CCAT Spectroscopy Opportunities

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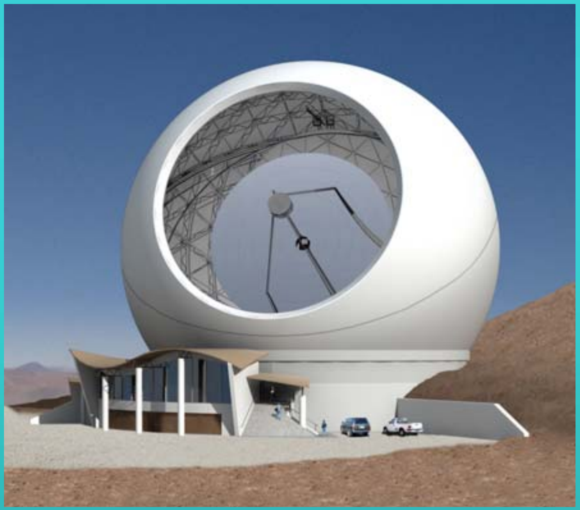
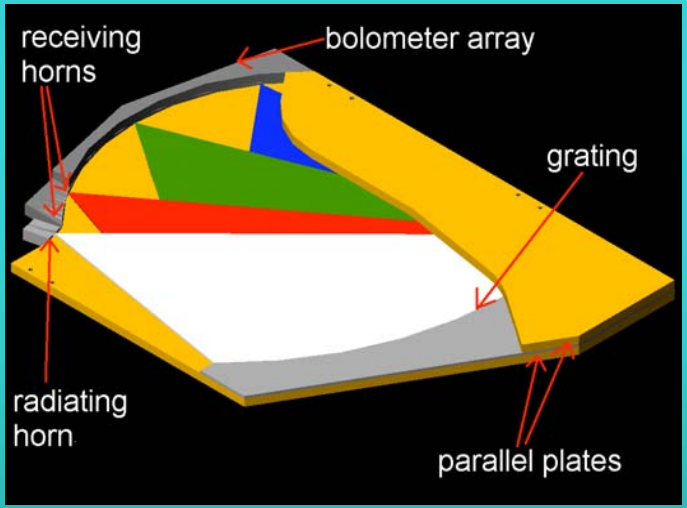
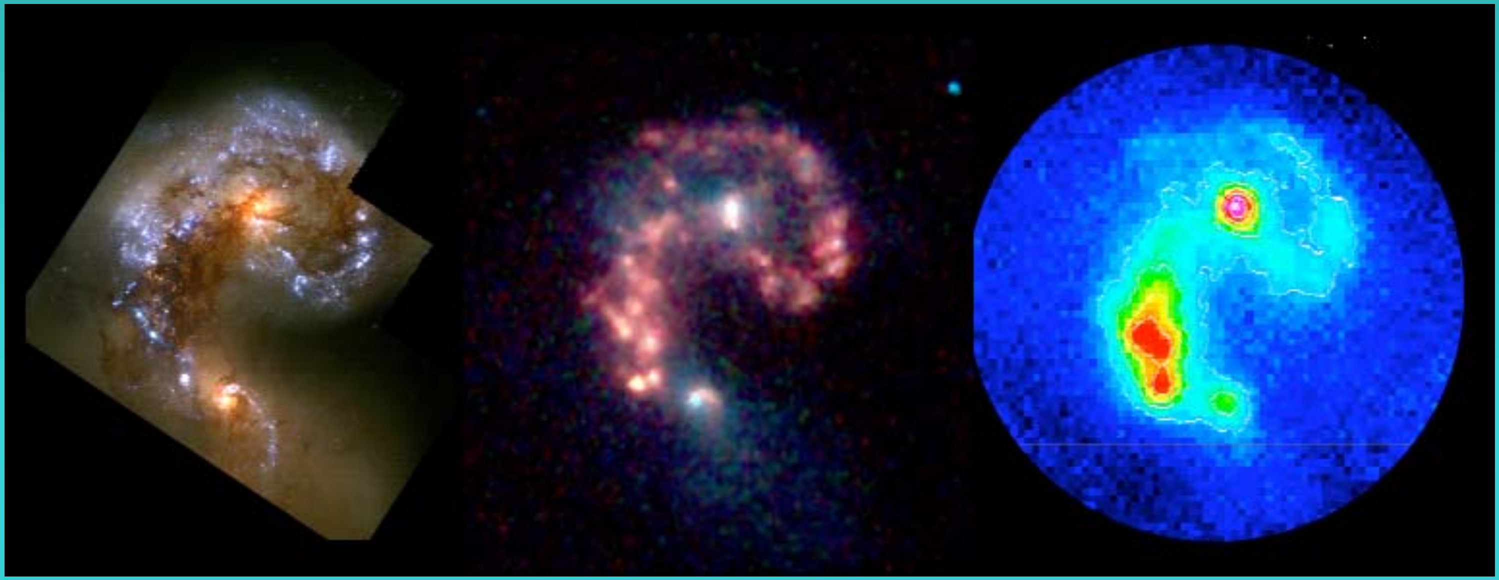




CCAT Workshop
Spectroscopy with CCAT: Science and Instrumentation Opportunities
Boulder, CO
May 13 &14, 2008

