Star Forming Galaxies at z=0.8: an Hα approach

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Villar et al 2008 (ApJ 677, 169)
Villar et al 2011 (arXiv: 1107.4371)

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Motivation

- z=0 Local Universe
  - Ellipticals and Spirals in place
  - Decrease in the cosmic SFR density

- z~1 Universe in transition
  - Ellipticals and Spirals still forming
  - The SFRd starts to decrease

- z~2 Primeval Universe
  - Formation of Hubble types
  - Maximum of SFRd and QSO activity

Region at z~0.8 is excellent to study the transition between the Universe at high-z and the local Universe

What is the SFRd in this transitional epoch?

How and where is the Star Formation taking place?

The Hα approach

Samples of Hα-selected star-forming galaxies

- ☑ Hα as an excellent CURRENT SFR tracer, AGN sensible
- ☑ Same rest-frame selection criteria
- ☑ Narrow-band → Total line fluxes. No aperture corrections
- ☑ Line selected →
  - ☑ Well defined volume
  - ☑ Complete and representative samples
  - ☑ Wide coverage in the parameters space
- ☑ Known fields → Multi-wavelength complementary data

- ❑ Evolution of the Hα-based SFR
- ❑ Properties of galaxies

Sample and Data

- **Extended Groth Strip**

  CAHA 2004/2006: Groth2/Groth3
  - Two fields; FOV 15' x 15'
  - Lim. flux cgs:

    Groth2: $12 \cdot 10^{-17}$ Groth3: $8 \cdot 10^{-17}$

- **GOODS-North Field**

  CAHA 2006: HDFN
  - One field; FOV 15' x 15'
  - Lim. flux cgs: $15 \cdot 10^{-17}$

Total area explored ~625 arcminutes^2

- Final sample of 165 Hα emitters, 94 (57%) confirmed by spectroscopy.

- **Multi-wavelength data**

Optical to nIR:

EGS: *ugrizBRIJK* ; GOODS-N: *UBVRIzHKs*

Spitzer: *IRAC* y *MIPS* 24μm

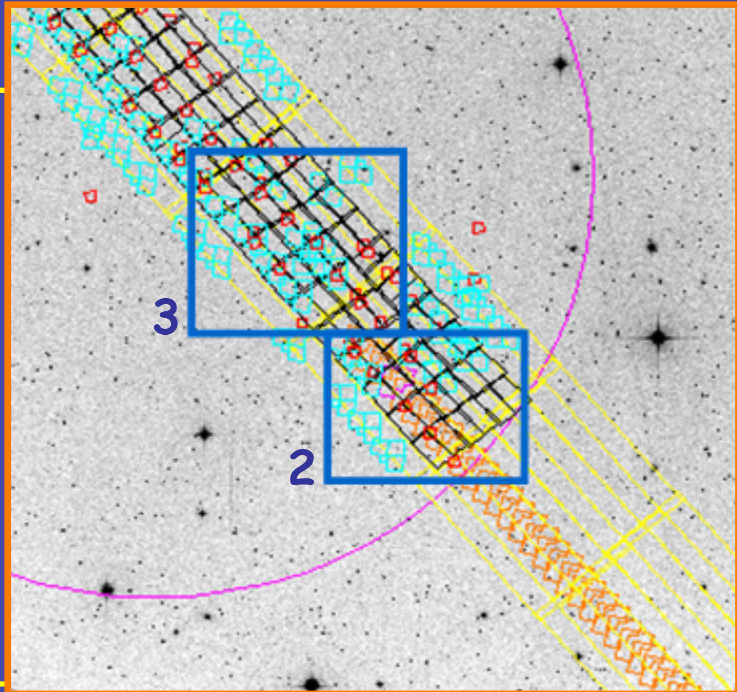
Galex: *FUV* y *NUV*

HST ACS: EGS: *vi* ; GOODS-N: *bviz*

Optical spectroscopy:

EGS:~15,000 sources

GOODS-N:~1,500 sources

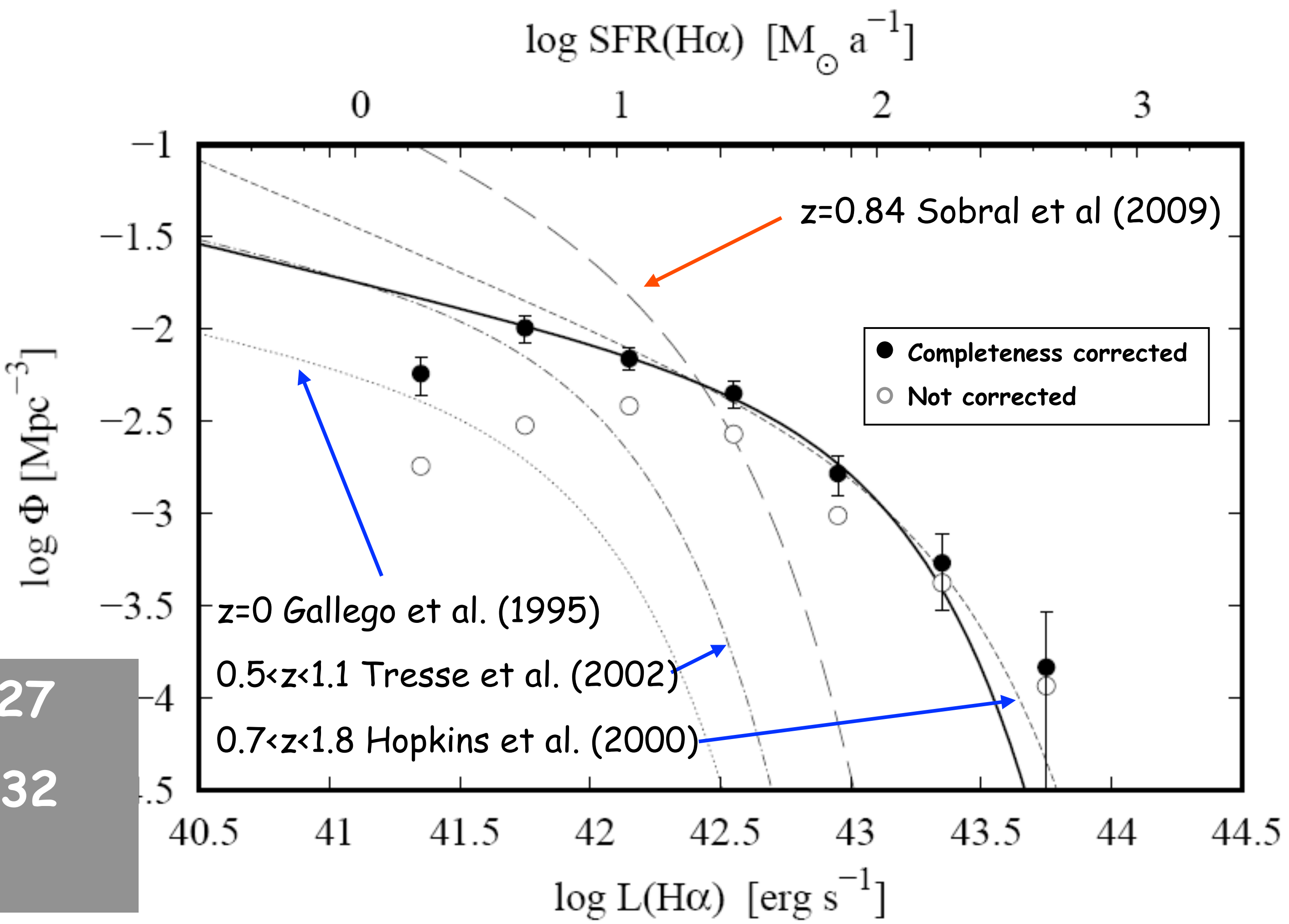


Hα Luminosity Function

Luminosity function: extinction and completeness corrected.

