KODIAQ: First Results, First Data Release

Metals and Baryons in the Highly Ionized Circumgalactic Gas at z~2-4

Support for this research has been made by NASA through ADAP grant NNX10AE84G.

KECK OBSERVATORY DATABASE (OF) IONIZED ABSORBERS (TOWARD) QUASARS

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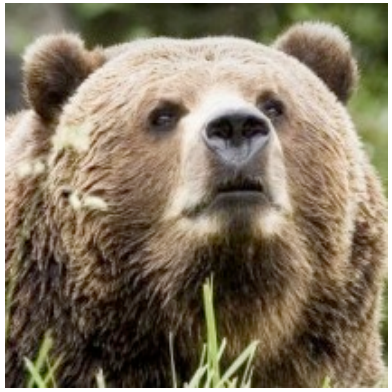
The KODIAQ Team



VINCENT BURNS
(ND)

ASHLEY ARMSTRONG
(ST MICHAEL'S COLLEGE)

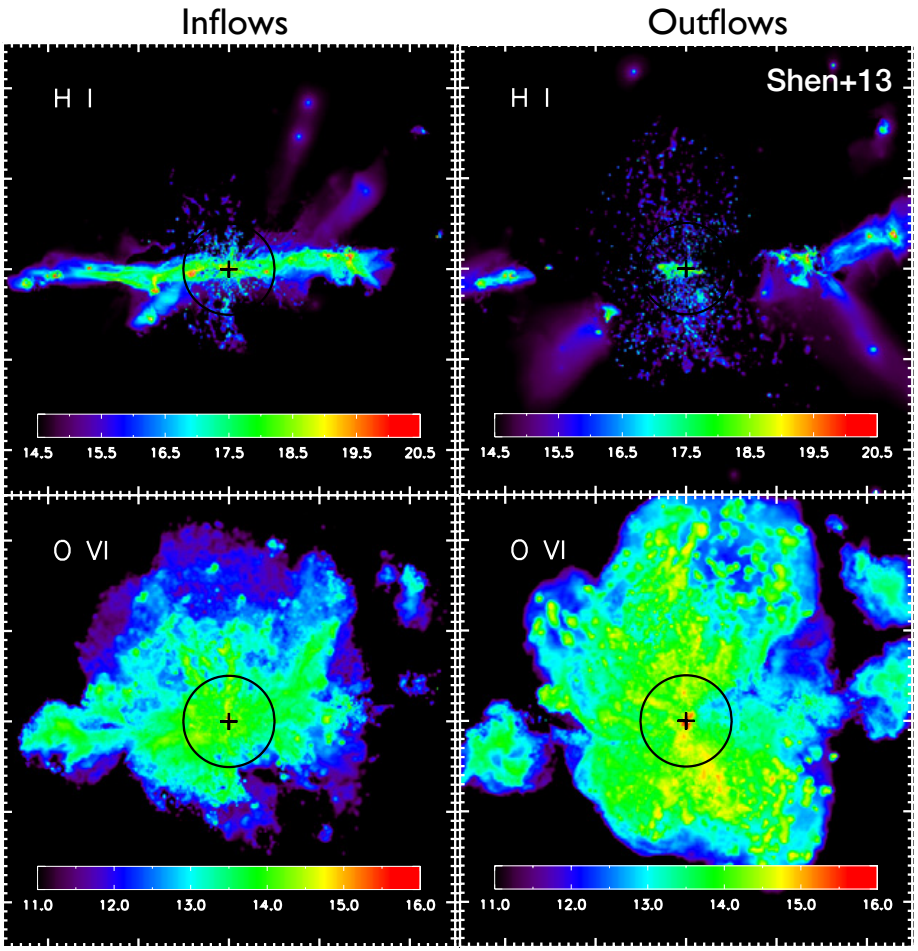
XAVIER
PROCHASKA
(UCSC)

(ART WOLFE)
(UCSD)

(FORMER UNDERGRADUATE STUDENTS)

The KODIAQ Survey: Scientific Motivation

- Study the hot, highly ionized gas of the dense CGM at the peak star-formation rate epoch.
- Determine the contributions of the dense CGM to the cosmic baryon and metal budgets at z~2-4.
- KODIAQ Z: tracing the metallicity distribution of the CGM.



➡ **select absorbers based on their HI content log N(HI)≳17.3** (and eventually >16)

➡ **primary ion to probe gas is OVI** (also CIV, SiIV, and NV + low ions)

KODIAQ

The KODIAQ Survey: Motivation

Date	P.I.	CCD	Side	Exp. Time	EXHANG	XDANG	Decker	Binning	λ_{low}	λ_{mid}	λ_{high}	$\lambda_{r,low}$	$\lambda_{r,mid}$	$\lambda_{r,high}$
					Q013340+040059	z_{em}= 4.15000								
27-Dec-2006	Wolfe	MOSAIC	RED	3600	4.22800e-05	0.460500	C1	2,1	4350.00	6360.00	8690.00	844.660	1234.95	1687.38
27-Dec-2006	Wolfe	MOSAIC	RED	3600	4.22800e-05	0.460500	C1	2,1	4350.00	6360.00	8690.00	844.660	1234.95	1687.38

