Probing Inflation and Neutrinos by measuring CMB Polarization with ABS, SPTPol, and ACTPol

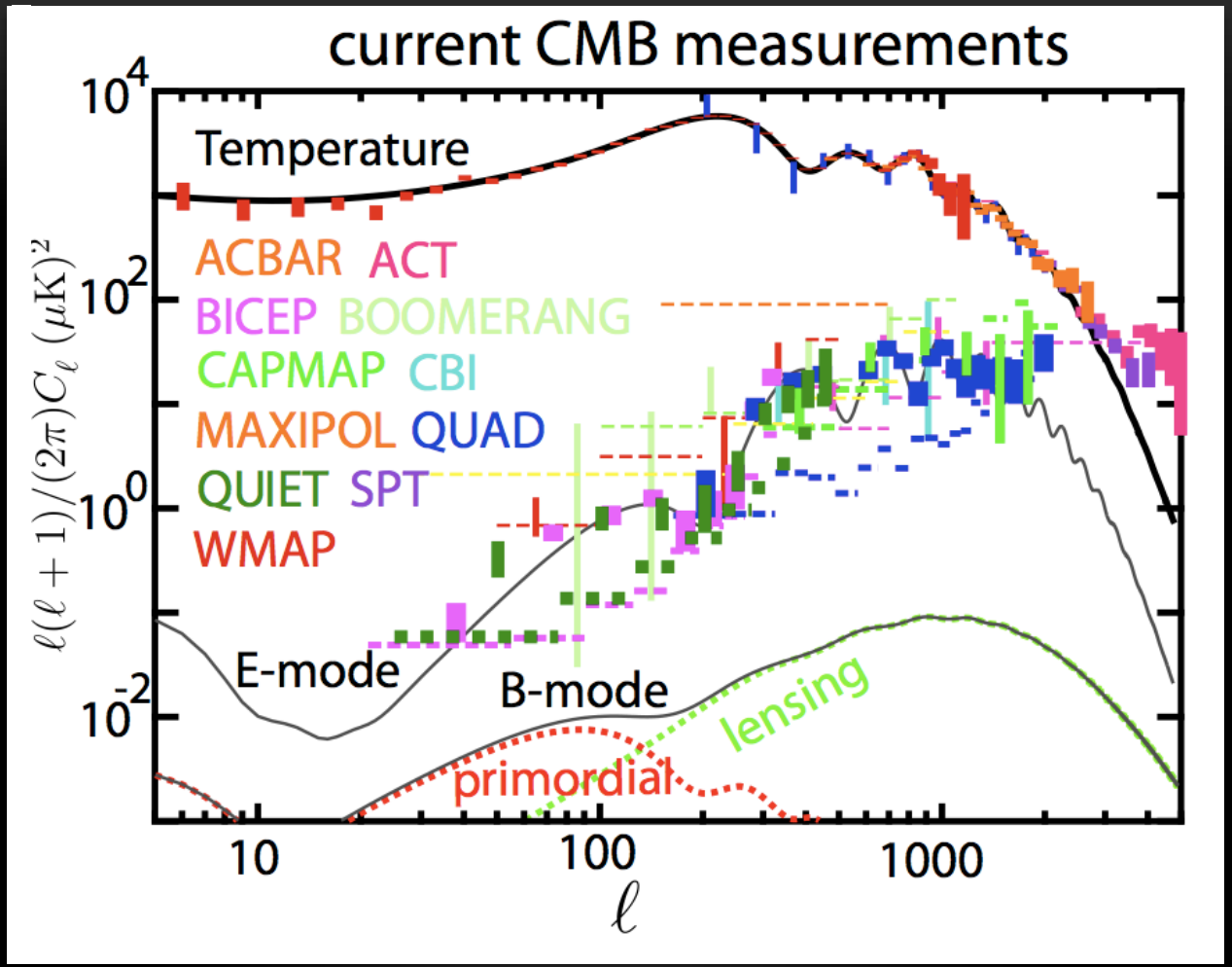
Michael Niemack

National Institute of Standards and Technology
in Boulder, CO

New Worlds, New Horizons

March 9, 2011

Cosmic Microwave Background Anisotropy Power Spectra



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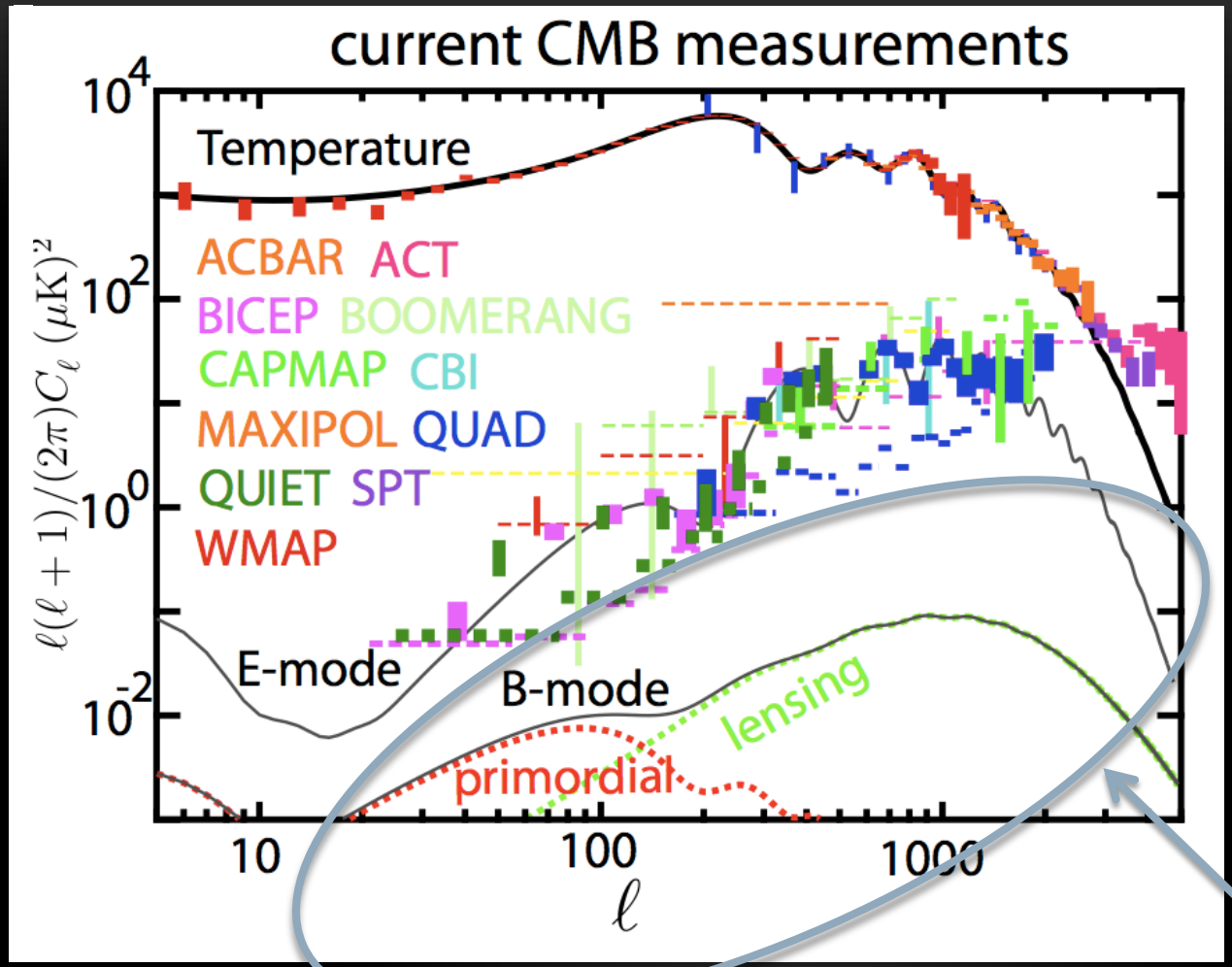