Villar et al. (2008)

- V/V_{MAX} Method (Schmidt, 1968)
- Completeness corrected
- Extinction corrected
- Field to field variance corrected



$\log L^* = 43.03 \pm 0.27$

$\log \varphi^* = -2.76 \pm 0.32$

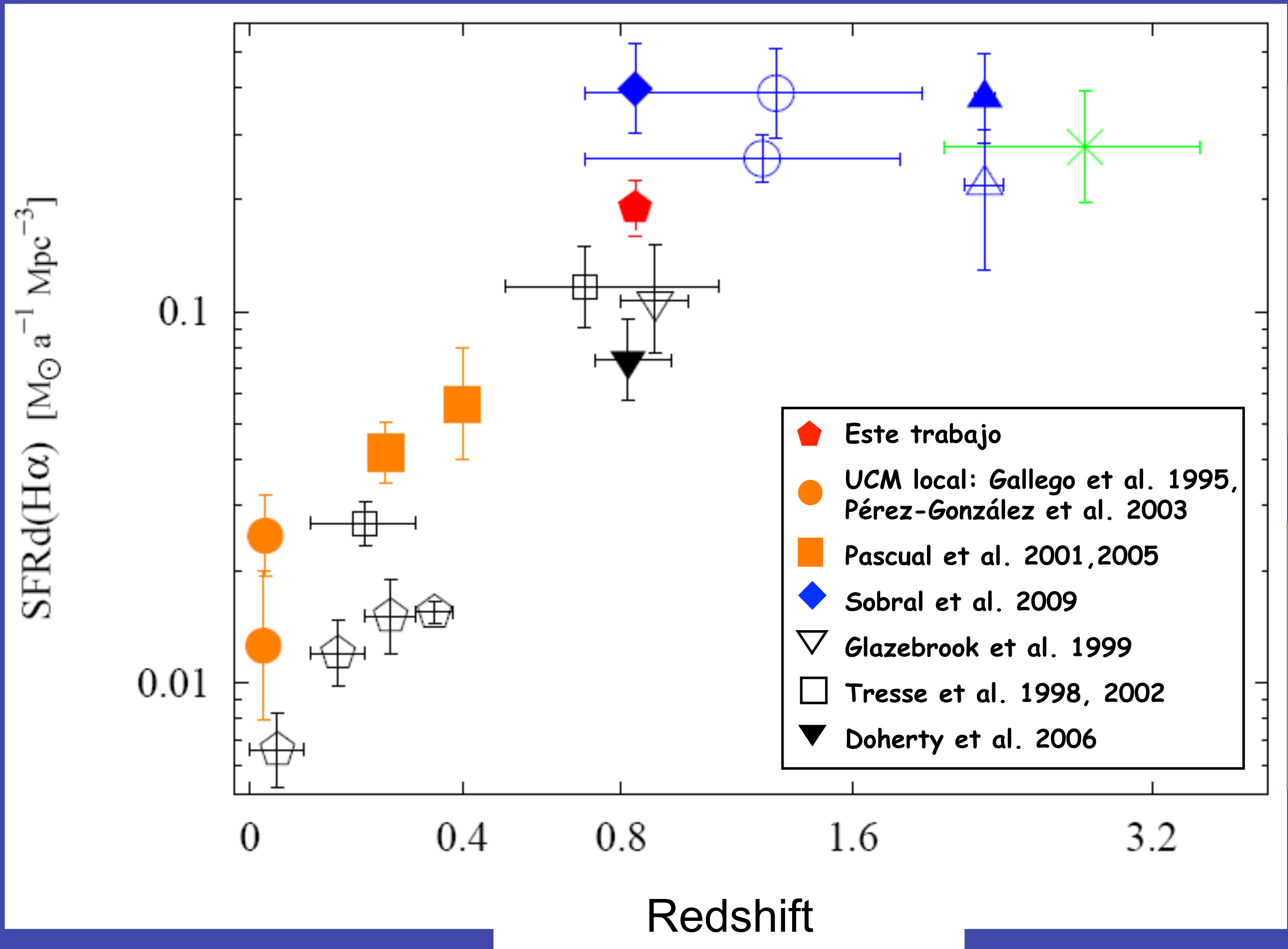
$\alpha = -1.34 \pm 0.18$

Hα Star Formation Rate Density

- From the luminosity function → luminosity density

Villar et al. (2008)

$$\mathcal{L} = \int_0^\infty L\phi(L)dL = \phi^* L^* \Gamma(\alpha + 2)$$



The star formation rate density is $0.19 \pm 0.03\ M_\odot yr^{-1}\ Mpc^{-3}$, ~10 times higher than in the local Universe

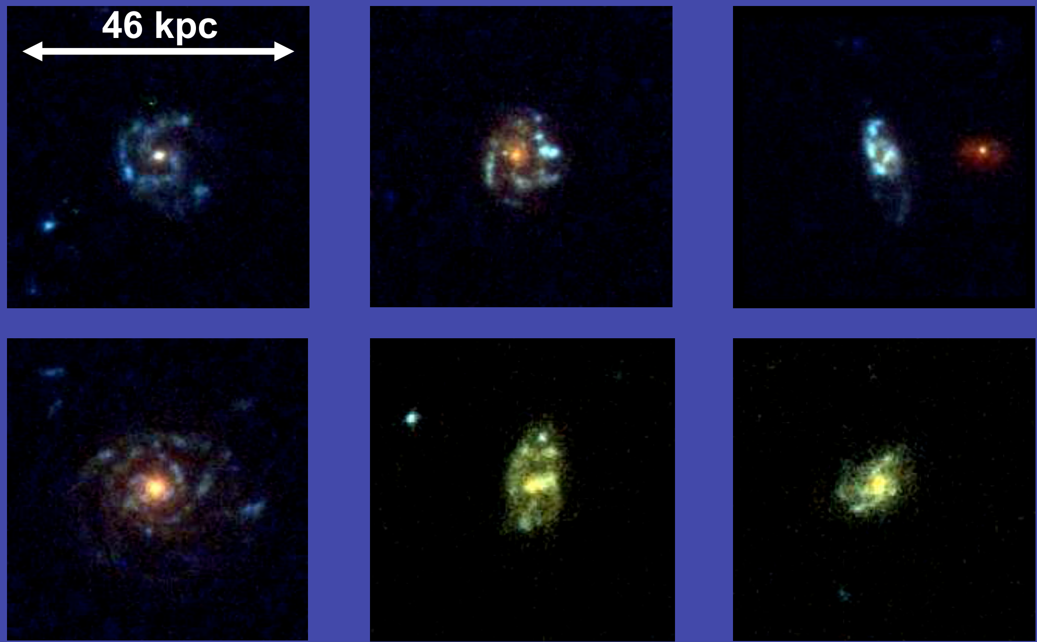
Evolution of the star formation rate density:

$\propto (1+z)^\beta$ $\beta = 4.0 \pm 0.5$

Properties: Morphology

Visual clasification of 91 objects observed with ACS

Disk/Spiral: 67%



Merger: 8%

Irregular/Compact: 19%

Spheroidal: 2%

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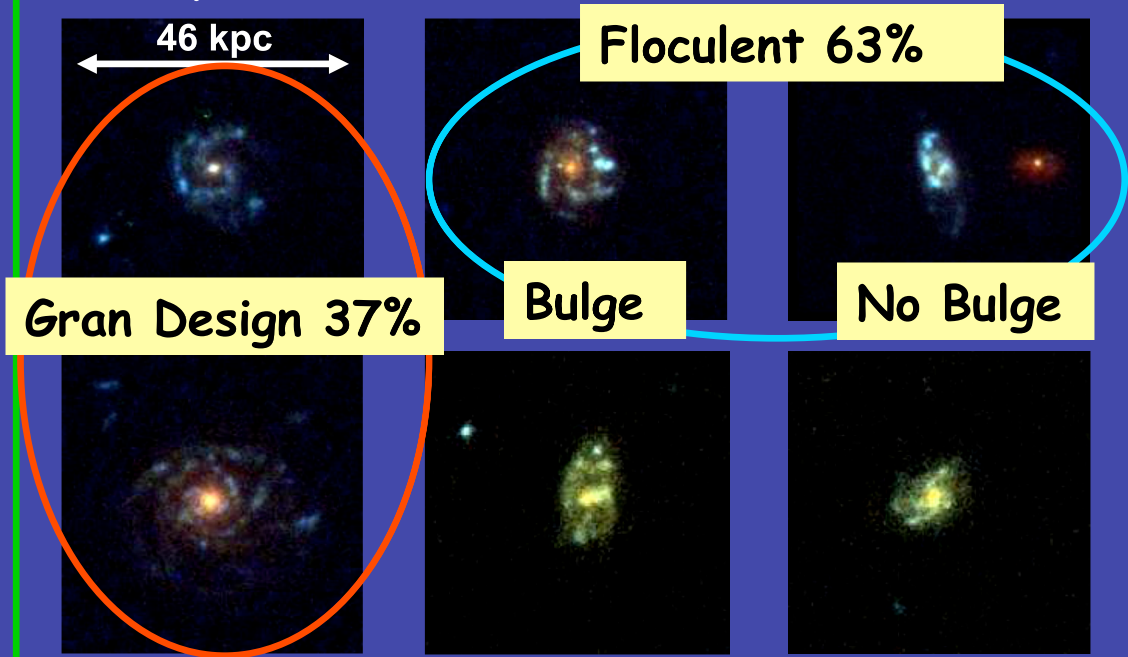

