Downsizing & Galaxy Formation

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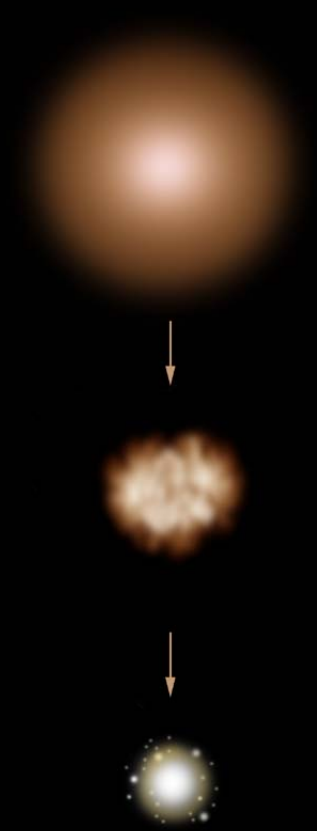
OCIW

Gemini Deep Deep Survey Team

2nd Mitchell Symposium - April 2006

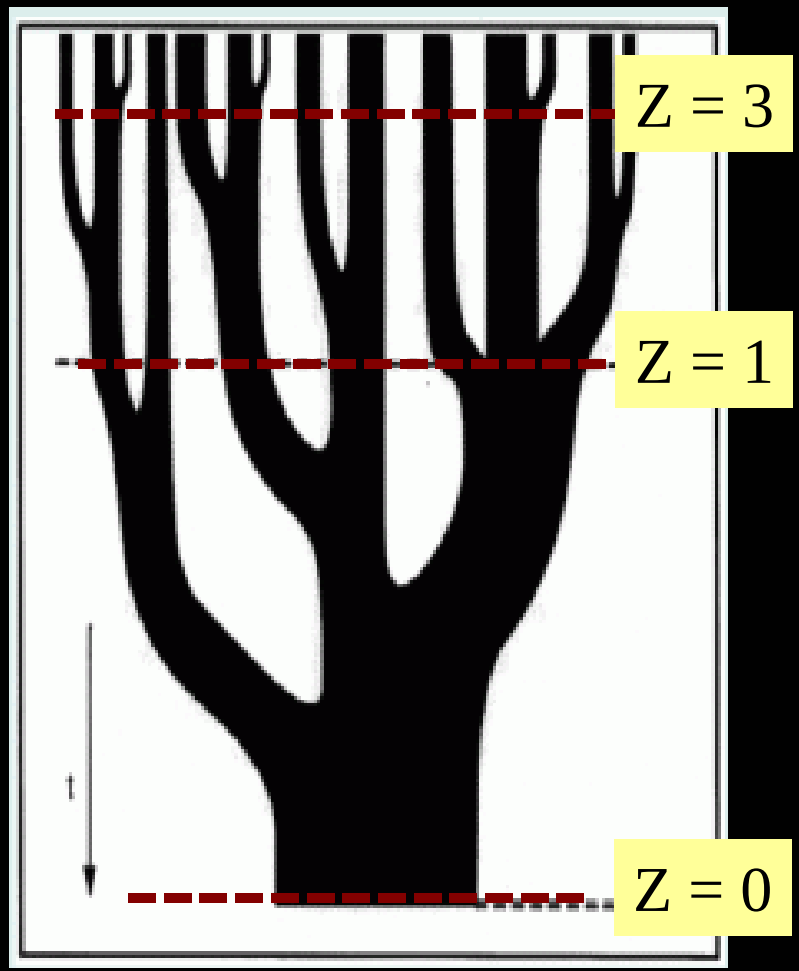
How are Galaxies Formed?

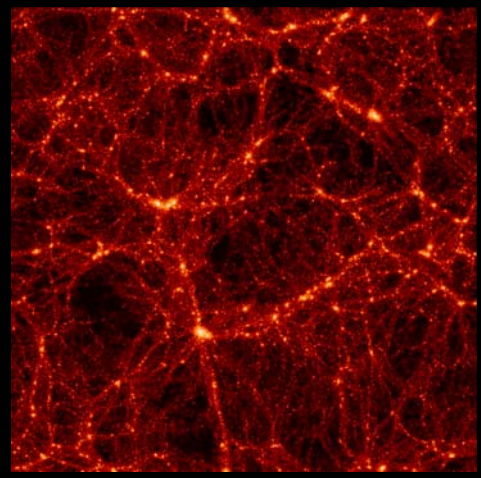


Monolithic Collapse
ala ELS

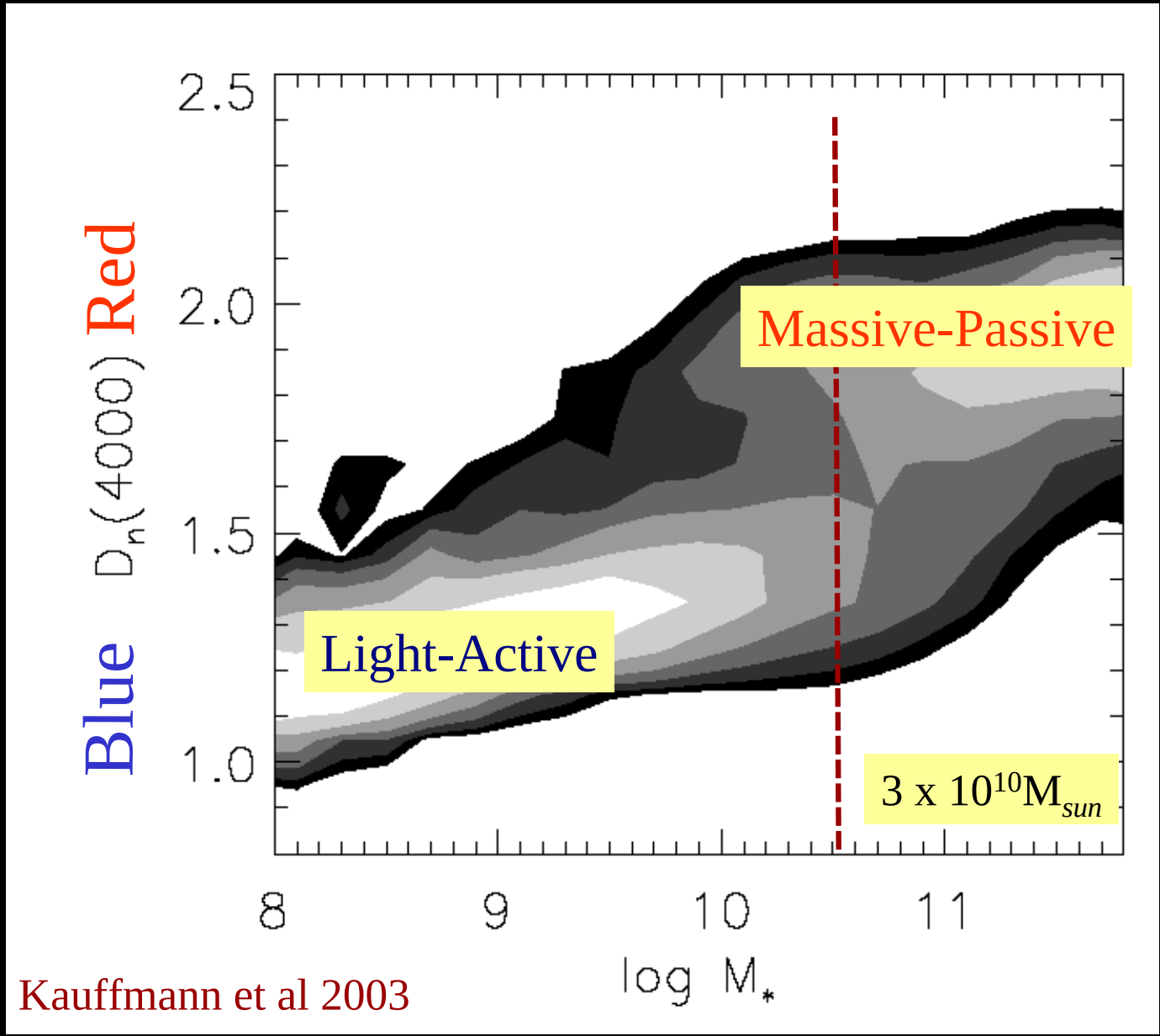
Hierarchical
Assembly

The Hierarchical Merger Tree



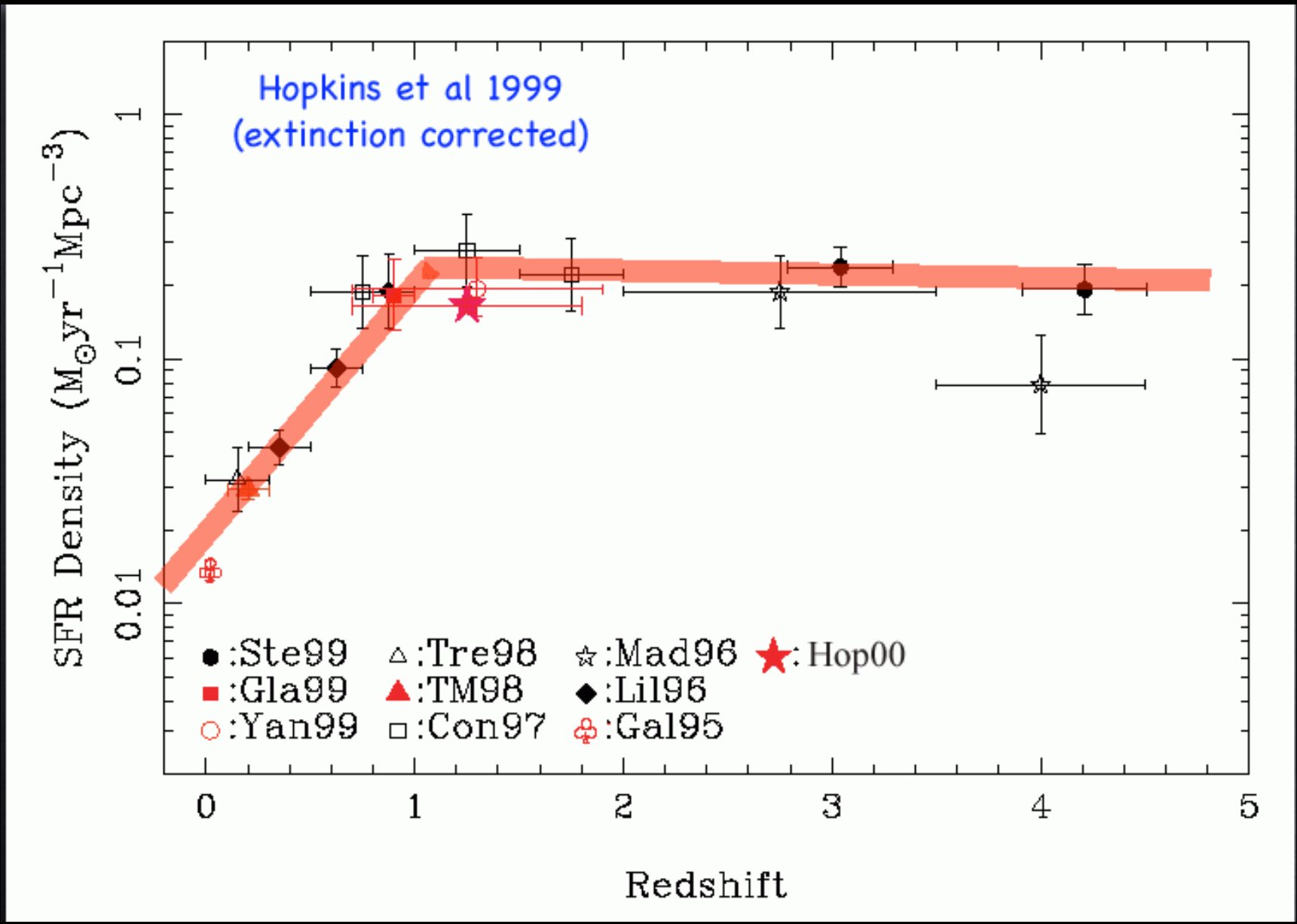


Two Kinds of Galaxies

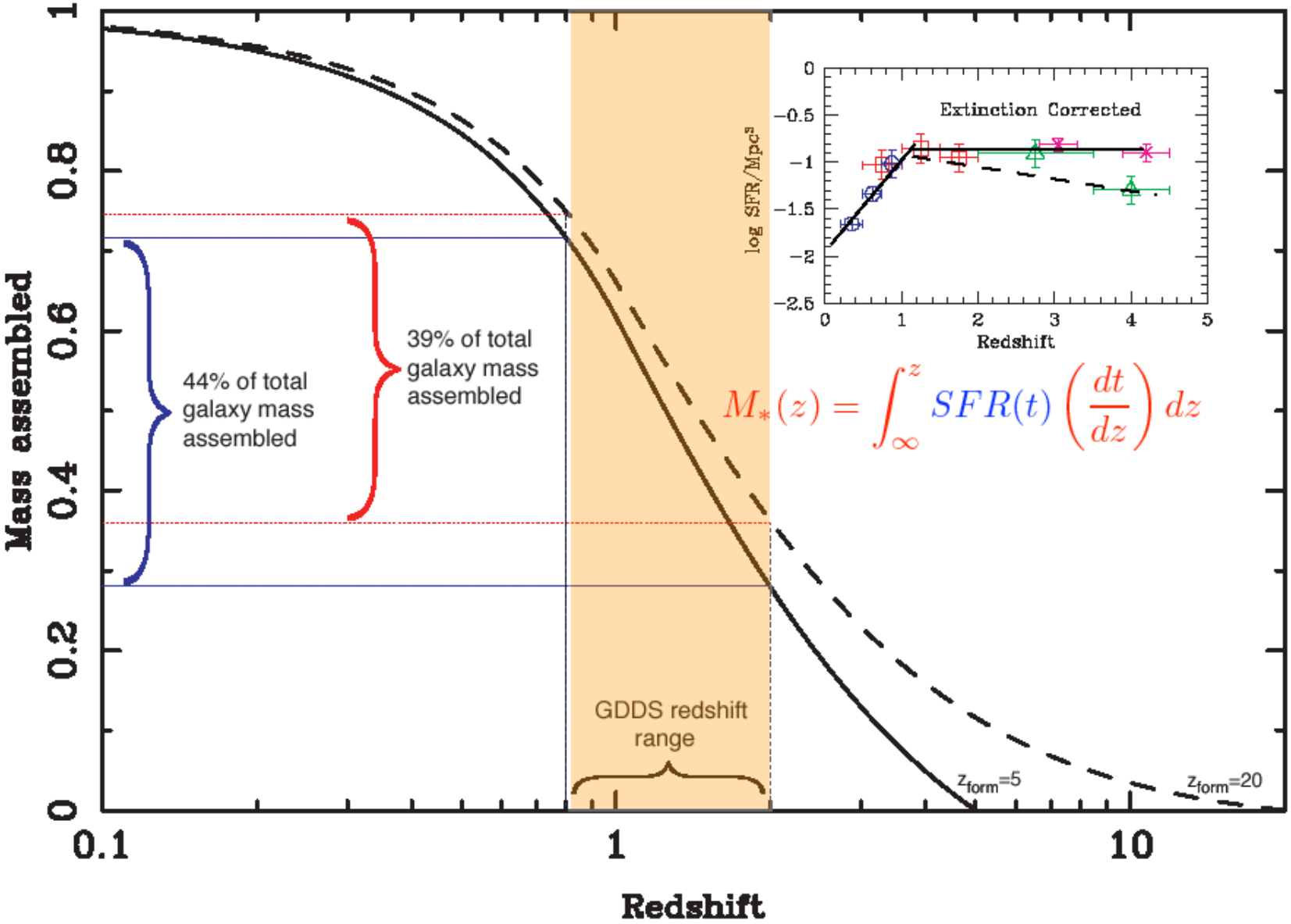


Kauffmann et al 2003

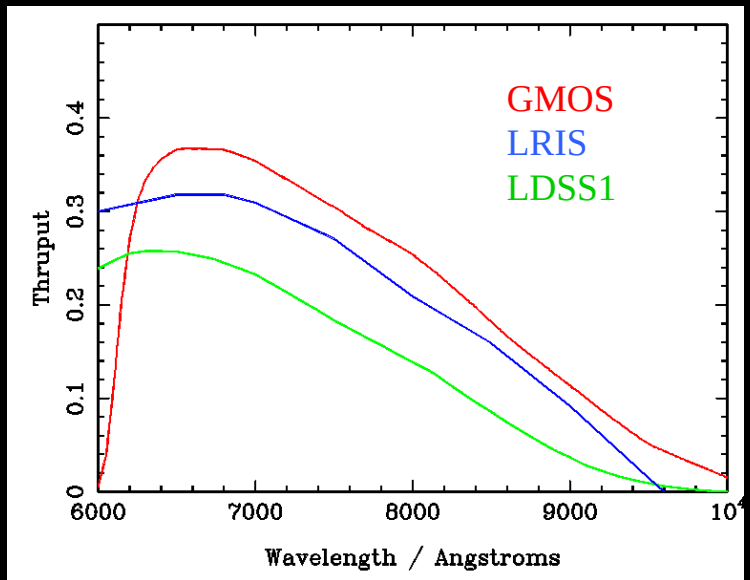
Star Formation History



Mass Assembly History



Gemini Deep Deep Survey



30 hour exposures - 300+ redshifts

I (Vega) ~ 24.5 $1 < z < 2$

Abraham, Glazebrook, PMcC, et al.

