Cosmic Microwave Background Polarimetry with CLASS

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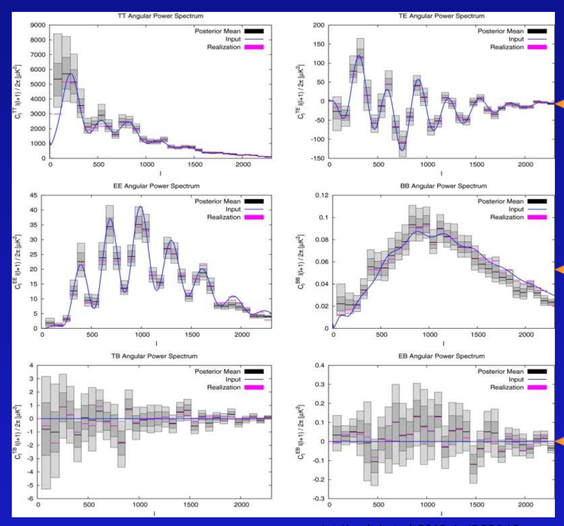
INTRODUCTION

The cosmic microwave background (CMB) is the remnant signal of our early universe which contains vast amounts of information about the formation, evolution and current state of our universe. Recently, projects such as COBE, WMAP and Planck have transmogrified our understanding of the standard model of cosmology and greatly improved constraints on many critical parameters. Studying the polarization of the CMB will provide insights to tensor perturbations in primordial density distributions. These tensor perturbations, more commonly known as gravitational waves, can be used to tighten constraints and increase understanding of inflationary theory. The project I am working on, the Cosmology Large Angular Scale Surveyor (CLASS), will advance this study by looking for signs of polarization. CLASS is a telescope which will be located high up in the Atacama Desert of Chile, and will observe large areas of the southern sky in 3 band passes centered at 40, 90 and 150 GHz. The polarization signal is so weak that the detectors, combinations of Transition Edge Sensors (TESs) and Super Conducting Quantum Interference Devices (SQUIDs) have to be cooled to well below the temperature of deep space; on the order of 100 mK. Testing these detectors is obviously very important and difficult because we need to make sure that they work at temperature and also that they ensure exceedingly low noise. During the internship I worked on designing a test dewar for these detectors using Solidworks design software.

Why do we need CLASS?

Measuring the CMB polarization (both scalar and tensor modes) is integral to confirming our cosmological theories but there are some difficulties associated with it.



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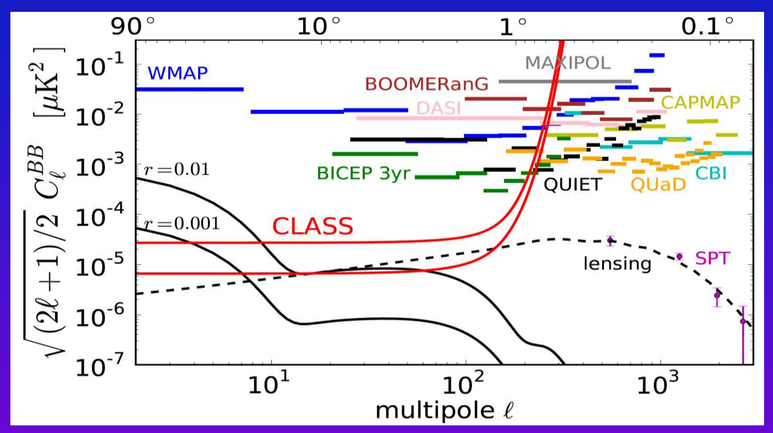
The amplitude of the E-mode spectrum is orders of magnitude less than that of the Temperature

The amplitude of the B-mode spectrum is orders of magnitude less than that of the E-mode

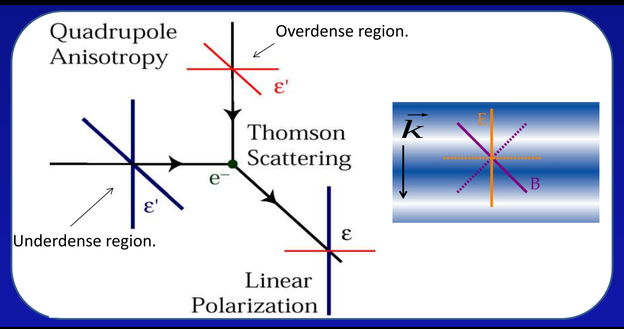
B-modes orthogonal to both temperature and E-modes.



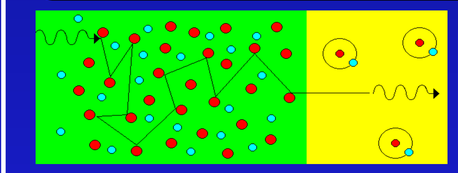
CLASS sensitive enough to measure the B-modes at low multipoles (large angular scales). Complex foreground removal techniques are also necessary to eliminate unwanted radiation from synchrotron, dust and free-free processes.

