The X-ray absorption in GRB afterglows

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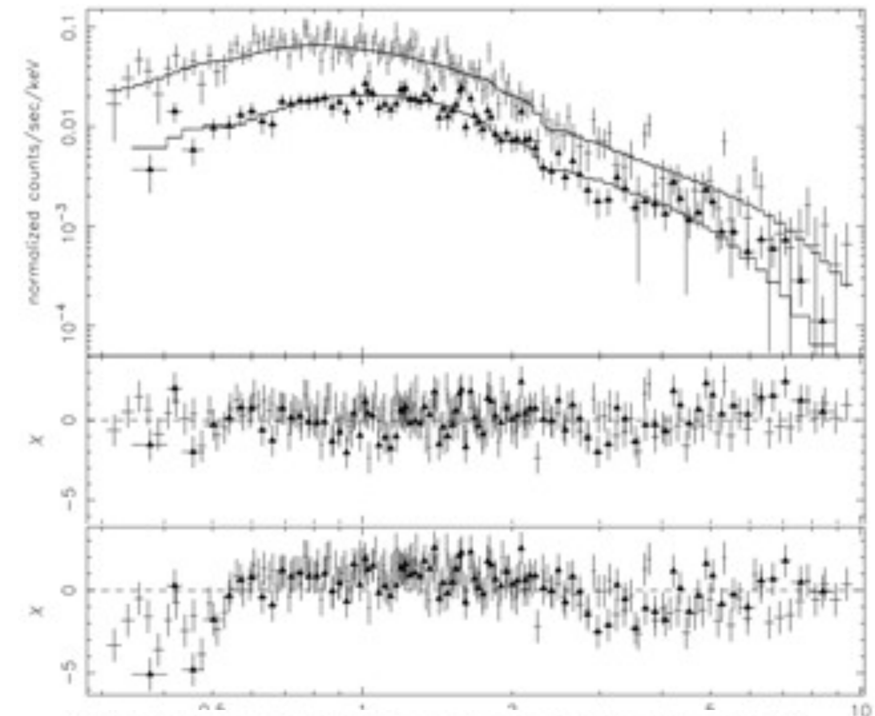
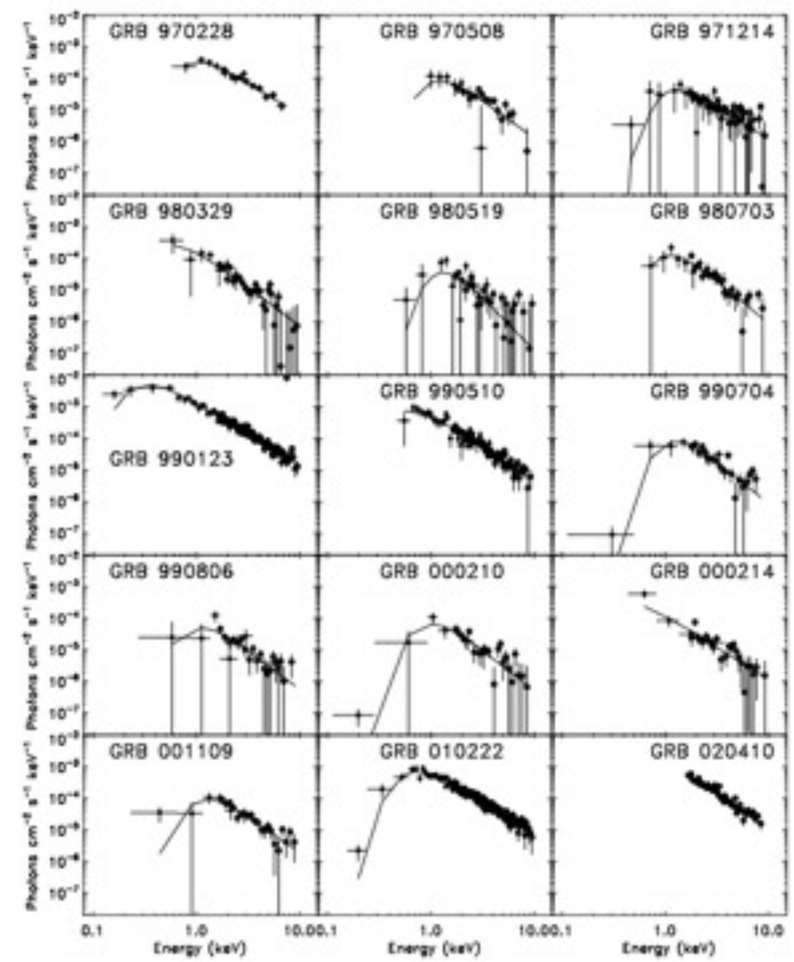
Overview

- Downturn at low energies deviating from a power-law
- Very similar to photoelectric absorption observed in the galaxy
- Fit well by photoelectric absorption by metals at host redshift
- Values well above Galactic





- Galama and Wijers, in average.; Watson et al. single afterglow; de Pasquale/Gendre/Stratta et al., Campana et al., Evans et al. samples

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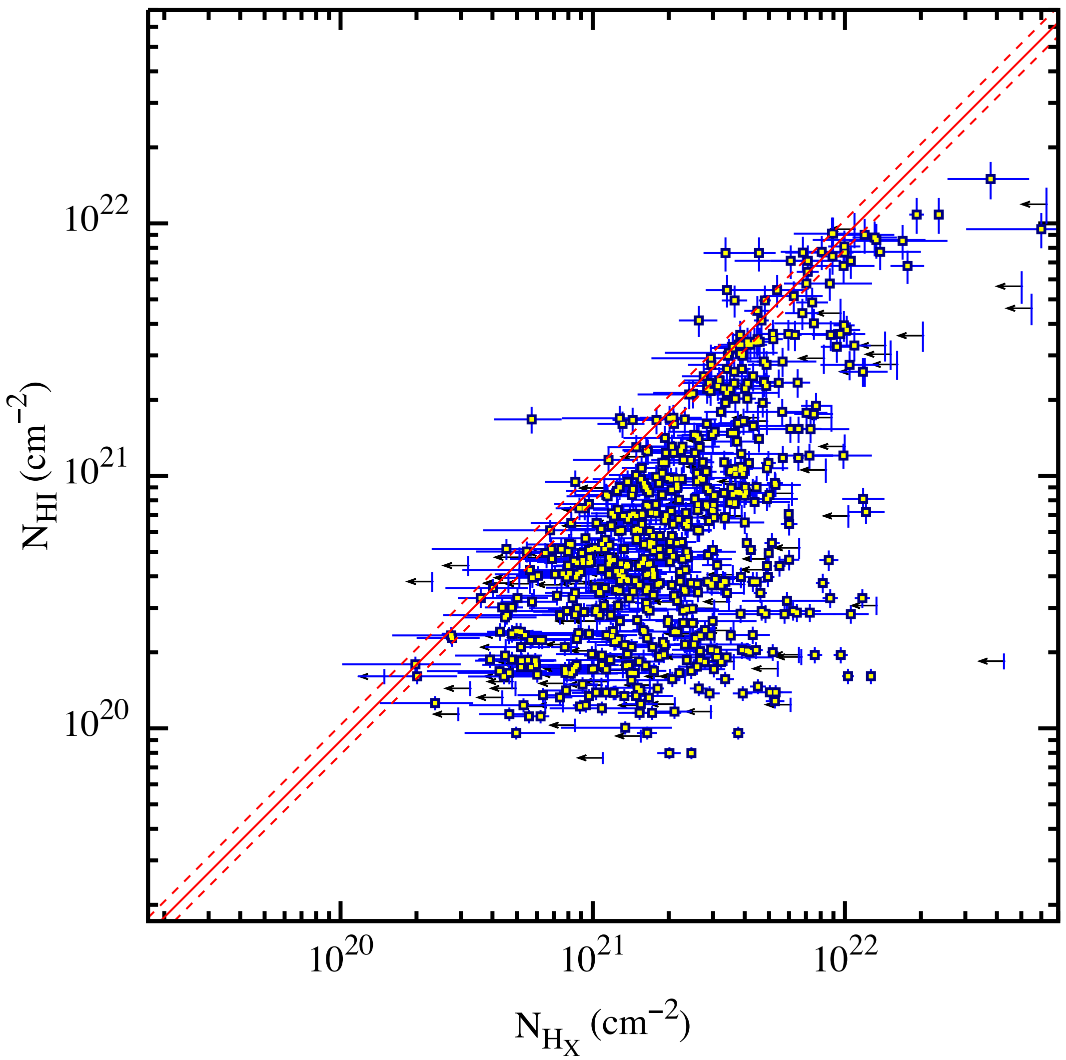

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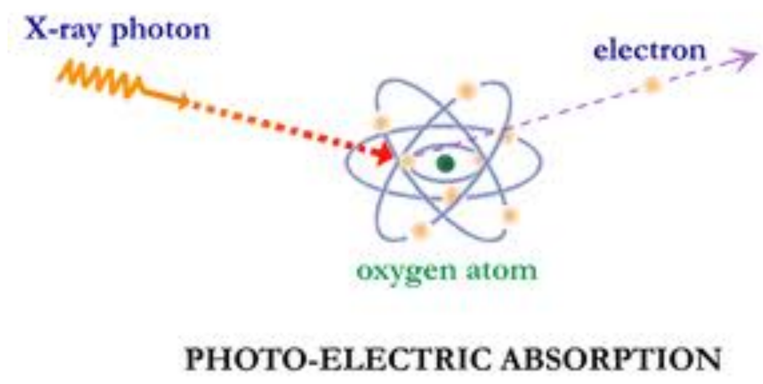
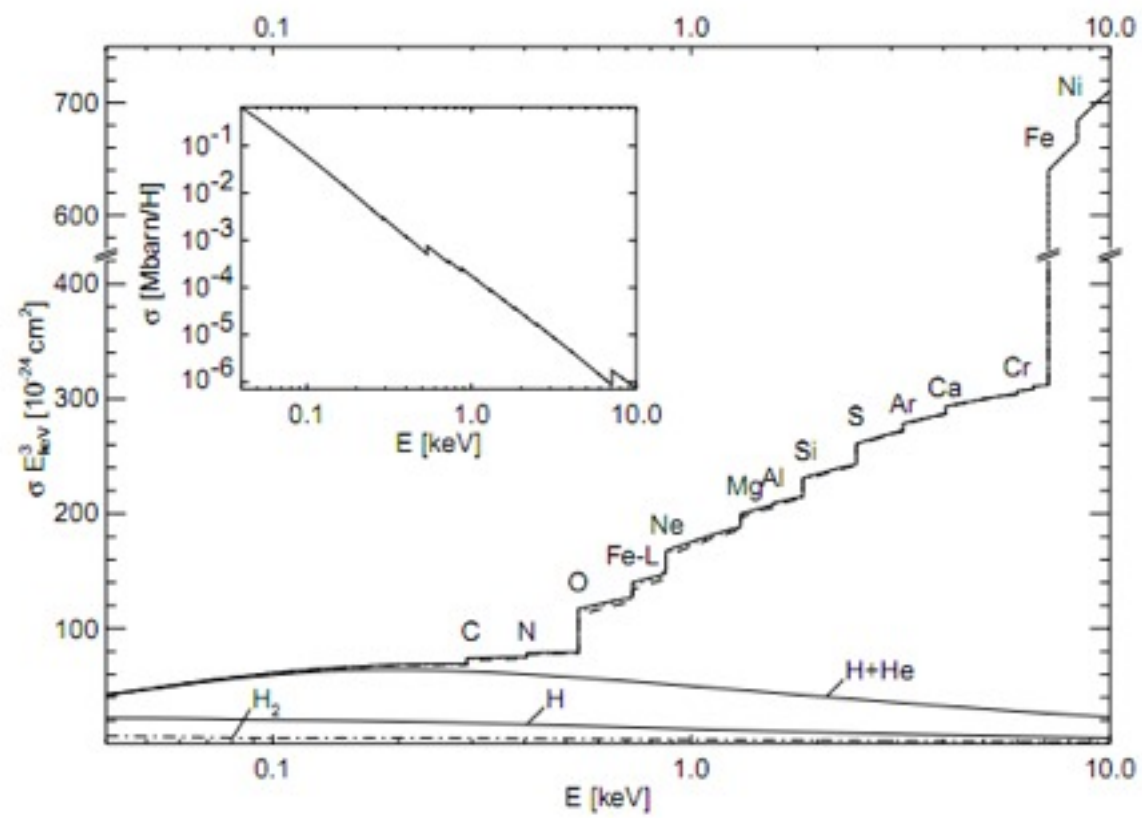
What causes the X-ray absorption?

- Photoelectric absorption
- Inner shells of metals dominate
- He, C, O, Fe, Si, S etc.
- Relatively insensitive to ionisation state or phase (i.e. in normal situations, X-rays see almost all metals)
- Use column density in hydrogen as a useful proxy, but actually, insensitive to hydrogen





