I. Abstract

We present the results of an analysis of spatio-spectral data obtained with the Wide-field Imaging Interferometry Testbed (WIIT). The motivation for this research is the need to create a model for and characterize the performance of a space based far-IR interferometer, and to develop an algorithm that turns spatio-spectral interferometer data into a “data cube” consisting of high resolution images in a series of spectral channels. This will open the gateway into high resolution astronomy in the far-IR realm, which will allow the astrophysics community to understand the formation of planets in protoplanetary disks, find exoplanets and learn more about their properties, and learn about the formation and evolution of galaxies. These are some of the questions we know to ask, but we expect to find more.

Using data obtained from WIIT I measured a “visibility curve” relating the interferometric fringe visibility to the baseline separation of the two collecting mirrors, compared it to a theoretical model and calculated the angular size of a source. WIIT simultaneously provides spectral as well as spatial data and allowed me to create spectra by Fourier transforming interferograms. In this poster I compare the spectrum obtained from a Fast Fourier Transform (FFT) with that obtained with a Direct Fourier Transform (DFT), and show the effects of different apodization windows on the DFT, which are designed to enhance the signal-to-noise ratio (SNR) of the resulting spectrum.

II. Introduction

One of the technical hurdles in the development of space based far-IR interferometry is the need to prove that the interferometric data can be used to give us the accurate spatial and spectral data necessary to a mission’s scientific objectives. The purpose of my research was to participate in characterizing the performance of WIIT, a laboratory testbed, which serves as a proxy for a space based far-IR interferometer.

III. Background

• All of the major components of WIIT are shown to scale. The distance from the test scene to the collimating mirror is 2.43 m.
• Light rays intercepted by each "collimator mirror" traverse a different path until they reach a 50/50 beamsplitter, where the rays combine. The optical path difference (OPD) between the two arms is varied by moving the optical delay stage, resulting in alternating constructive and destructive interference. The alternating brightness is captured in the pixels of the CCD.
• The interferometric baseline is the separation of the collecting mirrors. Baseline lengths from 360mm to 236 mm can be measured with WIIT.
• Test scenes are generated in the Calibrated Hyperspectral Image Projector, CHIP produces high resolution scenes with the desired spatial and spectral complexity in the wavelength range 380 – 780 nm.

IV. Methods

• Interferometry is the technique of separating and recombining light to extract information.
• When light from a single source is recombined, the waves interfere constructively or destructively like the merging ripples that arise when two stones are tossed into a lake.
• Creates a fringe pattern with bright and dark spots controlled by varying OPD.
• Constructive interference results in a maximum intensity.
• Destructive interference results in a minimum intensity.

• This is an interferogram.

• To derive spectra from the interferograms of the binaries it is necessary to apply a Fourier Transform
• Transforms data from OPD space to Frequency space.
• There are 2 different ways to calculate the transform.
• the Fast Fourier Transform (FFT).
• the DFT directly calculates the FT for each spectral point and works on unevenly sampled data removing the need for interpolation.
• See figures at bottom of column for the raw FT’s.
• We also applied an apodization window.
• • Apodization emphasizes signal and deemphasizes noise.
• We used a Gaussian window.
• • Does not have a very sharp turnover, which can cause issues with FT.

Eventually all of the interferometric data will be fed into the Spatio-Spectral Synthesis Software, which yields a single ‘data cube.’

A data cube is a 3 dimensional image with two spatial dimensions and one spectral dimension.
• The van Cittert-Zernike Theorem says that a high fidelity image can be reconstructed from interferograms if enough baseline positions (lengths and angles) are sampled.

V. Discussion and Conclusions

The goal of my research was to show that meaningful spatial and spectral information can be extracted from the interferometric data produced by WIIT.

The reduced chi-squared value for the fit was ~0.5. This tells us that the model is overfitting the data which can come from improperly fitting noise, which I suspect this is from the data that diverges at long baselines. This is not surprising because at long baselines the fringe packet were barely distinguishable from noise in the interferograms. We found that the fringes vanished abruptly beyond a certain baseline length. This unexpected result led to the discovery of a vignetting problem in the optical system. We also found a gradient of pixel efficiency, with poor response in a region where I was unable to find fringe source reference sources. Both of these issues were fixed by the WIIT Instrument Team.

We learned that the phase reference sources produced with CHIP are probably small enough, but not bright enough to produce high signal-to-noise ratios at long interferometer baselines. (In future experiments, the brightness of these sources will be increased.

For the spectra derived from the FT’s it was found that they both peak at the same wavelength and appear to have a similar shape, apart from the noisy region at short wavelengths, as can be seen in the FT at the end of the prior section. Additionally, in the hope that the signal-to-noise could be increased and the short wavelength noise could be deemphasized, a Gaussian window was applied to the data before it went through the DFT. The results can be seen below. It is a promising result, but another window function may give better results.

VI. Future Research

Work towards the proof of concept of a space based far-IR interferometer, such as SPIRIT, continues to progress. There are four realms of research that should be considered for the future. First, during my last week at Goddard I plan to apply a “raised sine” apodization window to the interferograms. The raised sine will taper less abruptly than the Gaussian function I use above. Recently, the CHIP light bulb began to fluctuate in brightness. We applied the Fourier Transform to a time series of brightness measurements and found that the fluctuations have a distinct pattern. The bulb will be replaced and new measurements will be made. It is also necessary to continue work on testing a software package, such as Astrometry.net, that can be used to identify patterns in the phase reference sources and coaxial data measured at multiple baselines. This analysis is currently being done by the WIIT Algorithm Team. Finally, although not directly related to WIIT, I am working emphasizing the need for parallel research on far-IR detectors as this is arguably the biggest challenge facing far-IR astronomy today.

VII. Acknowledgements and References

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