

Cosmology with the Keck Array

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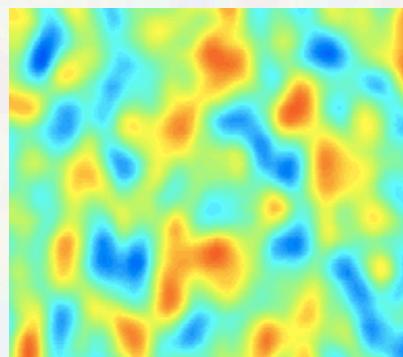


July 18, 2012
SCAR Open Science Conference

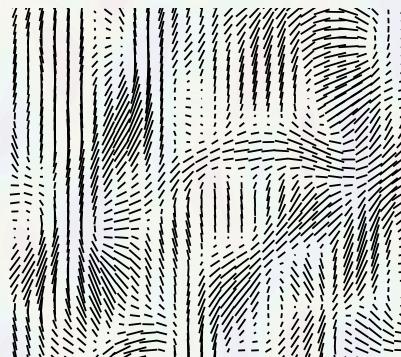


Cosmic Microwave Background Polarization

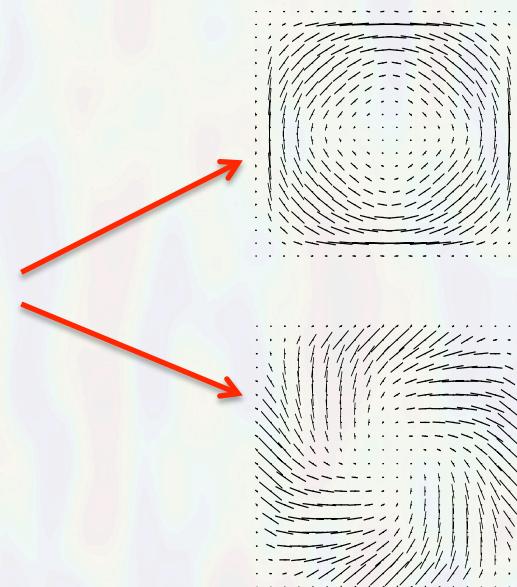
- Millimeter wave radiation emitted 300,000 yrs after the Big Bang
 - We observe at 150GHz
- Maps of polarization field can be decomposed into two components: a field with gradient ('E' mode) and a field with curl ('B' mode).



Temperature



Polarization



E mode

B mode

Inflation

Inflationary Paradigm:

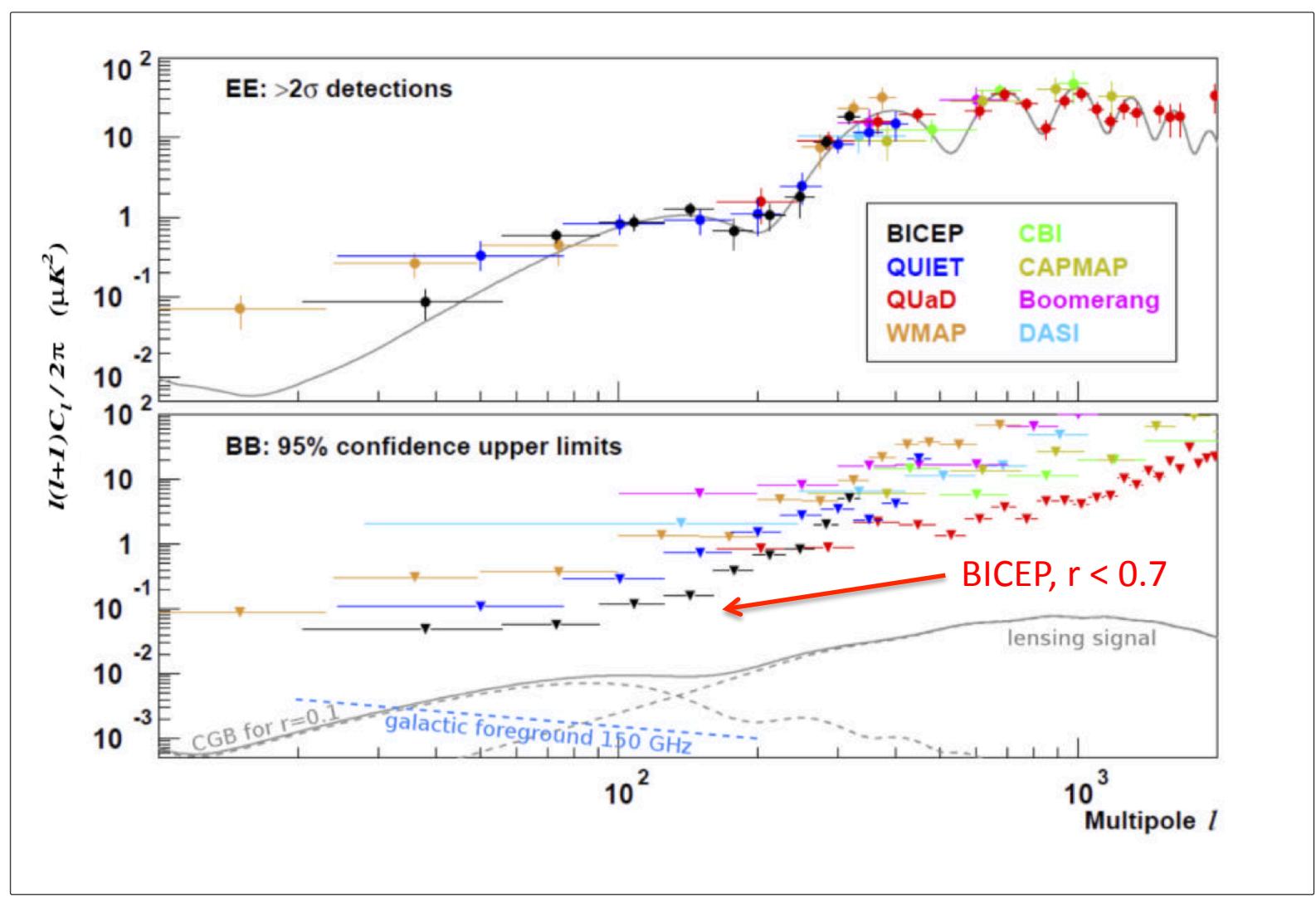
- Circumstantial evidence: flatness, Isotropy, lack of monopoles, adiabatic & Gaussian fluctuations, etc..
- Direct evidence: CMB polarization with a curl component ('Bmode') caused by primordial gravitational waves from inflation.

