The Magellan/MagE Survey for Molecular Hydrogen in High Redshift Galaxies

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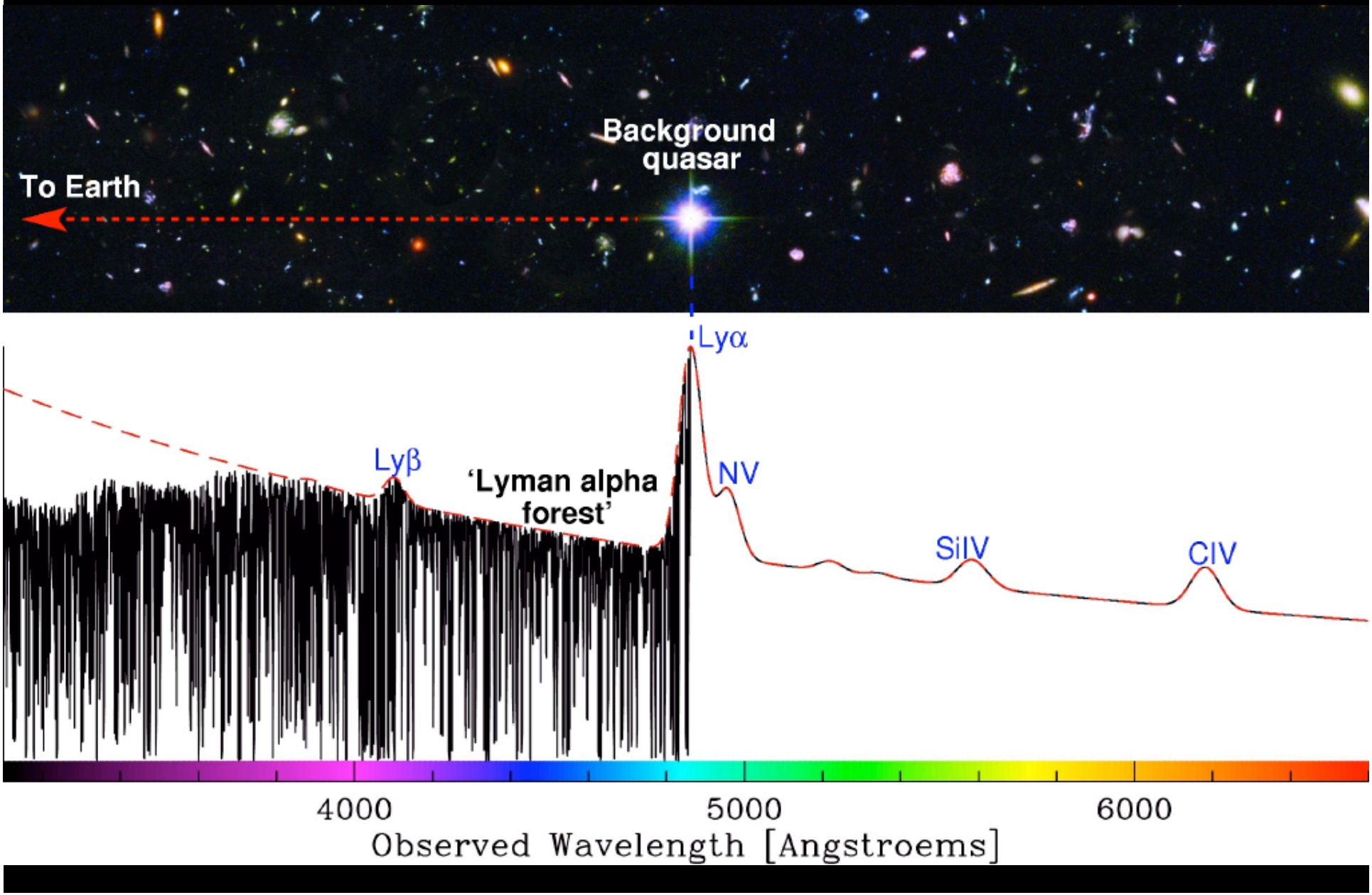
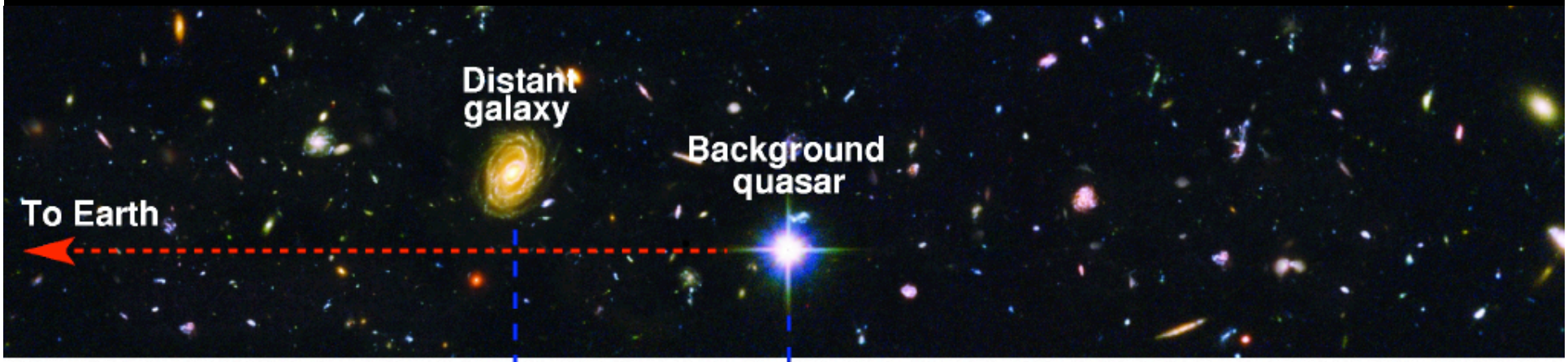
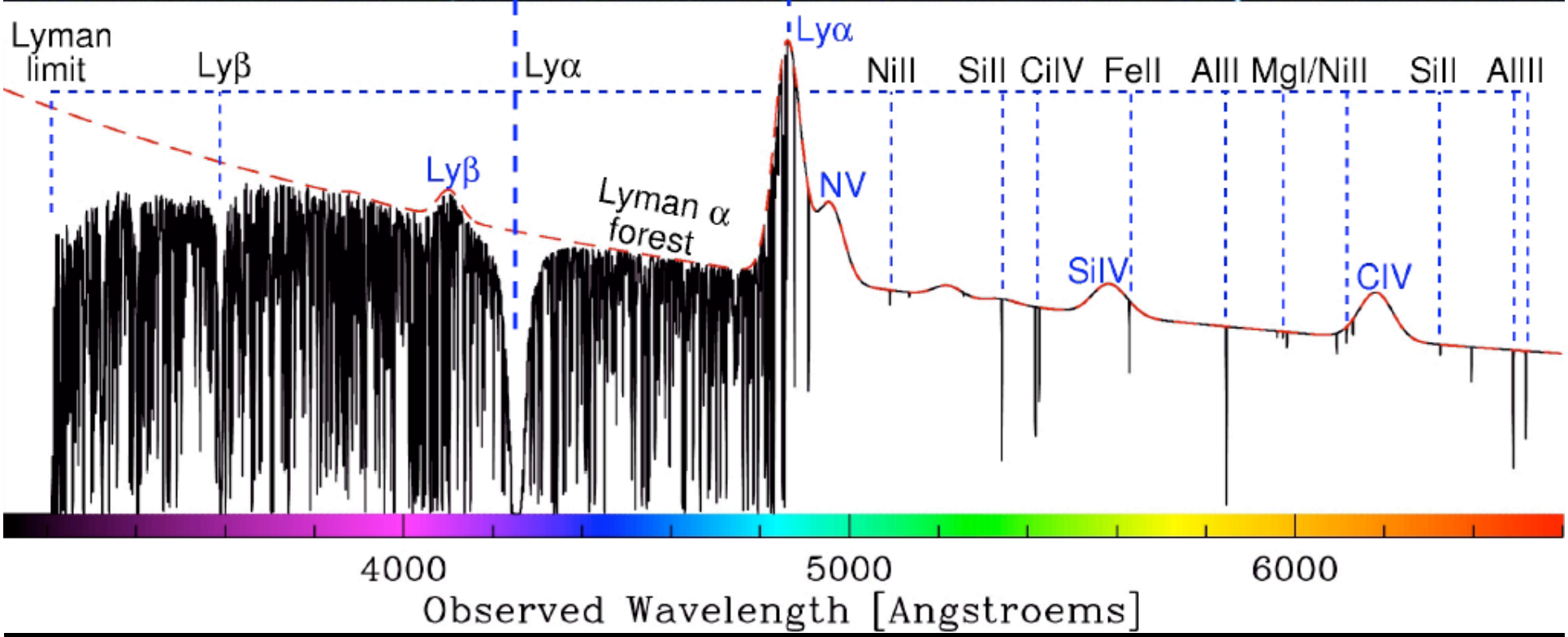
Typical Quasar Spectrum



Typical Quasar Spectrum





DLA - Star Formation Connection?

