The LWA1 Low Frequency Sky Survey

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Boulder, CO

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Overview

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  -
  - Missing spacing correction
- Maps & Spectral Indicies
- The Low Frequency Sky Model
- Conclusions

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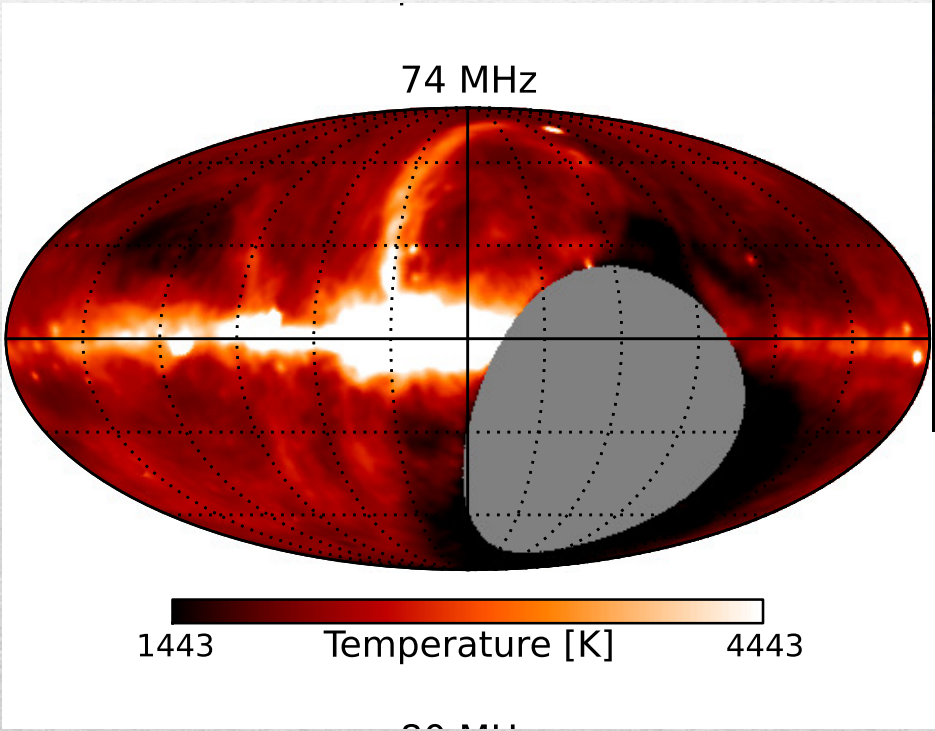
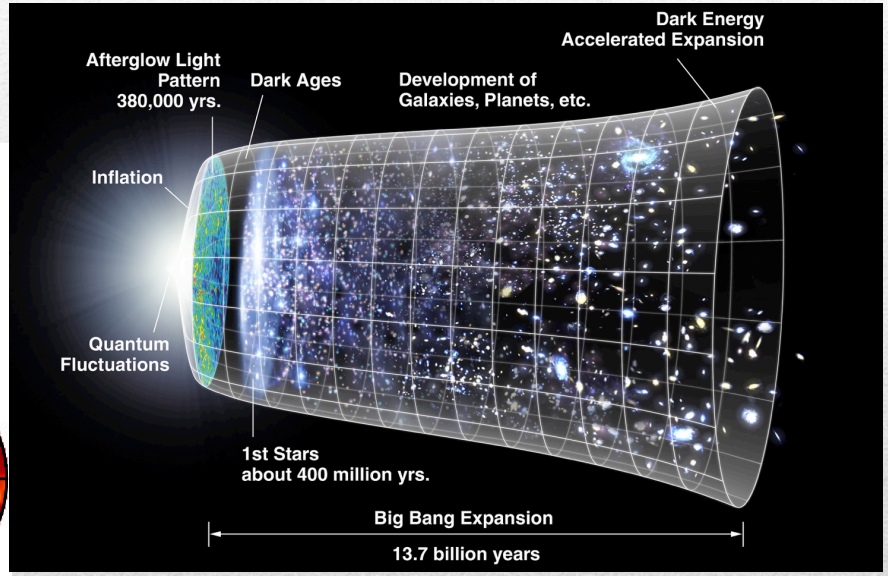
Kevin Stovall (UNM/NRAO)

Overview

- Motivation
- LWA1
- Approach
  - Data acquisition
  - Calibration
  - Missing spacing correction
- Maps & Spectral Indices
- The Low Frequency Sky Model
- Conclusions and Future Directions

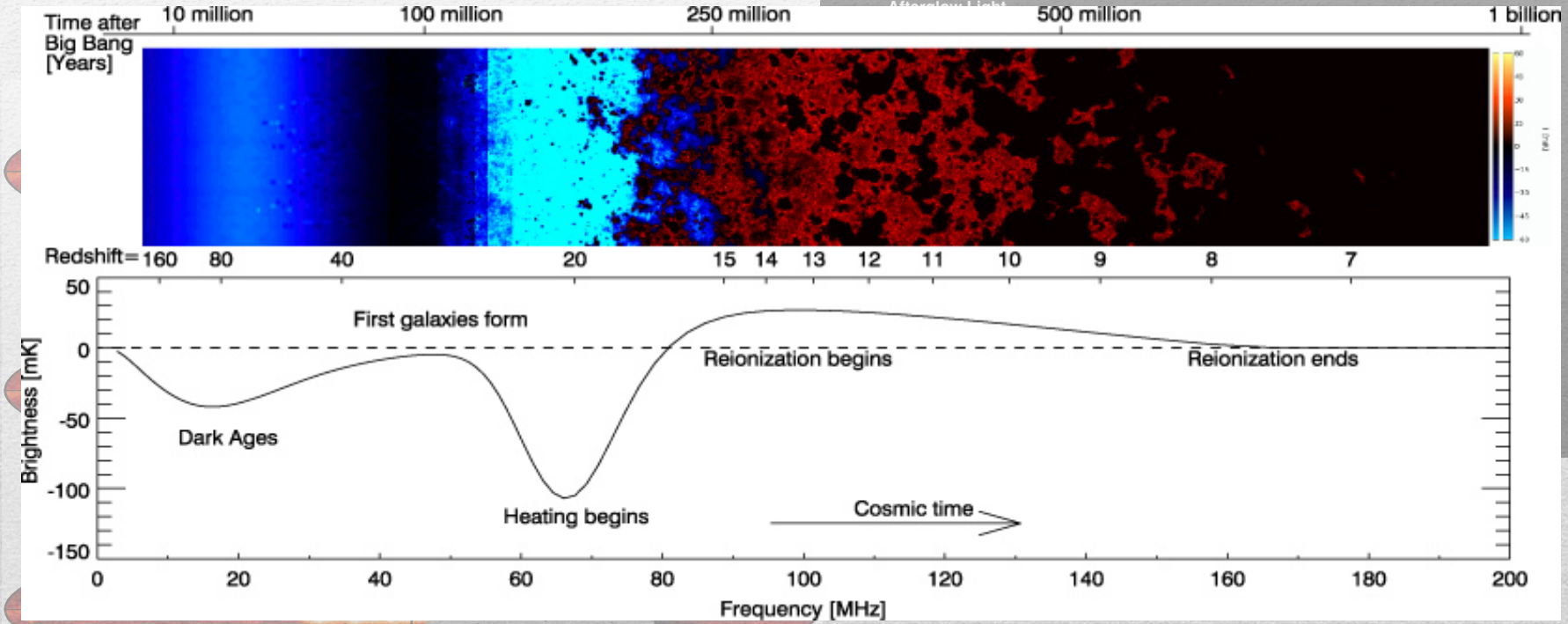
Motivation





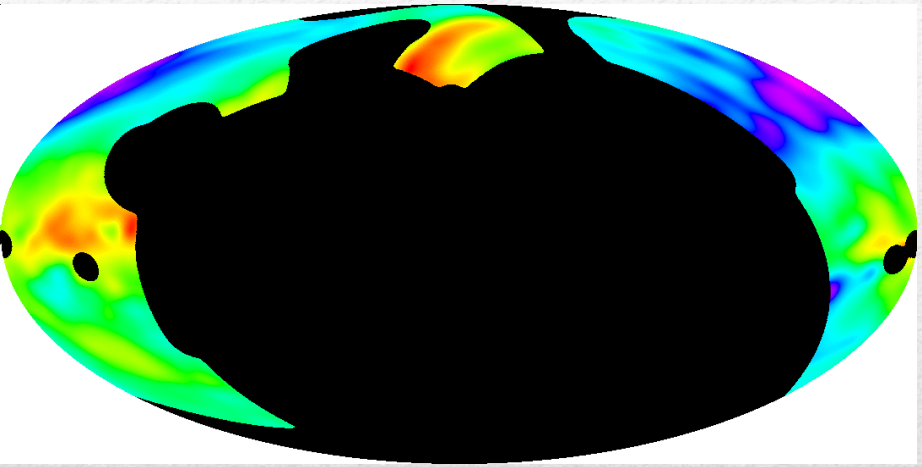
NASA/WMAP Science Team

Motivation


Time after Big Bang [Years]
10 million
100 million
250 million
500 million
1 billion
Redshift=
160
80
40
20
15
14
13
12
11
10
9
8
7
Brightness [mK]
50
0
-50
-100
-150
First galaxies form
Reionization begins
Reionization ends
Dark Ages
Heating begins
Cosmic time
0
20
40
60
80
100
120
140
160
180
200
Frequency [MHz]

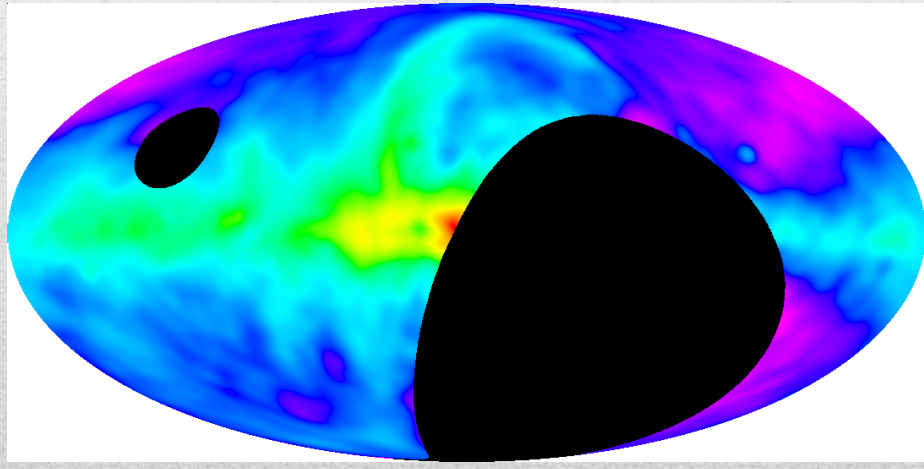
Dark Energy
Accelerated Expansion
1384
Temperature [K]
3618

