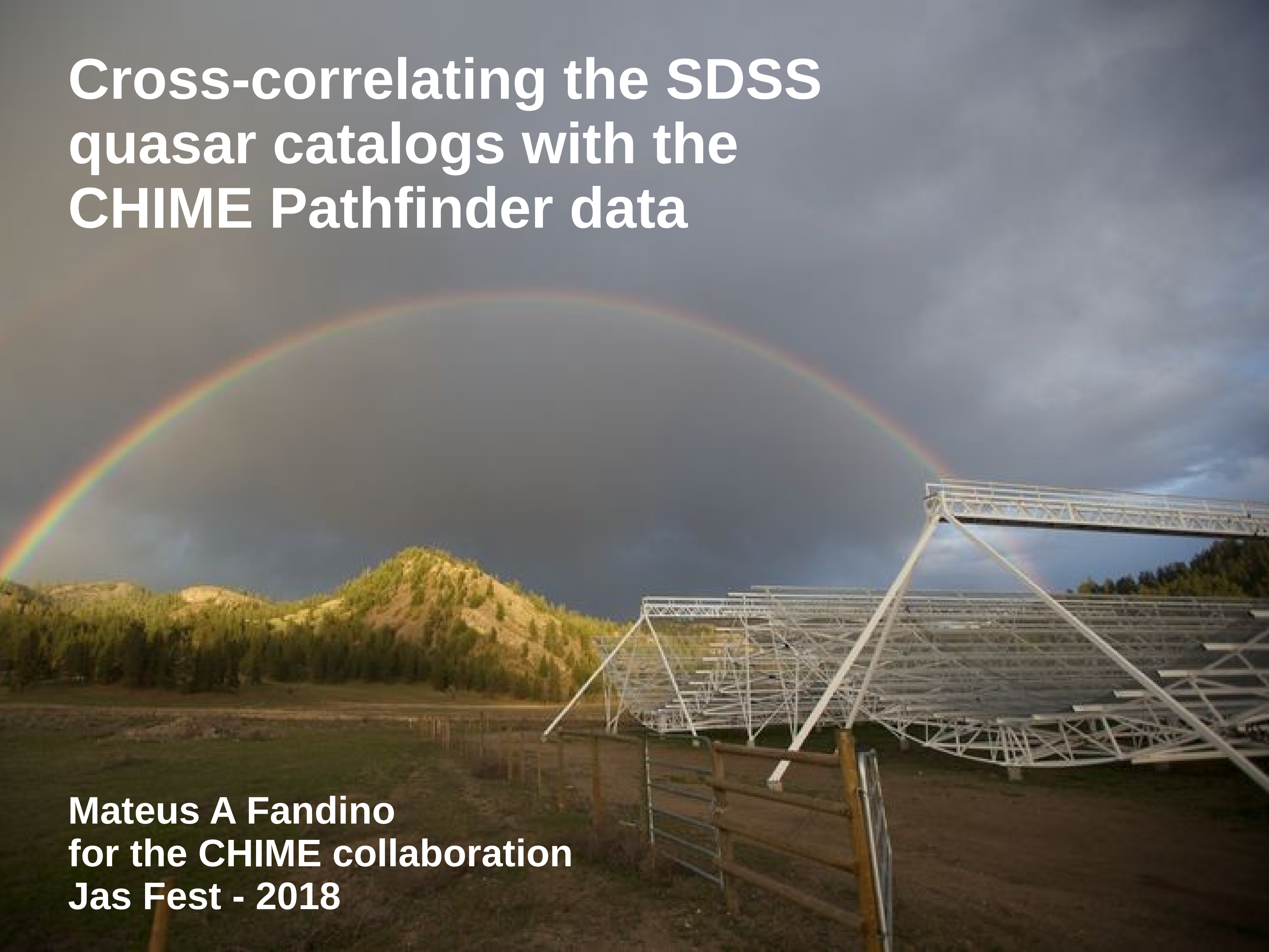
Cross-correlating the SDSS quasar catalogs with the CHIME Pathfinder data