Stellar Mass Determinations

100,000 Model Spectral Energy Distributions

f(Age, SF history,abundance, reddening)

+

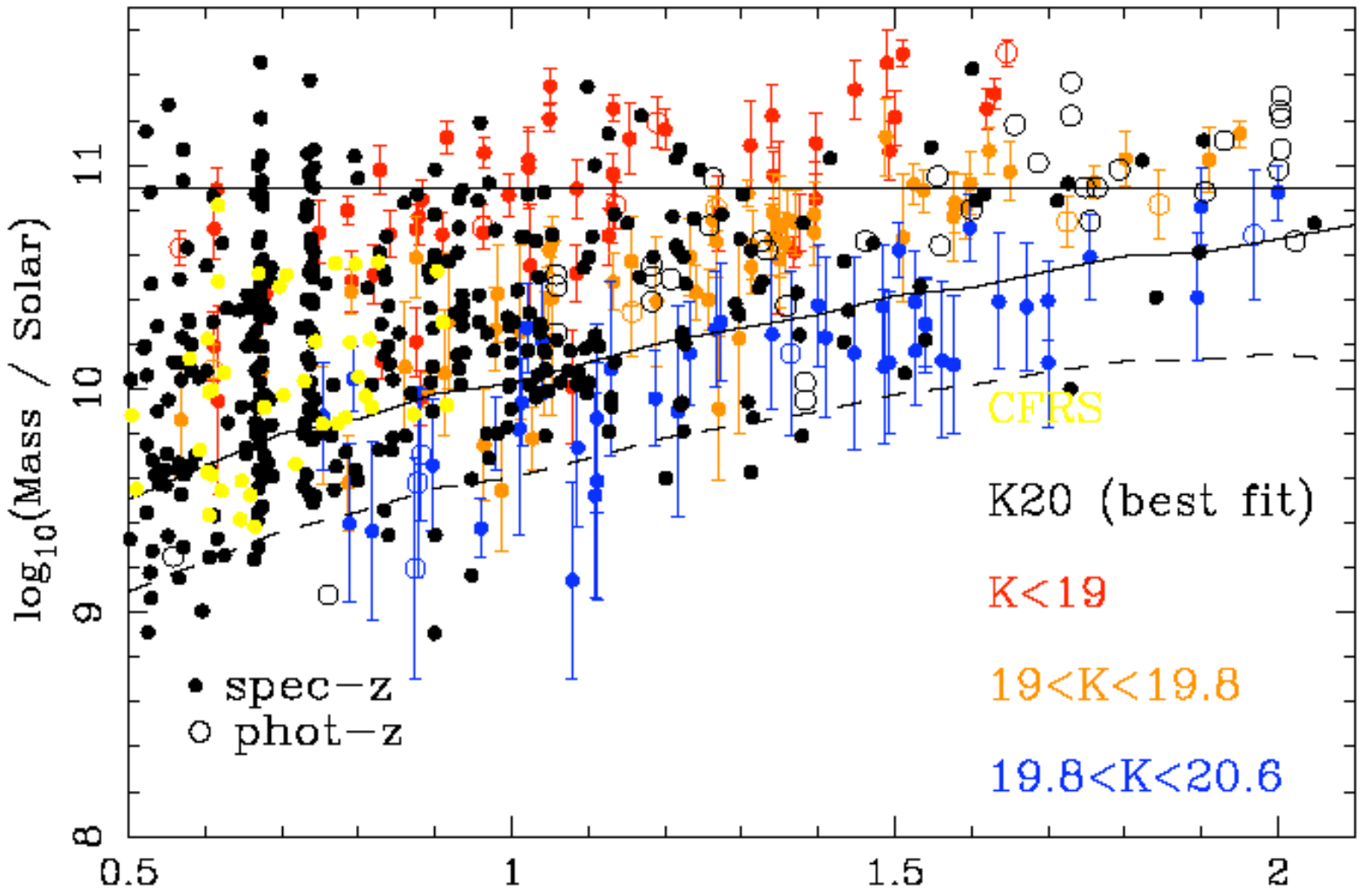
Observed Spectral Energy Distributions, Redshifts

$\chi^2 \Rightarrow$ Best-fit Template, range of templates

$\Rightarrow$ Best-fit M/L, range X M_K

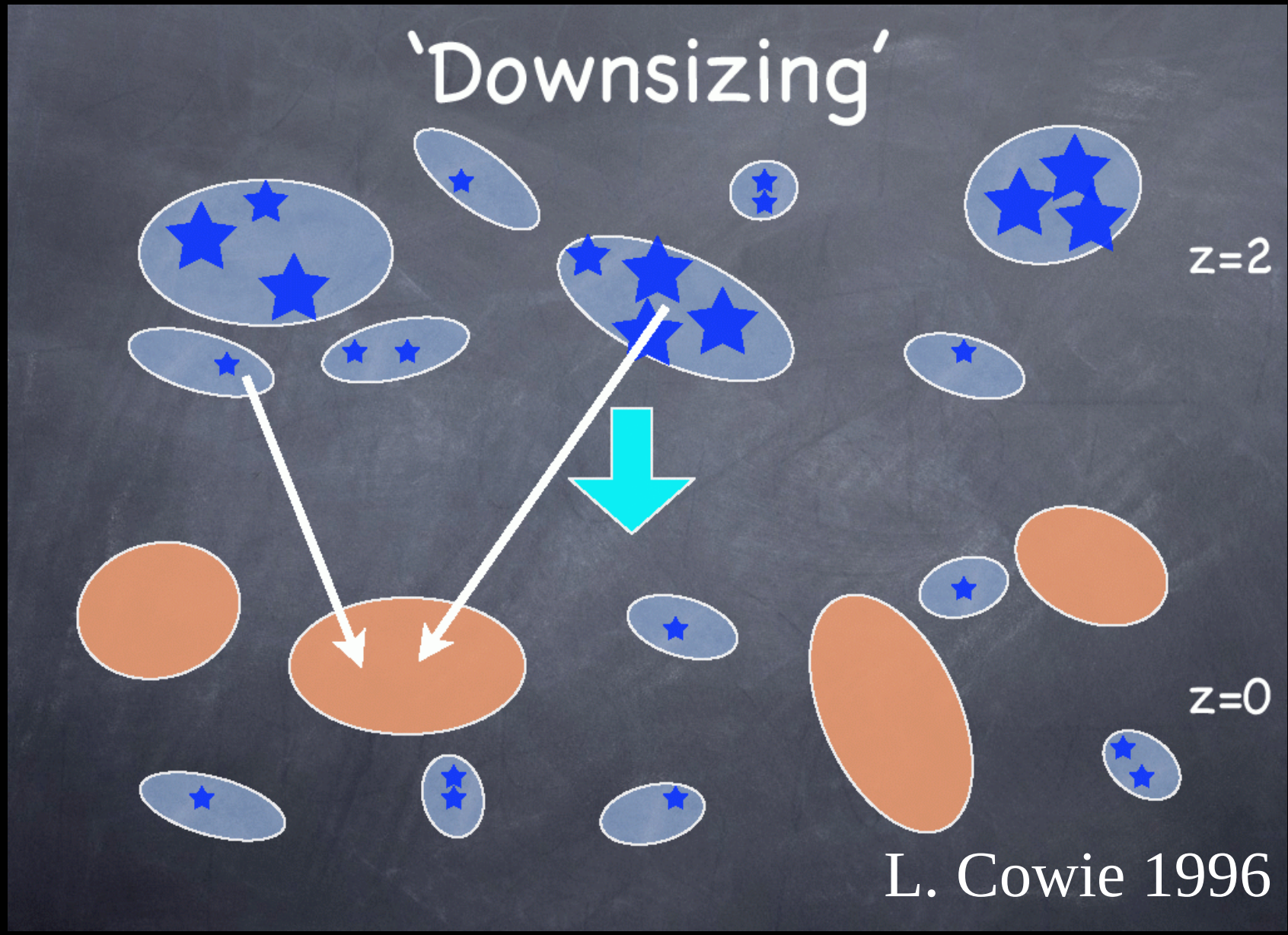
= M_{star}, range

The Most Massive Galaxies



Glazebrook et al.

Mass Downsizing



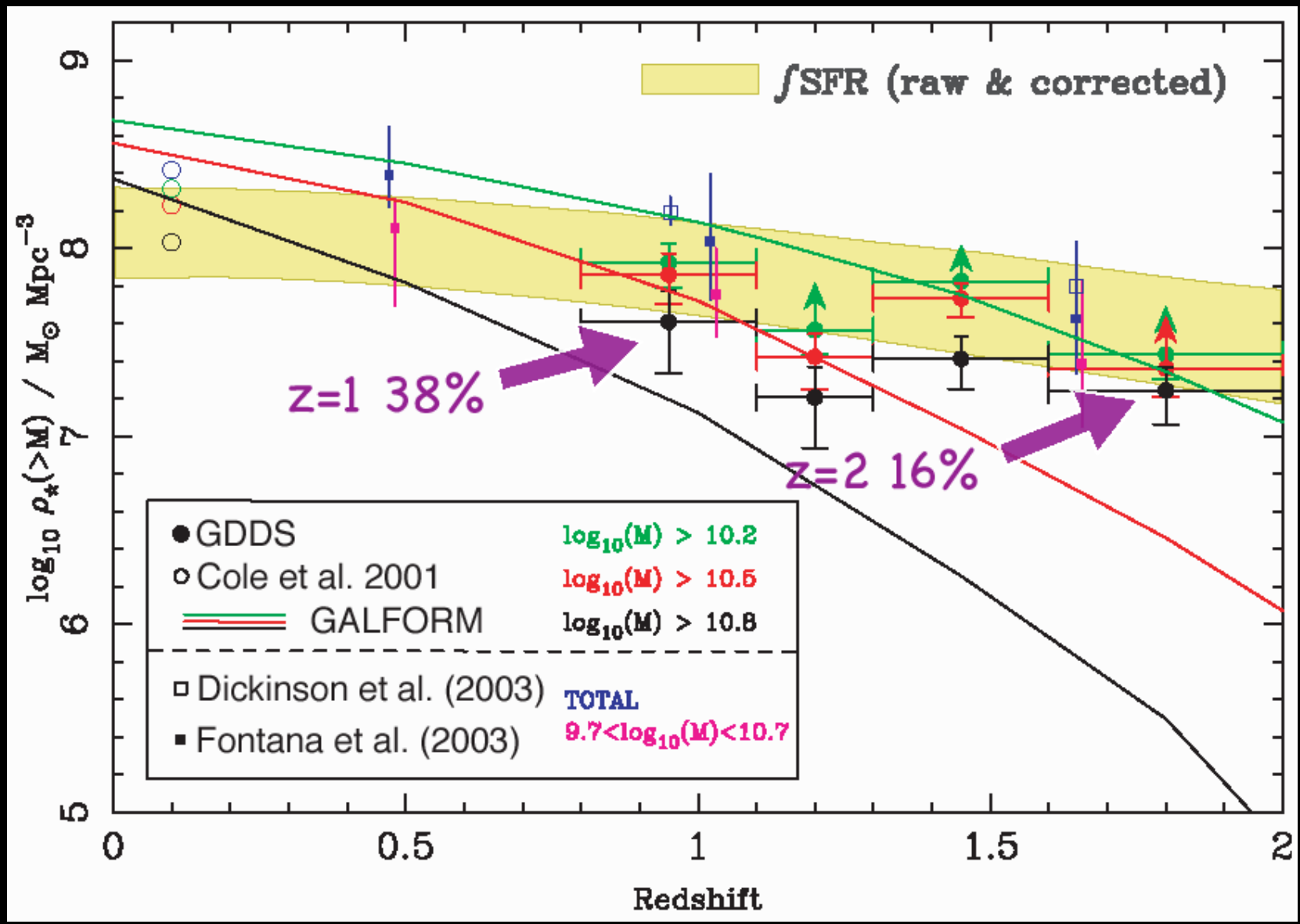
Three Views of Downsizing

- *Stellar Mass Density Evolution*
- *Star Formation Histories by Mass*
- *Early Assembly of Massive Galaxies*

