Mass-Metallicity-SFR Relation at z~2

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Talk Outline

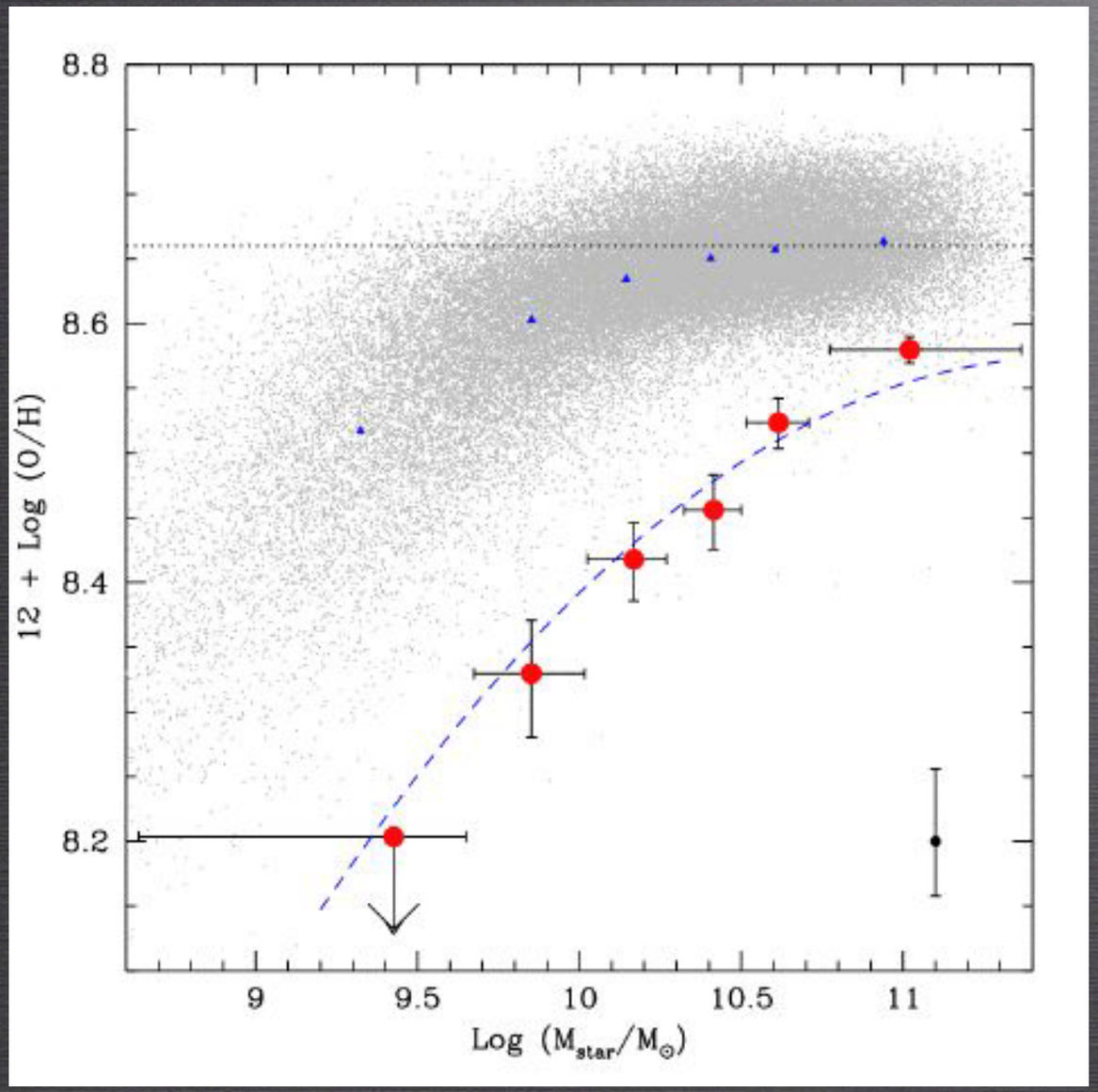
-> Introduction: MZR, FMR

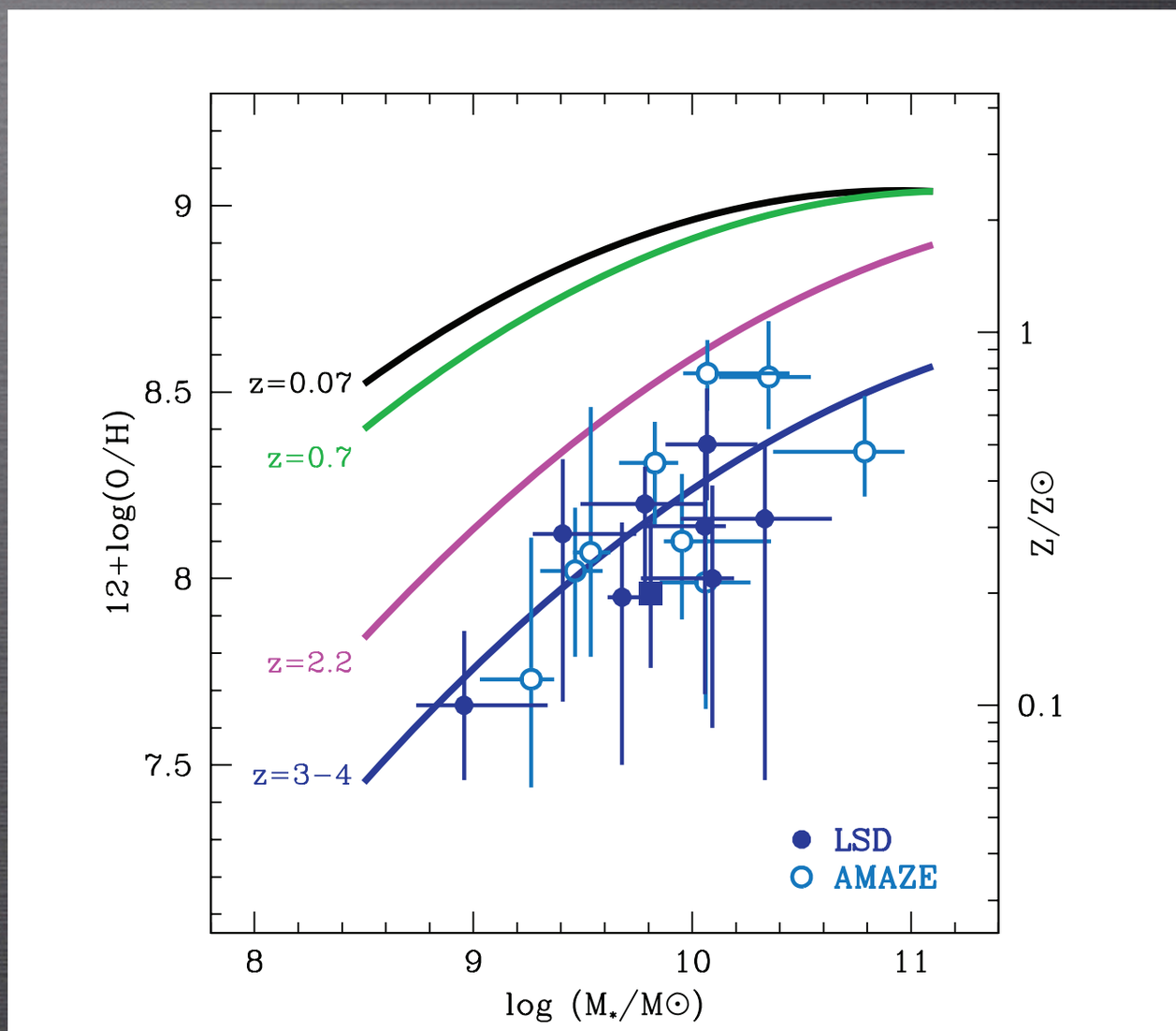
-> 3D-HST Grism Spectroscopy

-> MZR and FMR at z ~ 2

-> Photoionization Conditions at z ~ 2

Mass-Metallicity Relation (MZR)



