Optimizing the Total Power Dish Size for the ngVLA Interferometer

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GRAD MAP

① Introduction

The next generation Very Large Array (ngVLA), Figure 1, is a proposed radio telescope interferometric array. It will operate between 1.2 GHz -116GHz. We are using the inner core configuration of ~100 dishes spaced out over ~1000m with an additional Total Power dish. The Total Power Dish is added to recover larger scale emission and produce a higher fidelity image.

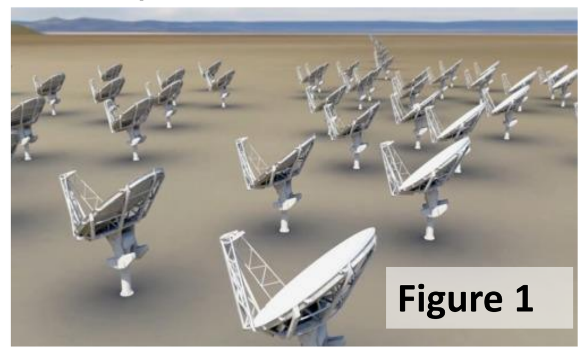

Figure 1

② Radio Interferometry Background

- Radio interferometry is the process of forming an image made by measurements from pairs of dishes.
- The number of pairs of dishes equals:

$$\frac{N(N-1)}{2}$$

where N is the number of dishes.
- Higher number of dishes = more well-sampled image.

There are 4 angular scales:

- $\frac{\lambda}{D_{max}}$ ~ Angular resolution of the array; smallest angular scale detectable by the interferometer; D_{max} is the diameter of the ngVLA array
- $\frac{\lambda}{D_{min}}$ ~ Angular resolution of the minimum dish separation; largest angular scale detectable by interferometer; D_{min} is the distance between dishes inside the array
- $\frac{\lambda}{d}$ ~ Angular resolution of a single dish; where **d** is the diameter of the single dish
- $\frac{\lambda}{D}$ ~ Angular resolution of the Total Power dish; where **D** is the diameter of the dish

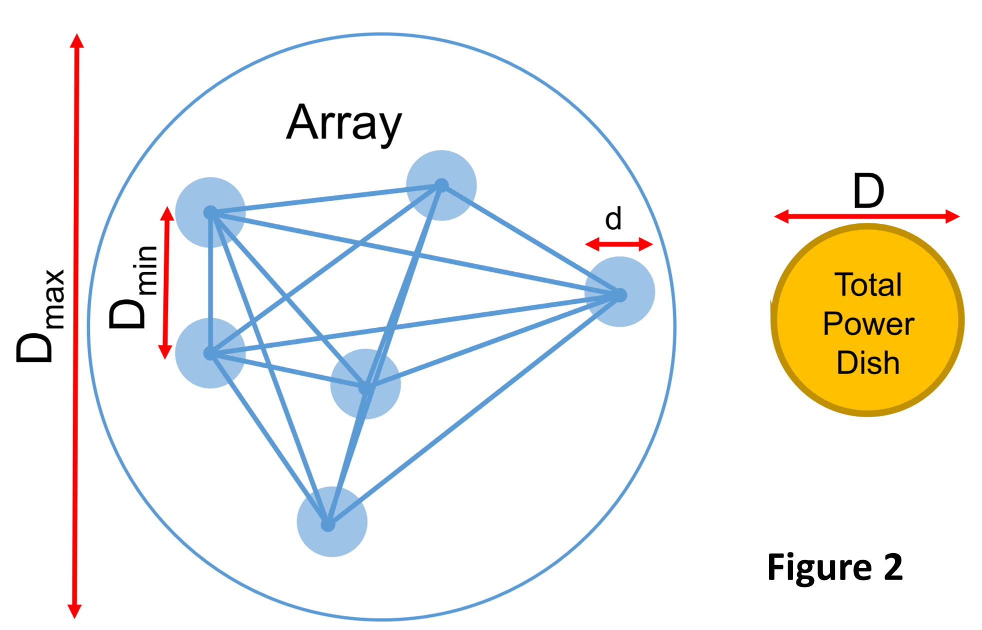

Figure 2

- In Figure 2, there are 6 dishes in the array, therefore there are 15 pairs (as shown with the blue lines).
- Also shown is the Total Power Dish.

