Observing the EoR with the Murchison Widefield Array

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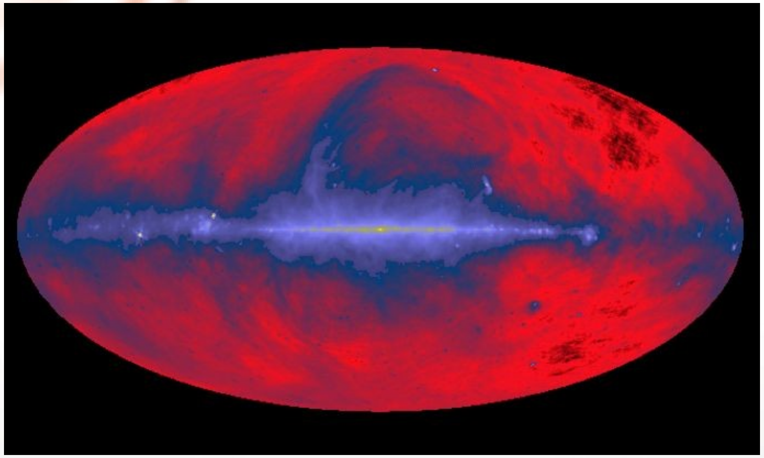
On behalf of the international MWA consortium

Follow project progress at:
www.facebook.com/Murchison.Widefield.Array

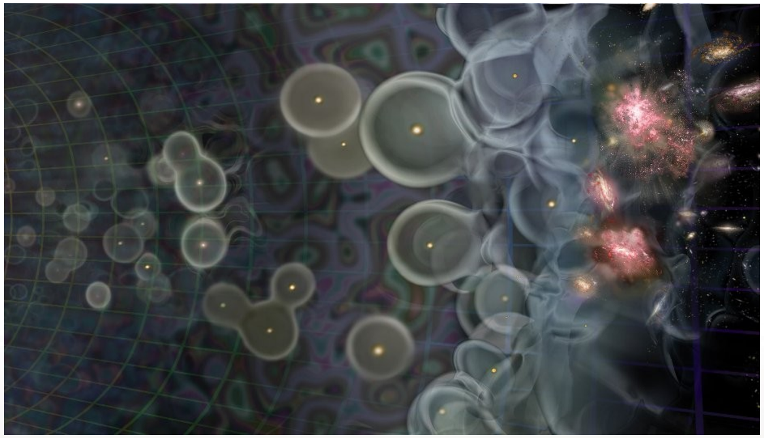
Play the movie, Sam...

MWA Key Science

Galactic & Extragalactic



Epoch of Reionisation



Solar & heliospheric physics

Transient & variable sources

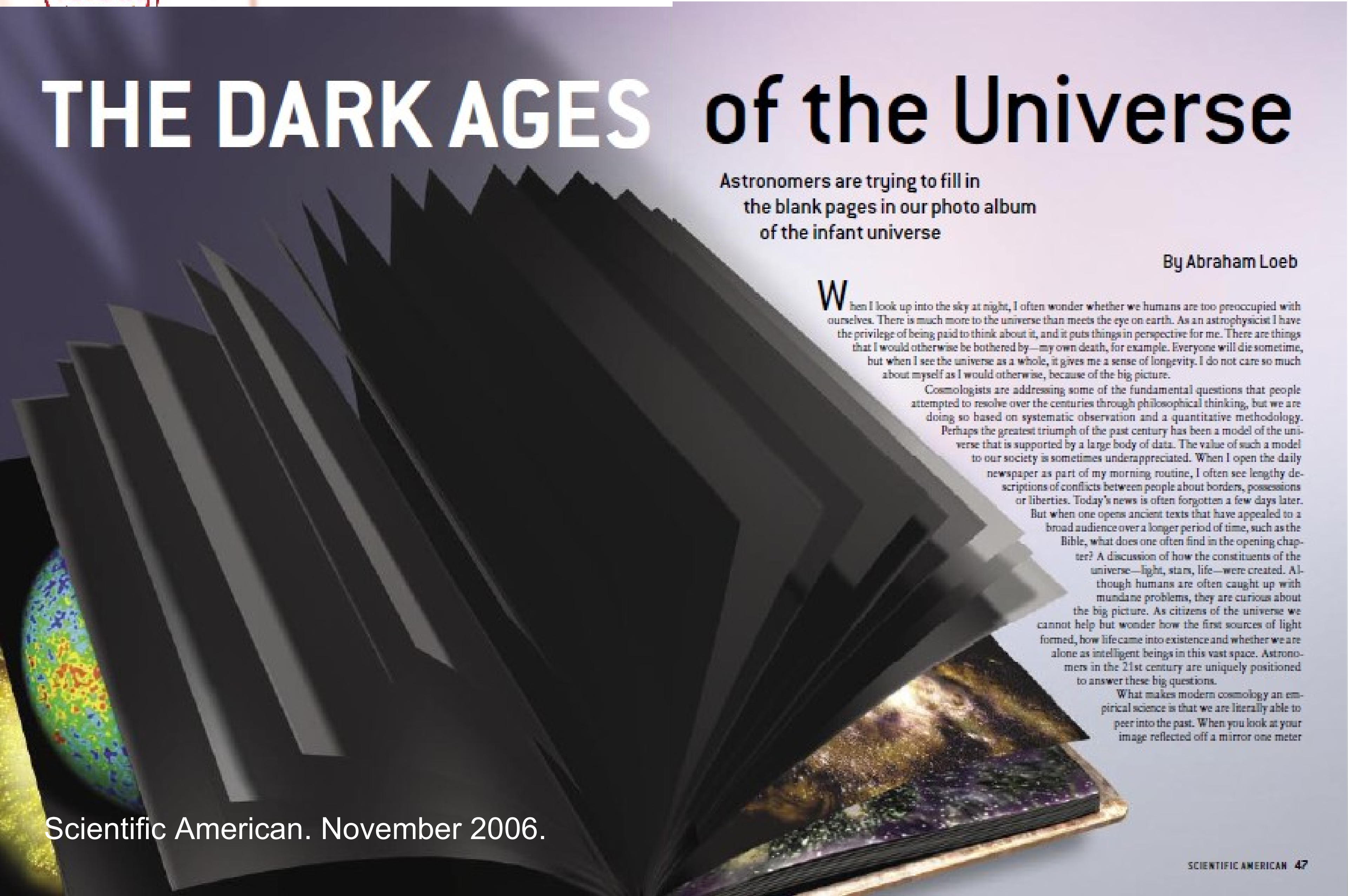
MWA specs @ 150MHz

Table 1. System Parameters for the MWA

Parameter	Symbol	150 MHz
Number of tiles	N	128
Area of one tile at zenith (m^2)	A_{eff}	21.5
Total collecting area (m^2)		2 752
Receiver temperature (K)	T_{rcv}	50
Typical sky temperature[a] (K)	T_{sky}	350
Field of view[b] (deg^2)	Ω_p	610
Instantaneous bandwidth (MHz)	B	30.72
Spectral resolution (MHz)		0.04
Temporal resolution		0.5 s uncalibrated 8 s calibrated
Polarisation		Full Stokes
Minimum baseline (m)		7.7
Maximum baseline (m)		2 864
Angular resolution (1.5-km array)		~3 arcmin
Angular resolution (3-km array)		~2 arcmin

Tingay et al 2013. PASA 30 7T

MWA Science – Epoch of Reionisation



THE DARK AGES of the Universe

Astronomers are trying to fill in the blank pages in our photo album of the infant universe

By Abraham Loeb

When I look up into the sky at night, I often wonder whether we humans are too preoccupied with ourselves. There is much more to the universe than meets the eye on earth. As an astrophysicist I have the privilege of being paid to think about it, and it puts things in perspective for me. There are things that I would otherwise be bothered by—my own death, for example. Everyone will die sometime, but when I see the universe as a whole, it gives me a sense of longevity. I do not care so much about myself as I would otherwise, because of the big picture.

