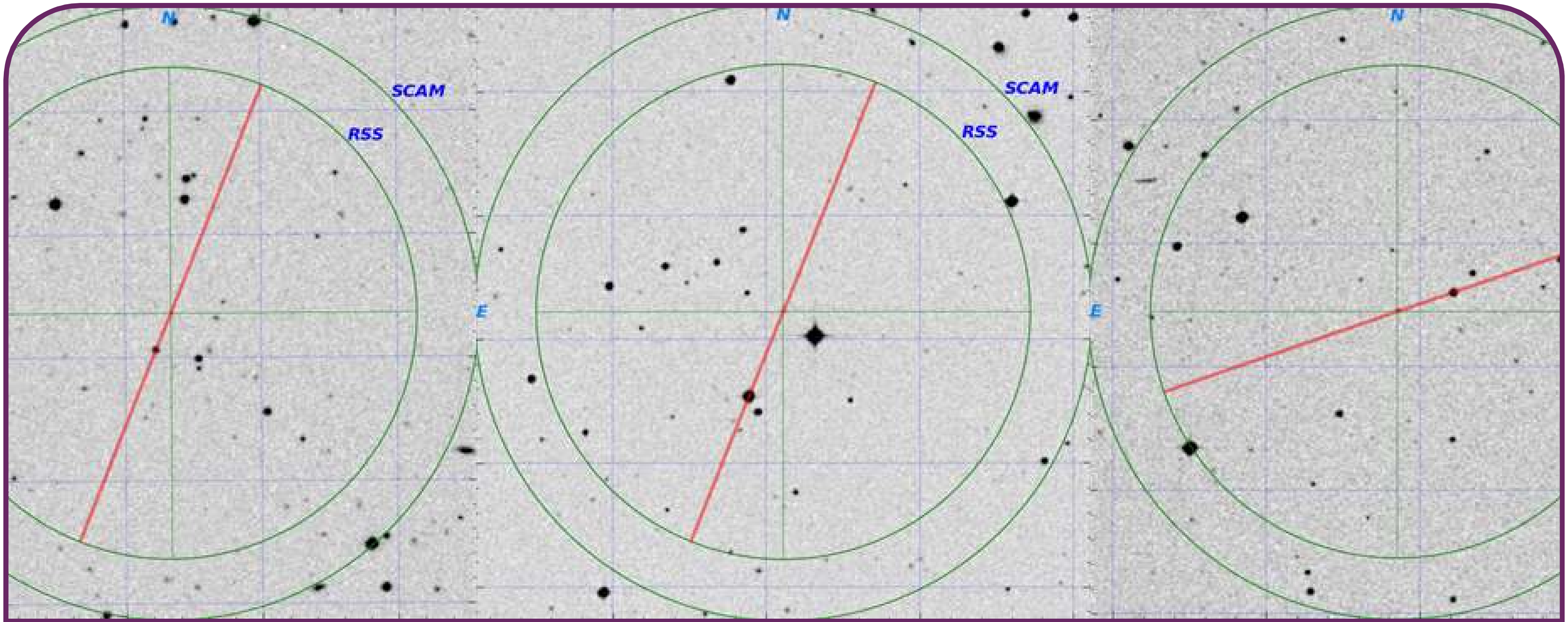
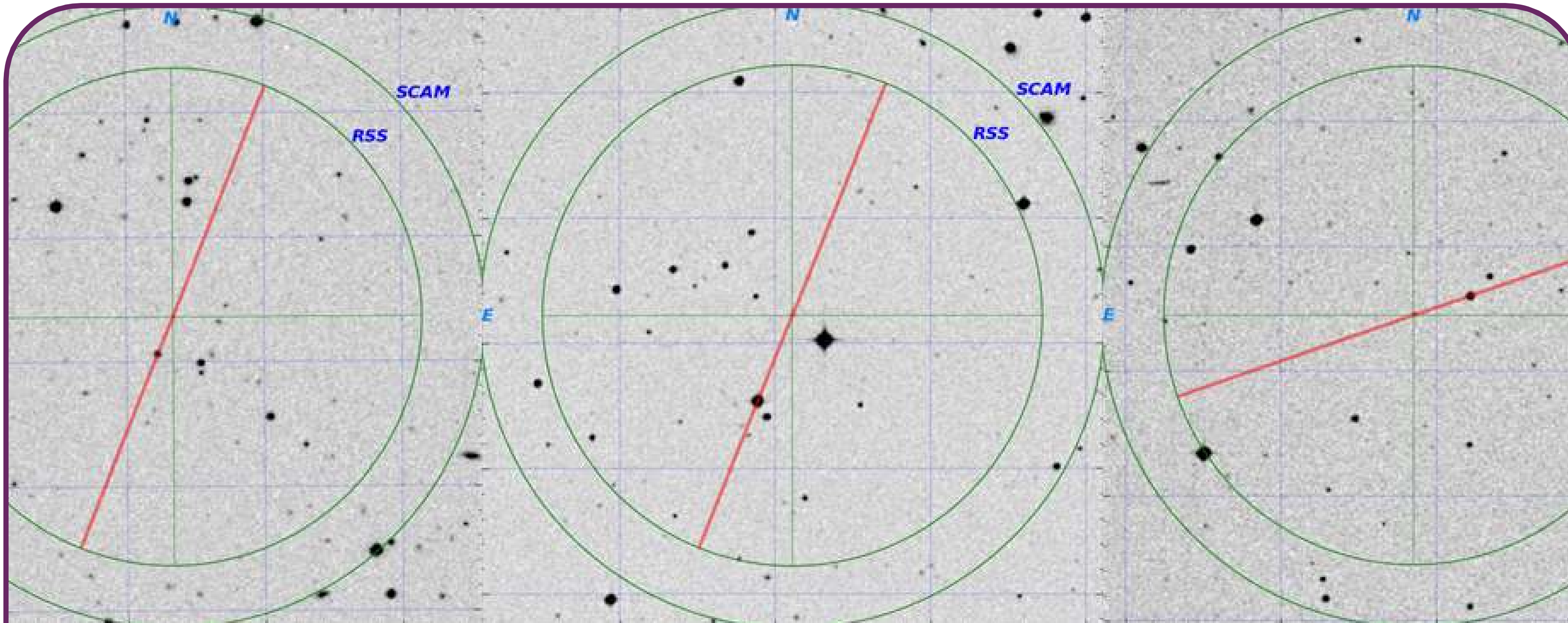


Probing the true evolution of the mass-metallicity relation with SALT

Rob Yates – MPA, Munich

Advances with SALT Workshop: 15th November 2018

Max-Planck-Institut für Astrophysik



Probing the true evolution of the galaxy stellar mass-metallicity relation with SALT- RSS

ISM

Rob Yates – MPA, Munich

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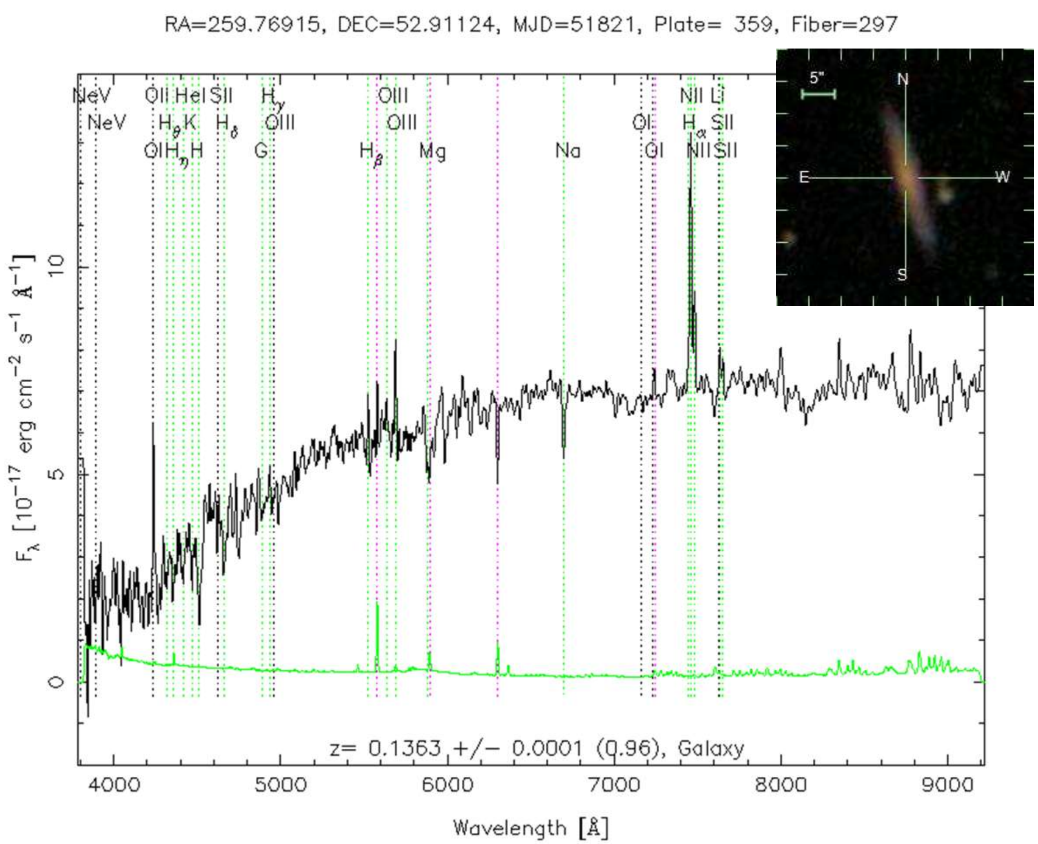
Strong-line metallicity

