Stellar mass and Star Formation surface densities in GRB hosts compared to field galaxies: evidence of a trend with redshift

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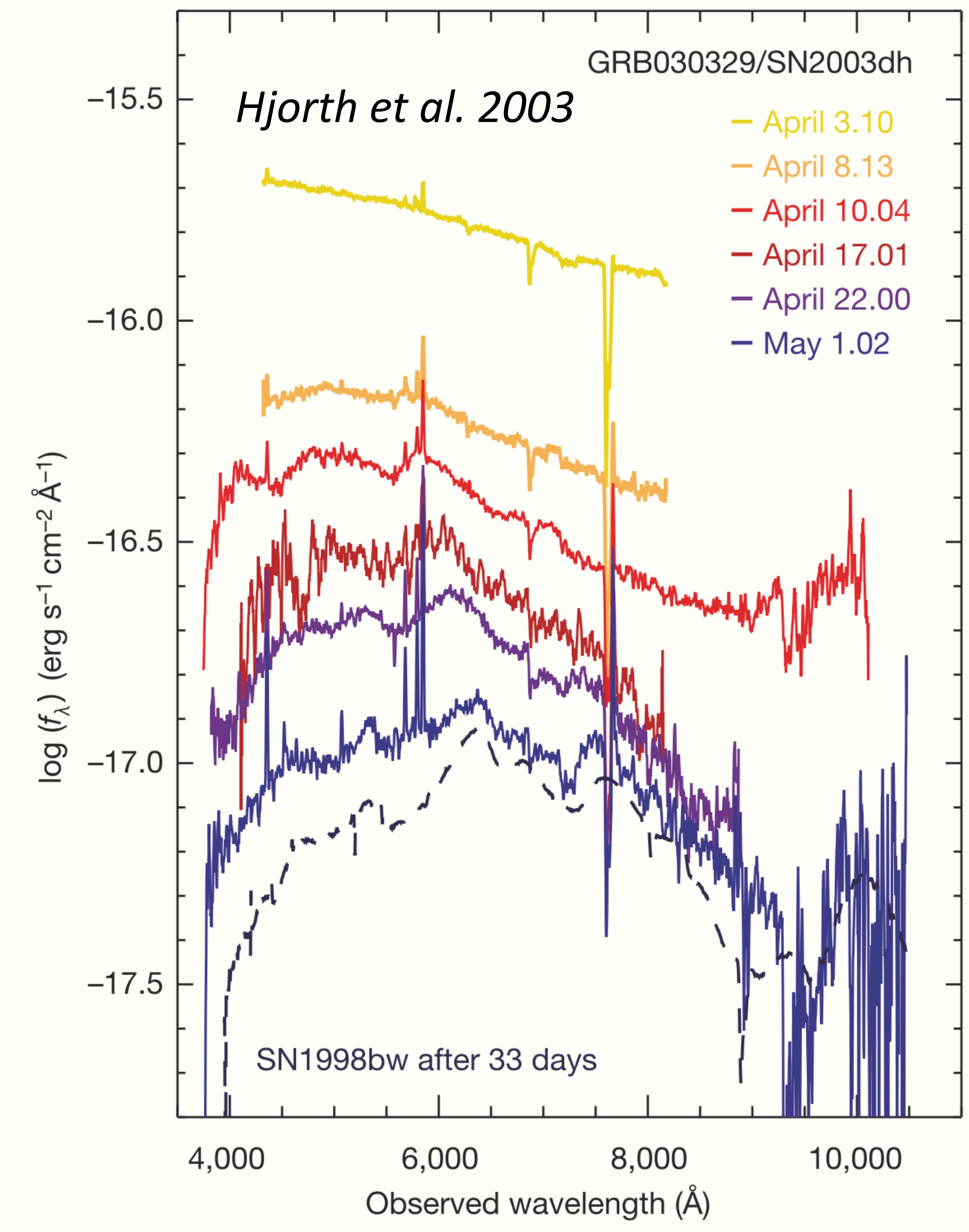
Gamma Ray Bursts (GRBs)

- GRBs are extreme explosive phenomena :
  - Highly energetic : $E_\gamma = 10^{53}$ erg
  - Very short : from few seconds to few minutes
  - Random in the sky

- Two classes of GRB :
  - Short-duration gamma ray bursts (SGRBs)
  - **Long-duration gamma ray bursts** (LGRBs)

- Connected to the **death of massive stars** :
  - Suggested theoretically in the 1990s (*Woosley 1993*)
  - LGRB favoured in **faint, blue, actively** and **star-forming** galaxies (e.g *Le Floc'h et al. 2003*)
  - LGRB occurred in the **UV-bright regions** of their host galaxies (e.g *Fruchter et al. 2006* + *Lyman et al. 2017*)
  - **Spatial** and **temporal coincidence** of a supernova and a LGRB (e.g *Hjorth et al. 2003*)

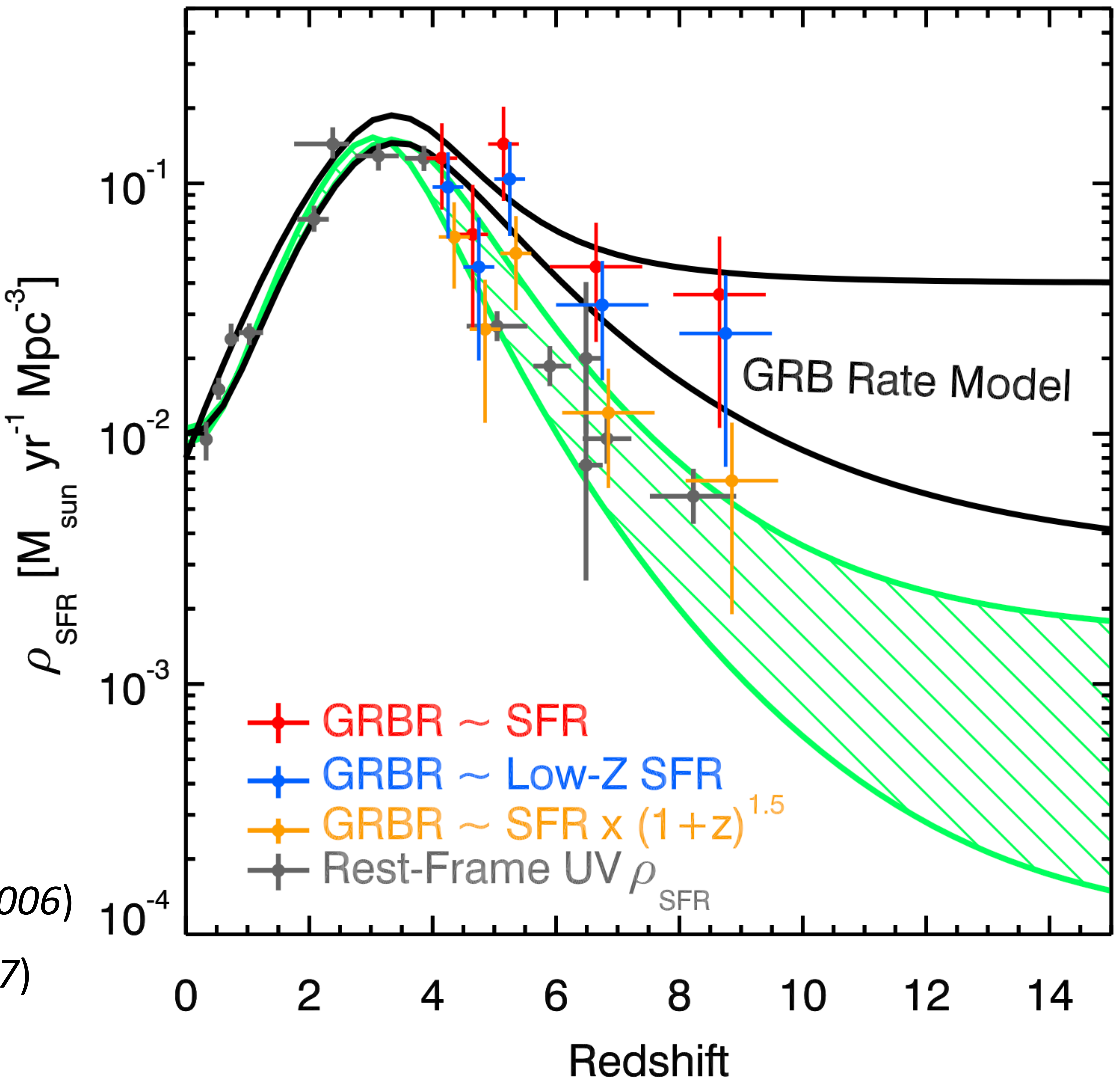


Star Formation History and GRB progenitors

- Due to the short life-time of massive stars (< 50-100 millions years) :
  - ⇒ GRBs are linked to the recent Star Formation inside their host galaxy
  - ⇒ The GRB rate could constraint the **Star Formation History**

- Tension at high redshift ($z > 4$) between SFRD derived from UV-selected galaxies and GRB predictions.
  - Values from UV-selected galaxies underestimated?
    Discovery of 39 massive star-forming and dusty galaxies at $z > 3$ (Wang+19)
  - Do GRBs trace the SFR in an unbiased way?

- First clues from theory : GRBs associated with **SN Ic-BL**
  - **Single-star** collapsar model → fast-spinning star with low metallicity (*Yoon et al. 2006*)
  - **Binary-star** model with tidal interactions (*Fryer & Heger 2005 + Cantiello et al 2007*)



Robertson+Ellis 2012

Possible bias

What can we learn from the host galaxy?

