The Lowest Mass Galaxies at Cosmic High Noon

The Redshift One LDSS3 Emission line Survey

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I. Baldry, G. Davies, G. Hau, I-H. Li, P. McCarthy, M. Sawicki

(the "ROLES" collaboration)

ROLES

Gilbank et al. 2010a MNRAS 405, 2419

Survey Method and SFRD results

Gilbank et al. 2010b MNRAS 405, 2419

Empirical (mass-dependent) correction to [OII] SFRs

Gilbank et al. 2011 MNRAS 414, 304

sSFR—mass and SF^{ing} mass fn

ROLES-1.0

[OII] @ z~1

Ramraj, Gilbank et al. 2017 MNRAS 466, 3143

"HST Hα grism spectroscopy of ROLES: a flatter low-mass slope for the z~1 SSFR-mass relation"

ROLES-Hα

Hα @ z~1

Ongoing, w/. ZFOURGE team

ROLES-1.5

[OII] @ z~1.5

ROLES-1.0

Targets selected from GOODS-S and MS-1054 fields (deep K+multicolour photometry)

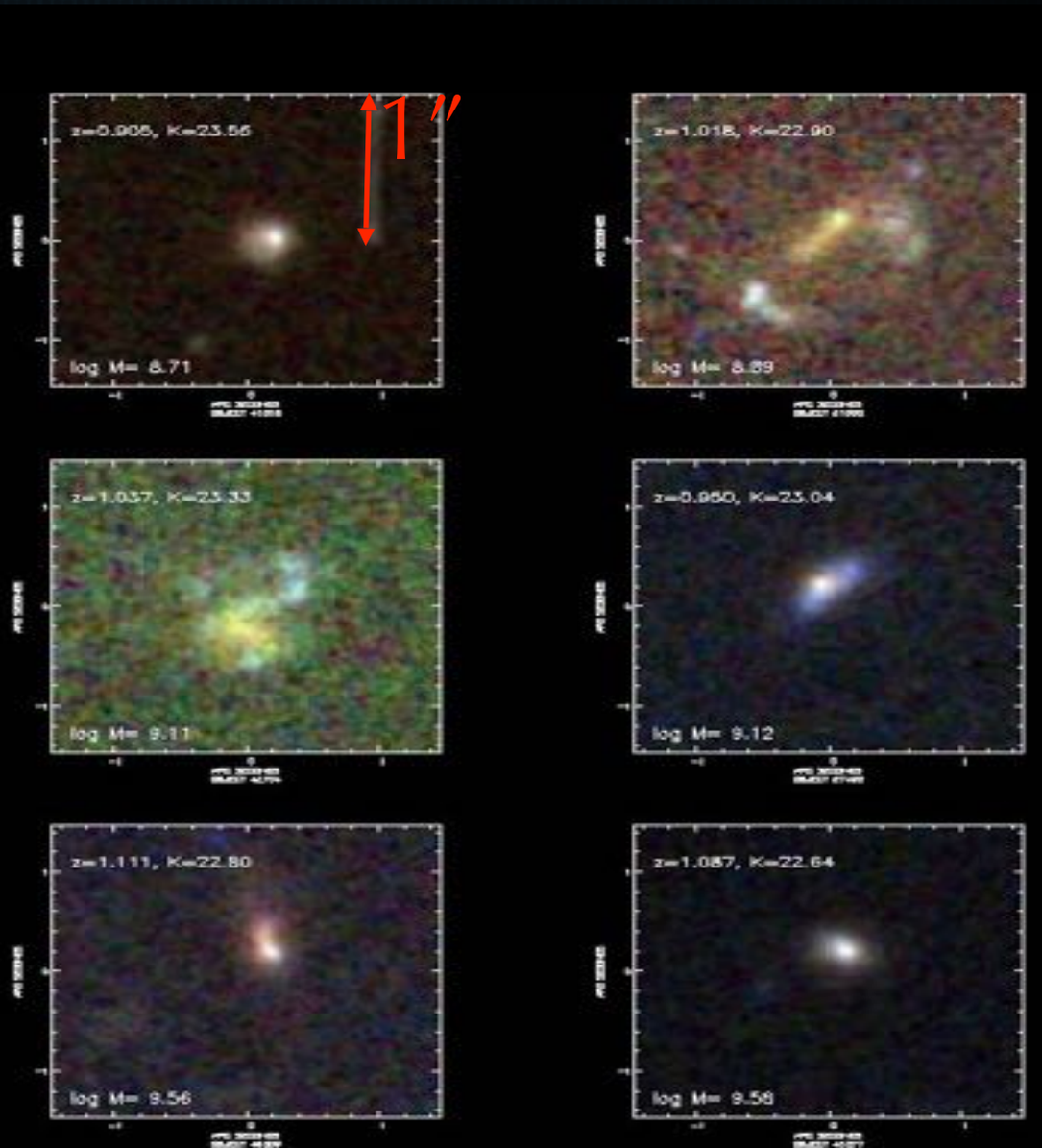
Low mass sample (ROLES):

$\log(M_*/M_\odot) \sim 8.5\text{-}9.5$

$22.5 < K_{AB} < 24.0$

photo-z to ID most probable emissions line

+ ESO public spectroscopy for higher mass galaxies



ROLES

LDSS3/6.5m-Magellan *N&S* spectroscopy

7000Å—8000Å

band-limited spectroscopy

[OII]λ3727 : $0.889<z<1.149$

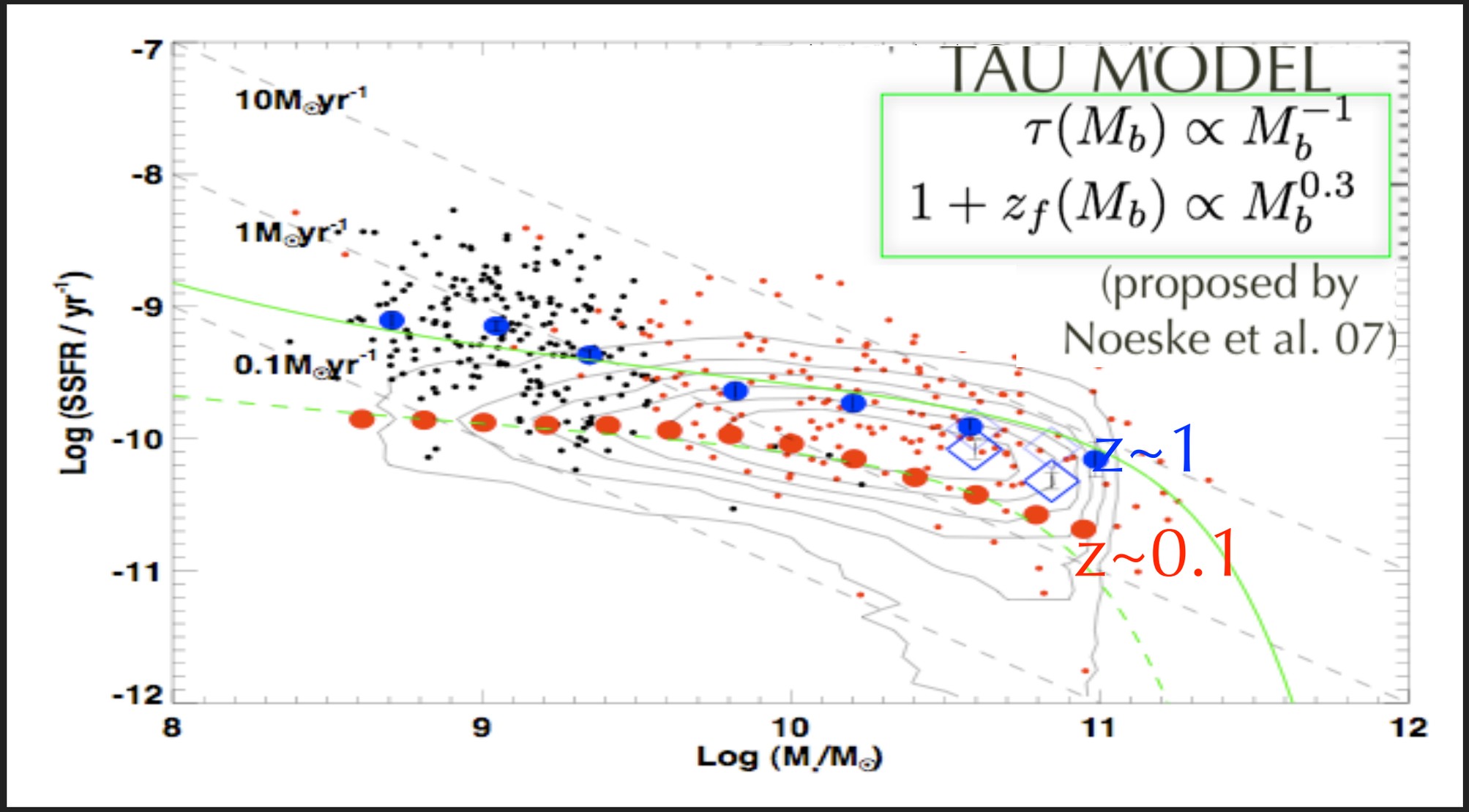
SFR from empirical, mass-dependent correction to L([OII])

285 confirmed z~1 dwarf galaxies with $SFR_{corr} \gtrsim 0.3 M_{\odot} yr^{-1}$

~200 slits per mask, 19 masks total

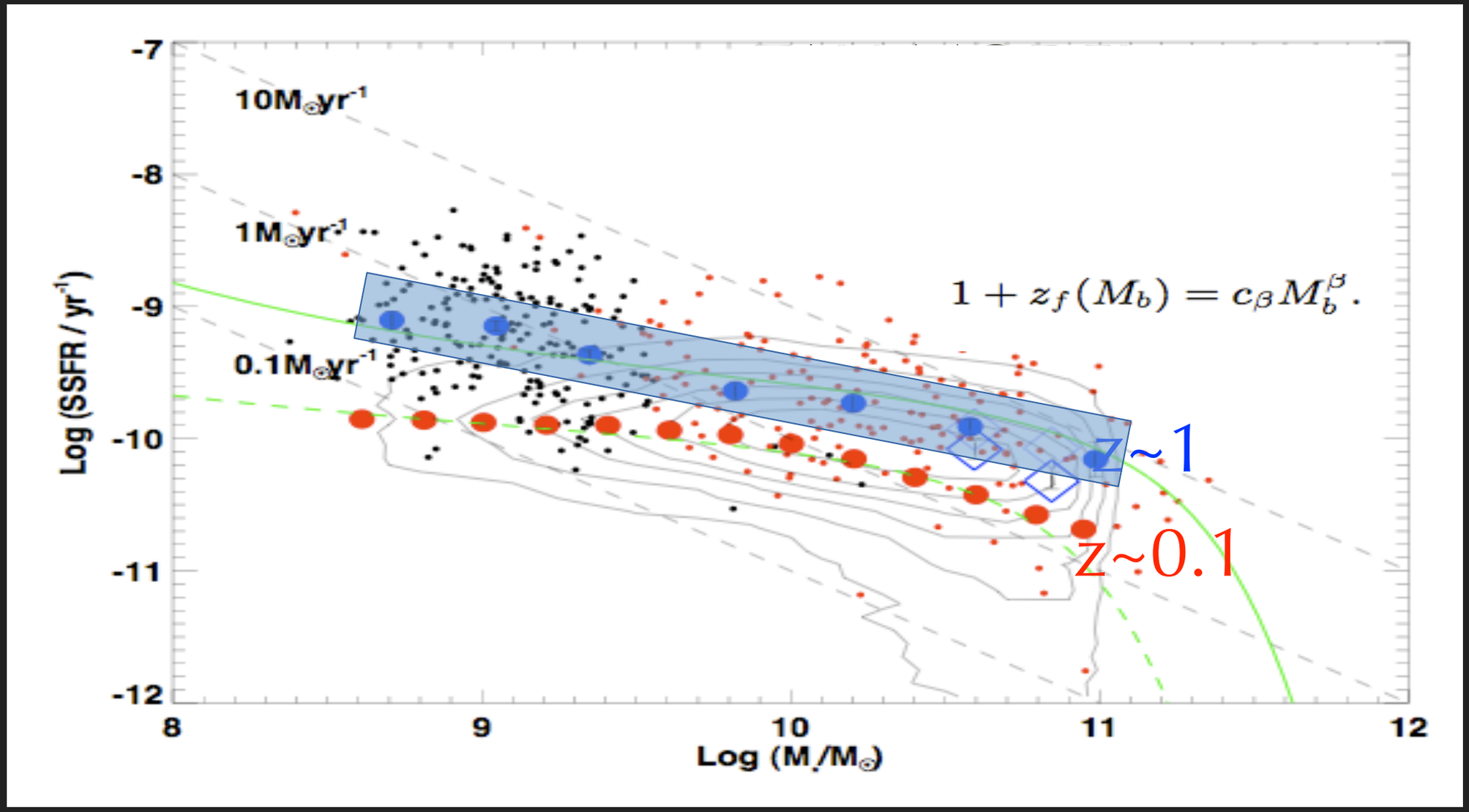
LDSS3 spectra

sSFR—M* Relation



Gilbank et al. 2011, MNRAS, 414, 304

sSFR—M* Relation



Gilbank et al. 2011, MNRAS, 414, 304

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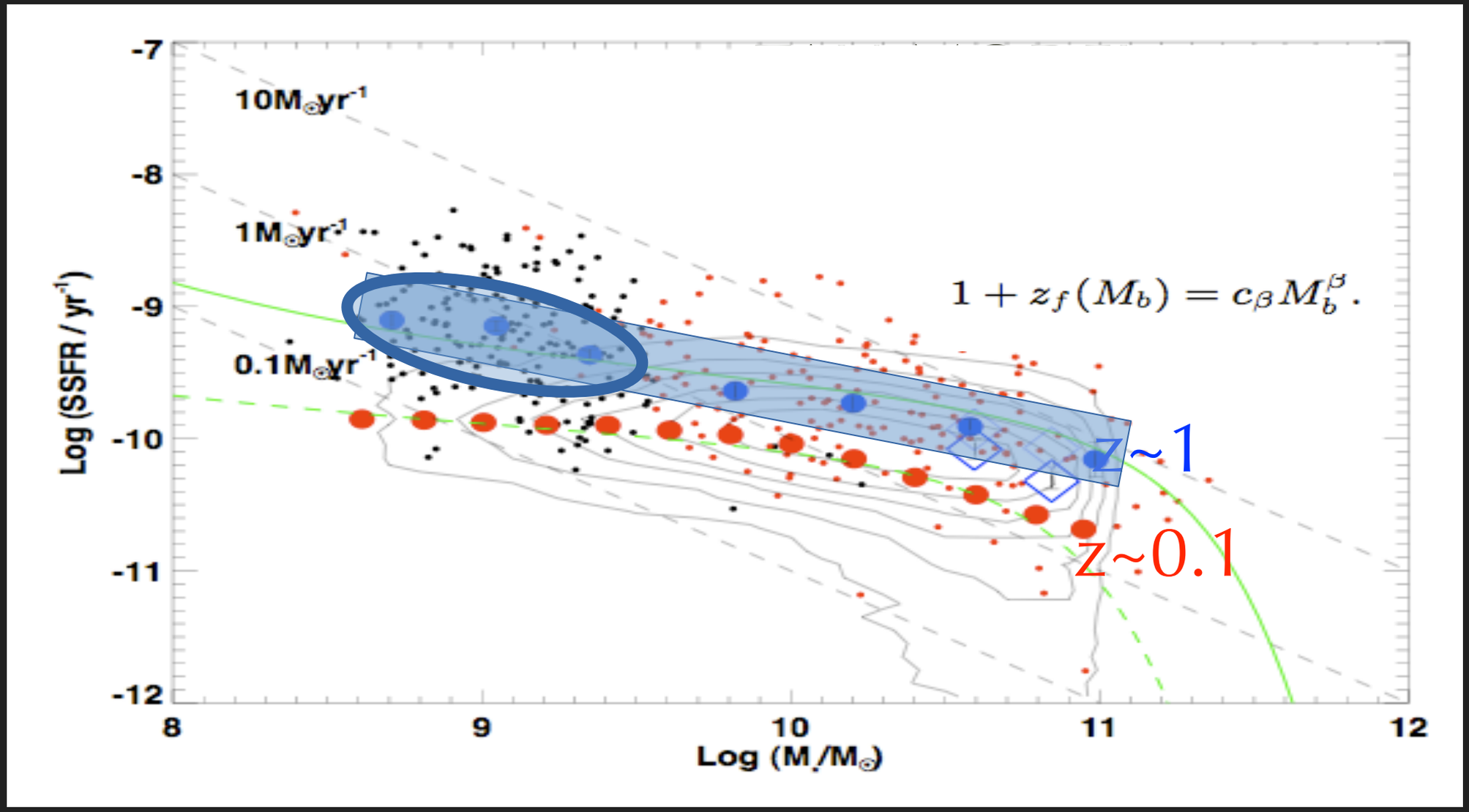
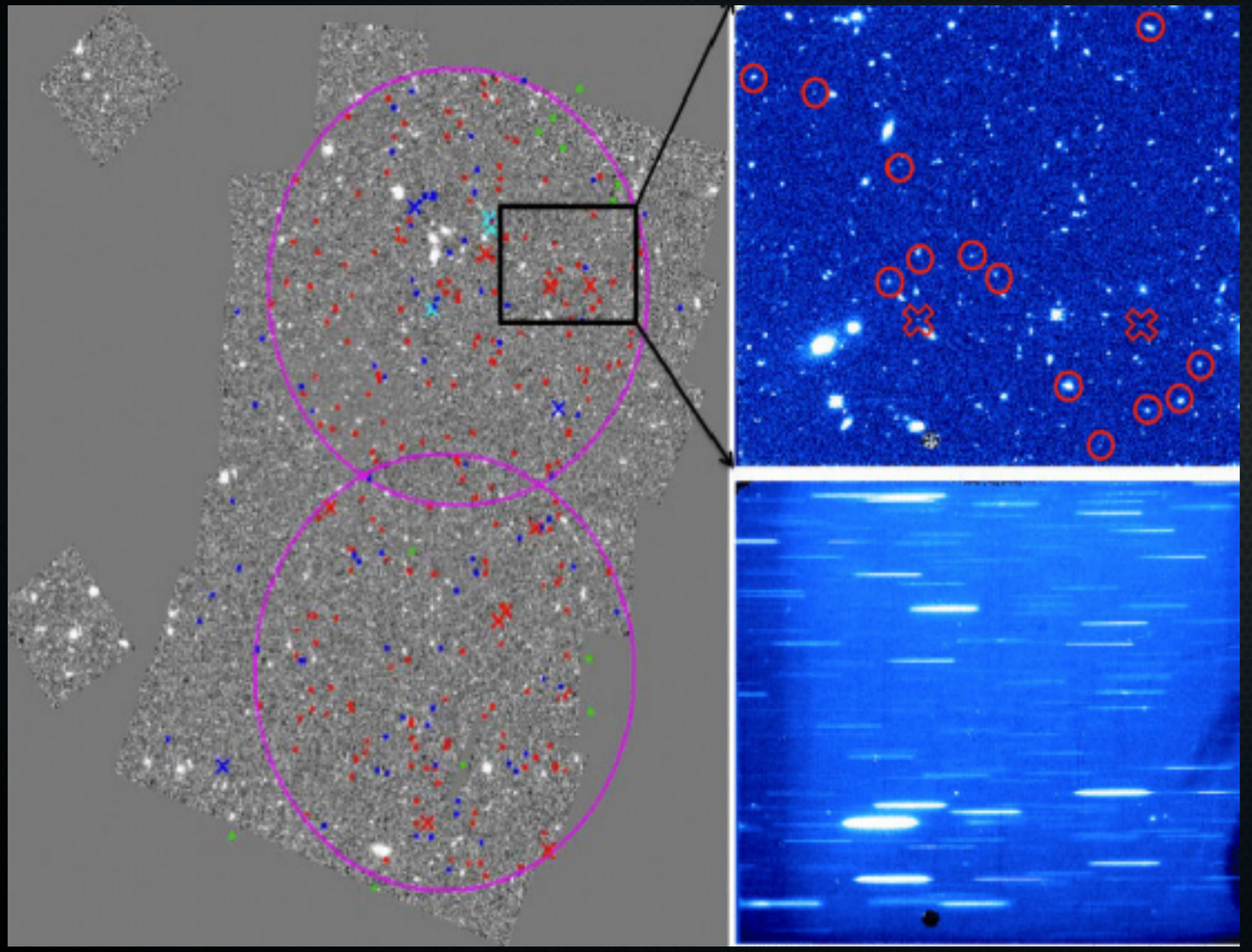


