THESIS TITLE

by

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A thesis submitted in partial satisfaction of the

requirements for the degree of

Master of Astrophysics

in

Astronomy

in the

Graduate Division

of the

University of California, Berkeley

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Professor TBD
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Fall 2018

The thesis of Kara Kundert, titled THESIS TITLE, is approved:

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THESIS TITLE

Abstract

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In this memo, we seek to lay out a case for the use of absorber in an interferometric study of the spatial monopole of the 21cm reionization signature (i.e. the “global signal”). As discussed in previous memos, we believe that the way to optimize the sensitivity to the monopole term comes from the use of absorptive walls between the antennas to impose an artificially high “horizon”, or temperature discontinuity, onto the beam of each antenna, thereby pushing the monopole into higher order spatial terms (Kundert 2016). With the new simulation, we are able to manipulate many parameters of our virtual interferometer, including but not limited to the antenna spacing, absorber wall height, and the attenuating properties of the absorber itself. From our exploration of these parameters, we are able to now state with certainty that we are able to detect the monopole term of the sky using a classical interferometer.

To Ossie Bernosky

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Acknowledgments

These are the acknowledgements.

Chapter 1

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1.1 Simulation

discuss: layout of simulation, frequency-invariant beam, how absorber acts as modifier to the beam, math and measurements behind absorber vs. frequency, everything that feeds into getting visibilities by u-mode

The basis of our simulation lies in the calculation of a visibility using Eq. (1.1).

$$V(u,v) = \int A(\hat{s}) \cdot I_{sky}(\hat{s})\ e^{-2\pi i \frac{\vec{b} \cdot \hat{s}}{\lambda}} d\Omega \tag{1.1}$$

From this equation, we have three parameter spaces to play in: the beam of the antenna $A(\hat{s})$, the behavior of the sky $I_{sky}(\hat{s})$, and the baseline vector $\vec{b}$. For ease of organization, we'll now split our discussion into two parts, sky characteristics vs. system characteristics.

Sky Characteristics & Parameters

At present, our goal is to better understand how an interferometer receives signal from a monopole sky, so we're only inputting skies without any spatial variation. However, while we are only inputting spatially flat maps into the simulation, spectral variation across our science band is an option. The simulation has functions for both spectrally-flat (for calibration and verification purposes) and synchrotron-characteristic sky maps, using Eq. (1.2) as our basis for calculating brightness temperature as a function of frequency. These maps are then converted to Janskys in order to be usable as the $I_{sky}(\hat{s})$ term in the visibility calculation using Eq. (1.1).

$$T(\nu) = T(\nu_{150}) \left(\frac{\nu}{\nu_{150}} \right)^{-\beta} \tag{1.2}$$

System Characteristics & Parameters

This leads us to the characteristics of our interferometer itself. Within this framework, there are two key areas of interest to us: how our sensitivity to the monopole varies with the separation between antennas, and how it changes in the presence of different absorber structures and materials. Another way of viewing it would be: how do the characteristics of the individual elements and of the array design affect our ability to make this measurement.

Let us first consider the array design, i.e. baseline separations. For this simulation, we import a model array using the AIPy AntennaArray framework, which enables us to carry around an array with known geometry and baseline separations, along with individual antenna beam patterns and accessible frequencies. With this information and the previously made sky maps, we are now able to calculate our visibilities across many frequencies by using Eq. (1.1).

Intuitively, we expect that the sensitivity to the global signal will be maximized with the smallest baseline separations, which correspond to a position in the uv-plane close to the origin, or the zero-spacing mode. The trade-off of this, from a design perspective, comes in the difficulty of ameliorating cross-talk in a densely packed array. We want to optimize our array design to space our antennas as loosely as possible while also maintaining workable sensitivity to the monopole term, as this will best enable us to mitigate systemic problems in our instrument and perform a successful experiment.