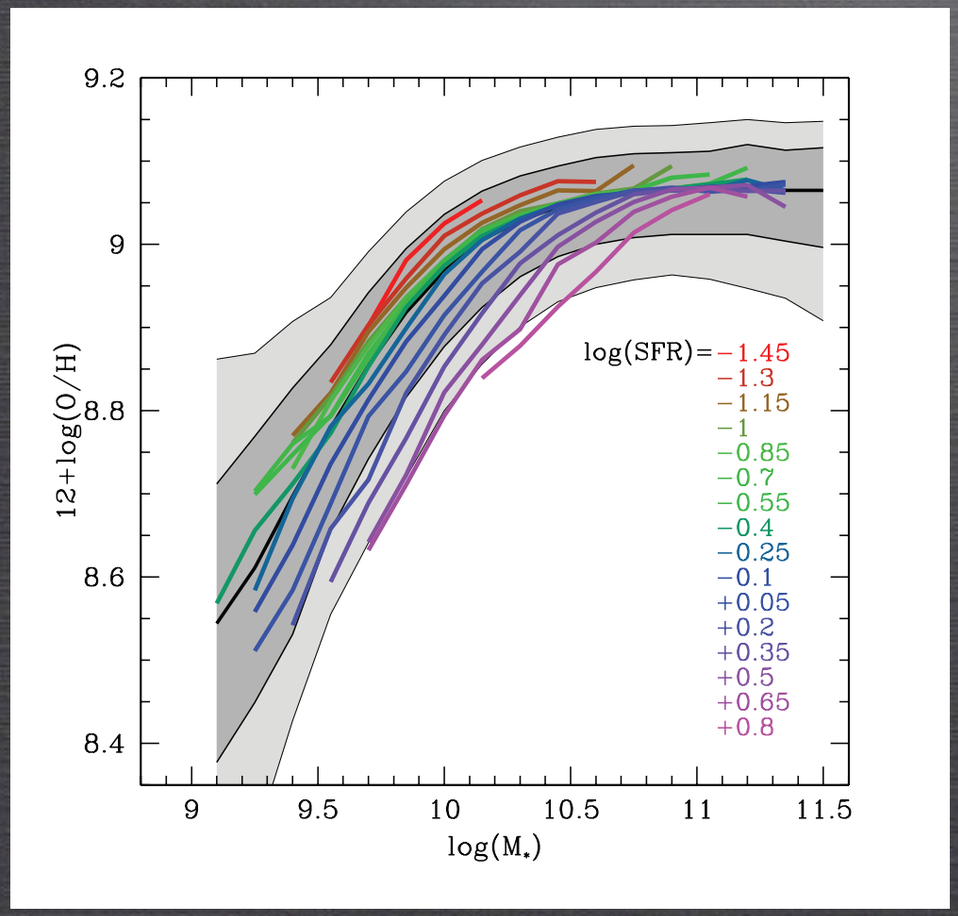


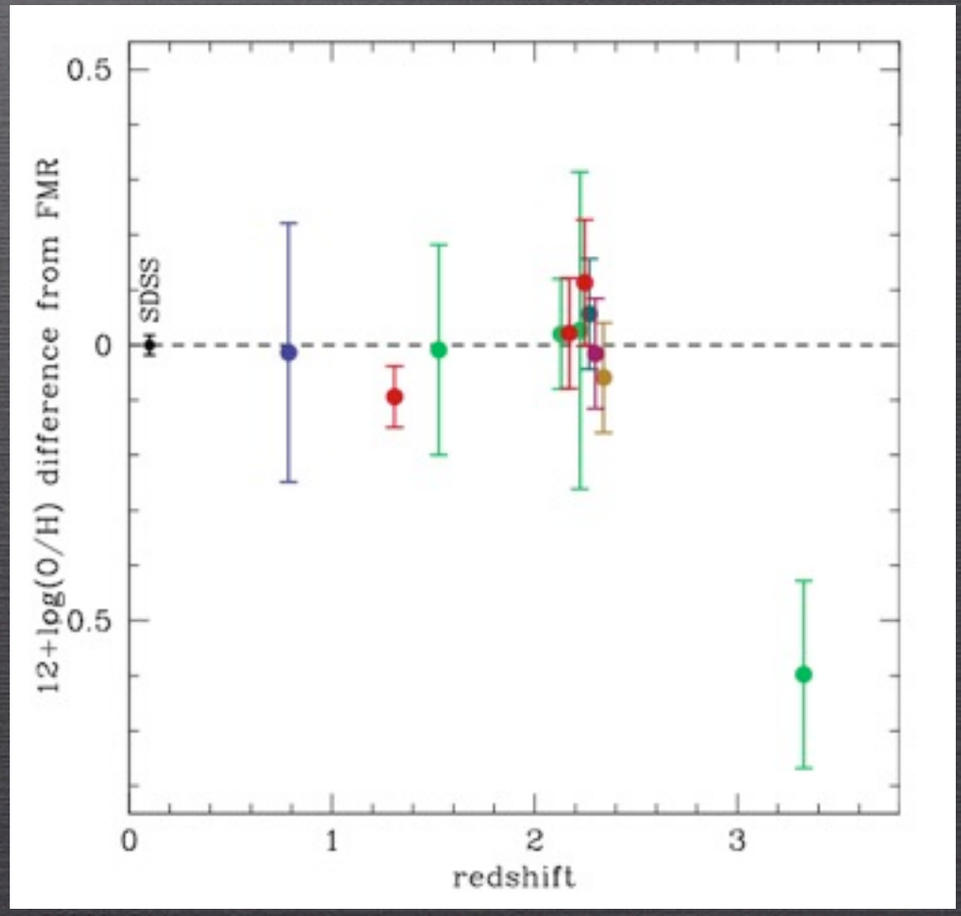
Mass-Metallicity-SFR

Fundamental Metallicity Relation (FMR)
(Mannucci+2010, Lara-Lopez+2010)

No evolution in the FMR up to z~2

$$12 + log(O/H) = 8.90 + 0.37m - 0.14s - 0.19m^2 + 0.12ms - 0.054s^2$$





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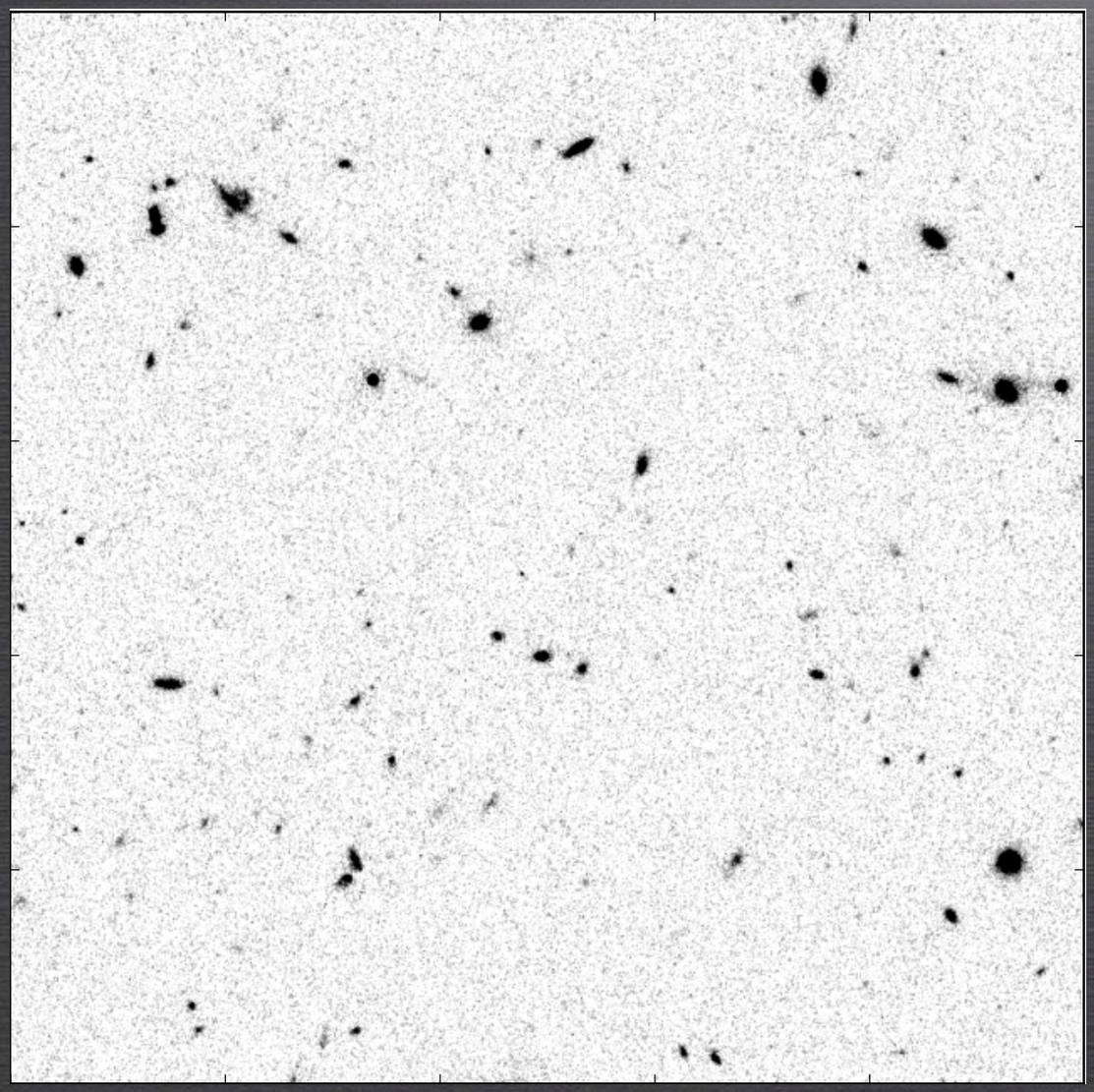
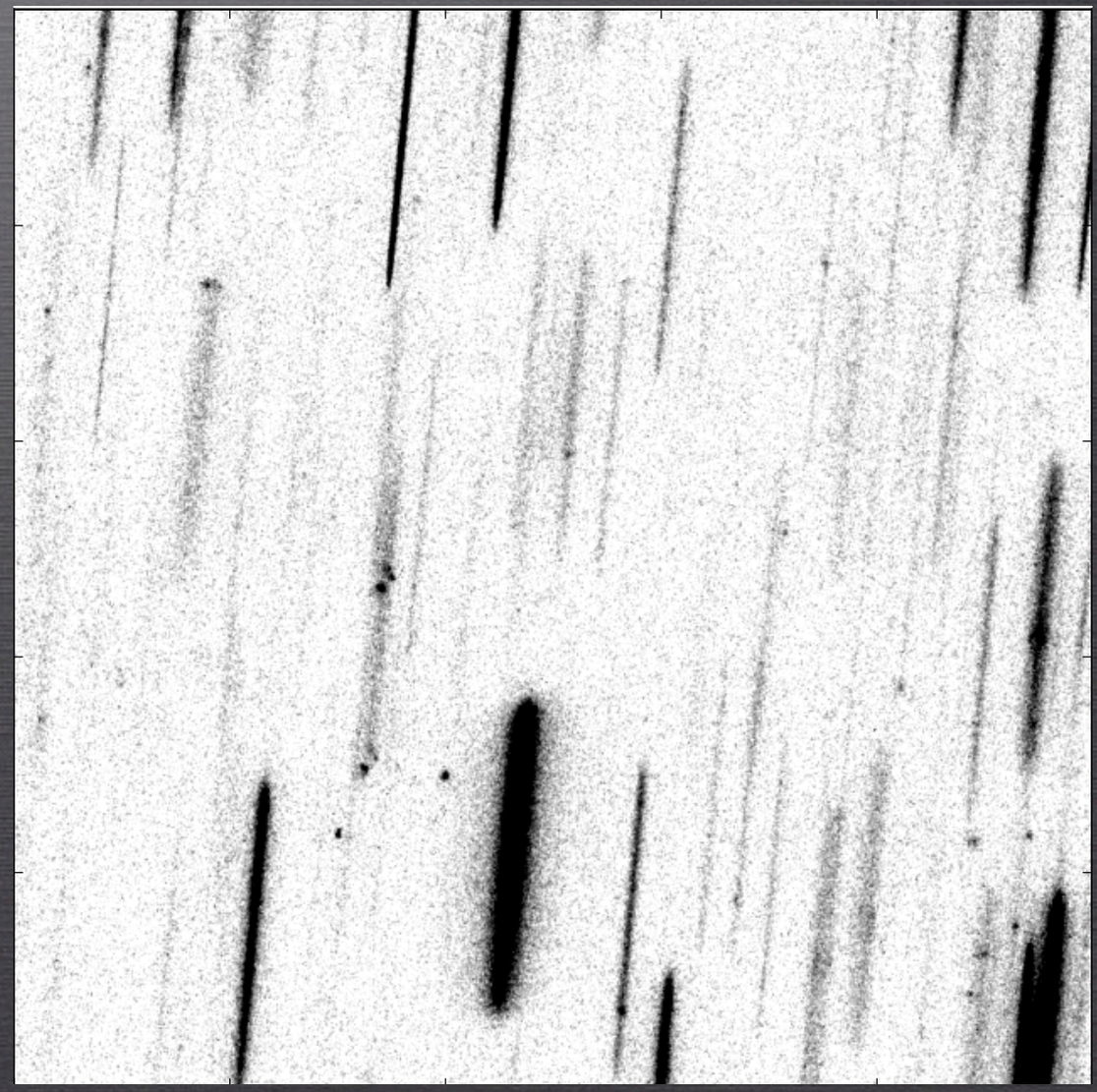
3D-HST: Near-IR Grism Spectroscopic Survey

