Using GRB host galaxies to characterize the GRB "bias"

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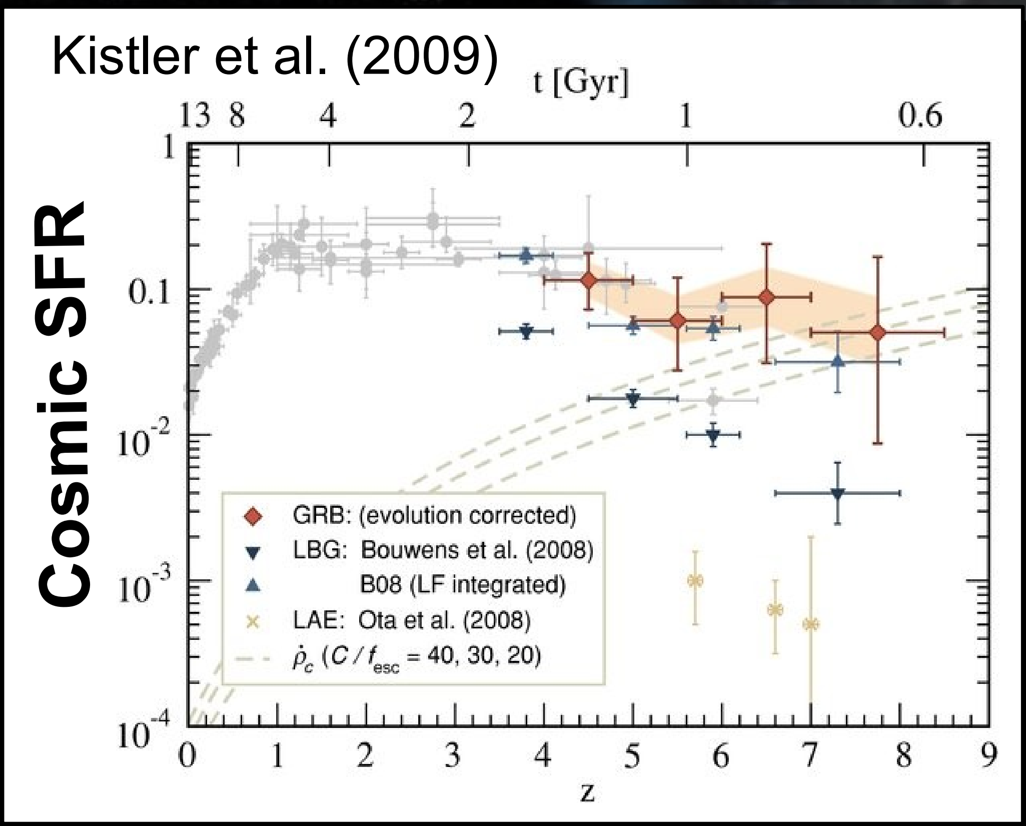
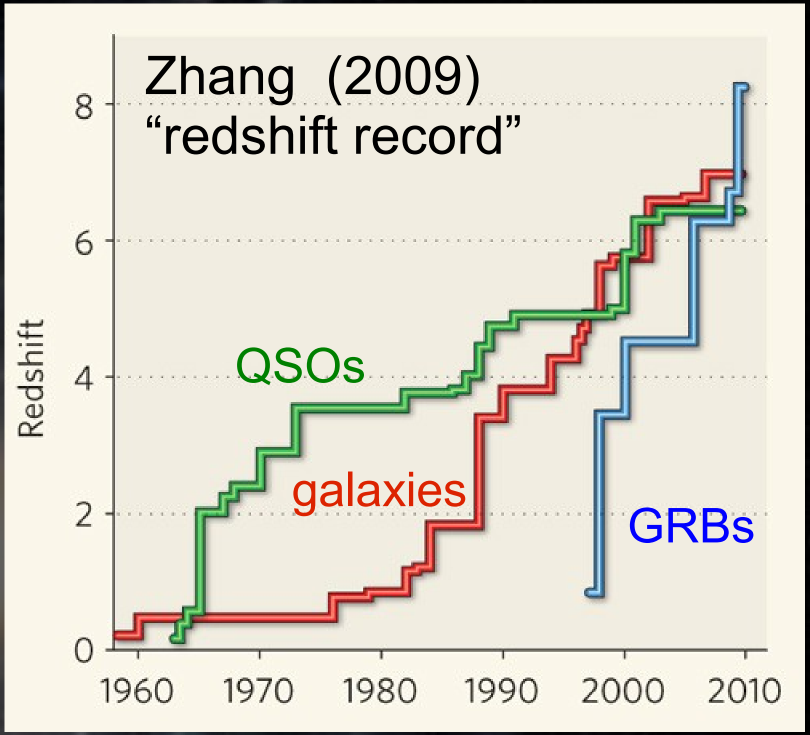
On the GRB-SFR "bias"

Gamma Ray Bursts are used to detect very high redshift galaxies and measure the evolution of the cosmic SFR (Star Formation Rate).

