

Reproducing the Kinematics of Damped Lyman-Alpha Systems

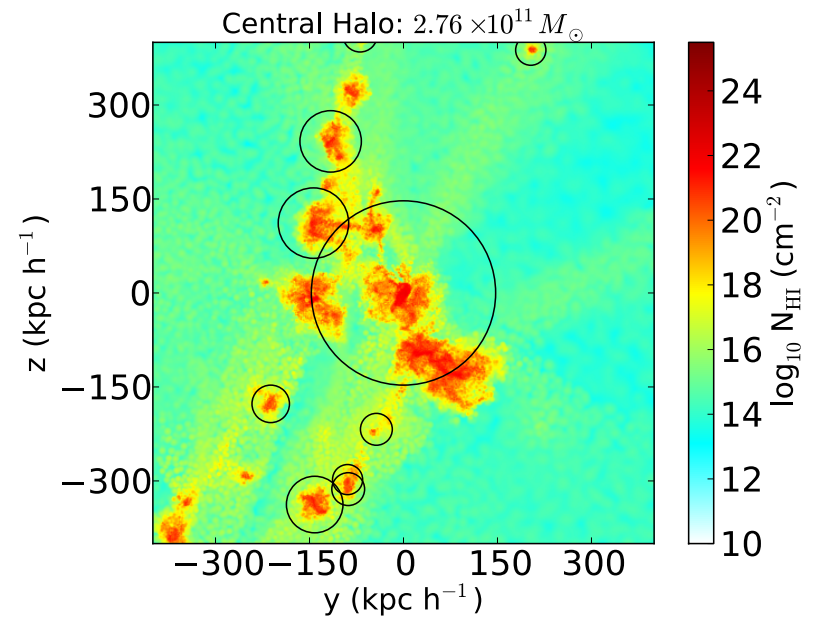
Simeon Bird, CMU

[arXiv:1407.7858](https://arxiv.org/abs/1407.7858)

with Martin Haehnelt, Marcel Neeleman and the Arepo team

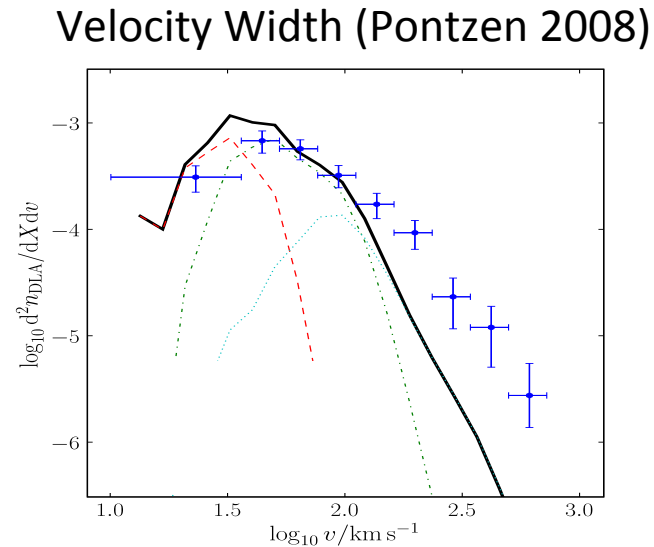
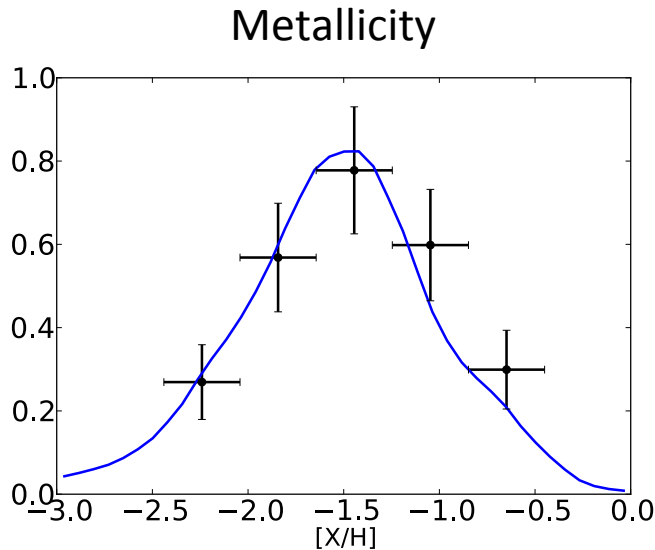
What are DLAs?

- Strong HI absorbers
- $N_{\text{HI}} > 2 \times 10^{20} \text{ cm}^{-2}$
- Nearly-star-forming gas



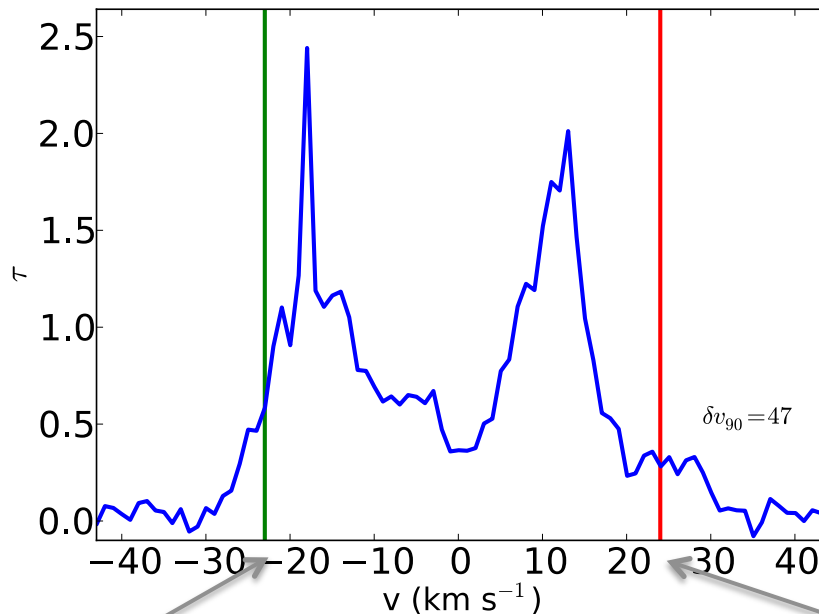
What hosts DLAs?

- Can match number, metallicity with halo mass 10^{10} - 10^{11} (arXiv:1405.3994)



- But velocity dispersion too low (e.g. Pontzen)
- Larger halos?

