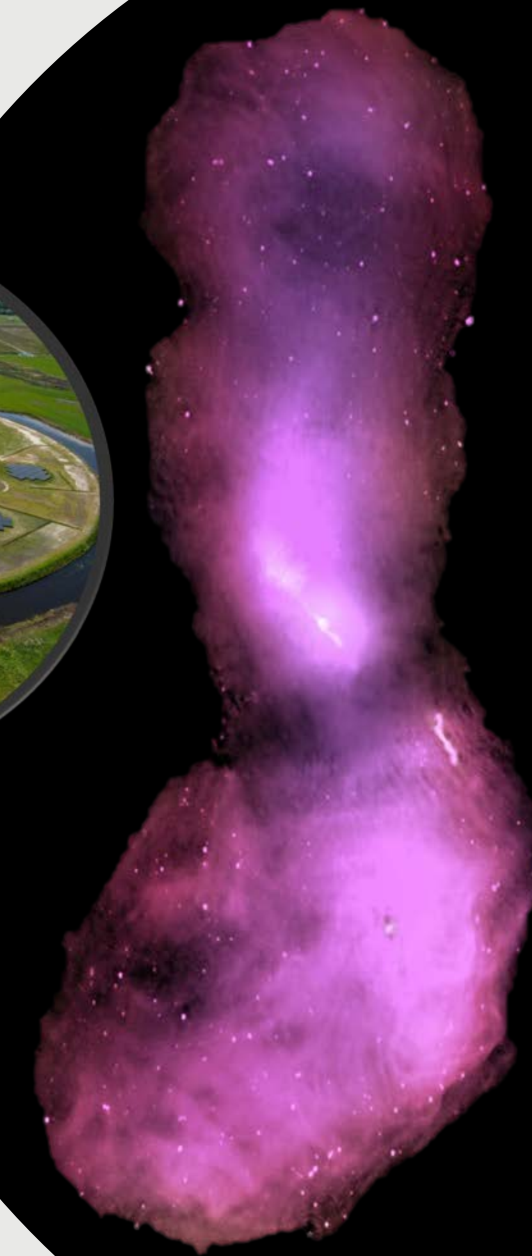
ASTRON

HI Absorption in the Epoch of Reionisation

The talk of upper limits



Joe Callingham
ASTRON Postdoctoral Fellow

ASTRON,
Dwingeloo, The Netherlands
30th of August 2018

MWA MURCHISON WIDEFIELD ARRAY

LOFAR

On behalf of

- James Allison (Oxford)
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- Elaine Sadler (CASS/USyd)
- Elizabeth Mahony (CASS)
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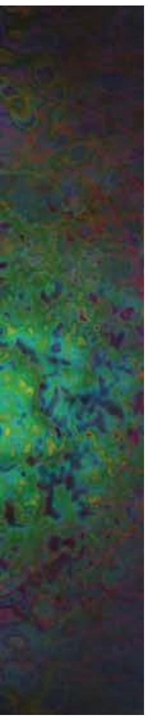
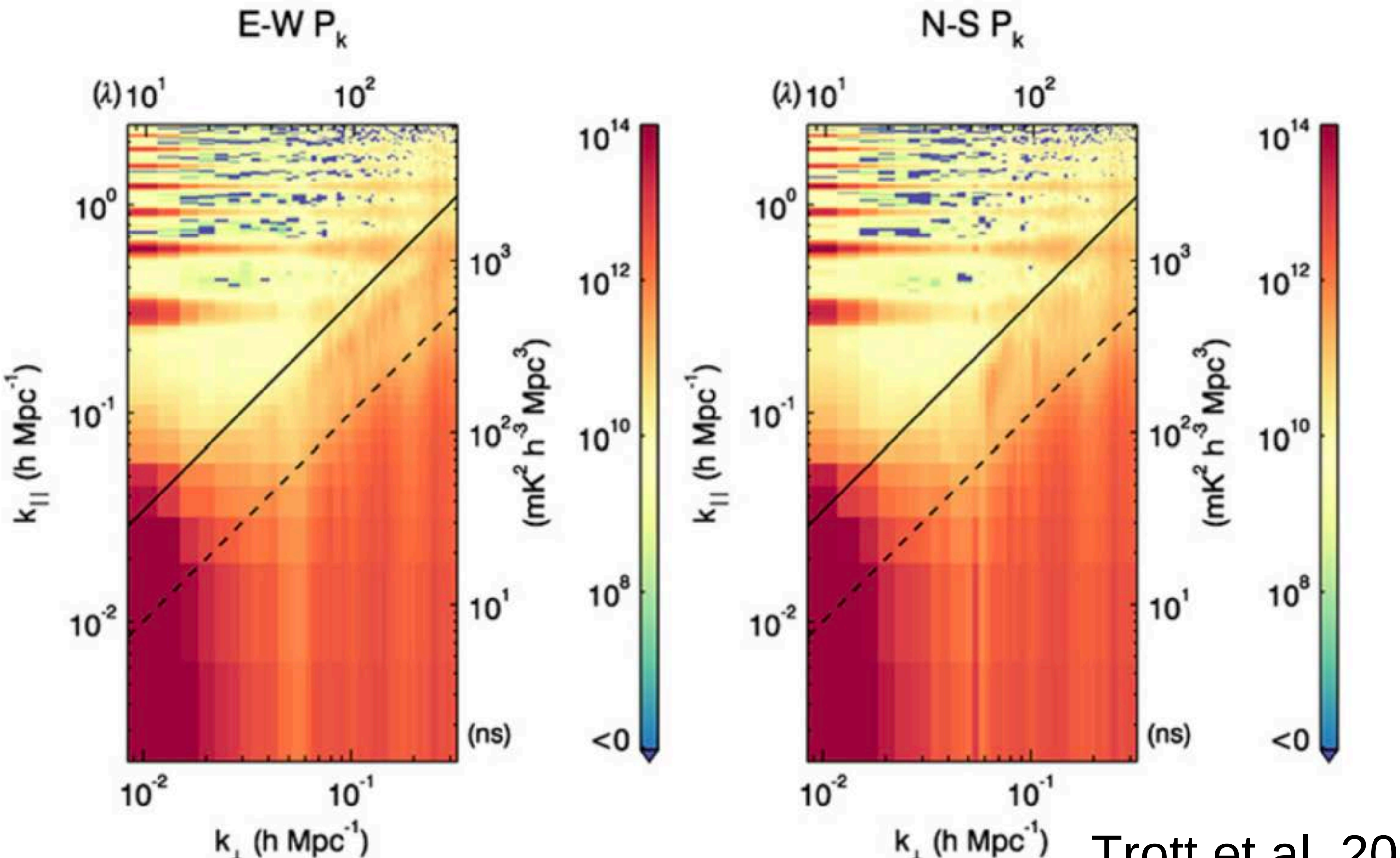
Kimberly Emig (Leiden/ASTRON)

Epoch of Reionisation

- Key science driver of low frequency instruments is understanding neutral hydrogen in the period of the epoch of reionisation (EOR)