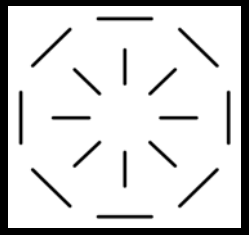
Cosmic Microwave Background Anisotropy Power Spectra

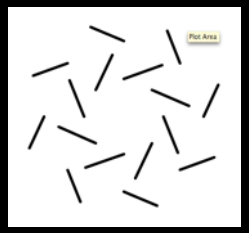


Polarization Anistotropies

Curl-free E-modes



Divergence free B-modes



Not yet measured

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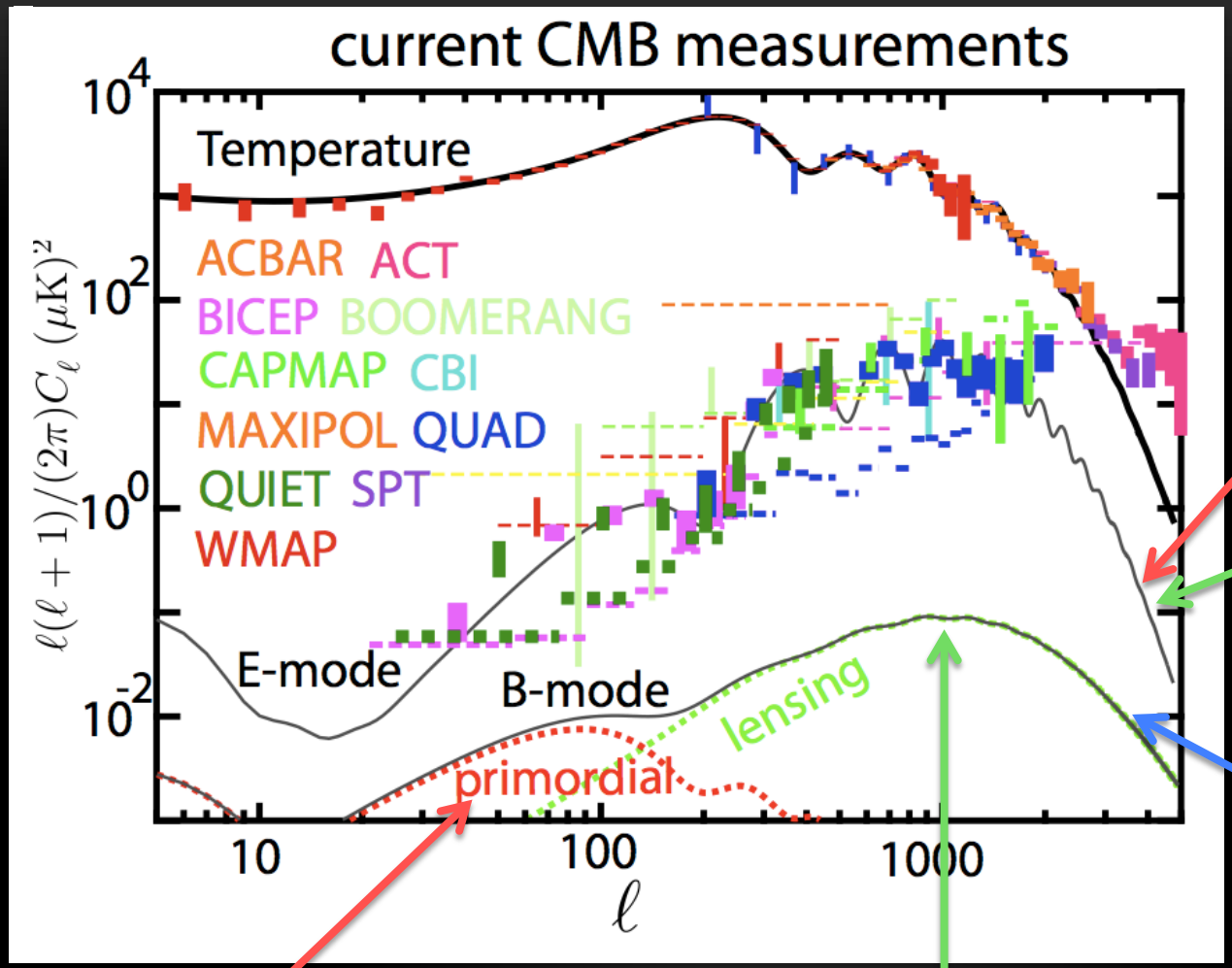
Cosmic Microwave Background Anisotropy Power Spectra



