The Atacama B-Mode Search: Status and Future Prospects

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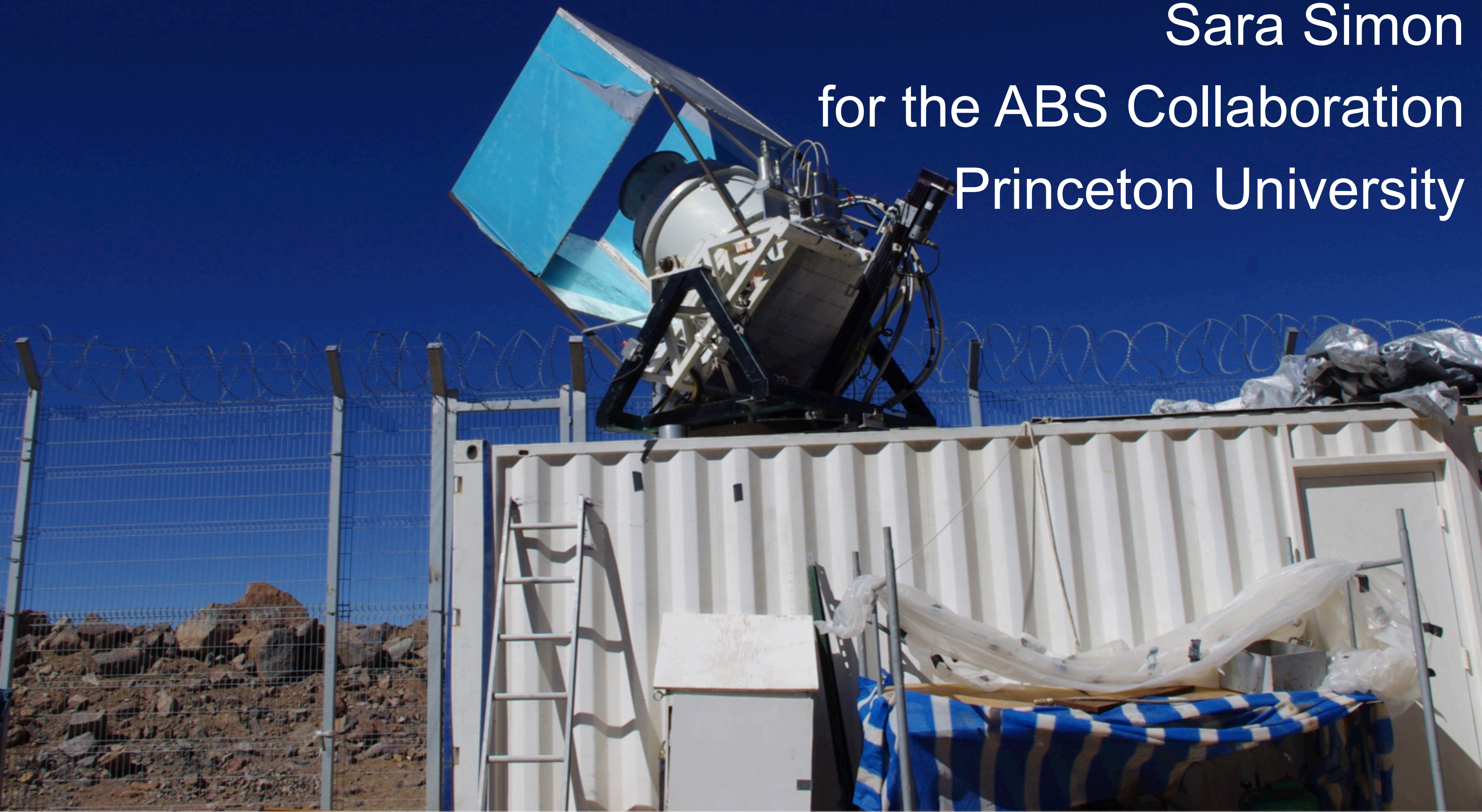


Topics of Discussion

- Cosmic Microwave Background (CMB) Polarization Overview
- ABS Instrument
- Calibrations
- Status and Future Prospects