Measuring DLA Velocity Structure

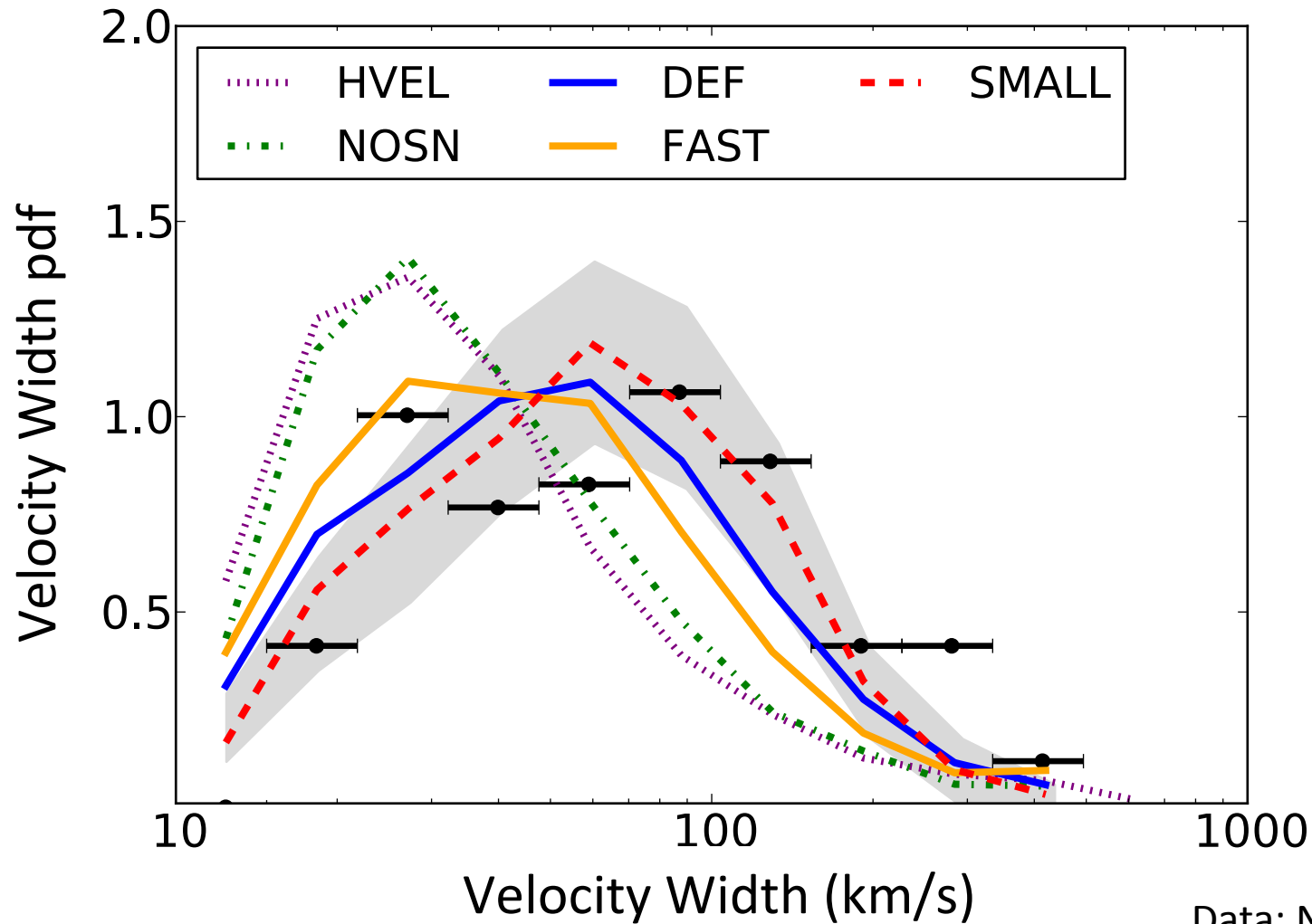


Use metal lines:
Lyman- α saturated

Velocity width: 90% of total optical depth

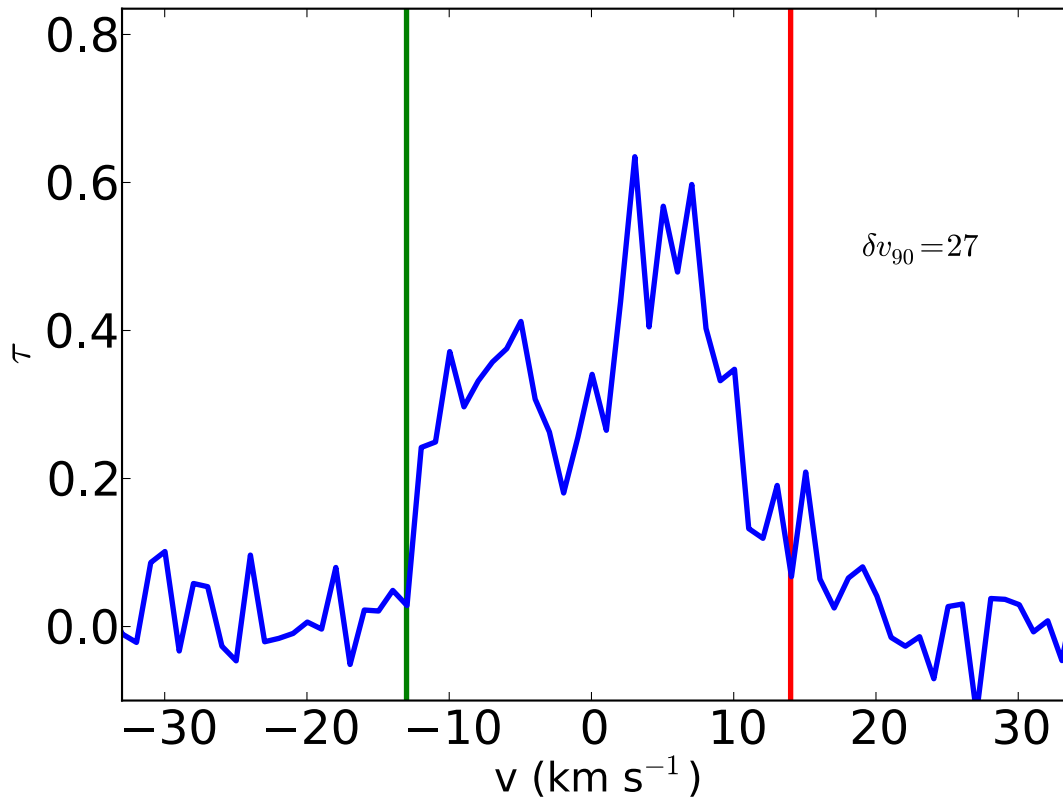
Correlates with halo virial velocity

Velocity Widths



Data: Neeleman+ 2013

How did we do this?



Run cosmological hydro simulation (25,10 Mpc)

Sample snapshot randomly for 5000 DLA spectra

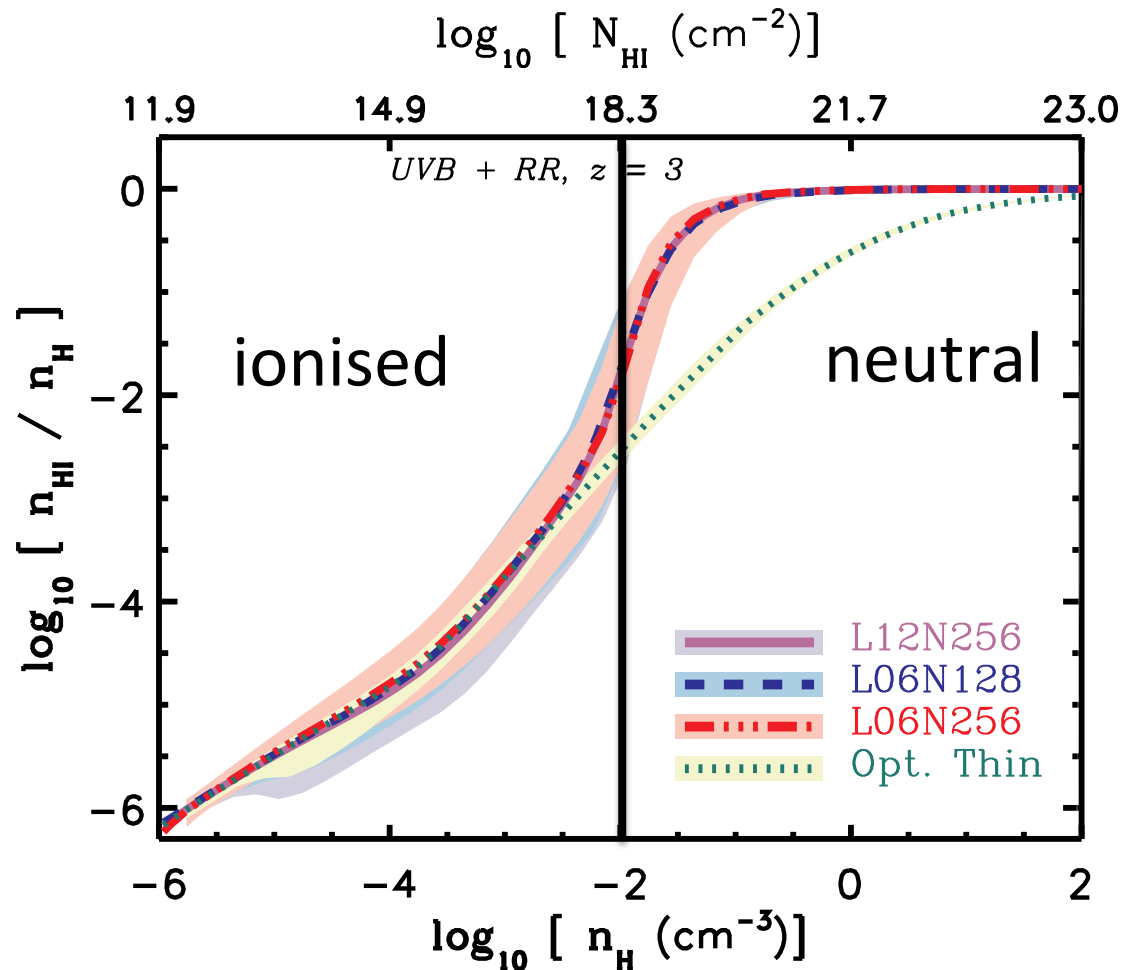
How did we do this?

