Using the Long Wavelength Array to Search for Cosmic Dawn

February 21\textsuperscript{st}, 2020

Christopher DiLullo
With: Greg Taylor and Jayce Dowell
University of New Mexico
21-cm Cosmology

A Possible Detection! – Bowman et al. 2018

LETTER

An absorption profile centred at 78 megahertz in the sky-averaged spectrum

Judd D. Bowman, Alan E. Rogers, Raul A. Monsalve, Thomas J. Mozdzen, & Nivedita Mahesh
LWA-SV

- 256 dual-pol antennas
- 100 m x 110 m ellipse oriented N/S
- 3 simultaneous beams
  - 2 tunings/beam
  - 20 MHz bandwidth / tuning
- Beamforming advantages
  - Spatial selection on the sky
  - *In situ* calibration via second beam
The Sky at 74 MHz

Observational Setup

- 2 simultaneous beams on Virgo A and Science Field
- 3 hr runs with tuning centers at 67 and 75 MHz.
- Spectrometer mode with 1024 9.57 kHz channels and 80 ms time resolution.
- RFI excision using a pseudo-spectral kurtosis flagging criterion.
Modelling

- Smooth polynomial model: \( T(\nu) = \sum_{n=0}^{N-1} a_n \left( \frac{\nu}{\nu_c} \right)^{n-2.5} \)
r.m.s. vs. Integration Time

r.m.s. Error Across Full Bands

- XX
- YY
- $m = -0.5$
Custom Beamforming

- \( Y(\theta, \phi) = R(\theta, \phi) \times (W \cdot V(k)) \)
  - \( Y(\theta, \phi) \) – array response
  - \( R(\theta, \phi) \) – antenna gain pattern
  - \( V(k) \) – steering vector

- Change array beam response via weighting vector, \( W \).

- Beam shape can be made independent of frequency and pointing direction.

- Lose sensitivity as more antennas are down-weighted.
Custom Beamforming

Unshaped Beam

Shaped Beam

1-D Beam Model Slice

FWHM = 2.868

Distance along Cyg A Arc from Pointing Center (deg)
Custom Beamforming – 5° Results

Observed Driftcurve for Unshaped Beam

Observed Driftcurve for Shaped Beam

Simulated Beam Driftcurve using LFSM
Summary

• Beamforming offers a different method to detect the global 21-cm absorption signal.
• LWA-SV currently is limited to a residual r.m.s. of order $\sim 7$ K within 2 minutes of integration.
• Custom beamforming could control sidelobes and avoid chromatic effects.
• Challenging, but progress is being made.

Contact: Chris DiLullo
       cdilullo@unm.edu