Subaru observations of GRB afterglows

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Subaru Telescope

contents

- gamma-ray bursts (GRBs) as cosmological probe
- Subaru observation of GRB 050904

Opt/NIR GRB afterglow

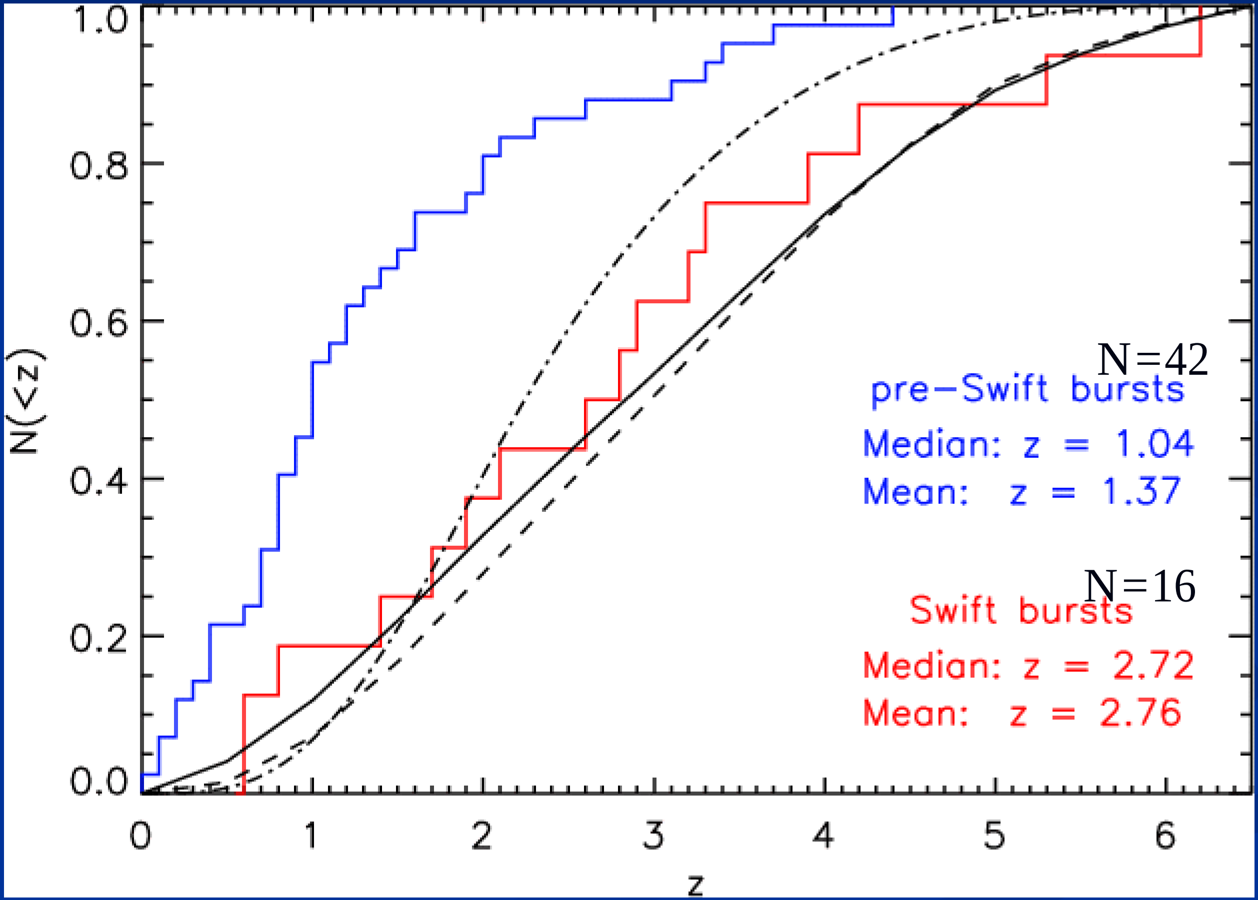
- Bright source at distant universe
  - GRB060206 (z=4.05) 17.3 mag. at 15 minutes after the burst.
  - GRB050904 (z=6.295) 19 mag. at 5 minutes after the burst.

Not all GRB have opt/NIR afterglow…..

Brightness is decreasing…..

GRBs as cosmological probe

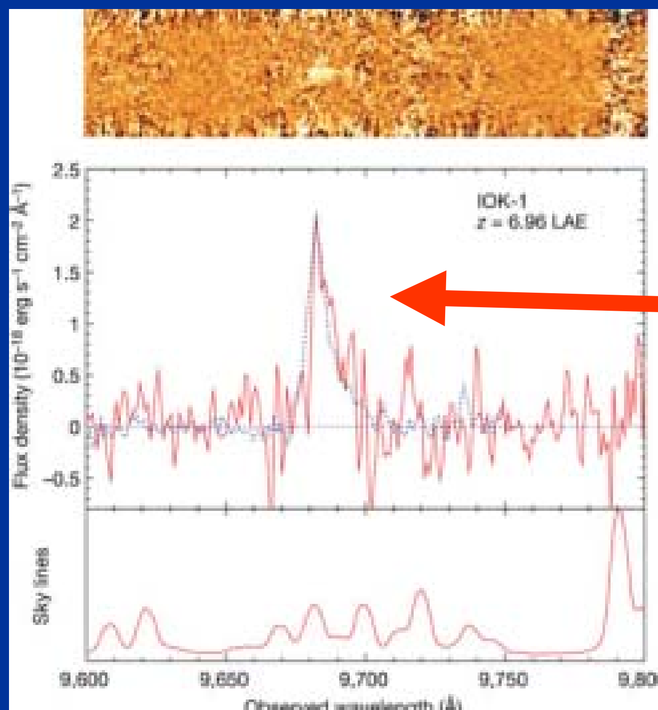
- GRBs are high-redshift (z > 2) sources.



