Evolution of galaxies from mass selected samples

ACS GTO team (Holden, vdWel, Ford, Illingworth et al)

FIRES Survey: Labbe, Wuyts, Kriek, Rudnick, Forster Schreiber, van Dokkum, Moorwood, Rix, Rottgering, Trujillo, van der Werf, Illingworth, van Starkenburg, MF,

MUSYC near-IR survey: van Dokkum (PI),

Gawiser (co-PI), Lira (co-PI), Urry, Maza,Mendez,Altmann, Blanc, Francke,Barrientos, Infante, Urry, Quadri, Toft, Marchesini, Brammer,Taylor,MF

Kriek

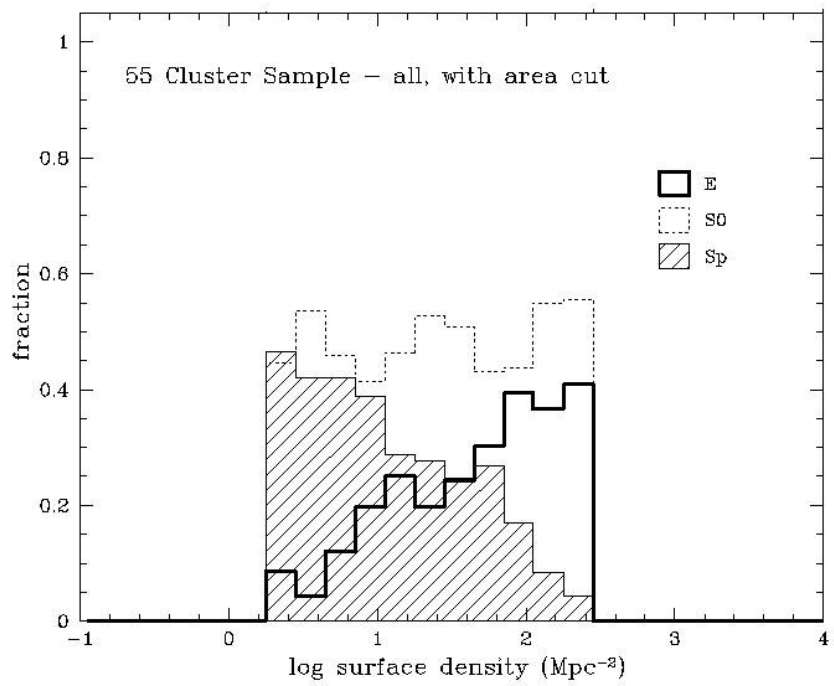
Our goal is: study galaxy evolution

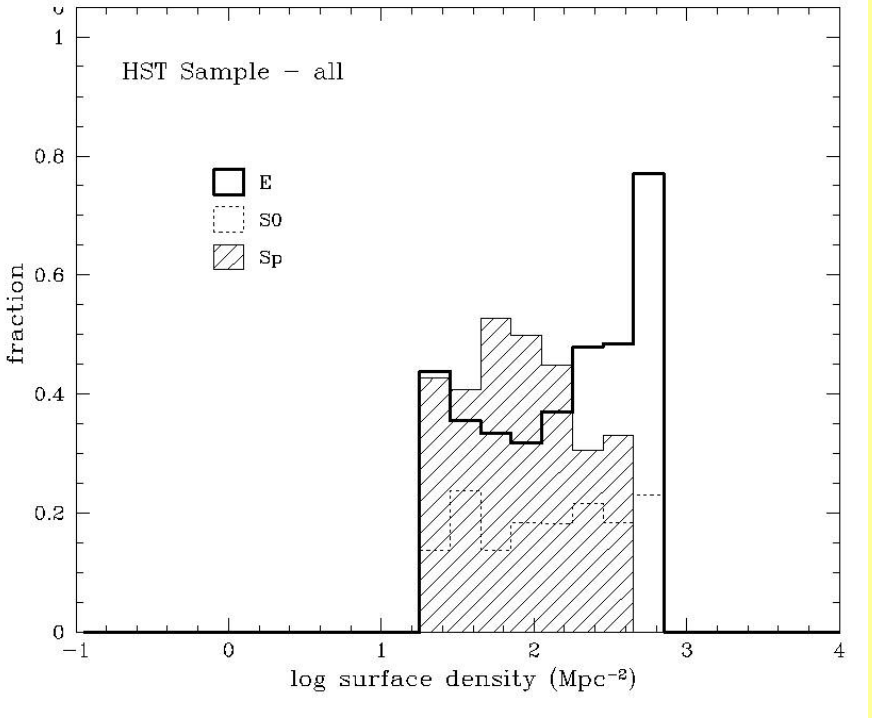
- This requires a proper census of the universe !

2 case studies

- Structure of galaxies at z=1 as a function of environment
- Evolution of Galaxies at z=2-3

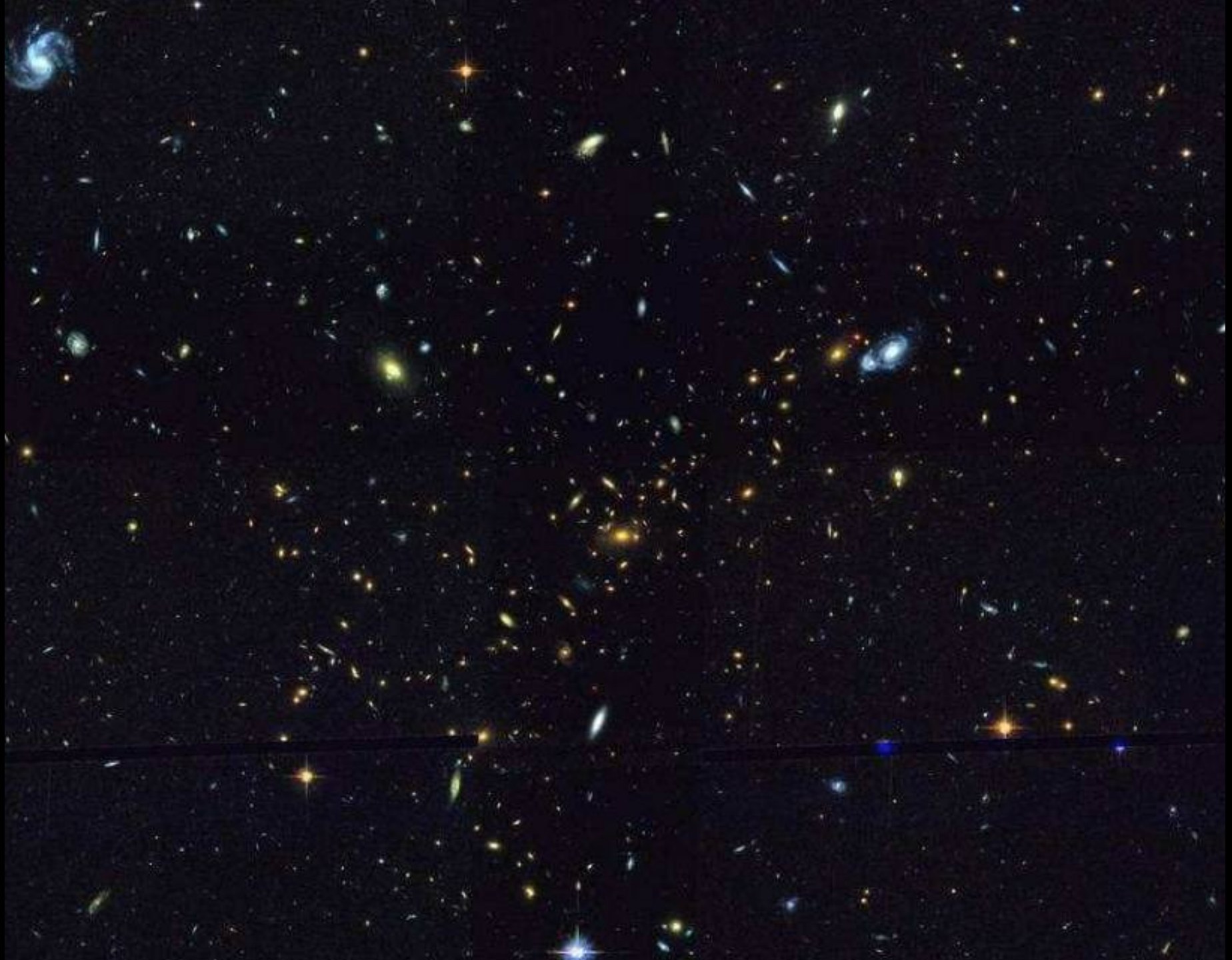
Evolution Morphology-density relation (Dressler et al 1997)