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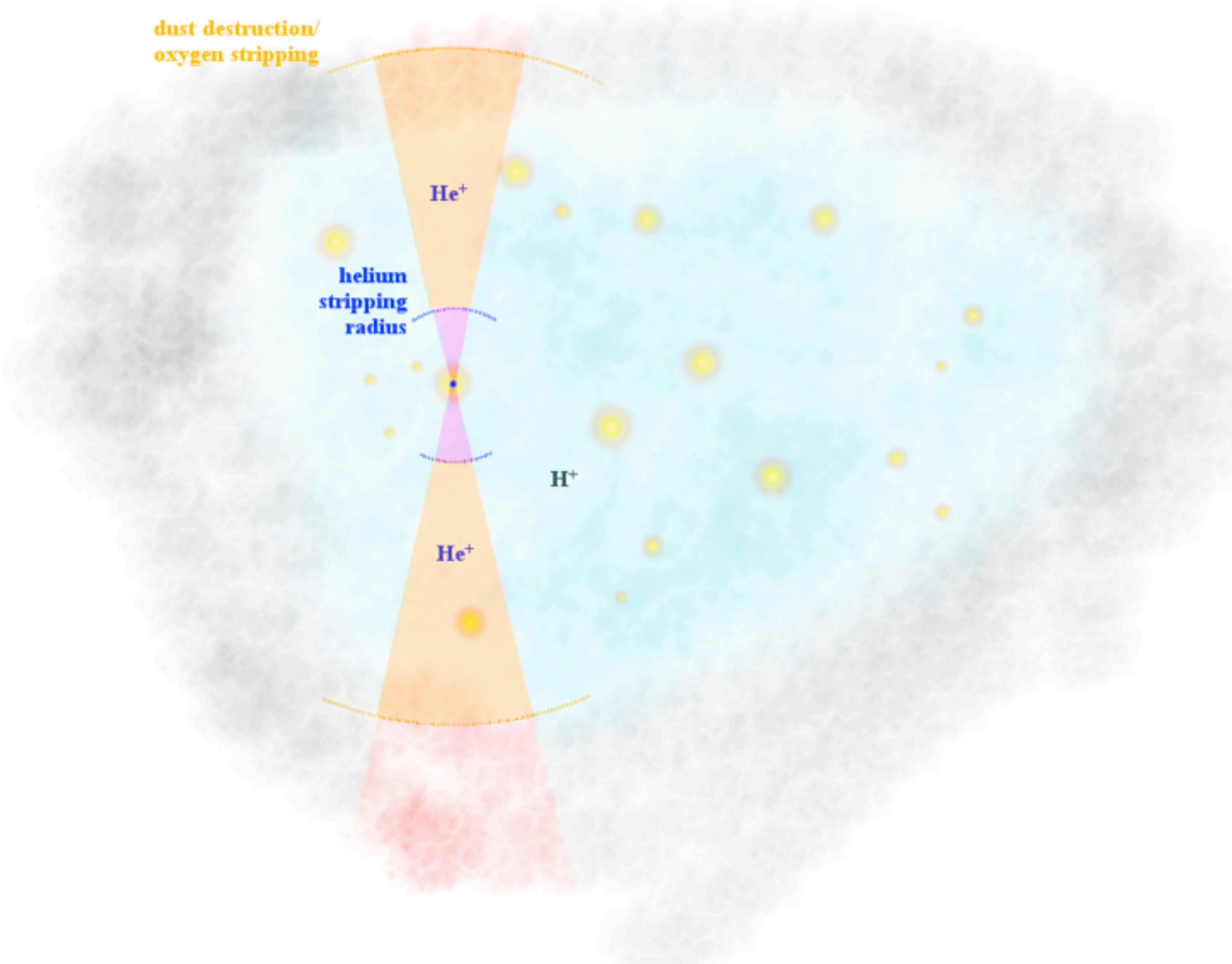
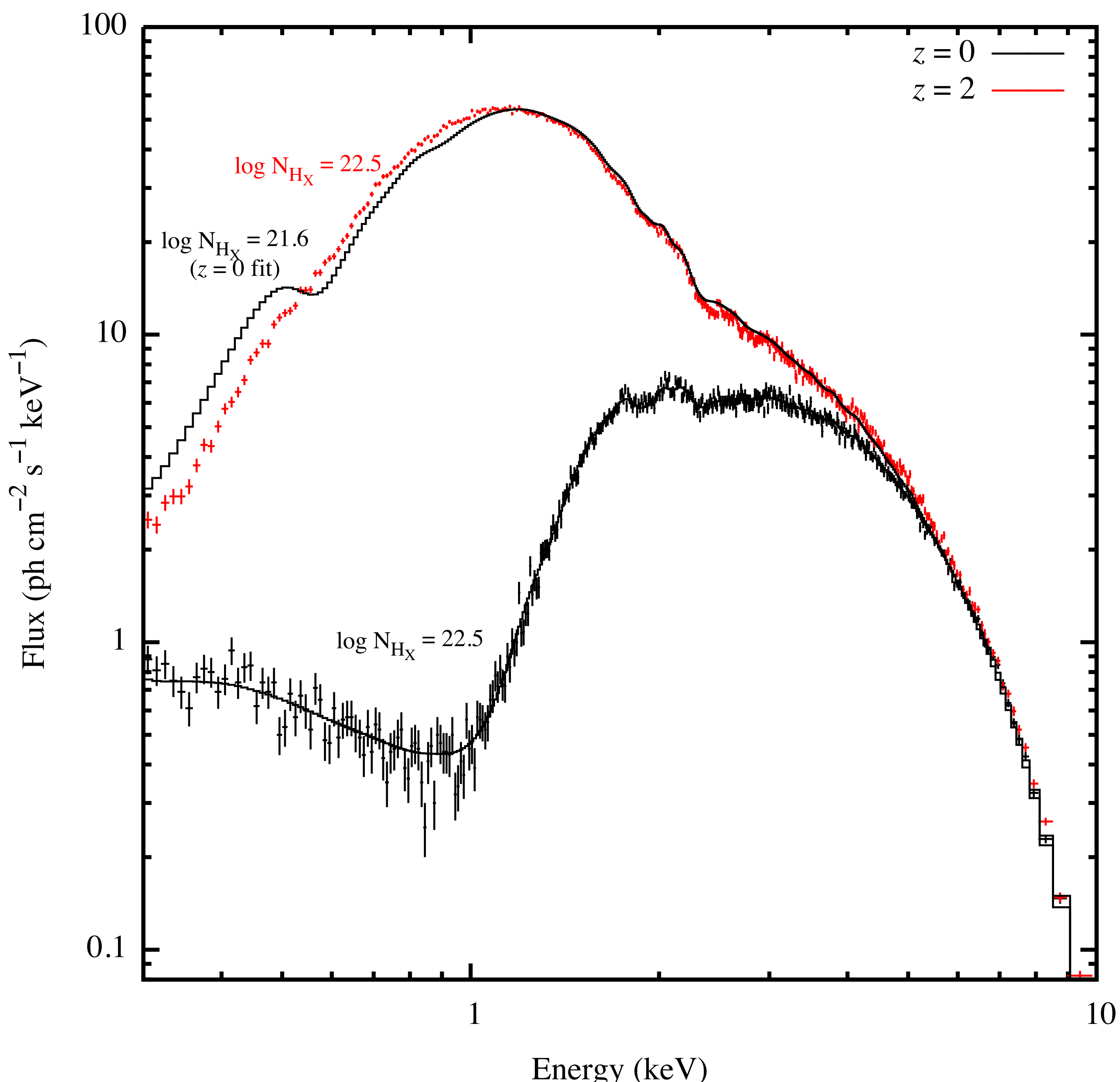


What causes X-ray absorption in GRBs?

H II regions — helium

Redshift dependence

- Little redshift information in low-res X-ray spectra
- Get redshifts from optical
- But! Inferred absorption strongly redshift dependent:
- $N_{H_X}(z) \approx (1+z)^{2.5} N_{H_X}(0)$



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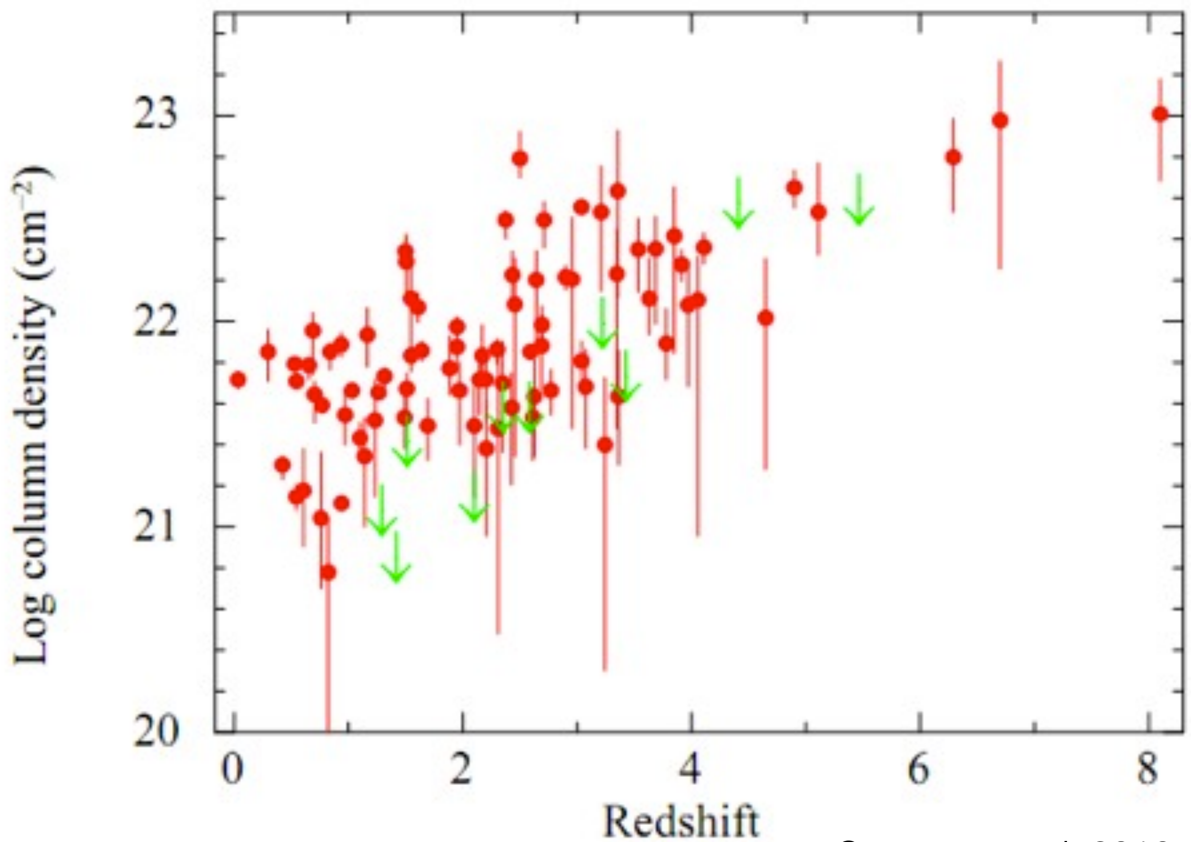
The redshift distribution

- Oddity—X-ray absorption rises with redshift. Why?
- Expect detectability threshold to rise with redshift [$N_{H_X}(z) \approx (1+z)^{2.5}\, N_{H_X}(0)$]
- But missing low redshift, high absorption GRBs



Campana et al. 2010

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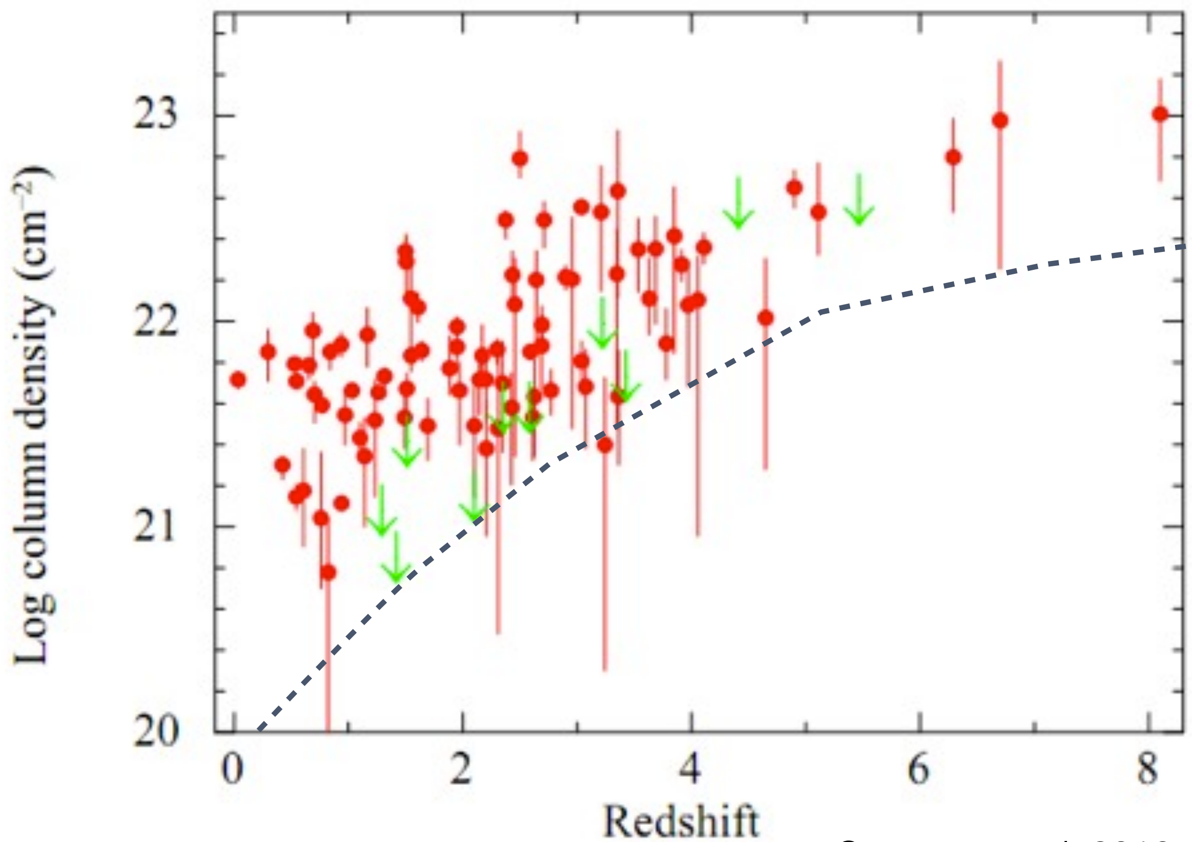

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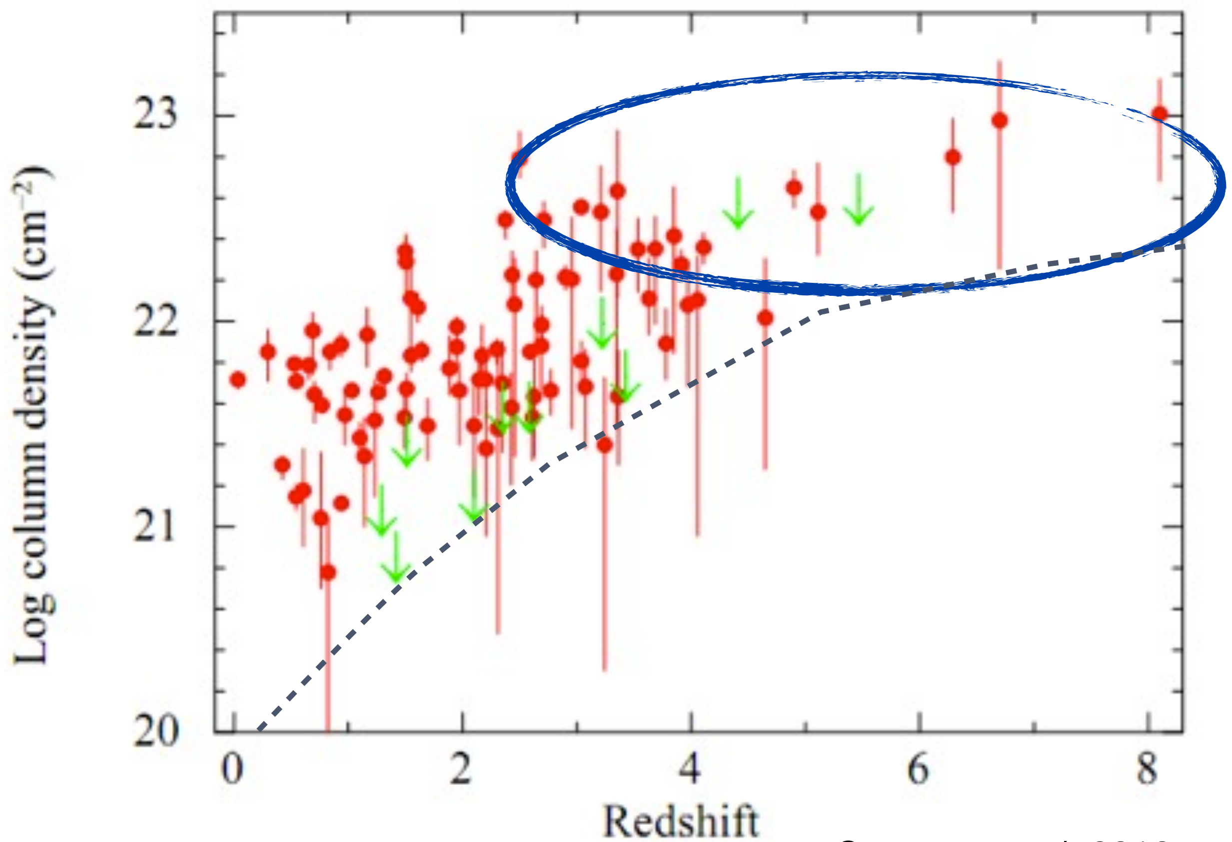