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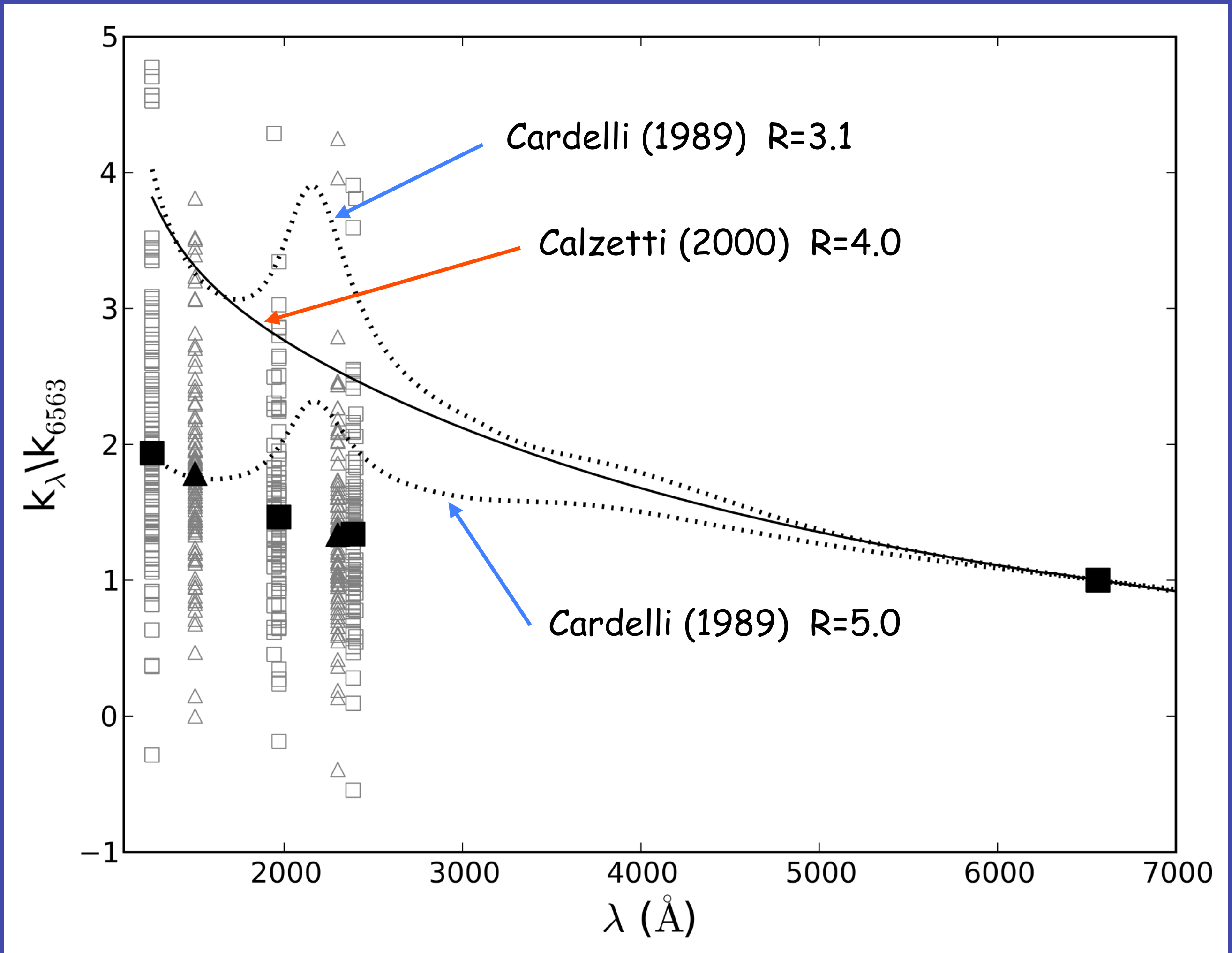
Extinction Law & Star Formation

A check on the extinction law

- Assuming that SFR(UV)=SFR(Hα)=SFR(IR).
- This allows us to "sample" the extinction law.



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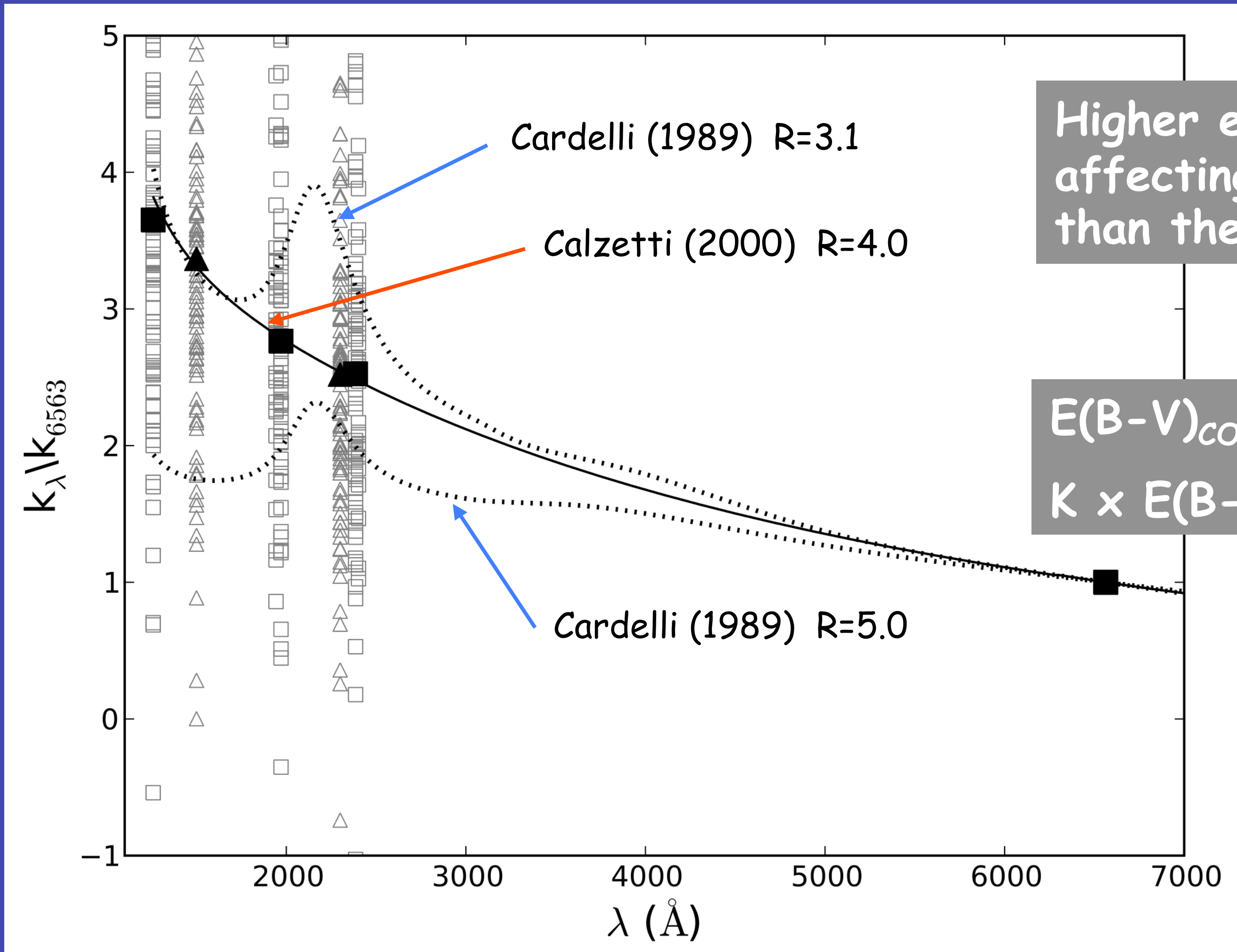

Higher extinction affecting the gas than the stars.