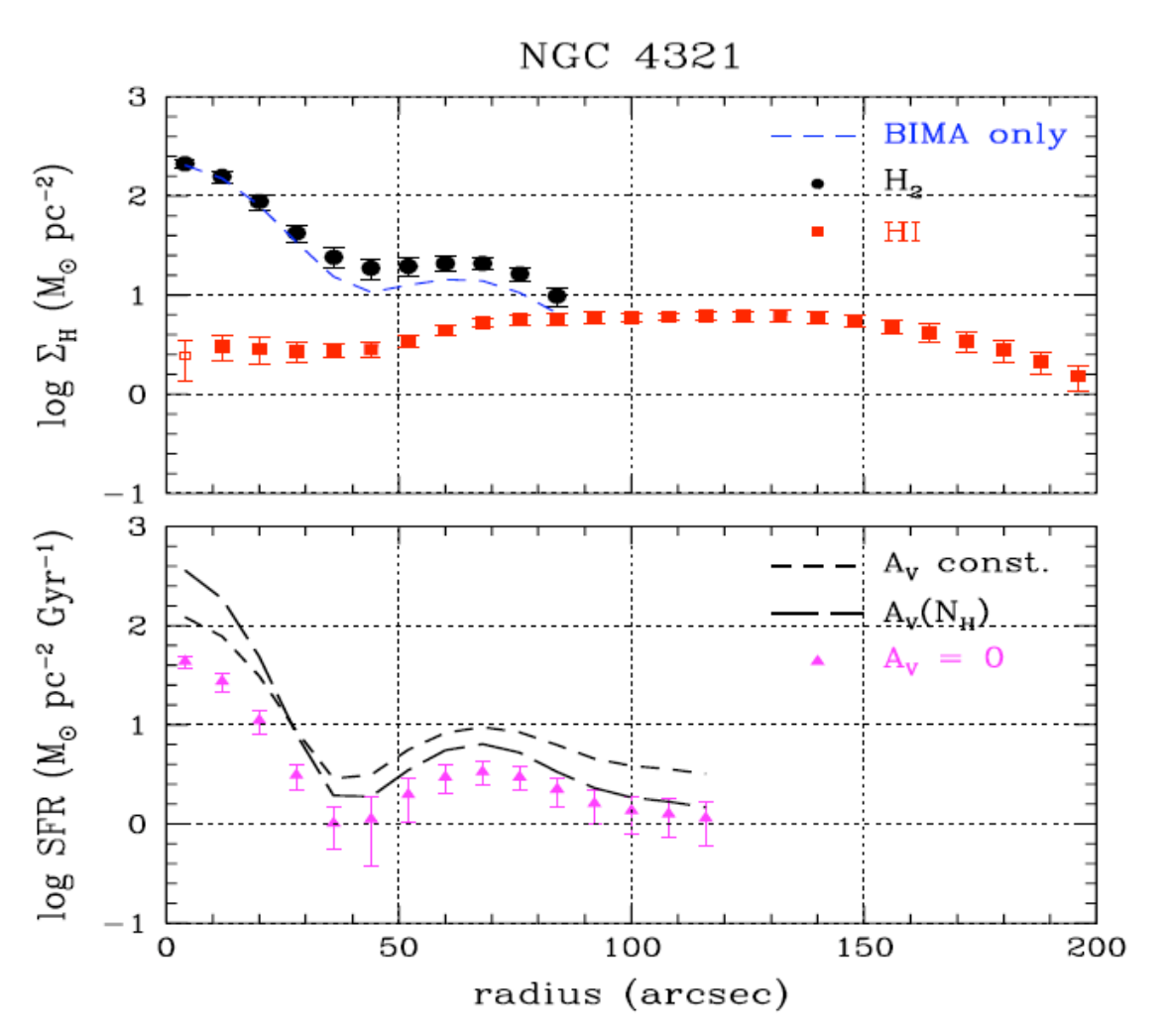
- Stars form out of neutral, not ionized, gas
  - By definition, DLA gas is primarily neutral ($N(HI) > 2 \times 10^{20}$ cm^{-2})
- DLA metalicities are generally [M/H] > -2.6, typically 1/30th solar
  - well above the IGM
  - Implies either *in situ* star formation or enrichment from earlier generations of stars
- [M/H] increases with cosmological time
- CII* λ1335.7 absorption implies SF
  - (Wolfe et al. 2003a & b)

Key Question

- So there is evidence of star formation in DLAs, but where is the gas that is actually turning into stars?

