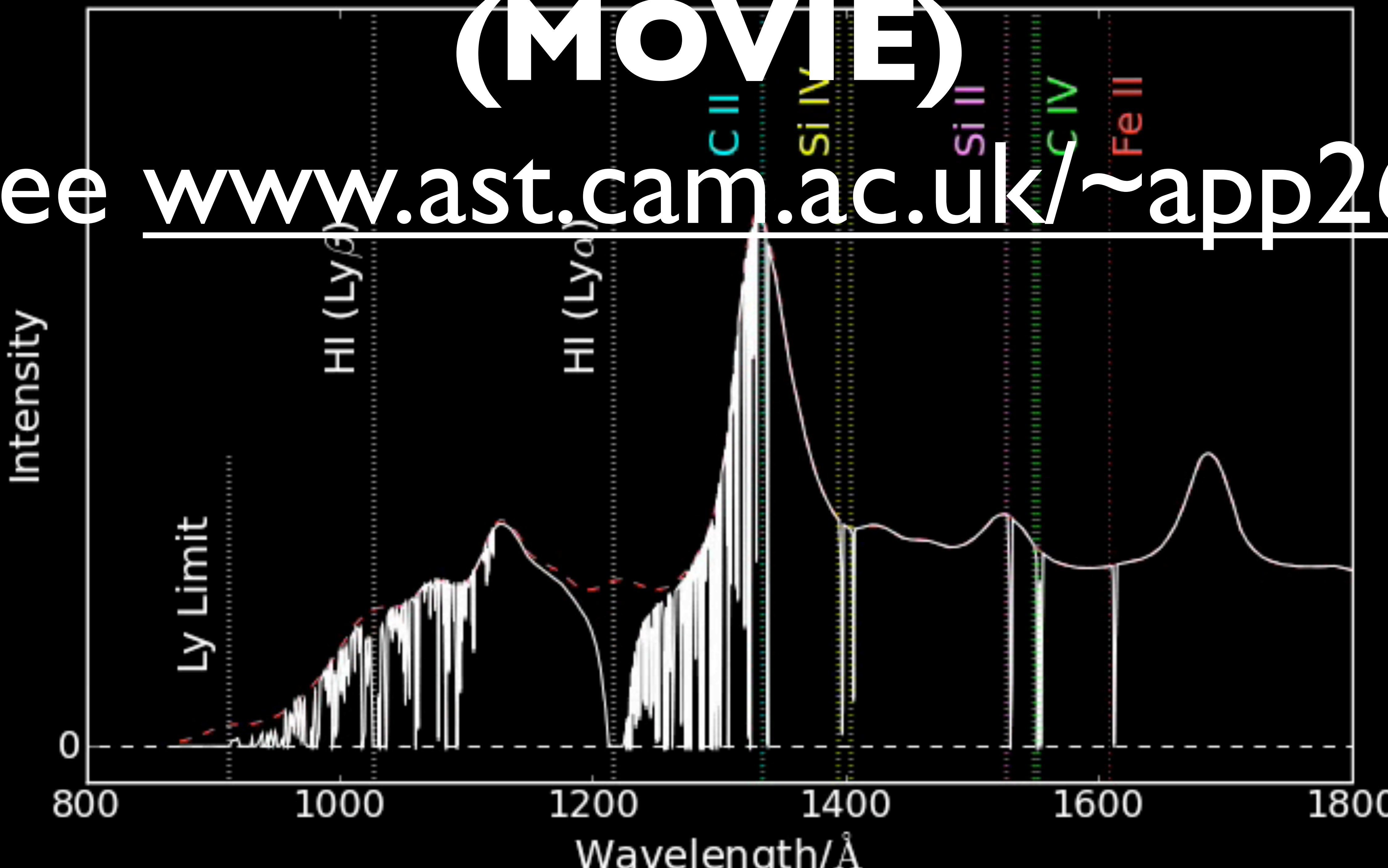
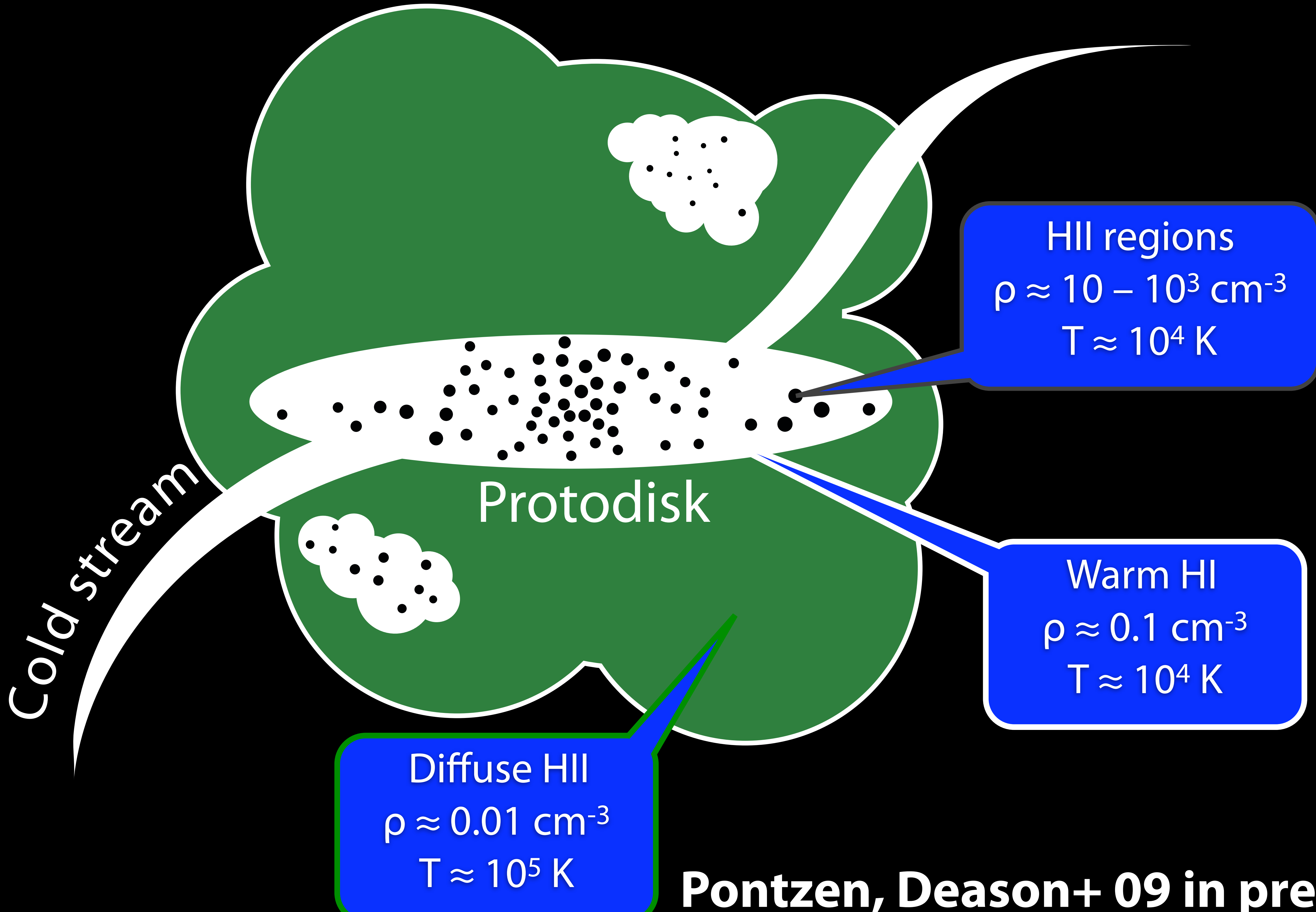
Andrew Pontzen (IoA Cambridge)
Alis Deason, Max Pettini (IoA Cambridge)
Fabio Governato & many others (UW Seattle)

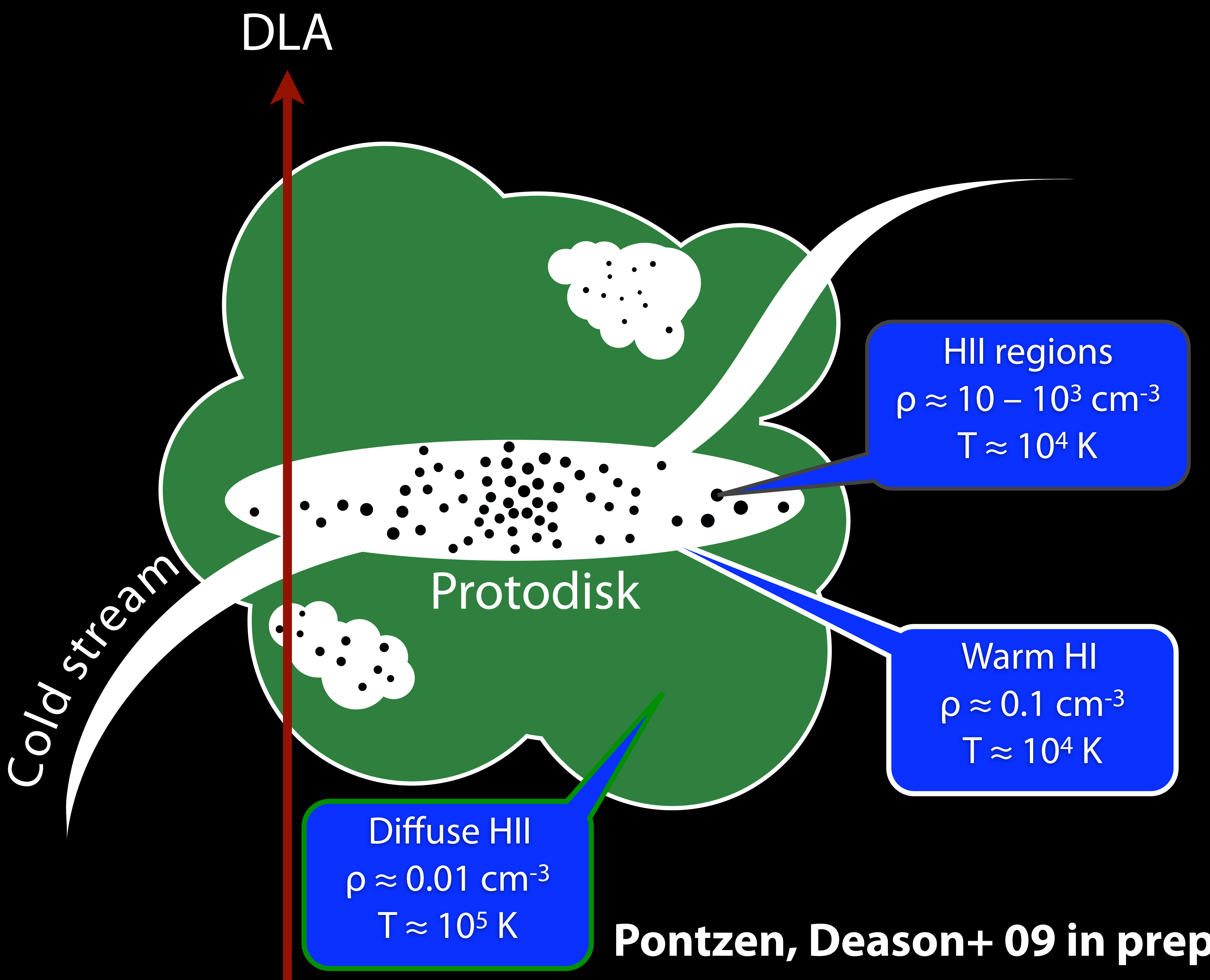
(MOVIE)