$$[l(l+1)C_{Bl}/2\pi]^{1/2} = 0.024(E_{inf}/10^{16}\text{GeV})^2 \mu\text{K}$$

Zaldarriaga, 2003

Peak of BB power spectrum

Goal: $r=0.02$



Chaing et al 2010

Foregrounds

- Dust

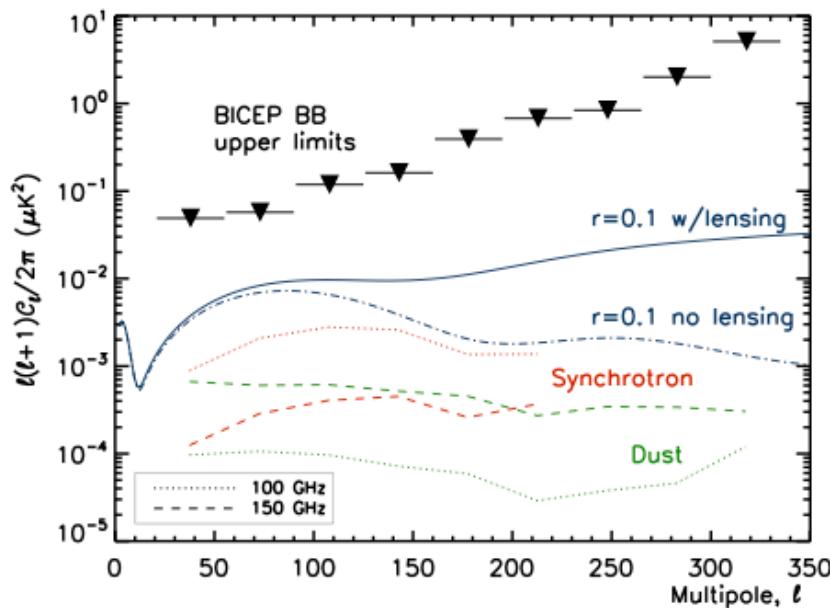
Likely to be leading contributor

- Synchrotron

Dominate at lower frequencies

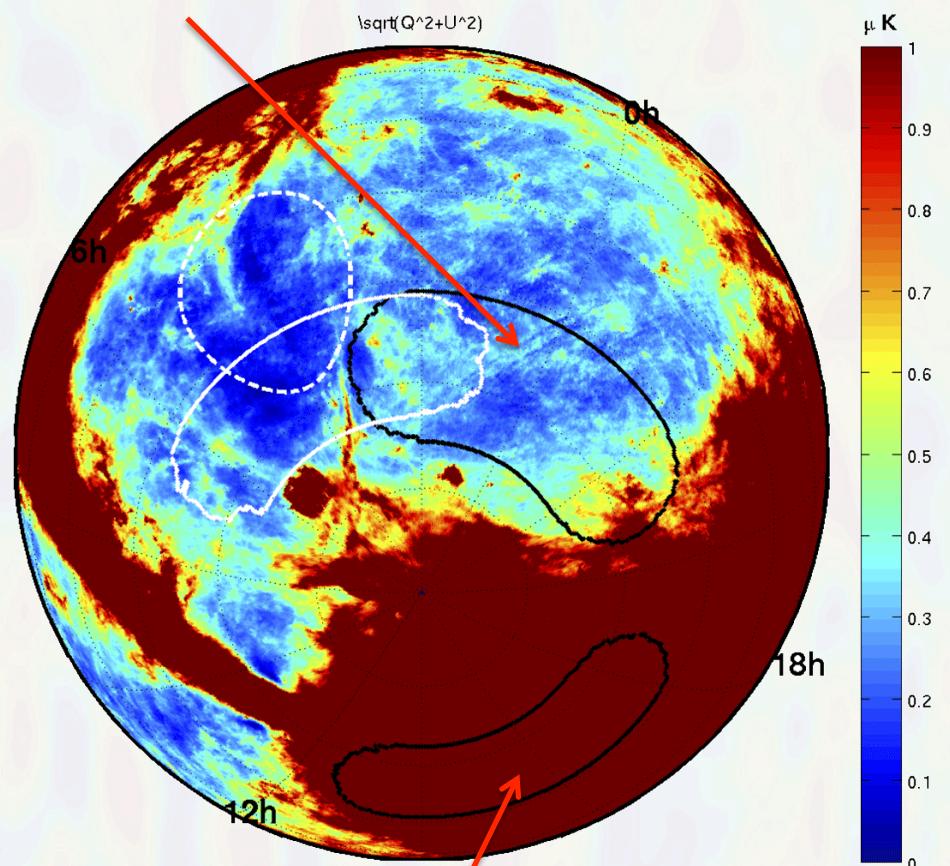
- Point Sources

not expected to be a problem at our angular scale



Chaing et al 2010

Keck CMB field
“Southern Hole”



Model Based on O’dea 2011

Why the South Pole?

- Low perceptible water vapor (0.25mm)
 - *High millimeter transparency*
- Stable atmosphere
 - *reduced atmospheric noise*
- Uninterrupted observations of the “Southern Hole”
 - *greater observing efficiency*
- Great support Staff / Infrastructure

Experimental Progression

- BICEP : 96 NTD Bolometers (Colin Bischoff's talk)
Best limits to date : $r < 0.7$
- BICEP2 : 512 TES Bolometers (Randol Aikin's poster)
10x mapping speed of BICEP
- KECK Array: 2560 TES Bolometers
5x mapping speed of BICEP2

