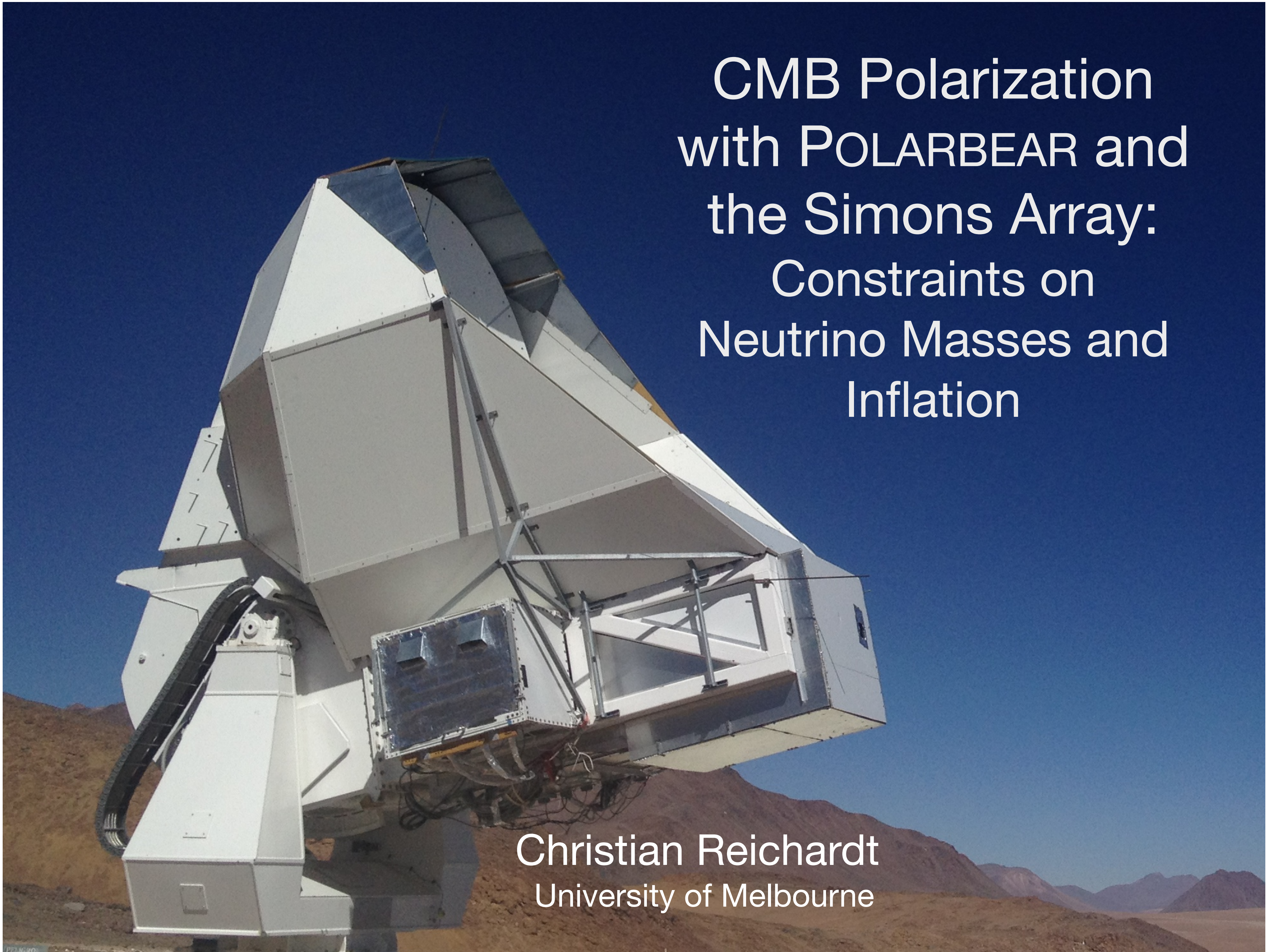
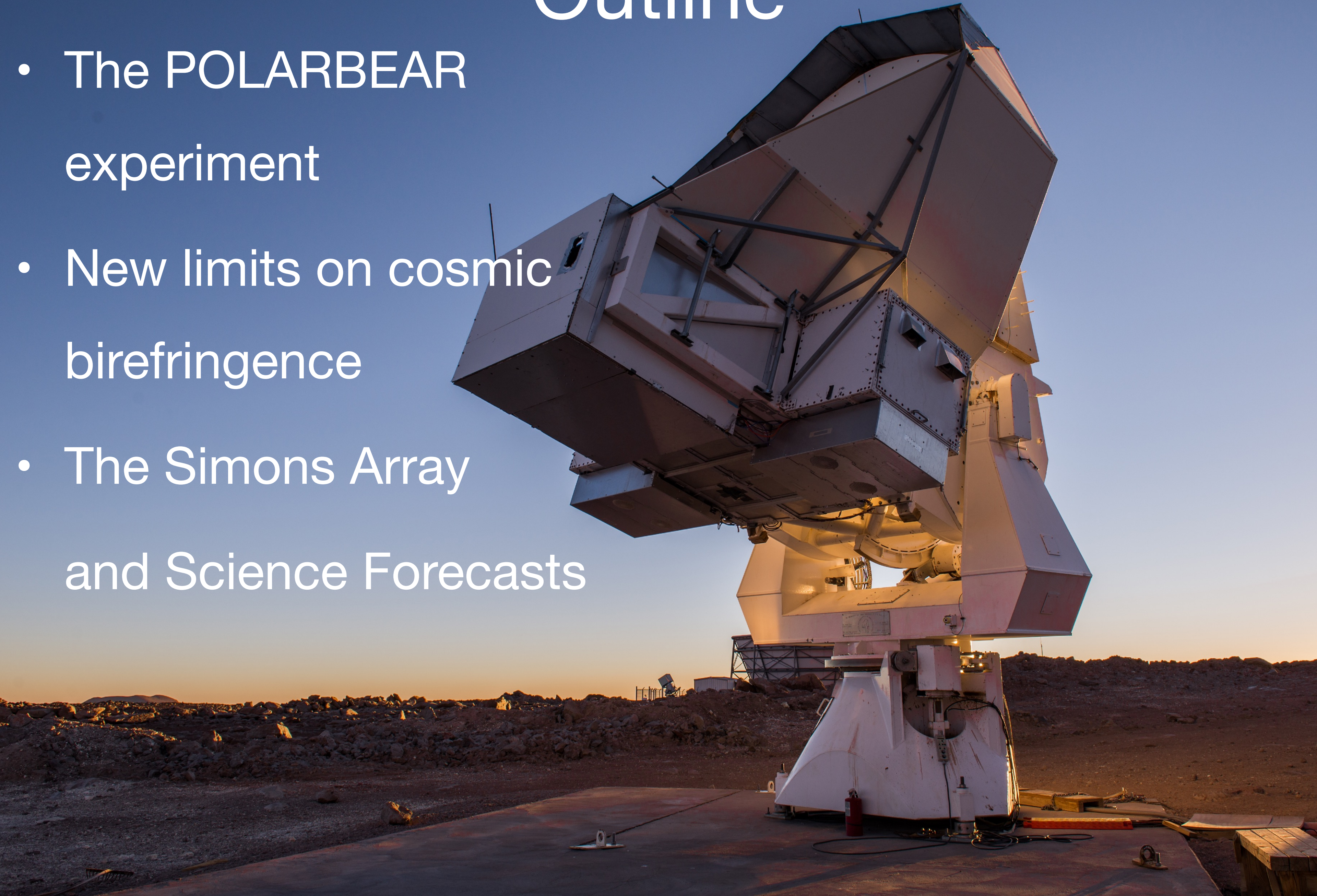