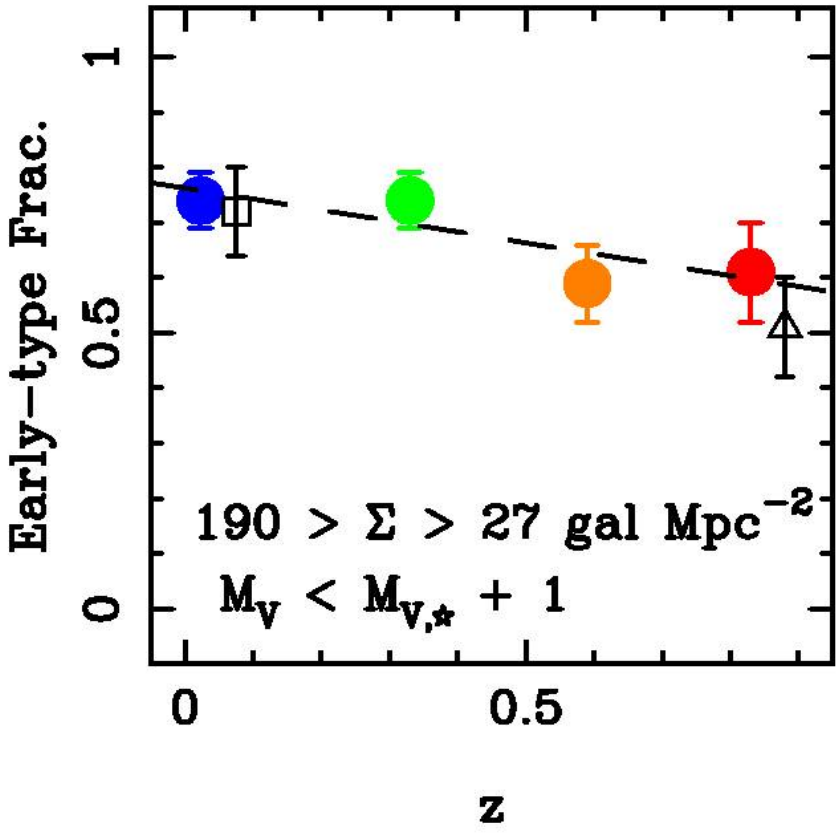


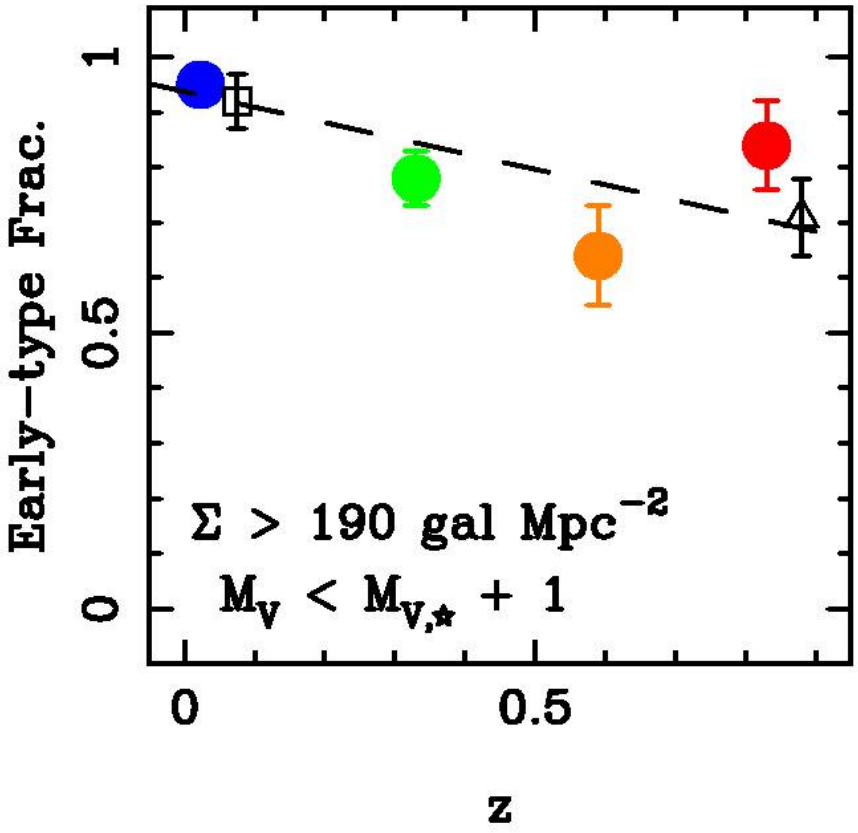
Low redshift

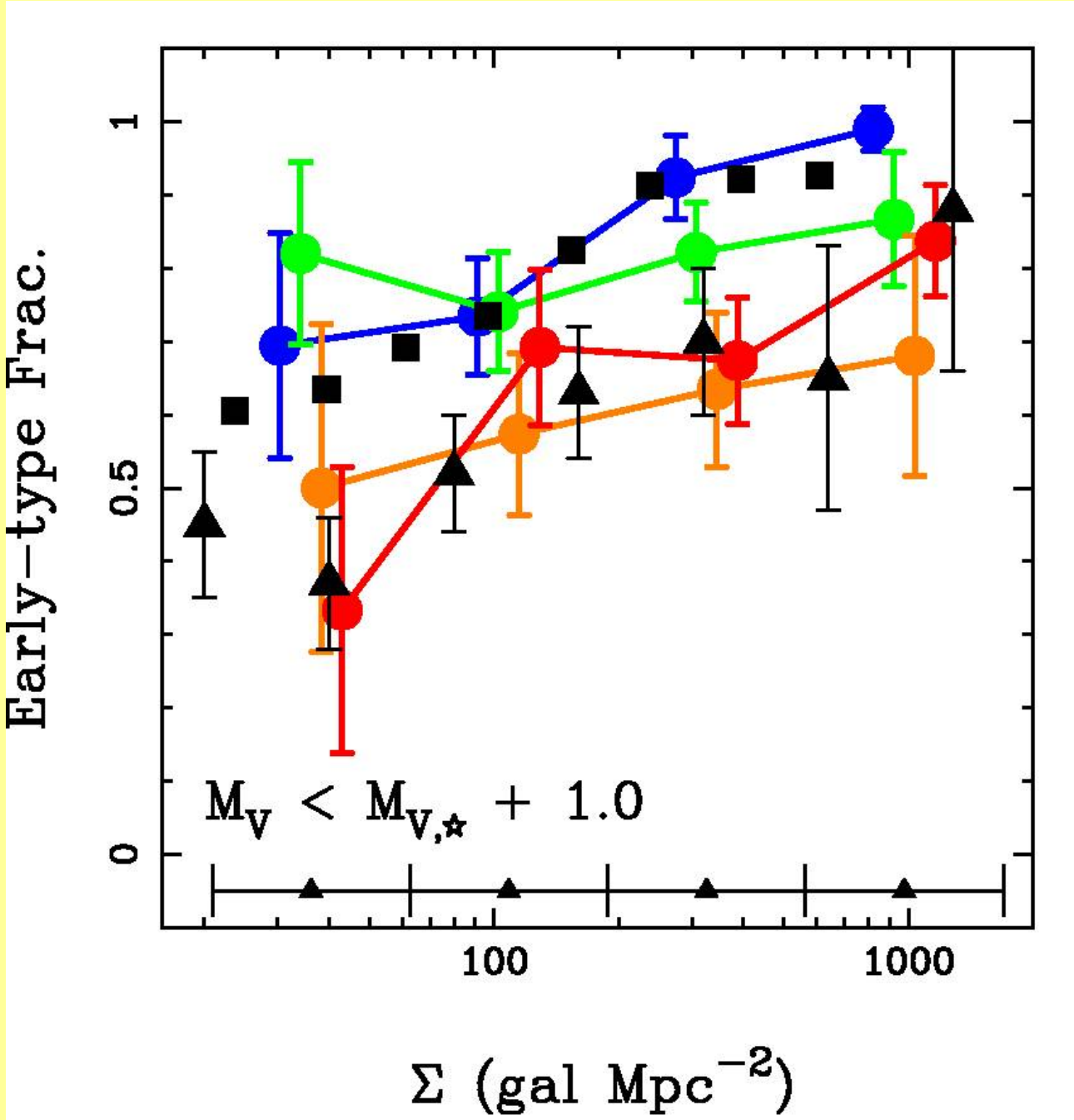
Z=0.5

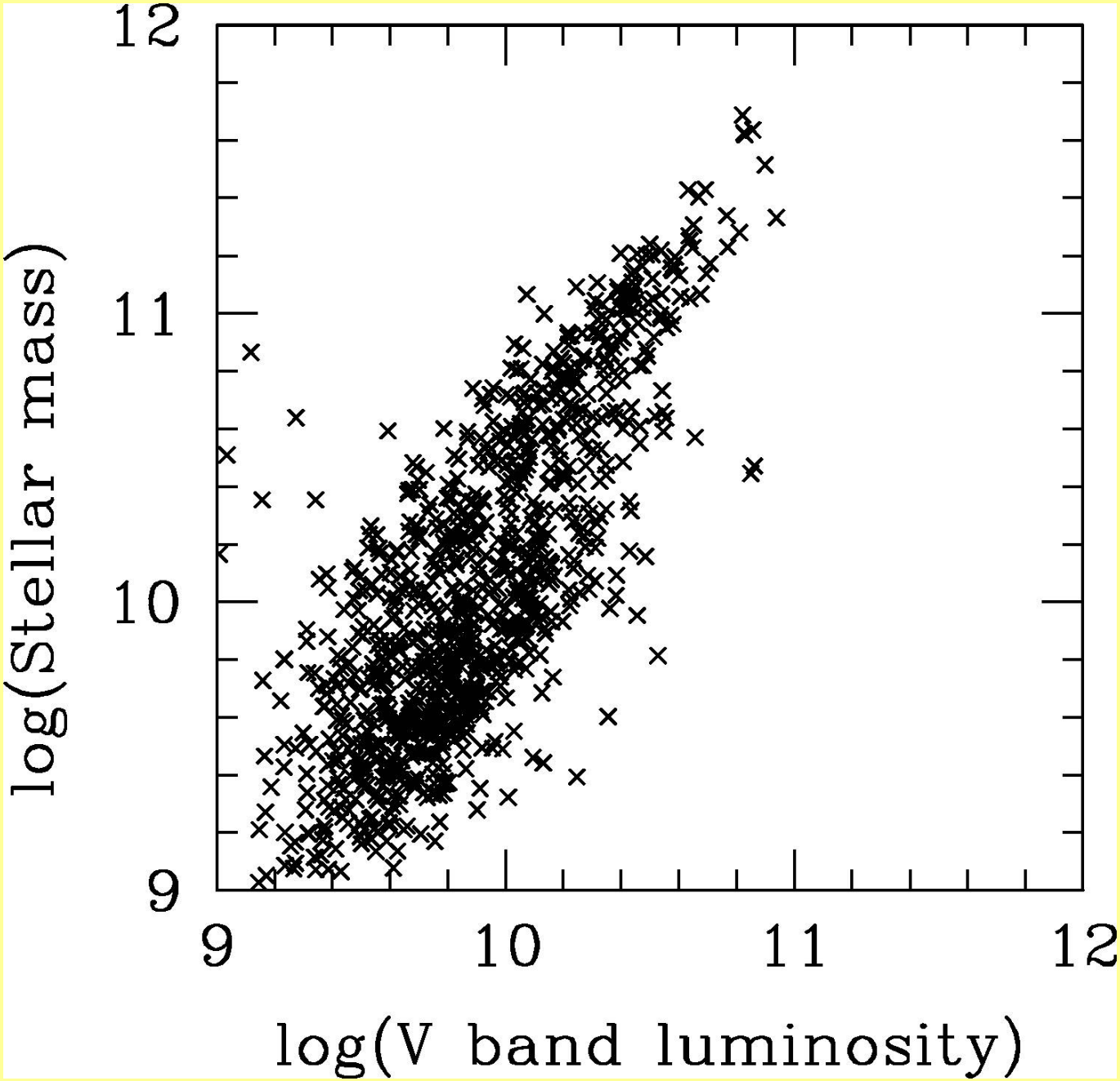


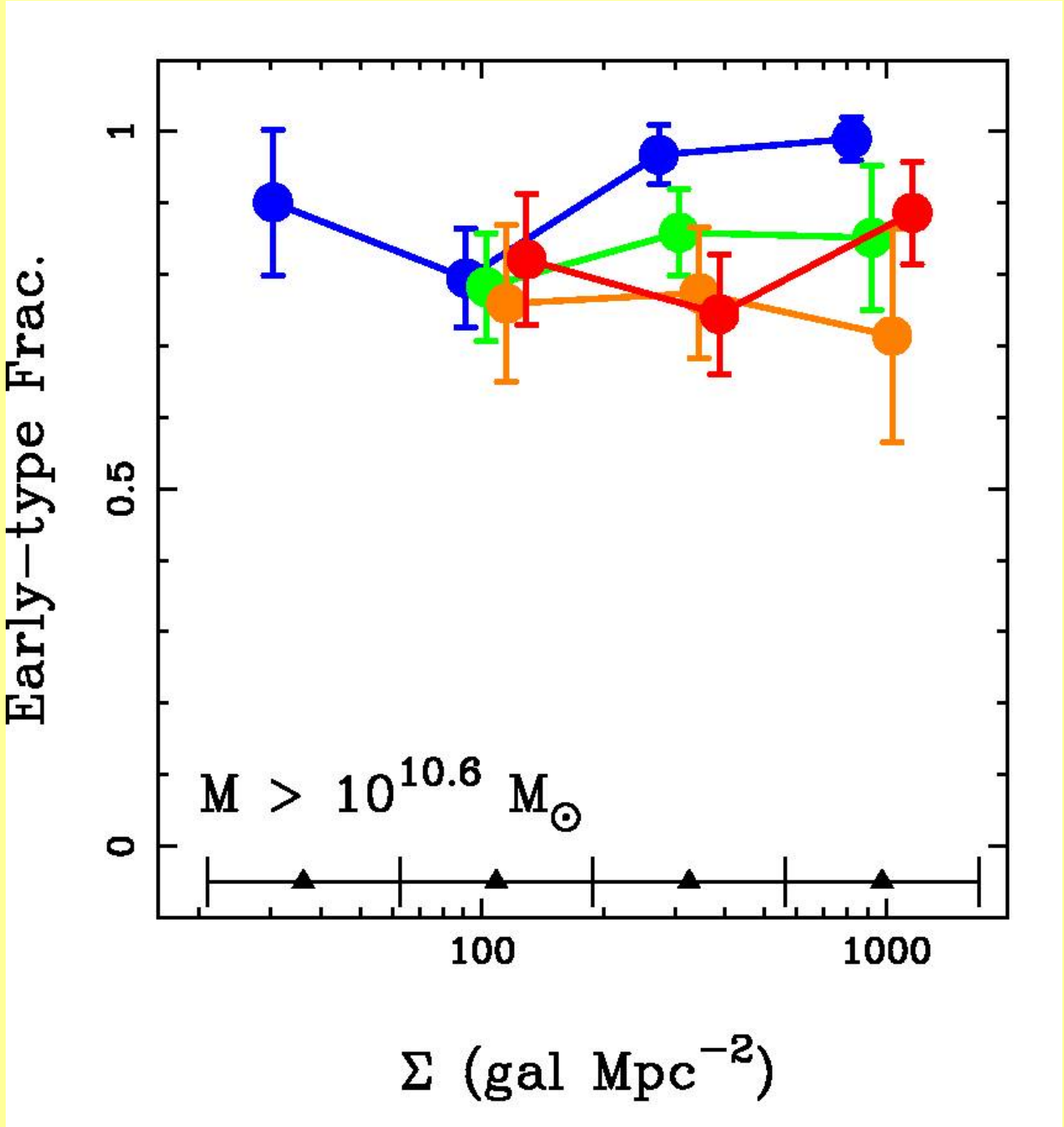
Extending to z=0.8

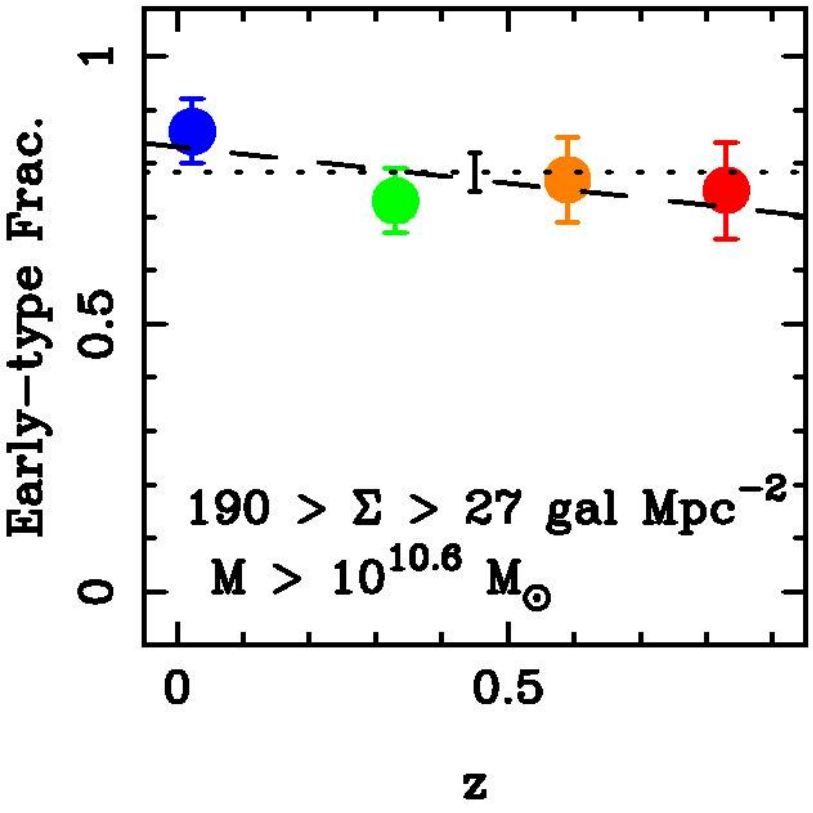


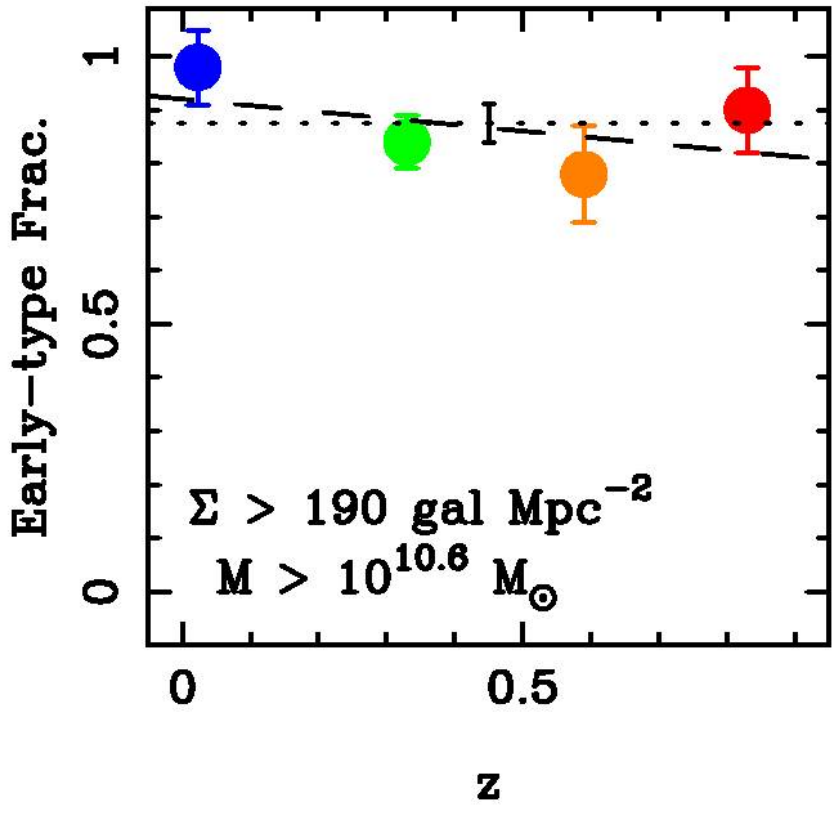



Early−type Frac.
1
0.5
0
$M_V < M_{V,\star} + 1.0$
100
1000
Σ (gal Mpc^{-2})


12
11
10
9
log(Stellar mass)
9
10
11
12
log(V band luminosity)