Mateus A Fandino
for the CHIME collaboration
Jas Fest - 2018

Outline

Motivation

Instrument/Datasets

Redshift stack

Realistic simulations

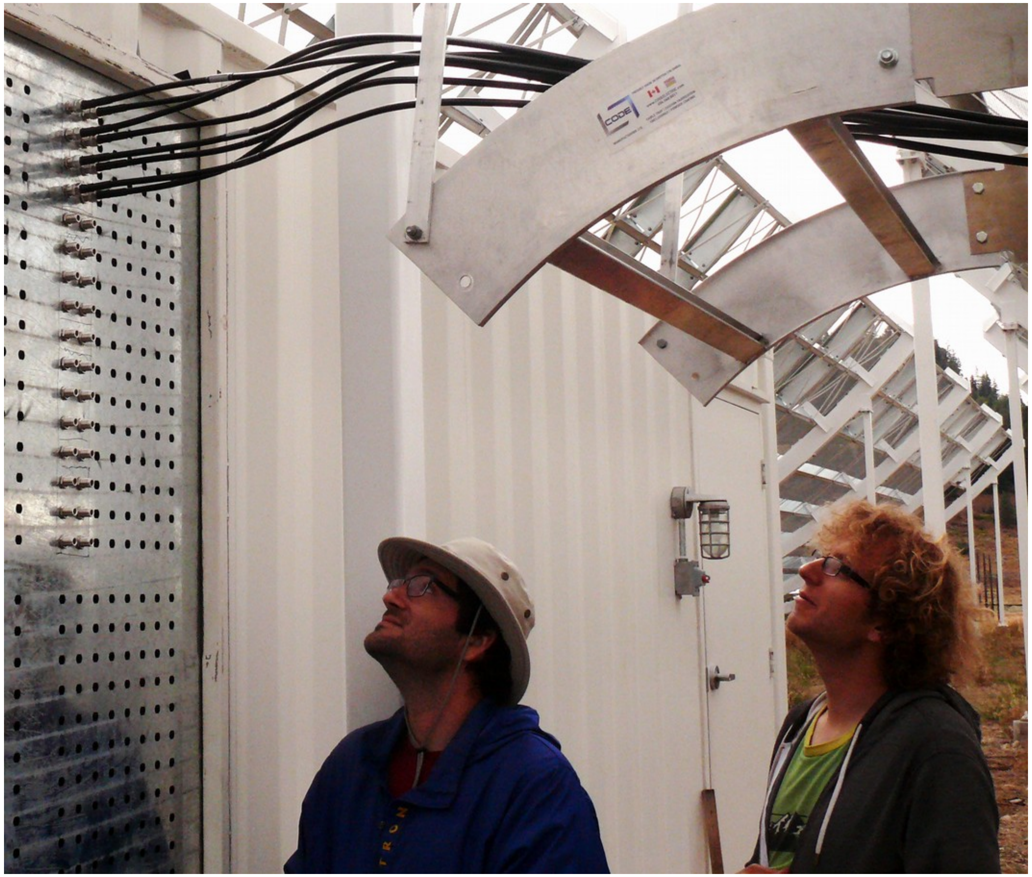
+ Mock catalogs

+ Expected signal

Pathfinder results

Next steps

Collaboration with J Richard Shaw



Motivation

Different tracers of LSS

Circumvent calibration challenges

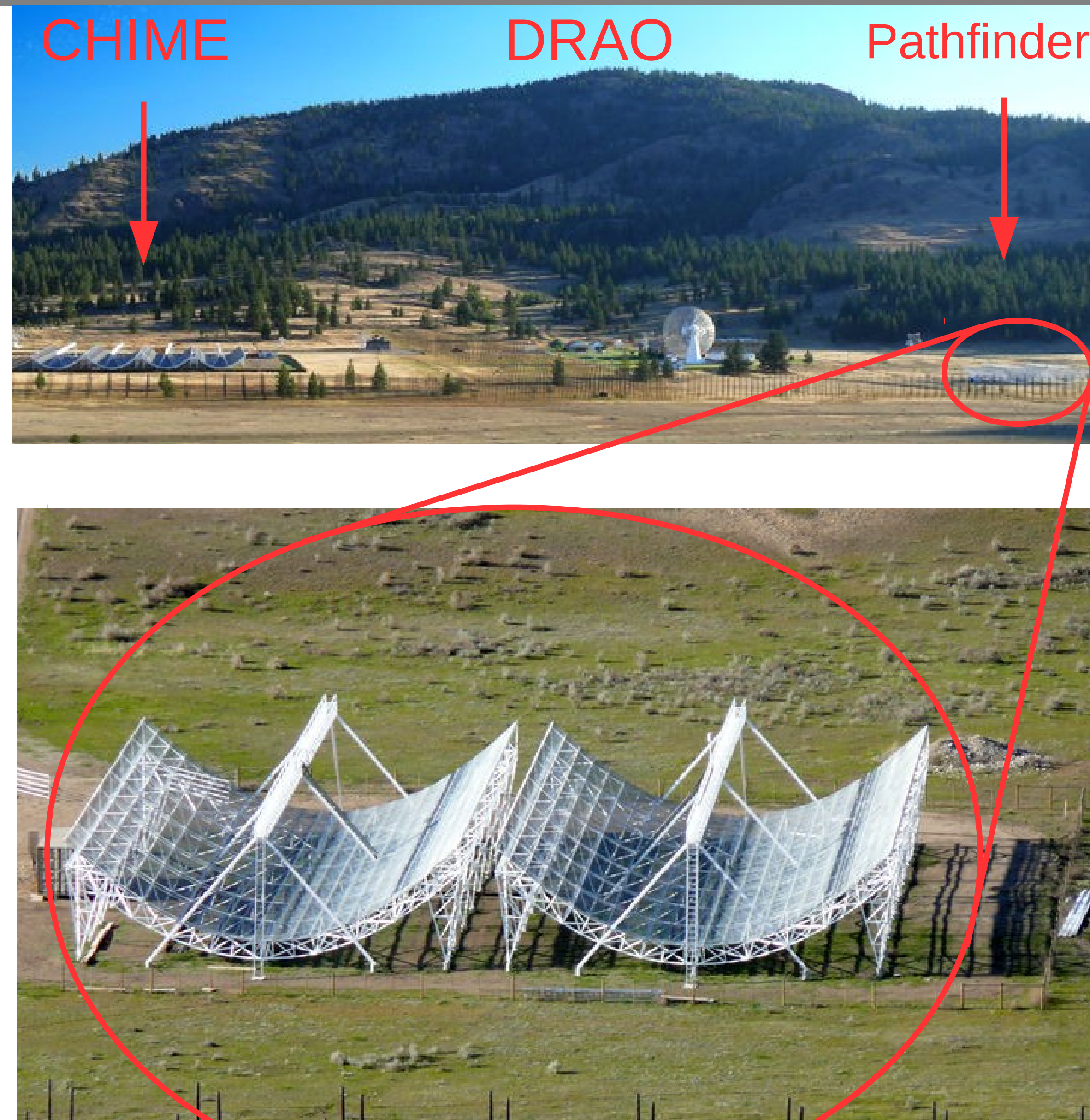
Early detection of HI signal

A possible probe on:

- HI x Quasar correlation
- HI and quasar bias
- Overall HI abundance (Ω_{HI})
- HI fraction in massive halos (containing quasars).

Instrument – CHIME Pathfinder

- Scaled down (1/8) version of CHIME
- 2 cylinders (20x36m)
- 128 dual polarization feeds
- Full N^2 correlation at 20 seconds cadence (1 TB/day)
- Over 3 years of data collection

