Gamma-ray Bursts: the Ancient Keys of Cosmic Exploration

Time-domain
Science Definition Team

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What is a Long GRB?

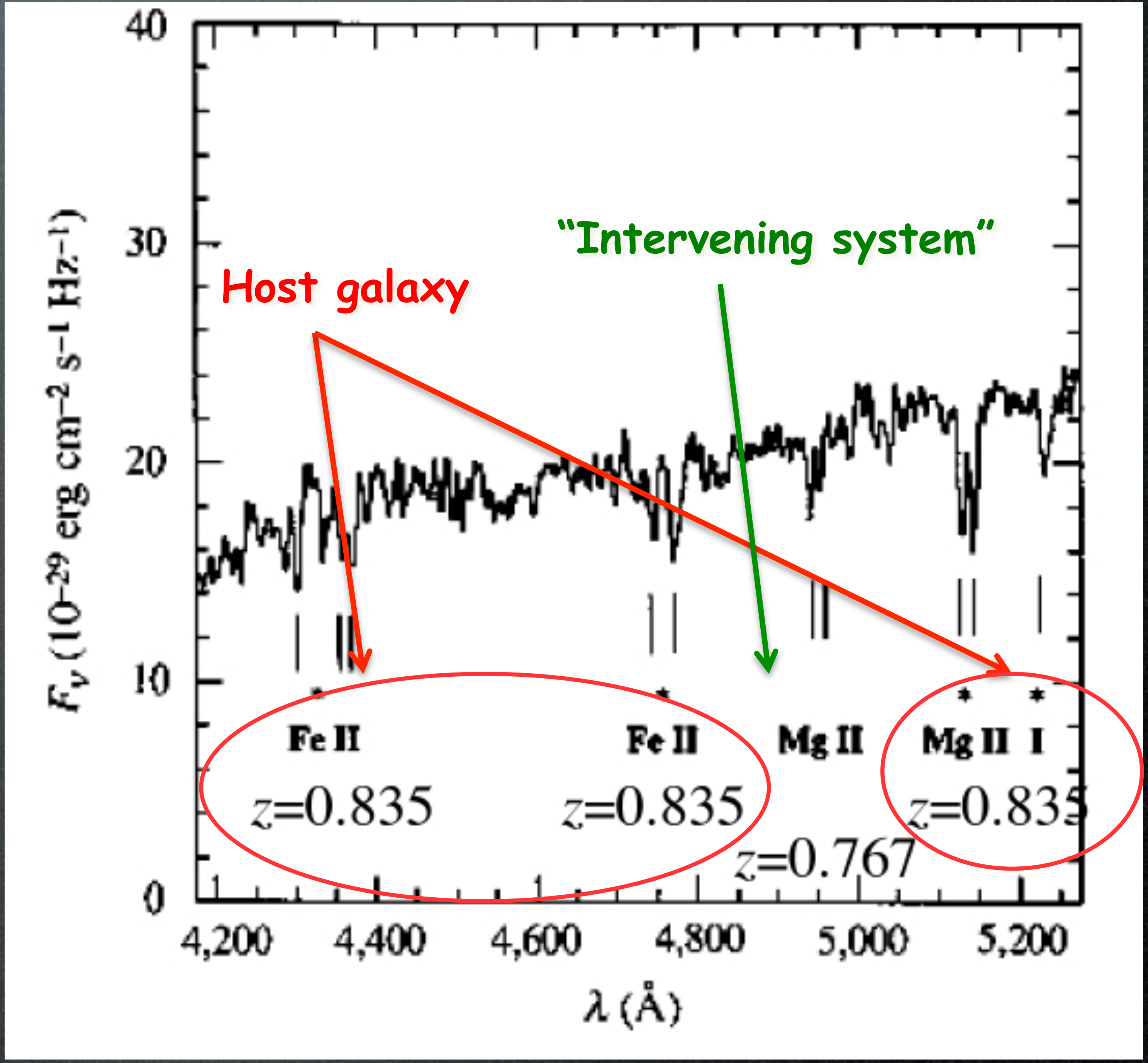
- Gamma ray bursts represent the **most powerful** explosions known in the gamma-ray Universe.
- They are probably produced by the explosion of Massive stars (>30$M_{\odot}$) and they are **cosmological objects** (z > 20, PopIII stars?)
- Their interaction with the surrounding material carries information about the GRB **progenitor and the host galaxy**.
- Represent the best tool for investigating the early stages of the Universe history, Star-formation and **re-ionization epoch**

GRBs as "tracers"

GRB afterglow spectra present signature of material not only in its **vicinity** but also of "**intervening systems**" unrelated to the GRB: these are located somewhere along the GRB line of sight.

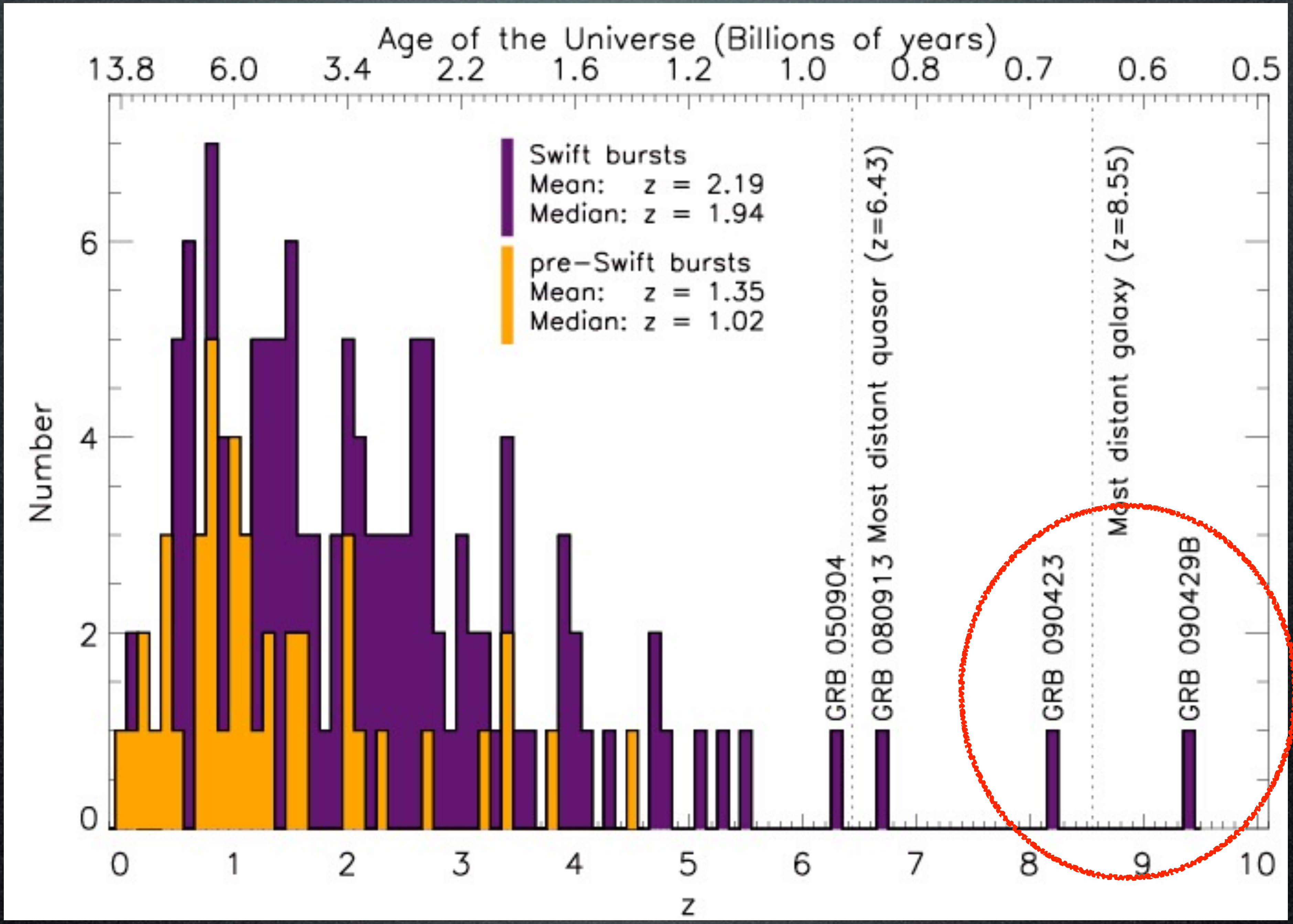
GRB 970508 occurred in a galaxy at

$z = 0.835$



We can use GRBs as tools for investigating the **ISM** and **IGM** at cosmological distances