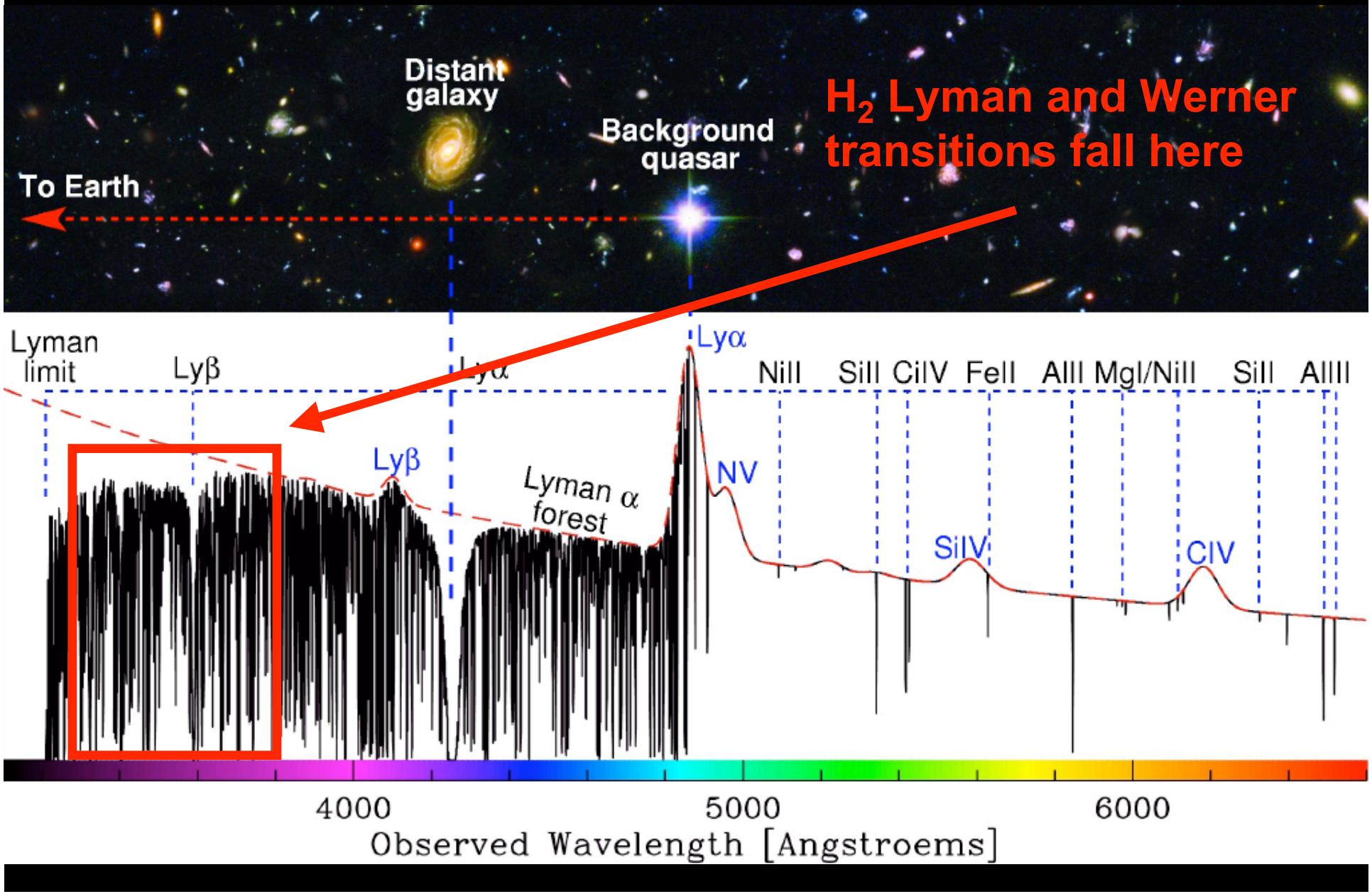
- Star formation requires H_2, so…

Star Formation follows H_2

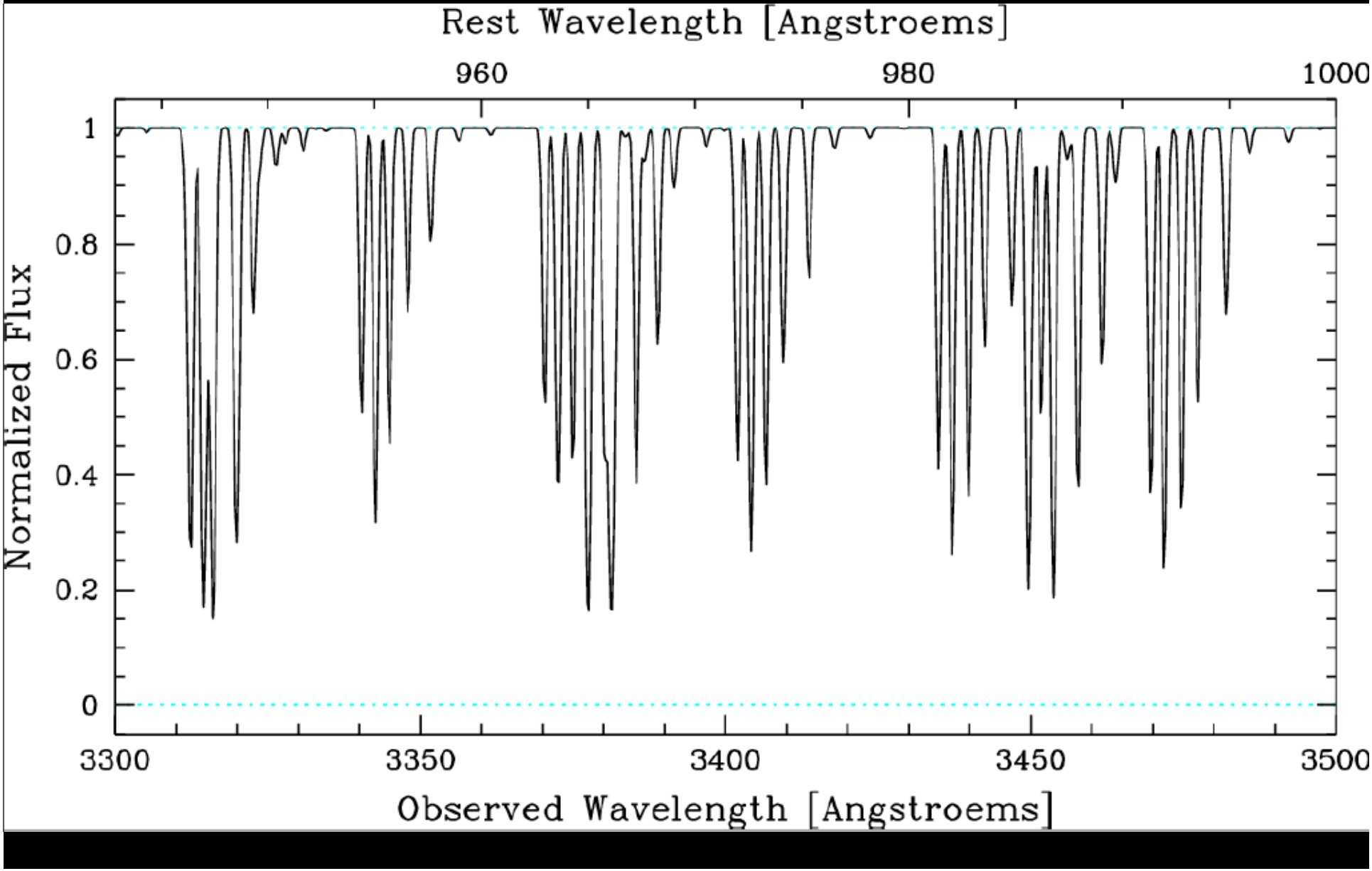


Wong & Blitz 2002

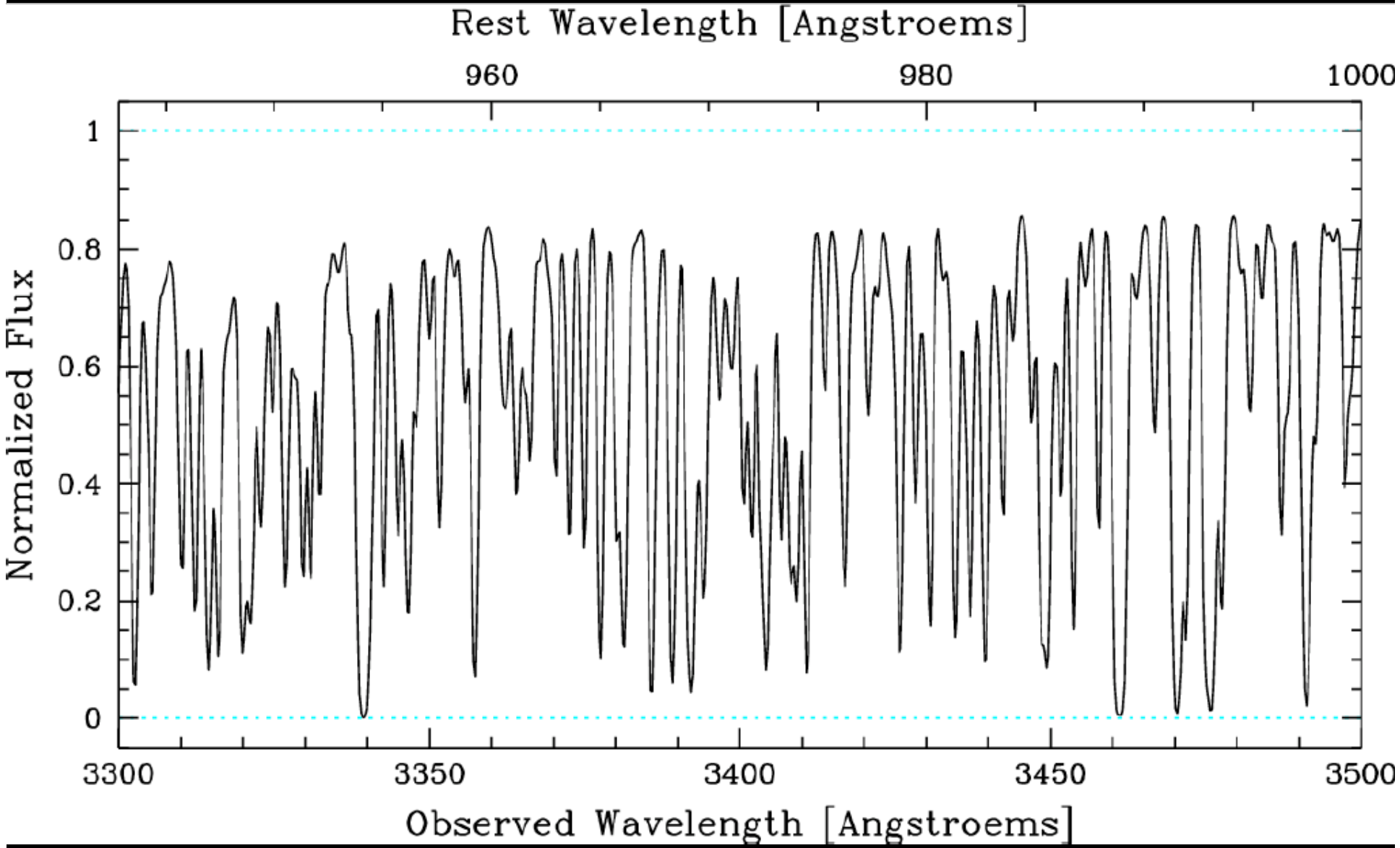
Where to look for H_2 in DLAs?