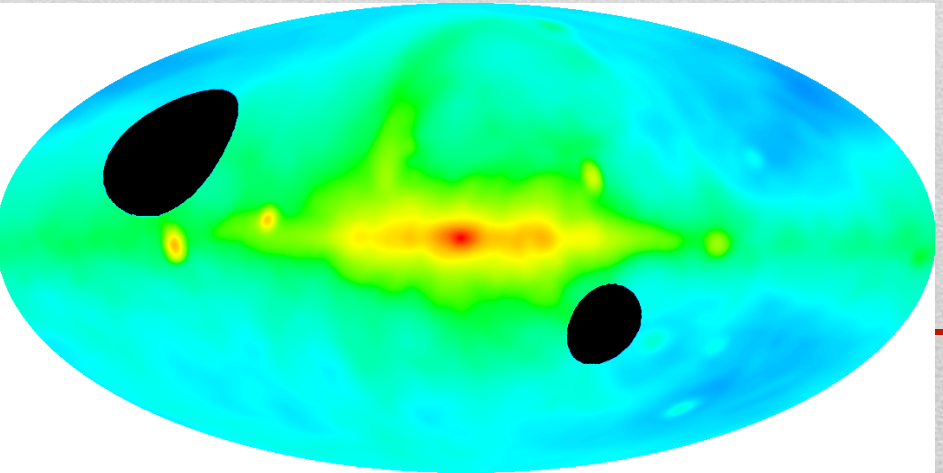
Motivation



Caswell (1976) - 10 MHz

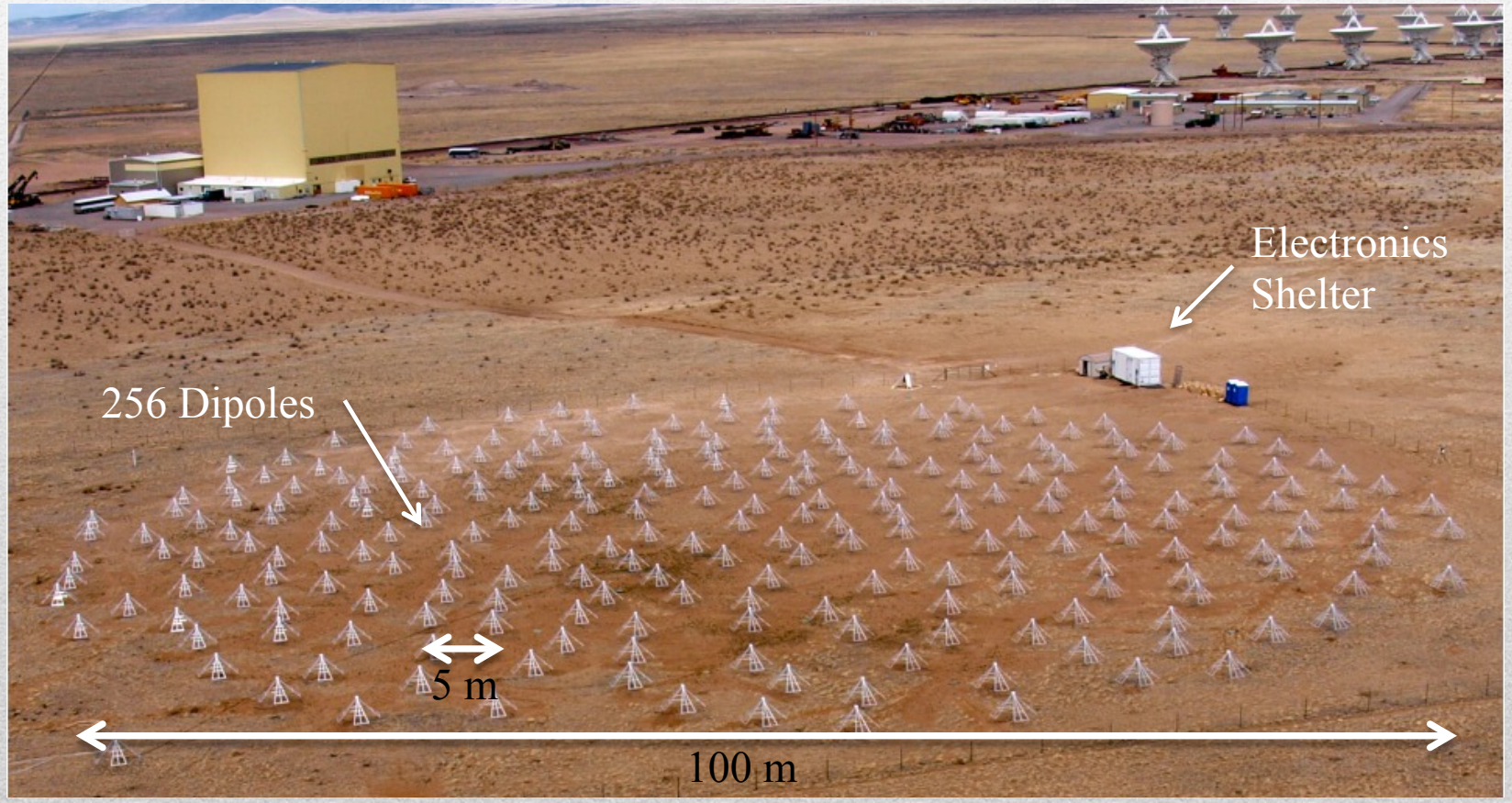
Rogers et al. (1999) - 22 MHz





Alvarez et al. (1997);
Maeda et al. (1999) – 45 MHz

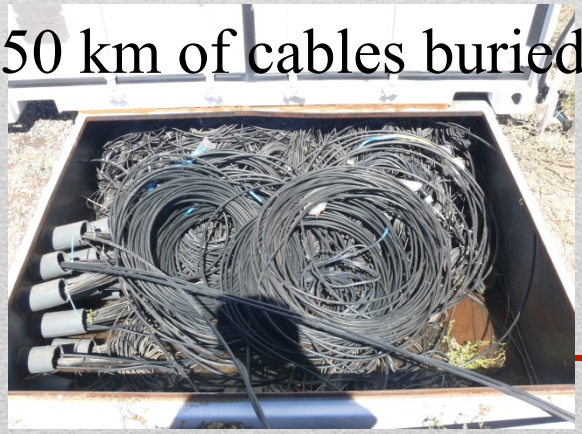
LWA1

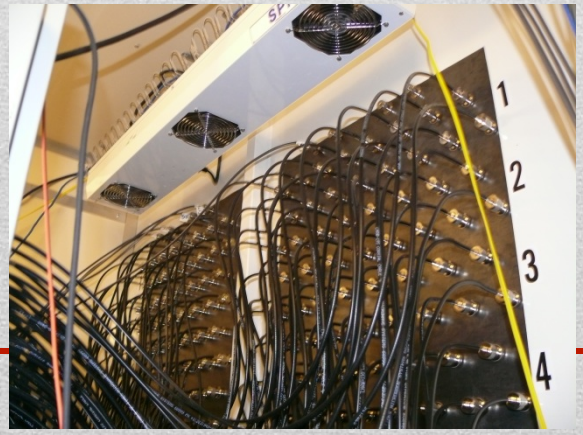


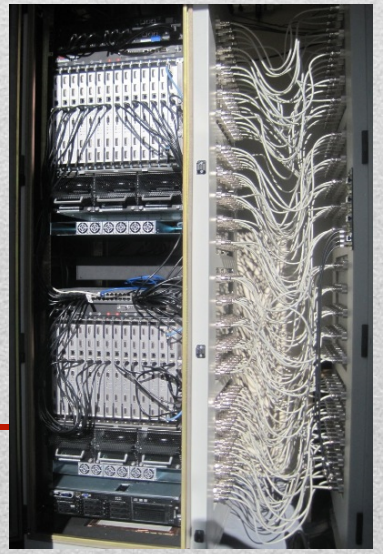
LWA1

LWA1 shielded electronics shelter
(100 dB shielding w/ RF tight racks)

