CHARACTERISING RADIO TELESCOPES WITH COMMUNICATION SATELLITES

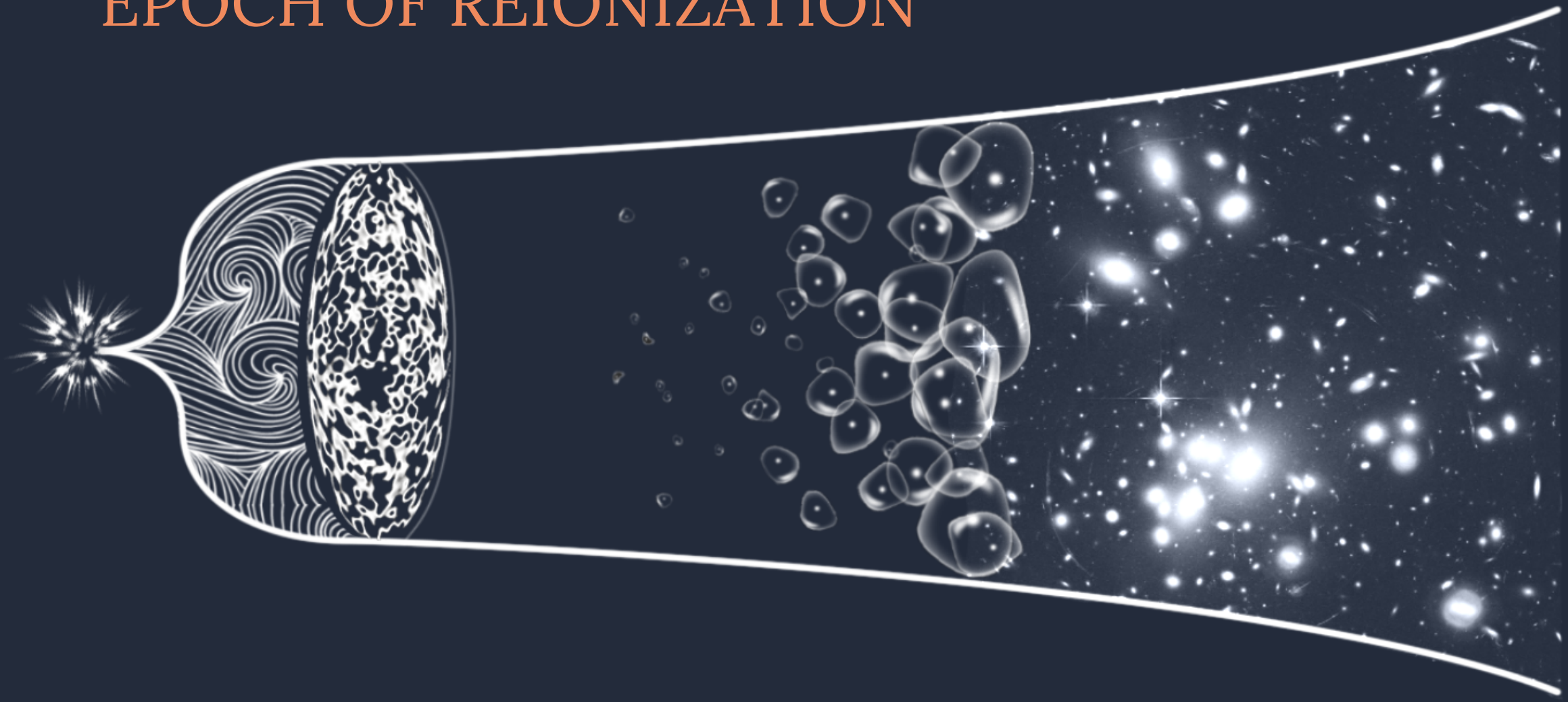
AMAN CHOKSHI

WITH DR. JACK LINE & DR. NICHOLE BARRY

ASTRO 3D

THE UNIVERSITY OF MELBOURNE

EPOCH OF REIONIZATION



0	380,000	150 MILLION	1 BILLION	13.8 BILLION
BIG BANG	RECOMBINATION	REIONIZATION BEGINS	REIONIZATION ENDS	TODAY

ANALOGY - EOR SIGNAL

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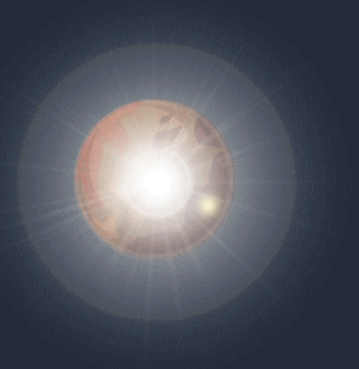
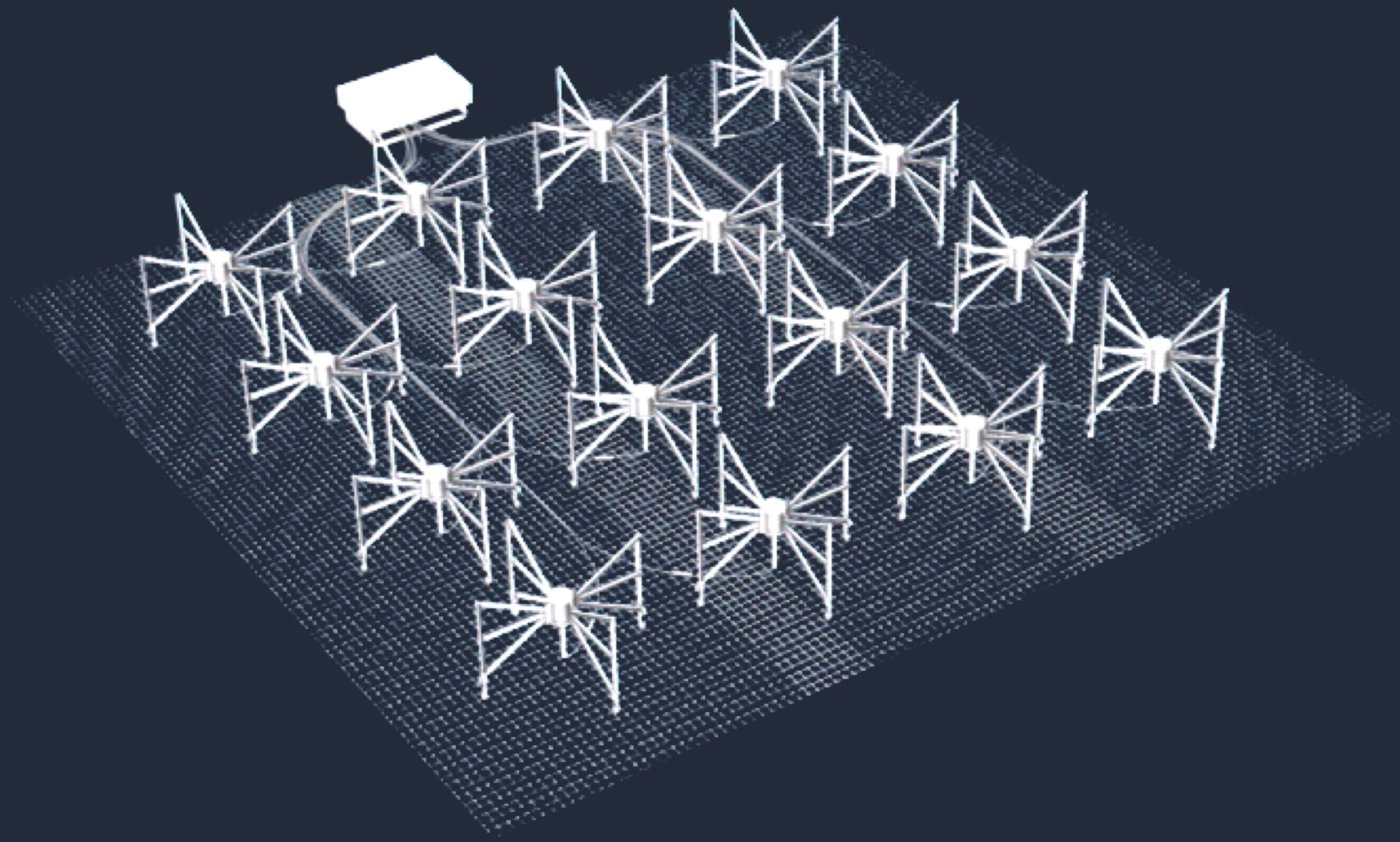
EOR SIGNAL ≈ 10 nK
FOREGROUNDS ≈ 200 K



THE MURCHISON WIDEFIELD ARRAY

- Radio Interferometer
- 128 tiles - pseudo-random configuration
- Each tile has 16 dual-polarization bow-tie antennas
- Frequency: 70 – 300 MHz
- Field-of-View at 150MHz ≈ 30 ° (Hubble FoV is 700 times smaller)

MWA TILE



MWA BEAM

- Response of antenna to the sky
- Instrumental “beam shapes” lead to non-uniform weighting of sky
- Knowing the beam shape is critical to understanding our data

THE EXPERIMENT

- Beam shape of MWA tiles have been accurately simulated
- In 2016 Dr. Jack Line found significant differences between the simulated and measured beam of 6 MWA tiles
- His experiment demonstrated the feasibility of measuring the shape of the MWA beam, in-situ, using satellites

