The host galaxies of the *Swift*/BAT6 complete sample of LGRBs: hints on the LGRB efficiency and progenitors

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Context

Can Long GRBs (LGRBs) be used to

trace Star Formation?

- To answer this we need to understand:
  - What are the Long GRBs **progenitors?**
  - What are the **factors** (e.g. metallicity) that can influence **the link between SFR and LGRB rate** (LGRB efficiency)?

➡ Need for a **complete sample** of LGRB and their host galaxies

Our sample: presentation

- BAT6 sample (Salvaterra+12) of *Swift LGRBs* with selection on **peak flux of gamma-ray prompt emission,** and favorable observing conditions (Jakobsson+06)

  ➡ 58 LGRBs with **97% redshift completeness**

  ➡ Extends up to z ~ 6

- So far our study covers all the host at **z < 2 (28 hosts)**

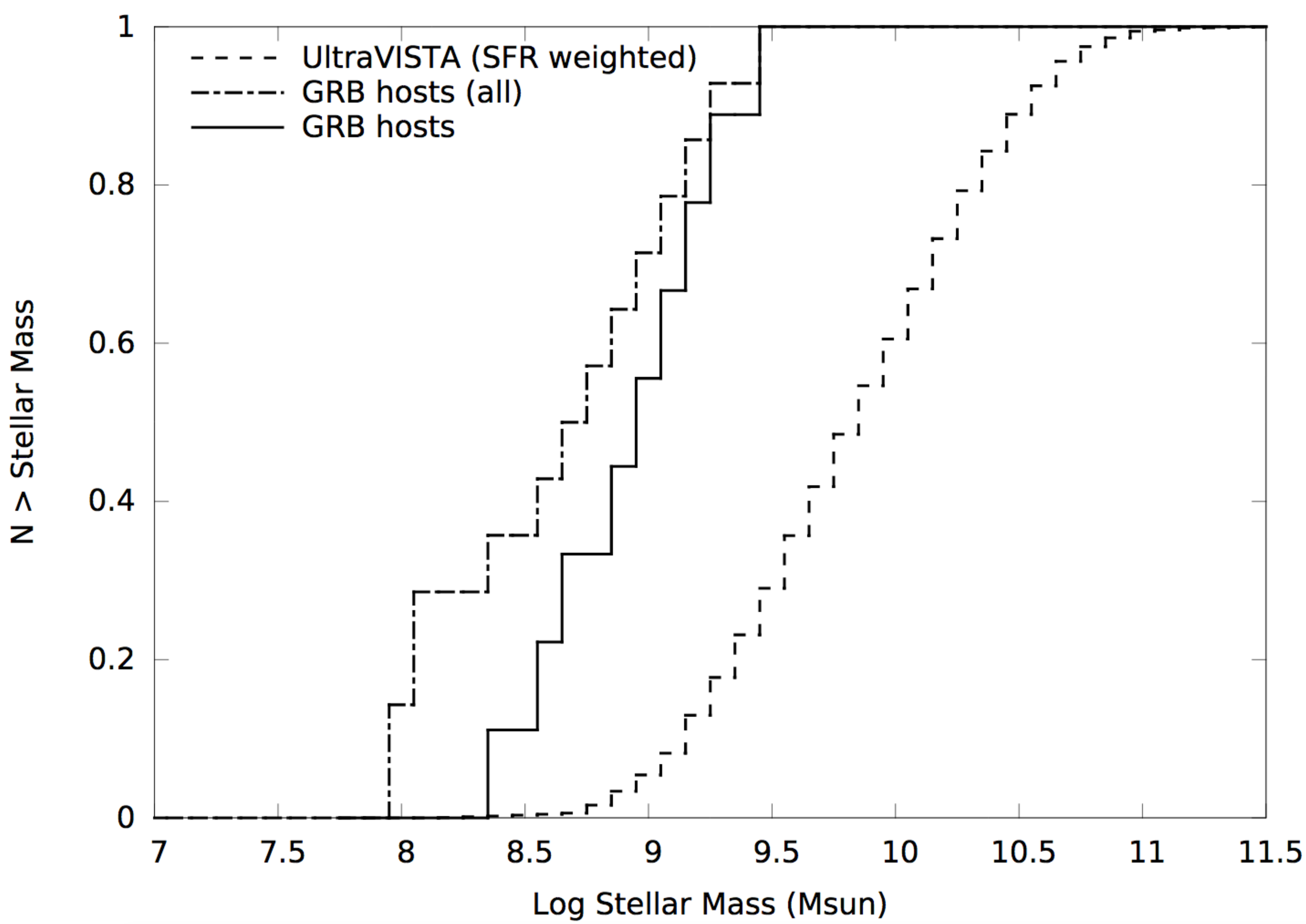
  ➡ Galaxies **not selected according to their flux**
  no correlation between prompt and host properties

Method

- The aim is to **study the properties** of this complete sample and **compare** with "typical" SF galaxies from surveys.

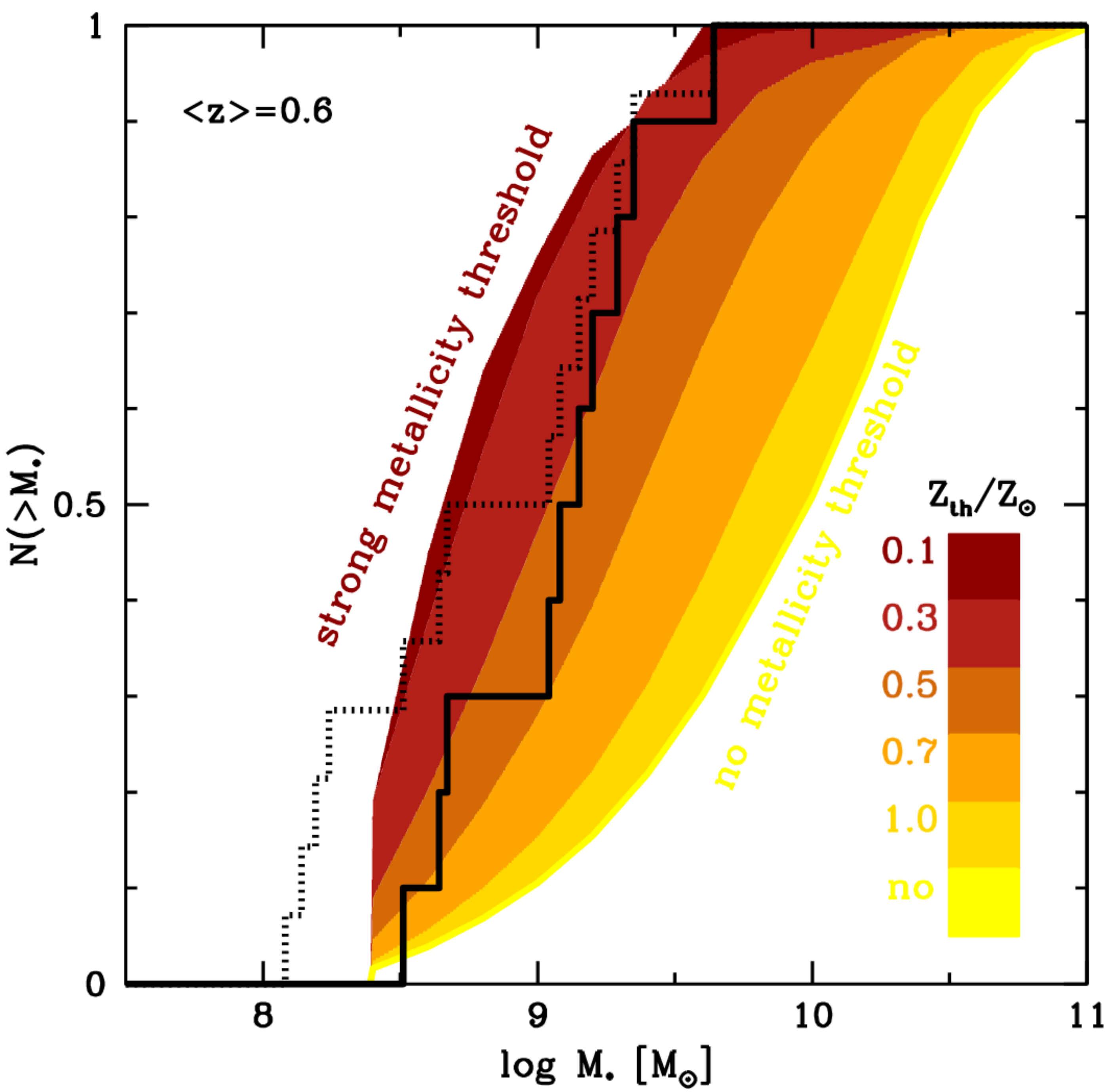
- If we assume **LGRBs are tracers of Star Formation** then we expect the various distributions of their hosts to follow the ones of "typical" SF galaxies, **weighted by their SFR**

