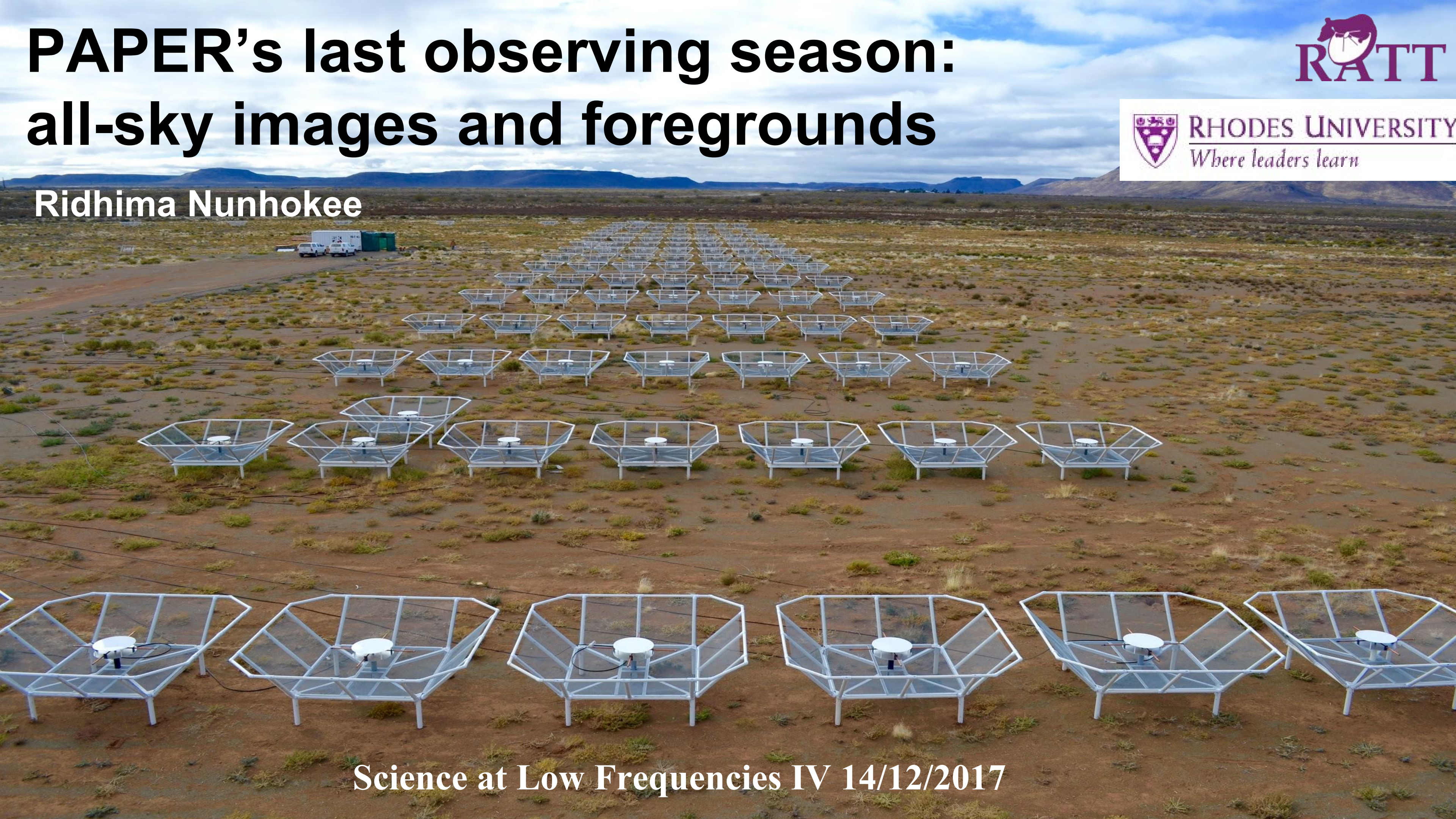
PAPER's last observing season: all-sky images and foregrounds

Ridhima Nunhokee

RATT

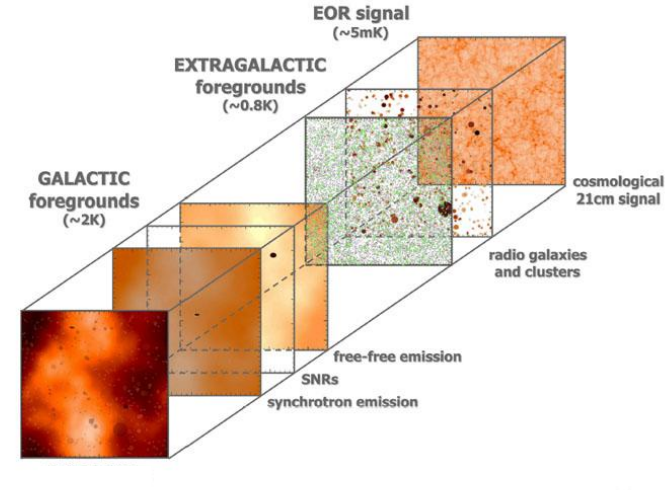
RHODES UNIVERSITY
Where leaders learn



Science at Low Frequencies IV 14/12/2017

Challenges

Bright foregrounds



3 to 5 orders of magnitude
brighter than the 21 cm signal

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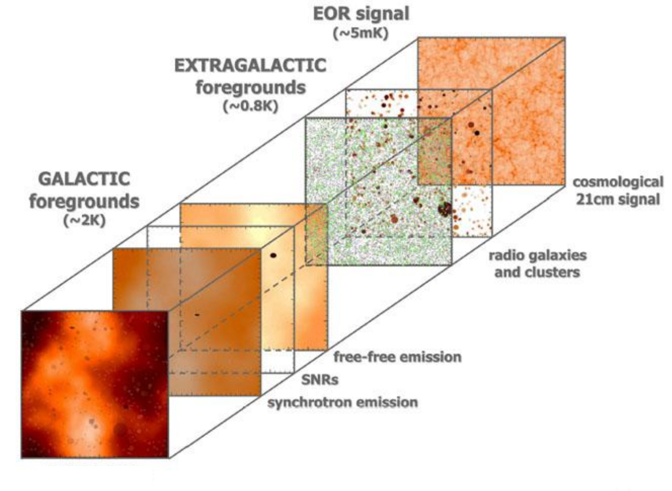


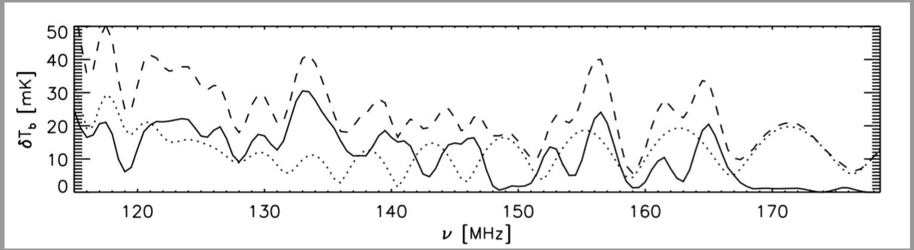
3 to 5 orders of magnitude brighter than the 21 cm signal

