Oxygen abundance measurements from emission lines in high redshift galaxies: issues and open problems

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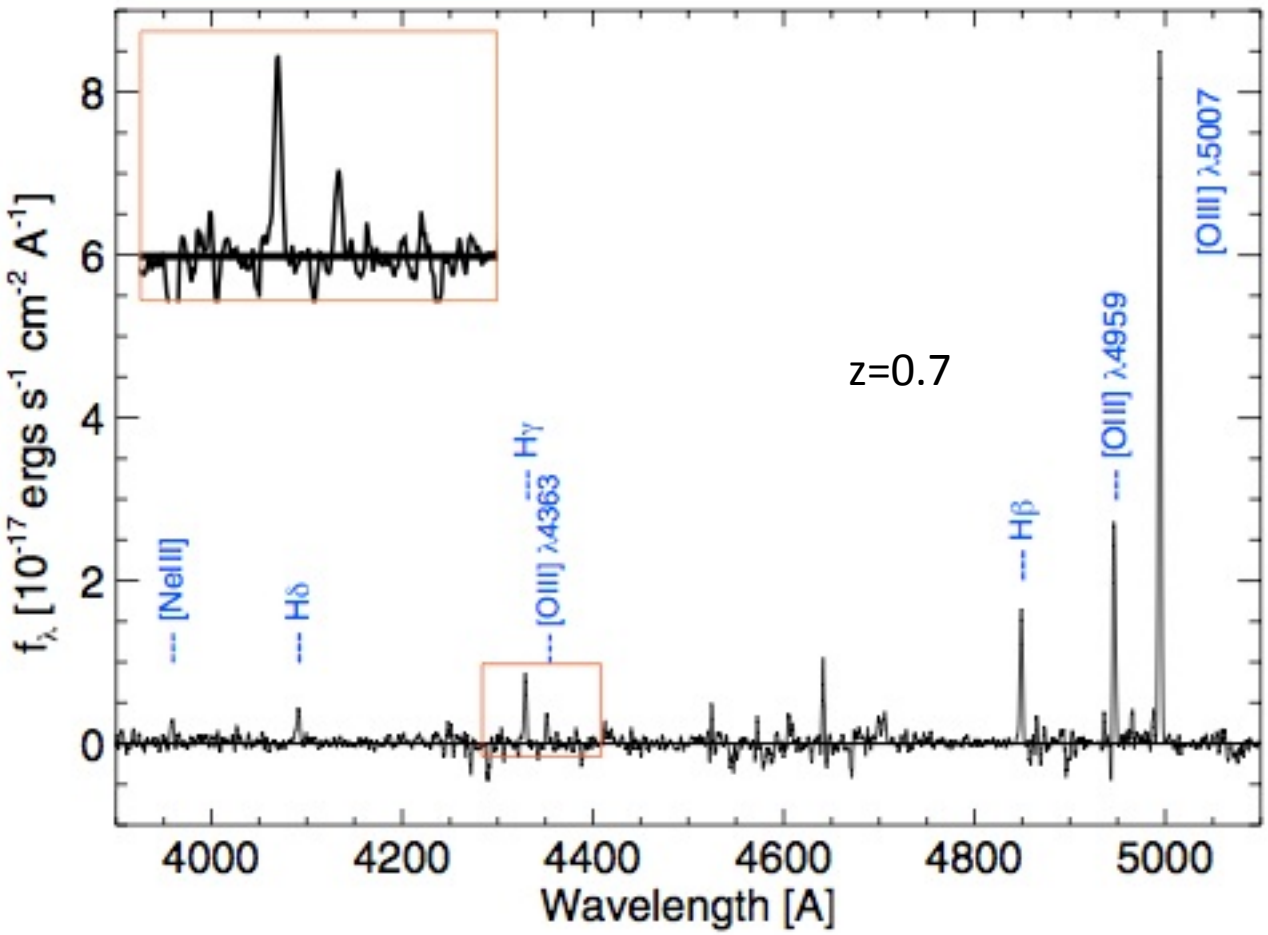
CAVENDISH ASTROPHYSICS

Only a few “direct” (Te) metallicity measurements at high-z



Atek+11
Kakazu+07

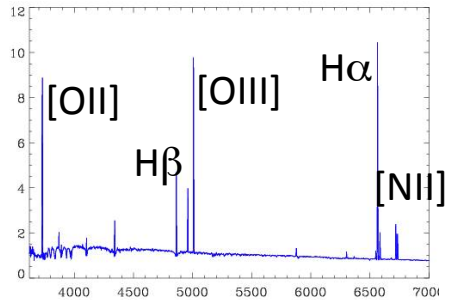
99% of high-z surveys use **strong line diagnostics**

Different diagnostics used at different redshift
(**N2** often preferred, easy to use)

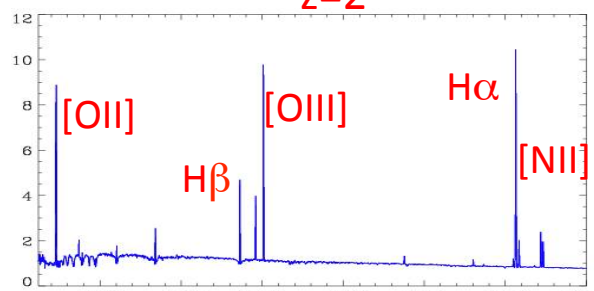
Different calibrations adopted

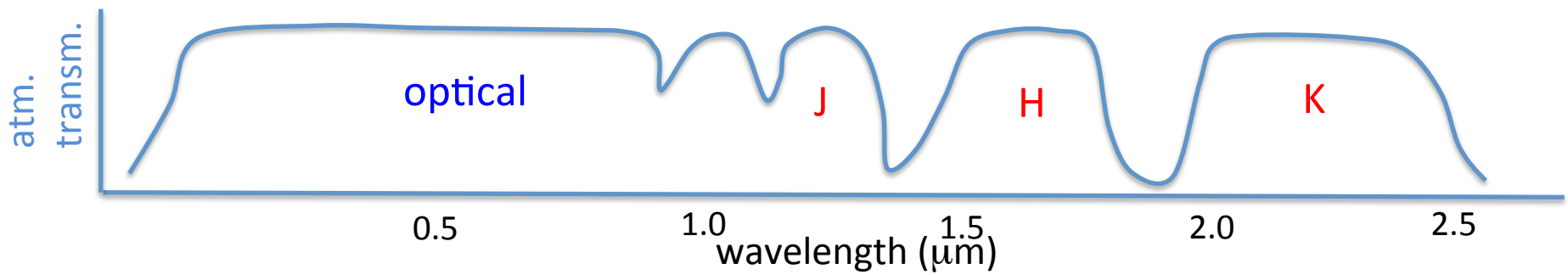
→ Often not easy to compare results at different redshifts

