QUIET: CMB Polarization

B. Winstein (U.S. PI)

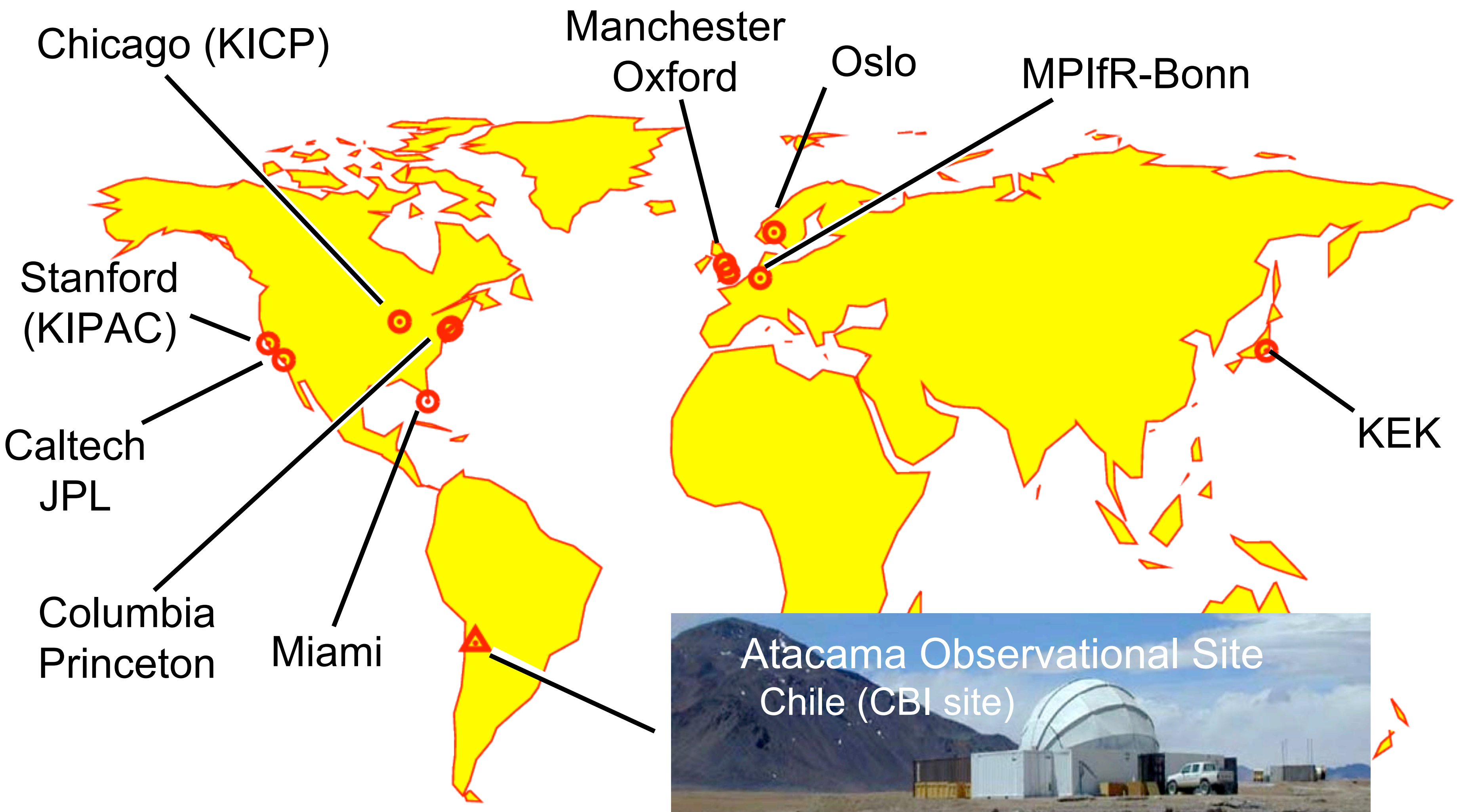
(http://quiet.uchicago.edu)

- Unique HEMT technology
  - Signal manipulation before detection: helps systematics
- We have the best (polarization) sensitive array now taking data
  - 44 GHz receiver operating since 10/08
    - Integration was done at Columbia
- Will switch frequencies in May
  - ~100 90 GHz detectors
    - Integration happening at Chicago
- Particle Physics connections:
  - Science: gravity waves at GUT-scale energies
  - Electronics
  - Data management/analysis
  - KEK & FNAL groups quite active
- Phase II (~1500 detectors)
  - Should be launched in 2010

Scope/History/Groups: QUIET

- Proposed for 100 detectors
- Approved
- Depoyed
- Sensitivity
- Phase II schedule

Q/U Imaging ExperimenT Collaboration



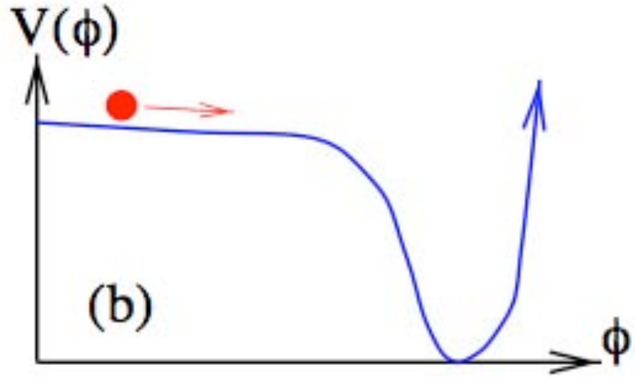
5 countries, 12 institutes, ~30 people

What Are Our Scientific Goals?

- Signature of Inflation

Optimism for Gravity Waves ?

(Pagano et al., astro-ph 0707.2560)

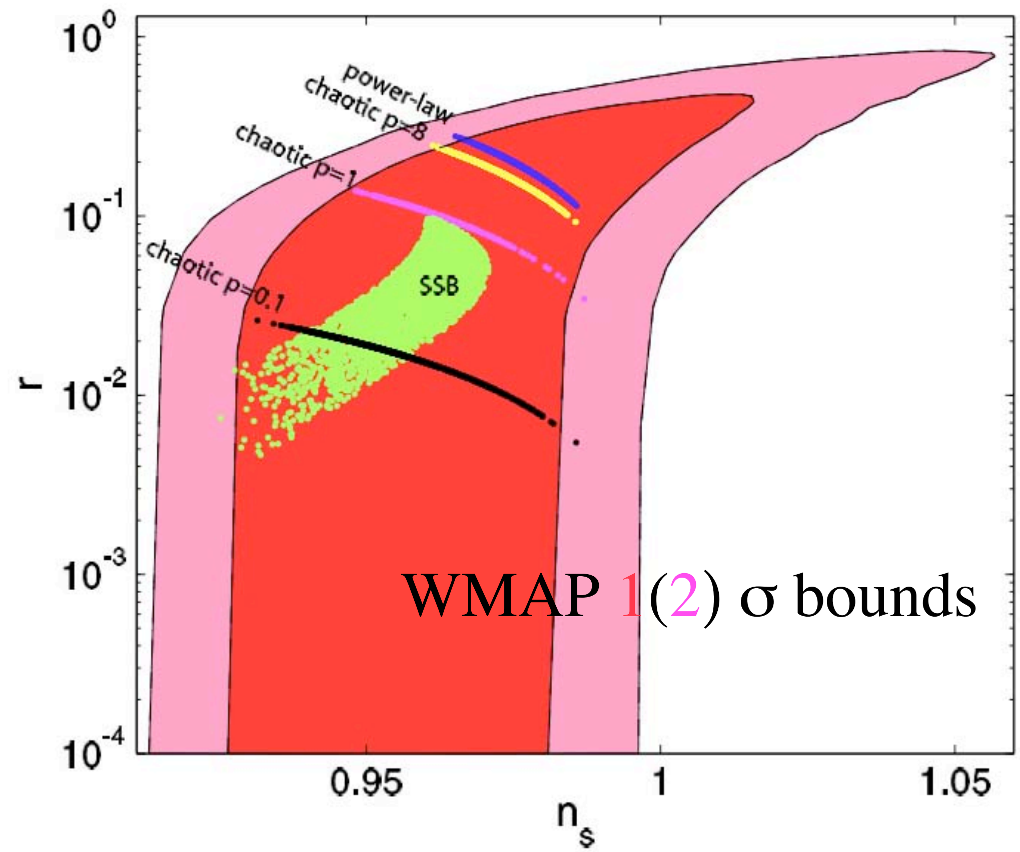


$$\varepsilon = \frac{m_{PL}^2}{16\pi}\left(\frac{V'(\phi)}{V(\phi)}\right)^2 ; \eta = \frac{m_{PL}^2}{8\pi}\left(\frac{V''(\phi)}{V(\phi)}\right)$$

$$n_S \approx 1 - 6\varepsilon + 2\eta$$

$$r \equiv T/S = 16\varepsilon$$

$$n_S \neq 1 \Rightarrow r \neq 0$$



Things that go bump in the CMB polarization: features from inflation versus reionization

