An internal driver of galaxy evolution is needed to produce galaxy "downsizing"

P. Monaco
Universita` di Trieste - INAF-OATs

In collaboration with:

F. Fontanot, G. De Lucia, R. Somerville, L. Silva, E. Vanzella, B. Lo Faro, S. Cristiani, P. Santini, A. Grazian, A. Fontana & the GOODS-MUSIC team

Galaxy secular evolution: is it all that matters? Milano 2011

The many manifestations of downsizing:

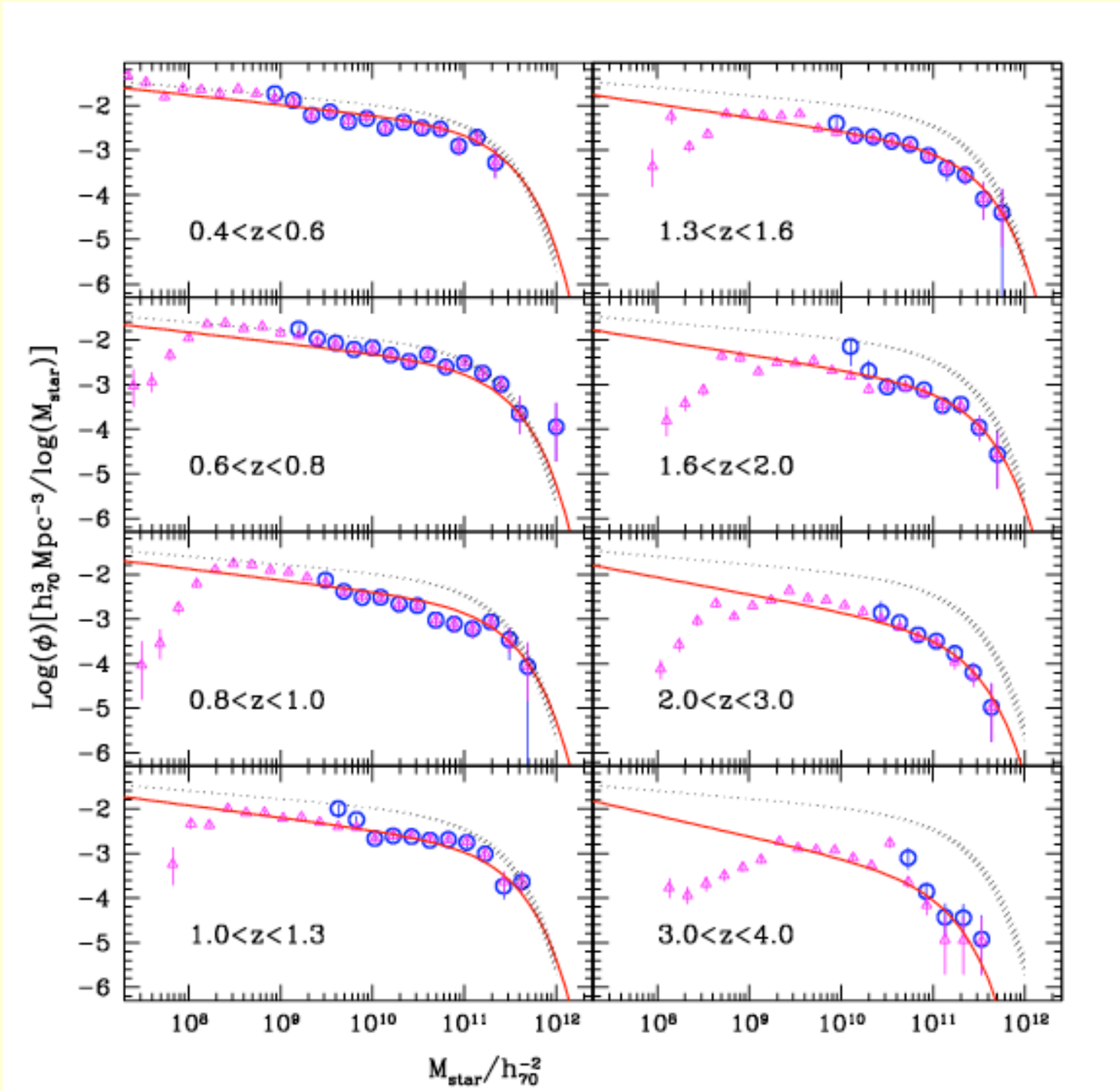
Fontanot, De Lucia, PM, Somerville & Santini, 2009, MNRAS 397, 1776

- archaeological DS
  more massive galaxies host older stellar populations
- star formation DS:
  the mass of the typical SF galaxy grows with z
- stellar mass DS:
  the number density of smaller galaxies evolves faster since $z \lesssim 1$
- chemical DS:
  the metallicity of smaller galaxies evolves faster with z
- chemo-archaeological DS:
  more massive ellipticals have higher [a/Fe] ratios
- AGN DS:
  the number density of fainter AGN peaks at lower z

Downsizing in stellar mass: GOODS-MUSIC

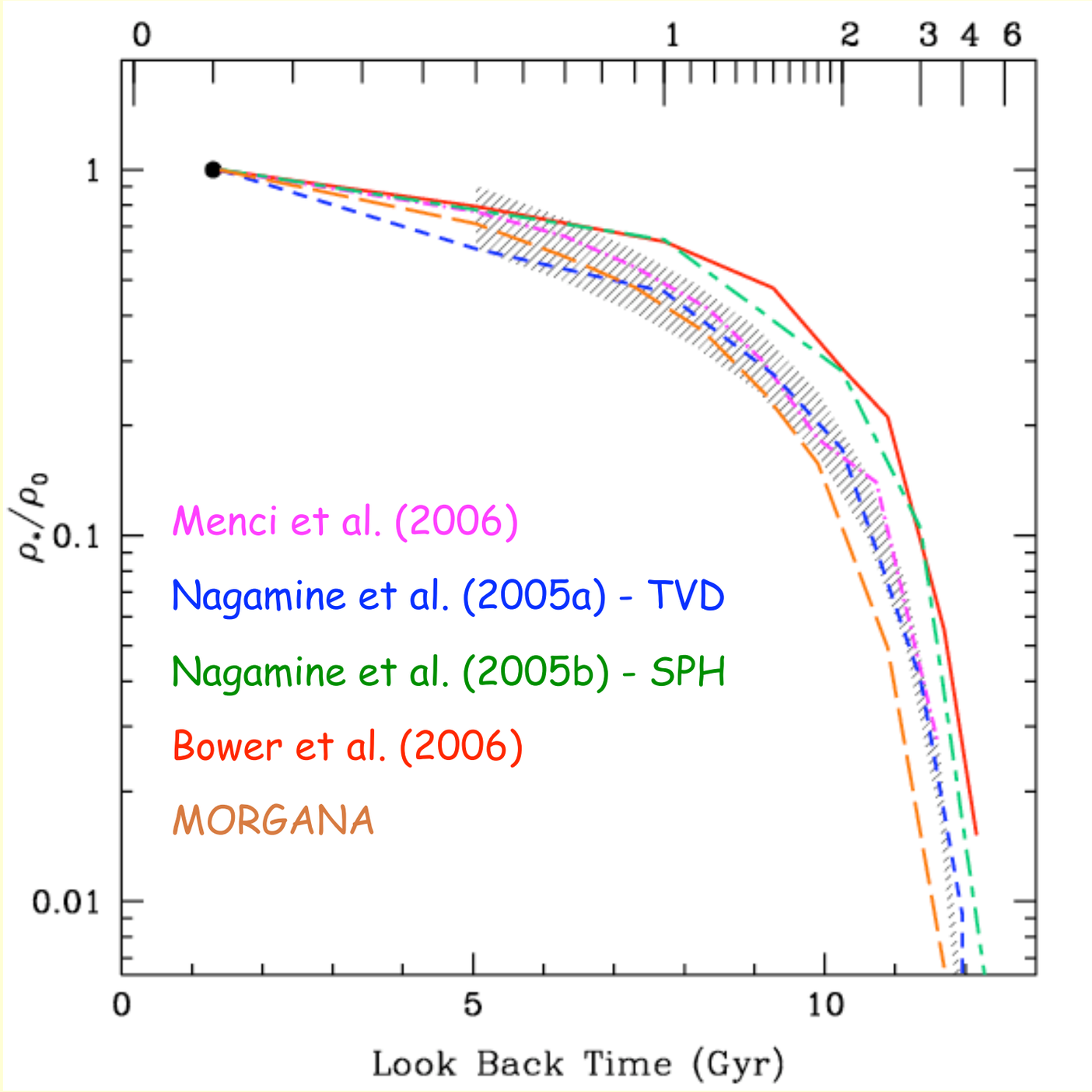
Fontana, PM et al. 2006, A&A 459, 745

- ~3000 K-selected galaxies in GOODS-S
- complete to Ks~23.5 (AB)
- broad-band coverage from U to MIR (ACS@HST, VLT, IRAC@Spitzer)
- 28% spectroscopic redshifts
- well-trained photometric redshifts for all galaxies (14 bands)
- reliable stellar mass estimates up to z~4

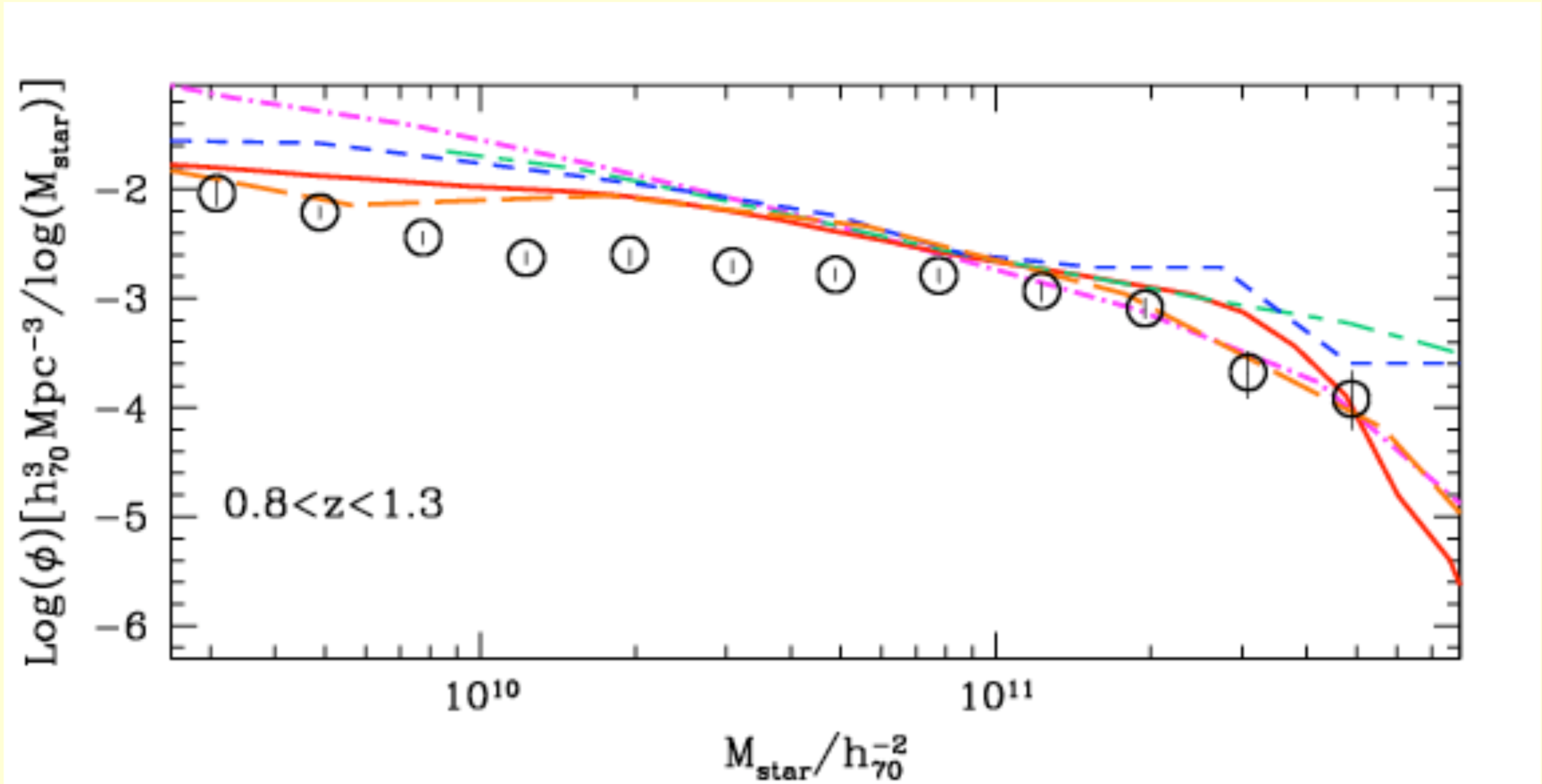


Stellar mass density in massive galaxies ($>10^{11}$ M_{sun}): data vs models

The average assembly of massive galaxies is reproduced by models (+ De Lucia, Somerville etc.)