Trott et al. 2016

Low Frequency HI absorption

- 21cm line redshifted to 230 MHz at redshift $z \sim 5.2$

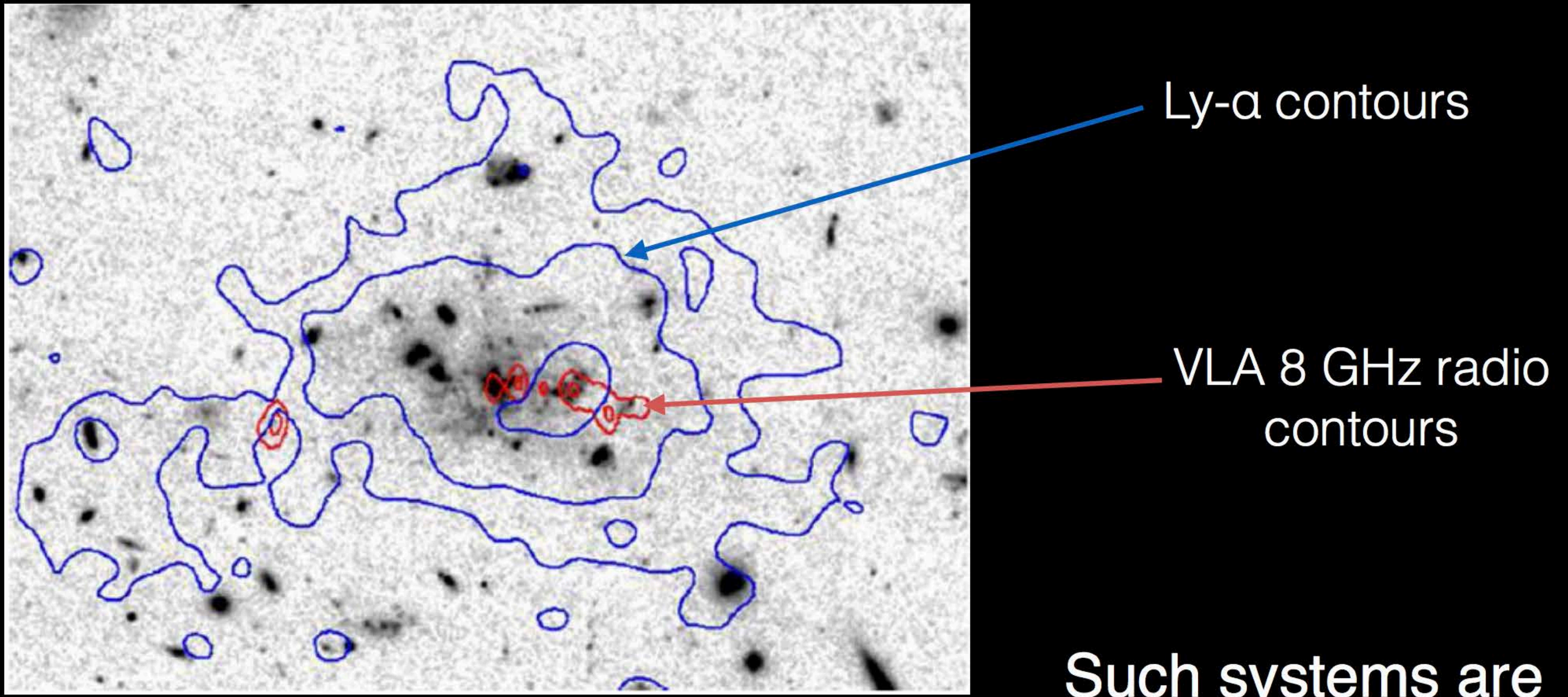
LOFAR and the MWA

› MWA sensitive between 72 and ~230 MHz (z ~ 18 to 5.2)

› LOFAR HBA sensitive between 120 to 250 MHz (z ~ 11 to 4.7)

What do you learn at high-z?

- Early cluster formation and clustering – radio galaxies regulate gas cooling (Croton+ 06, Emonts+ 14)

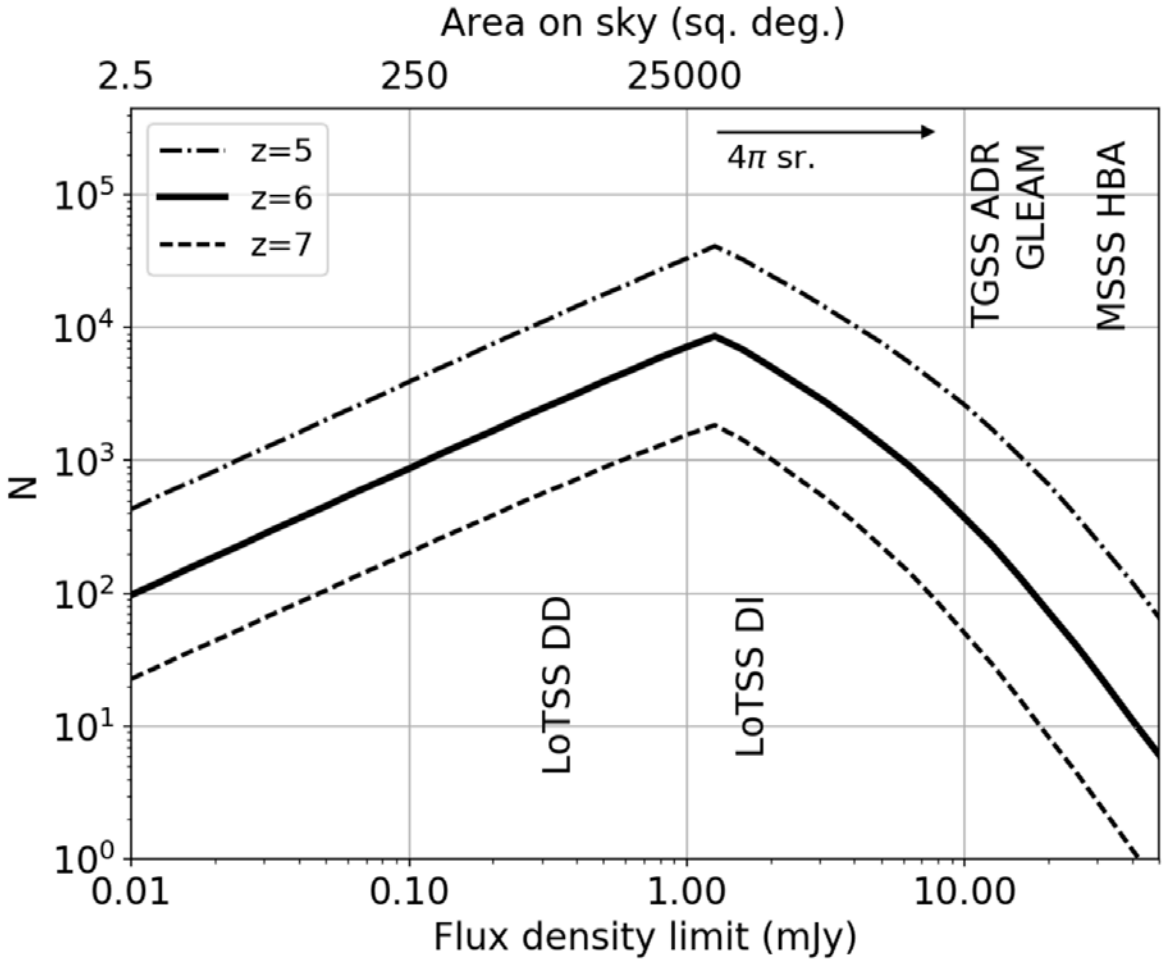


Deep HST ACS image of the high-redshift radio galaxy (HzRG) "Spiderweb", at the centre of a protocluster at $z = 2.2$ (Miley et al. 2006)

Such systems are instrumental in studying massive galaxy formation and AGN feedback

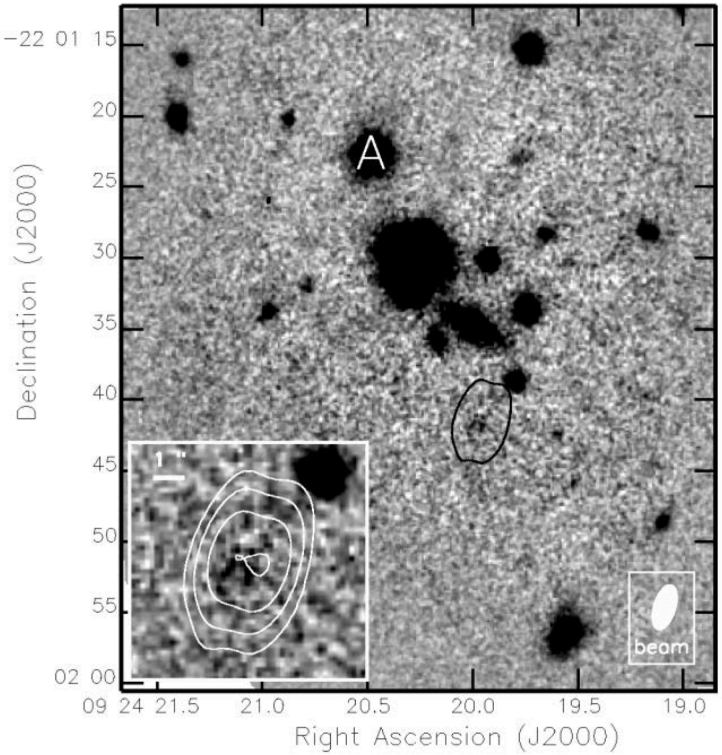
How many bright radio sources at $z > 5$

