CMB Polarization Measurements

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KIPAC/Stanford Physics/SLAC
The Science

Temperature spectrum

E-modes from density fluctuations

Gravitationally lensed E-modes (dark energy, massive neutrinos)

B modes from primordial gravitational waves
Blue shading spans current limits and minimum detectable from CMB

Reionization bump

X300 fainter!

B modes

E modes

WMAP

Sept. 18, 2008

SLUO 2008 Annual Meeting
QUaD experiment (KIPAC campus) power spectra
The goal

- Current experiments targeting $r \sim 0.1-0.2$
- **Next generation targeting** $r \sim 0.01$ e.g. Silverstein (SLAC) predicts $r=0.07$
- A space mission would target $r \sim 0.005$?

![Diagram showing existing data and projections from current experiments and next generation, in design phase.](image-url)
The Challenge

* Need ~ 1000 detectors (c.f. 30 QUaD, Planck)
  – Project size must increase to meet this challenge

* Careful system engineering to minimize systematic effects that will otherwise dominate
  – Signal < 1 pt in $10^8$ of background
  – Optimum experimental design not yet determined
  – Novel approaches needed for the next generation

* Analysis complexity will increase
  – More detectors = more data streams
  – Project management/data distribution issues

* Need culture change from small collaborations, few postdoc/grad students
The Experimental Landscape Circa 2005
(NASA/NSF/DOE taskforce on CMB research)

New KIPAC projects: CHIP, Keck
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

$[\ell(\ell+1)C_\ell/2\pi]^{1/2}$ (µK)

Multipole number $\ell$

$r=0.1$
$r=0.01$
Detector Development brings together KIPAC/SLAC and JPL: Miniaturization of coherent detector technology

State of the art prior to CHIP

SLAC expertise in RF design and FPGA electronics is being applied to CHIP
Enabling Technology: Antenna-coupled bolometers (Kuo)

* Large arrays of bolometers
* KECK array (Caltech led, KIPAC involvement)

Dual-Tc TES bolometer
Load resistor
Dual-polarization antenna/summing network
Compact LC Filter

7.5 mm (150 GHz)

0.8 μm
Projects with KIPAC Involvement

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* Thousand-pixel detector development is at the core of the KIPAC effort

* KIPAC/SLAC poised to play a leadership role in the next generation of experiments