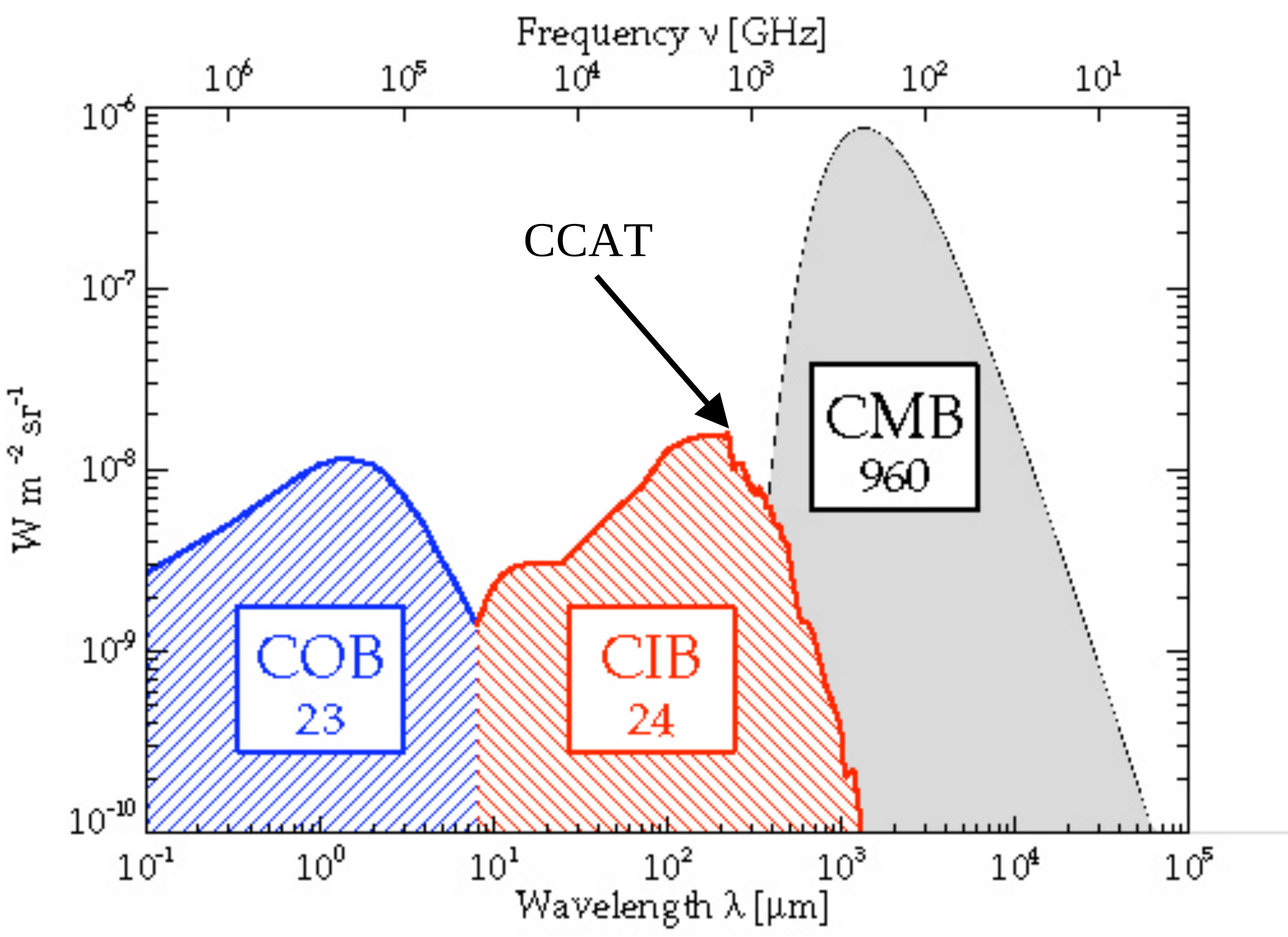
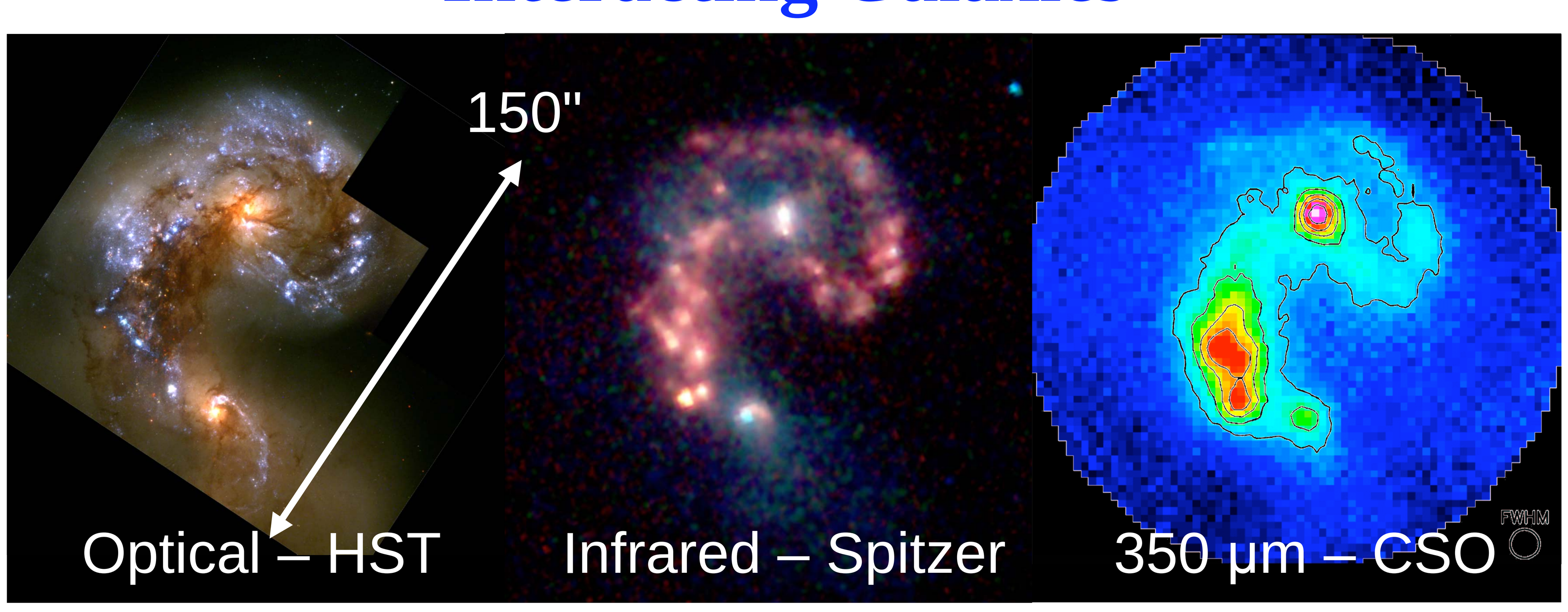
Submillimeter Astronomy with CCAT

