QUIET

Q /U Imaging ExperimenT

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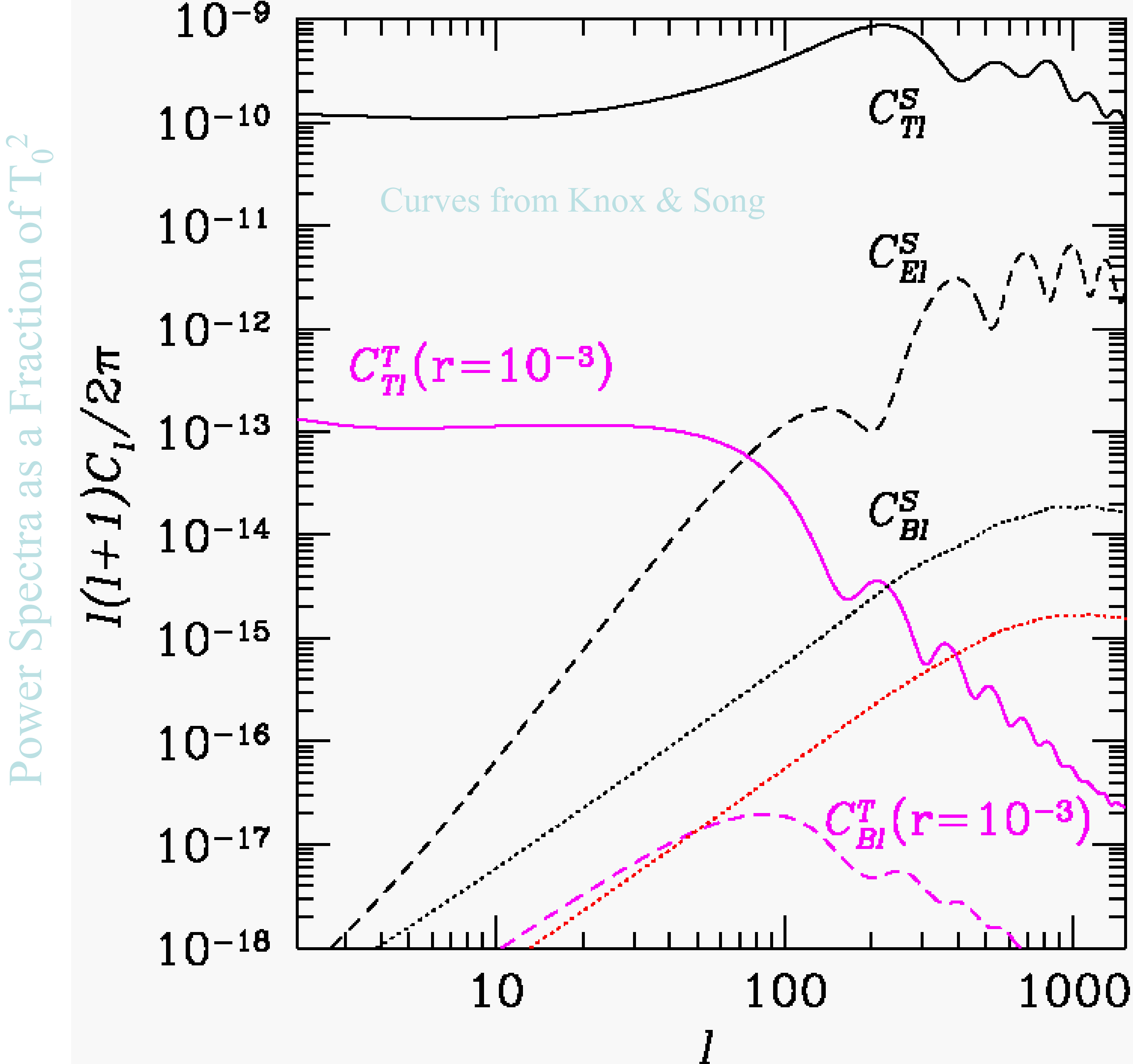
Key Points

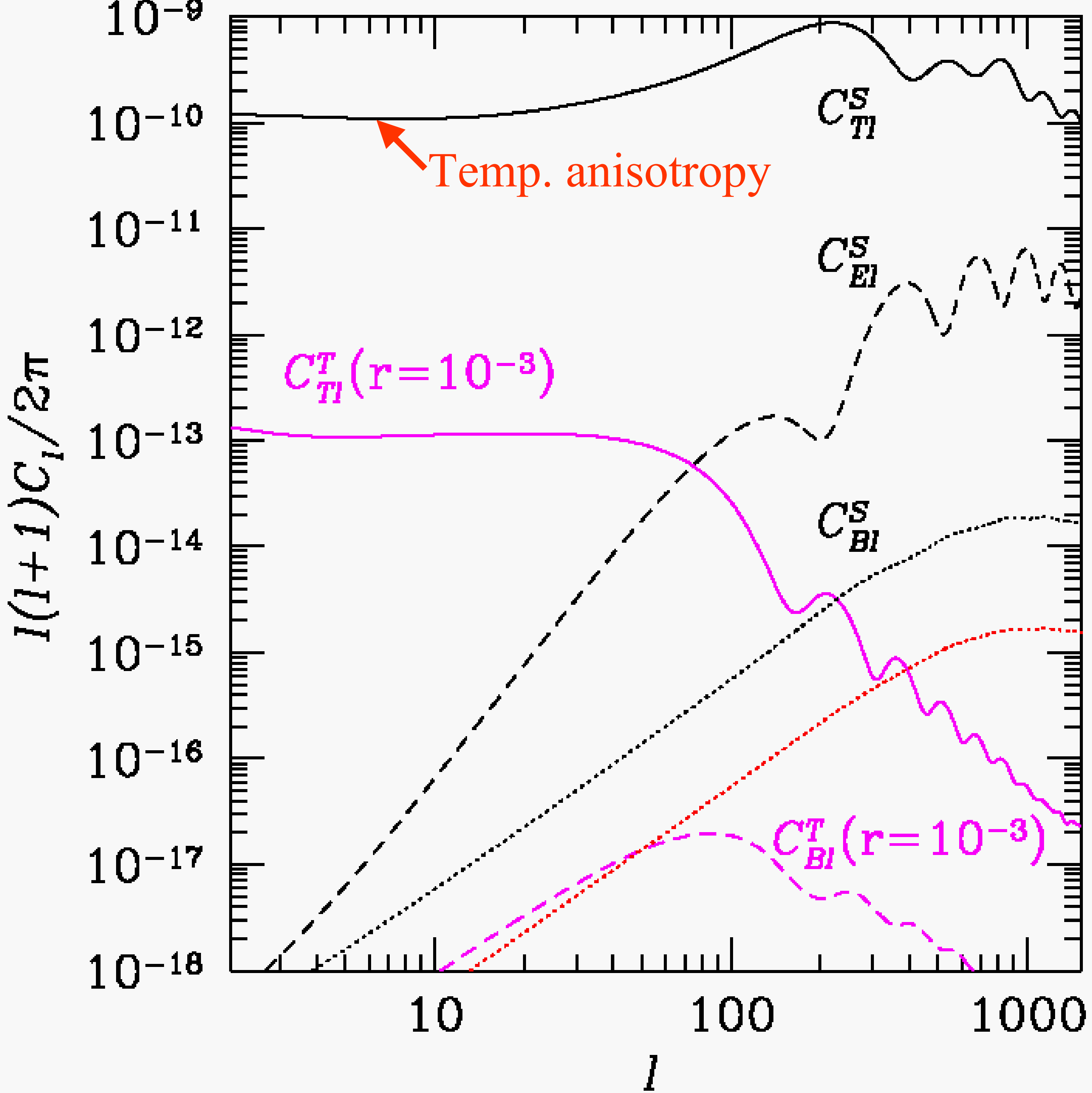
- CMB Polarization Science is Rich
- Difficulties demand alternative approaches
- Exploiting coherent detectors: CBI & CAPMAP
- JPL is producing "polarimeters on a chip"
  - massive arrays are possible
- Systematics well understood
- Different frequencies
- Sensitivity compares to ground-based bolometers
- Collaboration is strong; proposal in preparation
- We'll bring existing telescope to Atacama Desert

The Next Step in Polarization

- Science Targets
  - Precision E-mode spectrum
  - Lensing of the E-modes
  - Primordial Gravity Waves
- Technology: mass production of coherent polarimeters
- The QUIET Collaboration



Power Spectra as a Fraction of T_0^2
$l(l+1)C_l/2\pi$
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
Curves from Knox & Song
C^S_{Tl}
C^S_{El}
C^S_{Bl}
$C^T_{Tl}(r=10^{-3})$
$C^T_{Bl}(r=10^{-3})$
10
100
1000
l



10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10
100
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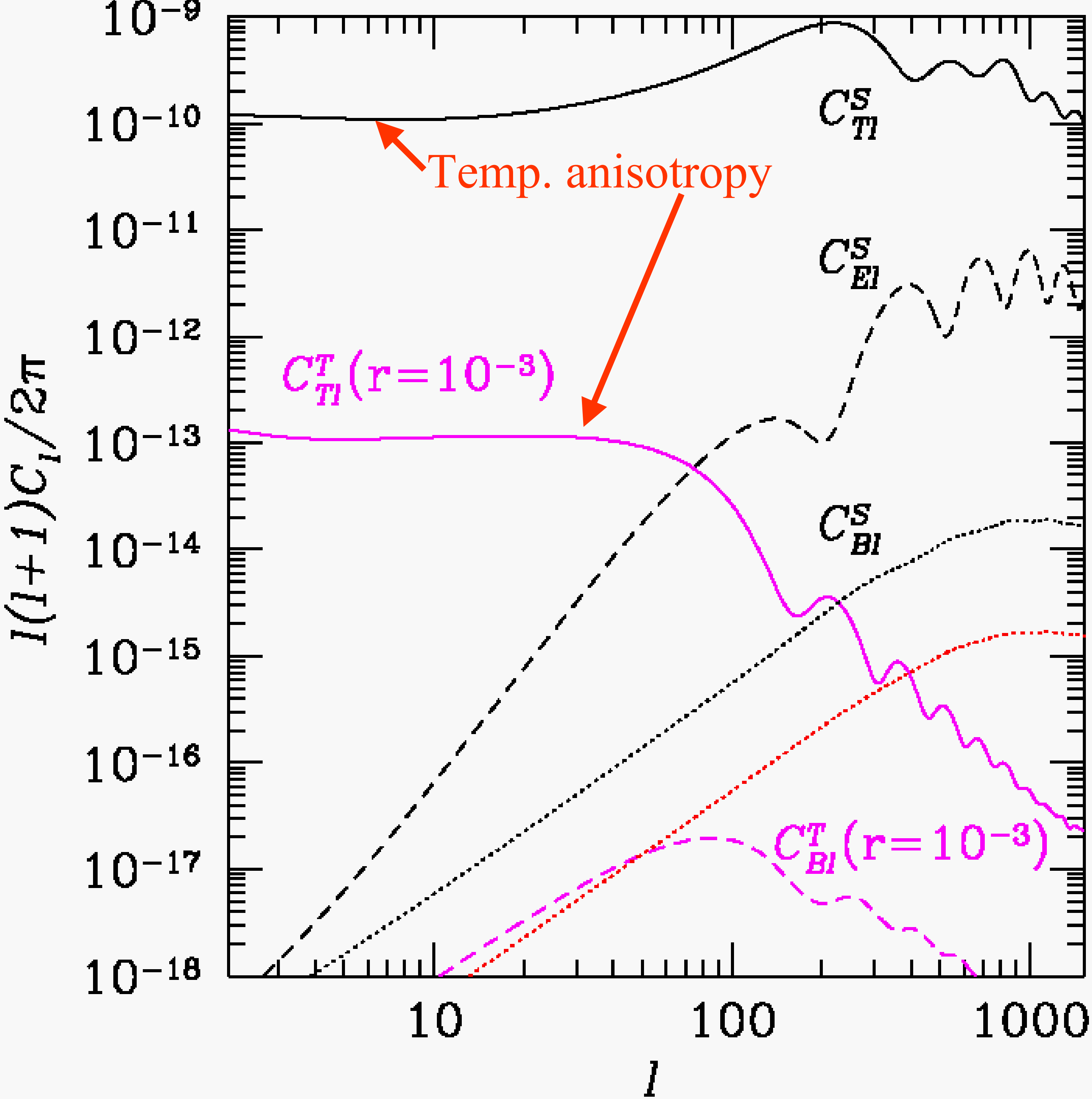
$l(l+1)C_l/2\pi$
C^S_{Tl}
Temp. anisotropy
C^S_{El}
$C^T_{Tl}(r=10^{-3})$
C^S_{Bl}
$C^T_{Bl}(r=10^{-3})$