The KODIAQ Database

- >300 unique quasars (many with high S/N).
  - >25,000 individual exposures
- Data processed by hires_redux package.
- All have been continuum fitted + coadded.
  - *We provide fully reduced + intermediate data products.*
- First 170 QSOs released on May 15, 2015.
  - *See J. O'Meara et al. (2015, arXiv:1505.03529).*

THE FIRST DATA RELEASE OF THE KODIAQ SURVEY

J.M. O'Meara[1], N. Lehner[2], J.C. Howk[2], J.X. Prochaska[3], A.J. Fox[4], M. A. Swain[5], C. R. Gelino[6], G. B. Berriman[6], & H. Tran[7]

Submitted to the Astronomical Journal

KODIAQ

The KODIAQ Database

KODIAQ

The KODIAQ Database

KODIAQ

Home | Documentation | KOA Helpdesk

The Keck Observatory Database of Ionized Absorption toward Quasars (KODIAQ) is a repository of reduced, continuum normalized quasar spectra derived from public HIRES raw data served through the Keck Observatory Archive (KOA). Data are provided in one dimensional flux and error fits files. Intermediate data extraction products are also available. The data are summarized in O'Meara et al. (submitted to AJ) and Lehner et al. 2014, ApJ 788, 119. KODIAQ was funded through NASA ADAP grant NNX10AE84G.

The KOA web pages are supported under most common hardware platforms and operating systems, but on tablets such as iPads and Androids, features using mouse click-and-drag functionality are not available. Internet Explorer is not supported - we recommend Firefox or Chrome for Windows users.

Note: pop-up windows need to be enabled for the interactive spatial search results.

Pre-Packaged KODIAQ Data

QSO Spectra	Download All (Tar file of 170 QSOs) **(275M compressed, 389M uncompressed)** Browse QSOs
Intermediate HIRedux Reduction Products	Wget script to Download All Browse HIRedux products

Search for KODIAQ data

Position/Object Name

(Leave this field blank to return all data)
(Examples: UM673 or PHL 3703 or SMS87 0142-100 or 01:45:16 -09:45:17 Equ J2000)

Radius 1.0 arcmin

(Resolved by NED first then SIMBAD)

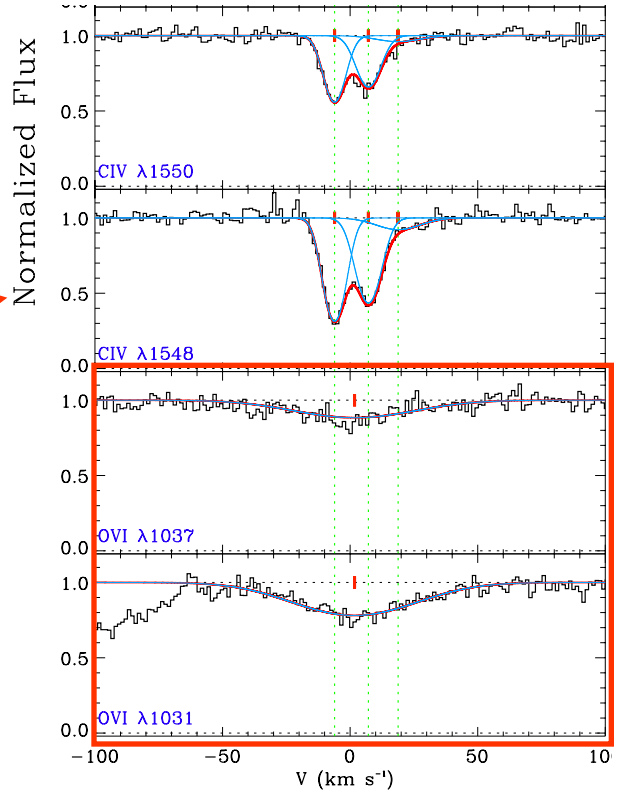
Submit Search Reset

KODIAQ

KODIAQ would not exist without…

KODIAQ: treasures in the forest.

Early science preview: C IV and OVI do not trace the same phenomena in the z~2-3 CGM.



For KODIAQ we have so far required *both* lines of the O VI doublet to be clean.

KODIAQ

CGM OVI is strong

- When OVI detected, it's often present in large quantities:

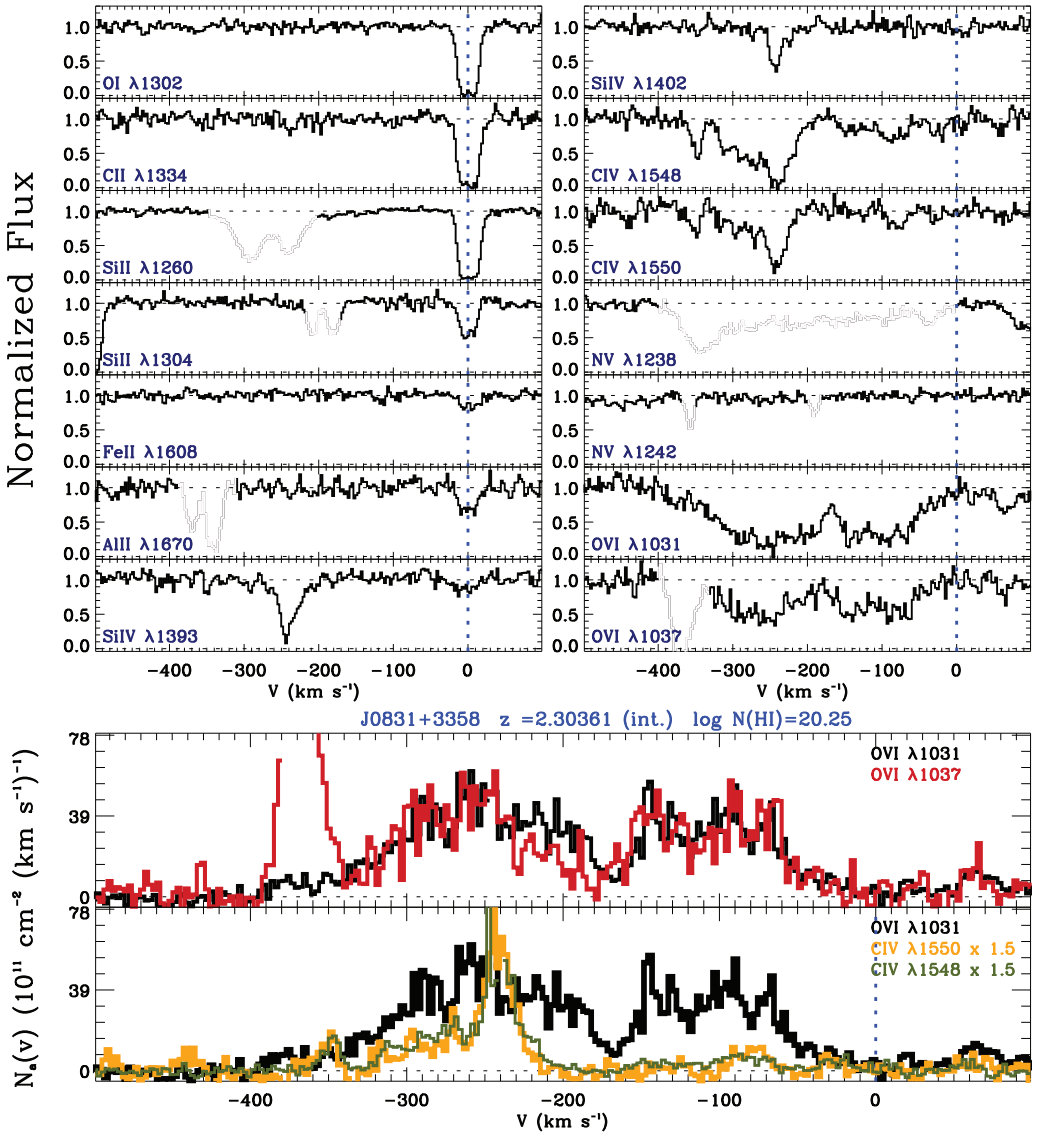
$$\log\langle N_{OVI}\rangle = 14.9$$

O VI Detection rates:

DLAs: 100%

sub-DLAs: 63%

LLSs: 71%



Lehner+ (2014)