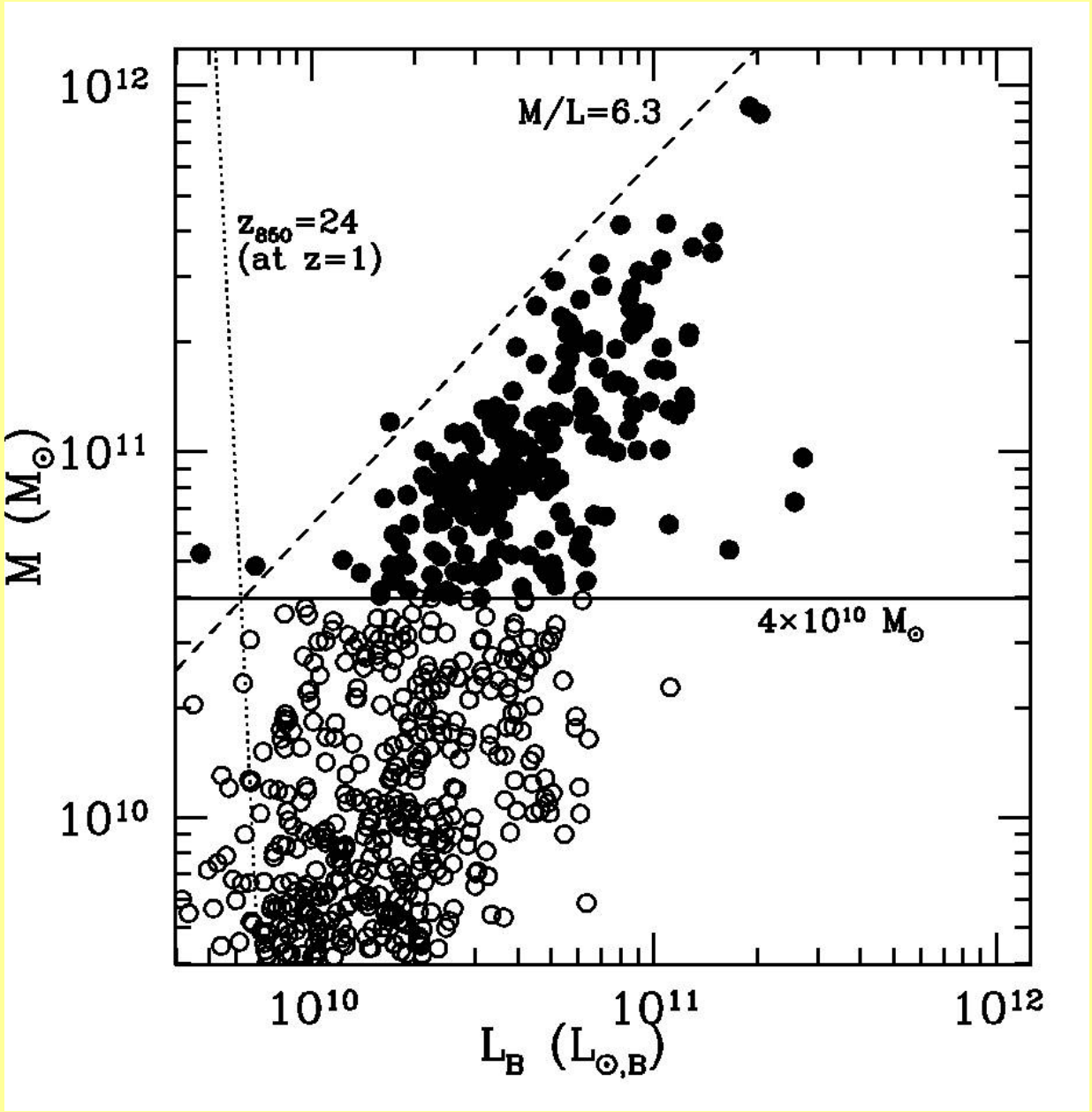

Early−type Frac.
0
0.5
1
M > 10^10.6 M⊙
100
1000
Σ (gal Mpc^−2)

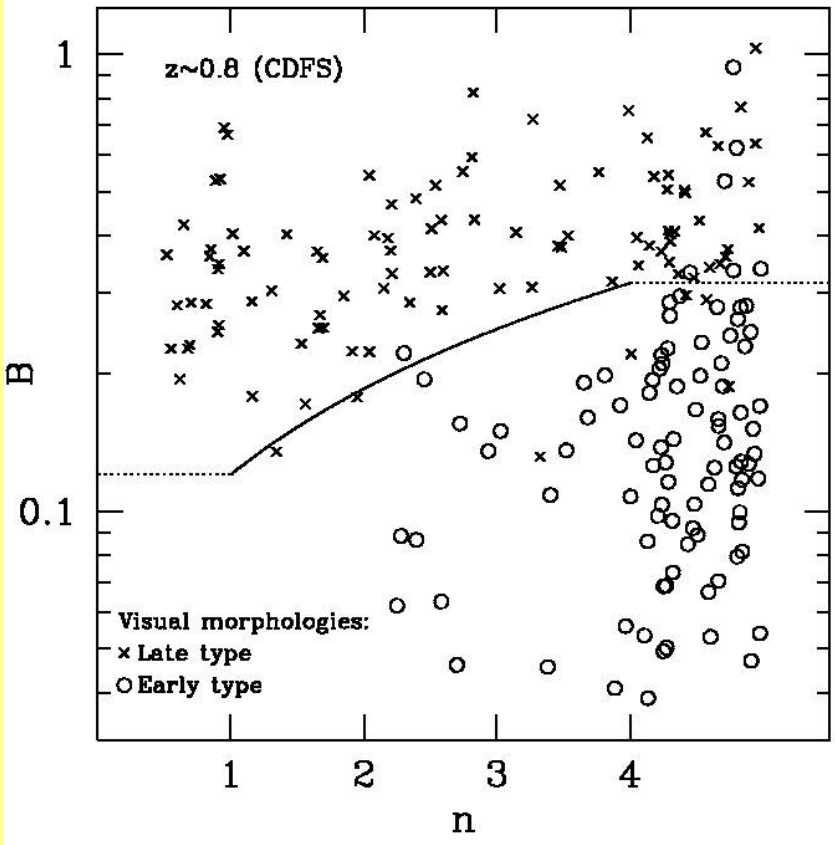

Early−type Frac.
1
0.5
0
0
0.5
z
190 > Σ > 27 gal Mpc^{-2}
M > 10$^{10.6}$ M$_\odot$

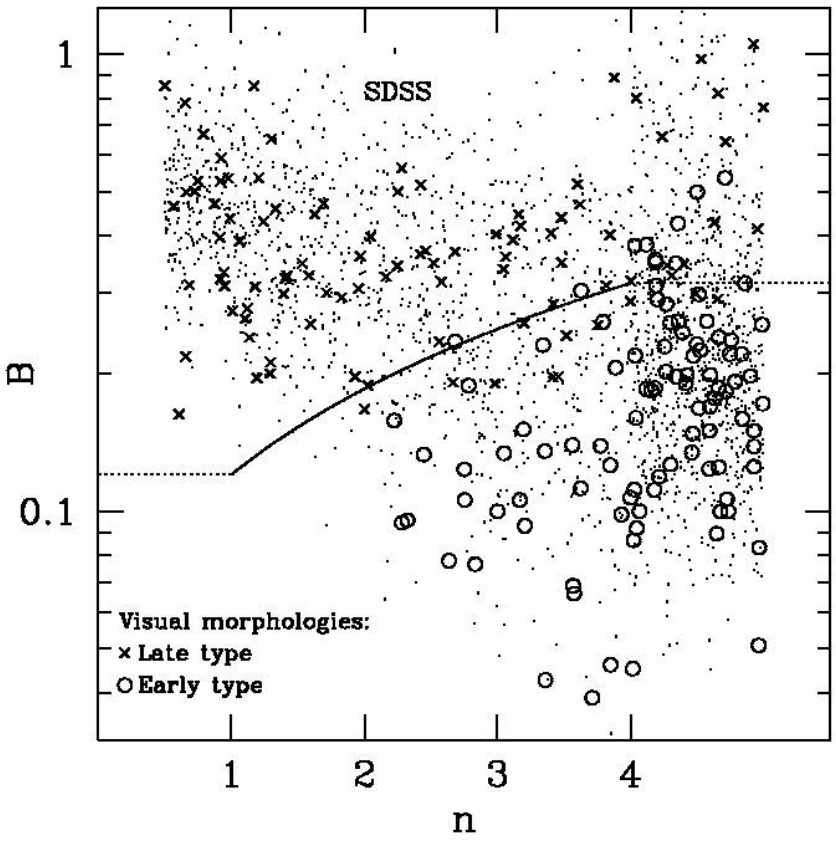

Early−type Frac.
1
0.5
0
0
0.5
z
Σ > 190 gal Mpc^{-2}
M > 10$^{10.6}$ M$_\odot$

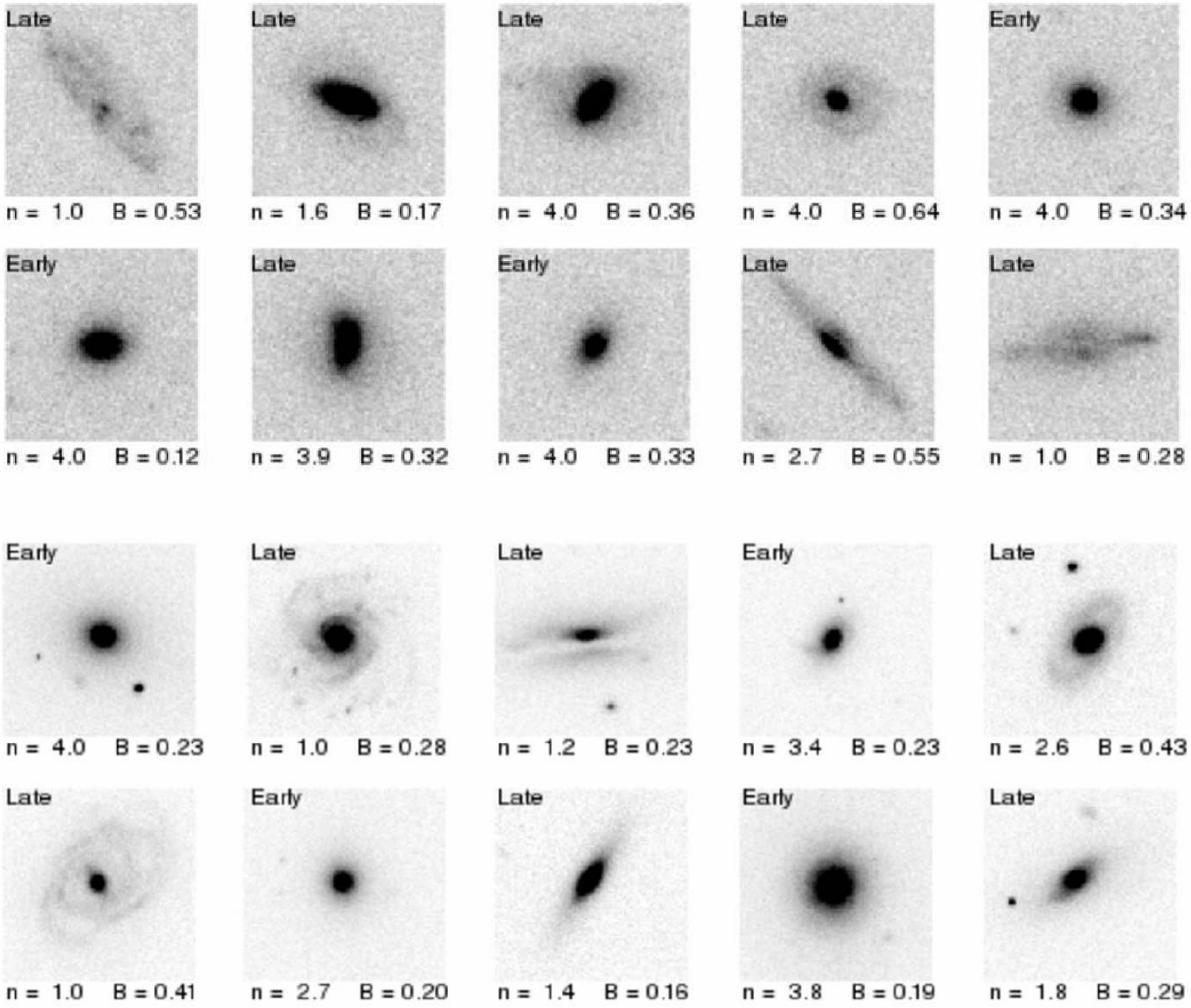
Conclusion

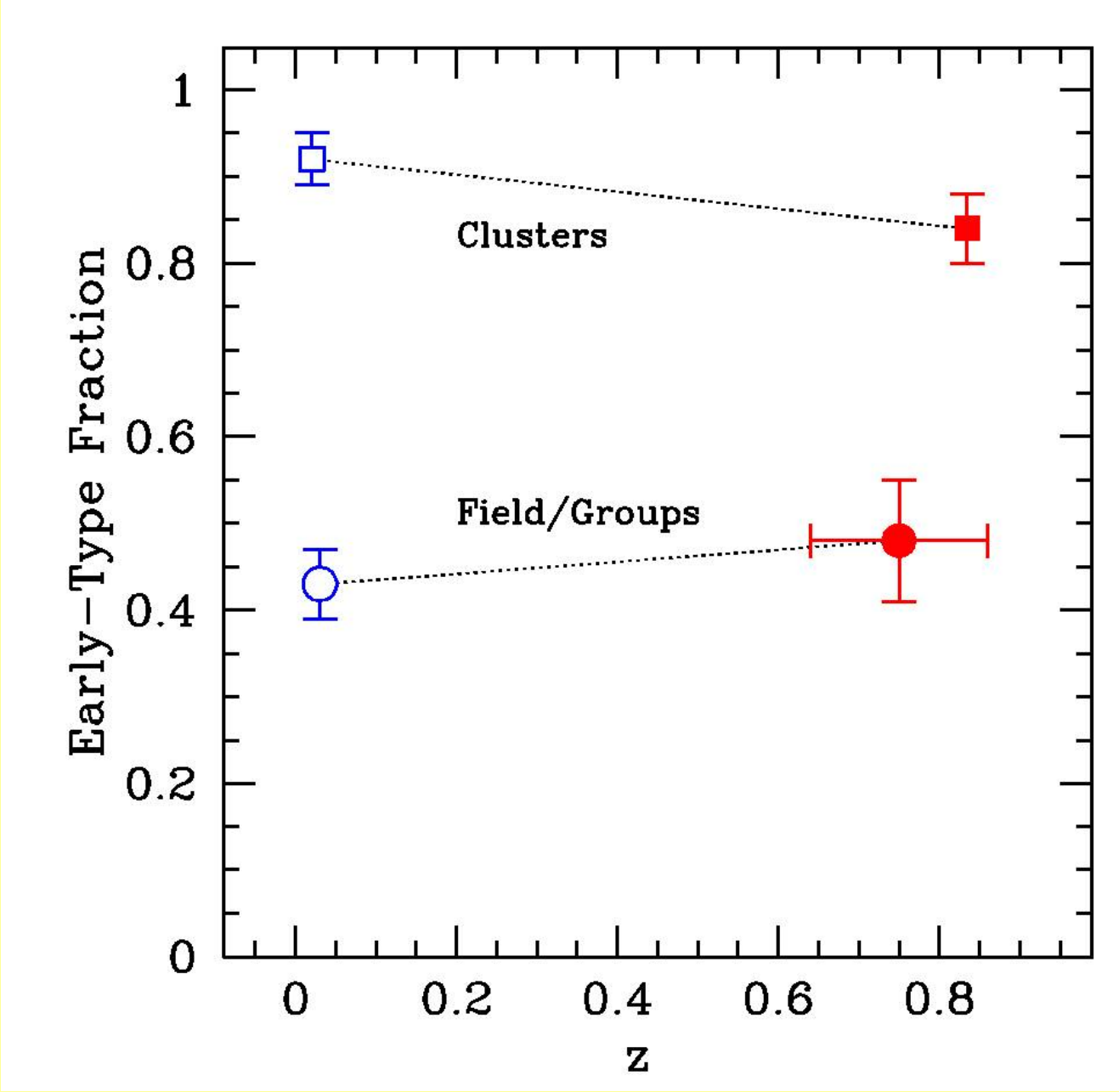
- Hardly any evolution in Morphology density relation for mass selected sample (Mstar >10**10.6)
- How about the field ?