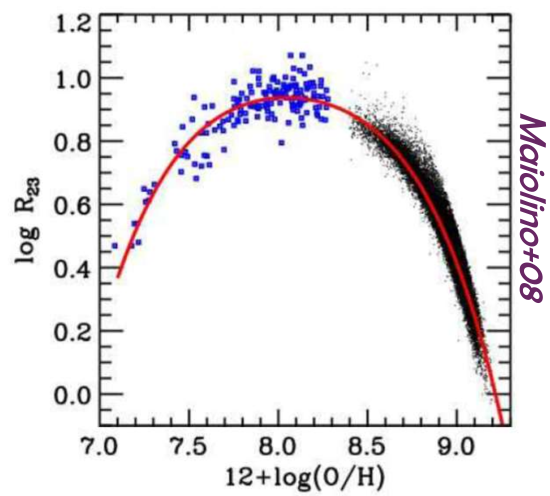
Metallicity (i.e. oxygen abundance) in HII regions is usually measured via strong recombination and collisionally-excited emission lines (SLs)



$$\mathrm{R23} = \frac{[\mathrm{O\,II}]\lambda3727 + [\mathrm{O\,III}]\lambda4959 + [\mathrm{O\,III}]\lambda5007}{\mathrm{H}\beta}$$

$$\mathrm{N2} = \frac{[\mathrm{N\,II}]\lambda6584}{\mathrm{H}\alpha}$$

Ratios are calibrated to metallicities measured 'directly' or from photoionisation models

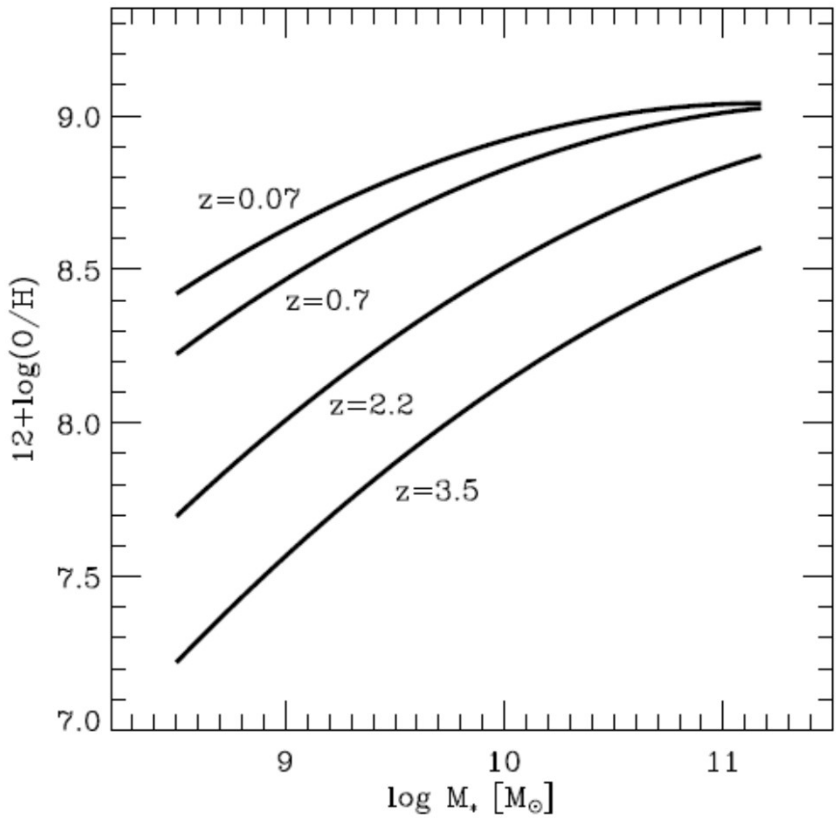


Canonical paradigm

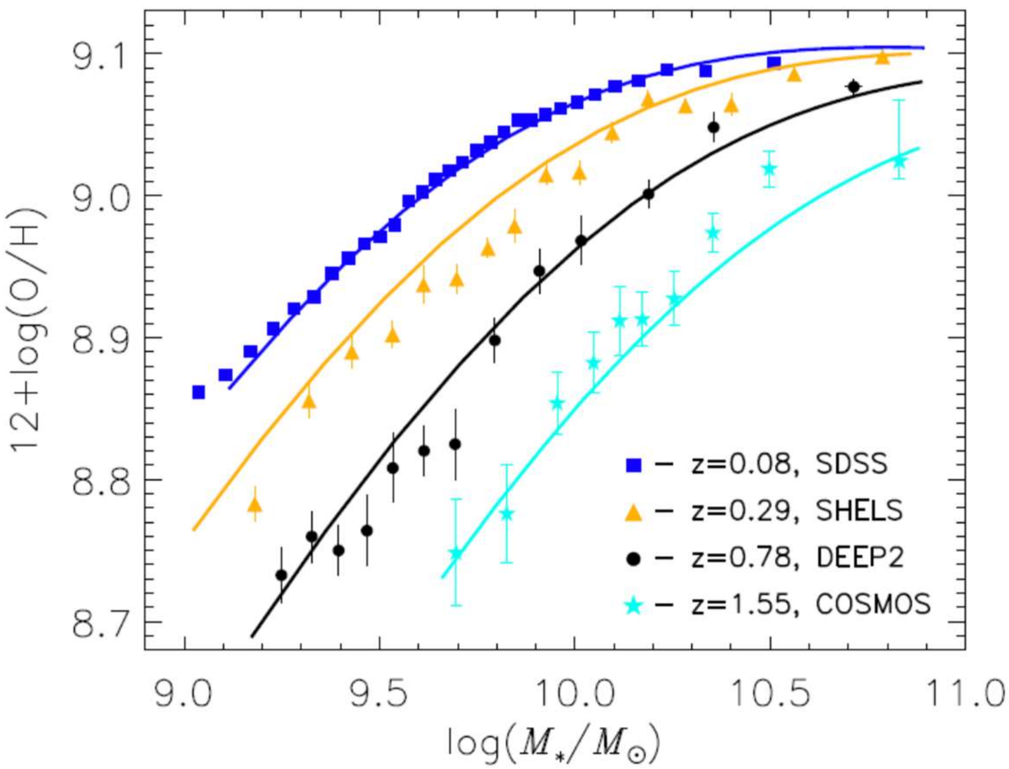
Evolution of the MZR has been well studied using SL diagnostics

(e.g. *Erb+06; Maiolino+08; Zahid+14; Steidel+14; Hunt+16; …*)

Maiolino+08



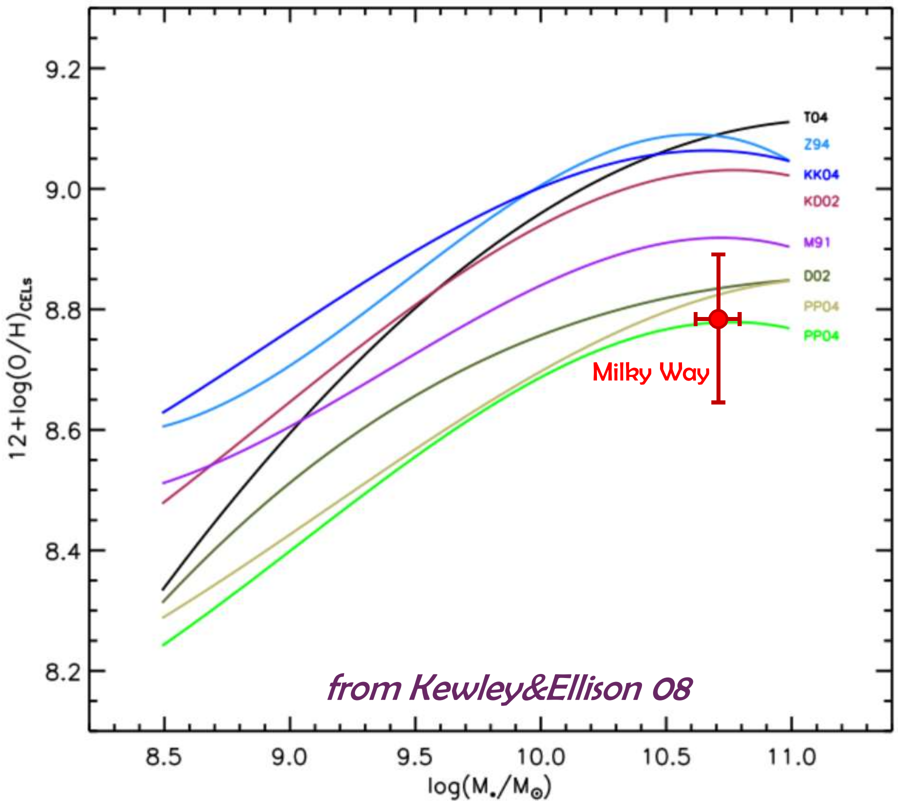
Zahid+14



Main result: There is significant (mass-dependent) evolution of the MZR

Canonical paradigm: problems

Low-z: Different diagnostics give discrepant MZRs



- Normalisation varies by up to ~0.4 dex *(e.g. Kewley & Ellison 08)*
- Many MZRs inconsistent with MW values