Driven factor for the production of GRBs:

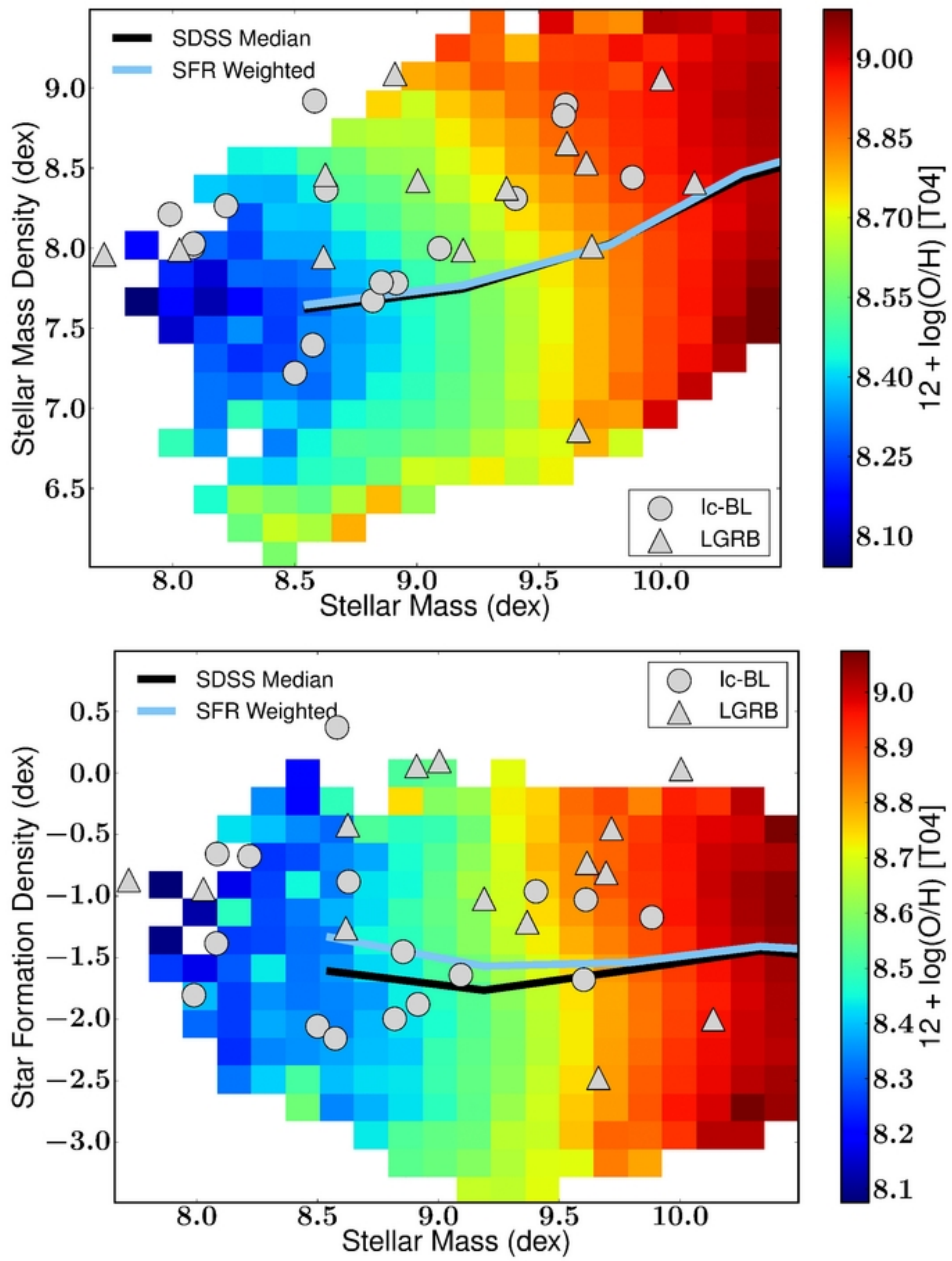
- Low metallicity environment: $Z_{\text{th}} < (0.5 - 1.0)\, Z_{\odot}$ (*Vergani et al. 2015, Perley et al. 2016b, Palmerio et al. 2019)*
  → Due to the cosmic evolution, this bias should disappear at z > 3

Is metallicity alone sufficient?

- Extreme star-formation intensity (*Perley et al. 2015*)
  → LGRB rate enhanced in intense starbursts
- Gas inflow (*Michalowski et al. 2016*)
- Interactions and mergers of galaxies (Arabsalmani et al. 2019)
- **Stellar density** (*Kelly et al. 2014*)
  → preference for high M_{*} and SF surface densities until z < 1.2

Star Formation surface density $= \Sigma_{\text{SFR}} = \log\left(\frac{\text{SFR}/2}{\pi R_e^2}\right)$

How does the density parameter evolve at higher redshift?



Kelly et al. 2014

Sample selection

Selection of the GRB host galaxies :