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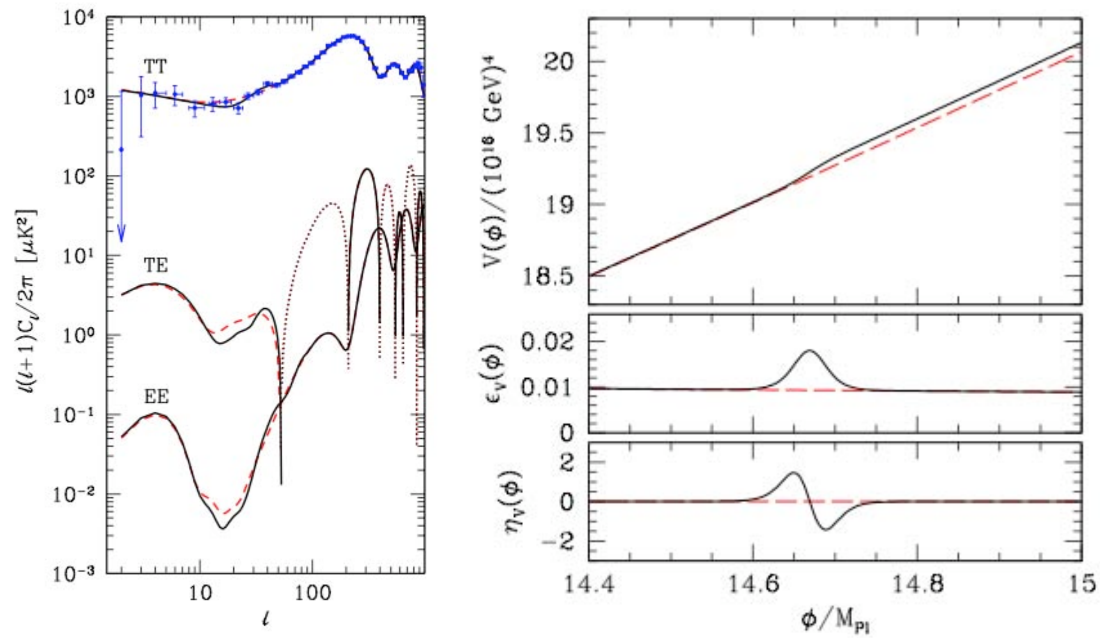
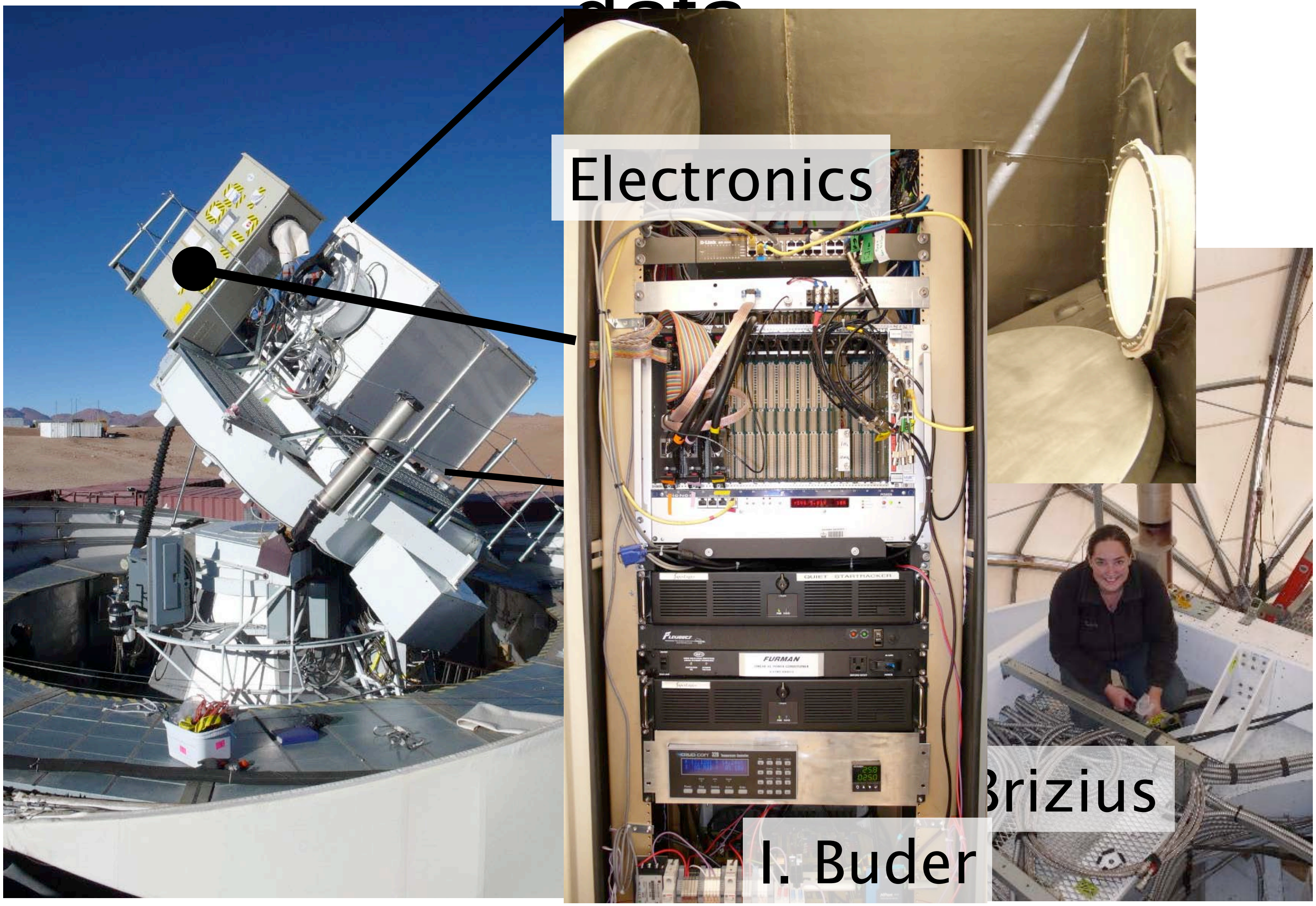
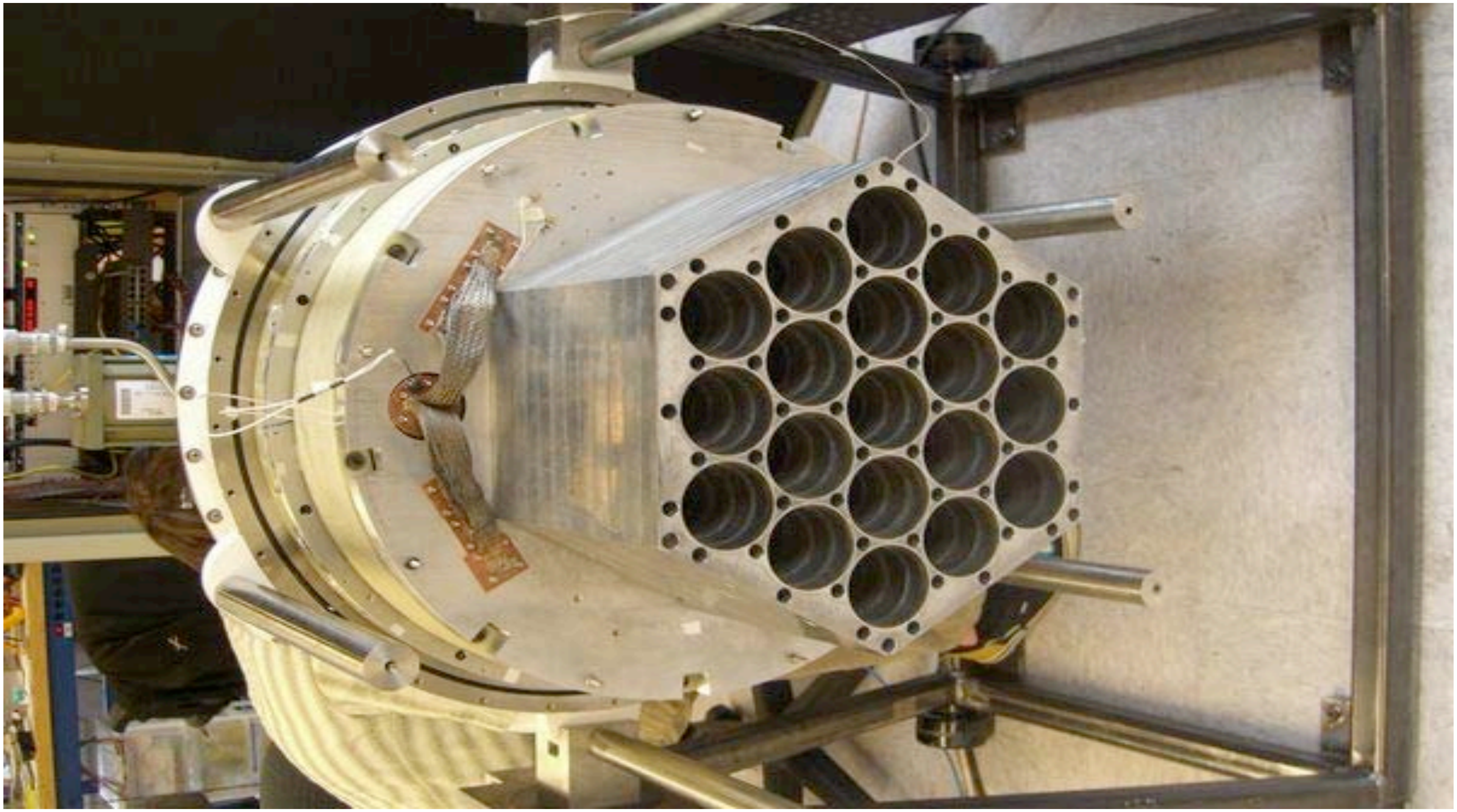