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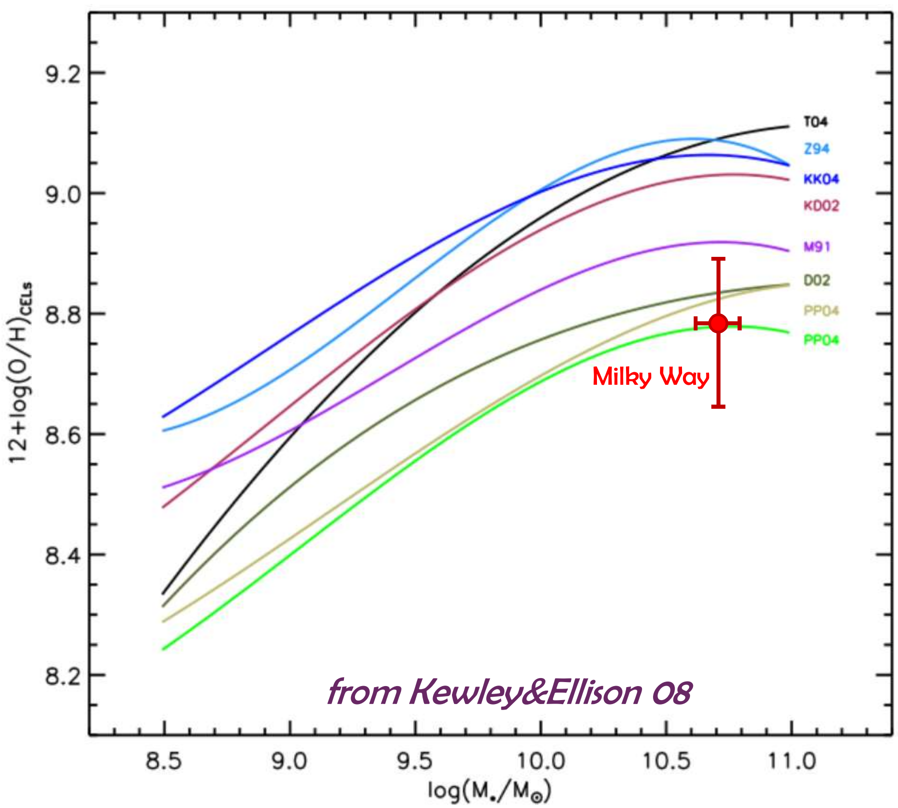

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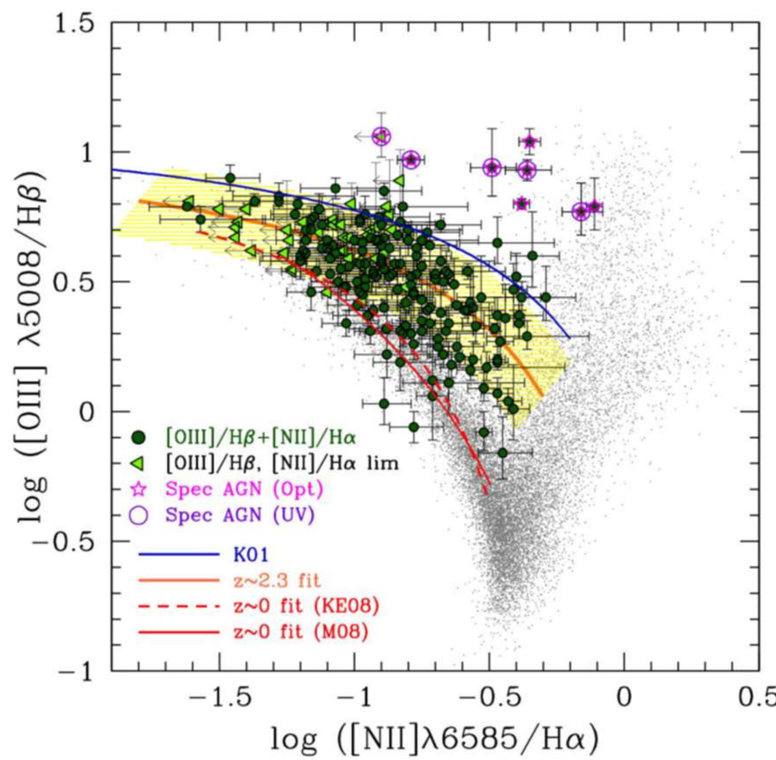
High-z: Physical conditions in HII regions change with redshift

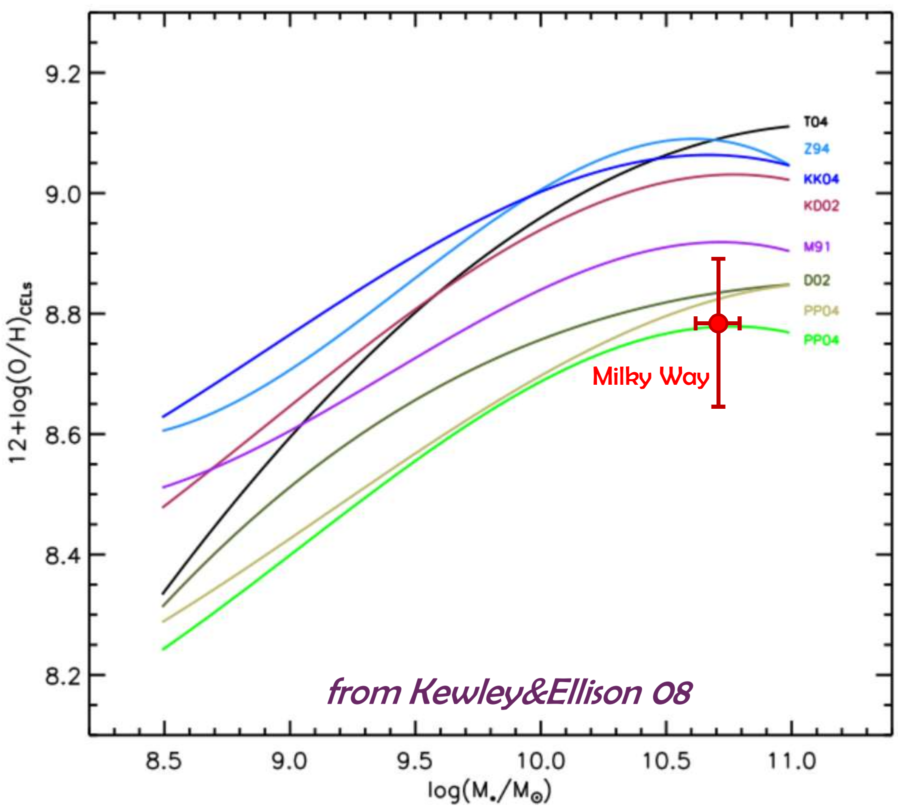


Steidel+14

- High-z galaxies have higher: SFRs, nebular excitation, ionising field strength, gas pressures, electron densities, [O/N], dust content, diffuse gas contamination, etc… *(e.g. Brinchmann+08; Kewley+13; Dopita+16; Strom+17b)*

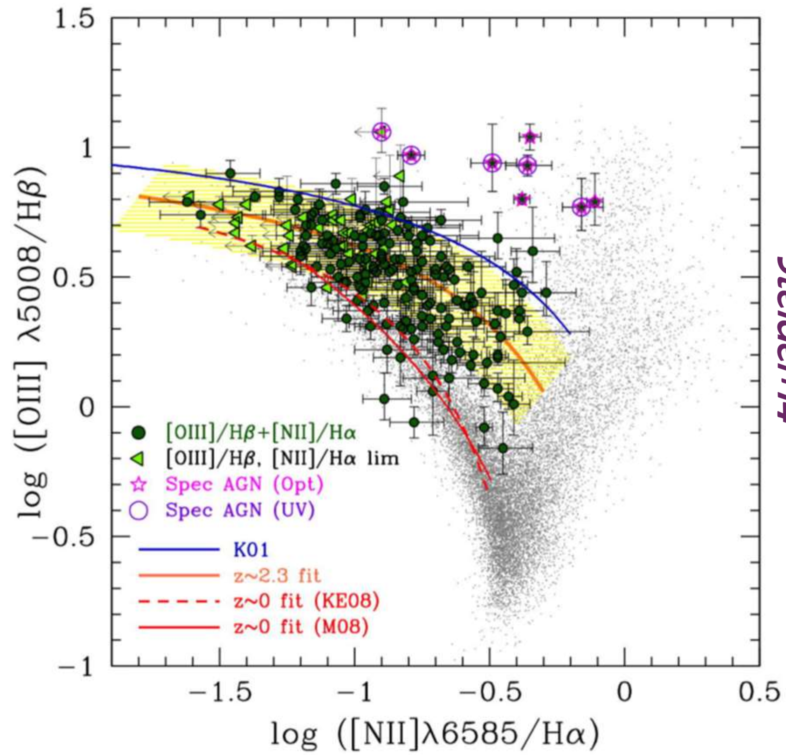
Canonical paradigm: problems

Low-z: Different diagnostics give discrepant MZRs



from Kewley&Ellison 08

High-z: Physical conditions in HII regions change with redshift



Steidel+14

Should locally-calibrated SL diagnostics be trusted at high (or low) redshift?

(e.g. Erb et al. 2006; Cullen et al. 2014; Krühler et al. 2015; Dopita et al. 2016; Strom et al. 2017a,b; ...)

