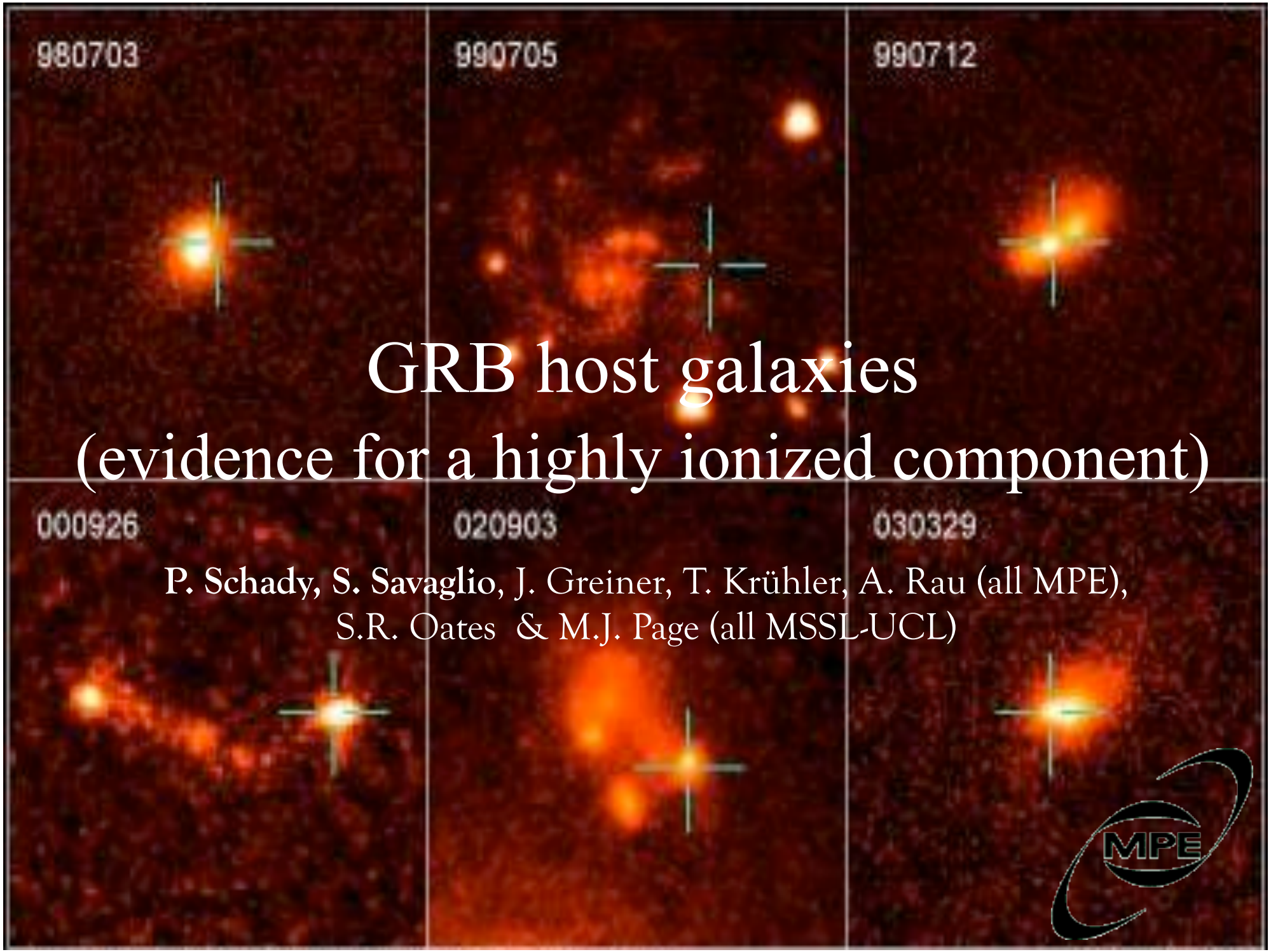
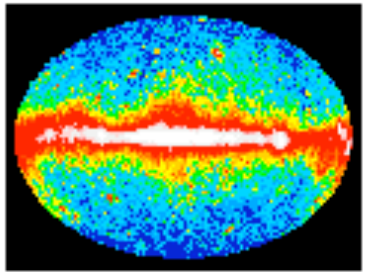
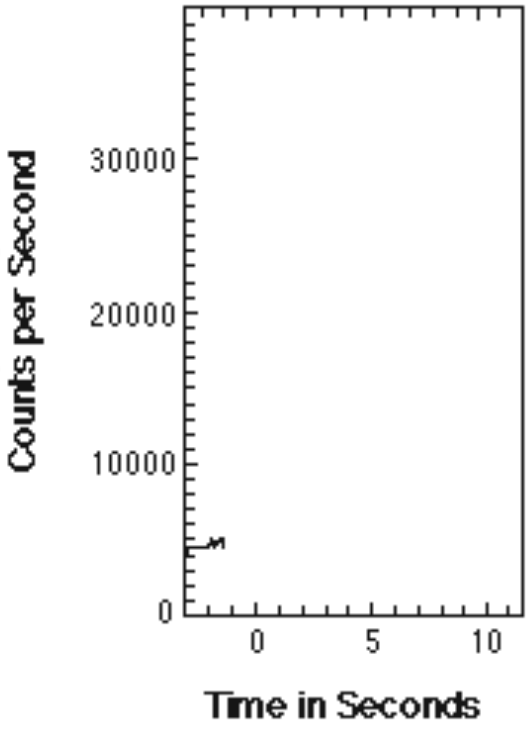


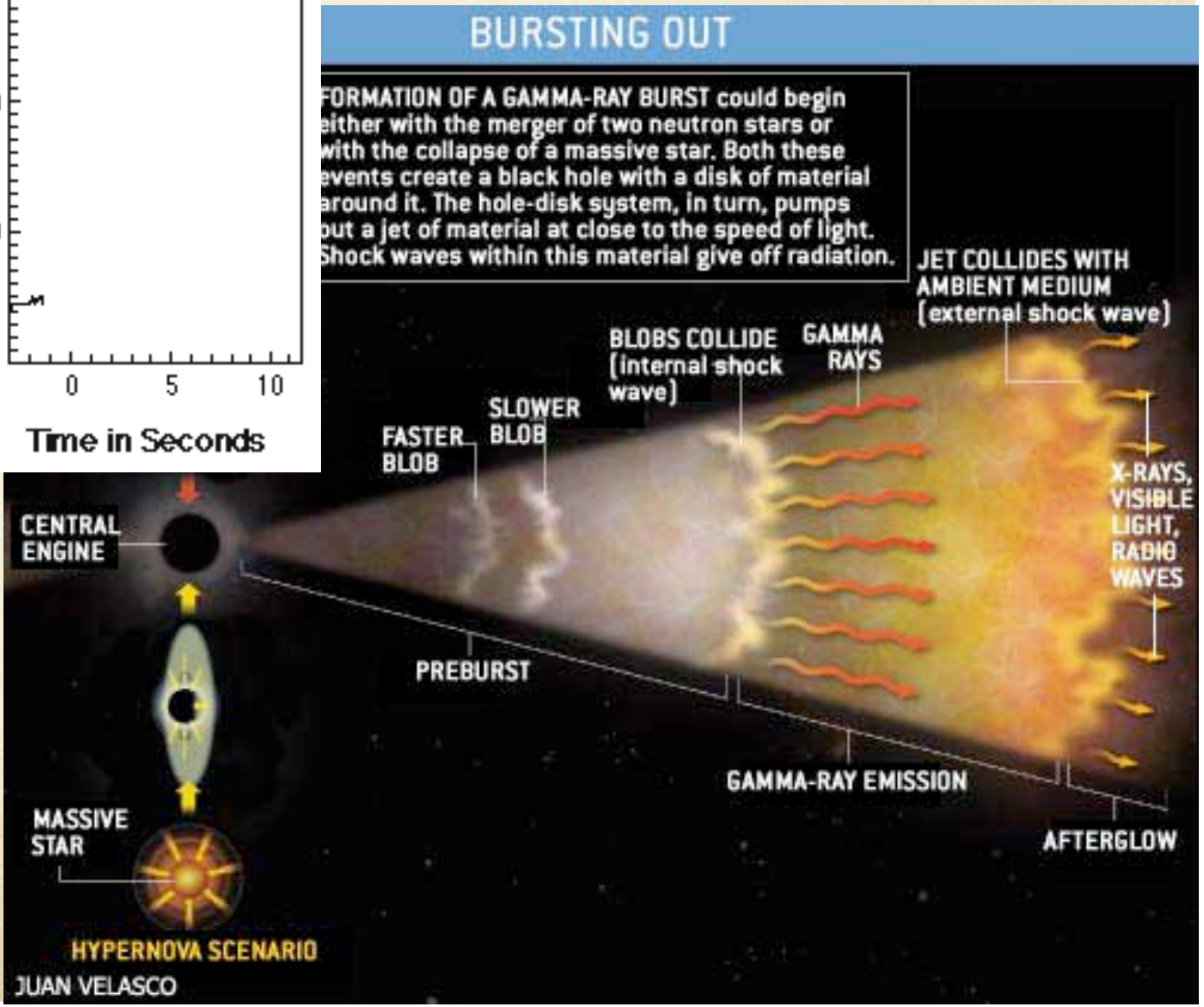
GRB host galaxies
(evidence for a highly ionized component)

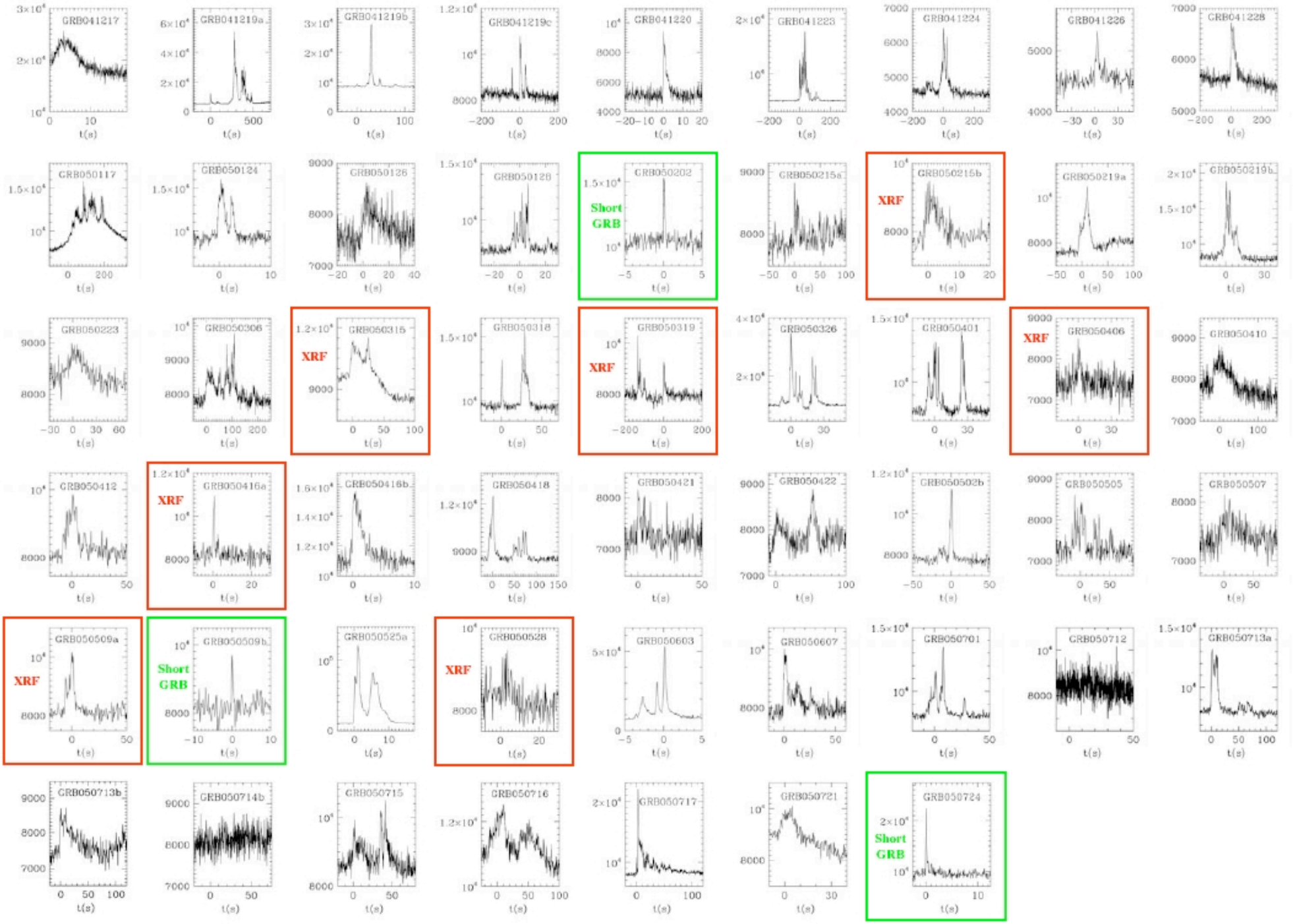
P. Schady, S. Savaglio, J. Greiner, T. Krühler, A. Rau (all MPE),
S.R. Oates & M.J. Page (all MSSL-UCL)

