

# Massive Galaxies at High Redshift from

K20 (PI A. Cimatti)

+

GOODS (PI M. Giavalisco)

mostly based on Daddi et al. 2003 (ApJL GOODS Special Issue)

Zürich August 19, 2003 — A. Renzini

# A STRINGENT TEST ON THE FORMATION OF EARLY-TYPE AND MASSIVE GALAXIES

Andrea Cimatti

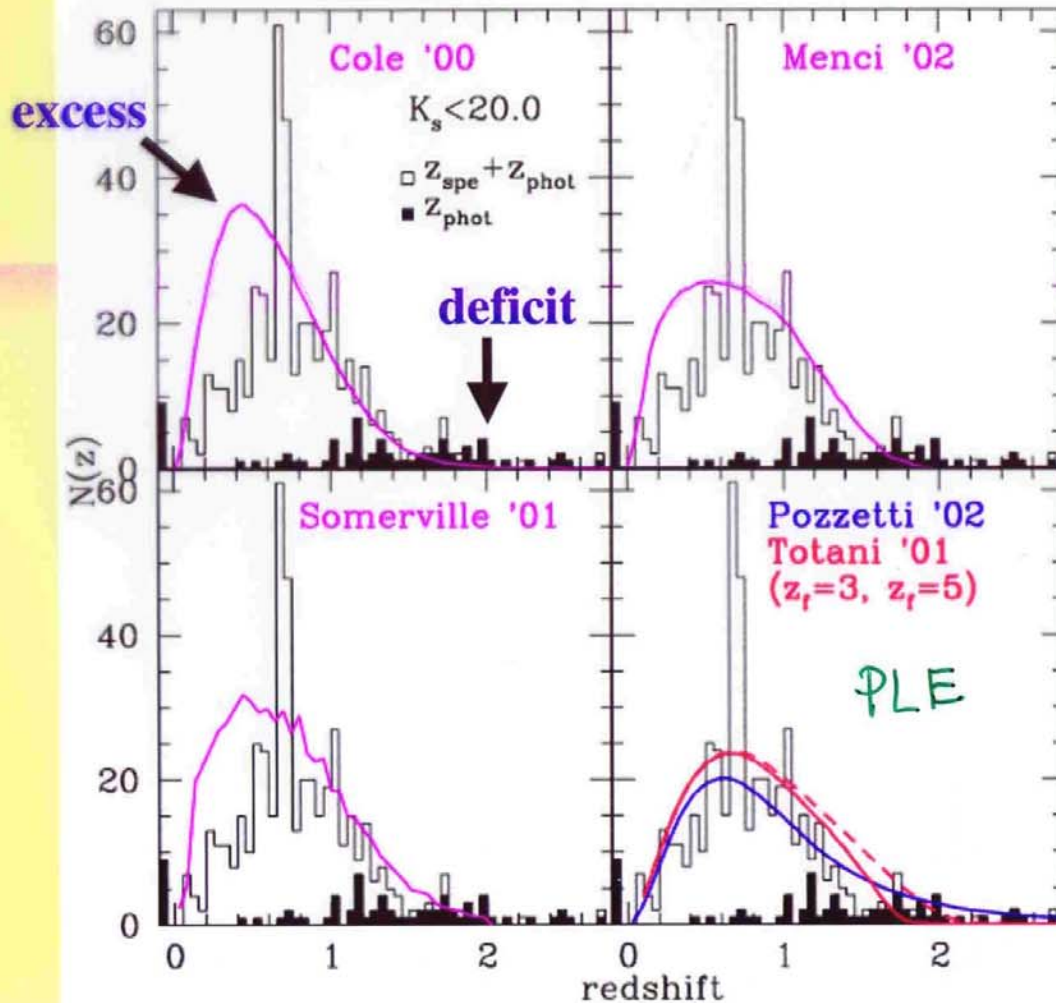
INAF – Arcetri (Italy)

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(Arcetri), N. Menci (Roma), M. Mignoli (Bologna), E. Pignatelli  
(Padova), F. Poli (Roma), L. Pozzetti (Bologna), A. Renzini (ESO),  
P. Saracco (Milano), J. Vernet (Arcetri), G. Zamorani (Bologna)