Inflationary potential

Neutrino mass via BBN and He abundance

Early Dark Energy

Smoking gun of inflation?

Neutrino mass via LSS

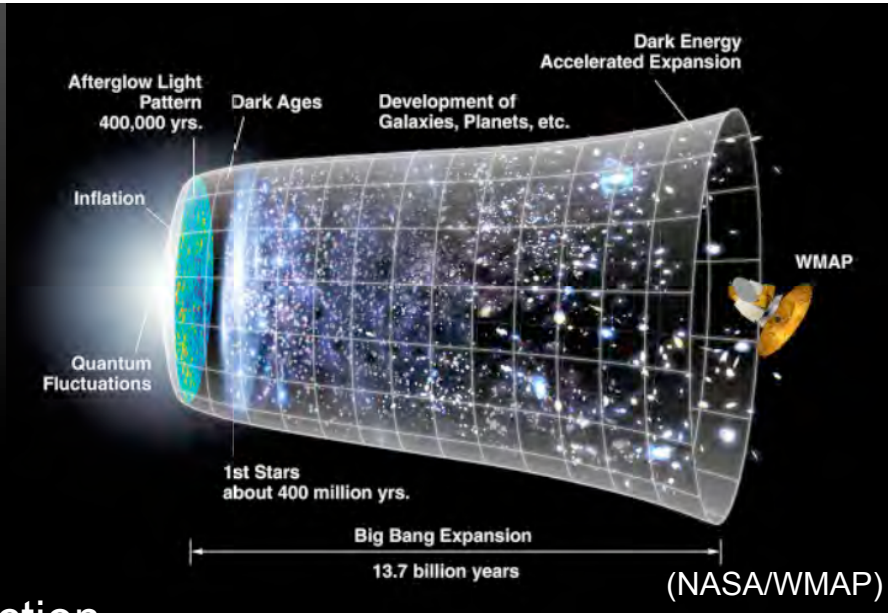
M. Niemack, NIST

Primordial B-modes from Inflation

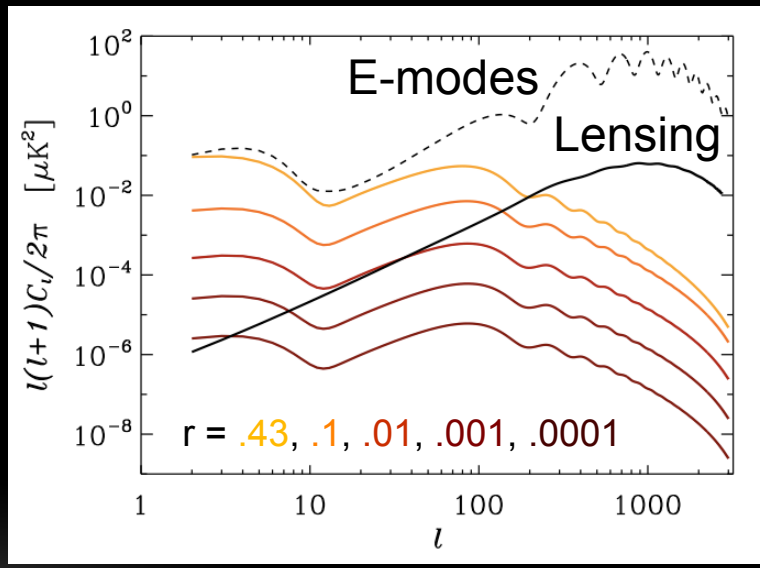
- Probe the Grand Unified Scale
  ~10^{16} GeV

- Inflationary Gravity Wave (IGW) prediction
  "The smoking gun of inflation"
  - Primordial B-mode signal
  - Amplitude, r = T/S => energy scale
  - Measurements limited by lensing

- WMAP + BAO + SN => r < 0.22
  (Komatsu et al., ApJS 2009)

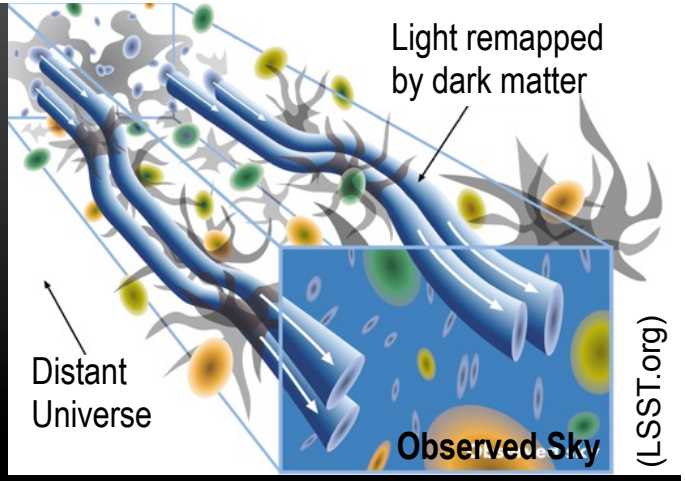


(NASA/WMAP)



(K. Smith et al., CMBPol, 2009)

