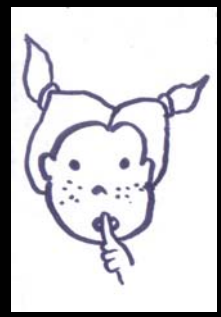
QUIET (QU Imaging Experiment)



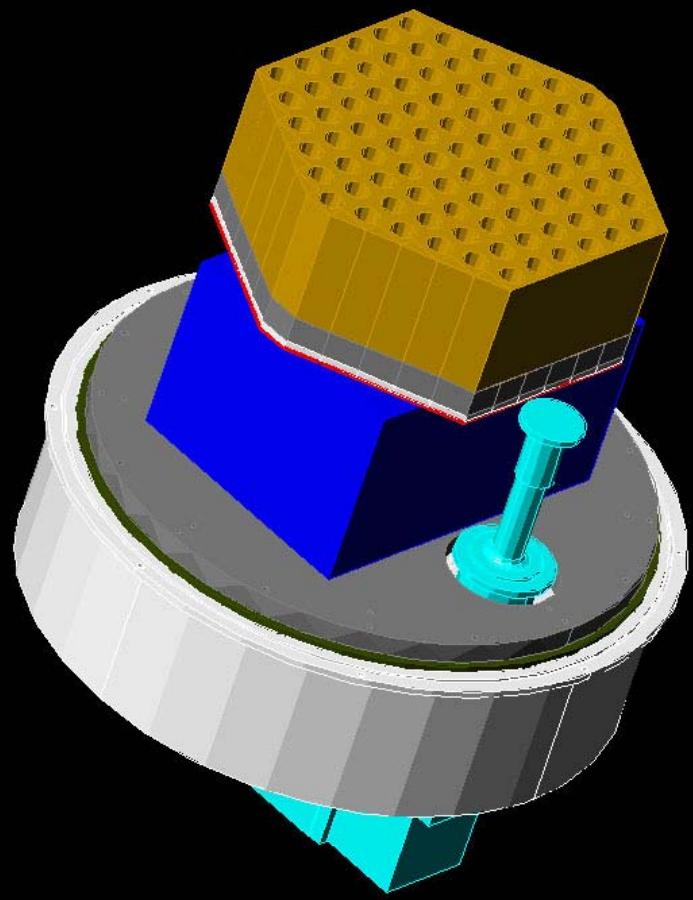
Amber Miller – for the quiet collaboration

20th IAP Colloquium on CMB Physics and Observations

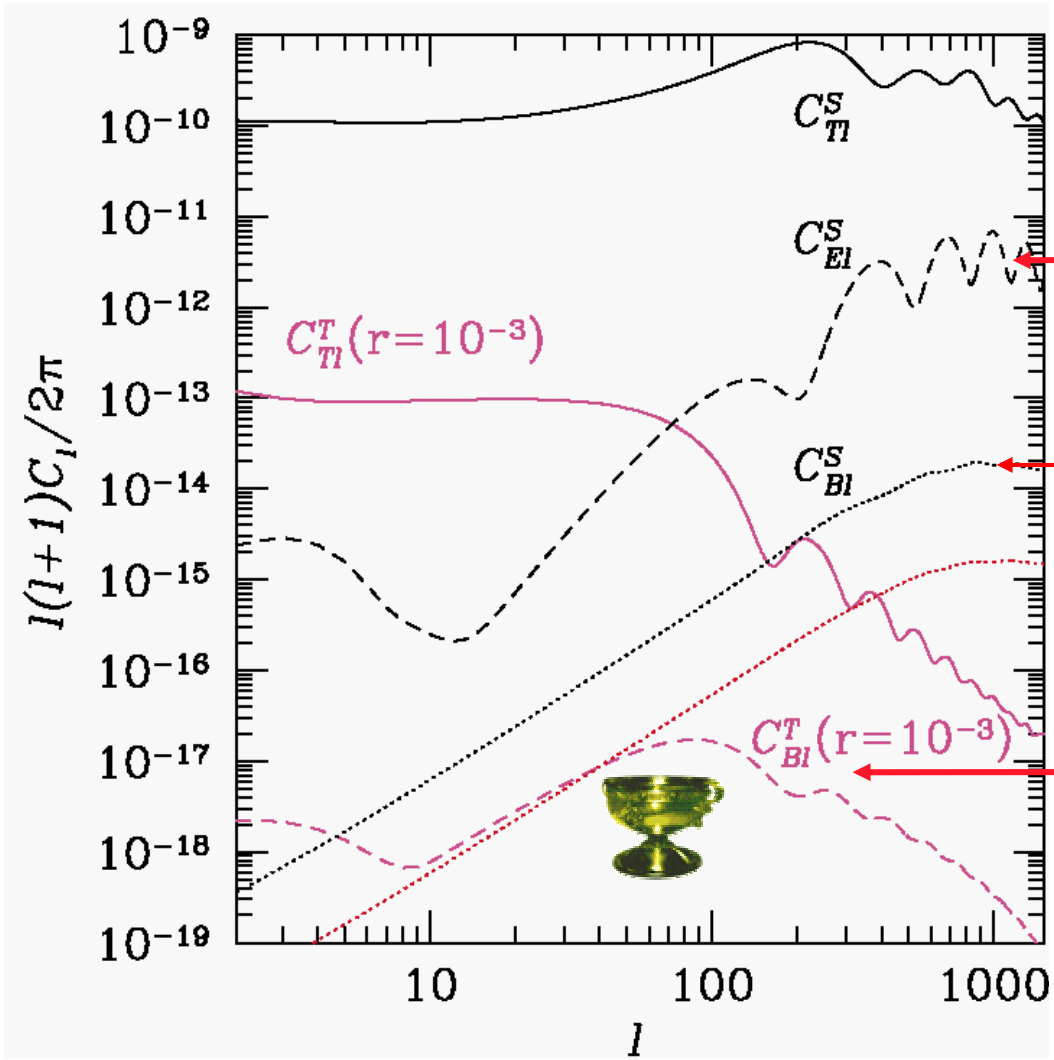
QU Imaging ExperimenT (QUIET)

<u>The Collaboration</u>

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



CMB Polarization Science Targets



Fine scale E-pol

E → B lensing

Grav. Waves

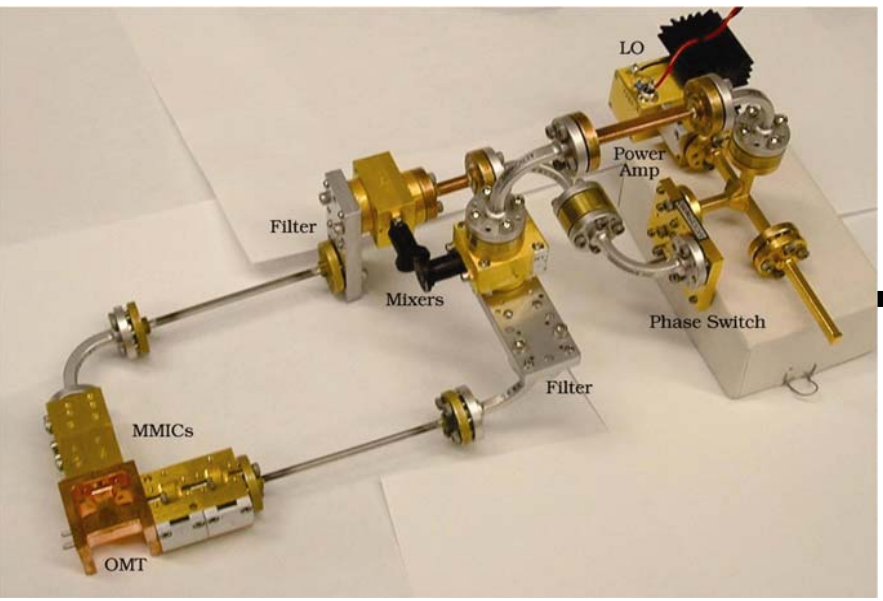
$E_{inf} \sim 6 \times 10^{15}$ GeV

(slow-roll Inflation)