Cosmologists are addressing some of the fundamental questions that people attempted to resolve over the centuries through philosophical thinking, but we are doing so based on systematic observation and a quantitative methodology. Perhaps the greatest triumph of the past century has been a model of the universe that is supported by a large body of data. The value of such a model to our society is sometimes underappreciated. When I open the daily newspaper as part of my morning routine, I often see lengthy descriptions of conflicts between people about borders, possessions or liberties. Today's news is often forgotten a few days later. But when one opens ancient texts that have appealed to a broad audience over a longer period of time, such as the Bible, what does one often find in the opening chapter? A discussion of how the constituents of the universe—light, stars, life—were created. Although humans are often caught up with mundane problems, they are curious about the big picture. As citizens of the universe we cannot help but wonder how the first sources of light formed, how life came into existence and whether we are alone as intelligent beings in this vast space. Astronomers in the 21st century are uniquely positioned to answer these big questions.

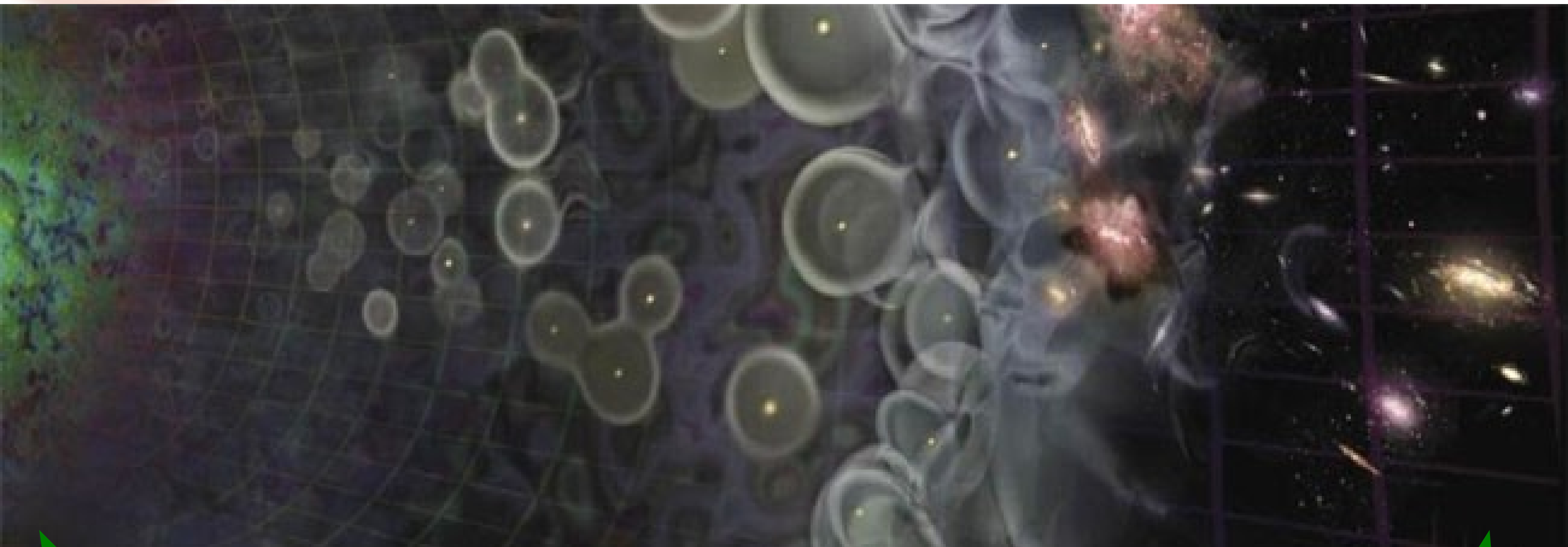
What makes modern cosmology an empirical science is that we are literally able to peer into the past. When you look at your image reflected off a mirror one meter

SCIENTIFIC AMERICAN 47

Scientific American. November 2006.

Science: The Epoch of Reionisation

What happened here?



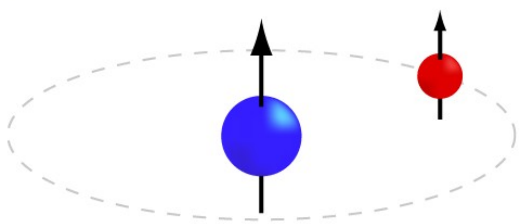
Cosmic microwave background emitted T=300,000 years

Cosmic dawn

Reionisation: Approx T=1 billion years

Today T=13.7 billion years

21 cm Hyperfine Line of Hydrogen



$$n_1/n_0 = (g_1/g_0)\exp(-T_\star/T_S)$$

$$T_\star \equiv hc/k\lambda_{21\mathrm{cm}} = 0.068\,\mathrm{K}$$

- For a cloud of hydrogen gas between us and the CMB, the 21 cm resonant interaction changes the CMB brightness temperature:

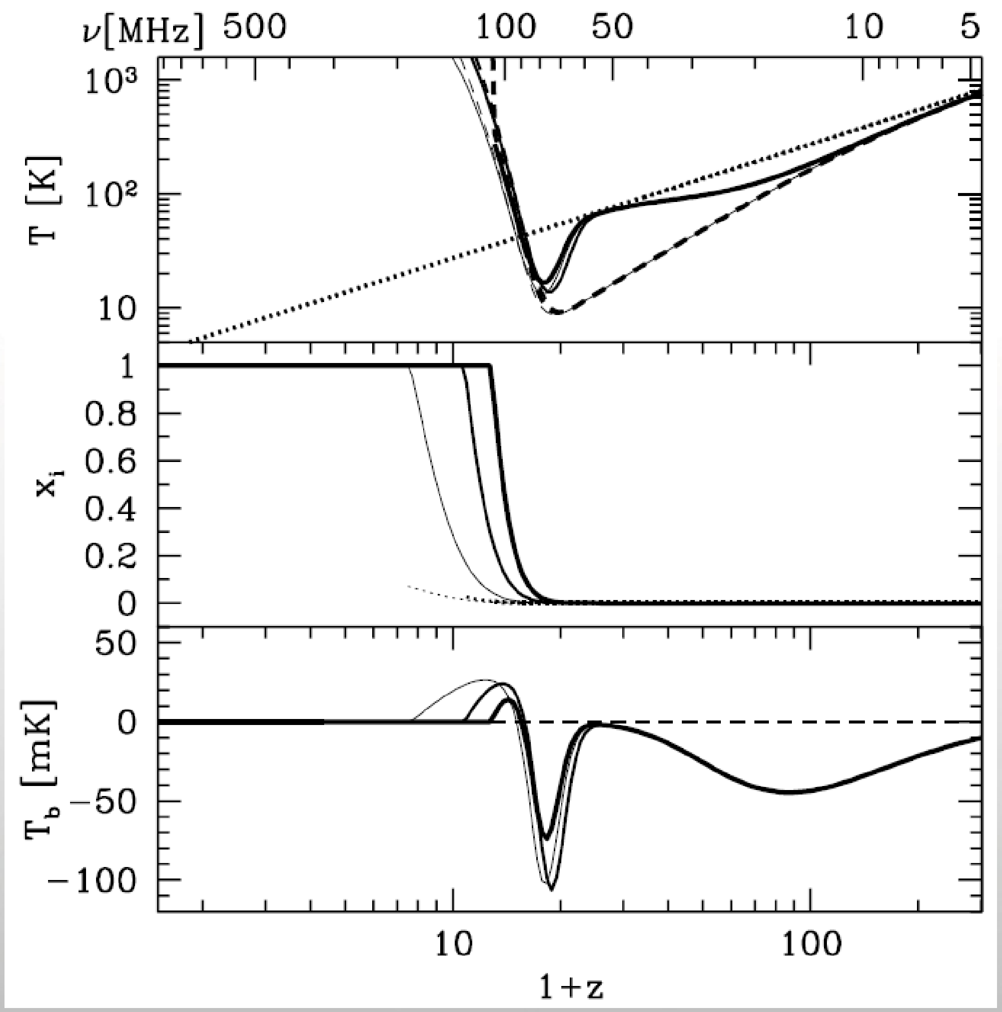
$$\delta T_b = \tau(T_s - T_\gamma)/(1+z)$$

$$\tau = \frac{3c\lambda^2 h A_{10} n_{\mathrm{H}}}{32\pi k_{\mathrm{B}} T_s (1+z)(dv_r/dr)} x_{\mathrm{HI}}$$