Background Limited => More detectors = More sensitivity

2011

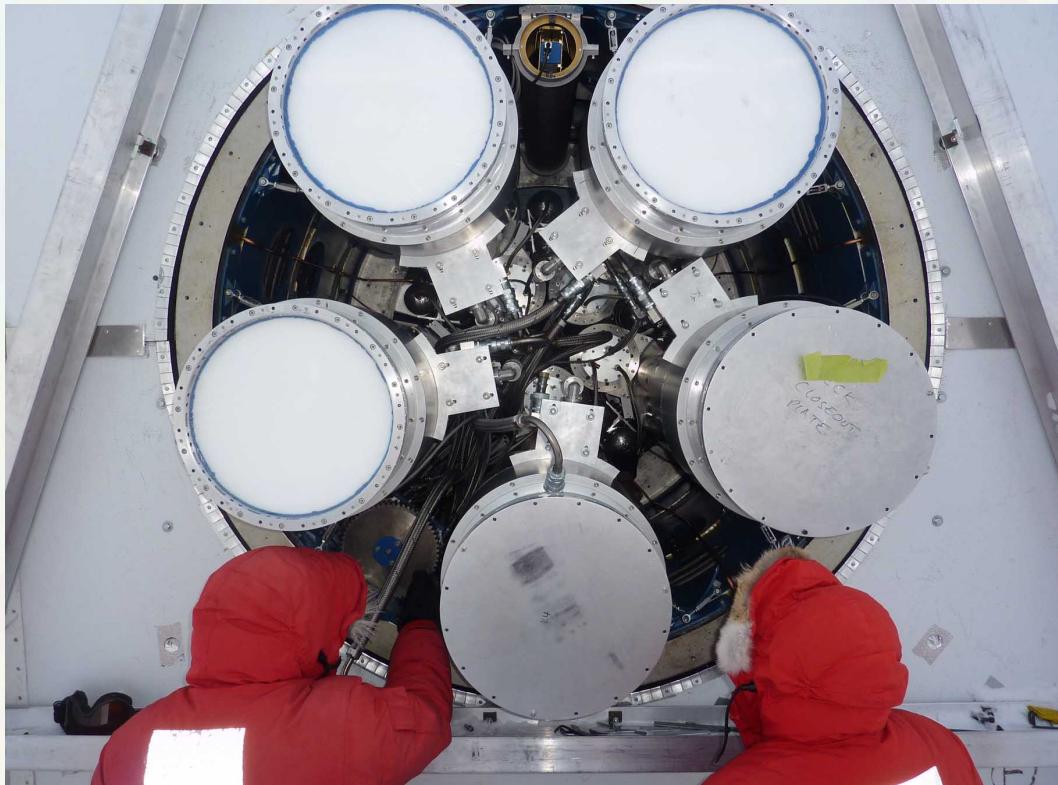


2012

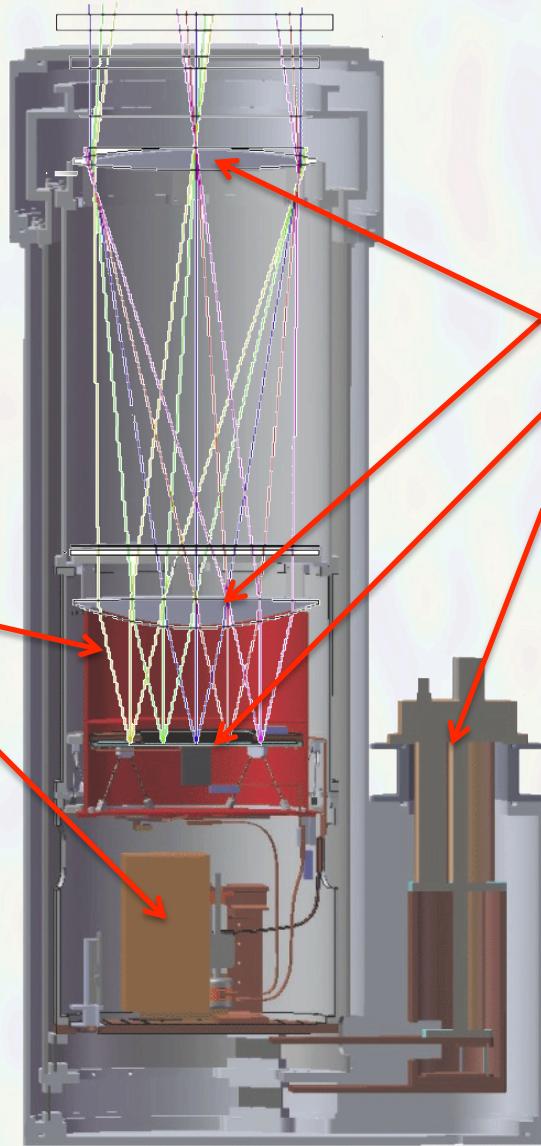
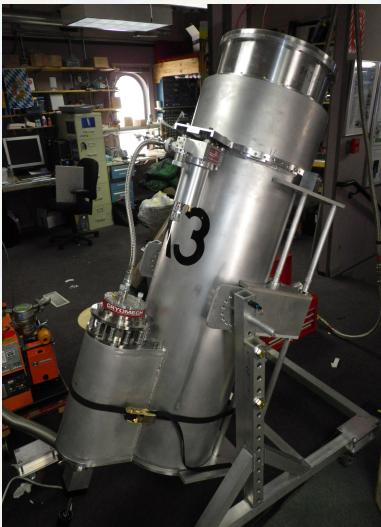