Slide: adapted from Todd Gaier

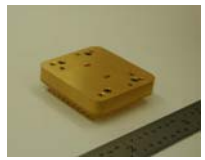
Breakthrough in MMIC Packaging makes QUIET possible

CAPMAP 90 GHz Polarimeter

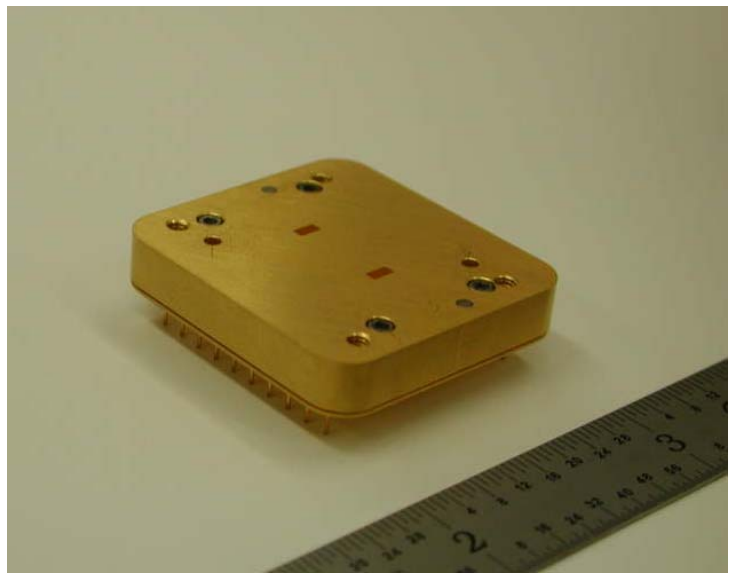


X-Y Polarizer

~ $40K and 50 physicist-hours for checking, characterizing, etc



QUIET Polarimeter IC

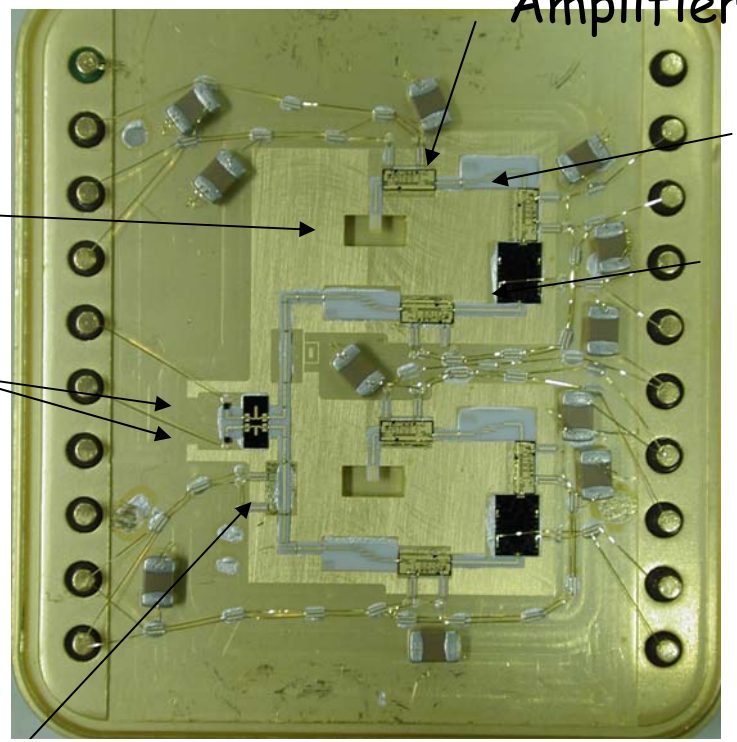


~ $500 and automated assembly and test, completely scalable

Slide: Todd Gaier

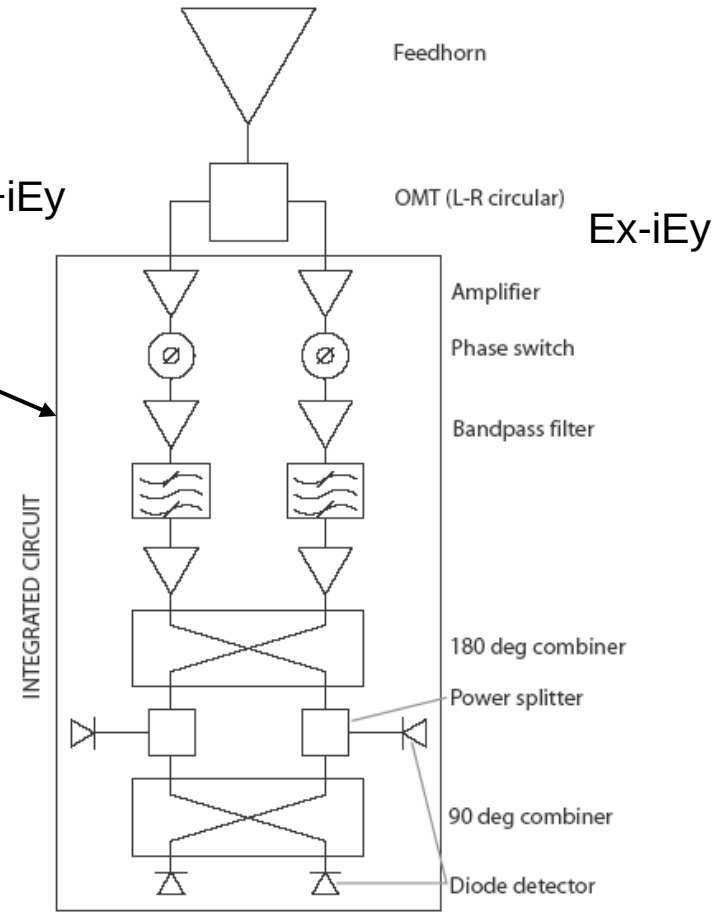
Polarimeter on a Chip

Array element:Complete 90 GHz Polarimeter receiver in a plug-in Module: Tsys=50K, $\Delta\nu/\nu$=0.2



Slide: adapted from Todd Gaier

Q/U Polarimeter-Functional Schematic



Note – combination of 180 and 90 degree combiners have the same effect as the hybrid phase combiner on SPORT

Diode outputs following 180 degree phse combiner are demodulated, low-pass filtered, and differenced ➔ **Stokes Q paramter**

Diode outputs are demodulated, low-pass filtered, and differenced ➔ **Stokes U paramter**

Slide: adapted from Todd Gaier

Some nice things about HEMTs

- **Require simple cryogenics (20K)**
- **Readout circuitry can be at room temperature**
- **Polarization Modulation can be done electronically (phase-preserving technology)**
- **Can get both Q and U Stokes parameters using a single pixel**
- **Technology now exists to integrate into large arrays**
- **conventional wisdom says that bolometers have much higher sensitivity but at low frequencies and from the ground, HEMTs are comparable.**

Bolometer & Amplifier Sensitivity

The convention for polarization sensitivity used here is $(T_x - T_y)/2$.