Synthetic H_2 Spectrum

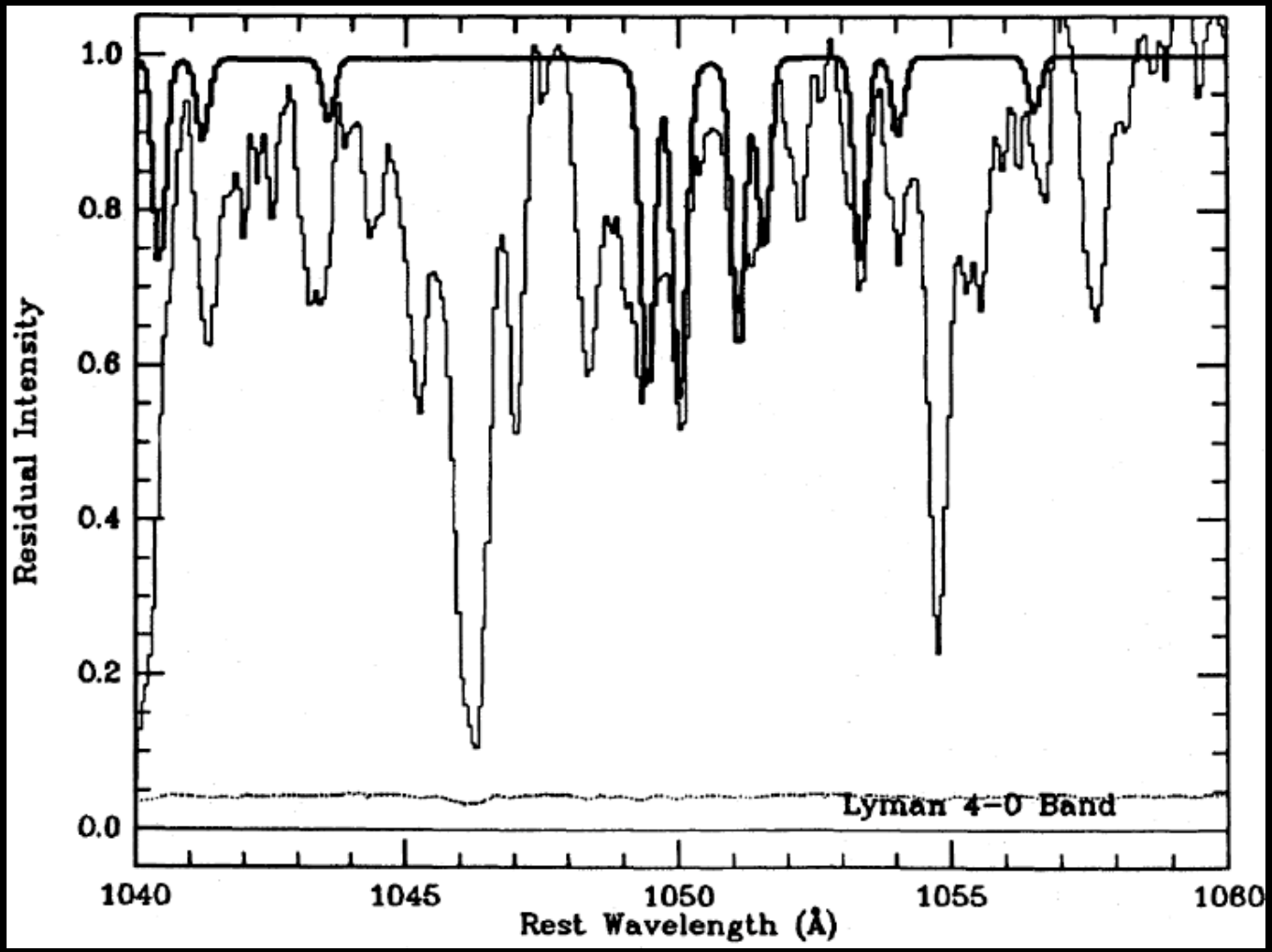


Synthetic H_2 + forest spectrum



Surveys for H_2 in DLAs

H_2 detected by Levshakov and Varshalovich (1985)



Foltz et al. 1988 H_2 confirmation spectrum

Surveys for H_2 in DLAs

H_2 detected by Levshakov and Varshalovich (1985)

Ledoux et al. (2003)

33 mainly archival VLT/UVES spectra

13 - 20% detection rate

Noterdaeme et al. (2008)

77 mainly archival spectra

10 - 16% detection rate

molecular fractions of log f = -1 $\Rightarrow$ -6

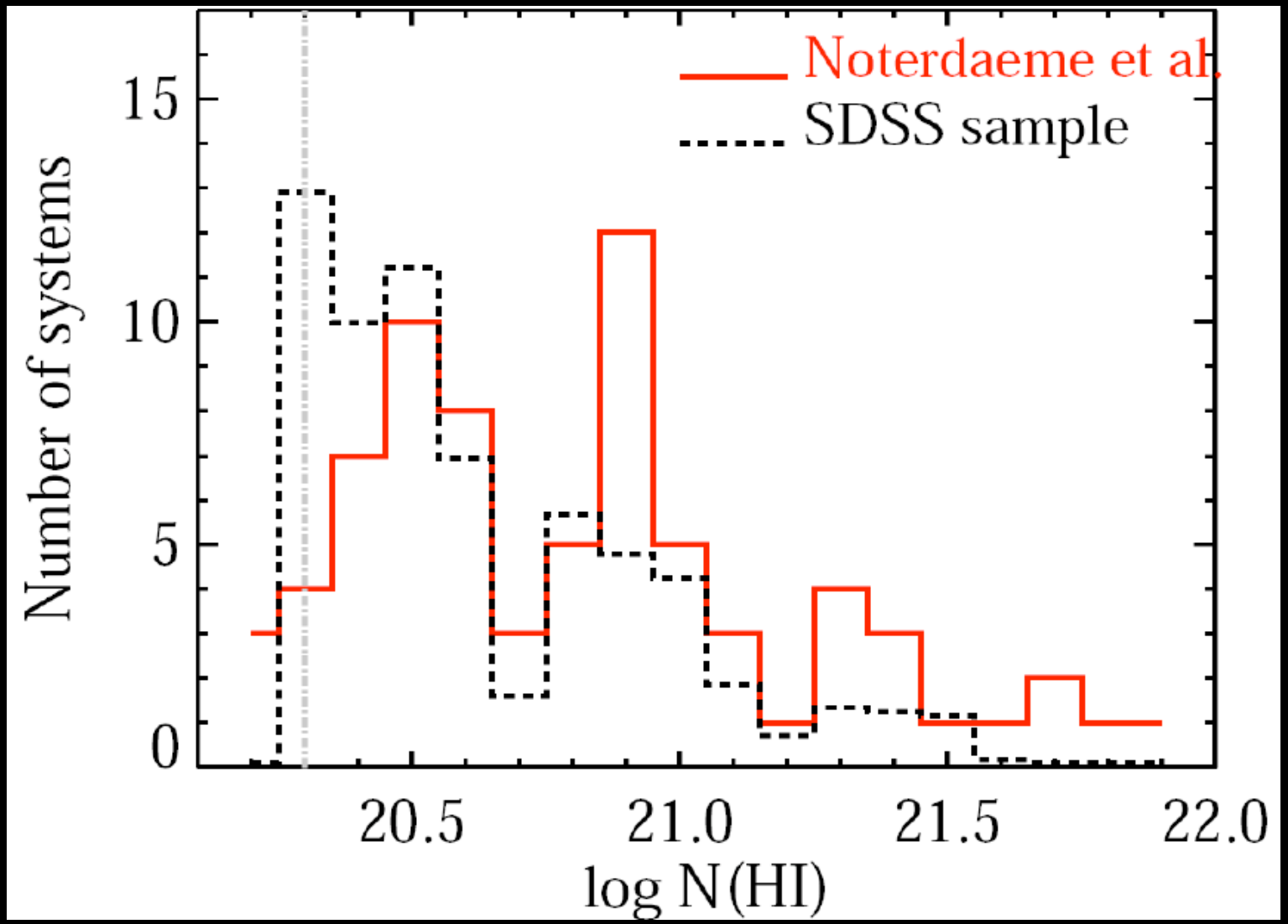
BUT….strong biases exist:

-- bright quasars selected for hi-res spectroscopy

-- strong metal-absorption selection in the archive

-- mainly high N(HI) systems targeted

Surveys for H_2 in DLAs

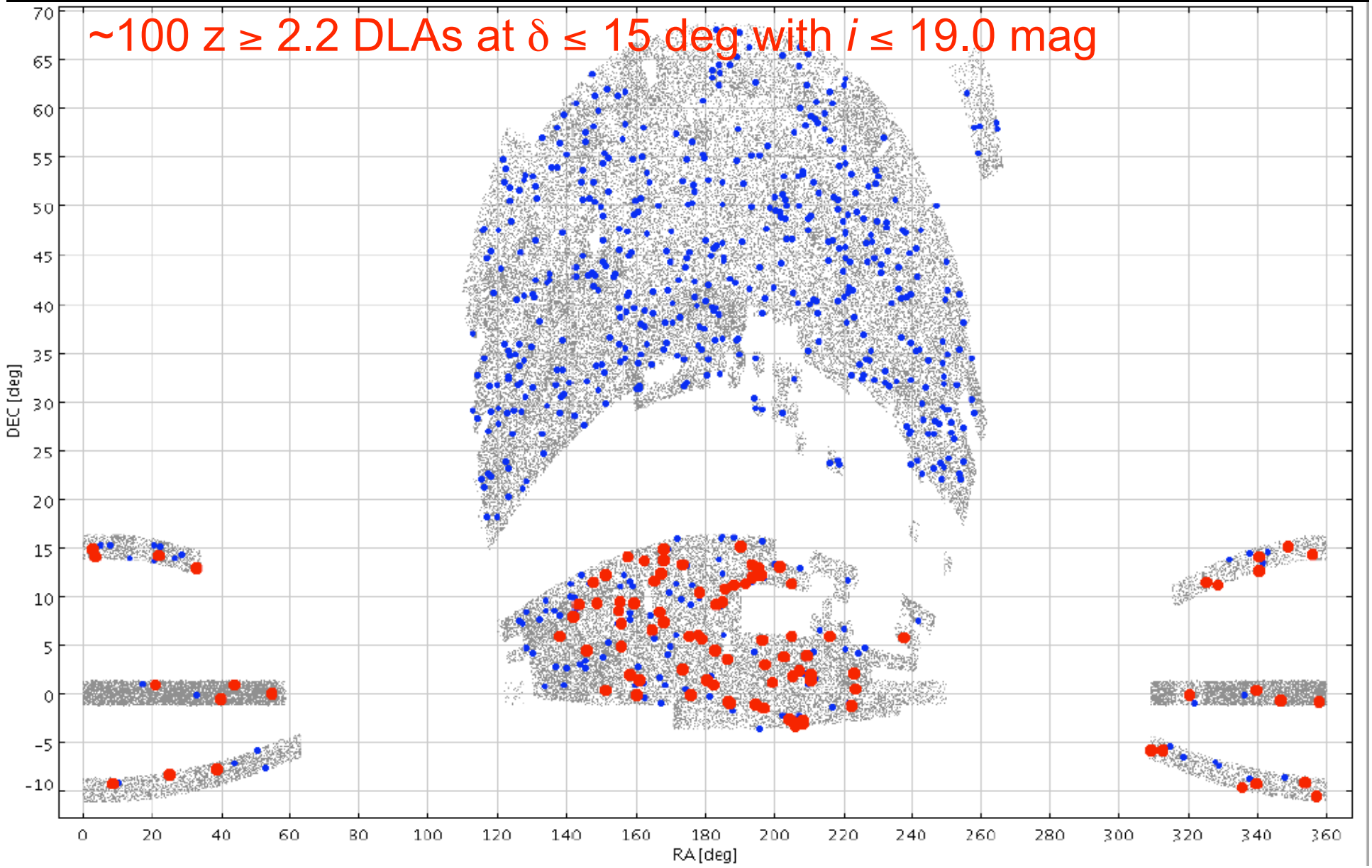


The Unbiased Magellan/MagE H_2 Survey

- MagE spectrograph is ideal for this survey
  - R ~ 4000 (~ 71 km/s)
  - Very UV sensitive

- ~ 100 $z \geq 2.2$ DLAs
  - $\delta \leq 15$ deg
  - $i \leq 19.0$ mag

The Unbiased Magellan Survey



Survey Status

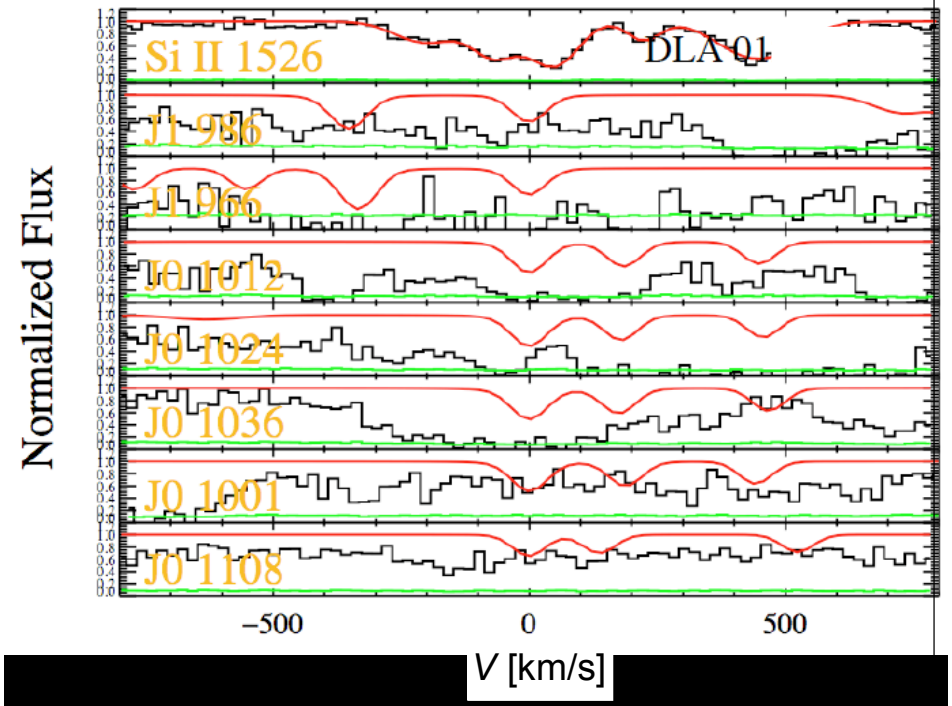
- 8 Magellan/MagE nights
  - Only ~ 70% useful due to weather
  - Some follow-up done w X-Shooter

- Final Sample: 110 DLAs
  - 96 DLAs observed (including archival data & X-Shooter data)
    - 9 missed because of bad weather
    - 5 more in archive

- No strong, obvious H_2 absorbers found!
  - 1 strong absorber already studied (UVES, Noterdaeme et al., 2007) was in sample
  - Based on past (biased) surveys with ~10% detection rate we would have expected several
    - Noterdaeme et al. (2008): 9/77 w log $N(H_2)$ >17.5 and log f_{H2} > -2.8

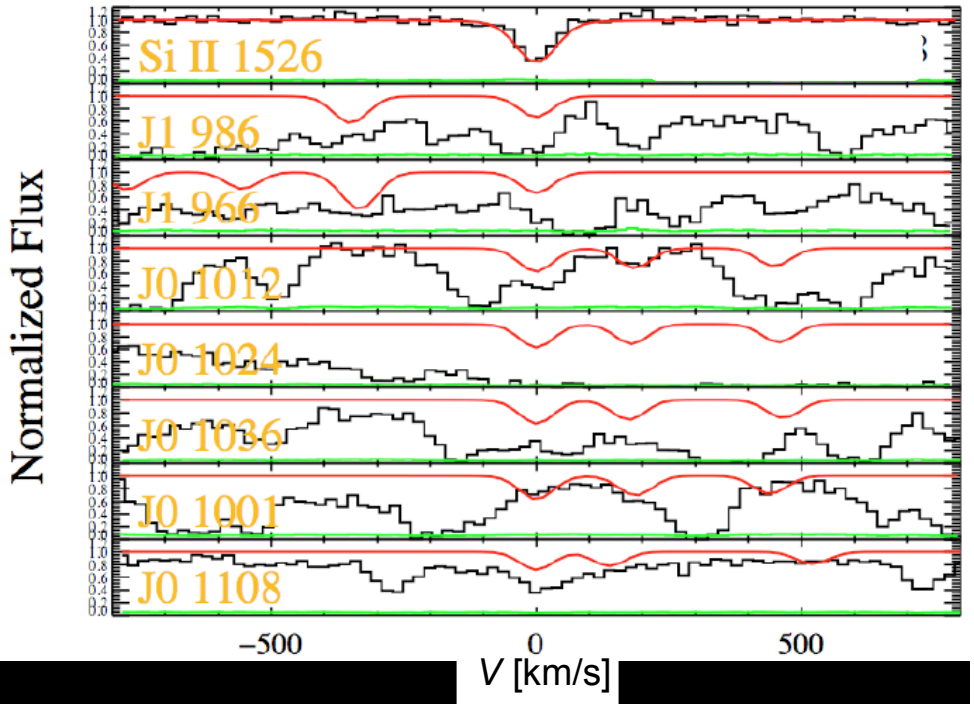
- Indicates low H_2 incidence and low H_2 covering fraction

