



CCAT

2008 April 8

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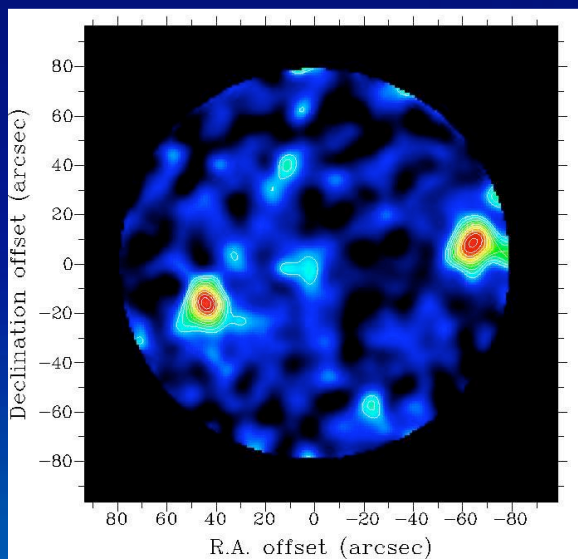
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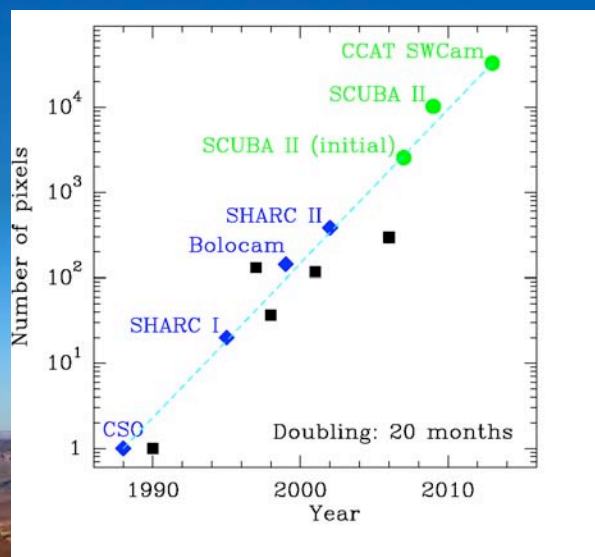
Why CCAT ?



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CCAT
25 m, 10 μ m rms
Cerro Chajnantor





CCAT Overview

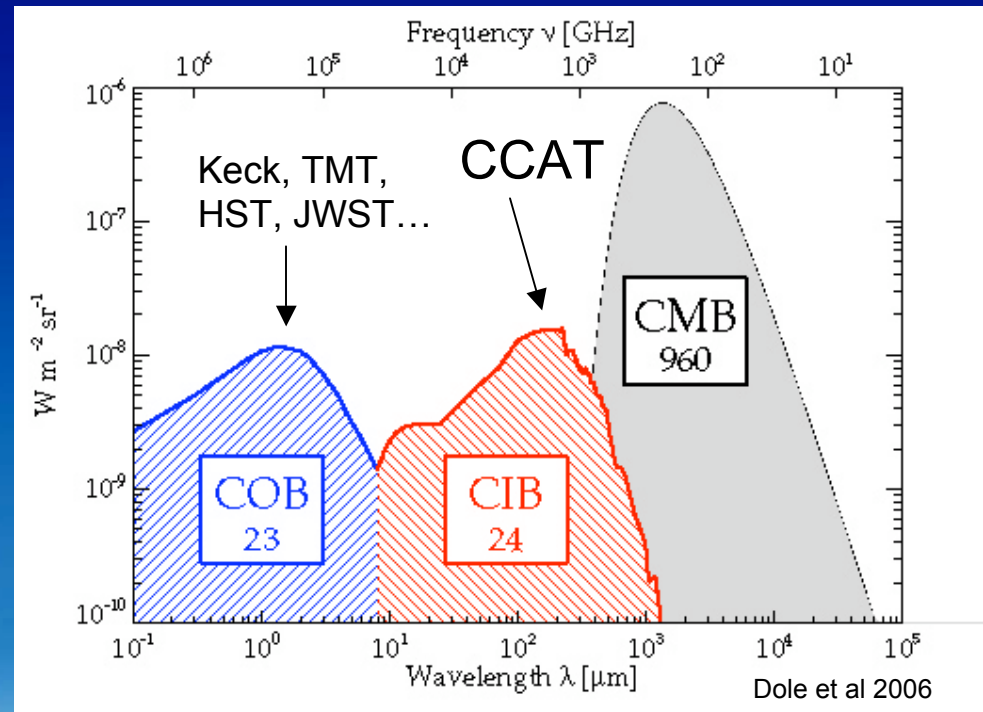
- Big: 25 m diameter submm telescope
 - high aperture efficiency at 200 μm
- Wide: Field of View $> 15'$
 - large format bolometer array cameras
- High: dry, tropical mountain site
 - 5600 m, median PVW < 1 mm
 - wide sky coverage
- Complement ALMA





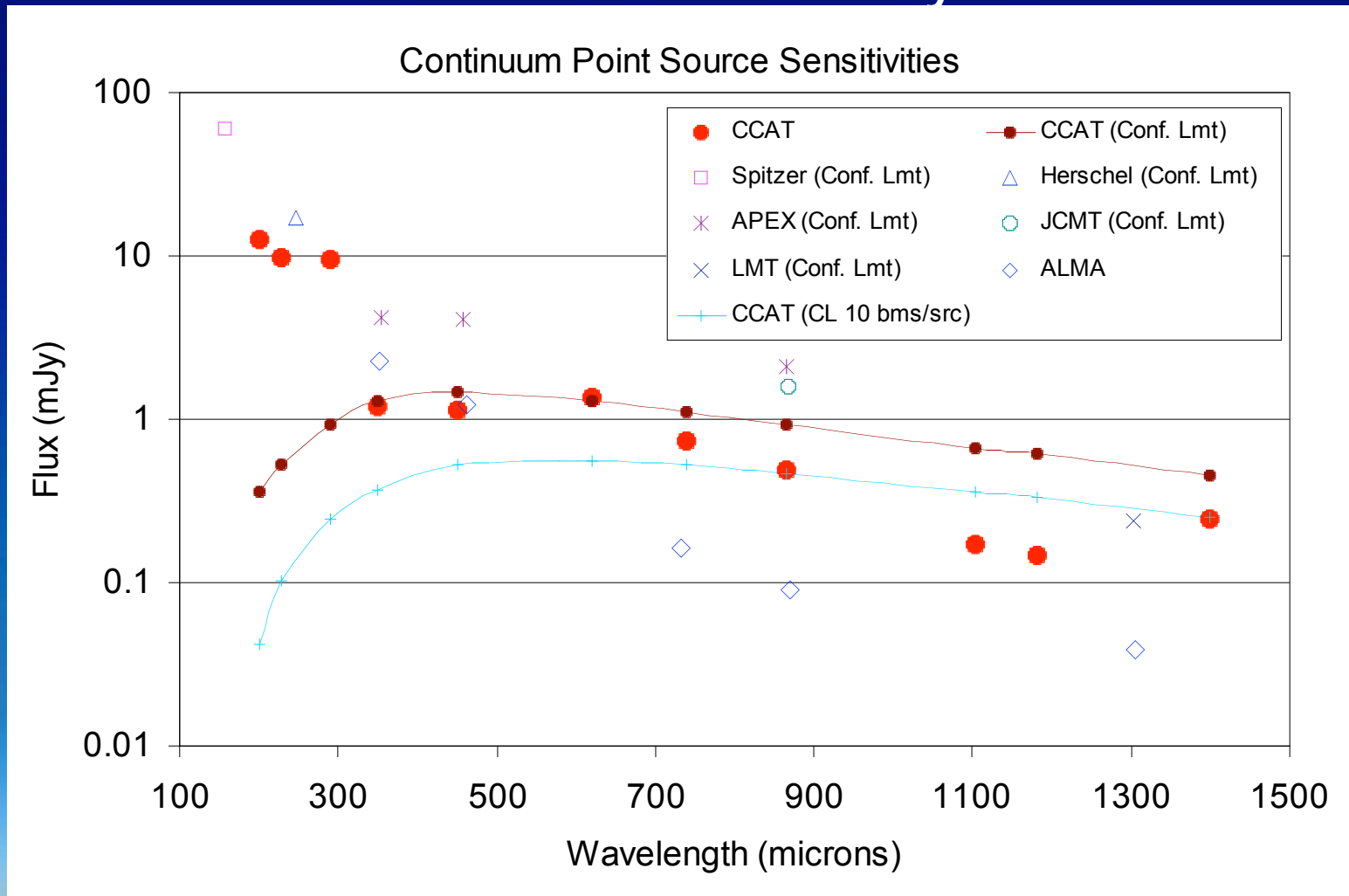
CCAT Science Strengths

- Past decade: submillimeter astronomy is important !!
- CCAT:
 - Large and sensitive
 - Designed for wide-field imaging
 - Wide spectral coverage
 - *Excellent* performance at 350 μm
 - site, surface
 - 3.5" resolution @ 350 μm
 - Multicolor information (SED)
 - Study high z tail of CIB sources
- CCAT will complement ALMA
 - Fast continuum mapping vs. high angular & spectral resolution
 - Comparable sensitivities: identify targets for ALMA
- Clusters (SZ), submm galaxies, star-forming regions & cores, debris disks, KBOs