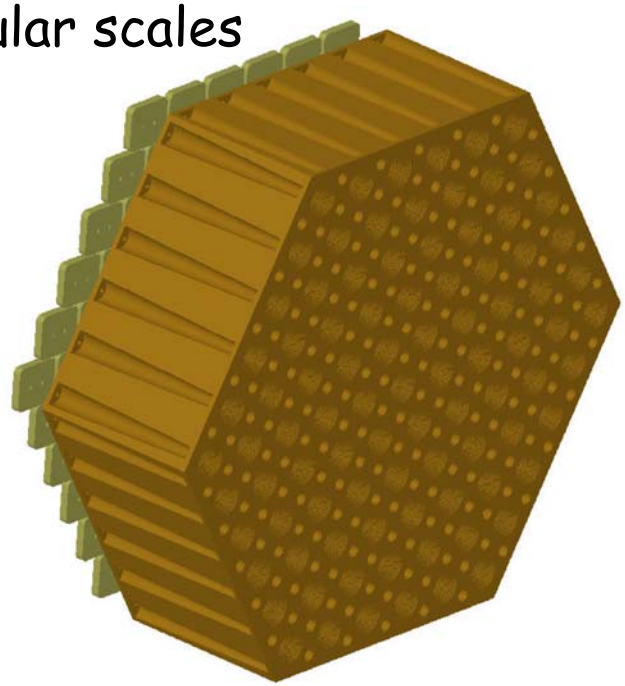
	From Space (~2010)		From Ground (2004)	
Frequency [GHz]	Bolometer [μK s$^{1/2}$]	HEMT/$\sqrt{2}$ [μK s$^{1/2}$]	Bolometer [μK s$^{1/2}$]	HEMT/$\sqrt{2}$ [μK s$^{1/2}$]
30	39	38	250	120
45	33	42	250	110
70	28	50	250	180
100	28	64	250	204
150	27	100	250	450
220	39	210		
350	130			

[a] Bolometer values from J. Bock, private communication.

[b] The $\sqrt{2}$ in the HEMT values comes from the fact that Q and U can be measured simultaneously behind one feed.

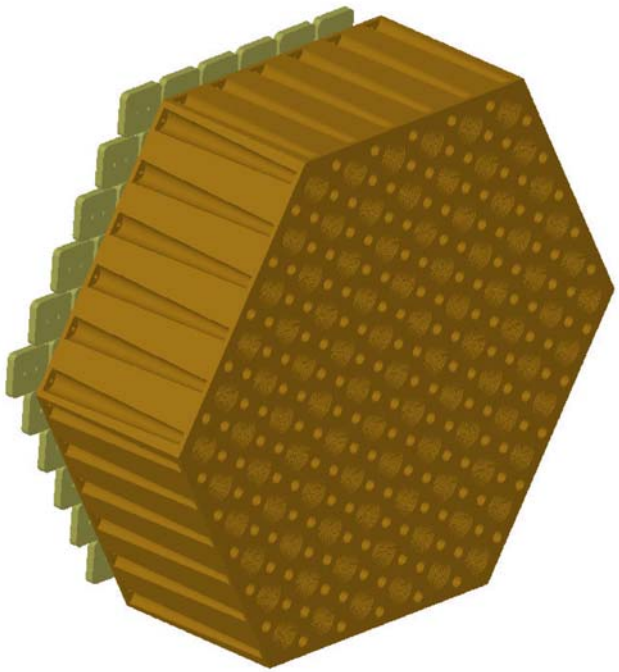
QUIET Collaboration Scope

- Pathfinders:
  - 100-element W-band array on 1m telescope
  - 37-element Q-band array on 1m telescope
- Two optical platforms:
  - Novel 1m-scale telescope on CBI in Chile for large angular scales
  - Lucent 7m telescope in Chile for small angular scales
- Two frequencies at each angular scale:
  - 1000-element W-band arrays
  - 300-element Q-band arrays
- Operate for 3+ years

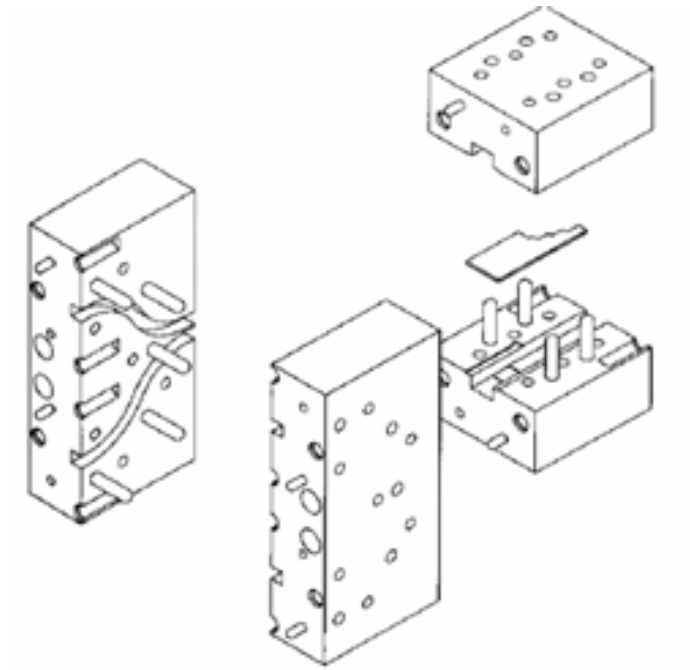


Platelet Corrugated Feed Arrays

91-Element layout



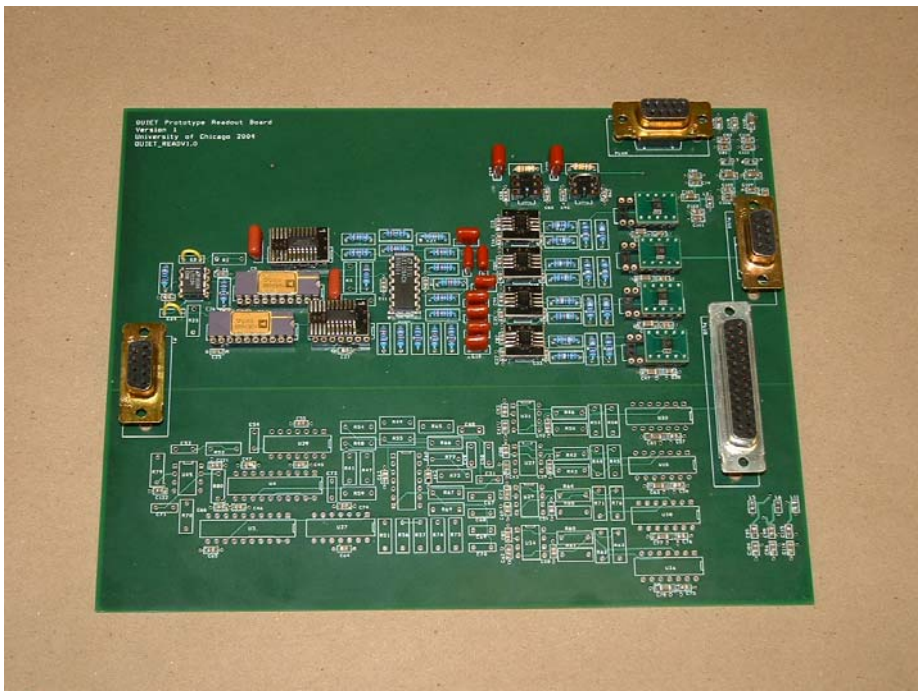
Septum OMT
(decomposes the incident wave into left and right circular components



