

Exploring New Map Creation Methods for BINGO

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Introduction and Objectives

Through sparsity data modeling methods, it is expected to obtain more accurate forms of map making, through greater capacity for source detection, component separation and signal reconstruction.

Sparsity Data Model

A given signal X is sparse when most of its inputs are zero

$$X = [x_1, \dots, x_N]^T, X \in R^N$$

As the linear combination of T elementary waveforms

Sparse representation of data

Signal atoms

$$X = \Phi\alpha = \sum_i^T \alpha[i]\phi_i$$

Decomposition coefficients of X

$$\alpha[i] = \langle X, \phi_i \rangle$$

Dictionary

$$\Phi = [\phi_1, \dots, \phi_T]$$

Starlet Wavelet Transform (IUWT)

- Isotropic Undecimated Wavelet Transform (IUWT) is adapted for astronomical data, where the sources are approximately isotropic.
- Starlet Transform decomposes an $(n \times n)$ image into layers $[J=1, J]$, and is represented by :

$$c_0 [k, l] = c_j [k, l] + \sum_{j=1}^J w_j [k, l]$$

Diagram illustrating the decomposition of an image into smoothed and detail components:

- The term $c_j [k, l]$ is labeled "Image".
- The term $\sum_{j=1}^J w_j [k, l]$ is labeled "smoothed image".
- The term $c_0 [k, l]$ is labeled "Image detail coefficient".
- A curved arrow points from the label "Image" to the term $c_j [k, l]$.
- A curved arrow points from the label "smoothed image" to the term $\sum_{j=1}^J w_j [k, l]$.
- A curved arrow points from the label "Image detail coefficient" to the term $c_0 [k, l]$.
- Annotations on the right side of the equation:
 - "Image scale" next to (2^{-j}) .
 - "Scale function" next to $\phi(x)$.

- The wavelet transform is calculated using a bank of filters.

$$h_{2D}, g_{2D} = \delta - h_{2D}$$

- ‘h2D’ is tensor product of two one-dimensional (1D) filters ‘h1D’.
- Delta is the Dirac function

- With this, we have that the next layer will be:

$$c_{j+1}[k, l] = \sum_m \sum_n h_{1D}[m] h_{1D}[n] c_j[k + 2^j, l + 2^j n]$$

$$w_{j+1} = c_j[k, l] - c_{j+1}[k, l]$$

- The next step is to choose a scaling function to obtain the coefficients of the convolution mask (filter in one dimension).
- After this process of convolving the data, and obtaining a smoothing of the image, the discrete wavelet transform is obtained from this difference:

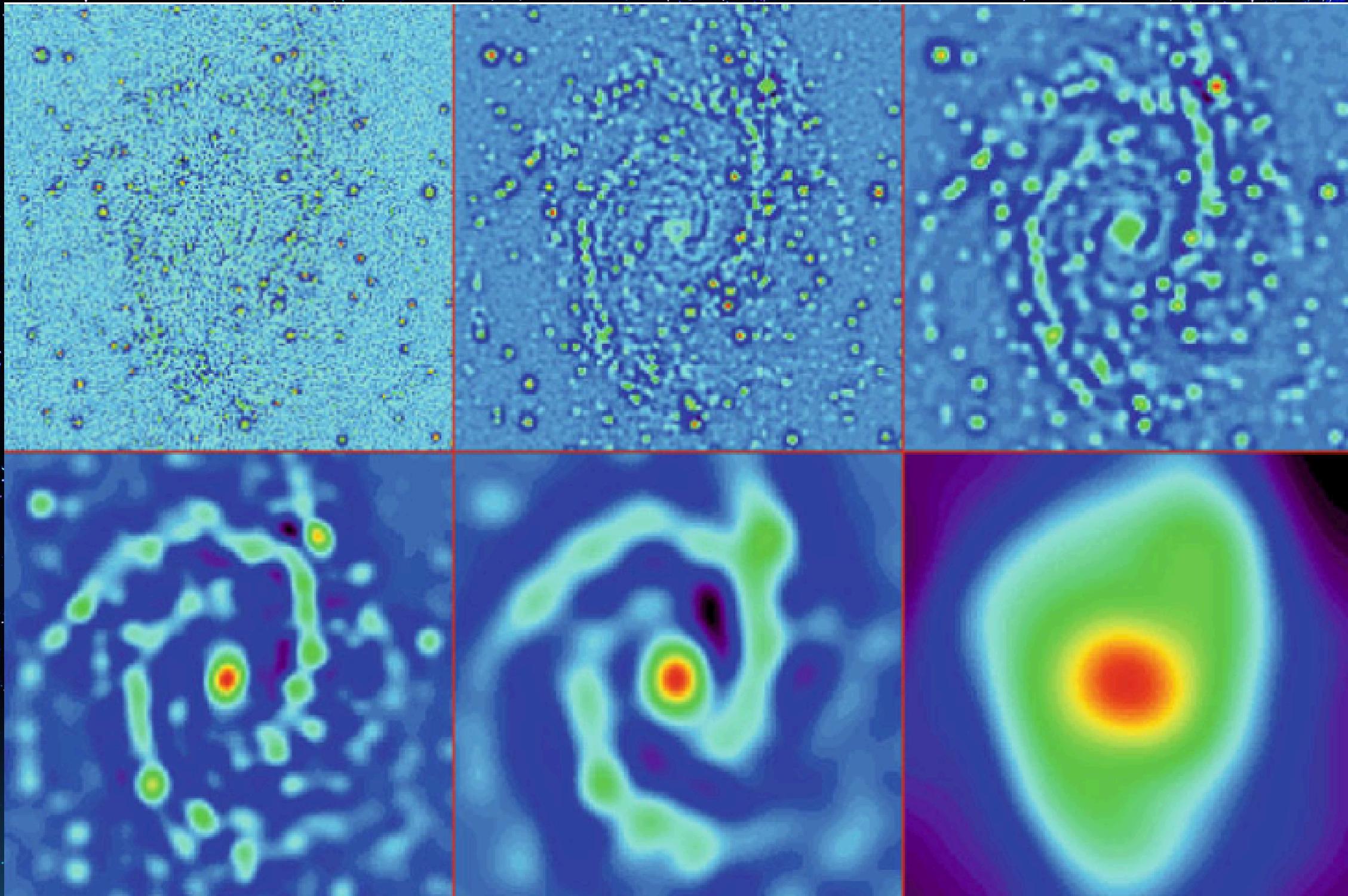
$$c_j [k, l] - c_{j+1} [k, l]$$

- The process is repeated until all j desired layers are obtained.

$$\alpha = \{w_1, \dots, w_j, c_j\}$$

- Alpha presents the wavelet transform of the data.