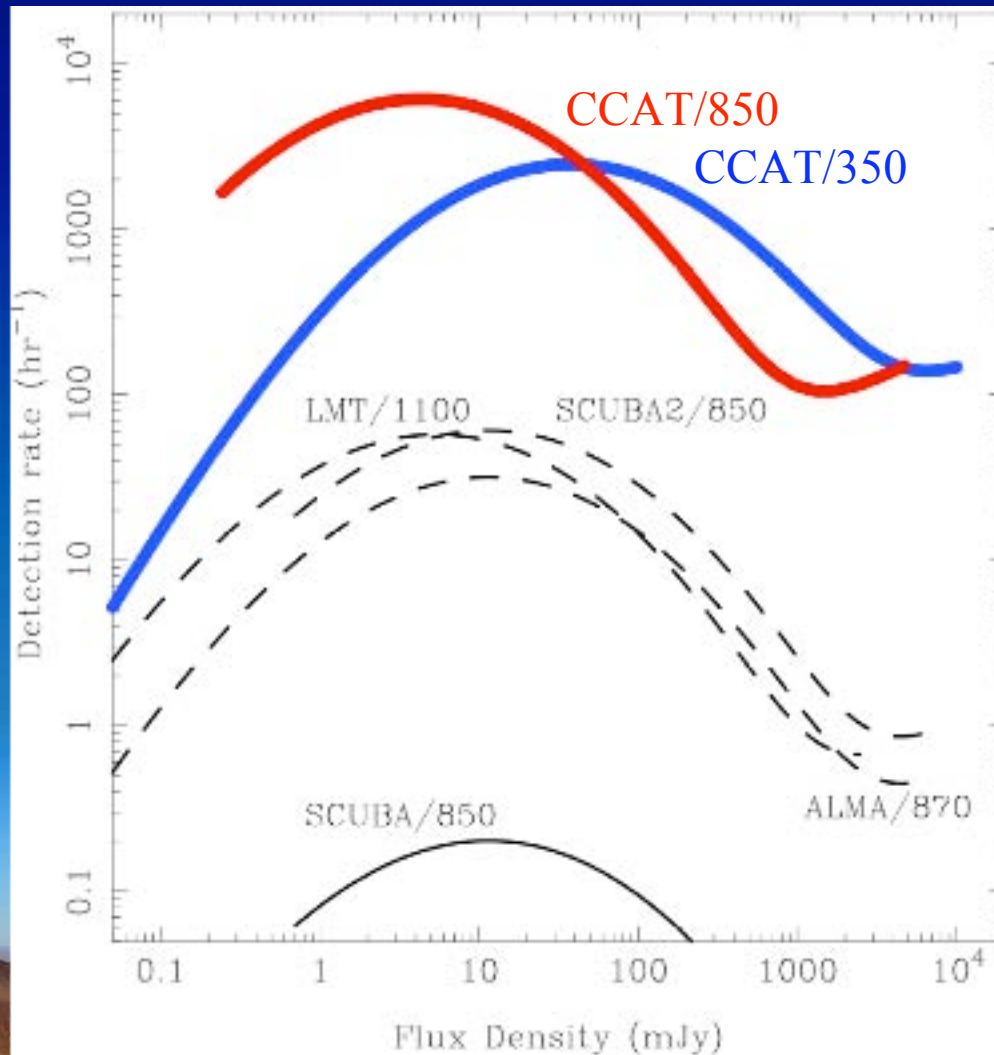
CCAT Sensitivity



Continuum sensitivities 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.



Submm Galaxy Detection Rate



- 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:
 - $\sim 150 \times$ SCUBA2; $\sim 300 \times$ ALMA
 - About 100-6000 per hour
 - Lifetime detection of order 10^{7-8} galaxies: $\sim 1\%$ of ALL galaxies!
- '1/3 sky survey': $\sim 1000 \text{ deg}^2$ at $3 \text{ deg}^2 \text{ hr}^{-1}$ in 5000 hr



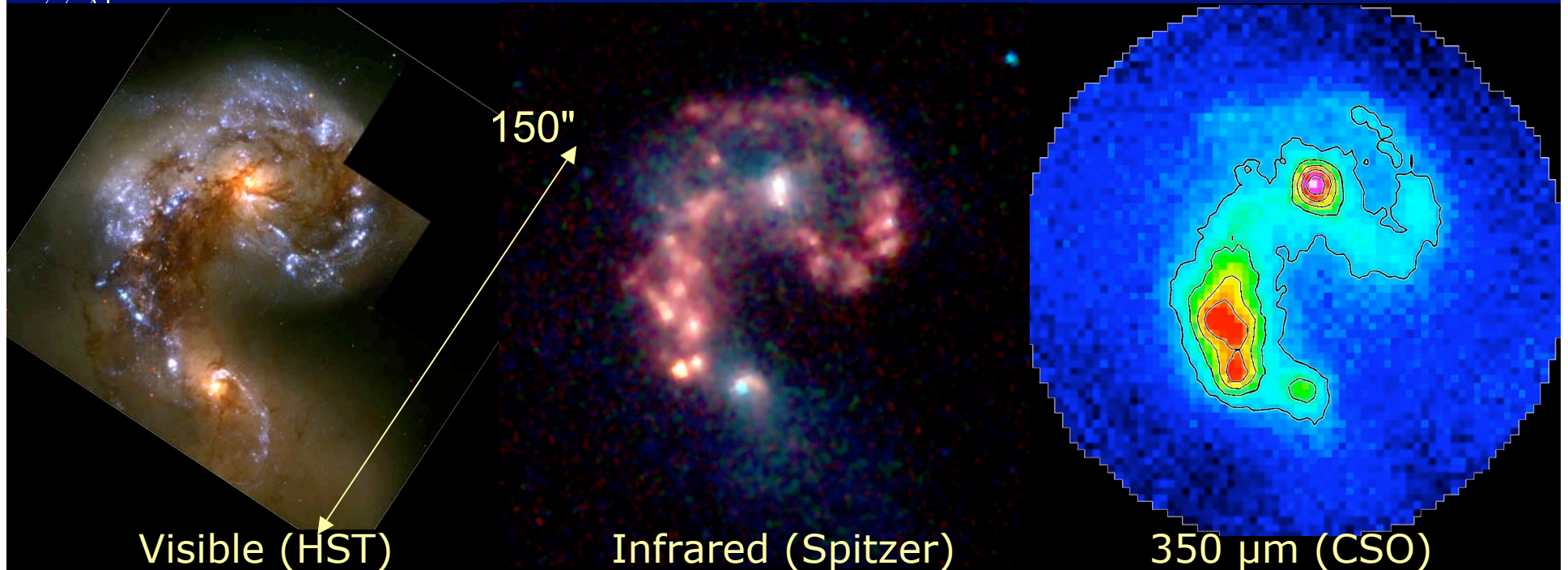
Distant Submm Galaxy Surveys

- CCAT Detection Rate Will Provides Huge Samples
 - Find rare distant red objects; i. e., opt/IR (or 350 μm) dropouts
 - Address clustering properties of submm galaxies
 - Map large scale structure, high density regions
 - Measure submm galaxy luminosity function
- CCAT Confusion Limit Fainter than Other Surveys
 - Higher precision number counts
 - Are faint submm galaxies more quiescent ?
- Surveys Guide Detailed Follow-on Studies with ALMA
 - CCAT will provide accurate positions





Nearby Interacting Galaxies



Images of the Antennae show the submillimeter reveals active star formation regions hidden at shorter wavelengths. The bulk of the luminosity emerges in the submillimeter. CCAT will provide a submillimeter image with a spatial resolution similar to the infrared image. Mapping this galaxy would require hundreds of pointings with ALMA. With CCAT's high mapping speed and sensitivity, a complete survey of all galaxies in the local volume would be practical.