# N(z): observations vs. models

Cimatti et al. 2002

K20-IV



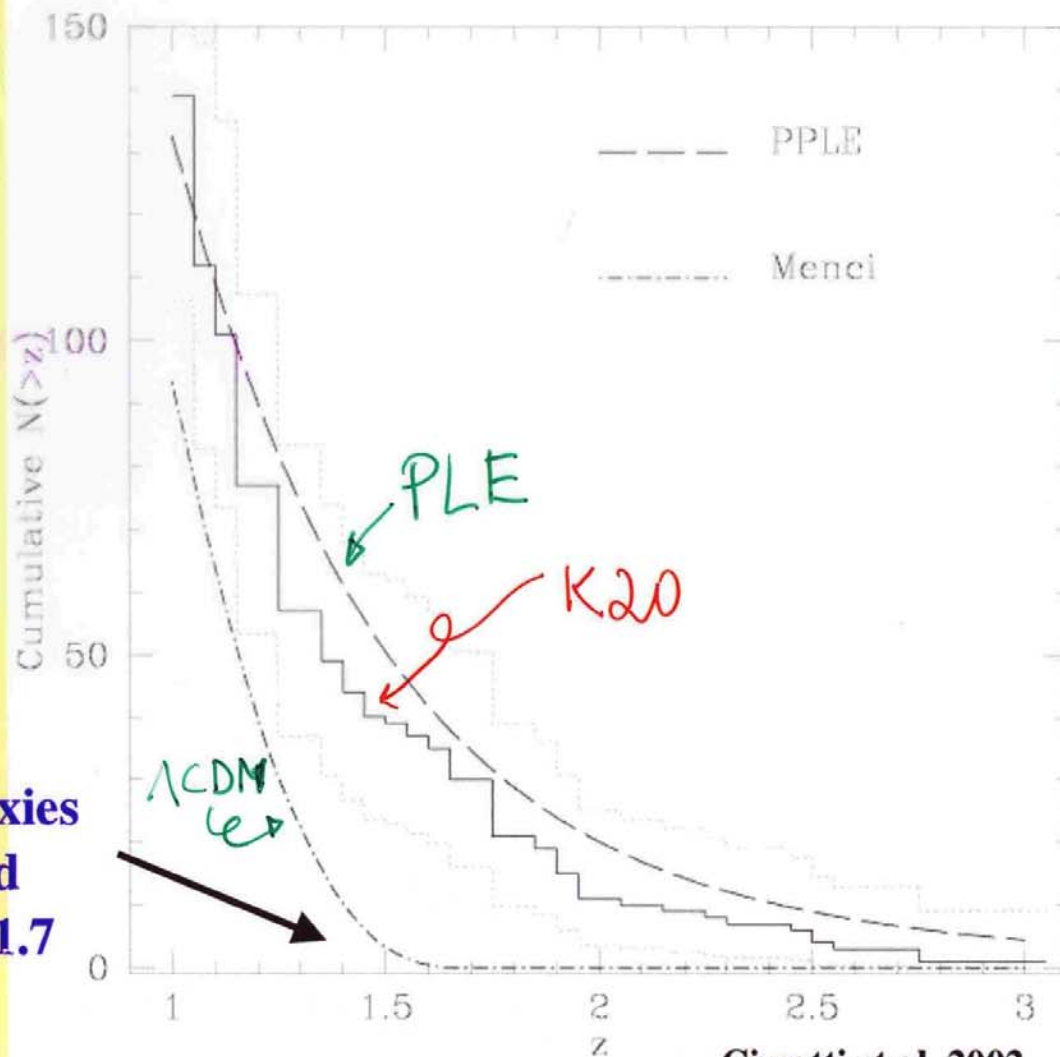
$\sim 550$  gals  
to  $K_s < 20$

$> 92\%$  spectra.