Overcoming challenges

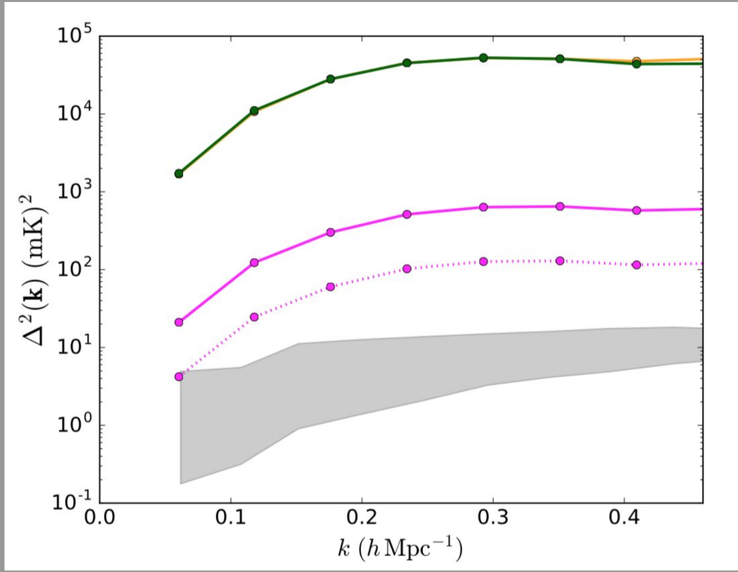
Foreground Separation

- **Foreground Subtraction**
  - Attempt to model and subtract foregrounds from the data
- **Foreground Avoidance**
  - Identify a region in power spectrum space where foreground contamination is sub-dominant. This region is called the **EoR window**.

Overcoming challenges



Jelic et al., 2010



Nunhokee et al., 2017

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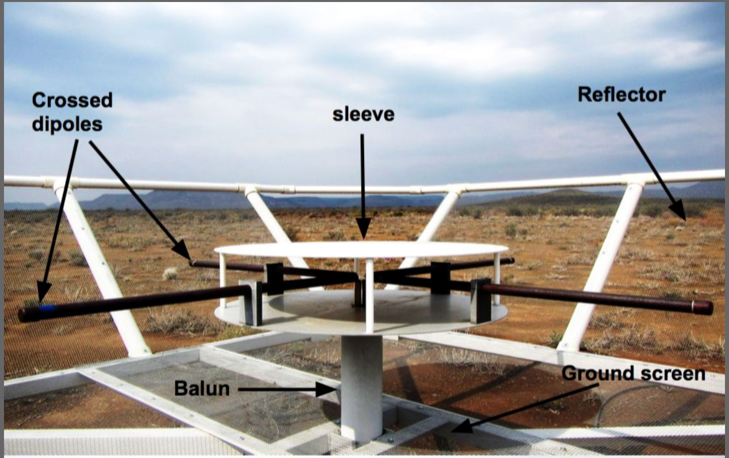
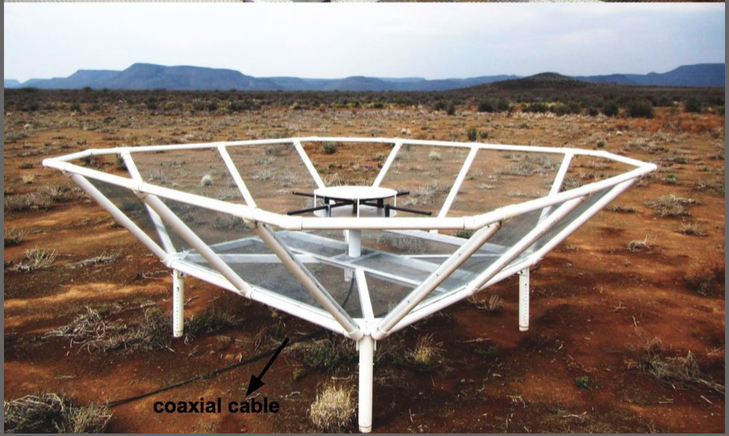
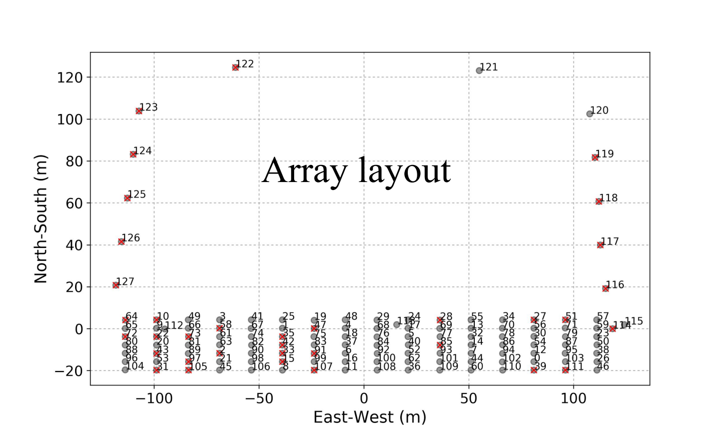
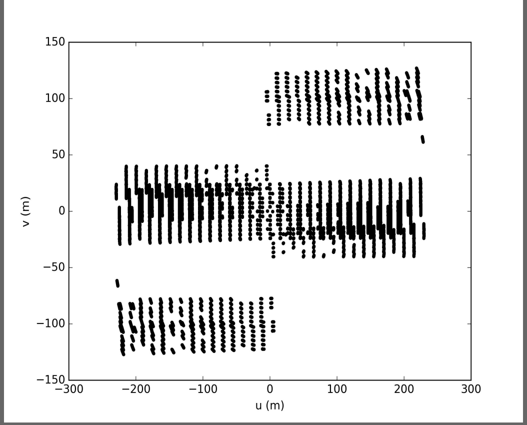
PAPER-128 Layout