Gilbank et al. 2011, MNRAS, 414, 304

HST NIR grism spectroscopy (Hα at z~1)

Ramraj et al. 2017 MNRAS 466, 3143



Parent sample from Gilbank et al. 2010 MNRAS 405, 2419

[OII] emitters selected from GOODS-S

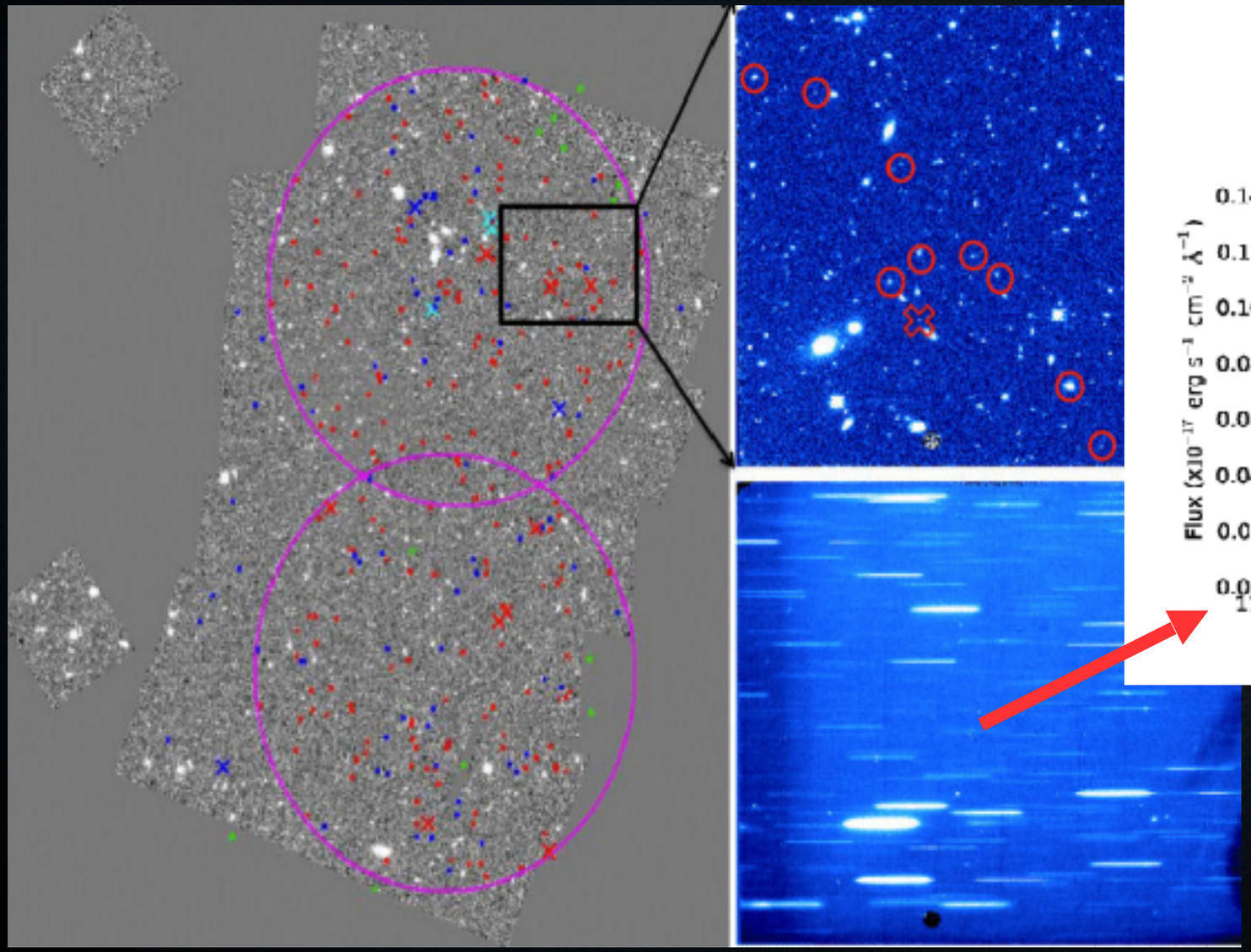
WFC3/G141 grism spectroscopy

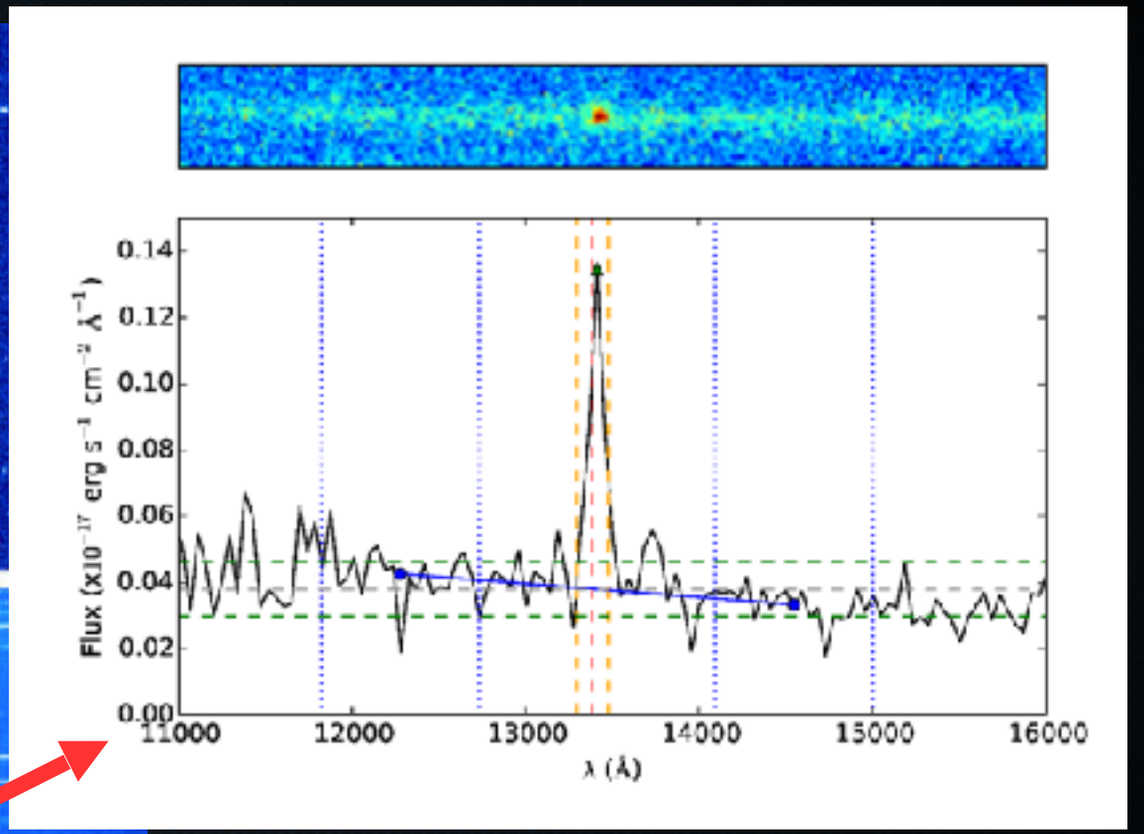
11 000Å—16 500Å

(= 0.7<z<1.5 for Hα)

Search for Hα at predicted wavelength from [OII] z

HST NIR grism spectroscopy (Hα at z~1)





281 [OII] emitters in GOODS-S WFC3 fields.
56 are Hα emitters (S/N>5)

Dust Correction

Dust calculated from SED-fits, A_{stars}.

Hα extinction, assuming different conversions:

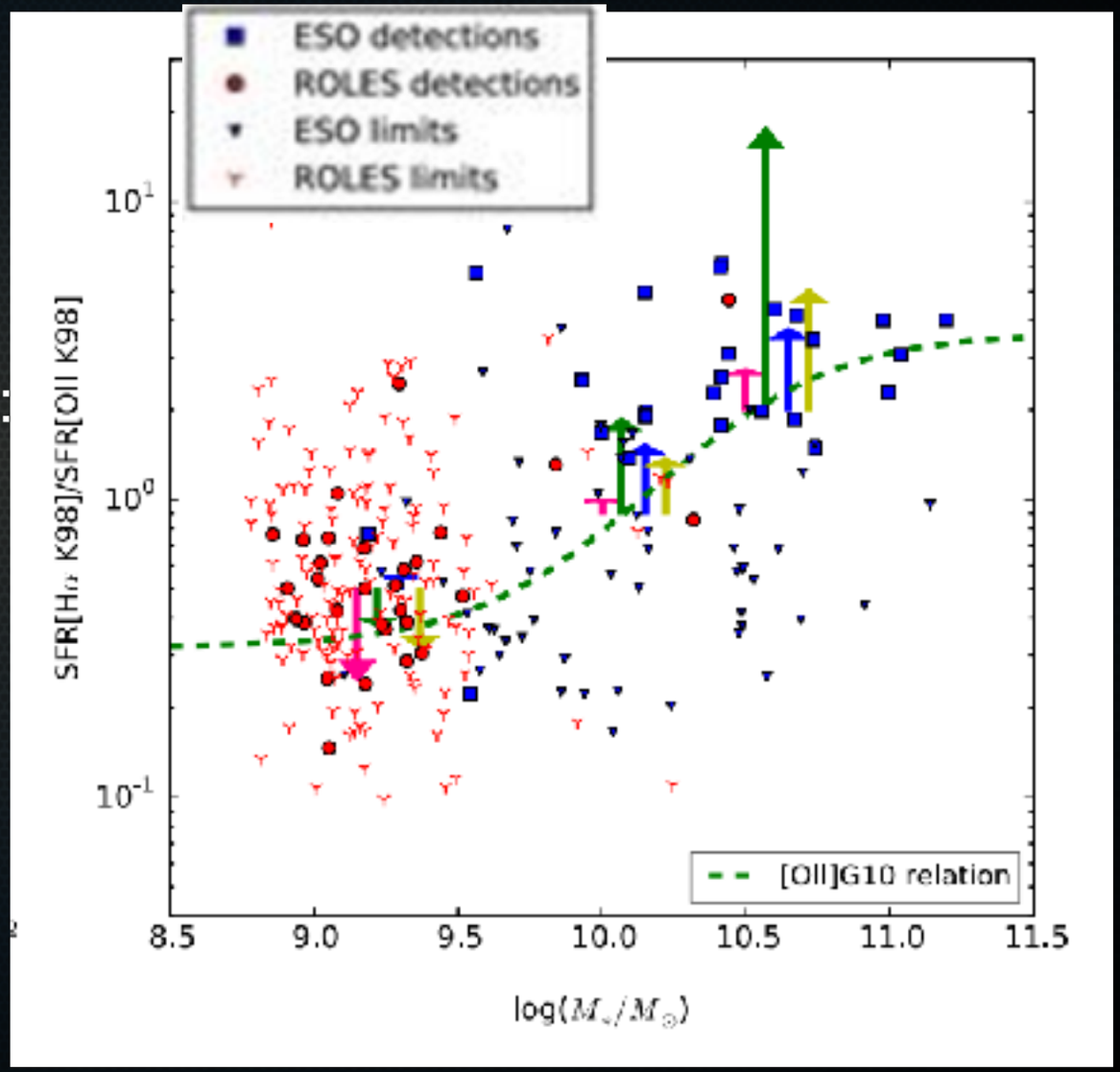
$A_{gas} = A_{stars}$

$A_{Calzetti}$ $(A_{stars}/0.44)$

A_{Wuyts} $(1.9A_{stars} - 0.15A^2_{stars})$

$A_{gas} = 1.4\ A_{stars}$ $(\sim A_{Reddy})$

(Calzetti+ 2000, Wuyts+ 2013, Reddy+ 2015)



Ramraj et al. 2017 MNRAS 466, 3143

Dust Correction

Dust calculated from SED-fits, A_{stars}.

Hα extinction, assuming different conversions:

$A_{gas} = A_{stars}$ conservative

$A_{Calzetti}$ $(A_{stars}/0.44)$

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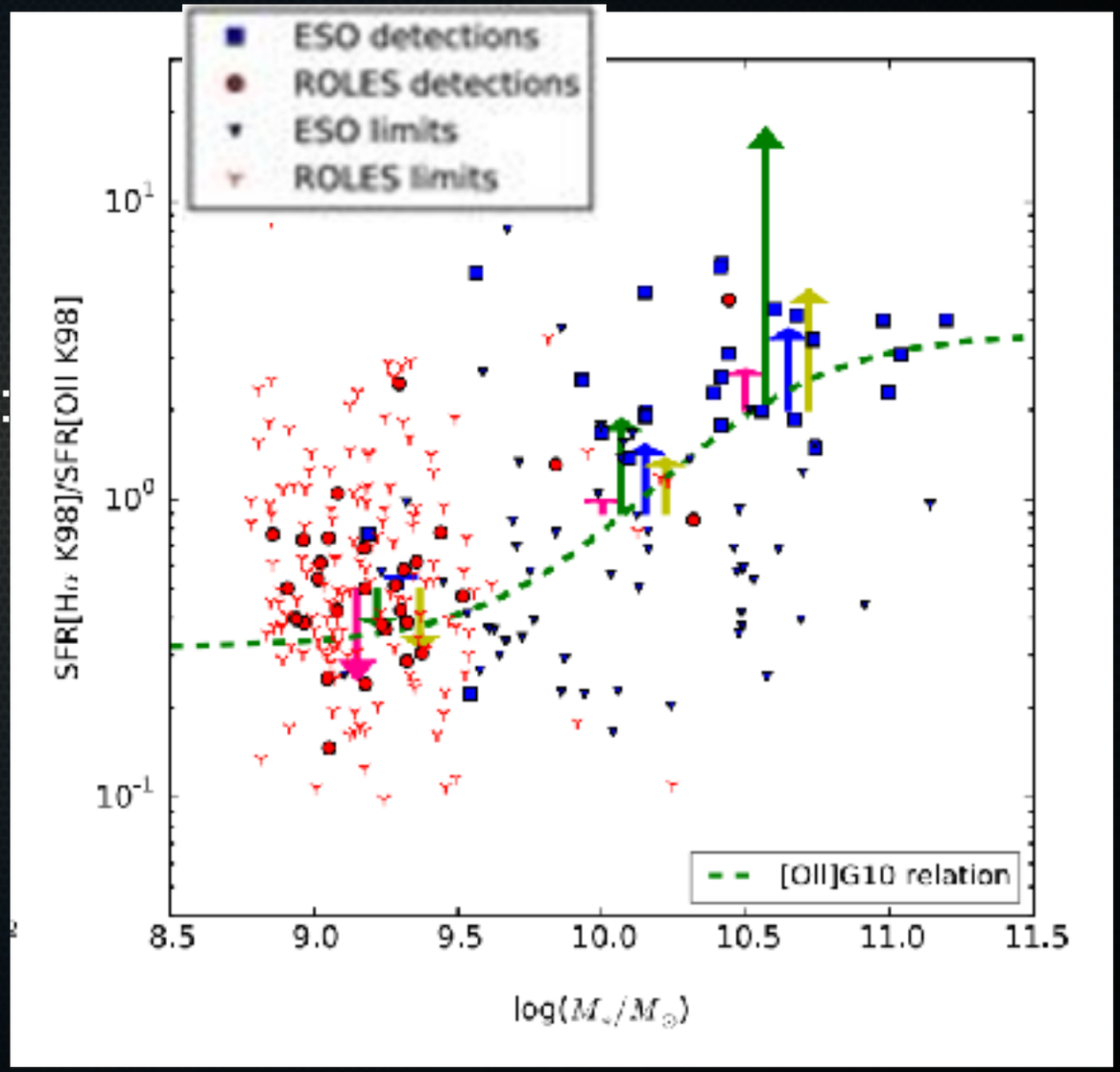
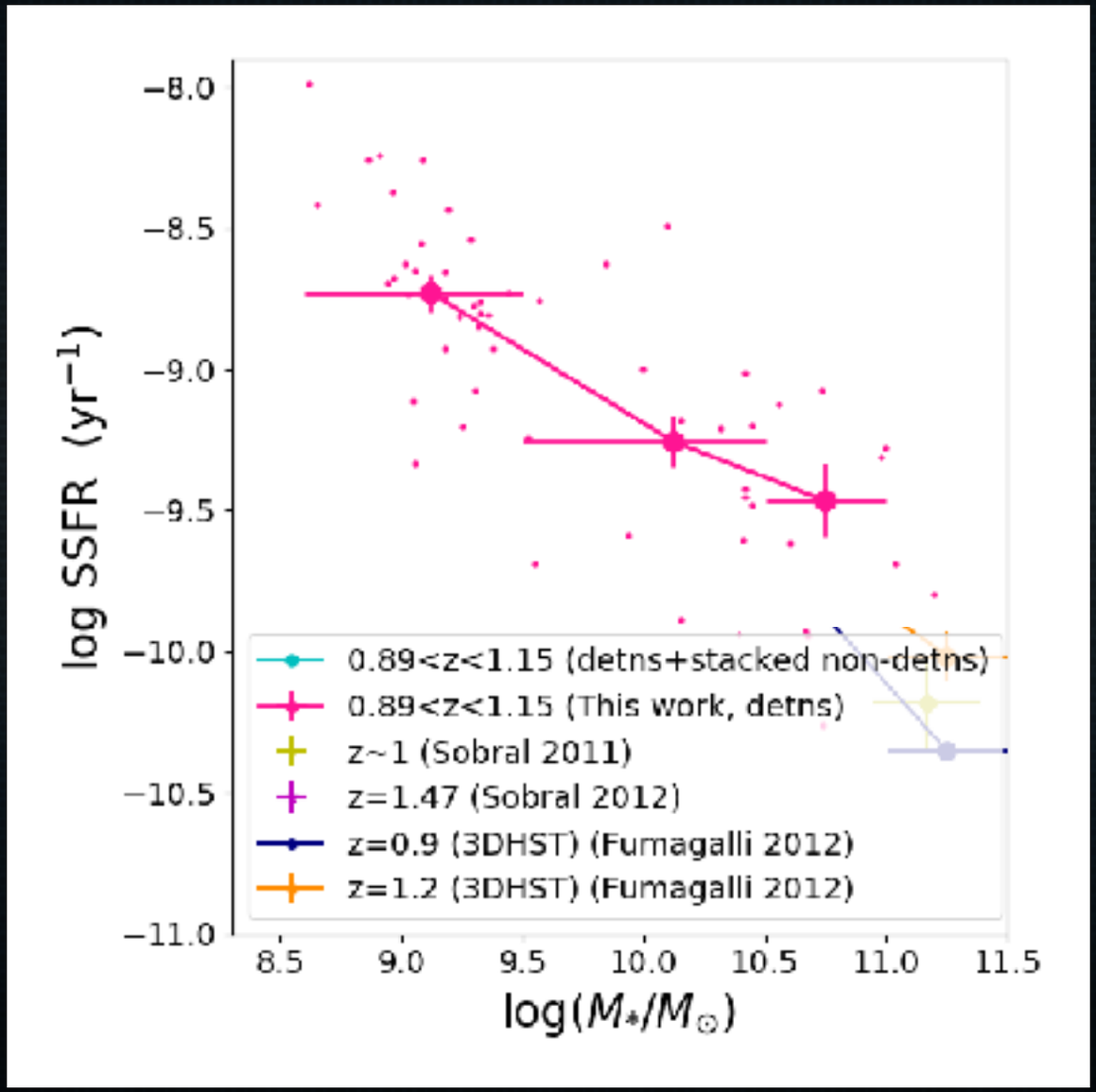
(Calzetti+ 2000, Wuyts+ 2013, Reddy+ 2015)



