# The evolution of the mass-metallicity relation at z>3

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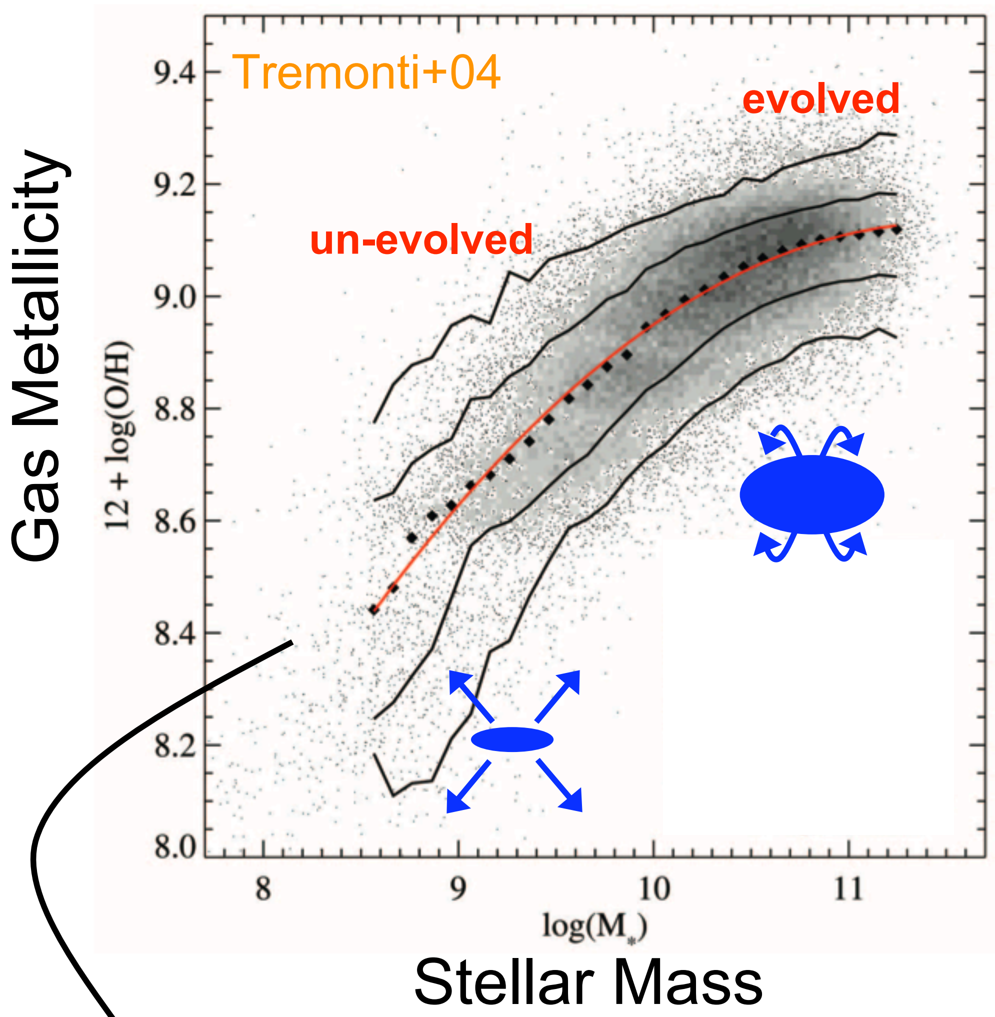
**F. Matteucci, G. Pastorini, L. Pentericci,**
**A. Pipino, G. Risaliti, M. Salvati, L. Silva**

# The local mass-metallicity relation



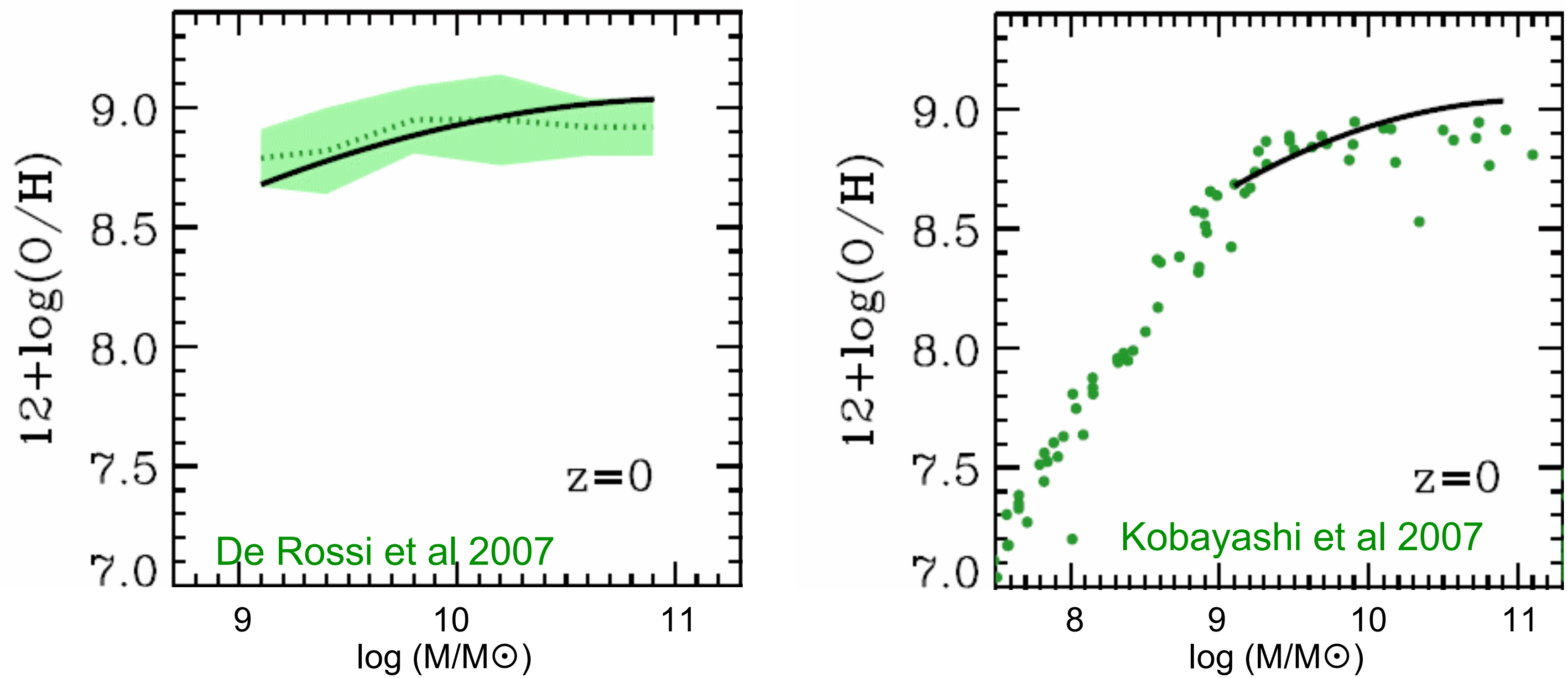

Sensitive tool to test models of galaxy evolution

**Three possible drivers:**

Mass loss (outflows)
Downsizing
IMF variations

# The local mass-metallicity relation

Many models reproduce the local M-Z relation

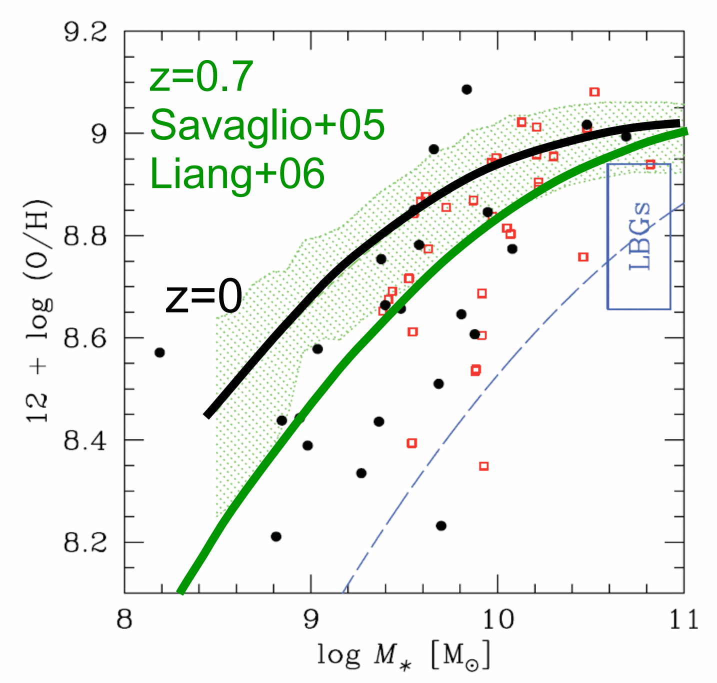


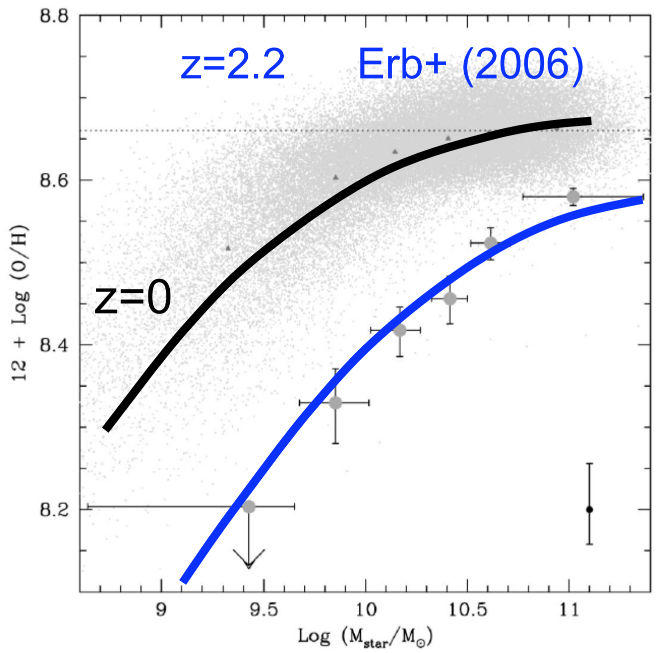

Kobayashi et al., 2007; Brooks et al., 2007; de Rossi et al., 2007; Dave' & Oppenheimer, 2007; Dalcanton, 2007; De Lucia et al., 2004; Tissera et al., 2005; Koppen et al., 2007; Cid Fernandes et al., 2007; Finlator & Dave, 2007, Panter et al. 2008

These models predict significant evolution of the M-Z relation as a function of redshift...