LGRB host properties: Stellar Mass z < 1



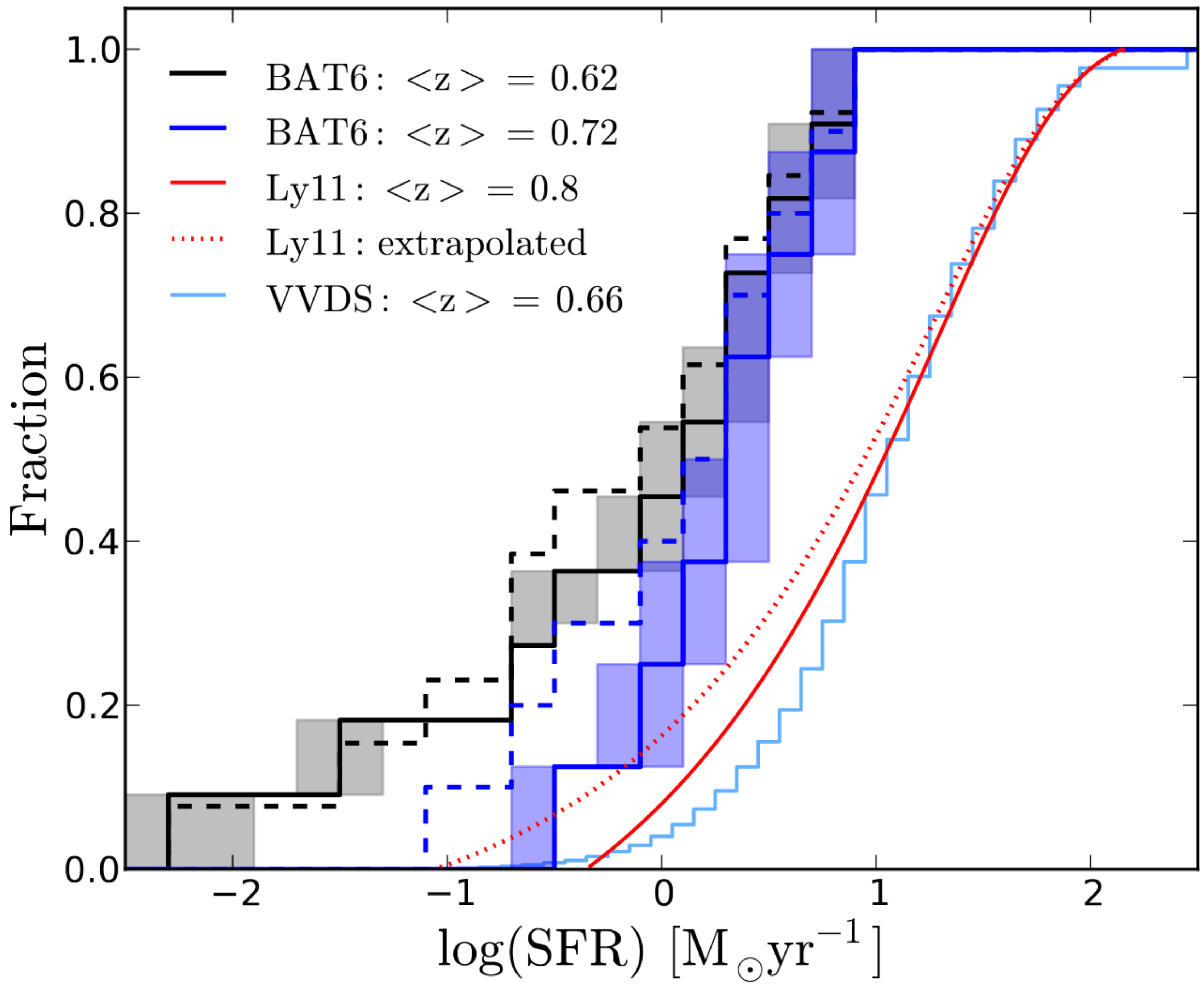
Vergani et al. 2015

LGRB host properties: Stellar Mass z < 1



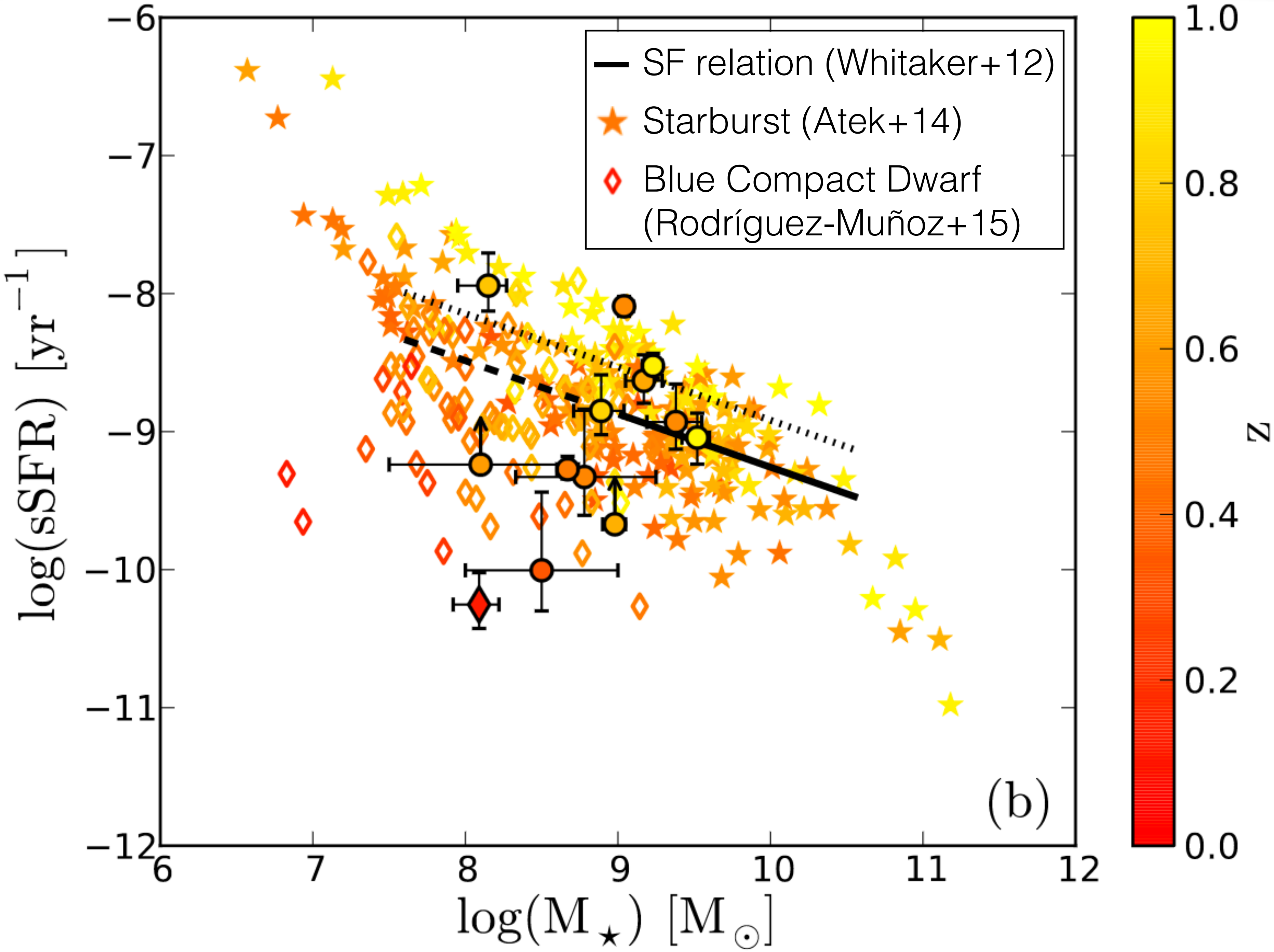
Vergani et al. 2015

LGRB host properties: Star Formation Rate z < 1



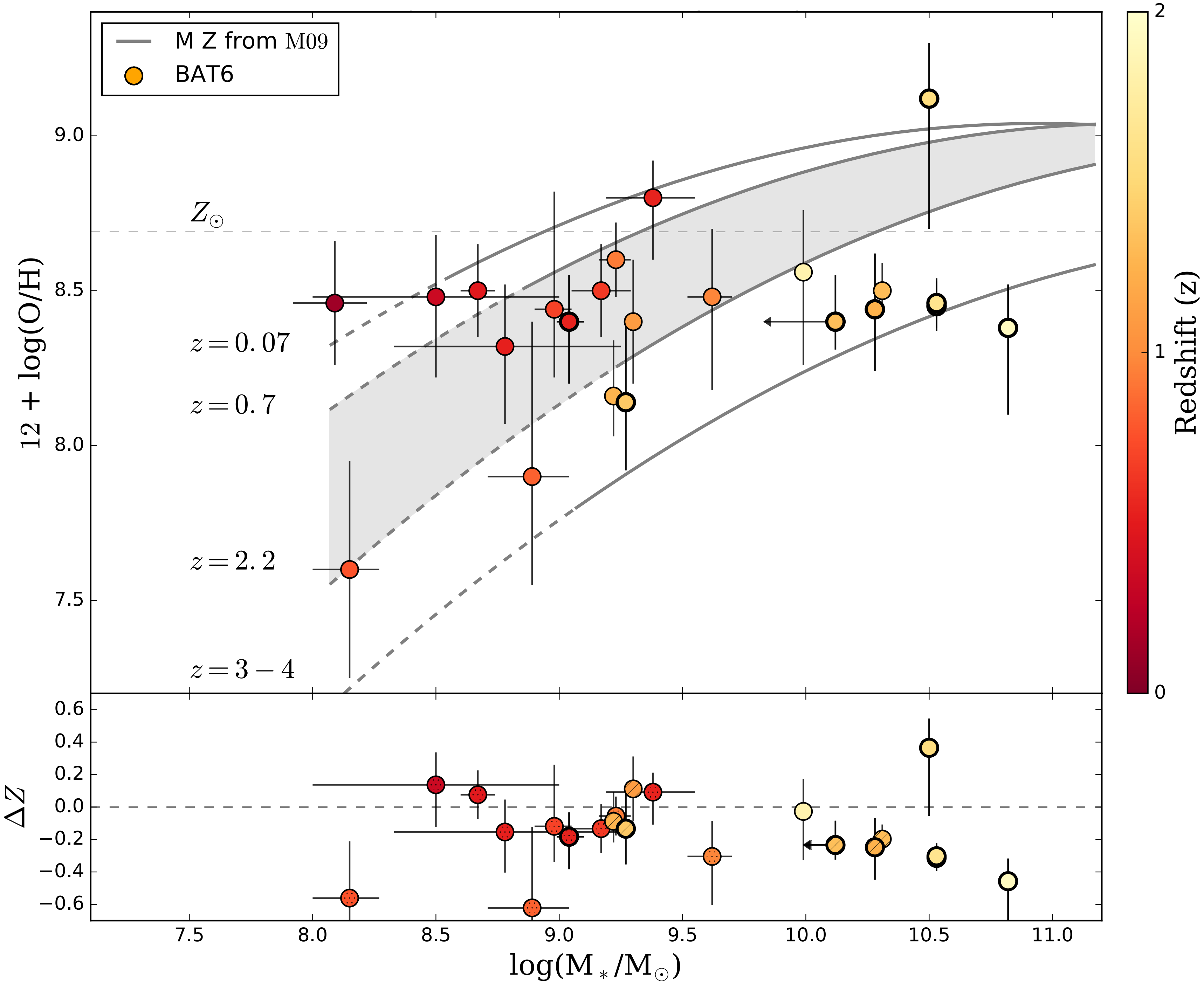
Japelj et al. 2016

LGRB host properties: Specific Star Formation Rate z < 1



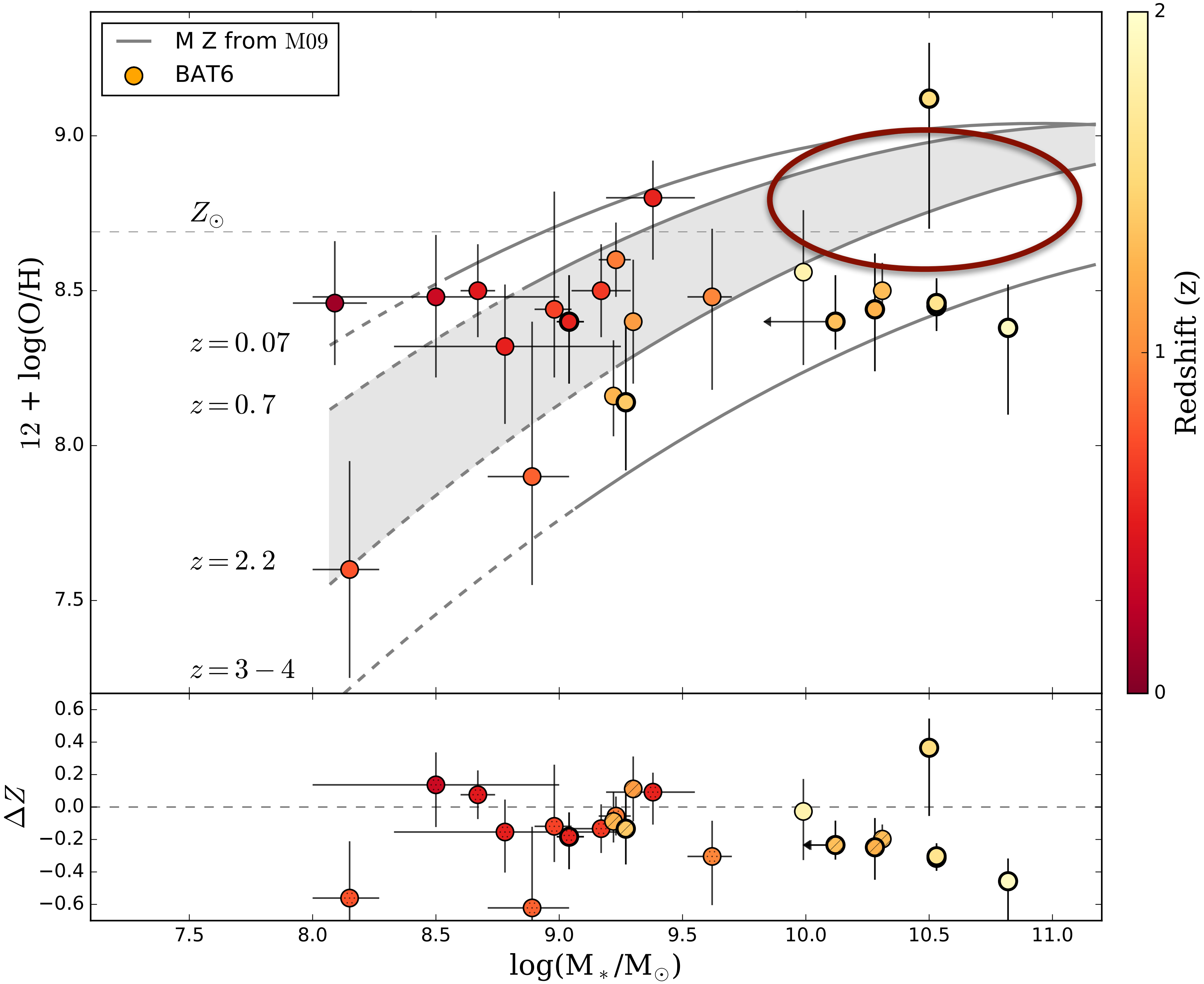