All the Light in the Universe



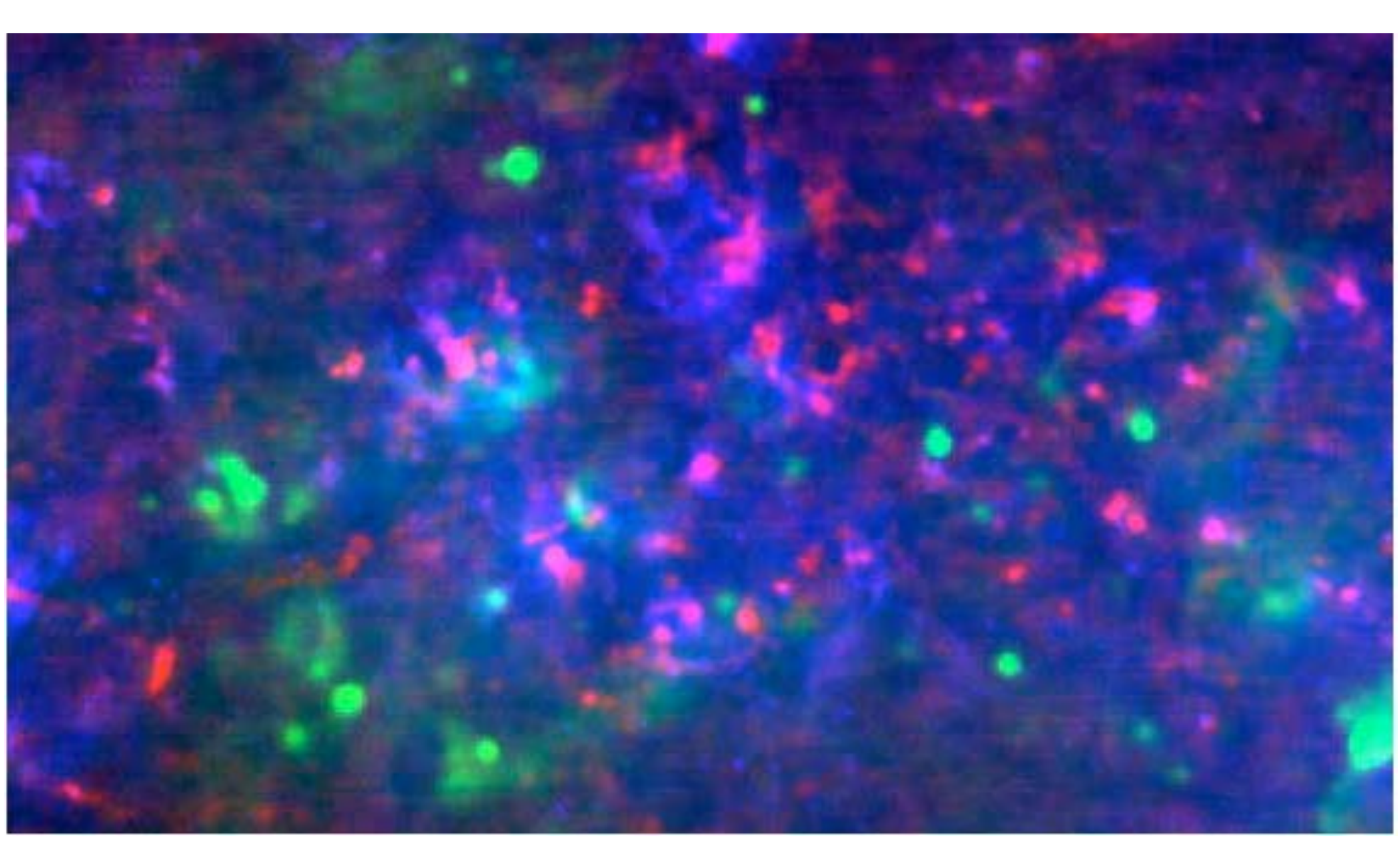
CCAT surveys will catalog distant dusty start-burst galaxies that emit the reprocessed starlight making up the FIR – submm background, which equals the energy density of the optical background (Dole et al. 2006).

