

Feedback and Feeding:

The Physical Conditions and Kinematics of Gas within the High-Redshift CGM

Gwen Rudie (Carnegie)

Amber Roberts (U de Chile)

Sean Johnson (Princeton/Carnegie)

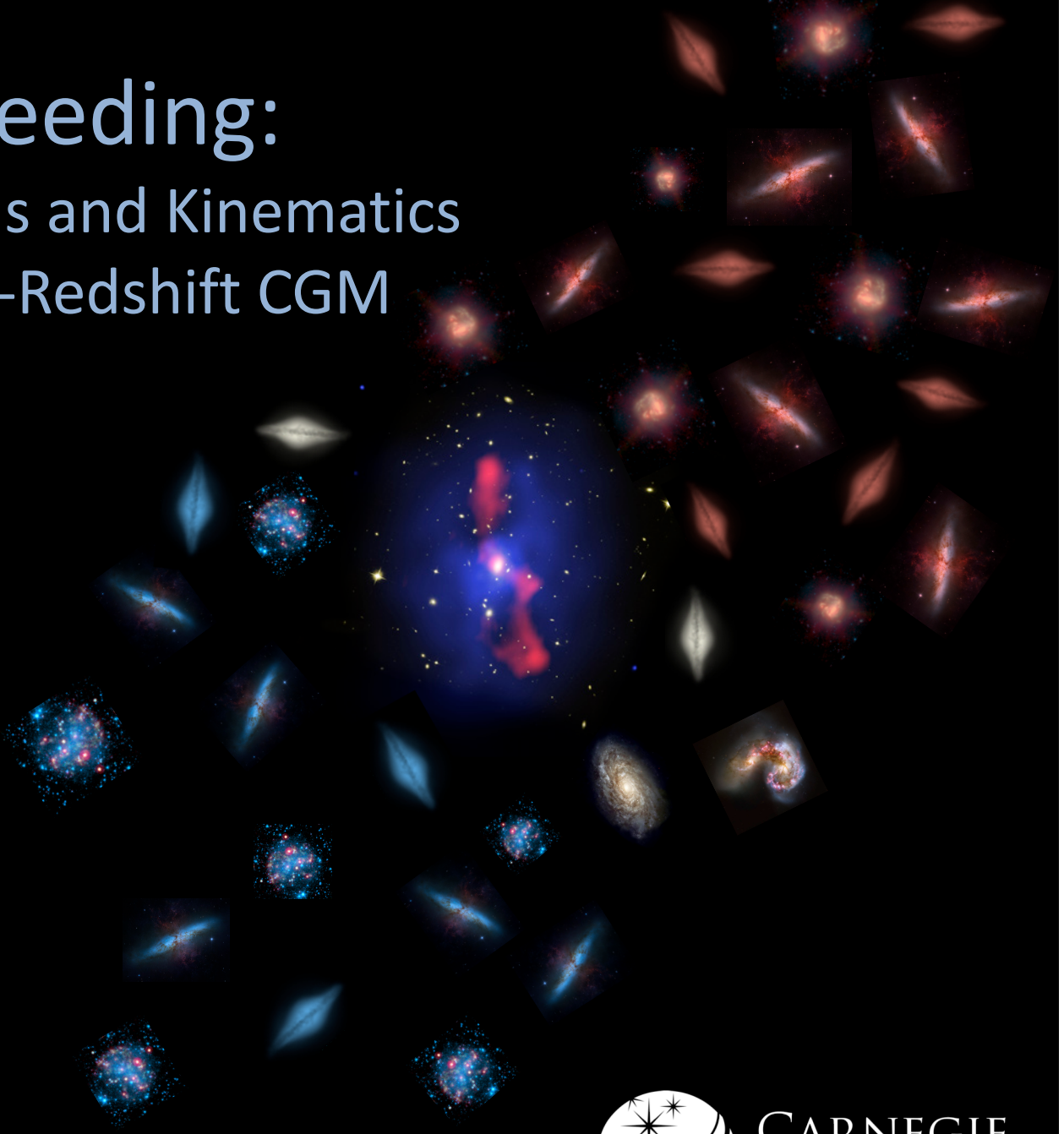
Yuguang Chen (Caltech)

Allison Strom (Carnegie)

Chuck Steidel (Caltech)

Ryan Trainor (Franklin & Marshall)