CCAT Galactic Plane Survey

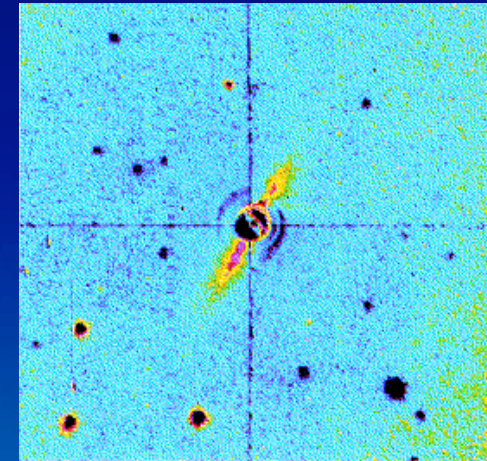
- Measure the Galaxy-wide star formation rate and history
- Obtain the complete inventory of cold dust in the Galactic Plane
- Determine the relative importance of global and local triggers for star formation
- Provide templates, recipes and prescriptions for Xgal science
- CCAT mapping speed ($0.9 \text{ deg}^2 \text{ hr}^{-1}$) and sensitivity (8.5 mJy) enable:
 - a complete survey of the “inner” Galactic Plane
 - detect *all* star forming regions (i. e., cool dust)
 - not just massive star regions (i. e., warm or hot dust)



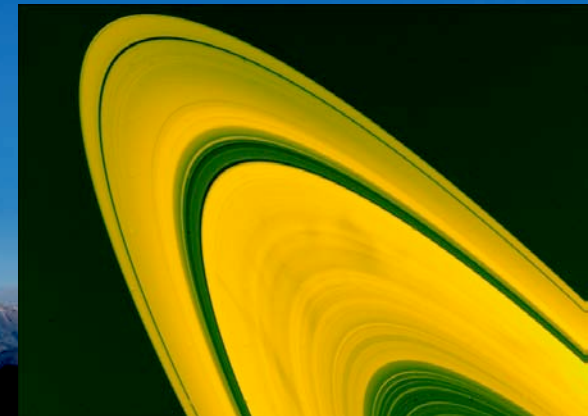


Debris Disks with CCAT

- Debris disks, a.k.a. “Vega phenomenon”, a.k.a. “extra-zodiacal dust”:
 - solid particles around main sequence stars, especially younger ones (10-100 Myr); gas has been absorbed into giant planets or expelled
 - Produced by collisional grinding of planetesimals in Kuiper belts; probably episodic
 - trace orbital dynamics (analogous to Saturn’s rings)
- CCAT objectives
 - high-quality images of statistical sample of nearby disk systems
 - surveys for undiscovered cold disks ($T < 40$ K) around nearby stars
 - important data points on spectral energy distribution
 - characteristics of particles \Rightarrow evolutionary clues?
 - much better measurement of mass than is possible with scattered light images
 - unbiased surveys for disks in stellar clusters



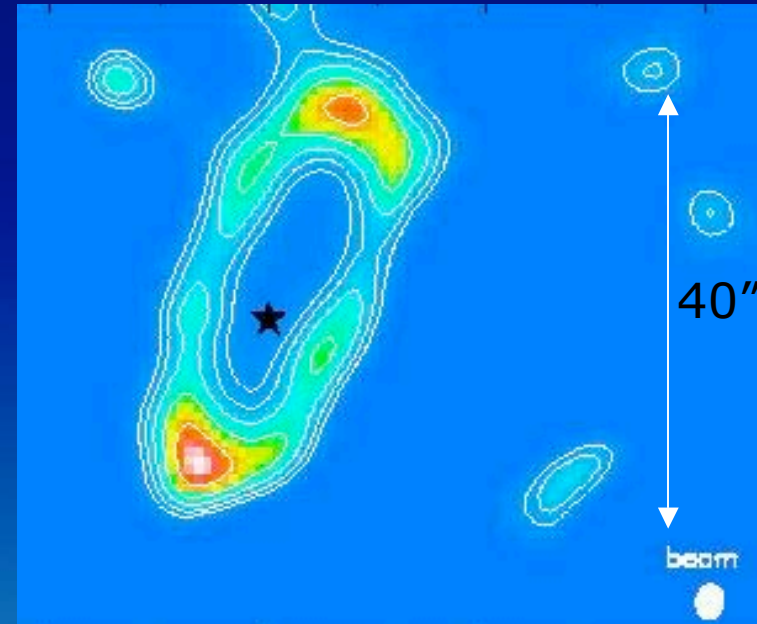
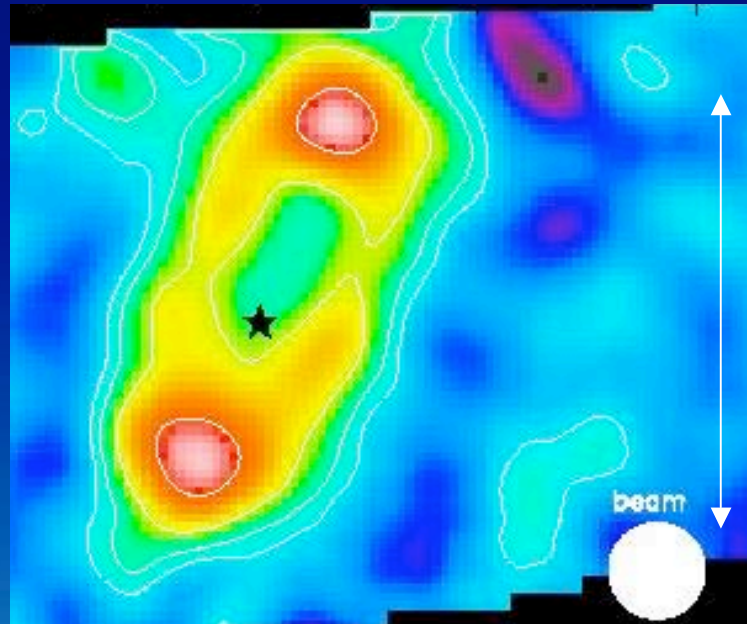
β Pictoris: debris disk discovery image
Smith & Terrile (1984)