Jakobsson et al. 2006, A&A, 447, 897)

What we can learn from distant GRB afterglows' spectra

- Chemical composition of interstellar matter/inter-galactic matter.
  - High-z galaxies   only hydrogen detected…

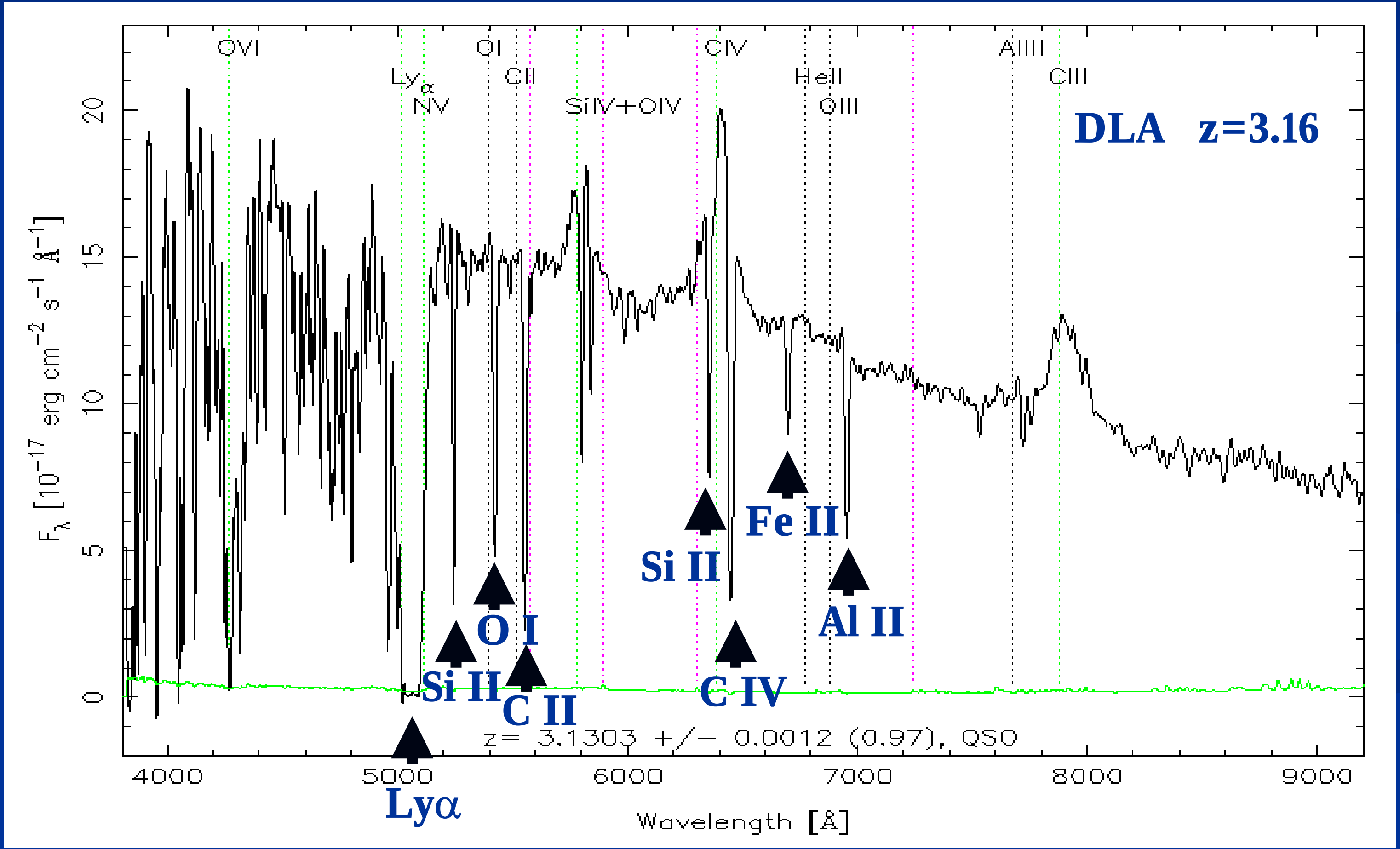


Hydrogen
(Ly α)
emission

Iye et al.
Nature 443, 186 (200

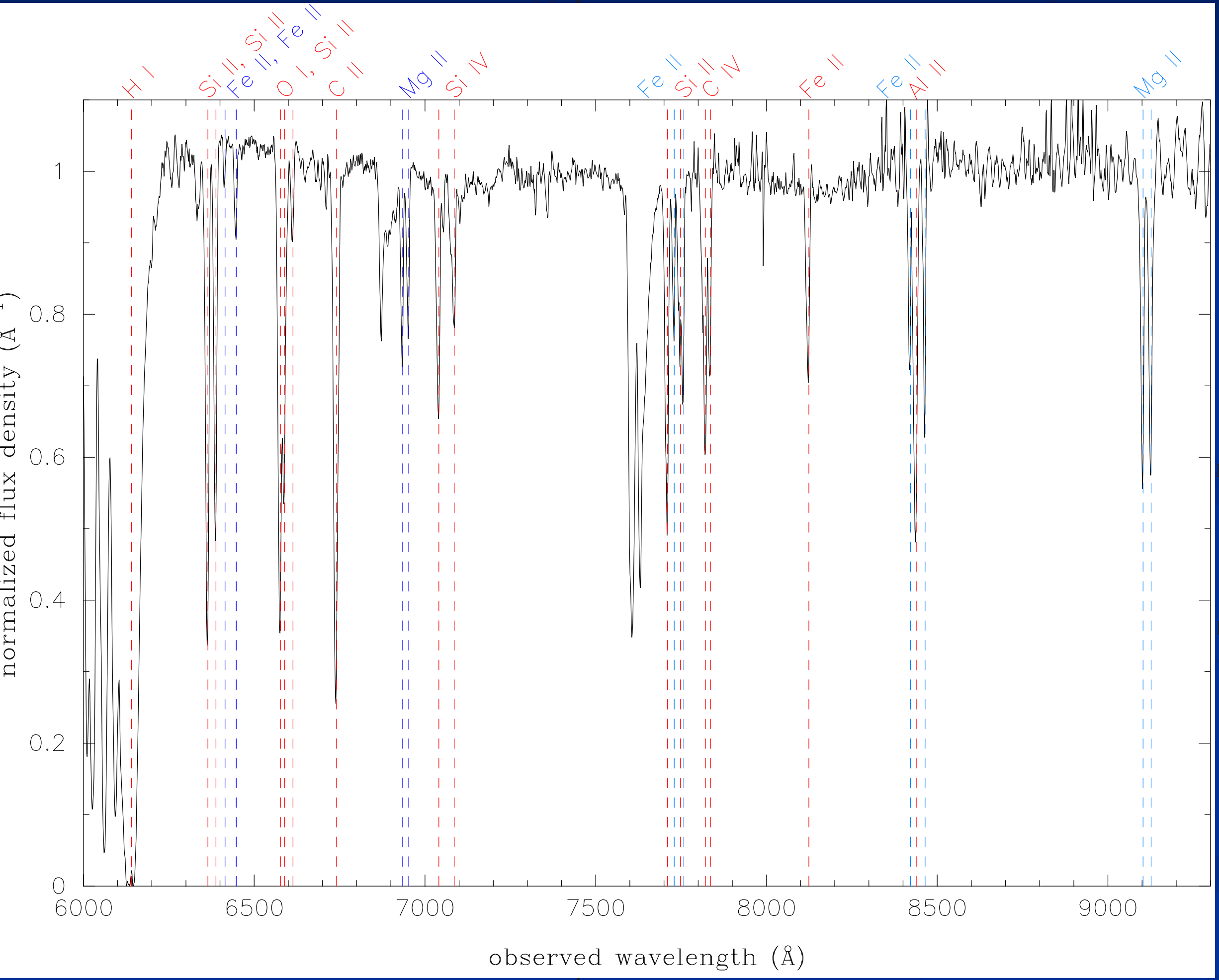
QSO damped Lyman-α absorption

- QSO DLA has been tracer of metallicity of the universe.