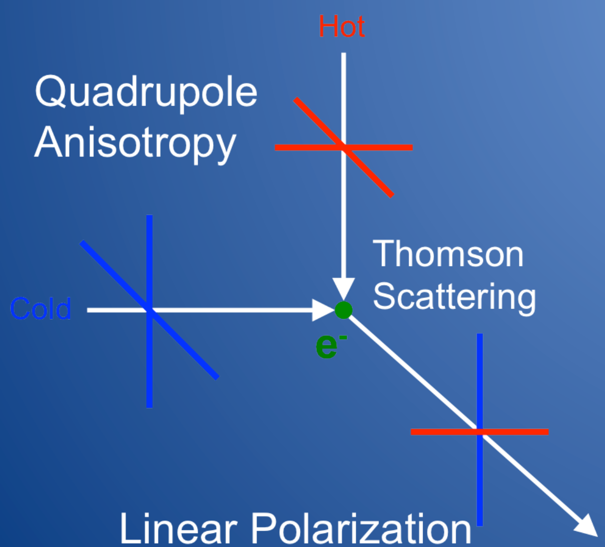
Polarization in the CMB

CMB linearly polarized at decoupling by Thomson Scattering → Need quadrupolar anisotropy to cause linear polarization →

- Scalar (Density) Perturbations
- Tensor (G-wave) Perturbations
- Vector (Vorticity) Perturbations

E-mode Polarization (Even Parity)

B-mode Polarization (Odd Parity)



U. Seljak and M. Zaldarriaga, 1997
M. Kamionkowski, A. Kosowsky, and A. Stebbins, 1997

Inflation and B-modes

Inflation

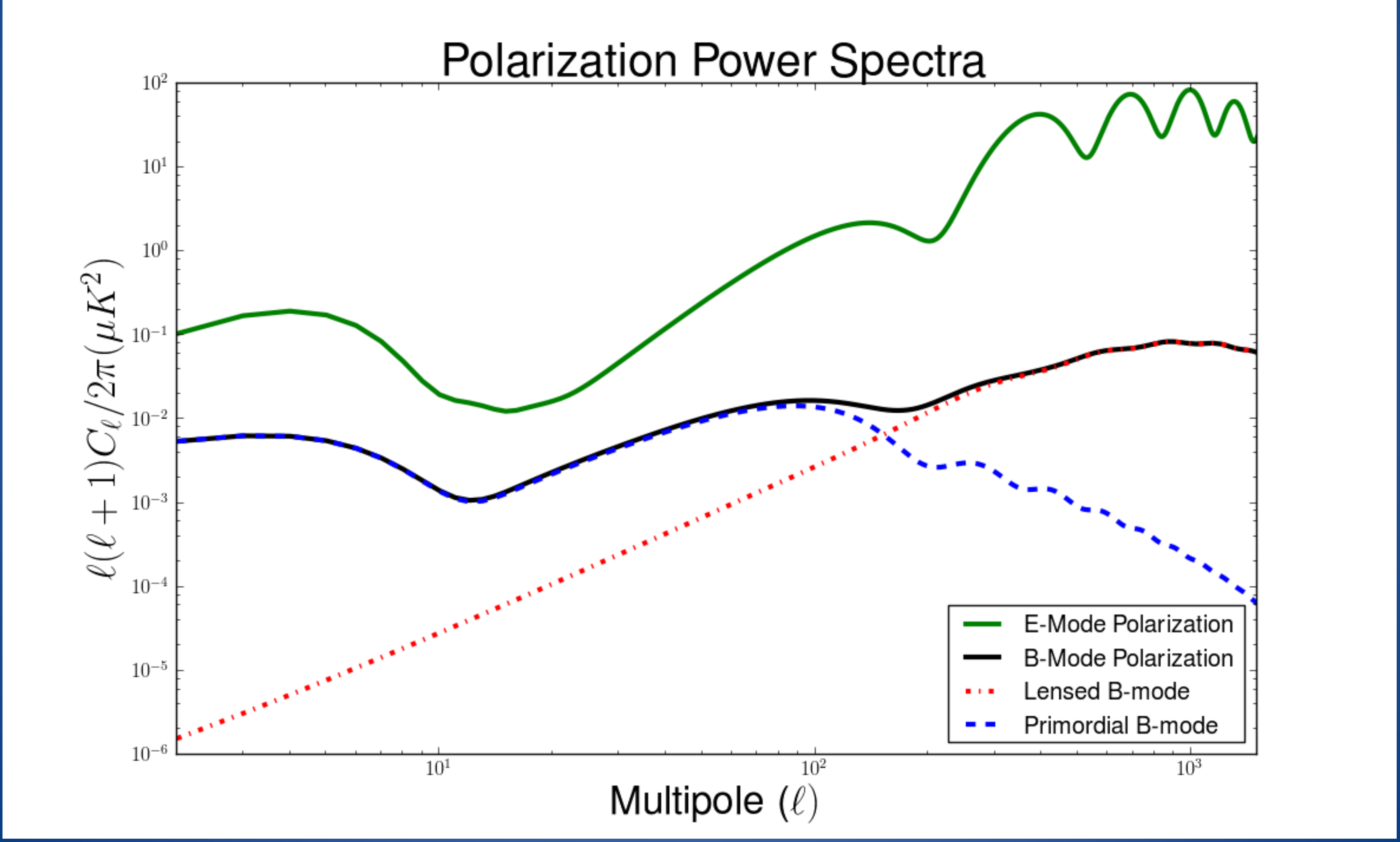
→ Rapid expansion damps vector perturbations → No contribution to polarization from vector perturbations

