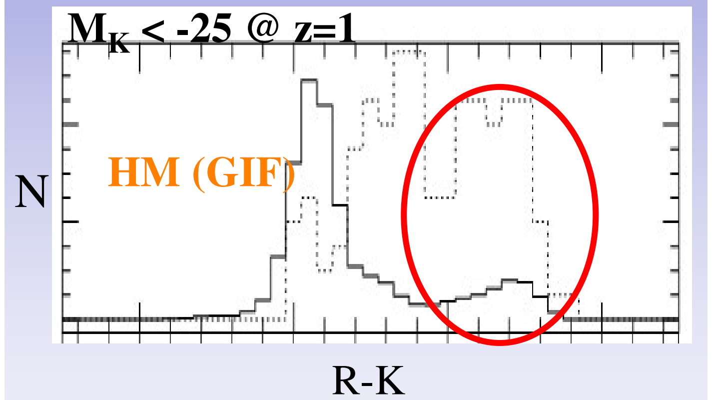
Evolution of the NIR LF and Stellar Mass Function

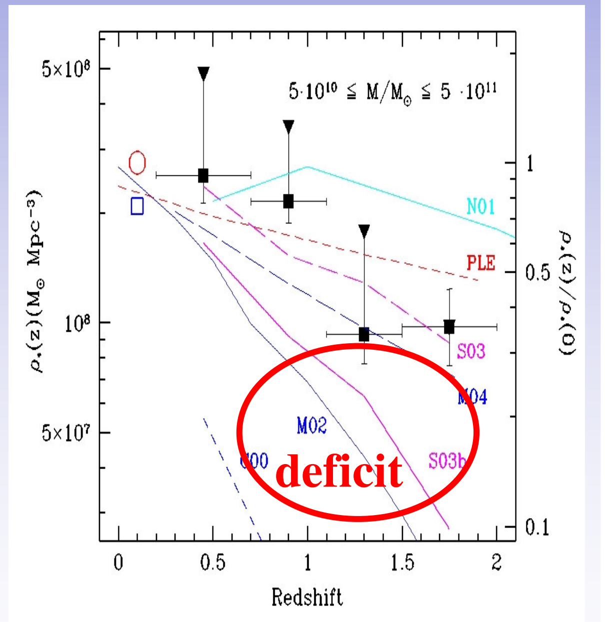
K20

Near-IR Luminosity Function (**Pozzetti,** et al. 03)
Mass Function up to z~2, (Fontana**, Pozzetti** et al. 04)



Luminous/Massive red ellipticals fully in place up to z=1-1.5

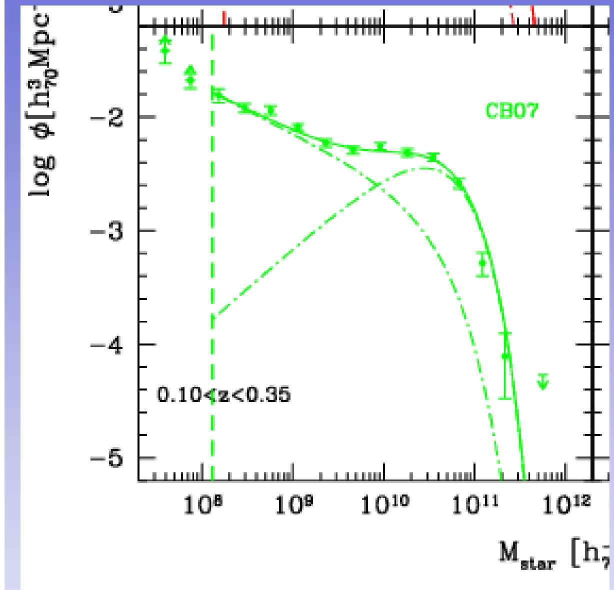


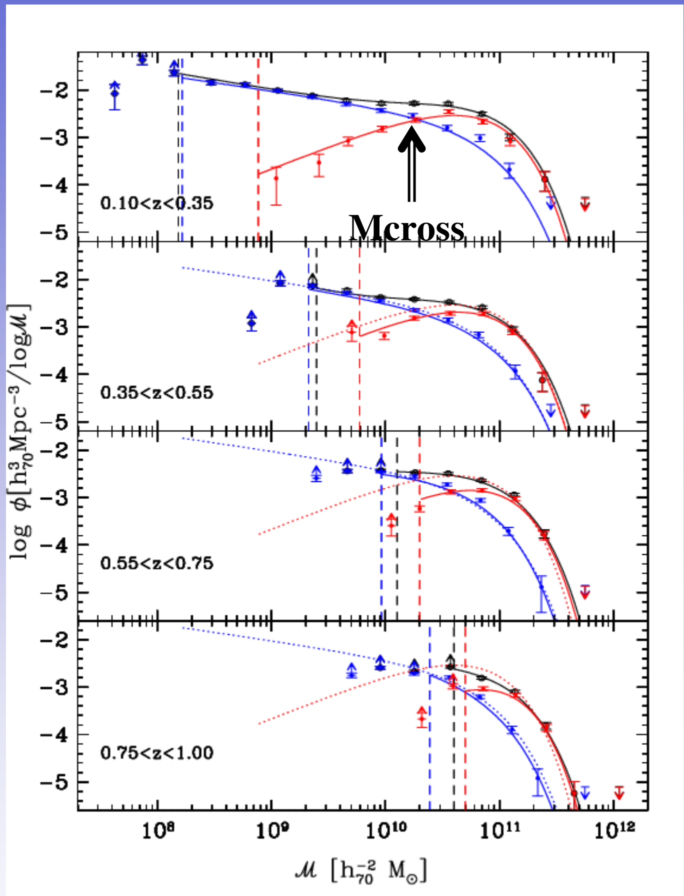


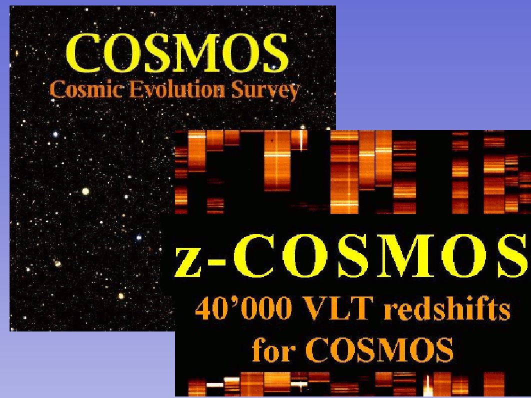
Hierarchical models (HM):
underpredict luminous/red/massive galaxies at z=1
overpredict the population of low-Luminosity/Mass galaxies

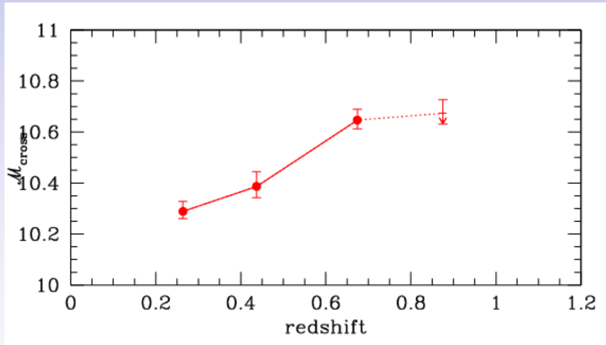
Bimodality in the Stellar Mass Function

Pozzetti et al. (in progress)





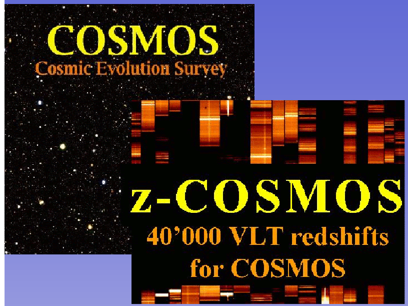


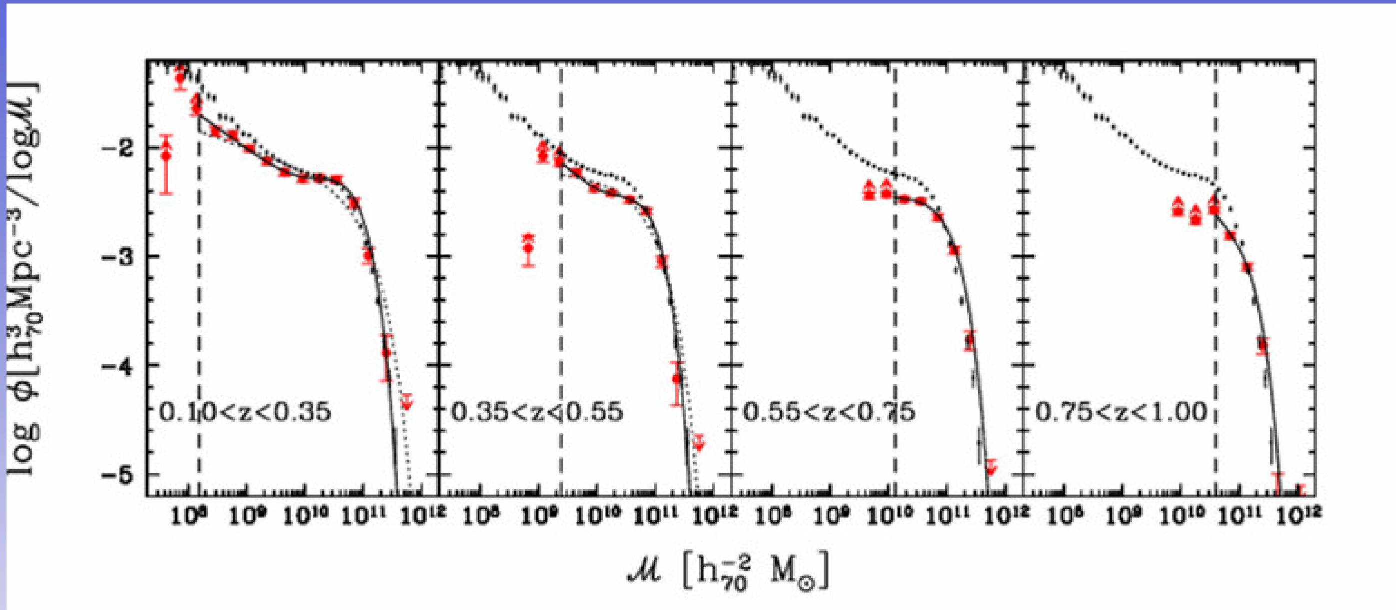


The total MF is better described by 2 population

- ➔**2 different populations related to galaxy bimodality: ETGs+LTGs**
- ➔**Increase with redshift the fraction of massive star forming blue galaxies**