# The mass-metallicity relation at high redshift

The M-Z relation observationally determined out to z~2.2




Higher redshifts, z>3, little explored yet:

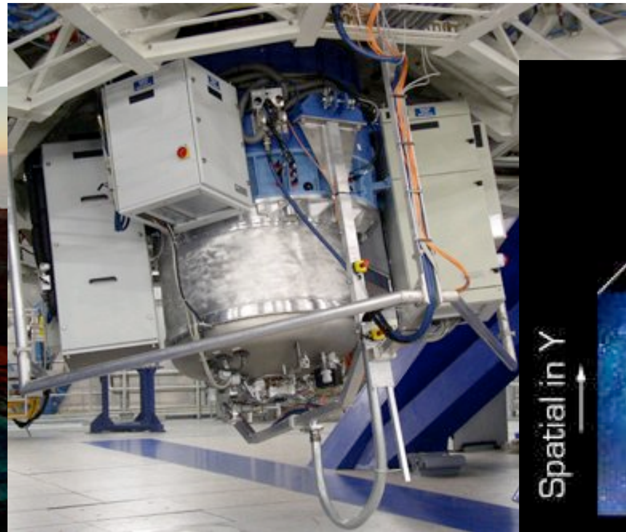
- Models expect strong evolution of the M-Z relation
- Before the peak of cosmic star formation (5-10% of stars formed)
- Strong Evolution of the merger rate
- Formation of massive galaxies

# AMAZE

## Assessing the Mass-Abundance redshift (z) Evolution

R. Maiolino (PI), T. Nagao, F. Mannucci, A. Marconi, A. Fontana, S. Ballero, A. Cimatti, A. Fontana, G.L. Granato, A. Grazian, F. Matteucci, G. Pastorini, L. Pentericci, A. Pipino, G. Risaliti, M. Salvati, L. Silva, F. Calura, C. Chiappini, F. Cocchia, M. Meneghetti

- Goal: **determine the mass-metallicity relation at 3<z<5**
- ESO-VLT large programme (2006-2008), 180 hrs
- Near-IR (1.5-2.4μm) integral field spectroscopy with SINFONI
- 30 LBG's at 3<z<5