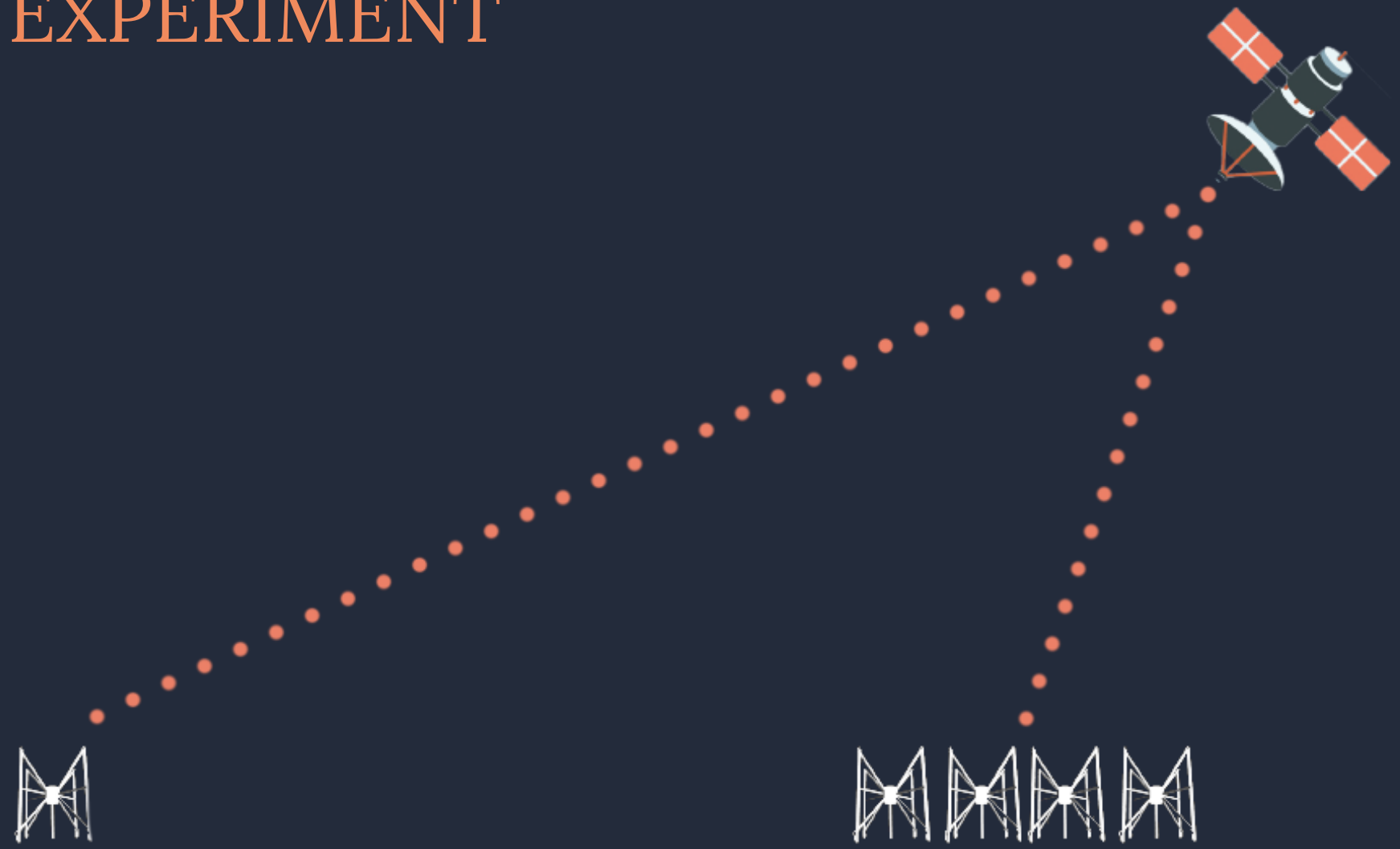
THE EXPERIMENT

- We aim to measure the beam shape of 14 Tiles in 2 Polarizations
- Determine how real beam shapes differ from “ ideal” simulations
- These differences could impact the detectability of the incredibly faint EOR signal, and warrant further investigation
- By the end of this experiment we aim to generate a fully functional beam model, which can be incorporated into the data reduction pipeline, to significantly improve the EoR lower limit.

THE EXPERIMENT

- We set up two reference antennas
- Simplest possible antenna, with a well known beam shapes
- Made by placing a single MWA dipole on a 5 x 5m reflective mesh
- Simultaneous record satellite passes with reference and MWA tiles
- References used to correct for modulation of satellite signal
- Gradually build up 2D image of MWA tile beam