Direct metallicities:

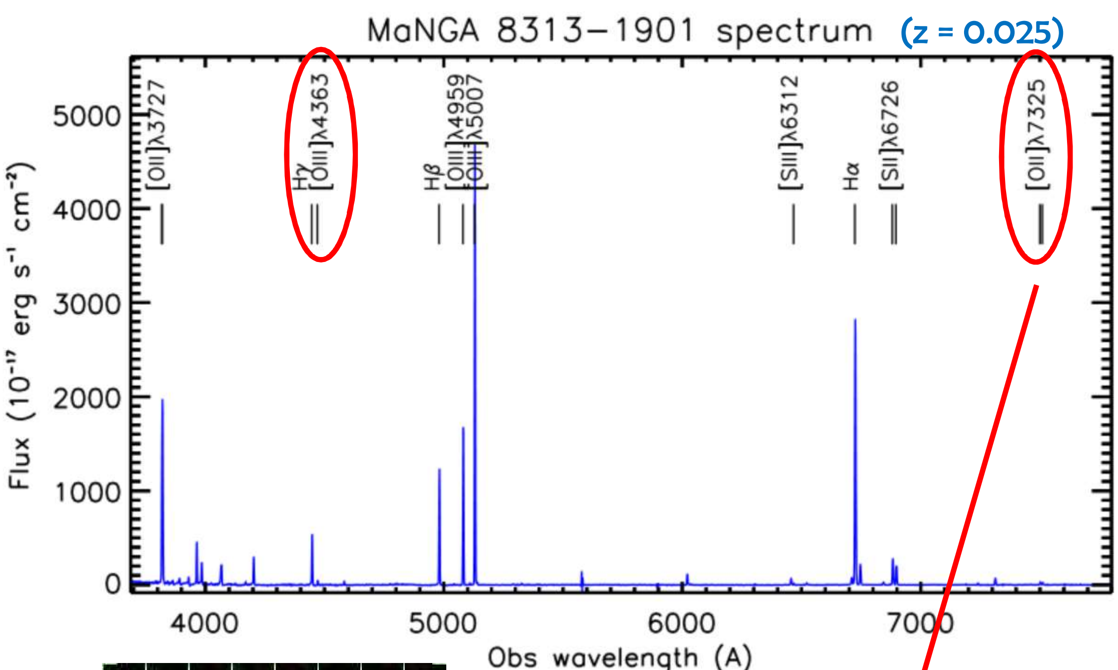
Low redshifts

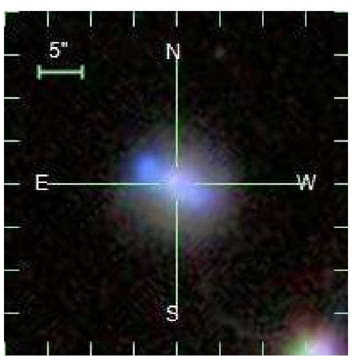
($0 < z < 0.25$)

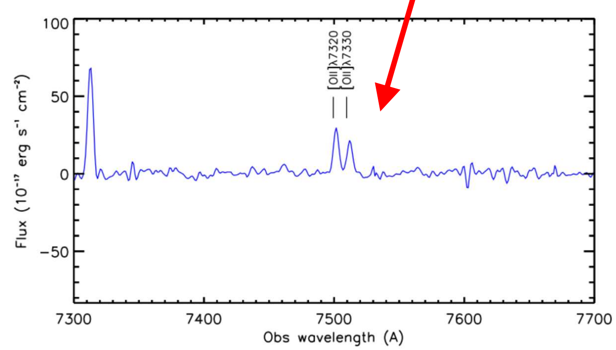
Electron temperature method

Electron temperature (T_e) based metallicities are considered more accurate.

Their measurement requires the auroral lines [OIII]4363 & [OII]7325 ~ $\mathcal{O}$(0.01 Hβ)







1

$$T_e = a\left[-\log\left(\frac{R_{\rm obs}}{1+d\left(N_e/T_e^{1/2}\right)}\right)-b\right]^{-c}$$

Nicholls+14a

2

$$\mathrm{O^+/H^+} = \frac{[\mathrm{O\,II}]\lambda\lambda3726,3729}{\mathrm{H}_\beta}\, g_1\, \alpha_{\mathrm{H}\beta}\, \sqrt{T_e(\mathrm{O\,II})} \cdot \exp\left[E_{12}/kT_e(\mathrm{O\,II})\right] \times \frac{\beta}{E_{12}\Upsilon_{12}}$$

$$\mathrm{O^{++}/H^+} = \frac{[\mathrm{O\,III}]\lambda\lambda4959,5007}{\mathrm{H}_\beta}\, g_1\, \alpha_{\mathrm{H}\beta}\, \sqrt{T_e(\mathrm{O\,III})} \cdot \exp\left[E_{12}/kT_e(\mathrm{O\,III})\right] \times \frac{\beta}{E_{12}\Upsilon_{12}},$$

3

$$Z_{\rm Te} \equiv 12 + \log(\mathrm{O^+/H + O^{++}/H})$$

O^+/H can be inferred from [OIII]λ4363 for such systems

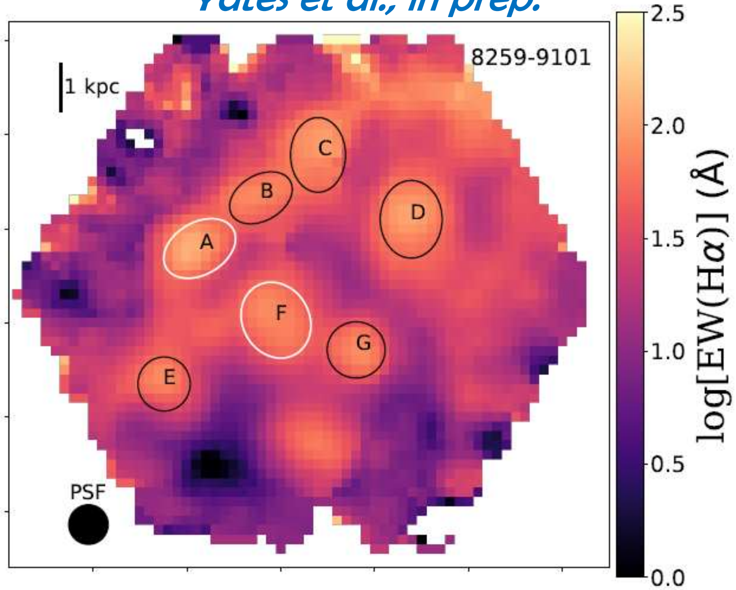
Low-redshift data set

Sample comprises 257 emission-line systems:

- Individual HII regions, composite HII regions, and whole-galaxy spectra.

- Includes:
  23 new composite HII regions from MaNGA,
  8 new superluminous-supernova host galaxies.

Yates et al., in prep.



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- Individual HII regions, composite HII regions, and whole-galaxy spectra.

- Includes:
  23 new composite HII regions from MaNGA,
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- Decent coverage of ‘star-forming main sequence’
  (sample is not heavily biased by starbursts)

Yates et al., in prep.

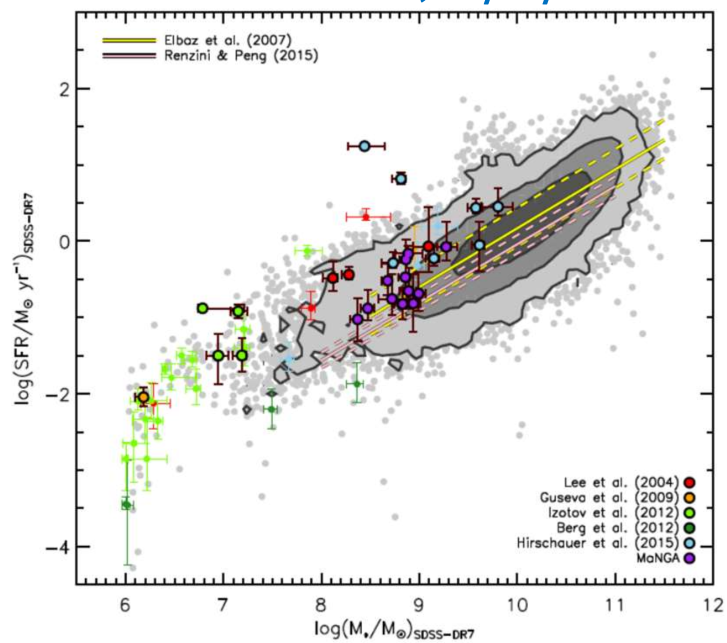
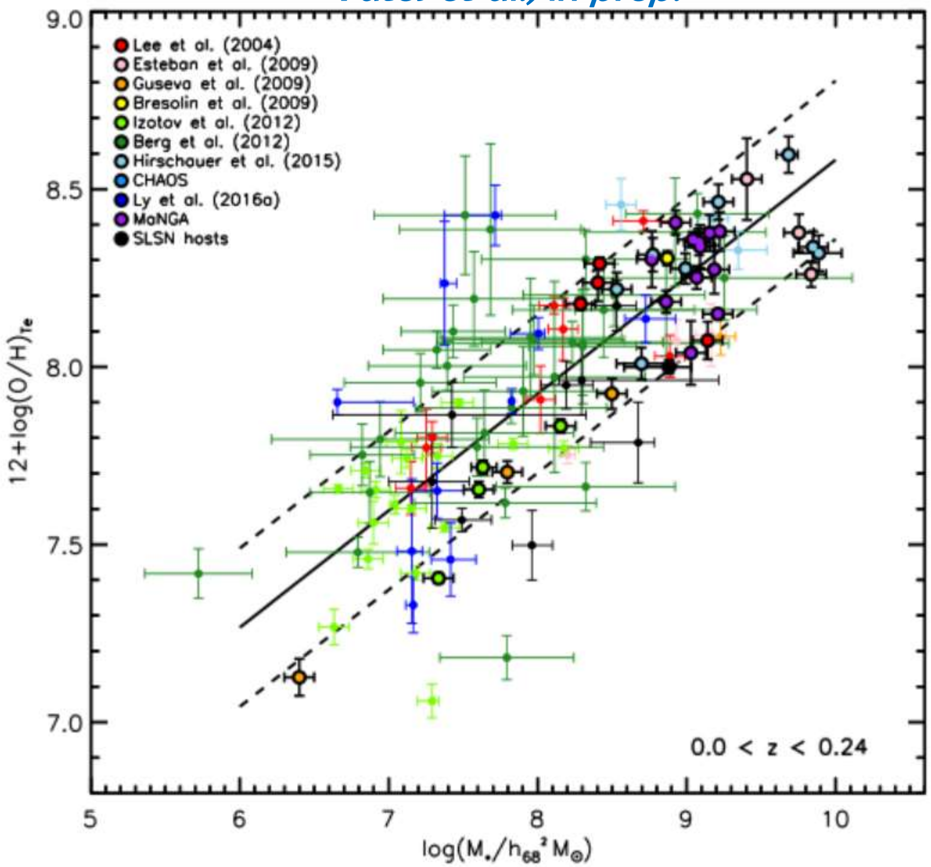


Figure 1. The M_*-SFR relation for galaxies in our low-redshift dataset with counterparts in the SDSS-DR7 catalogue. Local ‘main sequence’ (MS) relations from Elbaz et al. (2007) and Renzini & Peng (2015) are also plotted for comparison.

