First results of the Mass–Metallicity relation in the zCOSMOS survey



Enrique Pérez Montero & Thierry Contini

Observatoire Midi-Pyrénées – Toulouse (France)

in collaboration with

F. Lamareille, M. Mignoli *(Bologna)*,

J. Brinchmann *(Porto)*,

C. Maier *(Zürich)*,

& the zCOSMOS team

V reunión proyecto coordinado Estallidos. Granada 28th February – 2nd March 2007

Introduction

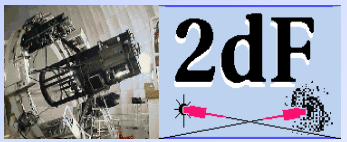
- Evolution of **galaxies** and **large-scale structures**
  on cosmological timescales

➔ constraints on **models of galaxy formation & evolution**

- When and how did galaxies form?
- Links between high-z ("young") and
  local ("old") galaxies?
- Timescales for galaxy evolution?
- Dependance with environment?
- ....

Introduction

- Needs for **large statistical samples of galaxies at various epochs**



- **"Local"** Universe: **~ 10^6 galaxies up to z ~ 0.3**



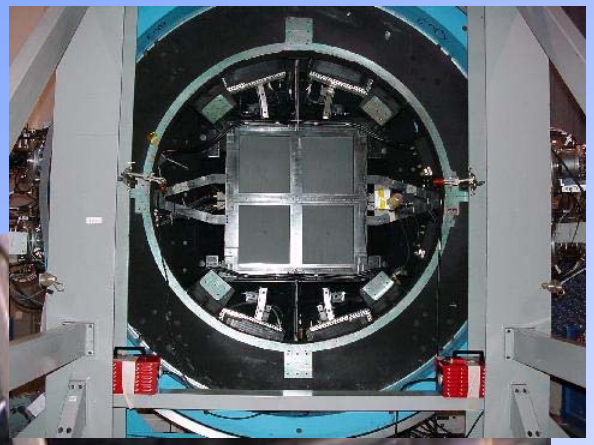
- **"Small"** (~ 10^3 galaxies) **samples** between **z=0.5 and z ~ 4**
  obtained so far: CFRS (up to z ~ 1), LBGs (z ~ 3-4), etc

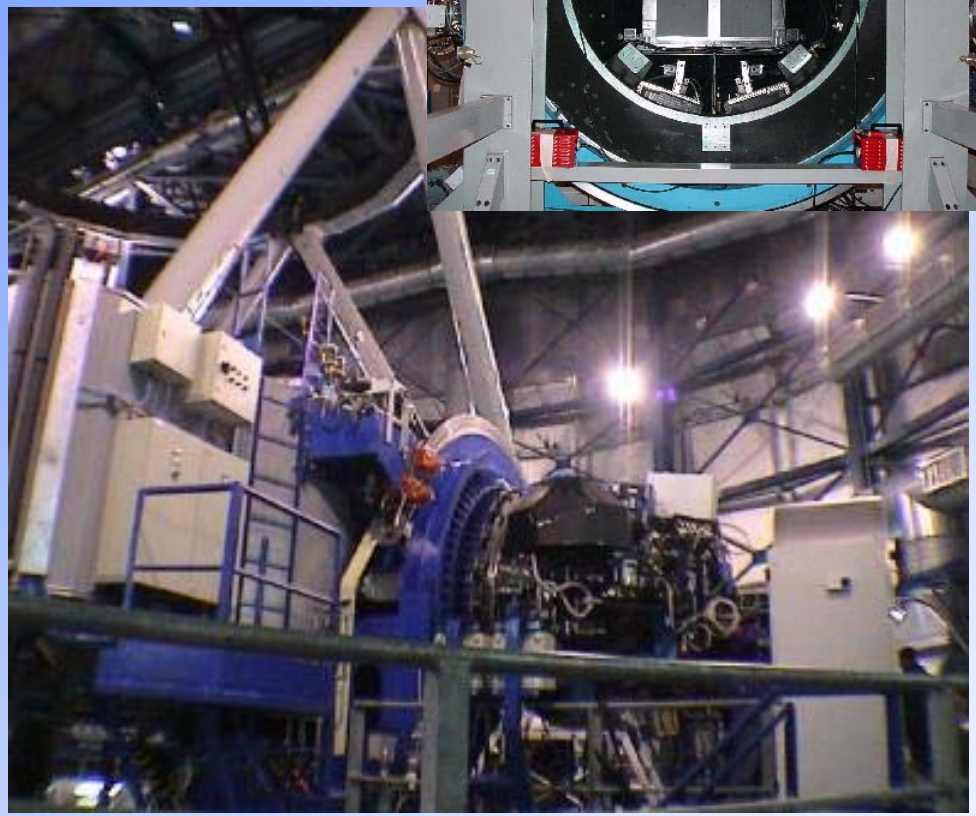
- Large ongoing (VVDS, DEEP, COSMOS, GDDS...) surveys on the largest telescopes (VLT, Keck, Gemini...) to gather **large numbers of high-redshift galaxies in large volumes**, similarly to SDSS & 2dF

The redshift machines

VVDS using *VIMOS* on VLT

~ 600 spectra simultaneously
@ R~250





DEEP2 using *DEIMOS* on Keck

~ 160 spectra simultaneously
@ R~5000



Physical properties derived from high-z spectra

Quantity	*z < 0.45*	*0.45 < z < 0.95*	*z > 0.95*
STB vs. AGN	Hα, [NII], [SII] [OIII], Hβ	[OIII],[OII],Hβ	*X-rays, FIR?*
SFR	Hα	Hβ	[OII] *(-> z=1.55)*
Reddening	Hα/Hβ	Hβ/Hγ	
Gas-phase Metallicity	[NII]/Hα [NII]/[OIII]	R_{23}	UV abs. lines? [NII]/Hα in NIR
Stellar mass	$(D_{4000} + H\delta_A)(0.3 < z < 1.3)$ + photometry		
Stellar mass, age metallicity & SFH	stellar cont. + abs. lines + photometry		

The zCOSMOS Survey

PI: **Simon Lilly** - ETH Zürich

- **Large program (~ 600 hours) on VLT/VIMOS started mid 2005**
- **Part of the multi-λ (XMM, GALEX, SPITZER, VLA, ...) coverage of the COSMOS HST/ACS 1.4x1.4 deg^2 field**
- **Large collaboration between Bologna, Marseille, Milano, Munich, Toulouse, & Zürich (~ 30 people)**
- **Strategy:**

Bright Sample: (270 hours)

ACS selected: $I_{AB} < 22.5$, **$z < 1.5$**

Red **Medium Res. grism**

~ 27000 redshifts full area

Faint Sample: (270 hours)

UBVR+BzK selection: high redshift $1.0 < z < 2.5$)

Blue **Low Res. grism**

~ 13000 redshifts central area

Ongoing large & deep spectroscopic surveys

Survey	Redshif range	R=λ/Δλ	Ngal	Limiting mag.
SDSS, 2dF	$z < 0.3$	~ 2000	~ 10^6	$R_{AB} < 17.8/19.5$
VVDS	$0.2 < z < 4.0$	~ 250	~10^5	$I_{AB} < 22.5/24$
zCOSMOS	$0.2 < z < 4.0$	~ 600/250	~ 10^4	$I_{AB} < 22.5/24$
DEEP2	$0.7 < z < 1.5$	~ 2000	~ 10^4	$R_{AB} < 24$
GDDS	$1.0 < z < 2.0$	~ 500	~ 10^2	$I_{AB} < 24.5/K_{AB} < 20.5$

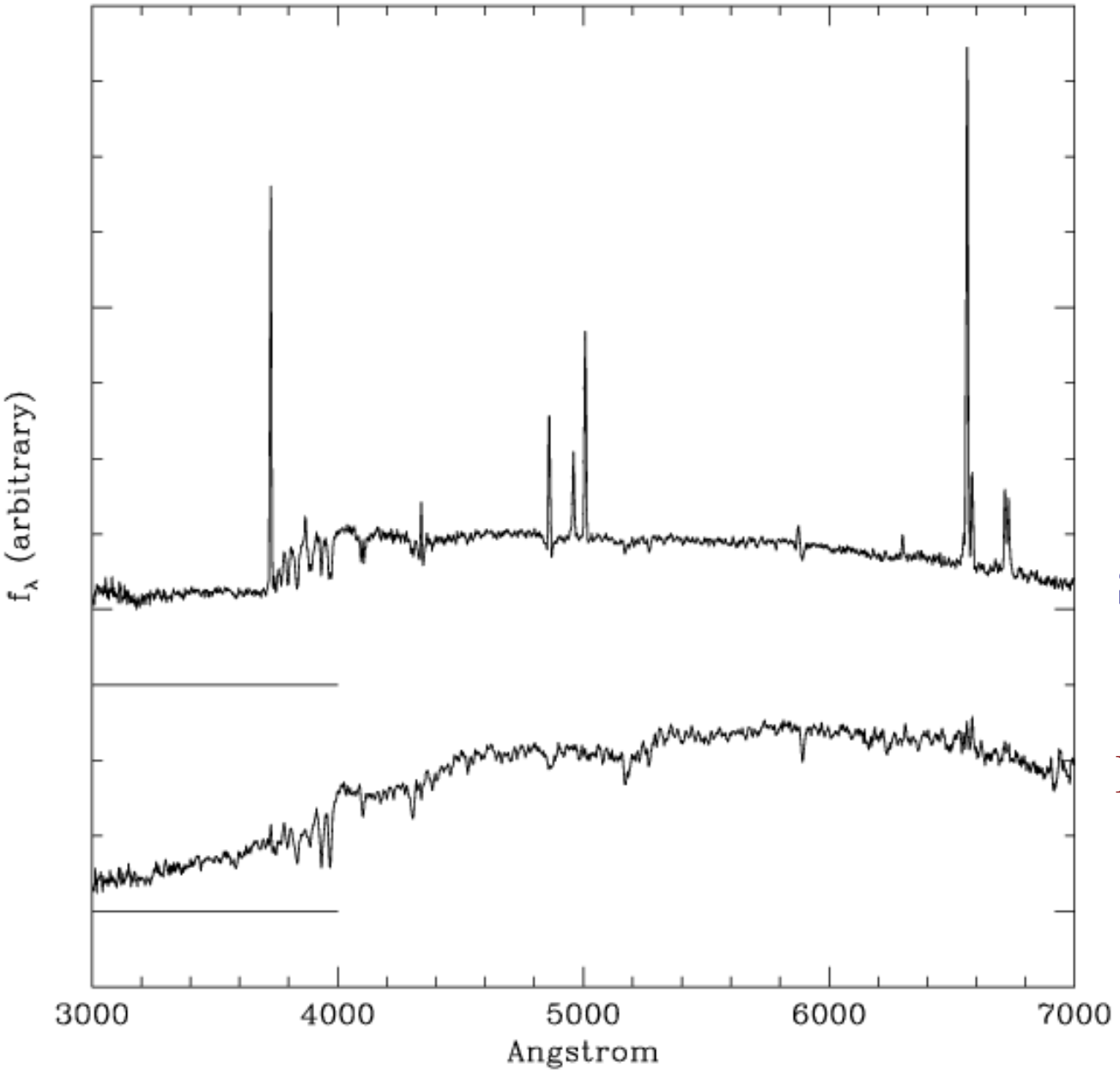
VVDS & zCOSMOS: low/medium spectral resolution BUT ...