Redshift distribution



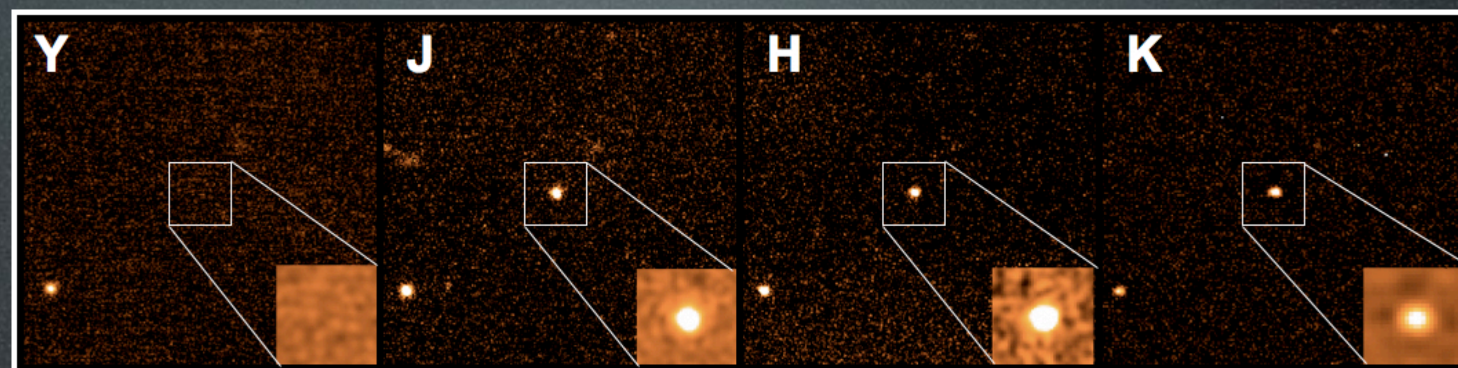
Jakobbsson et al. 2011

GRB 090423

Redshift determination

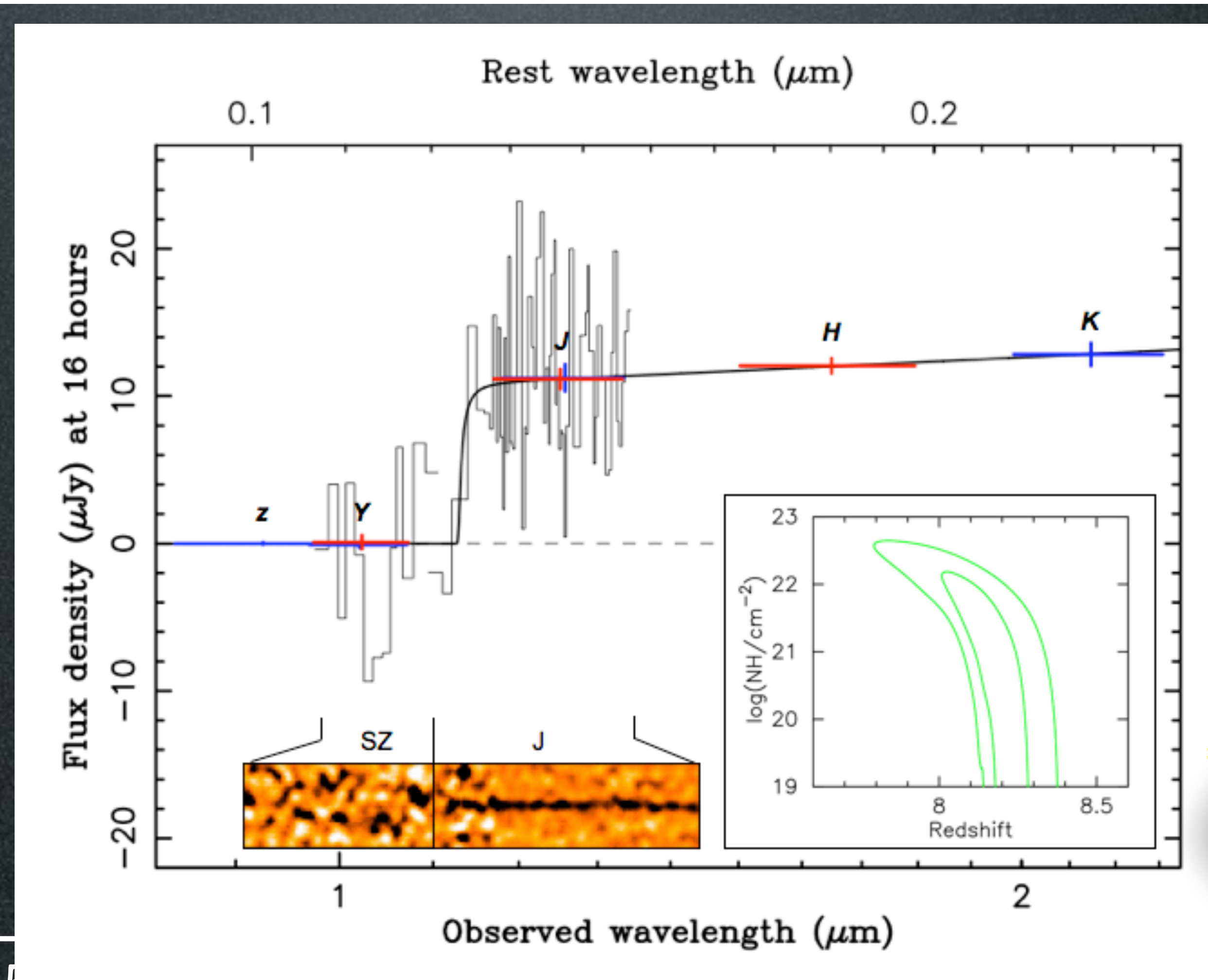
We can determine the redshift of a GRB based on absorption spectroscopy or just by rapid multiband imaging (photometric).

e.g. NIHTS+LMI on DCT will be ideal!



GRB 090423

z = 8.2



See also

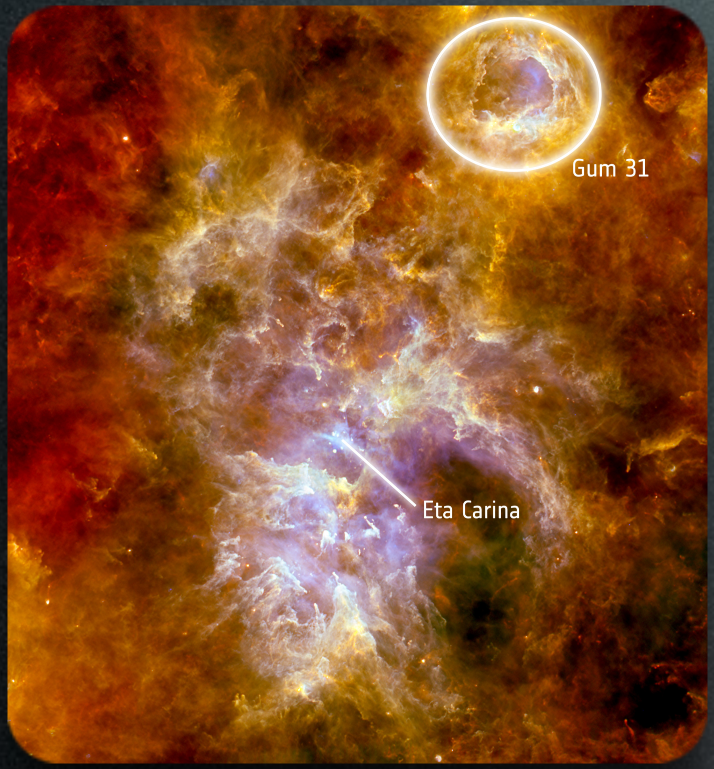
GRB 090429B

z ~ 9.4

(Cucchiara+11)

TMT+IRIS

Tanvir et al. 2009, Salvaterra et al. 2009



Eta Carinae Complex

Can GRBs be probes of primordial Star-formation?

Likely GRBs are produced by 30-40 $M_\odot$ (either in isolation or as runaway from a binary system)

They play an important role in shaping the primordial Universe.

1. To trace **Star-formation** * **(bias?)**
2. To Study the **cosmic metal build-up**
3. To investigate **re-ionization epoch**

* see S. Vergani's poster

Following the Hydrogen way:
GRB-Damped Lyman-α Systems (DLA)

We know that most of GRB at z>2.0 exhibit strong HI **damping wings** in their spectra (**DLA**).

This reservoir of neutral gas is a key ingredient of star formation. Quasars DLA have been studied for decades in absorption.

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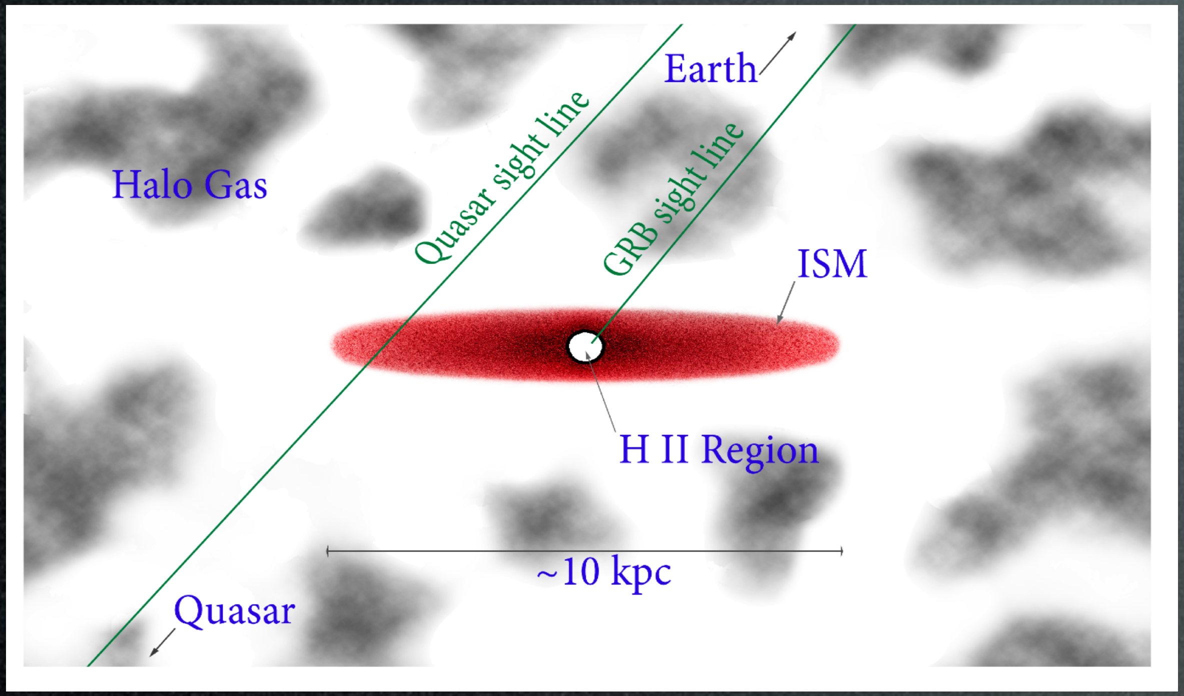
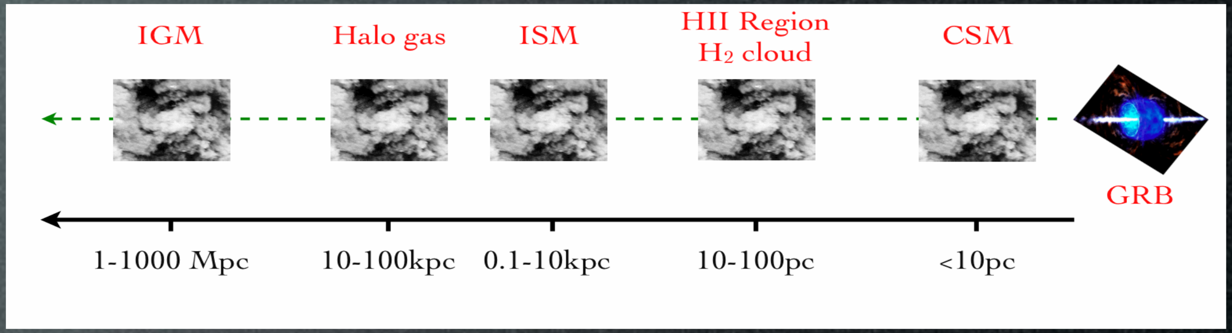
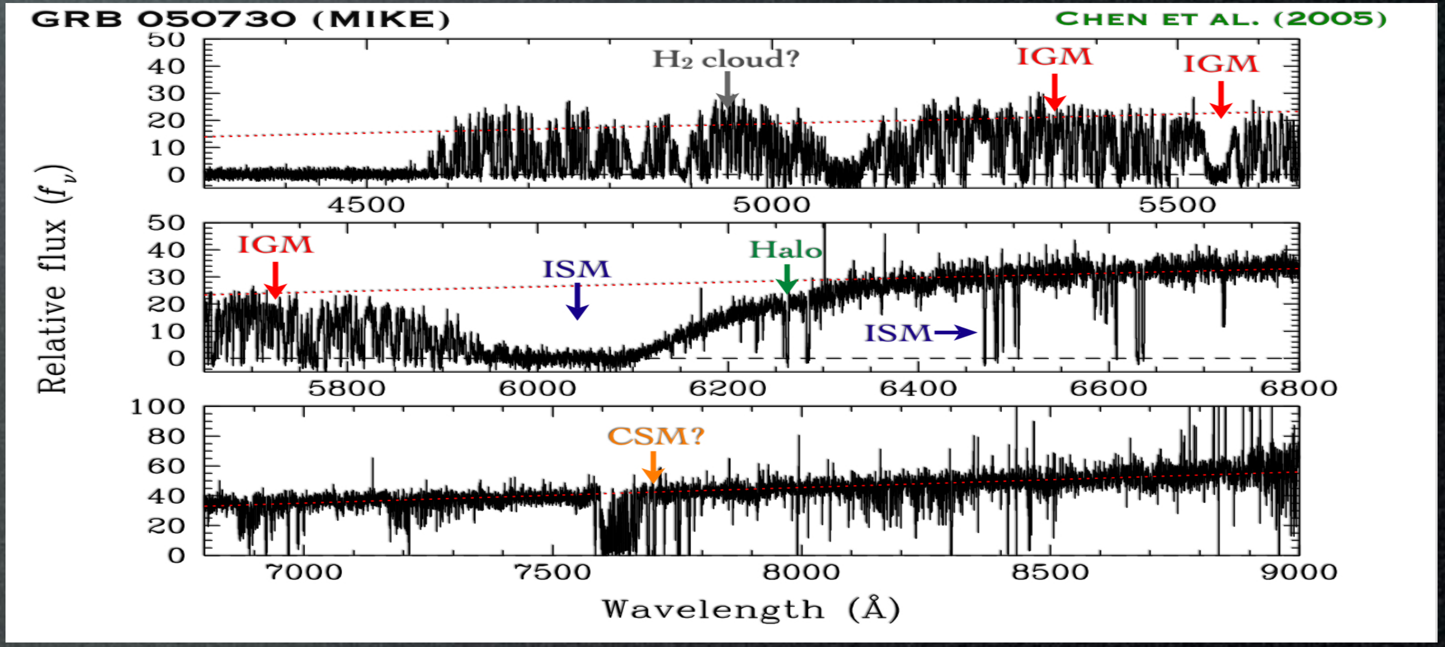