$E(B-V)_{CONTINUUM} = K \times E(B-V)_{GAS}$

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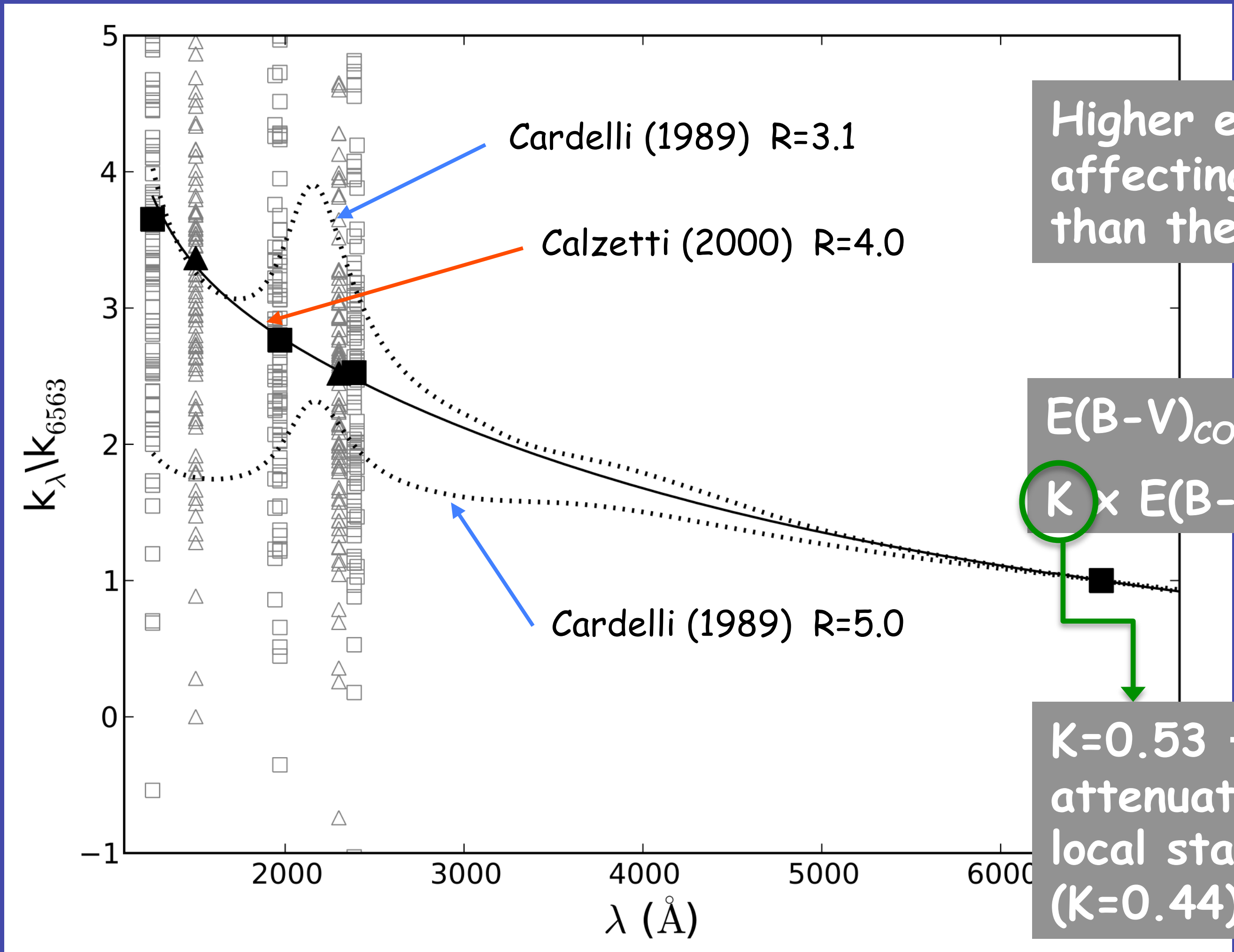

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K=0.53 → gas less attenuated than in local starbursts (K=0.44)

Extinction Law & Star Formation

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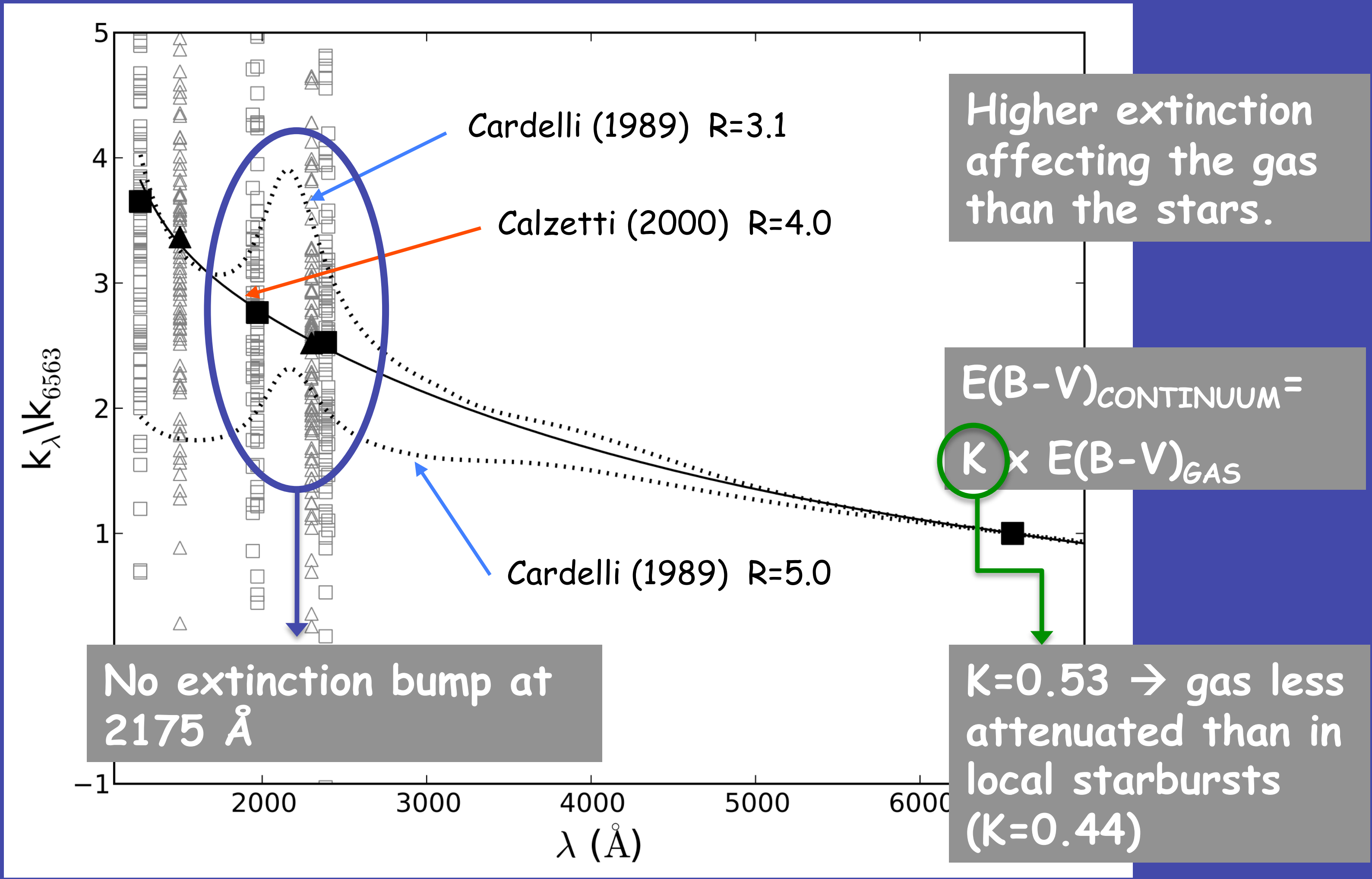
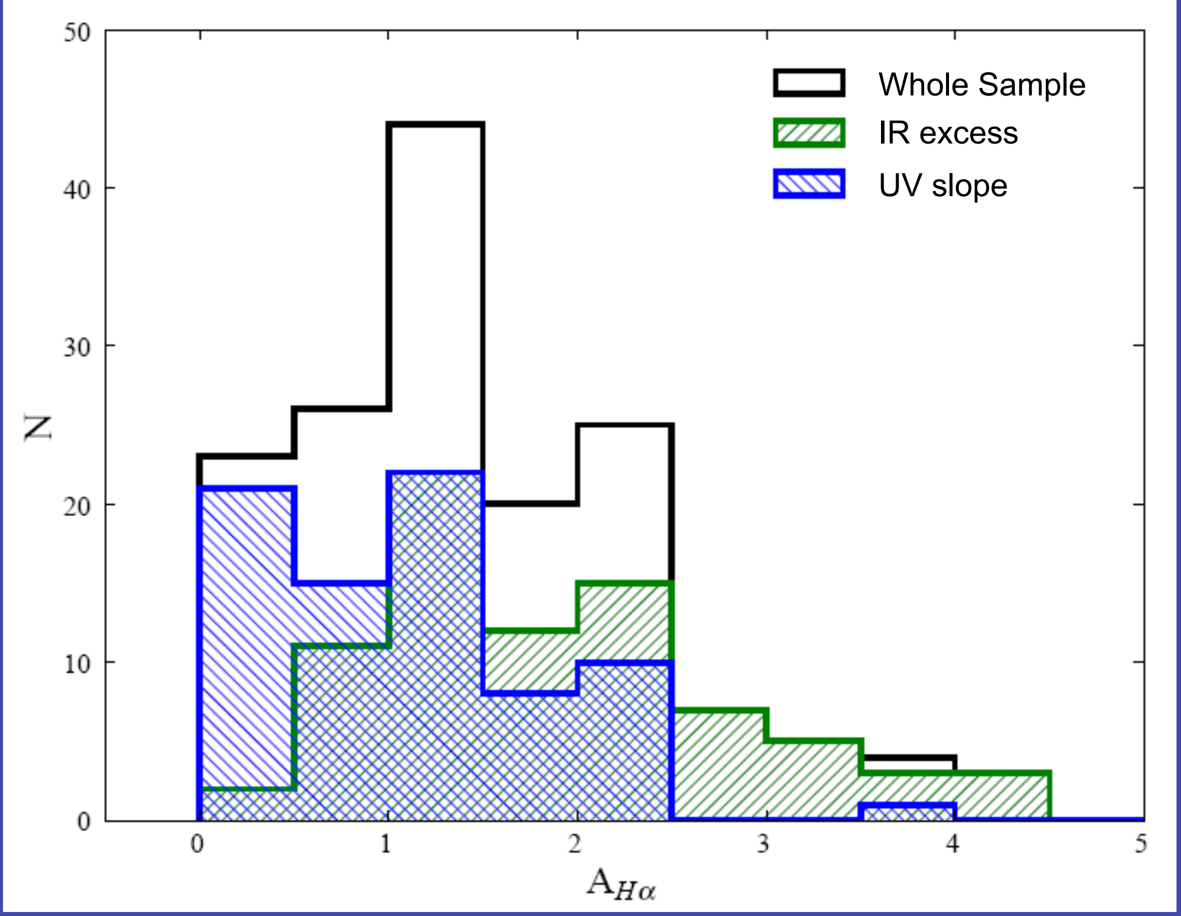