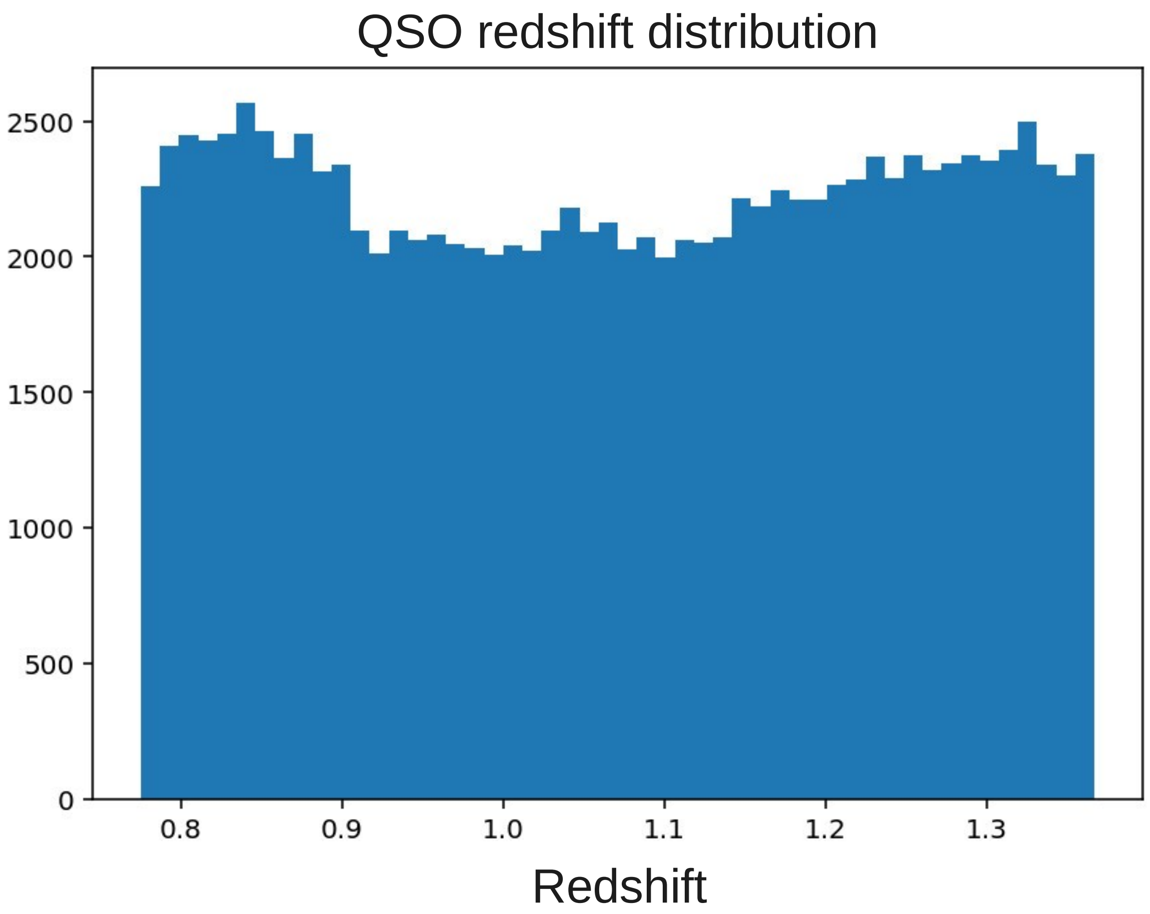


arXiv:1406.2288,

arXiv:1406.2267

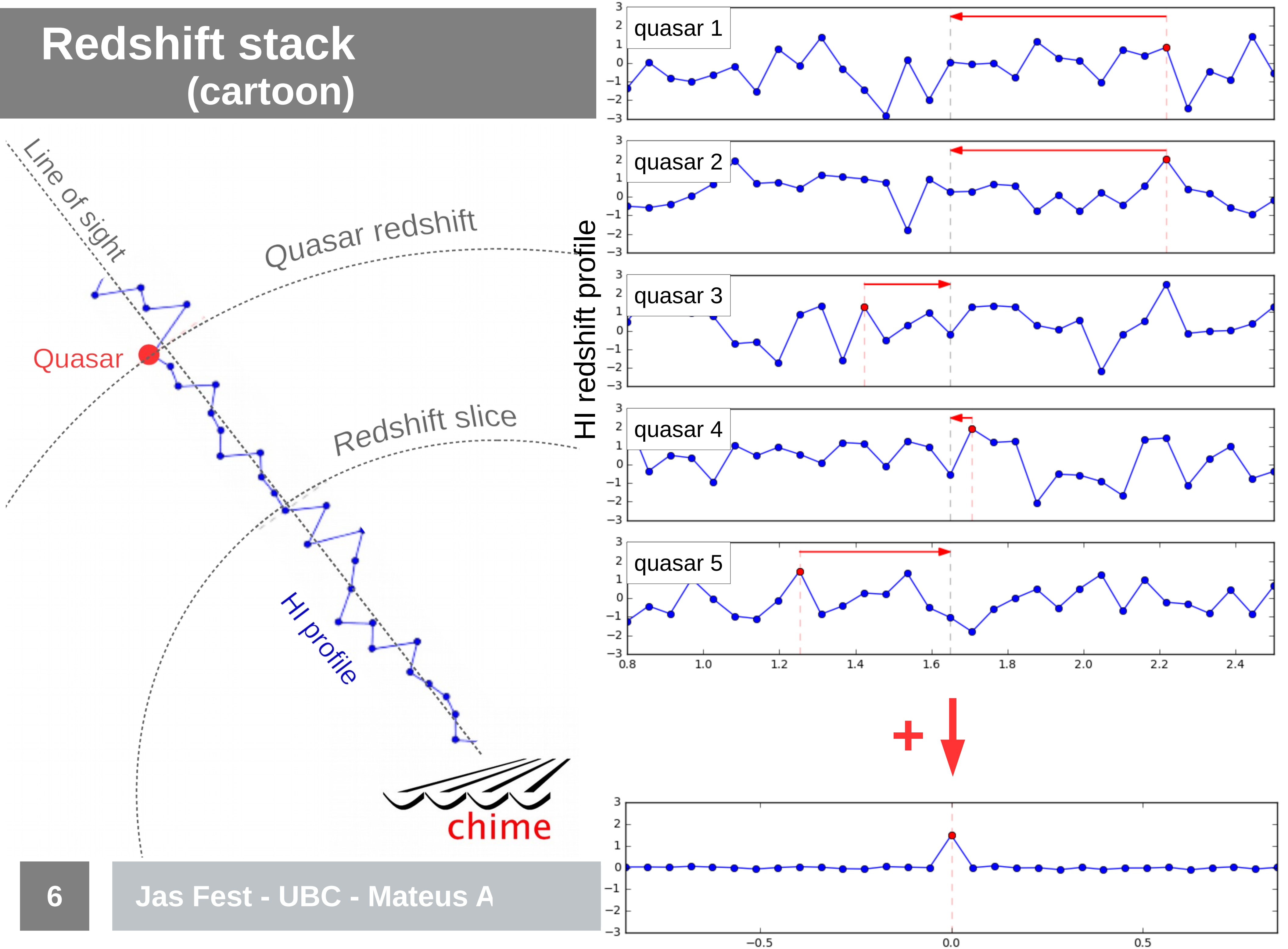
Quasar dataset – SDSS Catalog

- **DR 7, 9, 10, 12, 14**
- **Only using 1/2 band for simplicity here.**
- **More than 100,000 quasars in the CHIME lower half redshift range**



arXiv:1208.0022, arXiv:1508.04473, arXiv:1101.1529, arXiv:1712.05029

Redshift stack
(cartoon)



Realistic simulations

Need more realistic simulations.

Provide estimate for the amount of lost signal / amount of integration needed.