- high statistics

- minimal selection

- multi-λ coverage

Composite spectra from zCOSMOS "bright" galaxies

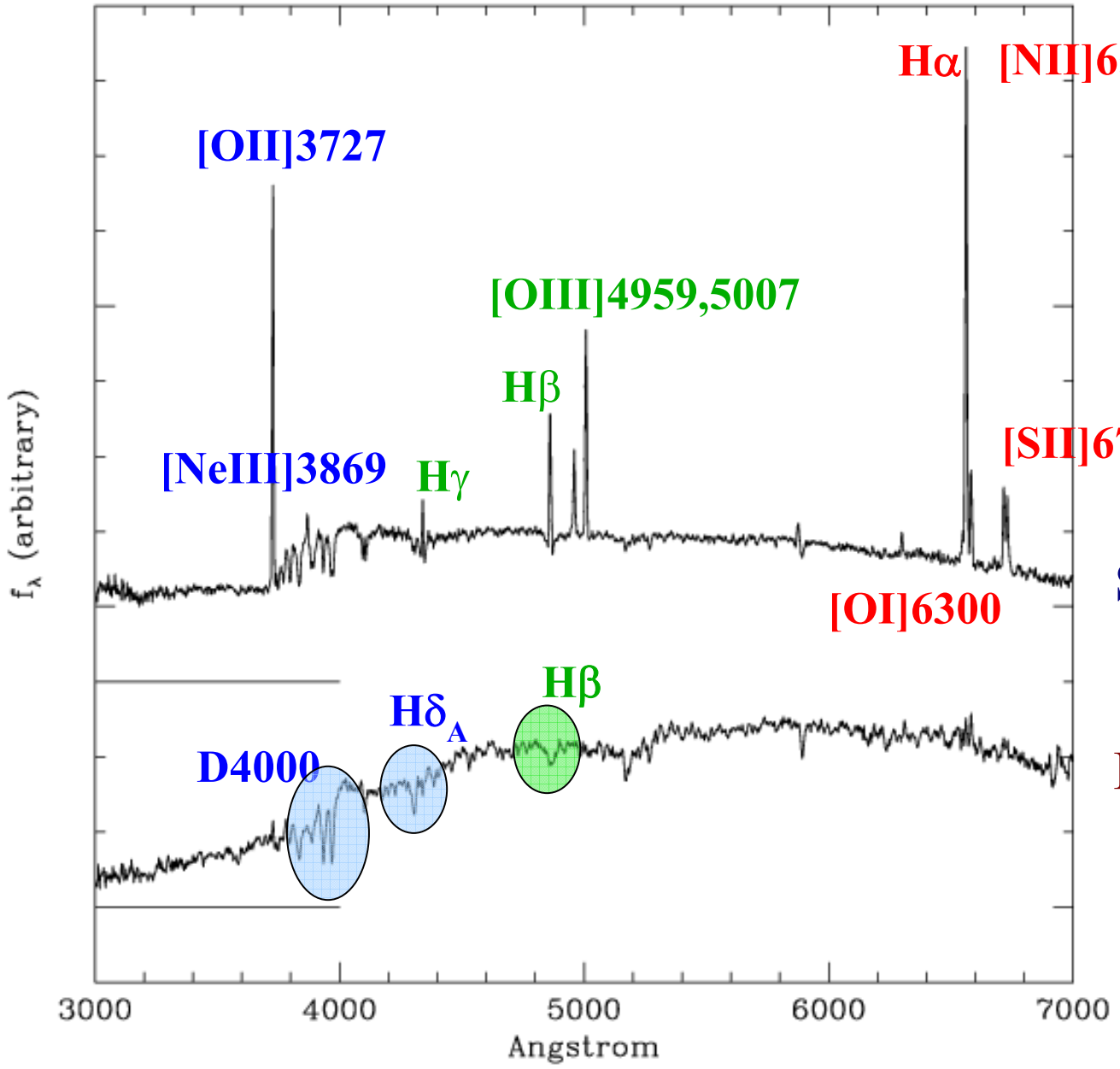


Star-forming

Early-type

Lilly et al. (2007), ApJS

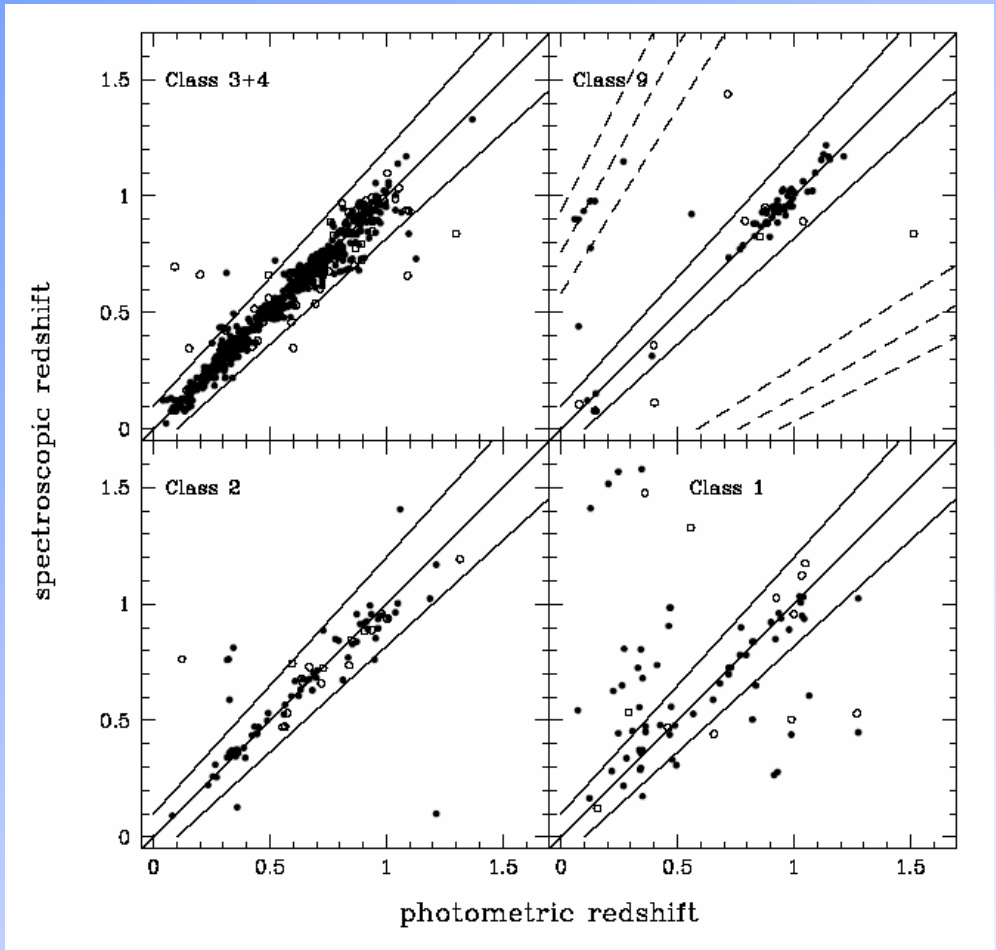
Composite spectra from zCOSMOS "bright" galaxies



Lilly et al. (2007), ApJS

The sample

First 1040 zCOSMOS galaxies (I_{AB}<22.5) observed in 2005, with medium-resolution (R=580) spectroscopy - $\Delta\lambda$ = 5500 - 9700 Å

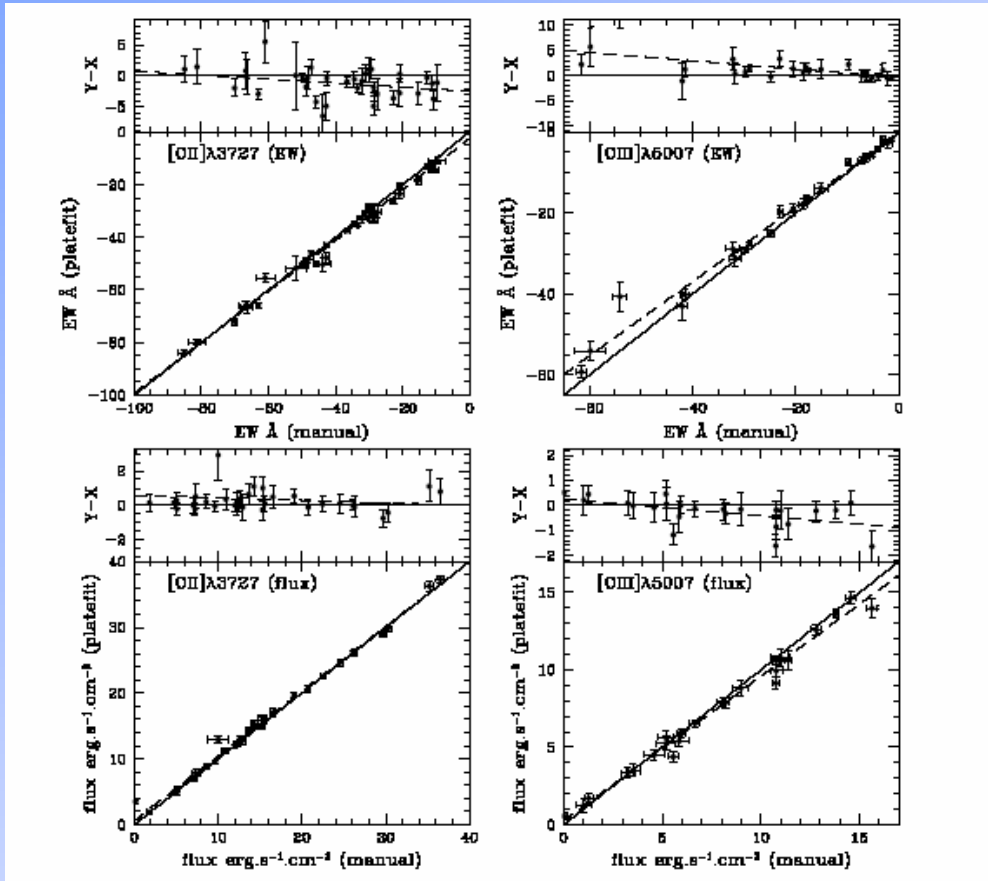


Redshift measurement is done using a multi-step method, from the automatic tool KBREAD, followed by detailed visual instpection.

Spectroscopic redshifts provide more accurate redshift determination for objects with good confidence.

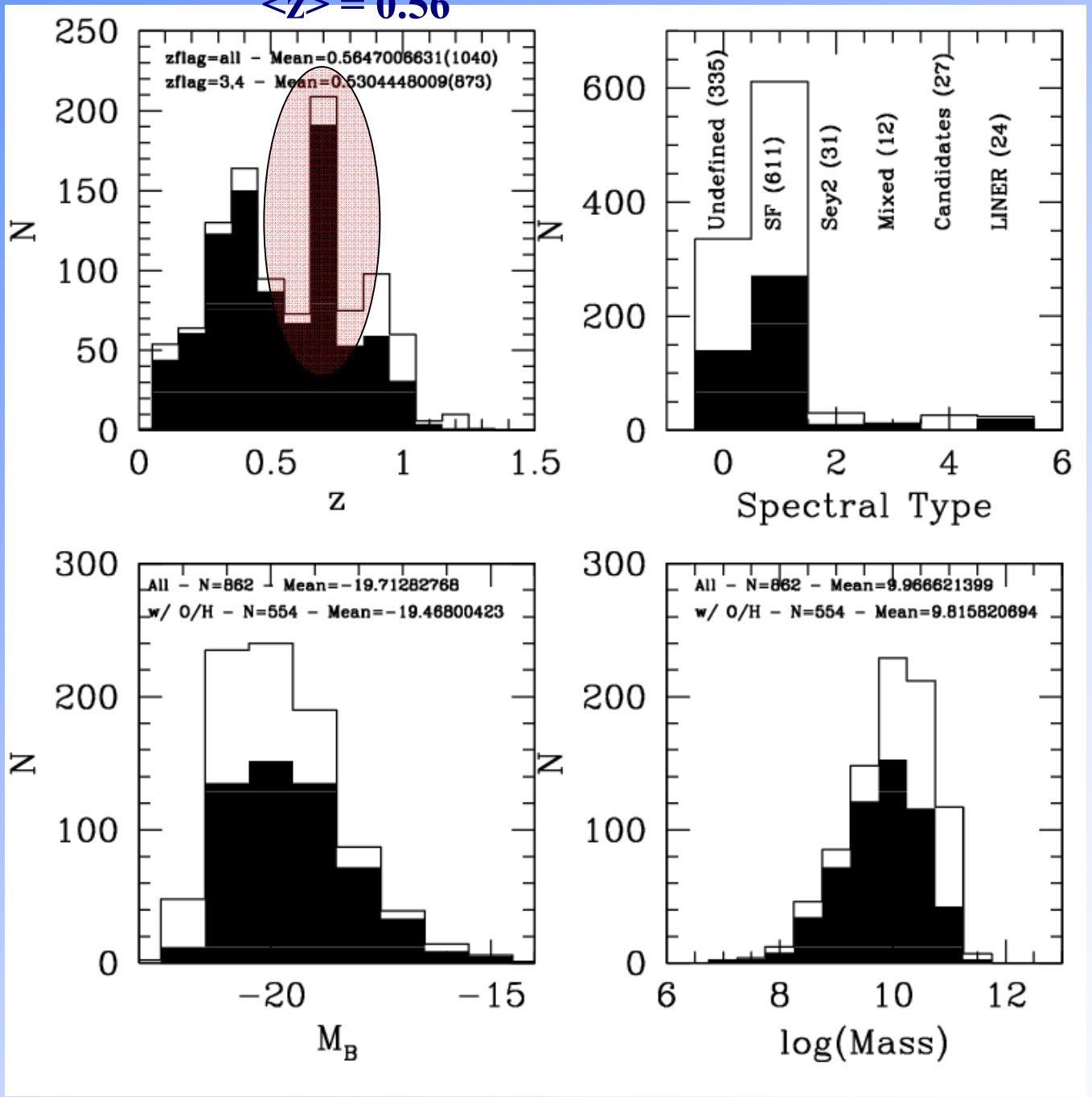
The sample

Automatic fitting of the stellar continuum and the absorption lines with library spectra STELIB (Le Borgne et al., 2003) and stellar population synthesis models GALAXEV (Bruzual & Charlot, 2003) and m easurement of emission lines and EW is done with the software "*platefit*" (Tremonti et al., 2004)



When comparing automatic measurements with manual ones (IRAF) There is a very good agreement for bright lines and good for the weaker
(Ph.D. thesis F. Lamareille)