QUIET is currently collecting data

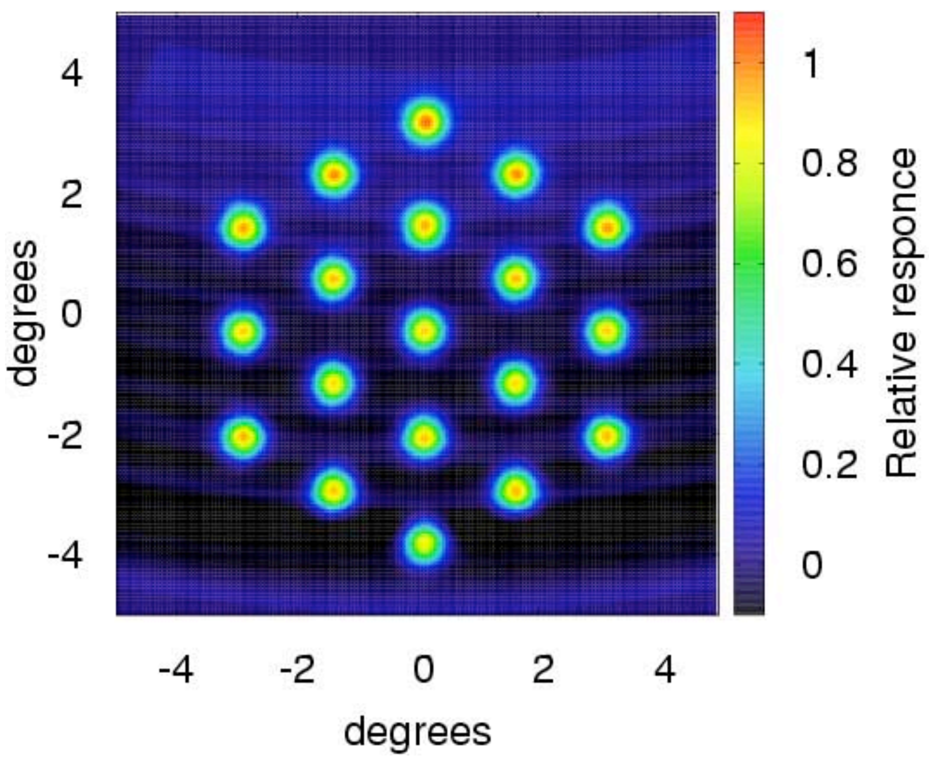


Q-band Receiver

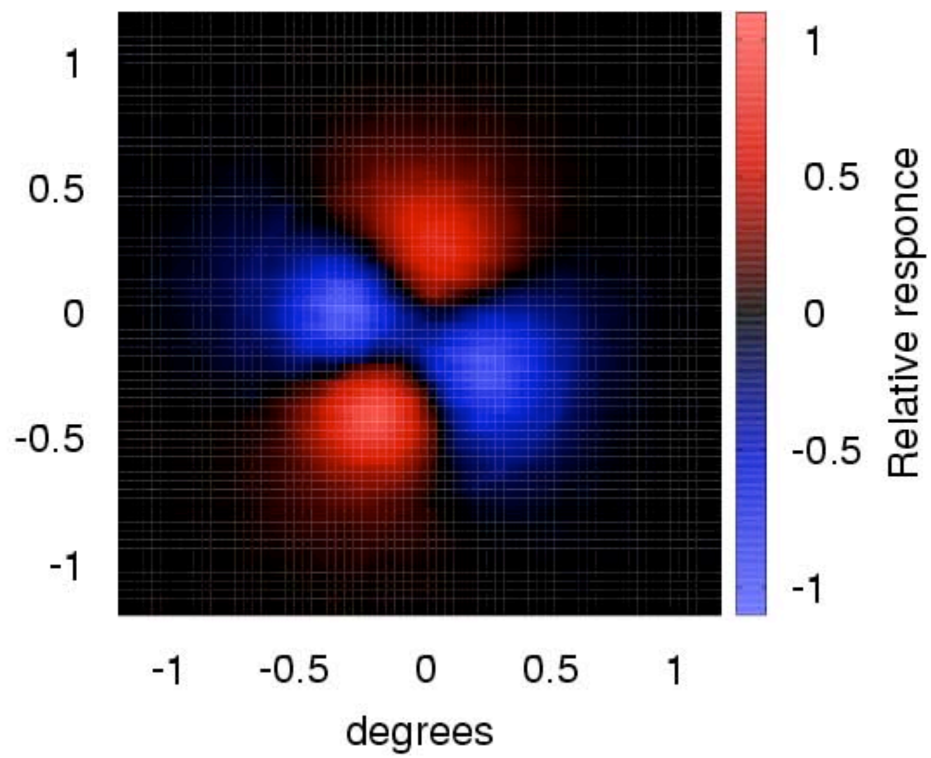


The Moon in Q-band

Total power

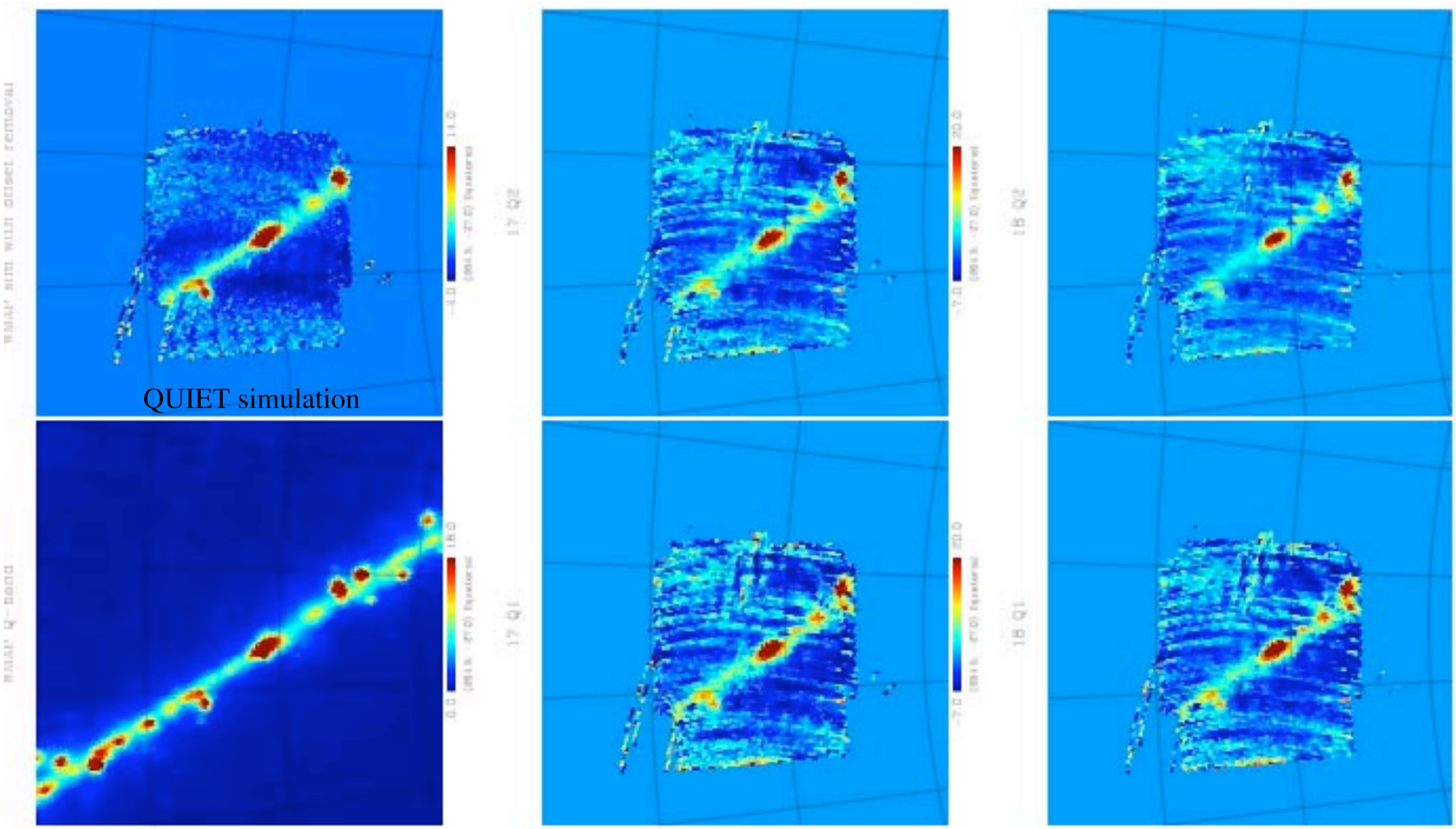


Polarization



The Galaxy in Q-band

(Hardware & Analysis: D. Samtleben, MPI)



WMAP

~5hrs of QUIET data

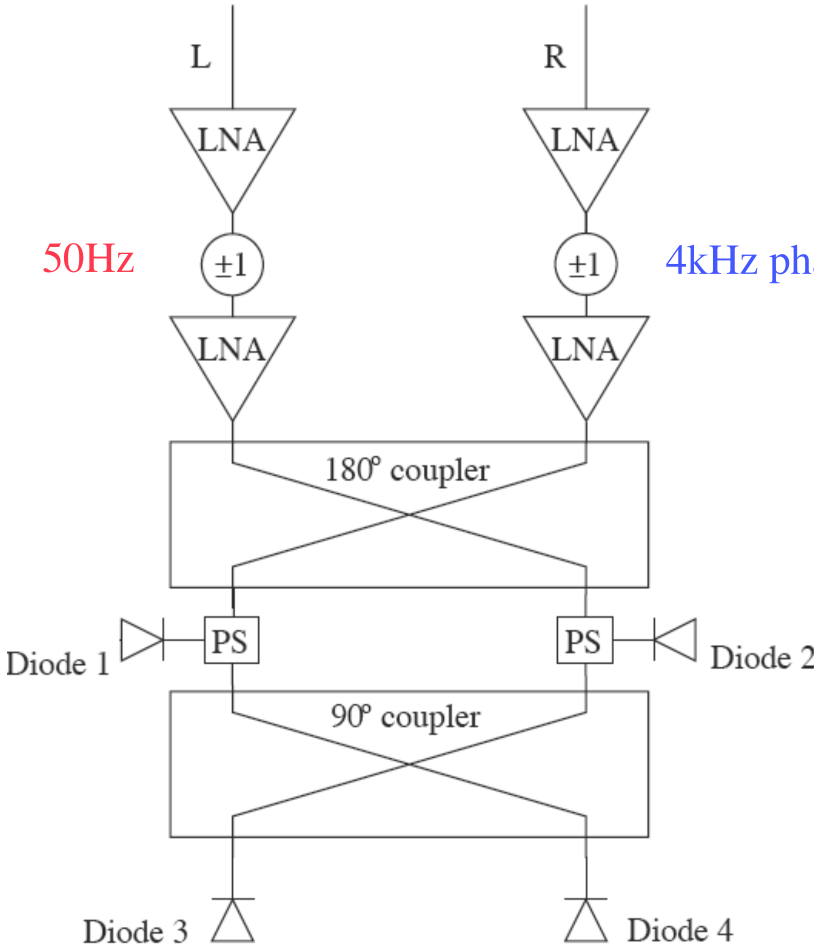
Preparing the 91-element W-band Array in the Chicago Lab

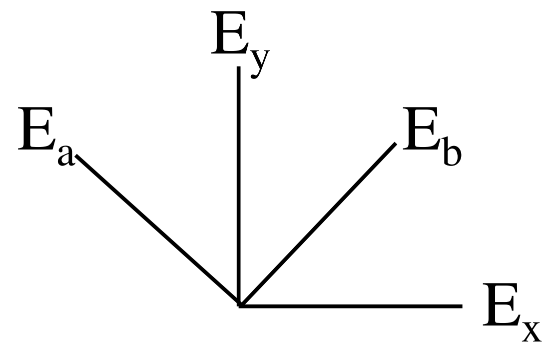
The Picture of the Field

Table 1: Future Suborbital CMB Polarization Experiments.

