EARLY-TYPE GALAXY SHAPES AND SIZES OUT TO Z=3

FROM CANDELS & 3D-HST

Arjen van der Wel
Max Planck Institute for Astronomy (Heidelberg, Germany)

CANDELS & 3D-HST

Grogin et al. (2011); Koekemoer et al. (2011)
Brammer et al. (2012); Skelton et al. (2014)

CANDELS (Faber & Ferguson)
- Multi-Cycle Legacy Program -- 902 orbits
- NUV -- NIR imaging over 788 sq. arcmin. / 5 fields

3D-HST (van Dokkum)
- Treasury Program -- 245 orbits
- optical/NIR grism spectroscopy of 4 CANDELS fields

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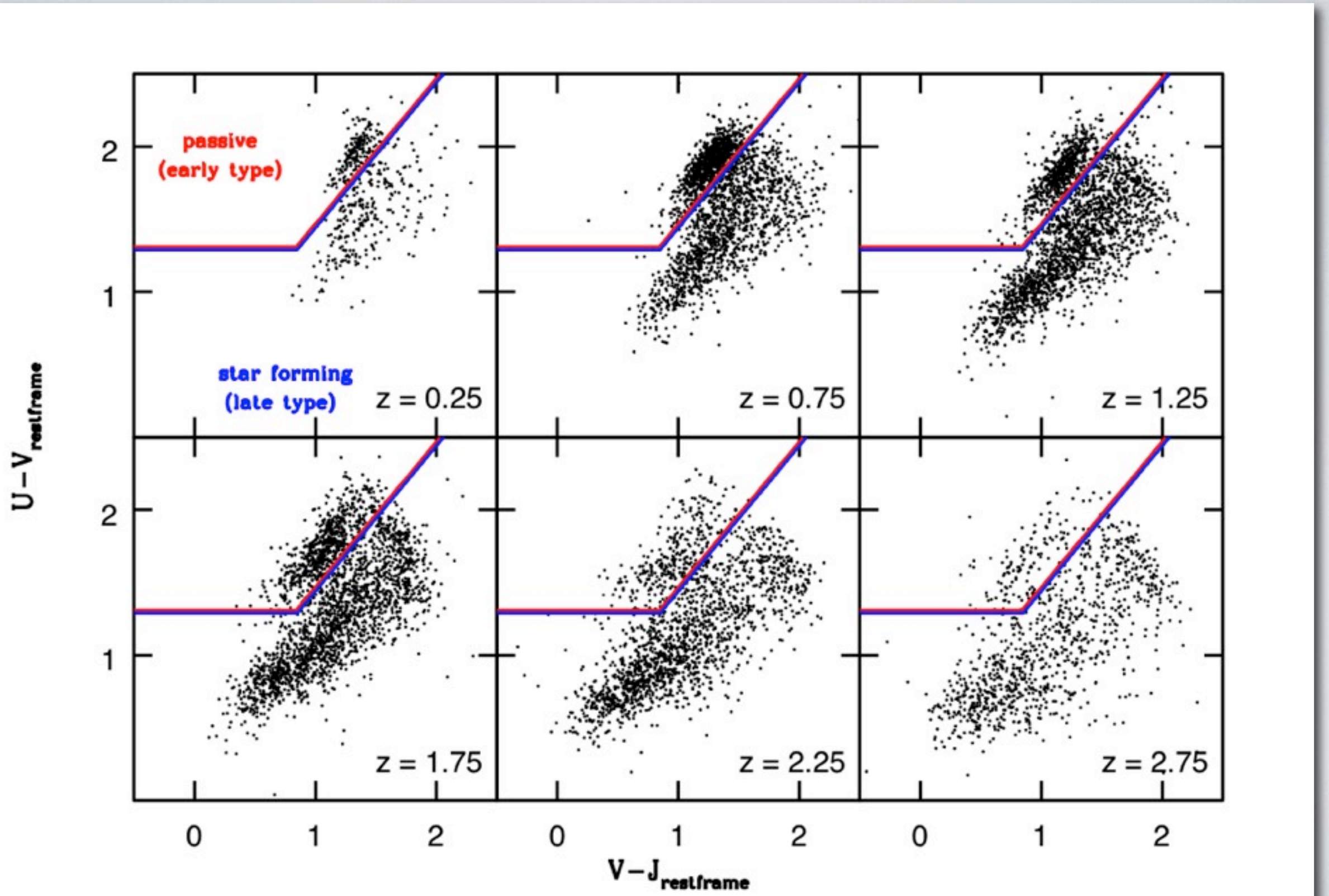
For this talk
- ~40,000 galaxies at $0 < z < 3$
- with robustly measured half-light radii (*van der Wel+12; van der Wel+14)*
- redshifts, stellar masses, colors (*Skelton+14, Momcheva+ in prep.)*

Color-color separation into two types *(e.g., Wuyts+07)*



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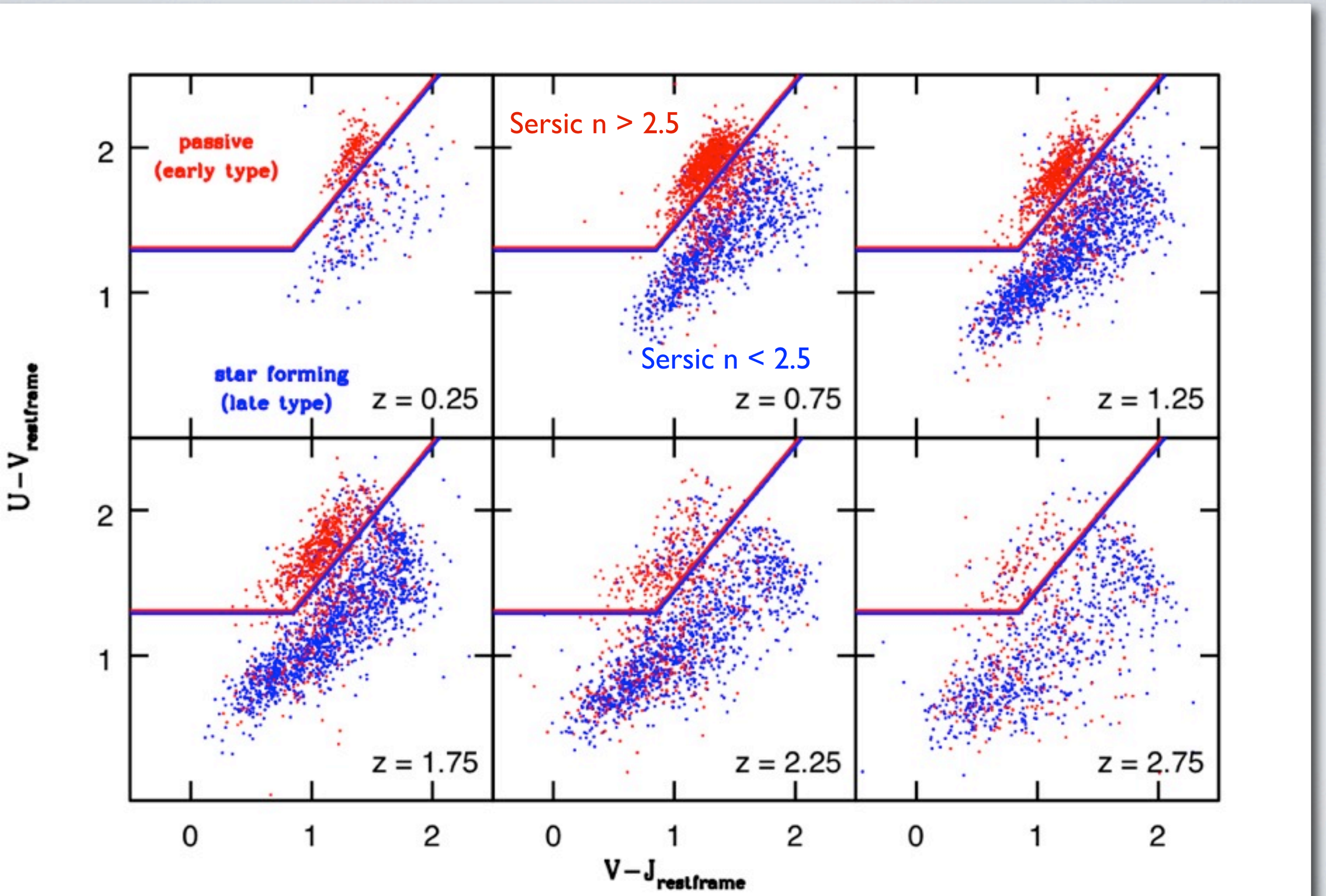

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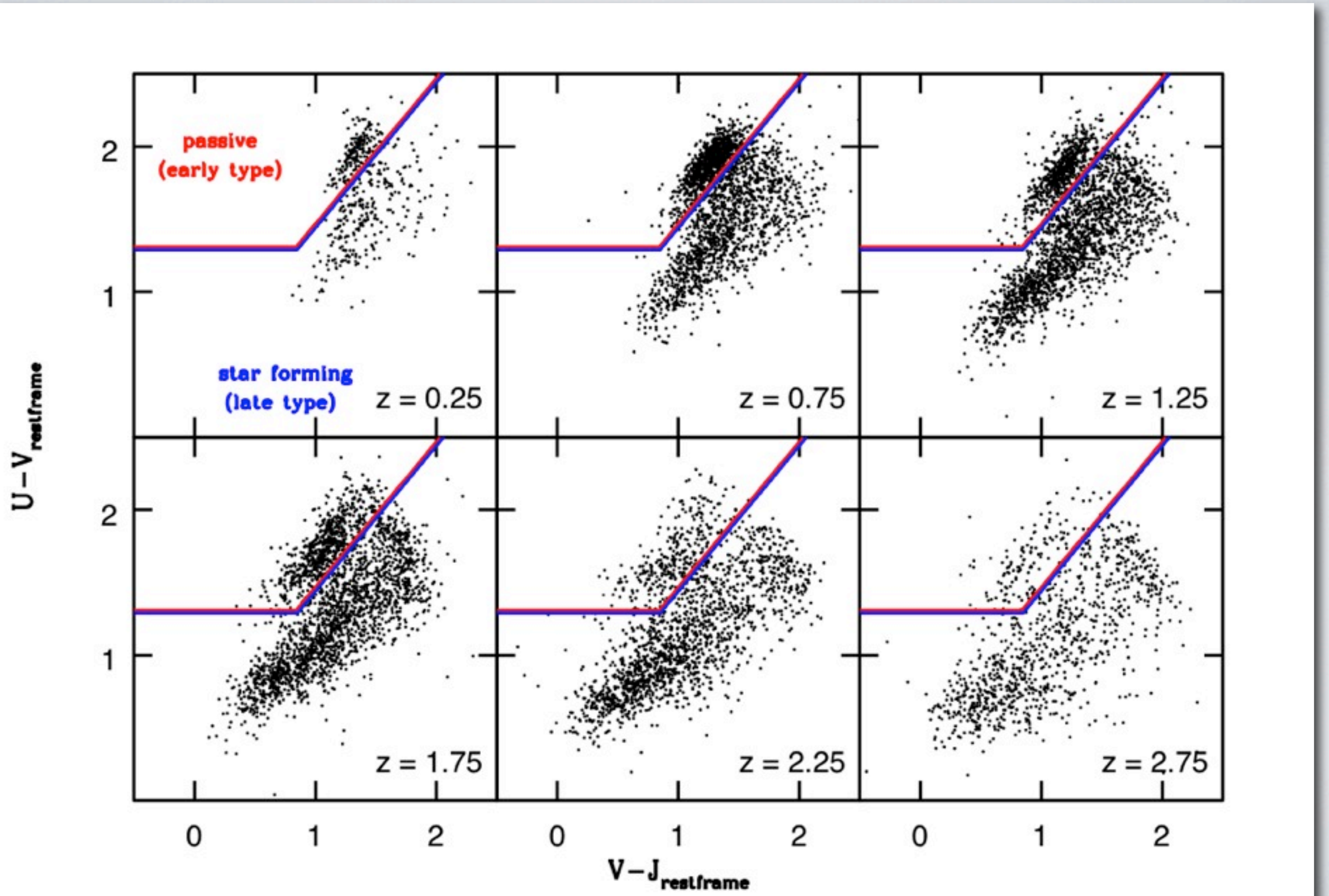
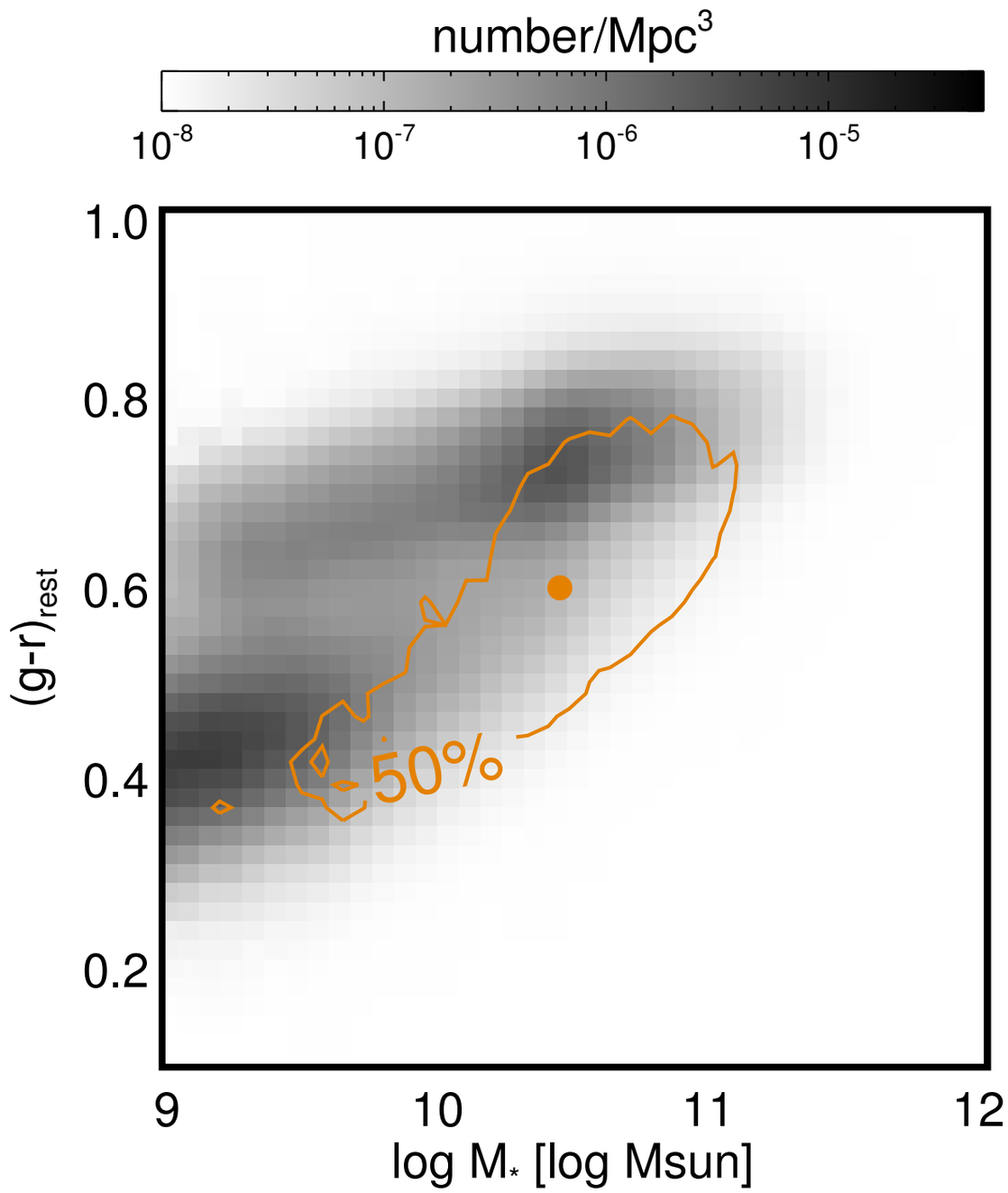


