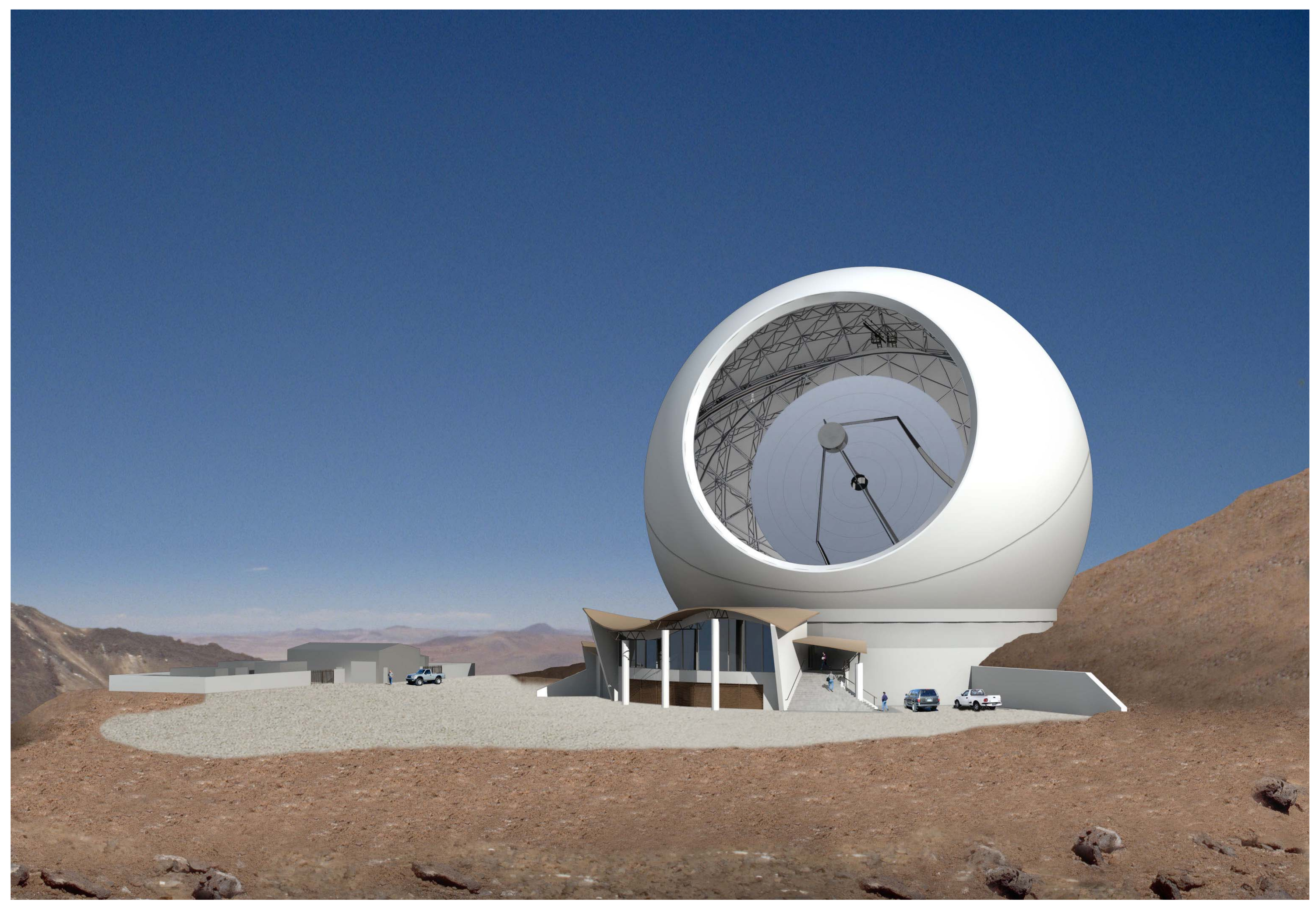
The Cornell Caltech Atacama Telescope (CCAT)