Possible weak H_2 absorbers

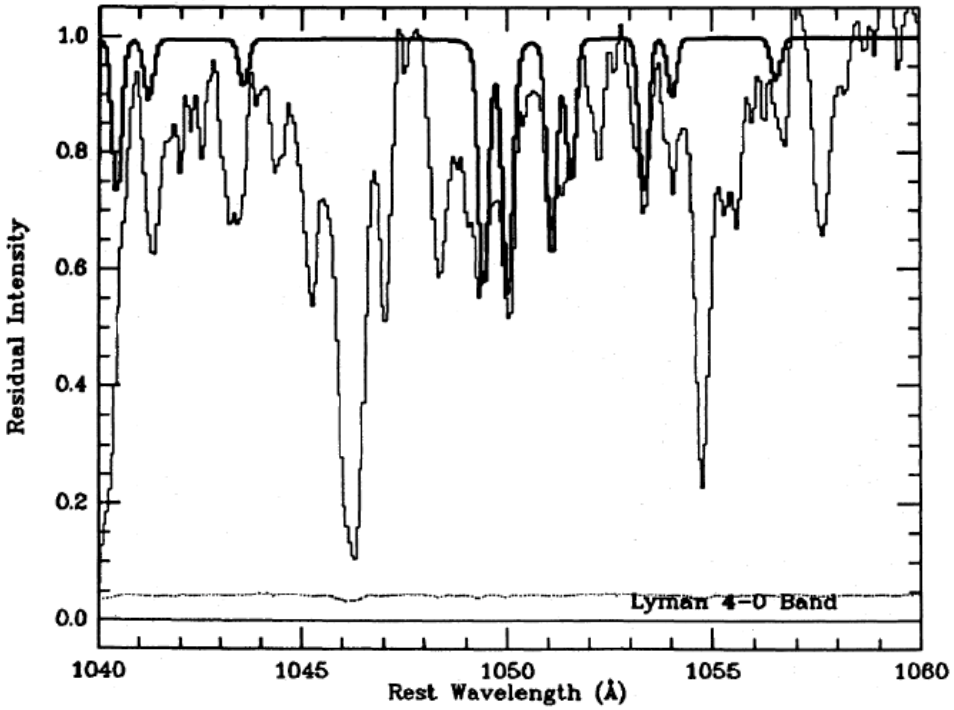


$N(H_2)^{total} \sim < 10^{17}$ cm^{-2}

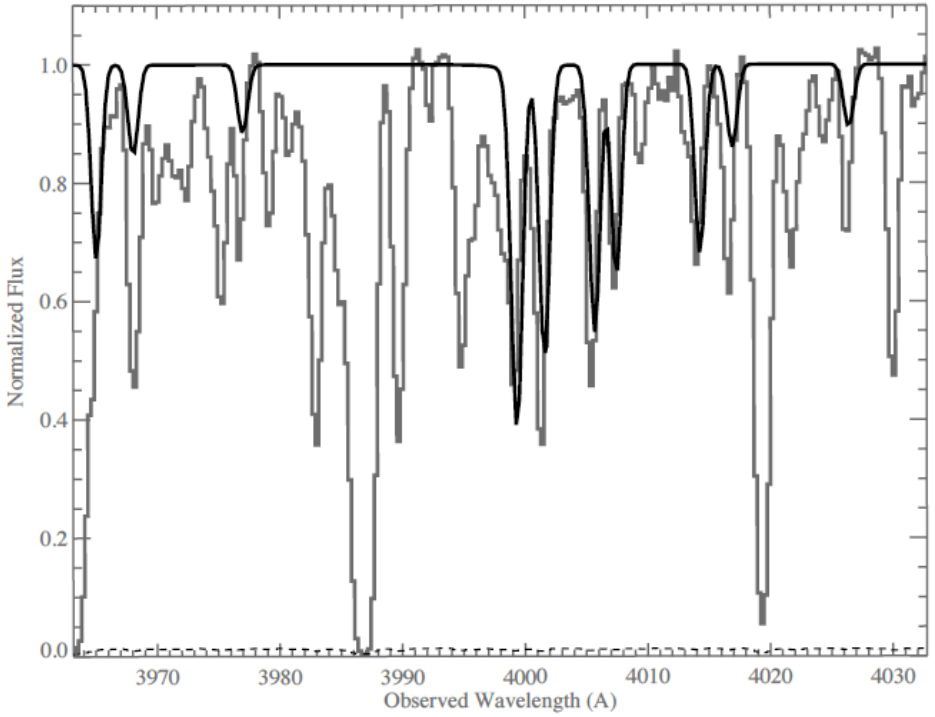
log f ~ < -3



Proof that we *can* detect H_2

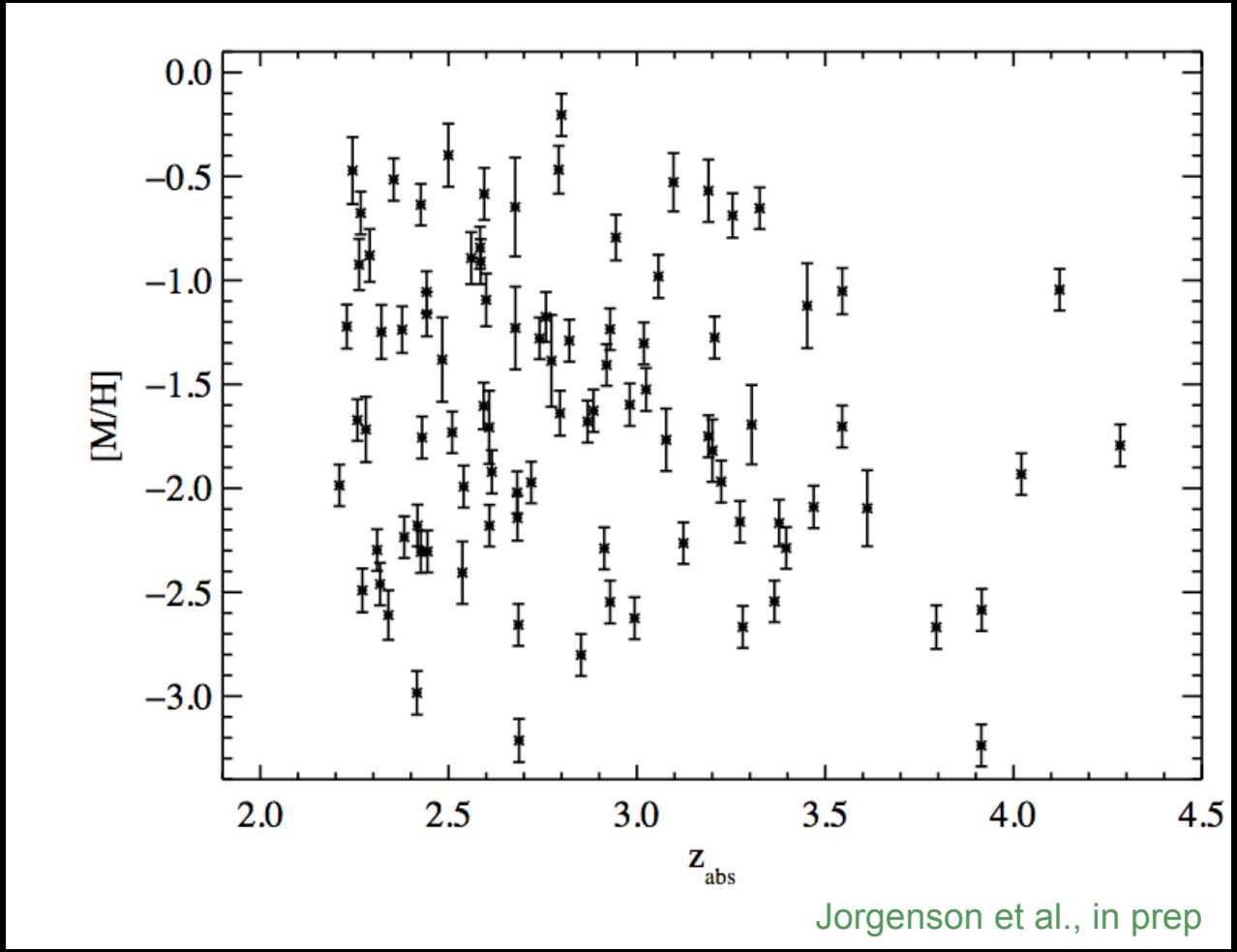


☆ Foltz et al. (1988) H_2 discovery spectrum with 1 Angstrom resolution (thin line) and H2 template (thick line).



☆ Our Magellan/MagE control spectrum of the Foltz object, taken 2009 (thin line) and H2 template (thick line).