CMB Polarization with POLARBEAR and the Simons Array: Constraints on Neutrino Masses and Inflation

Christian Reichardt
University of Melbourne

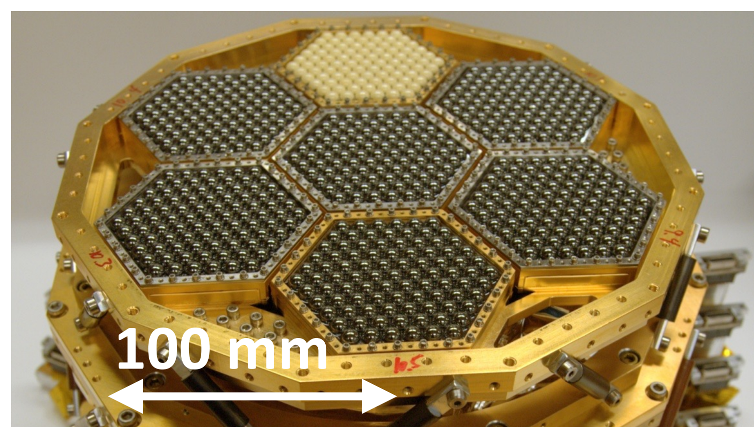
Outline

- The POLARBEAR experiment
- New limits on cosmic birefringence
- The Simons Array and Science Forecasts



POLARBEAR

- Atacama Plateau, high & dry
  - Elevation: 5200 m
- 3.5 m telescope
  - 3'.5 FWHM beam at 150 GHz
  - Sufficient to resolve lensing signal
- 1274 polarization-sensitive TES bolometers
  - Coupled using dipole antennas and lenslets



POLARBEAR Collaboration

MEXT
SIMONS FOUNDATION

UC Berkeley
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Yuji Chinone
Ari Cukierman
Tijmen de Haan
Josquin Errard
Neil Goeckner-Wald
John Groh
Grantland Hall
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Yasuto Hori
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Mike Myers
Chris Raum
Paul Richards
Blake Sherwin
Ian Shirley
Bryan Steinbach
Aritoki Suzuki
Nathan Whitehorn
Oliver Zahn

Imperial College
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Stephen Feeney
Andrew Jaffe

UC San Diego
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Carlo Baccigalupi
Giulio Fabbian
Giuseppe Puglisi