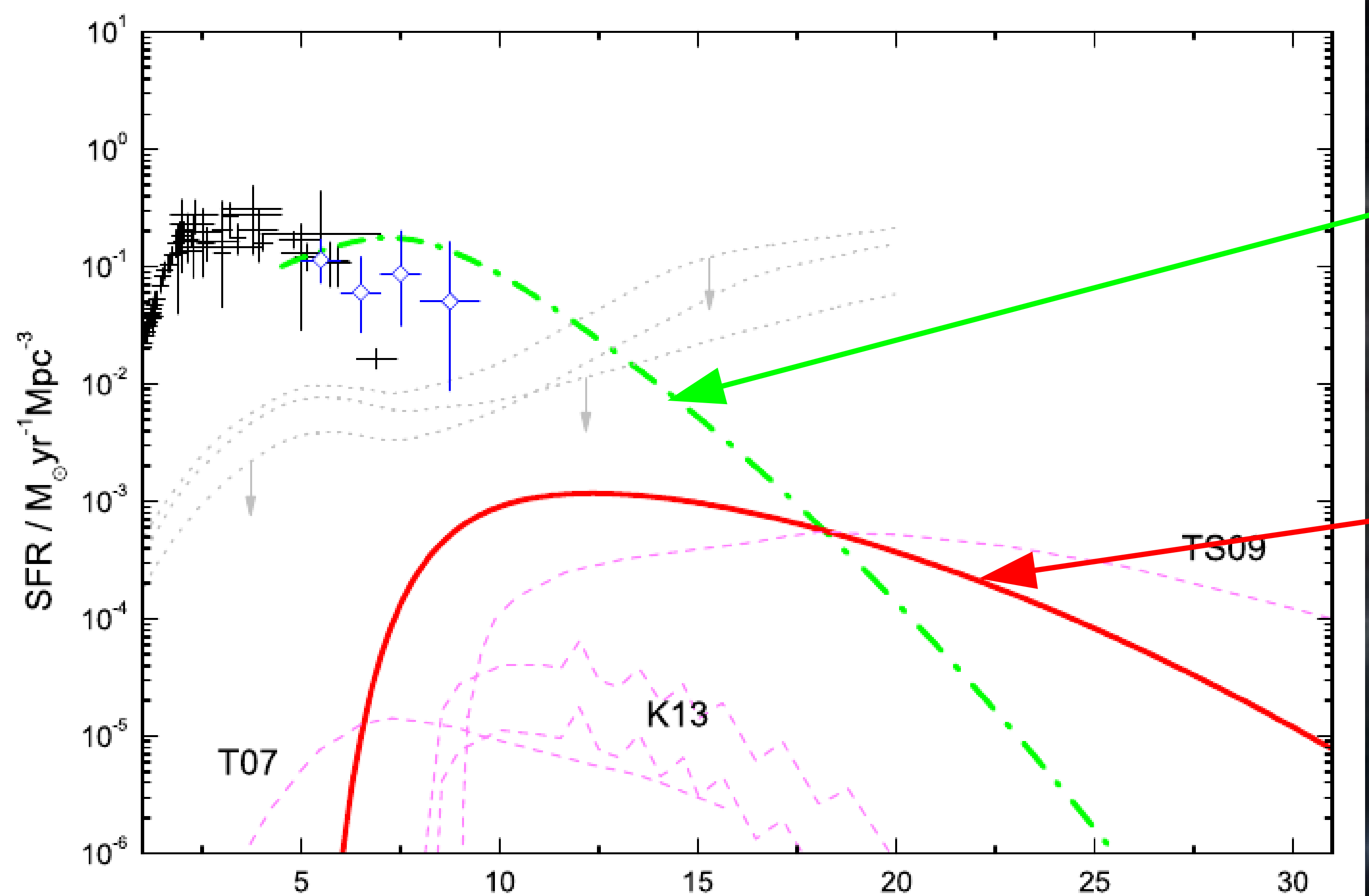




z ~ 9.4 GRB0429B
(Cucchiara et al. 2011)

For this, it is important to quantify the GRB bias B:
GRB Rate = B x SFR

On the GRB-SFR "bias"



Tan et al. (2015)

"normal" population

Primordial "pop III" population

For this, it is important to quantify the GRB bias B:
GRB Rate = B x SFR

On the GRB-SFR “bias”

- **Models of the rate of GRBs** vs redshift implementing galaxy evolution, assumptions on GRB progenitor, sensibility of instruments... -> **GRB enhanced at high redshift**

B = B0 (1+z)**n ; n=0.5 – 2.3

(e.g. Daigne et al. 2006, Kistler et al. 2009, Virgili et al. 2011, Salvaterra et al. 2011, Robertson & Ellis 2012)

- Characterizing the **properties of the hosts**
  - Studying the abundance & abundance ratios (Calura et al. 2009)
  - Low luminosities and blue colors (Le Floc’h et al. 2003), low stellar masses or star formation rates (e.g. Castro Ceron et al. 2010)
  - Lower metallicities (Modjaz et al. 2008; Levesque et al. 2010; Han et al. 2010; Mannucci et al. 2011)
  - Irregular morphologies (Fruchter et al. 2006)
  - Larger specific star formation rates (Christensen et al. 2004; Castro Ceron et al. 2006).

- In the following, we try to define a “statistical” method to infer *quantitatively* the variation of the bias B with other parameters

Measuring the bias B from SFR distributions

Number of star forming galaxies per unit logSFR:

$$dN_{SFG} = \Phi_{SFG}(\log SFR)\, d\log SFR$$

In each bin the rate of GRB per galaxy is B SFR, thus, (integrating over a given "observation" time):

$$dN_{GRB} = \underbrace{\Phi_{SFG}(\log SFR)\, B\, SFR\, d\log SFR}$$

By definition, the Host SFR distribution: Φ_{GRB}

$$B = SFR^{-1}\, \Phi_{GRB}(\log SFR) / \Phi_{SFG}(\log SFR)$$

Φ_{GRB} = SFR function of GRB hosts (e.g. GHostS database)

Φ_{SFG} = SFR function of star forming galaxies from e.g. UV , H-alpha or Far-Infra-Red surveys (e.g. Boissier et al. 2010 & ref within)

Variation of the GRB bias B with M*

The stellar mass function of star forming galaxies at redshift lower than 1 is ~ constant.

Number of star forming galaxies :

$$dN_{SFG} = \Phi_{SFG}(\log M^*)\, d\log M^*$$

In each bin the rate of GRB is B SFR, thus:

$$dN_{GRB} = \underbrace{\Phi_{SFG}(\log M^*)\, B\, SFR}\, d\log M^*$$

By definition, the Host Mass Function: Φ_{GRB}

$$B = SFR^{-1}\, \Phi_{GRB}(\log M^*)/\Phi_{SFG}(\log M^*)$$

Φ_{GRB} = M* function of GRB hosts (e.g. GHostS database)

Φ_{SFG} = M* function of star forming galaxies

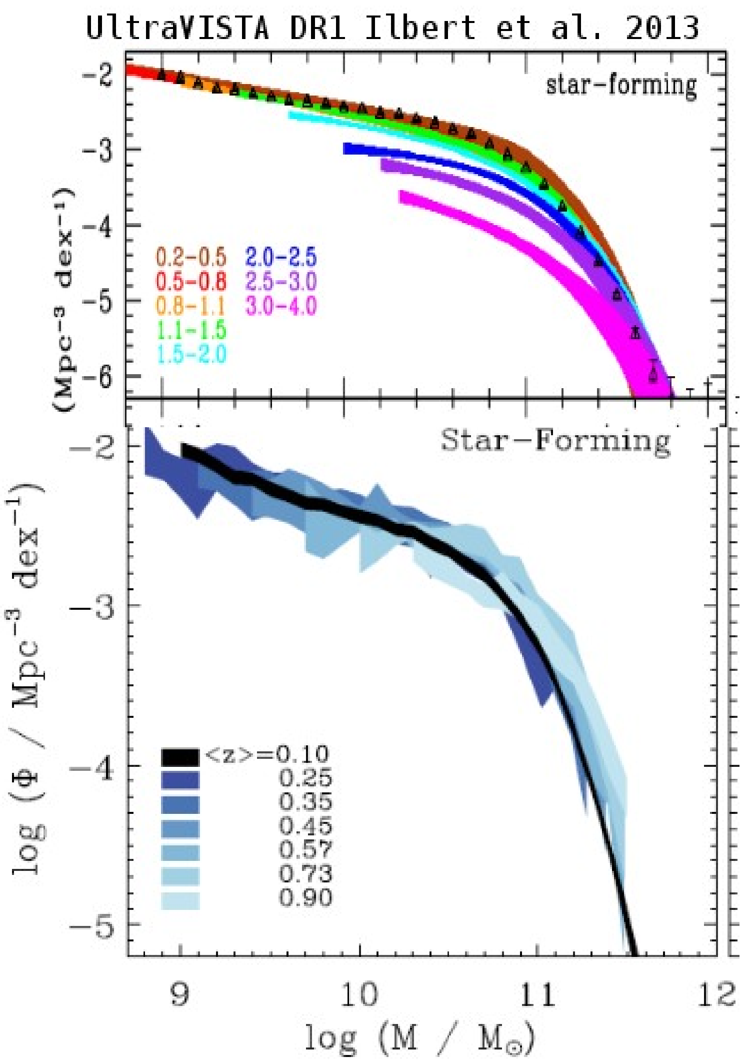
Measuring B at redshift lower than 1

Moustakas et al. (2013) or Ilbert et al.(2013) have measured ΦSFG for star forming galaxies.