10^{-9}
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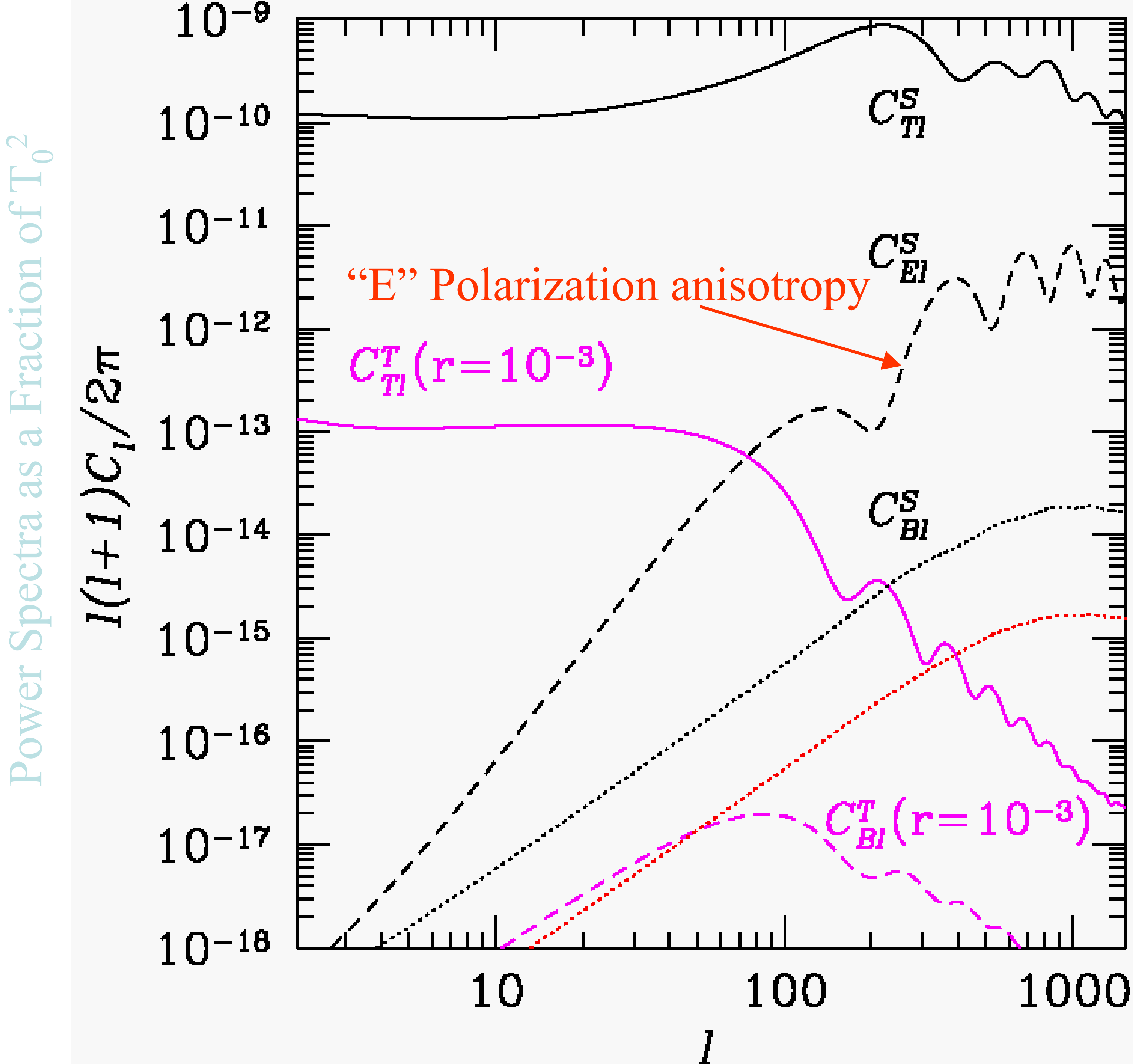
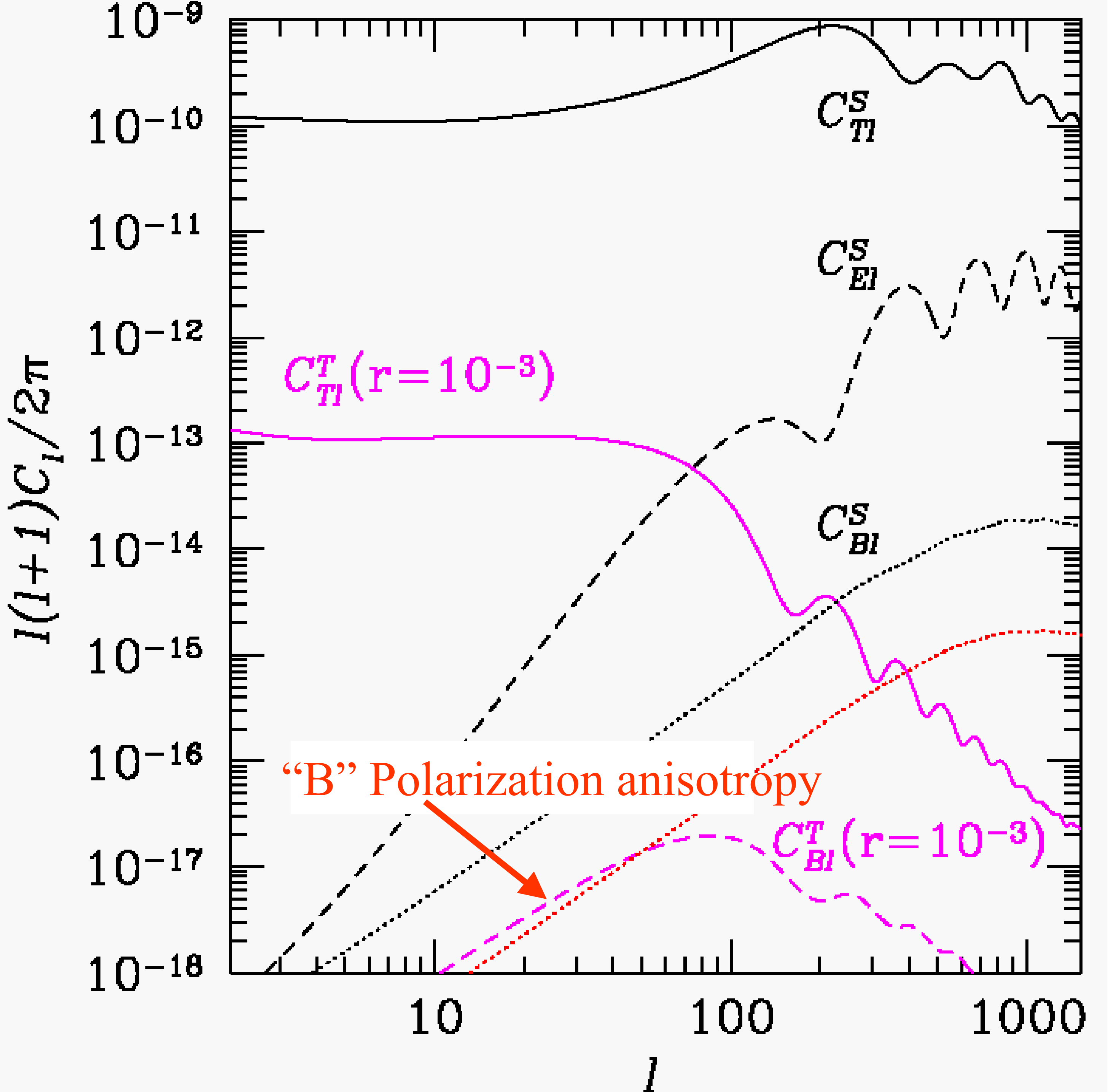
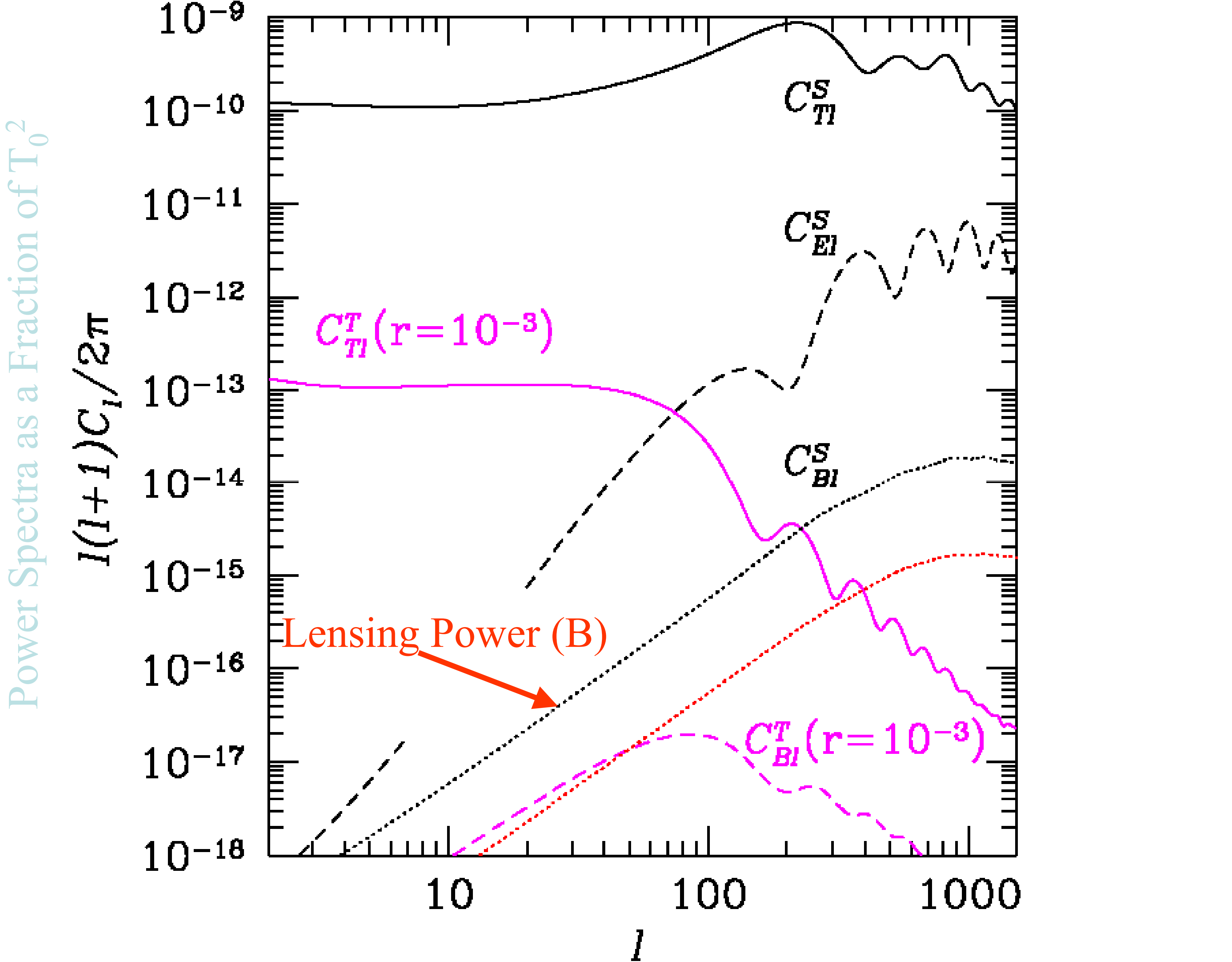