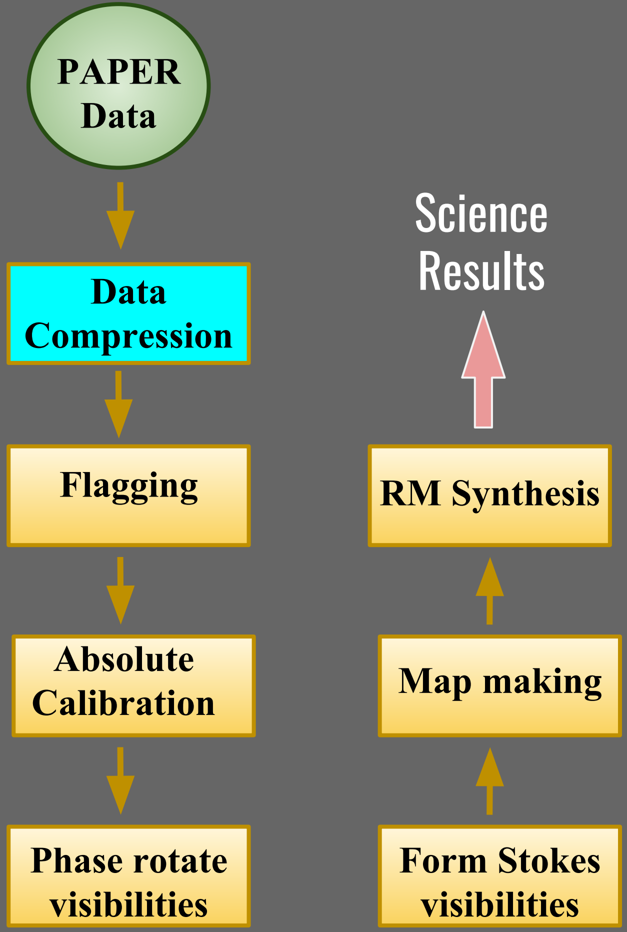






UV-coverage : single frequency channel

Calibration and Imaging Pipeline



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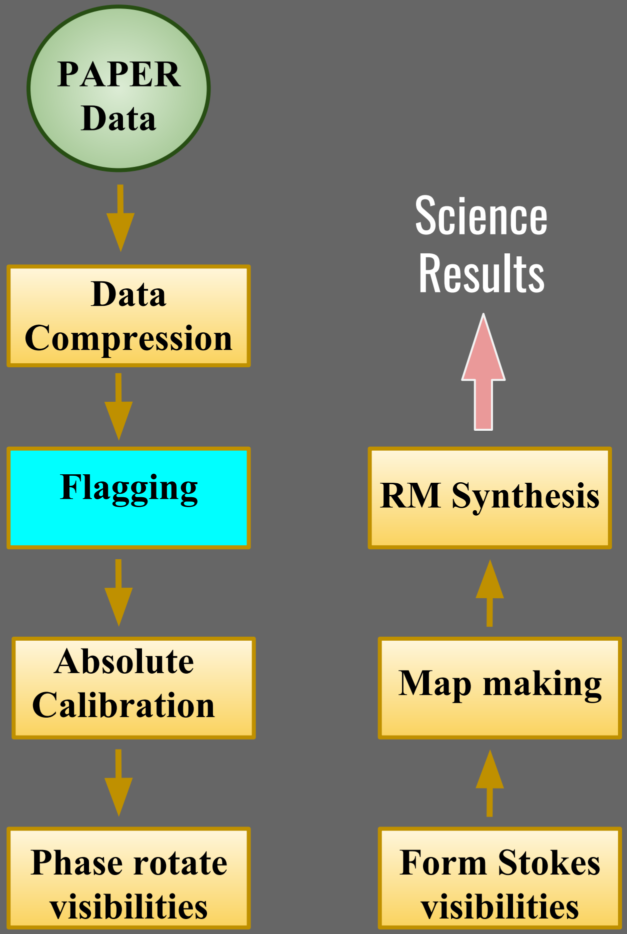

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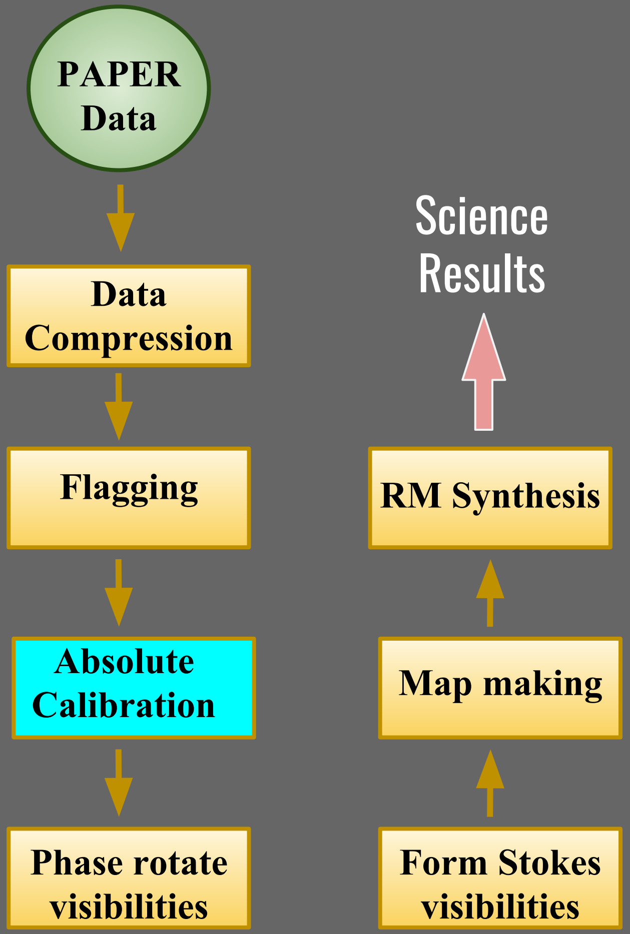
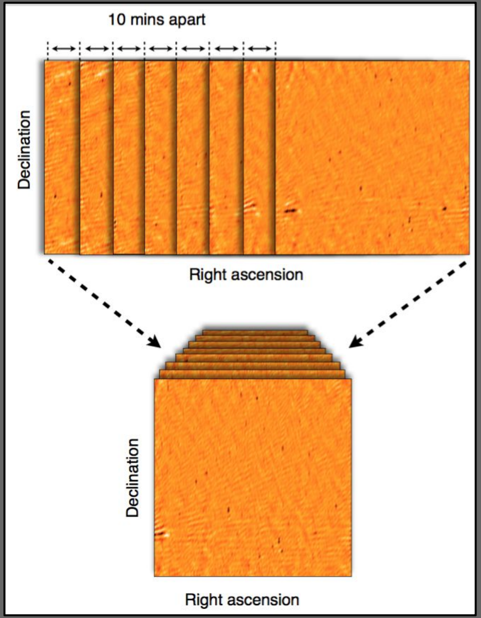


-use Pictor A as our point calibrator source, with a flat frequency spectrum of 1 Jy

-scale visibilities according to Jacobs et al ., 2013.