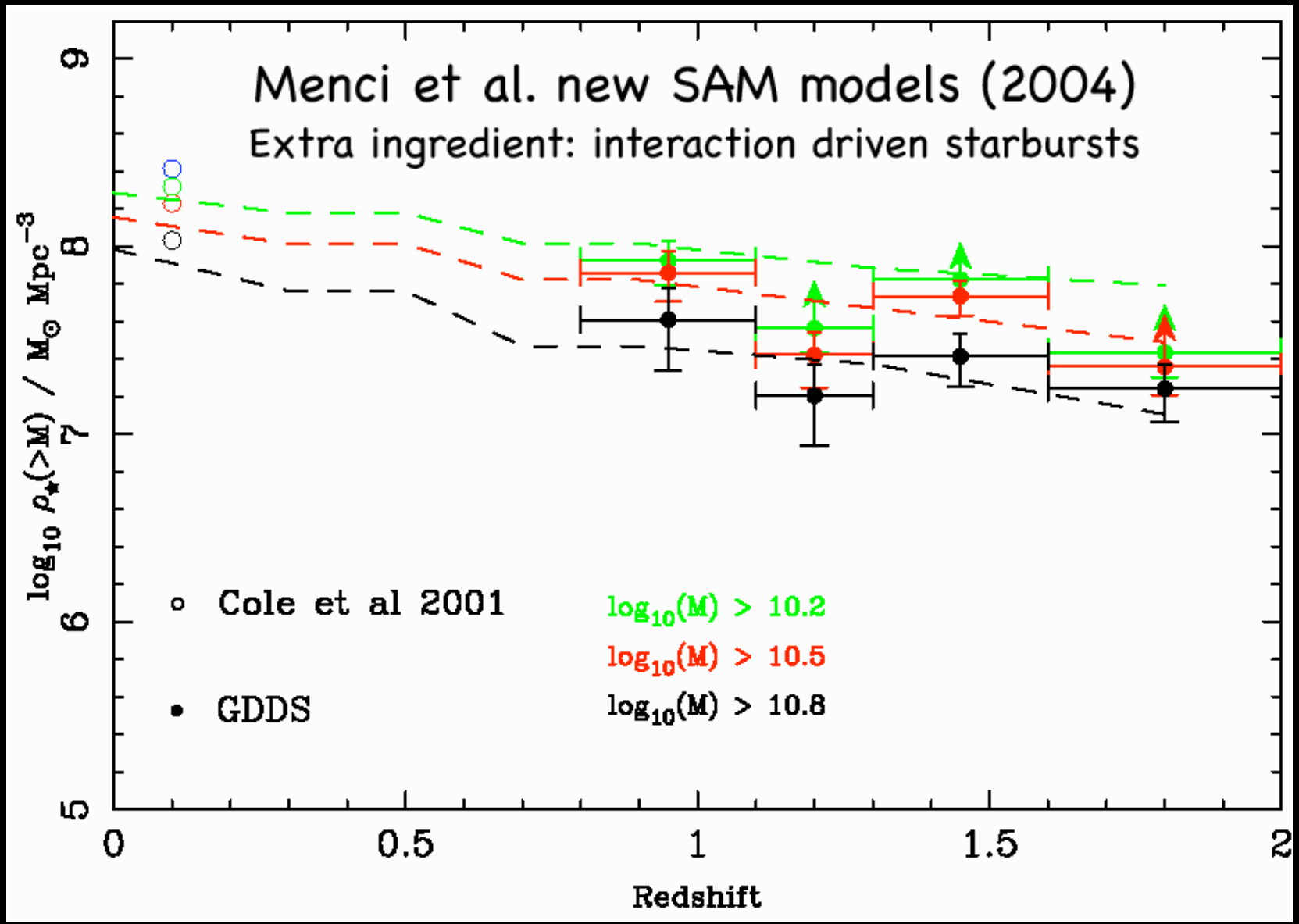
Stellar Mass Density

Cosmic Stellar mass density has not evolved at the high-mass end since z ~ 2

The Evolving Stellar Mass Density



New, improved semi-analytic models

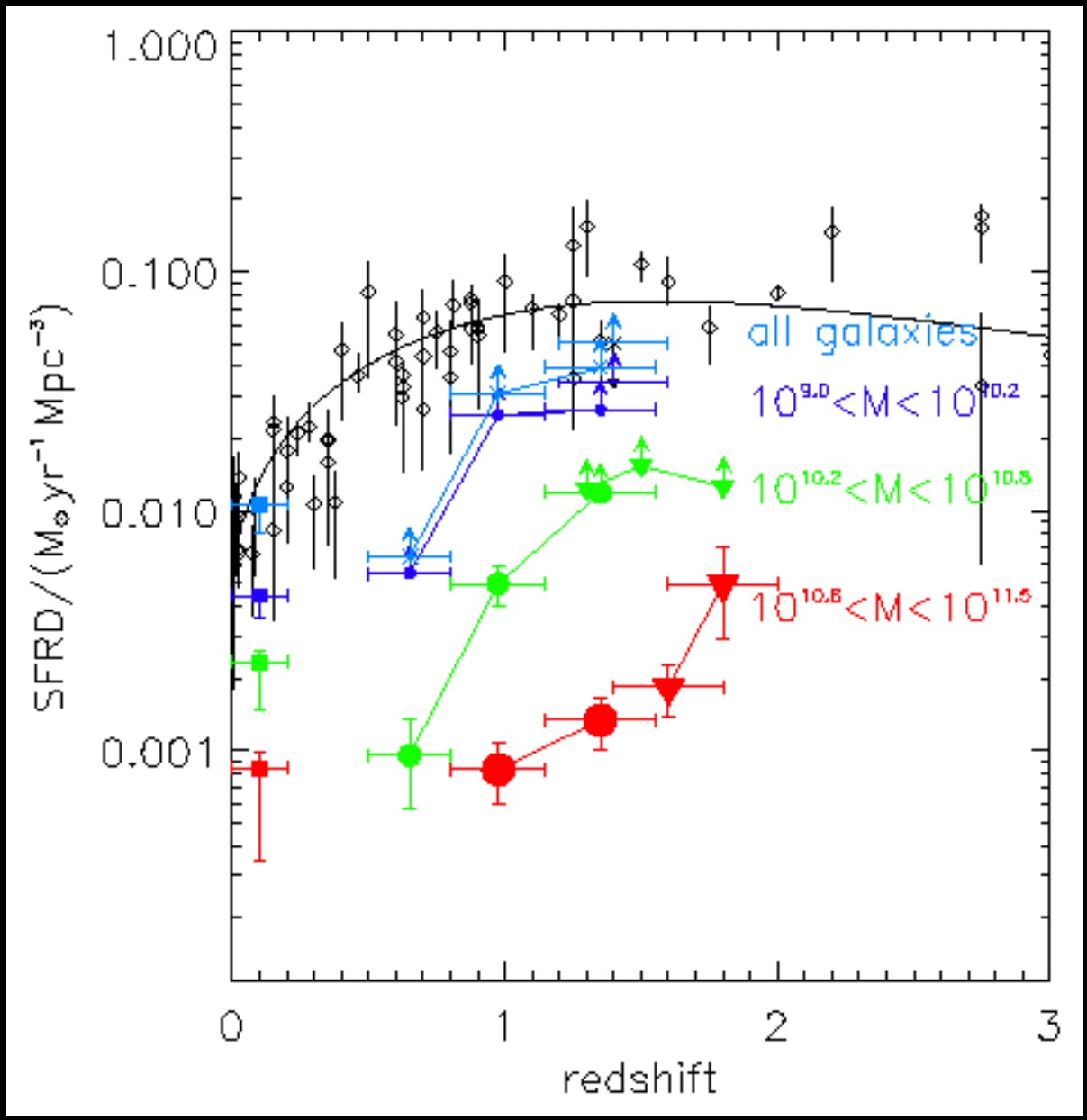


Star Formation Histories by Mass

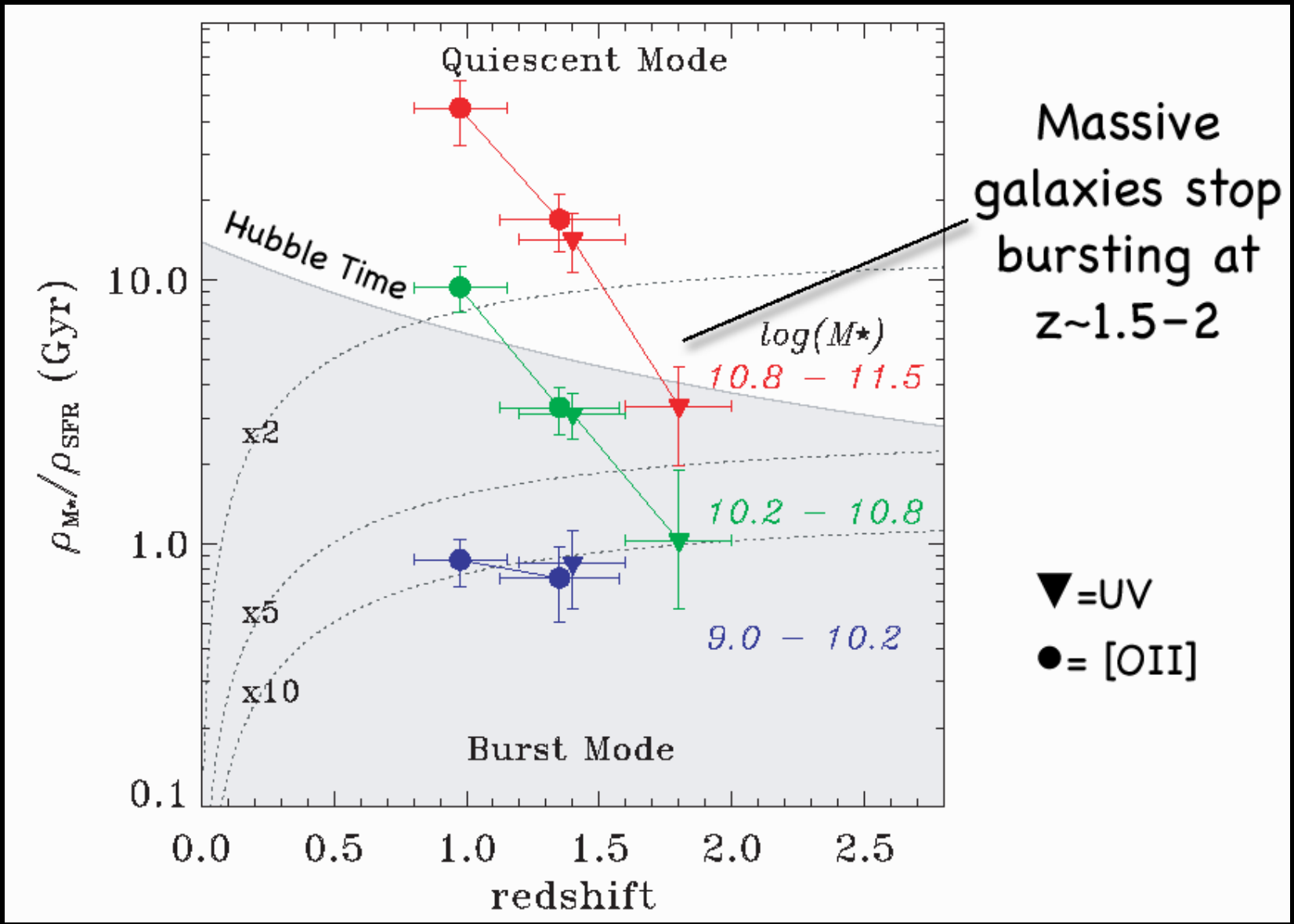
Massive Galaxies ceased star formation at z > 2, low mass galaxies continued active star formation to late epochs

Star Formation Histories

Juneau et al.



Mass Downsizing



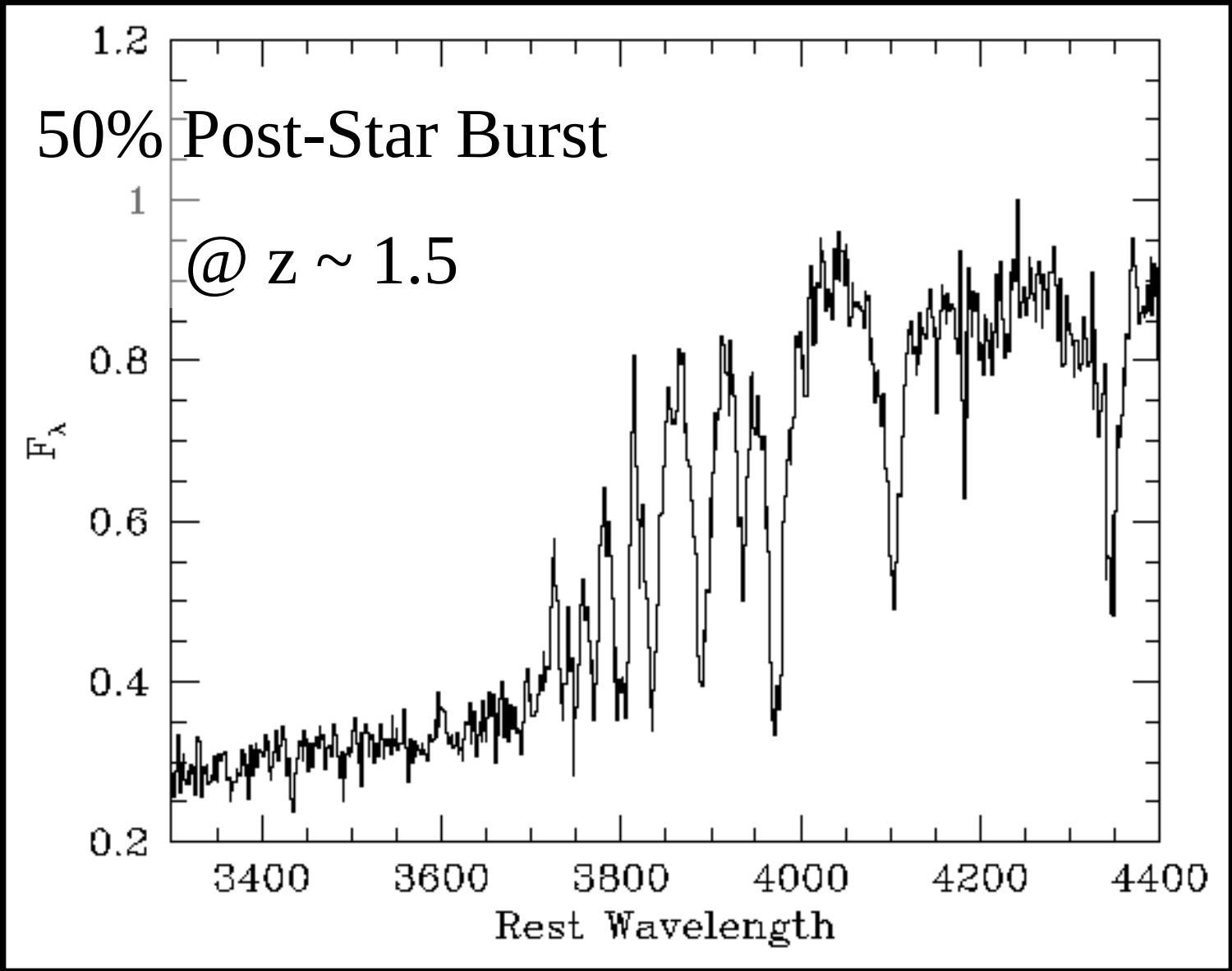
Massive galaxies stop bursting at z~1.5–2

▼=UV

●= [OII]

Post Starburst Galaxies

Only 1 in 10,000 galaxies in LCRS have similar EWs



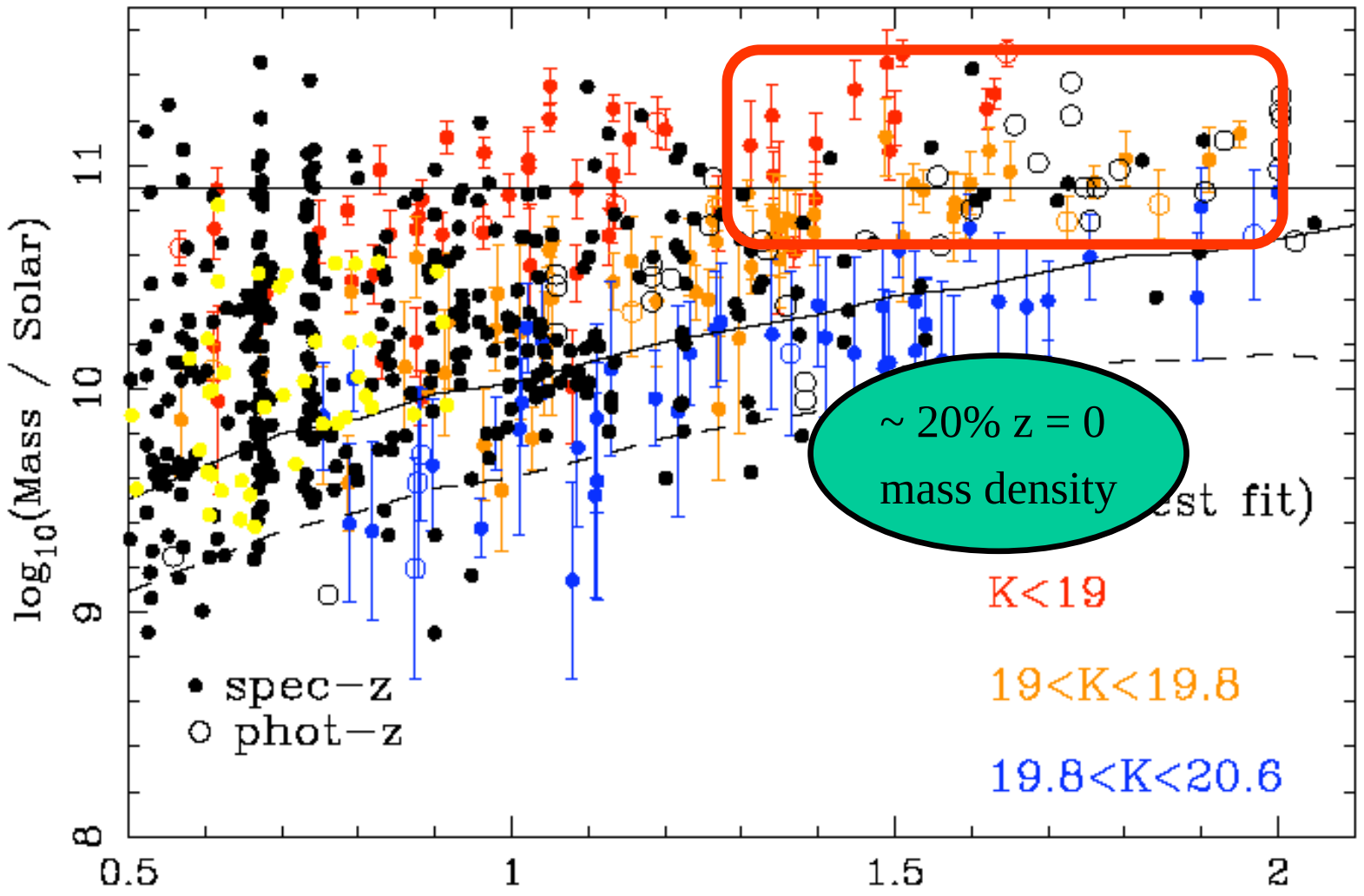
Early Assembly of Massive Galaxies

10% of today's stellar mass was assembled into

massive galaxies at z > 3,

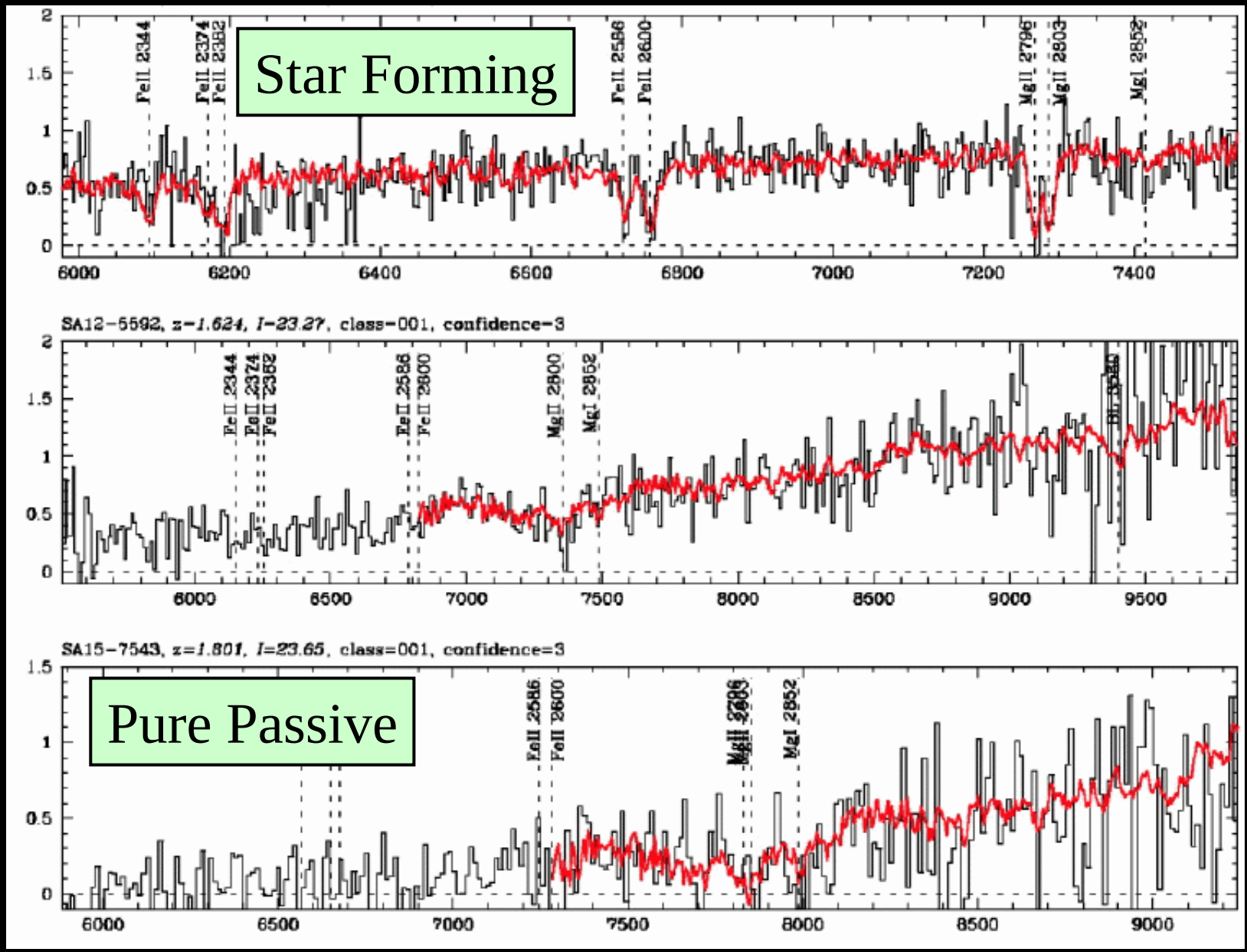
and 5% before z ~ 4.