UNIVERSITY OF Miami
DEPARTMENT OF PHYSICS

Princeton University

Bias and Readout Electronics



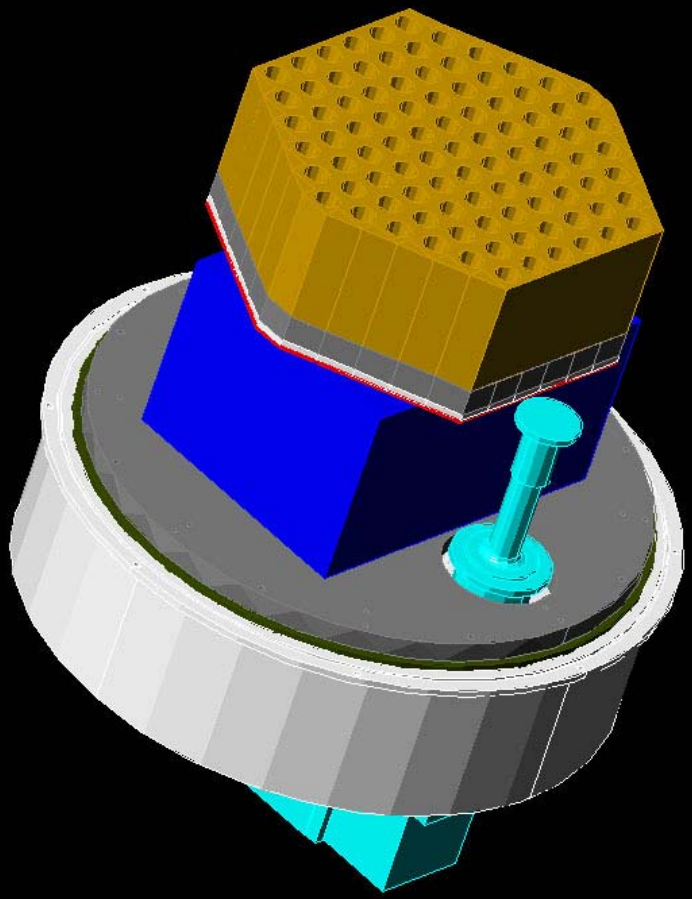
Module Board- 20K, holds 91 QUIET Modules, Bias protection, routes signals to 810 pins

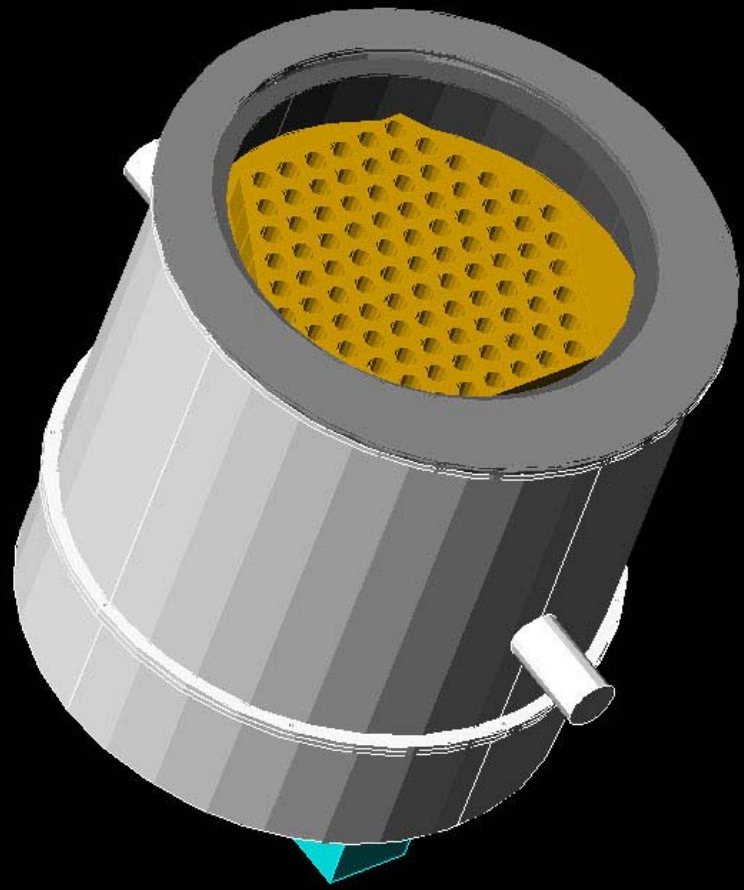
Thermal Isolation Board- Routes 810 signals, provides 20K-300K thermal isolation (<500 mW parasitic load TBC)

Bias Electronics Board(s)- 300K, Provides controllable HEMT bias and phase switch signals to all elements. Provides diode bias to all modules. Provides low noise readout for 91x4 diodes.

Data acquisition board – provides further amplification, blanking, demodulation, and digitization of the polarimeter signals. Also provides a DC level out at a slow rate corresponding to the total power on the detectors

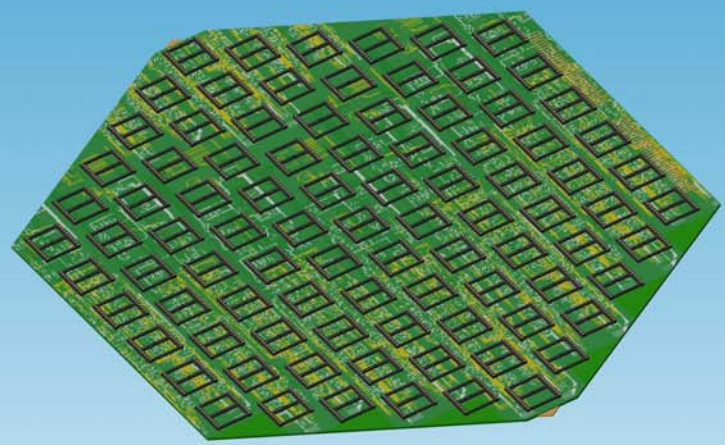
pathfinder cryostat – designed to house 91 w-band modules or 37 Q-band modules