(1) Selected all GRBs with a redshift estimation

(2) Identified those with **HST - WFC3/F160W** data

(3) Assignment of the host galaxie reported in the literature

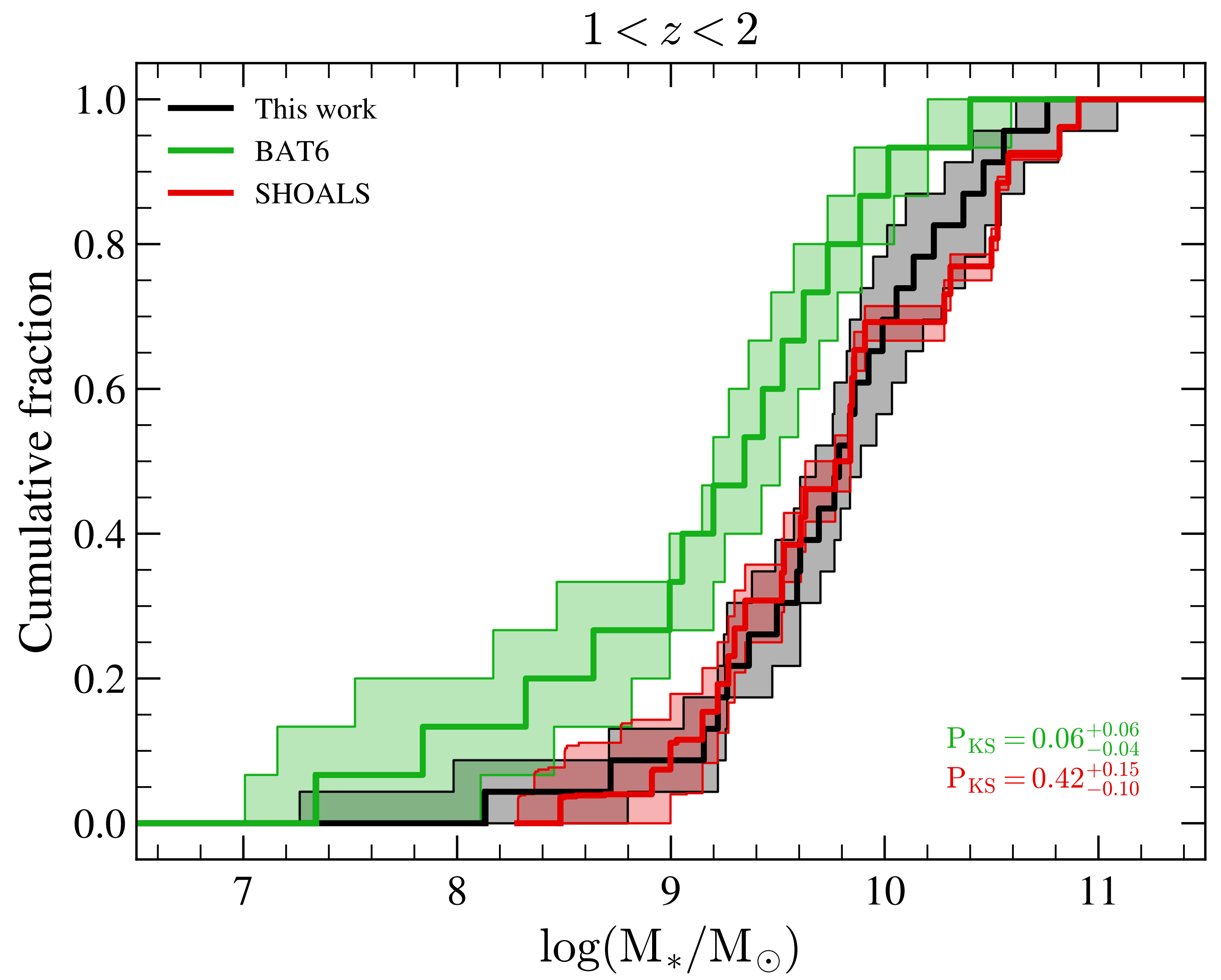
(4) Removed suspicious cases

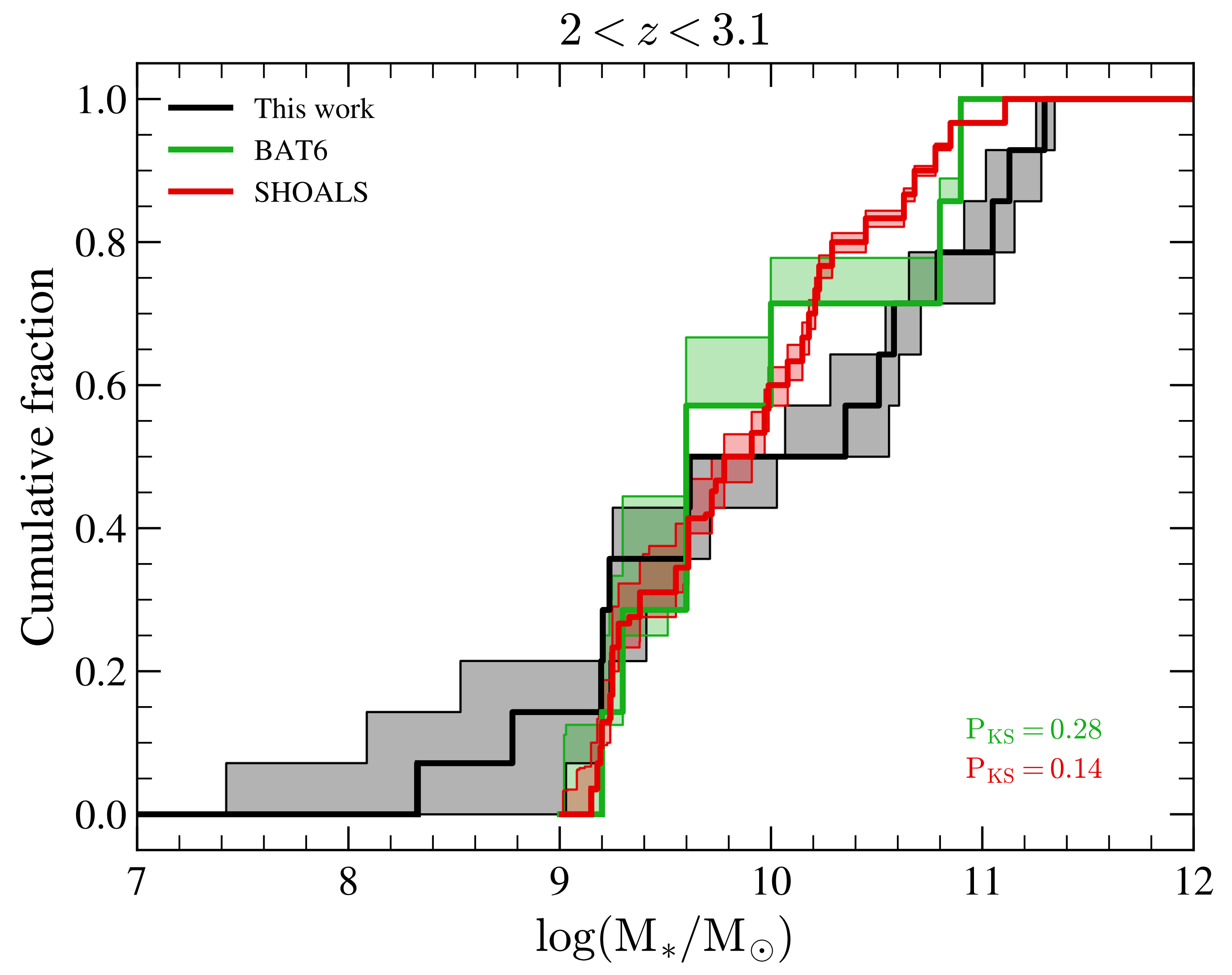
Redshift bin	1 < z < 2	2 < z < 3.1
(1) All GRBs	148	126
(2) HST images	28	16
(3) Hosts detected	24	14
(4) Total	23	14

⚠ Possible selection bias :

- Require a precise localisation of the GRB to measure z
- Require HST observations

⇒ Comparaison to unbiased GRBs sample such as **SHOALS** or **BAT6** using a script kindly provided by Jesse Palmerio (*Palmerio et al. 2019*)





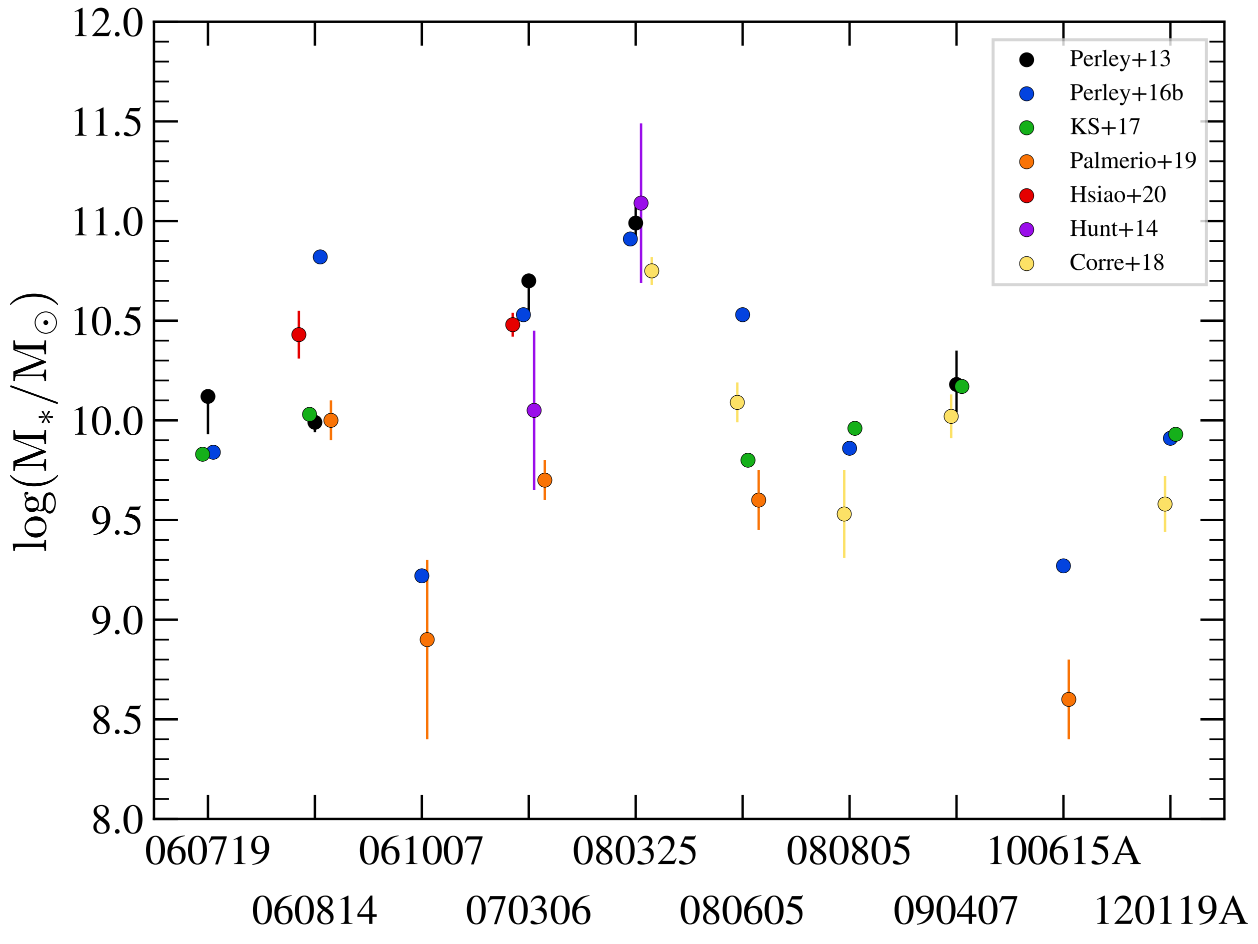
Physical properties of GRB hosts

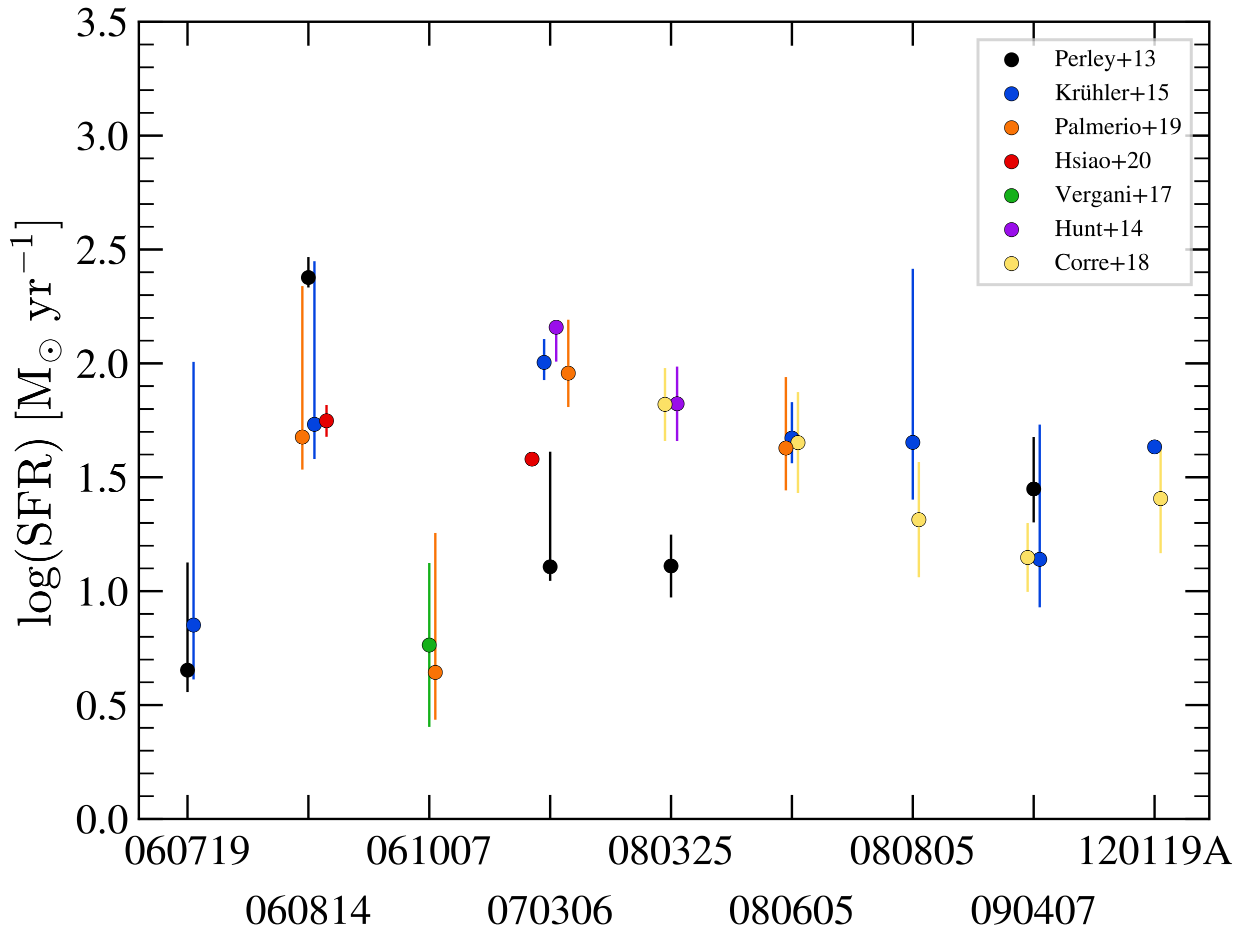
Compilation of M_* and SFR from the literature :