Power Spectra as a Fraction of T_0^2
$l(l+1)C_l/2\pi$
C^S_{Tl}
C^S_{El}
"E" Polarization anisotropy
$C^T_{Tl}(r=10^{-3})$
C^S_{Bl}
$C^T_{Bl}(r=10^{-3})$
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10
100
1000
l



10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
$l(l+1)C_l/2\pi$
10
100
1000
l
C^S_{Tl}
C^S_{El}
C^S_{Bl}
$C^T_{Tl}(r=10^{-3})$
$C^T_{Bl}(r=10^{-3})$
"B" Polarization anisotropy


Power Spectra as a Fraction of T_0^2
$l(l+1)C_l/2\pi$
l
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10
100
1000
C^S_{Tl}
C^S_{El}
C^S_{Bl}
$C^T_{Tl}(r=10^{-3})$
$C^T_{Bl}(r=10^{-3})$
Lensing Power (B)

We see our way to an eventual sensitivity 400 times that of WMAP

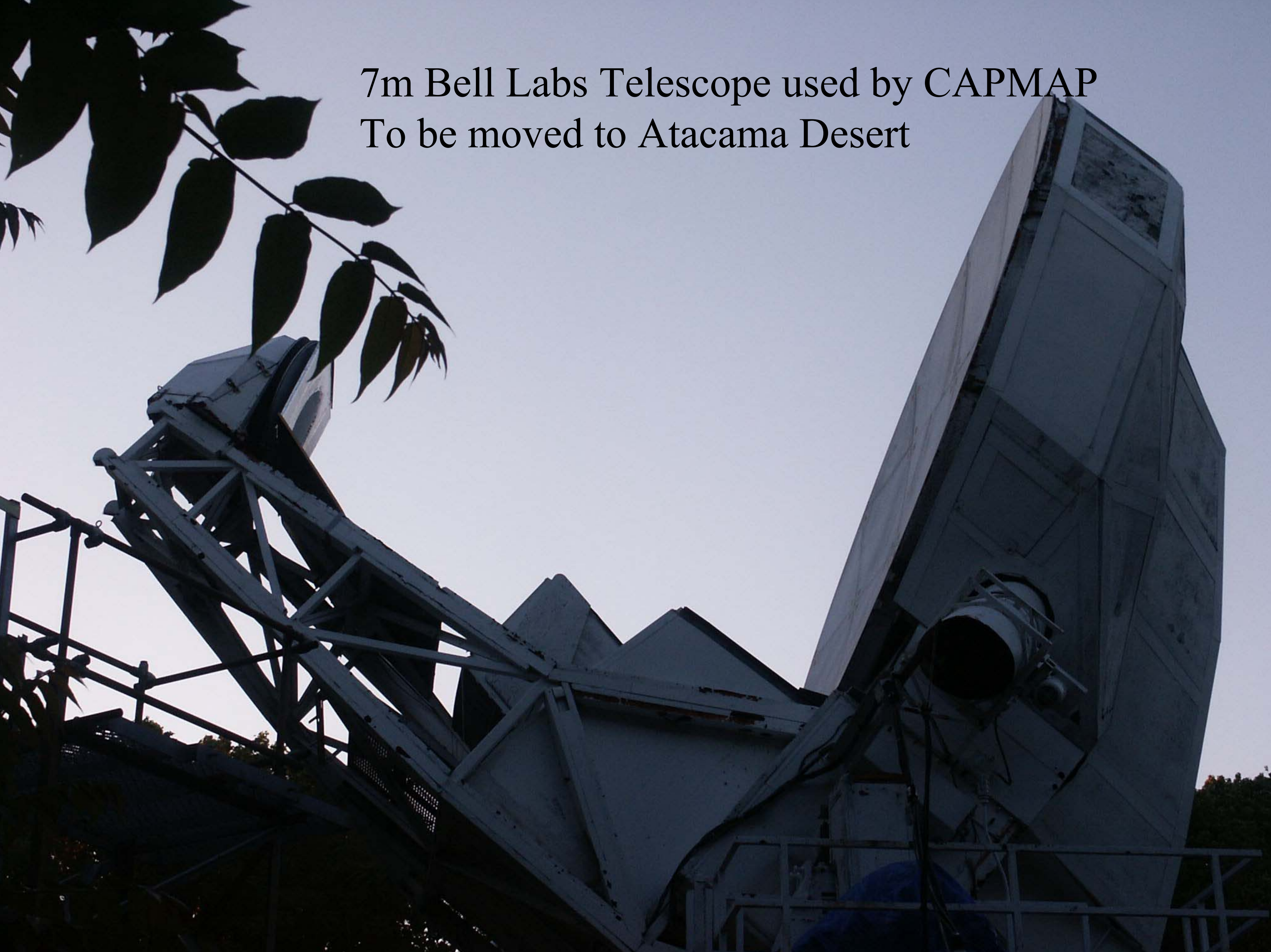
Optimally concentrated into a patch of sky 13 deg x 13 deg

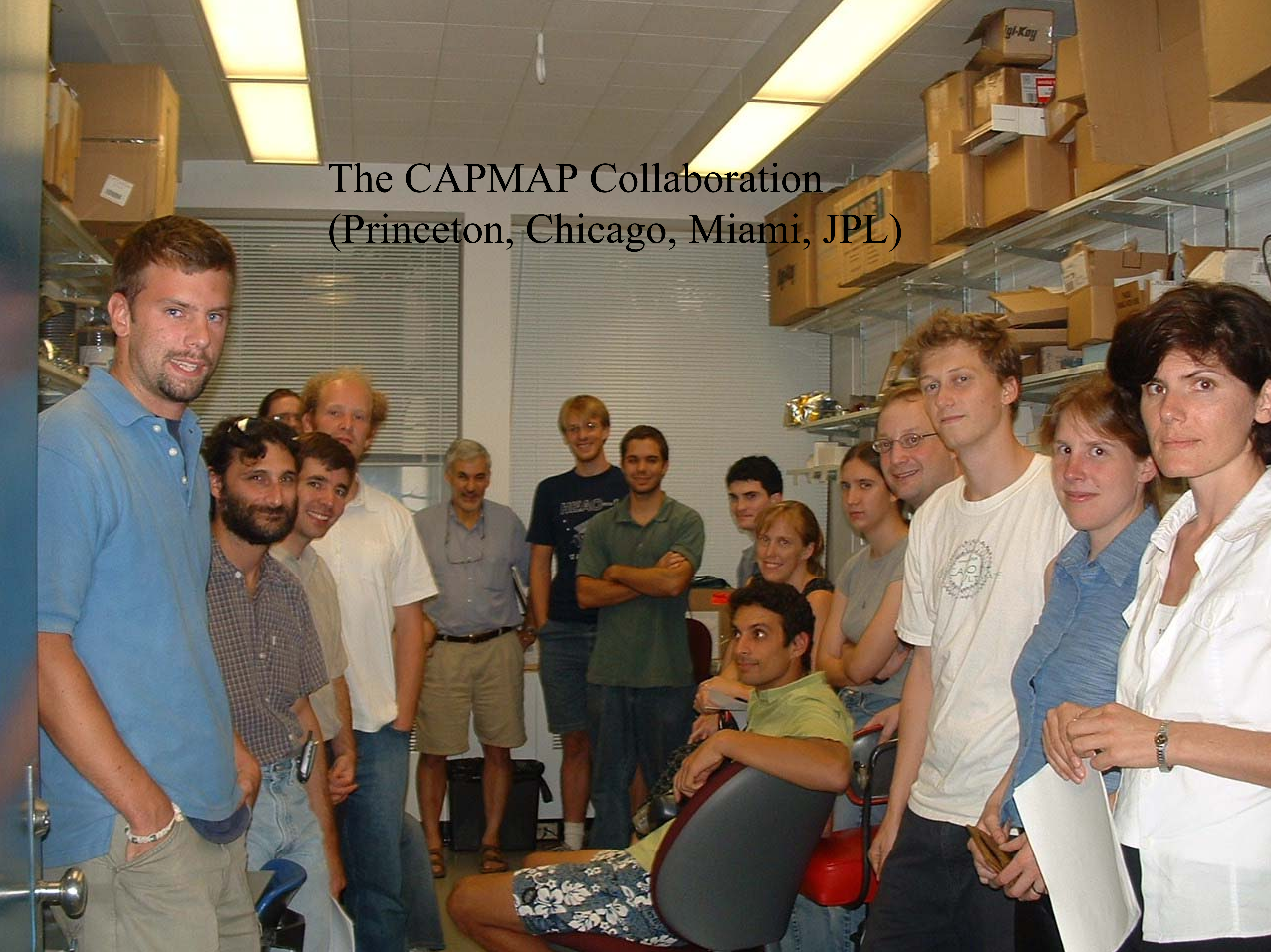
This will give a sensitivity to T/S=0.001