Extinction

- F_{dust}/F_{FUV} as indicator of the dust obscuration (Buat et al. 2005).
- Galaxies with no MIPS detection: UV slope.
- We obtain A(Hα) through A(FUV) and the Calzetti et al (2000) law
- A(Hα)~1.5 mag. on average at z=0.84 (Villar 2008; Garn 2009)
- A(Hα)~1 mag. in the local Universe (Gallego et al 1995; Brinchmann et al 2004)

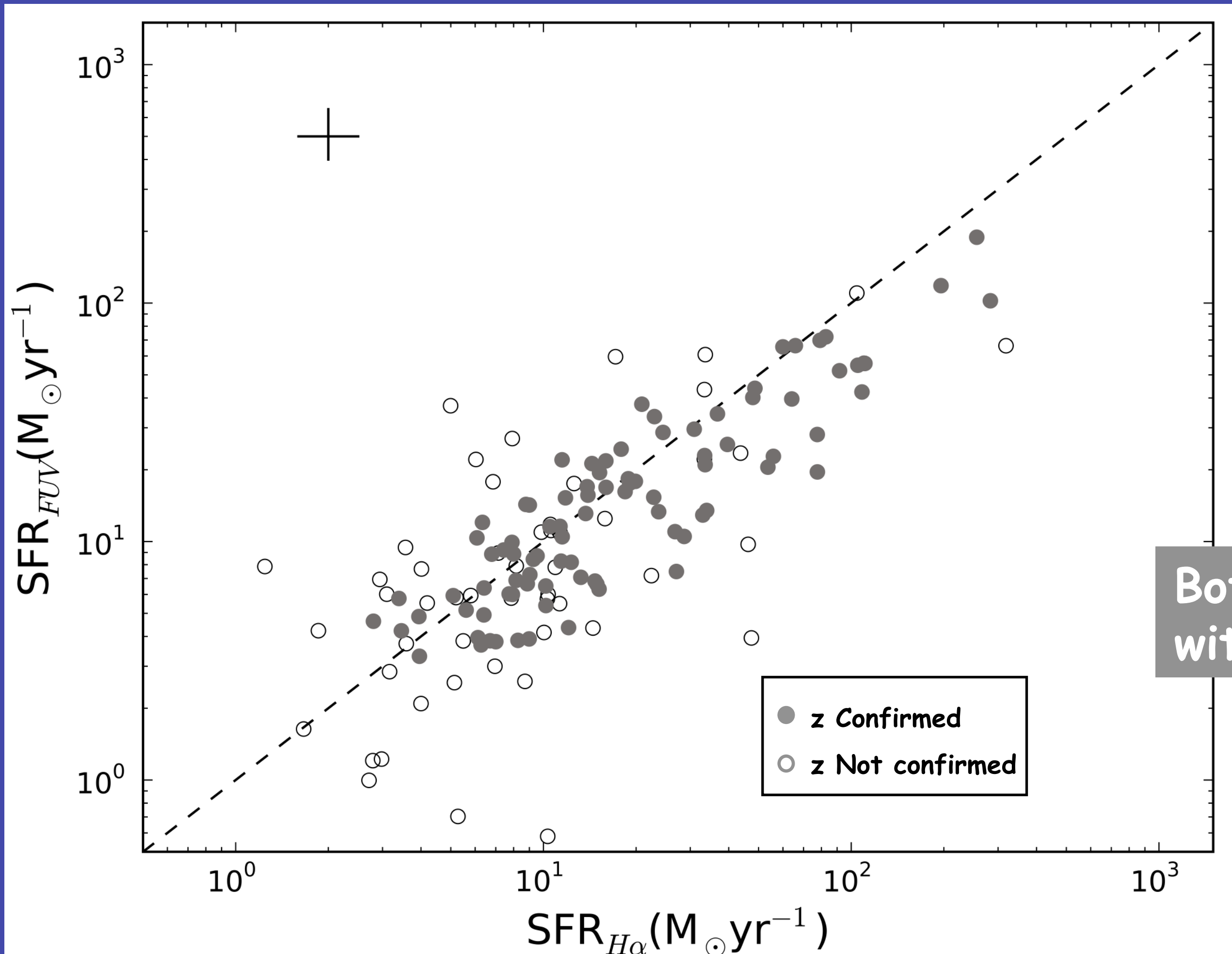
Star forming galaxies at z=0.84 have extinctions ~0.5 mag. higher than those at the local Universe.