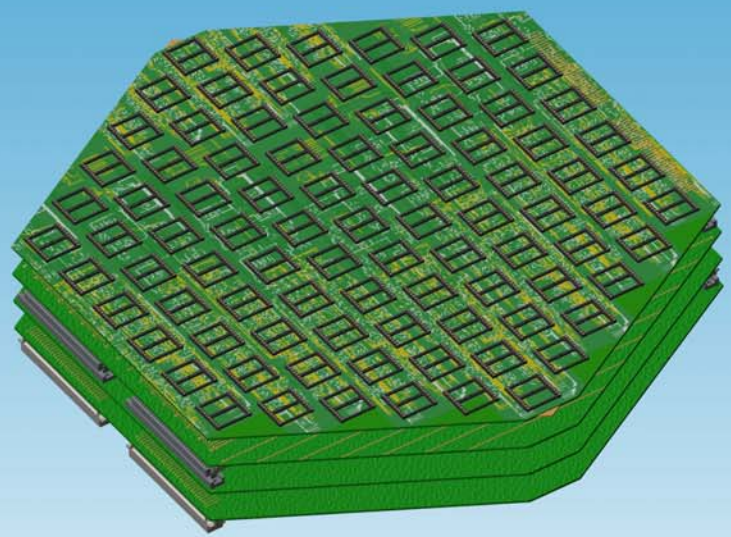


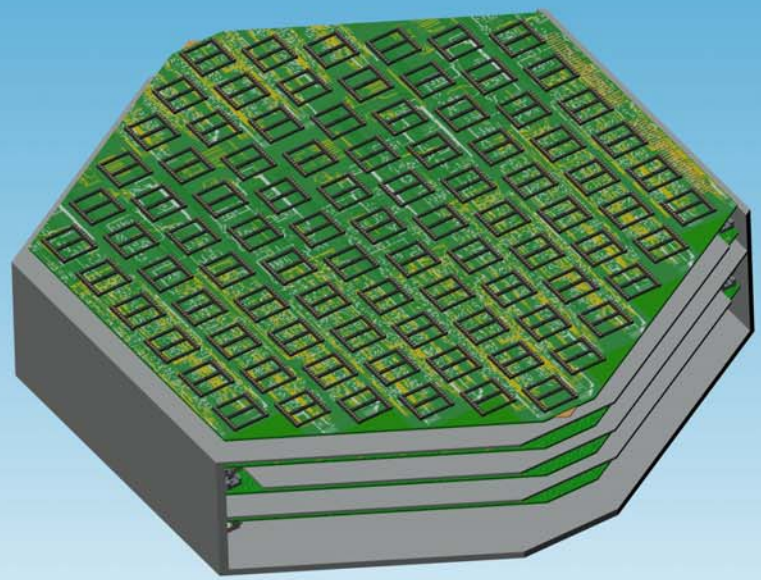


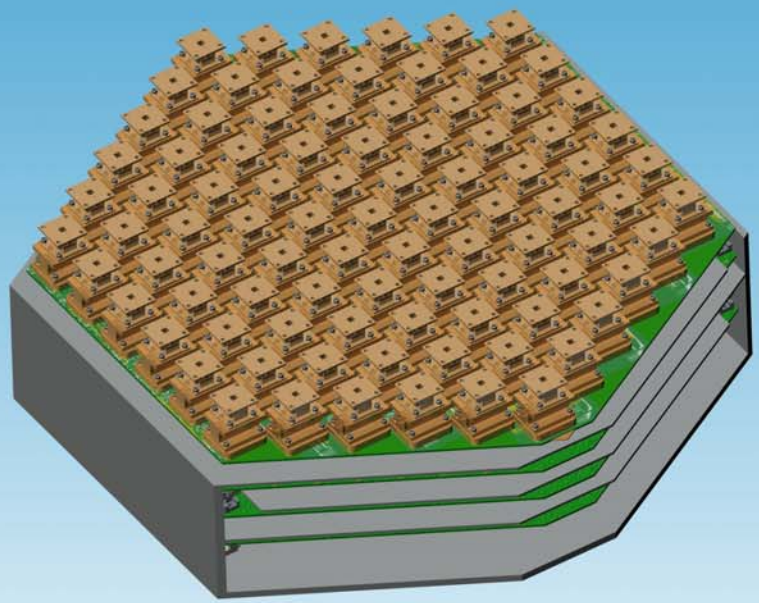
Drawings: Stephen Muchovej

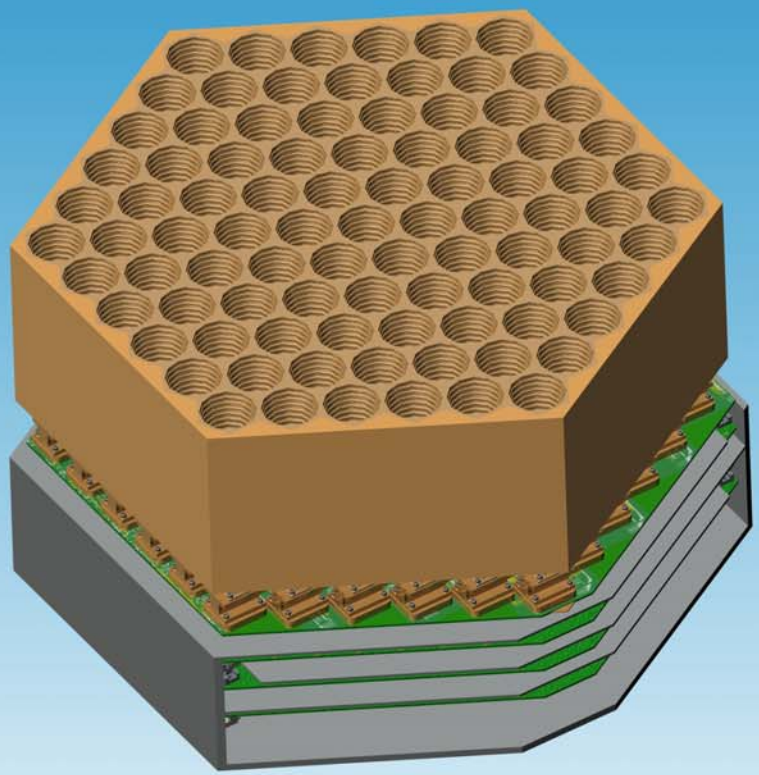
COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