(1) SED with FIR measurement using energy balance code * (e.g CIGALE)

(2) SED with Optic/IR measurement * (e.g LePhare)

(3) M/L ratio, SFR_{H_α}





If no estimation are available → derived our M_* using a M/L ratio :

(1) Select all objects at $z_{target} \pm 0.1$ from COSMOS2015 (*Laigle et al. 2016*)

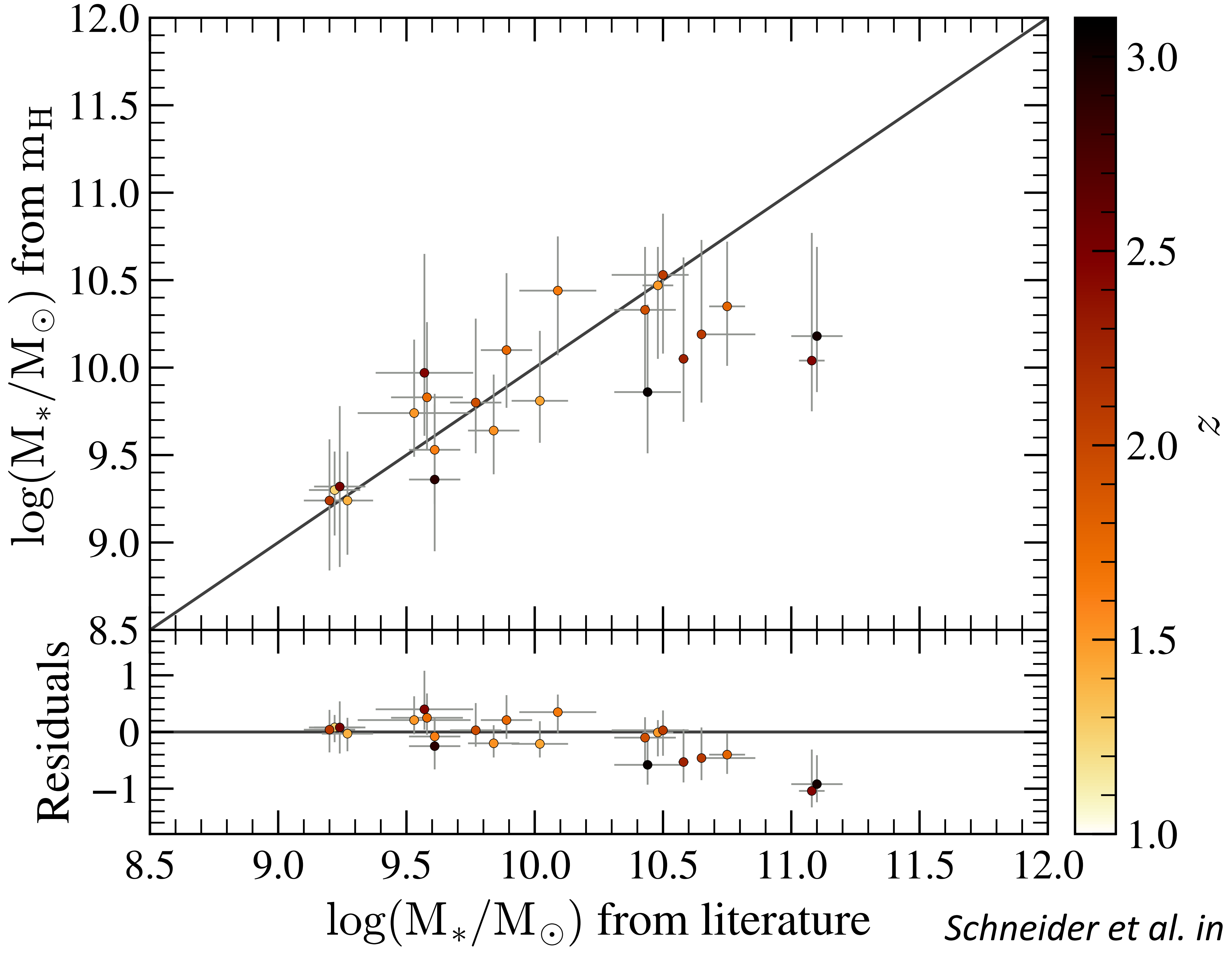
(2) Fit the relation $M_* = a \times H_{mag} + b$

(3) Derive the F160W AB magnitude from HST image

(4) Correct color filter (F160W → H band) and galactic extinction

(5) Apply the M/L to the corrected magnitude

(6) Propagate the magnitude error



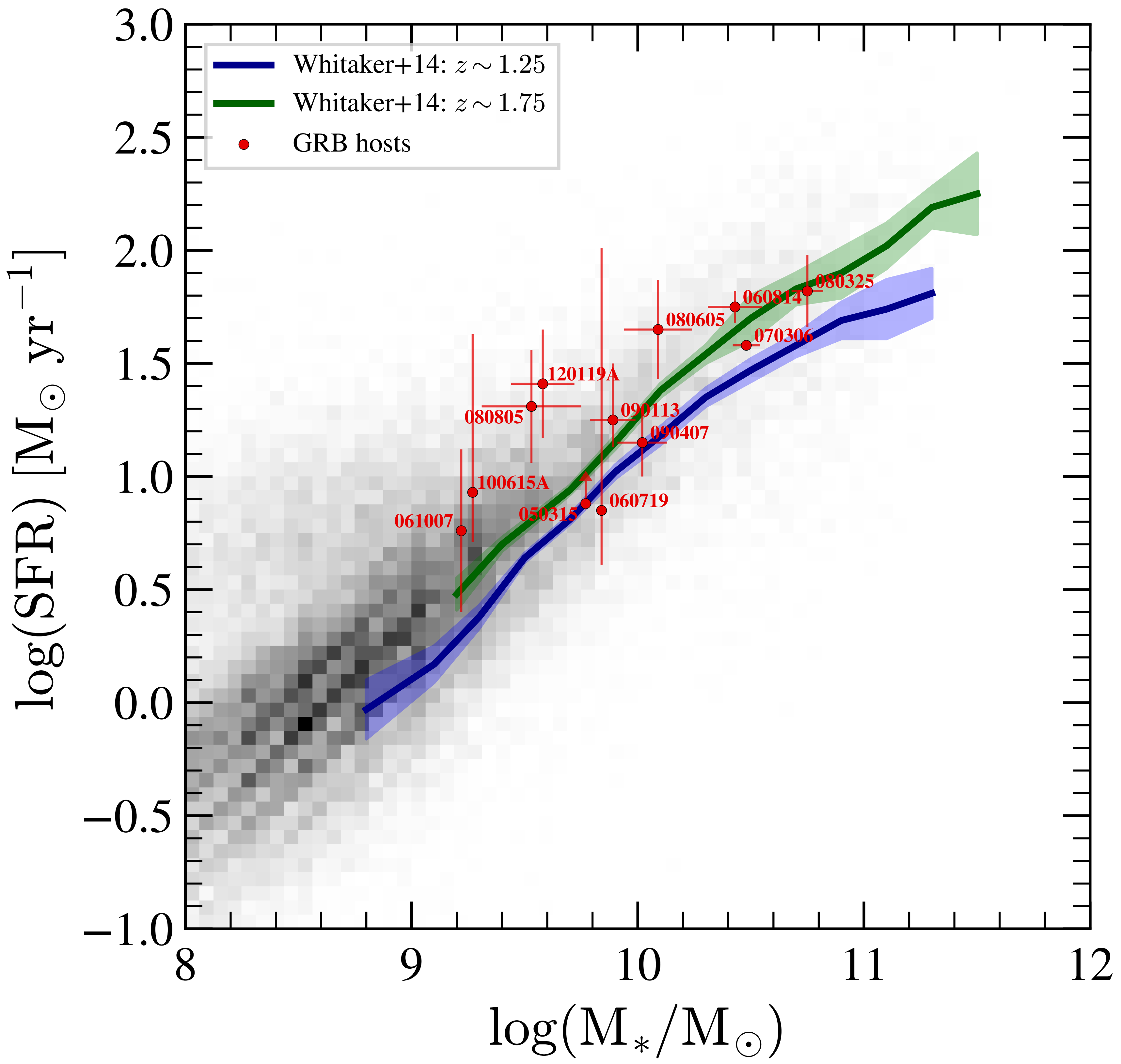
Schneider et al. in prep.