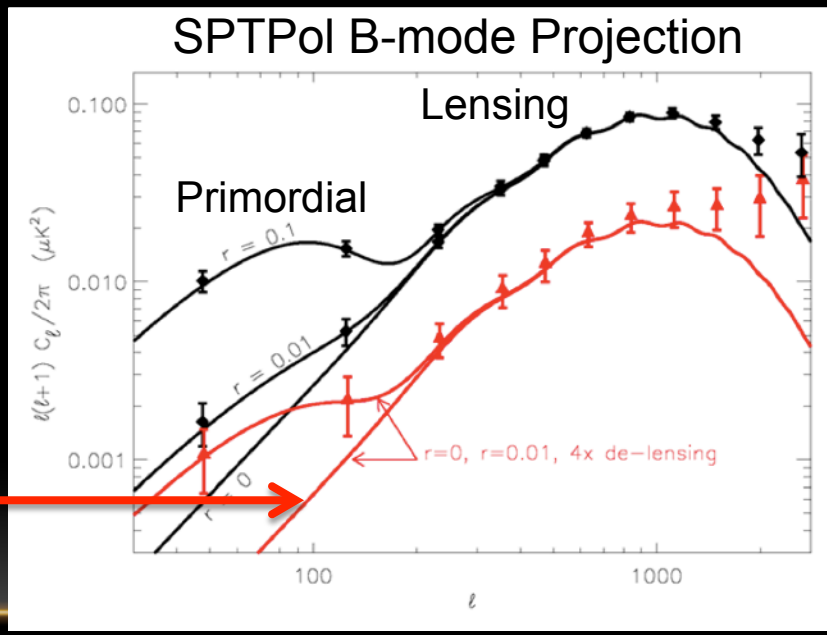
Gravitational Lensing



- Remaps E-mode polarization into B-modes
  (as well as temperature anisotropies)
- High source redshift (z ~ 1100) => CMB lensing peaks at z ~ 3
- Measurement of z ~ 3 mass distribution
  - Neutrino mass sum
    - Current constraints: $\Sigma m_\nu < 0.7$ eV
    - Potential: $\Sigma m_\nu \sim 0.05$ eV
  - Early dark energy

(K. Smith et al., 2009)

- Improve IGW search sensitivity by delensing



(McMahon et al., LTD 2009)

Neutrino Masses

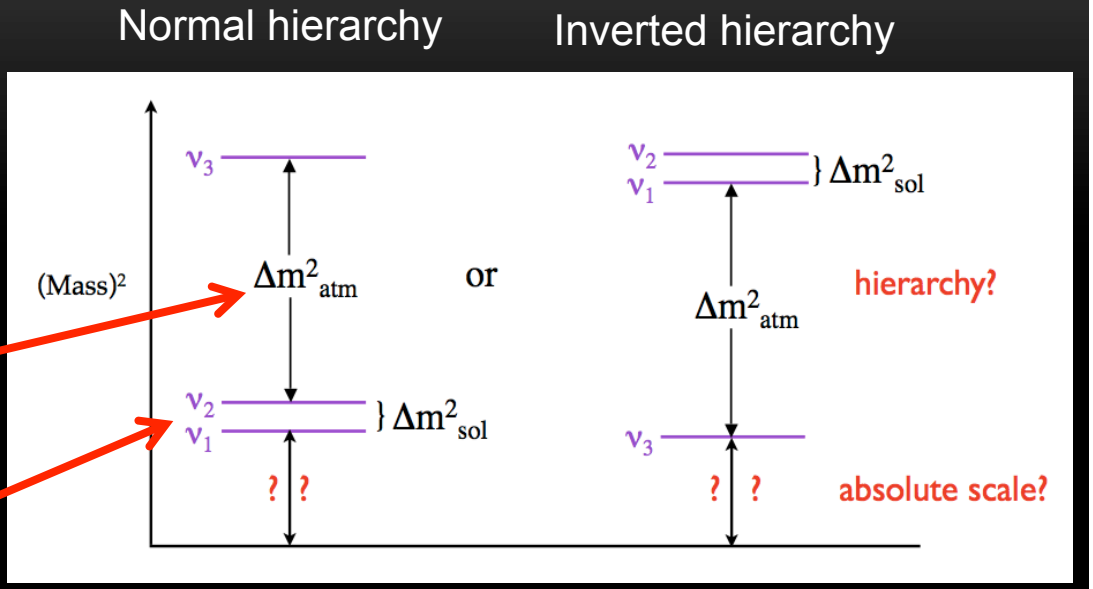
- Mass hierarchy and absolute scale unknown

- Atmospheric neutrinos
  => $\Delta m_{\nu 23} = 0.05$ eV
- Solar neutrinos
  => $\Delta m_{\nu 12} = 0.009$ eV

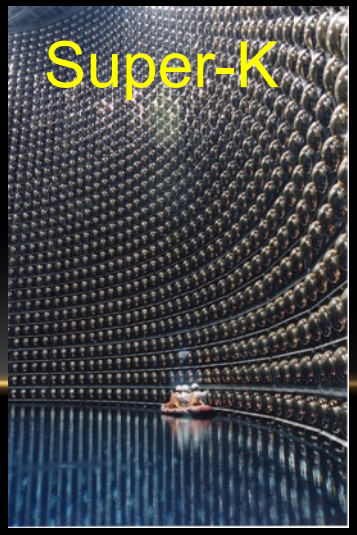
$\Rightarrow \Sigma m_\nu > 0.05$ eV

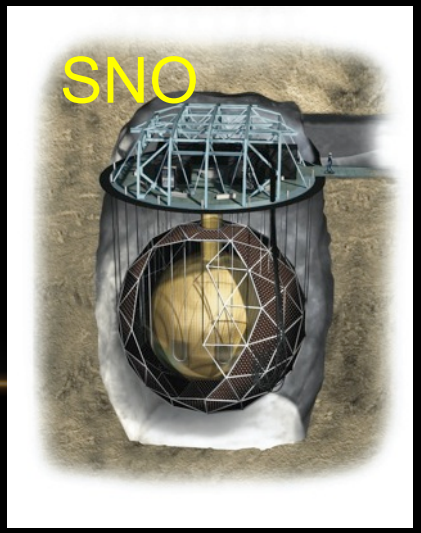
(KATRIN – future exp. ~ 0.2 eV)