Simon J. E. Radford (Caltech) on behalf of the CCAT Project

The CCAT Project

In 2004 February Cornell University and the California Institute of Technology signed an agreement that will lead to the construction and operation of a 25 m diameter telescope for submillimeter astronomy on a high mountain in the Andean highlands of the Atacama desert in northern Chile. Scheduled for completion at the beginning of the next decade, this Cornell Caltech Atacama Telescope (CCAT) will be the largest and most sensitive facility of its class as well as the highest altitude astronomical facility on Earth. In 2006 January, the project completed a Feasibility Concept Design Study, developing the technical specifications and evaluating possible technological approaches. An external committee reviewing the Study concluded, "*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.*" In 2007 July, the University of Colorado, the University of British Columbia leading a Canadian university consortium, and the UK Astronomy Technology Centre on behalf of the UK community joined Cornell and Caltech in signing an Interim Consortium Agreement to develop the project. Late in 2007, the Universities of Cologne and Bonn stated their intent to join the project. Other institutions have also expressed interest.



Concept view of CCAT at 5600 m on the candidate site near the summit of Cerro Chajnantor, Chile.

M3 Engineering

Scientific Objectives

Combining high sensitivity, a wide field of view, and a broad wavelength range, CCAT will have an unprecedented capability to make deep, large area multiwavelength submillimeter surveys that address a large variety of astrophysical problems. Highlights include:

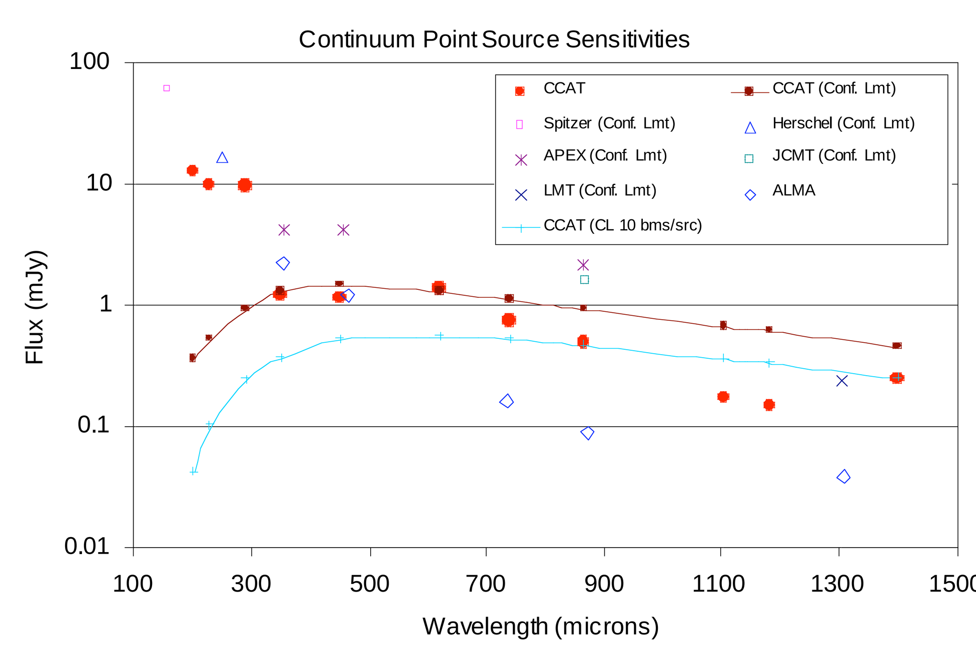
Galaxy formation and evolution: CCAT will detect hundreds of thousands of high redshift submillimeter starburst galaxies, allowing investigation of the star formation history of the early universe and of the evolution of the population, the luminosity distribution, and the clustering of these galaxies.

Dark Matter and dark energy: CCAT's high resolution images of the Sunyaev-Zel'dovich effect in hundreds of clusters of galaxies will illustrate in detail how clusters form and evolve, aiding the determination of the dark energy equation of state and other cosmological parameters from SZ survey catalogs.

Star Formation: CCAT will provide the first complete census of cold, dense Galactic molecular cores that collapse to form stars. In nearby clouds, CCAT will detect 0.08 $M_\odot$ cores, smaller than the lowest mass stars.

Protoplanetary and debris disks: CCAT will survey nearby young star clusters to determine the prevalence and evolution of protoplanetary and debris disks, identifying targets for high-resolution imaging with ALMA.

The Kuiper belt: CCAT will determine basic physical data – sizes and albedos – for hundreds of Kuiper belt objects.



