Murchison Widefield Array Survey Imaging

Steve Ord, Lincoln Greenhill, Randall Wayth, Daniel Mitchell

Harvard-Smithsonian Center for Astrophysics

Outline

- MWA Imaging Pipeline & Formats
- Survey Strategies and Storage

Pipeline

Removes the effects of imaging, ionosphere, and the instrument.

But is not the final data-product

- Input map in instrumental co-ordinate frame - high degree of instrumental polarisation
- Distorted by the ionosphere
- Distorted by wide-field effects

Has to operate in real-time producing an image every 8 seconds

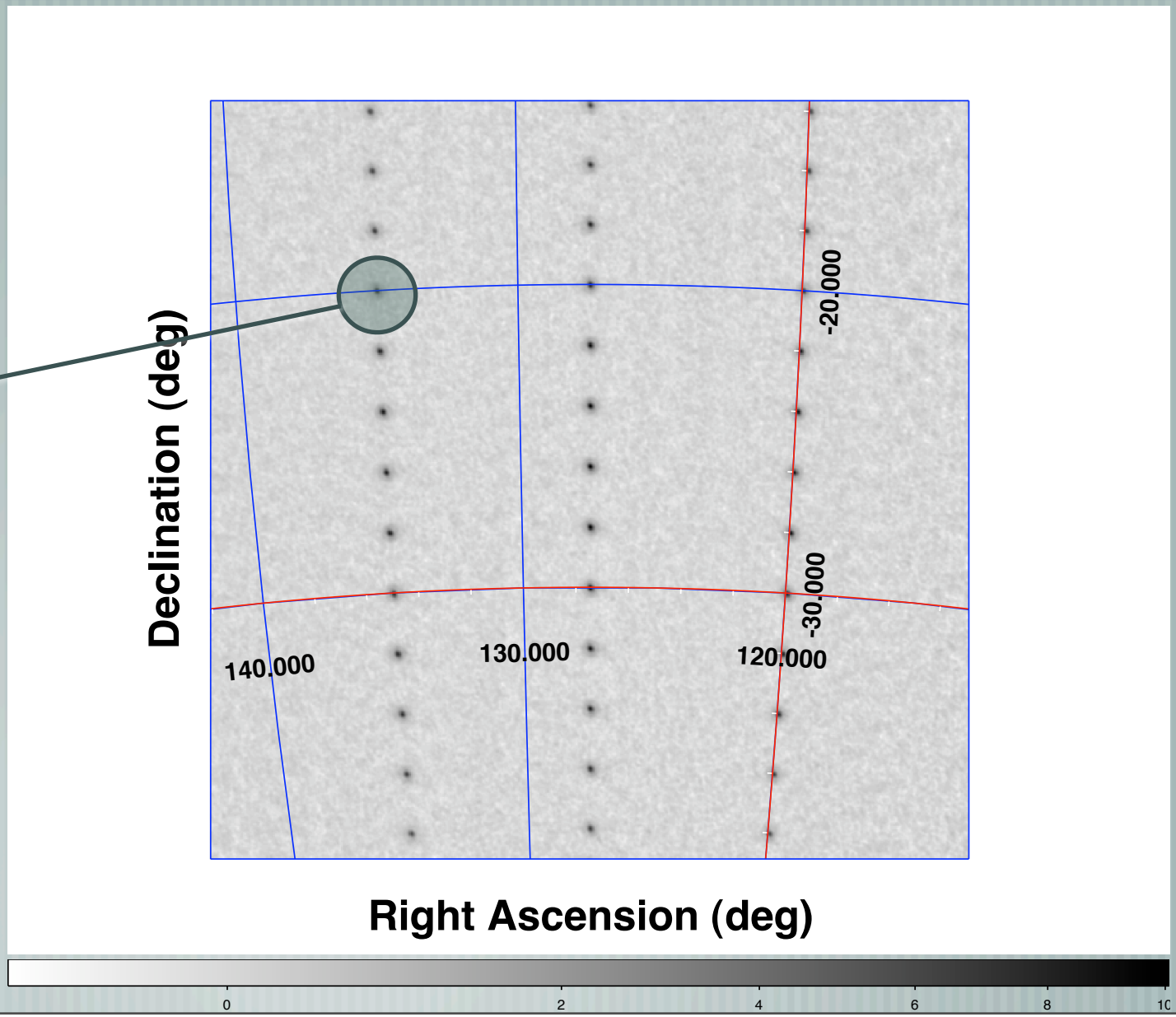
Instrumental Polarisation

Measured polarisation is due to the projection of the instrument dipoles onto the sky

We remove this by constructing the inverse projection for each pixel.