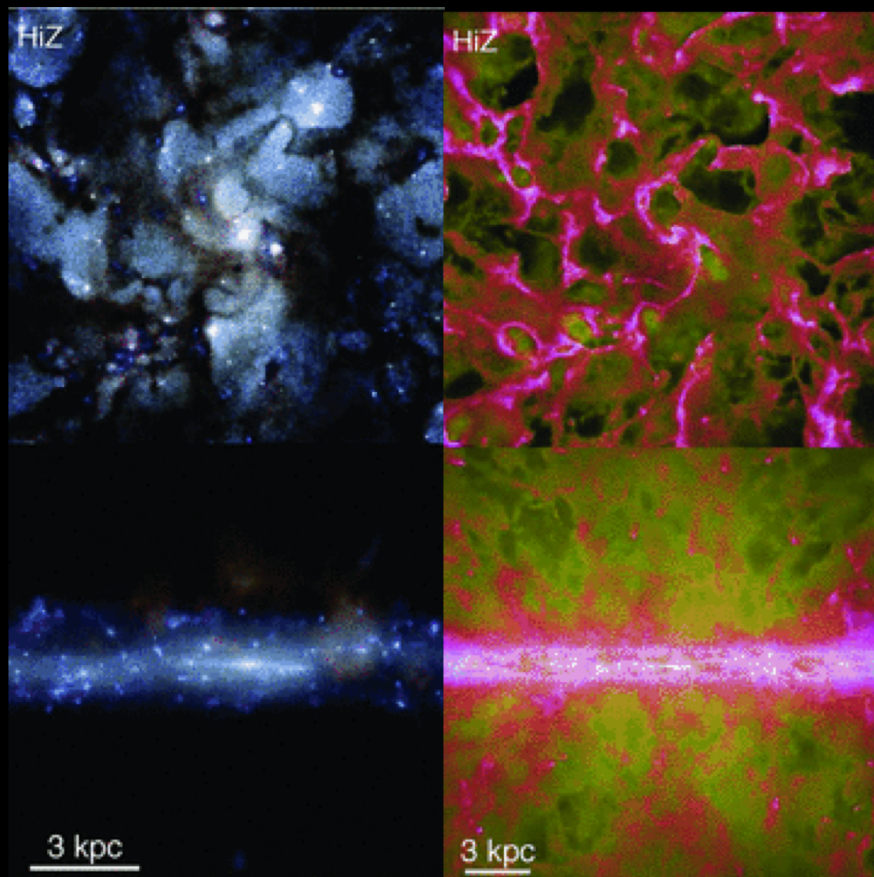
Max Pettini (Cambridge)



