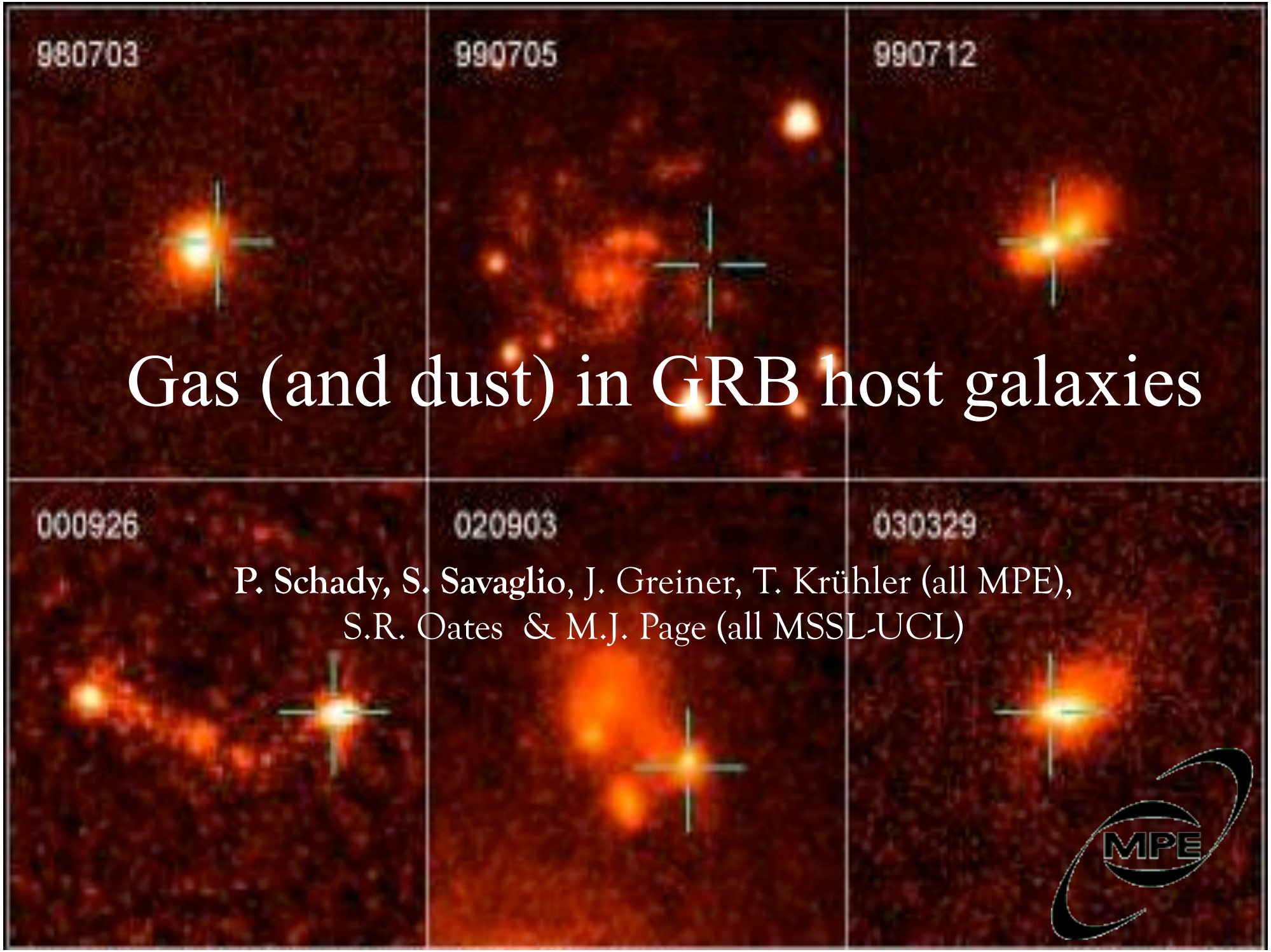
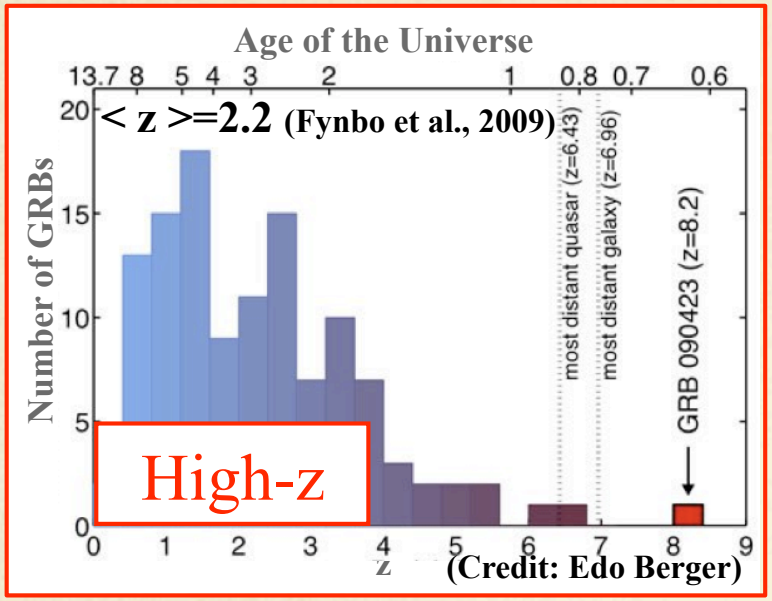


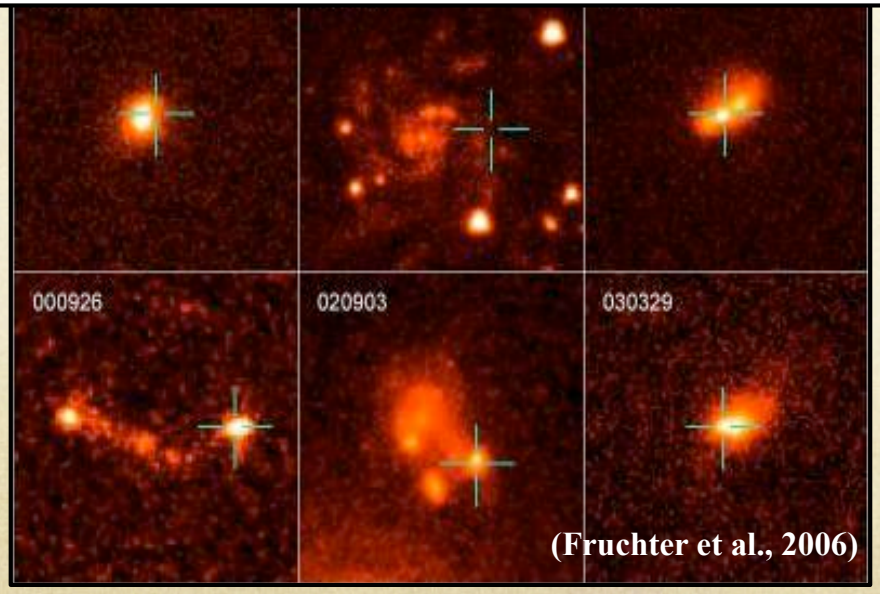
Gas (and dust) in GRB host galaxies

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

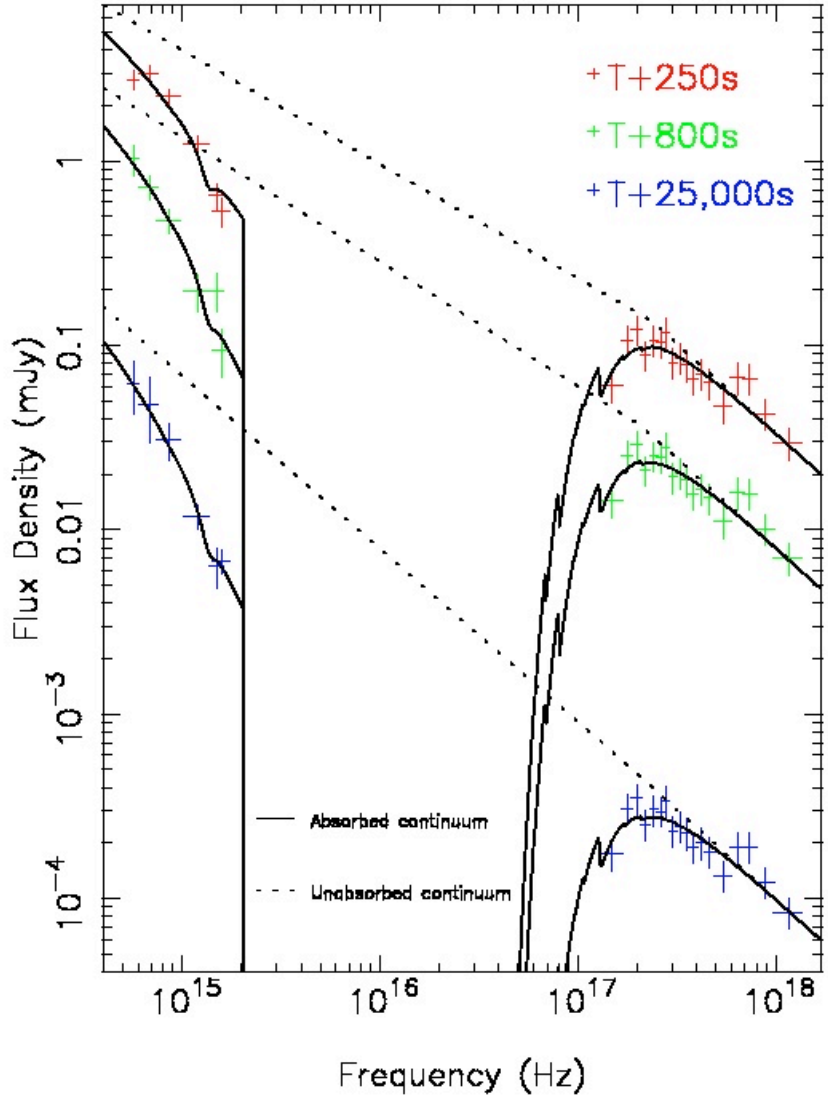
GRB hosts: probes to the distant Universe