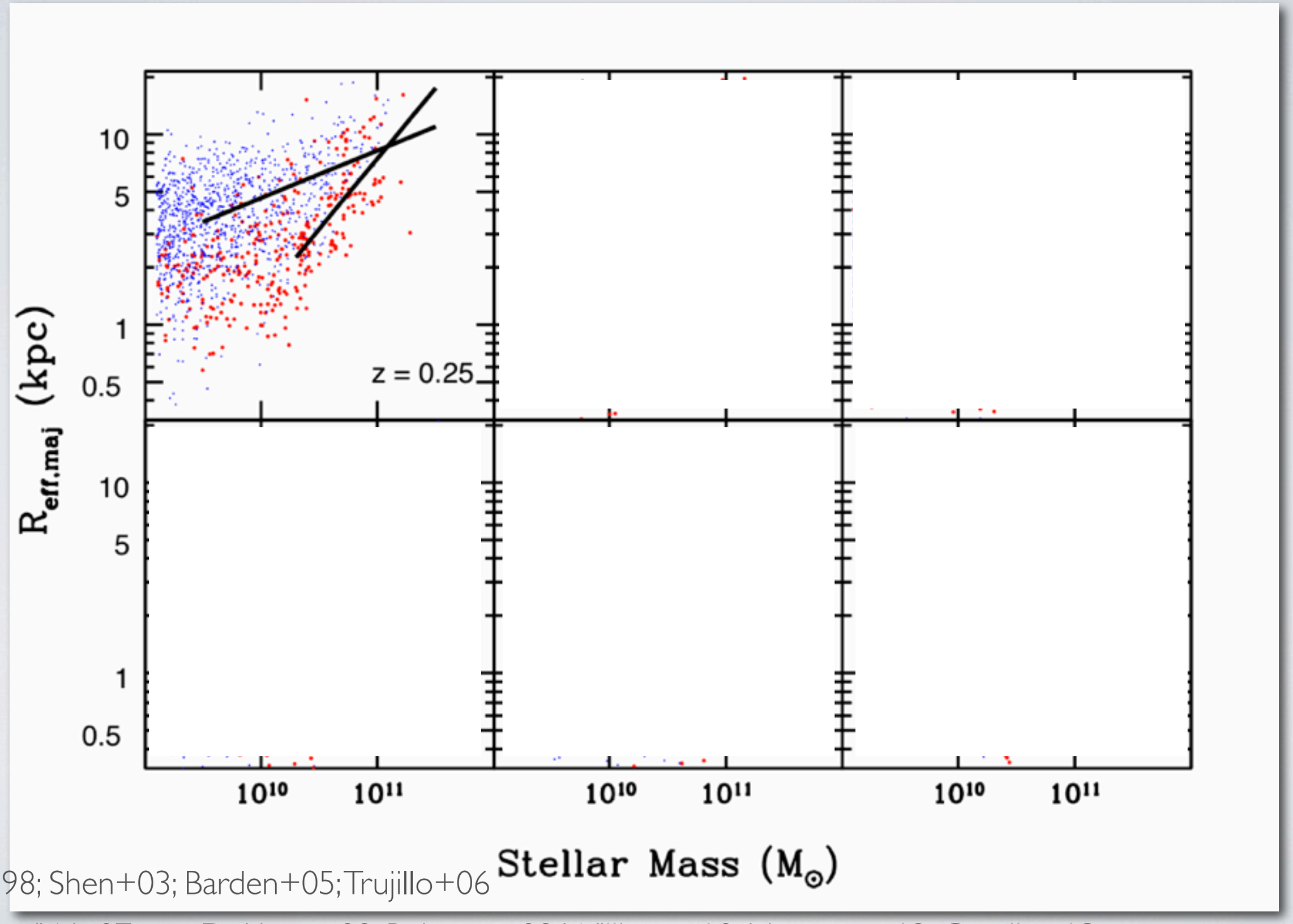


z ~ 0.1

The green valley:
the most fertile soil
for star formation

Stellar masses and SFRs from SDSS+WISE
(Chang, van der Wel, Da Cunha, Rix, in prep.)

Evolution of the size-mass distribution



Lilly+98; Shen+03; Barden+05; Trujillo+06

Zirm, vdW+07; van Dokkum+08; Buitrago+08; Williams+10; Newman+12; Carollo+13

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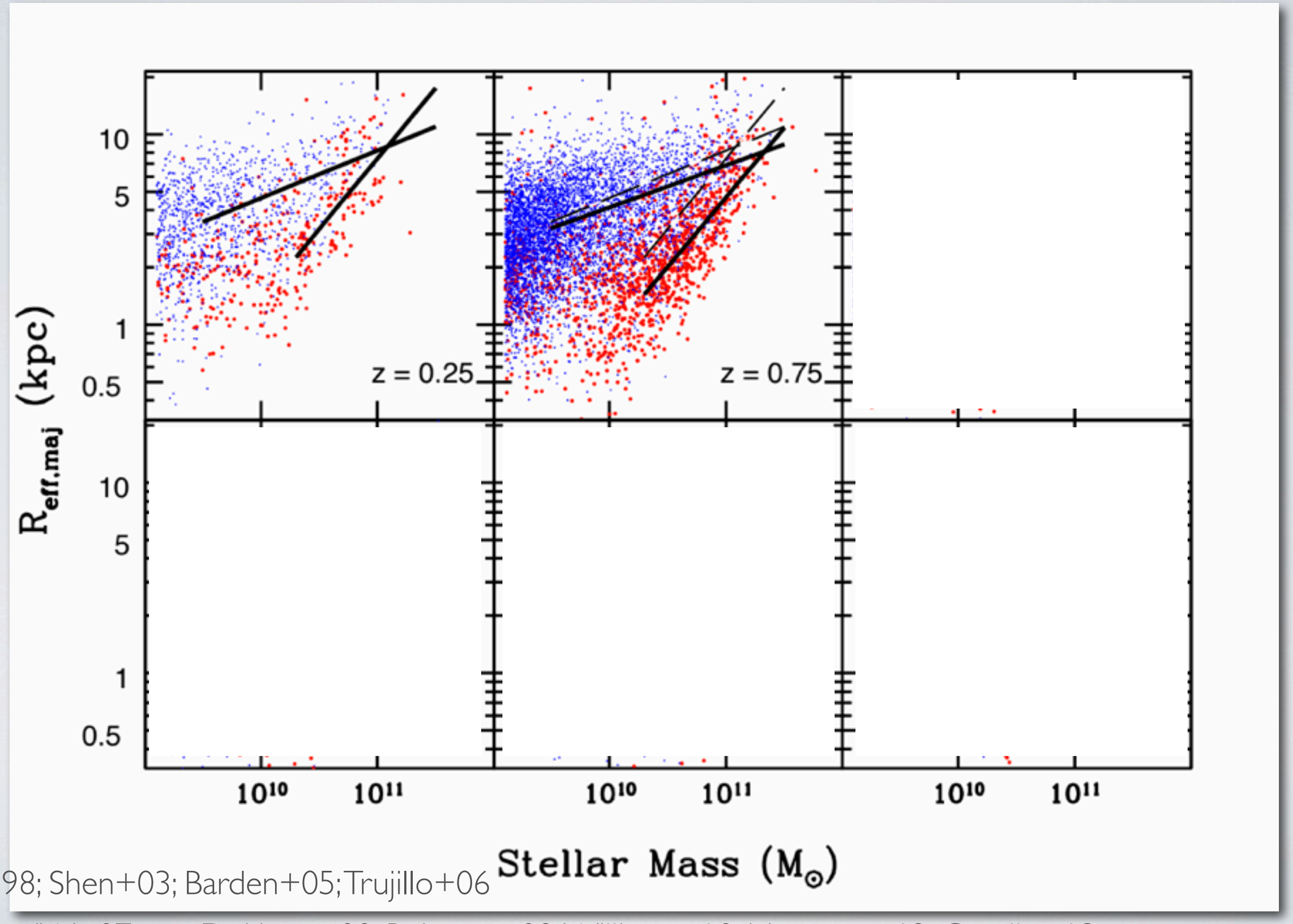

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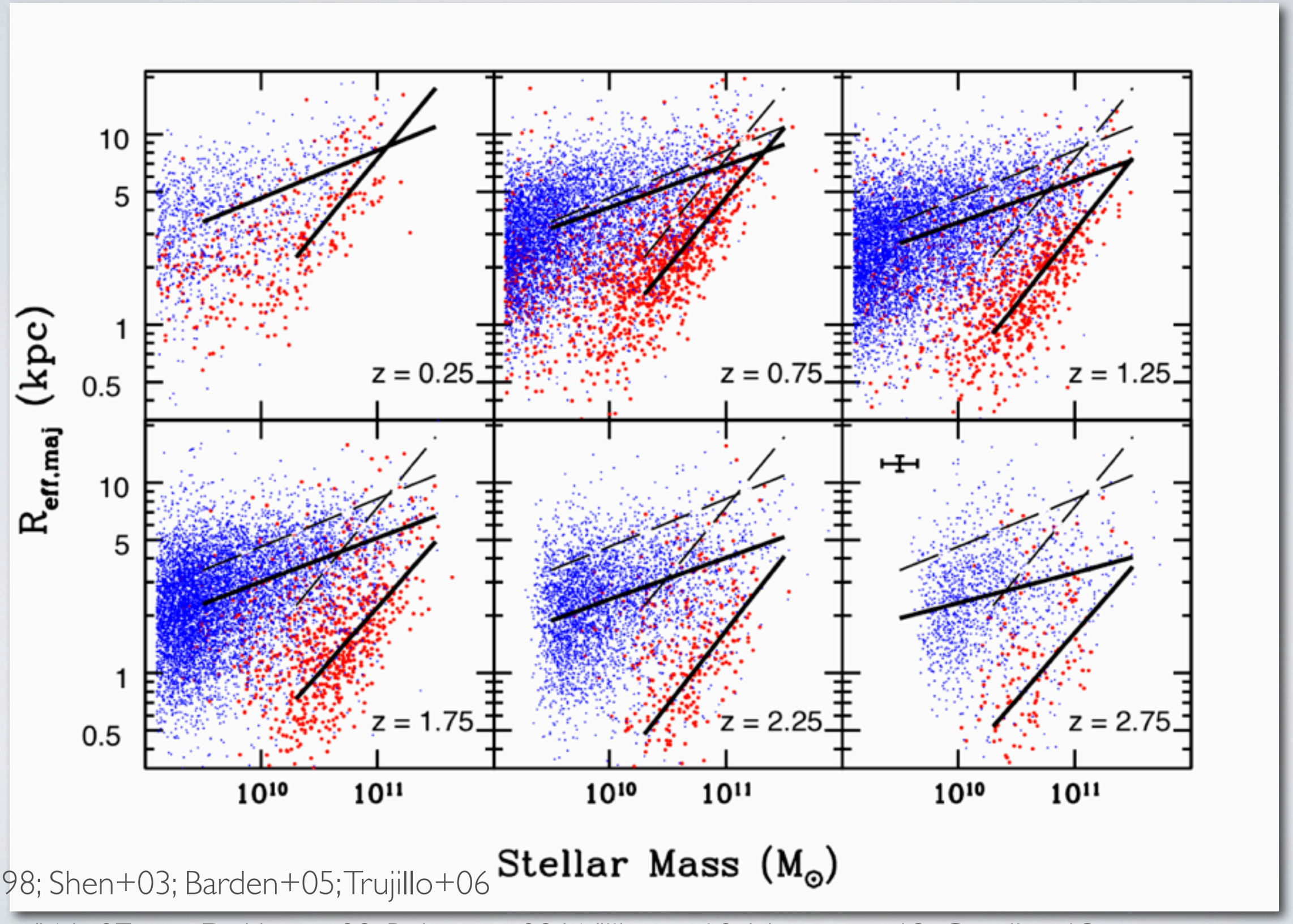