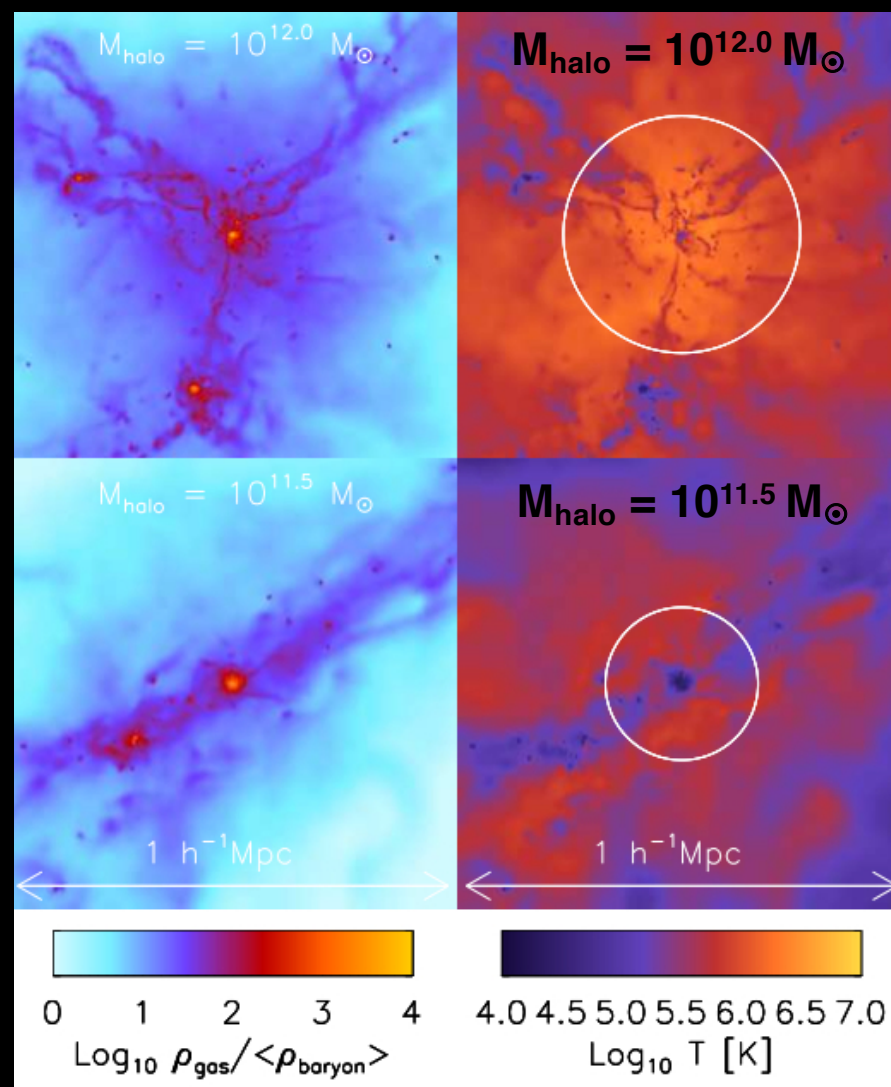
CARNEGIE
SCIENCE

Much of the content of this talk has been removed from the online version as it is unpublished. Please contact Gwen at gwen@carnegiescience.edu if you would like more information on the omitted portions of her talk.