The Most Massive Galaxies

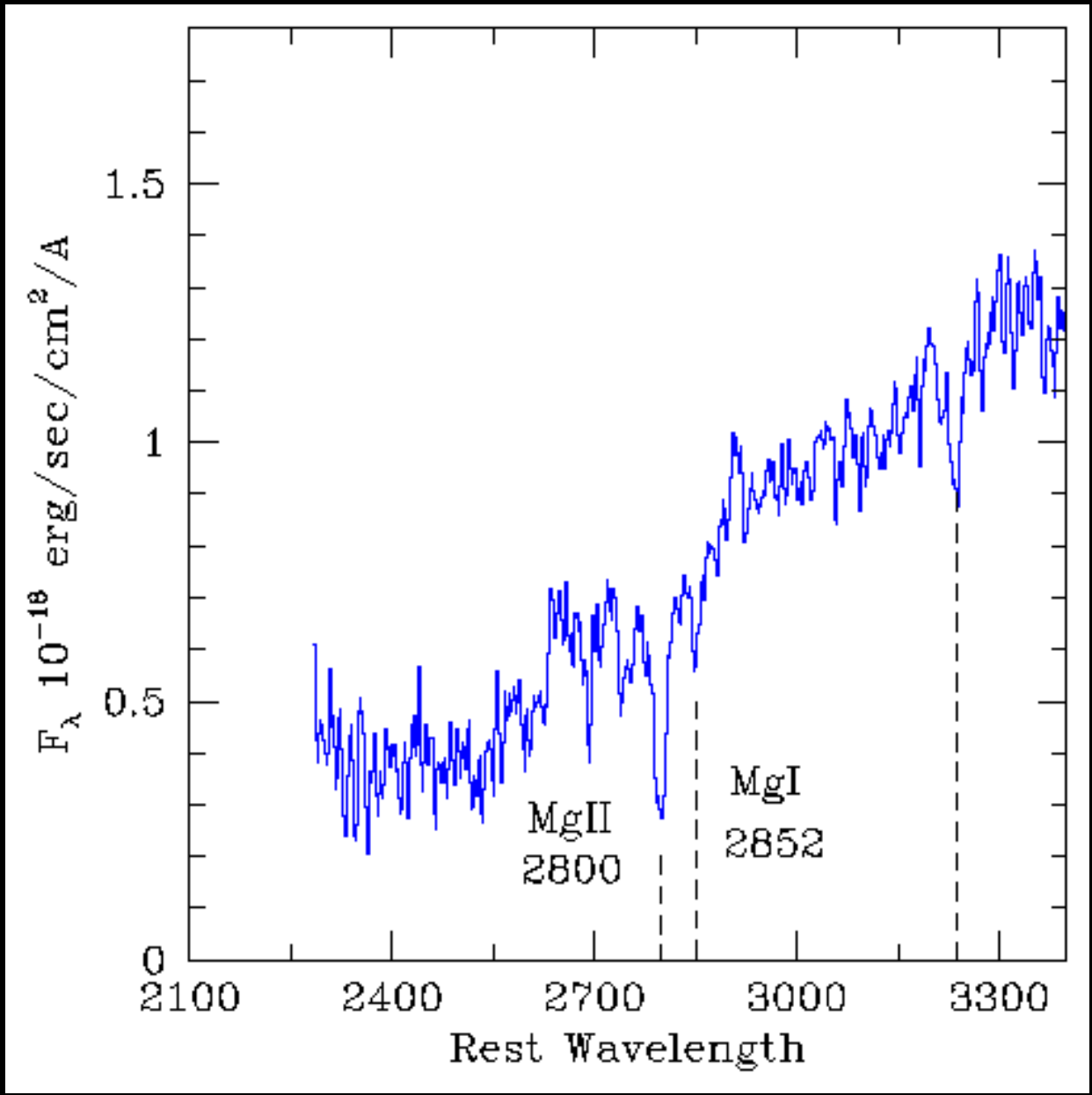


Glazebrook et al.