Mass-assembly dowsizing

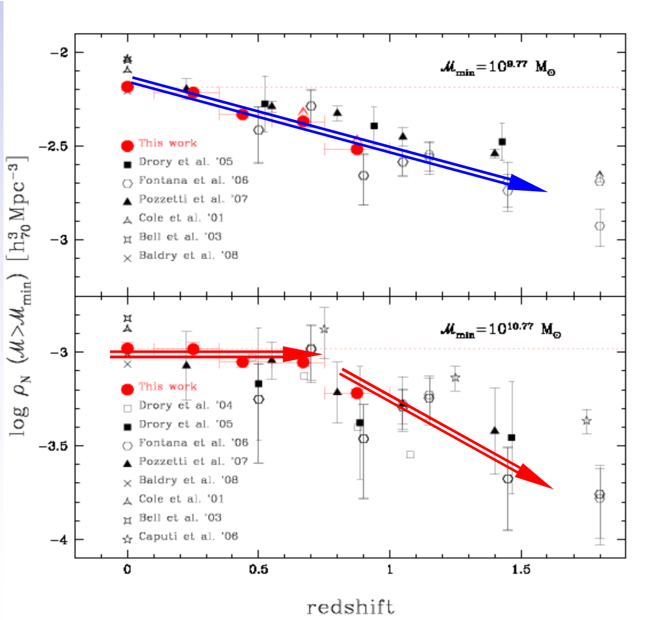




mass-dependent evolution of the number/mass density:

Massive tail is present up to z=1.

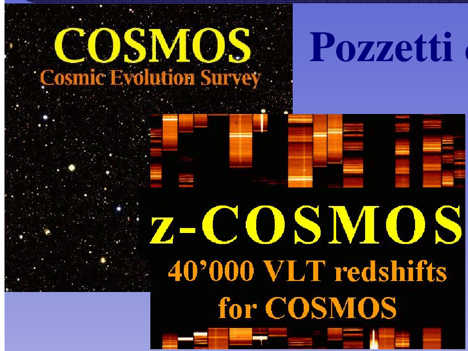
Continuous evolution for intermediate/low-mass galaxies



Mass assembly is earlier in more massive galaxies

in contrast with hierarchical models

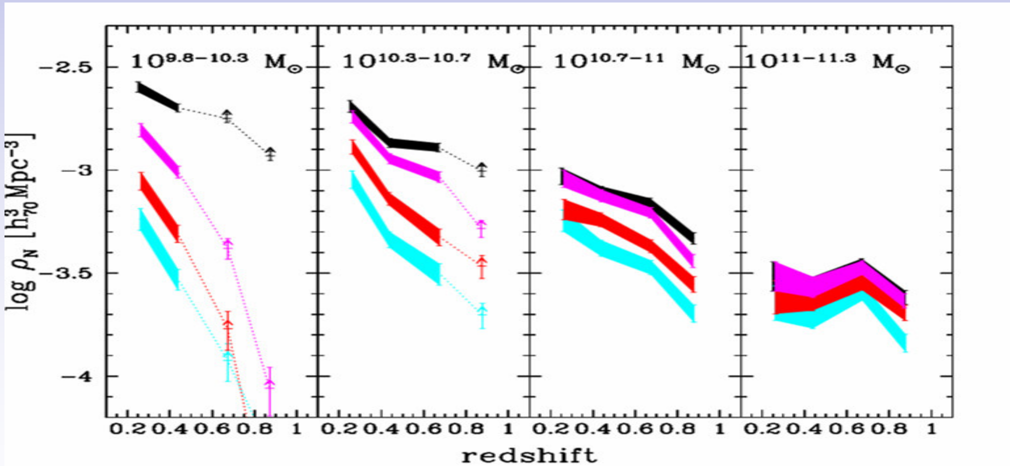
Evolution of early type galaxies (ETGs)

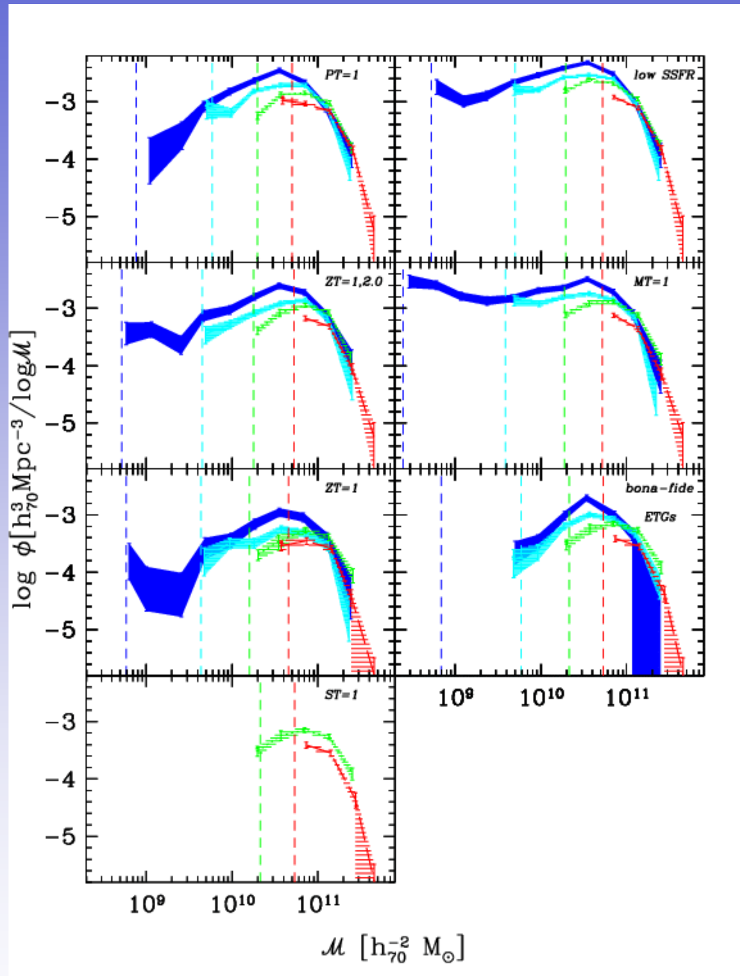


Pozzetti et al. (in progress)

ETGs defined using different criteria (colors, morphology, spectral features, SFR or an intersection of them)

Increase with cosmic time since z=1 of the number densities of intermediate-mass ETGs.





Mass-assembly downsizing for ETGs

in contrast with hierarchical models

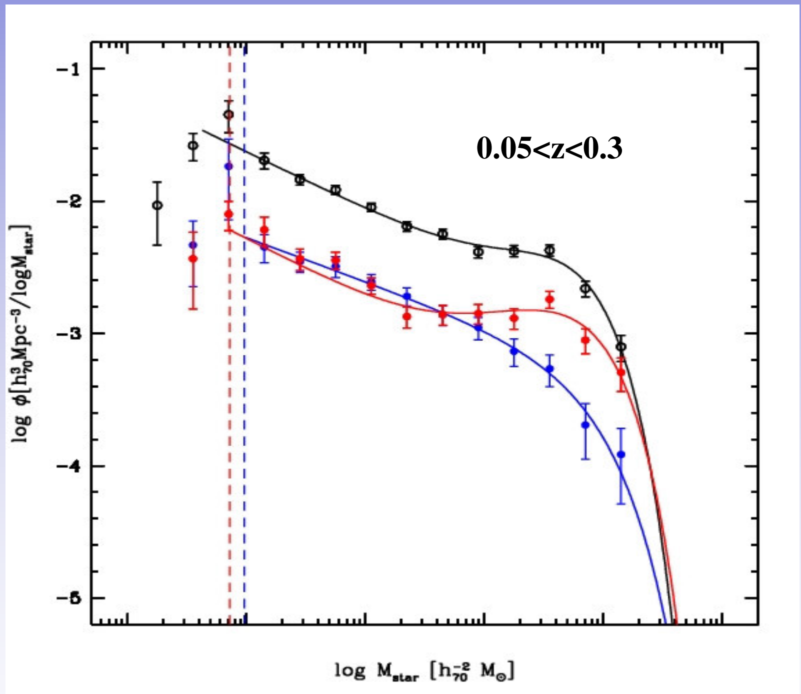
Stellar Mass Function in different environments

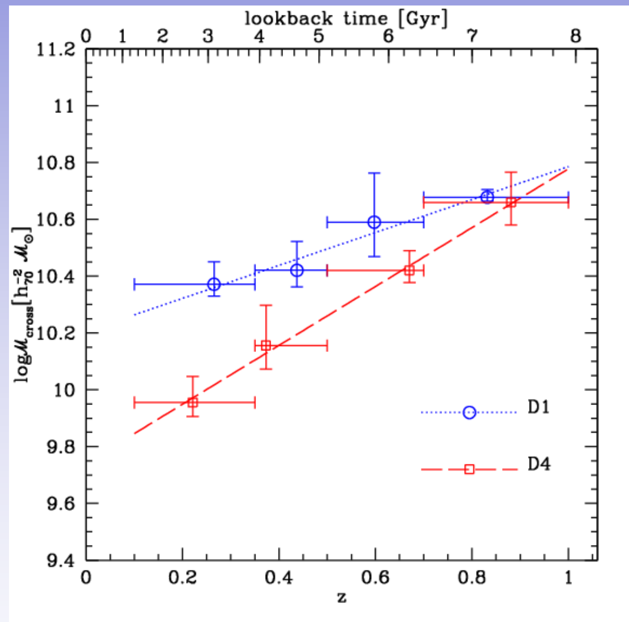
COSMOS
Cosmic Evolution Survey

z-COSMOS
40'000 VLT redshifts
for COSMOS

Bolzonella et al. (in progress)

Evolution mainly driven by the Mass and/or by the environment ?