- Filling in the constants in optical depth for ΛCDM gives:

$$\boxed{\delta T_b \approx 25\, x_{\mathrm{HI}}(1+\delta)\left(\frac{1+z}{10}\right)^{1/2}\left[1-\frac{T_\gamma(z)}{T_S}\right]\left[\frac{H(z)/(1+z)}{\mathrm{d}v_\parallel/\mathrm{d}r_\parallel}\right]\ \mathrm{mK}}$$

How to get at EoR? - Global Signal



Pritchard & Loeb, 2008.

Spatially resolved 21 cm background

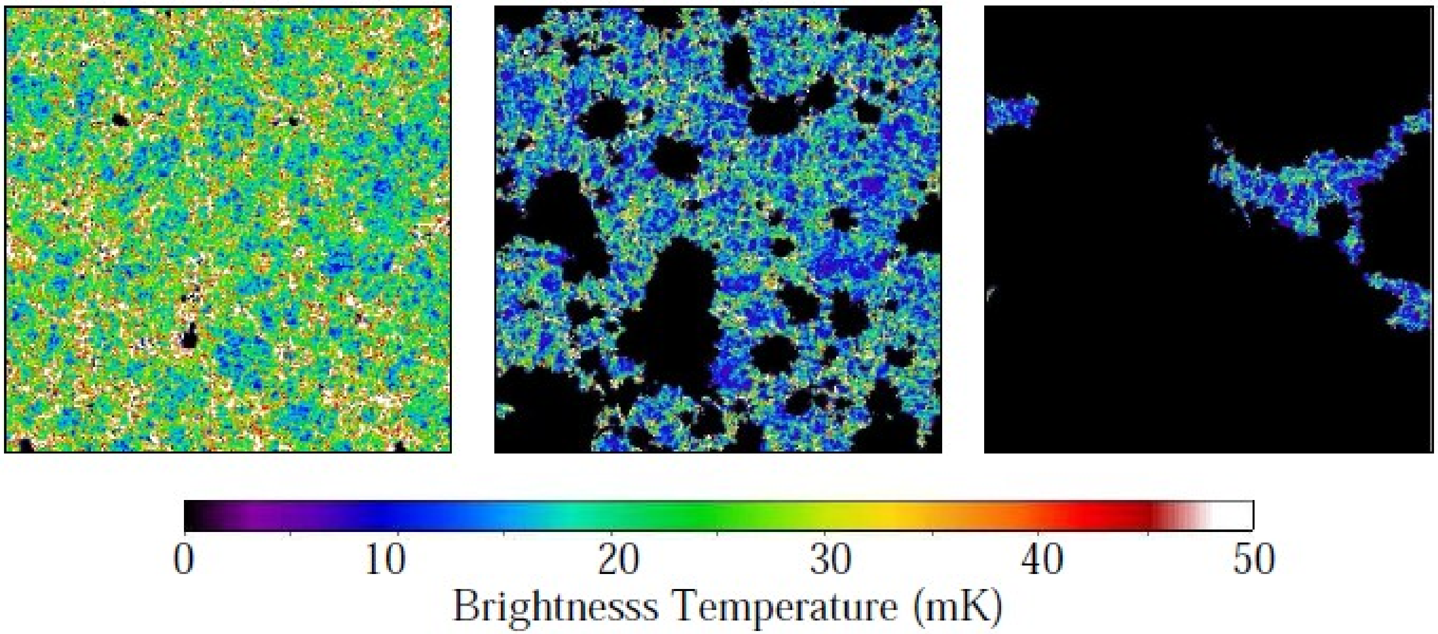
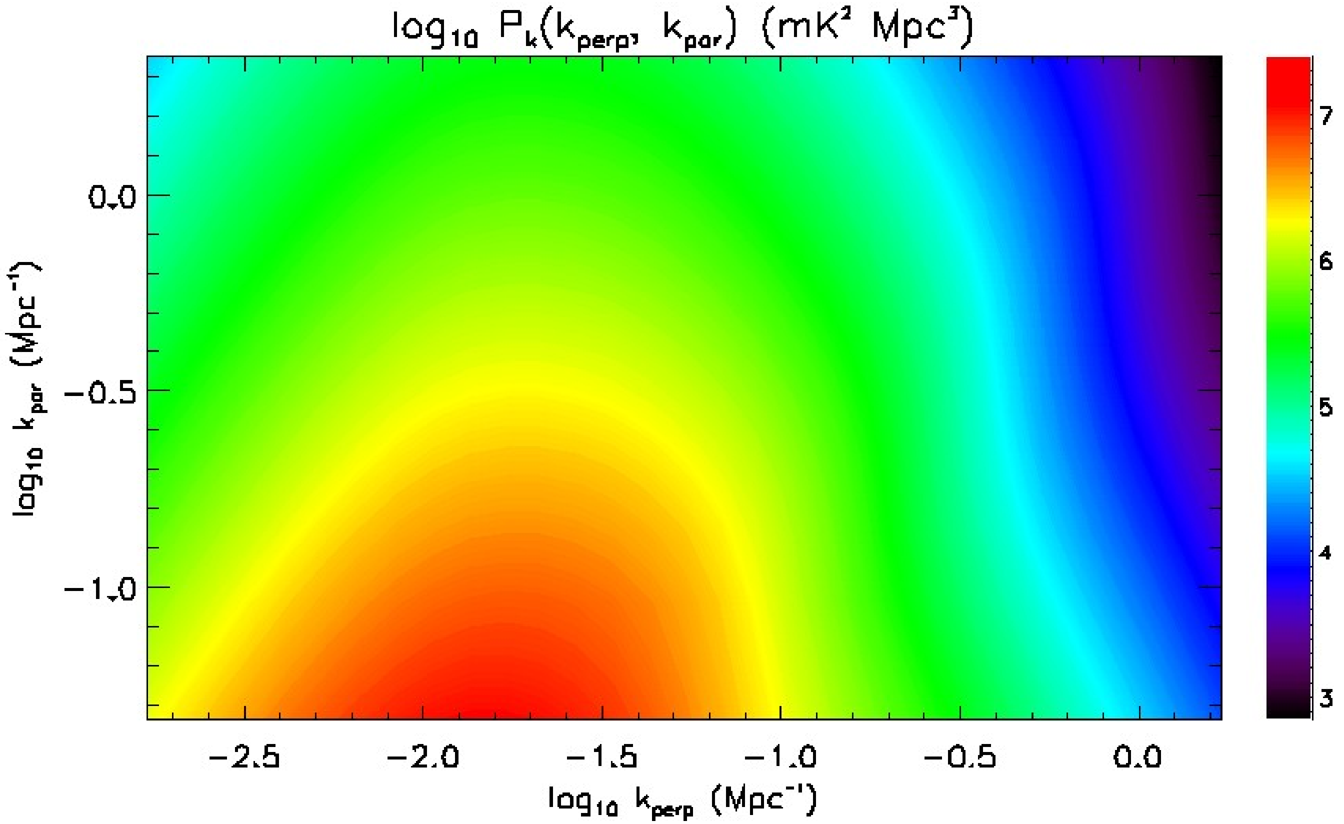


Figure 1: Simulated 21 cm brightness temperature maps from simulation S1 in McQuinn et al. (2007) at three epochs calculated under the assumption that $T_S \gg T_\gamma$. The left panel is an almost fully neutral IGM (before reionization at $z = 12$) such that the 21cm emission traces the matter density. The middle panel is during reionization ($x_{HI} \approx 0.5$, which occurs at $z = 8$ in this simulation): The dark regions represent ionized regions around galaxies. Lastly, the right panel shows the residual emission near the end of reionization ($z = 6$). Each panel is 100 comoving Mpc across and subtends 0.5° (a small fraction of the MWA field of view).