Japelj et al. 2016

LGRB host properties: Metallicity z < 2



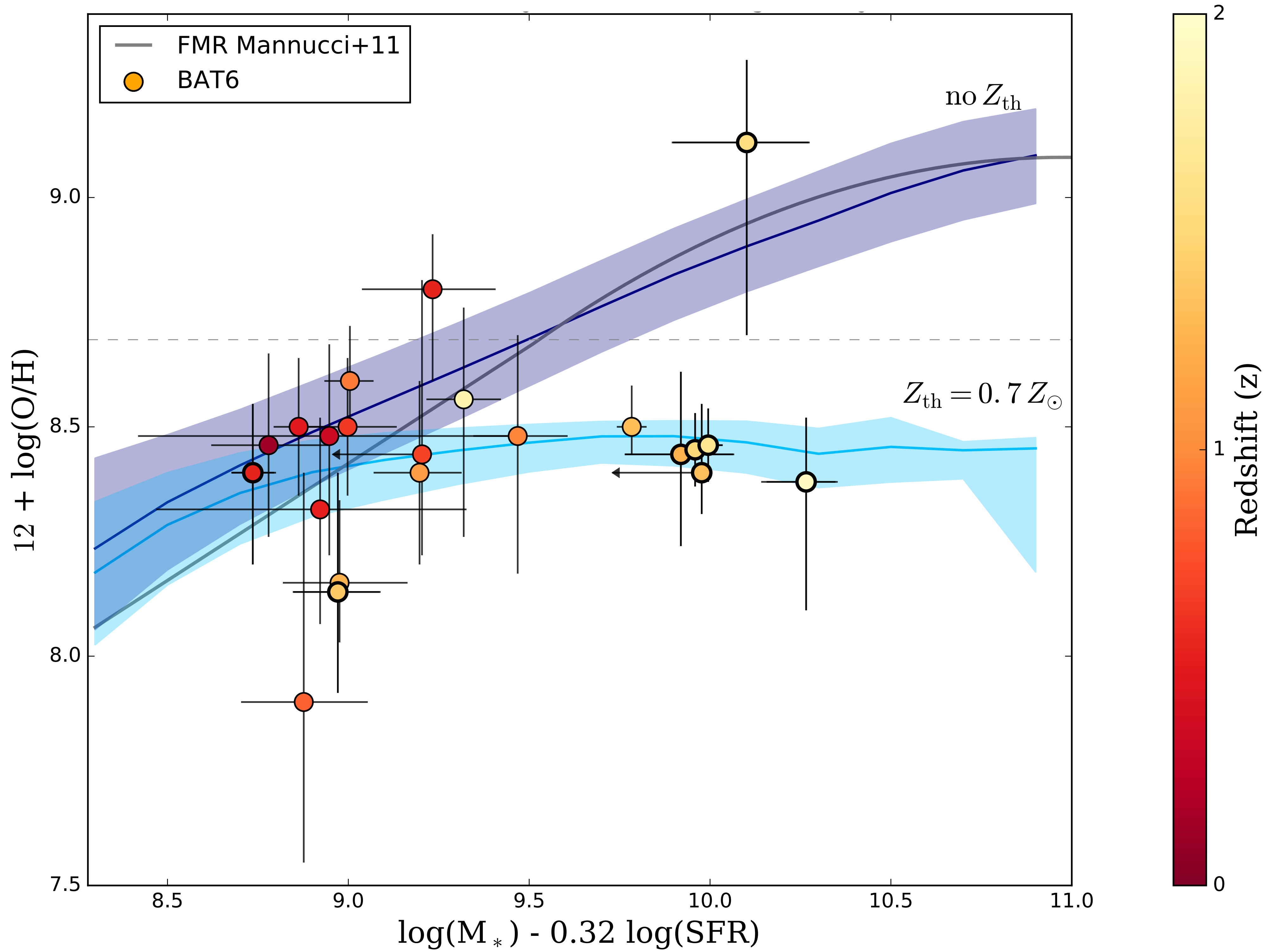
Vergani, JTP et al. 2017

LGRB host properties: Metallicity z < 2



Vergani, JTP et al. 2017

Fundamental Metallicity Relation



Vergani, JTP et al. 2017

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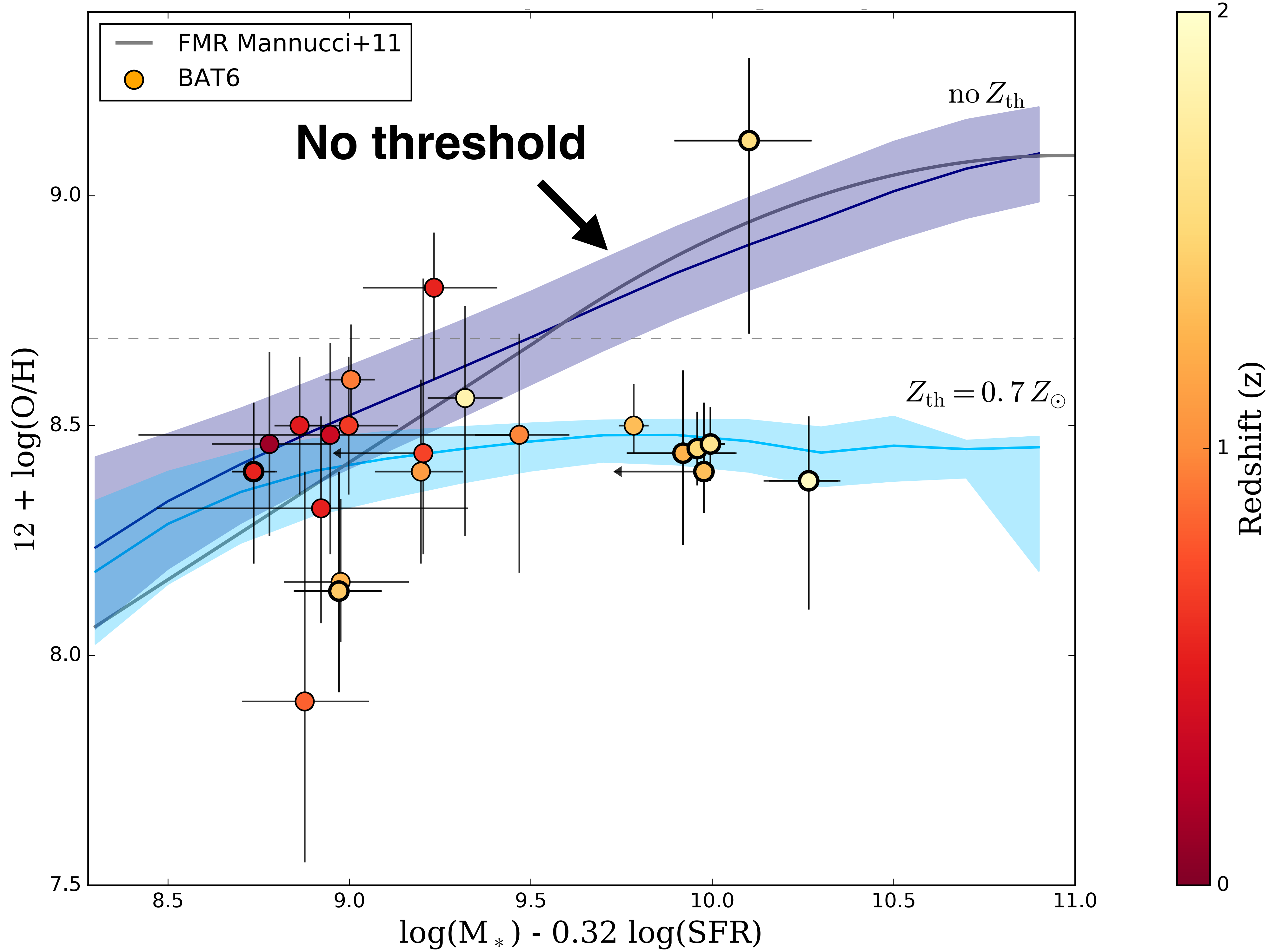
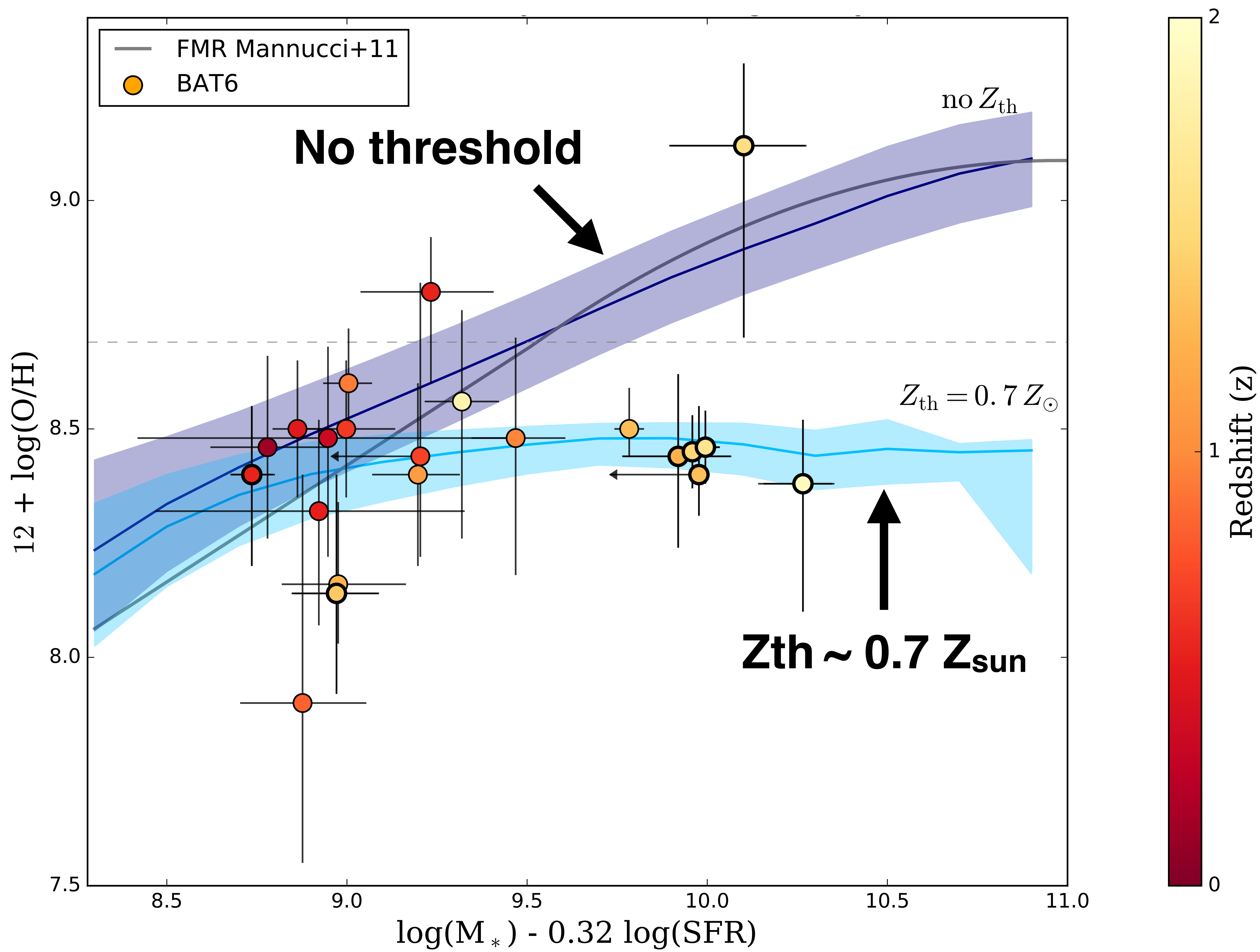