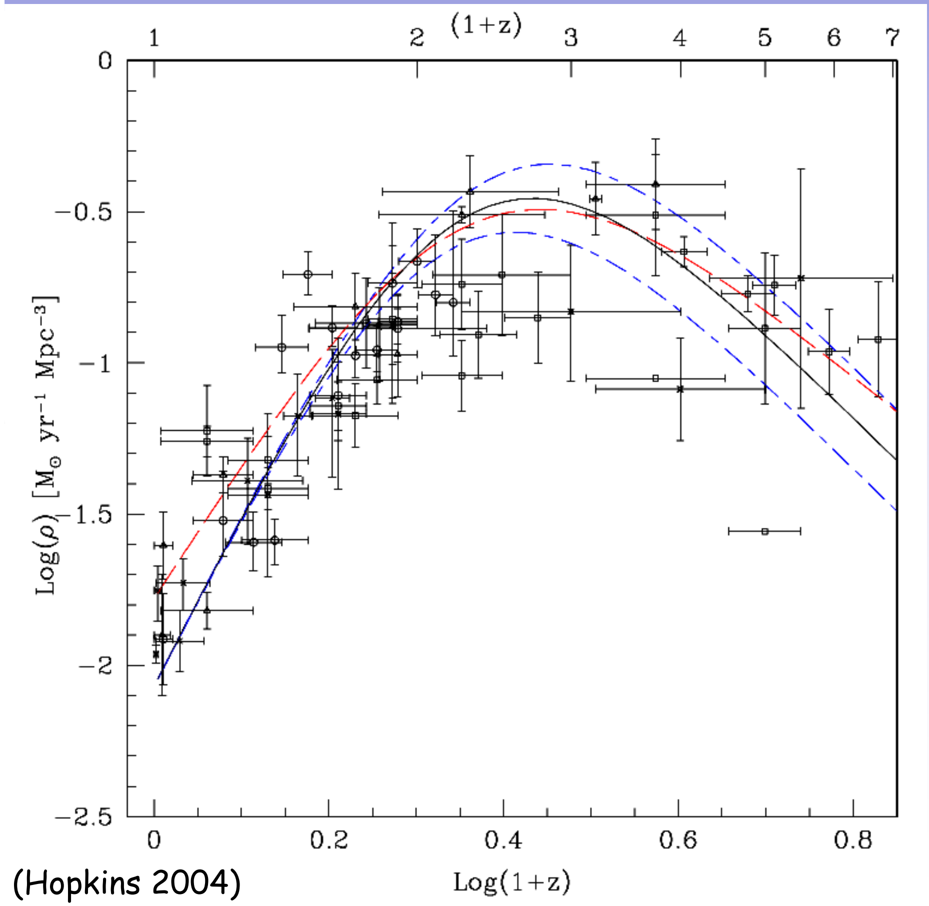
MFs by environments:

In **highD** MF show a higher massive tail of red galaxies compare to **lowD**

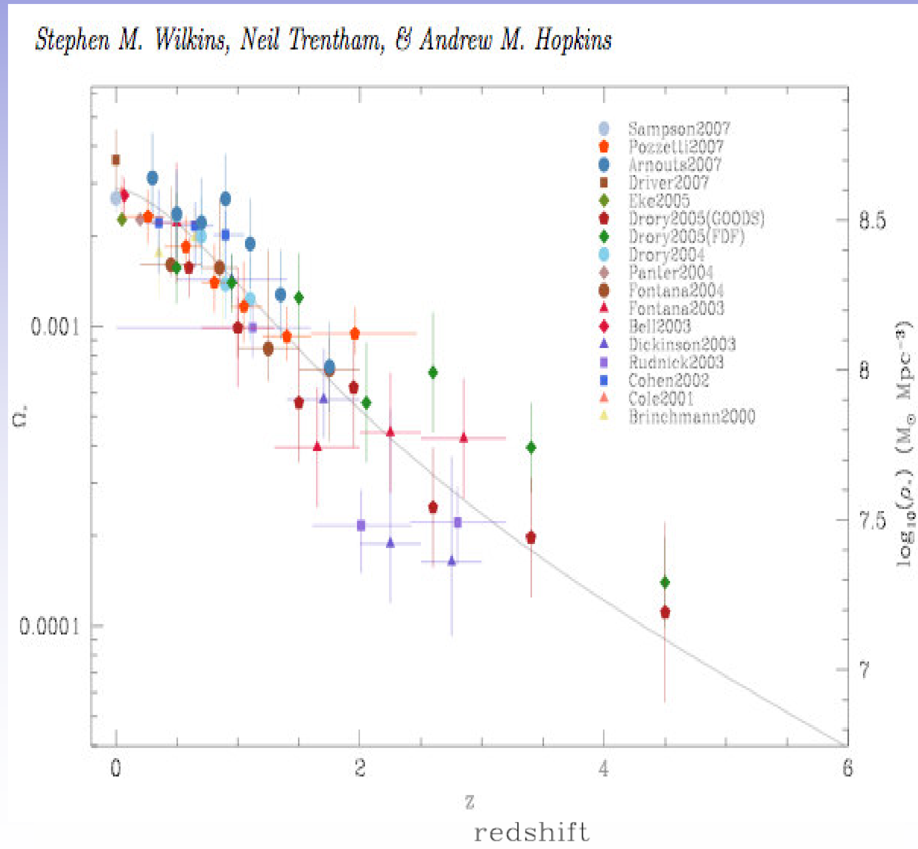
Faster evolution of galaxy population (red/blue) in **highD** compare to **lowD**

STAR FORMATION HISTORY
&
STELLAR MASS HISTORY

...SFH up to z --> 6 ...SMH up to z --> 4



(Hopkins 2004)



Highlights & global picture

Redshift = 0.1-1.2

- Galaxies have similar properties of local ones (BIMODALITY):

ellipticals are old/massive/without SFR &

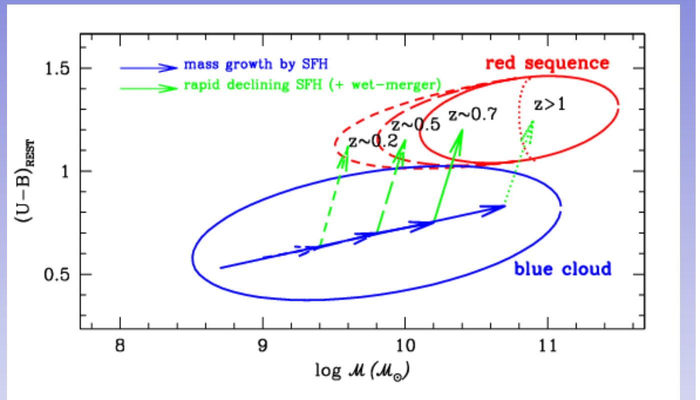
spirals are young/low-mass/high SFR

- **Mass-assembly and age- downsizing:**

  1- Massive early type (ETG) assembled their stars and stellar mass earlier and faster

  2- Star forming galaxies (LTG) assembled their stellar mass more continuously and later

- Transformation from **active** to **passive** with cosmic time (merger only marginal)
- **The enviroment have a marginal effect on the evolution**



Redshift >1.2-2.

- **Old ETG massive** at z>1 and up to z=2, but decrease in number densities and are **superdense**
- New population of **massive SF** objects gas-rich disks **(sBzKs)** at z=1.4-2.5

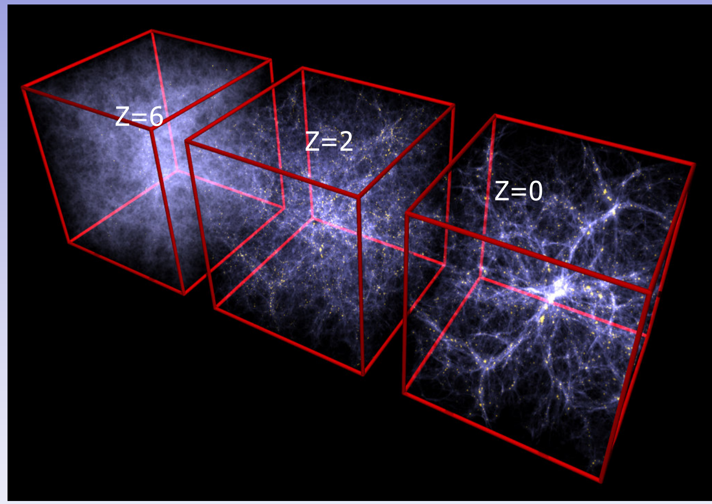
Hierarchical models :

- Underpredict of luminous/red/massive galaxies at high-z
- Overpredict low-Luminosity/Mass galaxies at all redshifts
- Predict age- but not mass-assembly downsizing

Future: EUCLID

PI. A.Cimatti (UniBo) & A.Refregier (France)