redshifts

$\sim 99\%$  incl.  
photo- $z$ 's

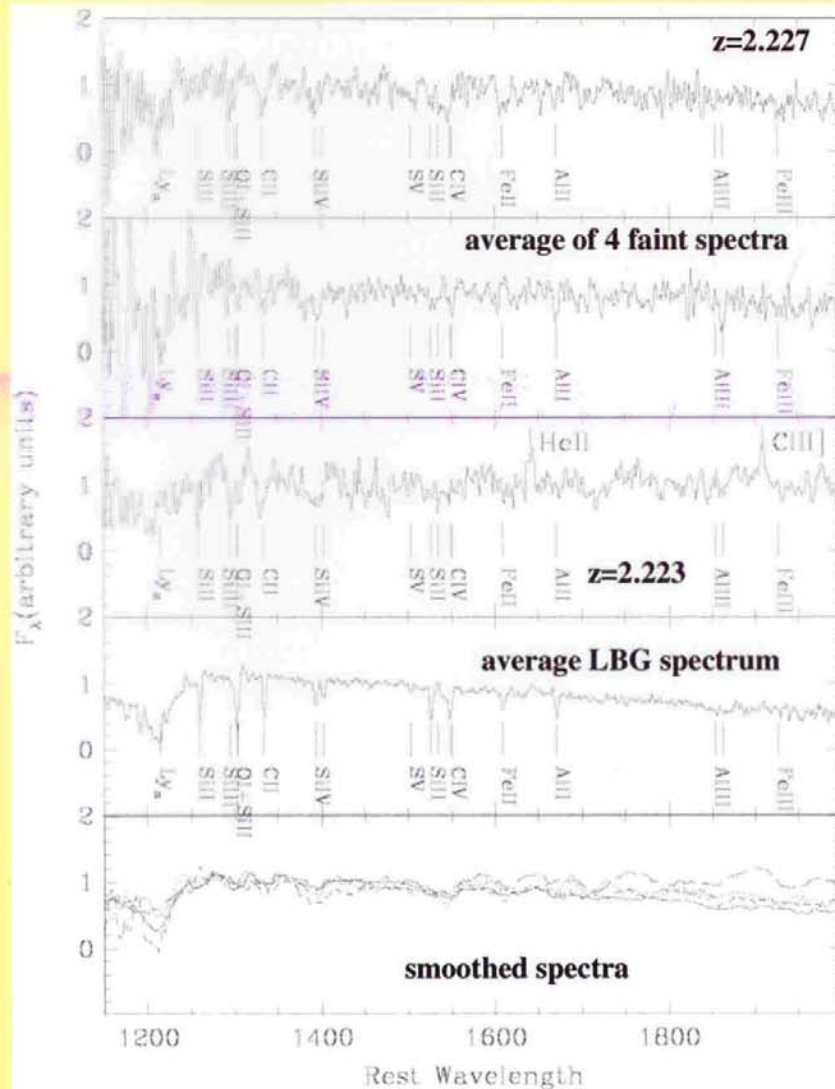
# Cumulative number of galaxies



No galaxies  
expected  
with  $z > 1.7$

Cimatti et al. 2002

## Spectroscopic confirmation of $z \sim 2$ galaxies



No Ly $\alpha$  emission

$E(B-V) \sim 0.3-0.6$