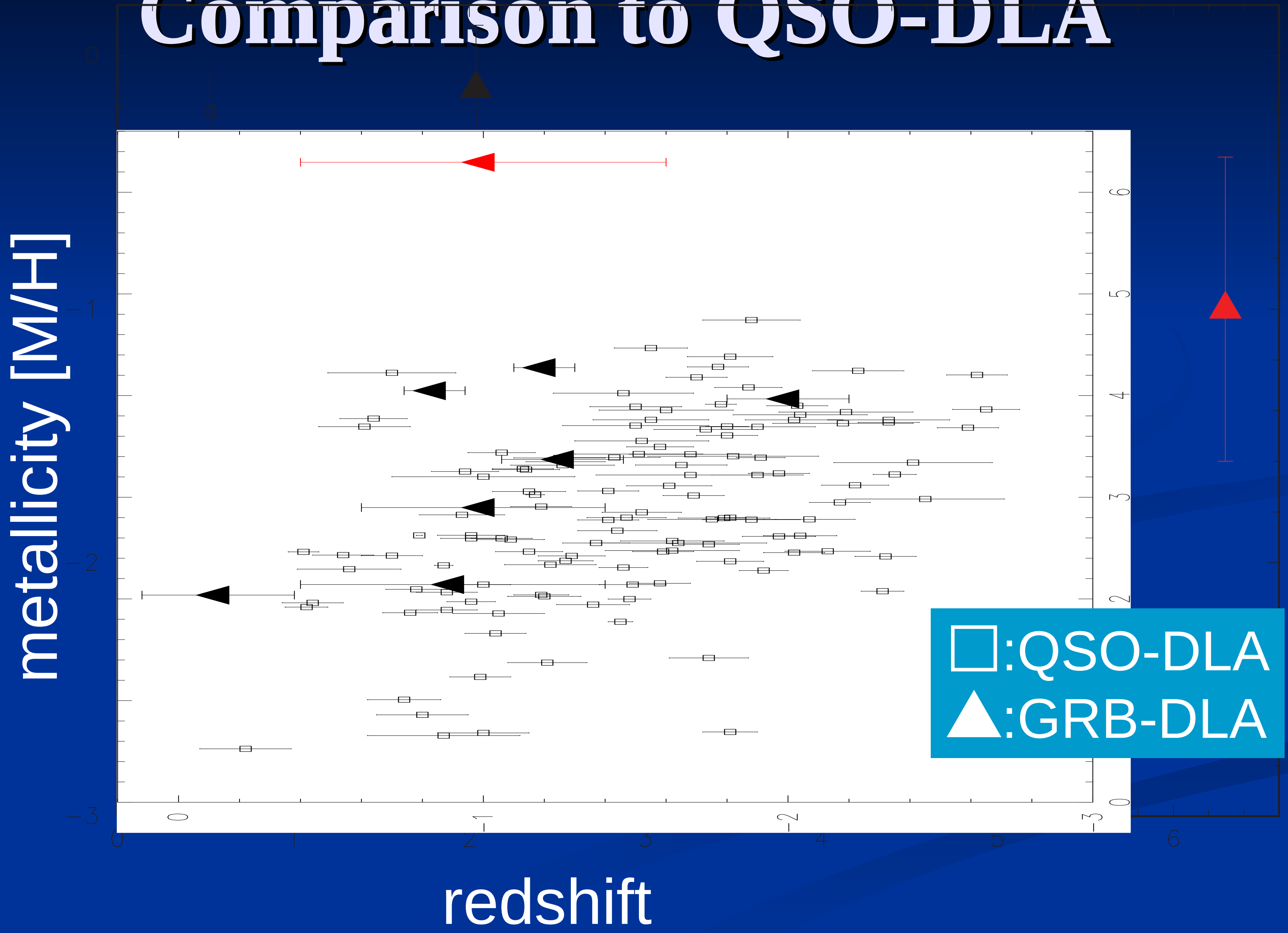
Taken from SDSS database

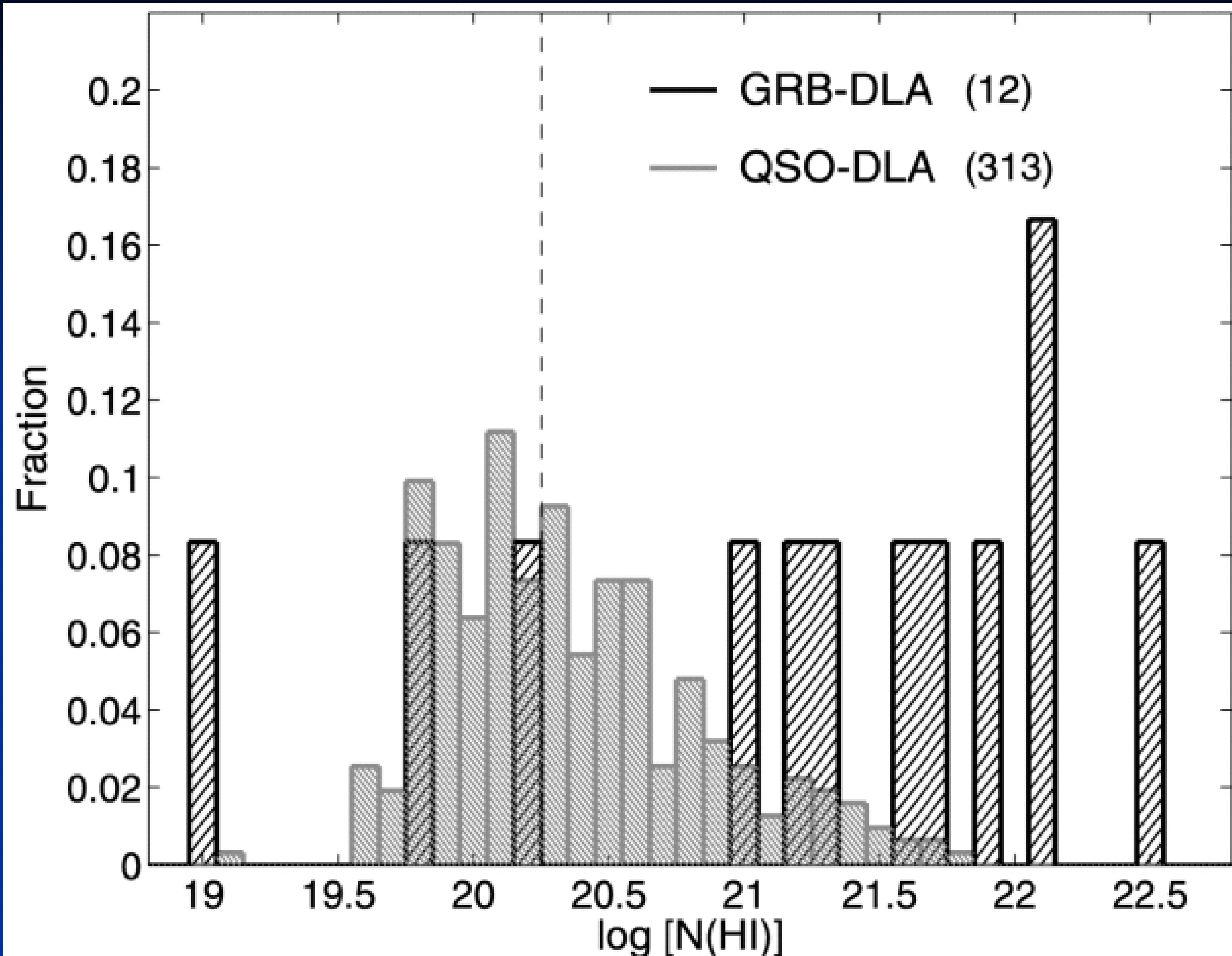
GRB DLA - GRB060206



Red
DLA z=4.05
Blue
z=2.255
Cyan
z=1.48

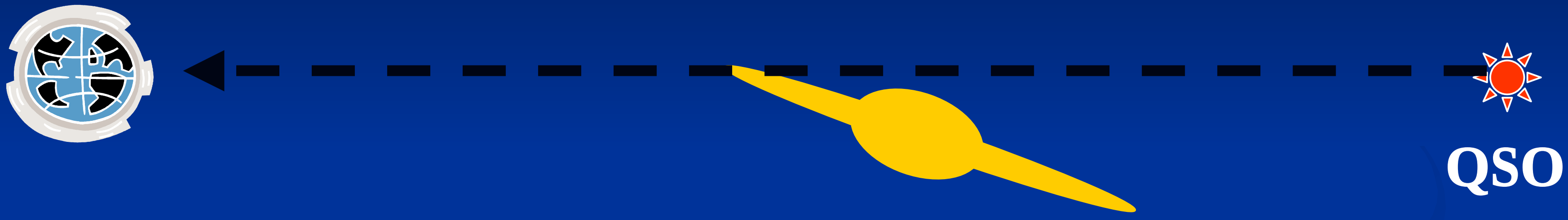