Star Formation

Comparison of tracers: UV vs. Hα

- L_{FUV} obtained from the SED fits
- Both tracers are extinction corrected

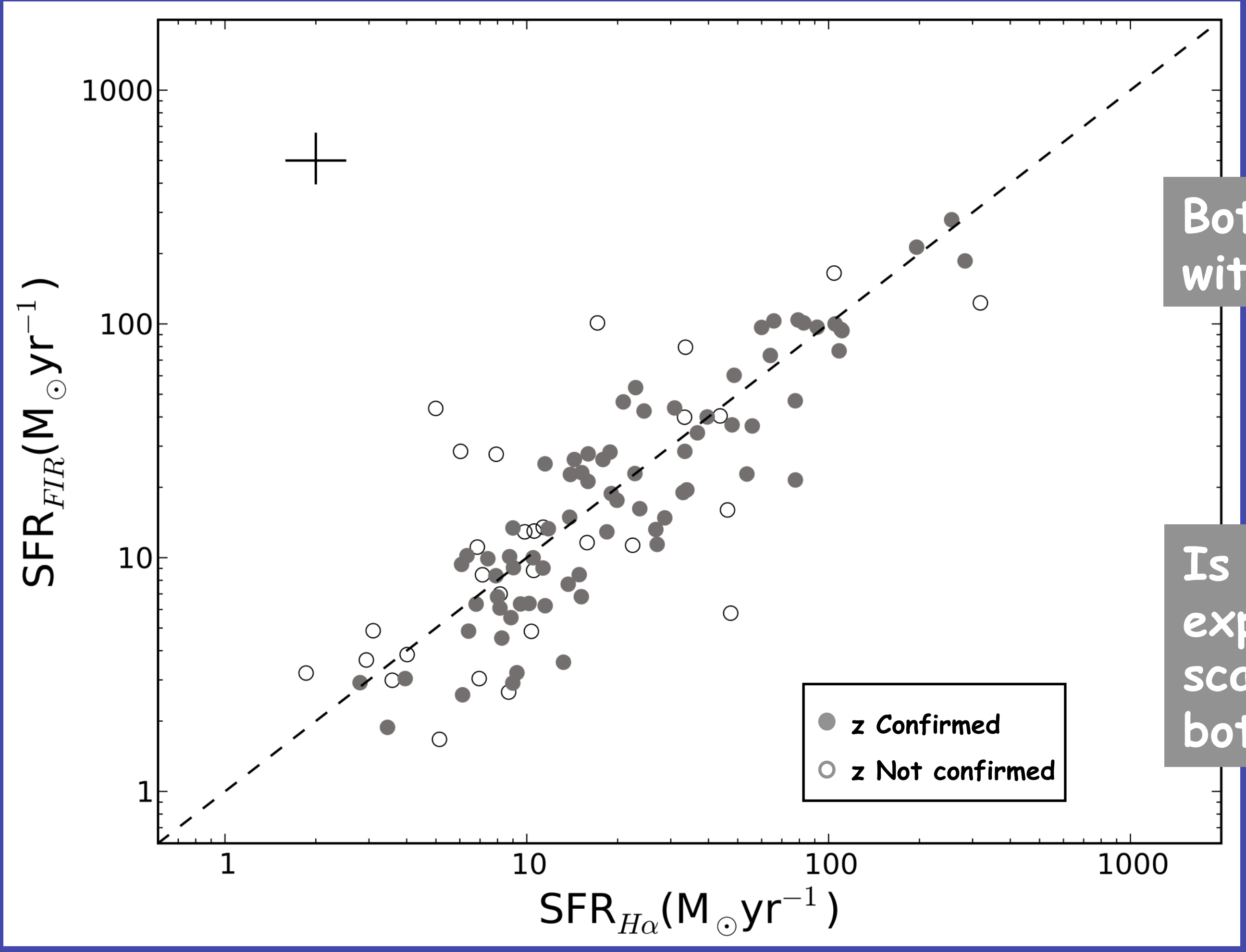


Both tracers agree within a factor of ~3

Star Formation

Comparison of tracers: IR vs. Hα

- L_{IR} obtained through MIPS
- Hα tracer extinction corrected



Both tracers agree within a factor of ~3

Is there any reason to explain the observed scattering between both tracers?

Star Formation

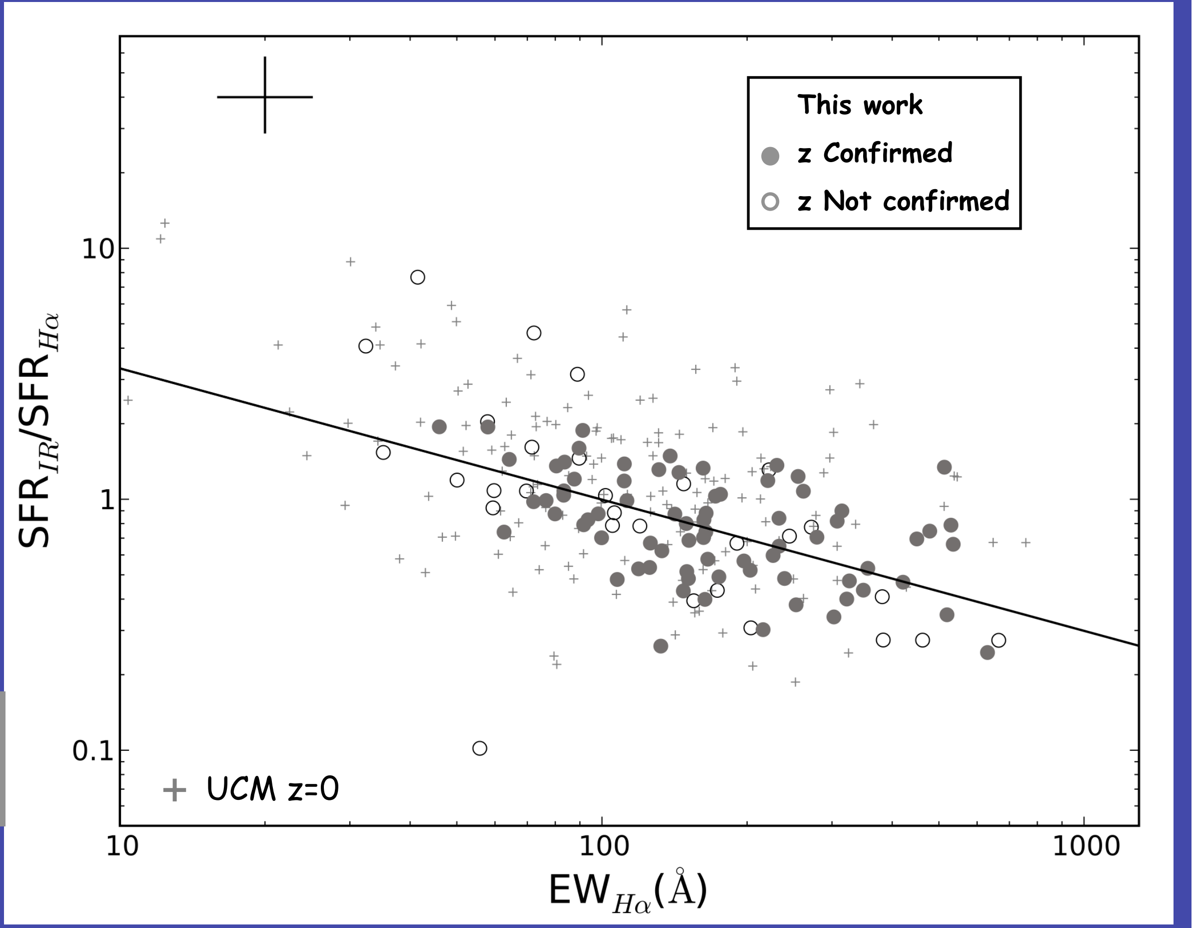
Scattering among tracers

- UV and IR calibration depend on the star forming regions age
- EW(Hα) tells us the weight of the young over the evolved population. (Pérez-González et al. 2003)

Part of the scattering could be explained due to difference in the age of galaxies.