Survey Status

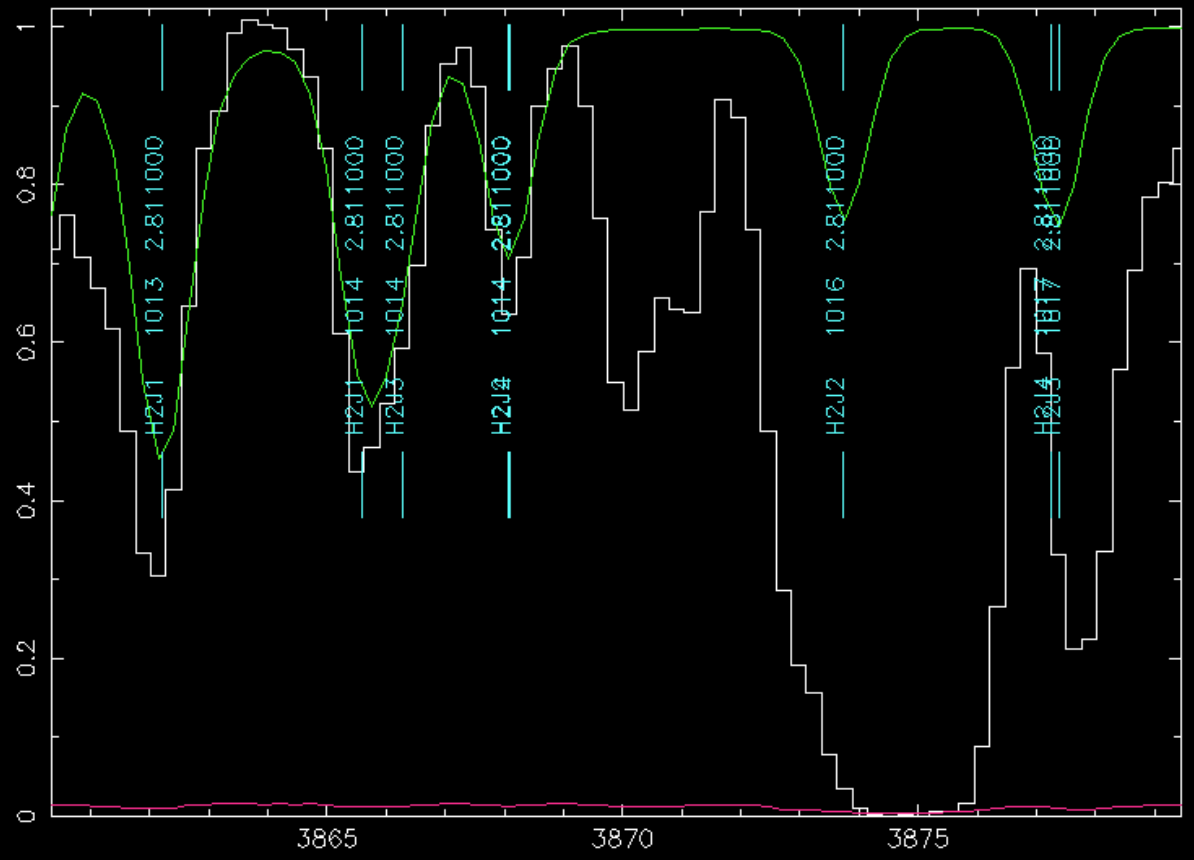


Jorgenson et al., in prep

Measuring N(H_2) upper limits in DLAs

- Use routine in RDGEN package
  - www.ast.cam.ac.uk/~rfc/rdgen.htm (Bob Carswell)
- Given z_{abs} and b (Doppler parameter), create a grid of Voigt profiles convolved with instrumental profile
- Each line is compared w data and χ^2 determined for pixels where Voigt profile is below the data
  - If not the case, the column density is increased
- This yields the highest possible column density even in the presence of blends because it is only those pixels where the fit violates the data that contribute

Measuring $N(H_2)$ upper limits in DLAs



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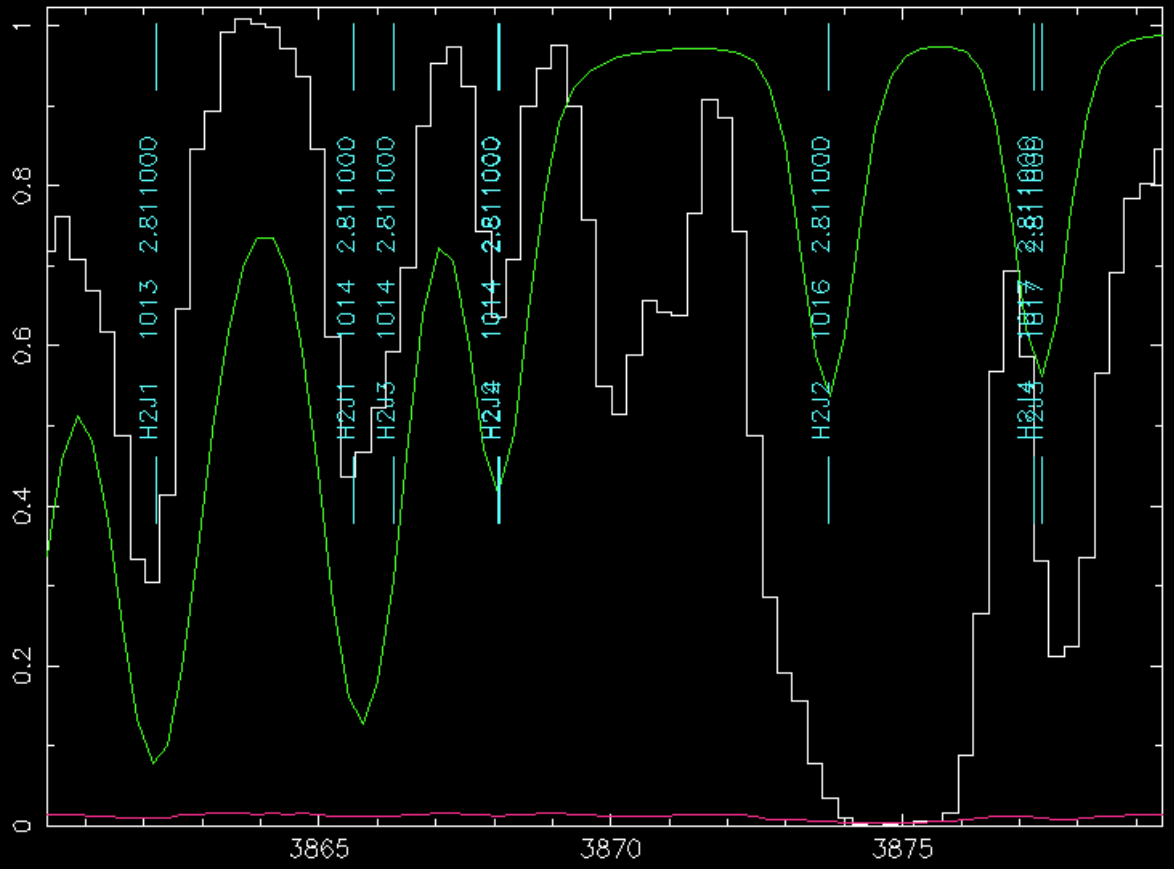
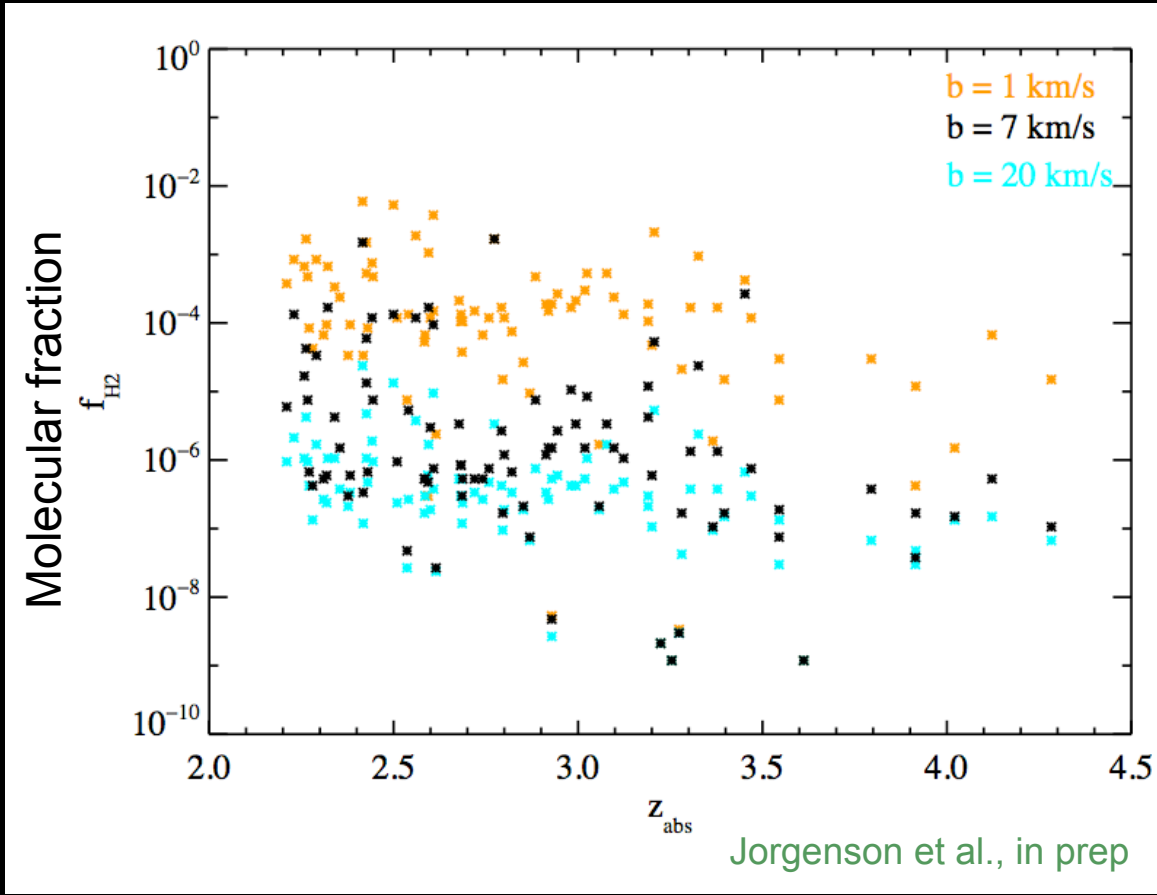
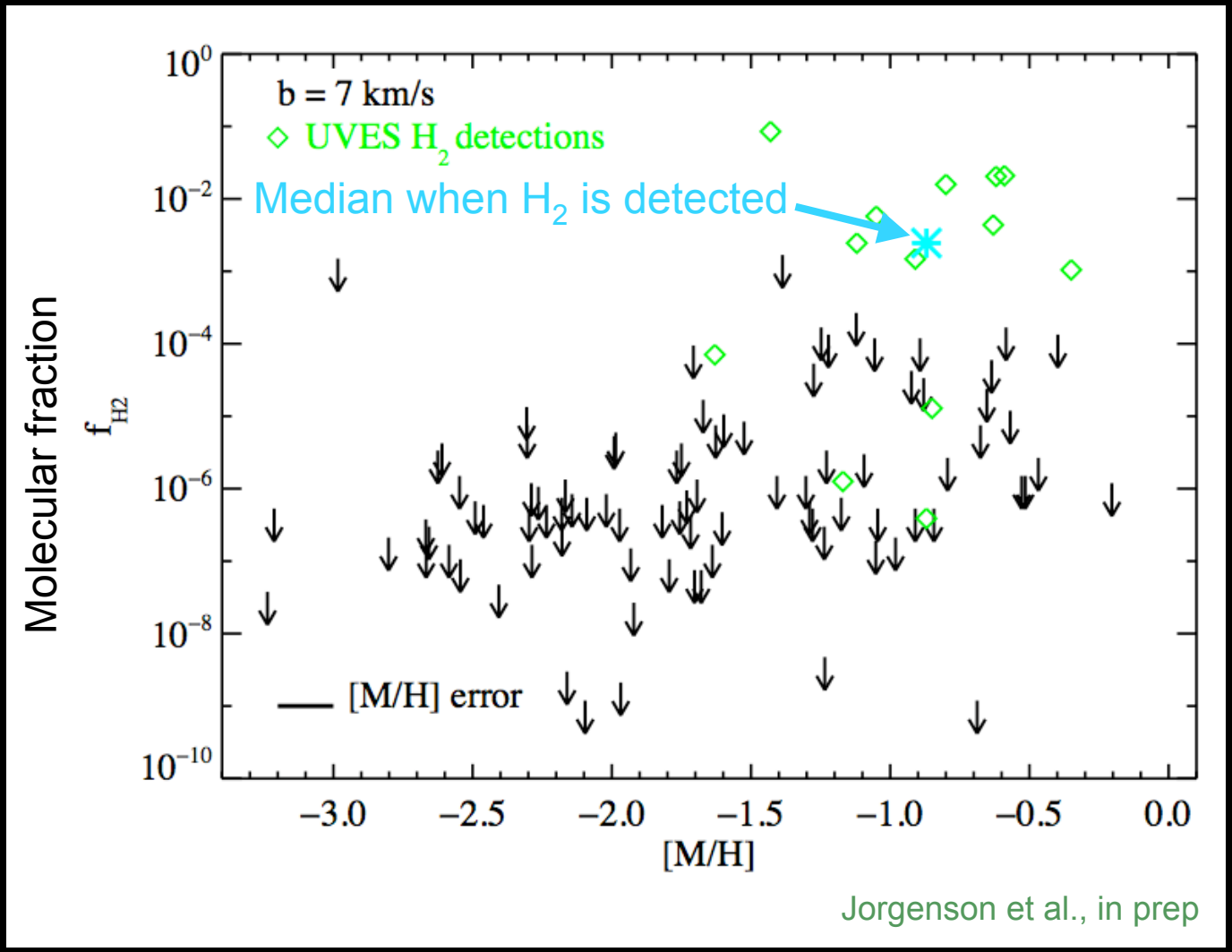


