Gamma-Ray Bursts as Tracers of the Remote Universe

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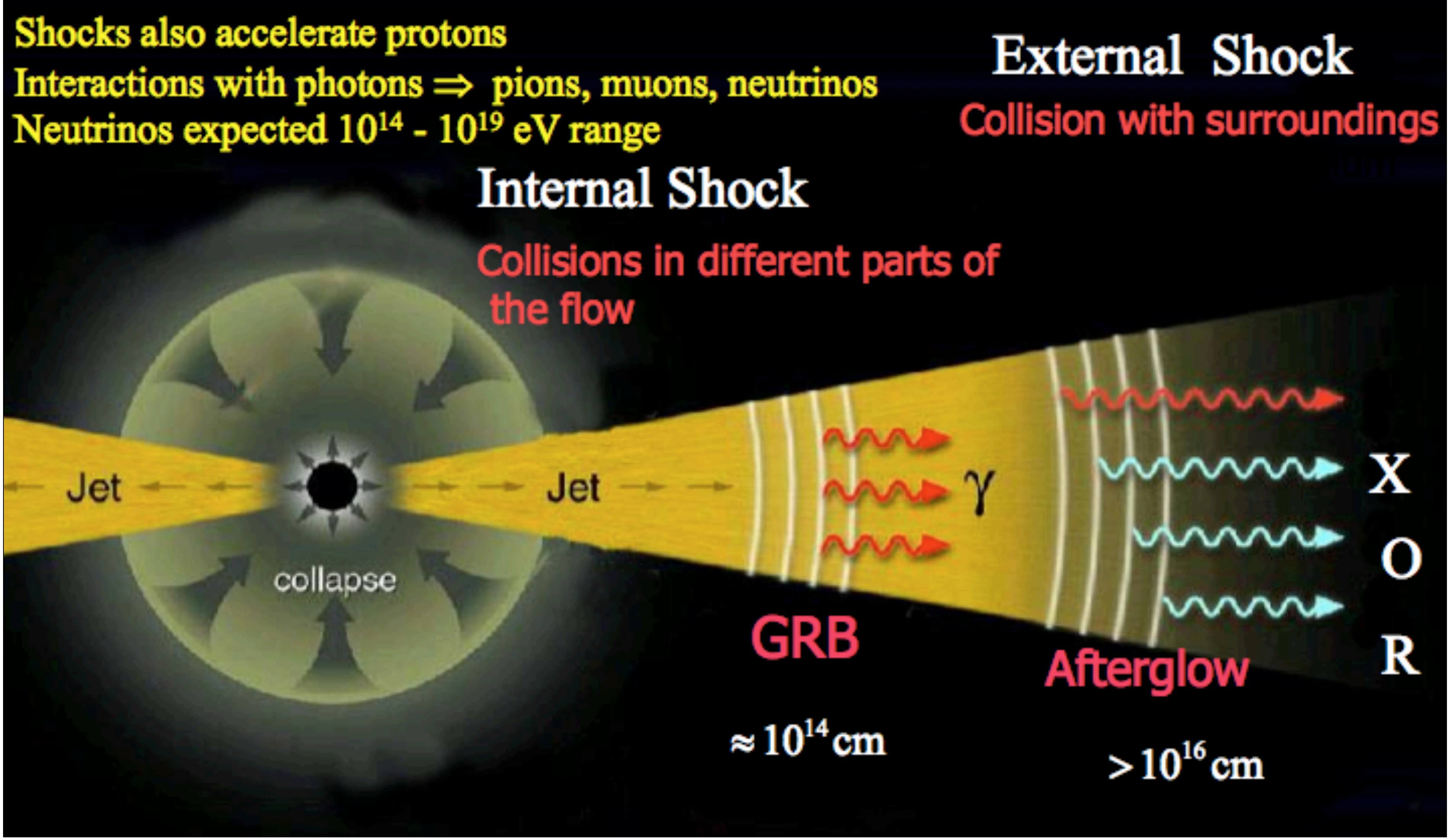
Vladimir Sudilovsky *(MPE & Guilford College)*

What is a Gamma-Ray Burst (GRB) ?

Very-massive fast-rotating star ➜ core-collapse supernova (Long GRB) or NS-BH merger (Short GRB)



Fast Facts about GRBs

1967: year of the first detection of a GRB, by the US military satellite Vela

1973: the first science paper on GRBs is published

1997: the first redshift is measured, GRBs are cosmological sources

148: number of GRBs with measured redshift today

6.3: redshift of the most distant GRB ever found

0.01 seconds: duration of the shortest GRBs, in the γ-ray emission phase

200 seconds: duration of longest GRBs, in the γ-ray emission phase

10^{51} ergs: typical energy emitted by a GRB, in a couple of minutes

10 billion years: the time required by the sun to emit the same energy

10^{54} ergs: energy emitted in gravitational waves and neutrinos

Rate: 1 event / 10^5 yr / galaxy (after beaming correction)

a few / day / universe

Pre-history of GRBs

- In 1975 already 100 different theories proposed
- More than 4000 refereed papers
- 4 decades of controversies

Stecker & Frost 1973	Stellar superflares
Harwit & Salpeter 1973	Impacts of comets onto neutron stars
Lamb et al.1973	Accreting compact objects
Zwicky 1974	Nuclear Goblins (bodies - 3-10 m in size - of nuclear density inside stars)
Pacini & Ruderman 1974	Old slowly spinning neutron stars (dead pulsars)
Grindlay et al. 1974	Relativistic Dust Grains from pulsars
Whipple 1974	Comets
Chanmugam 1974	Magnetic white dwarfs
Sofia & van Horn 1974	Collisions of chunks of antimatter of mass about 10^{15} g with normal stars
Fabian & Pringle 1975	Do not favor the possibility that supernovae might be sources of gamma-ray bursts
Bruk & Kugel 1976	Melting of neutron stars
Schmidt 1978	Nonrelativistic sources - cannot be further away than a few kpc from the sun
Uknonwn:	"Exhaust from alien warp-drive engines"

- 1968 Stirling A. Colgate prediction: γ-ray emission from SNs in distant galaxies

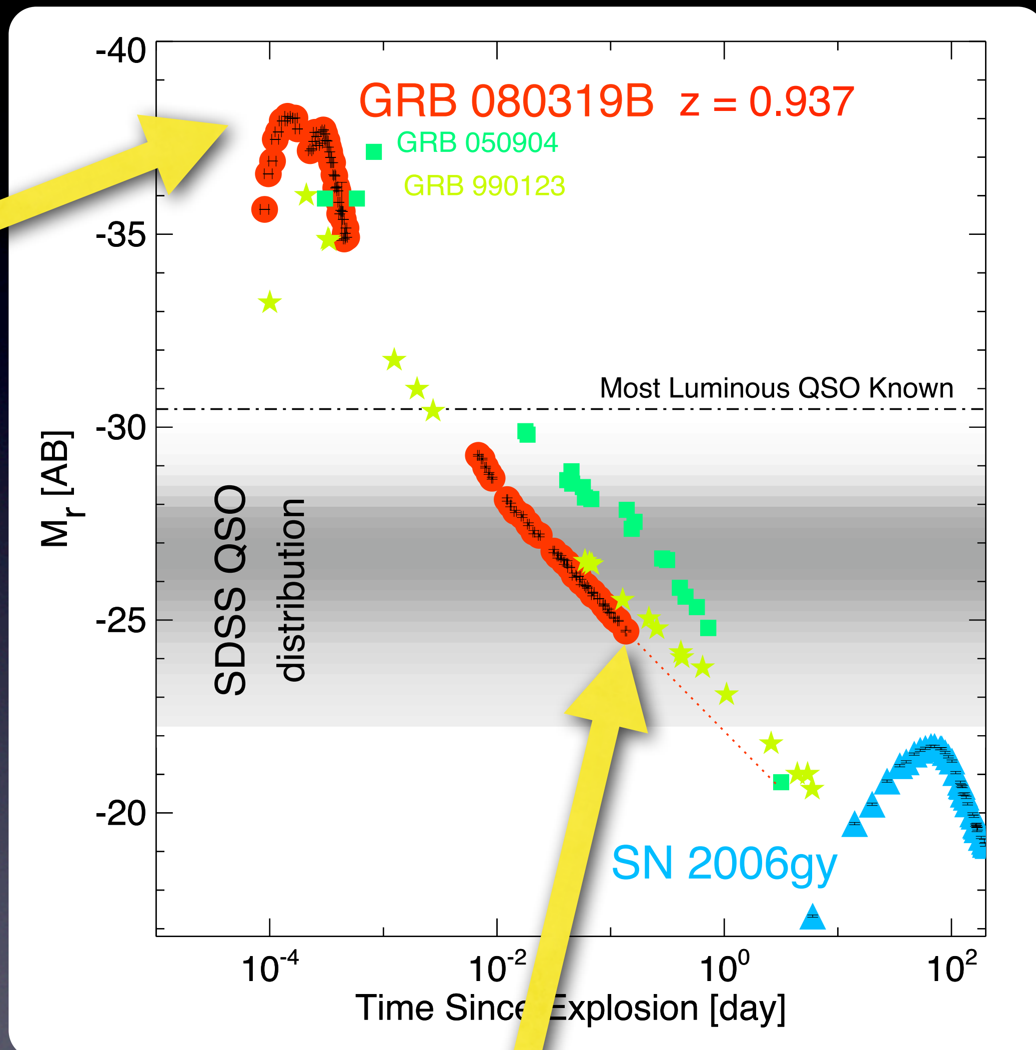
The good and the bad about gamma-ray bursts

They fade away very quickly

They fade away very quickly

Gamma-ray bursts: exceptional events

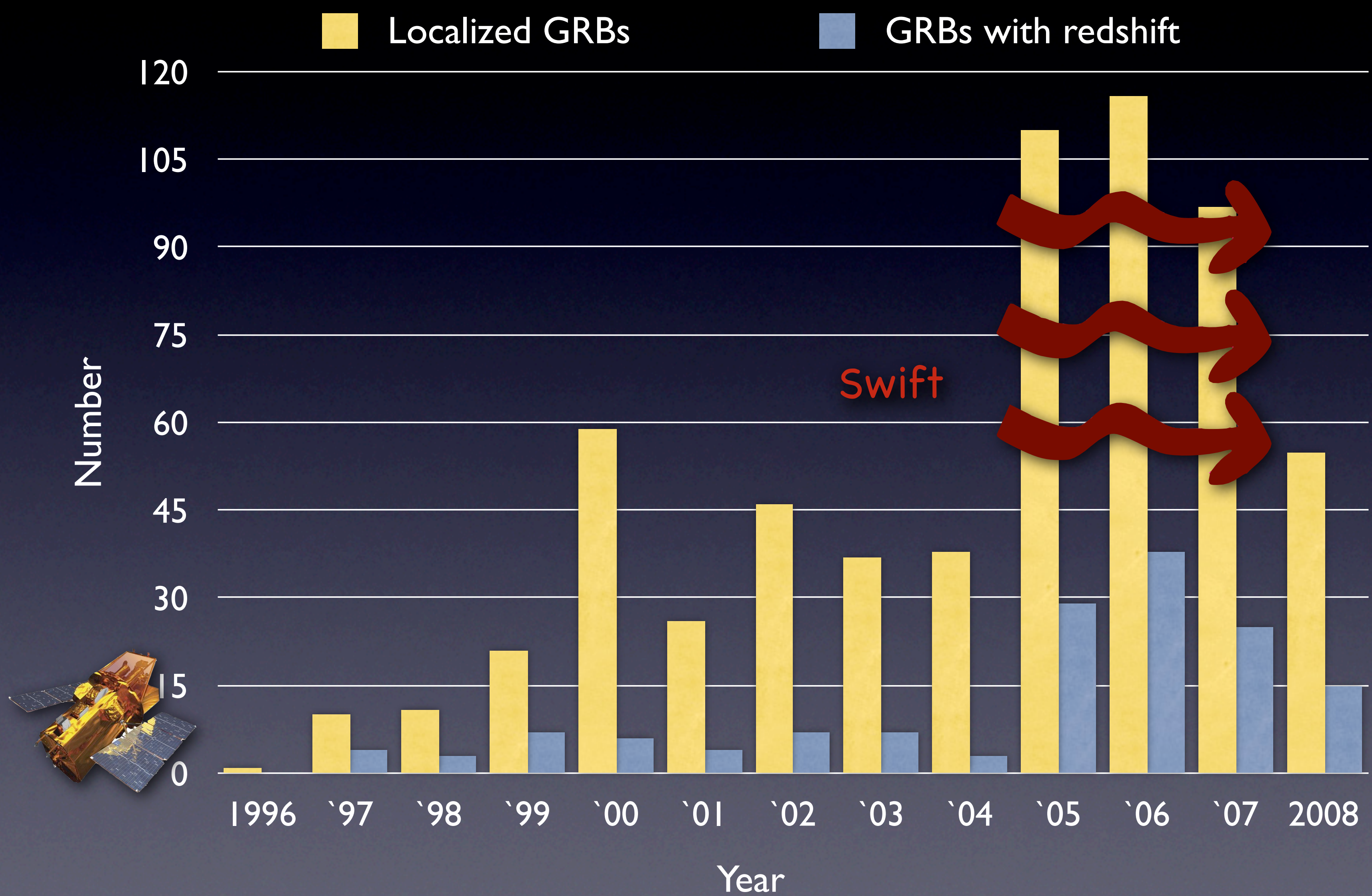
Visual magnitude m=5.6



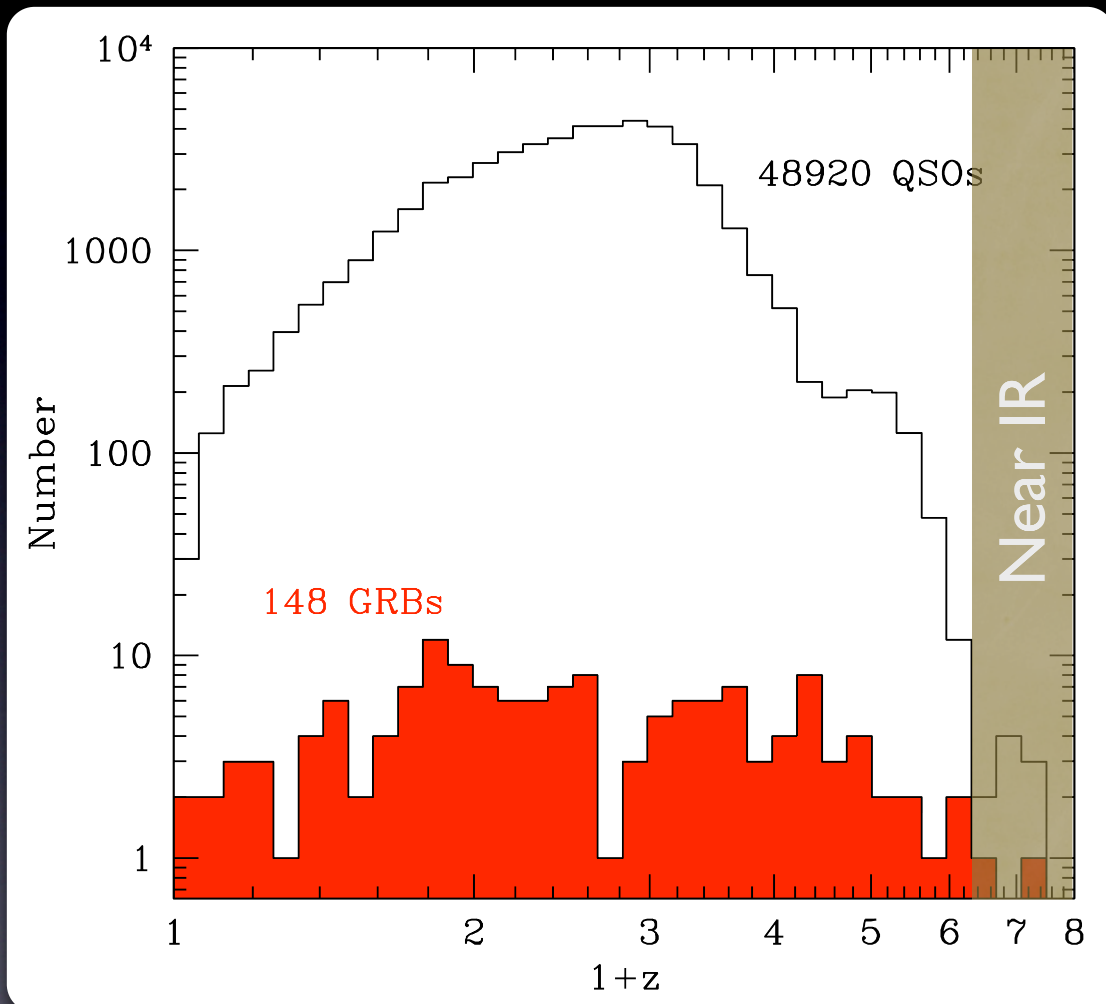
Bloom et al. (2008 March 24, ApJ Submitted, 42 pages)