Calibration and Imaging Pipeline



PAPER Data

Data Compression

Flagging

Absolute Calibration

Phase rotate visibilities

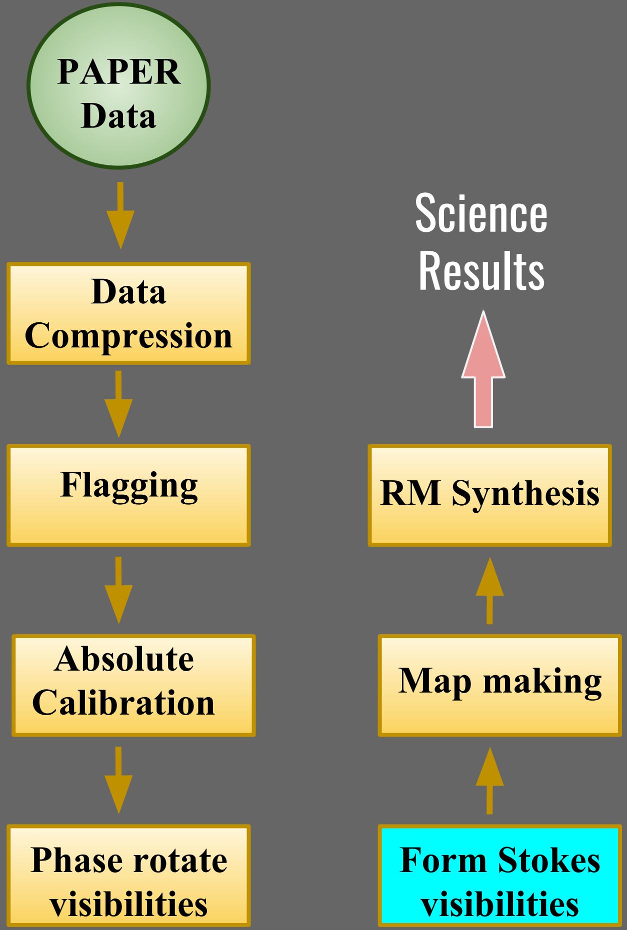
Form Stokes visibilities

Map making

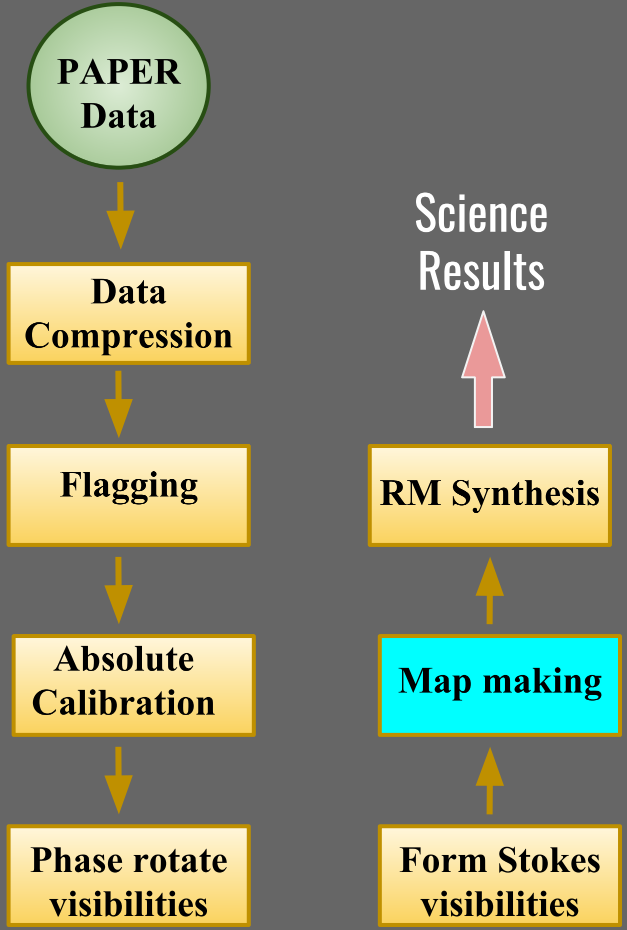
RM Synthesis

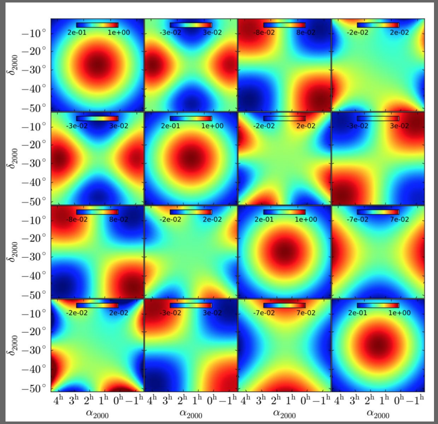
Science Results

Calibration and Imaging Pipeline



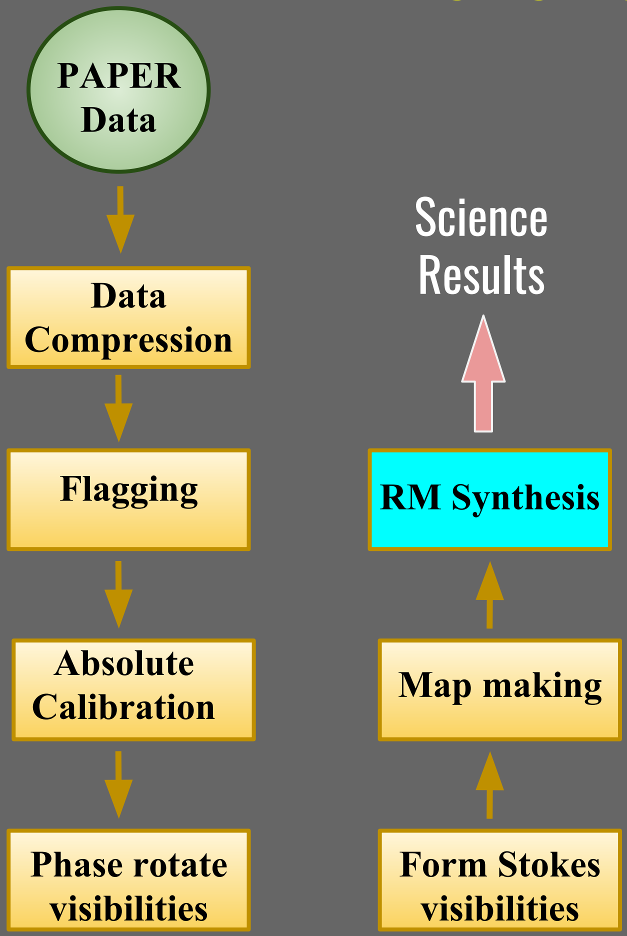
Calibration and Imaging Pipeline



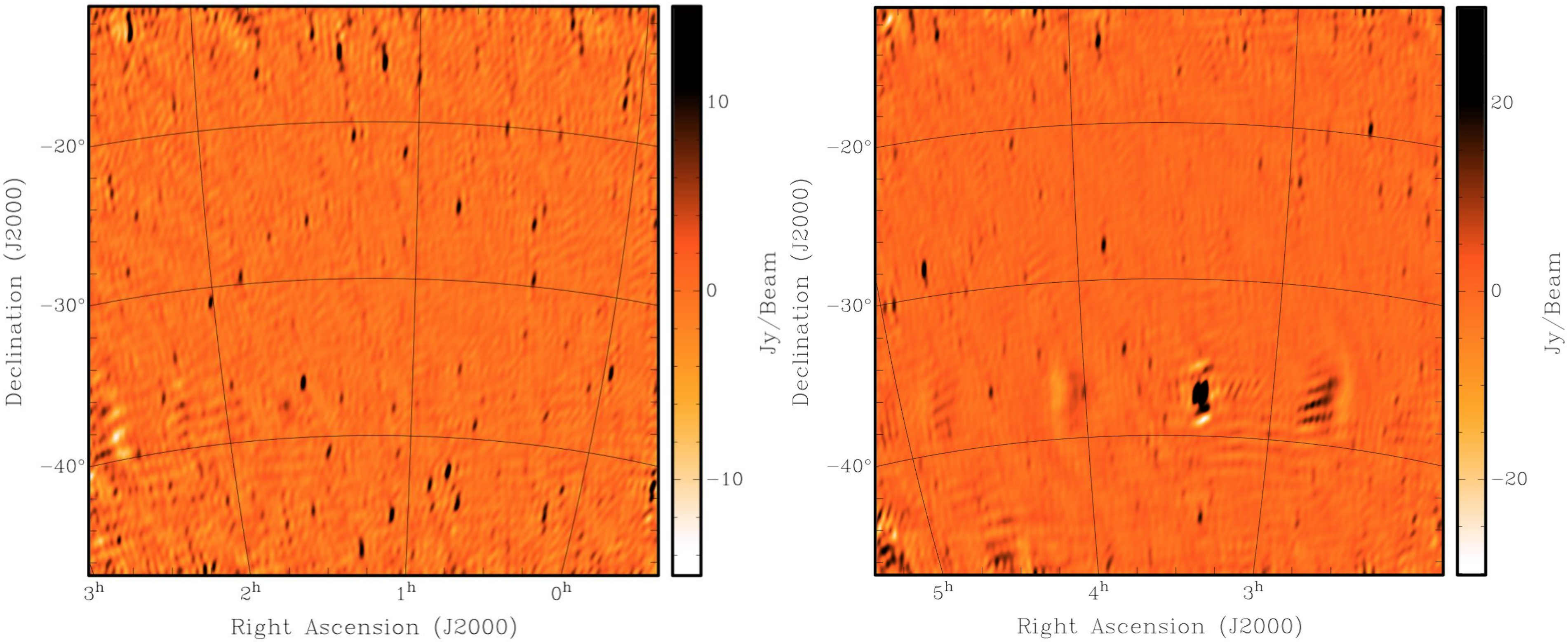