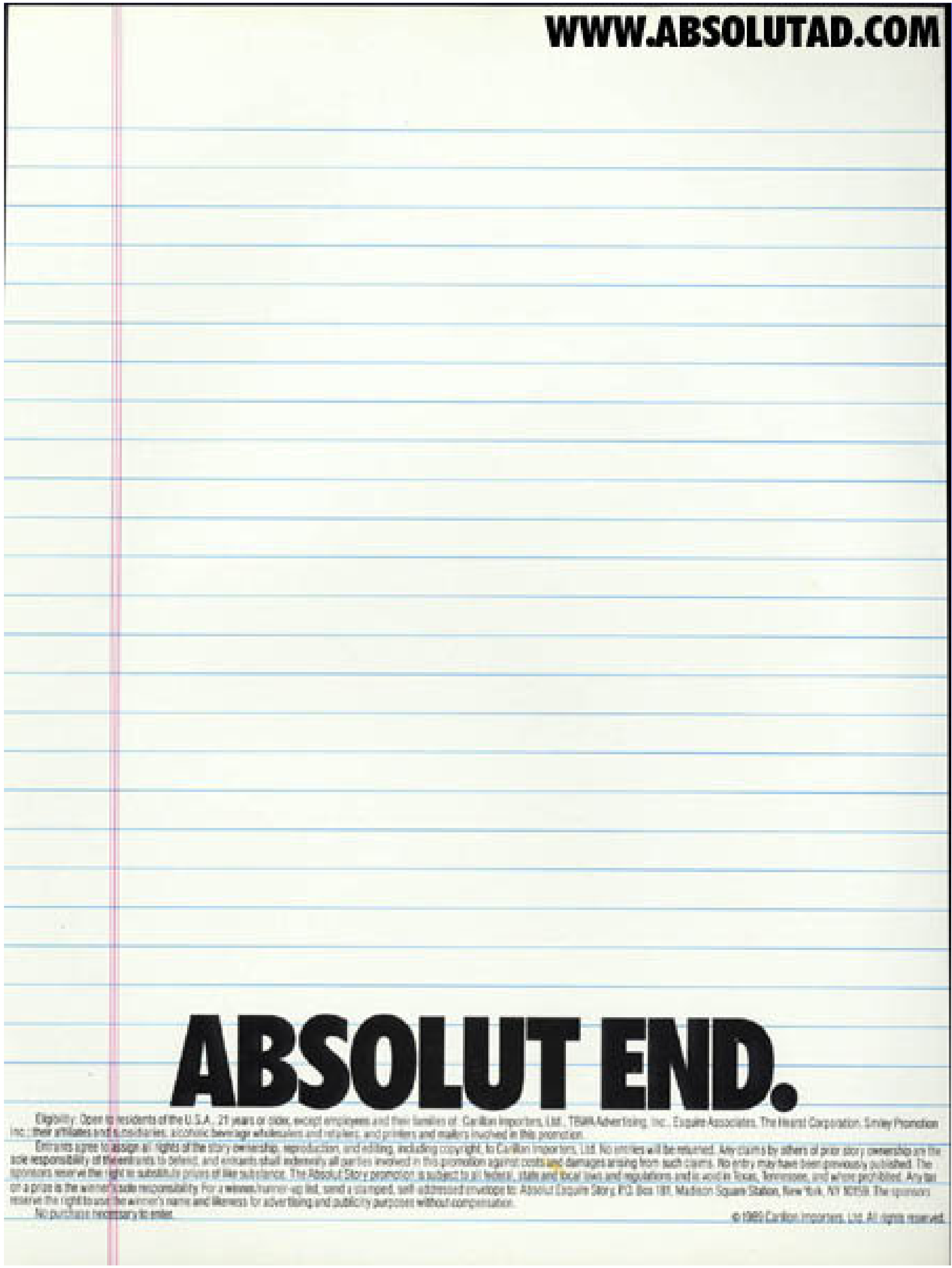
Merging of SPACE and DUNE mission for ESA-cosmic vision program

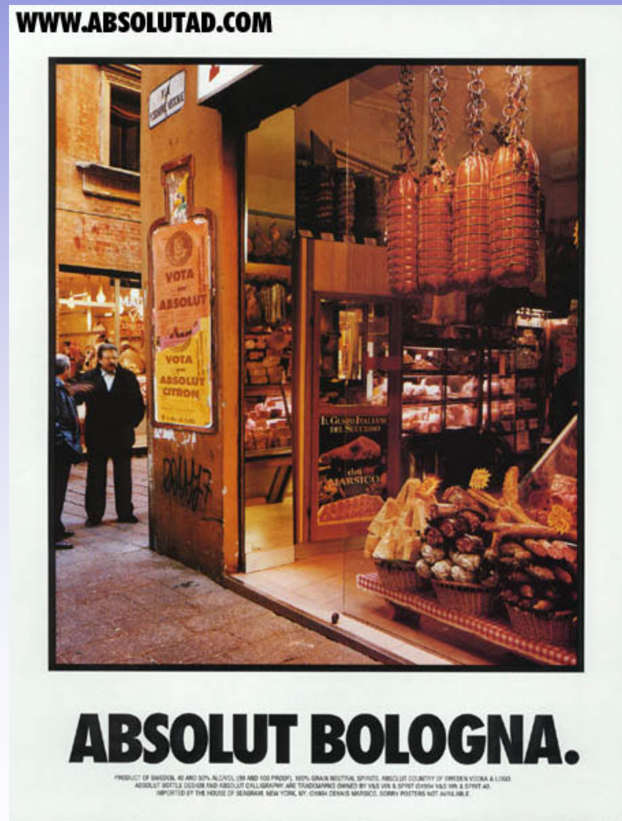


All-sky (20 Kdeg^2)
optical (AB<24.5) + **NIR (H_{AB}<24)** imaging
and multi-object spectroscopic survey at **H_{AB}<22**
Deep (H_{AB} < 24) NIR spectroscopy of about 10-30 deg^2

3D evolutionary map of the Universe during the last 10 Gyr

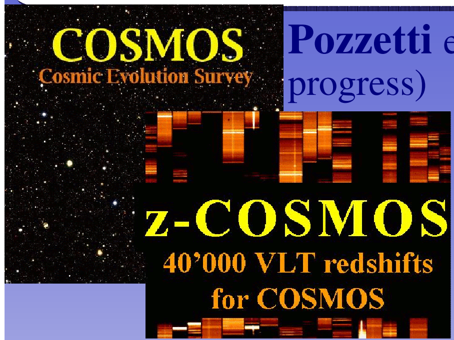
- Most stringent constraints on **Dark Energy with BAO**
- Formation and co-evolution of galaxies/AGN in all environments
- The very distant Universe: galaxies and quasars up to z ≈ 10





Provided by Lara

Stellar Mass Function by types



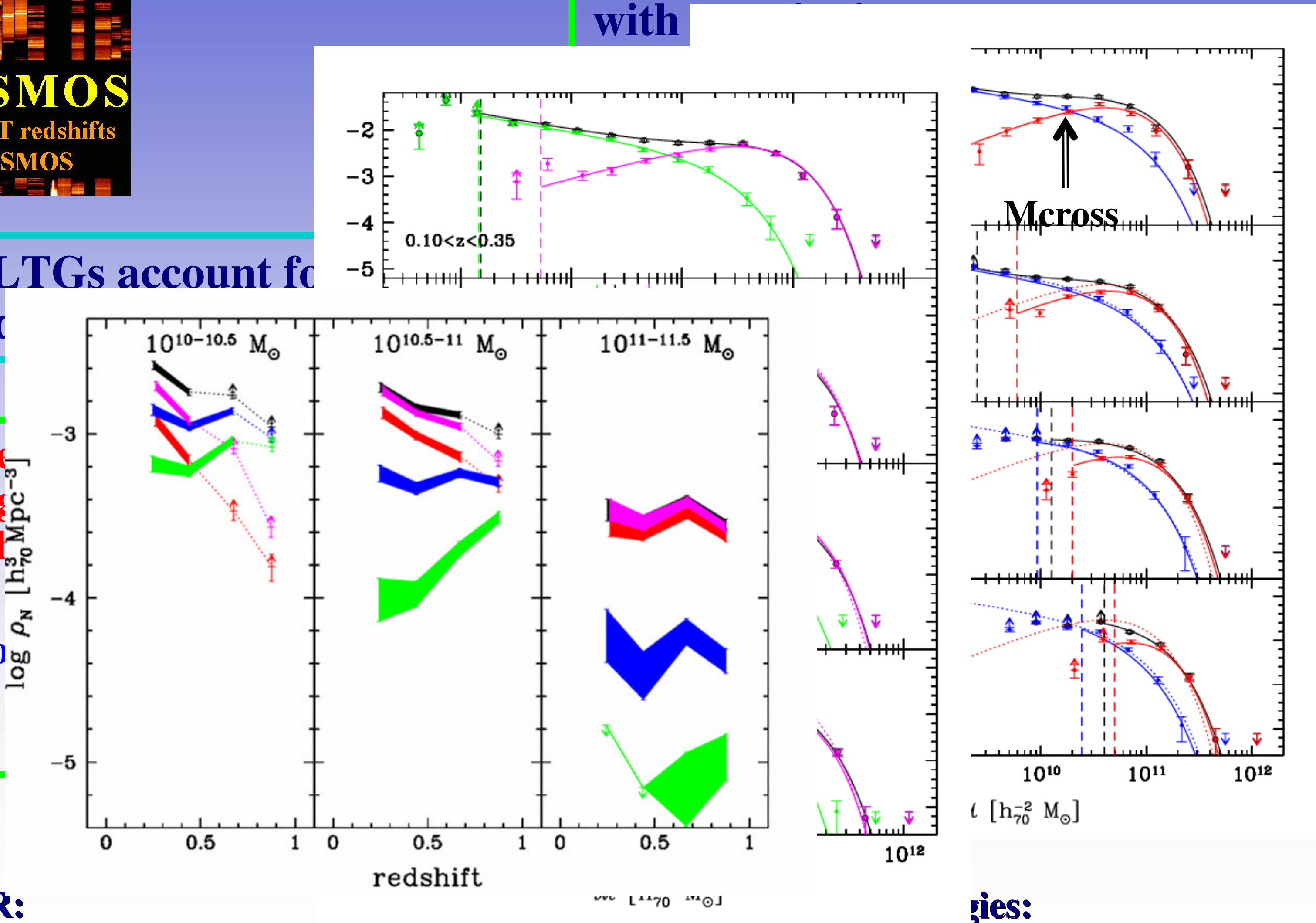
Pozzetti et al. (in progress)