Vergani, JTP et al. 2017

Fundamental Metallicity Relation



Vergani, JTP et al. 2017

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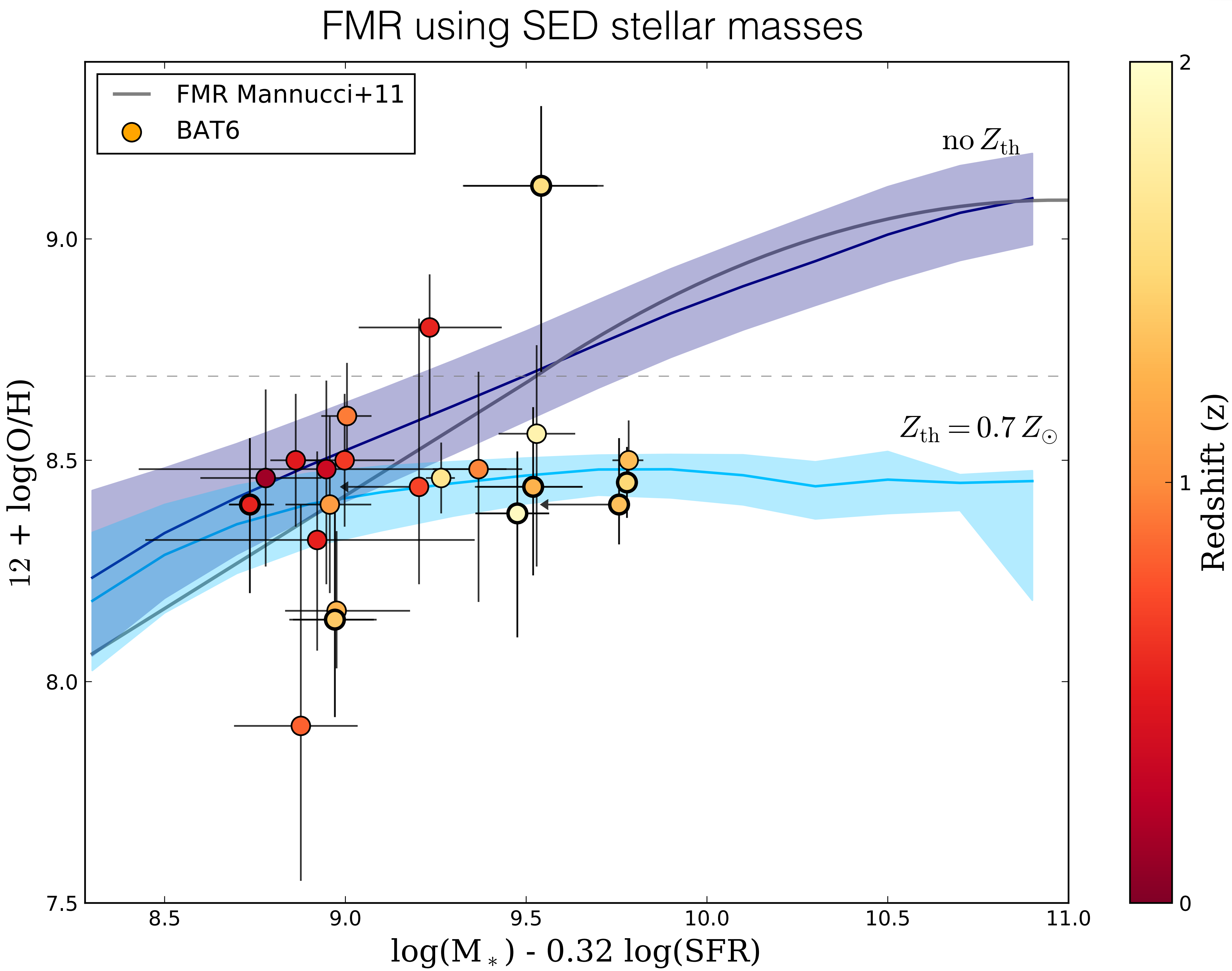
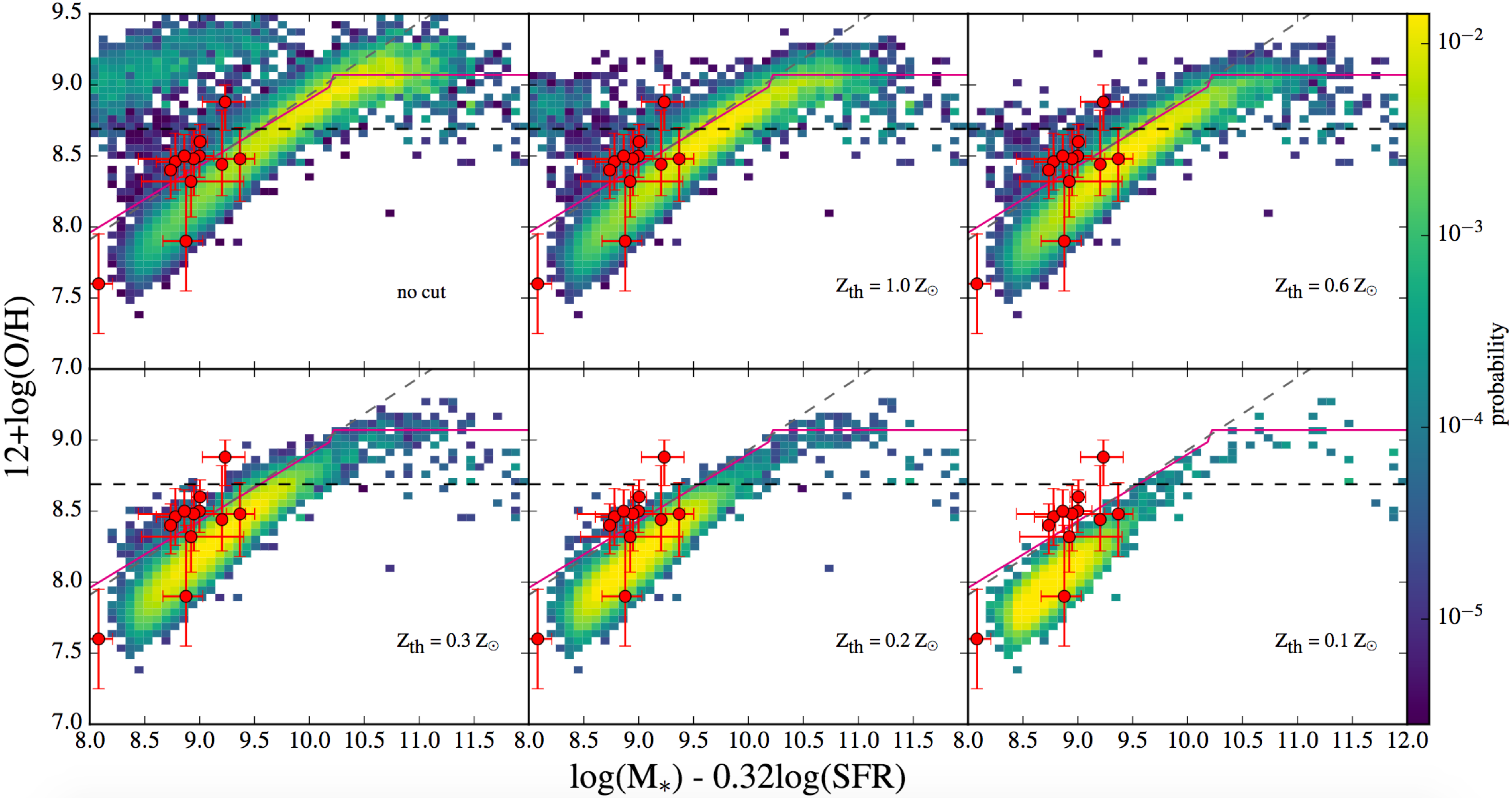


Fundamental Metallicity Relation



Bignone et al. 2017

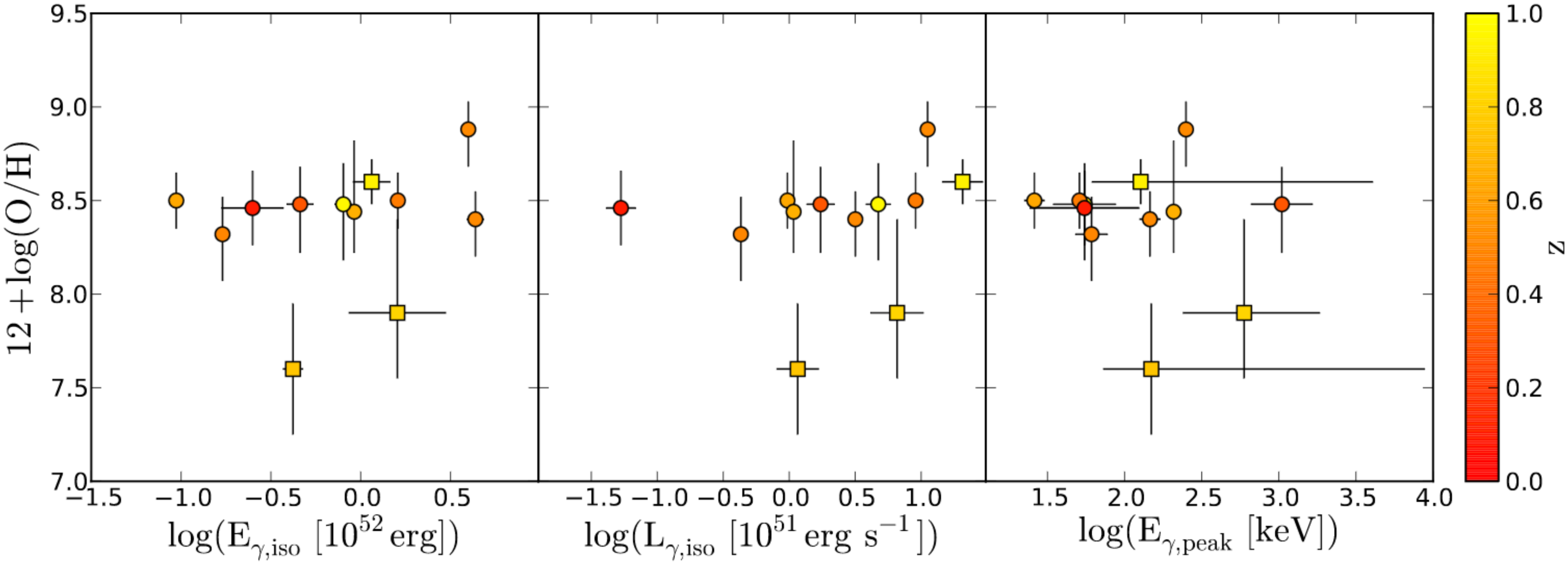
Conclusion and perspectives

- Metallicity plays a role but not as expected from most single-star progenitor models
  - Binary star LGRB progenitor? Multiple channels?
- If metallicity threshold is the main factor, we expect LGRB hosts to trace star formation at high redshift
  ($z \sim 3$-4, *e.g.* Vergani+15, Perley+16…)
- Next steps:
  - Compare the distributions of stellar mass, SFR, etc… to galaxy surveys also up to $z = 2$
  - Go to higher redshift and increase statistics