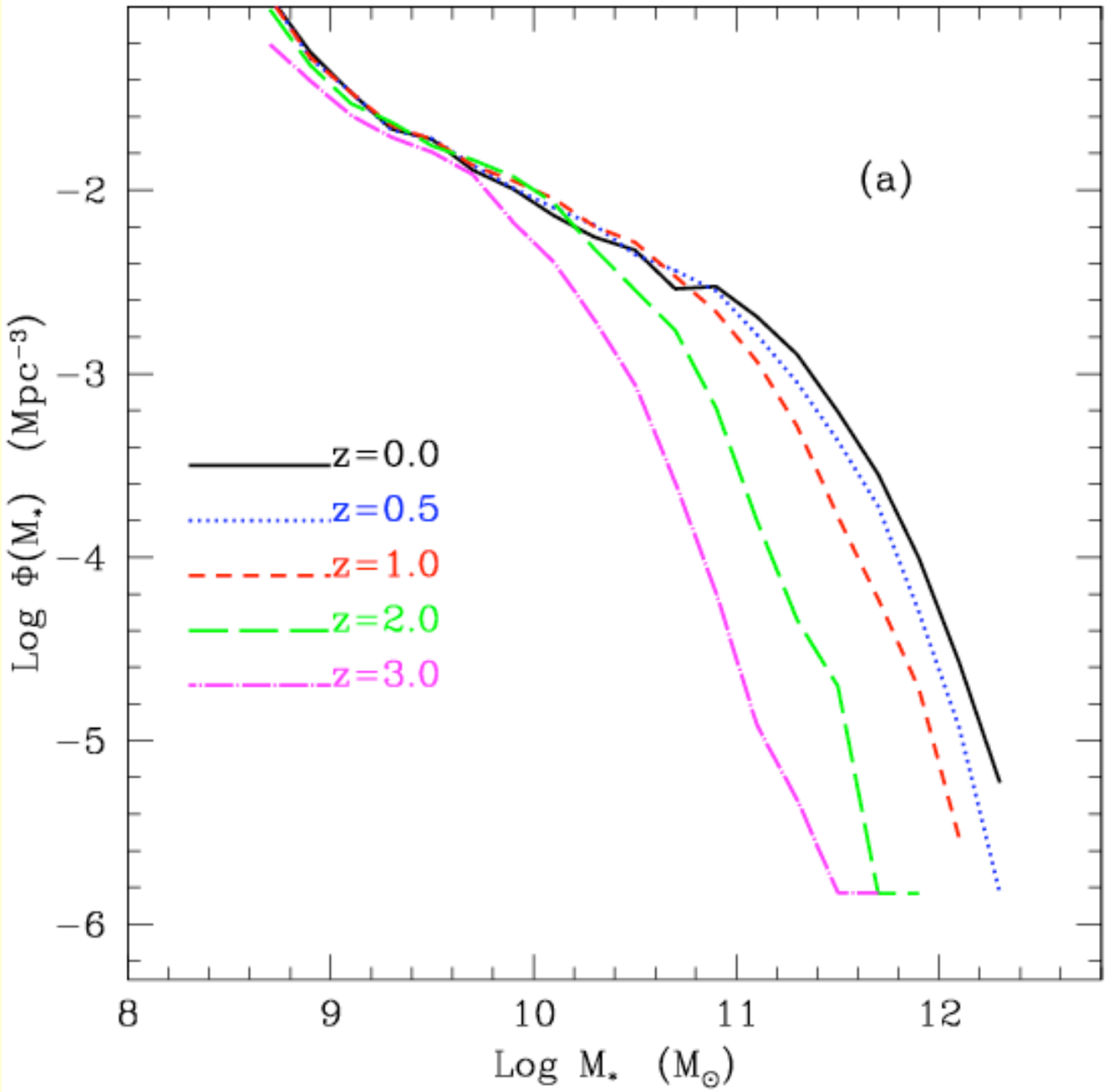
Stellar mass function at z~1

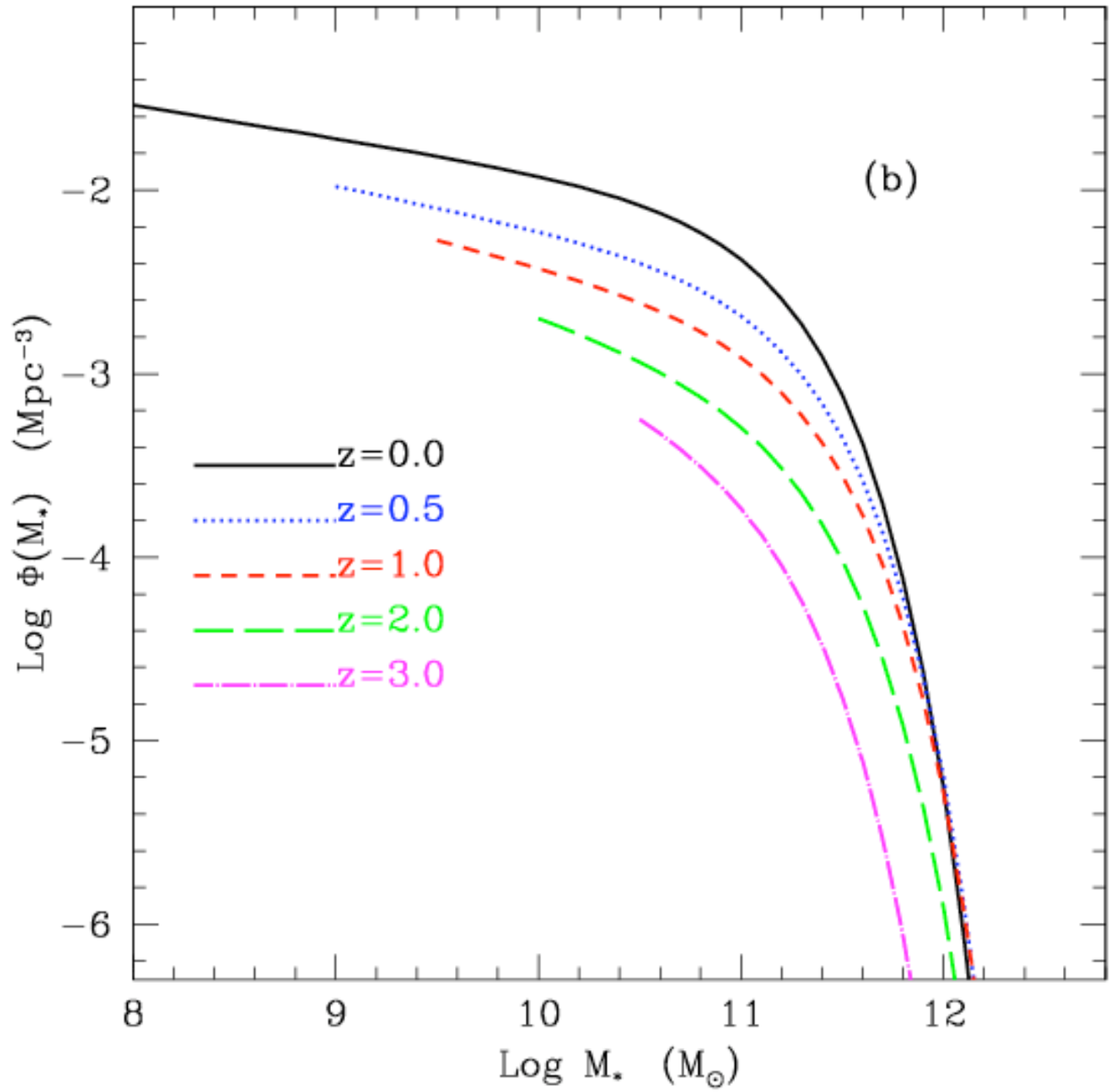


All models consistently overpredict the number of ~10^{10} M_{sun} galaxies at z~1

Downsizing?!?

(Fontanot, PM, Silva & Grazian, 2007, MNRAS 382, 903)





Model

Data

DS in stellar mass

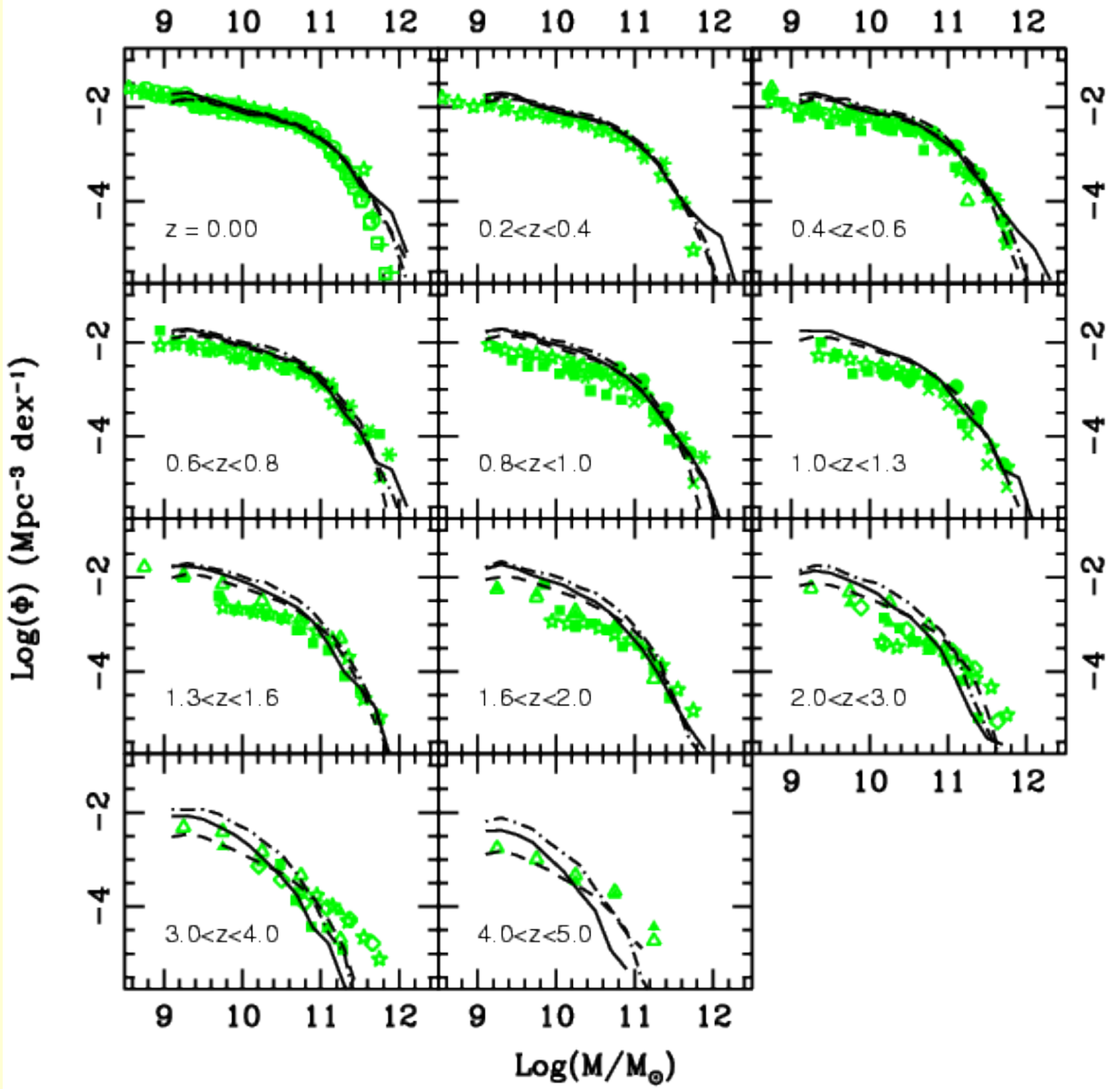
comparison of three models:

- Garching-De Lucia
- Monaco & Fontanot (Morgana)
- Somerville 08

(assumed error on mass: 0.25 dex)

with observational estimates of stellar mass functions by:

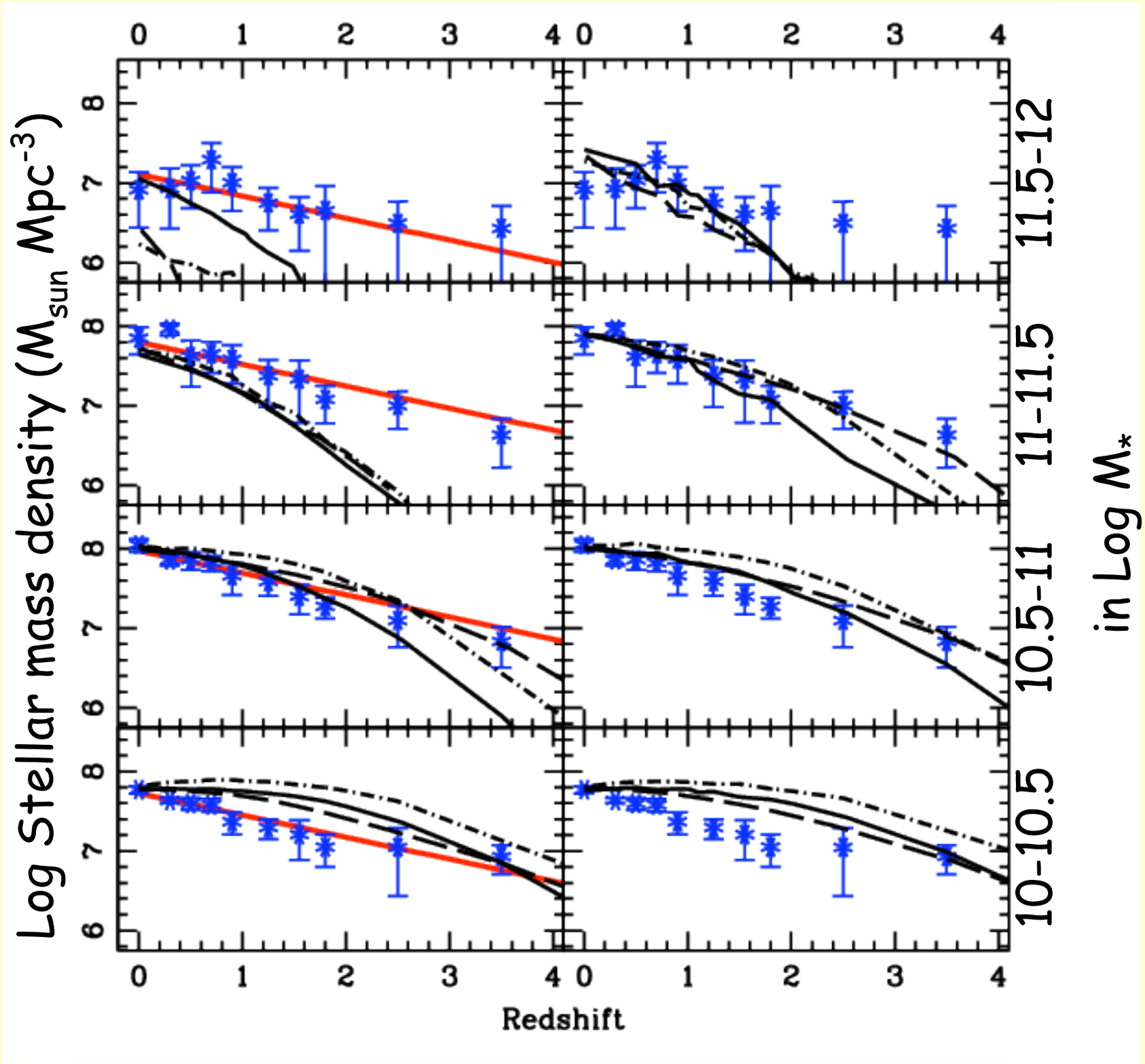
- Panter+ 07, SDSS
- Cole+ 01, 2MASS
- Bell+ 03, 2MASS+SDSS
- Borch+ 06, COMBO17
- PerezGonzalez+ 08, Spitzer
- Bundy+ 06, DEEP2
- Drory+ 04, MUNICS
- Drory+ 05, FDF+GOODS
- Fontana+ 06, GOODS-MUSIC
- Pozzetti+ 07, VVDS
- Marchesini+ 08, 3 fields



Good agreement at high masses

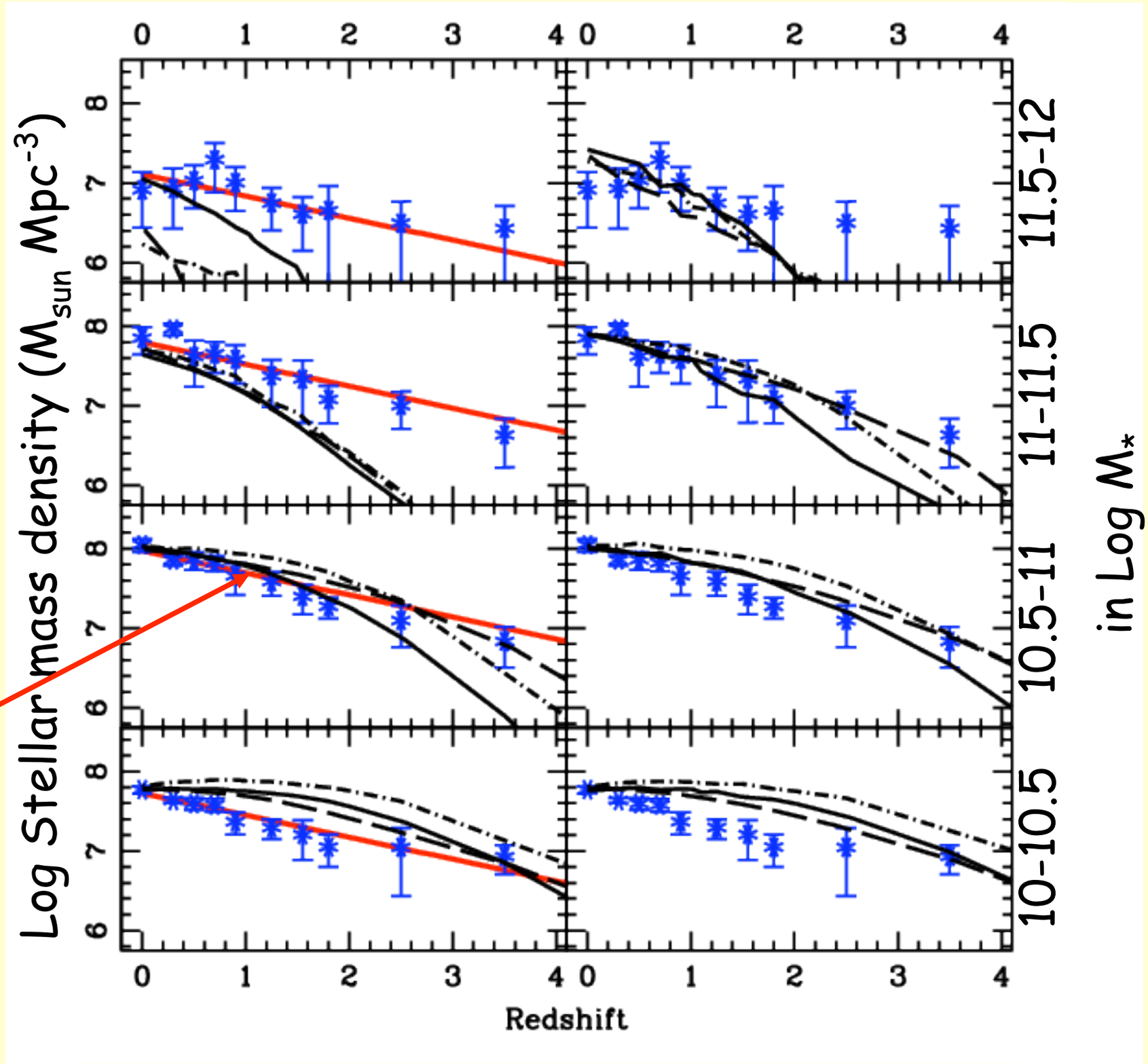
no downsizing at small masses

Without error in stellar mass



With 0.25 dex error in stellar mass

Without error in stellar mass



With 0.25 dex error in stellar mass

is there DS in the data or is it a density evolution?

Underestimate IF errors
in mass are neglected!