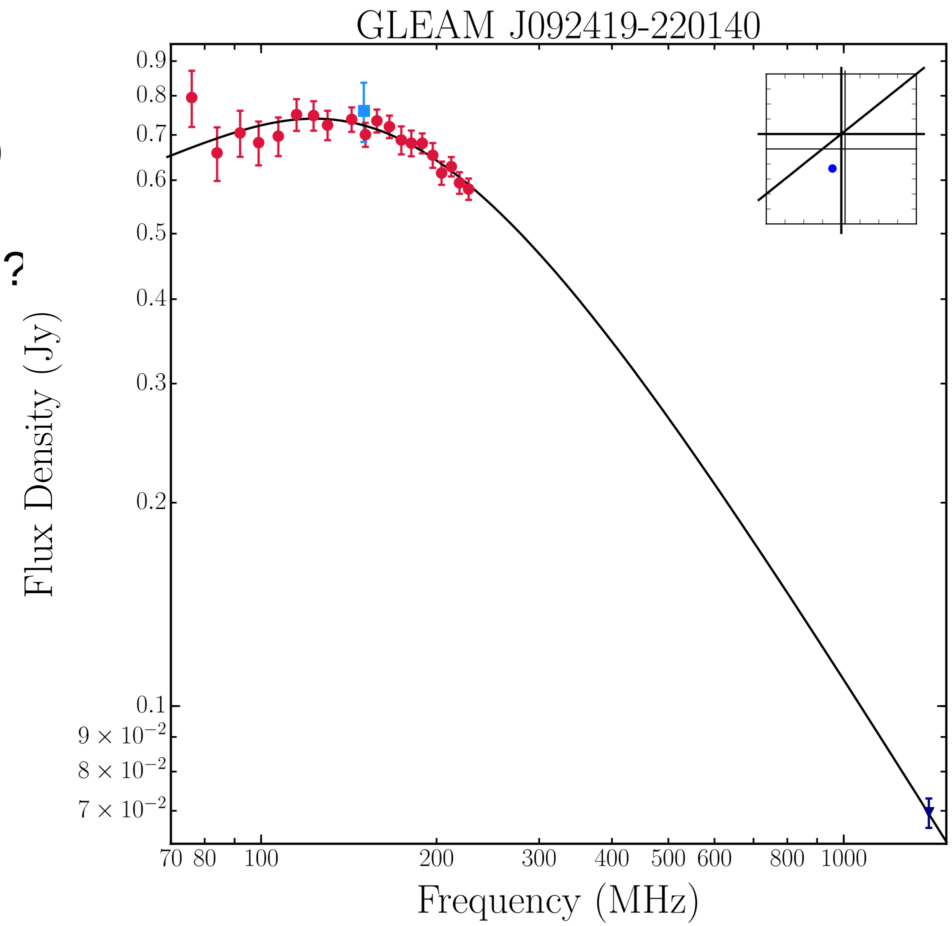
- After modeling SMBH mass function and various energy losses, Saxena+16 showed that we expect on the order of ~10 radio sources with $S_{200\ MHz} > 100$ mJy at $z > 5$. Only detected HI absorption out to $z = 3.2$.



Precedent set by van Breugel+ (1999)

- Selected by ultra-steep spectrum criteria
- Powerful radio galaxy at $z = 5.19$
- Slightly resolved at 1.2” – double?

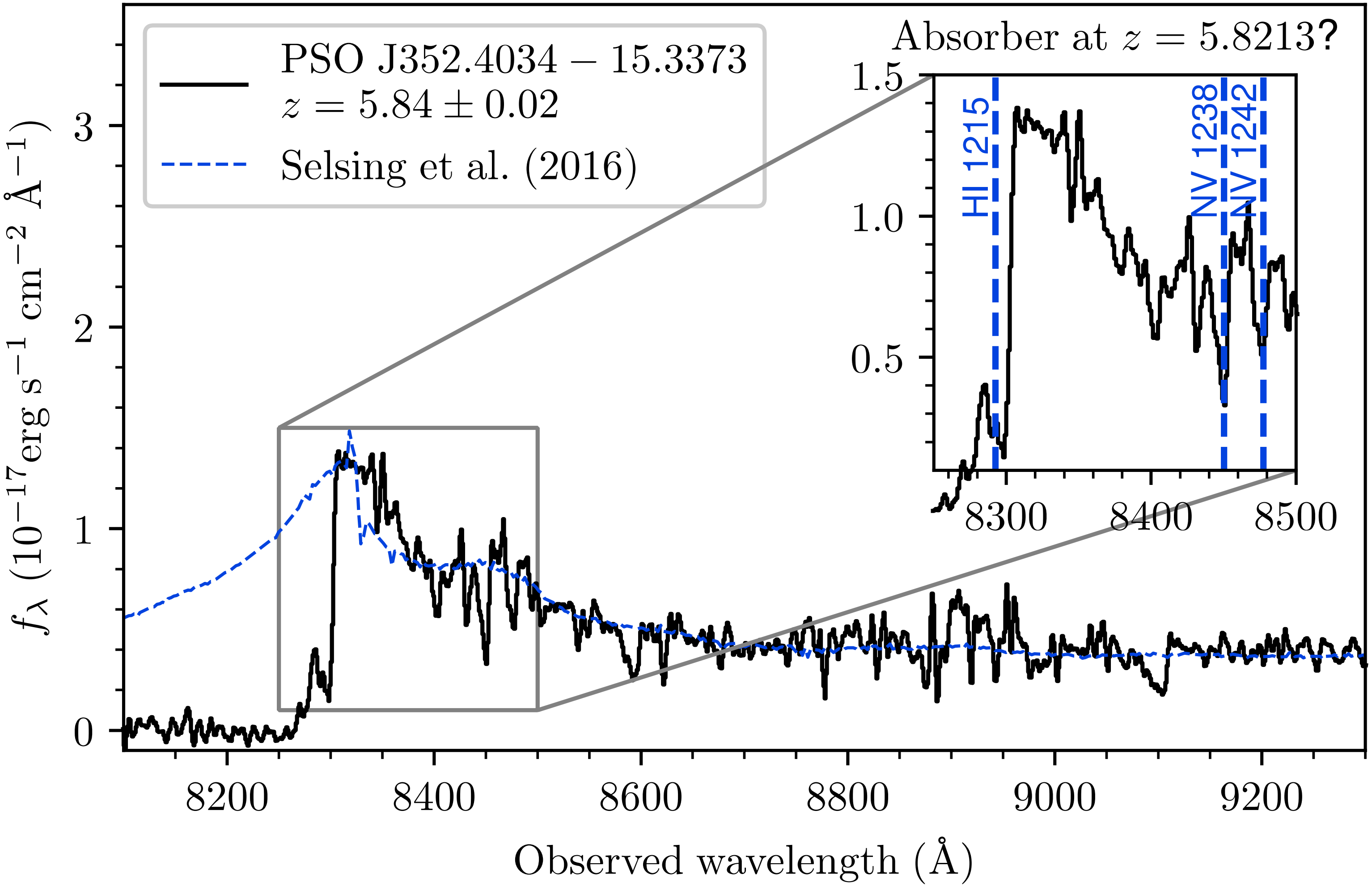




Callingham et al. (2017)