$$\tilde{\mathbf{s}}_i^p(\hat{\boldsymbol{r}}, \nu) = \frac{\sum_{i=1}^{n} \mathbf{s}_i^p(\hat{\boldsymbol{r}}, \nu)\mathrm{diag}\left(\mathbf{A}_i^p(\hat{\boldsymbol{r}}, \nu)\right)}{\sum_{i=1}^{n} \mathrm{diag}\left(\mathbf{A}_i^p(\hat{\boldsymbol{r}}, \nu)\right)^2}.$$

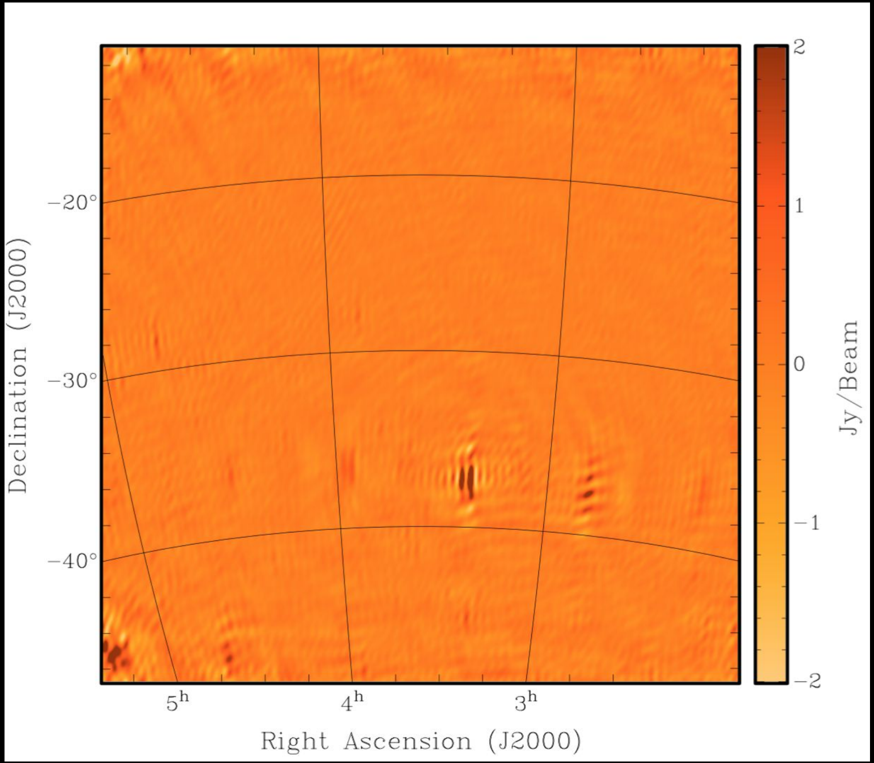
Calibration and Imaging Pipeline



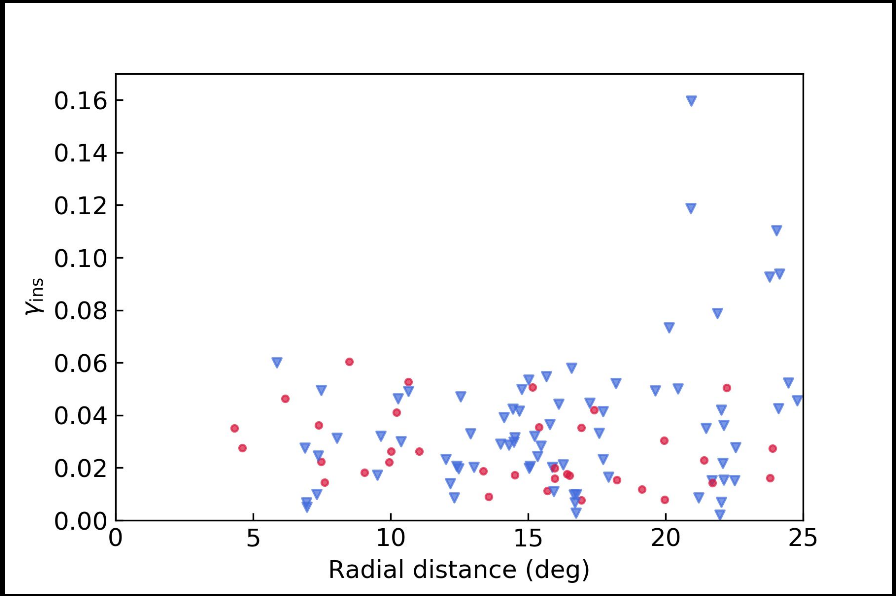
Stokes I map : 120-175 MHz averaged over 40 days of observations