ΦSFG is CONSTANT at redshift < 1

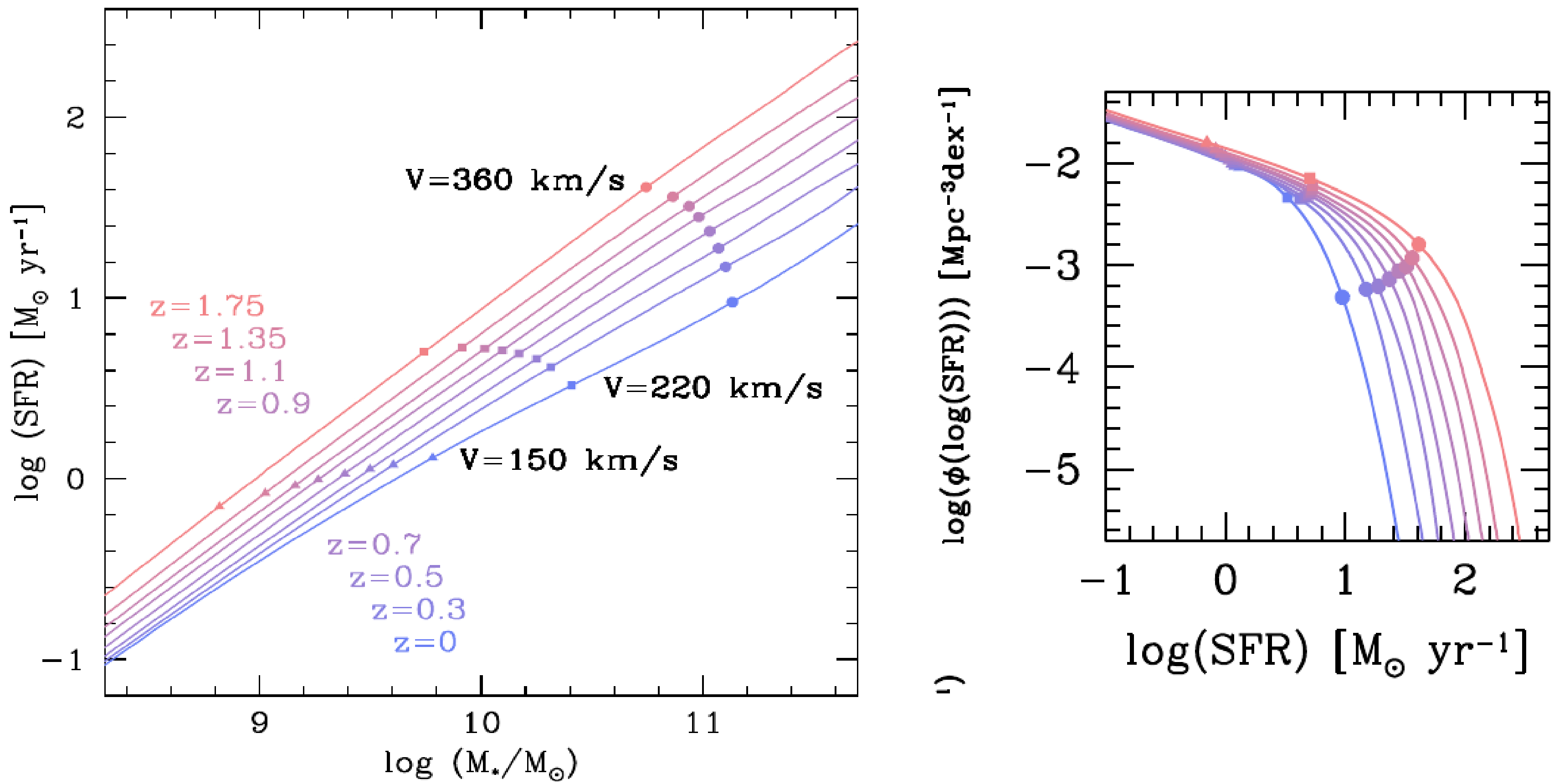
This will allow simple calculations at these redshifts.

We however still need M*-SFR relation in galaxies (Boissier et al.2010)



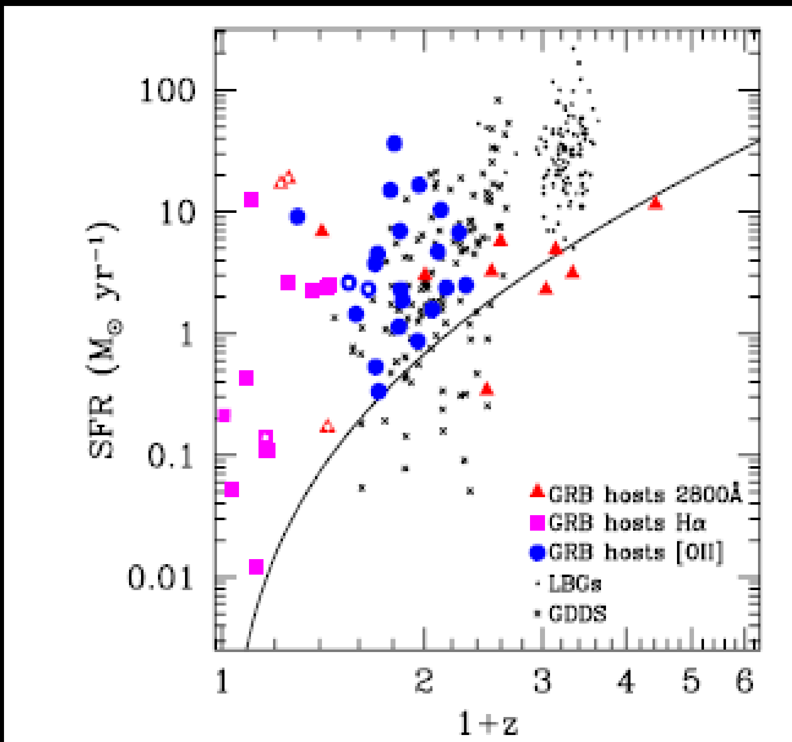
Measuring B at redshift lower than 1

For Star Forming Galaxies, we use a semi-empirical model (Boissier et al. 2010) that is contructed to reproduce the constant stellar mass function.