2012 configuration: 5 receivers

=> *increased # of detectors*



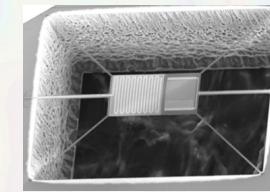
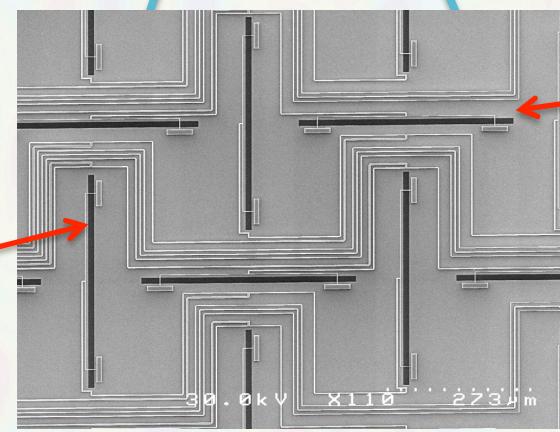
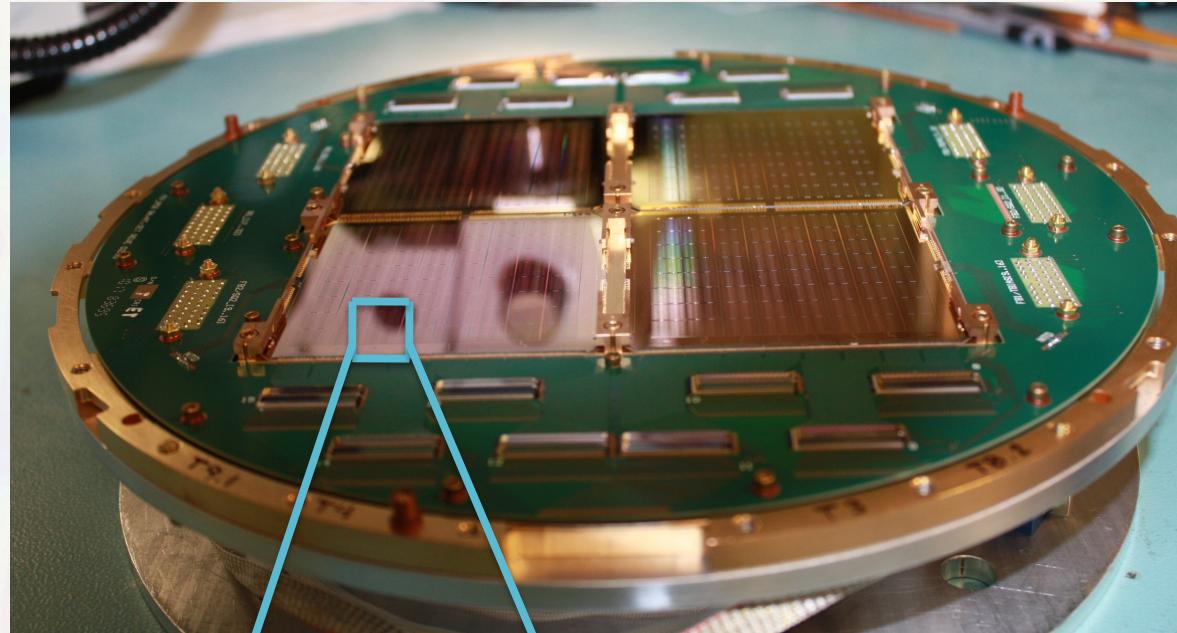
Receiver Design: similar to BICEP2



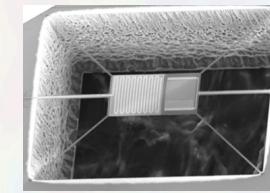