see www.ast.cam.ac.uk/~app26/

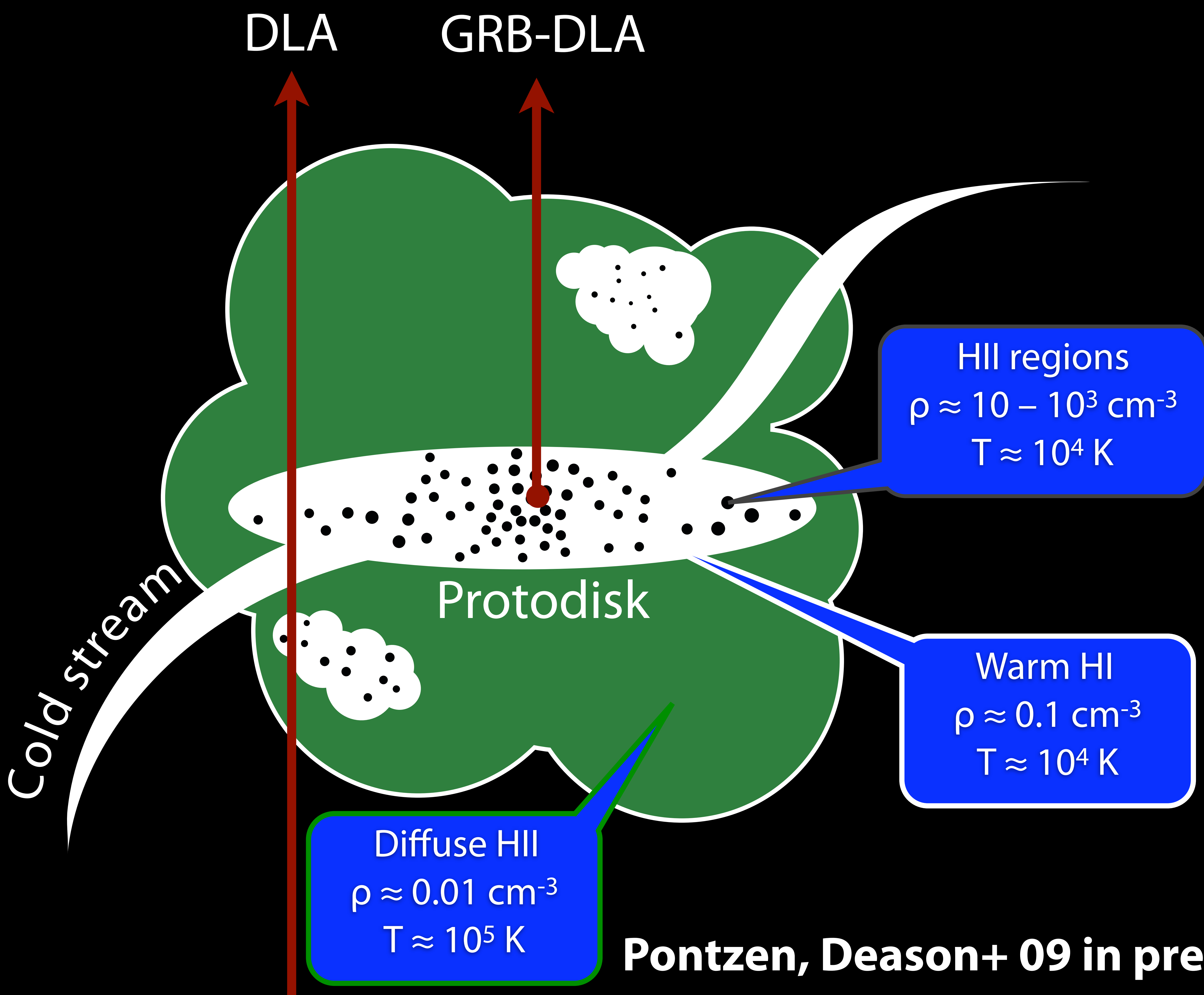




Pontzen, Deason+ 09 in prep



Pontzen, Deason+ 09 in prep



Pontzen, Deason+ 09 in prep

Governato et al 2007

Forming Disk Galaxies in ΛCDM Simulations

F. Governato[1,2], B. Willman [3], L. Mayer[4], A. Brooks[1], G.Stinson[1], O.Valenzuela[1], J.Wadsley[5], T.Quinn[1]

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[2] *INAF, Osservatorio Astronomico di Brera, via Brera 29, 20121, Milano, Italy*
[3] *NYU, Department of Physics, 4 Washington Place, New York, NY 10003*
[4] *ETH, Ramistrasse 101, CH-8092 Zurich.*
[5] *Department of Physics and Astronomy, McMaster University, Hamilton, Ontario L88 4M1, Canada*

5 February 2008

ABSTRACT

We used fully cosmological, high resolution N-body + SPH simulations to follow the formation of disk galaxies with rotational velocities between 135 and 270 km/sec in a ΛCDM universe. The simulations include gas cooling, star formation, the effects of a uniform UV background and a physically motivated description of feedback from supernovae. The host dark matter halos have a spin and last major merger redshift typical of galaxy sized halos as measured in recent large scale N–Body simulations. The simulated galaxies form rotationally supported disks with realistic exponential scale lengths and fall on both the I-band and baryonic Tully Fisher relations. An extended stellar disk forms inside the Milky Way sized halo immediately after the last major merger. The combination of UV background and SN feedback drastically reduces the number of visible satellites orbiting inside a Milky Way sized halo, bringing it in fair agreement with observations. Our simulations predict that the average age of a primary galaxy's stellar population decreases with mass, because feedback delays star formation in less massive galaxies. Galaxies have stellar masses and current star formation rates as a function of total mass that are in good agreement with

The Simulations...

IN:

- Cosmological UV (SS approx + RT post-process)
- Two parameter star formation (Stinson+ 2006)
- Tuned to produce realistic z=0 SFRs
- Volume renormalization / high resolution (down to 10^4 solar masses gas)

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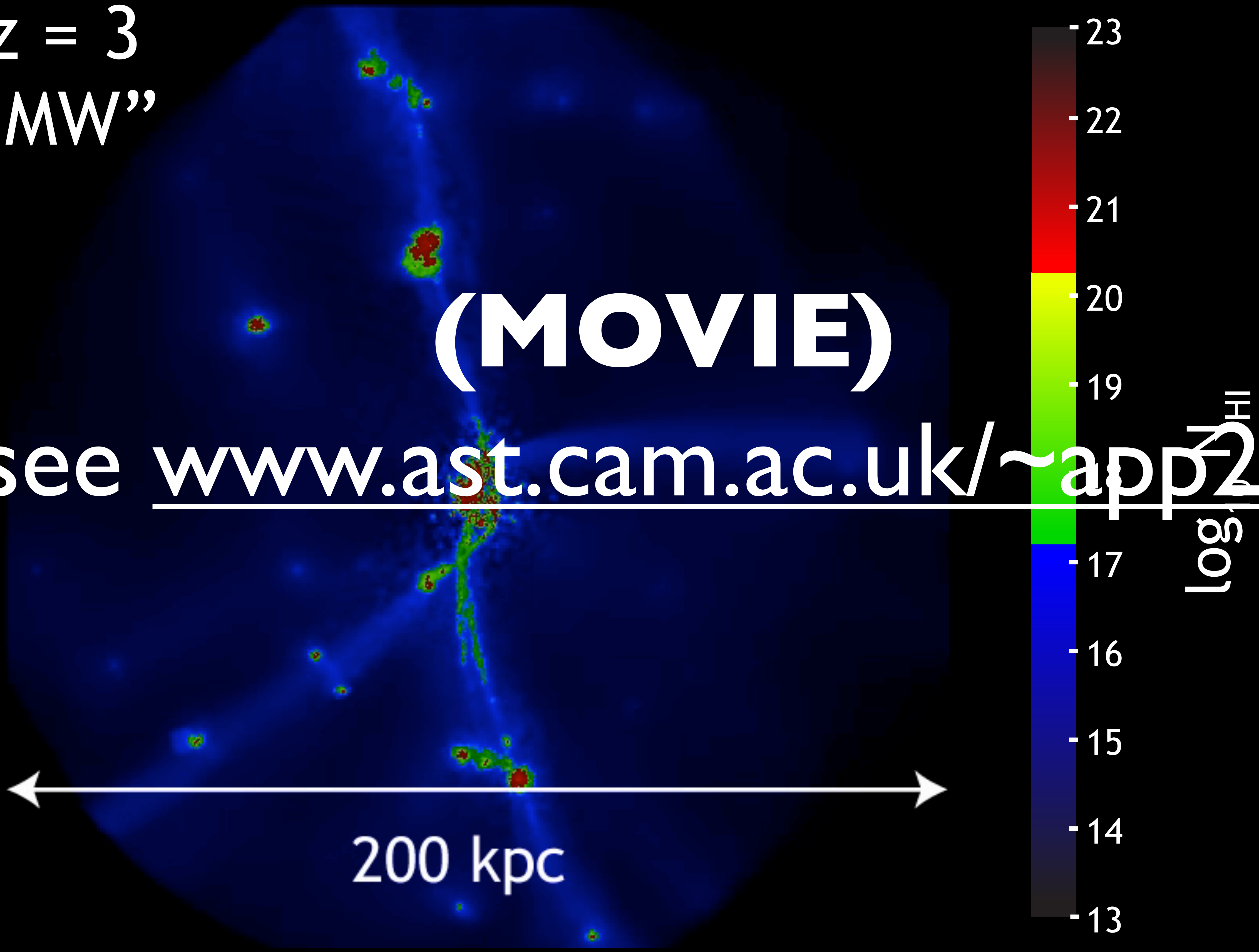
OUT:

- Land on Tully-Fisher relation (lum vs v_{rot})
- Realistic LF (inc. distribution of MW satellites)
- As resolution increases, bulges getting even smaller (= flat rotation curves)
- Stellar Mass-Metallicity relation sensible for 0<z<3 (Brooks et al 2006)

z = 3
“MW”

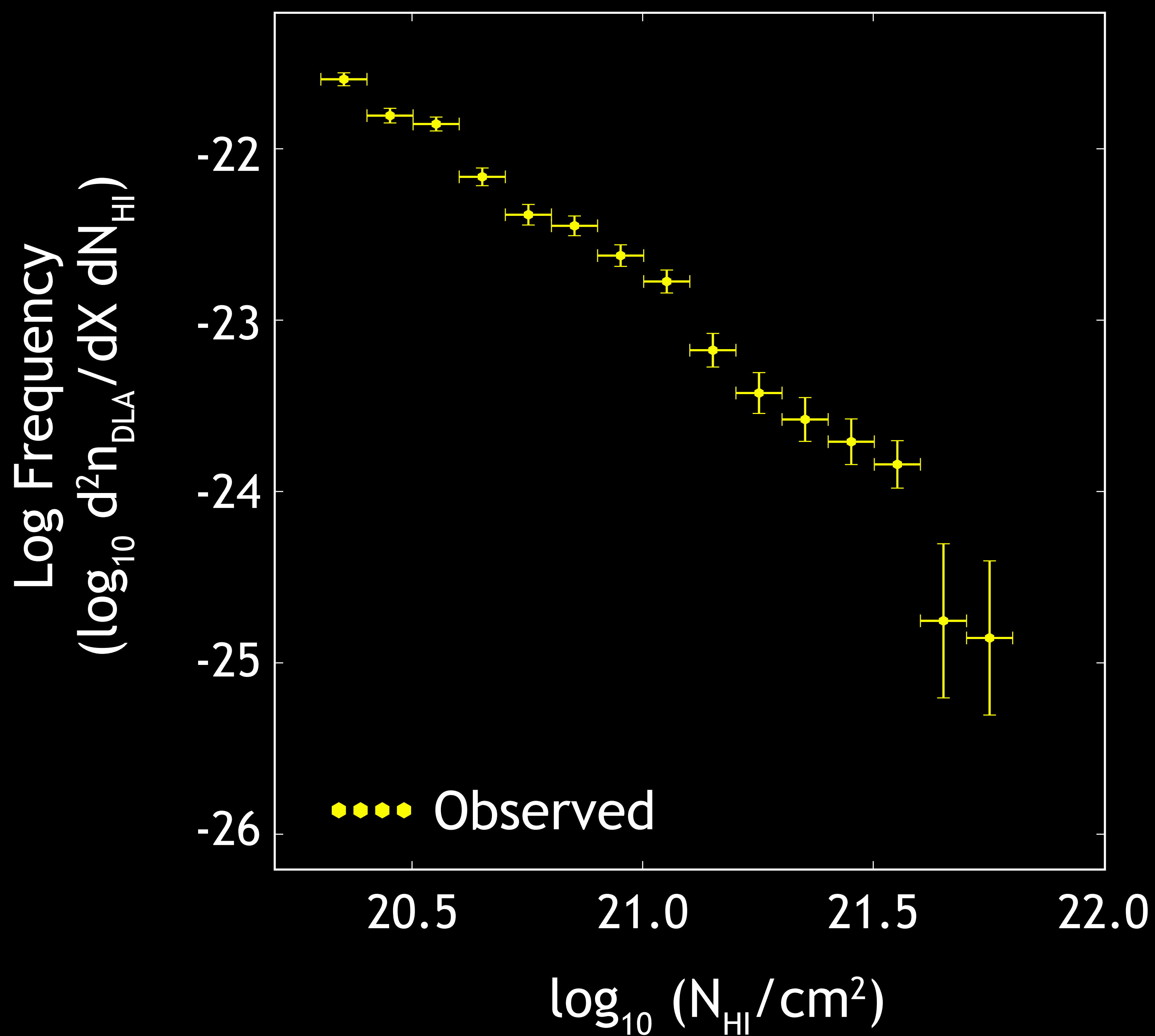


(MOVIE)

see www.ast.cam.ac.uk/~app26/

Rendering by SimAn: OpenGL / python simulation analysis environment
www.ast.cam.ac.uk/~app26/siman

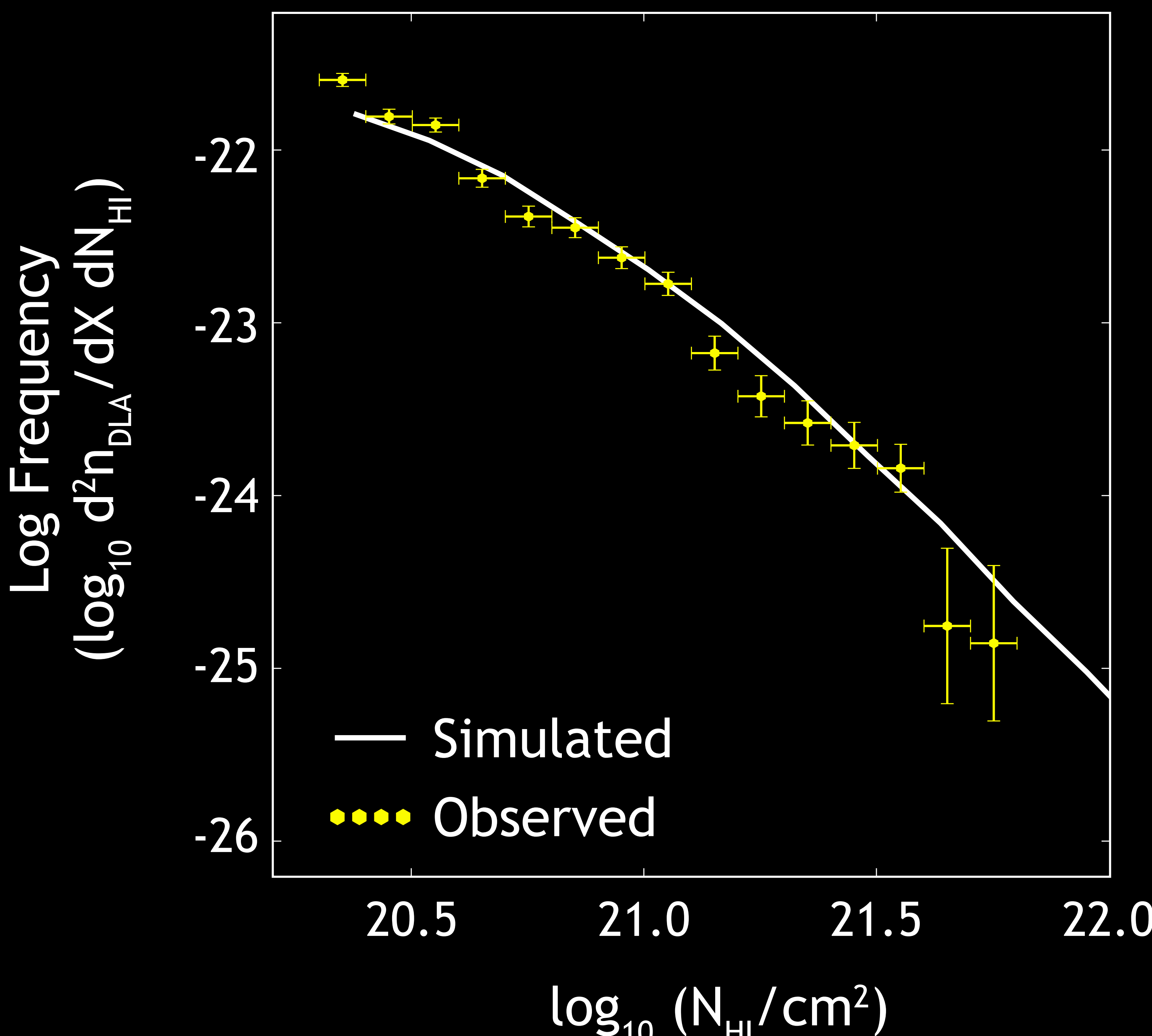
Column Density Distribution



Observational data = SDSS DR5 (Prochaska et al)