	Technology	FWHM (arcmin)	Frequency (GHz)	Detector Pairs	Modulator
US-led balloon-borne:					
EBEX (Oxley et al., 2004)	TES	8	150/250/410	398/199/141	HWP
Spider (Montroy et al., 2006)	TES	60/40/30	96/145/225	288/512/512	HWP/Scan
PIPER I	TES	21/15	200/270	2560/2560	VPM
PIPER II	TES	14	350/600	2560/2560	VPM
US-led ground-based:					
ABS(Staggs et al., 2008)	TES	30	150	200	HWP
ACTpol(Fowler et al., 2007)	TES	2.2/1.4/1.1	90/145/217	$\sim$ 1000	Scan
BICEP 2(Nguyen et al., 2008)	TES	37	150	256	HWP/Scan
Keck Array(Nguyen et al., 2008)	TES	55/37/26	100/150/220	288/512/512	HWP/Scan
MBI(Korotkov et al., 2006)	NTD	60	100	4	Int.
Poincare(Chuss, 2008)	TES	84/30/24	40/90/150	36/300/60	VPM
PolarBeaR(Lee et al., 2008)	TES	7/3.5/2.4	90/150/220	637	HWP
QUIET I(Samtleben, 2008)	MMIC	20/10	44/90	$\sim$100/1000	ϕ-switch
SPTpol(Ruhl et al., 2004)	TES	1.5/1.2/1.1	90/150/225	$\sim$ 1000	Scan
European-led ground-based:					
BRAIN(Polenta et al., 2007)	TES	60	90/150	256/512	Int.
C_ℓOVER(Piccirillo et al., 2008)	TES	7.5/5.5/5.5	97/150/225	3x96	HWP
QUIJOTE(Rubino-Martin et al., 2008)	HEMT	54-24	10-30	34	HWP

QUIET L/R Correlator: Simultaneous Q/U measurements





$$|L \pm R|^2 = \left|\left(E_x + iE_y\right) \pm \left(E_x - iE_y\right)\right|^2 = \underline{4E_x^2, 4E_y^2}$$

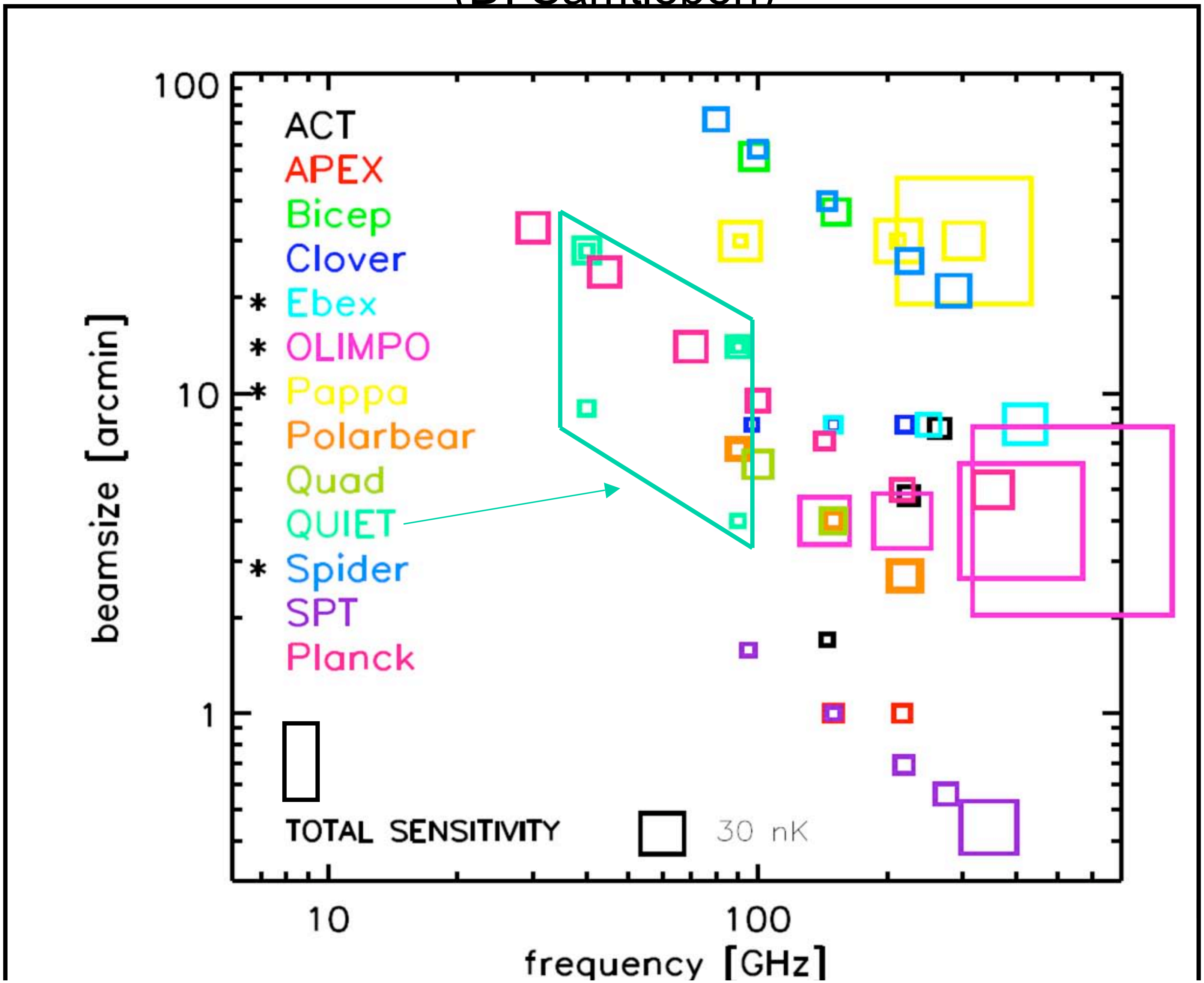
Q

$$\left|(L \pm R) + i(L \mp R)\right|^2 = |L \mp iR|^2 = |L|^2 + |R|^2 \mp 2\,\mathrm{Im}\left(RL^*\right)$$

$$\mathrm{Im}\left(RL^*\right) = \mathrm{Im}\left(E_x + iE_y\right)^2 = 2E_xE_y = \underline{E_a^2 - E_b^2}$$

U

Future CMB experiments
(D. Samtleben)



Why?

- V. CONCLUSION
- Cosmic microwave background polarization offers an extraordinary opportunity to gain a
- first glimpse into the physics that shaped our Universe. Experimentalists have demonstrated
- that a coordinated attack on this problem over the coming decade will likely detect primordial
- gravity waves – thereby providing extensive information about new physics at ultra-high
- energy scales – or severely constrain the scenario responsible for the origin of the Universe.

Why DOE?

"CMB research is another example of relatively small investments with big payoffs for particle physics and of fruitful cooperation between agencies: DOE supported Smoot's work on COBE, resulting in the recent shared Nobel Prize. In recent years, DOE has received requests for only very small amounts of support for CMB research, with the bulk of the funding coming from NSF and NASA, but DOE-funded technical contributions have been key. Both NSF and DOE should remain open regarding future investment in this area if the correct opportunity arises. In any case, small levels of continued support for detector development are certainly warranted."

(from the P5 report, 29 May 2008)

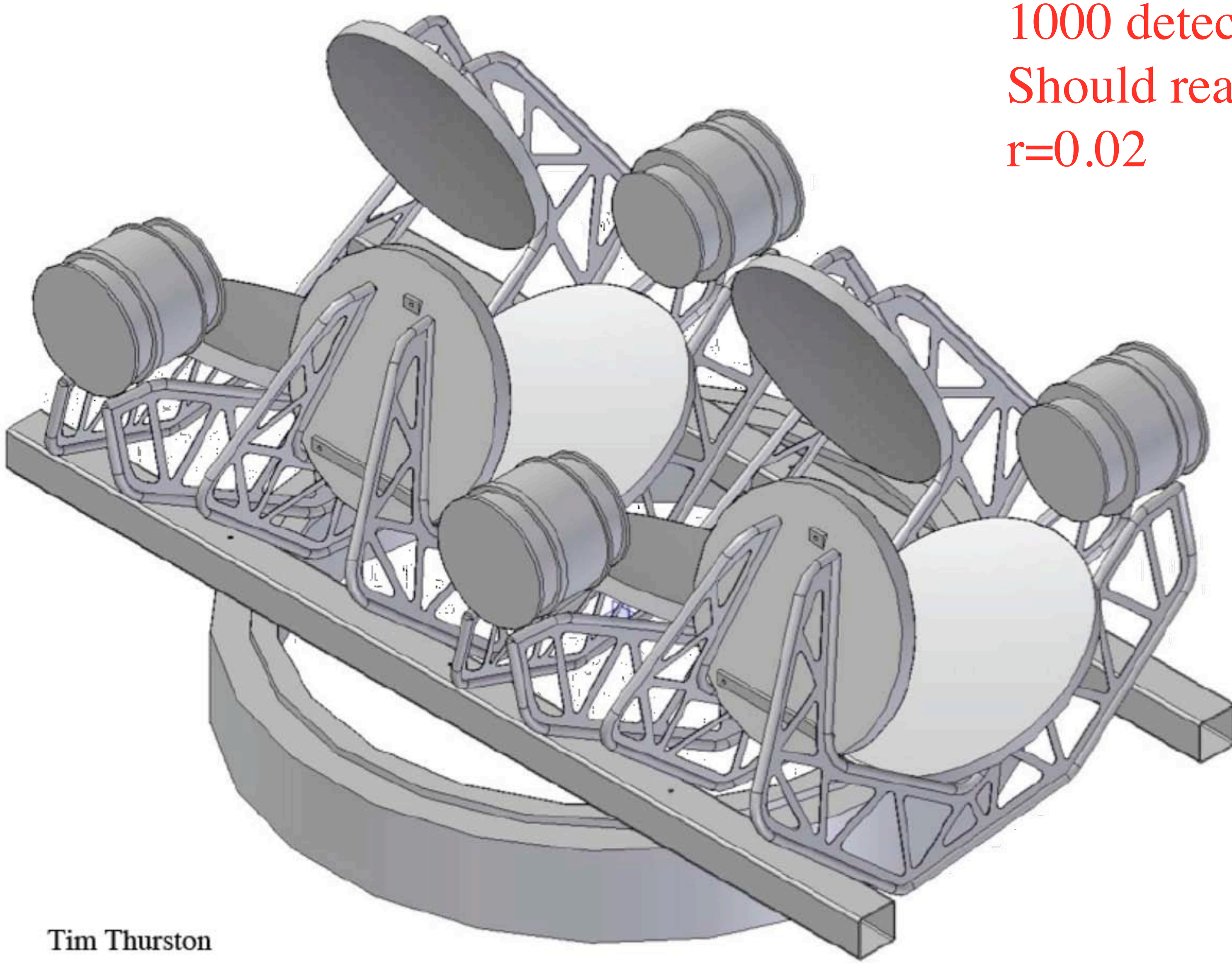
Why QUIET?