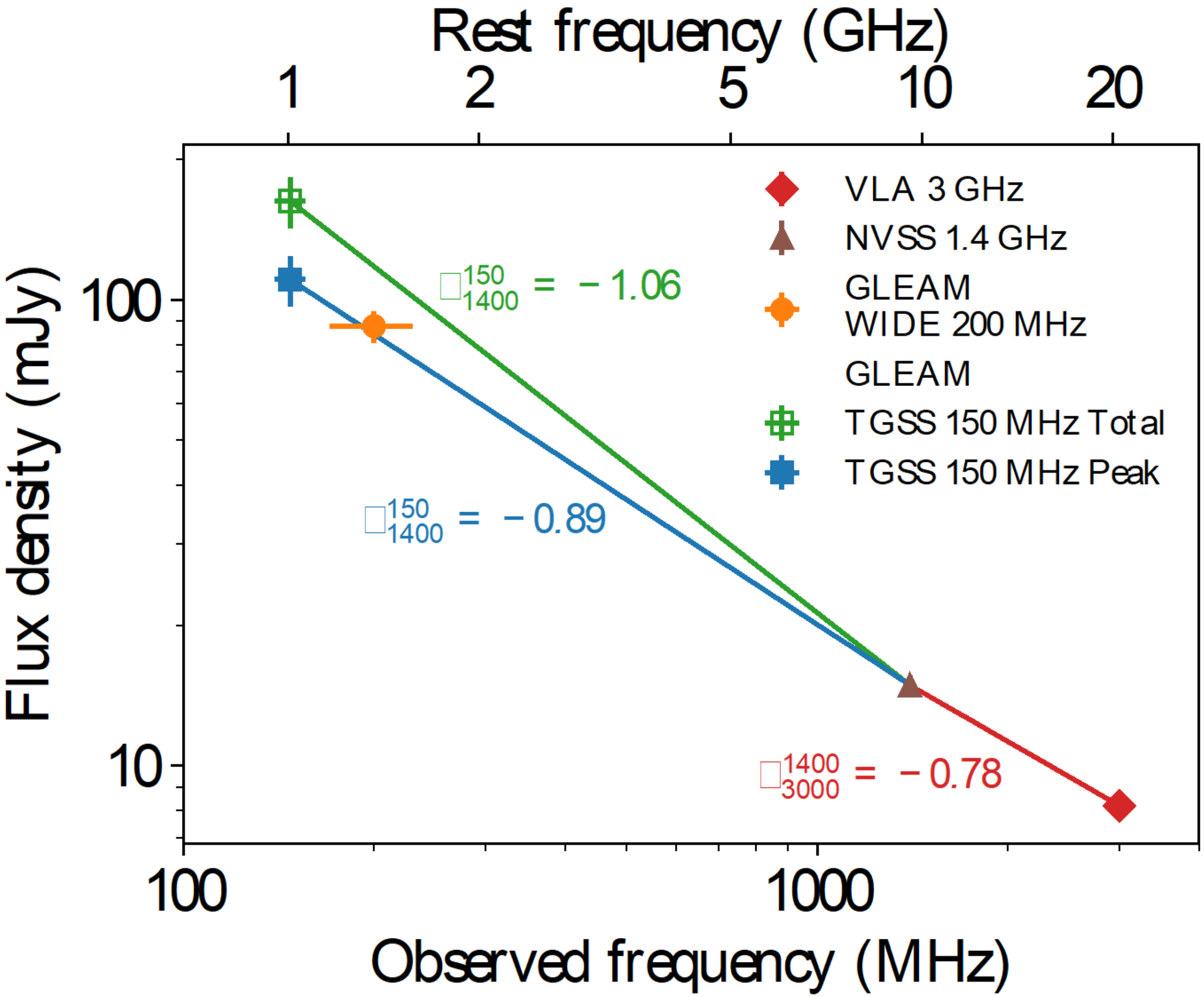
PSO J352.4034-15.3373

- Associated HI asorption would be at 208 MHz



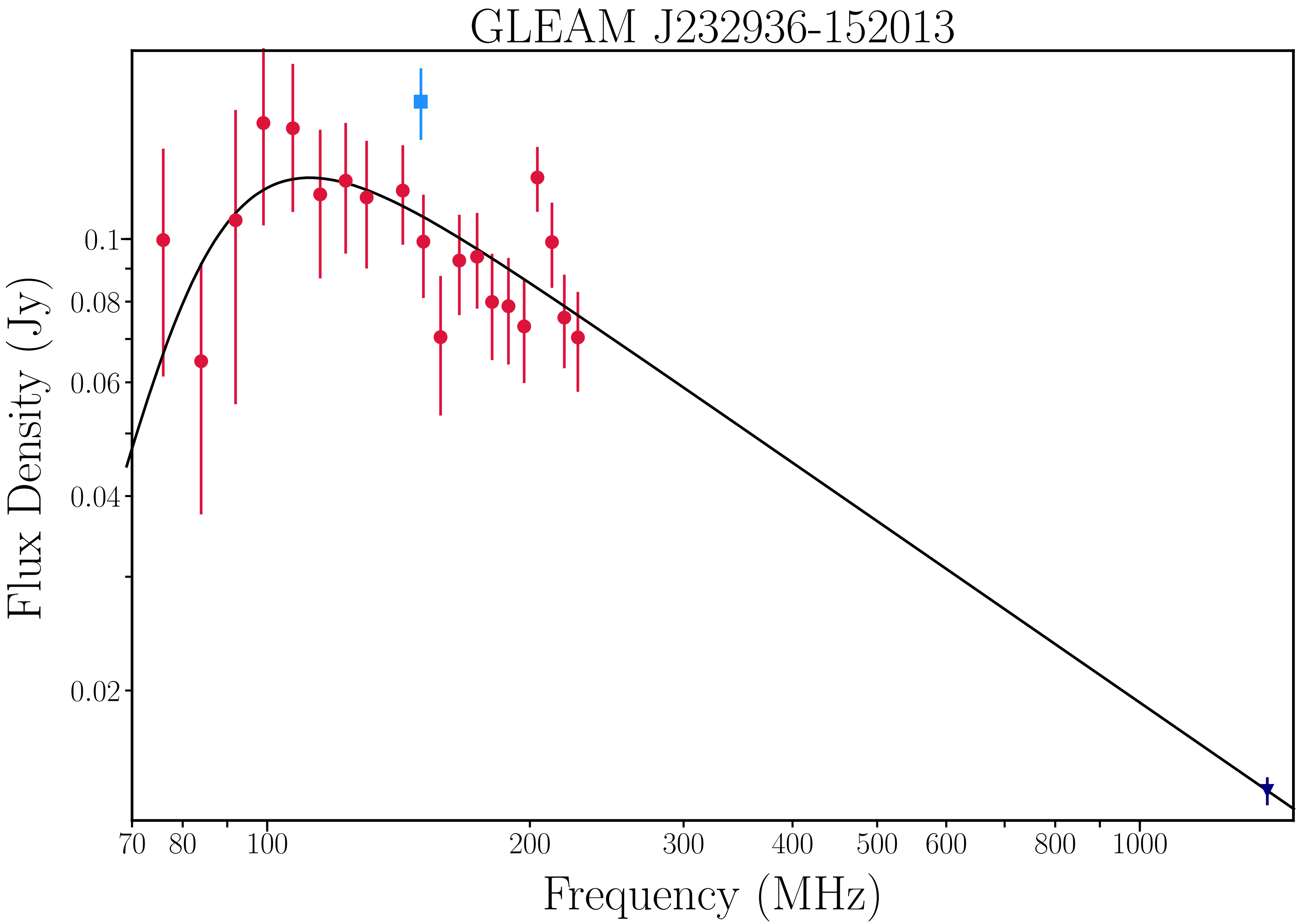
Banados et al. (2018)

PSO J352.4034-15.3373



Banados et al. (2018)

Peaked-spectrumed?