The Circumgalactic Medium: Snapshots of Feedback and Feeding

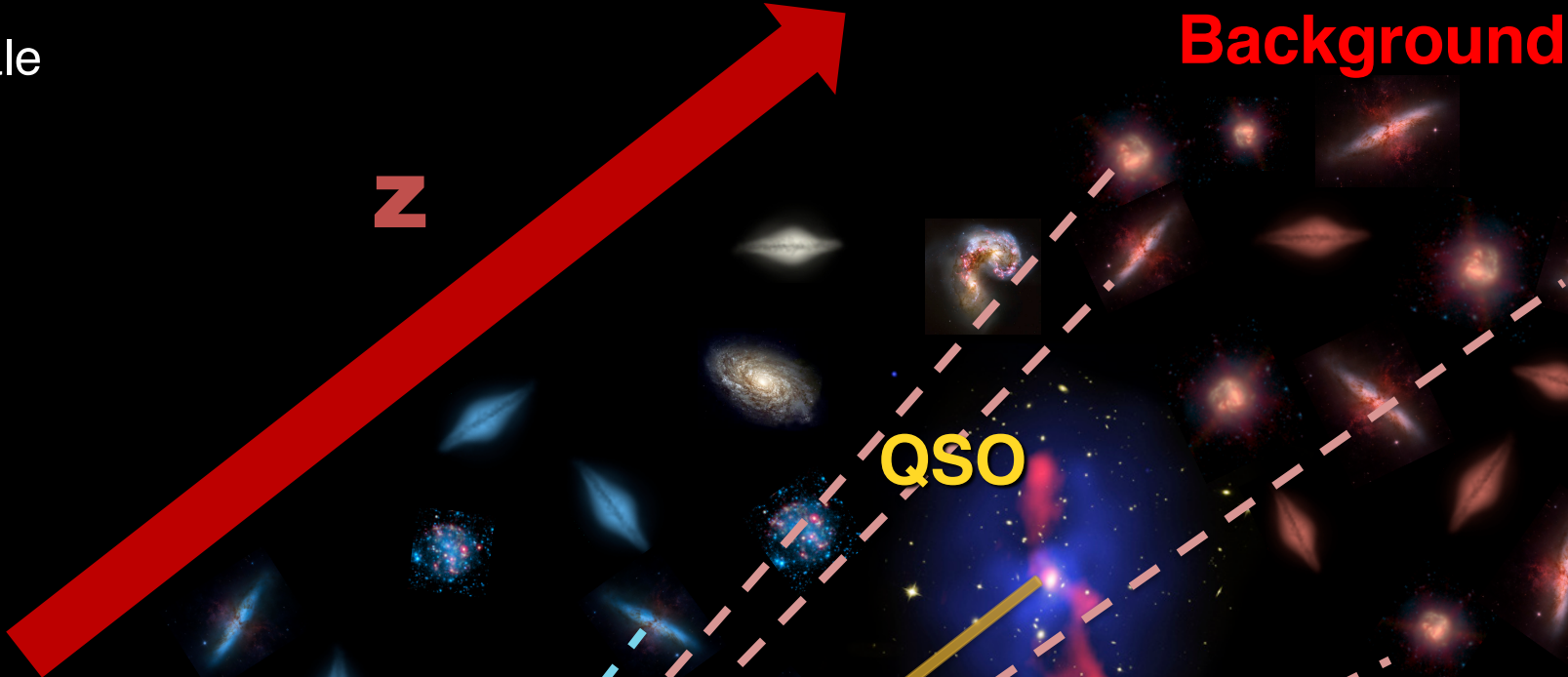


Hopkins, Quataert, & Murray 2012



van de Voort, et al. 2010

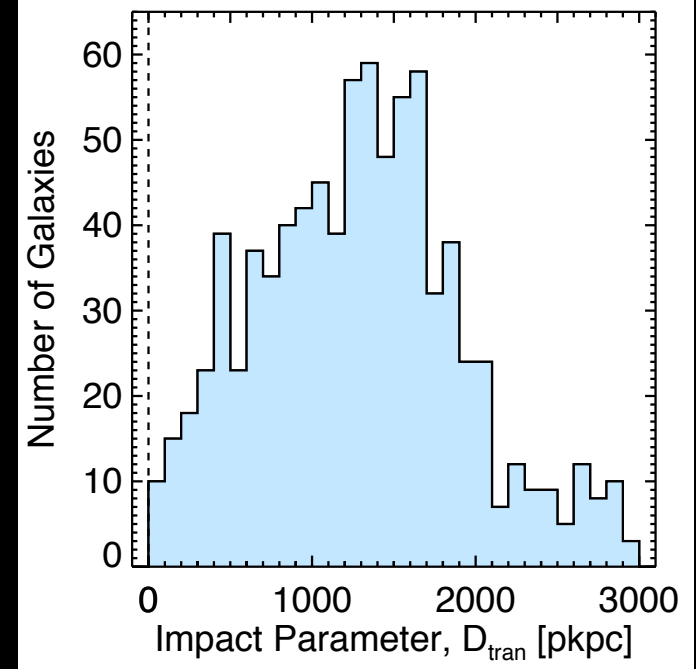
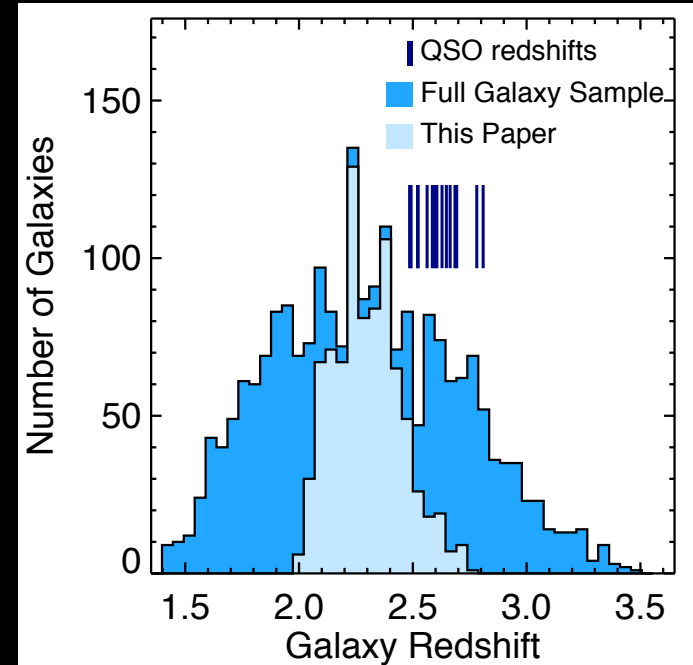
Universe not drawn to scale