→ Produces gravitational waves (tensor perturbations) → Production of E-mode and B-mode polarization

BUT E-modes are also produced by scalar perturbations, so the primordial B-modes would be the clearest signal of inflation

U. Seljak and M. Zaldarriaga, 1997
M. Kamionkowski, A. Kosowsky, and A. Stebbins, 1997

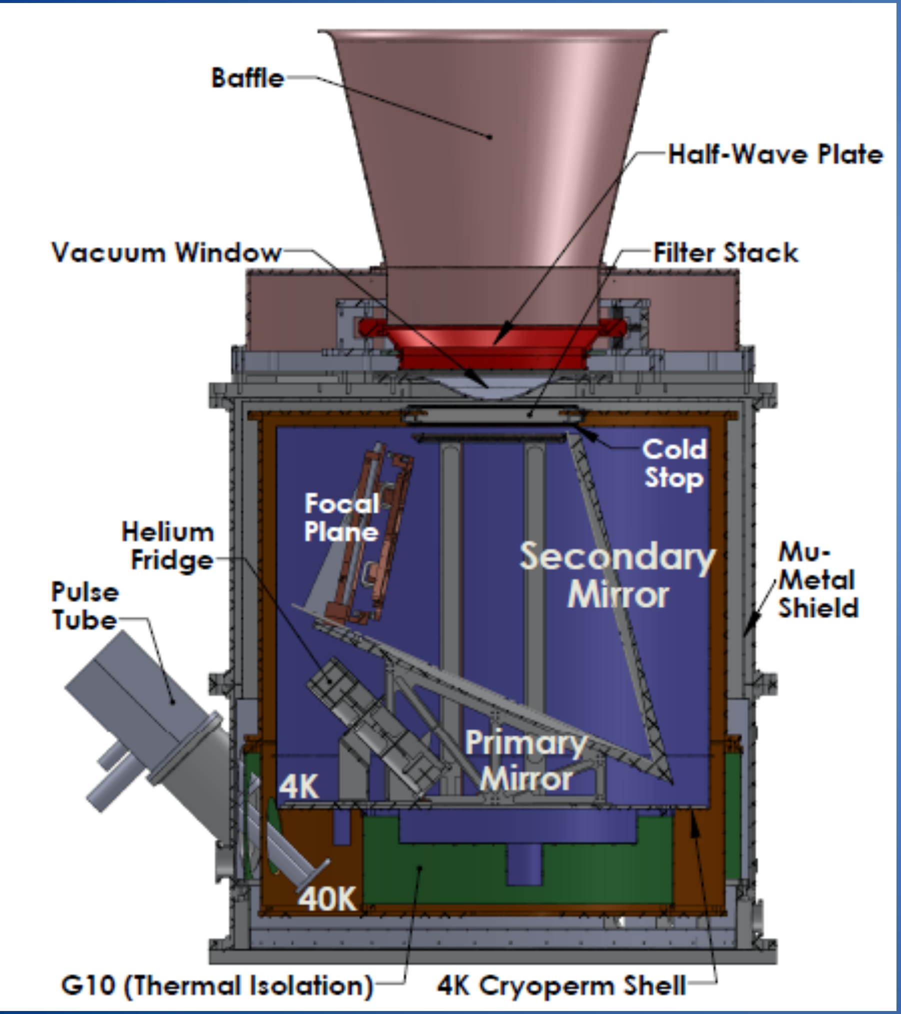
The Primordial B-mode Signal is small!