SFR  $\sim 100-500$  Msol/yr

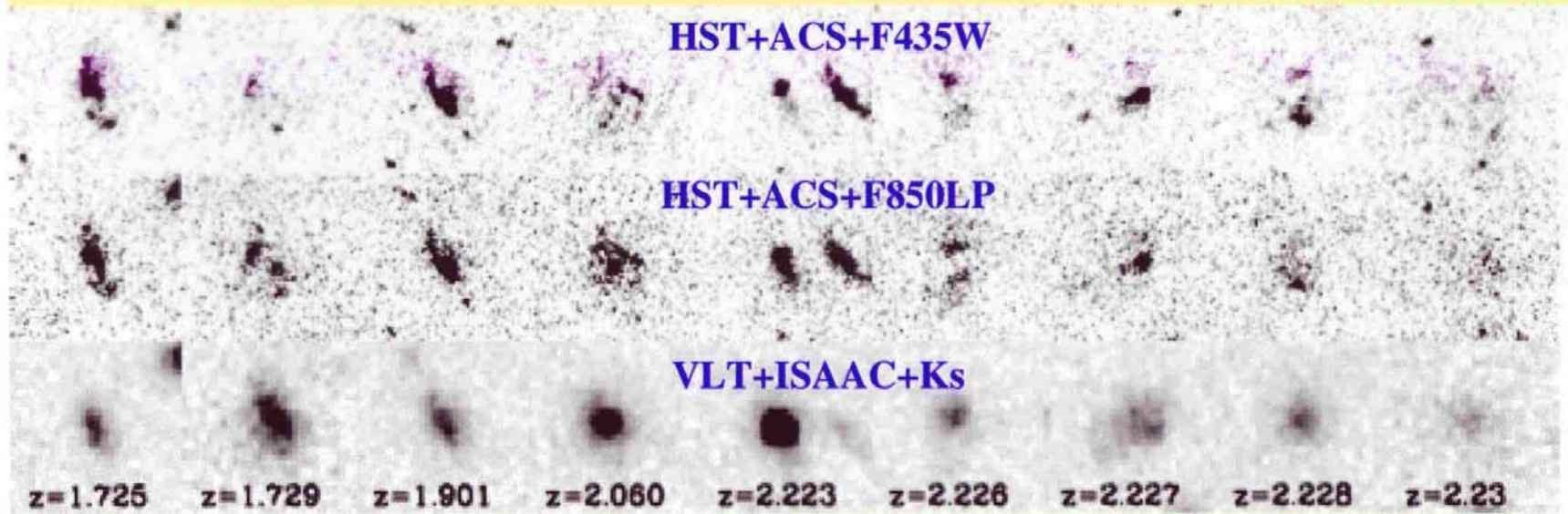
Masses  $\sim 10^{11}$  Msol

Strongly clustered

Mergers

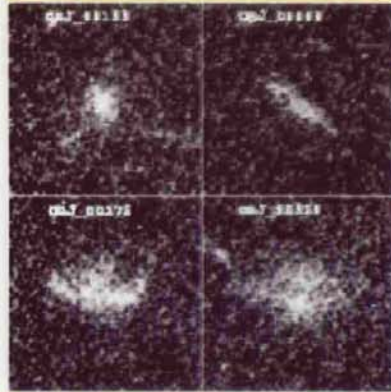
K20+GOODS

# Morphology of $z \sim 2$ galaxies

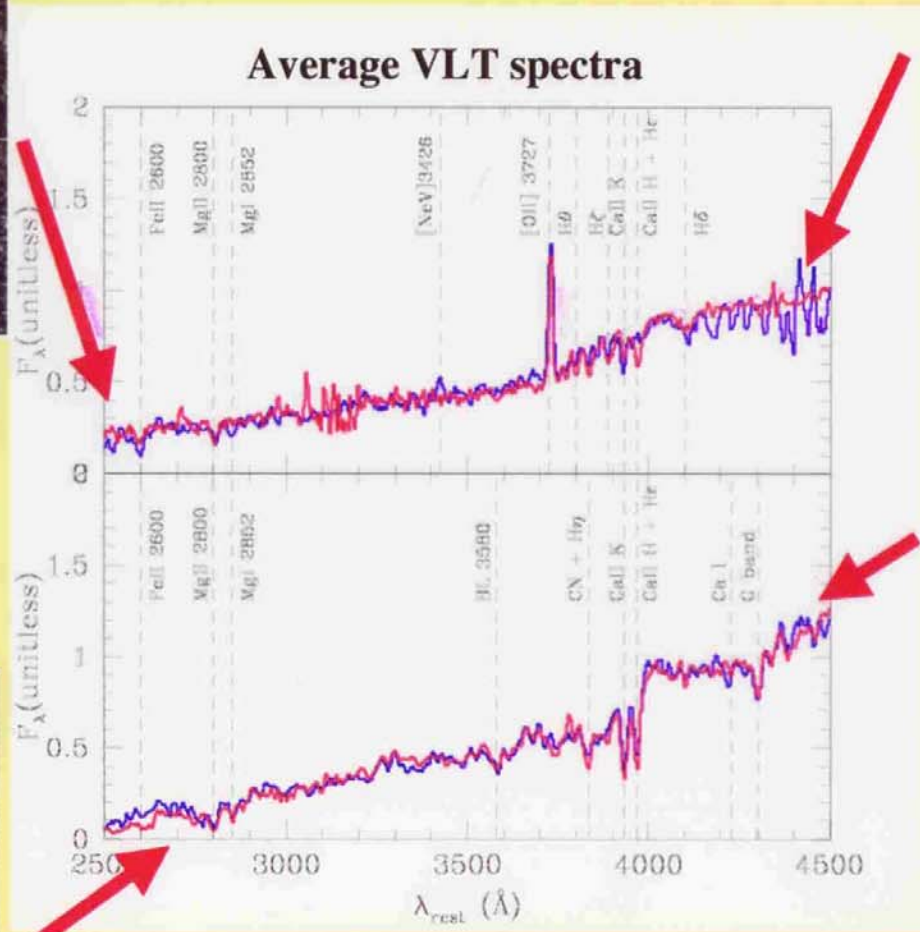
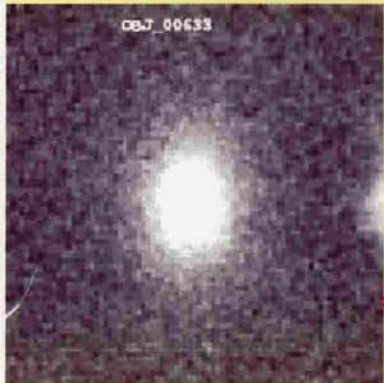