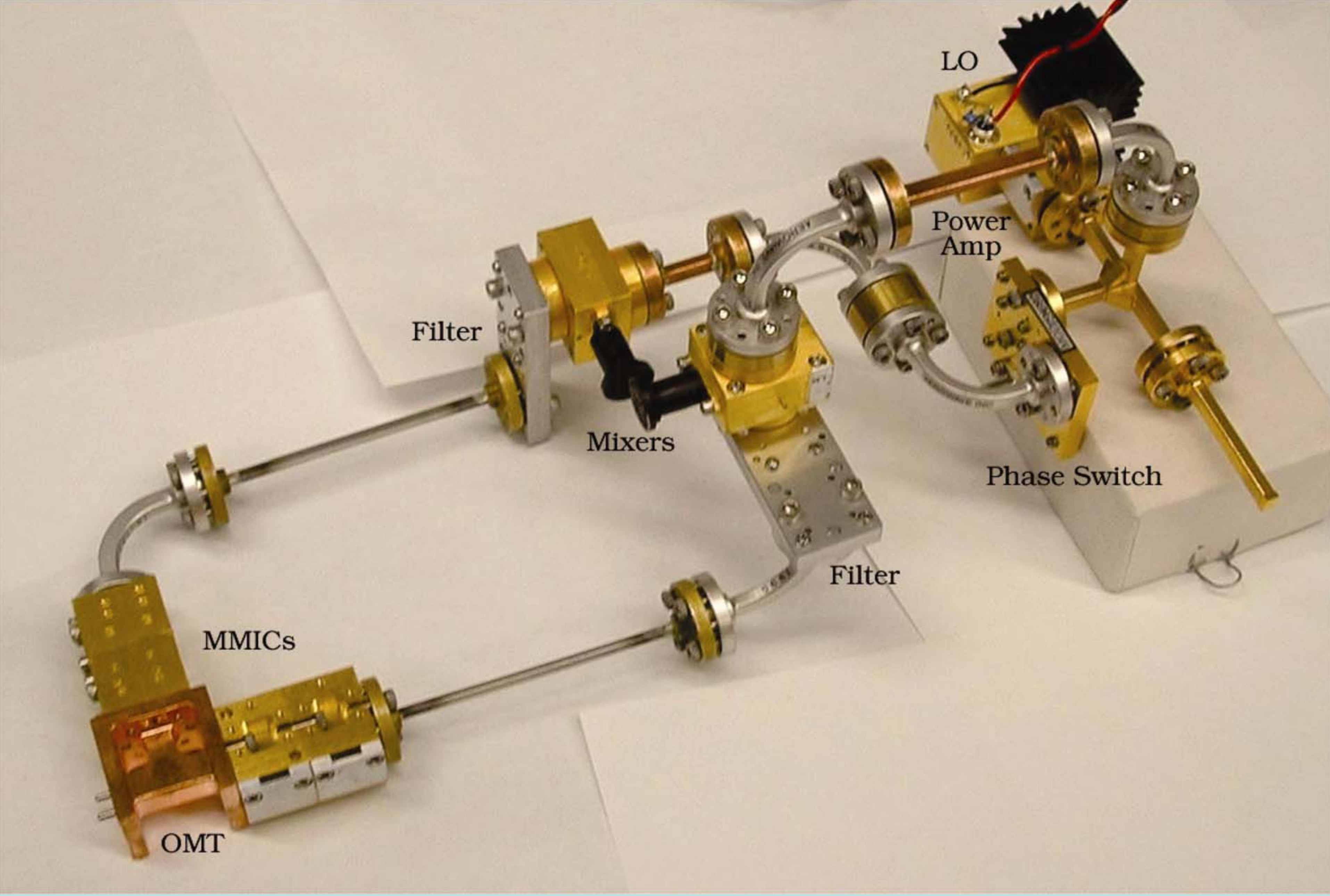
But foregrounds will be a challenge

Table 3: Sensitivities to Detect Polarization Signals. N is the equivalent number of "WMAP's" needed for a 3 standard deviation effect, given for both the full sky and optimized scenarios. The W values in this table are the total required sensitivities of the detectors.

Signal	W (full)	N^{full}_{wmap}	W (opt)	f^{opt}_{sky}	N^{opt}_{wmap}
"E", $l = 1000$			$300nK$	1.3×10^{-3}	.02
lensing, $l = 1000$			15 nK	1.3×10^{-3}	8
"B", $r = 10^{-3}$	500 pK	6,400	2 nK	4.4×10^{-3}	400
"B" , $r = 10^{-4}$	170 pK	64,000	630 pK	4.4×10^{-3}	4000
"B", cleaned $r = 10^{-4}$	100 pK	150,000	370 pK	4.4×10^{-3}	9500


7m Bell Labs Telescope used by CAPMAP
To be moved to Atacama Desert


The CAPMAP Collaboration
(Princeton, Chicago, Miami, JPL)



CAPMAP 90 GHz Polarimeter

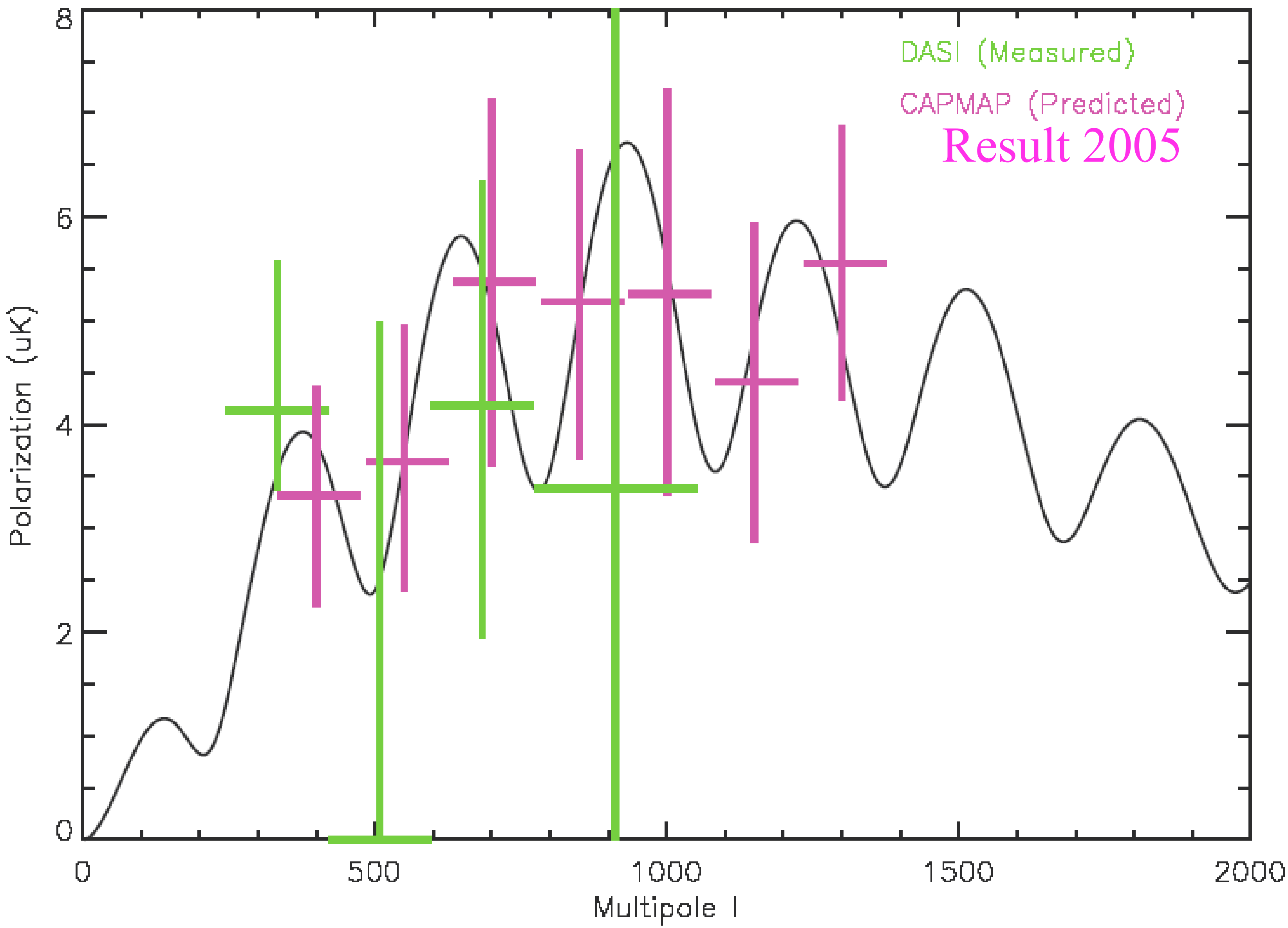
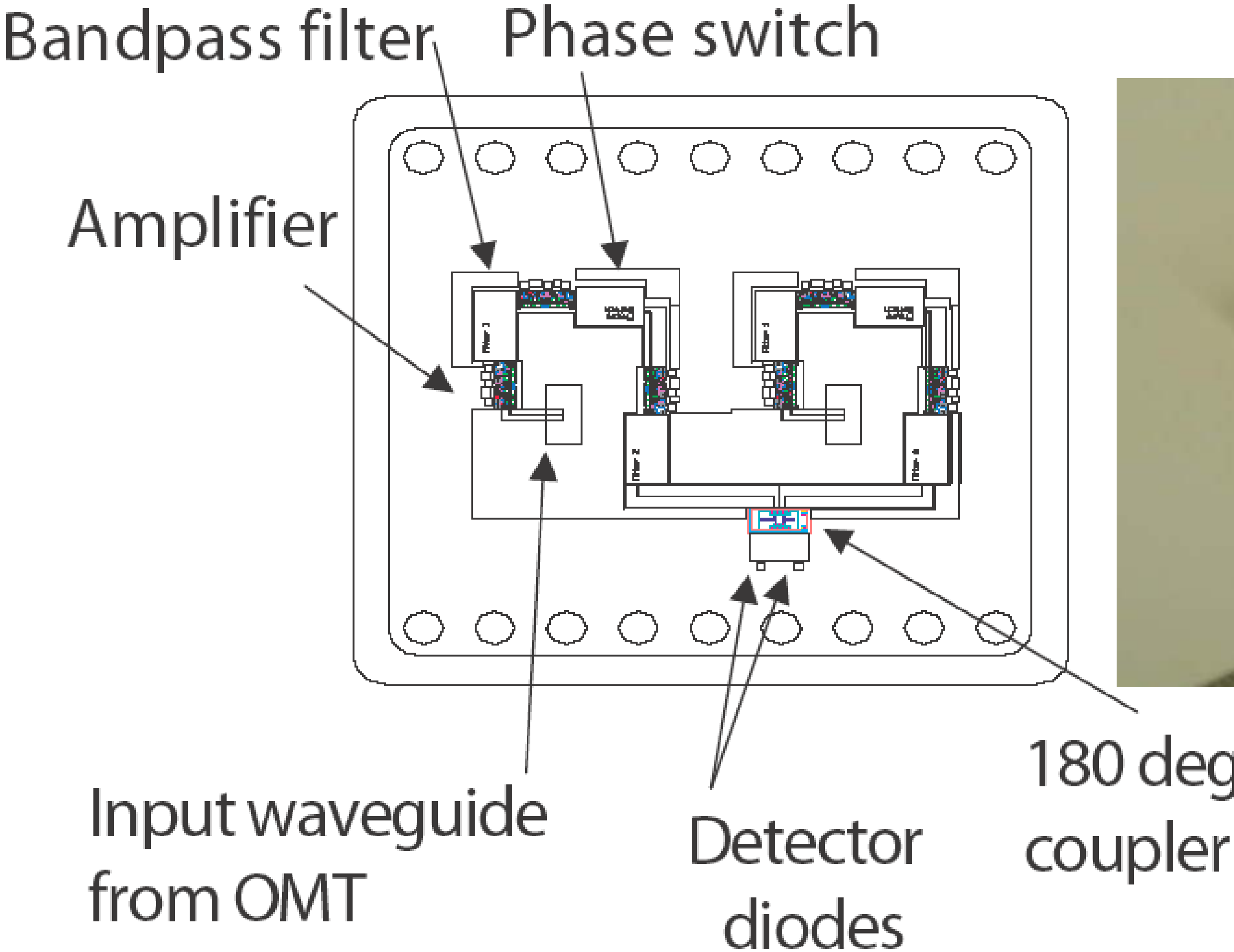
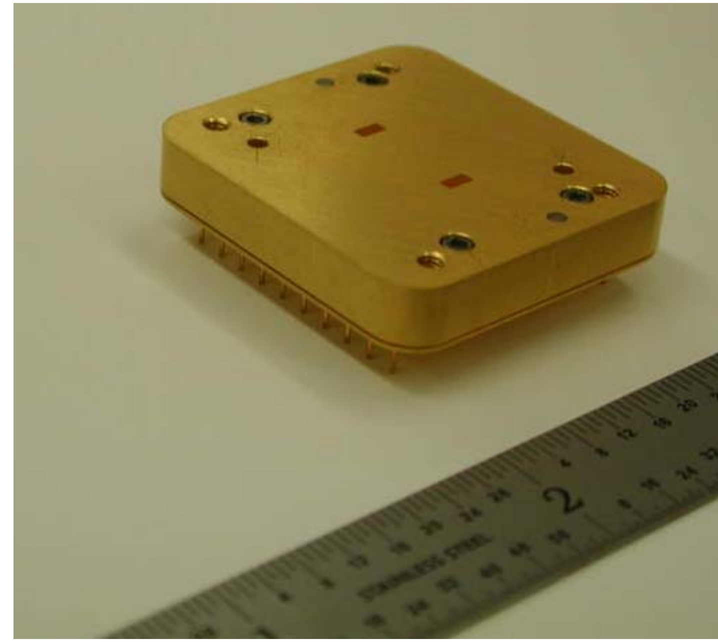