Prochaska et al. 2006





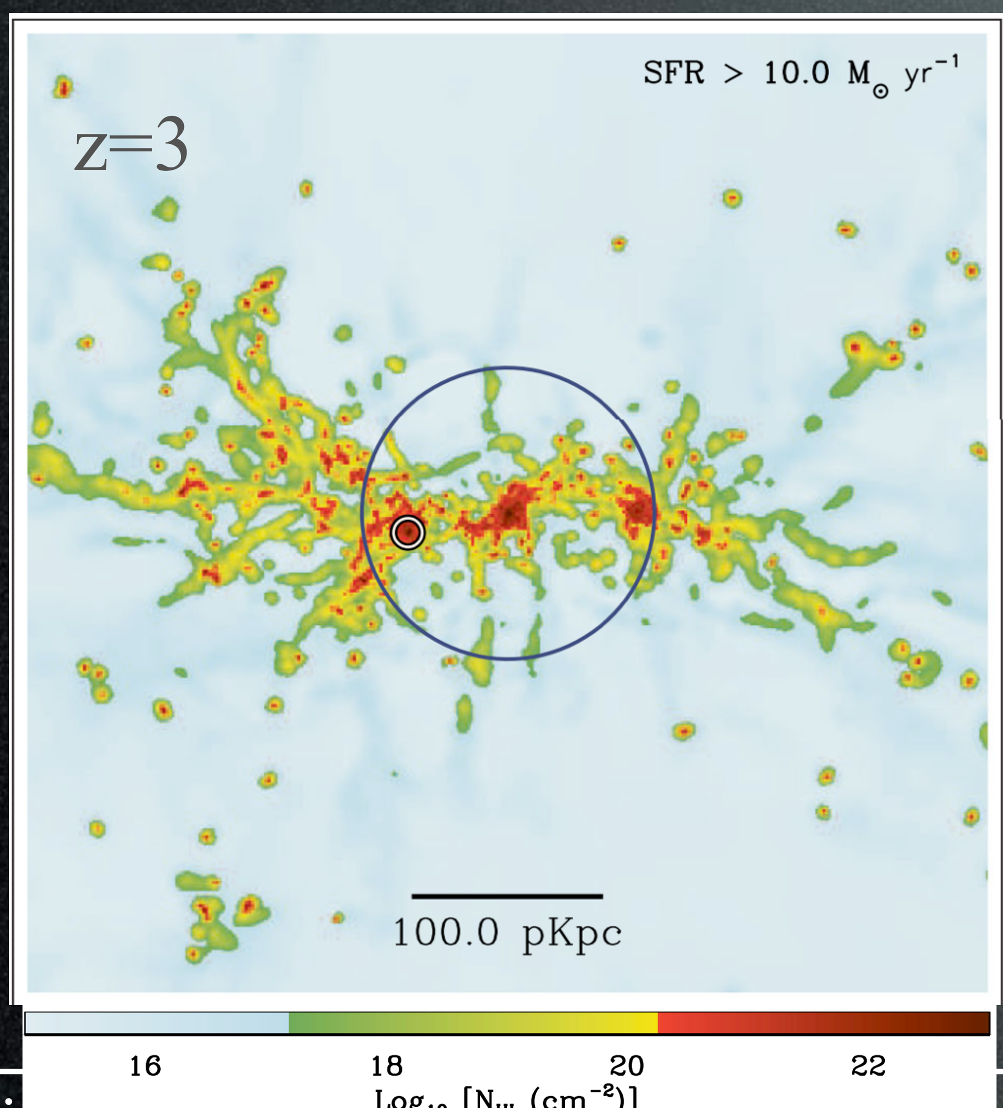
Quasars have complex galaxy features and randomly intersects "blob" of material...detected as intervening systems in higher-z QSO.

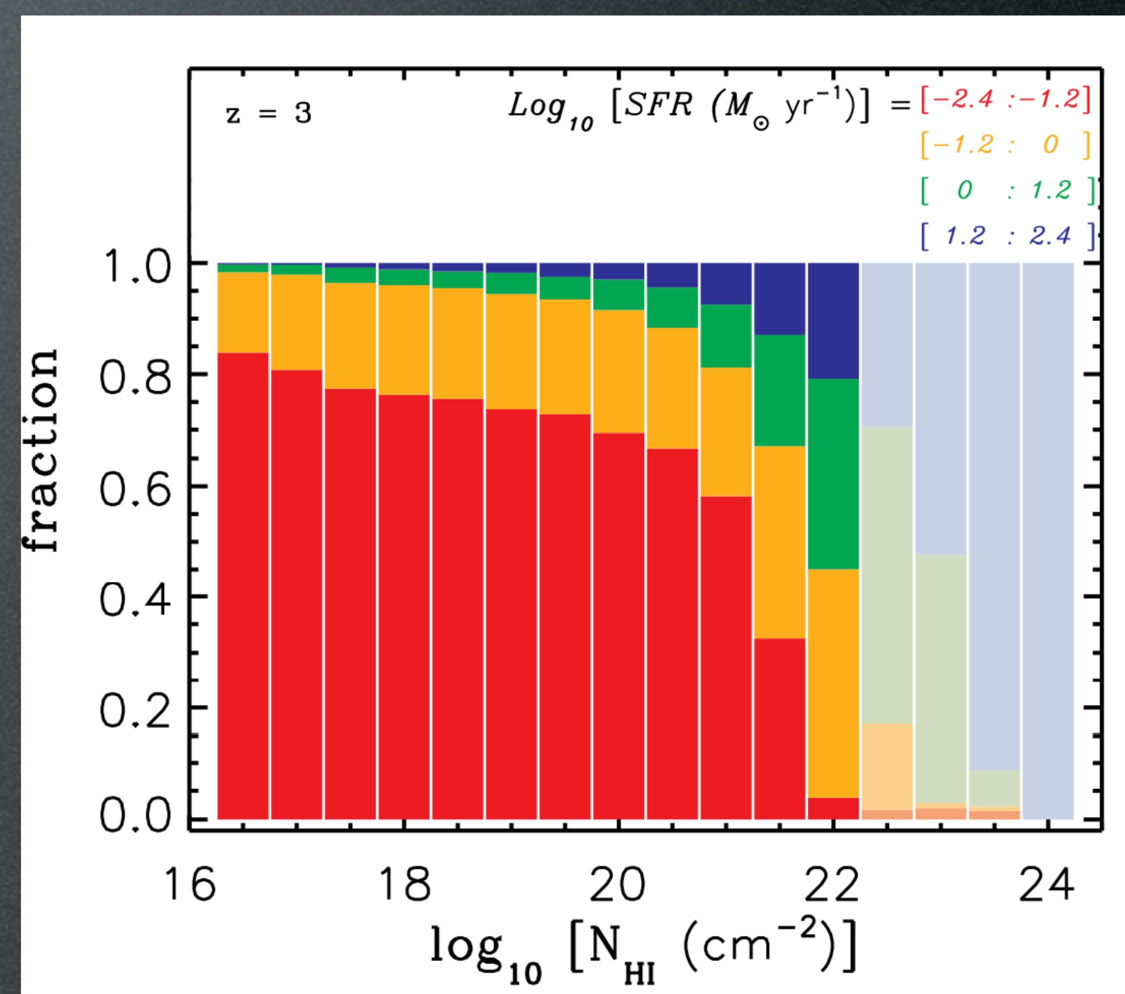
GRB-DLAs are much simpler, GRBs are bright ... then GRBs fade away.

