



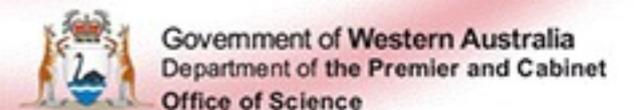
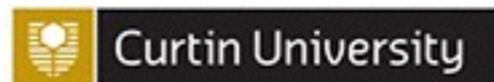
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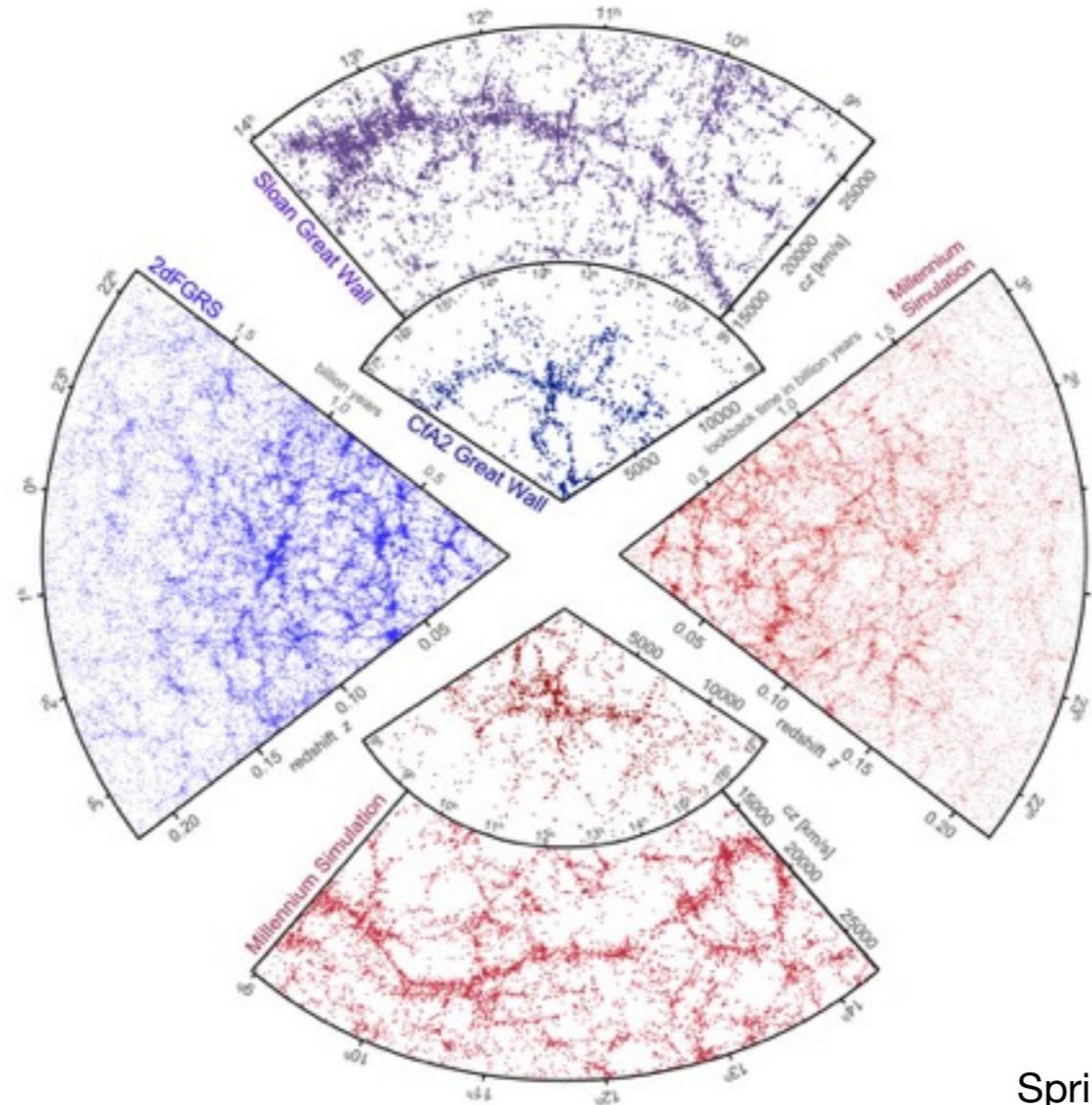
Parkes 21 cm Intensity Mapping Experiments

Jonghwan Rhee (ICRAR/UWA)

In collaboration with:

Lister Staveley-Smith (ICRAR/UWA), Laura Wolz (Univ. of Melbourne),
Stuart Wyithe (Univ. of Melbourne), Chris Blake (Swinburne Univ.)





Springel et al. 2006

- **3D mapping of the Universe is a powerful tool to study large-scale structures.**
- **Galaxy redshift surveys at optical wavelength.**
(e.g. CfA redshift survey , 2dFGRS, SDSS, WiggleZ, GAMA)

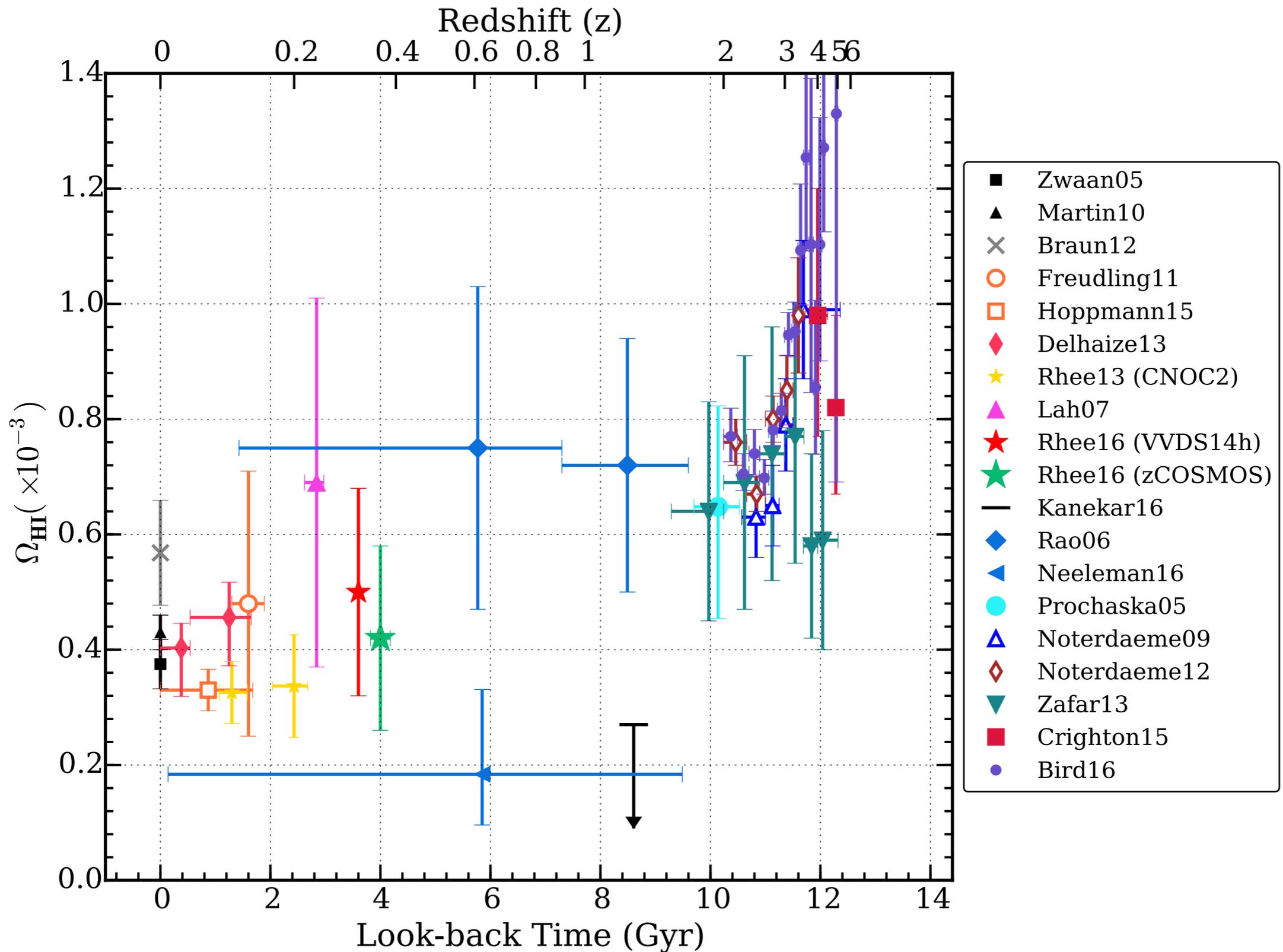


Mapping the Universe in 21 cm

- Neutral hydrogen is a good tracer of matter distribution
- HI 21 cm line can be directly translated into redshift.
- Measuring the collective HI 21 cm emission from many galaxies *without individual detection*.
- Cosmological probe for measuring the baryon acoustic oscillation (BAO) feature and Redshift Space Distortion (RSD).
- Constraining cosmic HI density (Ω_{HI}) evolution at intermediate redshift ($0.5 < z < 2.0$).