"Science with the MWA"
arXiv:1212.5151

EoR 2-D power spectrum

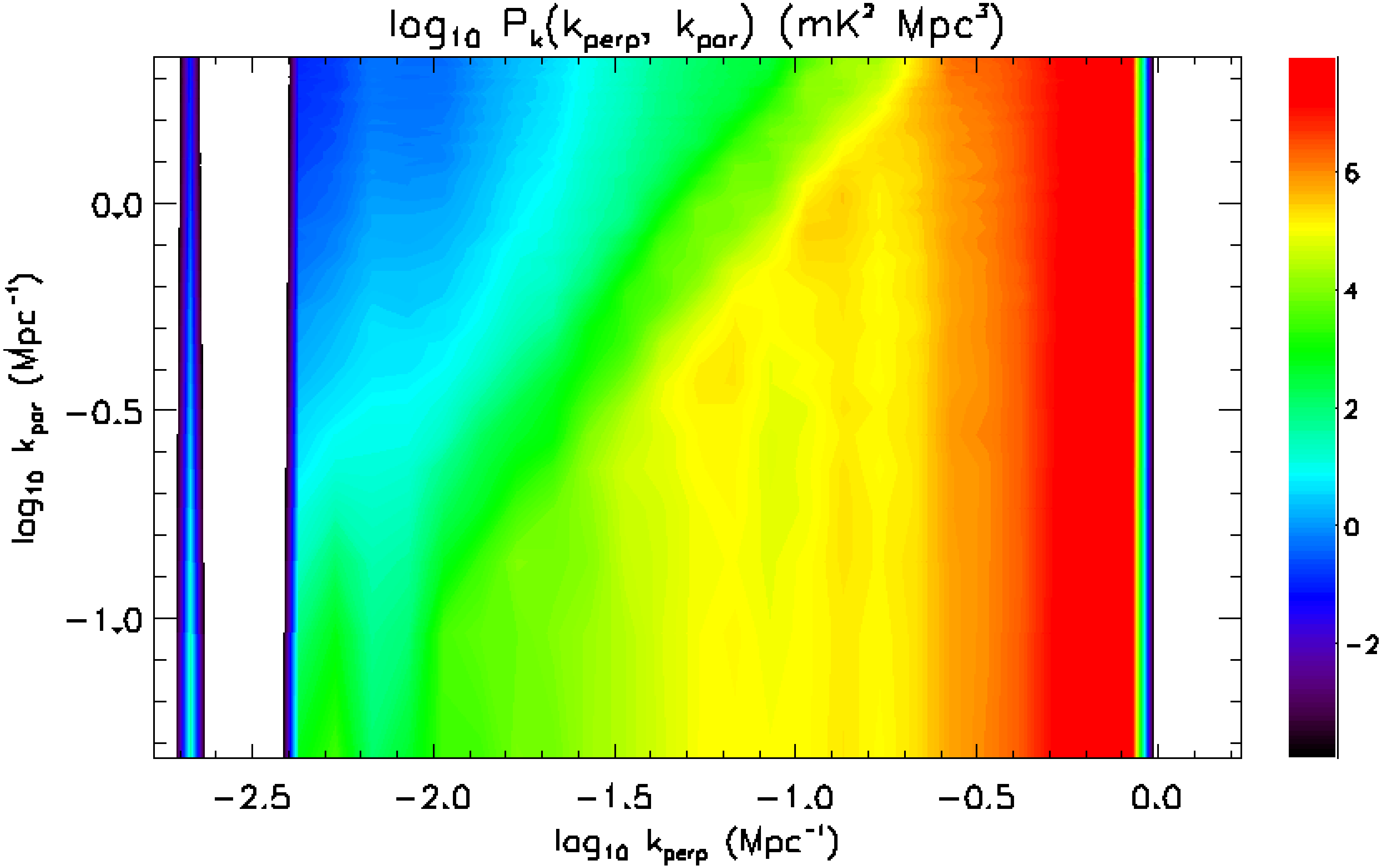
Expected EoR signal for a simple model



Trott, Wayth & Tingay 2012. ApJ 757

EoR 2-D power spectrum

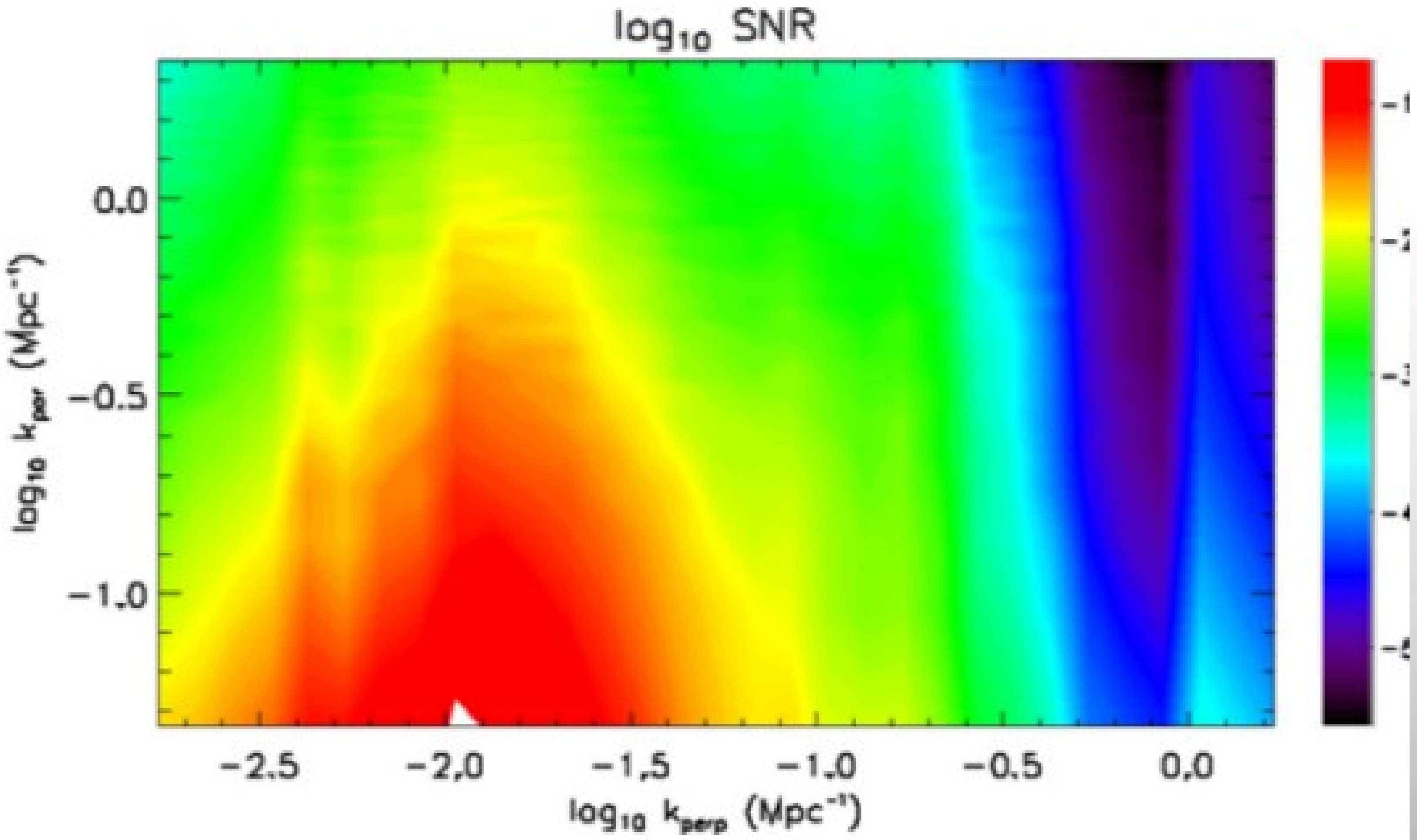
Residual power spectrum from imperfect source subtraction