JAXA
Tomotake Matsumura

UC Irvine
Chang Feng

National Institute for Fusion Science
Suguru Takada

Cardiff University
Peter Ade

NASA Goddard
Nathan Miller

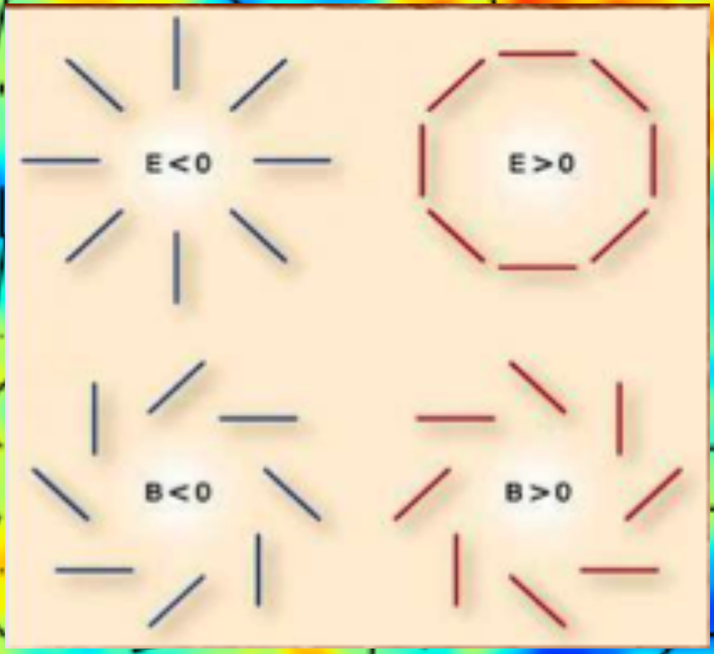
Princeton
Zigmund Kermish

Católica (PUC)
David Boettger
Rolando Dunner

And many more in years past

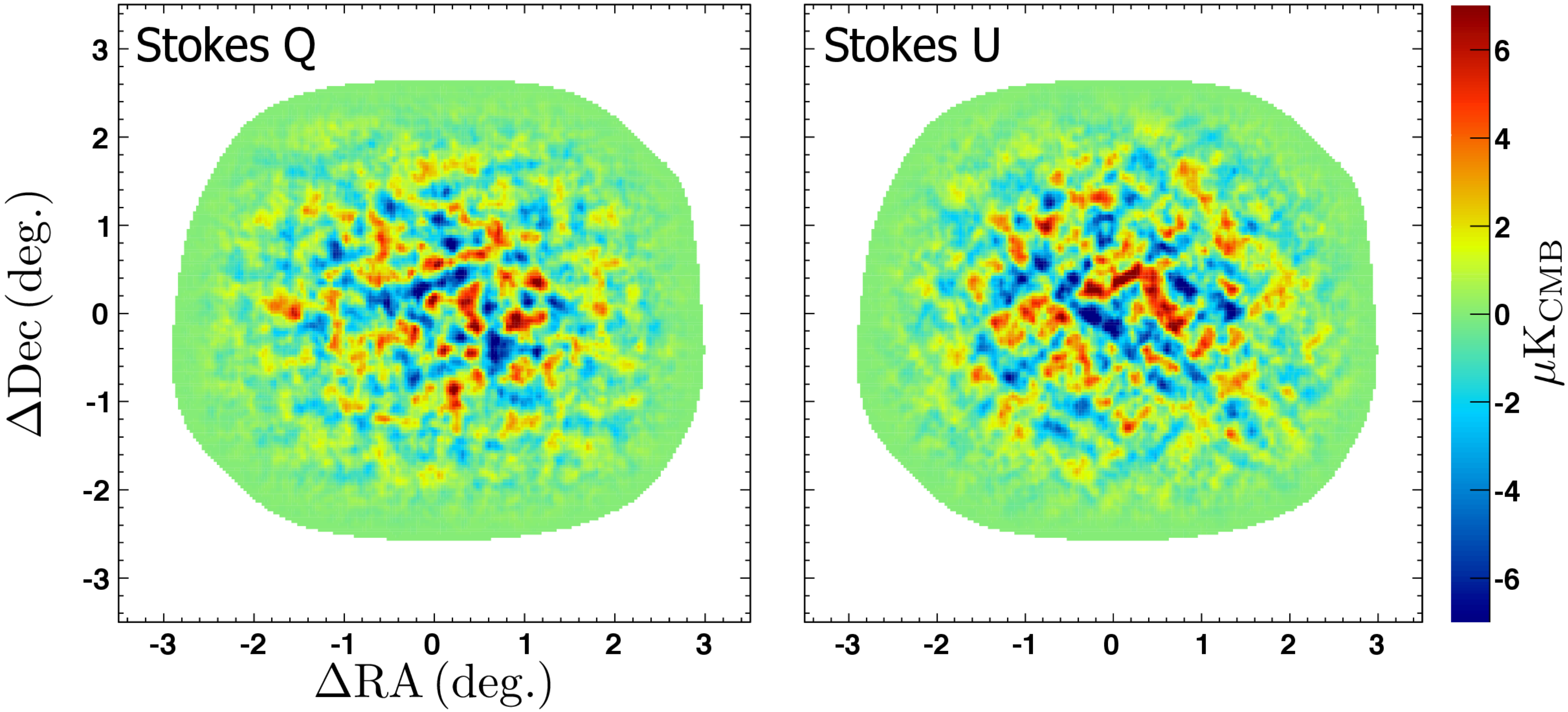
POLARBEAR Science Goals

Measure B-modes in CMB polarization to learn about inflation, the sum of the neutrino masses, …



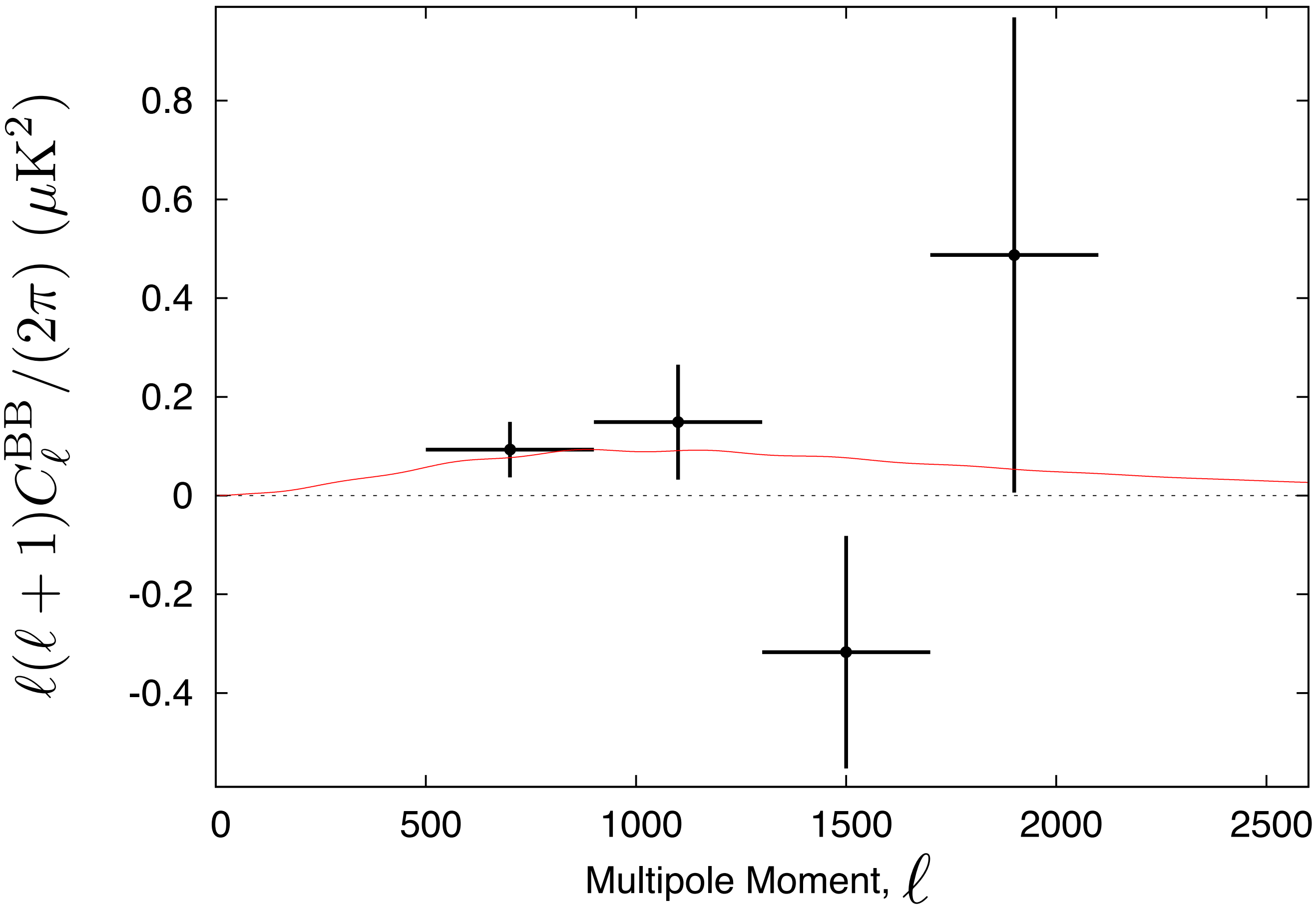
PB: 1 of 3 fields

1st year data



Direct Spectrum Measurement

POLARBEAR collaboration arXiv:1403.2369



- A_{BB} = 1.12 ± 0.61 (stat) +0.04/-0.10 (sys) ± 0.07 (mult)