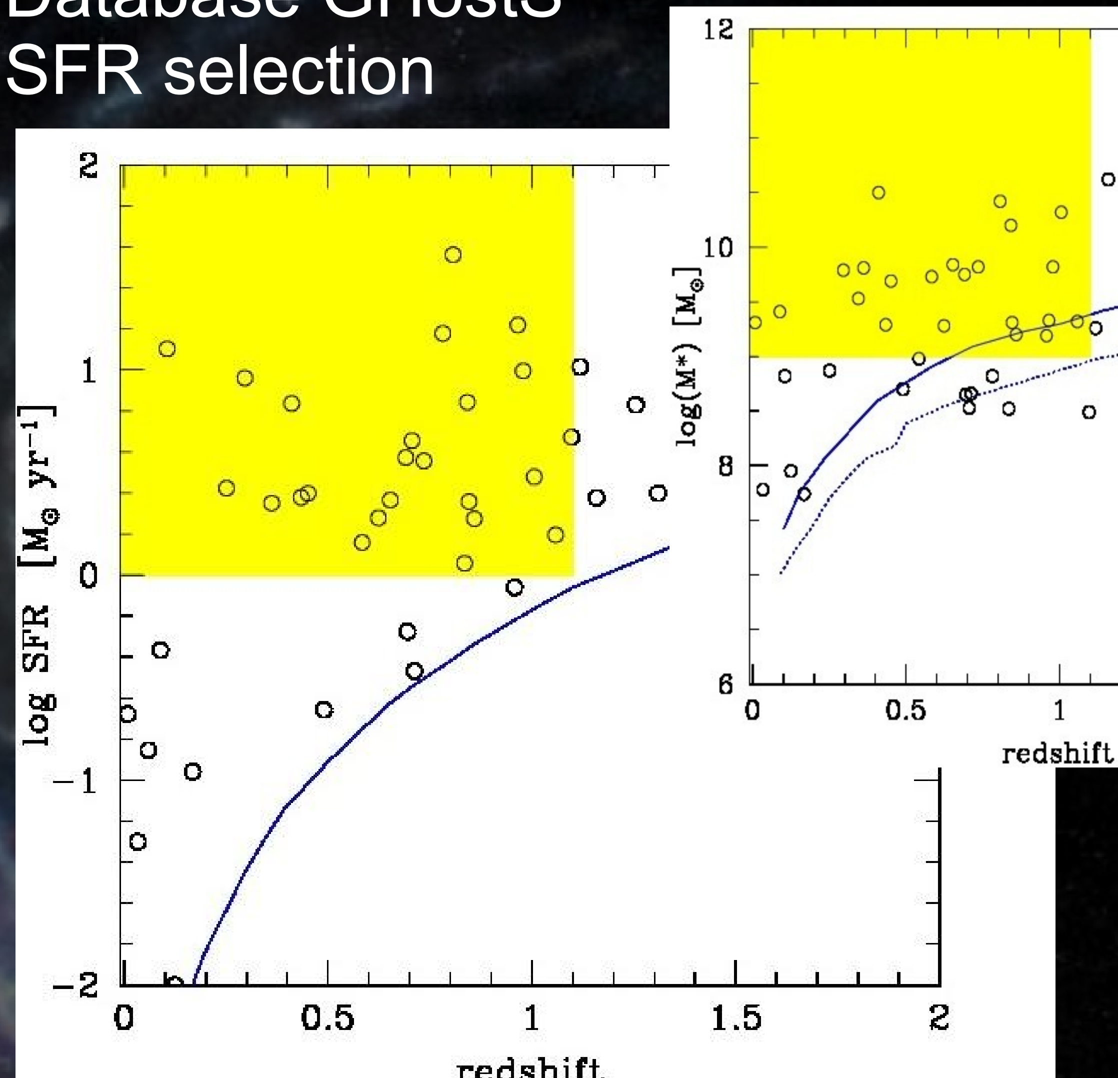
These models fit well the properties of galaxies at redshift lower than ~ 1.1