Pontzen+ 08

Column Density Distribution

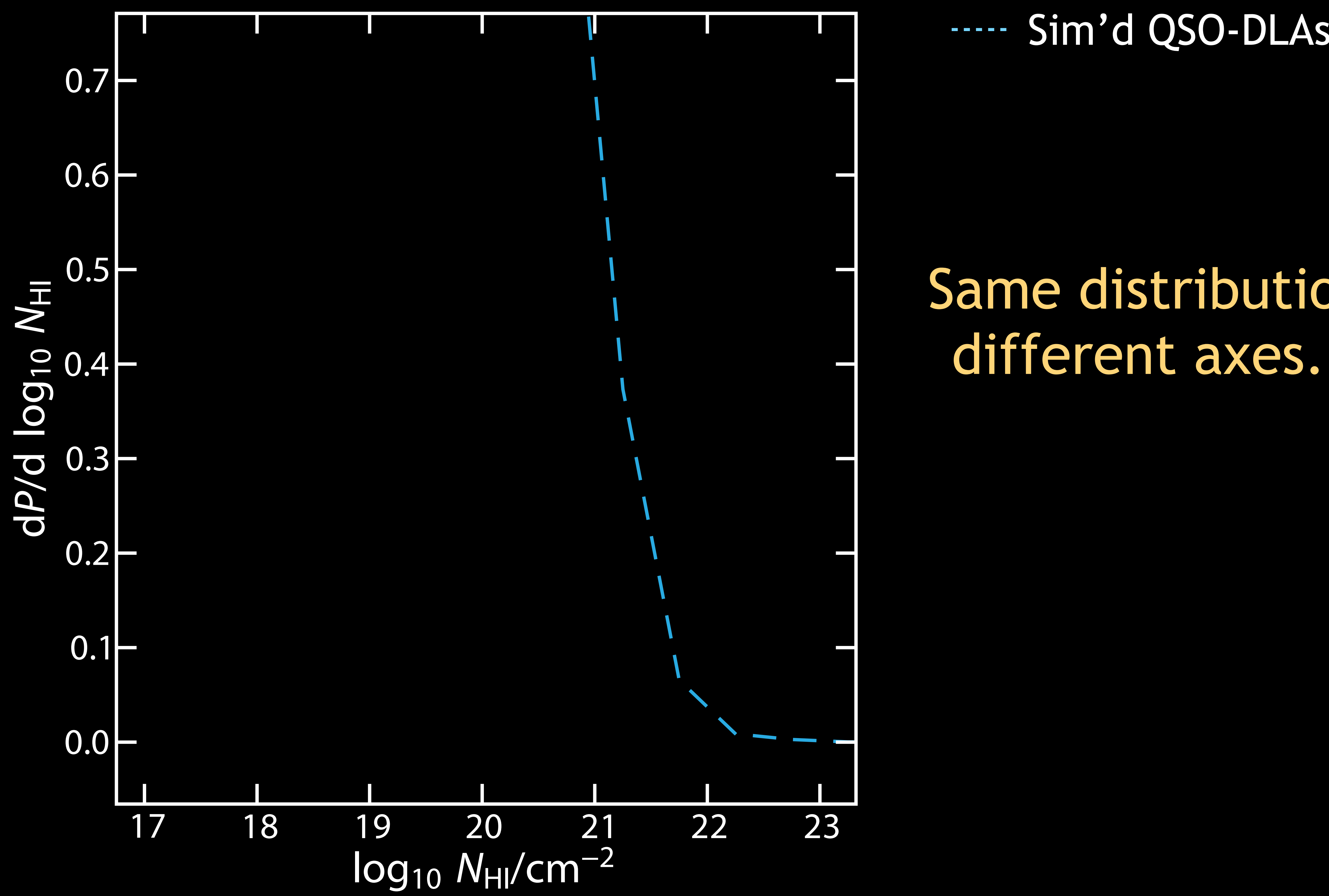


Success, with no free parameters!

Observational data = SDSS DR5 (Prochaska et al)