KODIAQ

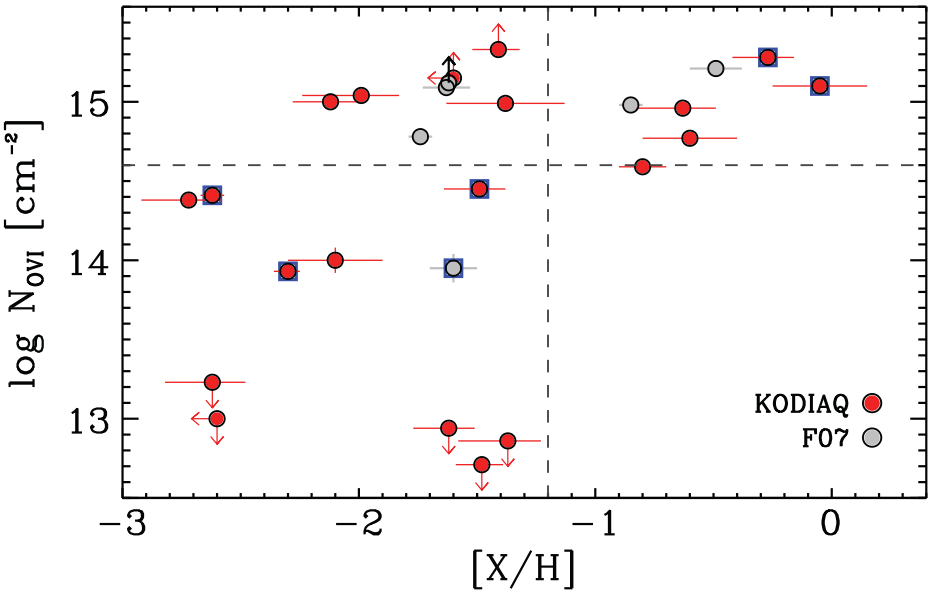
CGM OVI is strong

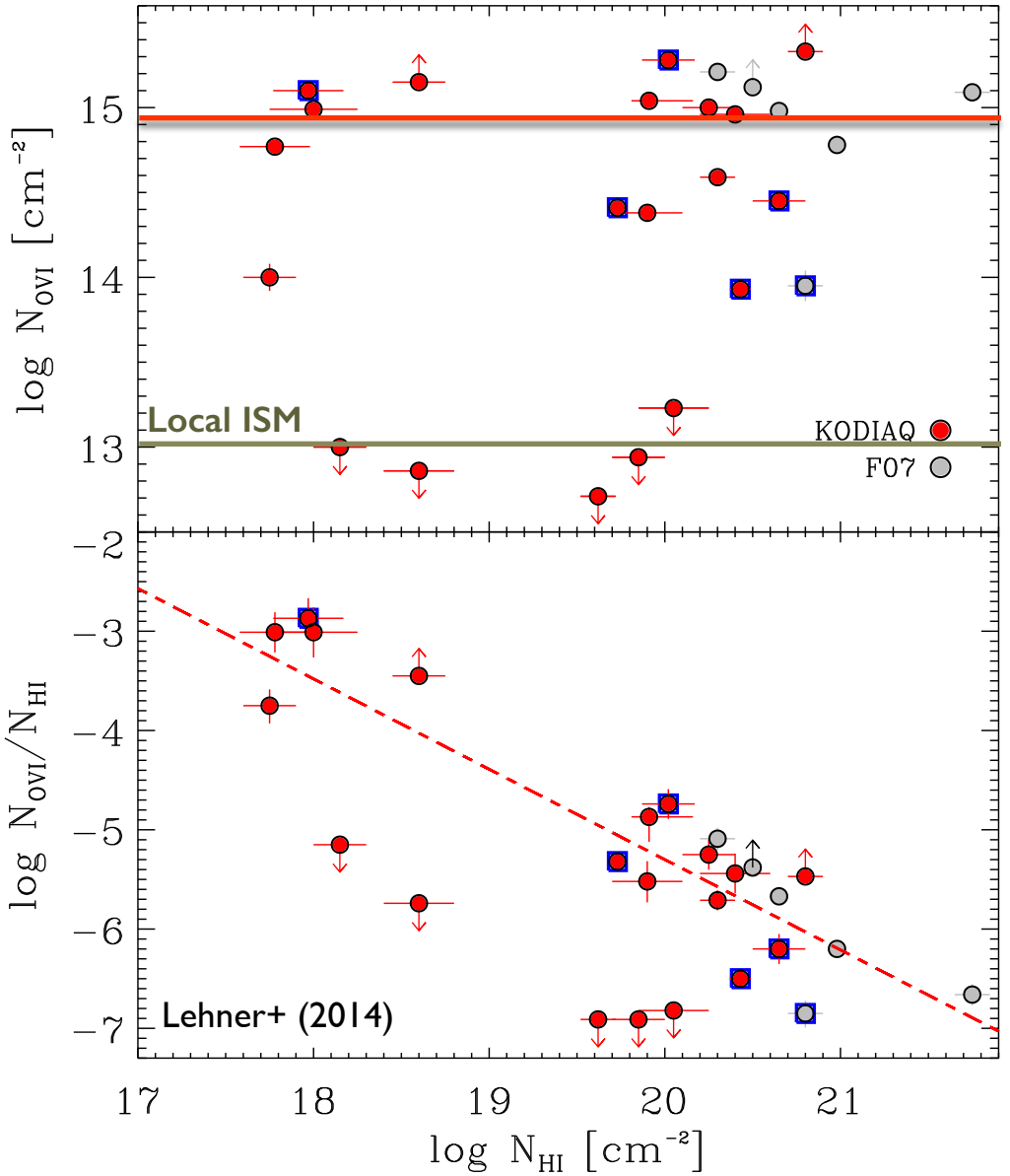
- When OVI detected, it's often present in large quantities:

$$\log\langle N_{OVI}\rangle = 14.9$$

Similar to local starbursts!

- When OVI is not detected, it is *very* low.