Figure 29: **DASI Results and CAPMAP Projections on the Polarization**



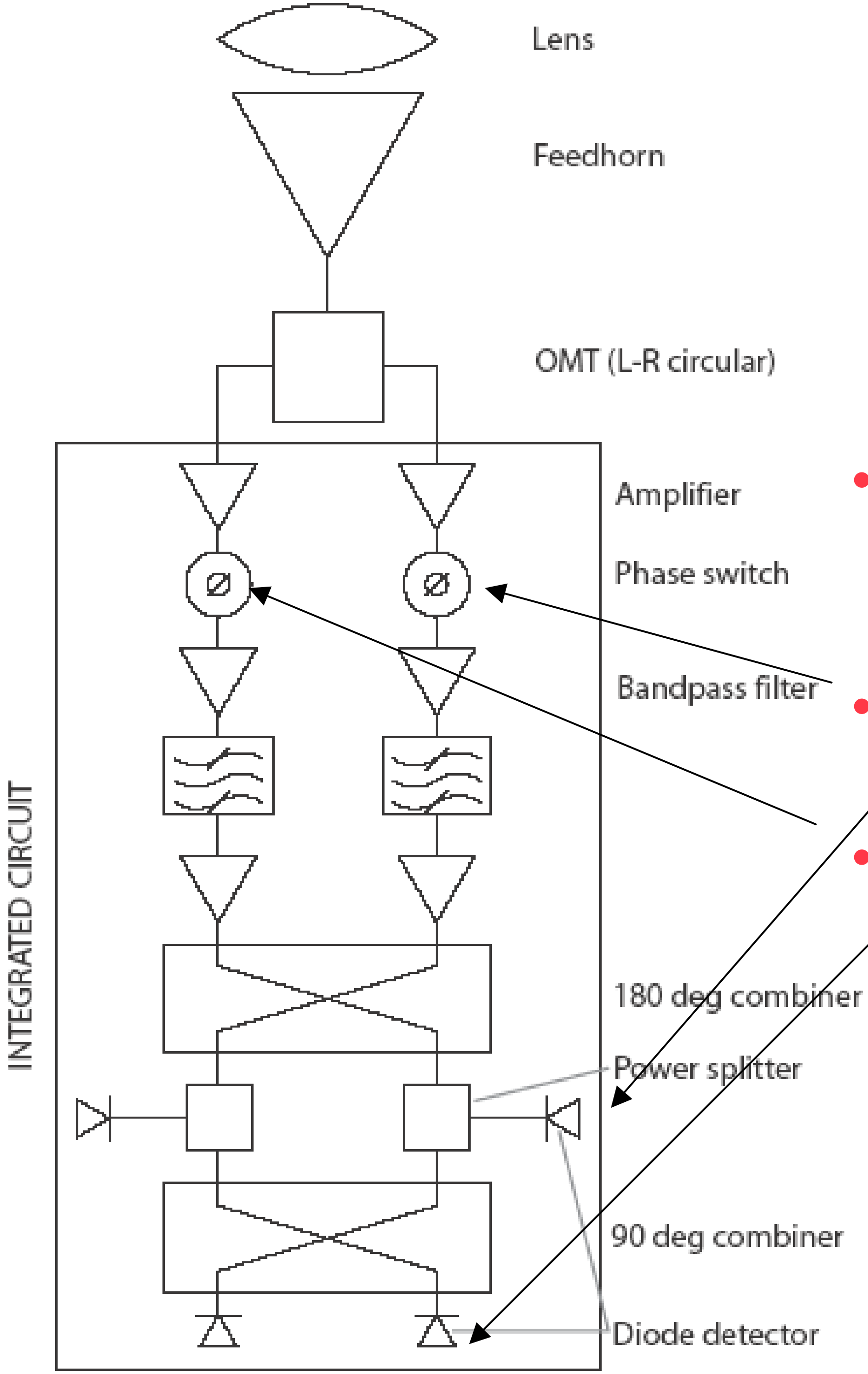


Small (1” x1”) package, mass-producible planar arrays

Under development at JPL for 1 year (T. Gaier)