Two Important Ingredients

1. Gas shielding from ionising background
2. Stellar feedback model

Shielding

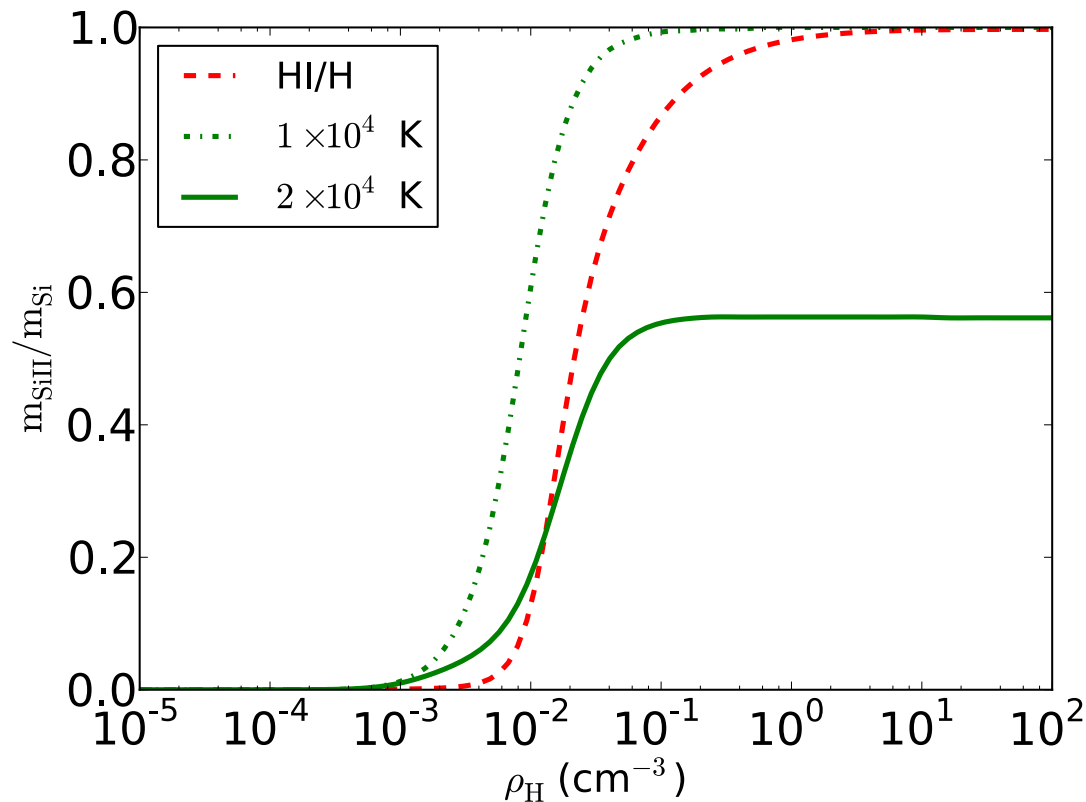
Photoionisation rate reduced by self-shielding



Shielding for Metals

Same self-shielding for $E > 1$ Rydberg

SII at lower density than HI ($16.3 > 13.6$)



Stellar Feedback

DEF: Outflows with velocity proportional to halo circular velocity (high mass loading to suppress star formation in dwarfs)

Mass loading: $\eta \propto v_{\text{w}}^{-2}$

Wind velocity: $v_{\text{w}} = 3.7\sigma_{1\text{D}}$

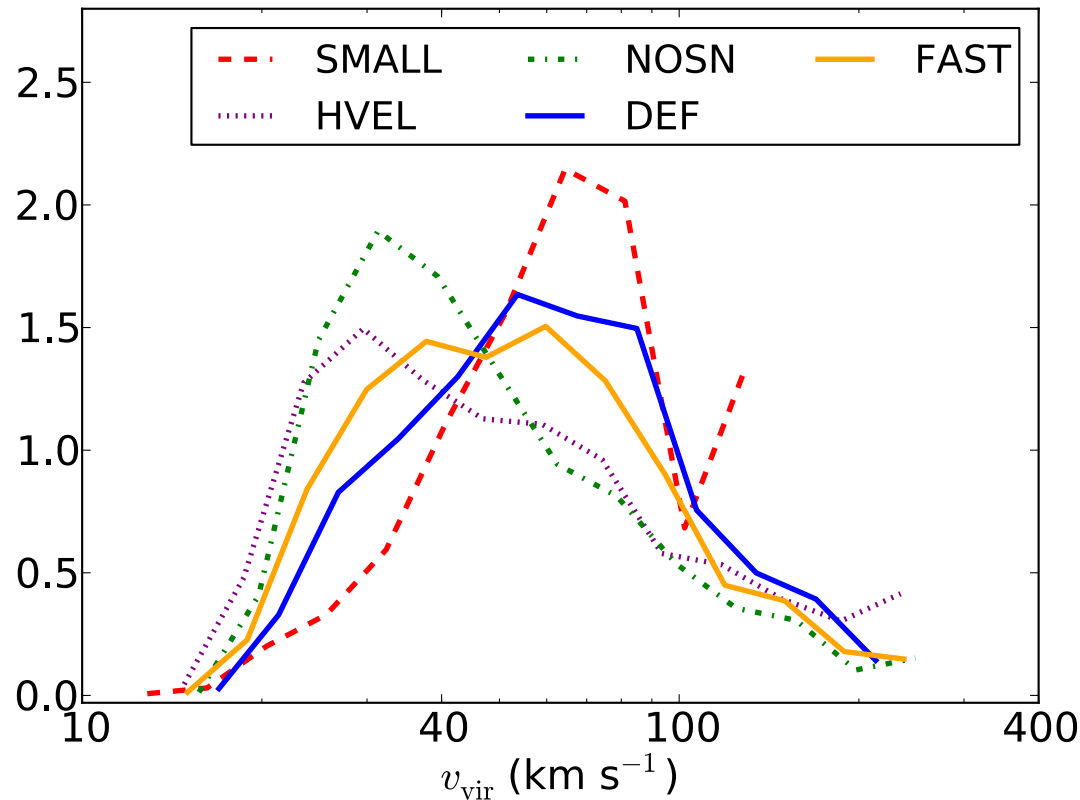
Outflows in small halos SLOWER but push out more mass