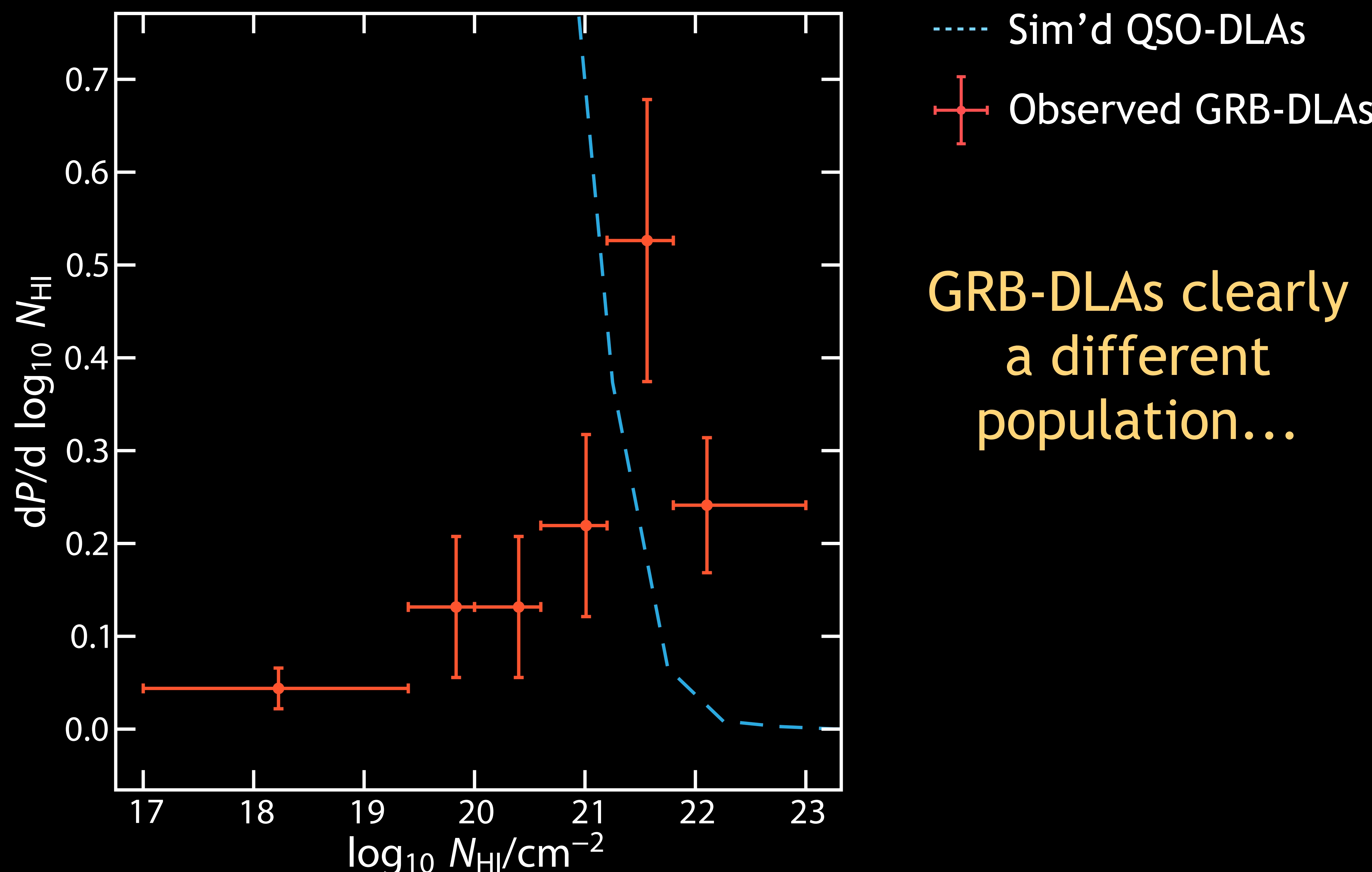
Pontzen+ 08

Column Density Distribution



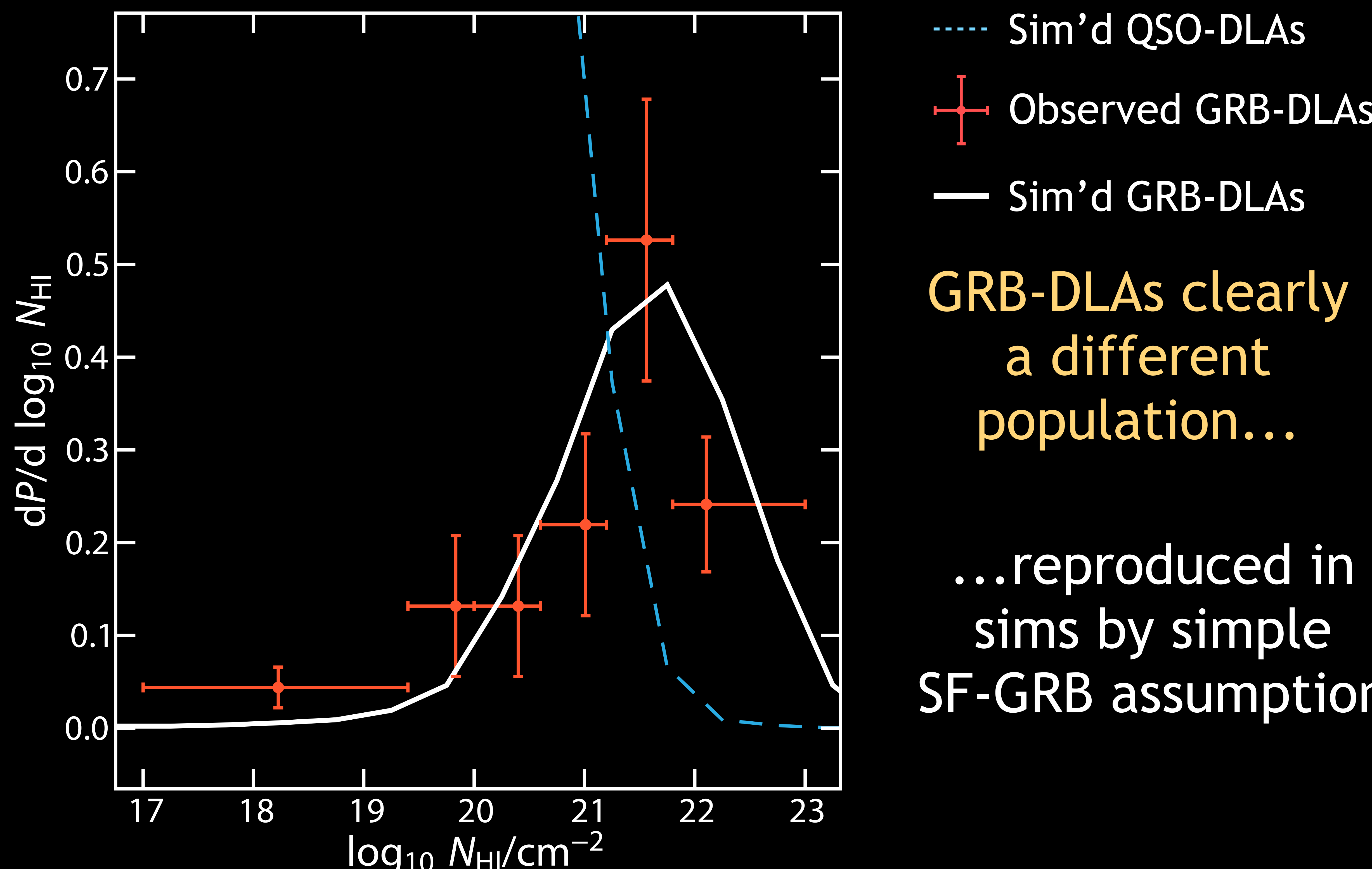
Same distribution, different axes...

Column Density Distribution



GRB-DLAs clearly a different population...

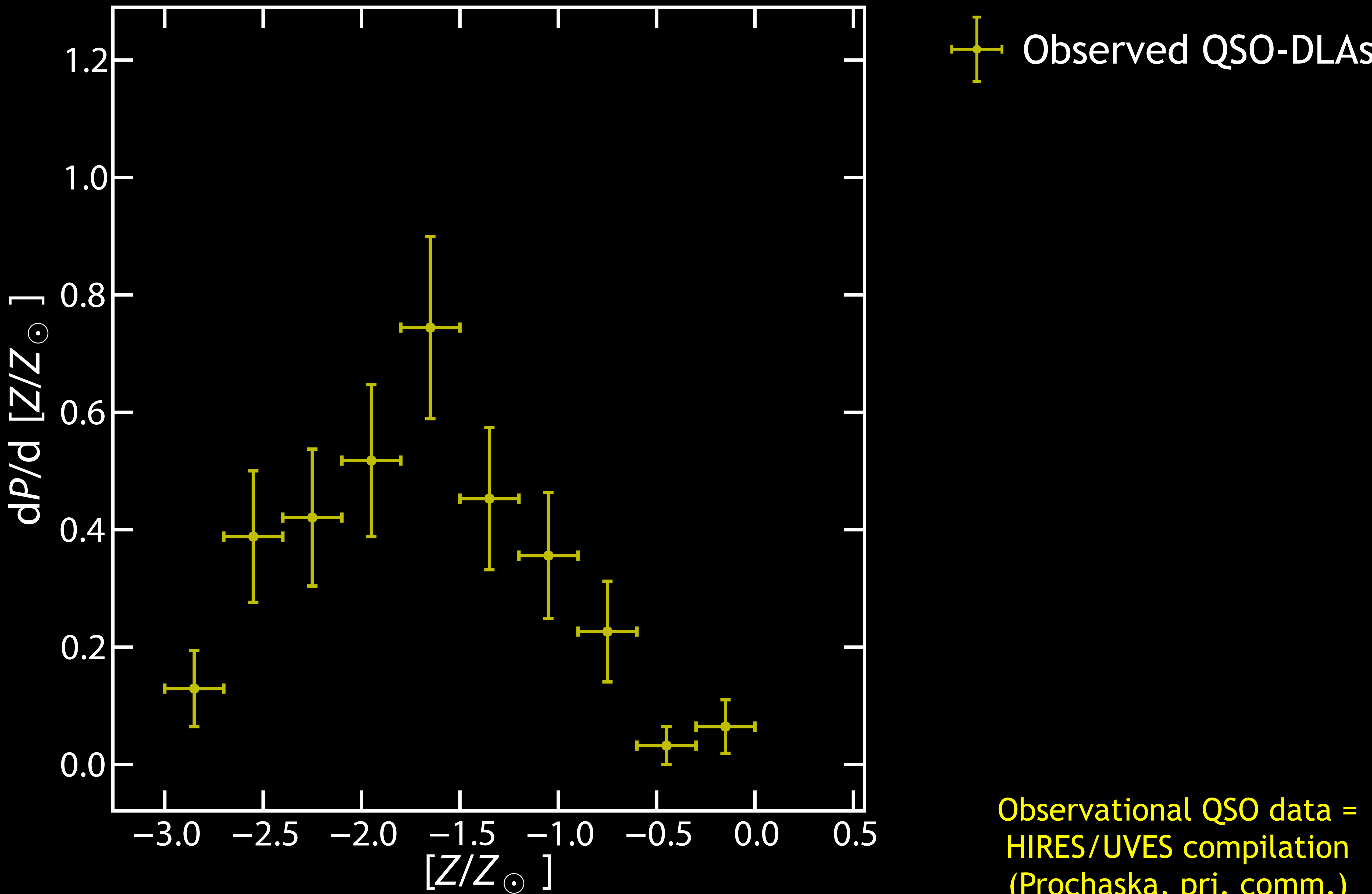
Column Density Distribution



GRB-DLAs clearly a different population...

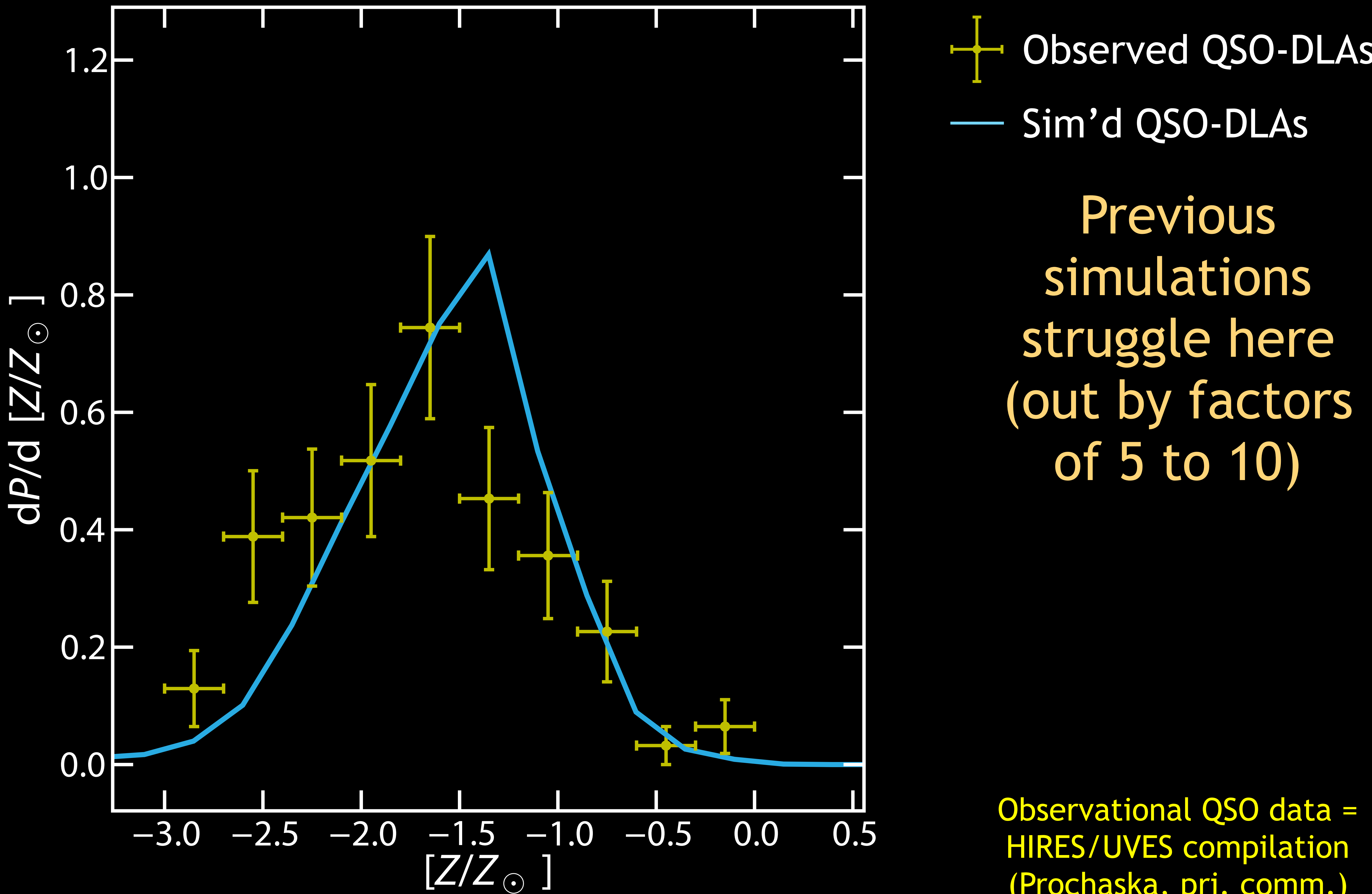
...reproduced in sims by simple SF-GRB assumption

Neutral Gas Metallicities



Observational QSO data =
HIRES/UVES compilation
(Prochaska, pri. comm.)