Following the Hydrogen way

- Stars form from **cold gas** in ionic and molecular form (HI, H_2)
- Chemical abundances **require HI**
- **Metals** are produced and recycle in SF episodes

  - **Damped Lyman-α systems**: HI ≥ $10^{20.3}$ cm^{-2}



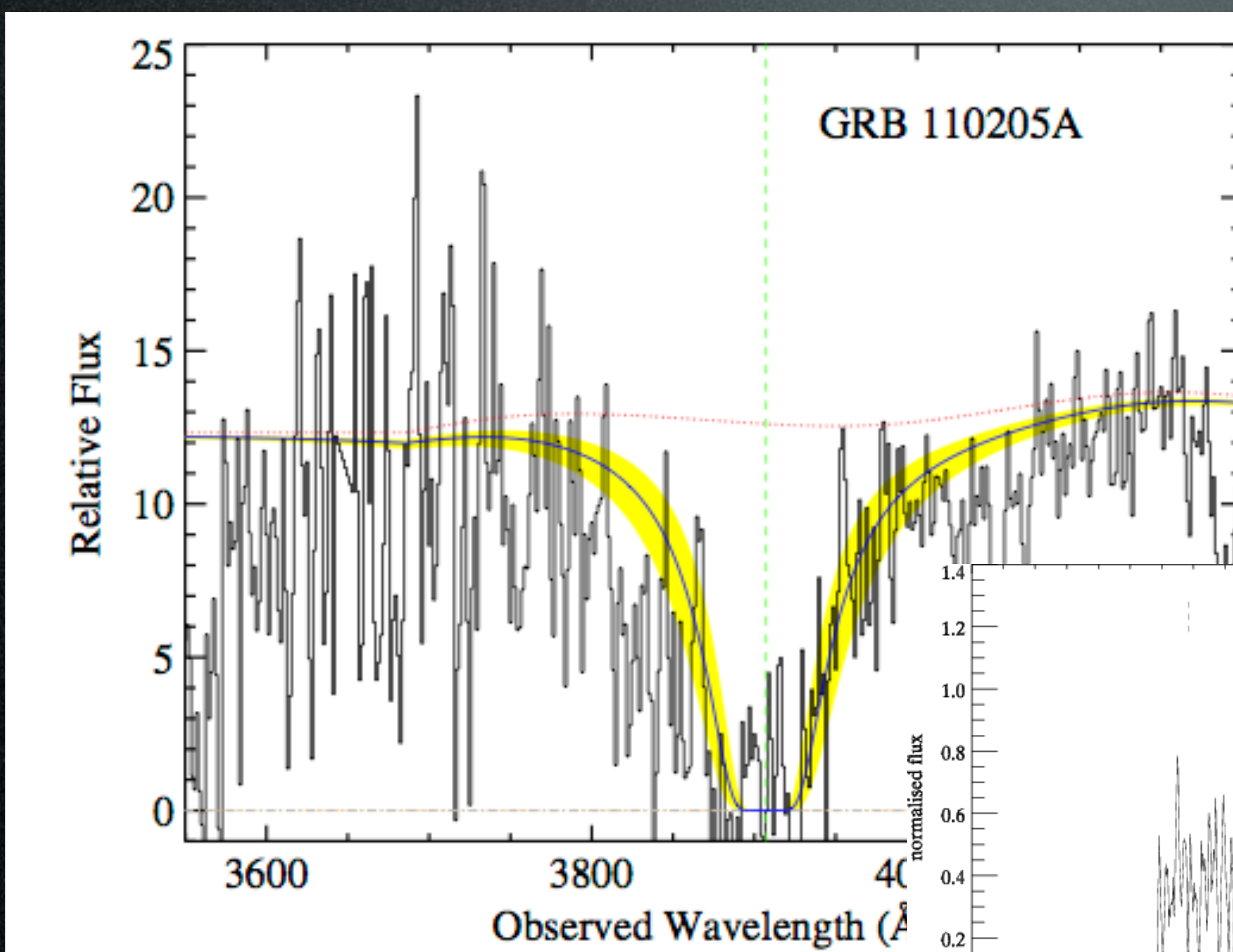


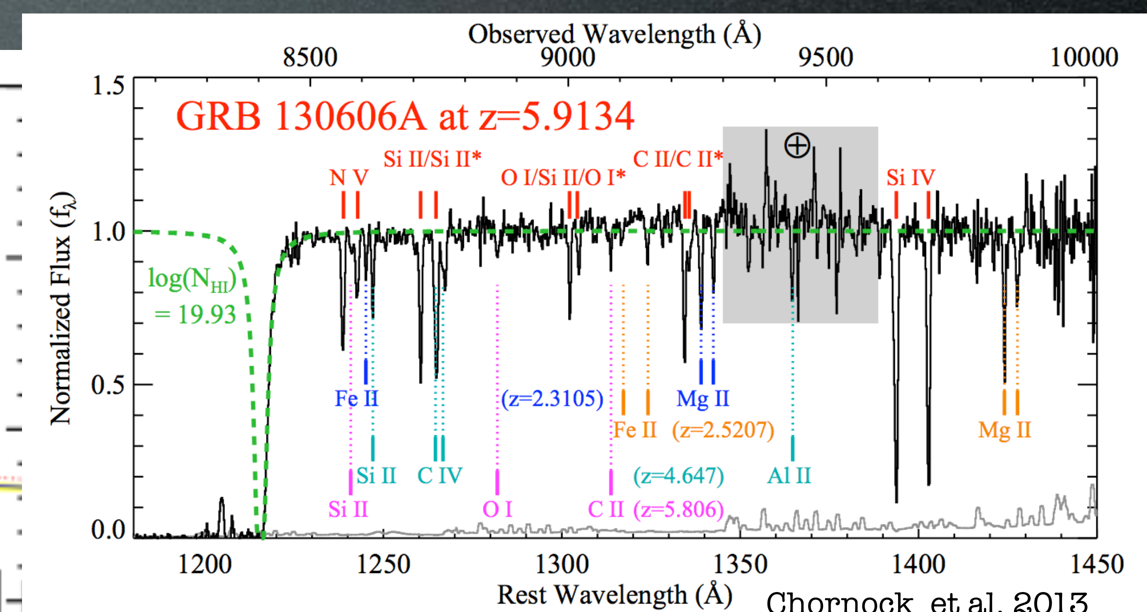
Rahmati+13

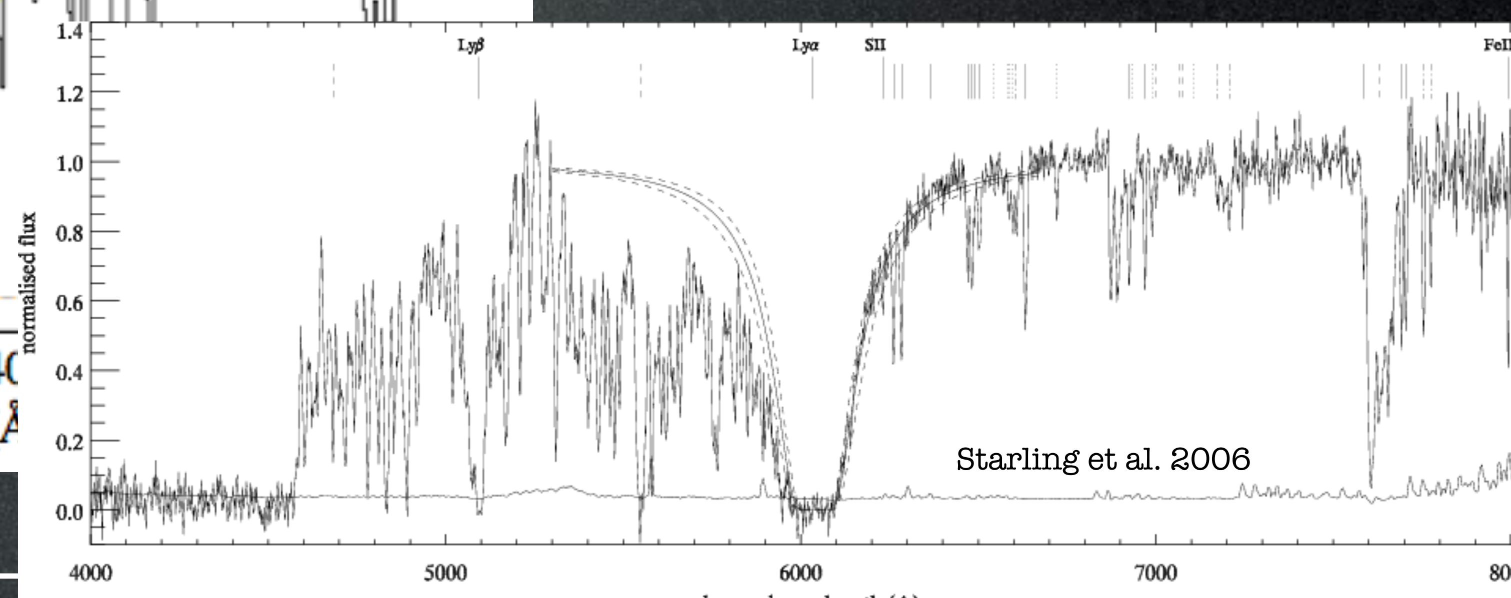
Following the Hydrogen way

DLAs are identified at $z>1.5$, usually **along Quasar** lines of sight. In the case of GRBs, they appear **at the location** of the GRB hosts.

HI is determine by the fitting of the Lyman-alpha line: the broader it is the large is the amount of HI near the GRB and along the l.o.s.