Low-redshift direct MZR

Yates et al., in prep.



Clear positive correlation over ~4 orders of magnitude in stellar mass

Quite large scatter: $\sigma(Z_{Te})$ = 0.24 dex

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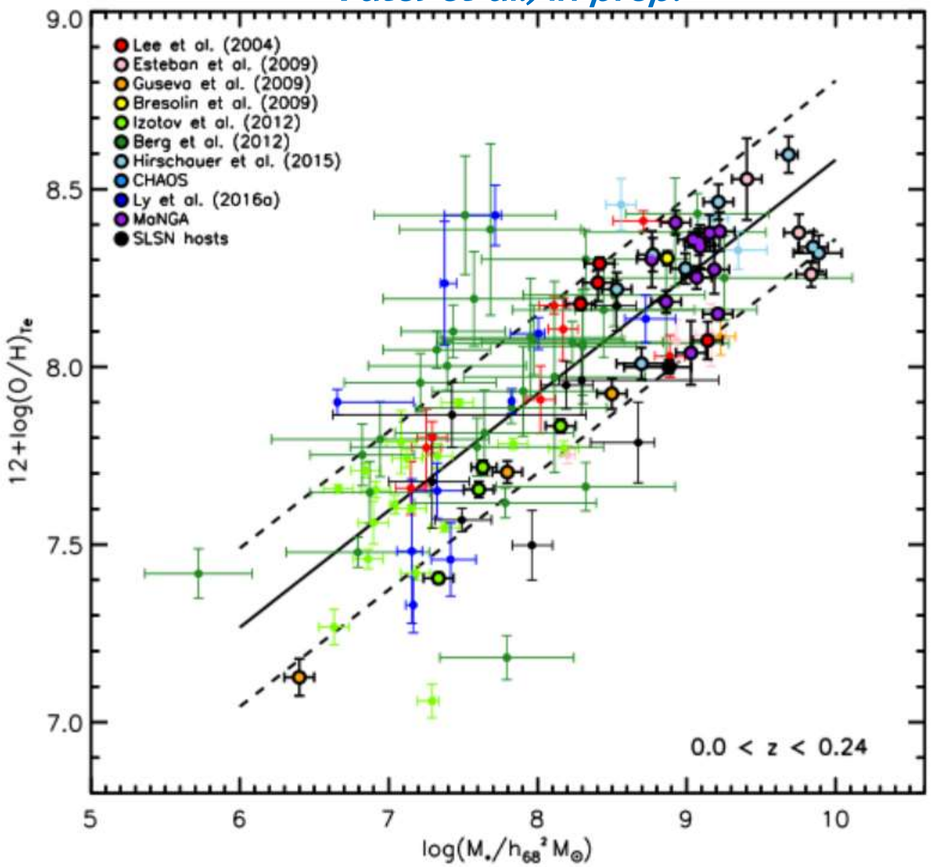

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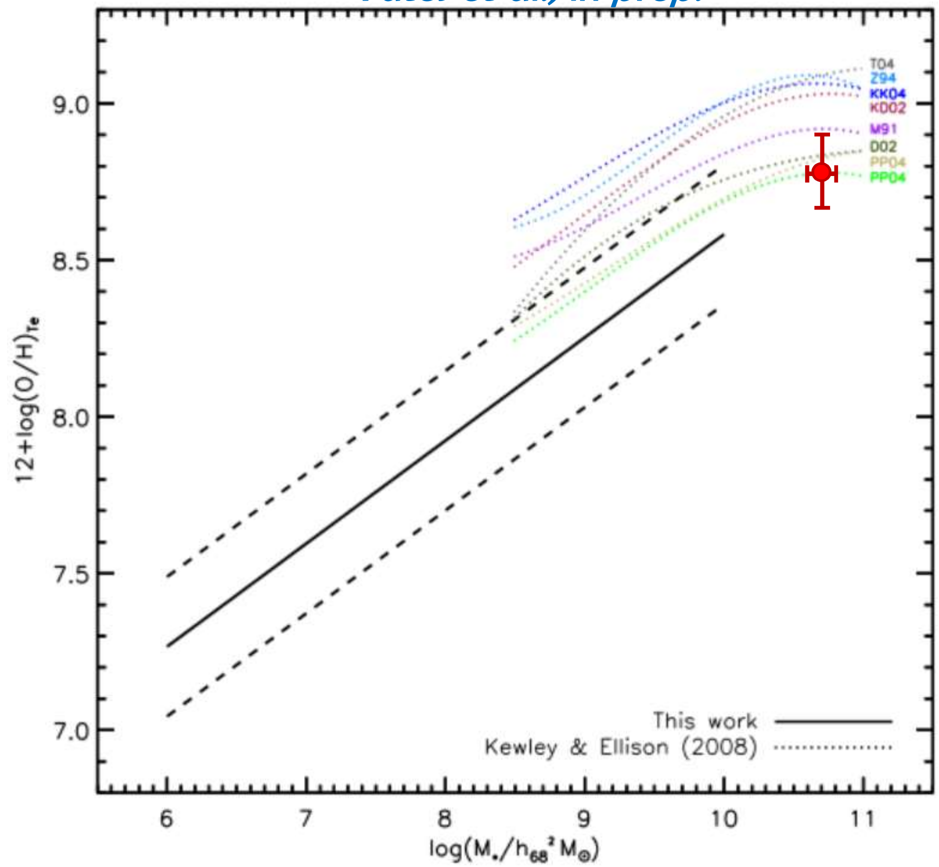
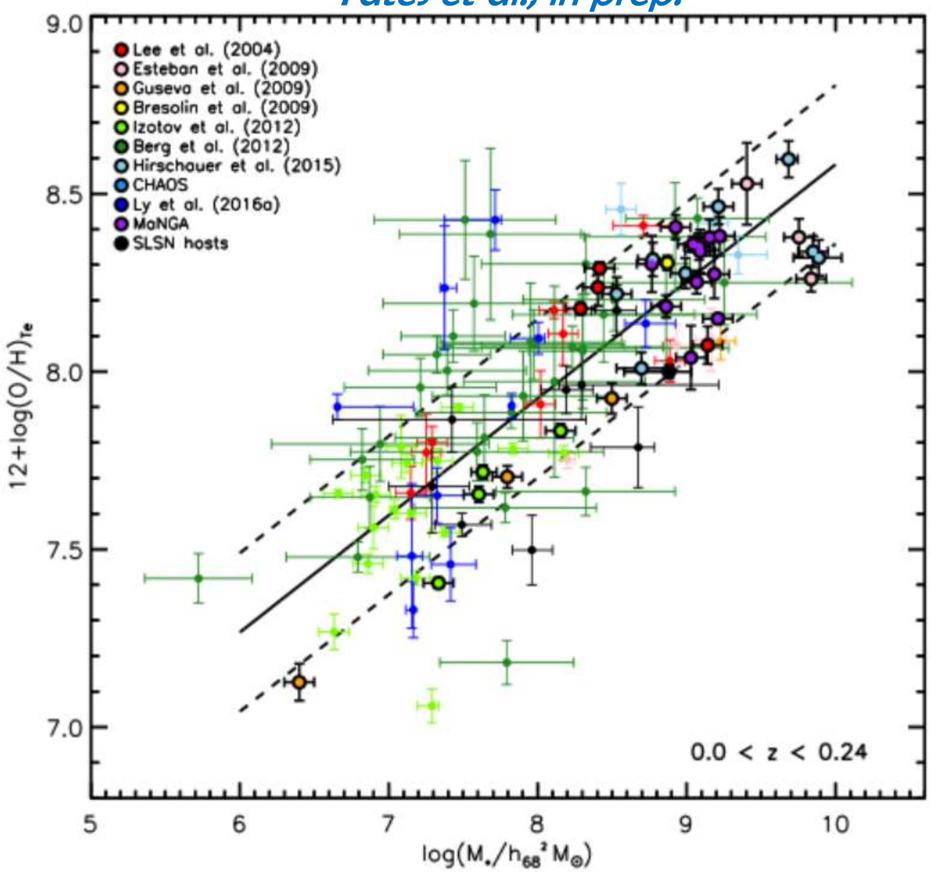
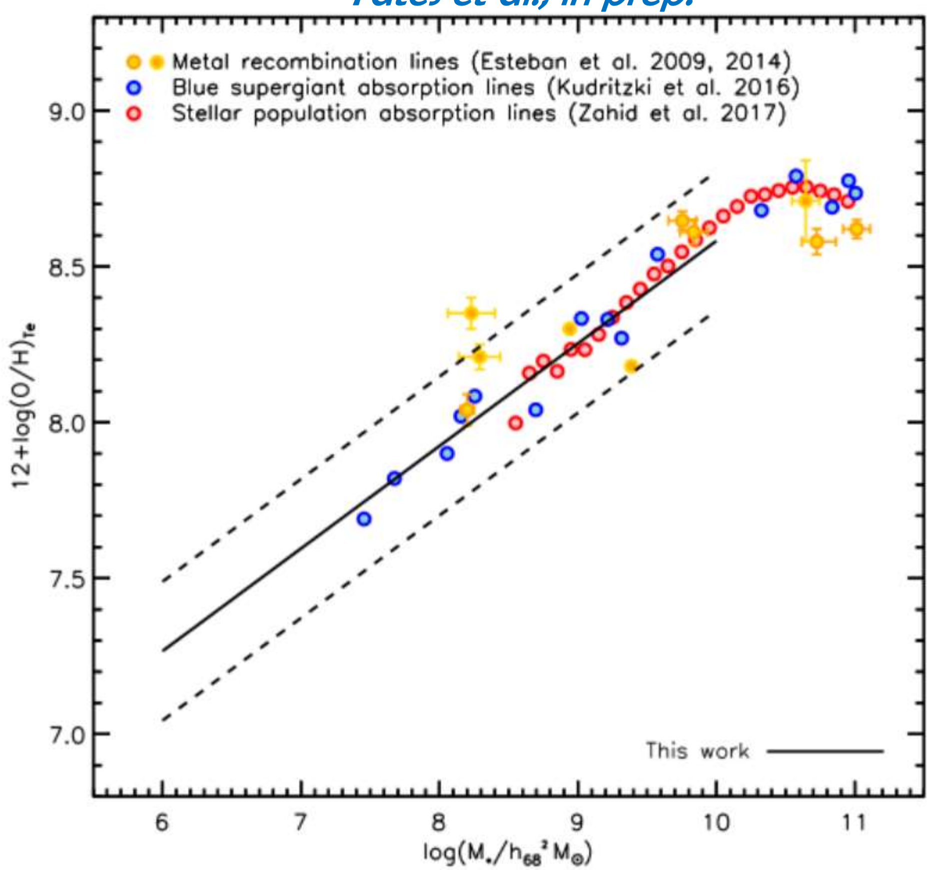