THE EXPERIMENT



REFERENCE ANTENNA

MWA TILE

THE MATHS

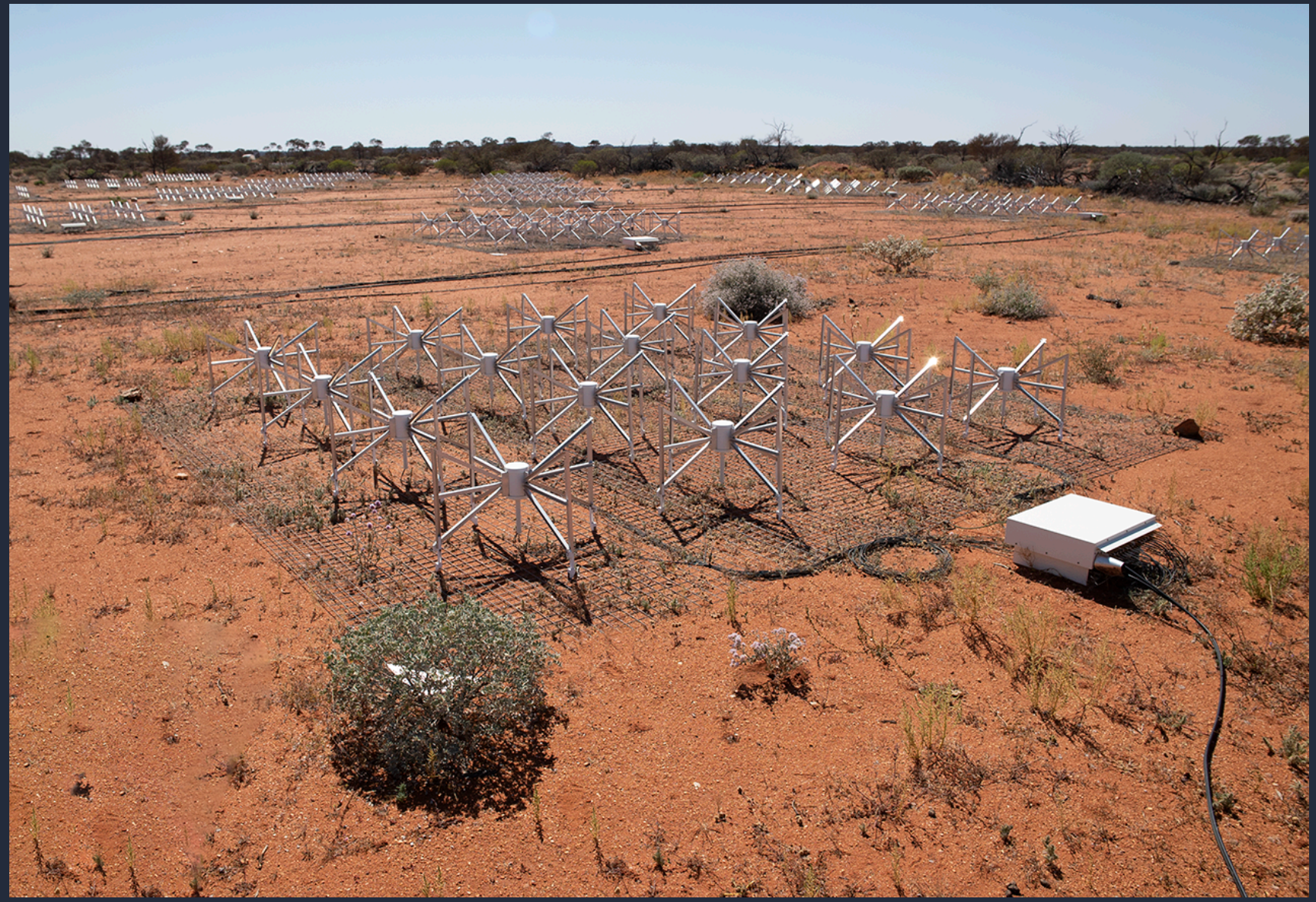
$$B_{MWA} = \frac{P_{MWA}}{P_{REF}} B_{REF}$$

THE EXPERIMENT

- The raw voltages from the receivers are recorded by RF Explorer Spectrum Analysers
- A suite of Raspberry Pis control the RF explorers, initiate and synchronize observation and transfer data to a remote server
- This experiment was designed to use off-the-shelf components, be relatively cheap, and record beam data in parallel to the regular observation schedule