Ramraj et al. 2017 MNRAS 466, 3143

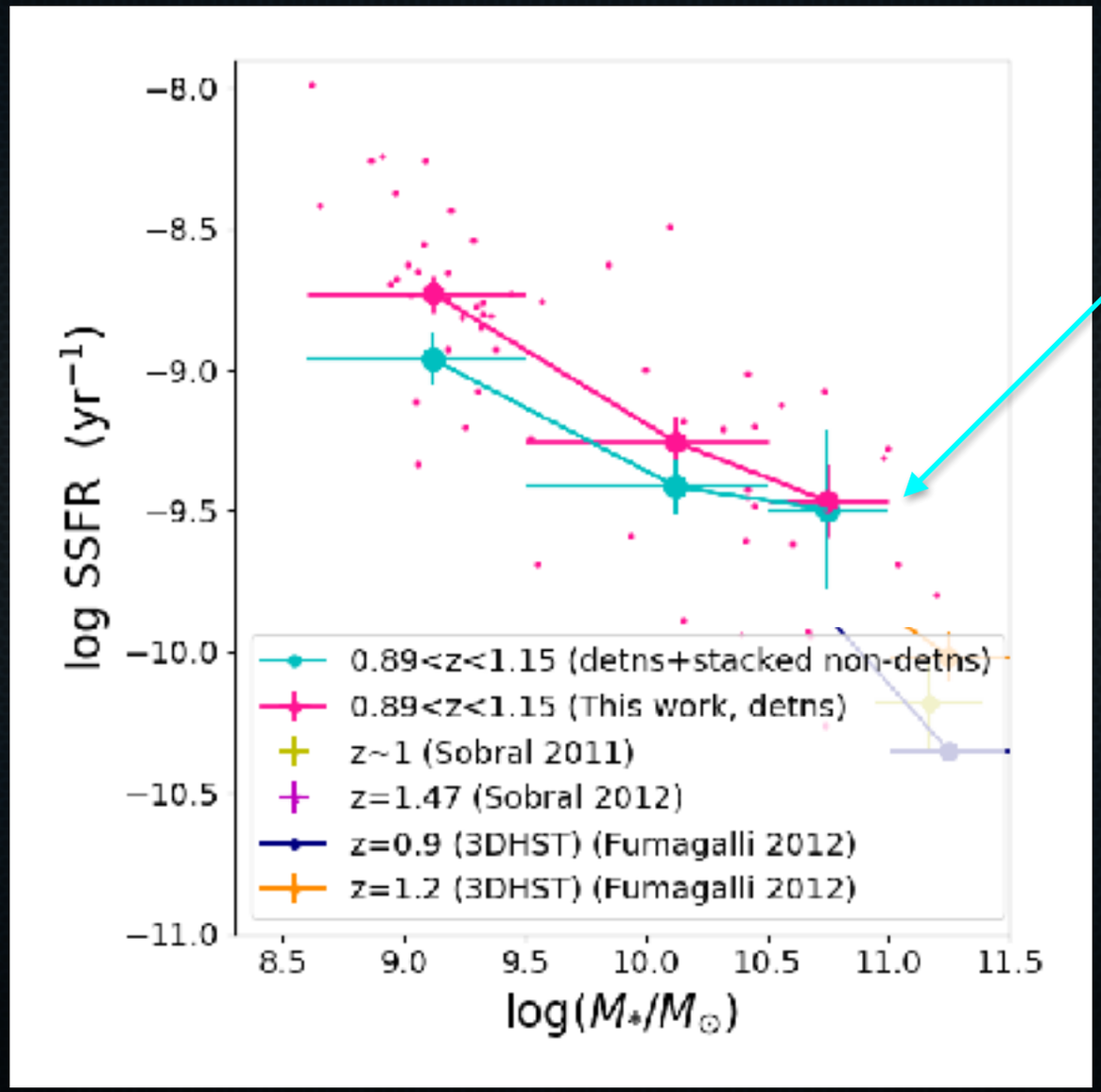
sSFR—M_* Relation

Comparison with other Hα surveys



Ramraj et al. 2017
MNRAS 466, 3143

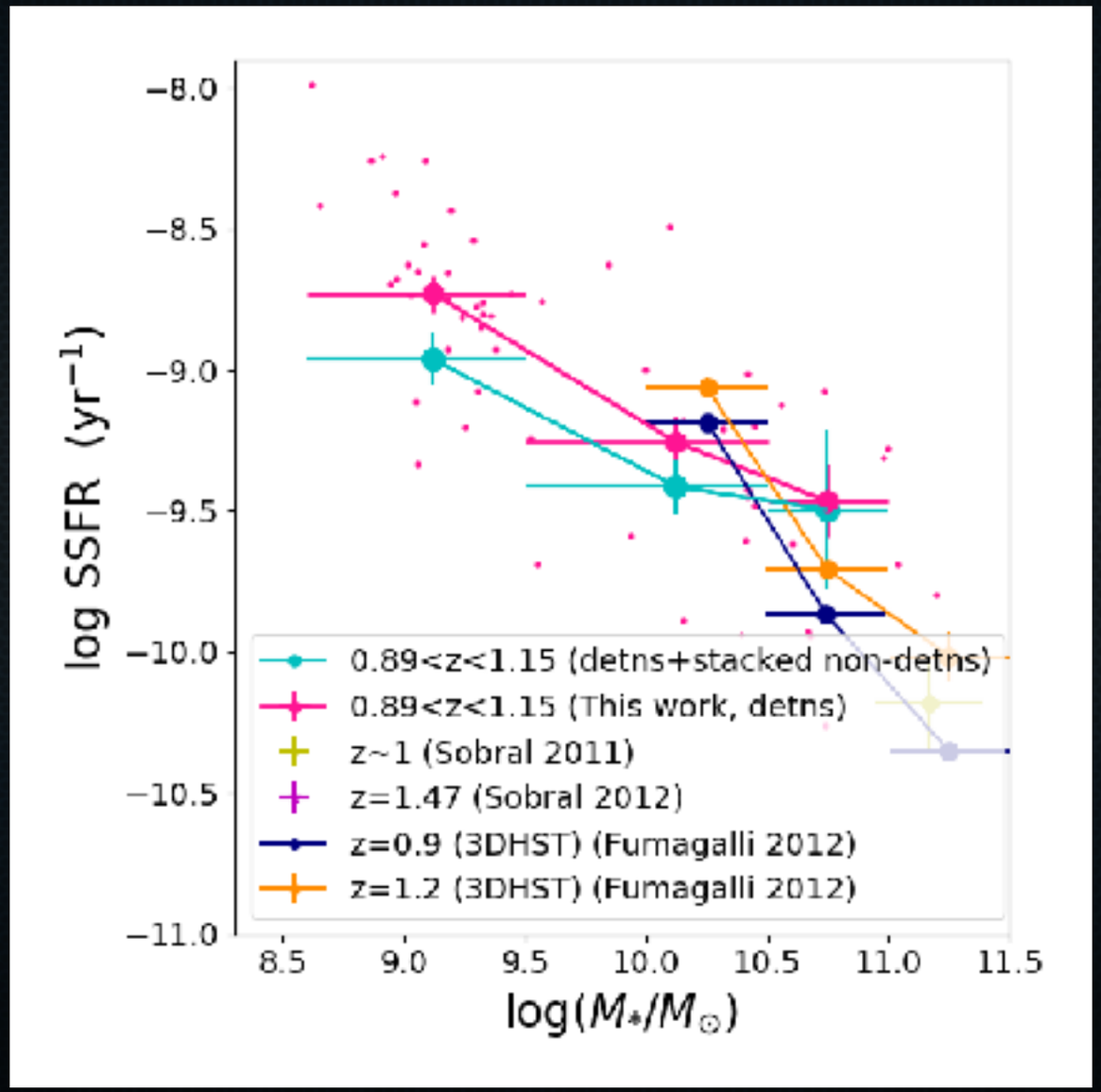
sSFR—M_* Relation



Stacked non-detections *(all mass bins significantly detected in stack)* **weighted sum with detections**

Ramraj et al. 2017
MNRAS 466, 3143

sSFR—M_* Relation



Ramraj et al. 2017
MNRAS 466, 3143

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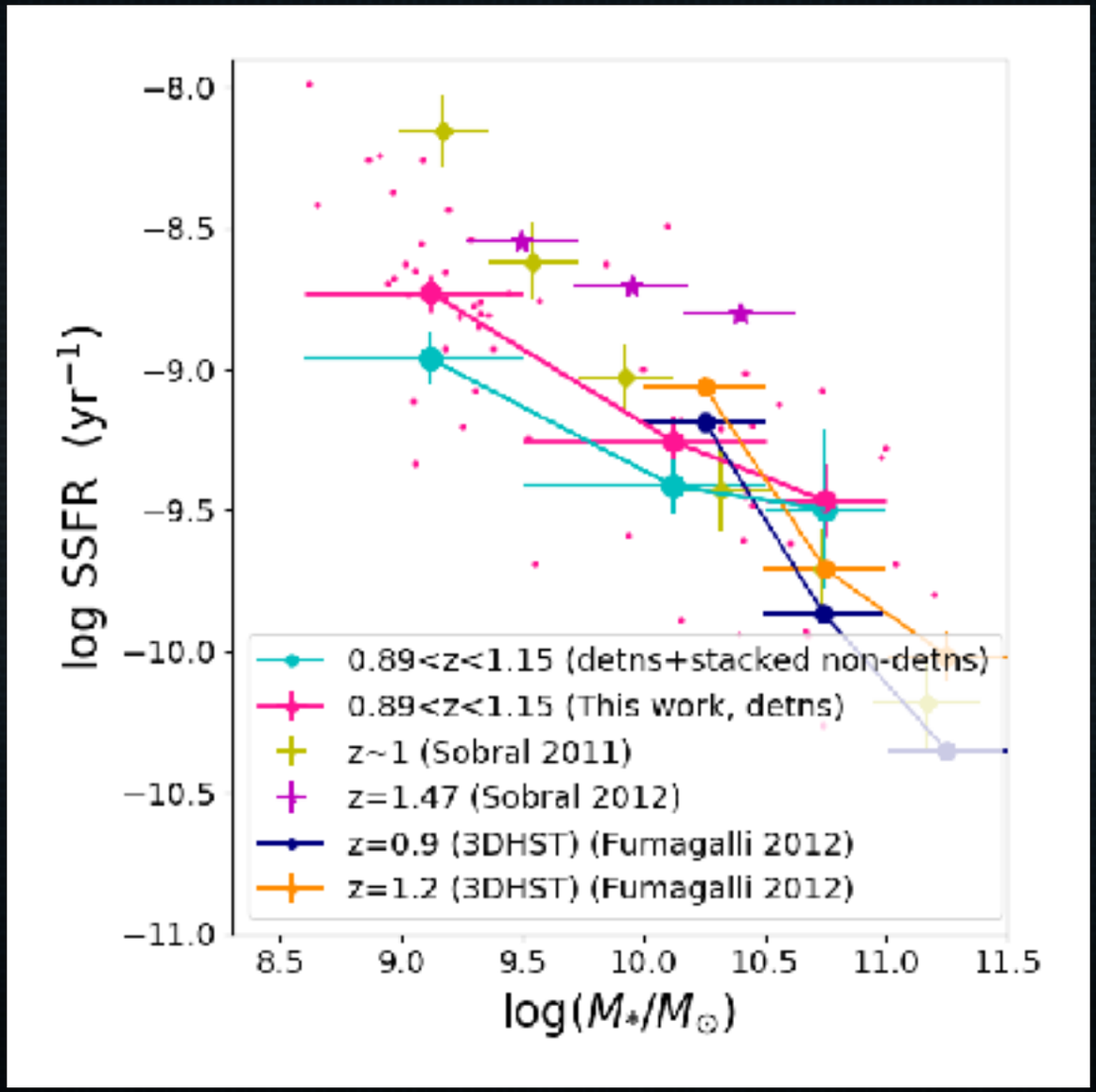
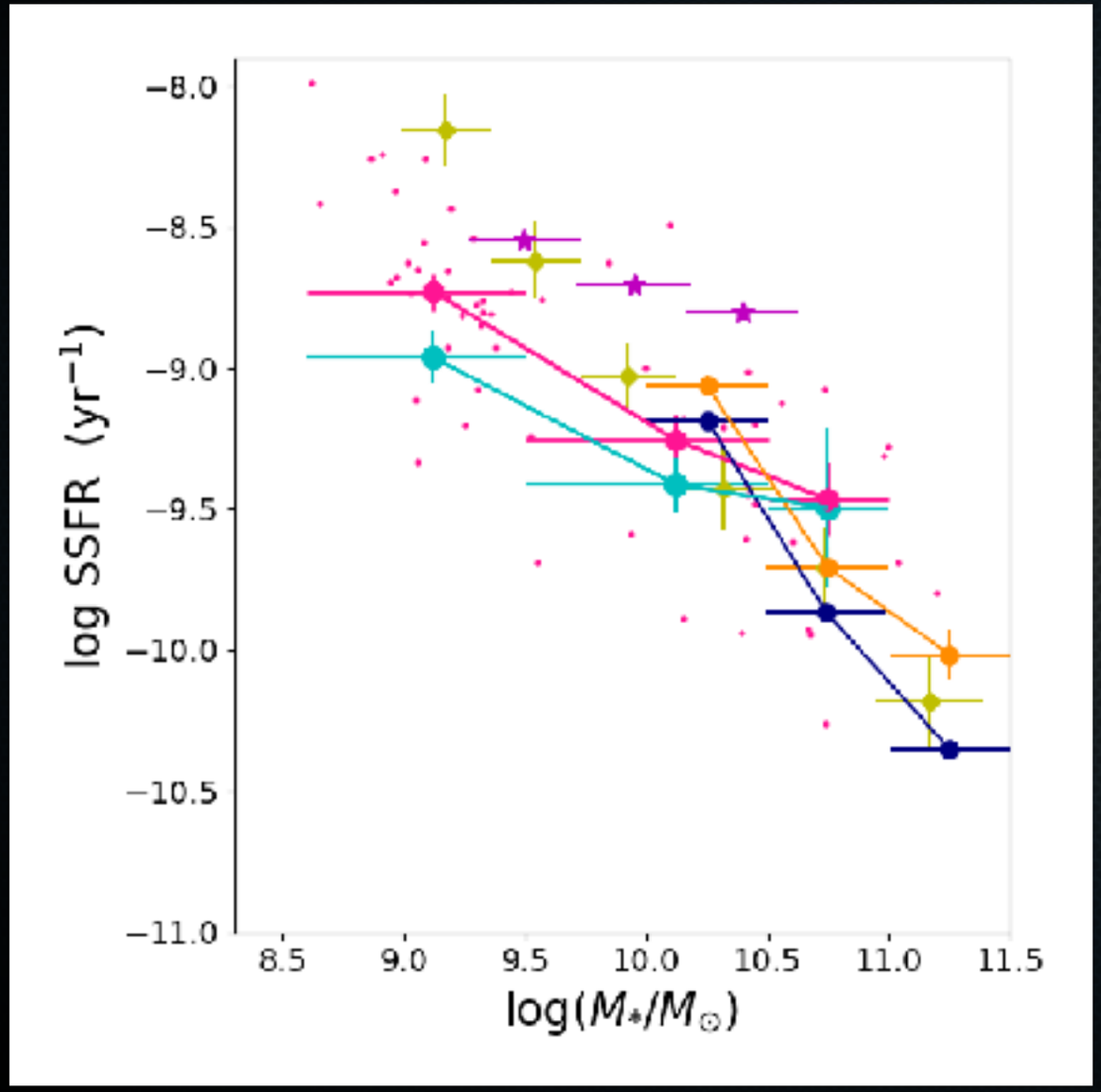


Ramraj et al. 2017
MNRAS 466, 3143

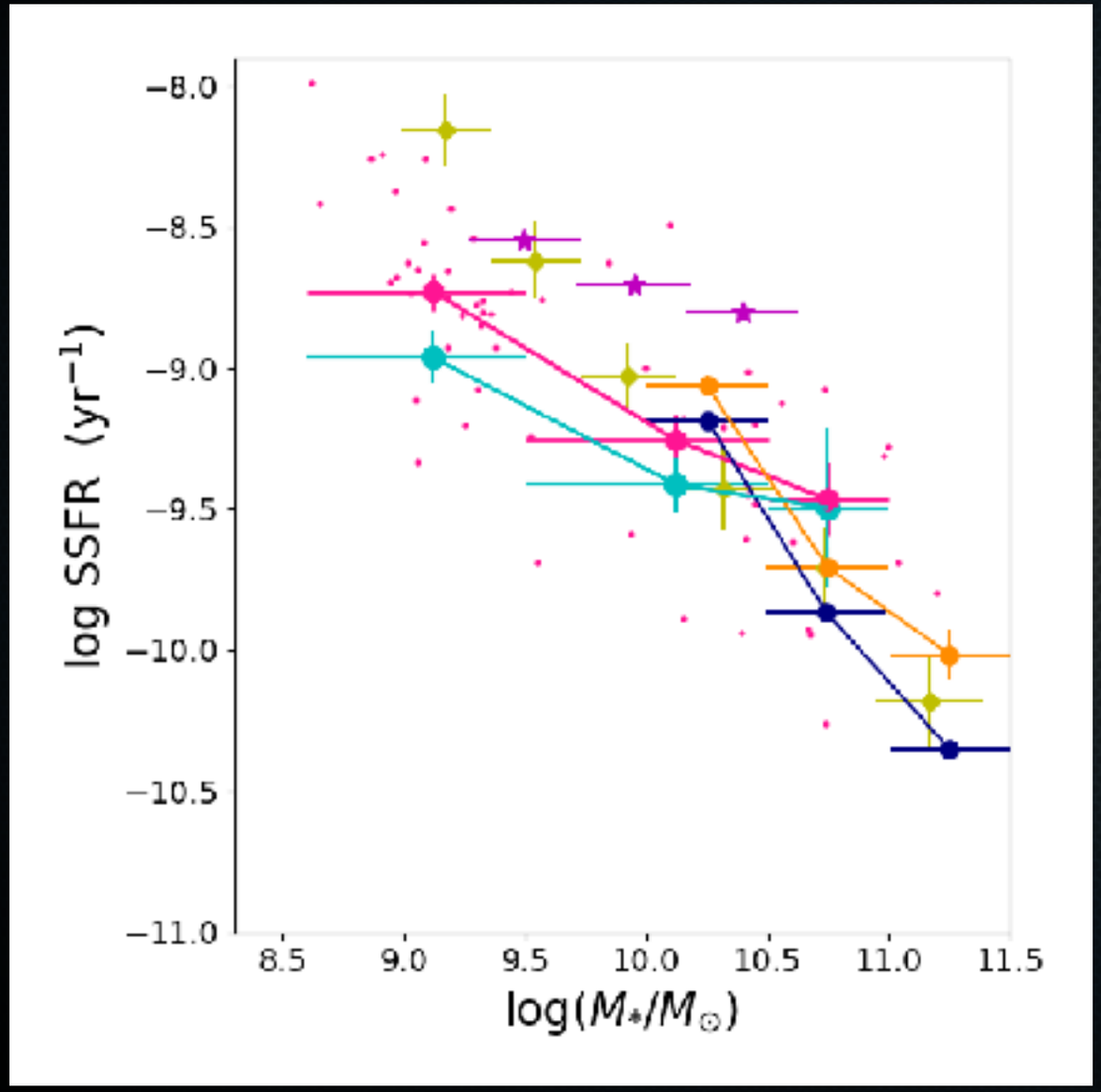
sSFR—M_* Relation



Flatter low mass slope
measured in ROLES-Hα vs other (shallower) Hα surveys

Sample	SSFR–mass slope, α
This work, detections	−0.50 ± 0.04
This work, stack	−0.47 ± 0.04
Sobral et al. (2011) ($z \sim 1$)	−1.00 ± 0.07
EAGLE ($z \sim 1$)	−0.14 ± 0.05
Stripe 82 ($z \sim 0.1$), log (M_*) < 10	−0.08 ± 0.01