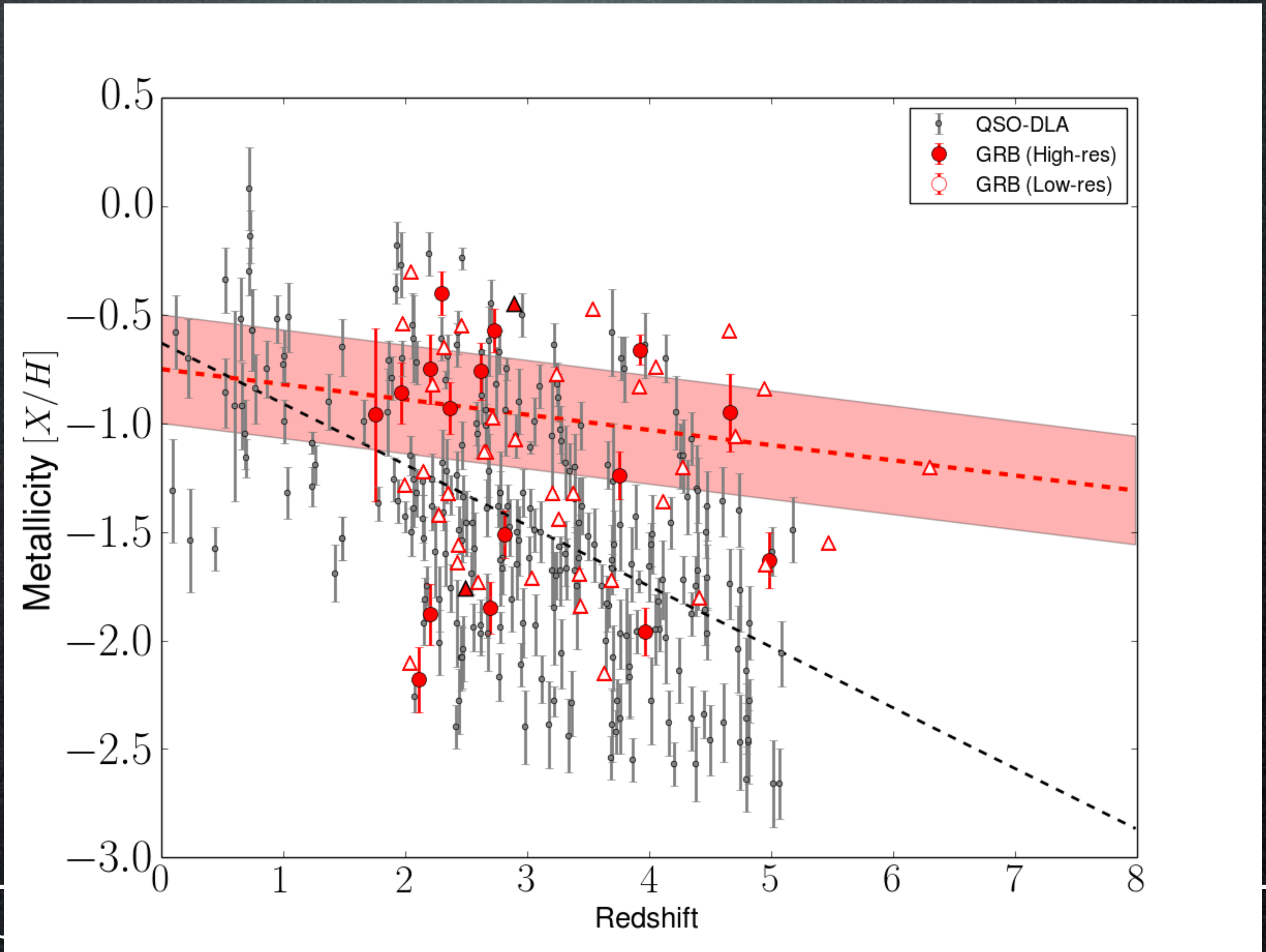
Cucchiara et al. 2011

The GRB-DLA sample

- 56 DLAs, 12 sub-DLAs until May 2014 (see also Arabsalmani+14, Sparre+14).
- Derived metal (S, Si, Zn) abundances via **Apparent Optical Depth** technique (same as the QSO-DLA control sample).
- Since 60% of the GRB sample is obtained with mid/low resolution spectrographs (R<1200) we consider those metallicities **lower-limits.**
- We perform a **survival analysis** in order to determine the metallicity trend across the redshift explored.

Results

- GRB/QSO-DLAs have **same metallicity in the 1.8<z<3**
- At z> 3 GRB-DLAs probe a higher metallicity content (**$Z/Z_{\odot}$ > -1.0**)
- The **trend is shallower** then QSO-DLAs, indicating that GRB hosts are metal enriched already at z=5, via **SNe** (or **AGBs pollution**)



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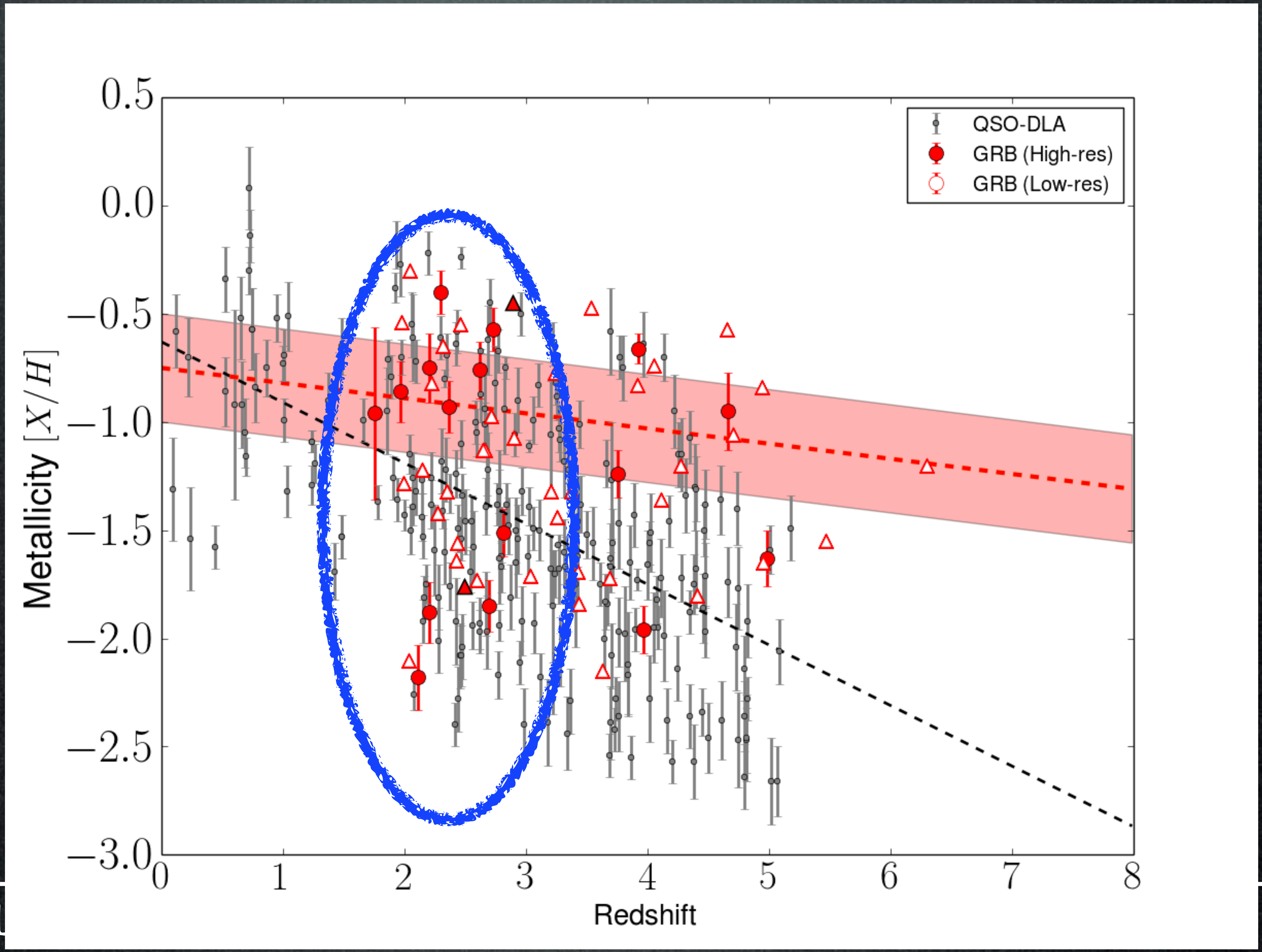

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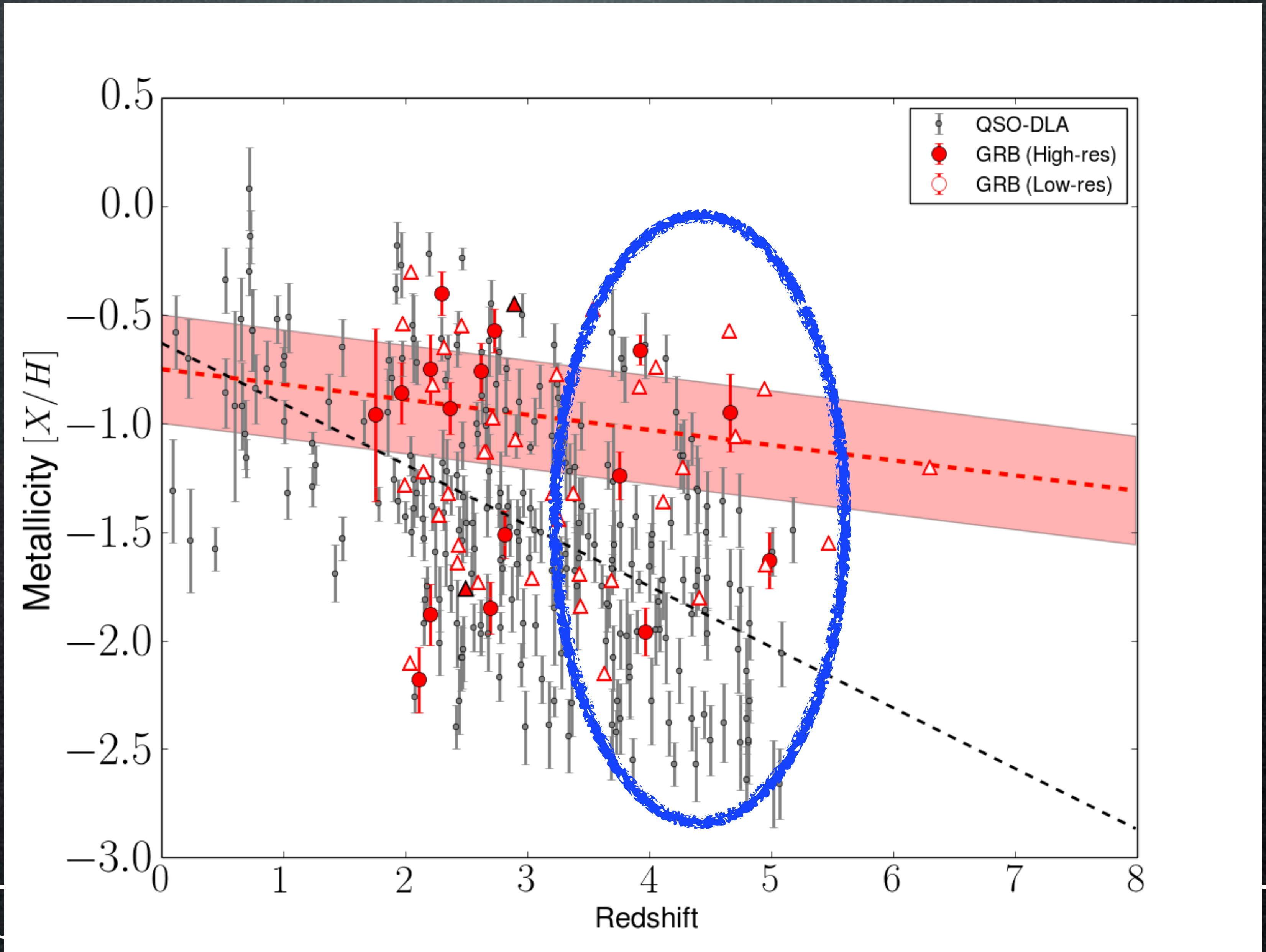

Now we look at the hosts

The emission lines to derive SFR AND metallicity are in the capabilities of current NIR spectrographs.
(e.g. **DCT/RIMAS,** Gemini/GNIRS/Flamingos-2, Keck/MOSFIRE).

Stay tuned!

