BFORE
The B-mode Foreground Experiment

Michael D. Niemack, Cornell University Physics Department, Ithaca, NY

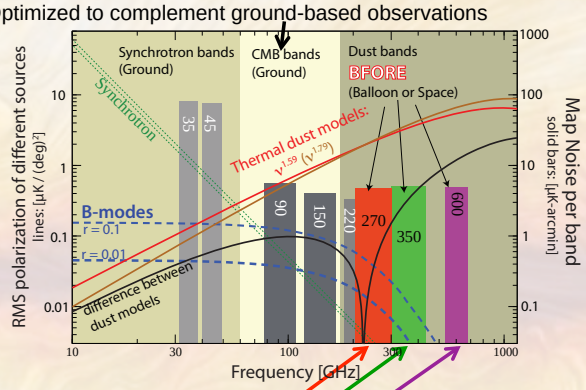
Peter Ade, Francesco de Bernardis, Francois Boulanger, Sean Bryan, Mark Devlin, Joanna Dunkley, Steve Eales, Haley Gomez, Chris Groppi, Seth Hillbrand, Johannes Hubmayr, Philip Mauskopf, Jeff McMahon, Marc-Antoine Miville-Deschênes, Enzo Pascale, Giampaolo Pisano, Giles Novak, Douglas Scott, Juan Soler, Carole Tucker

ABSTRACT

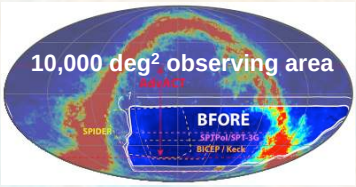
The B-mode Foreground Experiment (BFORE) is a proposed NASA balloon designed to make optimal use of the sub-orbital platform by concentrating on three dust foreground bands (270, 350, and 600 GHz) that complement ground-based cosmic microwave background (CMB) programs. BFORE will survey ~1/4 of the sky with 1.7 - 3.7 arcminute resolution, enabling precise characterization of the galactic dust that now limits constraints on inflation from CMB B-mode polarization measurements. In addition, BFORE's combination of frequency coverage, large survey area, and angular resolution enables science far beyond the critical goal of measuring foregrounds, including velocity measurements or constraints on thousands of galaxy clusters, a new window on the cosmic infrared background, and probes of magnetic fields in the interstellar medium. We review the science case, timeline, and instrument design, which is based on a compact off-axis telescope coupled to >10,000 superconducting detectors.

OBSERVATIONS AND SCIENCE

- Goal: Improve Inflation constraints by characterizing foregrounds
- Optimized to complement ground-based observations

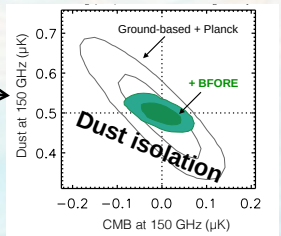


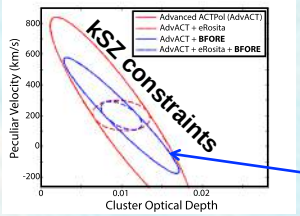
- BFORE will characterize galactic dust foregrounds that limit current B-mode constraints [1] at **270**, **350**, **600 GHz**
- Planck measurements suggest several dust bands are likely needed for a definitive detection of inflationary B-modes with $r \leq 0.01$ [2]



- **> 5x deeper than Planck** across 10,000 deg²
- Overlap with Advanced ACTPol, SPT-3G, BICEP/ Keck, Polarbear, CLASS…

- Break degeneracies from spatially varying dust [2]
- Enable new measurements of galactic magnetic fields & CIB

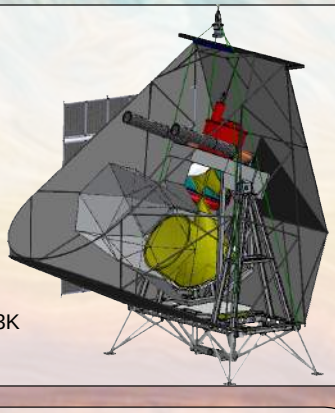




- Kinematic Sunyaev-Zel'dovich (kSZ) measurements of individual clusters
- kSZ figure-of-merit is tripled compared to Advanced ACTPol alone (based on [3])