Allow to interpret the results in terms of quantities of interest:

- HI x Quasar correlation
- HI fraction in massive halos containing quasars.
- $\Omega_{HI}, \ b_{HI}, \ b_{QSO}$

Simulations – Zeldovich Approximation

From linear theory

(energy conservation)

$$\nabla \cdot \boldsymbol{\psi} = -\delta$$

ZA

Zeldovich approximation

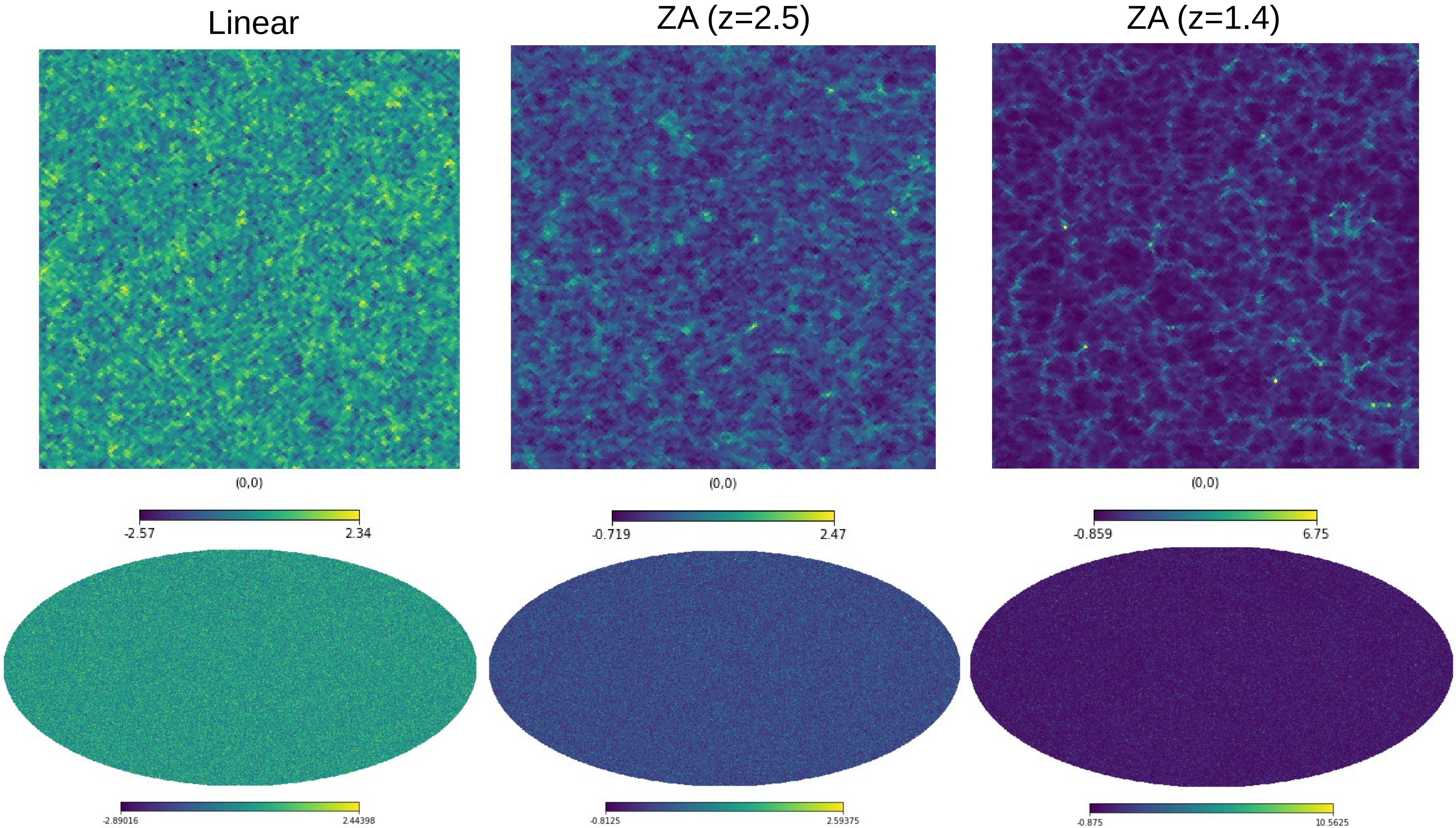
$$\boldsymbol{\chi} = \boldsymbol{q} + \boldsymbol{\psi}$$

RSD

Redshift space distortions

$$\boldsymbol{s} = \boldsymbol{q} + \boldsymbol{\psi} + f\left(\boldsymbol{\psi} \cdot \hat{n}\right)\hat{n}$$