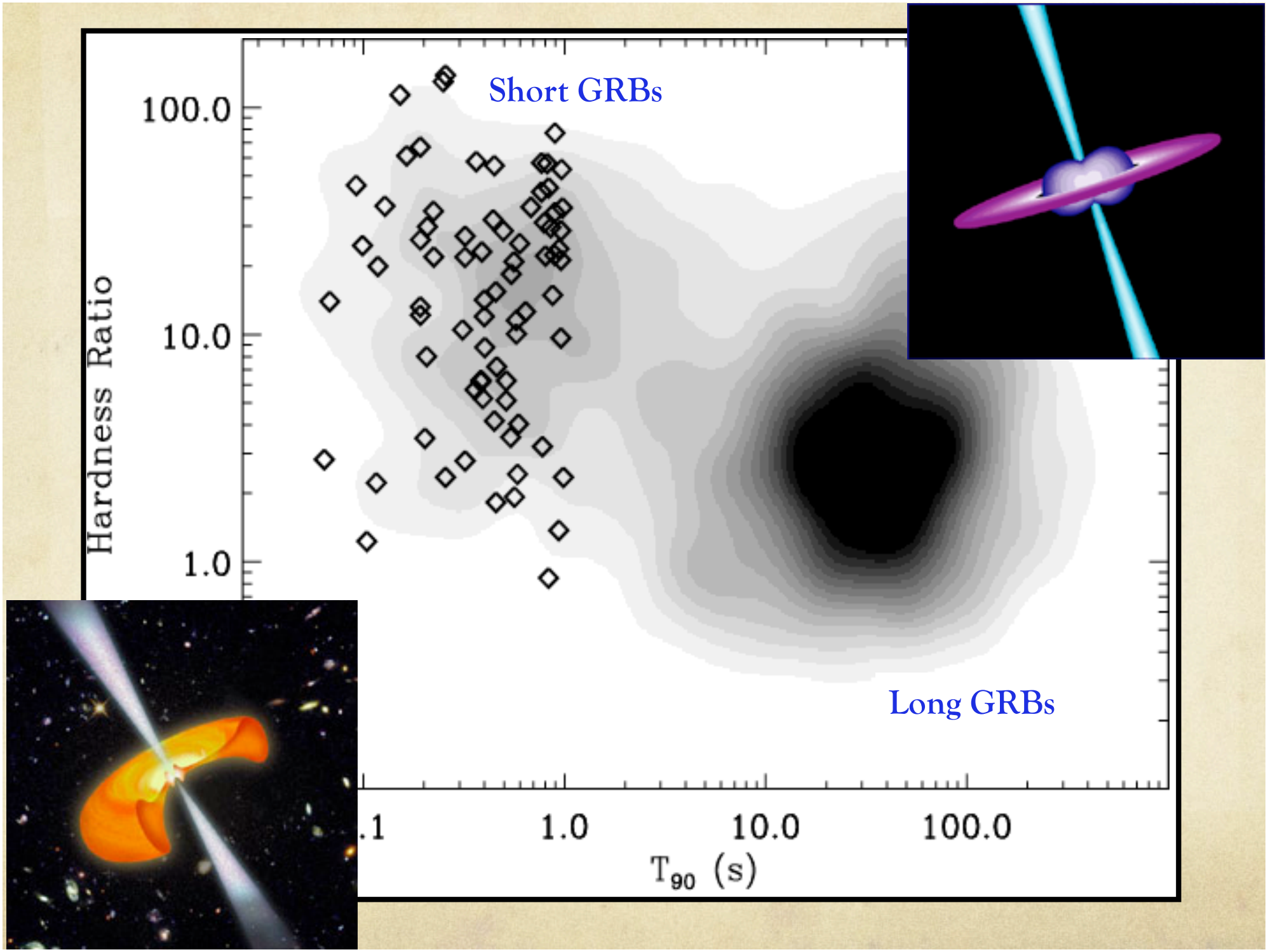
What's a Gamma-Ray Burst?



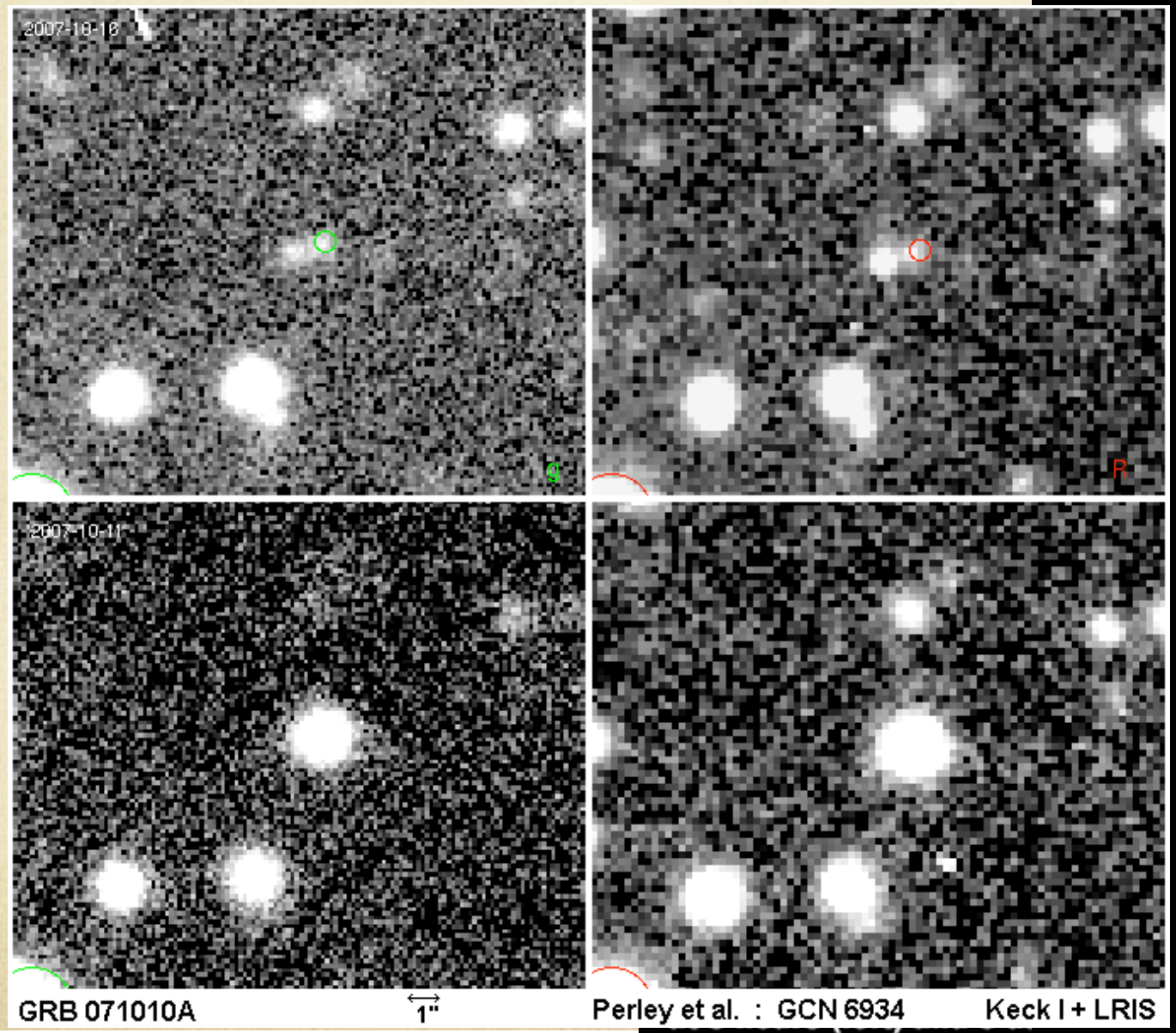


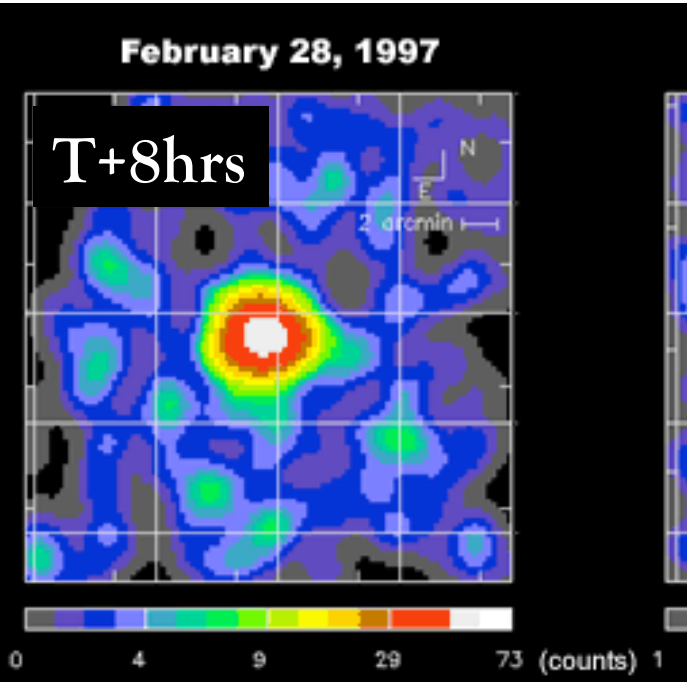


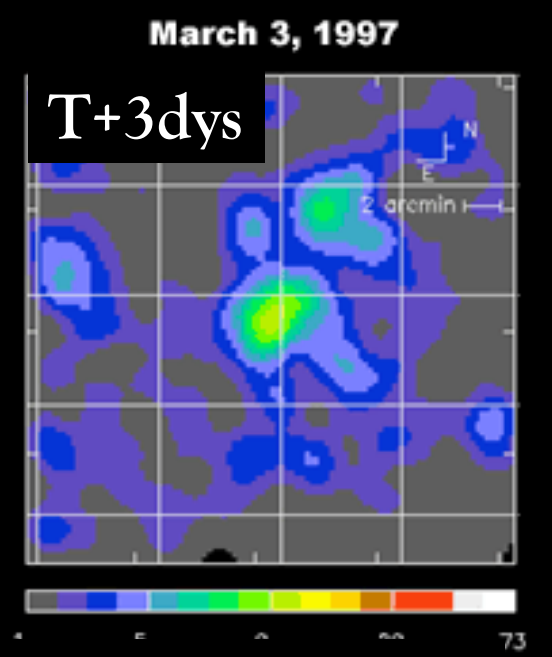

GRB041217
GRB041219a
GRB041219b
GRB041219c
GRB041220
GRB041223
GRB041224
GRB041226
GRB041228
GRB050117
GRB050124
GRB050126
GRB050128
Short GRB
GRB050202
GRB050215a
XRF
GRB050215b
GRB050219a
GRB050219b
GRB050223
GRB050306
XRF
GRB050315
GRB050318
XRF
GRB050319
GRB050326
GRB050401
XRF
GRB050406
GRB050410
GRB050412
XRF
GRB050416a
GRB050416b
GRB050418
GRB050421
GRB050422
GRB050502b
GRB050505
GRB050507
XRF
GRB050509a
Short GRB
GRB050509b
GRB050525a
XRF
GRB050528
GRB050603
GRB050607
GRB050701
GRB050712
GRB050713a
GRB050713b
GRB050714b
GRB050715
GRB050716
GRB050717
GRB050721
Short GRB
GRB050724
t(s)


Short GRBs
Long GRBs
Hardness Ratio
100.0
10.0
1.0
.1
1.0
10.0
100.0
T90 (s)