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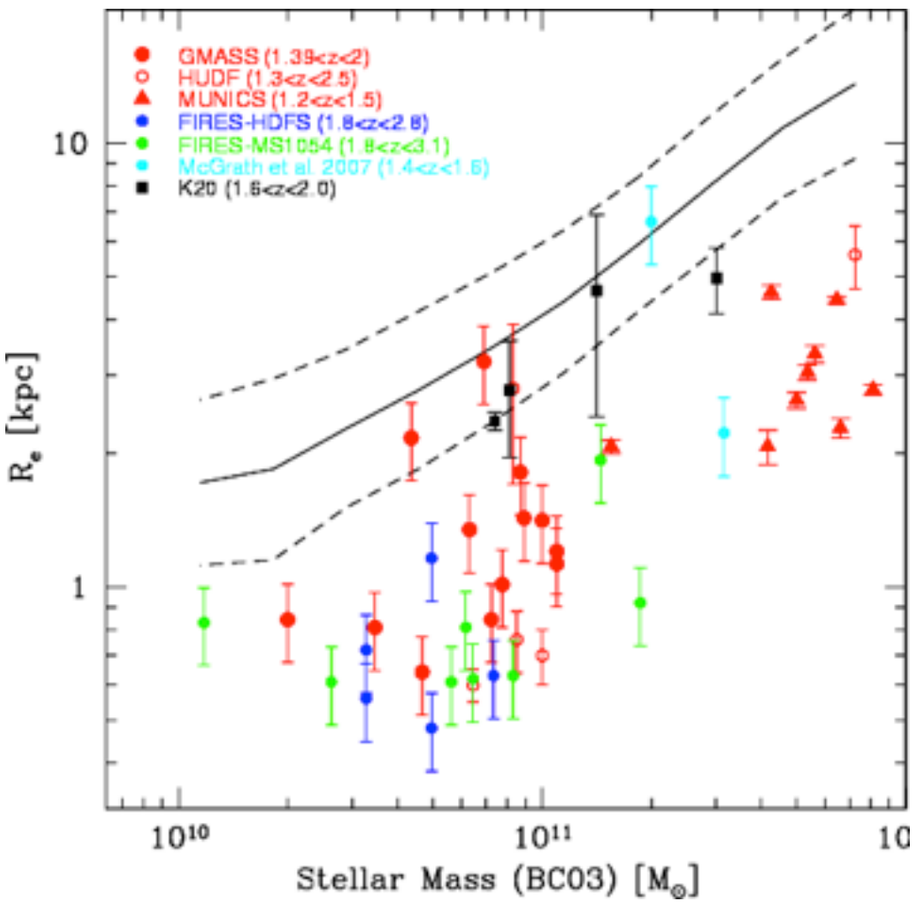
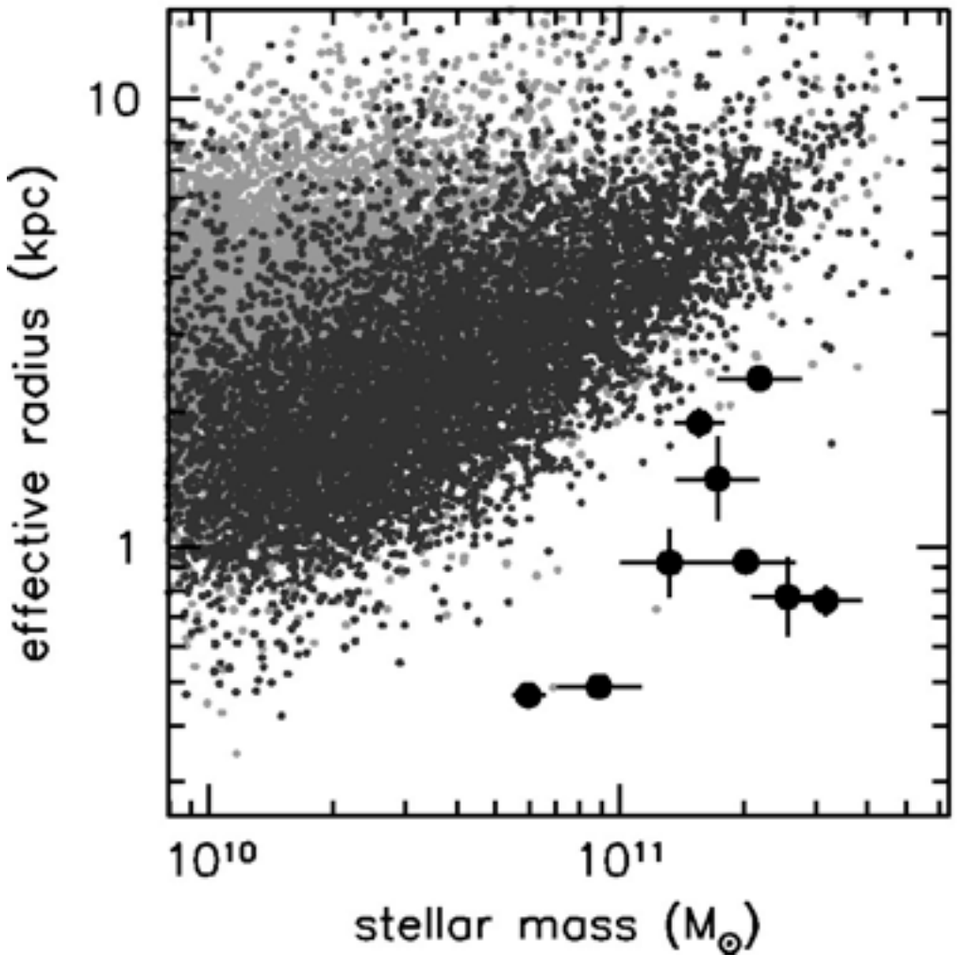
1.2 < z < 2 (Cimatti+08)



2 < z < 2.5 (van Dokkum+08)



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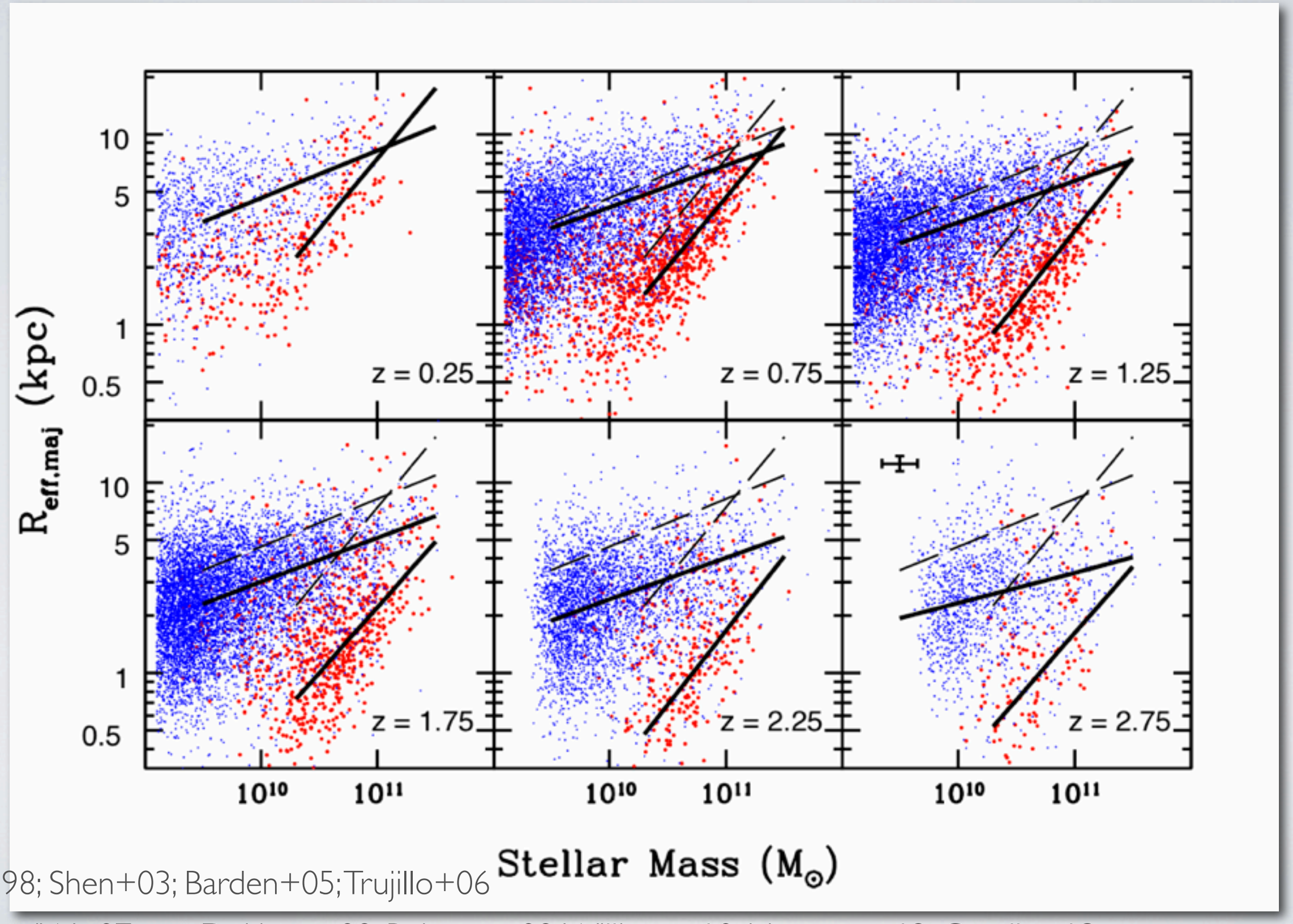

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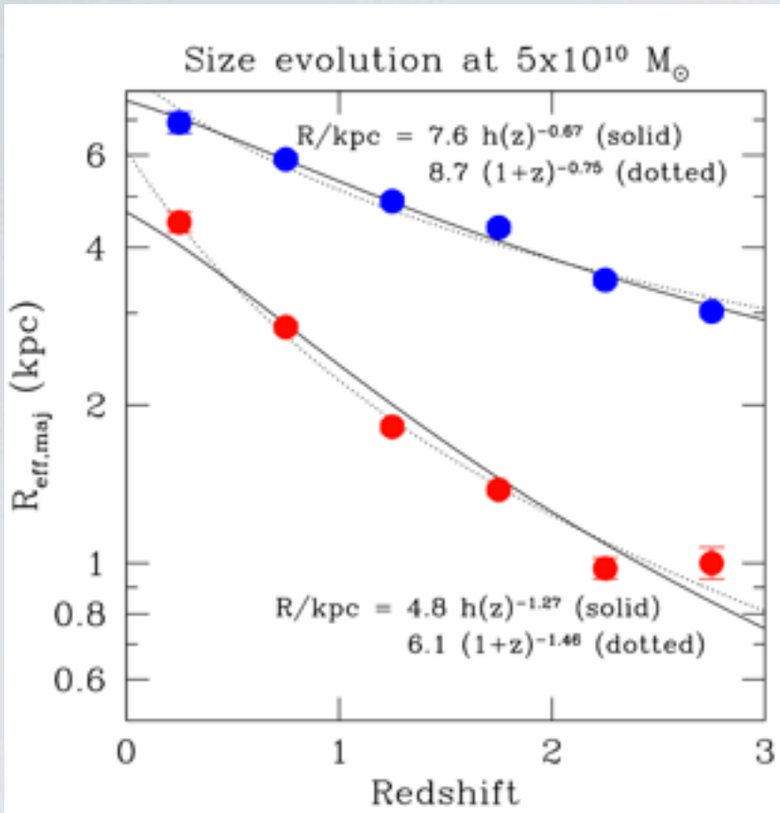
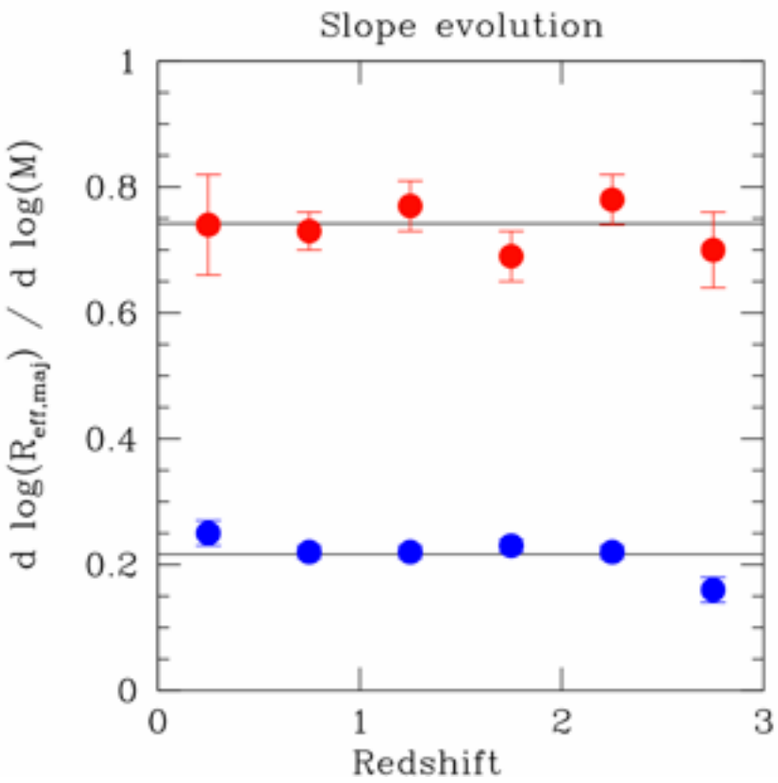
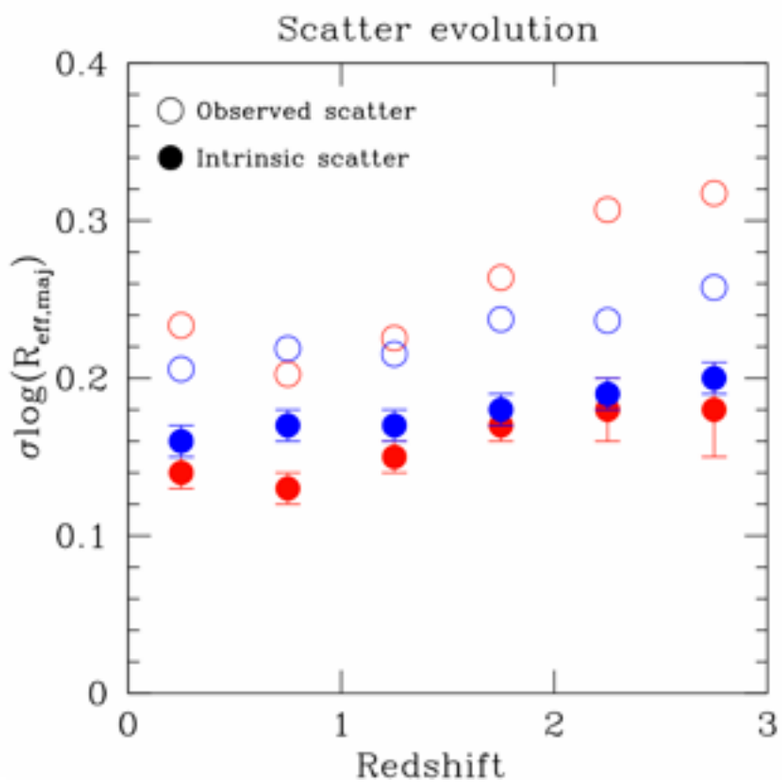
Late-type (star-forming) galaxies







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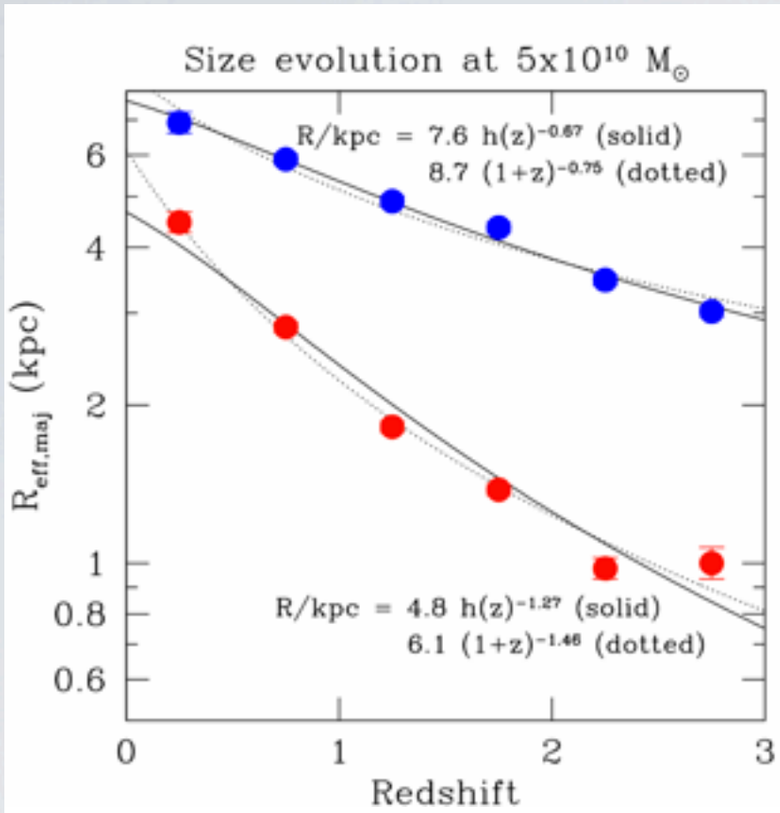