Debris Disks

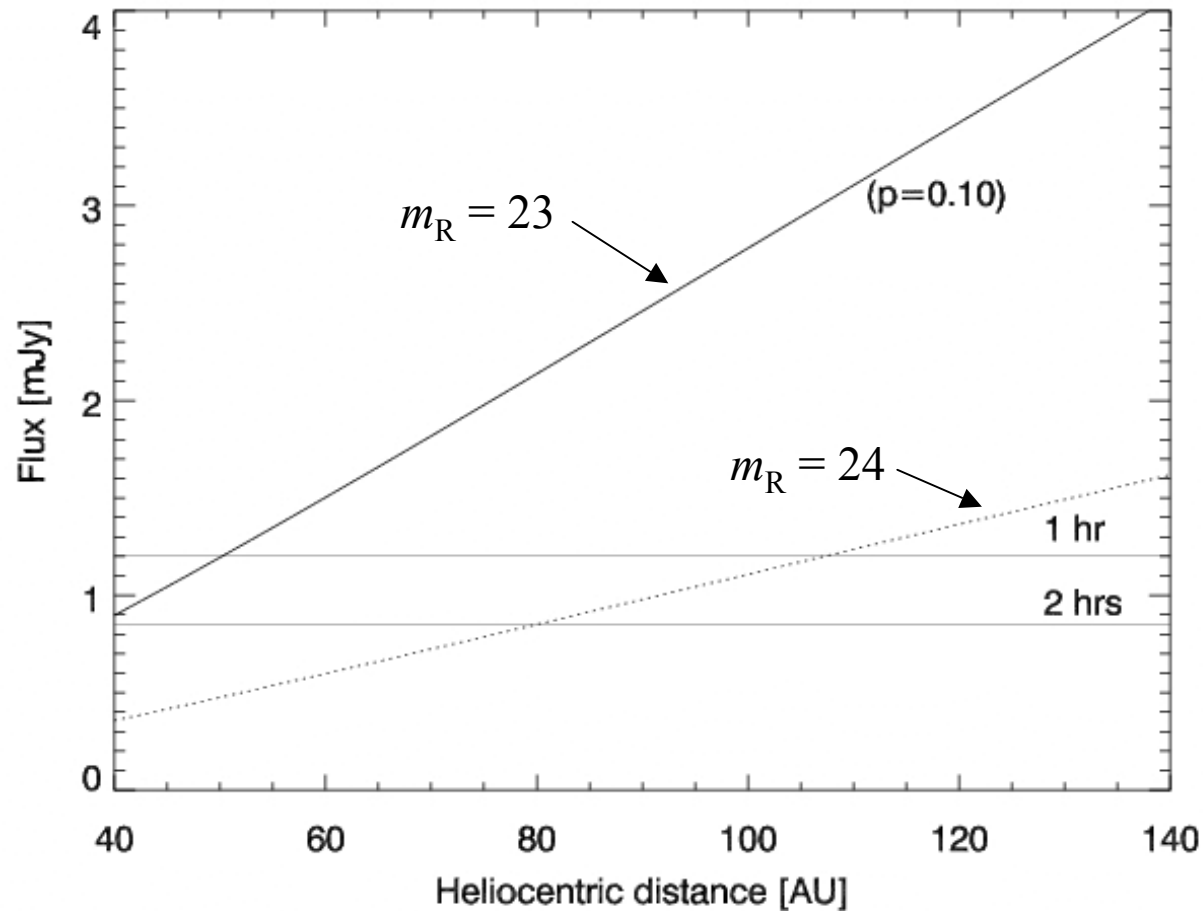
CSO/SHARC II Marsh et al. 2005



Images of Fomalhaut debris disk at $350\ \mu\text{m}$. The observed image (*left*), with $10''$ resolution, shows a complete debris ring encircling the star. With enhanced ($3''$) resolution (*right*), we can infer the presence of a planet due to the asymmetry of the ring. CCAT will achieve this resolution intrinsically and be capable of $1''$ resolution with image enhancement techniques. CCAT imaging will measure the entire flux and should show substructure pinpointing the location of the planet. Imaging this system would require dozens of ACA pointings.



KBO submm advantage



Optical brightness (refl.)

$$B \propto R^{-4}$$

Submm flux (thermal)

$$S \propto R^{-5/2}$$

Submm advantage

$$\propto R^{+3/2}$$

Predicted 350 μm flux for KBOs with 4% albedo ($m_R = 23$, solid, and $m_R = 24$, dotted). Horizontal lines show the 5 σ detection limits for one and two hour observations, respectively, with CCAT.



CCAT Technical Goals

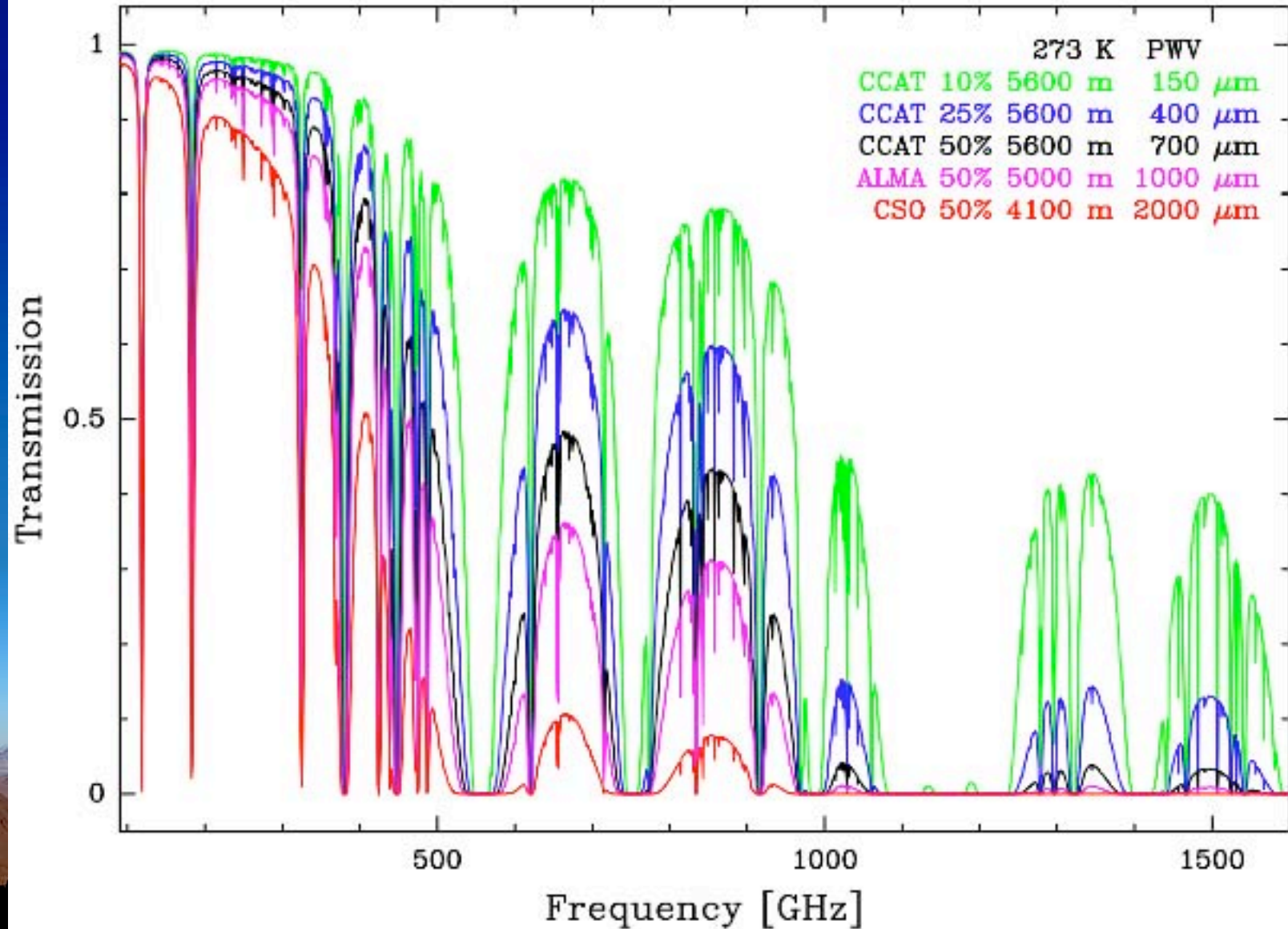
	Requirement	Goal	remark
Wavelength	350 – 1400	200 – 2500	μm
Aperture	25 m		
Field of view	10'	20'	
Half WFE	$< 12.5 \mu\text{m}$	$< 9.5 \mu\text{m}$	rms
Site condns.	$< 1.0 \text{ mm}$	$< 0.7 \text{ mm}$	median pwv