GRB Afterglows

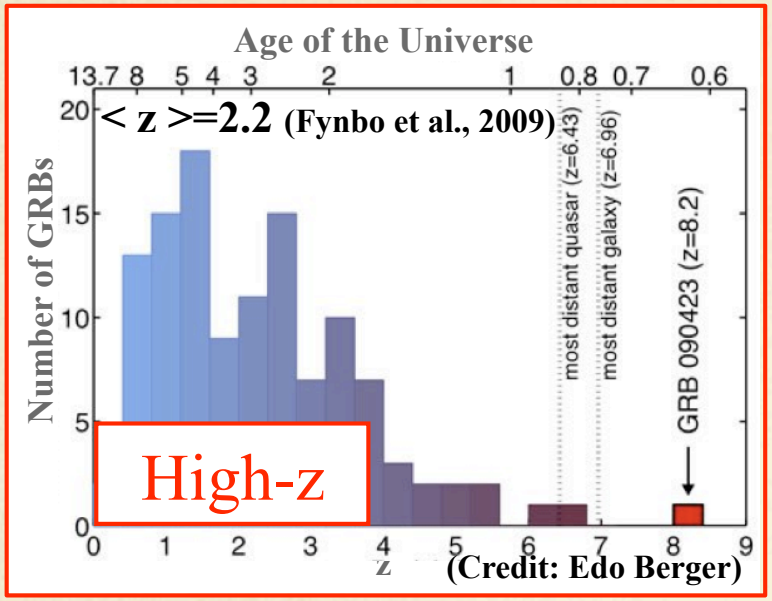




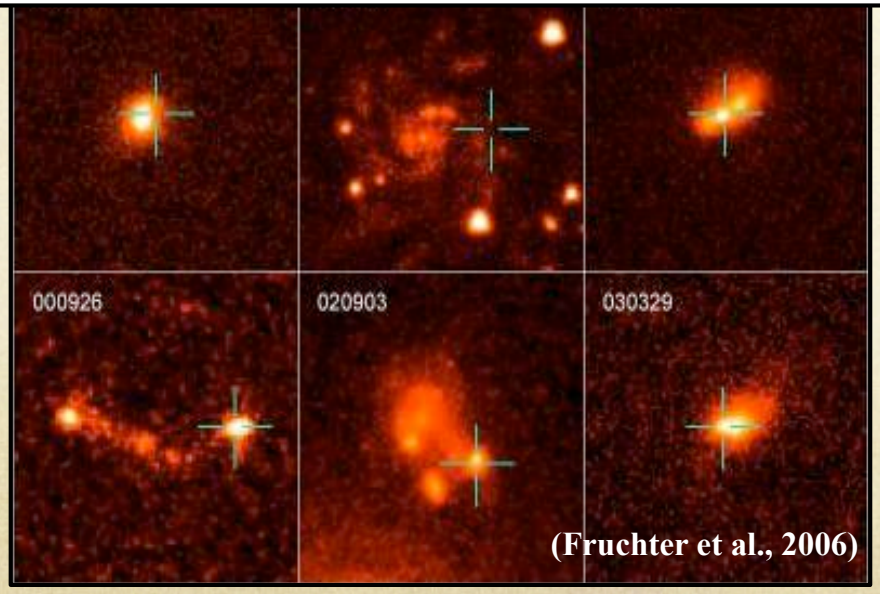


GRB 970228

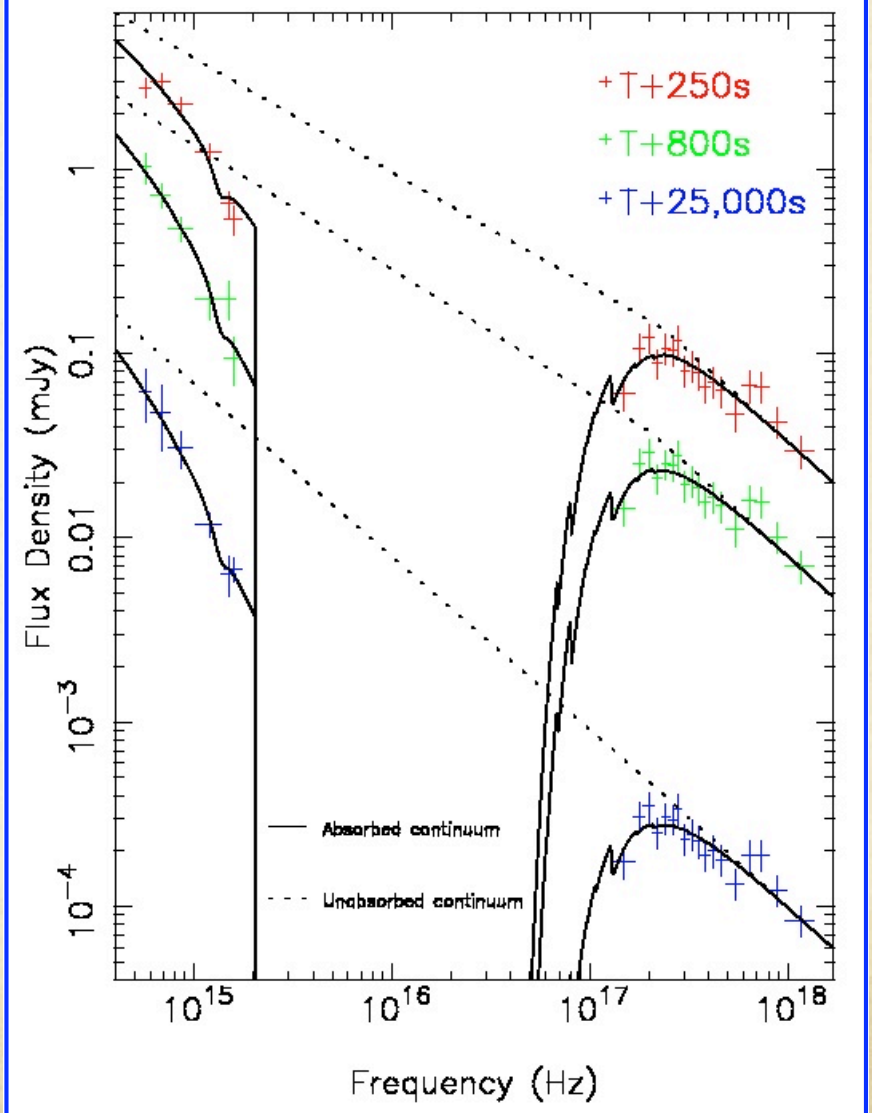
GRB hosts: probes to the distant Universe



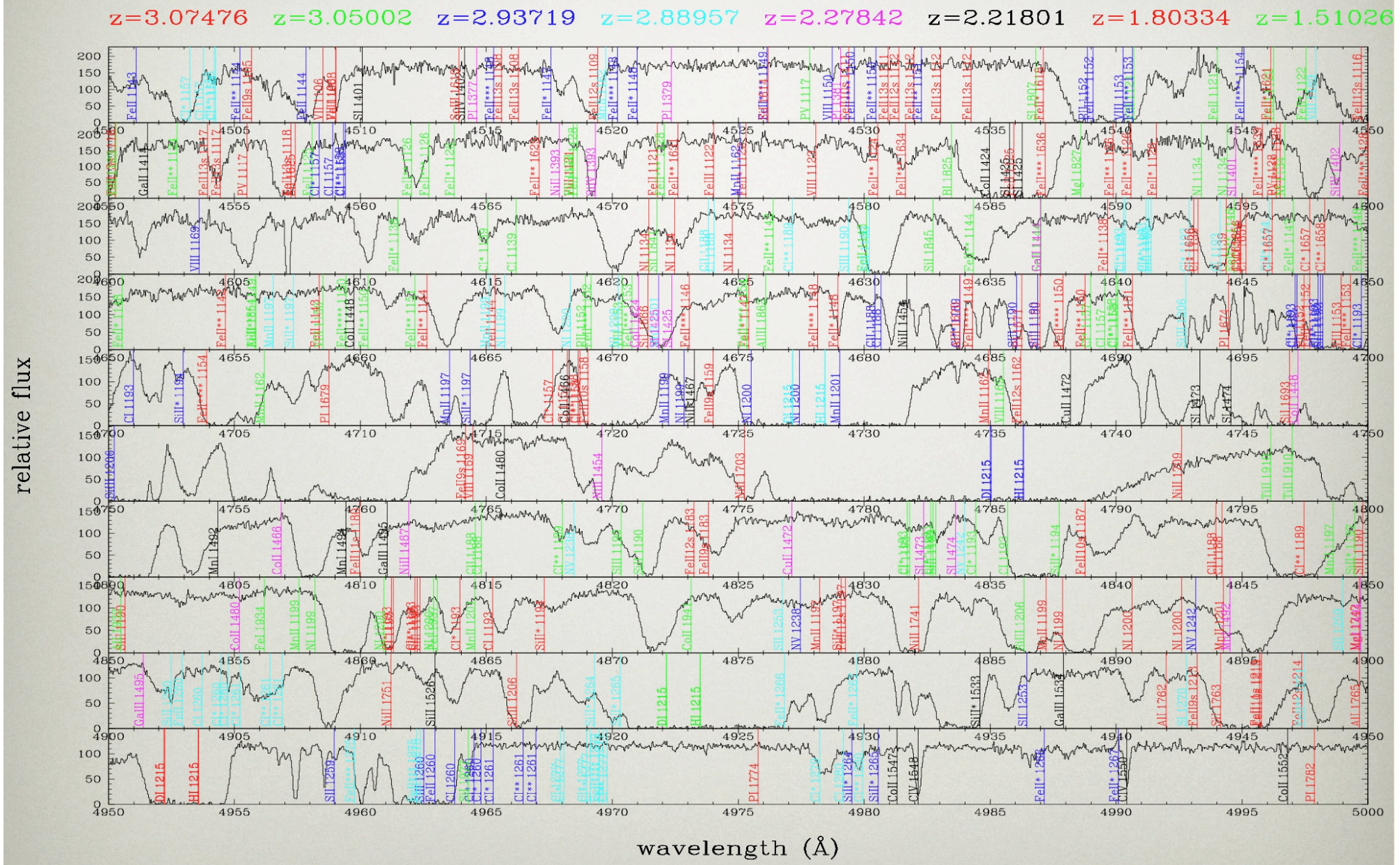
Probe young, star forming galaxies



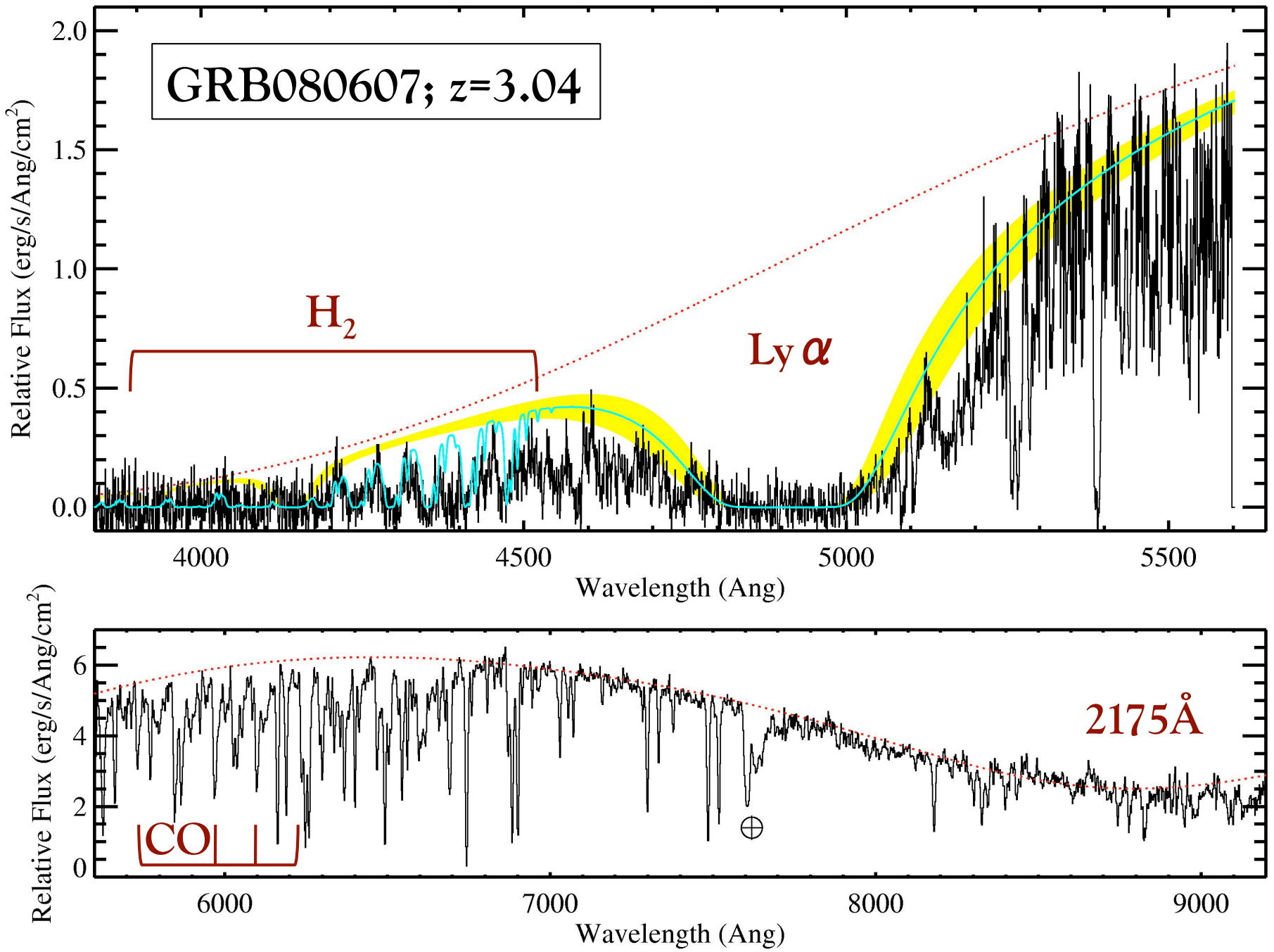
Highly luminous synchrotron featureless spectra



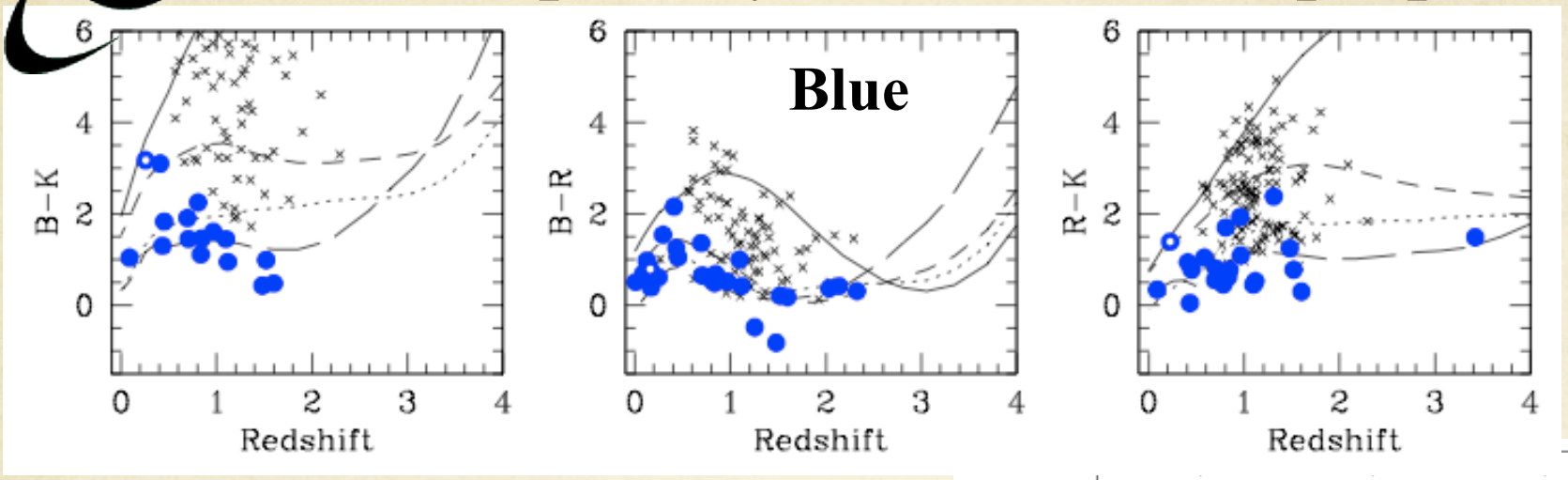
EXAMPLE: GRB 060607



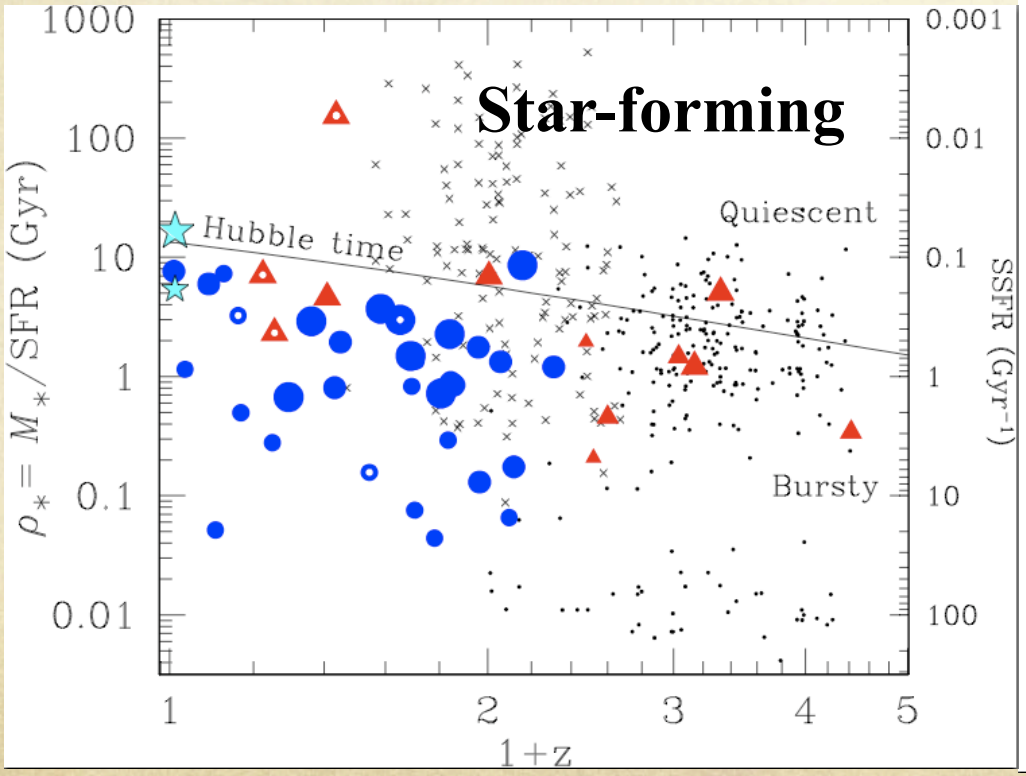
SMETTE, SAVAGLIO, LEDOUX ET AL. (2008)