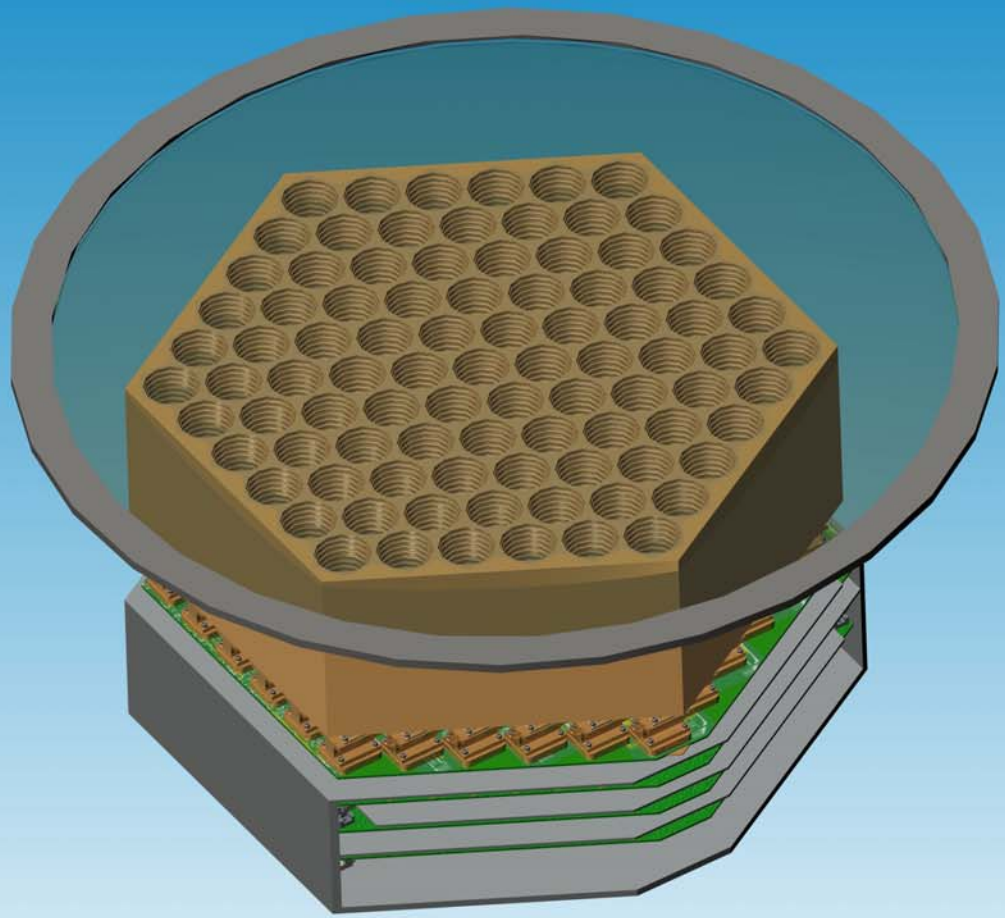


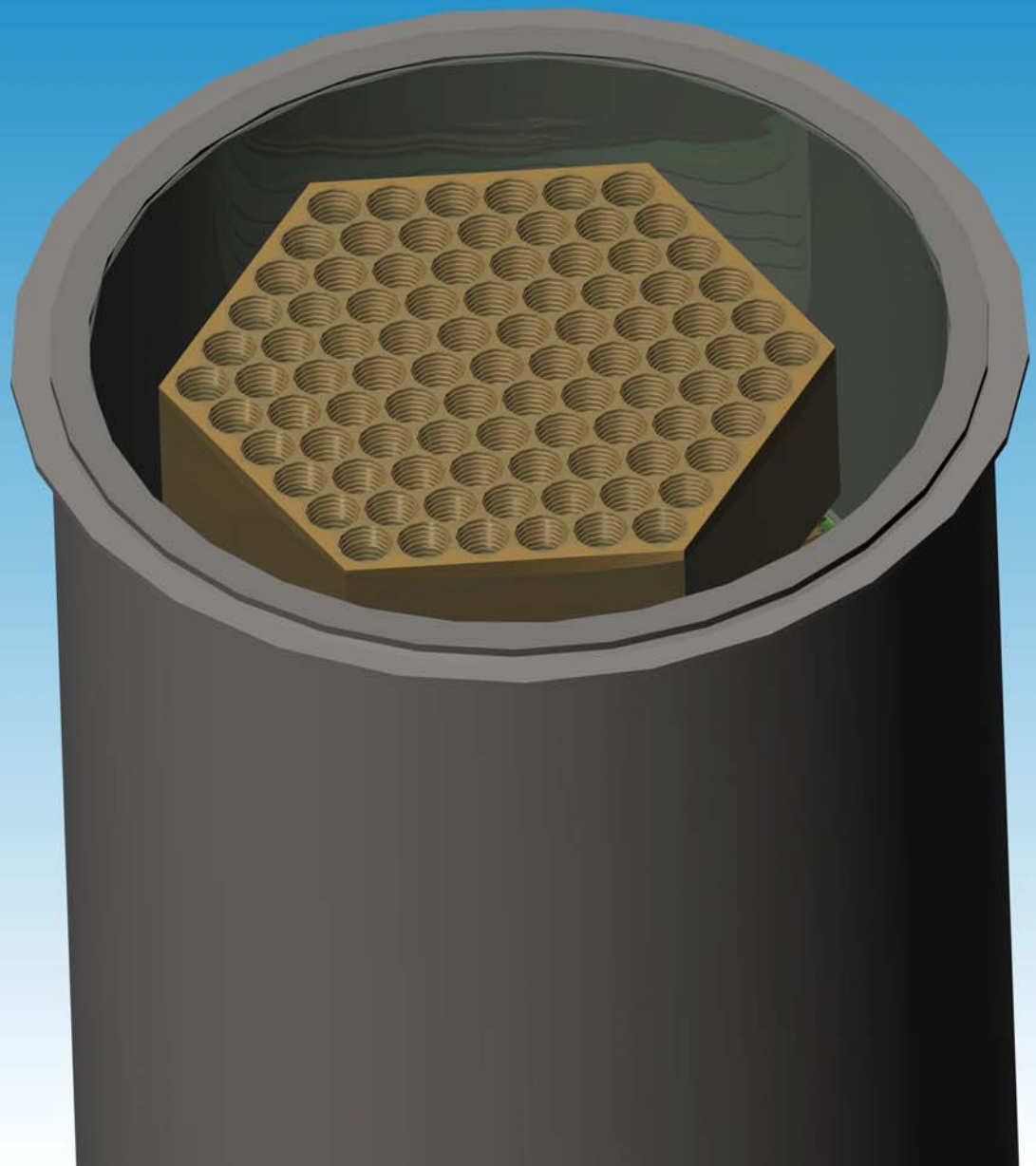












The site – the Atacama Desert

- CBI site is accessible via roads off the Jama road.
- takes only ~50 min. to get from San Pedro to QUIET

Also…

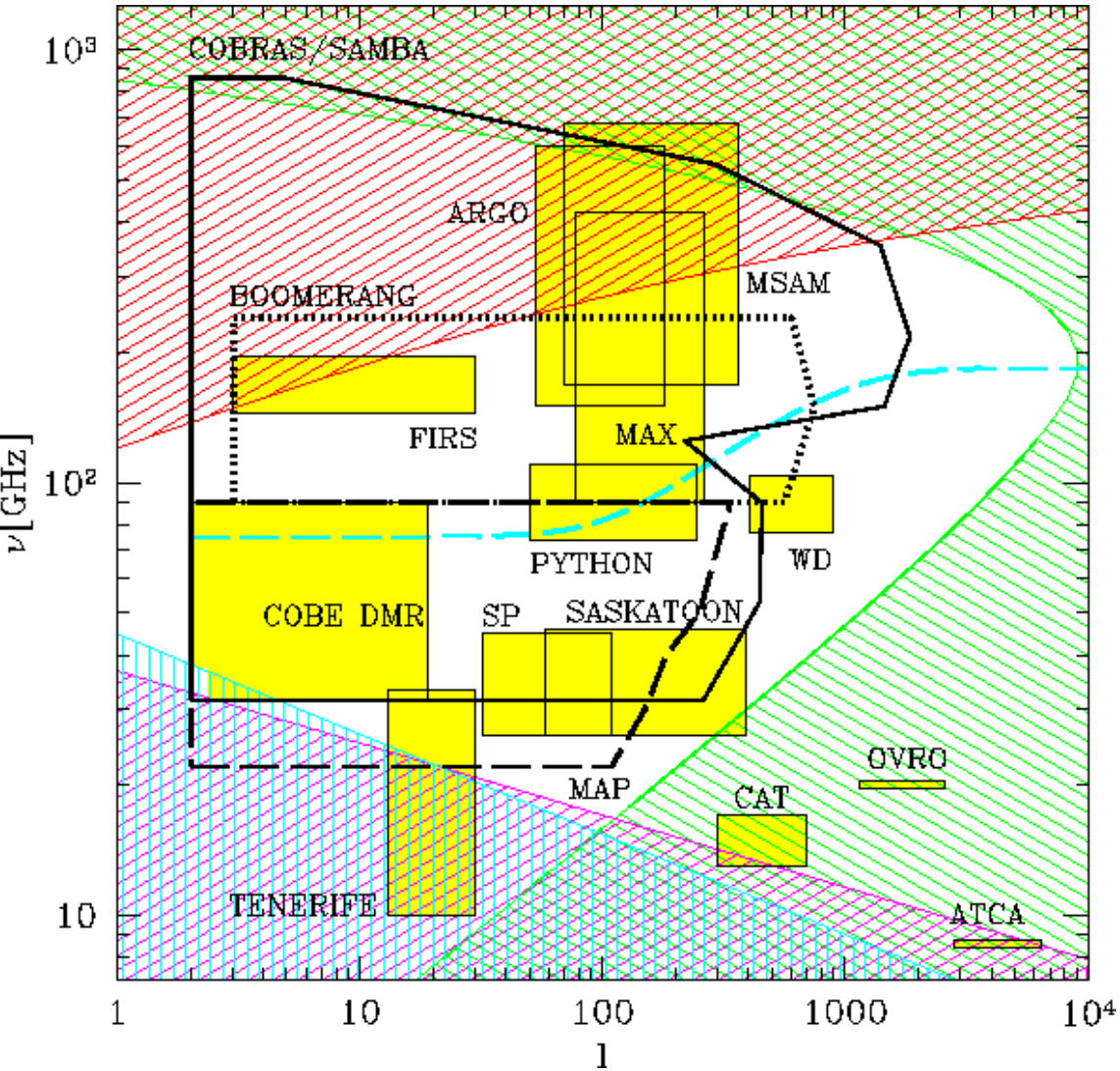
CHILE: the Atacama Plateau

Large Scale QUIET

Small Scale QUIET

- 5000 meter (~16,000 ft.) elevation
- atmospheric transmission 0.988
- 1.38 mm PWV
- At the current CBI site, Near the former Toco site (future ACT site), Near the future site for ALMA – site has sufficient space for Lucent 7m telescope
- Logistical support available from San Pedro de Atacama