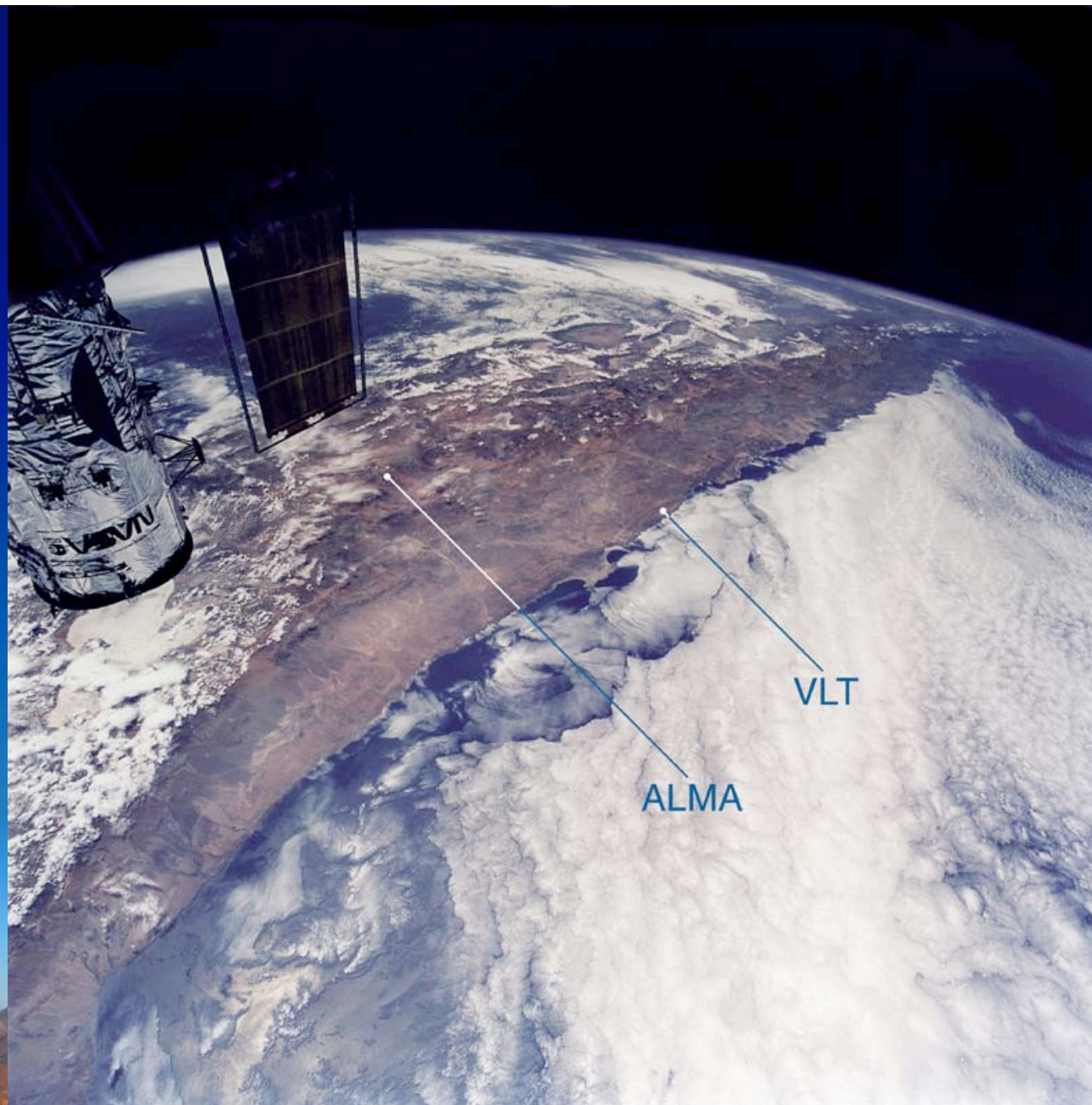
These Goals and Advanced Bolometer Arrays Will Make
CCAT a Revolutionary New Observatory



Atmospheric Transmission

ATM 2002 Model (Pardo et al.)





View of Northern Chile (NASA Space Shuttle)

ESO PR Photo 24b/99 (8 June 1999)

© ESO - ESA - Claude Nicollier





Cerro Chajnantor 5612 m



1 km

APEX CBI ALMA (5050 m)

ASTE & NANTEN2 (4800 m)



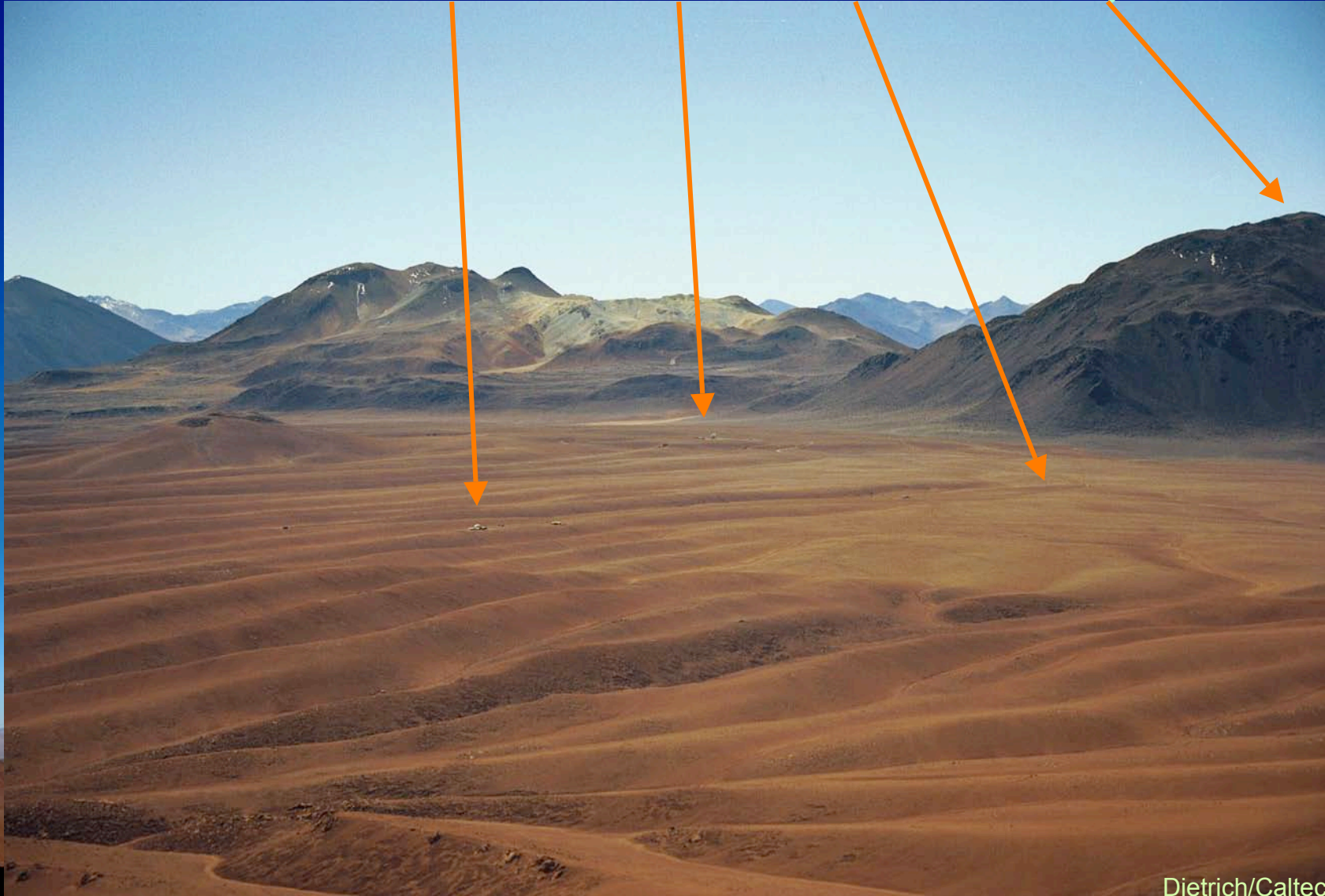
Chajnantor Plateau (5000 m)