sSFR—M_* Relation

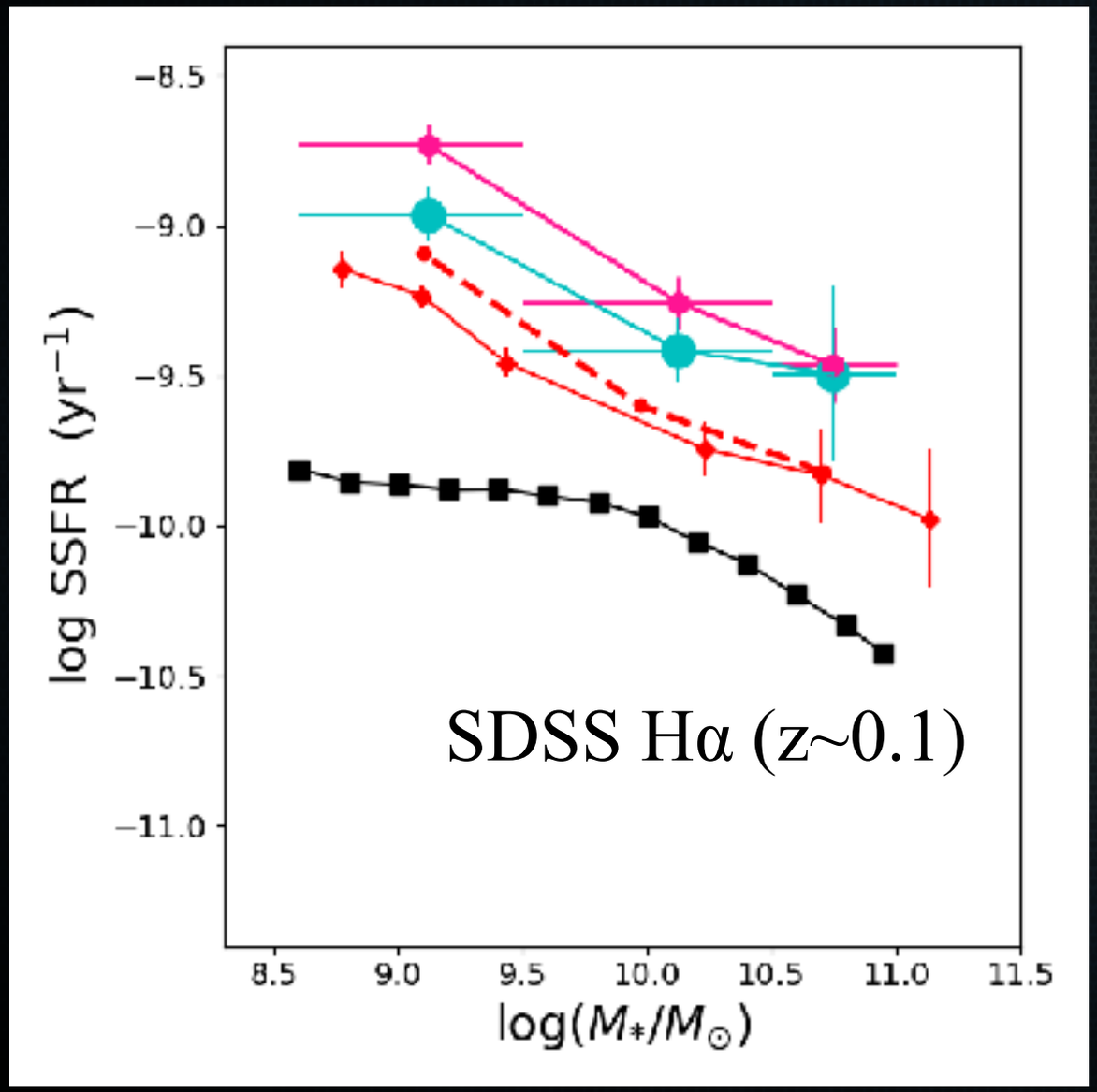


Flatter low mass slope measured in ROLES-Hα vs other (shallower) Hα surveys

Sample	SSFR–mass slope, α
This work, detections	−0.50 ± 0.04
This work, stack	−0.47 ± 0.04

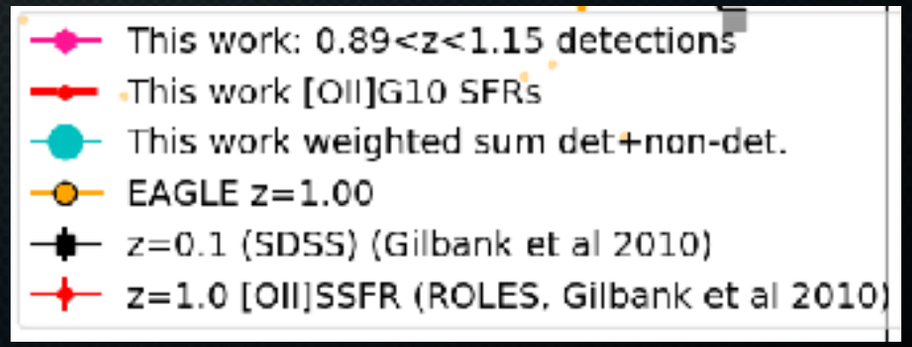
Alternate dust corrections negligibly change results:
A_{Wuyts} gives α = -0.46+/-0.05
$1.4A_{stars}$ gives α = -0.46+/- 0.04

sSFR—M* Relation

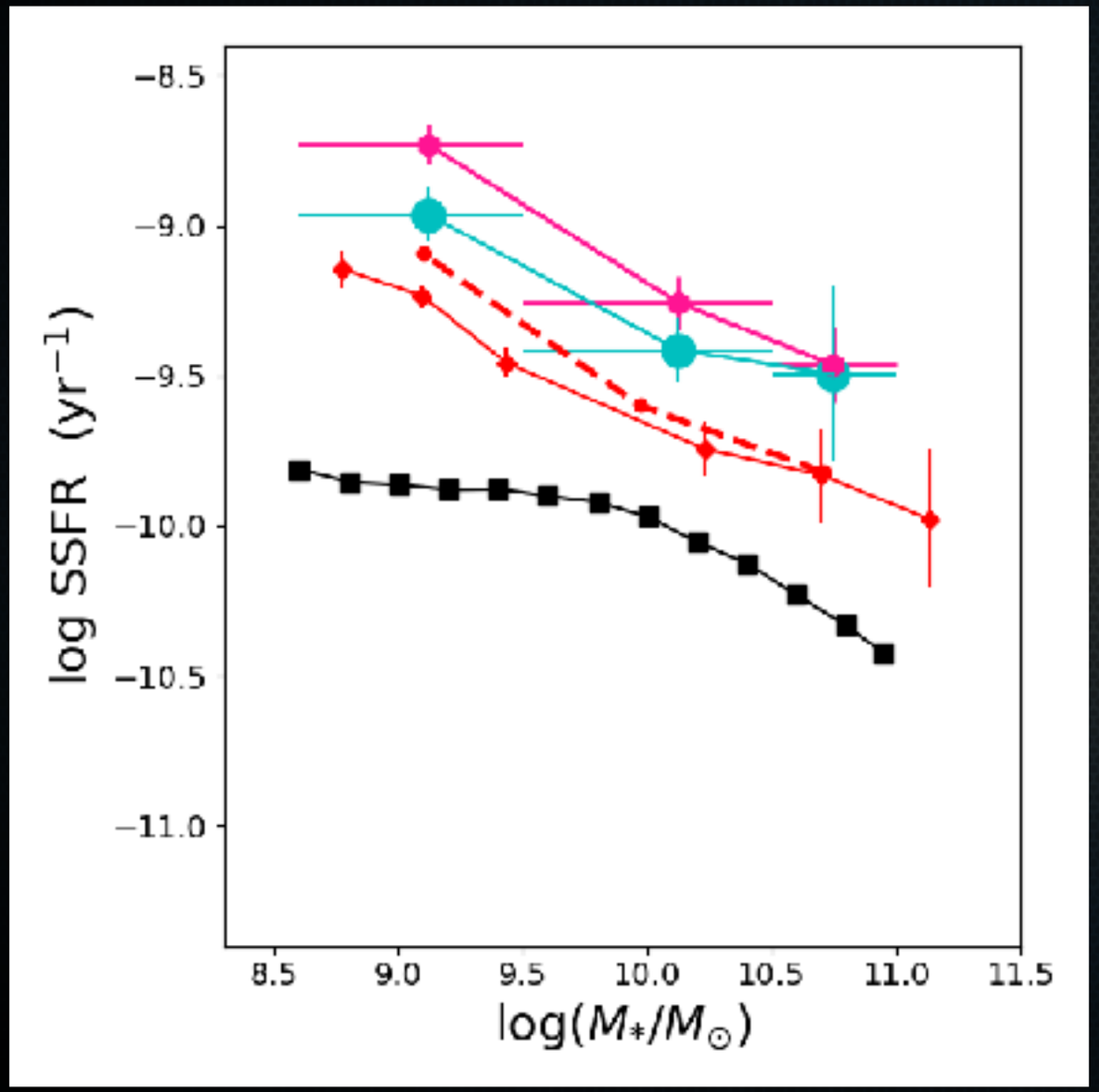


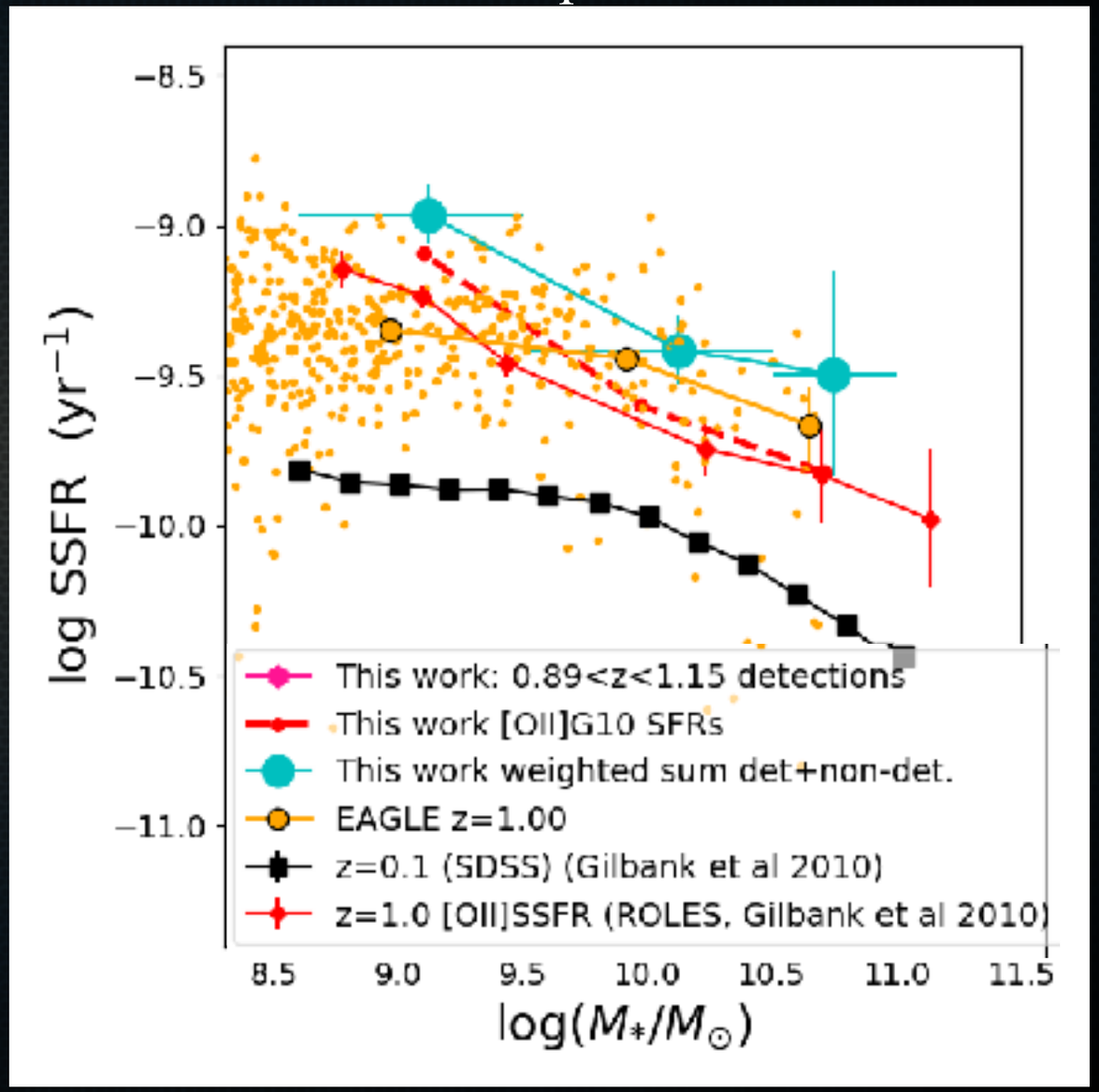
z~1 ROLES Hα (detections)

z~1 ROLES [OII]



sSFR—M_* Relation Comparison with simulations





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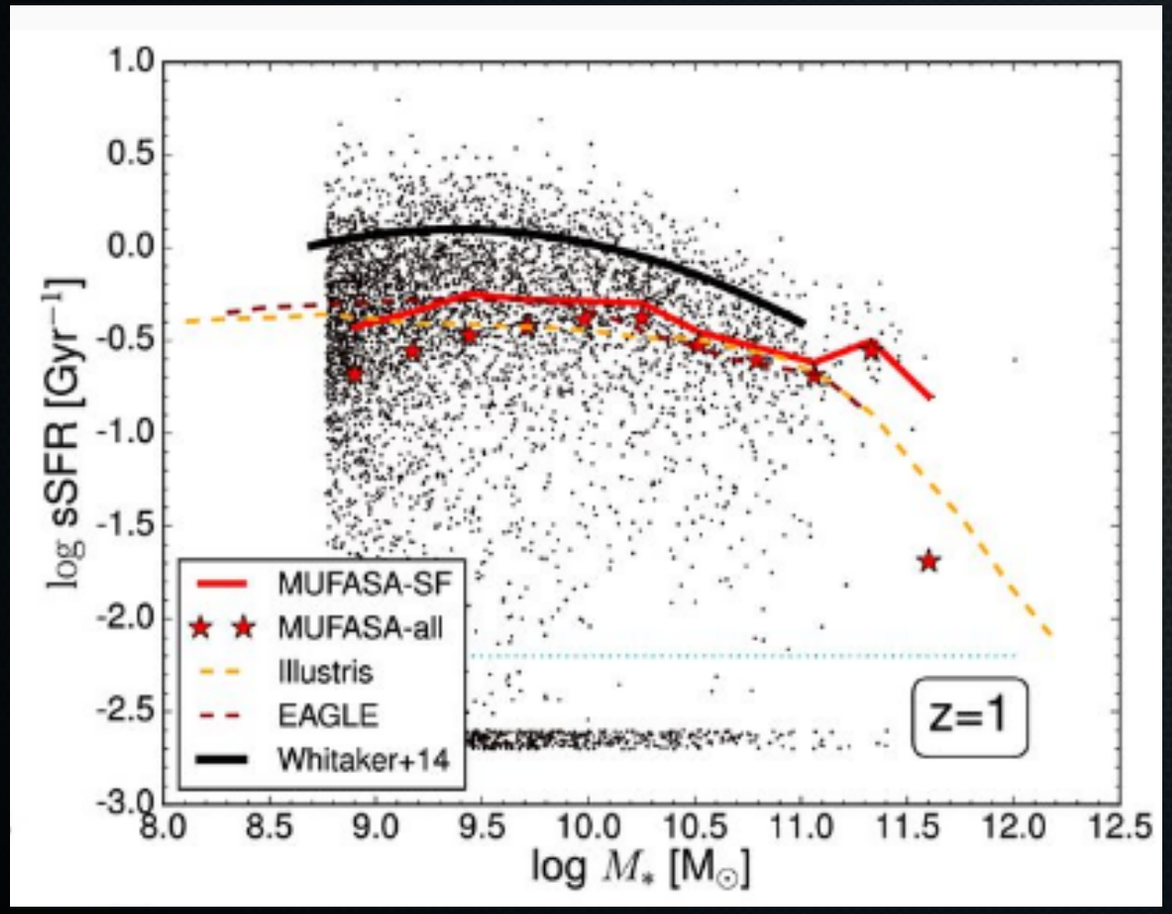
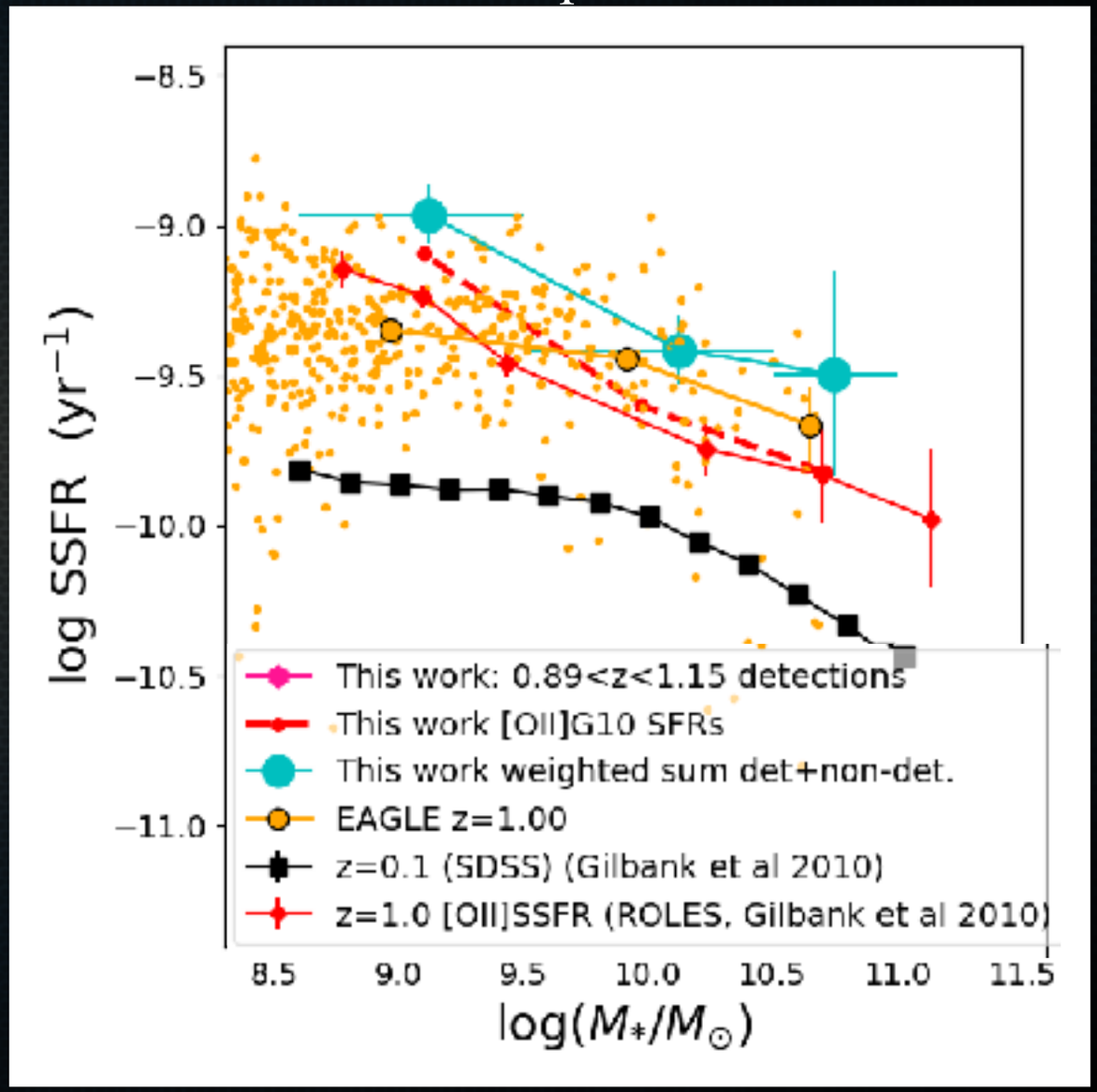