-> Low resolution (R~130) near-IR spectroscopy (1.1 - 1.7μm)

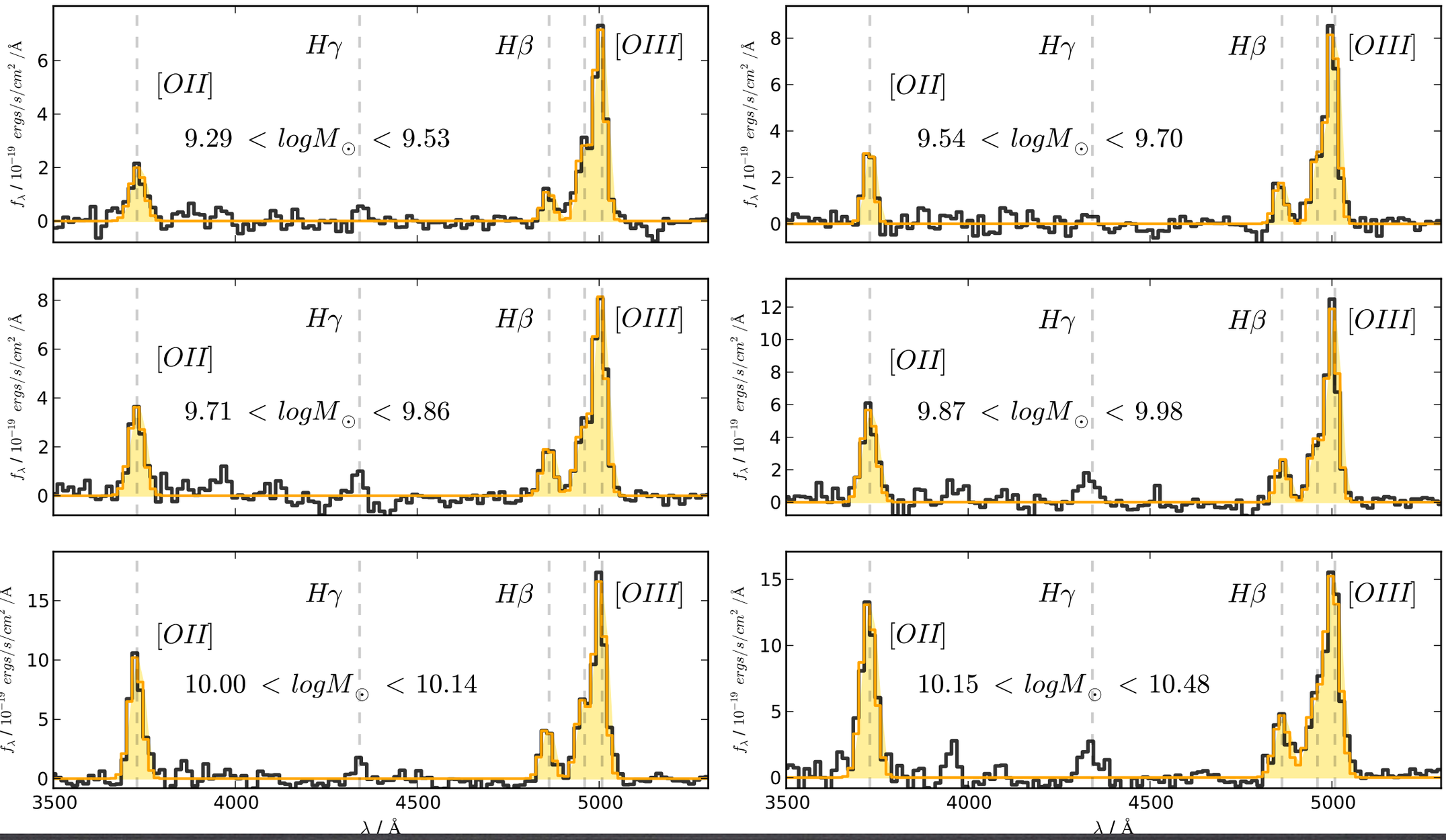
-> Rest frame optical spectra of galaxies in redshift range 1 < z < 3.5



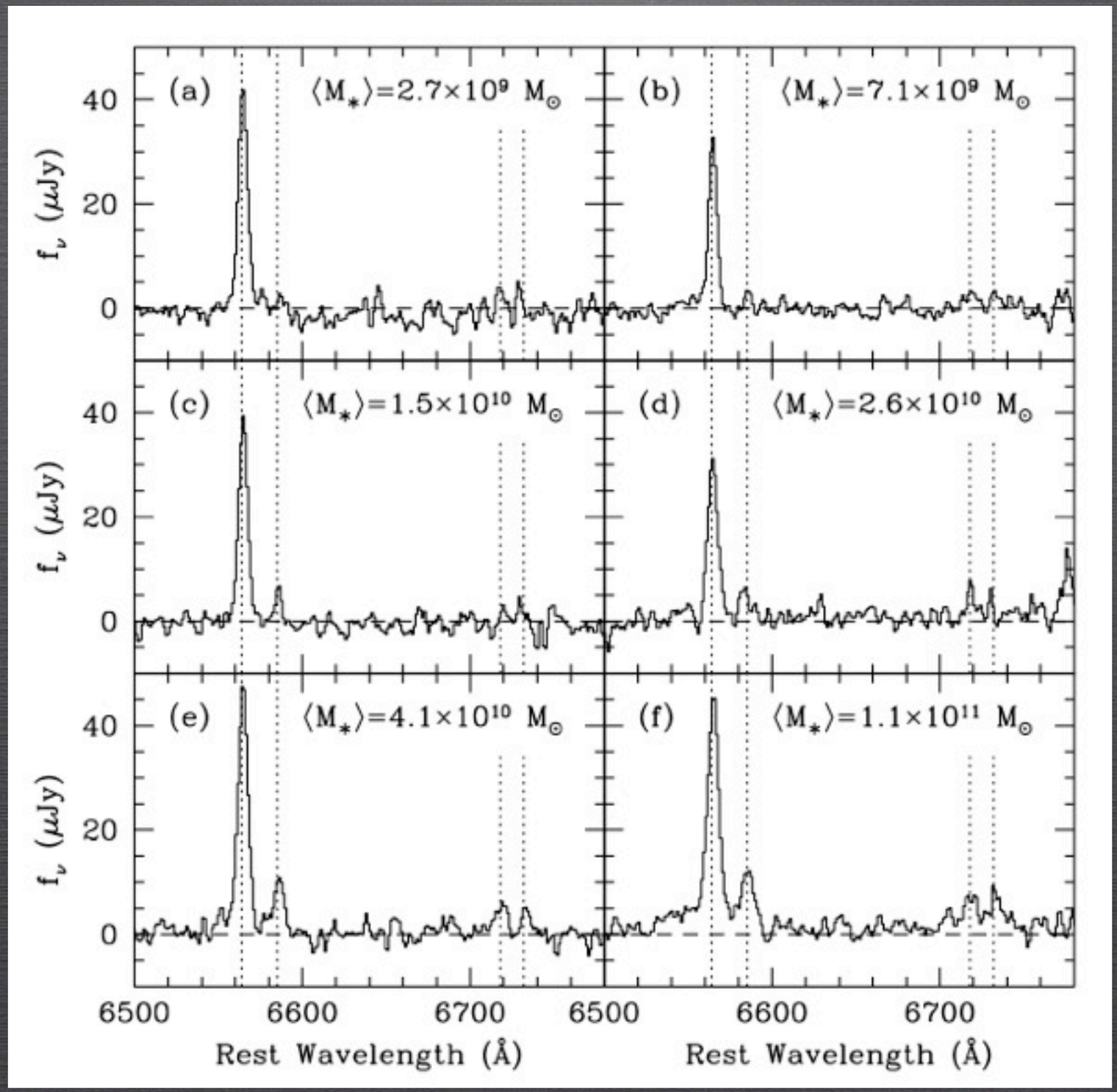


93 galaxies at 2.0 < z < 2.3

Stack galaxies into 6 bins of stellar mass



Comparison sample



z = 2.2 sample of 87 galaxies
(Erb+2006)