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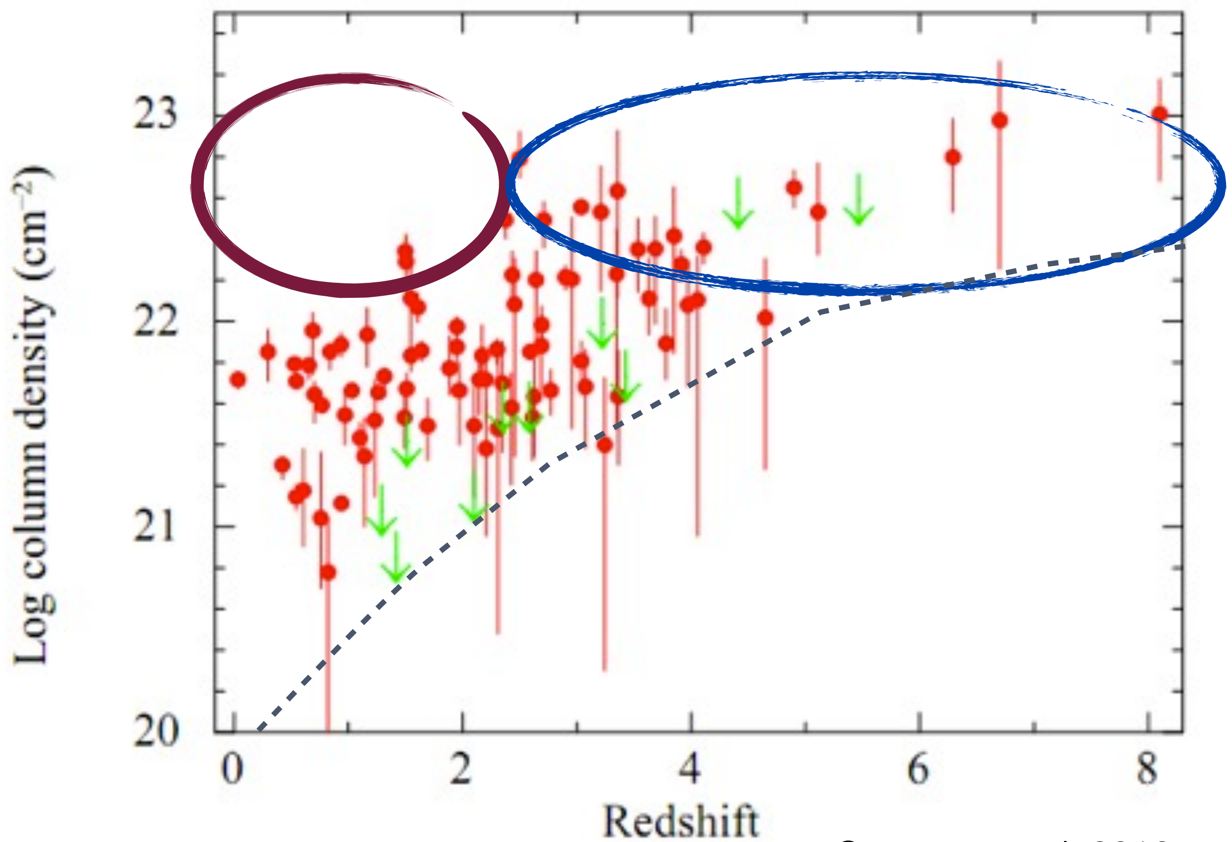

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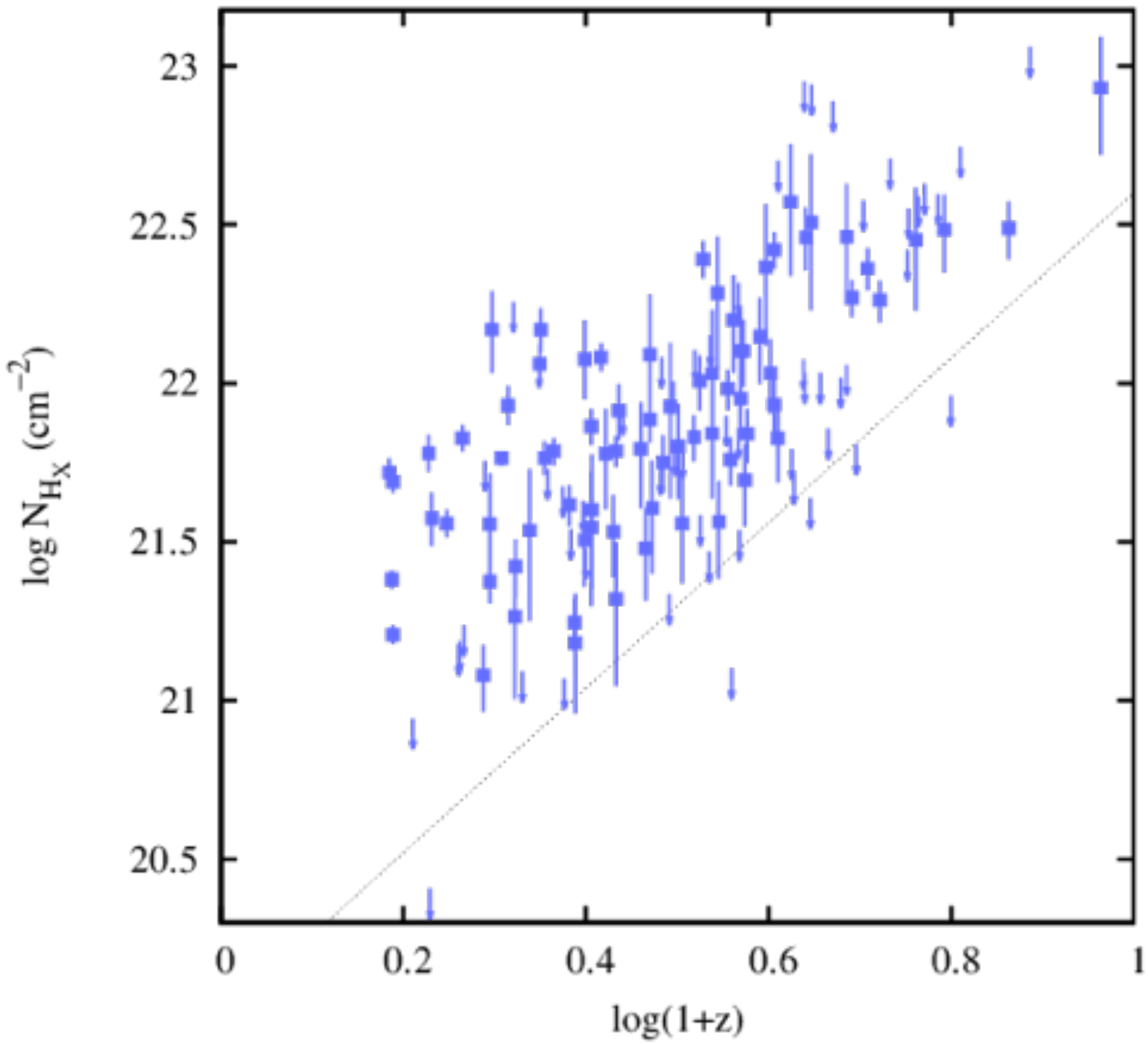
Solution: Dust bias

- X-rays unbiased by dust
- But redshifts from optical
- Bias obtaining redshifts

Watson & Jakkobson 2012



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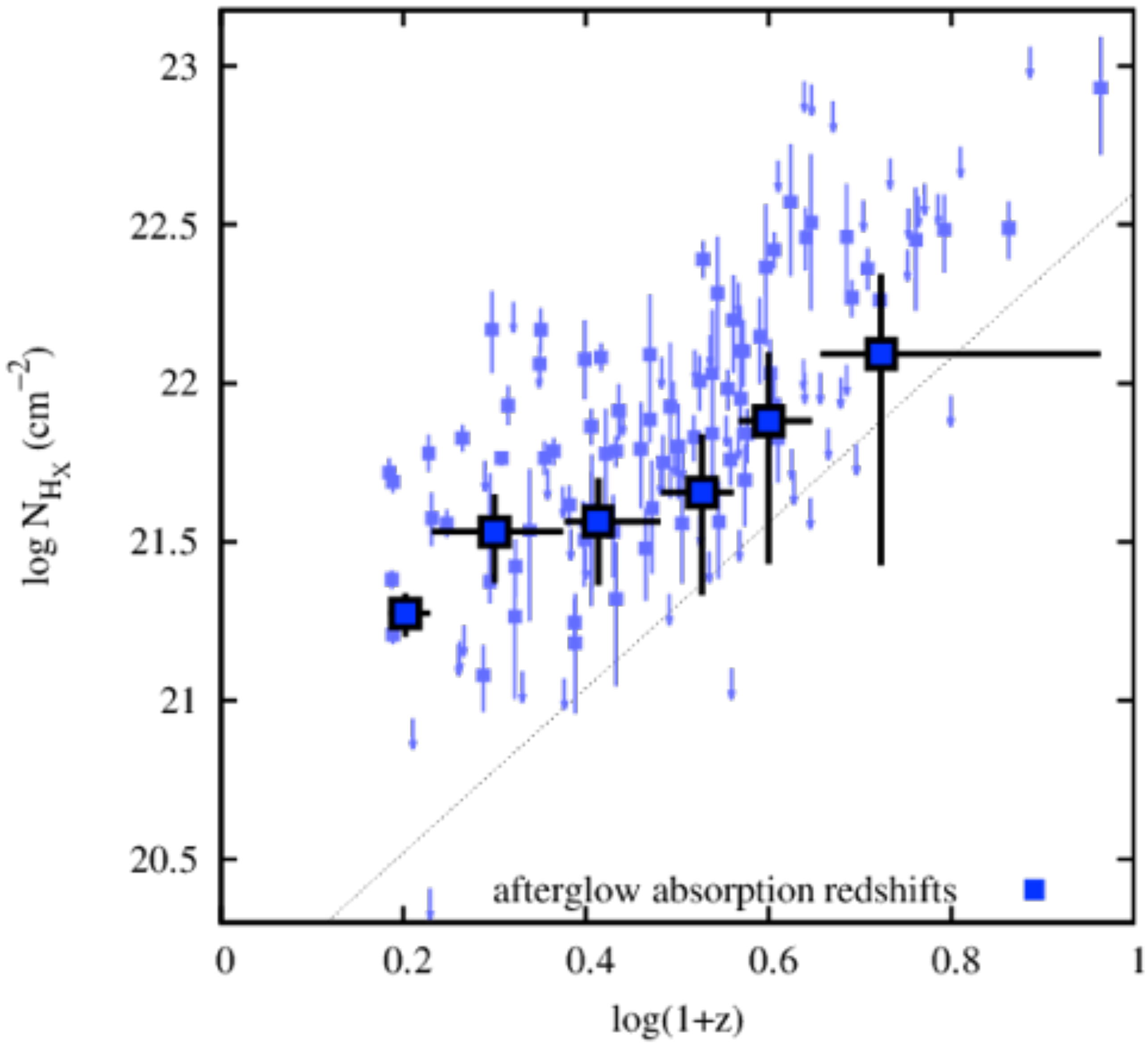

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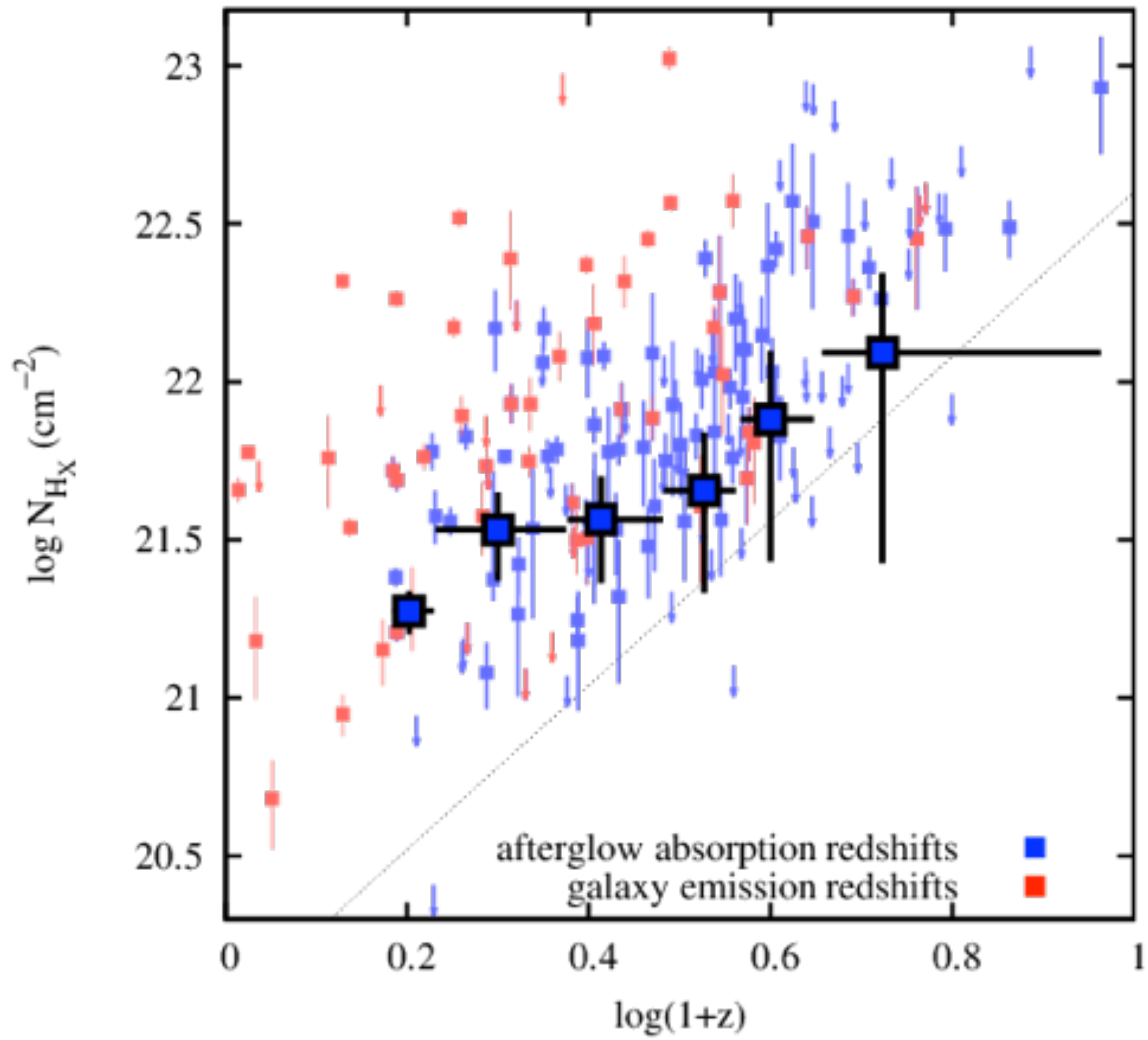