Lessons learned in Phase I (leading up to “why fnal”)

Science and Technical Risks

Phase II Telescopes

1000 detectors
Should reach
r=0.02

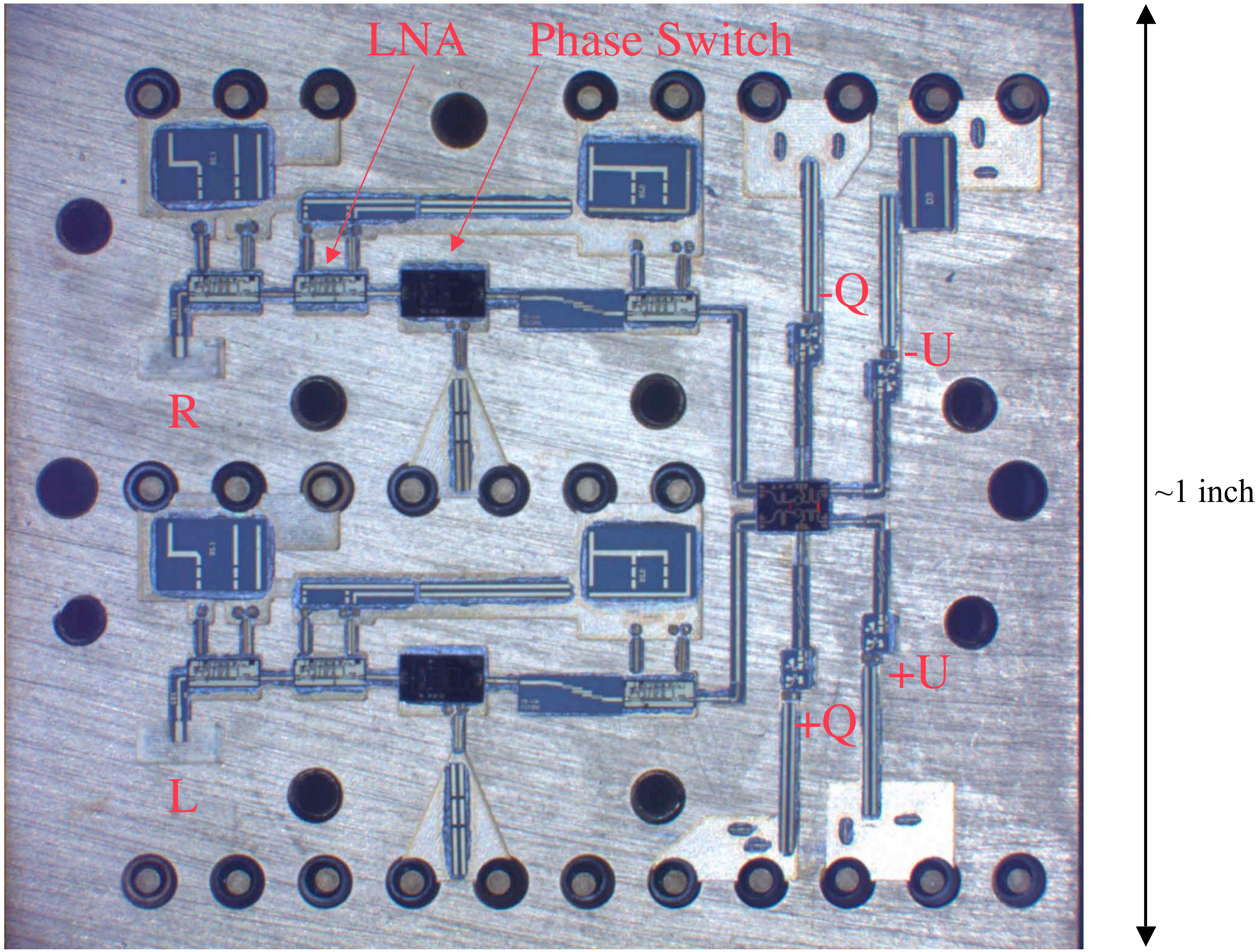


Tim Thurston

Plan to Achieve This Goal

- This technology is clearly worth pursuing
- QUIET Phase II would use perhaps 1500 Modules
  - Need to improve performance: T_{rec} ~ 50 K (10Q.L.)
    - Otherwise can't compete with Bolometers
  - Need a plan to produce them more rapidly (18 months)
    - Last 64 Phase I modules came at 10/month
    - FNAL is interested here as are other groups within QUIET
  - Proposal needs to be submitted in August
    - Production of new modules: 3/10 - 3/11
  - L/R OMT leakages need improvement
- Upgrades to T_{rec} ~ 3Q.L. will make for a long-lived, productive program

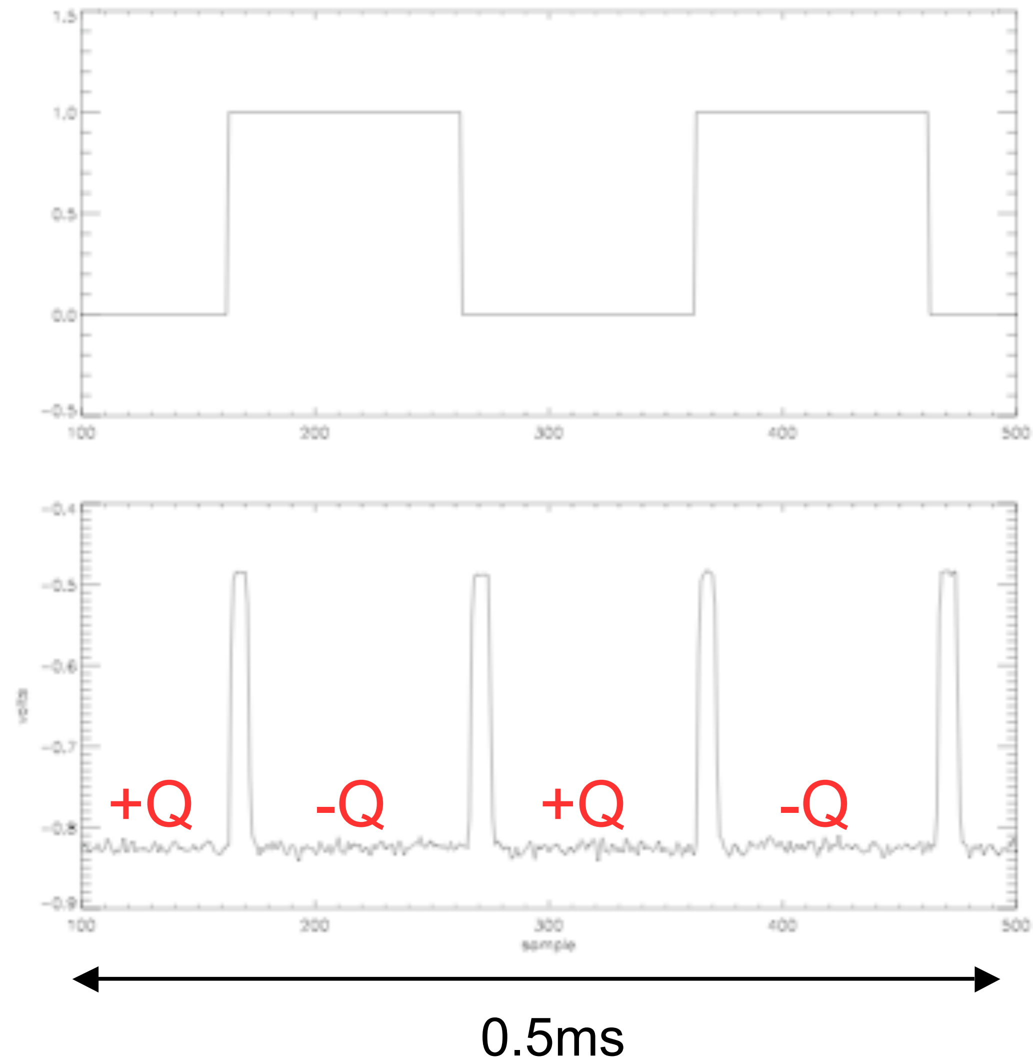
QUIET‘s 90 GHz Radiometer on a Chip“



High Speed Sampling

18 bits @ 800 kHz

- Q/U measurement every 250 μs
- Monitors high-frequency noise
- Permits Quadrature Samples
  - TOD noise with no signal
- Demodulation with FPGA