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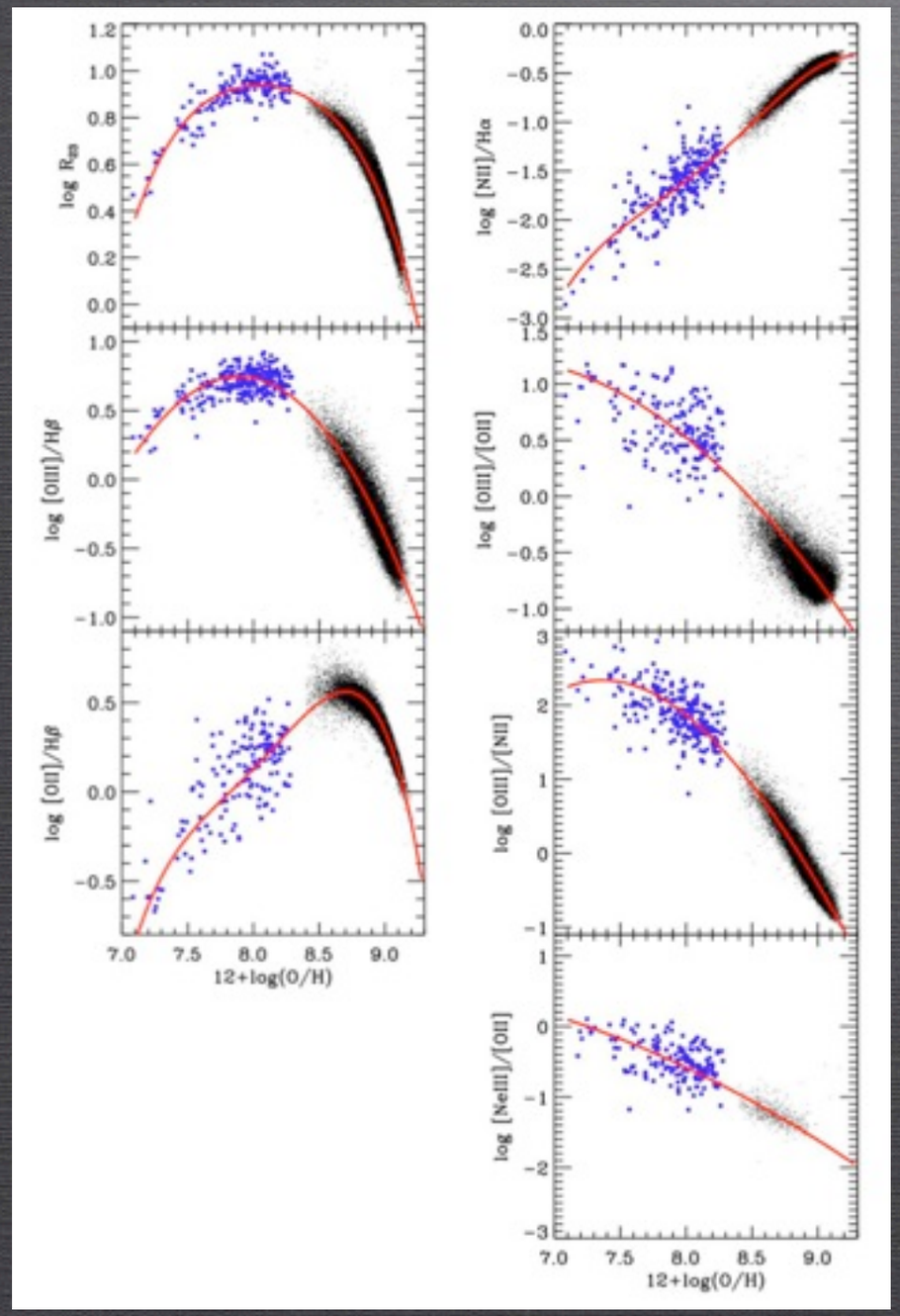
Measuring Metallicities

Method follows the empirical emission line ratio calibrations of Maiolino+2008



Log(R)

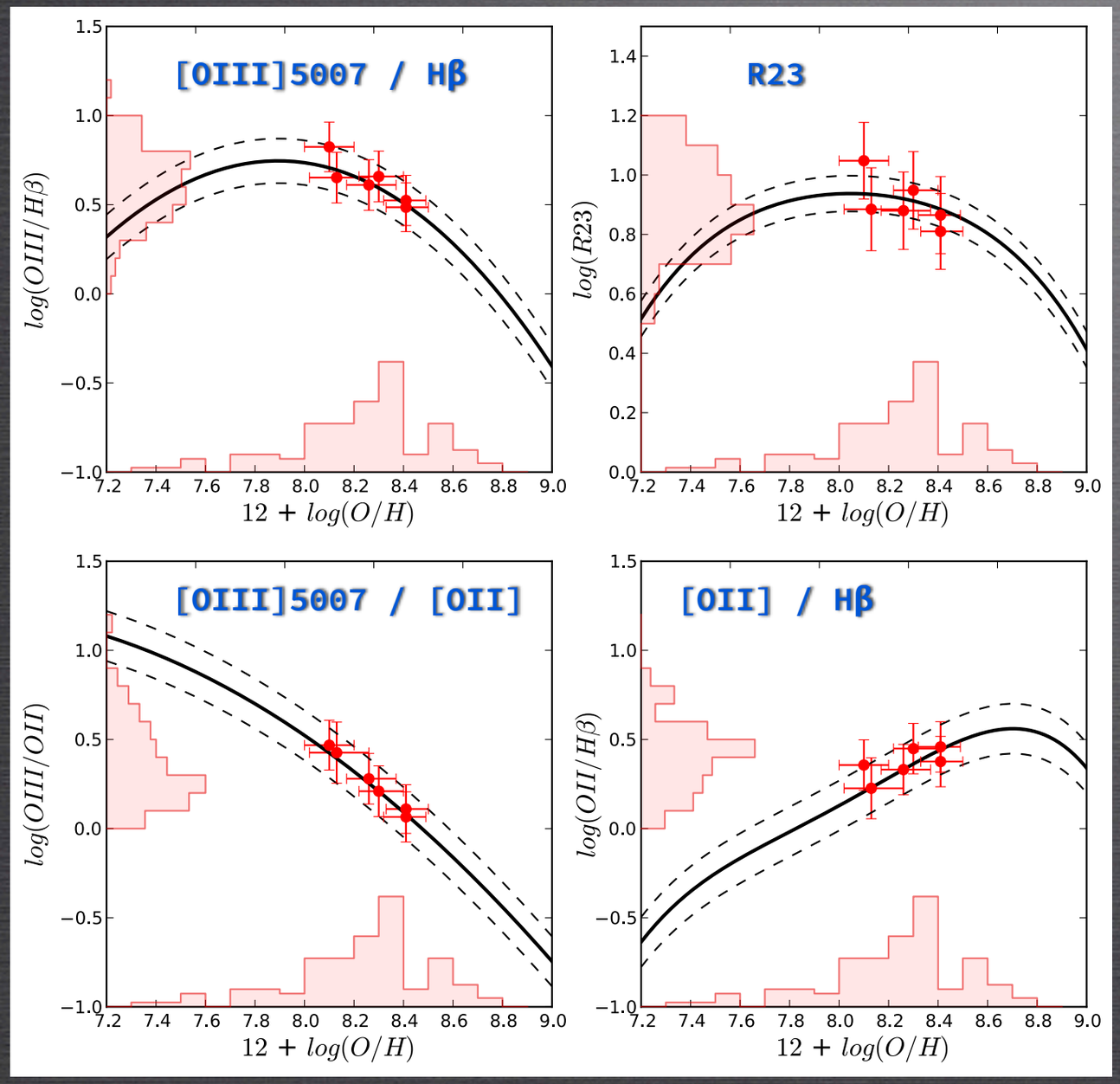
12 + log(O/H) ⟶

Calibrated nebular emission line ratios in the local Universe:

~ 260 low metallicity galaxies using direct method [OIII]4636 (T_e method)

~ 22,000 SDSS galaxies metallicities derived from photoionization models (Kewley & Dopita 2002)

Measuring Metallicities



Use four available emission line calibrations to measure metallicites:

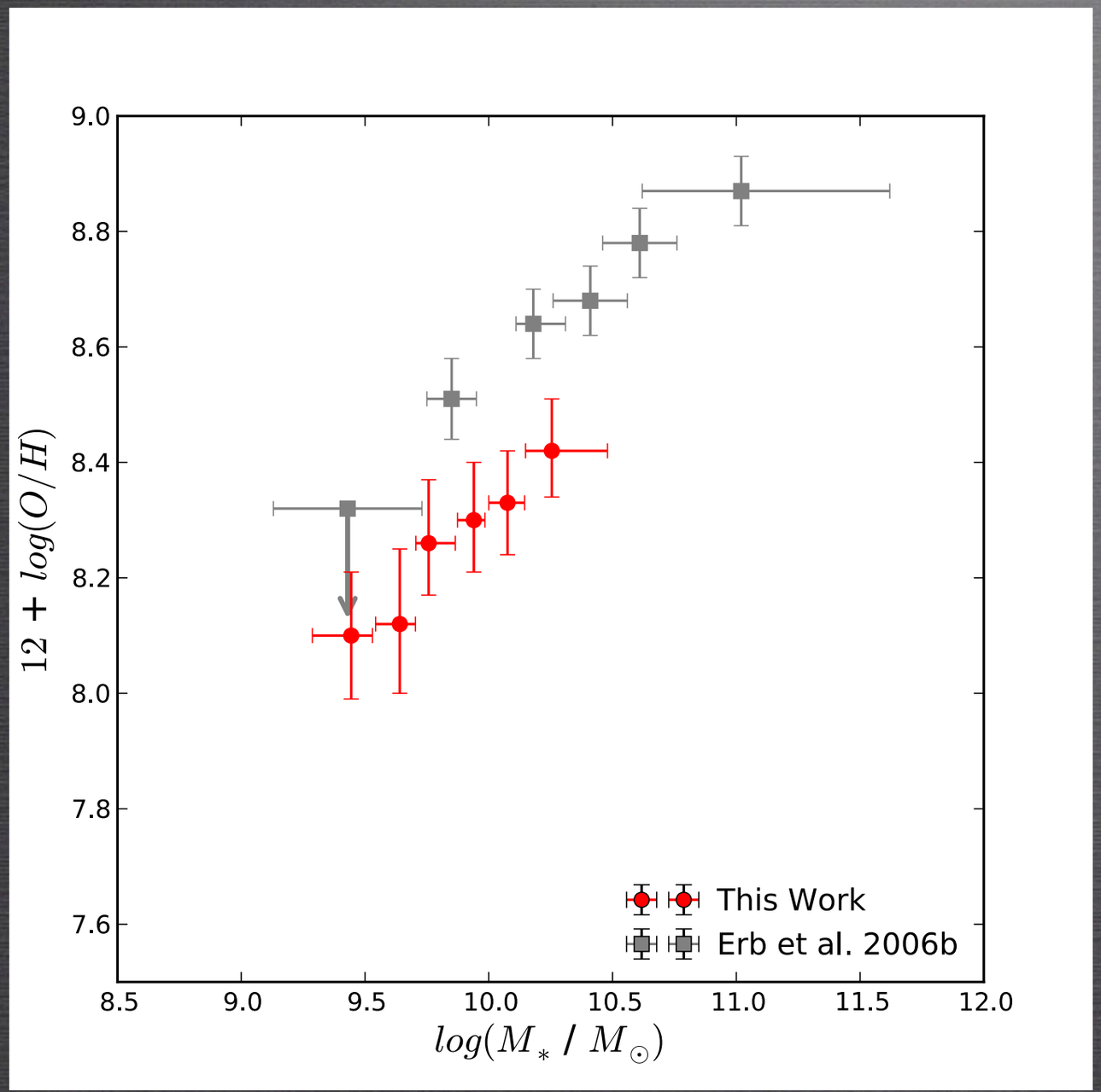
-> R23

-> [OIII]5007 / Hβ

-> [OIII]5007 / [OII]