Without error in stellar mass

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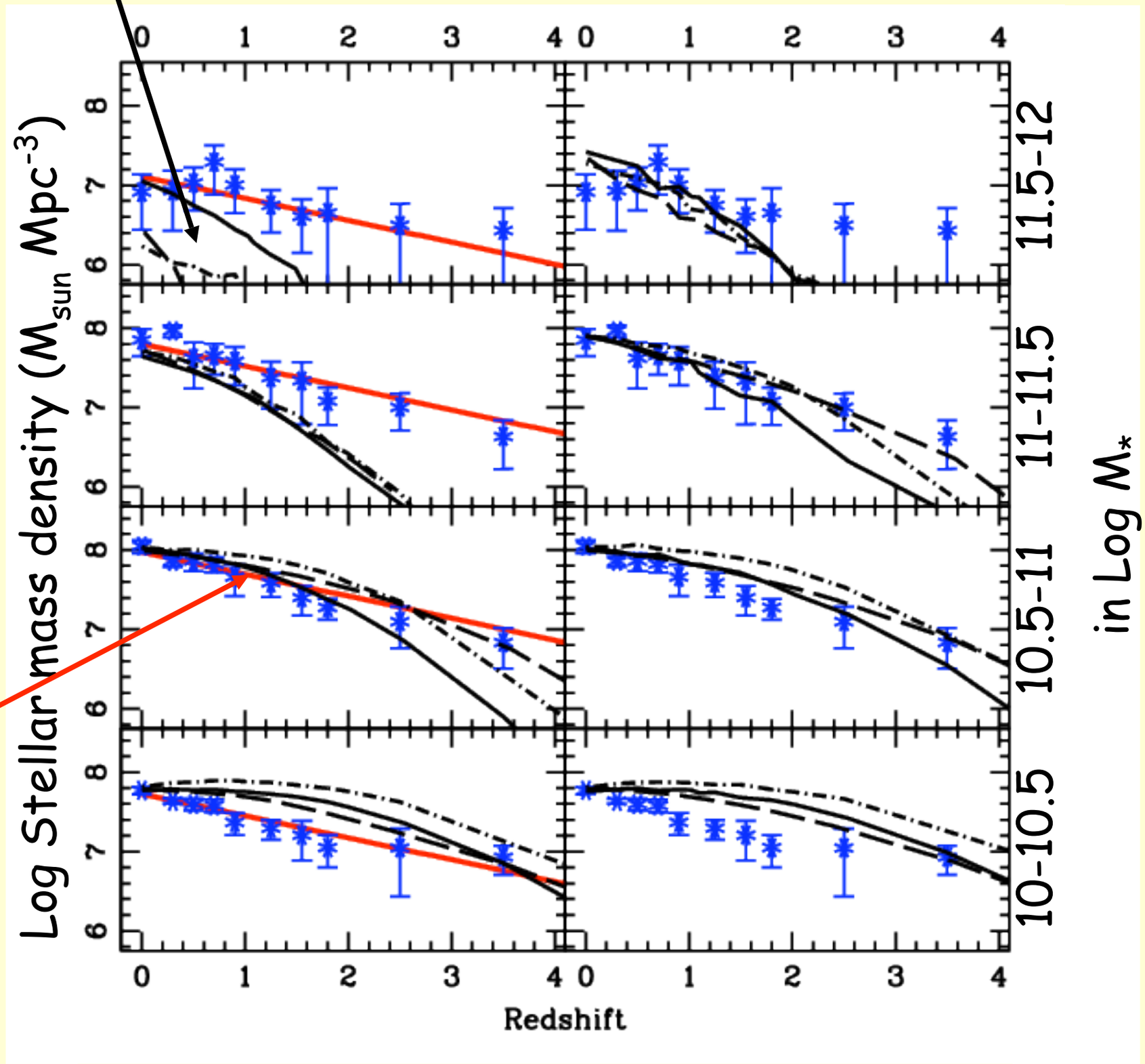
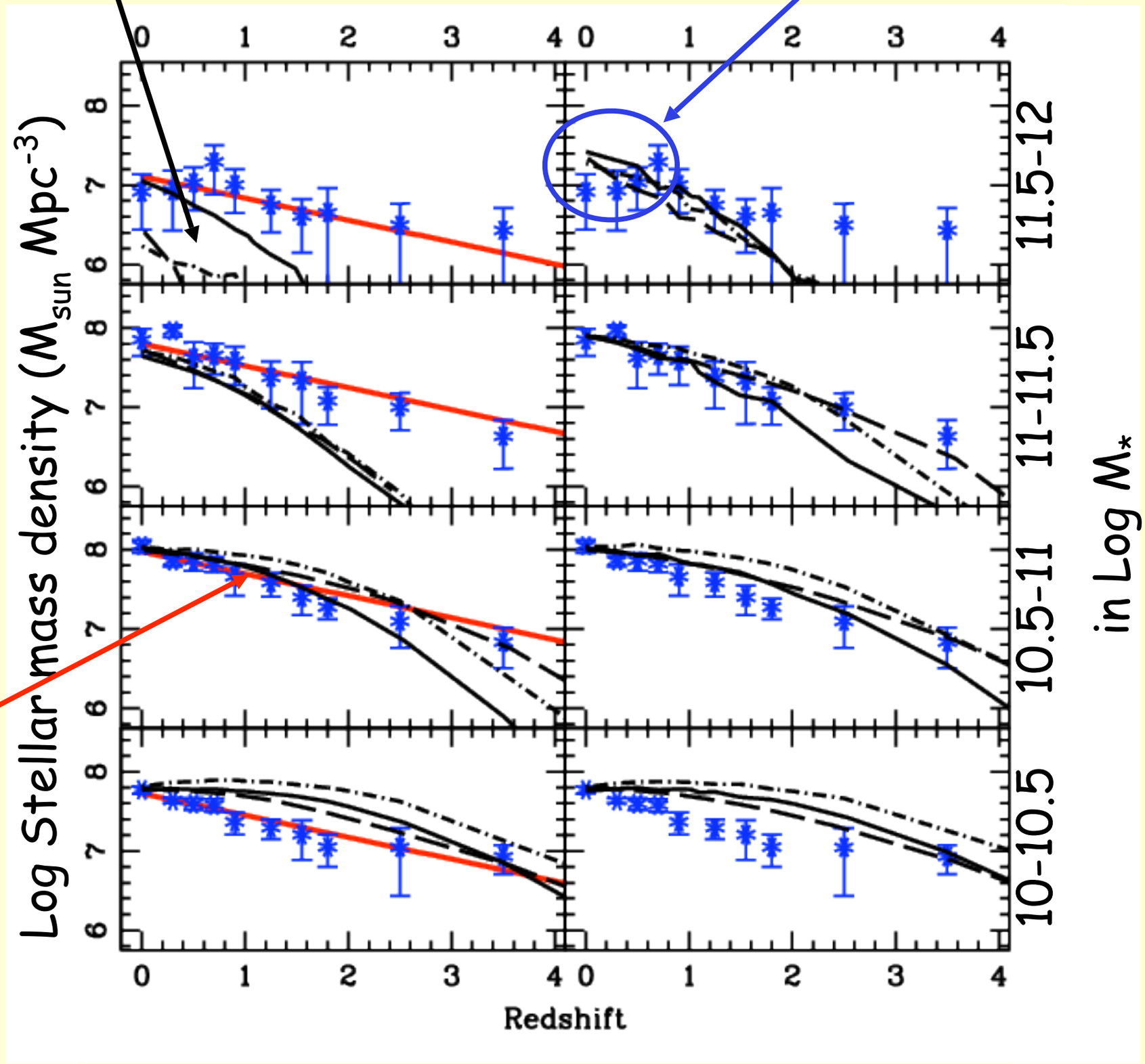


Underestimate IF errors in mass are neglected!

merger-driven growth of very massive galaxies

Without error in stellar mass



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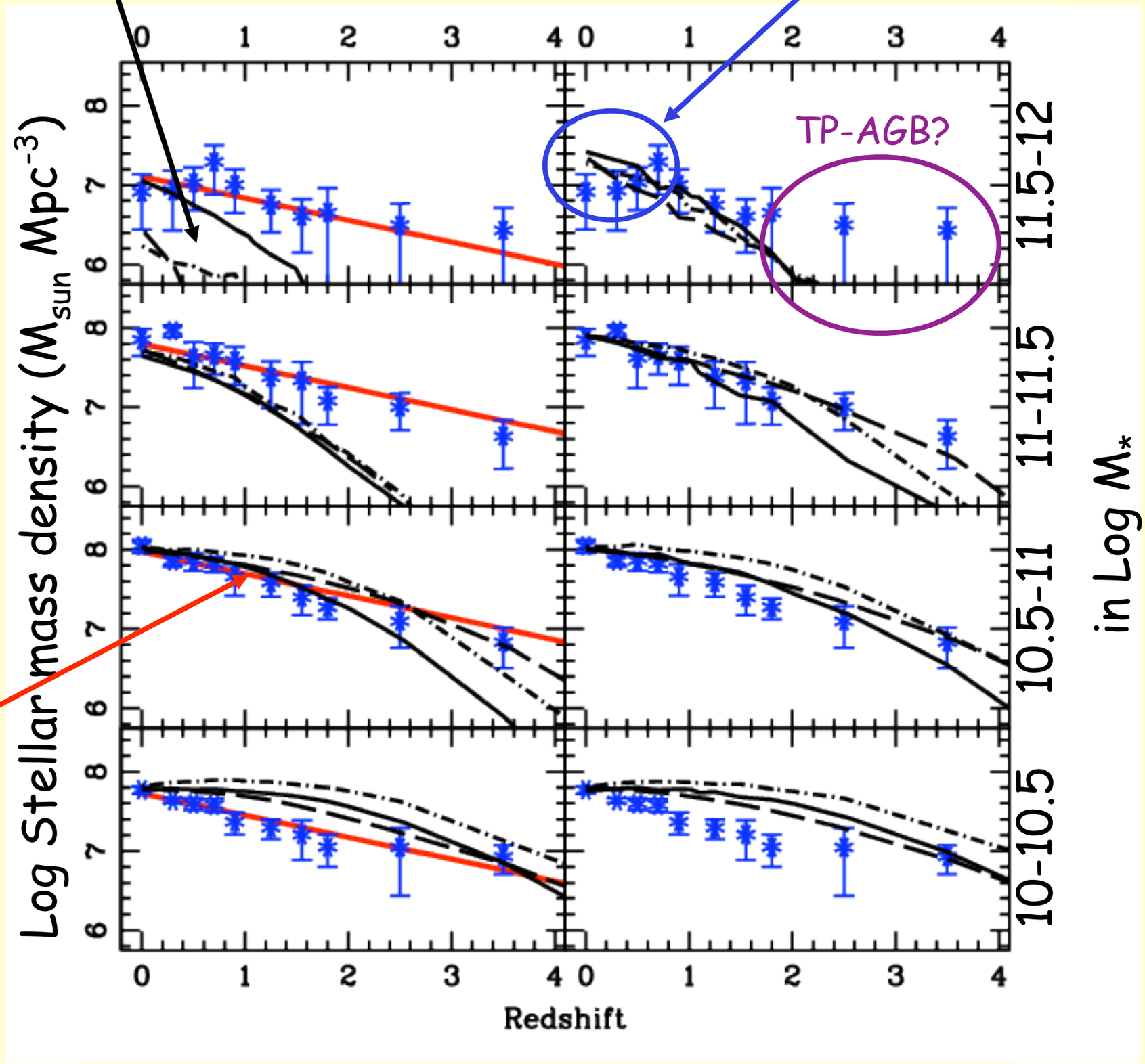

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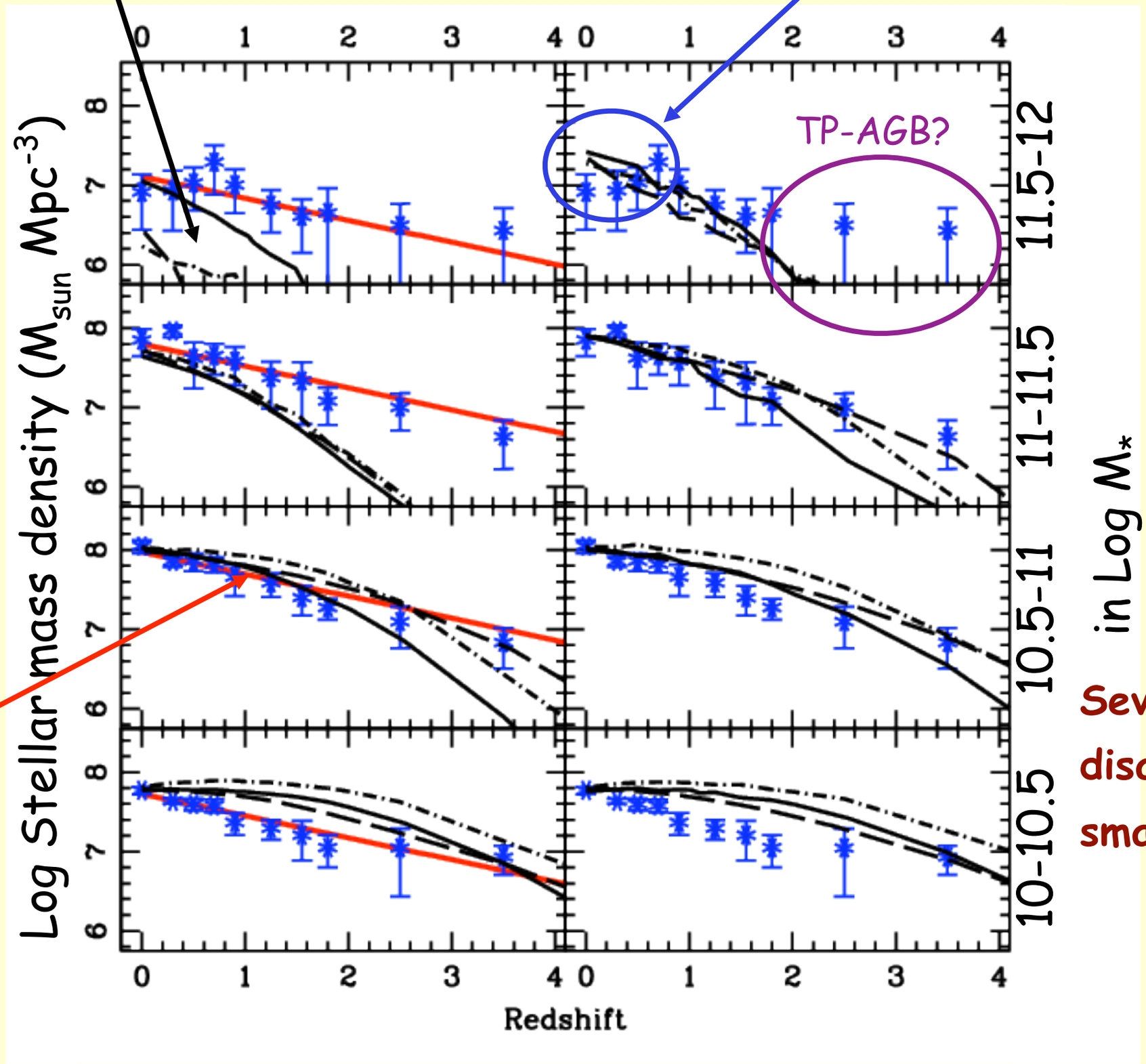