Estimate of Instrumental Polarization Fraction



Stokes Q map between 120 to 175 MHz averaged over 4 days of observation



Instrumental polarization fraction as a function of radial distance with respect to the phase center

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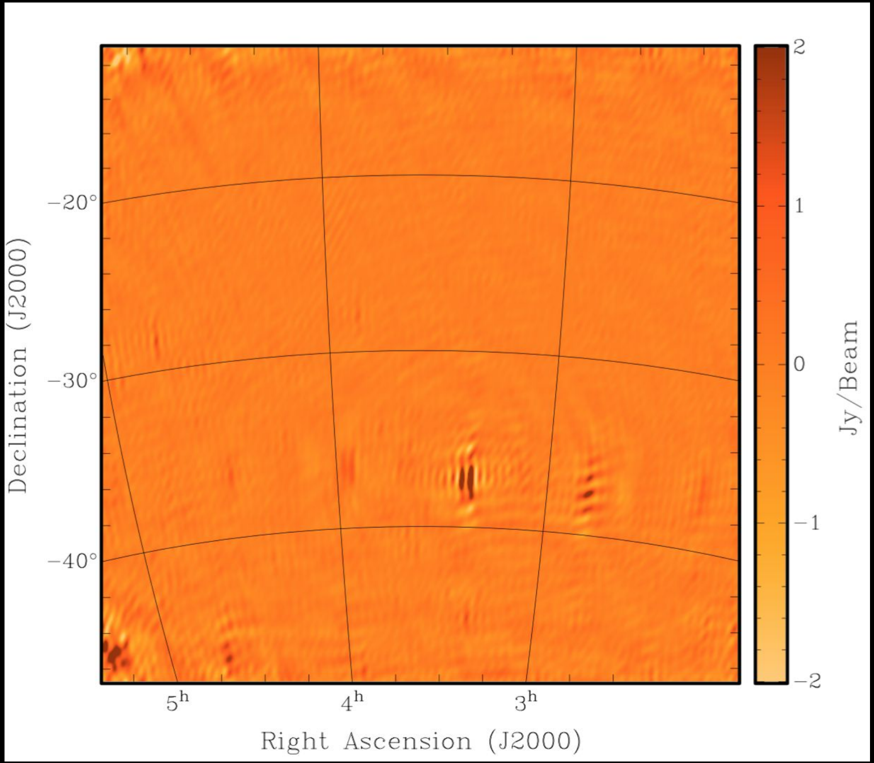

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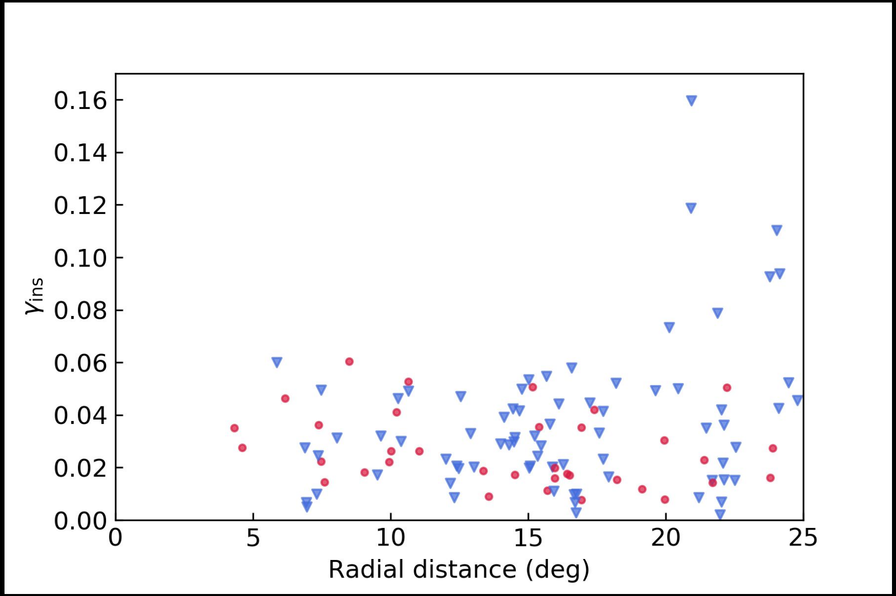


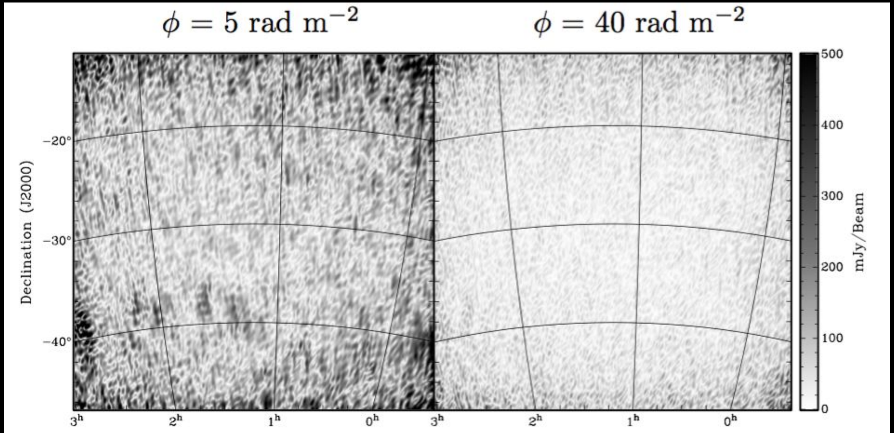
Instrumental polarization fraction as a function of radial distance with respect to the phase center

Average instrumental polarization fraction ~ 4%

Estimate of Observed Polarization Fraction

Rotation Measure Synthesis

$$P(\lambda^2) = W(\lambda^2) \int_{-\infty}^{\infty} F(\phi)^{-2i\phi\lambda^2} \, d\phi$$