-> [OII] / Hβ

Mass-Metallicity Relation (MZR)

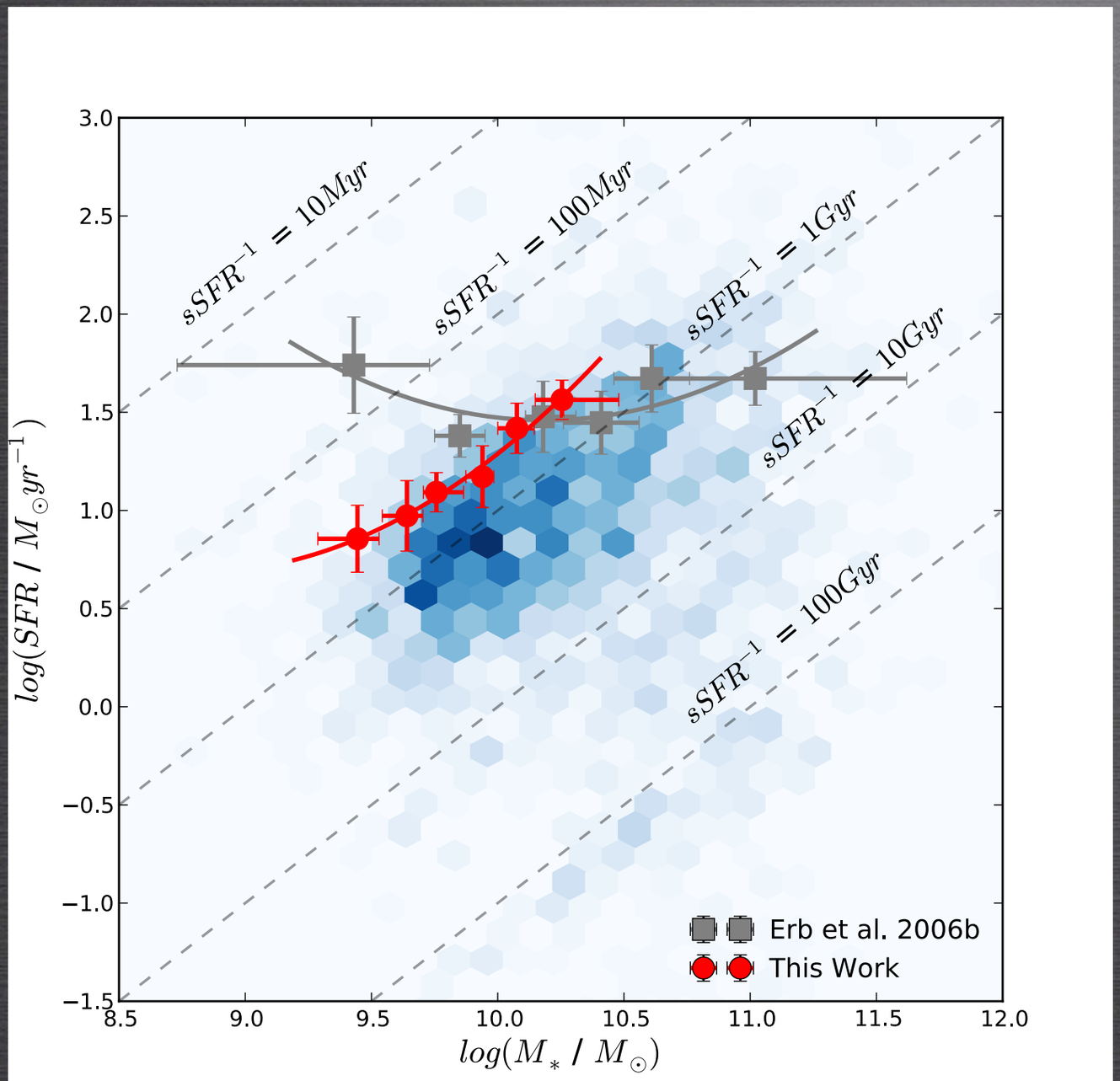


Find a MZR consistent with other studies across 0 < z < 3: metallicity increases with increasing stellar mass

Compare with Erb et al. 2006 MZR at z ~ 2 who measure metallicites with the [NII]/Hα ratio

Fundamental Metallicity Relation (FMR)

$$12 + log(O/H) = 8.90 + 0.37m - 0.14s - 0.19m^2 + 0.12ms - 0.054s^2$$

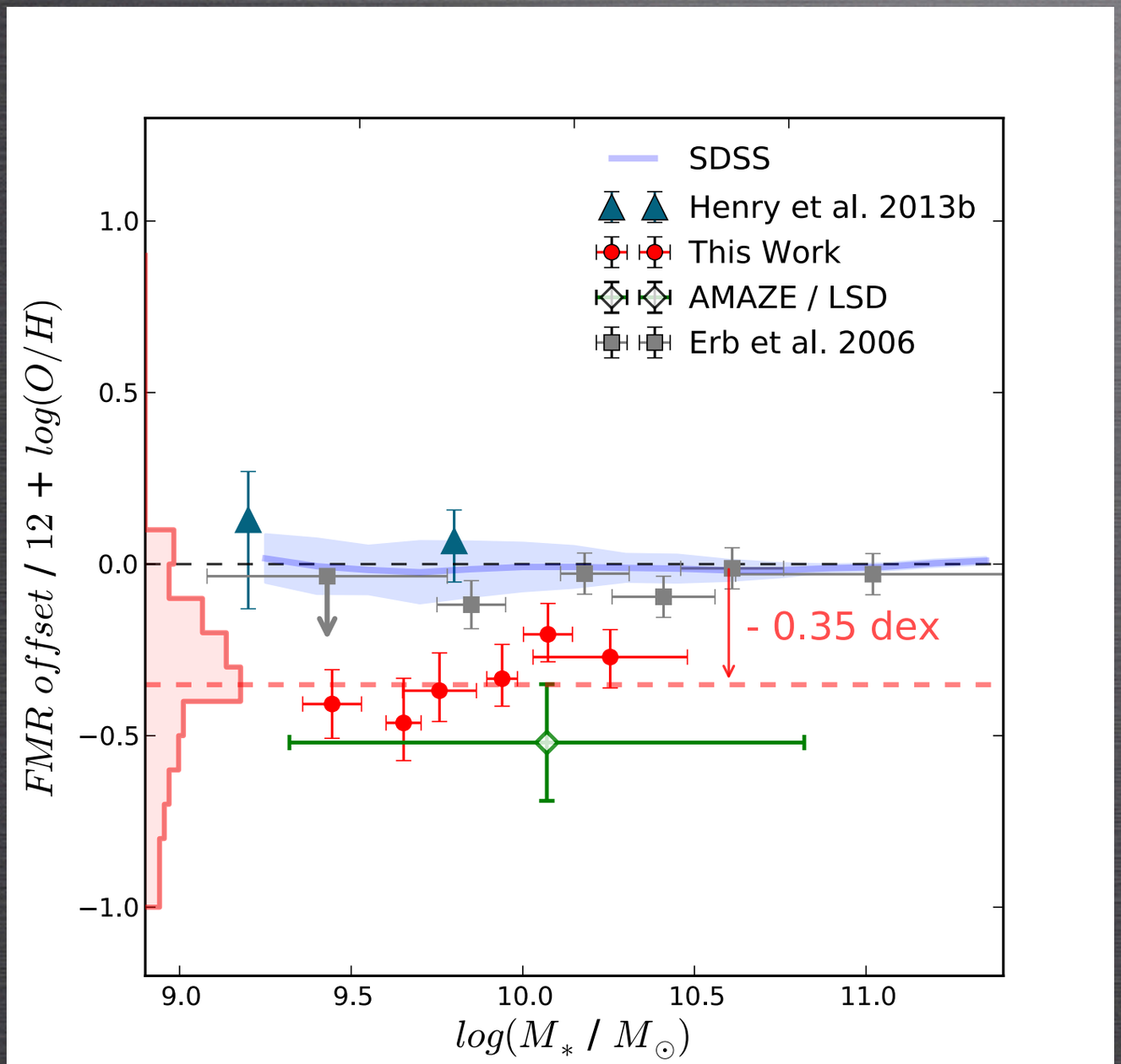


Median SFR of total sample ~ 20 $M_\star yr^{-1}$

Across the range of stellar mass, we measure lower SFR in stacks than Erb+2006

According to the FMR this should results in higher metallicites

Fundamental Metallicity Relation (FMR)