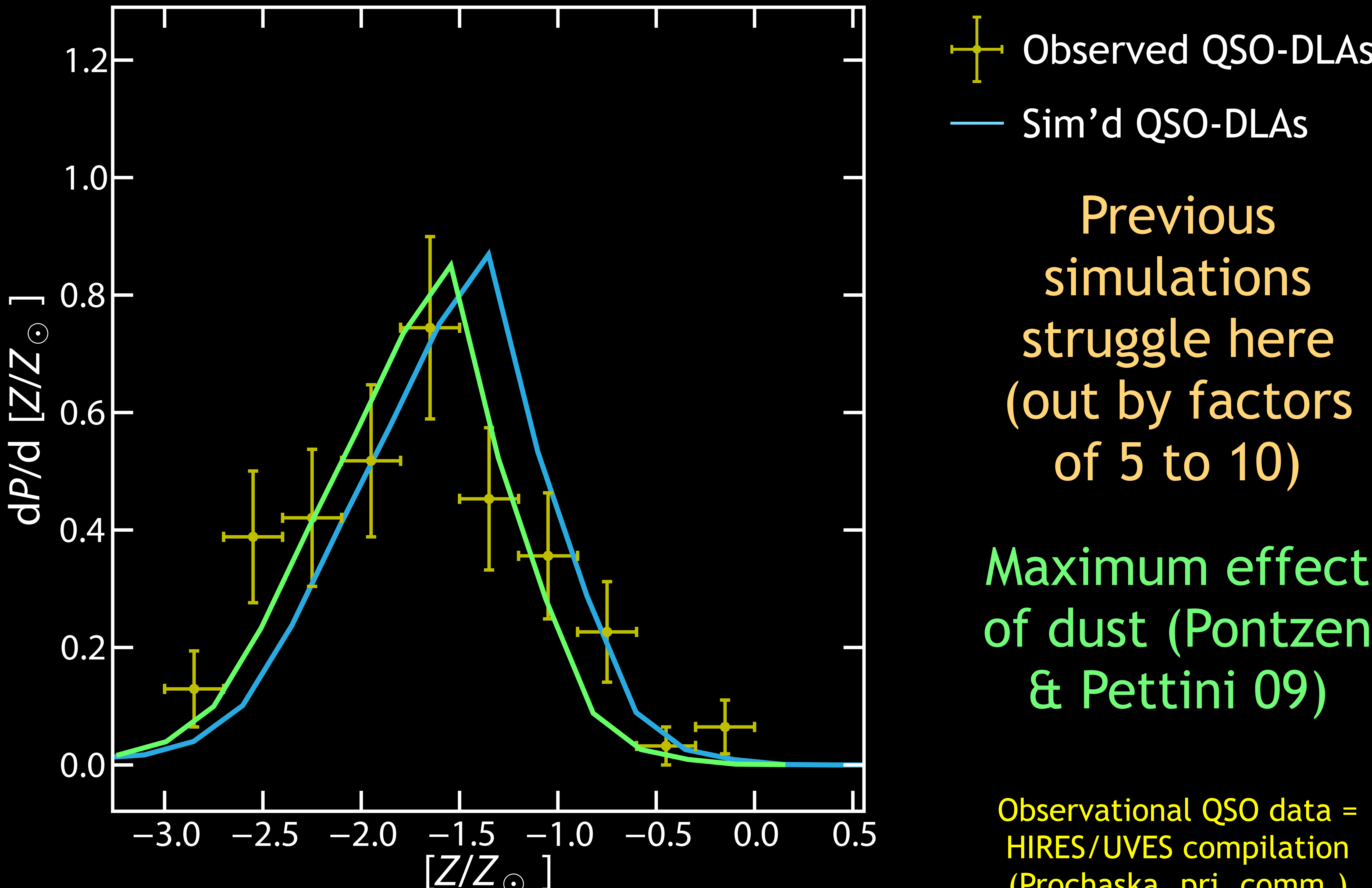
Neutral Gas Metallicities



Previous simulations struggle here (out by factors of 5 to 10)

Observational QSO data = HIRES/UVES compilation (Prochaska, pri. comm.)

Neutral Gas Metallicities

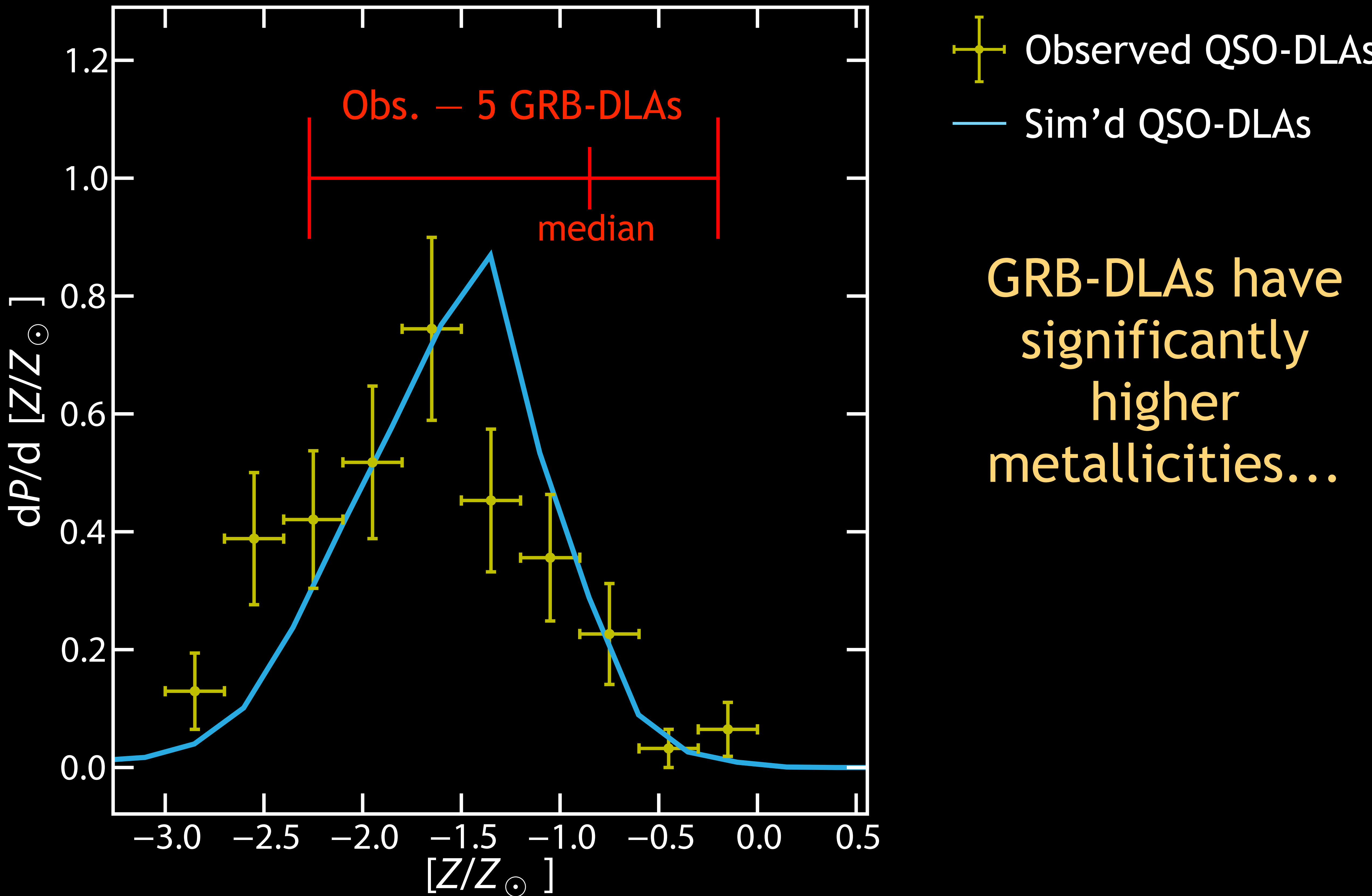


Previous simulations struggle here (out by factors of 5 to 10)

Maximum effect of dust (Pontzen & Pettini 09)