RM cubes generated using averaged Stokes 1 map phased at LST=1.2 hours

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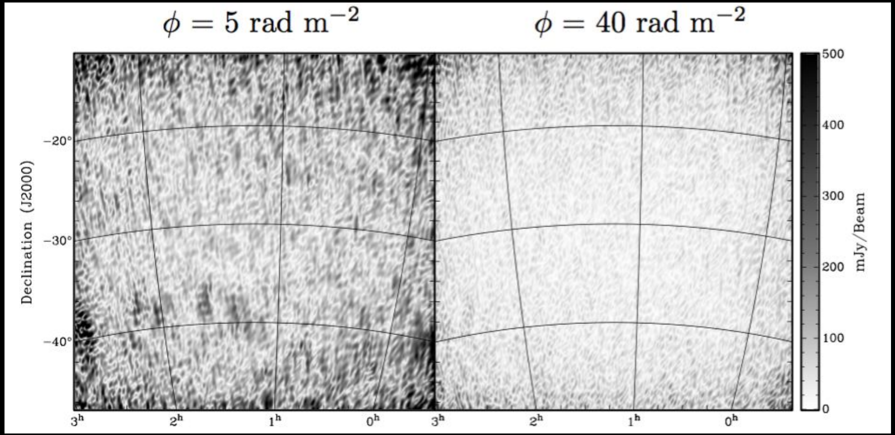
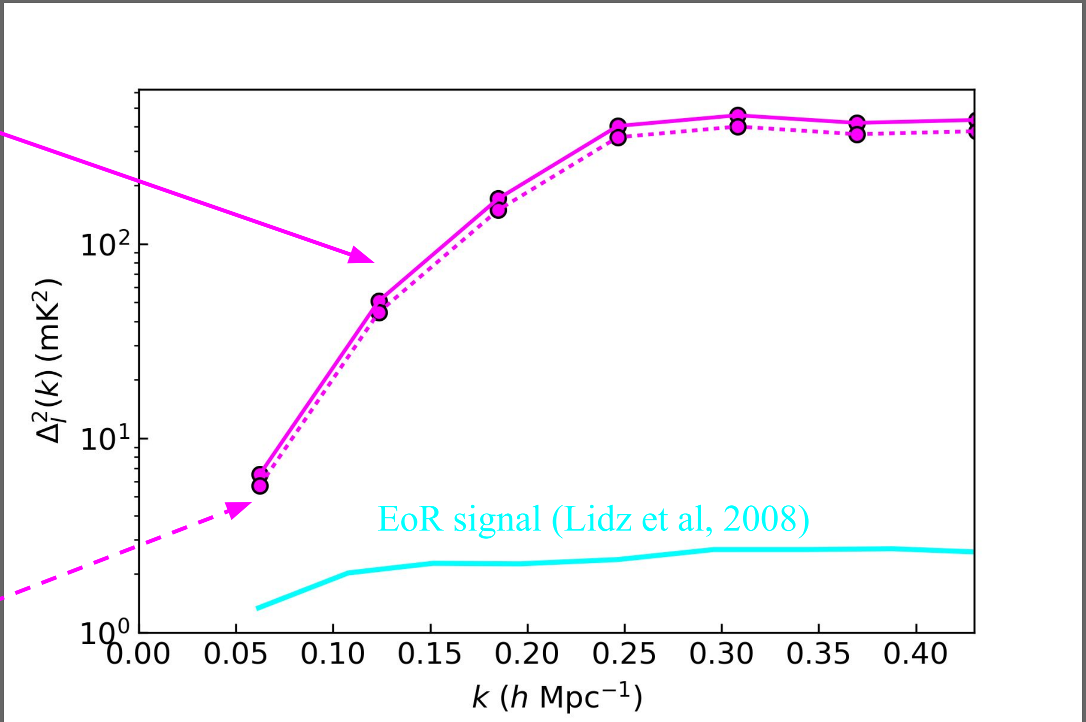


RM cubes generated using averaged Stokes 1 map phased at LST=1.2 hours

Average observed polarization fraction ~ 0.28%

Implications on the 21 cm power spectrum

Predicted Leakage from polarized foregrounds to total intensity (Nunhokee et al., 2017)

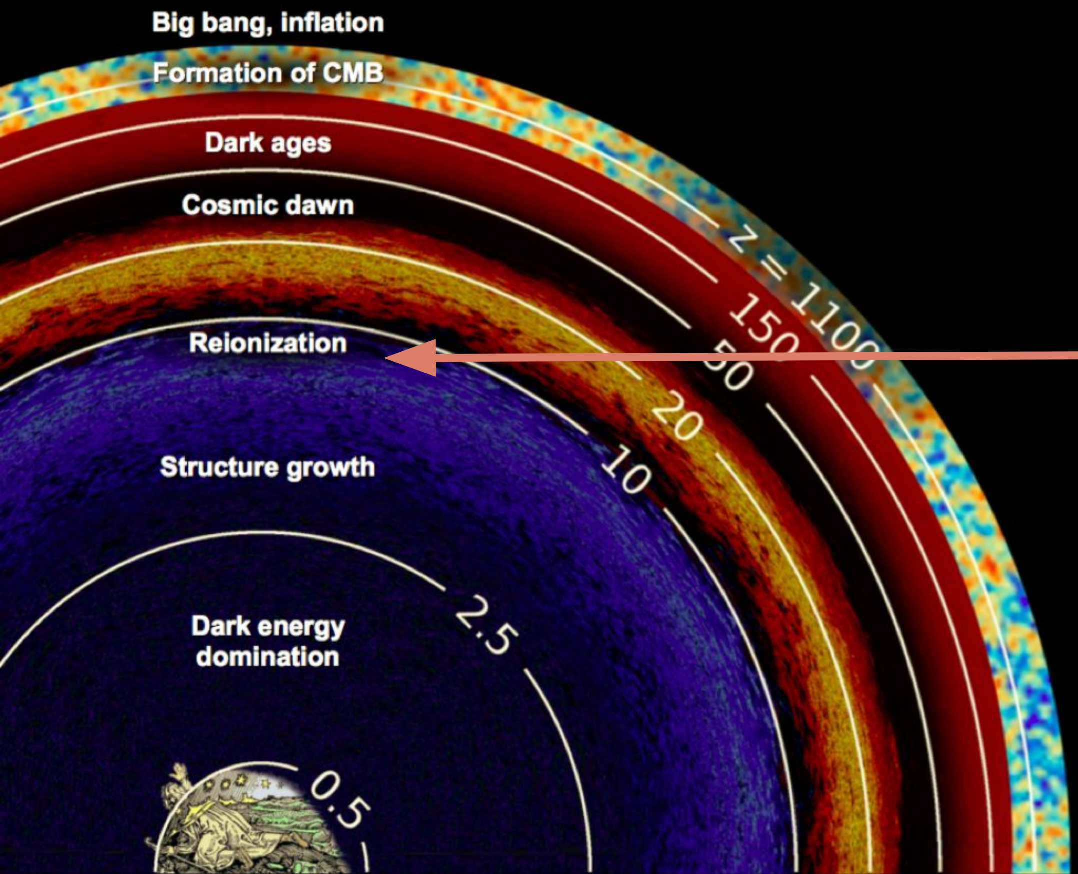


Observed Leakage from polarized foregrounds to total intensity

Conclusions

- 21 cm power spectrum is a renowned statistical technique to measure the EoR signal.
- A fraction of polarized signal leaking into total intensity will contaminate our 21 cm measurements because of the polarized beam of the instrument.
- It is therefore, crucial to quantify the level of leakage into Stokes I on the 21 cm power spectra.
- The polarization leakage is severe for point sources, 1-2 orders of magnitude greater than the EoR signal for $k > 0.05\,h\,\mathrm{Mpc}^{-1}$.