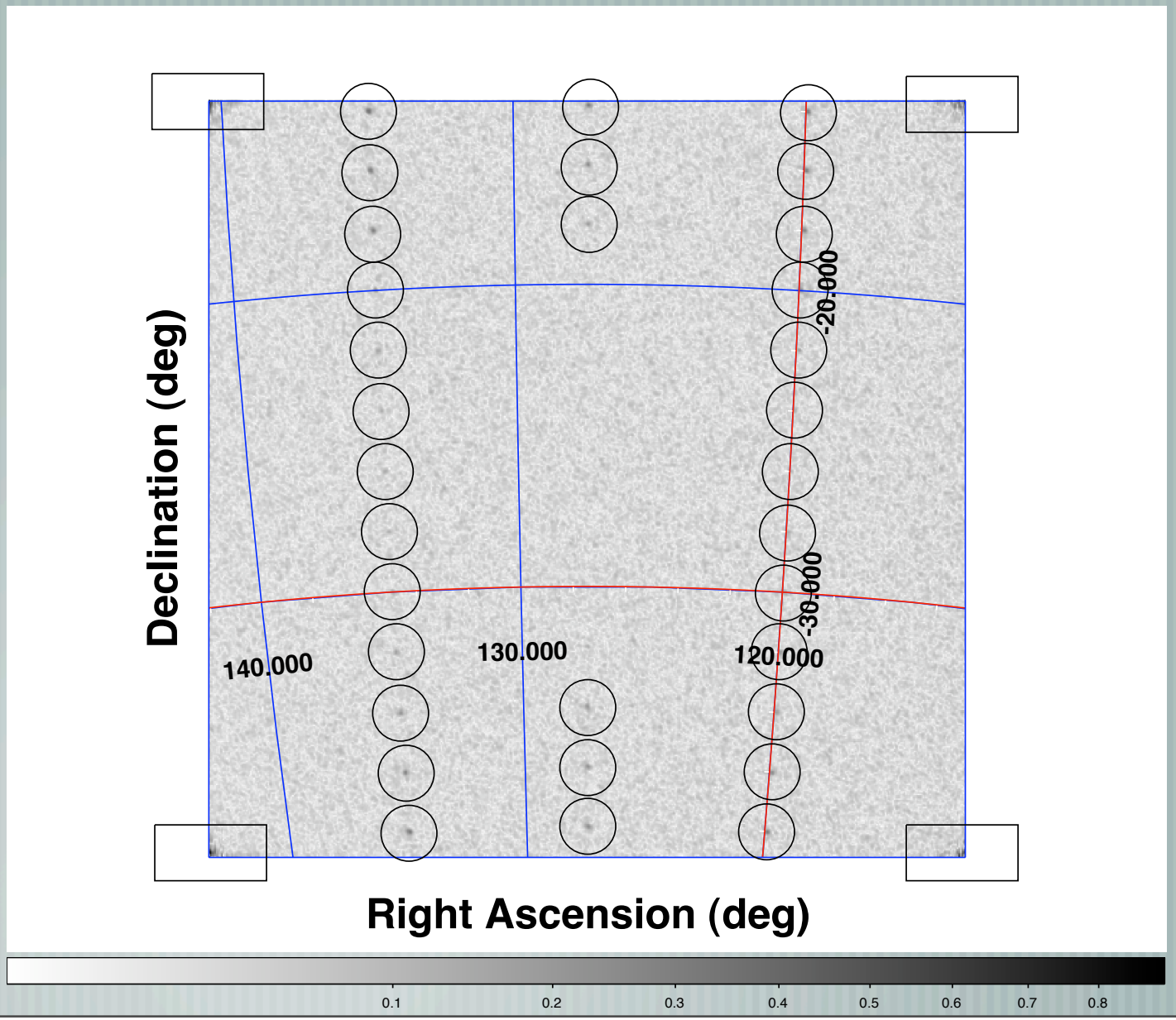
Instrumental Polarisation

Set of unpolarised point sources



Instrumental Polarisation

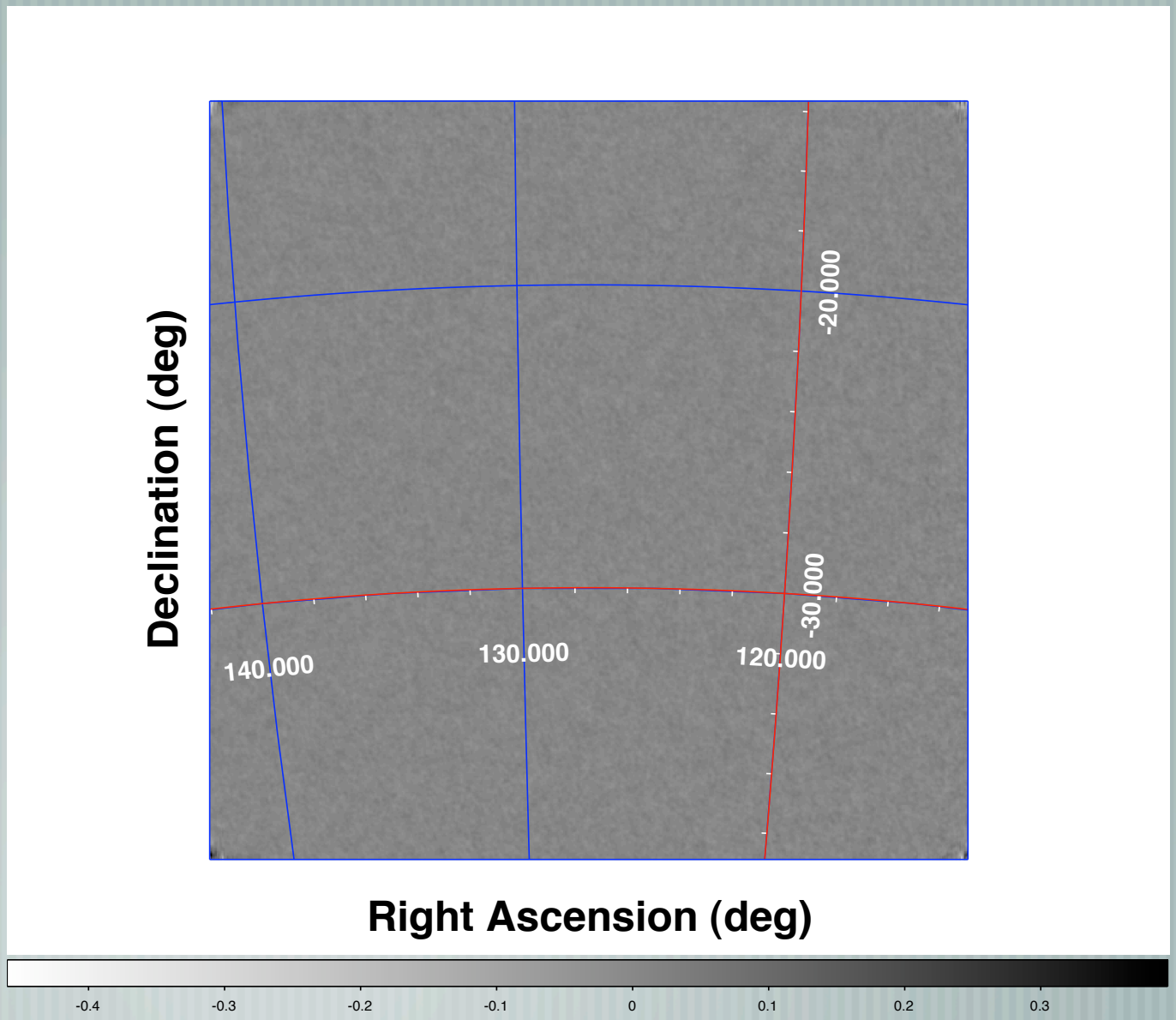
Residual linear polarisation - due to uncorrected instrumental polarisation



Instrumental Polarisation

The correction is performed in the image plane - so can remove all of the projected instrumental polarisation

But only the average instrumental leakage



Resampling

We are removing the wide-field and the ionospheric effects by resampling the measured sky distribution onto a regular grid in sky coordinates.

Imaging snapshots from an instantaneously co-planar array.
Which allows us to remove wide-field effects via a non-linear coordinate transformation in the image plane.

We are characterizing the ionospheric distortion during calibration.
But removing the effect during the resampling.