CCAT Sensitivity

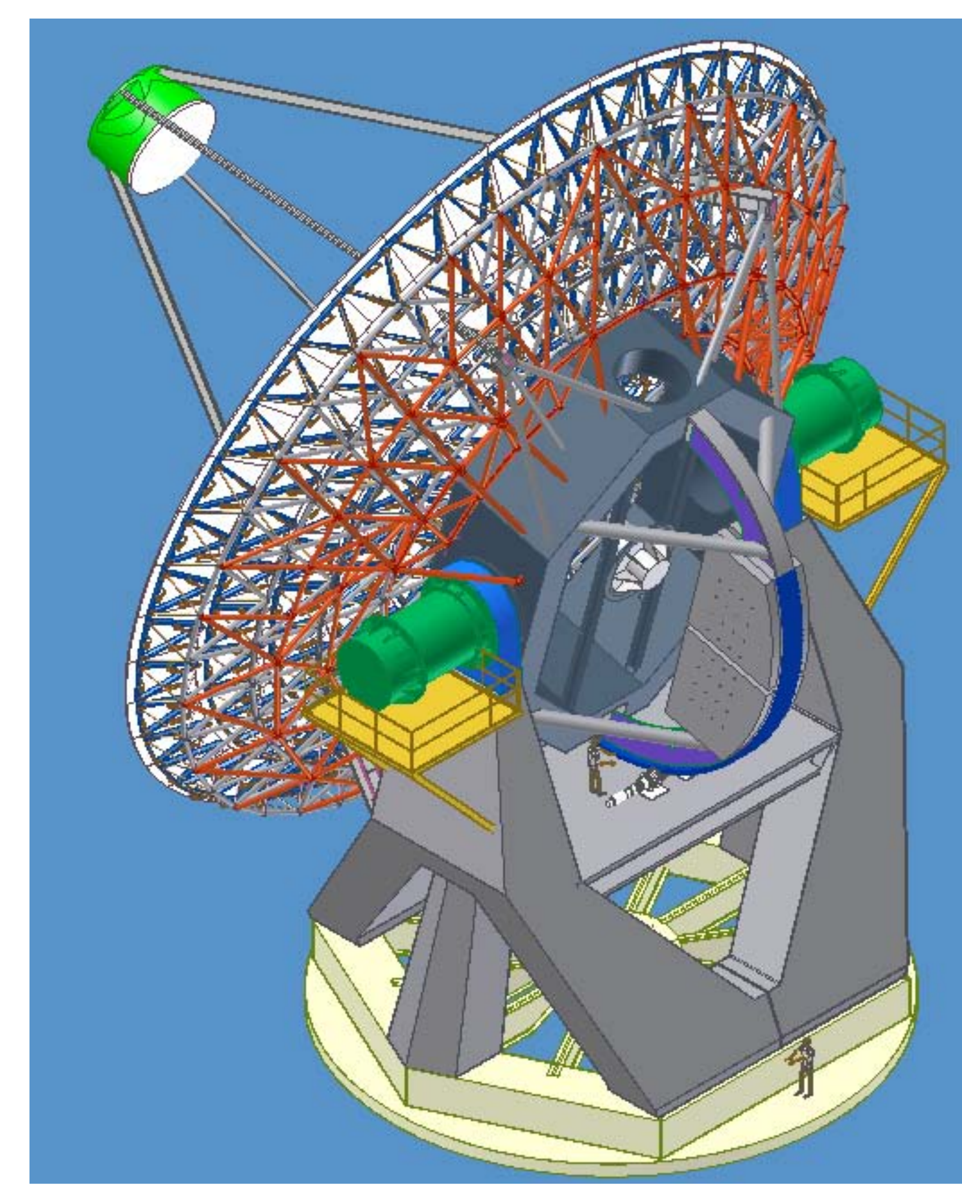
Equipped with large format bolometer arrays, CCAT offers superb sensitivity for deep surveys. Because of its wide instantaneous field of view, its mapping speed is an order of magnitude greater than any other instrument. Here the one hour, 5 σ sensitivity limits and the estimated confusion levels are compared for CCAT and several other instruments.