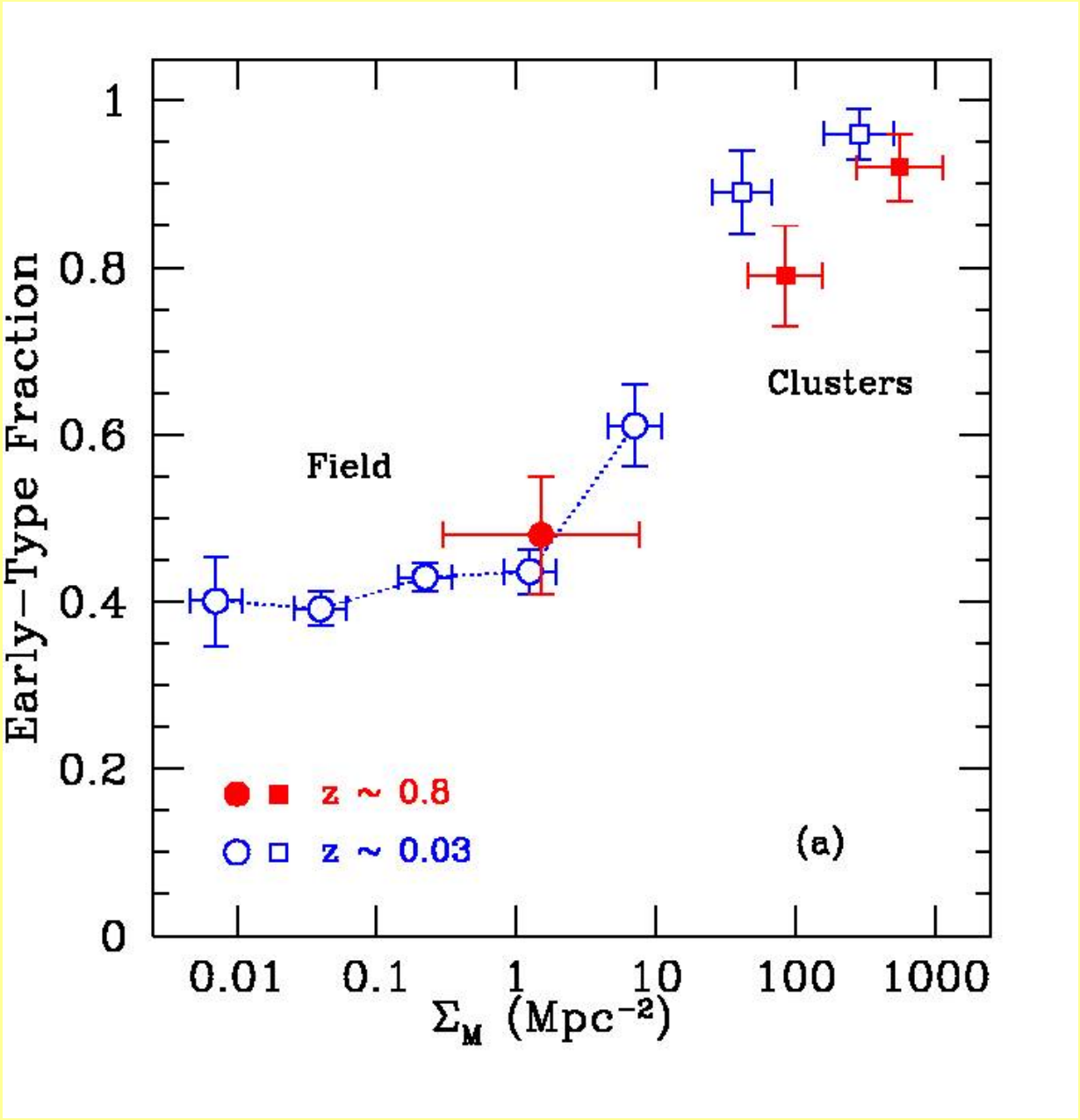

10^{12}
10^{11}
10^{10}
M ($M_\odot$)
M/L=6.3
z_{850}=24
(at z=1)
4×10^{10} $M_\odot$
10^{10}
10^{11}
10^{12}
L_B ($L_{\odot,B}$)


z~0.8 (CDFS)
1
0.1
B
1
2
3
4
n
Visual morphologies:
× Late type
○ Early type


SDSS
1
0.1
B
1
2
3
4
n
Visual morphologies:
× Late type
○ Early type


Late
n = 1.0 B = 0.53
Late
n = 1.6 B = 0.17
Late
n = 4.0 B = 0.36
Late
n = 4.0 B = 0.64
Early
n = 4.0 B = 0.34
Early
n = 4.0 B = 0.12
Late
n = 3.9 B = 0.32
Early
n = 4.0 B = 0.33
Late
n = 2.7 B = 0.55
Late
n = 1.0 B = 0.28
Early
n = 4.0 B = 0.23
Late
n = 1.0 B = 0.28
Late
n = 1.2 B = 0.23
Early
n = 3.4 B = 0.23
Late
n = 2.6 B = 0.43
Late
n = 1.0 B = 0.41
Early
n = 2.7 B = 0.20
Late
n = 1.4 B = 0.16
Early
n = 3.8 B = 0.19
Late
n = 1.8 B = 0.29


Early-Type Fraction
z
Clusters
Field/Groups
0
0.2
0.4
0.6
0.8
1

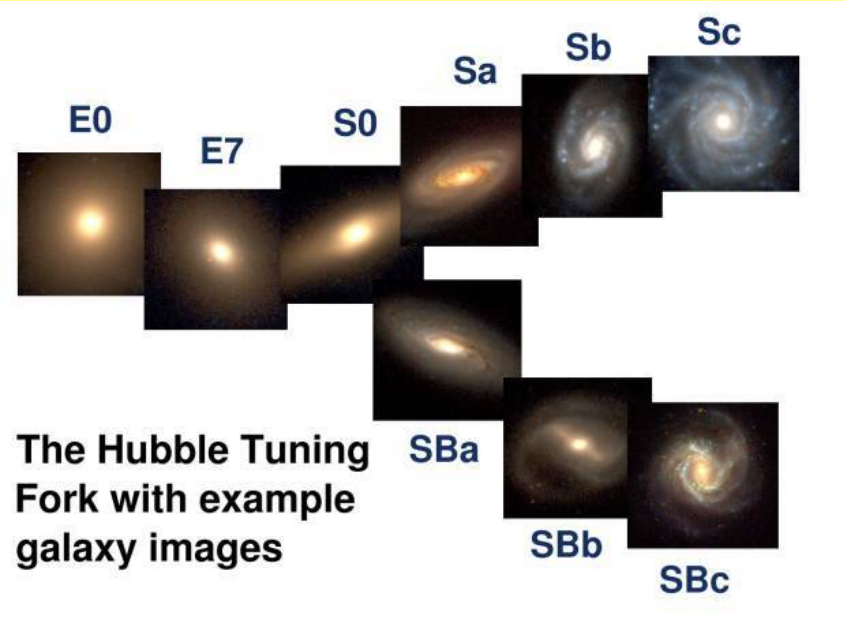

Early−Type Fraction
1
0.8
0.6
0.4
0.2
0
Field
Clusters
z ~ 0.8
z ~ 0.03
(a)
0.01
0.1
1
10
100
1000
Σ_M (Mpc^{-2})

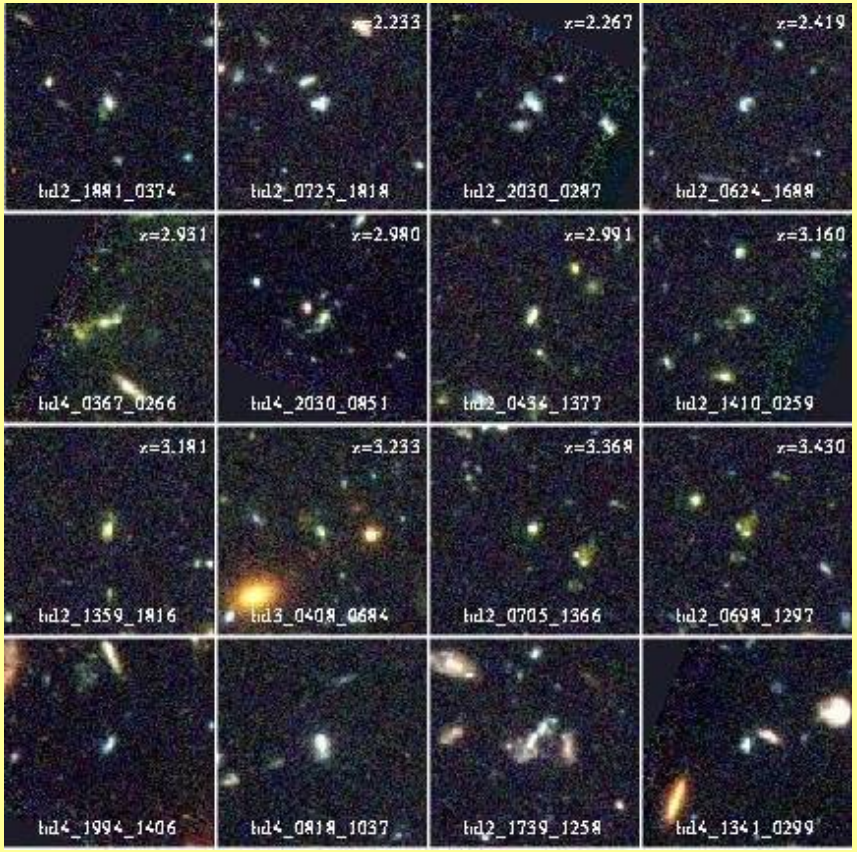
Conclusion

- Morphology-density relation does not evolve strongly
- But galaxies evolve in density, mass -> they evolve along this relation