The AntennaArray framework also enables us to carry around models of the beams of the antennas, which is a convenient way to import absorbers into the simulation. Essentially, within the context of the simulation, the absorbers act as a modification term on the beam pattern, changing the way that each individual antenna sees the sky. This works as follows:

To start, we need a beam. HYPERION uses SARAS-style fat dipole antennas in our instrument, which means we need to use a frequency-invariant dipole beam pattern in our simulation to match (Patra et al. 2013). This is the base beam model used throughout the simulation, calculated using Eq. (1.3).

$$A(\theta, \phi, \nu) = \cos\left(\frac{\frac{\pi}{2}\cos\theta}{\sin\theta}\right) \tag{1.3}$$

The next step is to add the absorber, which we do via modification of the AIPy Antenna beam. The absorber structure in our simulation is essentially a cylindrical wall of uniform height centered around each antenna, so that the antenna sees a rotationally symmetric structure. The parameters we can play with are the absorptivity of the material (i.e. how much attenuation does the absorber provide at each frequency), the height of the absorber walls, and how smooth the transition from absorber to sky is. This calculation is done using Eq. (1.4),

$$B(\theta, \phi, \nu) = \left[10^{\alpha(\nu)/20}\left(\frac{1}{2} + \frac{1}{2}\tanh\left(\frac{\theta - (\frac{1}{2} - \theta_0)}{a}\right)\right) + \left(1 - \left(\frac{1}{2} + \frac{1}{2}\tanh\left(\frac{\theta - (\frac{1}{2} - \theta_0)}{a}\right)\right)\right)\right] \tag{1.4}$$

where $\alpha(\nu)$ is the absorptivity by frequency of the absorber, θ_0 is the cutoff angle of the structure (i.e. θ_0 is the height of the absorber walls), and a is the smoothing parameter that blends the transition between the absorber and the sky.

This term is then combined with the Antenna beam, giving us Eq. (1.5).

$$A'(\theta,\phi,\nu) = A(\theta,\phi,\nu)B(\theta,\phi,\nu) \tag{1.5}$$

Chapter 2

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2.1 Results

lay out the case that absorber helps us maximize interferometric sensitivity to monopole, lay out the case that we can use the characteristics of this sensitivity to potentially help us pick out monopole vs. higher order terms (some kind of filtering around sensitivity vs. u mode)