Probe young, star forming galaxies

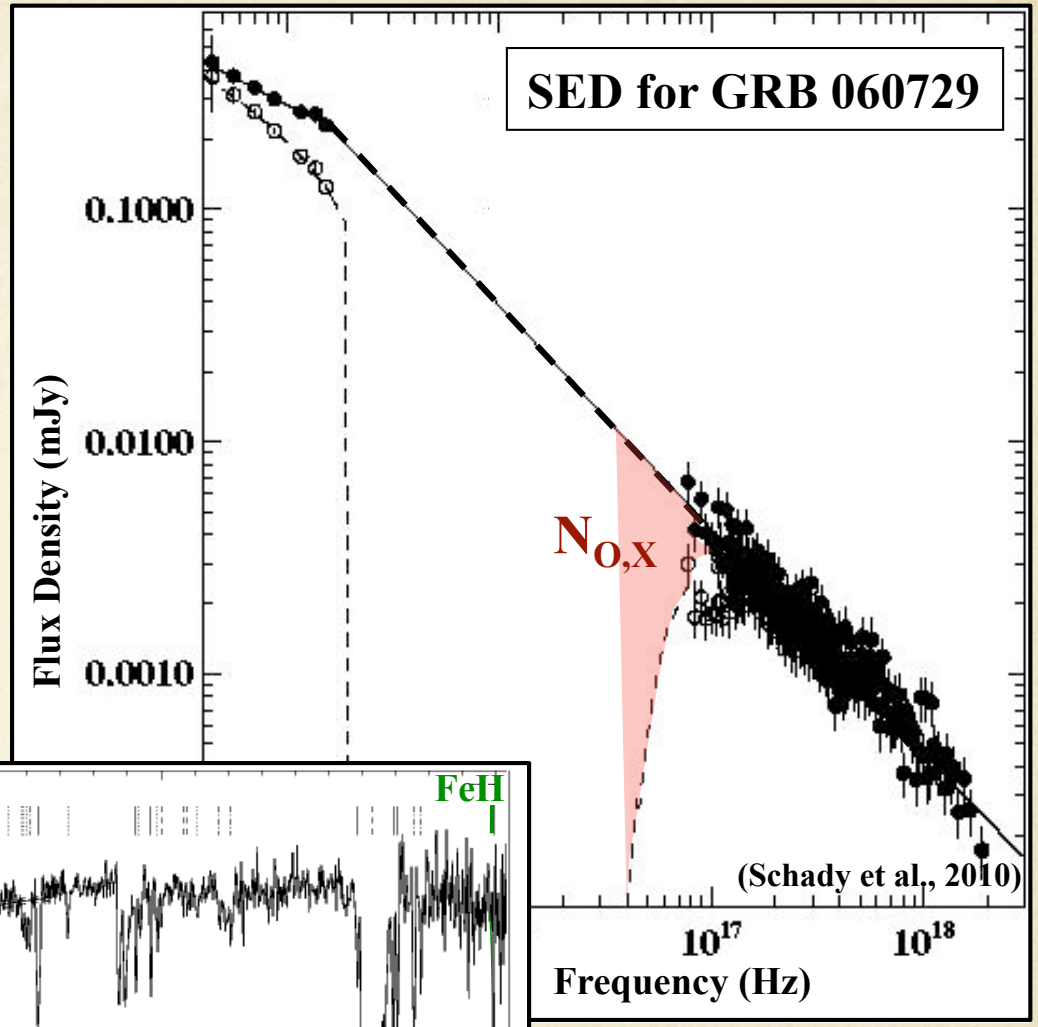


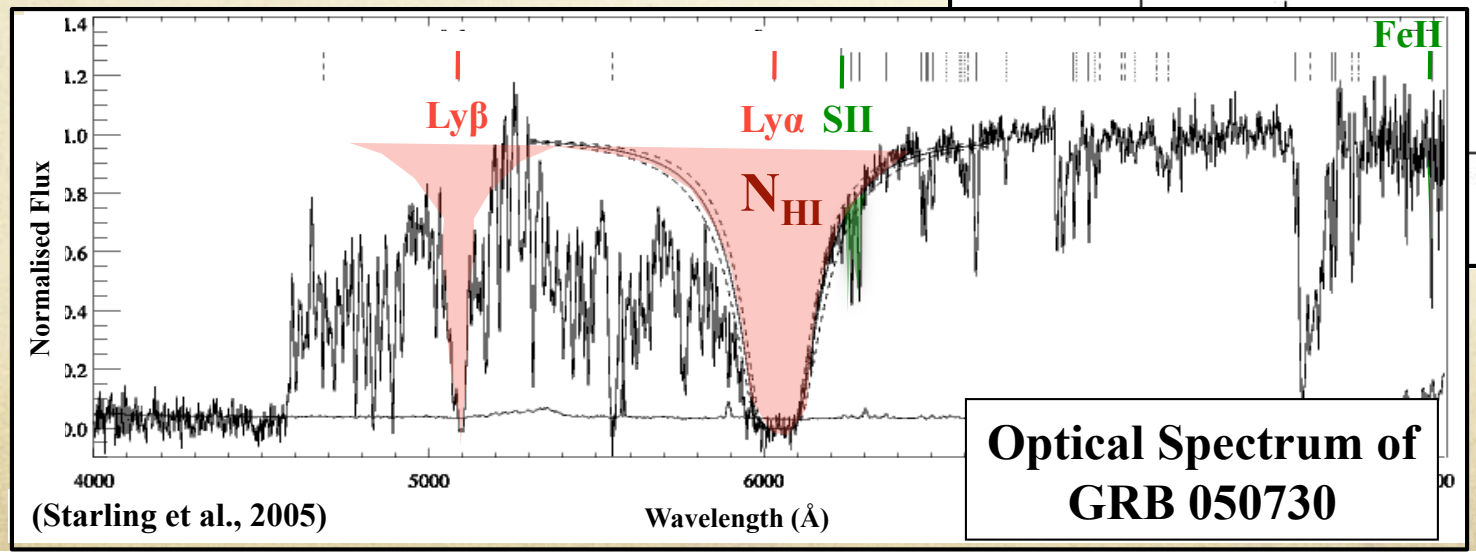
Highly luminous synchrotron featureless spectra



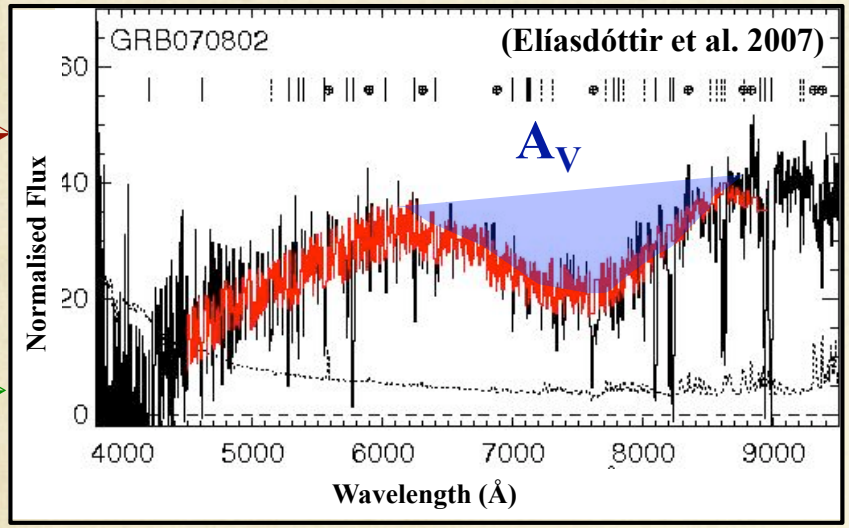
Broadband Photometry and Spectroscopy

- **Rich in gas:**
  - **soft X-ray absorption, $N_{O,X}$**
  - **Lyα absorption, N_{HI}**
- **Large range in host metallicities:**
  - **typically subsolar ($\langle Z \rangle = 0.3 Z_{\odot}$)**