Stellar Feedback

Four models (25,512):

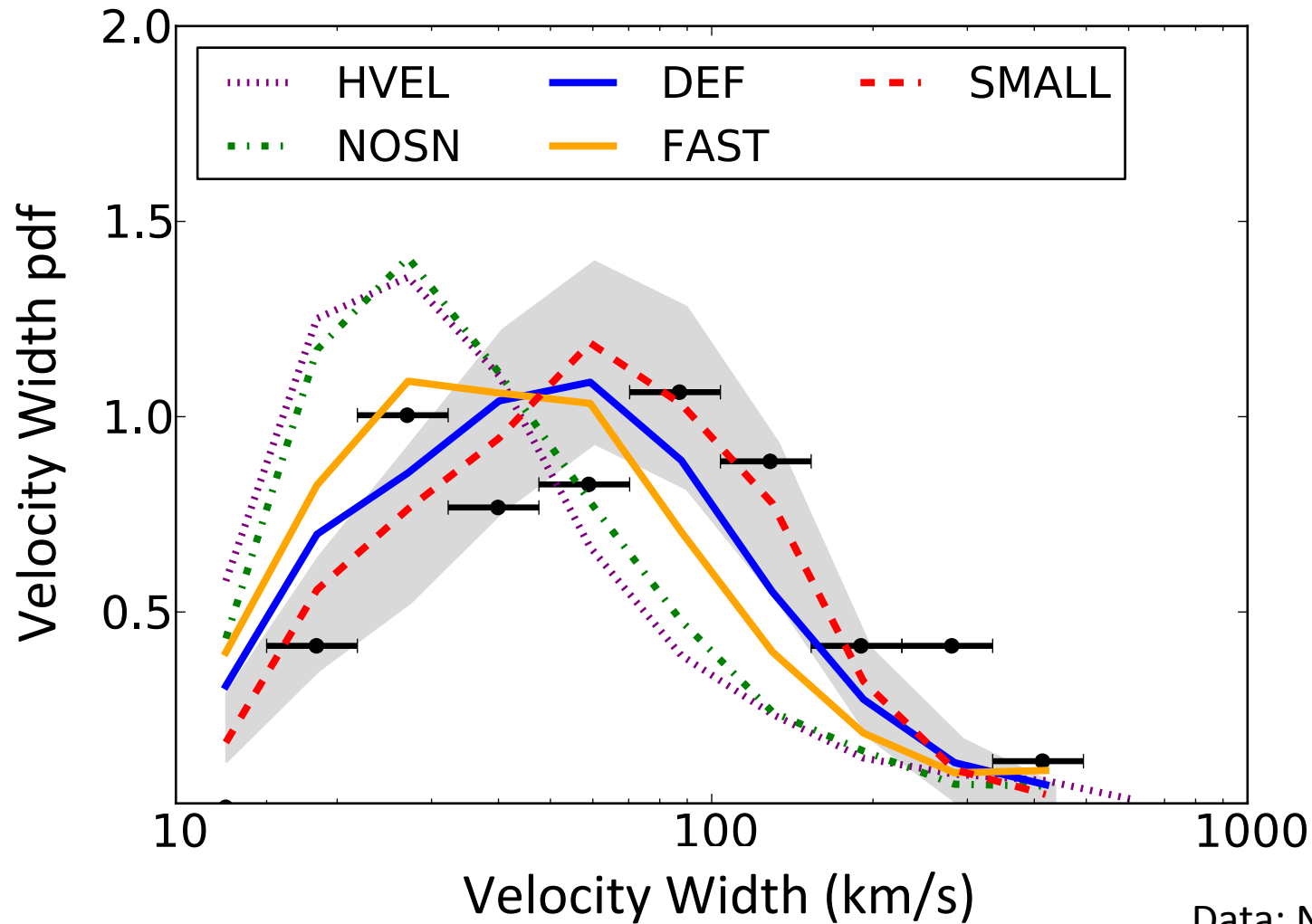
1. NOSN: No (effective) feedback
2. DEF: Stellar feedback with velocity proportional to halo circular velocity
3. FAST: Same as DEF with 50% faster winds
4. HVEL: Constant velocity winds: 600 km/s
5. (SMALL: As DEF but 10 Mpc box)

Host Virial Velocity



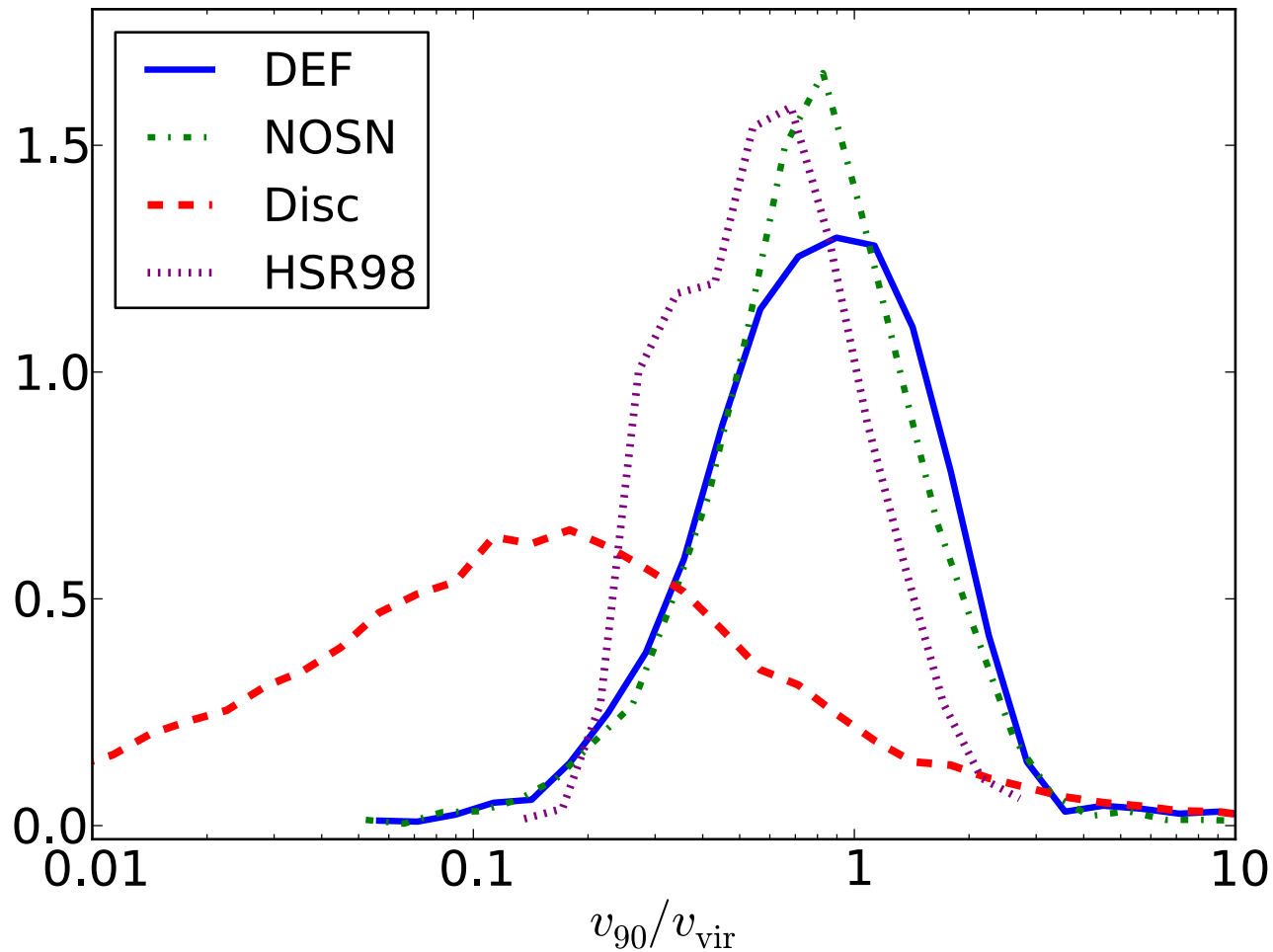
- Feedback suppresses halos $< 40 \text{ km/s}$
- Characteristic velocity now 70 km/s