- If neutrino mass sum < 0.1 eV
  => Normal hierarchy



(Haxton 2010)



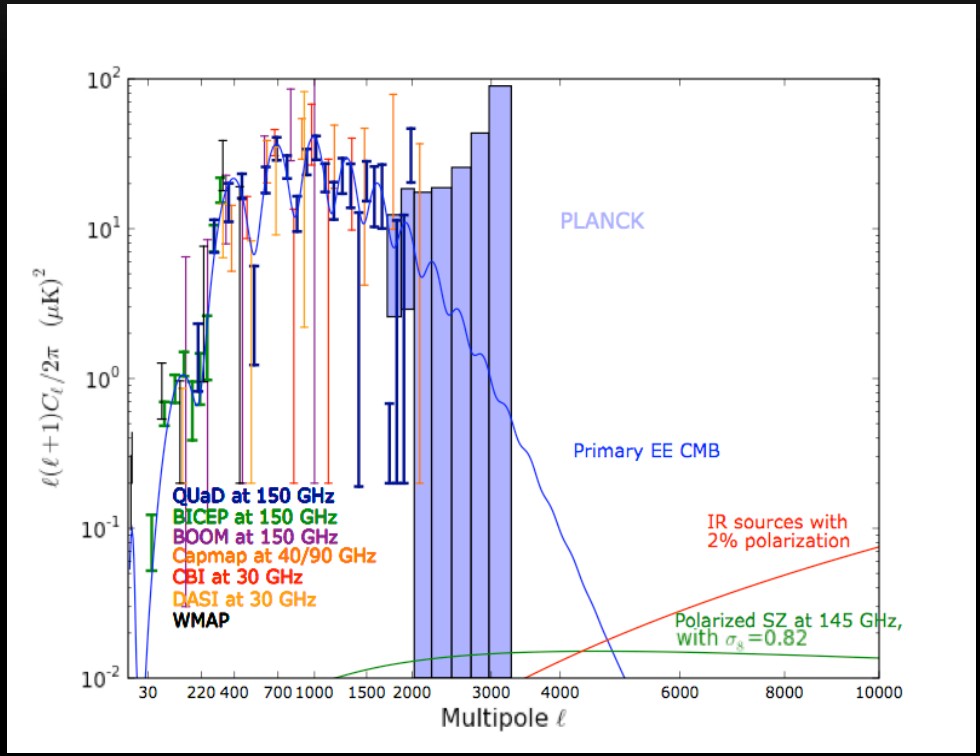


Small angular scale E-mode Polarization

- E-mode signal > foregrounds to $\ell \sim 5{,}000$ (vs. $\ell \sim 2{,}500$ for temperature)

- Spectrum tilt gives inflation potential parameters
  - n_s from temperature
  - n_s running from E-modes

- He recombination imprint
  => He abundance to ~1%
  Probe BBN at recombination



- Neutrino number and mass impact nucleosythesis

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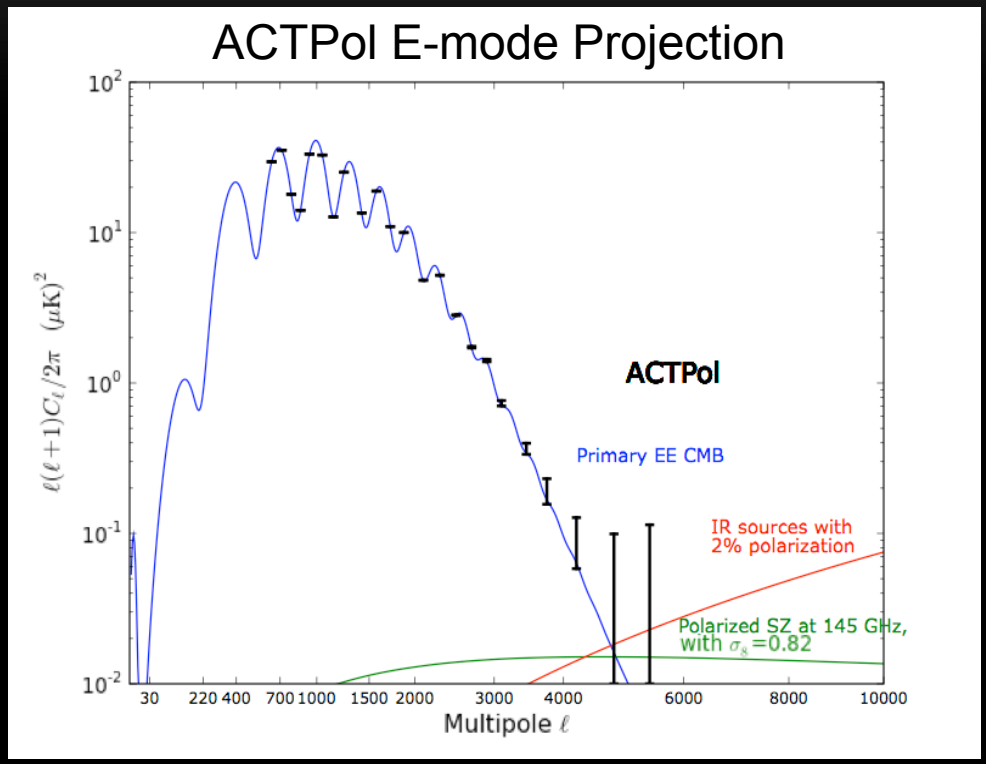