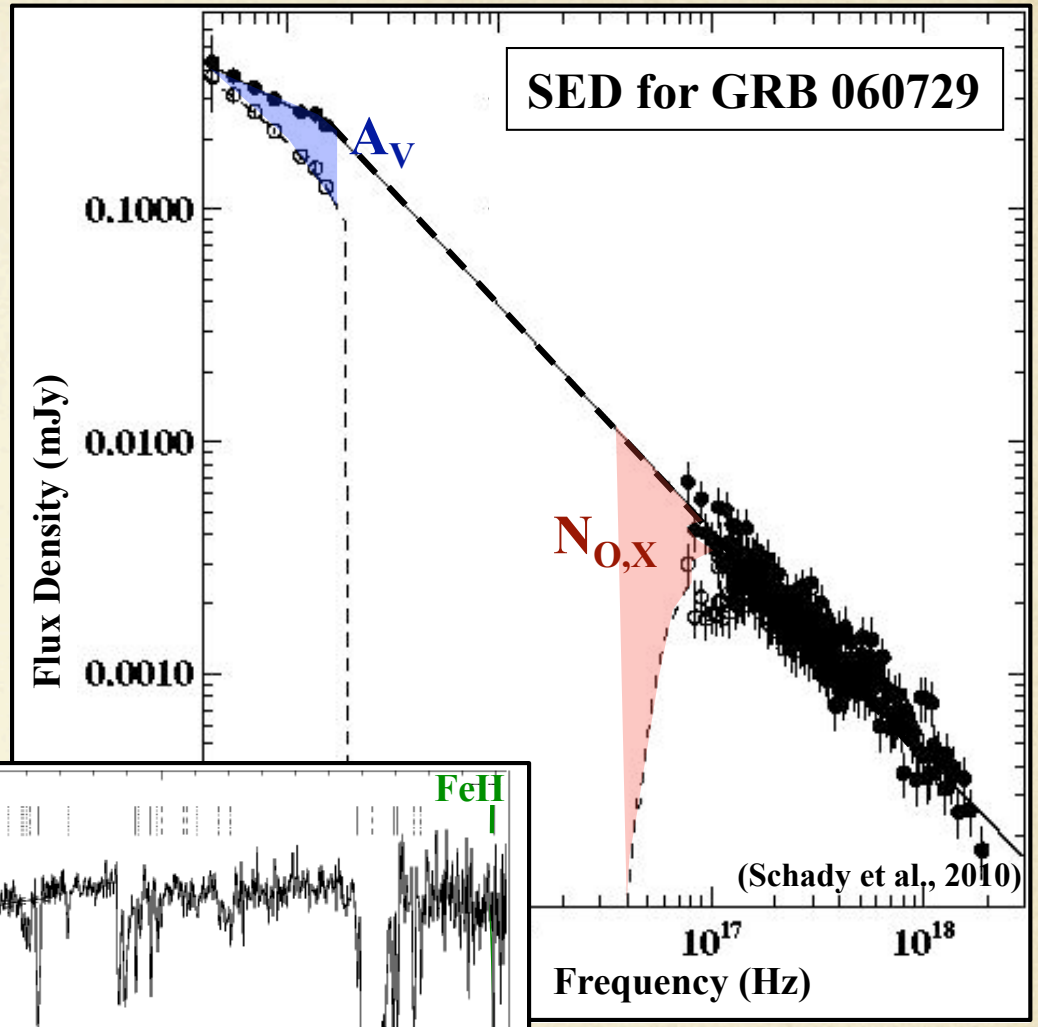


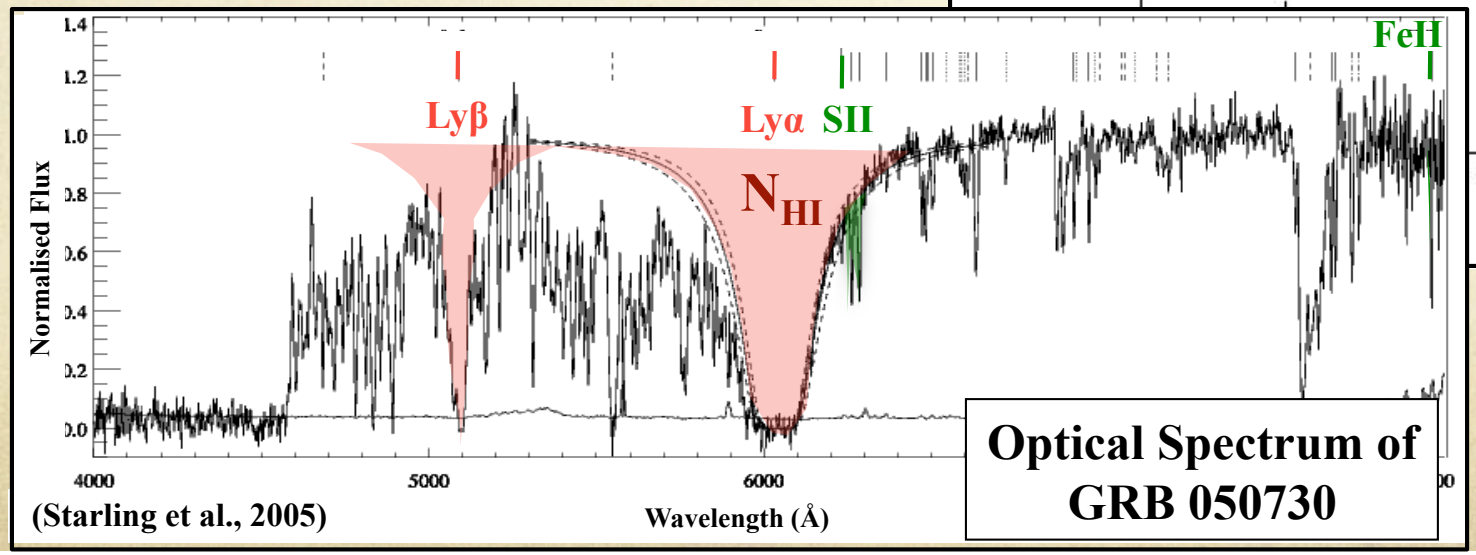


Broadband Photometry and Spectroscopy



➢ **Dust extinction, A_V, not so large**



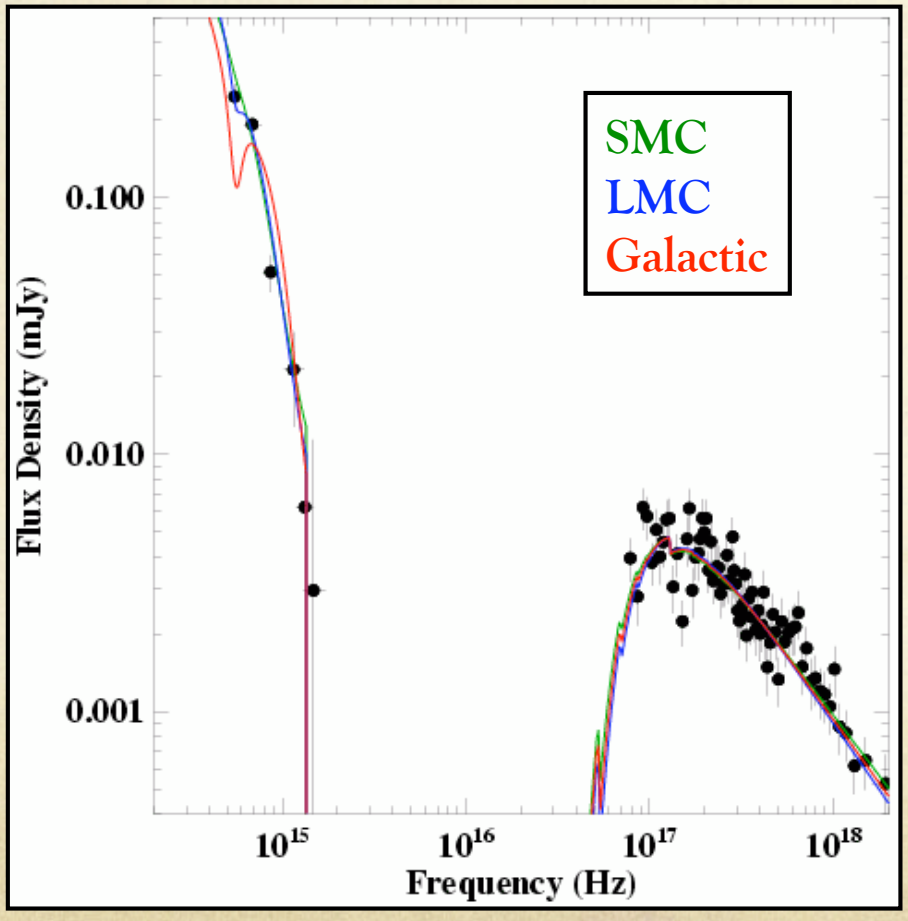


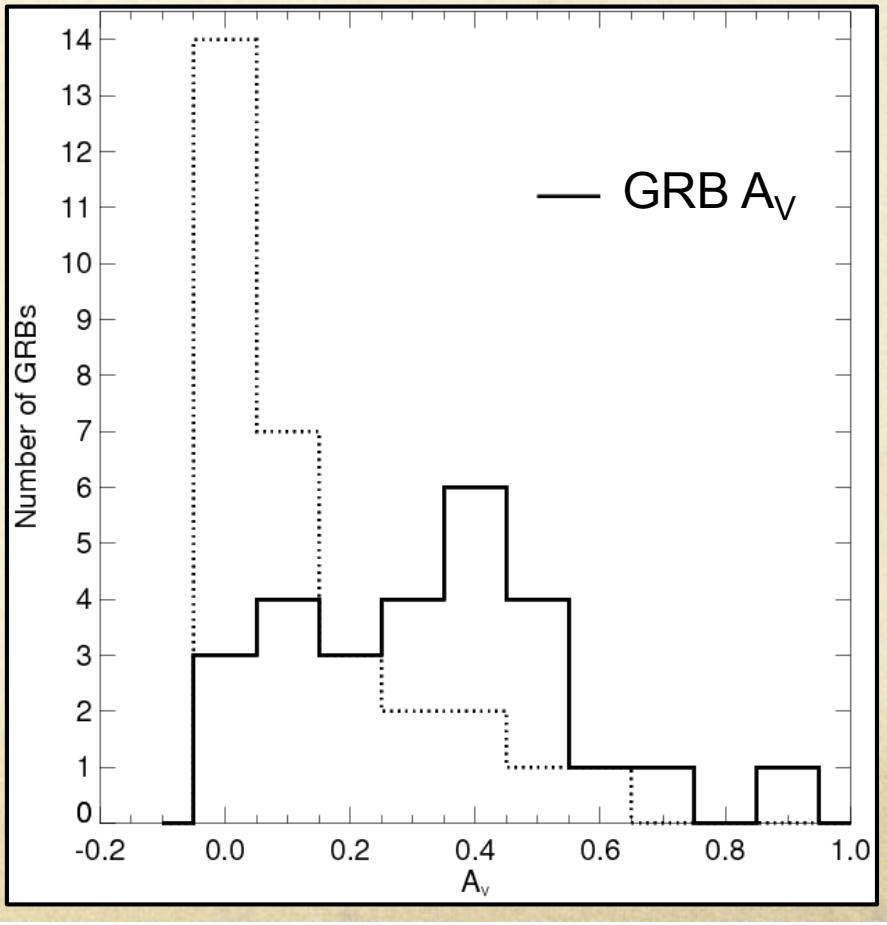
GRB Host Dust Extinction

Best-fit extinction laws:

SMC: 55%, LMC: 27%, MW: 18%

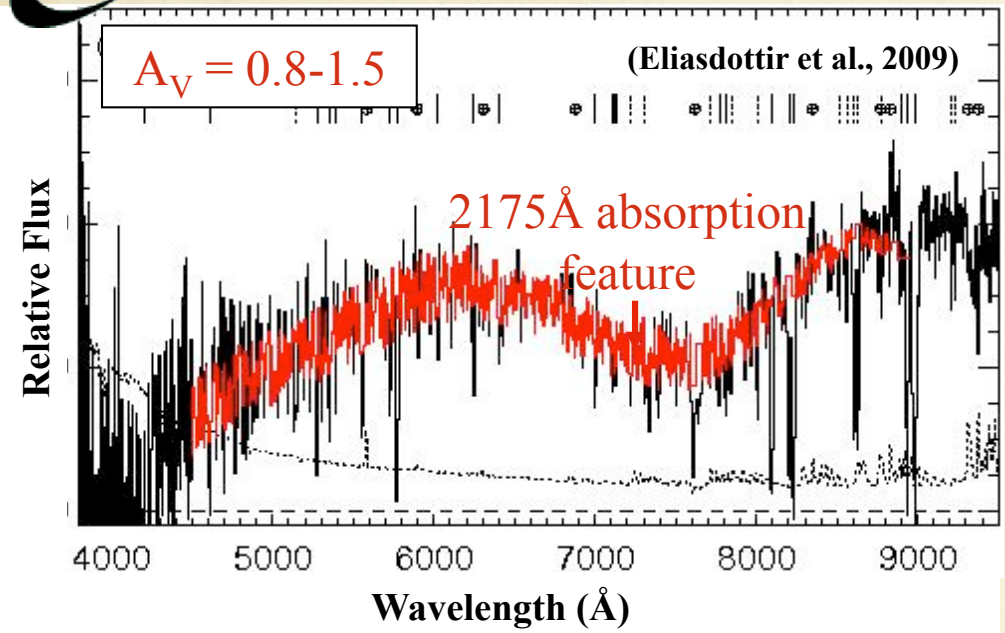
(see also Stratta et al. 04, Kann et al. 06, Starling et al. 07)