The Atacama B-mode Search

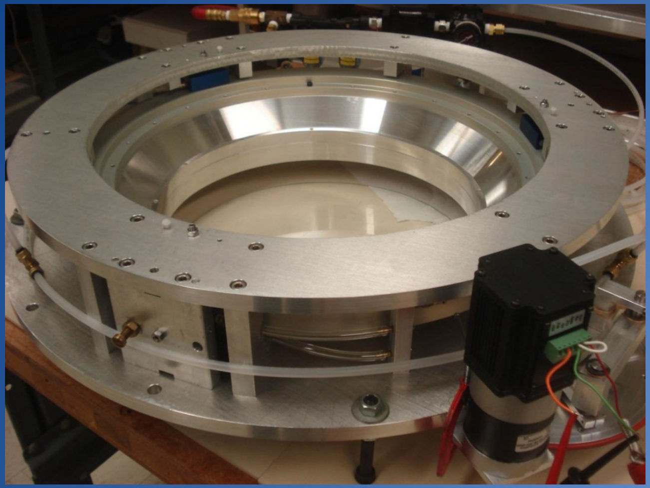
- Ground based at elevation of 5100 m in the Atacama Desert in Chile
    - Low moisture
    - Year-round access and observation
    - Cross-lined maps
- Searching for B-mode polarization on large angular scales (l~50 to l~500)
    - Angular Resolution of 32 Arcmin (FWHM)
    - 480 polarization-sensitive Transition Edge Sensor (TES) bolometers at 150 GHz
    - Receiver NEQ ~30 $\mu K\sqrt{s}$
    - Unique cold optics and continuously rotating half-wave plate (HWP)

Optics

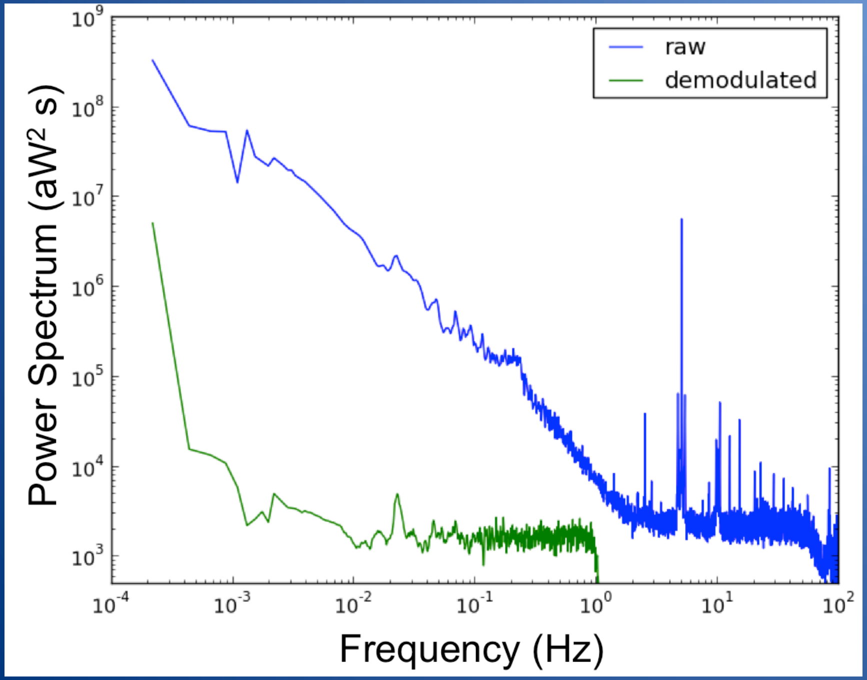


- Crossed-Dragone telescope
  - Optimized for low cross-polarization and a clean beam
  - No need for cryogenic lenses
- Aperture size of ~25 cm
- ~60 cm mirrors are cooled to 4 K
  - Reduces loading and increases sensitivity