z=0



z=2





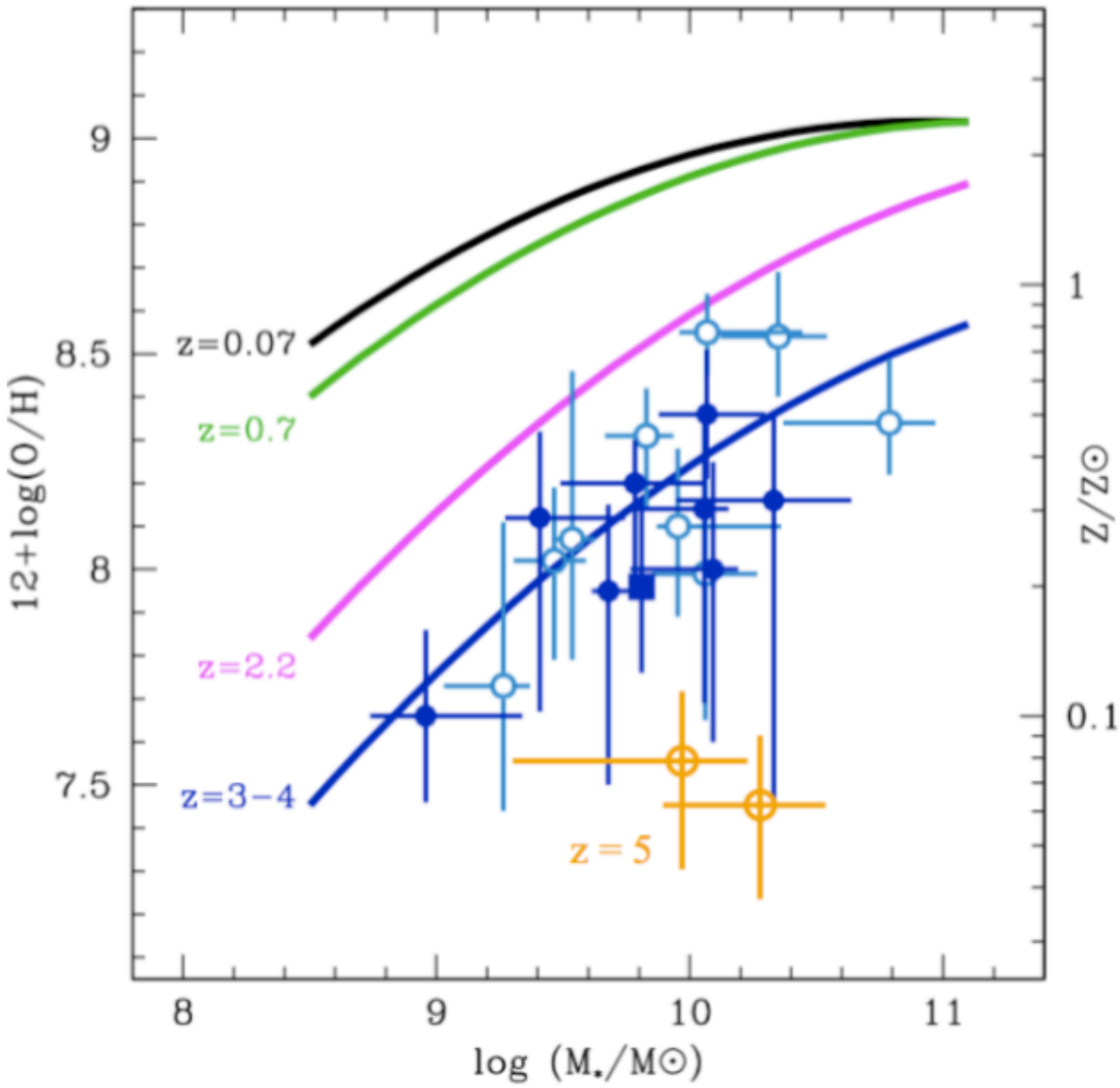
Main goal:

constrain the redshift evolution of the metallicity scaling relations in galaxies

↓

constrain galaxy evolutionary models

Mass-metallicity relation



z ≈ 0.07 SDSS (Kewley&Ellison08)

z ≈ 0.7 GDSS+CFRS (Savaglio+05)

z ≈ 2.2 LBG (Erb+06)

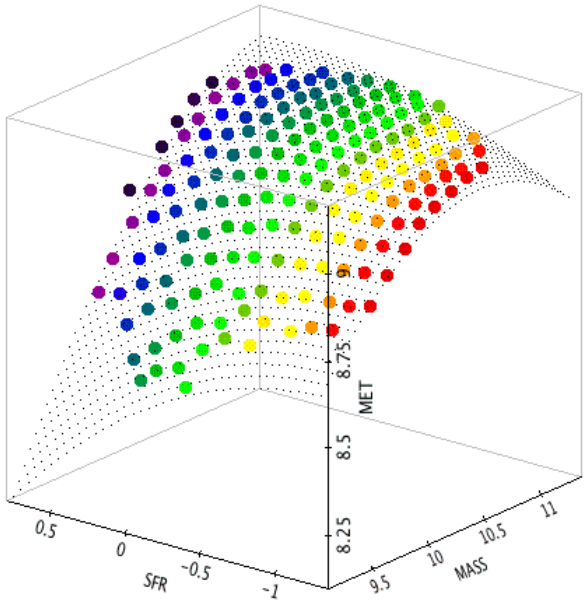
z ≈ 3.3 ○ AMAZE (Maiolino+08,+10)
● LSD (Mannucci +09)

z ≈ 5 ○ AMAZE (Maiolino+08,+10)

Part (all?) of this evolution ascribed to secondary dependence on SFR

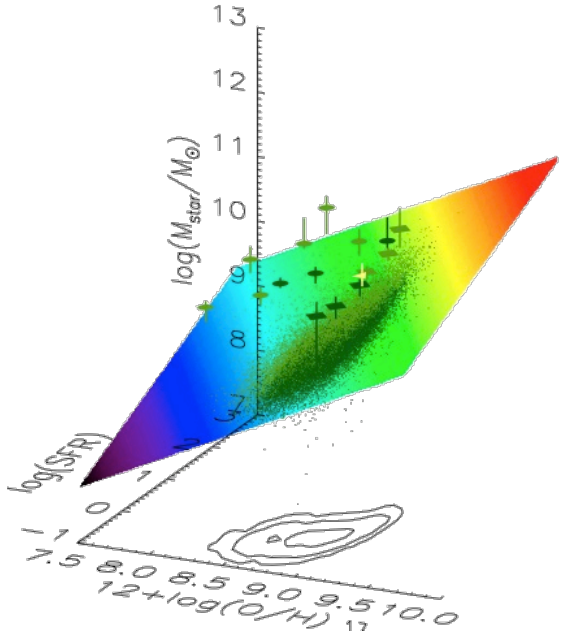
Mass-Metallicity-SFR relation

Curved



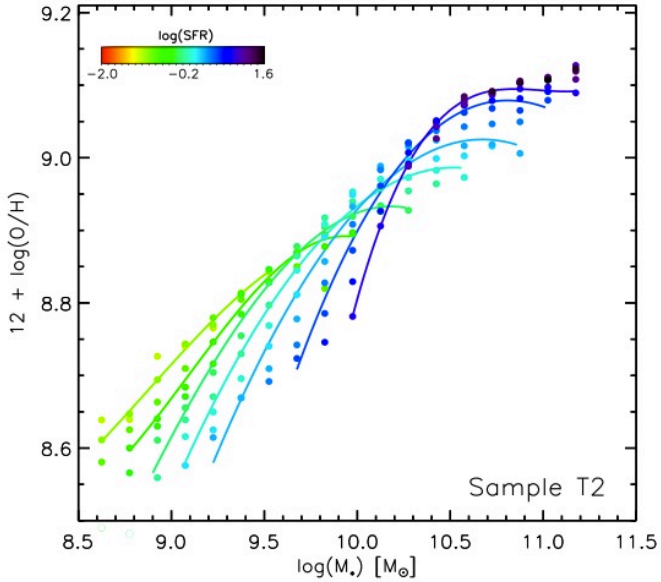
Mannucci+10

Flat



Lara-Lopez+10

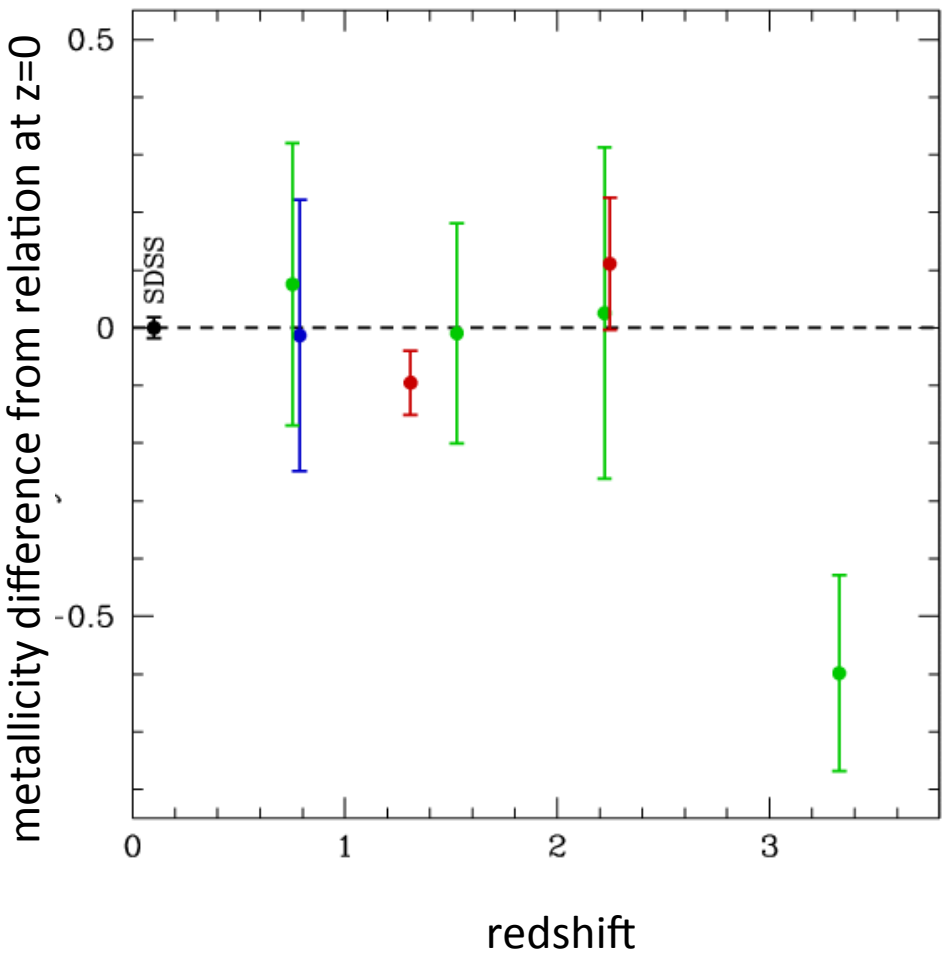
Twisted



Yates+11

other relations in the literature…

Part/all of the redshift evolution of the mass-metallicity evolution disappears in the mass-metallicity-SFR relation, at least up to z~2