The first 1k zCOSMOS galaxies

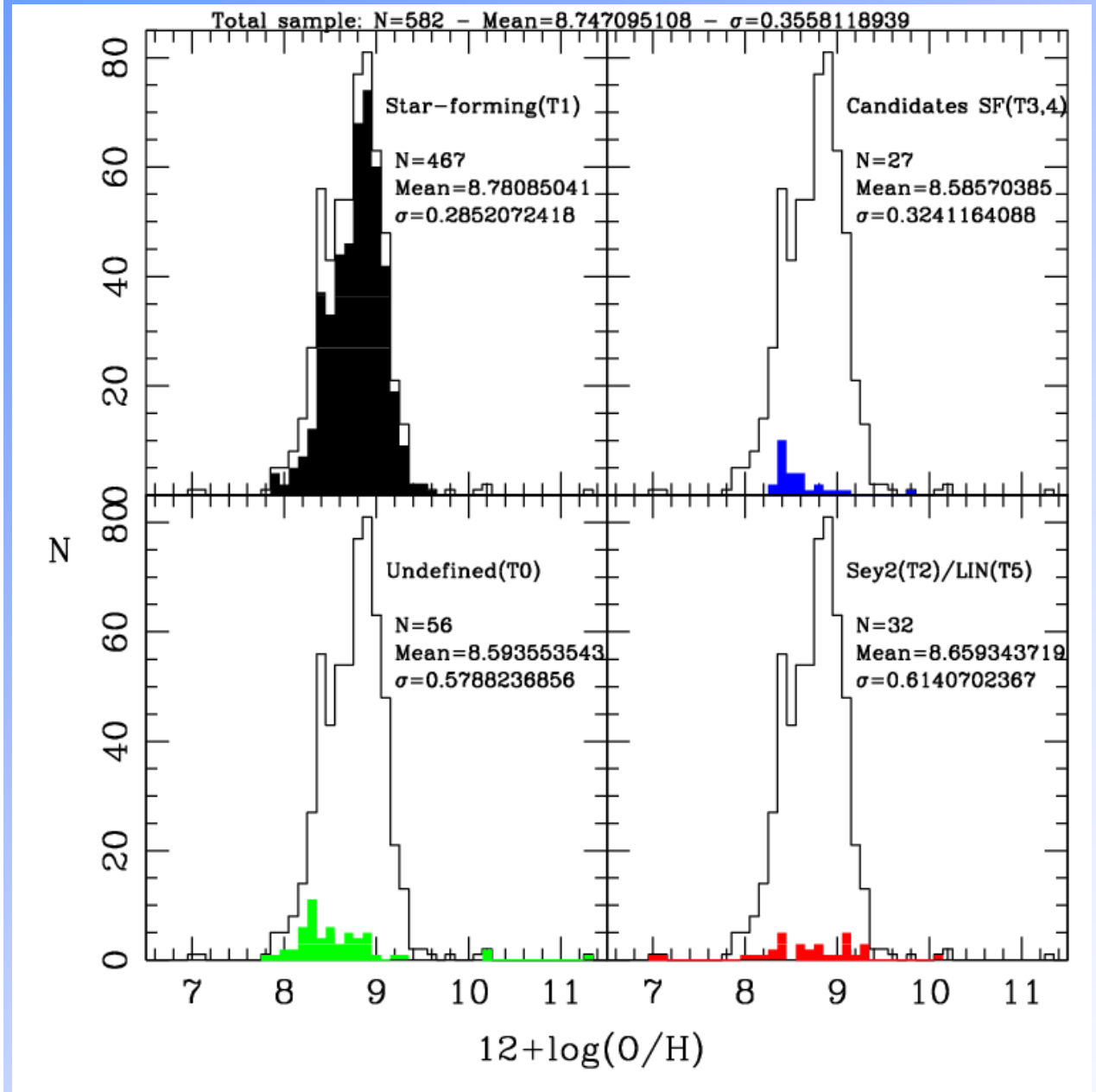


611 (~60%) secure
star-forming galaxies
+ 39 "candidates"
+ 31 (3%) Seyfert 2
+ 24 (2%) LINERs
+ 335 (~30%) undefined

M_B & Mass estimated
from SED fitting with **BC03**
declining exponential SFH
+ secondary bursts

<log(M)> = 9.8

Metallicity distributions

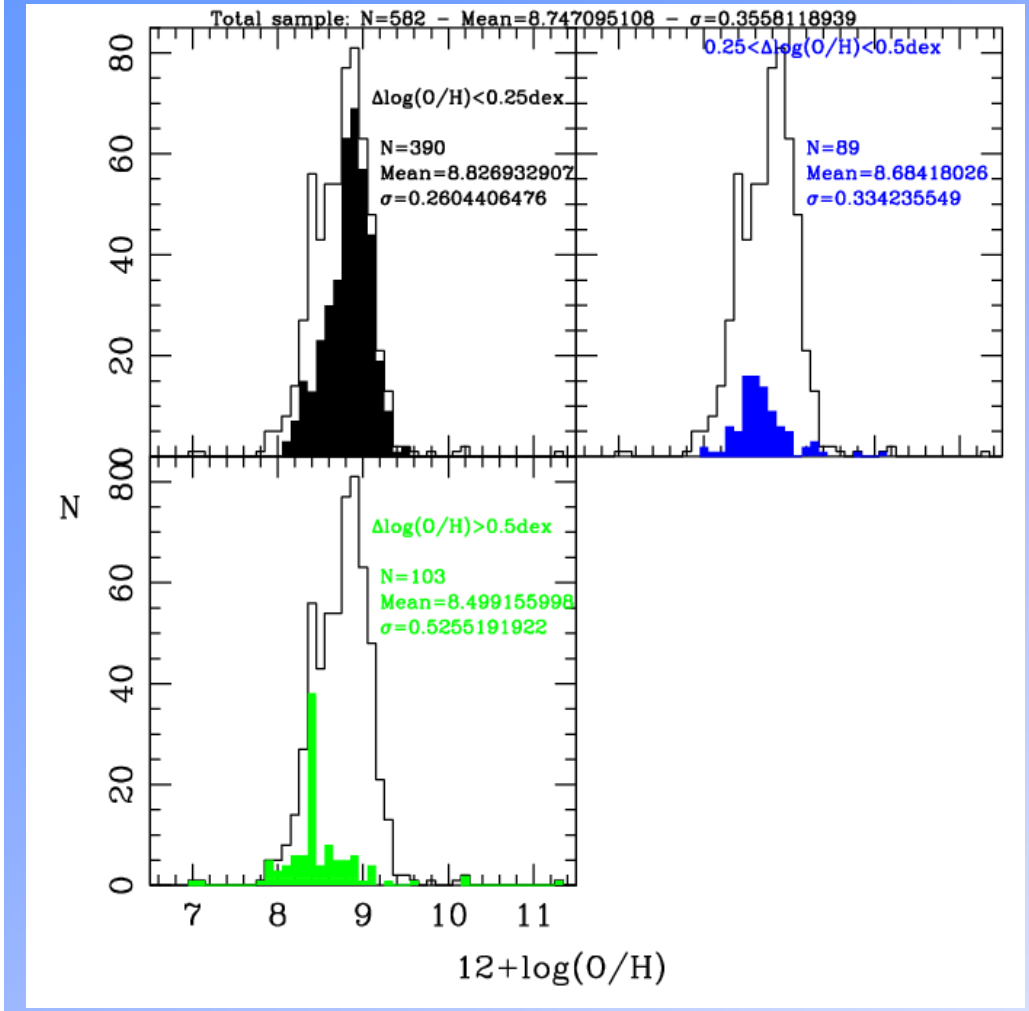


O/H estimated using 2 empirical methods:

[OIII]5007/[NII]6584
up to z~0.45

R23=([OII]3727+[OIII]5007)Hβ
up to z~0.9

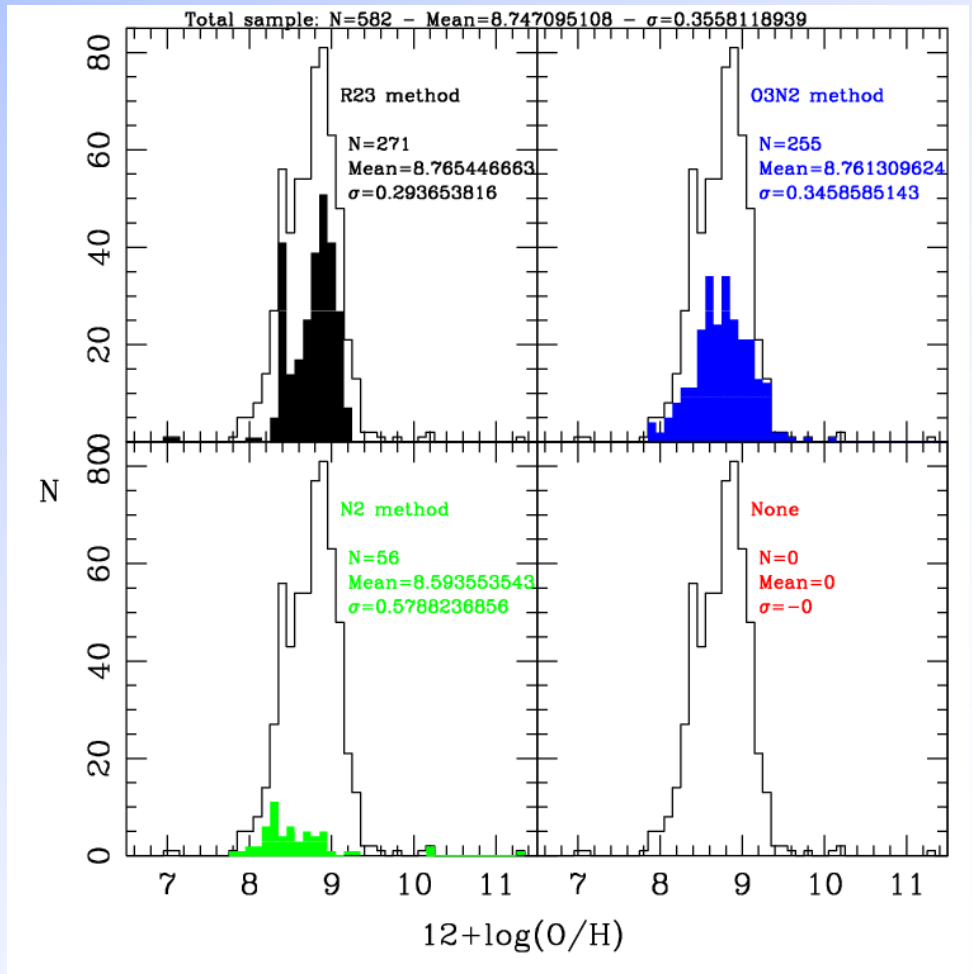
Converted into CL01 metallicities using calibrations based on SDSS galaxies
(Lamareille 2006, PhD thesis)