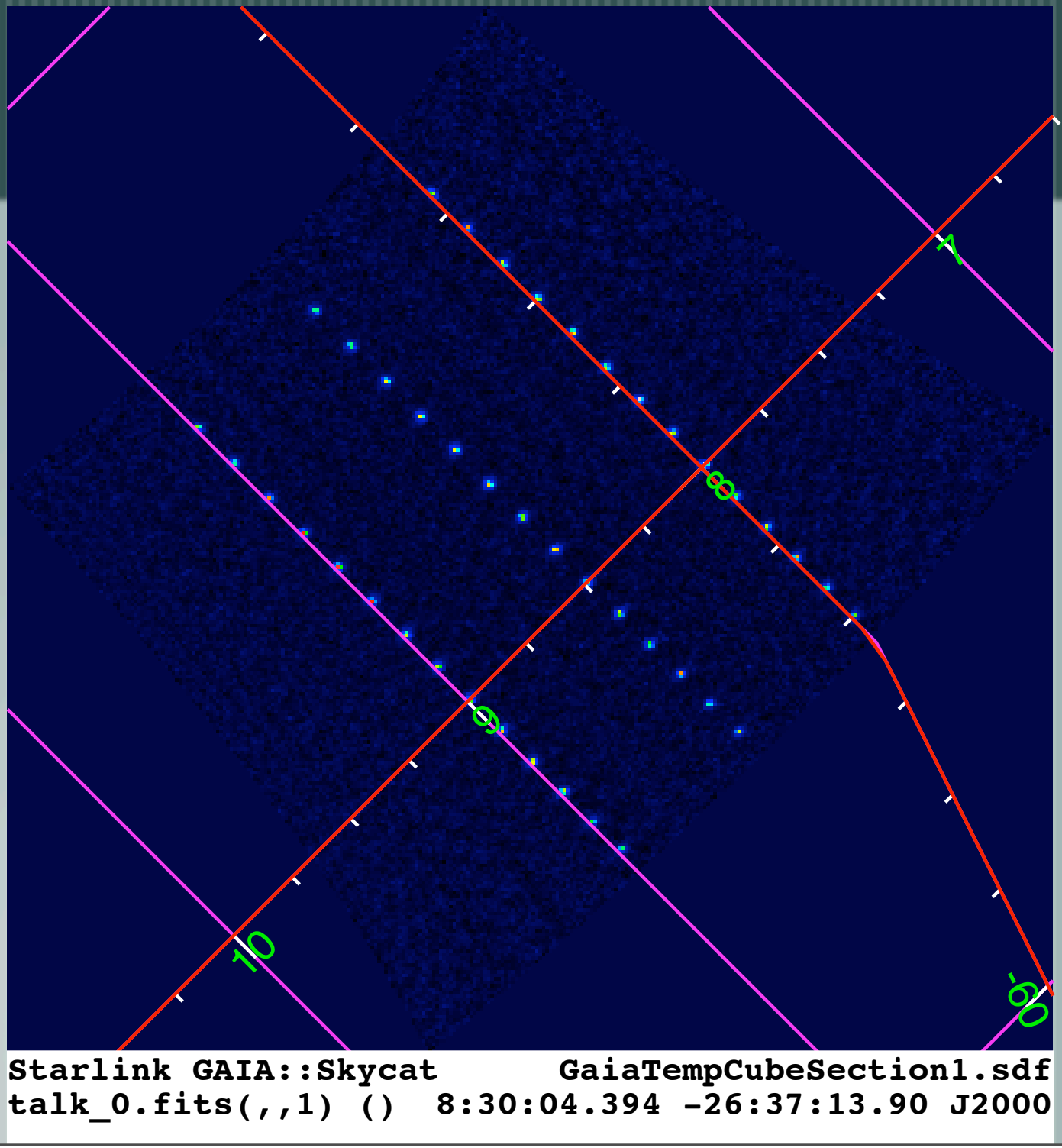
Resampling

Requires a resampling scheme that introduces as few artifacts as possible.

We are currently using a redistribution algorithm that calculates the overlap of the input pixels with an output storage projection

Very computationally intensive: requires multiple 2D polygon overlap calculations for every pixel. Currently uses more FLOPS than any other part of the RTS

Input test image regridded into the storage porjection (HPX)