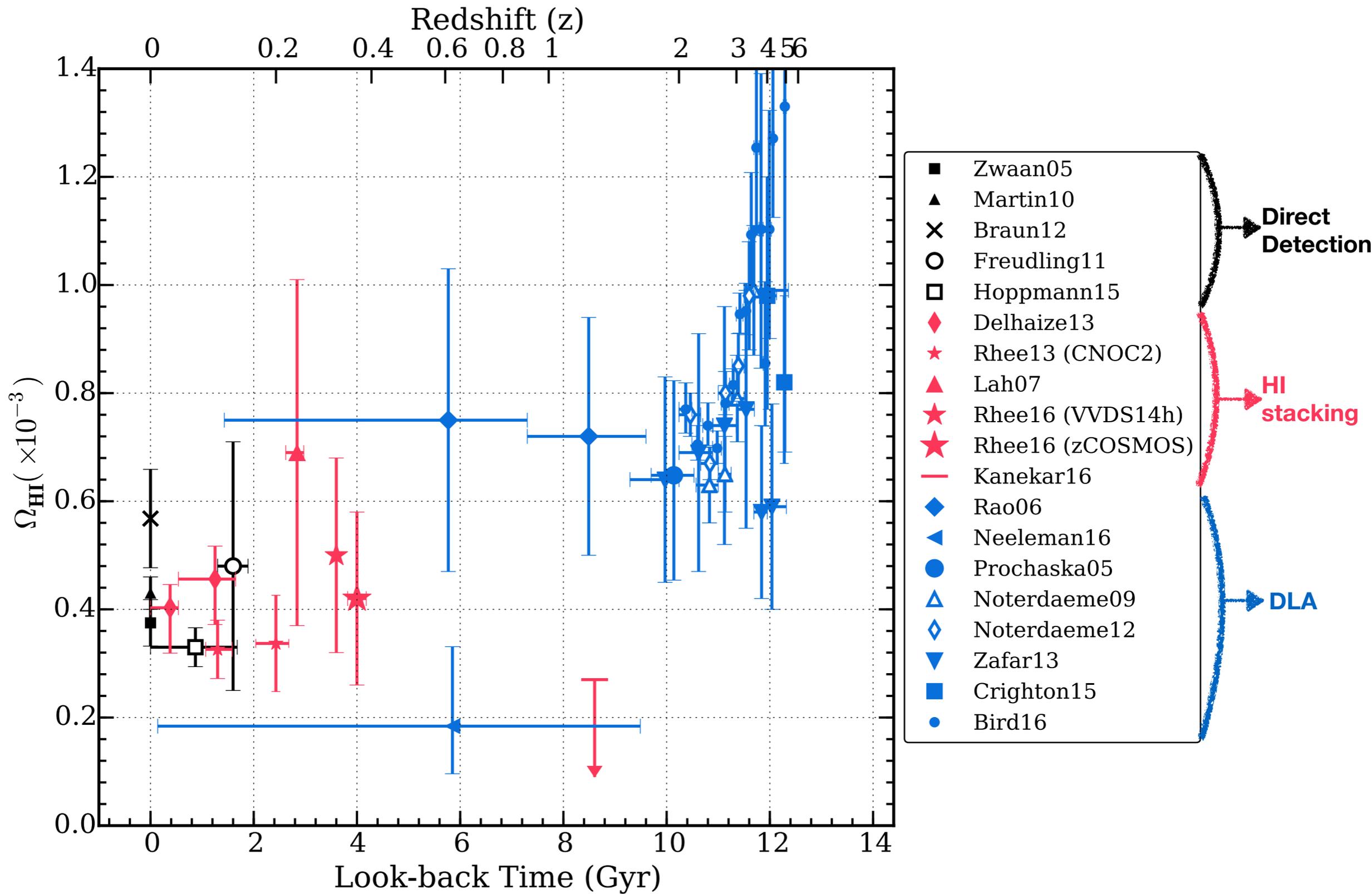


HI gas evolution over cosmic time



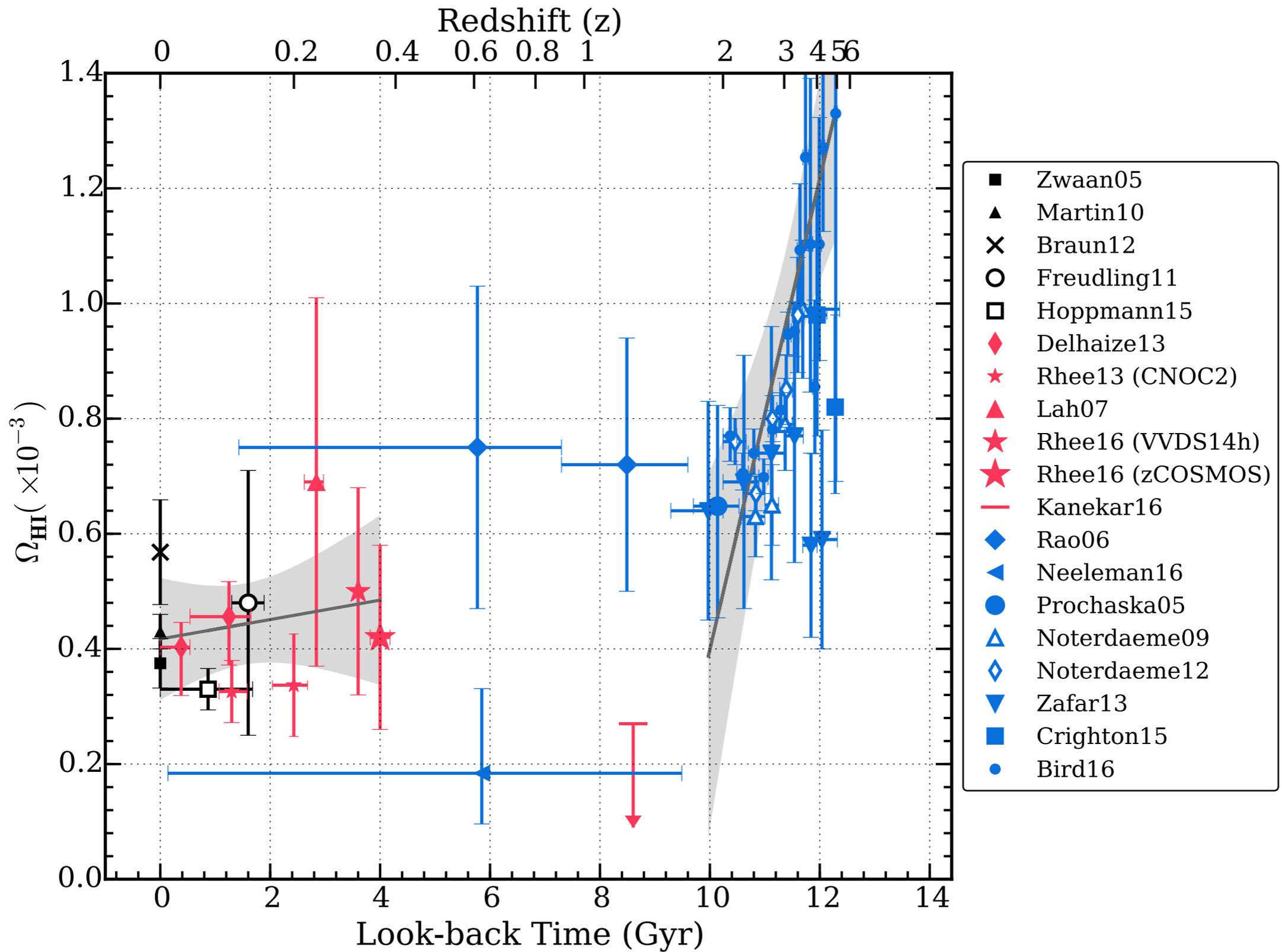


HI gas evolution over cosmic time



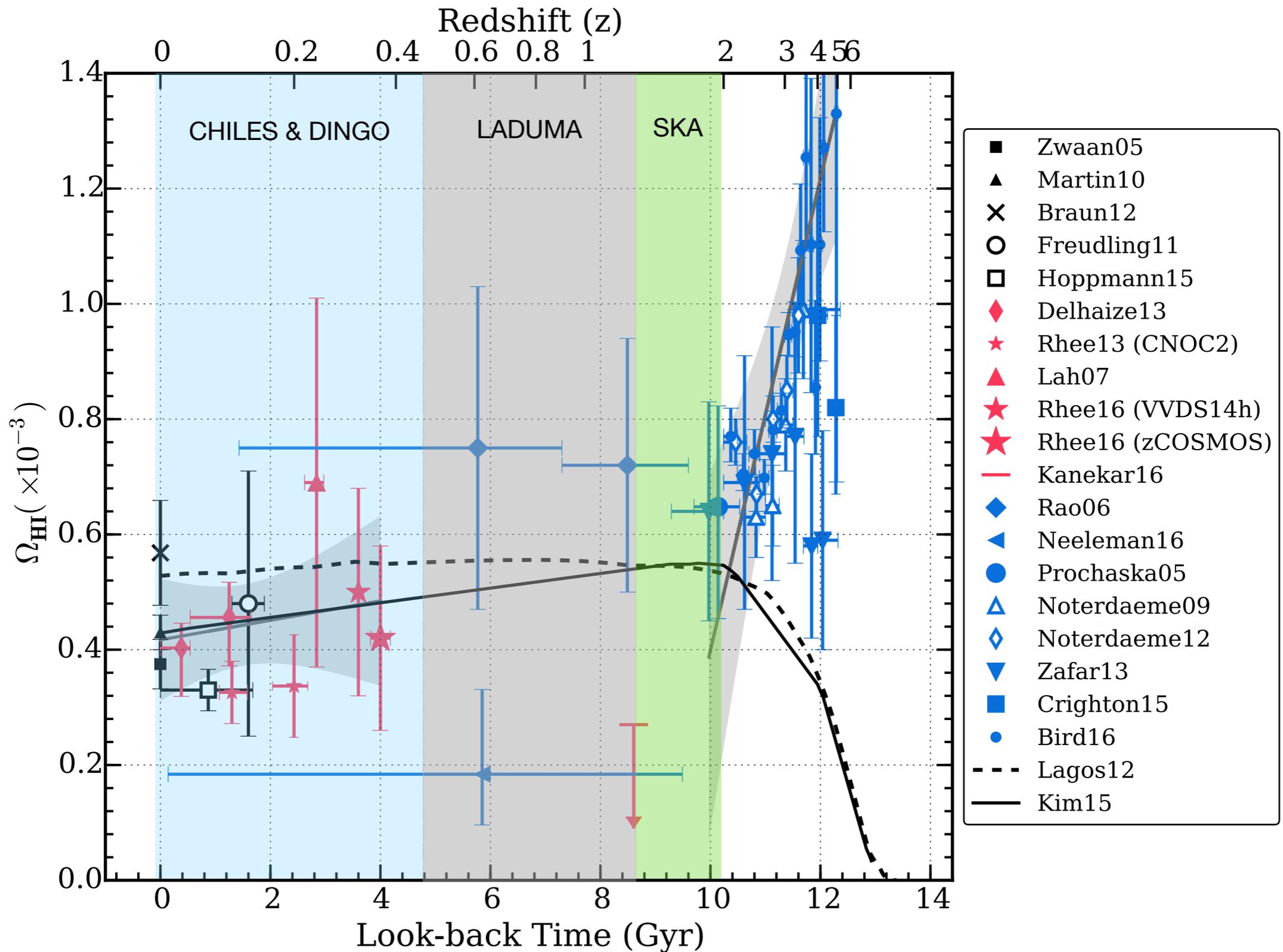


HI gas evolution over cosmic time





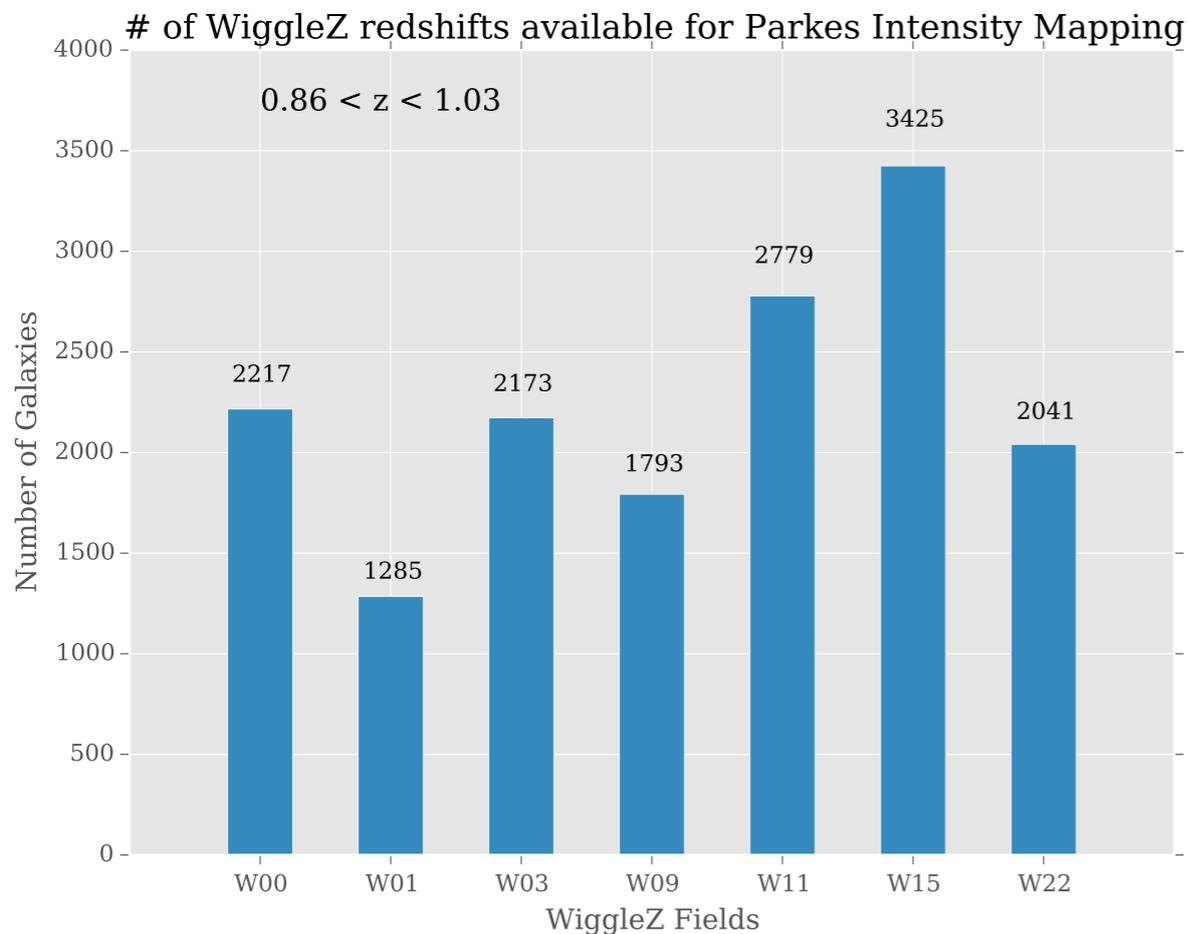
HI gas evolution over cosmic time





Parkes Intensity Mapping

- Parkes telescope used to map the WiggleZ fields.
- Single beam 50cm receiver at frequency:
700 - 764 MHz ($0.86 < z < 1.03$, $\langle z \rangle \sim 0.94$),
