DeLITE – deLensing Inflation by Tomography

S. T. Staggs, M. D. Niemack, J. McMahon, M. Devlin, J. Dunkley, M. Halpern,
N. Halverson, K. Irwin, T. A. Marriage, E. Pascale, K. M. Smith, D. N. Spergel

PRINCETON UNIVERSITY · NIST · MICHIGAN · Penn · UNIVERSITY OF OXFORD · UBC · University of Colorado Boulder · JOHNS HOPKINS UNIVERSITY · CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

INTRODUCTION

DeLITE is a scientific balloon mission planned to measure the imprint on the cosmic microwave background (CMB) of gravitational waves from the inflationary epoch during the first 10^{-35} s after the big bang.

DeLITE will measure the polarized sky in four frequency bands in a clean 1000 deg^2 region with high angular resolution (< 7′) to a sensitivity of 2.6 μK-arcmin, measuring the B-modes from ℓ = 50 to 2000.

CONTEXT

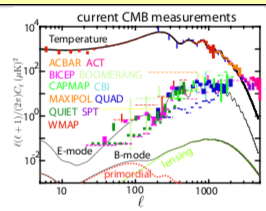

Fig. 1. Existing measurements of the CMB power spectra. No B-mode signals have yet been measured; the best limit is from BICEP.

INSTRUMENT

The deLITE camera uses 8200 detectors operating at four frequencies: 100, 140, 200 and 280 GHz.

The polarimeter arrays are dichroic versions of the feedhorn-coupled TES bolometer arrays developed by the Truce collaboration[1].

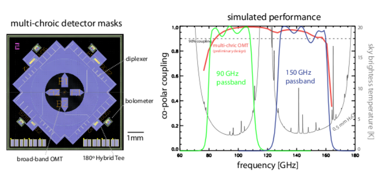

Fig. 2. Left: The detector layout for a multichroic pixel operating with bands at 100 and 140 GHz. The four fins arranged in a cross in the center form a broad-band orthomode transducer (OMT) that couples two orthogonal linear polarizations into diplexing filters and hybrid tees so that the intensity of each can be measured in two frequency bands on separate TESes. Right: The bandpass of the OMT is shown in red, with the individual bands in ble and green. ; see also the posters of J. McMahon, M. Niemack, and B. Schmitt.

The camera couples to a 2-m Dragone-Mizuguchi telescope with a 10° field of view via cryogenic refracting optics. This design maximizes resolution and sensitivity but reduces the number of detector arrays needed to fill the focal plane.

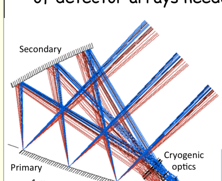

Fig. 3. Ray trace through the telescope and re-imaging optics. Red/brown rays focus on three 100/140 GHz arrays; blue rays focus on a 200/280 GHz array.

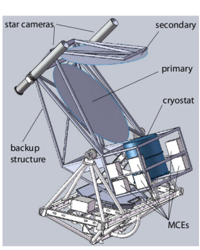

Fig. 4. The deLITE gondola shown here is based on the BLAST platform. The detectors are cooled to 100 mK with ADRs to optimize sensitivity.

DeLITE will observe during multiple long duration balloon (LDB) flights from Antarctica.

PRIMARY OBJECTIVE

The primary objective of deLITE is to make a definitive detection of the primordial B-mode signal if its amplitude is r > 0.01. A firm upper limit at this level would rule out a broad class of inflationary models. DeLITE's sensitivity and resolution permit a 3σ detection even if the signal is as low as r=0.004.

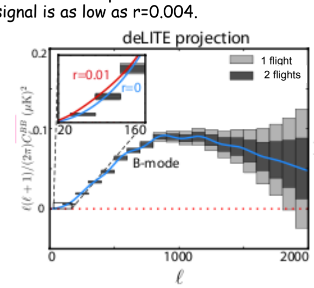

Fig. 5. Projected deLITE errorbars from realistic simulations.

WHY HIGH RESOLUTION?

The primordial B-mode signal is small compared to the gravitational lensing signal (see Fig. 6).

Robust separation of signals. DeLITE simultaneously measures small (7′) and large (~10°) angular scales, tracing the transition from the primordial recombination peak to the lensing peak.

Delensing. Specifically, we can 'delens' the DeLITE map by identifying the lensing-induced correlations among the small angular scale modes, optimizing sensitivity to the primordial B modes. (See also Fig. 6 below.)