Brief Background

The Antenna Galaxies



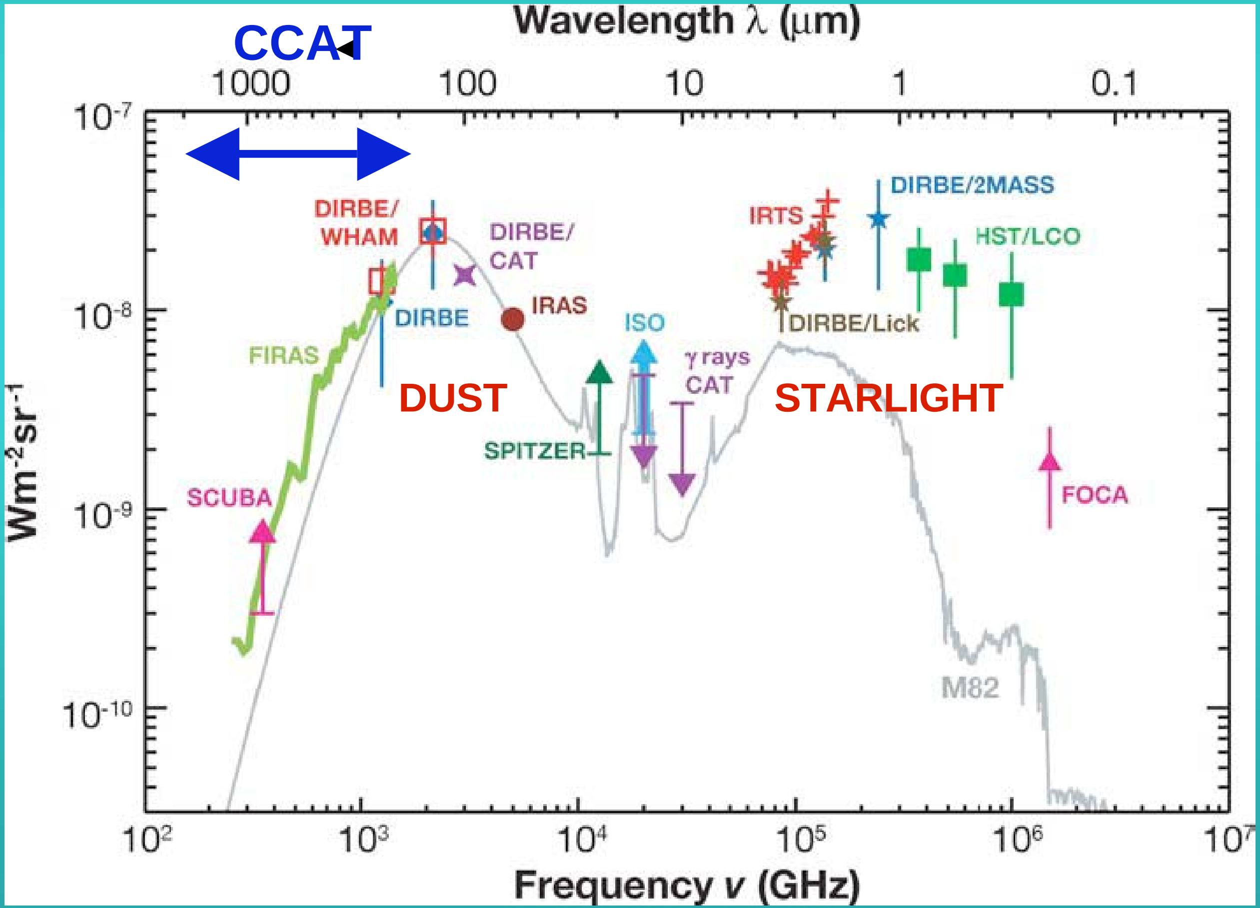
Visible (*HST*) Near-Infrared (*Spitzer*) Submillimeter (CSO)

The interstellar medium in galaxies obscures star formation and supermassive black hole formation, intercepting optical & UV radiation and reemitting it in the infrared and submillimeter.

For a realistic model of galaxy formation, we must understand the galaxies that give rise to the (enormous)

Cosmic Far-Infrared Background Radiation

COBE (1996): The Cosmic FIR background nearly equals the extragalactic optical/UV background → dust-obscured galaxy (star) formation