Lower normalisation than SL-based MZRs

Good correspondence with MW

Low-redshift direct MZR





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Good agreement with other direct methods for measuring metallicity

Direct metallicities:

Intermediate redshifts

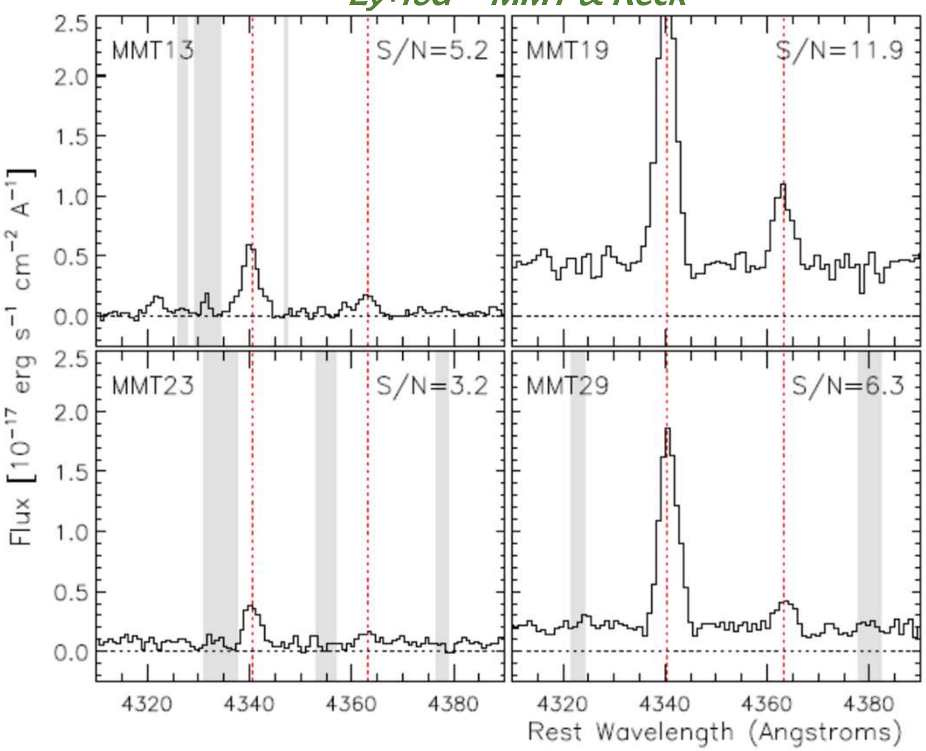
(0.2 $< z <$ 0.4)

Current intermediate-redshift T_e samples

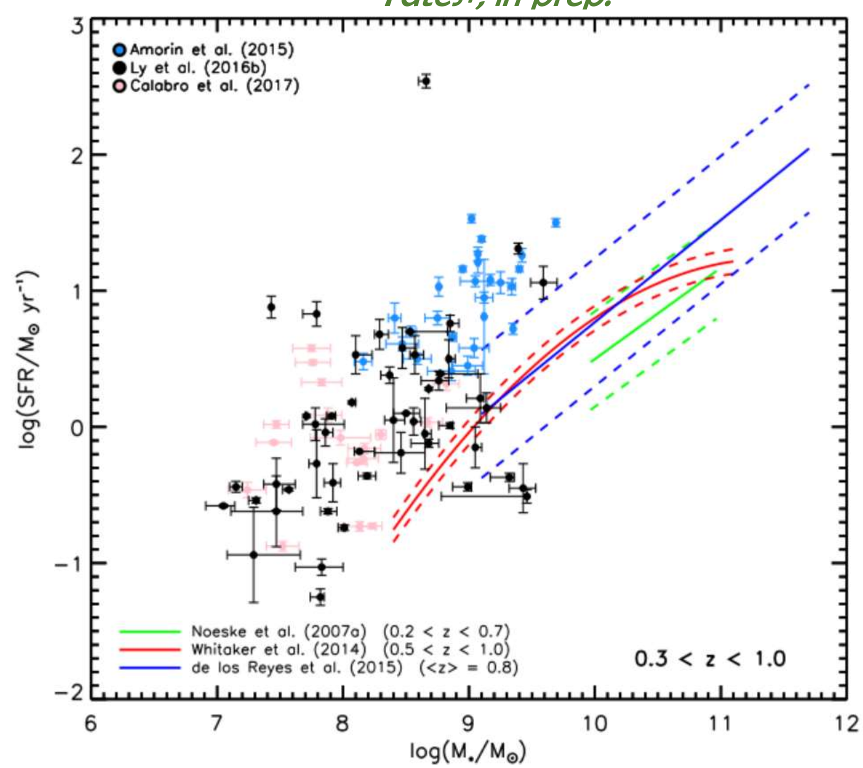
- Current samples only total ~33 systems at 0.3 < z < 1.0 with measured T_e(OIII).
  (zCOSMOS Amorín+15; MACT Ly+16a; and VUDS Calabrò+17)

- These samples are biased to higher-SFRs. Therefore, could under-estimate the typical metallicity at fixed mass (see FMR, *Mannucci+10*).

Ly+16a – MMT & Keck



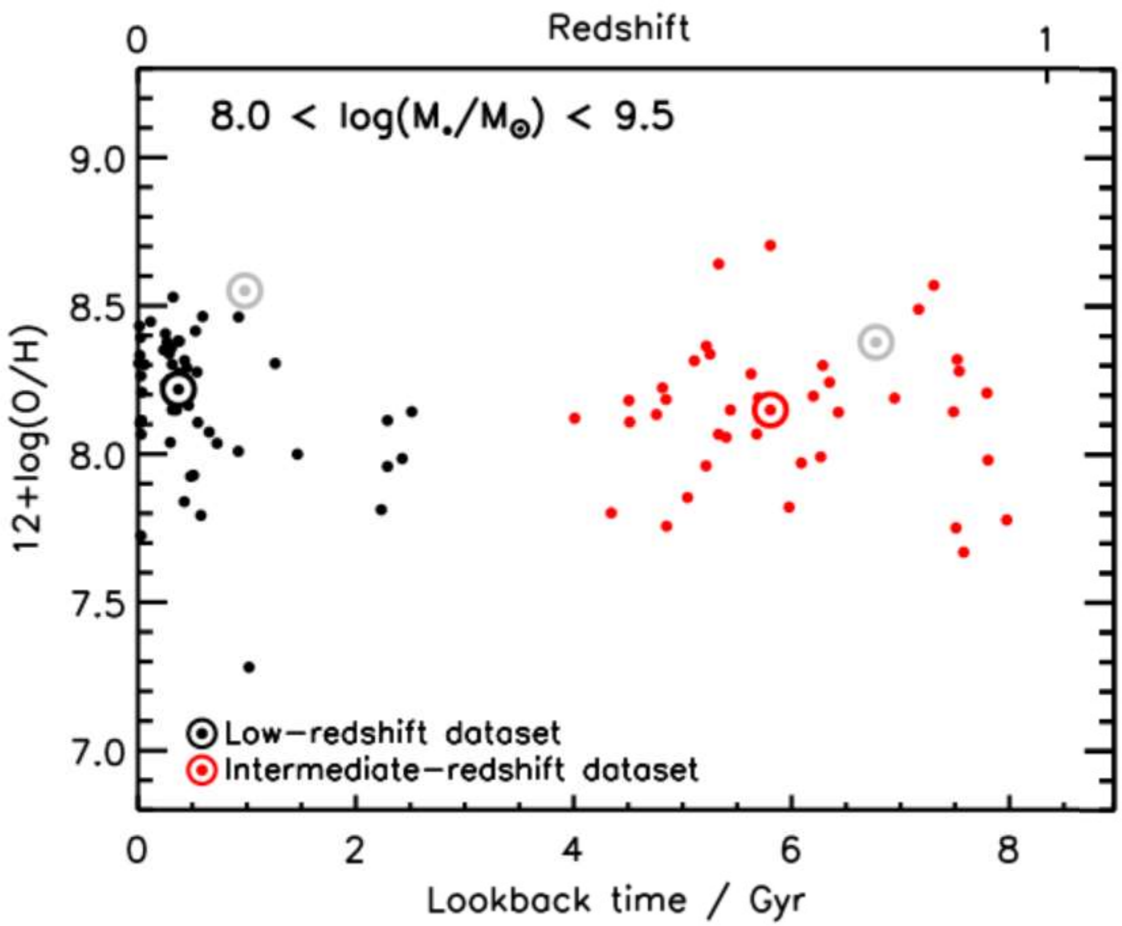
Yates+, in prep.