Simulations – ZA



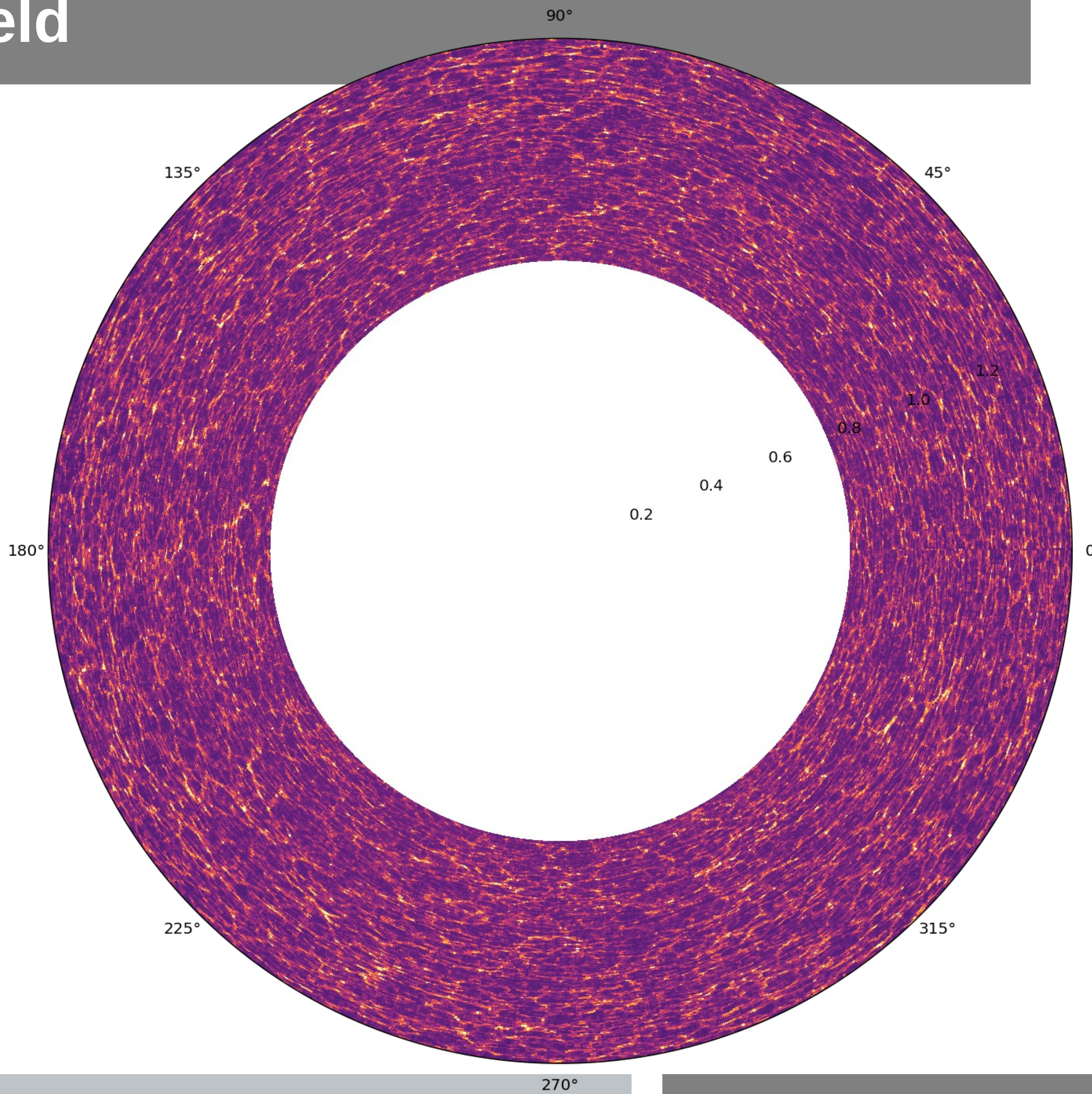
Simulations – HI Field

- Density field by displacing mass points
- Lagrangian bias from

Sheth-Mo-Tormen HMF (arXiv:astro-ph/9907024)

+

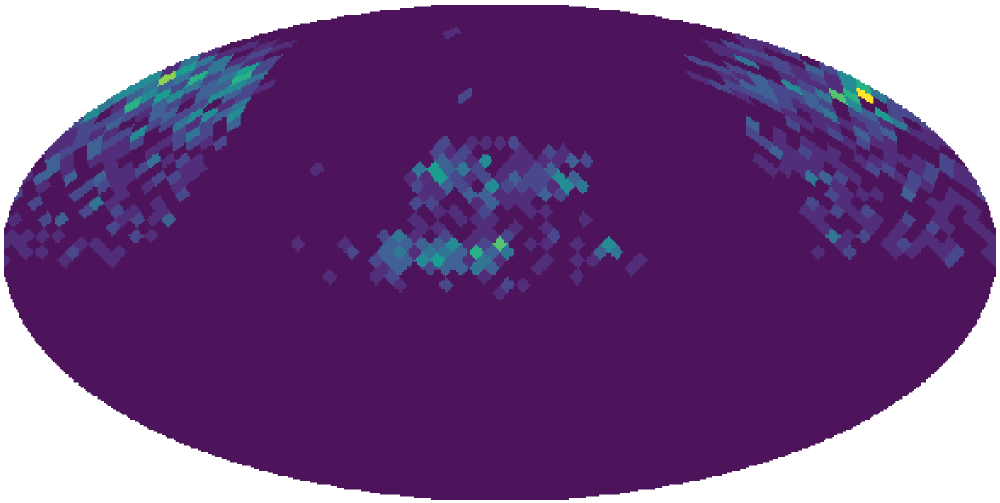
M_{HI} from arXiv:1804.09180



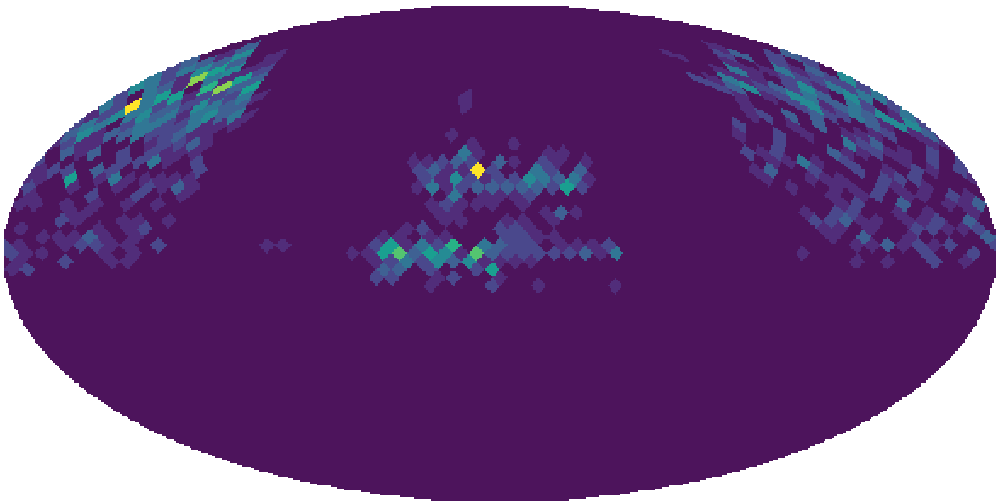
Simulations – Quasar Field

- Lagrangian bias from arXiv:1705.04718
- SVD the original catalog to approximated the Selection Function with rank-7 reconstruction.
- Selection Function X Quasar density maps gives a PDF to draw random quasars from.