Daddi et al. 2003

# Extremely Red Objects (EROs)



HST+ACS  
z-band



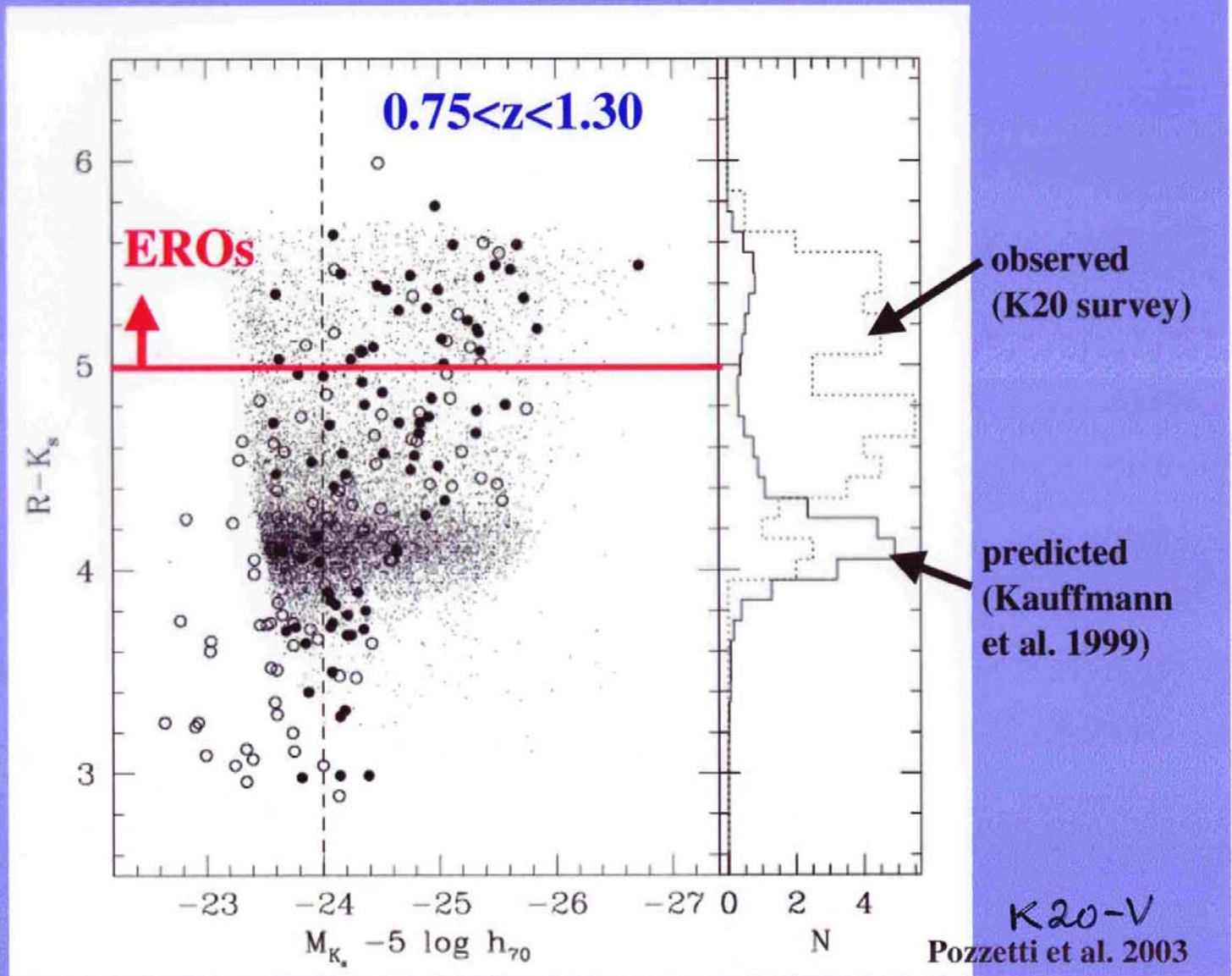
**Dusty star-forming**  
 ~60%  
 $z \sim 0.8-1.6$   
 $E(B-V) \sim 0.5-1.0$   
 SFR ~ 20-100 Msun/yr  
 >20% SFRD @  $z \sim 1.3$