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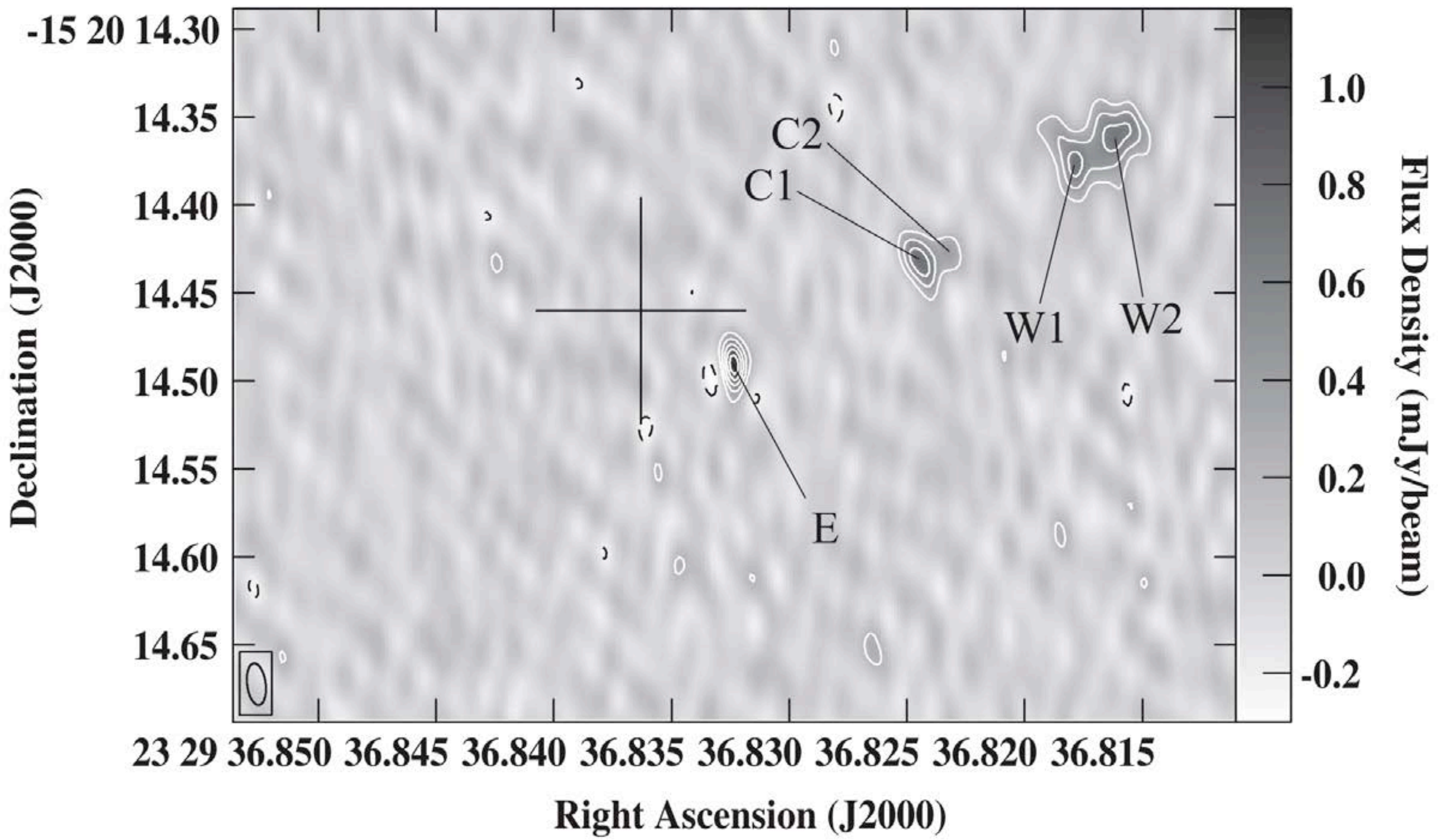
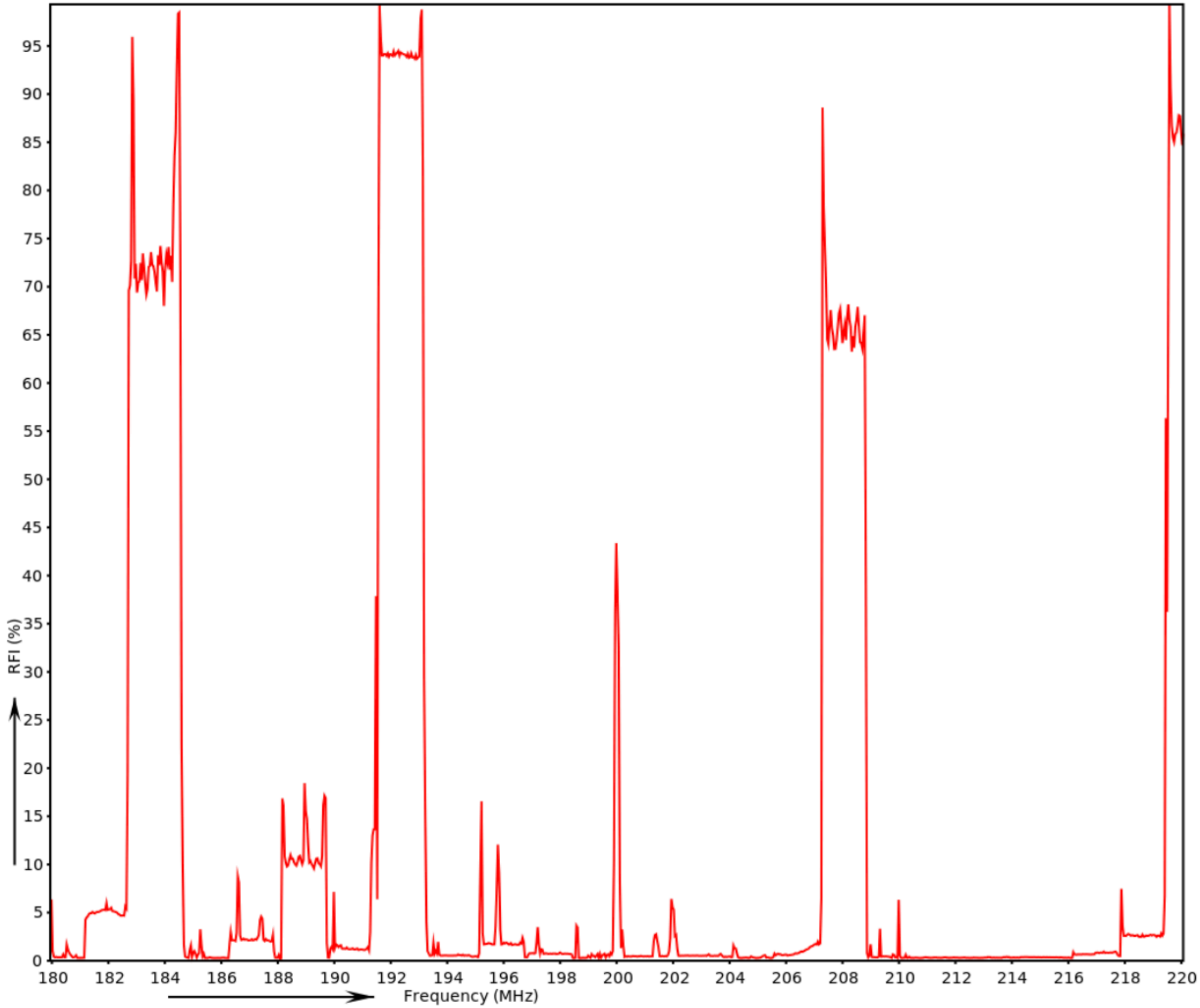


Momjian et al. (2018)