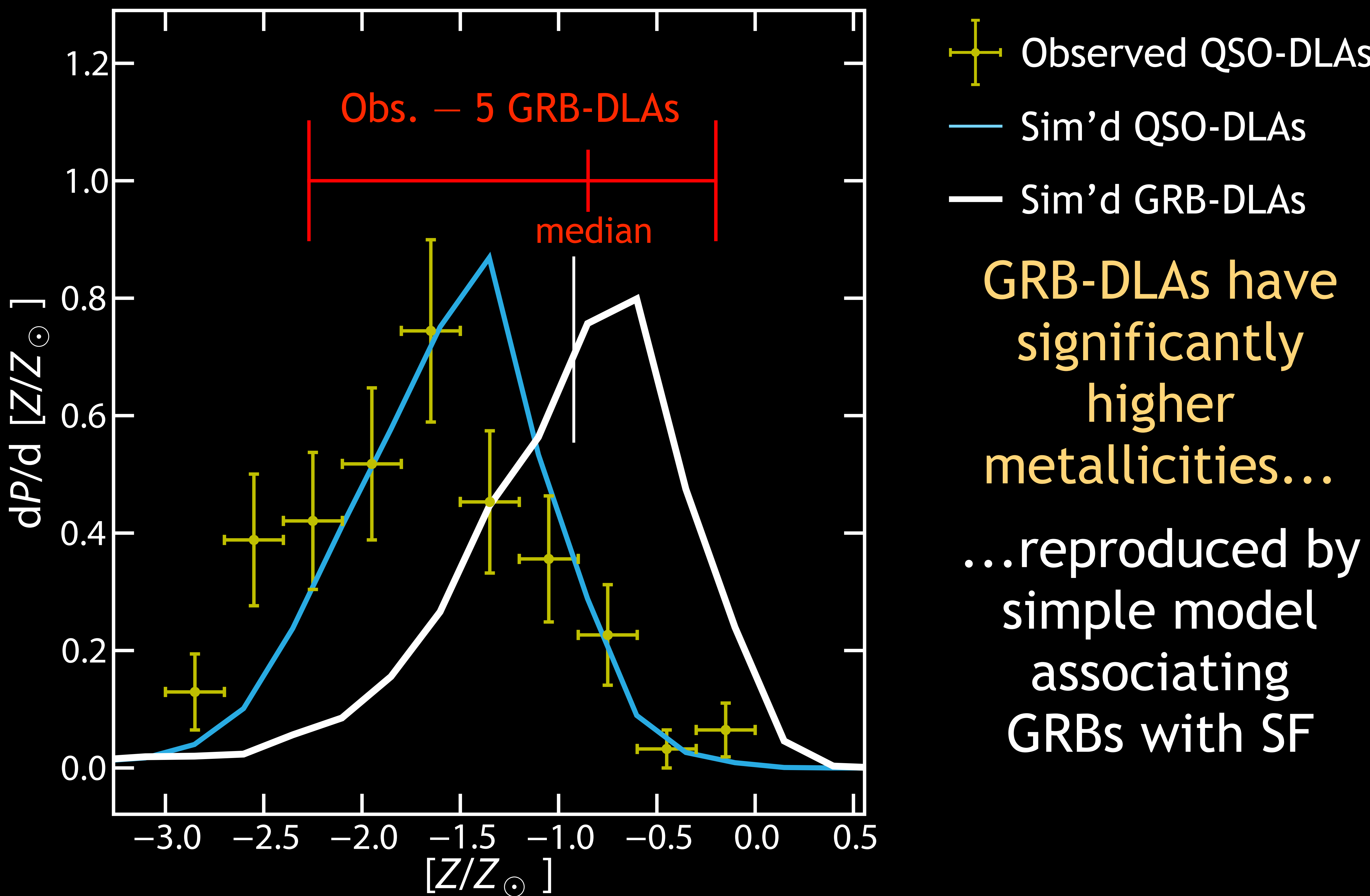
Observational QSO data = HIRES/UVES compilation (Prochaska, pri. comm.)

Neutral Gas Metallicities



GRB-DLAs have significantly higher metallicities...

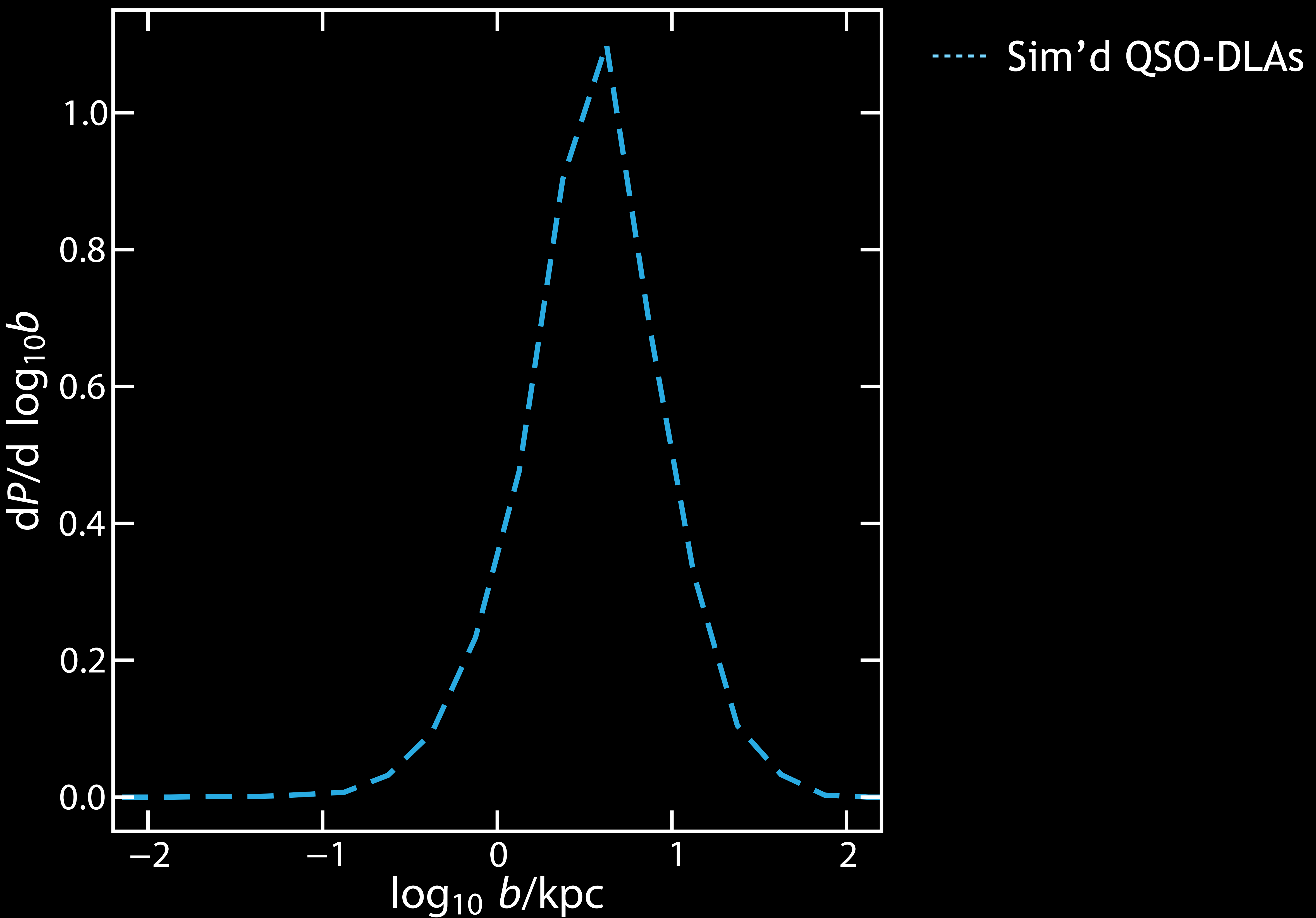
Neutral Gas Metallicities



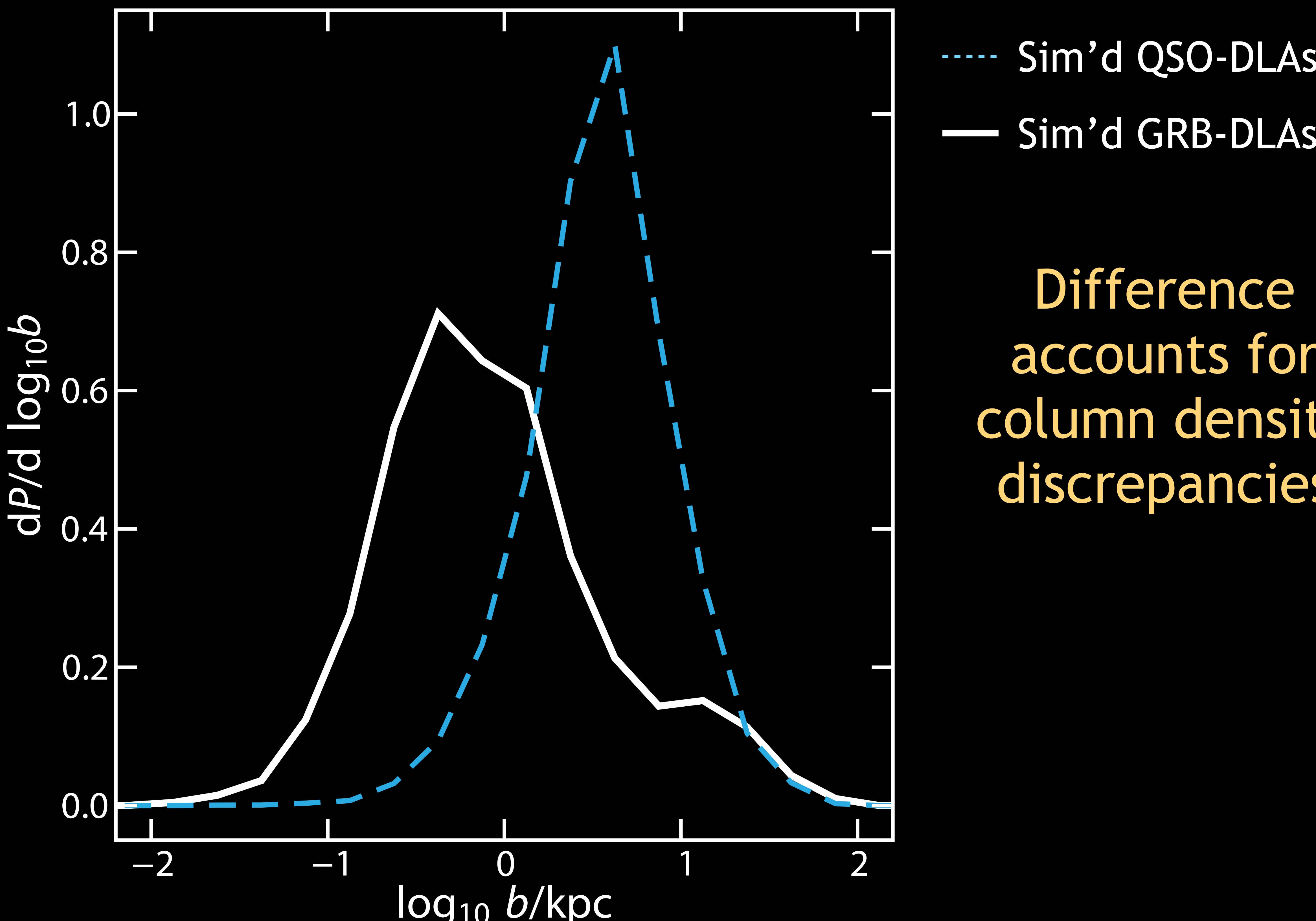
GRB-DLAs have significantly higher metallicities...