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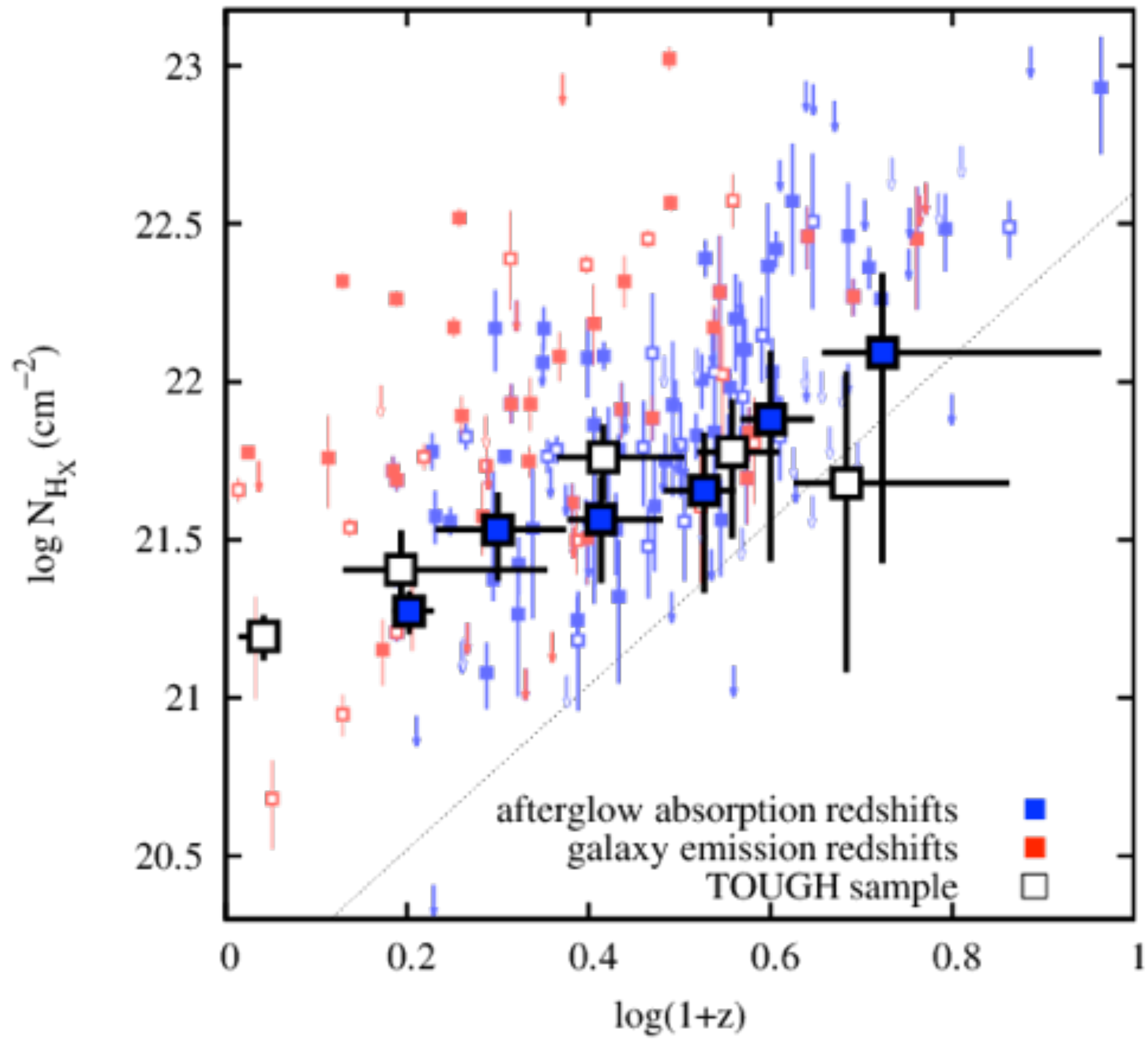

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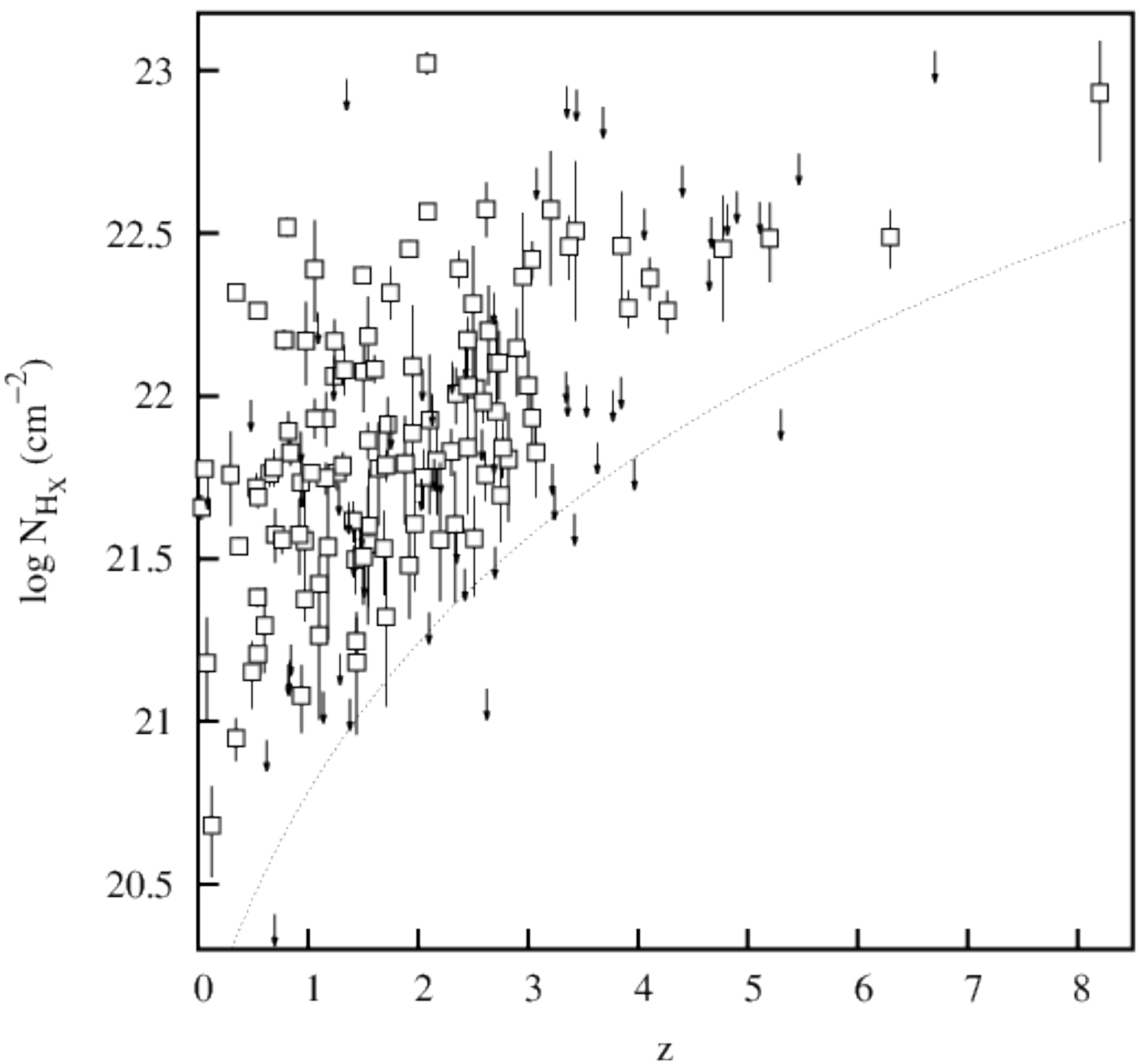

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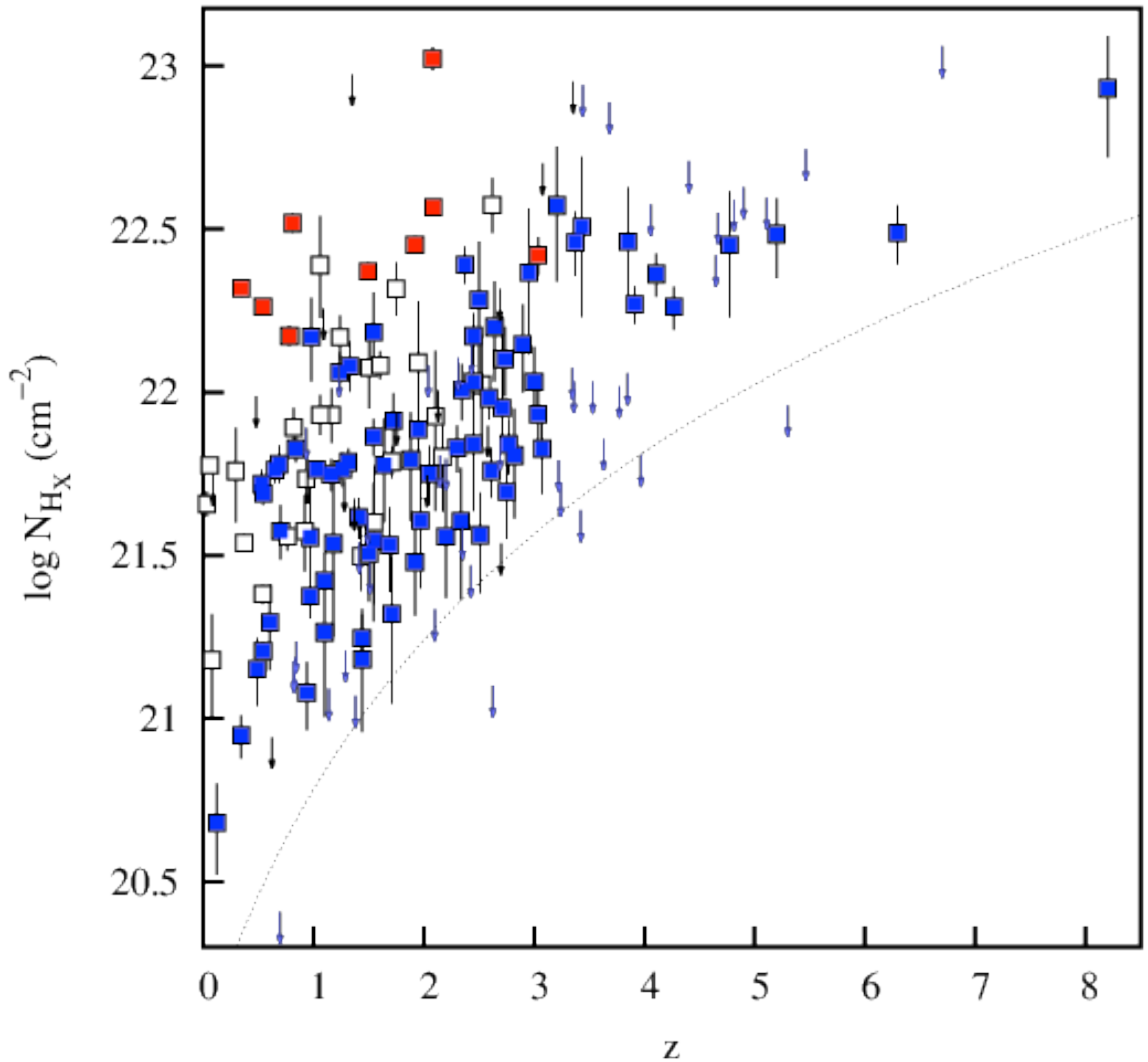

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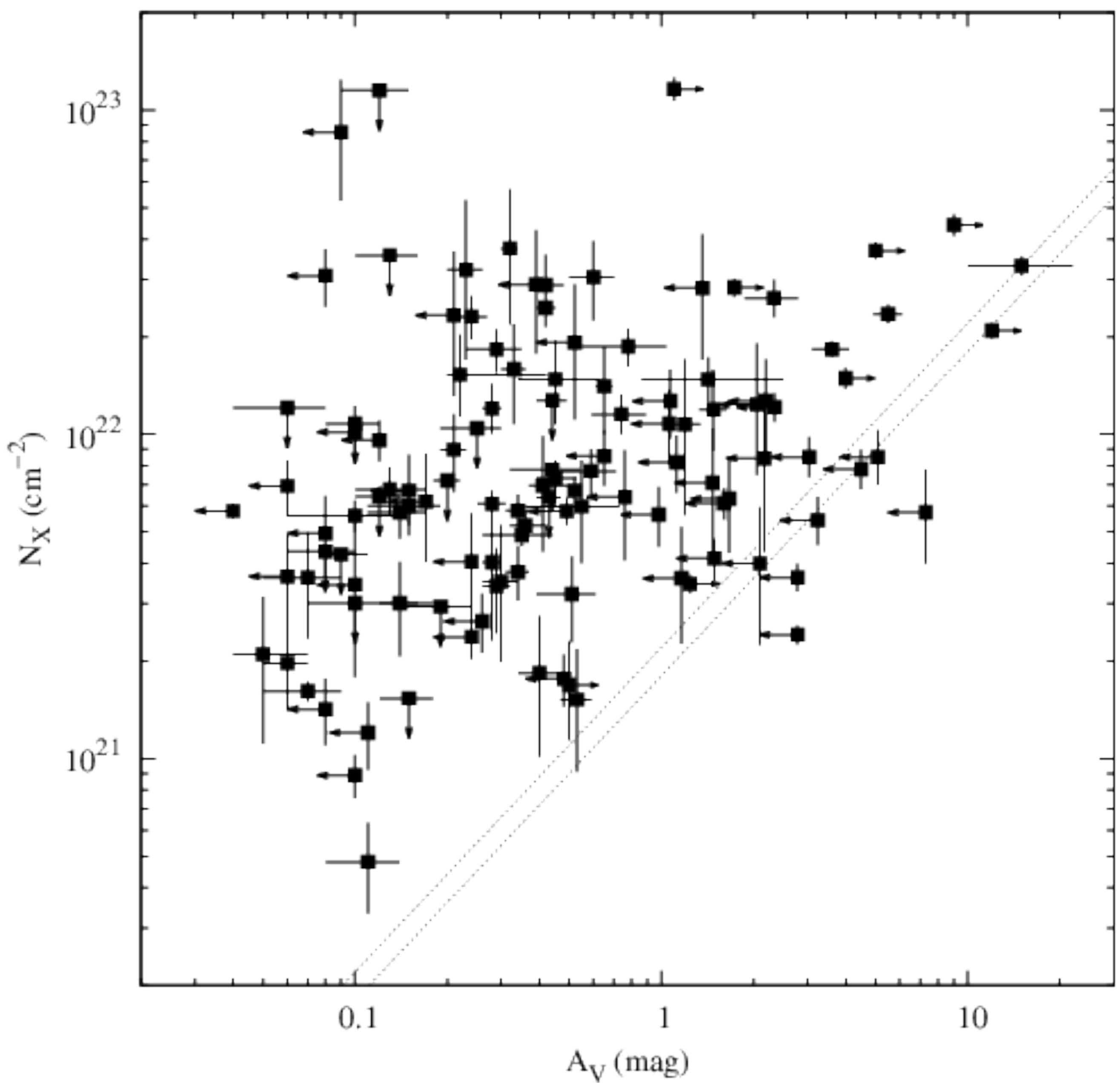
No N_{HX}-A_V correlation

- Evolving N_{HX}/A_V

Watson & Jakobssen 2012



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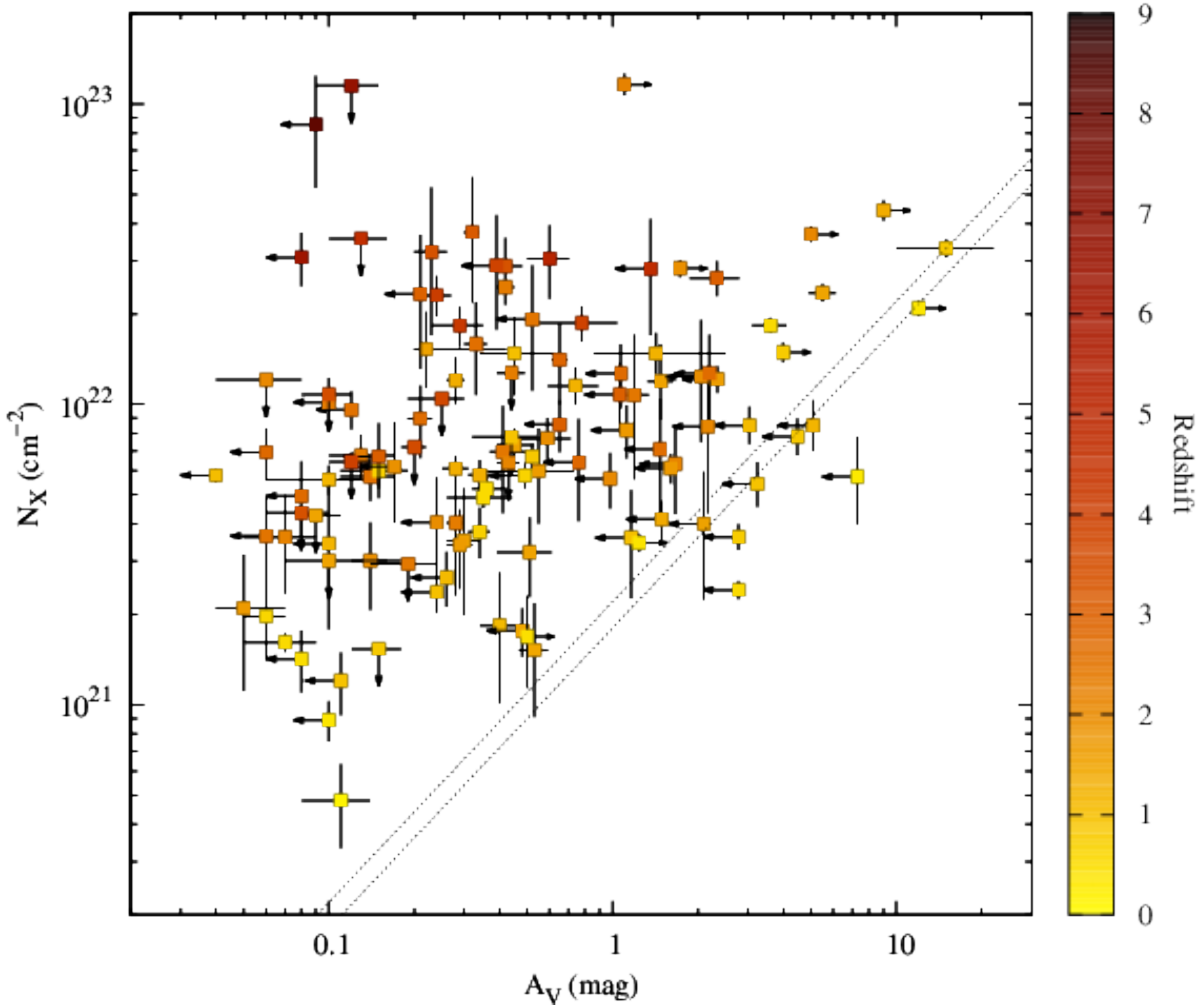
N_{HX}-A_V correlation ?