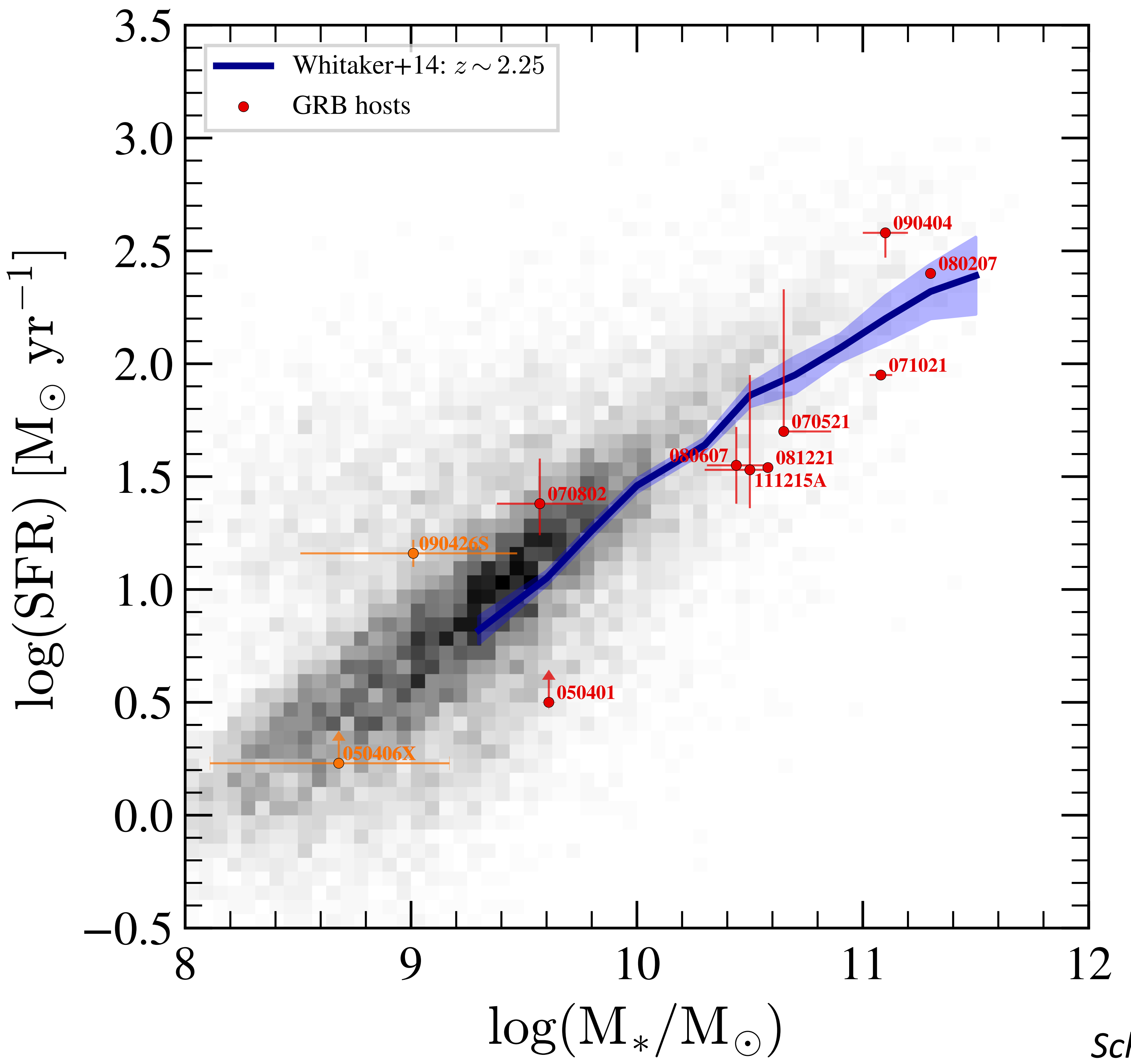
* converted to same IMF (*Chabrier 2003*)

The star-forming Main Sequence

Reference sample from a deep survey :

- **3D-HST** (*Skelton et al. 2014*) **=** CANDELS (NIR Deep Extragalactic Legacy Survey) + WFC3 spectroscopic
- Composed of 5 extragalactic fields
  → AEGIS, COSMOS, GOODS-North, GOODS-South and UDS
  → Redshift, SFR and M_* are available for more than 150 000 objects





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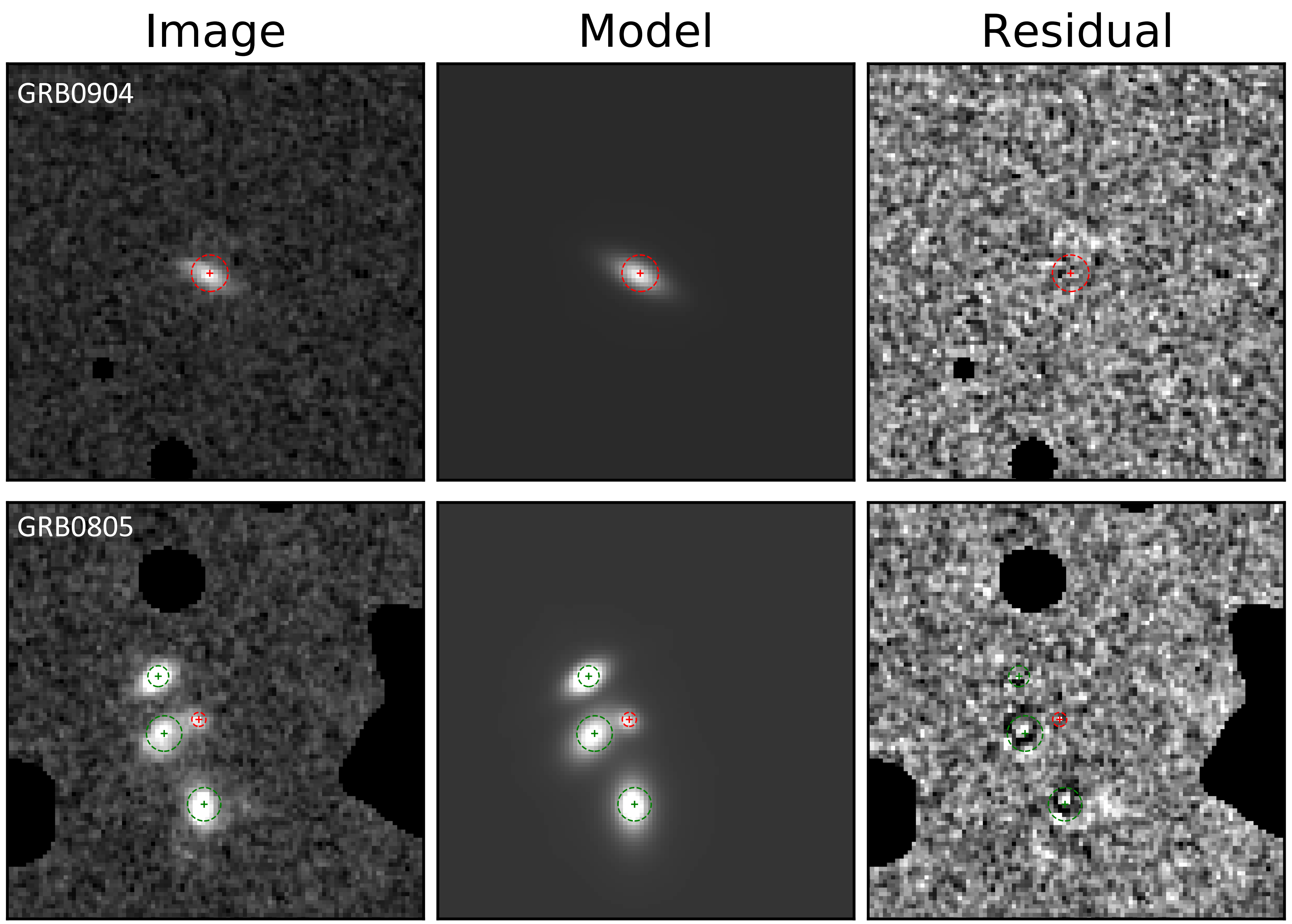
Half light radius

Derive the Σ_{M} and Σ_{SFR} require the half light radius (R_e)

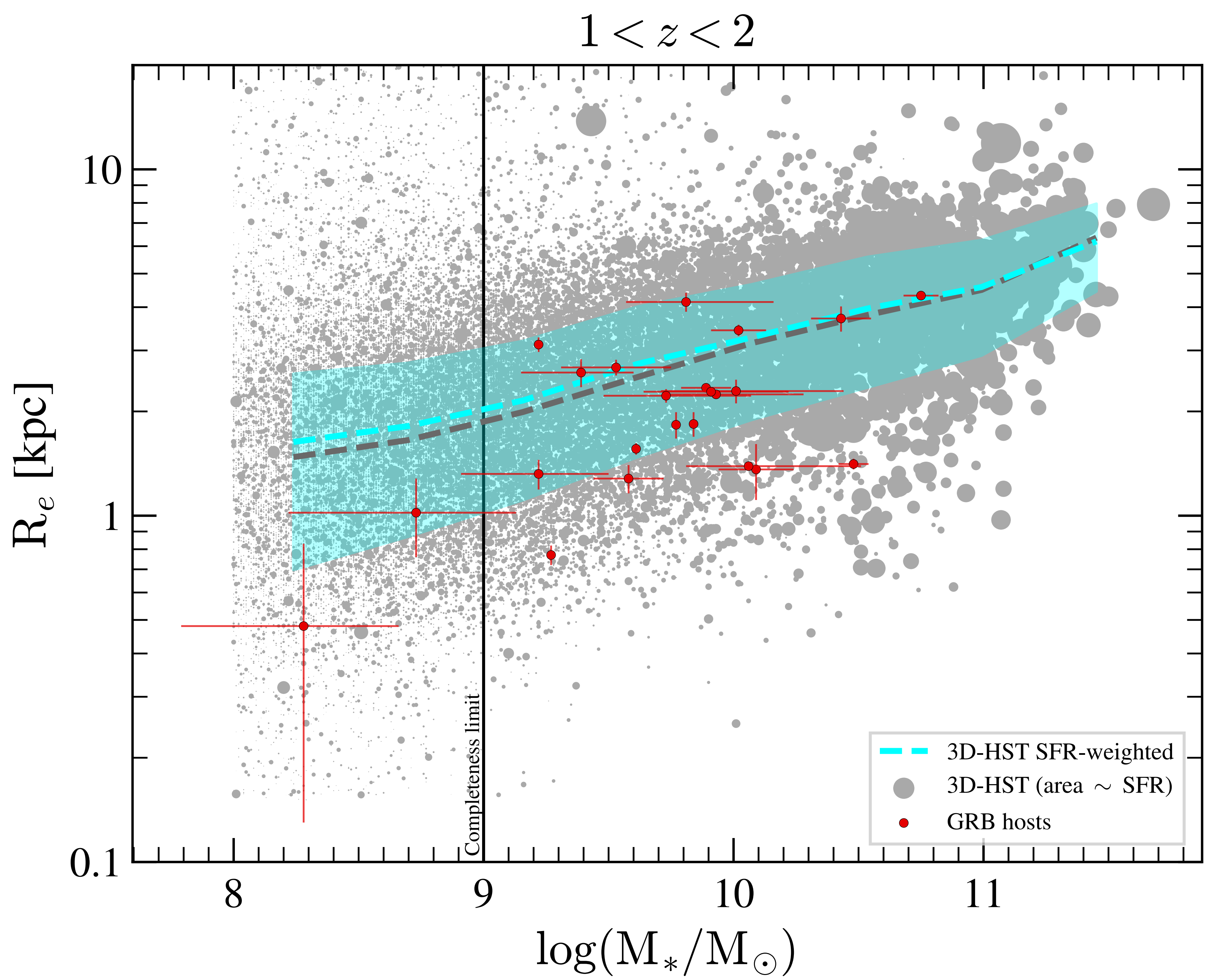
- Parametric approach using **GALFIT** (*Peng et al. 2010*)
  → 2D fitting algorithm
  → Fit the surface brightness with a **single** Sérsic profile :
  → return 6 parameters :
    - (x, y)
    - AB mag
    - R_e
    - n
    - axis ratio
    - position angle