Telescope Concept

During the CCAT's scientific lifetime, bolometer arrays will become available that are many times larger than present instruments. To accommodate these large format cameras, the Ritchey-Chrétien optical design is optimized for a wide field of view. The telescope has an azimuth-elevation mount and is enclosed in a calotte style dome. Two Nasmyth foci outboard of the elevation bearings provide ample space for instruments. To achieve high aperture efficiency for short wavelength (200 μm) observations, an active surface adjustment system will be used with closed loop positioning of the primary mirror panels. The mirror surface will be measured with holographic observations of planets. Edge sensors and optical angle and distance metrology are among the techniques under consideration for maintaining the panel alignment.

Performance Goals

Aperture	25 m diameter
Wavelength	200–2200 μm
Field of view	20′
Pointing	0.2″
Half wavefront error	10 μm rms
Primary focal ratio	0.4
Nasmyth focal ratio	8.0
Site altitude	5600 m
Water vapor (median)	< 1 mm



Concept design of the CCAT structure. Major instruments will be mounted at the Nasmyth foci outside the elevation bearings. Hydrostatic azimuth bearings support the alidade.

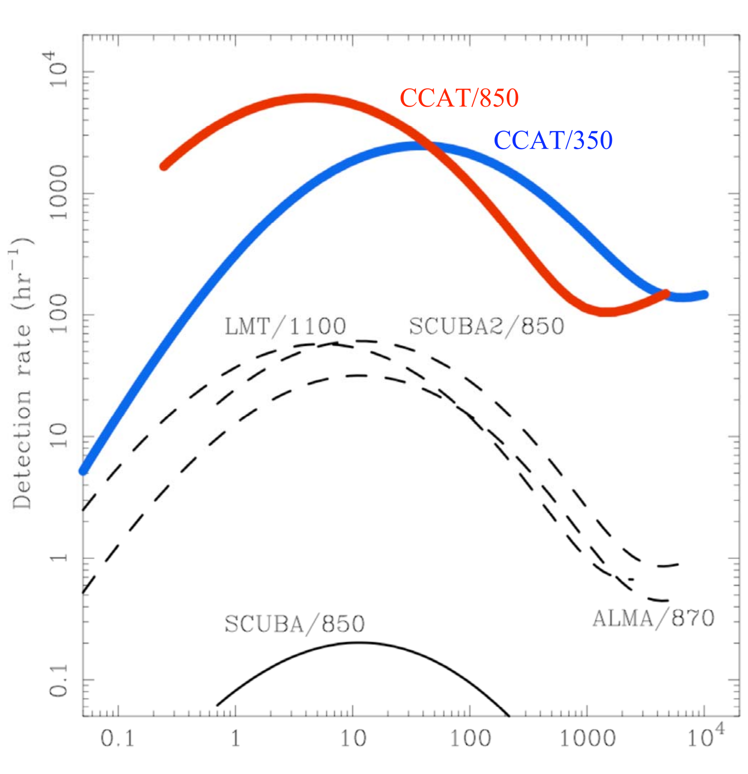
VertexRSI

Project Schedule

Feasibility Concept Design Study	2005–2006
Feasibility Study Review	2006 Jan
Technical Development	2006–2007
Subsystem Development	2008–2010
Construction & Integration	2010–2013
Commissioning	2013–2014

CCAT and ALMA

The CCAT is a powerful complement to ALMA. With its tremendous collecting area, flexible configuration, advanced receivers, and powerful correlator, ALMA will excel at high resolution imaging and spectroscopy. CCAT, on the other hand, will emphasize wide field continuum surveys. At short wavelengths, where the continuum point source sensitivities of CCAT and ALMA are similar, a large format bolometer camera on CCAT is far more efficient for large area surveys and mapping.



Submm Galaxy Surveys

CCAT surveys will detect hundreds of thousands of submillimeter galaxies from the most intense era of galaxy formation at z = 1–4. This enormously rich catalog will identify prime candidates for follow up and detailed study with ALMA. Here the estimated submillimeter galaxy detection rate for CCAT with a modest 32 × 32 (1024) pixel camera is compared with some other facilities: JCMT/ SCUBA2 at 850 μm, LMT at 1100 μm, and ALMA at 850 μm. These estimates incorporate fields of view, sensitivities, the density of galaxies on the sky, and the confusion limit (cutoff to curves on the left). Even with this modest camera, CCAT has a much higher detection rate than the other facilities. Moreover, the planned CCAT cameras are substantially larger, further increasing the detection rate.