Interacting Galaxies



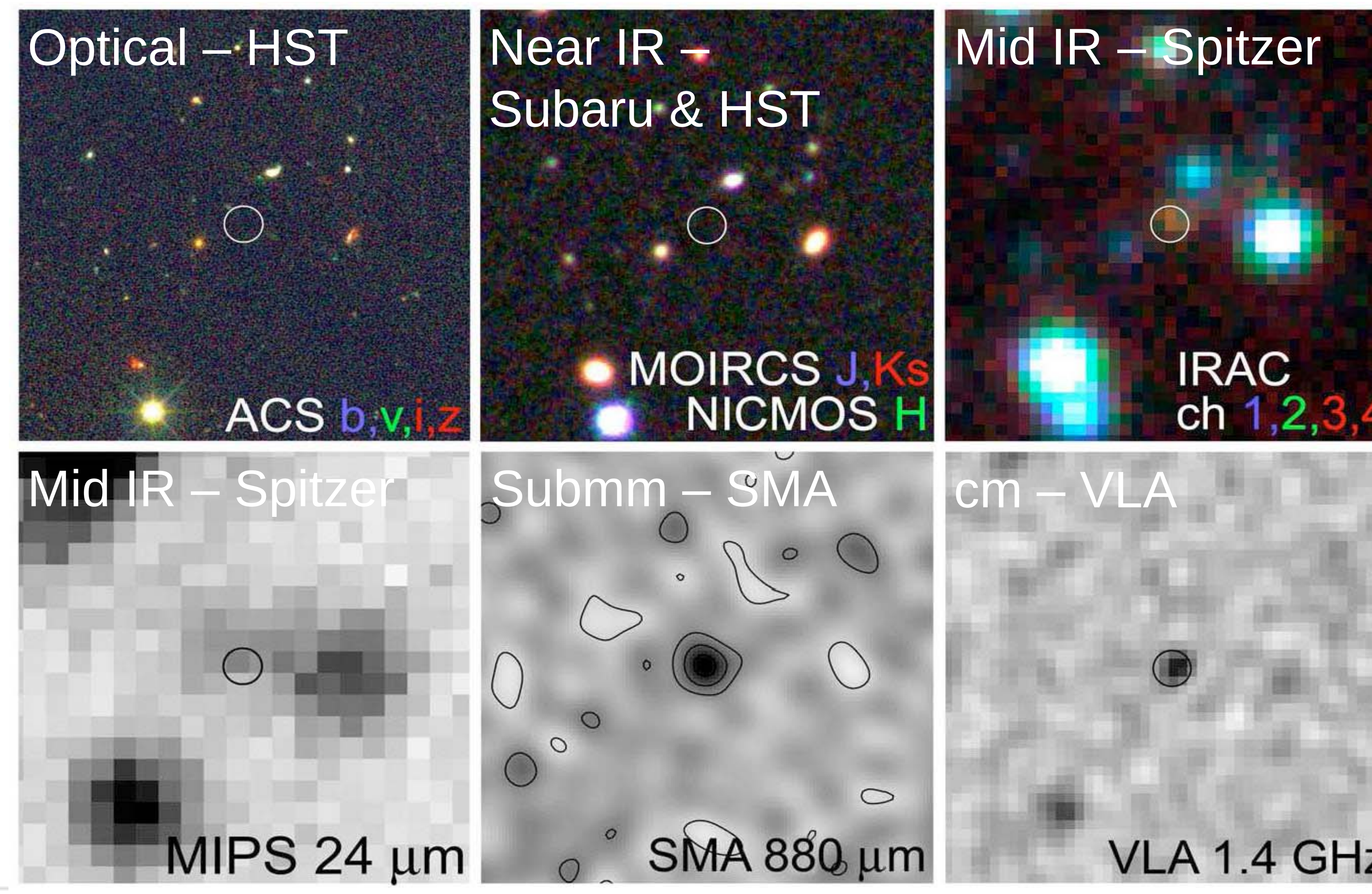
In the Antennae, regions of active star formation hidden by interstellar dust at optical wavelengths are revealed in the submillimeter, where the majority of the luminosity emerges. Mapping this galaxy would require hundreds of pointings with ALMA. CCAT will provide a submillimeter image with a spatial resolution similar to the infrared image.