Mannucci+10

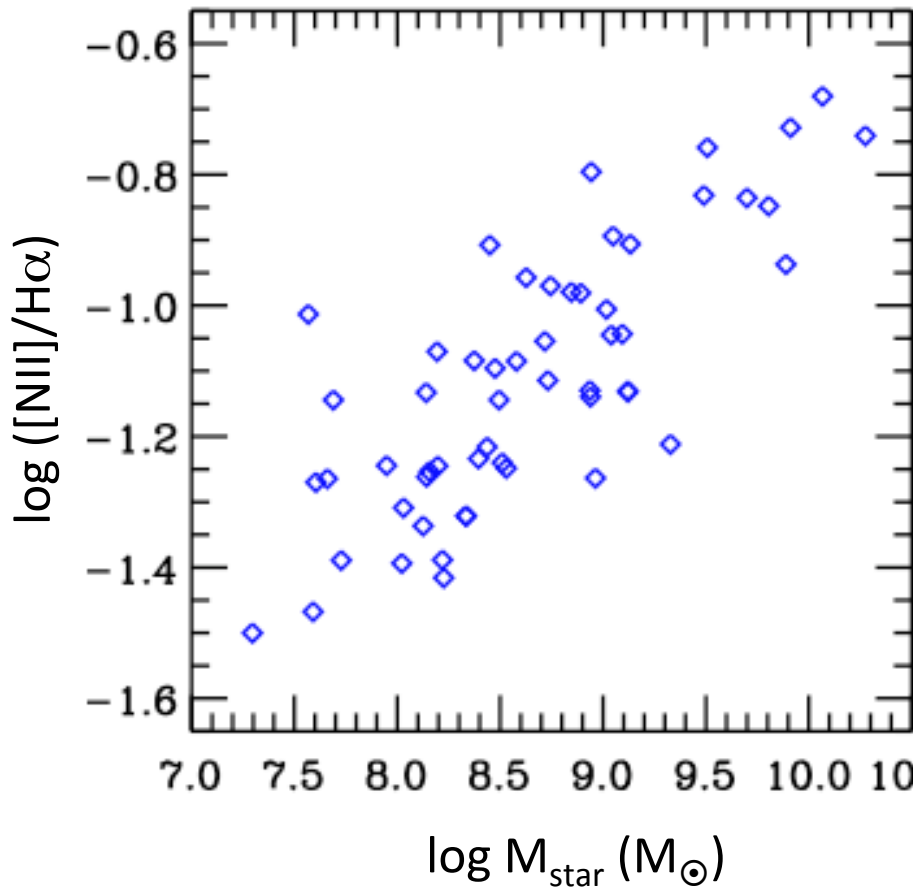
Fundamental issues (1)

Most (~all) of these studies use N2, O3N2 or calibrations based on photoionization models which assume N/O~O/H, i.e. N/H~$(O/H)^2$

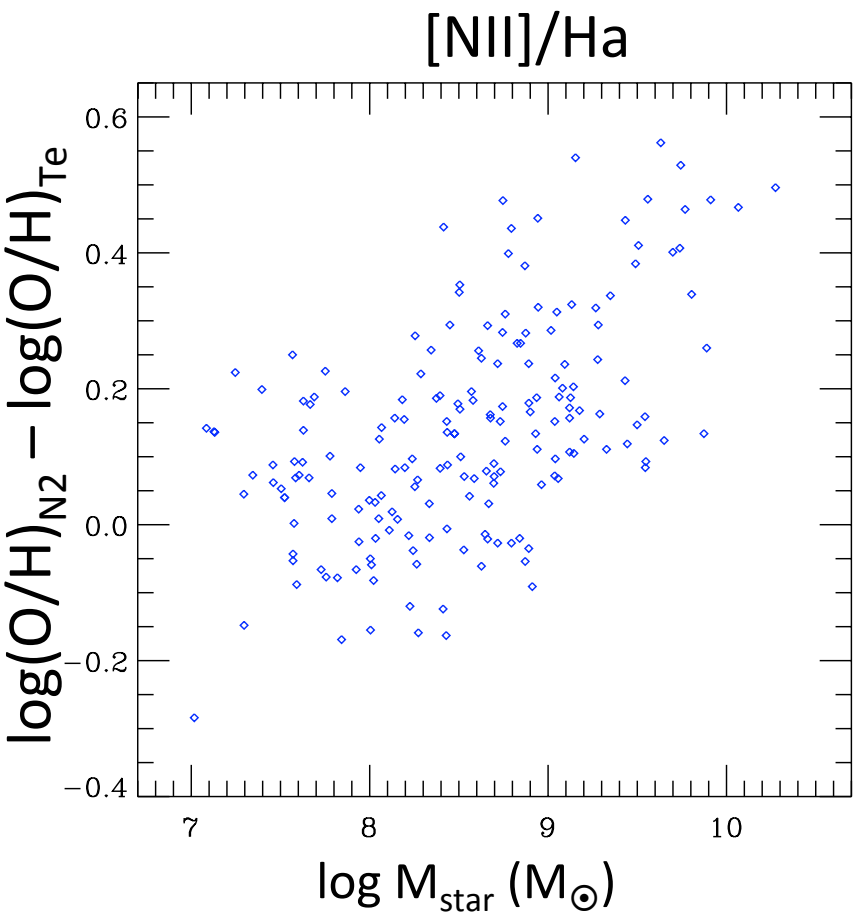
These actually measure the N/O abundance, NOT the O/H abundance

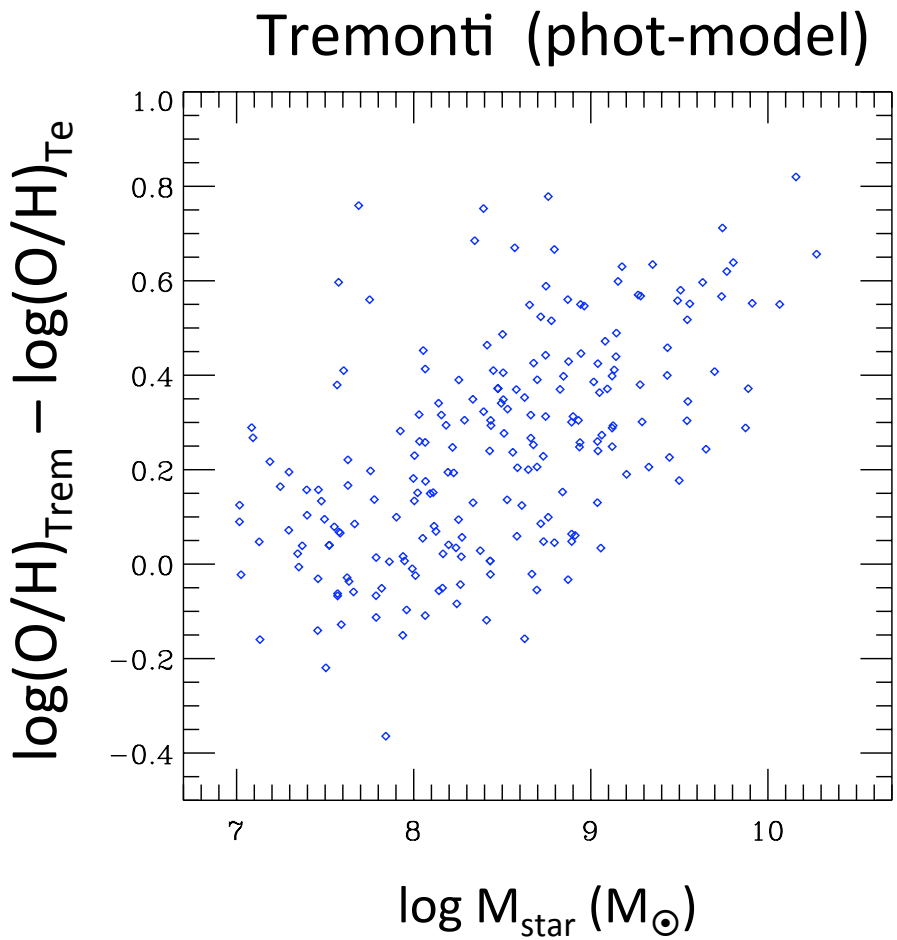
Since N/O depends on the star formation history, these diagnostics depend INTRINSICALLY on some galaxy parameters such as the stellar mass.