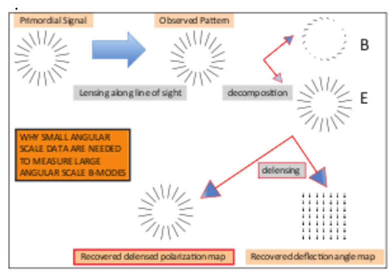

Fig. 6. Gravitational lensing by intervening mass deflects the rays, partially converting pure Emodes into B-modes . Small-scalbe B-modes encode the 'deflection map' which can clean both large and small scales in the maps.

Cosmic Shear. Moreover, the high-resolution data from deLITE will reveal the evolution of the universe. The deflection angle map reconstructed from the correlations among the small-scale modes traces the projected mass from here to the surface of last scattering.

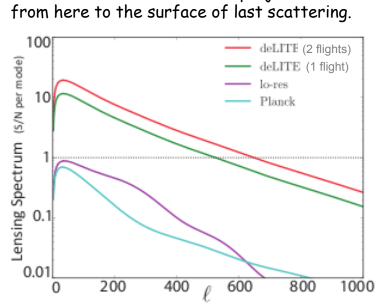

Fig. 7. The signal to noise per mode for deLITE measurements of the lensing spectrum – deLITE reconstructs the deflection map down to 15′. Results from Planck and a fictional low-resolution (40′) instrument (with the deLITE sensitivity) are plotted for comparison.

DELITE PRECIS

- Polarized map sensitivity: 2.6 μK-arcmin
- Sky coverage: cleanest 1000 deg^2
- Angular resolution: < 7′
- Platform: Long duration balloon from Antarctica

Instrument Resolution and Sensitivity

Frequency (GHz)	Bandwidth (GHz)	Angular Resolution	NEQ Sensitivity (μK√s)
100	35	7′	2.3
140	35	5′	2.7
200	70	4′	6.3
280	70	3′	15

- Telescope:
  - 2 m aperture crossed Dragone-Mizugichi
  - Cryogenic re-imaging optics with cold Lyot stop
- Polarimeter arrays from NIST:
  - low R_N MoCu TES with time domain multiplexing
  - cooled to 100 mK for optimal sensitivity
  - 512 silicon-fabricated feedhorns each
  - 3 dual 100/140 GHz arrays
  - 1 dual 200/280 GHz array

COMPACT AREA

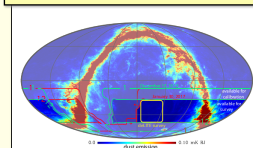

Fig. 8. The yellow square indicates the low-foreground deLITE survey region, superposed on the 94 GHz dust emission map (Schlegel, Finkbeiner, Davis, 1998). Other lines indicate regions of sky accessible to deLITE during Antarctic LDB flights.

DeLITE targets the low-foreground 1000 deg^2 of the sky indicated above in Fig. 8.

DeLITE collects data in four frequency bands, permitting removal of residual foregrounds.

Projections of constraints on r in various scenarios (see Fig. 9 below) confirm the advantage of high angular resolution in light of the fact that most regions of the sky have much larger foregrounds than the targeted deLITE 1000 deg^2.

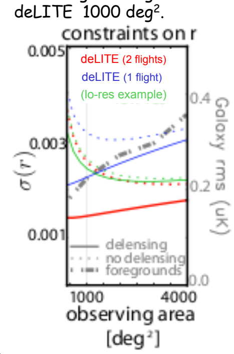

Fig. 9. Projected sensitivity to the tensor to scalar ratio r, as a function of the area of sky observed. The solid red curve gives the nominal deLITE results after delensing, while the dashed red curve indicates results without delensing. The solid green curve compares to a fictional low-resolution (40′) experiment with the same detector sensitivity as deLITE.

The dot-dash curve shows the rms foreground signal from the Dunkley et al 2009 model, which increases rapidly with area.

Since the foregrounds reduce the available area, the advantages from delensing are clear.

ACKNOWLEDGEMENTS

We gratefully acknowledge the work of the TRUCE collaboration in developing and testing the feedhorn-coupled TES-based polarimeter arrays.

CONTACT INFORMATION

Suzanne Staggs
Physics Dept; Princeton, Princeton, NJ 08544
staggs@princeton.edu

[1]Truce collaboration publications; http://casa.colorado.edu/henninjw/TRUCE/TRUCE.html