Measurements of CMB Polarization Anisotropy and Searches for Galaxy Clusters with Bolometer Arrays

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Outline

- CMB Polarization Science
- Galaxy Cluster Survey Science
- Development of Bolometer Arrays
- Experiments
  - POLARBEAR
  - APEX-SZ
  - South Pole Telescope
Polarization Science
Gravity Waves from Inflation

- Gravity waves put stress on photon-baryon fluid
  - Generation of B-mode polarization
- Detection => “smoking gun” of inflation
- Amplitude of B-mode gives Energy Scale
  - One possibility: GUT level $10^{16}$ GeV
  - 12 orders of magnitude higher energy than accelerators!
- Observable evidence of String Theory?
E-modes and B-modes

- Density fluctuations give *scalar* perturbations $\Rightarrow$ E-mode
- Gravity Waves give *tensor* perturbations $\Rightarrow$ B, E modes
- Defects and strings give *vector* perturbations $\Rightarrow$ B-mode
We need a large increase in sensitivity!
Galaxy Cluster Survey using SZ Effect Science Case
In contrast to X-ray emission, SZ surface brightness is independent of cluster redshift, clusters can be seen at any distance!
Cluster surveys probe (1) volume-redshift relation, (2) abundance evolution, (3) structural evolution.
Large Focal Plane Bolometer-Arrays

- Approaching single pixel photon noise limit
  - Next Step: Large format bolometer arrays
- Transition-edge Sensor Bolometer
  - Entire fabrication is by optical photolithography
  - Multiplexed readout in development
POLARBEAR


- Ground-Based 3 meter Telescope at White Mountain CA
  - Characterize E-modes
  - Search for B-modes
- First Light 2004-2005
  - LDRD seed funding
New Detector Technology: Antenna Coupled Bolometer

1 mm

• Fabricated in UCB Microlab by M. Meyers

Silicon Lens used to focus the beam

Filipovic et. al. 1993

SEE TALK Y08 BY MIKE MYERS
POLARBEAR-I Performance

A.H. Jaffe

- 15 x 15 deg. observed
- 1.2 μK rms per 5’ pixel
- 200 nK rms per 30’ pixel (re-pixelized map)
- T/S = 0.35 assumed
CMB Polarization Satellite

- One of three NASA “Einstein Probes” in roadmap is for CMB Polarization
- Study Proposed of mission named Experimental Probe of Inflationary Cosmology “EPIC” (JPL, CIT, UCB, LBNL, Minn, NIST, UColo, Stanford, CMU, Cardiff, Chicago, Dartmouth, Fermilab, Davis)
Telescope Specifications:
• 12 m on-axis ALMA prototype.
• 45” resolution at 150 GHz.
• Located at 16,500 ft in the Chilean Andes.
• Assembly near complete in Chile!
• Berkeley Component NSF funded
• First light late 2004
South Pole Telescope


- 8m, off-axis design
- 1.3’ resolution
- 100% time SZ observations
- Best mm-wave site
- First light 2006-2007
- NSF Funded: Chicago, Berkeley, CWRU, SAO

APEX/SPT Complementarity: APEX will be operational 2-3 years before SPT, but SPT will have ~5x faster cluster finding rate.
TES Bolometer Array

- 6 identical wedges

Array mask

14 cm
Horn Antenna Coupled Bolometers
Sunyaev-Zel’dovich Effect Surveys

TES Spider Absorber Bolometer
APEX-SZ 54-Bolometer Wedge
Cosmology with APEX-SZ

courtesy M. White
Single SQUID multiplexer

- One SQUID per row
- AC-bias => sum signals => demodulate

- 8-ch prototype tested with resistors
- Bolometer test

SEE TALK E02 BY TREVOR LANTING
Conclusion

• Much more to learn from CMB photons!
  – Polarization: Probe of physics at $10^{16}$ Gev
  – Galaxy Clusters: Characterize Structure Formation, Dark Energy

• Needed step in instrumentation is imminent

• Control of systematic errors will be critical
STOP
PolarBeaR Performance

- $r =$ tensor to scalar ratio
- $n =$ tilt of primordial spectrum

**POLARBEAR-I**
- (300 Bolometers @ 300 mK)

**POLARBEAR-II**
- (3000 Bolometers @ 100 mK)
Dark Energy and Mass Limit Systematic Errors

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Pulse-Tube Cooler Testing

- Closed He gas cycle
  - No cryogens
  - Reduces logistical and personnel demands
- 250 mK for 50 hours
- Microphonics tests underway

Dan Schwan