KODIAQ

CGM O VI is broad

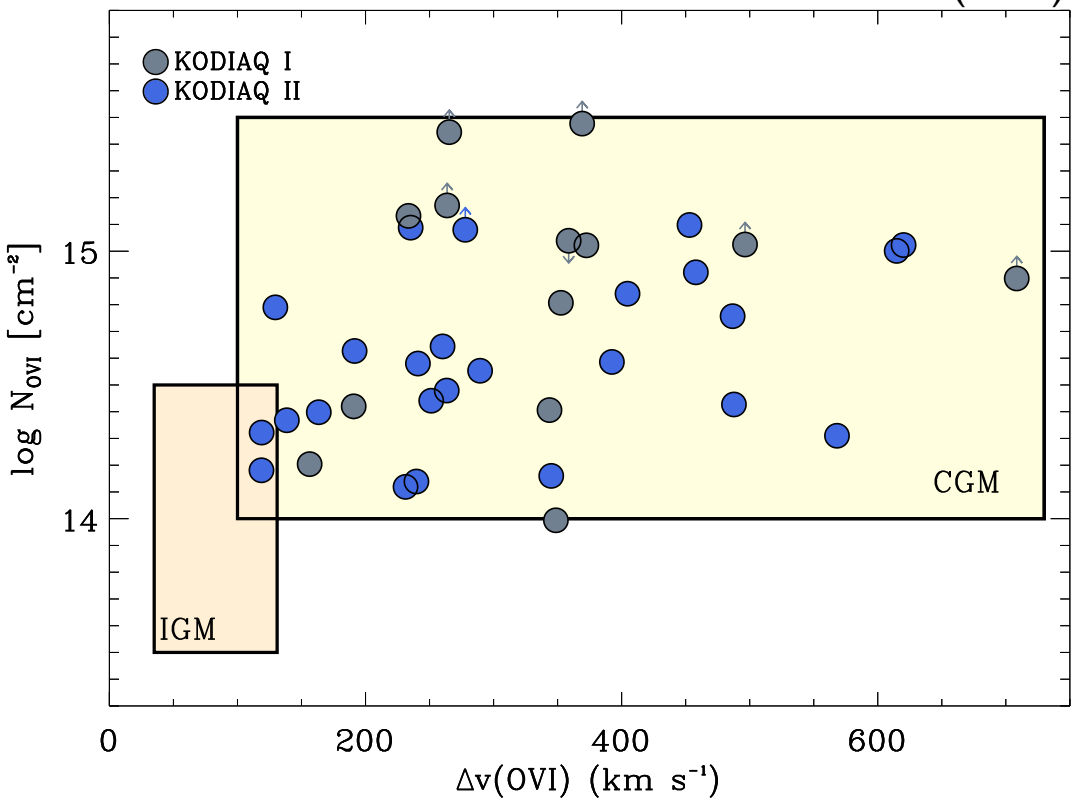
- CGM O VI is very broad, both in total Δv and b-value.
- CGM O VI (H I-selected) is much broader than blindly-selected O VI.

Δv(CGM) ≈ 300 km/s (Lehner+ 2014)

Δv(IGM) ≈ 66 km/s (Muzahid+ 2012)

- O VI is broader than other ions, notably C IV, Si IV, Si II.

Lehner+ (2016)



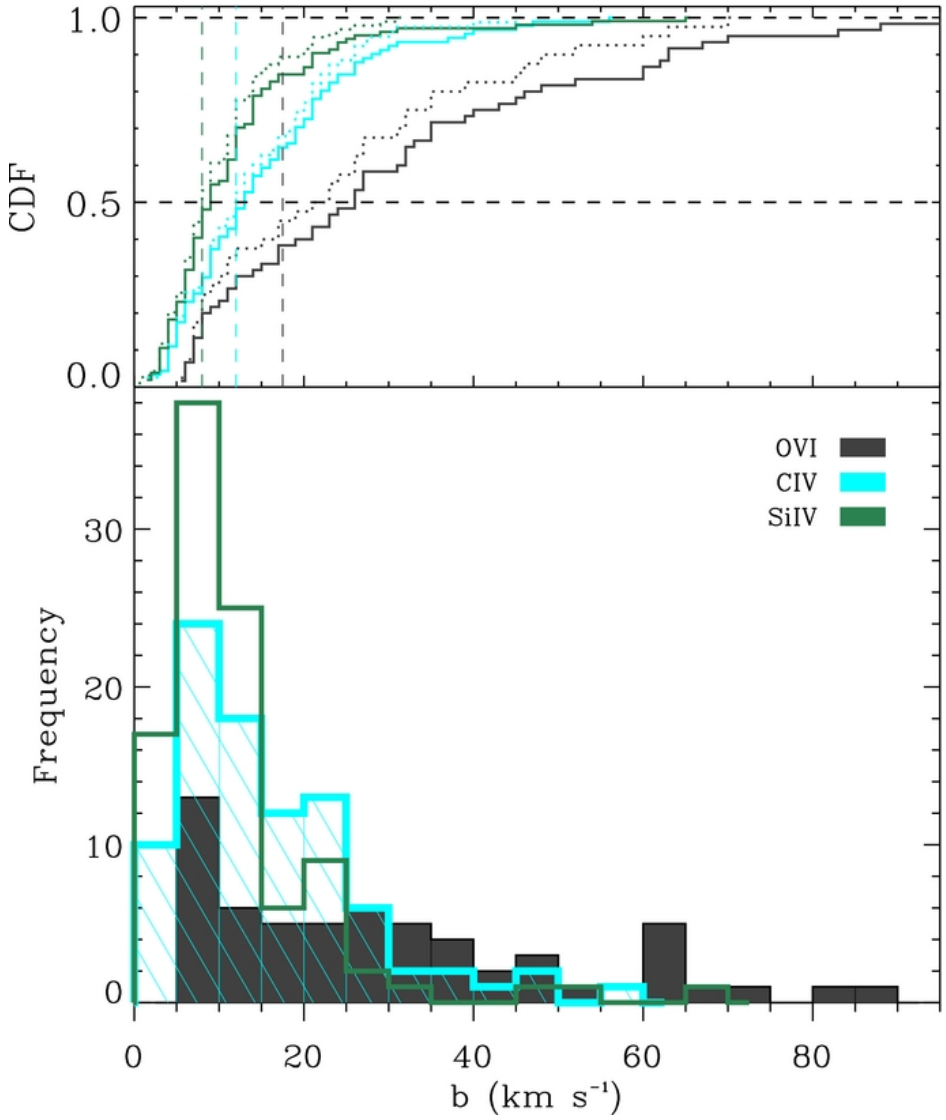
KODIAQ

CGM O VI is broad

- CGM O VI is very broad, both in total Δv and b-value.
- CGM O VI (H I-selected) is much broader than blindly-selected O VI.