- Nb Magnetic Shield
- He3 / He4 sorption fridge

- 26 cm aperture refractive optics
- Focal Plane
- Pulse Tube 4K cooler

Each Focal Plane = 512 TES Bolometers

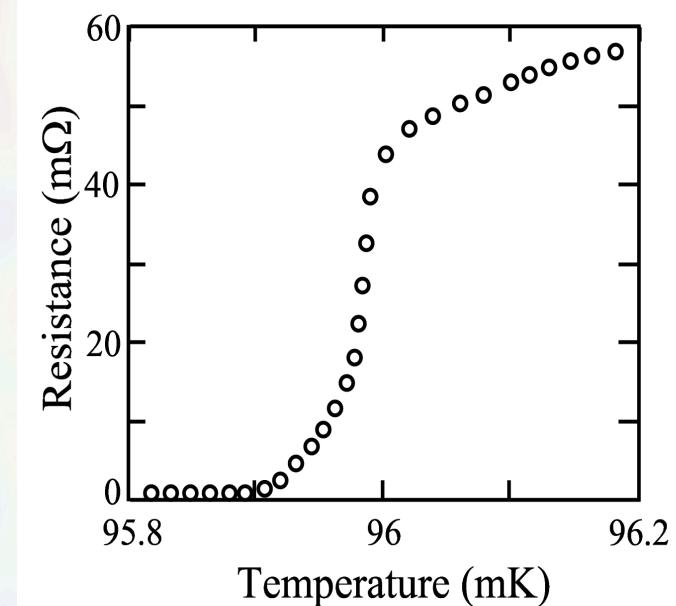
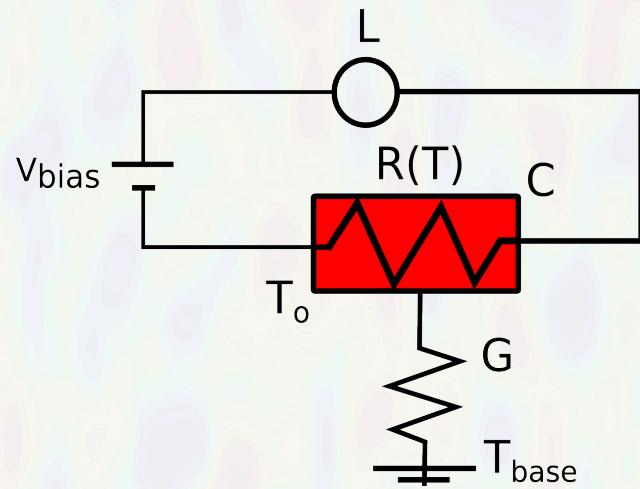
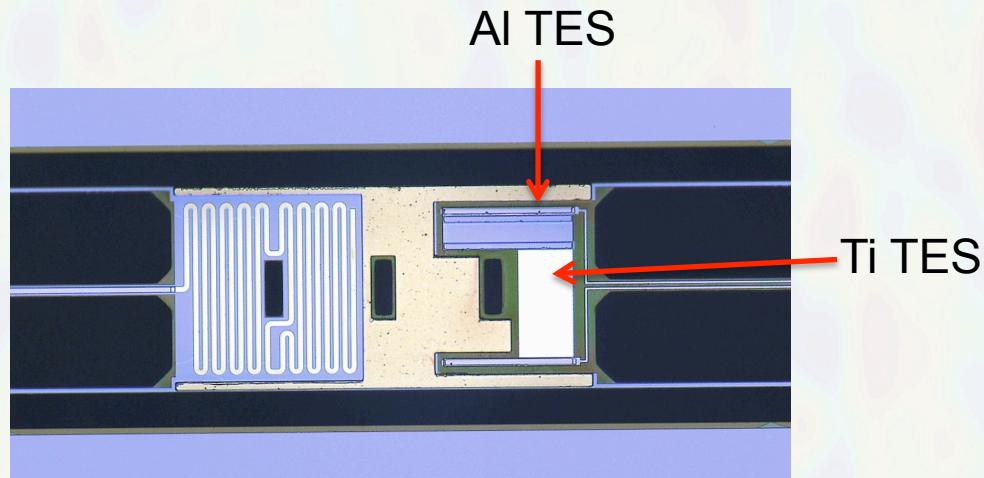