Instrumentation

CCAT's scientific objectives emphasize wide field imaging and surveys, large cameras are planned as initial facility instruments. Both cameras will use closed cycle cryogenics consisting of pulse tube coolers followed by ^{4}He and ^{3}He or ADR stages. A short wavelength (200–620 μm) camera will Nyquist sample a 5′ × 5′ field of view at 350 μm with an array of 32,000 directly illuminated TES silicon bolometers of the type now produced for SCUBA2. Mesh filters well matched to the atmospheric windows and mounted in a wheel immediately behind the Lyot stop select the observing wavelength.

Extending the technology now under development for the CSO, the long wavelength (740–2000 μm) camera will use an array of slot dipole antenna coupled MKID resonators with frequency bands separated by microstrip bandpass filters to provide simultaneous multicolor observations. The central 10′ field is Nyquist sampled at 850 μm and the telescope's entire 20′ diameter field of view is fully sampled at longer wavelengths. These cameras are challenging, but can be achieved with modest advances in the current array technologies.

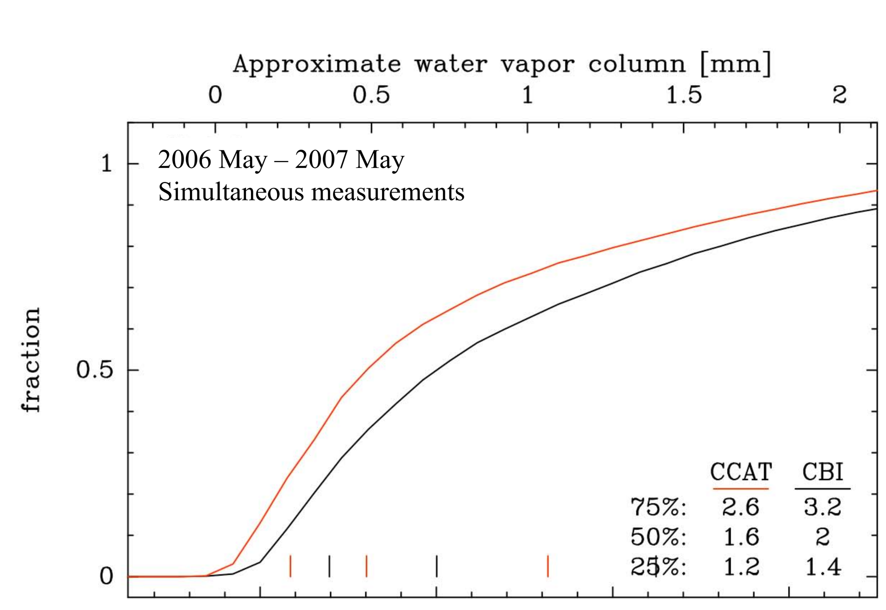
There is considerable interest in spectroscopy with CCAT, and concepts for both multiobject direct detection grating spectrometers and heterodyne receiver arrays are being explored. Existing instruments will be brought to CCAT to enhance the scientific yield of the two cameras. Although these existing instruments cannot accomplish all the primary CCAT science objectives, they will provide important supplementary capabilities, especially in the early years of operation.

The Site

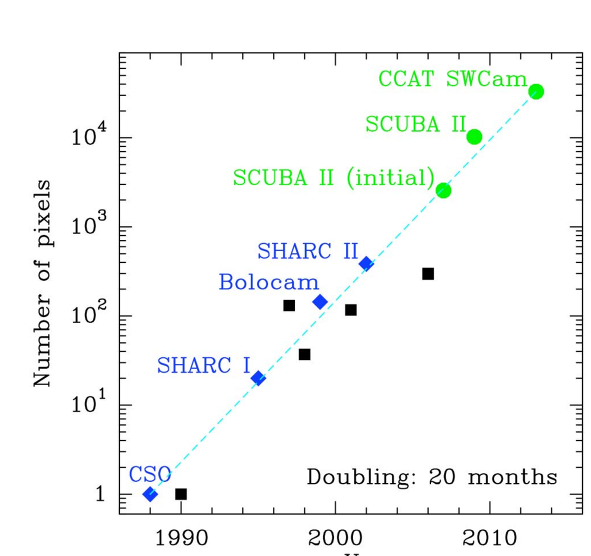
Consistently superb observing conditions are crucial for achieving the CCAT's scientific objectives. The high mountains in the vicinity of San Pedro de Atacama in northern Chile, among the driest places on Earth, offer several possibilities. At the 5000 m Chajnantor plateau, site of the CBI, APEX, and ALMA telescopes, long term measurements demonstrate conditions are among the best known. During the winter, May to August, of 2000 the median PWV was 0.6 mm. Under typical conditions, the PWV is 2-4 times lower at night than during the day. Ground based observations at super-terahertz frequencies are possible about 15% of the winter time.