N.B.: We find individual O VI components with b-values implying non-equilibrium cooling.

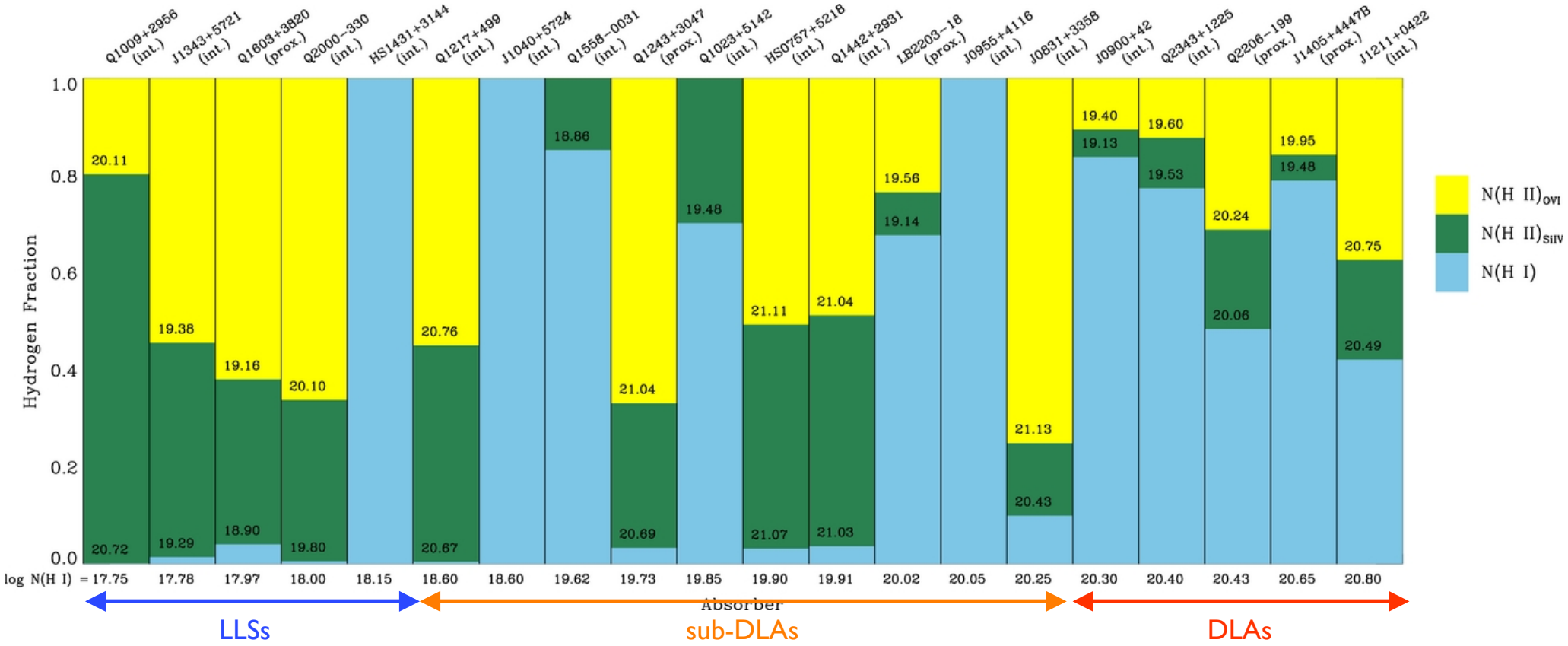
This only happens for high-metallicity gas, higher than seen in the H I-bearing gas.



Lehner+ (2014)