High-SSFR population decrease with

ETGs vs LTGs account fo
MF bimod

Intermediate
RED/E+Bulg
increase with

Blue/Sp+Irr
remain almo
unchanged

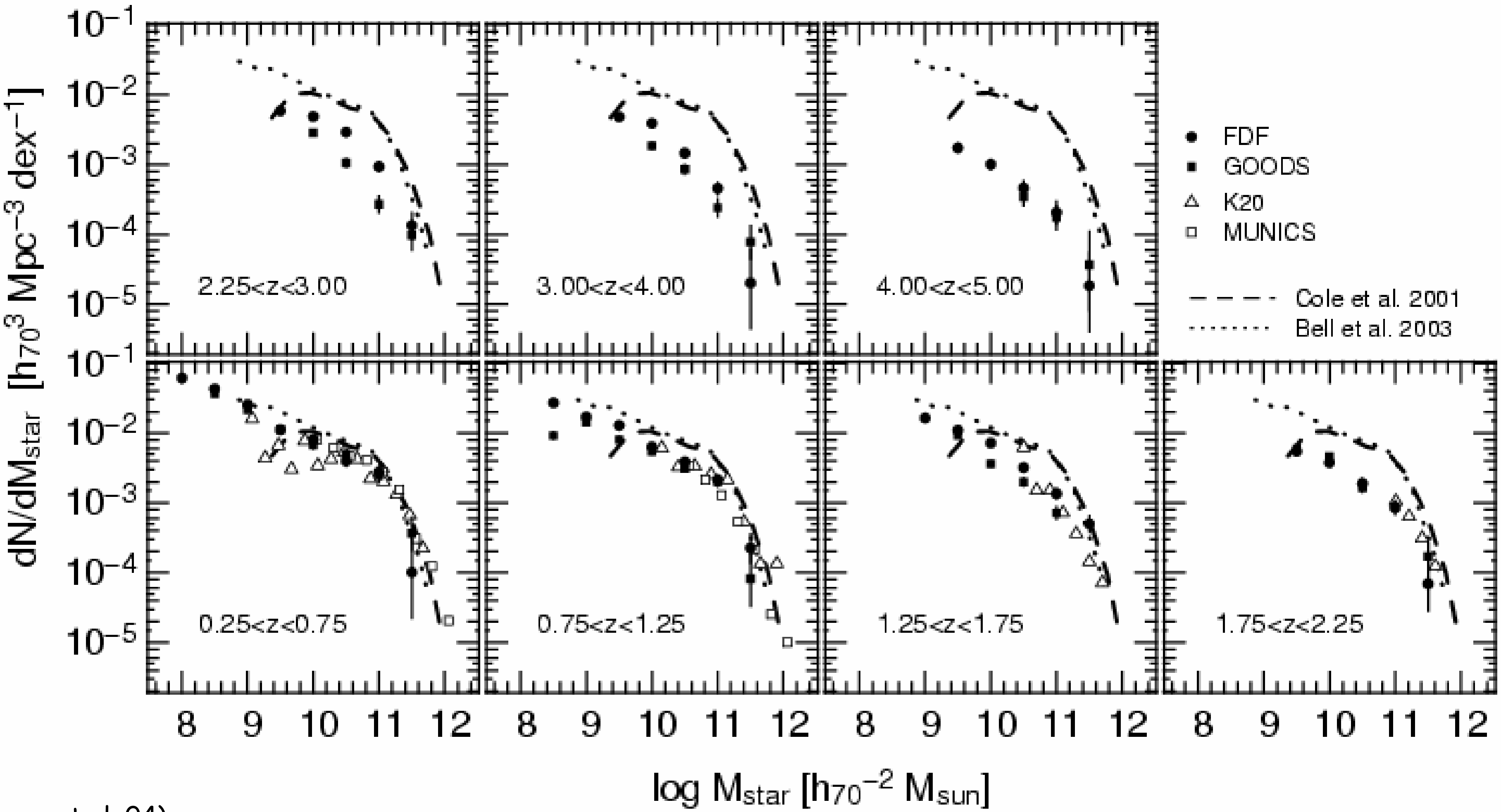


MFs by SSFR:
SSFR<10^{-10} vs. **SSFR>10^{-10}**

galaxies

...gies:
Red/E+Bulge(ETGs)vs.Blue/Sp+Irr (LTGs)

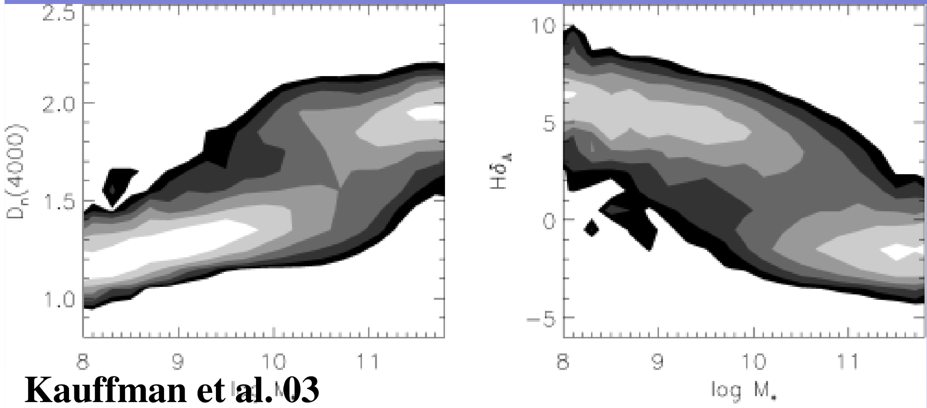
Other surveys: MUNICS, GDDS,FDF



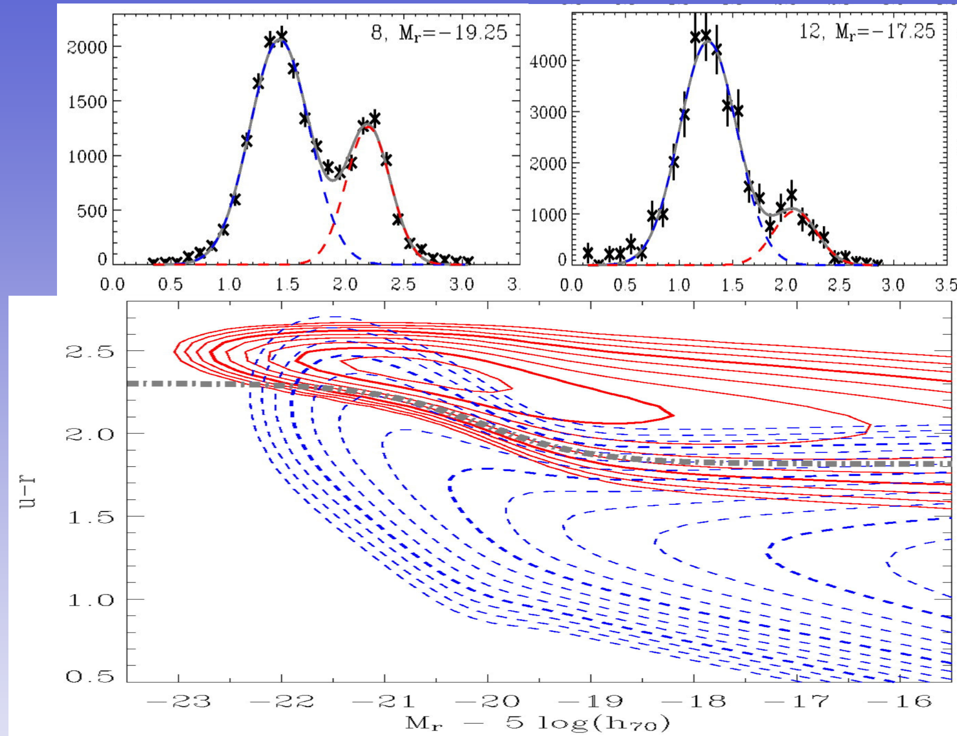
(Drory et al. 04)

SDDS

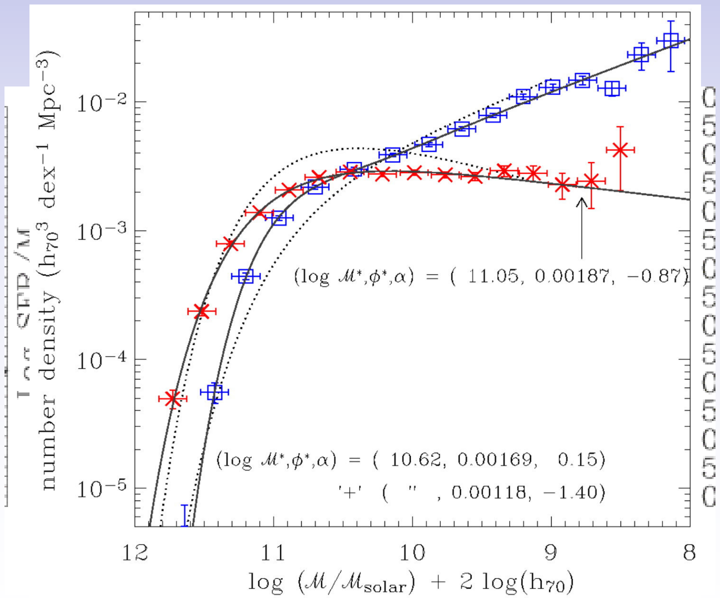
Color-magnitude bimodality:
luminous/massive objects are red/ellipticals/old



Kauffman et al. 03



Baldry et al. 2004

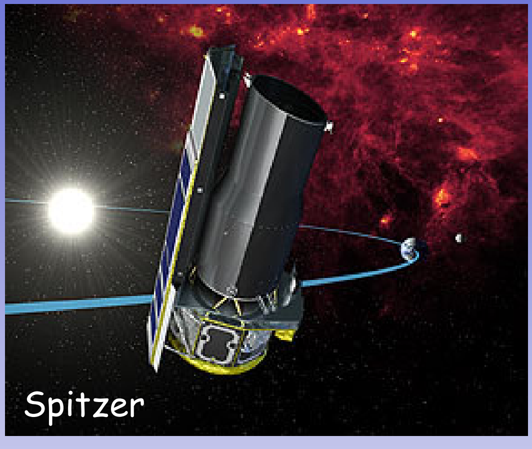


Specific SFR relation vs. Mass:
SFR/M decrease with Mass

MF and LF by color types:
red galaxies dominate the luminouse/massive part of LF/MF (Baldry et al. 04, Bell et al. 03)

GMASS

Galaxy Mass Assembly ultradeep Spectroscopic Survey



ESO VLT + FORS2 Large Program (145h; PI Cimatti)
Collaboration with GOODS Team (Dickinson et al.)