What are we looking for?

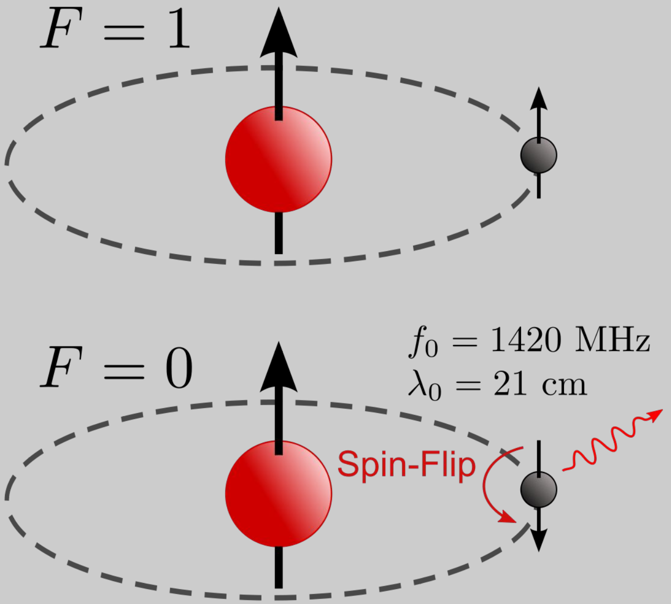


Reionization era: transition from once neutral to a reionized universe z~15-6

Why and How?

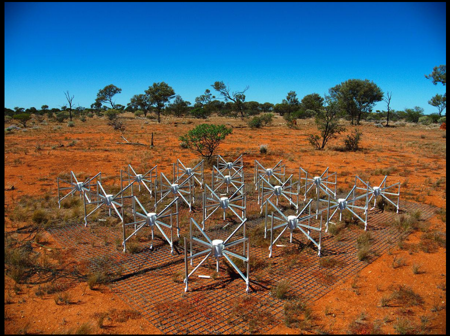
The Epoch of Reionization (EoR) is one of the unexplored territories

21 cm hydrogen line is a good tracer of the evolution of the IGM



Ongoing Experiments

Murchison Widefield Array
Western Australia

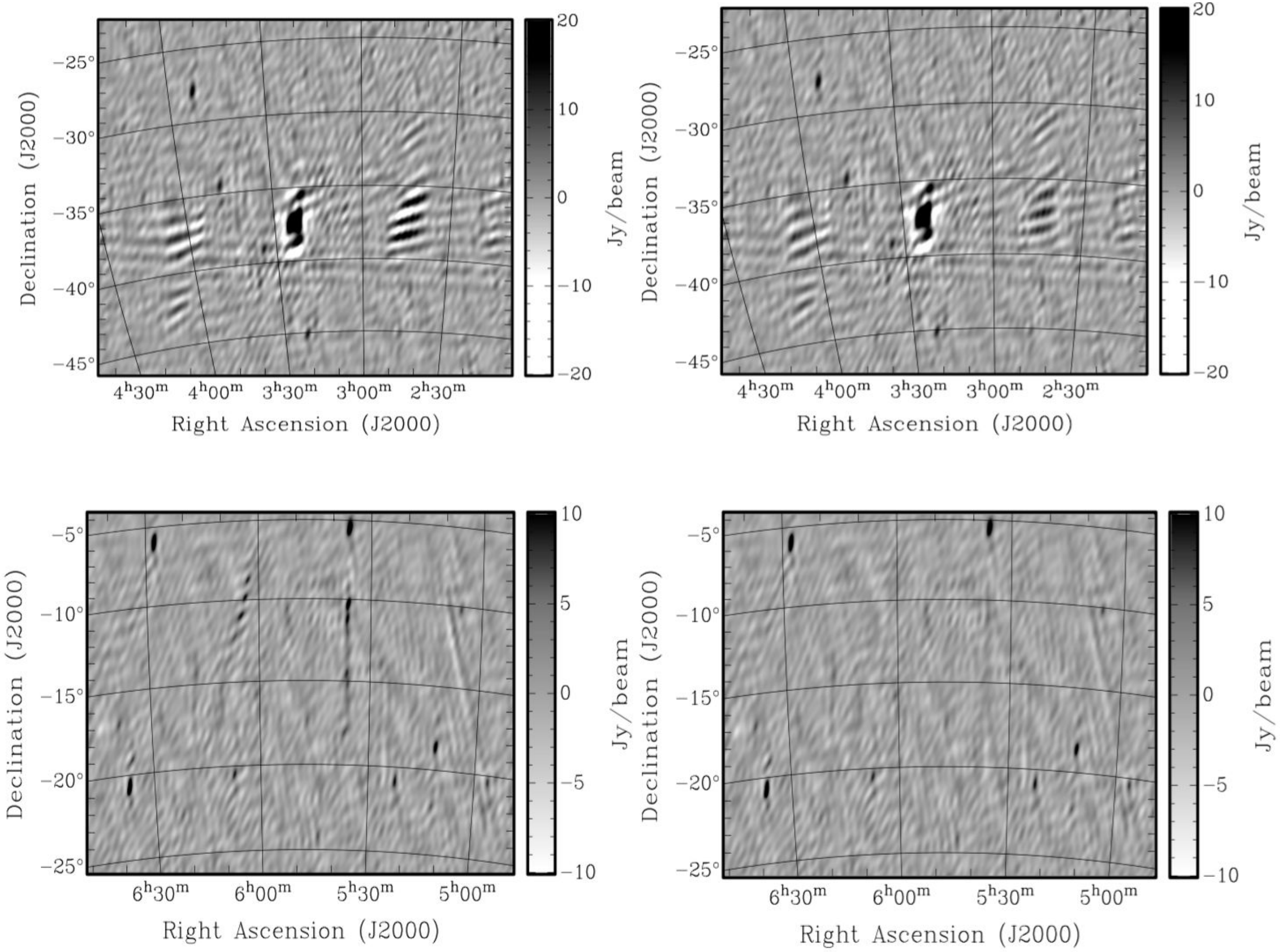


Low Frequency Array
Netherlands

Giant Metre Wavelength
Pune, India

Precision Array to Probe the
Epoch of Reionization
Karoo, South Africa

Hydrogen Epoch of
Reionization Array
Karoo, South Africa



Declination (J2000)
Right Ascension (J2000)
Jy/beam
−25°
−30°
−35°
−40°
−45°
4h30m
4h00m
3h30m
3h00m
2h30m
20
10
0
−10
−20
−5°
−10°
−15°
−20°
−25°
6h30m
6h00m
5h30m
5h00m
5
−5