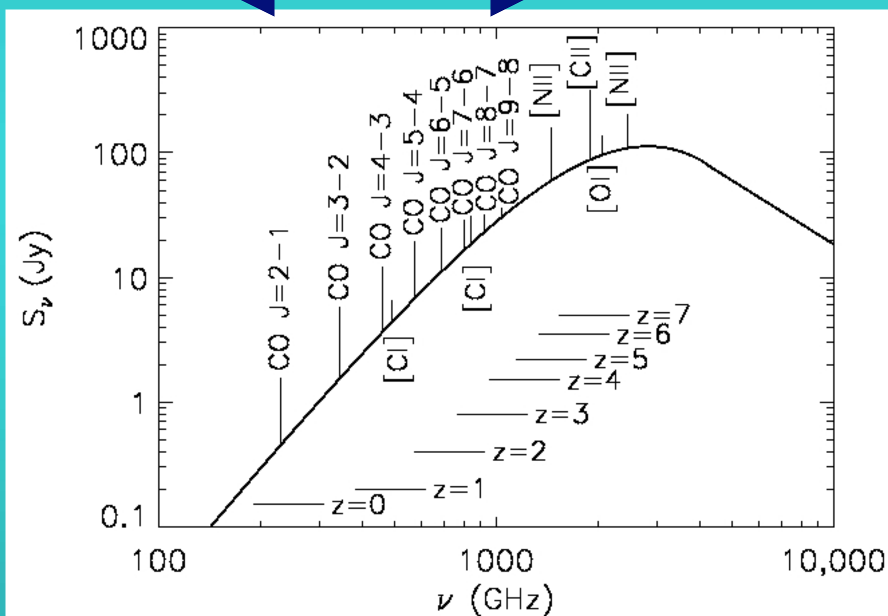


Lagache, Puget, & Dole 2005

Millimeter-Wave-to-Far-Infrared Spectra

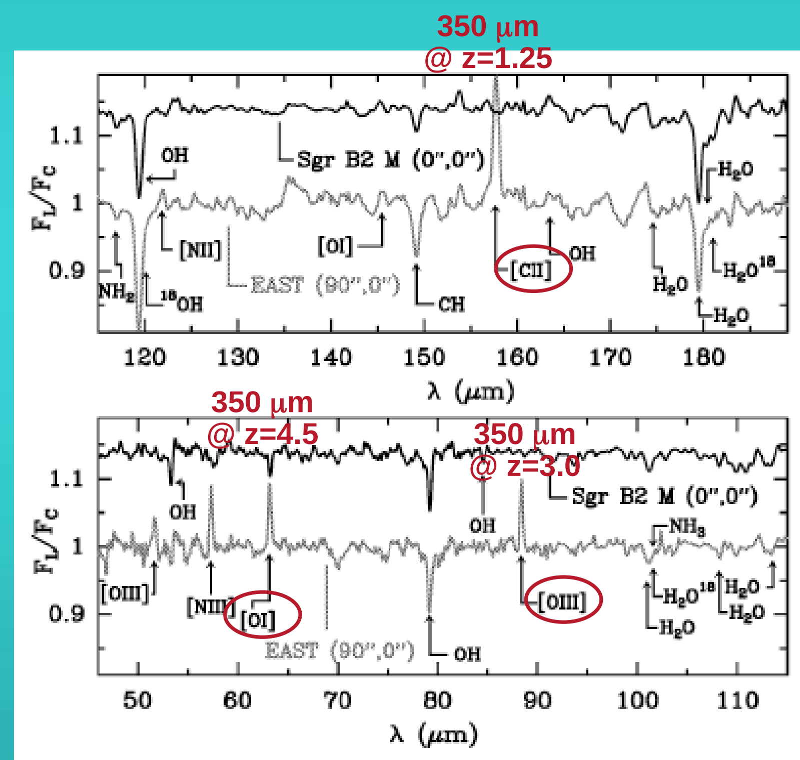
Rest-frame Sub/Millimeter

CCAT



Model Spectrum

Rest-frame Far-Infrared: Redshifted into submillimeter for z ≥ 1

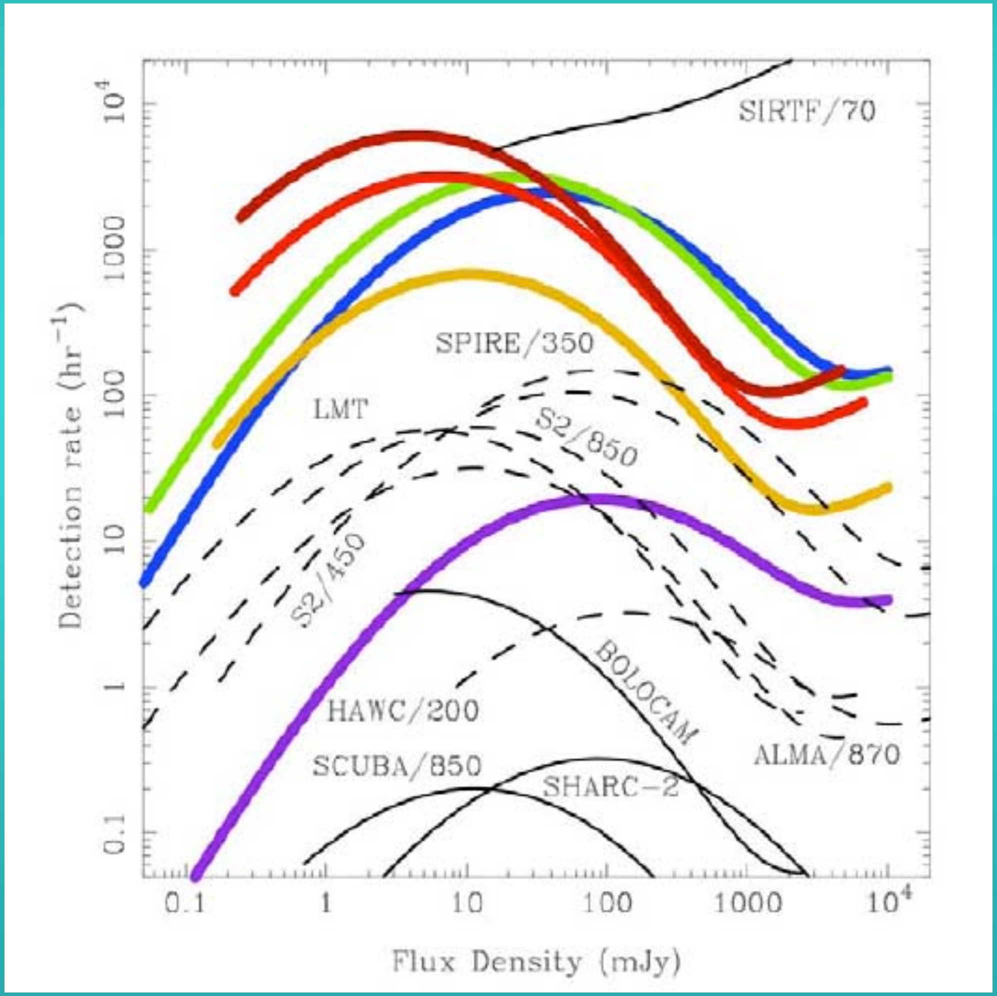


Sgr B2 Spectrum, ISO LWS, Goioechea et al. 2003