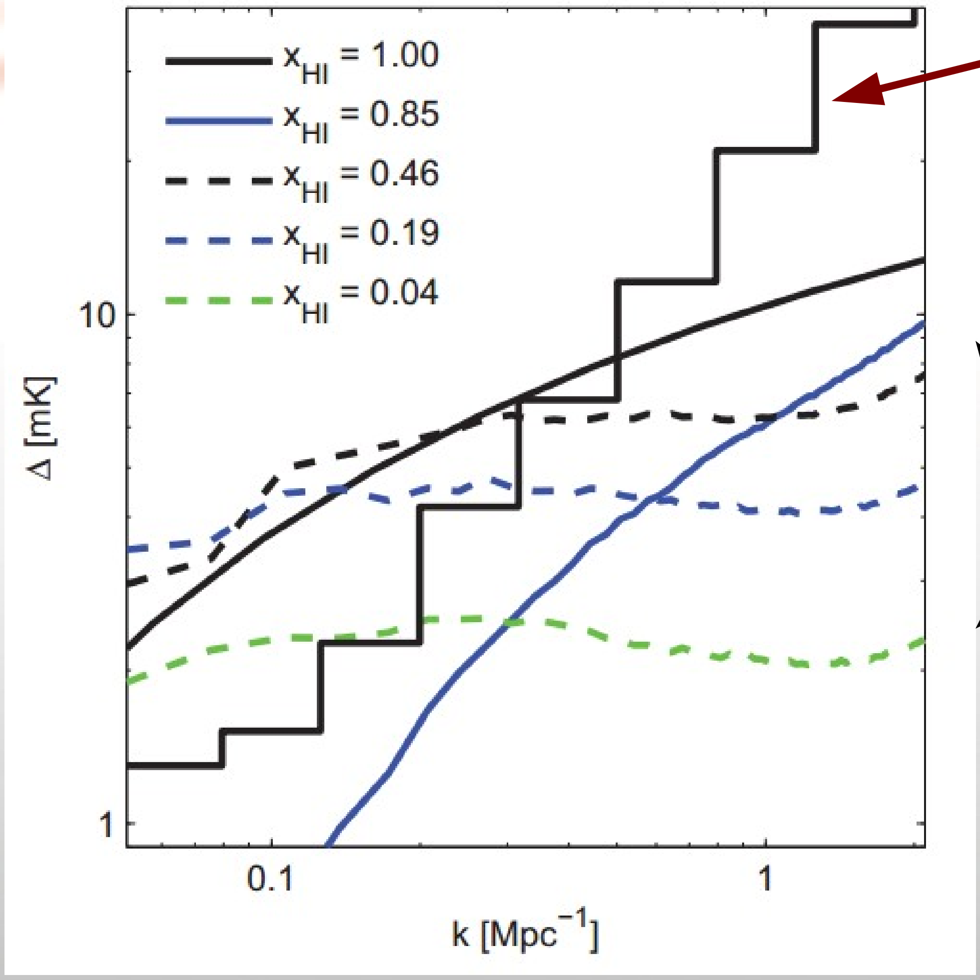
Trott, Wayth & Tingay 2012. ApJ 757

EoR 2-D power spectrum

SNR vs thermal noise – not enough for current generation instrument



EoR 1-D power spectrum



MWA thermal noise (1600 h)

Reionisation scenarios

Large angular scales

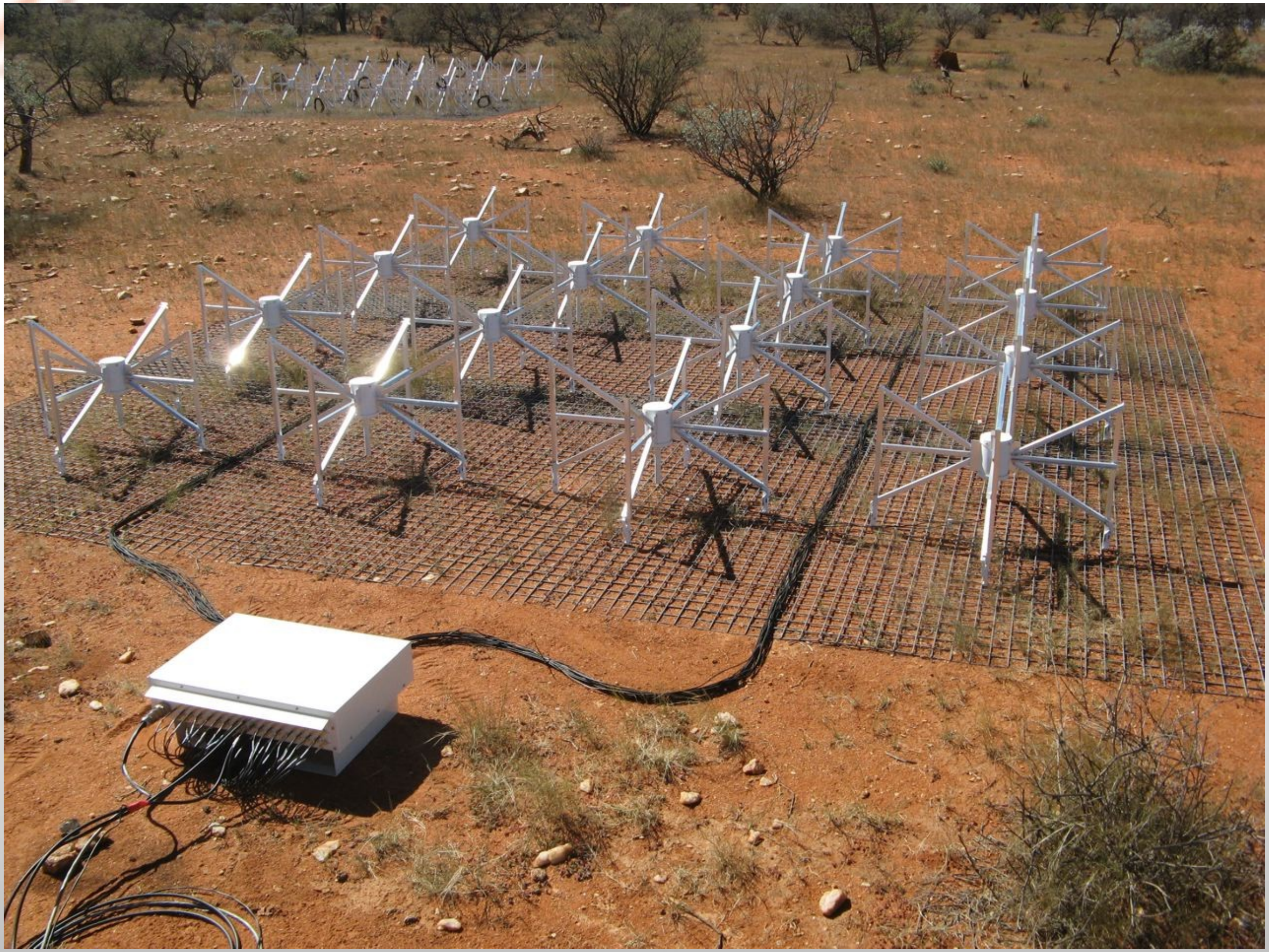
Small angular scales

Beardsley et al 2013
MNRAS 429

Distinguishing EoR models - What's in it for the simulators?