6.9 hours after m=19

Gamma-ray bursts: exceptional events

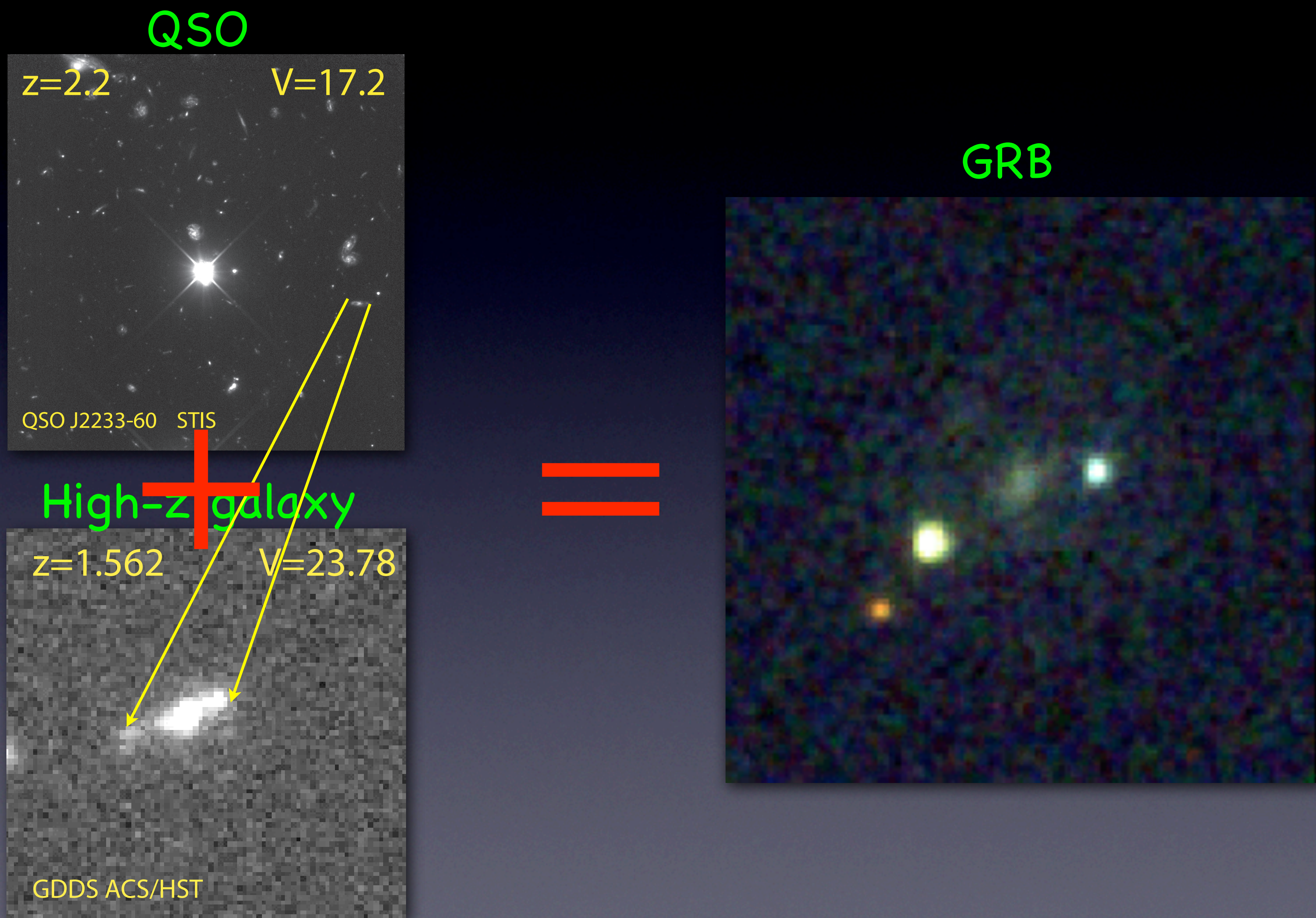


Gamma-ray bursts: exceptional events

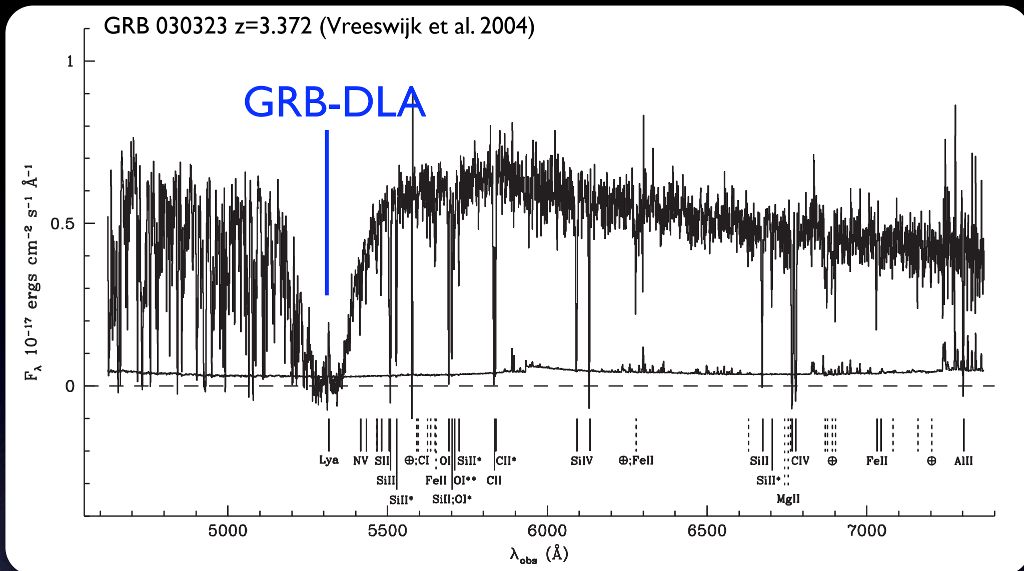


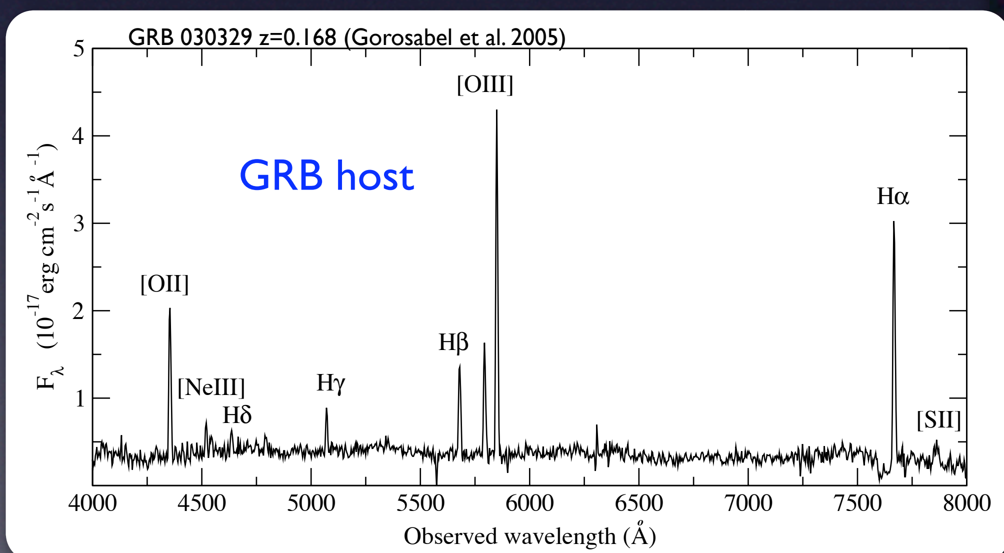
Log (time)

Gamma-ray bursts: exceptional events



Gamma-ray bursts: exceptional events



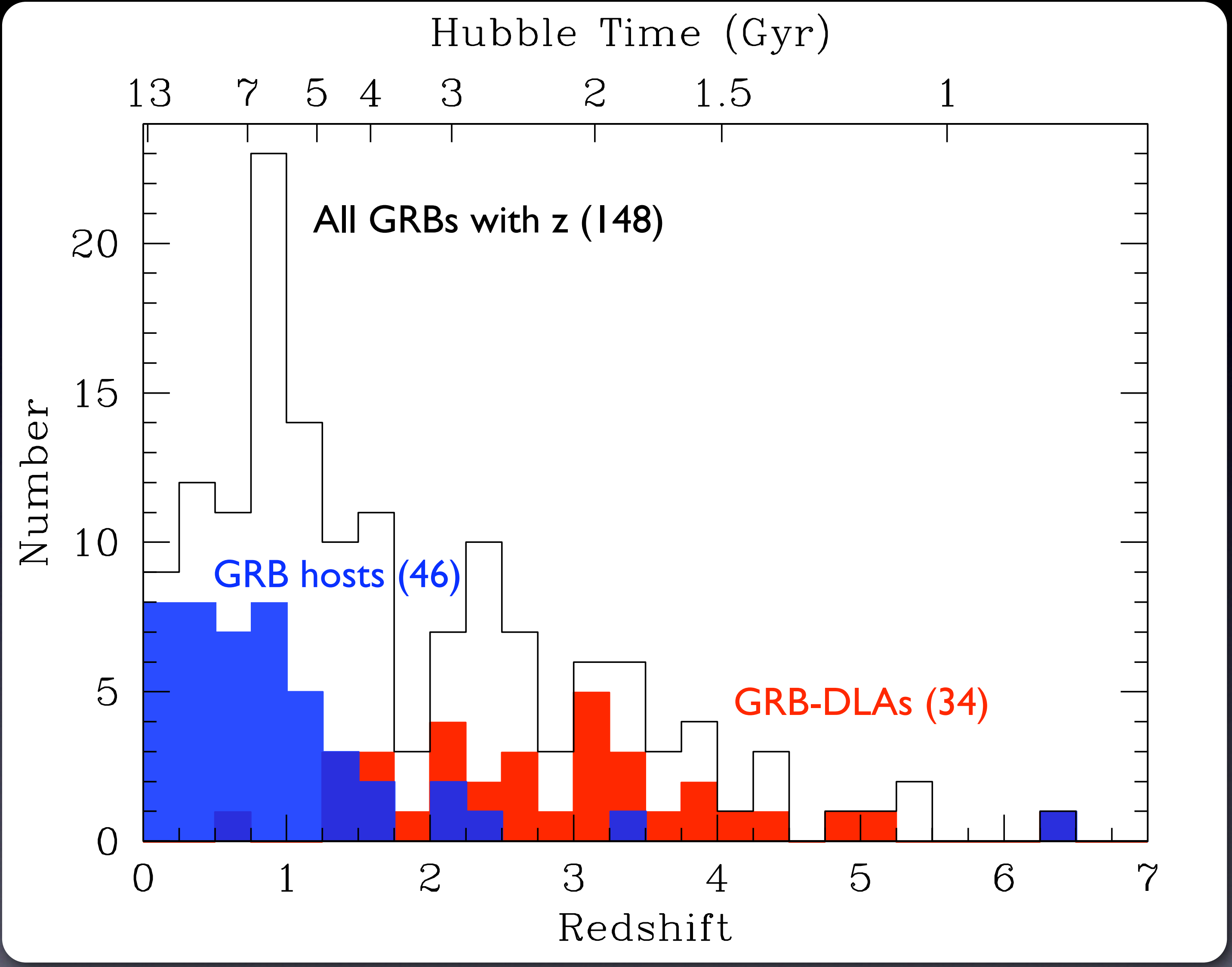


Gamma-ray bursts: exceptional events

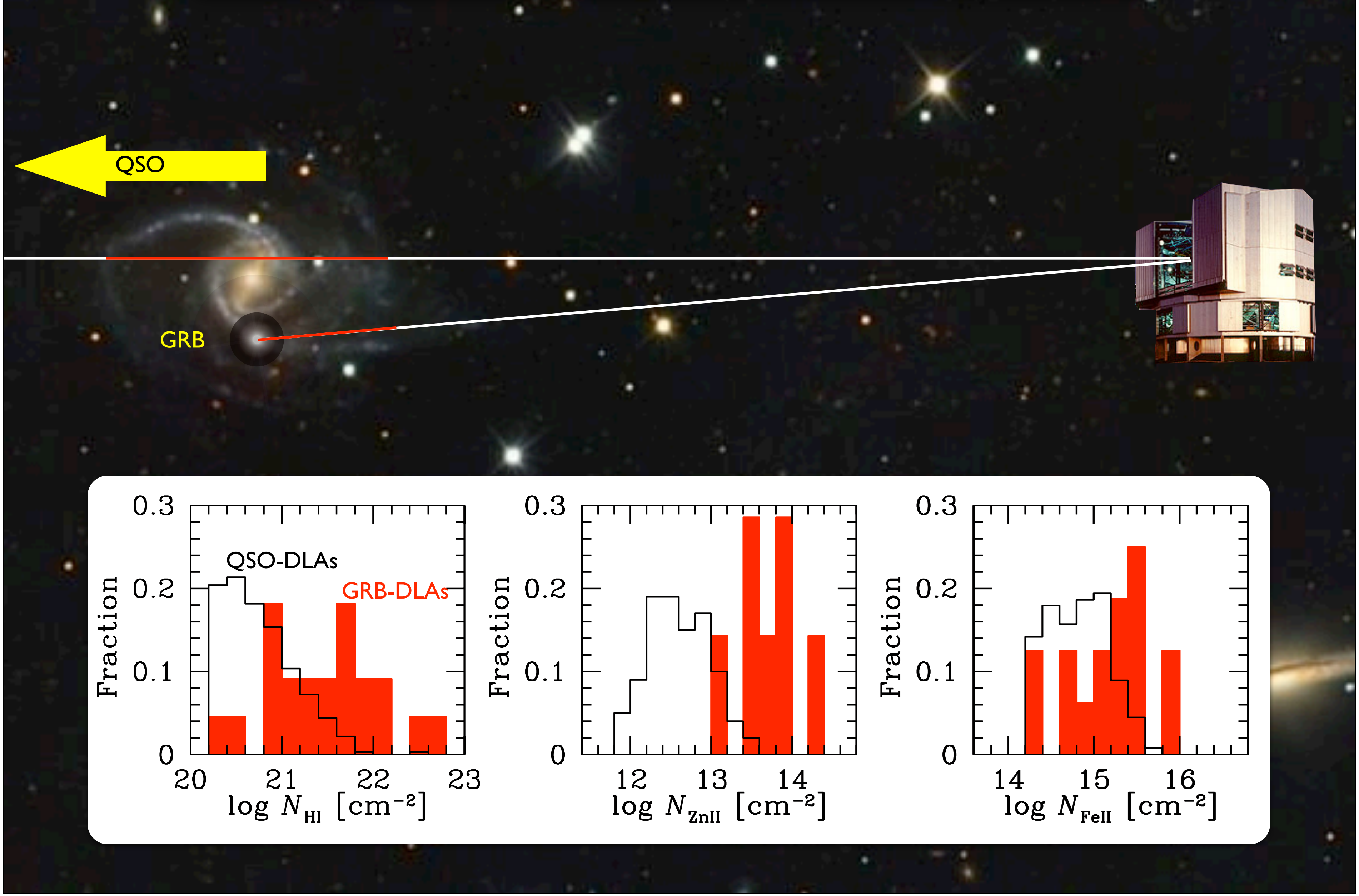
What can we study? A partial view...