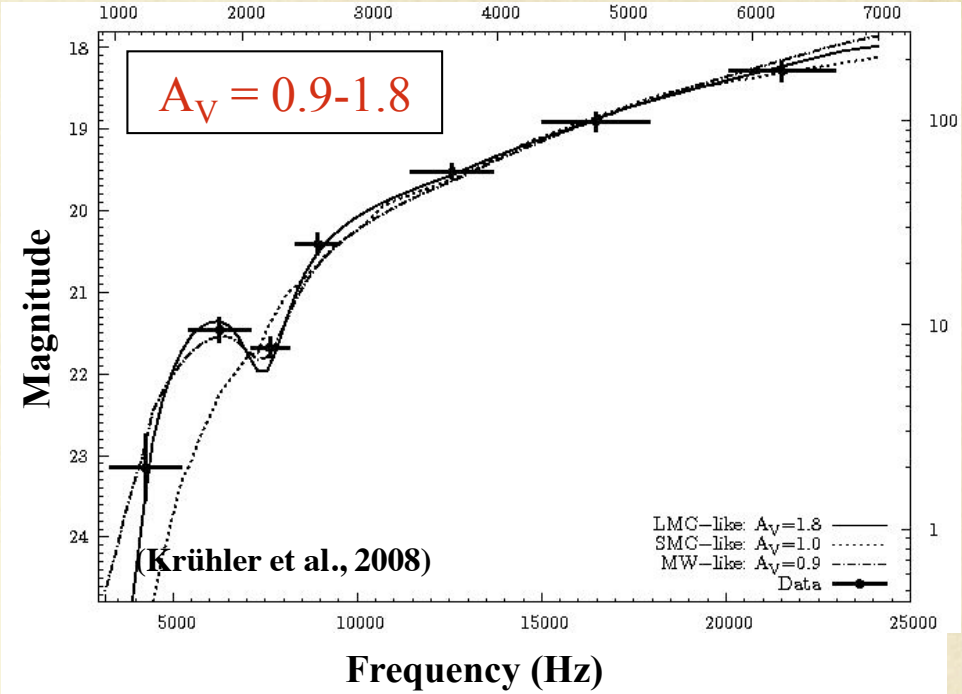


But….