Comparison to QSO-DLA



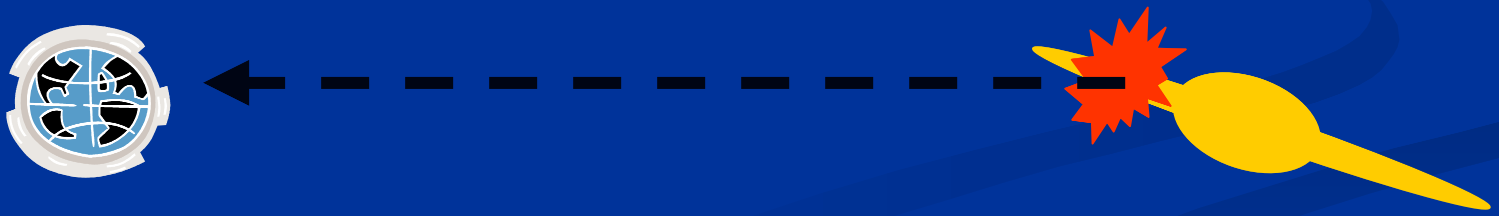


Berger et al. 2006, ApJ, 642, 979

- QSO –DLA
  - Random direction toward intervening galactic disk.



- GRB-DLA
  - Star forming region.