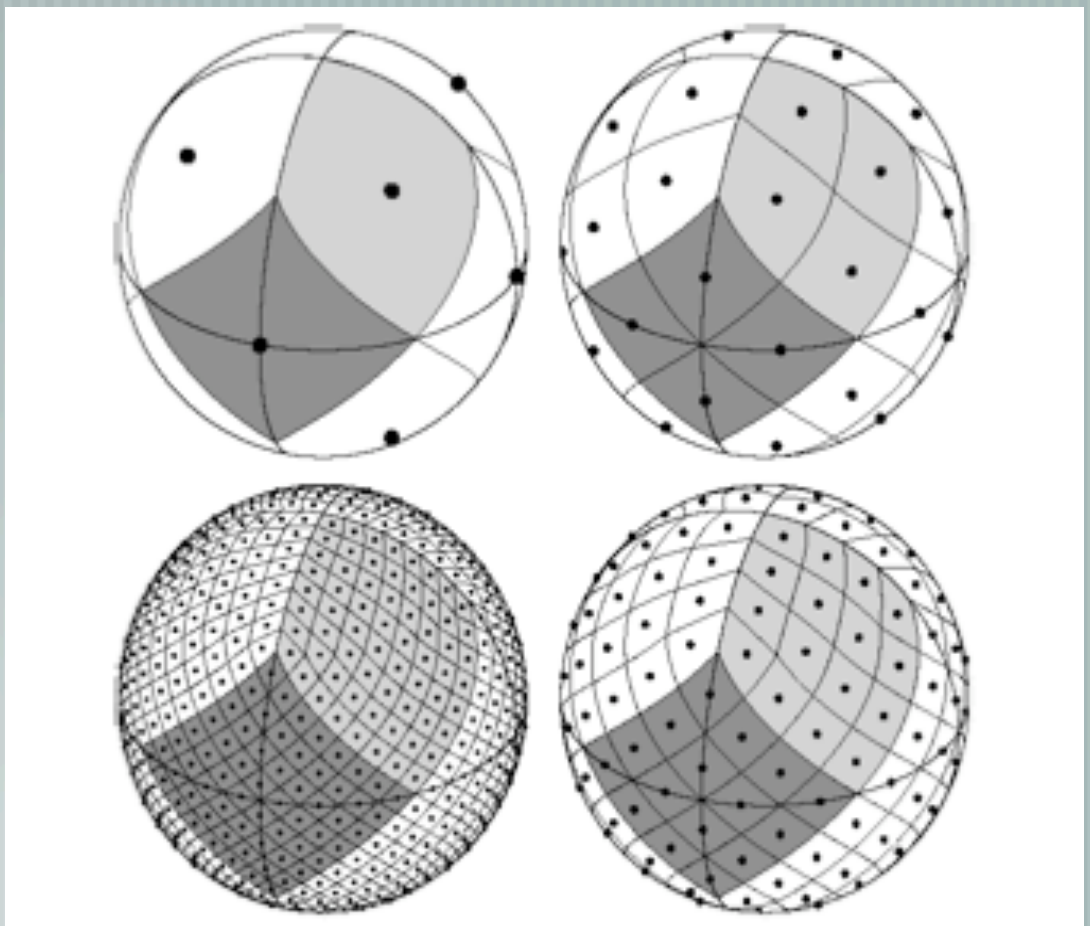
The Storage Projection

Hierarchical, equal area, isolatitude, pixelisation

Divides the sphere into 12 facets

Each facet subdivided in NxN pixels

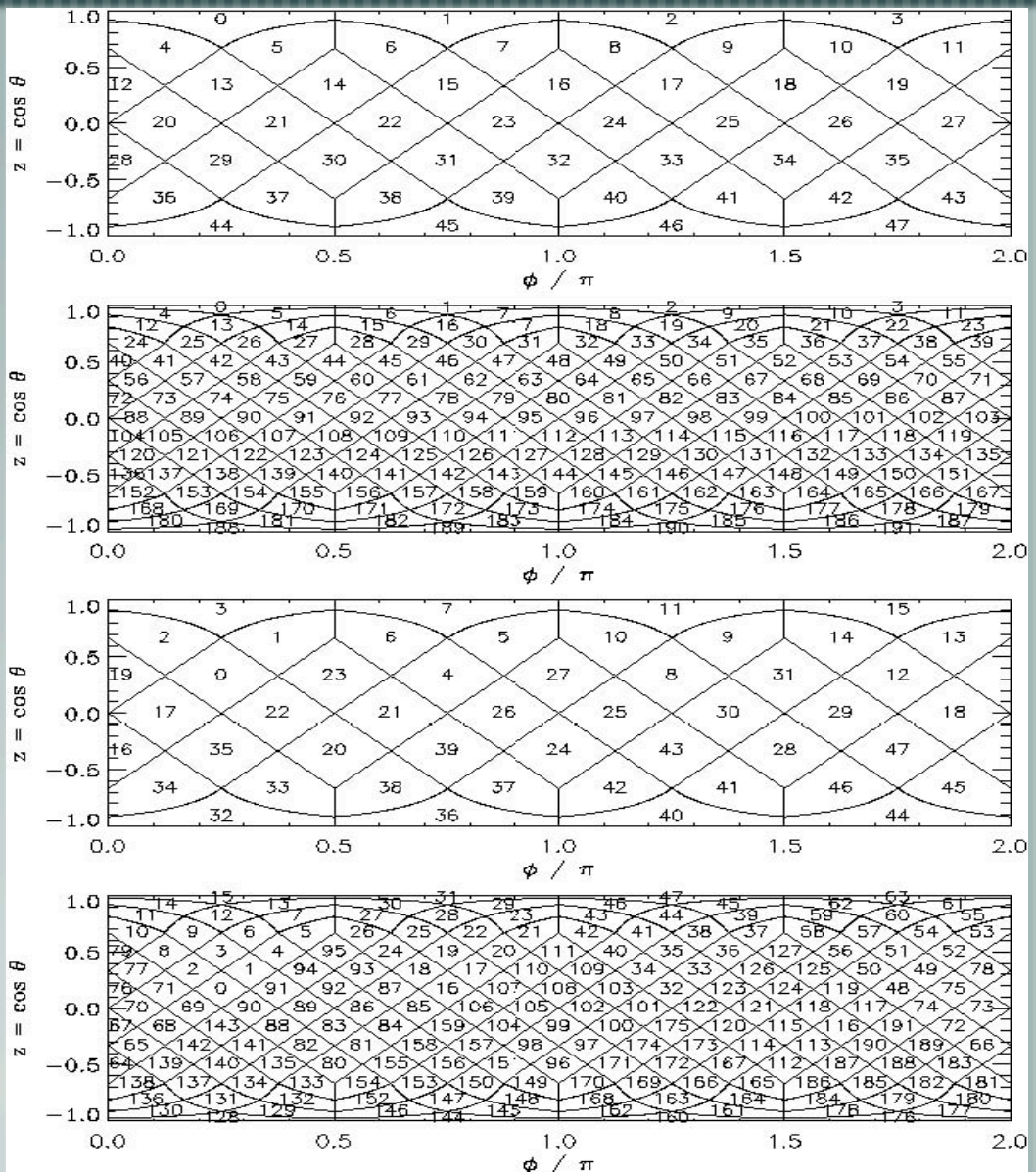
All equal sky area



Pixel Ordering

Original HEALPix ordering is excellent for spherical harmonic analysis or nearest neighbour calculations but terrible for imaging.

Storage format of RTS & Survey is an ordered list of HEALPix pixels, indexed by their pixel number.

