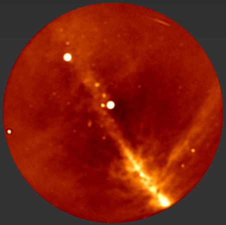


21 cm Fluctuations of the Cosmic Dawn with the Owens Valley LWA

Michael Eastwood (Caltech), Gregg Hallinan (Caltech)

December 4, 2015

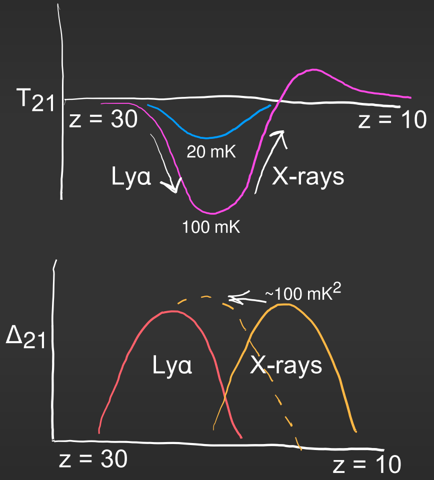
Caltech JPL

CfA

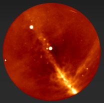
LEDA
Large-Aperture Experiment to Detect the Dark Ages

LWA

The Cosmic Dawn

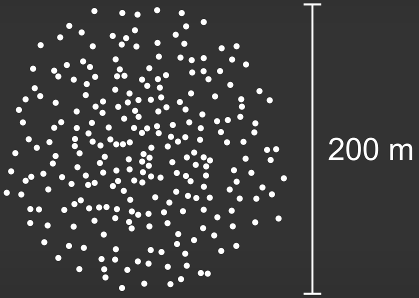


Kaurov & Gnedin 2015, Fialkov & Barkana 2014

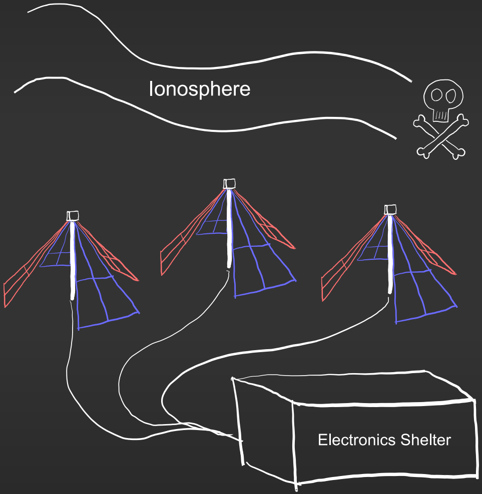


The Owens Valley LWA

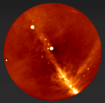
- 251 dual-polariztion antennas within a 200 m diameter core (288 antennas total)
- 512-input correlator
- 30 to 80 MHz instantaneous



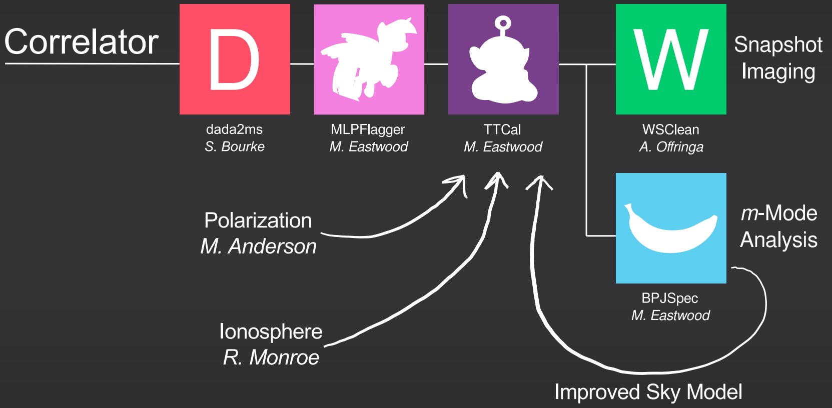
A Cartoon



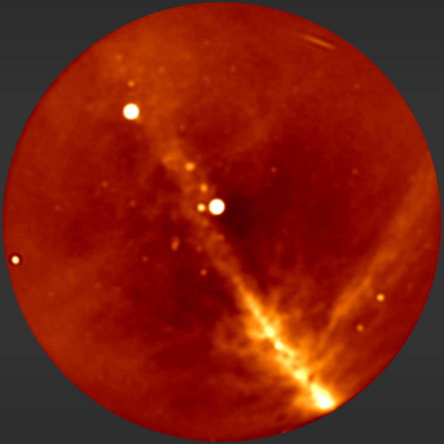
Data Reduction Pipeline



Data Reduction Pipeline



Example Snapshot Image



Note: this image was made using only the core 251 antennas.