(Niemack et al., SPIE 2010)

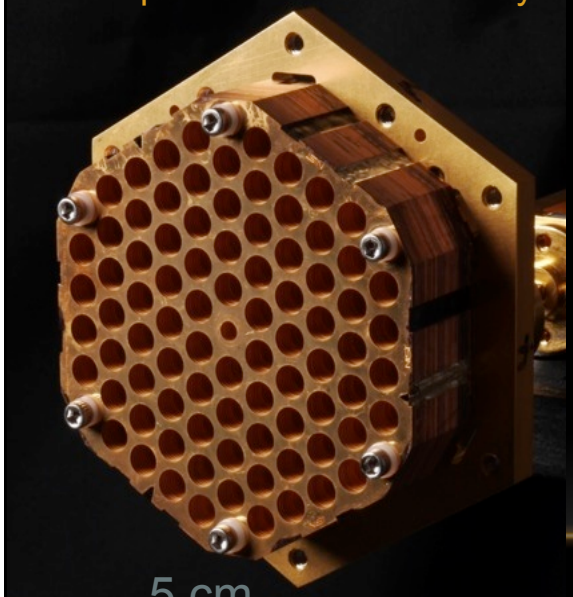
- Neutrino number and mass impact nucleosythesis

- ACTPol projection: $\sigma(\Sigma\, m_\nu) \sim 0.05$ eV

NIST Polarimeters

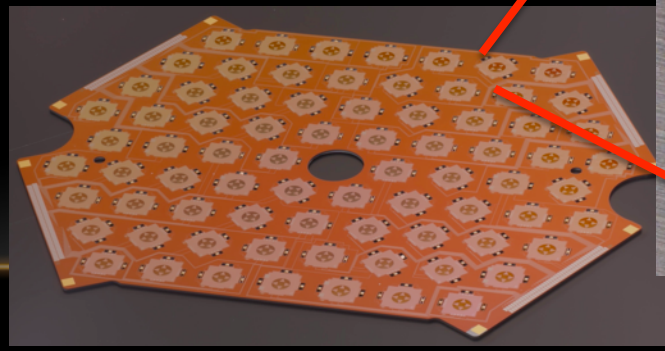
- Feedhorn-Coupled Superconducting Transition-Edge-Sensor Polarimeters
  - Truce Collaboration: NIST, UC Berkeley, CU Boulder, U Chicago, U Michigan, Princeton U, NASA GSFC, Stanford U
  - Extensive 150 GHz prototype testing
- Monolithic corrugated silicon feedhorn arrays