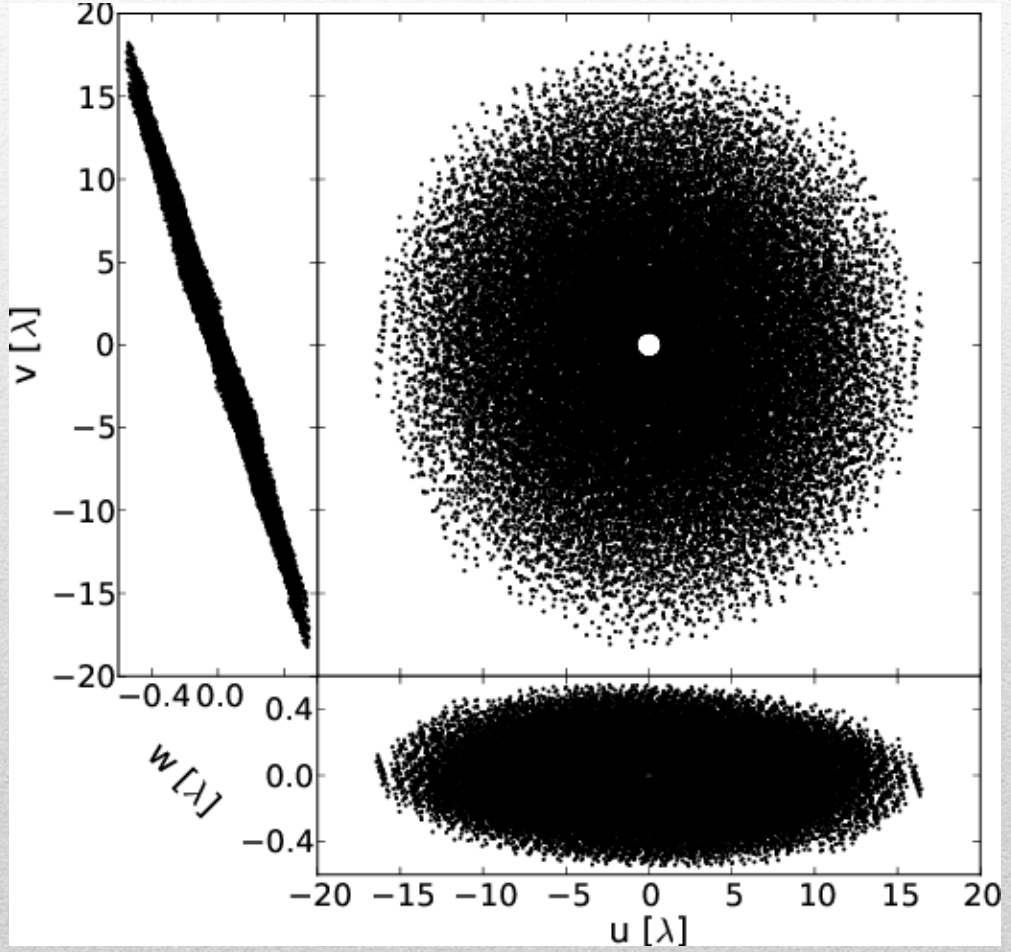
~50 km of cables buried



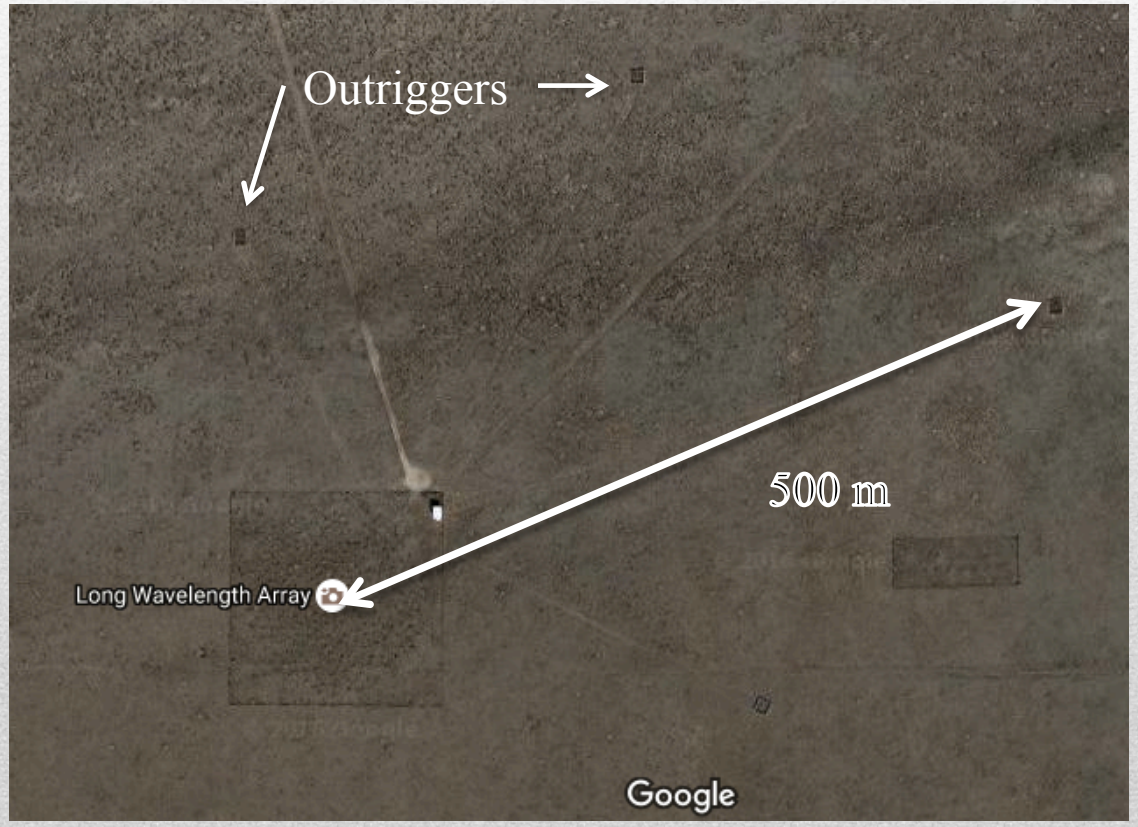




LWA1



LWA1



Approach - Data

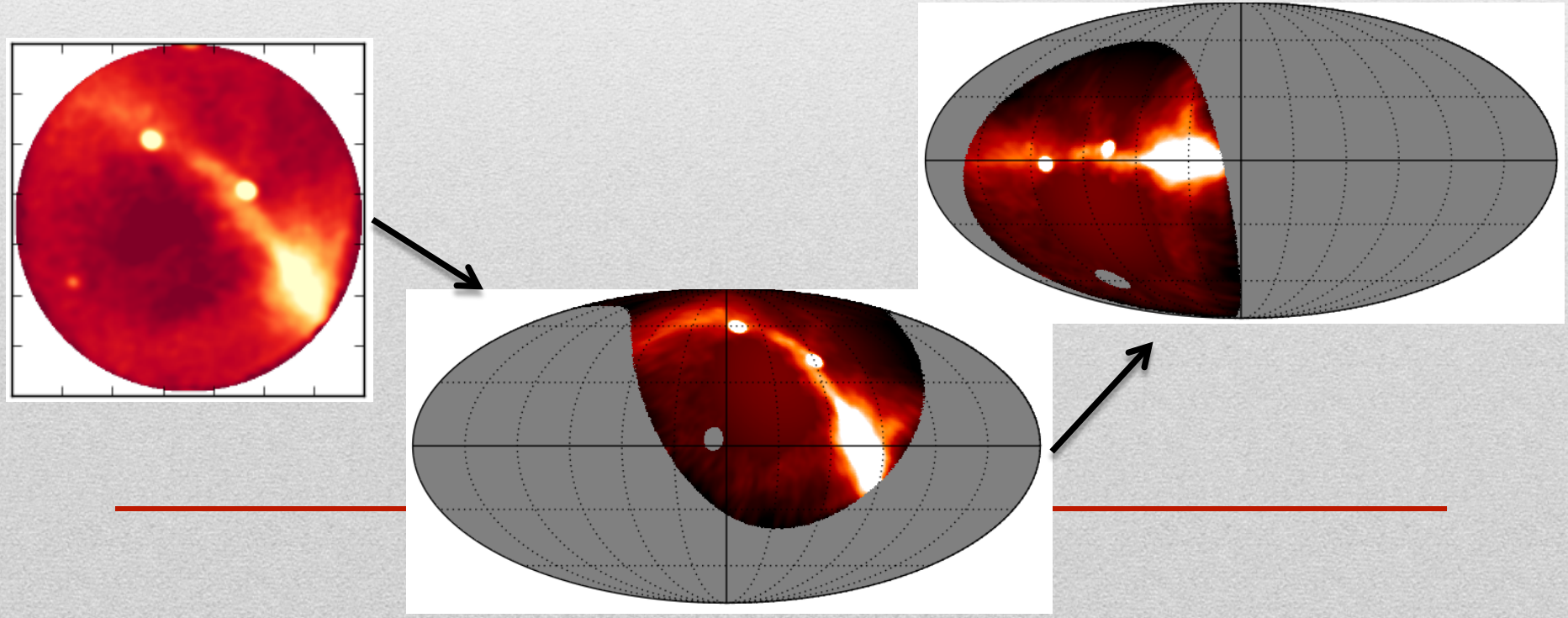
- Three methods of data collection at LWA1:
  - TBN, TBW, and Beamforming
- Used TBW to gather all of the bandwidth in 61 ms chunks
  - 61 ms is short but not so short as to be uninteresting
    - Confusion limited at degree resolutions
  - Each capture is ~10 GB
  - Use many captures to build up sky coverage
    - Snapshots every 15 minutes over a 24 hour period
    - Multiple epochs to help remove the Sun

Approach - Calibration

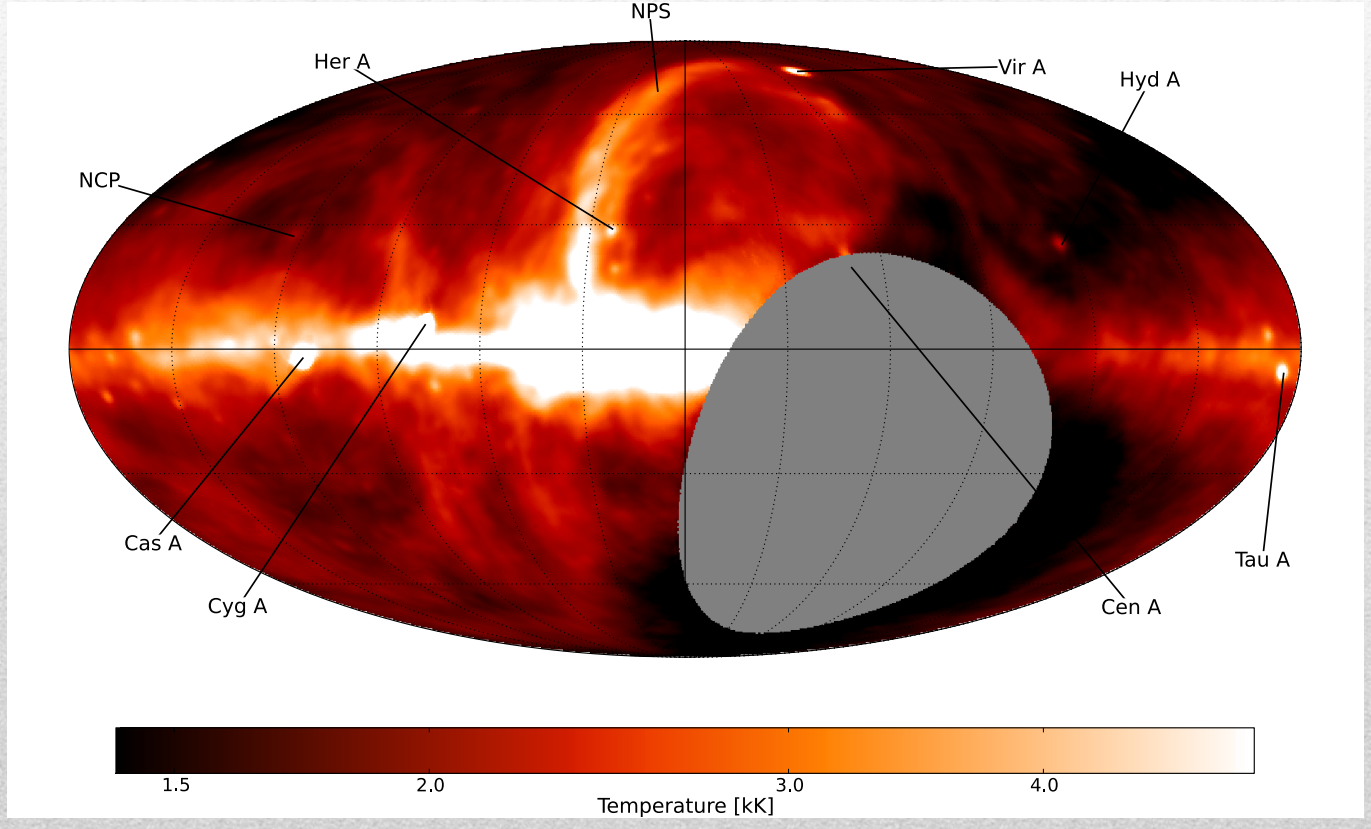
- Three main problems: flux calibration, imaging, and missing spacings
- Multi-part strategy
  - Use lab measurements to constrain what we can
    - Front end and analog receiver electronics
  - Use simulations for things we can't easily measure
    - Beam pattern and impedance mis-match loss
  - Tie the brightness of "A team" sources to an existing flux scale, like Baars
  - Use the LEDA total power system to constrain the total flux
  - Used MFS + forward modeling to constraint the missing scales