**E/S0 galaxies**  
 ~40%  
 $z \sim 0.9-1.5$   
 ~3 Gyr old  
 $z(\text{form}) > 2$   
 $N \sim N(\text{PLE})$   
Clustered  
 $M(\text{stars}) > 10^{11} \text{ Msun}$

Cimatti et al. 2002,2003

K20-I

# Luminous red galaxies at $z \sim 1$



## The Precursors of $z = 0$ E/S0 Galaxies

⇒ Look for the most clustered population at each redshift!!

★ At  $z = 0$  E/S0 Galaxies have  $r_o \simeq 10$  Mpc

Best Precursors (so far):

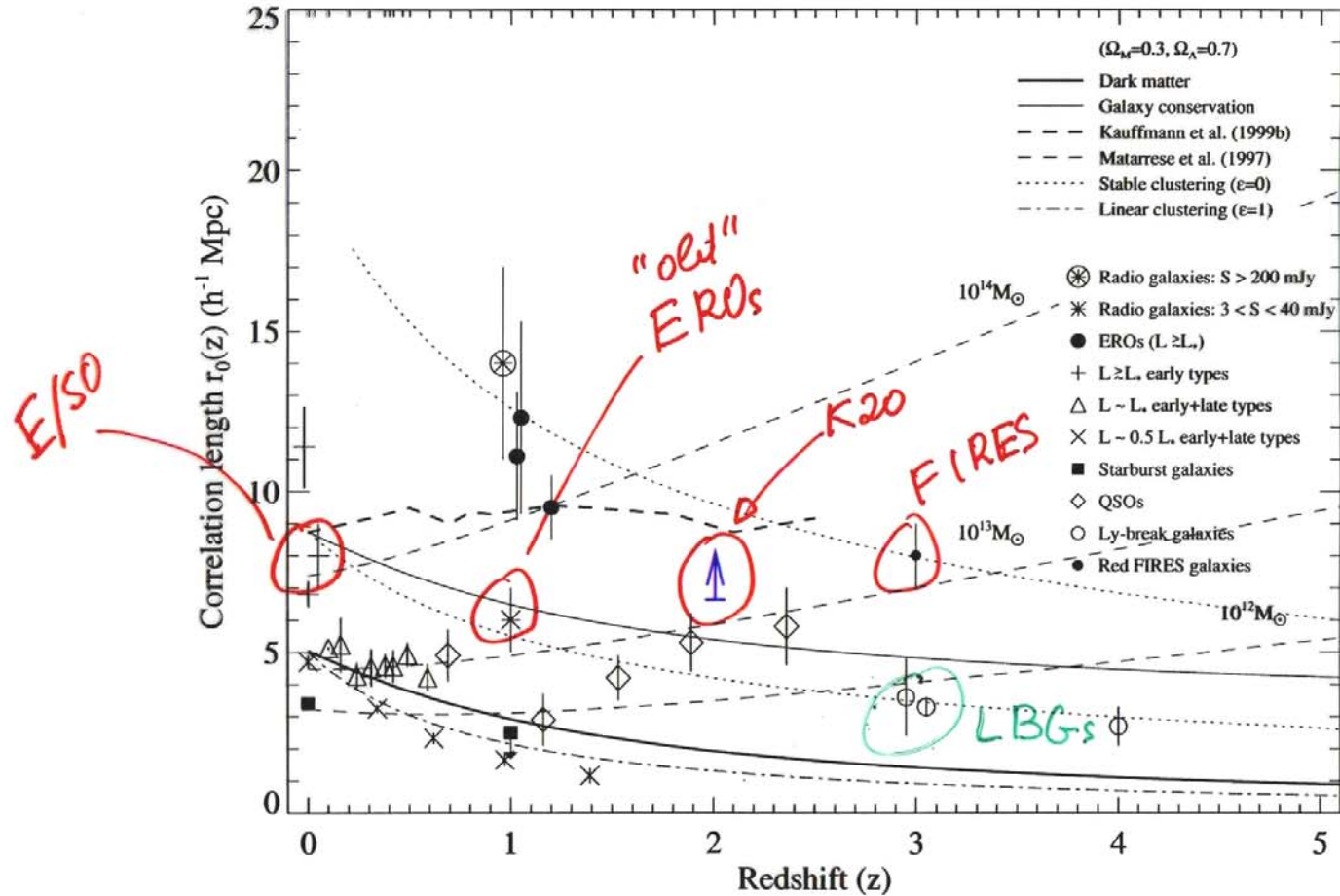
★ At  $z \simeq 1$  : Old EROs ( $R - K > 5$ ; No em. lines) ⇒  $r_o \simeq 10$  Mpc

