Polarimeter Receiver Prototyping and Testing for the South Pole Telescope Upgrade

Constantinos Melachrinos

November 24, 2008

Abstract

Experimental evidence, such as the observation of the Cosmic Microwave Background (CMB) has so far been supportive for the inflationary Big Bang model of cosmology. At the same time, this evidence imposes other mysteries, such as the fact that dark matter and dark energy actually consist of 95% of the observable universe, in contrast to the 5% of ordinary matter we can directly observe.

The South Pole Telescope, located in Antarctica, is a significant detector that will help investigate the mysteries of dark energy and inflation. The forthcoming upgrade of the South Pole Telescope, planned for 2010, will include a polarimeter with increased sensitivity. Measurements of the CMB polarization anisotropy to a high accuracy will describe the angular power spectrum of the B-mode polarization. In turn, searches for signals from inflationary gravitational waves in the B-mode spectrum will examine the inflationary theory. In addition, analysis of the spectrum will improve the measurements of Ω_m and Ω_b cosmological constants and put constraints on the neutrino mass.

The next generation polarimeter receiver to be deployed to the South Pole Telescope is being designed and constructed by a collaboration of eight institutions, led by the University of Chicago. In this project I will be working under the supervision of Prof. Carlstrom for the prototyping and testing of the polarimeter receiver. The polarization detectors are bolometers using transition edge sensors, operating at 250 mK. The change in the current required to voltage bias the sensors when they are at their superconducting transition is inversely proportional to the radiative load on the bolometers. Readout electronics with sensitivity of a few picoAmps or less are required, so superconducting quantum interference devices (SQUIDs) are used. The receiver will employ 2000 detectors and therefore multiplexing the detector readouts is necessary to reduce thermal loading from the wiring to the 250 mK stage of the cryostat. These types of bolometric detectors and TES readouts are at the cutting-edge of CMB instrumentation research.

My project will be to assemble and test a digital frequency multiplexed readout system. I will be involved in all stages of assembling the hardware, including the test cryostat and readout electronics. I will then test that detectors and readout and fully characterize the performance. My experience in both software and electrical engineering will enable me to carry out these duties, while improving my grasp of how hardware is being used in detectors in physics. I am genuinely interested in learning more about the experimental efforts in cosmology and I am looking forward into contributing at first hand.

What I hope to achieve:

- Study and understand the current experimental attempts in cosmology, which will be an introduction to the paper
- Modify the test receiver and install the new readout system.
- Assemble the room temperature electronics for the digital frequency multiplexing device for SQUID readout which will be used as bias to the readout bolometer
- Install, test and modify software for the multiplexed readouts using Python and C