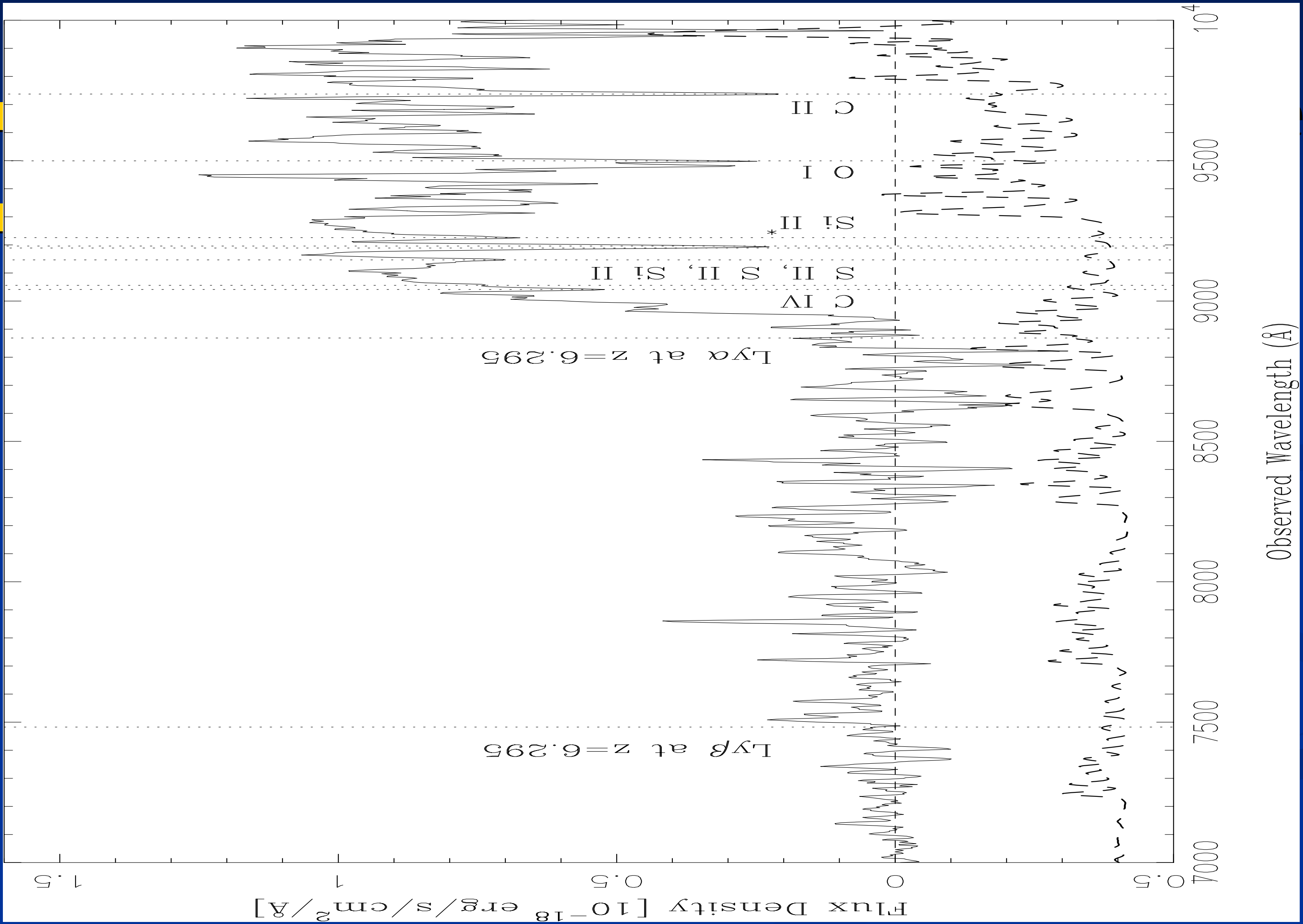


GRB050904

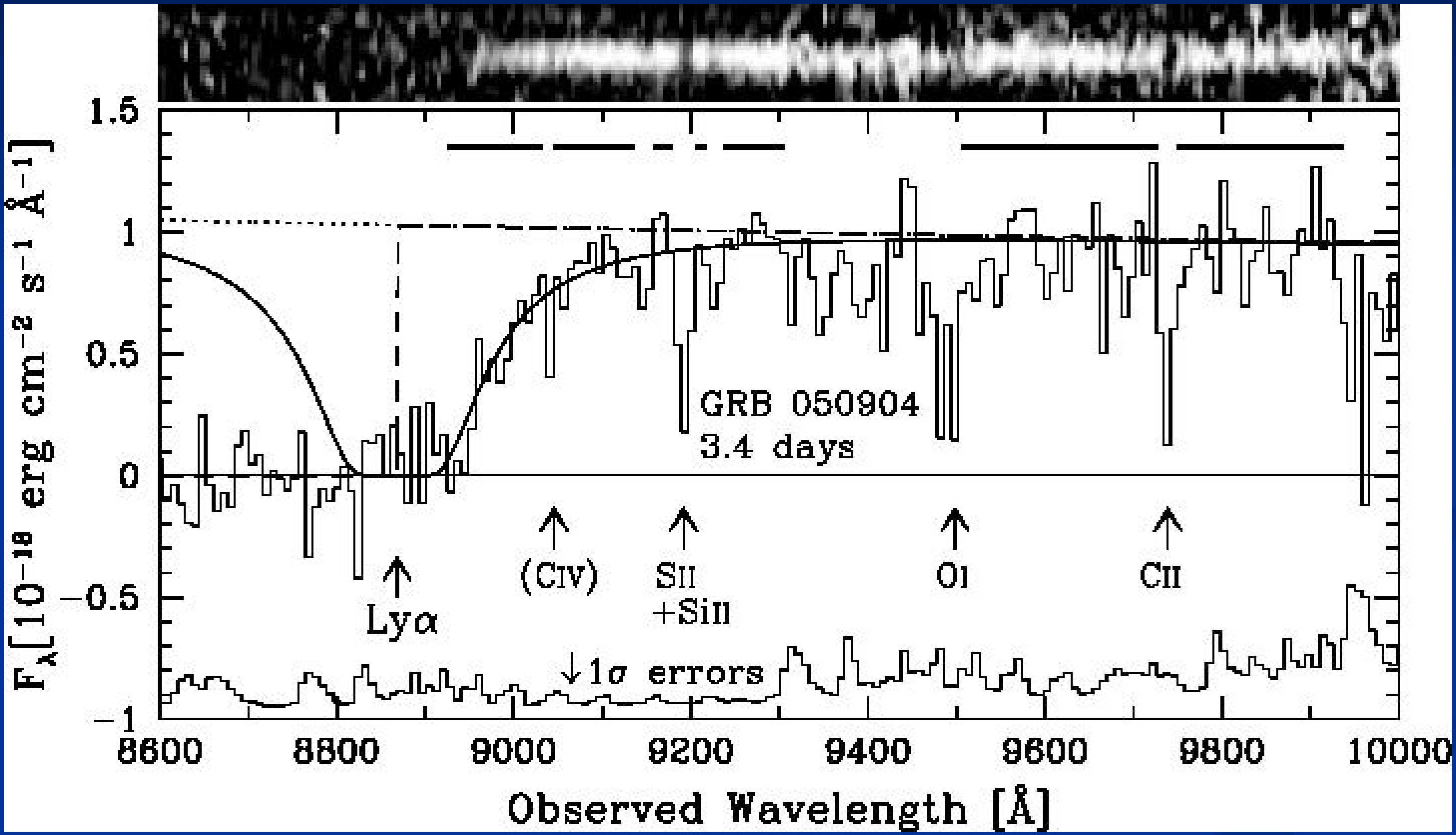
- Swift satellite detected a burst at 4 Sep. 2005, 01:51:44 (UT)
- 3 hours later, no optical afterglow.
- A bright near-infrared afterglow.

Optical light is absorbed by intervening hydrogen.
Possibly high redshift GRB!

Subaru/FOCAS spectroscopy



Spectrum of GRB050904



Absorption line (1)

- Heavy elements

	z	EW(rest) (Å)	log N (cm^{-2})
S II 1253.8	6.295	0.52 +/-0.15	$15.67^{+0.16}_{-0.20}$
S II 1259.5	6.295	0.84 +/-0.51	$15.82^{+0.62}_{-0.60}$
Si II 1260.4	6.296	1.14 +/-0.36	$14.29^{+0.57}_{-0.39}$
Si II* 1264.7	6.295	0.54 +/-0.15	$13.69^{+0.17}_{-0.18}$
O I 1302.2	6.295	1.41 +/-0.26	$15.99^{+0.44}_{-0.36}$
C II 1334.5	6.296	1.69 +/-0.32	$15.96^{+0.62}_{-0.51}$

Abosrption line (2)

- Hydrogen
  - Damped Lyman α absorption
    log N_{HI}~21.6

absorber

- N (Si II* 1264) / N (Si II 1260) → electron density
  - log N (Si II* 1264) / N (Si II1260) = -0.6
  - log n_{HI} = 3.1 ～ 4.7 cm^{-3} ($T=10^3$ K, Silva & Viegas 2002)
  - Since log N_{HI} = 21.6 cm^{-2}, thickness is 1 ～ 0.03 pc.
  - Abosrber is much smaller than a whole galaxy.

metallicity

[S/H]	-1.0 +/-0.6
[C/H]	-2.0 +/-0.6
[O/H]	-2.3 +/-0.4
[Si/H]	-2.8 +/-0.6

S/Si (-1.8) is close to Milky Way cold disk (-1.3), and different from warm disk / halo (-0.1, -0.5).