Galaxies with O/H from Te and 8.2 < 12+lg(O/H) < 8.3



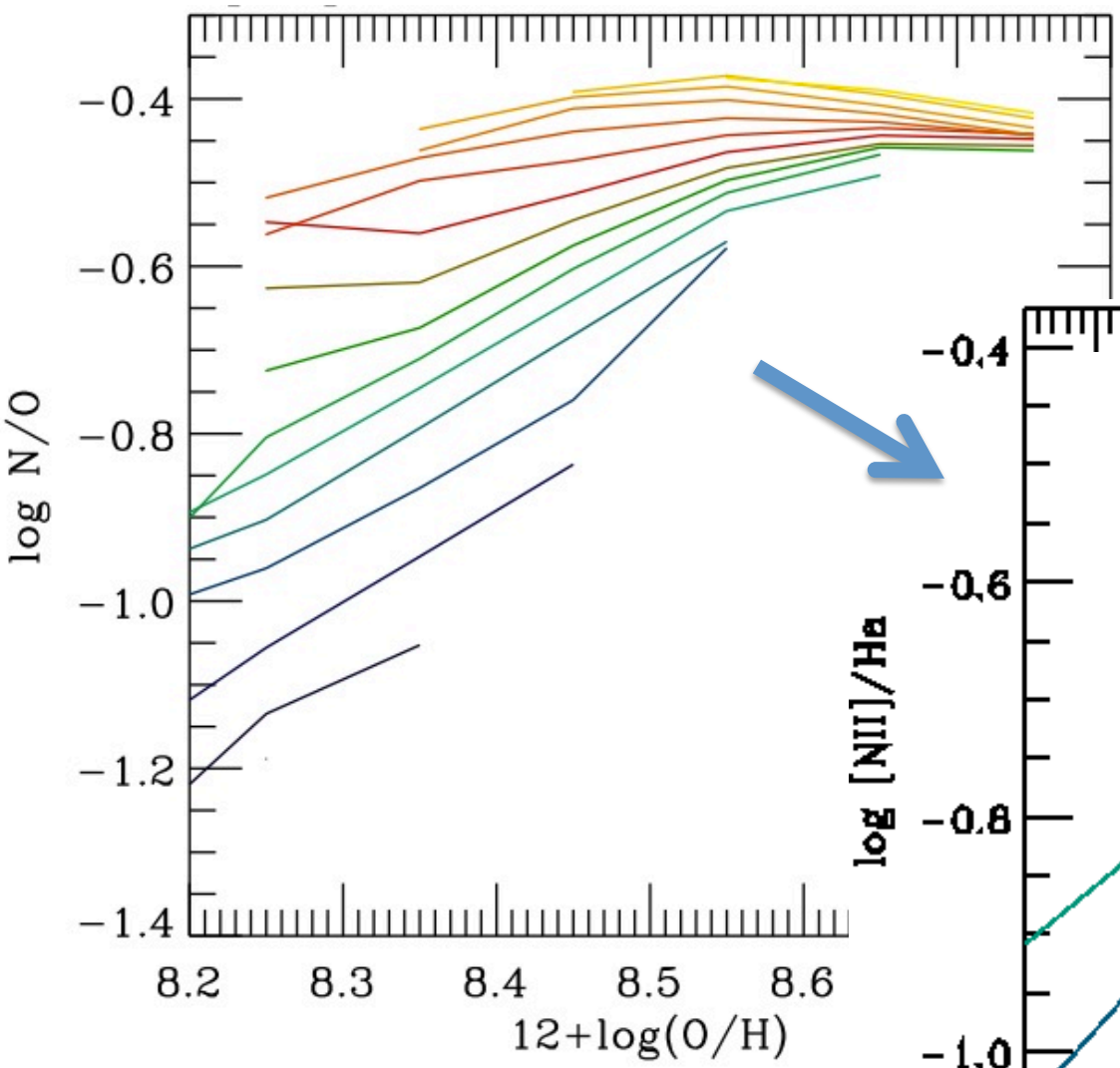
Difference between metallicity inferred from strong lines diagnostics and 'true" metallicity (from direct Te method) depends on Mass

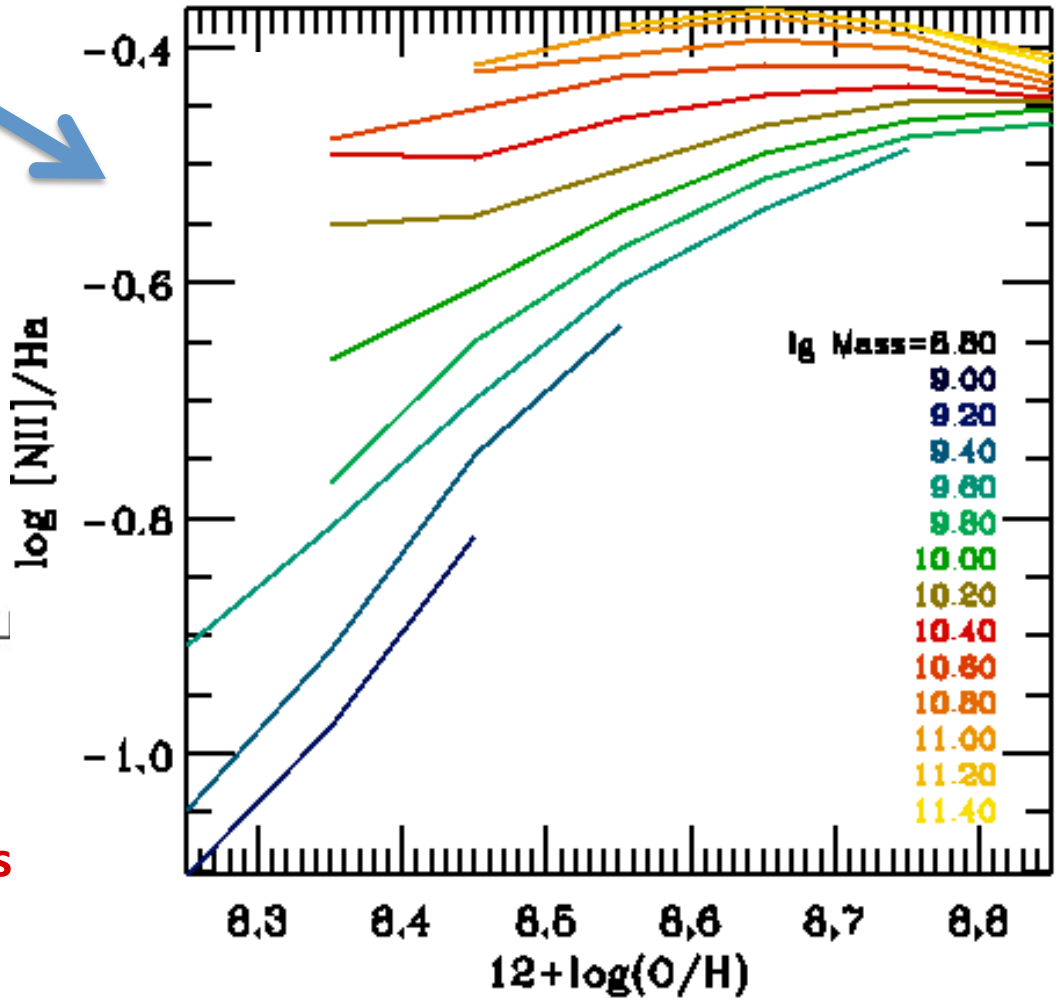




The use of these diagnostics introduces spurious O/H dependences on stellar mass or removes real dependences on stellar mass