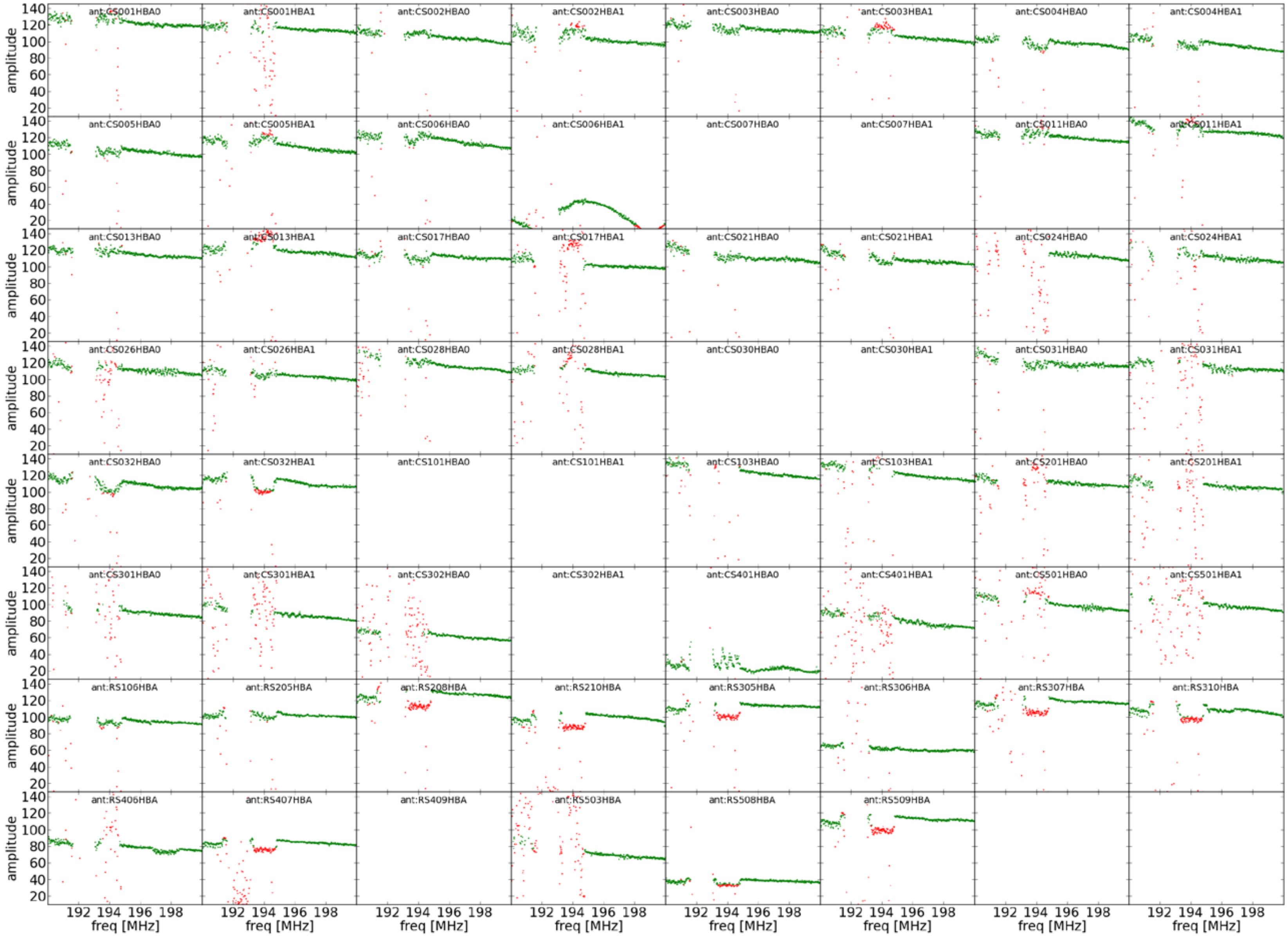
LOFAR Observations

- Assuming ideal RFI conditions, 10 hour observation with LOFAR can achieve an RMS noise of of 10.2 mJy/beam per 0.61 kHz channel (256 channels per sub band).
- At 208 MHz the source is ≈ 100 mJy, which gives an RMS sensitivity to absorption of approximately 10% per 0.88 km s^{-1}.
- Estimate a 3-σ 21cm optical depth sensitivity of approximately 0.06 across the line (assuming 30 km s^{-1} line width).
- For spin temperatures in the range 100 to 1000 K, this corresponds to a 3-σ column density $N_{HI} = 0.3-3\times10^{21}$ cm^{-2}.

RFI Environment at LOFAR



2 hours of data 190-200 MHz
- Preliminary



2 hours of data 190-200 MHz
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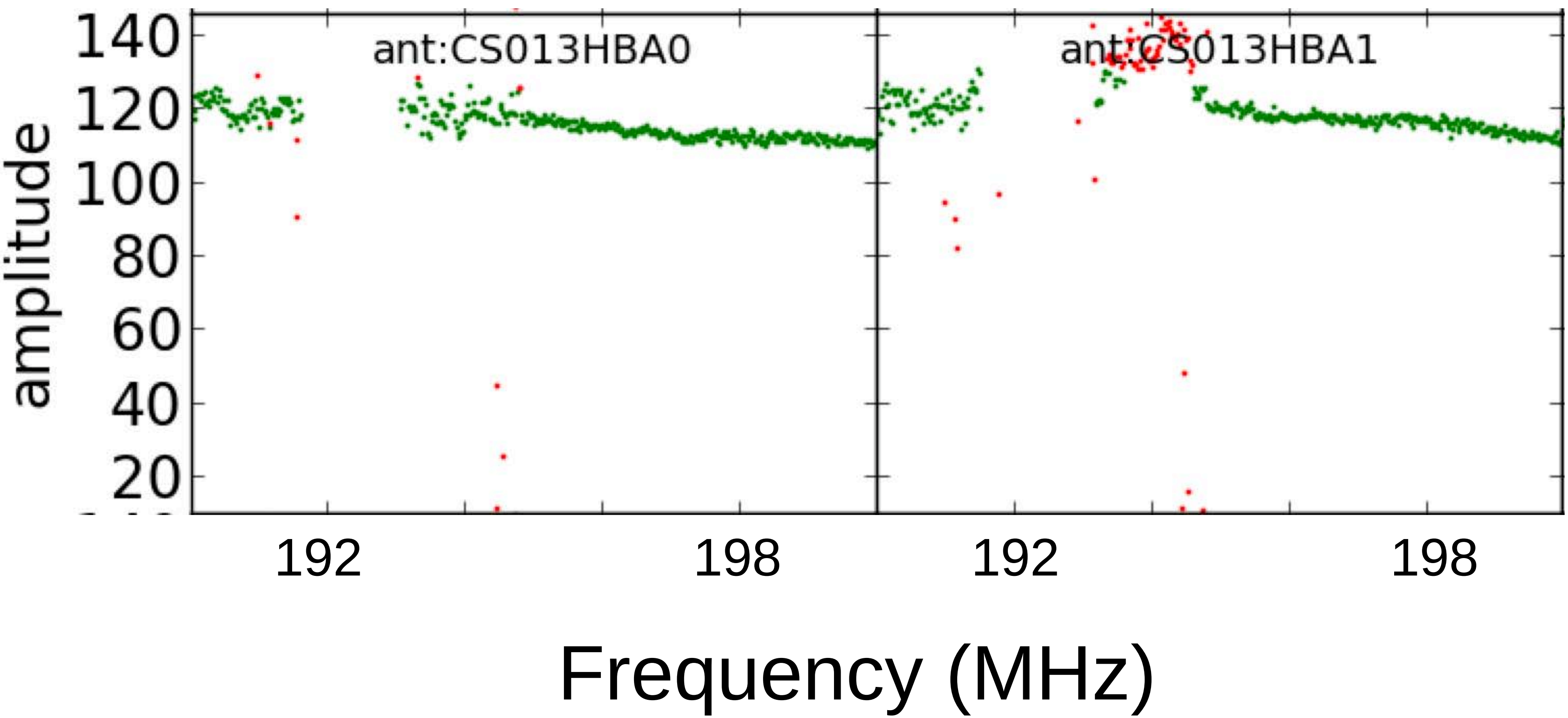
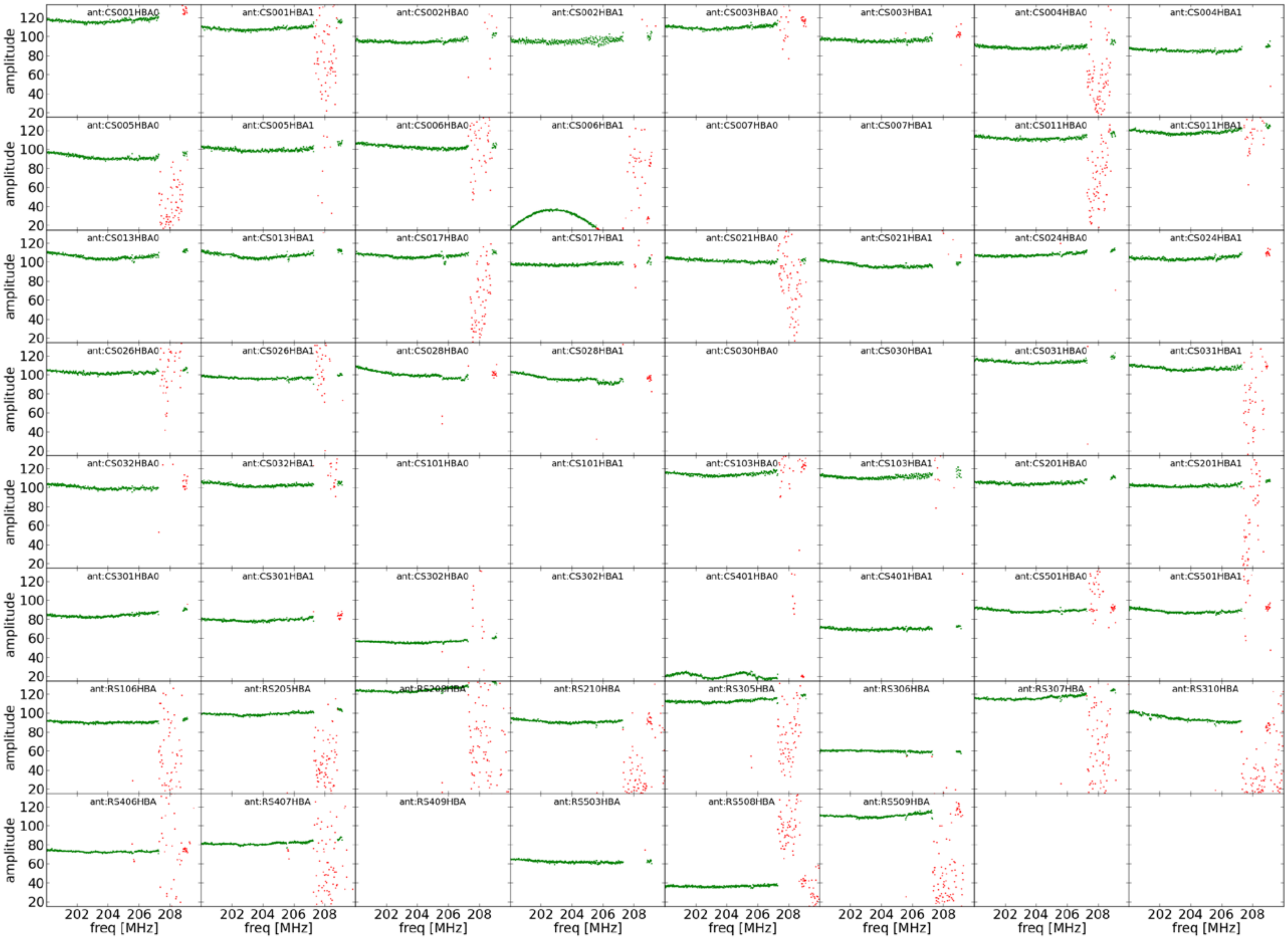
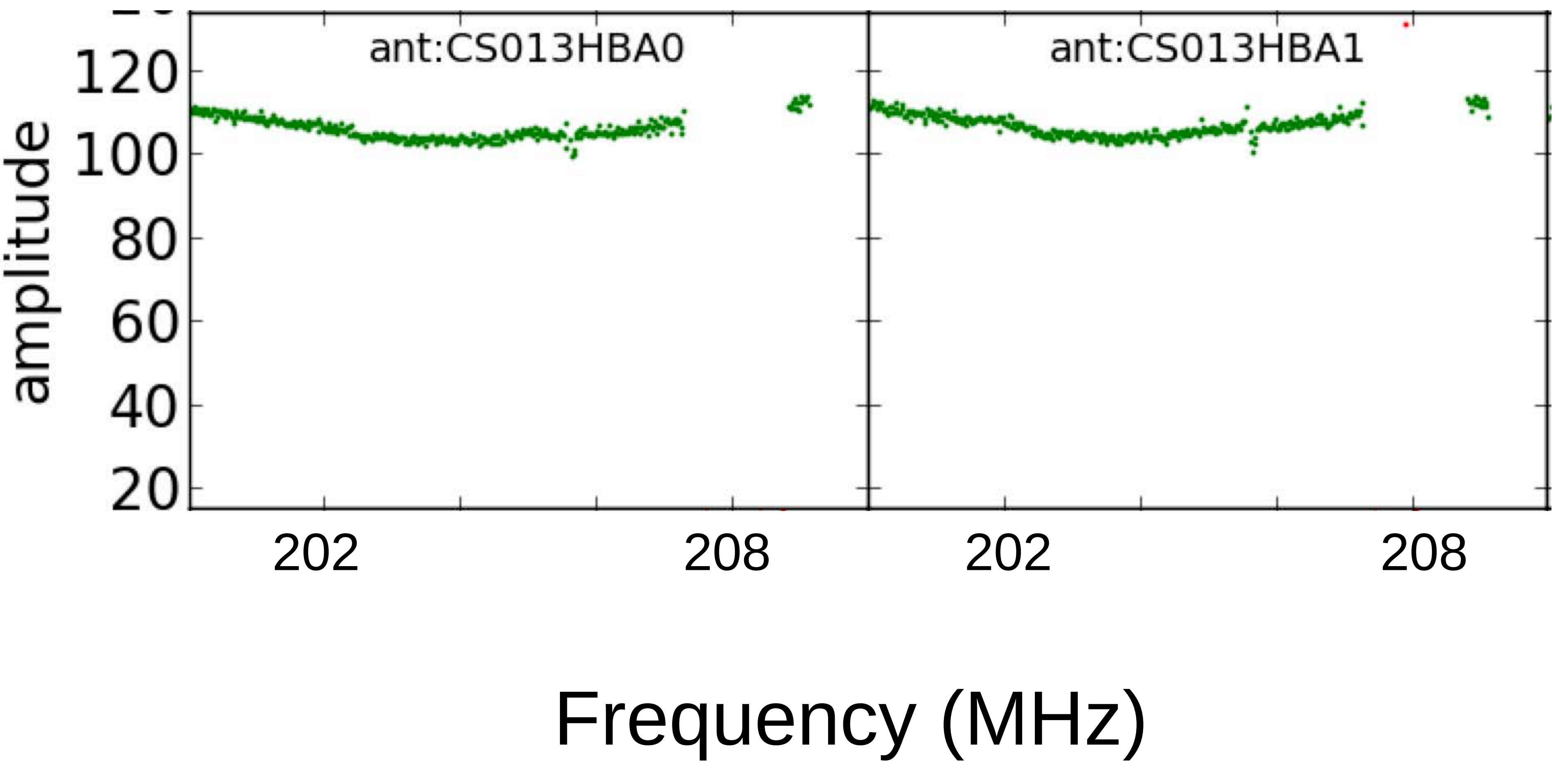