⇓

This supports GRB occurred in molecular cloud.

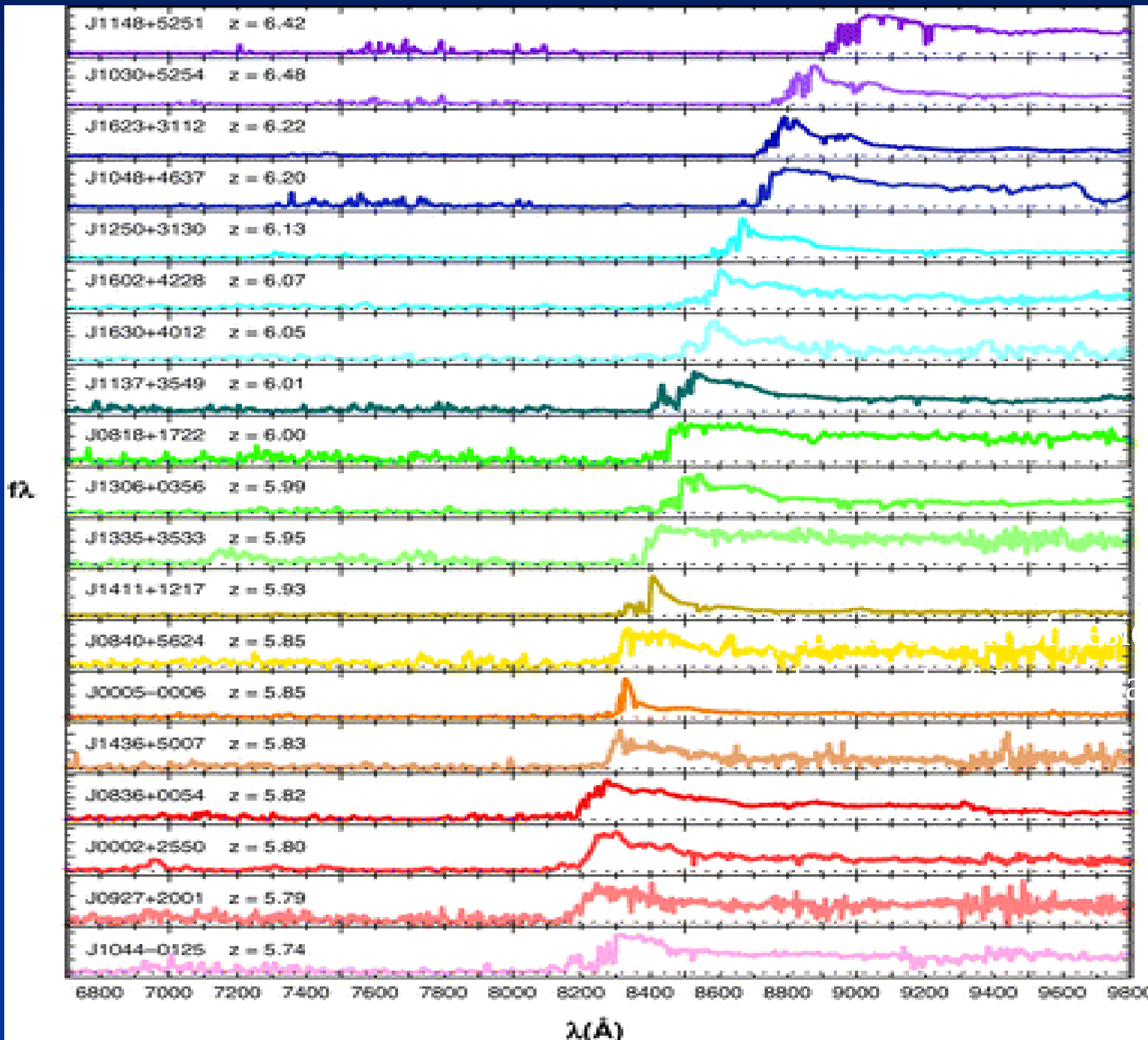
Cosmic Reionization

- Fully ionized universe after Big Bang.
  - Thick to Thomson scattering.
- As the universe expanded, recombination occurred. We then observe CMB radiation.
- Current universe is fully ionized.
- "Reionization" must occur.

Observational constraints

- WMAP satellite results suggest
  - Reionization occuurred z~11
- High redshift QSOs' spctra suggest
  - Neutral fraction rapidly increased around z~6.
  - Neutral fraction is > 10^{-3} at z > 6.