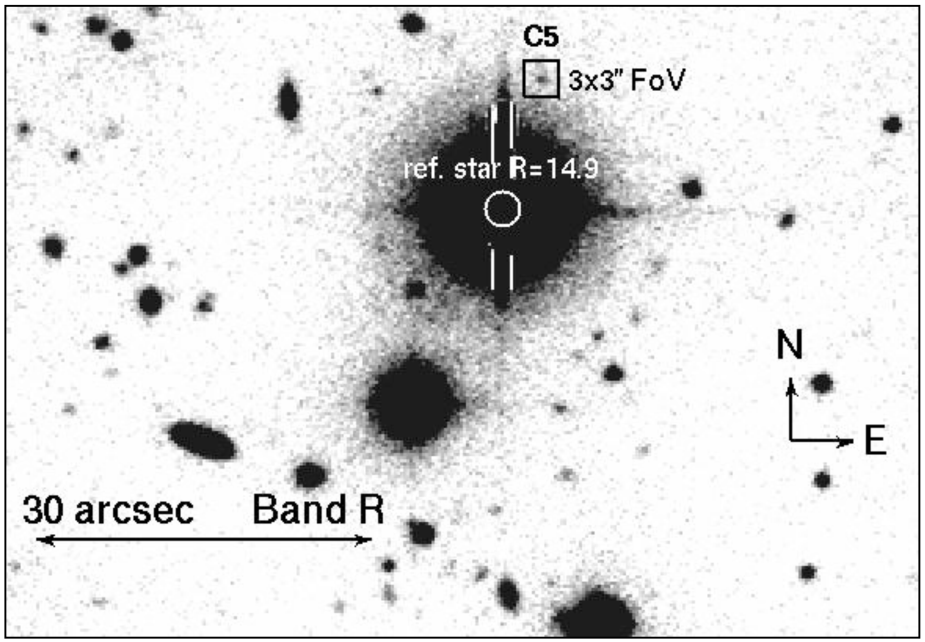


# LSD

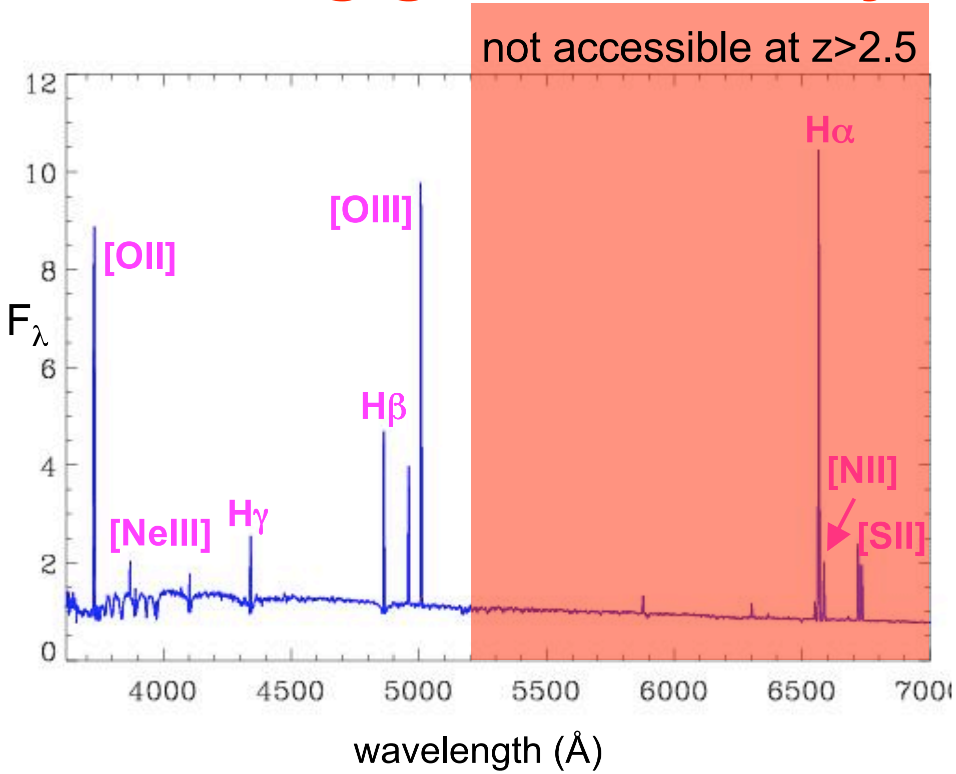
## LBG Stellar populations and Dynamics

F. Mannucci (PI), R. Maiolino A. Marconi, G. Risaliti, A. Gnerucci,
G. Cresci, L. Pozzetti, M. Lehnert, G. Pastorini

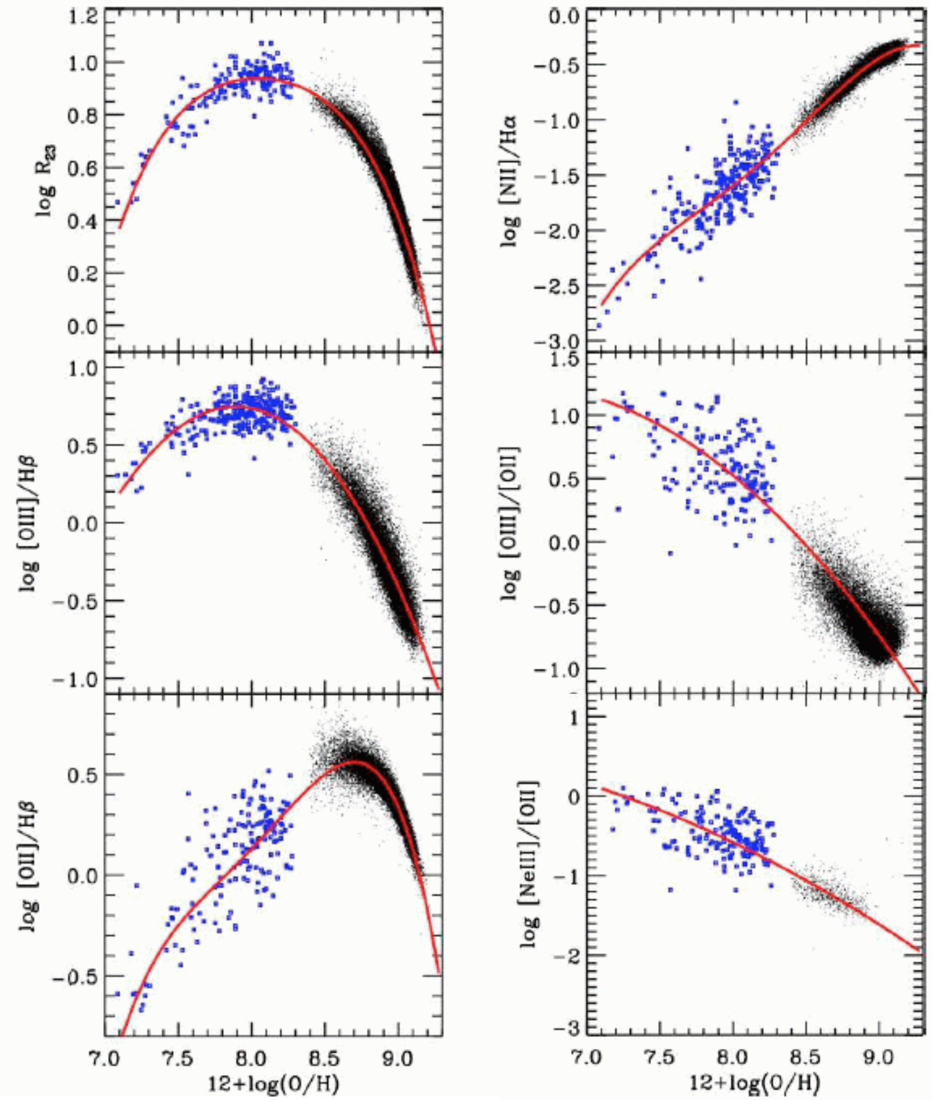
- Spatially resolved morphology and kinematics
- Near-IR (1.5-2.4μm) integral field spectroscopy with SINFONI with natural guide star Adaptive Optics
- 10 LBG's at z~3.1



# Measuring gas metallicity



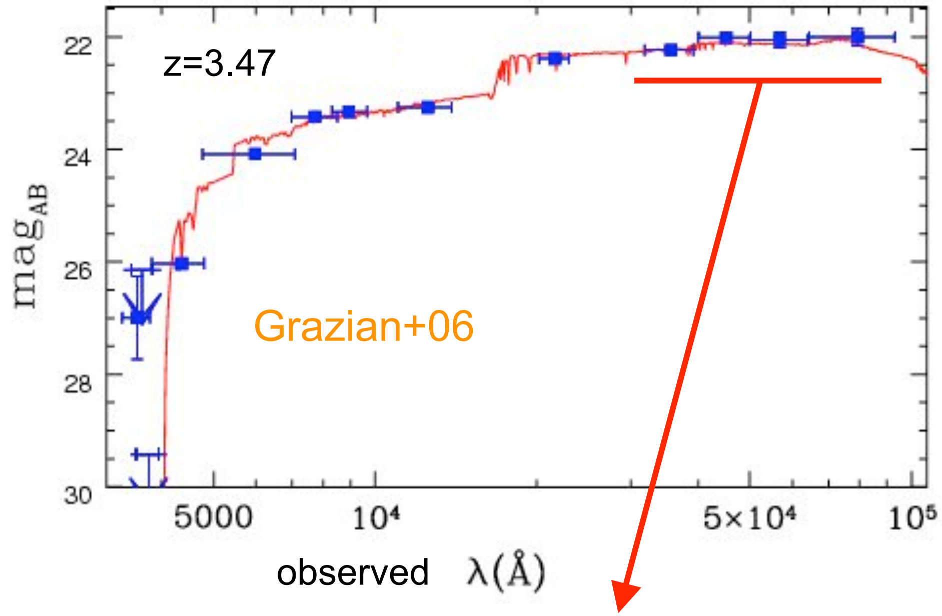

Maiolino+08




- Exploit strong line diagnostics involving [OII],[NeIII],Hβ,[OIII]
- Multiple diagnostics:
  - remove ambiguities
  - account for dust reddening

# Measuring stellar mass

Need to sample rest-frame near-IR (1-2μm) light



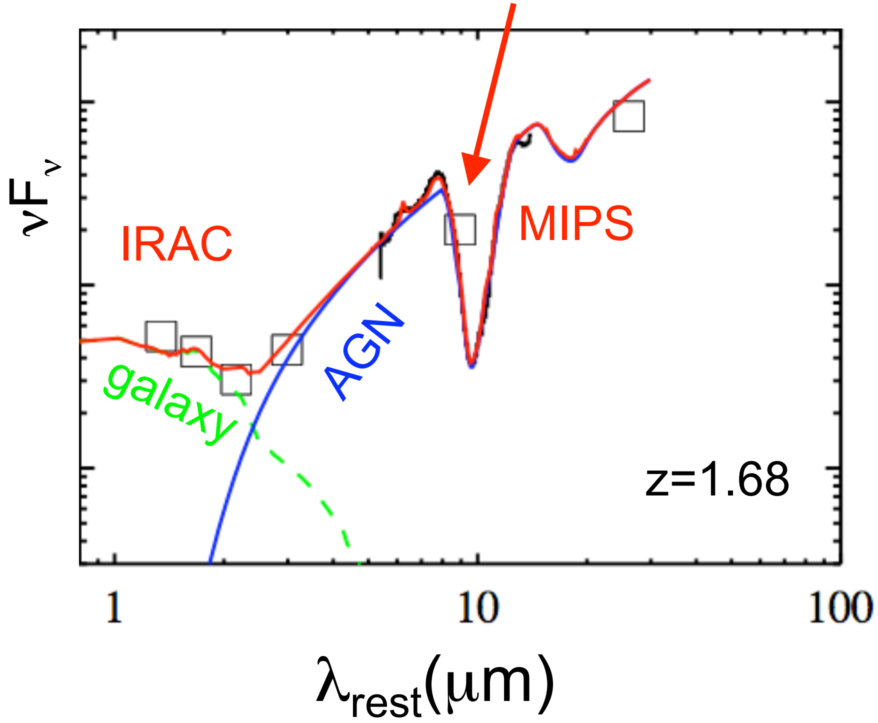

Galaxies with Spitzer-IRAC (3.6-8μm) data

Both Bruzual & Charlot (2003) and Maraston (2005) galaxy templates

# Removing AGNs (would affect line ratios)

Not enough to discard optically and X-ray identified AGNs.
Many obscured, high-z AGNs only show up
at mid-IR wavelengths