Foreground

The Keck Baryonic Structure Survey

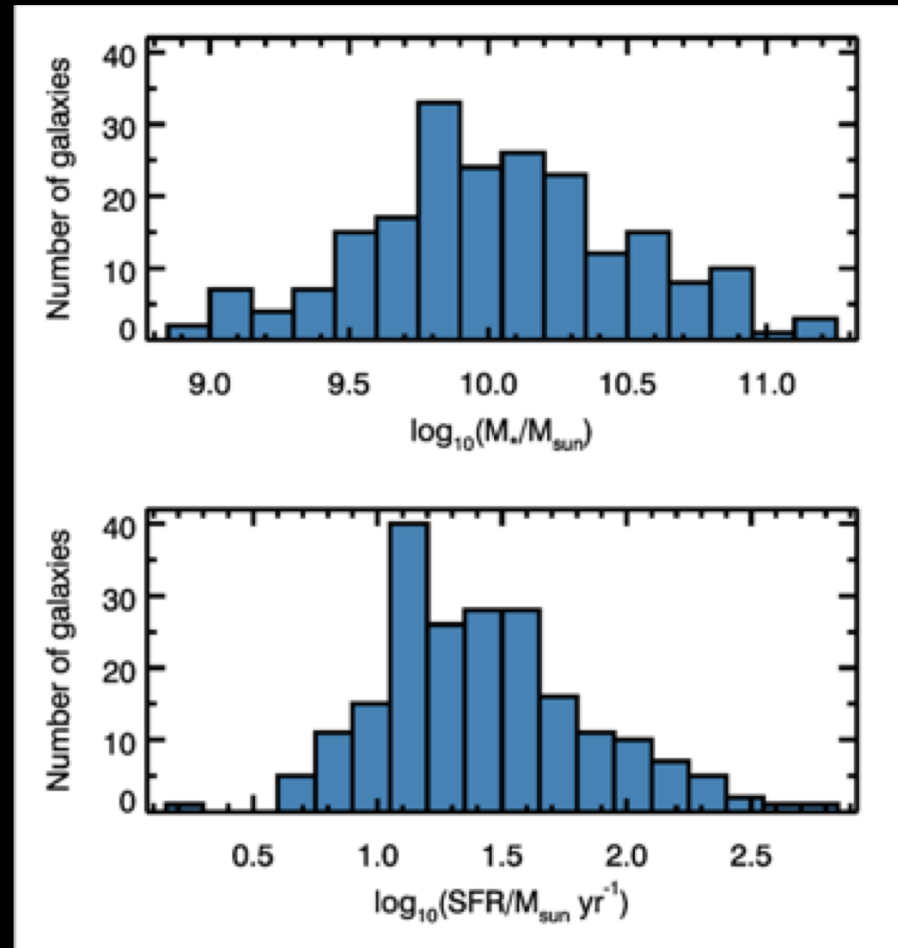
- 15 fields with the brightest QSOs in the sky $2.5 < z < 2.9$ at the Peak Epoch of Star Formation
- HIRES QSO spectra
 - 7 km/s resolution
 - S/N 50 – 200 (Ly α)
- Large Galaxy Redshift Survey
 - >2300 galaxies with Keck/LRIS
 - >1100 galaxies with Keck/MOSFIRE
 - ~400 with J, H, and K bands
 - >900 with CGM constraints



GCR+ 2012a

The KBSS Galaxy Sample

- $0.25 L^* < L < 3 L^*$
- $30 \text{ Myr} < \text{Age} < 3 \text{ Gyr}$
- $\text{SFR} \sim 3\text{-}300 M_{\odot}/\text{yr}$
- $10^9 < M_* < 10^{11} M_{\odot}$
- $\langle M_{\text{DM}} \rangle \sim 10^{11.9} M_{\odot}$
- Virial Radius $\sim 90 \text{ kpc}$