More from Mike Shull, Gordon Stacey, & Jeremy Darling

CCAT Will Become Overwhelmed Quickly with Its Own New Galaxy & Protostar Catalogs

Detection rates of distance submillimeter-emitting galaxies (A. Blain)



CCAT 32x32 detector array
200 μm
350 μm
450 μm
620 μm
750 μm
850 μm

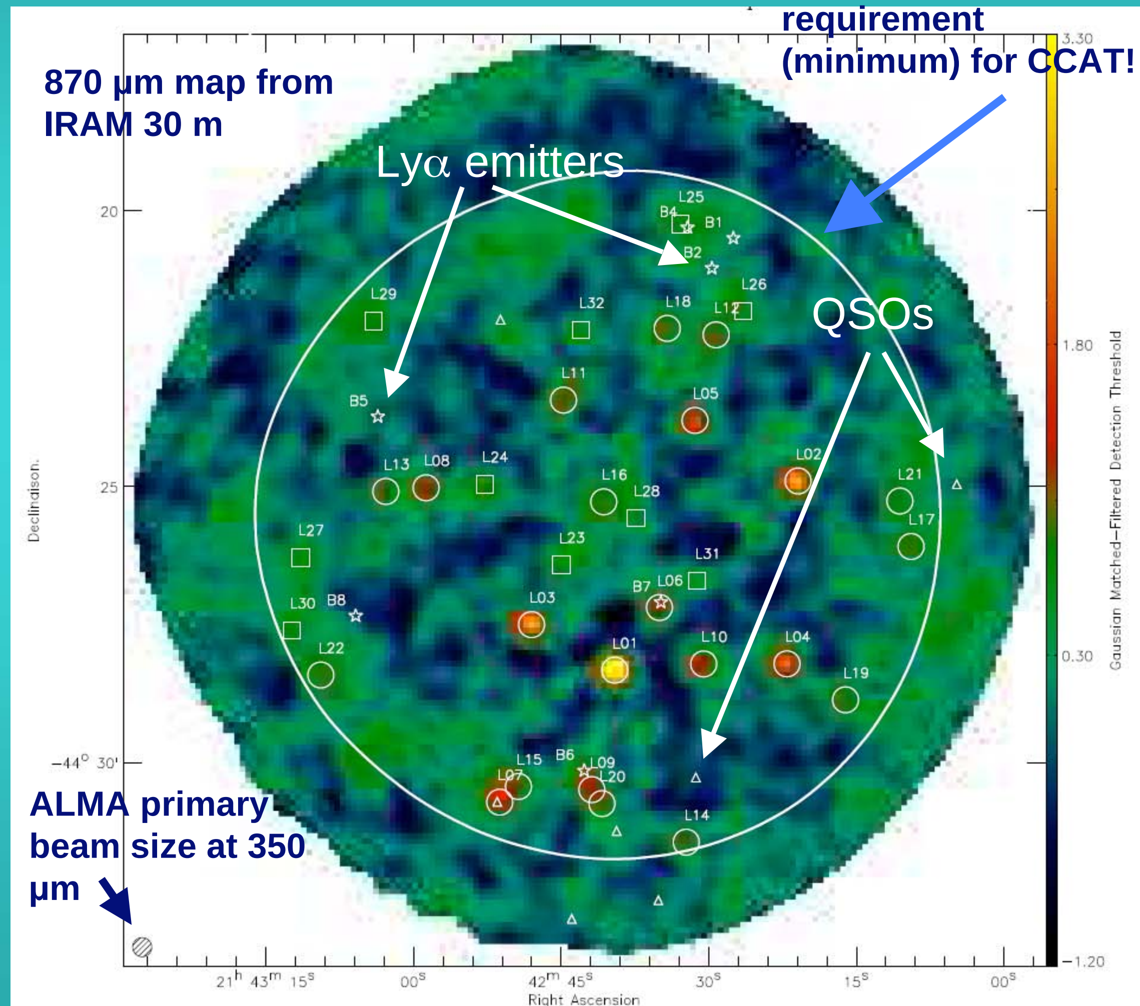
Why Do We Need *Multi-Object* Spectroscopic Capability?