1. *Star formation under extreme conditions*
2. *Massive stars (supernovae, WR)*
3. *Black Holes*
4. *Reionization of the universe*
5. *Cosmic chemical evolution*
6. *SFR density of the universe*
7. *Small galaxies at high redshift*
8. *Galaxies at z>7*

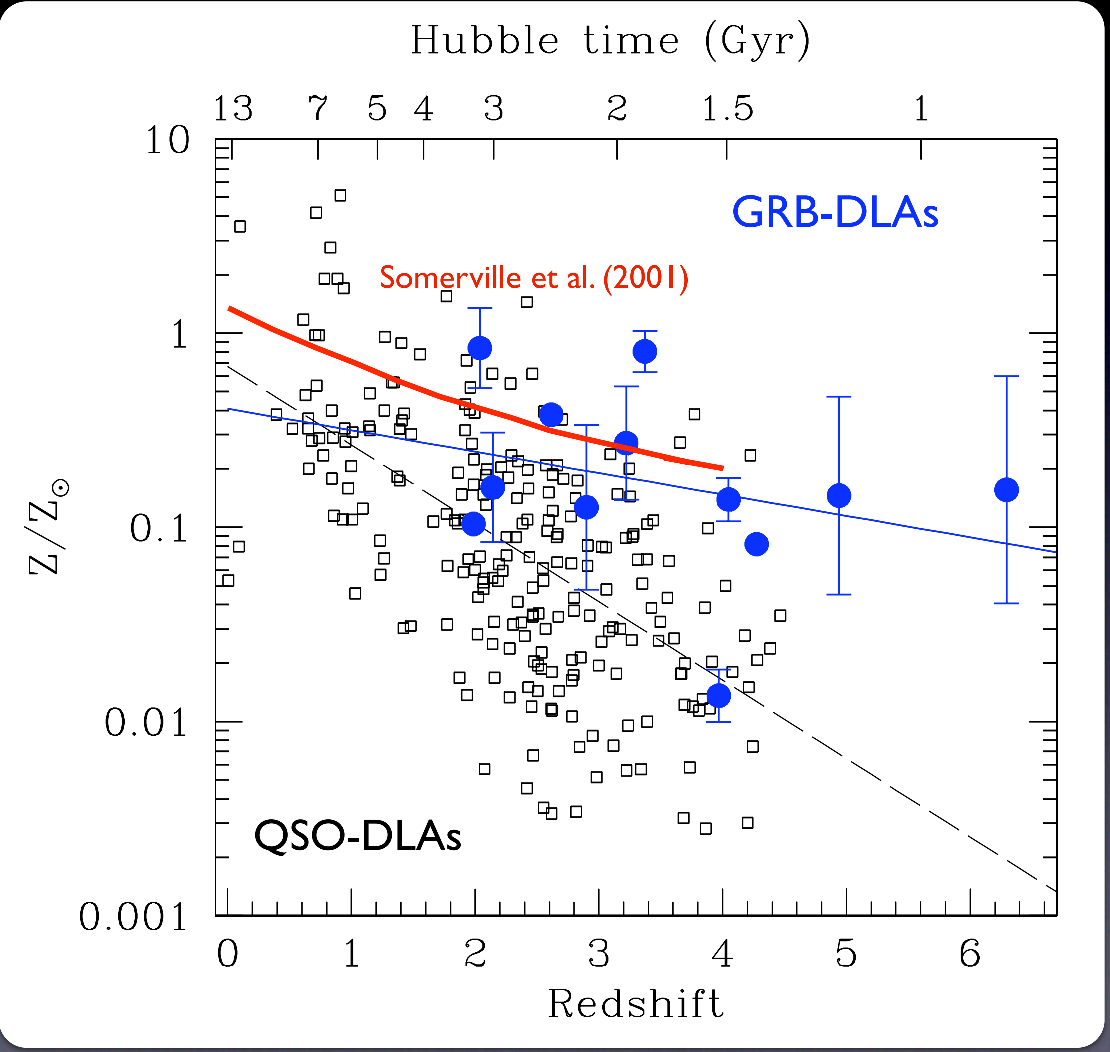
GRB redshift distribution



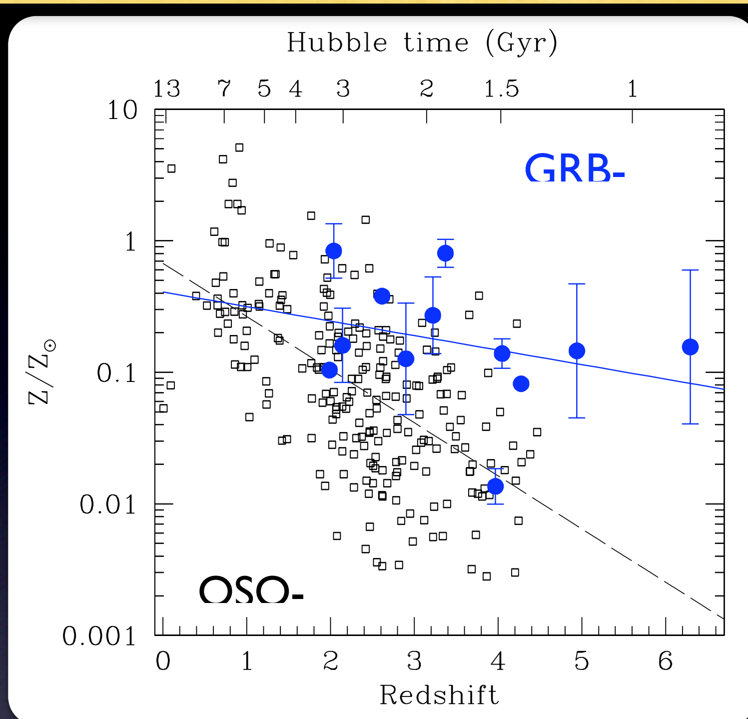
Chemical enrichment from GRB-DLAs

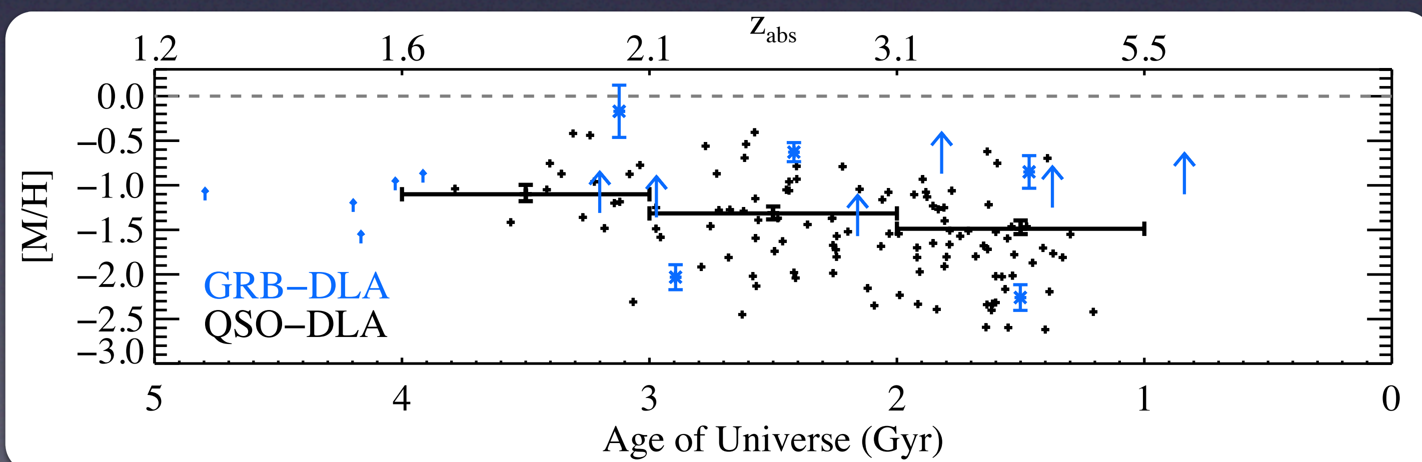


Chemical evolution from GRB-DLAs



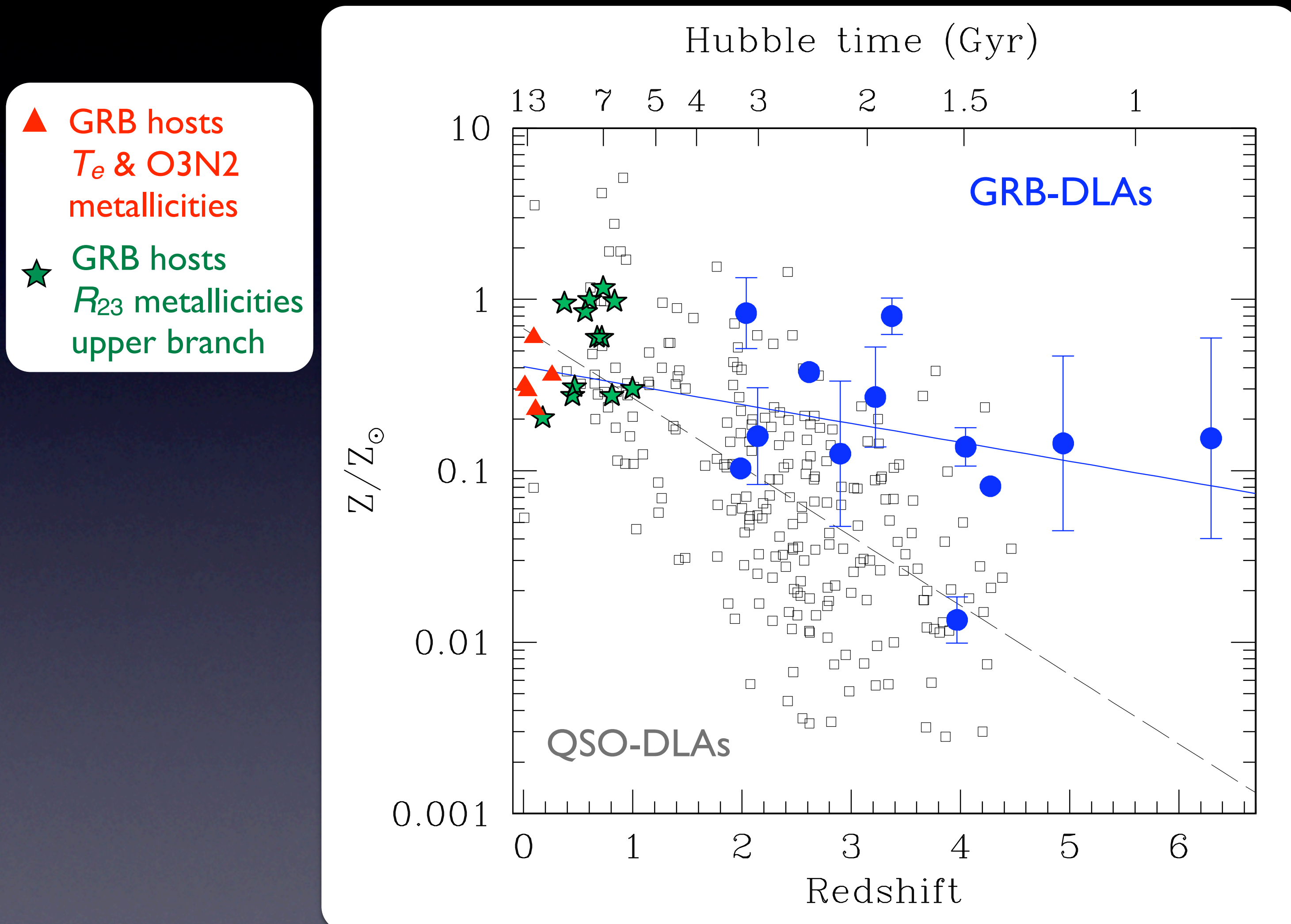
Chemical evolution from GRB-DLAs



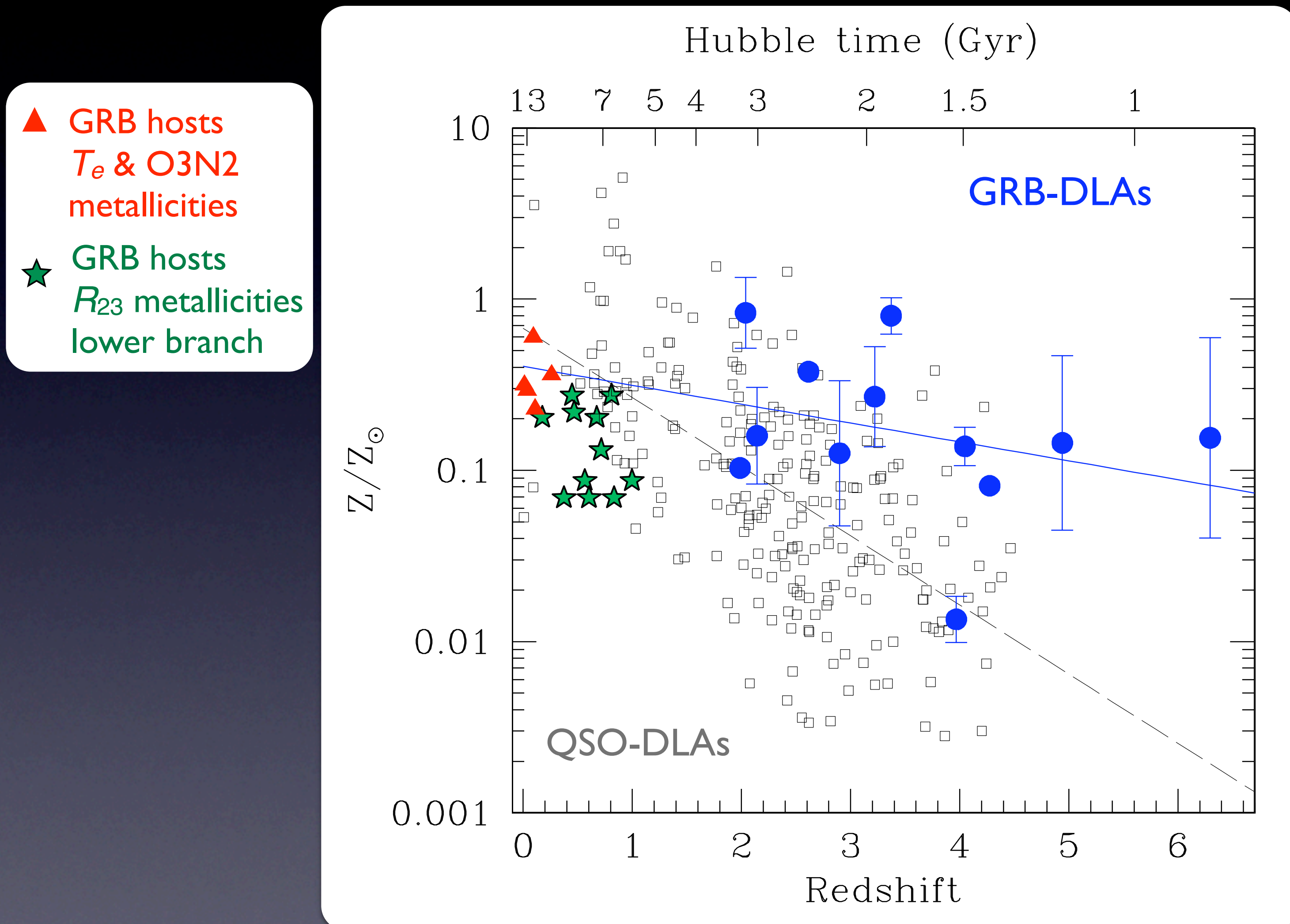


Prochaska, Chen, Dessauges-Zavadskyand, & Bloom (2008)

