Research Statement

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My research interests have focused on new techniques for radio astronomy and pushing existing telescopes to their full potential. My dissertation research has been on the development of PAPER, the Precision Array for Probing the Epoch of Reionization. This interferometer is being built in the Karoo, South Africa, to detect the signal of intergalactic hydrogen from the period in the universe's history when the first galaxies were forming. This important cosmological probe is highly sought after as it will hold clues to the structure and composition of the early universe.

The spin-flip transition of hydrogen, normally at 1.4 GHz, is predicted to be redshifted by $z{\sim}11$, so PAPER is designed to work at low frequencies, or in the $100-200$ MHz range. As this is new territory for radio astronomy, we've been building the project in stages, testing and evaluating our equipment and methods along the way. I have been involved in the array design and build-out since the first four-antenna prototype in Green Bank, West Virginia. I evaluated the data from this early stage to experimentally determine the receiver temperature of each element. In the process, we discovered that the response of the receivers, amplifiers, and cable were fluctuating with the ambient temperature.

More recently, I have been investigating the effects of ionospheric density fluctuations on the precision of PAPER measurements. As the foreground sources are several orders of magnitude brighter than the reionization signal, careful characterization of such effects will be needed to fully understand the cosmological signal. The first search for such fluctuations with the PAPER instrument show that small timescale fluctuations do not seriously affect the position measurements of bright astronomical sources. This research is being submitted as an invited paper to a special issue of Radio Science that bridges the gap between ionospheric science and radio astronomy.

Though this first study directly fits interferometer visibility data to a measurement equation, the next work, currently in progress, will track source positions in the wide field and wide band images that can be produced with this interferometer. Between the physical field-work in setting up the array and exploration of difficult imaging techniques, this project has been ideal for gaining a deep understanding of radio astronomy and interferometry, neither of which are immediately intuitive. I have developed a laboratory exercise using PAPER data to explore the basics of antenna location in an interferometer and an exercise in array configuration optimization.

On a recent trip to South Africa, I helped build the array out to 64-elements. The final infrastructure will have twice this many antennas and is scheduled to be completed in 2012. We have just begun to scratch the surface of ancillary science that can be done with this array. I have begun to develop experience with CASA, the new software package designed at the National Radio Astronomy Observatory, to calibrate and image data from PAPER. This software package will come into heavy use in the future with the EVLA and ALMA, so I am fortunate to be able to learn the package in its early stages of development.

In the future, I would like to take the results of my ionospheric calibration to simulate the effects that this natural phase screen will have on the detection and characterization of the signal of reionization. Though we are expected to detect the power spectrum with an array of 128 antennas, it will take another level of sensitivity, that of the proposed Hydrogen Epoch of Reionization Array (HERA), to extract information about the galaxies of 12 billion years ago. This new level of sensitivity will require an even deeper understanding of atmospheric and instrumental residuals. Along the way, however, PAPER can be used to make a survey of the sky at 150 MHz, vastly improving existing catalogs made in this regime and probing the spectral index of active galactic nuclei (AGN) to frequencies that represent older populations of relativistic electrons.

During my education, I have been involved in other projects that explore the environments around AGN. In 2008, with Jim Braatz of the NRAO, I participated in a search for water megamasers around AGN with the Green Bank Telescope. We discovered that eve weak AGN could have extremely bright maser activity. I got my first experience with radio astronomy on the Very Long Baseline Array, first at MIT Haystack Observatory and later at the NRAO in Socorro, New Mexico. I developed extensive experience with AIPS while conducting a multi-frequency survey of compact symmetric objects (CSOs), or parsec-scale radio jets of AGN that seem to have just recently (within 10,000 years) begun their activity. This activity may be episodic, however, and high resolution images at lower frequencies would confirm this.

My very first experiences with radio astronomy were particularly challenging. While the VLBA can be a difficult instrument to calibrate, this was compounded by the fact that I was using some of the highest frequency bands available and measuring polarization that was just a few percent of the source flux. However, my experience was rewarding, and I would not shy from using similarly challenging data sets to train new students. Far from the more intuitive methods of optical or infrared astronomy, working with radio interferometers is a unique training experience in physics, optics, and problem-solving that would compliment a student's astronomical training.