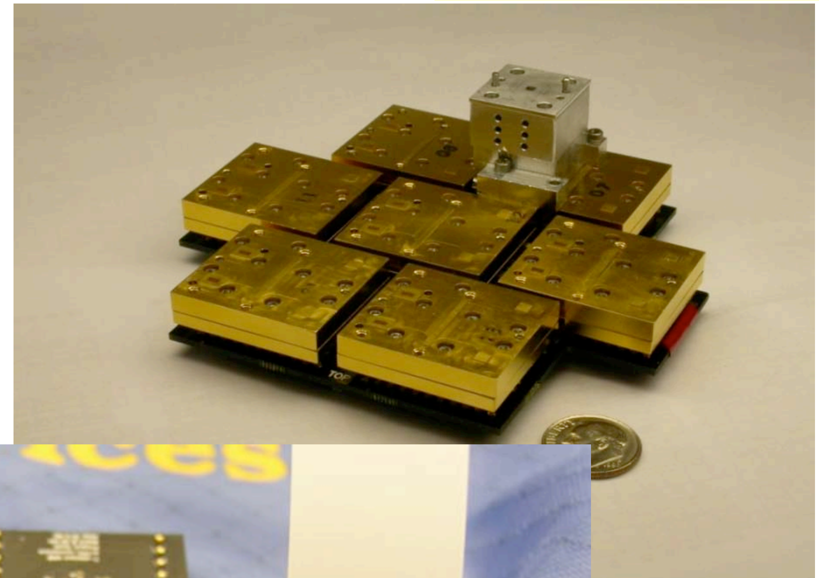


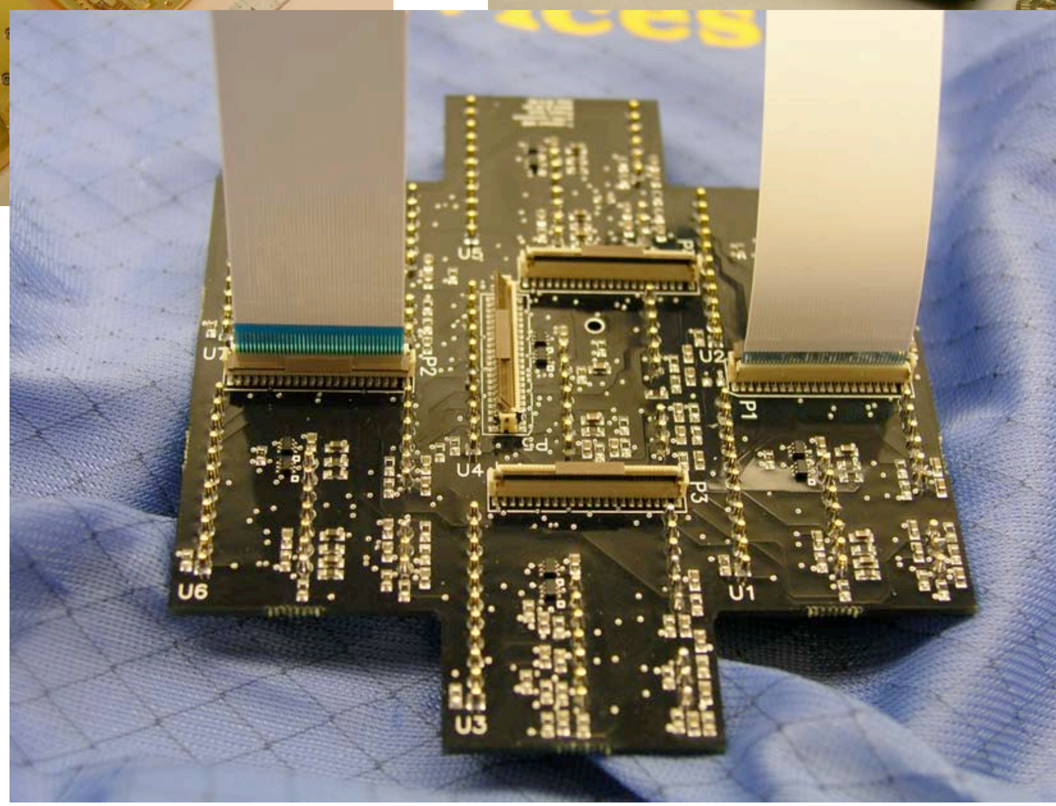
Key Advances Will Come From Isolation of B-modes

„Radiometer on a Chip“

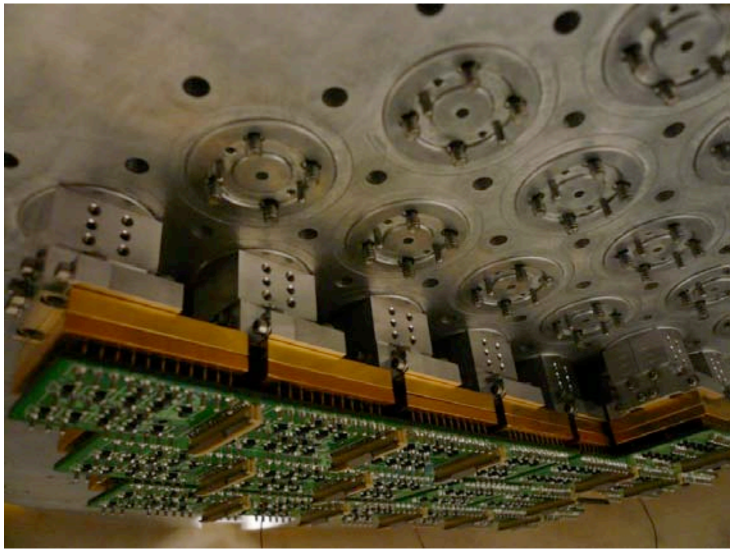
Q-Band (44 GHz)

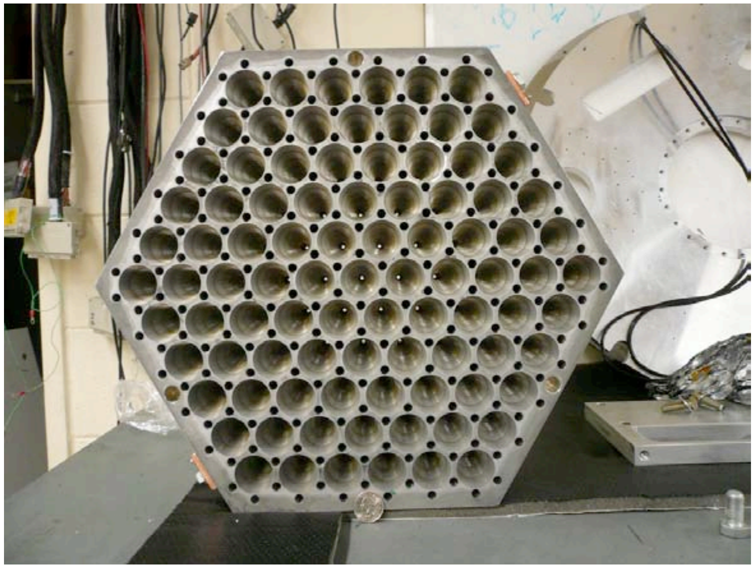
W-Band (90 GHz)