→ Speed of follow-up & galaxy clustering

Submillimeter galaxies in the vicinity of z = 2.38 Lyα clouds J2143-4423
(Galaxy “protocluster”?)
Circles: probable detections (22)
Squares: possible detections (10)

Photometric redshifts indicate seven or more 5 – 20 x 10^{12} L_{solar} galaxies with 2.0 < z < 2.8
⇒ *spectroscopic* redshifts are needed.

Approximate F.O.V. requirement (minimum) for CCAT!



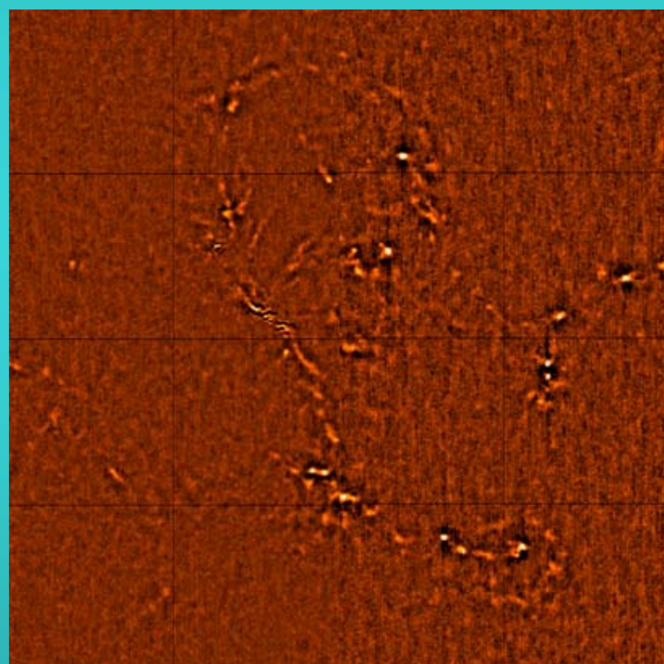
Beelen et al., astro-ph/0803.1615

Why Do We Need *Multi-Object* Spectroscopic Capability?