Direct evolution of the MZR

Our initial analysis suggests little MZR evolution over cosmic time...

We estimate:	~Δ0.08 dex (0.02 < z < 0.54)
Maiolino+08:	~Δ0.17 dex (0.07 < z < 0.70)
Zahid+14:	~Δ0.24 dex (0.08 < z < 0.78)



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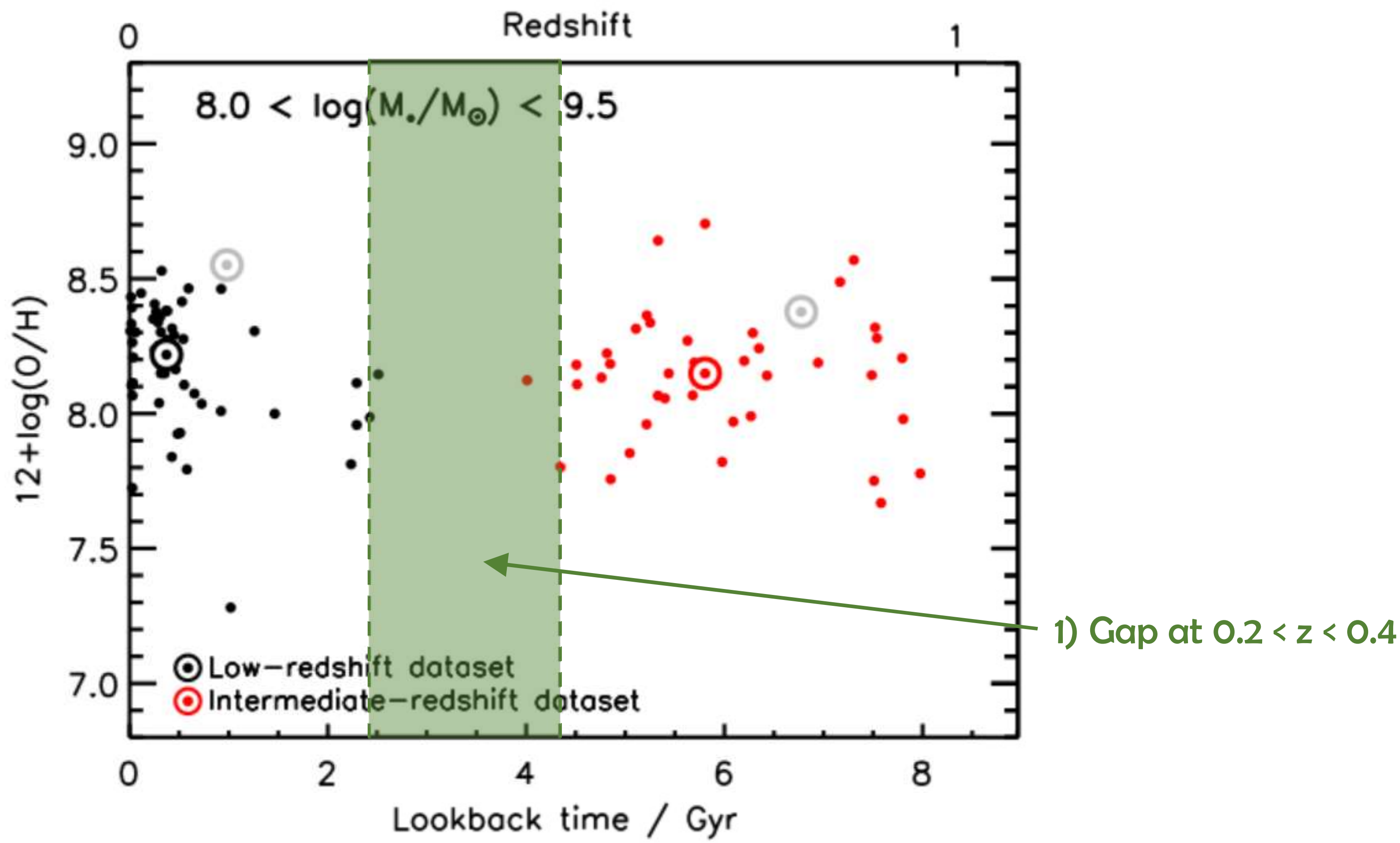

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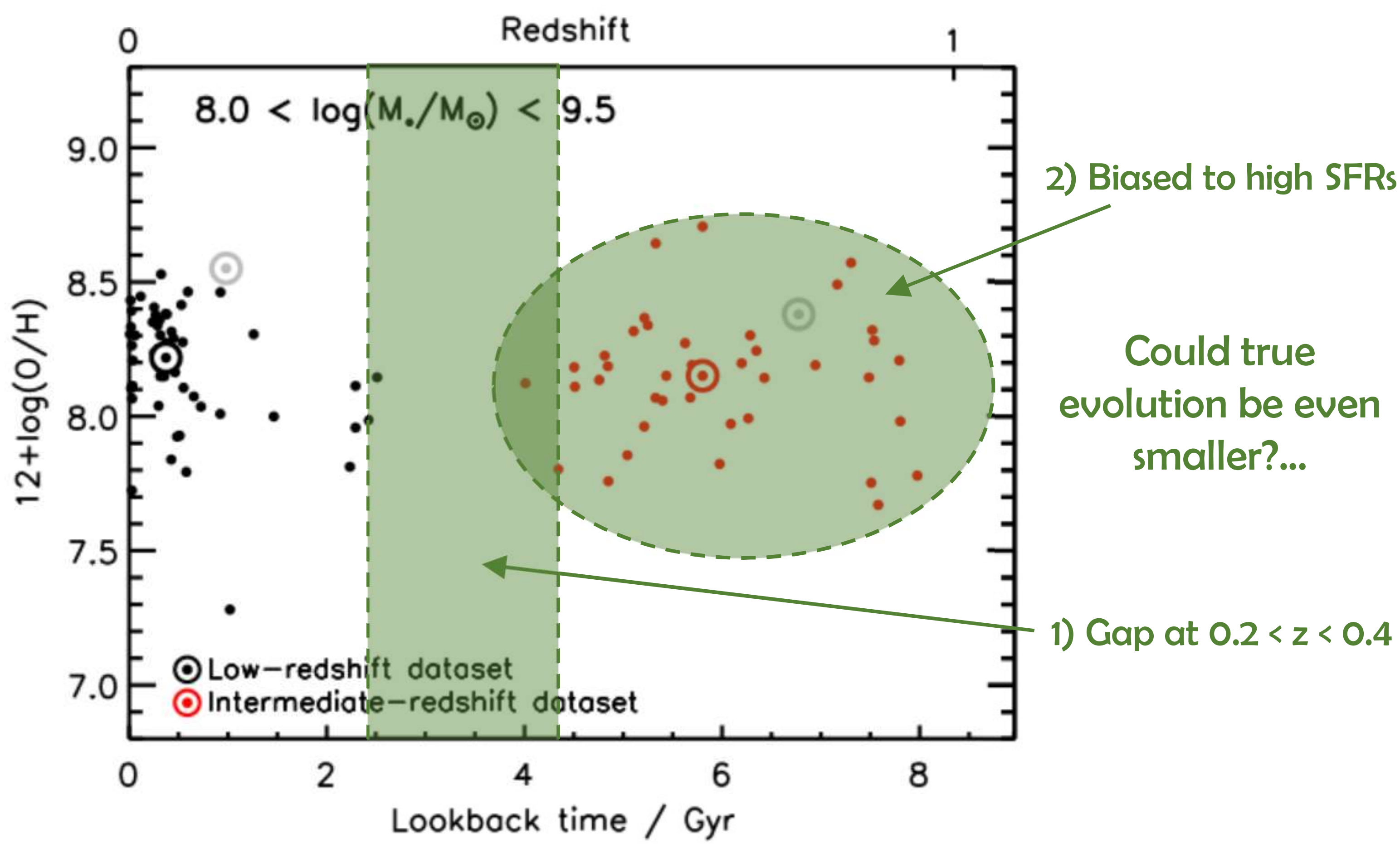
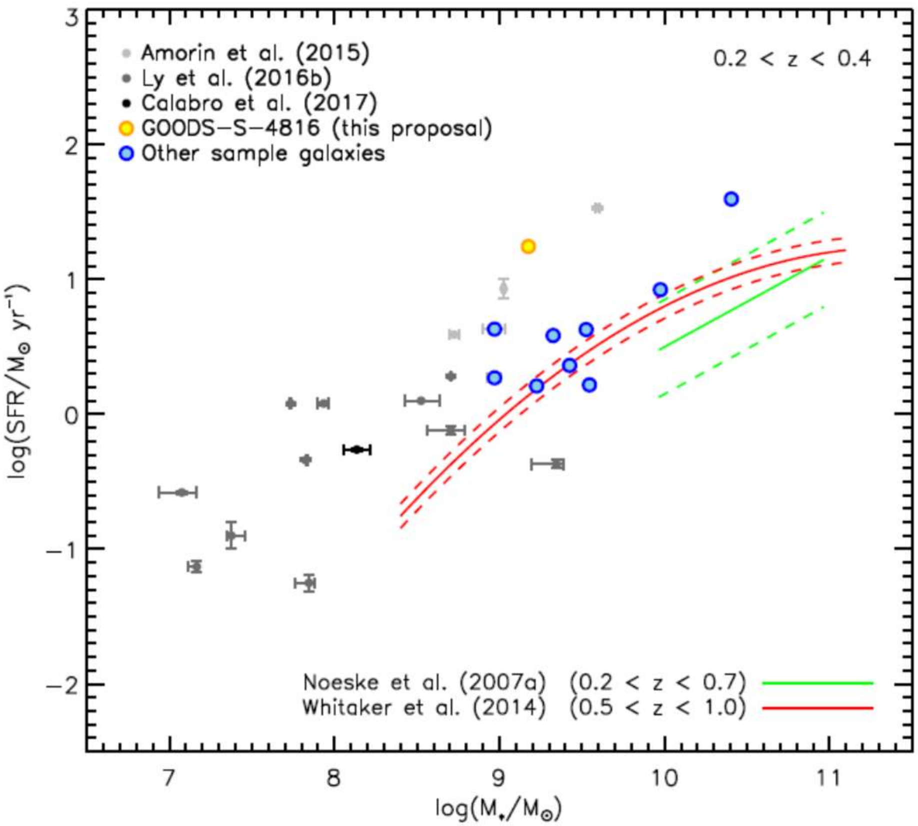


Could true evolution be even smaller?...