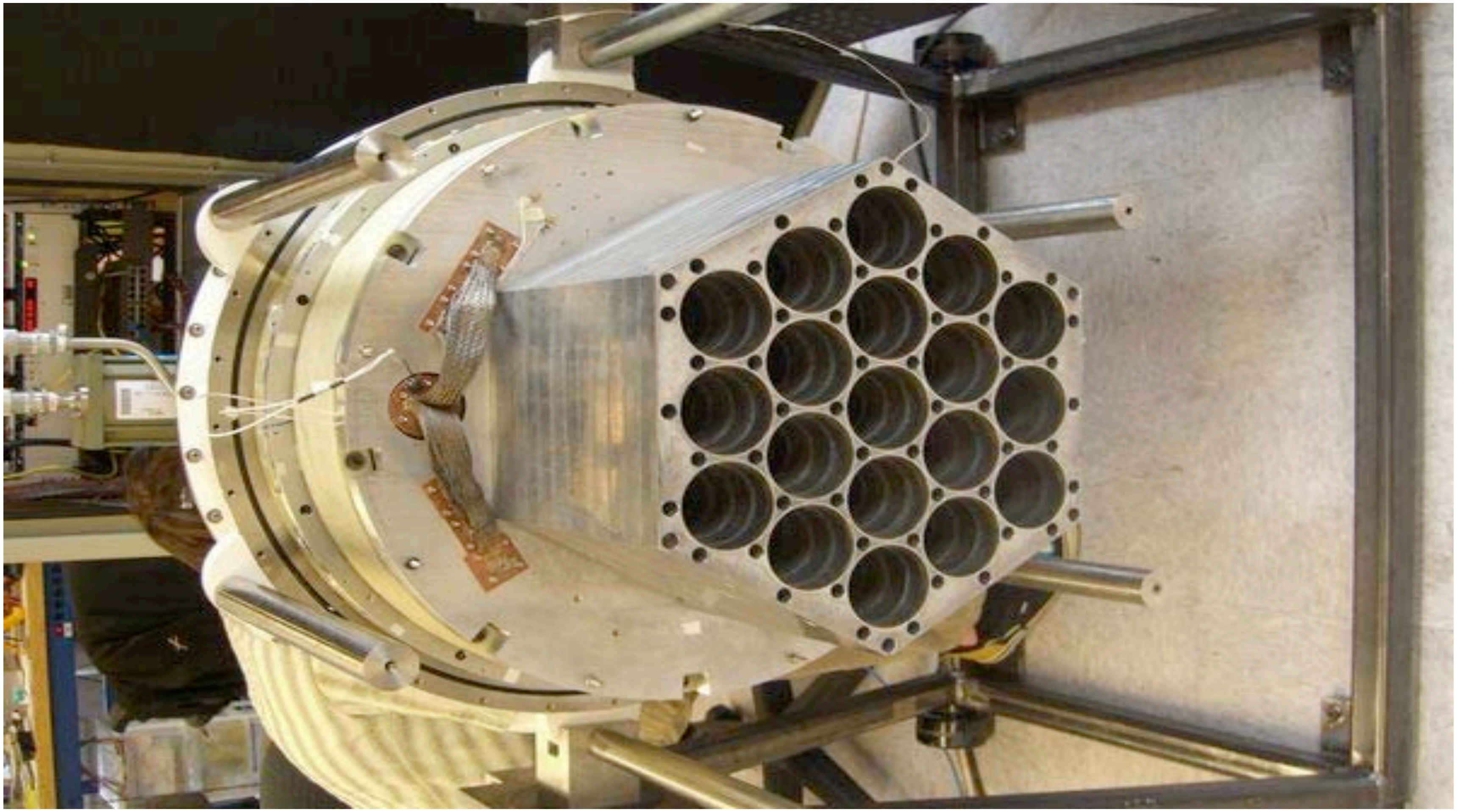
W-band Receiver Integration





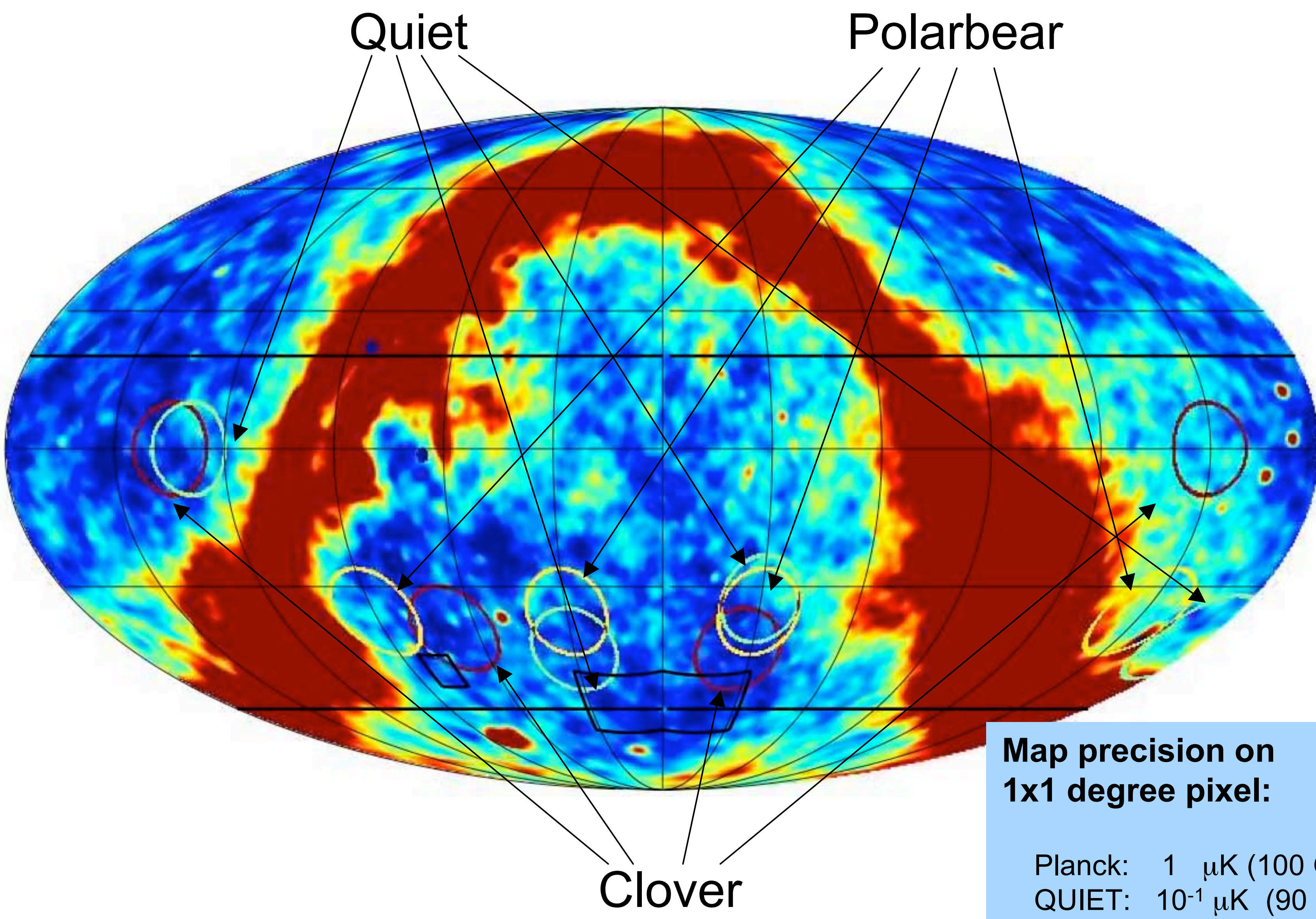
Q-band Receiver

(Integrated at Columbia
operating since 10/08)



CMB Patches

(D. Samtleben)



Map precision on 1x1 degree pixel:

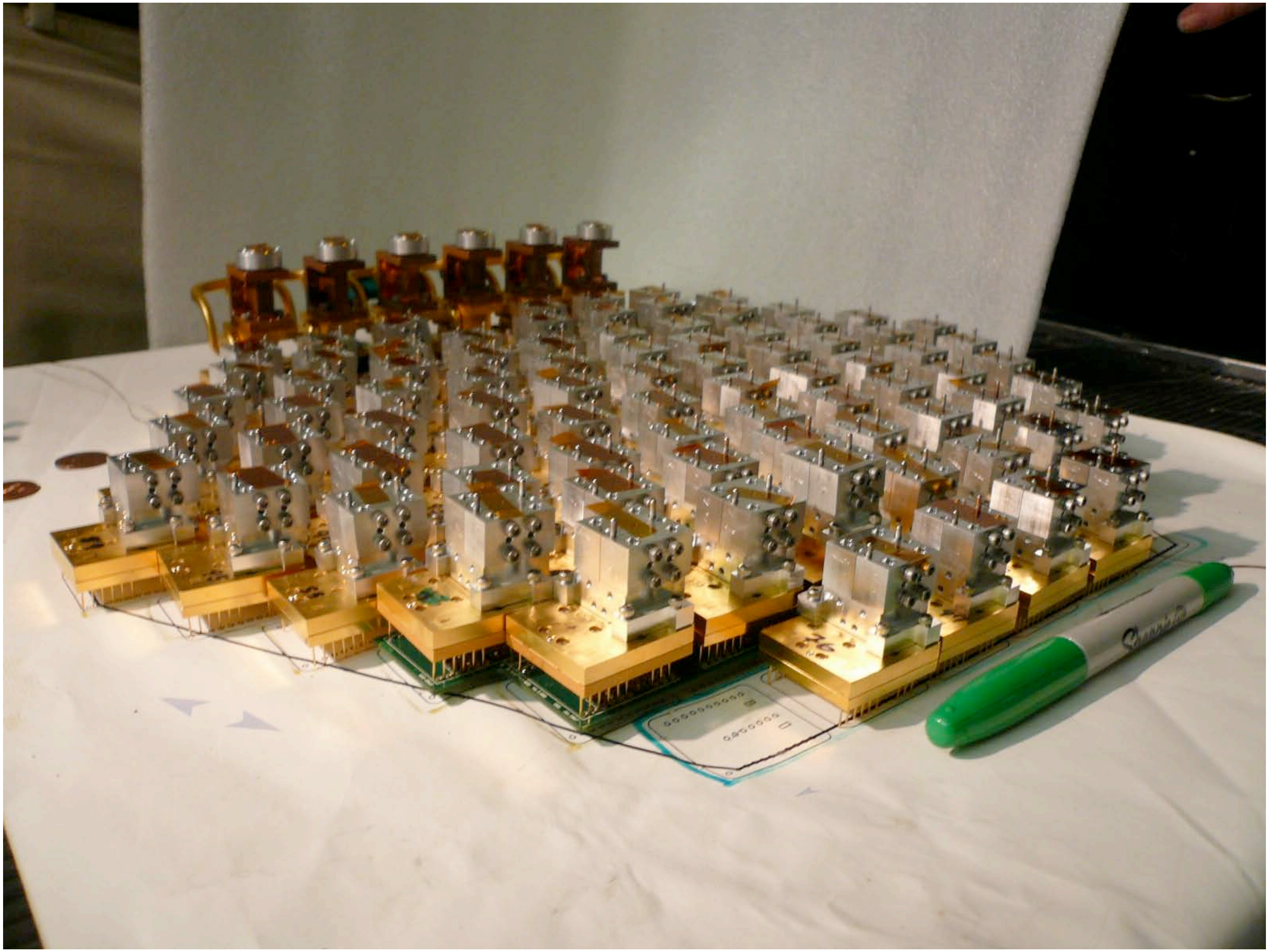
Planck: 1 μK (100 GHz)
QUIET: 10^{-1} μK (90 GHz)

QUIET & Polarbear

We’ve agreed to scan the same patches

(surely CLOVER will follow)