2048 channels (31.25 kHz)
- Scan rate: 0.25 or 2 deg/min, FWHM: 30'
- WiggleZ contains 15,713 redshifts in the redshift.

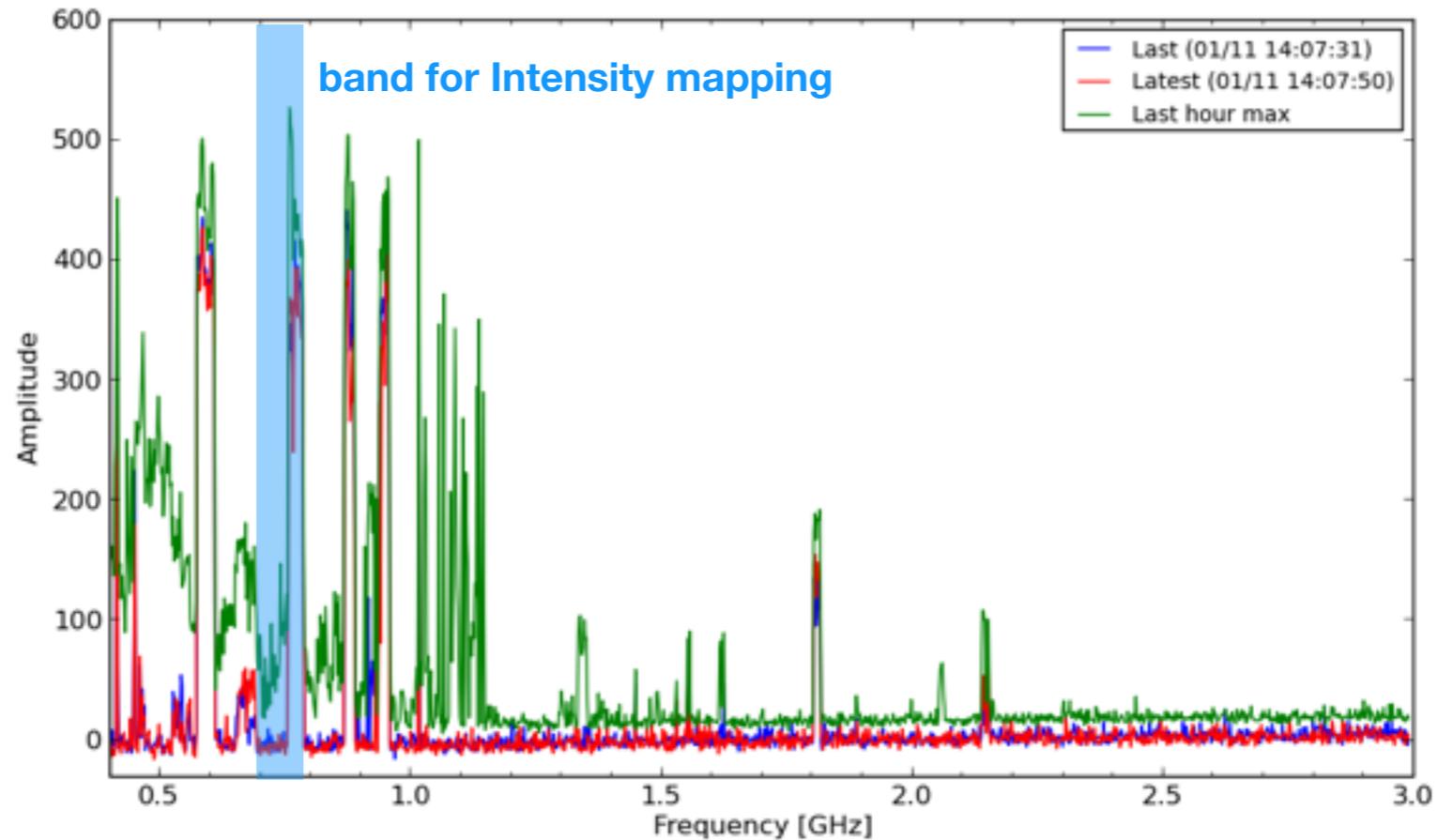


WiggleZ survey fields

Name	RA _{min} (deg)	RA _{max} (deg)	Dec. _{min} (deg)	Dec. _{max} (deg)	Area (deg ²)
0h	350.1	359.1	-13.4	+1.8	135.7
1h	7.5	20.6	-3.7	+5.3	117.8
3h	43.0	52.2	-18.6	-5.7	115.8
9h	133.7	148.8	-1.0	+8.0	137.0
11h	153.0	172.0	-1.0	+8.0	170.5
15h	210.0	230.0	-3.0	+7.0	199.6
22h	320.4	330.2	-5.0	+4.8	95.9