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- We select GRB hosts **independently** from their overall properties (mass, luminosity)

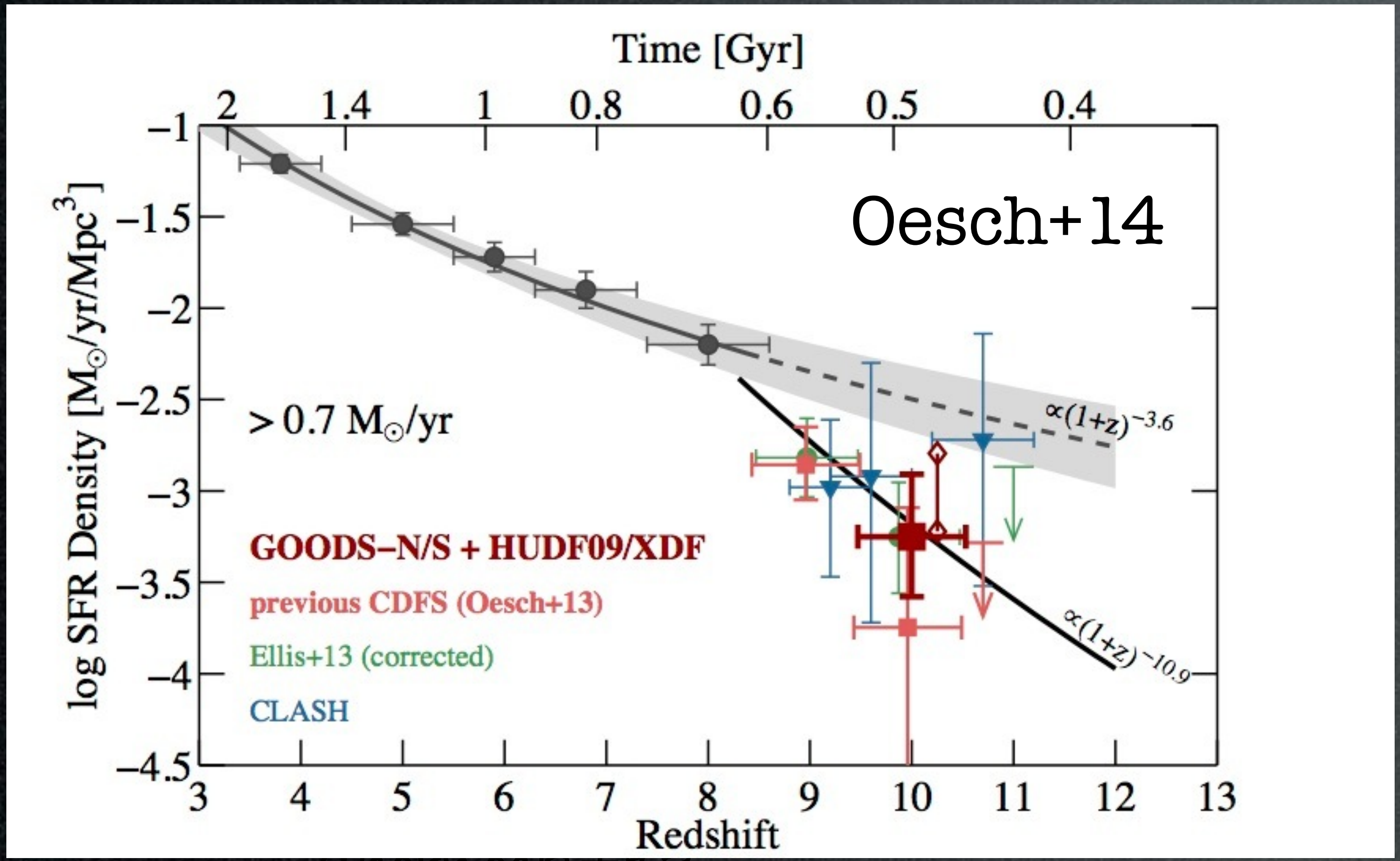
- A subset of GRB-DLAs hosts have been monitored with DCT/LMI

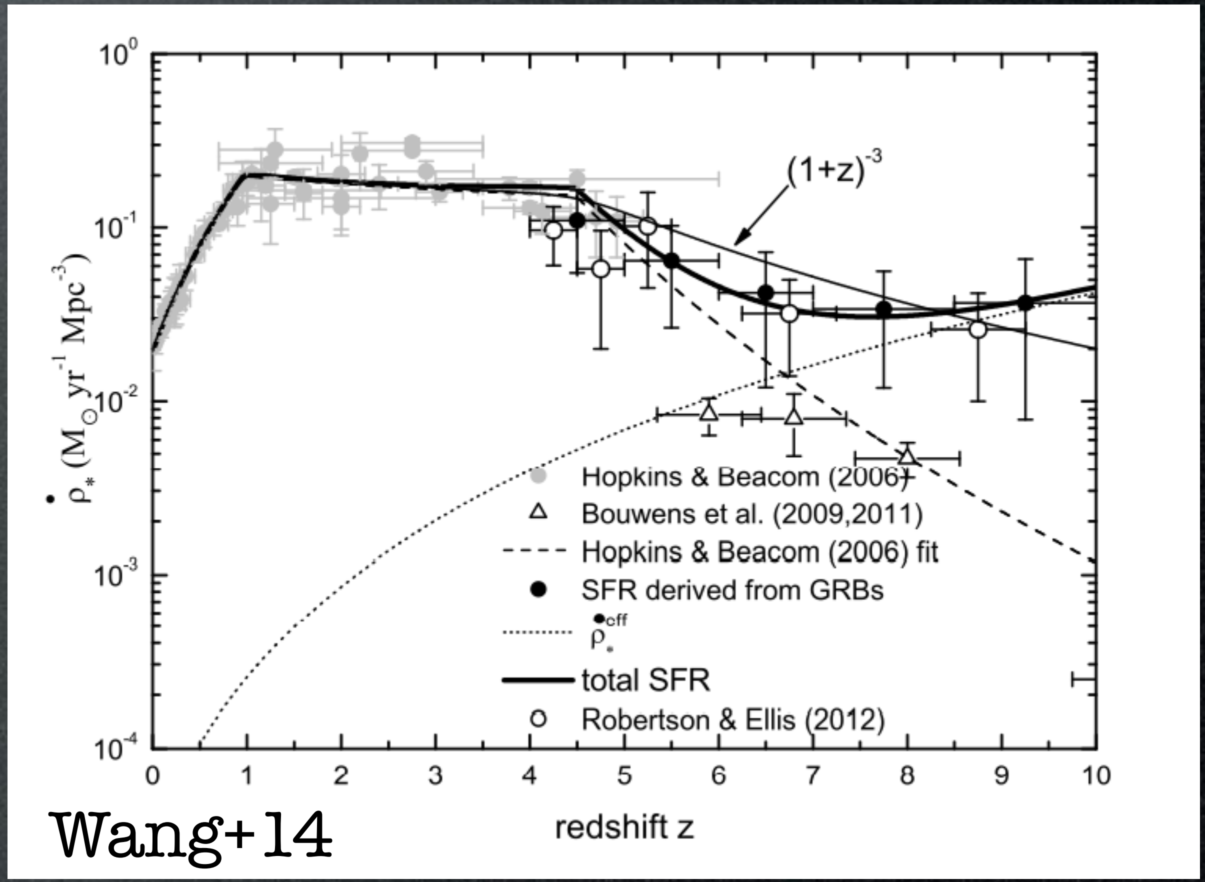
- We obtained some LBT/LUCI2 data.

Stay tuned!

JWST and 30m telescopes

- **TMT/IRIS** could observe z=8-10 GRBs within 2 days of the explosion and obtain high Resolution spectroscopy!!!
- **NIRSpec/JWST** will be able to obtain R>4000 spectroscopy of GRB afterglow up to 1 week post burst
- GRB hosts can then be studied in detailed using **WFIRST/JWST/TMT** and derive global information of the first galaxies



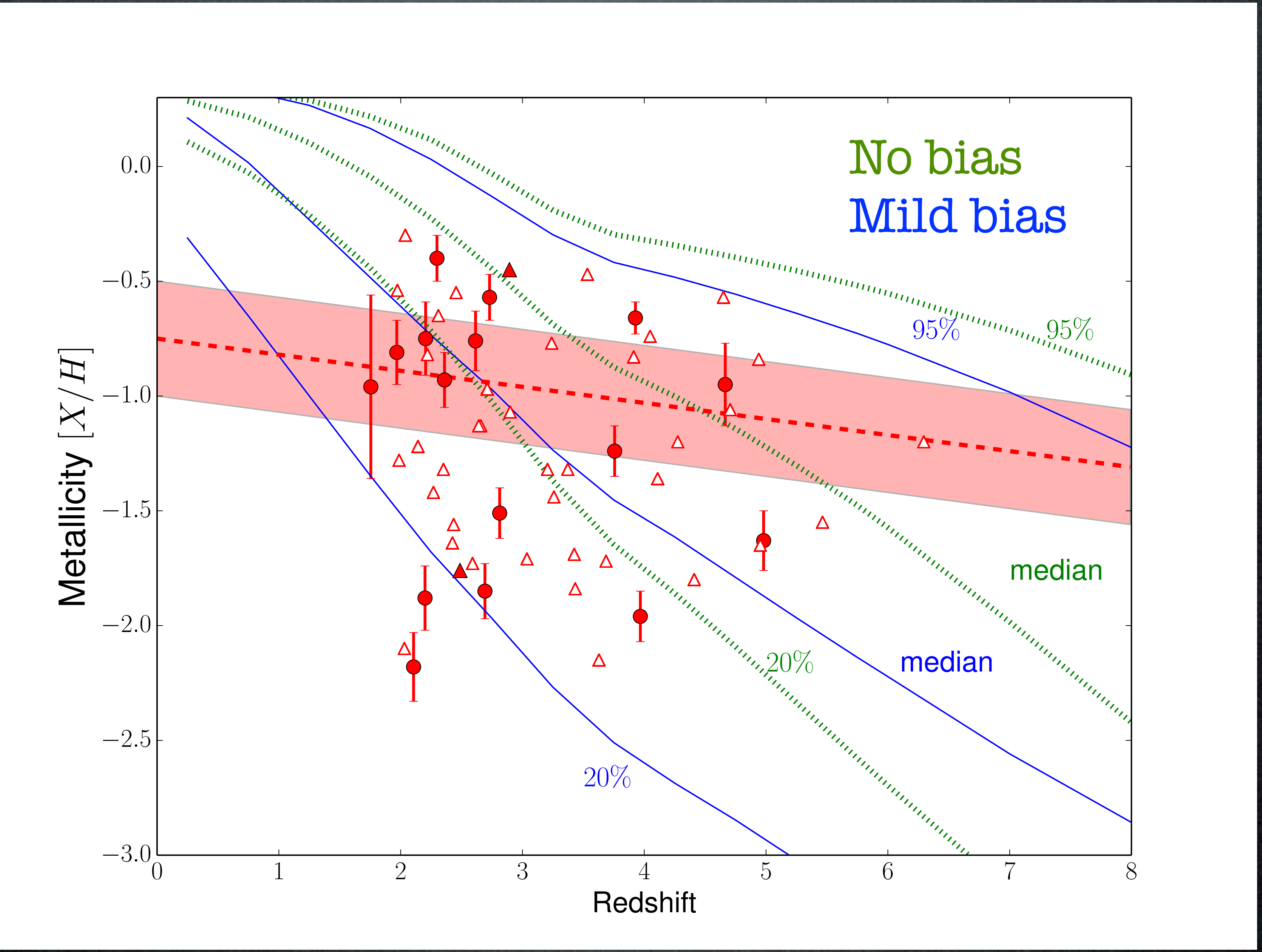


Conclusions

- GRB are an incredible and unique tool to study the z<20 Universe
- The afterglow spectra provide the **ONLY** chemical diagnostic of **SF regions** in galaxies at z>3.
- GRB-DLAs shows a **metal enriched** environment up to z=6
- GRBs hosts will be keys to study the **cosmic SFR** independently of Galaxy Mass, Luminosity, or Metallicity
- **JWST and TMT** facilities will greatly benefit from GRB science and rapid Opt/NIR follow-ups