With 0.25 dex error in stellar mass

Severe disagreement at small masses

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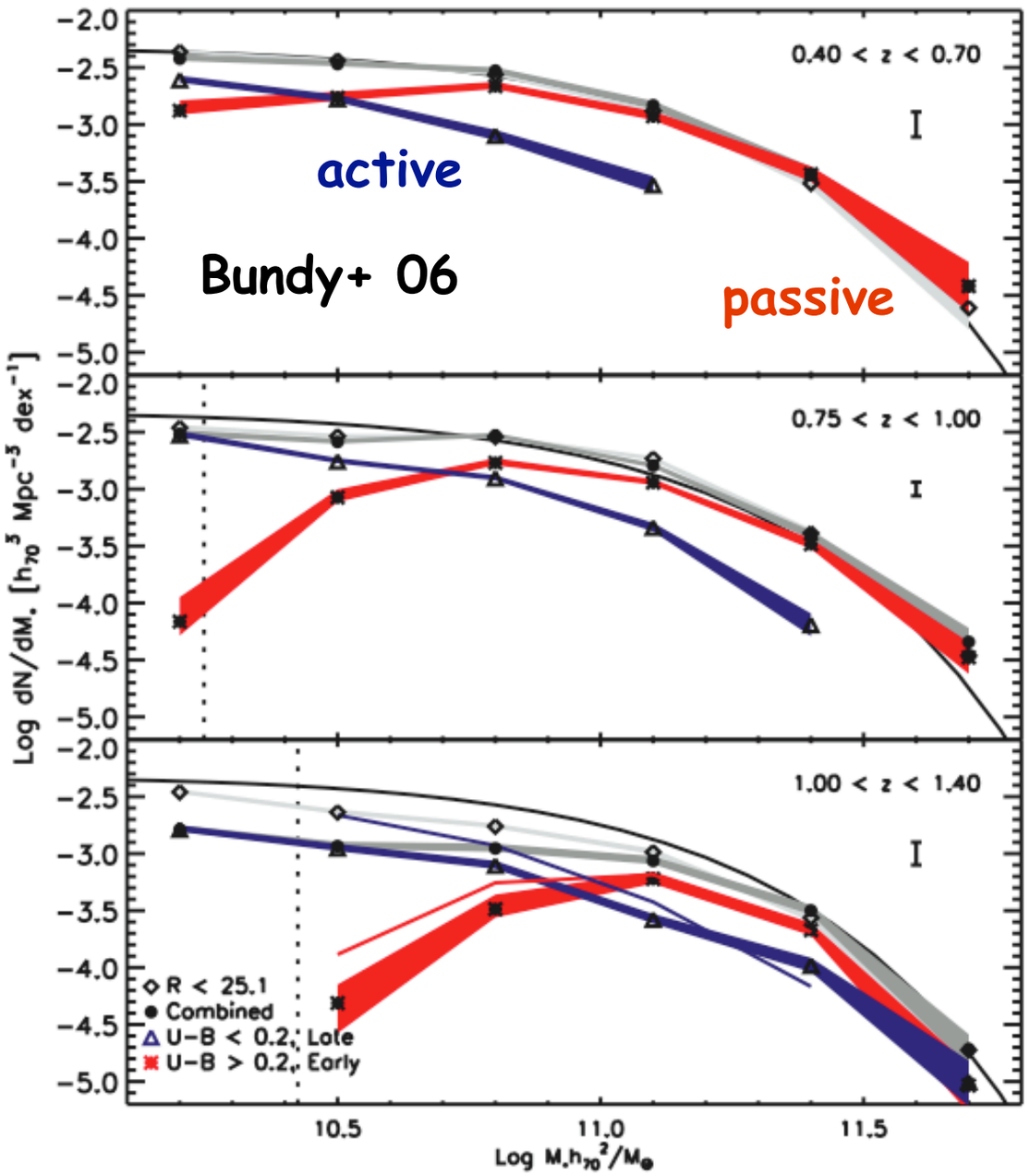
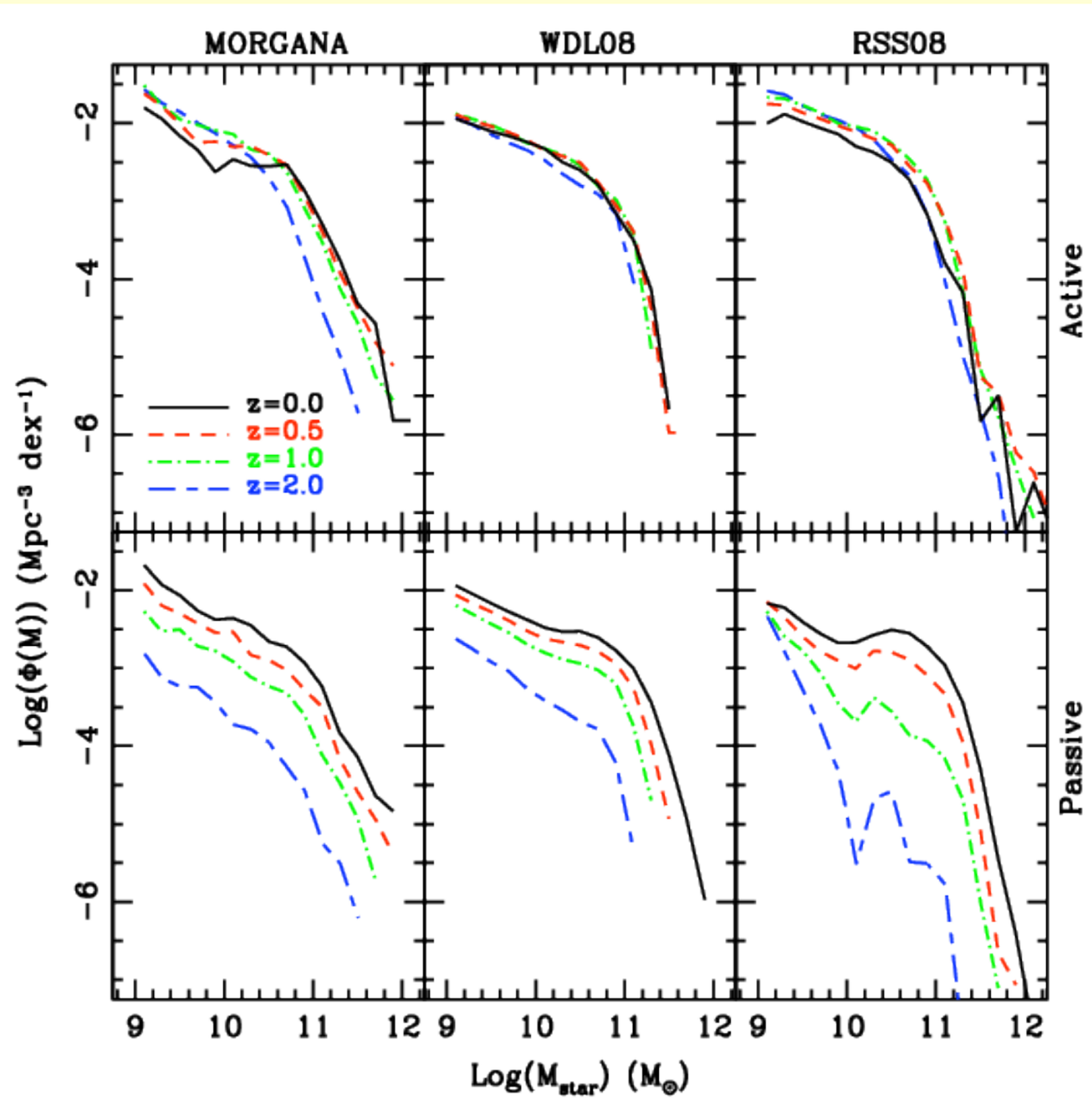
Downsizing in star formation rate

z<2:

- no/slow evolution of active galaxies
- gradual build-up of passive galaxies





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the mass function of model passive galaxies does not peak!

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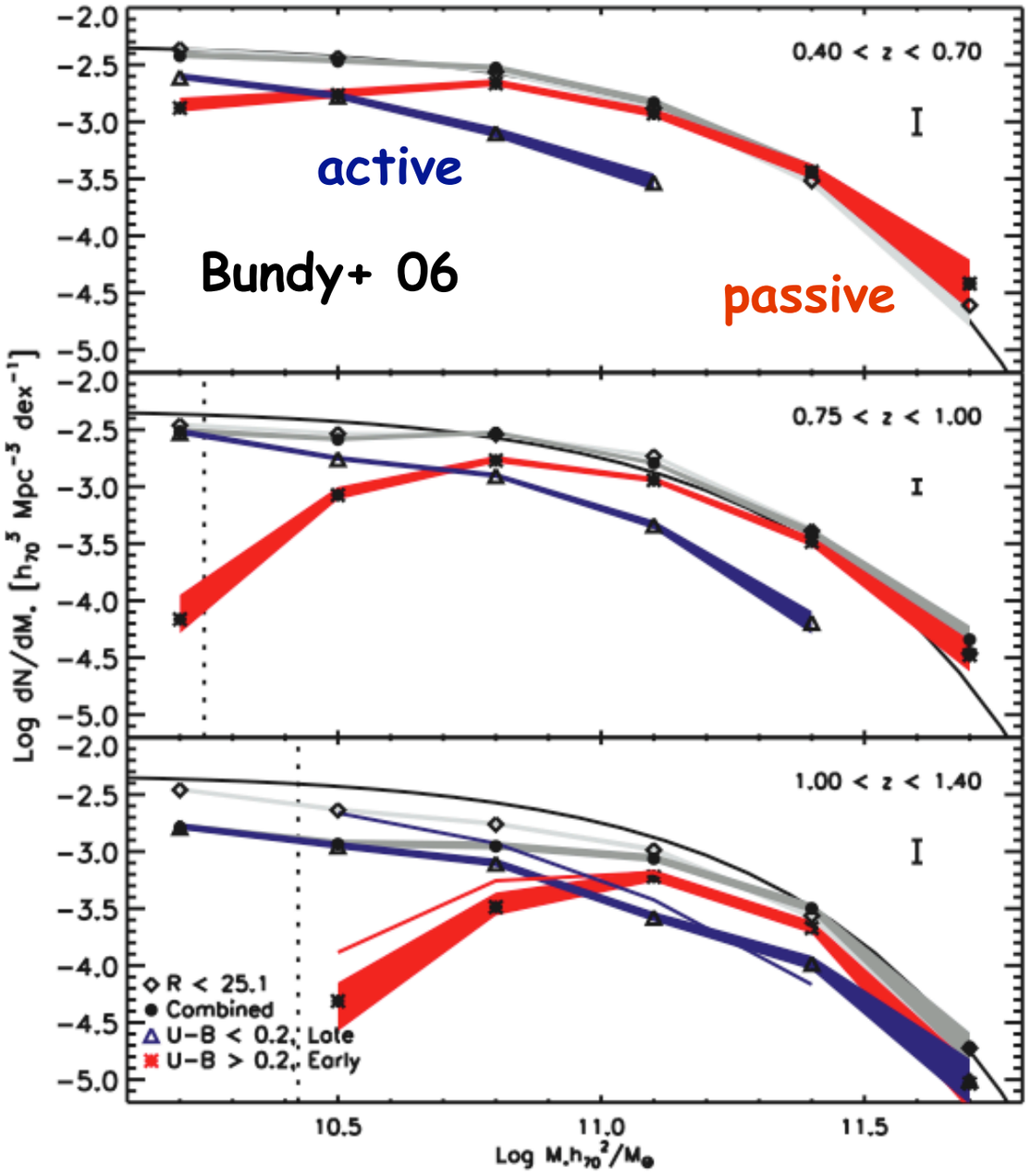