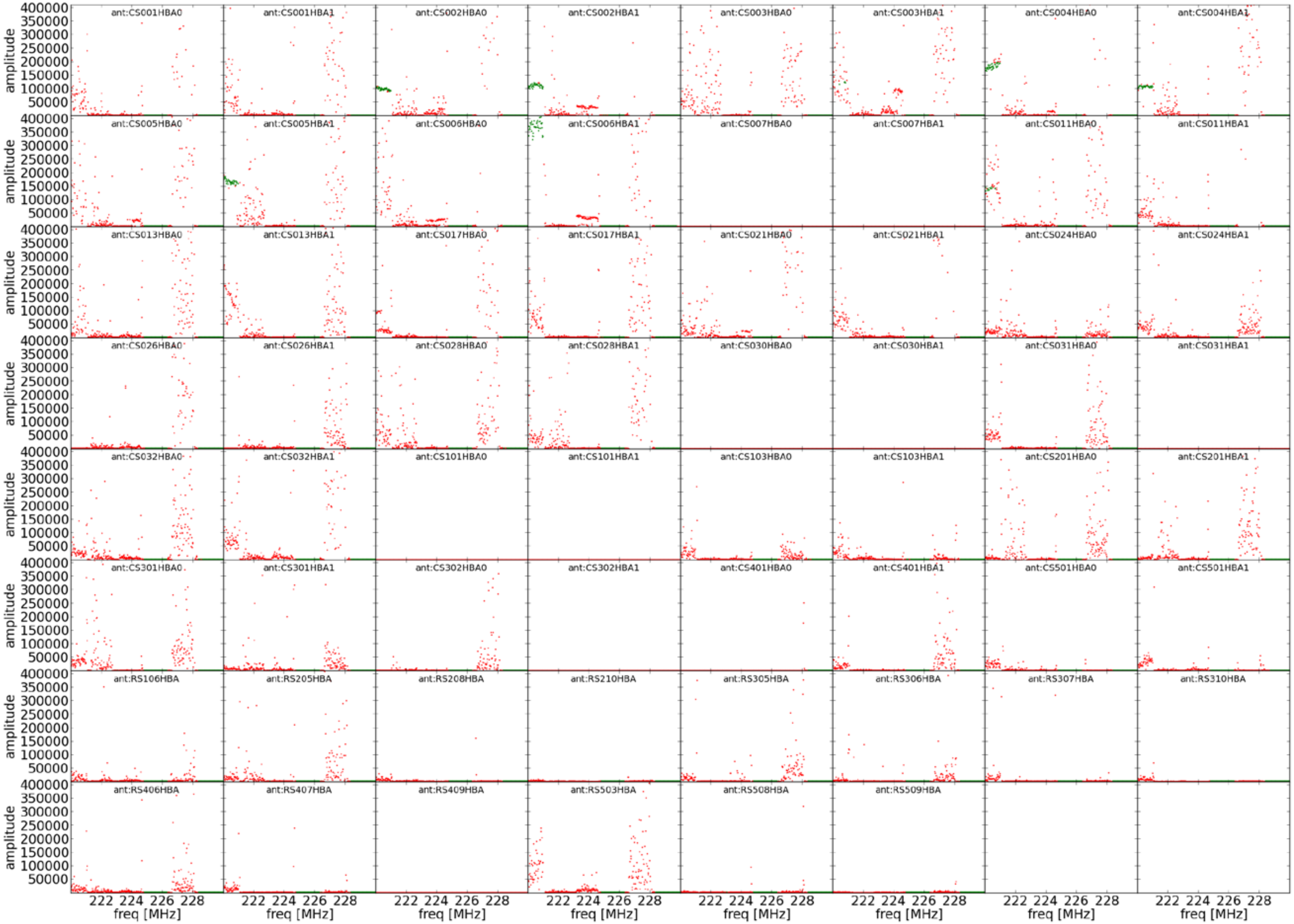
2 hours of data 200-210 MHz - Preliminary