A



B

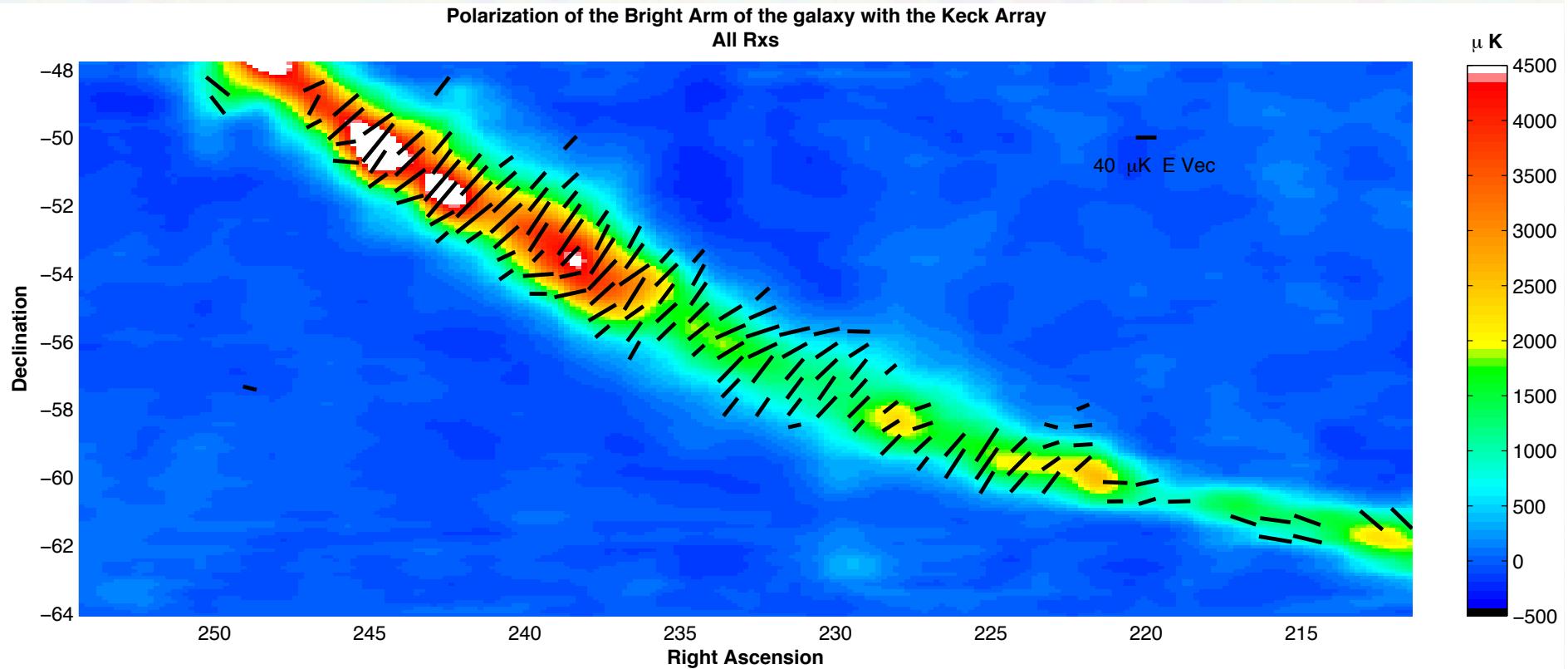
TES Detectors



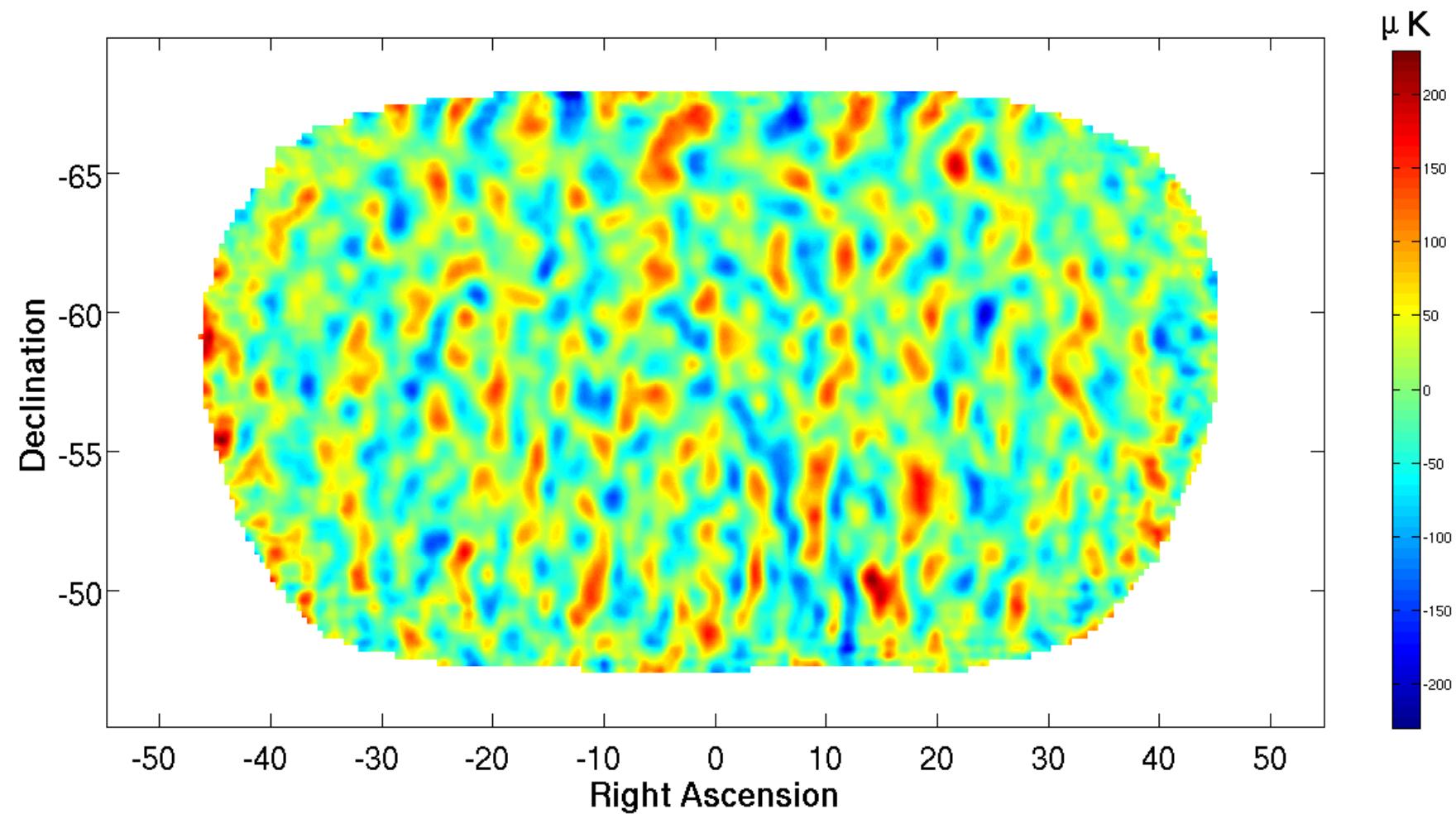
Irwin & Hilton

- Voltage biased for stable electrothermal feedback

Bright Arm of the Galaxy, 2011 (3rxs):



CMB Temperature, 8 days of 2012:



Achieved Sensitivity

TABLE 1. Achieved NET comparison

Experiment	# detectors	NET/detector ($\mu\text{K}\sqrt{s}$)	Array NET ($\mu\text{K}\sqrt{s}$)
BICEP (2007)¹			54.3
100 GHz	44	516	
150 GHz	30	433	
BICEP2 (2011)¹	394	315	15.9
Keck Array (2012)²	1872	440	11.7

[1] Brevik, J.A. *et al*, SPIE (2010) V 7741(1), 77411H.