Chemical evolution from GRB-DLAs



Chemical evolution from GRB-DLAs



Chemical enrichment from GRB-DLAs

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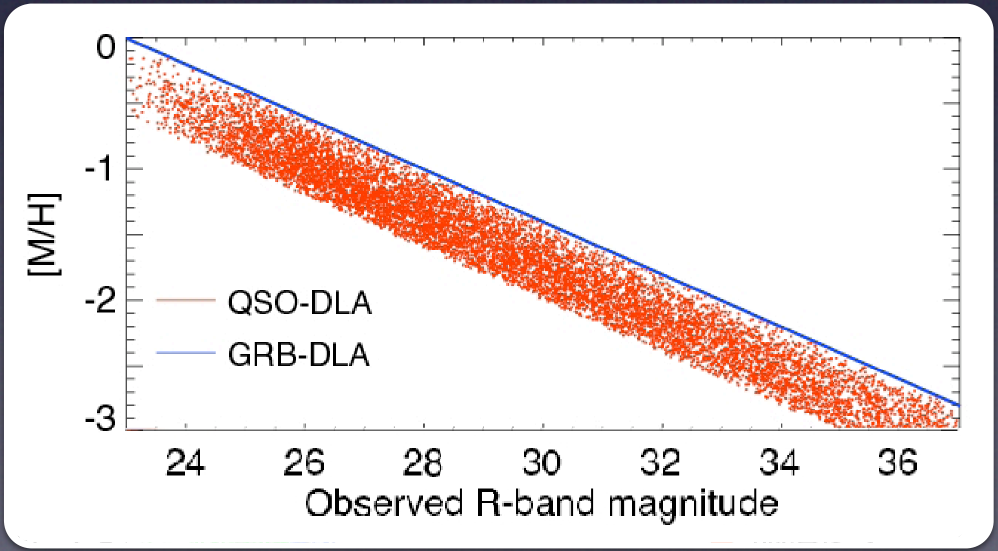
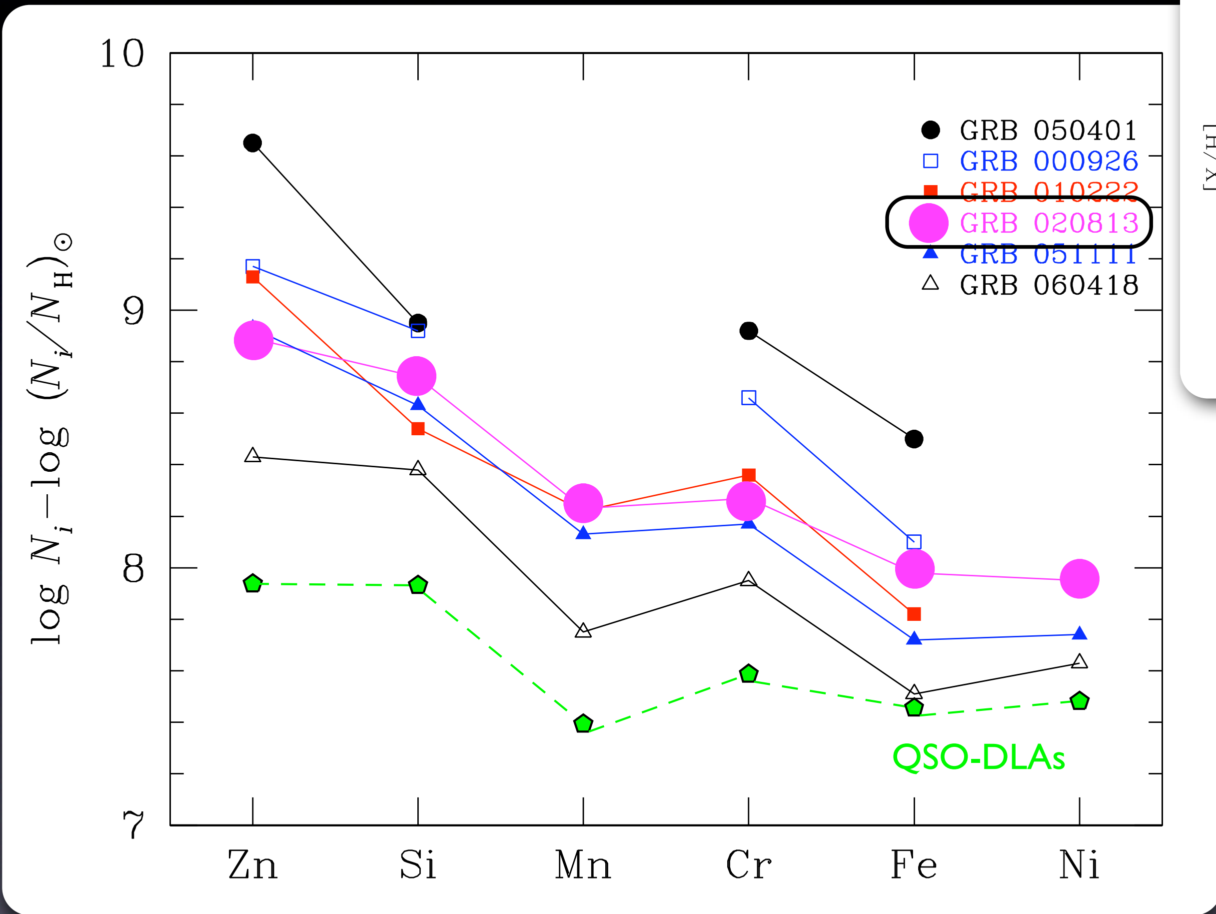
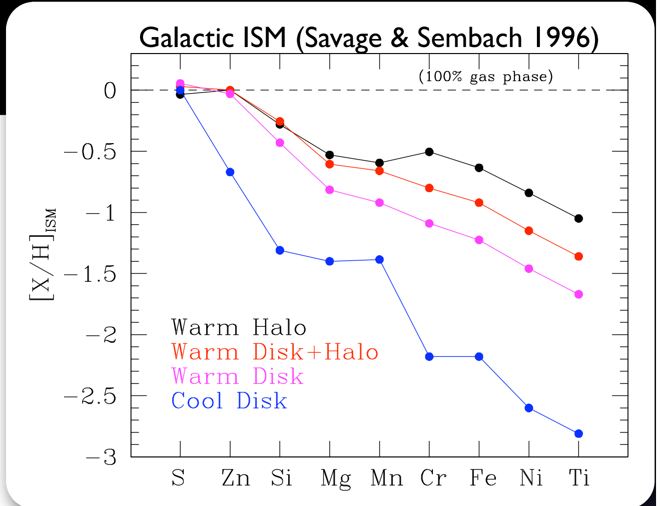
Prochaska, J. X.; Chen, H. W.; Dessauges-Zavadsky, M.; Bloom, J. S.: P*robing the Interstellar Medium near Star-forming Regions with Gamma-Ray Burst Afterglow Spectroscopy: Gas, Metals, and Dust*, 2007, ApJ, 666, 267

Fynbo, J. P. U.; Prochaska J. X.; Sommer-Larsen J.; Dessauges-Zavadsky, M., Møller P.: *Reconciling the Metallicity Distributions of Gamma-ray Burst, Damped Lyman-α, and Lyman-break Galaxies at z ≈ 3* , 2008, A&A, astro-ph/0801.3723



Dust depletion in GRB-DLAs

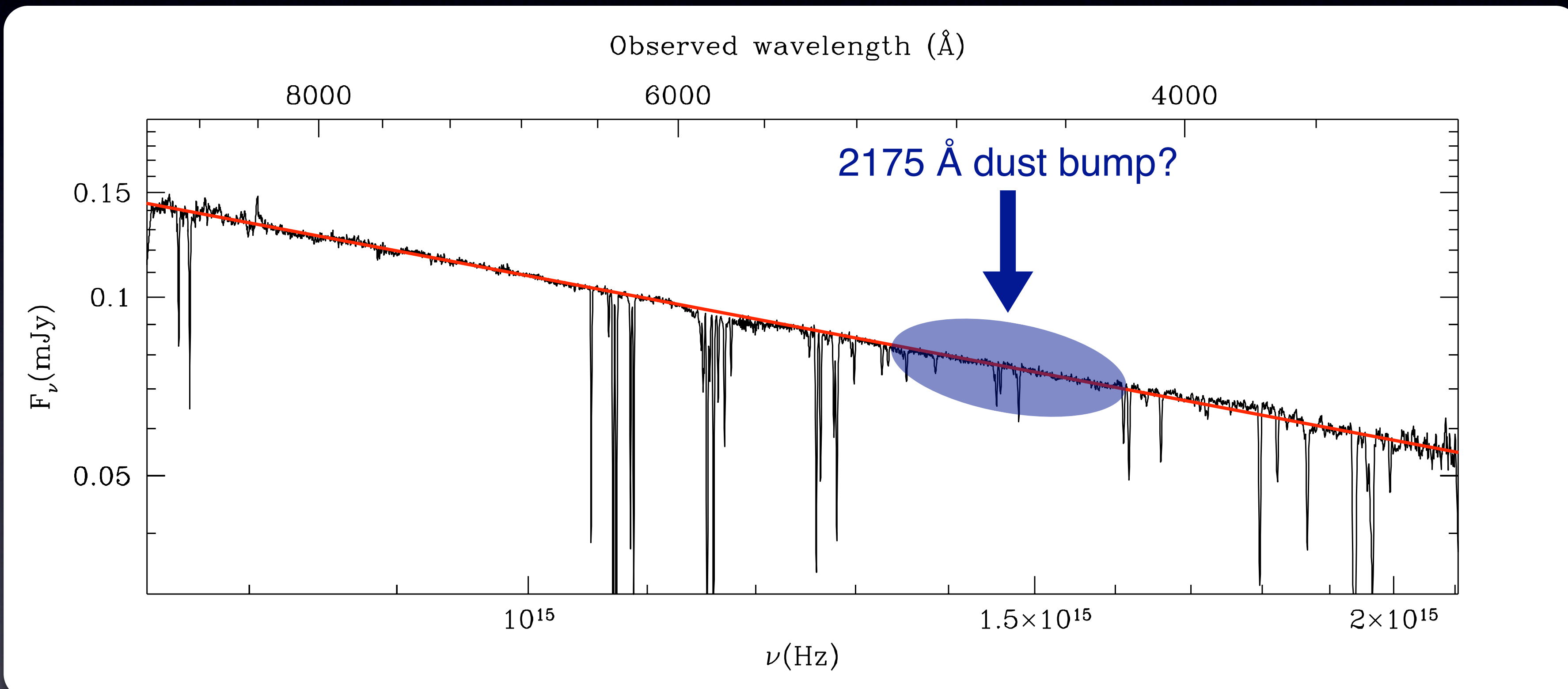




Savaglio (2006)

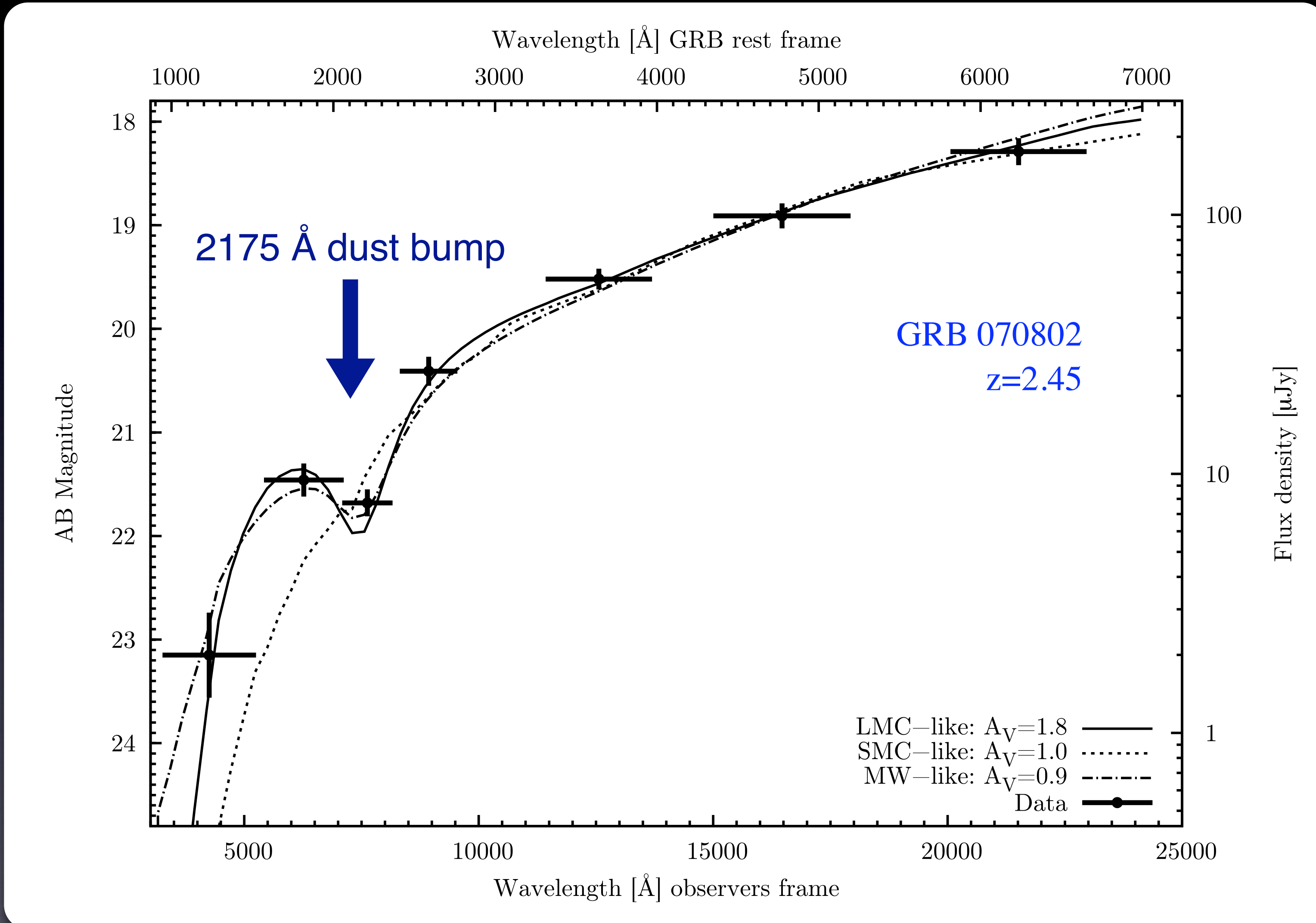
Dust extinction in GRB-DLAs

GRB 020813 (z=1.255)