FMR offset of our sample ~ 0.35 dex

Similar offset (~ 0.5 dex) seen with AMAZE/LSD sample at z ~ 3

Erb+2006 galaxies consistent with FMR

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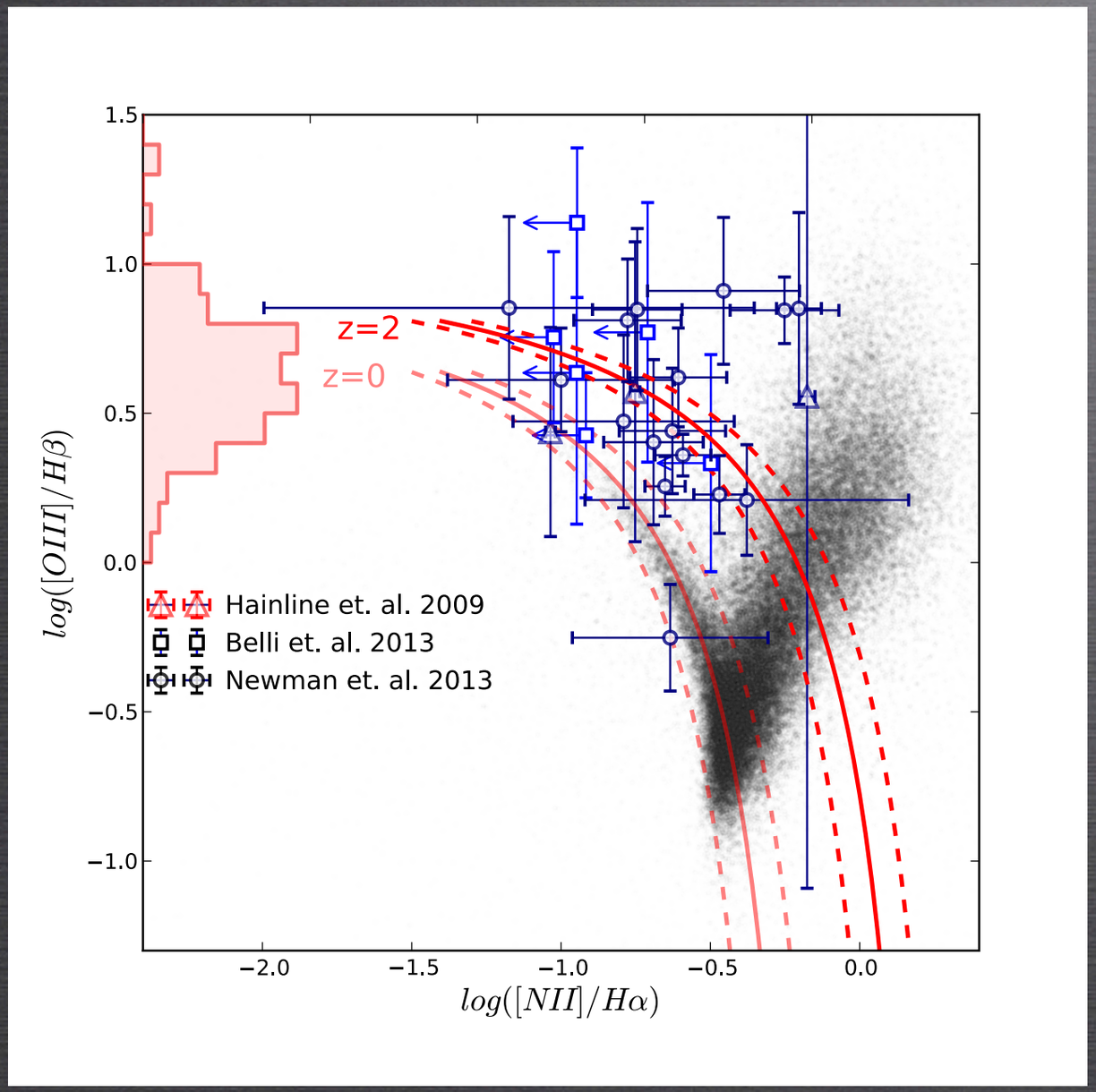
Photo-ionization Conditions: BPT Diagram

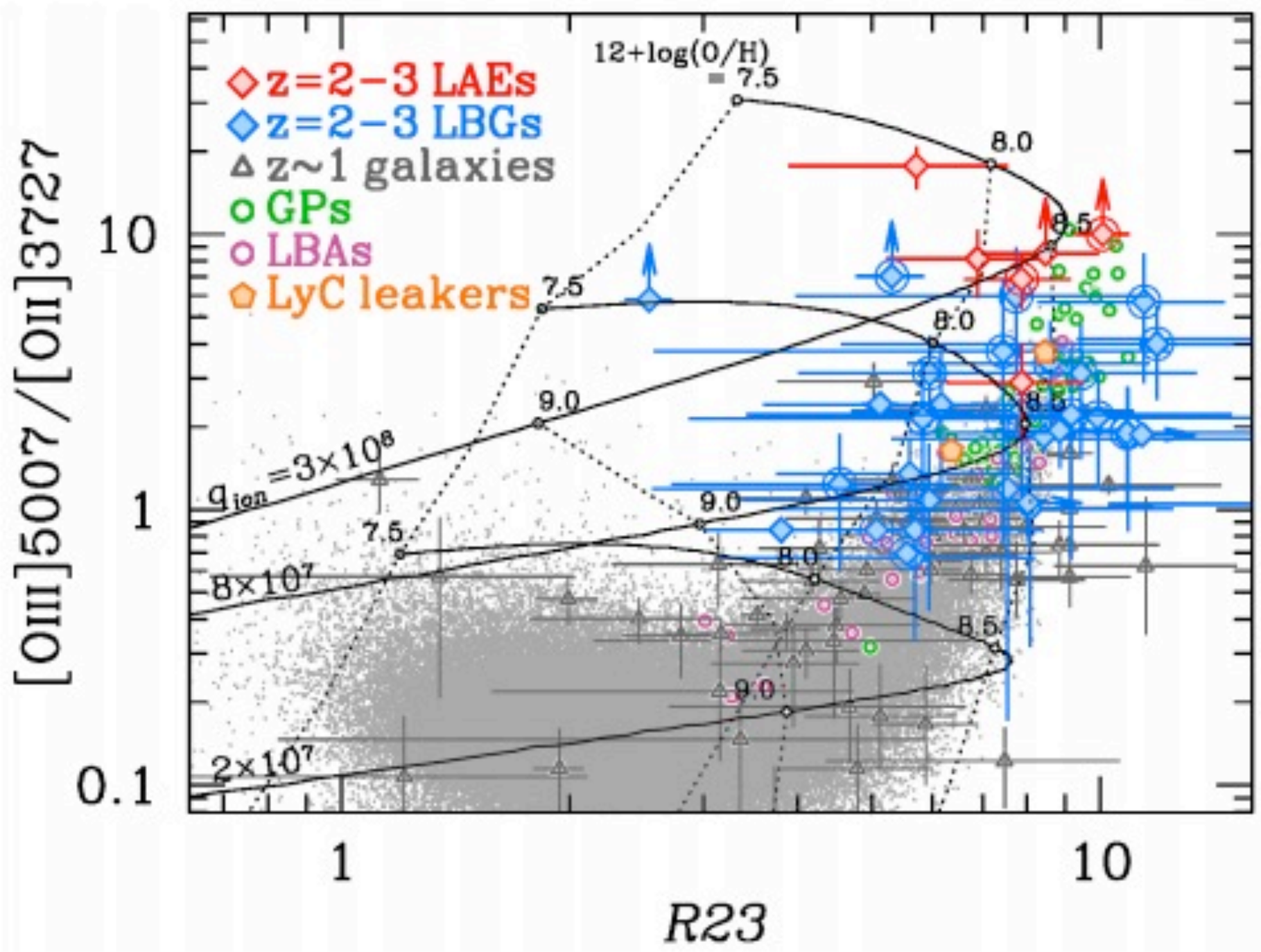


Evidence for change in ionization conditions of the ISM at high-z

Galaxies offset from the SFR sequence in the BPT diagram

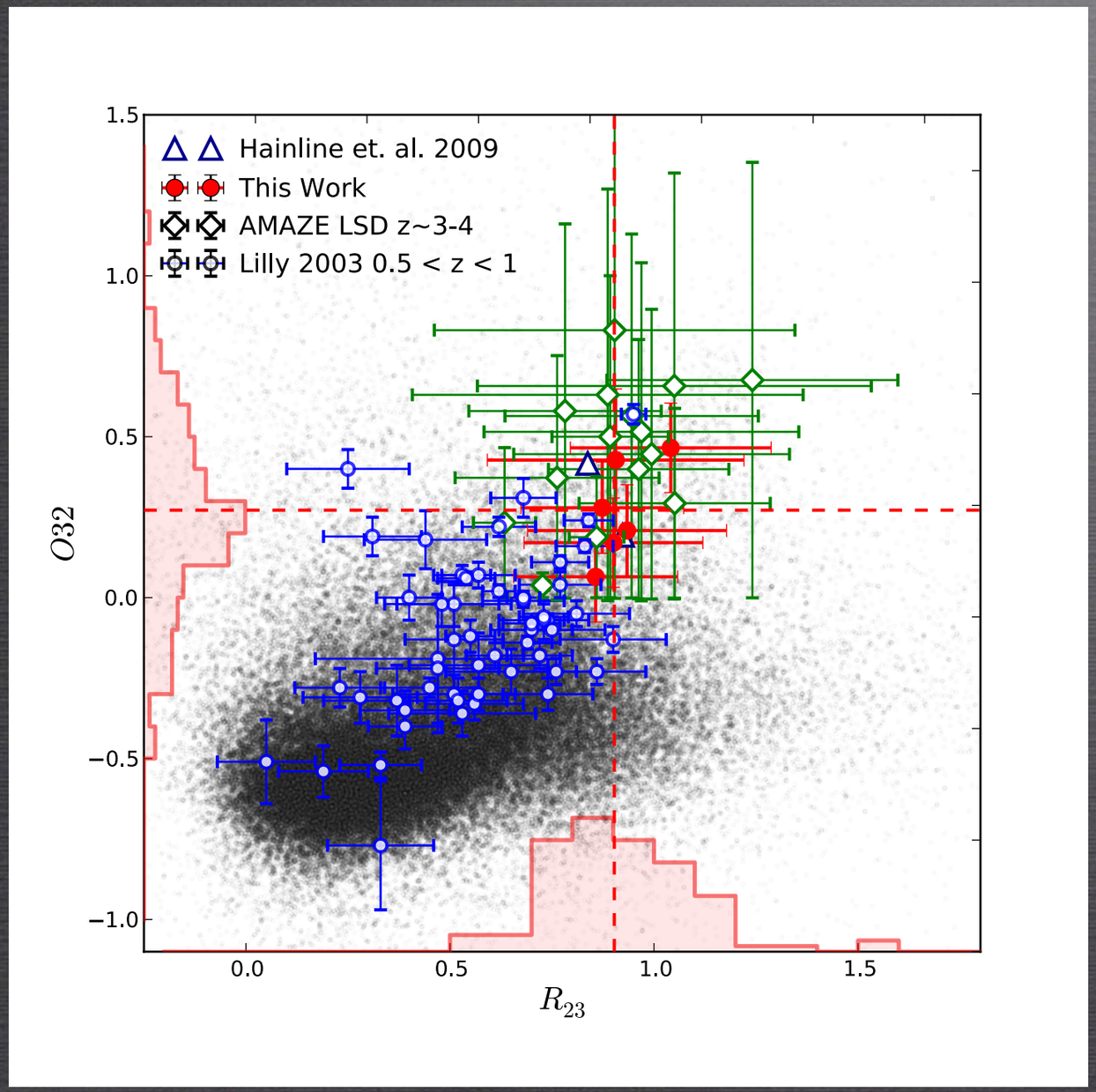
Increased ionization parameter/ shape of ionizing radiation field, density of ISM (Brinchmann +08, Kewley+2013)