Origin of CMB polarization

During the primordial era, photons and electrons were coupled via Compton scattering. It turns out that this scattering is very efficient at polarizing photons. Quadrupole perturbations are needed for B-modes.

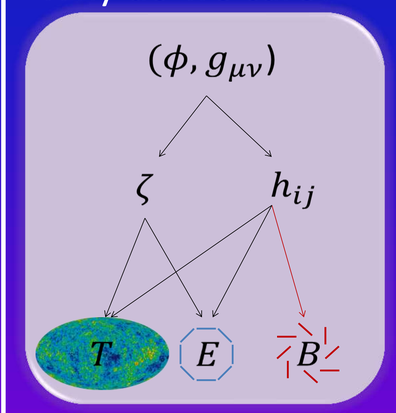


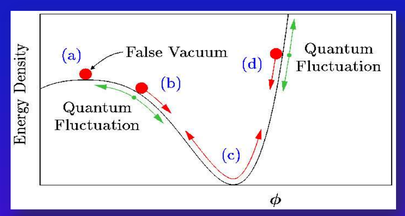
Once electrons and photons decoupled, the perturbation spectrum was 'frozen in', so measuring the B-mode power spectrum today gives the spectrum at time of decoupling.

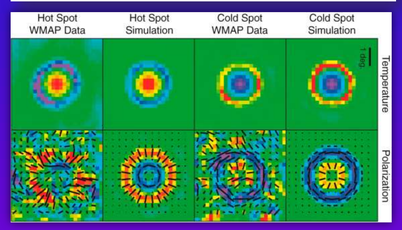


The tight coupling needed for Compton scattering attempts to thermalize the photons. This suppresses any multiple moments, in turn suppressing the B-mode power spectrum.

Why do we care?

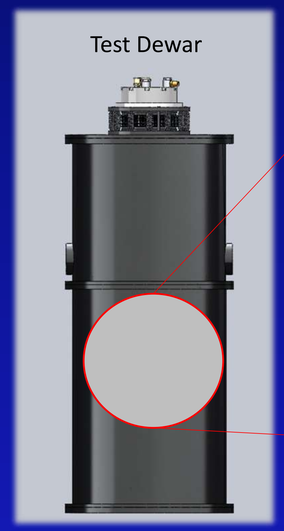


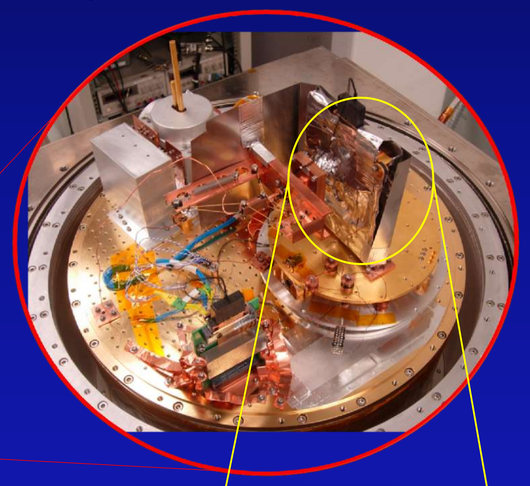


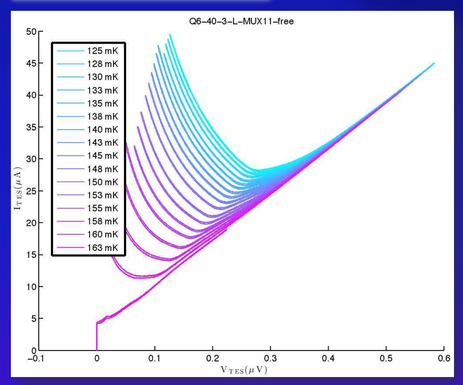


Amplitude of gravity waves (tensor perturbations) are proportional to the expansion rate of the early universe. The expansion rate is then proportional to the energy scale of the inflation. The inflation energy scale is predicted to be trillions of times higher than that probed by the Large Hadron Collider (LHC).

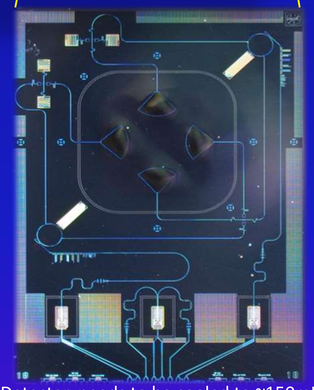
CLASS detector testing







I-V curves taken at increasing temperature. Voltage is swept over a small range, and the change in current (Resistance) is measured. Those curves which show large current changes are superconducting. The final curve (163 mK) was not superconducting.



Detector, needs to be cooled to ~150mK.

References & Acknowledgements:

Dodelson, Scott. Modern Cosmology. Academic P, 2003.

http://lambda.gsfc.nasa.gov

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