KODIAQ

CGM baryons are substantial at z~2-3



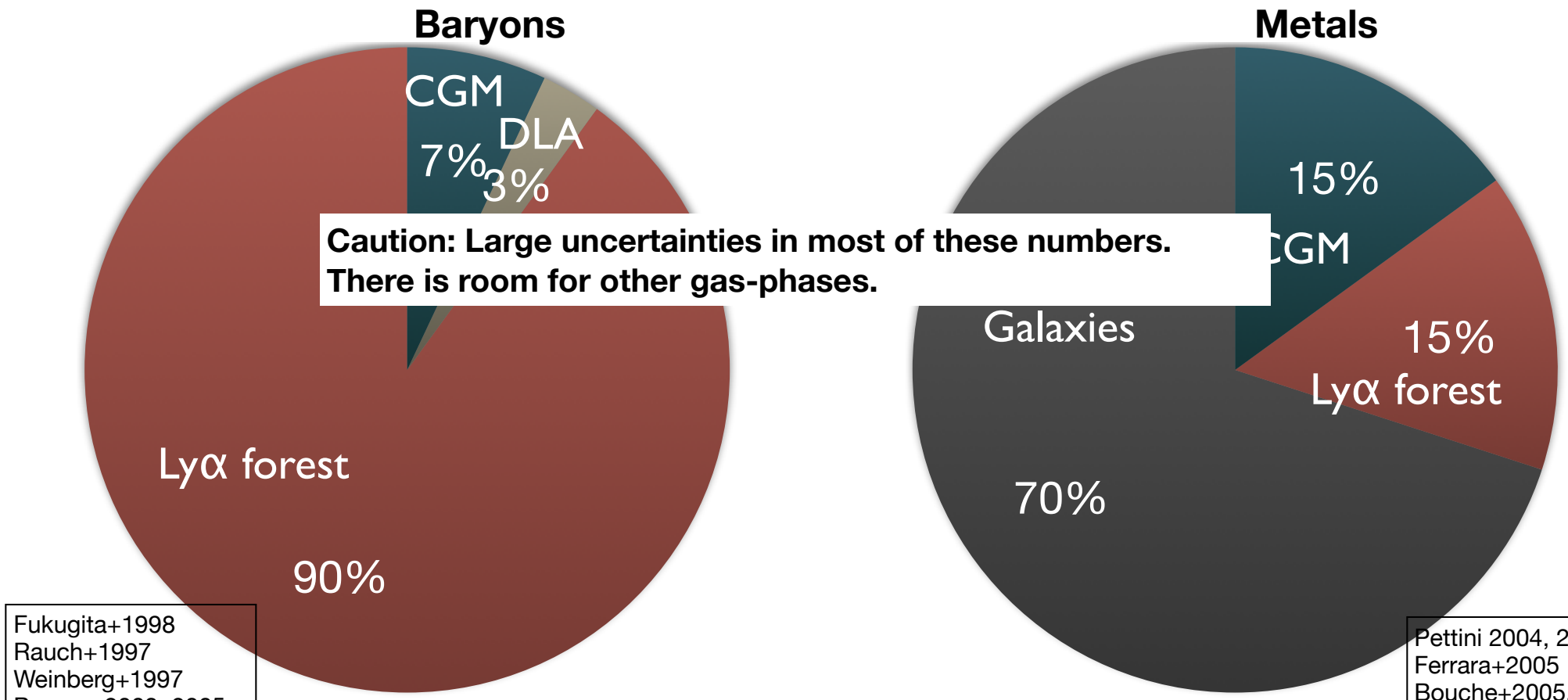
see also Fox+07 for the DLAs

$N(HII)_{OVI} = N(OVI)/(f_{OVI}\ (O/H))$

$N(HII)_{SiIV} = N(SiIV)/(f_{SiIV}\ (Si/H))$

KODIAQ

The CGM at z~2-3 harbors substantial baryons, metals



Fukugita+1998
Rauch+1997
Weinberg+1997
Peroux+2003, 2005
Prochaska et al. 2005

Pettini 2004, 2006
Ferrara+2005
Bouche+2005,2008
Peeples+2014

Highly-ionized gas in the CGM represents:

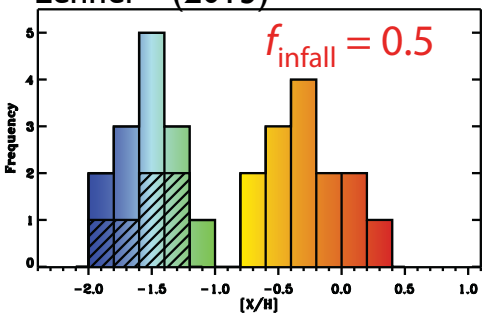
>5-20% of all the metals produced at z ~ 2–3.

>3-14% of all the baryons at z ~ 2–3.

KODIAQ

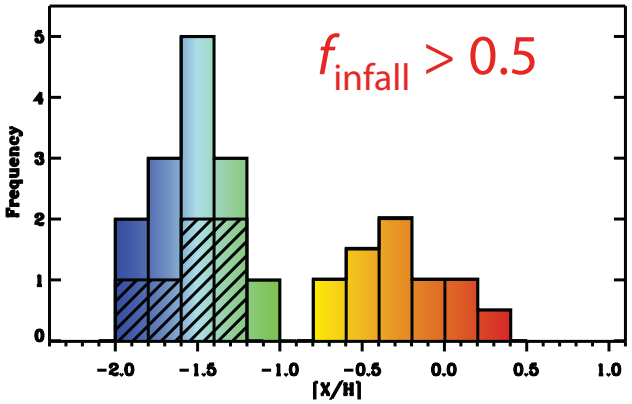
KODIAQ-Z: Metallicity of the CGM at z=2-4 (300 LLSs)

Lehner+ (2013)



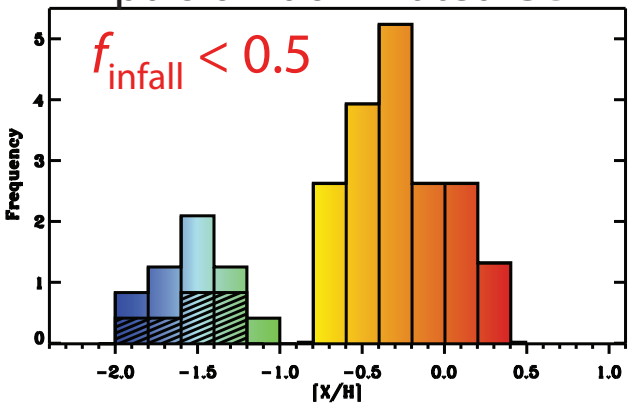
Is the high SFR density driven by more infall?