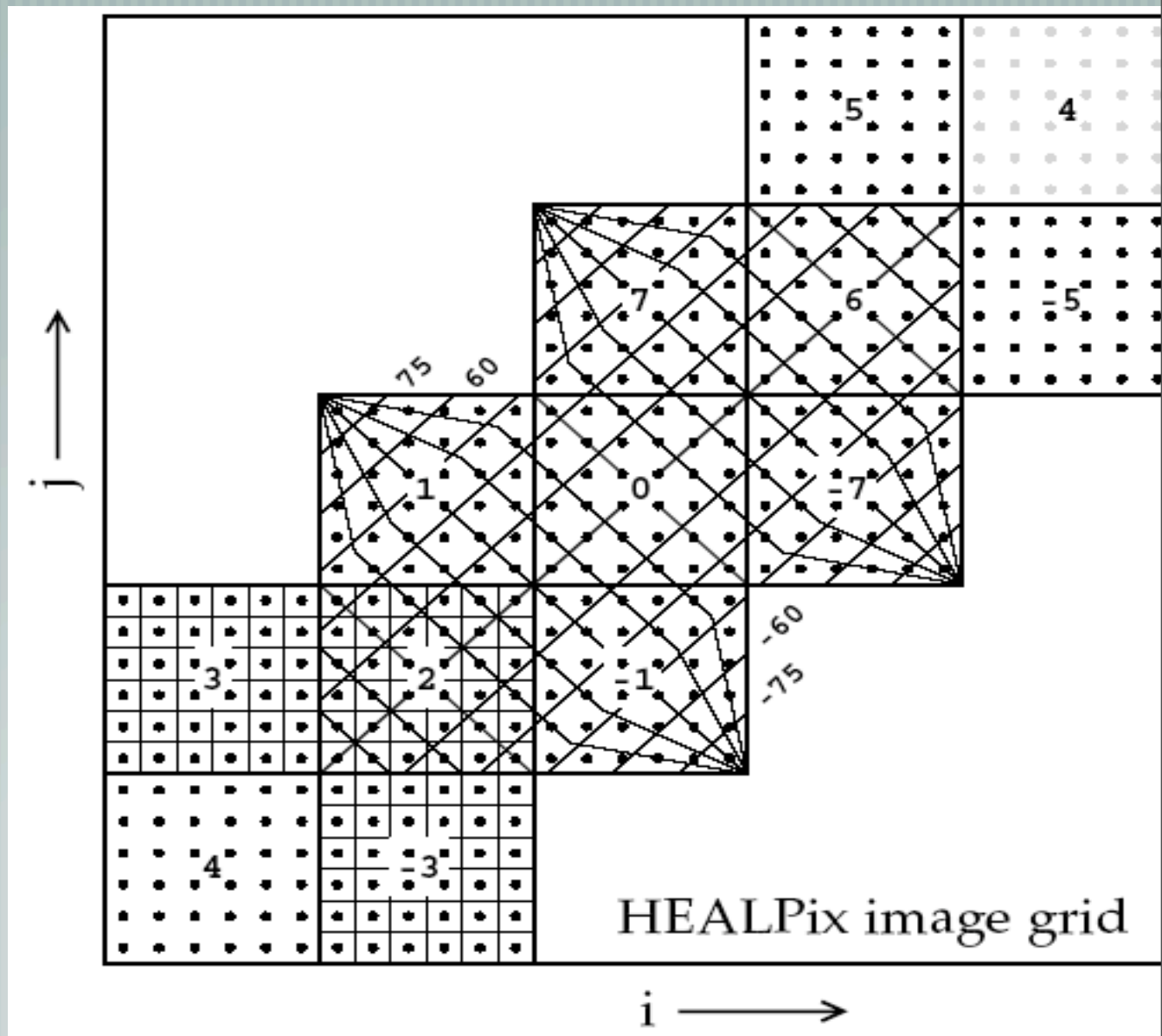


HPX Imaging Pixelisation

Re-orders the pixels in a form suitable for imaging

Very easy to reorder the pixels - no resampling required

Although the coordinate system is rotated by 45 degrees



Data Product .... Problems?

The Survey is very wide band (80->300 MHz)

The data product places constraints on the Survey storage strategy - HEALPix has a limited set of resolutions.