- Evolving N_{HX}/A_V

Watson & Jakobssen 2012



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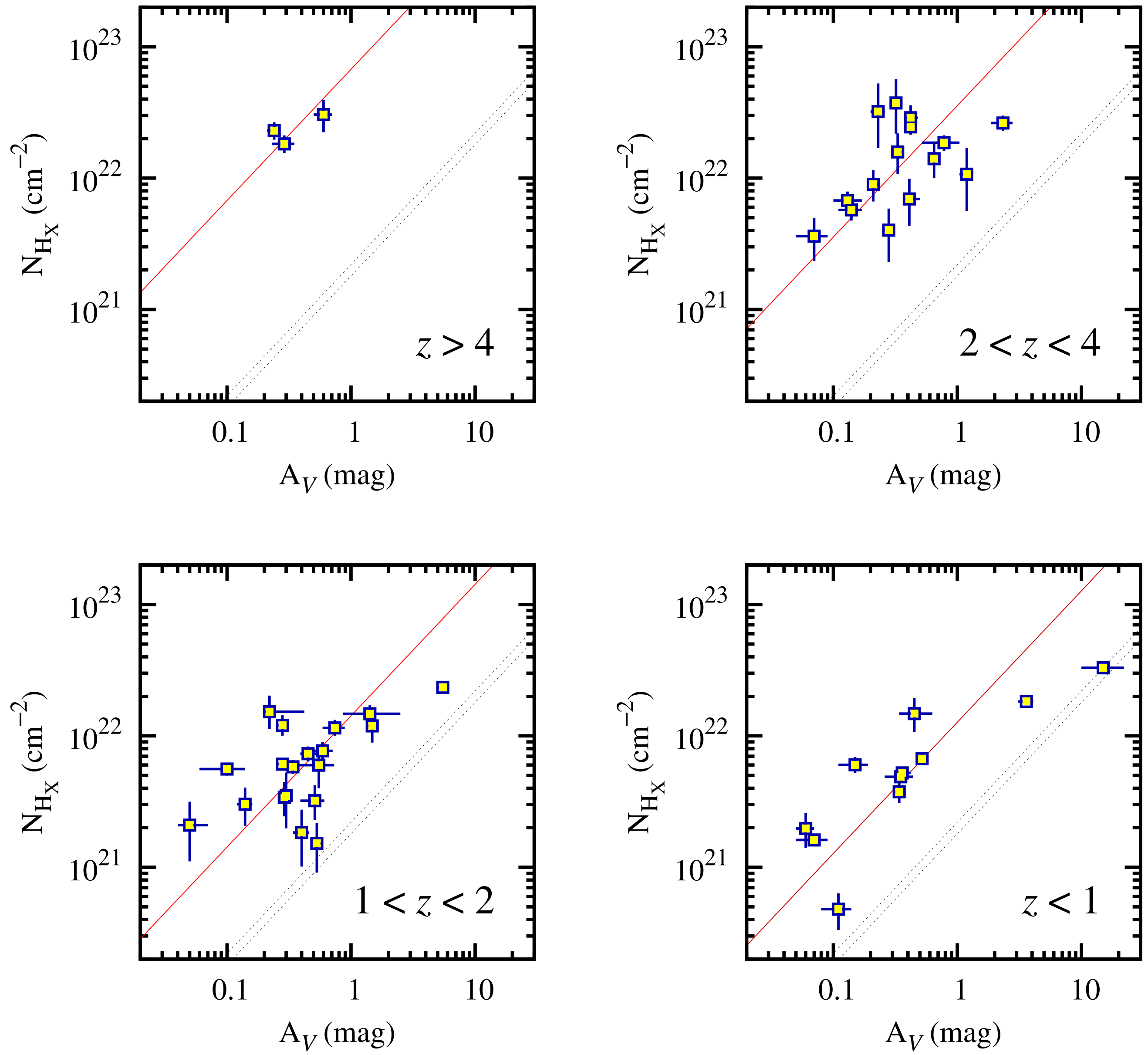
Evolving N_{H_X}-A_V correlation

- Correlation between N_{H_X} and A_V at $z < 1$, $1 < z < 2$, and $2 < z < 4$.
- But mean ratio rises with redshift

N_{H_X} — A_V correlation confirmed by Covino et al. 2013



Watson et al. 2013

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(SUB-)Conclusion

- Dust produced more effectively from metals at lower redshifts? Unlikely
- Still do not understand:
  - Where is the X-ray absorption?
  - Its real column density distribution
  - Ionisation state
  - Abundances

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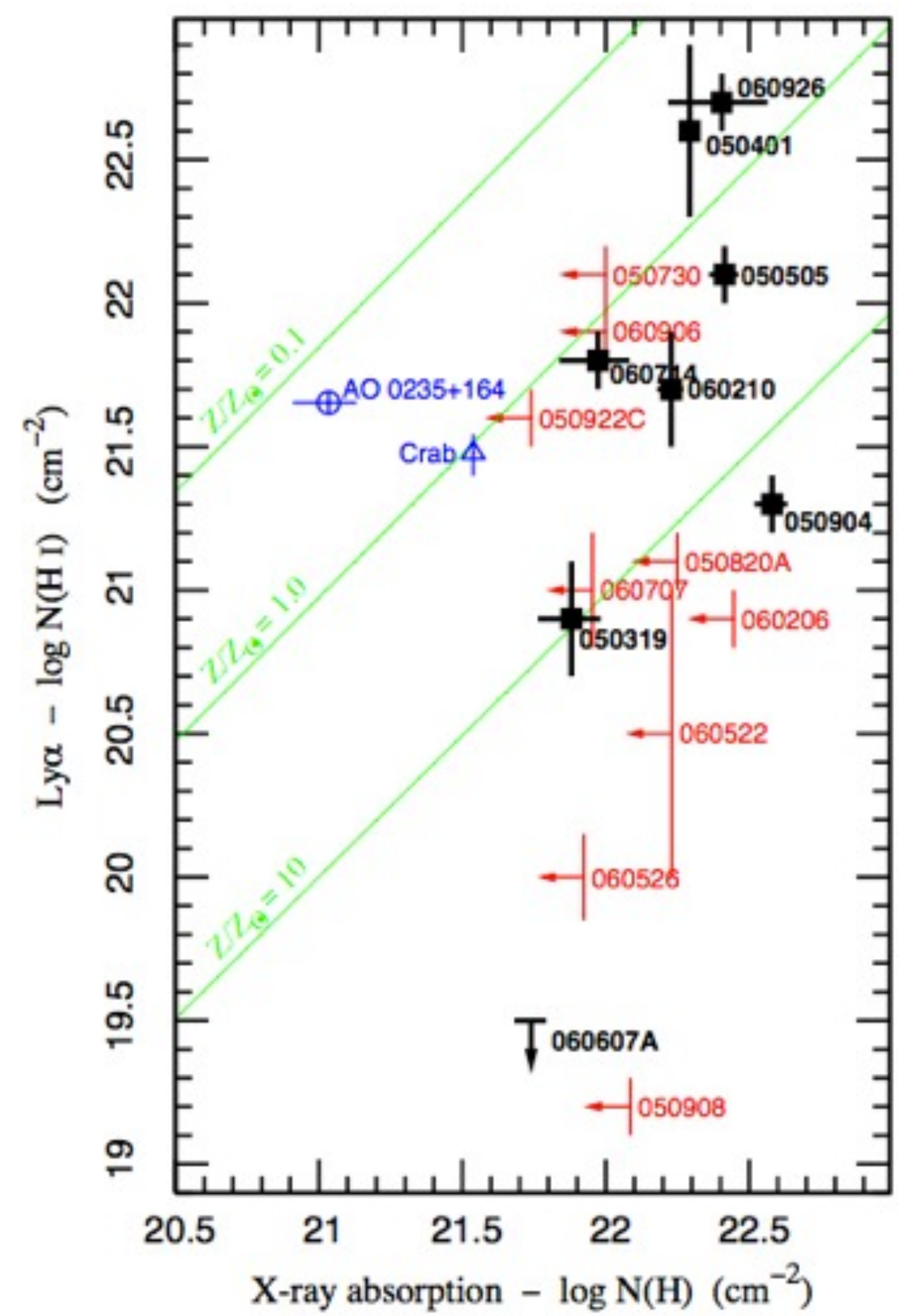
Proposals

- Molecular cloud
- Intrinsic curvature
- Underestimated Galactic
- Intervening neutral absorbers
- Warm/hot IGM



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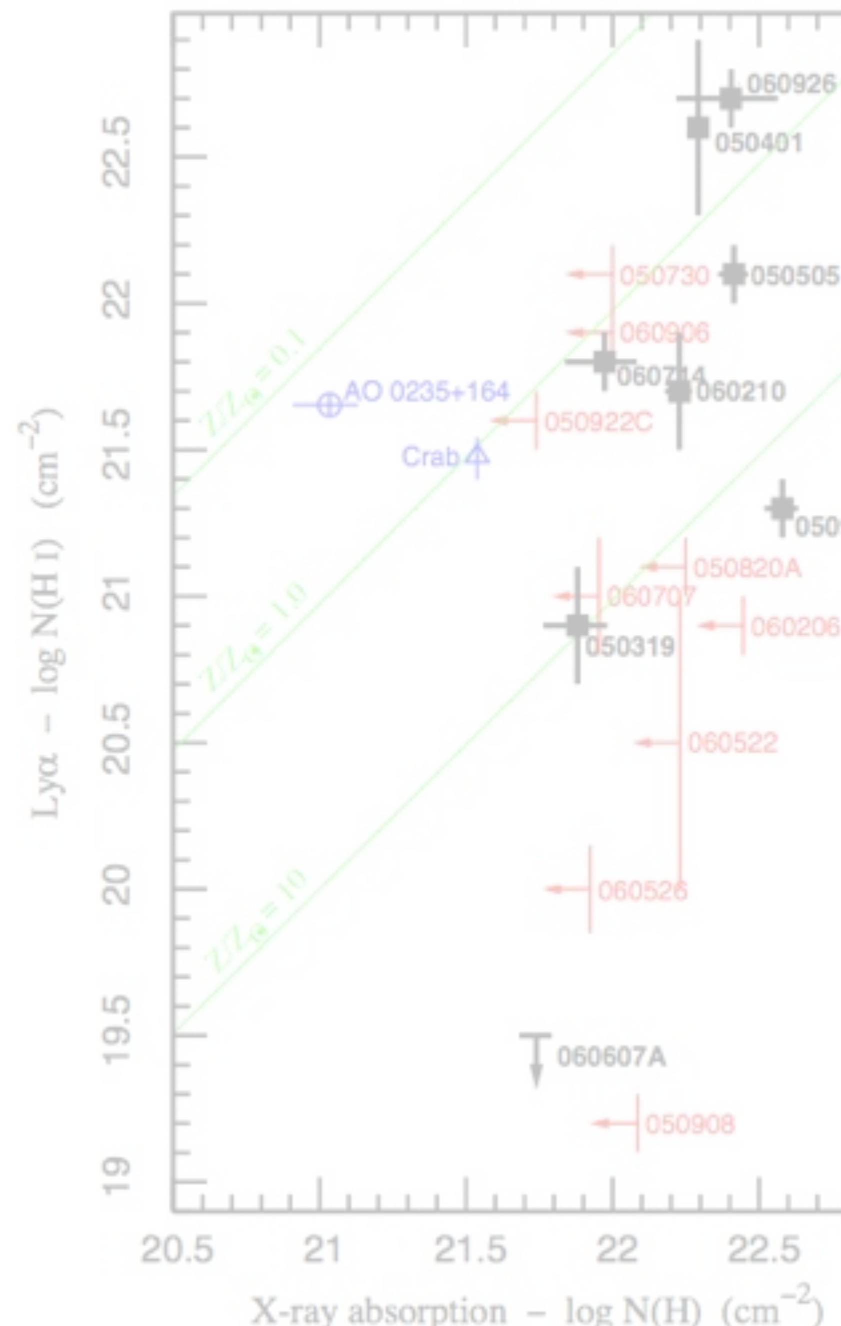

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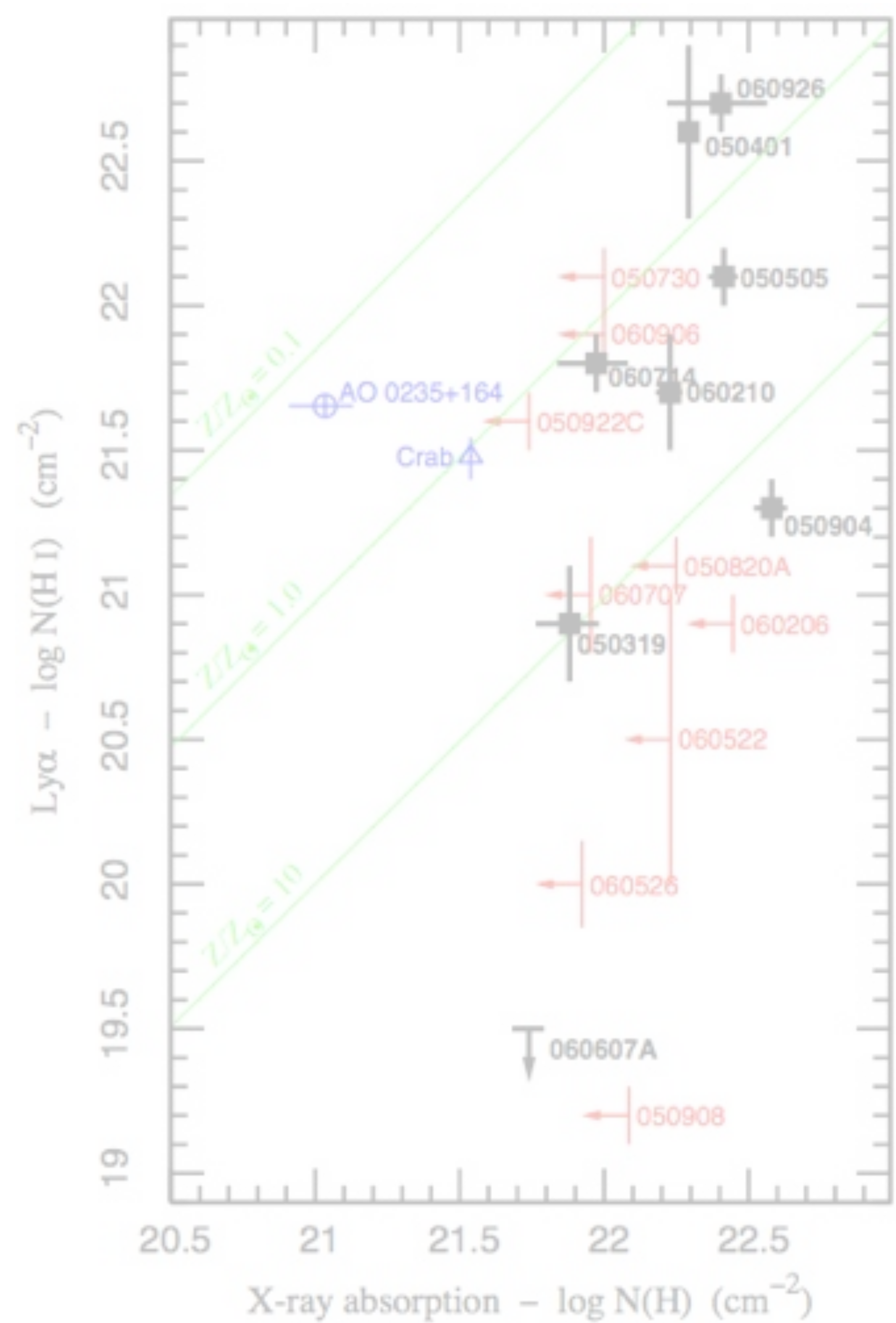