Thank you

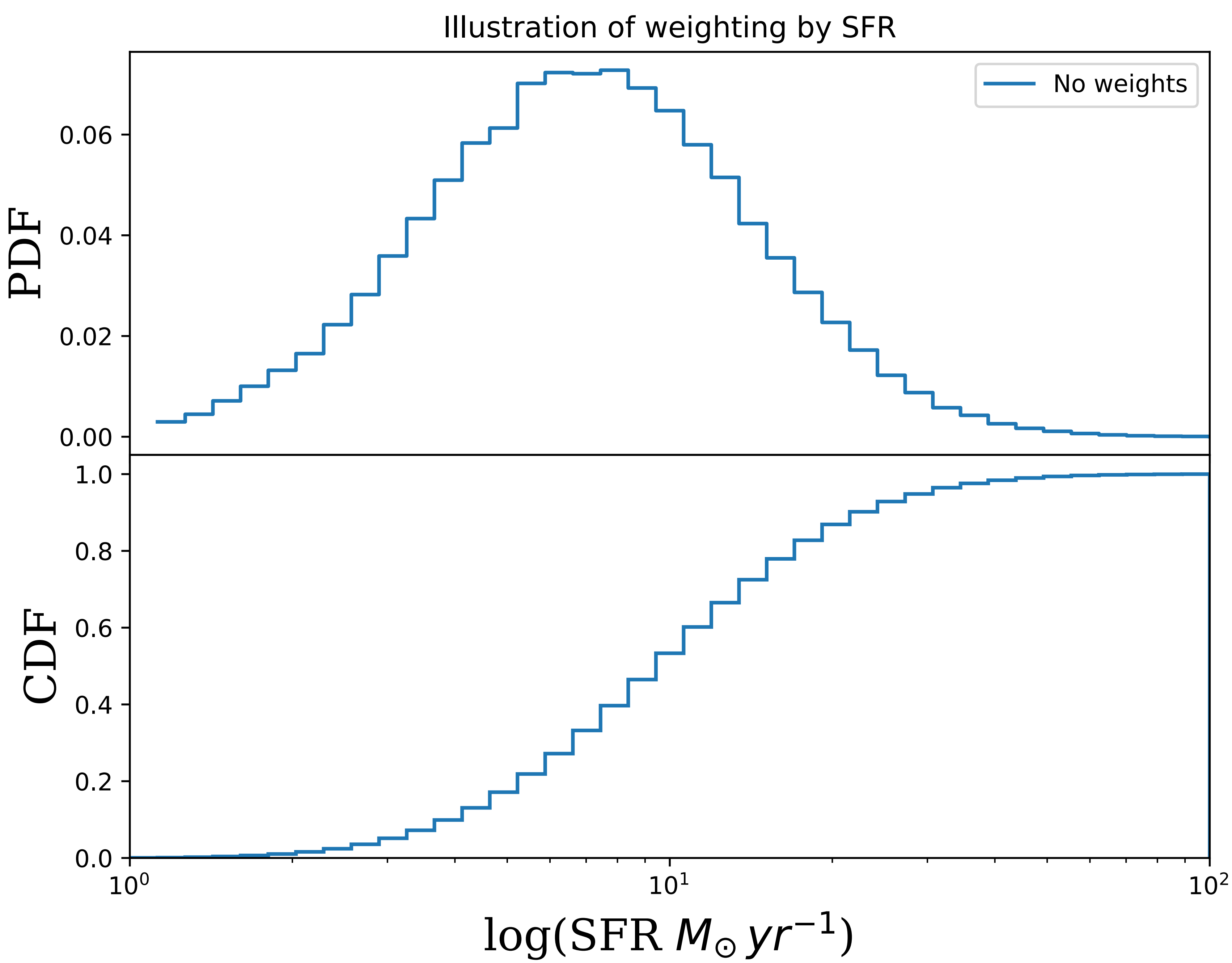
Děkuji

Correlations between prompt and host properties at z < 1

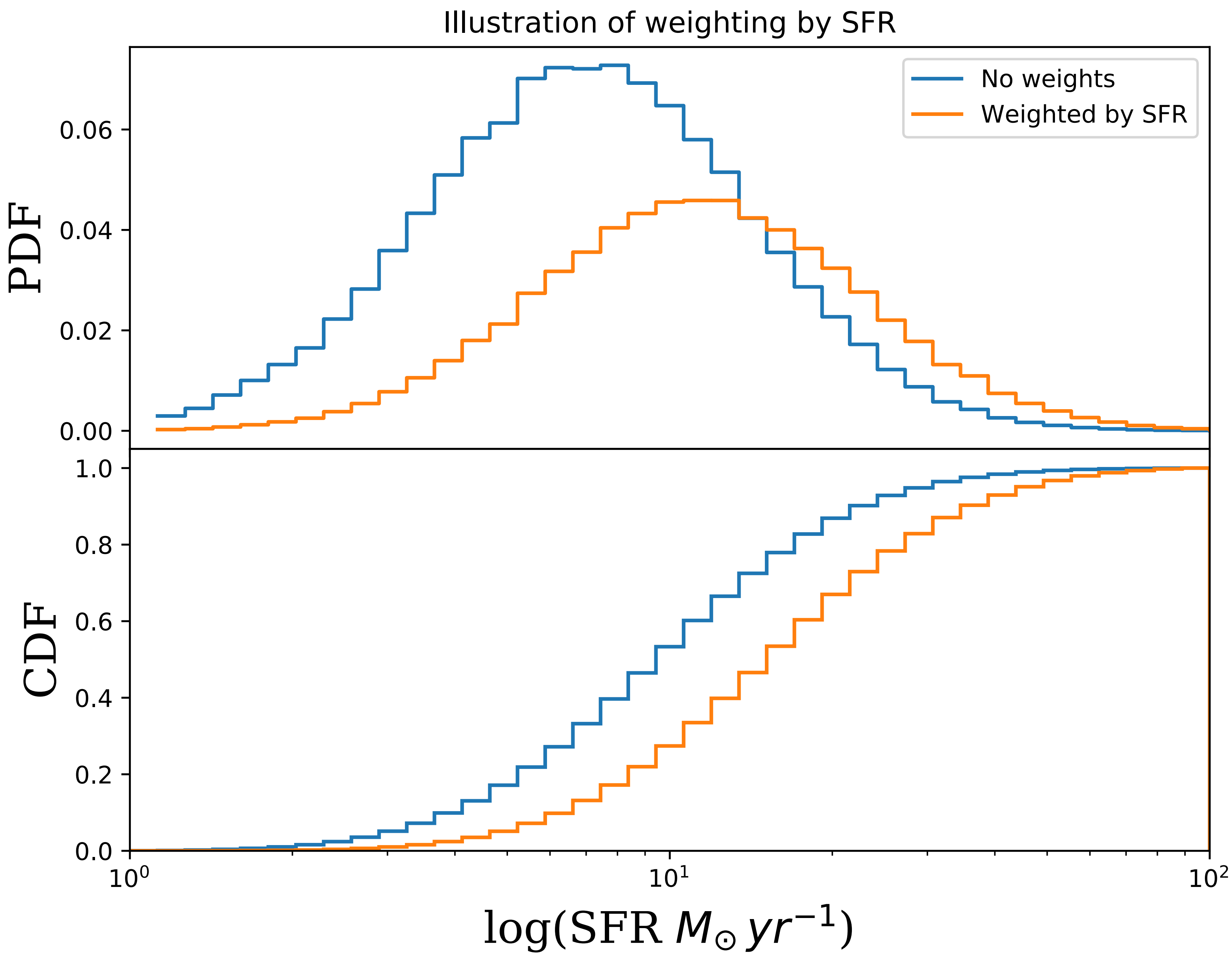


Japelj et al. 2016

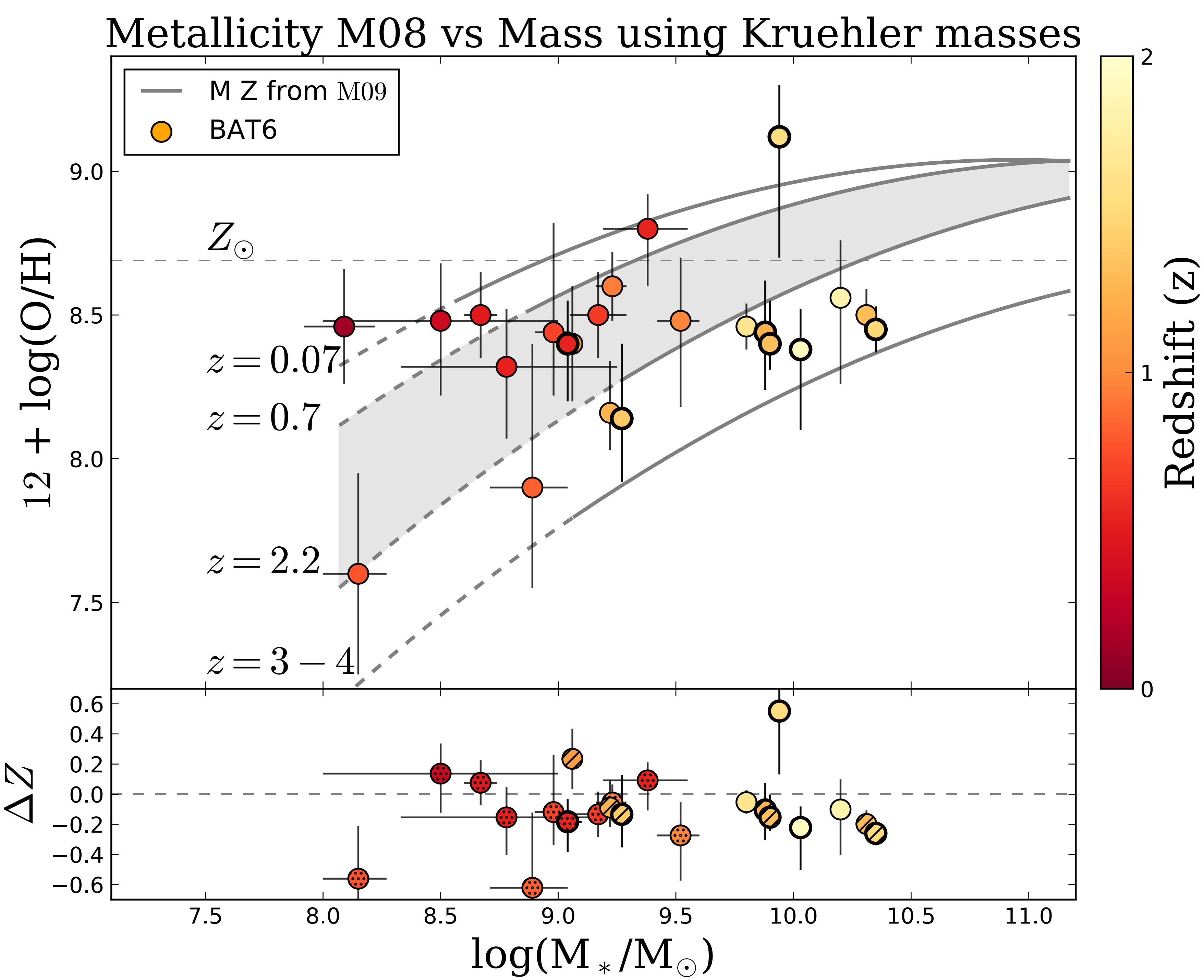
SFR weighting



SFR weighting



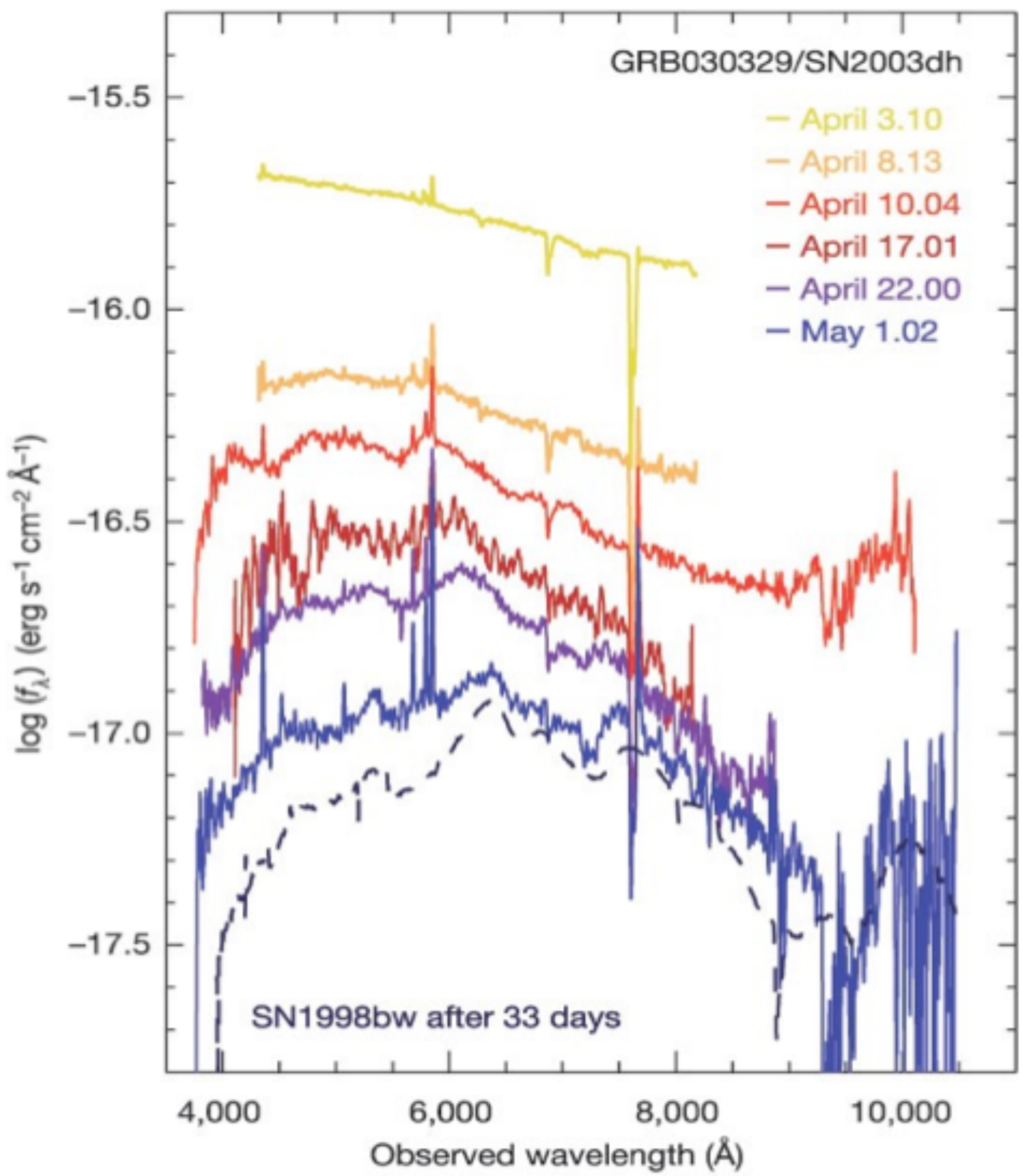
LGRB host properties: Metallicity z < 2



BAT6 favorable observing conditions