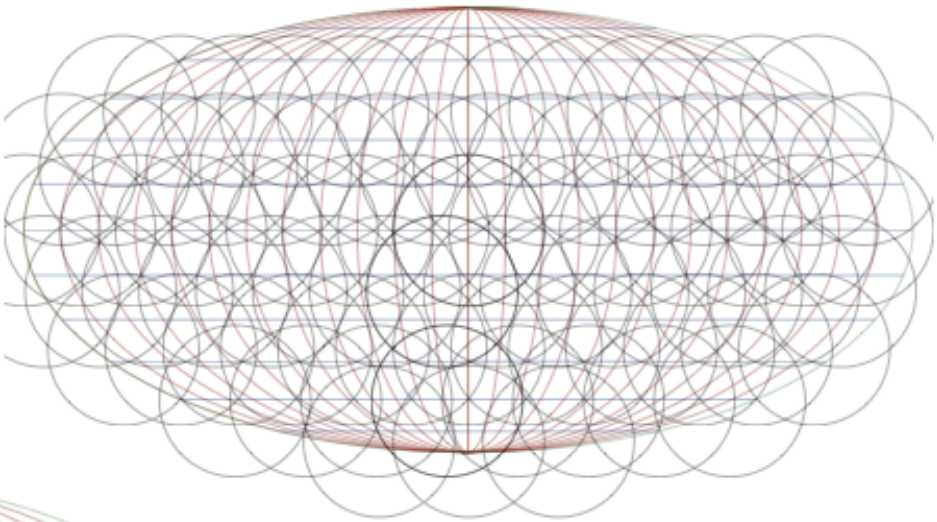
In order to keep the pixel scale the same throughout the data-set we would have to massively oversample the sky at low frequencies.

An alternative is to introduce BANDS into the Survey concept.

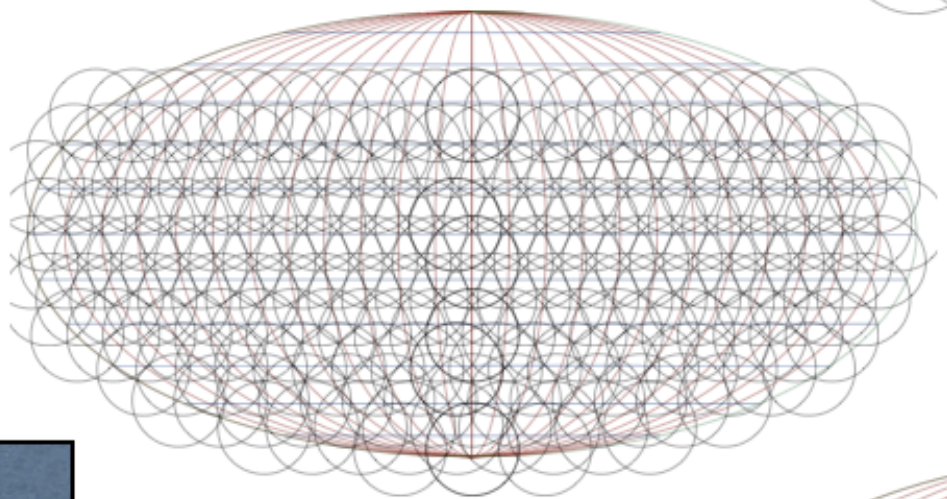
3 different pixel resolutions - associated with 3 different HEALPix scales and 3 different Survey pointing layouts.