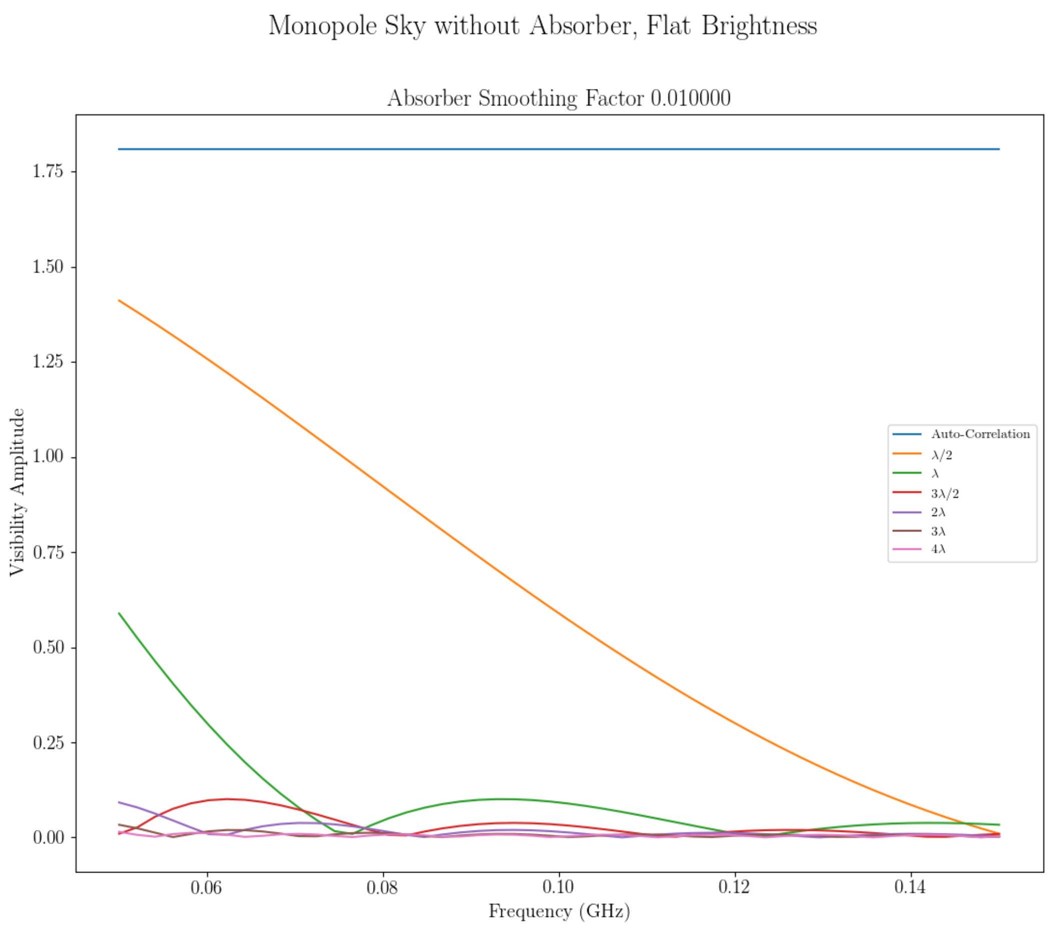

Figure 2.1: Shown here is the absolute value of the visibility of a spectrally flat monopole sky with no absorber walls versus frequency. As can be seen already, the interferometer does have non-zero sensitivity to the monopole, though it is plainly clear that the autocorrelation term (i.e. Baseline 0) is more sensitive than any of the non-zero interferometric baseline pairings listed in Table **??**.

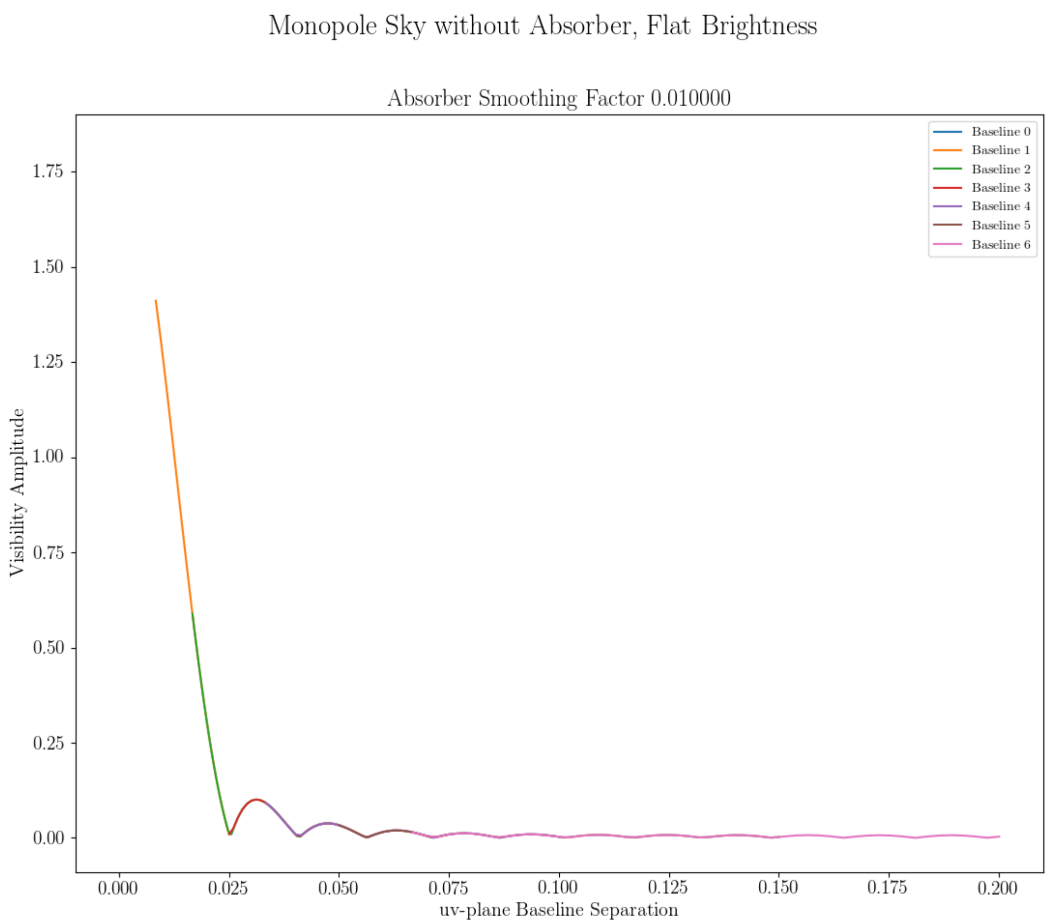

Figure 2.2: Shown here is the absolute value of the visibility of a spectrally flat monopole sky with no absorber walls versus uv-baseline. As can be seen already, the interferometer has a non-zero sensitivity to the monopole at non-zero baseline separations.

Chapter 3

Conclusion

review all chapters and results, but pithier

Bibliography

Kundert, K. 2016, The Relationship Between System Temperature and Sky Beam Coverage, Memo 1, HYPERION

Patra, N., Subrahmanyan, R., Raghunathan, A., & Shankar, N. U. 2013, Experimental Astronomy, 36