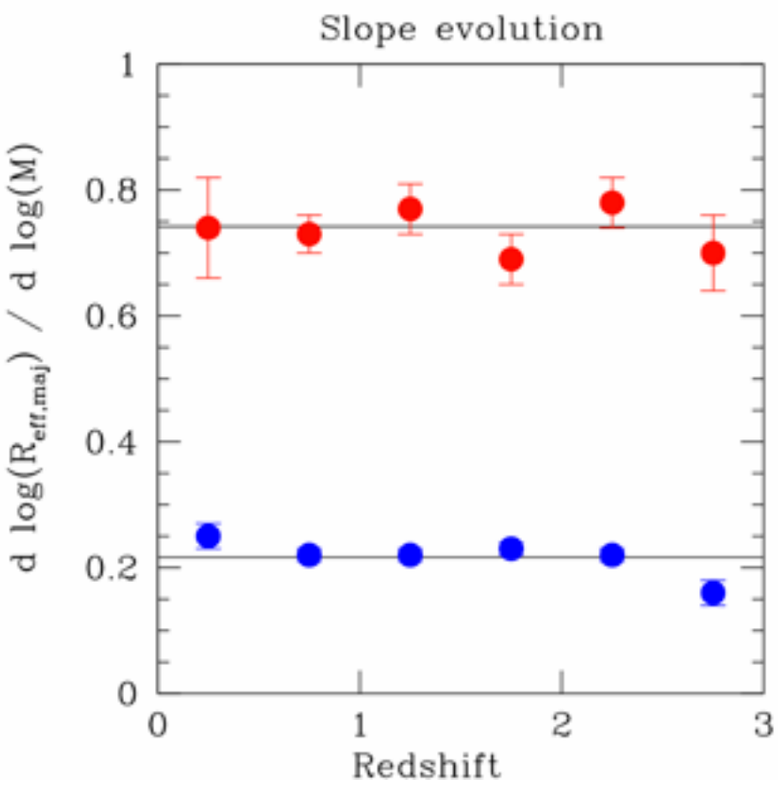

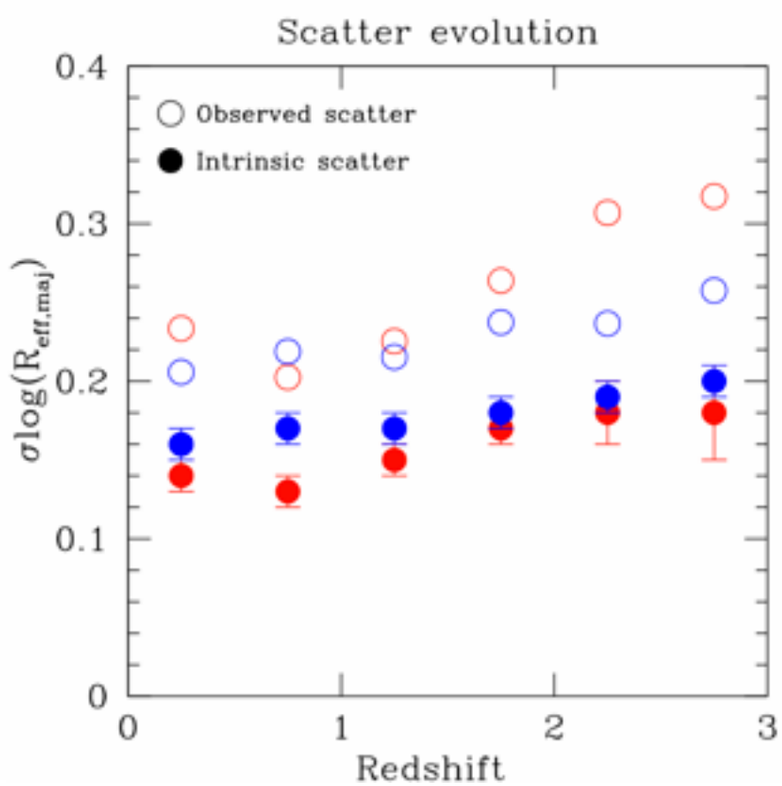

- Galaxy size proportional to halo size at all z

  $R \propto H_z^{-2/3}$ (halo R measured w.r.t. critical density)

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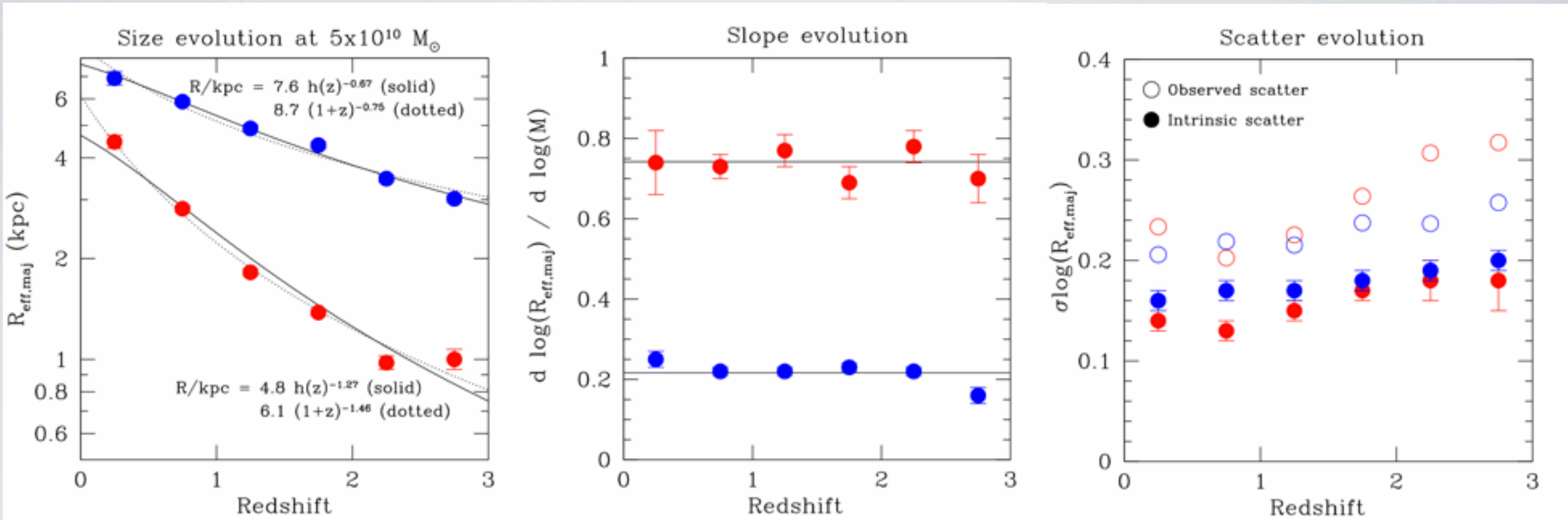

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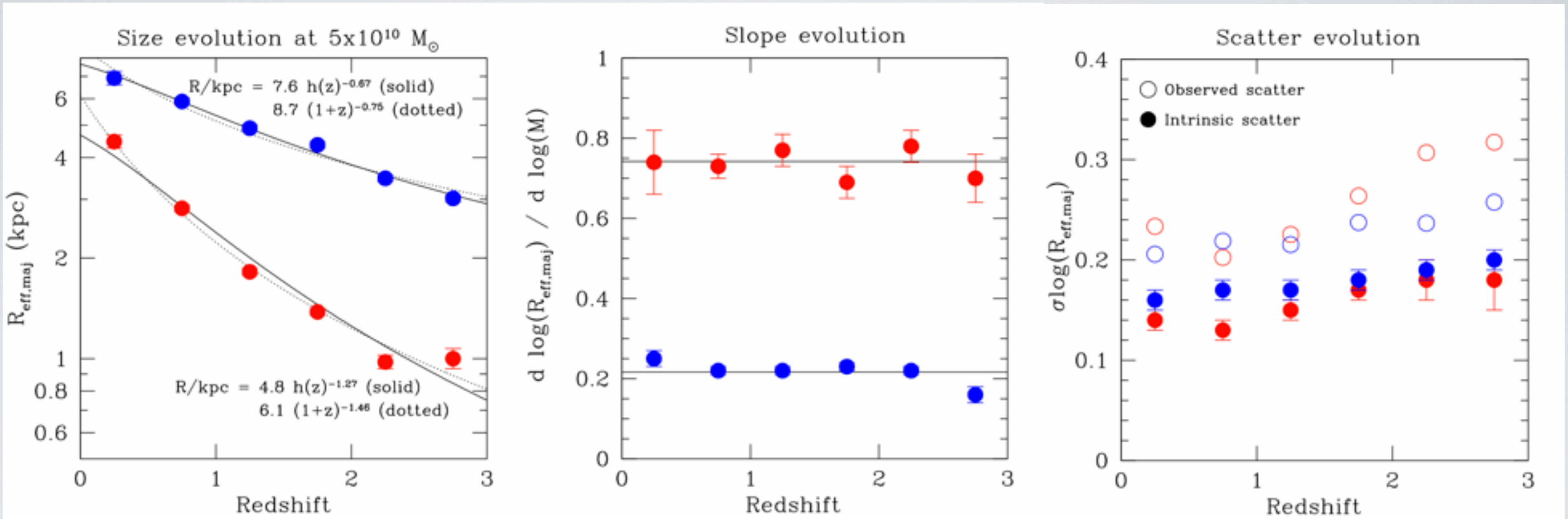

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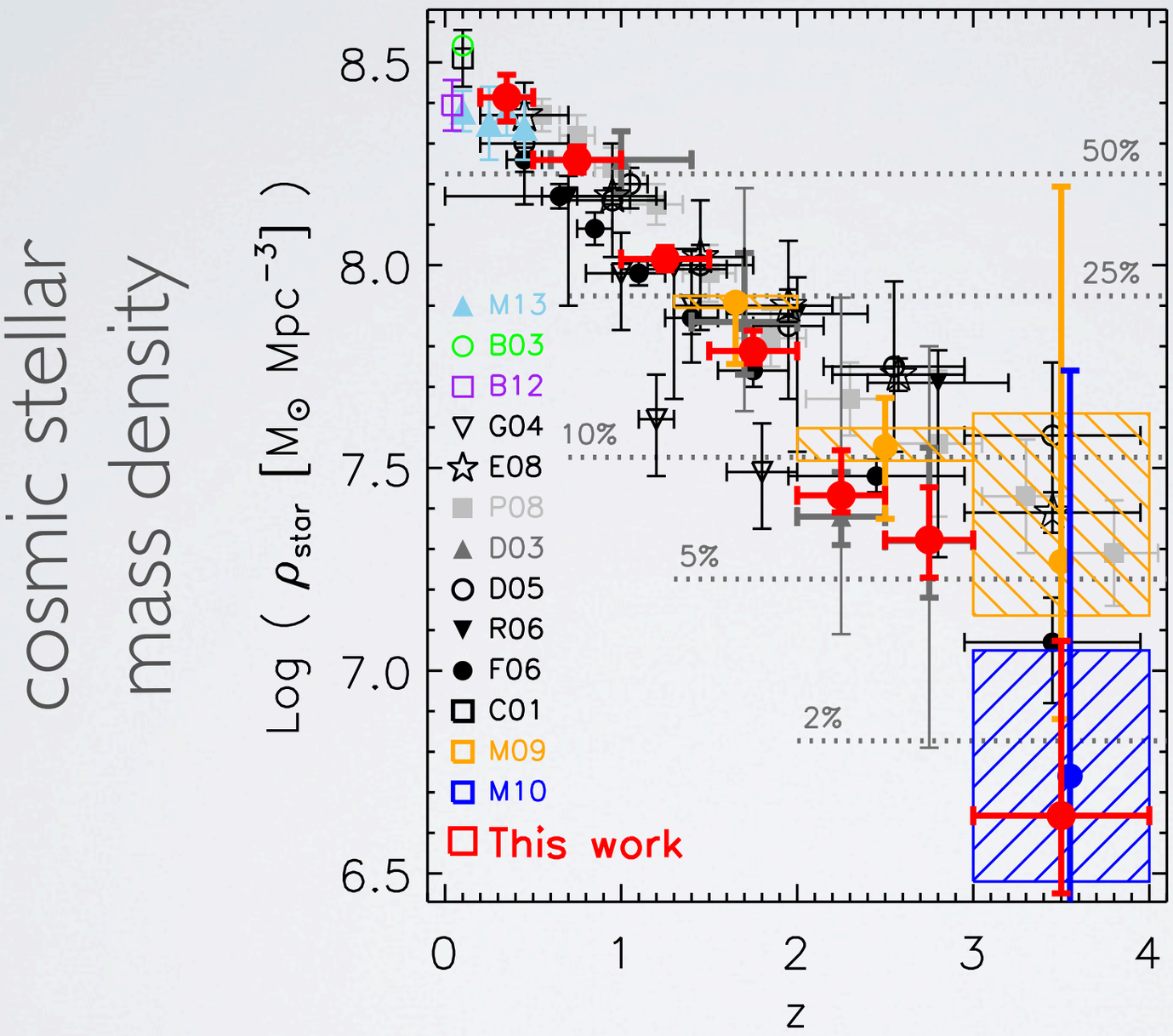
- Scatter somewhat smaller than scatter in spin at all z?
  $\sigma(\log R) \approx 0.15 - 0.2 \Leftrightarrow \sigma(\log \lambda) \sim 0.24$

90% (50%) of all stars formed since z ~ 2.5 (z ~ 1)

Muzzin et al. (2013)