Symbols Used:

λ = wavelength of incoming source
d = diameter of a single dish in the array
D = diameter of the Total Power dish
D_{max} = largest separation between dishes in an array
D_{min} = smallest separation between dishes in an array
uv = Fourier Transform counterpart of sky coordinates xy

③ Problem

- It is difficult, expensive, and currently impossible to build a radio dish as large as the ngVLA (~1000m in D_{max}).
- Therefore, radio astronomers build much smaller dishes and combine the information collected from them through interference patterns.
- Since there is separation between the dishes in the array, there will be gaps in the uv plane
- A Total Power dish is an additional dish not pairing with the other dishes to provide spacings between 0 and D.

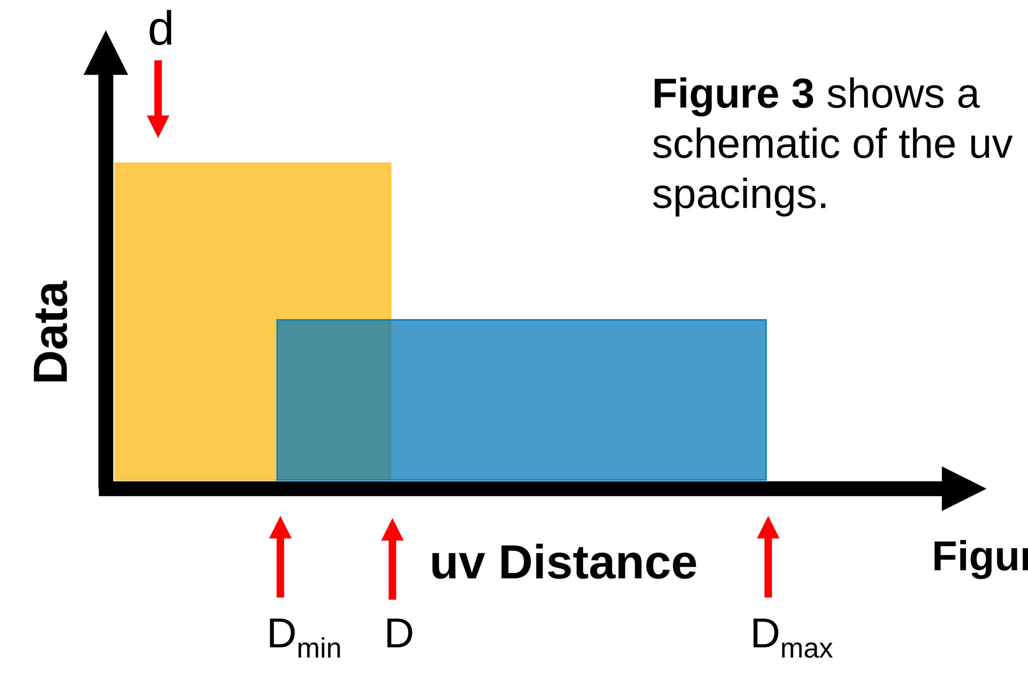

Figure 3 shows a schematic of the uv spacings.

Figure 3

④ Goal

We want to find the best dish size for the Total Power dish that can be added to the current ngVLA model. To find the best dish size of the Total Power dish, we used a model map, Figure 4, as our simulated galaxy and ran scripts that we created in Common Astronomy Software Application (CASA).