Half-Wave Plate



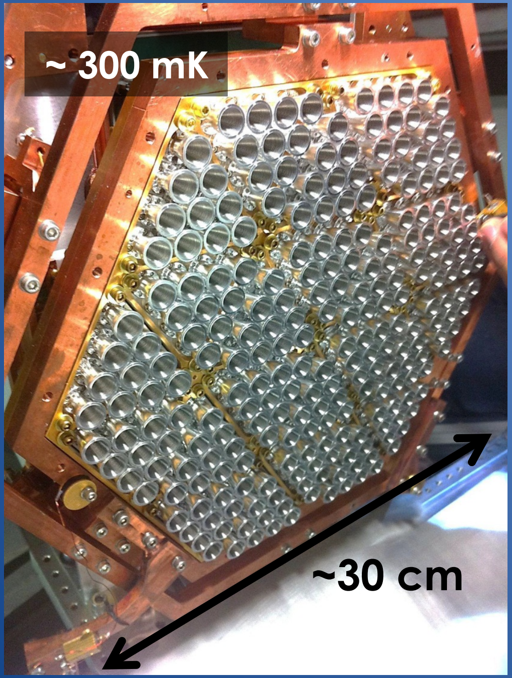
- 330 mm diameter α-cut sapphire plate rotated on air bearings
- 2.5 Hz rotation causes fast, continuous 10 Hz polarization modulation
  - Eliminates need for pair differencing
  - ~1% emission only causes ~5% reduction in sensitivity
  - Reduces sensitivity loss from filtering timestreams
  - Suppresses 1/f noise (preliminary knee frequency is ~1 mHz)

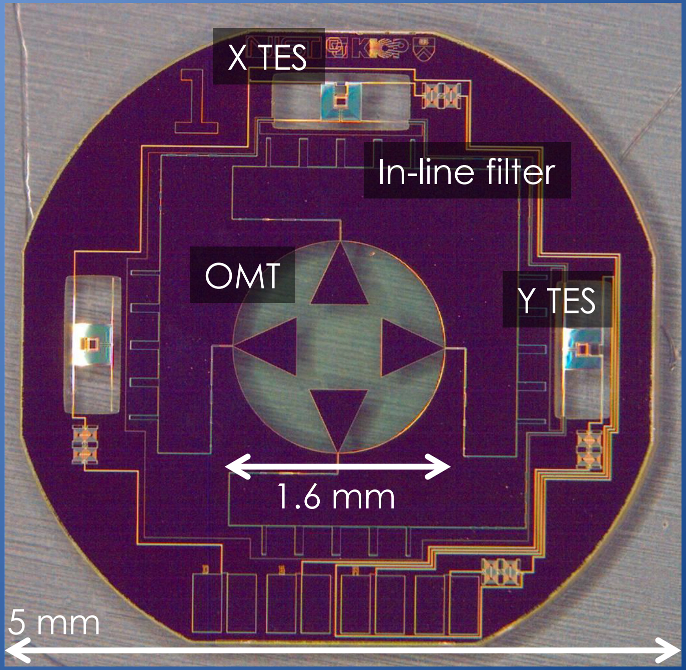


Spectrum of Single Detector Timestream (~1hr)

ABS Focal Plane

- 240 pixels fabricated by NIST in 24 pods of 10
  - Each pixel coupled to a single-moded corrugated feedhorn
  - 2 TES bolometers sensitive to orthogonal polarizations on each pixel
  - 80% of channels are regularly functional
  - Readout with time domain multiplexing to reduce thermal loading