MWA SURVEY

Band 1
84 pointings.
Frequency of 96 MHz
1 x 32 MHz band.
NSIDE 1024



Band 2
213 pointings.
Frequency of 147 MHz
3 x 32 MHz band.
NSIDE 2048



Imaging the full beam.

60 percent overlap between adjacent beams

Assuming 16 second slew times and 32 second integration times

Total Survey time in seconds:

BAND 1 == 4032 (67 min)
BAND 2 == 30720 (8.5 hours)
BAND 3 == 110272 (1.2 days)

Band 3
574 pointings.
Frequency of 247 MHz
4 x 32 MHz band.
NSIDE 4096

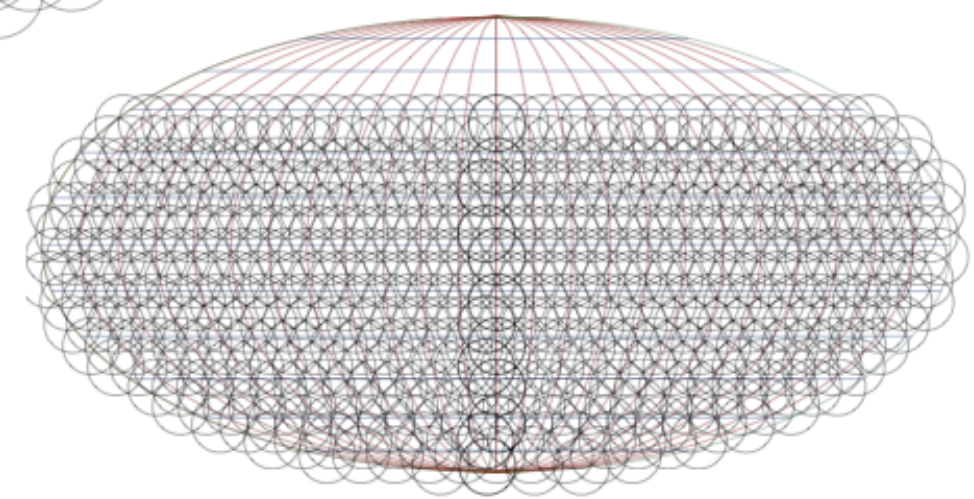
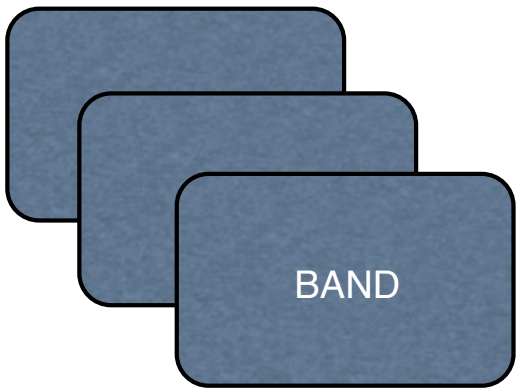


Table 1: Survey Storage Requirements

BAND	NSIDE	Number of pixels in all sky	Number of pixels in Survey Area	Resolution	Storage per channel
1	1024	12,582,912	9,437,194	206”	240 MB
2	2048	50,331,648	37,748,736	103”	960 MB
3	4096	201,326, 592	150,994,944	51.5”	3.8 GB
-	8192	805,601,280	604,200,960	25.75”	15 GB
	30 MHz bands	Number of Channels	Storage All Sky	Survey Area Only	
1	1	768	180 GB	135 GB	
2	3	2304	2.160 TB	1.6 TB	
3	4	3072	11.4 TB	8.5 TB	

From sky position and frequency. The first step is to get HEALPix number of desired sky position via a trivial subroutine call



First level of indexing is by observing band of desired frequency

Channel 0

Channel 1

Channel 2

Second level of indexing is by frequency channel within a band

Channel N

Each declination range consists of an ordered list of HEALPix pixels. For that declination range.

As the pixelisation is the same for all channels within a BAND a sky position lookup can return the reference for that pixel in all channels.

The number of declination ranges can be increased to keep the individual file size low without impacting the algorithm

+40 to +10

+10 to -10

-10 to -40

-40 to -90

Each channel divided into declination ranges - each containing a continuous range of HEALPix pixels

Summary

- Removing instrumental polarisation via application of inverse feed transfer matrix.
- Wide field effects & Ionosphere removed by resampling in the image frame.
- Storage frame is the HEALPix all sky pixelisation.
- Imaging provided in the HPX projection.