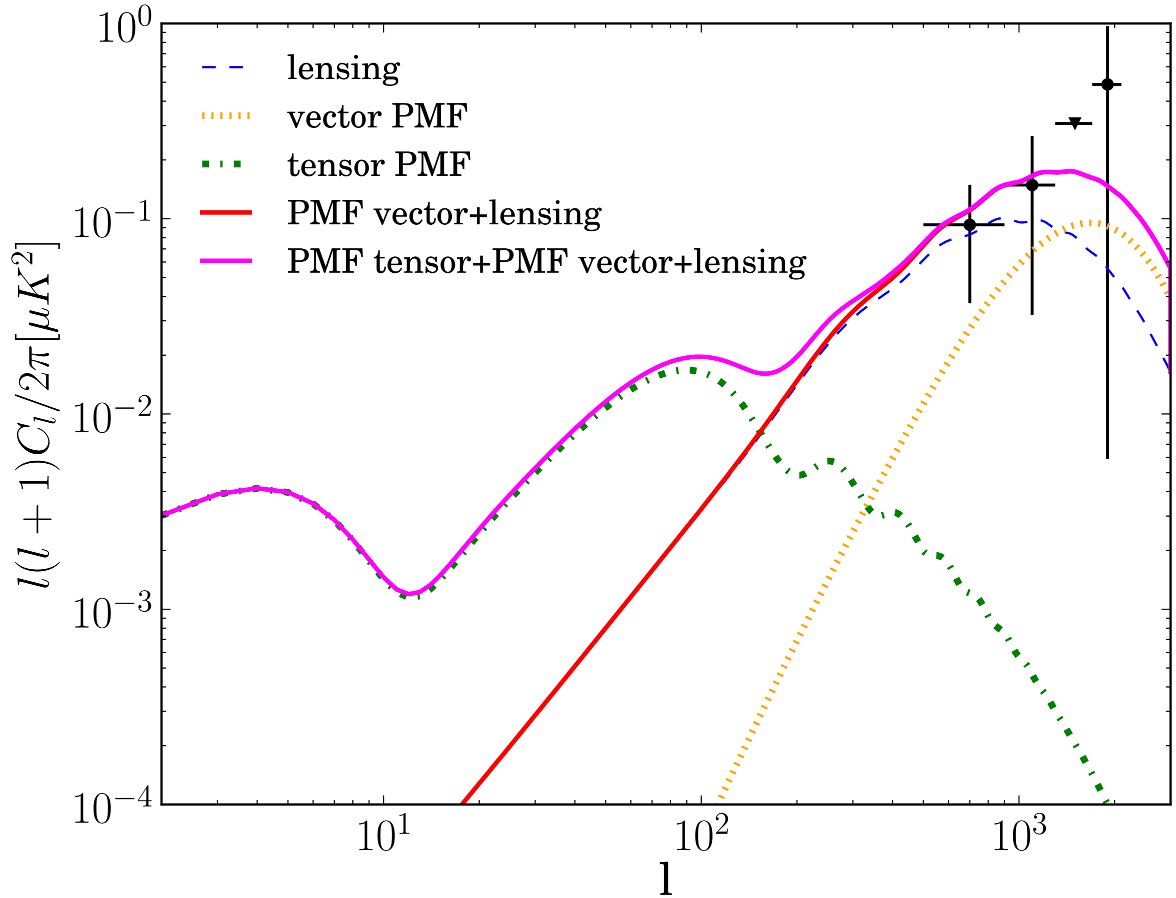
Faraday Rotation

- A primordial magnetic field would Faraday rotate CMB photons
  - Hypothesized to explain observed galactic magnetic fields.
  - Rotates polarized E- into B-modes; thus correlating them
- Cosmic birefringence leads to similar observational effect
  - due to eg a coupling between photons and a pseudo-scalar field
- Pathway to test for exotic physics!

Faraday Rotation / Cosmic Birefringence

- Two detection paths
  1. B-mode power spectrum.
  2. 4-point correlation to pull out non-Gaussian signature (similar to lensing)
- We're assuming a rotation that is **not** uniform across the sky

Primordial Magnetic fields from the BB spectrum



Take the B-mode power spectrum from PB collaboration, et al. 2014.

Fit to a combination of B-modes from gravitational lensing and PMFs.