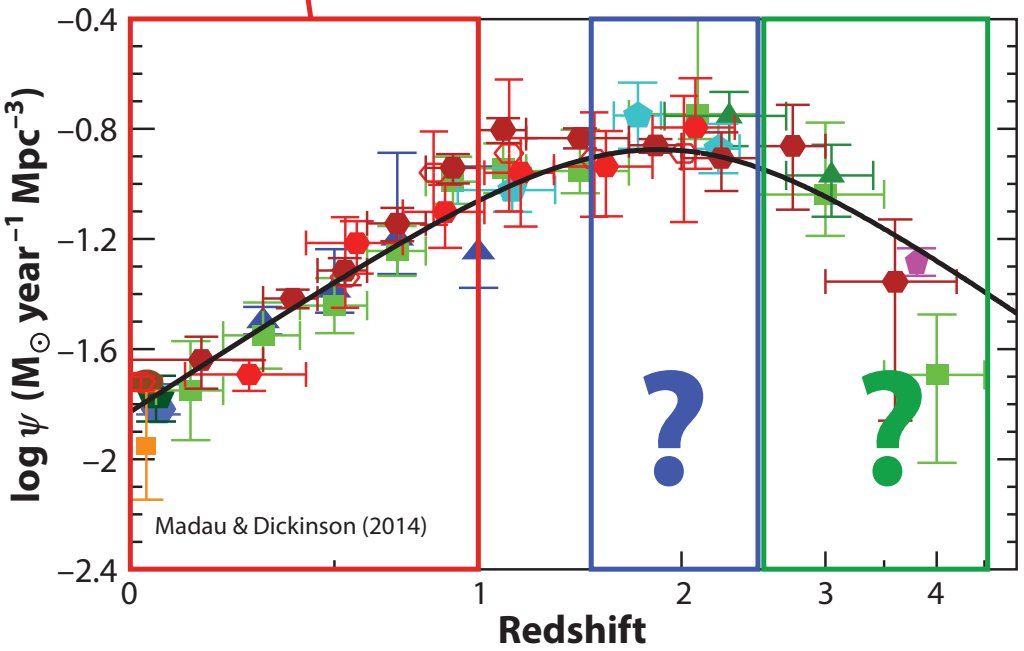
Infall-dominated CGM

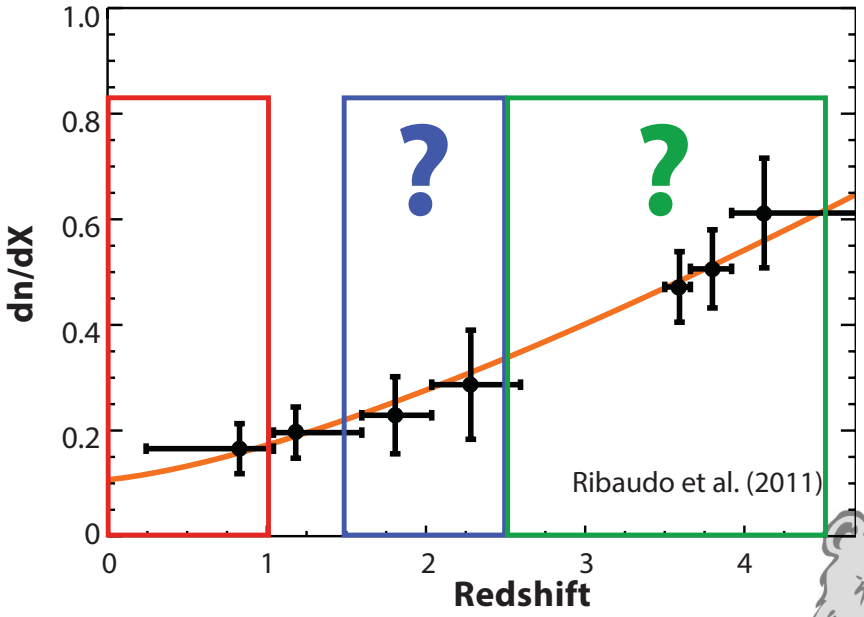


Is there more metal-enriched expulsion due to higher SFR density?

Expulsion-dominated CGM







KODIAQ

KODIAQ Results

- Optically-thick systems probe gas in the vicinity of galaxies – the CGM – at z ~ 2-3.
- O VI in the CGM is much different than the IGM, similar to expectations from active winds.
- The highly-ionized CGM contains substantial fractions of all galactic baryons and all metals at z ~ 2-3.