Optically Invisible Distant Starburst

GOODS 850-5

ACS b,v,i,z

MOIRCS J,Ks
NICMOS H

IRAC ch 1,2,3,4

MIPS 24 μm
SMA 880 μm
VLA 1.4 GHz

Wang et al. 2008
Half of starlight ends up in far infrared – how?
Submm galaxies are hard to find

Detection rate at current telescopes is 1–2 per night
Why CCAT?

CCAT
25 m, 10 μm rms
Cerro Chajnantor
Continuum sensitivities per pixel of CCAT and other instruments (5σ in 1 hour) with confusion limits (30 beams source⁻¹). CCAT sensitivities computed for precipitable water vapor appropriate to that band.
CCAT is an ultrafast mapper

Assumptions
- 32 x 32 (1024) pixel detector, Nyquist sampled, 350 μm & 850 μm
- Observationally verified counts (good to factor 2)
- Confusion and all sky limits

350 μm & 850 μm detection rates are compatible, but
Confusion at 350 μm is deeper than at 850 μm
Detection rates:
- ~150 x SCUBA2; ~300 x ALMA
- About 100-6000 per hour
- Lifetime detection of order $10^{7-8}$ galaxies: ~1% of ALL galaxies!

‘1/3 sky survey’: ~1000 deg$^2$ at 3 deg$^2$ hr$^{-1}$ in 5000 hr
Bolometer Performance: Sensitivity Improves

- **1995:** Bolocam
- **1999:** Zspec

### Plot Details:
- **Noise Equivalent Power (NEP):** $\text{W Hz}^{-1/2}$
- **Year Range:** 1940 to 2010
- **Sensitivity Improvement Rate:** $d \log_{10} \text{NEP} / dt = -0.5 \text{ yr}^{-1}$

**Key Data Points:**
- **Andrews et al., superconducting NbN, 14 K**
- **Boyle & Rogers, carbon**
- **Low @ TI, Ge, 2 K**
- **Kisch & Rollin, InSb HEB, 1.8 K**
- **Low @ NRAO, Ge, 1.2 mm**
- **Werner @ Palomar, 1.2 mm**
- **Hauser & Notarys, composite, 1.8 K**
- **Nishioka, Richards, Woody, 1.2 K**
- **Harvey, 1.3 K (KAO)**
- **Clarke, Al superconducting, 1.2 K**
- **Lange, 1 K, ion implant**
- **Nishioka, Richards, Woody, 0.35 K**
- **Lesyna, Roellig, Kittel 0.1 K ADR**
- **Fischer et al (UCB), NTD Ge, 0.3 K**
- **Nahum & Martinis, SIN, 0.1 K**
- **Tanaka et al (UCB) 0.1 K**
- **SCUBA 0.1 K**
- **Bock et al. spiderweb 0.1 K**
- **W TES 0.1 K**
- **Lee/UCB 0.1 K**
- **SCUBA 2 Mo/Cu TES, 0.1 K**
- **BLIP - ground imaging**
  - $v/\Delta v = 300$ spectroscopy
- **BLIP - space $R=1000$**
- **CIT/JPL spiderweb + NTD Ge, 0.1 K**
- **Kenyon et al, Si$_3$N$_4$ Mo/Au TES, 0.14 K**
- **Kenyon et al, Si$_3$N$_4$ Mo/Au TES, 0.07 K**
- **Wei et al, Ti/Nb nano-HEB-TES, 0.065 K**
While Array Size Increases
### CCAT Performance Goals

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Goal</th>
<th>remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>350 – 1400 μm</td>
<td>200 – 2500 μm</td>
</tr>
<tr>
<td>Aperture</td>
<td>25 m</td>
<td></td>
</tr>
<tr>
<td>Field of view</td>
<td>10'</td>
<td>20'</td>
</tr>
<tr>
<td>Half WFE</td>
<td>&lt; 12.5 μm</td>
<td>&lt; 9.5 μm</td>
</tr>
<tr>
<td>Site condns.</td>
<td>&lt; 1.0 mm</td>
<td>&lt; 0.7 mm</td>
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</tbody>
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These Goals and Advanced Bolometer Arrays Will Make CCAT a Revolutionary New Observatory
Atmospheric Transmission (model)

ATM 2002 Model (Pardo et al.)