390 (67%) with **Δlog(O/H) < 0.25**

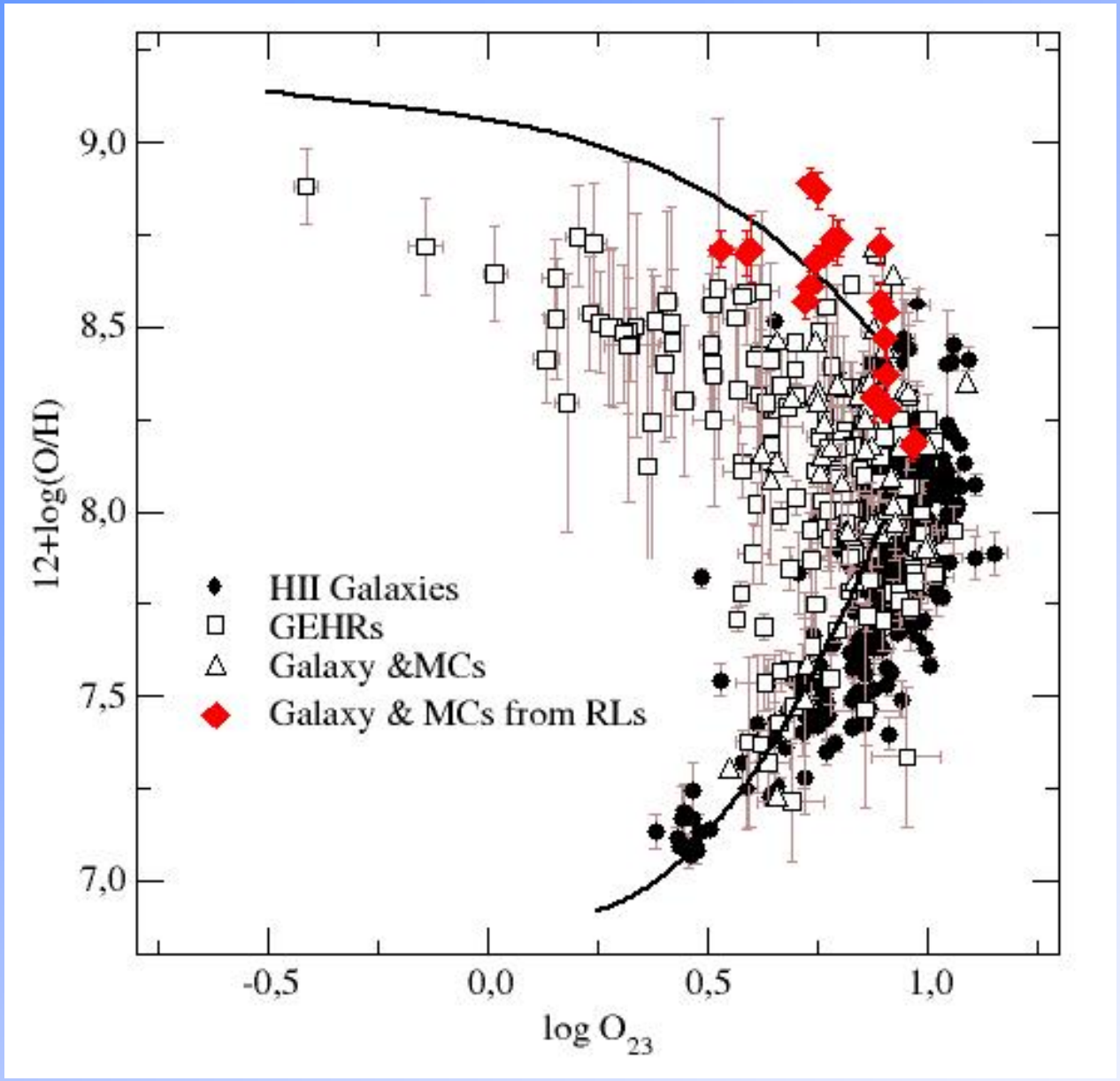
89 (15%) w/ **0.25 < Δlog(O/H) < 0.5**

103 (18%) with **Δlog(O/H) > 0.5**



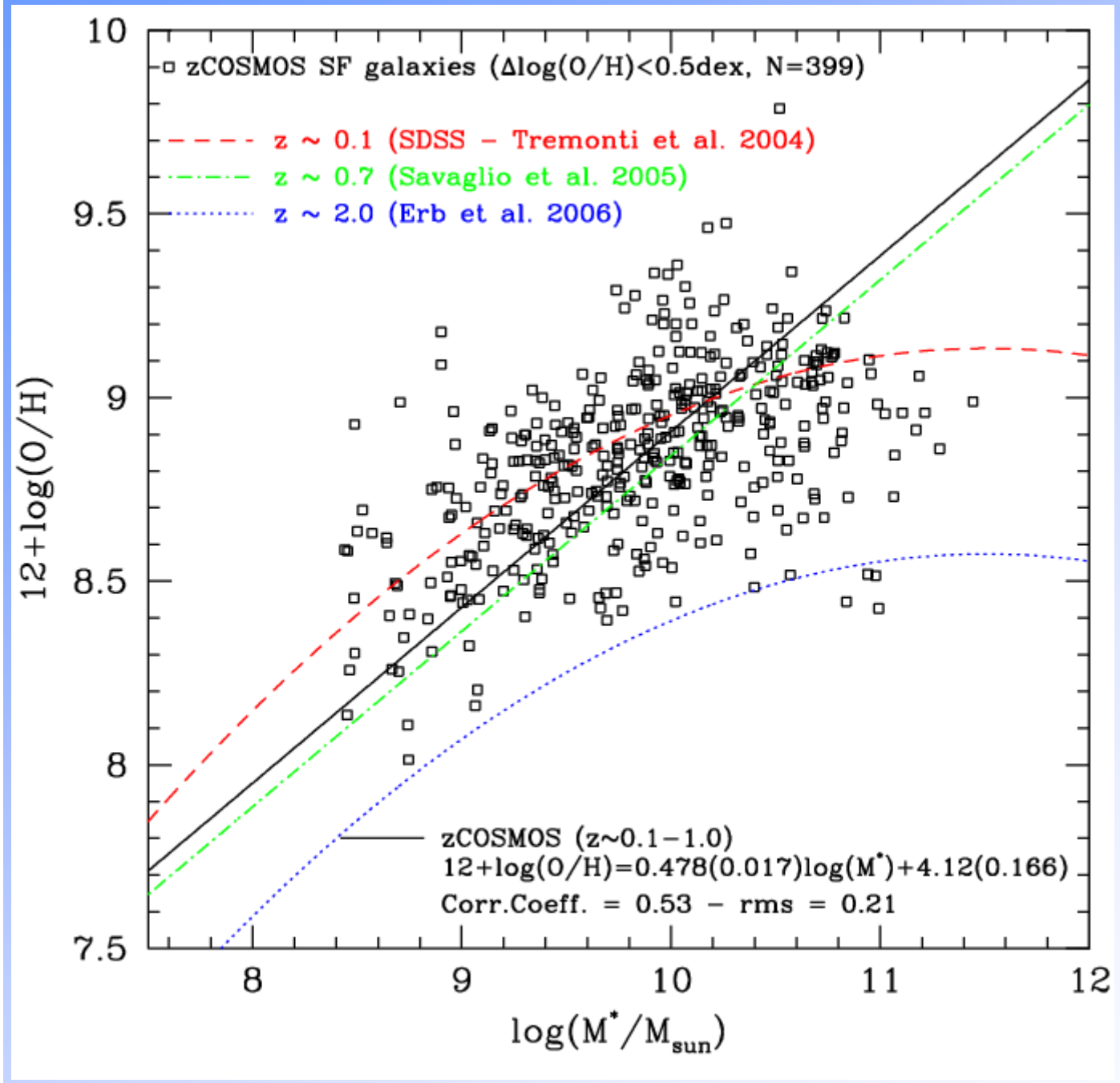
Δlog(O/H) > 0.5

Turnaround region of log(O/H) vs. O23 relationship



It exists besides a non-quantifiable uncertainty associated to the upper branch of the log(O/H) vs. O23 relationship

MZ relation for 399 zCOSMOS galaxies



z ~ 0.7

(Savaglio et al. '05)

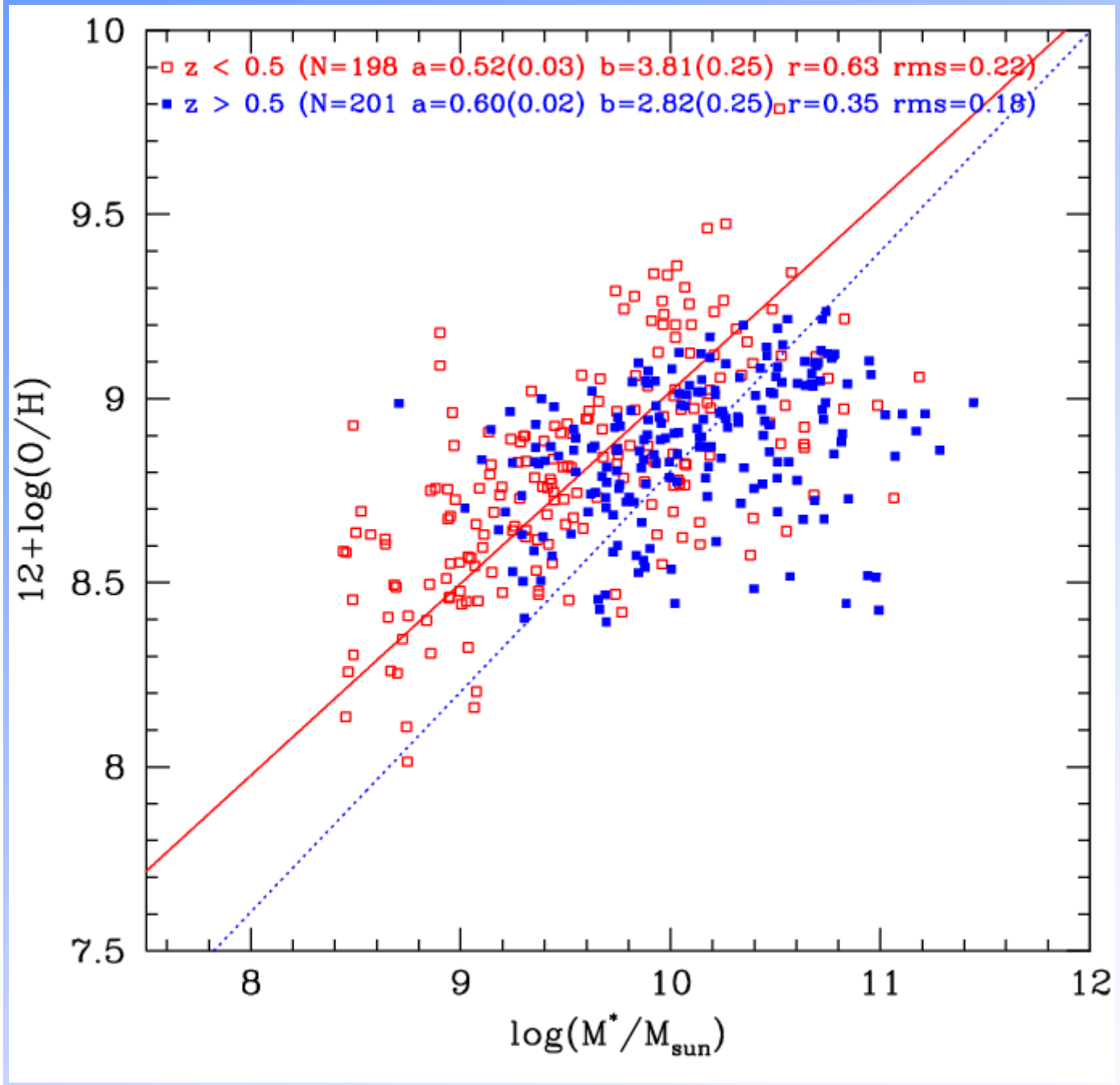
z ~ 0.1

(Tremonti et al. '04)

z ~ 2.0

(Erb et al. '06)

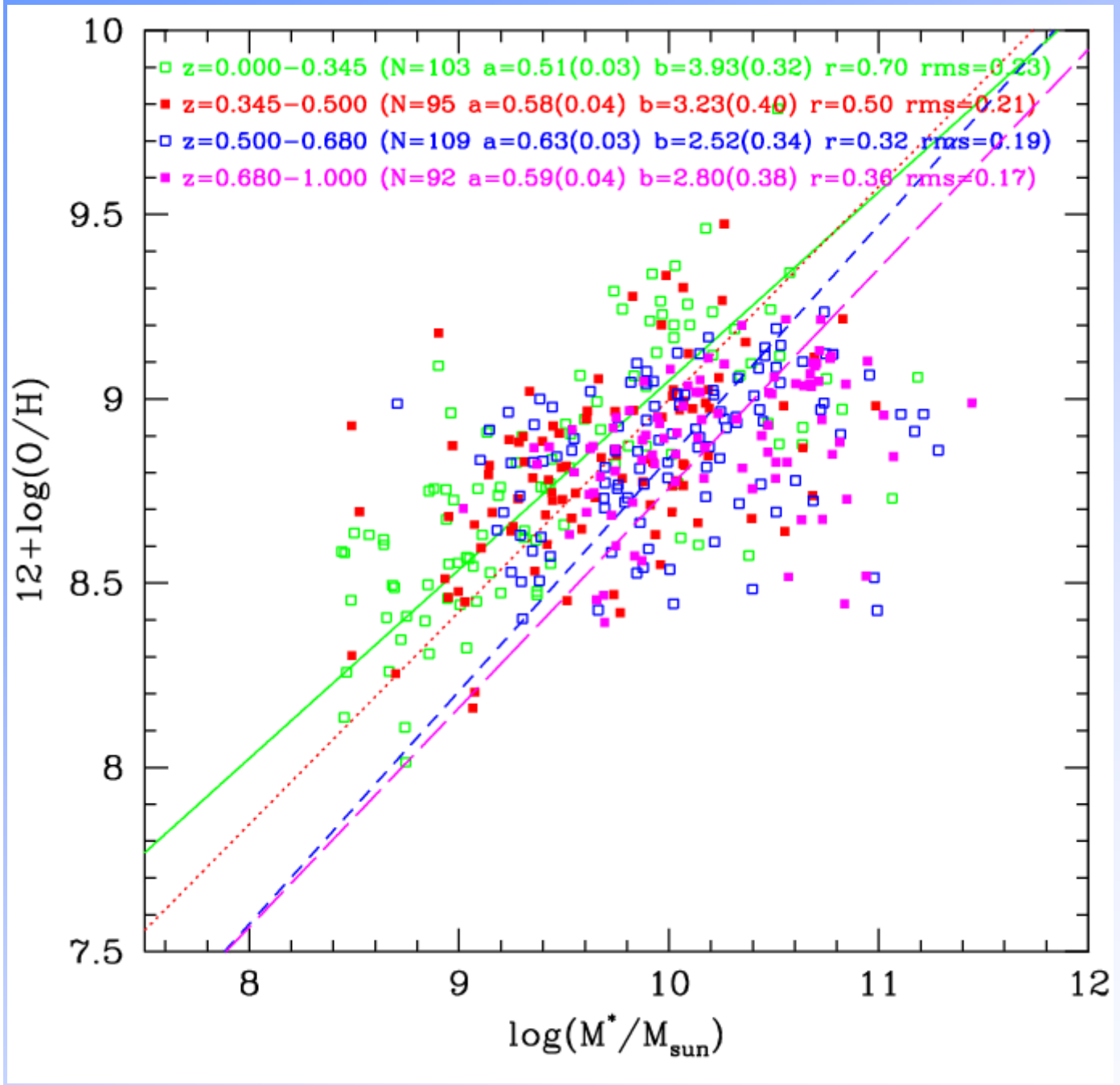
MZ relation for 399 zCOSMOS galaxies



z=[0.1-0.5]

z=[0.5-0.9]