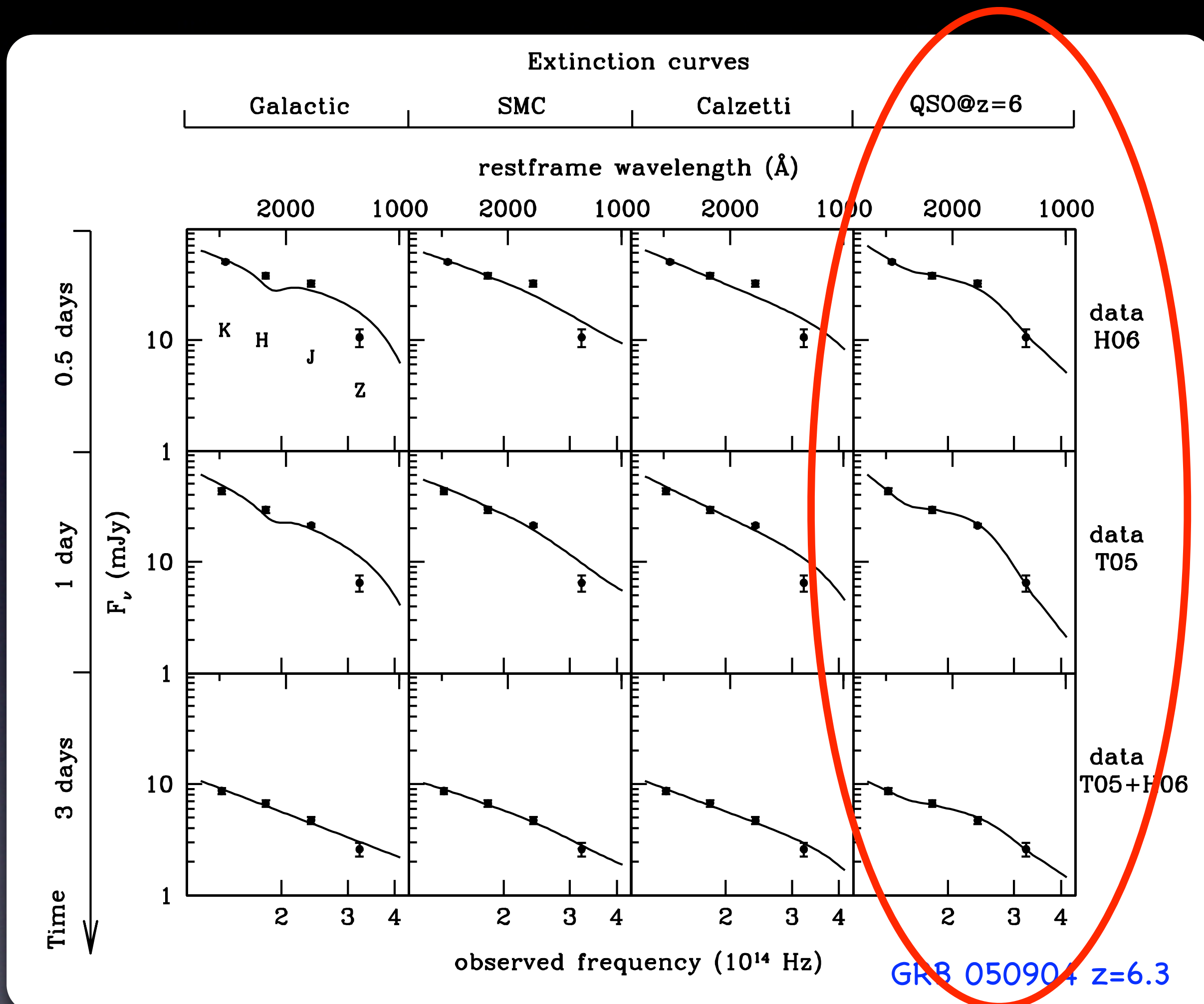
Barth et al. (2003)
Savaglio & Fall (2004)

Dust extinction in GRB-DLAs



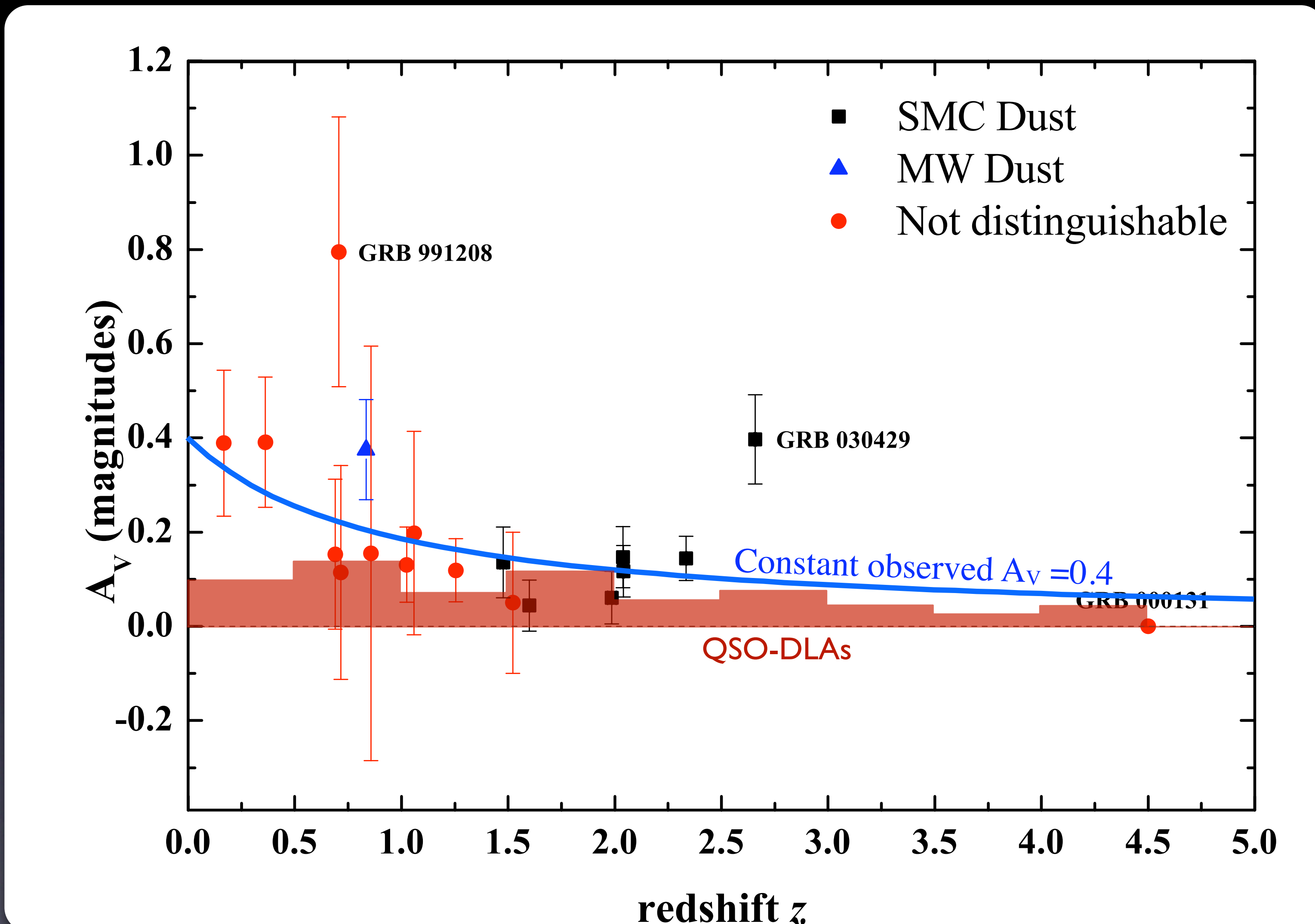
Krühler et al. (2008)

Dust extinction in GRB-DLAs



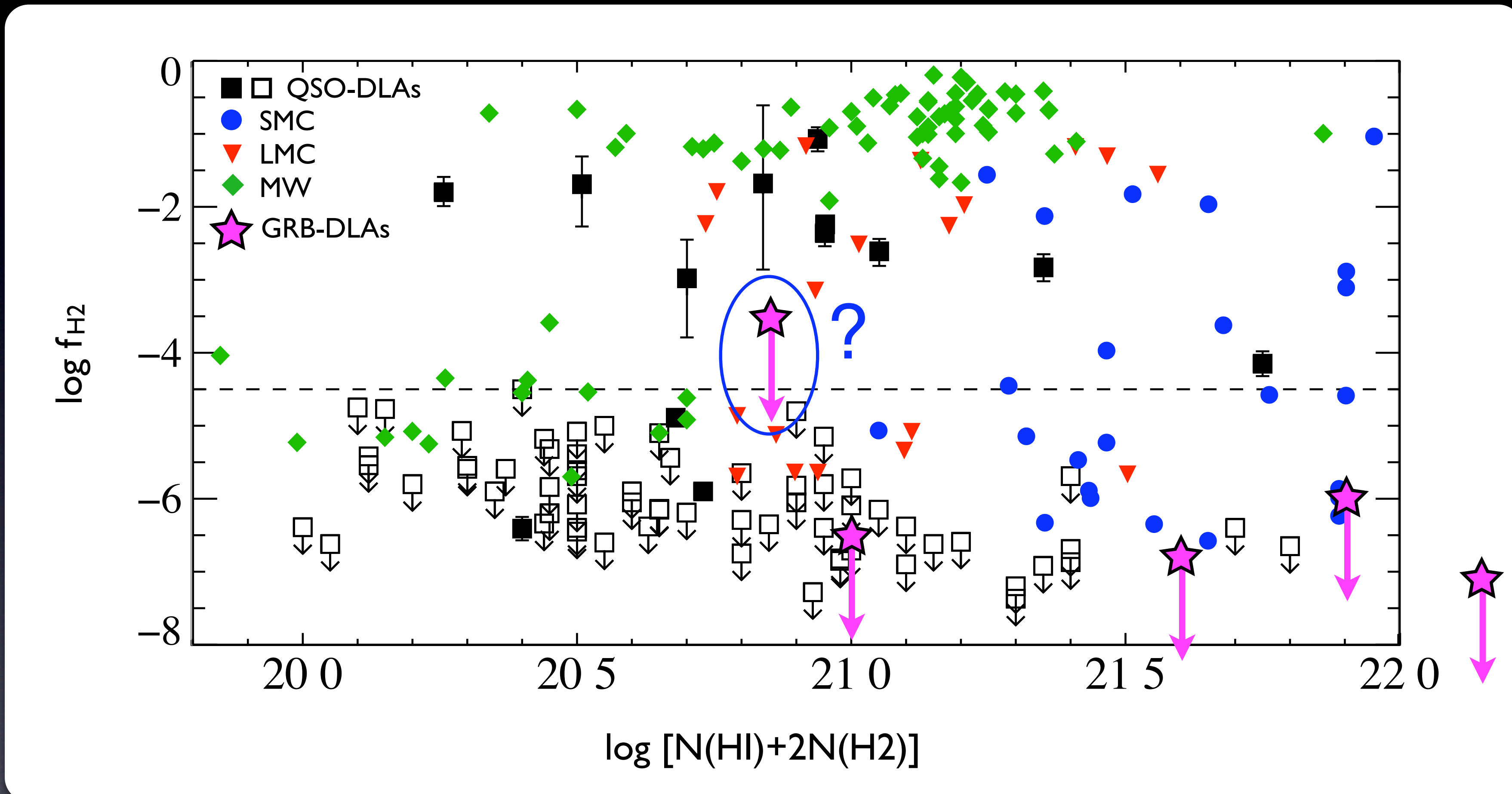
Stratta, Maiolino, Fiore & D'Elia (2007)

Dust extinction in GRB-DLAs



Kann, Klose, & Zeh (2006)
Friedman & Bloom (2005)

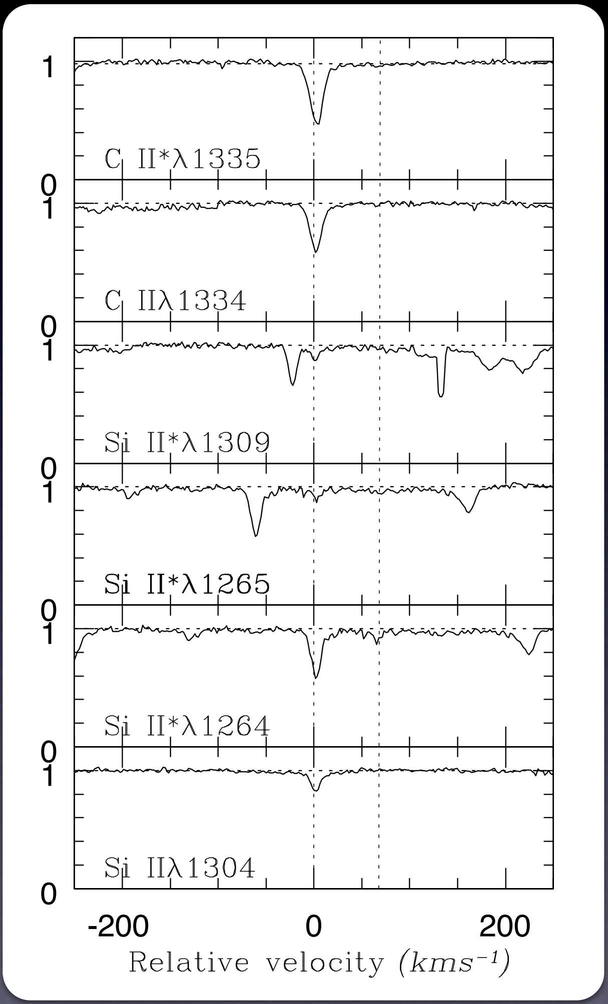
Molecular hydrogen in GRB-DLAs



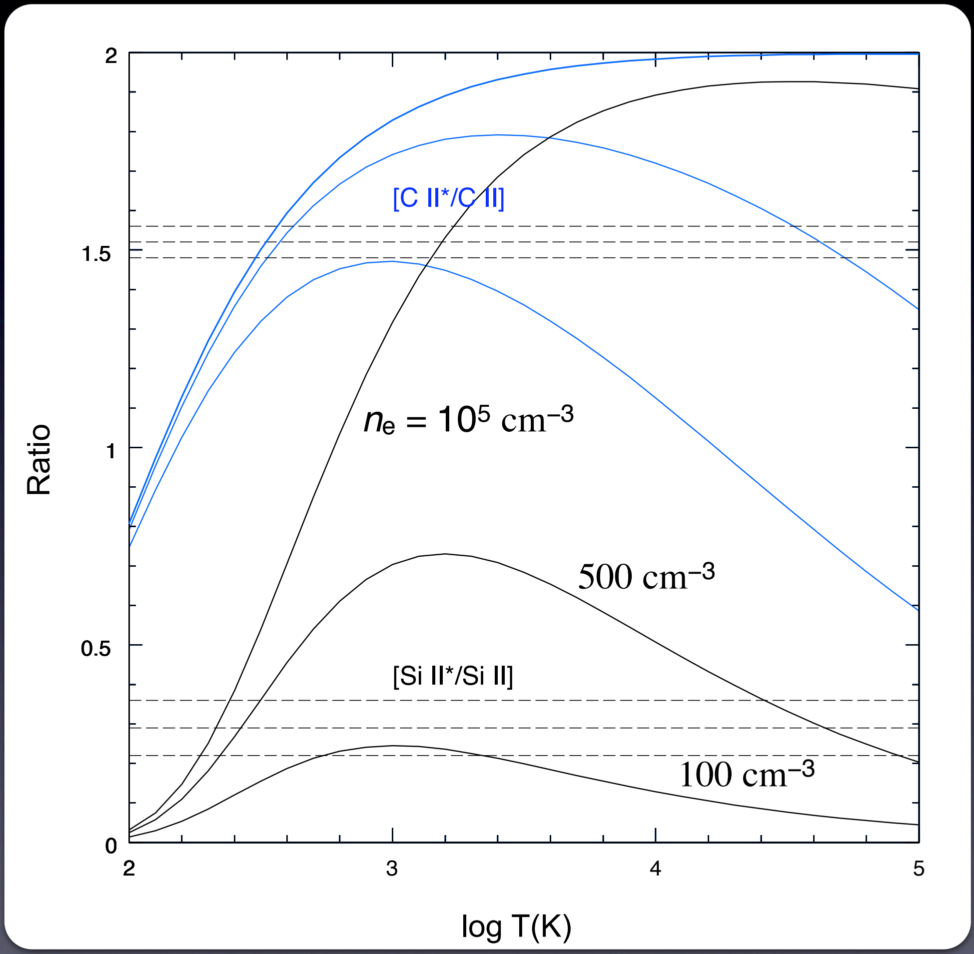
Noterdaeme, Ledoux, Petitjean, & Srianand (2008)
Tumlinson, Prochaska, Chen, Dessauges-Zavadsky, & Bloom (2007)