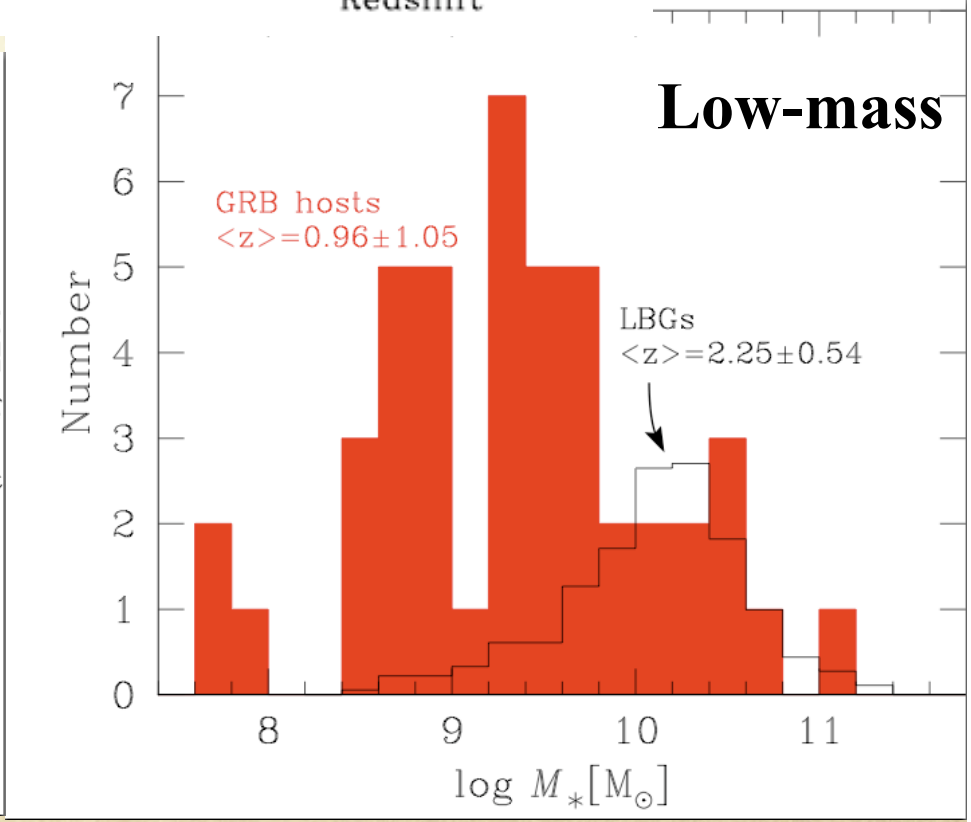

GRB080607; z=3.04
H2
Ly α
Relative Flux (erg/s/Ang/cm2)
Wavelength (Ang)
2175Å
CO
⊕
Prochaska+09