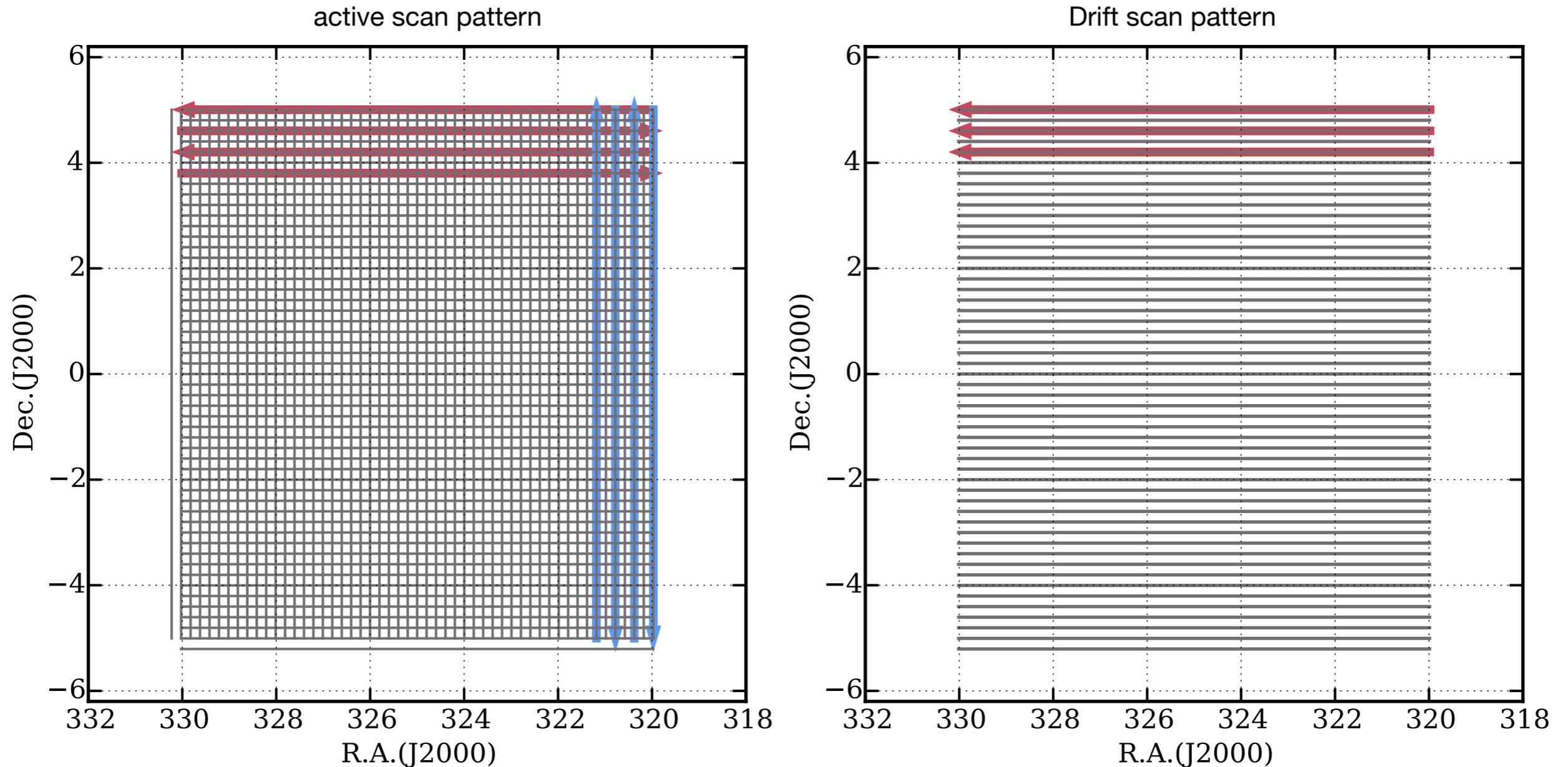
Challenges: RFI



- RFI contamination.
 - Broad-band RFI @ 720, 740, 760MHz (UHF TV chan)
 - 4G transmitter @ 763 MHz
- RFI flagging: threshold-clipping



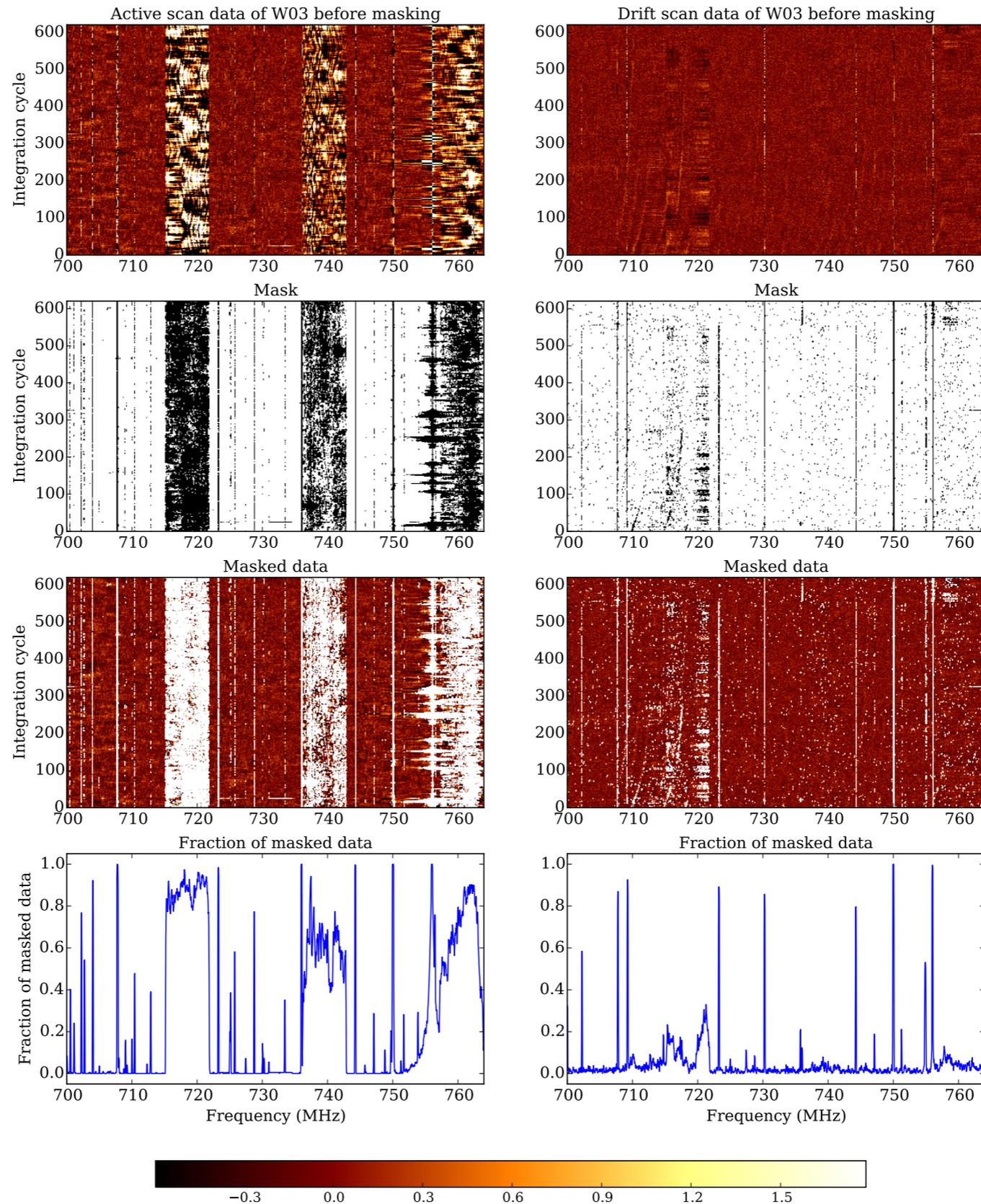
Active scan vs. Drift scan



- Active scan: basket-weaving pattern, 2°min^{-1} scan rate
- Drift scan: only ra direction scan, $0.25^{\circ}\text{min}^{-1}$ scan rate