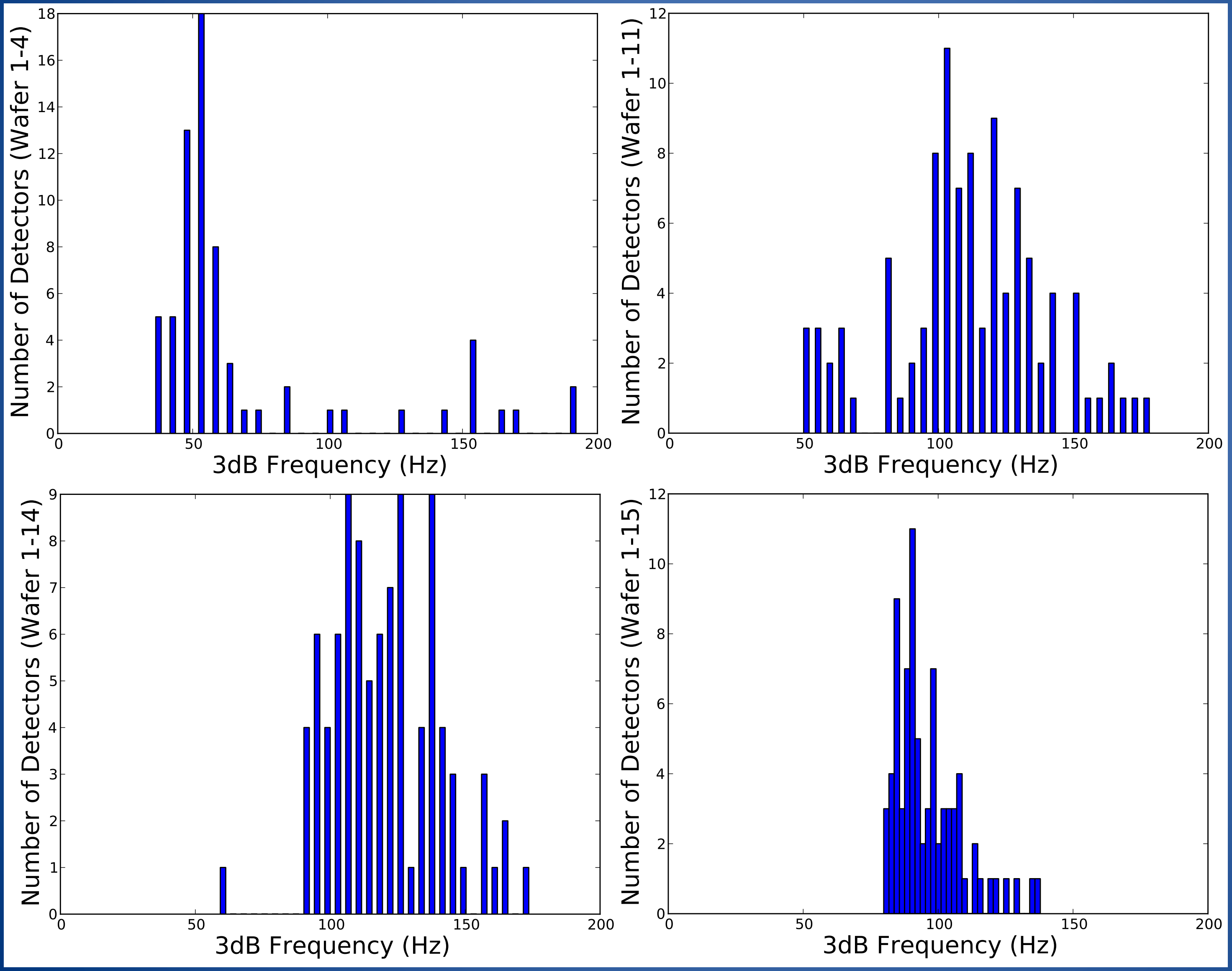
Calibrating ABS

- Thorough characterization of the instrument is crucial for attaining sensitivity needed to measure B-modes
- Routine sky dips and observations of the moon, Saturn, Jupiter, Venus, and RCW 38
  - Calibrate beam, pointing, and detector optical efficiencies
- Spectral response measurements using a Fourier Transform Spectrometer (FTS)
- Wire grid measurements and Tau A observations
  - Polarization angles and responsivity
- Time constant measurements

Time Constants

- Amplitude Measurements
  - Chopped Infrared source at varying frequencies
  - Data taken in inclement weather
  - Most detectors saturated (max 107 fits)
  - Highly sensitive to changes in loading (weather)
- Phase Measurements
  - Vary HWP rotation speed with a sparse polarizing wire grid in place (treat as single-pole filter)
  - File with minimum number of fits had 356 fits
  - Insensitive to changes in loading
  - Preferred method