Galactic Star Formation



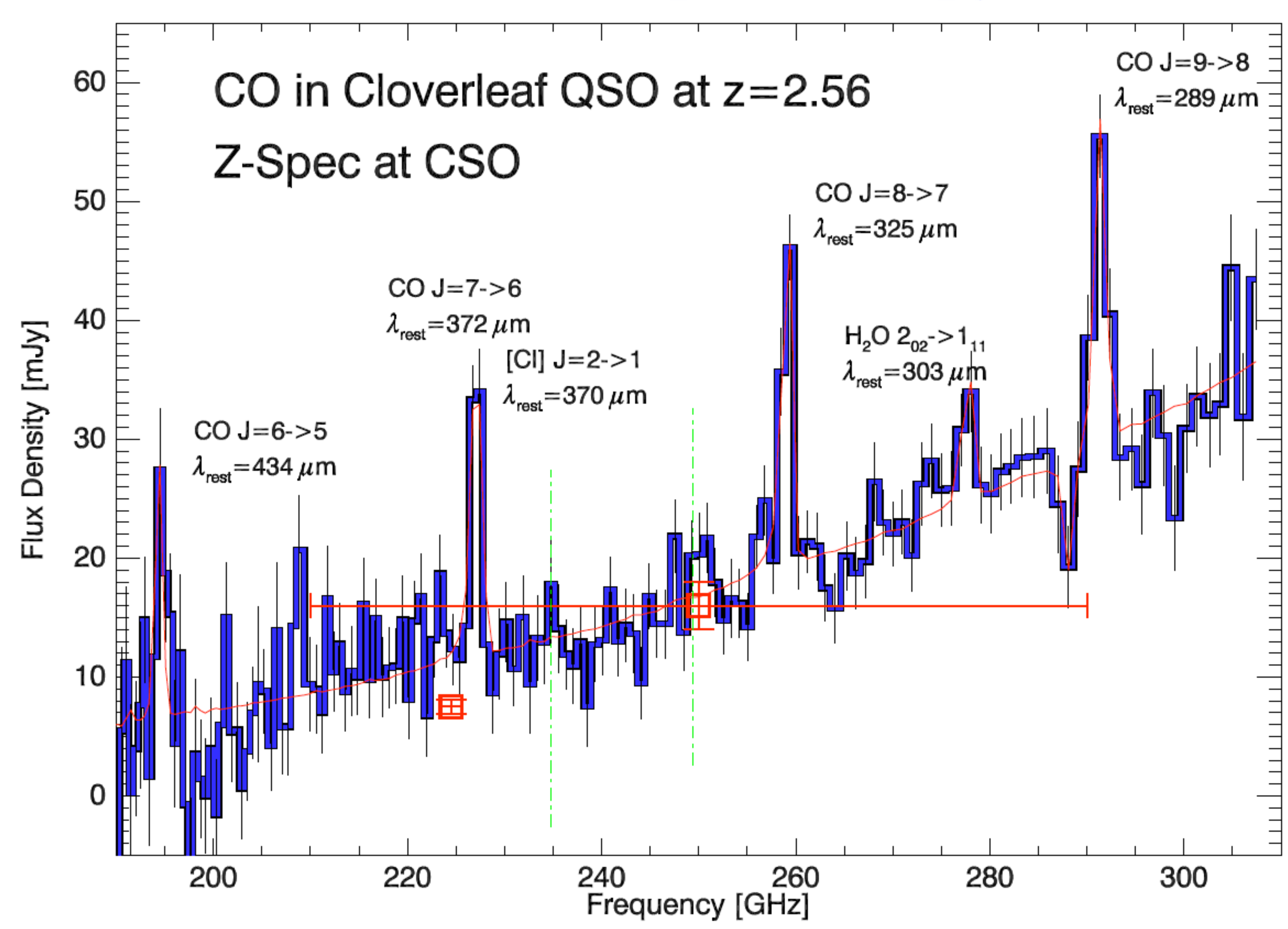
1.1 mm (CSO), **8 µm (Spitzer)**, **20 cm (VLA)**

Obscured Distant Starbursts



Even though Goods 850-5 is the second brightest submillimeter source in the Goods survey, it is invisible at optical and near infrared. Likely an obscured starburst at high redshift, $z > 4$, it is one of the most luminous galaxies known (Wang et al. 2008). Surveys with CCAT will discover many more of these rare objects with sufficient angular resolution for direct identification and follow up.