★ At  $z \simeq 2$  :  $K < 20$  K20 Starburst Galaxies ⇒  $r_o \gtrsim 8$  Mpc

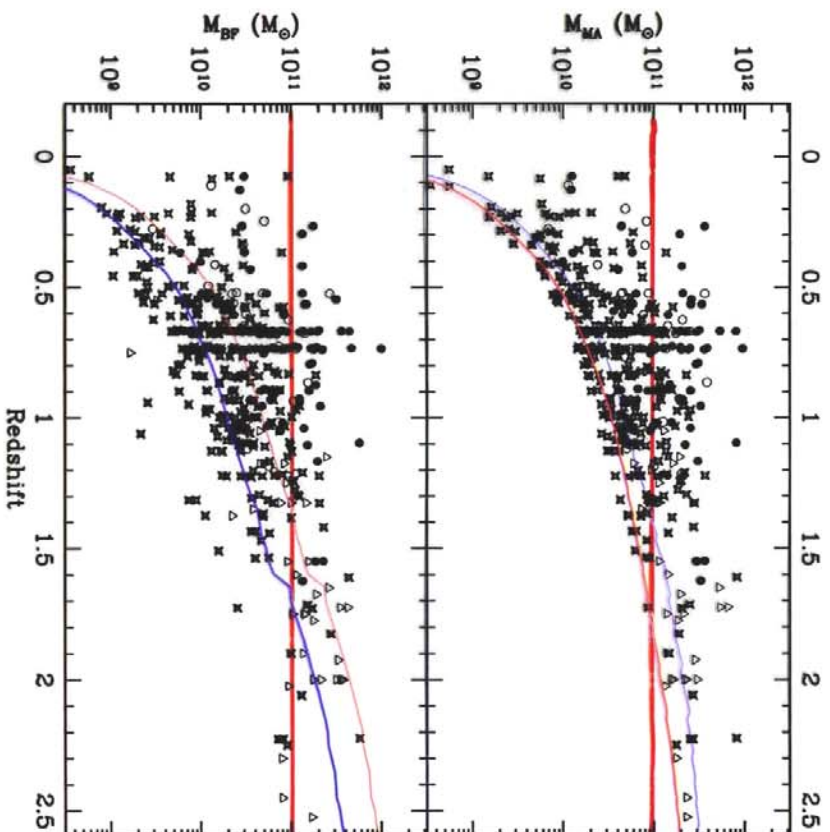
★ At  $z \simeq 3$  : FIRES Objects; SCUBA Sources ⇒  $r_o \simeq 8 - 10$  Mpc