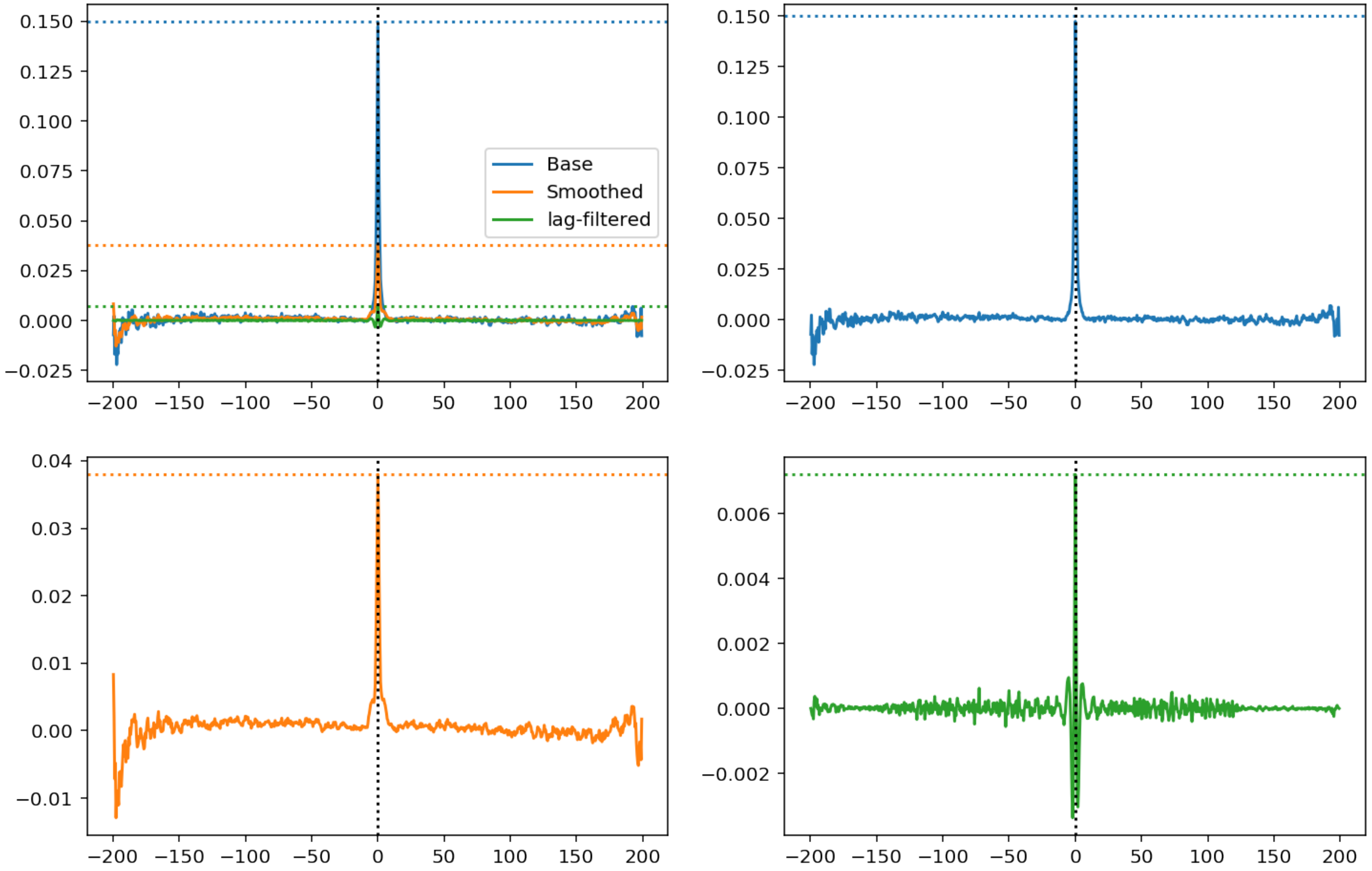
Original catalog



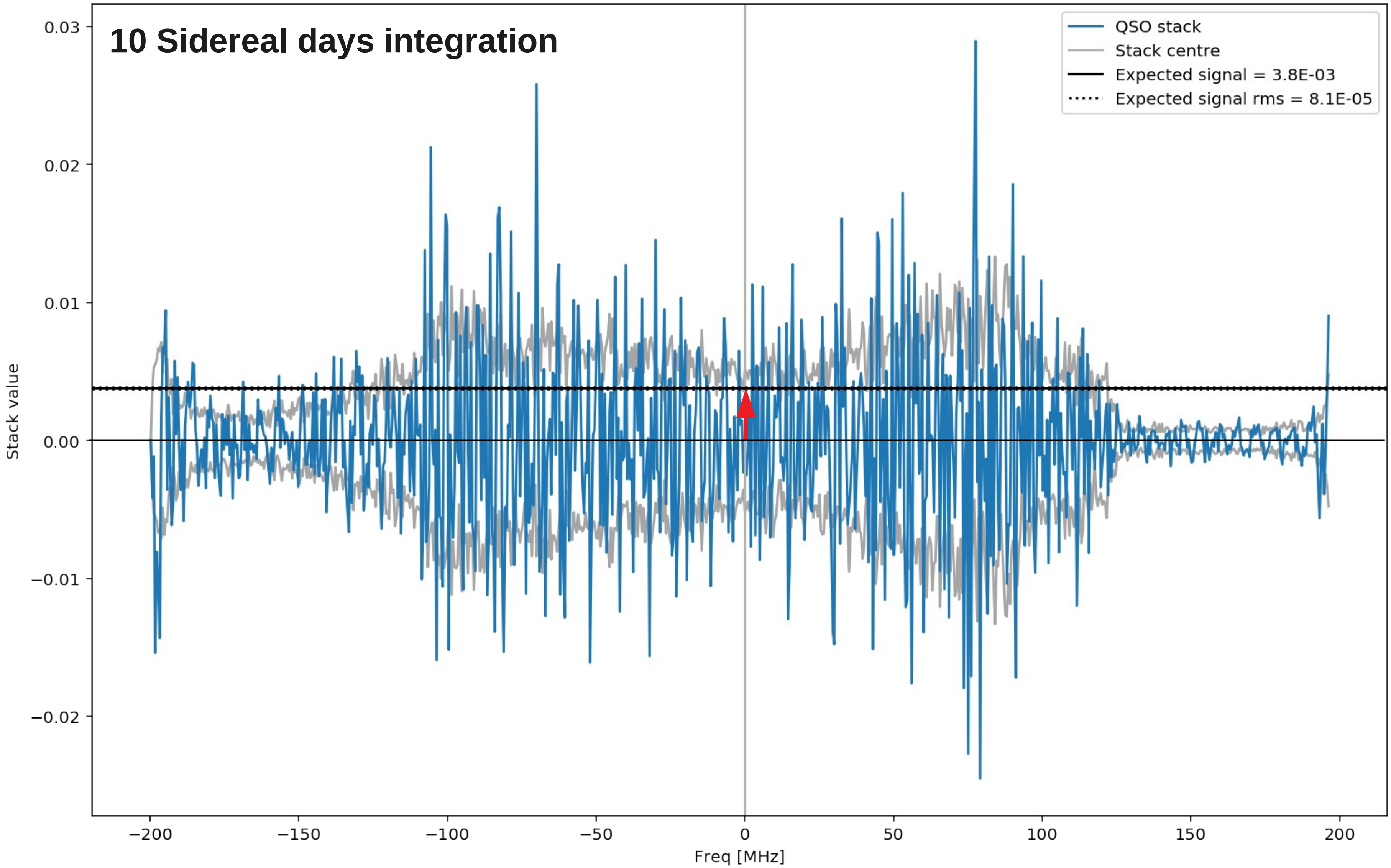
Mock catalog



Simulated Stack Signal



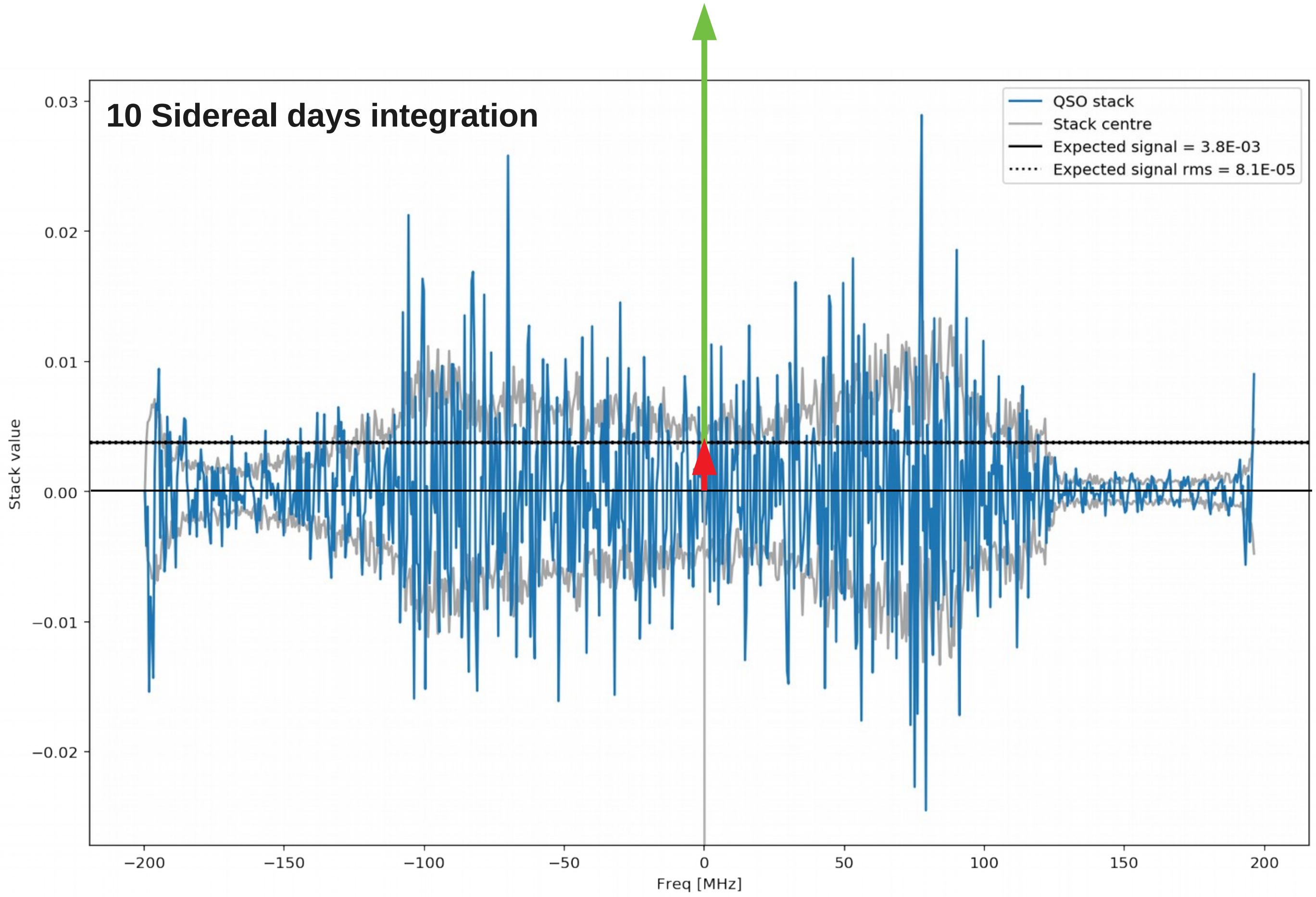
Data Stack – Pathfinder - Expected Signal



Data Stack – CHIME Data

CHIME data:

- Higher resol. (x 3)
- More sensitivity (x 9)



Thank you!

chime