Spectral Types at z > 1.3

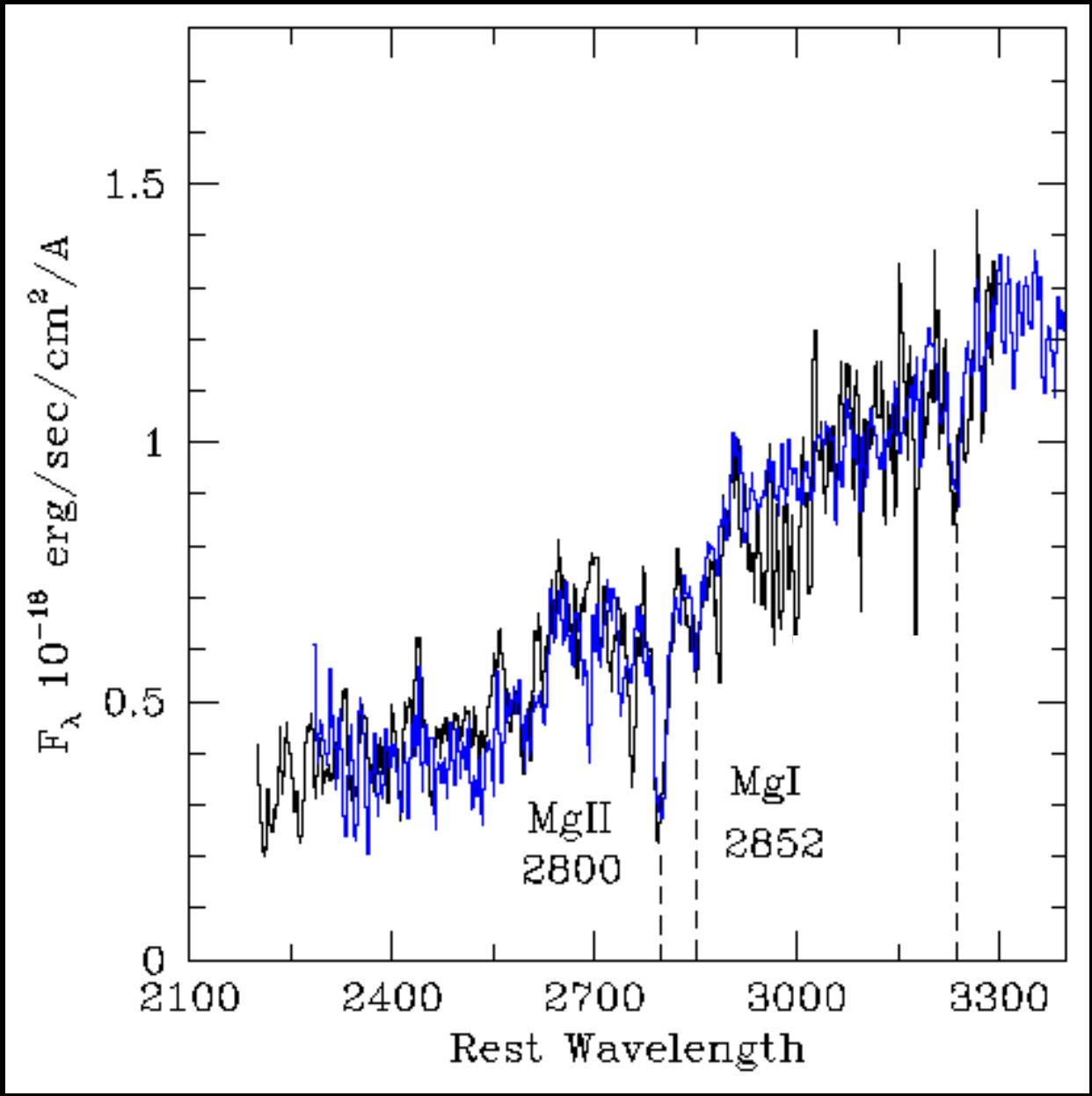


Old Galaxies at 1.3 < z < 1.8



<z>=1.3

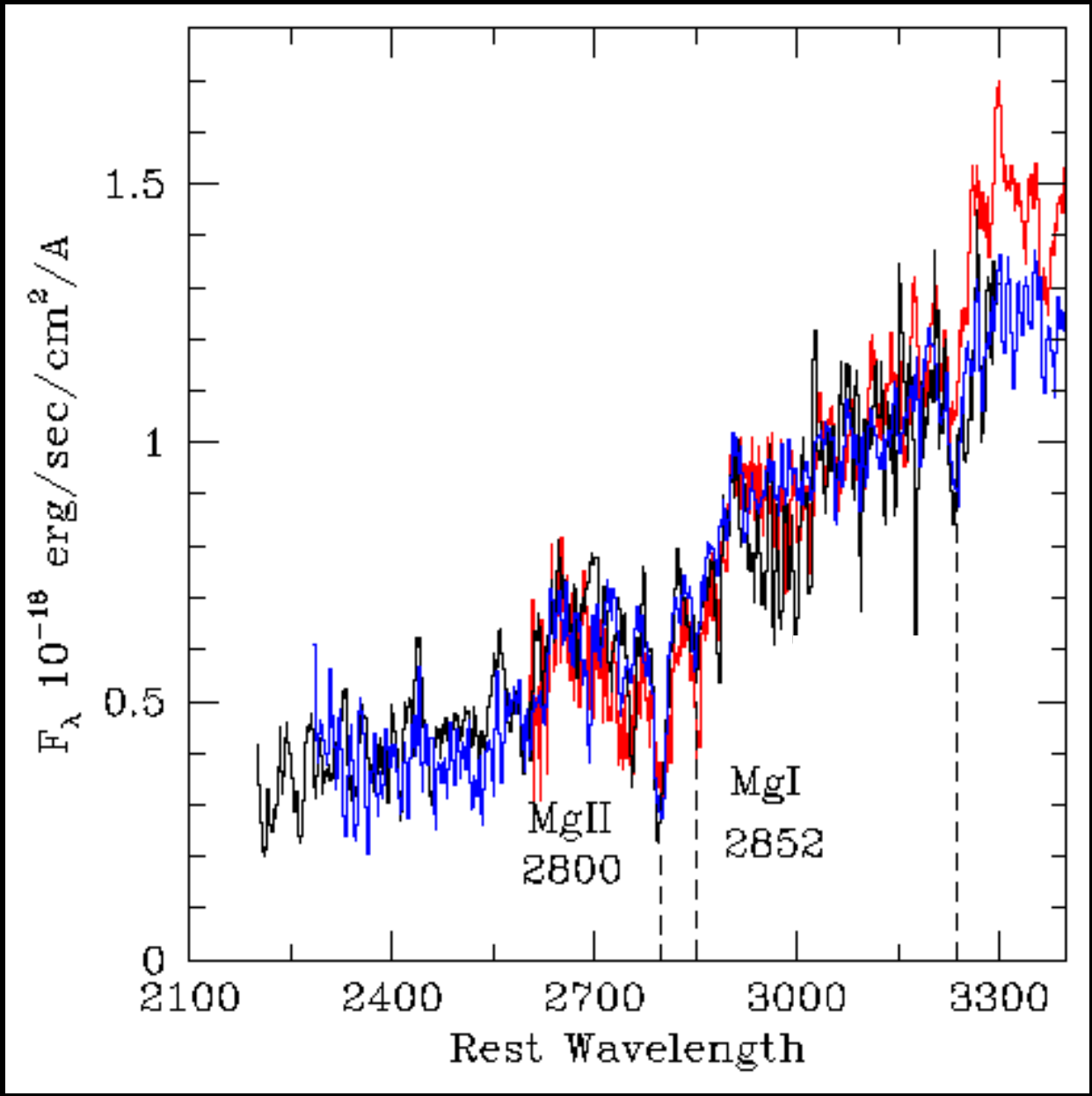
Old Galaxies at 1.3 < z < 1.8



<z>=1.3

<z>=1.8

Old Galaxies at 1.3 < z < 1.8

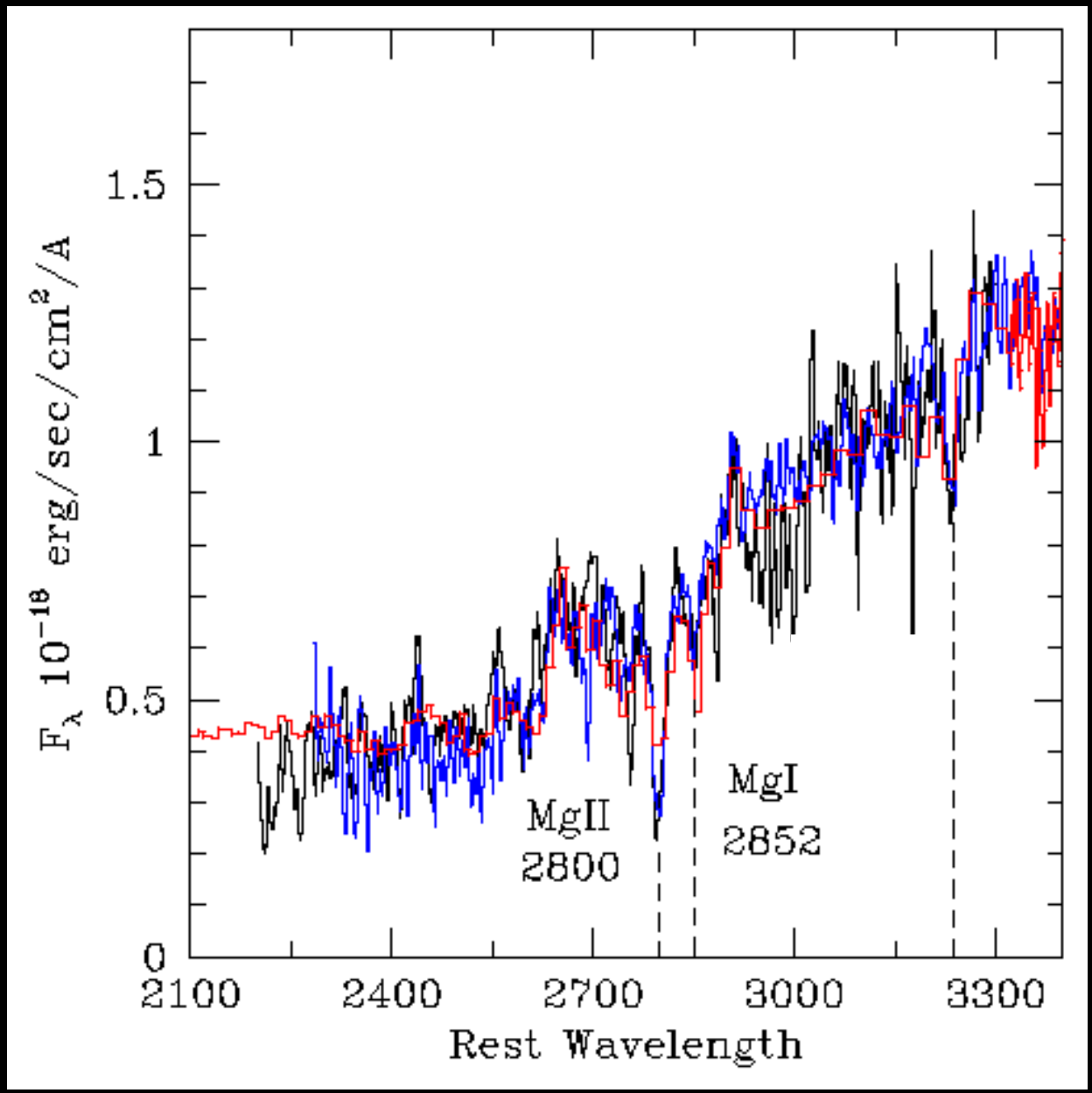


<z>=1.3

<z>=1.8

<z>=0.3

Old Galaxies at 1.3 < z < 1.8



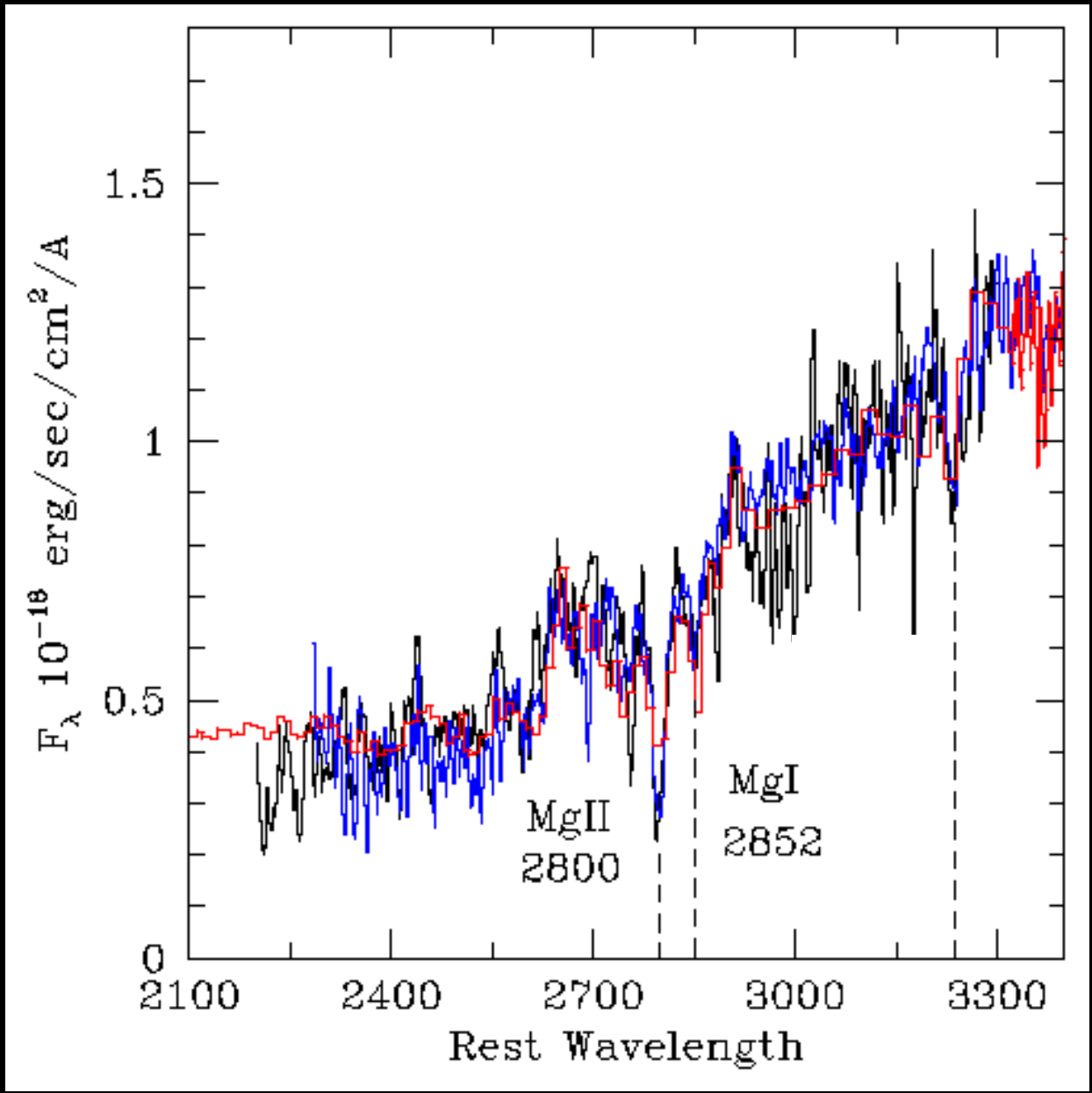
<z>=1.3

<z>=1.8

2Gyr

Pegase Model

Old Galaxies at 1.3 < z < 1.8



Age Fitting of 20 individual Galaxies

$1.3 < z < 2.0$

$\langle z_f \rangle \sim 2.5$

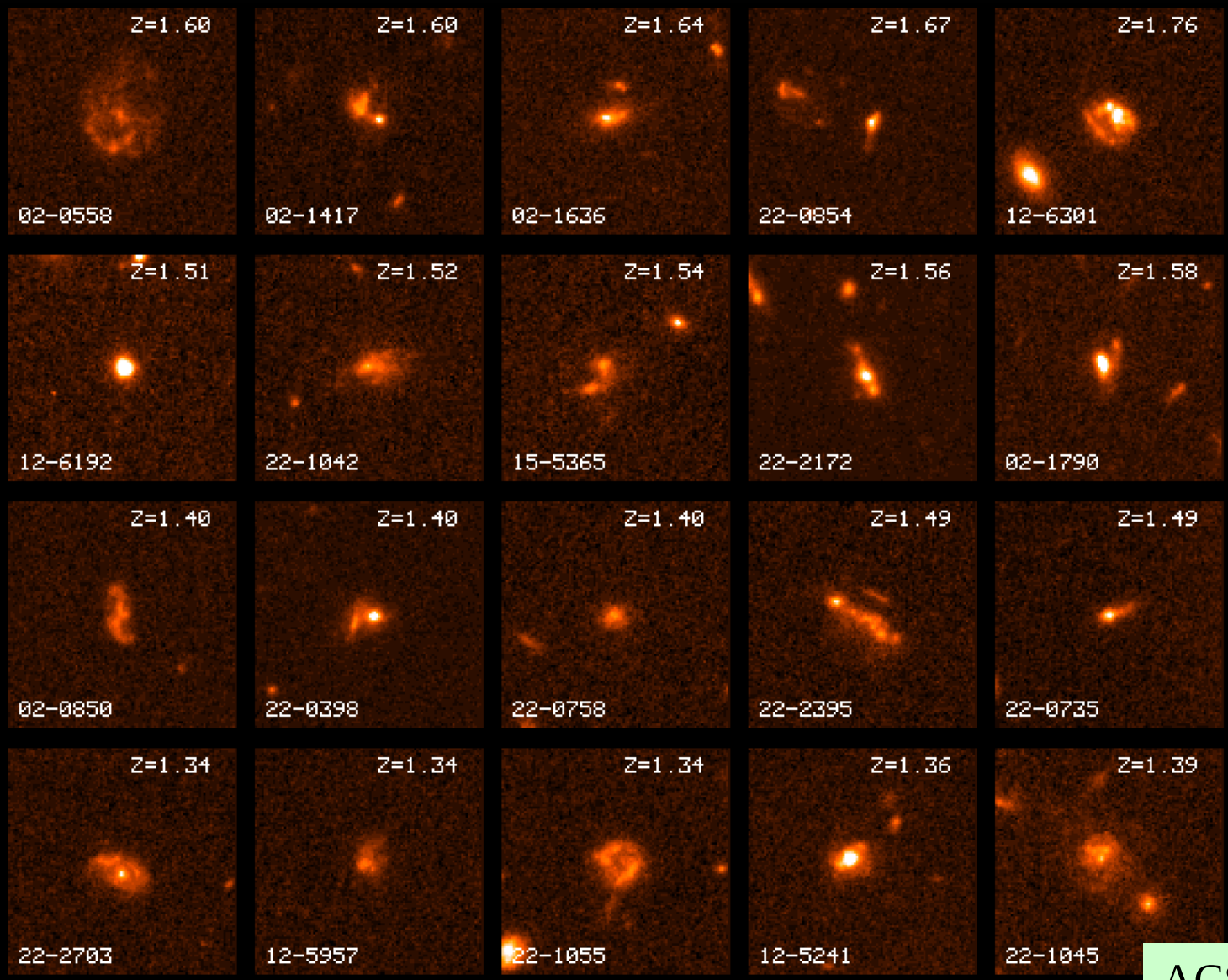
[Fe/H] > 0

E(B-V) ~ 1

$\langle z_f \rangle \sim 4$

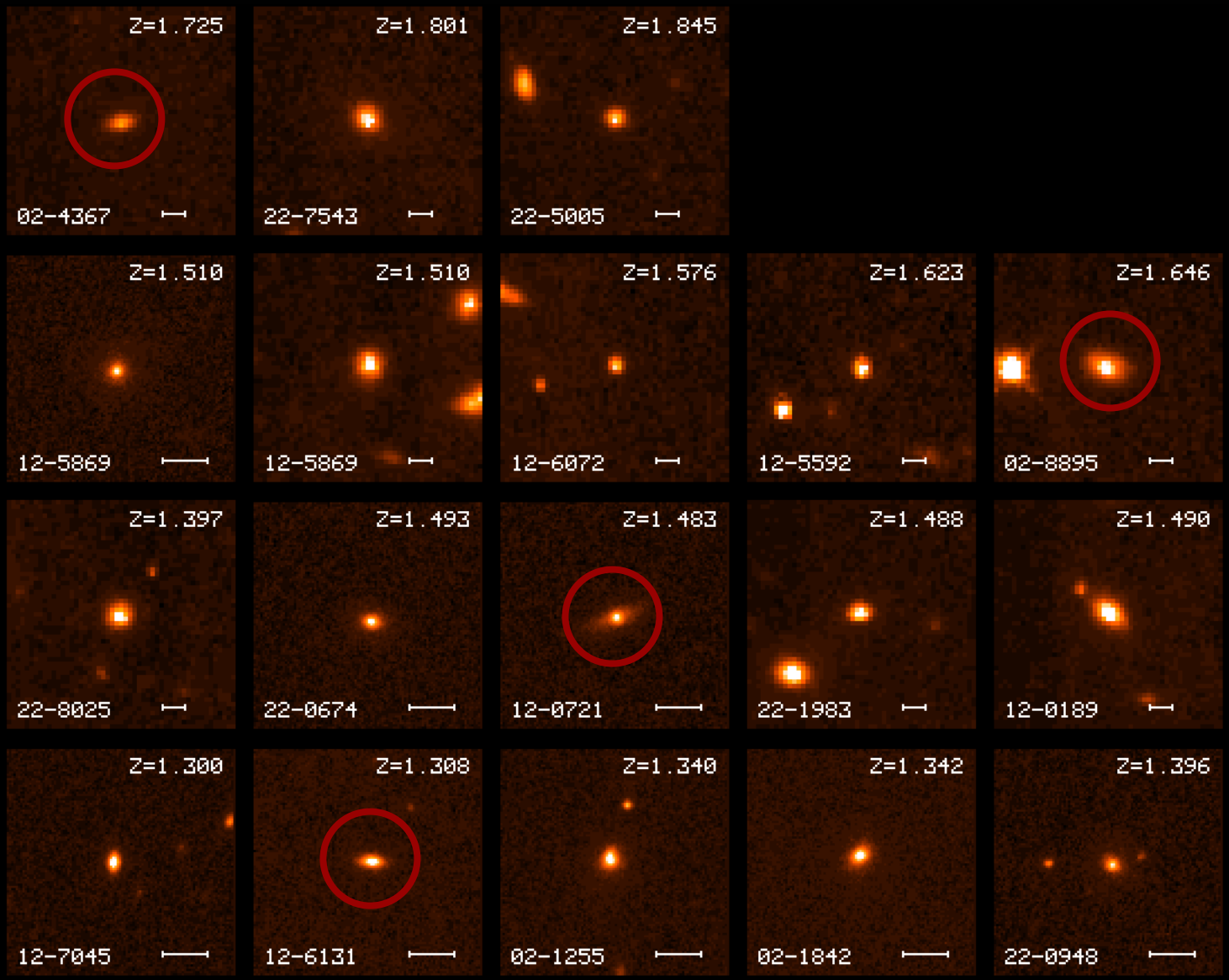
[Fe/H] = 0

Star Forming Galaxies 1.3 < z < 2.0



ACS F814W

Pure Passive Systems



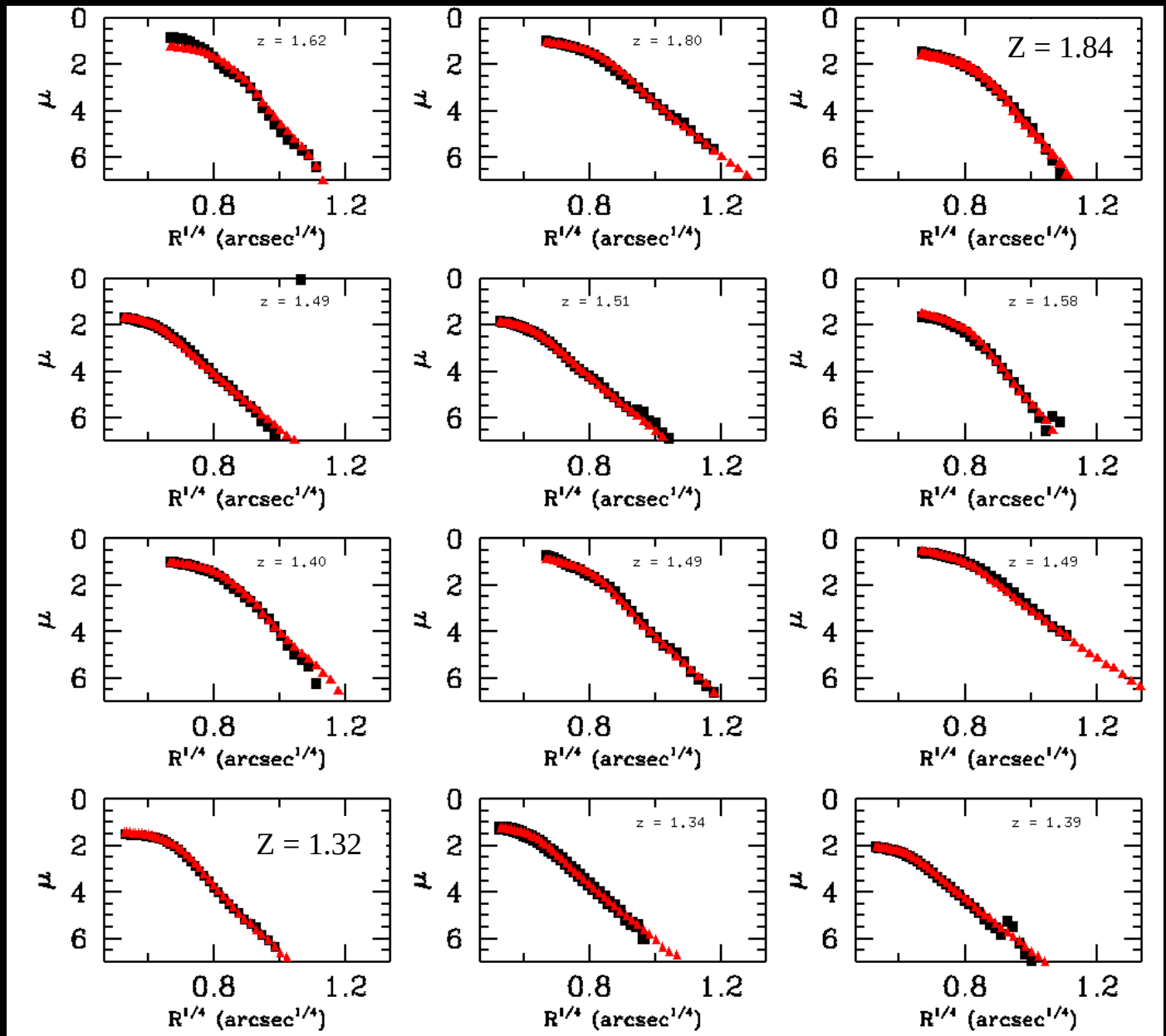
ACS
F814W

NICMOS
F160W

75-80%

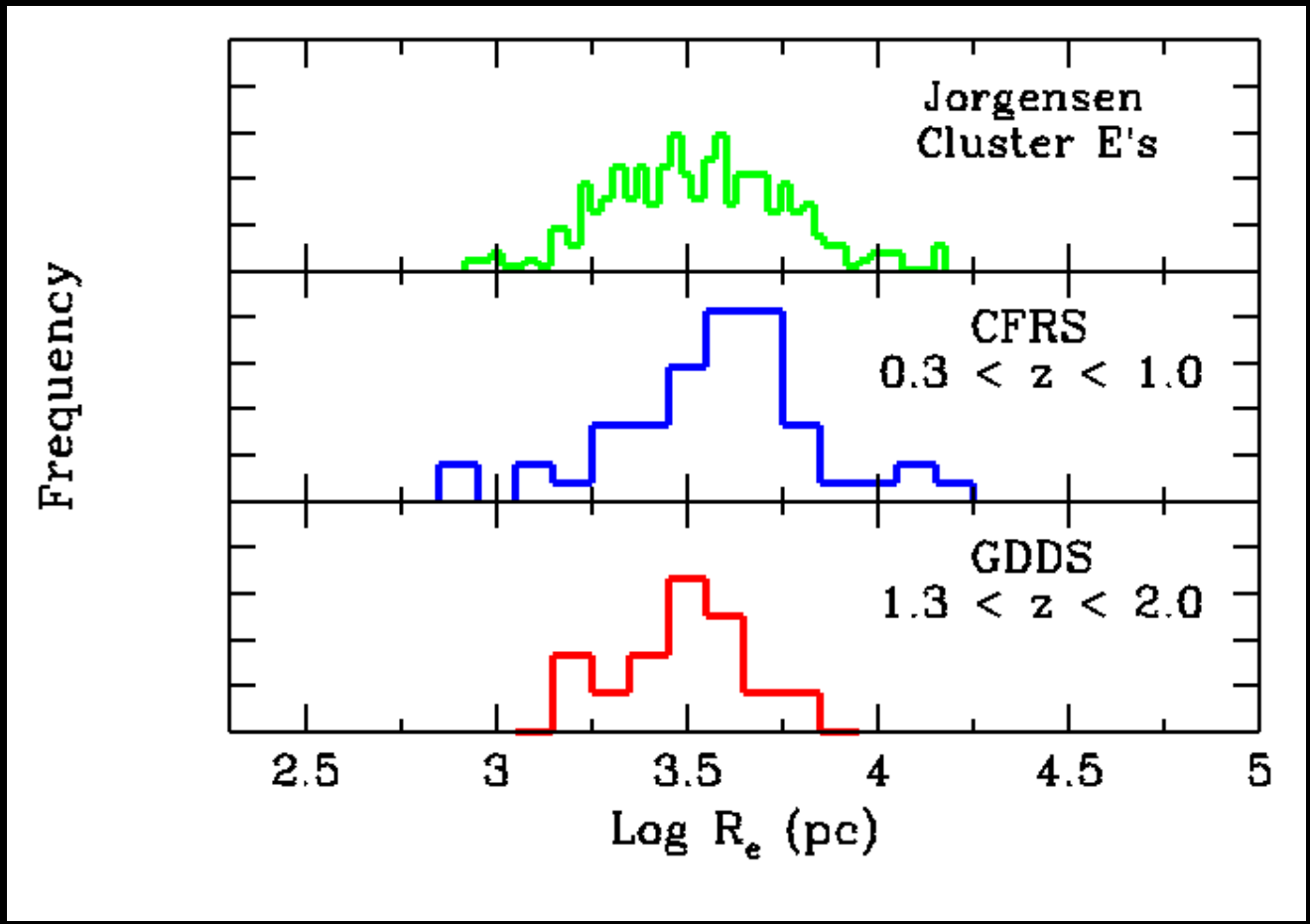
Spheroids

Surface Brightness Profiles



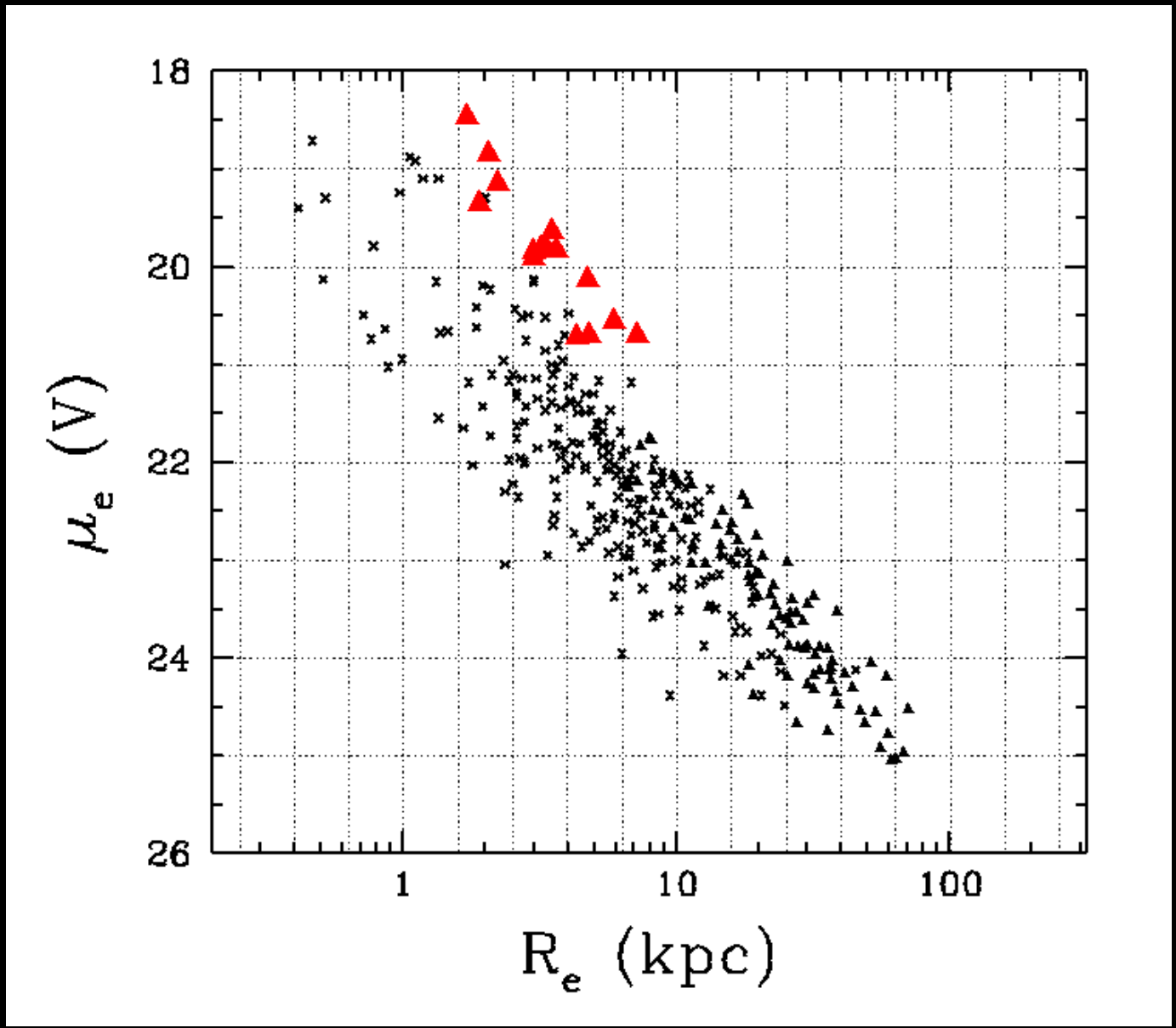
$0.3 < R_e < 1''$

Size Distribution