Approach - Mosaicing

- Re-project the snapshots onto a sphere and co-add
- Used HEALpix for the final maps

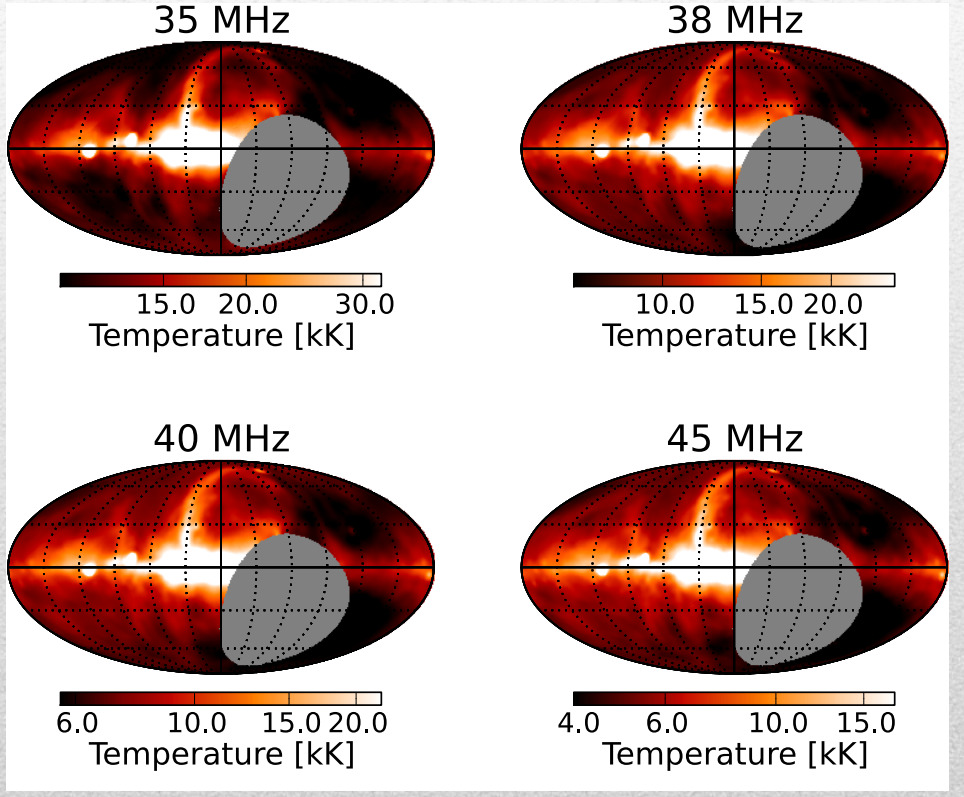


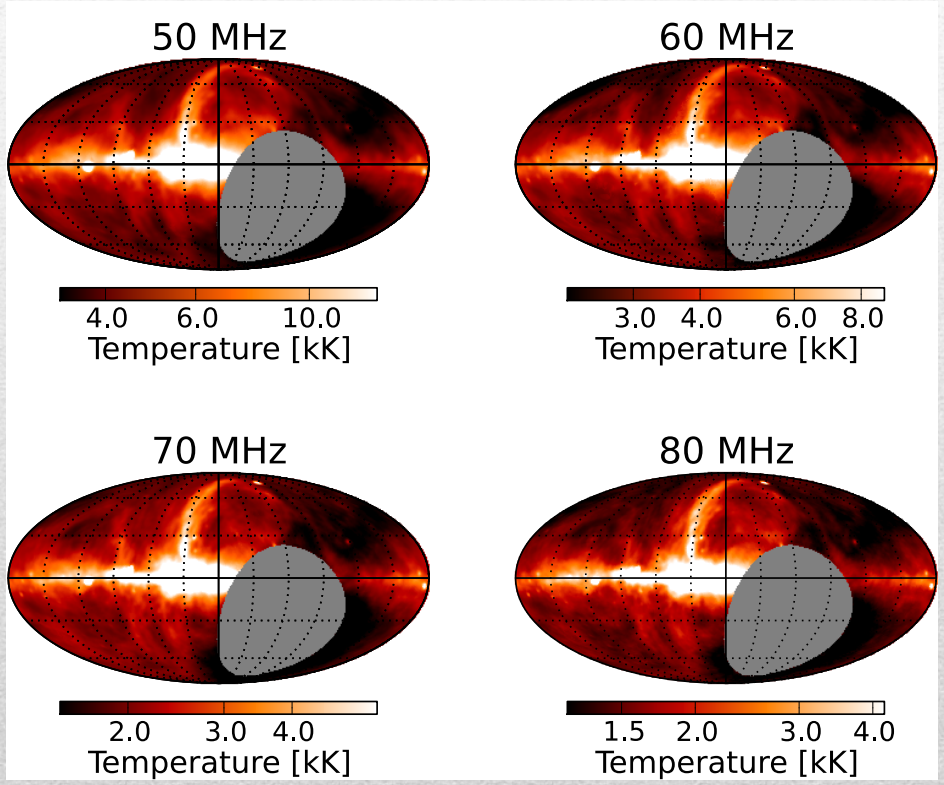
Maps


NPS
Her A
Vir A
Hyd A
NCP
Cas A
Cyg A
Cen A
Tau A
1.5
2.0
3.0
4.0
Temperature [kK]