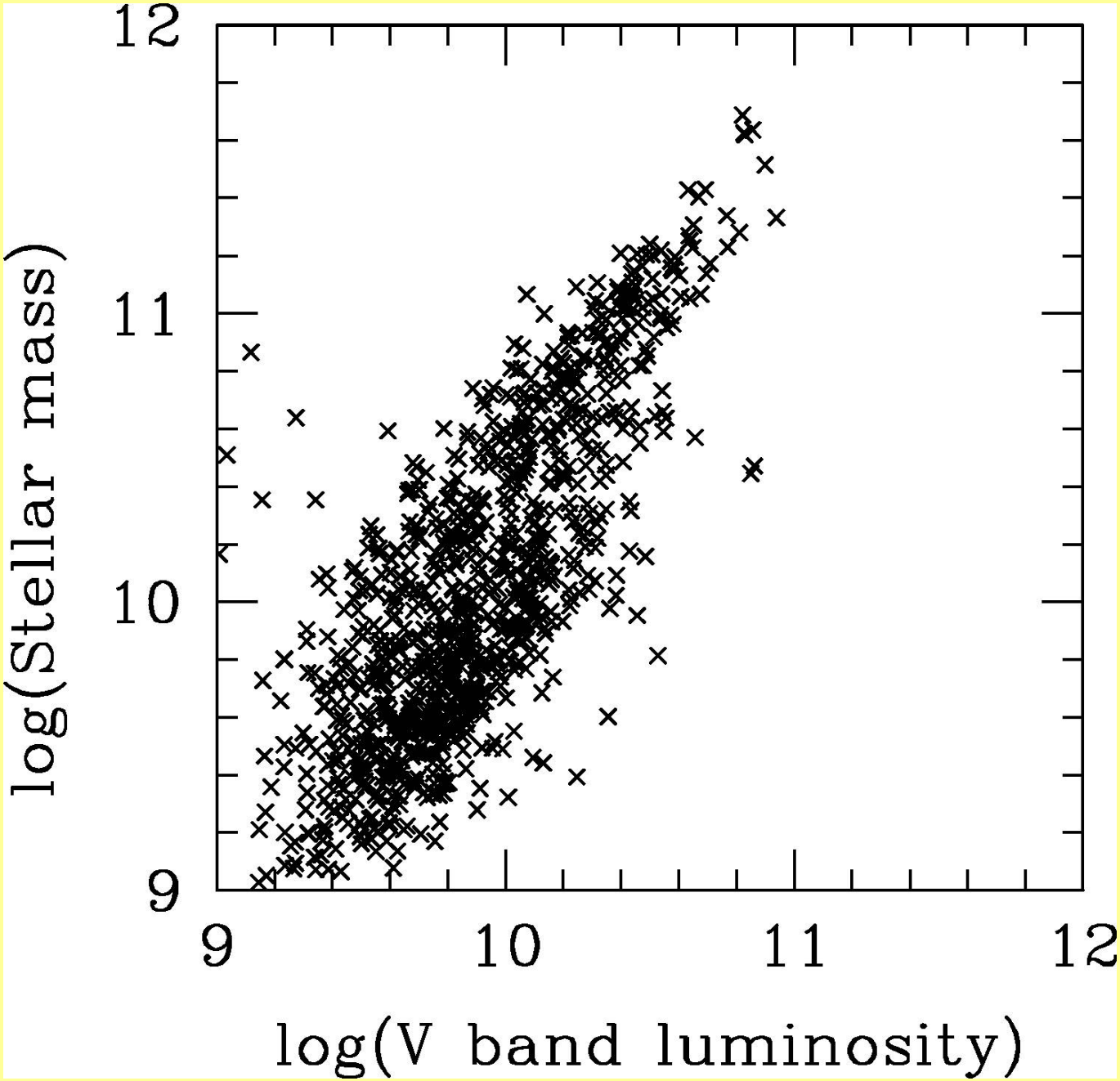
Z=0-1.2

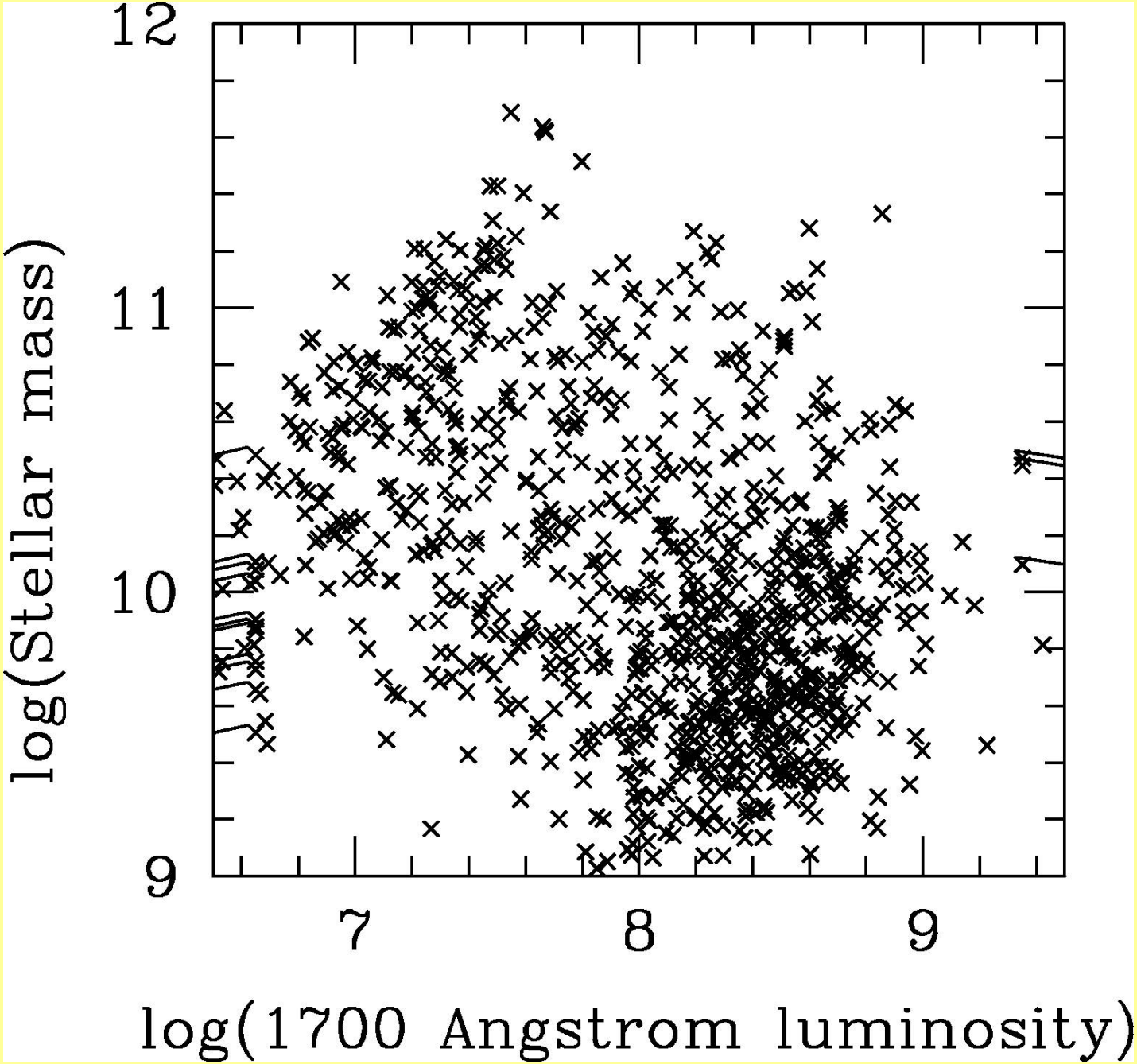
z=2-20


E0
E7
S0
Sa
Sb
Sc
SBa
SBb
SBc
The Hubble Tuning Fork with example galaxy images


z=2.233
z=2.267
z=2.419
z=2.931
z=2.980
z=2.991
z=3.160
z=3.181
z=3.233
z=3.368
z=3.430

Do we have mass-selected sample at z> 2 ?


12
11
10
9
log(Stellar mass)
9
10
11
12
log(V band luminosity)


12
11
10
9
7
8
9
log(Stellar mass)
log(1700 Angstrom luminosity)

Here: select z>2 galaxies in rest-frame optical

- Requires deep J,H,K-band imaging (up to 30hours with VLT)

Main advantage:

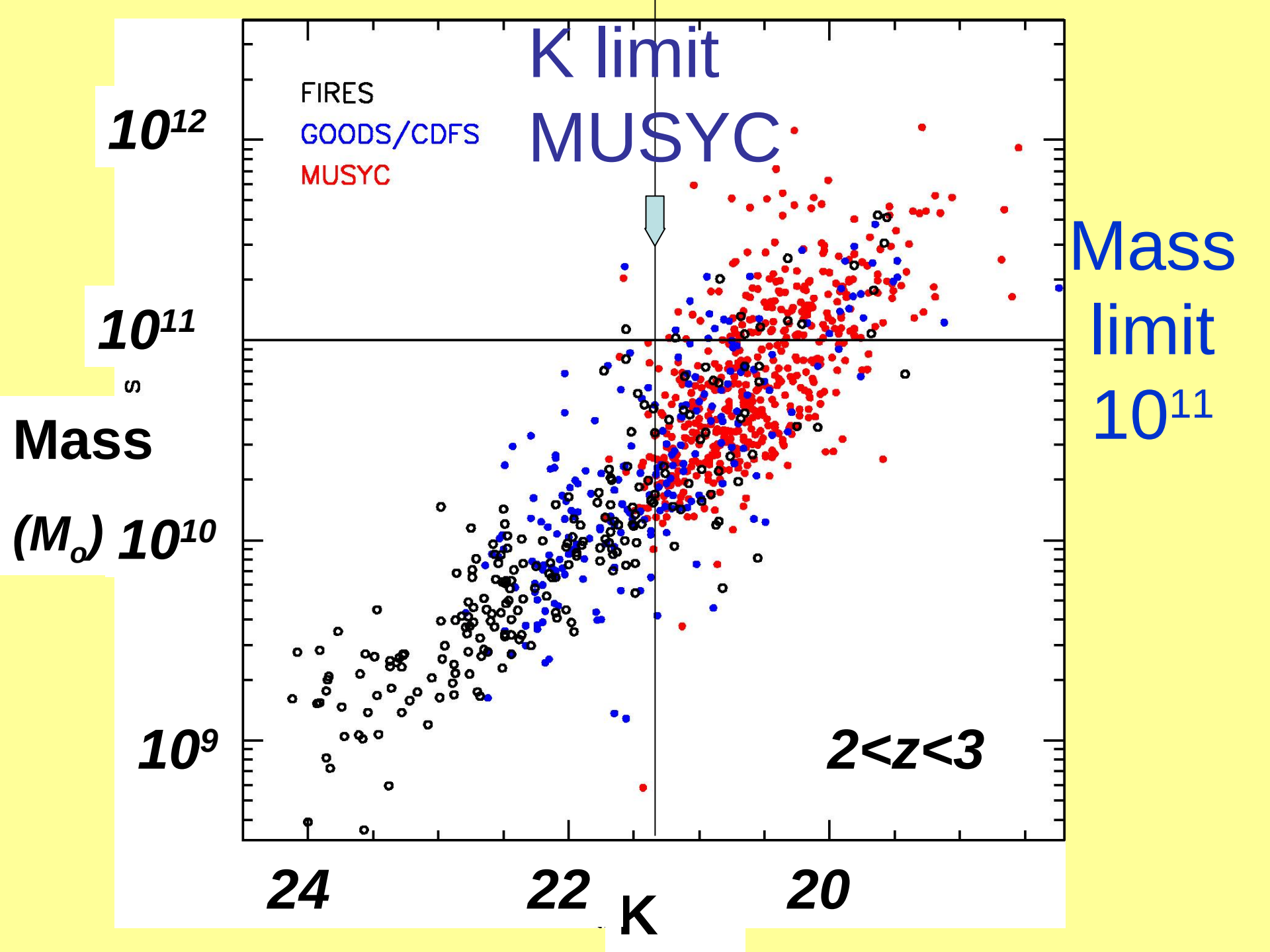
- Selection similar to z<1
- Closer to a mass selected sample

Main disadvantage:

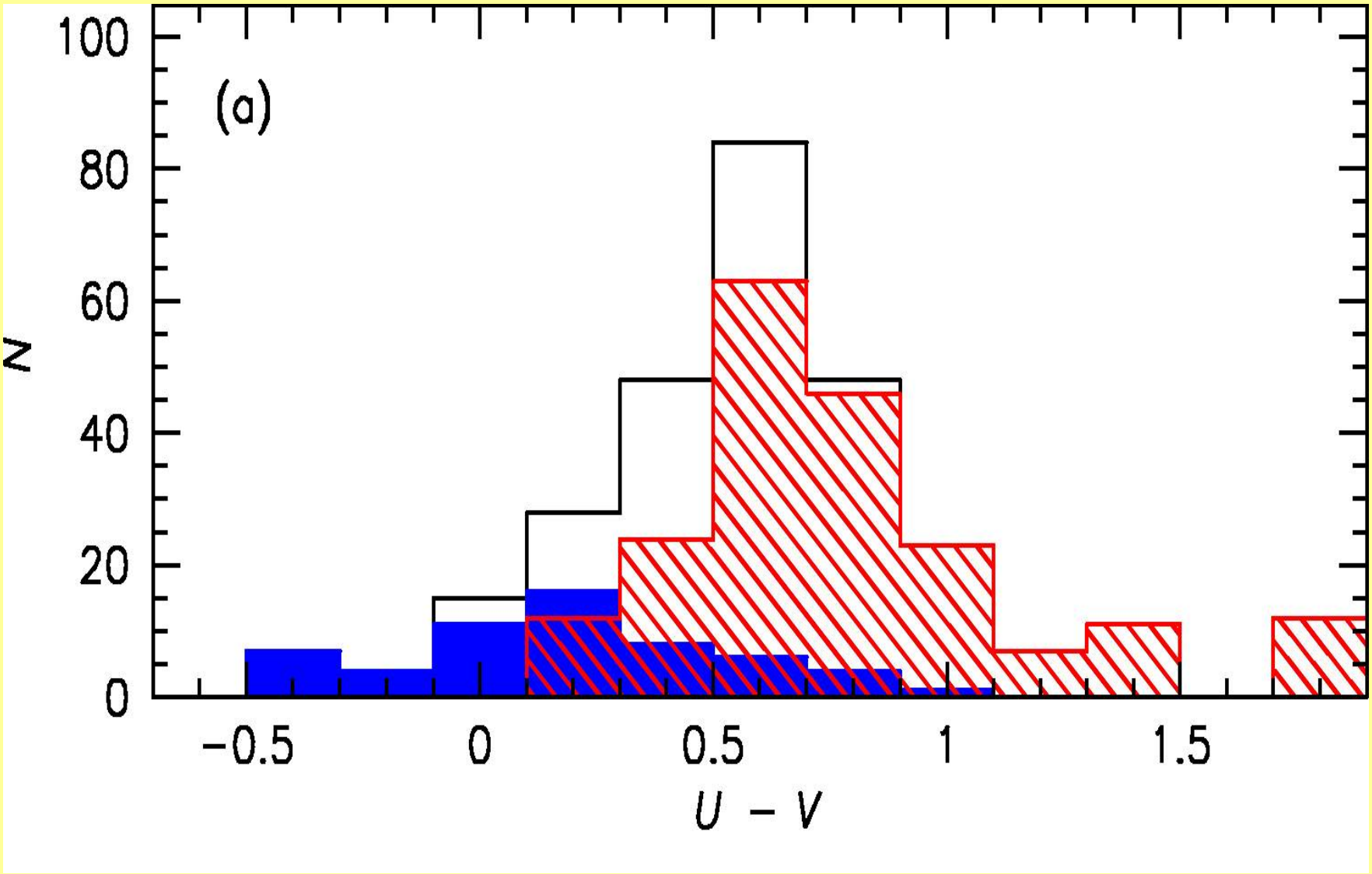
- Use photometric redshifts

Available Surveys:

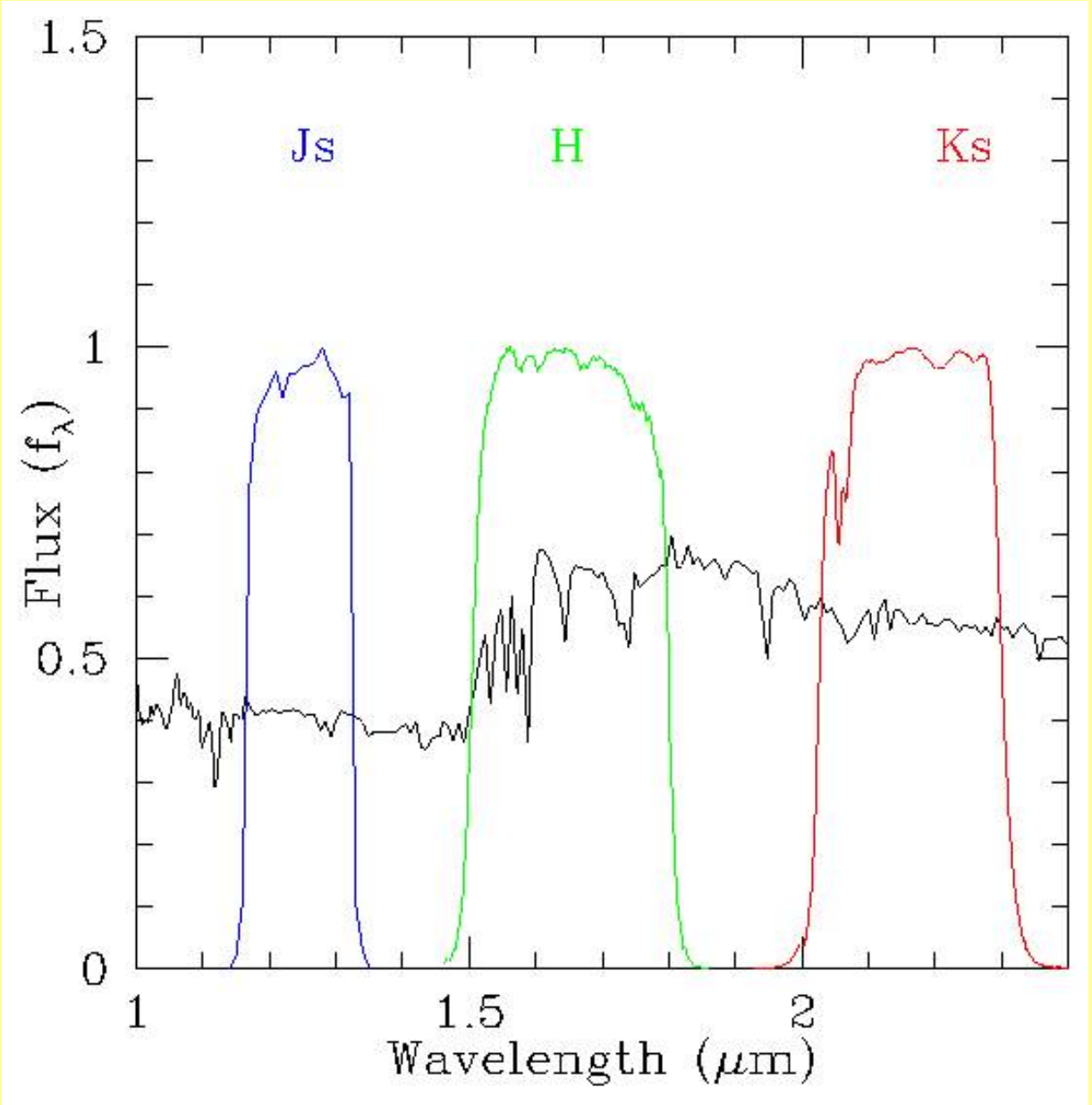
- FIRES: HDF-South + MS1054
  2.5’x2.5’ 5’x5’
  VLT
- GOODS: CDF-South 10’x15’
  VLT
- MUSYC near-IR: 10’x18’ + 10’x10’
  CTIO-4m