Measuring the bias B from SFR distributions



Savaglio et al. 2009

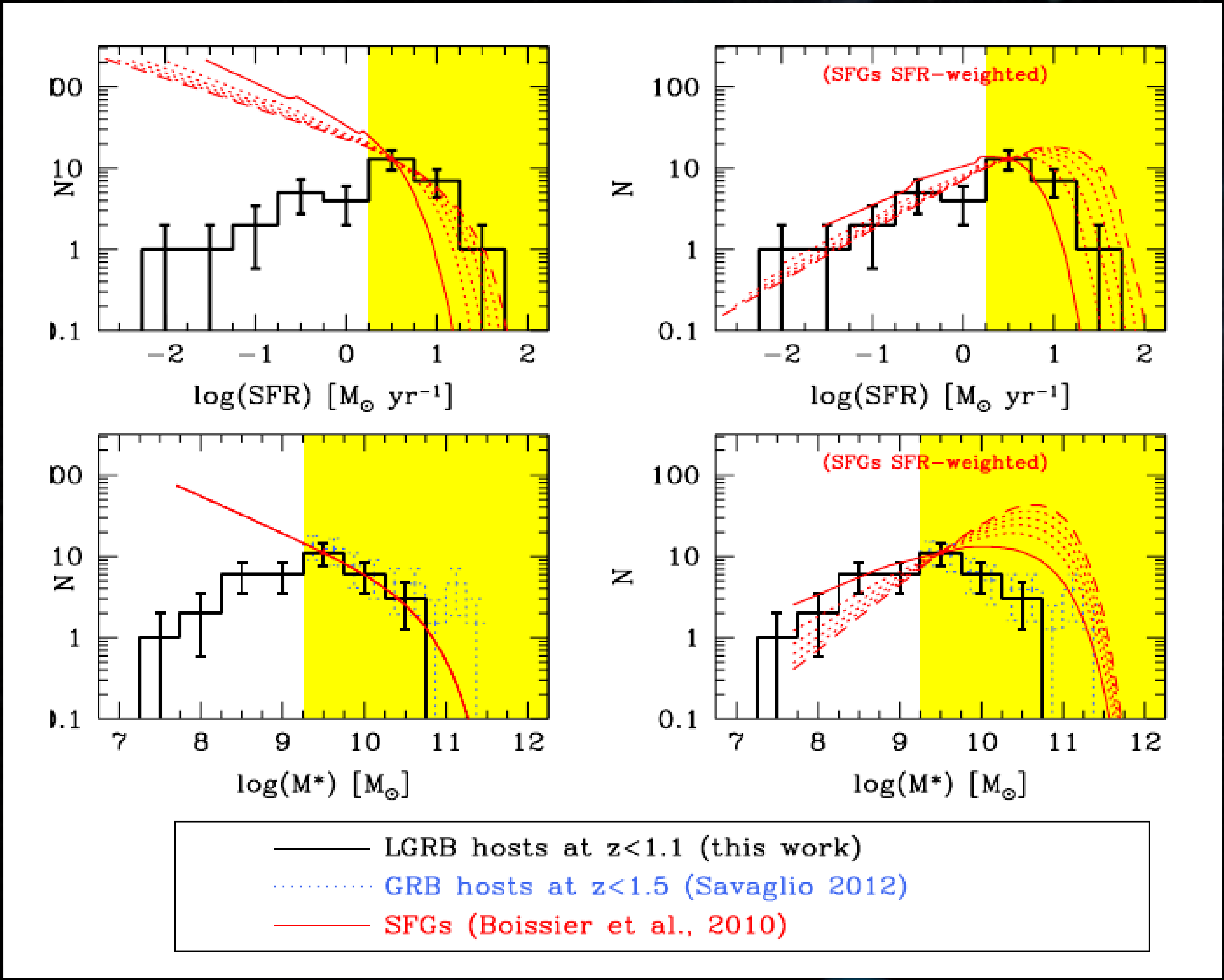
Database GHostS
SFR selection



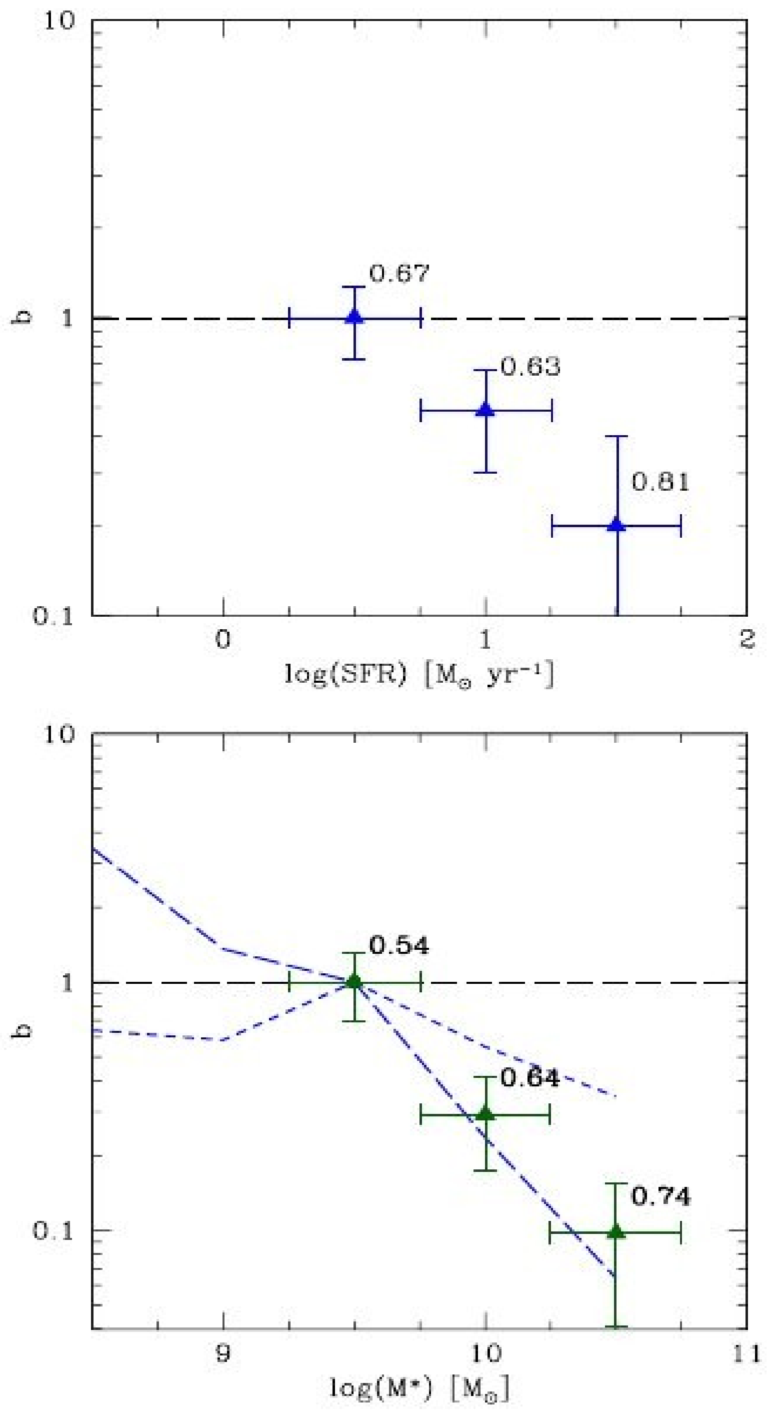
Boissier et al. (2013).

Assumptions:
-We do not miss any GRBs at redshift lower than 1.1
(or we miss GRBs in a SFR-independent way)
-We are always able to determine SFR in the yellow box.

Measuring the bias B from SFR distributions



Measuring the bias B from SFR distributions

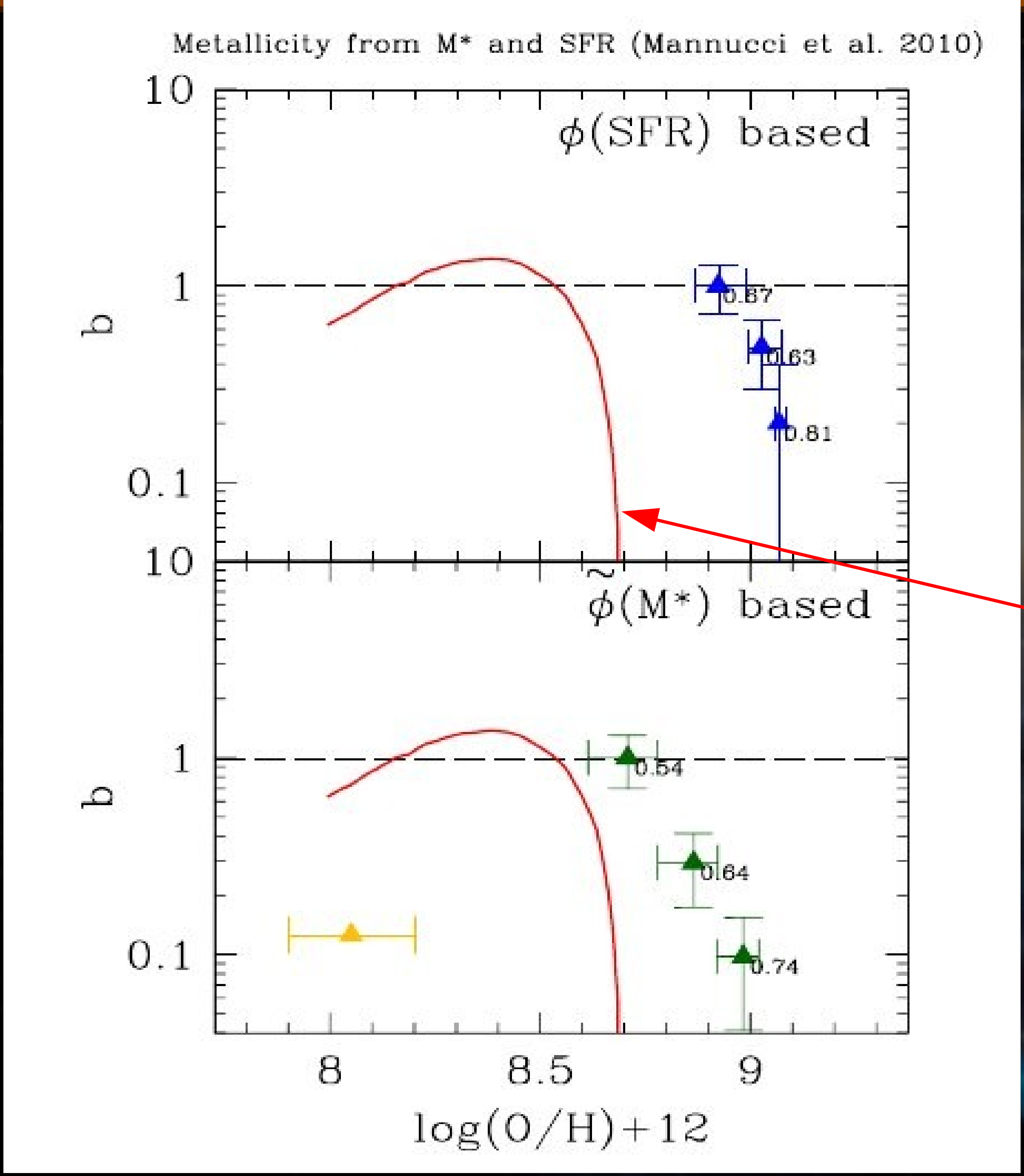


The “bias” depends on the SFR and on the stellar Mass

Limits :
-SFR functions from Boissier et al. 2010 may be not perfect
-SFR functions varies with reference

Boissier et al. (2013).