Even better conditions prevail on nearby mountain peaks. For CCAT, we have selected a candidate site at 5612 m near the summit of Cerro Chajnantor, about 5 km NNE of ALMA, where an access road has been constructed by the University of Tokyo. In 2006 May, we deployed instruments to evaluate observing conditions at this site. Simultaneous measurements of the 350 μm atmospheric transparency at the CCAT site and at the CBI during this past year (2006 May – 2007 May) show the transparency is consistently better at the higher site. These instruments continue to accumulate data.

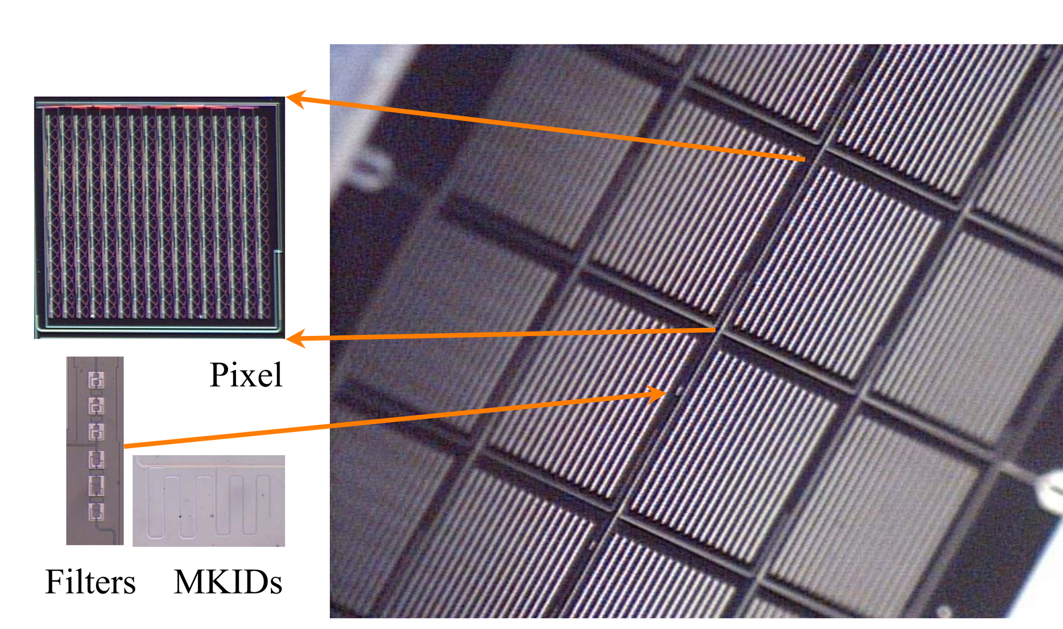
Site evaluation instruments on the candidate CCAT site at 5612 m near the summit of Cerro Chajnantor, Chile (G. Gull).



Apparent 350 μm zenith optical depth measured simultaneously at the candidate CCAT site and at the CBI.



Historical development of (almost) background limited, submillimeter bolometer array cameras.



Prototype two color (1300 μm and 850 μm) antenna coupled focal plane. Each pixel is a 16 × 16 slot dipole array coupled through microstrip filters to MKID resonators (insets; A. Vayonakis).

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CCAT Project **http://www.submm.org**

The Cornell Caltech Atacama Telescope is a joint project of Cornell University, the California Institute of Technology with the Jet Propulsion Laboratory, the University of Colorado, the University of British Columbia leading a Canadian university consortium, and the UK Astronomy Technology Centre on behalf of the UK community.

2008 May

Far-Infrared Astronomy from Space

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