Galaxies with Spitzer-MIPS 24μm data



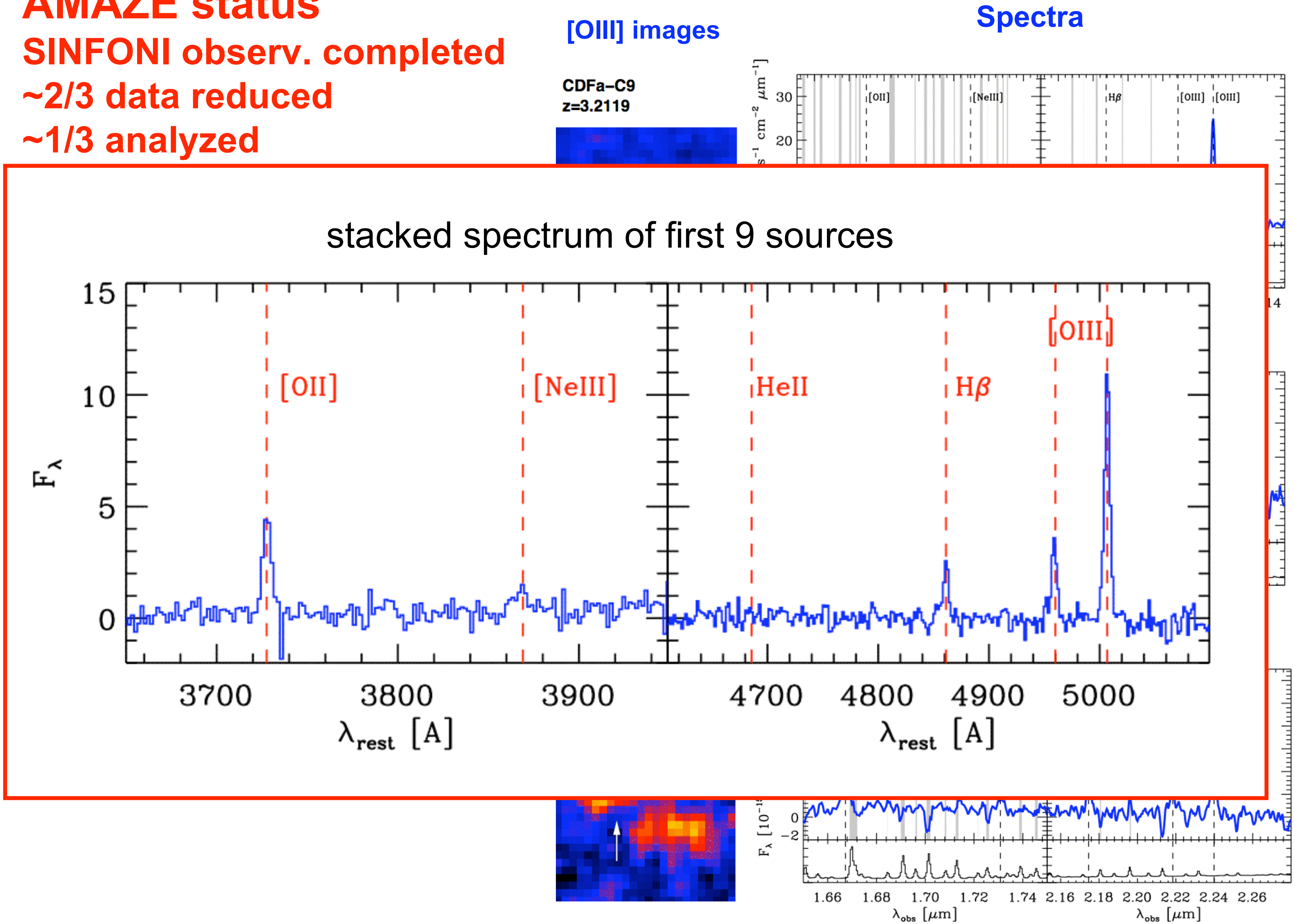

Sajina+07, Alonso-Herrero+05,07,
Martinez-Sansigre+05,07, Polletta+06,
Daddi+07, Fiore+07

# AMAZE status

## SINFONI observ. completed

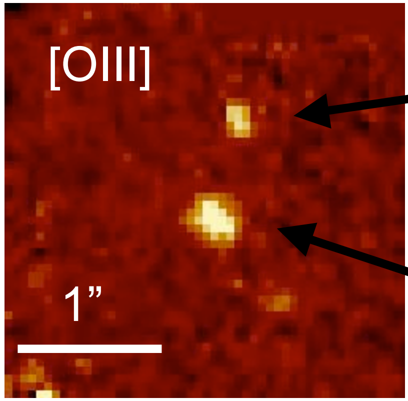
## ~2/3 data reduced

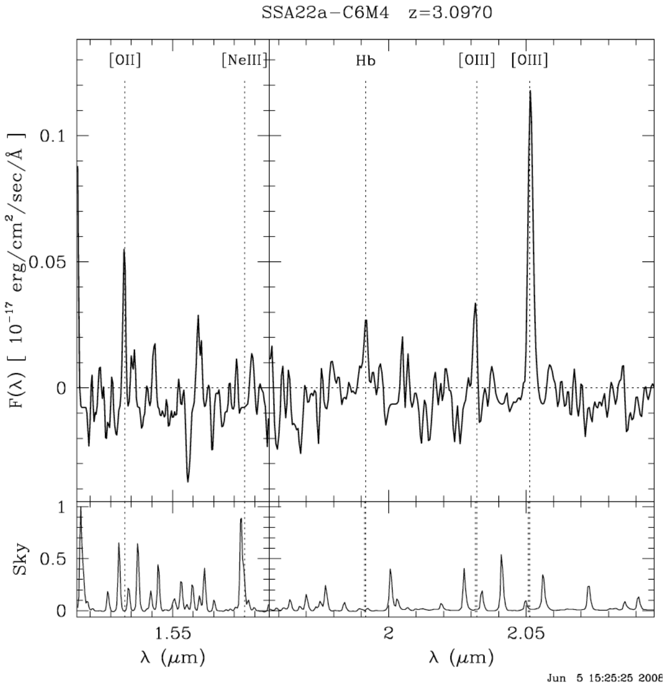
## ~1/3 analyzed

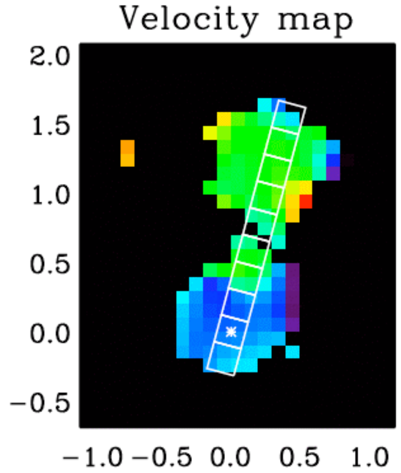


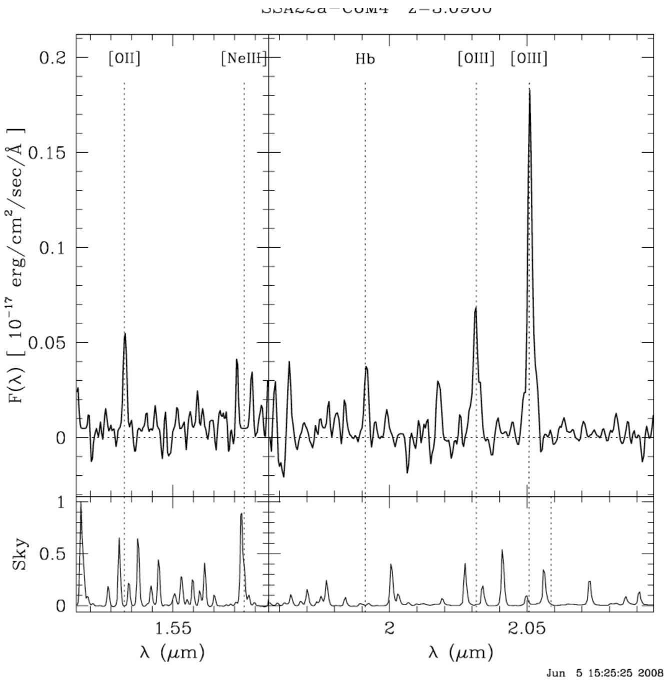
# LSD status

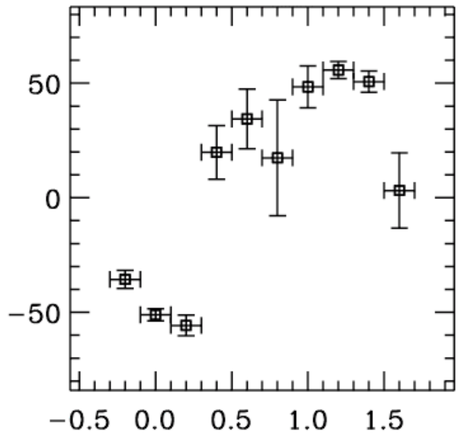
## SINFONI observ. completed
## Data reduction completed
## SPITZER observ. ongoing