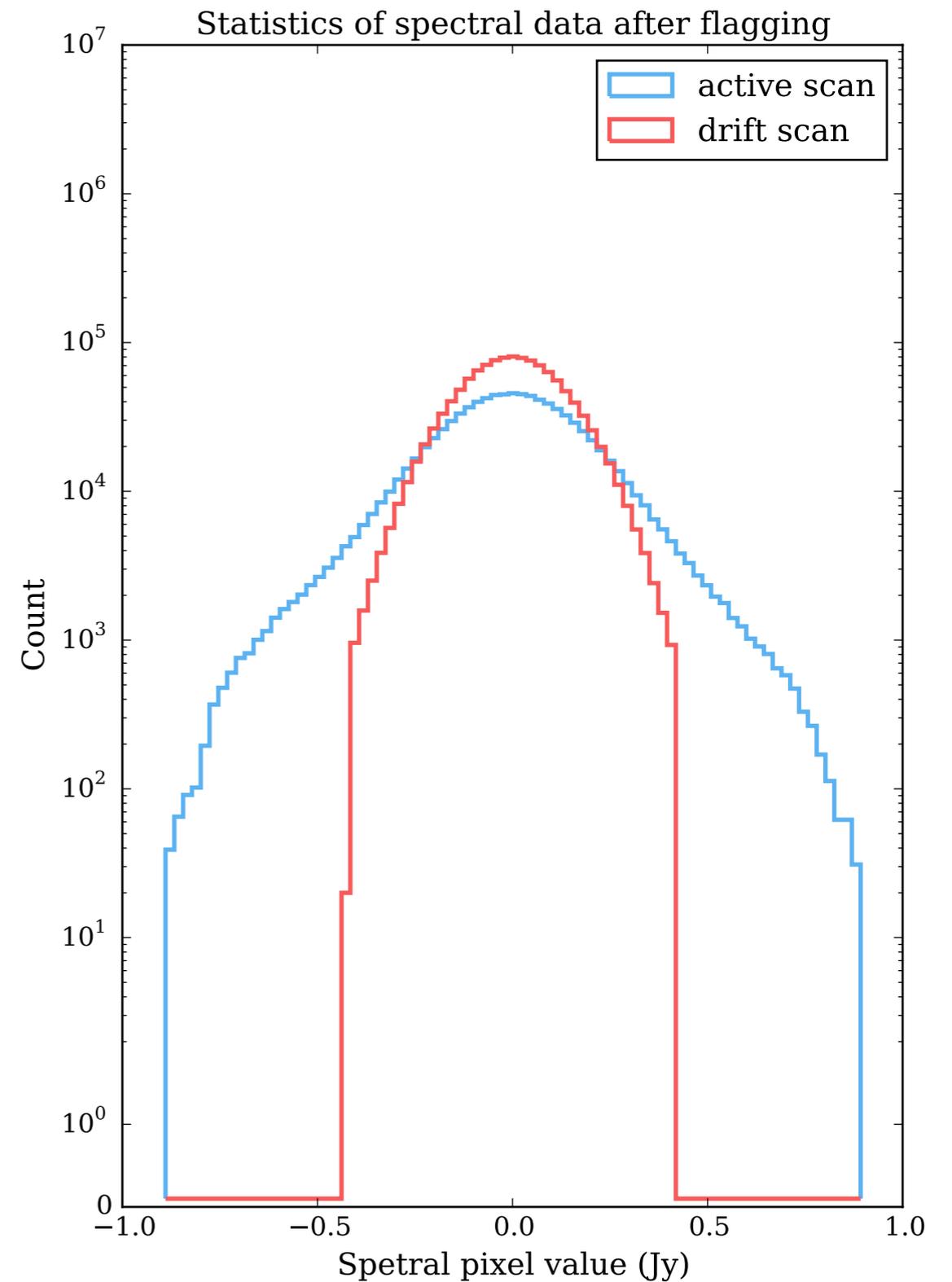
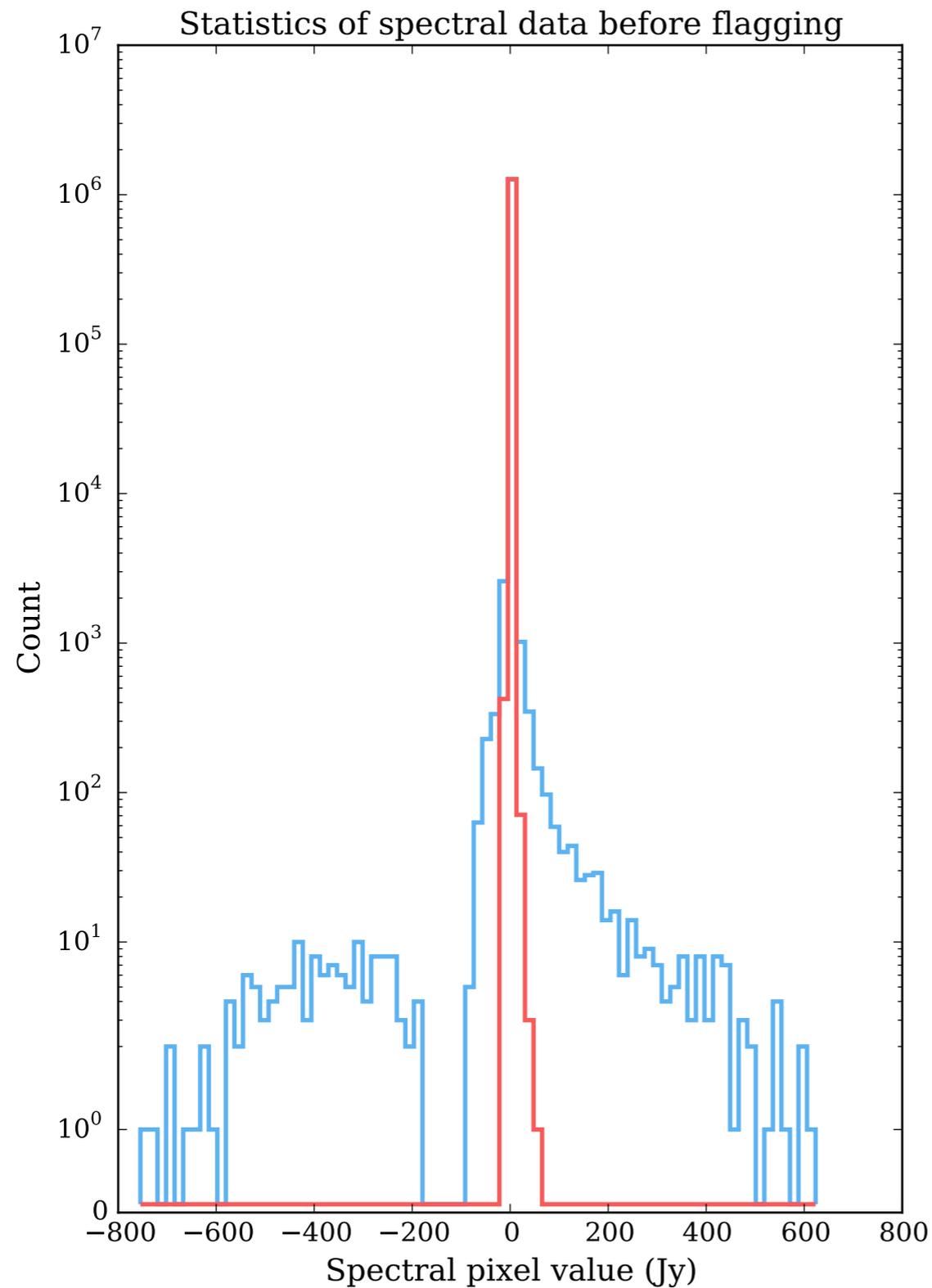


Drift scan vs. active scan

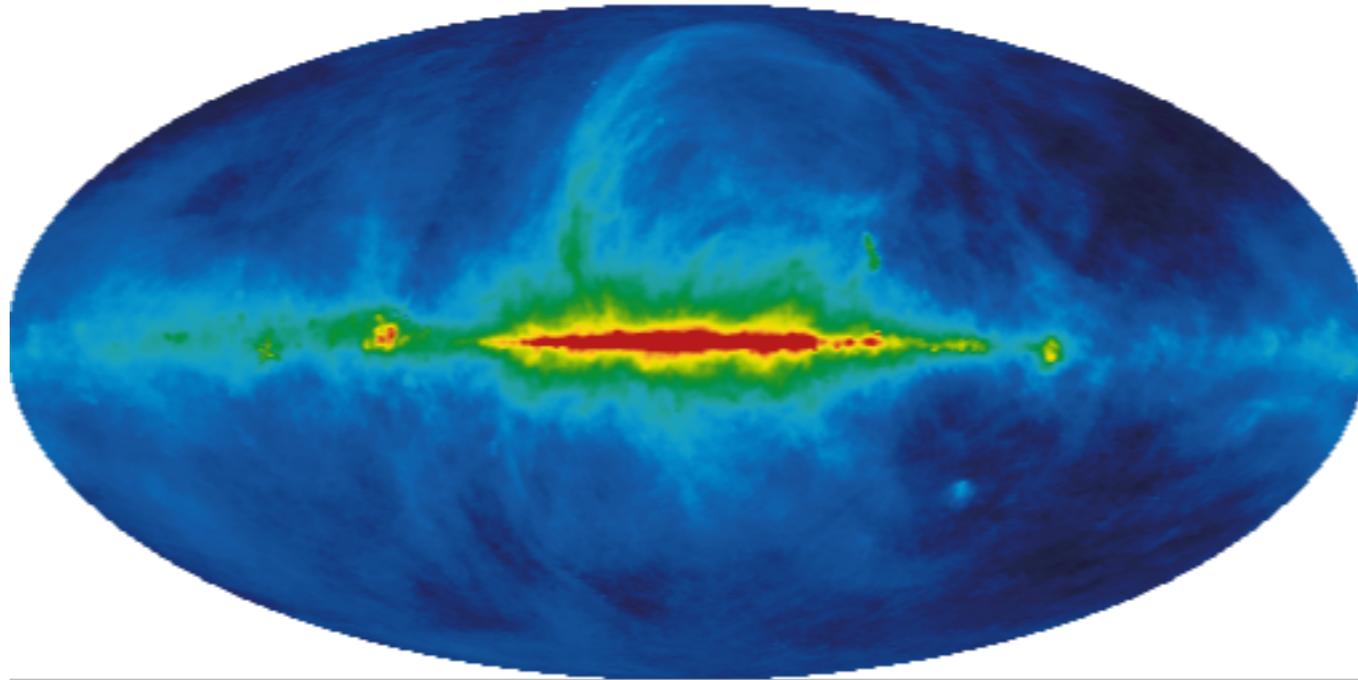




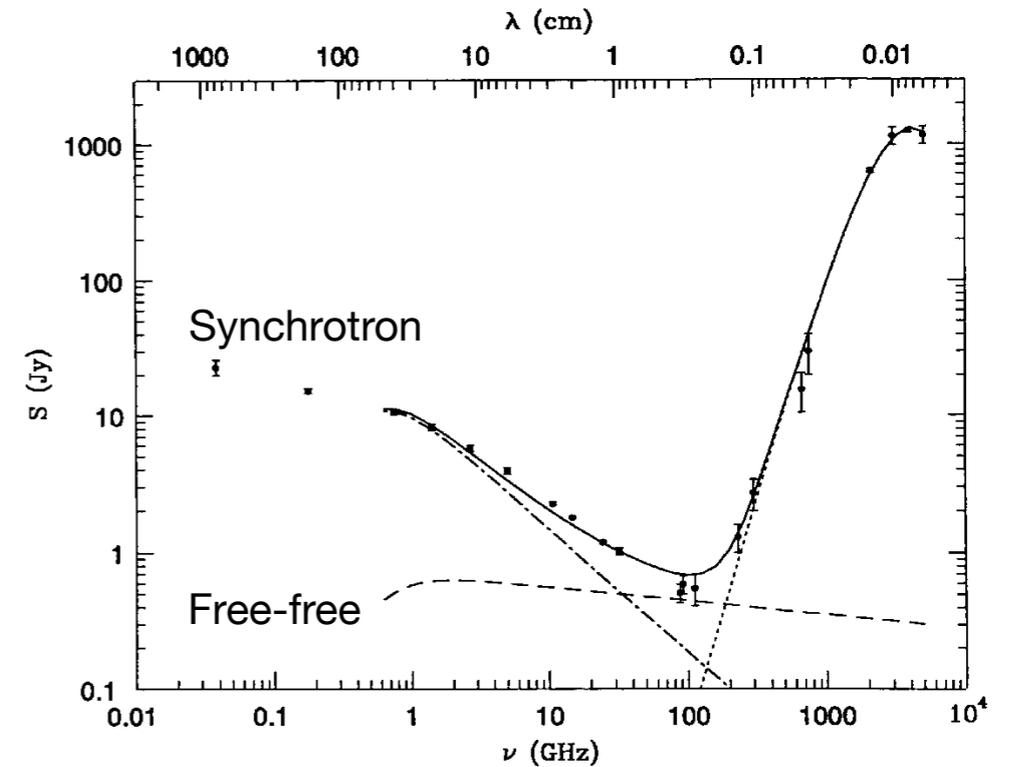
Drift scan vs. active scan



Challenges: Foregrounds



Haslam map at 408MHz



Condon (1992)

- Foreground emissions from Galactic and extragalactic sources ($\sim 10^4$ stronger than HI signal).
- Synchrotron emission and free-free electron emission



Independent Component Analysis (ICA)