MZ relation for 399 zCOSMOS galaxies



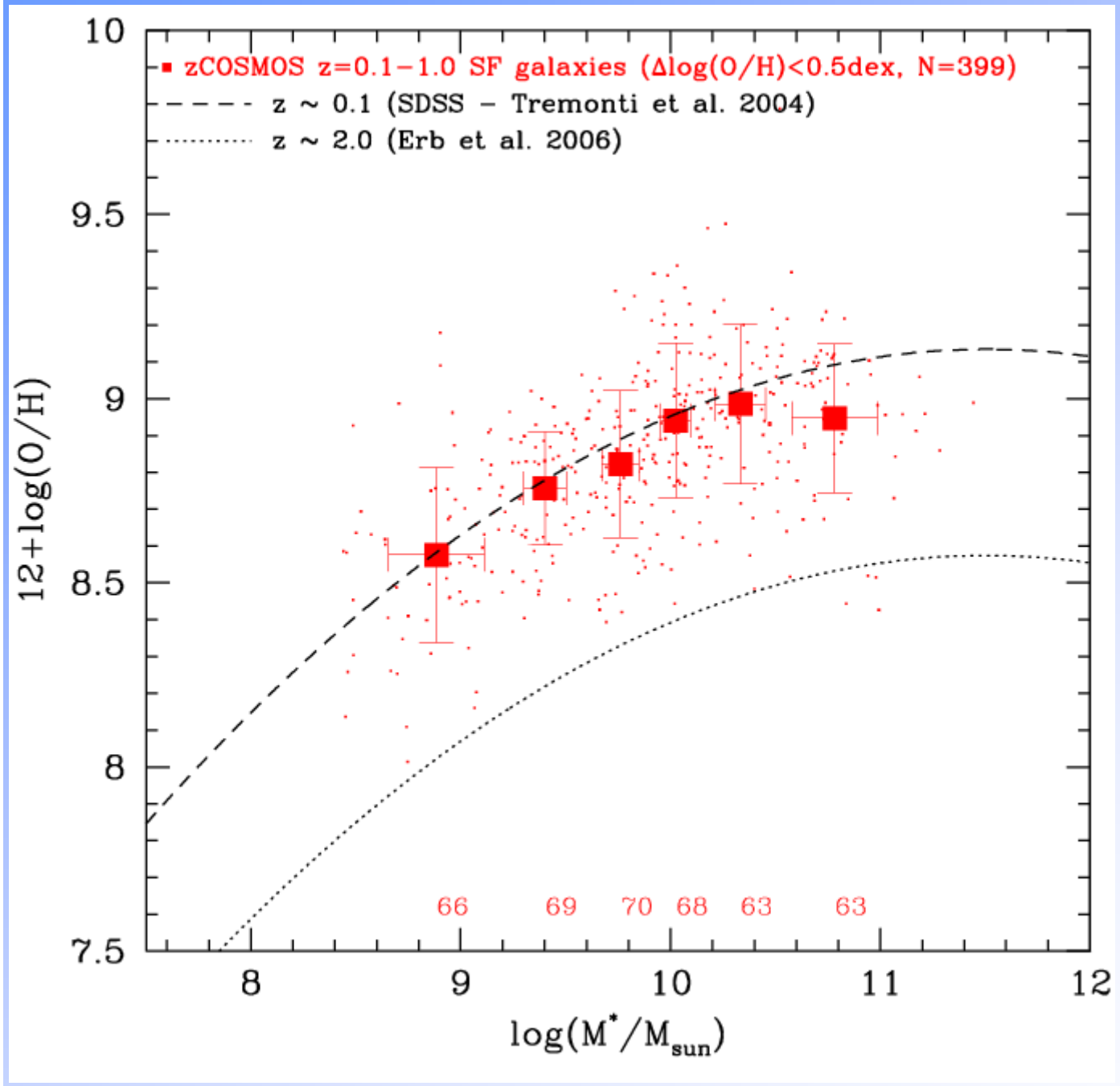
0.10 < z < 0.35

0.35 < z < 0.50

0.50 < z < 0.68

0.68 < z < 0.90

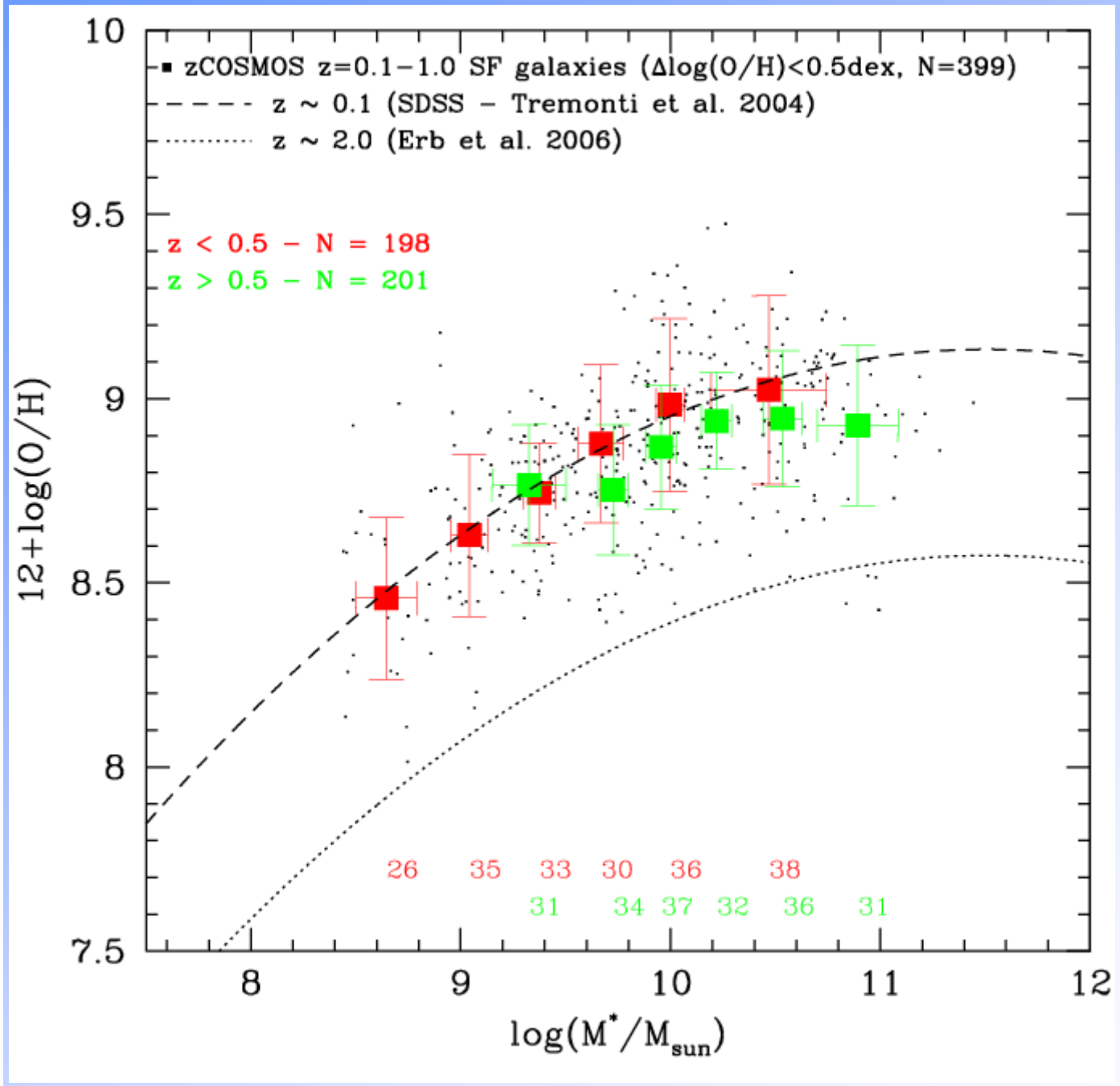
MZ relation for 399 zCOSMOS galaxies



all redshifts

z=[0.1-0.9]

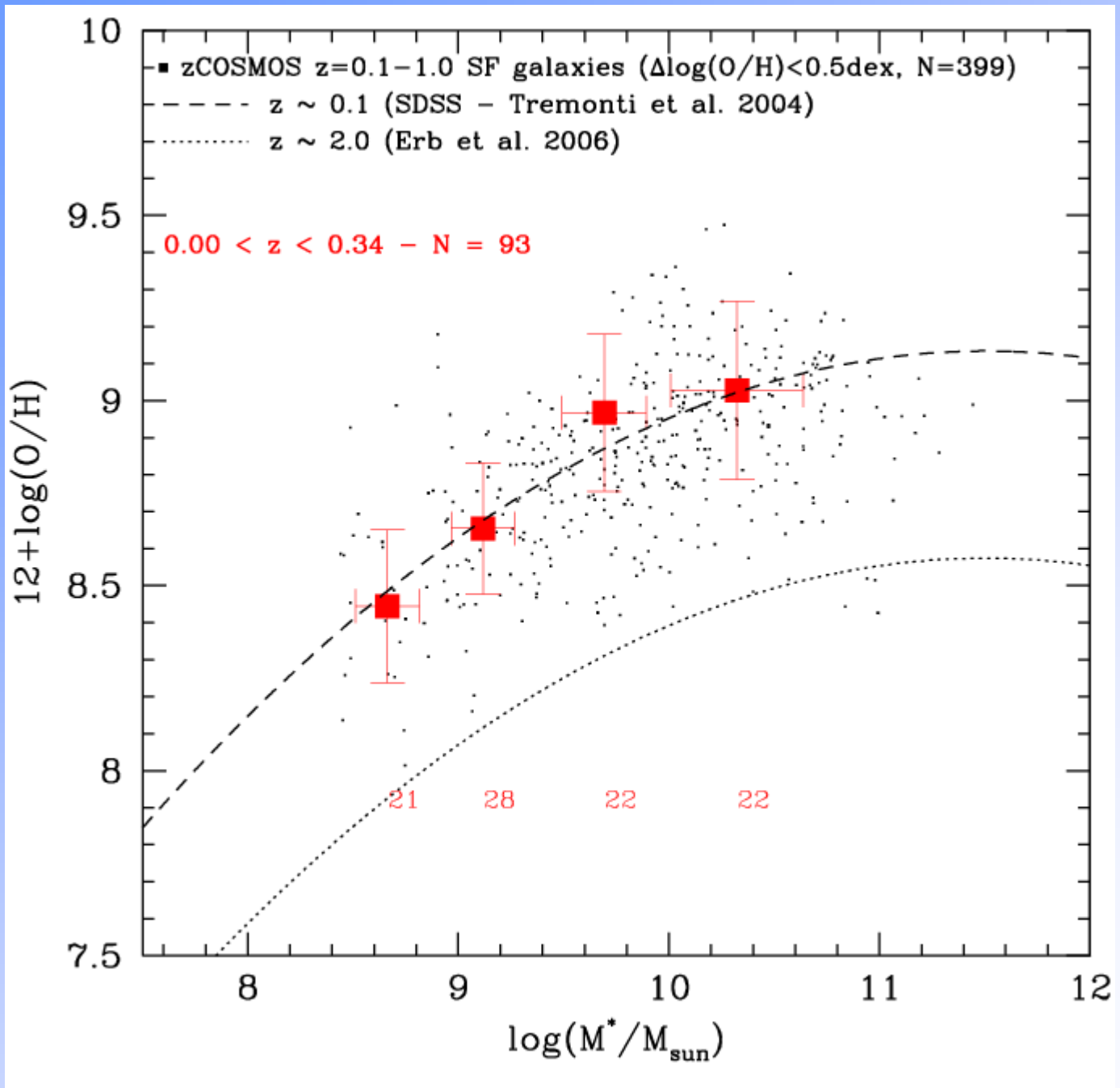
MZ relation for 399 zCOSMOS galaxies



z=[0.1-0.5]