CBI

APEX

ALMA

Co. Chajnantor



Cerro Chajnantor 5612 m



View SW from ASTE; access road constructed by U. Tokyo

Cerro Chajnantor 5612 m



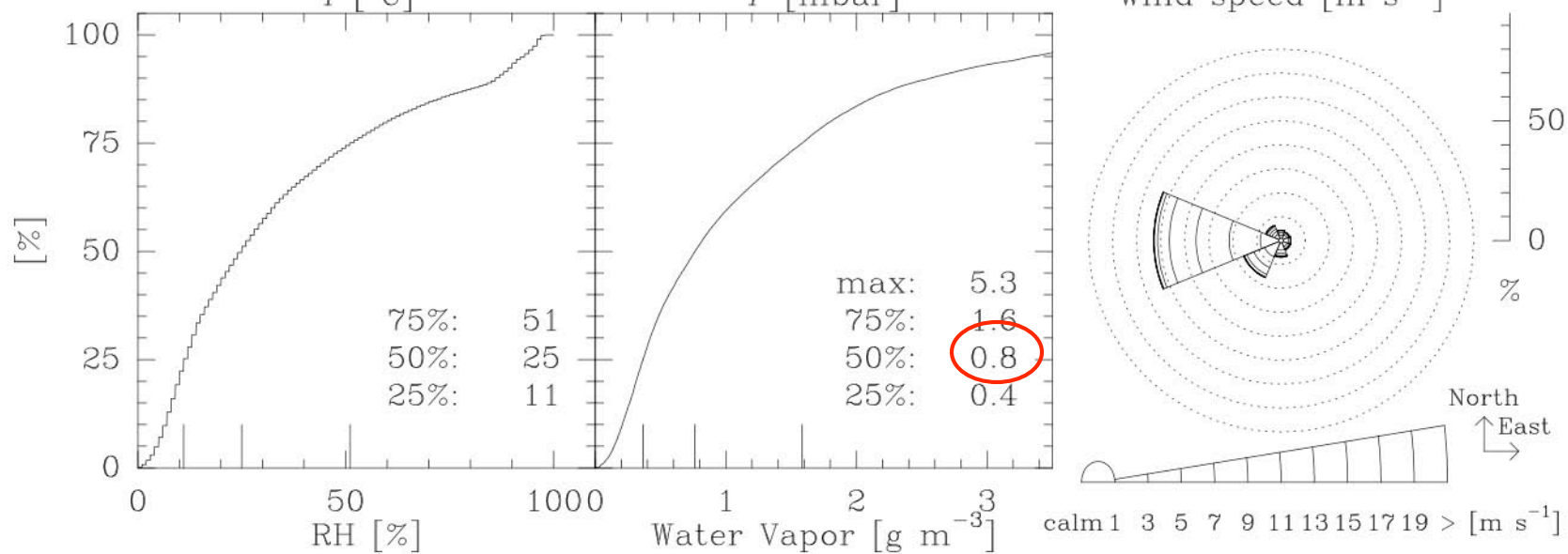
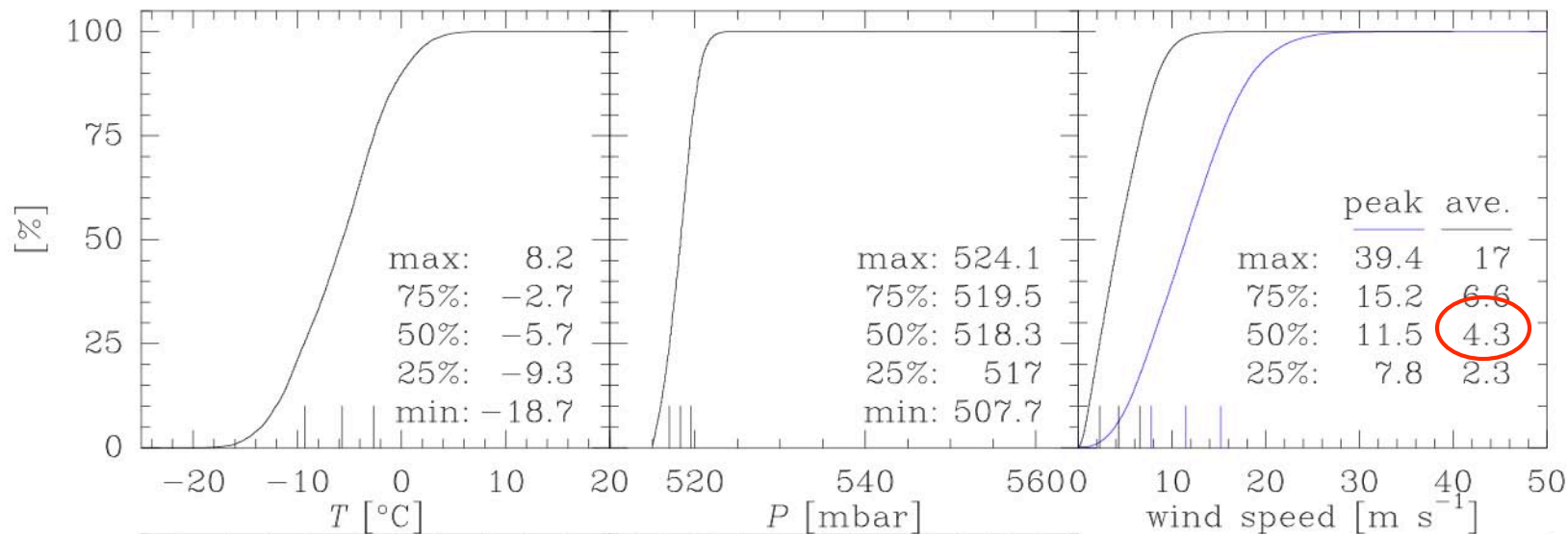
CCAT equipment overlooking ASTE & NANTEN2 @ 4800 m



Cerro Chajnantor (CCAT)

67300 points

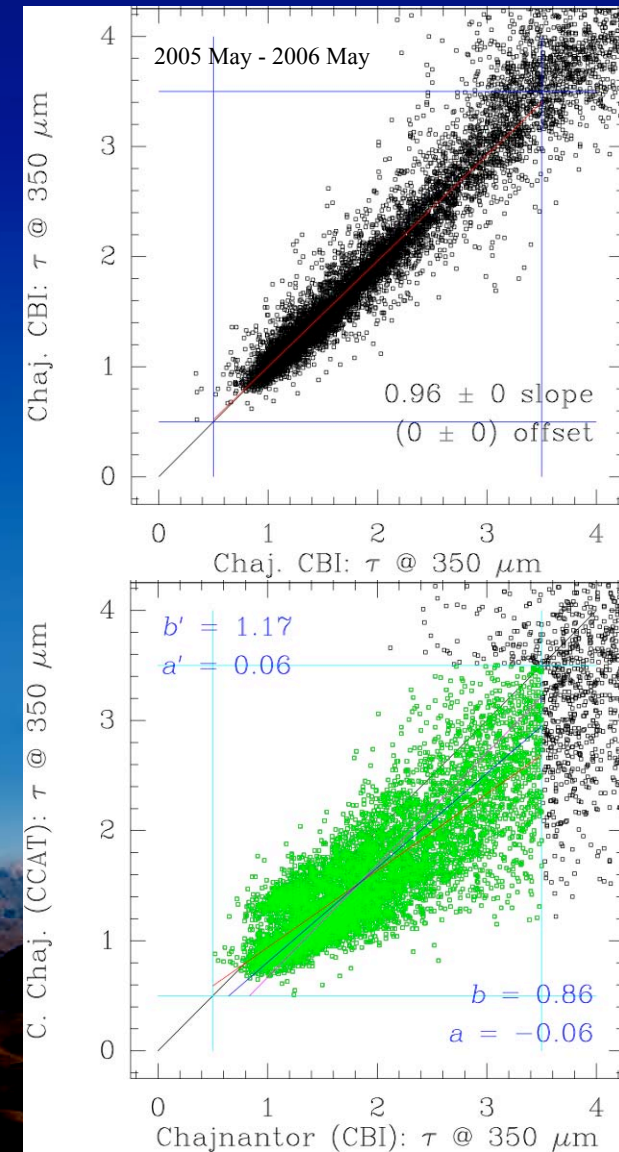
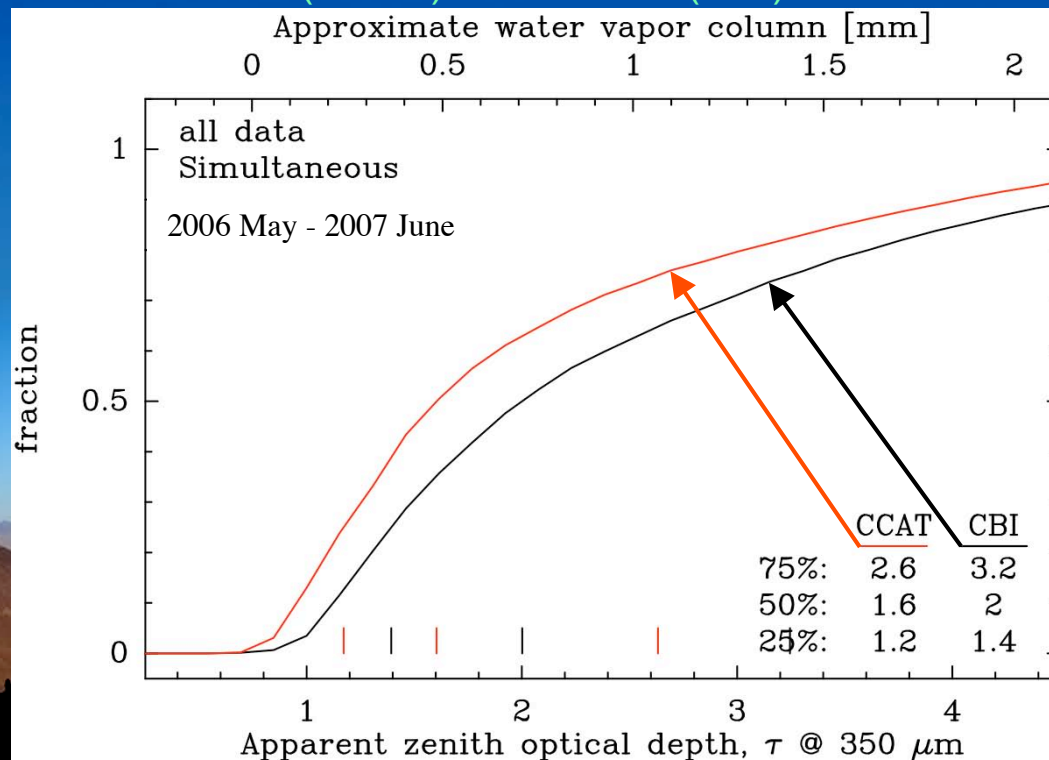
2006 May – 2008 April