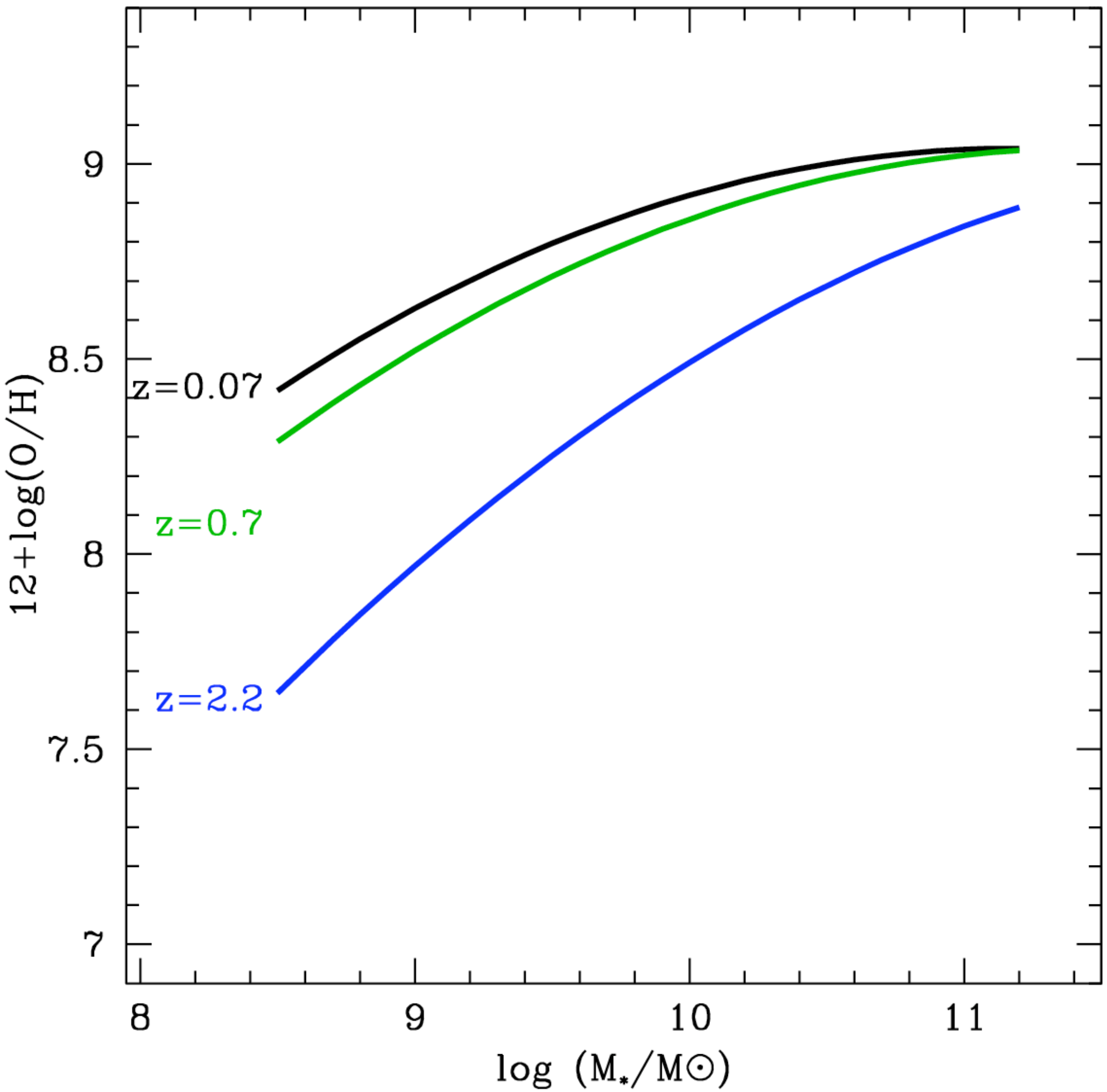



# The evolution of the mass-metallicity relation

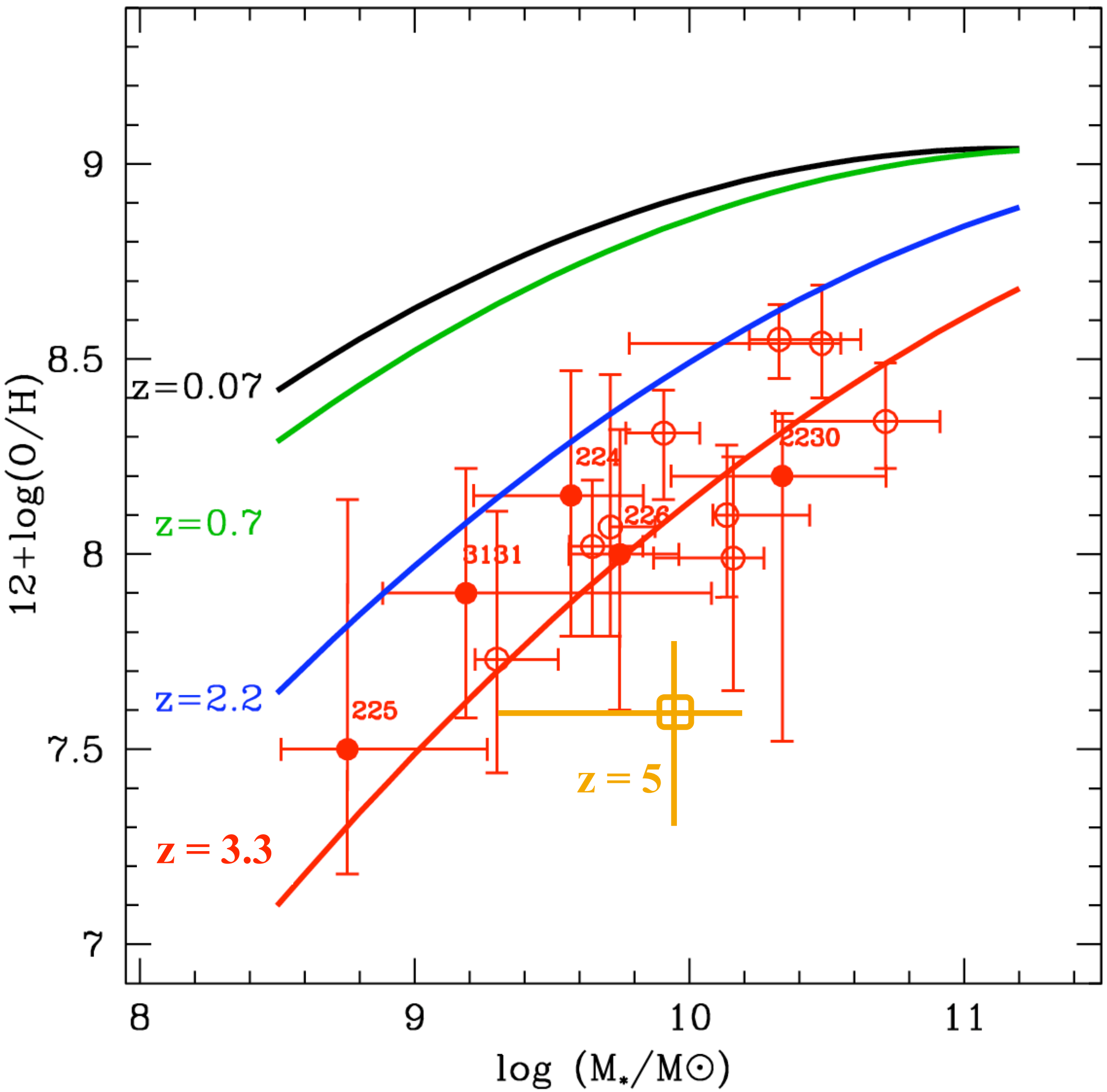



z~0.07 SDSS (Kewley&Ellison08)

z~0.7 GDSS+CFRS (Savaglio+05, recal.)

z~2.2 LBG (Erb+06, recalib.)

# The evolution of the mass-metallicity relation




z~0.07 SDSS (Kewley&Ellison08)

z~0.7 GDSS+CFRS (Savaglio+05, recal.)

z~2.2 LBG (Erb+06, recalib.)

z~3.3 ○ AMAZE (Maiolino+08)

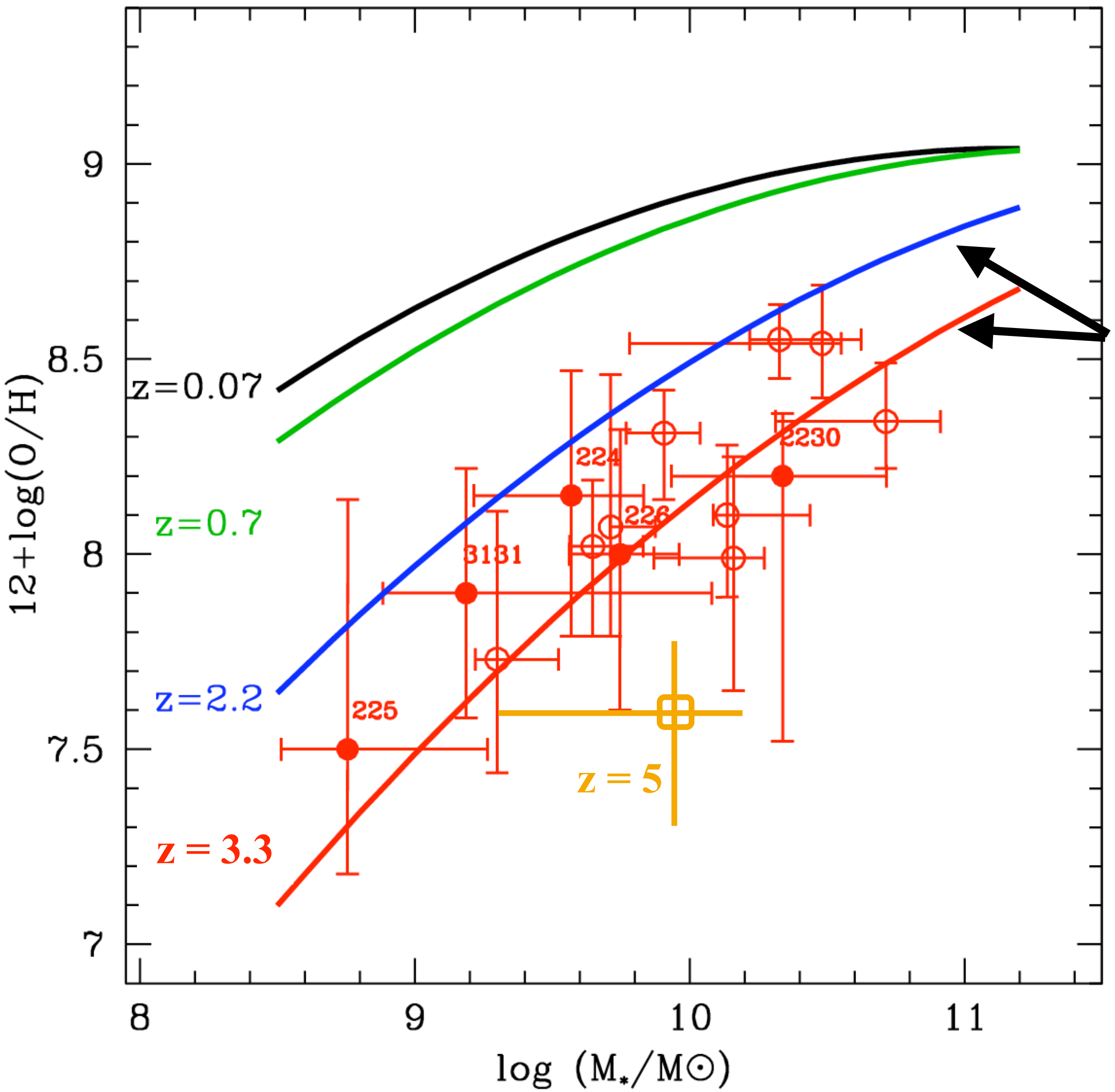
● LSD (Mannucci +08)

z~5 □ AMAZE (Maiolino+08)