Results

- Metallicity dependancies help in distinguishing between single and binary channel of Long GRBs progenitors
- The distribution of metallicity is consistent with 2-mode of GRB production assuming a metallicity bias



Comparson with HST

GRBs lead the way to the exploration of the early epoch of the Universe history.

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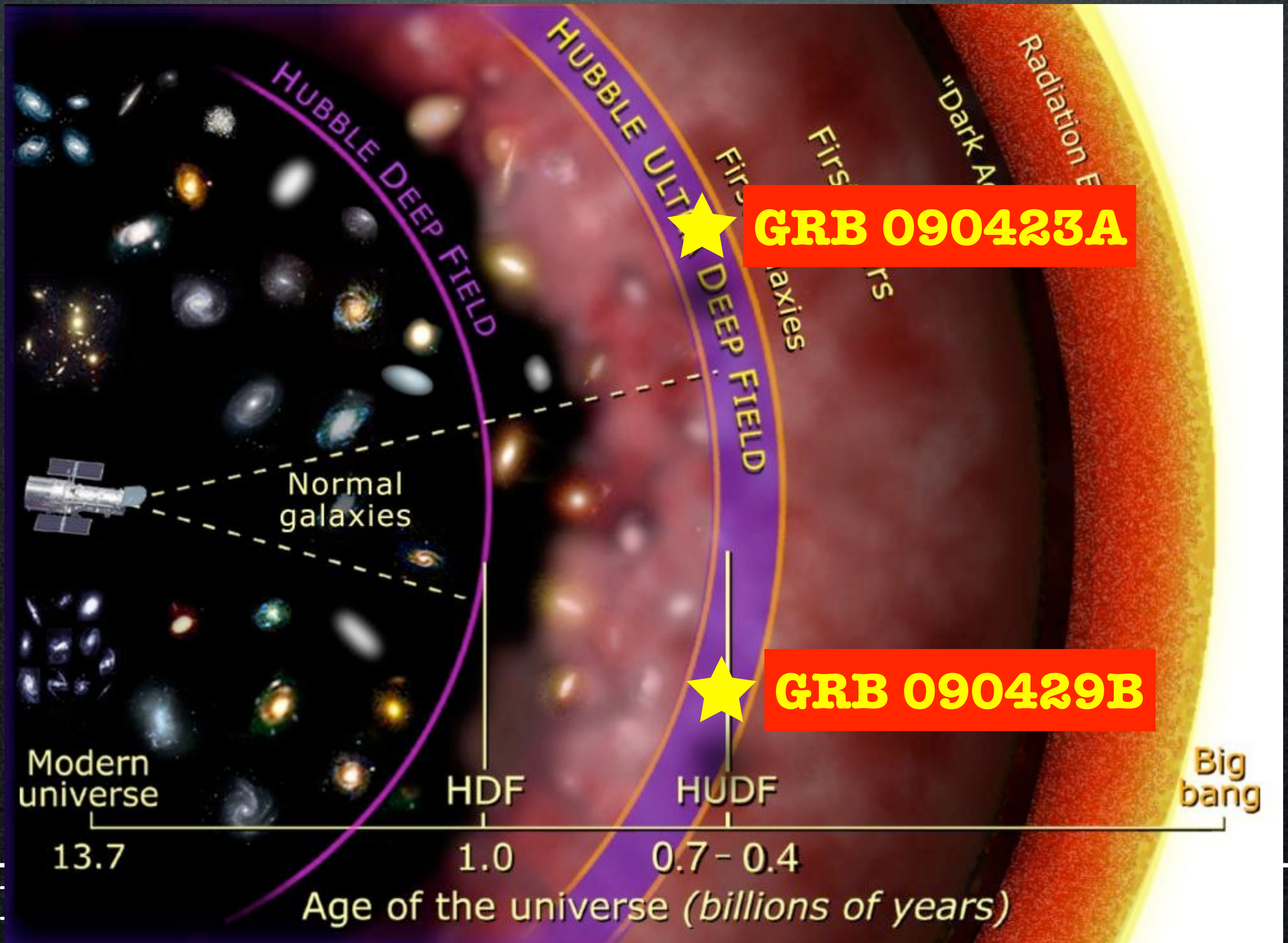
HST (10+ years) vs GRBs (7 days)



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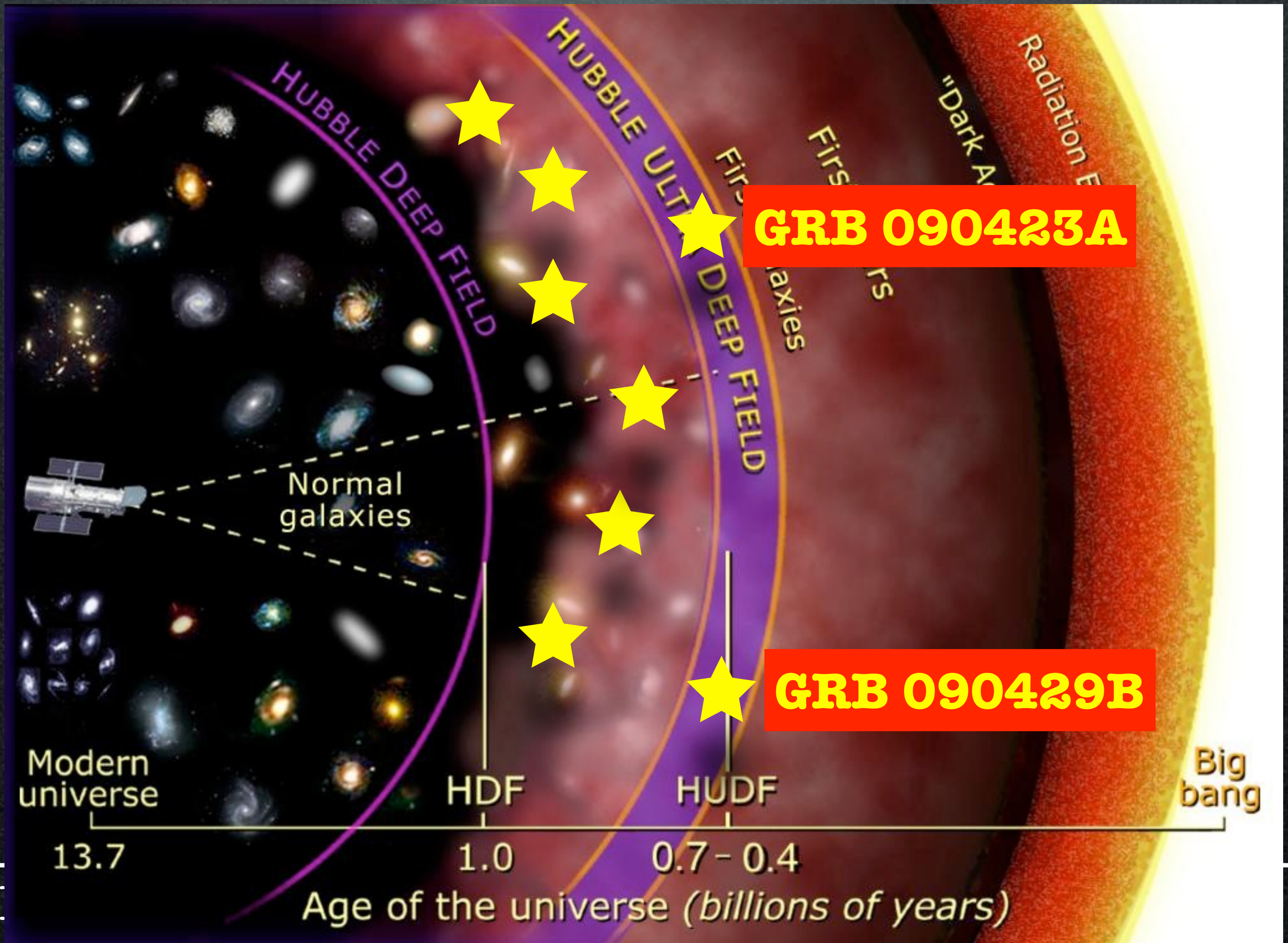
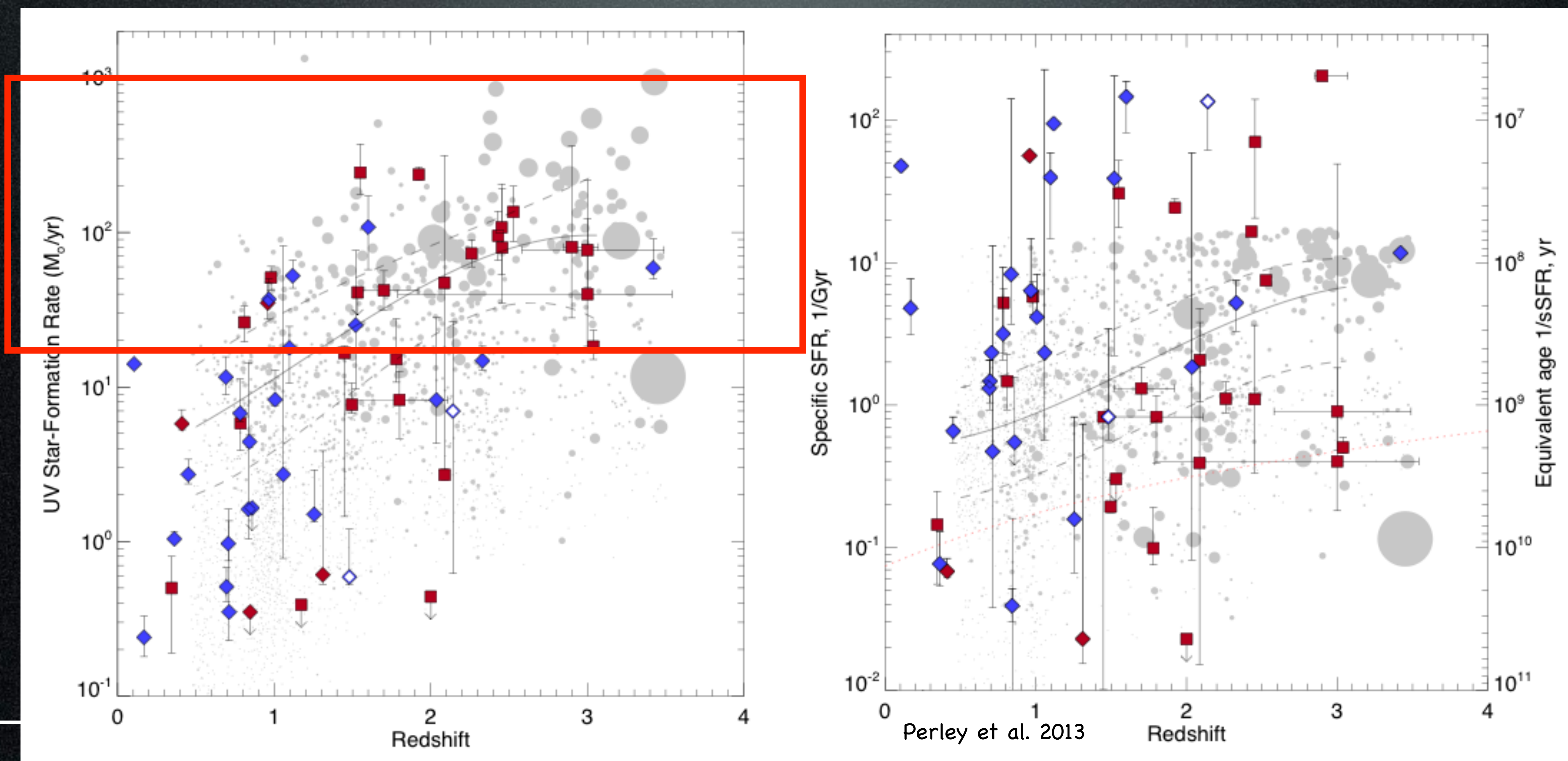