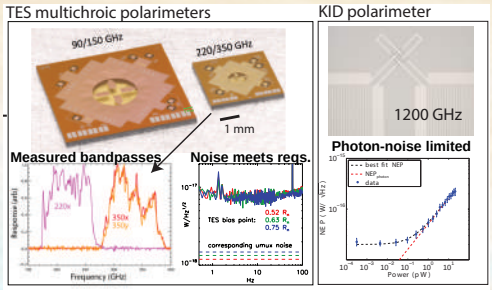
INSTRUMENT OVERVIEW

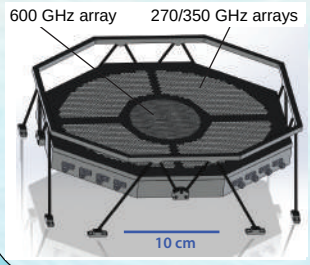
- Aperture: 1.35 meters
  => 1.7' to 3.7' resolution
- 3 degree field-of-view
- Secondary cooled to 4K
- Cold reflective HWP [4]
- Compound silicon lens isolates AR coatings [5]
- ^{3}He fridge cools detectors to 0.3K
- Antarctic flight (28+ days)



DETECTOR ARRAYS

- **Feedhorn-Coupled Superconducting Polarimeters**
- Transition-Edge Sensor (TES) bolometers based on ACTPol multichroics [6,7] at 270/350 GHz
- Kinetic Inductance Detectors (KIDs) from BLASTPol [8] at 600 GHz





- Detector technologies selected based on demonstrated performance and optimization for different wavelengths
- **Microwave readout** of all detectors; microwave SQUIDs for TESes [9,10]
- Approximately 4,000 detectors at each frequency => ~12,000 detectors total (~6,000 dual polarization pixels)

TIMELINE AND ACKNOWLEDGEMENTS

First Antarctic flight target is 2018, enabled by reusing BLAST systems.

Proposal in review at NASA during summer of 2015.

Background image from the Planck satellite team and the ESA.

REFERENCES

[1] BICEP2/Keck and Planck Collab., "Joint analysis of BICEP2/Keck Array and Planck data," PRL 114, arXiv:1502.00612 (2015)
[2] Planck Collab. "Planck intermediate results. XXII. Frequency dependence of thermal emission from Galactic dust in intensity and polarization," A&A arXiv:1405.0874, (2015); *and* "Planck intermediate results. XXX. The angular power spectrum of polarized dust emission at intermediate and high Galactic latitudes," arXiv:1409.5738, (2014); *and* "Planck intermediate results. XXXVIII. E- and B-modes of dust polarization from the magnetized filamentary structure of the interstellar medium," arXiv:1505.02779 (2015)
[3] Knox, Holder, Church, "Effects of sub-mm and radio point sources on the recovery of Sunyaev-Zel'dovich galaxy cluster parameters," ApJ 612(1):96, arXiv:astro-ph/0309643 (2004)
[4] Pisano et al. "Development of large radii half-wave plates for CMB satellite missions," Proc. SPIE, arXiv:1409.8516 (2014)
[5] Datta et al. "Large-aperture wide-bandwidth anti-reflection-coated silicon lenses for millimeter wavelengths," AO 52:8747 (2013)
[6] Datta et al. "Horn Coupled Multichroic Polarimeters for the Atacama Cosmology Telescope Polarization Experiment," JLTP 176:670 (2014)
[7] Niemack et al. "Optimizing feedhorn-coupled TES polarimeters for balloon and space-based CMB observations," JLTP 167:917 (2012)
[8] Hubmayr et al. "Photon-noise limited sensitivity in titanium nitride kinetic inductance detectors," APL 106:073505 (2015)
[9] Mates, "The Microwave SQUID Multiplexer," PhD thesis, University of Colorado, 2011.
[10] Dicker et al. "MUSTANG2: a large focal plan array for the 100 meter Green Bank Telescope," Proc. SPIE 9153 (2014)