N/O vs O/H relation depends on stellar mass



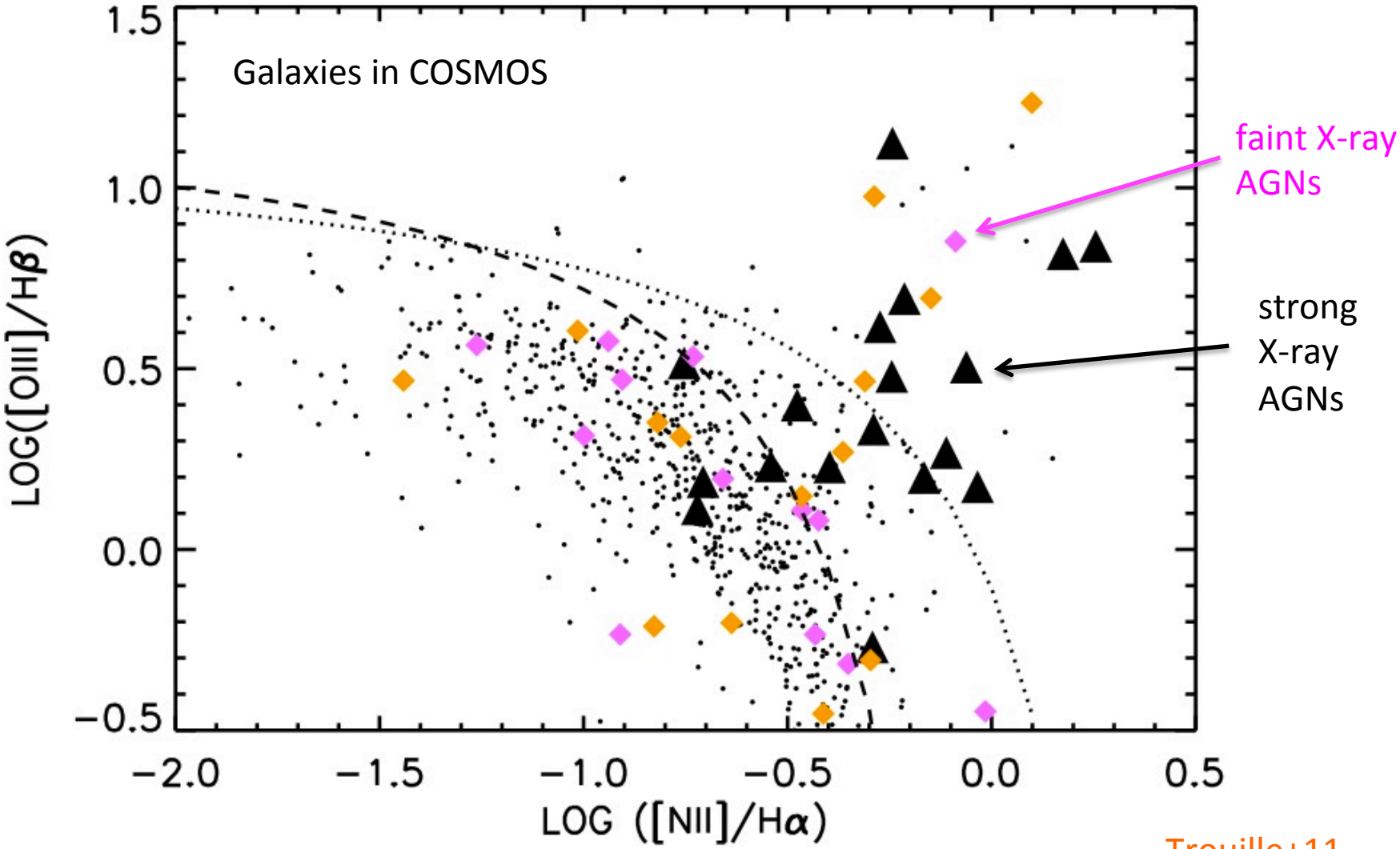


N2 calibration depends on stellar mass

Same effect applies to the O3/N2 on the Tremonti and KD calibrations

Fundamental issues (2)

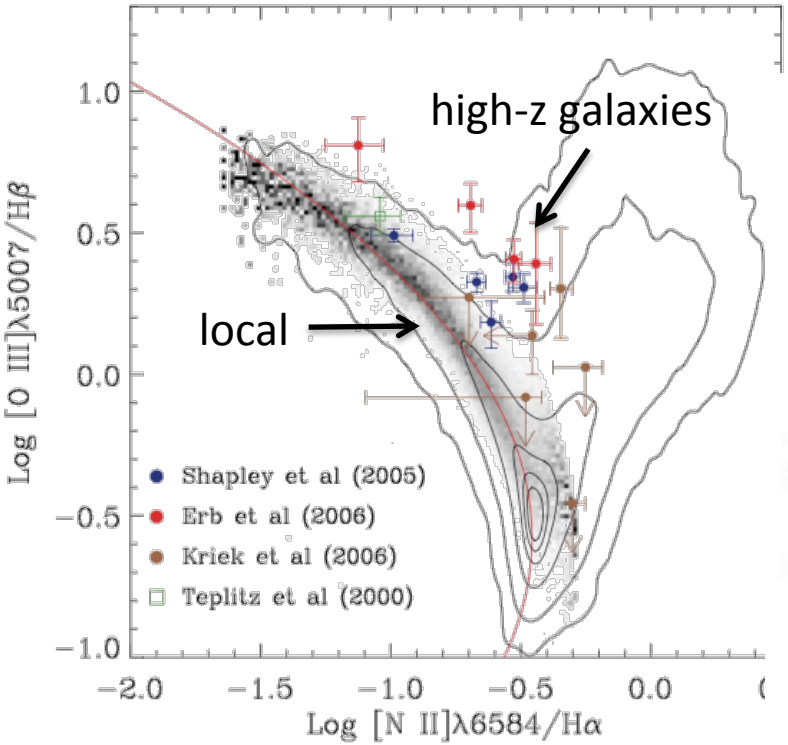
AGNs removal



Trouille+11

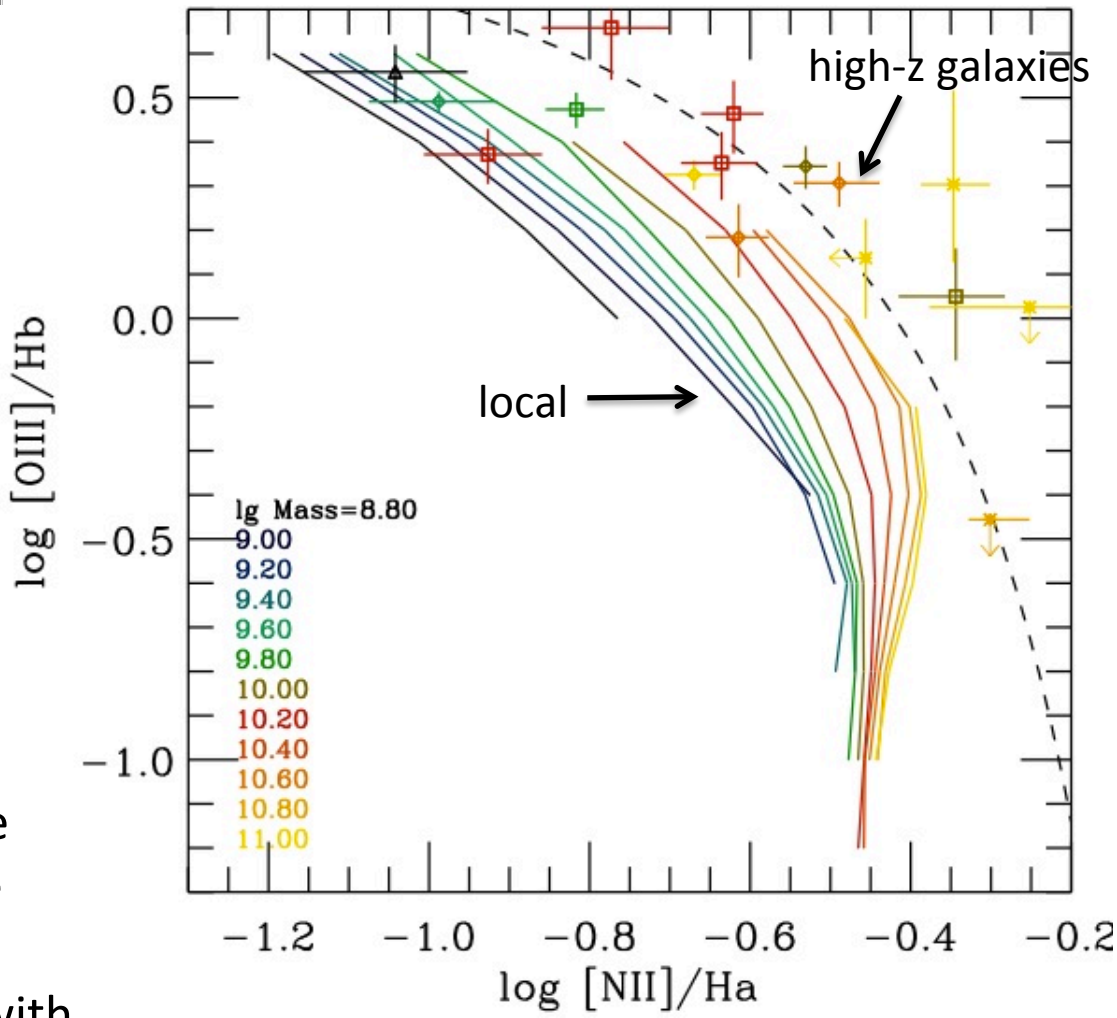
Even the conservative (Kauffman+03) selection curve does include a significant fraction of AGNs (-> O/H screwed up)