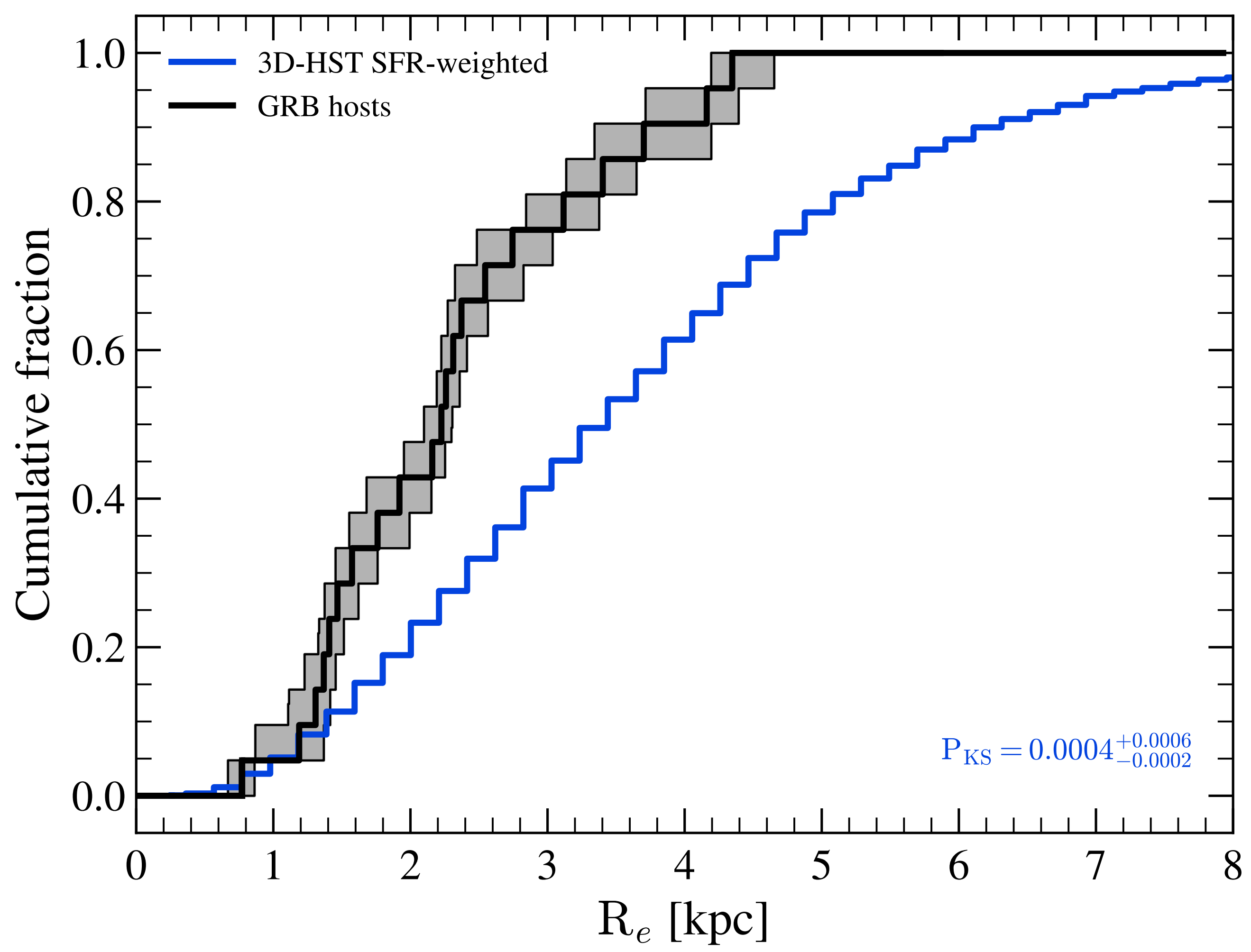
- Tested our pipeline on **3D-HST** objects (*van der Wel et al. 2014*)
  → control sample composed of more than **4,000 objects** randomly selected between 21 < mag < 28
  → good agreement between 3D-HST and our results

- Apply GALFIT on the HST image of the GRB host galaxies



Masse/size relation





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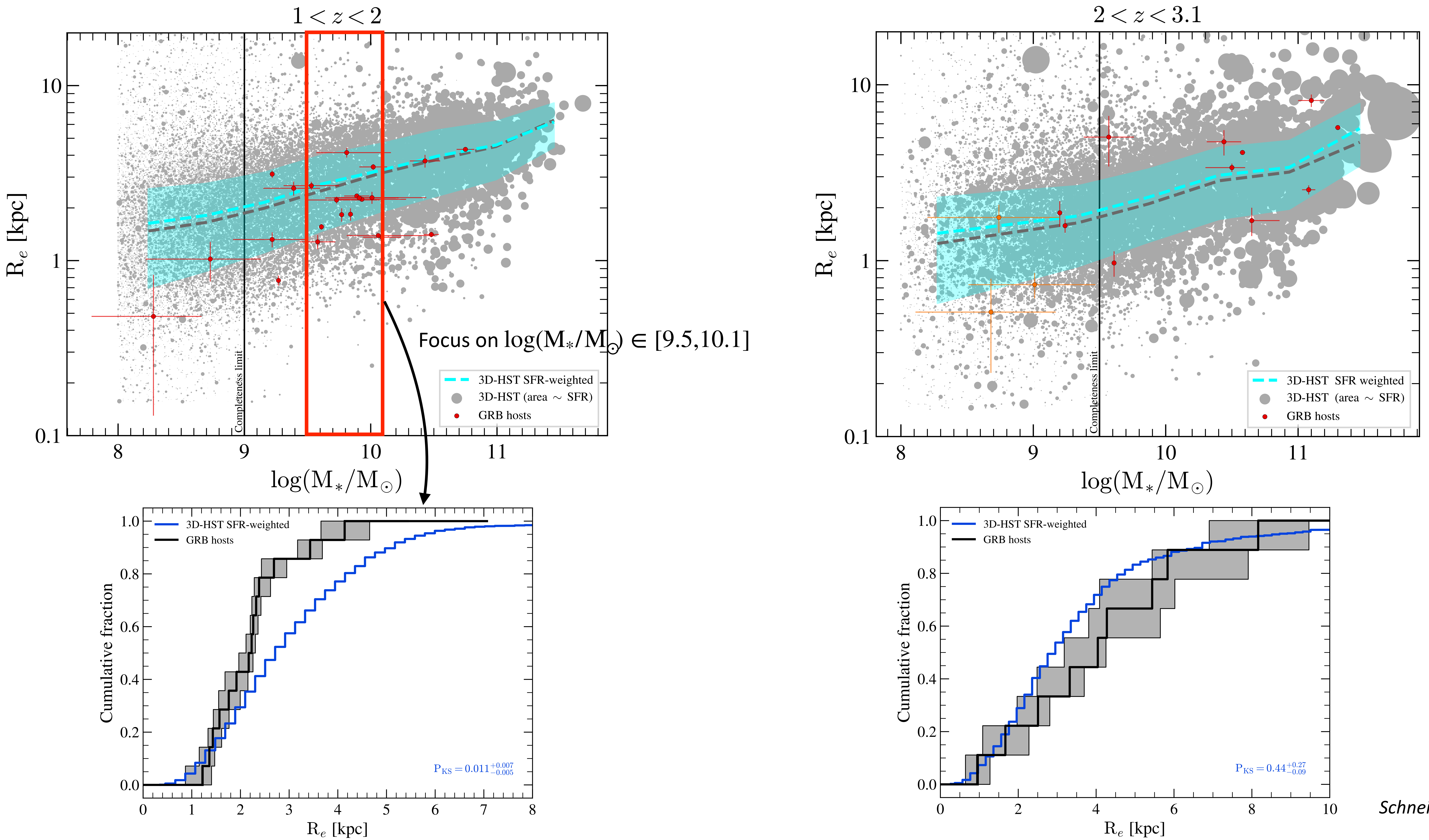