Set upper limit on PMF contribution

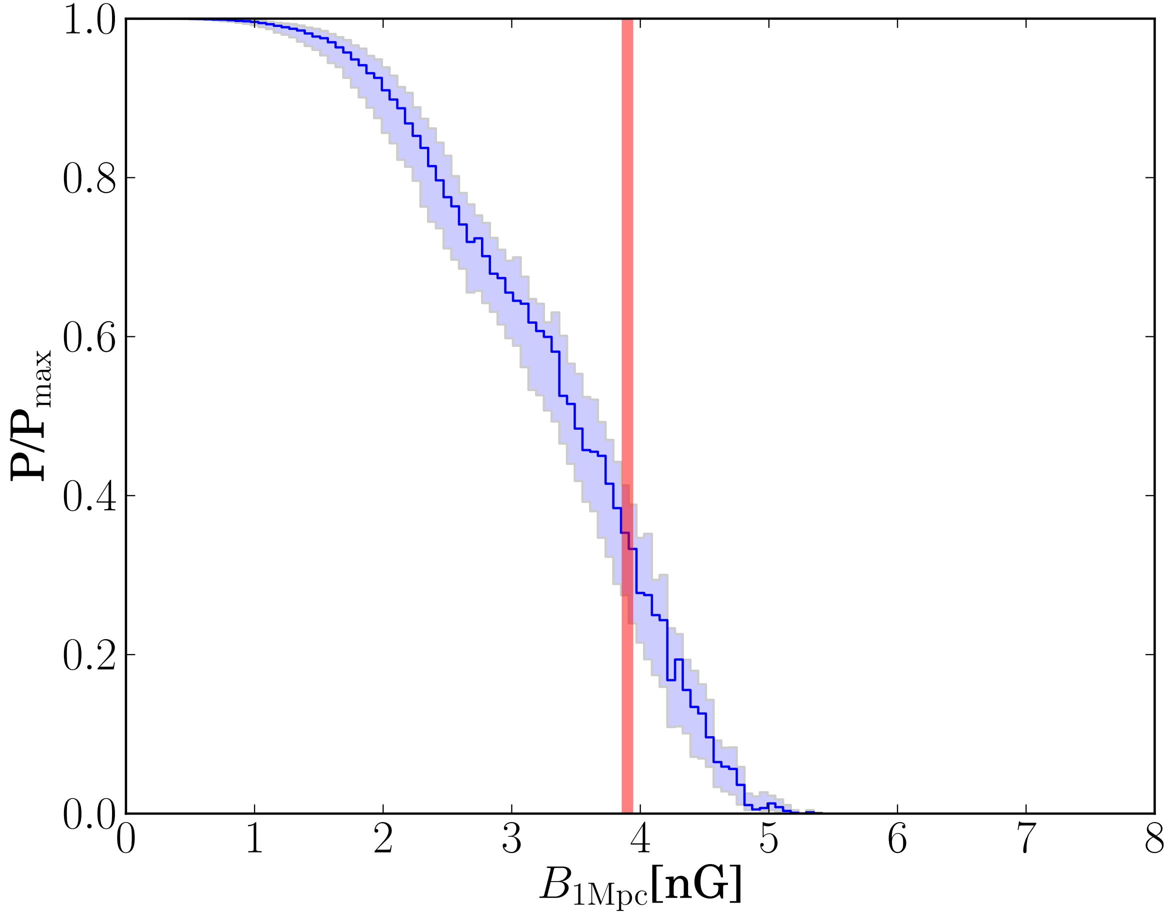
Limits from the B-mode spectrum

PB collab et al.
arXiv:1509.02461

- B < 3.9 nG at 95% CL.

vs Planck XIX 2015: < 4.4 nG

- Assuming uniform prior on B (result is prior dependent)

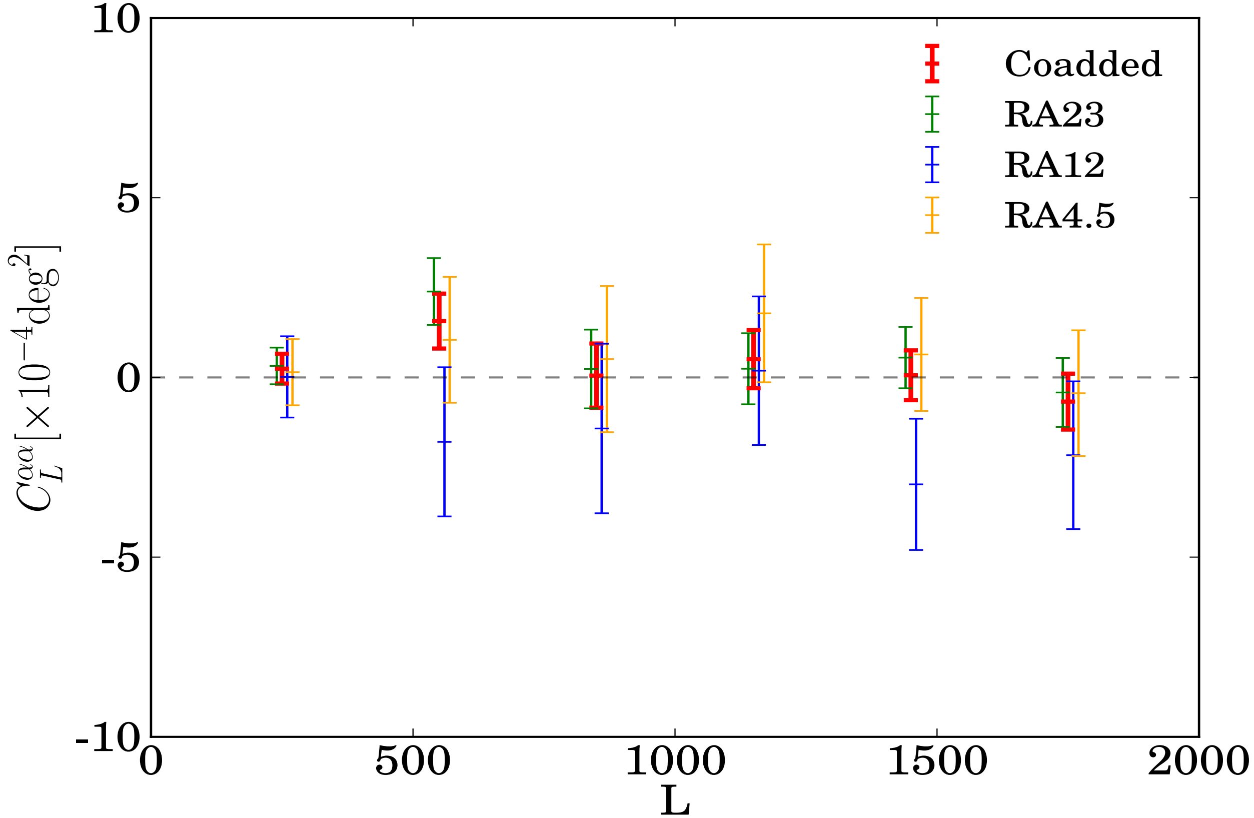


Rotation angle spectrum

Estimator:

$$\alpha_{EB}(\mathbf{L}) = A_{EB}(L) \int \frac{d^2\mathbf{l}}{(2\pi)^2} E(\mathbf{l}) B(\mathbf{l}') \frac{2\tilde{C}_l^{EE} \cos 2\phi_{\mathbf{l}\mathbf{l}'}}{C_l^{EE} C_{l'}^{BB}}$$