AGNs removal



Discarding objects above the AGN-HII dividing line biases the HII sample against N-rich galaxies with high N abundance

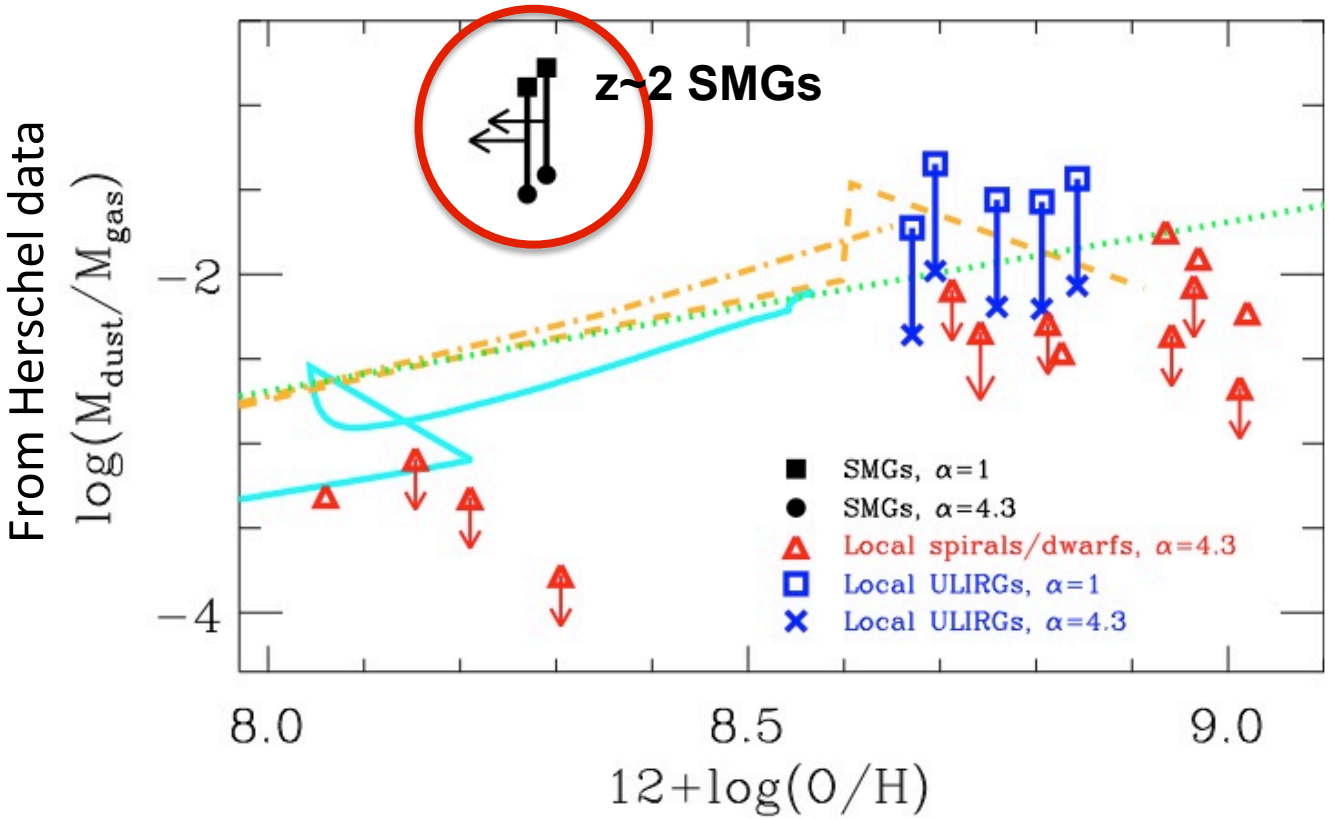
High-z objects deviating from the SF sequence are actually N-rich galaxies (due to selection effects, more massive)



See also Perez-Montero & Contini 2009

Fundamental issues (3)

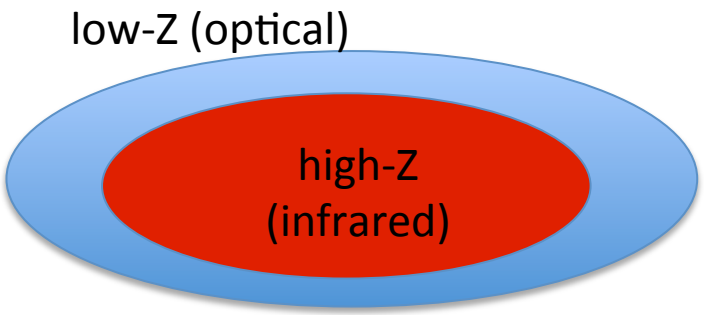
Effects of dust extinction



From optical lines

Santini+10

unrealistically high dust/gas ratio in high-z obscured galaxies given their (optical) metallicity

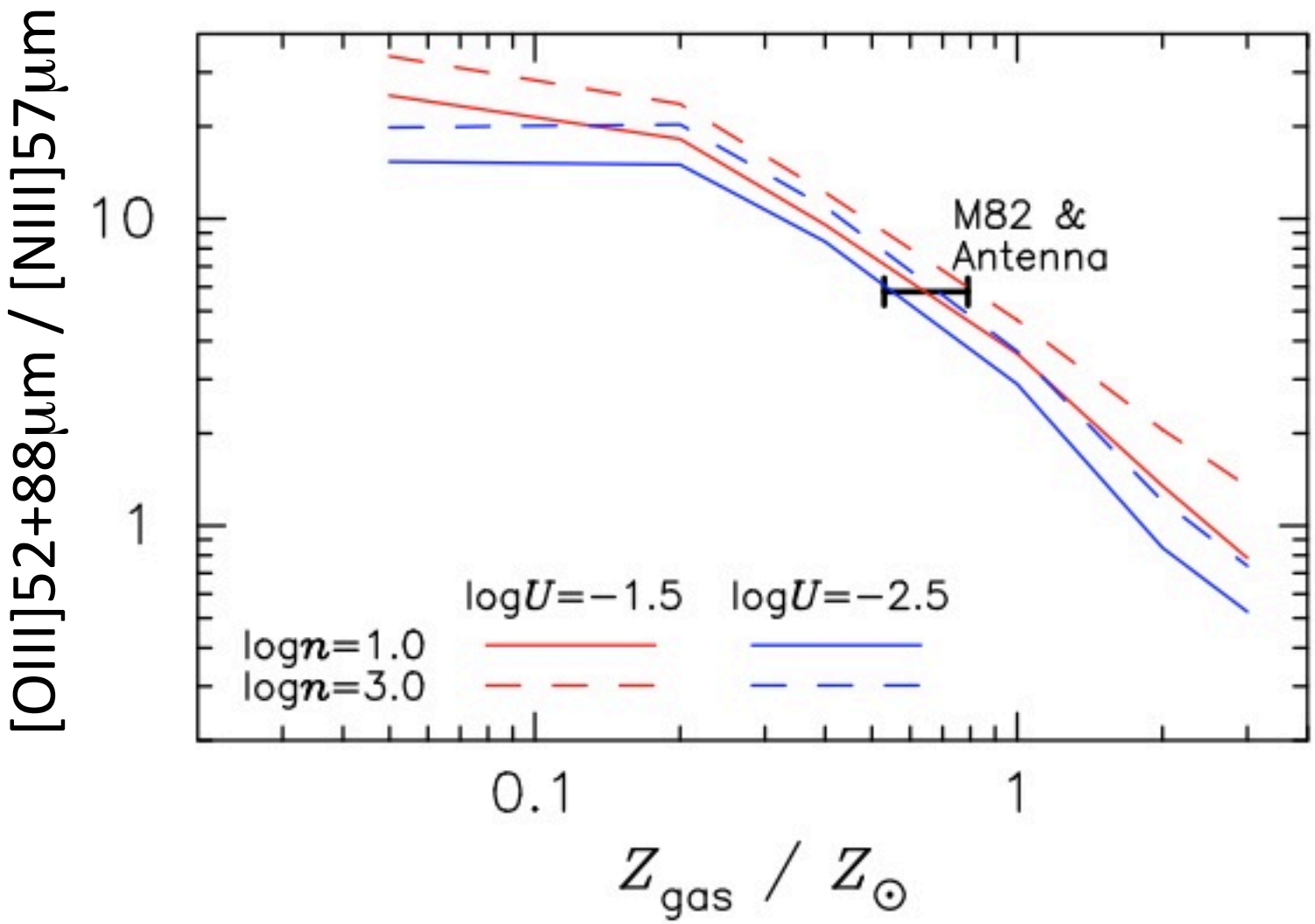


Revisiting the mass-metallicity-SFR relation

Using SFR traced in the far-IR from Herschel data
(unaffected by dust extinction)