Transmission

273 K PWV
- CCAT 10% 5600 m 150 μm
- CCAT 25% 5600 m 400 μm
- CCAT 50% 5600 m 700 μm
- ALMA 50% 5000 m 1000 μm
- CSO 50% 4100 m 2000 μm

Frequency [GHz]
Atmospheric Transmission (observed)

2005 January 24
Co. Sairecabur
93 μm PWV
Cerro Chajnantor 5612 m

APEX
QUIET ex. CBI
ALMA (5050 m)
ASTE & NANTEN2 (4800 m)

1 km
Cerro Chajnantor 5612 m

View SW from ASTE; access road constructed by U. Tokyo
Cerro Chajnantor 5612 m

CCAT equipment overlooking ASTE & NANTEN2 @ 4800 m
350 μm Transparency

- Two Tippers: CCAT (5600 m) & CBI (5050 m)
- Side-by-Side at CBI: Same Values
- Better Transparency at CCAT
- Less Water Vapor at CCAT
  - $\tau_{\text{off}} \approx 0.5$
  - Slope $\propto$ PVW
  - PWV(CCAT) $\leq 70\%$ PWV(CBI)
- Corroborated by humidity measurements
CCAT Concept Design

- **RC Optics, Nasmyth Foci**
- **Calotte Dome**
  - Internal storm shutter
- **High Performance Mount**
  - Precise pointing, 0.3" rms
  - Agile scanning motions
- **Active Primary Surface**
  - Kinematic panel supports
  - Closed loop control
  - Holography alignment
- **Cerro Chajnantor, 5612 m**
  - Instrument prep. & ops. areas
  - Oxygen enrichment in rooms
- **Base Facility near San Pedro**
Primary Mirror Panels

- Possible Panel Tech.
  - CFRP/Al Sandwich
- \( \sim 8 \text{ kg m}^{-2} \) Areal Density
- \( \sim 5 \mu m \text{ rms Total Error} \)
- Combine two functions
  - support structure
  - optical surface

- Thermal stability?
- Manufacturing tolerance?
- SBIR program
  - Vanguard Composites
  - JPL, Cornell
Hybrid Panels

- Separate functions: support and optical surface
- CFRP sub-frames provide stiff, thermally stable platform
  - Exploit excellent thermal & structural properties of CFRP
  - Sensors mounted to frames
- Precision reflecting tiles mounted on sub frame (similar to LMT)
  - Better manufacturing and performance of small panels
  - Tiles aligned with high precision measuring machine
- Extra layer of structure
  - Weight, complexity
- Development effort: NRW.hitech Köln, Bonn, and Vertex AT
Active Surface Alignment

- Sensing and Control Model
  - D. MacDonald (JPL), D. Woody (OVRO)
  - Sensor response to segment motions, modal analysis
  - Closed loop control to maintain surface
  - Low sensor sensitivity to global modes, i.e., focus, tilt, astig.
  - Thermal and gravity segment distortions disrupt control

- “Edge” Sensors
  - Displacement and dihedral information at segment borders
  - Necessary but not sufficient
CCAT Consortium

- Caltech
  - Includes JPL involvement
- Cornell University
- University of Colorado Boulder
- UK Astronomy Technology Centre (STFC)
- Canada (Univs. of BC & Waterloo)
- Germany (Univs. Köln & Bonn)
- Other Institutions Interested

Interim Consortium Agreement Signed in 2007
Full Project Agreement Anticipated
Project Phases and Schedule

• Feasibility/Concept Design Study
  – 2004 – 2006
  – Cornell, Caltech, & JPL: Develop Baseline Concept, Assess Feasibility, Initial Cost Estimate

• Consortium Development
  – 2006 – 2009
  – Expand Consortium, Develop Funding
  – Address Key Technical Issues

• Technical Development
  – 2009 – 2013
  – Detailed Design, Manufacture, Integration

• Commissioning Phase
  – 2014
  – Optimize Performance & Handover to Operations
“The CCAT will revolutionize Astronomy in the submm/FIR band and enable significant progress in unraveling the cosmic origin of stars, planets and galaxies. CCAT is very timely and cannot wait.”

From CAAT Design Review Committee Report (Robert W. Wilson, Chair)