- Decomposing the observed data into statistically independent components.

$$\text{Observed data} \leftarrow \mathbf{x} = \mathbf{A}\mathbf{s} = \sum_{i=1}^{N_{\text{IC}}} \mathbf{a}_i s_i$$

Independent component

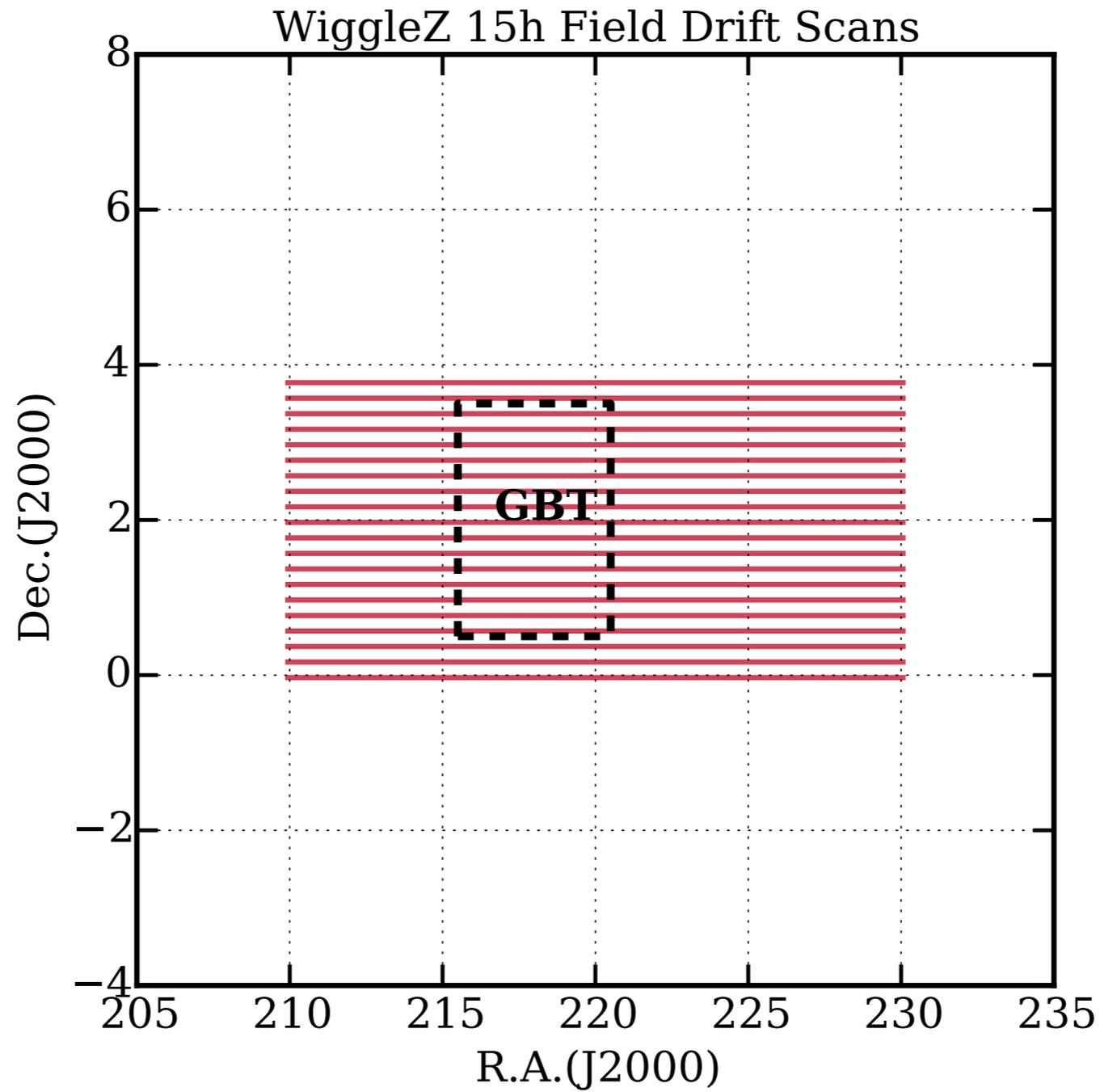
Mixing matrix

The diagram shows the equation $\mathbf{x} = \mathbf{A}\mathbf{s} = \sum_{i=1}^{N_{\text{IC}}} \mathbf{a}_i s_i$. An arrow points from the text 'Observed data' to the vector \mathbf{x} . Another arrow points from the matrix \mathbf{A} to the text 'Mixing matrix'. A third arrow points from the term $\mathbf{a}_i s_i$ to the text 'Independent component'.

- Scientific application in Astronomy: used as a promising foreground removal technique for CMB, EoR, intensity mapping (e.g. Bottino et al. 2008, Chapman et al 2012, Wolz et al. 2013)