Measuring T_e with SALT



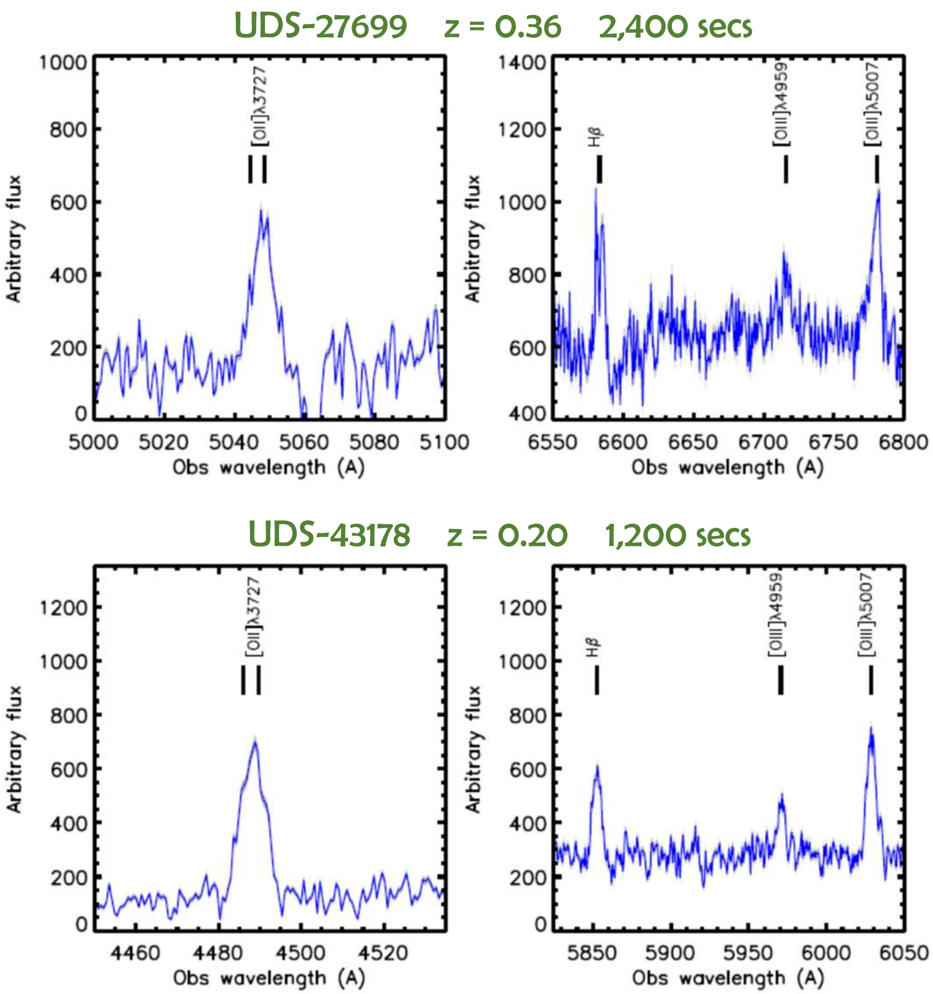
Objective:

- Measure faint [OIII]λ4363 auroral line in a sample of near-main-sequence galaxies at 0.2 < z < 0.4

Requirements:

- We predict at least 1 hr total exposure time on each target at seeing 1.3” with SALT-RSS (> 10,000 secs for some systems)

Measuring T_e with SALT



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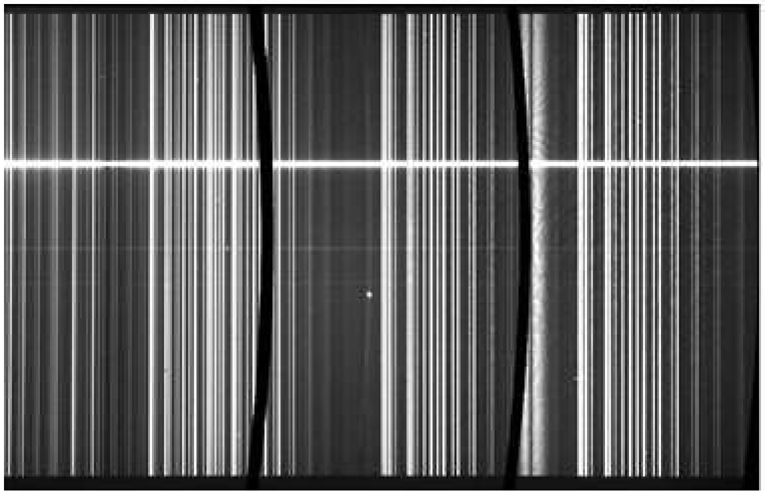
- *SLs already detected with SALT*

Measuring T_e with SALT

UDS-43178: **Before** sky subtraction



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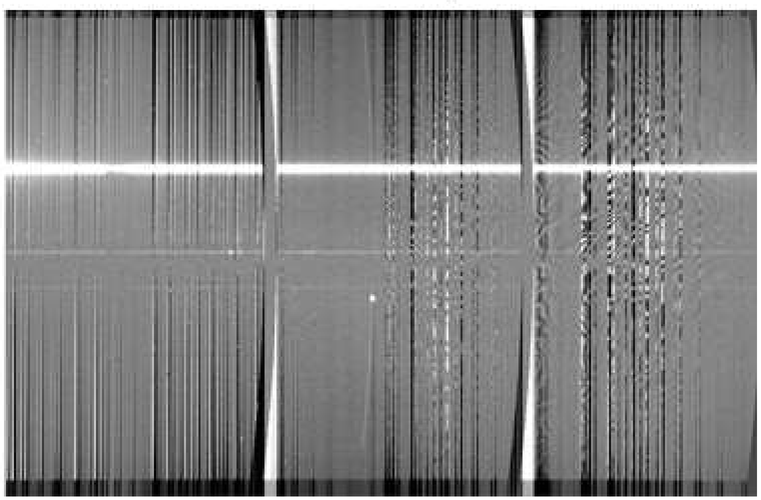

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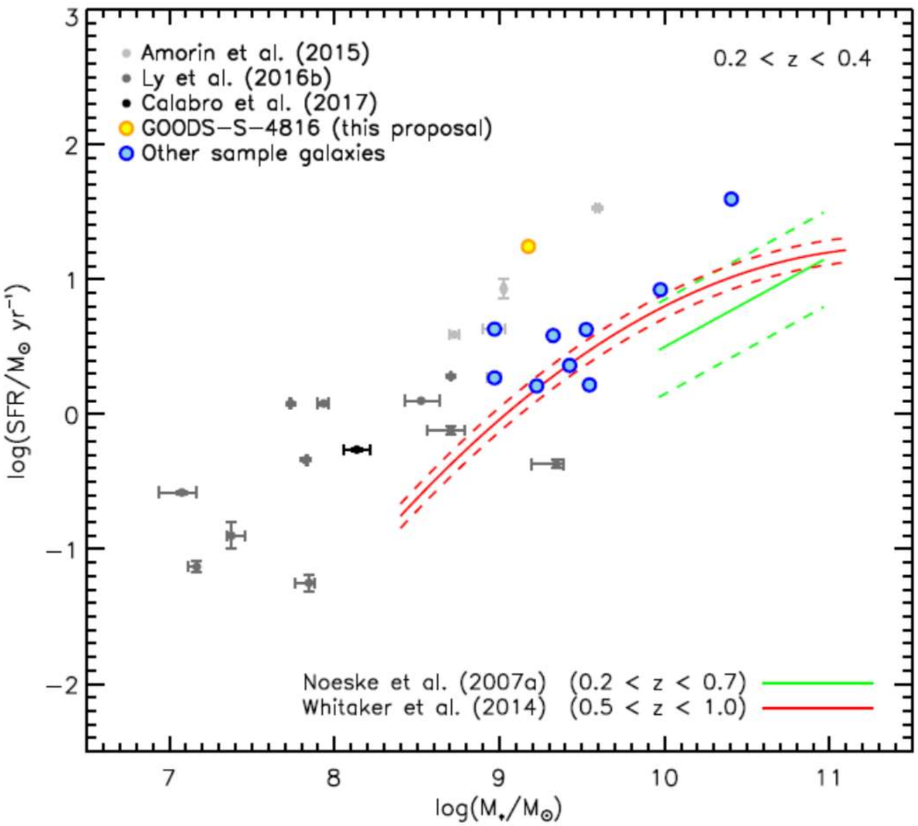
- *Potentially measure the* [OII]λ7325 *auroral line doublet in future too…*

Measuring T_e with SALT



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- *Potentially measure the* [OII]λ7325 *auroral line doublet in future too…*

Current proposal (2018-2-SCI-037):

- Detect [OIII]λ4363 in one of the brighter targets (GOODS-S-4816).
- Establish feasibility of detecting this faint line in the other systems

True evolution of the MZR

With SALT, we hope to more accurately constrain the true evolution of the MZR over cosmic time