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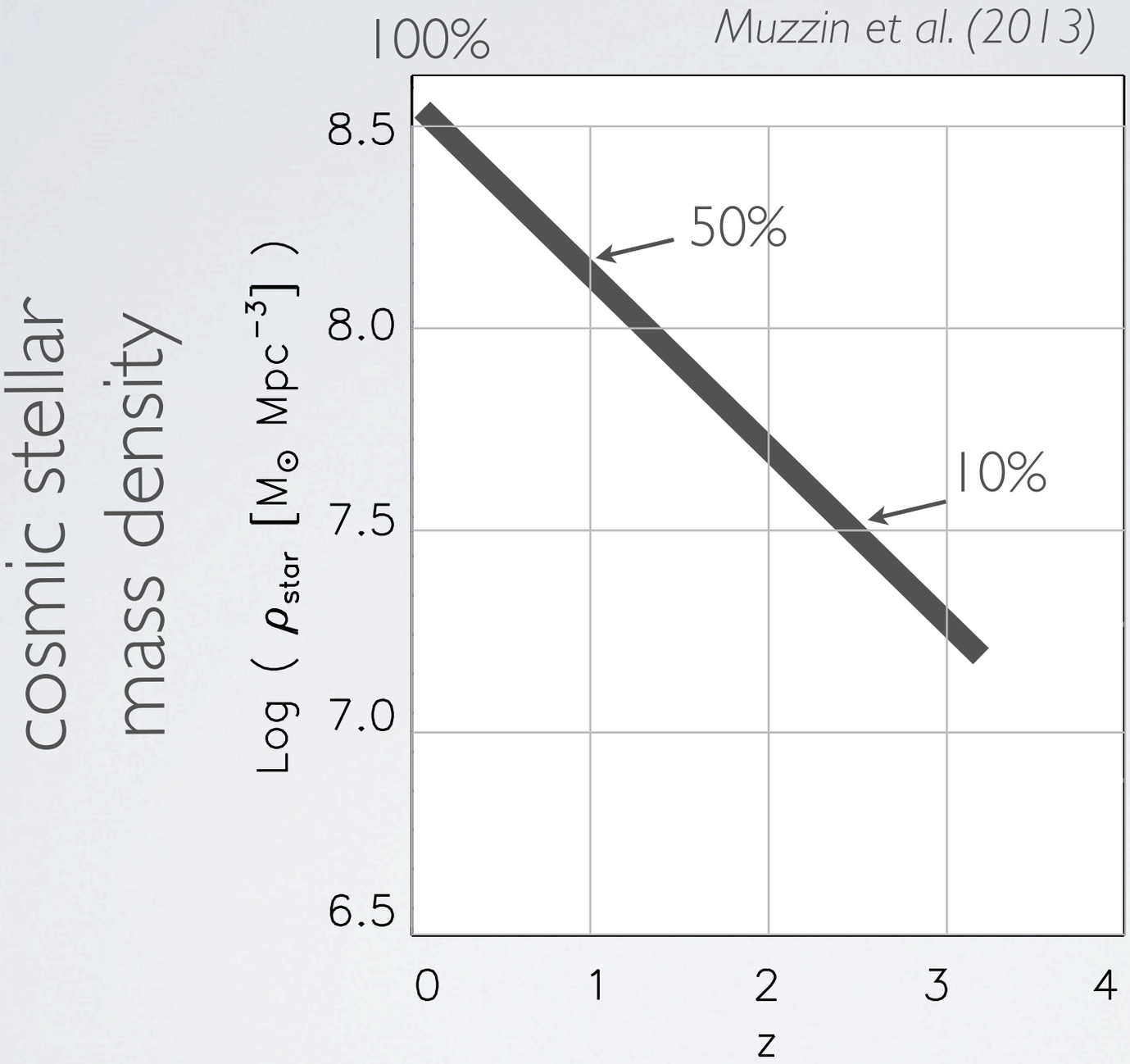
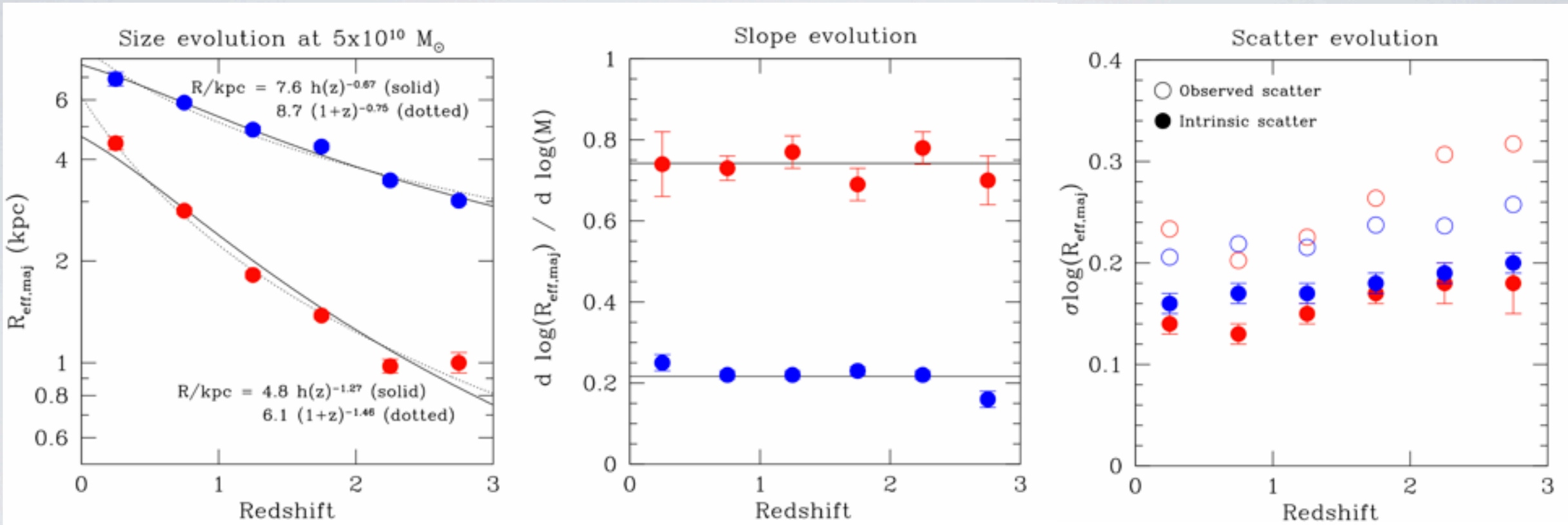


Early-type (quiescent) galaxies



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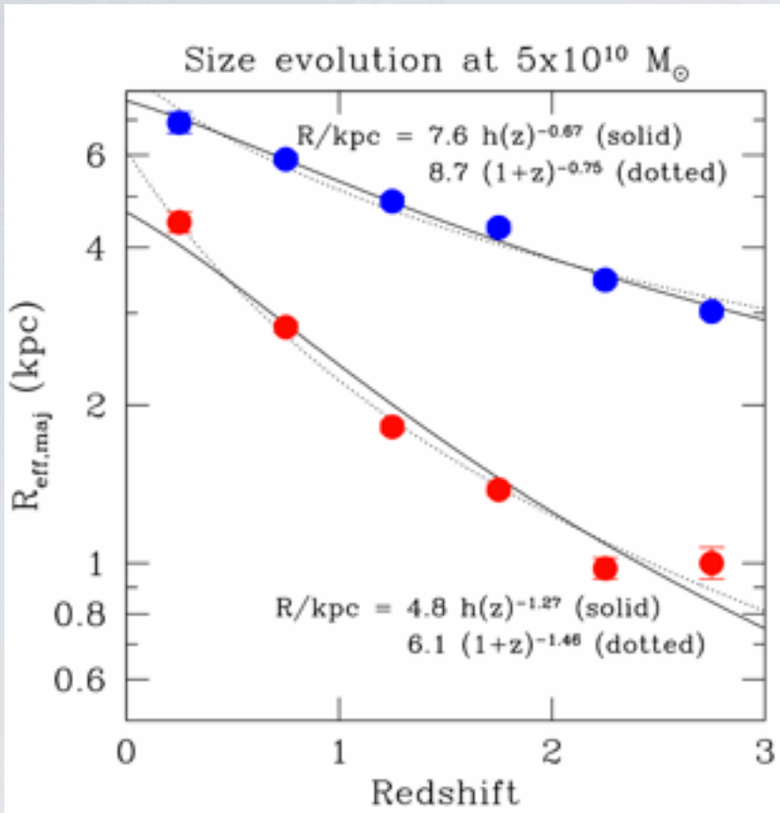
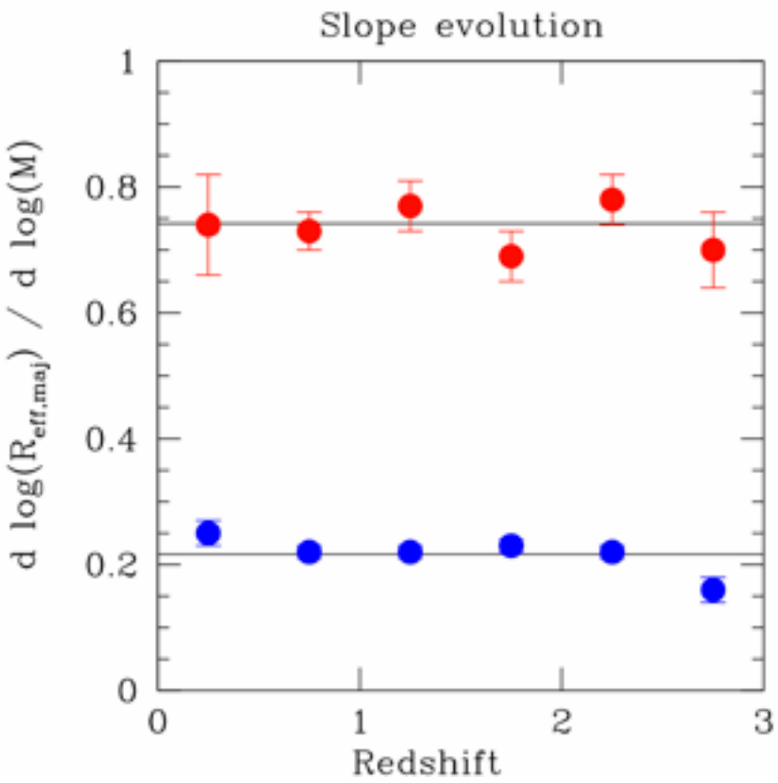
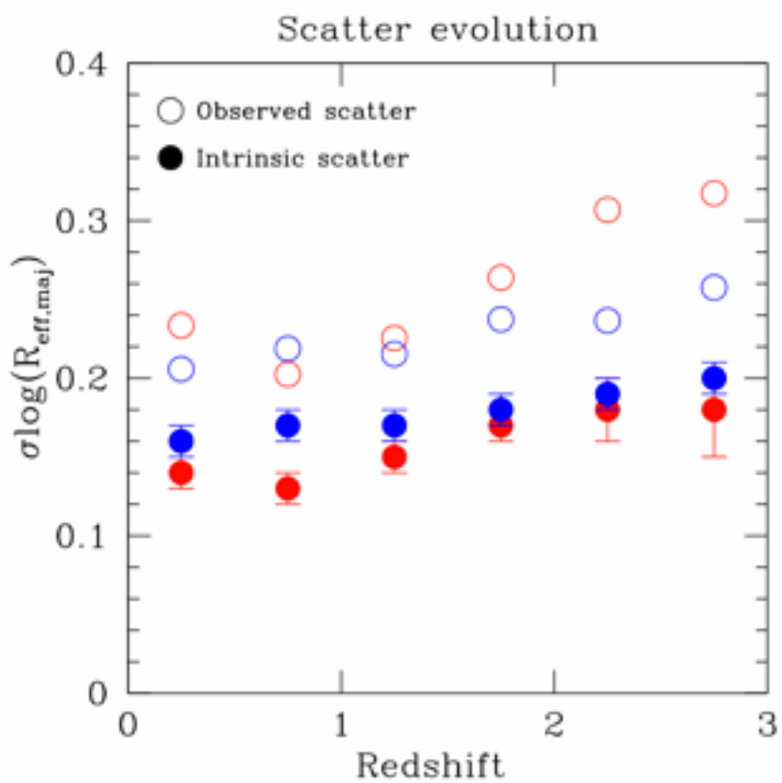


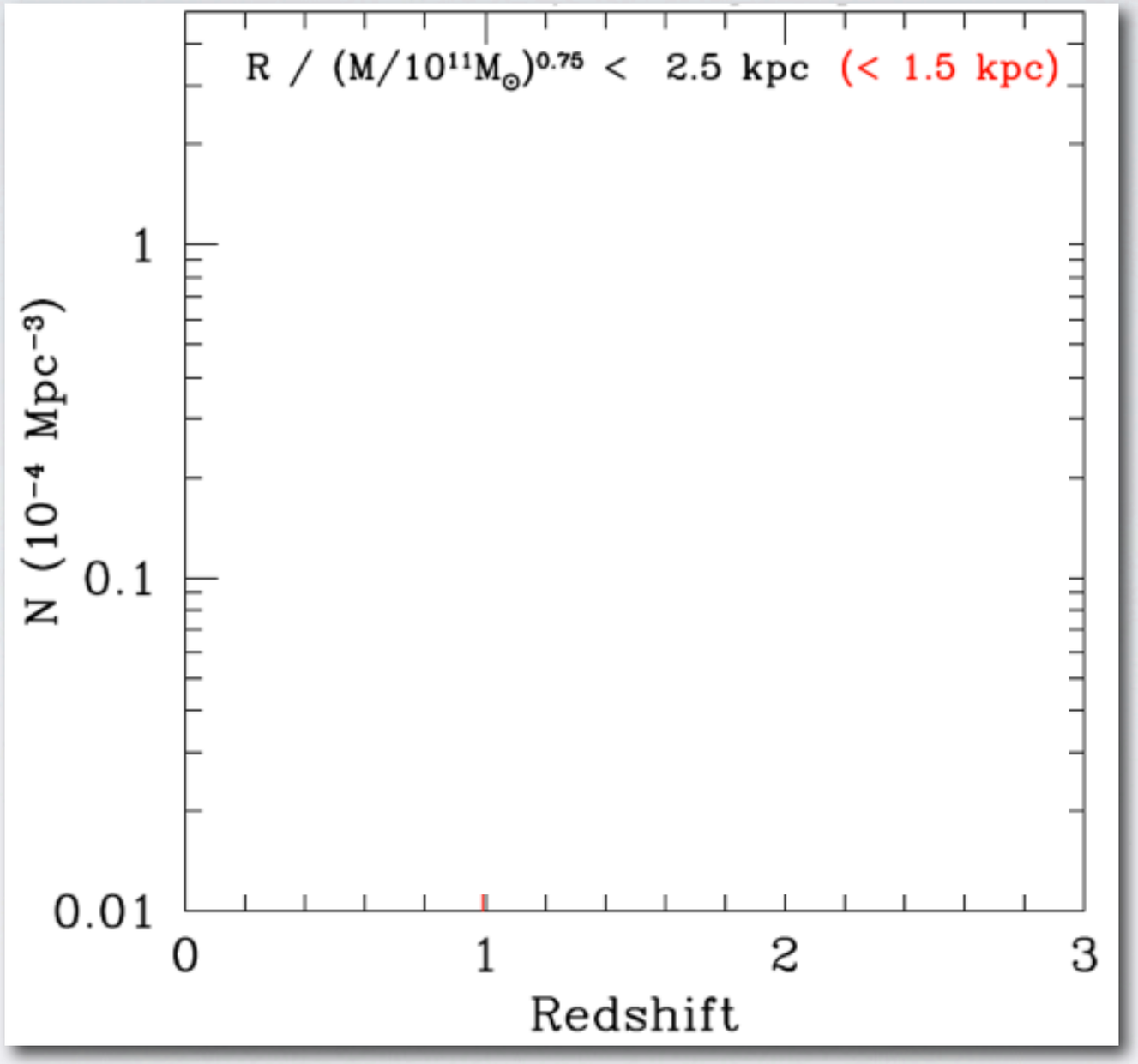


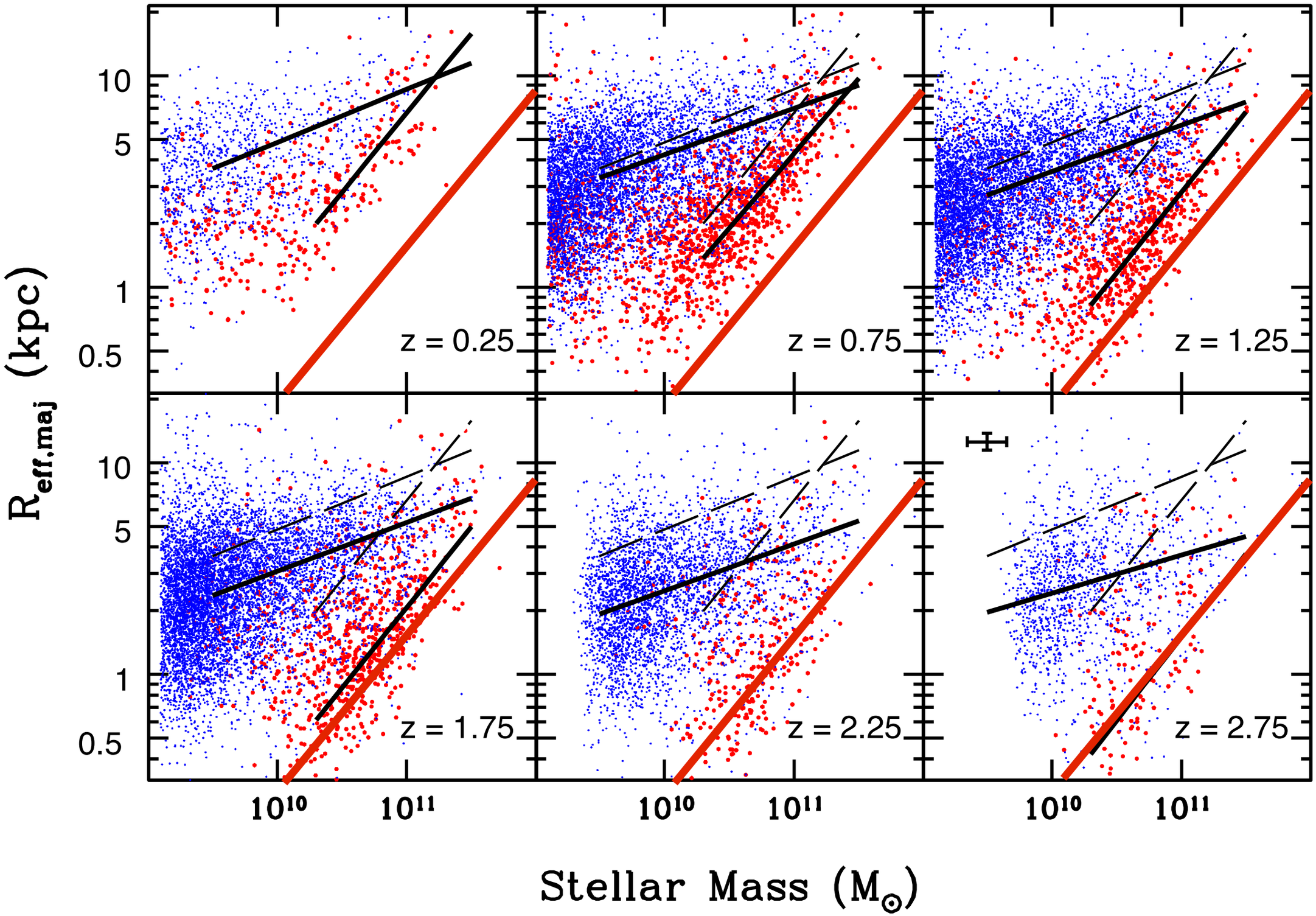


- Rapid size evolution at log M >10.3. At lower M: slower (like late types)