...reproduced by simple model associating GRBs with SF

Impact Parameters

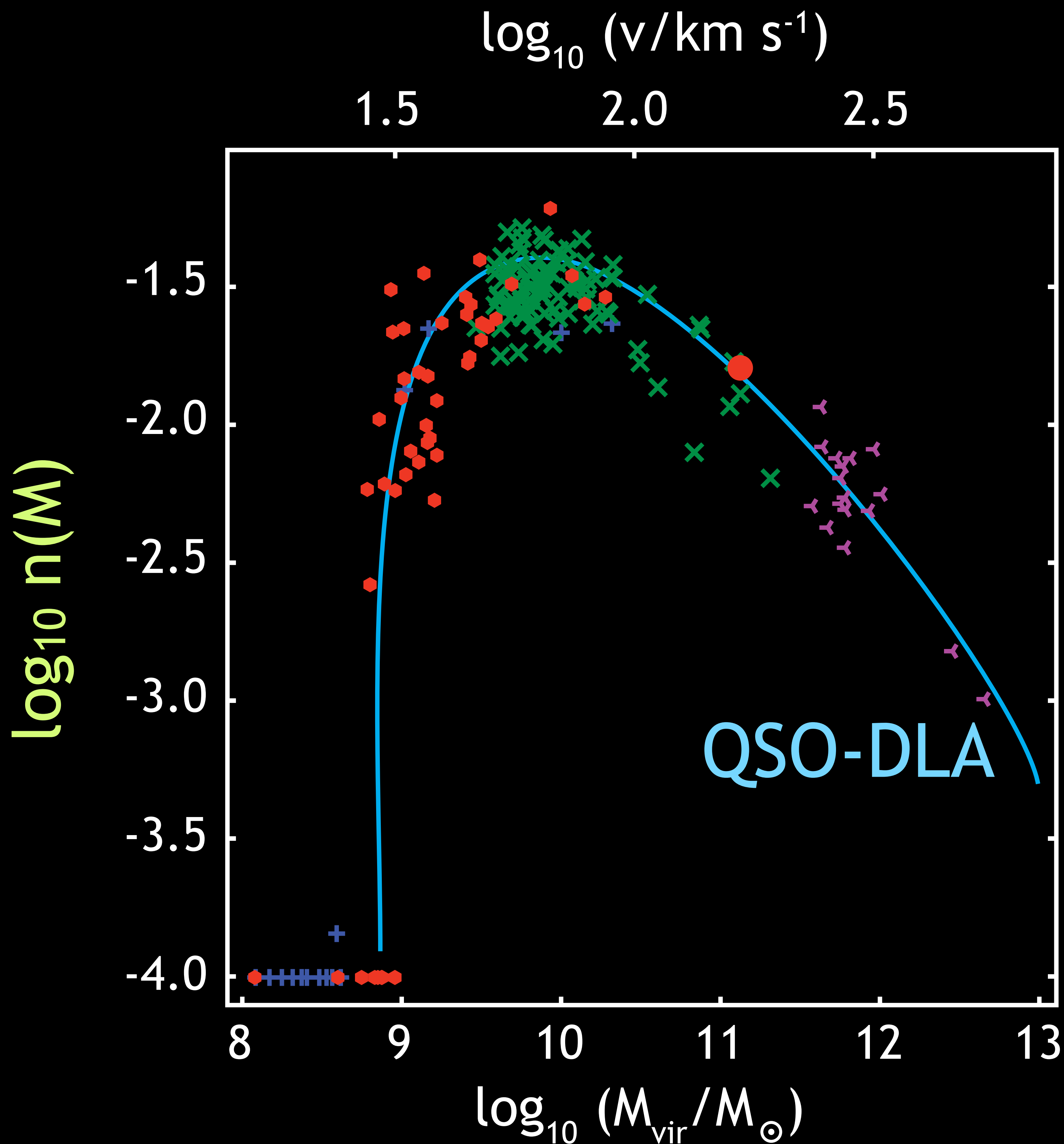


Impact Parameters



Difference accounts for column density discrepancies

What halos contribute?



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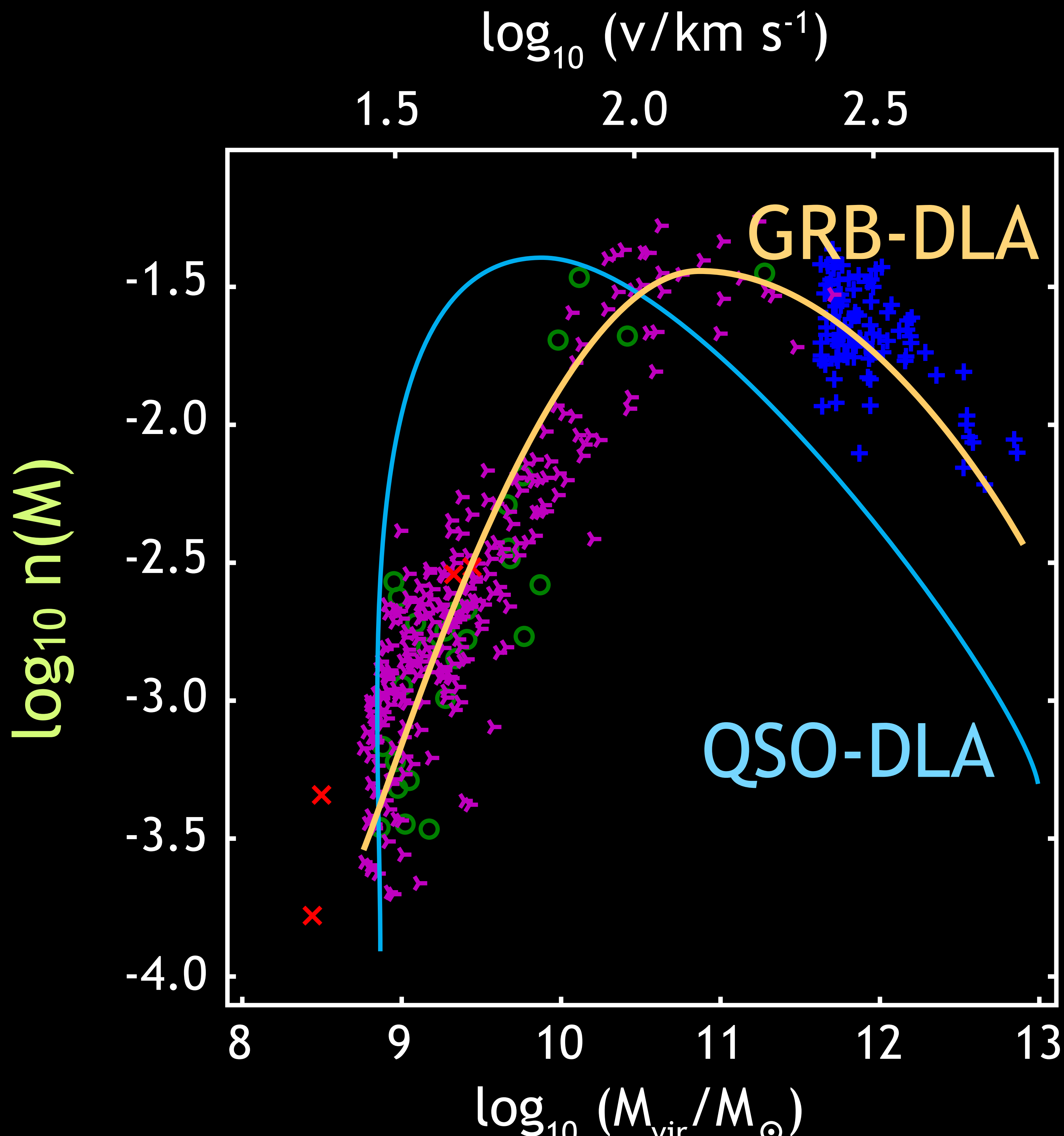

Difference accounts for metallicity discrepancies

$dM^*/dt \sim M_{vir}^{1.6}$

$\sigma_{HI} \sim M_{vir}^{1.0}$

Conclusions

- QSO & GRB-DLAs can be studied quantitatively in modern galaxy formation simulations
- Simple SF model for GRB-DLAs is reinforced
- GRB-DLAs vs QSO-DLAs
  - Higher mass population, more rapid SF: higher Z
  - Smaller impact parameters: larger N_{HI}
- Good statistics have potential to tell us a lot about the high-z ISM

Pontzen+ 08 MNRAS, 390, 1349 arXiv:0804.4474
Pontzen & Pettini 09 MNRAS, 393, 557 arXiv:0810.3236
Pontzen+ 09, in preparation, ask me for a draft!

Andrew Pontzen, IoA Cambridge; *apontzen@ast.cam.ac.uk*