All active elements perform well cold

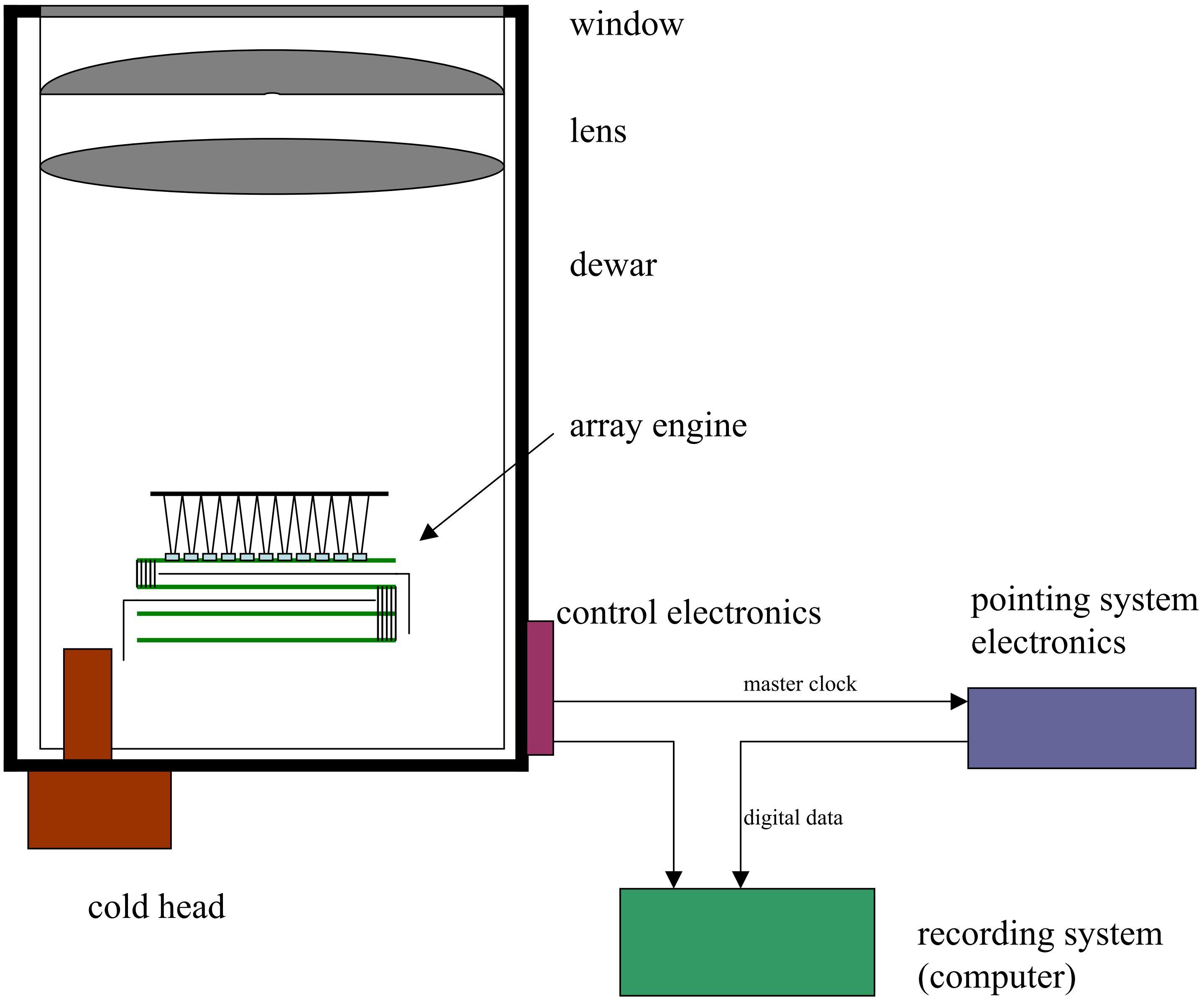
Schematic of 1 channel



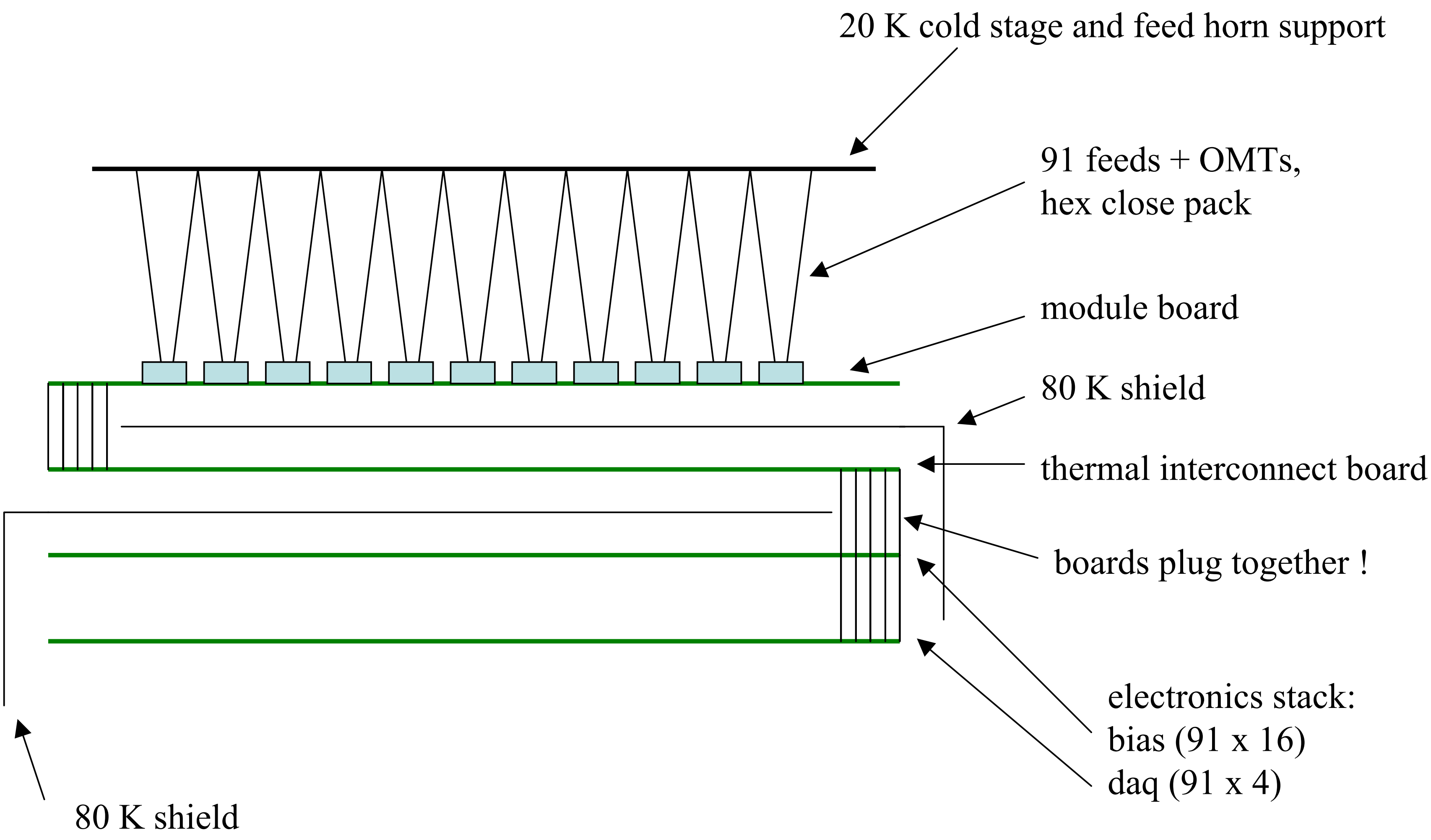
- Measures Q and U Stokes parameters simultaneously
- 4kHz phase switching
- 90-degree switch interchanges roles

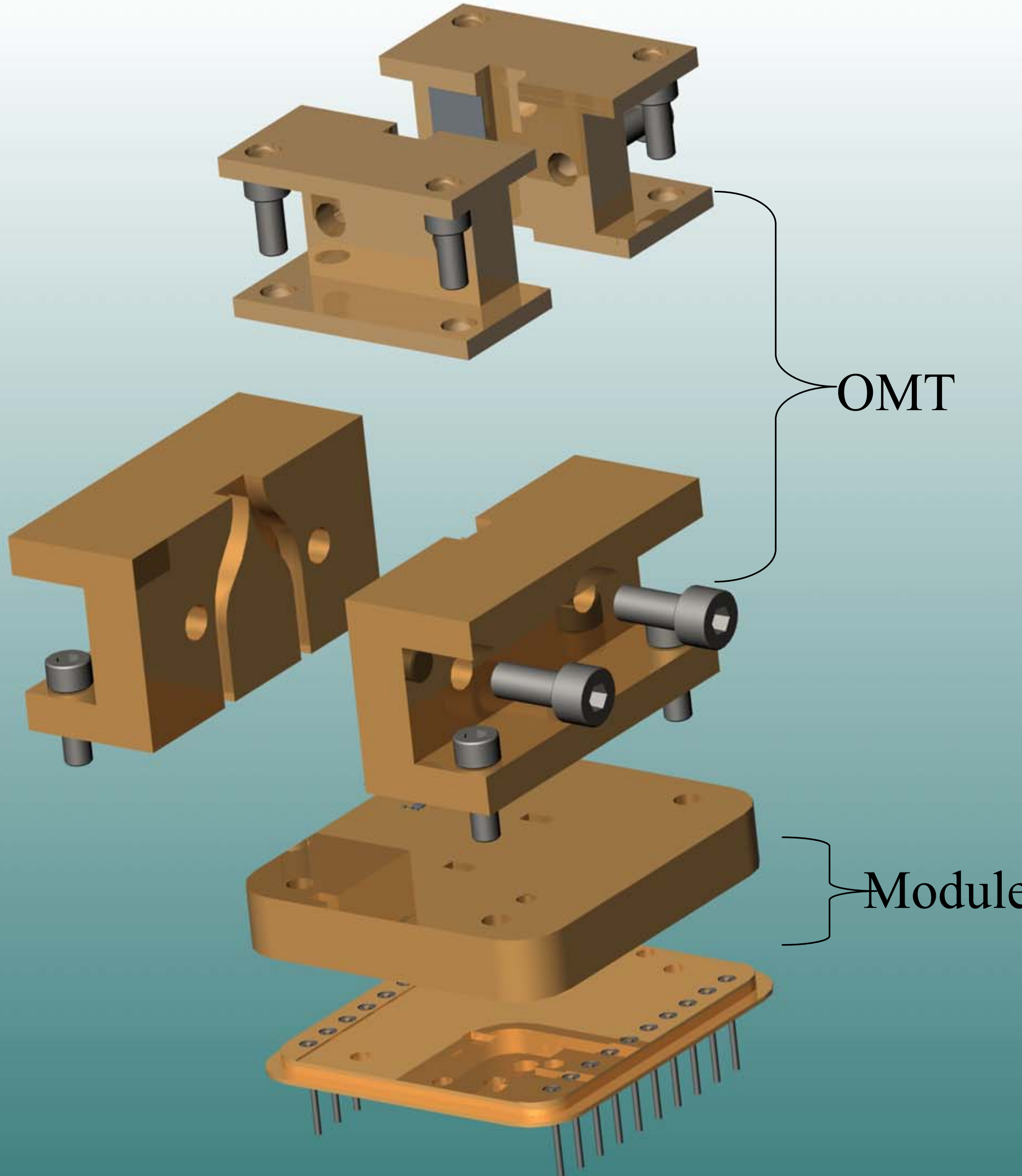
Output voltages give polarization <u>without</u> <u>differencing!</u>