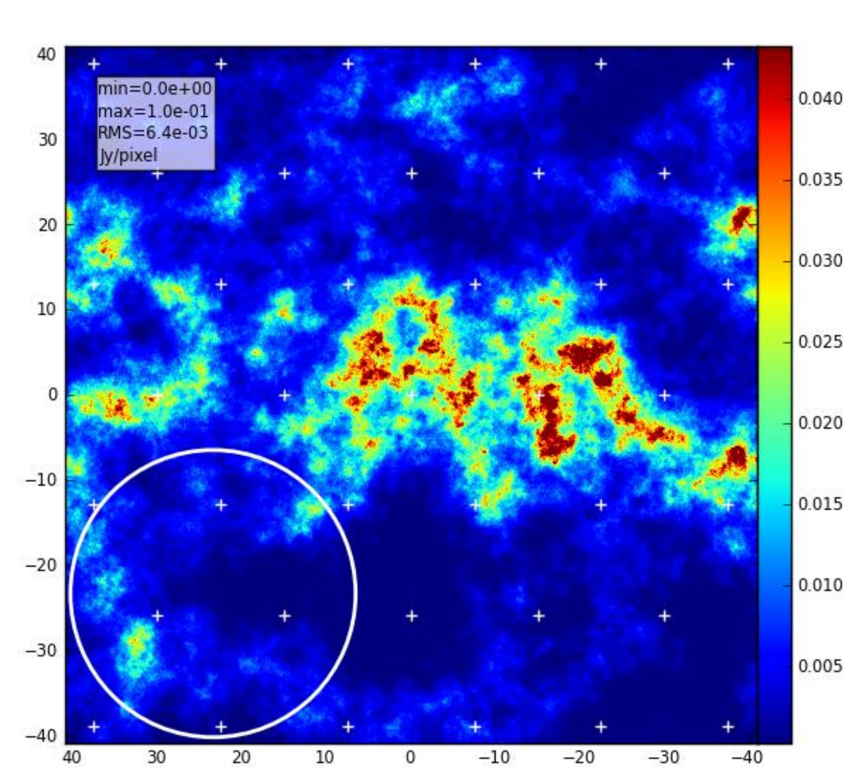

Figure 4

⑤ Method

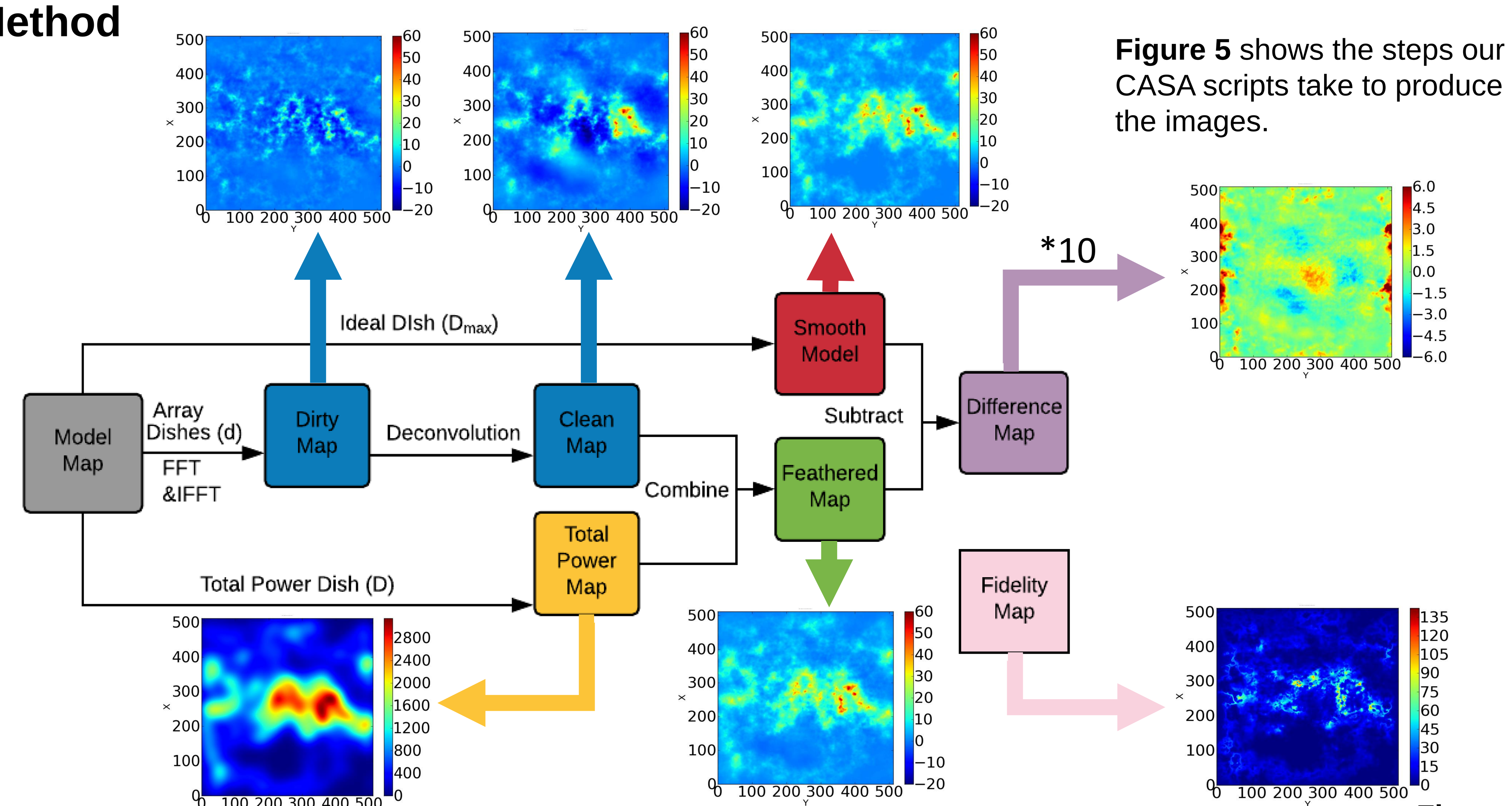

Figure 5 shows the steps our CASA scripts take to produce the images.