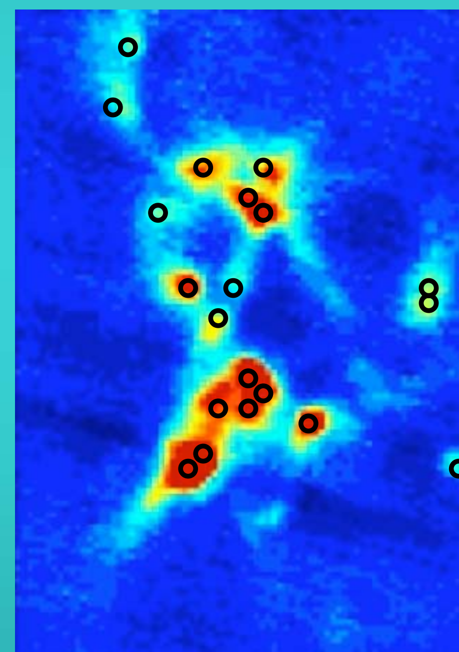
→ Sites of star formation are clustered

Bolocam 2 ° × 2° 1.1 mm continuum

Bally, Glenn, Aguirre, Drosback, Ginsburg, + UTexas & UBC



NGC1333, Bolocam
Enoch et al. 2006

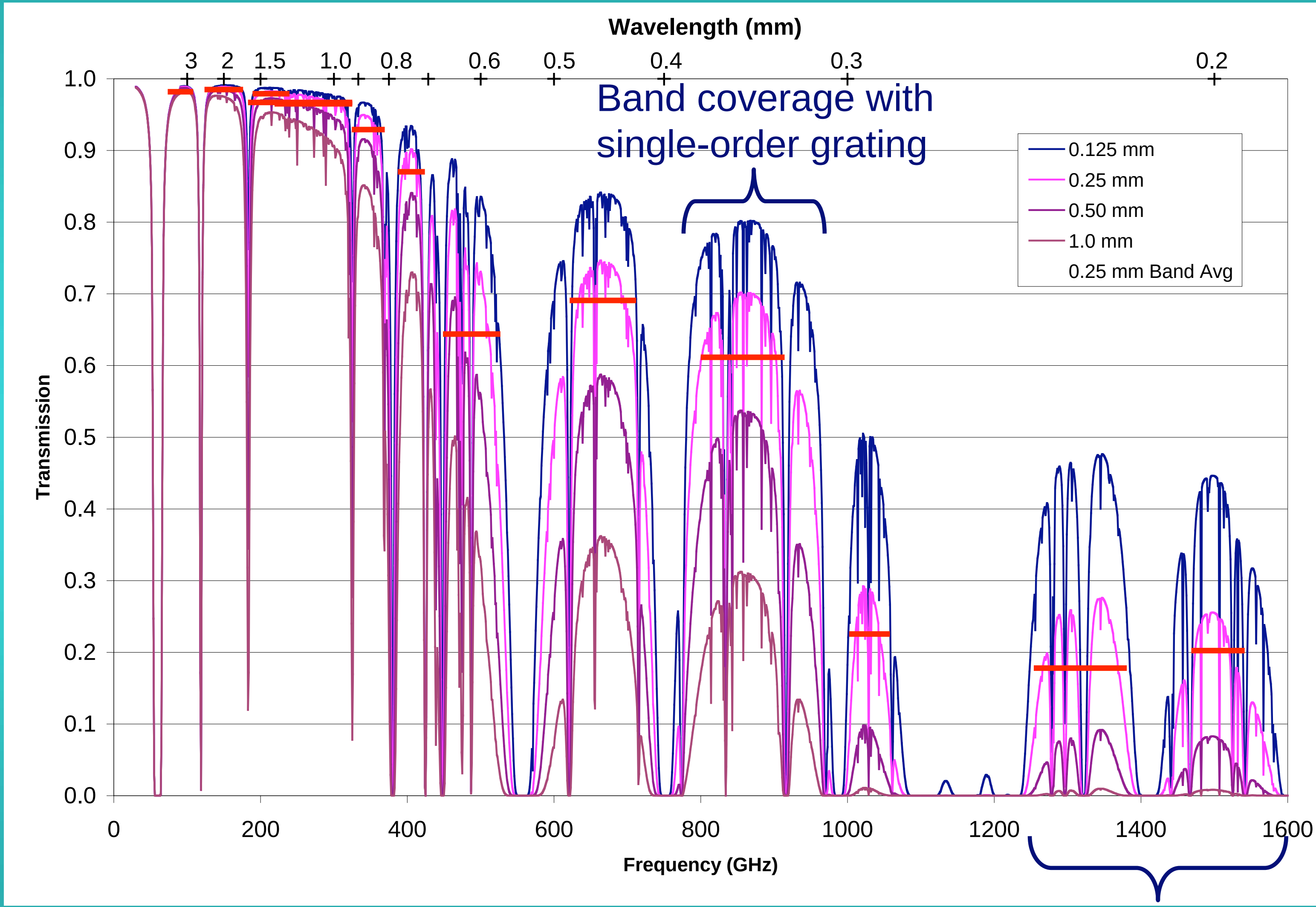


20´

CCAT Goal FOV; 20 fibers

More from Crystal Brogan & Chris Walker on heterodyne-receiver array mapping

CCAT Atmospheric Transmission Windows



Usable during the best weather

Simple Observing Speed Comparison

Assuming
- Identical atmospheric transmission (conservative for CCAT)
- Identical telescope surface RMSs (conservative for CCAT)
- Identical spectrometer sensitivities (very conservative for CCAT)
- Spectral resolution of R ~1,000 for line survey & redshift measurement

⇒With only one beam (i.e., one object, one fiber), CCAT do quick line surveys & redshift measurements with the same speed as ALMA

⇒With a handful of fibers & realistic sensitivities, CCAT would be >10x faster than ALMA in the 350 μm window

$$\frac{SPEED_{CCAT}}{SPEED_{ALMA}} = \frac{N_{CCATBeams}}{N_{ALMATelescopes}} \left(\frac{D_{CCAT}}{D_{ALMA}}\right)^2 N_{ALMATunings}$$