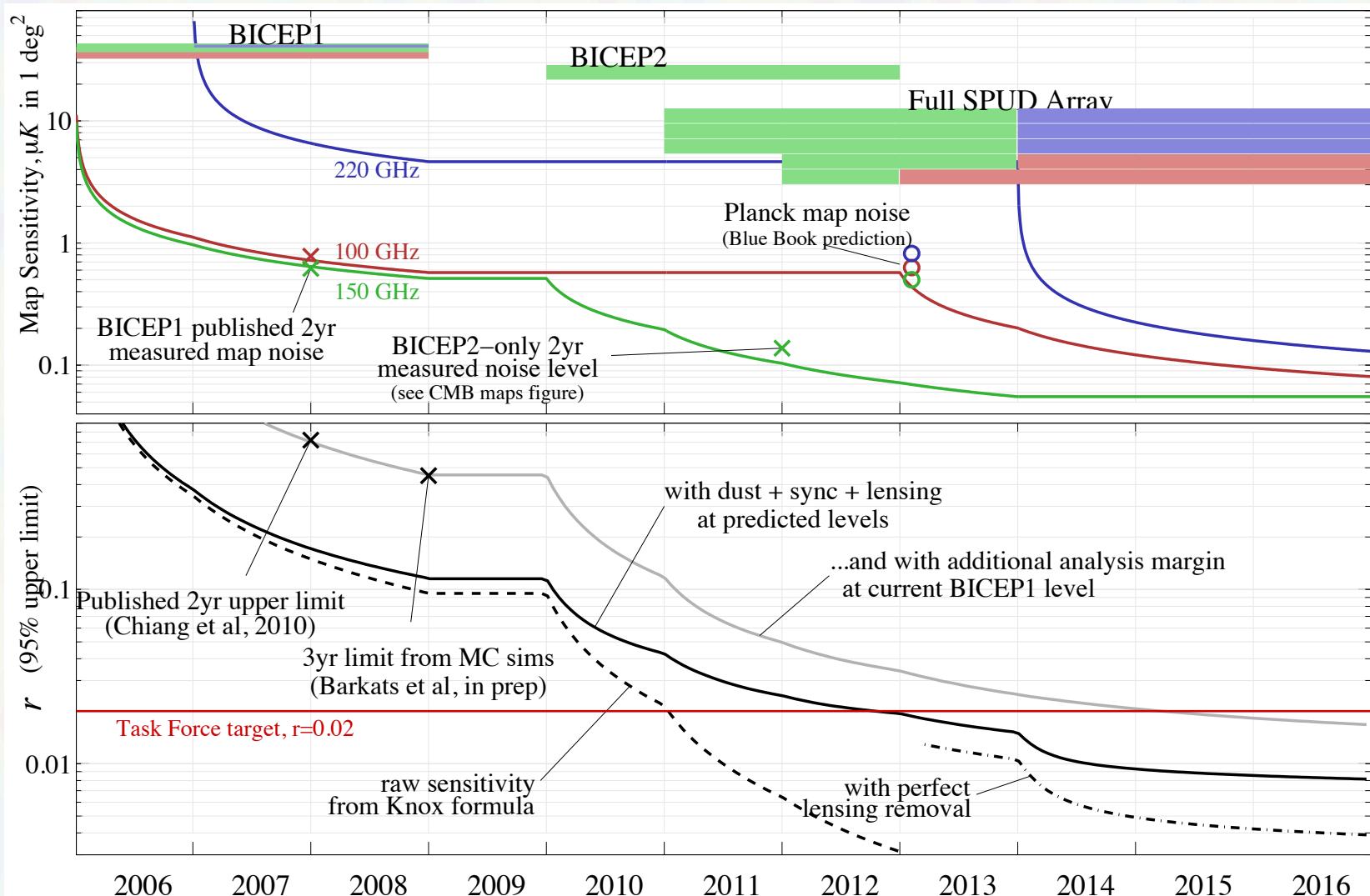
[2] Kernasovskiy, S. *et al*, SPIE (2012) In prep.

=> Keck Array currently has 21 times the observing speed of BICEP

Path to r=0.02

- More integration time
 - *planning to observe for many more years*
- Upgrade existing receivers:
 - *improved sensitivity*
 - *improved beam systematics*
- Careful understanding and removal of systematics
 - *calibrations*
 - *De-projection algorithms*
- Add 100GHz receivers
 - *constrain foregrounds*

Path to $r=0.02$



References

- [1] Zaldariagga 2003: arXiv:astro-ph/0305272v2
- [2] Chaing et al 2010: arXiv:0906.1181v3
- [3] O'Dea et al 2011: arXiv:1107.4612v1
- [4] Irwin & Hilton: Topics Appl. Phys. 99, 63-149 (2005)
- [5] Brevik et al 2011: Proc. of LTD 2010, V7741(1) V77411H
- [6] Kernasovskiy et al 2012: Proc. of SPIE