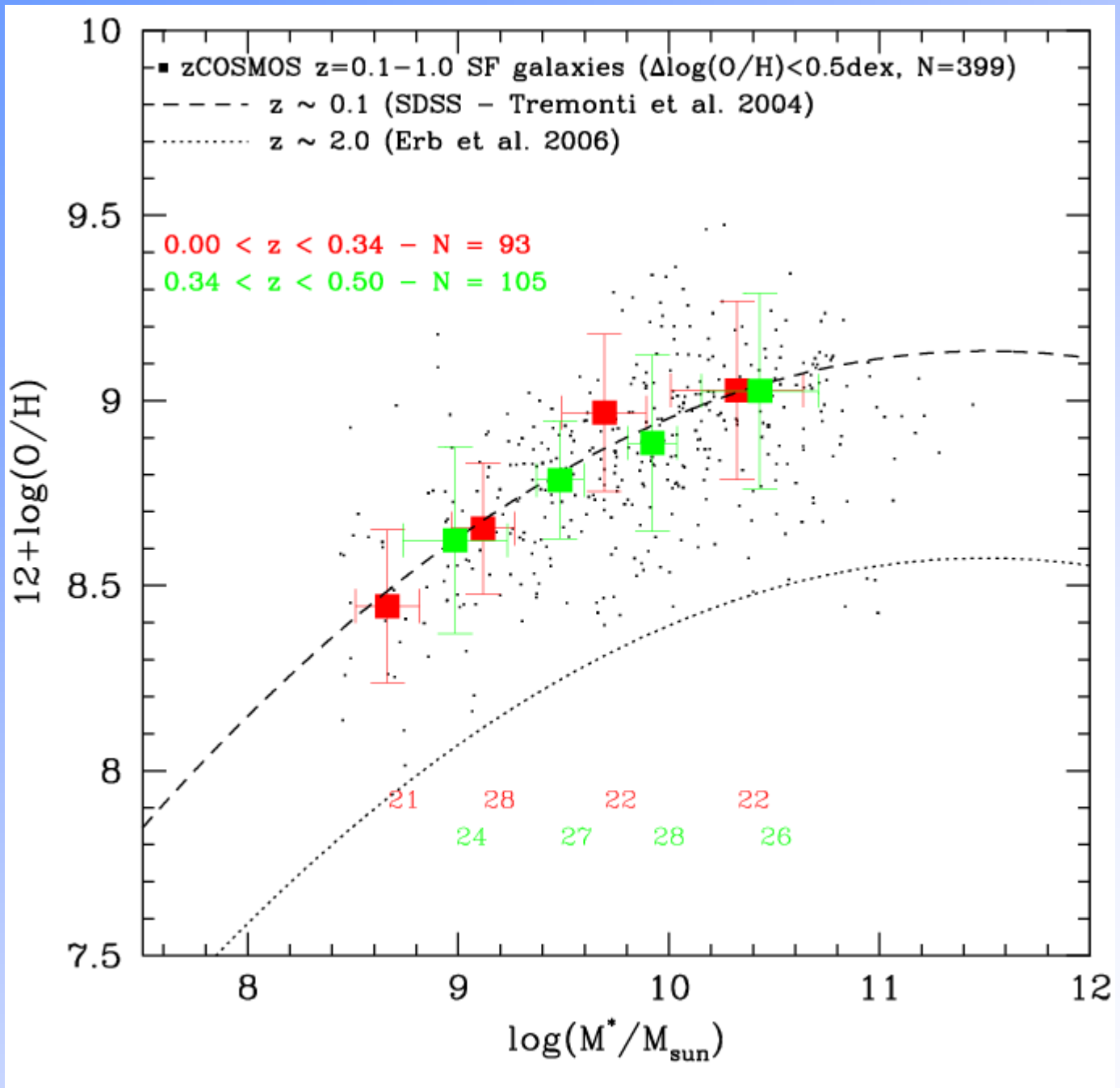
z=[0.5-0.9]