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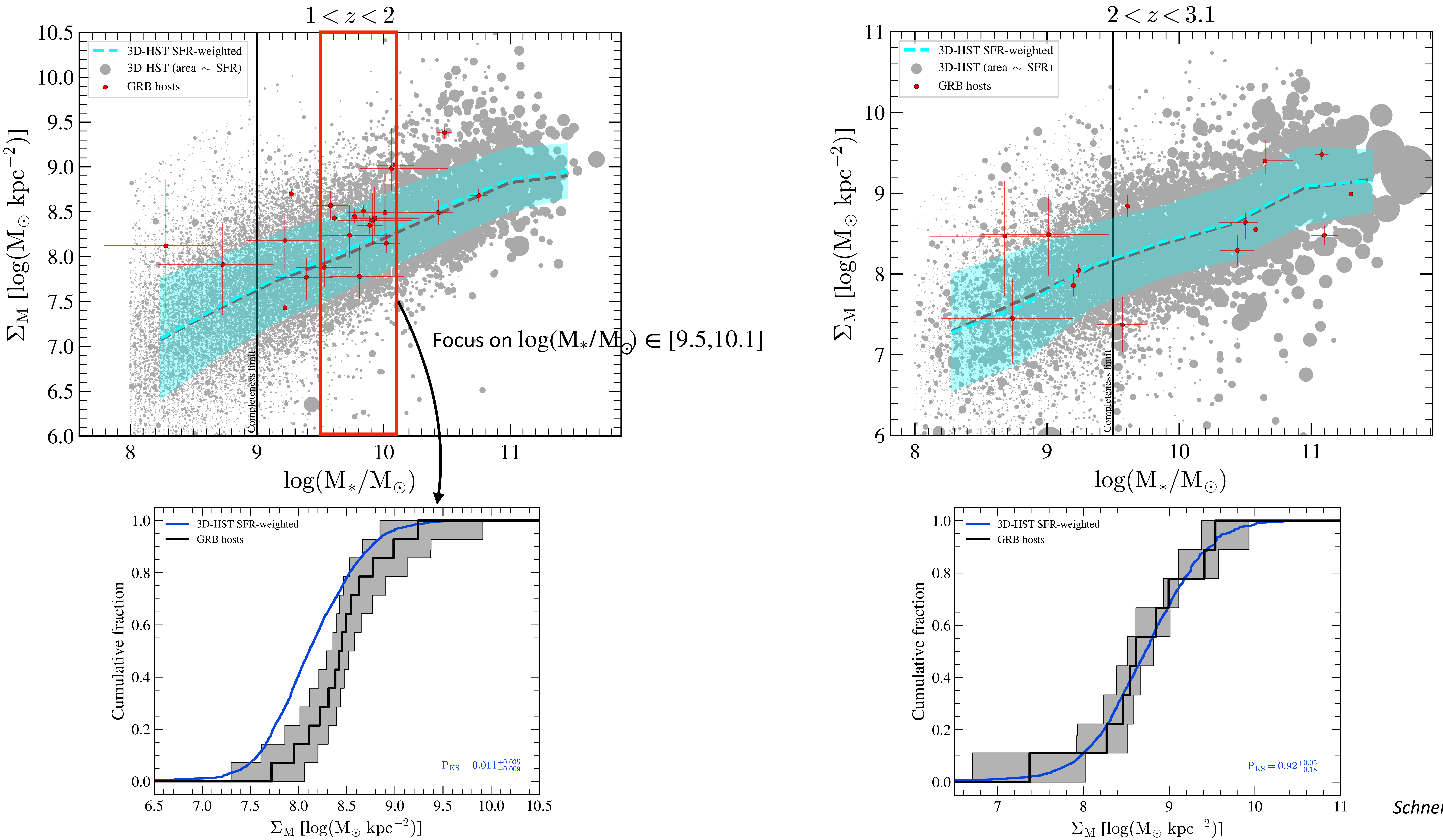
Stellar Mass density : Σ_M