Little or no evolution in the size distribution

Kormendy Relation at 1.3 < z < 2

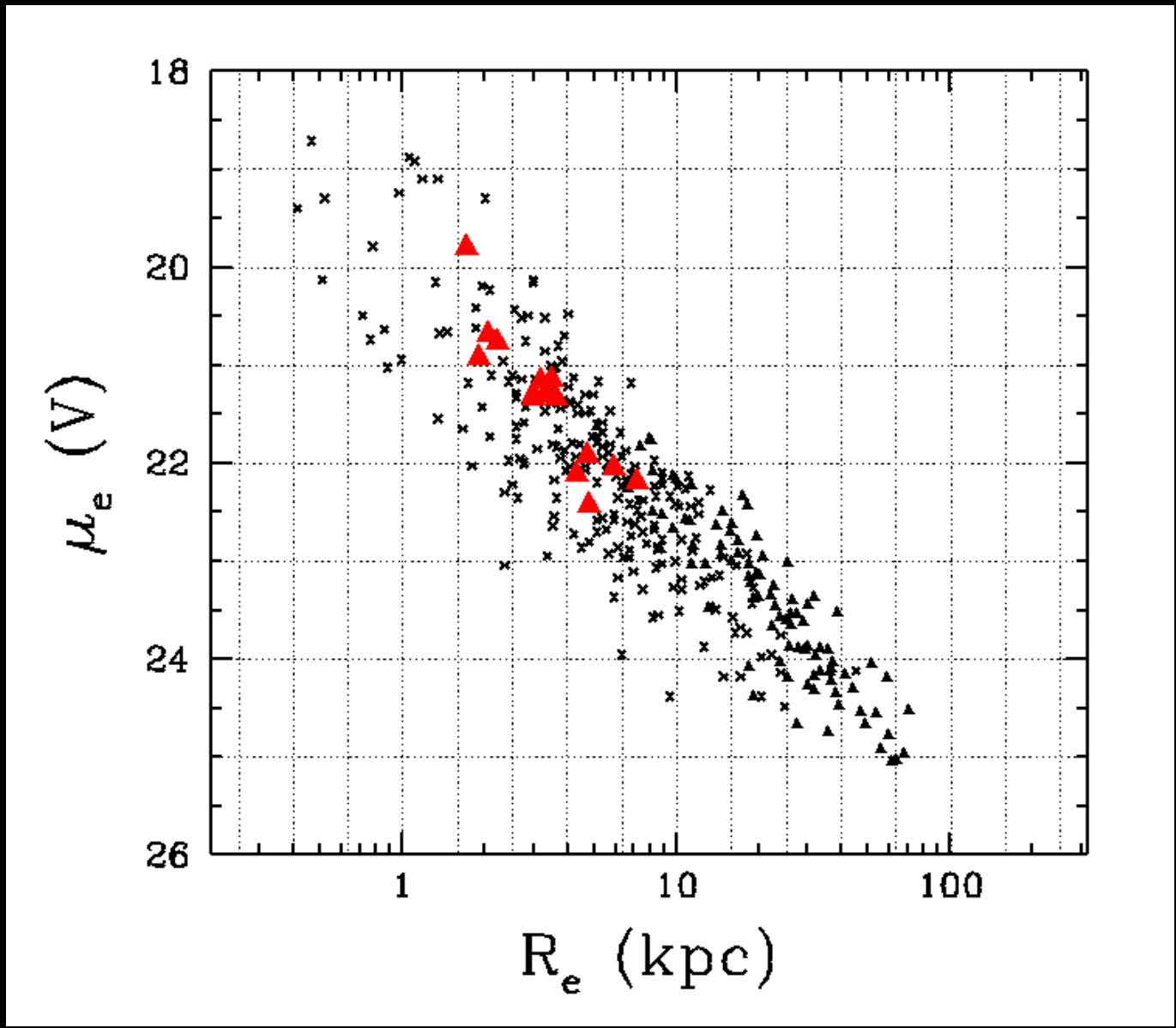


Rest Frame

V-Band

Kormendy Diagram

Kormendy Relation at 1.3 < z < 2

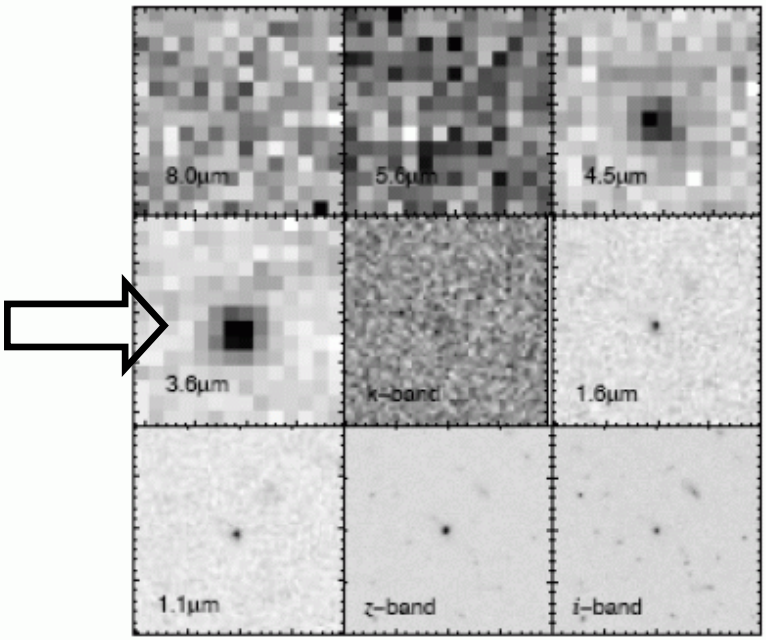


Passive Evolution

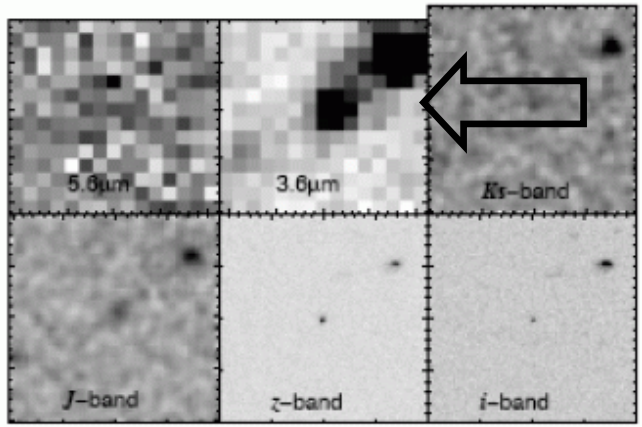
~1 mag per unit redshift

Spitzer detections of GOODS-S i-drops at z=6

#1 z=5.83



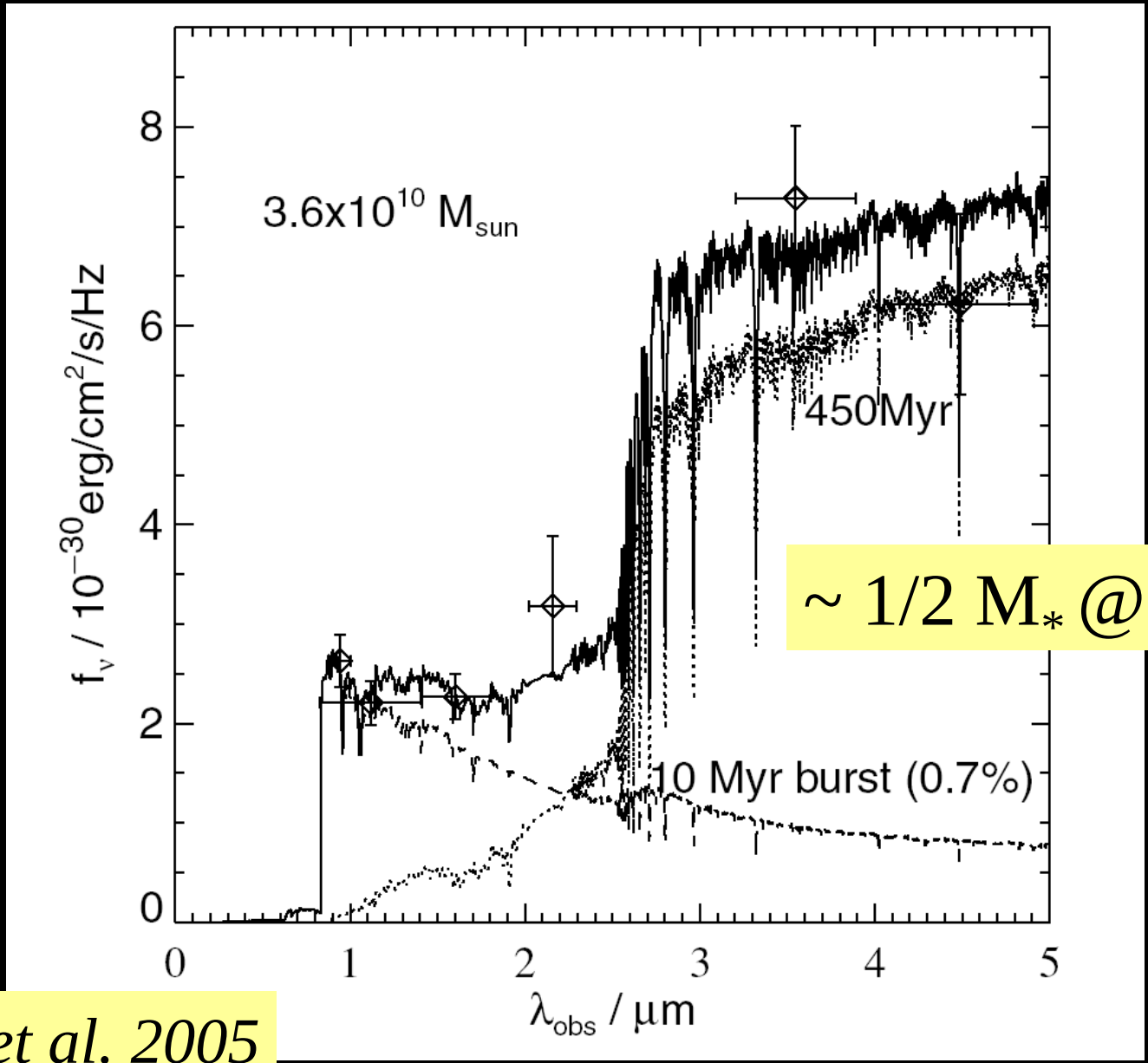
#3 z=5.78



Eyles et al (2005)

- 4 i-drops in GOODS-S confirmed spectroscopically at Keck
- Ly α emission consistent with SFR > 6 $M_\odot$ yr^{-1}
- IRAC detections from GOODS Super-Deep Legacy Program

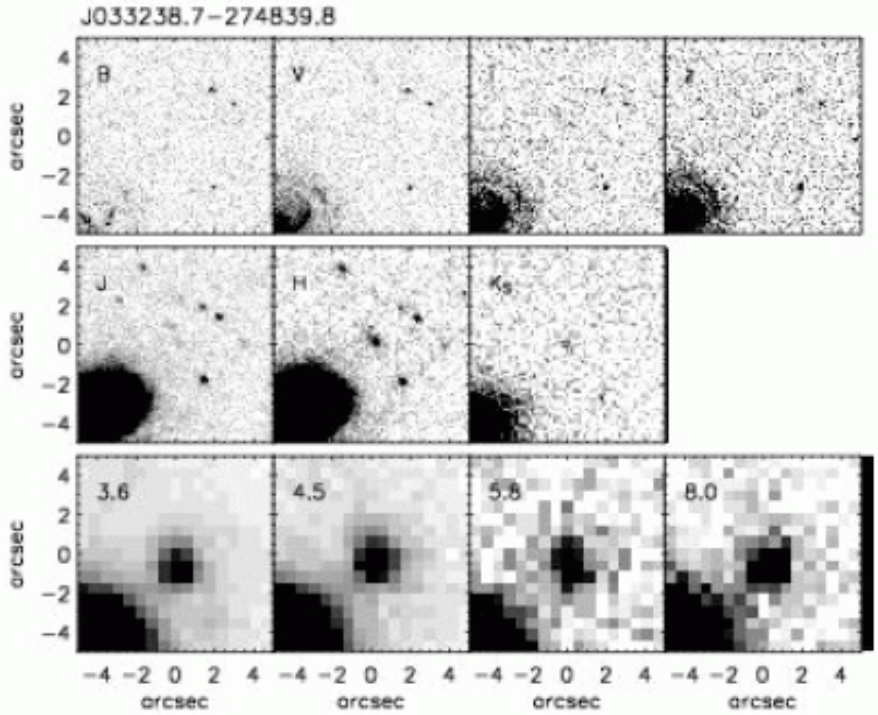
“Old” Galaxies at z ~ 6



~ 1/2 M_* @ z ~ 10!

Eyles et al. 2005

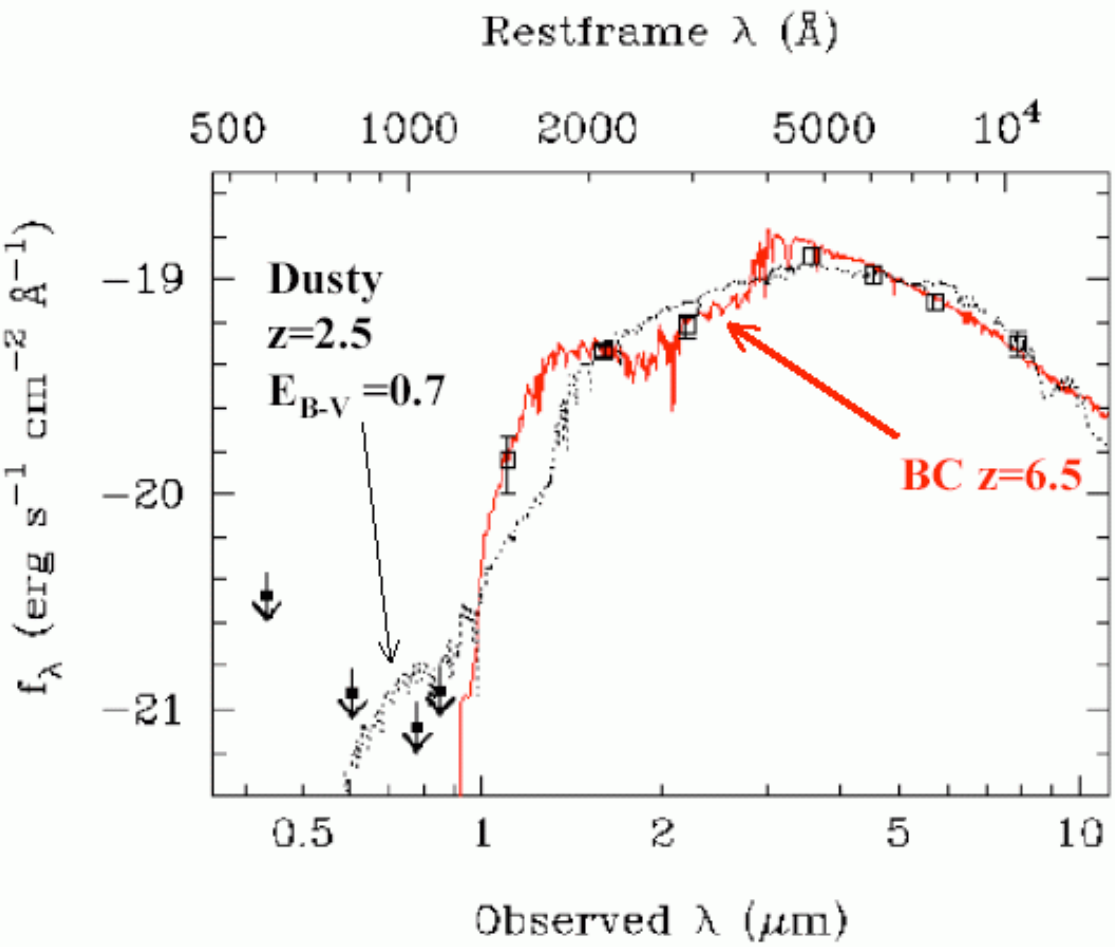
Spitzer detection of resolved J-drop in UDF



Criterion: $(J - H)_{AB} > 1.3$ plus no detection in combined ACS

JD1: smooth SED and X-ray emission (dusty AGN)
JD2: strong K/3.6μm break → potential high mass z~6.5 source

Mobasher et al (2005)