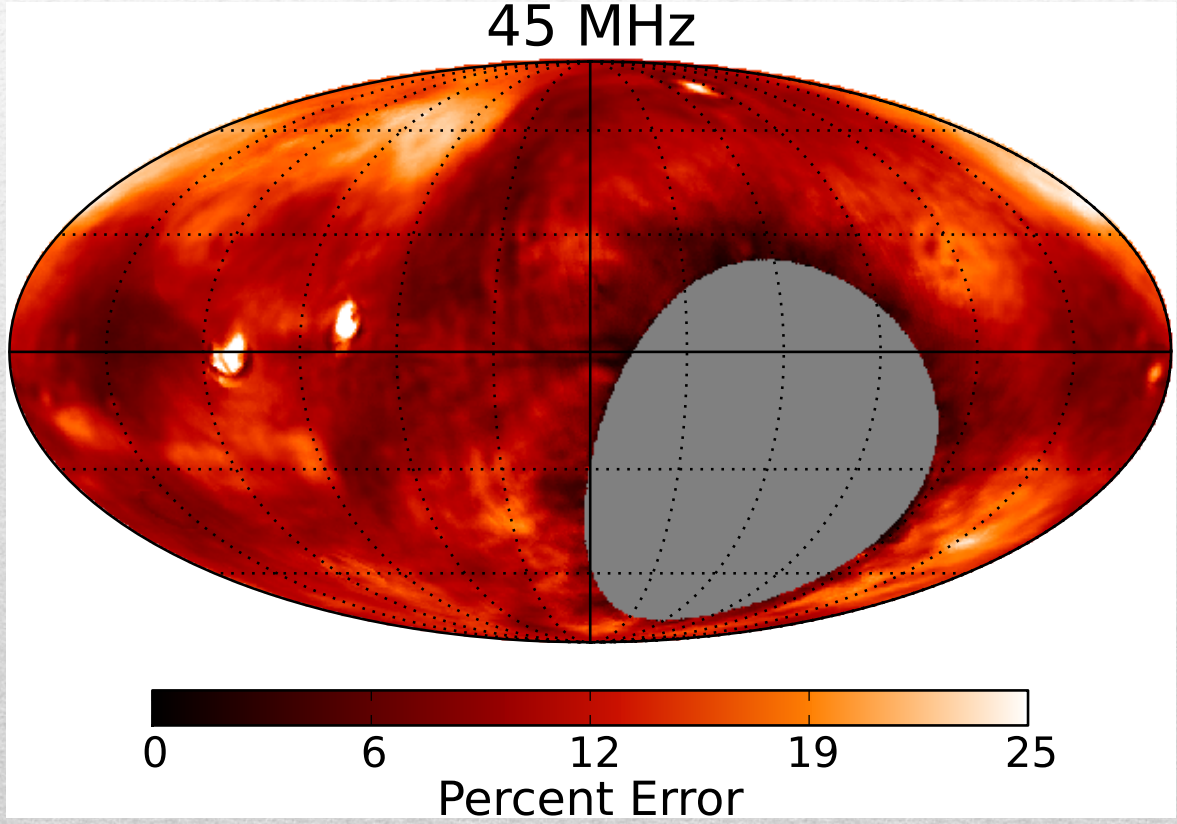
74 MHz

MAPS

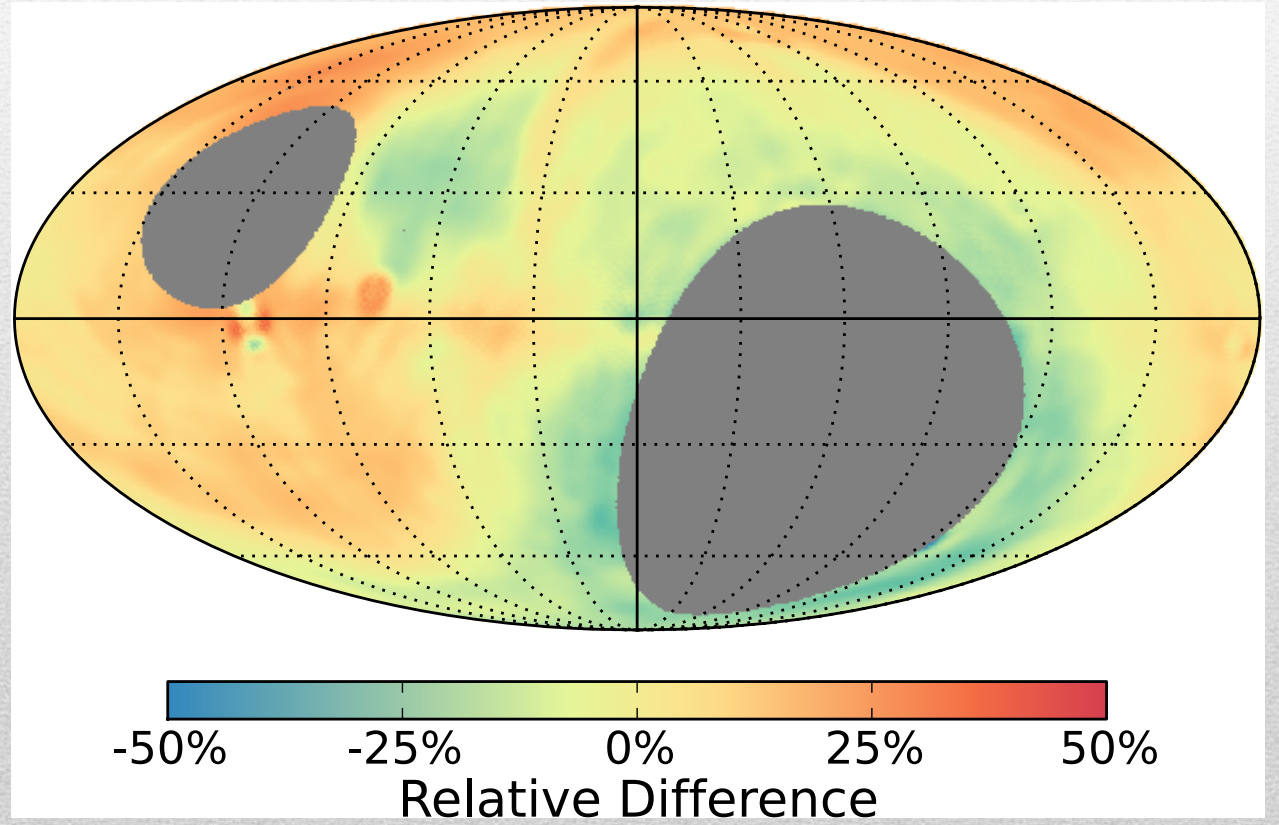

35 MHz
15.0 20.0 30.0
Temperature [kK]
38 MHz
10.0 15.0 20.0
Temperature [kK]
40 MHz
6.0 10.0 15.0 20.0
Temperature [kK]
45 MHz
4.0 6.0 10.0 15.0
Temperature [kK]


50 MHz
4.0 6.0 10.0
Temperature [kK]
60 MHz
3.0 4.0 6.0 8.0
Temperature [kK]
70 MHz
2.0 3.0 4.0
Temperature [kK]
80 MHz
1.5 2.0 3.0 4.0
Temperature [kK]

