Gamma-ray burst afterglows as probes of the ISM

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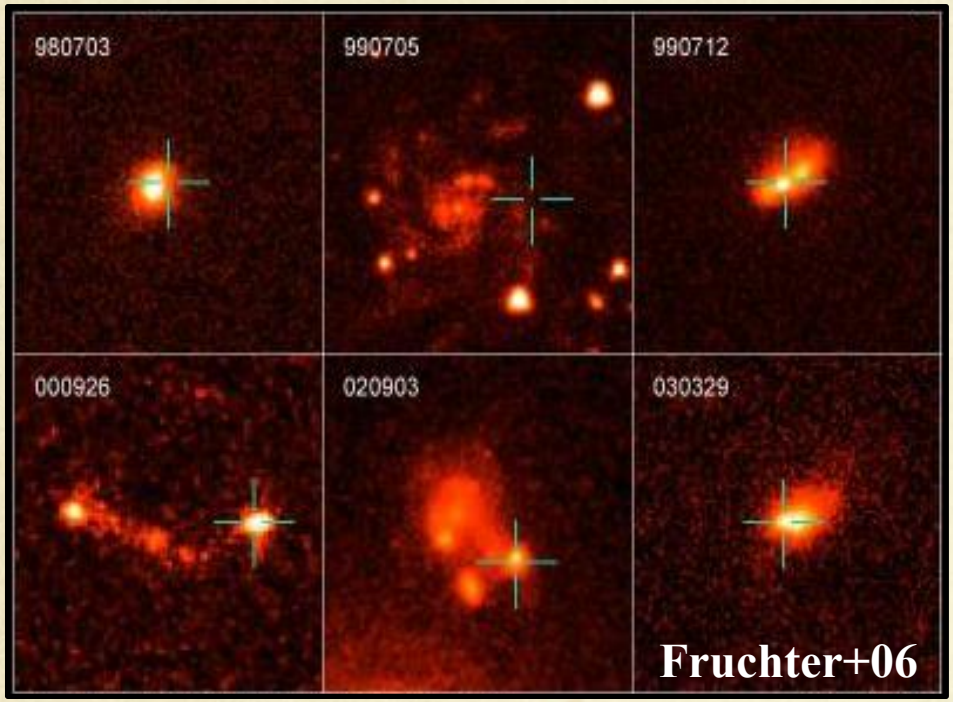
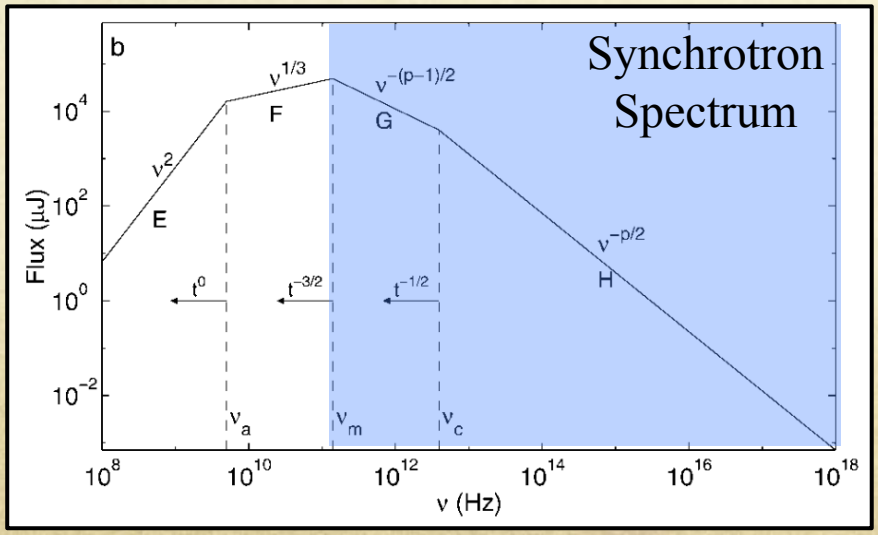
+ GROND and UVOT team