REFERNCE TILE

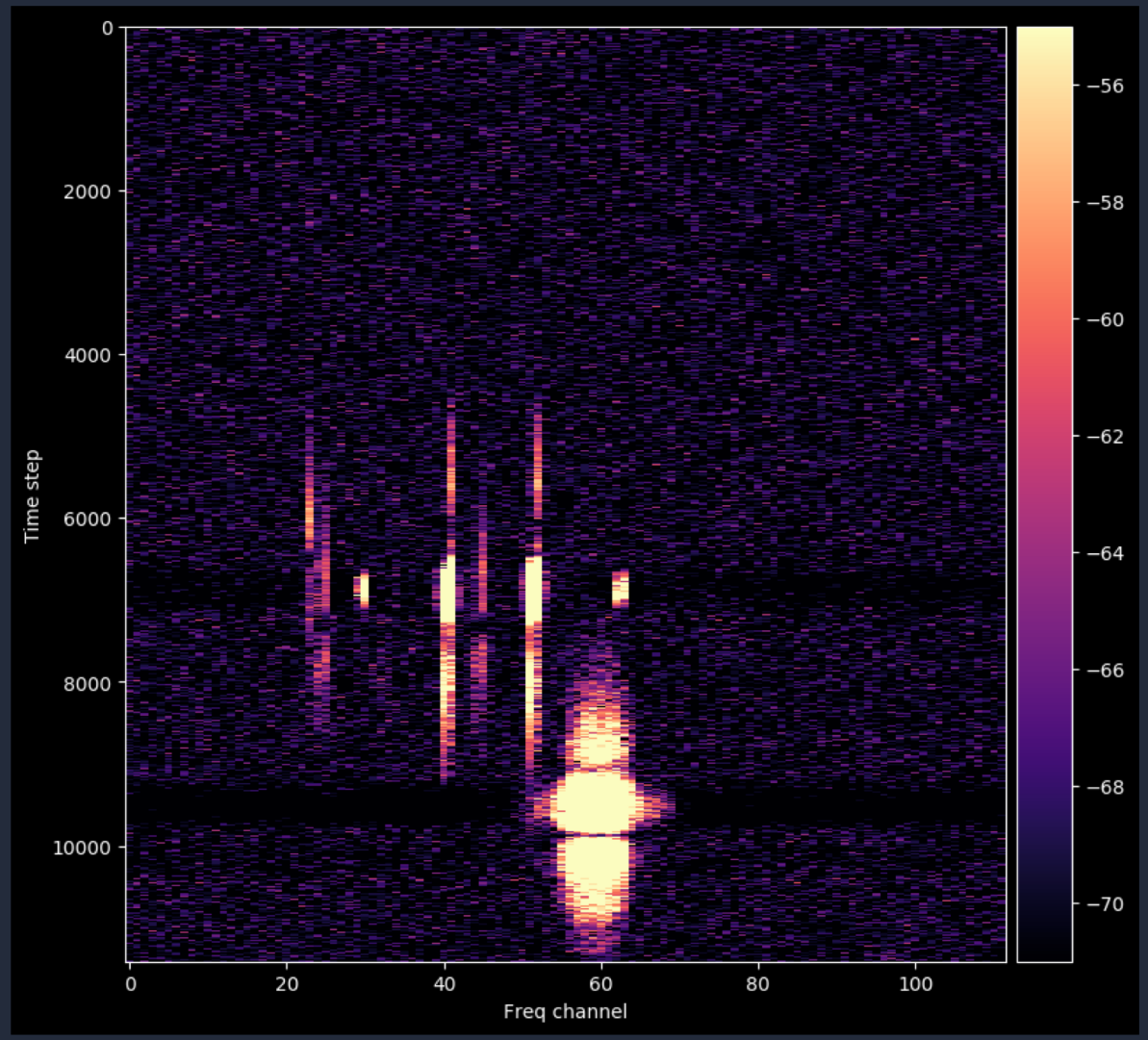
MWA TILE



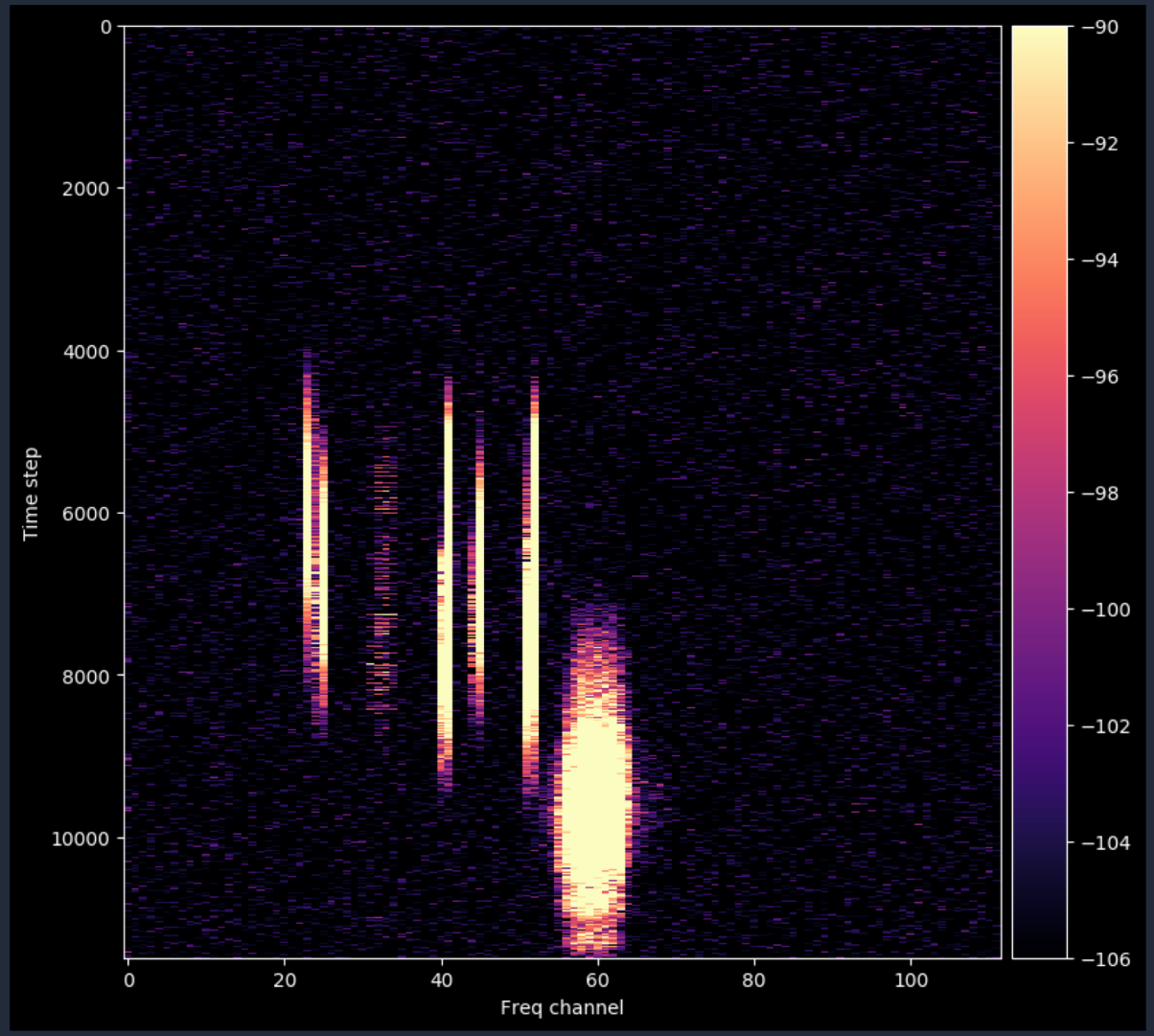
DATA REDUCTION

- RAW data is plotted as waterfalls
- An online satellite database, www.space-track.org, used to match waterfalls with satellite tracks
- The database gives us the exact trajectory of the satellite
- This is used to project our data onto a 2D map of the sky
- Months of observations are required to cover the whole sky, and build up a map with good SNR