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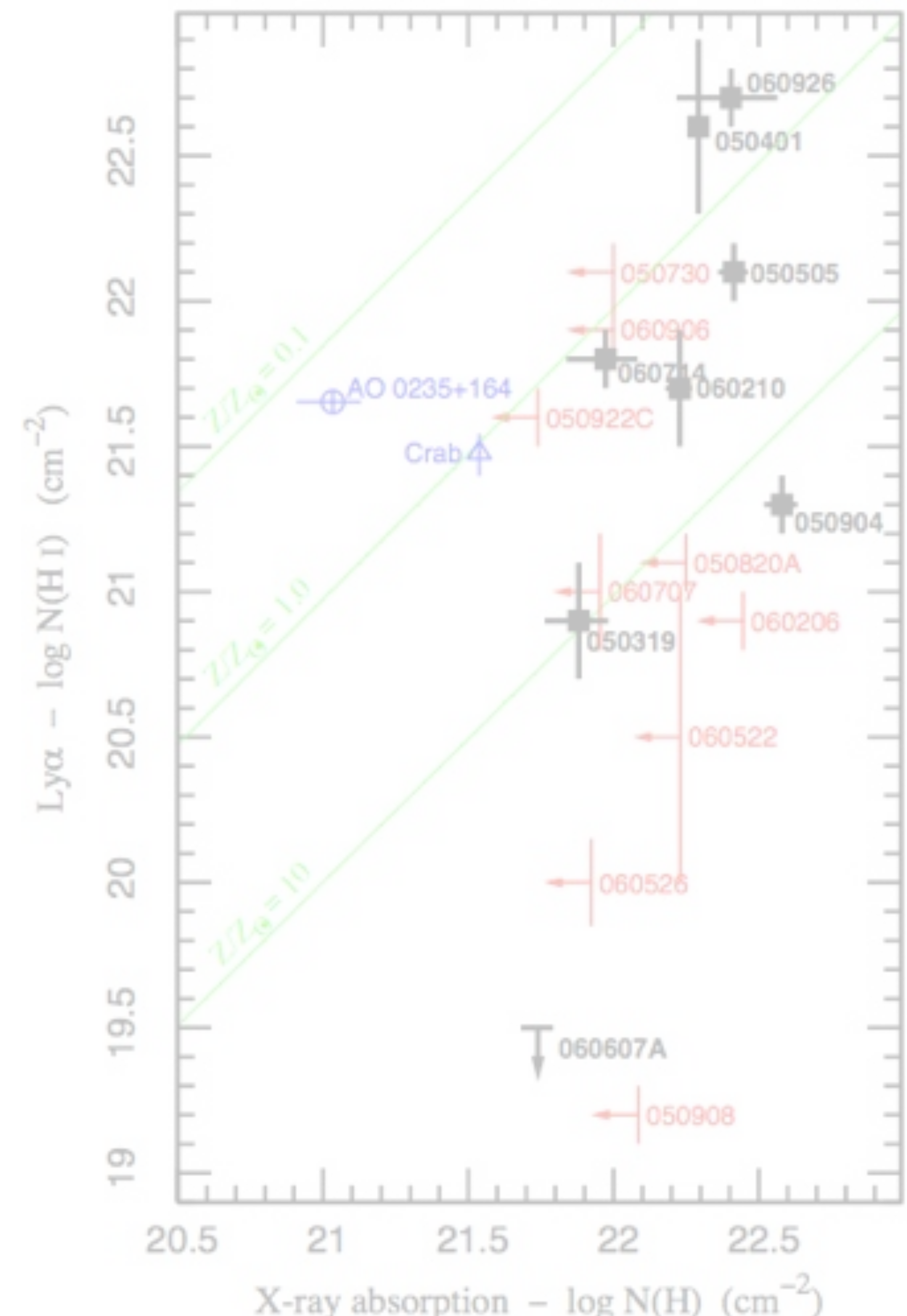

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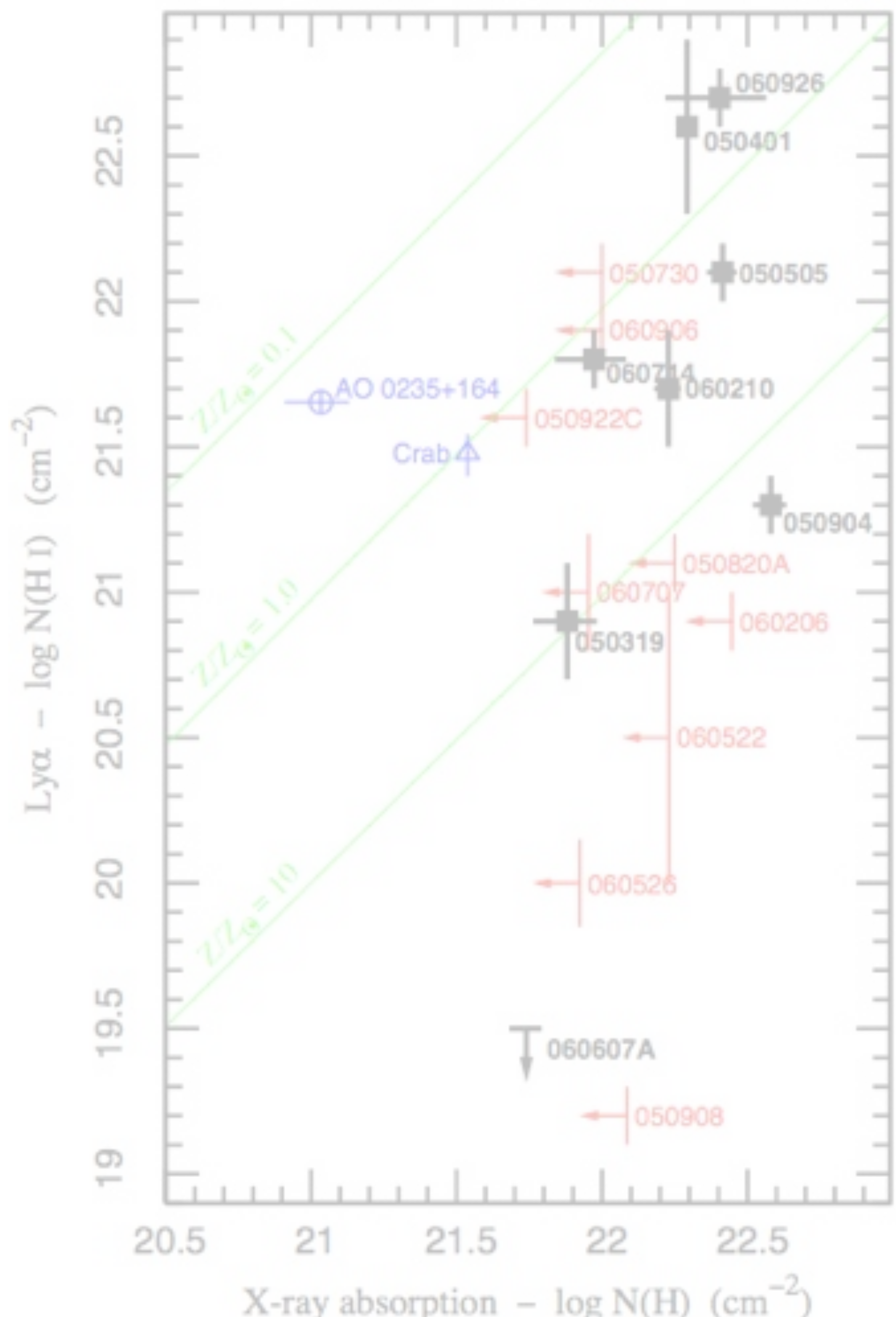

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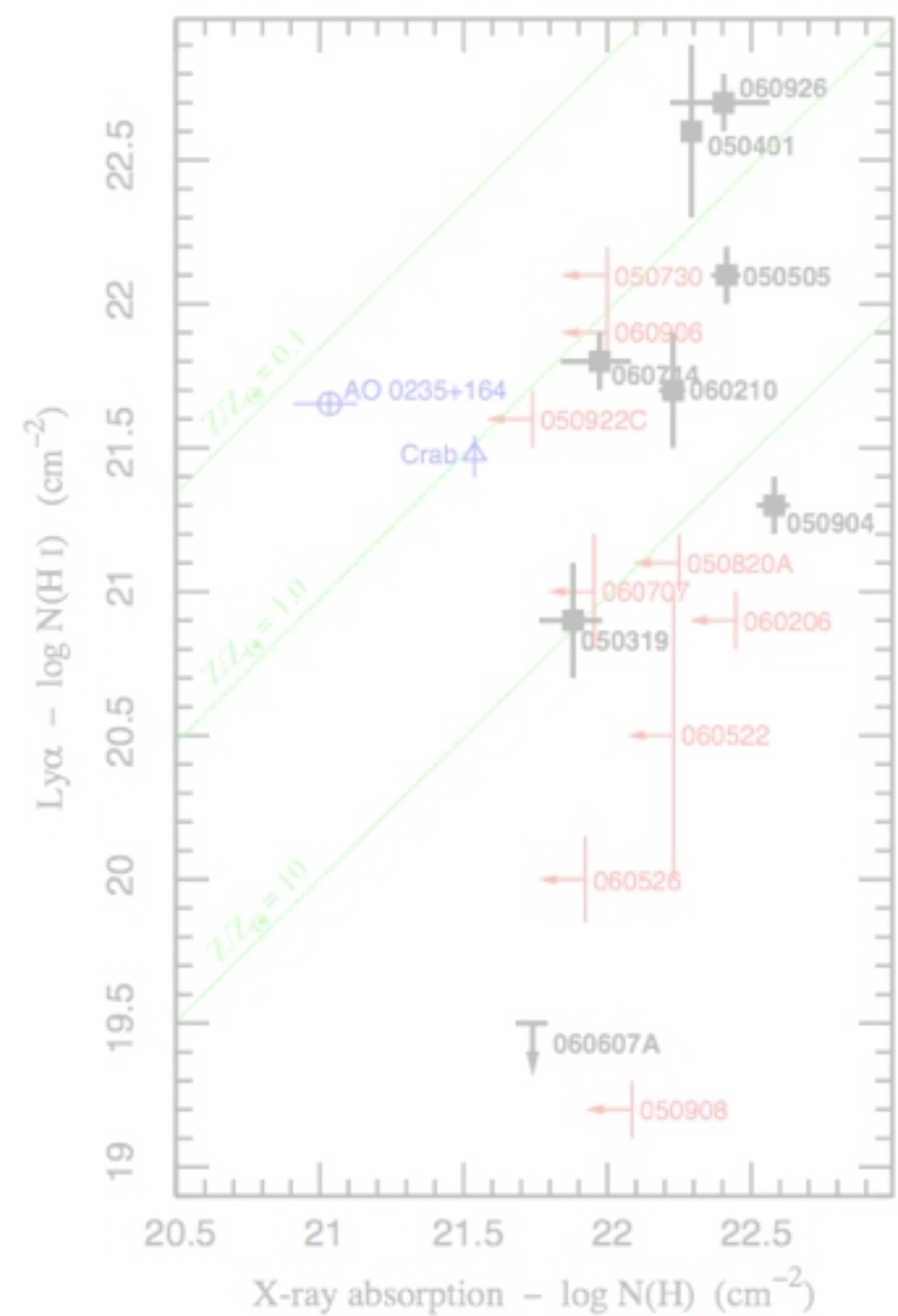

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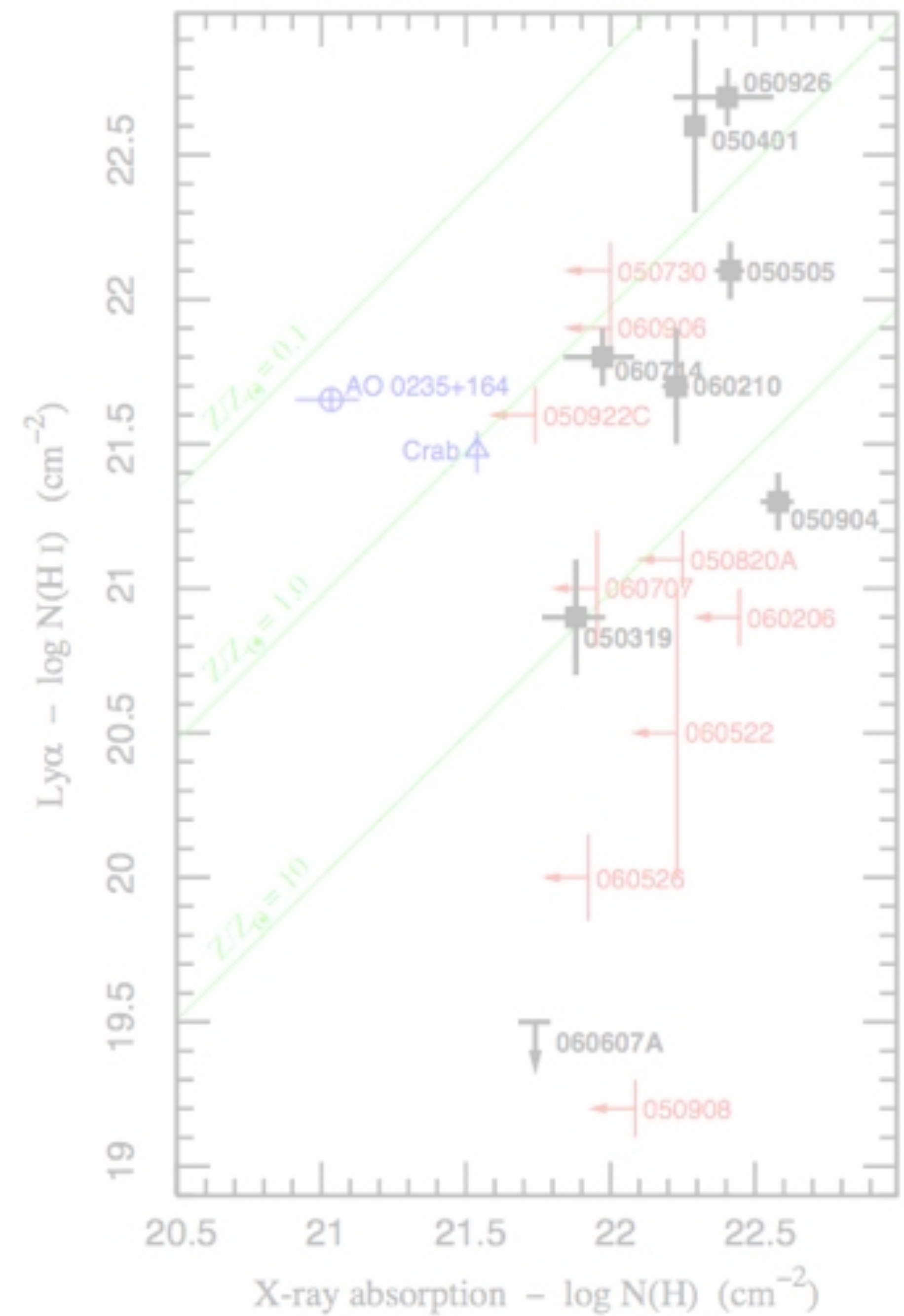