- Very well understood:
  - How to make model power spectra under ideal conditions
- Moderately well understood
  - Limits to instrument calibration and effects on data
- Not well understood:
  - Given some real data, how well can we discriminate between different early universe models?

MWA – New Science, New Design



MWA antenna “tile” - a low freq phased array

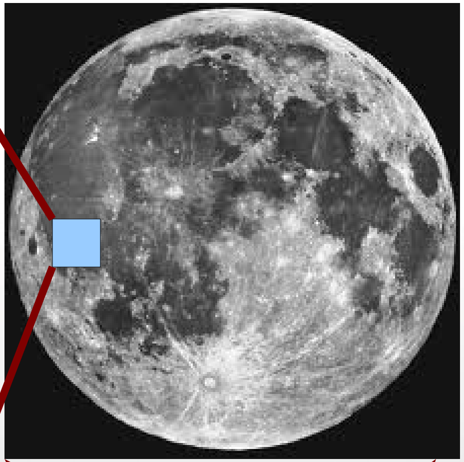
Towards the SKA...

- SKA low: It will be in Australia.
- 50% of science case is EoR

Surveying the sky with MWA

Hubble ultra-deep field (1/20th degree)

Moon's angular size: ½ degree

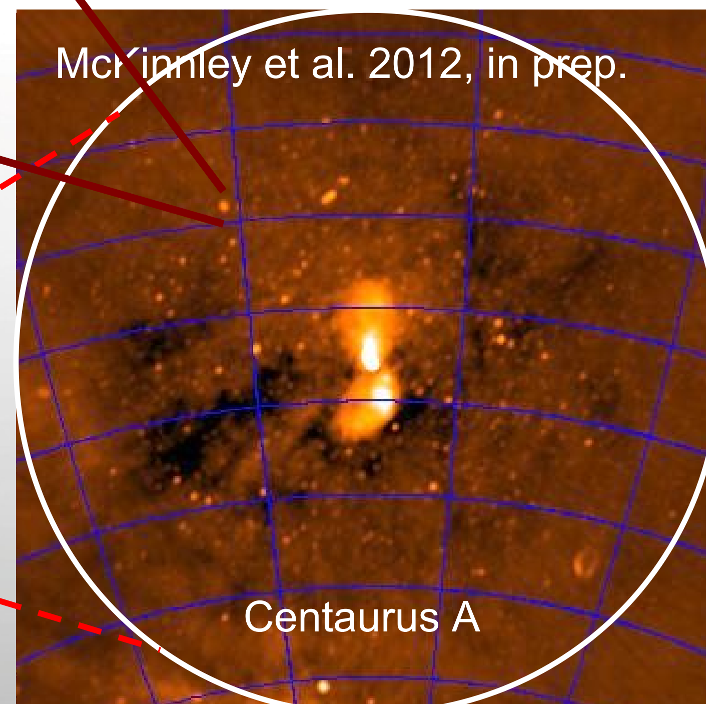


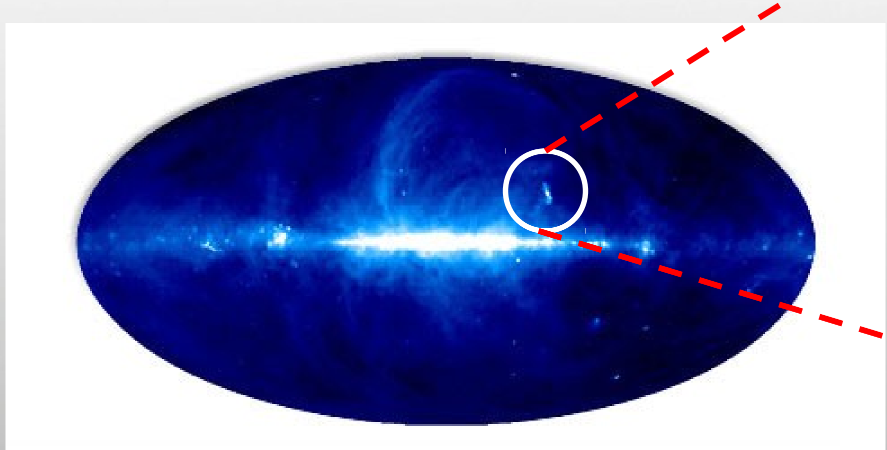
Approx field-of-view of a "dish"

Surveying the sky with MWA

½
degree

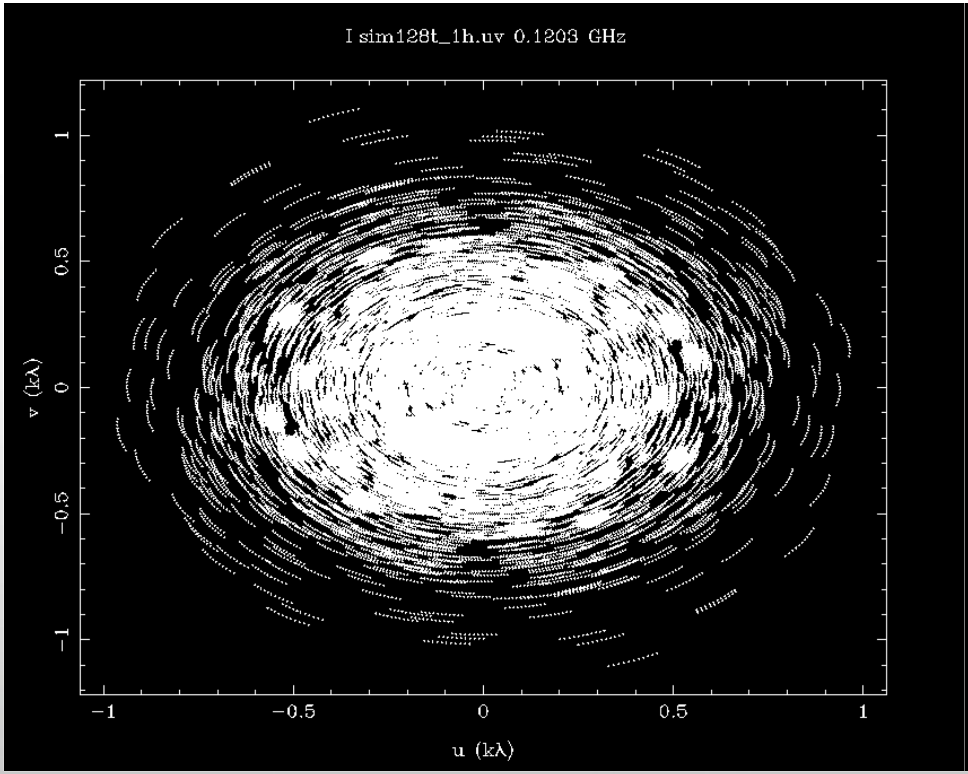
MWA's field of view:
30 degrees!