Better 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
 - $\text{PWV}(\text{CCAT}) \leq 70\% \text{PWV}(\text{CBI})$





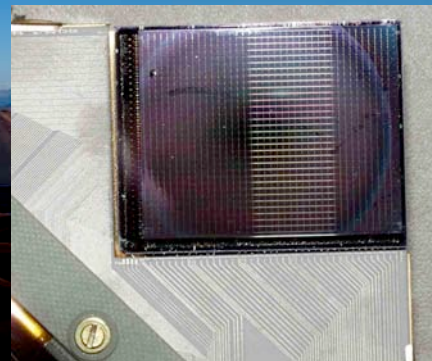
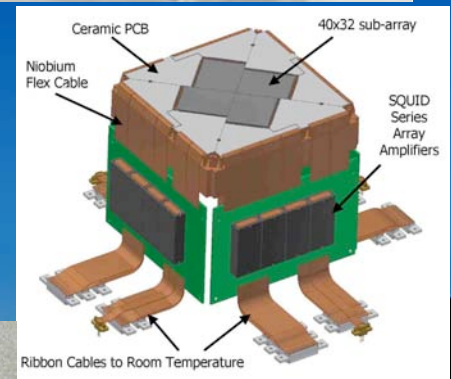
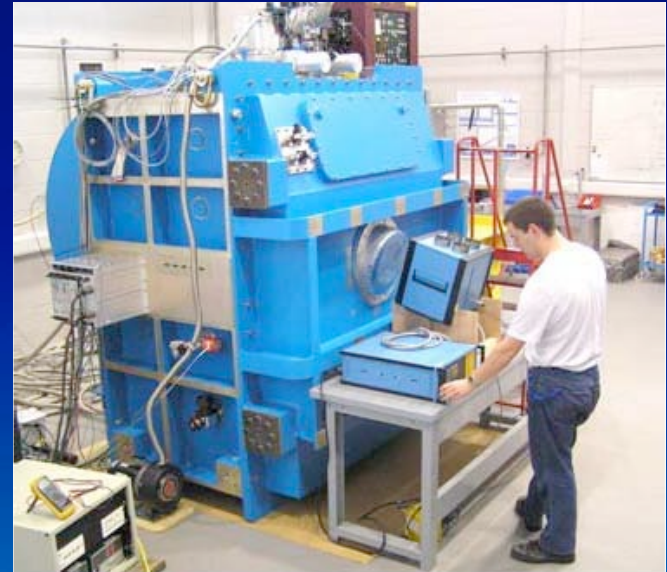
CCAT Instruments

- Direct Illumination Cameras
 - SCUBA2: 450 & 850 μm
 - SWCam: 200–620 μm
- Antenna Coupled Camera
 - LWCam: 700–2000 μm
- Spectrometers
 - Multiobject gratings
- Heterodyne Receivers
 - Array cameras
 - ALMA receiver, connect to ALMA, VLBI
- Legacy Instrumentation



Direct Illumination Cameras

- SCUBA2 (UK ATC, Canada)
 - To JCMT in 2007
 - On CCAT, would be:
 - Proven first light instrument
 - 2.7' at 450 μm , 5' at 850 μm
- CCAT SW Camera (concept)
 - 200 μm , 350 μm , 450 μm , 620 μm
 - Single color with filter wheel
 - NIST TES silicon bolometers
 - Total: 32 000 pixels
 - 5' field of view @ 350 μm

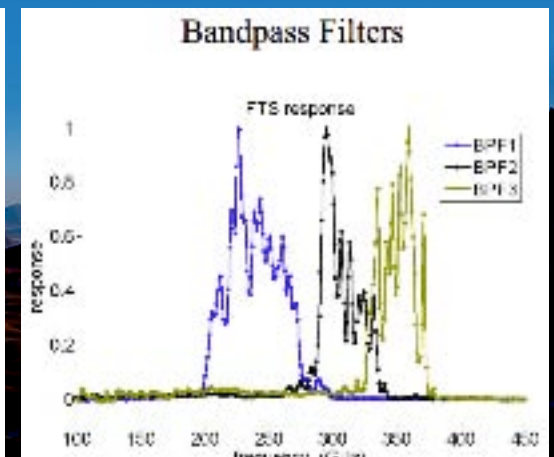
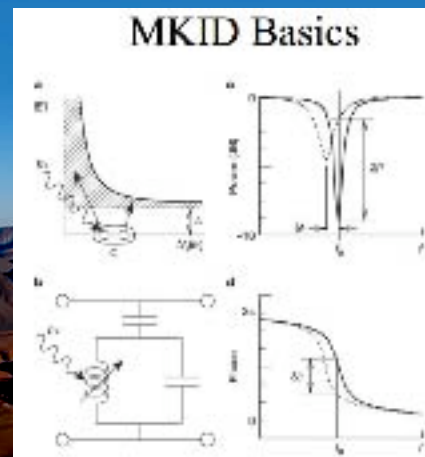
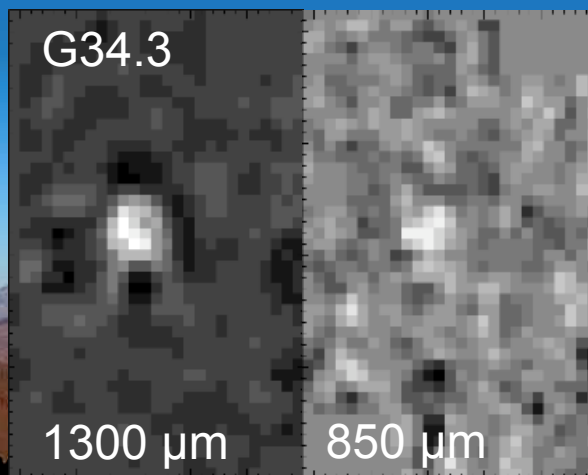
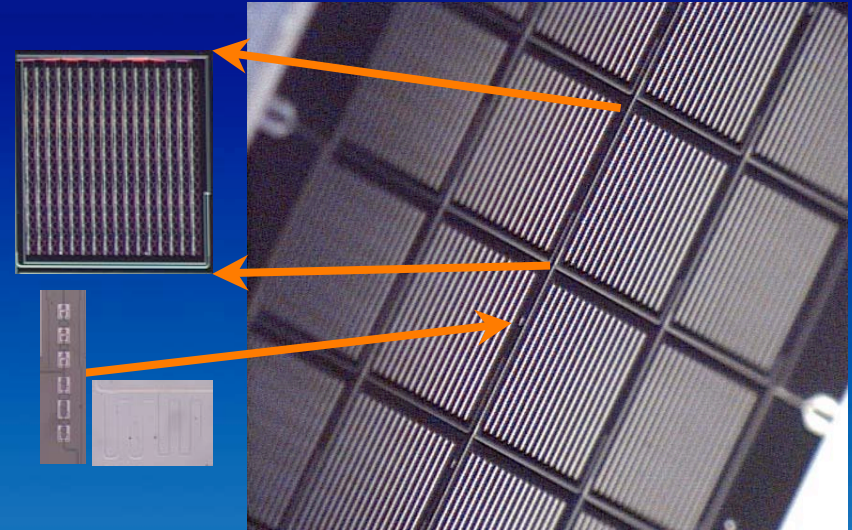