m-Mode Analysis

$$m\text{-mode} = \int \text{visibility} \times e^{-im\phi} \, \frac{\mathrm{d}\phi}{2\pi}$$

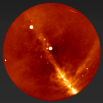
Shaw et al. 2014, Shaw et al. 2015

m-Mode Analysis

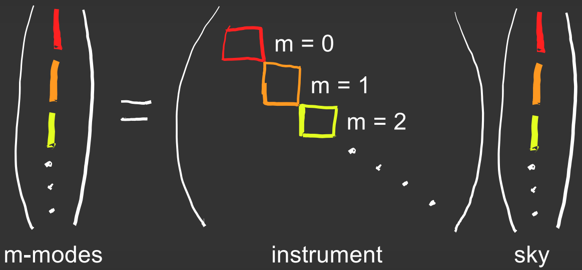
$$m\text{-mode} = \int \text{visibility} \times e^{-im\phi} \frac{\mathrm{d}\phi}{2\pi}$$

$$\begin{pmatrix} \vdots \\ m\text{-modes} \\ \vdots \end{pmatrix} = \begin{pmatrix} \ddots & & \\ & \text{transfer matrix} & \\ & & \ddots \end{pmatrix} \begin{pmatrix} \vdots \\ a_{lm} \\ \vdots \end{pmatrix}$$

Shaw et al. 2014, Shaw et al. 2015



The Transfer Matrix



All-Sky Imaging

$$v = Ba + \text{noise}$$

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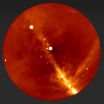
Least Squares Solution

$$\hat{a} = (B^* B)^{-1} B^* v$$



All-Sky Imaging

$$v = Ba + \text{noise}$$

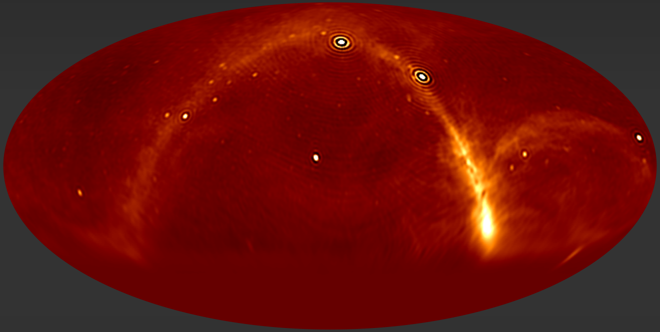
Least Squares Solution

$$\hat{a} = (B^*B)^{-1}B^*v$$

Least Squares with Tikhonov Regularization

$$\hat{a} = (B^*B + \epsilon I)^{-1}B^*v$$

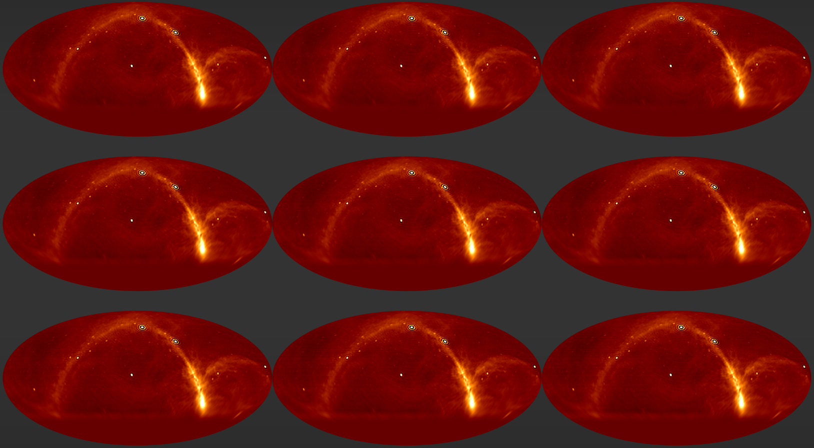
Example All-Sky Image



$$\nu \approx 45\,\mathrm{MHz}, \quad B = 24\,\mathrm{kHz}, \quad \tau \approx 12\,\mathrm{hr}$$

Eastwood et al. (2016, in prep.)