Davé, Thompson and Hopkins 2016



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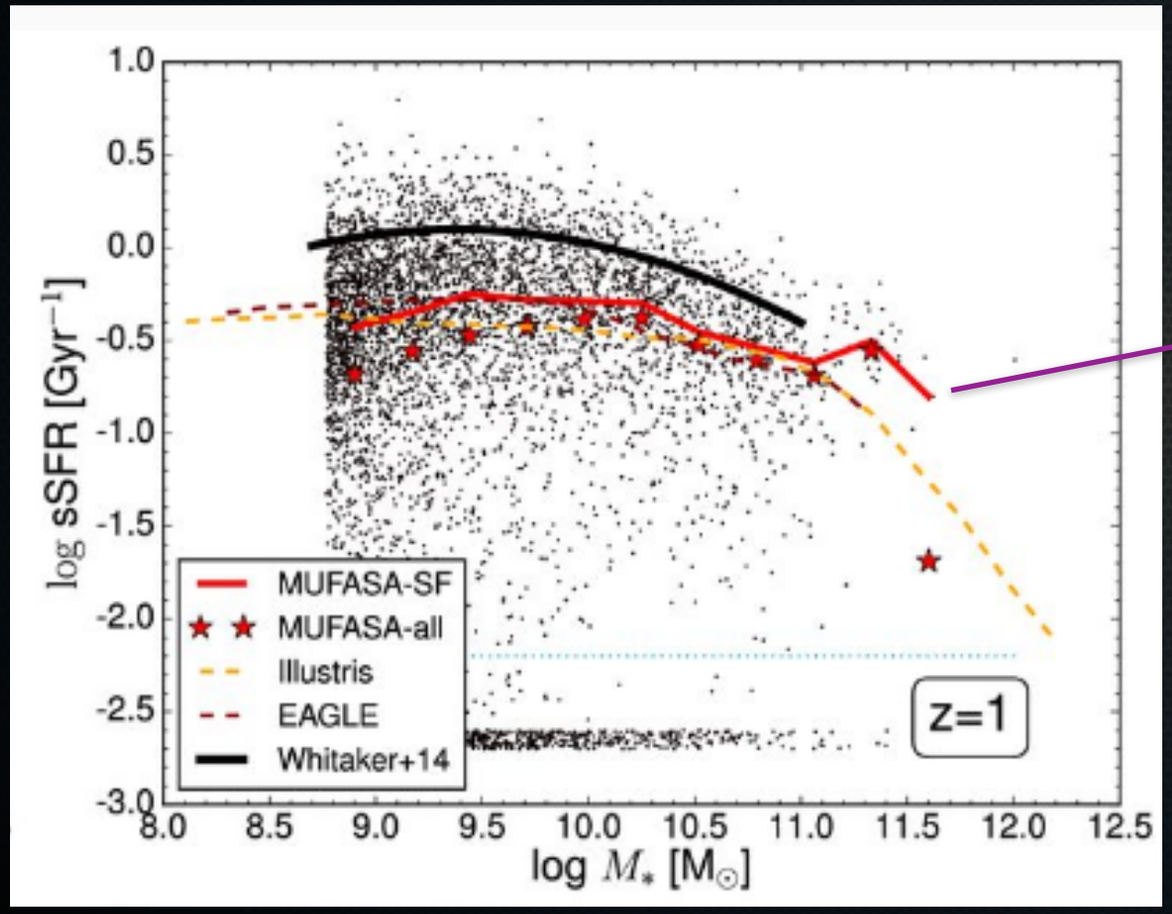

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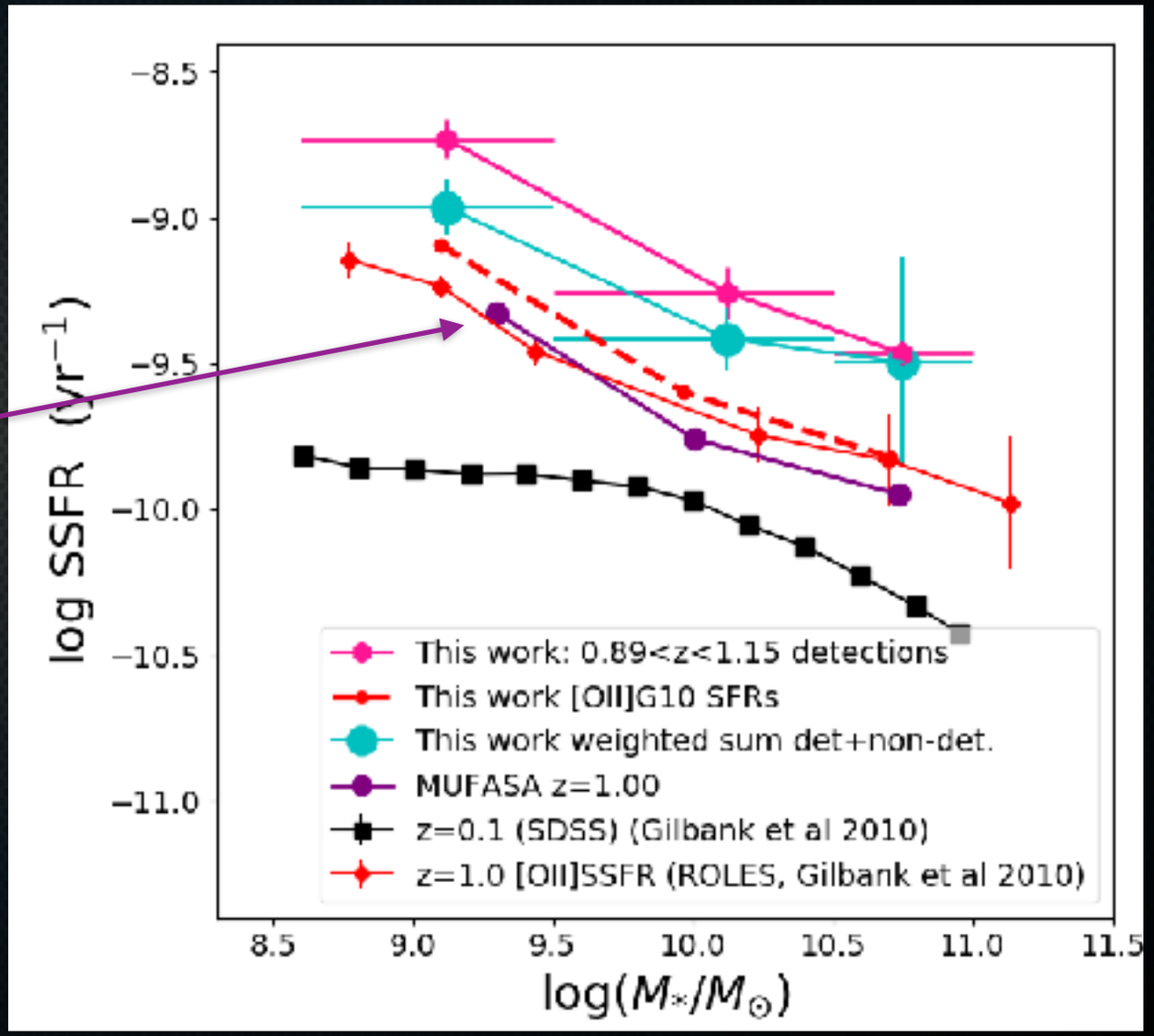
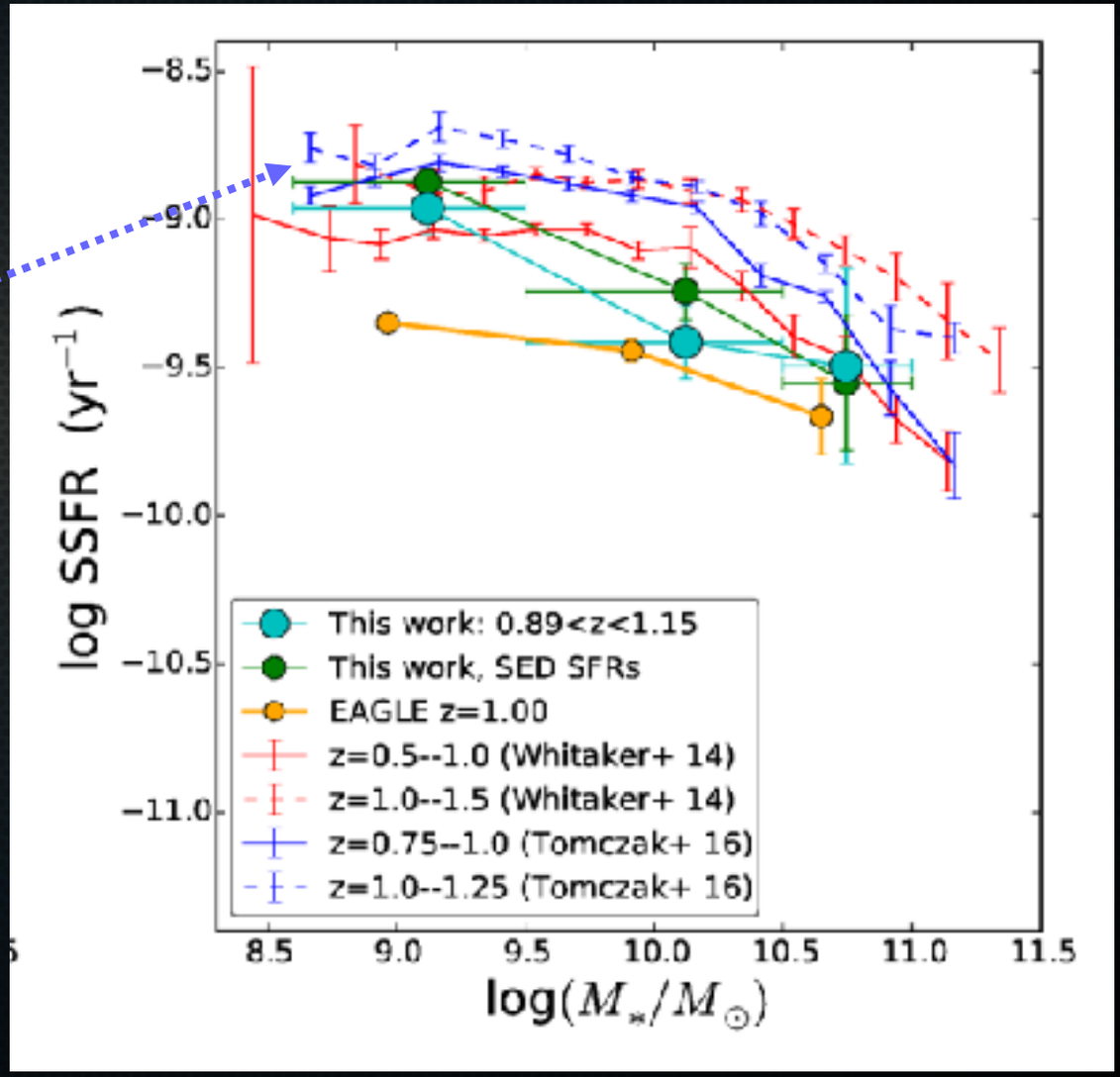


sSFR—M_* Relation

- Our deeper data show a flatter low-mass slope than other [shallower] studies
  - "Photometric studies" have suggested a flatter slope

Whitaker+ 2014: ~900 arcmin^2 from CANDELS
Tomczak+ 2016: ~400 arcmin^2
This work: ~100 arcmin^2 in GOODS-S

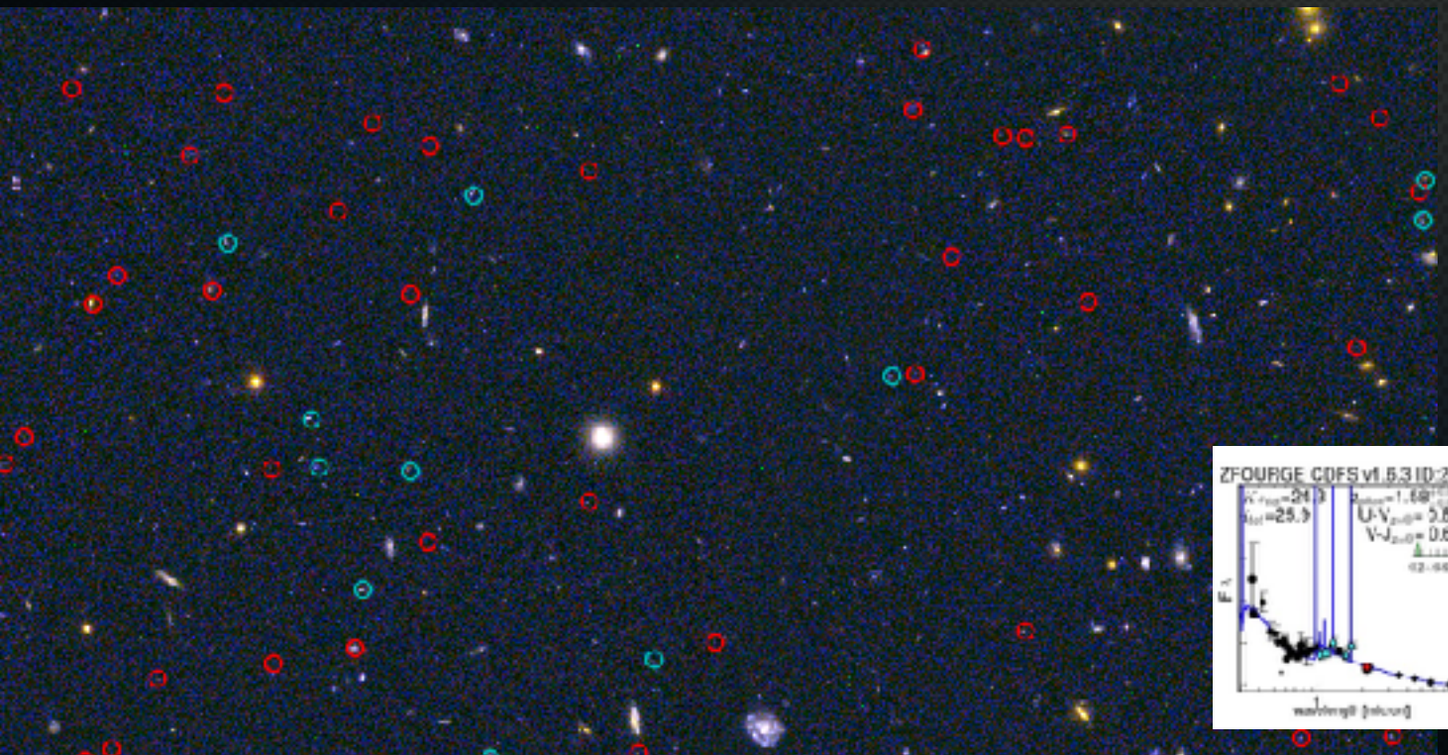
- These are closer to the models, but still significantly steeper



Ramraj et al. 2017 MNRAS 466, 3143

The Redshift One(.5) LDSS3 Emission line Survey (ROLES1.5)

David Gilbank, Ivan Baldry, Michael Balogh, Richard Bower, Karl Glazebrook, Glenn Kacprzak, Ivo Labbe, Ros Skelton, Adam Tomczak, Kim-Vy Tran



- 11 nights on Magellan with upgraded LDSS3c
- Push ROLES technique [OII] to z~1.5
- Pre-select galaxies from ZFOURGE

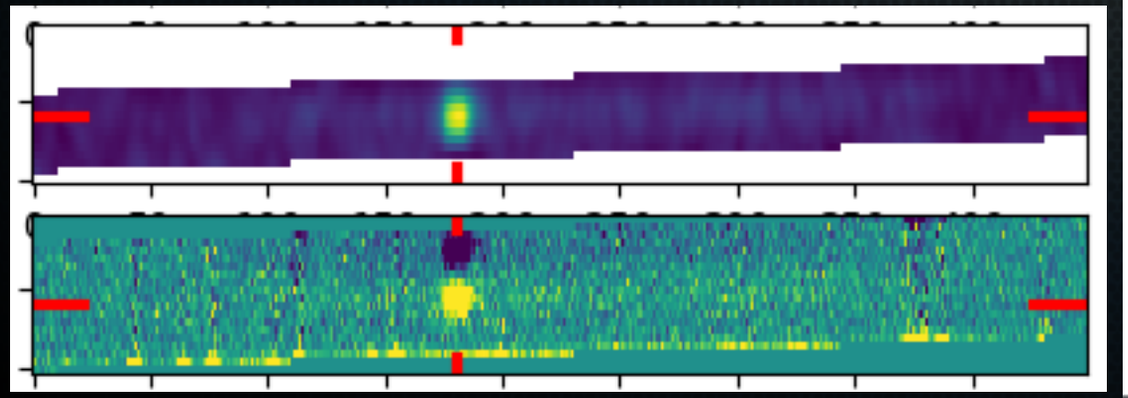
ROLES1.5

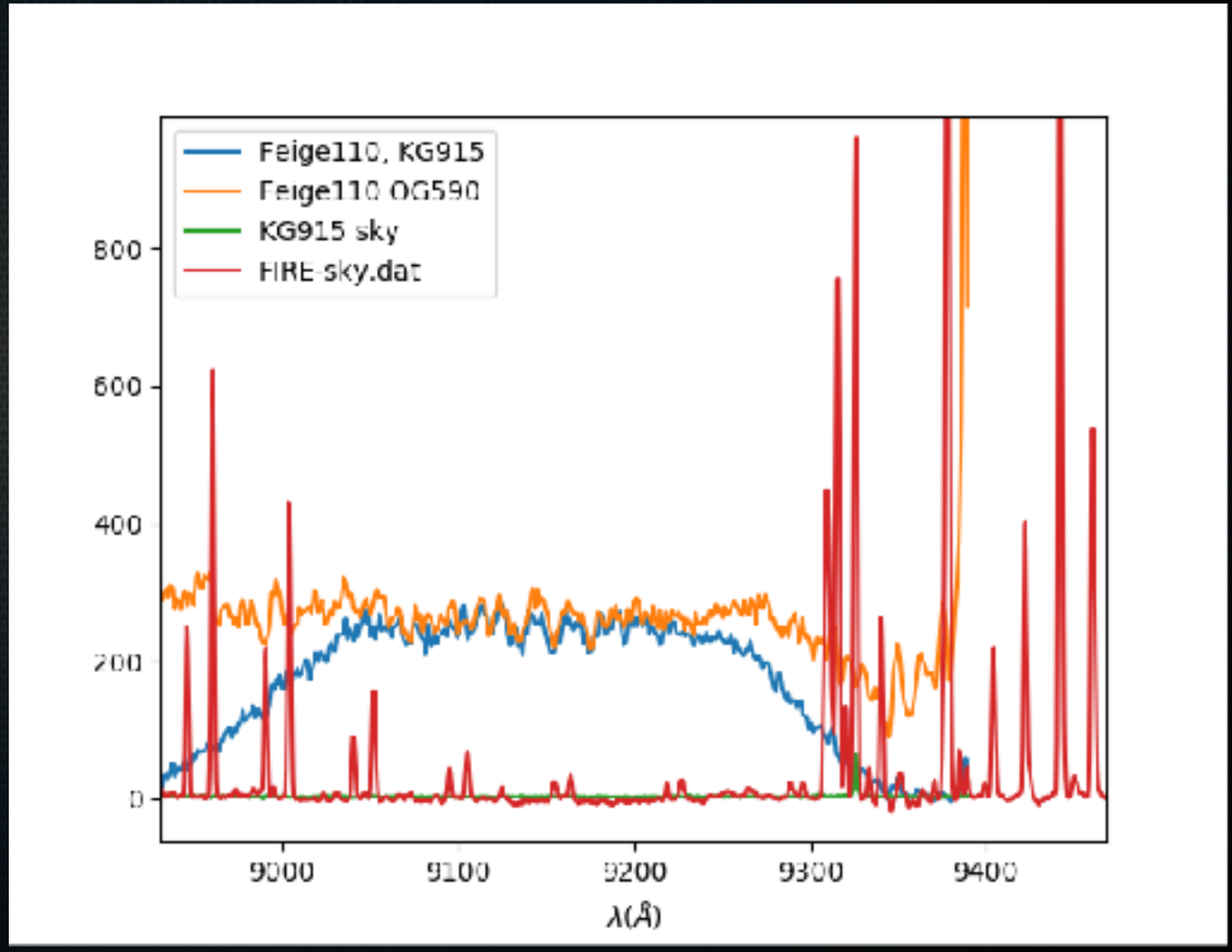
9000Å—9300Å filter (clean band in-between sky lines)