Antenna Coupled MKID Camera

- CSO camera (CIT, Colorado)
 - DemoCam, 4x4 pixels, two colors
 - CSO observations in 2007 April
 - Successor funded, NSF ATI
 - 24x24 pix, 4 color 750-1300 μm
- CCAT LW Camera (concept)
 - 750–2000 μm , 45 000 pixels
 - Up to 20' x 20' Field of View

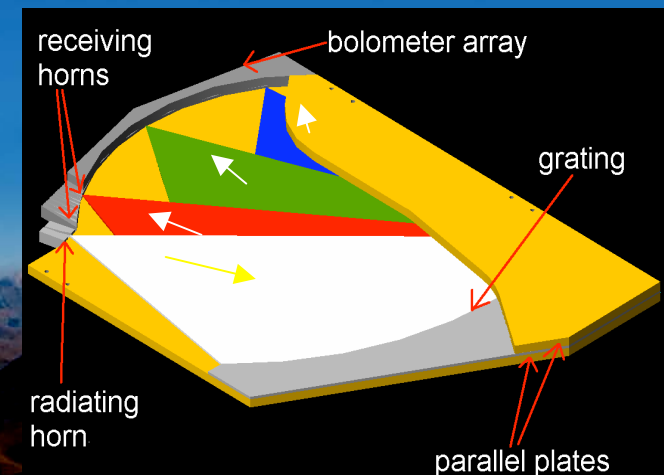
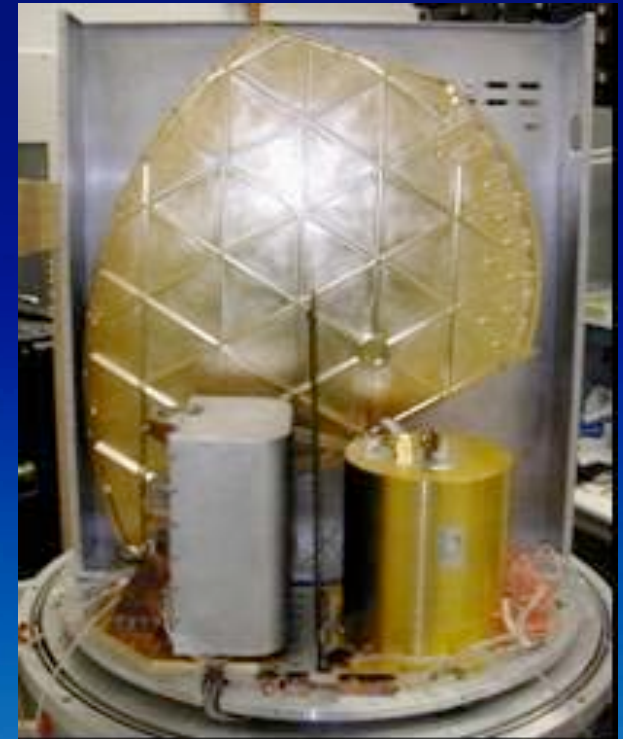
Antenna coupled array
1300 & 850 μm





Spectrometers

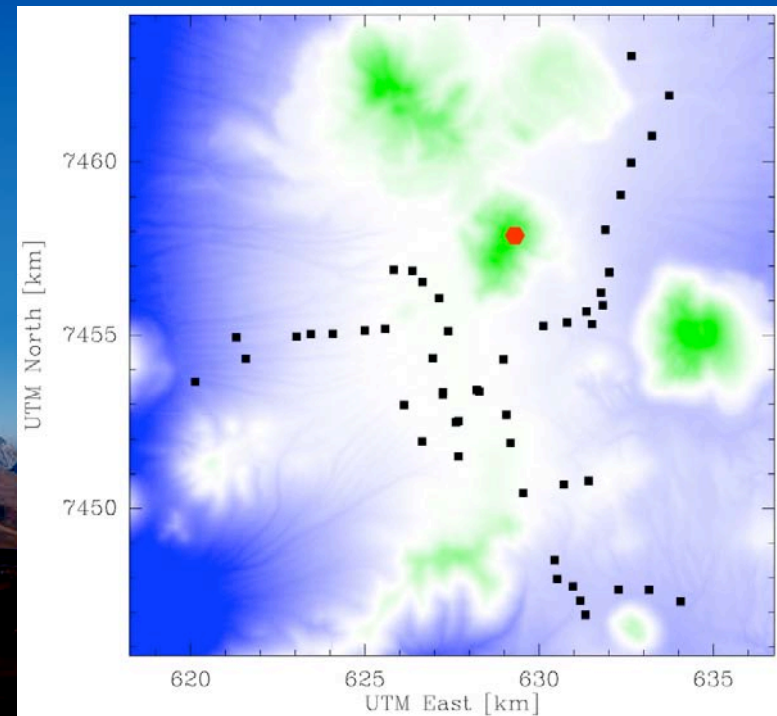
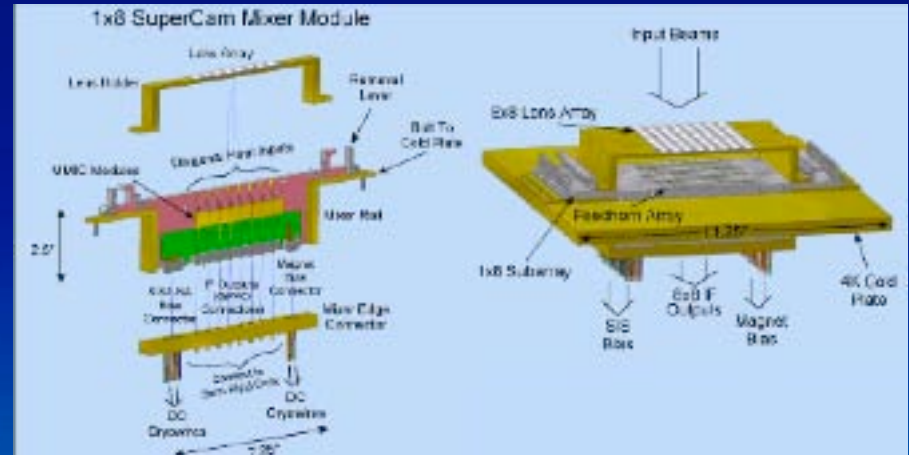
- Zeus (Cornell)
 - Long slit echelle grating
 - 350, 450, 610 μm , $R \sim 1000$
 - Already to CSO
- Z-Spec (CIT, JPL, Colorado)
 - Parallel plate grating cavity
 - 190–310 GHz, $R \sim 250$ to 400
 - Already to CSO (2005 June)
- Multiobject
 - Flexible dielectric waveguide
 - Optical relays
 - Laboratory studies





Heterodyne Receivers

- Super Cam (Arizona)
 - 64 pixels, 330–360 GHz
 - FPGA spectrometers
 - 1 GHz IF BW
 - Under development
- CHARM (concept)
 - 64–128 pixels, 650–700 GHz
 - 2–4 GHz IF BW
 - Digital spectrometers
- ALMA Receivers
 - Anchor for long baselines
 - At 350 μm , add 14% sens.
 - Improve dirty sidelobe levels
 - 9% \Rightarrow 7% (Holdaway)
 - Also VLBI





CCAT information
www.submm.org

“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)*