$Set:$

$$\frac{SPEED_{CCAT}}{SPEED_{ALMA}} = 1$$

$Solve\ for\ N_{CCATBeams}$

$$N_{ALMATelescopes} = 50$$

$$D_{CCAT} = 25m$$

$$D_{ALMA} = 12m$$

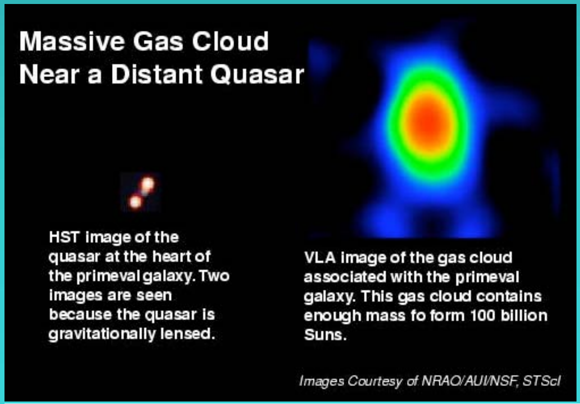
$$N_{ALMATunings} = 10$$

$$N_{CCATBeams} \cong 1!!$$

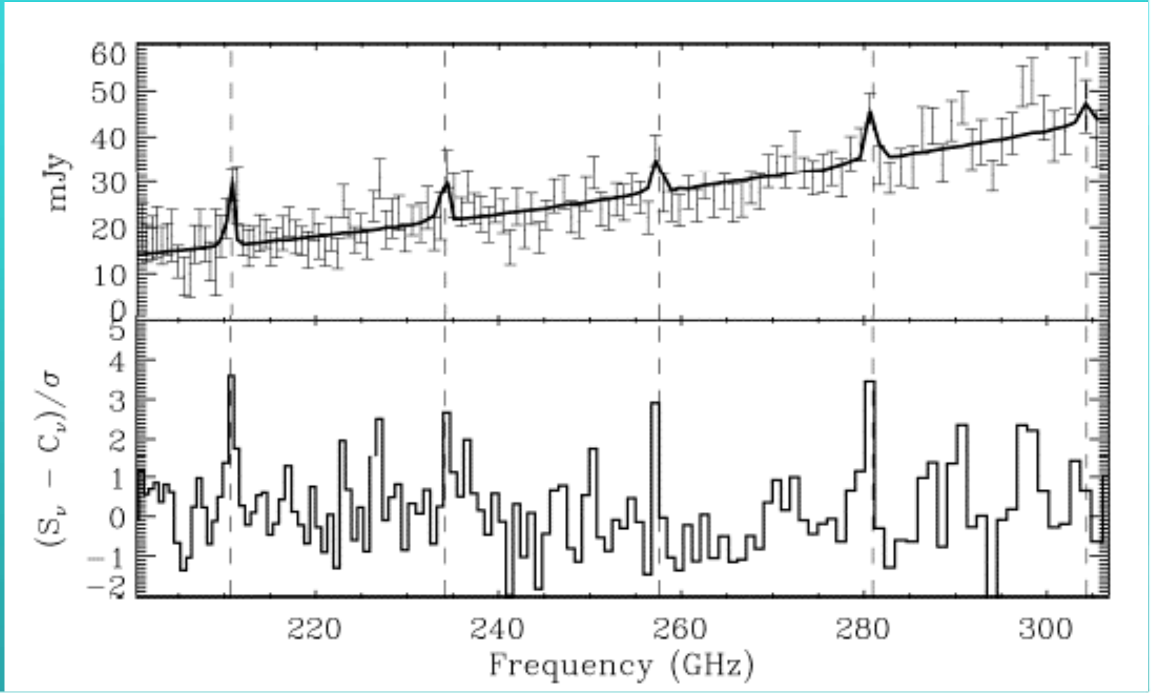
CCAT will be capable of (*and required for*) spectroscopic follow-up of its own continuum survey catalogs

CCAT Preview: Z-Spec Observations

First broadband mm-wave spectrum of a high-z galaxy



APM 08279+5255
z = 3.9122 BALQSO
CO
J = 9 – 8
J = 10 – 9
J = 11 – 10
J = 12 – 11 *New!*

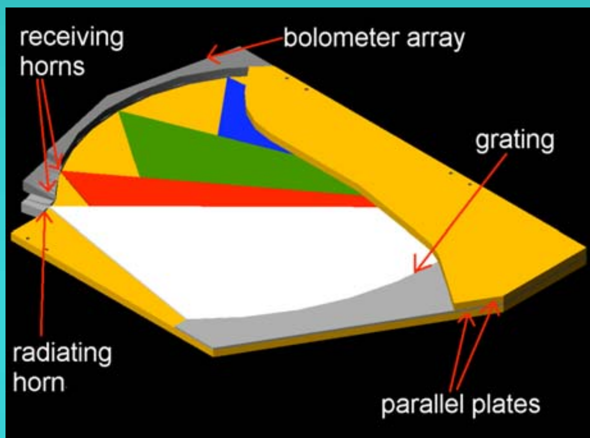


Caltech—Bret Naylor, Jonas Zmuidzinas
Cardiff—Peter Ade
CEA (France)—Lionel Duband
Colorado—James Aguirre, Randol Aikin, Lieko Earle, Jason Glenn, Phil Maloney, Corey Wood
JPL—Jamie Bock, Matt Bradford, Hien Nguyen
ISAS (Japan)—Hanae, Inami**,** Hideo Matsuhara

More from Matt Bradford and Lieko Earle

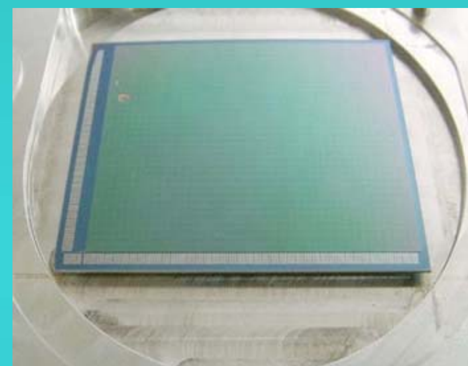
Multi-Object Spectrometer: Grating & Detectors

WaFIRS



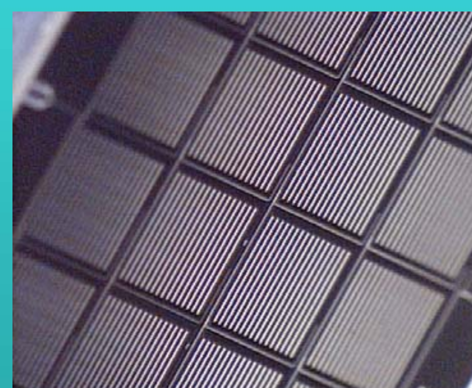
- Rowland grating
  - –Compact
  - –Stackable
- Demonstrated in Z-Spec
- R ~ 1,000 feasible in submillimeter
- FSR matches atmospheric windows

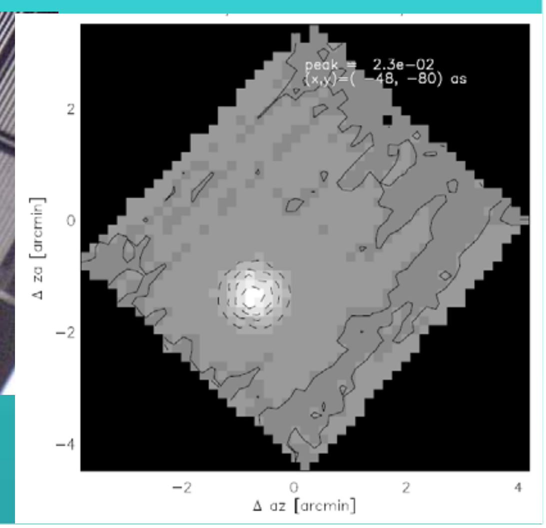
TESs, MKIDs: Arrays of tens of thousands of detectors