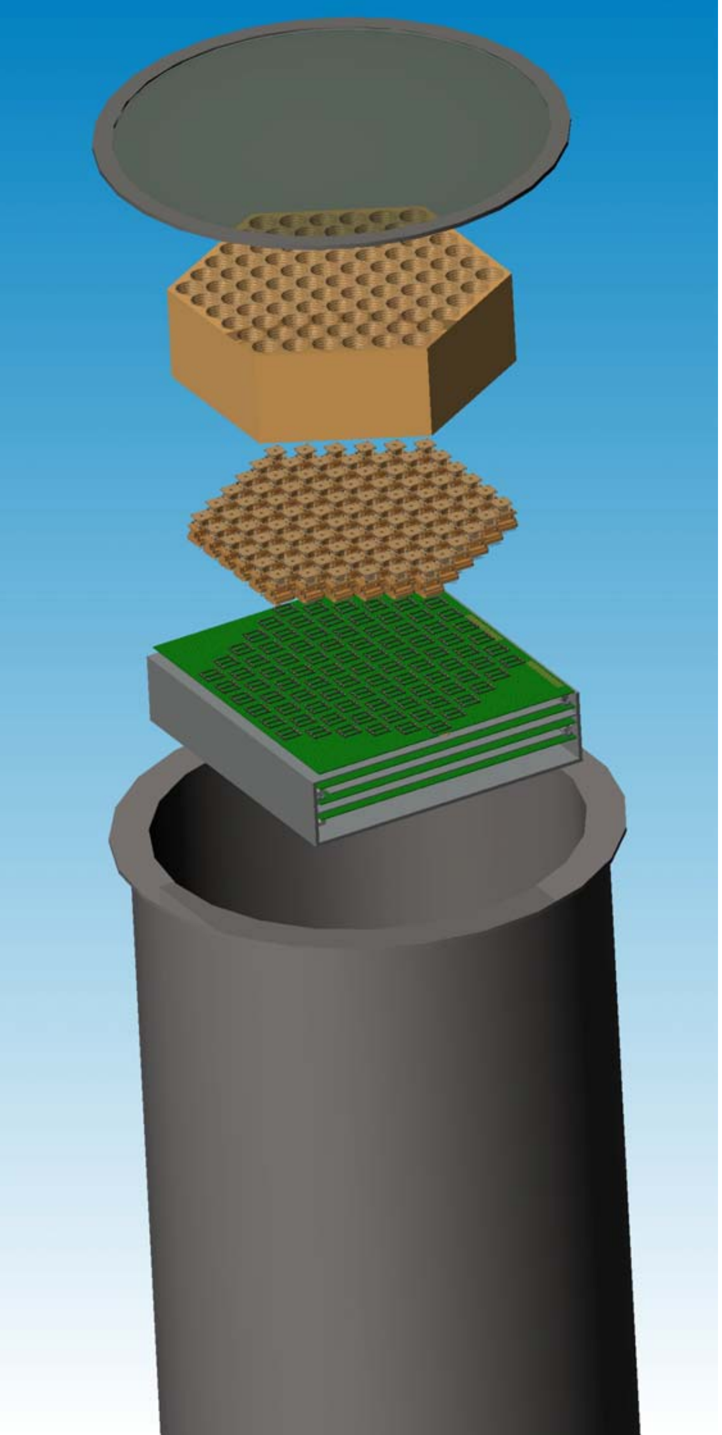
QUIET block diagram



Radiometer Engine Concept




OMT
Module



Lens

Horn array

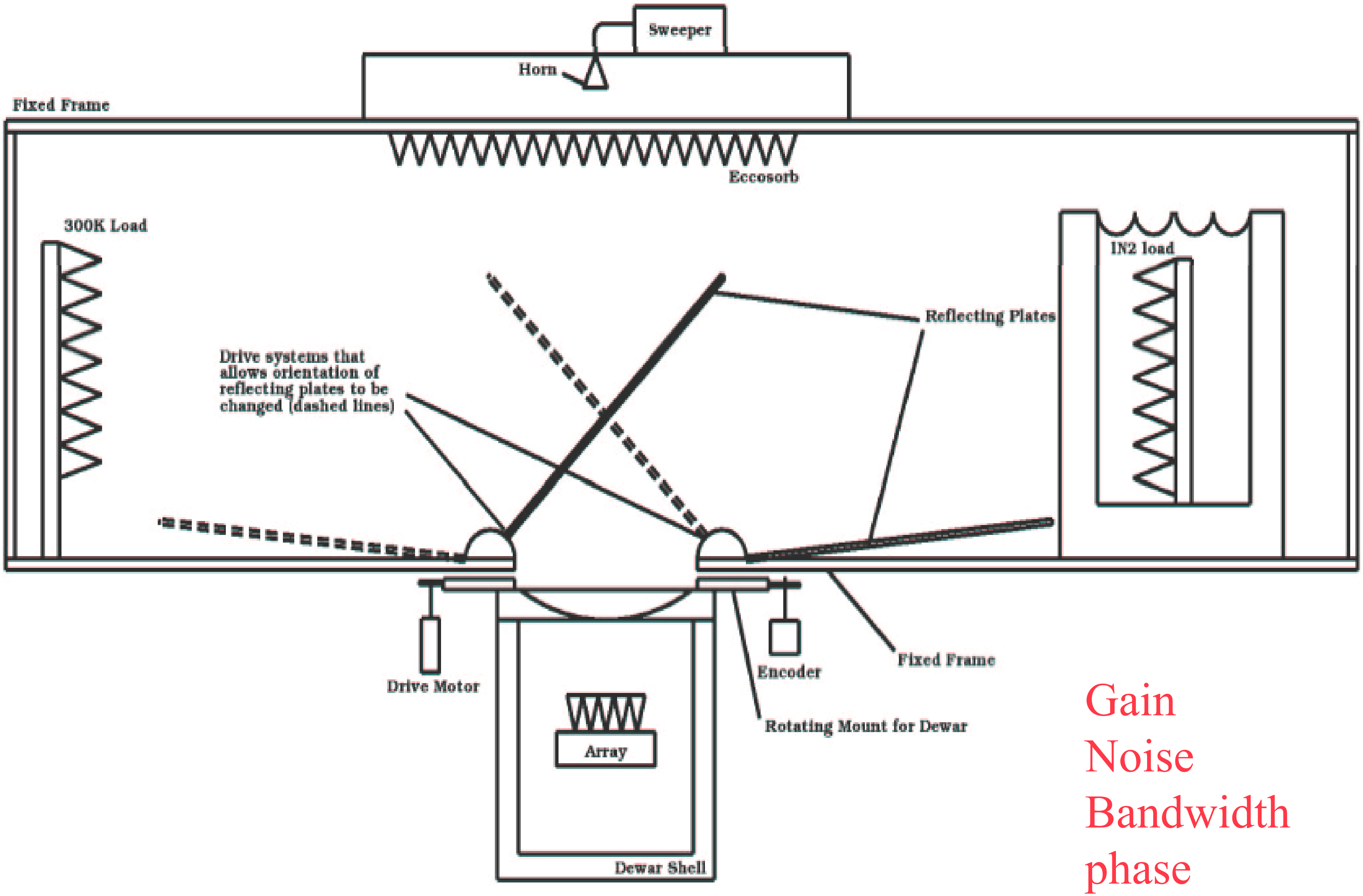
Ortho Mode Transducers

In dewar electronics boards

Cryostat

Measured Approach

- Go in stages on our current telescope
- We’ve developed a “super light source” which can allow insitu characterization of all important radiometer parameters:
  - Gain
  - Noise
  - Bandwidth
  - phase