Example All-Sky Images



Eastwood et al. (2016, in prep.)

Foreground Filtering

$$\langle vv^* \rangle = C = C_{\text{noise}} + C_{\text{signal}} + C_{\text{galaxy}} + \cdots$$

Shaw et al. 2014, Shaw et al. 2015

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$$C_{\text{signal}} = P \Lambda P^*, \quad \Lambda = \text{diag}(\lambda_i)$$

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Shaw et al. 2014, Shaw et al. 2015

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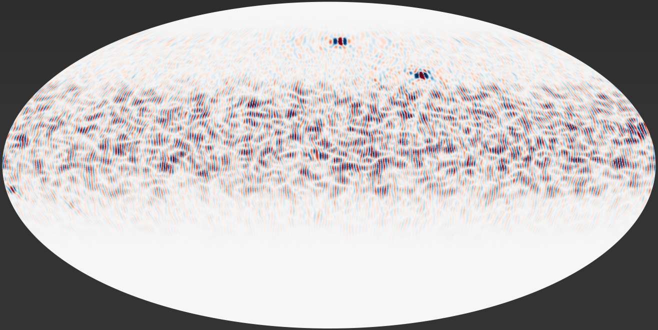
Only keep the modes where $\lambda_i > \text{threshold}$.

These modes are dominated by the cosmological signal.

Shaw et al. 2014, Shaw et al. 2015

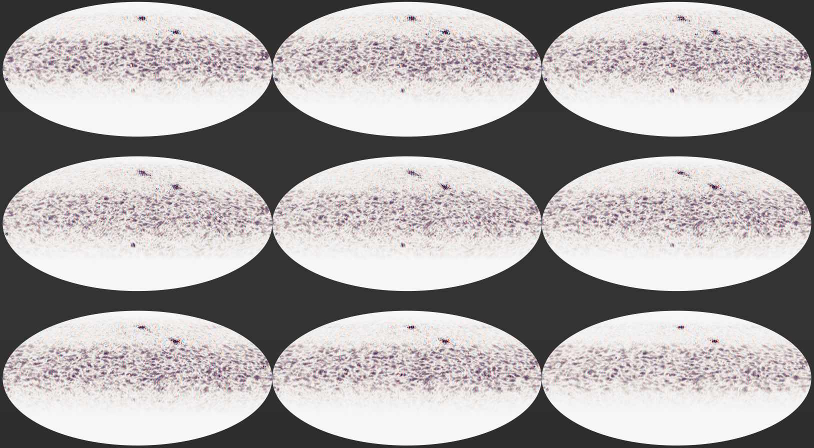
Example Foreground-Filtered Image



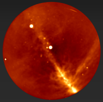
20 dB suppression for a filter using only ten 24 kHz channels
(image is just one of these channels)

Eastwood et al. (2016, in prep.)

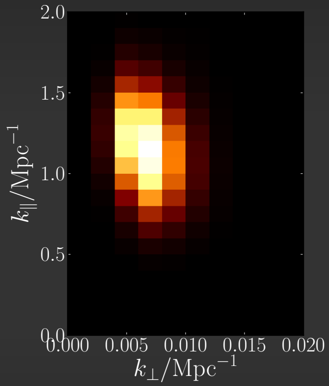
Example Foreground-Filtered Images



Eastwood et al. (2016, in prep.)



Power Spectrum Sensitivity



Preliminary! Calculations only use 10 frequency channels.

Eastwood et al. (2016, in prep.)

Summary

- Demonstrated all-sky imaging wtih m-mode analysis
- Preliminary foreground filters look promising
- All-sky imaging is a diagnostic tool for systematic errors and residual foreground contamination
- Early power spectrum and sensitivity estimates ongoing
- Paper coming early 2016