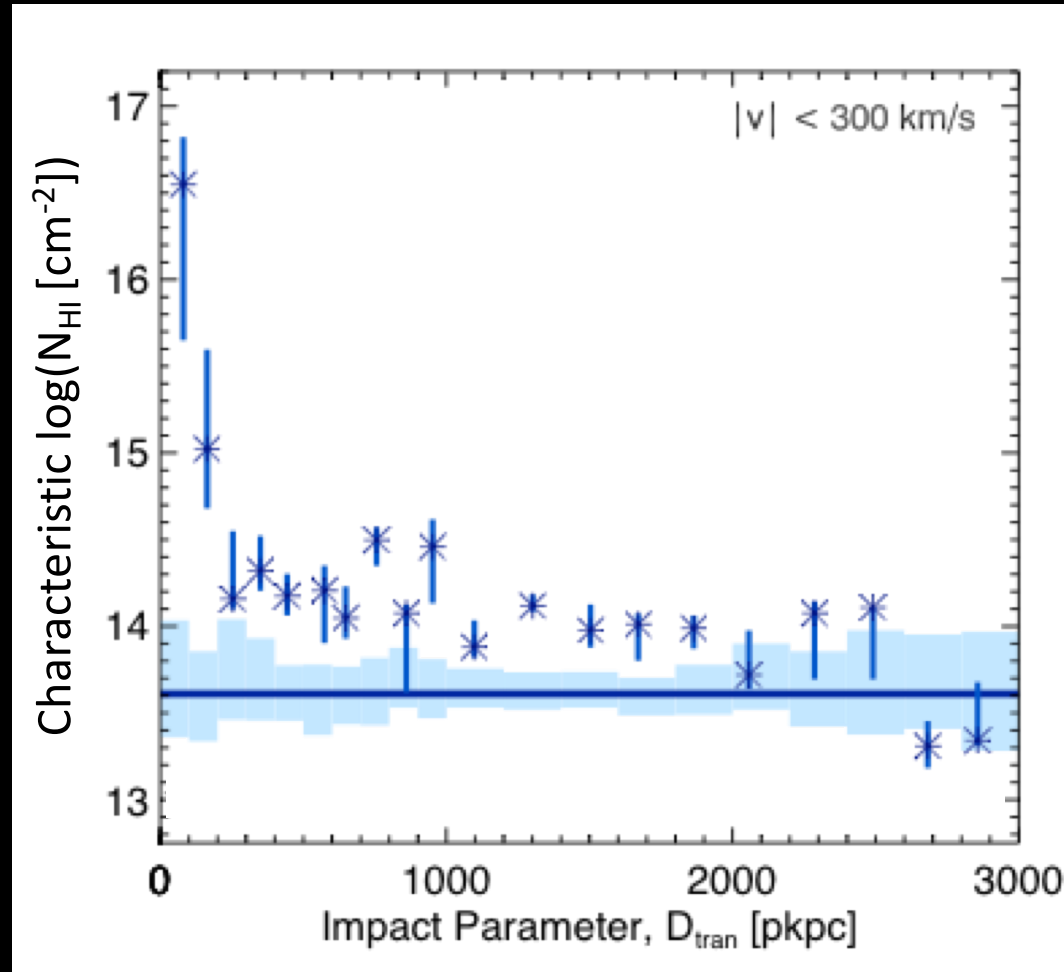
Strom et al. 2017

Trainor et al. 2012; Reddy et al. 2008; Strom et al. 2017

The High-Redshift CGM:

What is the CGM and out to what distance does it extend?

Spatial Distribution of HI



GCR+ 2012a

Significantly more HI within a few R_{vir}
Excess HI at > 2 Mpc

CIV Covering Fraction



Amber Roberts
(U de Chile)

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Roberts, GCR+ in prep

Enhanced metals also extend to
large distances from galaxies

What are the physical conditions of
gas in the CGM?

What does this tell us about
accretion and outflows?

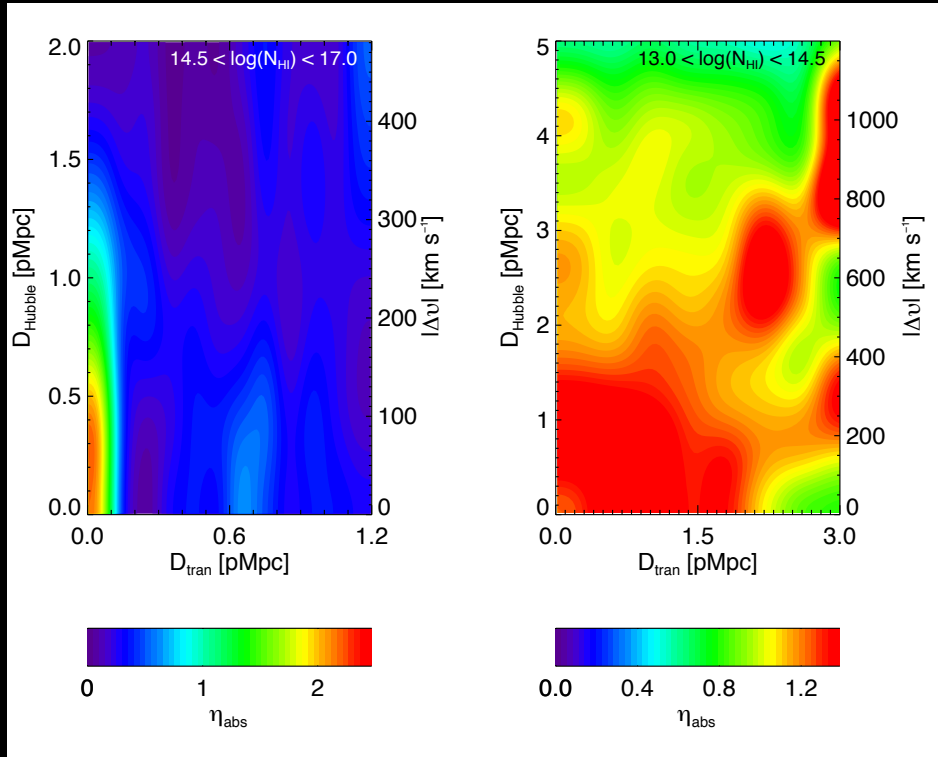
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Can we detect inflows and outflows
in the CGM?

What can the CGM kinematics
tell us about feedback?