GRB *optically selected* host properties

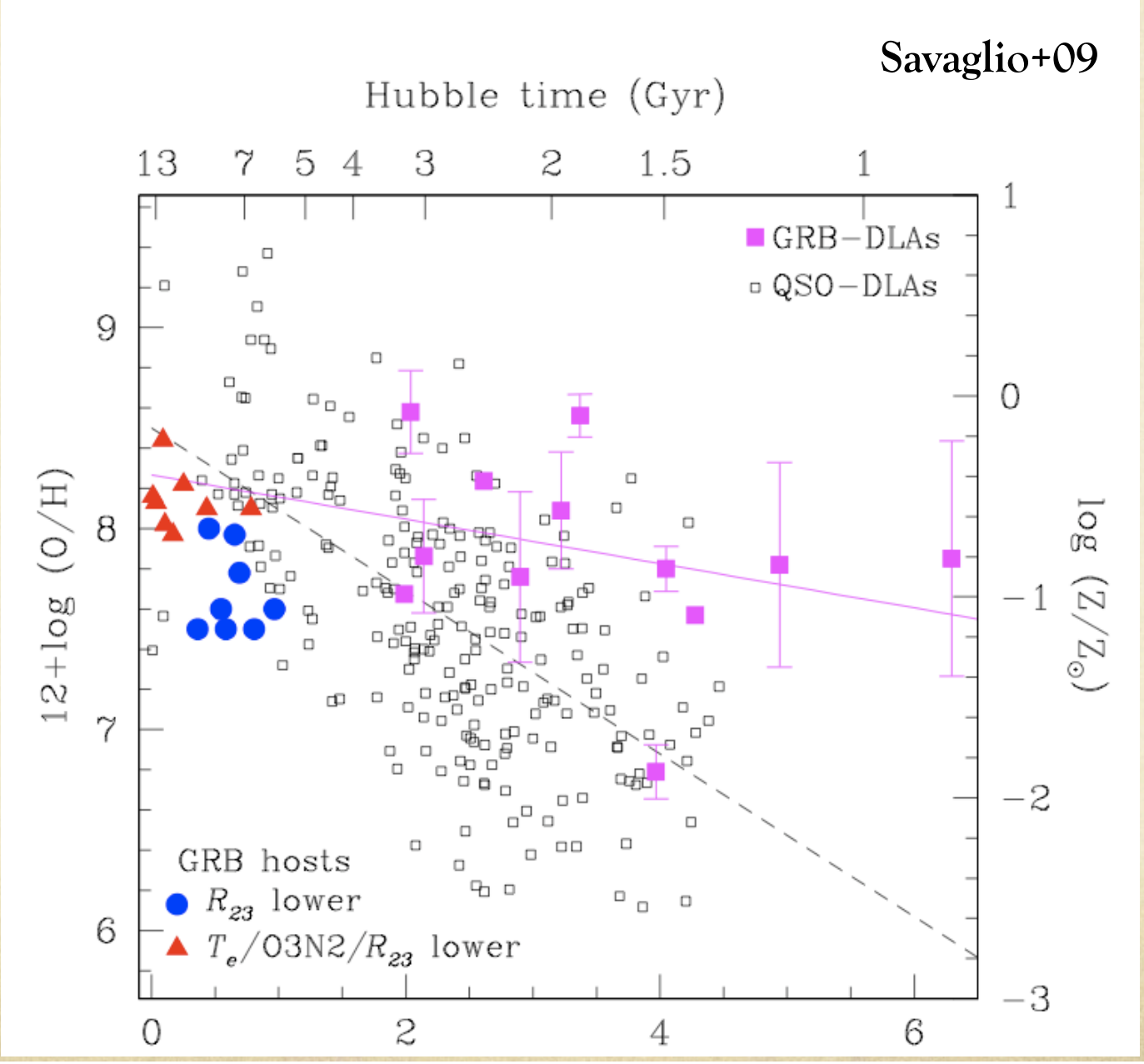


Savaglio+09

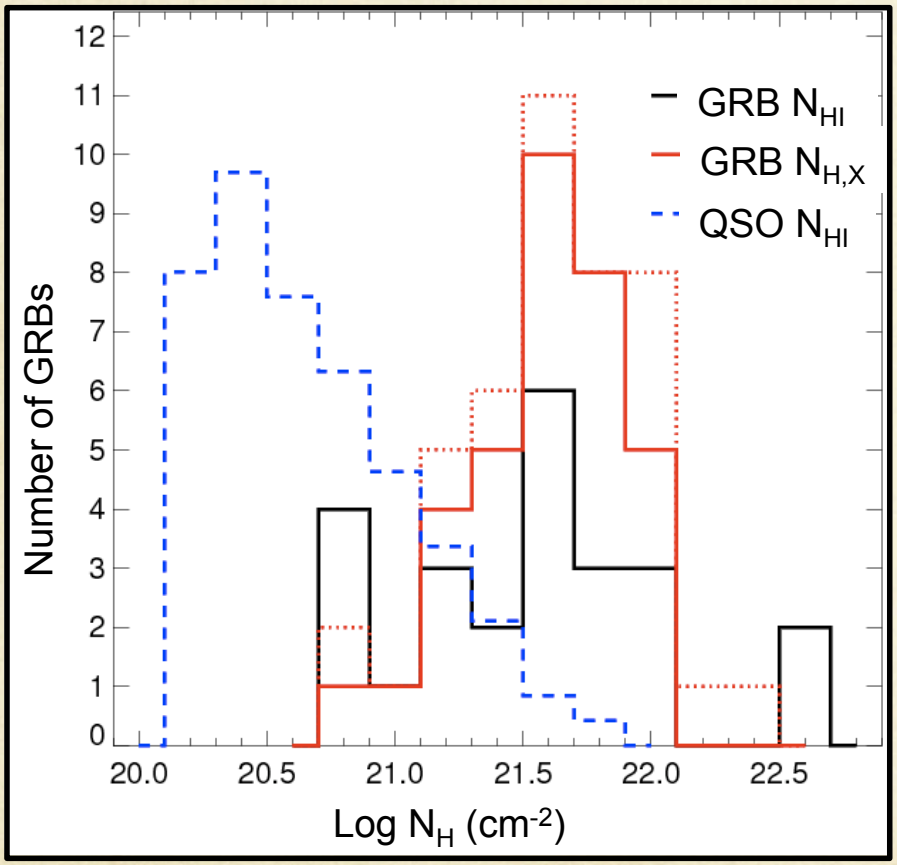


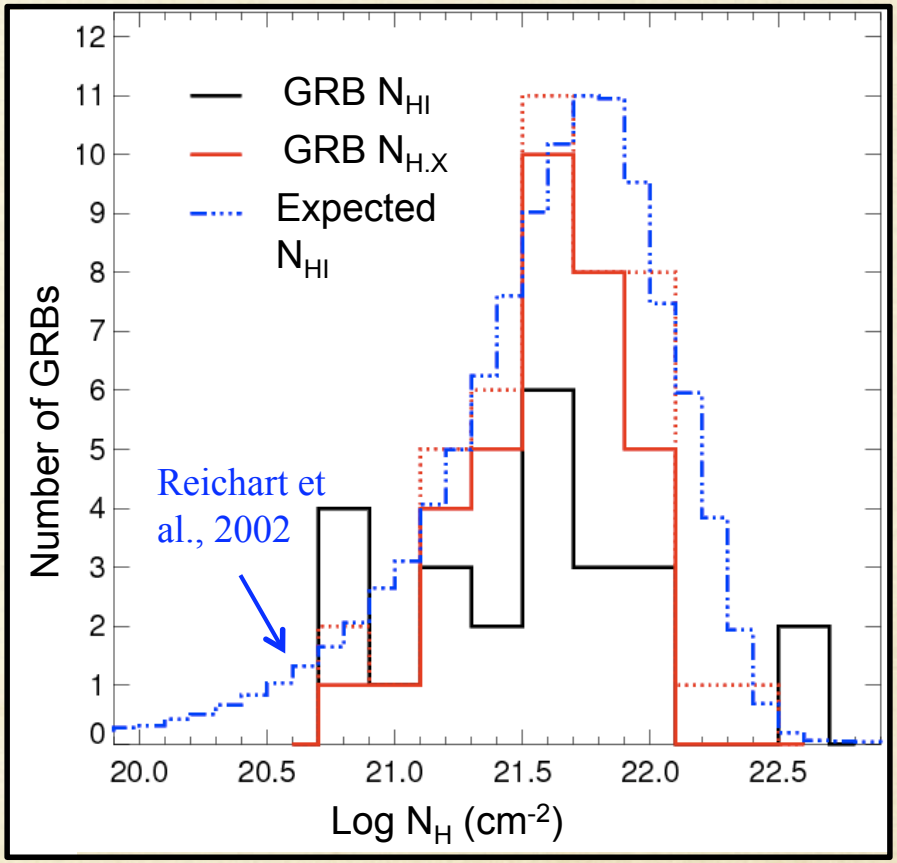


GRB hosts properties: metallicity



N_H distributions





Schady+10

N_{HI} vs. $N_{H,X}$

Typically

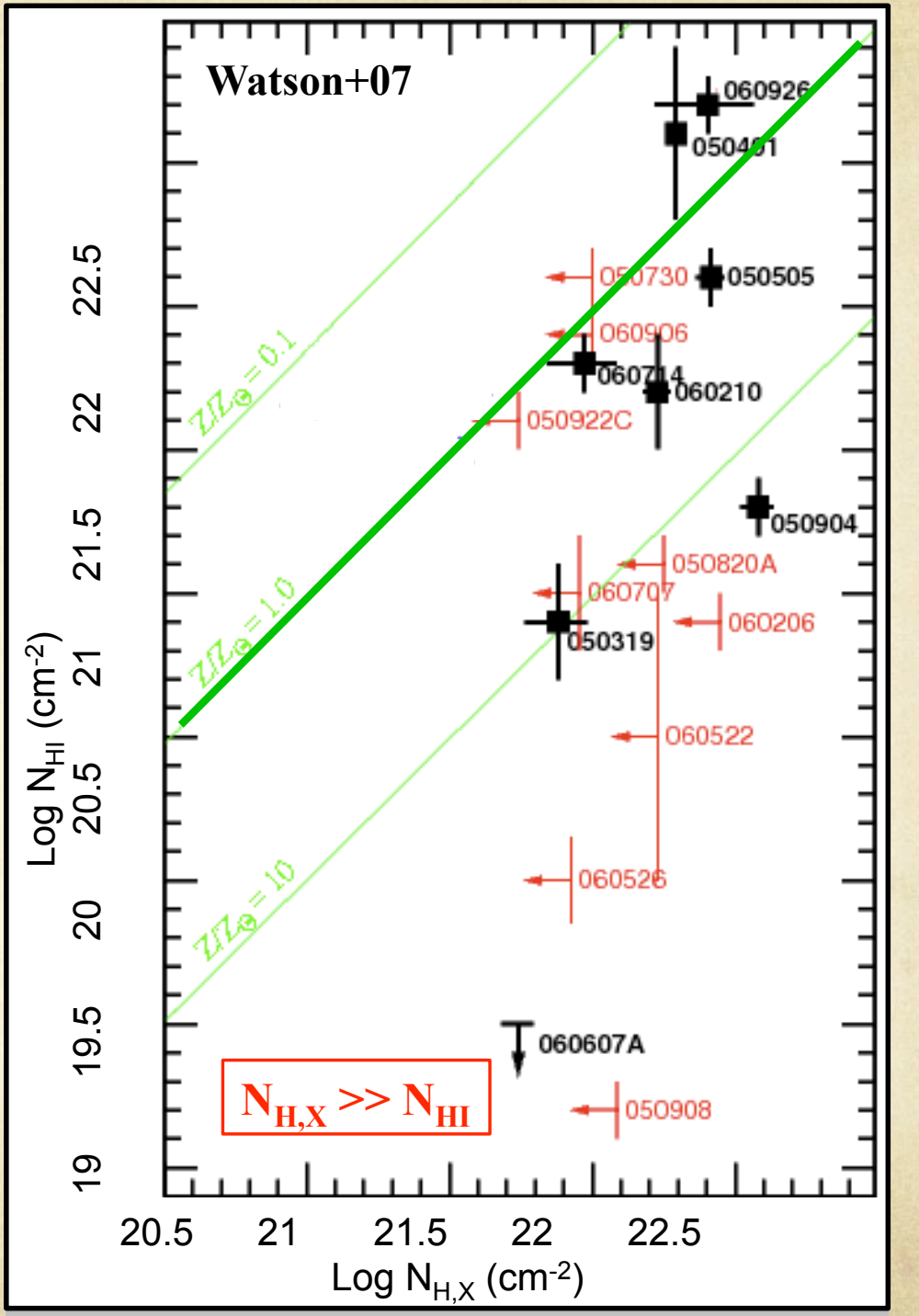
$$N_{H,X} >> N_{HI}$$

This could be because…

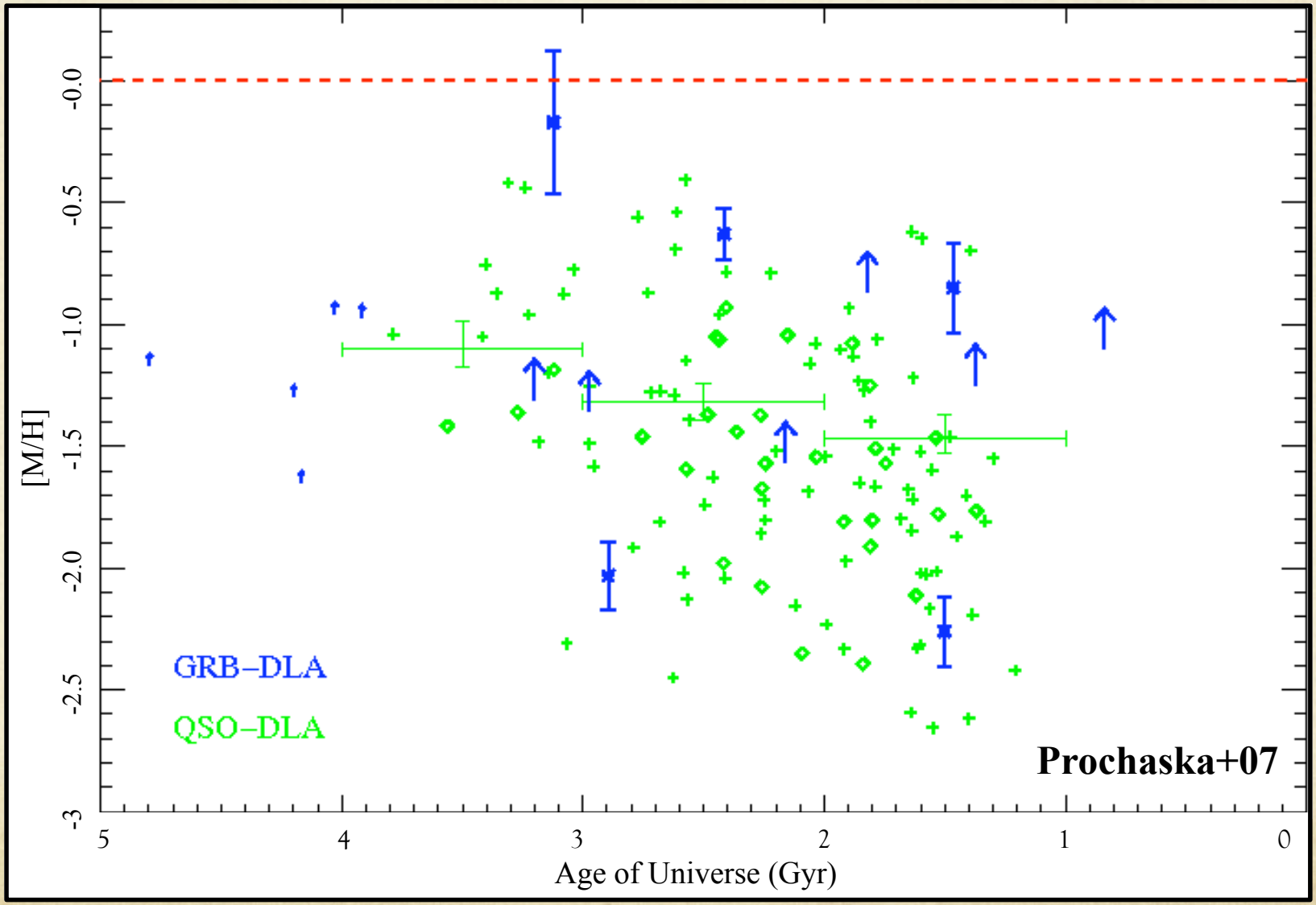
- **GRB host galaxies typically supersolar environments**

  and/or

- **X-ray observations probe larger column of gas than optical**



GRBs typically have sub-solar metallicity hosts, suggesting X-ray observations probe larger column of gas than the optical



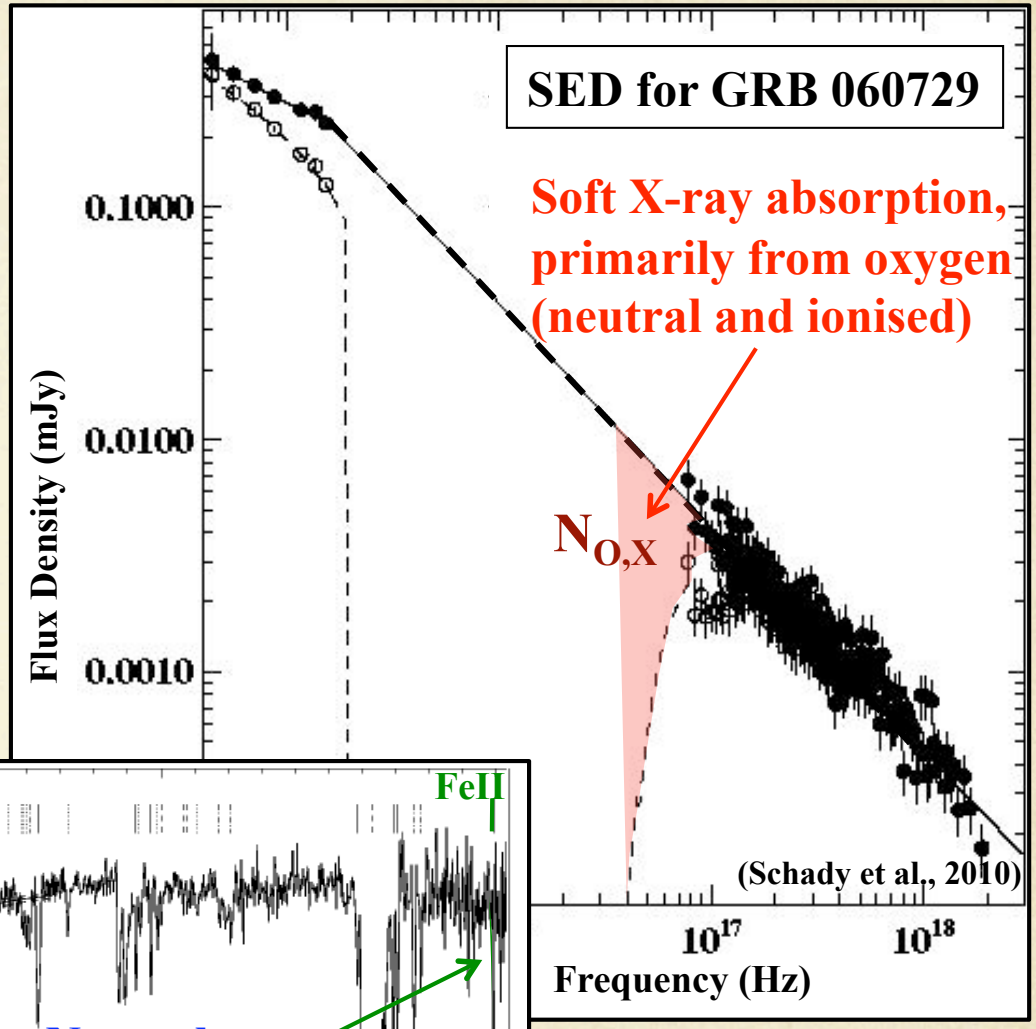
Absorption by metals and gas

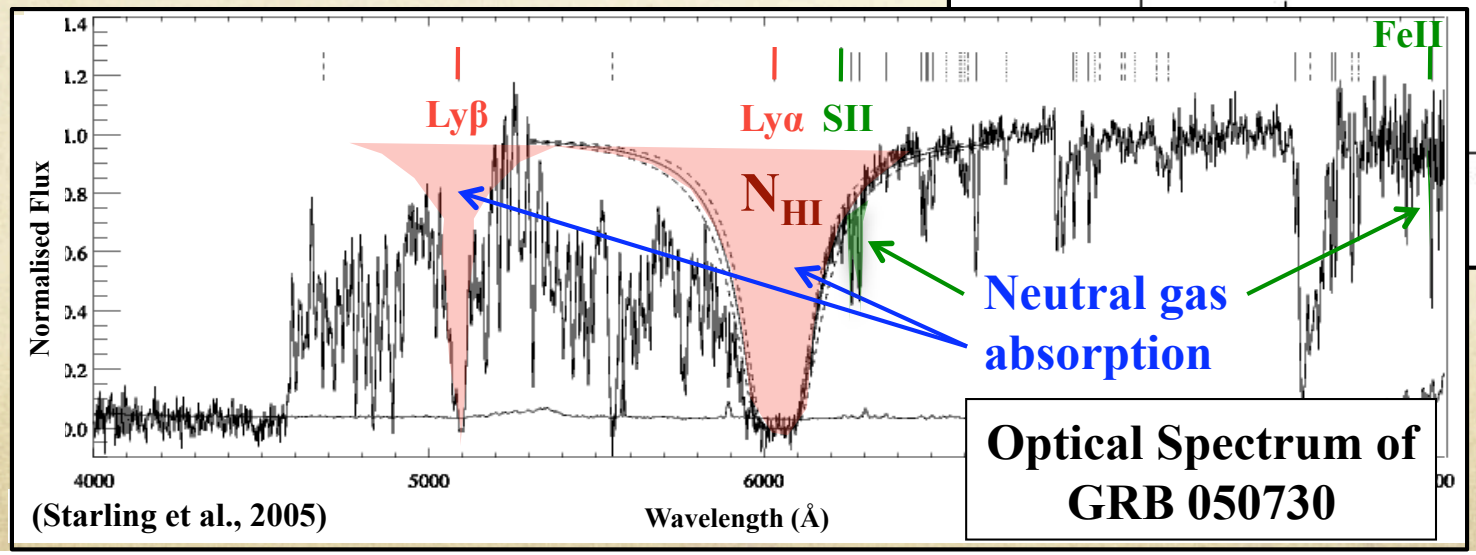
Optical spectra: probes neutral gas

- **Lyα**, **Lyβ**, weakly-ionised metal absorption lines (e.g. **SiII, ZnII,F eII**)

X-ray spectra: probes total gas

- absorption primarily from **oxygen** (neutral and ionised)