a collaboration between

THE UNIVERSITY OF BRITISH COLUMBIA

UNIVERSITY OF TORONTO

McGill

Dominion Radio Astrophysical Observatory

NRC · CNRC

Extra slides

Simulation – Proof of concept

HI from linear (Gaussian) LSS

+

Foregrounds

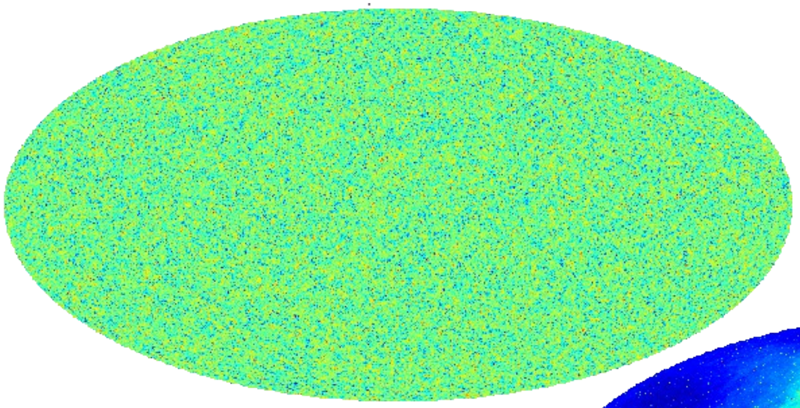
(Galaxy +

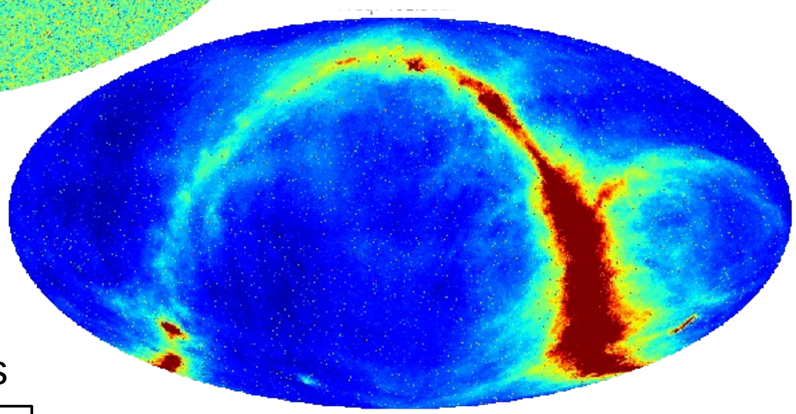
Point sources)

