ACTPol

A Polarization Sensitive Receiver for the Atacama Cosmology Telescope

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ABSTRACT

The six-meter Atacama Cosmology Telescope (ACT) in Chile was built to measure the cosmic microwave background (CMB) at arcminute angular scales. We are building a new polarization sensitive receiver for ACT (ACTPol). ACTPol will characterize the gravitational lensing of the CMB and aims to constrain the sum of the neutrino masses with ~ 0.05 eV precision, the running of the spectral index of inflation-induced fluctuations, and the primordial helium abundance to better than 1 %. Our observing fields will overlap with the SDSS BOSS survey at optical wavelengths, enabling a variety of cross-correlation science, including studies of the growth of cosmic structure from Sunyaev-Zel'dovich observations of clusters of galaxies as well as independent constraints on the sum of the neutrino masses.

SCIENCE AND OBSERVATIONS

ACTPol will simultaneously measure temperature and polarization at the primary science band of 150 GHz and a secondary band at 90 GHz (with the possibility of a 220 GHz replacement) [1]. Two surveys are currently planned: a wide ~4000 deg^2 region overlapping with the SDSS BOSS survey [2] and deep regions covering ~150 deg^2 and overlapping with deep optical, infrared, and X-ray observations. Target 150 GHz map depths for these surveys are 20 μK/arcmin^2 for the wide region and 3 μK/arcmin^2 for the deep region.

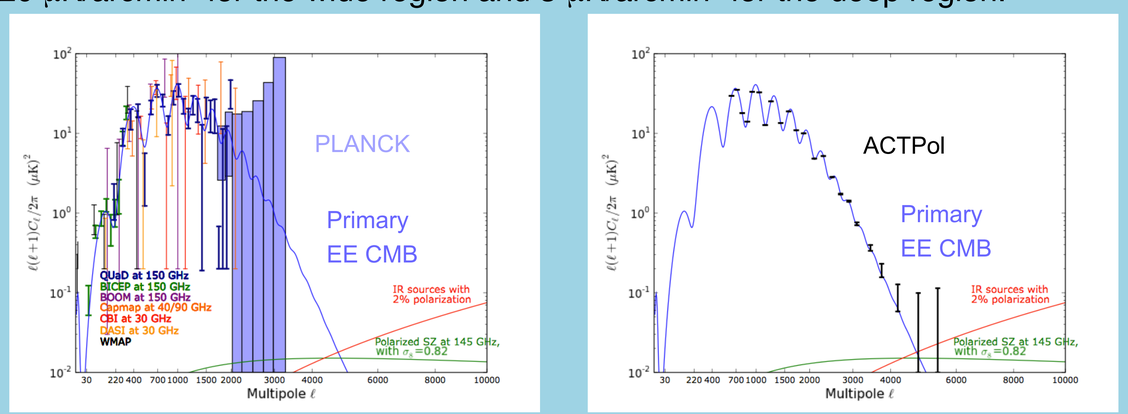


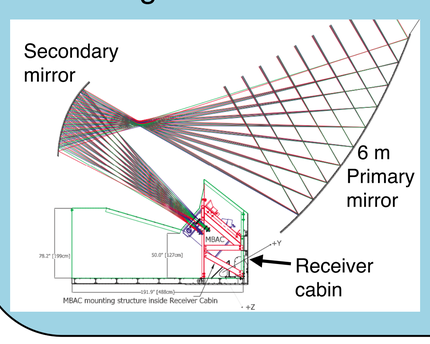
Fig. 1 - (left) Current measurements of the CMB primordial E-mode polarization power spectrum and projections for the Planck satellite (based on "Bluebook" sensitivities). (right) Projected ACTPol error bars.

ACTPol science objectives include [1]:

- Inflation: Improve constraints on n_s, the spectral index of inflation, and α_s, the running of the index, through high-multipole CMB E-mode spectrum
- Neutrinos: Measure the sum of the neutrino masses with 0.05 eV precision through E-mode and lensing spectra and cross-correlations
- Dark Energy: Characterize the matter power spectrum at high redshift (z ~ 3) through CMB lensing, which will probe models of early dark energy
- Big Bang Nucleosynthesis: Constrain the primordial He abundance to better than 1 % through high-multipole E-mode spectrum
- Clusters: Measure the Sunyaev-Zel'dovich effect from ~1000 clusters
- Inflationary Gravity Waves: Attempt to delens the CMB and thereby improve the sensitivity of Inflationary Gravity Wave Searches

ATACAMA COSMOLOGY TELESCOPE

- Location: Cerro Toco, Chile 5190 m
- Mid-latitude allows crosslinking and equatorial observations
- Dual ground shields minimize pickup



- Off-axis aplanatic Gregorian design [3]
- ACT measurements of CMB temperature [e.g. 4,5]
  ⇒ Strong constraints on cosmological parameters

Fig. 2 - (above) ACT with comoving ground shield installed, but unfinished 13 m stationary shield. (left) Ray trace of optics with receiver cabin outline.