K limit
MUSYC
FIRES
GOODS/CDFS
MUSYC
Mass limit 10^{11}
10^{12}
10^{11}
Mass
(M_o) 10^{10}
10^{9}
2<z<3
24
22
20
K

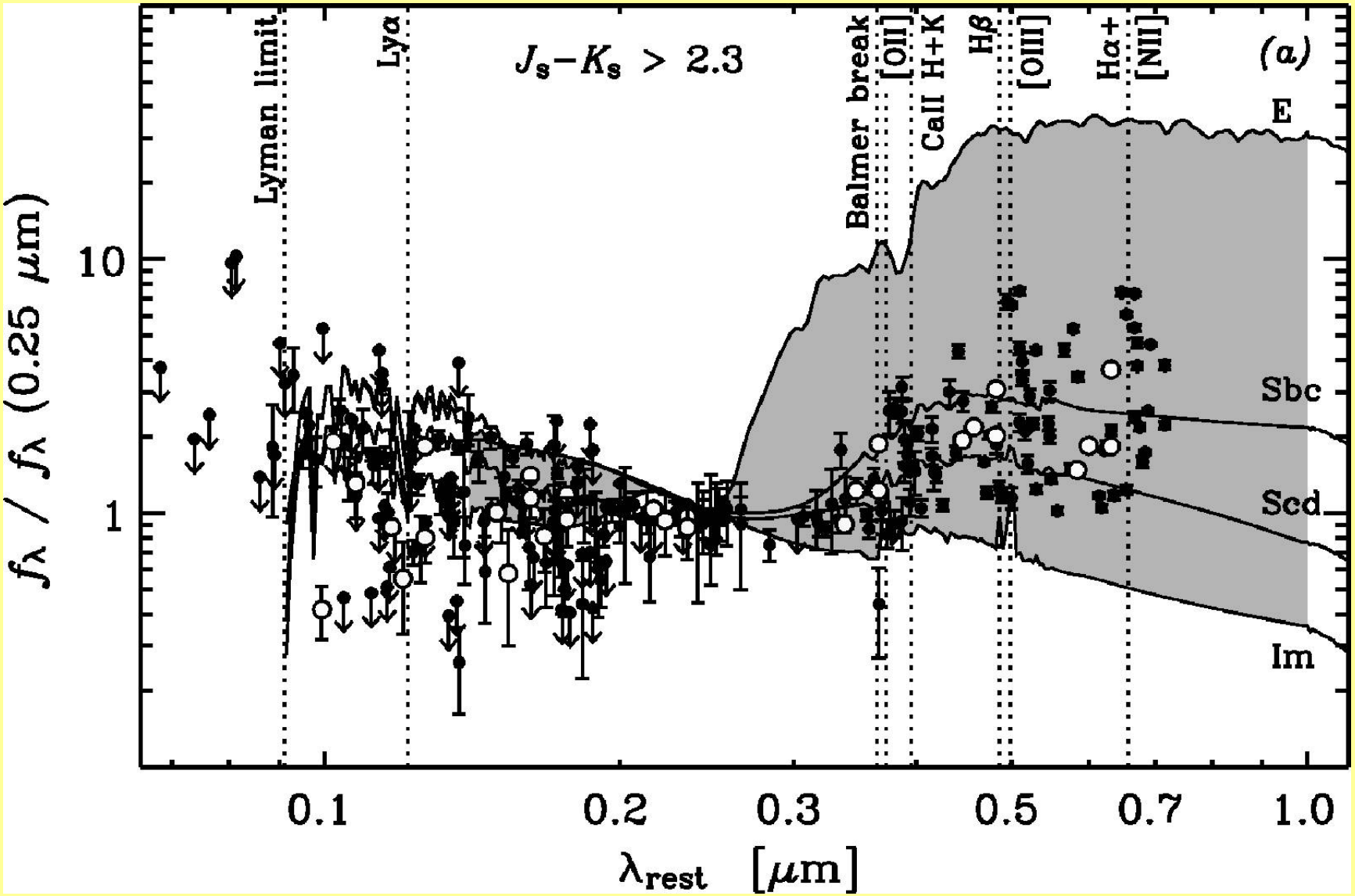
Restframe U-V color distribution



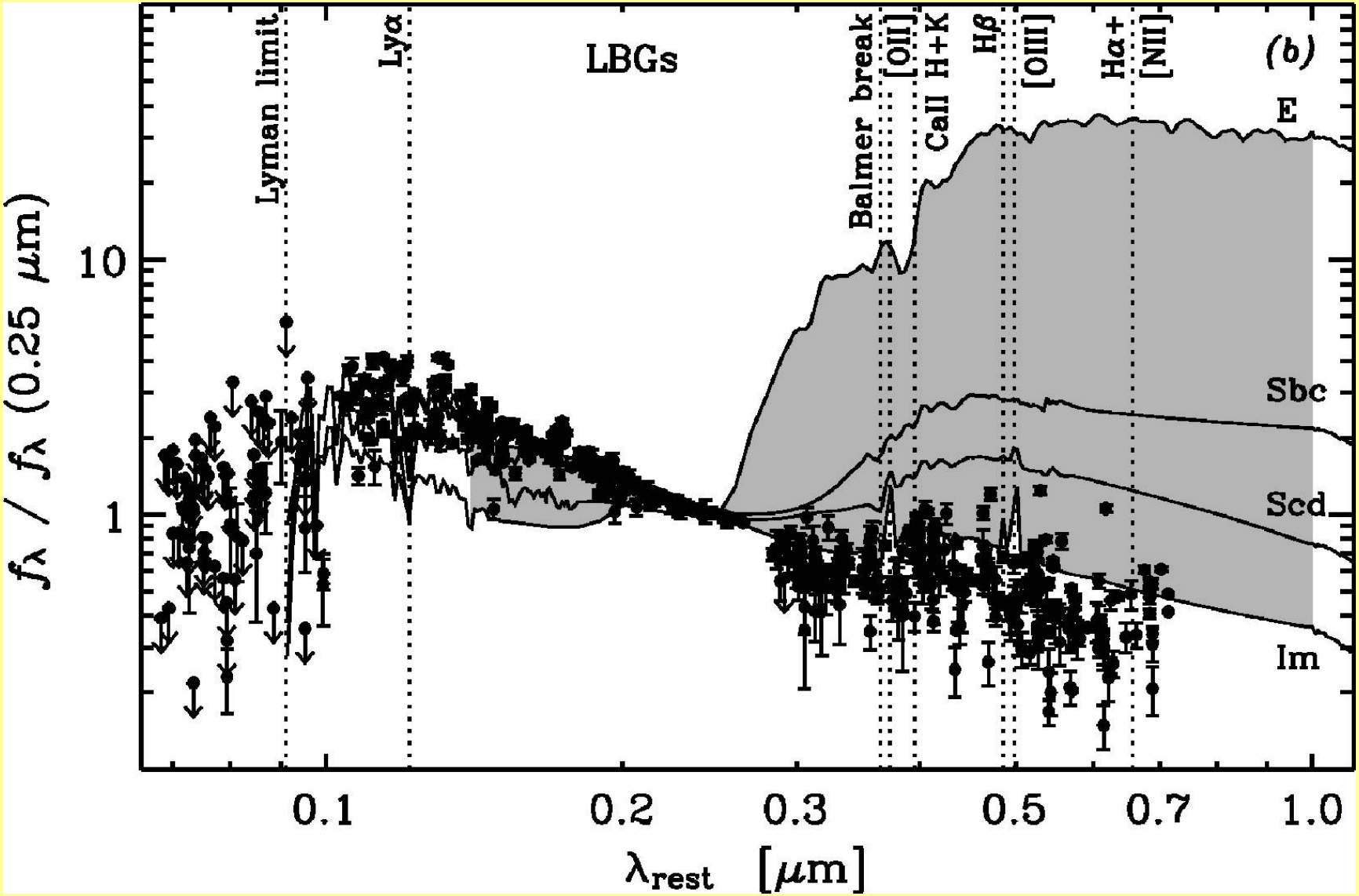
Distant Red Galaxies at z > 2 : J – K > 2.3



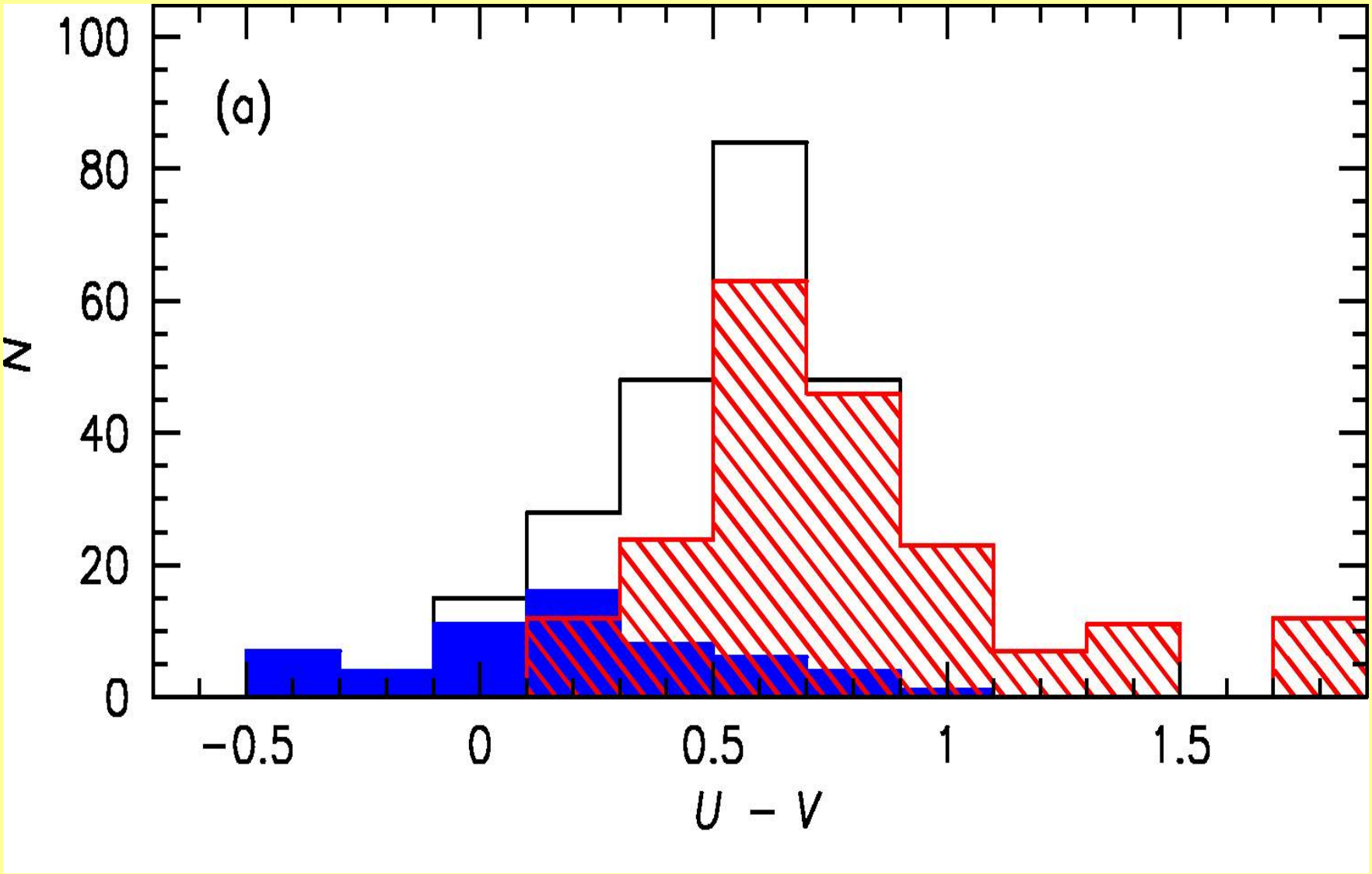
DRG Age=1.5Gyr, A_v =2.5



Average SED of Lyman Break



Restframe U-V color distribution



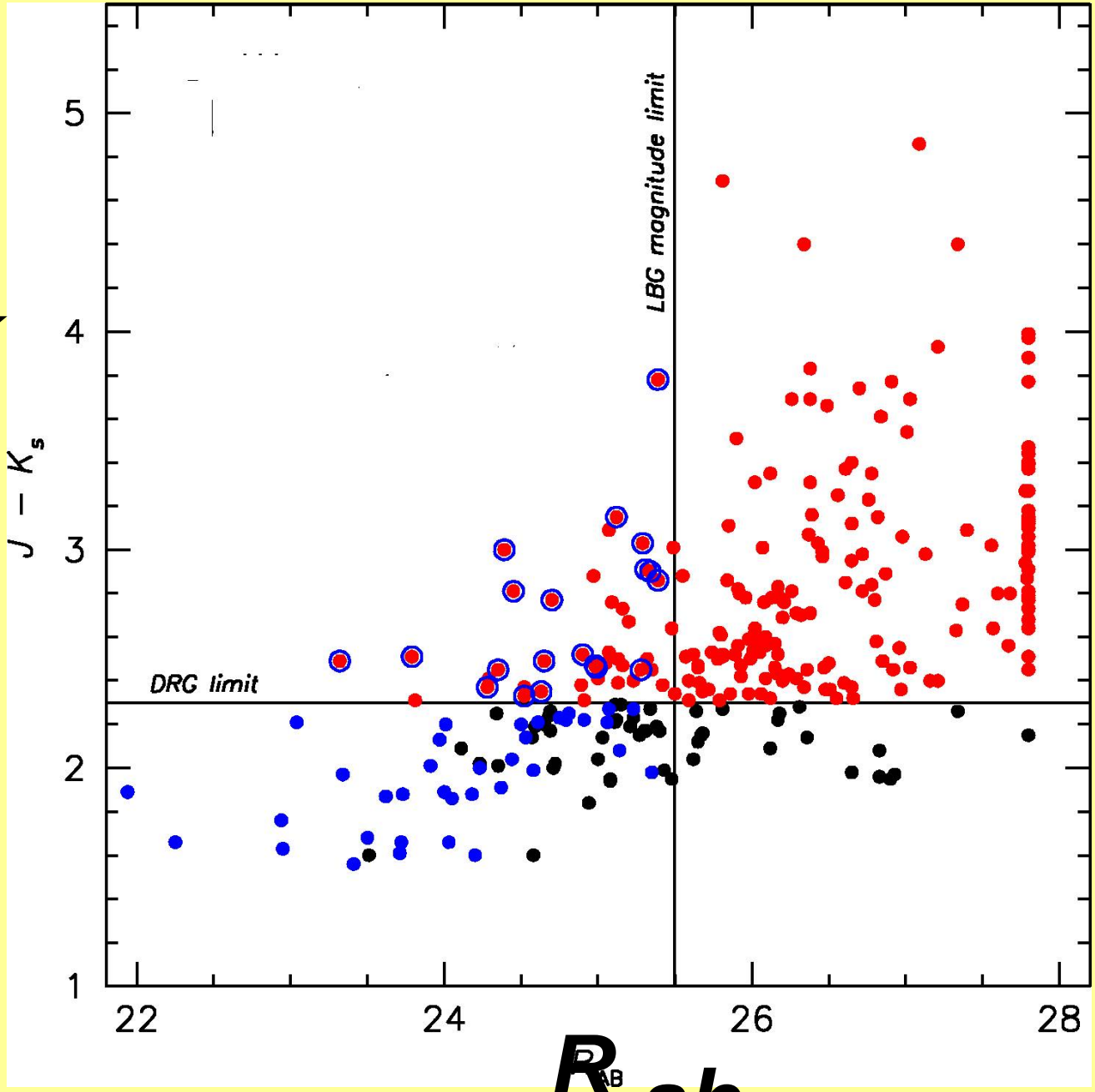
Conclusion

- At massive end, red galaxies dominate the galaxy population at z=2-3 (~77% by mass)
- The range in luminosities and colors is very large !