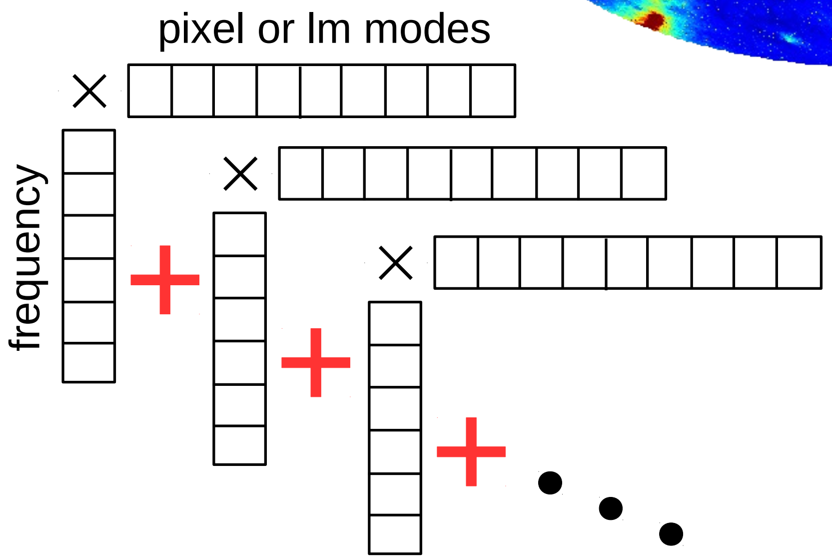
↓

SVD filtering

(remove higher modes)







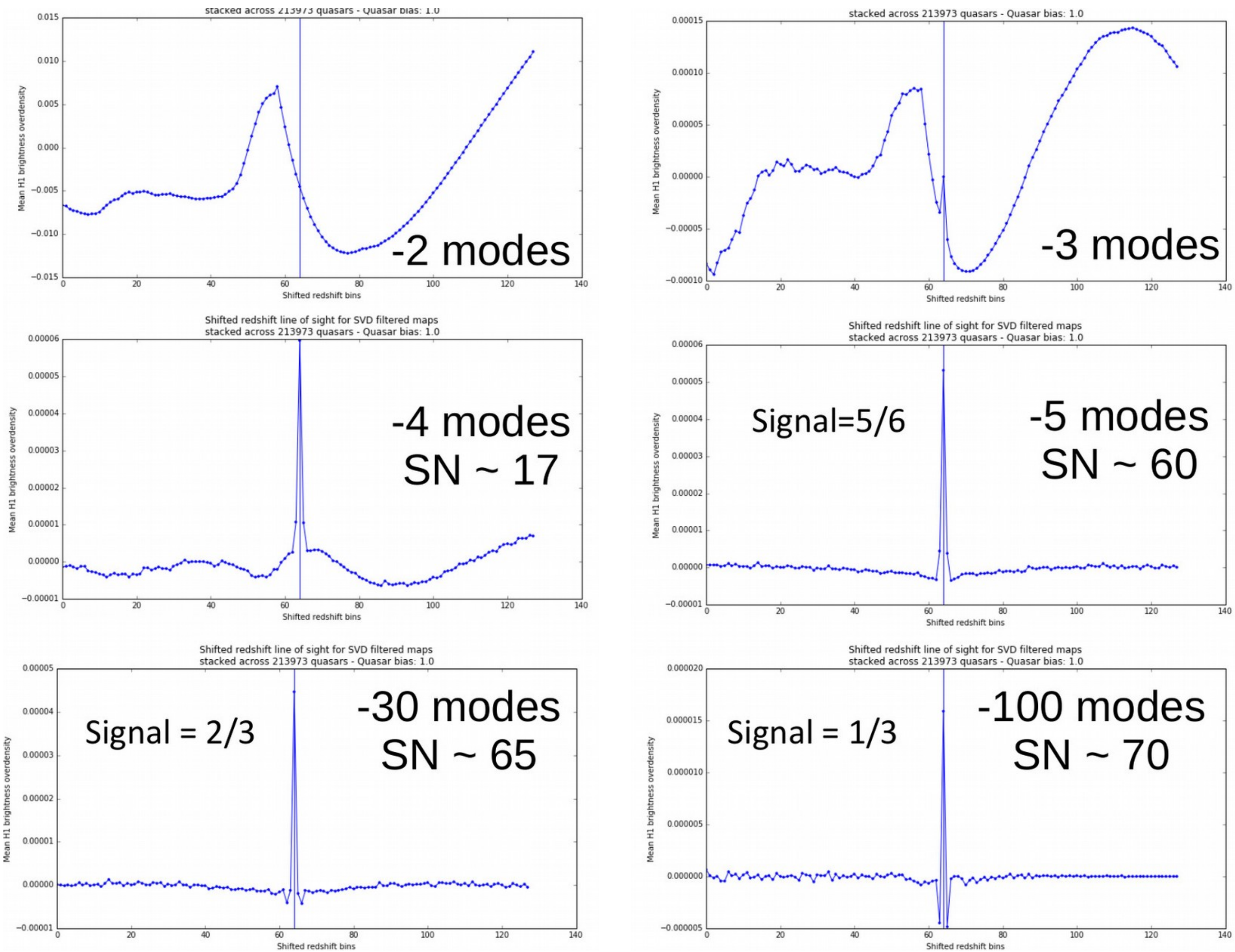
Simulations – Proof of concept

Noise-free

~200,000 quasars stacked

Foregrounds fall fast with number of modes removed.

HI signal falls roughly as n_rem/n_total



From linear theory

(energy conservation)

$$\frac{\partial\delta}{\partial t} = -\nabla\cdot\frac{d\chi}{dt} \rightarrow \boxed{\nabla\cdot\psi = -\delta}$$

ZA

Zeldovich approximation

$$\boxed{\chi = \boldsymbol{q} + \psi}\,, \quad \psi(\boldsymbol{k}, t) = i\frac{\boldsymbol{k}}{k^2}\delta_L(\boldsymbol{k}, t)$$

RSD

Redshift space distortions

$$\boldsymbol{s} = \chi + \frac{\boldsymbol{v}\cdot\hat{n}}{aH} = \chi + f(\psi\cdot\hat{n})\hat{n} \rightarrow \boxed{\boldsymbol{s} = \boldsymbol{q} + \psi + f(\psi\cdot\hat{n})\hat{n}}$$

Spherical realization

$$\psi = -\nabla(\Phi), \quad \Phi = \nabla^{-2}\delta = \left(\frac{a}{4\pi G\bar{\rho}_0}\right)\phi$$

$$P_\Phi(k) = \frac{1}{k^4}P_\delta(k) \rightarrow C_l^\Phi(z, z')$$

Unit Conversion

$$\frac{2k_B\Omega}{\lambda^2\times10^{-26}}\sim\frac{2k_B}{\alpha A\times10^{-26}}=1\sim0.5\times10^3$$

$$A=0.3\times20=6\,m^2$$