There exists a similar correlation among SFR_{UV}/$SFR_{H\alpha}$ and EW(Hα)

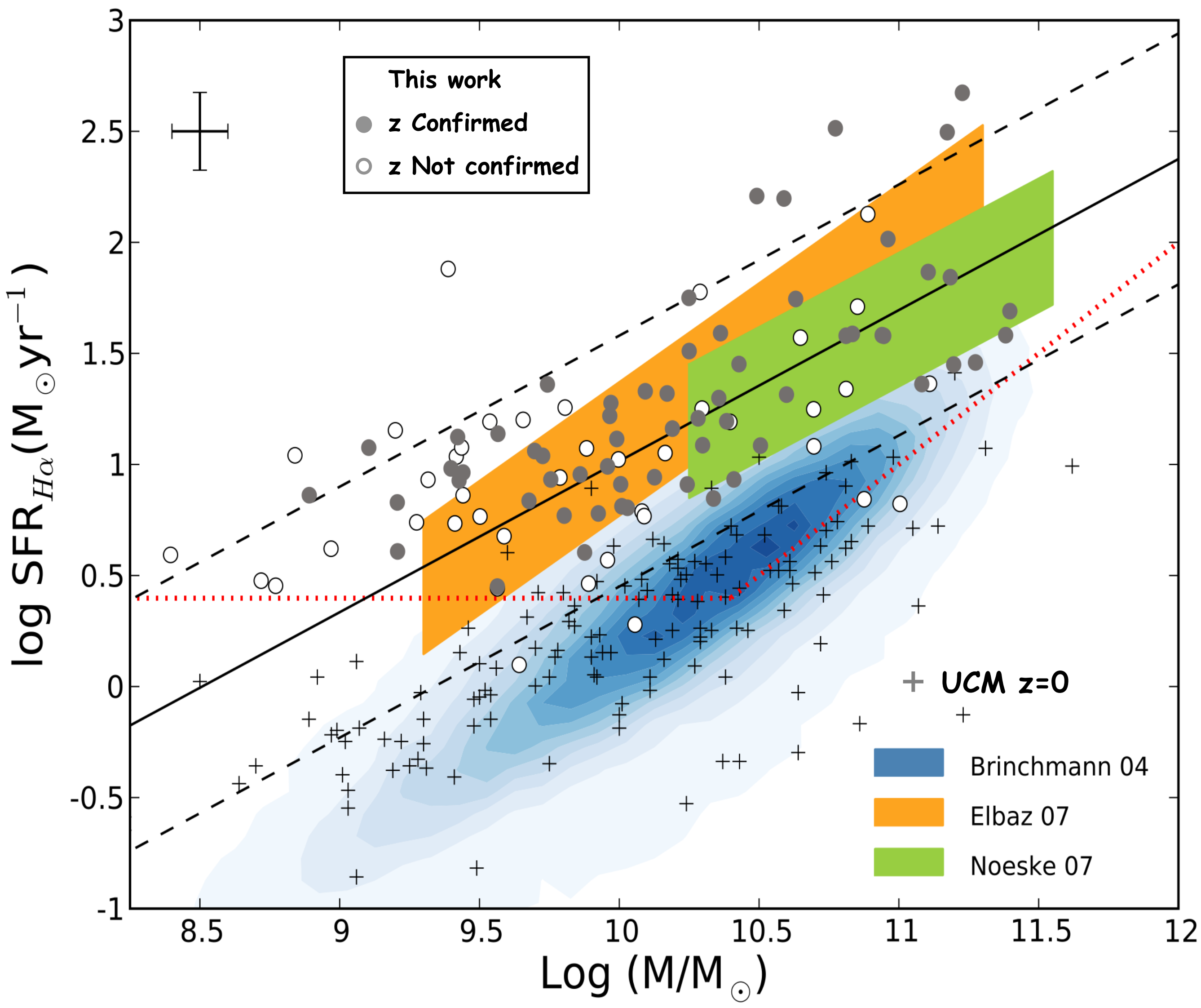
The effect is similar in the local Universe



Stellar Mass

The star formation and stellar mass are correlated

Slope in good agreement with other samples (Noeske et al. 2007)



Stellar Mass

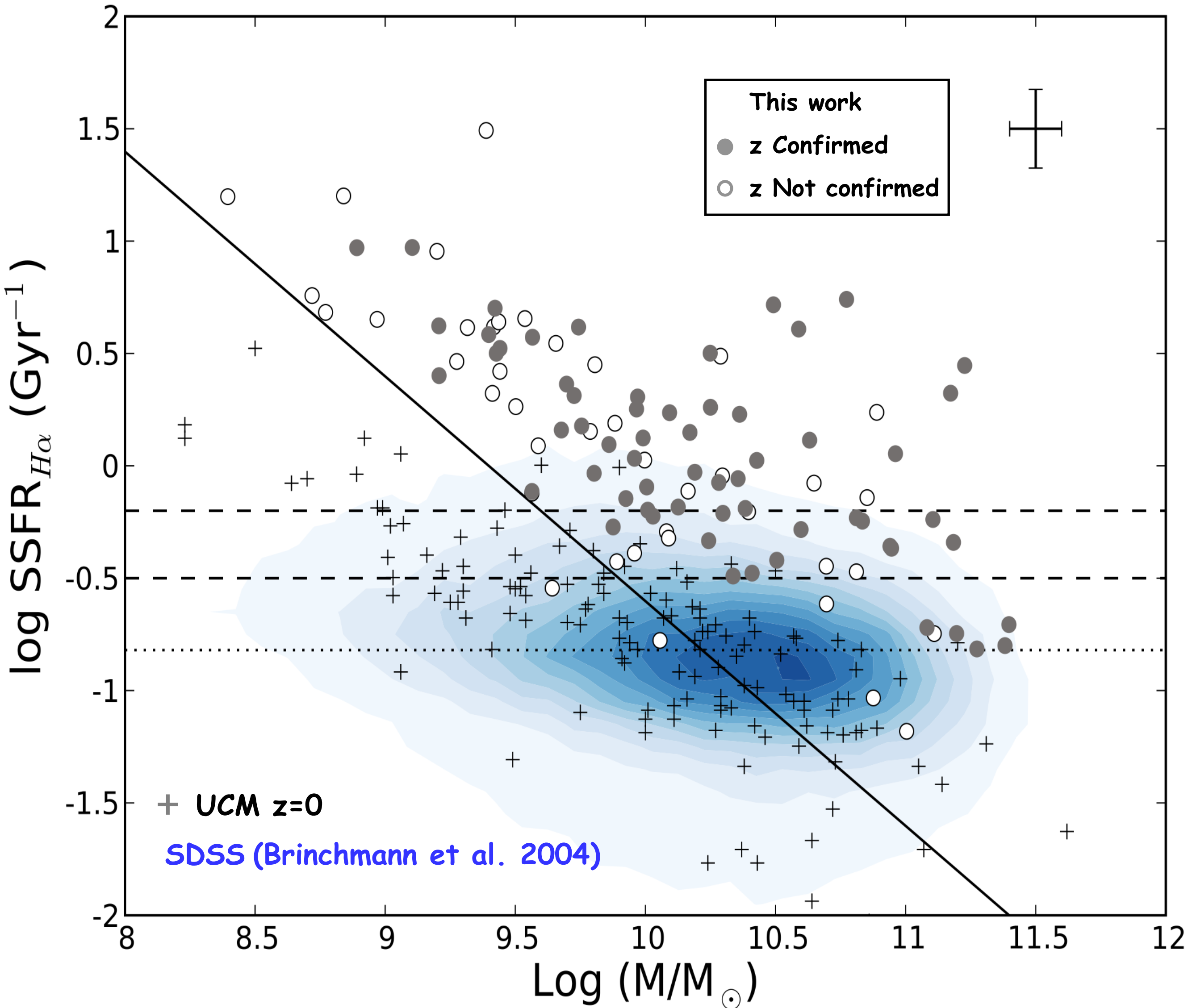
The star formation and stellar mass are correlated

Slope in good agreement with other samples (Noeske et al. 2007)