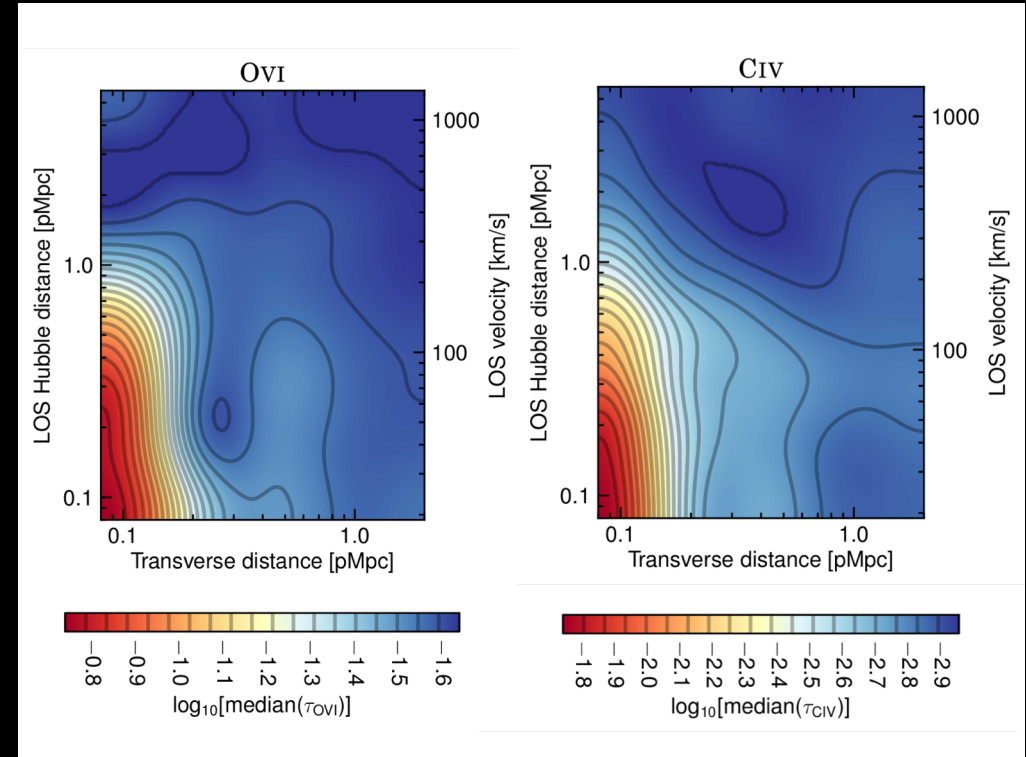
Gas Kinematics

Hydrogen



GCR+ 2012a and Rakic+ 2012

Metals



Turner et al. 2014

HI and Metals show coherent inflow on Mpc scales
Large peculiar velocities at small scales suggestive of outflows