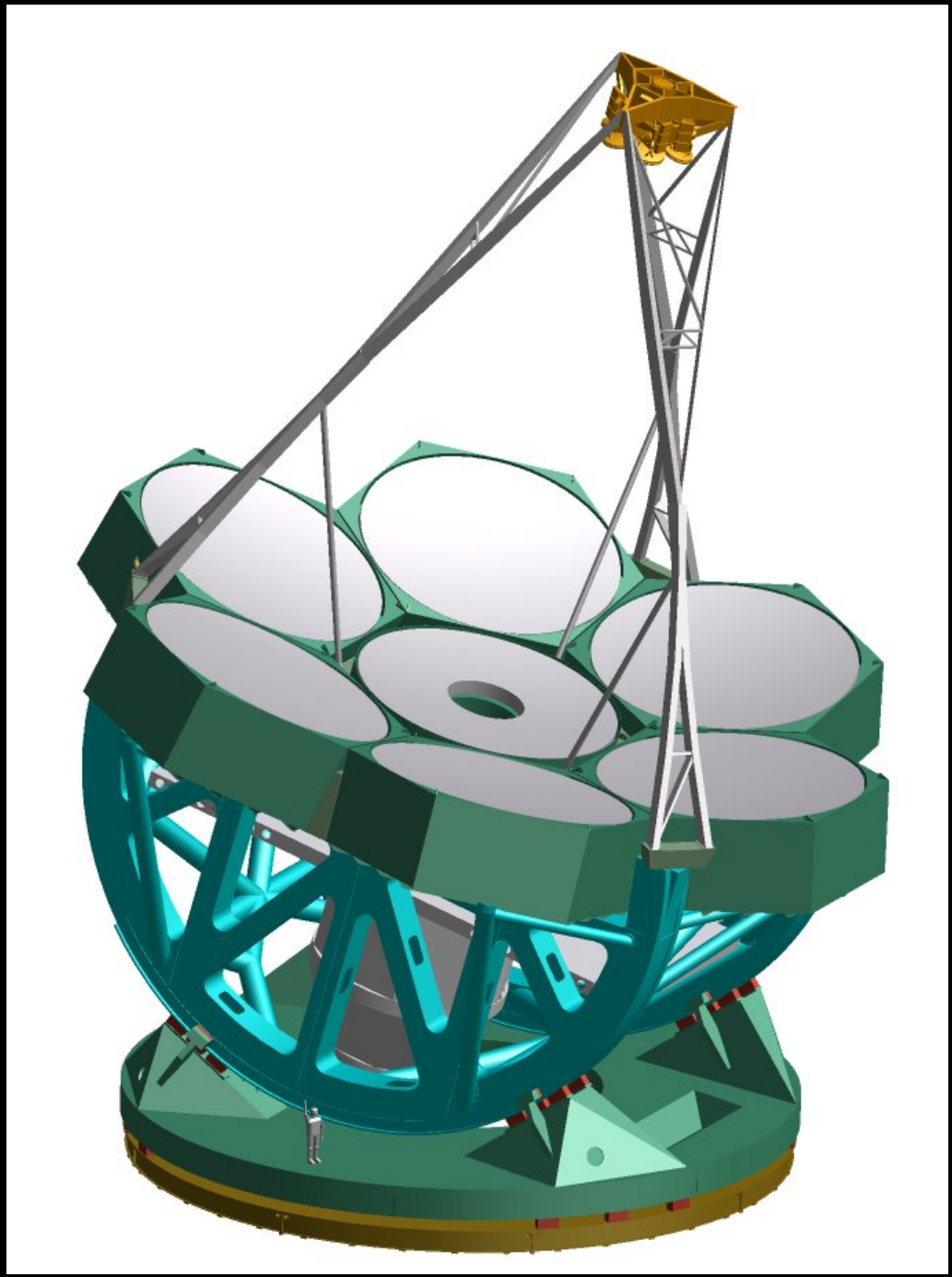
10 M_*!

STARBURST99: z=6.6; E_{B-V}=0.0; Z=0.02

Bruzual & Charlot: z=6.5; E_{B-V}=0.0; Z=0.004

Stellar Mass: 5-7 × 10^{11} $M_\odot$; epoch of formation: z > 10

Mobasher et al. 2005



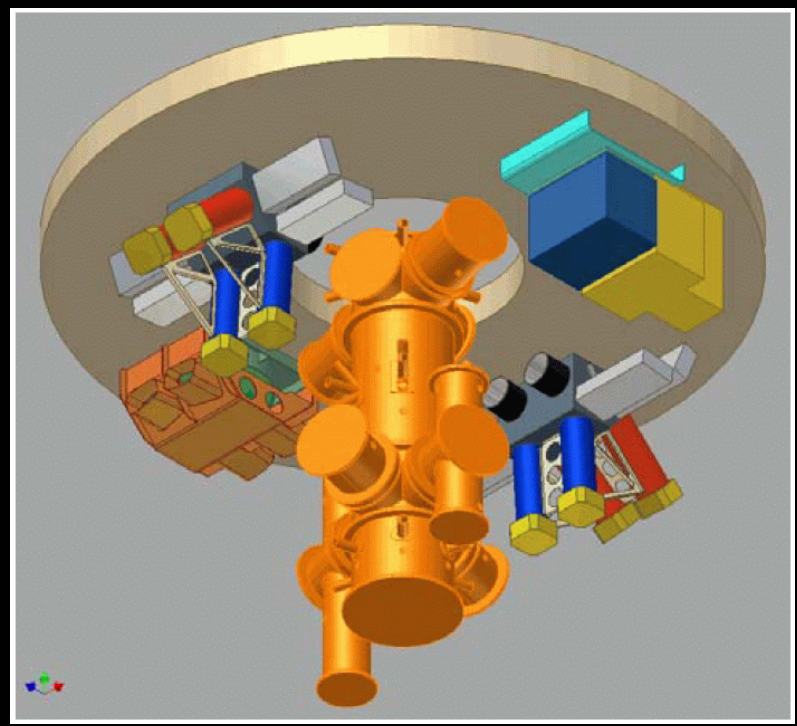
``Up-Sizing''

Giant Magellan Telescope

24m Aperture

18′ x 18′ VMOS

7′ x 7′ NIRMOS

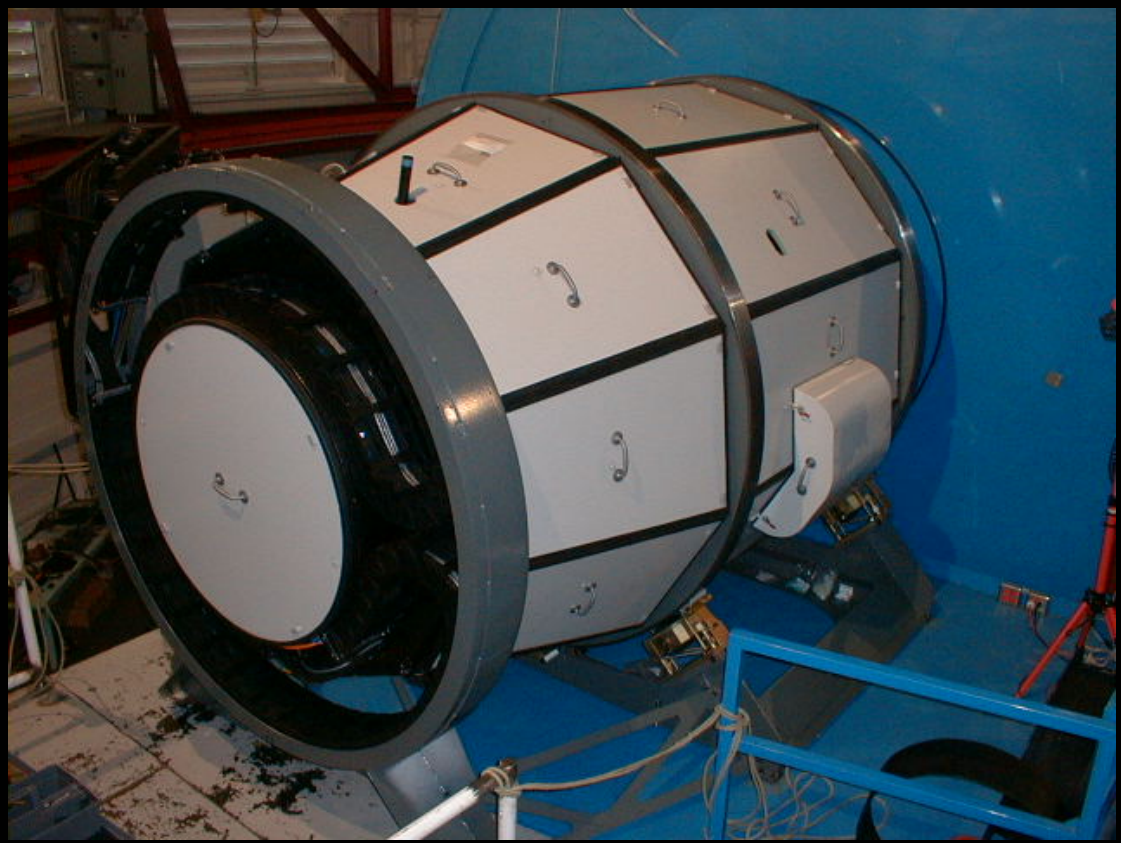


Conclusions

- Galaxy Formation Proceeds from high to low masses
- Some of today's massive galaxies formed quite early
- Good prospects for JWST and ELTs

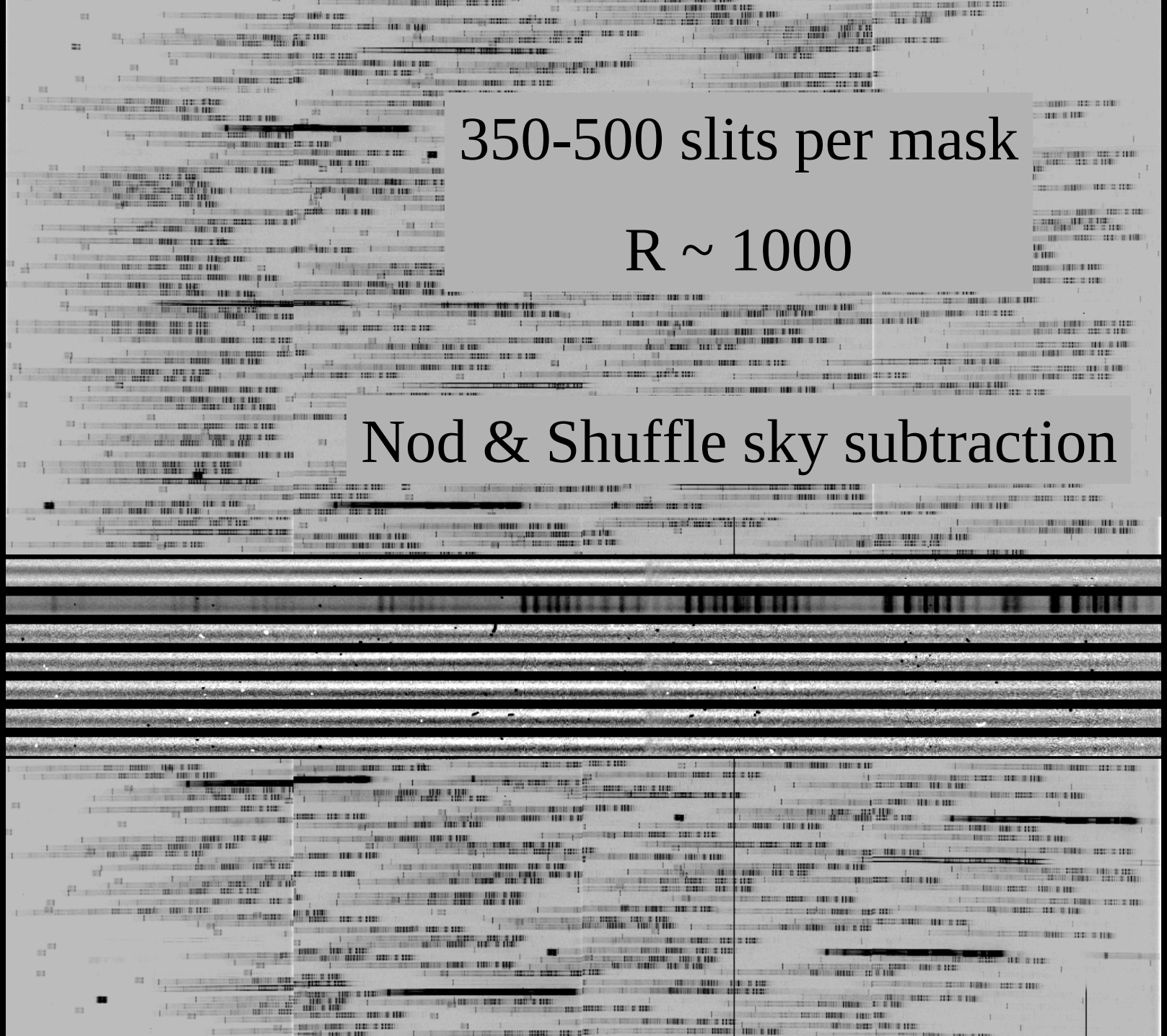
Wider or Deeper Surveys?