Example



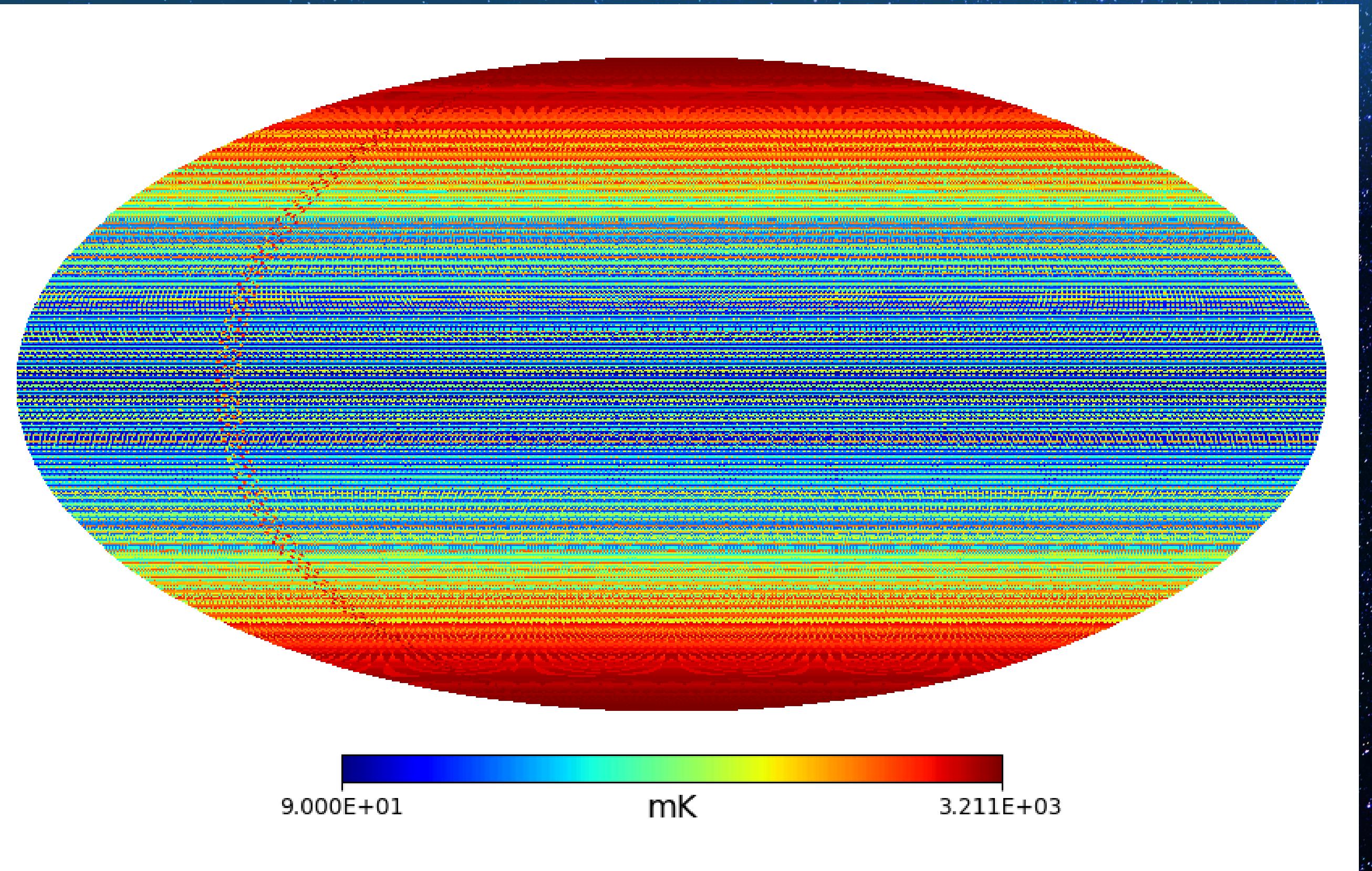
Starlet Transform in Astronomical Data Processing
Wavelet transform of NGC 2997 by the IUWT. The co-addition of these six images reproduce exactly the original image.

RESULTS so far

- To be able to use algorithms that make use of the tools presented, it was necessary to amplify the declination range in the BINGO TODs simulations, so that the entire sky was covered.
- New files with corresponding sky coordinates were produced.
- Making some modifications to the original code "hitmap.py" it was possible to obtain three maps of the entire sky.