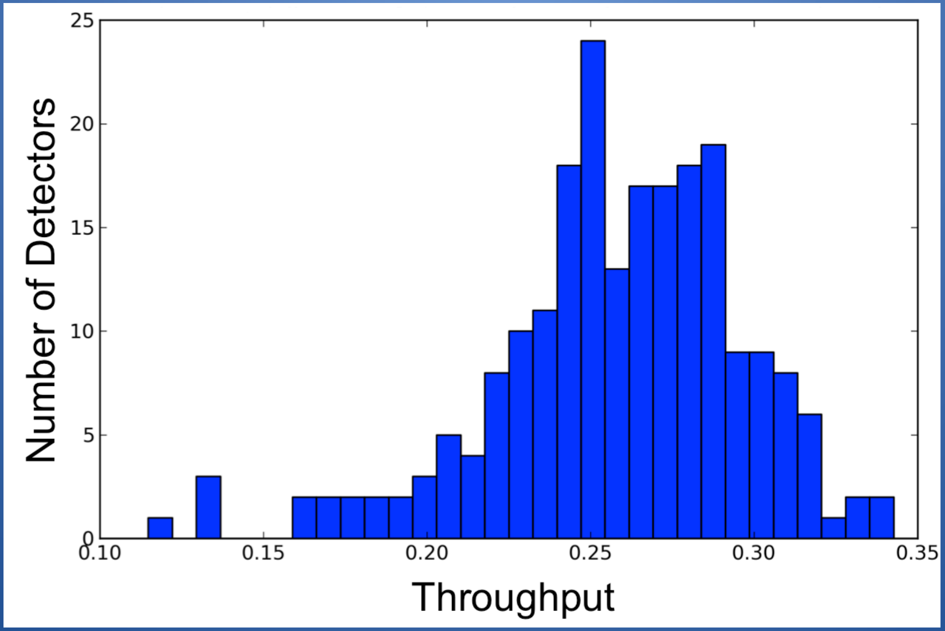
Time Constants II



- The detectors are fast enough for the 10 Hz polarization modulation
- Even the lowest median 3dB frequency only causes a 3% signal reduction

Total Optical Efficiency

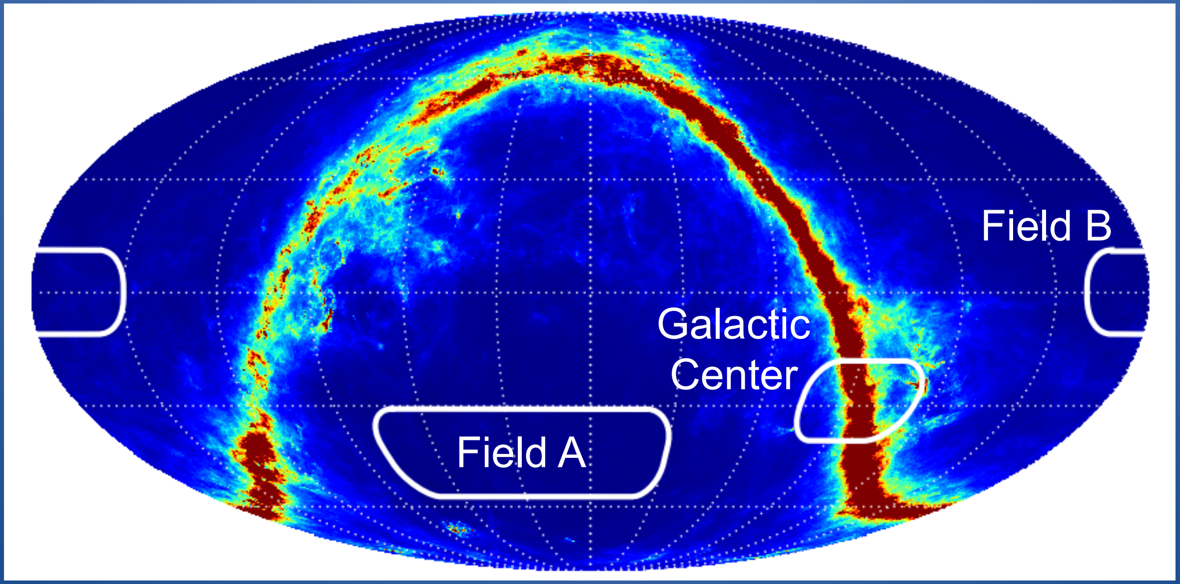
- Detector response dependent on elevation angle, atmospheric brightness, and detector efficiency
    - Found by measuring peak-to-peak amplitude from sky dips
    - Isolate optical efficiency
- Observations of Jupiter from a few detectors provide absolute calibration



K. Visnjic, 2013

Status

- ABS is observing!
- ABS was deployed in February 2012 and began second season of observations in March 2013
- ABS observes a large field in the Southern Hole and a smaller secondary field
  - Both have low foregrounds
- CMB observations are azimuthal scans (~0.04 Hz)



Analysis of First Season

- Map making is currently underway
- Preliminary maps have been made
- Further characterization of instrument is ongoing

Future Prospects

- ABS is expecting to make some of the most sensitive measurements of the CMB
- Analysis of first season data is ongoing
- An upgrade is currently in development
  - Improved detectors
  - Possible multichroic expansion

Thank You

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