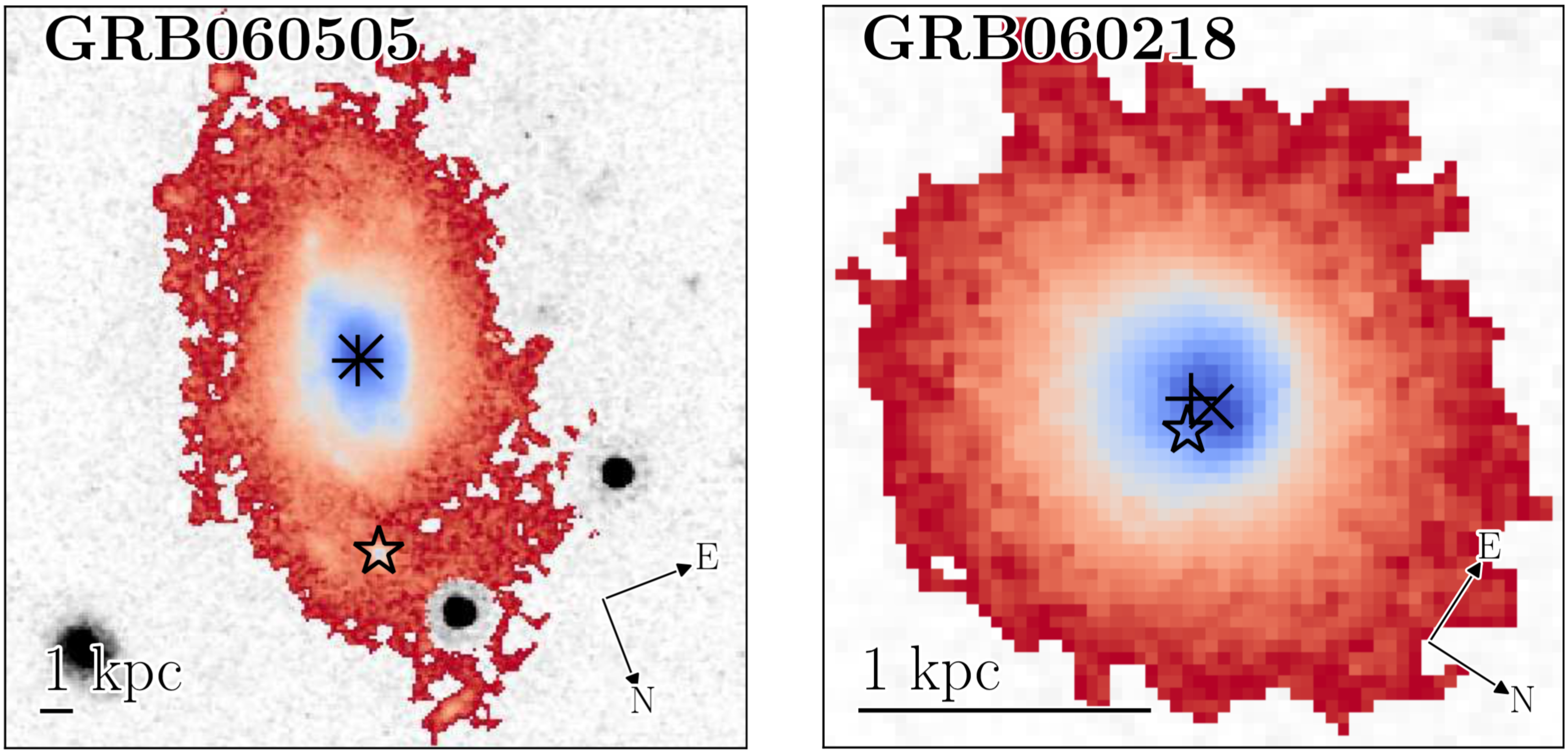
- Burst was well localised by *Swift*/XRT and the information was distributed quickly
- Low galactic extinction (A_V < 0.5)
- Burst declination is between -70° and +70°
- Its angular distance to the sun is greater than 55°
- No nearby bright stars

Association of LGRBs with type Ibc Supernovae



credits : Hjorth et al. Nature, 423, 847 (2003)