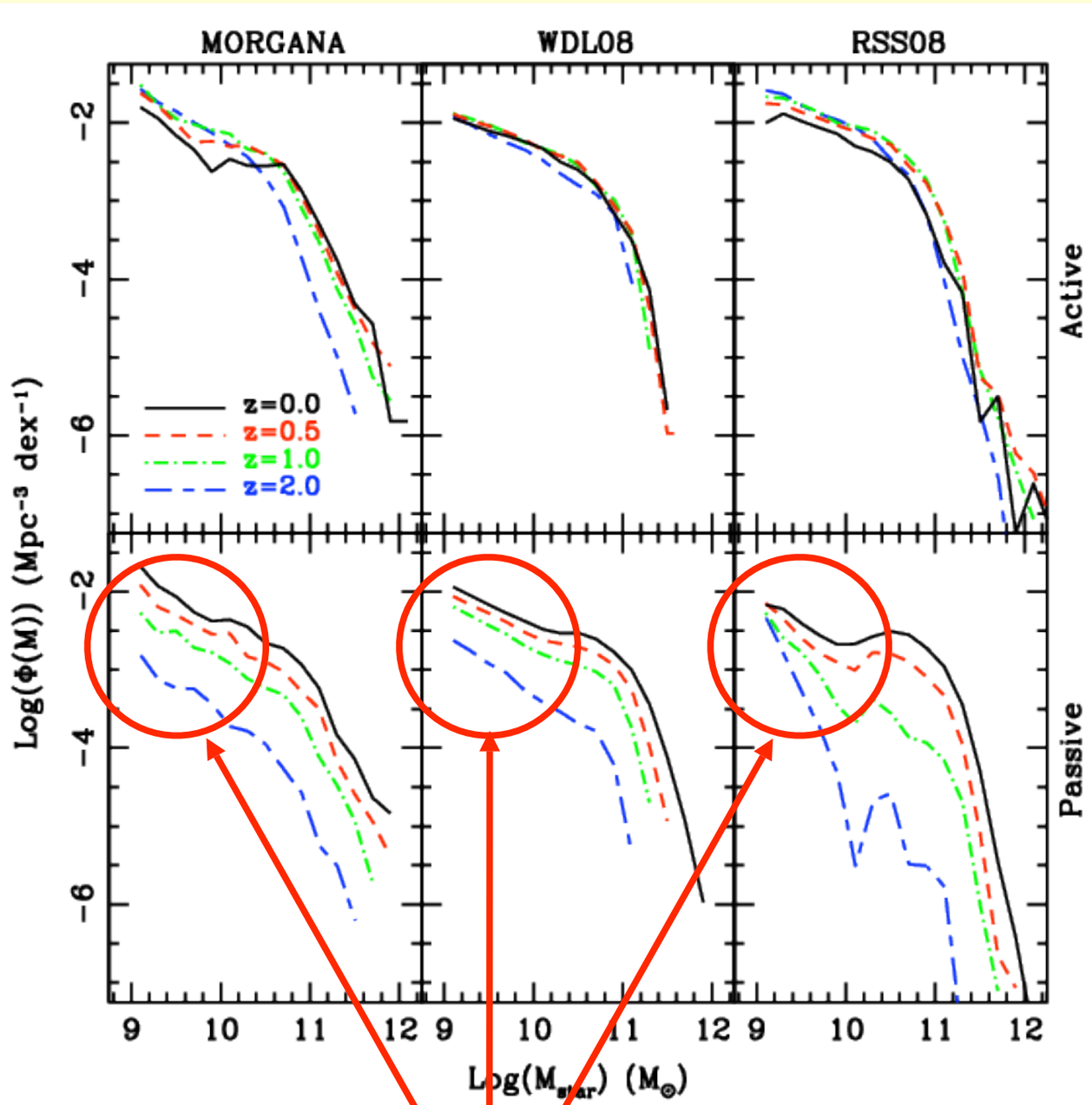

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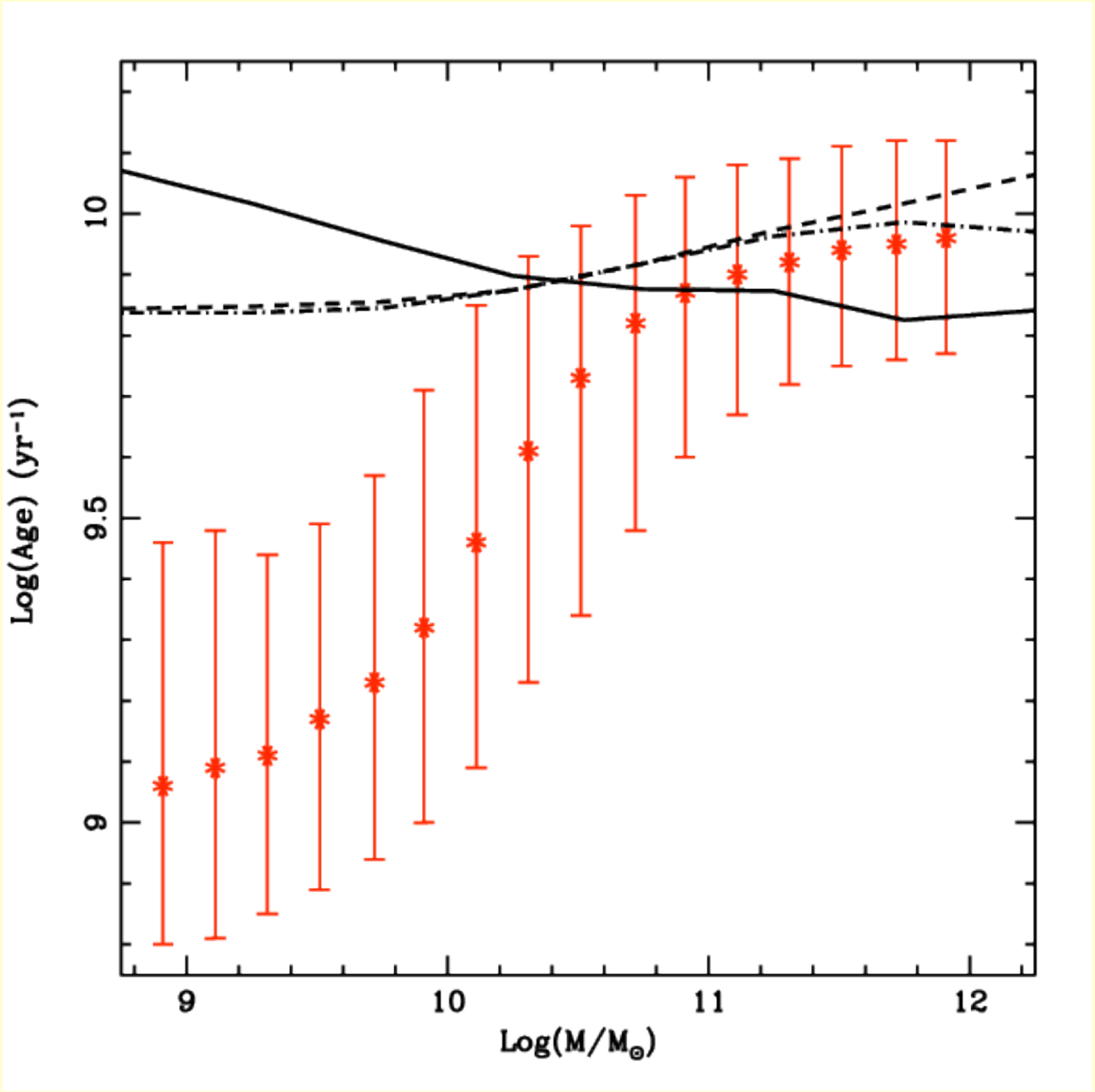
Archaeological downsizing



Ages from from Gallazzi+ 06, SDSS

Severe problems with less massive galaxies

Small galaxies (<10^{11} M_{sun}) in these models form too early:

- they are too passive at z<3
- they are already in place at z=1
- they are too old at z=0

No environmental effect: when the problem raises these galaxies are mostly central

We expect an excess in the prediction of small star-forming galaxies at high redshift

Important to look into the faint high-redshift Universe

Lyman-break galaxies: "observing" a model

- Produce galaxies in a box
- Output their properties on a time grid
- Transform time into line-of-sight distance and redshift
- Transform number densities in surface densities
- Produce GRASIL spectra and magnitudes (with Chabrier IMF)
- Add noise and Lyman-alpha emission to model magnitudes
- Select samples using the same color criteria as observations
- Compare number counts and redshift distributions to data
- Compare to luminosity functions derived from observations