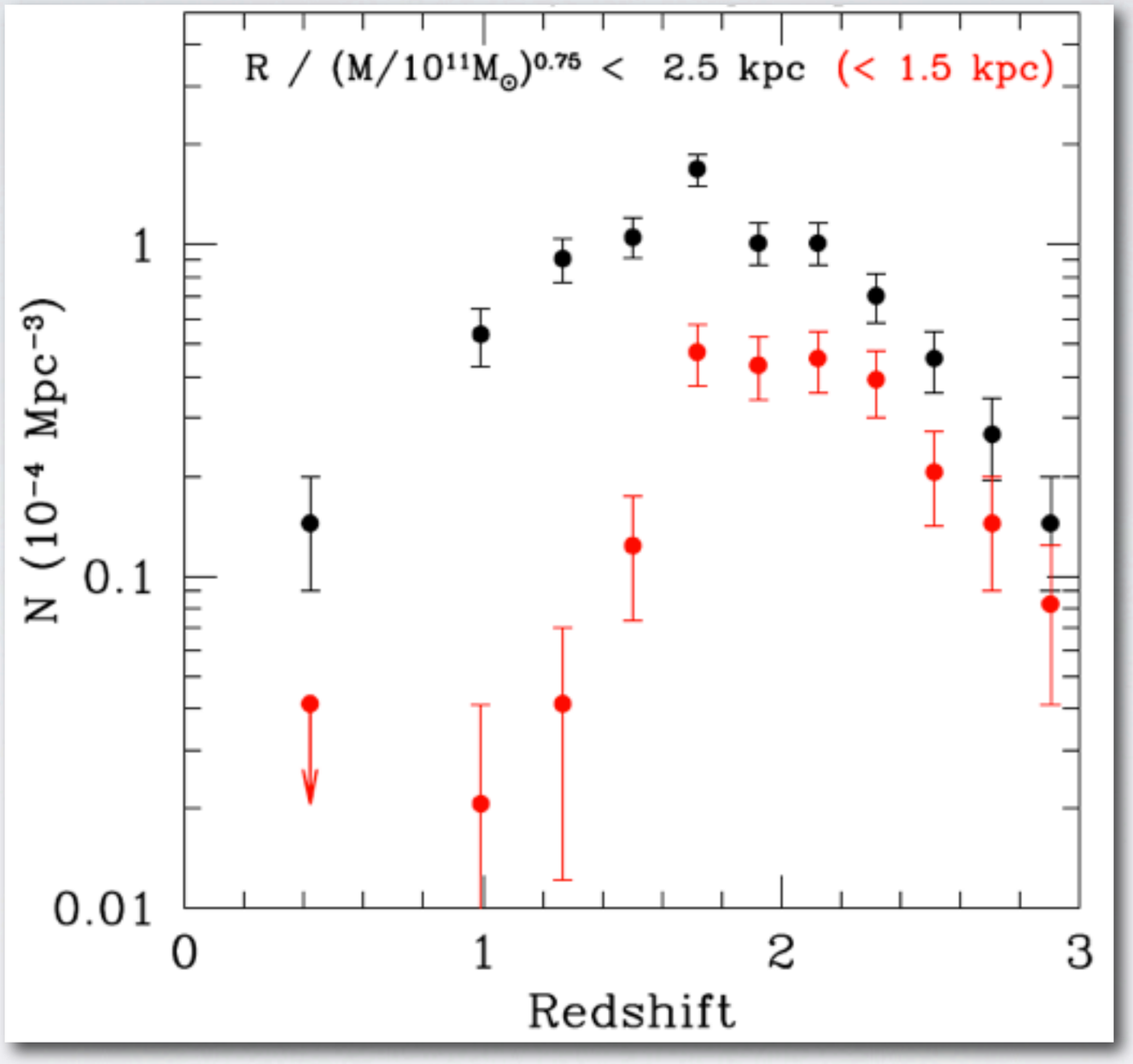
- Quenching and subsequent growth conserve scatter and slope
  No evolution in slope: R ~ M^0.7
  No (or little) evolution in scatter: σ (log R) ≈ 0.13 - 0.18

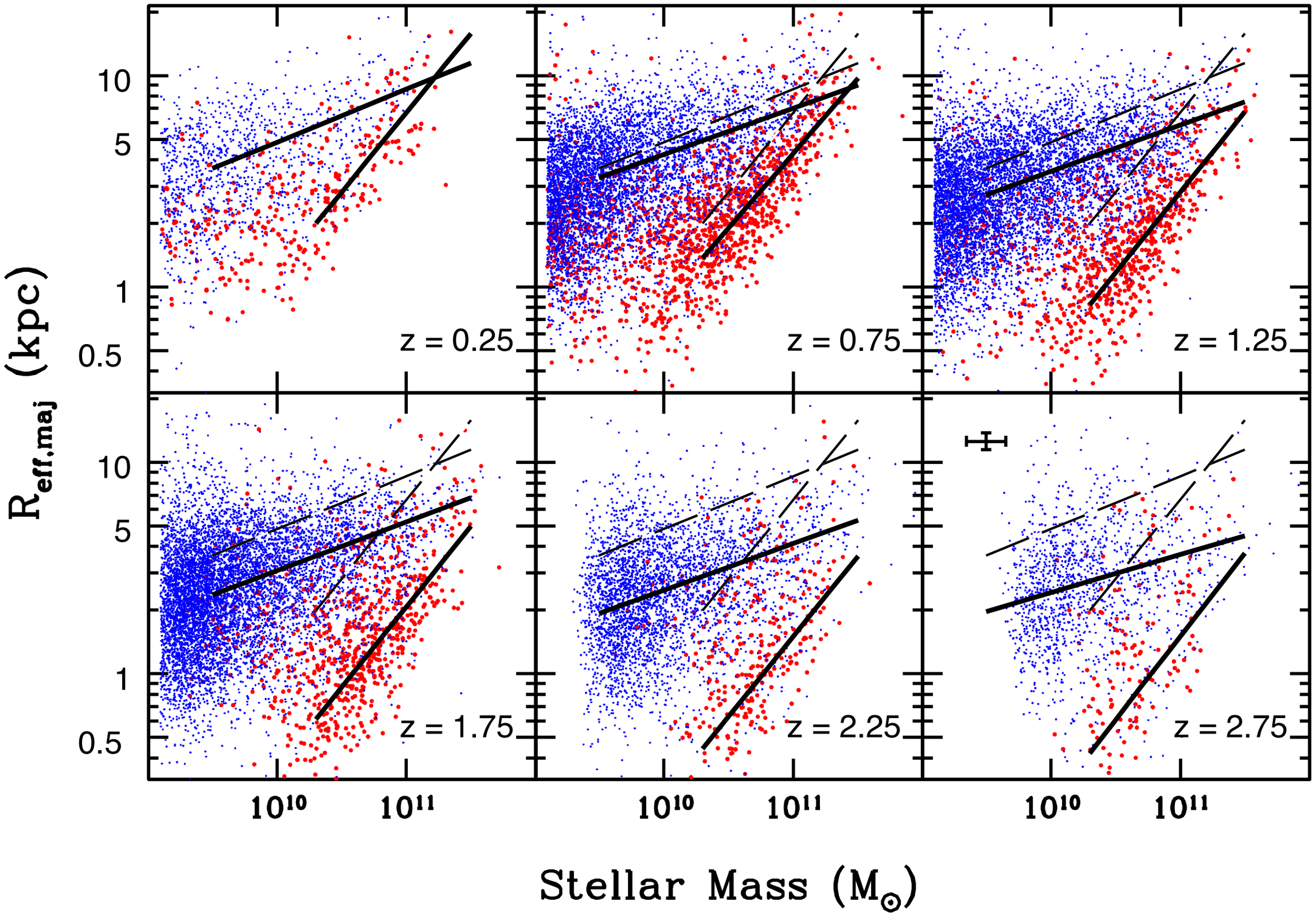
Co-moving number density evolution of compact early types




z = 0.25
z = 0.75
z = 1.25
z = 1.75
z = 2.25
z = 2.75
10
5
1
0.5
$R_{eff,maj}$ (kpc)
10^{10}
10^{11}
Stellar Mass ($M_\odot$)

Co-moving number density evolution of compact early types

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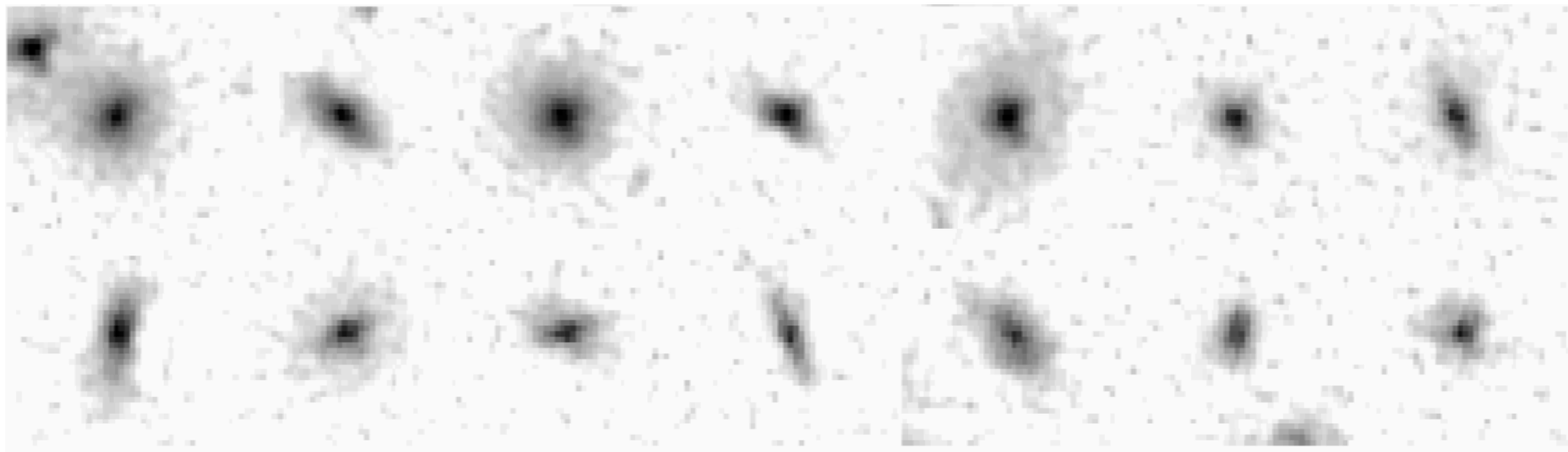
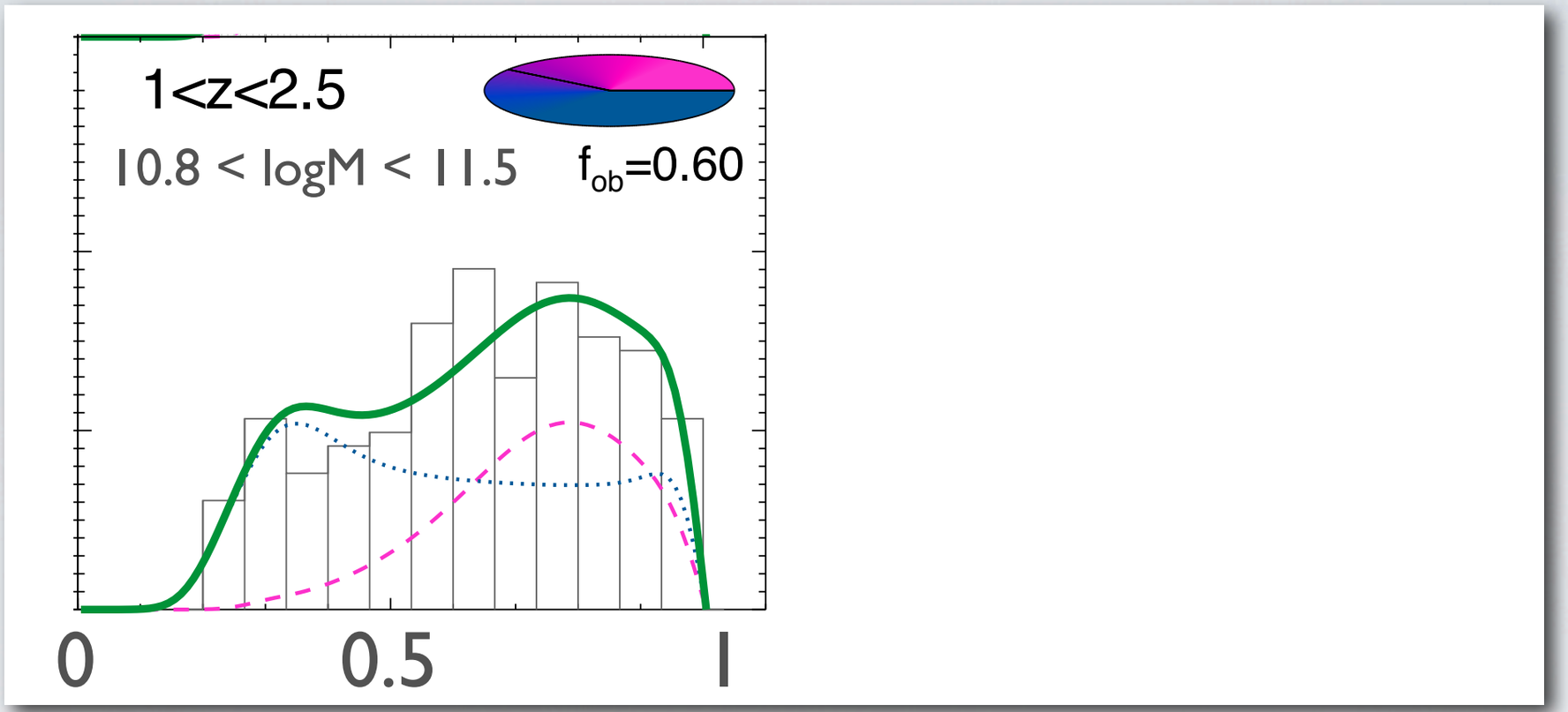
10^{11}
Stellar Mass ($M_\odot$)