[OII] z: 1.414—1.495

1340 unique objects (17 masks)

targeted in GOODS-S, COSMOS, UDS fields





Summary

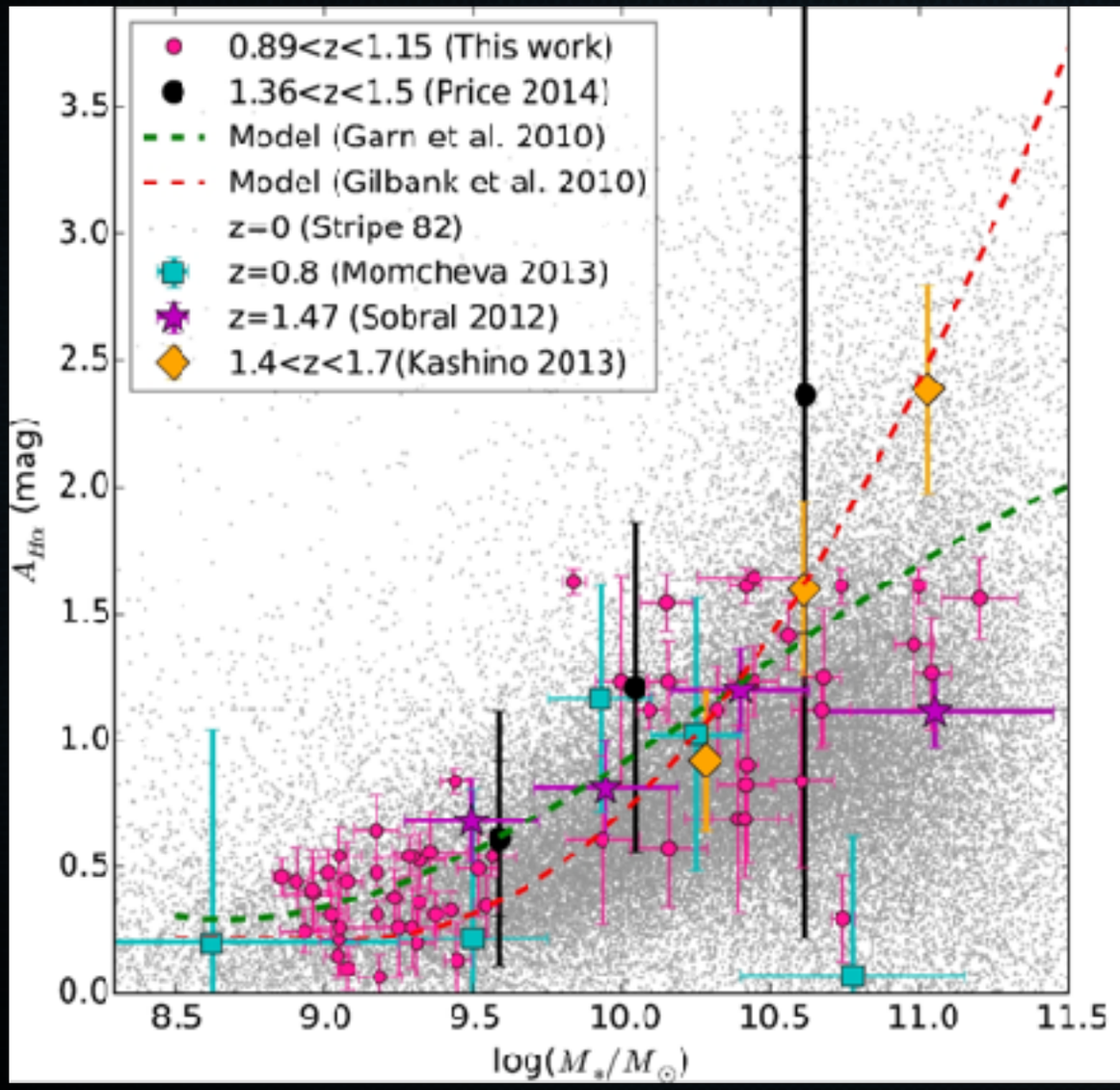
Using Hα spectroscopy, the [stacked] spectroscopic sSFR—mass relation at z~1 is flatter than measured with previous shallow Hα surveys

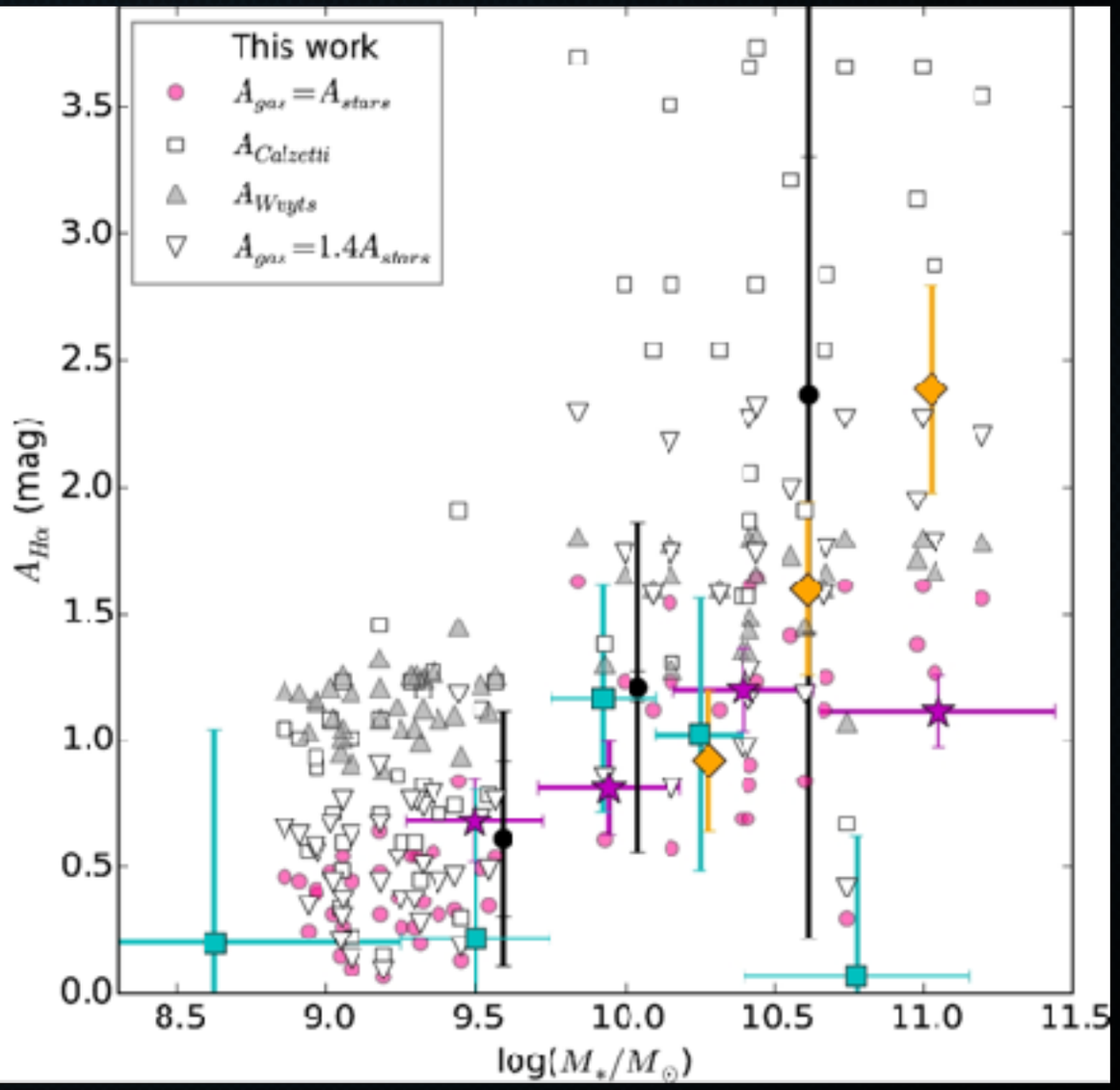
This is closer to the slope measured by ‘photometric’ surveys but still steeper than the [generic] prediction of GF models

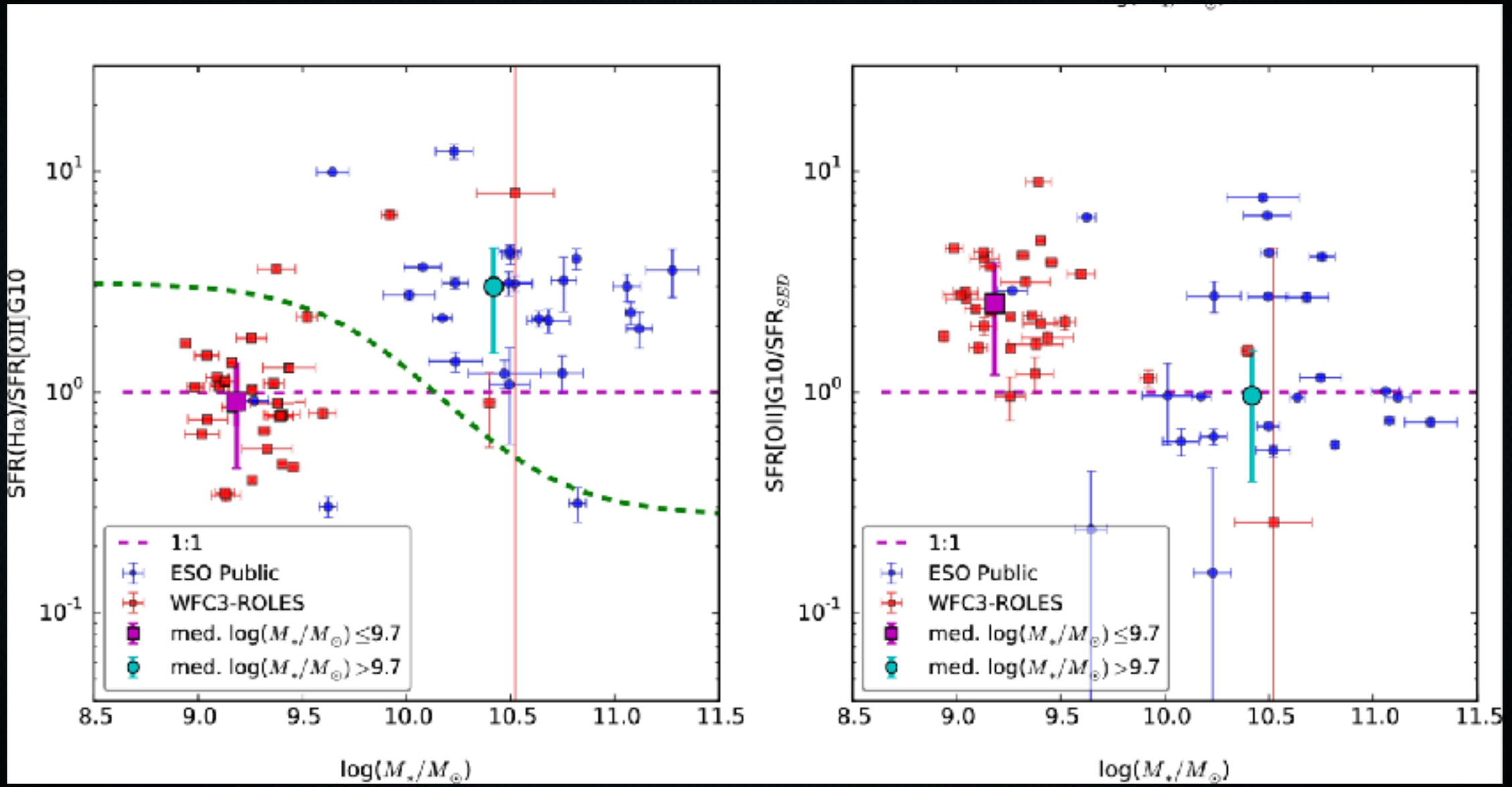
On-going [OII] spectroscopic survey at z~1.5 using ZFOURGE photo-z targeting.

Extra Slides

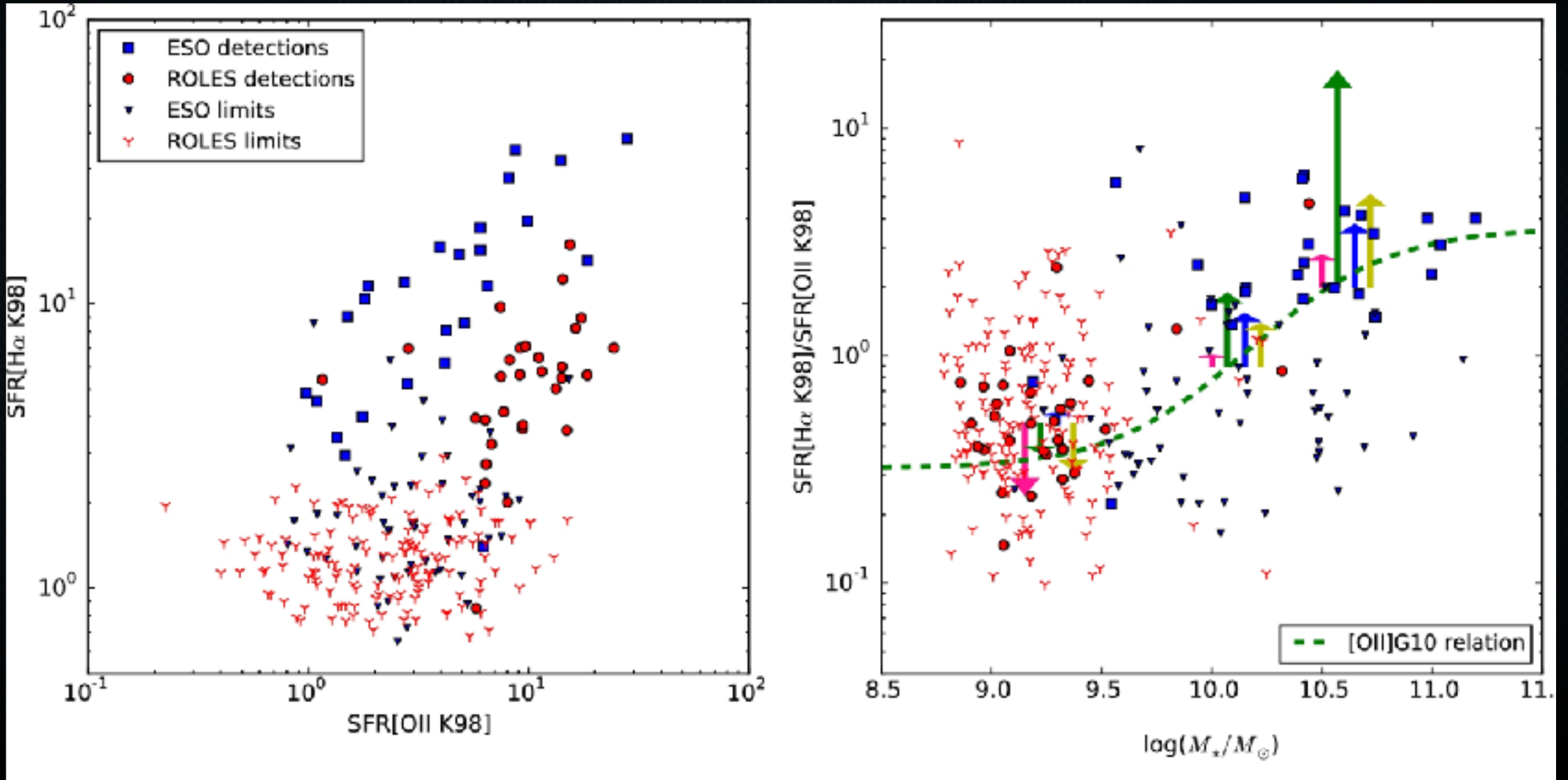
Extinction — Mass



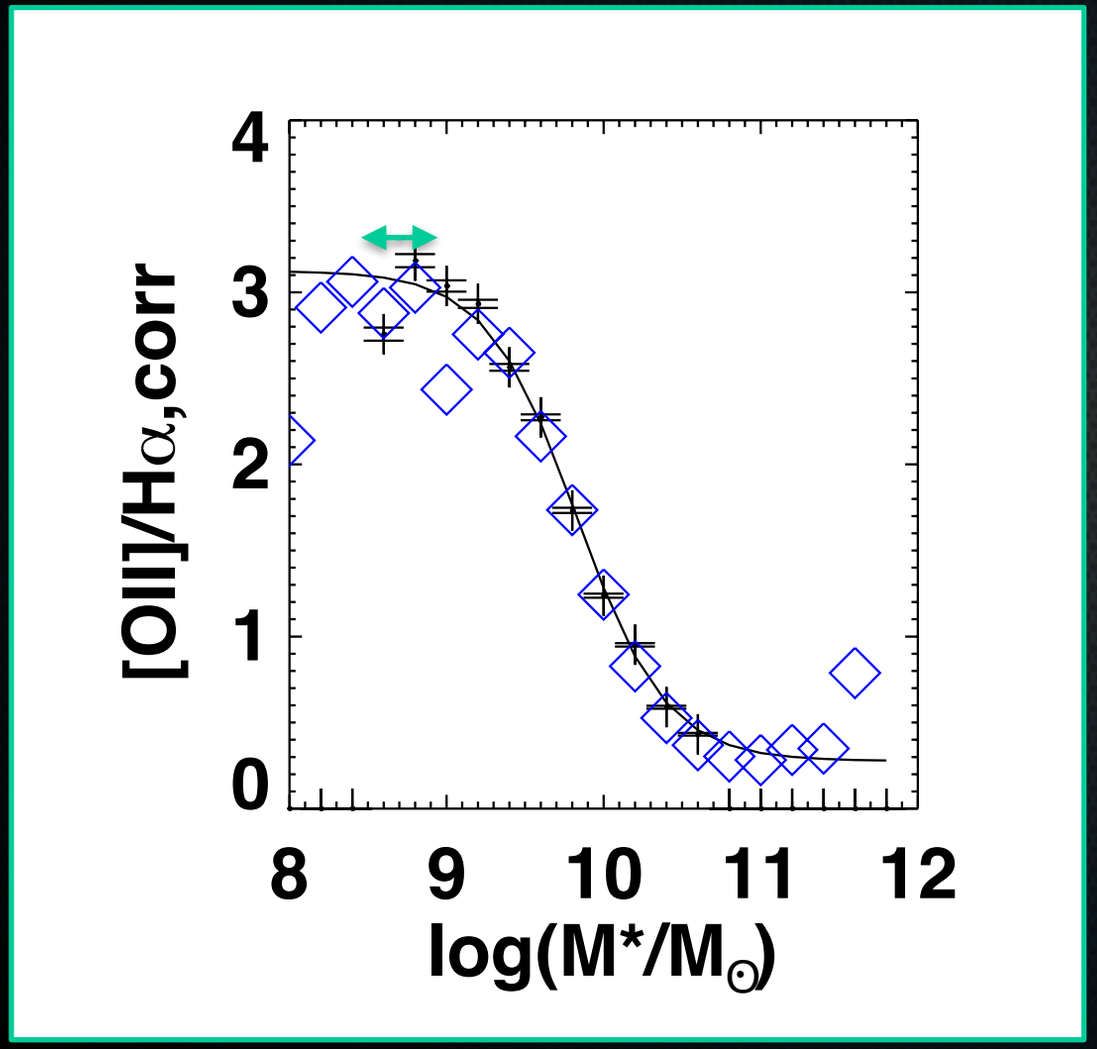



SFR(Hα)/SFR[OII]G10
SFR[OII]G10/SFR$_{SED}$
10^1
10^0
10^{-1}
8.5
9.0
9.5
10.0
10.5
11.0
11.5
log($M_*/M_\odot$)
1:1
ESO Public
WFC3-ROLES
med. log($M_*/M_\odot$) ≤9.7
med. log($M_*/M_\odot$) >9.7