Wider

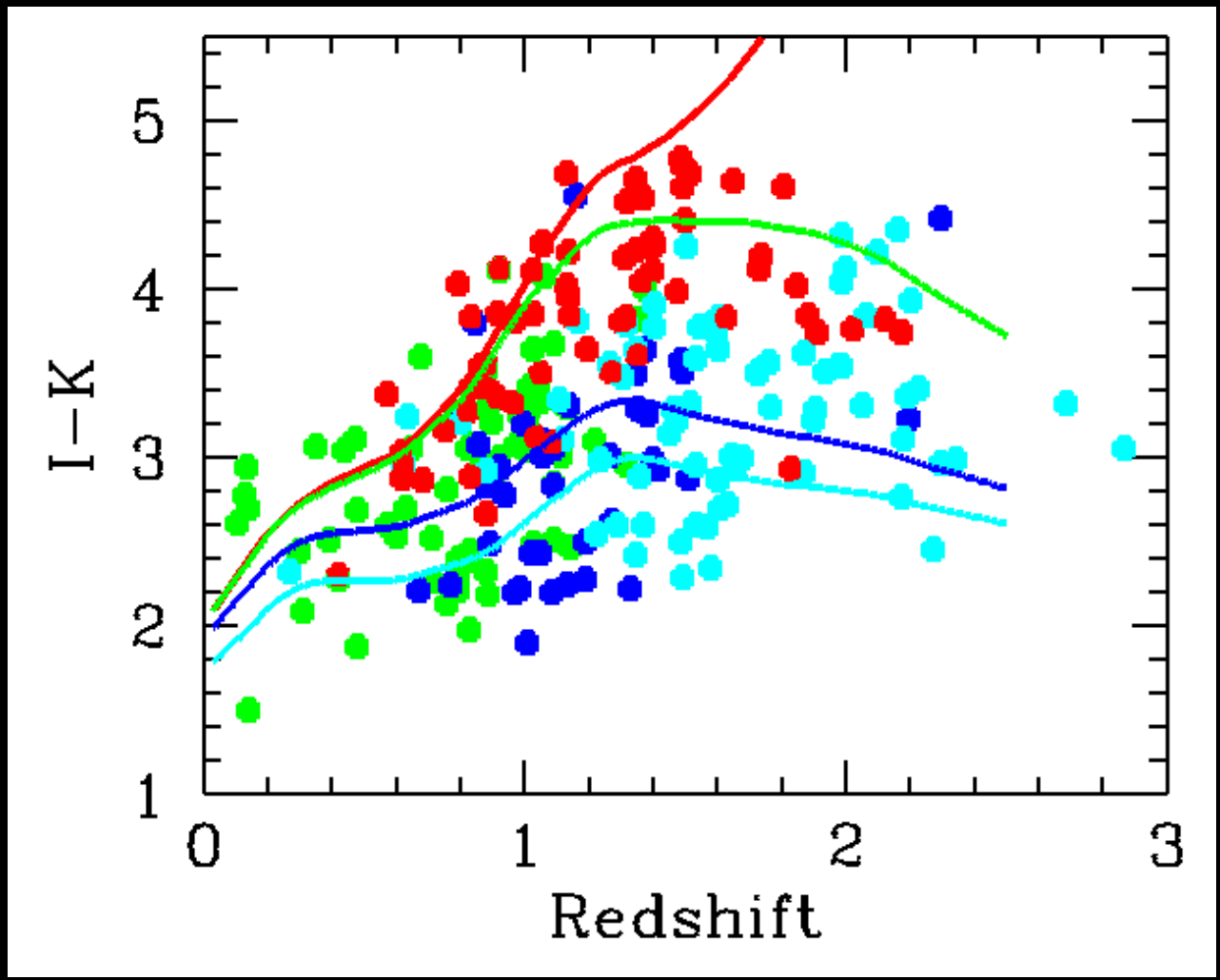


IMACS on the 6.5m Baade Telescope

27′ Diameter field of view


350-500 slits per mask
R ~ 1000
Nod & Shuffle sky subtraction

Spectral Evolution



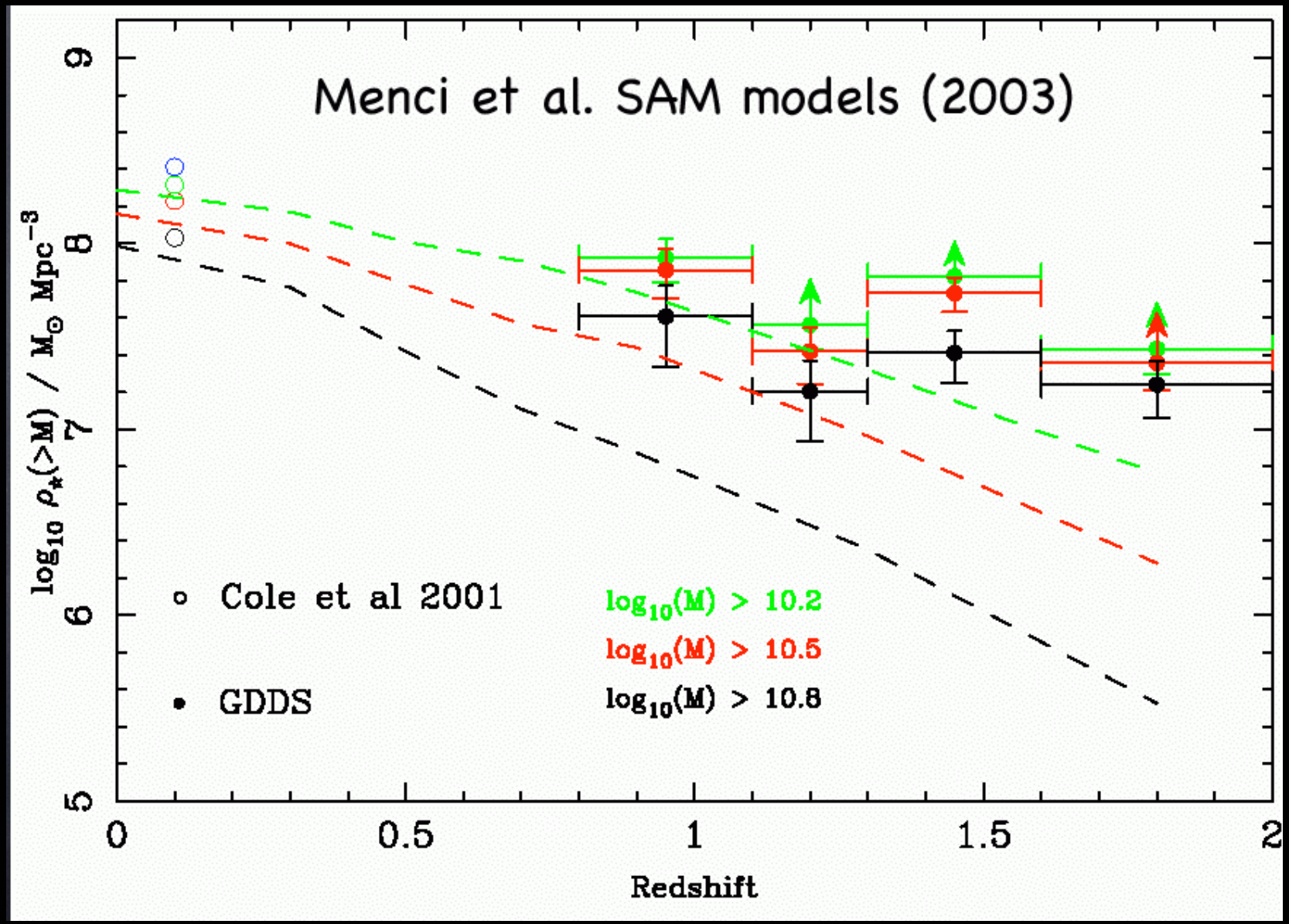
Spectral Classes

Passive

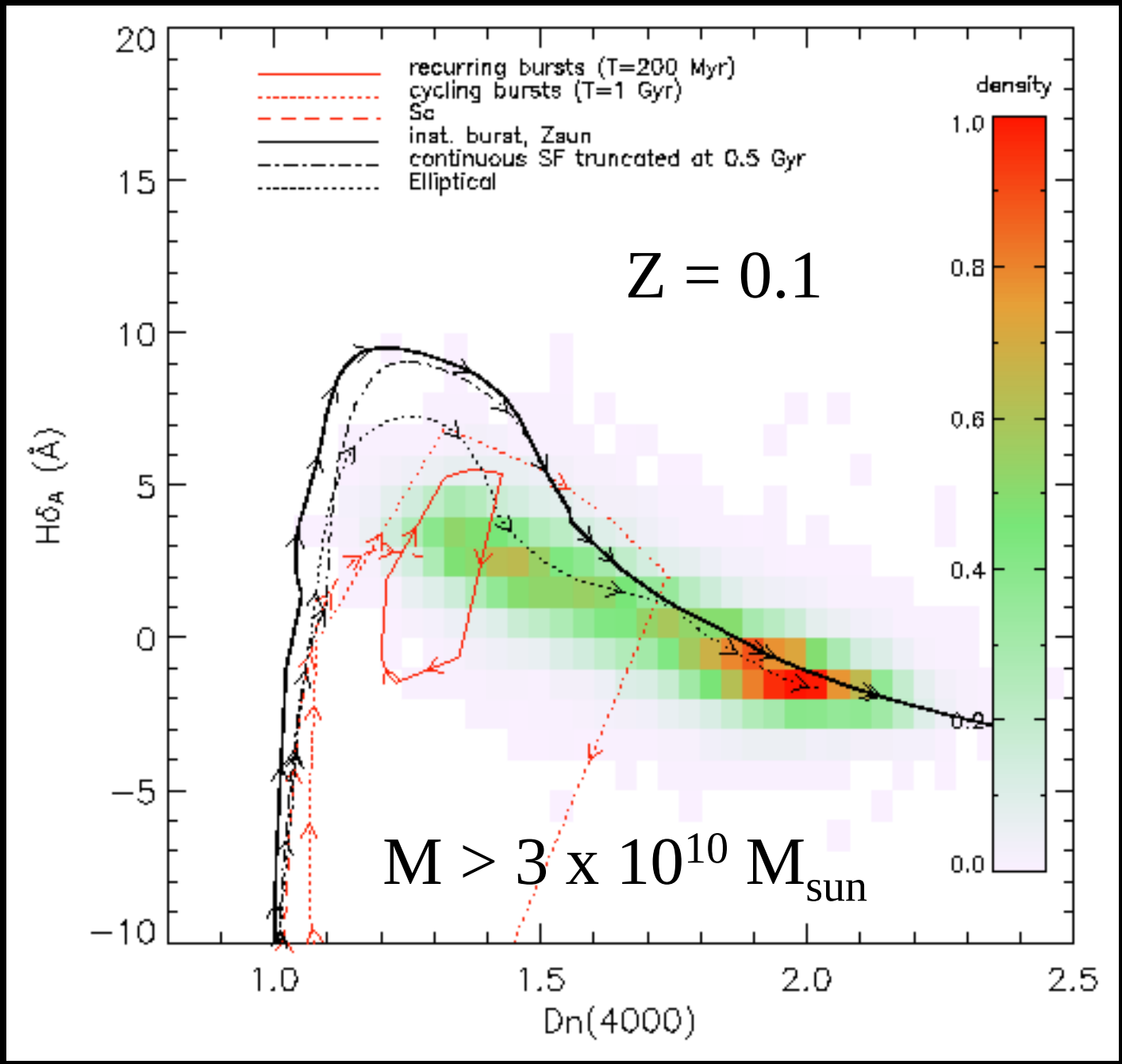
Intermediate

Composite

Young

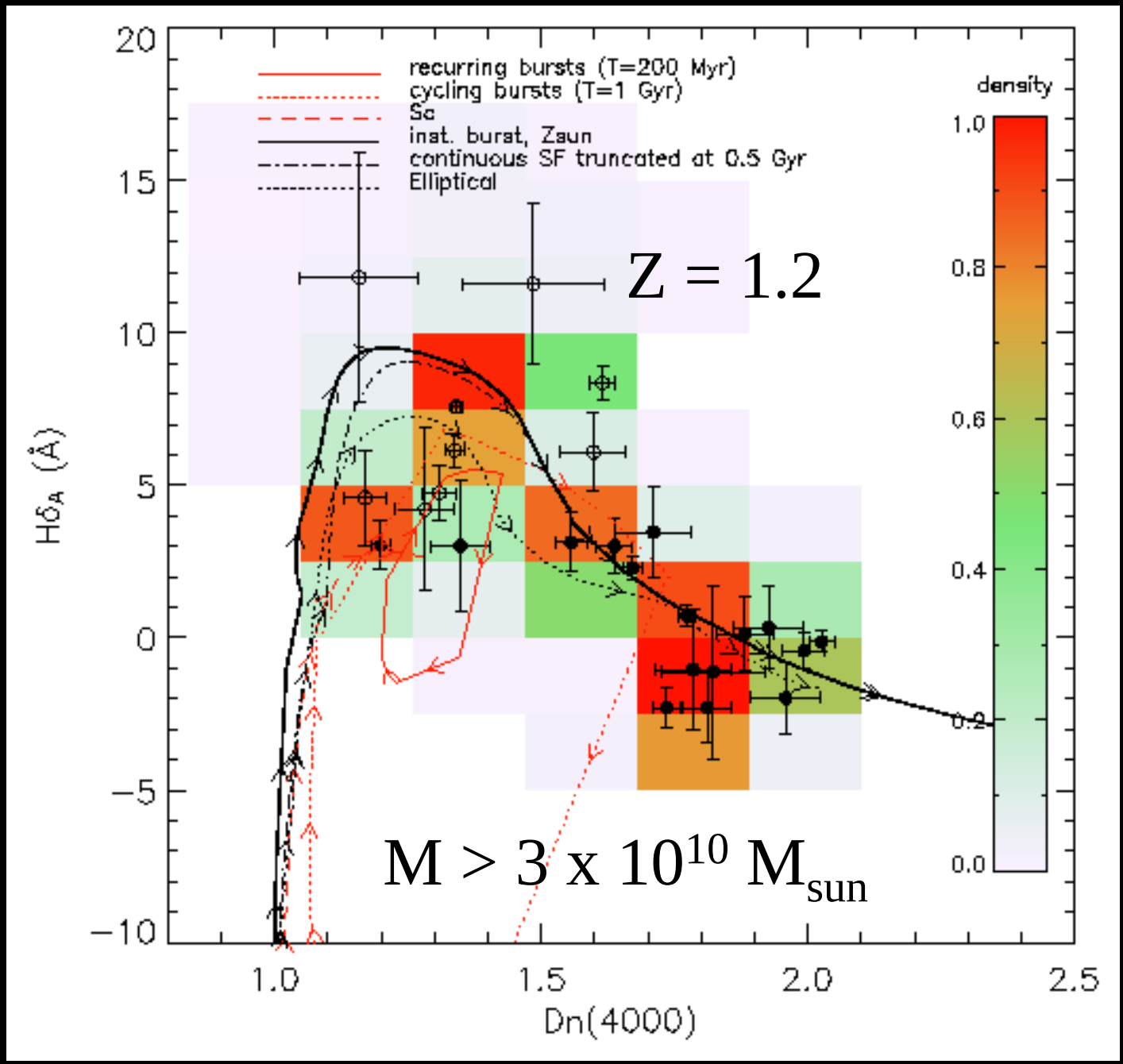

Menci et al. SAM models (2003)
$\log_{10} \rho_*(>M)$ / $M_\odot$ Mpc^{-3}
Redshift
Cole et al 2001
GDDS
$\log_{10}(M) > 10.2$
$\log_{10}(M) > 10.5$
$\log_{10}(M) > 10.8$
0
0.5
1
1.5
2
5
6
7
8
9

Emission Absorption



Le Borgne et al.

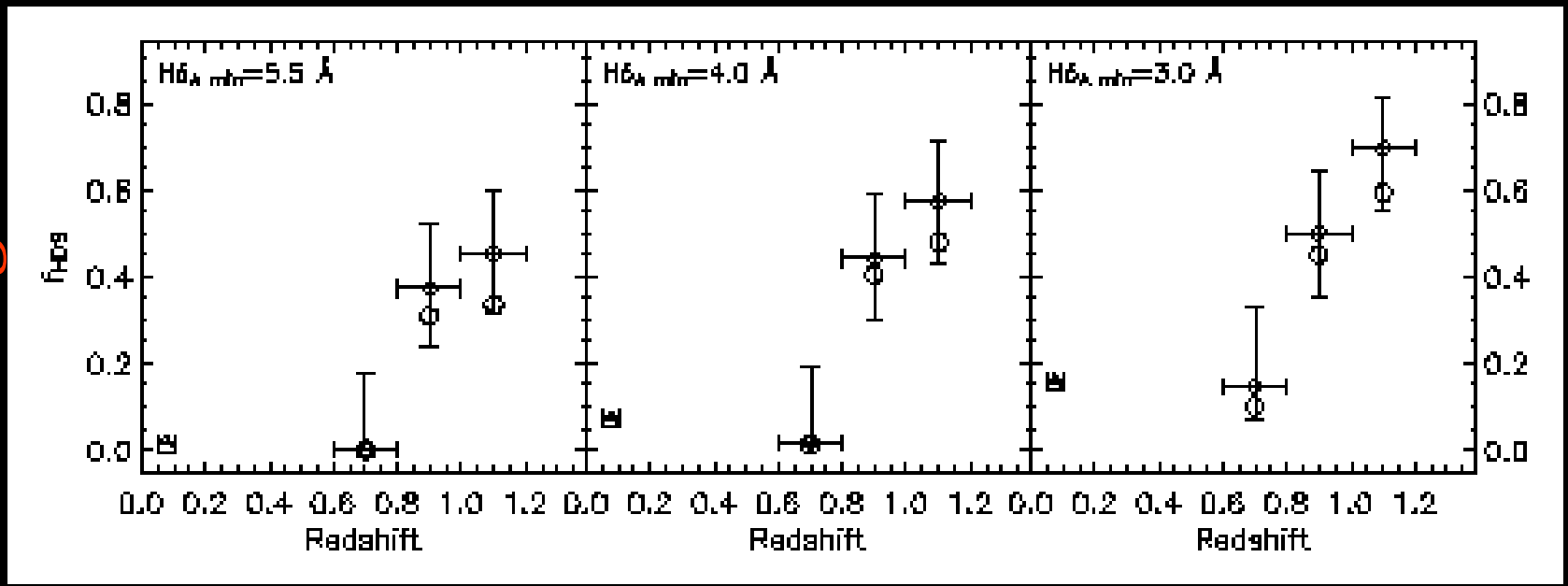
Emission Absorption



Le Borgne et al.

Post-Starburst Galaxies

Hδ Strong Fraction



$M > 3 \times 10^{10} M_{sun}$

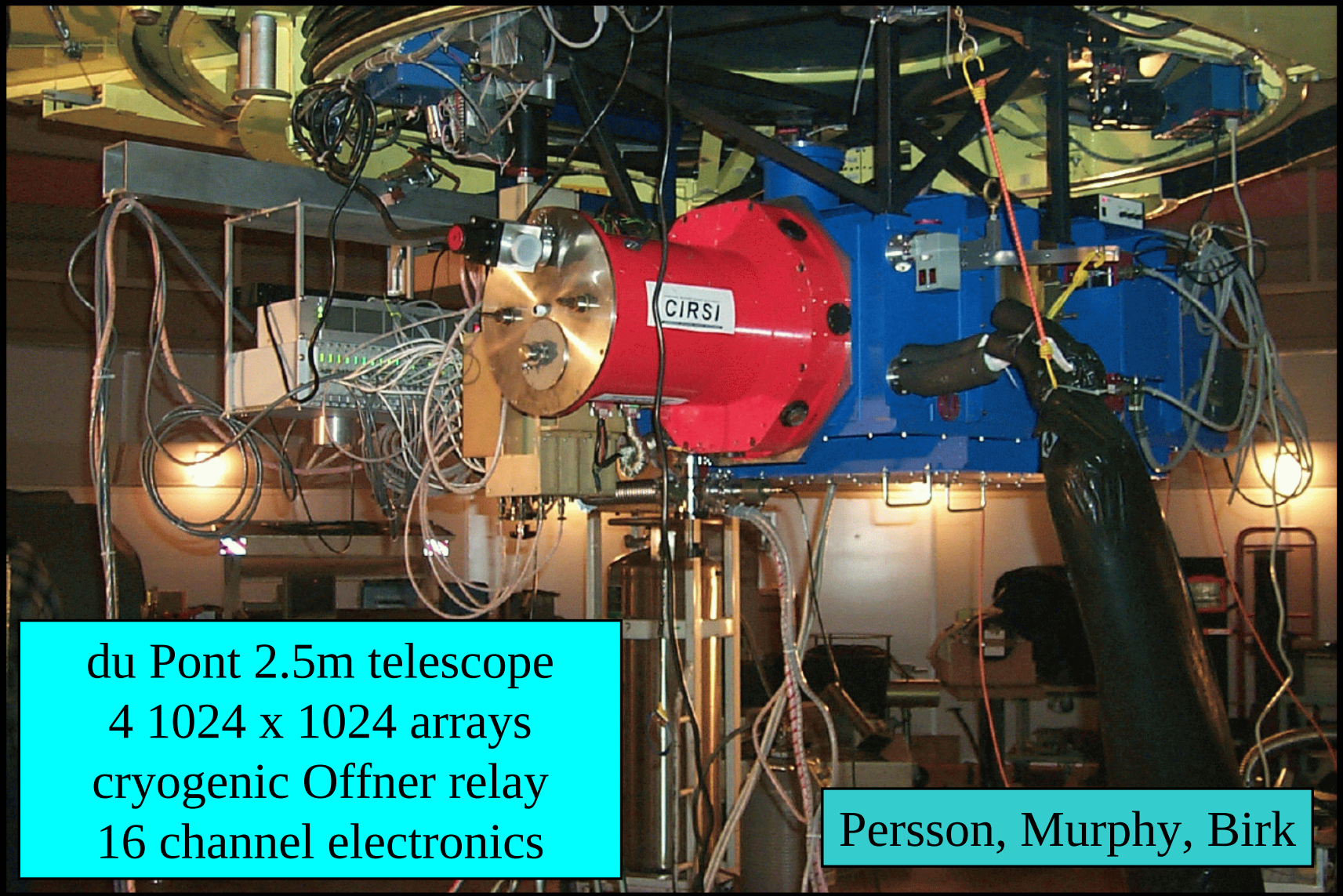
50% of massive galaxies are post-starburst

Systems at z ~ 1 !

Massive Post Starburst Galaxies

Intermediate Mass Galaxies had their star formation truncated at z ~ 1.5

CIRSI + LCO Wide Field IR Camera



du Pont 2.5m telescope
4 1024 x 1024 arrays
cryogenic Offner relay
16 channel electronics

Persson, Murphy, Birk

Post-Starburst Galaxies

Le Borgne et al.