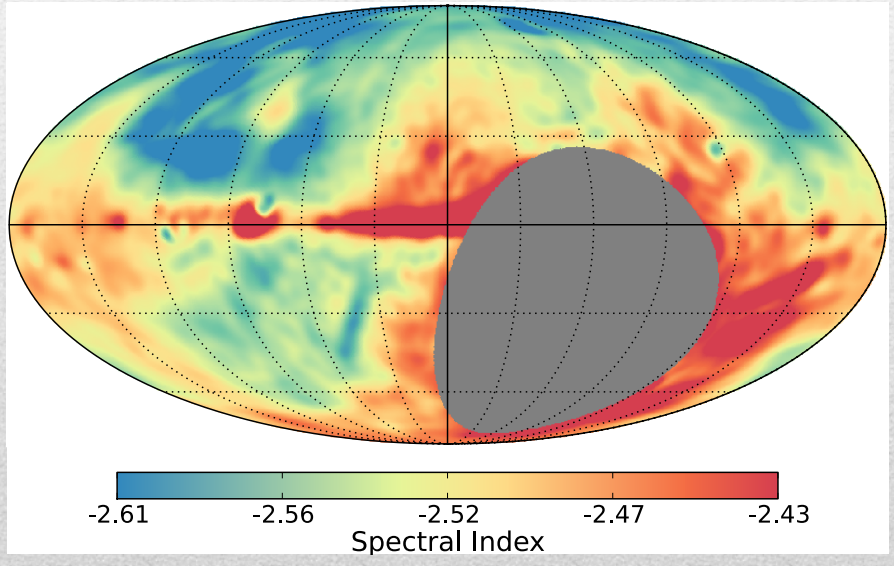
Uncertainty

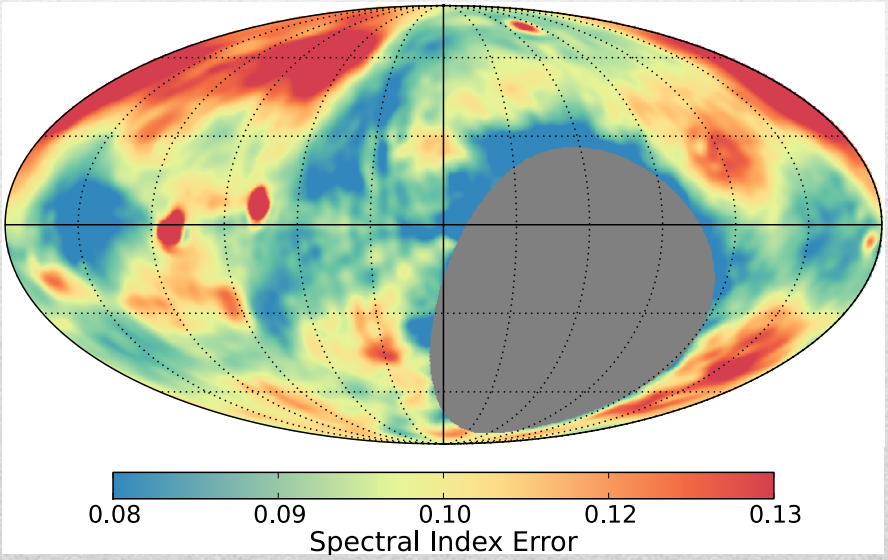


Comparisons

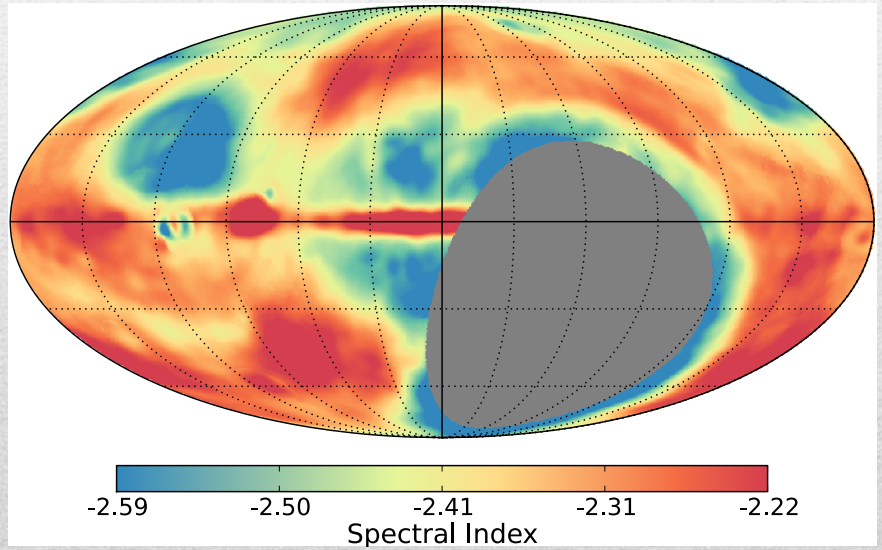


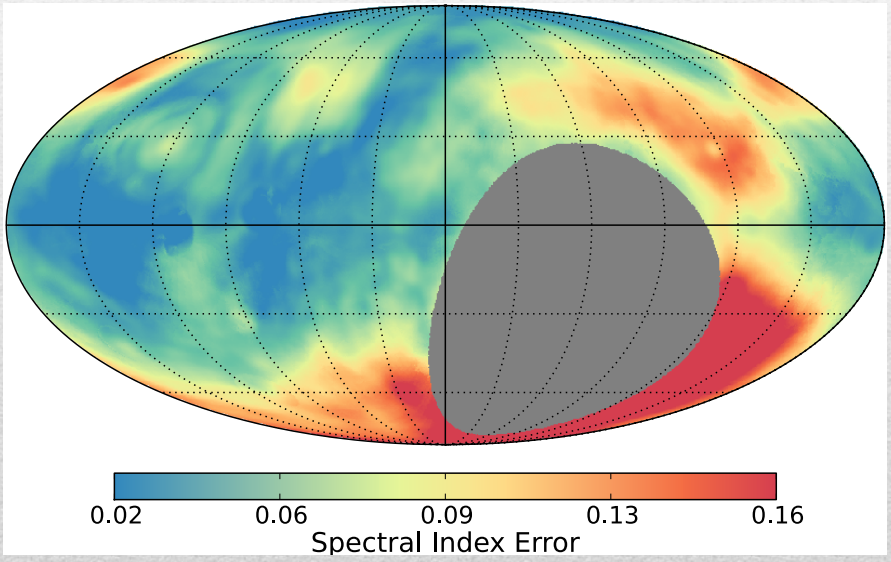
Spectral Index



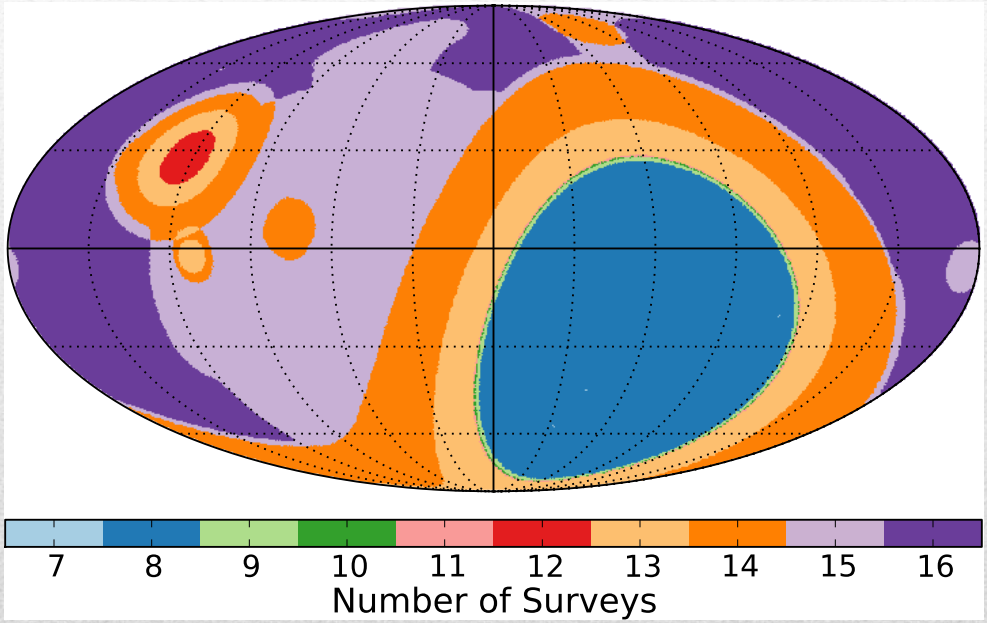


Spectral Index

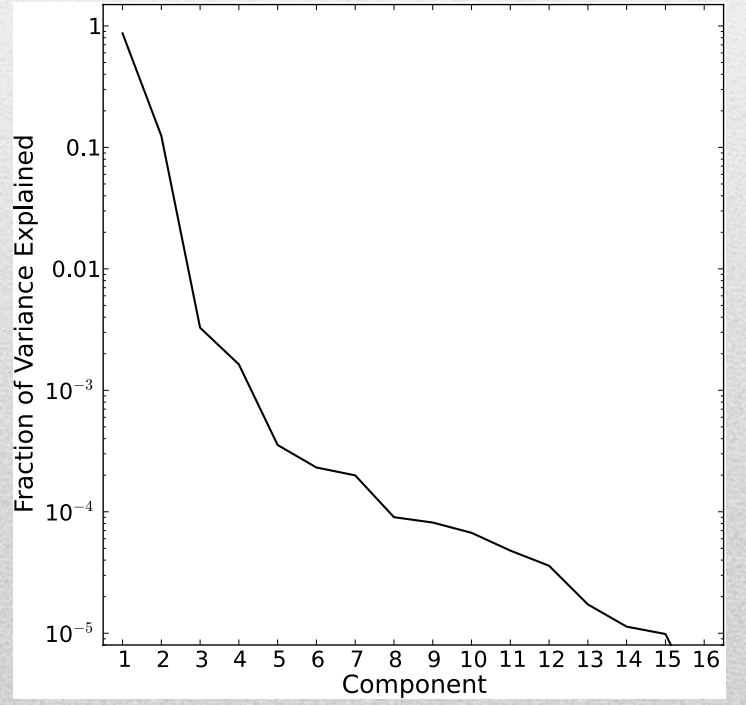




The Low Frequency Sky Model



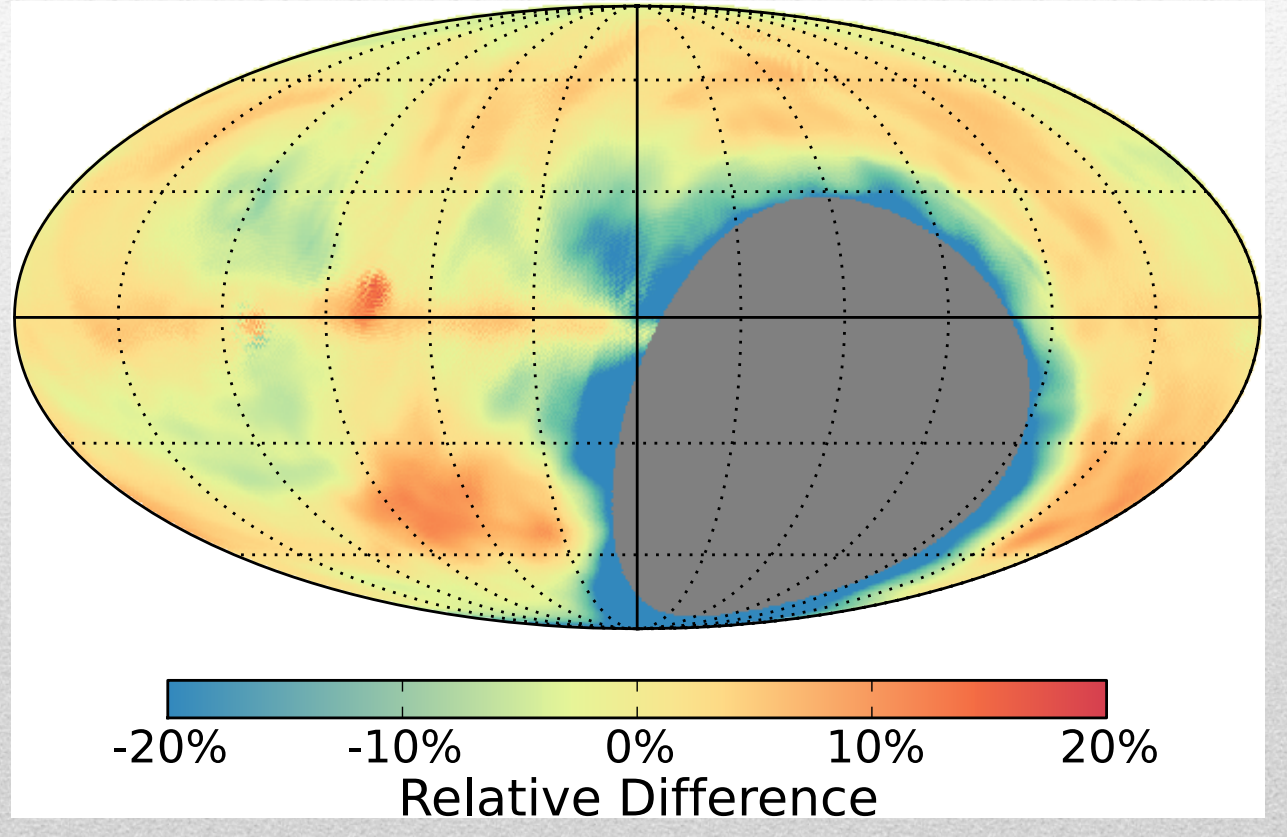
GSM-style
principle component analysis



Our maps, plus literature maps at:

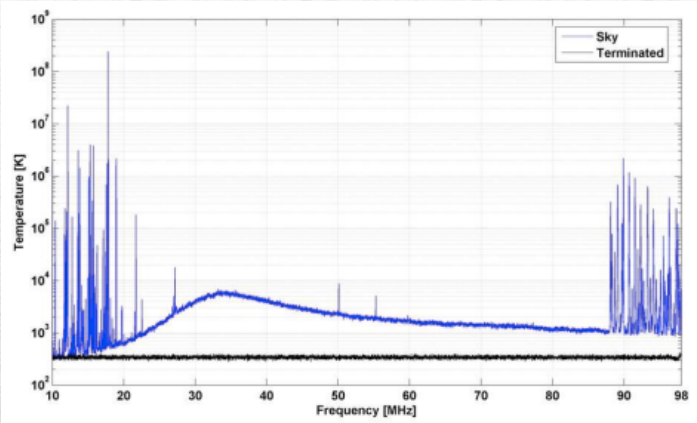
- 10, 22, 45 MHz
- 408 & 820 MHz
- 1.4 GHz
- WMAP bands