(in preparation)

Metallicity from far-IR diagnostics (extinction free)

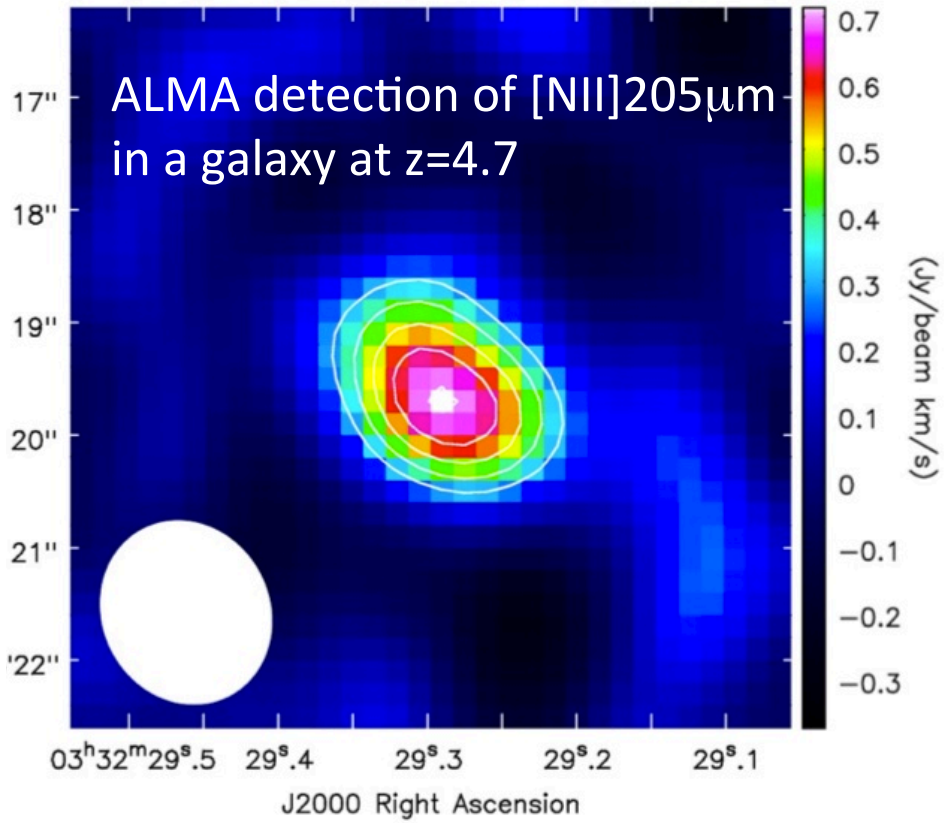


Nagao+11

difficult to observe in local galaxies
(though ongoing Herschel programs)

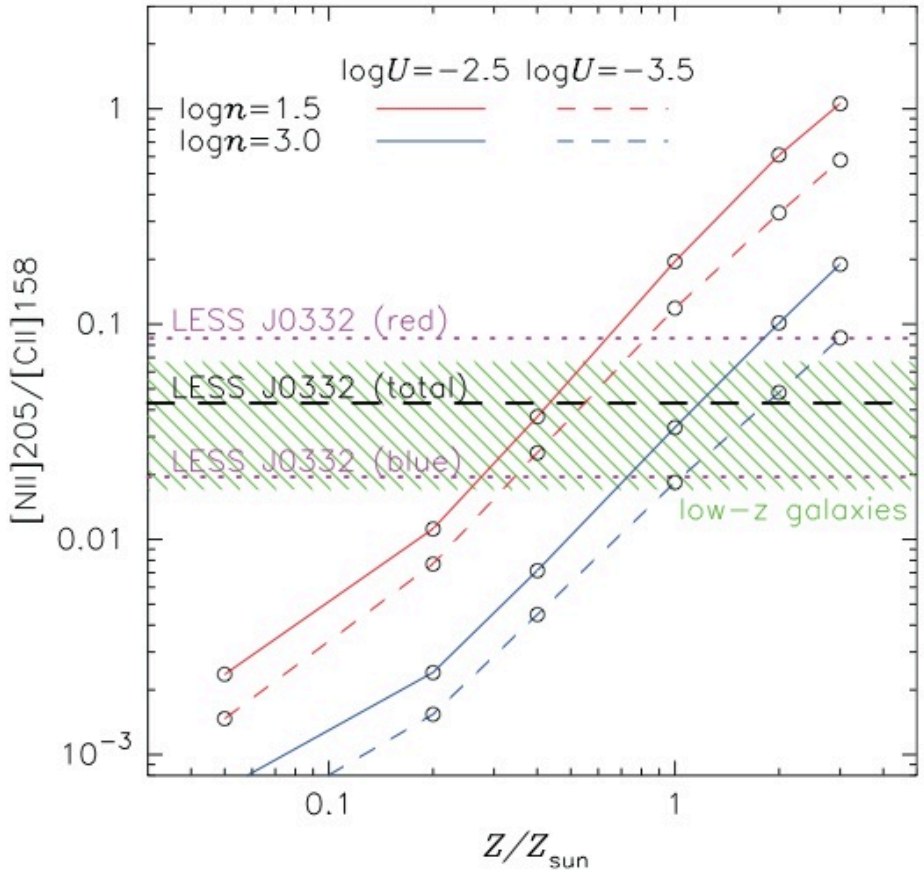
Metallicity from far-IR diagnostics

At high-z these fine structure lines are redshifted in to the submm/mm atmospheric bands