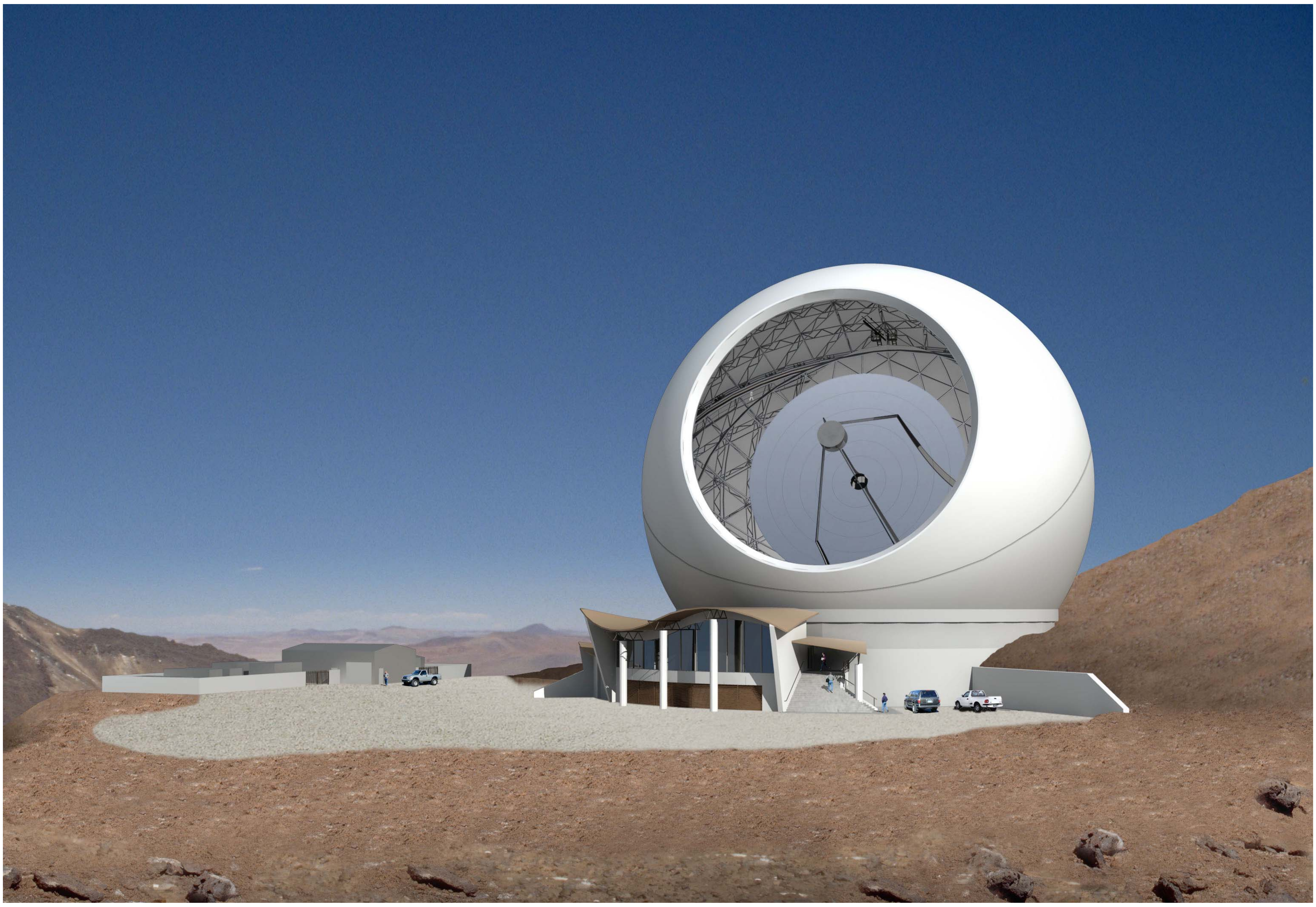
Wide Band Spectroscopy



Strong molecular and atomic lines in a wide band spectrum of the Cloverleaf illustrate the potential of submm spectroscopy for determining the redshifts of distant dusty startburst galaxies (Bradford et al.). With similar instrumentation, CCAT will measure spectroscopic redshifts for the galaxies discovered in its complement continuum surveys.

Galactic Plane Survey: Dense cloud cores, the best tracers of star formation, are key to understanding massive stars and star clusters (Bally et al.). CCAT will provide a complete census of these cores, reaching $< 0.1\ M_\odot$ in nearby clouds.

The Cornell Caltech Atacama Telescope (CCAT)

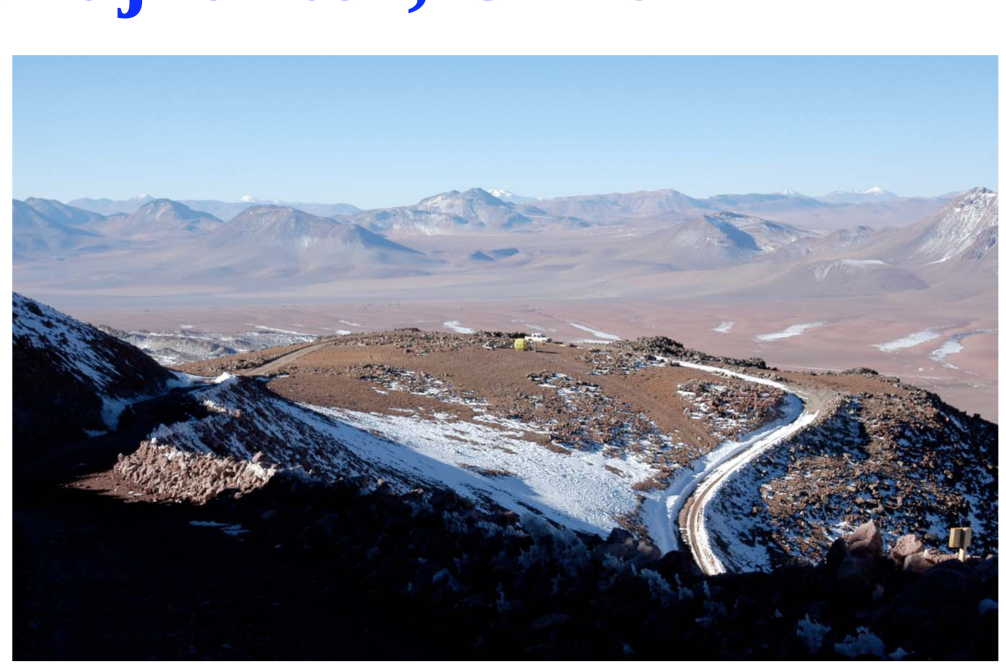


The CCAT Project

Submillimeter astronomy is poised for major advances in the coming decade. The international ALMA interferometer will provide a powerful facility for detailed studies of individual objects. A 25 m diameter telescope for optimized for wide field submillimeter imaging and surveys, CCAT is conceived to complement ALMA. With high sensitivity continuum cameras, CCAT will have a survey speed many times higher than any other facility. CCAT will be the largest and most sensitive facility of its class. CCAT will capitalize on continuous innovations in instrumentation to address a broad range of scientific opportunities.

The Site: Cerro Chajnantor, Chile

Consistently superb observing conditions are crucial for CCAT's scientific objectives. At 5612 m on Cerro Chajnantor, about 600 m above ALMA, the CCAT site enjoys a median PWV about 700 µm during the winter.



Design Study

A Feasibility Concept Design Study developed technical specifications for the telescope and evaluated technological approaches. Subsequent technical development has led to an Engineering Design in preparation for construction.