Velocity Widths

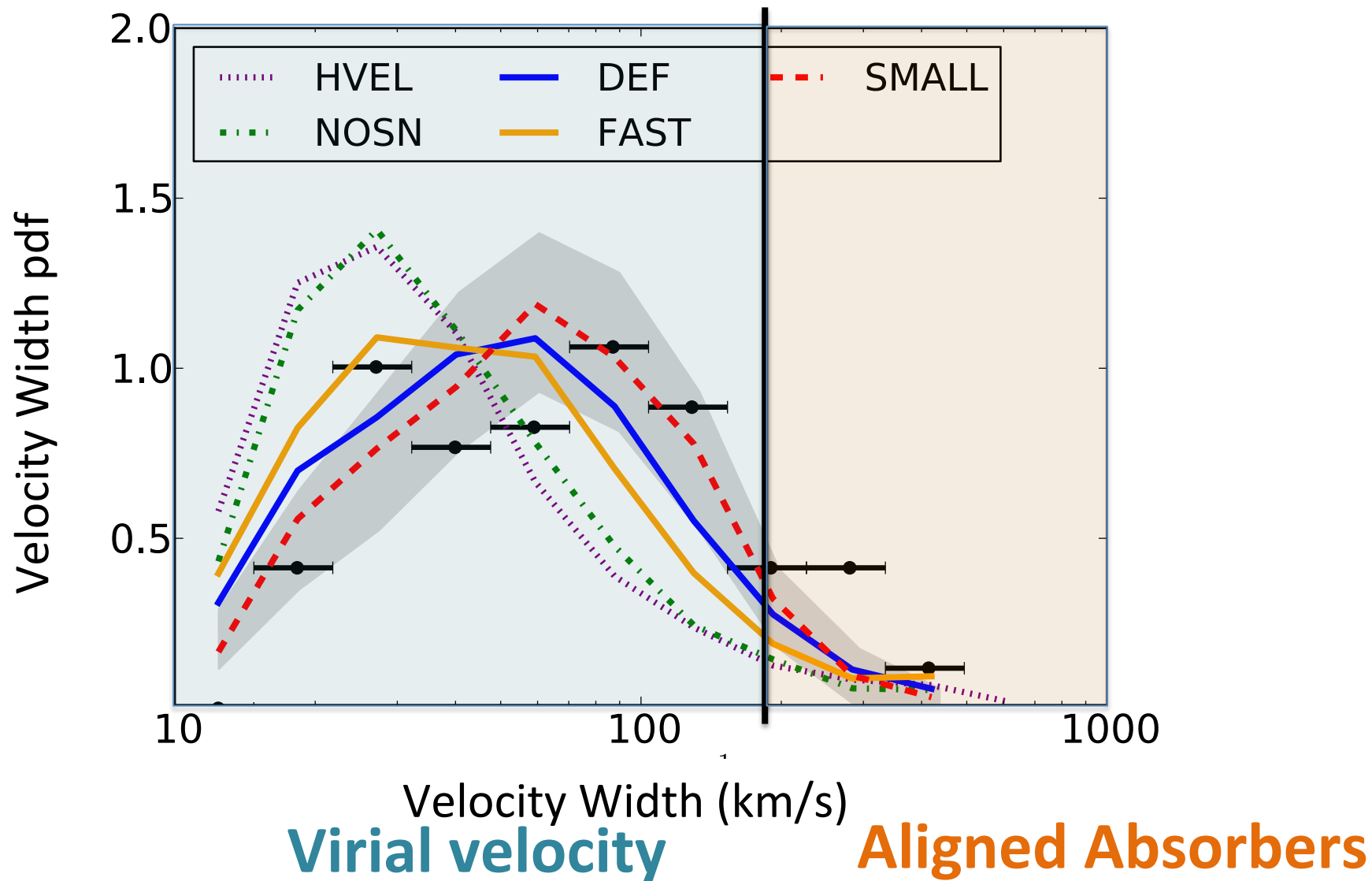


Data: Neeleman+ 2013

Velocity width approx virial velocity

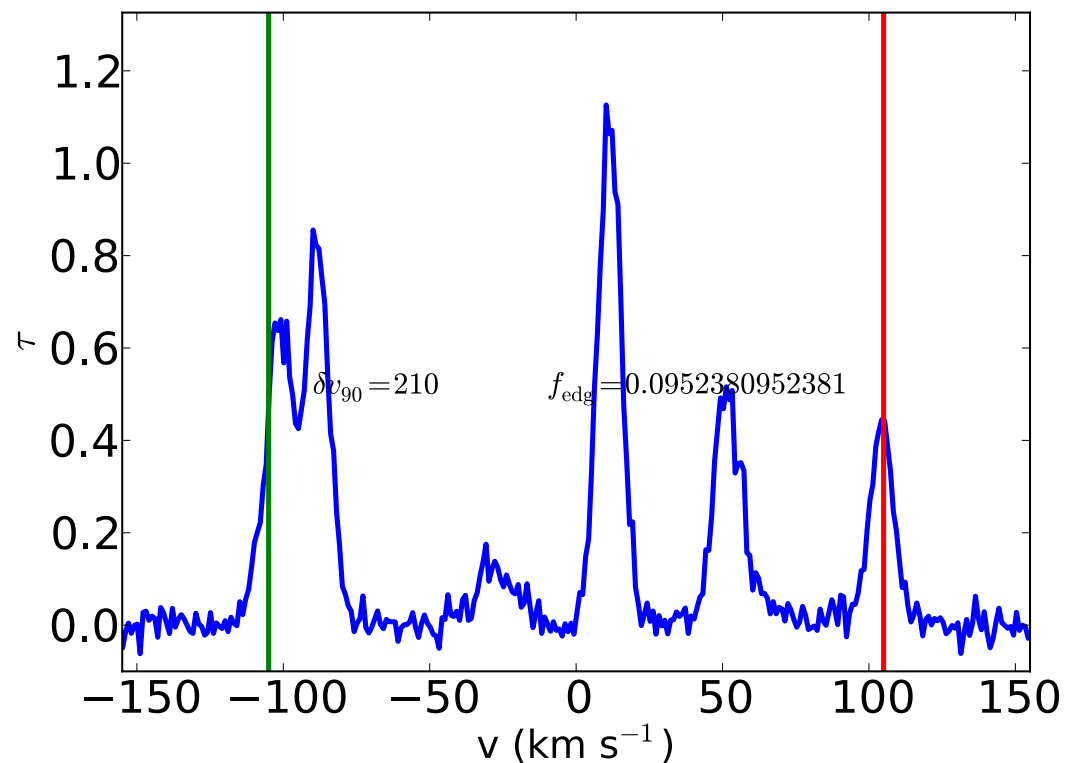
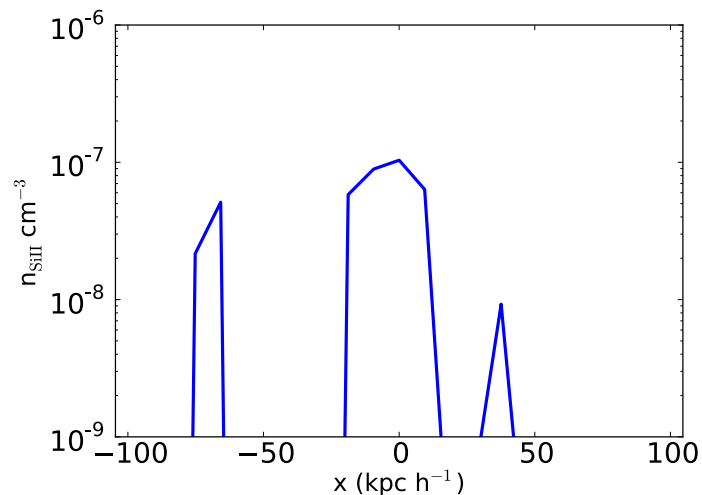
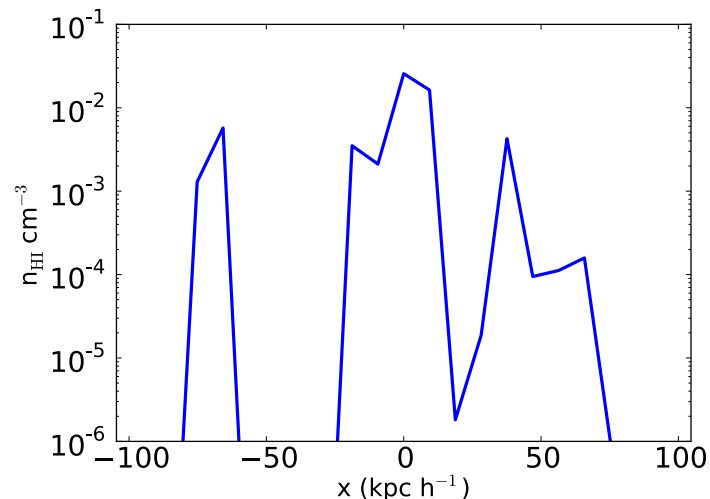