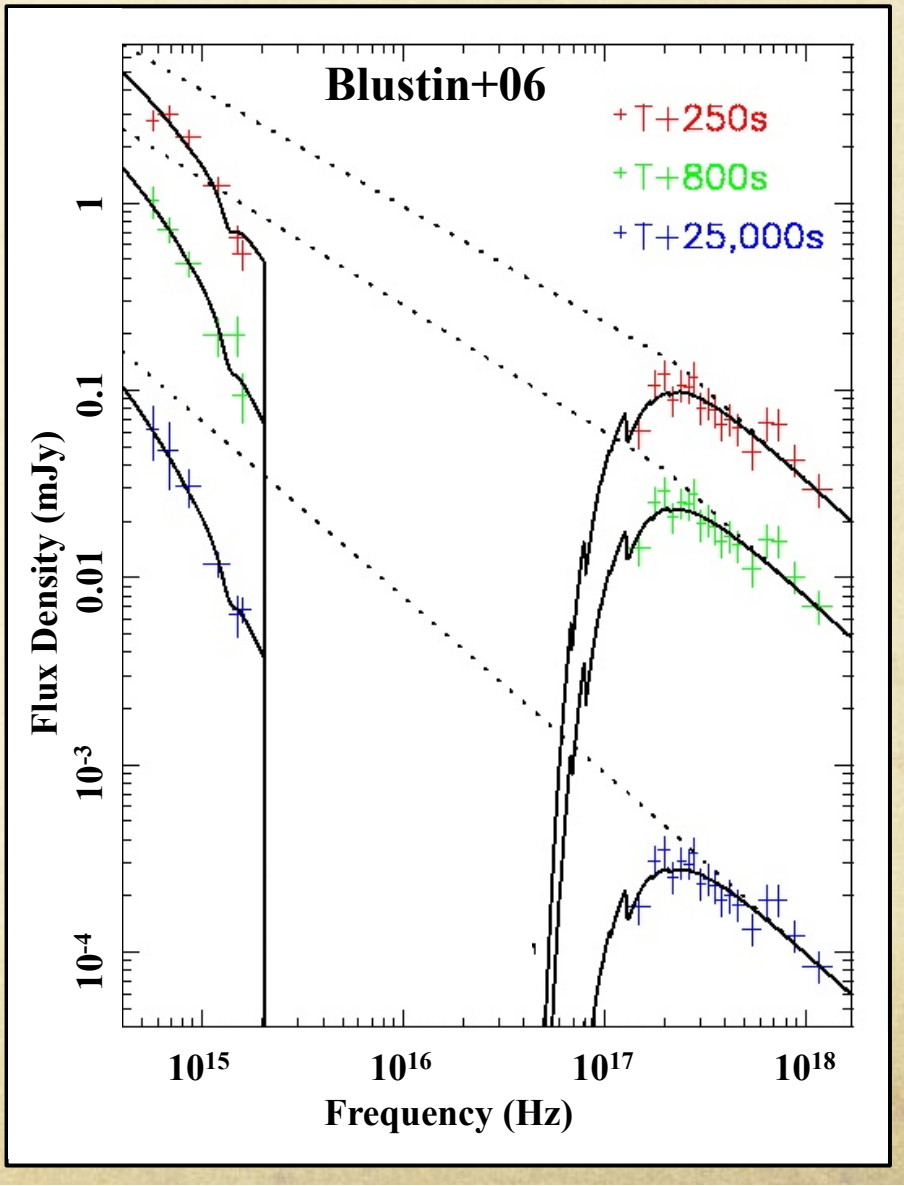
Probing the ISM of GRB Hosts

Probe young, star forming galaxies

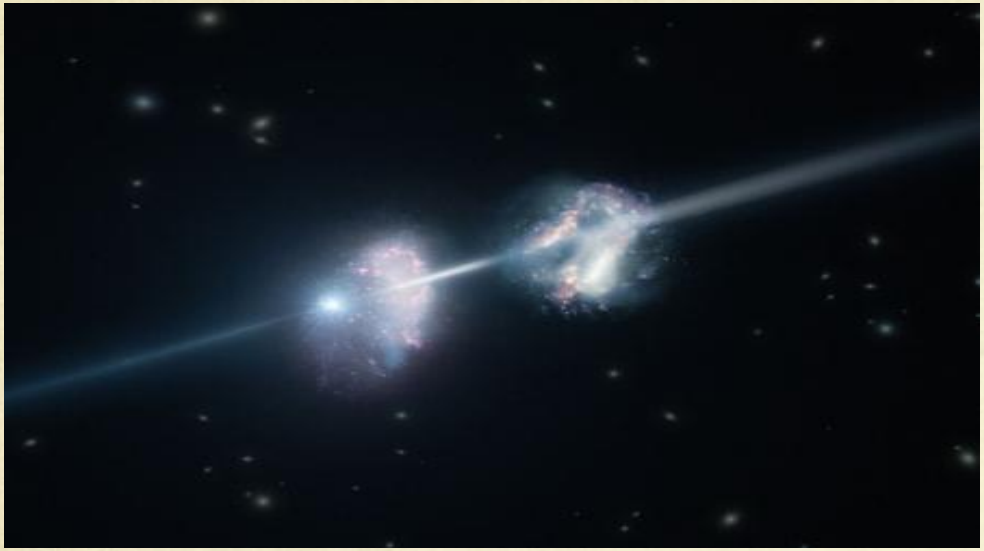


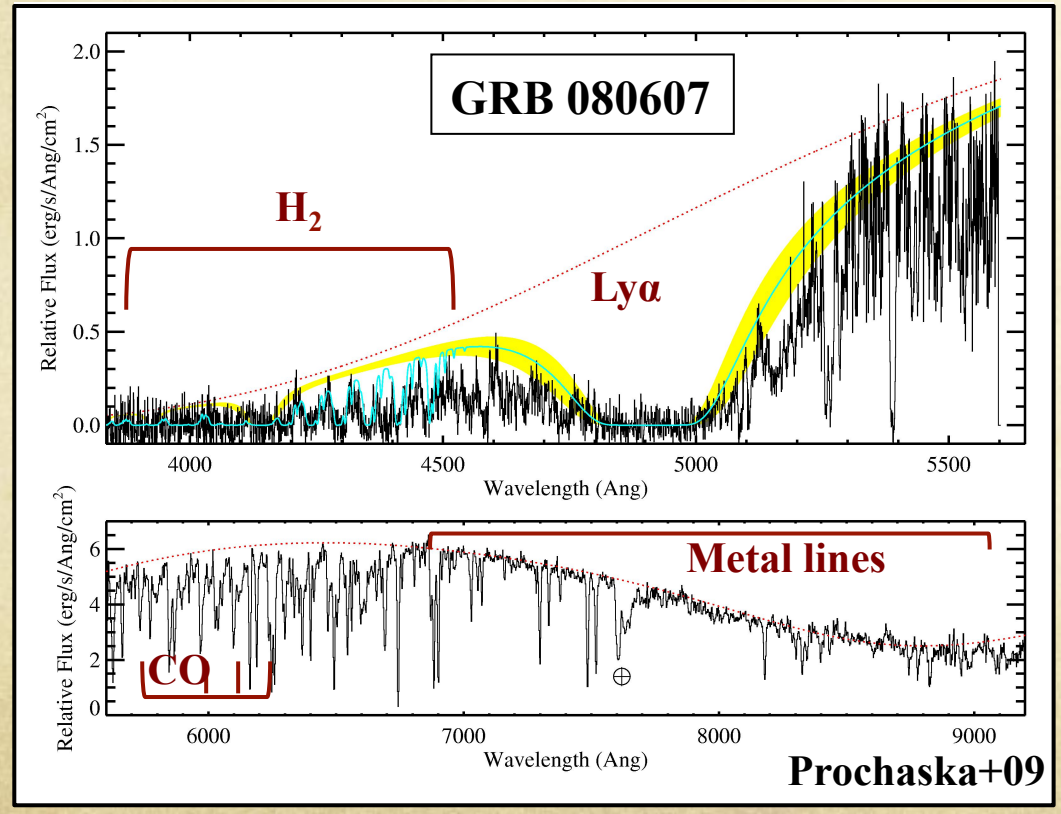


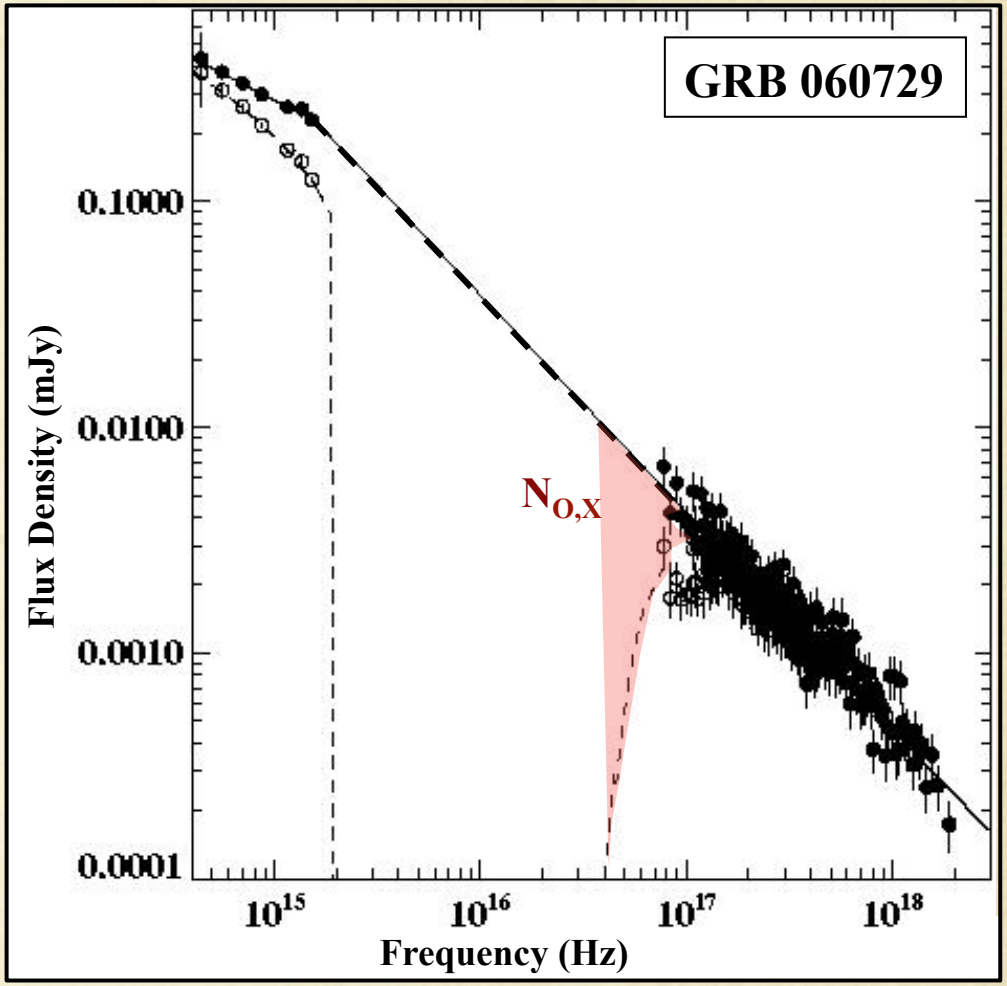
Highly luminous synchrotron featureless spectra