Gun-Peterson test

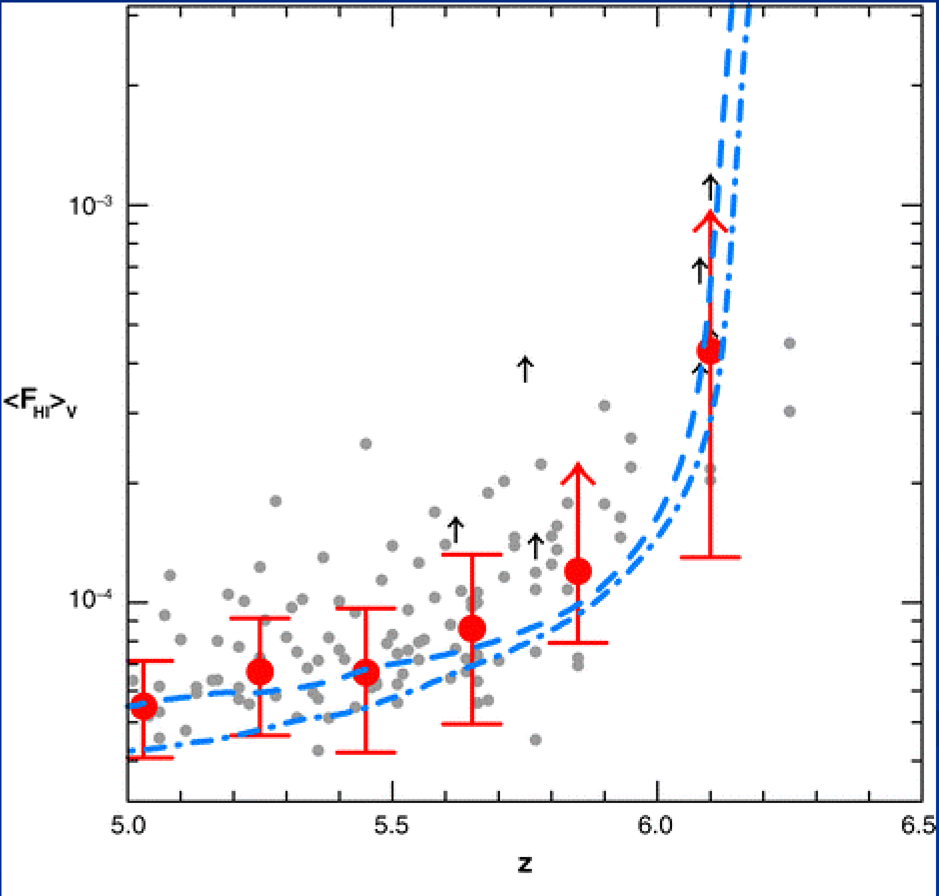


ual flux

Fan X, et al. 2006.
Annu. Rev. Astron. Astrophys. 44:415-62

Limit of GP test by QSO spectra

- Only traceable until neutral fraction (H II / H) $< 10^{-3}$

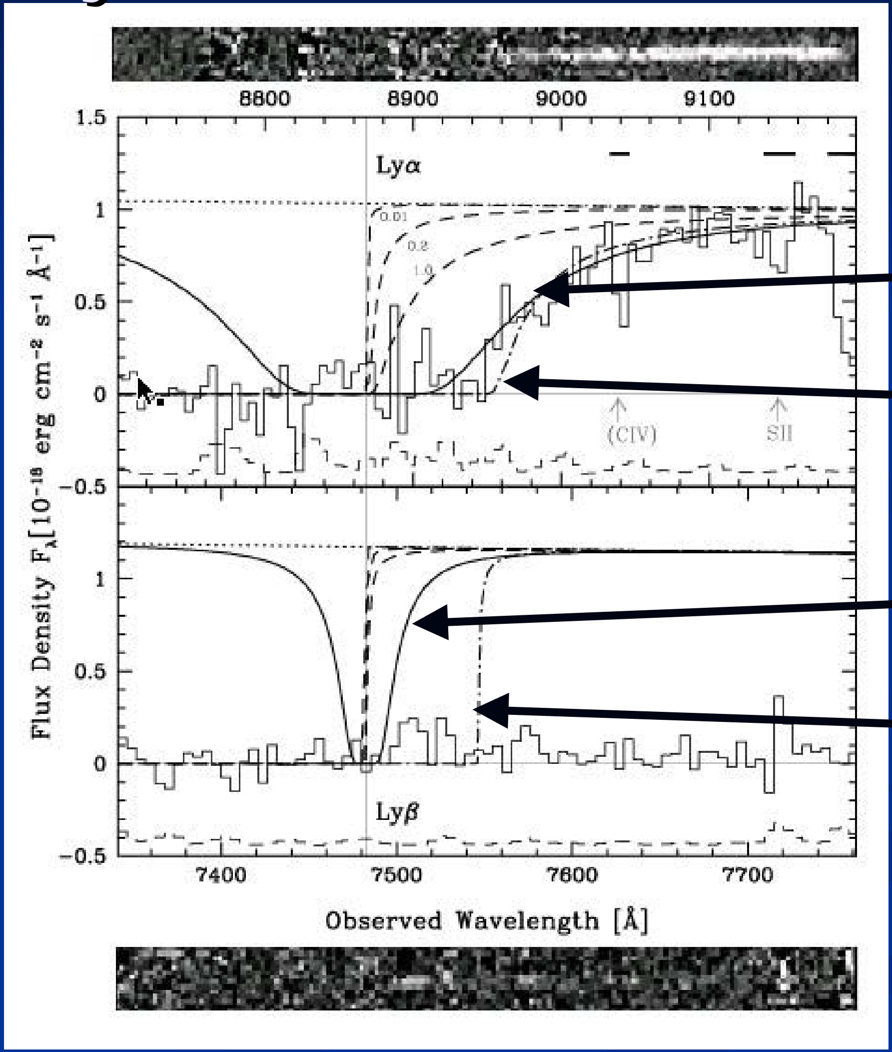


Fan X, et al. 2006.
Annu. Rev. Astron. Astrophys. 44:415–62

Implications for reionization by GRB050904

Hydrogen absorption is due to a host galaxy, not neutral intergalactic matter.

Higly ionized at z=6.3.
$n_{HI}/n_H < 0.6$



z=6.295 DL

z=6.36 IG

z=6.295 DL

z=6.36 IGM

Totani et al.
PASJ 58, 48
(2006)

Summary

- High-redhsift GRB afterglows provide us important imformations of early universe.
- GRB afterglows will be promising probe for cosmic reionization history.