Velocity Widths

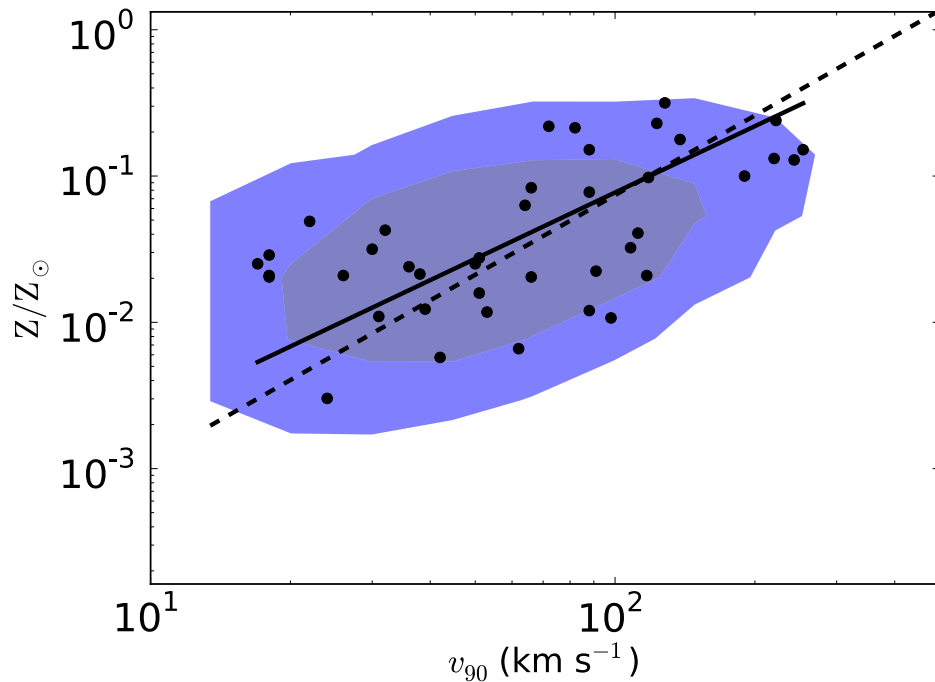


Aligned Absorbers

Most intersect a DLA and a LLS



Correlation with Metallicity



Statistical tests

- Power law fit – ok
- Pearson r - 0.4-0.6
- 2D KS-test - ok!

Blue shows where dots expected

Conclusions

- We match the DLA velocity widths and correlation with metallicity!
- Still small halos
- Did this with: Sill at low density
- Strong feedback suppresses halos with small virial velocity