Homogeneous analysis:

- Same metallicity calibration
- Same IMF and SPS model

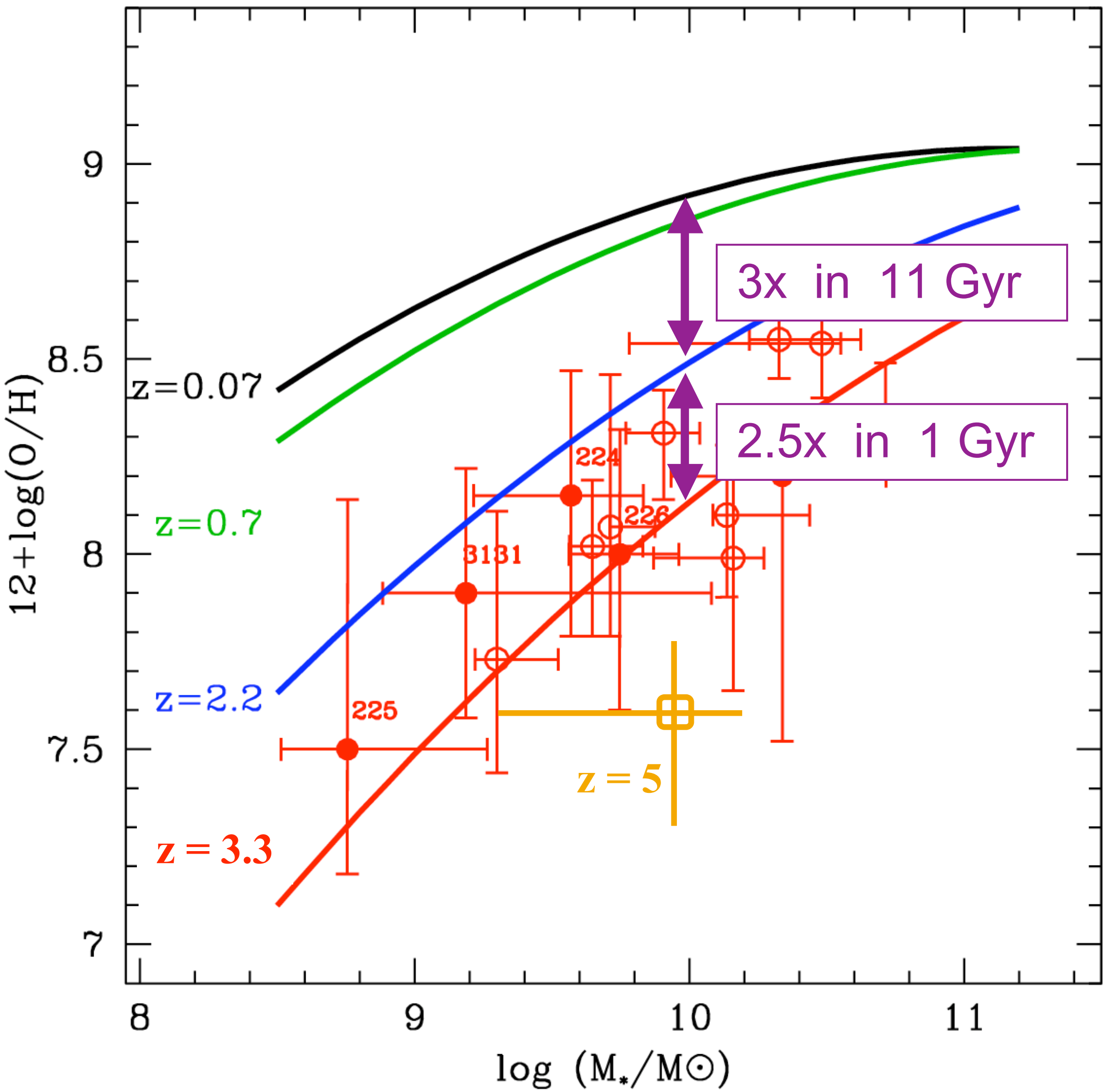
# The evolution of the mass-metallicity relation




**WARNINGS**:

- Does NOT trace the evolution of individual galaxies
- UV-selected (little dust-reddened) star forming (>20 $M_{\odot}$/yr) galaxies

# The evolution of the mass-metallicity relation

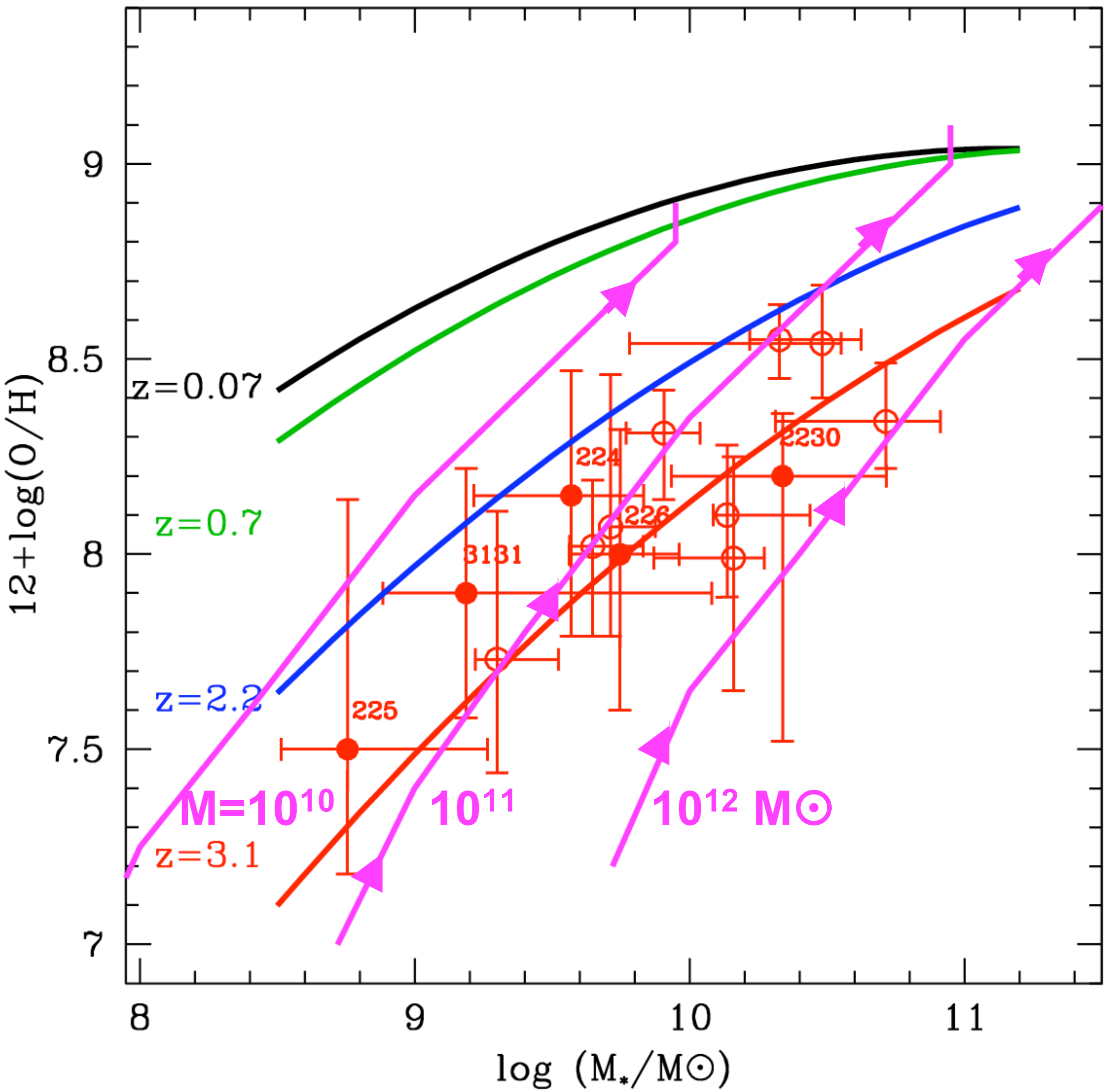



**Results**:

- Fast evolution, even at high masses

- Dependence on mass? ("chemical downsizing")