PB collab et al.
arXiv:1509.02461



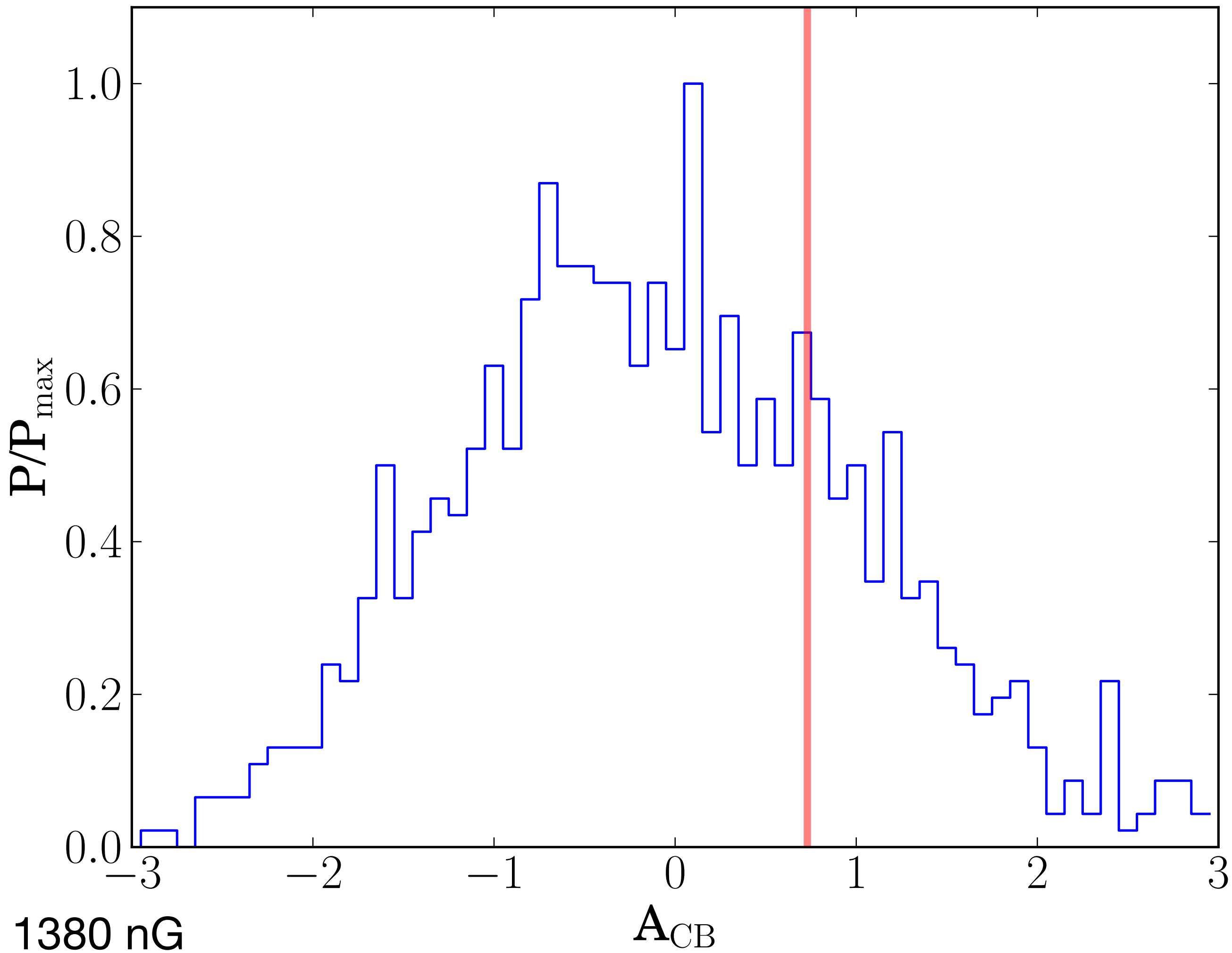
Consistent with zero

PB collab et al.
arXiv:1509.02461

Distribution of 0-signal simulations.

No evidence for non-zero rotations

Equivalent 95% CL upper limit of **<93 nG** on the primordial magnetic field



vs Planck XIX 2015: < 1380 nG

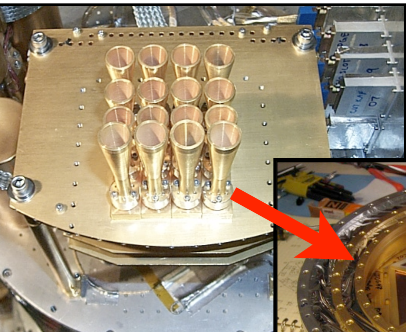
Take away message

- No evidence for primordial magnetic fields or cosmic birefringence (yet)
- Limits will continue to improve with better B-mode data

credit: B. Benson

What's Next? Go big!