$N(H_2)$ upper limits in DLAs

Molecular fraction = $f = 2N(\mathrm{H_2})/(2N(\mathrm{H_2}) + N(\mathrm{H\ I}))$

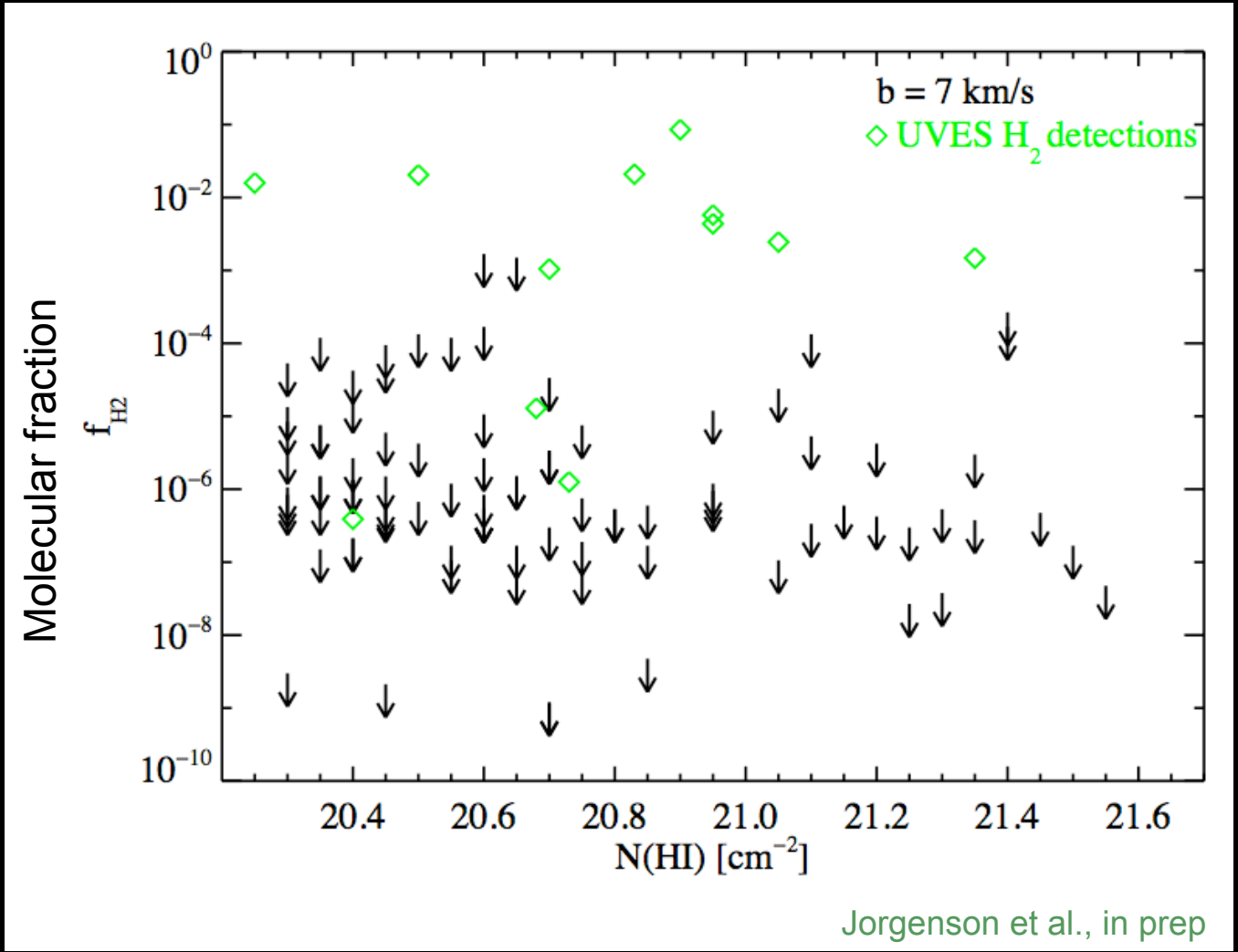


$N(H_2)$ upper limits in DLAs



Jorgenson et al., in prep

$N(H_2)$ upper limits in DLAs



Jorgenson et al., in prep

Summary

- 96 DLAs reveal very little H_2:
  - 1 (already known) detection out of 96
  - Covering factor:
    - For log $N(H_2)$ >17.5 cm^{-2} and log f_{H2} > -2.8 :
      - Noterdaeme et al. (2008): 9/77 ~ 12%
      - Unbiased MagE sample: 1/96 ~ 1%

- Upper limits on Molecular Fraction:

  (depends on assumed Doppler parameter)
  - Median for b = 12 km/s: $f_{H2} < 4.2 \times 10^{-7}$
  - Median for b = 1 km/s: $f_{H2} < 1.2 \times 10^{-4}$
  - Median of H_2 detections from UVES sample: $f_{H2} < 2.5 \times 10^{-3}$

Conclusions

- DLAs offer non-luminosity biased probes of high redshift galaxies and gas - star formation connection
- DLA - star formation connection not well understood
- H_2 incidence and covering fraction is one unknown aspect
- Blind, *unbiased* MagE survey reveals that covering factor and fraction of H_2 in DLAs is much lower than previously thought