Performance Goals

Aperture	25 m diameter
Wavelength	200–2200 µm
Field of View	20 arcmin
Resolution (diffraction)	3.5″ @ 350 µm
Pointing (offset)	0.2″ (rms)
Half Wavefront Quality	< 10 µm rms
Site altitude	5600 m
Atmospheric Water Vapor	< 1 mm (median)

Schedule

Feasibility Concept Design	*Completed* 2006
Consortium Development	2006–2007
Technical Analysis	2006–2008
Engineering Design	2009–2011
Construction & Integration	2011–2014
Commissioning	2014–2015

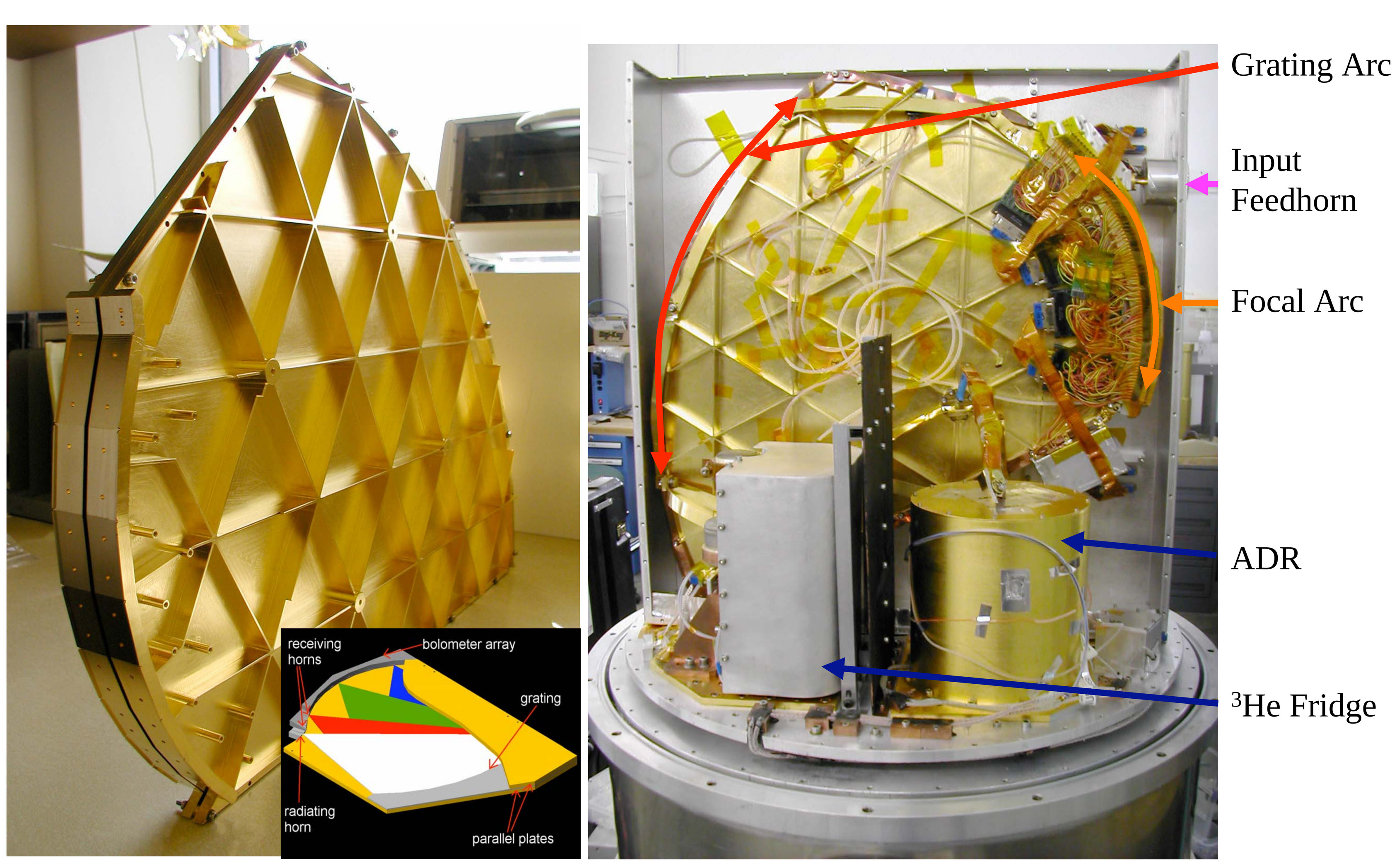
Novel Instrumentation for CCAT

Innovation Enables Observations

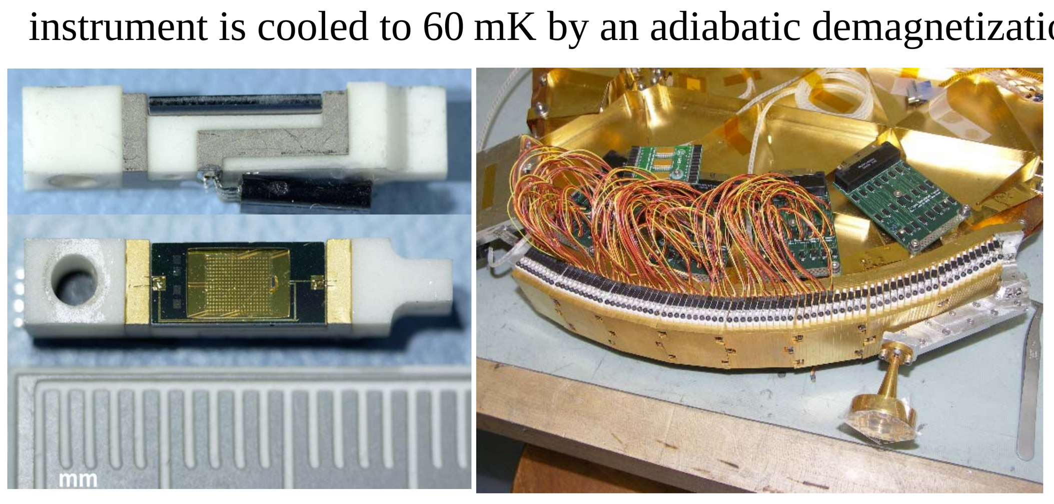
Astronomical discoveries are enabled by advances in instrumentation. Achieving CCAT's scientific objectives will be possible because of continuous technological innovation. Furthermore, CCAT will provide a platform for deployment of novel instrumentation. Because CCAT emphasizes surveys and wide field imaging, the primary instrumentation will be large format cameras. In addition, there is considerable interest in spectroscopy. Especially at the begining, existing instruments will be brought to CCAT to enhance the scientific return.