Remove Metallicity From Analysis

- **Total Gas:**

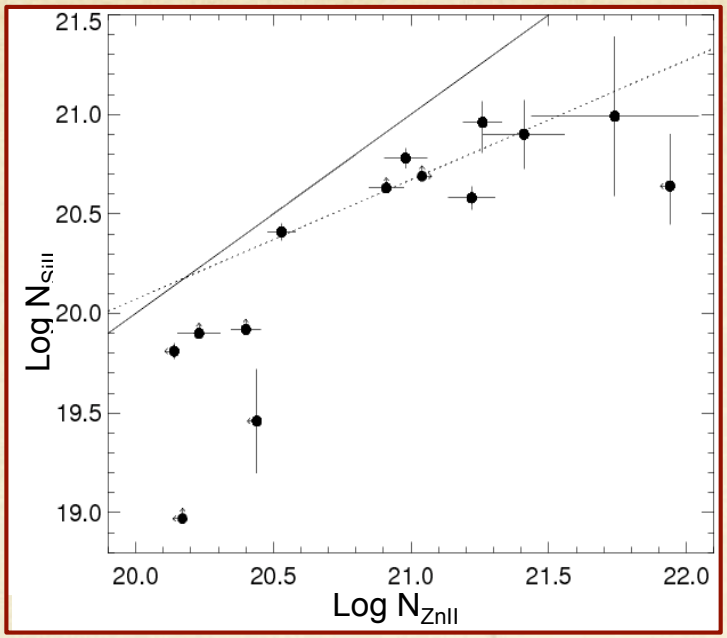
  X-ray absorption measurements trace primarily oxygen

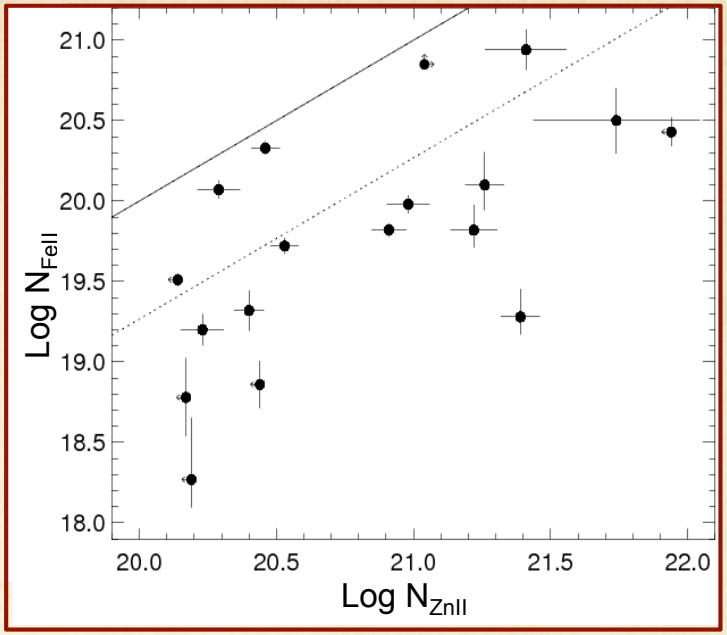
- **Neutral Gas:**

  weakly-ionised metal lines e.g. **Zn II**, **S II**, **Si II**, **Fe II**

Sample:

All GRBs with reported weakly-ionised metal line measurements, as well as X-ray spectral observations: **26 GRBs**





✓ **correct** refractory elements **for dust depletion** (i.e. N_{FeII} and N_{SiII})

✓ **normalise** all metal column densities to **same solar abundances**

For each GRB in sample have

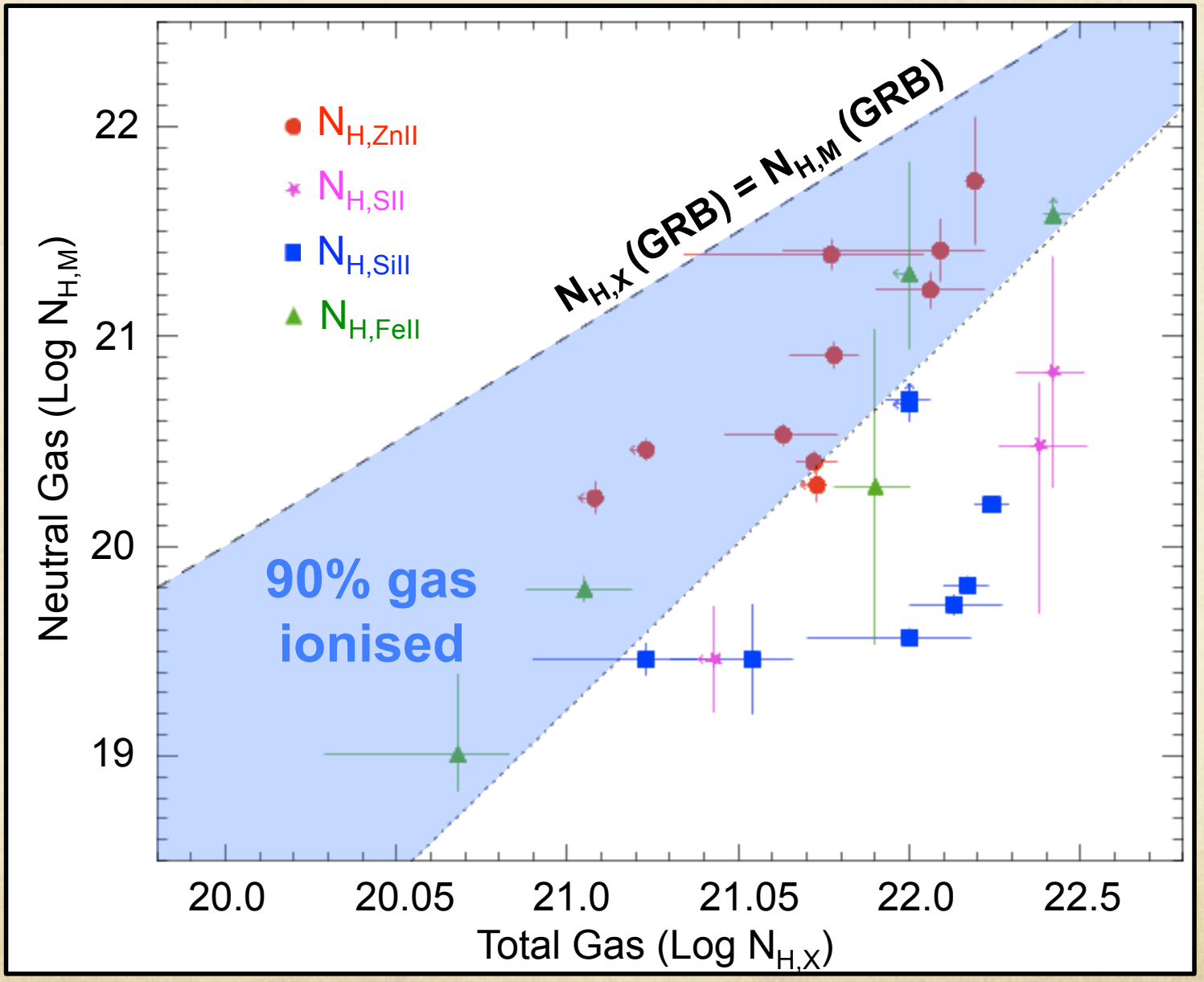
➢ $N_{O,X}$ **normalised to** $N_{H,X}$**:** traces total metals column density

For **MII** either **Zn II**, **S II**, **Si II** or **Fe II** (preferentially listed)

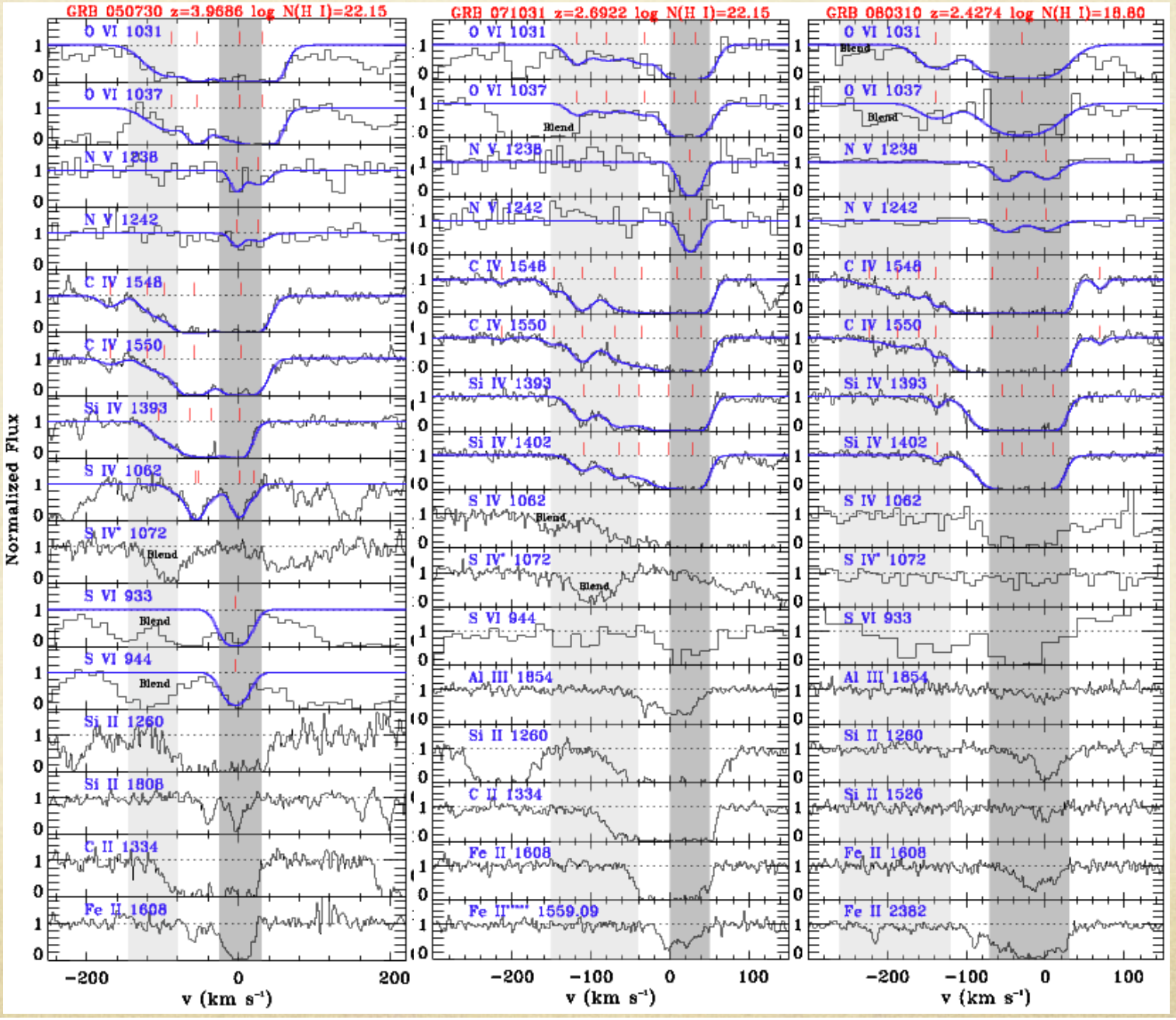
➢ N_{MII} **normalised to** $N_{H,MII}$**:** traces neutral metals column density

Neutral vs. Ionised Gas

Schady+11

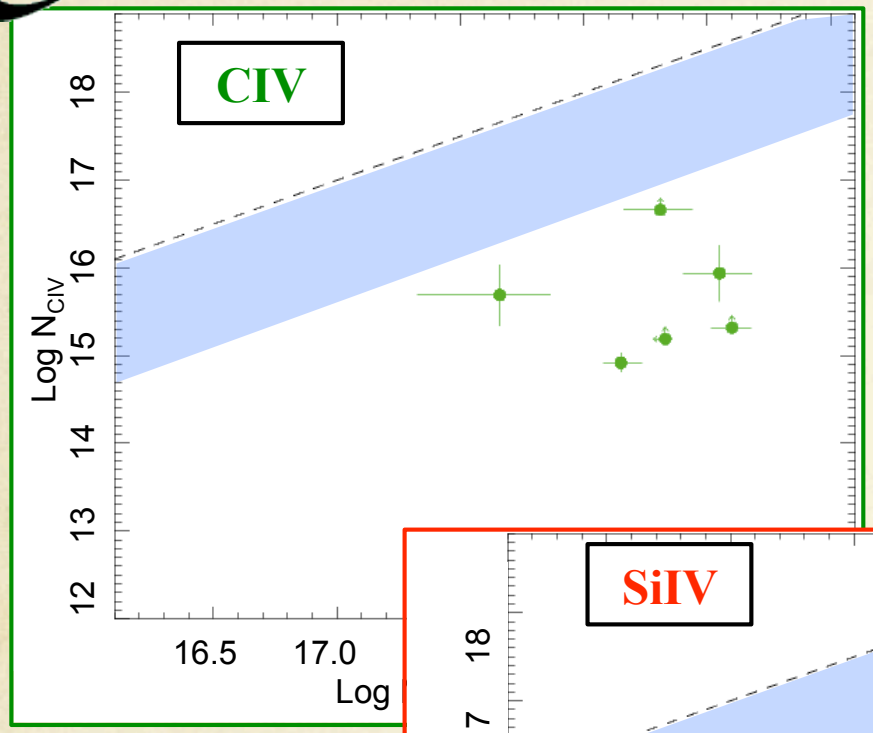


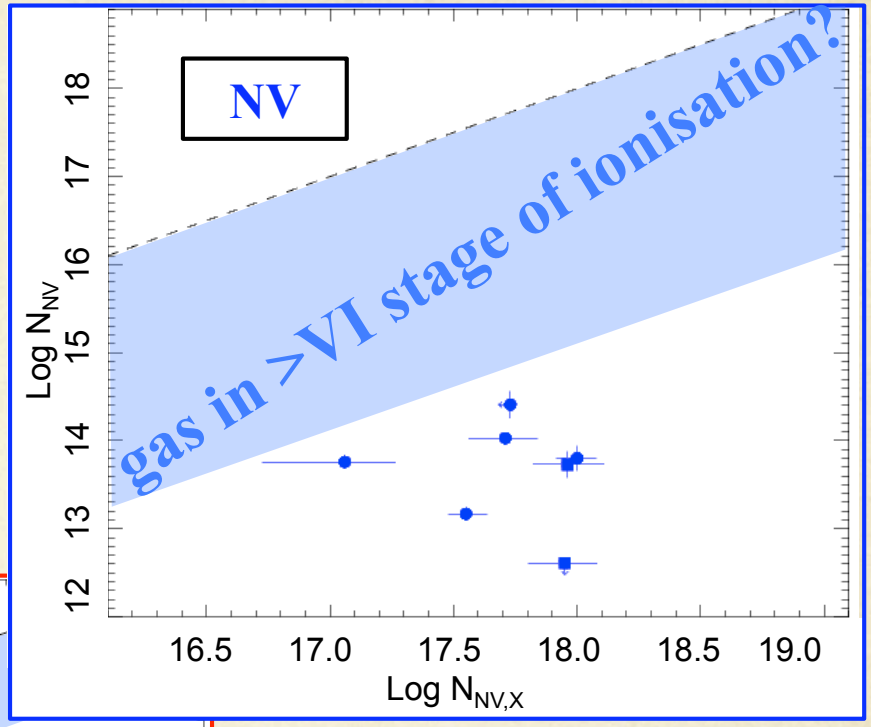
CIV, SiIV, NV and OVI as probes to circumburst medium?