Our [OIII]/Hβ consistent with other z ~ 2 galaxies



Nakajima+2013

Photo-ionization Conditions



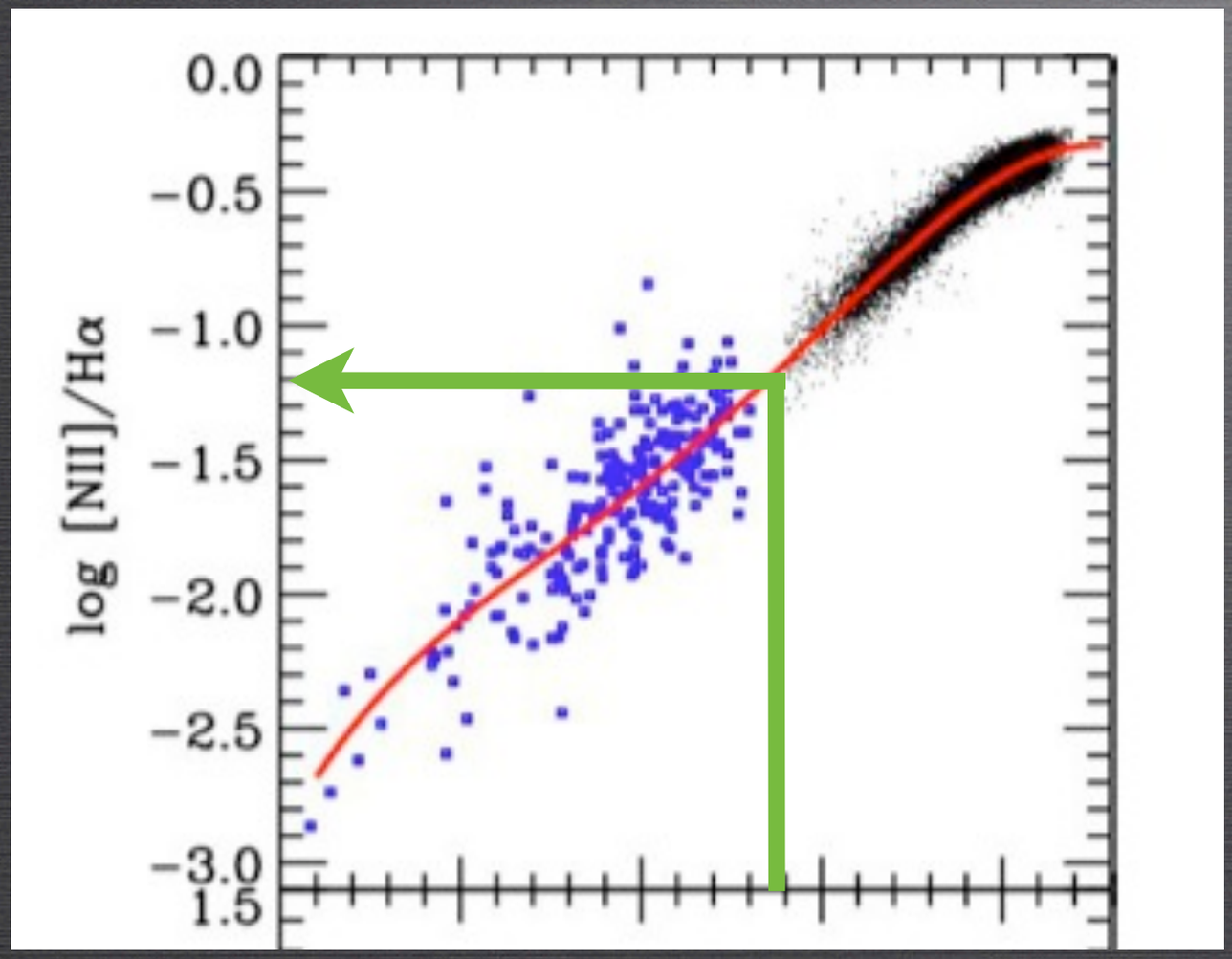
Evidence for elevated ionization parameter from the O32 diagram

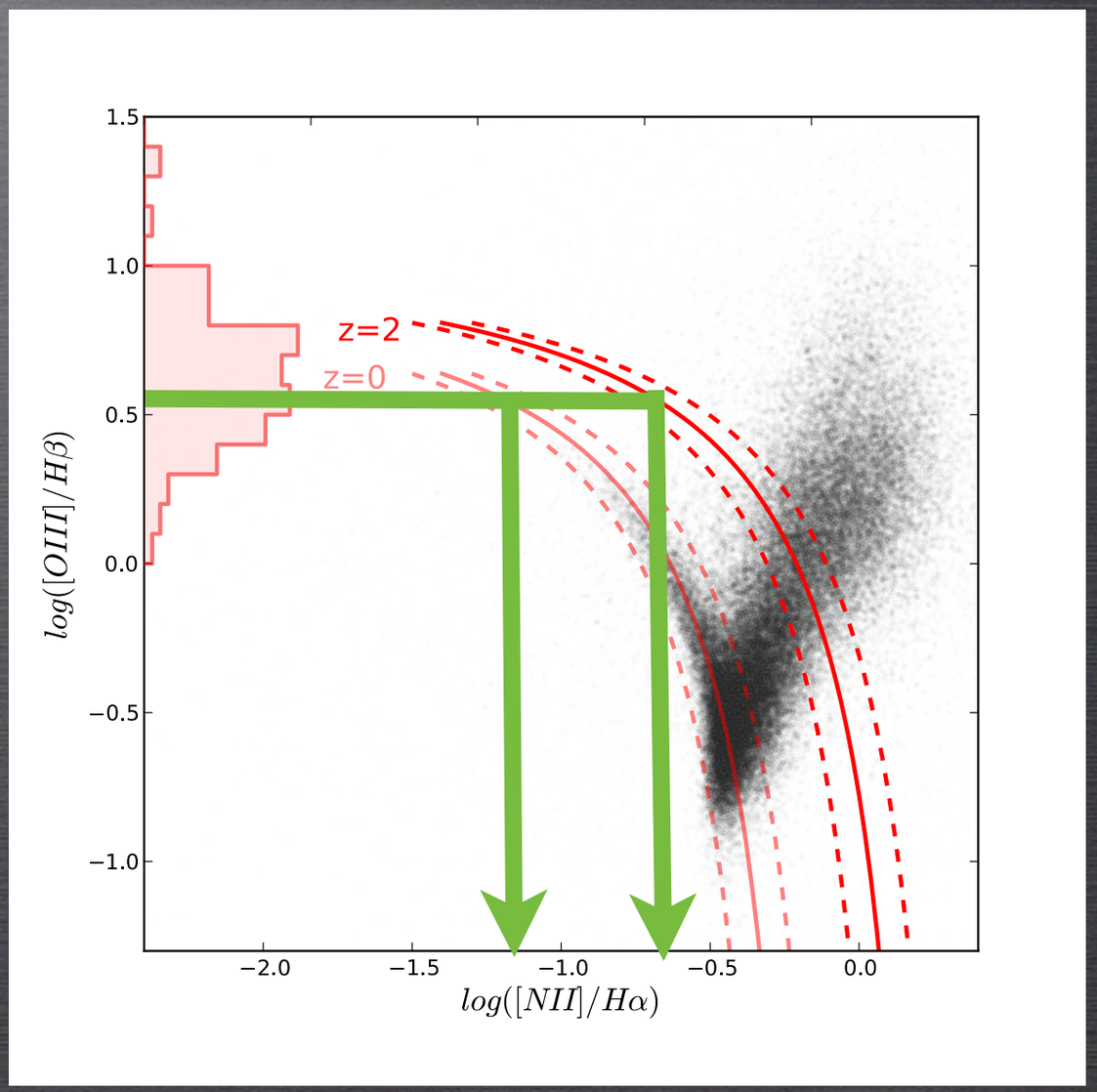
(e.g. Lilly+2003, Hainline+2009, Nakajima+2013)

At high R23 (low metallicity), galaxies at high-z show elevated [OIII]/[OII] ratio.

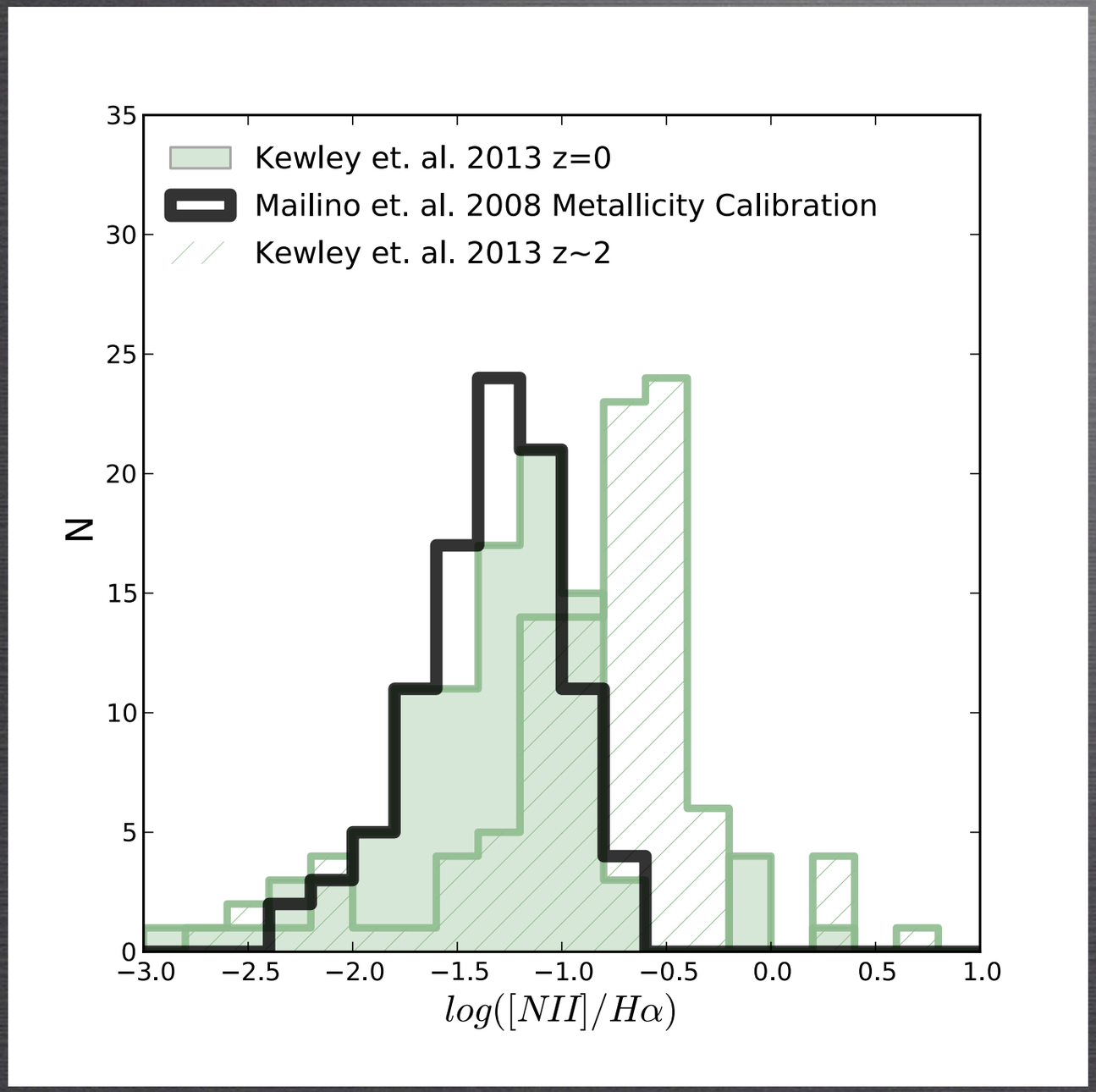
Implications for Metallicity Measurements