Gas Kinematics

Using $>200,000$
foreground/background galaxy pairs

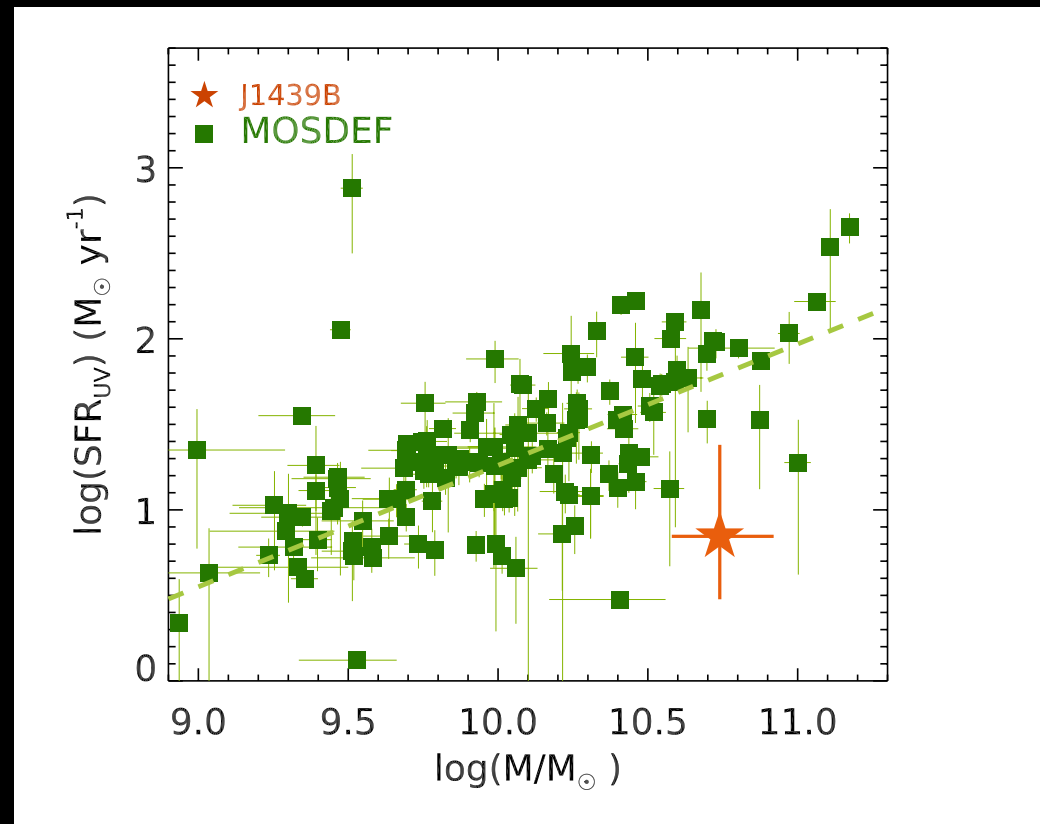
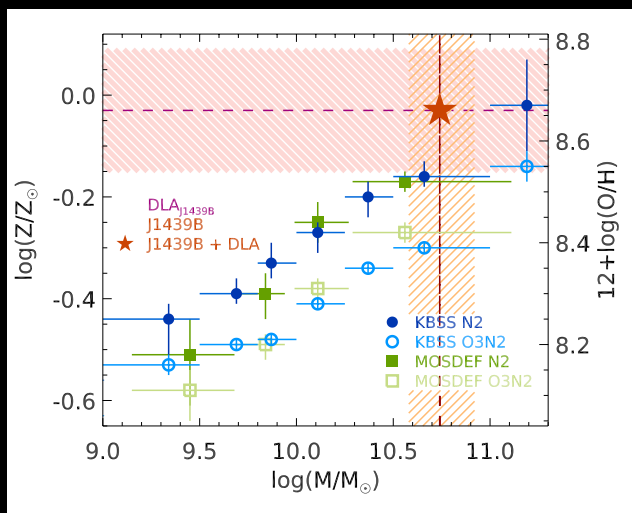
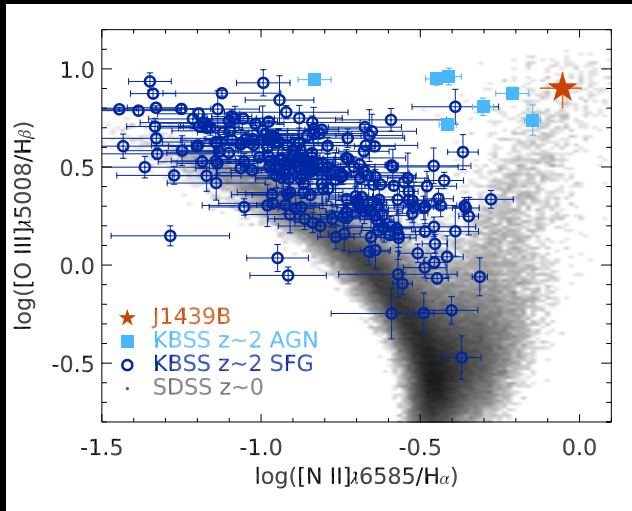


Yuguang Chen
(Caltech)

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See Yuguang's Poster!

A Solar-Metallicity 1000 km/s Molecular Wind from a $z=2.4$ AGN seen in Absorption



GCR+ 2017

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What can the evolution of the
CGM tell us about evolution in
feeding and feedback?

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Redshift Evolution of the CGM

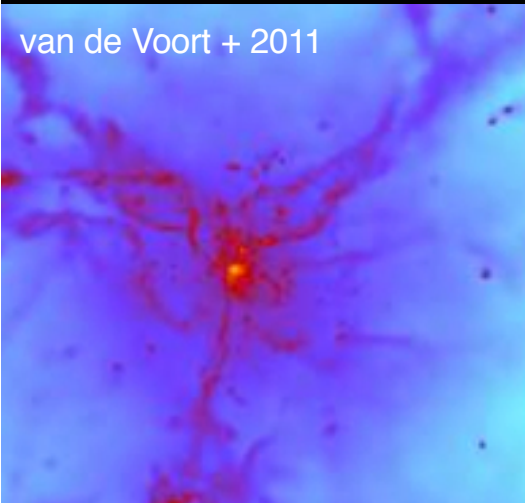
- More low- z CIV measurements would help
- Having an intermediate-redshift sample will be very interesting



The COS Ultraviolet Baryon
Survey

The CGM of $0.4 < z < 0.8$ galaxies

van de Voort + 2011



Conclusions

- HI and Metals are seen far from galaxies
 - Excess absorption to >1 pMpc
 - Strongly peaked within a few 100 kpc
- Gas in the CGM exhibits a wide range of temperatures
 - Broad agreement with theoretical paradigm of cold flows + outflows/accretion shocks
- Gas Kinematics shows evidence of inflows and outflows
 - Some CGM gas is unbound
- HI and Metals in the CGM evolve differently with z