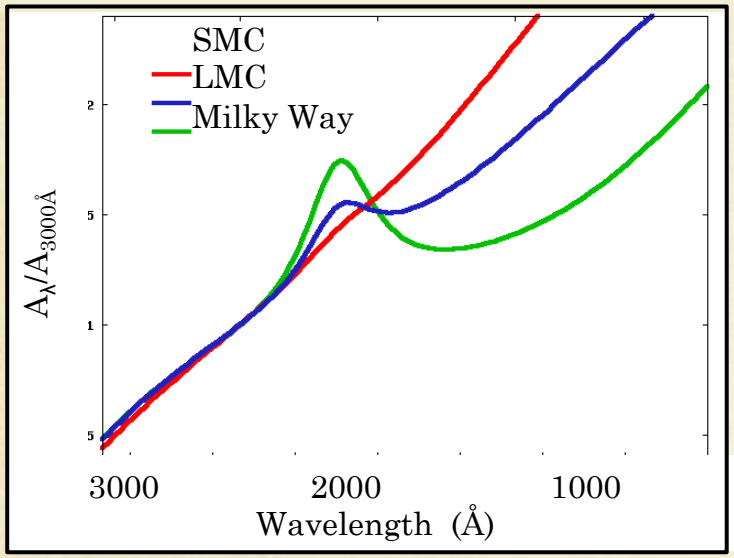
Gas Absorption

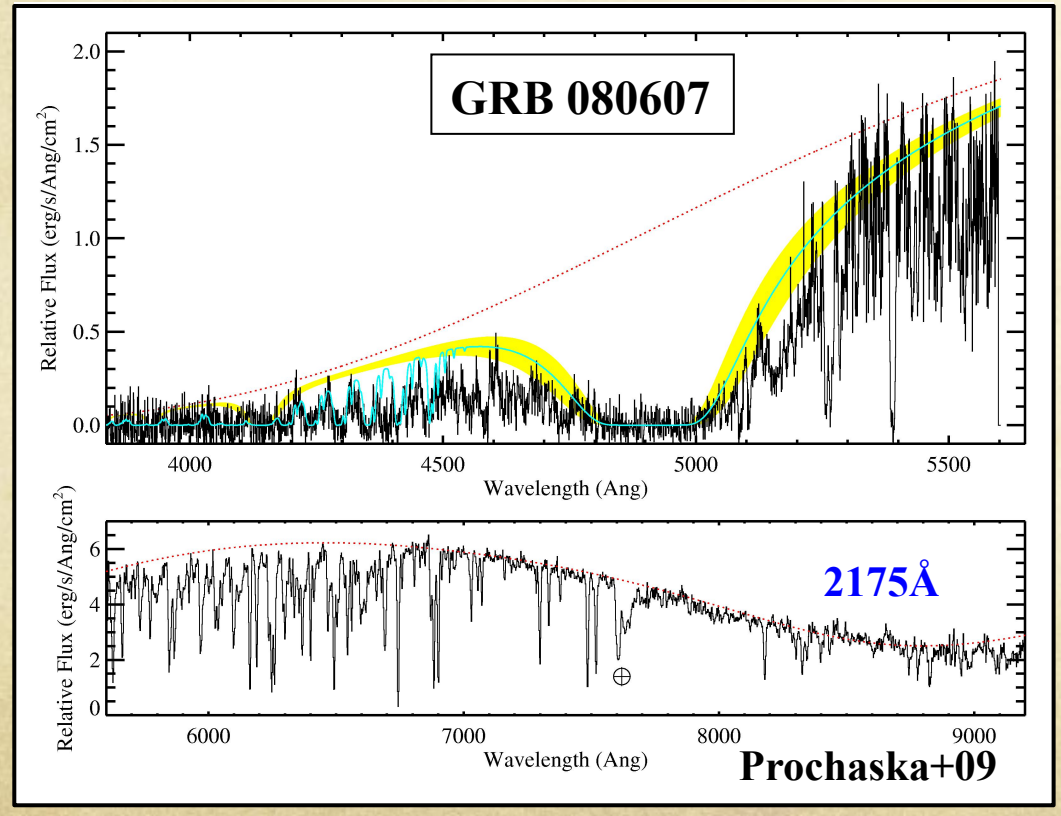


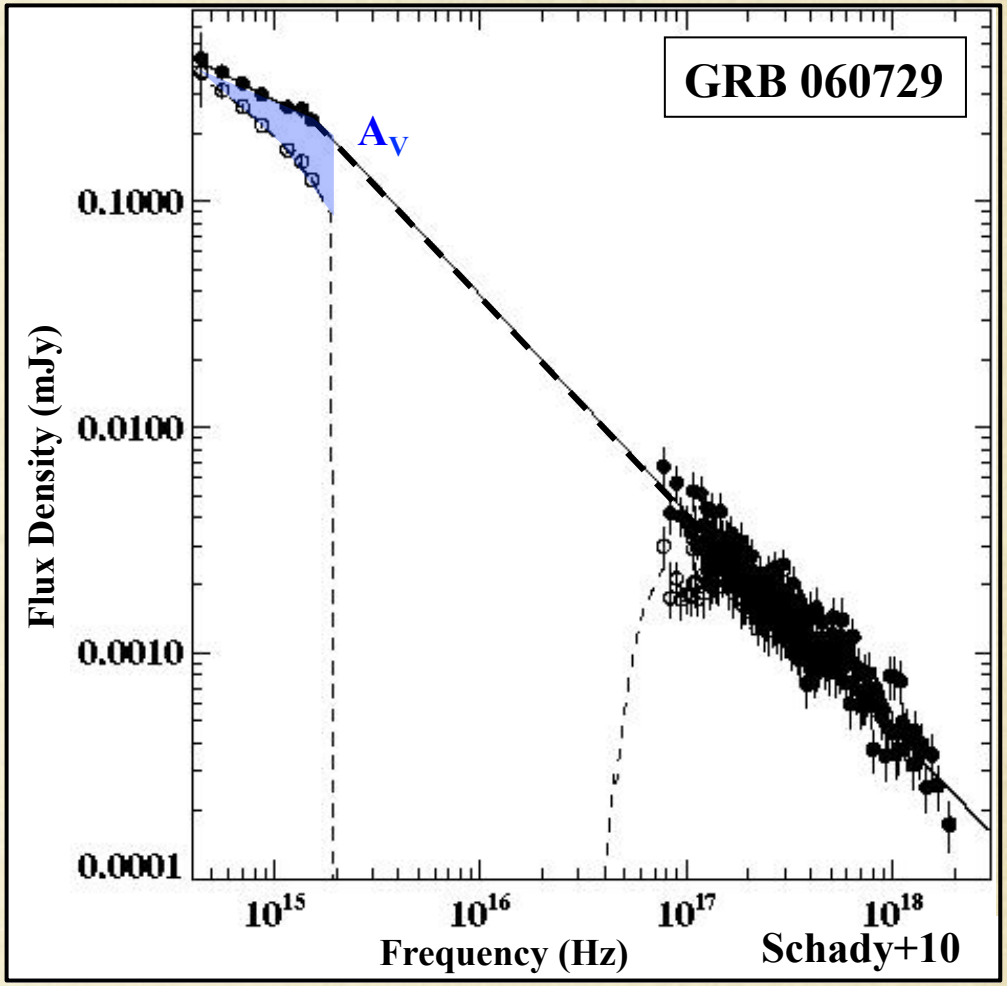




Dust Extinction

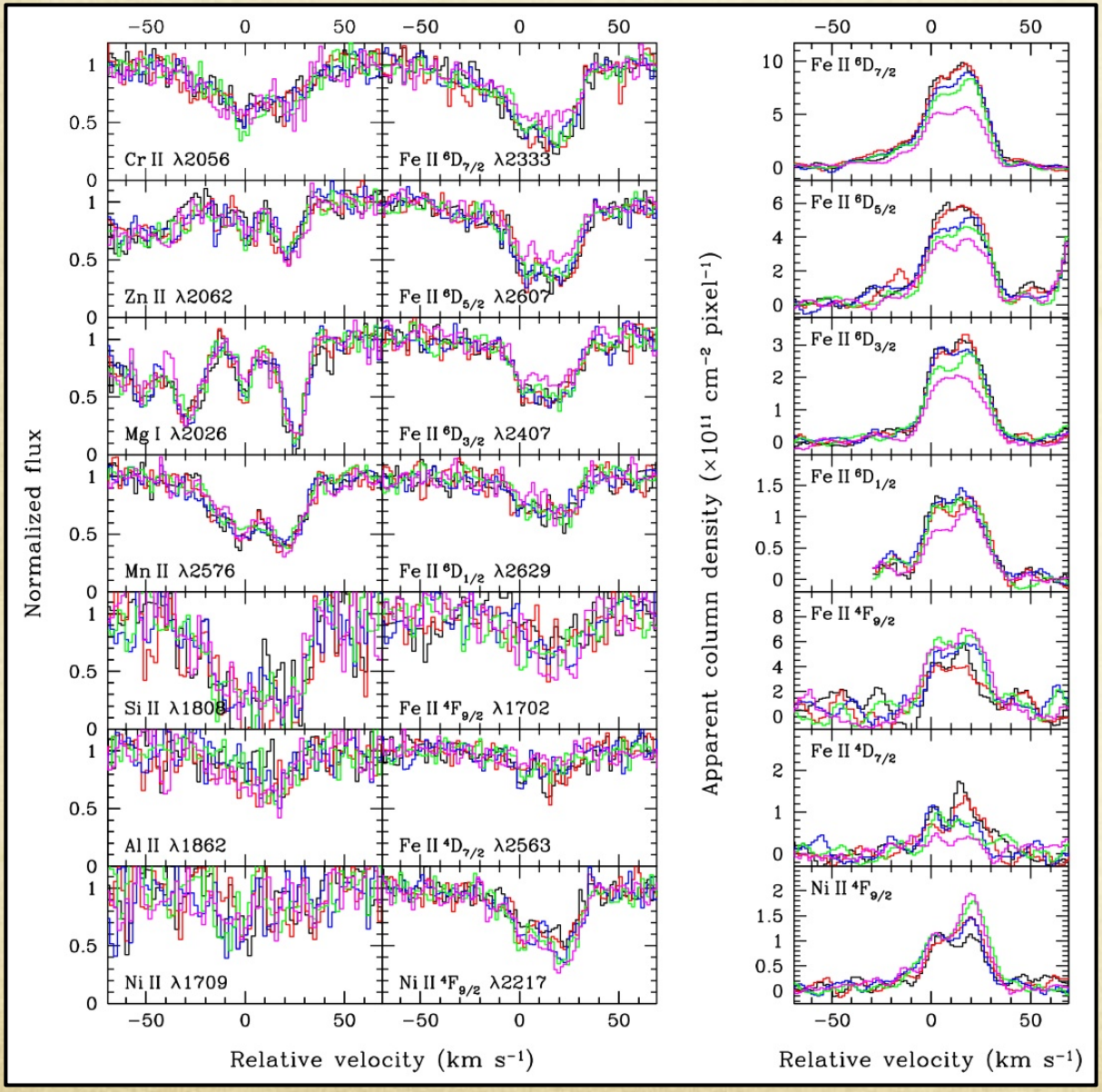


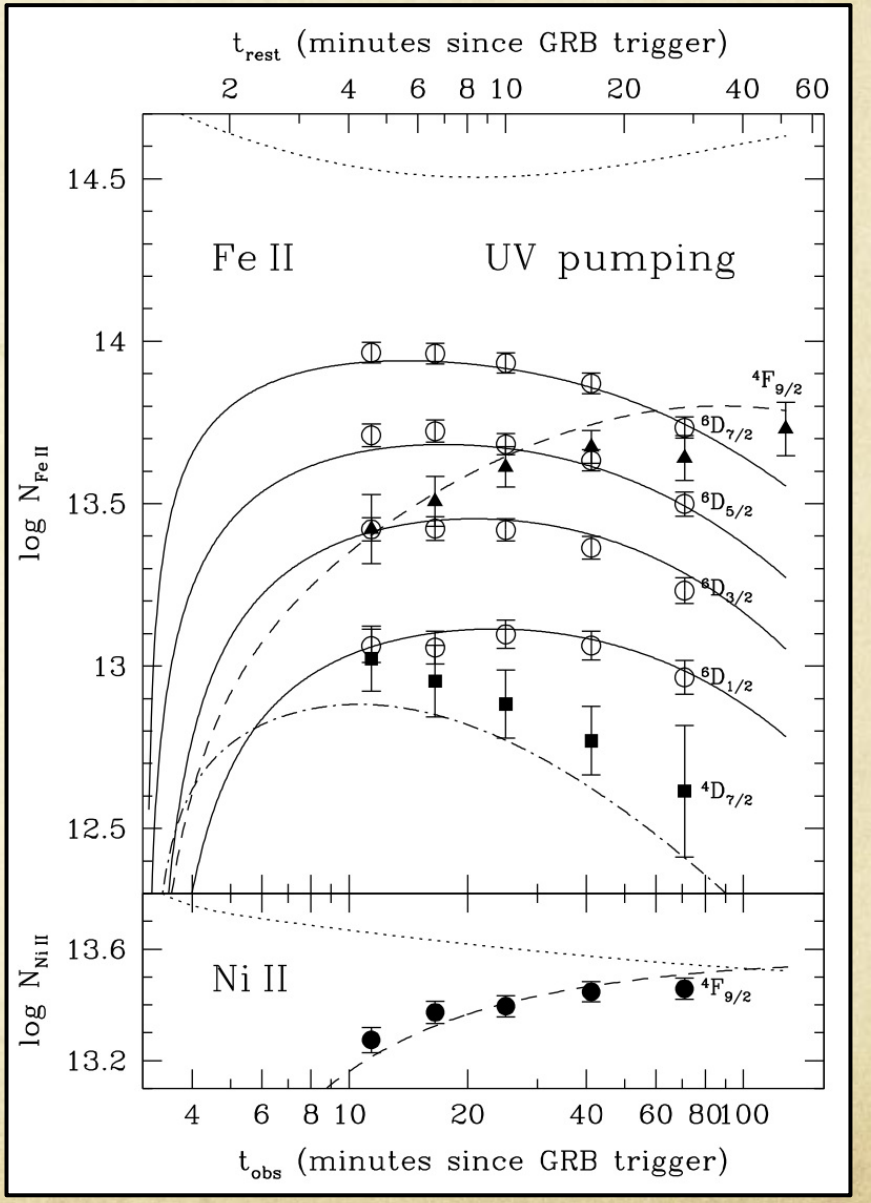




Location of Neutral Gas

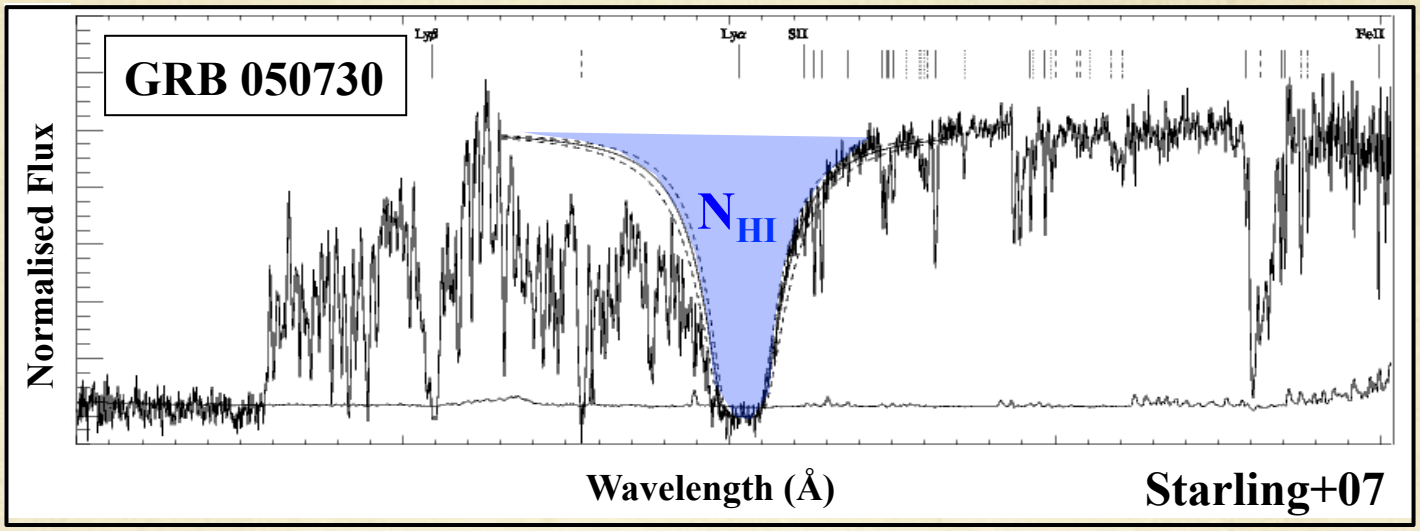
GRB 060418

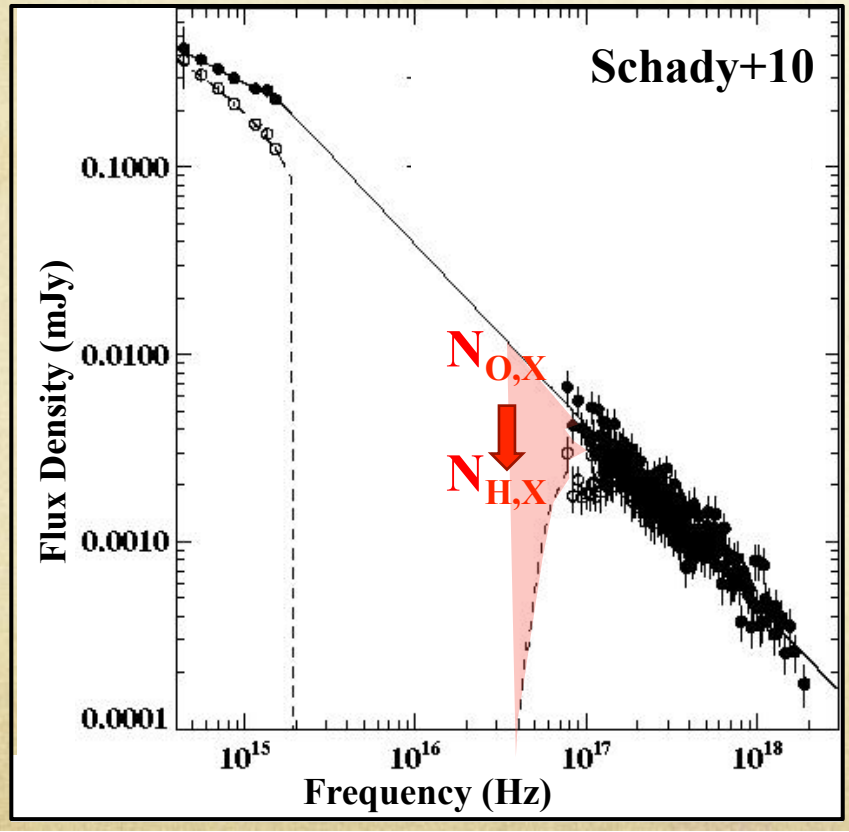




