QUIET (QU Imaging Experiment)

Amber Miller – for the quiet collaboration
20th IAP Colloquium on CMB Physics and Observations
QU Imaging Experiment (QUIET)

The Collaboration
- 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

Grav. Waves
\( E_{\text{inf}} \approx 6 \times 10^{15} \text{ GeV} \)
(slow-roll Inflation)

E → B lensing

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

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 phase combiner are demodulated, low-pass filtered, and differenced $\rightarrow$ Stokes Q parameter

Diode outputs are demodulated, low-pass filtered, and differenced $\rightarrow$ Stokes U parameter

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 \((T_x - T_y)/2\).

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<td>Bolometer [(\mu K s^{1/2})]</td>
<td>HEMT/(\sqrt{2}) [(\mu K s^{1/2})]</td>
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\(^a\) 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)
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
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

- 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

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
How do we prevent ourselves from being blinded?

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…
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

September 9, 2003 T.Gaier GBT mm Workshop
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

- 91 Elements, 2000 deg², 1 yr
- E-mode
- B-mode
- T/S=0.07

Small Scale

- 91 Elements, 200 deg², 1 yr
- 1000 Elements, 8000 deg², 1 yr
- 1000 Elements, 2000 deg², 1 yr
- 1000 Elements, 200 deg², 1 yr

Assumptions: w-band observations, Tsys = 57 K, 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…