Evolution of *MZ* relation up to z~1



0.10 < z < 0.35

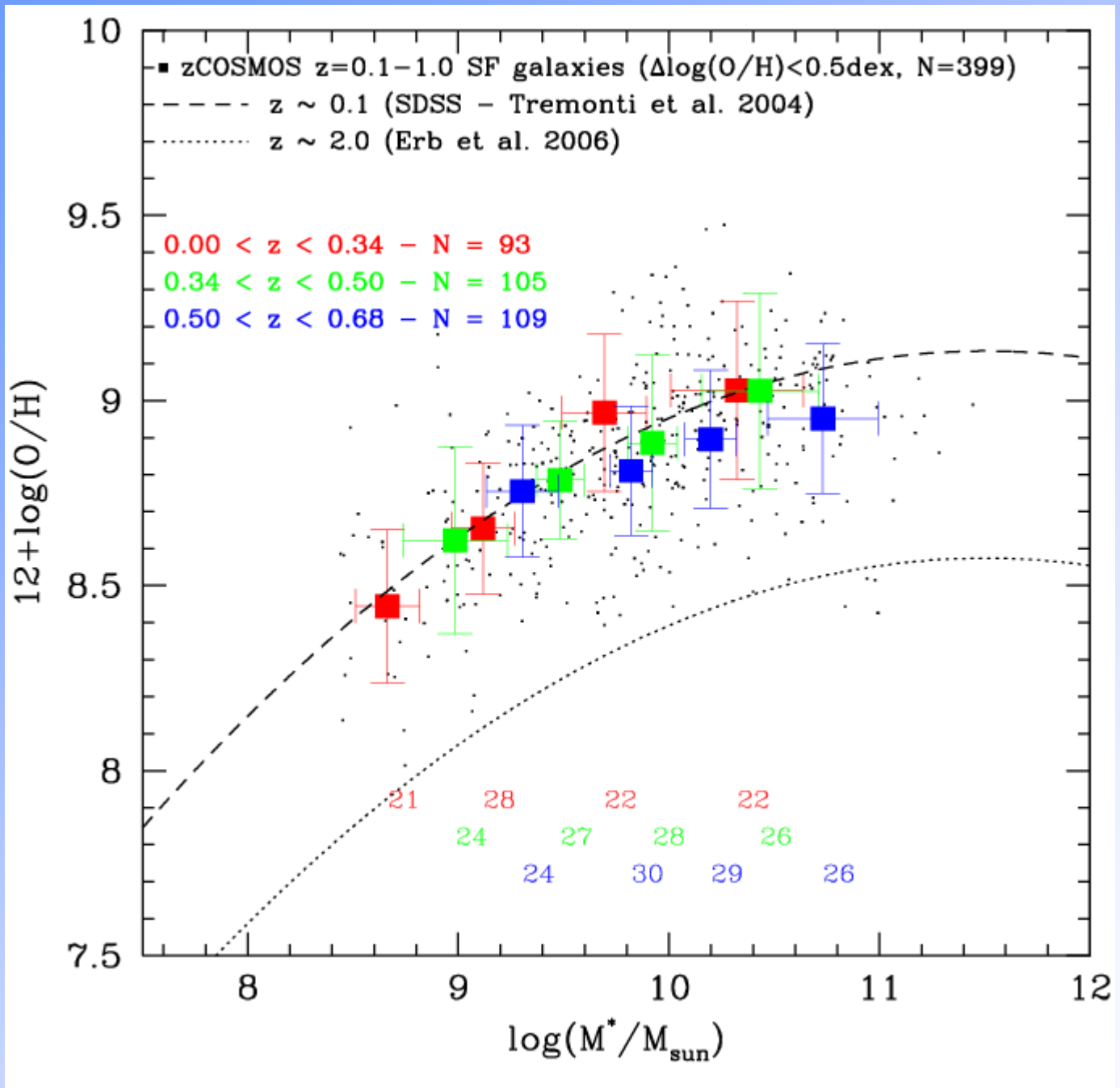
Evolution of *MZ* relation up to z~1



0.10 < z < 0.35

0.35 < z < 0.50

Evolution of *MZ* relation up to z~1

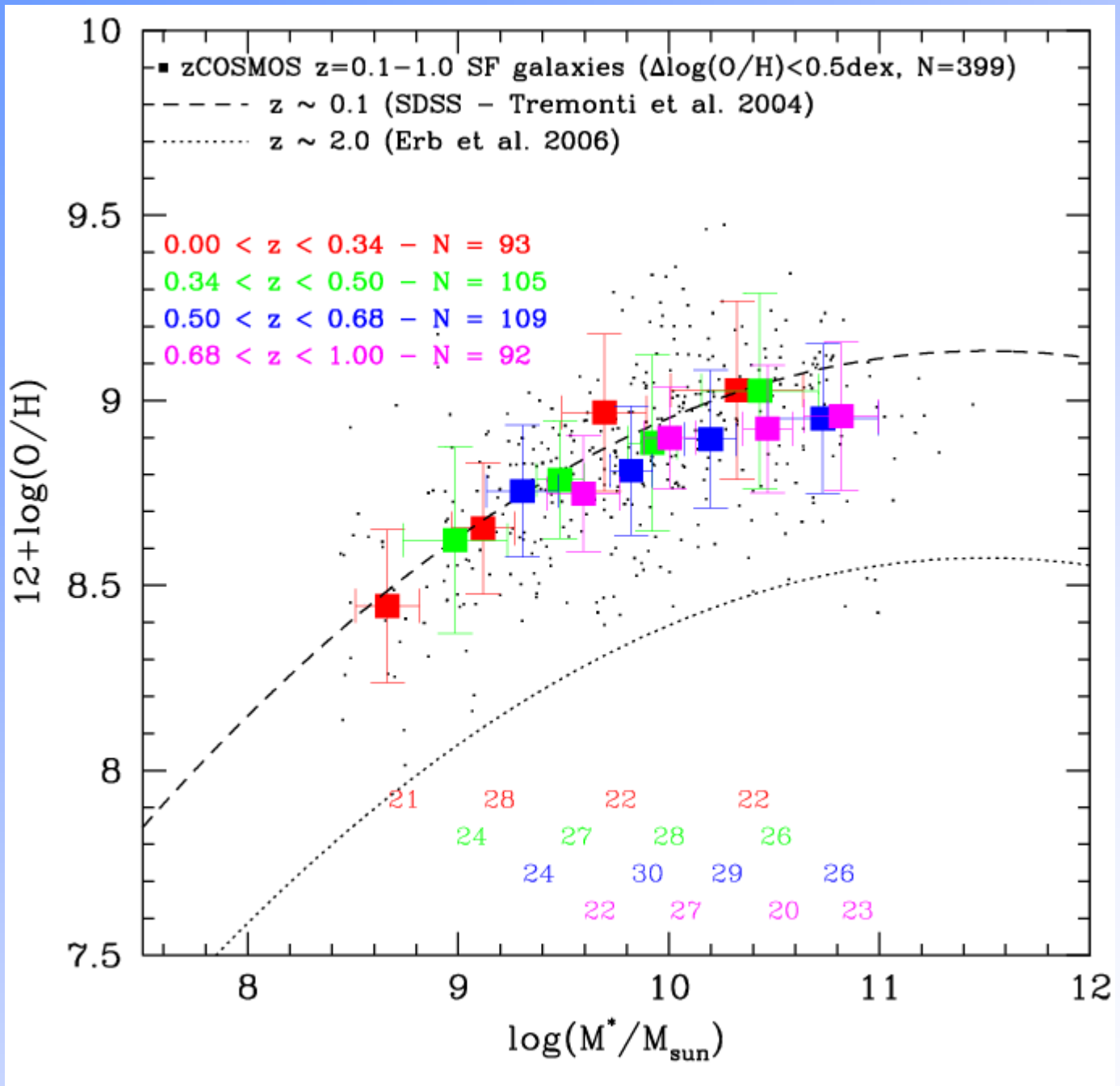


0.10 < z < 0.35

0.35 < z < 0.50

0.50 < z < 0.68

Evolution of *MZ* relation up to z~1



0.10 < z < 0.35

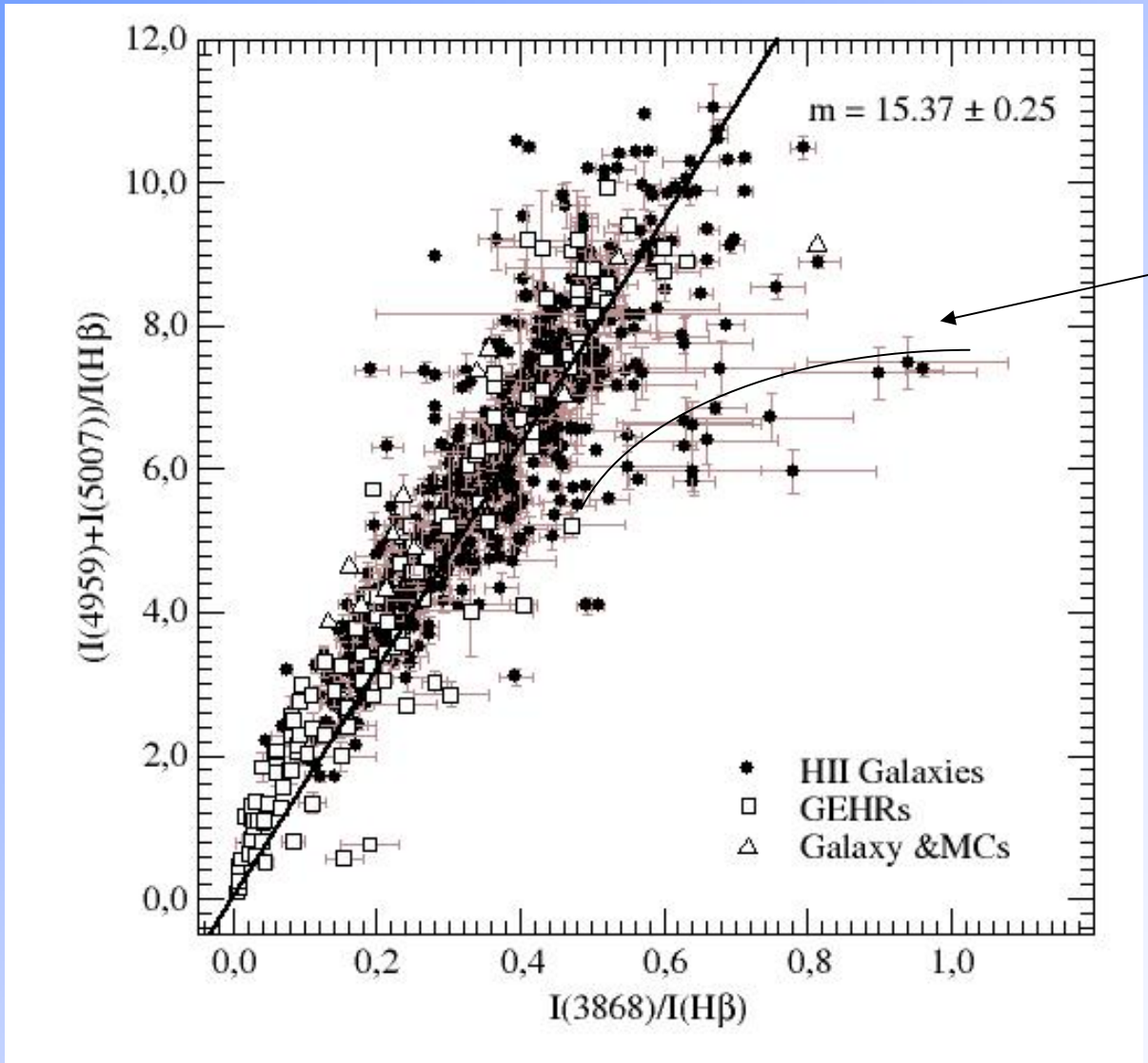
0.35 < z < 0.50

0.50 < z < 0.68

0.68 < z < 0.90

Metallicities upto z~1.3

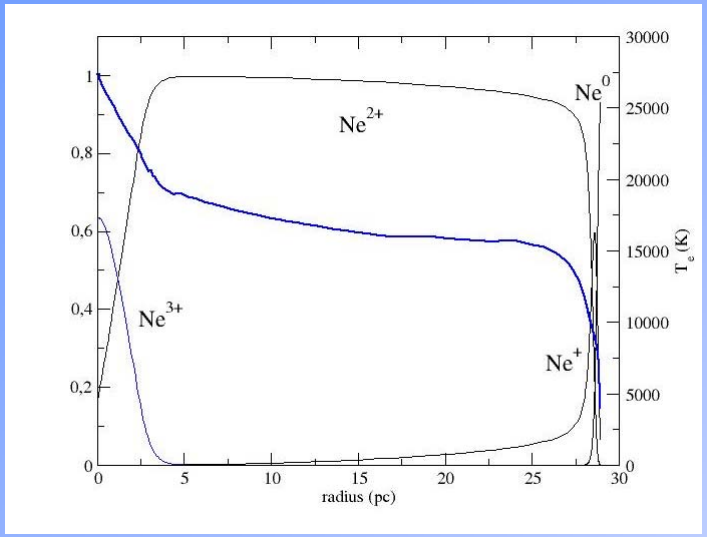
Based on the relation between [OIII] and [NeIII] emission lines.

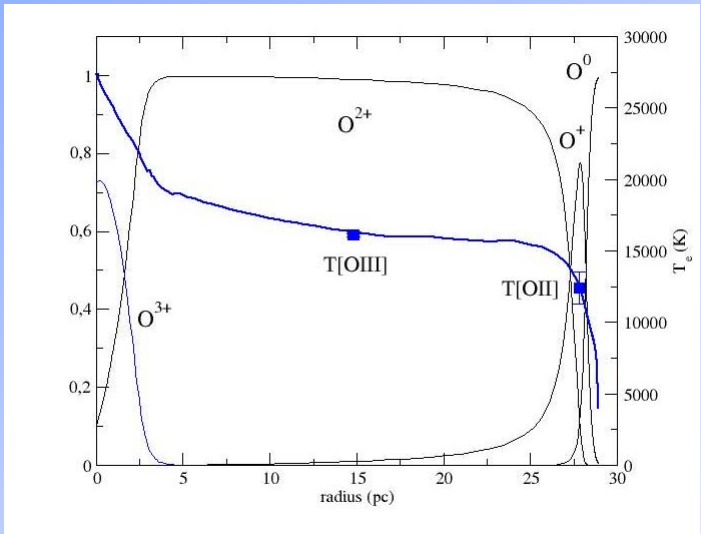


Unexpected deviation of some HII galaxies (e.g. UM382), shocks ?

Metallicities upto z~1.3

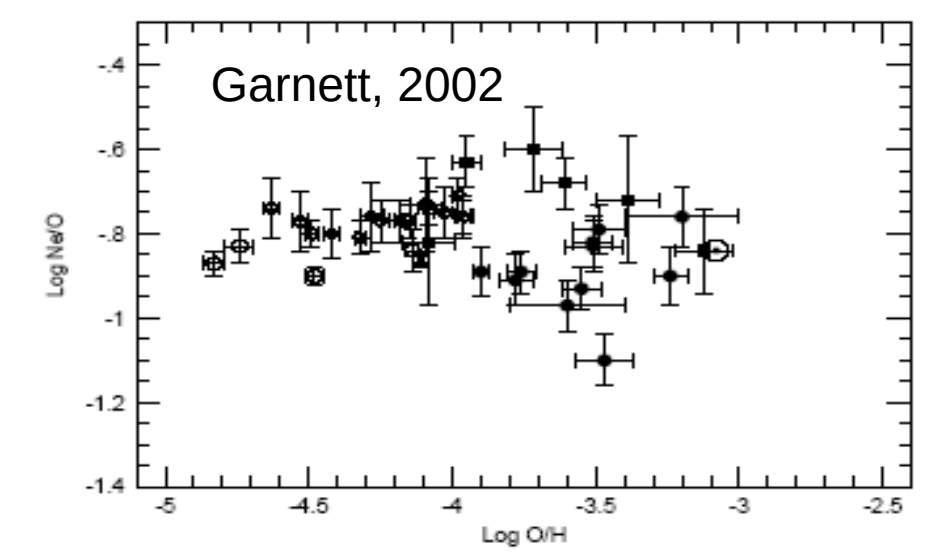
This is due to the identical ionization structure of Ne and O





$$\frac{Ne^{2+}}{Ne} = \frac{O^{2+}}{O}$$

and the constancy of the Ne/O relation in all regimes of metallicity

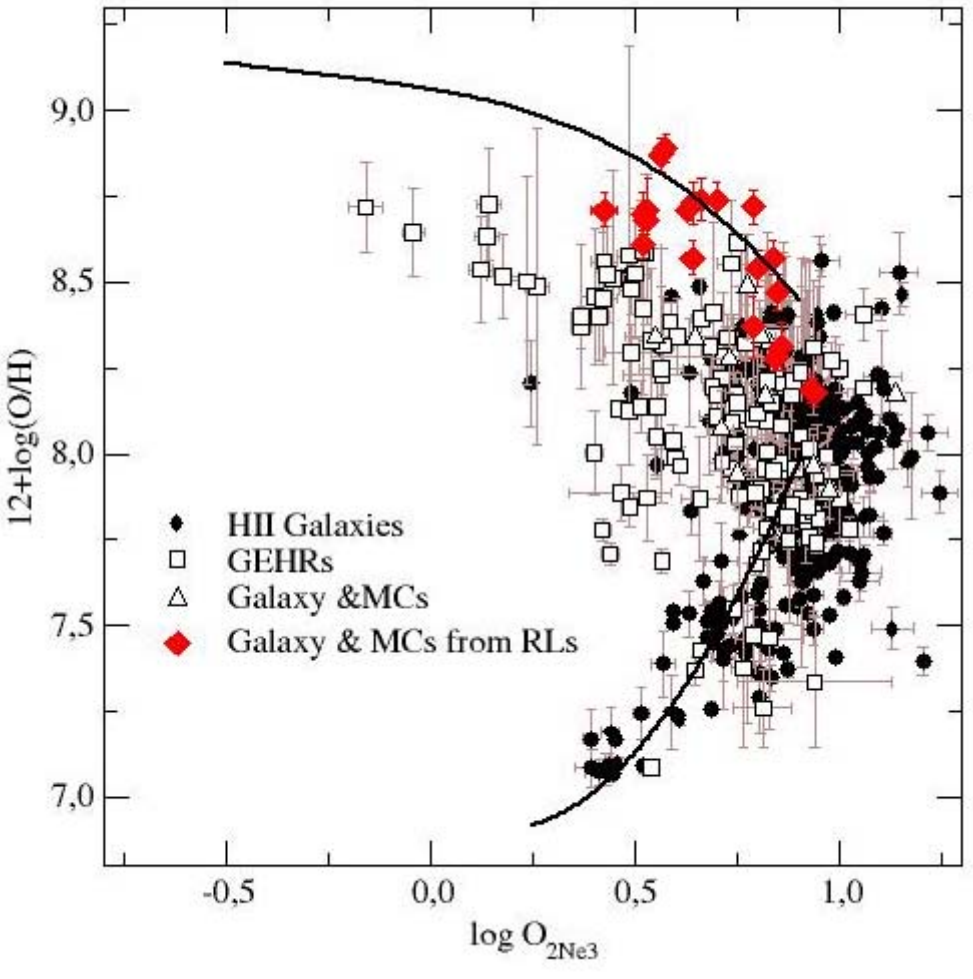


Metallicities upto z~1.3

Hence, new calibrators of metallicity, equivalent to O23 are possible

$$O_{2Ne3} = \frac{I([OII]3727\mathring{A}) + 15{,}37 \cdot I([NeIII]3868\mathring{A})}{I(H\beta)} \approx O_{23}$$

A sample of 766 objects with [OII], [NeIII], [OIII] and, at least, one electron temperature have been collected from the literature. The oxygen abundances have been recalculated in a homogeneous manner.



Metallicities upto z~1.3

$$O_{2Ne3'} = \frac{I([OII]3727\mathring{A}) + 15{,}37 \cdot I([NeIII]3868\mathring{A})}{I(H\delta)} \approx O_{23} \cdot \frac{I(H\delta)}{I(H\beta)}$$

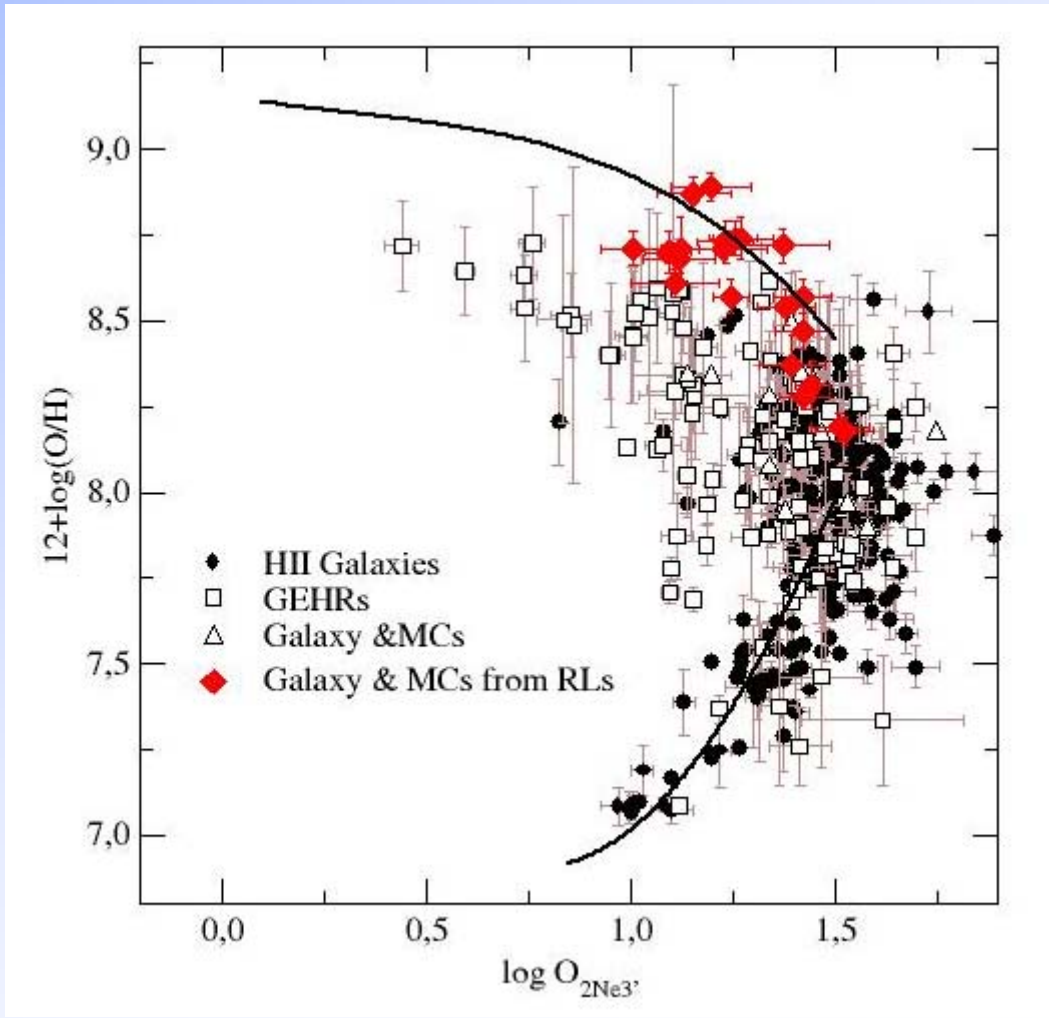
and, in relation to Hδ, allows metallicity determination upto 1.3 independent of reddening.