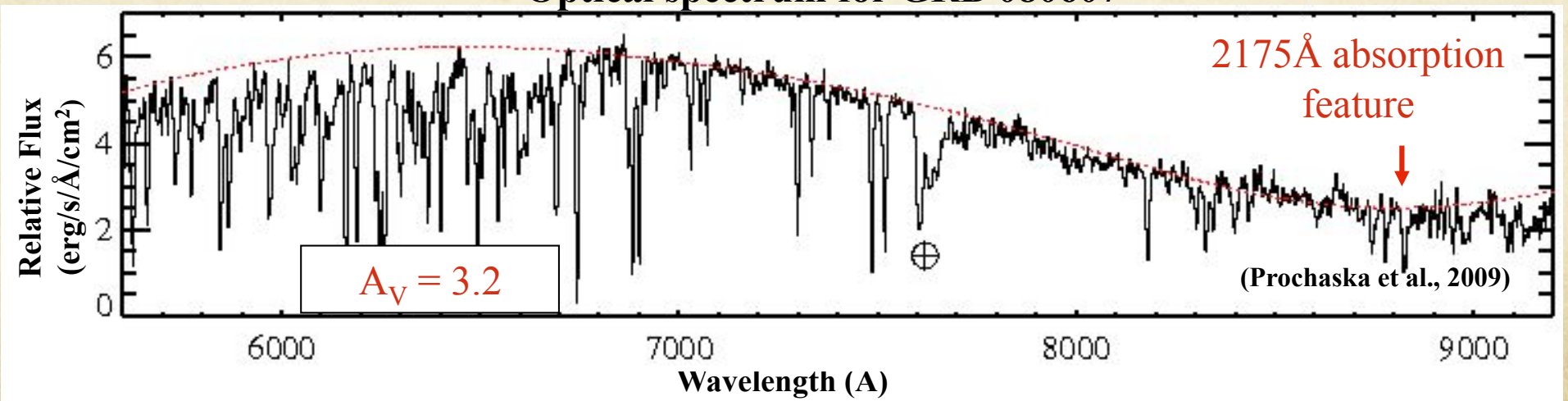
Optical spectrum for GRB 070802



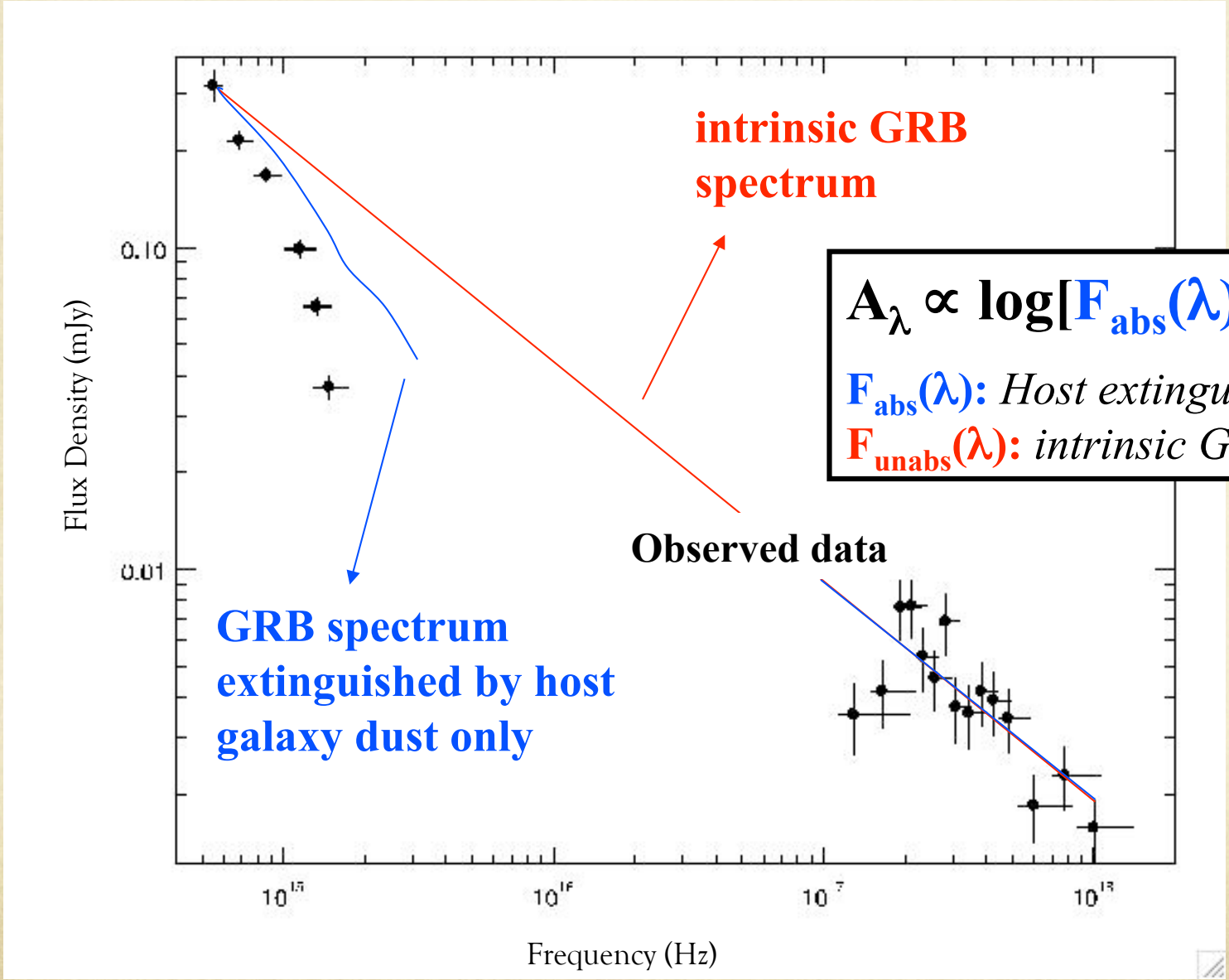
SED for GRB 070802



Optical spectrum for GRB 080607



Measuring the GRB extinction law

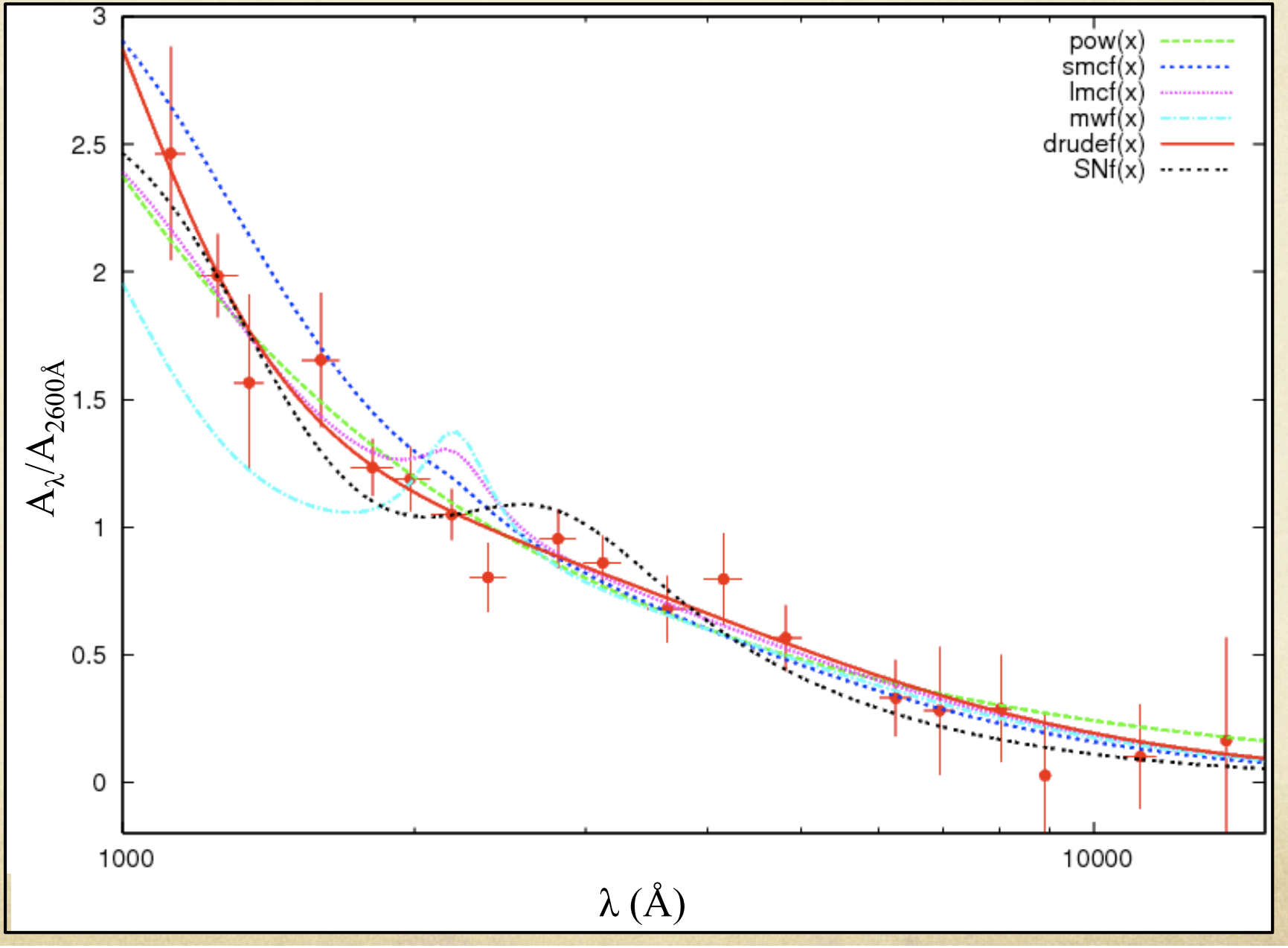


$$A_\lambda \propto \log[F_{abs}(\lambda)/F_{unabs}(\lambda)]$$

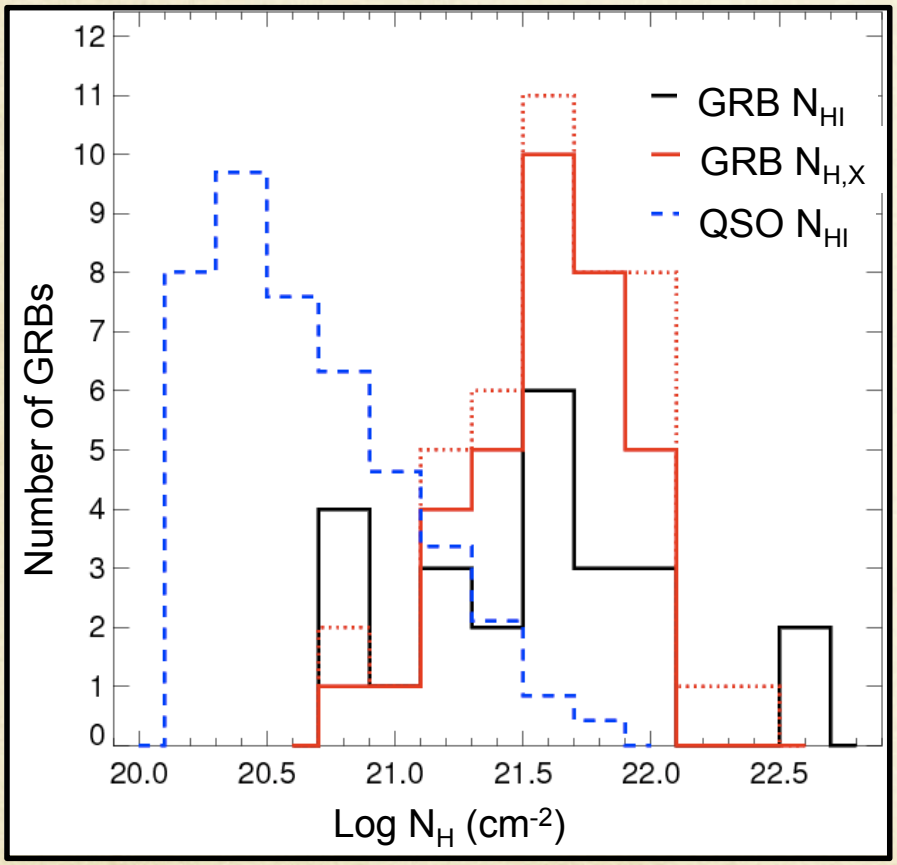
$F_{abs}(\lambda)$: *Host extinguished GRB spectrum*

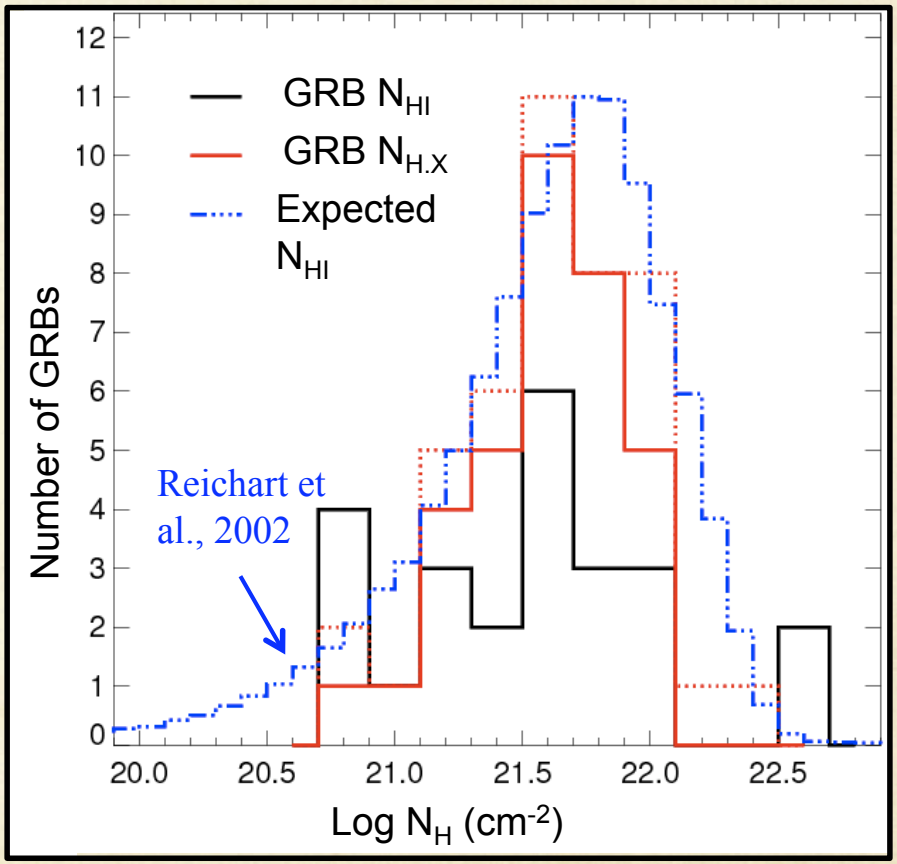
$F_{unabs}(\lambda)$: *intrinsic GRB spectrum*