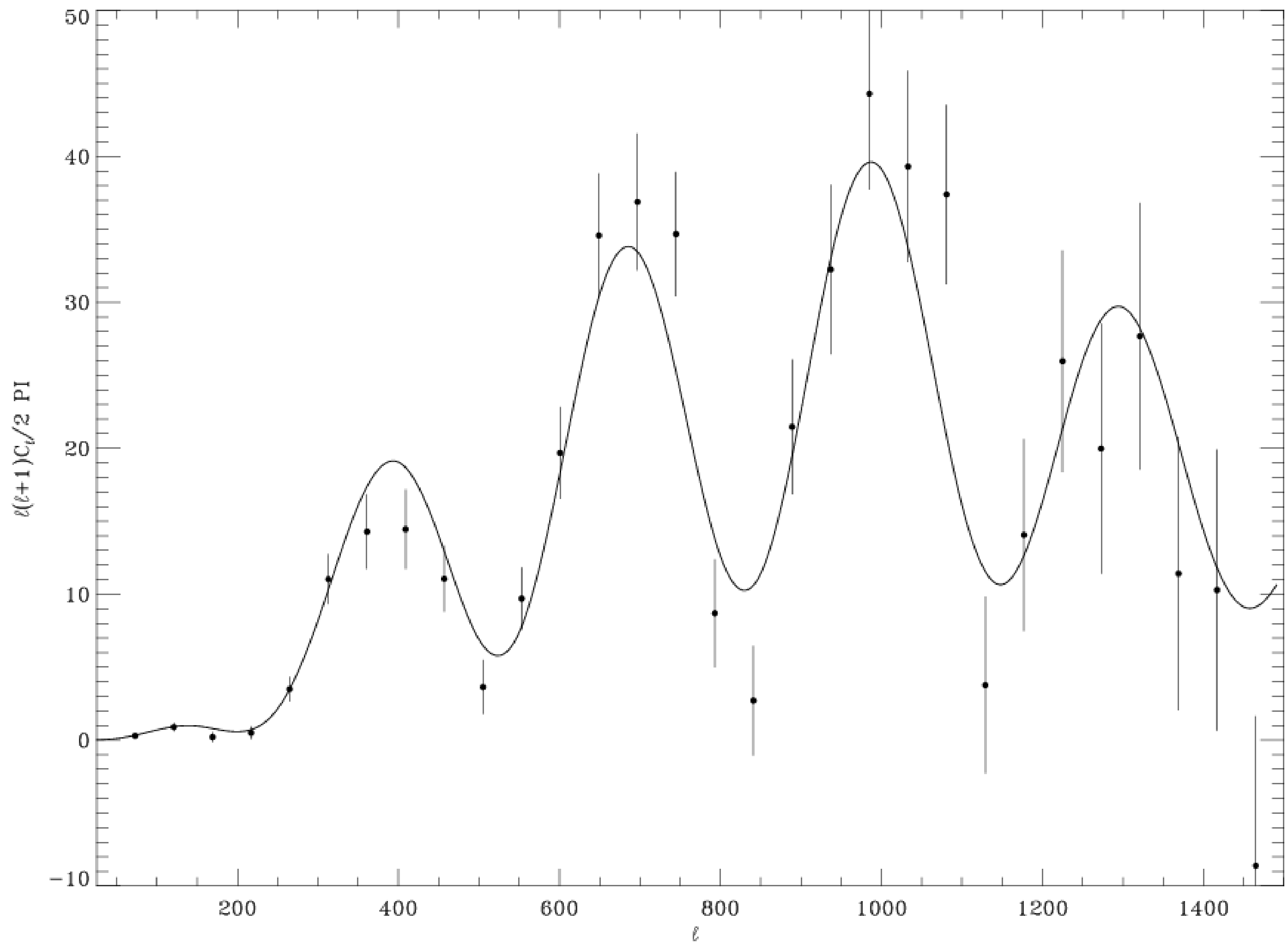


Gain
Noise
Bandwidth
phase

Super injection system: M. Hedman

Result 2006

One season at Crawford Hill



Tsys =115K

91 elements

200 sq. deg

4 arcmin beam

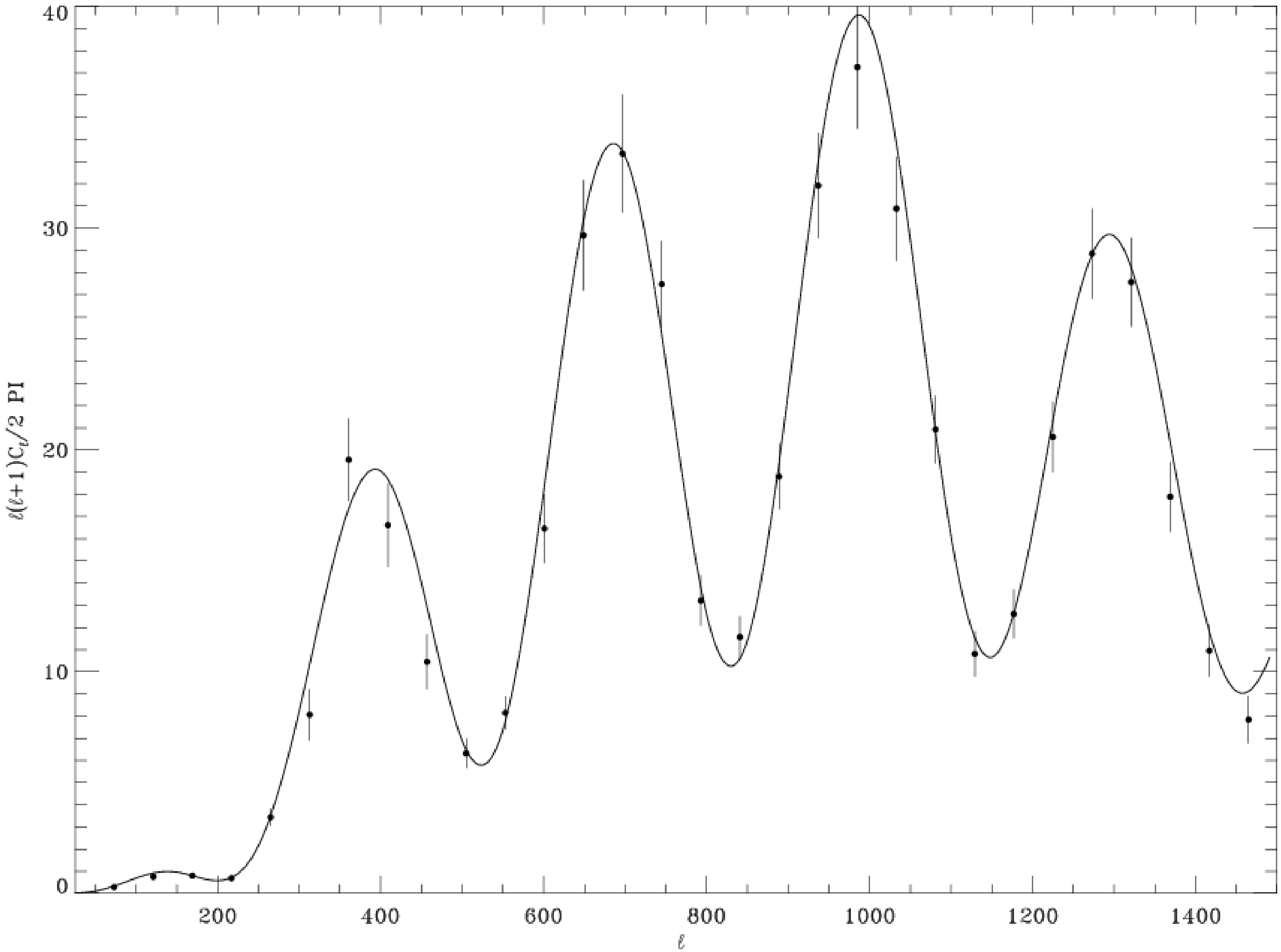
45 days integration

delta l ~ 50

The Site for QUIET: CBI at 16,700 foot altitude in Chilean Andes

Result 2007

Small scale experiment from Chile



Tsys =57K

91 elements

200 sq. deg

4 arcmin beam

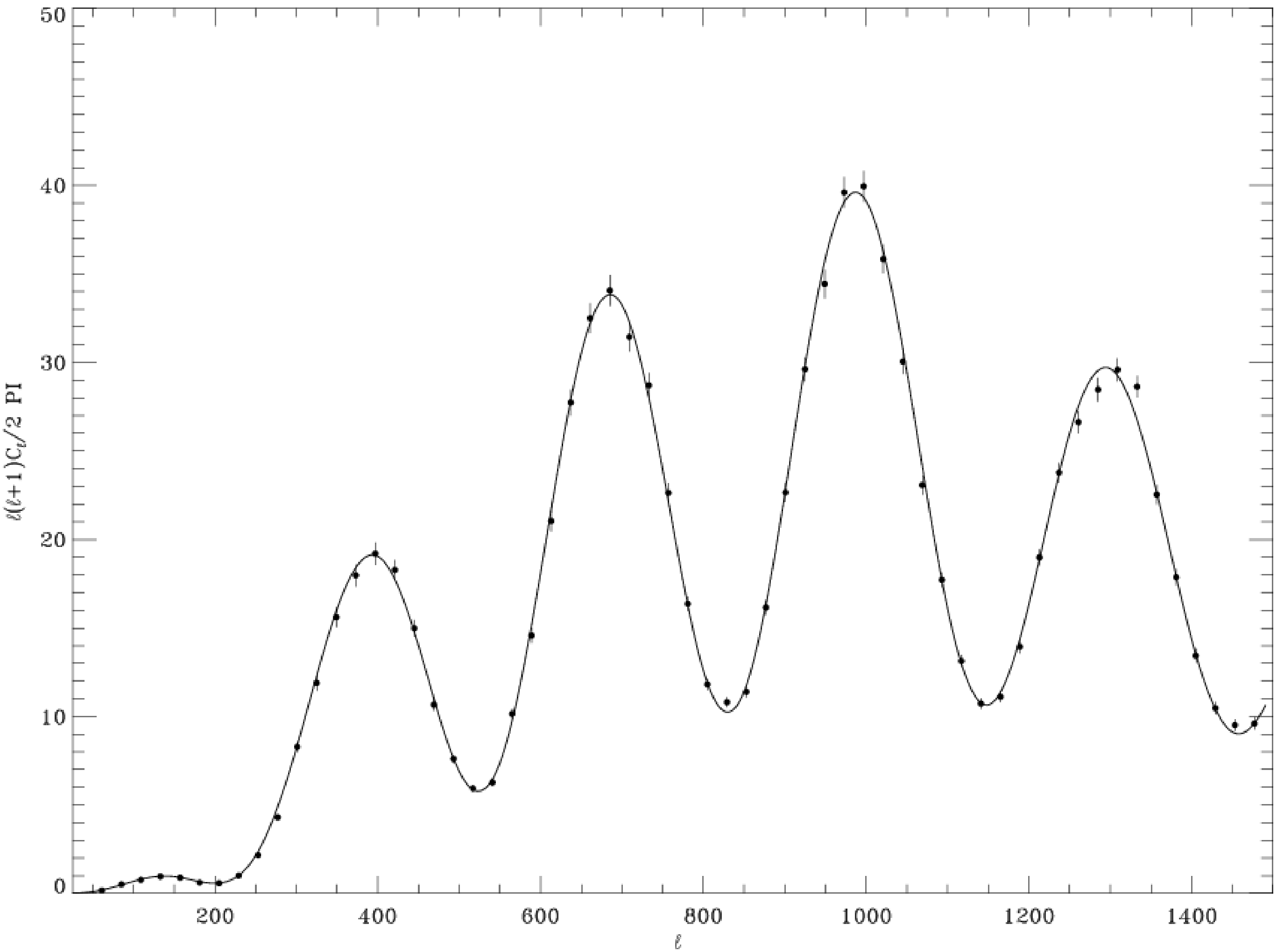
180 days integration

delta l ~ 50

"Measure" = 1600

Result 2008

900 element array small scale experiment from Chile



Tsys =57K

910 elements

4000 sq. deg

4 arcmin beam

360 days integration

delta l ~ 25

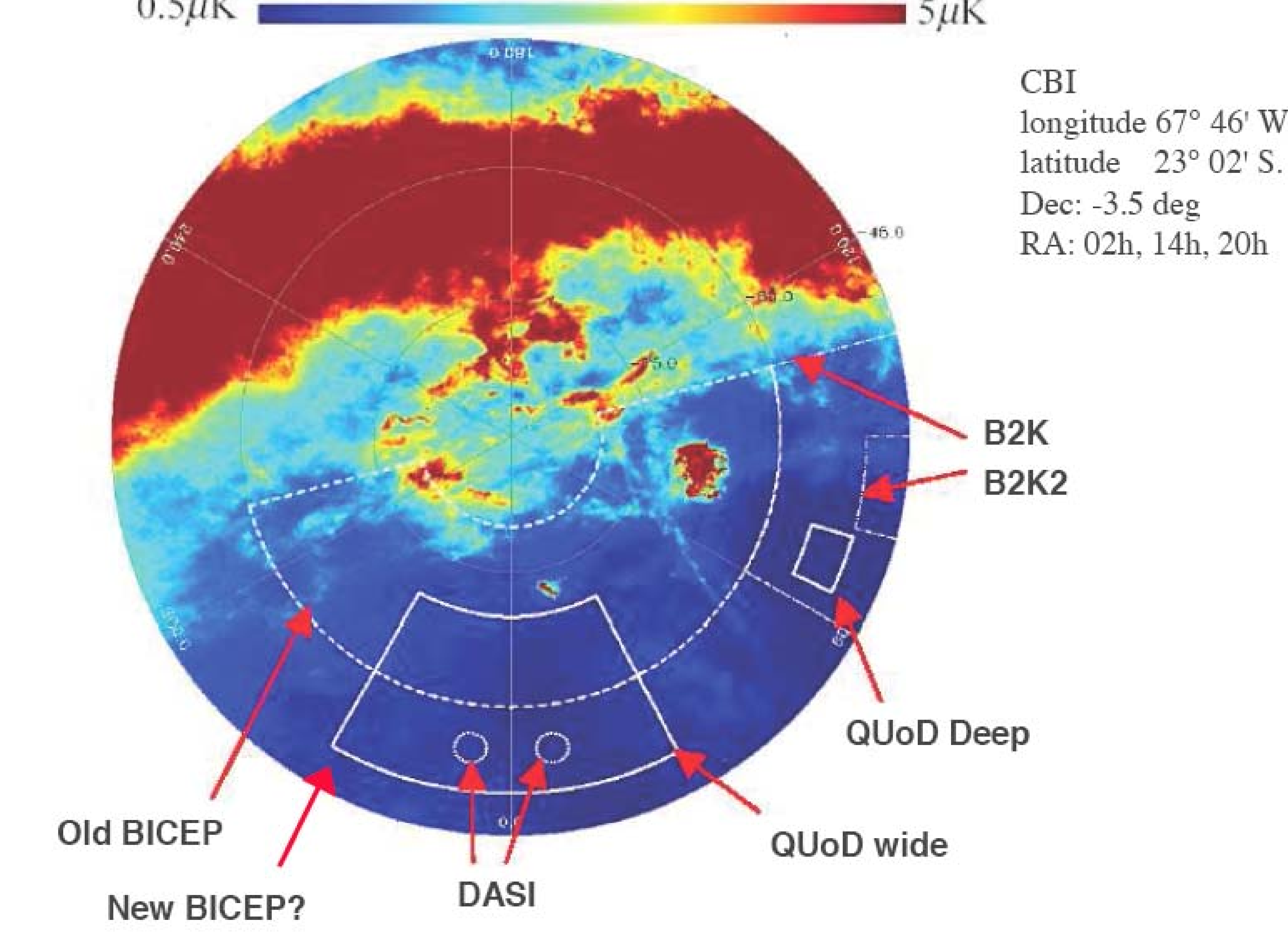
Fractional Foreground Estimation

	EE	BB lensing	BB r=0.01
Point Sources	0.001	0.1	0.2
Dust	0.001	0.1	1.5
Synch.	0.03	5	100

90 GHz
QUaD assumptions
Fraction of expected signal

Need to carefully select and characterize observing region

Signals are SMALL:
Multiple frequencies and techniques mandatory



0.5μK
5μK
CBI
longitude 67° 46' W
latitude 23° 02' S.
Dec: -3.5 deg
RA: 02h, 14h, 20h
B2K
B2K2
QUoD Deep
QUoD wide
DASI
Old BICEP
New BICEP?

QUIET Collaboration

- JPL (Gaier, Lawrence, Dragovan, Gorski, Seiffert)
- Chicago (Winstein, Samtleben, +students)
- CalTech (Readhead, Pearson, Shepherd)
- Princeton (Staggs, Farese, +students)
- Miami (Gundersen)
- Columbia (Miller)
- Harvard (Wilson)
- Berkeley (White)
- Goddard(Wollack)

- Weekly Telcons
- Have Proposal Outline
- Testing modules now
- 4/23 Columbia Meeting
- June & August Meetings
- Proposal in September

We all share the excitement of an approach nicely complementary to Bolometric detectors