The Low Frequency Sky Model

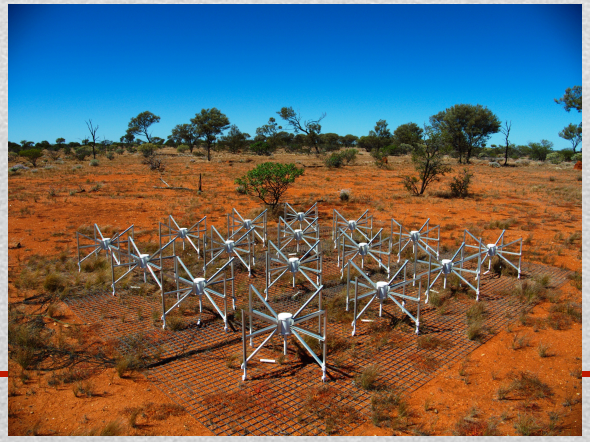


74 MHz

Future Directions



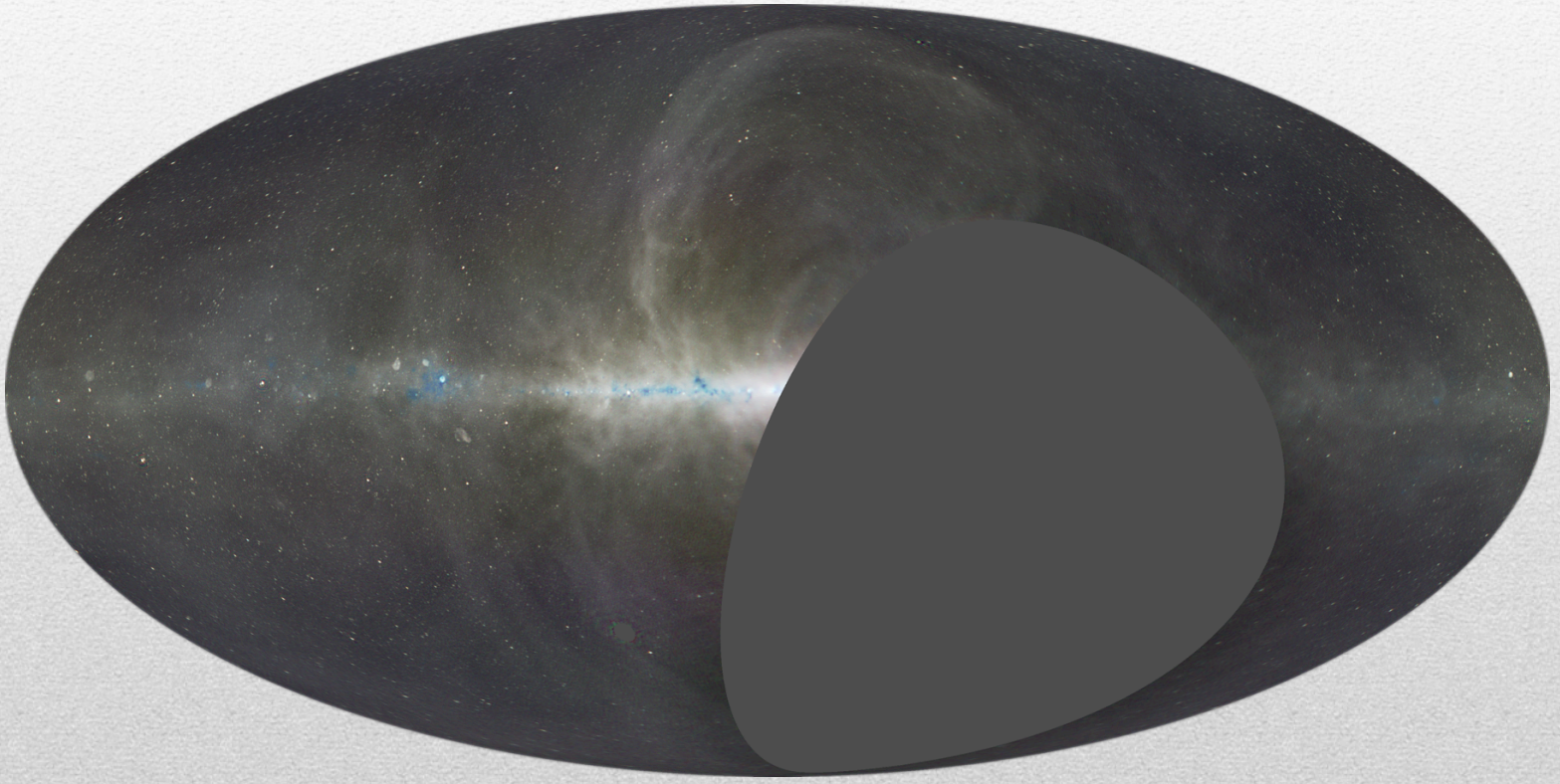
Henning et al. (2010)



MWA (Wikipedia)

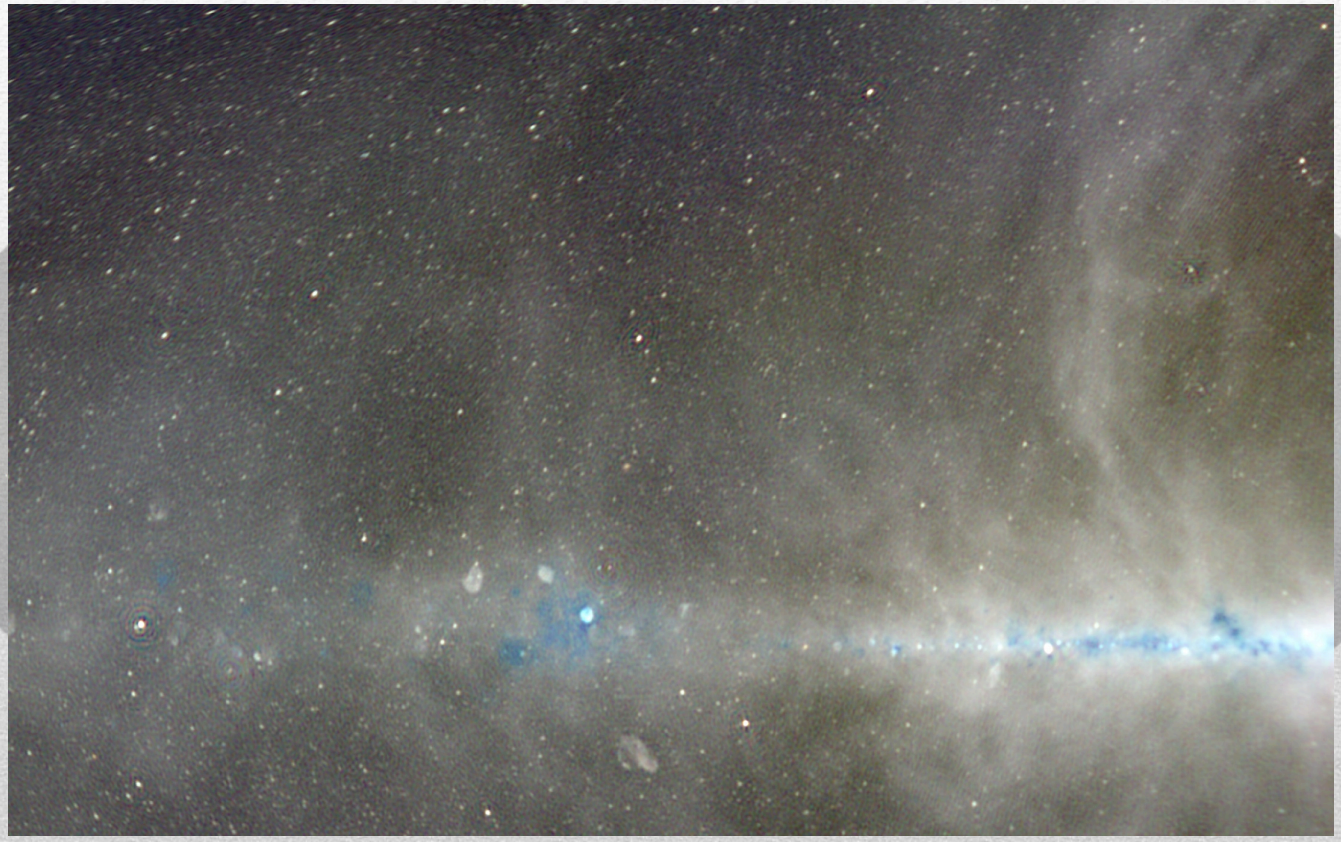
- Better understanding of the instrument
  - Dipole beam pattern
  - Frequency dependent losses
- Push to lower frequencies
  - Opens up new possibilities for absorption studies, new modeling methods
- Combine data with other instruments, investigate new approaches to imaging

Future Directions



Eastwood et al., ApJ, *submitted* (arXiv:1711.00466)

Future Directions



Eastwood et al., ApJ, *submitted* (arXiv:1711.00466)

Conclusions

- The LWA1 Low Frequency Sky Survey covers:
  - Nine frequency bands between 35 and 80 MHz of
  - The radio sky north of −40° at a
  - 2 to 5 degree resolution
    - MNRAS (2017) 469, 4537-4550
- The sky has been combined with existing data to create a new model for the low frequency radio sky
  - Uses new data to create an updated model of the sky below 400 MHz
- The survey maps and the model are available at:
  - https://lda10g.alliance.unm.edu/LWA1LowFrequencySkySurvey/

Backup Slides

LWA Science

Astrophysics

Cosmology
Observing cosmic dawn through redshift 30 absorption of the 21 cm line. High redshift radio galaxies, containing the earliest black holes

Acceleration, Propagation & Turbulence in the ISM
Origin, spectrum & distribution of Galactic cosmic rays, Supernova remnants & Galactic evolution, Pulsars and their environments

Solar Science & Space Weather
Radio heliography of solar bursts & coronal mass ejections, Solar magnetic fields

Exploration of the Transient Universe
New coherent sources, GRB prompt emission, poorly explored parameters space …

Iono- & Atmospheric Physics

Unprecedented continuous spatial & temporal imaging of the ionosphere

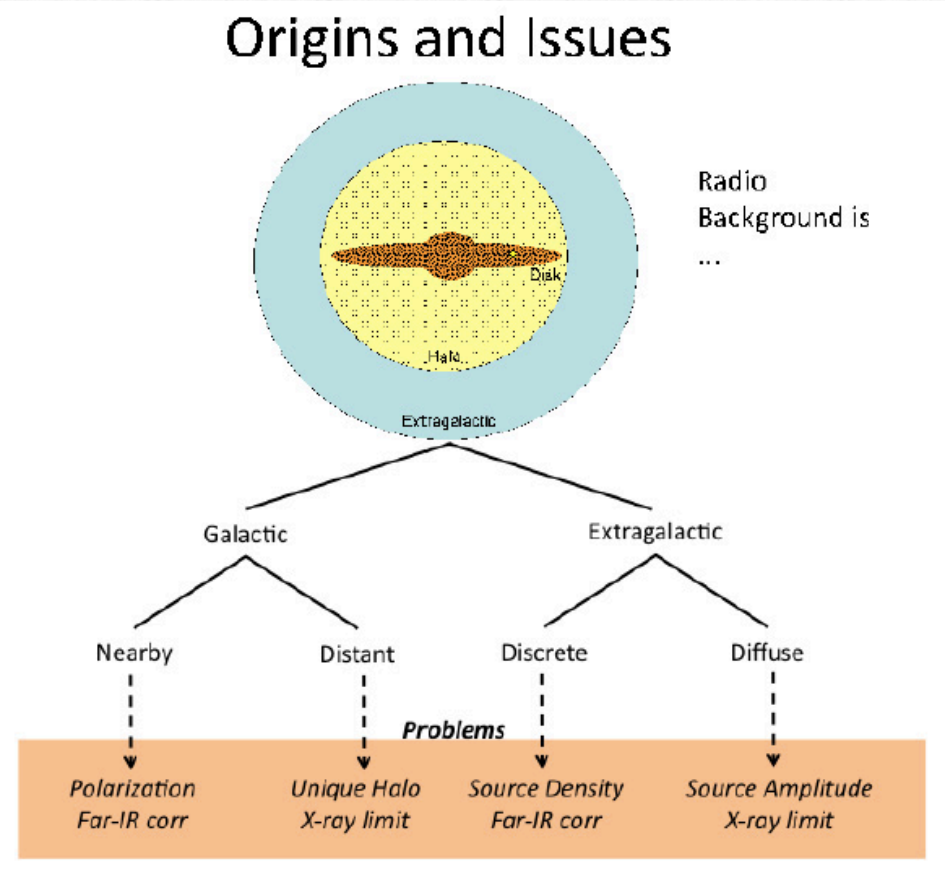
Test and improve global ionospheric models

High-time-resolution Imaging of Lightning

Your ideas?