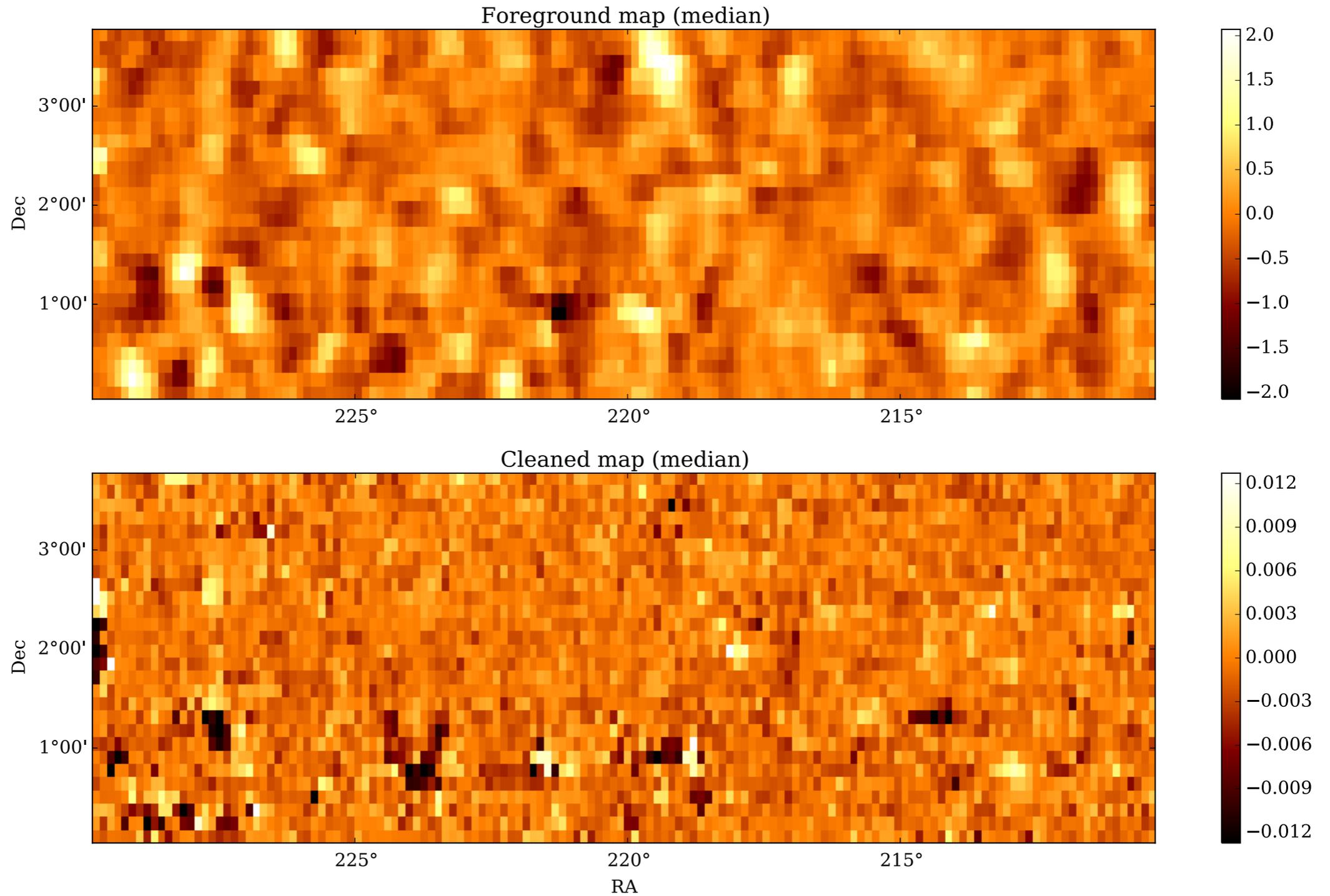


Foreground removal using ICA



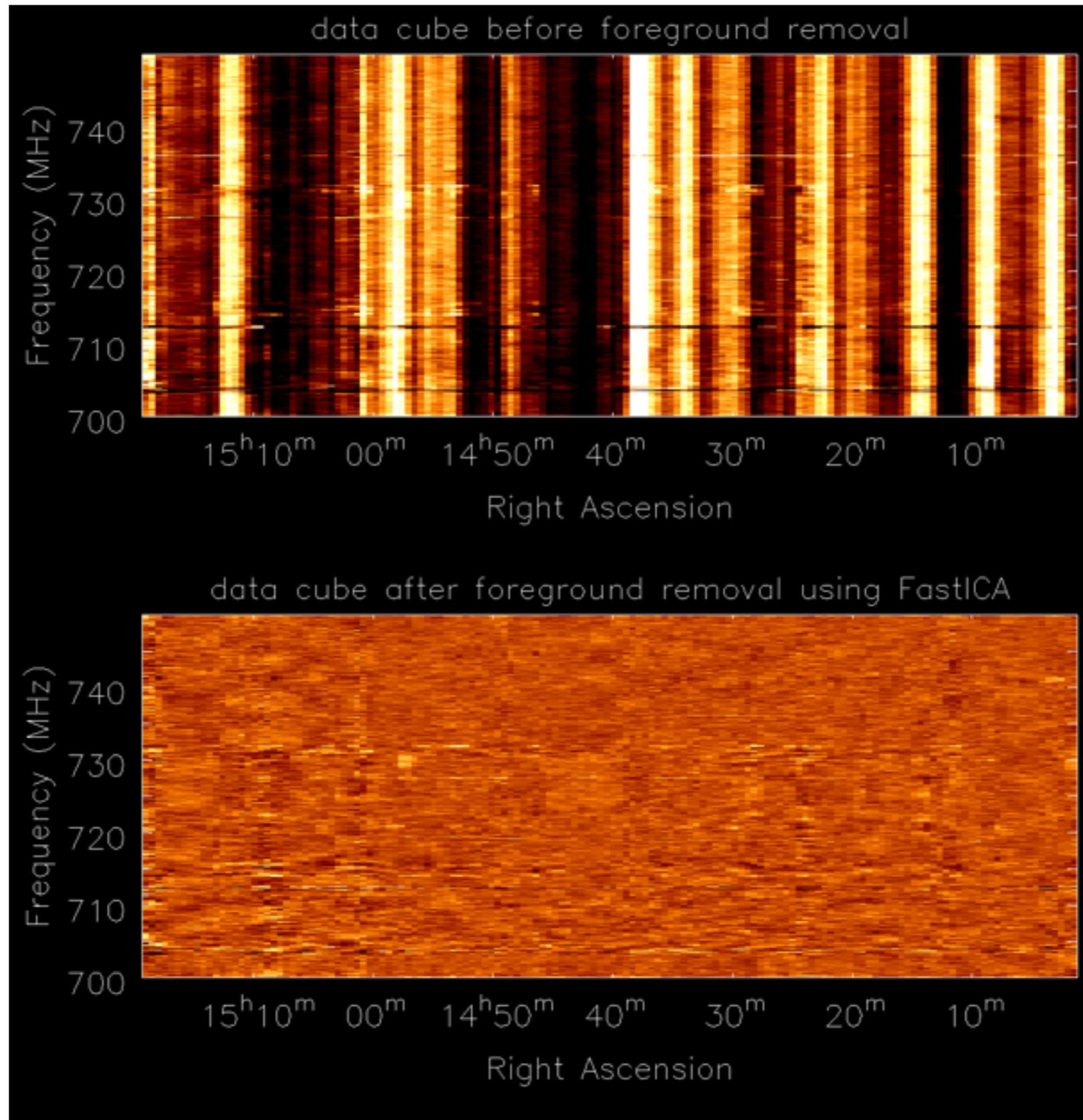


Foreground removal using ICA





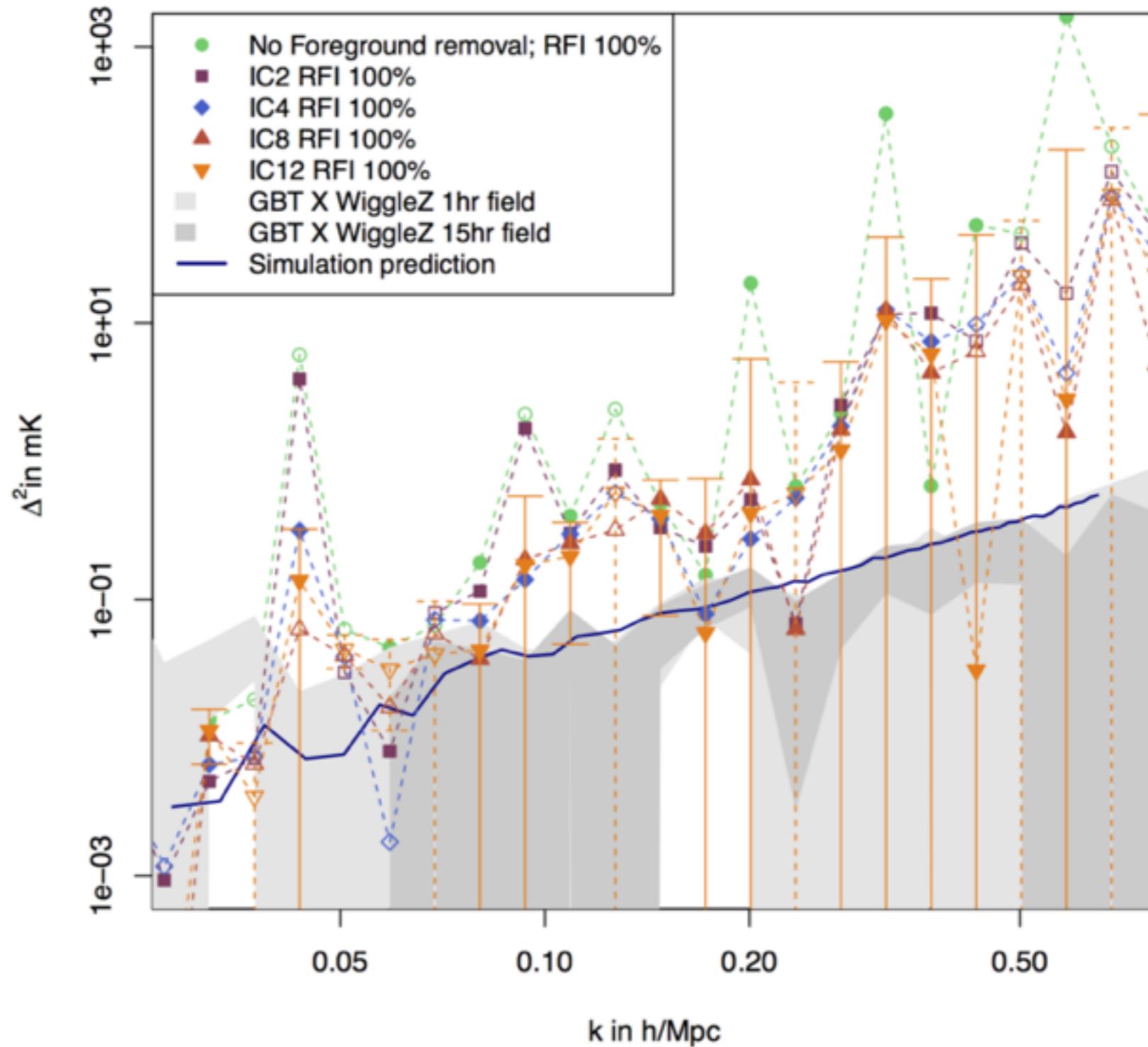
Foreground removal using ICA





Cross power spectrum

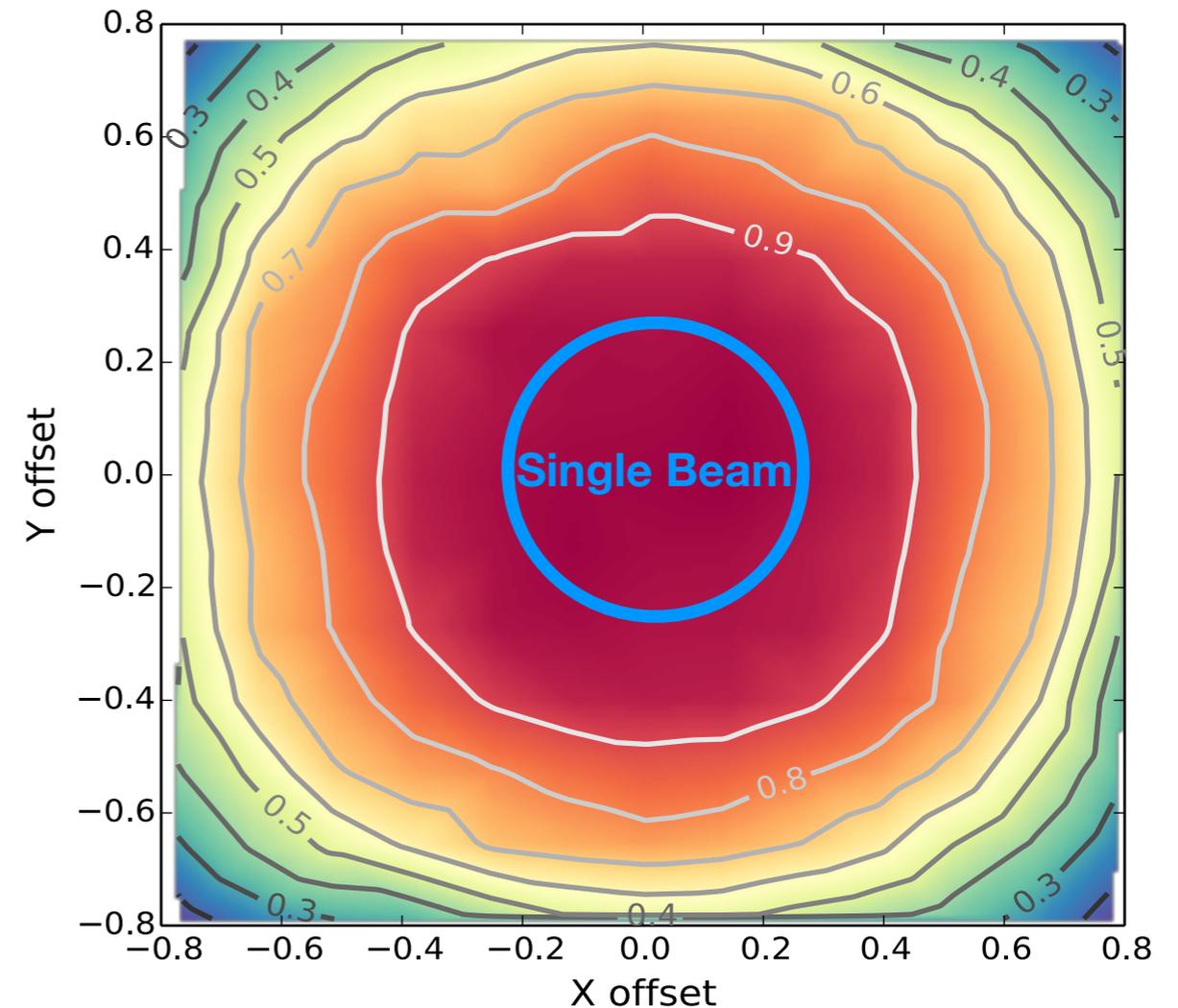
Cross power spectrum of W15d





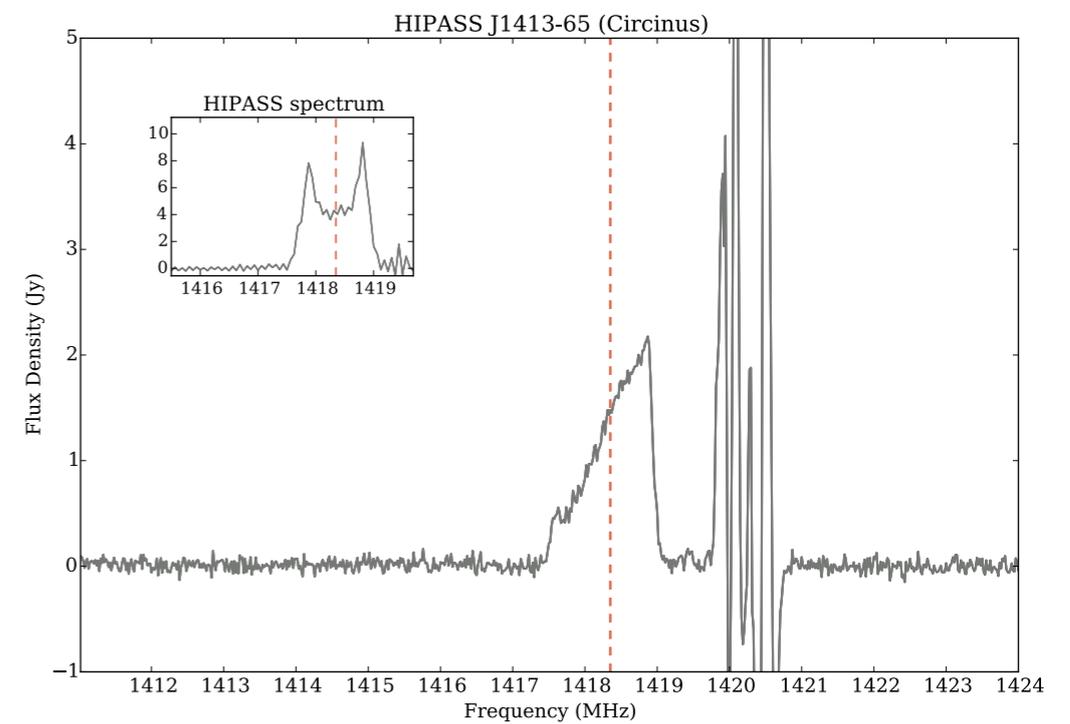
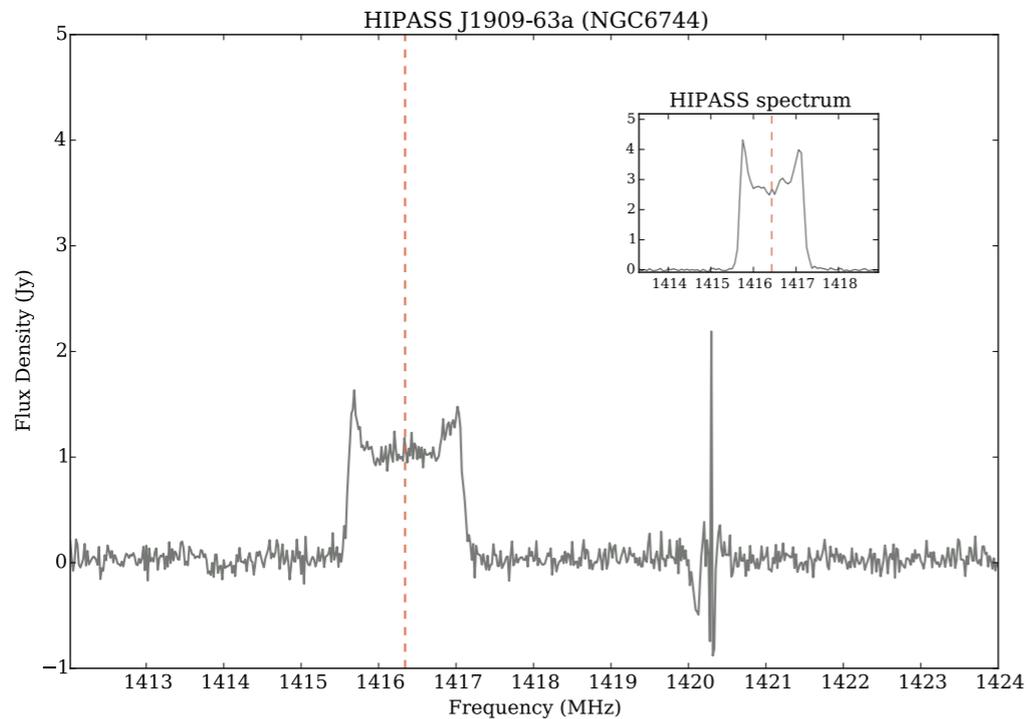
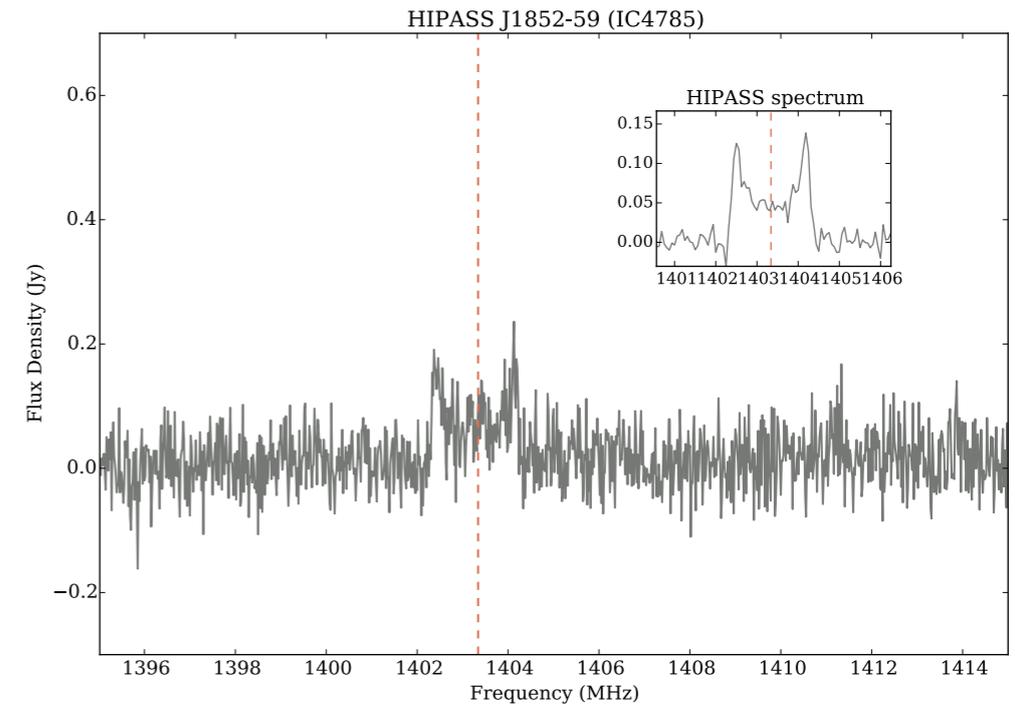
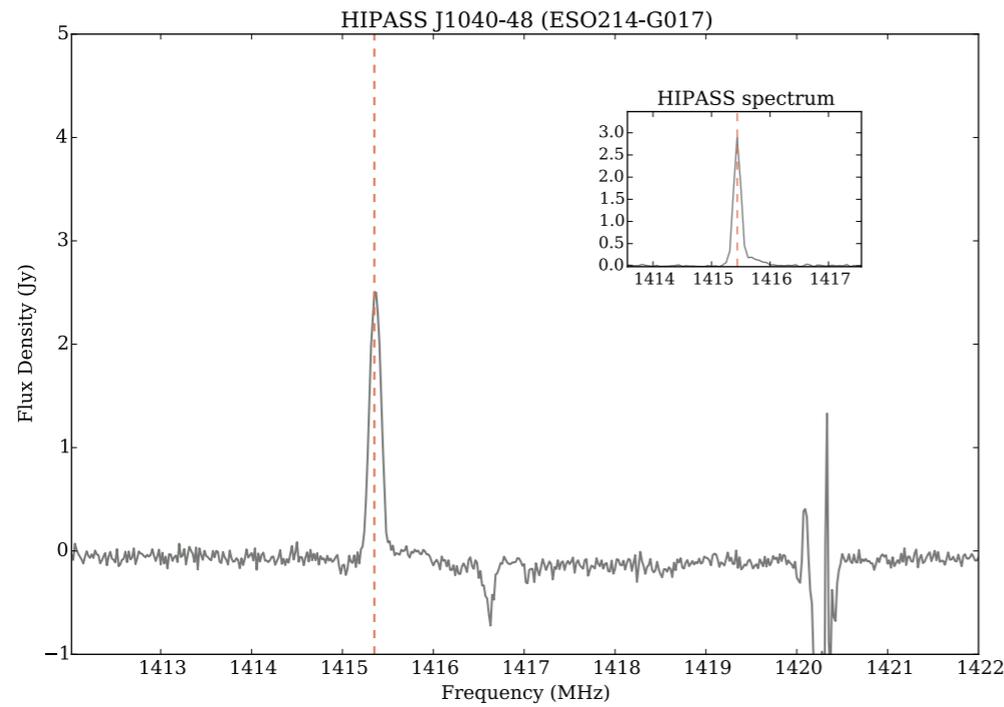
Fast Intensity Mapping using PAFs

- **Phased-array feed (PAF)** installed on the Parkes
- **Same Mk-II PAF as ASKAP** but modified for a single dish
- **Larger field of view**
 $0.2 \text{ deg}^2 \Rightarrow 1.4 \text{ deg}^2$
- **Wider bandwidth 384 MHz**
 $64 \text{ MHz} \Rightarrow 384 \text{ MHz}$
Band 1: 699.5 - 1083.5 MHz
Band 2: 1148.5 - 1532.5 MHz
- **2 WiggleZ fields @ band 1 + 1 GAMA field @ band 2** completed.





HI spectra from known galaxies





Summary

- **HI intensity mapping is a promising approach to constrain HI gas evolution at intermediate redshifts.**
- **Challenges: RFI mitigation and foreground**
- **Intensity mapping using PAF: more suitable for fast intensity mapping.**
- **Next generation PAF cryogenically cooled is being planned.**