Vreeswijk+07

Optical vs. X-ray

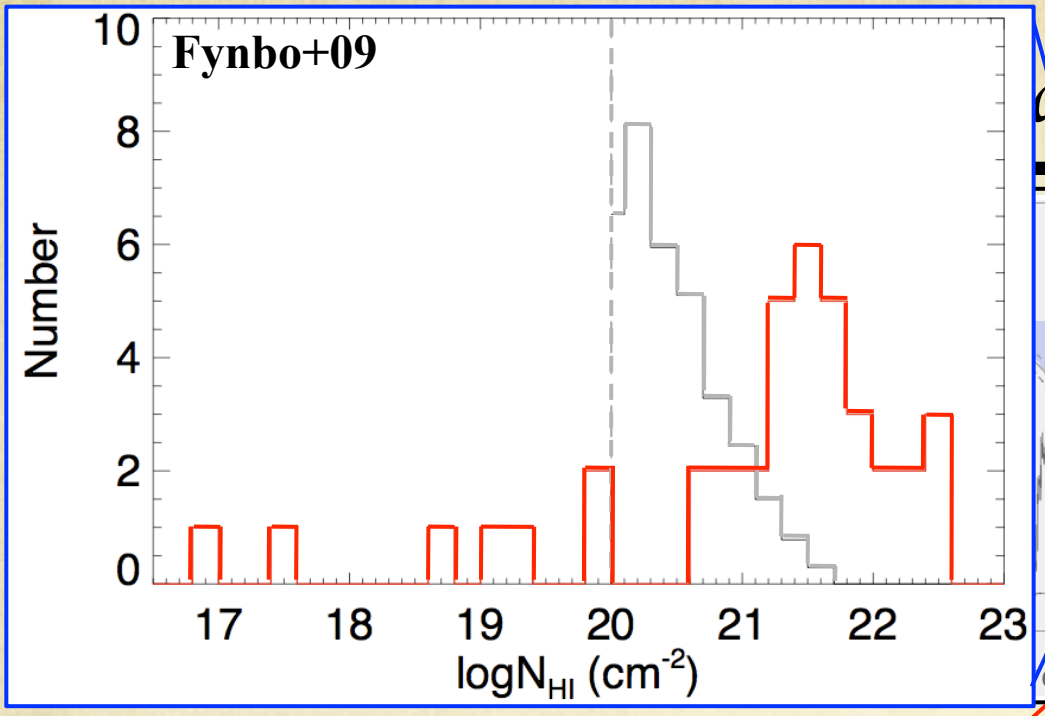


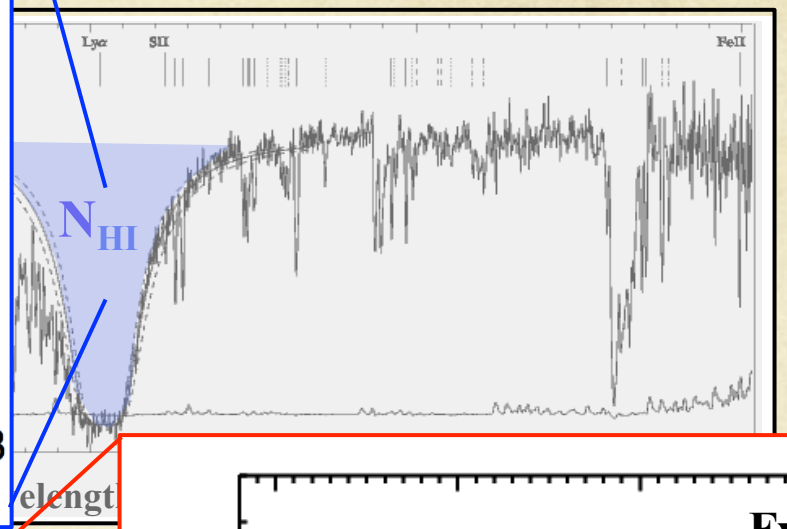


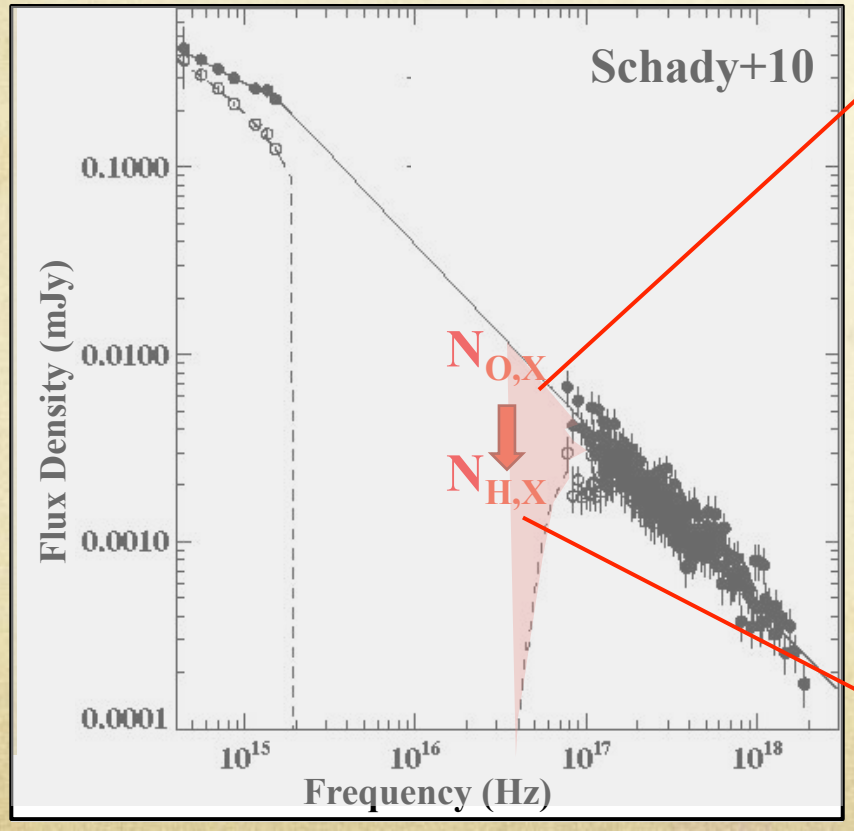
- ~30% of GRBs have spectroscopic redshift
- ~10% of GRBs at z>2, thus can detect Lyα absorption and meaure N_{HI}

- ~90% of GRBs detected in X-rays
- ~60% of X-ray afterglows have soft X-ray absorption in excess of Galactic