SFR indicator comparison



[OII] SFR Empirical Correction



Calibrated at z~0.1 from Hα SFR

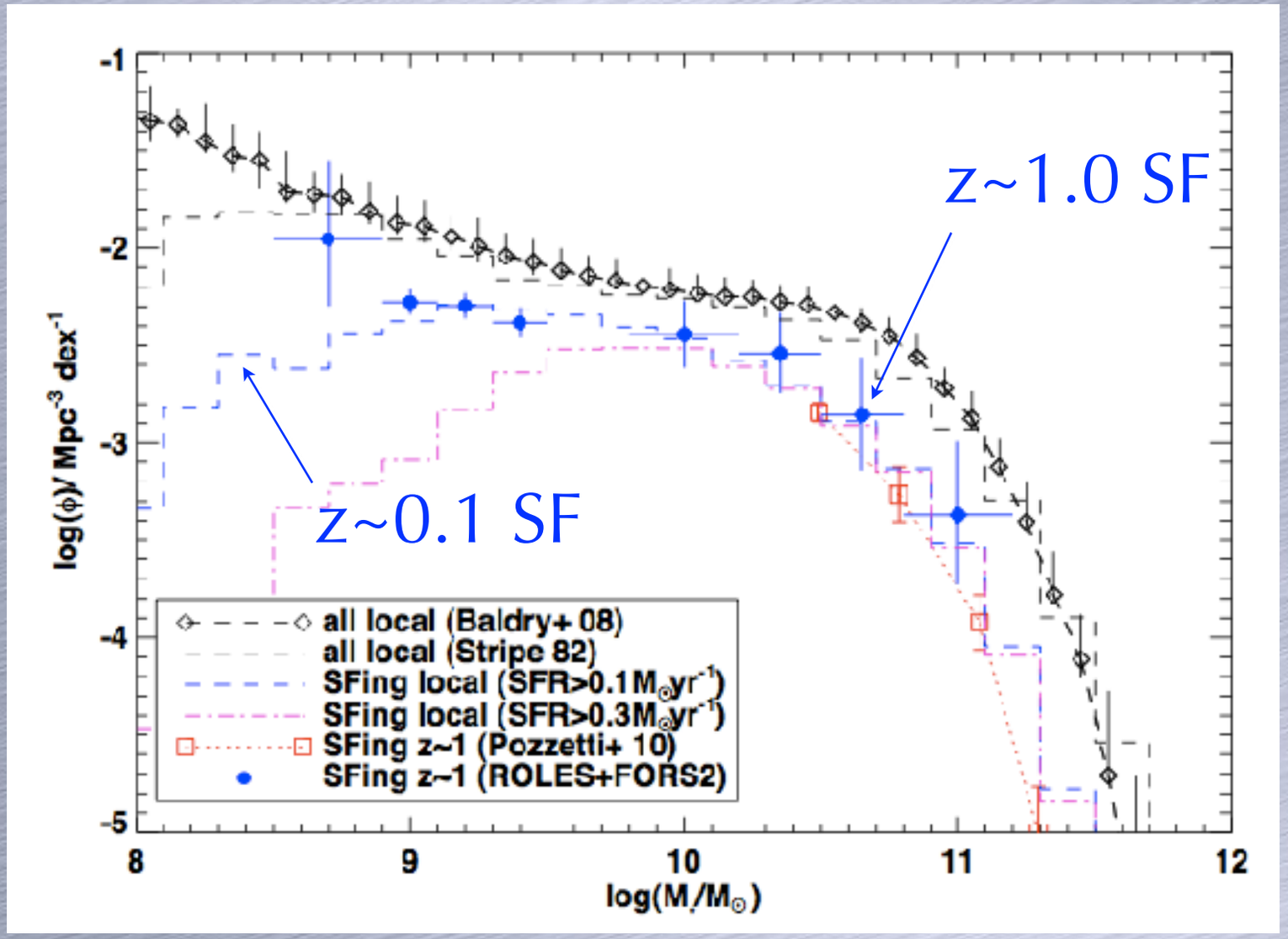
Accounts for mass dependent variation in
- Metallicity
- Extinction
- Ionisation Parameter
- ….

At z~1, at fixed Z, M_* changes by ~0.4 dex

Alternatively, at fixed M_*, Z decreases by 0.1-0.2 dex. => higher [OII]/Hα at a given SFR. This may be partly cancelled by increased dust extinction relative to z~0.

Gilbank, Baldry, Balogh, Glazebrook, & Bower 2010 MNRAS 405, 2419

Mass function of star-forming galaxies



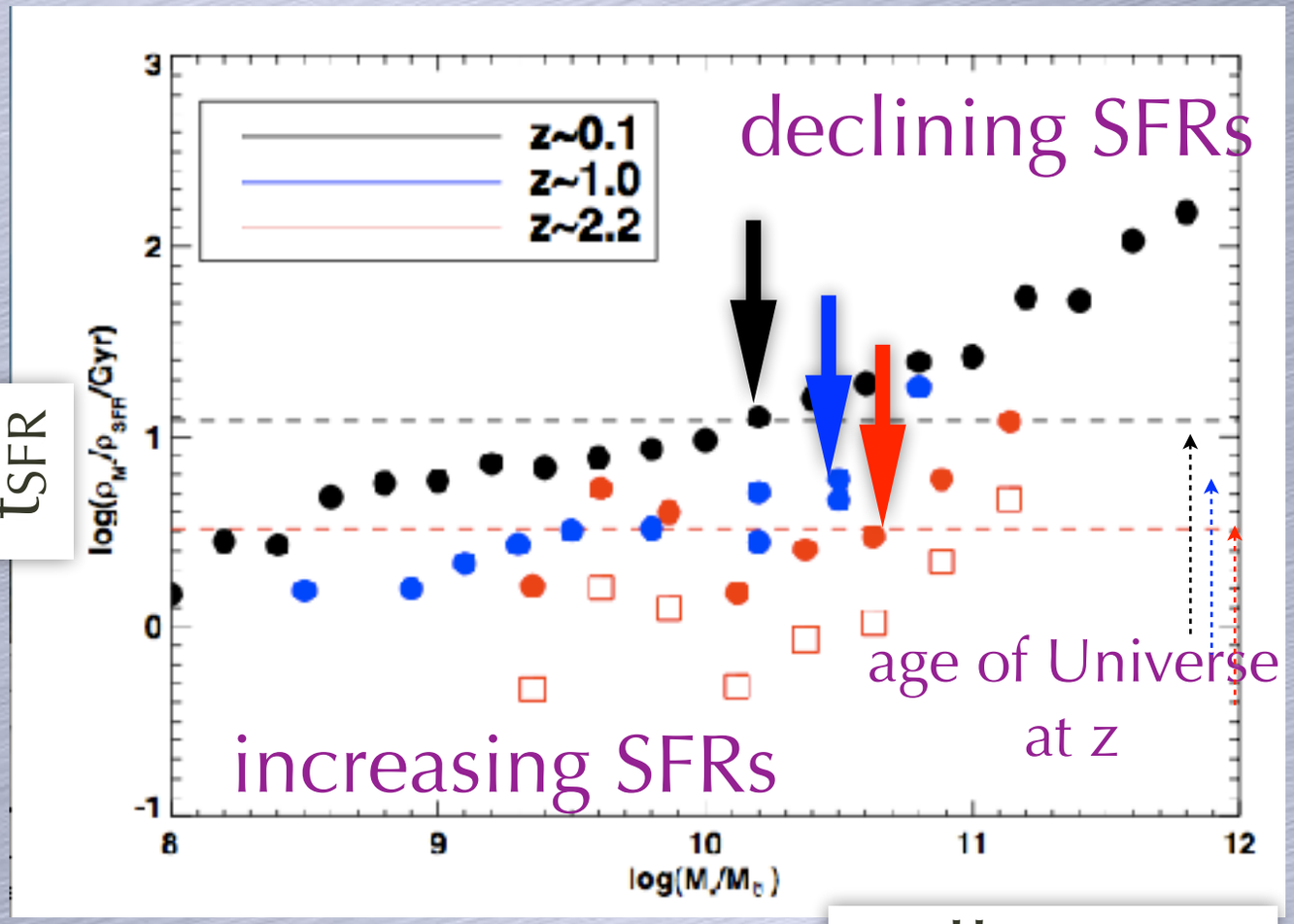
Gilbank et al. 2011, MNRAS, 414, 304

"Cosmic down-sizing"

$$t_{SFR} \propto \frac{M_\star}{SFR}$$

$$t_{SFR} \propto \frac{M_\star}{\dot{M}_\star}$$

Observational quantity to track behaviour over cosmic time



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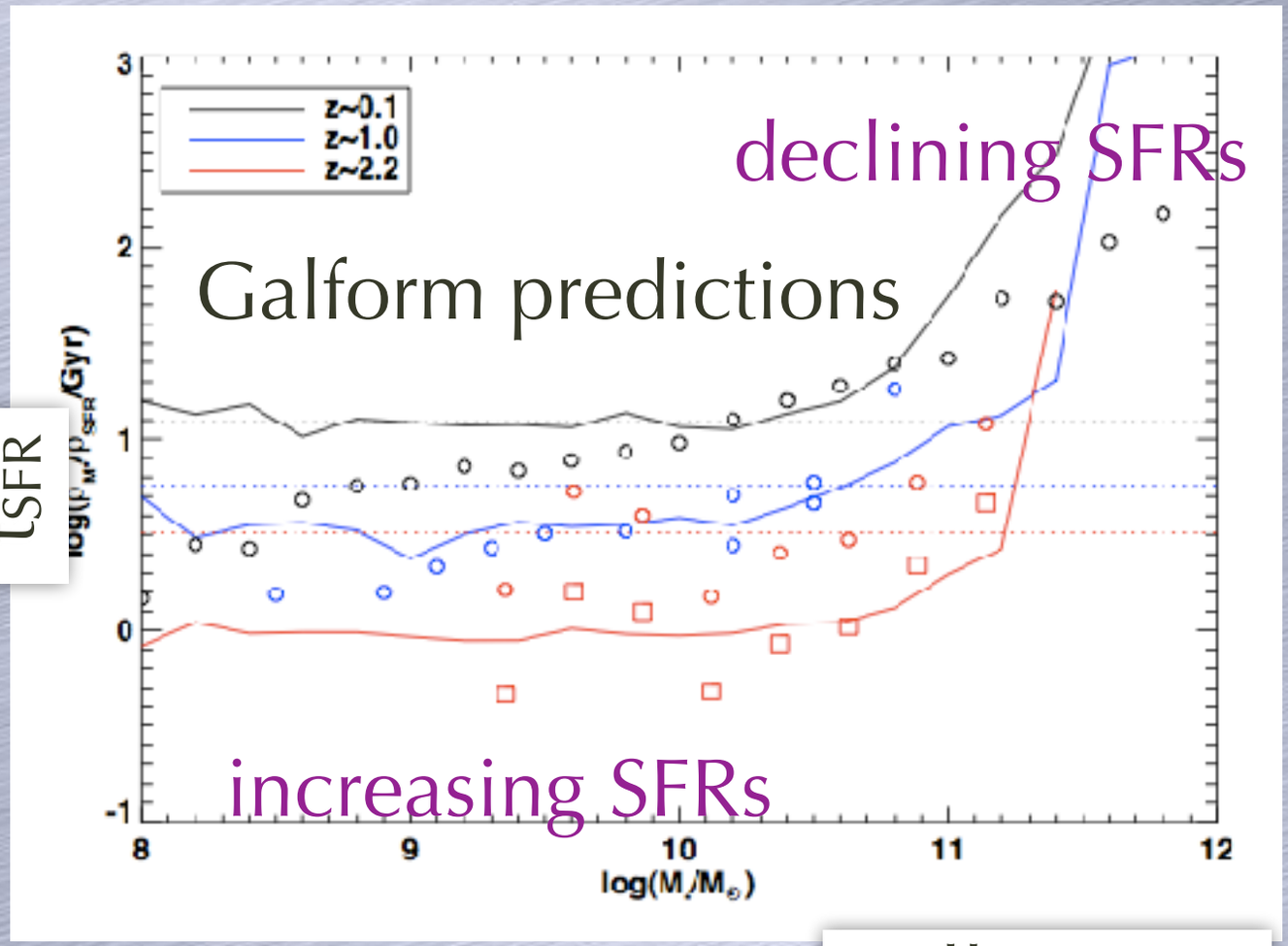

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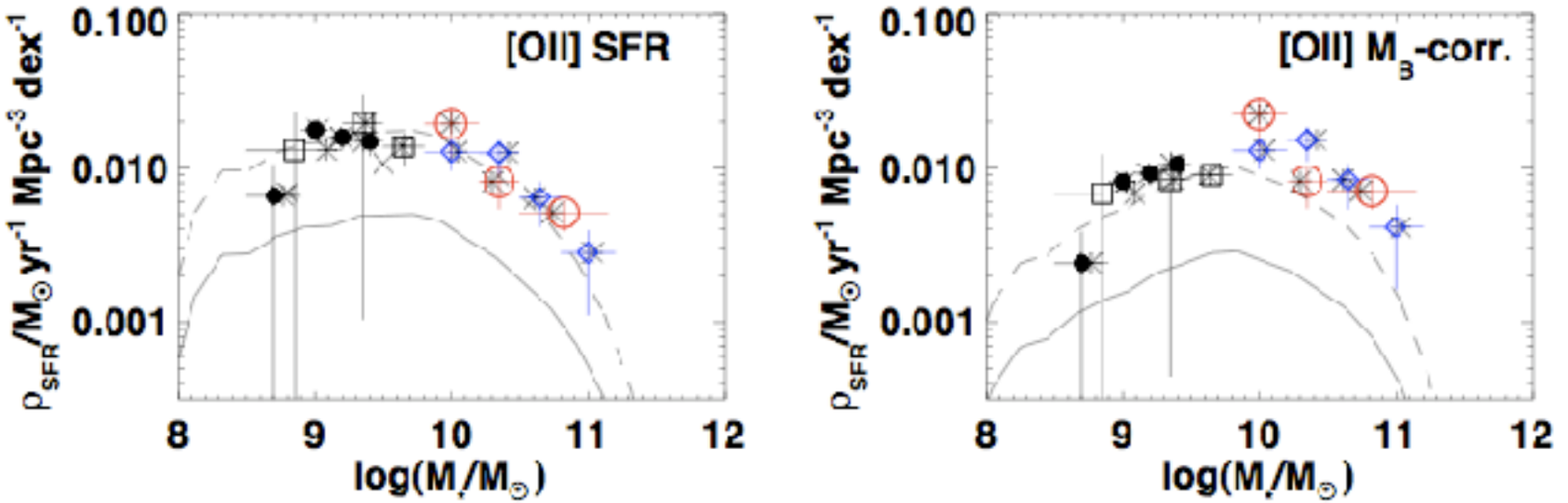
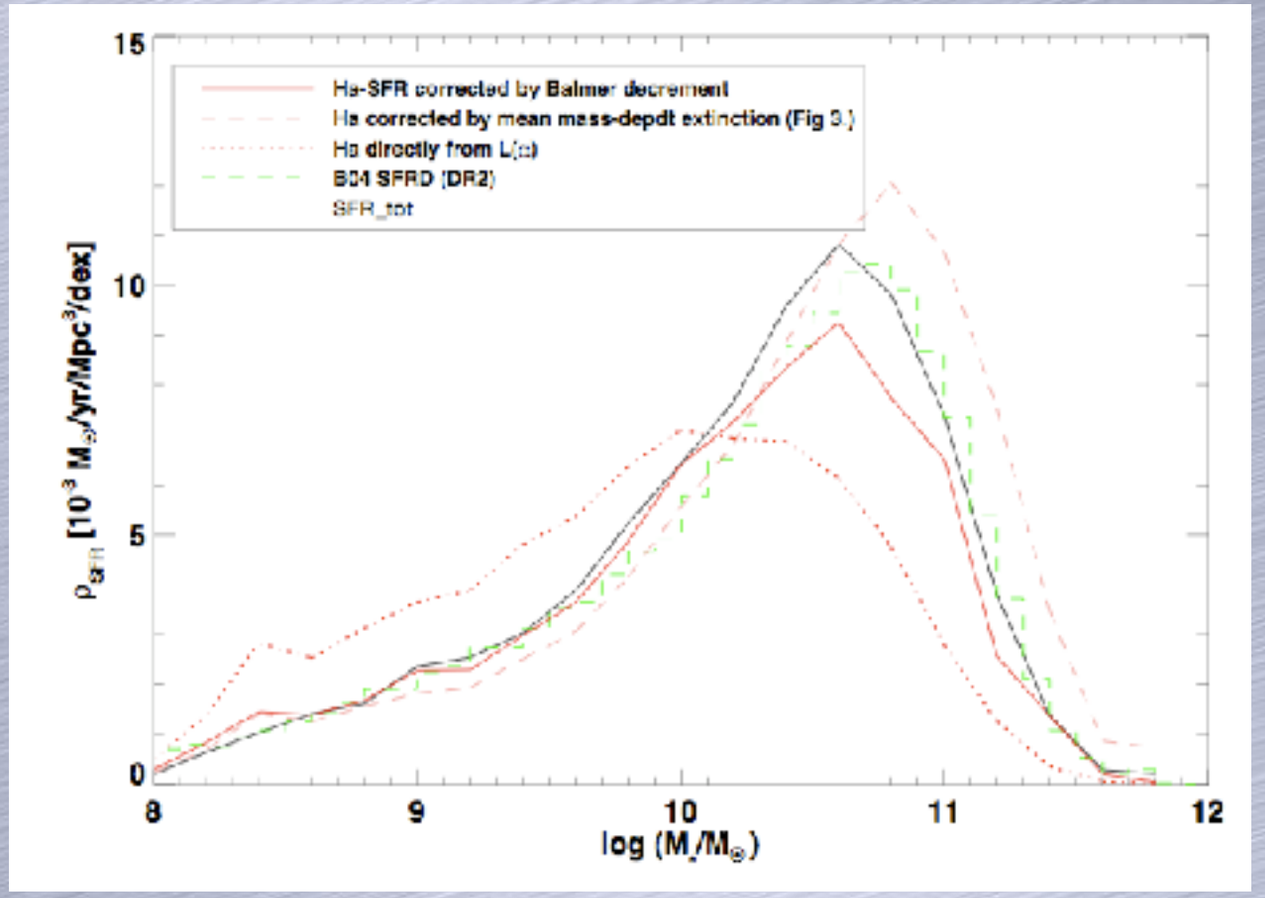
z~1 SFRD


