Using the Long Wavelength Array to Search for Cosmic Dawn

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21-cm Cosmology

Pritchard, Jonathan R., and Abraham Loeb. "21 cm cosmology in the 21st century.” Reports on Progress in Physics 75.8 (2012): 086901.
A Possible Detection! – Bowman et al. 2018

LETTER

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

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[Diagram showing absorption profile and temperature curves]
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

Dowell et al. (2017, MNRAS, 469, 4537)
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.
Raw Spectra

Science Field

Virgo A

Power [Arbitrary]

Frequency [MHz]
Temperature Calibration

Scale Factors

- XX
- YY

Scale Factor [K/PW]

Frequency [MHz]
Calibrated Spectra

Temperature Spectra
Science Field

Virgo A

Frequency [MHz]

Temperature [K]

XX
YY
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

- \( Y(\theta, \varphi) = R(\theta, \varphi) \times (W \cdot V(k)) \)
  - \( Y(\theta, \varphi) \) – array response
  - \( R(\theta, \varphi) \) – 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
Custom Beamforming – 5° Results

Observed Driftcurve for Unshaped Beam

Observed Driftcurve for Shaped Beam

Simulated Beam Driftcurve using LFSM

LST [hours]
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 ~ 7 K within 2 minutes of integration.
• Custom beamforming could control sidelobes and avoid chromatic effects.
• Challenging, but progress is being made.

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