Luminosity function vs Bouwens et al. 07

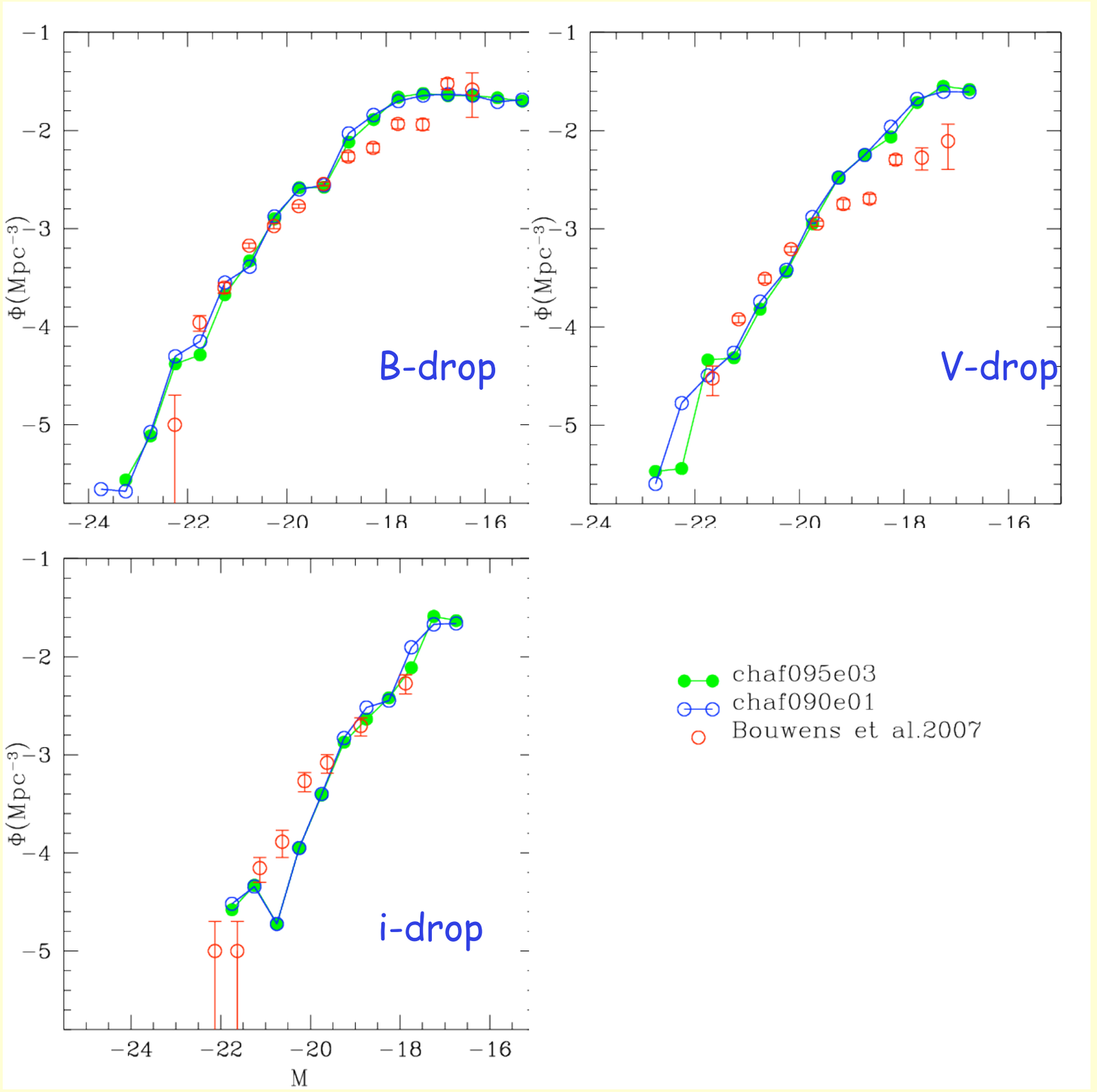
Lo Faro, PM, Vanzella, Fontanot, Silva, Cristiani, 2009, MNRAS 399, 827

first best-fit model

second best-fit model

Redshift intervals:

- 3.4 < z < 4.5 (B-drop)
- 4.5 < z < 5.5 (V-drop)
- 5.5 < z < 6.5 (i-drop)



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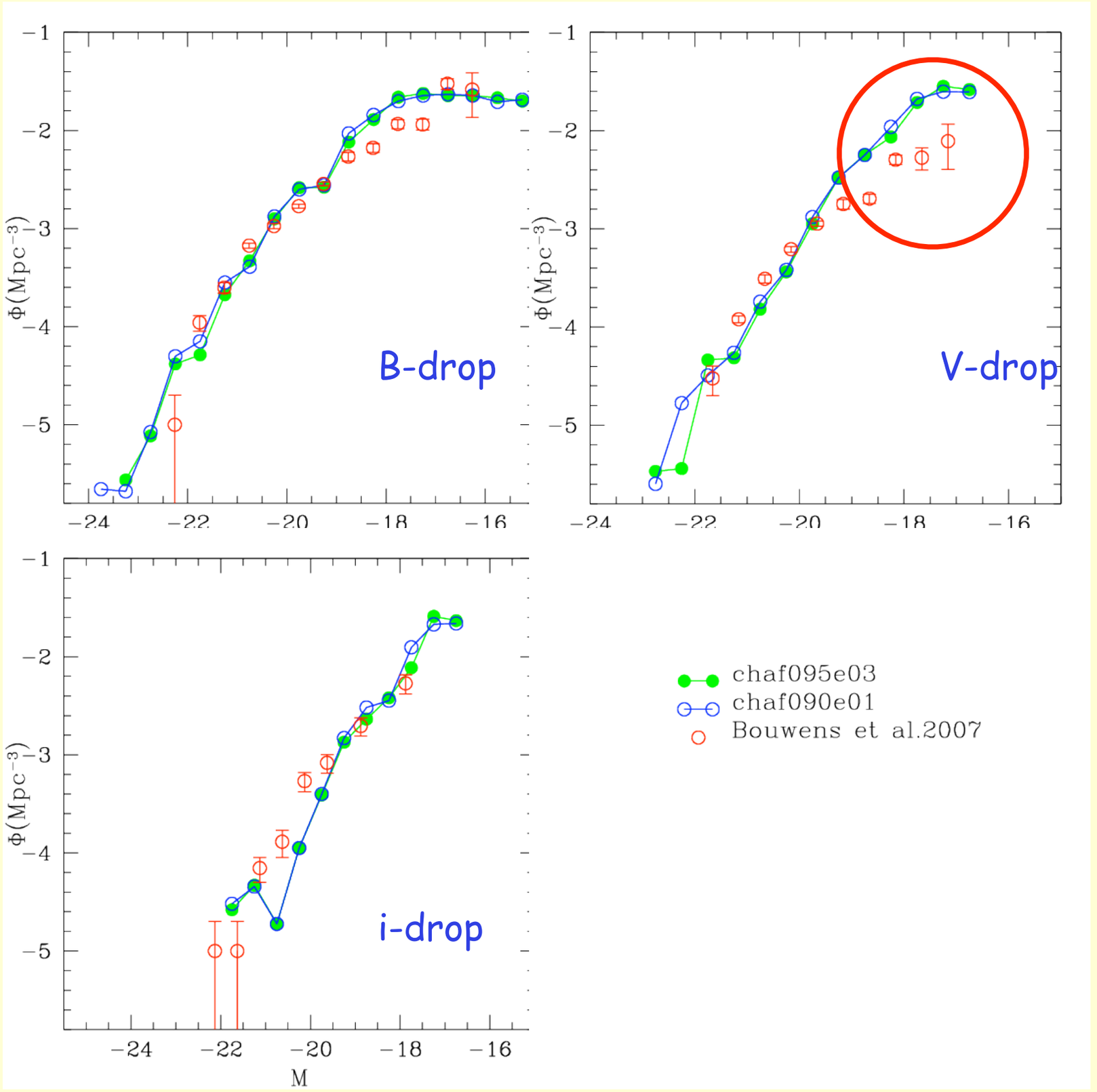


"Excessive" galaxies

absolute UV magnitude: M_{UV}~-18

star formation rate: SFR~10 M_{sun} yr^{-1}

apparent magnitude: z_{850}~27

stellar mass: M_*~10^8-10^9 M_{sun}@z~6 to 10^9-10^{10} M_{sun}@z~4

bimodal metallicity: Z~solar and Z~0.25 solar

hosted in halos of: M_h~10^{11} M_{sun}

with circular velocities: V_c~100-200 km/s

Important contributors to the IGM pollution

Waiting for ALMA, JWST and E-ELT!

Suppressing this excess of star formation (with a Dekel & Silk-like SN feedback)?

