CMB Polarization Measurements with POLARBEAR

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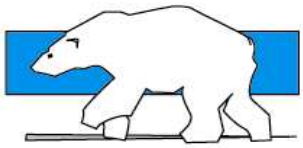
CMB polarization science

- Verification of inflationary picture
  - First peak in E-mode power spectrum
- Cosmological parameter estimation
  - Measure reionization epoch
  - Improve parameters from CMB temperature measurements
- Probe the distibution of matter
  - B-modes from lensing by large-scale structure
- Probe the epoch of inflation
  - B-modes from gravity waves

Twin Challenges of CMB Polarization Measurements

(1) Achieve sufficient sensitivity to detect the signals.

(2) Achieve sufficiently low systematic errors to make a robust measurement.



POLARBEAR

- Ground-Based at South Pole with VIPER telescope
- Characterize E-modes and Search for B-modes
- Staged deployment
  - POLARBEAR-I, under development
  - POLARBEAR-II, deeper search for gravity wave signal

POLARBEAR Team

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Theory/Data Analysis
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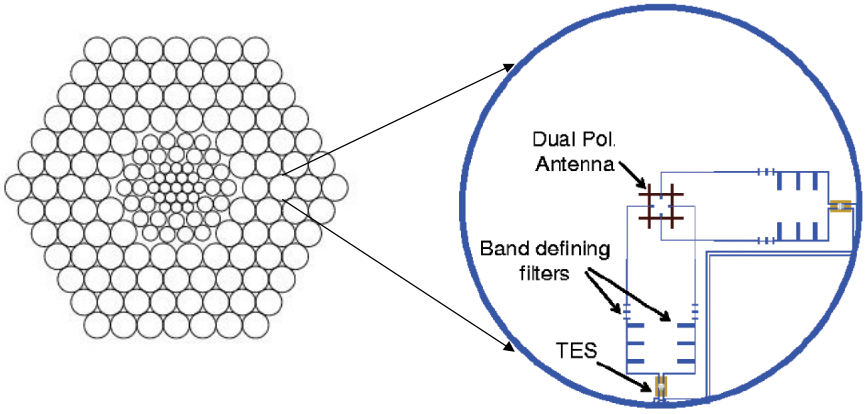
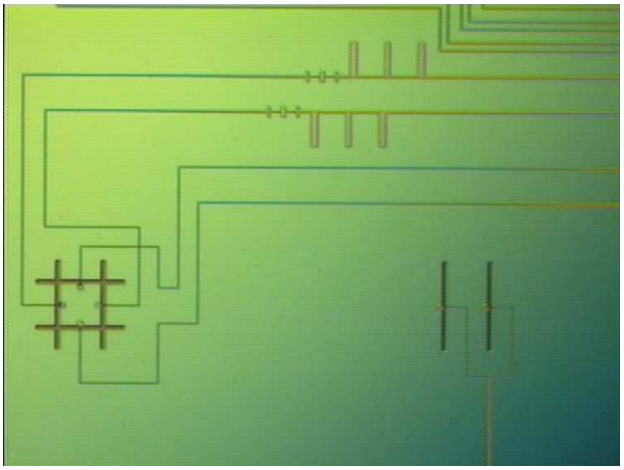
POLARBEAR-I focalplane



- 150 pixels x 2 polarizations = 300 single-color bolometers @ 300 mK
- 3 Frequency bands, 150, 250, and 350 GHz

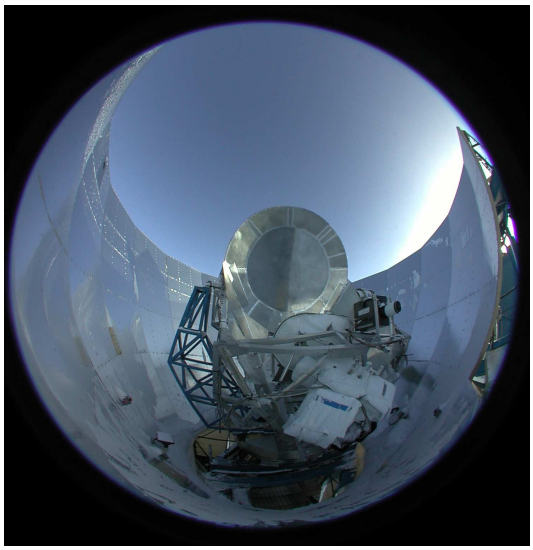
Antenna-coupled Prototype Pixel



POLARBEAR Sensitivity

- Single detectors approach photon statistics limit
  => Increase the array size: 10 => 300 => 1000+ possible
- Atmospheric emission is nearly unpolarized
  => Increase obs. time on ground: 3hrs => 600 days
- 10^5 effective increase in integration time
  (including lower sensitivity on ground)

VIPER at South Pole

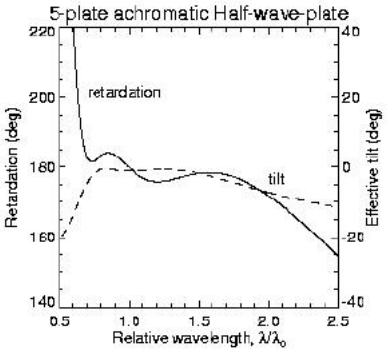


- South Pole best mm-wave site
- VIPER telescope well tested
- 2 meter primary gives 5' resolution at 150 GHz