Gold-plated silicon feed array

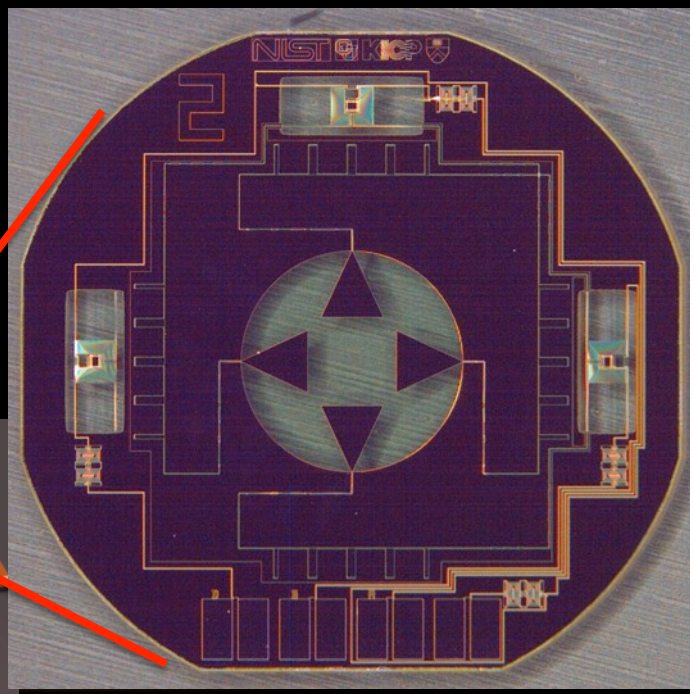


More info on poster by J. Hubmayr

Polarimeter array



Single Truce polarimeter



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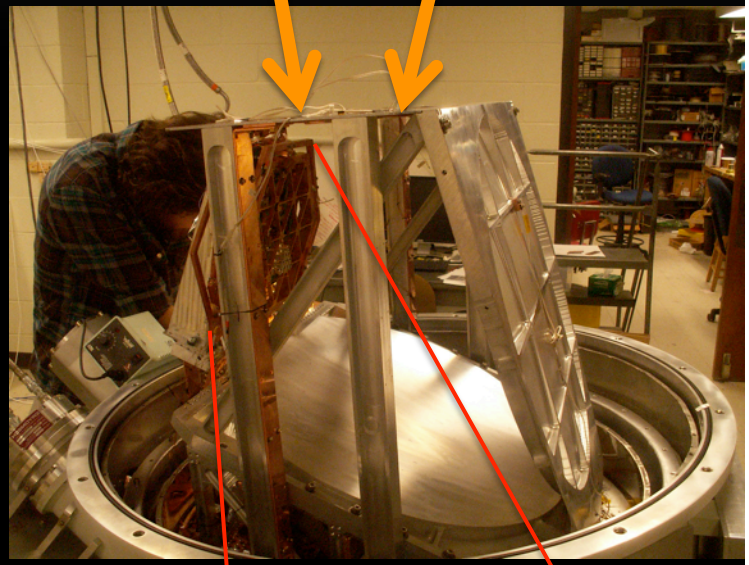
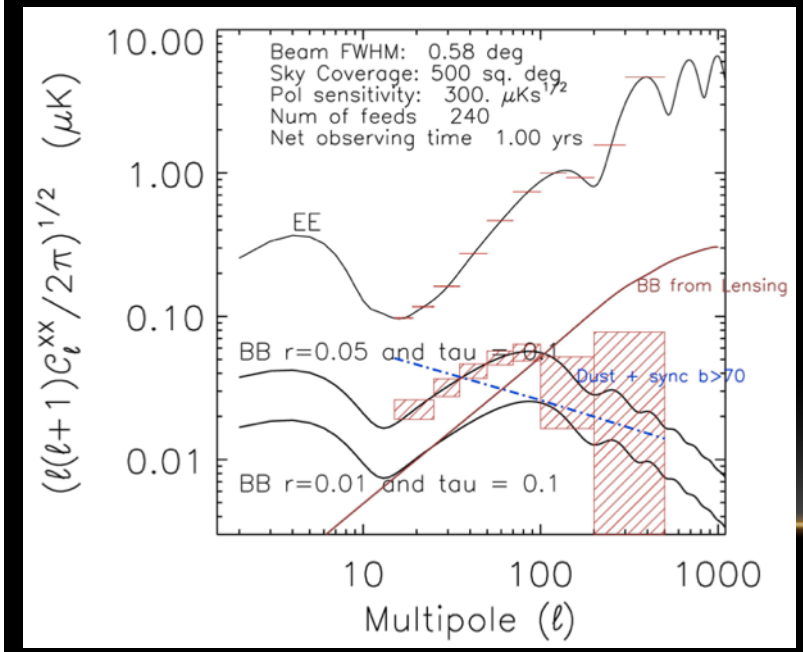
Atacama B-mode Search (ABS)

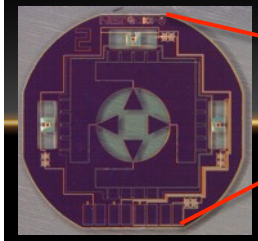
Princeton U., NIST, U. British Columbia

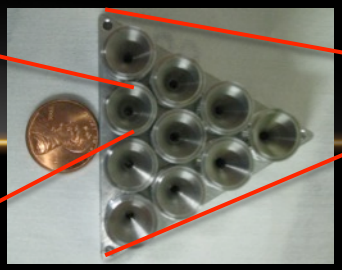
- 0.3 m cryogenic telescope in Chile
- Large angular scale IGW
- Detectors
  - 240 Individual 150 GHz polarimeters
  - First deployment of NIST polarimeters

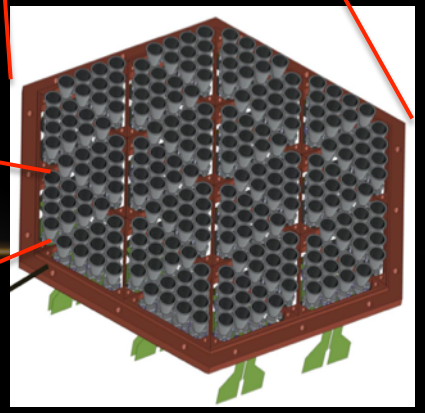
Deploy in 2011!





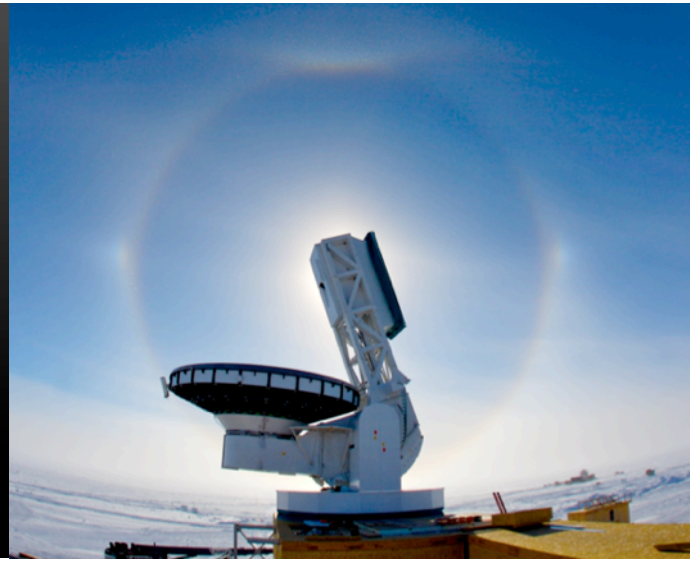




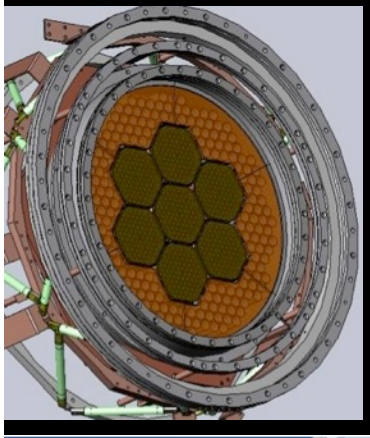


(Essinger-Hileman et al., SPIE 2010)