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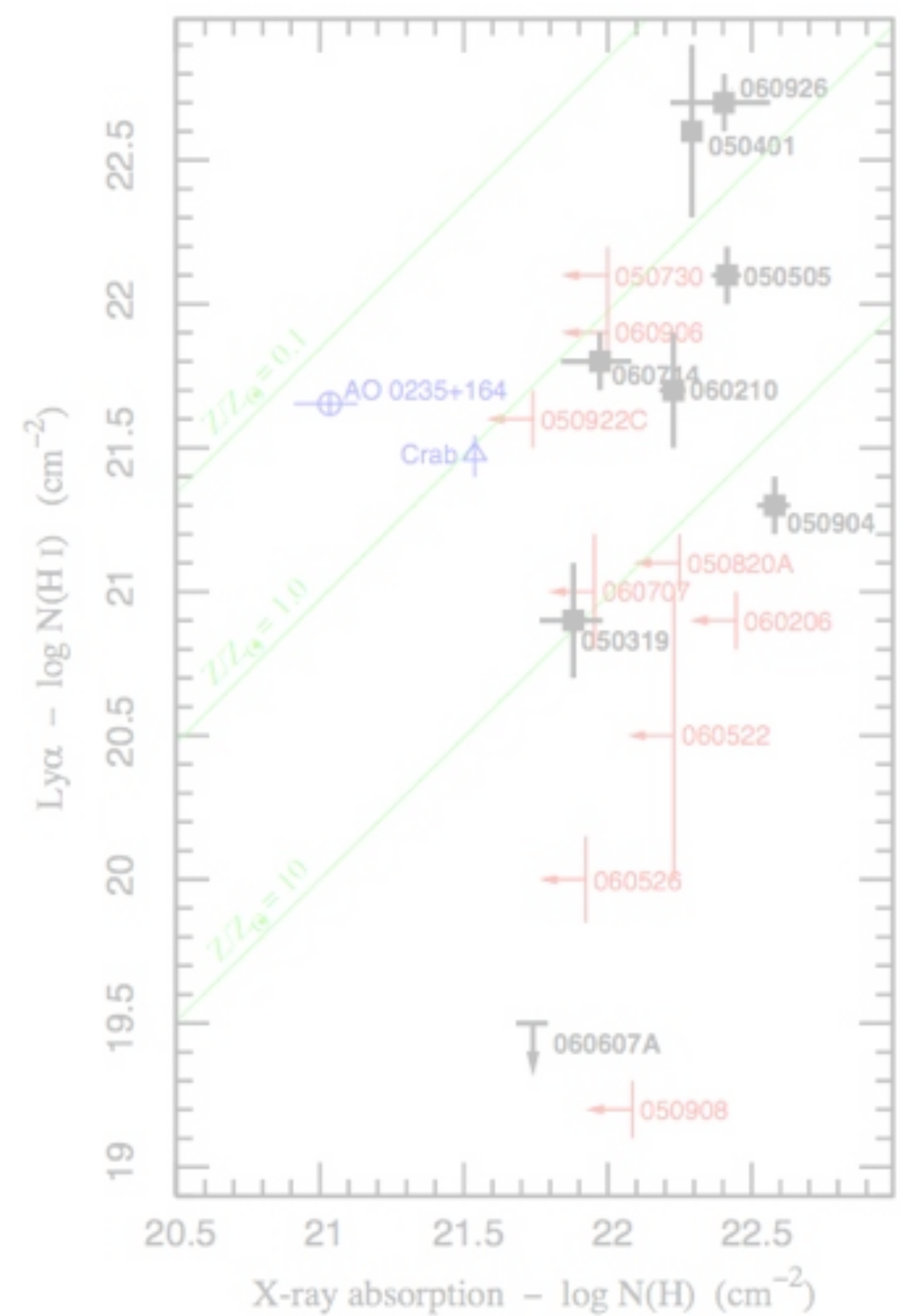

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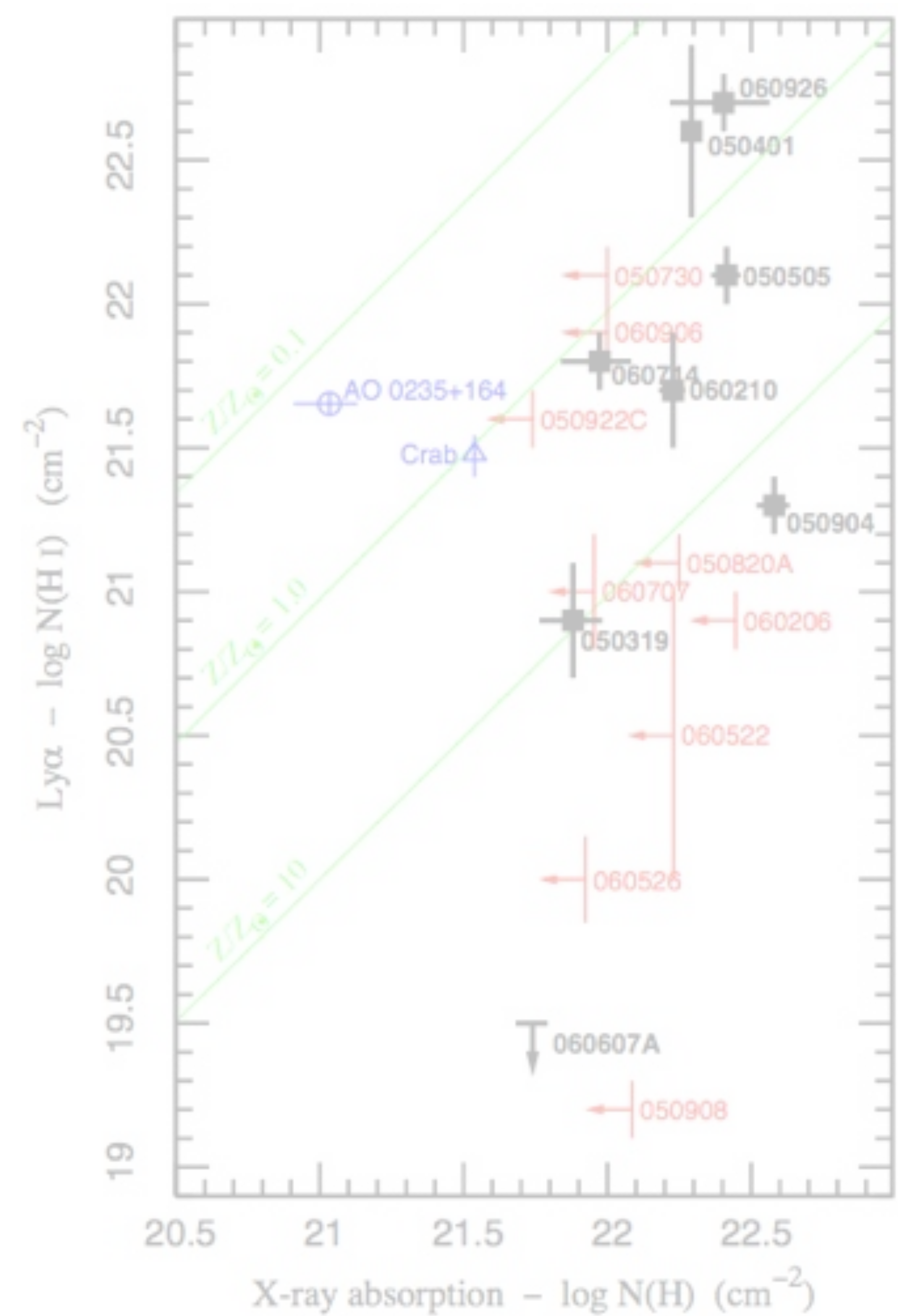

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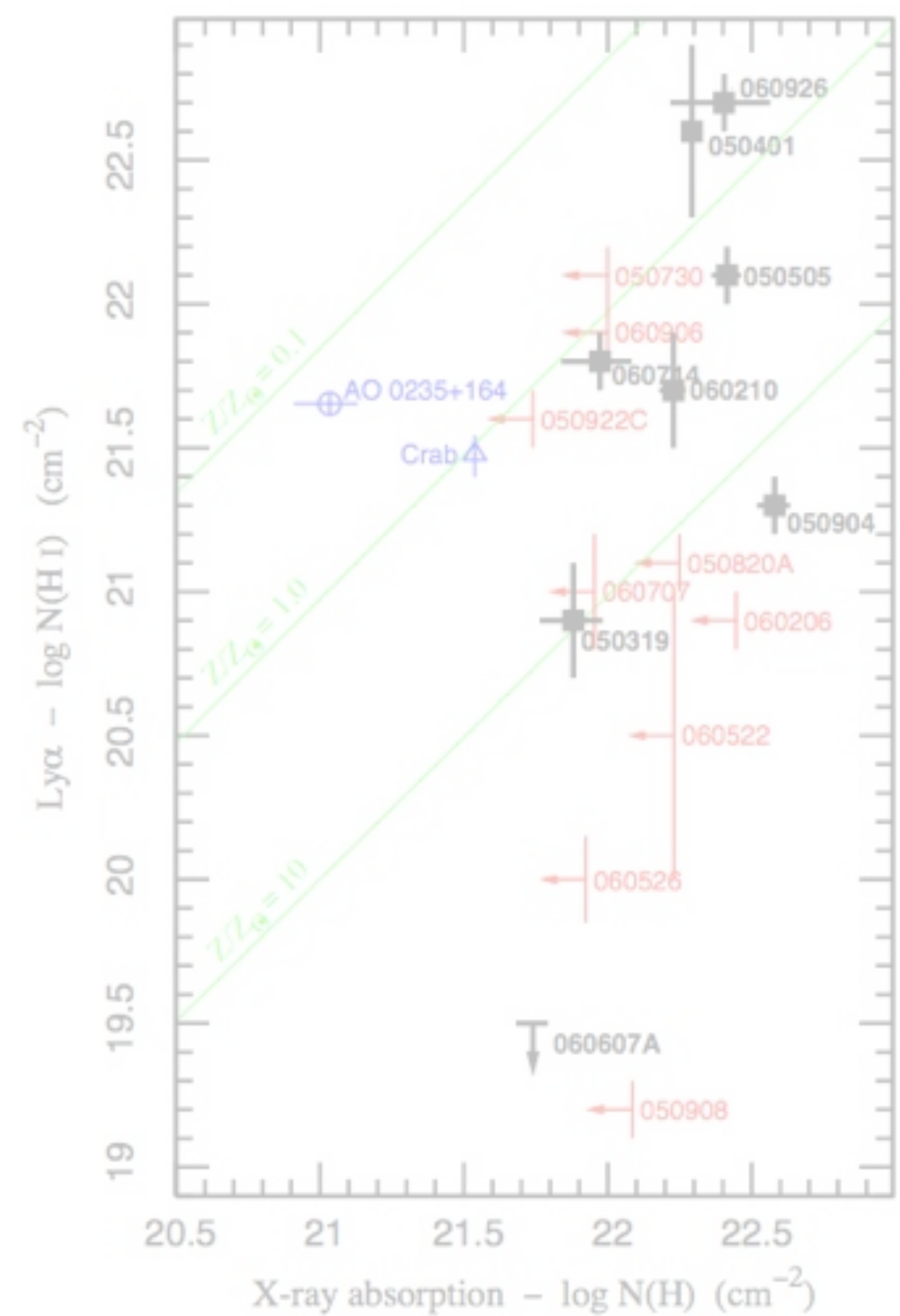

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Proposals

So what's Left?

- ~~Molecular cloud~~ — No: Should see neutral hydrogen
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- ~~Underestimated Gal. NH~~ — No: consistent with other surveys (dust, galactic sources)
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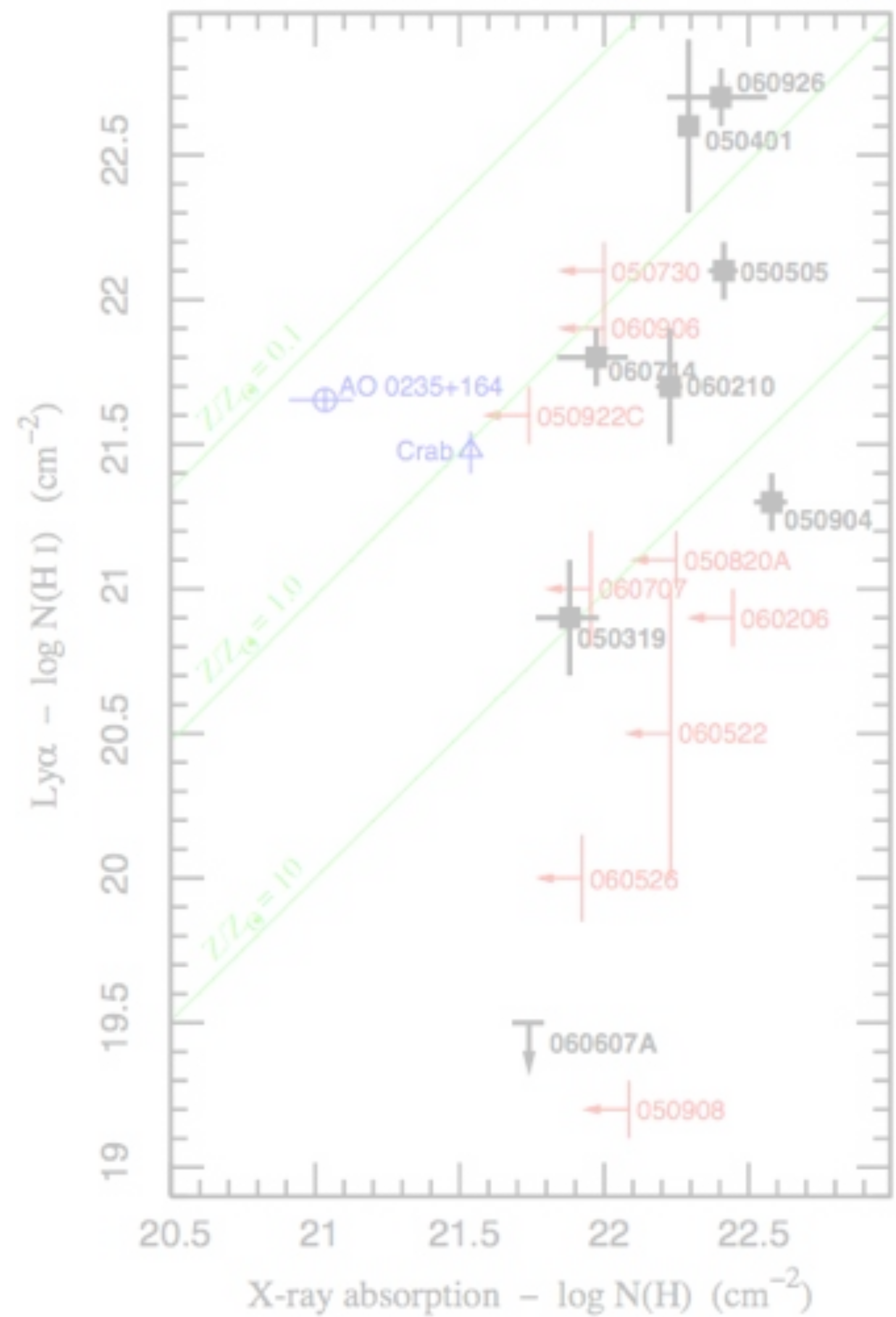