# Evolution of the Mass-Metallicity relation



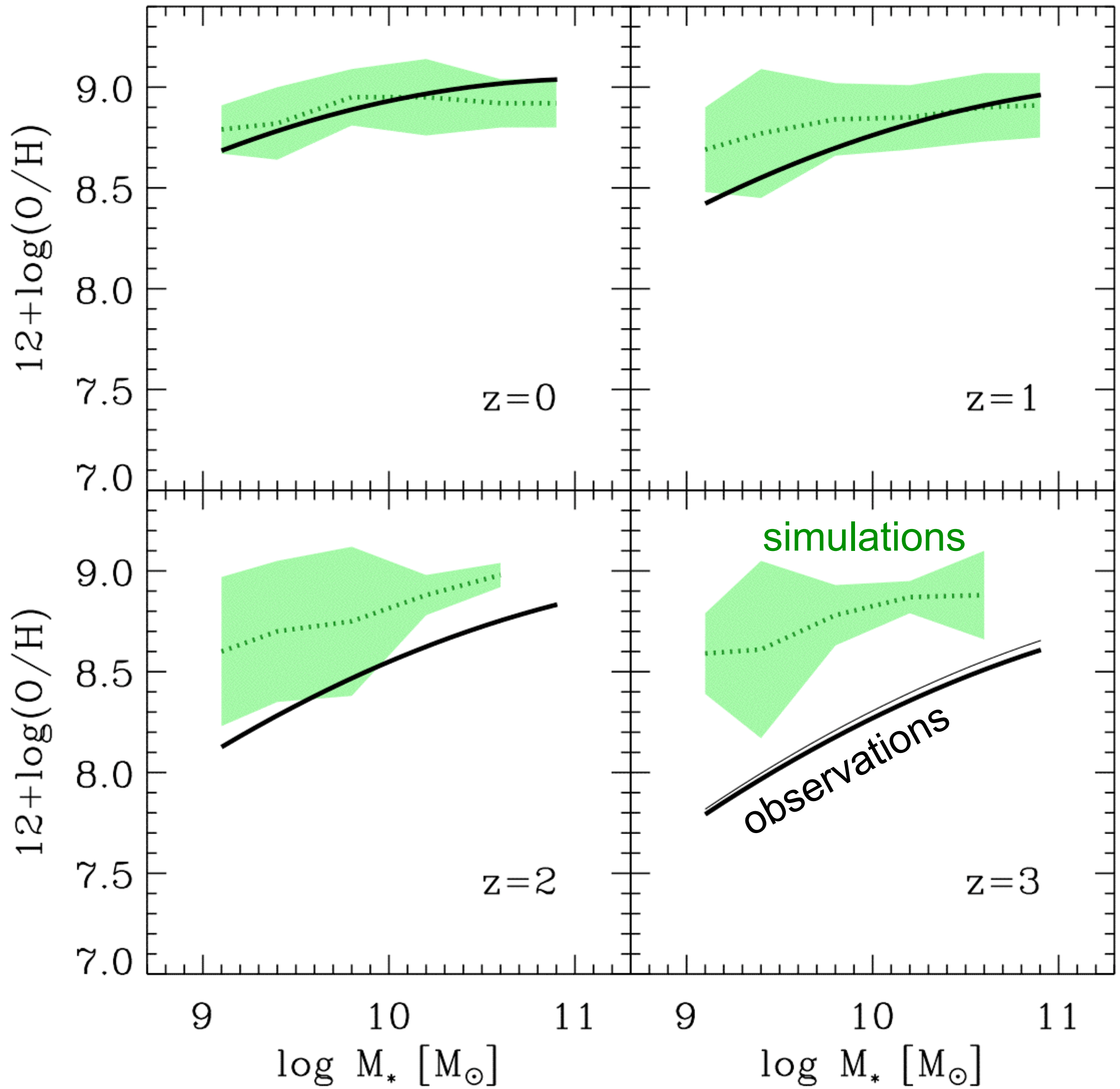

Granato et al (2004):