Variation of the GRB bias B with metallicity



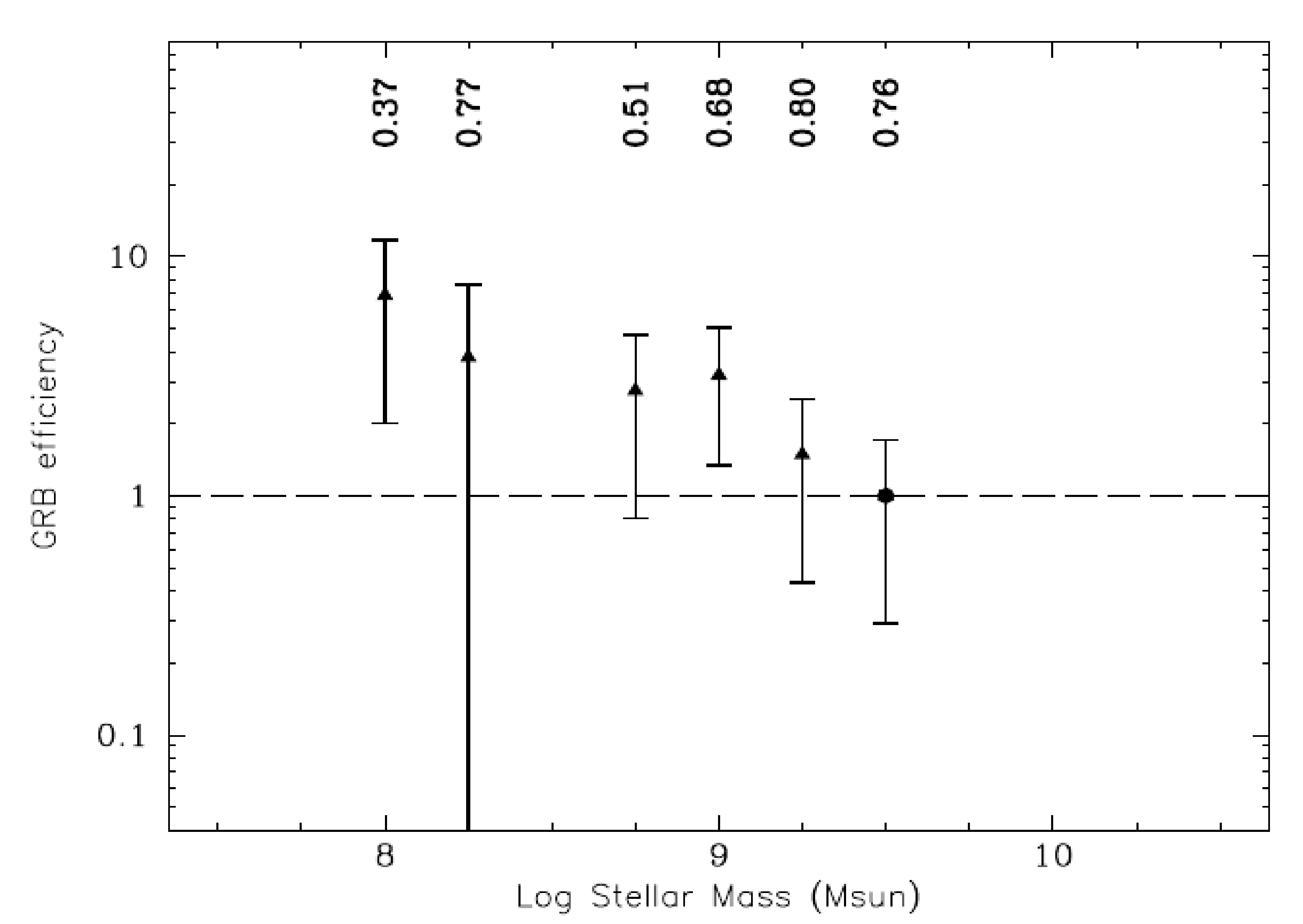
Combining the previous results with the mass-metallicity-SFR relationship (Mannucci et al. 2010), this suggests a dependence of the bias on the metallicity, that can be compared to models (e.g. Georgy et al.)

Limit: possible contribution of dark-bursts to this trend if dark bursts are in metal-rich/massive/dusty objects.

Boissier et al., (2013)