Grating Spectrometer

A grating spectrometer, Z-Spec exemplifies novel instrumentation for CCAT. Z-Spec can record a moderate resolution background limited spectrum of the entire 200–300 GHz atmospheric window at one time. It is ideal for line surveys of nearby IR bright interacting and starburst galaxies and for determining the redshift of distant dusty submillimeter bright galaxies. For CCAT, a mulitobject instrument would permit simultaneous study of an entire field.



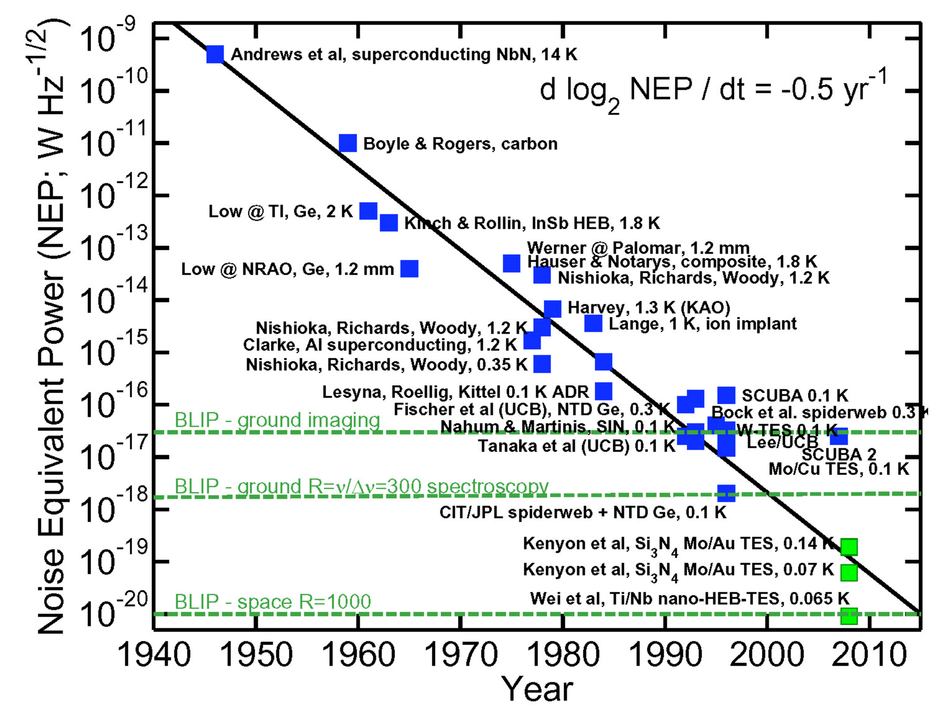
Z-Spec: *Left:* Waveguide structure with 2.5 mm spacing. *Insert:* Light from the input feedhorn is dispersed by the Roland grating to illuminate detectors along the focal arc. *Right:* The entire instrument is cooled to 60 mK by an adiabatic demagnetization refrigerator. (Bradford et al.)

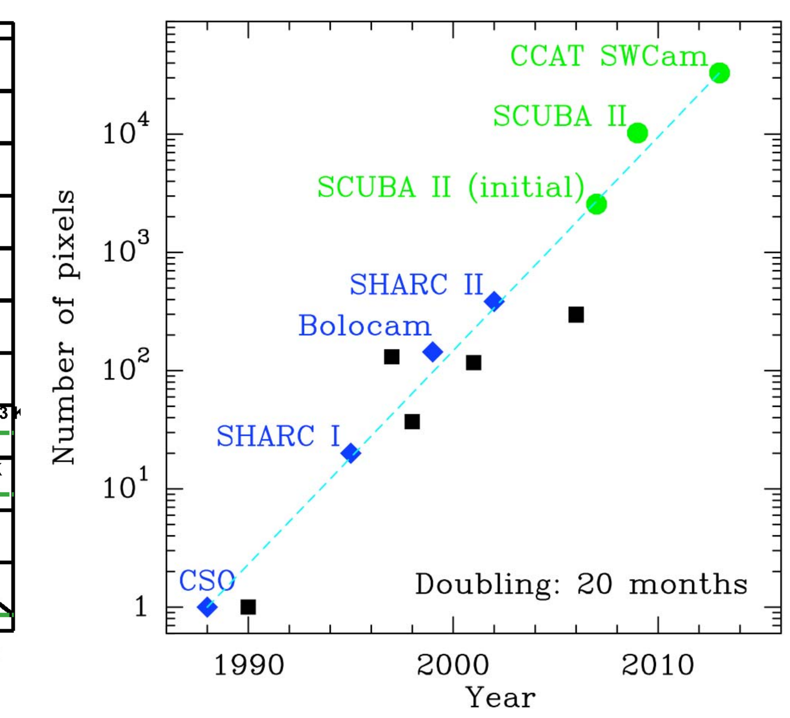


Left: Individual detectors are silicon nitride micromesh bolometers with NTD germanium thermistors, similar to those used on Herschel SPIRE.