[OII] SFR
[OII] M$_B$-corr.
[OII] emp. corr.
SED-fit SFR
$\rho_{SFR}/M_\odot yr^{-1} Mpc^{-3} dex^{-1}$
0.100
0.010
0.001
8
9
10
11
12
log(M/M$_\odot$)

Deriving local SFR calibrations from SDSS

- Stripe 82 (275 deg^2 strip, deeper than main SDSS)
- Derive stellar masses
- Derive SFRs using Hα, [OII], *u*-band, FUV from *GALEX*
- SFRD as function of stellar mass

Hα

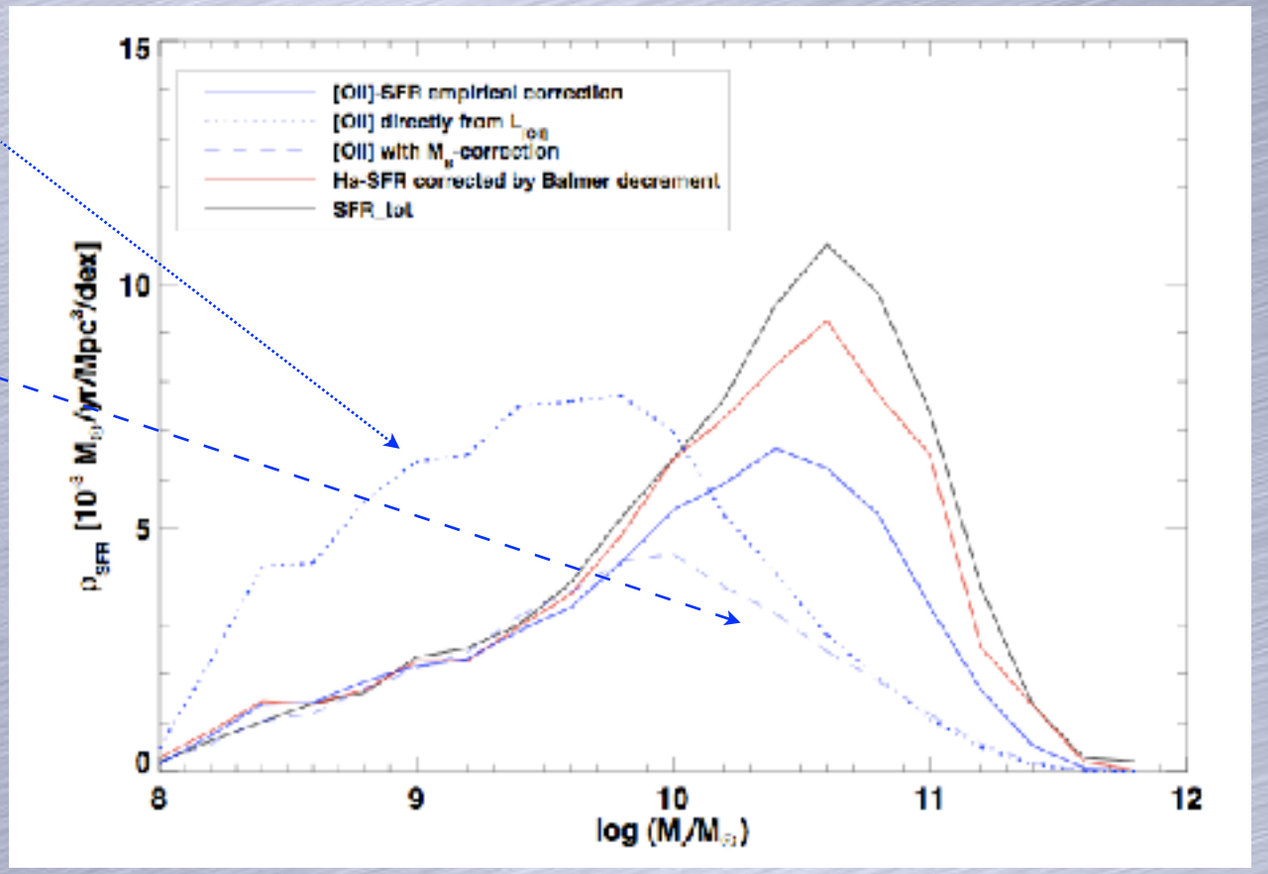


Deriving local SFR calibrations from SDSS

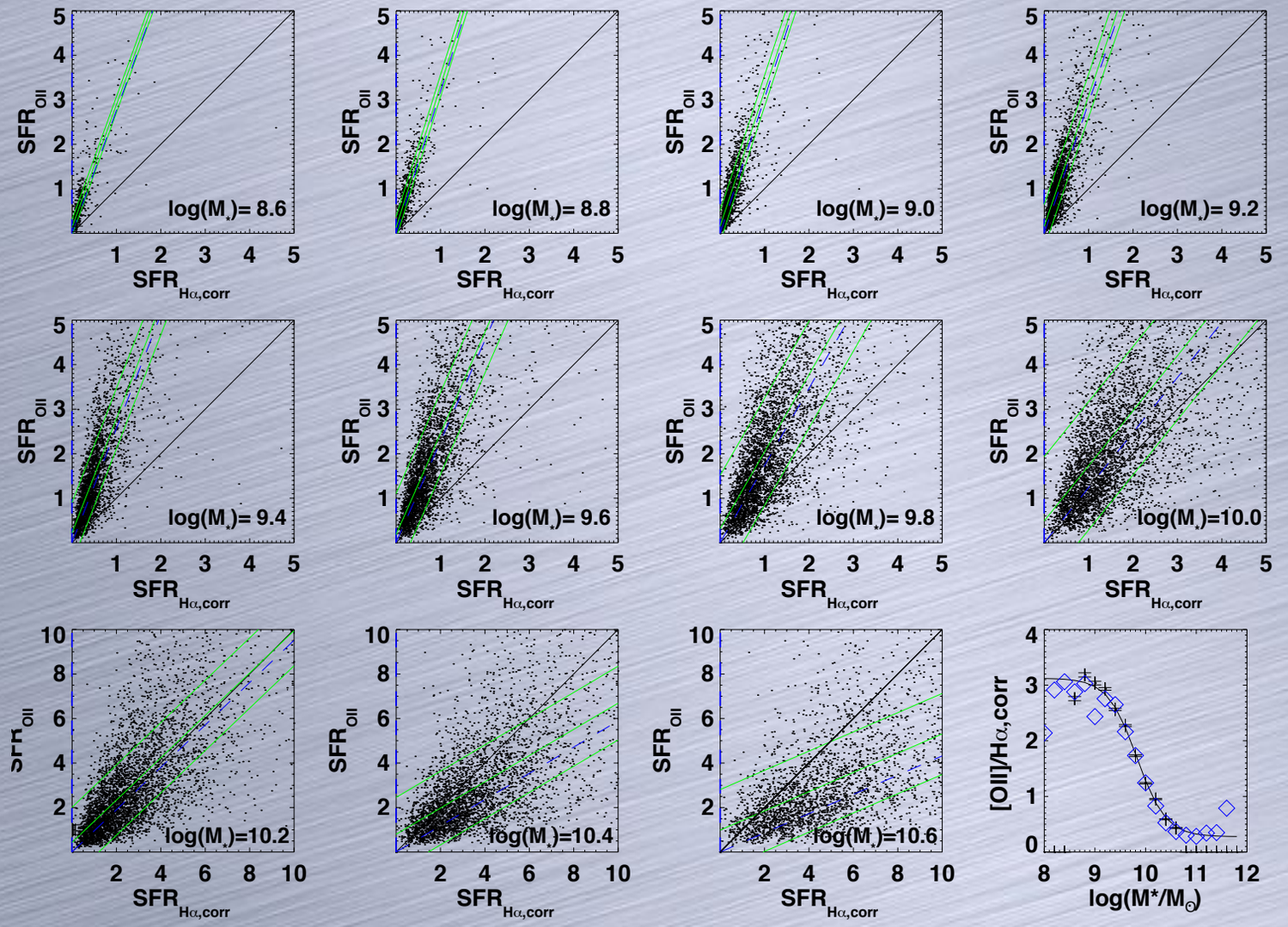
- Constant scaling from L([OII]) to SFR (as often assumed) gives v. different answer!
- Even empirical correction based on *B*-band luminosity severely underestimates SFRD at high mass

Conversion L([OII])<-->SFR depends on metallicity, dust and ionisation parameter

[OII]



Empirically correcting [OII] SFR



SFR([OII]$_{const}$)

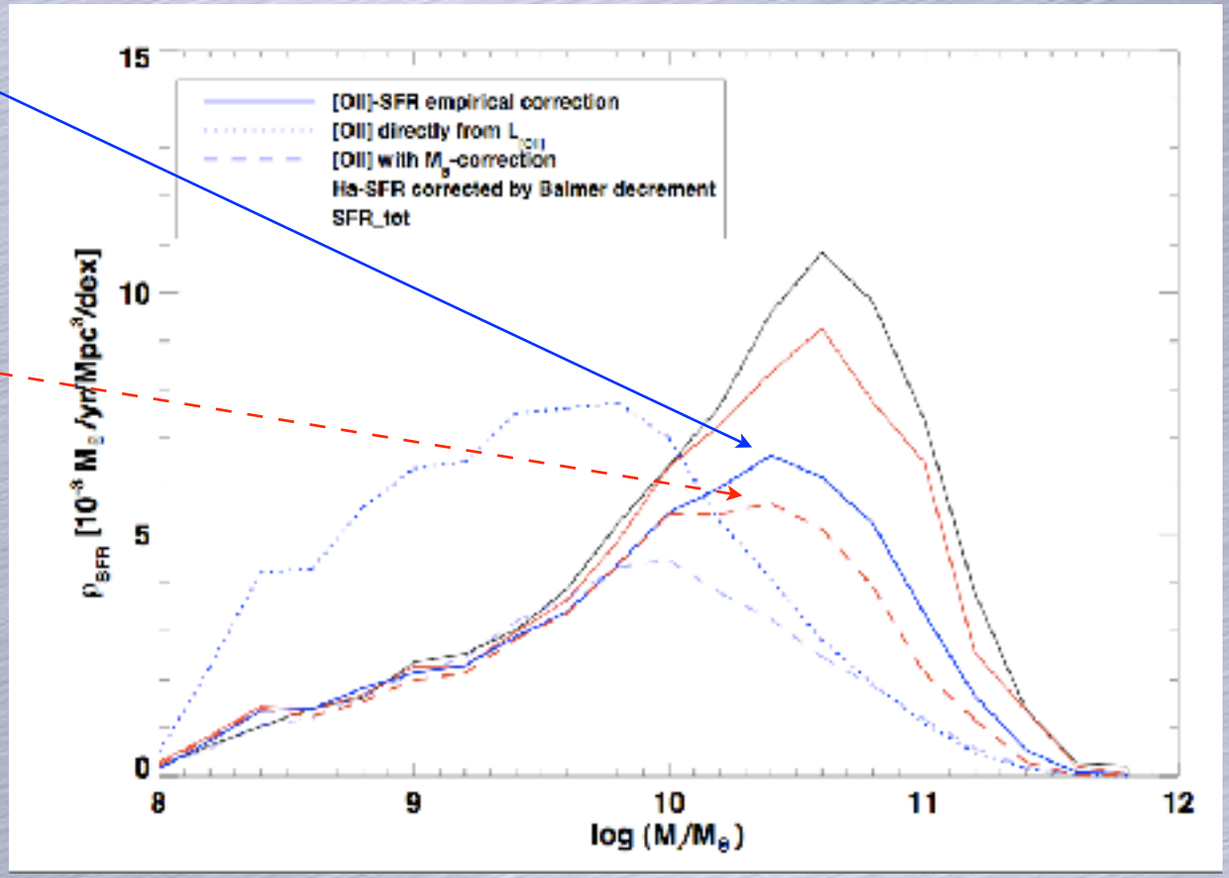
SFR(Hα$_{CORR}$)

Deriving local SFR calibrations from SDSS

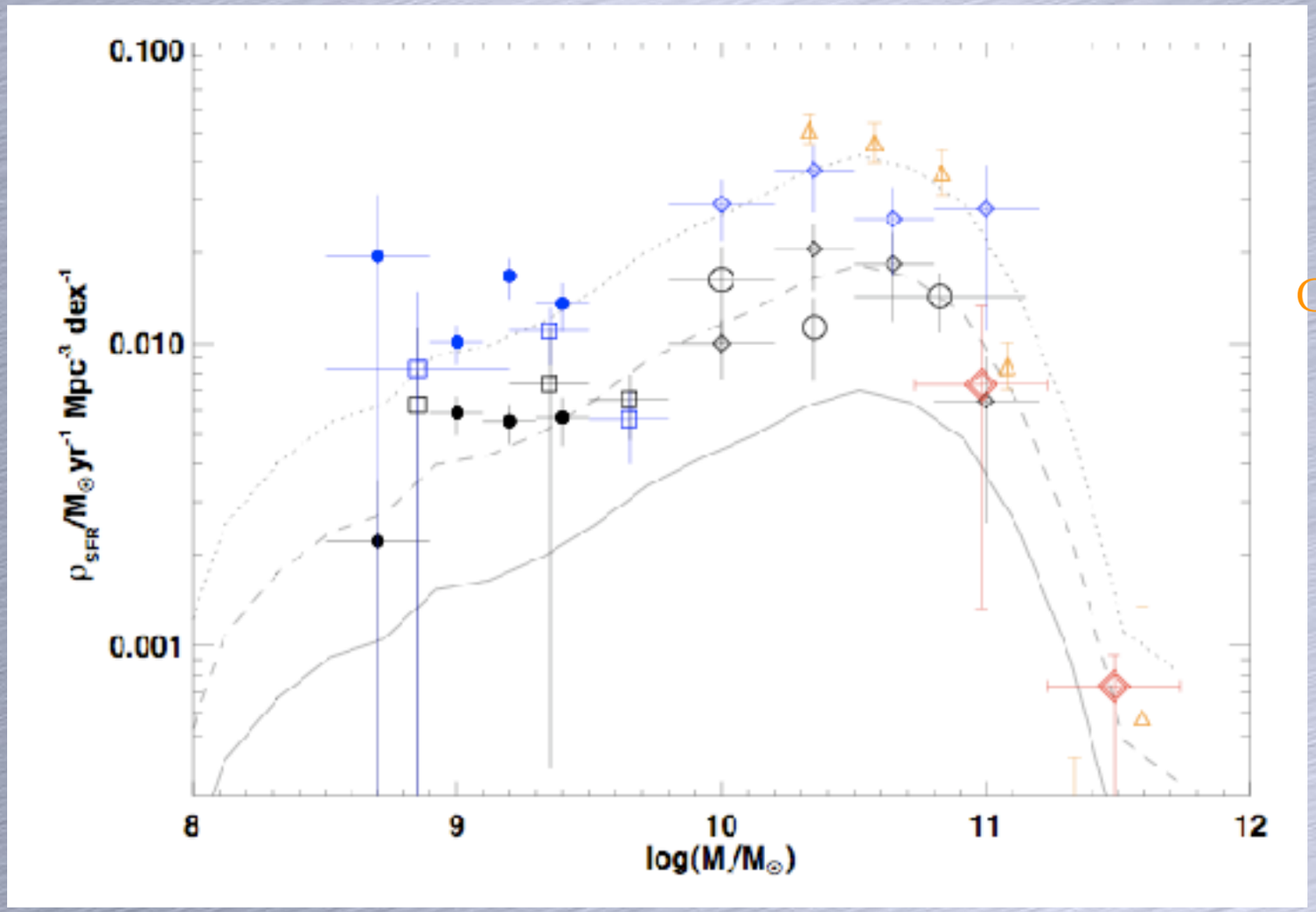
- New, empirical mass-dependent correction
- Hα SFRD for [OII]-selected galaxies

Conversion L([OII])<-->SFR depends on metallicity, dust and ionisation parameter

[OII]



z~1 SFRD

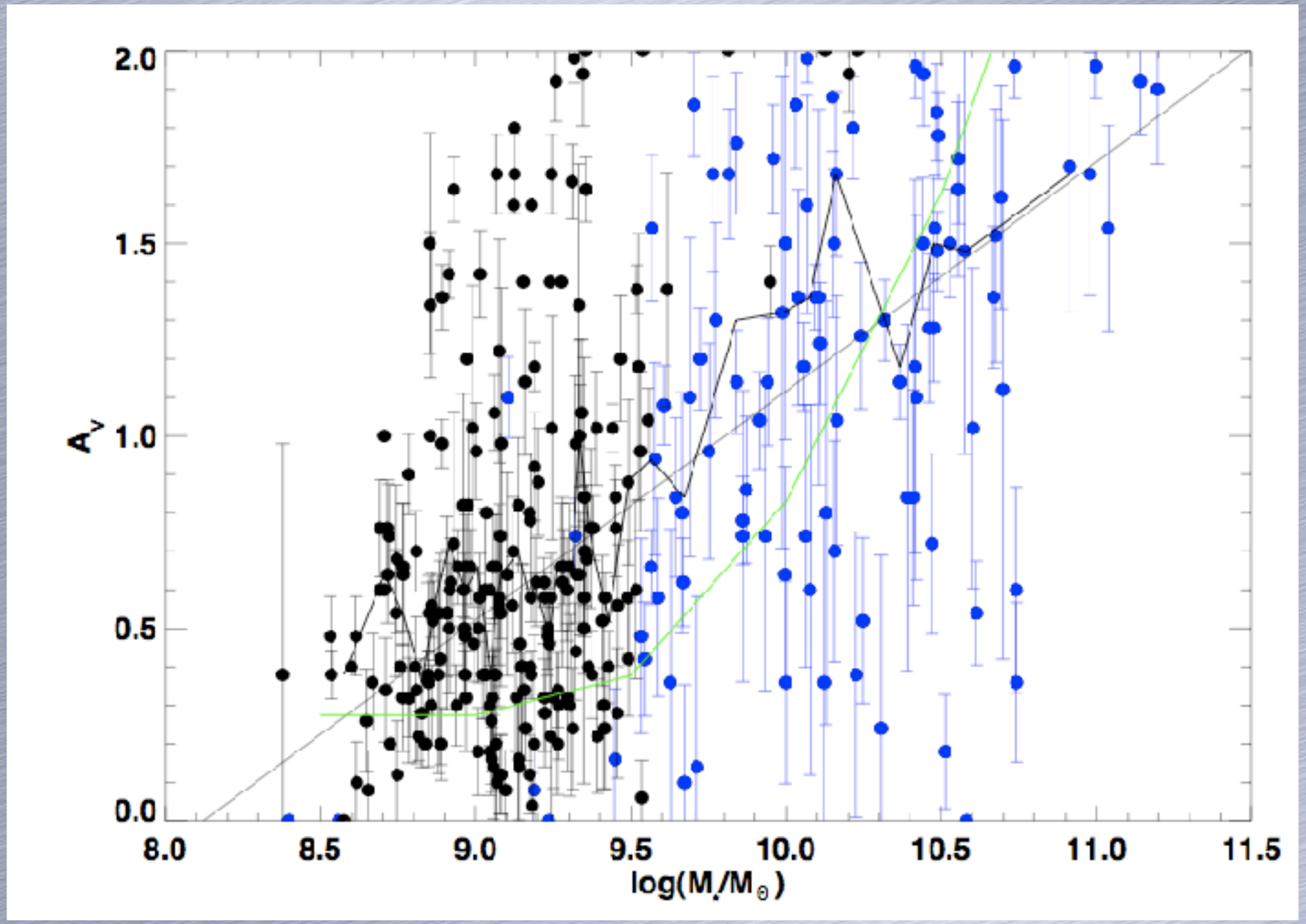


[OII]

"UV"

Cowie & Barger 08 UV

DEEP2 [OII]+24μm


2.0
1.5
1.0
0.5
0.0
A_V
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
log($M_*/M_\odot$)