Limits: sample selection

A clean complete sample at redshift lower than 1:
Vergani et al., submitted



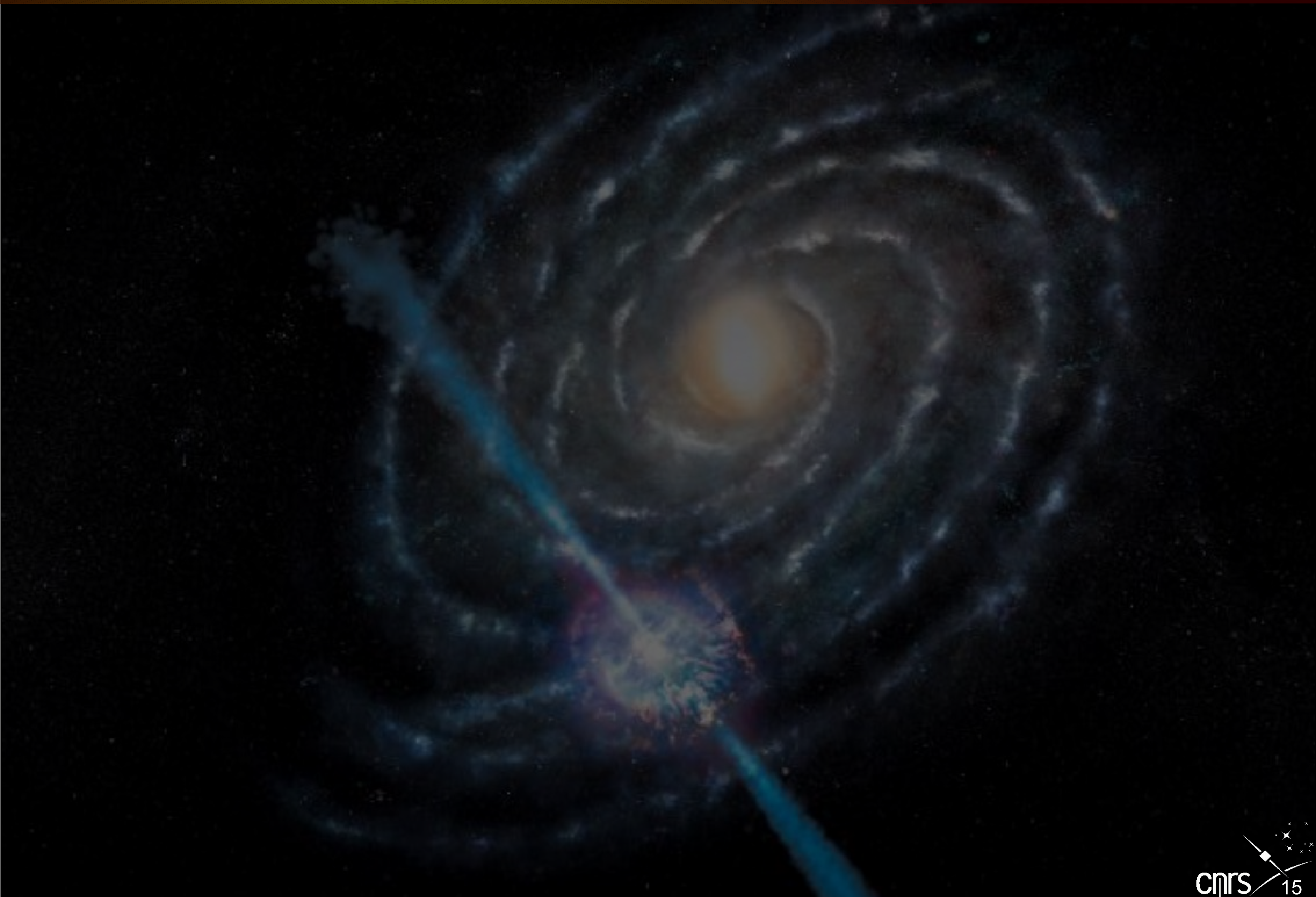
Summary & Perspectives

We have a method to study quantitatively the GRB "bias" with respect ot Star Formation for large samples.

- **Clues for the progenitors nature**
- **Constraints for the "cosmic" SFR**

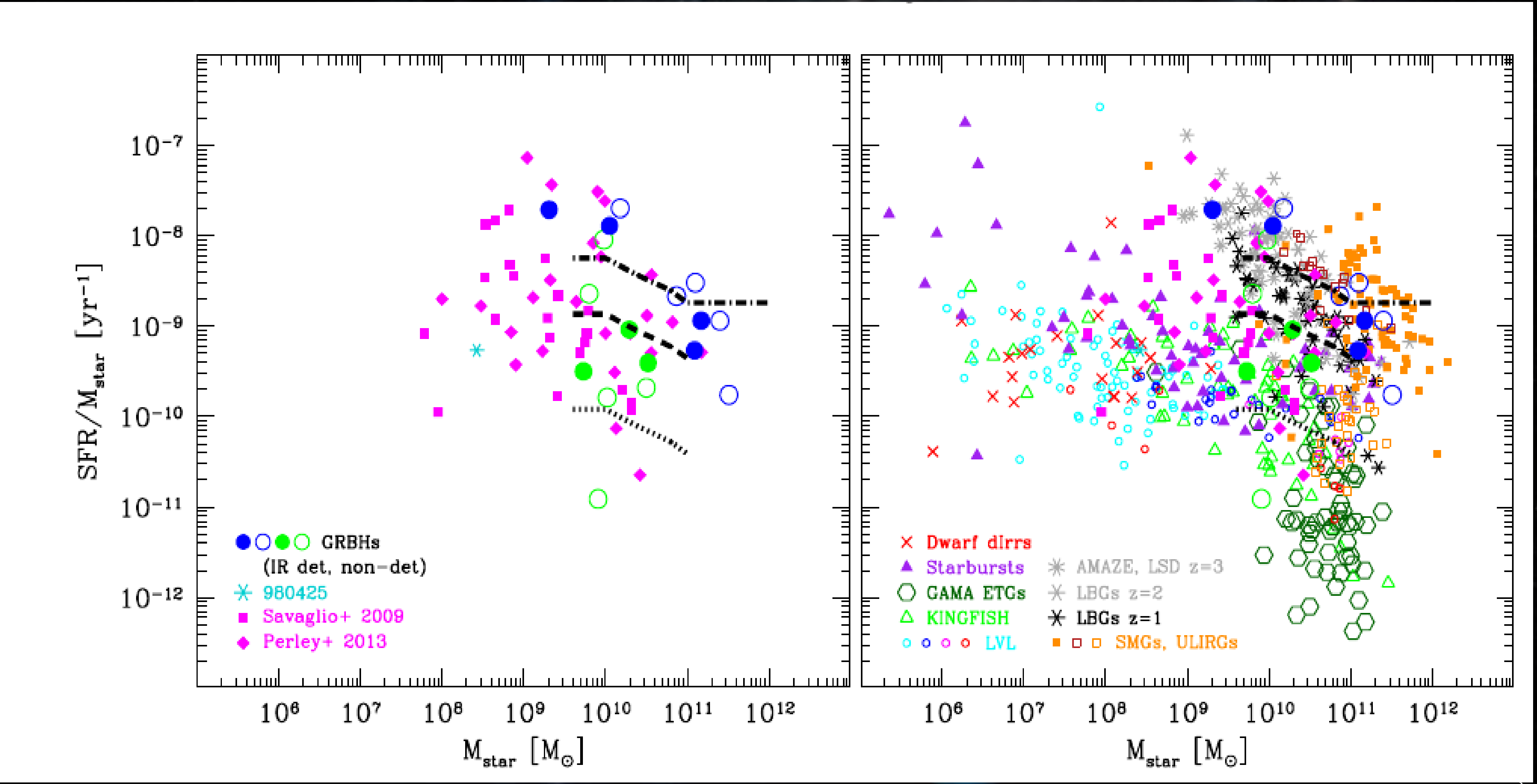
Perspectives:

- **We have large samples of GRBS.**
- **We will detect even more GRBs in the future (SVOM).**
- **Large telescopes & new instruments will bring better constraints on the properties of host galaxies.**
- **We need follow-up of complete samples of relatively low redshift GRBs.**
- **We need to improve the models (take into account the effect of interactions, increasing the SFR, push to high z).**