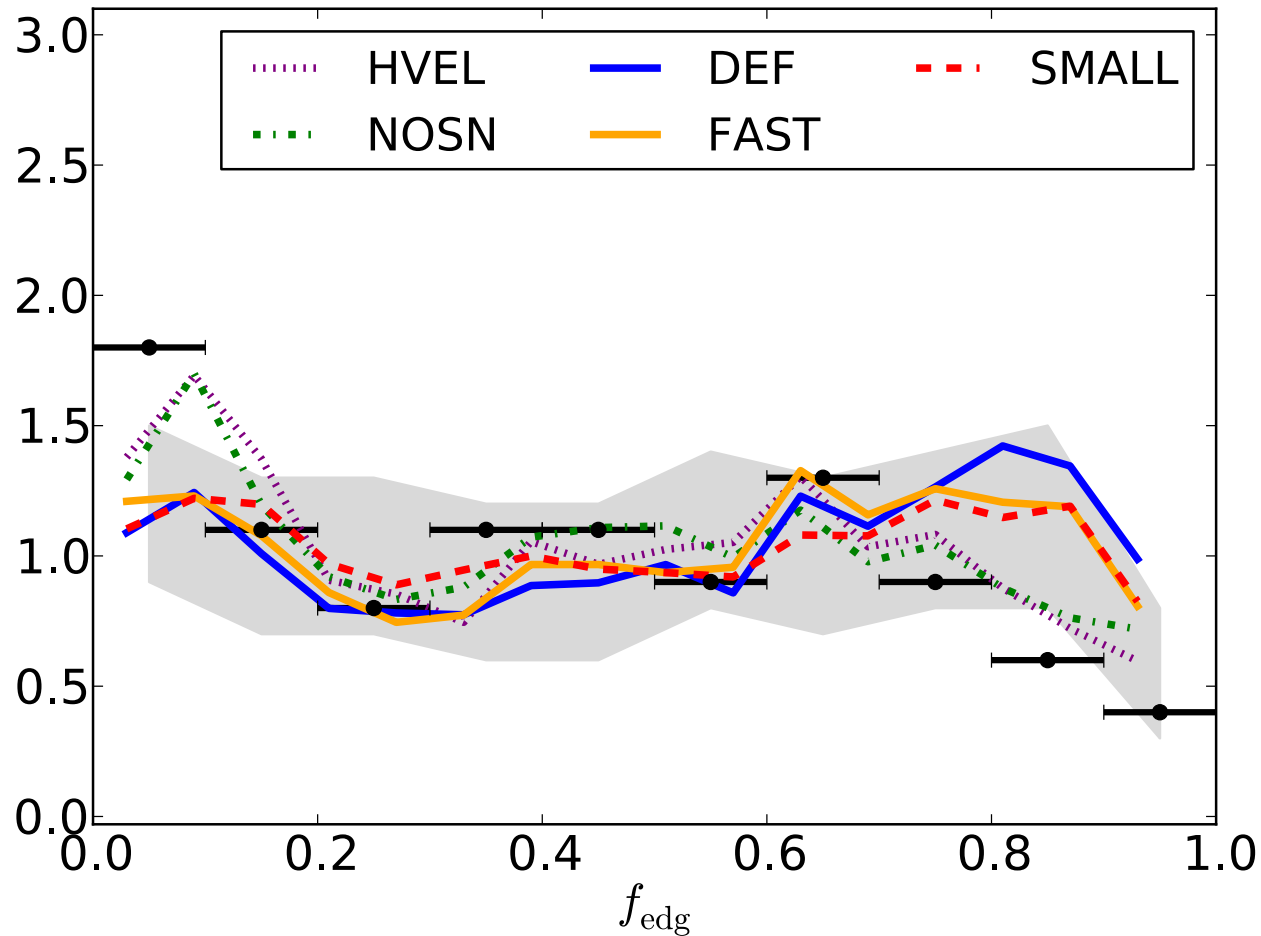
Edge-Leading Spectra

- Edge-leading statistic

$$\frac{v_{\text{pk}} - v_{\text{mean}}}{\Delta v / 2}$$

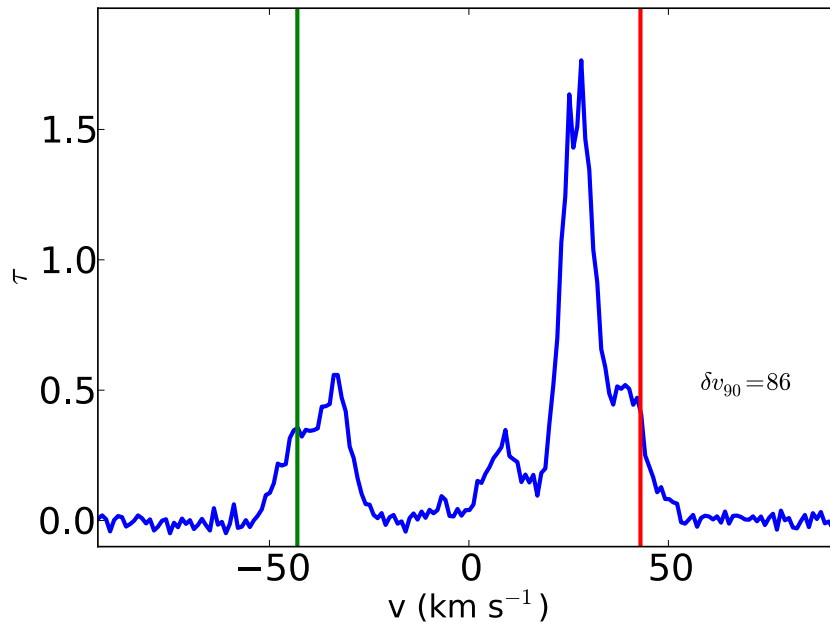
- Difference between position of peak and midpoint of total absorption in units of velocity width

Edge-Leading Spectra



Absorption concentrated at edges: marginally significant

Edge-Leading Spectra

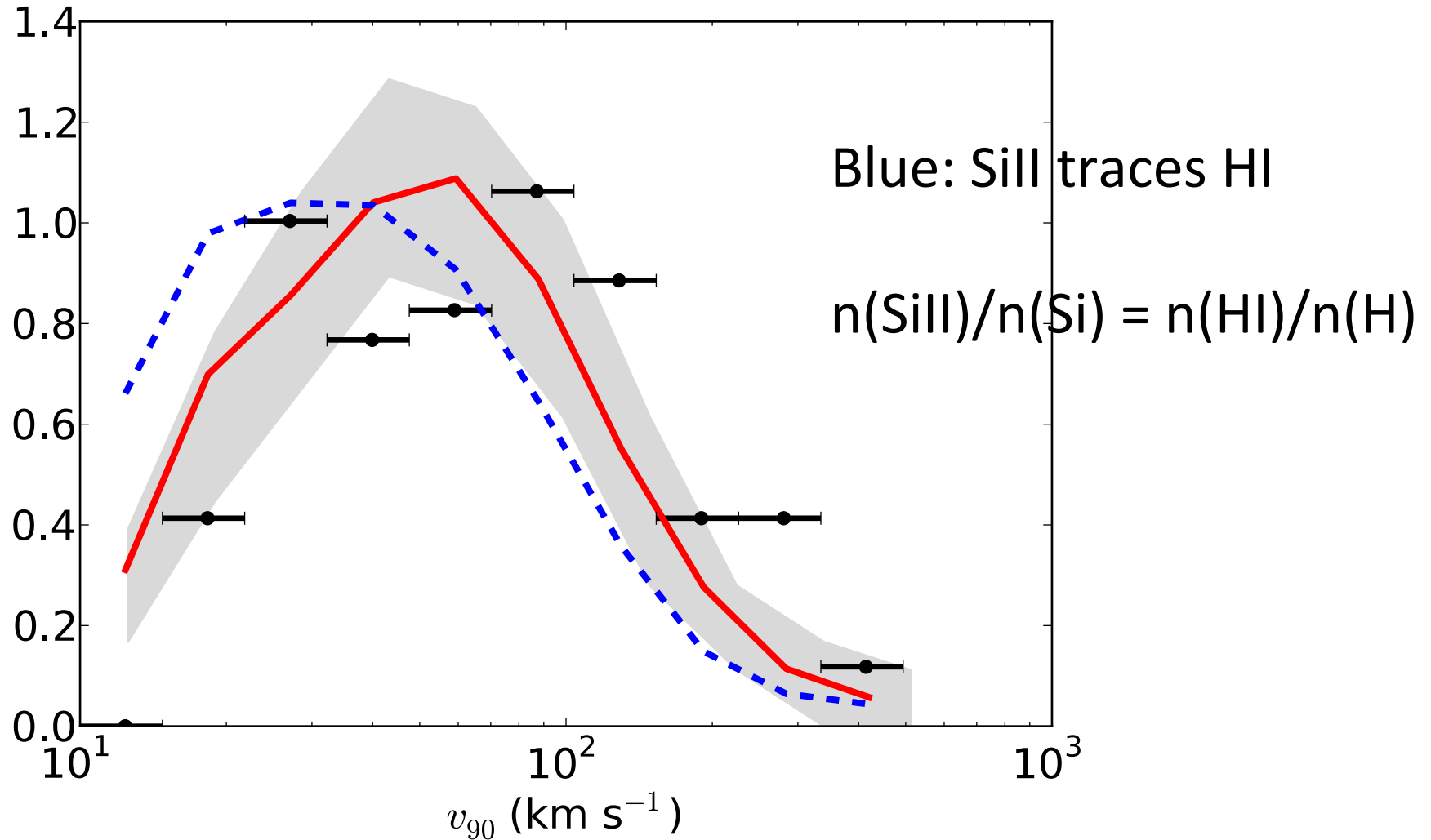


Too many multiple peak spectra?

