Focal Plane Array Program at NRAO

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NRAO
NRAO Focal Plane Array & Camera Program

• Long-Term Vision:
  – Technical Development for Square Kilometer Array
    • Beam Forming Arrays (Low Frequency through $\sim \lambda 1$ cm)
    • Increase FOV for interferometers – ALMA, EVLA

• Near-Term Vision
  – Scientific Enhancement for GBT through Large Format Arrays
    • Bolometer Cameras at 3 mm
    • Spectroscopic Systems at Key Frequency Bands
      – 3 mm (W-Band)
      – 1.3 cm (K-Band)
      – Others (e.g, 7 mm)
    – Testbed for SKA work – beam forming arrays
Status & Goals

• GBT Pathfinder Instruments
  – MUSTANG Bolometer Camera (64-pixels) – Early Science
  – 7-pixel K-Band (1.3 cm) Array under construction (for spectroscopy)

• Beam Forming R&D work
  – Collaborative program with BYU
    • MRI grant in progress
    • Instrumentation tests on 20 Meter telescope at GB

• MRI proposal to expand MUSTANG to 256 pixels submitted
• Proposal for 1000-element bolometer camera developed
• Concept for large format (e.g. 100-element) 3 mm array for GBT under development
MUSTANG (64 pixel bolometer array)

<table>
<thead>
<tr>
<th>Resolution</th>
<th>9” (FWHM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam spacing</td>
<td>4”</td>
</tr>
<tr>
<td>N-pixel</td>
<td>8x8</td>
</tr>
<tr>
<td>Current sensitivity</td>
<td>$T_{sys} = 140K$</td>
</tr>
<tr>
<td>Target sensitivity</td>
<td>$T_{sys} = 28K$</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>18 GHz</td>
</tr>
</tbody>
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- Currently 5x from photon noise
- Arrays 1x photon noise exist
- 4x increase in Npix ~$500k$
- 16x increase in Npix~$3M$

- 120 detectors on GBT ~ ALMA for 3mm continuum mapping speed
- First MUSTANG+GBT Detection of SZ!
  Bodes well for use of SZ as a detailed probe of ICM physics [Mason et al.]
Lensing Mass Map
Galaxy Density
Xray Surface Brightness

Optical + Xray (Left)
Bradac et al 2008

MUSTANG SZ (Right)
Similar angular scales
GBT Spectral Line FPAs

- 7-pixel prototype K-band Array to be released in late 2010
  - First element tested on the sky – results excellent

- Next step involves increasing the number of pixels
  - 100+ pixel W-band (3 mm) array
  - 61-pixel K-band (1.3 cm) array

- Signal transmission and processing infrastructure required
  - Need increased data transmission capability
  - Need new signal processing system
Large Format FPAs

- Building a large FPA has no technological blocks, but......
- Full cost of first large array is very expensive:
  - R&D into:
    - Packaging the system
    - Calibration algorithms to take advantage of the multiple beams
    - Data displays both for quick look (while observing) and data reduction
  - Need digitized data transmission system
    - Current system is $30k/line; Need R&D into something less expensive
  - New backend- FPGA technology would be straightforward to use
  - Estimated cost for first, large-format FPA is $25-$30M
  - Want to reduce this cost through R&D (w/ partners)
  - Subsequent arrays would be ~1/4 cost.
  - NRAO is seeking partners for such projects.
Science Application – Molecular Line Imaging of Comets

Cometary line emission is time-variable, with low surface brightness (large, filled aperture will be optimal). One molecular species gives rise to another (e.g. HCN \( \rightarrow \) HCO+), so rapid, sensitive imaging is key.

\[
\begin{align*}
\text{HCN} & \quad J=1-0 \\
\text{HCO+} & \quad J=1-0
\end{align*}
\]

Footprint of 10x10 array at GBT beam spacing (image resolution will be x7 higher)
Science Application – Molecular Line Imaging of Comets

Footprint of 10x10 array at GBT beam spacing (image resolution will be x7 higher)

A. Lovell – Comet Hale-Bopp / FCRAO
Optimizing the GBT for 3 mm Operation

- Holography project has reached 15% aperture efficiency at 90GHz
- Goal of 35% (20%) aperture efficiency at 90 (115) GHz

Phase-coherent Holography

Out-of-Focus (OOF) Holography
Optimizing the GBT for 3 mm – Continued: Dynamic Scheduling System (DSS)

• ≥20% of Green Bank’s weather is usable at high frequencies
  – GBT high frequency time is highly oversubscribed
  – Need to ensure the best possible use of a limited resource
  – GBT DSS will maximize science output at high frequencies

• GBT DSS will be released Fall 2010 in prototype form with enhanced versions to follow
Next Steps

• NRAO is writing “Requests for Information” papers for the Decadal Survey (due April 1) that will emphasize the FPA program

• Developing science and technology drivers for a 3 mm (W-Band) Array

• Actively seeking partners!
  – Contact Karen O’Neil in Green Bank