LGRBs in bright regions of SF galaxies



☆ LGRB position

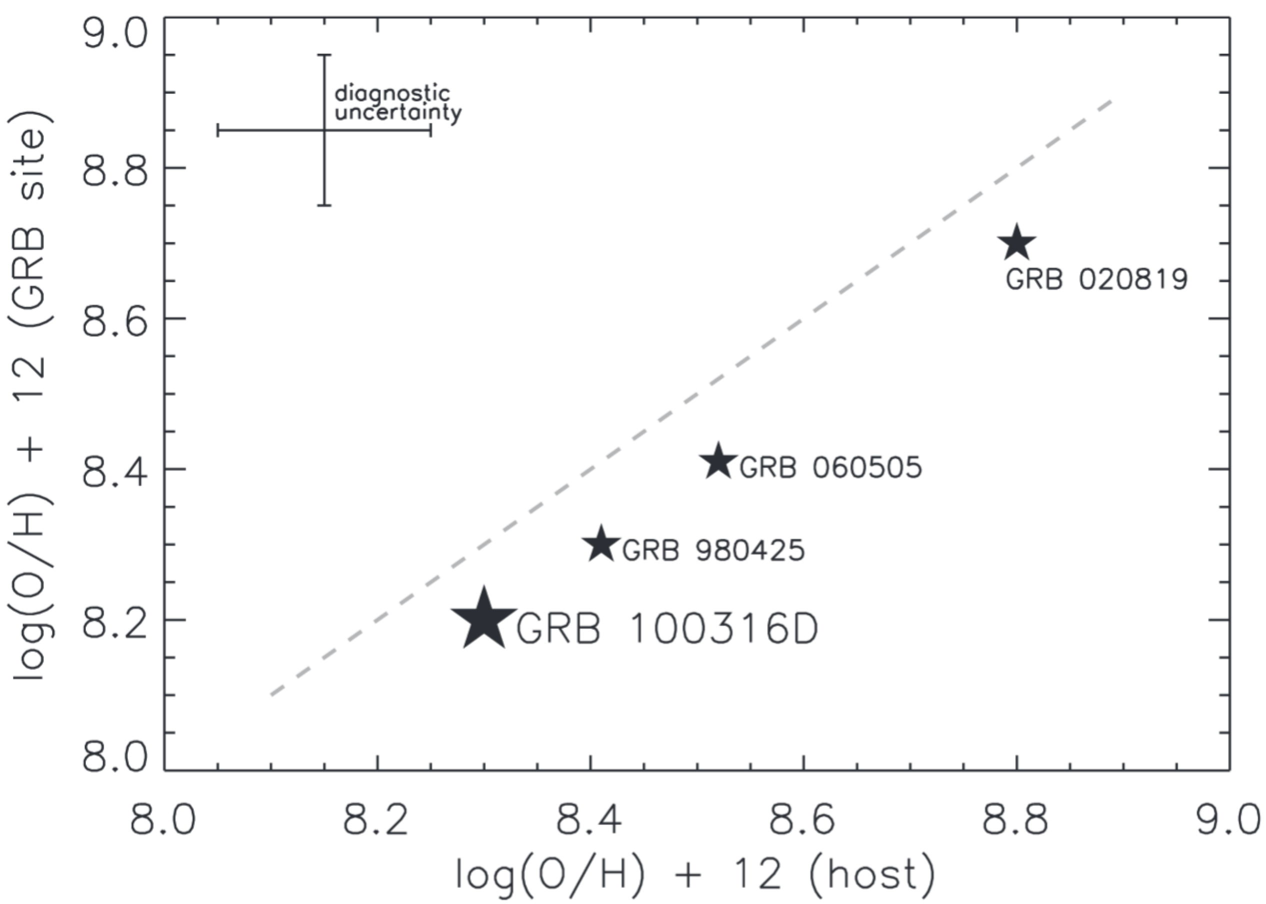
+ Host barycentre / brightest pixel

credits : Lyman et al. 2017

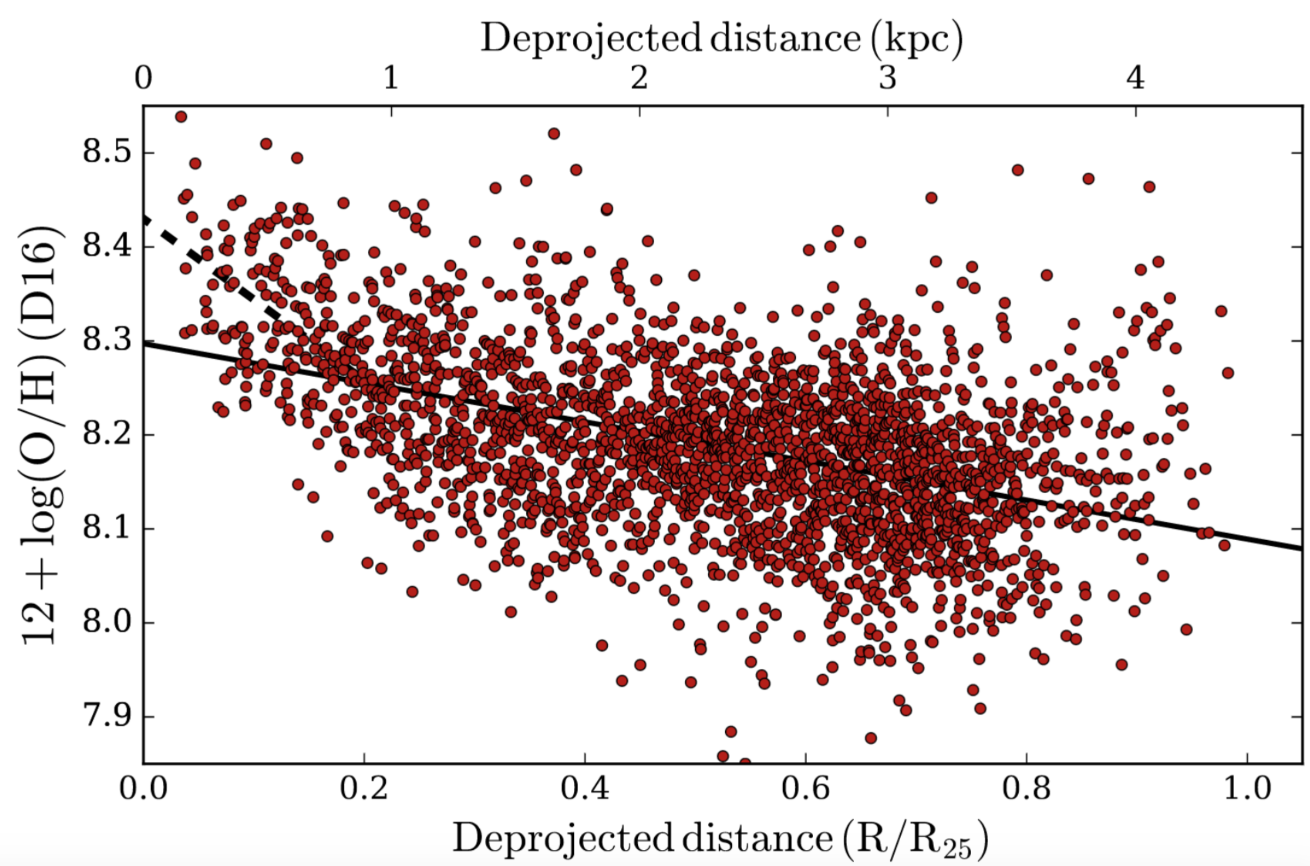
Metallicity gradient in LGRB hosts

Dispersion ~ 0.1 dex

Gradient : -0.06 dex per kpc



credits : Levesque+11



credits : Kruehler+17

Link between GRB rate and collapse rate

- Number of collapses per year per comoving volume : $\dot{n}_{coll}$ $[\mathrm{yr}^{-1}\,\mathrm{Mpc}^{-3}]$
- Number of LGRBs per year per comoving volume : $\dot{n}_{GRB}$ $[\mathrm{yr}^{-1}\,\mathrm{Mpc}^{-3}]$

➡ $\dot{n}_{GRB} = \eta(z)\,\dot{n}_{coll}$

with $\eta(z)$ the fraction of collapses that form a LGRB

- Collapse rate : $R_{coll} = \int_0^{z_{max}} \dot{n}_{coll}(z)\,\frac{dV}{dz}\,\frac{1}{1+z}dz$ $[\mathrm{yr}^{-1}]$
- GRB rate : $R_{GRB} = \int_0^{z_{max}} \eta(z)\,\dot{n}_{coll}(z)\,\frac{dV}{dz}\,\frac{1}{1+z}dz$ $[\mathrm{yr}^{-1}]$

Number of collapses

- Number of collapses per year per comoving volume is given by :

$$\dot{n}_{core-collapse}(z) = P_{core-collapse}(z)\,\frac{\dot{\rho}_*(z)}{\bar{m}(z)} \quad [\mathrm{yr}^{-1}\,\mathrm{Mpc}^{-3}]$$

where $\dot{\rho}_*(z)$ is the Star Formation Rate Density $[\mathrm{M}_\odot\,\mathrm{yr}^{-1}\,\mathrm{Mpc}^{-3}]$

and $\bar{m}(z)$ is the mean mass deduced from the IMF of stars:

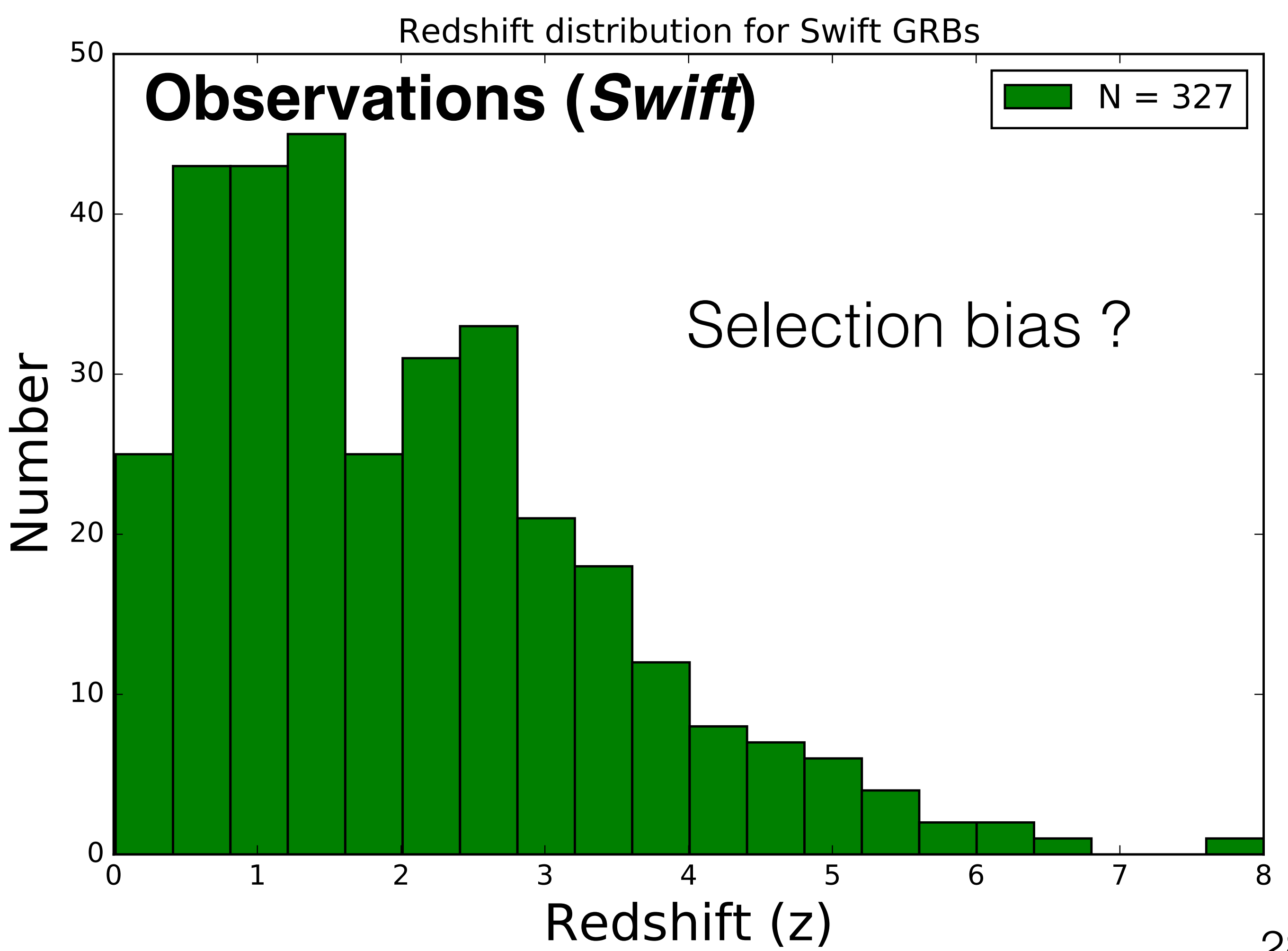
$$\bar{m}(z) = \int_{m_{inf}}^{m_{sup}} m\,p(m)\,dm \qquad [\mathrm{M}_\odot]$$

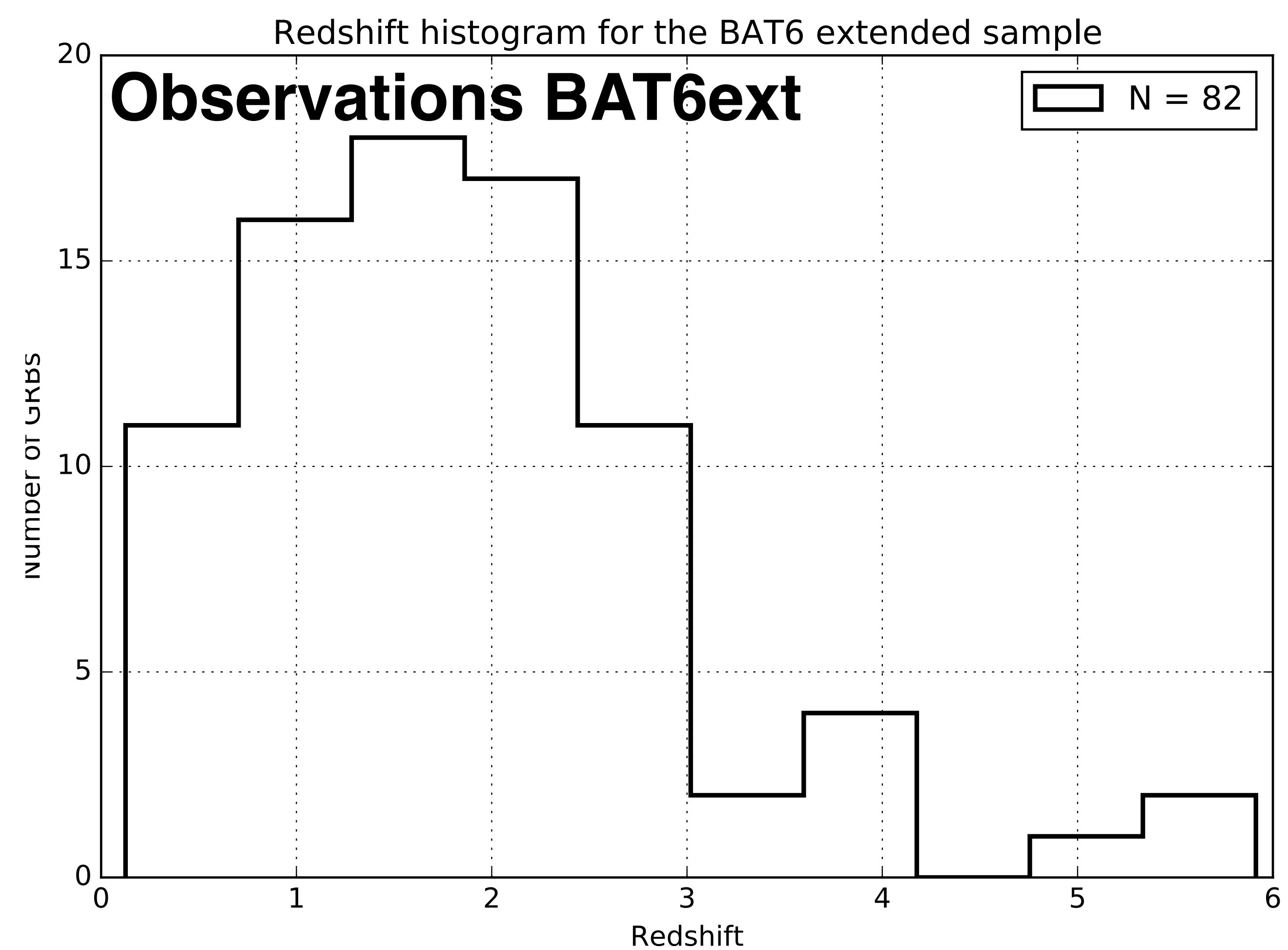
and $P_{core-collapse}(z)$ is the core-collapse probability:

$$P_{core-collapse}(z) = \int_{8\,M_\odot}^{m_{sup}} p(m)\,dm$$

Redshift distribution

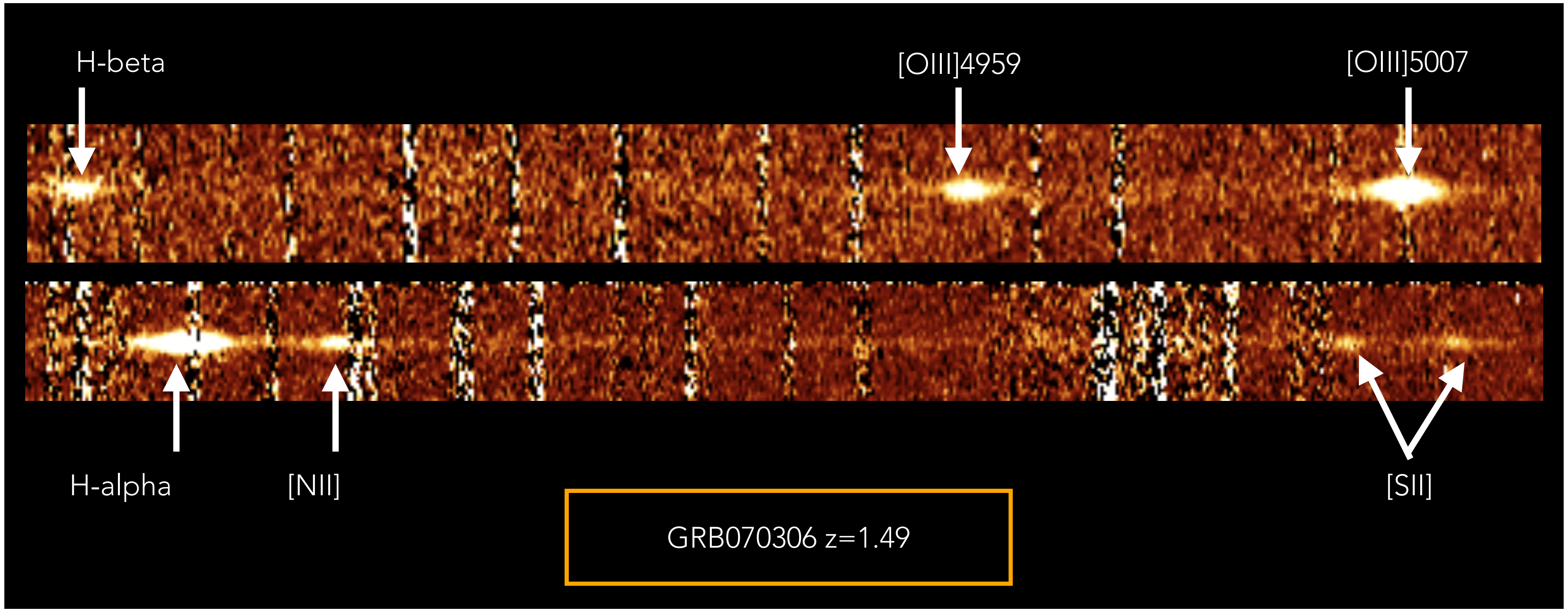
- Fundamental to understanding the LGRB production efficiency from stars
- Only ~30% of *Swift* GRBs currently have a redshift
- Assume $R_{GRB}(z) = a(z)\, SFR(z)$





Our sample : example of spectroscopy

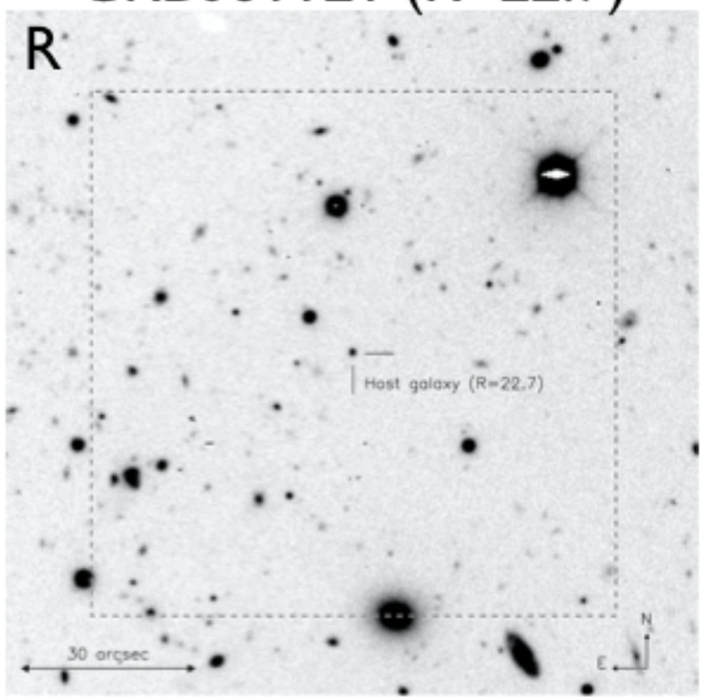
- Observed with **X-Shooter** spectrograph on the VLT (Typical resolution R ~ 7000 at 6000 Å)



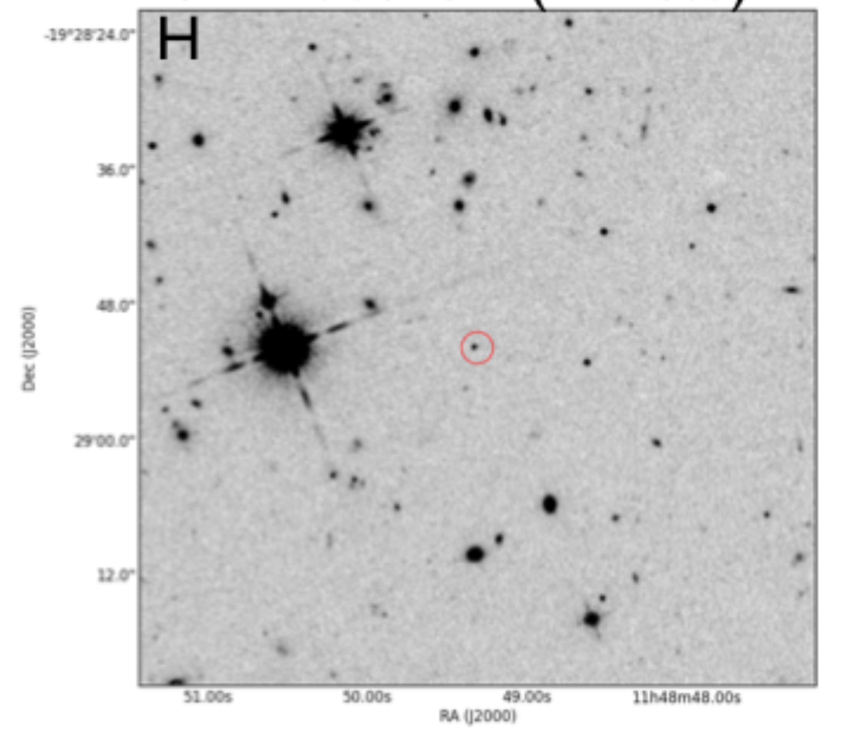
credit : S. D. Vergani

Our sample :
example of photometry

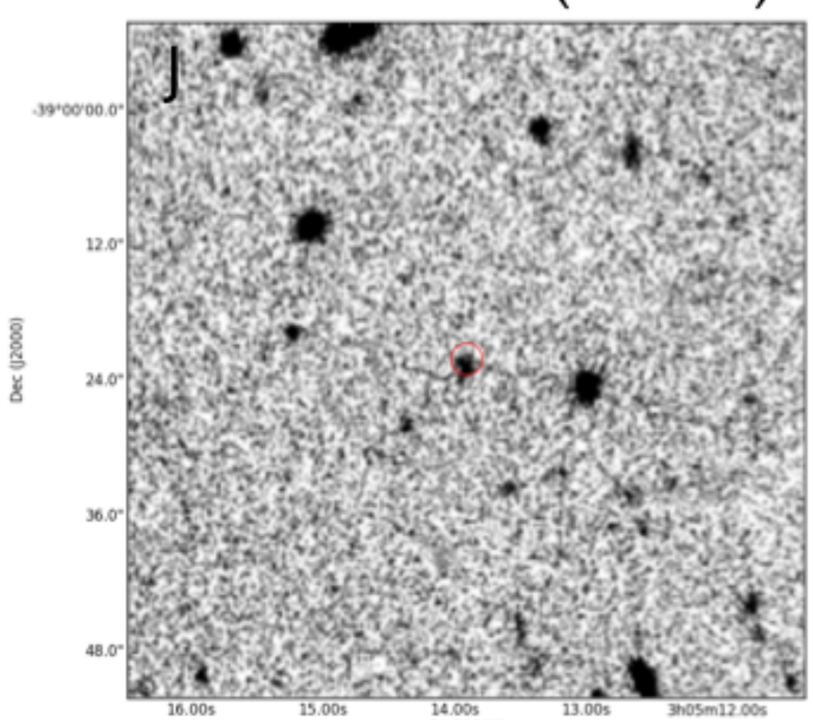
GRB061121 (R=22.7)



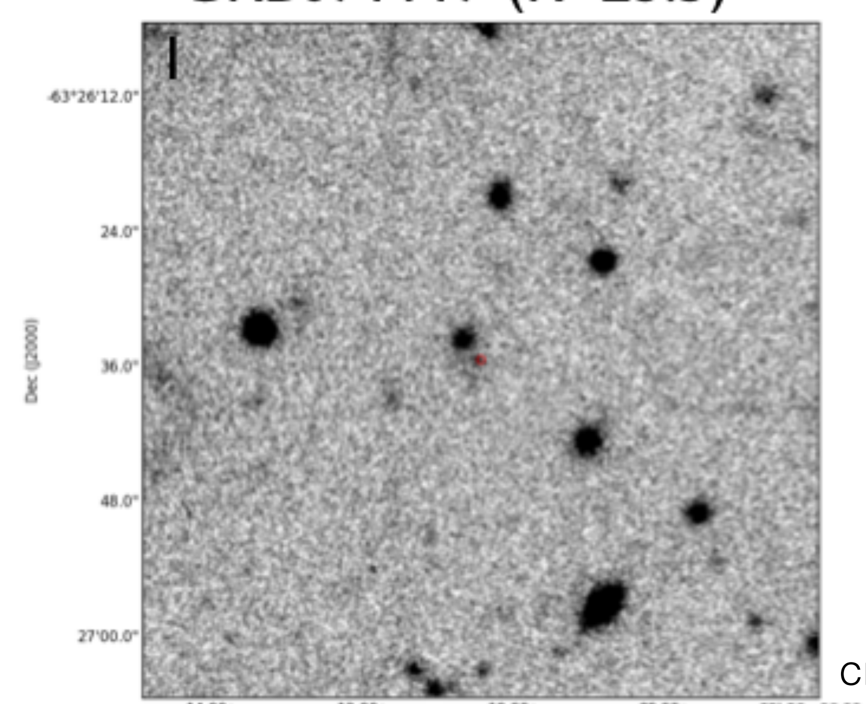
GRB100615A (R=25.0)



GRB090926B (R=23.0)



GRB071117 (R=23.5)



credit : S. D. Vergani

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