(Optically bright) GRB mean extinction law



N_H distributions





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

Typically

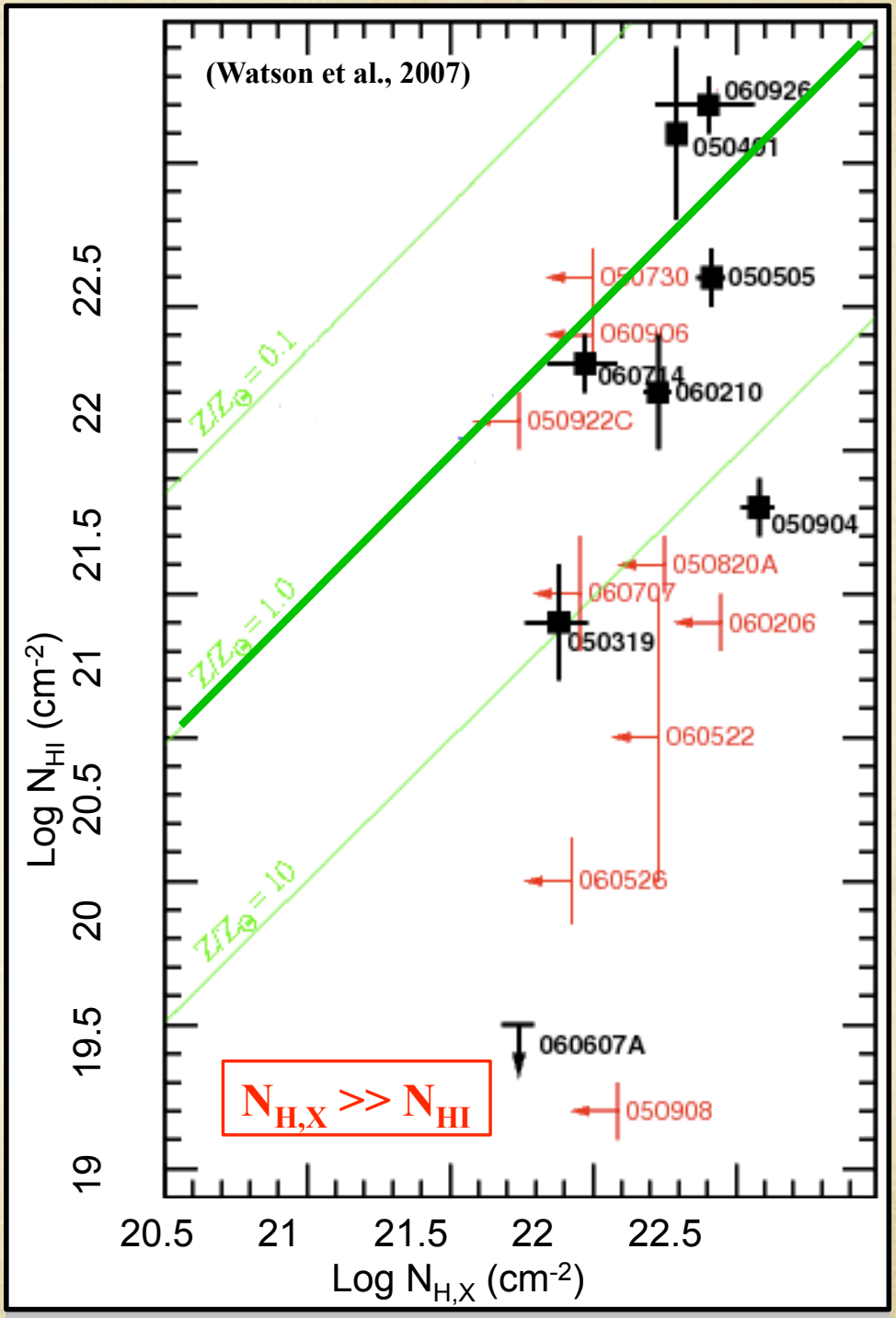
$$N_{H,X} >> N_{HI}$$

This could be because…

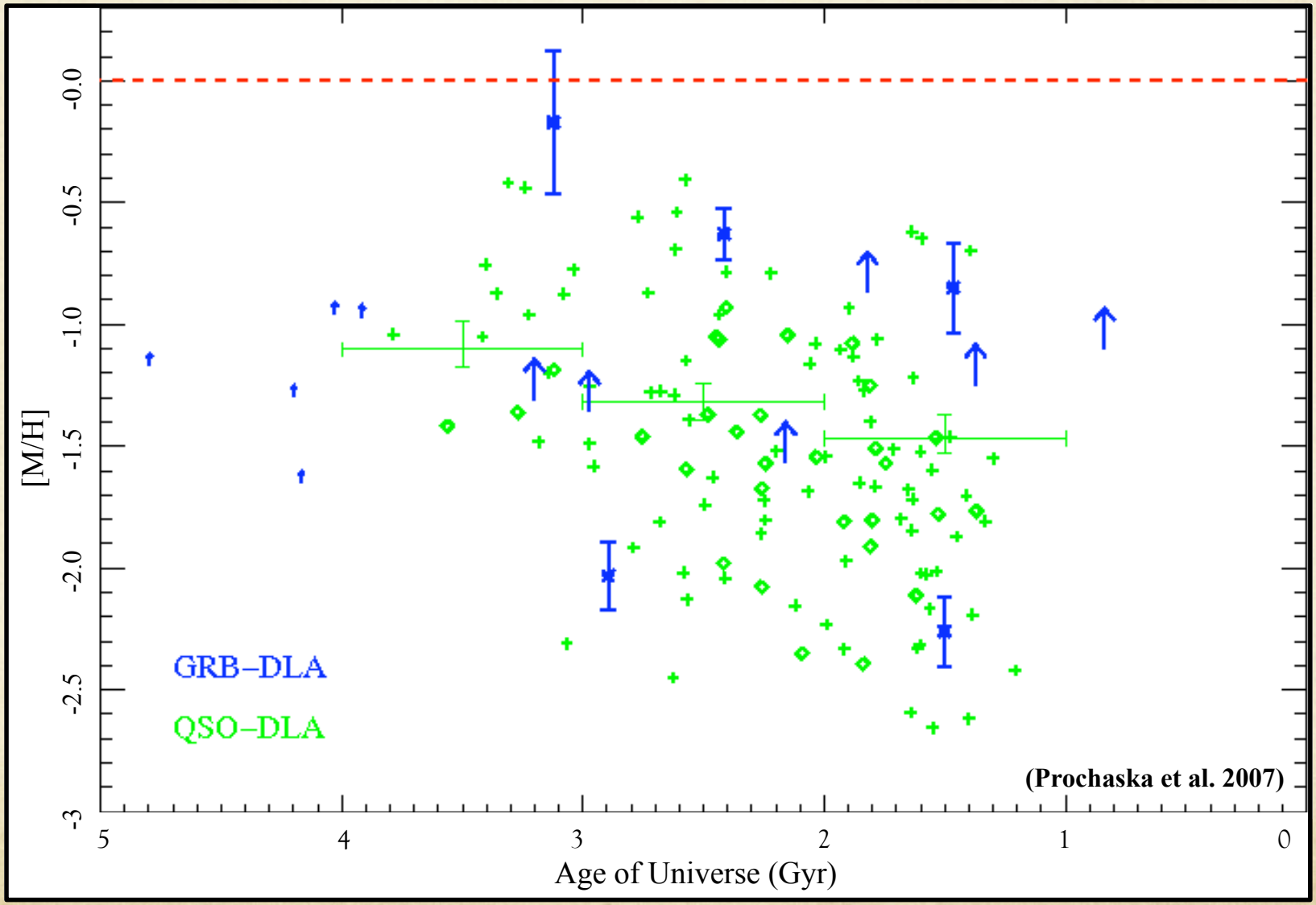
- **GRB host galaxies typically supersolar environments**