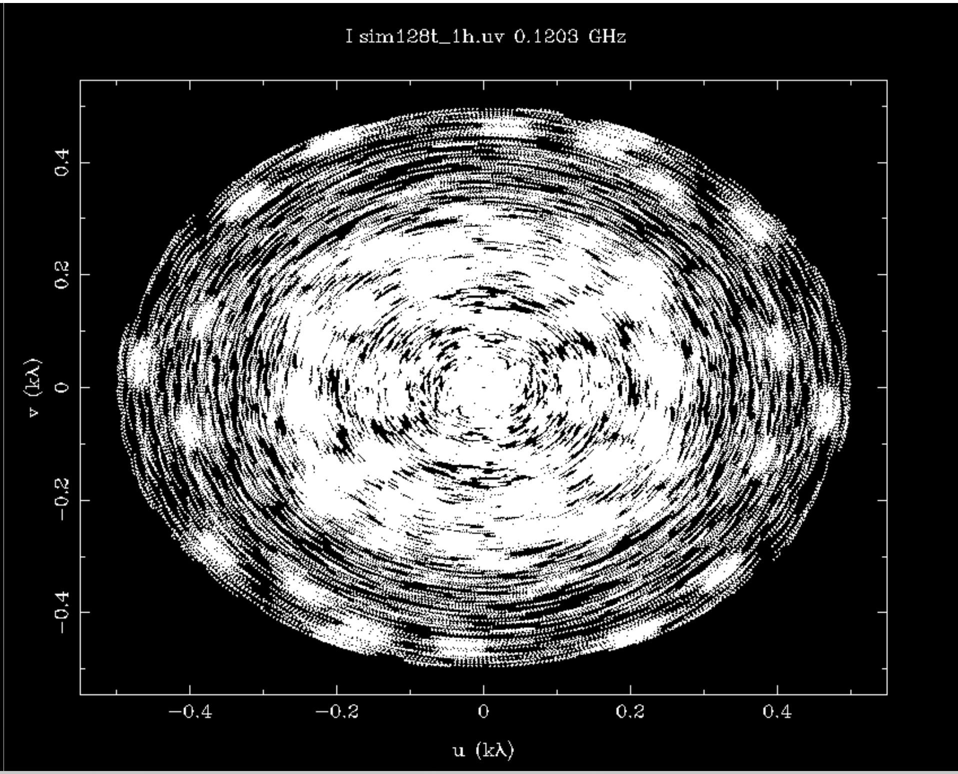


1h monochromatic u,v coverage

Full array

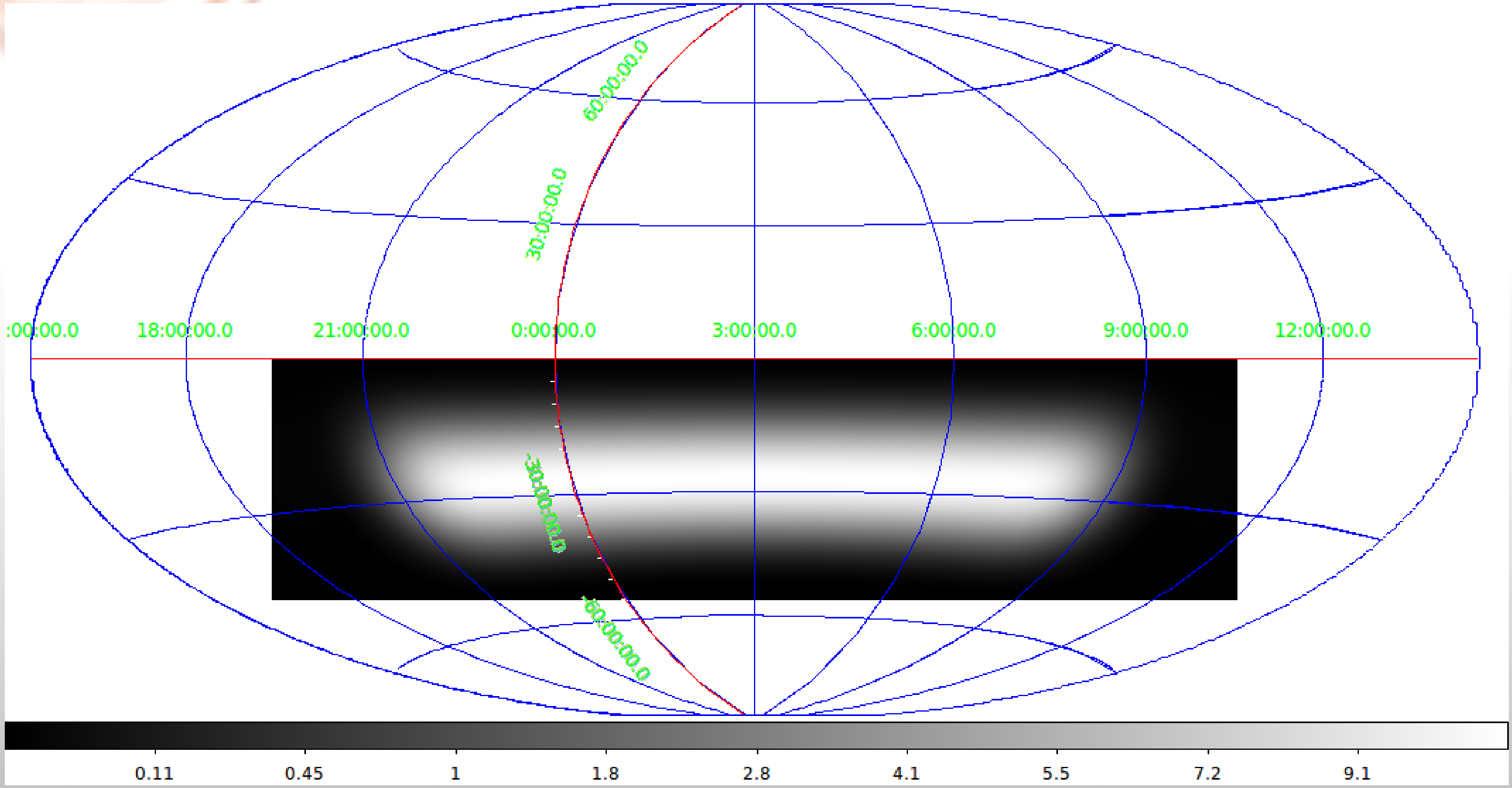


Baselines < 1km



Essentially full u,v below 300 wavelengths

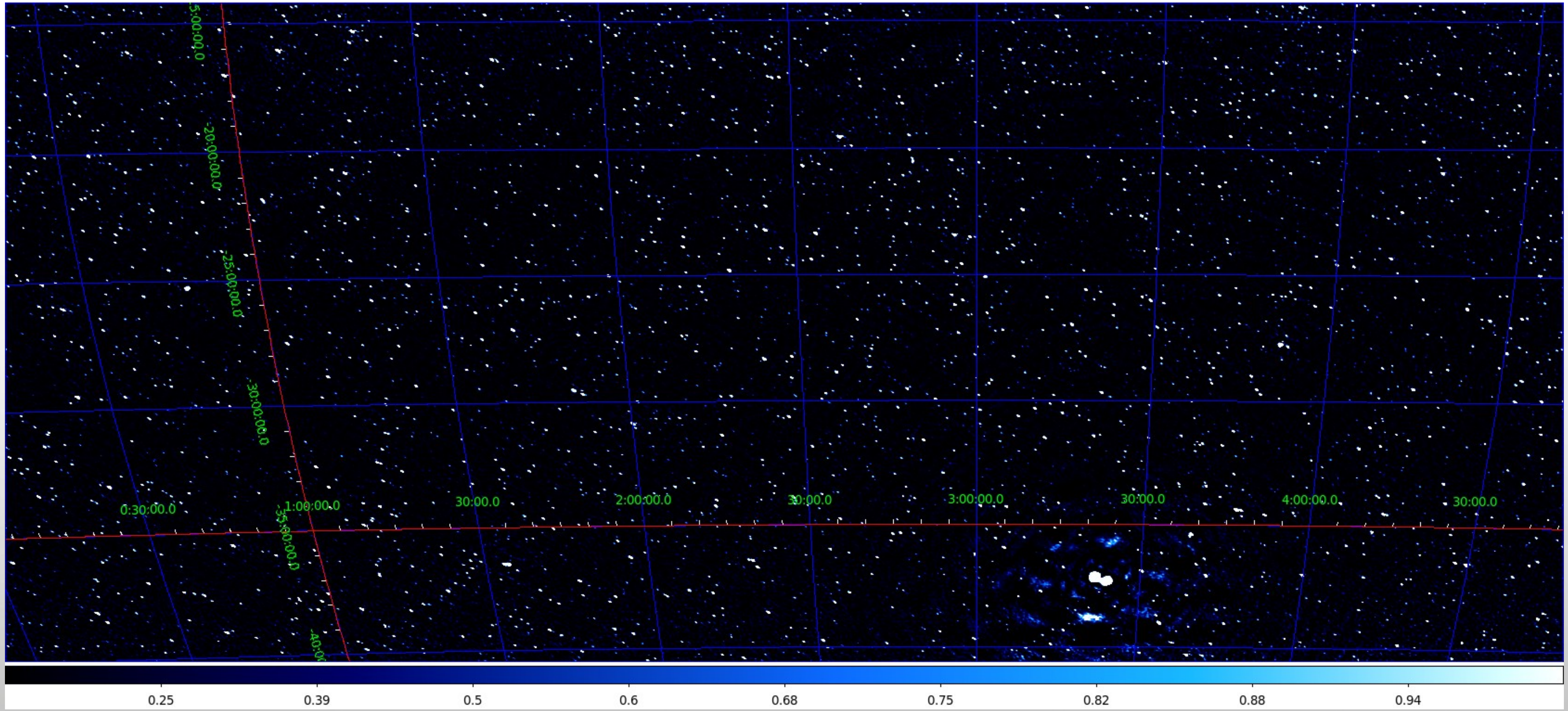
MWA sensitivity for a night-time zenith drift.



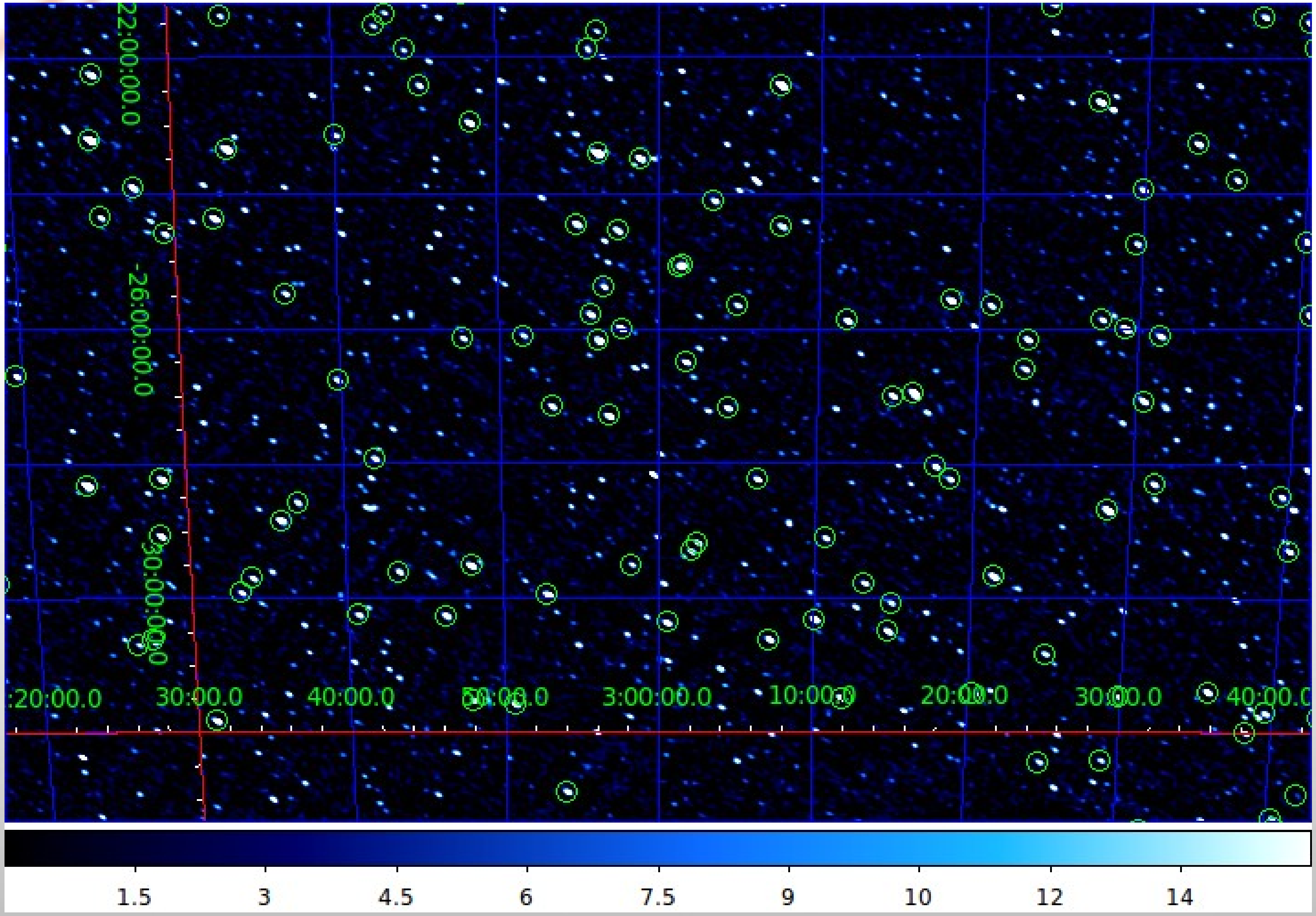