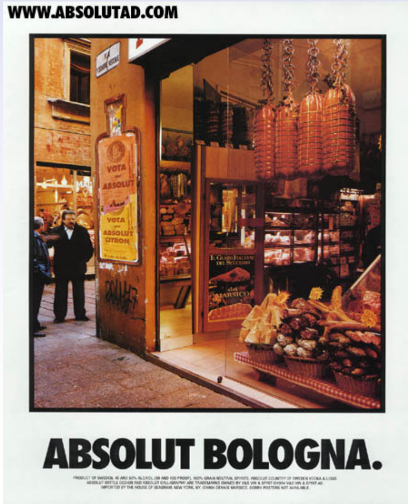
4.5μm-selected galaxies (m<23 AB) (Spitzer+IRAC)
(rest-frame NIR covered to z~3, accurate stellar masses)

51 arcmin^2 in the GOODS-S/K20/HUDF region

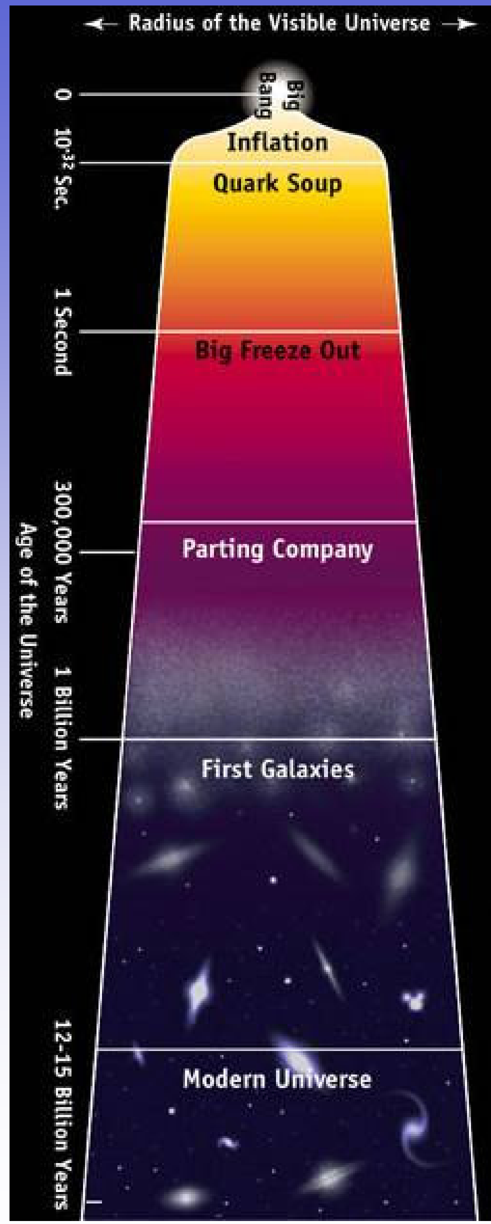
N~190 galaxies with z(phot)>1.4

Blue or red FORS2 spectra (B<26.5, I<26.0 AB)

12h-30h integration per mask (60-90h for repeated targets)



Photometric and redshift surveys: a key tool for cosmology



Main steps of a survey:

1. Multi-band photometry
2. Spectroscopy --> redshift is derived from the spectrum (from absorption or emission lines)

distance is derived from the redshift and physical properties like Luminosity, Mass, SFR can be determined once the distance is known

Monolithic vs. Hierarchical

Eggen,Lynden-Bell, Sandage '62, Larson '74

Galaxies(ellipticals and spirals) form at high redshift and evolve passively (no merging) with SFH with time scaling increasing from ell. to spiral

NO cosmological contest

White & Rees '78, Cole etal. '91, Kauffmann & White '93

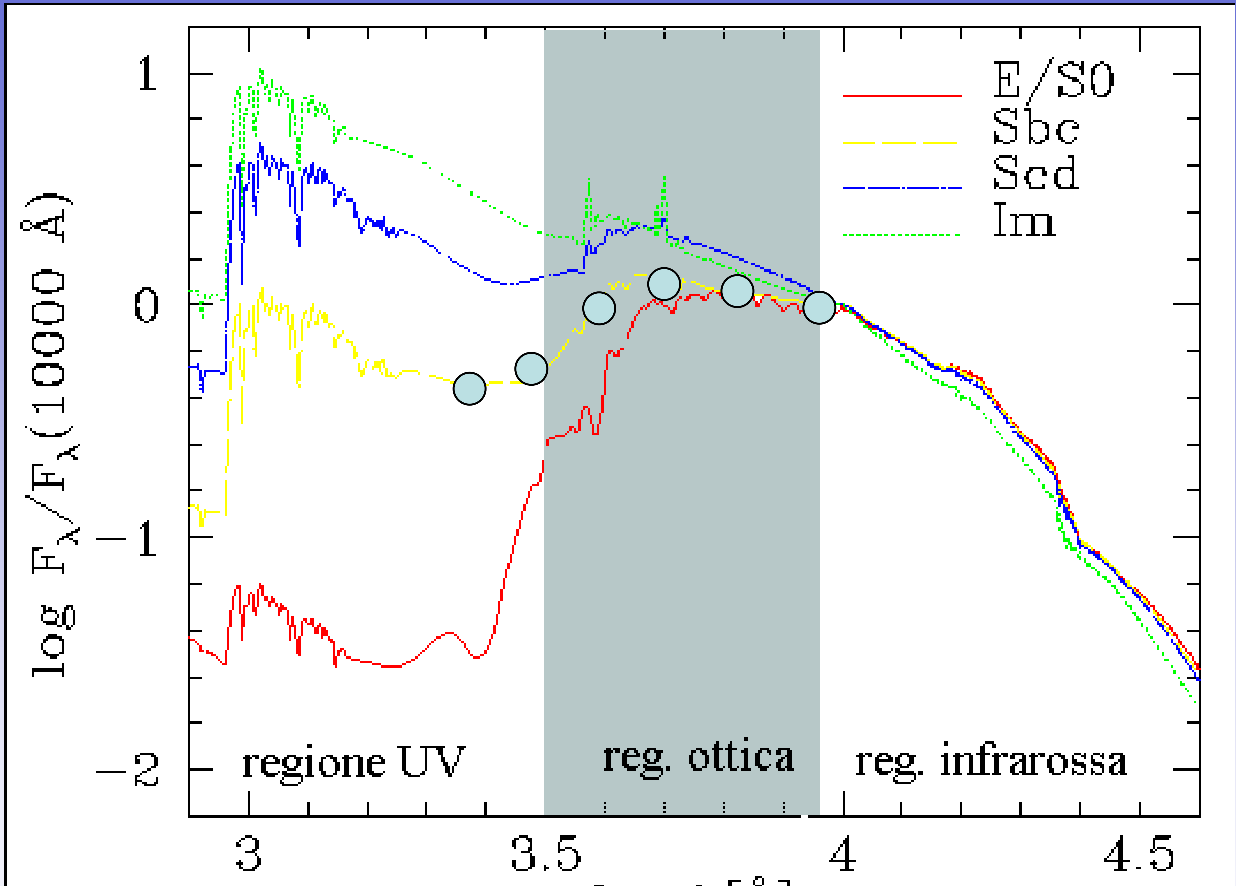
Galaxies (also ellipticals) form through merging of smaller disk at intermediate redshift:

Similar masses --->elliptical

Different masses ---> spiral

cosmological contest of CDM

Photometric Redshifts



(Bolzonella et al '00)

The idea, due to Baum (1957), consists in determine the redshift from multi-band photometry valuating the shift using different template of SED

(χ^2 SED fitting technique)

Allows to extend galaxy studies beyond the spectroscopic limits (R~25, K~19-20)

redshift

z-photo

HyperZ

(Bolzonella, Miralles & Pello' '00)

Near-IR Surveys

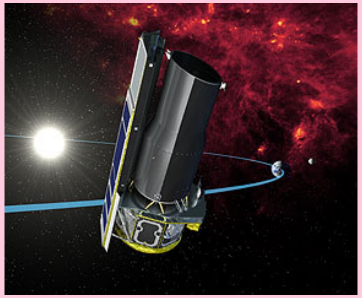
K20 VLT FORS1 & FORS2 LP (17nights) (PI Cimatti)

Ks<20, 52 arcmin^2 (CDFS+Q0055), 550 obj
multi-band photometry (U to Ks)

> 95% redshift completeness

K20: EROs, NIR Luminosity and Mass Function evolution, old galaxies at 1<z<2

GMASS VLT+FORS2 LP (145h) (PI Cimatti)
within a GOODS collaboration

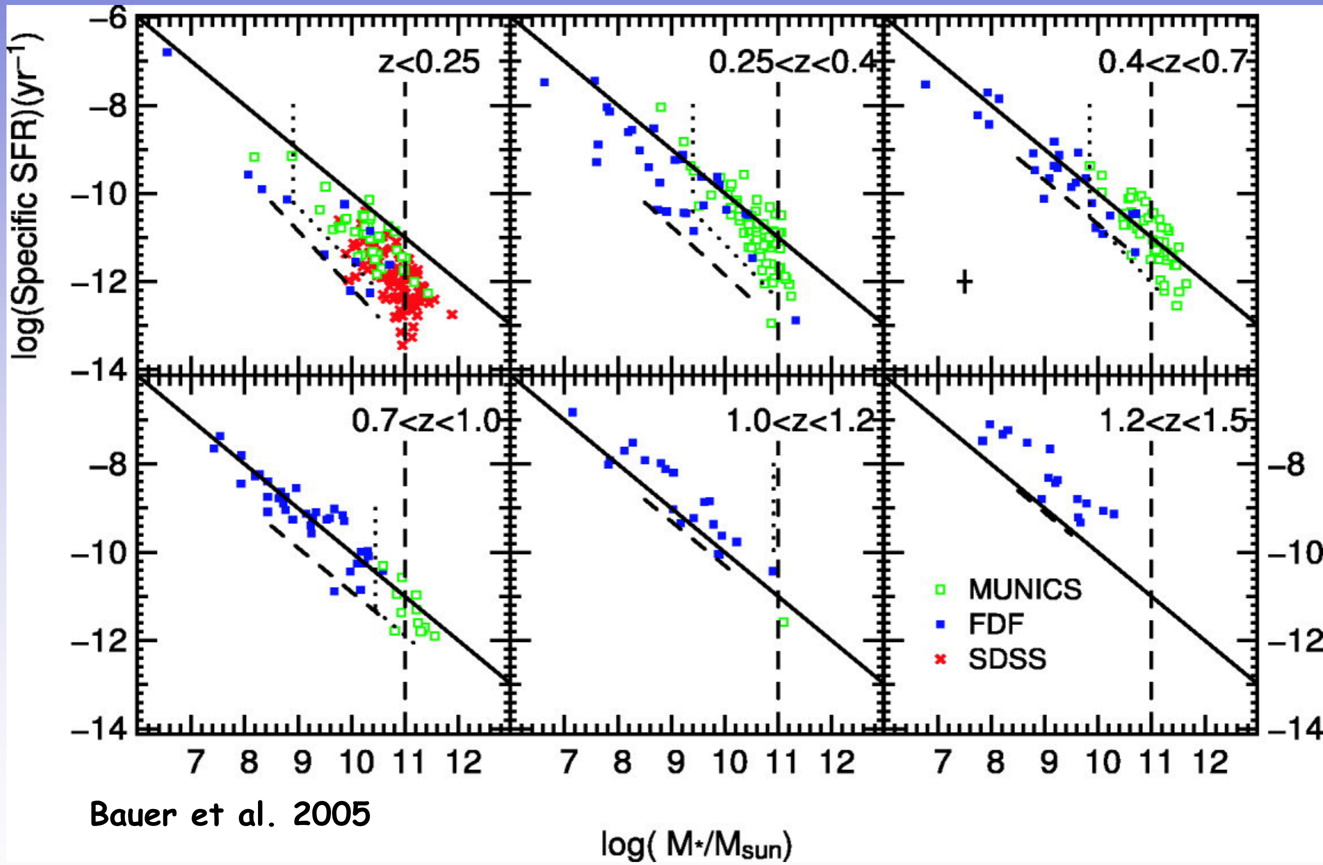


IRAC-selected m(4.5 μ m) < 23 (AB) + z(phot) > 1.4
50 arcmin^2 in the GOODS-South/HUDF