SCUBA-2 TES Subarray
1280 pixels (10,240 total)

592 x 4-color array camera (Colorado/Caltech/JPL)
More from James Schlaerth





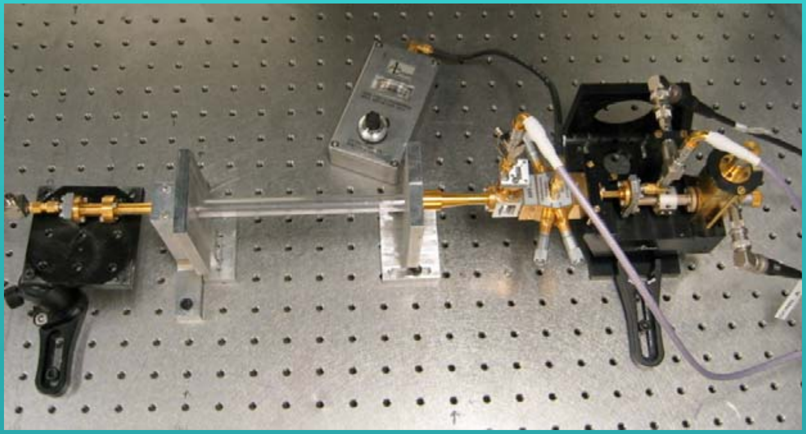
Multi-Object Spectrometer: Flexible Waveguides

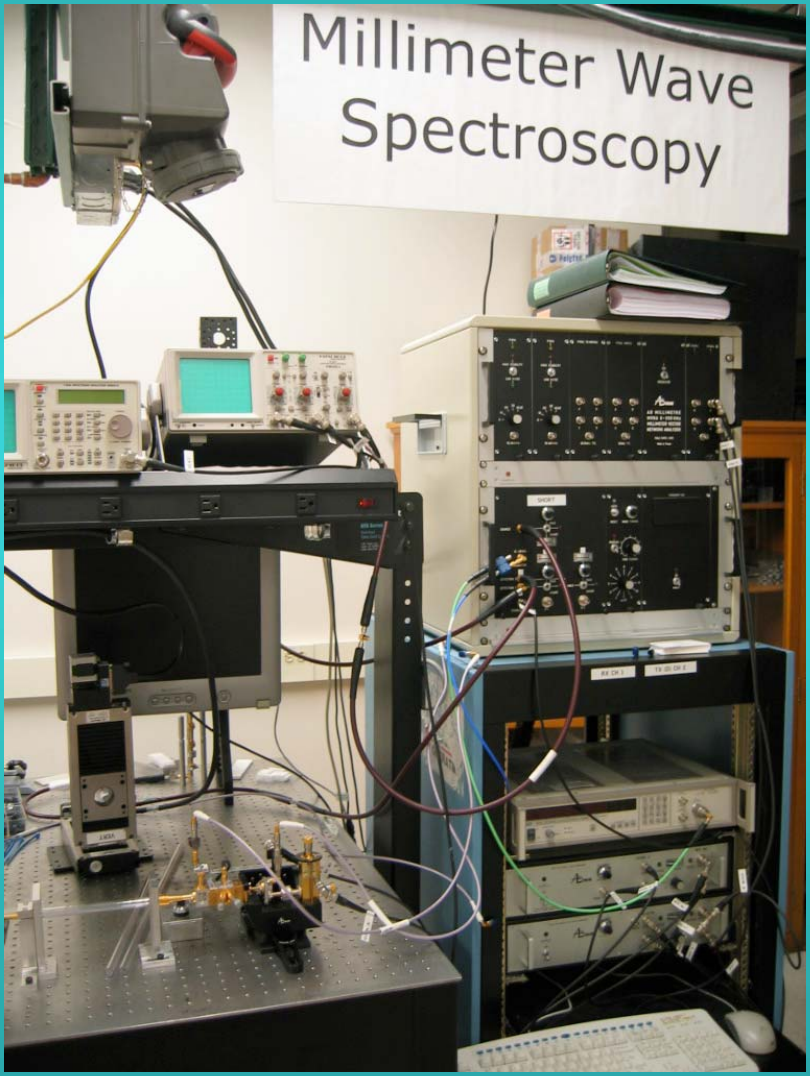
- Hollow polycarbonate tubing: partnership with Custom Microwave, Inc.
- Efficient, low stray light
- Reconfigurable
- 300 – 400 GHz scale-model testing & HFSS

U. Colo. – Jason Glenn, Al Gasiewski, Vladimir Leuski

Colo. School of Mines – John Scales, Brian Zadler

NIST – William Duncan





Broadband MOS Spectrometer for CCAT

1. CCAT will be overwhelmed quickly with its own source catalogs.
2. ALMA will be highly oversubscribed.
3. Thus, CCAT will have to provide its own spectroscopic survey follow-up (with detailed ALMA spectroscopy to follow).
4. Flexible submillimeter waveguides provide a natural technology for a MOS.