Figure 5

- As shown above, the Model Map data, recovered from the simulated ngVLA, goes through a Fast Fourier Transform (FFT) and an inverse FFT (IFFT). Next, the map is deconvolved, combined with the single dish data, and compared to the Smooth Model.
- The Smooth Model is the Model Map if an ideal telescope gathered the data.
- The Difference Map is the difference between the Smooth Map and Feathered Map, which we would like to be zero.

⑥ Fidelity

- We compare the fidelity to the dish size. The fidelity is a measure of the quality of the image and acts like a signal to noise ratio.

$$\text{Scalar Fidelity} = \frac{\text{Max Model}}{\text{Root Mean Square Difference}}$$

$$\text{Fidelity Map}_0 = \frac{\text{Smooth Map}}{\text{Smooth Map} - \text{Clean Map}}$$

$$\text{Fidelity Map}_1 = \frac{\text{Smooth Map}}{\text{Smooth Map} - \text{Feathered Map}}$$

- Scalar fidelity is the fidelity used for comparison in my project and is plotted in Figure 6.
- Fidelity Map_0 is the smooth map versus clean map and does not depend on the dish size.
- Fidelity Map_1 is the smooth map versus the feathered map.

⑦ Results

- The bigger the Total Power dish, the better the fidelity.
- More pointings does not always mean better fidelity.
- 23 pointings with a 100m dish gave the best fidelity.

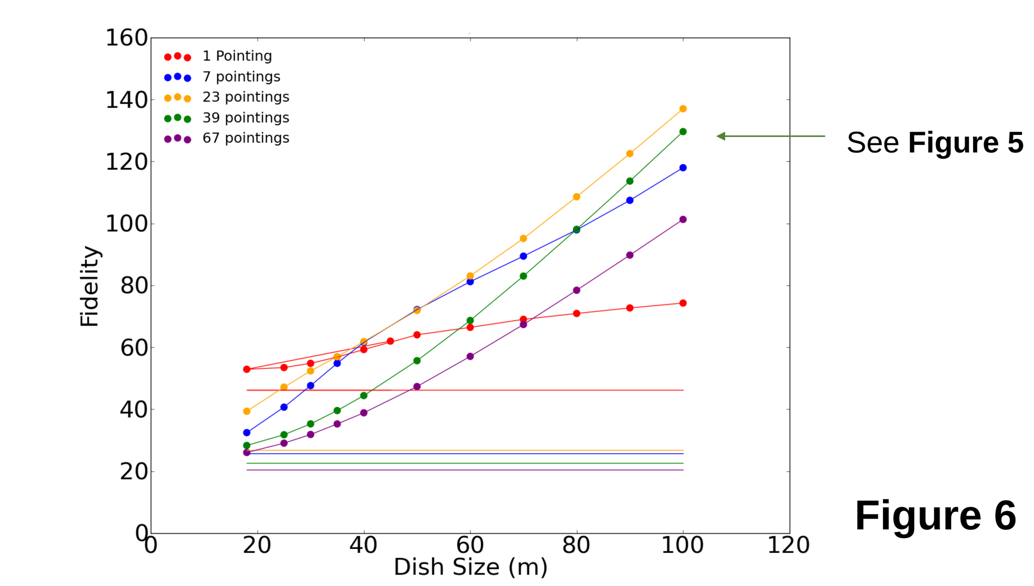

Figure 6

For more information and references, see:
http://ngvla.nrao.edu/

⑧ Conclusions and Future Work

- A mosaic of the pointings produces the best fidelity when there is a Total Power dish.
- Larger Total Power dish = better fidelity.
- If a full sky steerable radio dish, larger than 100m, is feasible, we would run simulations of that size.
- Future studies should vary the sky model, track length, declination, and introduce realistic noise.

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