Ultradeep spectroscopy to B=27, I=26, 11h-30h ==> 208 redshifts

GMASS: spectral evolution of early-type

SPECIFIC STAR FORMATION HISTORY



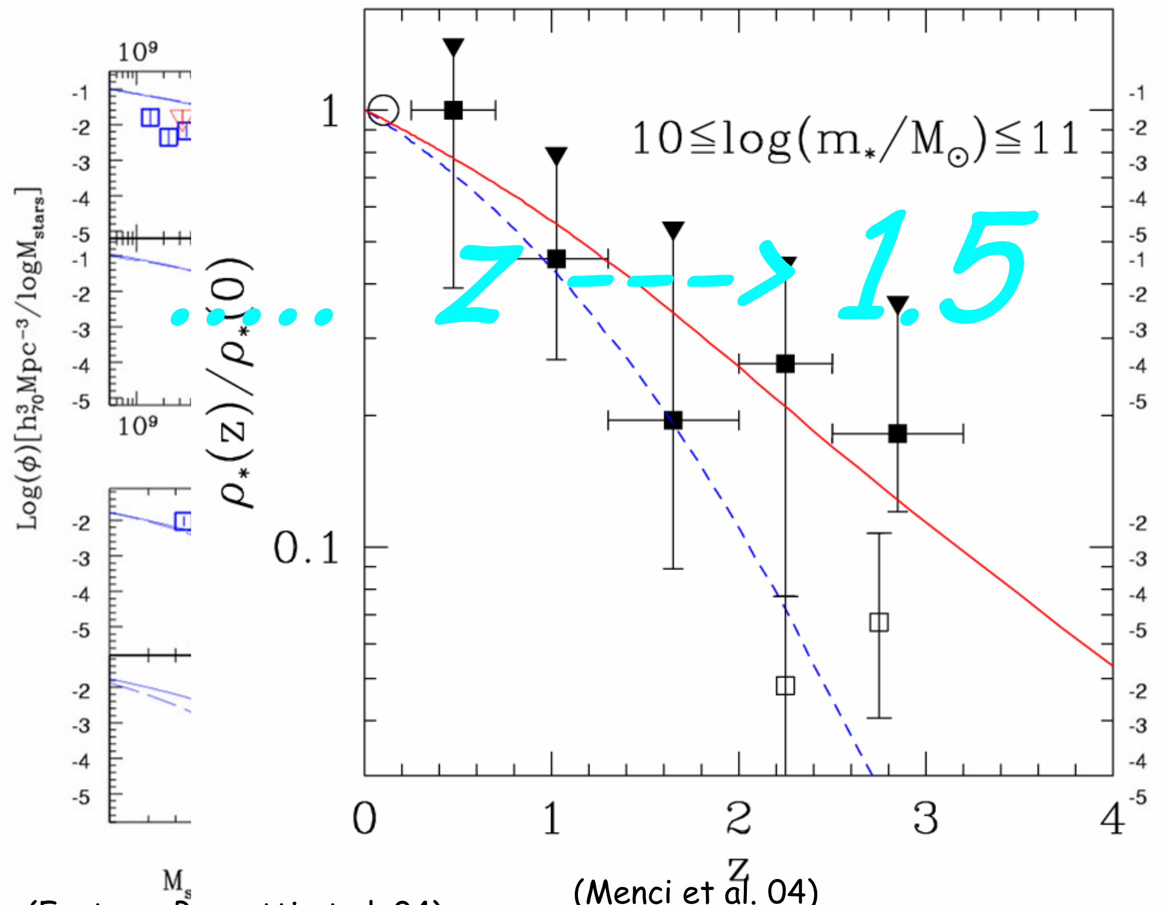
Bauer et al. 2005

Specific SFR relation vs. Mass:

SFR/M decrease with Mass and increase with z

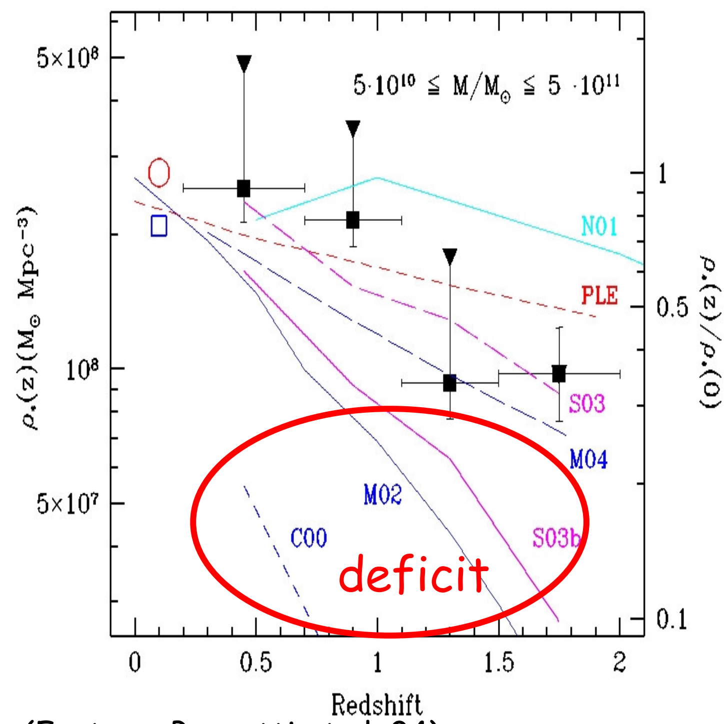
K20 MASS FUNCTION

→ *Slow decrease (50%) of mass density up to z~2*



(Fontana, Pozzetti et al. 04)

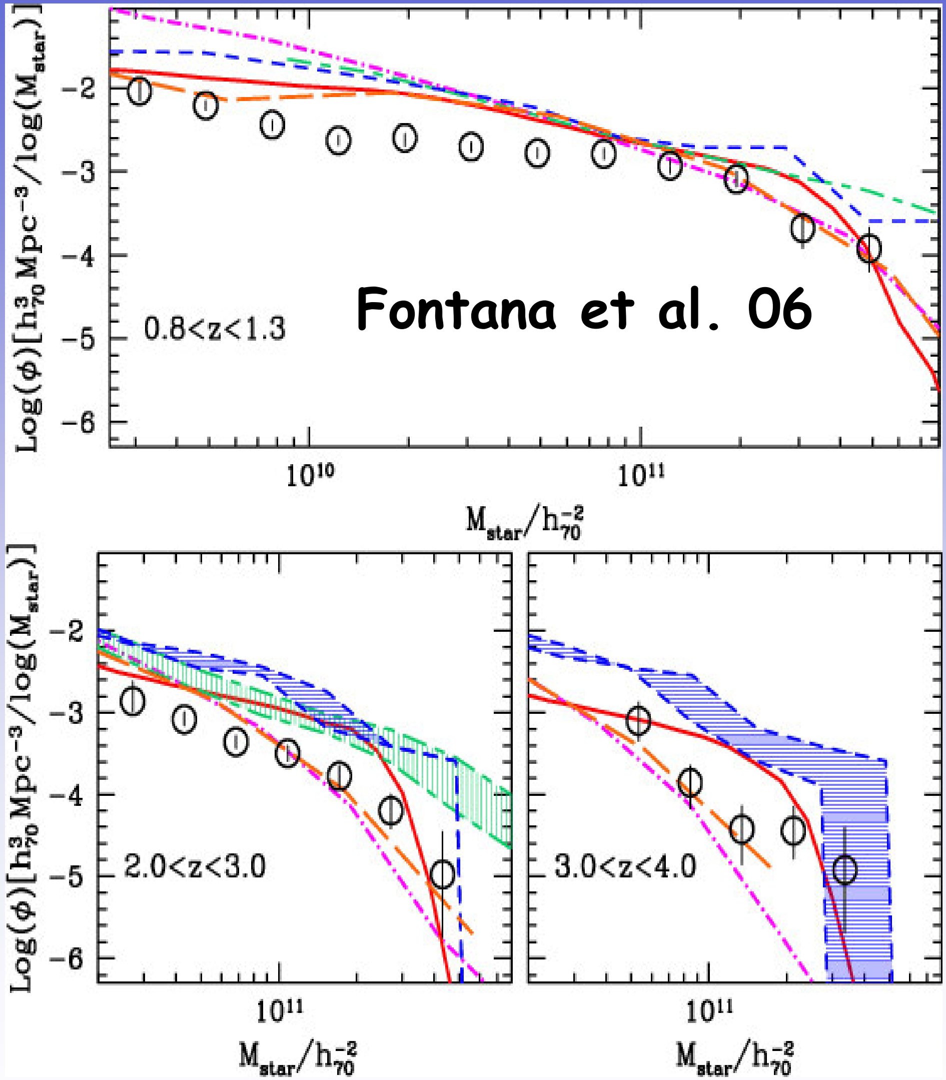
(Menci et al. 04)



(Fontana, Pozzetti et al. 04)

Most of current hierarchical merging models do not match the above results BUT Hydrodinamical match !