  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



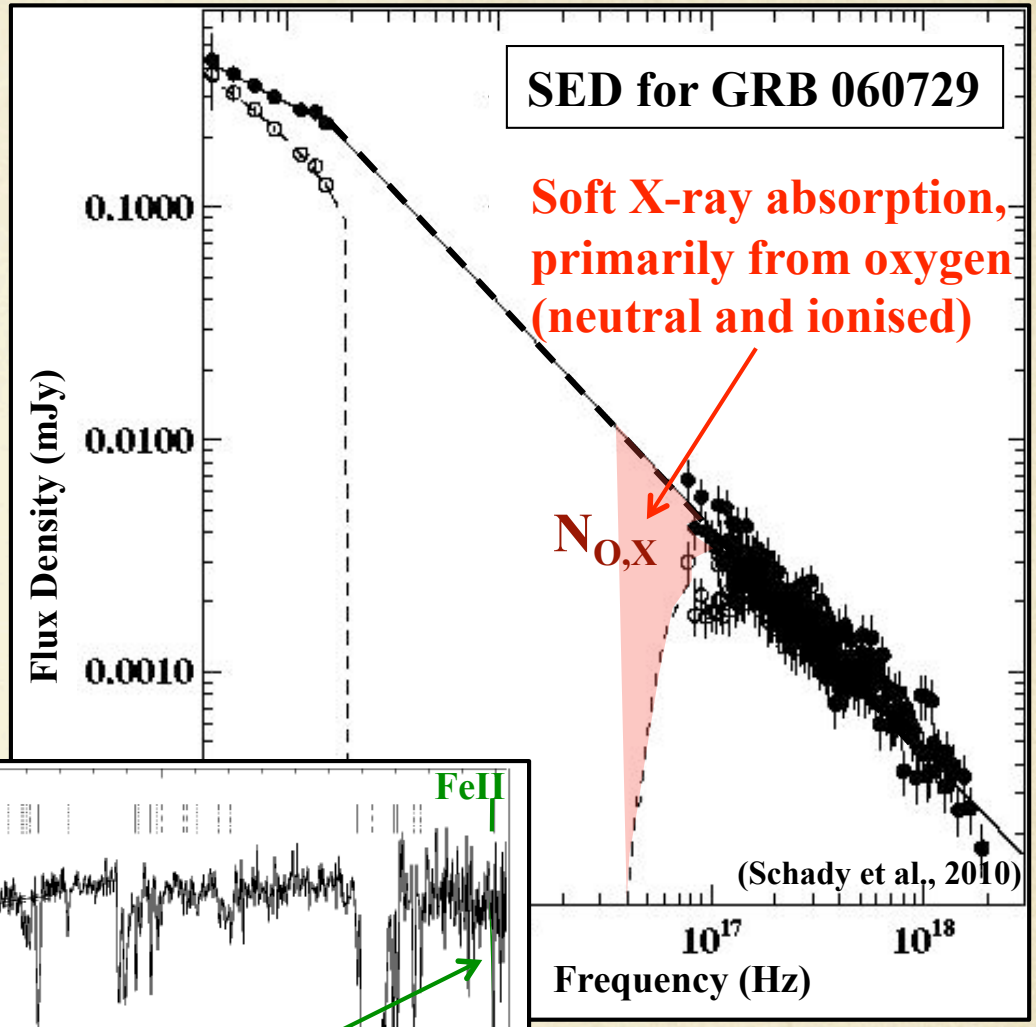
Absorption by metals and gas

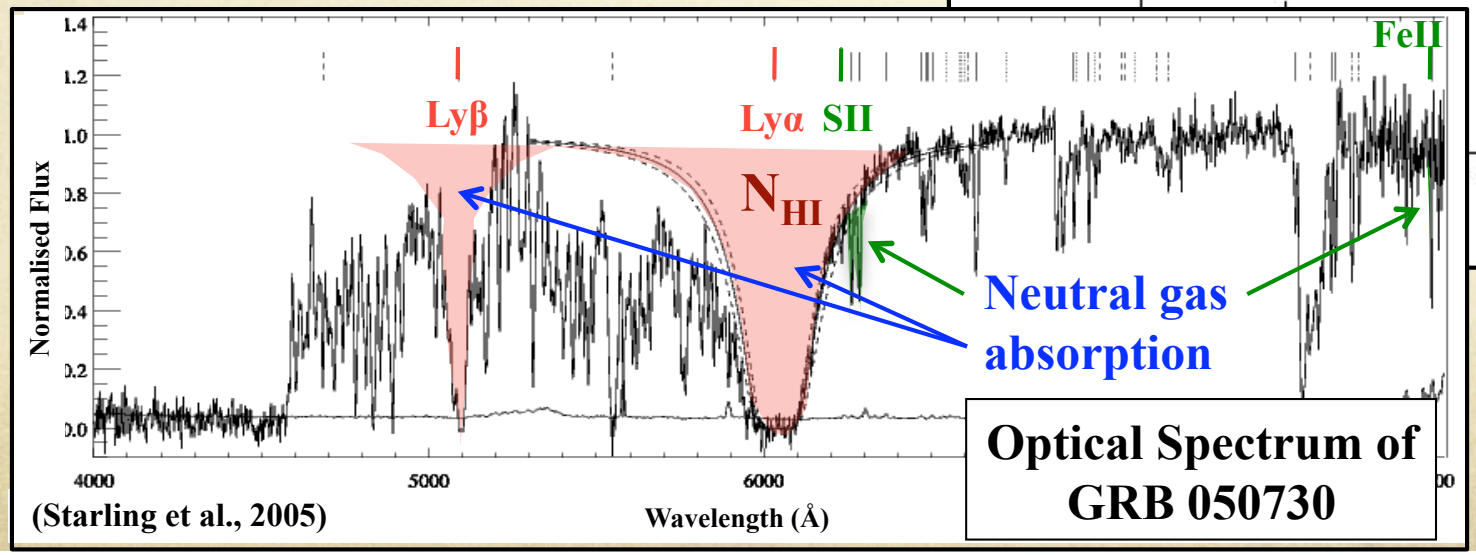
Optical spectra: probes neutral gas

- **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:**

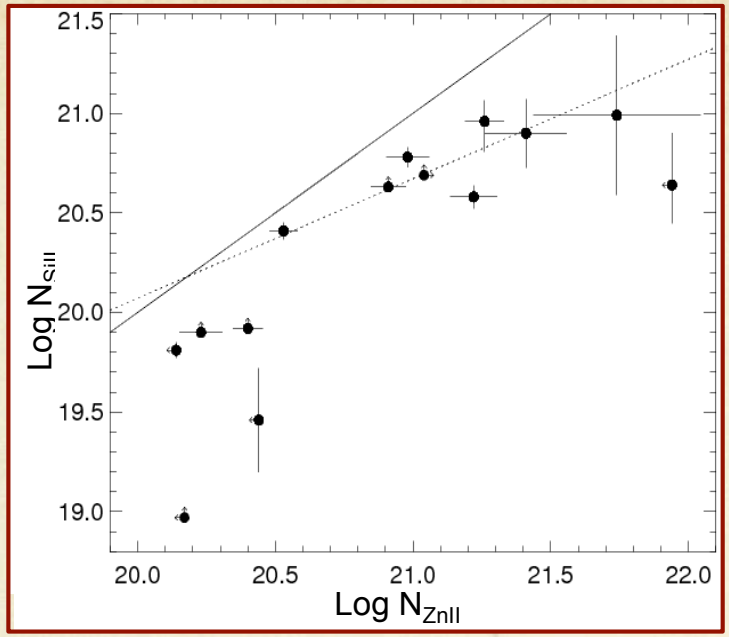
  X-ray absorption measurements trace primarily oxygen

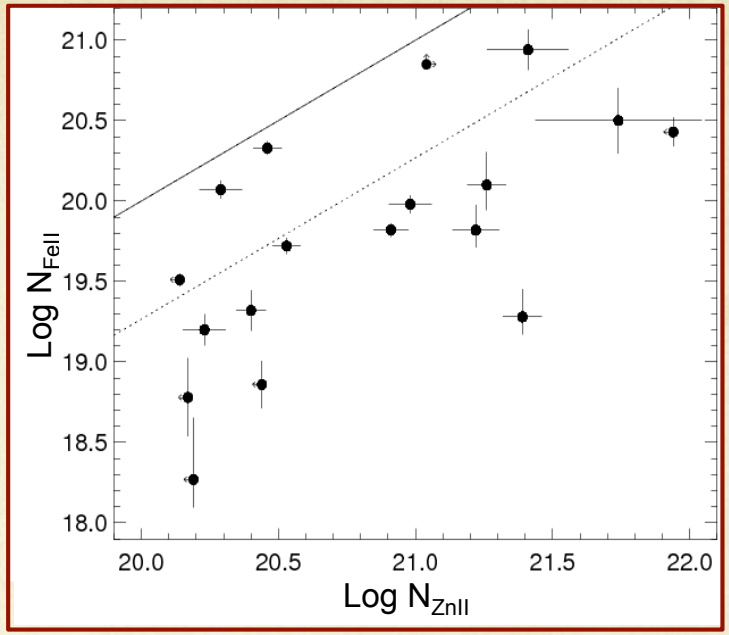
- **Neutral Gas:**

  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**

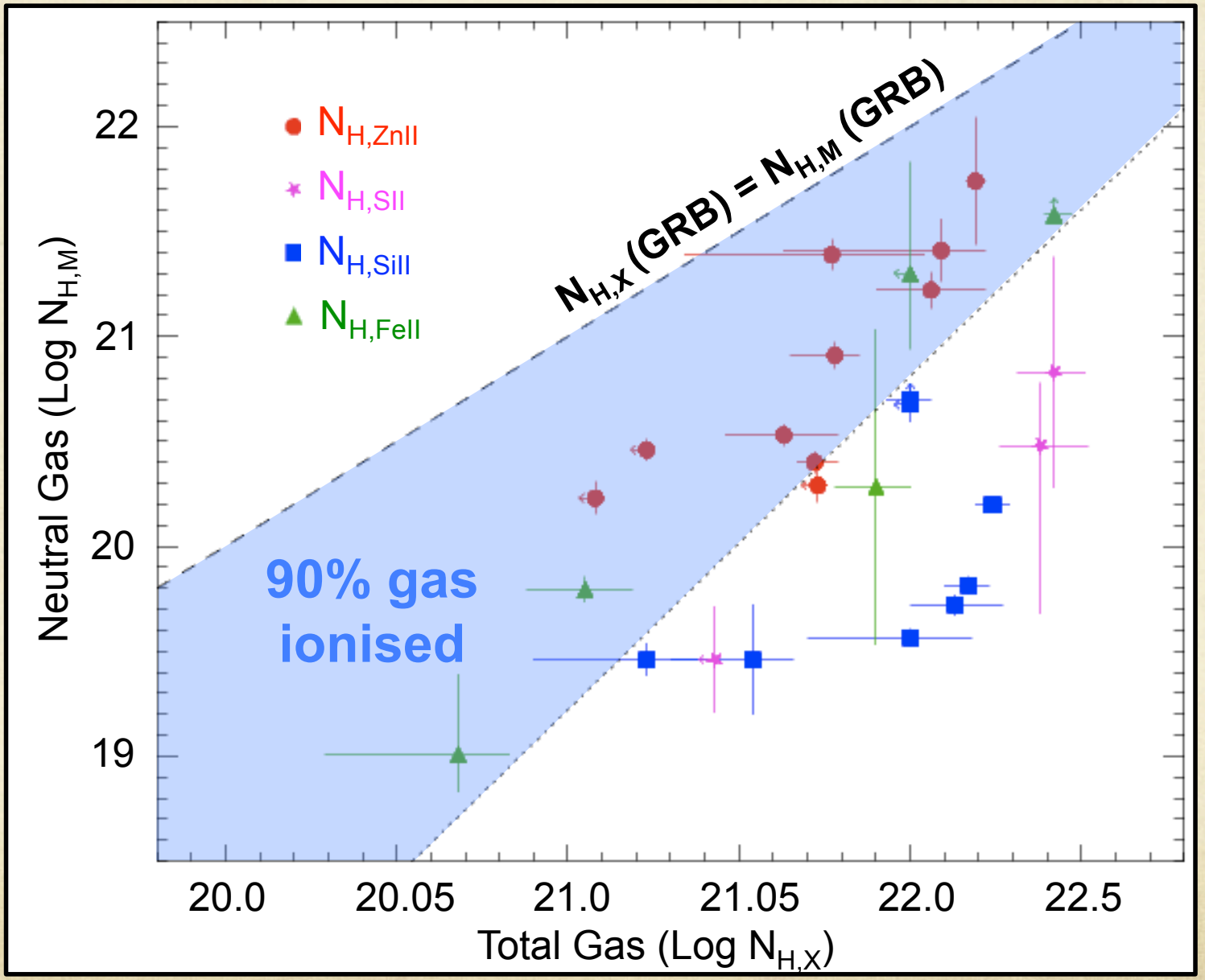
For each GRB in sample have

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

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

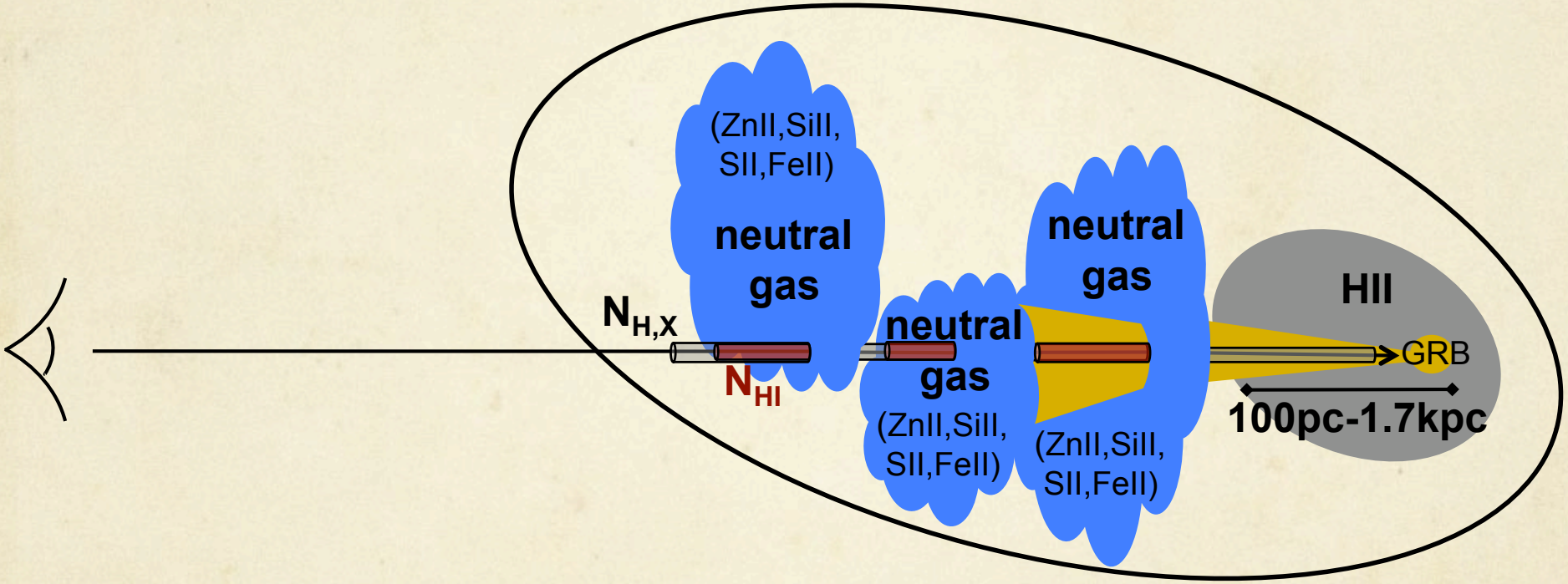
➢ N_{MII} **normalised to** $N_{H,MII}$**:** traces neutral metals column density