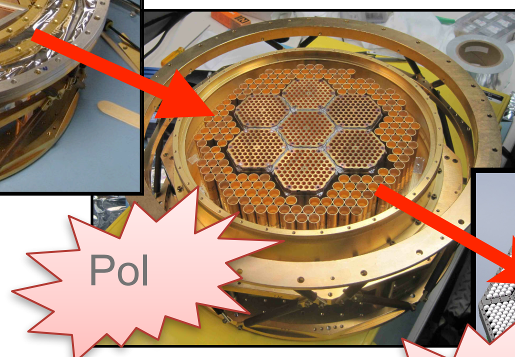
2001: ACBAR
16 detectors



2007: SPT
960 detectors

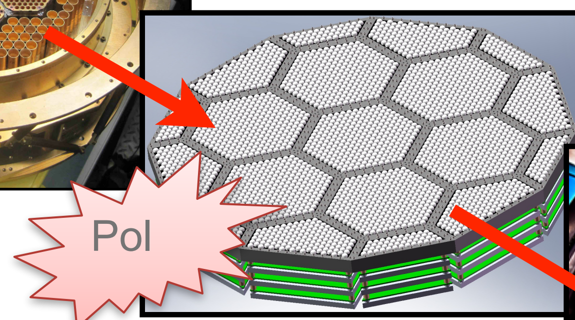
Stage-2

2012: PB
1500 detectors
2012: SPTpol
~1600 detectors



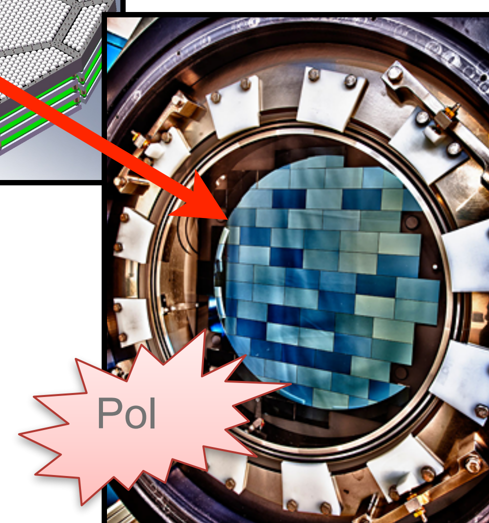
Stage-3

2017: Simons Array:
22,764 detectors
2017: SPT-3G
~15,200 detectors



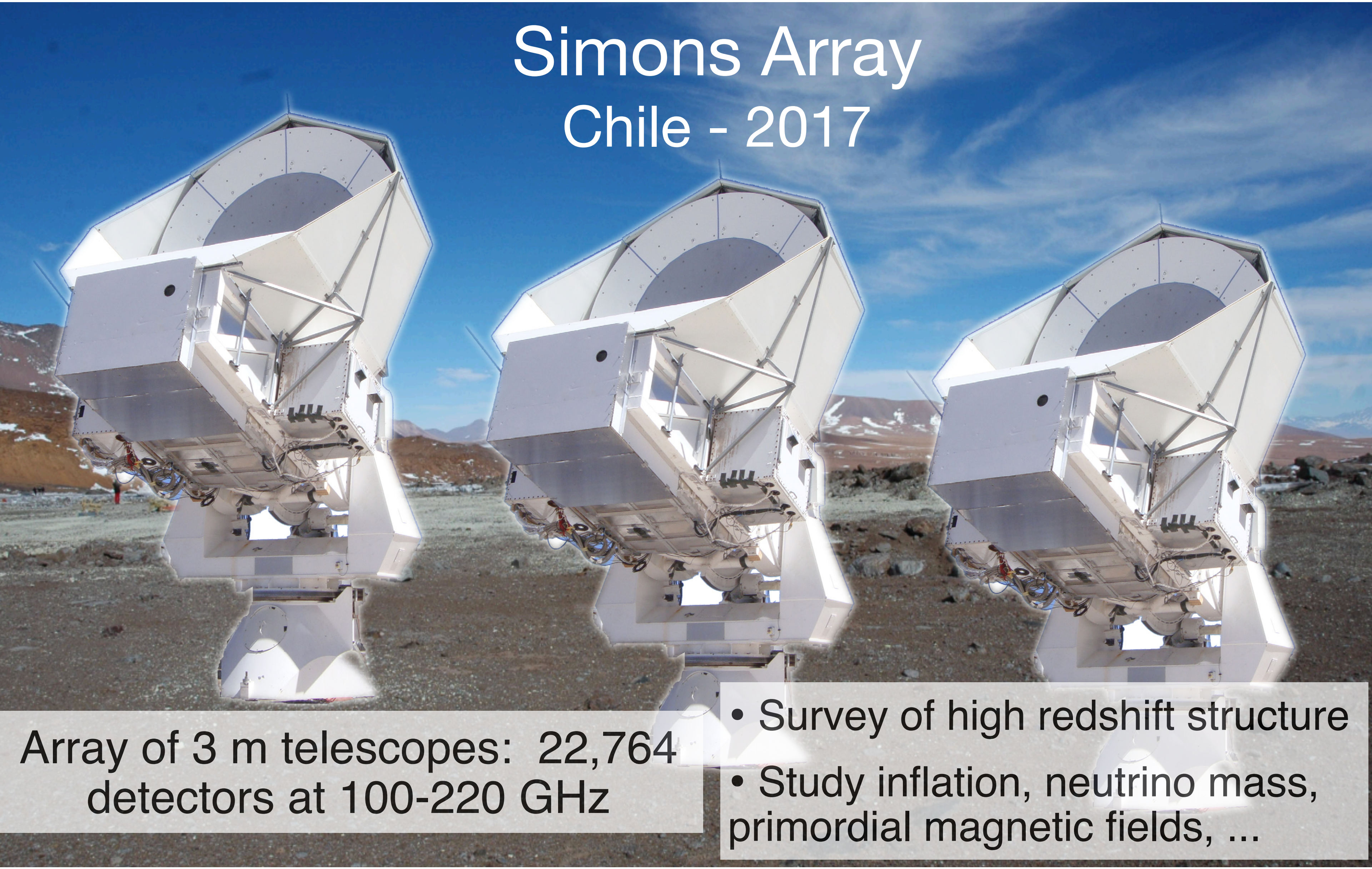
Stage-4

>2020: CMB-S4
100,000+ detectors



Detector sensitivity has been limited by photon "shot" noise for last ~15 years; further improvements are made only by making ***more detectors!***