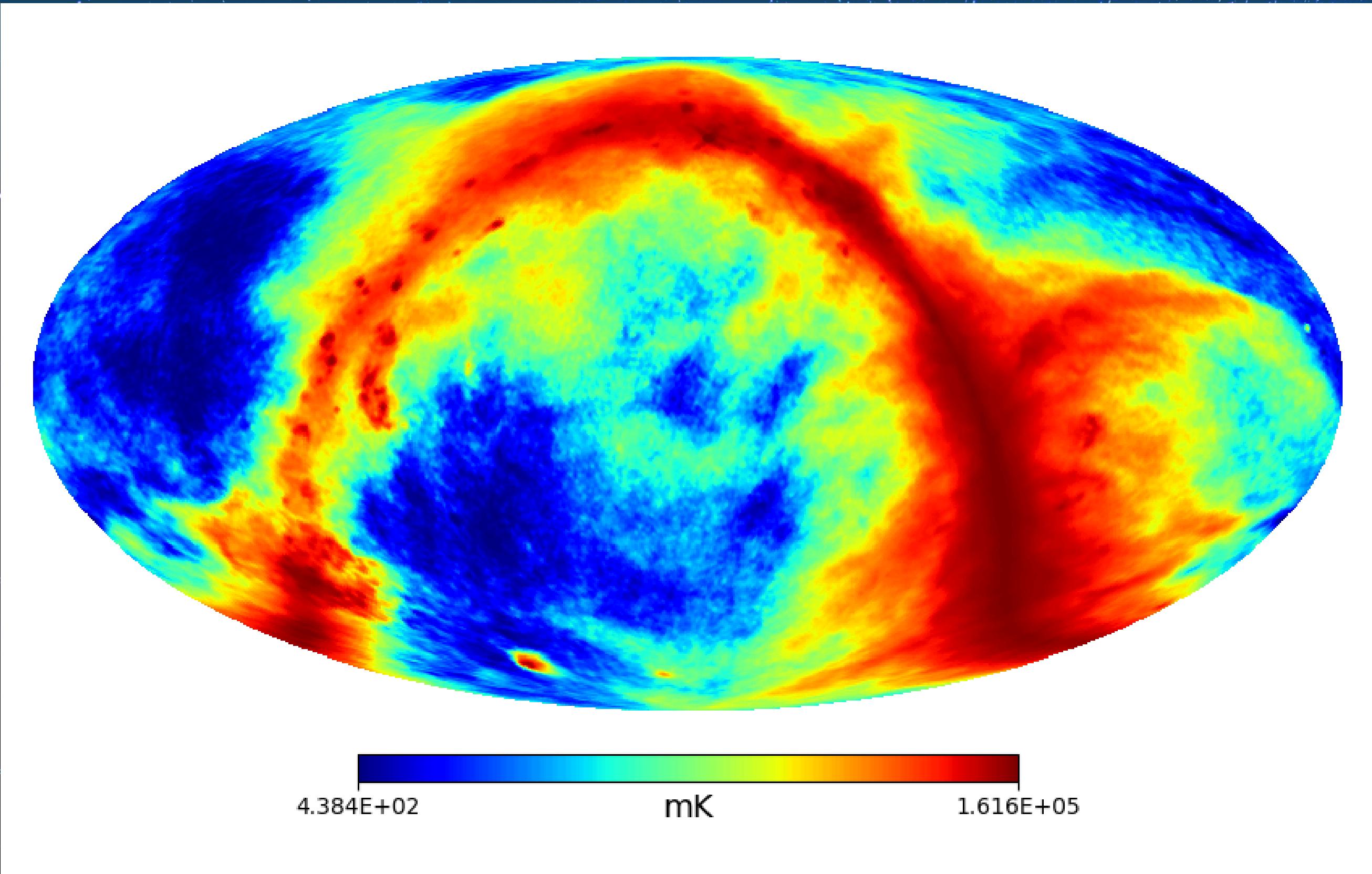
<https://doi.org/10.48550/arXiv.2107.01635>