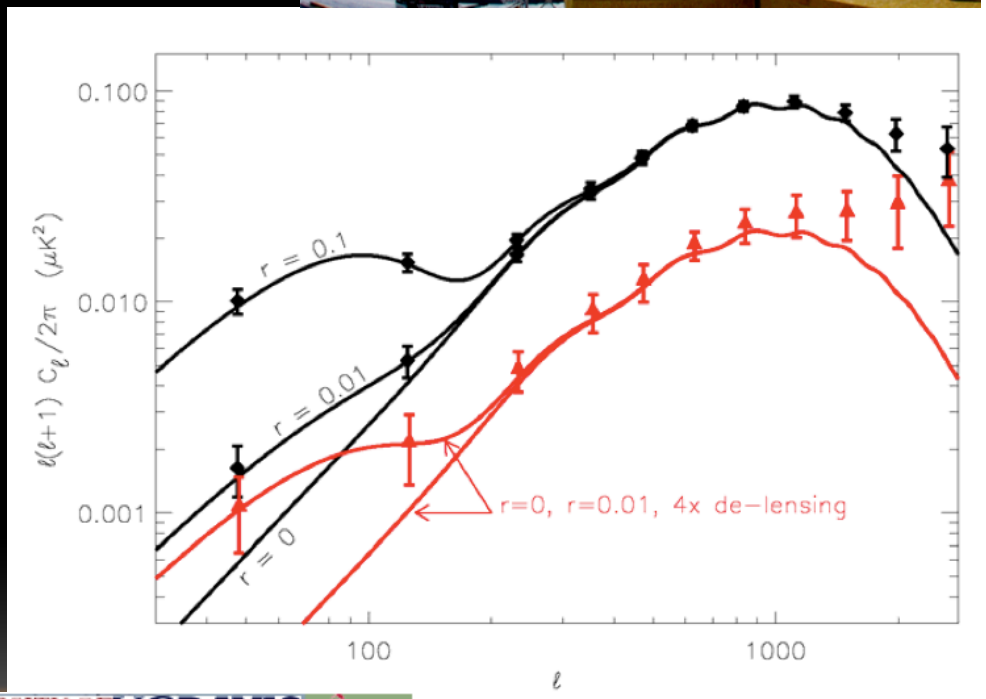
South Pole Telescope Polarimeter (SPTPol)



- 10 m telescope at South Pole
- Focus on IGW search (to r ~ 0.03) & lensing
- Detectors
  - NIST – 150 GHz – 588 polarim.
  - Argonne – 90 GHz – ~200 polarim.



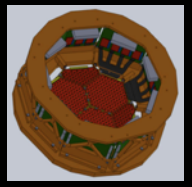
Deploy early 2012!

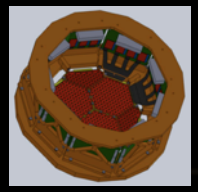


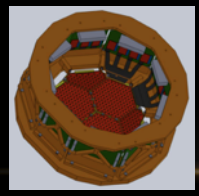
(J. McMahon et al., LTD 2009)

Atacama Cosmology Telescope Polarimeter (ACTPol)

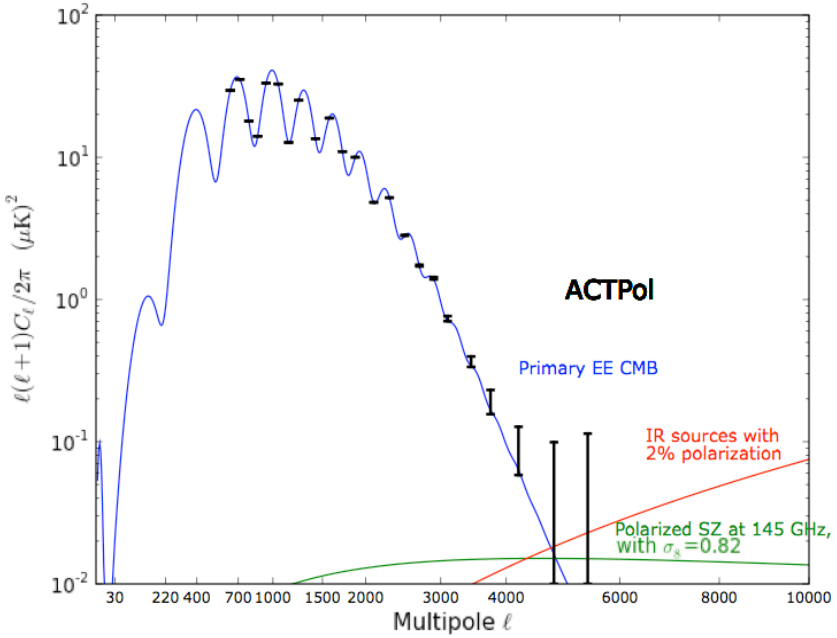
- 6 m telescope in Chile
- Focus on neutrino mass (σ ~ 0.05 eV), inflation potential, & cross-correlations
- Detectors
  - 2x 150 GHz arrays - 1012 pol.
  - 90 GHz ~ 300 pol. (or multi-chroic)







Deploy in 2012 and 2013!

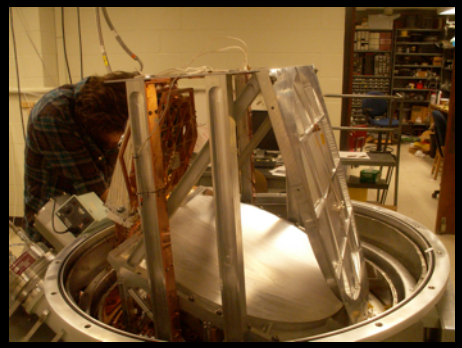
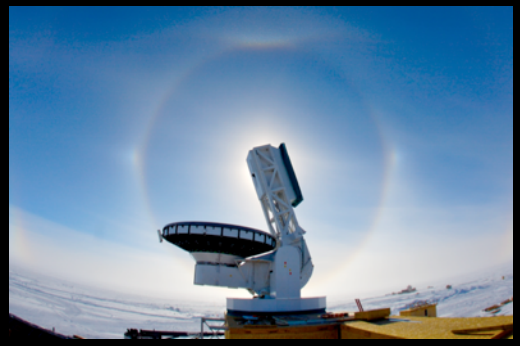


(Niemack et al., SPIE 2010)

Summary

- Upcoming CMB experiments will probe key inflation parameters and neutrino properties

- NIST polarimeter arrays will soon deploy on ABS, SPTPol, & ACTPol


- Subsequent CMB bolometer instruments should have many thousands of polarimeters (~ 10^4 detectors)

Thank you

This work is supported by NIST, NSF, NASA, and collaborating institutions.