Neutral vs. Ionised Gas



Neutral vs. Ionised Gas

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



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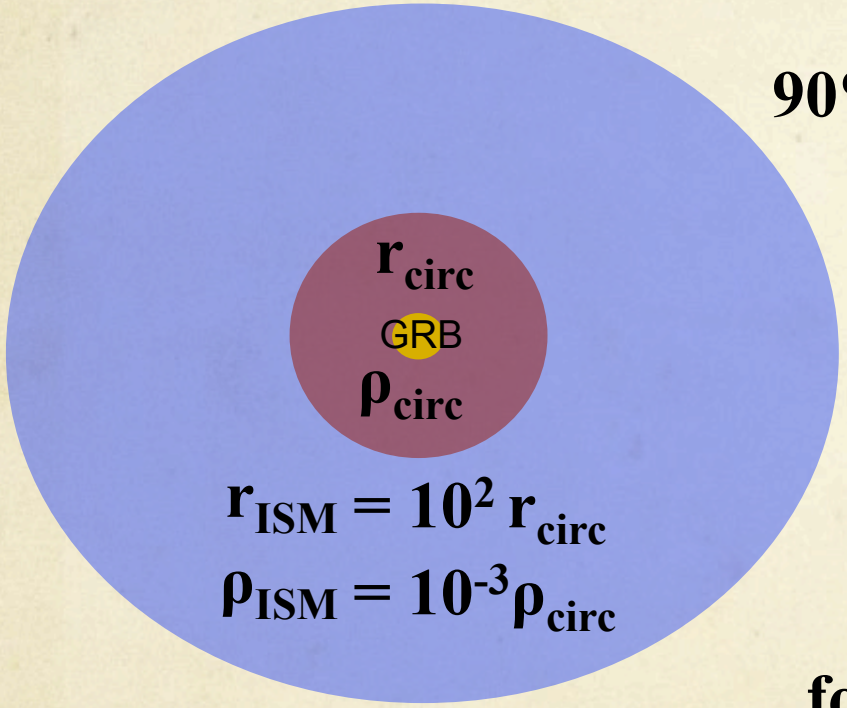
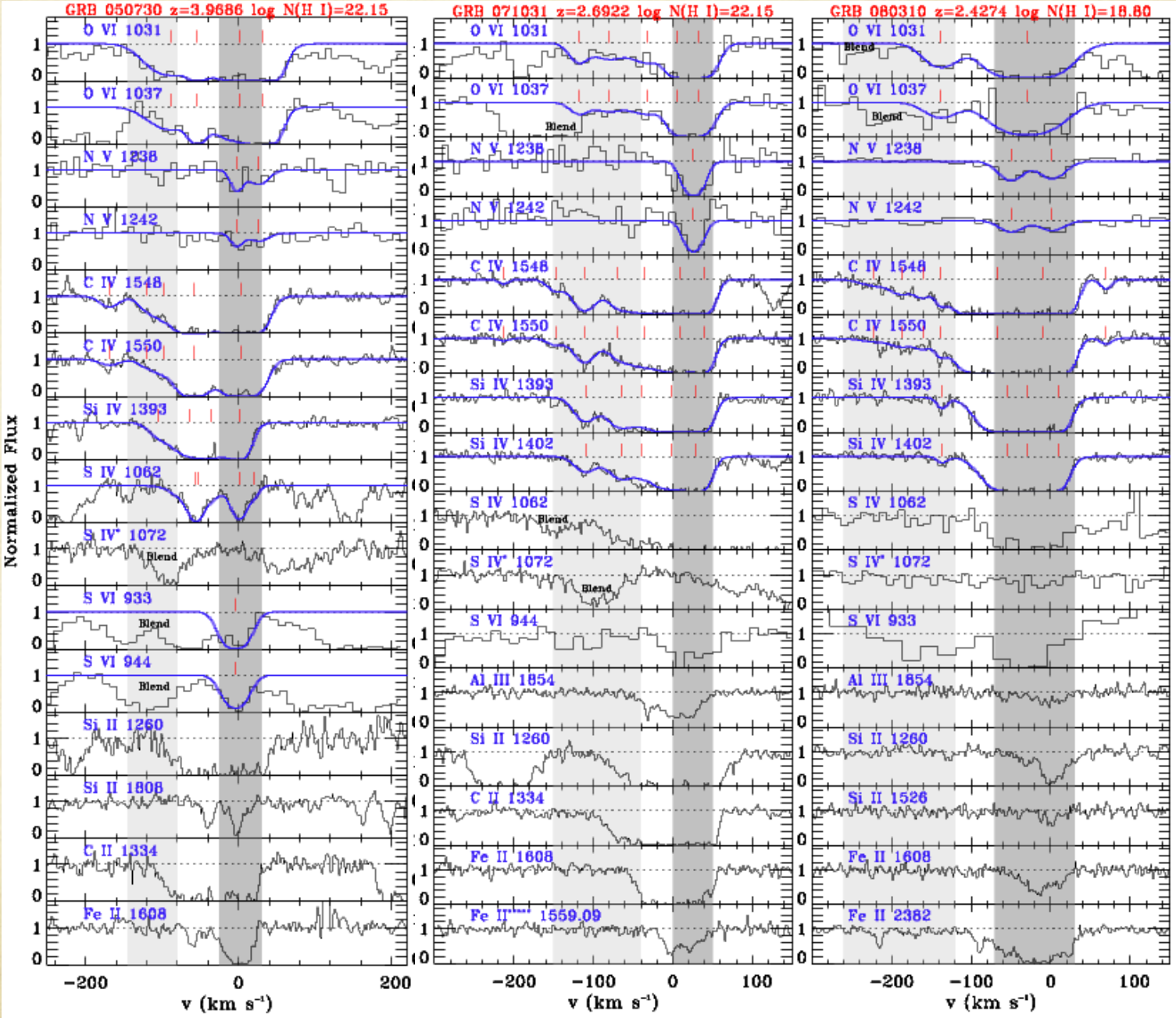


90% ionisation along line-of-sight implies:

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

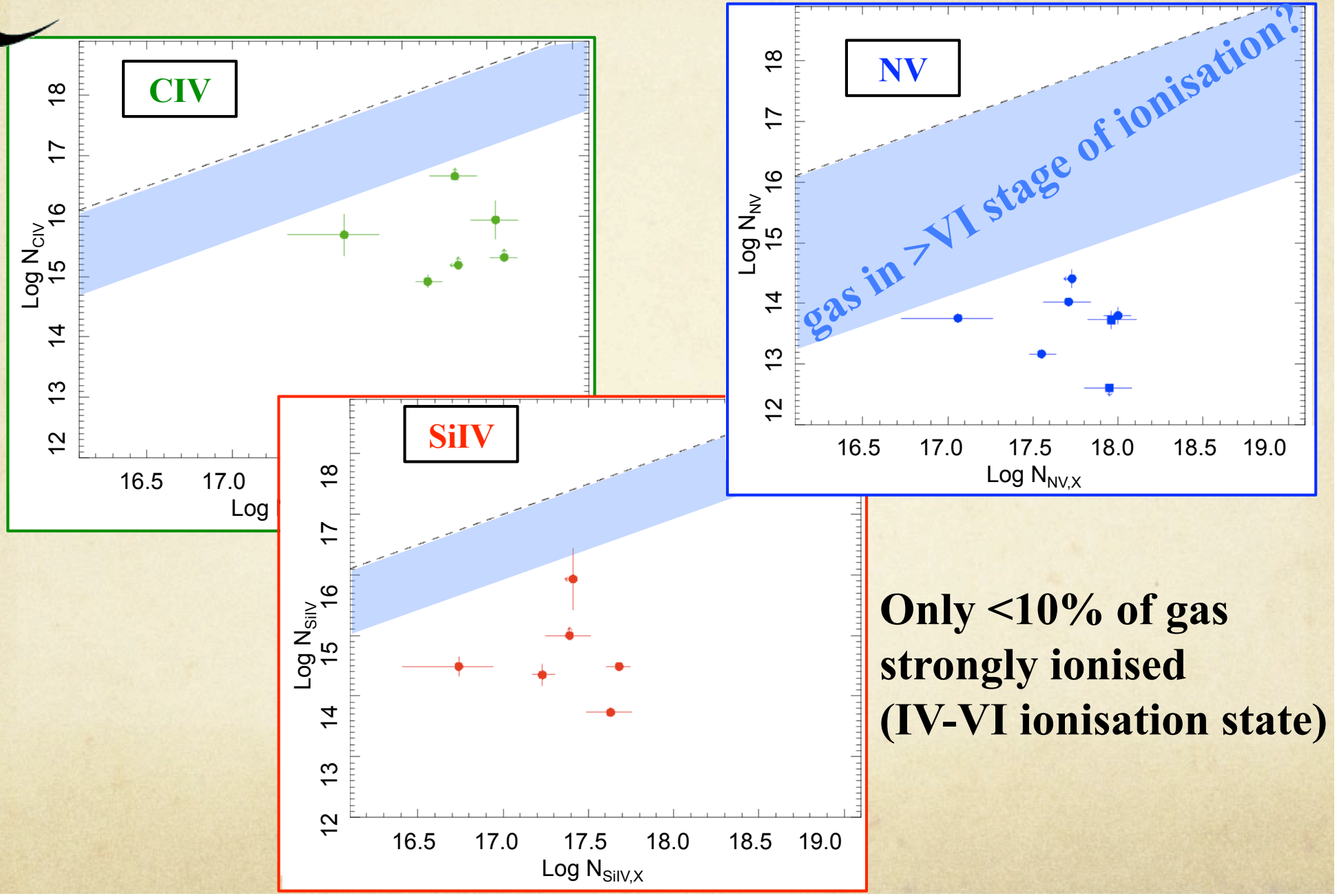
for $\dfrac{r_{ISM}}{r_{circ}} \approx 10^2$ $\dfrac{\rho_{circ}}{\rho_{ISM}} \approx 10^3$

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



(Fox et al. 2008)

Fraction of Strongly Ionised Gas



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

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 ?