Omniscopes: Large Area Telescopes With Reduced Computational Cost

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INTRODUCTION

A new method in radio astronomy uses an arbitrary array of radio telescopes whose signals can be correlated via Fast Fourier Transforms (FFTs). These hierarchies are omnidirectional and omnichormatic, and will thus referred to as *omniscopes*. While providing lower resolution, the financial and computational costs of omniscopes are significantly decreased.

METHOD

❖ The measured voltage (V) from each antenna can be represented as a multidimensional array.

❖ Convolution of this voltage array with a parity reversed copy of itself it produces a visibility vector.

❖ Each element of the visibility vector is the correlation of signals from antennae separated by a distance vector, then summed over all pairs of the same separation distance.

❖ The general equation for multidimensional convolution of FFTs is given as

$$G_{i_1 i_2} = \sum_{i'_1 i'_2 \ldots} F_{i'_1 i'_2} F_{(i'_1 - i_1),(i'_2 - i_2),\ldots,}$$

where *F* is the antenna voltage array and *G* is the visibility vector.

❖ Binning the visibility vector radially, the distribution for each hierarchy can then be compared to the those given in the Mileura Wide-field Array (MWA) experiment.

VISIBILITY COMPARISIONS

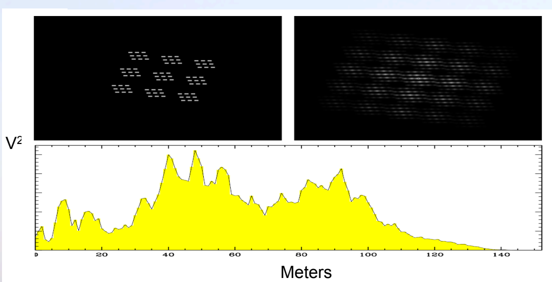

FIG. 1: The antenna layout of 5 × 3 antenna blocks arranged in 3 × 3 blocks (top left) convolved with its parity reversal gives the 2D distribution (top right), and binning this radially gives the 1D distribution (bottom) for the “3-level” layout, which is plotted on a linear scale.

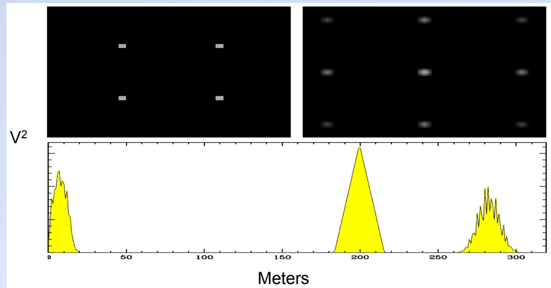

FIG. 2: Antenna layout (top left), 2D distribution (top right) and 1D distribution (bottom) for the “Blocks” layout consisting of four widely separated 16 × 16 antenna blocks.

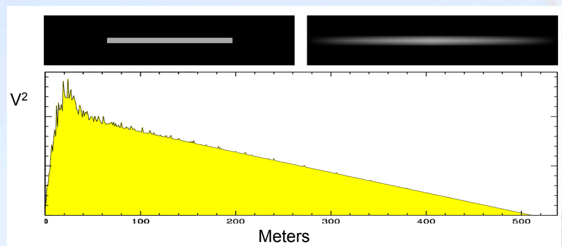

FIG. 3: Antenna layout (top left), 2D distribution (top right) and 1D distribution (bottom) for the “Plank” layout consisting of a single 512 × 32 antenna block.

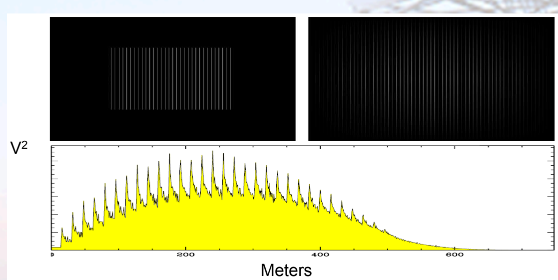

FIG. 4: Antenna layout (top left), 2D distribution (top right) and 1D distribution (bottom) for the “Strips” layout consisting of 32 separated rows of antennae.

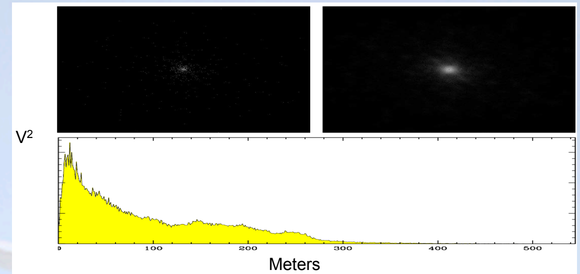

FIG. 5: Antenna layout (top left), 2D distribution (top right) and 1D distribution (bottom) for a the simulated MWA design from [Bowman et. al.] with r^{-2} antenna density.

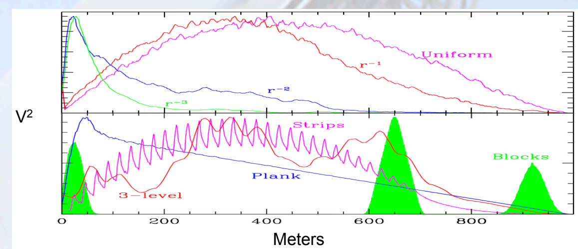

FIG. 6: The distributions from four simulated MWA layouts [Bowman et. al.] with N^2 computational cost (top) are compared with distributions from four hierarchical grids with $N\log_2 N$ computational cost (bottom).

CONCLUSIONS

❖ Using omniscopes in radio astronomy is effective as it requires fewer telescopes and computer computations.

❖Each explored hierarchy has advantages and limitations in its distribution of the measured visibility vector, but these are comparable to the results of the MWA experiment.

❖ The usage of omniscopes will encourage future radio astronomy research without blowing the budget.

References:

- M. Tegmark and M. Zaldarriaga (2009). Omniscopes: Large Area Telescope Arrays with only N log N Computational Cost.
- J. Bowman, M. Morales, and J. Hewitt . Constrains on Fundamental cosmological Parameters With Upcoming Redshifted 21 cm Observation. *The Astrophysical Journal, 661:1Y9, 2007 May 20.*