Foregrounds – Temperature Anisotropy



M. Tegmark

shaded regions indicate where foregrounds dominate primary CMB anisotropy

dust
free-free emission
synchrotron radiation
point sources

The white region in the center shows us that we got lucky…

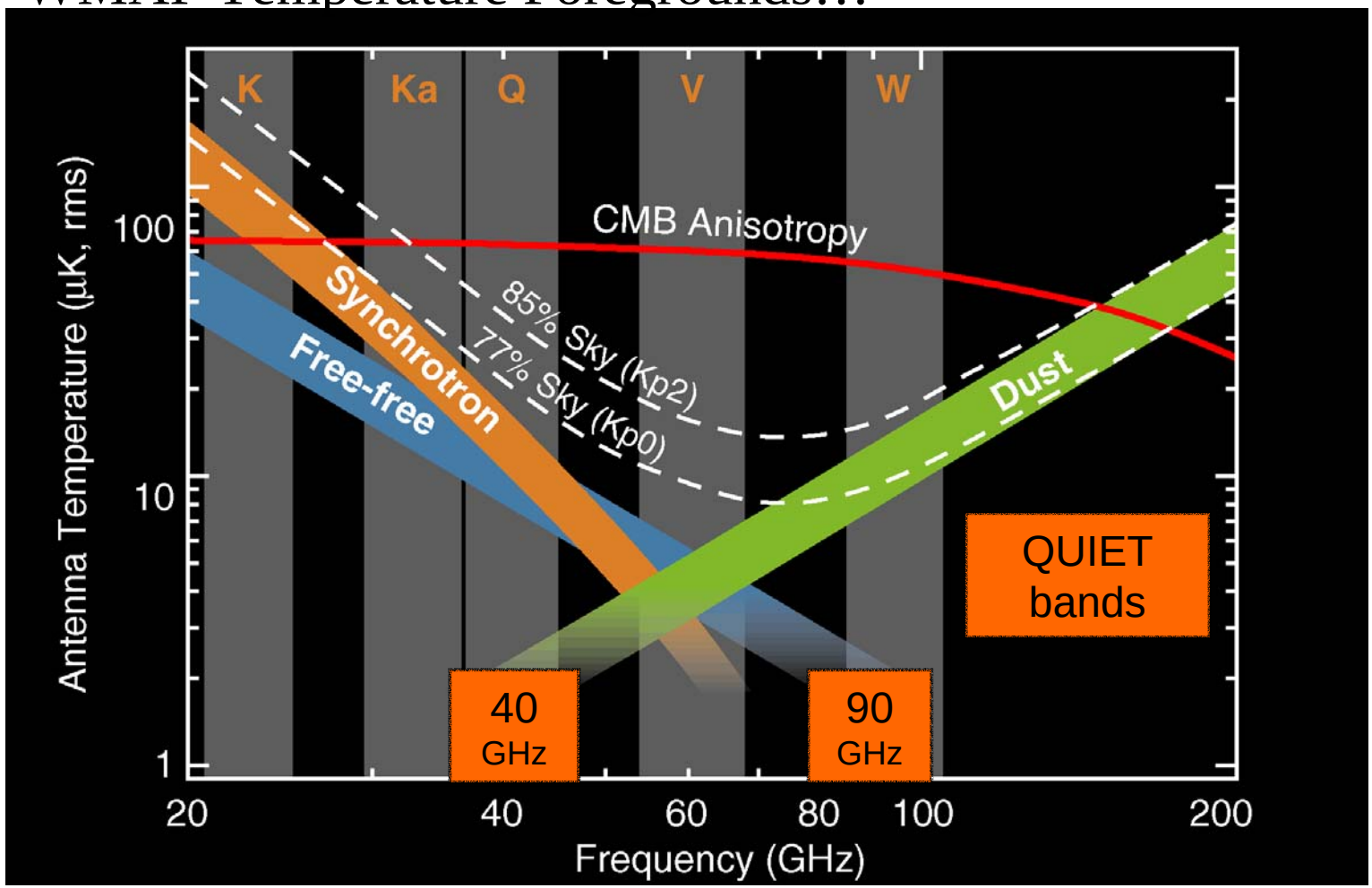
There is a large region over which foregrounds do not dominate primary CMB fluctuations

Foregrounds – Polarization Anisotropy

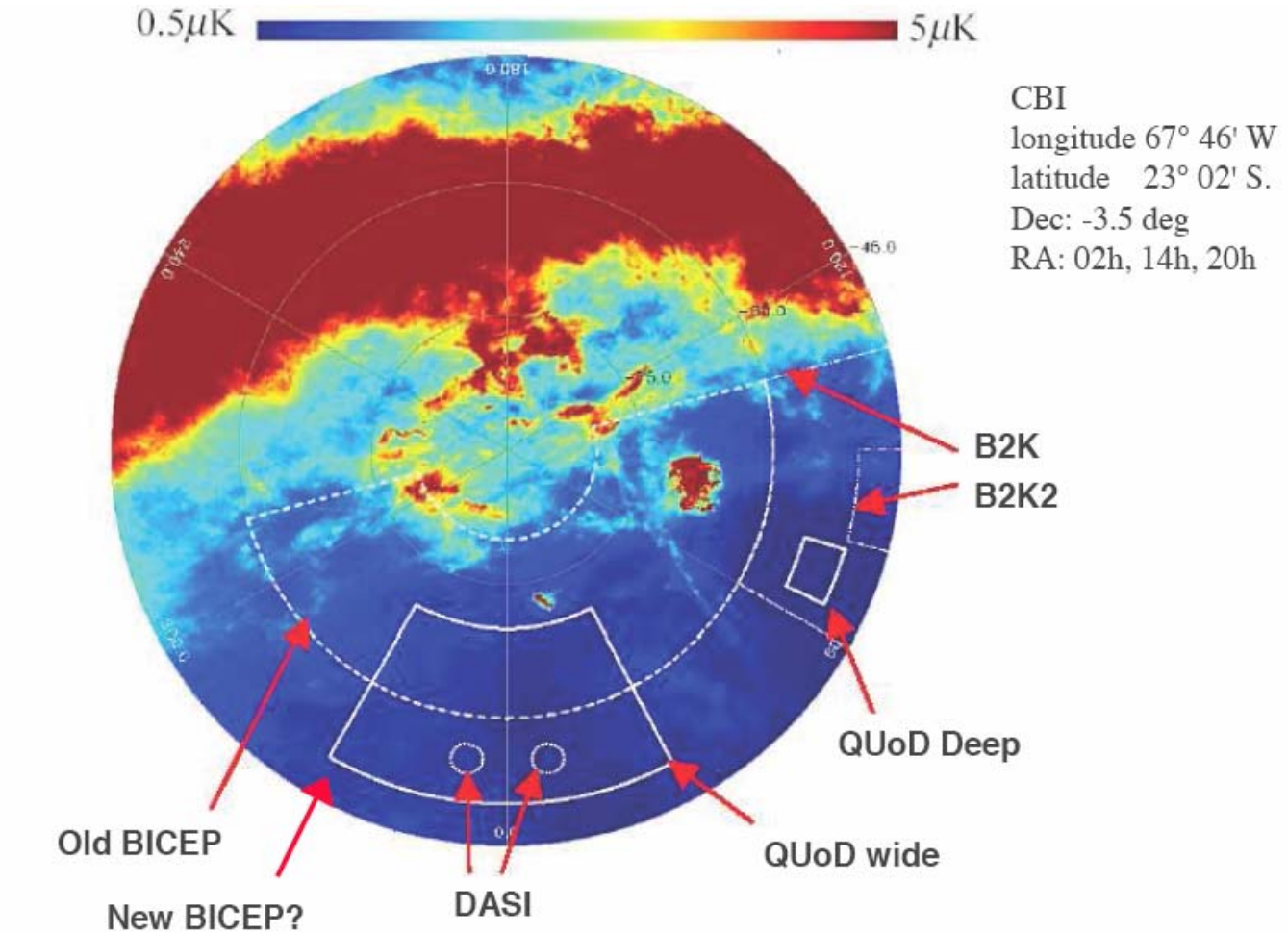
Foregrounds – Polarization Anisotropy

We don't know what the level of polarized foregrounds will turn out to be
One of QUIET's goals is to measure foregrounds – measure near temp foreground minimum