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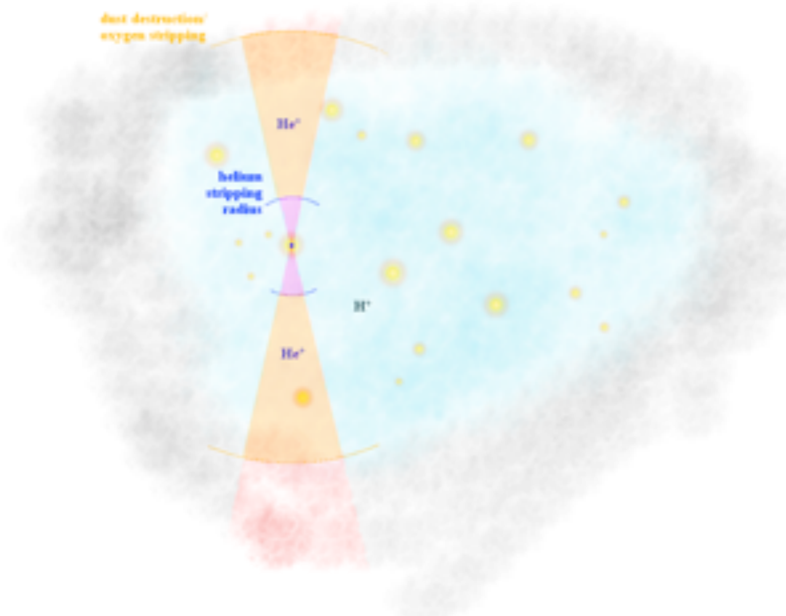
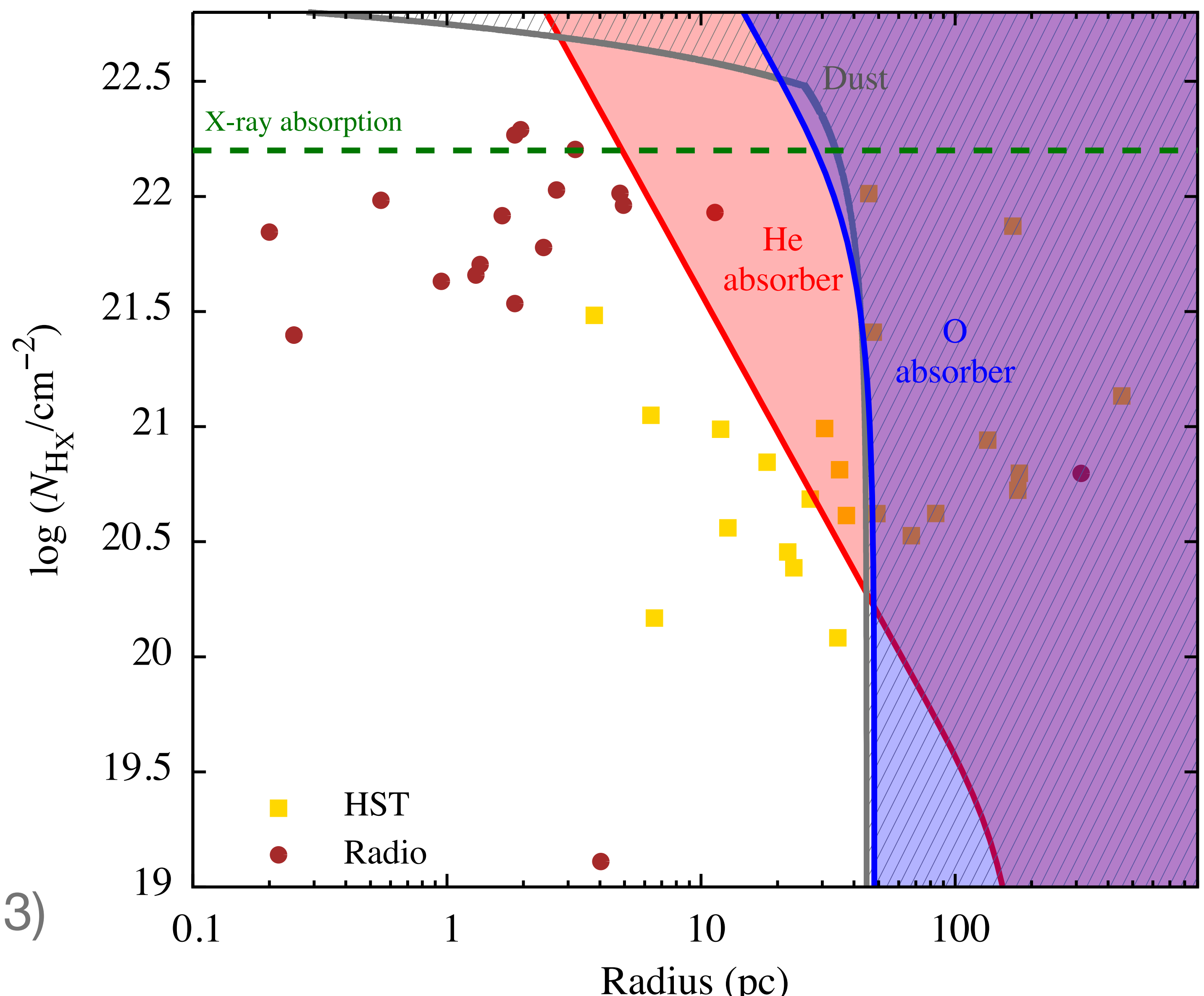
What's left

- Progenitor wind?
  - GRB destroys dust and strips gas out to large radii
  - Mass is too large to be progenitor wind
- HII region?
  - Previous problem — not enough HI observed
  - But if HI ionised by stars: He can absorb closer to the GRB than anything else
  - (H ionised by stars confirmed by Krongold & Prochaska 2013)





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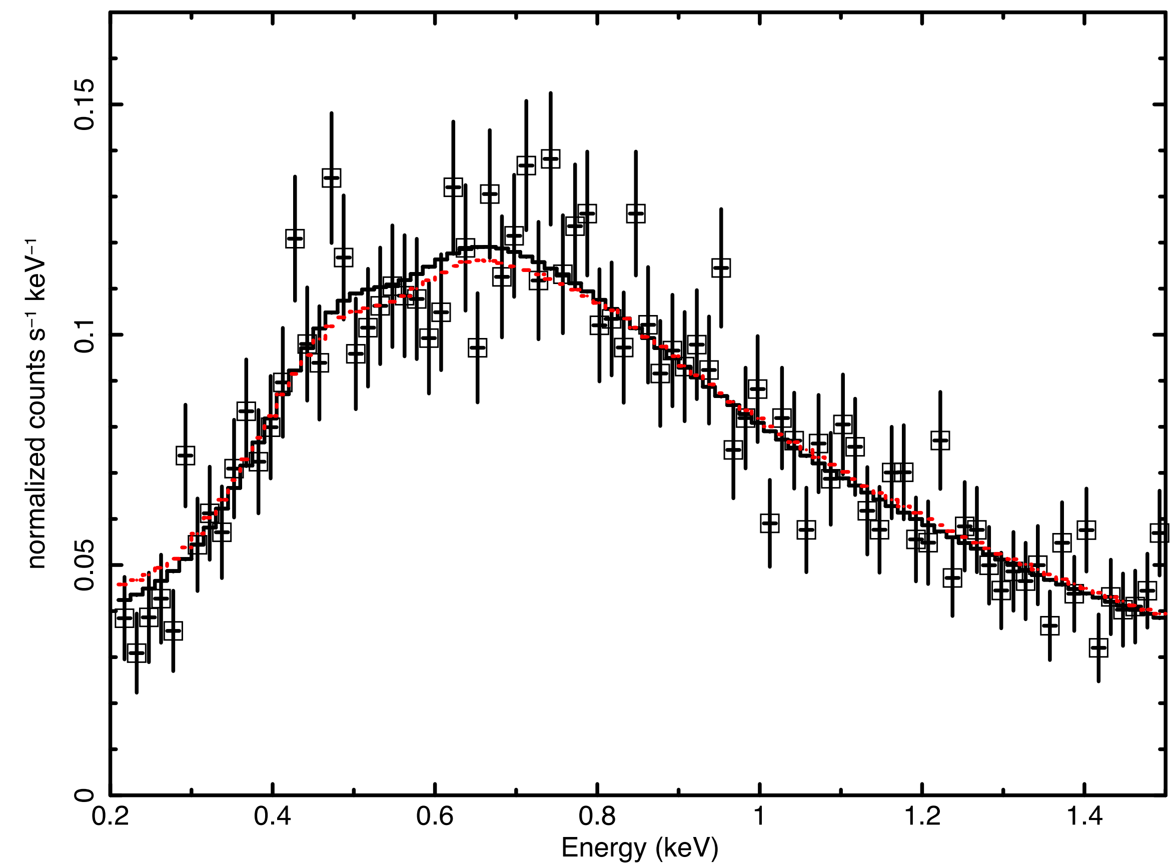
Signatures of He absorption

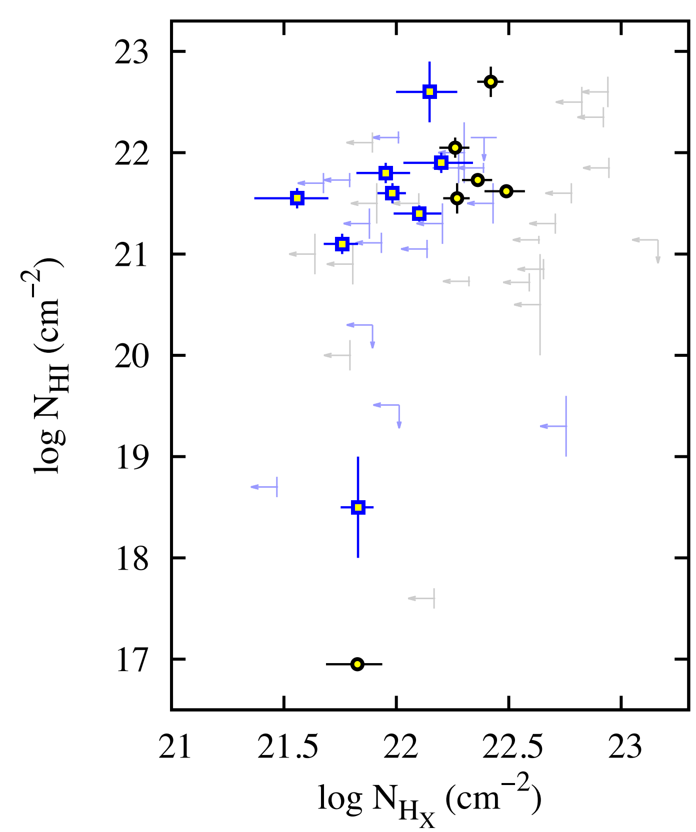
- No clear difference in low-res spectra between metal rich gas and He

- HII regions have higher column densities in dense environments => more likely to intersect a high density neutral cloud => approx. correlation between N_{Hx} and **gas (not metals)**

- N_{Hx} - N_{HI} correlation
  (confirmed by Covino et al. 2013)

- N_{Hx} - A_V correlation should change with redshift as mean cosmic metallicity drops.





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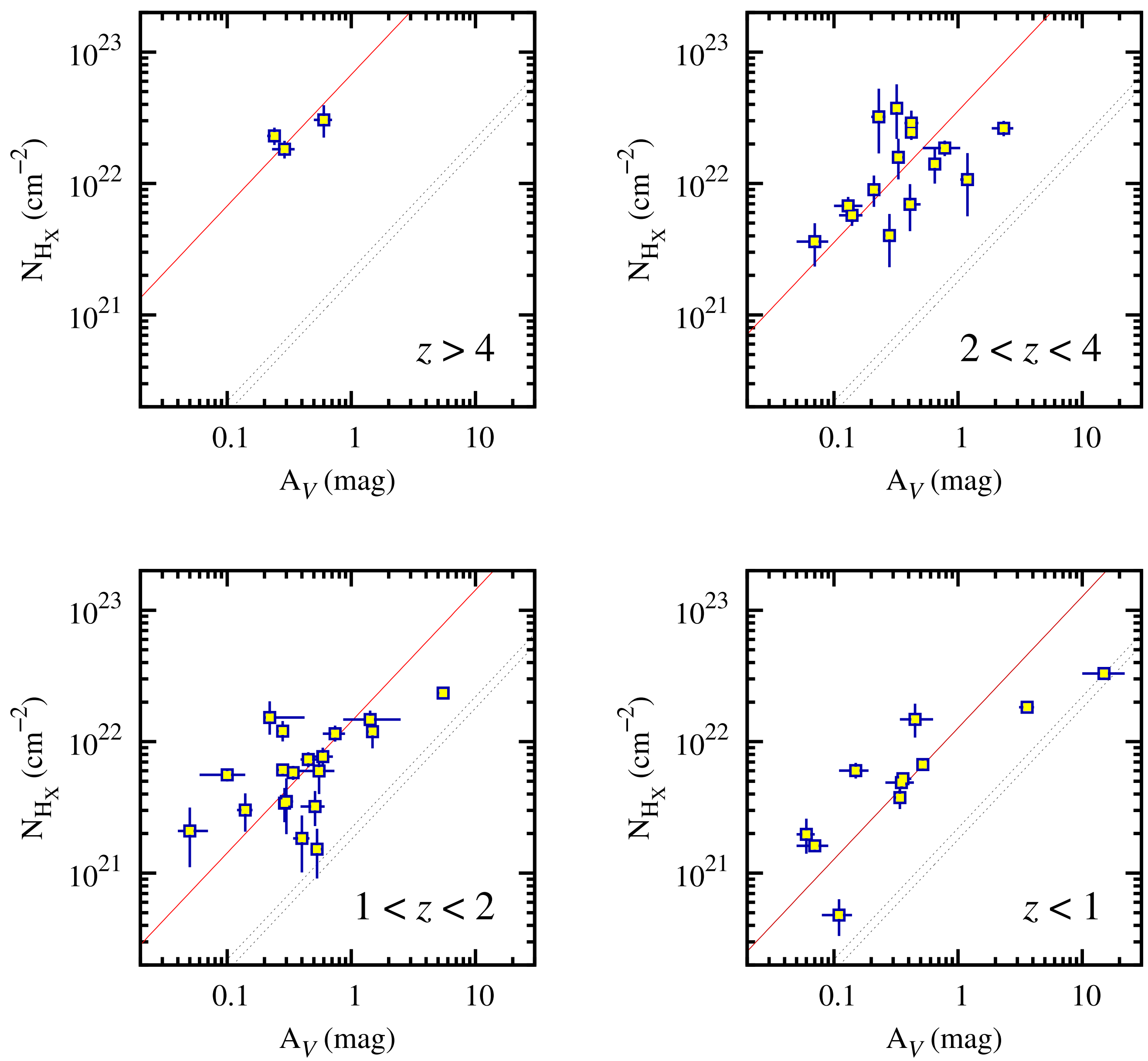

Watson et al. 2013.

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Conclusions

- The X-ray absorption in long GRB afterglows is primarily produced by He in the natal HII regions the stars that explode as GRBs.

- The GRB is powerful enough to destroy the dust and strip the metals associated with this gas

- The change in the N_{Hx}/A_V ratio with redshift is largely due to the change in cosmic metallicity

- Using information on the luminosity of a GRB and its N_{Hx} it should be possible to place limits on the sizes and densities of the HII regions of massive star-forming regions across a very large redshift range

END