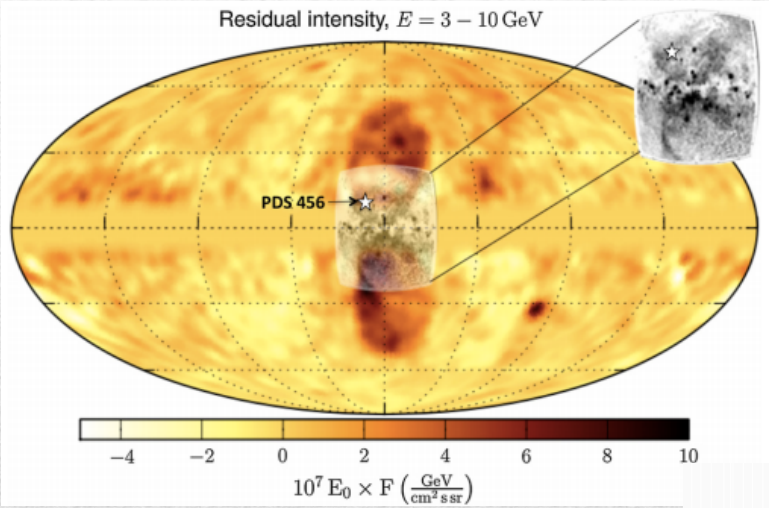
All of LWA1 time is open skies. Your observing proposals are welcome!

Radio Background

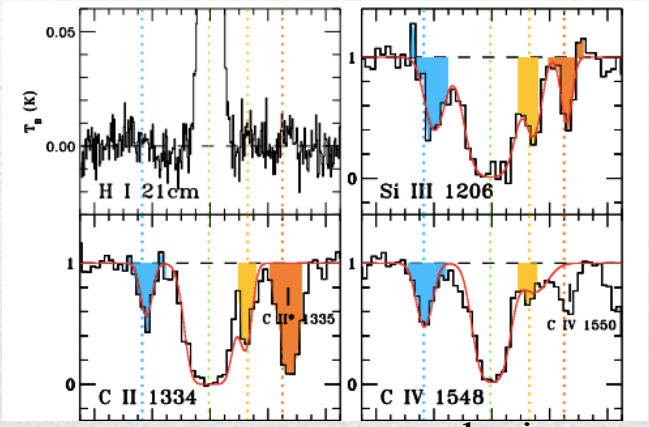


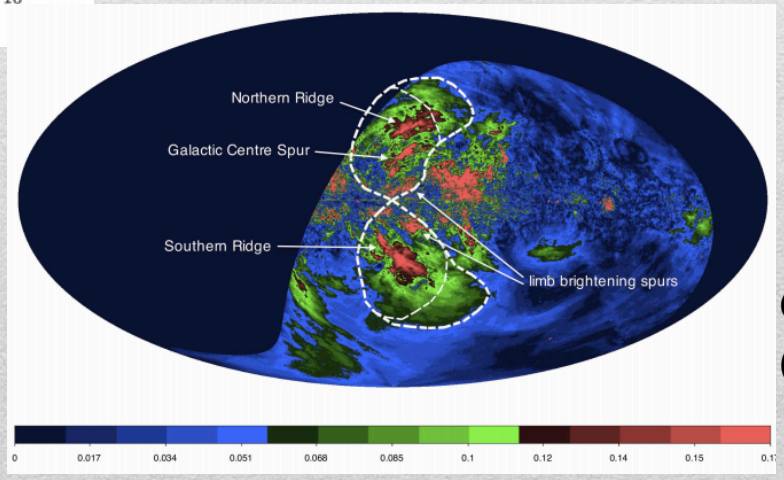
Singal et al., *in prep.*

Fermi Bubbles



Gamma Ray + X-ray
Fox et al. (2015)
Ackermann et al. (2014)

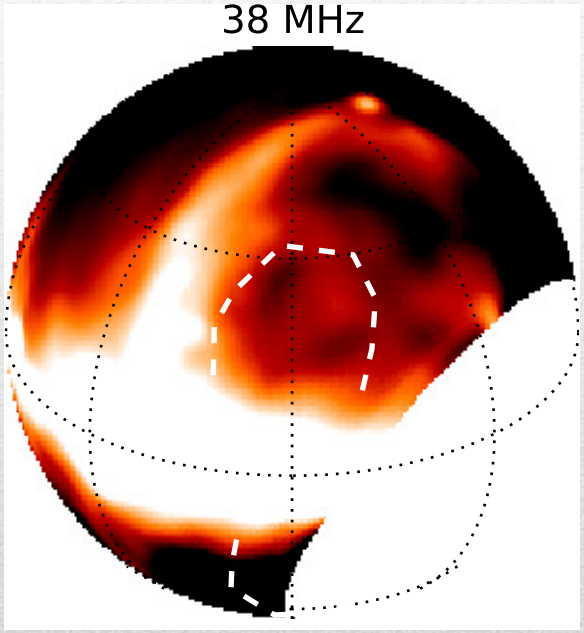


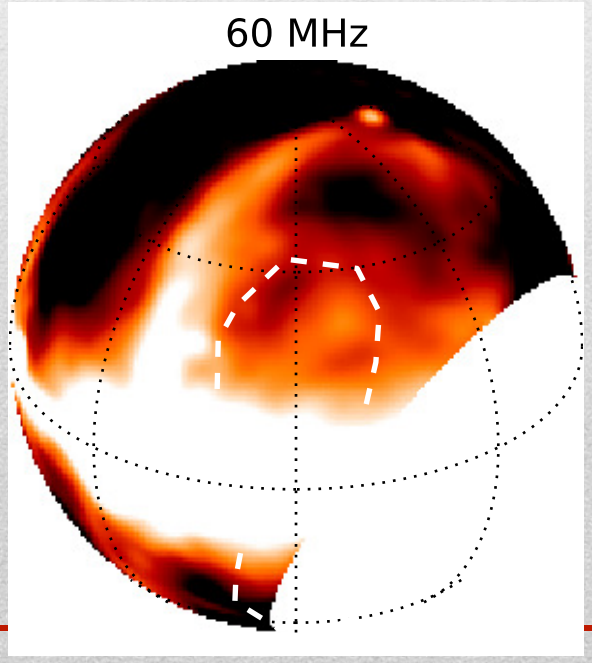


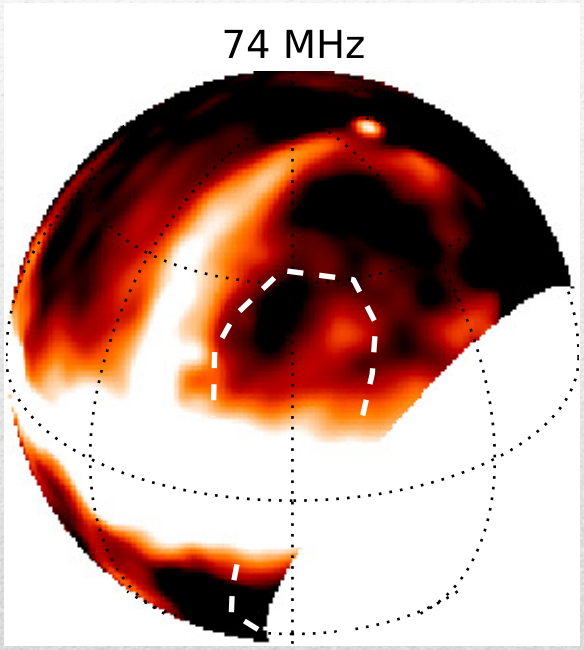
Carretti et al. (2013)

Polarized Jy/beam

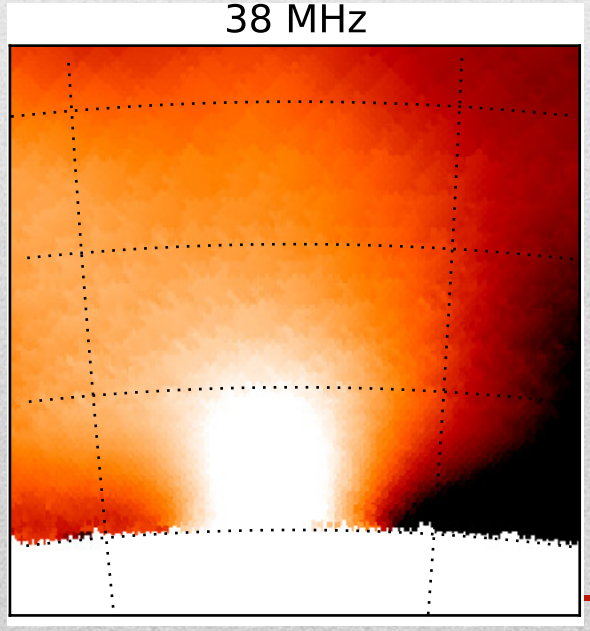
Fermi Bubbles

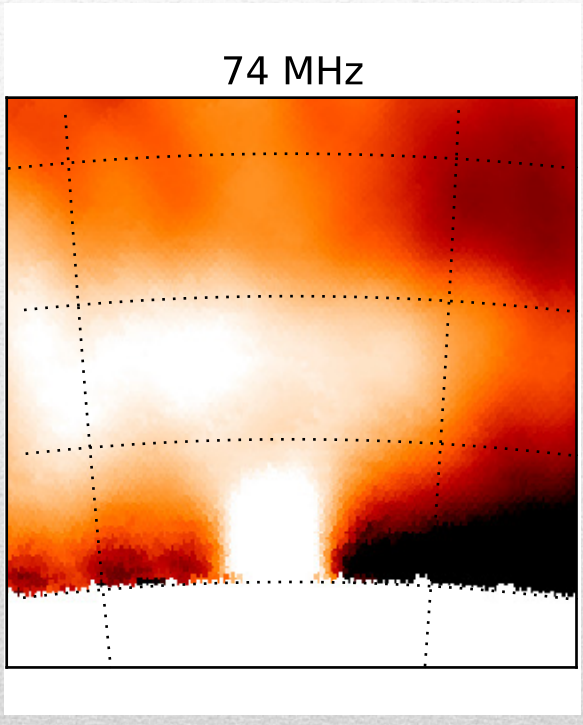






Centaurus A





20°