LBGs are less clustered ( $r_o \simeq 3$  Mpc) ⇒ likely precursors of lesser galaxies, e.g. “Milky Way” Bulges ...

adapted from Röttgering, Daddi, Overzier & Wilman, astro-ph/0307283



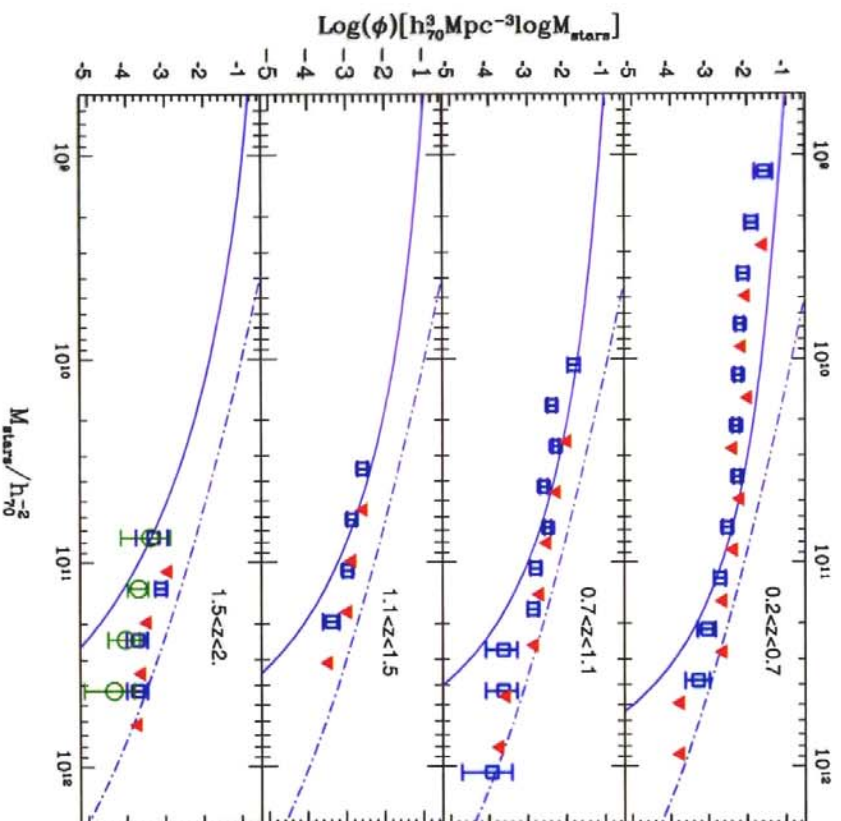
Fontana et al. 2003, K20-VI  
Stellar Masses from



R-K  
K

UBVRISK  
SED

Fonfane et al. 2003, K20-VI



## Conclusions From K20+GOODS+FIRES ...

★ Massive Galaxies are assembled at a substantially earlier time than so far predicted by CDM Semianalytical Models.

Also at odd with CDM expectations (dogmas):

★ At  $z \sim 2$  the most massive galaxies are already in place, with instead an apparent deficit of less massive galaxies: Anti-hierarchical!!! (K20-VI, Fontana et al. 2003, in the making).

★ Very little (if any) environmental dependence of Early-type/red galaxies, from  $z = 0$  all the way to  $z \sim 1$  (Bernardi et al. 1998, 2003; Kochanek et al. 2000; Hogg et al. 2003; van Dokkum & Ellis 2003; ...)

Will a better tuning of CDM/S-A model parameters suffice?

e.g. algorithms for:

- star formation,
- internal feedback,
- proximity feedback,
- what else ?

Or do we need to change something more basic?? e.g.:

- $\Omega_M < 0.3$ ?
- CDM Properties?
- what else ?

(Almost) FULL EMPIRICAL  
MAPPING OF GALAXY  
EVOLUTION TO  $z \sim 6.6$   
WITHIN REACH WITH  
PRESENT SPACE +  $8 \pm 2$  Telescopes

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