HM comparison

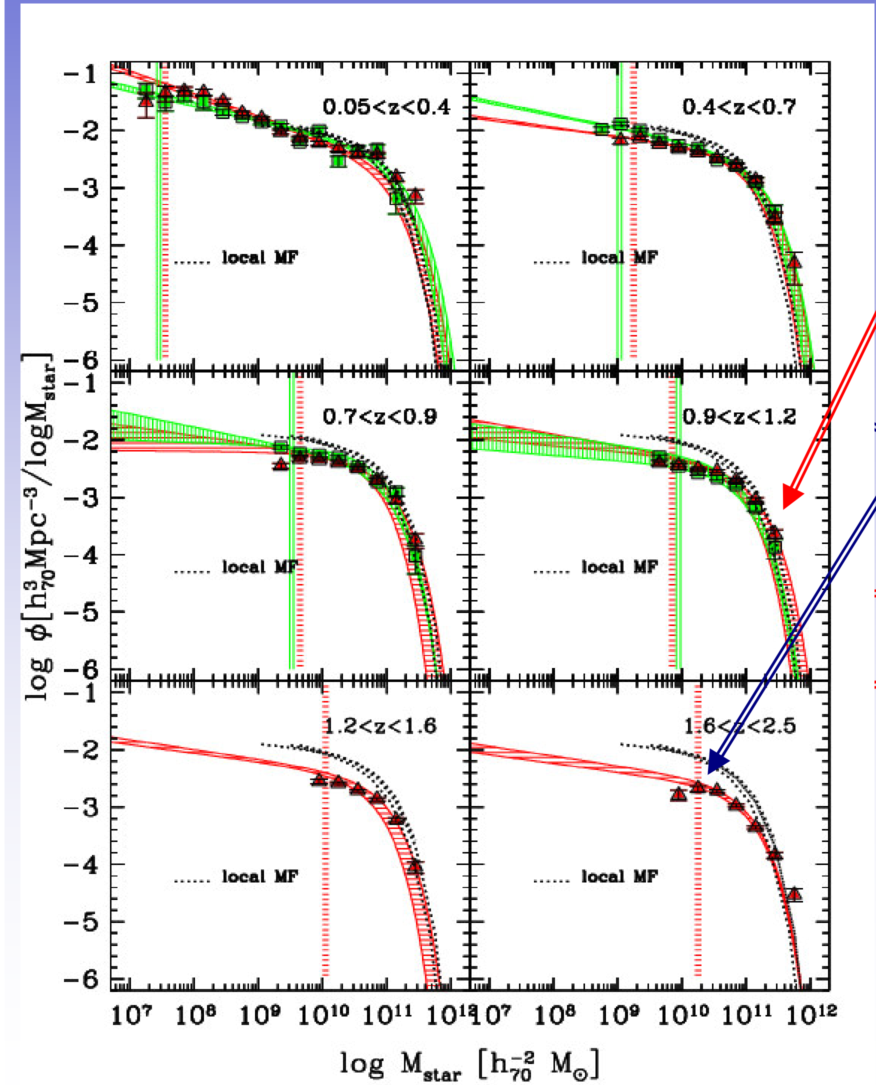


Some HM better in the massive tail but overpredict low-mass end

Evolution of the Stellar Mass Function and Number Density

I- and K- selected Mass function:

Pozzetti, et al., 2007



"Mass downsizing":

Mass dependent evolution of the number/mass density

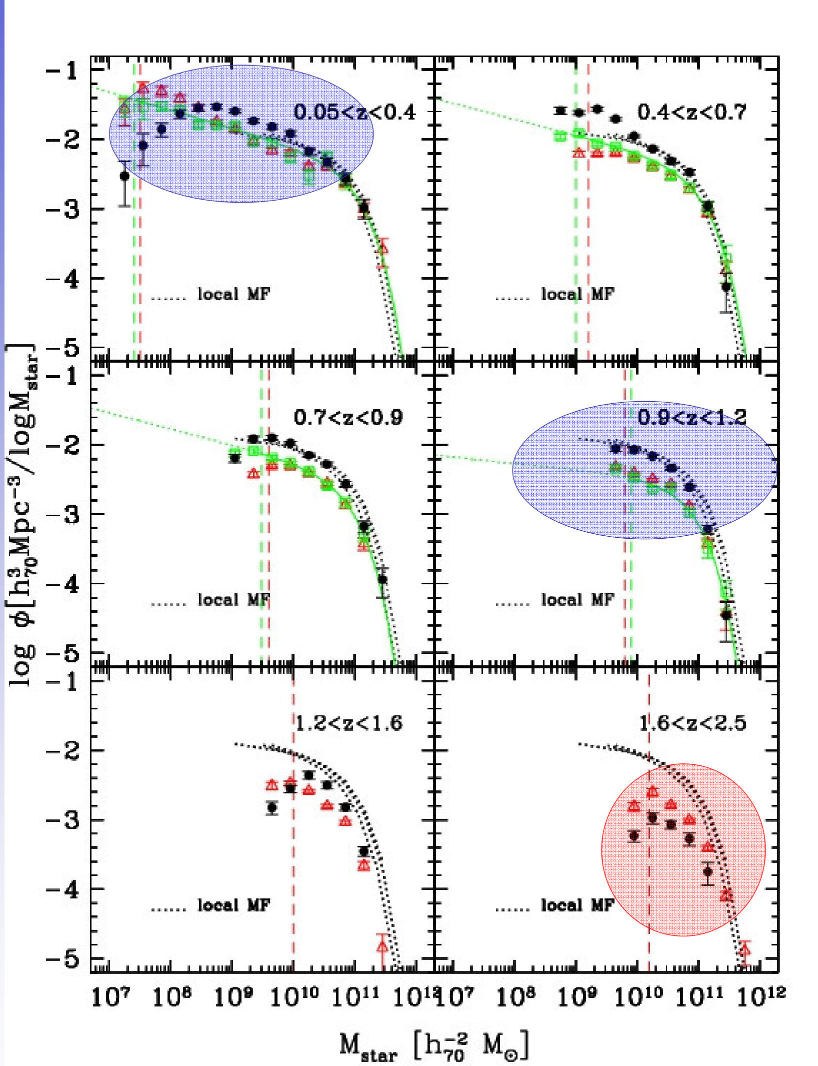
Massive tail is present up to z=1.5

Continuous evolution for intermediate/low-mass galaxies

Negligible evolution of massive galaxies (>10^{11} Msun) (<30%) up to z=0.8 and faster at higher-z (a factor of 3 at z=2)

Most of massive galaxies are in place up to z=1, less massive galaxies have assembled their mass later and continuously

HM Millenium Stellar Mass Function



Comparison with Millennium (in progress):

→ excess of intermediate/low-Mass galaxies(logM<10) galaxies compared to VVDS

Milder evolution with z compared to local and VVDS up to z=1.6 and faster at z>1.6

MFs: Millenium-StellarMass, VVDS-I-selected, VVDS-K-selected

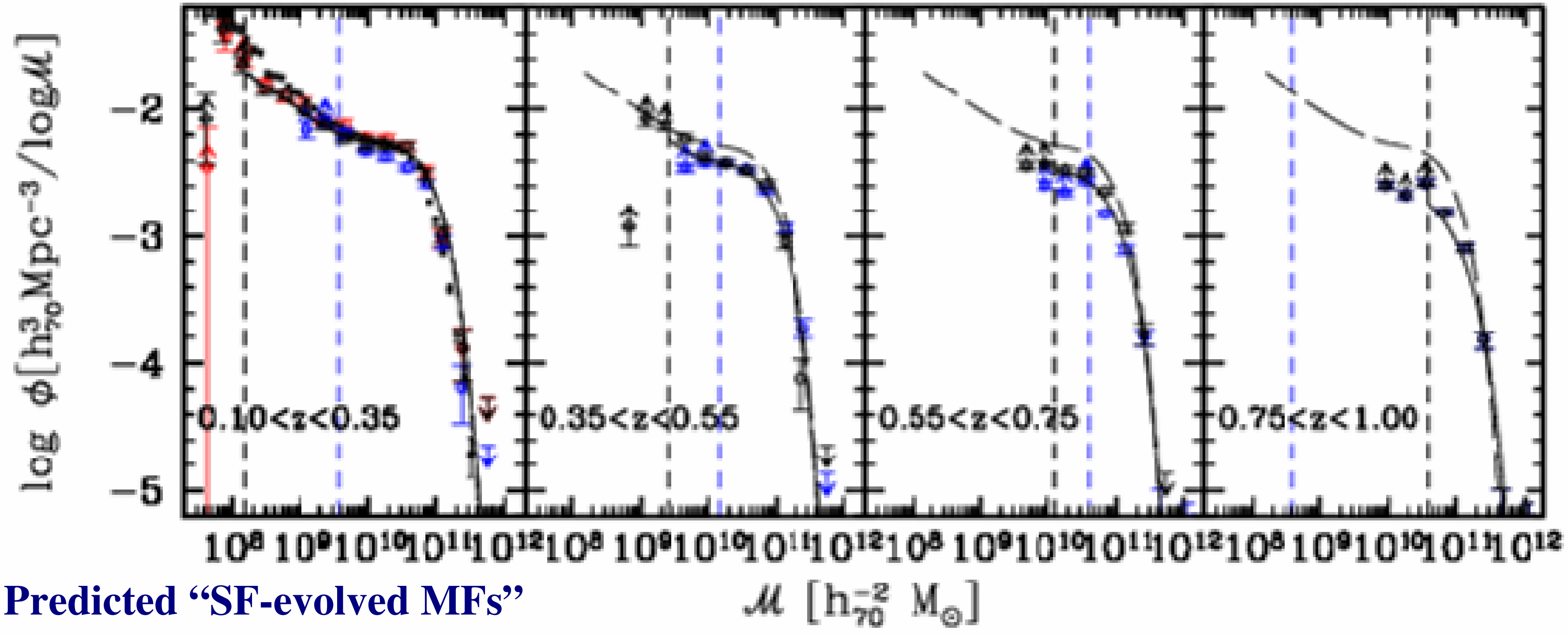
Dotted line: local MFs.(Cole et al. 2001, Bell et al. 03)

Dashed lines: limit due to I<24

Evolution in the Stellar Mass Function

COSMOS
Cosmic Evolution Survey

Pozzetti et al. (in progress)



Predicted "SF-evolved MFs"

Exponentially decreasing SFHs account for most of the MF evolution