2 hours of data 200-210 MHz
- Preliminary



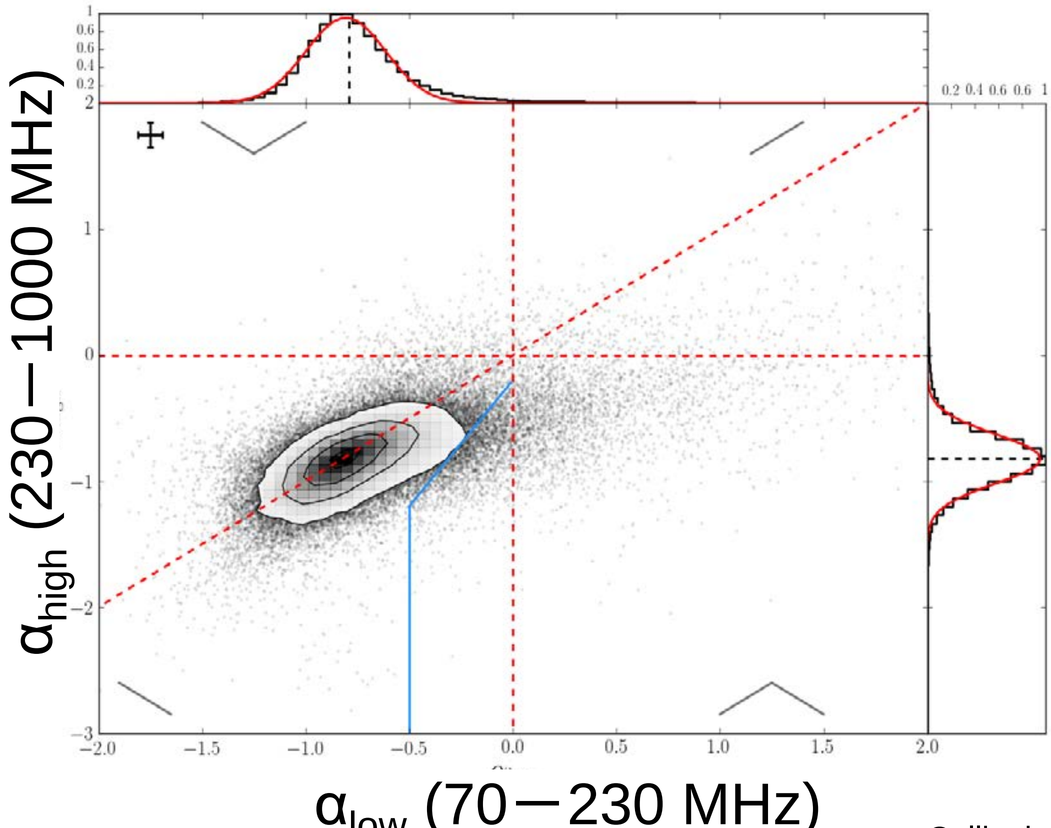
2 hours of data 220-230 MHz
- Preliminary



Going blind

- Potentially the peaked-spectrum nature of sources, combined with an ultra-spectrum optically thin spectral index, could betray high-z location

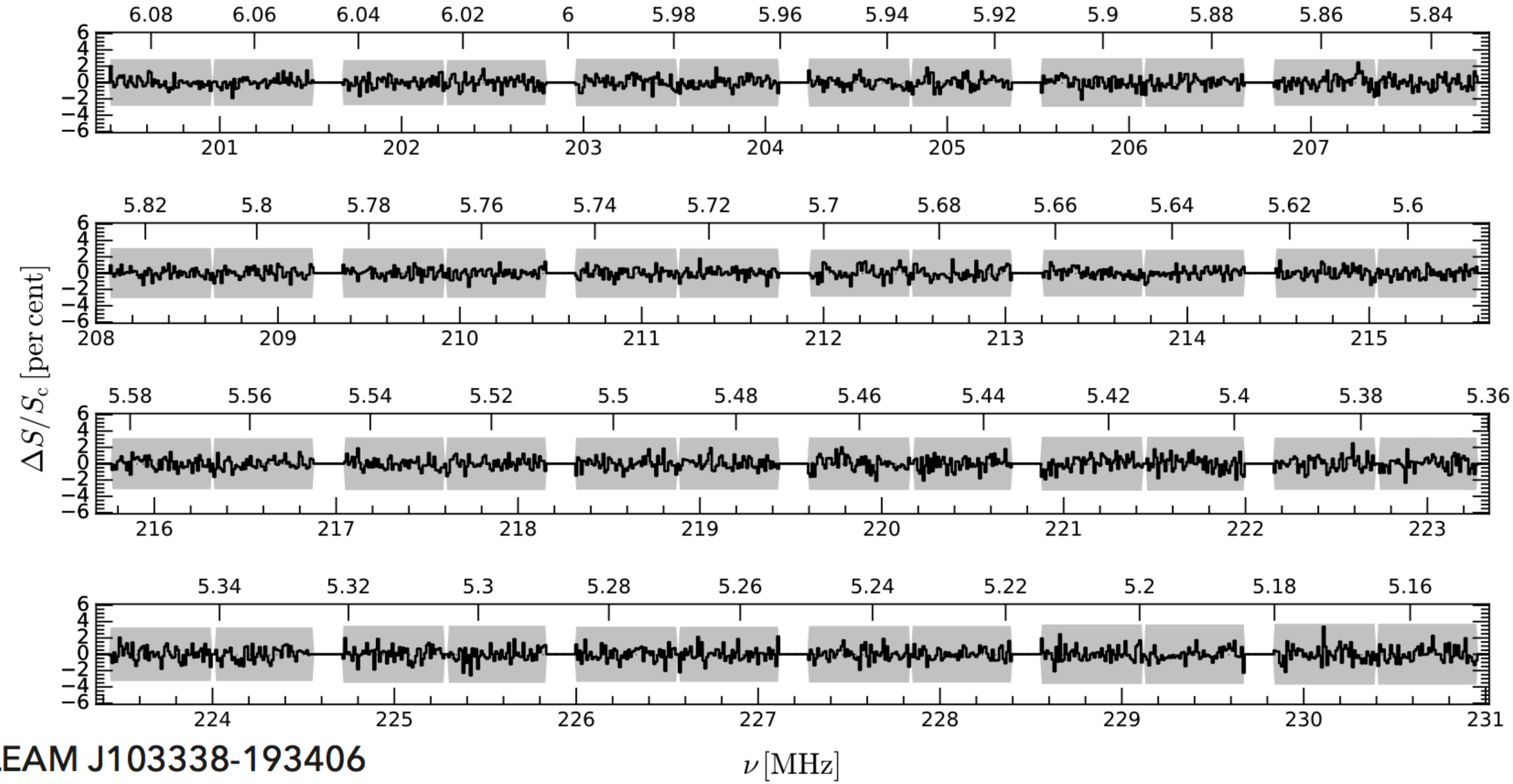
- Physically justified by steepening at higher frequencies caused by first order Fermi acceleration in a dense environment, which also frustrates the evolution of the jets.



Callingham et al. (2017)

Going blind

› Targeted the brightest of these (all > 0.5 Jy at 150 MHz) with the MWA



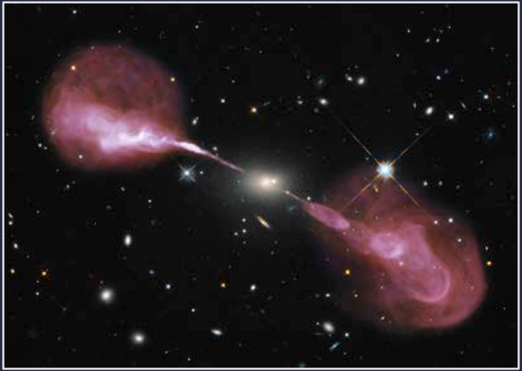
GLEAM J103338-193406

James Allison

Summary

- Entering new era where redshift > 5 radio sources are being readily discovered
- Potential to probe neutral HI gas during the EOR, also provides insight into Galaxy and cluster formation
- Reaching the expected noise in 190 to 205 MHz with LOFAR (~20 mJy/beam per 0.61 kHz channel) but RFI means the band above 208 MHz is nearly unusable
- LOFAR well positioned if we get sources
- MWA RFI environment significantly better but sensitivity is the main limitation
- Detection by Saxena et al. (2018) of another z ~ 5.72 radio source (expect HI absorption at 212 MHz) with a flux density of 170 mJy at 150 MHz.


MWA / Hurley-Walker


NASA, ESA, RIT, NRAO / AUI / NSF, Hubble Heritage


LOFAR / ASTRON