$$V^2_{sn} = e_{sn}\, E_{sn} / M_{star,sn}$$

massive outflow if

$$V_c < V_{sn}$$

at z~0 it must be minimal for

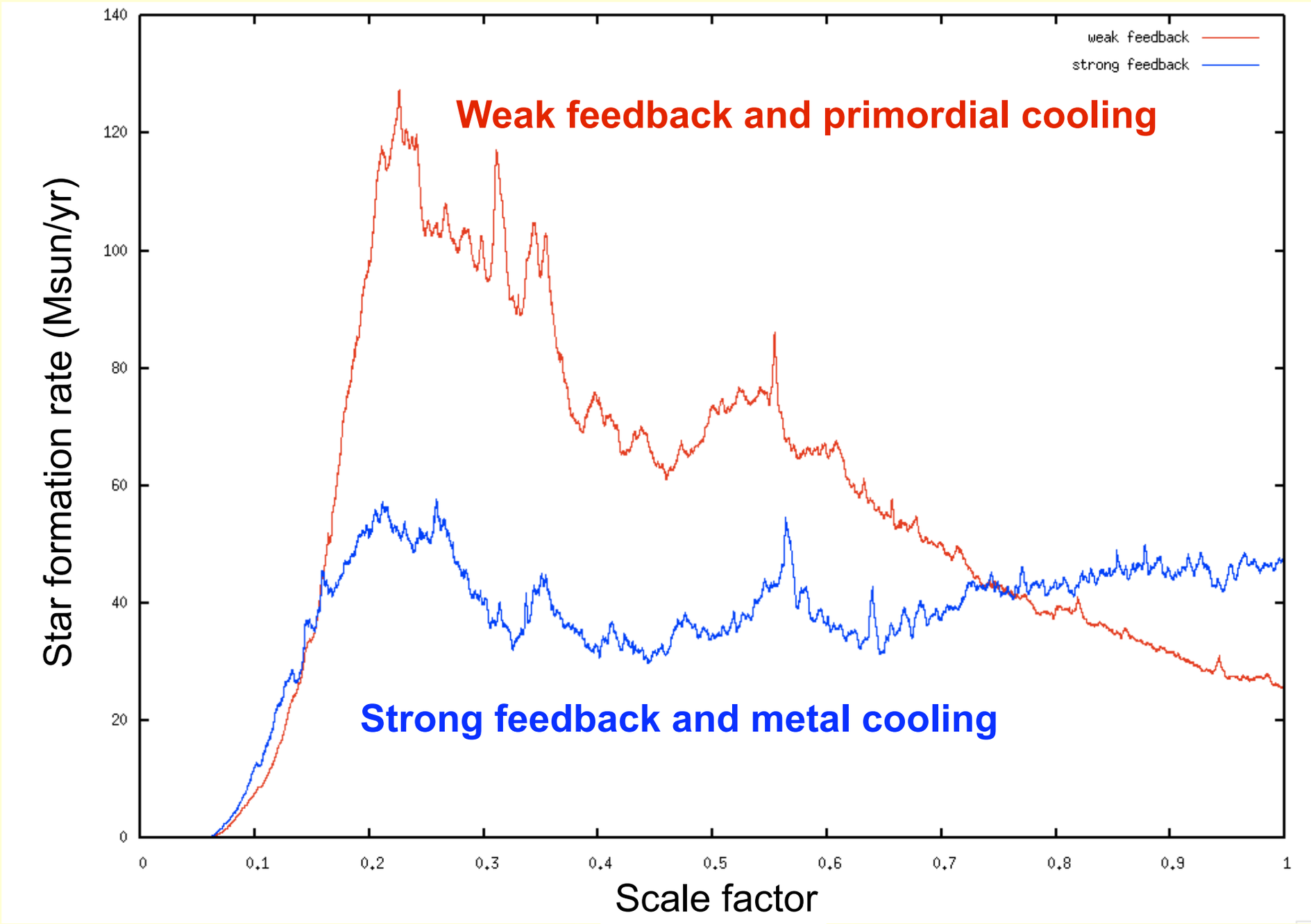
$$V_c = 220 \text{ km/s}$$

An (apparently) Pindaric flight

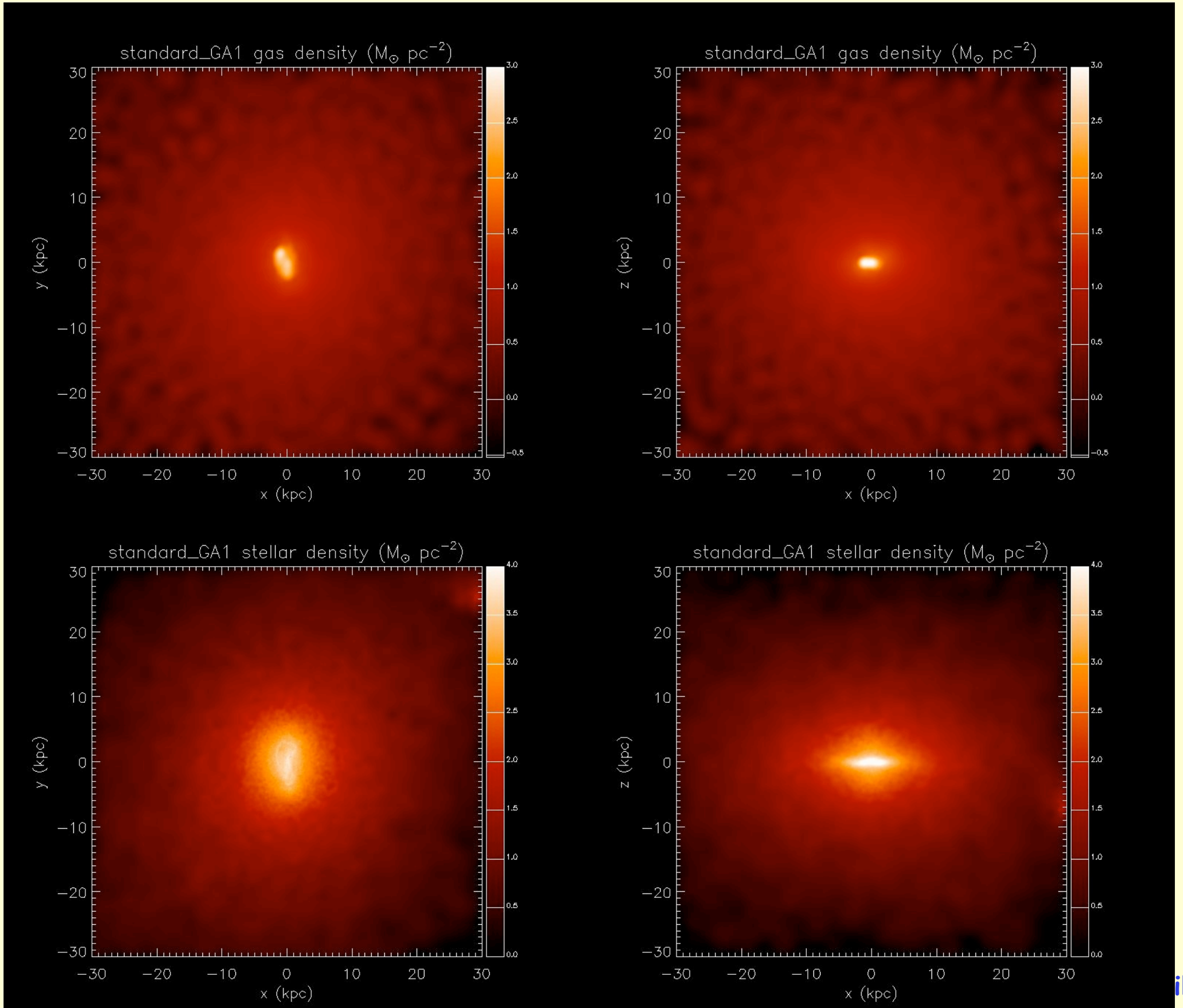
Initial conditions of a Milky Way-like halo
from Stoher et al. (2002)

N-body simulations of the formation of a spiral galaxy
(using Murante, PM, Giovalli, Borgani & Diaferio, MNRAS 405, 1491)

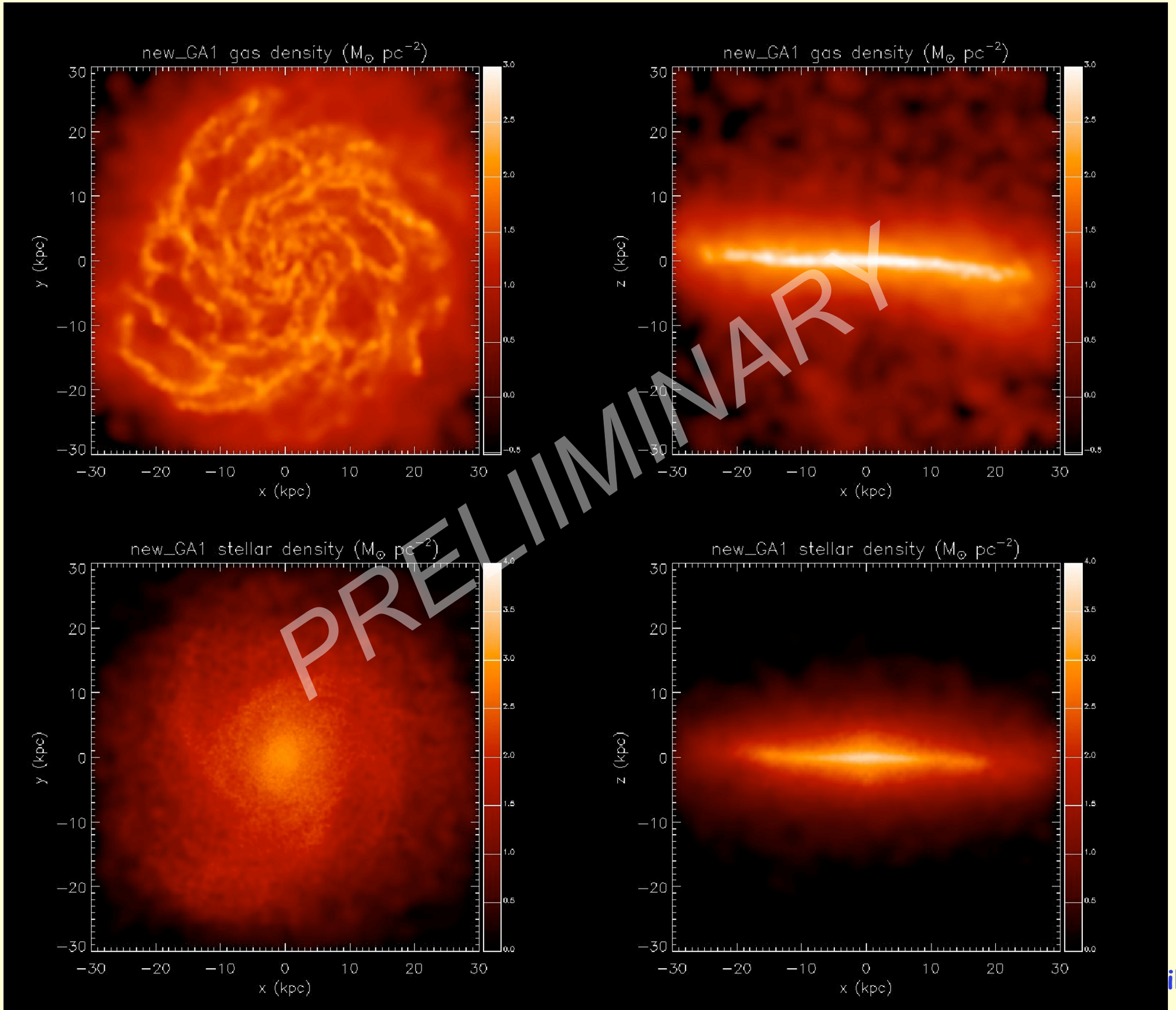
Conservation of angular momentum depends on stellar feedback



Weak feedback and primordial cooling



Strong feedback and metal cooling



ilano 2011

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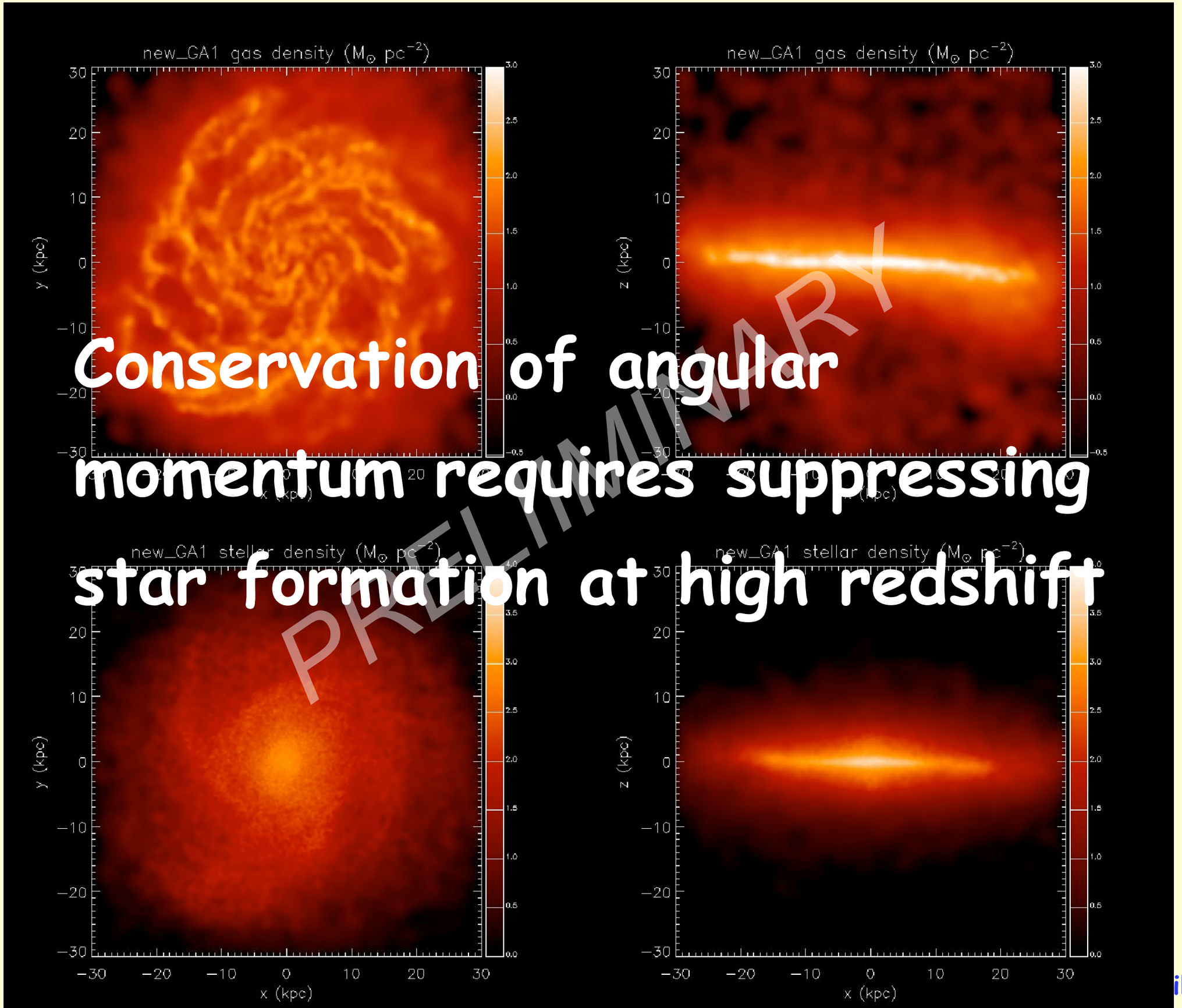

Conservation of angular momentum requires suppressing star formation at high redshift

Conclusions

- Stellar mass downsizing is **not** reproduced by galaxy formation models
- This is most likely caused by excessive star formation in small galaxies at z~5 (visible as faint V-dropouts)
- This excess is most likely connected to the difficuly of producing bulge-less galaxies in N-body simulations
- SN feedback cannot solve this discrepancy if effective energy injection per unit stellar mass is constant (as in Dekel & Silk 1986)
- This problem must be solved by an internal driver of galaxy evolution