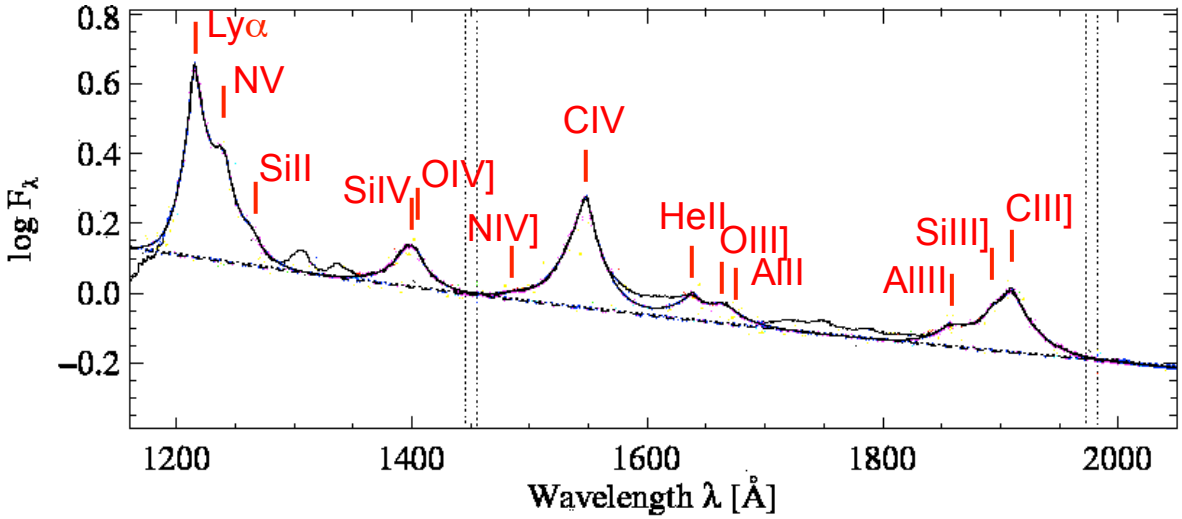


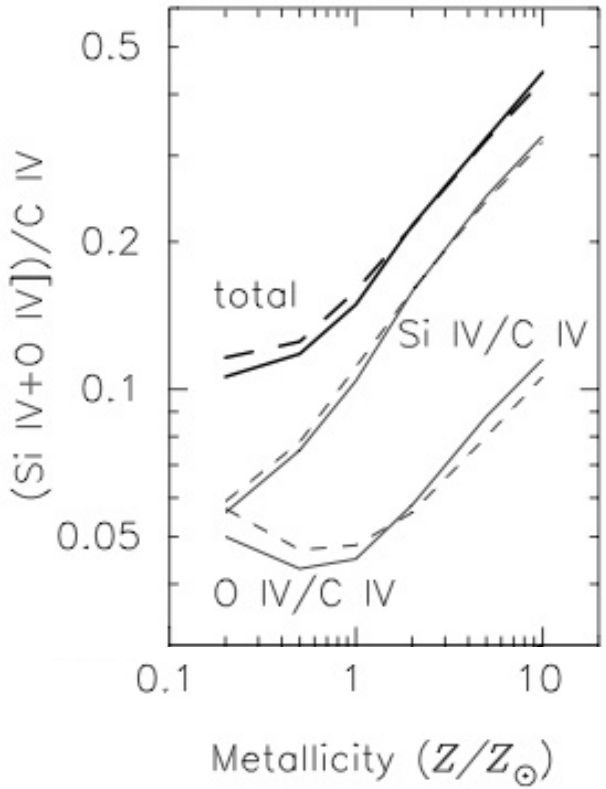
Nagao+12

First attempt to measure metallicities at high-z (z=4.7) with far-IR fine structure lines by using **ALMA**



Metallicity in high-z AGNs



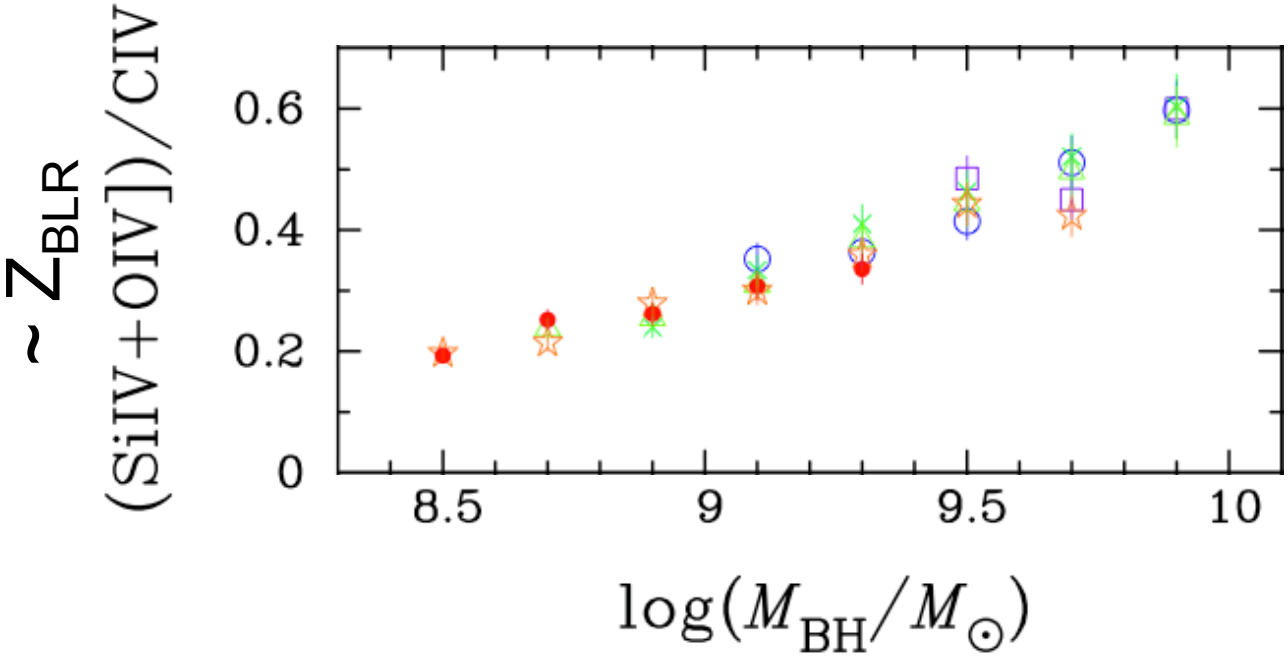


Strong emission lines -> can be detected with high S/N out to very high-z

Calibrations with photoionization models

Nagao+06

"M_{BH}-metallicity relation" in high-z AGNs



Matsuoka+11

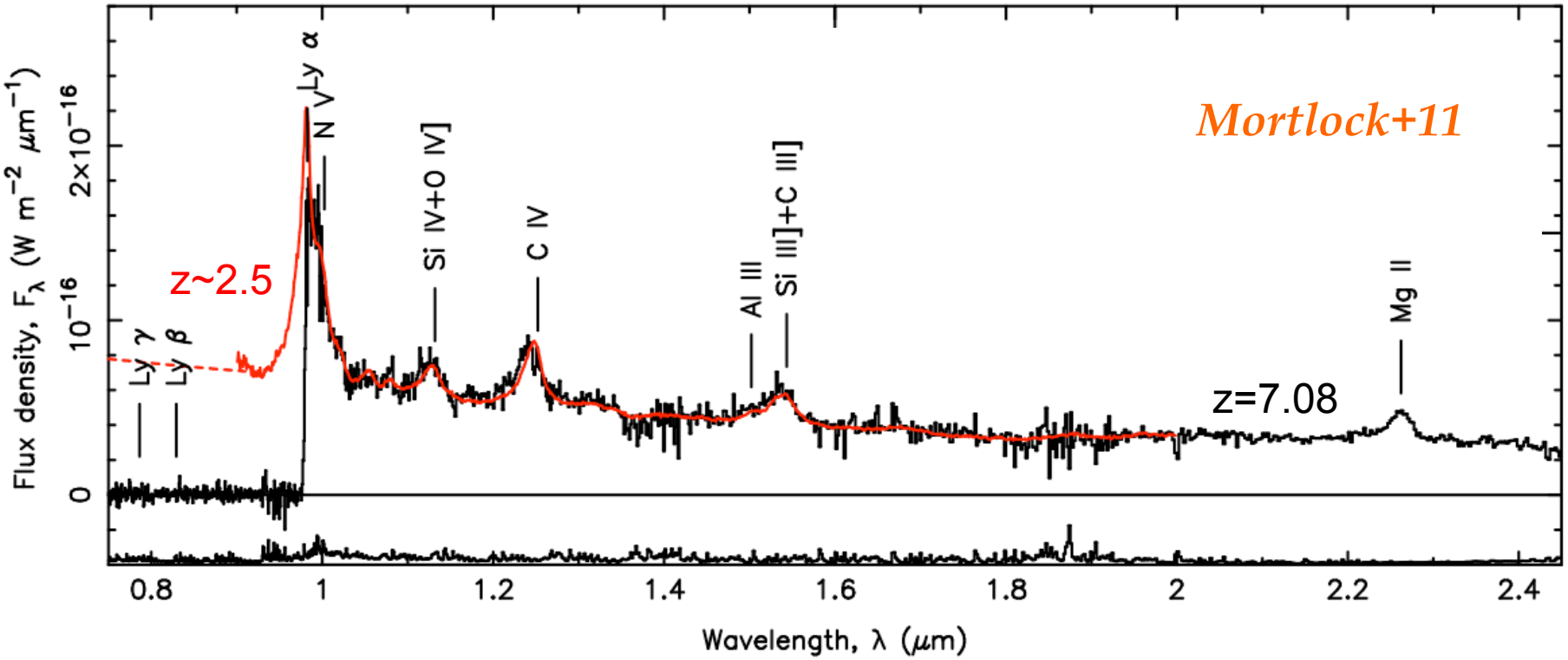
Mirrors the mass-metallicity relation in the host galaxy

It does not evolve, out to very high redshift

Juarez+09

Quasar ULAS J1120+0641 at **z=7.08**

age of the Universe 700 Myr !



Same relative line strength (=> same metallicity) as z~2.5 quasars

Yet… starting to fall short of time to produce some elements (e.g. carbon)

Summary

The investigation of metallicities at high-z through emission lines is a rapidly growing field

Key to constrain models of galaxy evolution

It is one of the main science cases for the next generation major (and most expensive!) facilities: JWST, E-ELT, TMT

Currently we are limited by the limited by some fundamental issues affecting the current results:

- Nitrogen abundance strongly affecting some of the metallicity scaling relations
- Inappropriate AGN removal
- Dust obscuration (we're only seeing the "skin" in most objects)