Fine-structure absorptions along GRB sight-lines

QSO associated narrow-absorption systems

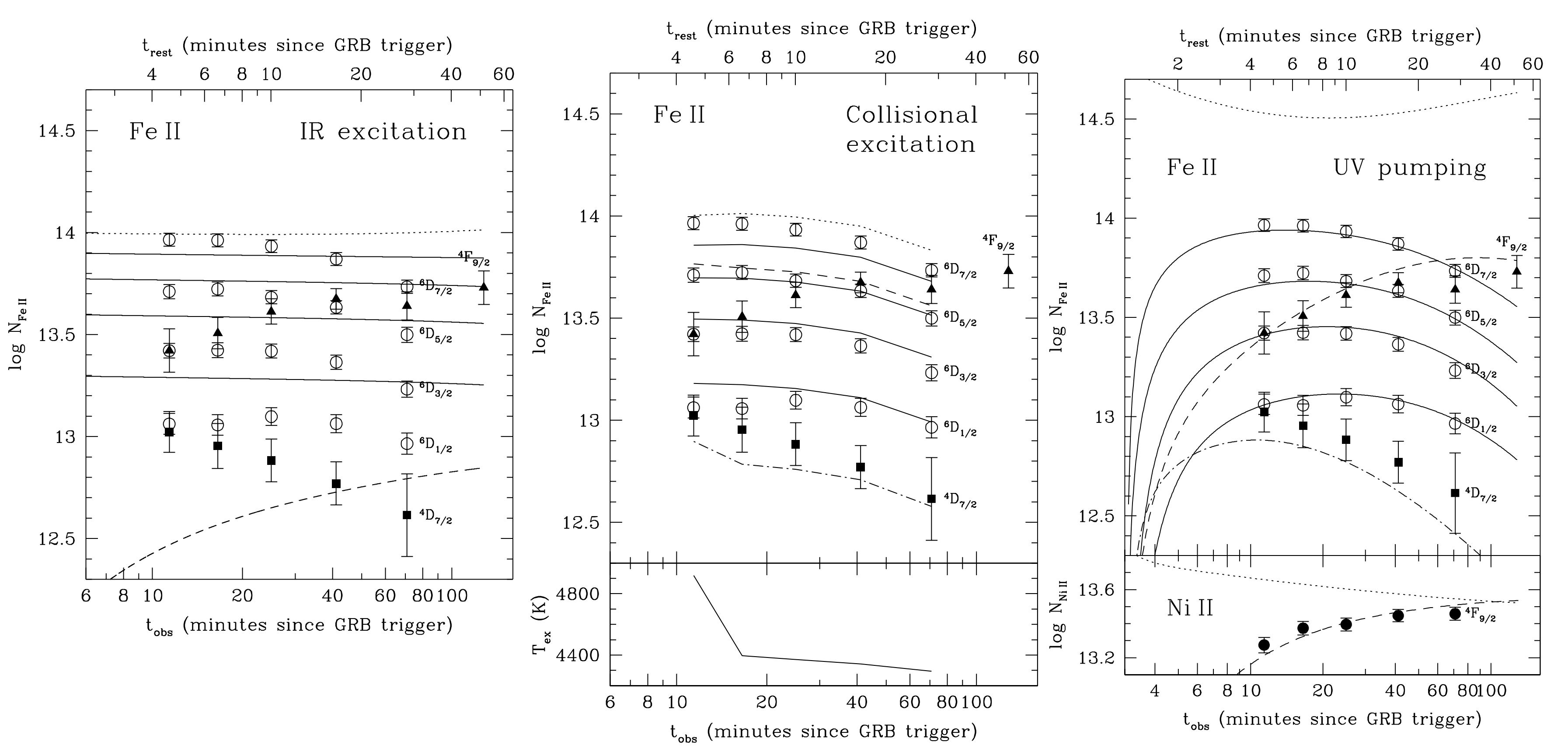


Srianand & Petitjean (2000)



Fine-structure absorptions in circumburst medium

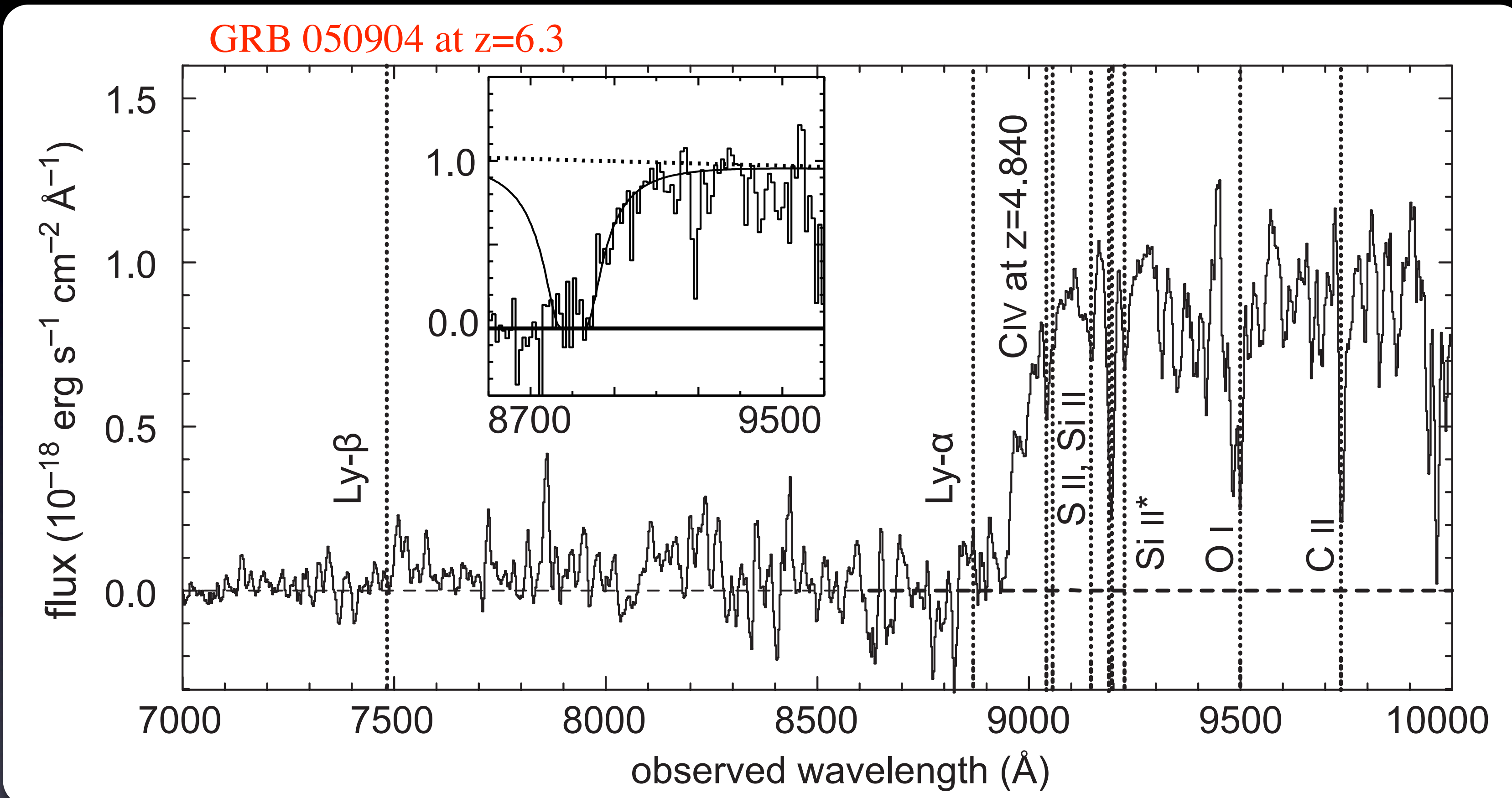
GRB 060418 z=1.490



Vreeswijk, Ledoux, Smette al. (2007)

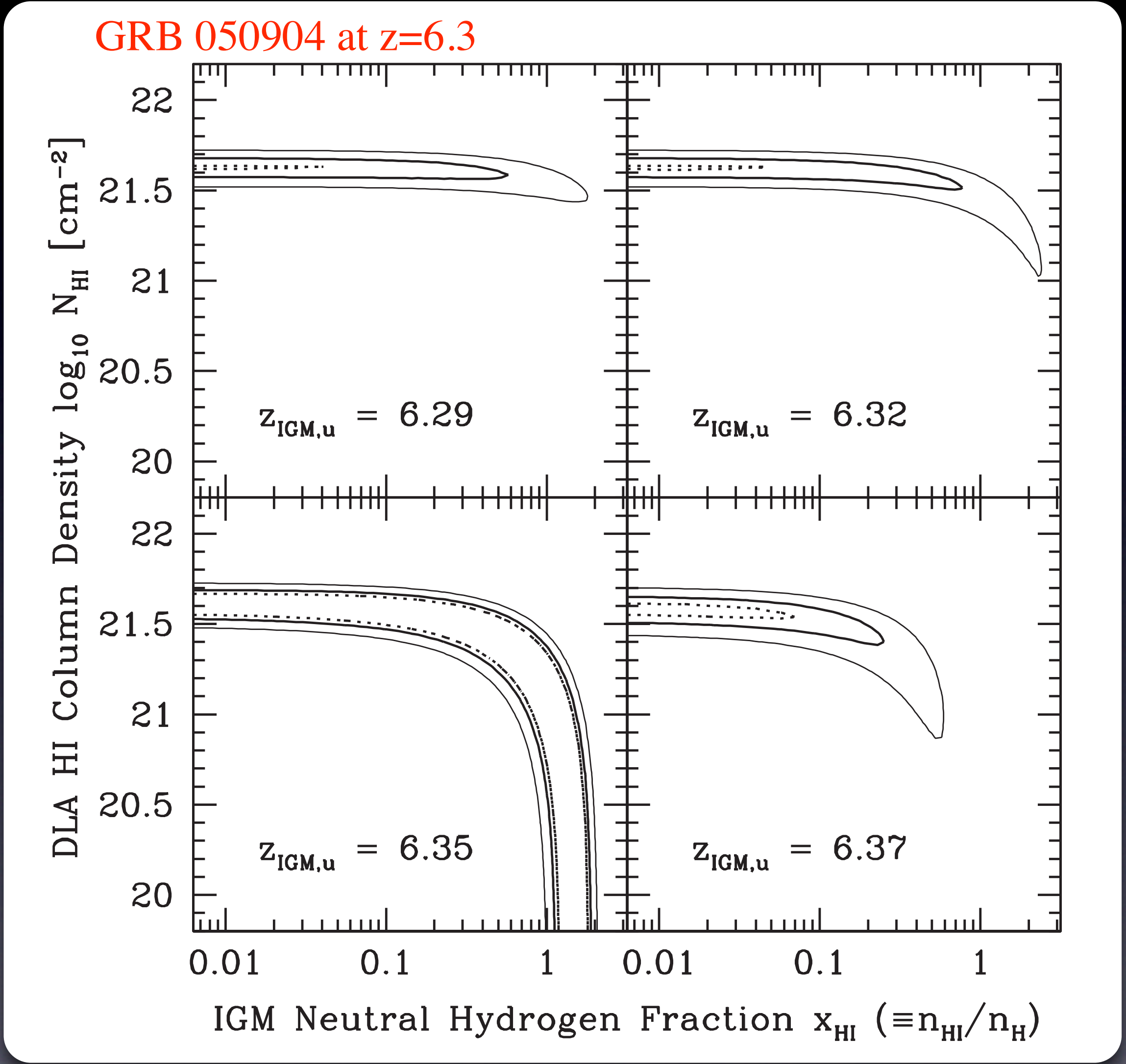
(see also Dessauges-Zavadsky, Chen, Prochaska, Bloom, & Barth 2006; Prochaska, Chen, & Bloom 2006)

Reionization of the universe



Totani et al. (2006)

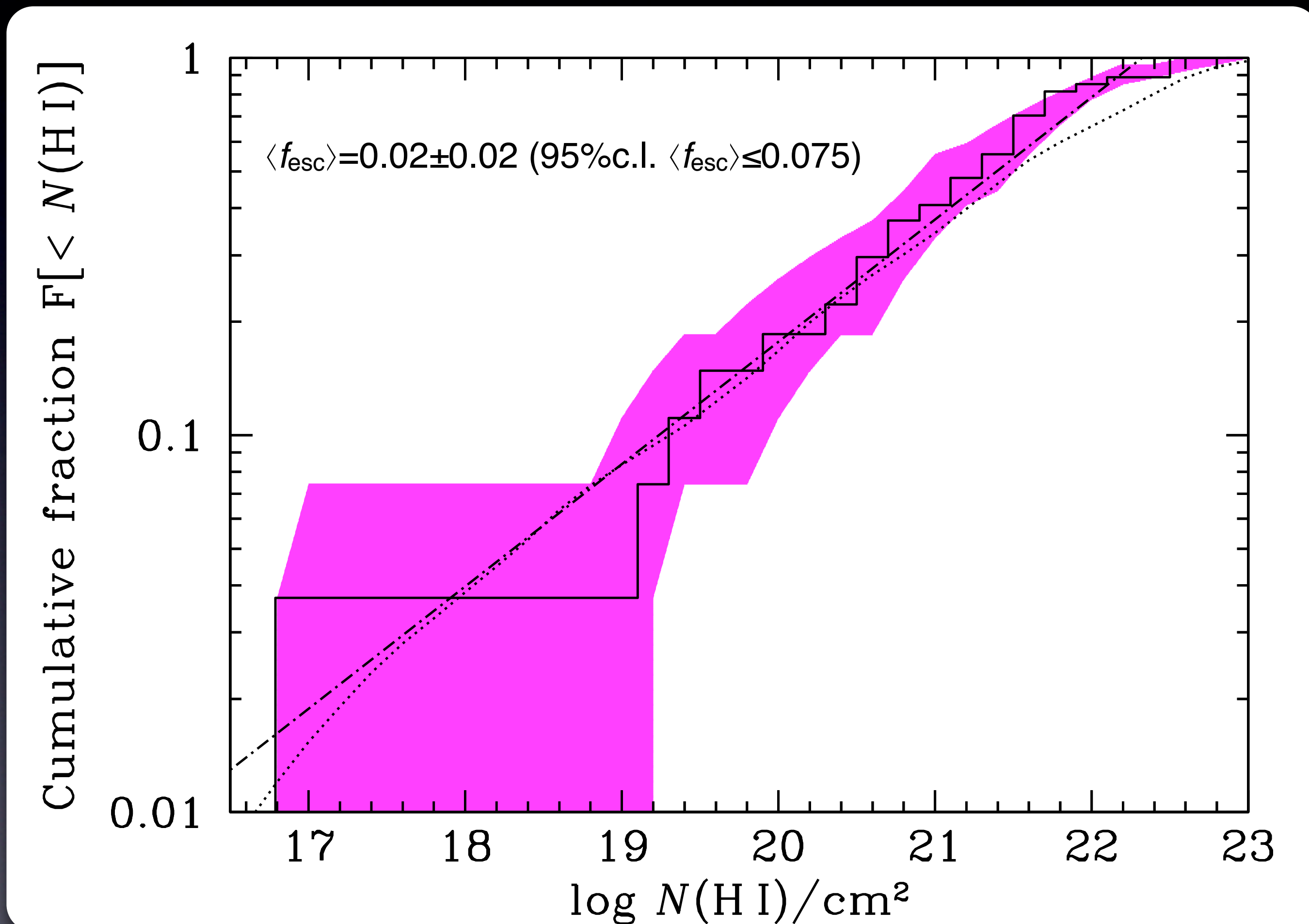
Reionization of the universe



Totani et al. (2006)