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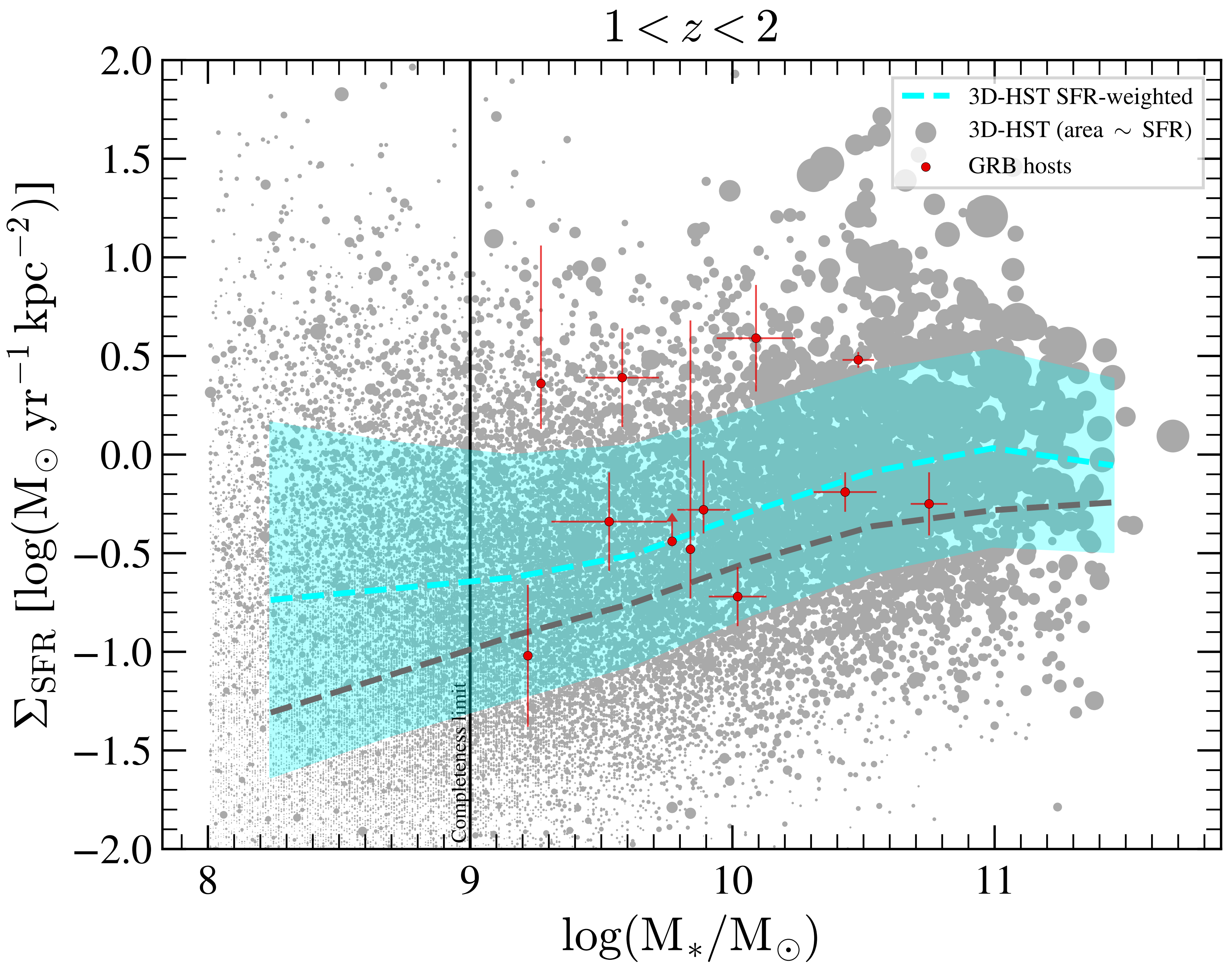
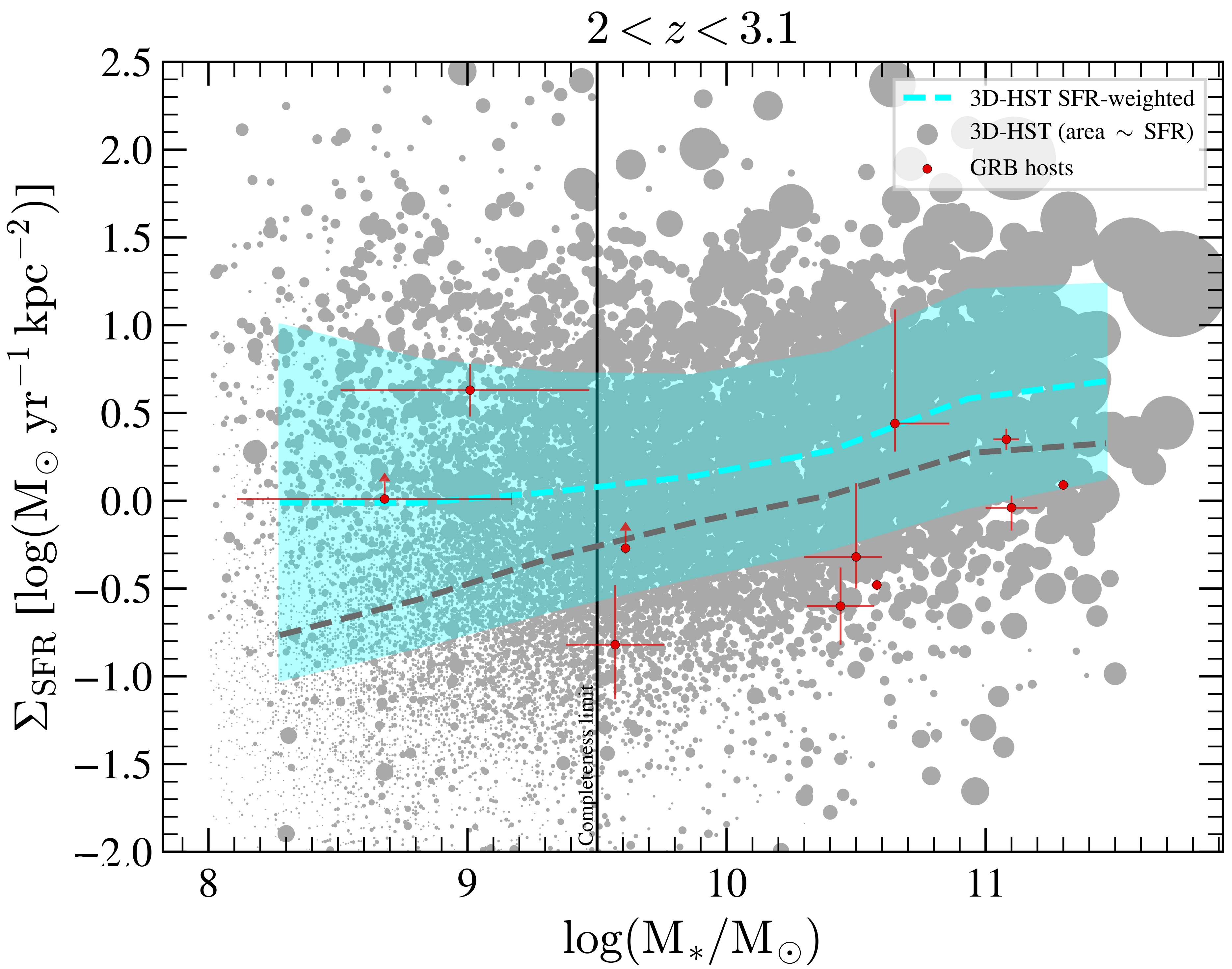
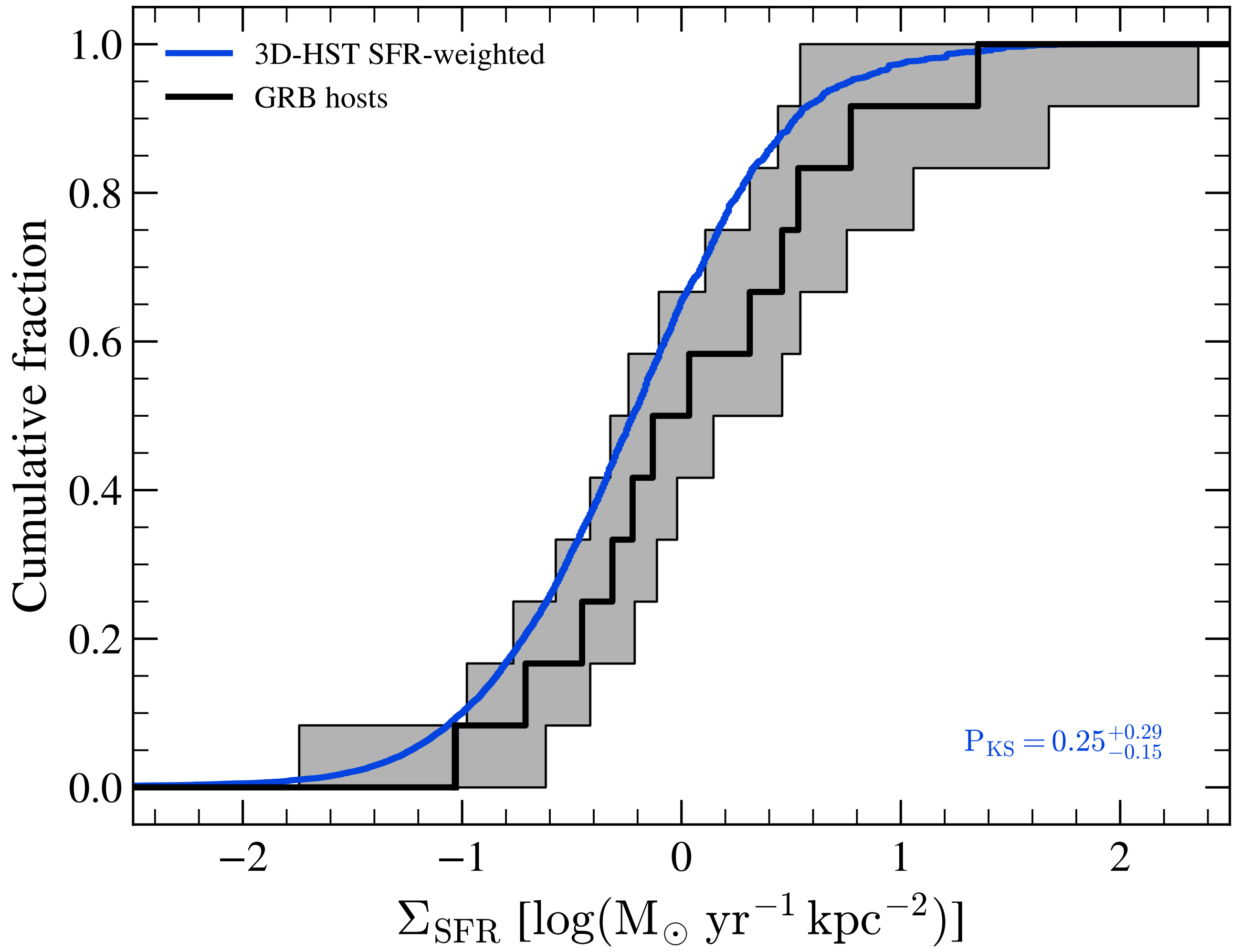
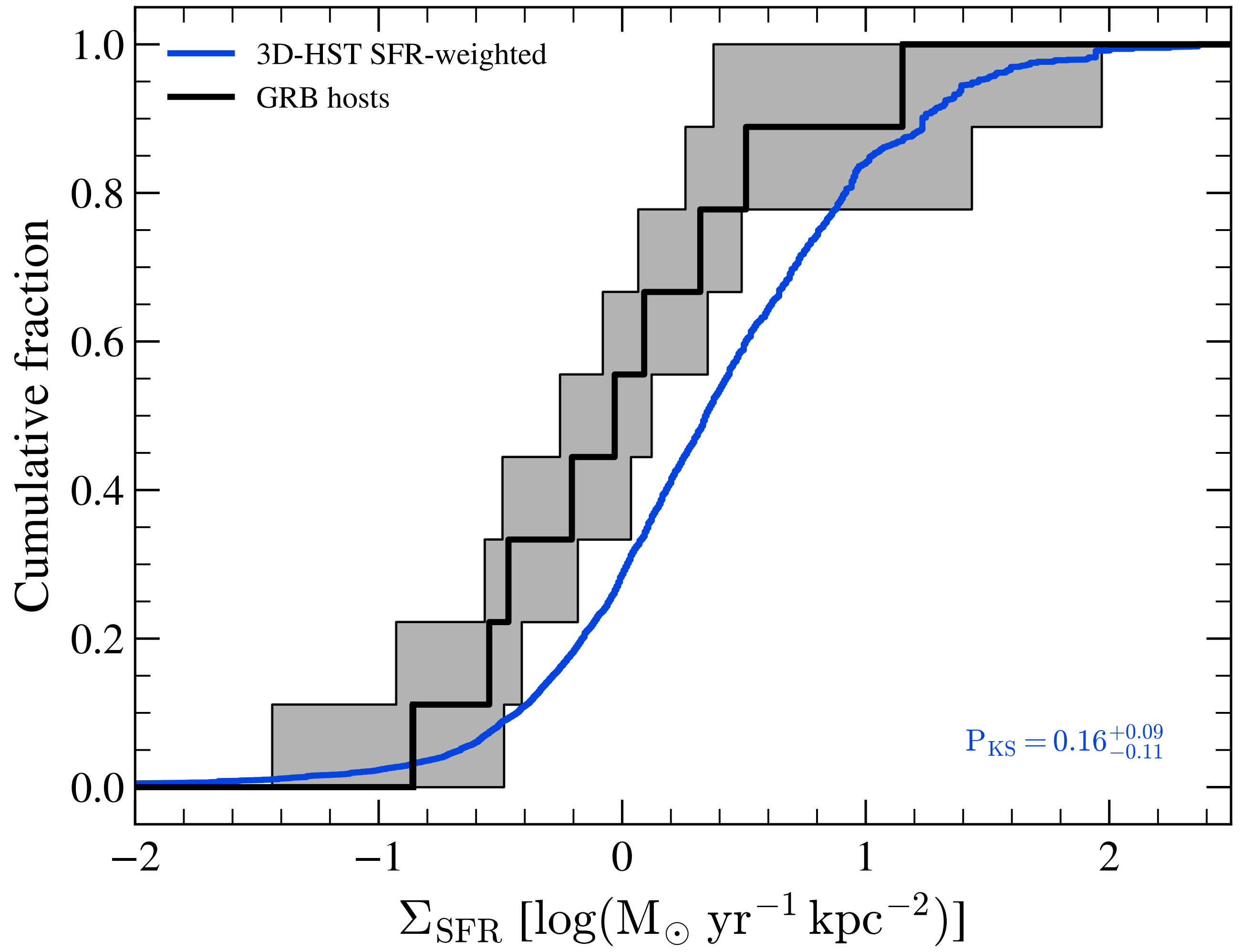
Star Formation density : Σ_{SFR}









Schneider et al. in prep.

Conclusion

- First, we proceeded to a state of the art of available **HST data** for GRB host galaxies in $1 < z < 3.1$
  - Identified a sample of 37 objects

- We developed and validated a pipeline to estimate the Re based on **GALFIT** by comparing results produced by 3D-HST team with GALAPAGOS

- Then, we performed a morphological characterization of the GRB host galaxies by using our Galfit pipeline

- We derived the Σ_M and Σ_{SFR} for the object of our sample
  - The trend to more compact galaxy, high stellar mass and star formation densities saw by *Kelly et al. 2014* in GRB host galaxies seems to be confirmed until at least $z < 2$
  - The situation appears to evolve at $z > 2$

- Finally, these results are consistent with the idea that LGRB are associated with dense star-forming regions. These dense regions could more efficiently produce linked star clusters where binary systems might be created more frequently.