Right: The focal arc has 80 individually mounted bolometers on bend blocks. Another 80 detectors are on the bottom. Input feedhorn at lower right.

Detector Improvement

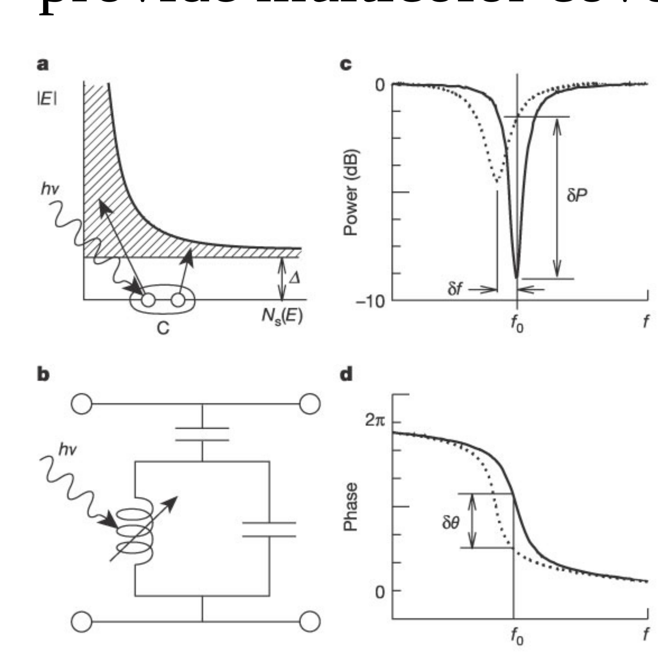




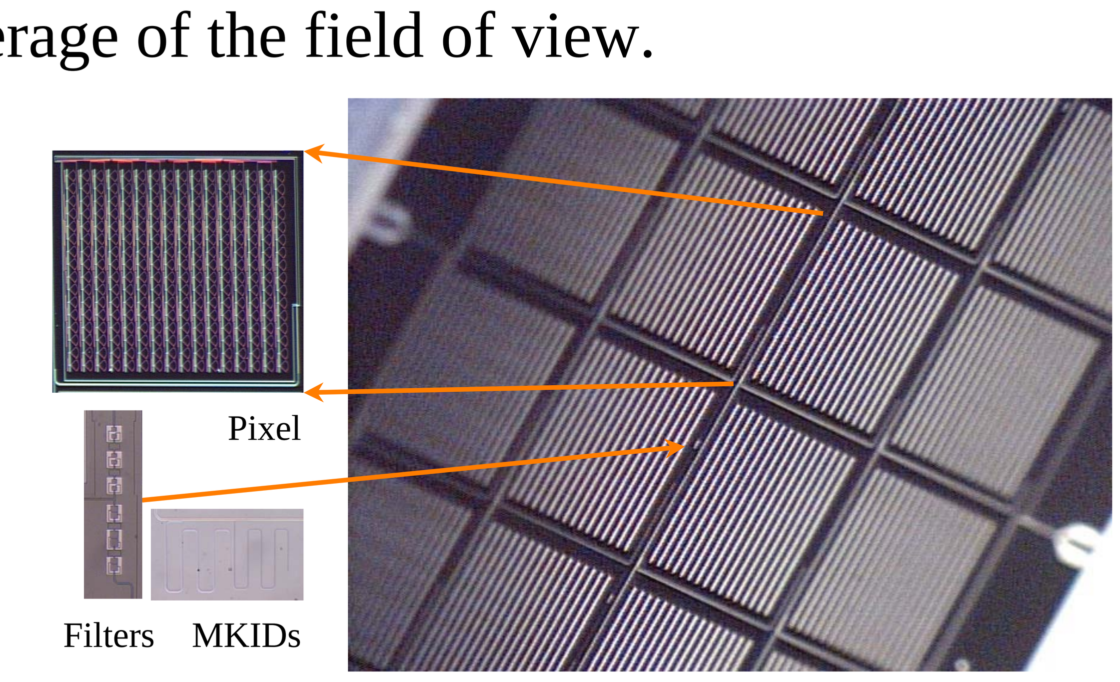
Over the past half century, the sensitivity of bolometer detectors for submillimeter wavelengths has improved by a factor of 10 billion, roughly doubling every two years. Since 1990, the size of bolometer array cameras has doubled every 20 months.

MKID Cameras

Pioneered at Caltech and JPL, microwave kinetic inductance detectors (MKIDs) are an emerging technology for submillimeter cameras. After successful astronomical tests of a 16 pixel, two color protoype, a 24 × 24 pixel, four color instrument is now under construction for the CSO. For CCAT, a concept long (740–2000 μm) wave-length camera uses an MKID array to provide multicolor coverage of the field of view.



MKID principle of operation. Absorbed photons break Cooper pairs in a superconductive film (a), creating quasiparticles and changing its impedence. The resulting shift of the resonance amplitude (c) and phase (d) in a surrounding circuit (b) can be measured (Day et al. 2003).



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

CCAT Consortium

http://www.submm.org

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The CCAT Consortium includes Cornell University, the California Institute of Technology with the Jet Propulsion Laboratory, the University of Colorado, the University of British Columbia for a Canadian university consortium, the UK Astronomy Technology Centre on behalf of the UK community, and the Universities of Cologne and Bonn.

Cornell University   UBC   Science & Technology Facilities Council UK Astronomy Technology Centre   JPL   CALTECH

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