Play survey movie...

Surveying the sky with MWA

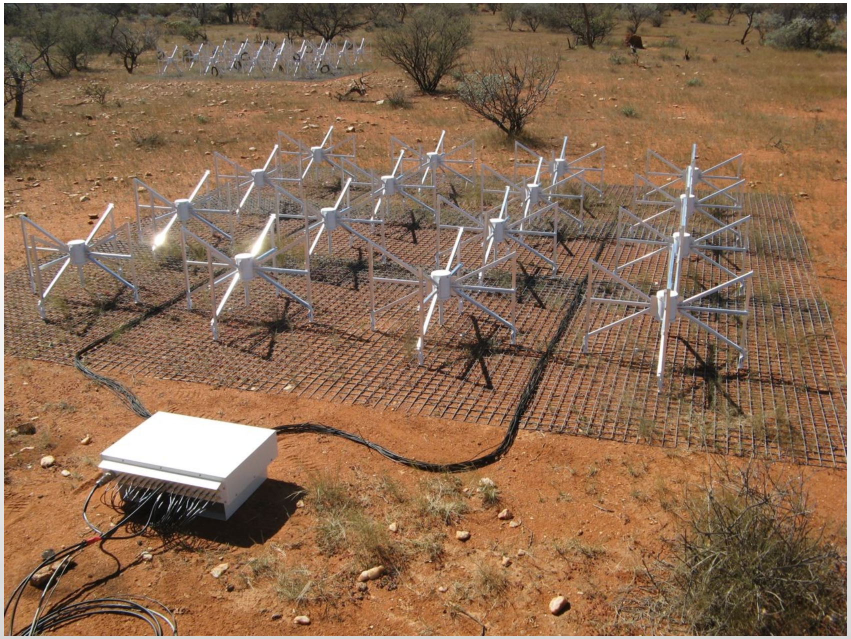
This is a section of a single night zenith drift scan



Single night zenith drift with MRC sources



Questions?



Timeline:

- All hardware installed now
- Call for proposals out
- Operations start July (this year)