The mass and specific star formation rate are anti-correlated

Galaxies at z~0.84 have higher SSFR than the local ones at the local Universe

Observational evidence of ***Downsizing***



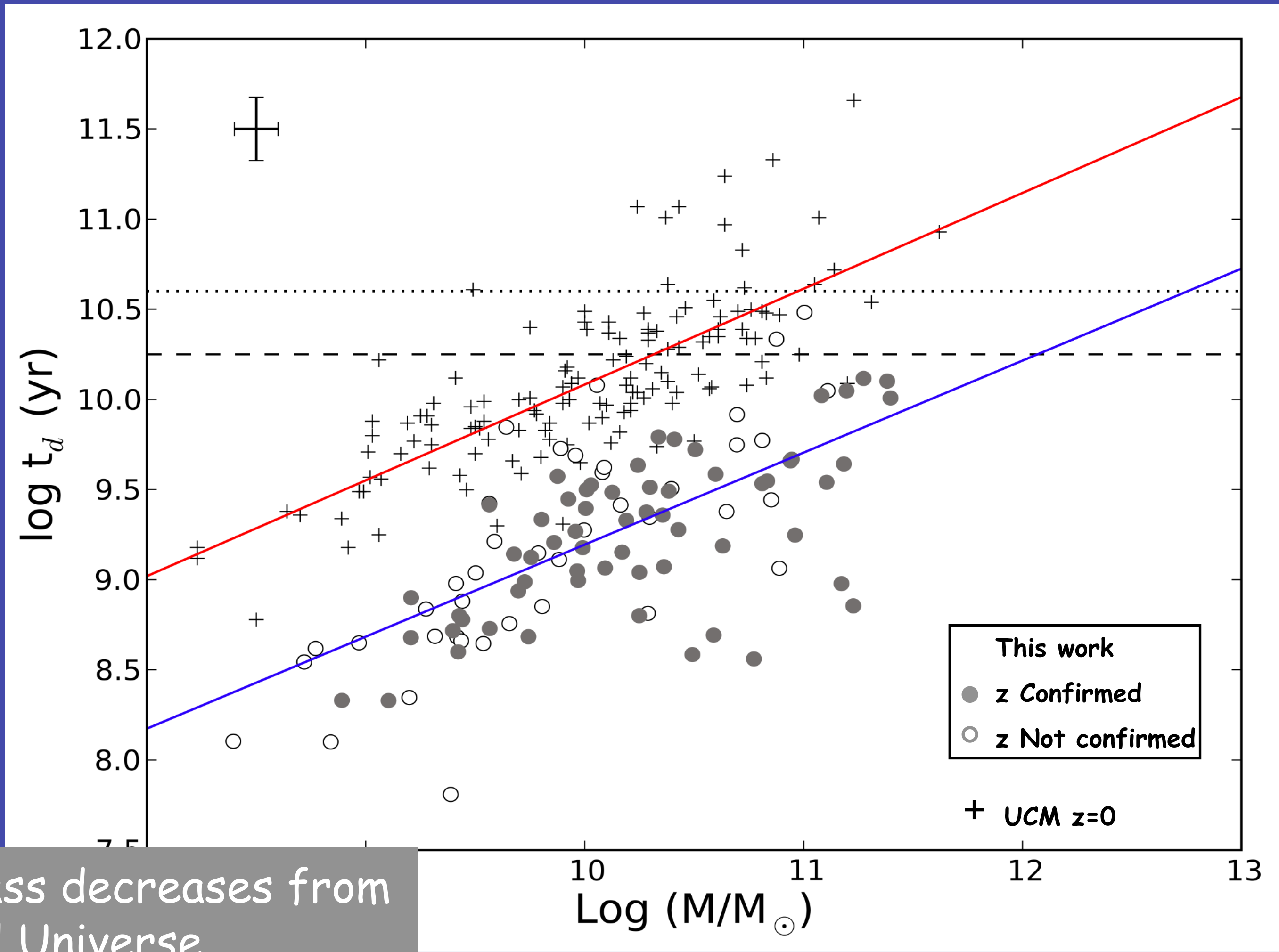
Quenching Mass

Doubling time t_d = $[SSFR \times (1-R)]^{-1}$

Quenching time t_Q
→ $t_Q = 3 \times t_H$

Quiescent galaxy if
$t_d > t_Q$

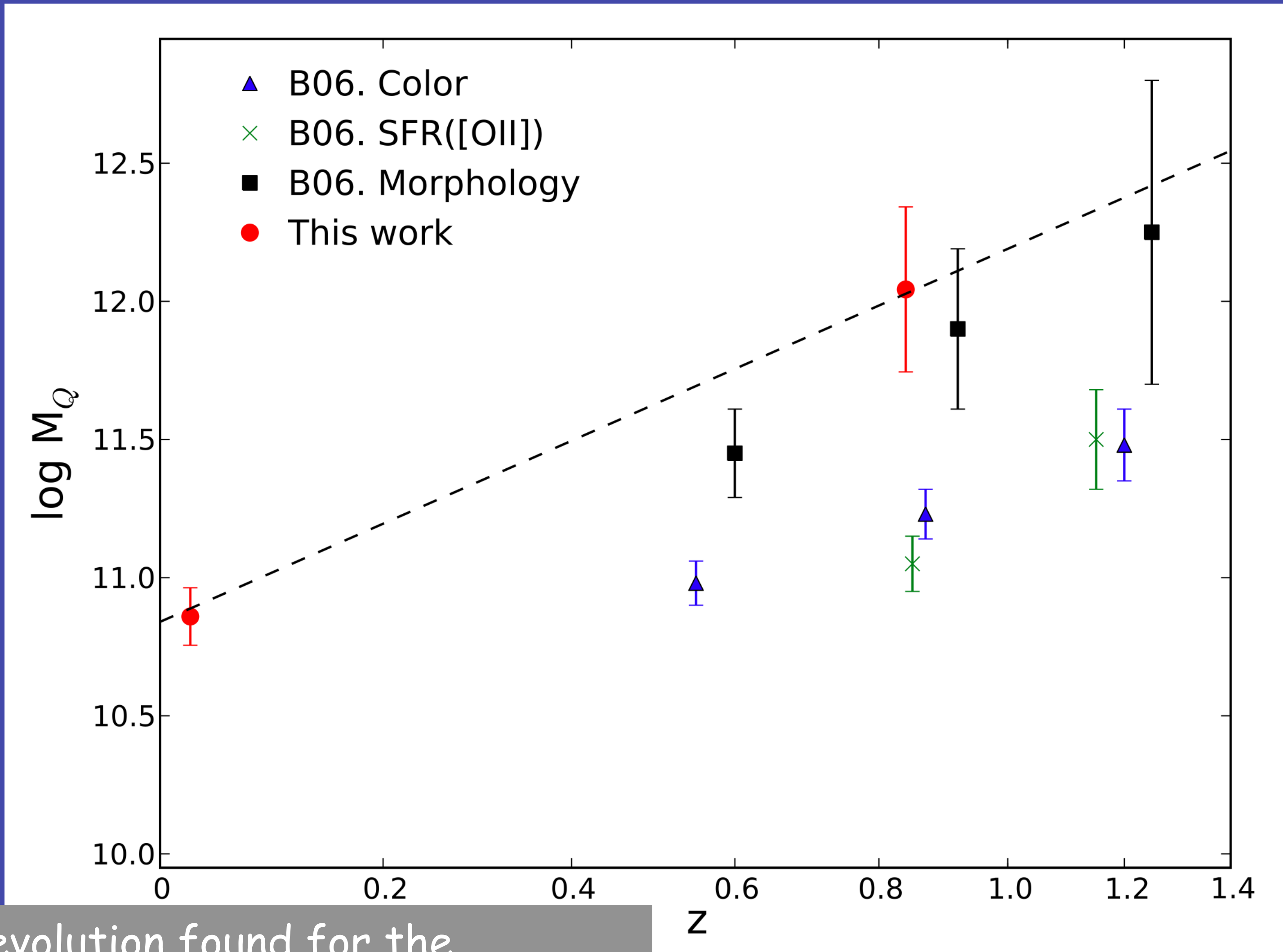
UCM Sample (z=0)
$M_Q \sim 8 \times 10^{10}\ M_\odot$
z=0.84 sample
$M_Q \sim 1.3 \times 10^{12}\ M_\odot$



The Quenching Mass decreases from z=0.84 to the local Universe
→**Downsizing**

Quenching Mass evolution

(Bundy et al. 2006)



The evolution found for the Quenching Mass is compatible with that found by Bundy et al (2006)

Conclusions

- Villar et al 2008 (ApJ 677, 169)
  Villar et al 2011 (arXiv: 1107.4371)

- The extinction properties agree with the Calzetti extinction law with $E(B-V)_{stars} = 0.53 \times E(B-V)_{gas}$. No 2175Å bump.

- The SFRs agree within a factor x3. The weighted age of the galaxy correlates with the discrepancy between tracers.

- There is a correlation between SFR and stellar mass. The SFR moves from more massive objects to less massive ones when we move from the local Universe to z~0.84 → *DOWNSIZING*

- We estimated an upper limit to the quenching mass $M_Q \sim 10^{12}\ M_\odot$, an order of magnitude higher than in the local Universe.

- Future work: MOSFIRE/Keck and EMIR/GTC