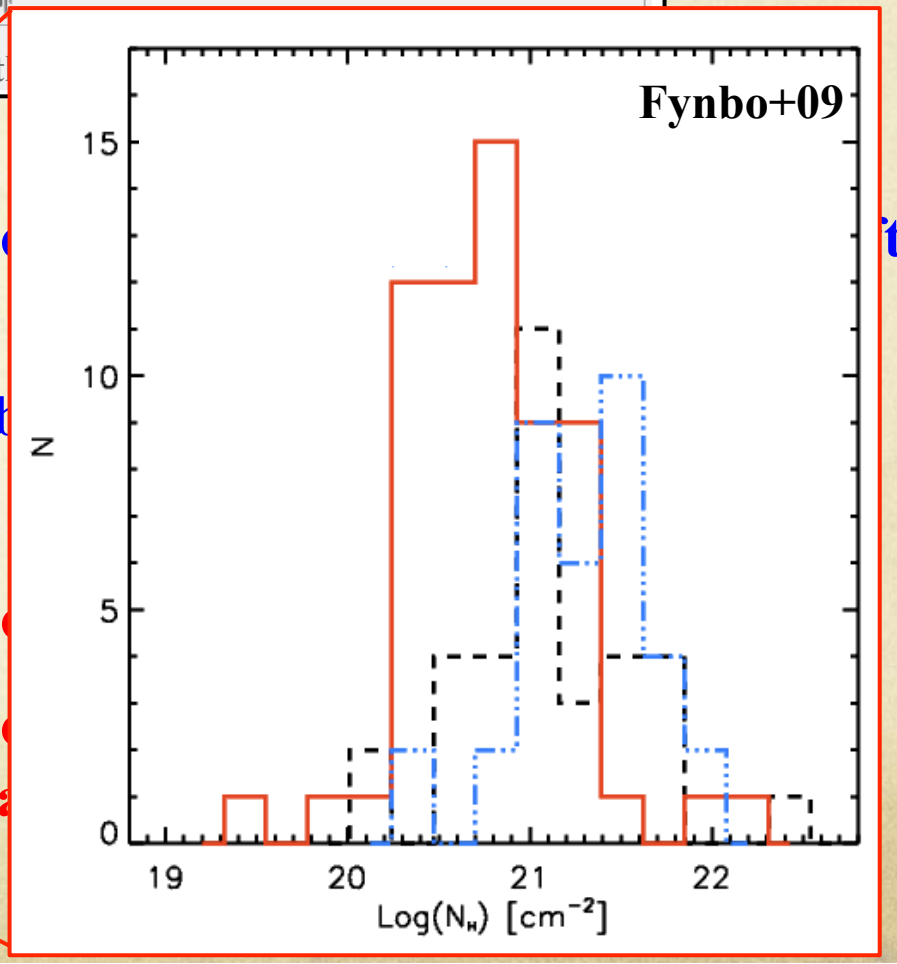
al vs. X-ray



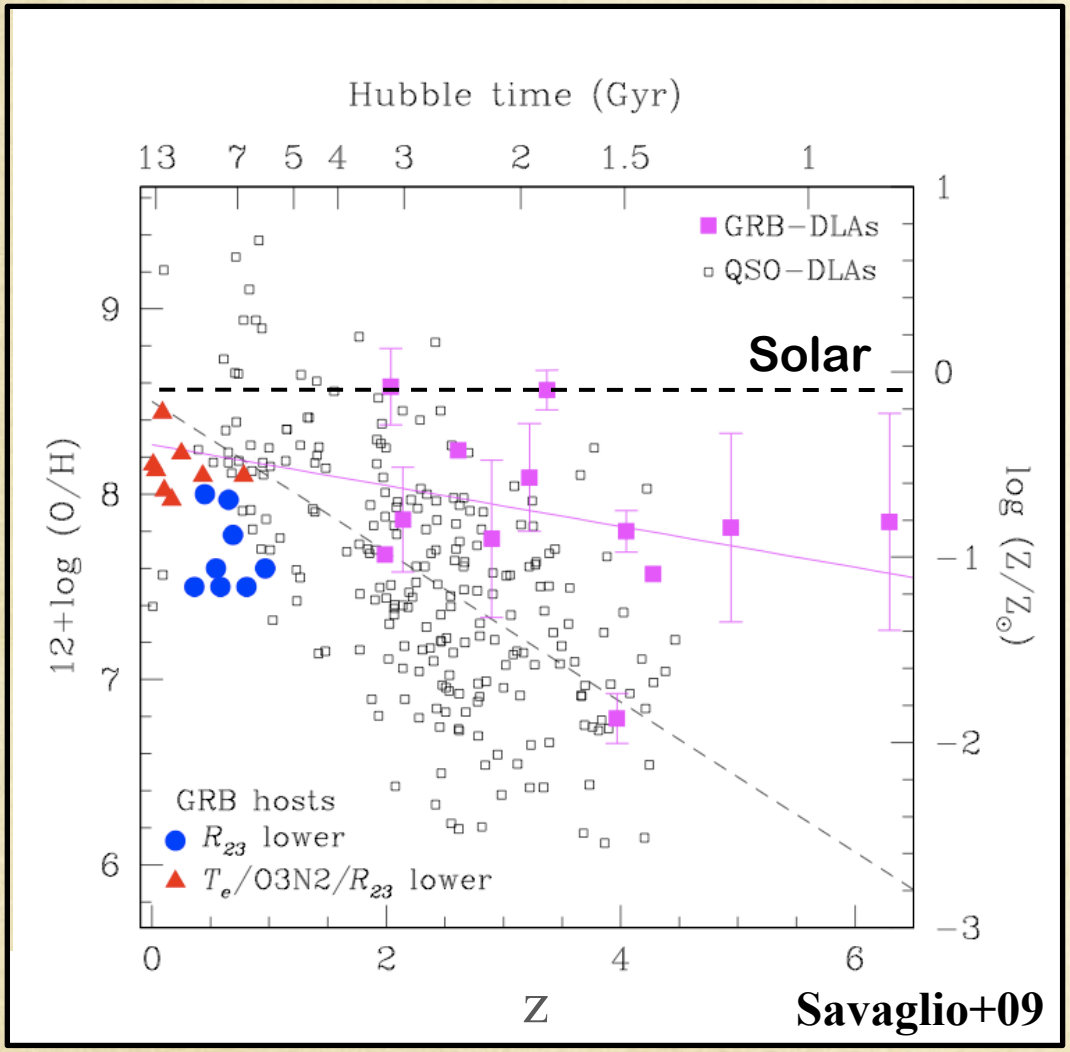


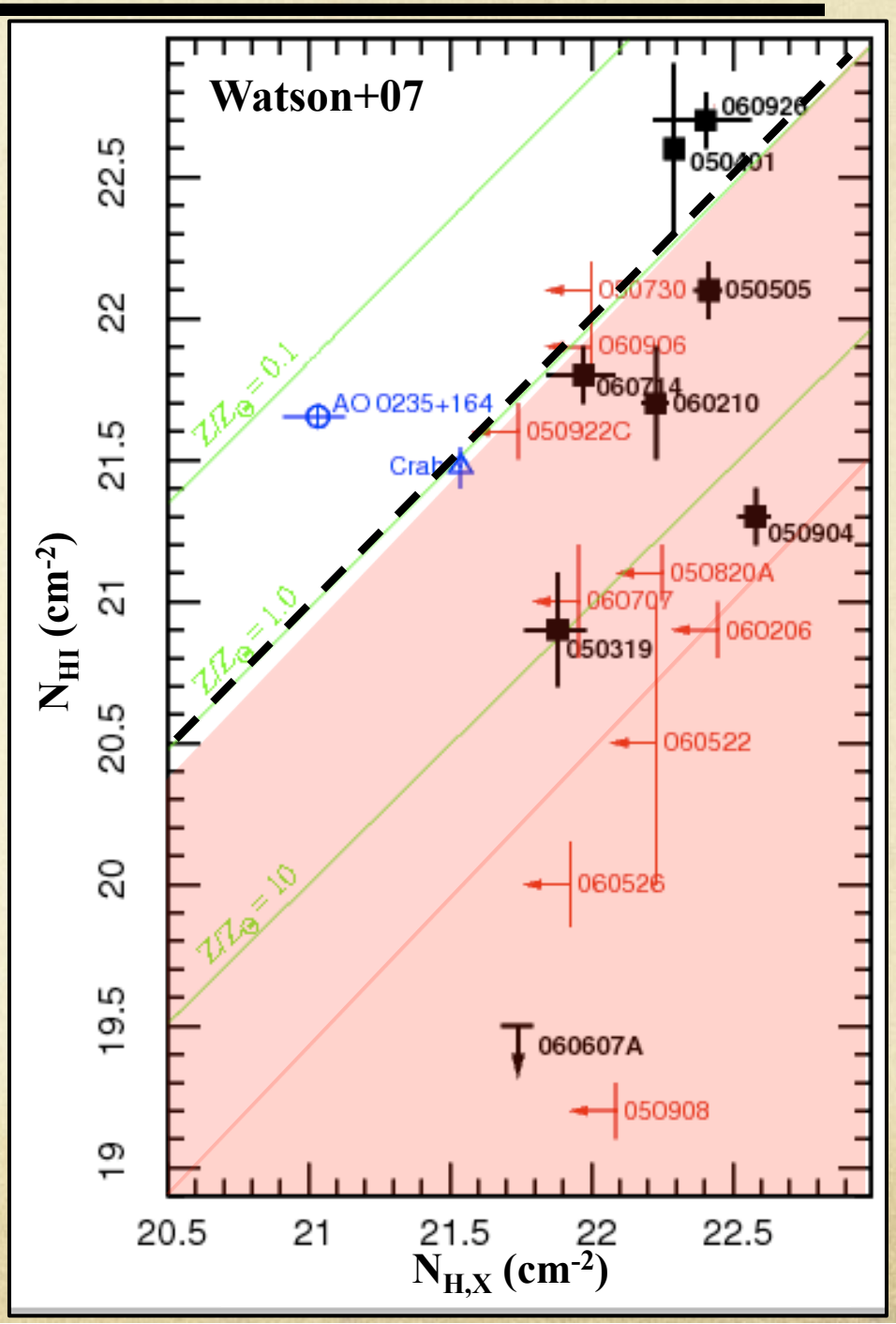


- ➢~30% (
- ➢ ~10%
  Lyα ab
- ➢~90% (
- ➢~60% (
  X-ray a



Optical vs. X-ray: Missing Gas Problem





Metals vs. Metals

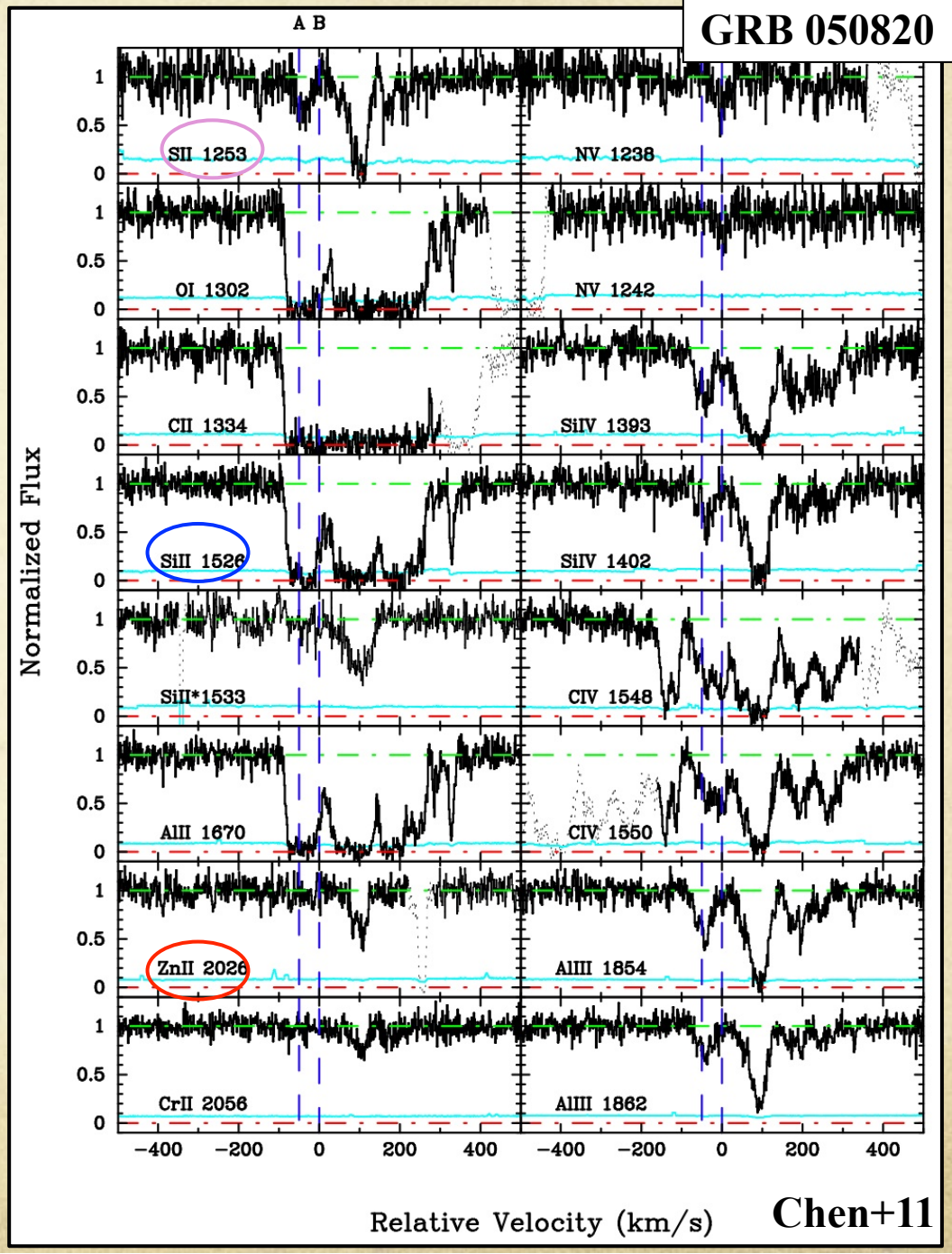
More natural to compare $N_{O,X}$ to metals

- Use weakly-ionised metal lines to trace neutral gas (**Zn II**, **S II**, **Si II** or **Fe II**)

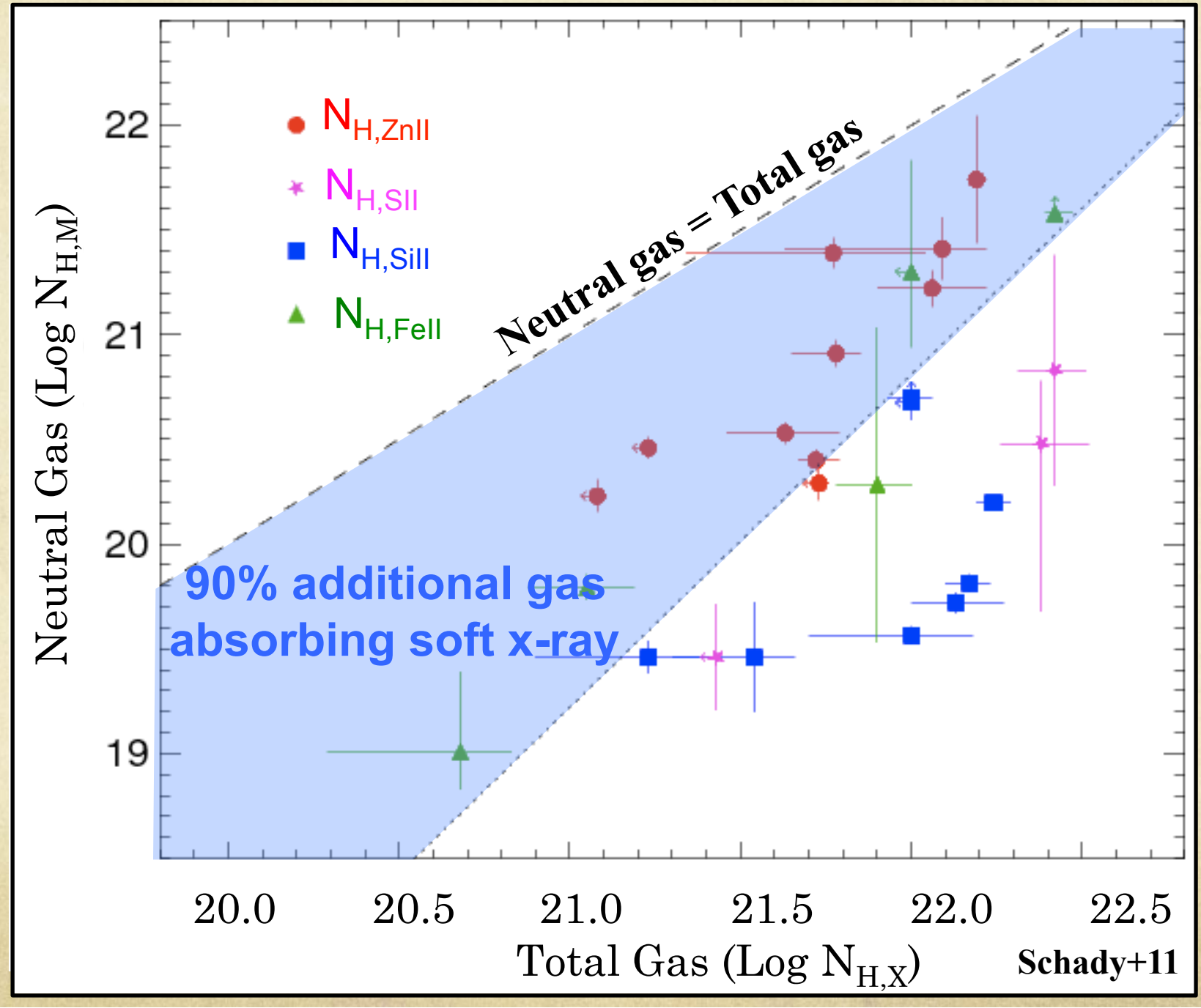
- Correct for dust-depletion

- Convert metal column densities to N_H (assuming solar abundances):