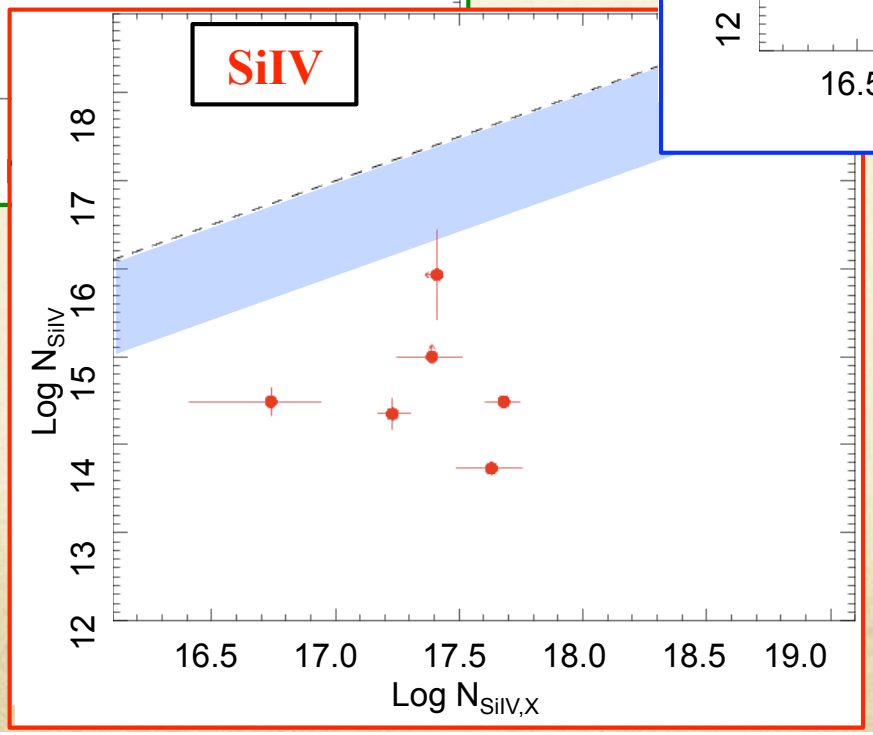


Fox+08

Fraction of Strongly Ionised Gas



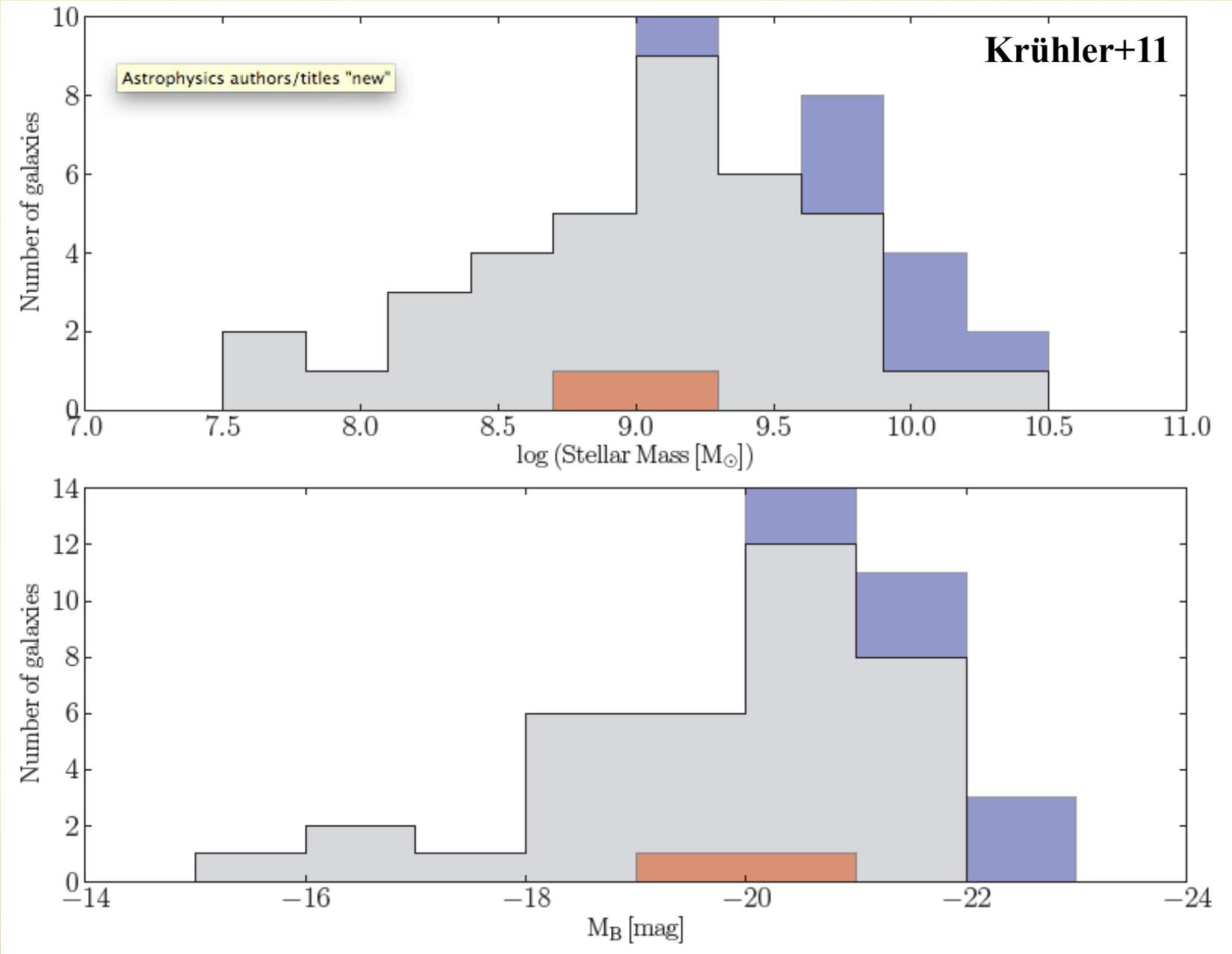




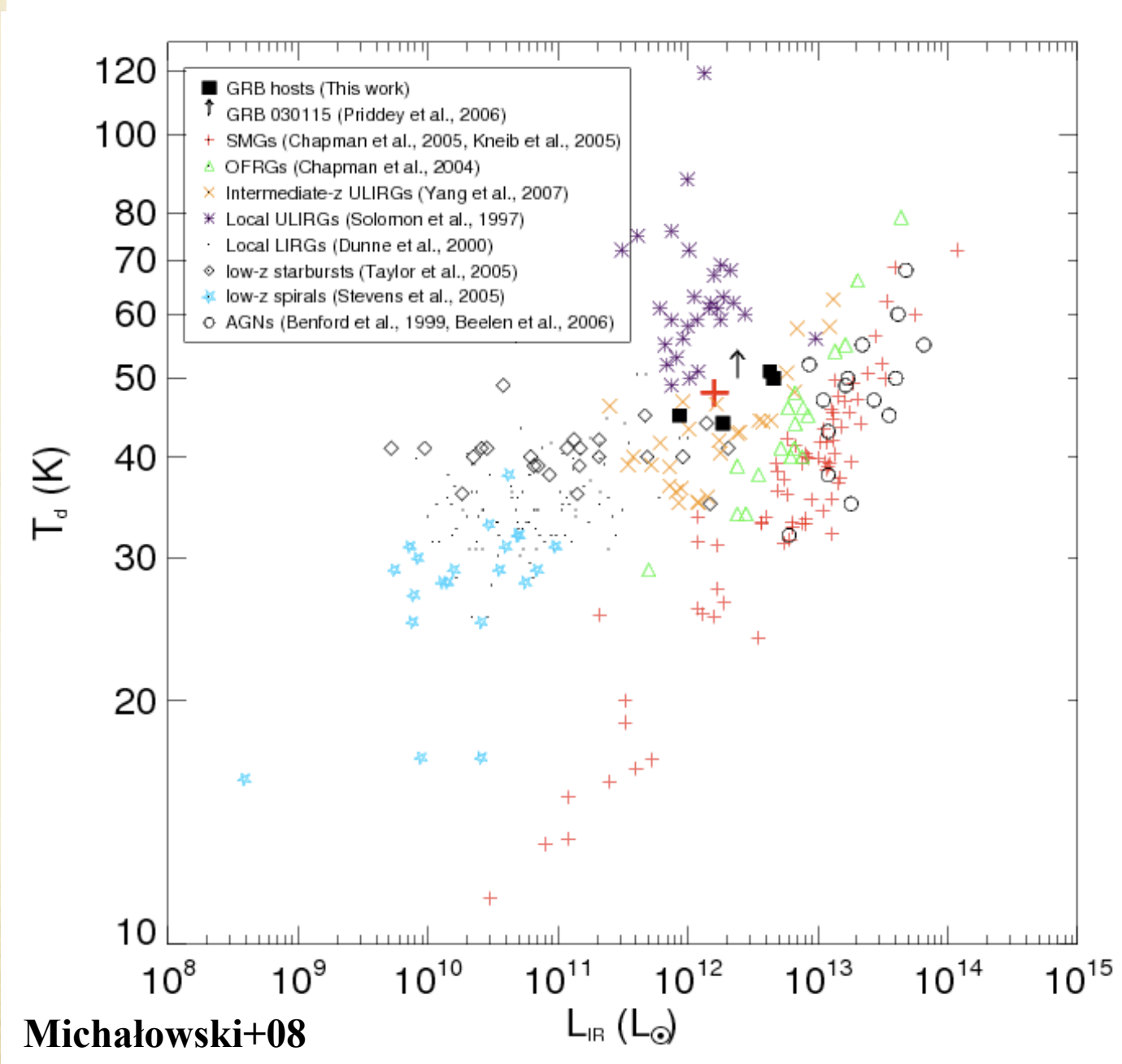
Schady+11

Only <10% of gas strongly ionised (IV-VI ionisation state)