To 80% of the sky

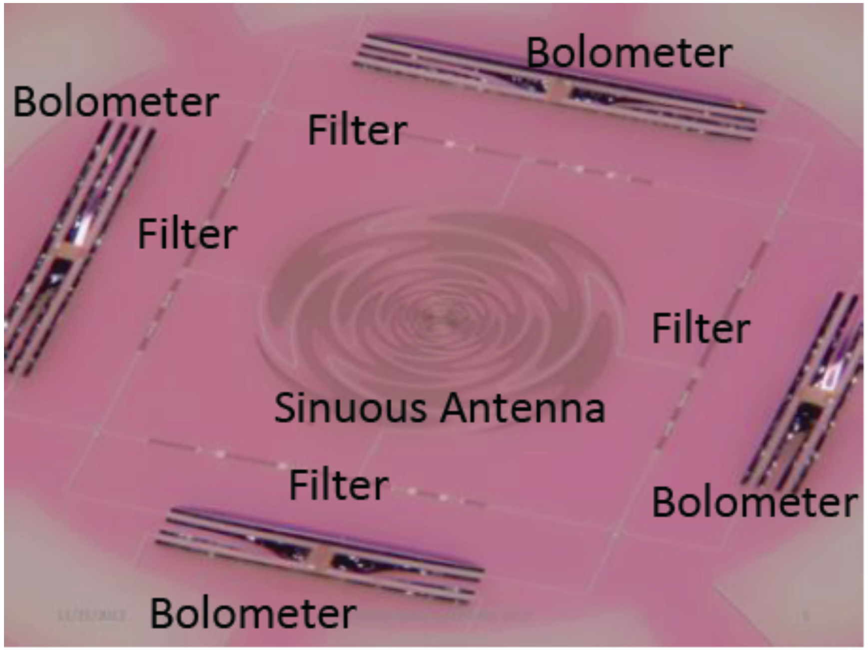


Simons Array
Chile - 2017

Array of 3 m telescopes: 22,764 detectors at 100-220 GHz

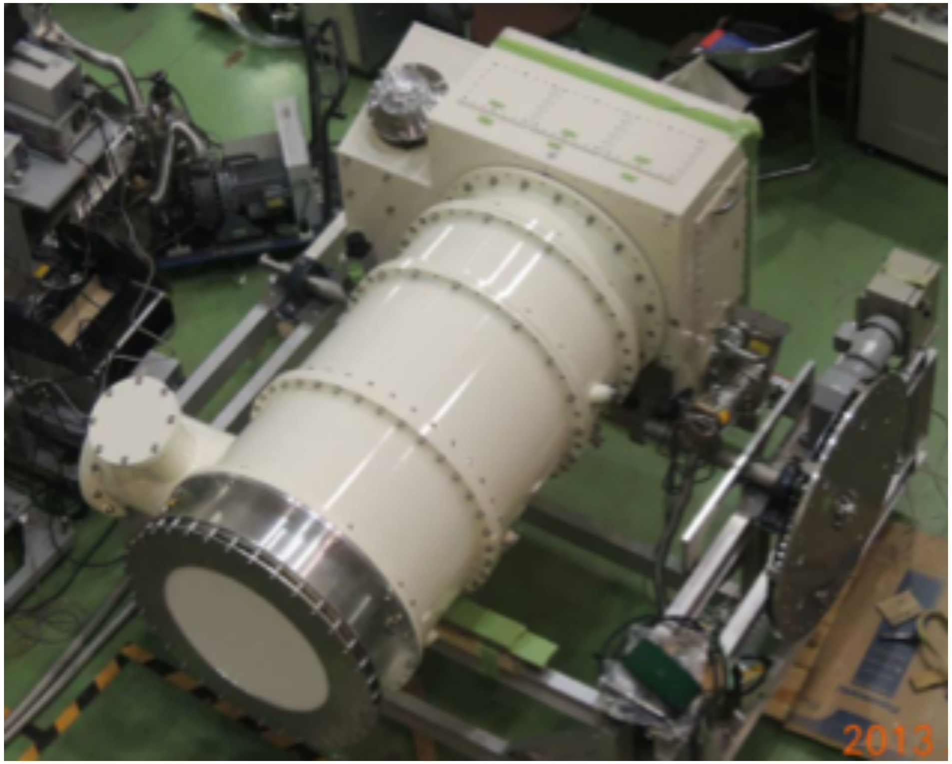
- Survey of high redshift structure
- Study inflation, neutrino mass, primordial magnetic fields, ...

Simons Array



Three new telescopes and receivers

New, dichroic pixels allow more detectors to fit on the focal plane.



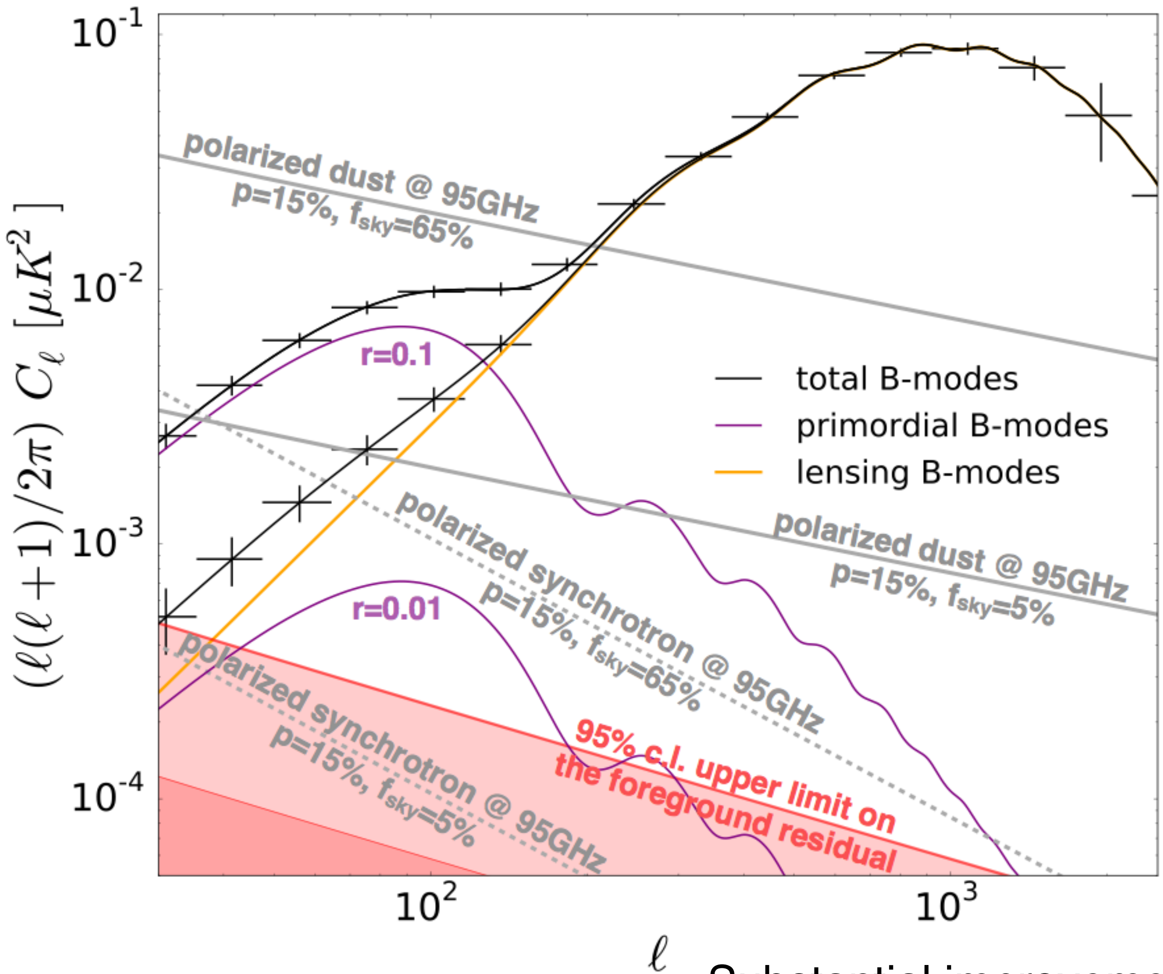
2016: POLARBEAR-2

- New telescope and receiver
- 7588 detectors (90/150 GHz)

2017: Install 2 more PB2's to complete the Simons Array

- 22,764 detectors
- 50% 150 GHz; 33% 90 GHz; 16% 220 GHz

Simons Array forecasts



Simons Array at 90, 150, & 220 GHz
plus
Planck and C-Bass

Inflation:

$$\sigma(r=0.1) = 6\cdot 10^{-3}$$

no fg subtraction: $(4\cdot 10^{-3})$

Neutrinos: with DESI BAO

$$\sigma(\Sigma m_\nu) = 40\ \mathrm{meV}$$

no fg subtraction: $(19\ \mathrm{meV})$

Substantial improvements over current data! e.g.,

$r < 0.09$ Planck 2015 XIII

$\Sigma m_\nu < 0.15$ eV Palanque-Delabrouille et al 2015

In conclusion

- First detections of “B-modes” in CMB polarization
  - New window into inflation and structure growth at z~2
  - Can be used to look for Faraday rotation/cosmic birefringence — no evidence for either yet

- First receiver of the Simons Array will be installed in next 6 months, with the full array operational in 2017.
  - ~23k detectors at 90, 150, 220 GHz
  - Giant leap in mapping speed and ability to control foregrounds