Disk-like quiescent galaxies at z ~ 2



van der Wel+11
(also see McGrath+08)

Evolution of the **3D** shapes of early types



Chang, van der Wel et al. (2013b)

also see
Holden, van der Wel et al. (2012)
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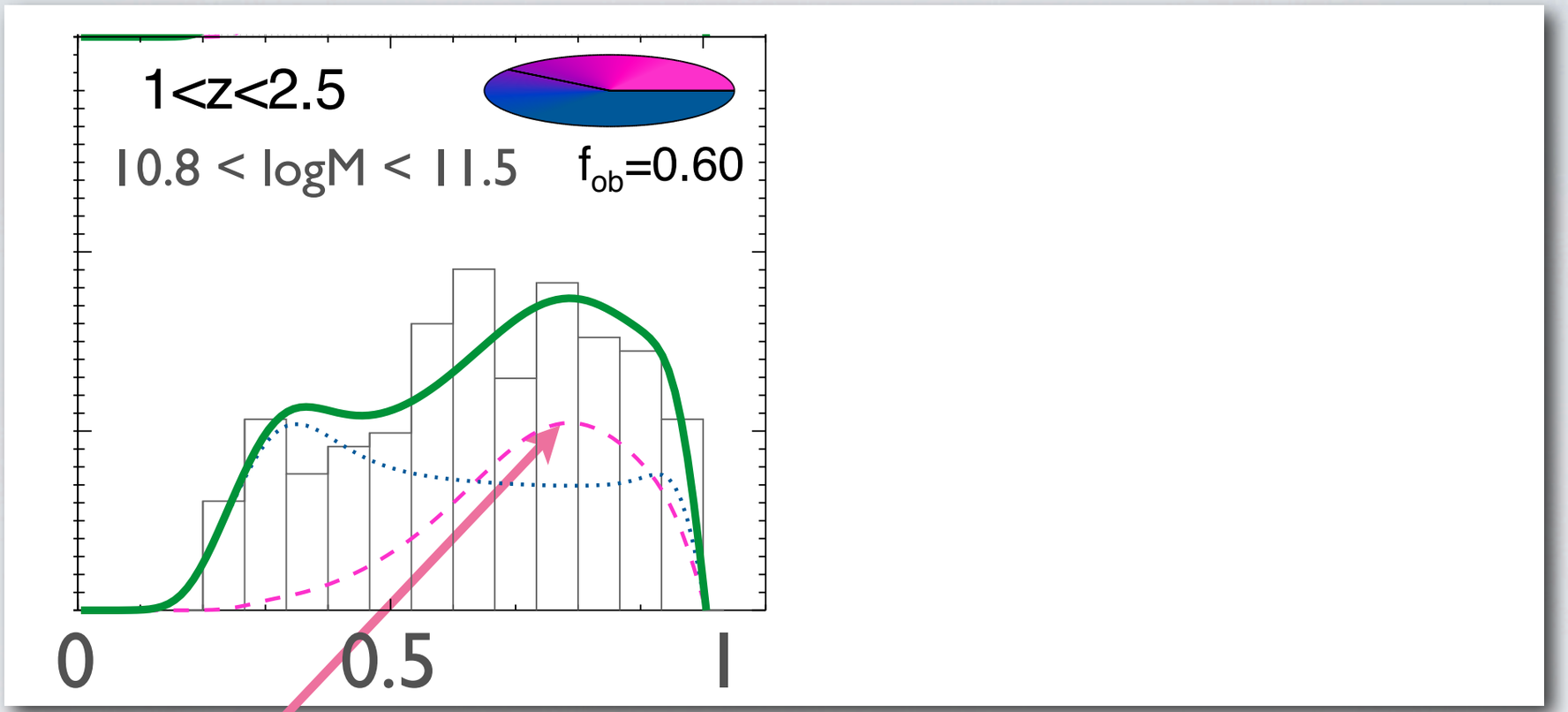

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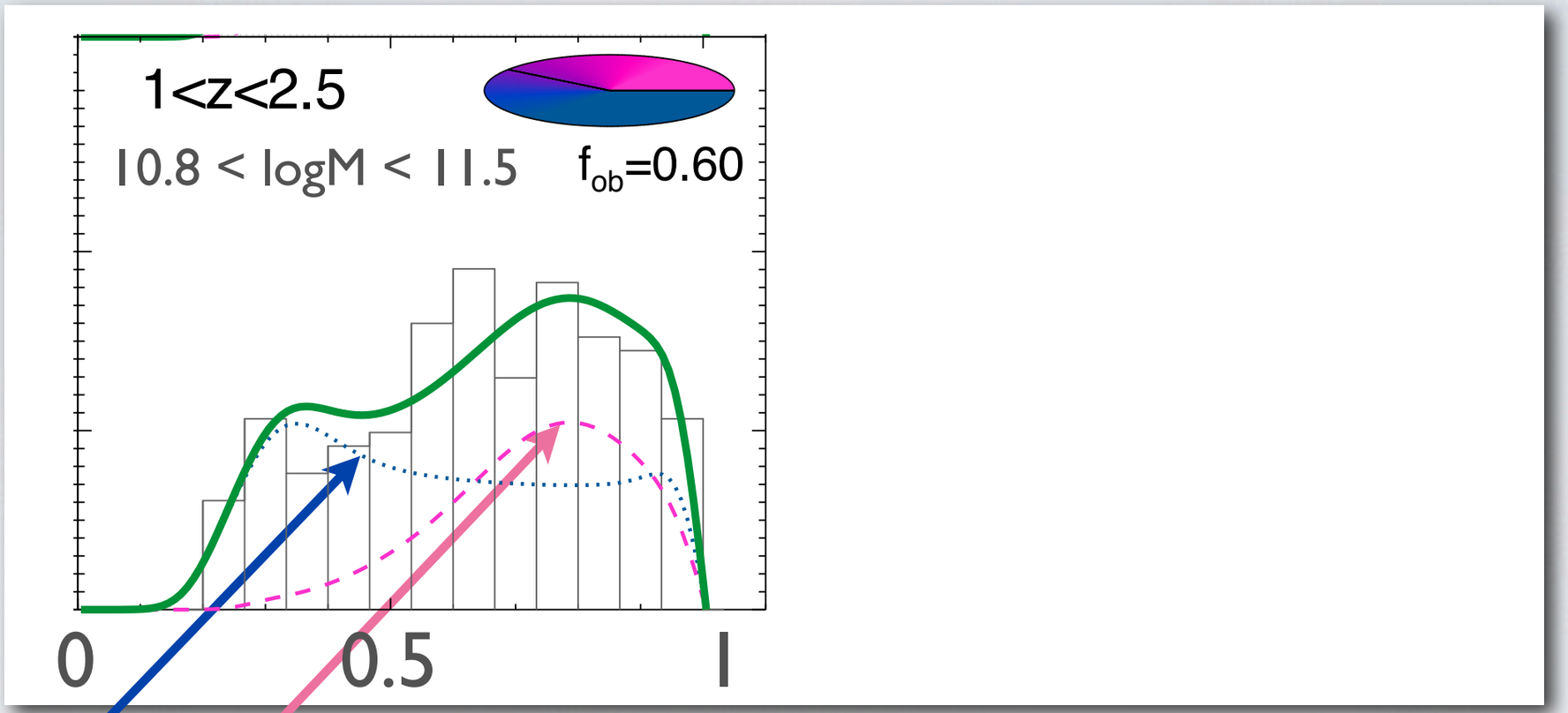

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The majority of massive early types at z > 1
are flat/disk-like, with intrinsic c/a~0.3

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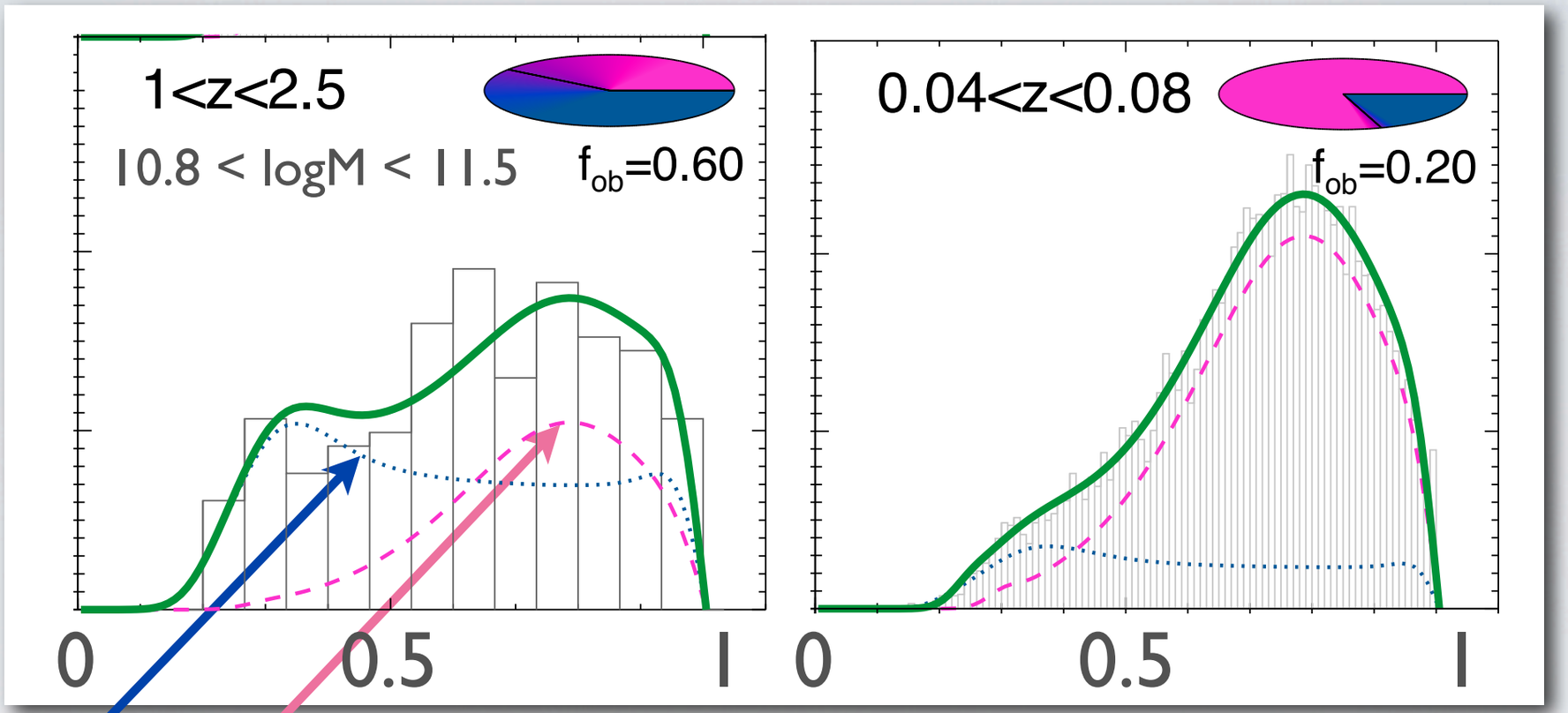

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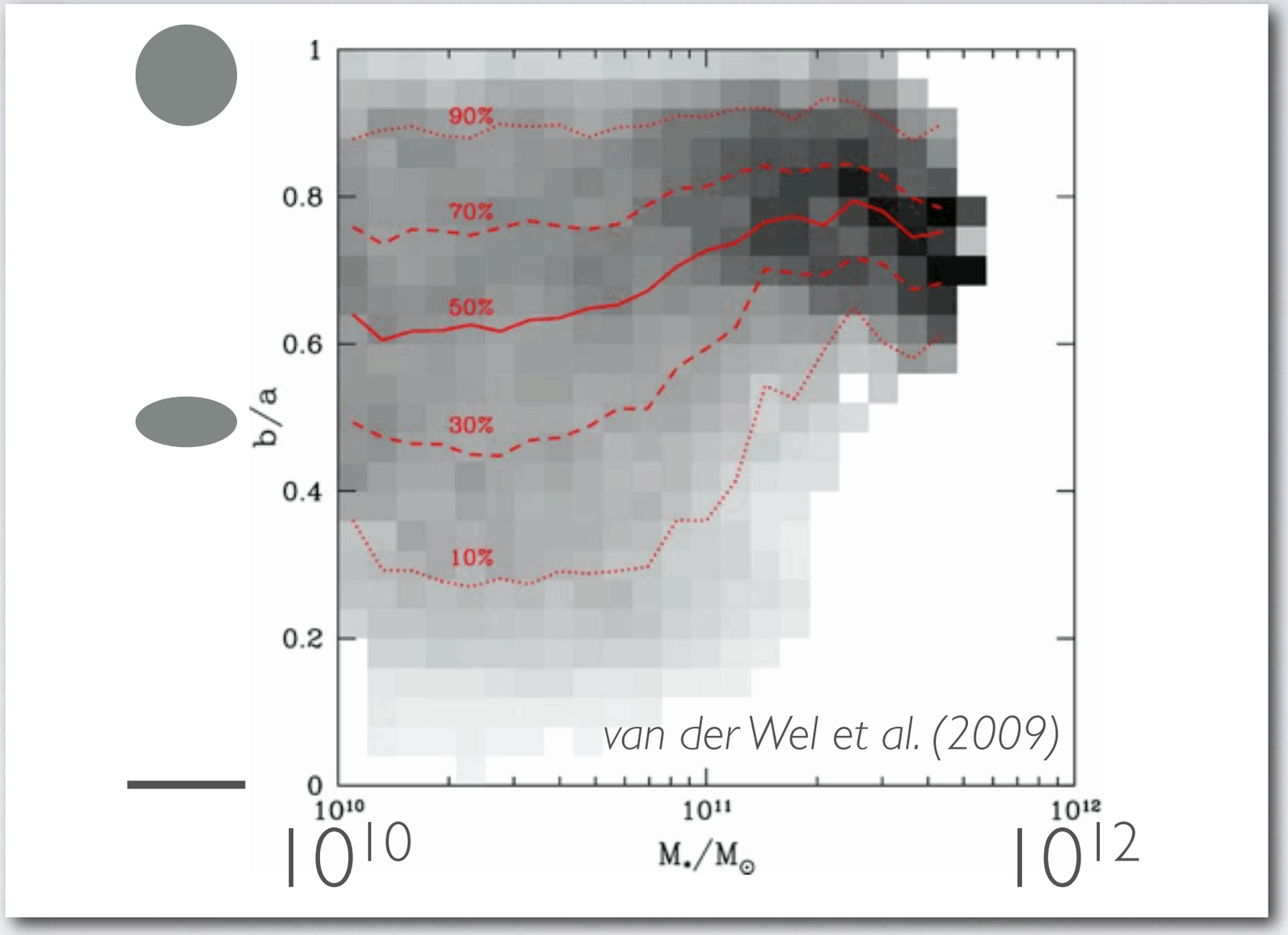
The merger origin of massive galaxies