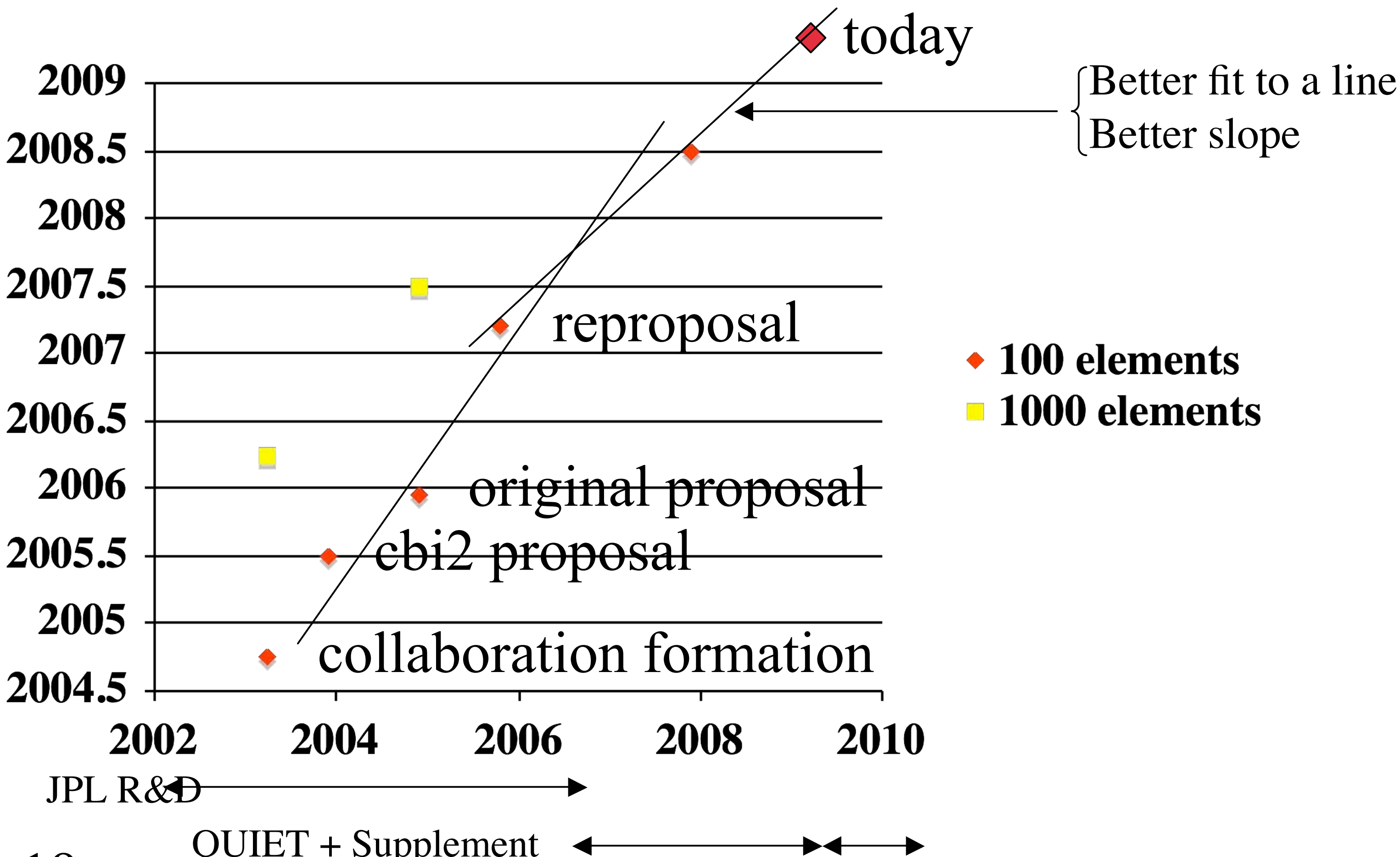
Hugely positive for systematics and the study and removal of foregrounds



Modules: K. Cleary

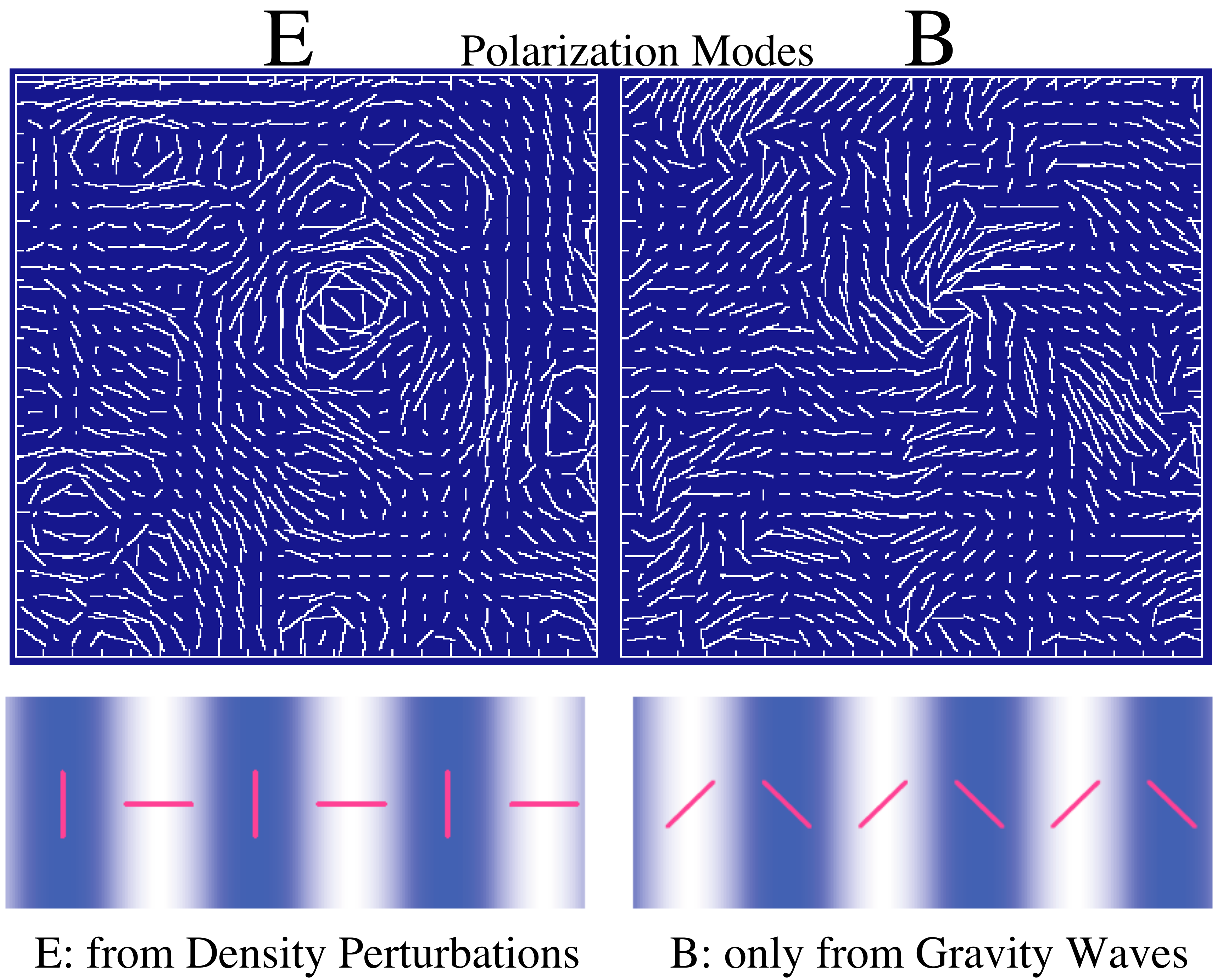
What We've Said about Schedules vs Time

(Dec 2007)



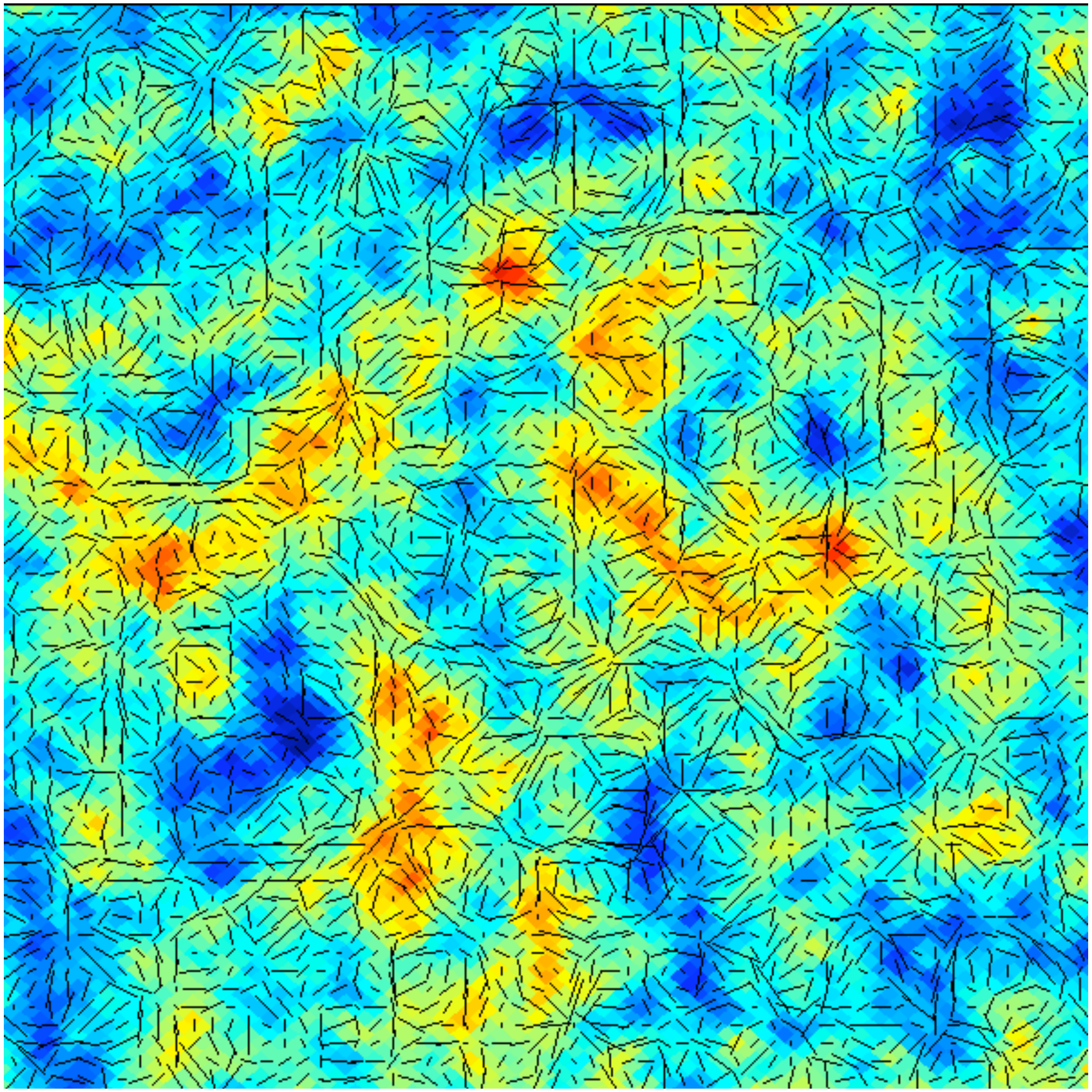
~~~15~~ 19 man years towards understanding modules from students and postdocs outside CIT/JPL
~~~

Operations Supported by Saint & NSF


E
Polarization Modes
B
E: from Density Perturbations
B: only from Gravity Waves

Simulated sky with T/S=0.2

10 deg by 10 deg field



Simulated sky with T/S=0.0

10 deg by 10 deg field