What's next?

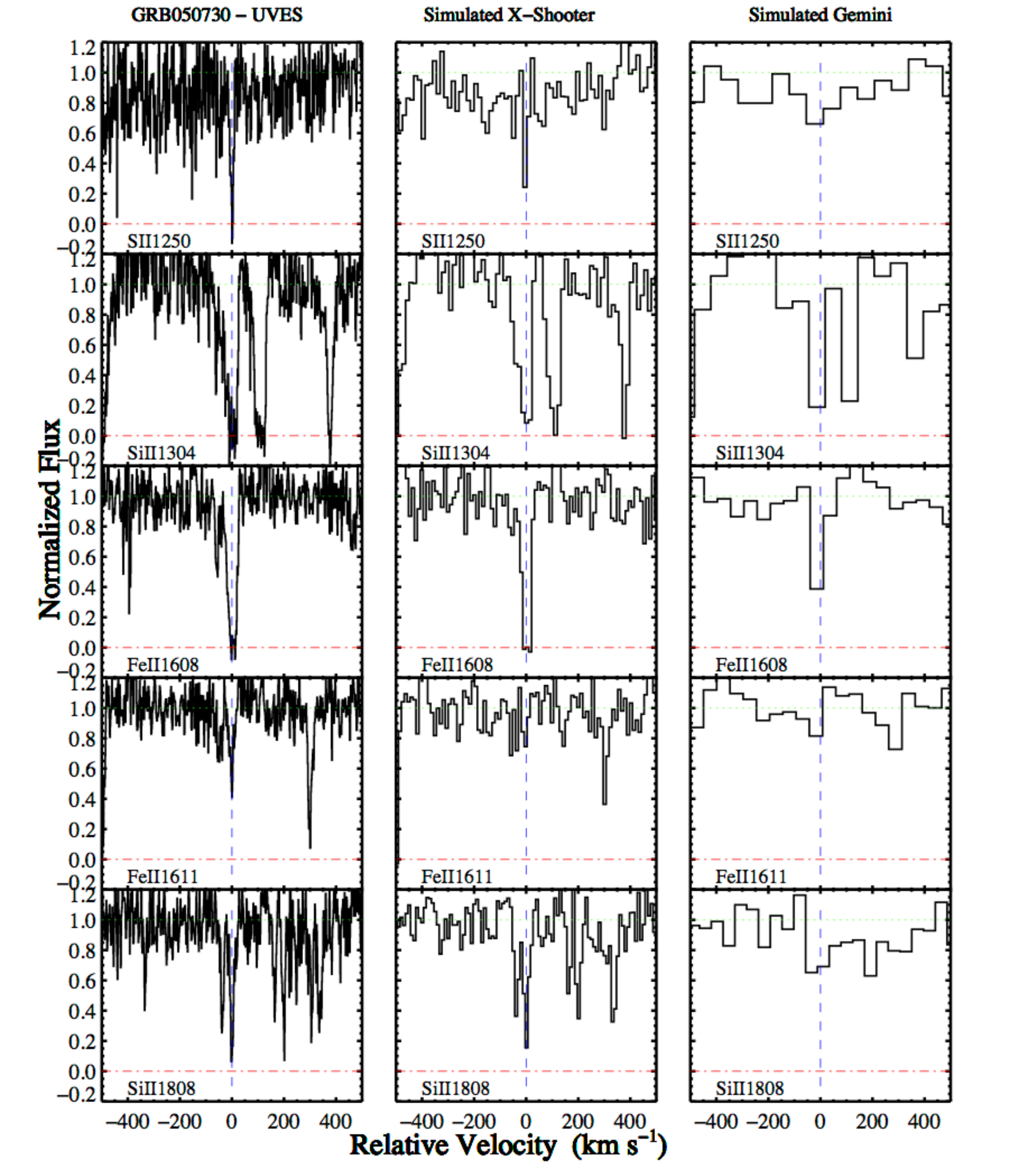
Perley et al. 2013 use multi band optical-IR obeservations of ``Dark'' GRB hosts (ground +HST -Spitzer) to observe their hosts.

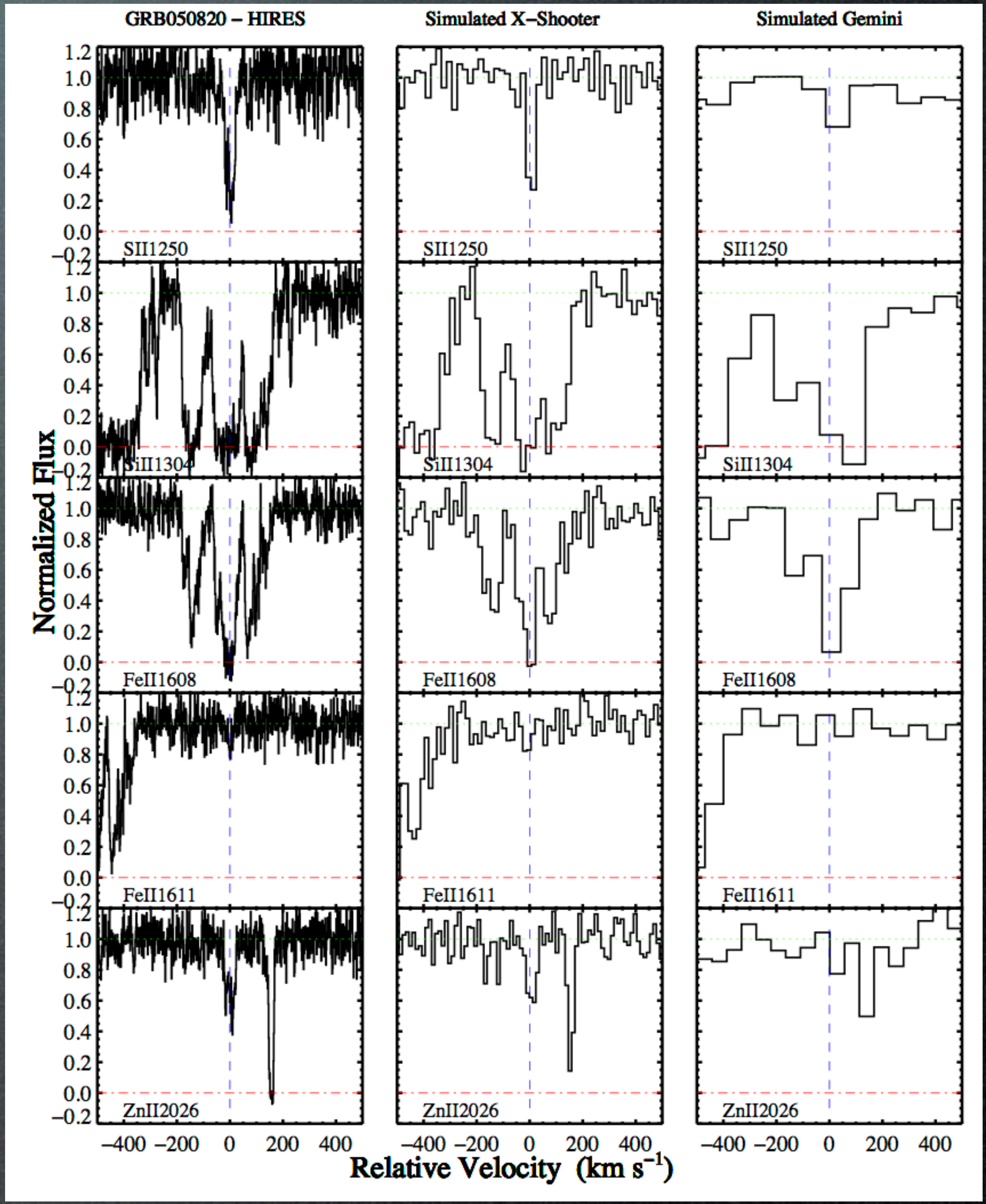
They derive high masses at z>1, but GRBs prefer low mass hosts at z<1, likely due to low-metallicity (metallicity cut-off, Kocevski et al. 2009).

Therefore GRBs are BIASED tracers of SFR.



High/low resolution complexity





GRB 050730 (z=3.967)

$Z/Z_{\odot} = 0.01$

GRB 050820 (z=2.61)

$Z/Z_{\odot} = 0.2$