WMAP Temperature Foregrounds…

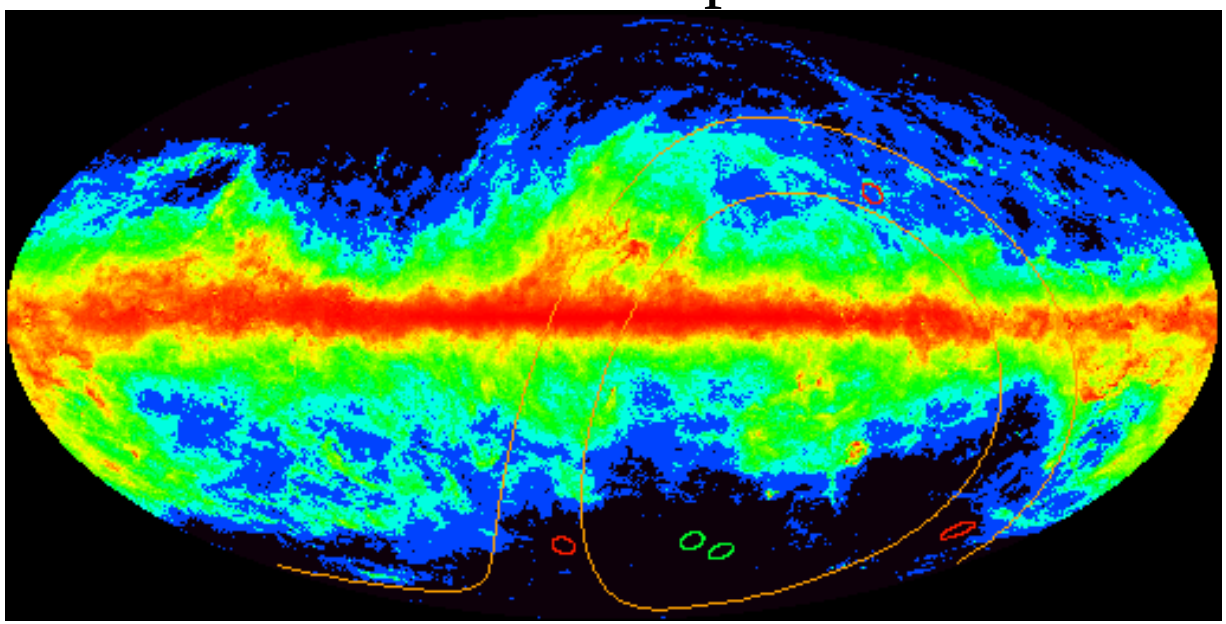


Southern Hemisphere Dust Map



Where to Observe?

- Identified three 5 deg. by 5 deg. regions
  - Each passes directly overhead from CBI
    - Can observe each for 6 hours a day
  - Each is 50% less anisotropic than DASI fields



STATUS & SCHEDULE of QUIET

- Lab tests of small array: summer ‘04
- Sky tests of small array: fall ‘04
- 100 element W-band array tests: summer ‘05
  - with large scale optics
- Deployment (large scale) in Chile: fall ‘05
- Lucent 7m moved to Chile: early ‘06
- 1000 element W-band array deployed in ‘06
- 300 element Q-band array deployed in ‘07
- Dual Operations: ‘07 and ‘08

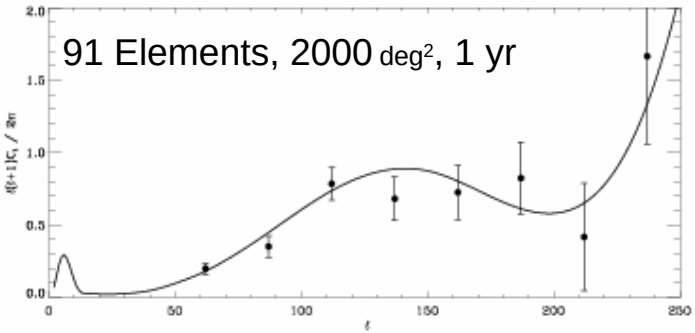
Underway with (primarily) NASA funding

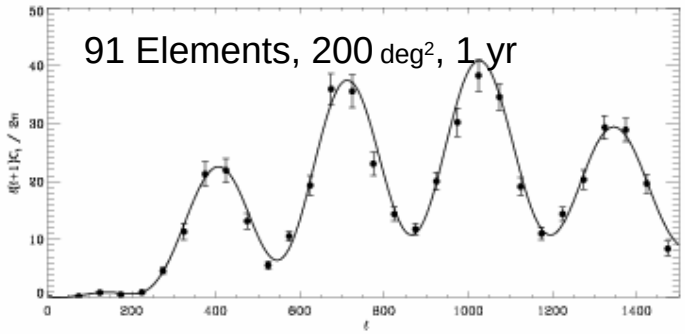
Projected QUIET Sensitivity

Large Scale

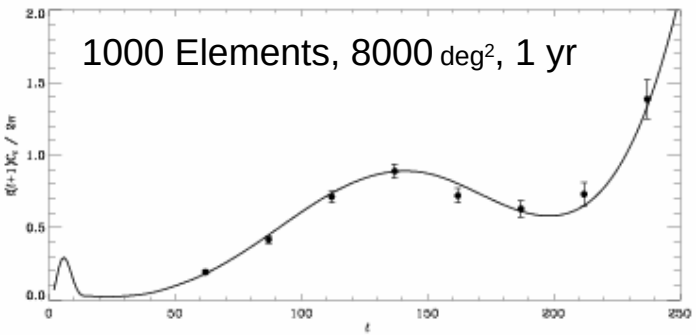
Small Scale

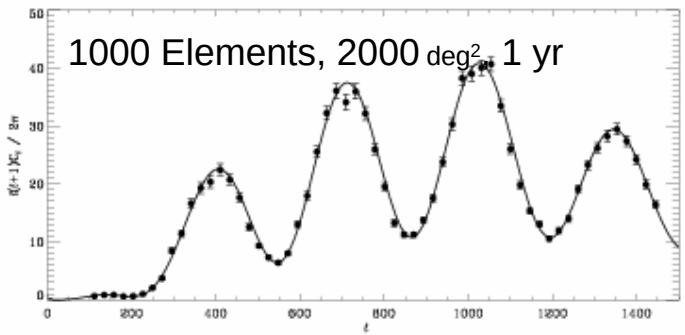
E-mode



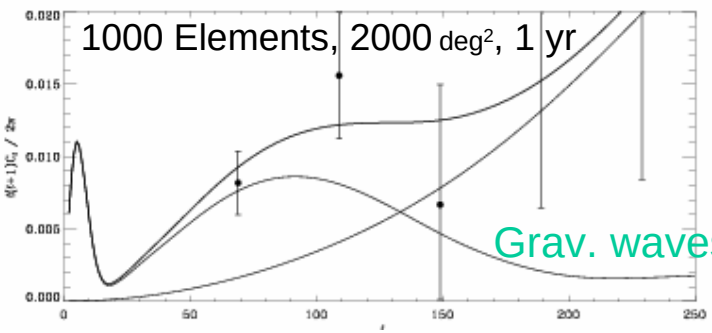


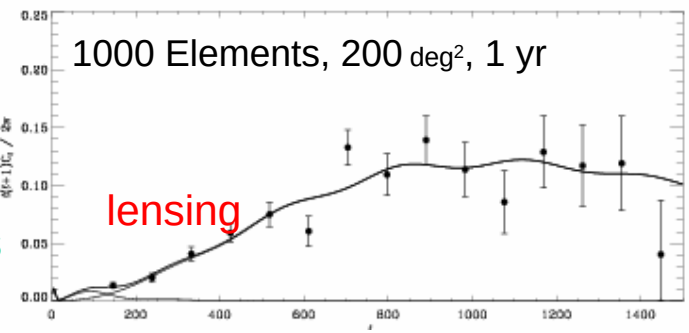
E-mode





B-mode
T/S=0.07





Assumptions: w-band observations, Tsys =57K, large-scale 0.7 degree beam, small scale 4 arcmin beam, 1 year=180 days of integration time

Conclusions

We're working on an exciting new project to build arrays of 1000s of coherent detectors for CMB polarization observations at both large and small scales

There is a long road ahead to understanding foregrounds, systematics, etc

Lots of interesting science can be done along the way as we pursue the quest for the holy grail…