  Median J-K = 2.49

  Median R = 25.9 !

(van Dokkum et al 2006)


J-K
J − Ks
LBG magnitude limit
DRG limit
5
4
3
2
1
22
24
26
28
RAB
R ab

Why are these galaxies red ?

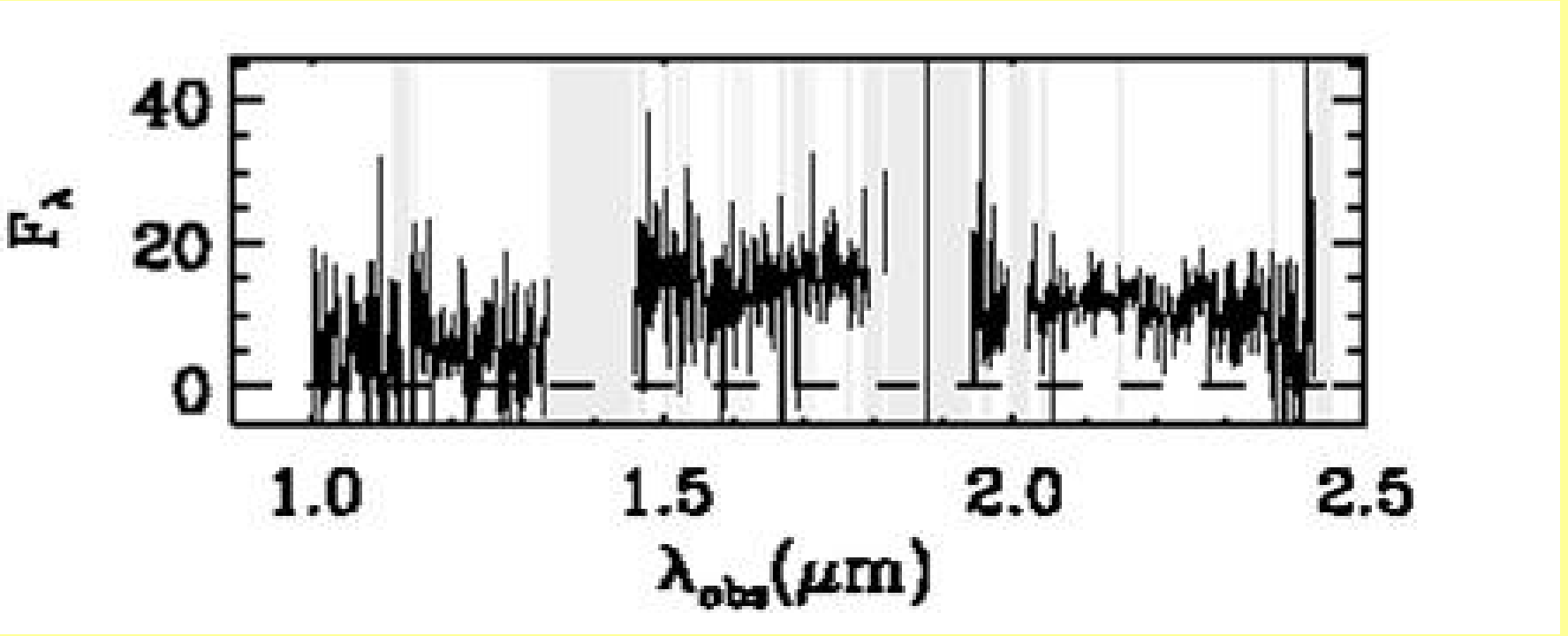
- Quiescent ? [low star formation]
- Young and Dusty ? [implies high SFRs]

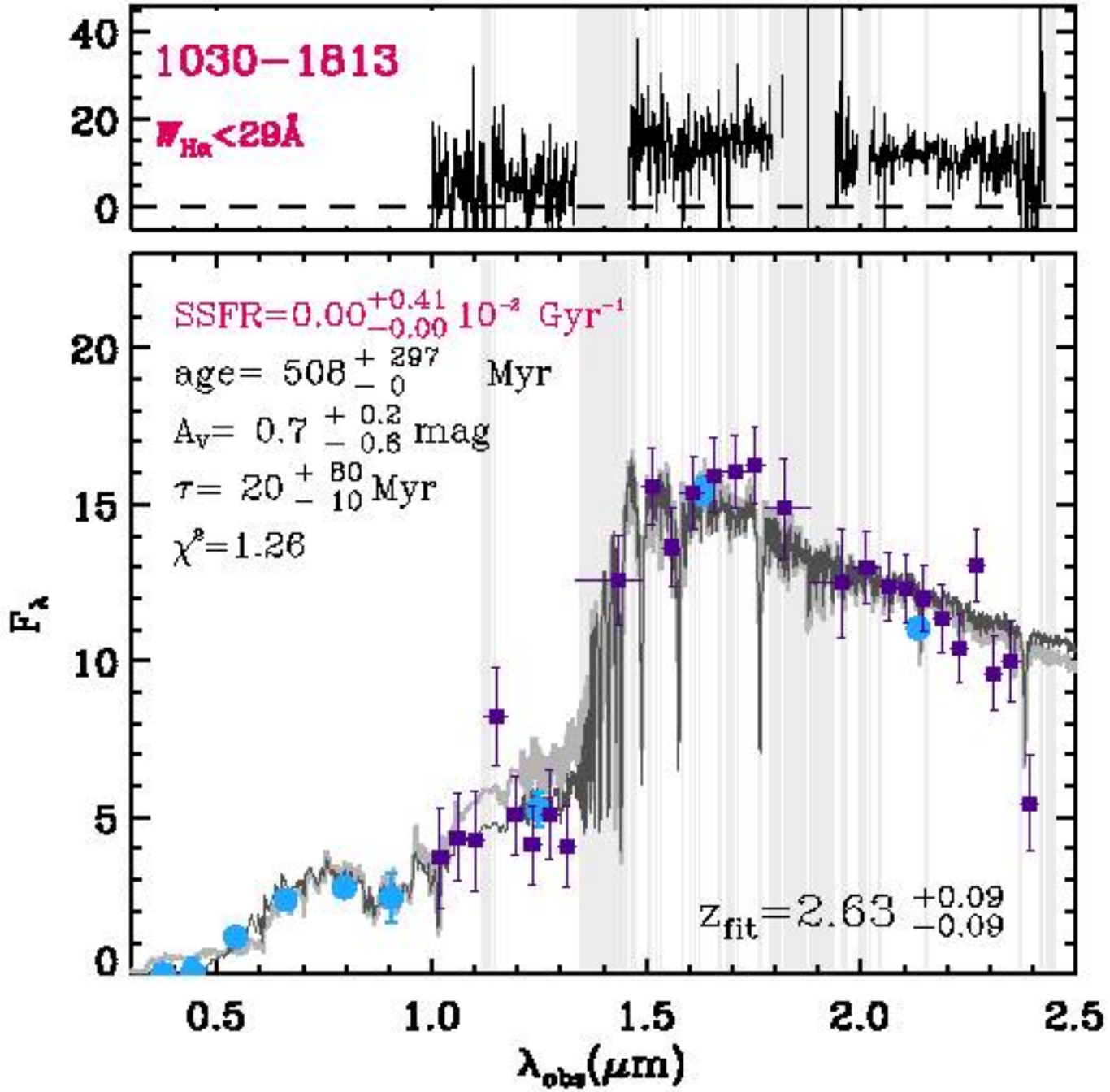
Difficult to distinguish without additional information

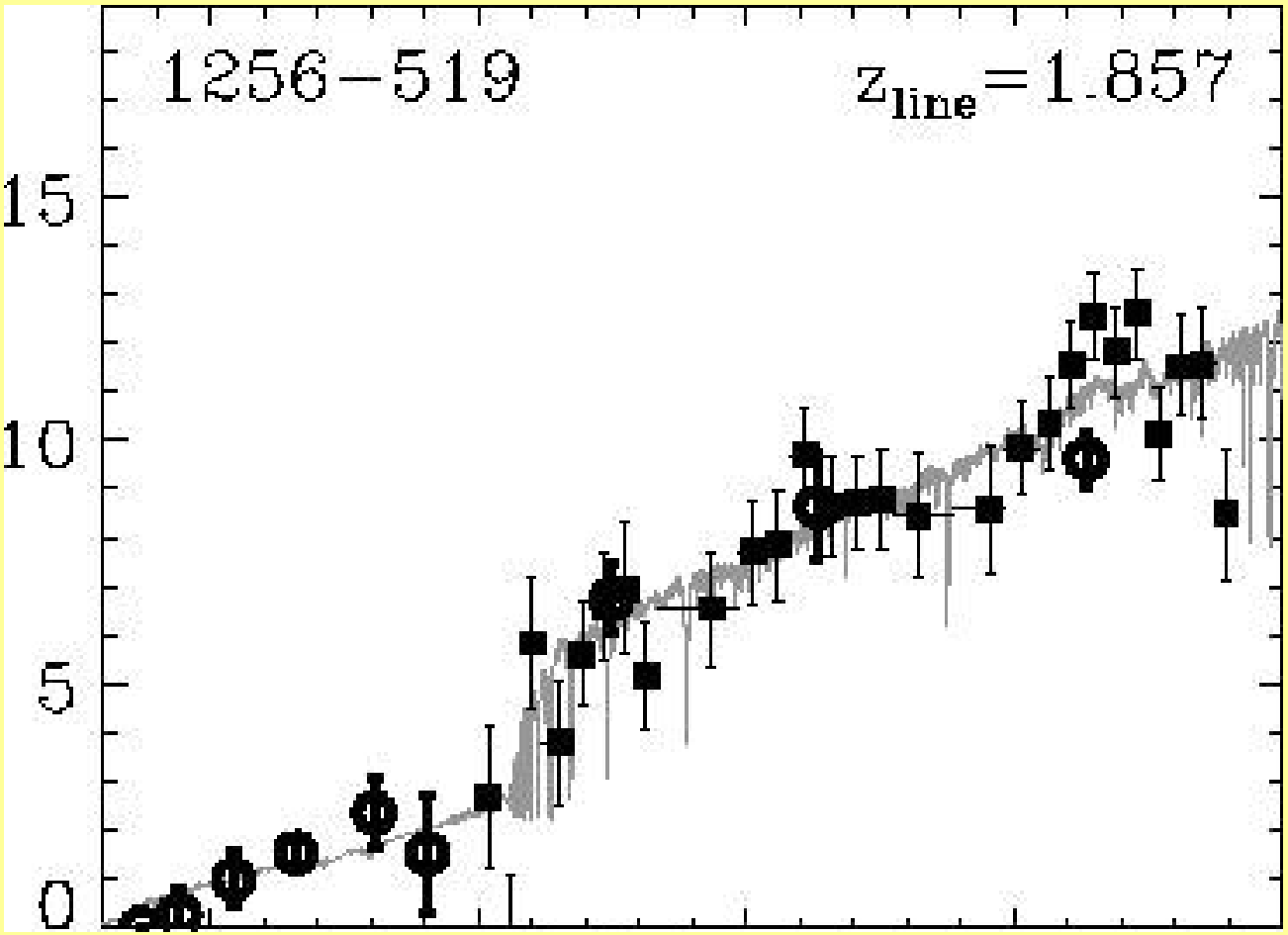
Obtain Near-IR spectroscopy

- Hard – long integration times, low multiplex
- Kriek et al.: obtained spectra of 36 galaxies with GNIRS on Gemini
- K band selected – much closer to mass selection
- Unique: J,H,K in one shot !

2 hour exposure



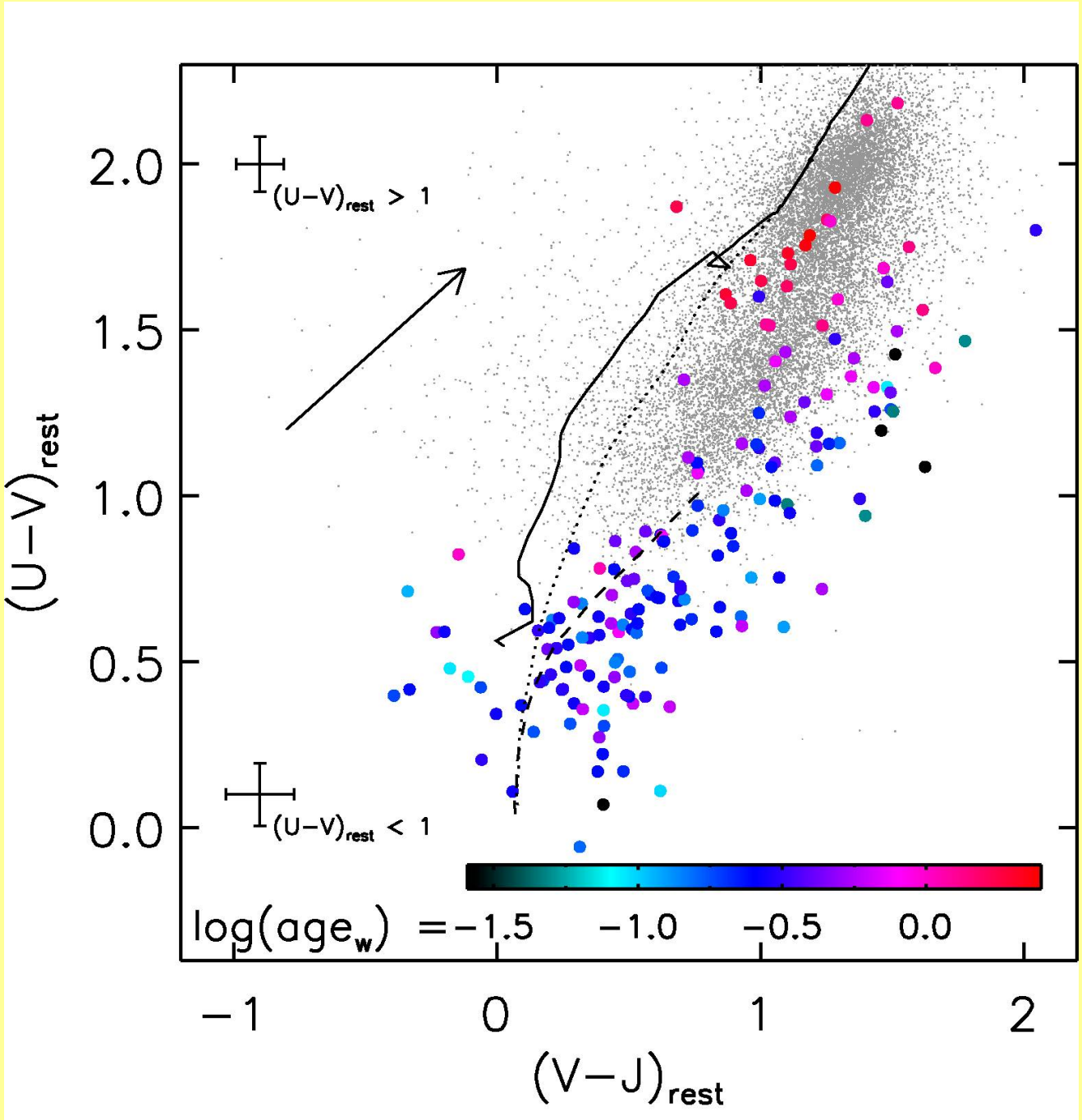

1030−1813
W_{Ha}<29Å
SSFR=0.00$^{+0.41}_{-0.00}$ 10^{-2} Gyr^{-1}
age= 508 $^{+297}_{-0}$ Myr
A_V= 0.7 $^{+0.2}_{-0.6}$ mag
τ= 20 $^{+80}_{-10}$ Myr
χ^2=1.26
z_{fit}=2.63 $^{+0.09}_{-0.09}$
F_λ
$\lambda_{obs}(\mu m)$


