RESEARCH STATEMENT

JAMIE TOLAN

My primary interests are the origins and evolution of the universe. Over the past few decades rapidly evolving instrument design and technology have allowed significant improvements to our model of the universe and constraints on the fundamental parameters which describe it. To maintain this rate of discovery it will be necessary not only to continue to develop current technology to detect fainter signals, but also to develop entirely new techniques to probe our universe. As we field these new experiments, it will also be necessary to develop sophisticated analysis tools to handle with increasing complexity and data volume. My goal is to align my research so that I am able to be involved with both the design and deployment of new instruments, as well as the development of data analysis techniques.

1. Present Research

By measuring the CMB polarization to unprecedented levels of sensitivity, we hope to constrain the level of B-mode polarization. Placing limits on level of B-mode signal allows us to rule out models of inflation and gain insight as to what happened in the first fraction of a second. I have been involved with three generations of experiments which are placing increasingly tight limits on inflation: BICEP, BICEP2 and the Keck Array. My primary focus and PhD thesis is on the Keck Array.

1.1. **BICEP and BICEP2.** The BICEP telescope was the first experiment specifically targeted at measuring the B-mode power spectrum of the CMB polarization at the South Pole. My involvement with BICEP has been focused on characterizing the extent to which foregrounds contaminate our measurement. Foregrounds consist of three general types: galactic thermal dust, galactic synchrotron and extragalactic compact sources . Using models of the galactic magnetic field and models of synchrotron and dust emission, we are able to extrapolate multifrequency observations to our observing bands at 100GHz and 150GHz. Compact source contamination can be checked for in our data using optimally filtered maps and cross correlating with sources from WMAP, Planck, and PMN catalogs.

The BICEP2 experiment is the pathfinder for the Keck Array, and utilized the same phased array antennas coupled to TES bolometers and SQUID time domain readout. My involvement with BICEP2 has been confined primarily to data analysis development, as the analysis pipeline is shared with the Keck Array. My most significant contribution to the

BICEP2 and Keck data analysis pipeline is to re-write our map making procedure from a procedural based code to a signal linear matrix operation which encodes our telescope pointing and data processing. This matrix based code will allow direct evaluation of a map based likelihood function, and will also hopefully eliminate E-mode to B-mode leakage, which otherwise will likely to limit our ability to place limits on B-mode polarization.

1.2. **Keck Array.** The Keck Array is collection of five co-aligned 512 element microwave polarimeters that have been observing since they were deployed to the South Pole in the winter of 2010. My contributions to Keck cover a wide range of topics from instrument design, deployment and data analysis.

The design of the Keck Array borrows extensively from previous generations of telescopes. The Keck Array inherited BICEP's simple 4K refractive optics, and BICEP2's detectors and readout. However, numerous design modifications were made to compactify the design and allow for use of a mechanical cooler rather than liquid cryogens.

I was responsible for selection of the type of mechanical cooler used in the Keck Array: Gifford-MacMahon vs Pulse Tube. The Gifford-MacMahon cooler is advantageous because the cooling power is independent of vertical orientation and its more compact design. However, based on tests comparing vibrations, thermal fluctuations, and magnetic fields we have selected the Pulse Tube for its low level of vibrations and thermal stability at 4K.

Next, I demonstrated that the cooling power of the Pulse Tube was sufficient for cycling a Simon Chase He3 sorption fridge. By optimizing the algorithm from my initial cycles, we have achieved very long hold times in our deployed systems; the shortest of the five cryostats lasts nearly 48 hours and many last up to 72 hours.

Due to limited space in our telescope mount, each Keck receiver had to be shrunk in size compared to BICEP2. This required modification to the thermal strap architecture, board layout and wiring. Armed with these design modifications, I was responsible for purchasing and assembling parts in the 4K insert for all five receivers. This included building thermally isolating carbon fiber support trusses for the focal plane, wiring and calibrating thermometry, and improving the sub-K thermal design.

Each Keck receiver contains four silicon detector tiles composed of 64 polarization sensitive pixels. The detector tiles are wire-bonded to superconducting PCBs containing the SQUID muxing chips and housed in a Focal Plane Unit (FPU). I was involved with the design and fabrication of the Keck PCBs and FPU structure.

Initial tests of Keck receivers we conducted at Stanford. After assembling each cryostat myself and another graduate student tested each receivers cryogenic performance, magnetic shielding, detector loading and readout yield. Learning from these tests, we were able to increase sub-K hold time, improve readout yield, as well as gain extensive experience assembling and cooling down cryostats.

Deployment of the Keck Array begin in November 2010 and first light was achieved with three receivers in February 2011. During the 2011-2012 season we deployed an additional two receivers and improved the sensitivity of the of the existing three by replacing a focal plane and increasing the sampling rate.

During deployments, I have been responsible for assembling each cryostat and preliminary tests. I also constructed an linear XY stage with a chopped thermal source, which we have used to measure near field beam response for all five receivers. We correlate these near field measurements with those taken in the far field to inform decisions on the fabrication processes of the detector tiles.

Currently, we are in the middle of the 2012-2013 season, during which we plan to take extensive calibration measurements and upgrade the existing five receivers to improve sensitivity.

2. Plan of Future Research

In the coming years, the sensitivity of CMB polarization experiments will continue to rapidly advance. The continued operation of the Keck Array and SPTpol, and new experiments, such as BICEP3, will allow us improve our constraints on inflation. To reach these goals, we will most likely need to remove galactic foreground contamination. My experience modeling these foregrounds will be useful, as will planned multifrequency observations. These experiments also will likely detect B-modes from gravitational lensing, opening up CMB polarization science to a new way to constrain fundamental parameters.

Beyond CMB measurements, I believe the next most promising intersection of new technology and cosmology is through 21cm measurements of the Epic of Re-ionization. In the case of 21cm observations, understanding foregrounds will possibly be even more important that CMB polarization, since the EoR signal is well below expected foreground signal. Many of these foregrounds are familiar to those studying the CMB: synchrotron, free free emission and extragalactic point sources. Observing signatures from the EoR may provide crucial insight into structure formation and the first luminous objects. The first generation experiments are under way now, and promise to yield exciting results in this new field.

Last updated: November 3, 2012