Drawbacks of O2Ne3':

- Those from O23.

- Lower signal to noise of [NeIII] and Hδ (only 12 galaxies in the 1 < z < 1.3 in the first 1k subsample)

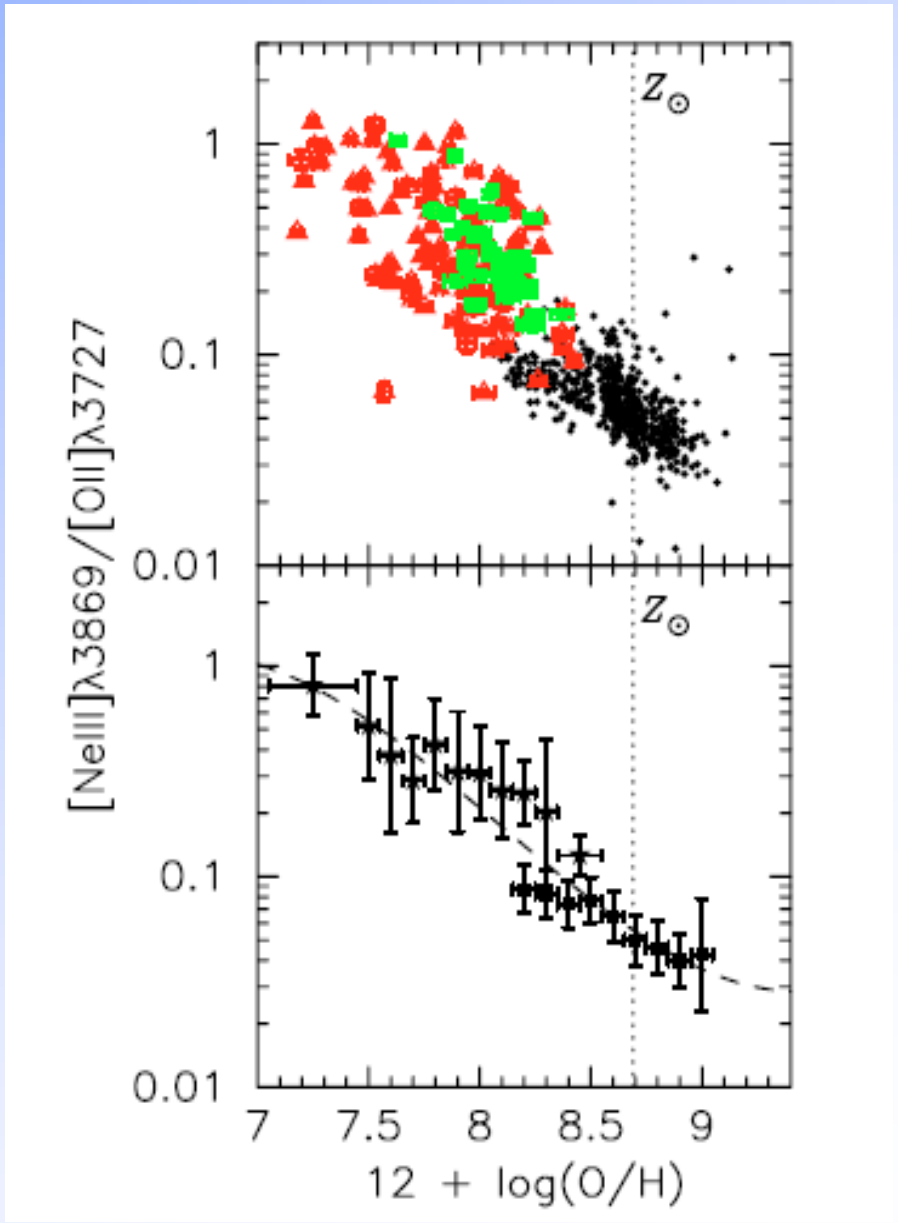
- Underlying stellar population.



Metallicities upto z~1.3

Nagao et al. (2006) also define other calibration based on [NeIII] and [OII] lines.

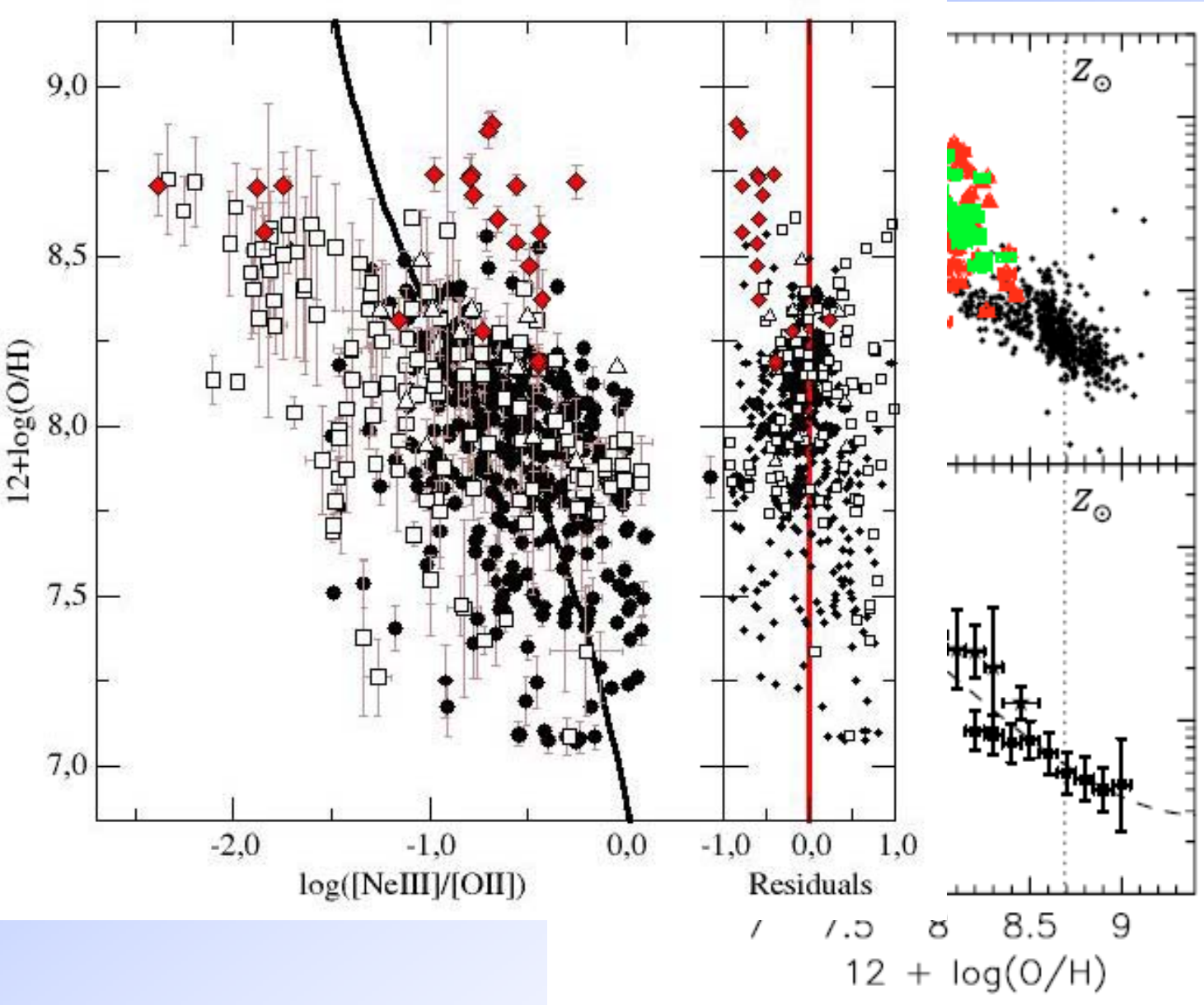
Nevertheless, since the [OIII]/[OII] quotient depends mostly on log U and effective T , this trend is reproduced as well by [NeIII]/[OII].



Metallicities upto z~1.3

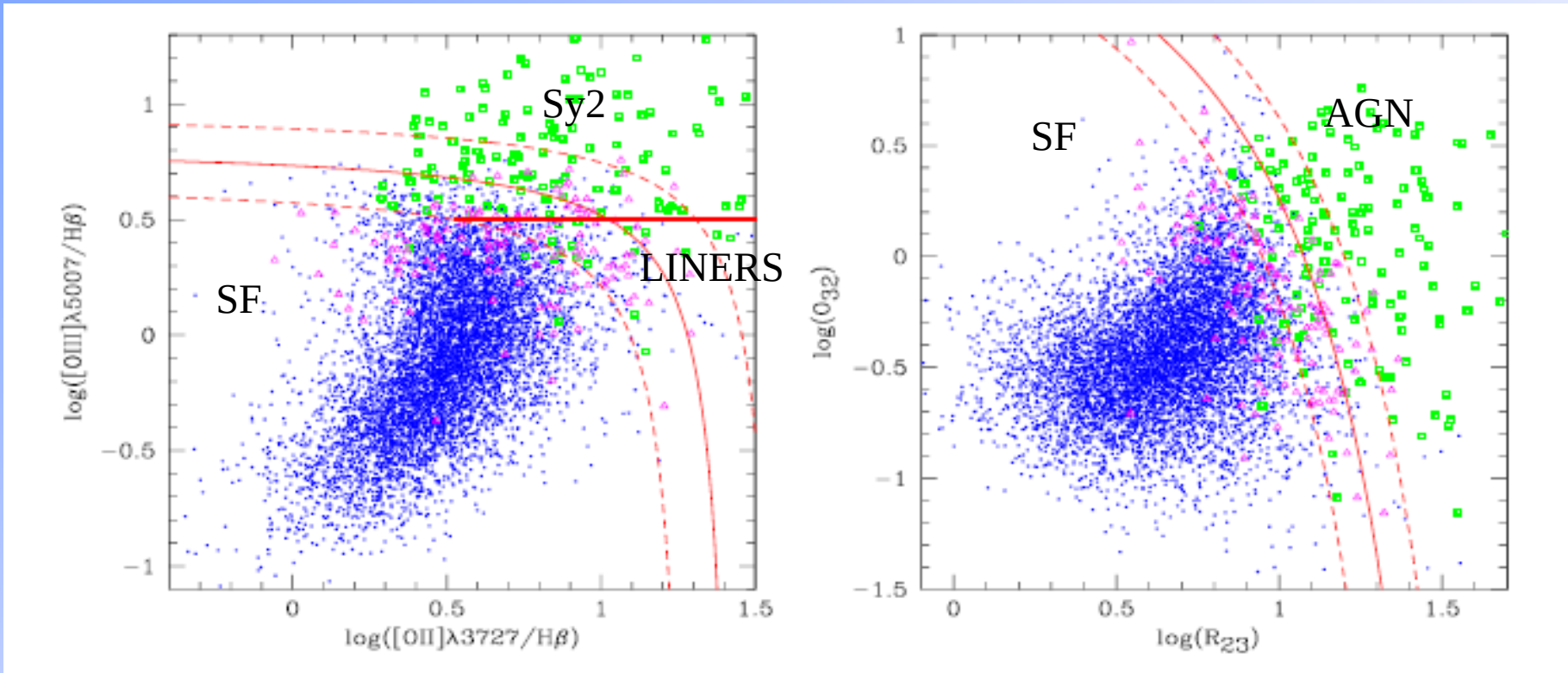
Nagao et
other cali
[NeIII] ar

Neverthe
[OIII]/[O
mostly or
, this tren
well by [



Spectral classification upto z~1.3

The use of the [OIII] vs. [NeIII] relation can even improve the redshift validity of other diagnostic diagrams based on [OIII] lines. For example, the blue spectral classification (2dFGRS, Lamareille et al., 2004)



Summary and conclusions

- **ZCOSMOS is a large VLT/VIMOS redshift survey covering $0 < z < 3$ in the COSMOS field. The bright sample comprises magnitude limited ($I_{AB} < 22.5$) sample of about 20k galaxies in the whole 1.4 deg^2 of this field.**

- **The M-Z relation have been studied for the first 1040 galaxies of the bright sample in the $0 < z < 0.9$ bin using the red part of the spectrum at medium resolution. Masses have been inferred from Bruzual & Charlot (2003) and Metallicities from O3N2 and O23 empirical parameters.**

- **Results for the MZ relation are compatible with those in the Local Universe (SDSS; Tremonti et al., 2004) and points to lower slopes at higher redshifts.**

- **With the use of the [NeIII] vs. [OIII] relation we will be able to extend the study up to redshift 1.3.**