Results so far



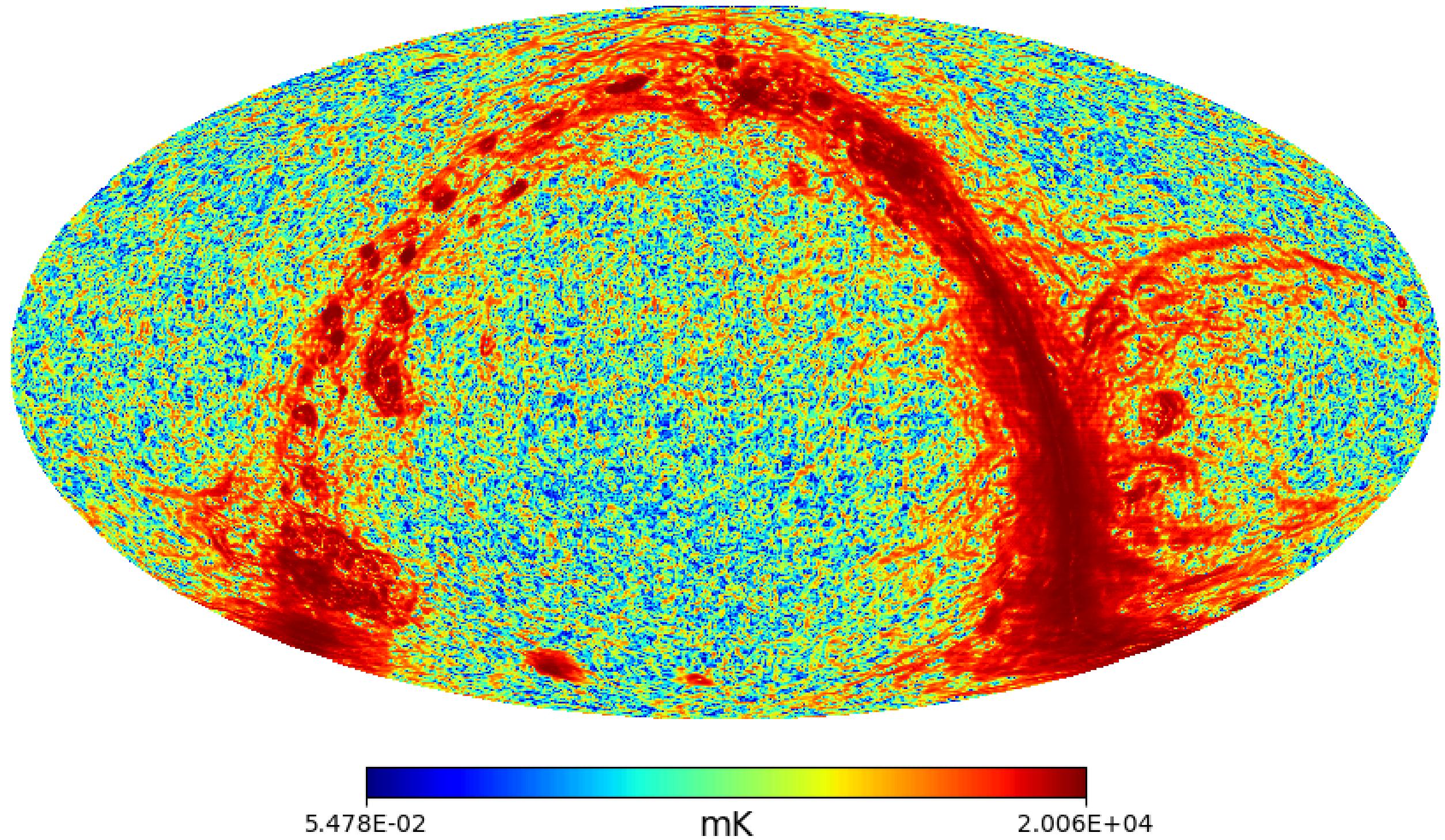
Sweep of the BINGO feed horns over time (TOD). Each line represents a feed horn, and each pixel expresses the amount of temperature data it contains.

Results so far



Average temperature values for each pixel, covering the entire declination range.

Results so far



Standard deviation of temperature values contained in each pixel, across the entire sky

Next Steps

<https://doi.org/10.48550/arXiv.2209.11701>

<https://doi.org/10.1093/mnras/staa2854>

Thank you!