$N_{H,MII}$ versus $N_{H,X}$



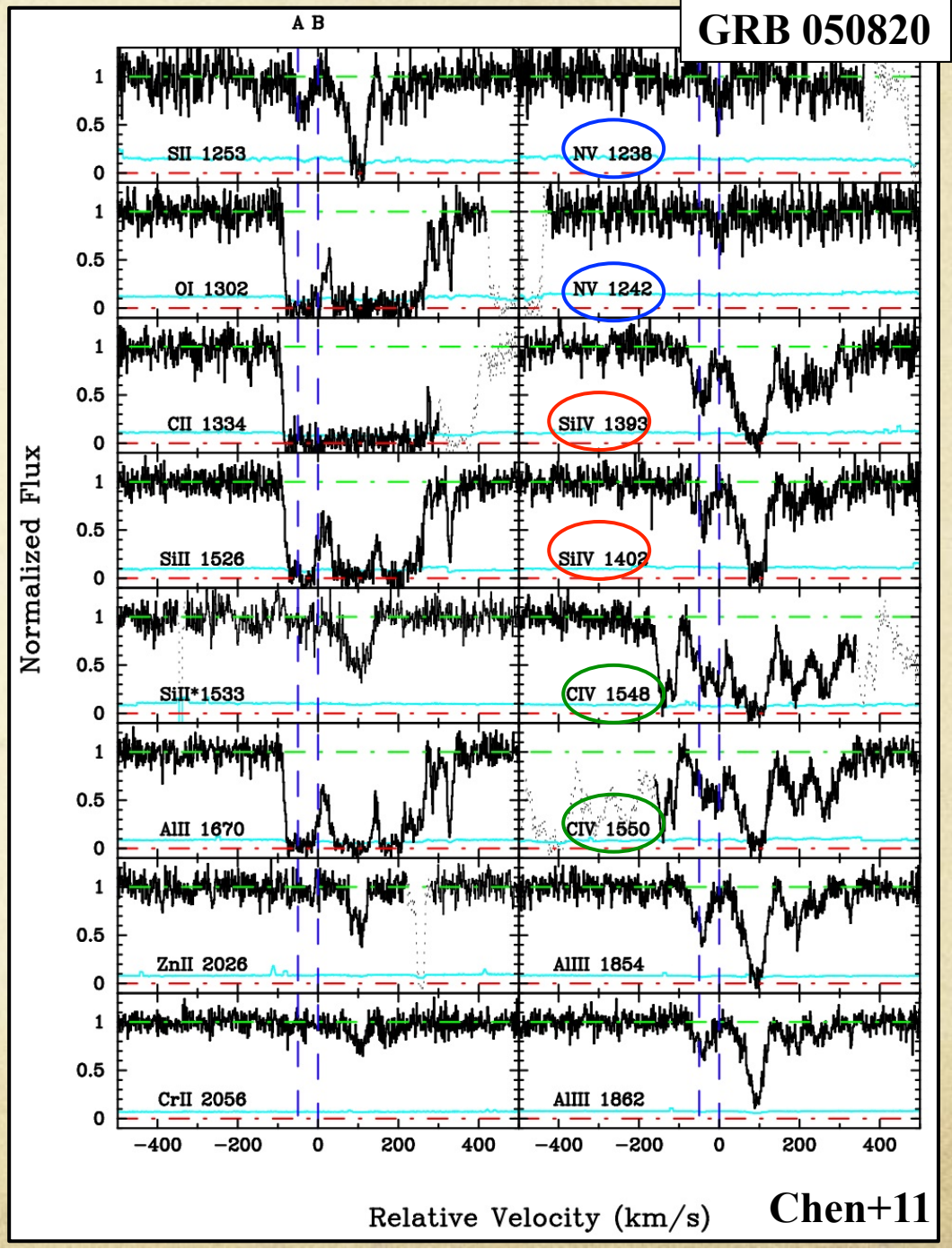
Neutral vs. Ionised Gas



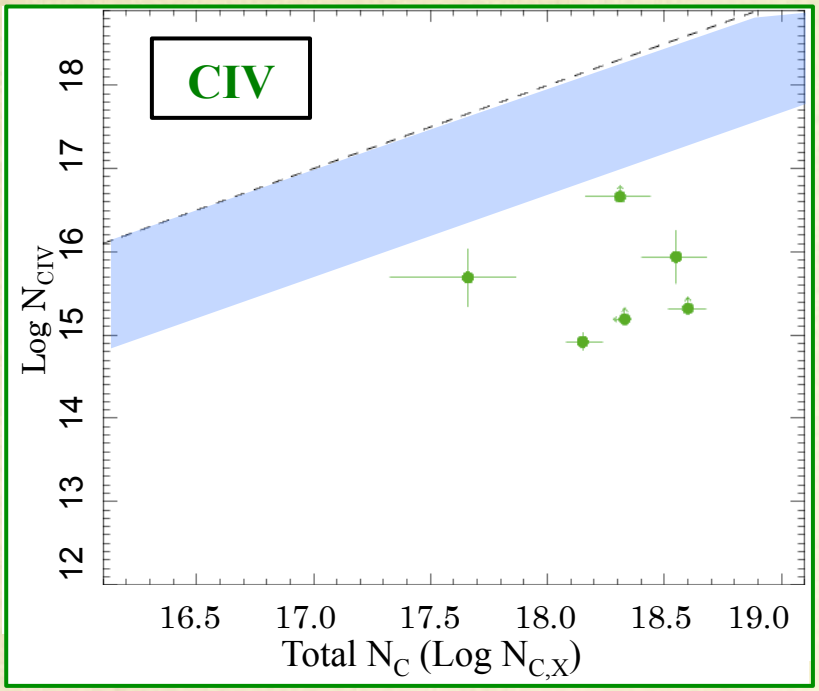
Contribution from Highly Ionised Gas

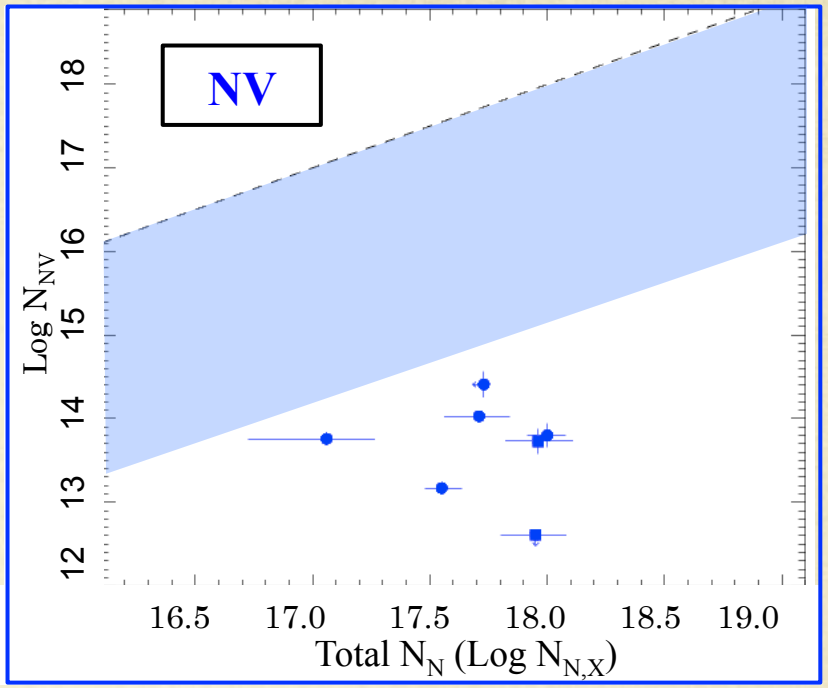
What is contribution to soft X-ray absorption from highly ionised gas?

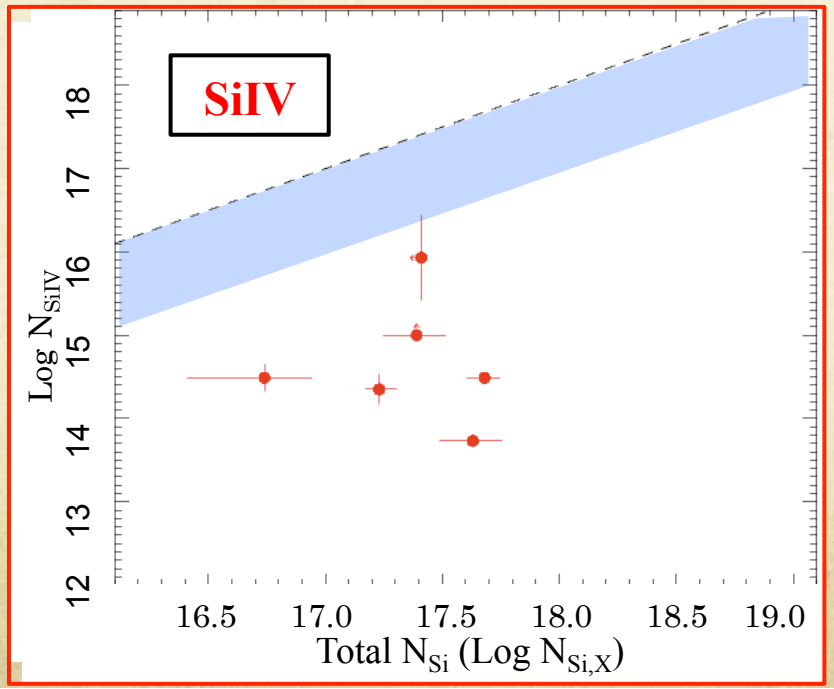
❖ CIV, SiIV, NV and OVI may trace gas closer GRB (Fox+08, Prochaska+08)



Contribution from Highly Ionised Gas







Only <10% of gas highly ionised (i.e. IP~140eV)