WATERFALLS

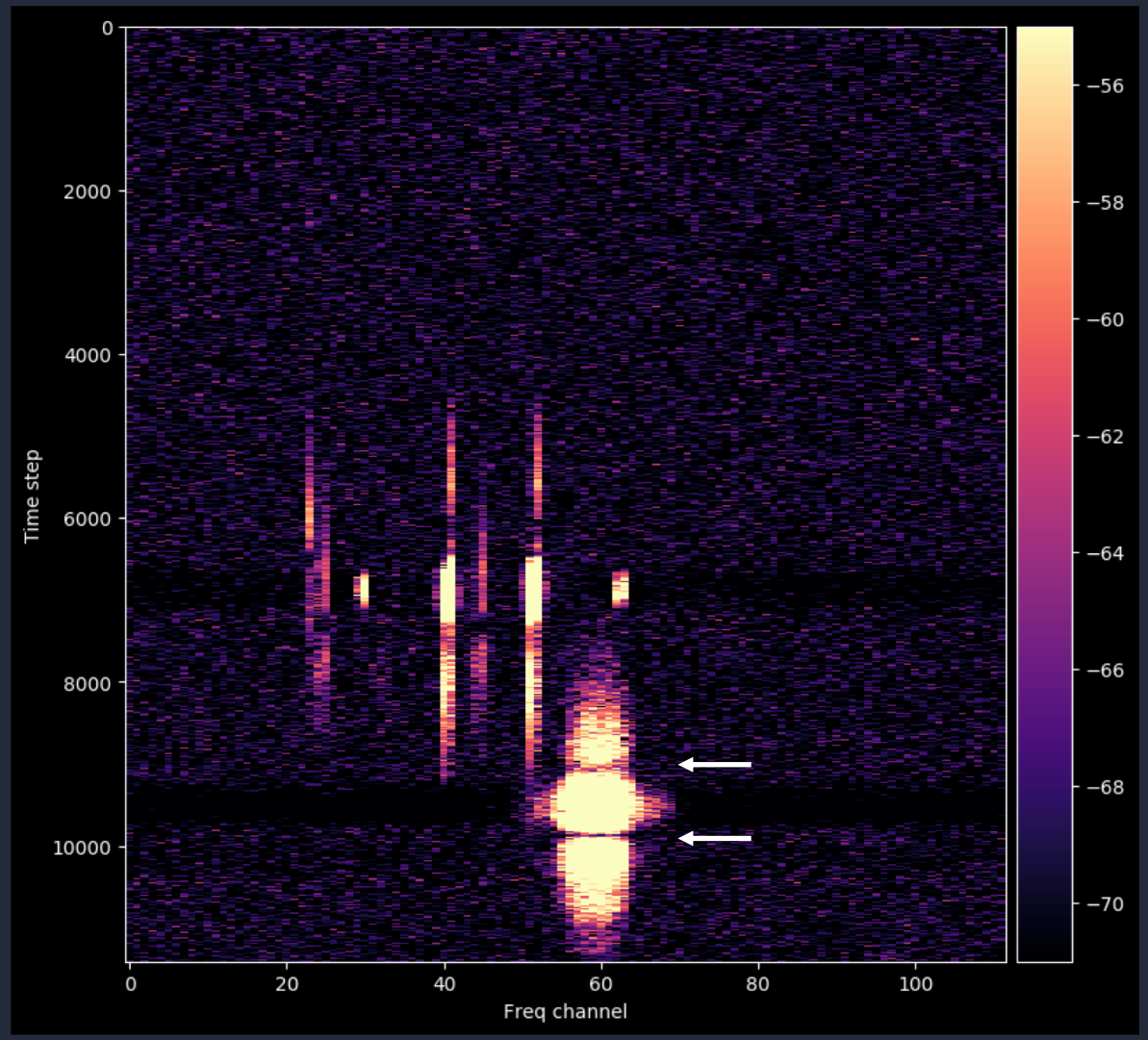


MWA TILE

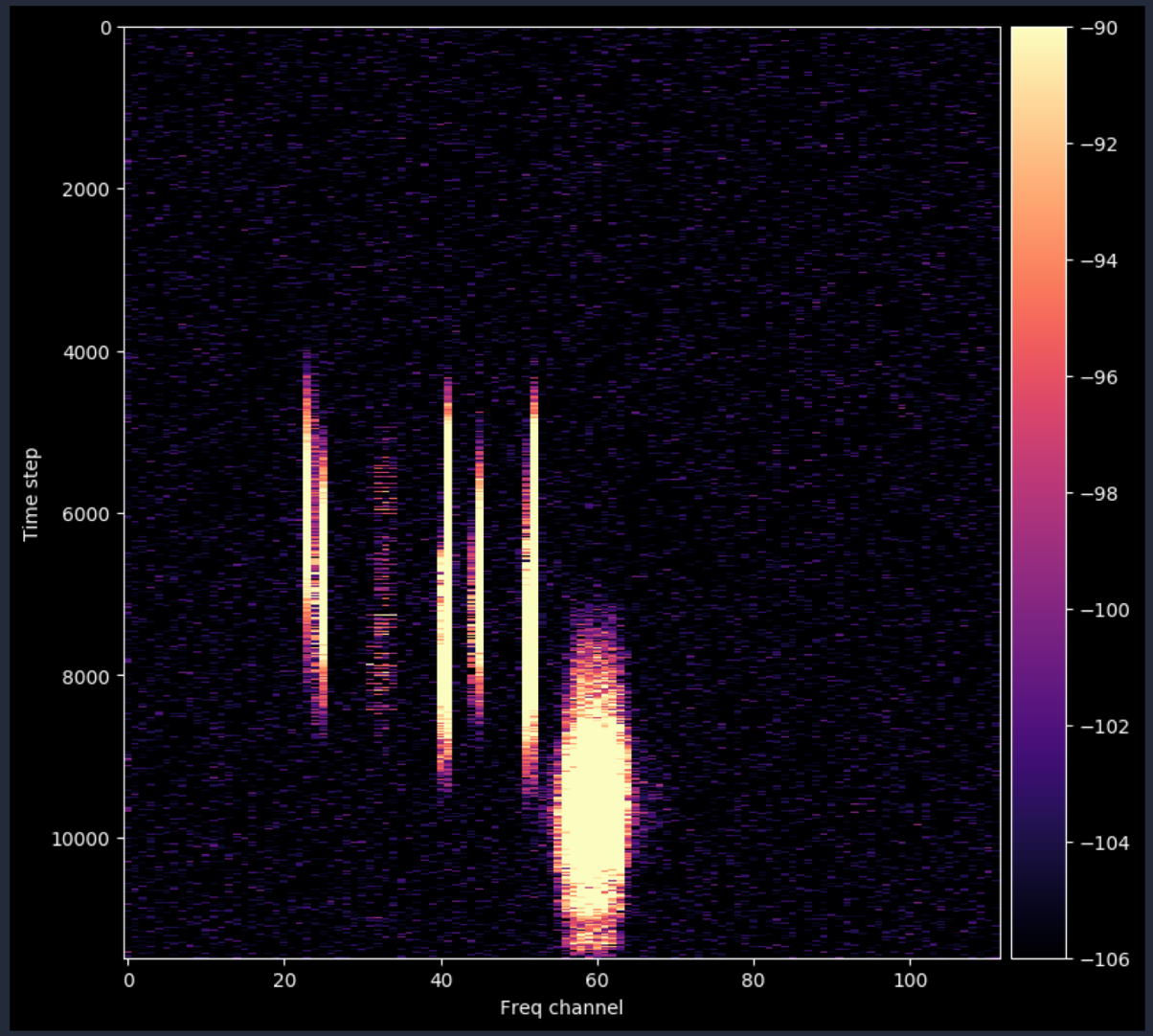


REFERENCE ANTENNA

WATERFALLS

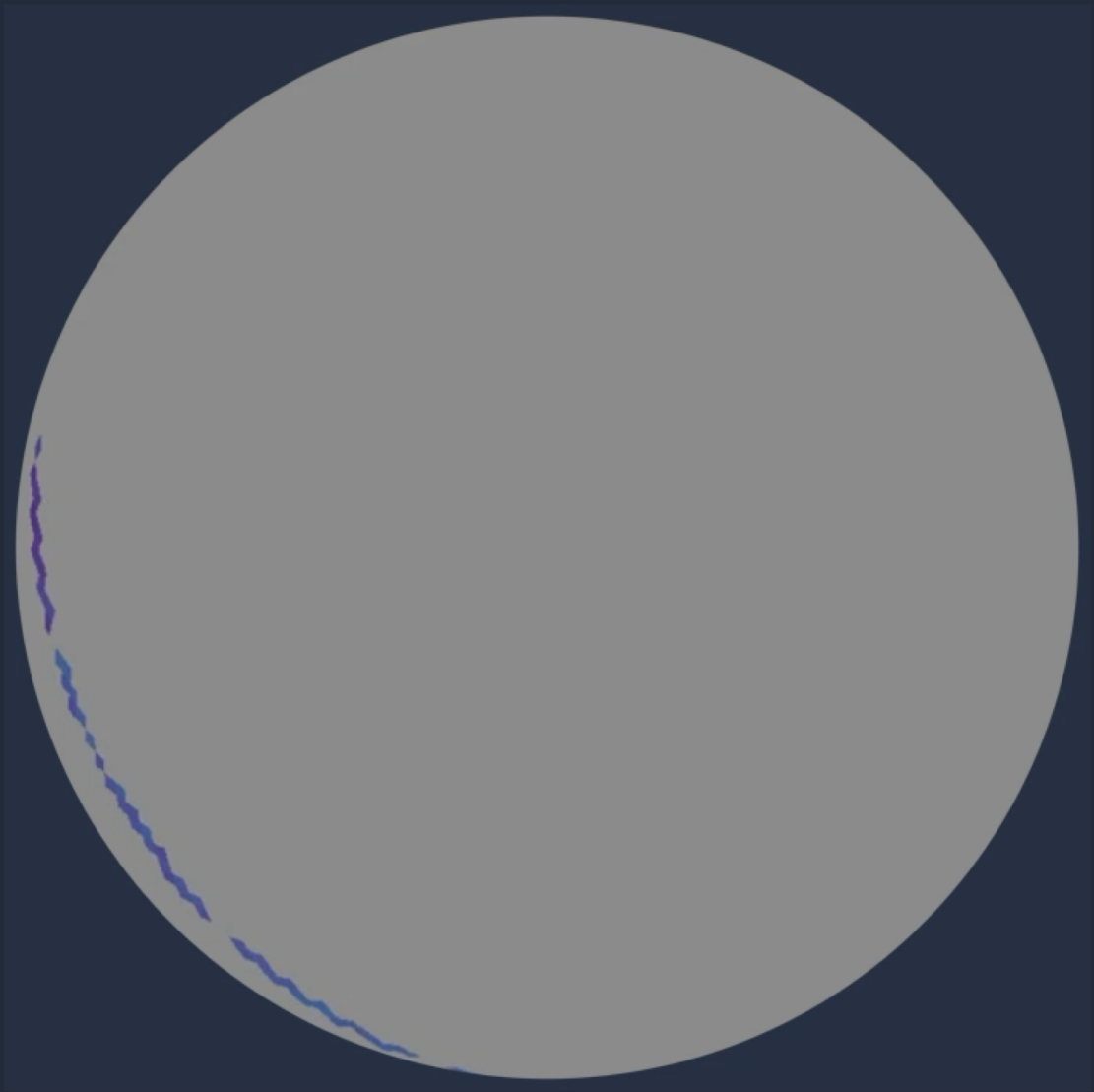


MWA TILE



REFERENCE ANTENNA

BUILDING THE BEAM



SATELLLITES USED

- ORBCOMM Constellation
- Communication satellites which operate at 137 MHz
- Bright radio emitters, with good sky coverage
- Unfortunately we are limited to a very narrow frequency channel

- Do you have ideas on how to identify other sats we see?

THANK YOU

achokshi@student.unimelb.edu.au
aman_chokshi