CMB Polarization Measurements

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The Science

* The energy scale of Inflation

* The *absolute* mass of neutrino (down to 0.04 eV)

* The property of Dark Energy

*Planck will not be able to do these!*
The Science

**E modes**

**B modes**

Temperature spectrum

E-modes from density fluctuations

Gravitationally lensed E-modes (dark energy, neutrino mass)

Reionization bump

X300 fainter!

Inflation?

B modes from primordial gravitational waves

Blue shading spans current limits and minimum detectable from CMB

Afterglow Light Pattern

400,000 yrs.

Dark Ages

Development of Galaxies, Planets, etc.

Inflation

Quantum Fluctuations

1st Stars about 400 million yrs.

Big Bang Expansion

13.7 billion years

SLAC  Sept. 17, 2009

SLUO 2009 Annual Meeting
• QUaD/BICEP (50~100 detectors) still miss the B-polarization by ~ 2 orders of magnitude.

• The current round of experiments (~1000 detectors) can only hope for a statistical detection.

• To perform high S/N imaging of lensing B-polarization, one must increase the survey speed by $10^2$. 
Larger and larger focal planes planned

BICEP-2 and SPIDER
Focal plane, 512 detectors
(fielding 2009/2010)

Keck Array = BICEP-2 x 3
(fielding 2010/2011)

POLAR-1 Focal plane
4,608 detectors
(planned for 2012)

POLAR Array = POLAR-1 x 10
Enabling Technology: Antenna-coupled bolometers (Kuo)

* Large arrays of bolometers
* Fully lithographic superconducting TES
* High yield, high performance demonstrated
Detector Development brings together KIPAC/SLAC and JPL: Miniaturization of coherent detector technology

State of the art prior to CHIP

Build into large arrays

SLAC expertise in RF design and FPGA electronics is being applied to CHIP

SLAC Users Organization

Sept. 17, 2009

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CHIP: A KIPAC-led International collaboration
Church (PI), Tantawi, Fox, Van Winkle

* CHIP is an interferometer
  – Interferometers have very low systematics; measure directly in Fourier space
* Phase I – 2x100 element interferometers
  – Project $r < 0.05$ in 2 years of observations
* Phase II – 8x100-element interferometers
  – Capable of $r < 0.01$ in 2 years of observations

DASI: 13 elements
University of Chicago
First detection of CMB polarization
Opportunities

* **Maxwell equations are linear**
  - RF techniques in accelerator physics are equally applicable in the CMB (participation from Tantawi)

* Reading out 10,000 detectors/channels
  - Faster (digital) electronics are in demand (participation from Fox)

* Data Analysis challenges
  - Supercomputers are often used for likelihood analysis and Monte Carlo simulations (DOE facilities at LBNL/SLAC)

* We need to form fewer, larger collaborations for large, expensive projects
  - QUIET-II, CHIP
  - POLAR Array