Work backwards to predict [NII]/Ha ratios in 3 ways:





Implications for Metallicity Measurements



Infer a theoretical [NII]/Ha value for our galaxies in 3 ways:

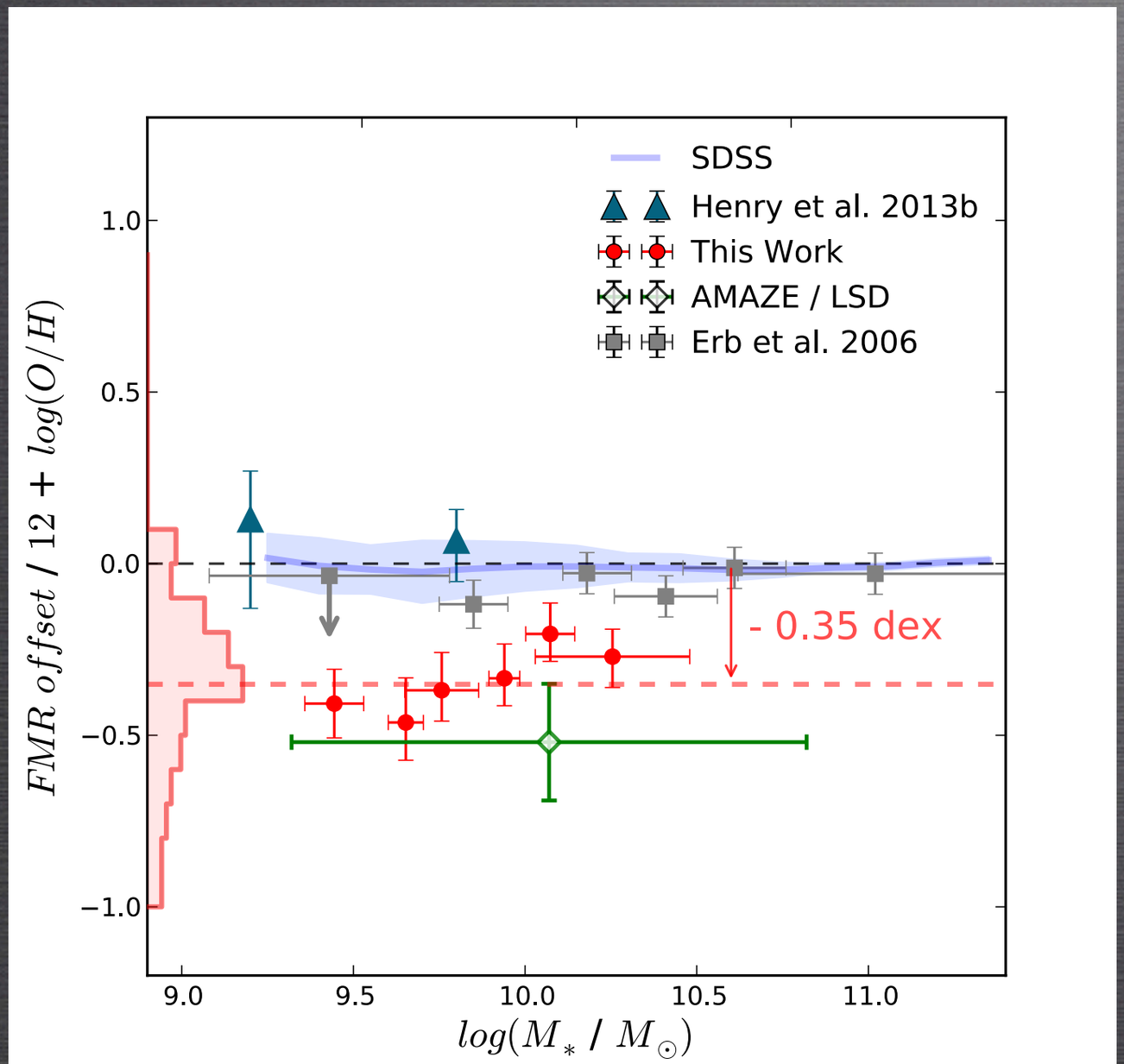
i) Using the Maiolino+2008 metallicity calibrations

ii) Using the SF sequence on the BPT diagram at z = 0

iii) Using the SF sequence on the BPT diagram at z = 2

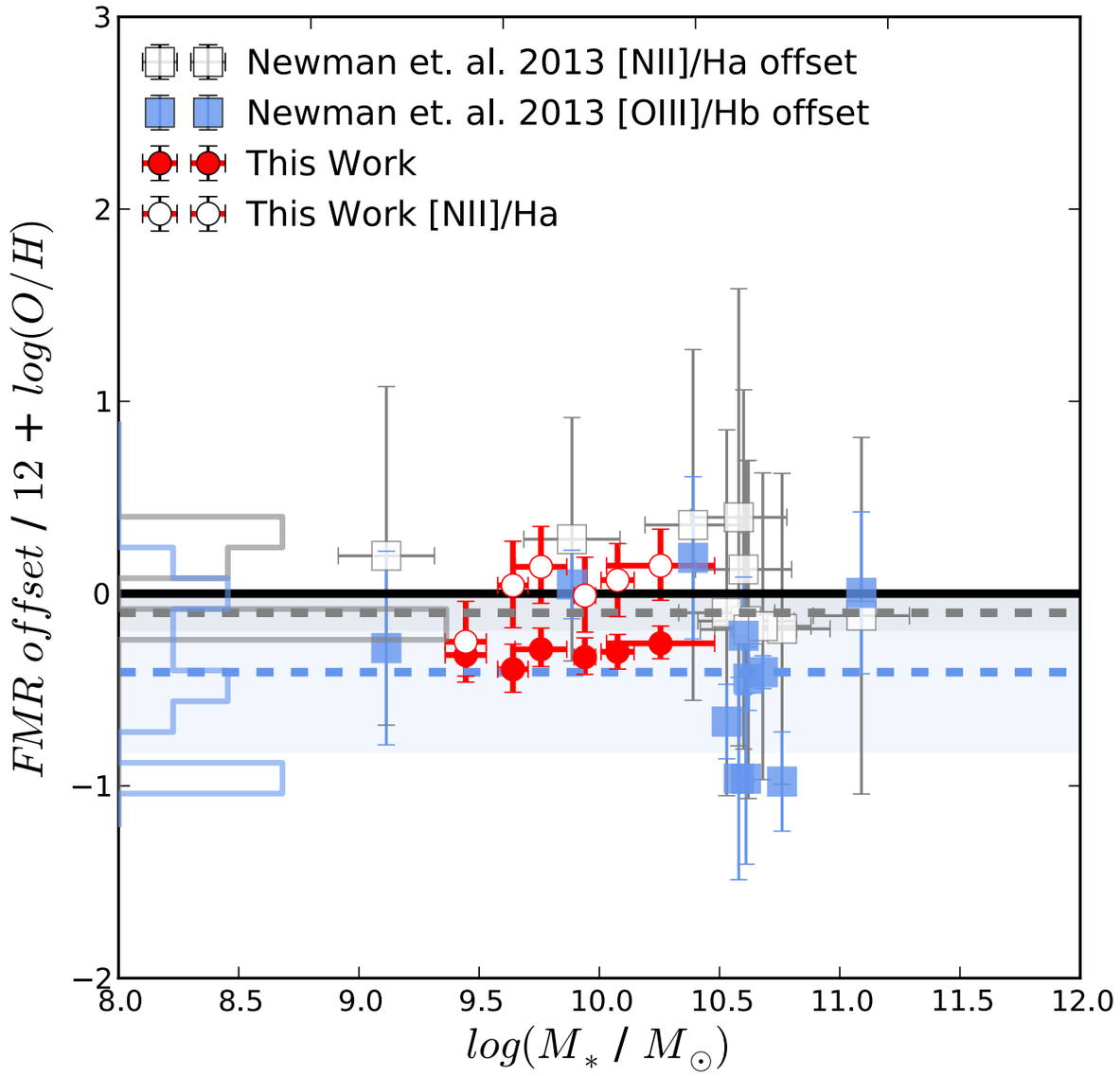
The z = 0 metallicity calibrations do not account for the redshift evolution of ISM conditions

Implications for Metallicity Measurements



Assuming a theoretical [NII]/Hα ratio from the BPT z = 2 sequence leads to higher inferred metallicites

Implications for Metallicity Measurements



See the same effect when using a sample of z ~ 2 from Newman+2013

The divergence of metallicity indicators at high-z in agreement with other studies (Newman+2013, Zahid+2013)

Summary

-> 93 galaxies at z ~ 2 with measured mass, metallicity, SFR

-> Find a MZR similar to those observed from 0 < z < 3

-> However observe an offset from the FMR, in contrast to the previous z ~ 2 results of Erb et al. 2006

-> Find evidence to suggest this discrepancy is due to a change in ISM conditions at high-z causing divergence of metallicities derived from [NII]/Hα and [OIII]/Hβ ratios from local calibrations

Future work

-> Obtain near-IR spectra at z ~ 2 in J-H-K band to measure [OII], Hβ, [OII], [NII], Hα. e.g. KMOS, MOSFIRE

-> Investigate the evolution of the [OIII]/Hβ ratio with redshift

Thanks!