SCHEDULE AND ACKNOWLEDGEMENTS

First light at 150 GHz in 2012; first light with complete instrument in 2013.

We thank the National Science Foundation as well as members and supporters of the ACT [3,4,5] and TRUCE [6,7,8,9] collaborations.

OPTICS AND RECEIVER

- Three independent optics paths in receiver
  - Two 150 GHz paths and a 90 GHz path
  - 1 degree diameter fields-of-view
  - Large diameter (> 30 cm) cryogenic silicon lenses
  - Telecentric, diffraction-limited focal planes (Strehl ratios > 0.9)

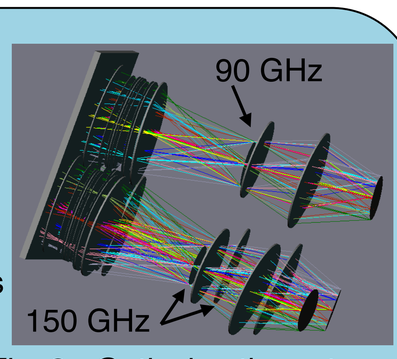
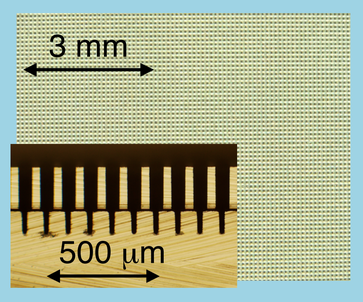
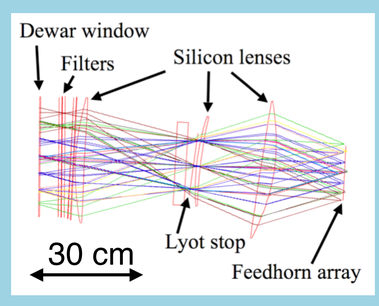


Fig. 3 - Optical path ray trace.





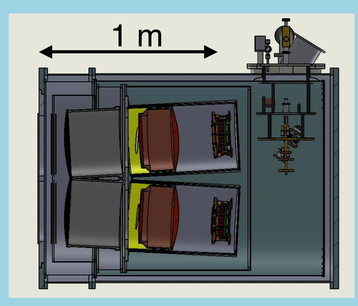


Fig. 4 - (left) Prototype anti-reflection coatings for lenses cut with a dicing saw. (middle) Ray-trace of 150 GHz refractive optics. (right) Preliminary receiver design with dilution refrigerator insert at upper right and dewar windows at left.

- Cryogen-free cooling
  - Dilution refrigerator with < 100 mK bath, backed by 2 pulse tube coolers

DETECTOR ARRAYS

- Feedhorn-Coupled TES Polarimeters [6,7]
  (also being developed for ABS [8] and SPTPol [9])
  - Micromachined silicon feedhorn arrays
  - Superconducting circuits couple to feeds
  - Transition-edge sensor (TES) bolometers for each polarization

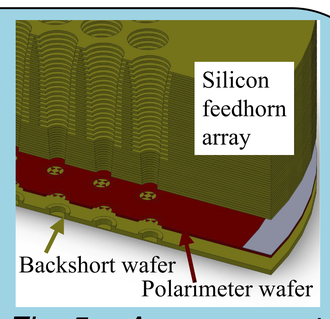
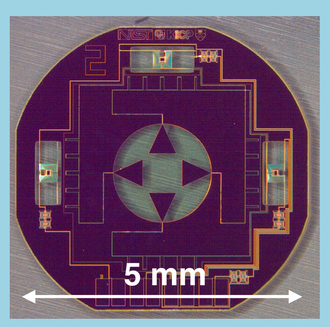
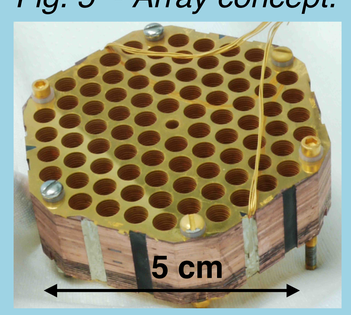
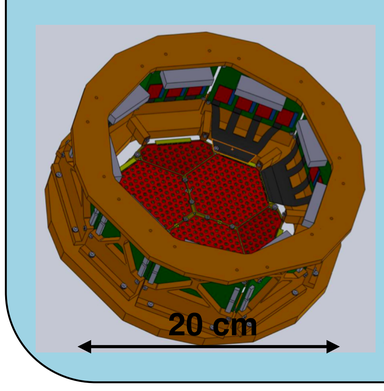


Fig. 5 - Array concept.

Fig. 6 - (right) Single TES polarimeter detector of the style to be deployed in ABS [8]. (far right) Prototype gold-plated silicon feedhorn array.







- Three ACTPol detector arrays
  - 140 mm diameter silicon feedhorn arrays
  - Five detector wafers totaling ~1000 TES per array
  - Time-division SQUID multiplexer readout [10]
  - Exploring possible multichroic 90/150 option

Fig. 7 - (left) Rear view of ACTPol 150 GHz array design.

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