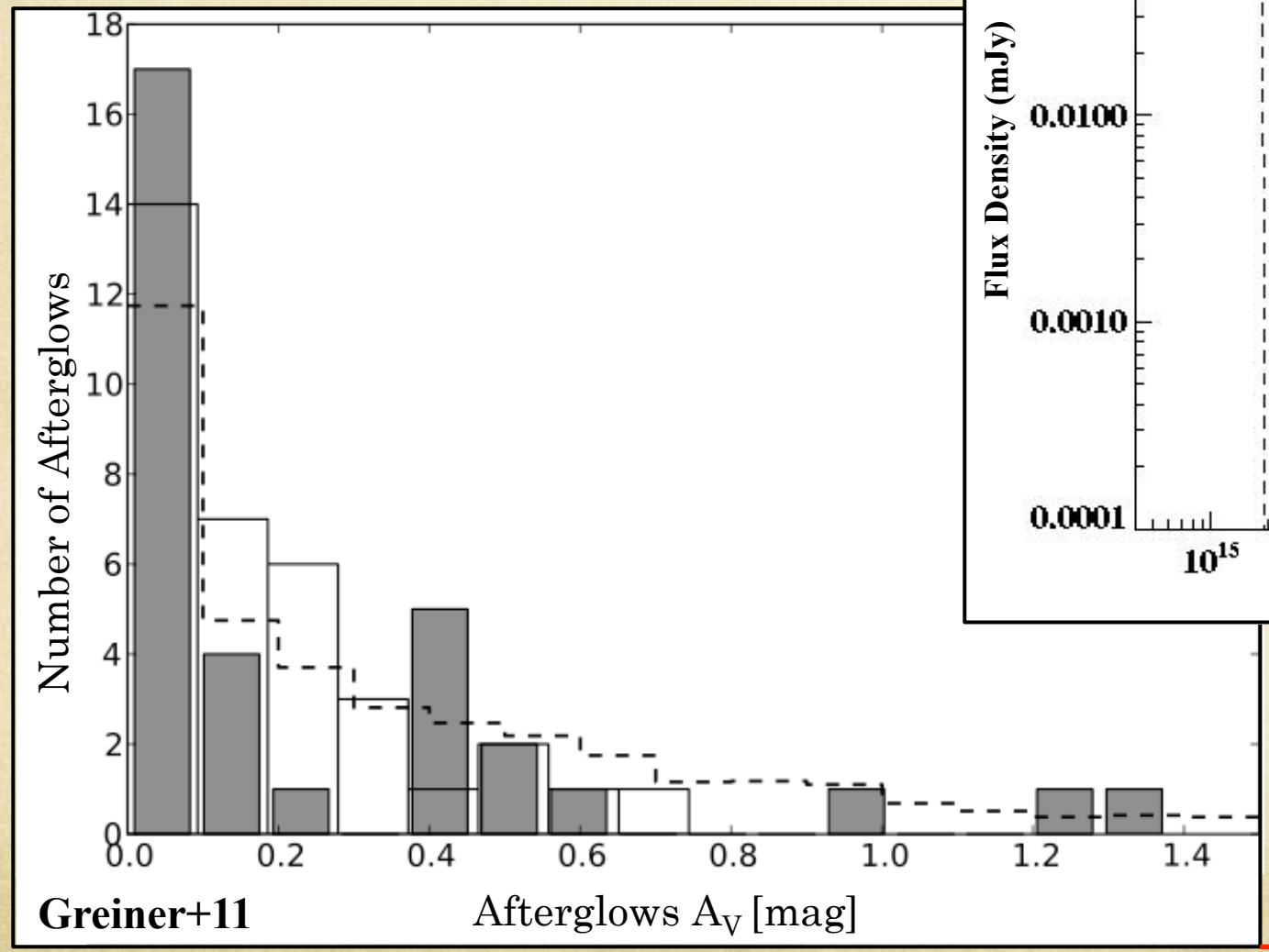
Schady+11

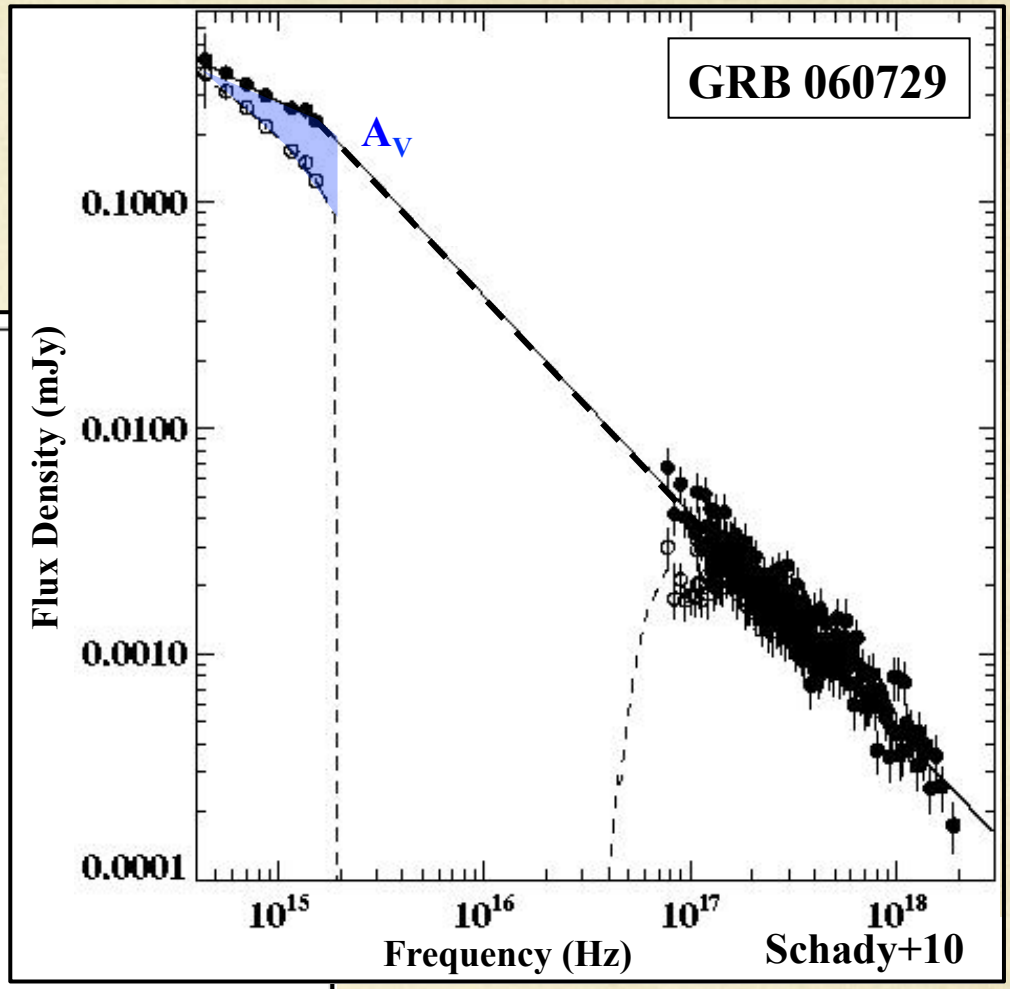
What is the Origin of the X-ray Excess?

- **Ionised gas is in highly ionised state i.e. not seen in optical**
  - Close to the GRB, within an ionised bubble
  - Within the halo of the host galaxy

- **X-ray absorbed by intervening gas external to host galaxy**
  - Intervening galaxies along line-of-sight (Campana+12)
  - A **W**arm **H**ot **I**ntergalactic **M**edium within local Universe (Bahar+11)
  - Milky Way soft X-ray absorption is underestimated

Location of Extinguished Dust





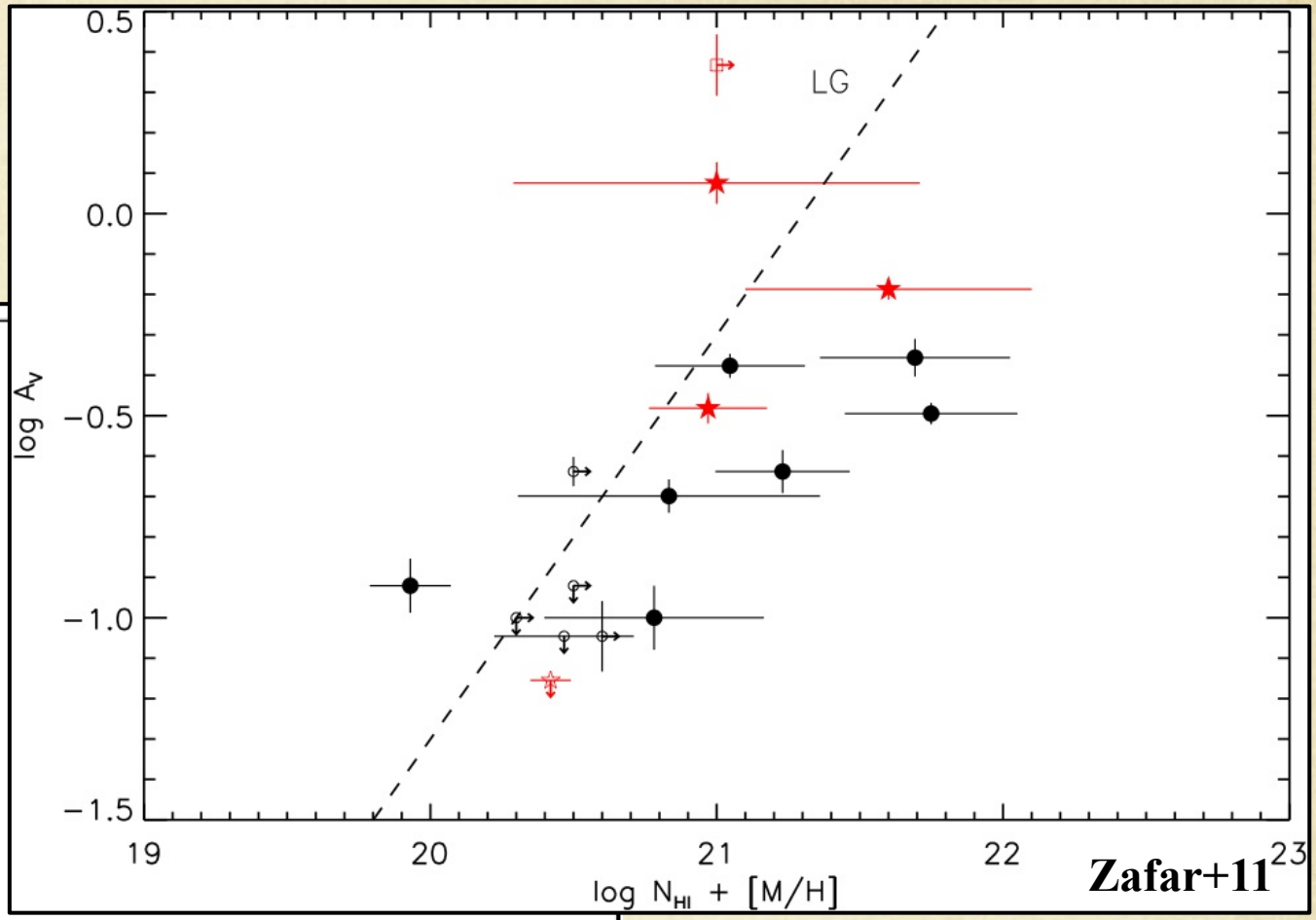
GRB080607
(Perley et al. 2009)

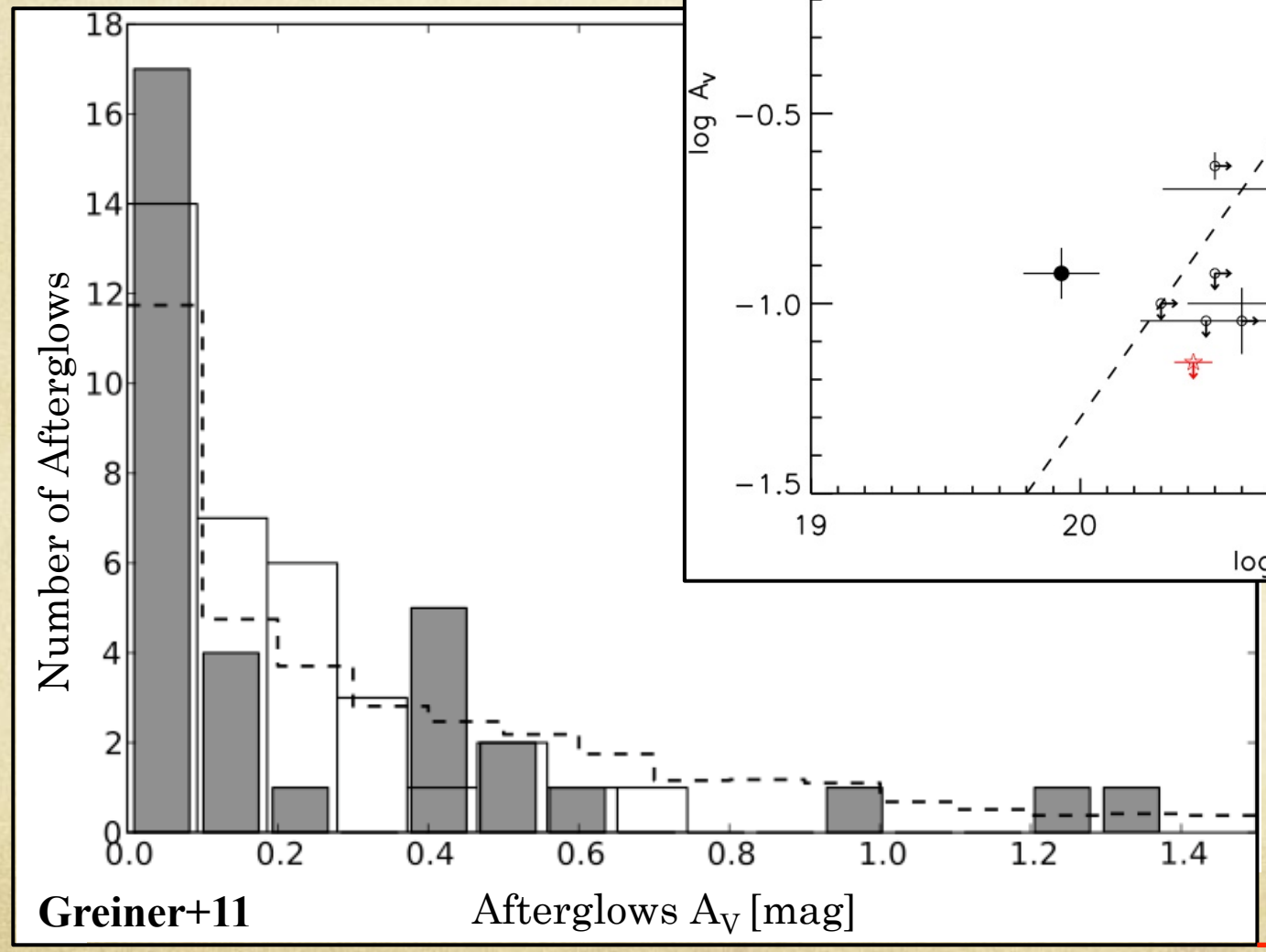
GRB070306
(Jaunsen et al. 2009)