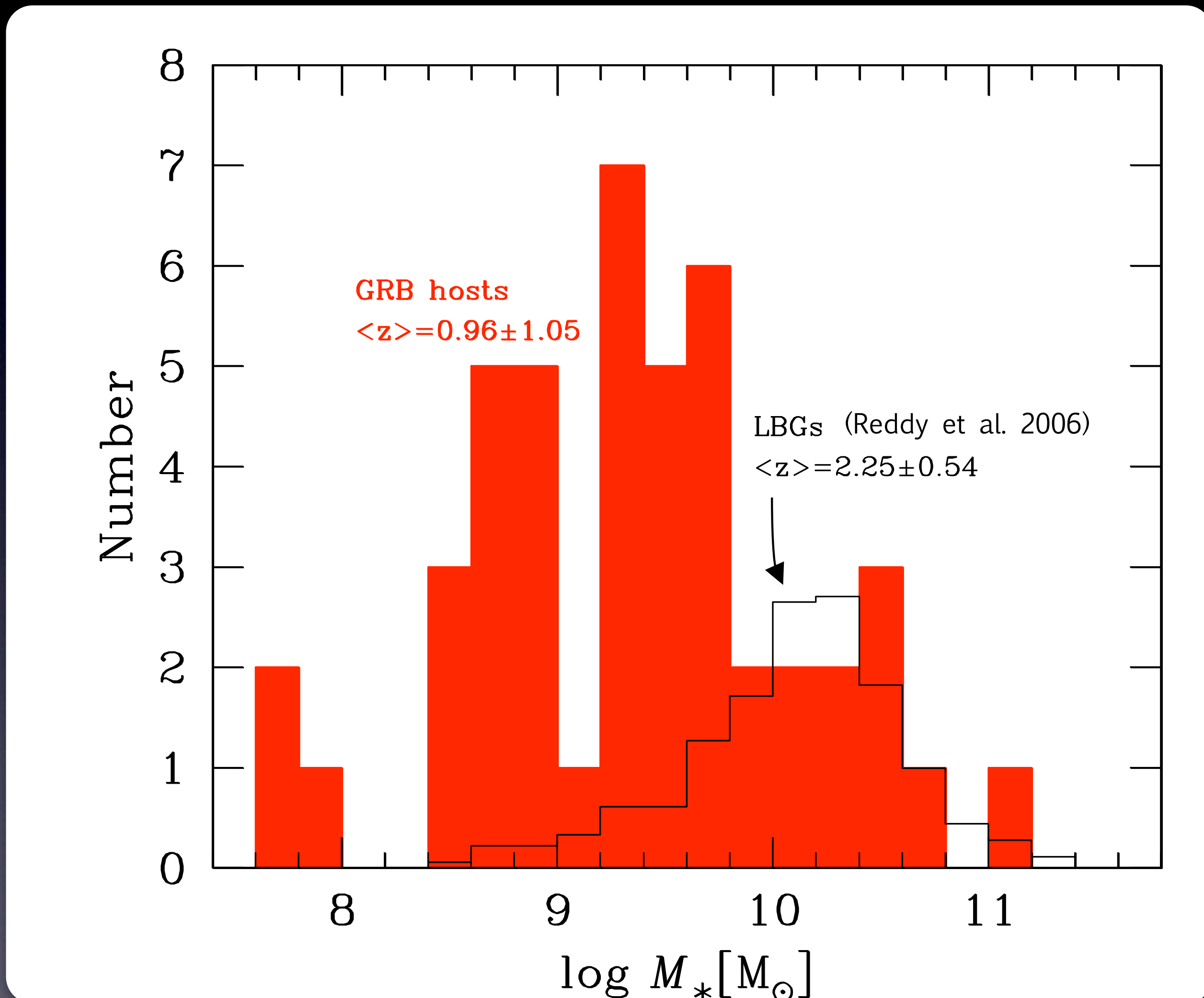
Escape fraction of UV photons

Spectra of GRB afterglows



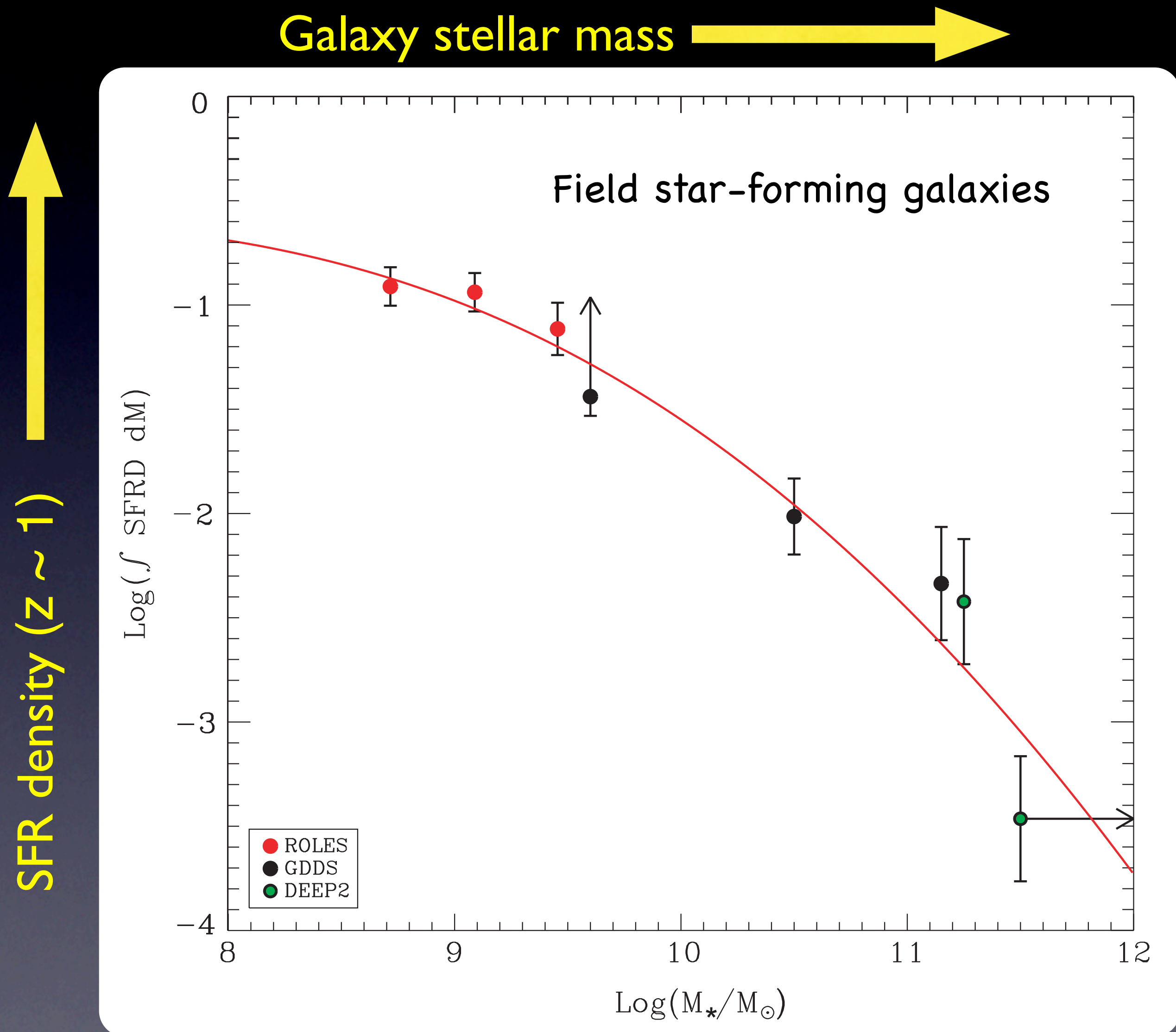
Chen, Prochaska, Gnedin (2007)

GRB host stellar masses



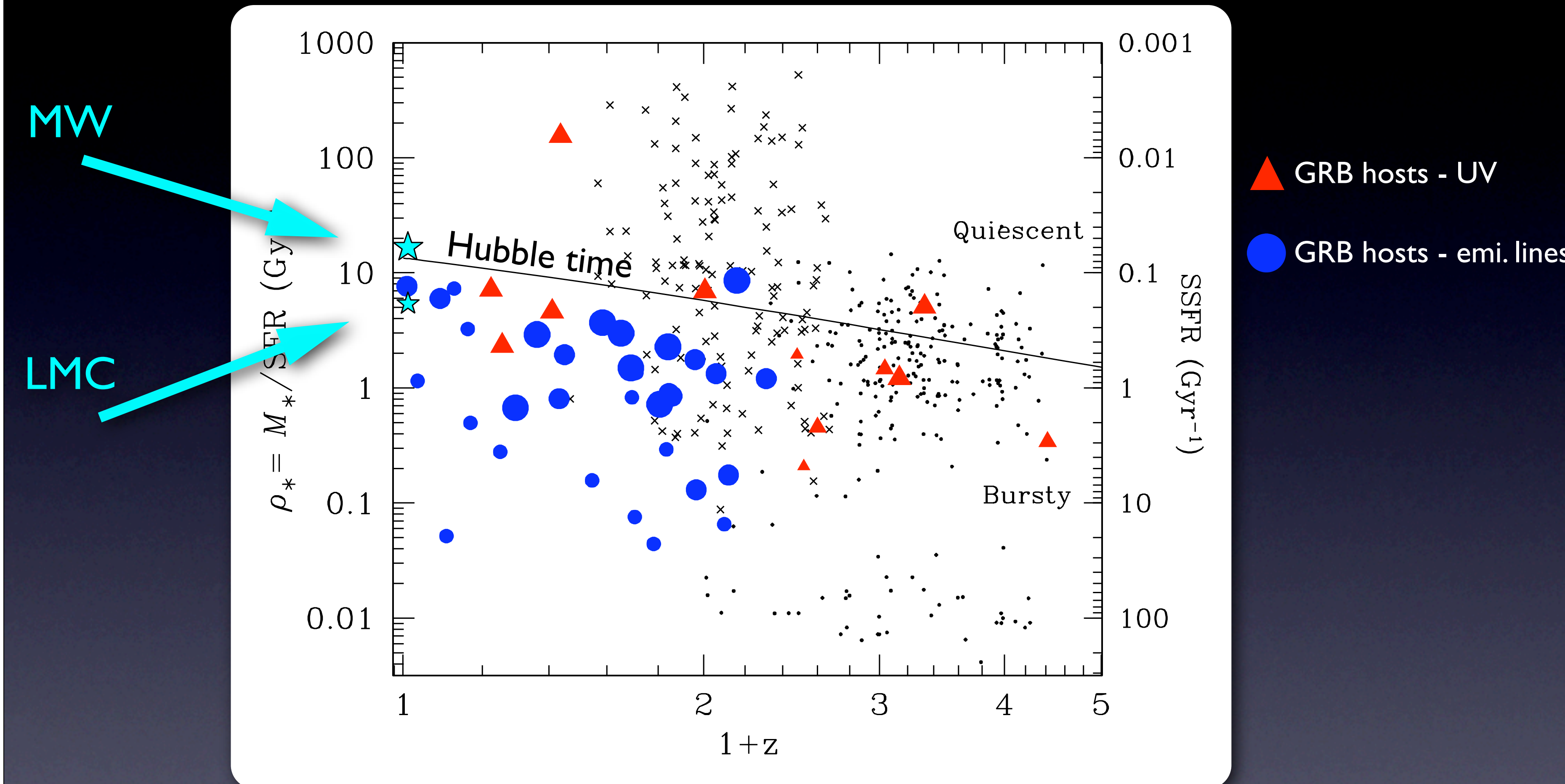
Savaglio, Glazebrook & Le Borgne (2008)

GRB host stellar masses



Davies et al. (in prep.)