monolithic collapse of a spheroid

# Comparison with models

De Rossi+07

hierarchical models
without feedback

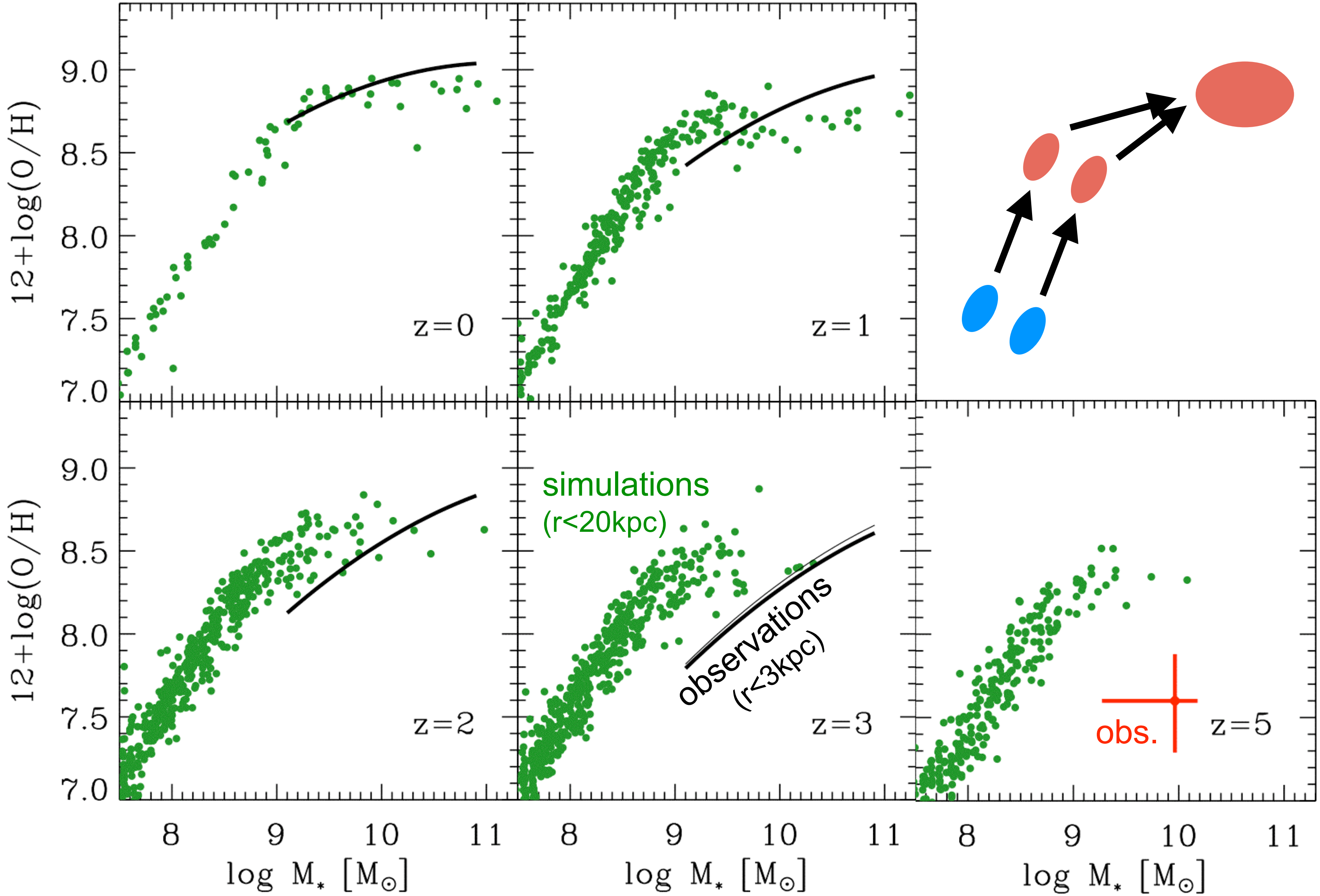



**~ bad**

# Comparison with models

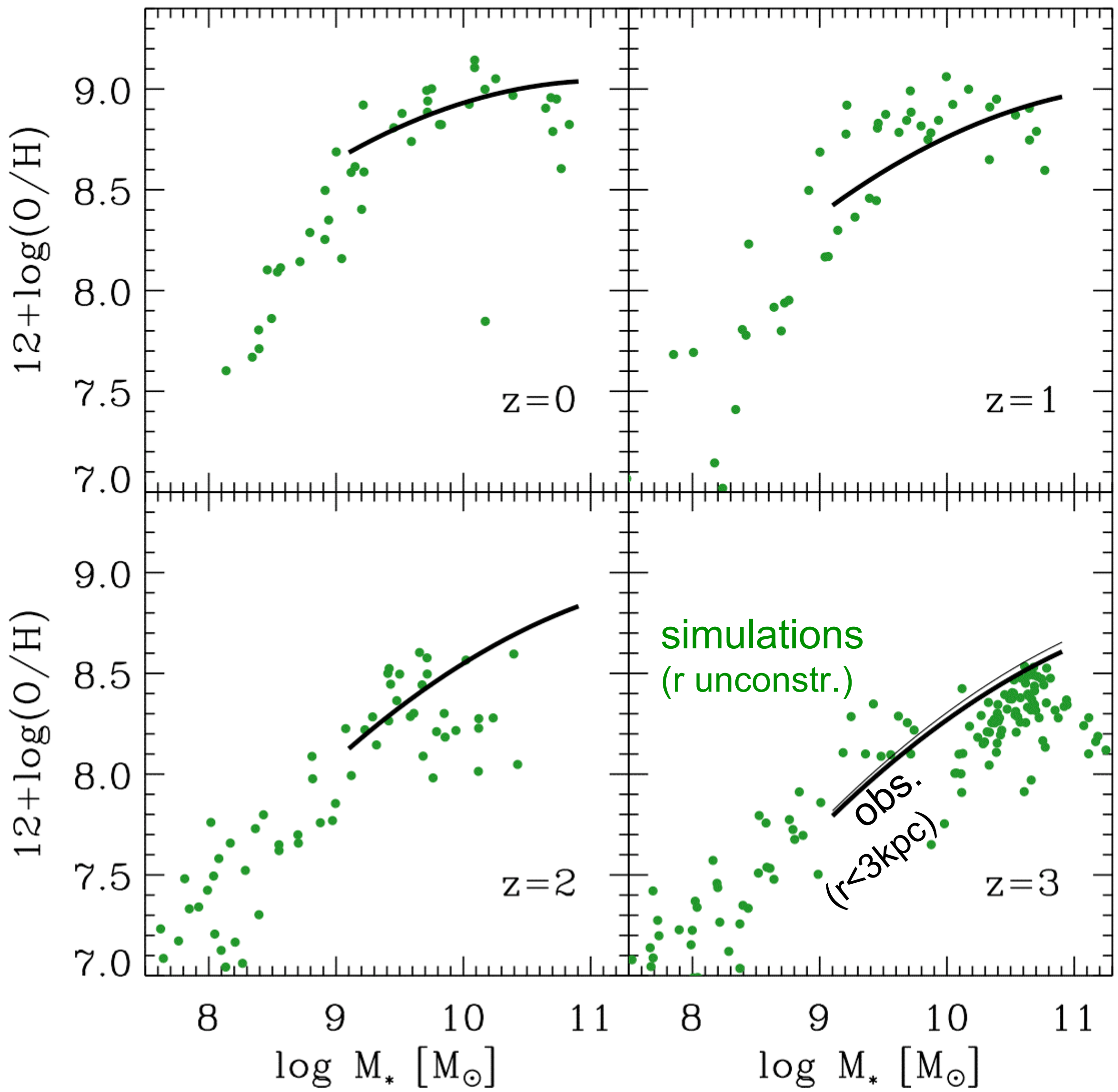
Kobayashi+07

hierarchical models with SN feedback

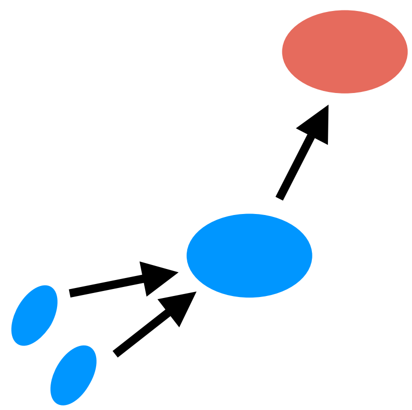


# Comparison with models

Brooks+07, Governato+07




hierarchical models with strong SN and UV feedback in small galaxies making their SF efficiency lower

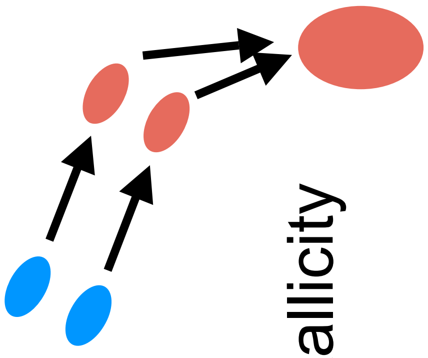


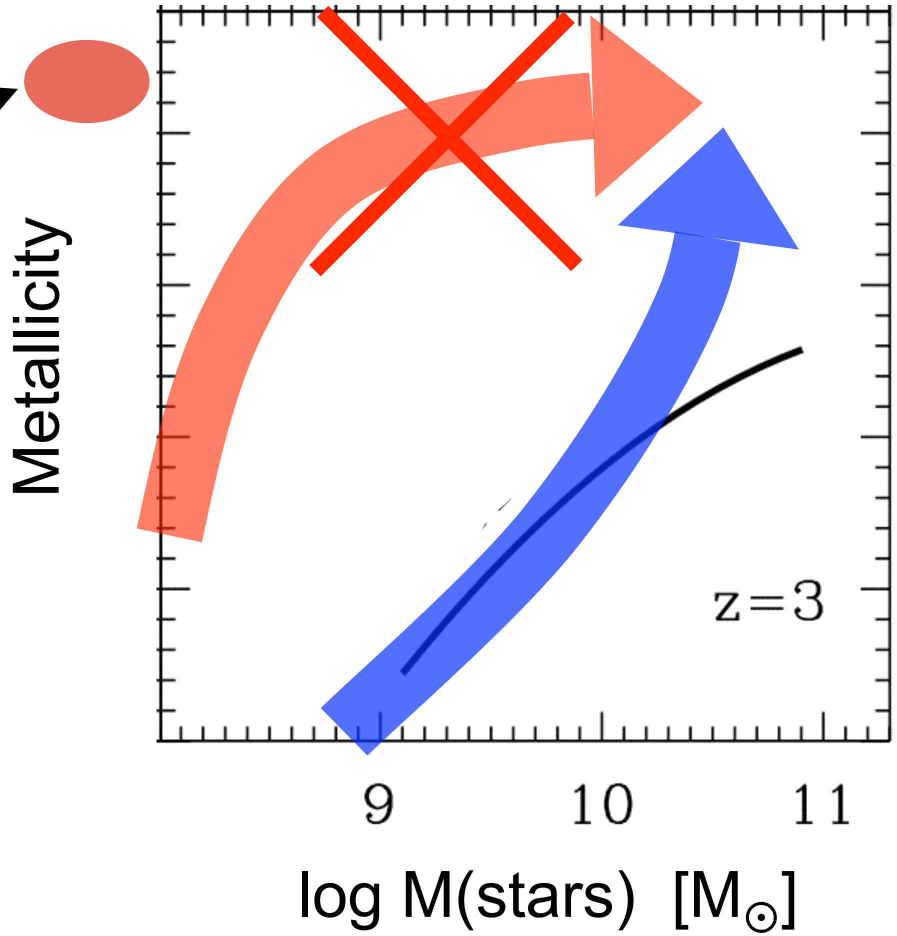
**~ good(?) especially if accounting for aperture mismatch**

(see also Finlator & Dave' 2008)

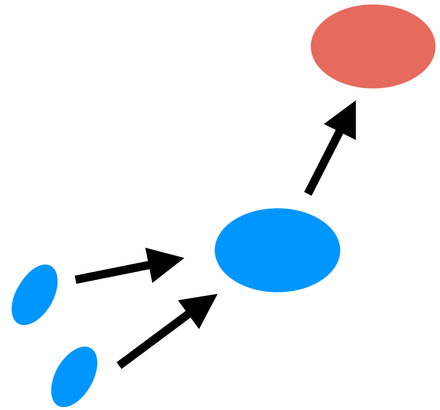
# Implications

Dry merging unlikely
to occur at z>3
(but possible at lower z)





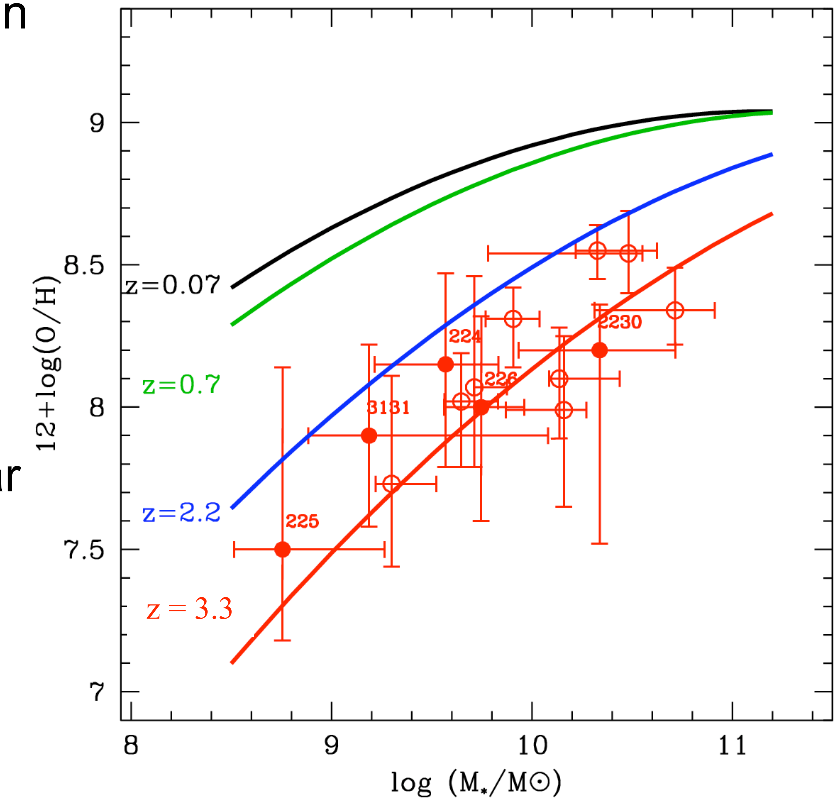

- Low star formation efficiency in low mass galaxies
- Most of the merging before most of the star formation



# Conclusions

- Strong evolution of mass-metallicity relation
  even at high masses
- Chemical version of downsizing (?)

1. Low star formation efficiency in low-mass galaxies
2. Most of the merging before most of the star formation




FUTURE WORK

- Total sample (~37 galaxies at z~3)
- Higher redshifts (a few galaxies at z~4-5)
- Accurate comparison with models (including selections)
- Metallicity gradients
- Stellar metallicities (FORS2 program approved)
- Dynamics
- Larger AO samples using Laser guide stars