GRBs with dust-rich hosts

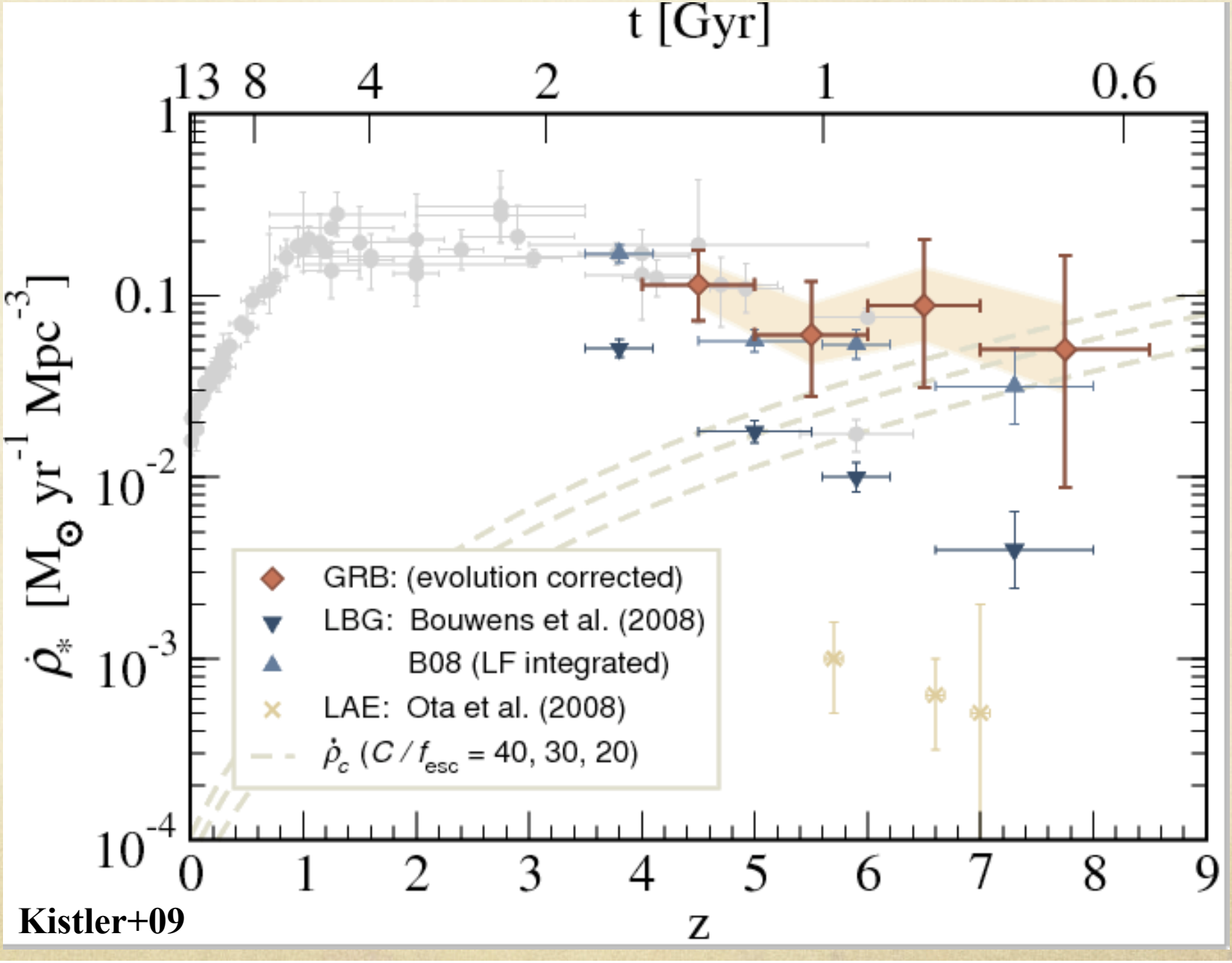


Broadband GRB SEDs



Michałowski+08

Cosmic star-formation density



Kistler+09

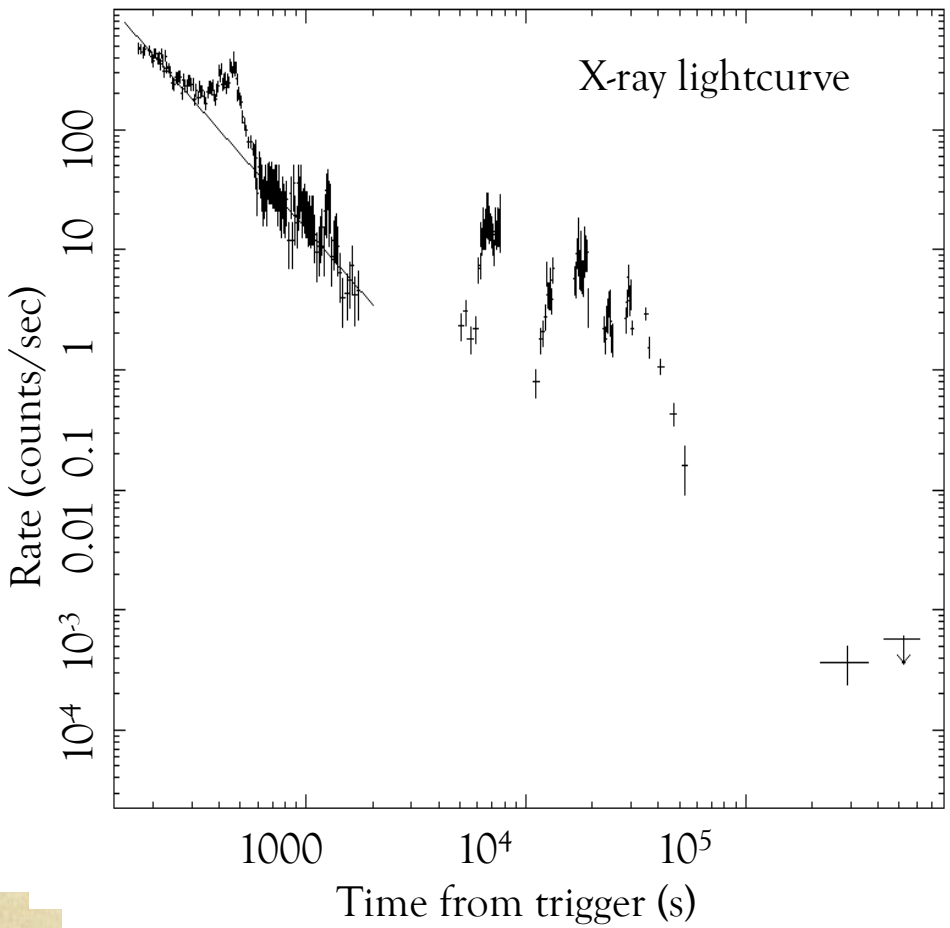
Summary

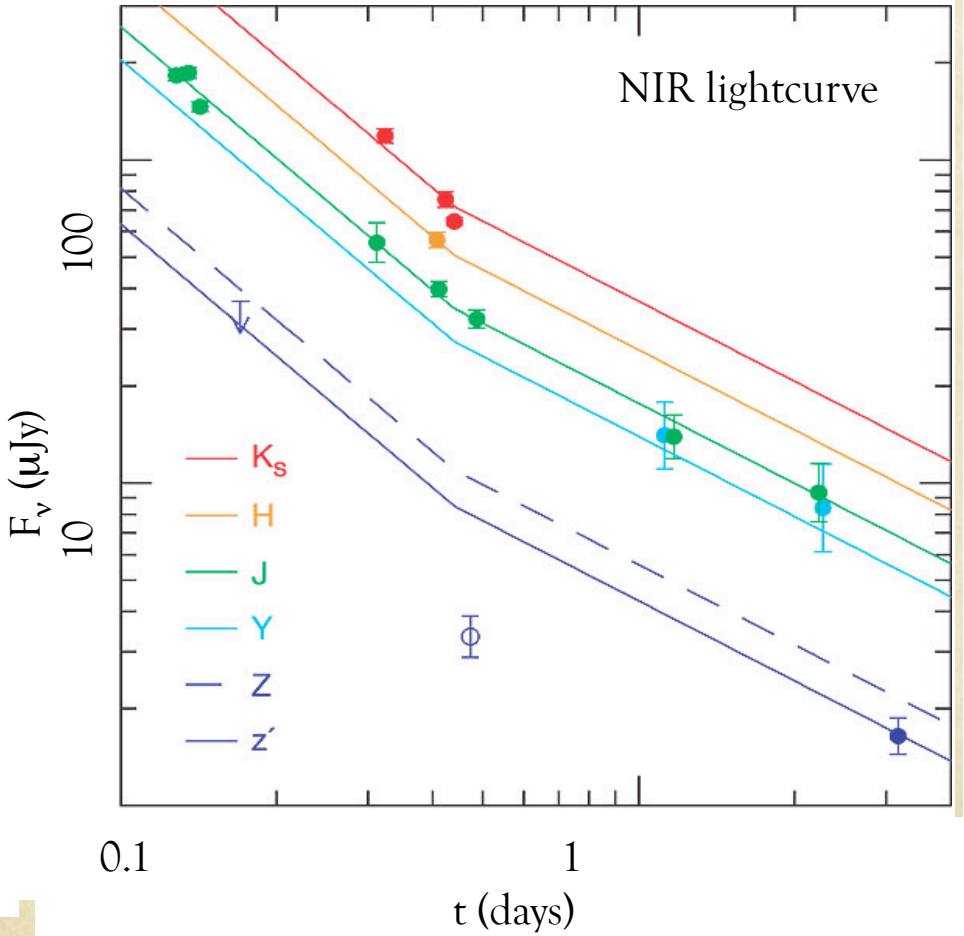
- Rich sample of GRB optical and X-ray afterglow spectra
  - Can probe A_V distribution and dust extinction law across cosmic time
  - Can probe ionisation state and abundance of host galaxy gas
- X-ray and optical energies probe different regions of gas
  - Low ions (e.g ZnII, SII, SiII, FeII) trace neutral gas
  - Soft X-ray bands probe all gas along line-of-sight
- Soft X-ray column densities typically an order of magnitude larger than neutral gas column densities
  - 90% of host galaxy gas along line-of-sight is ionised
  - ~ Large majority of gas is in a super ionised state ?
- Tentative SCUBA detections imply GRBs to be a hotter, younger, less-massive counterparts of SMGs.

GRBs as tracers to the epoch of reionization

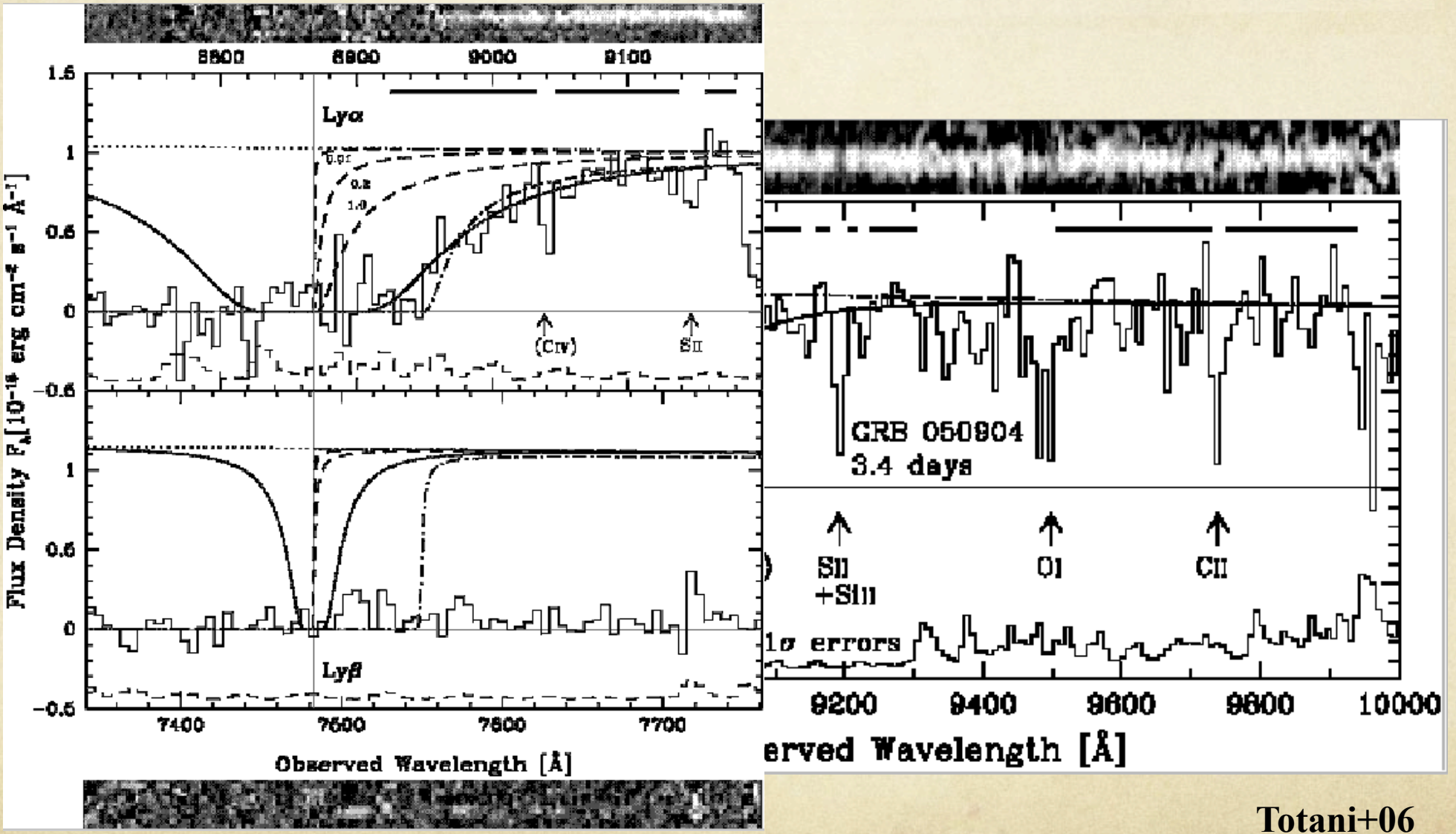
GRB 050904; z = 6.29

Haislip et al., 2006





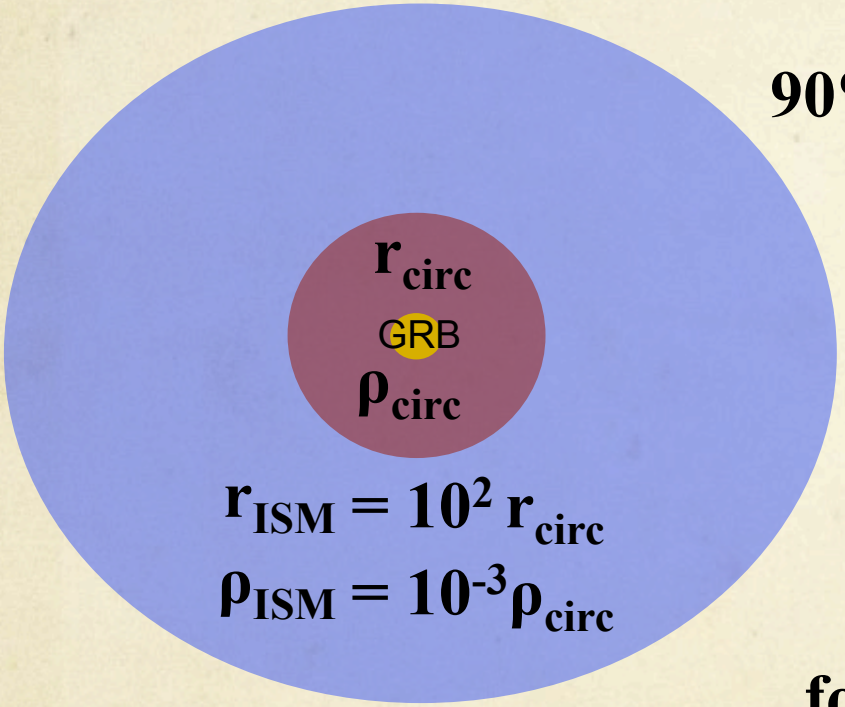
GRBs as tracers to the epoch of reionization



Totani+06

Neutral vs. Ionised Gas

Neutral gas lies 100pc–1.7kpc from GRB (e.g. Vreeswijk et al. 2004, Prochaska et al. 2007)



90% ionisation along line-of-sight implies:

$$r_{circ} \times \rho_{circ} = 10\, r_{ISM} \times \rho_{ISM}$$

for $\dfrac{r_{ISM}}{r_{circ}} \approx 10^2$ $\dfrac{\rho_{circ}}{\rho_{ISM}} \approx 10^3$