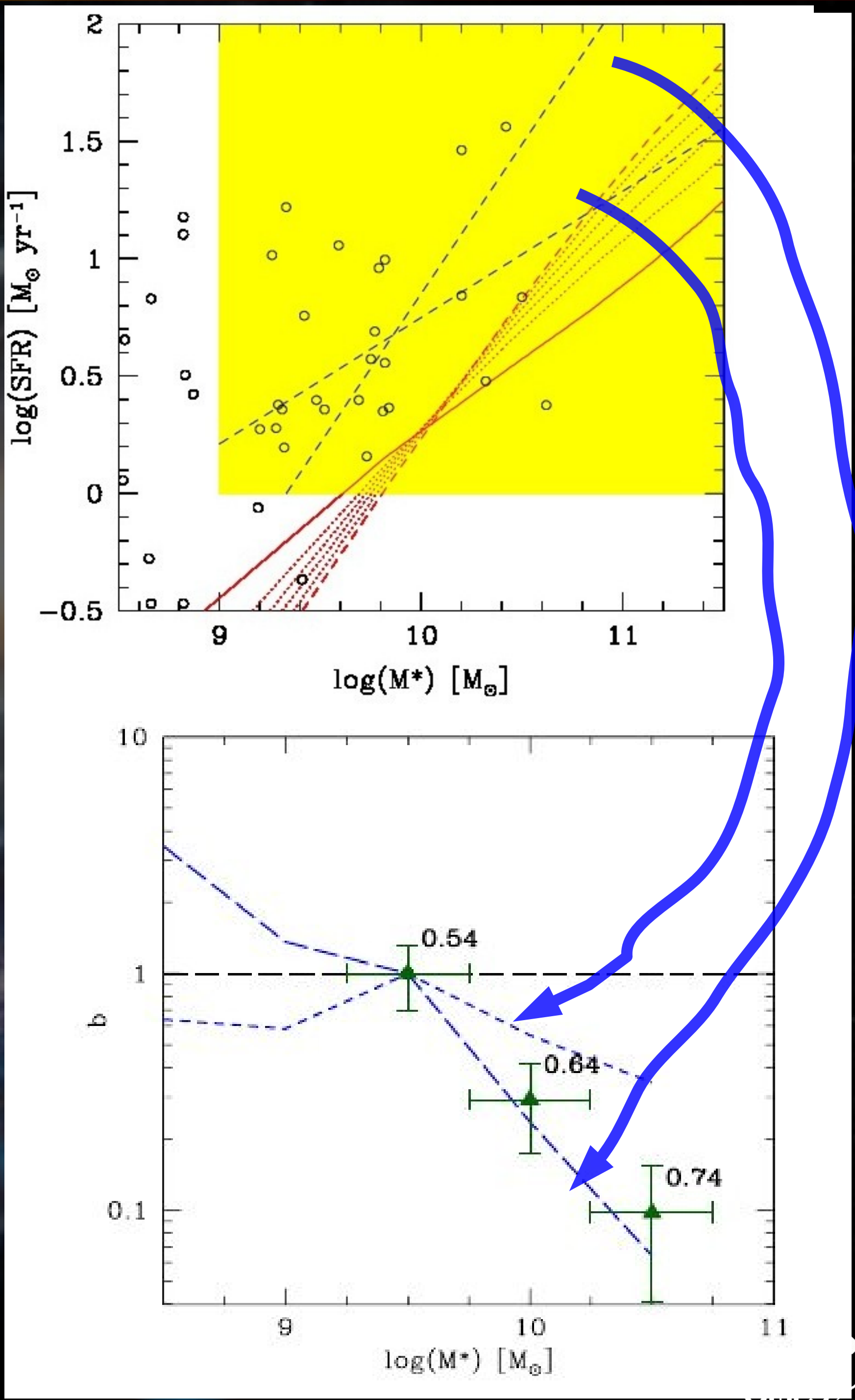
Limits: sample selection

Dark bursts, obscured bursts : we do not see them so well, and it might be correlated with metallicity
-> see Hunt et al. 2014 for the Herschel vision



Limits: specificity of the hosts galaxies

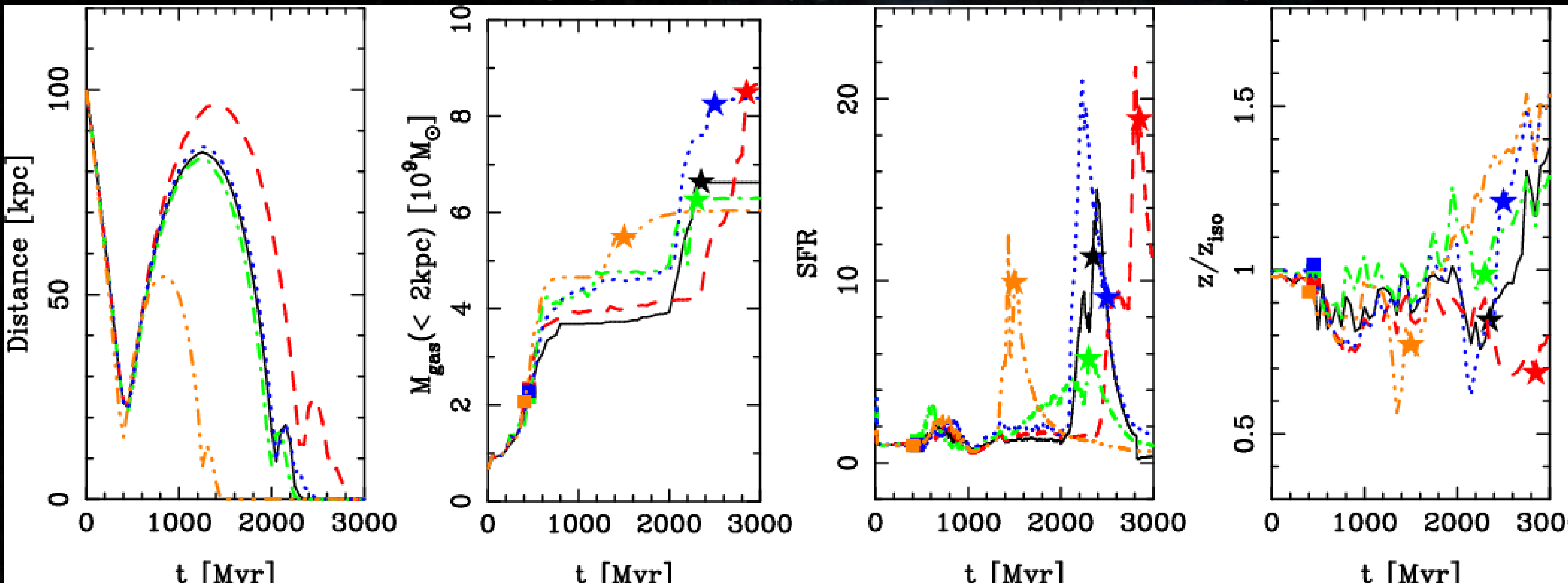
The method presented above assume that GRBs may occur in any star forming galaxies, so we use “star forming galaxies” as a “reference” and assume perfect relationships (no dispersion). However the observed SFR-stellar mass of GRB host is shifted.



Using the M*-SFR of the host: still a trend with M*.

Limits: specificity of the hosts galaxies

Simulations of interacting galaxies (Montuori et al. 2010):



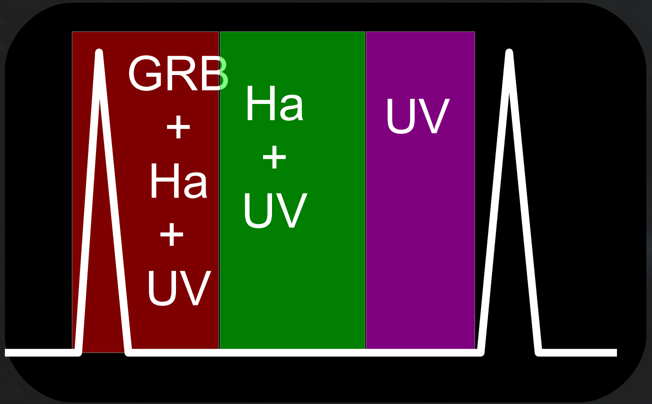
- enhancement of the SFR:
  the galaxy moves temporary above the M*-SFR relation
  and is more likely to produce GRBs
- dillusion of the metallicity due to in-flowing low-Z gas:
  the galaxy stays on the Mannucci et al. 2010 relationship

If this effect is independent of M* and of the SFR pre-interaction, our method will still work!

What may affect this bias B ?

Physics of the progenitor: **metallicity** dependence ? (e.g. Georgy et al., 2009, Niino et al.)

Variability of the SFR History



IMF: Initial Mass Function