1256−519
z_{line}=1.857
15
10
5
0
0.5
1
1.5
2
2.5

Analyze galaxies with 2<z<2.7

- 9 out of 20 no H-alpha emission line
- 2sigma upper limit EQW around 10 Angstrom
- Specific Star Formation Rate

SFR/M < 10^{-10}- 10^{-11} /yr


2.0
1.5
1.0
0.5
0.0
(U−V)rest
(U−V)rest > 1
(U−V)rest < 1
log(agew) = −1.5 −1.0 −0.5 0.0
−1
0
1
2
(V−J)rest

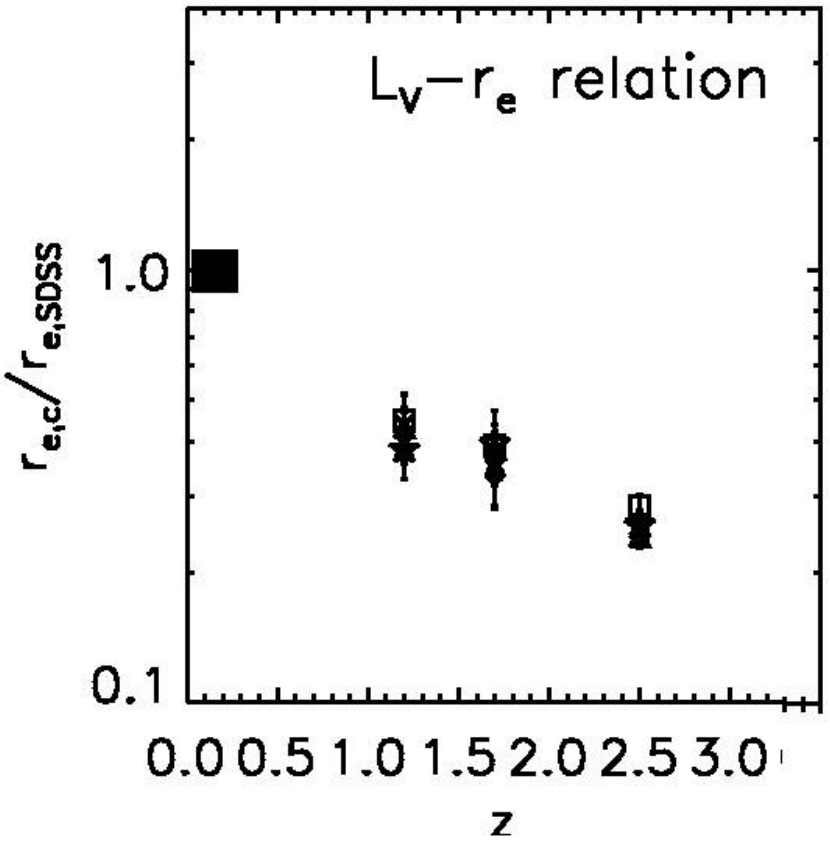
Several indicators show

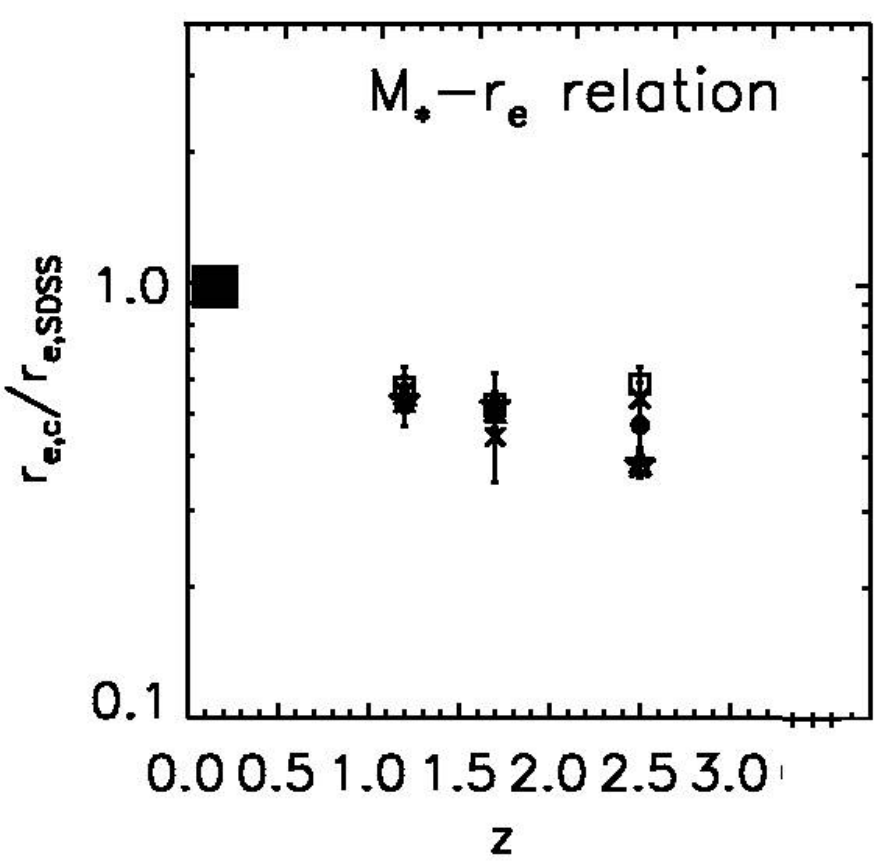
Significant fraction (40 % +- 10%) of quiescent galaxies

Others star forming with reasonably high star formation rates

General size evolution

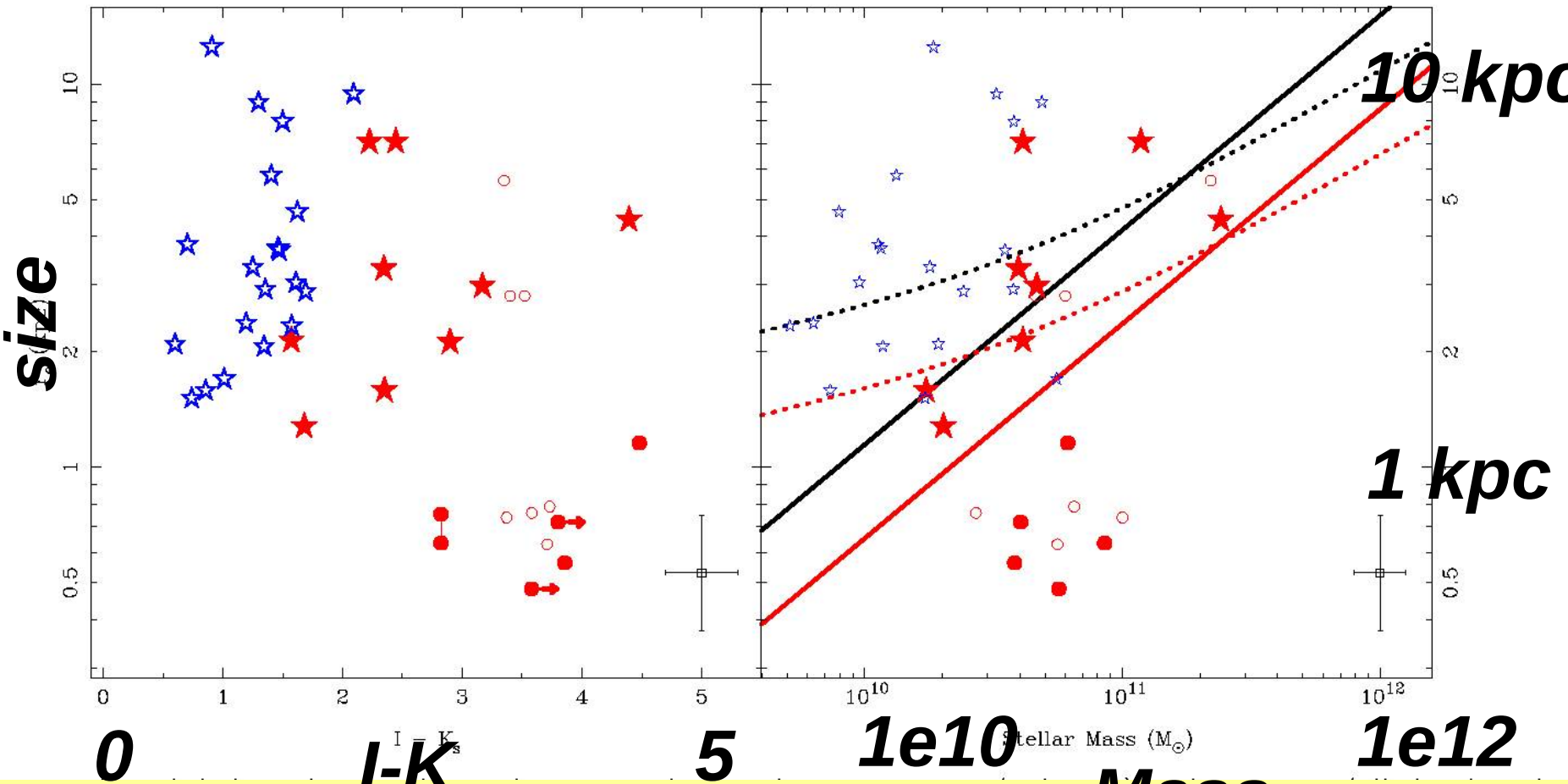
size as function of L, M, normalized to Sloan

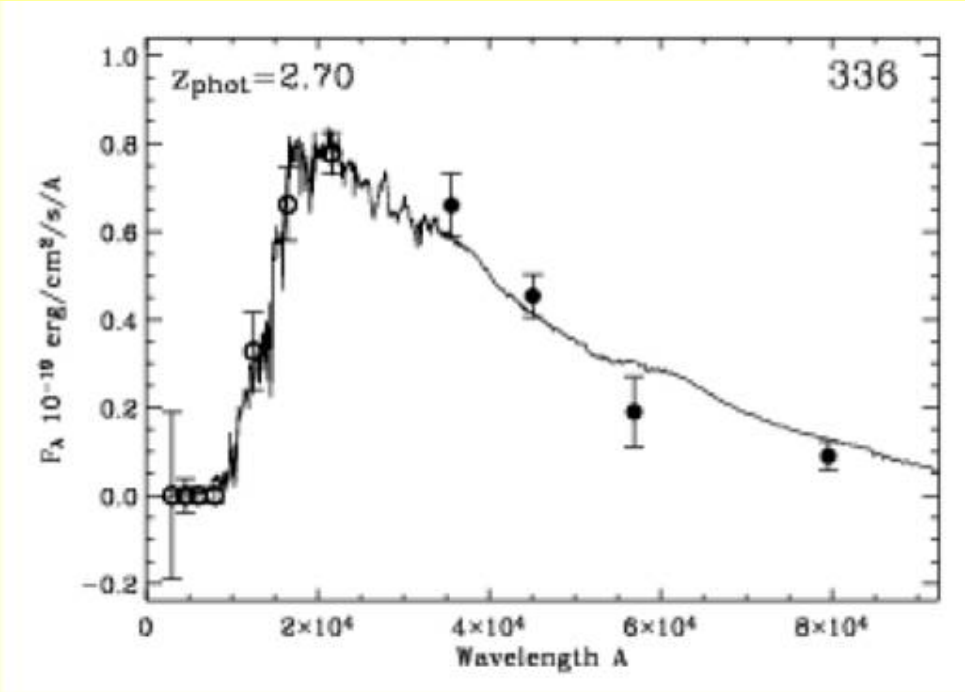


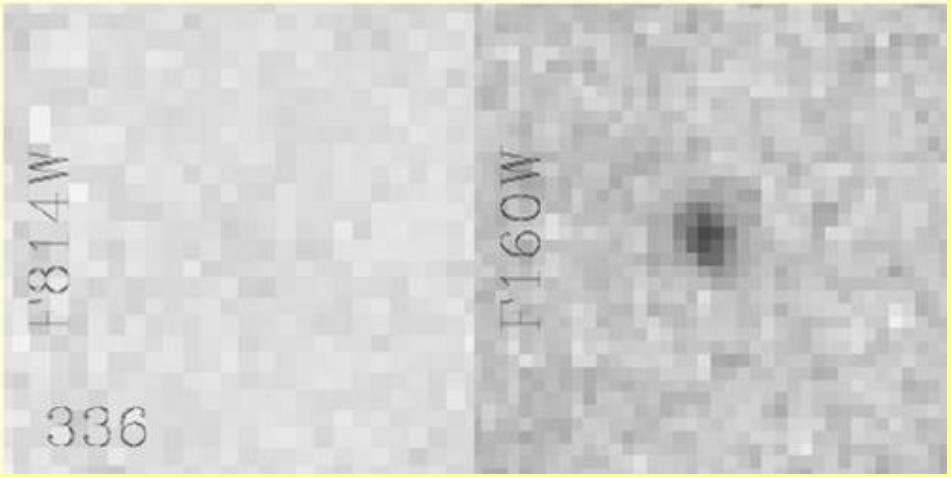


Trujillo et al 06

Size as function of I-K and Mass







Structure of red galaxies

Nicmos imaging of HDF-South

Zirm et al 06

Quiescent galaxies

- Low specific SFRs
- Very compact and dense -> formed very early ? (z=5 ?)

Conclusions

- Mass selected samples are required
- Massive galaxies show a wide range in properties to z=3
- strong evolution in number density

-> galaxies DO evolve

To do:

- Go deeper, wider

  WF3, VISTA, JWST
- Get spectroscopy for large samples

  8-10m ? ALMA, JWST
- Get real masses

  8-10m ? ALMA, JWST

end