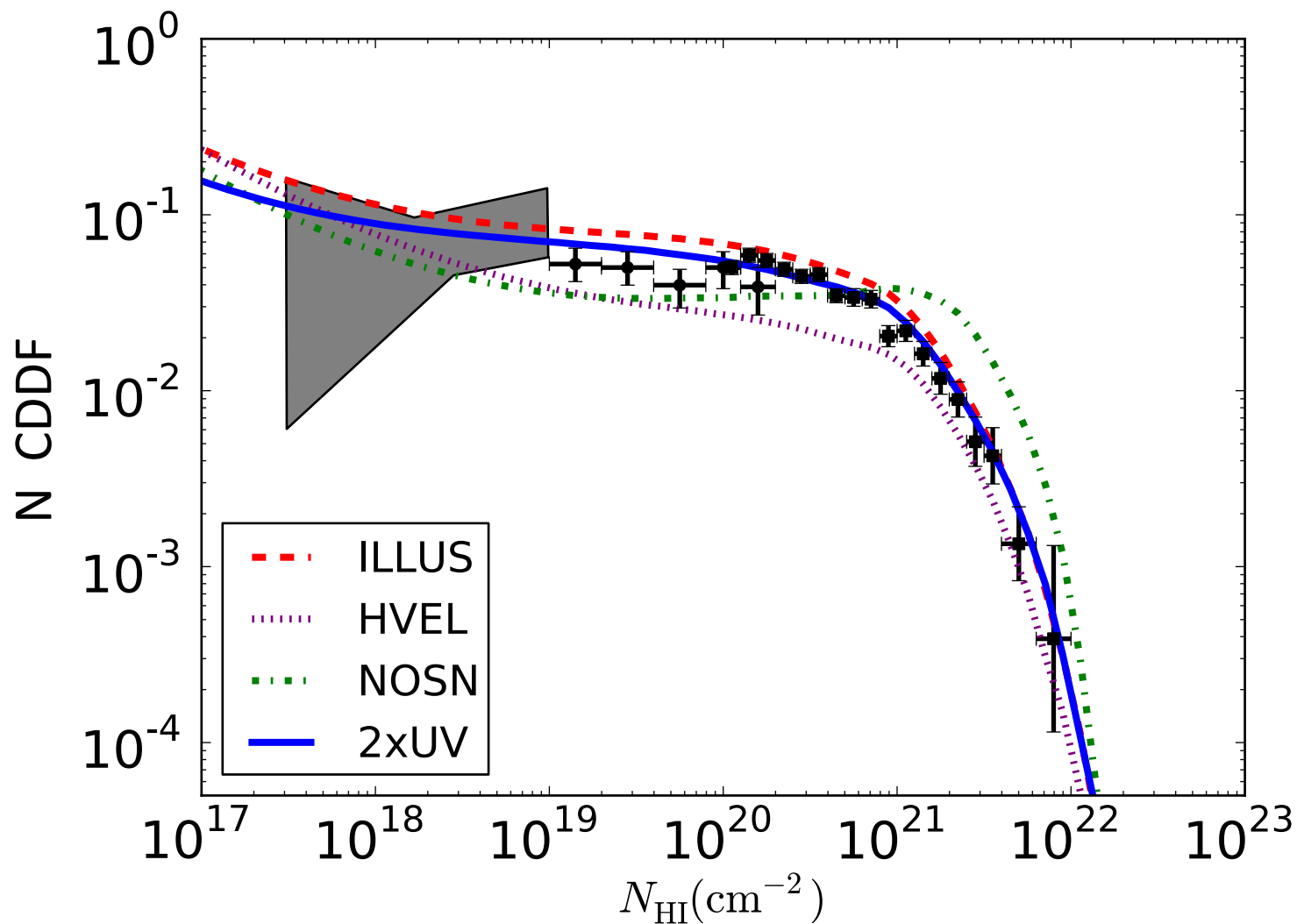
Velocity offset?

A guess: we are pushing out material with a special velocity.

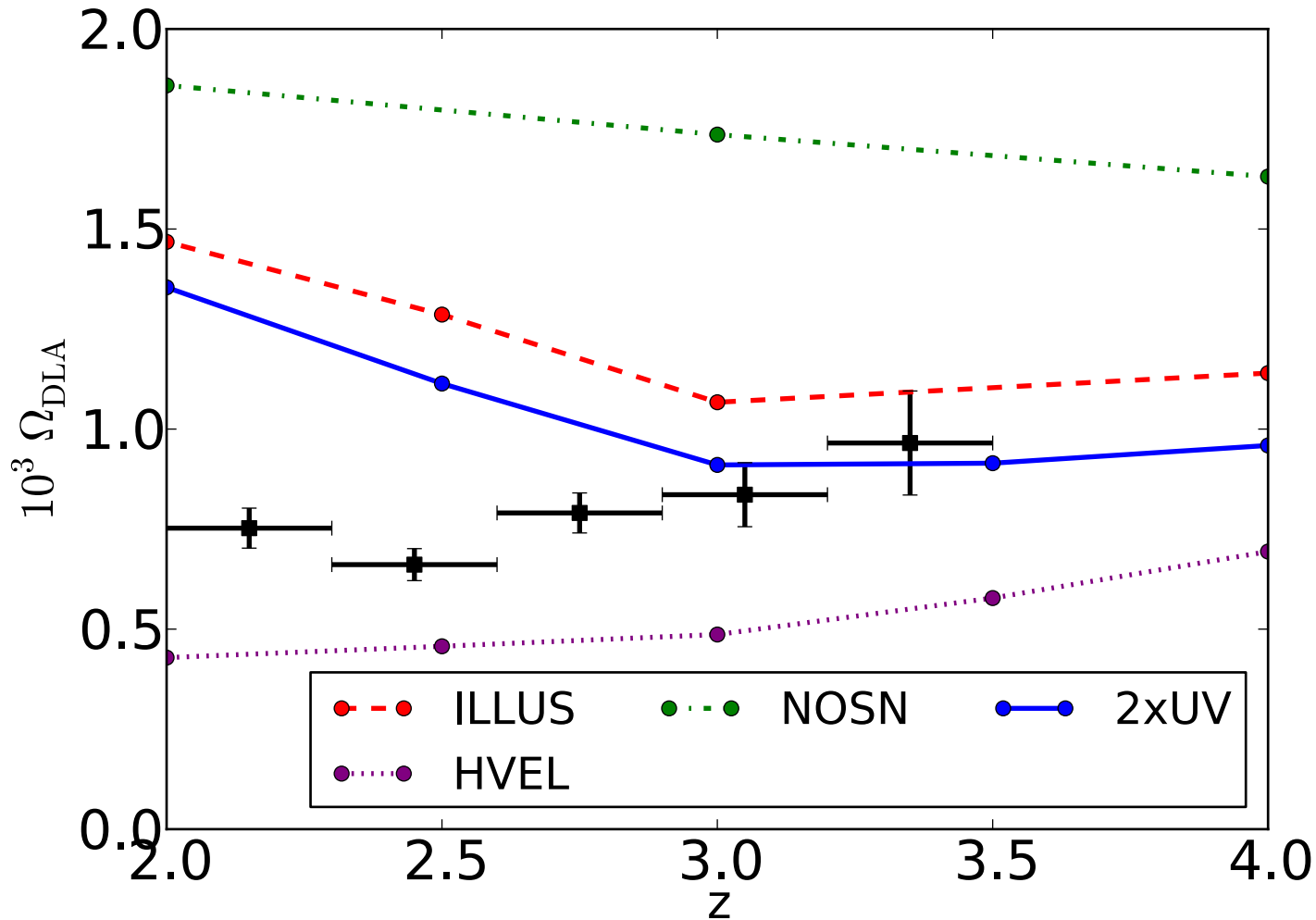
Comparison to Pontzen 2008



Column Density Distribution



Neutral Hydrogen Abundance



Data: Noterdaeme+ 2012