~10k galaxies at z ~0.06 early types from SDSS



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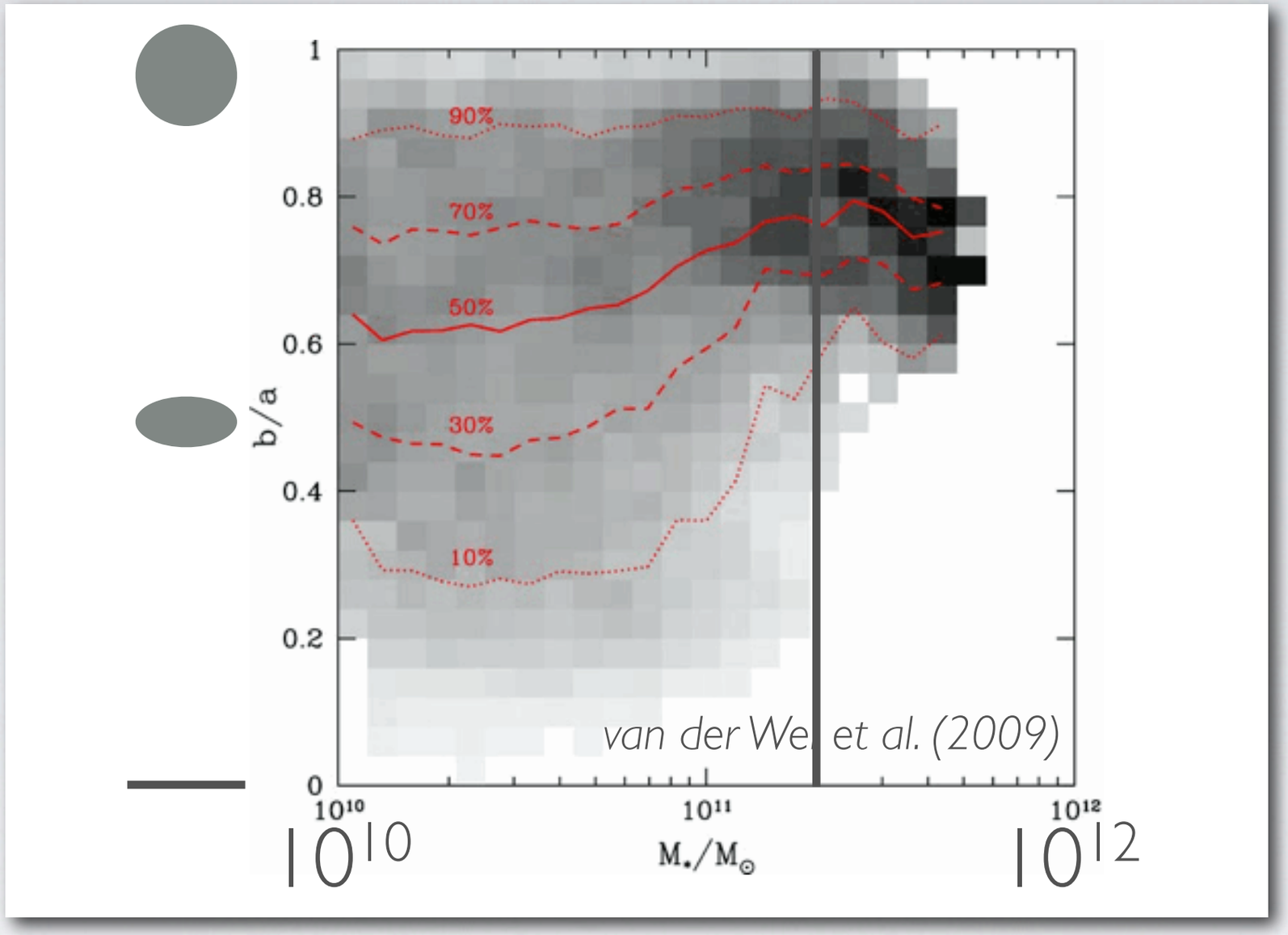


Beyond 2×10^{11} $M_\odot$ all galaxies are round

Mergers are the only way to grow beyond 2×10^{11} $M_\odot$

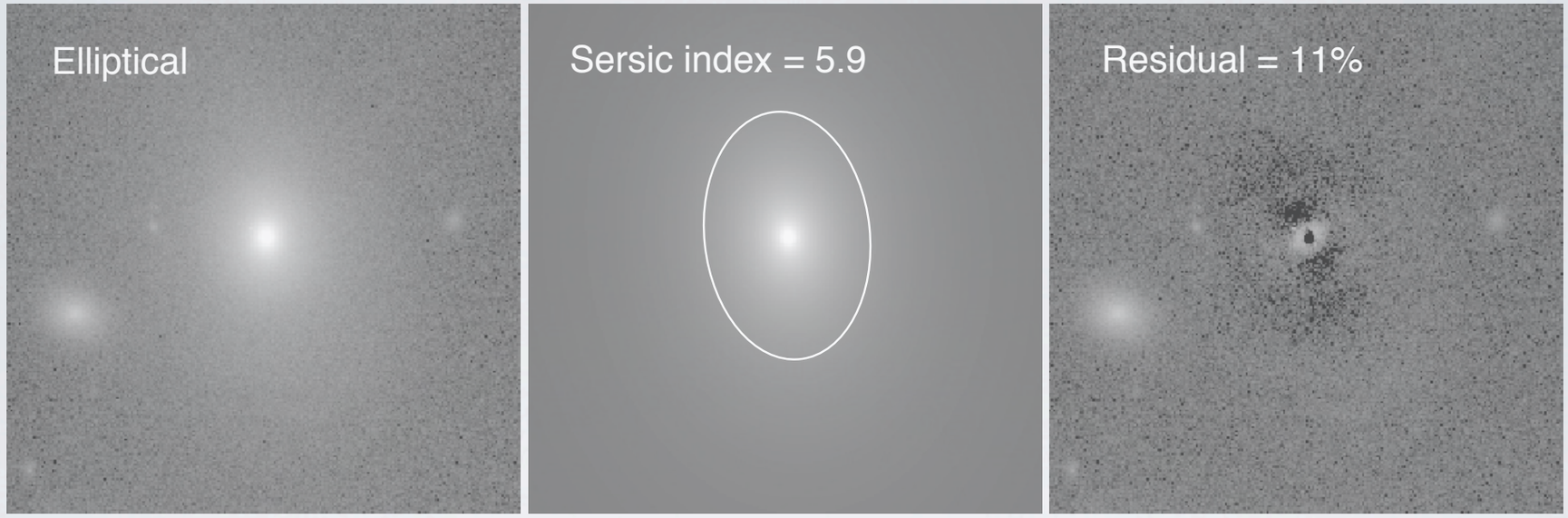
Conclusions

- The size-mass relations of early- and late-type galaxies differ strongly in intercept and slope at all redshifts

- Newly quenched galaxies at z~2 are compact and disk-like

- Subsequent evolution builds up extended envelopes and destroys the disk-like structure

How are sizes and shapes measured?

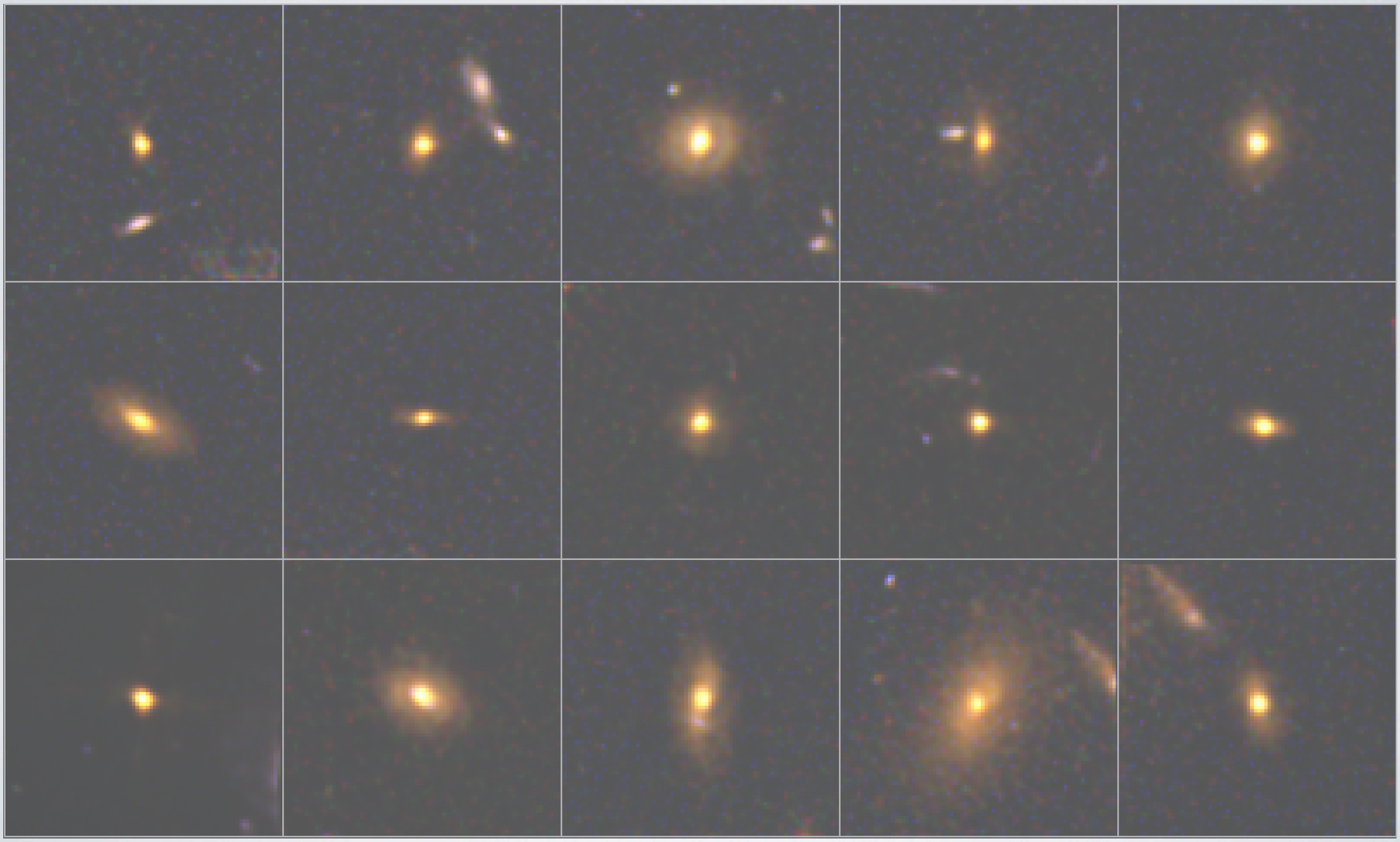


Sersic profile: $$\Sigma(r) = \Sigma_e \exp\left(-b_n\left[\left(\frac{r}{r_e}\right)^{1/n} - 1\right]\right) .$$

Quiescent galaxies in at z =1.6 - 2

2.4" / 20 kpc

stellar mass ~5 x 10^{10} M⊙



Koekemoer+11 (F814W, F125W, F160W)

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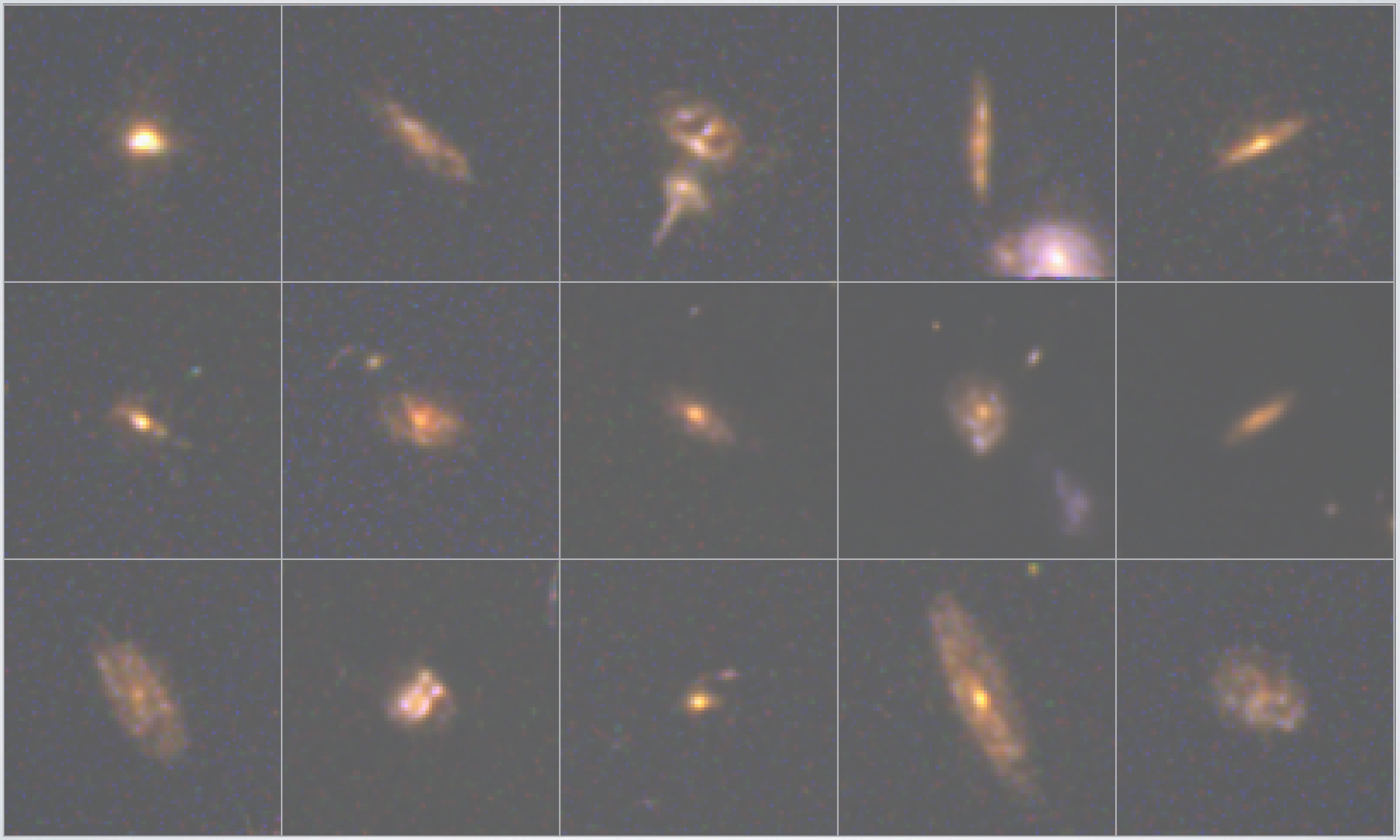

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Stellar rotation curves of z ~ 1 galaxies

van der Wel & van der Marel (2008)