Specific star formation rates of GRB hosts

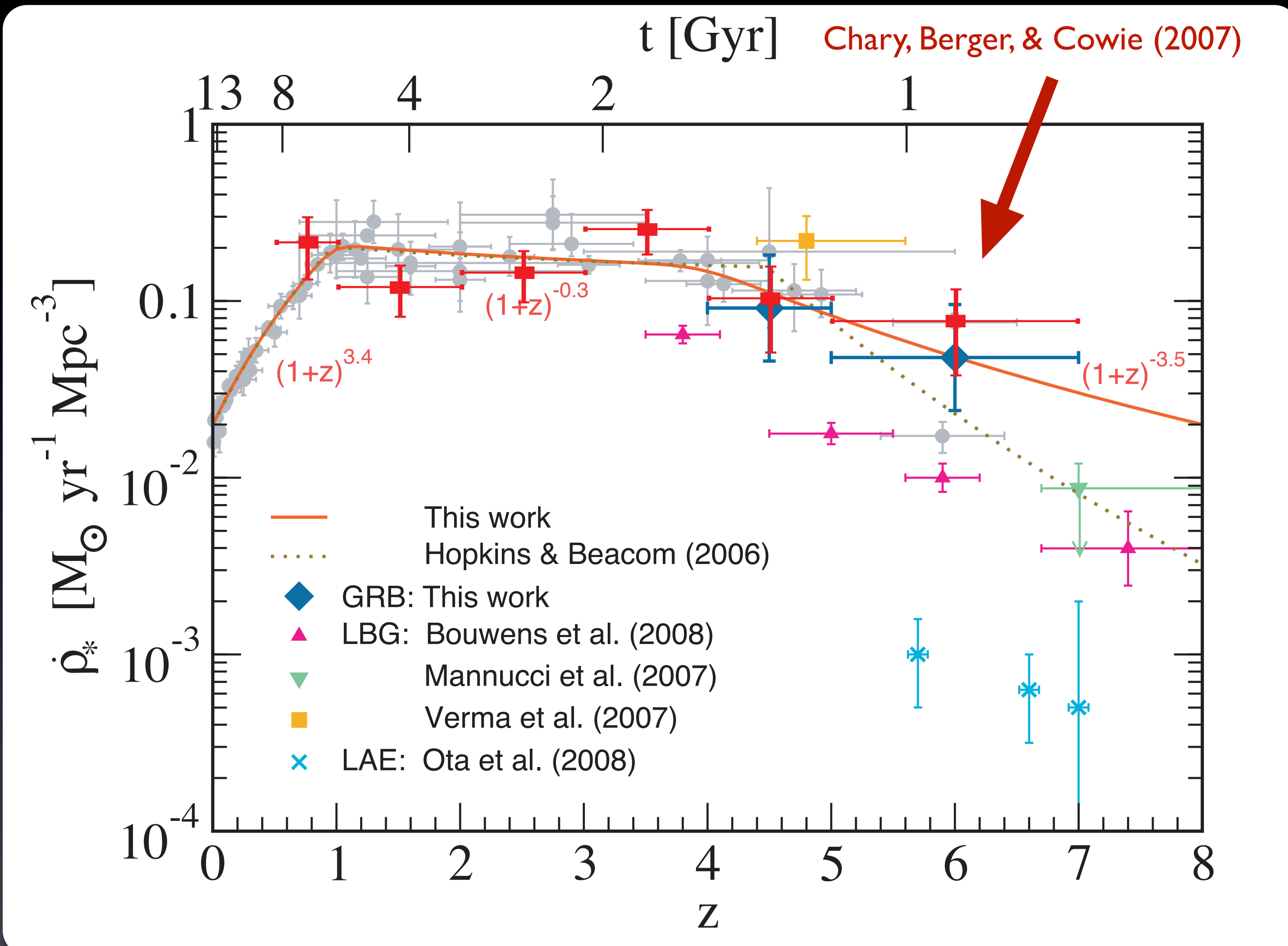


$SSFR = SFR/M_\star \quad yr^{-1}$

$\rho_\star = M_\star/SFR \quad yr$

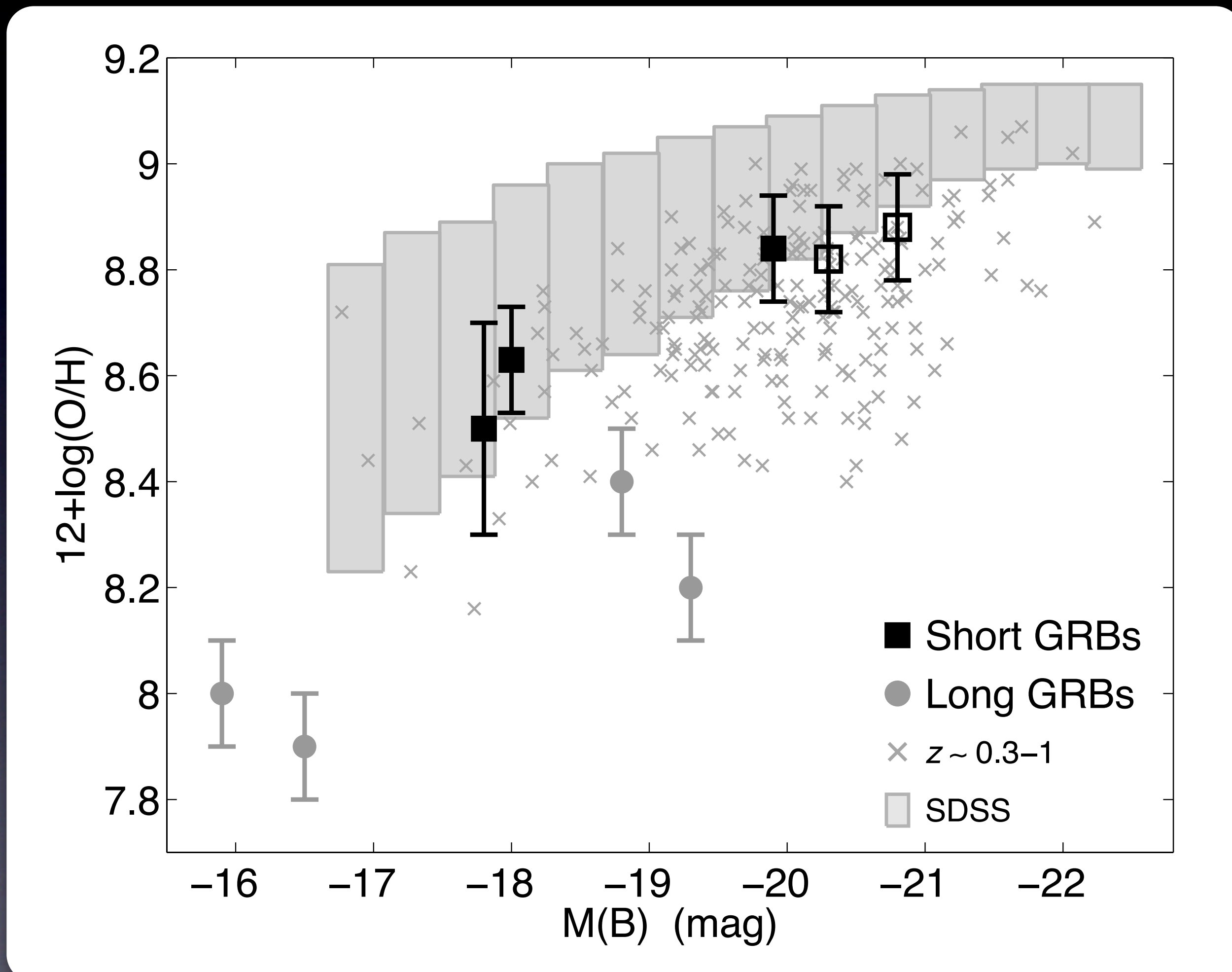
Savaglio, Glazebrook & Le Borgne (2008)

Star formation rate density of the universe



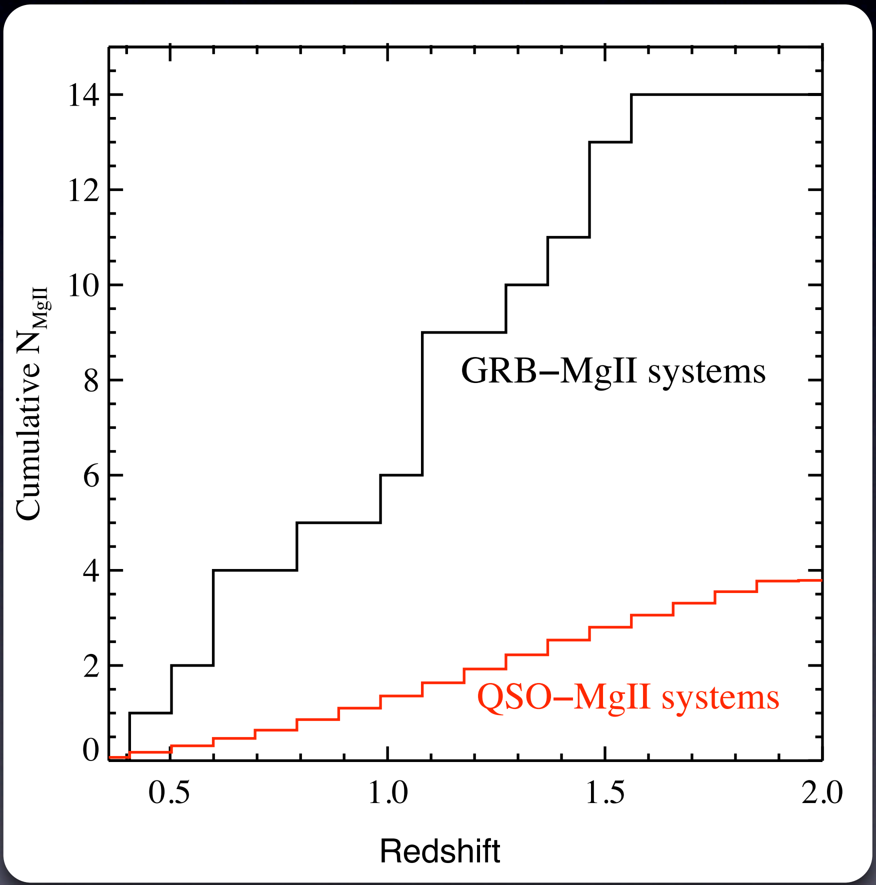
Yüksel, Kistler, Beacom, & Hopkins (2008)

Mass-metallicity relation in GRB hosts

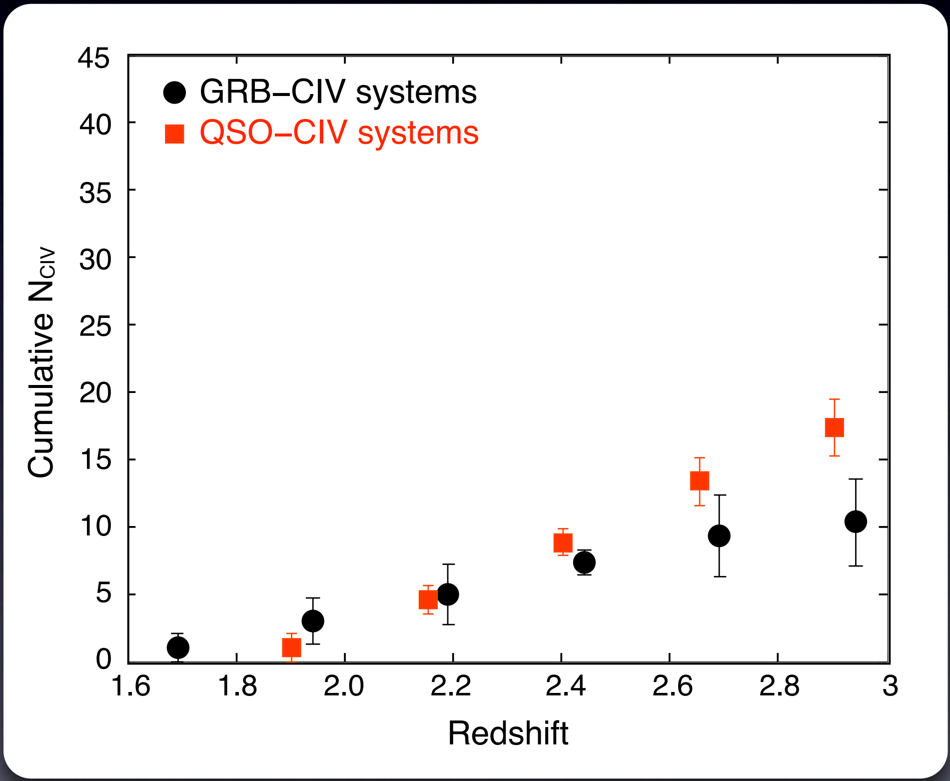


Berger (2008)

Metal absorption along GRB sight lines

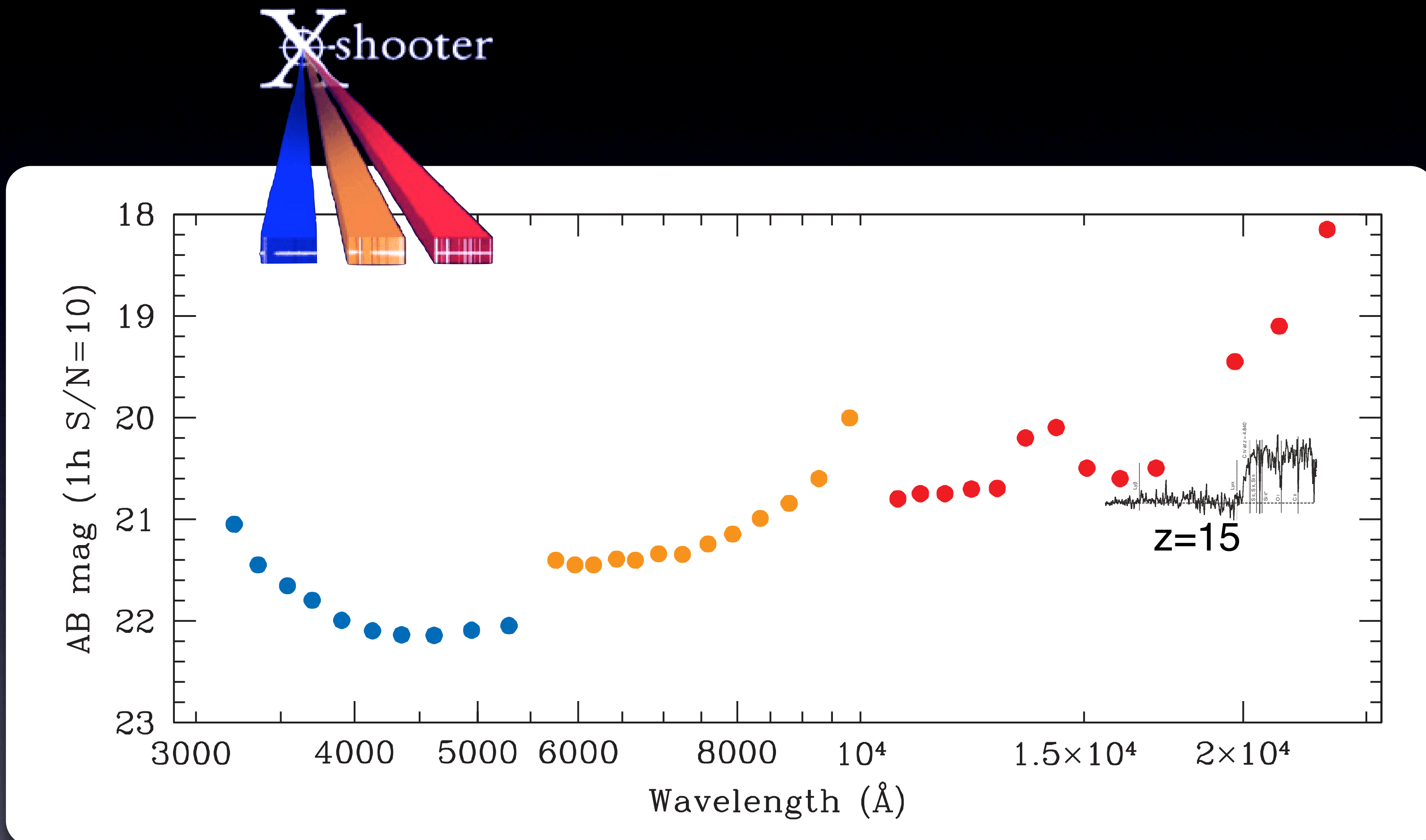


Prochter et al. (2006)



Sudilovsky, Savaglio, Vreeswijk, Ledoux, Smette, Greiner (2007)

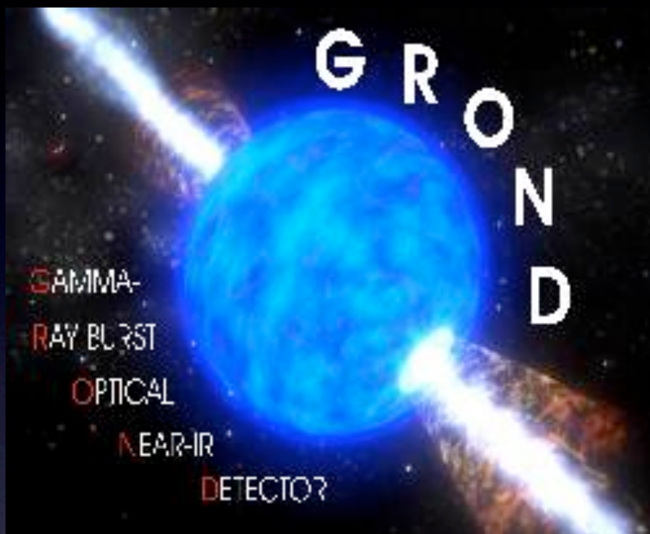
Present projects

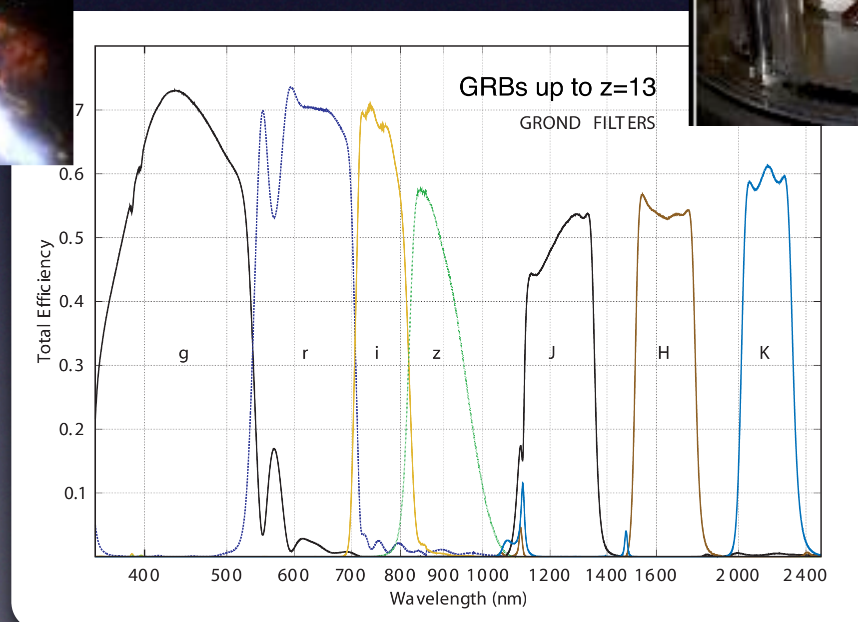


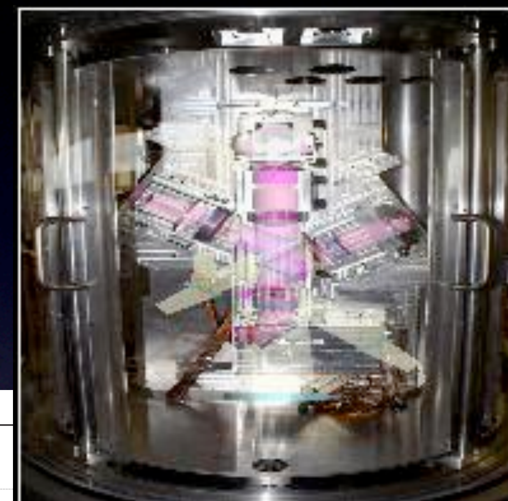
P.I. Board: S. D'Odorico (ESO), F. Hammer (GEPI), L. Kaper (Univ. Amsterdam), R. Pallavicini (INAF), P. Kjaergaard Rasmussen (NBI)

Present projects

GROND - Gamma-Ray Burst Optical/Near-Infrared Detector







Greiner (P.I.), Bornemann, Clemens Deuter, Hasinger, Huber, Huber, Krauss, Krühler, Küpcü Yoldas I, Mayer-Hasselwander, Mican, Primak, Schrey, Steiner, Szokoly, Thöne, Yoldas, Klose, Laux, Winkler (2007)

Conclusions

❶ GRBs shining through a universe hard to see in other ways

❷ GRB-DLA metallicities and dust higher than in QSO-DLAs

❸ SFRD higher than that measured with traditional surveys

❹ GRBs very promising probes of the $z>7$ universe