3.2

5.5

Location of Extinguished Dust





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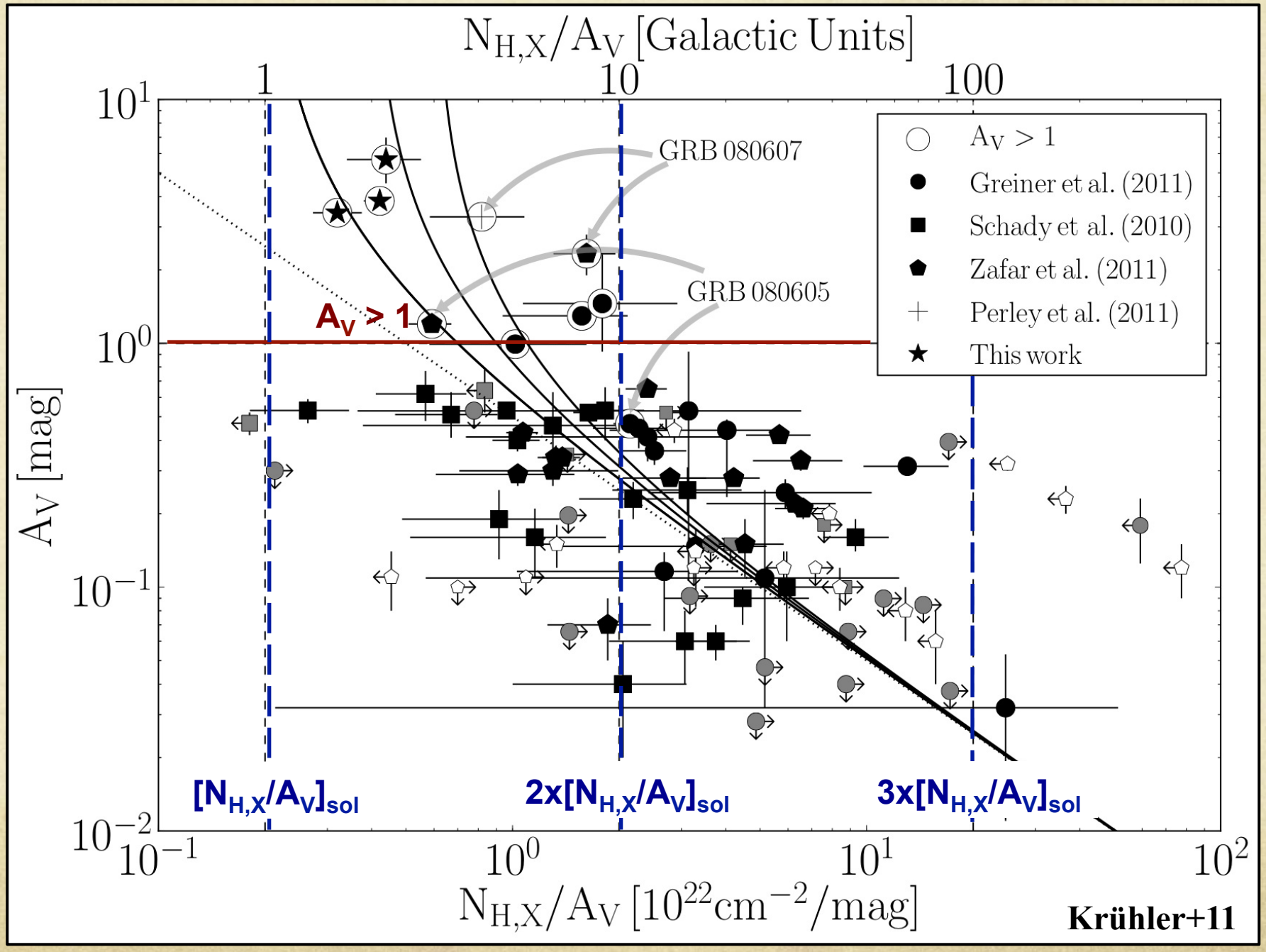
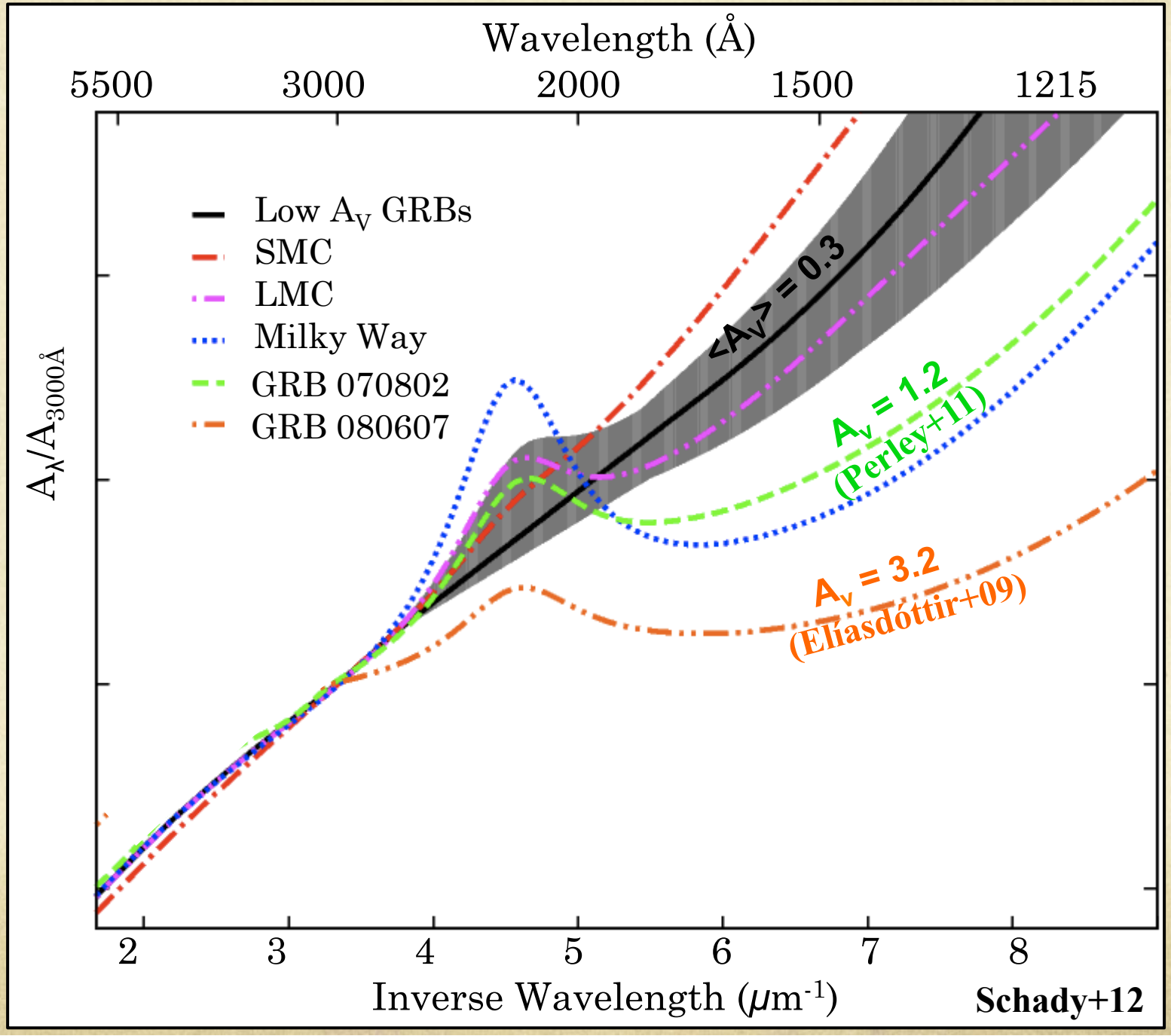
3.2 5.5

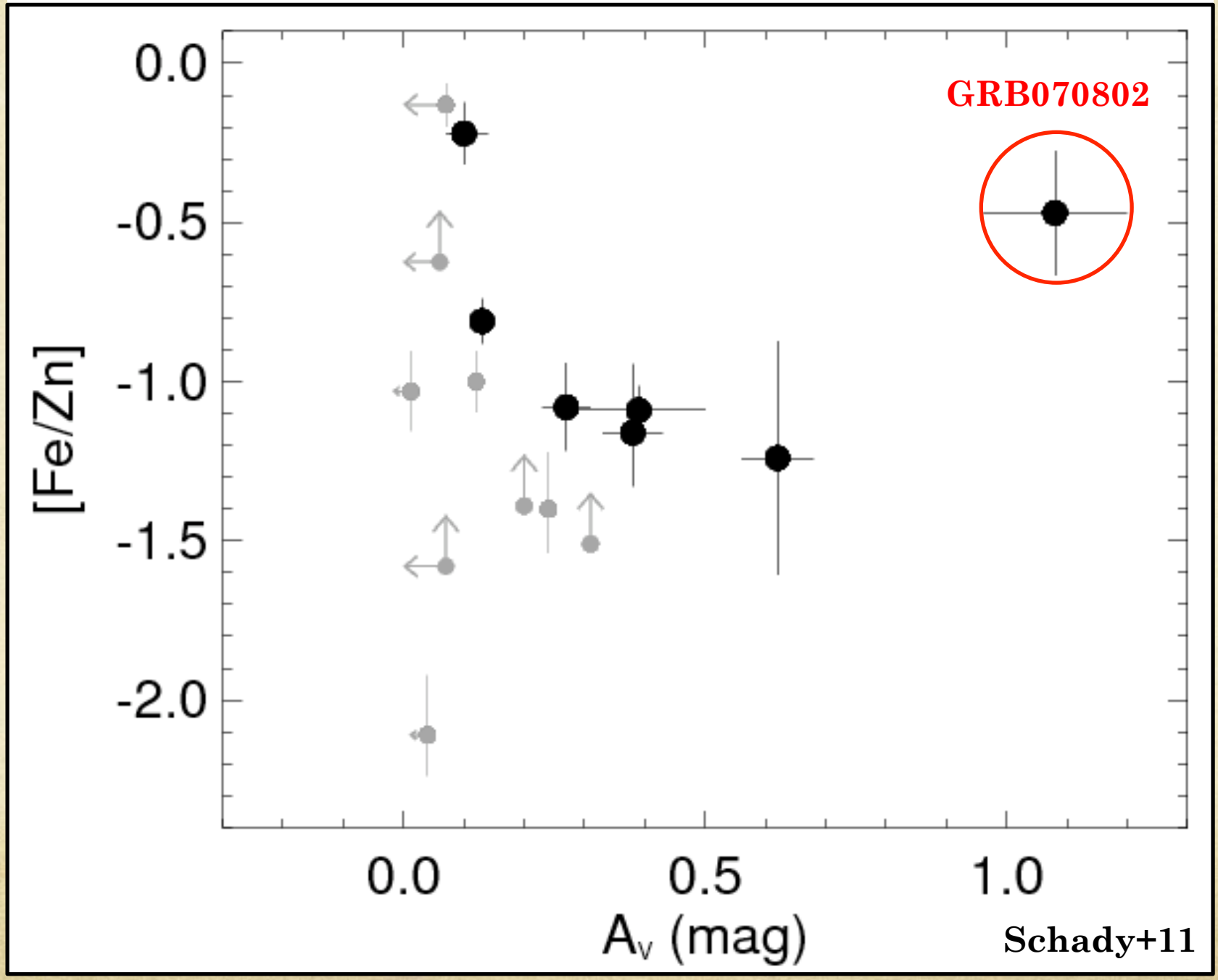
Metals-to-Dust ($N_{H,X}/A_V$)



Dust Extinction Curves



Dust Depletion vs. Dust Extinction



Conclusions

- **Rich sample of GRB optical and X-ray afterglow spectra**
  - Can probe ionisation state and relative abundances of host galaxy gas
  - Can probe A_V distribution and dust extinction law across cosmic time

- **Soft X-ray column densities typically an order of magnitude larger than neutral gas column densities**
  - Majority of host gas along line-of-sight is in a super ionised state ?
  - Soft X-rays absorbed by gas external to host; intervening galaxies, local WHIM, Milky Way?
  - Dust-to-metals ratio suggests soft X-rays absorbed within host

- **Line-of-sight dust extinction properties (A_V, extinction curve) dependent on global host galaxy properties?**
  - Older, more evolved galaxies have larger dust extinction and $A_V/N_{H,X}$, flatter extinction curves, more pronounced 2175Å bump