POLARBEAR Systematic Controls

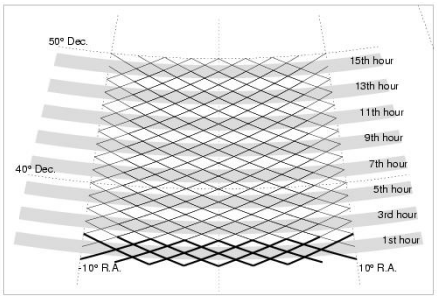
- Multiple levels of differencing, many time scales
  - Subtraction of signals from orthogonal antennas
  - Rotation of polarization, half-wave plate
  - Scan telescope
  - Rotation of sky
  - Re-map at different azimuths
- Low sidelobe telescope
- High SNR helpful for systematic tests
  - "Jack-knife" tests

Broadband half-wave plate



- "Achromatic" half-wave plate => ~ 2 octaves BW
- 50 GHz center frequency gives passbands at 150, 250, 350, … GHz

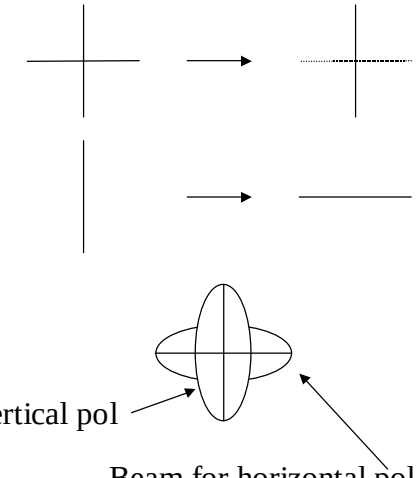
Observation Strategy



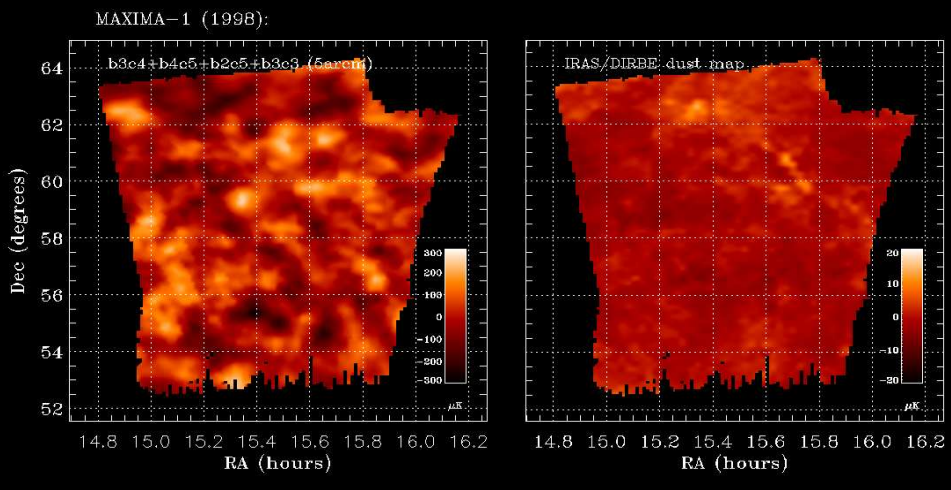
- Simultaneous Az and El scan to give cross-linking
- Multiple modulations
  - HWP, Telescope modulation, sky rotation

Systematic Errors con't

- Instrumental Polarization
- Cross-polarization
- Beam mismatch

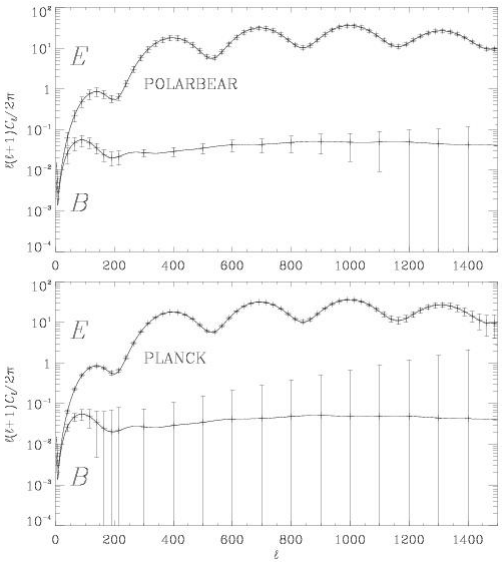


Galactic Dust Emission



POLARBEAR-I Performance

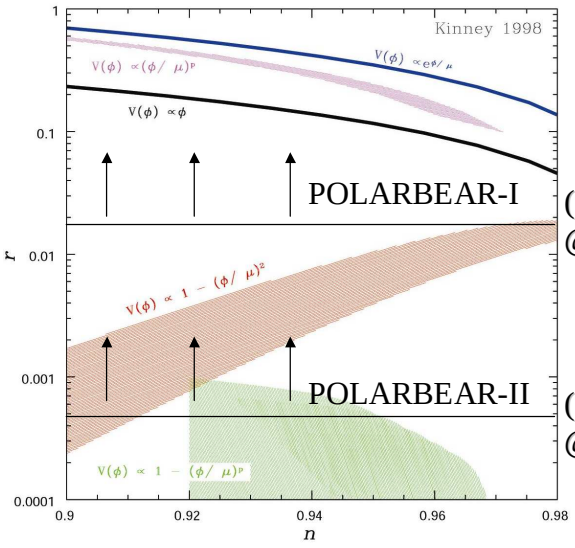
A.H. Jaffe



- 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

POLARBEAR Performance

r = tensor to scalar ratio



(300 Bolometers @ 300 mK)

(3000 Bolometers @ 100 mK)

n = tilt of primordial spectrum

Conclusion

- Much more to learn from CMB photons!
  - Cosmology and Fundamental Physics
- Needed step in instrumentation is imminent
- Control of systematic errors will be critical
- POLARBEAR-I: 2005 (300 Bolometers)
  - NSF proposal submitted
- POLARBEAR-II: (3000 Bolometers)

STOP