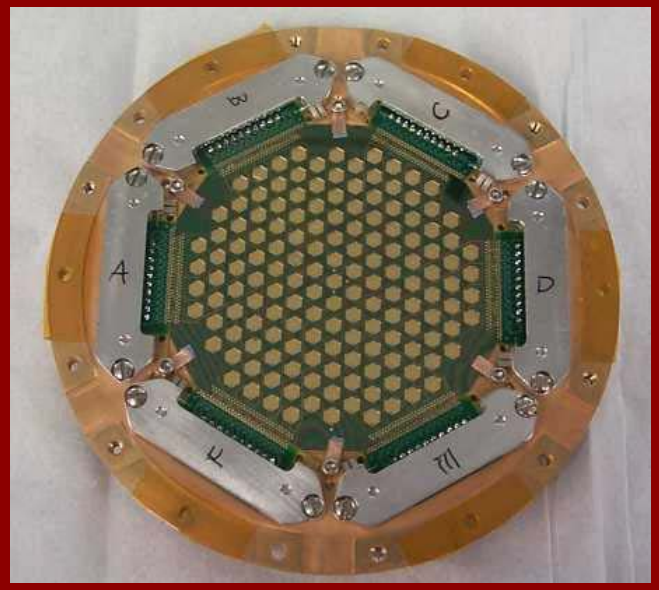
Upcoming Technology, Facilities, and Science at MM-Wavelengths

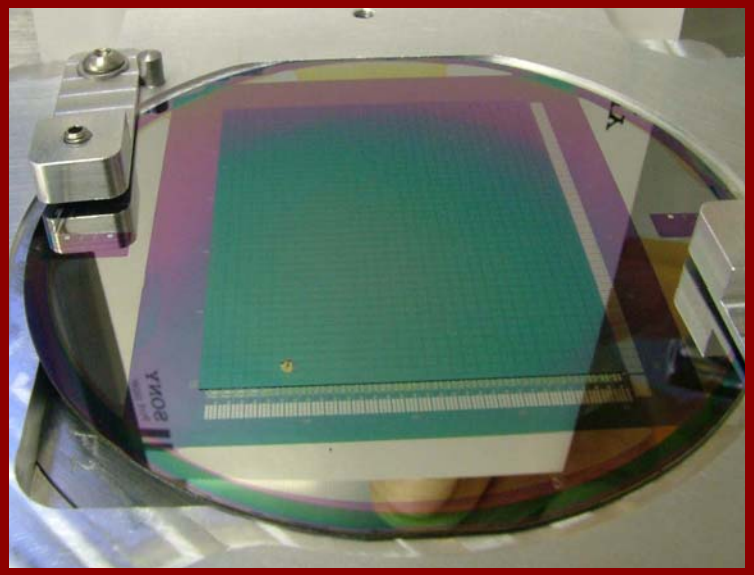
Grant Wilson
University of Massachusetts

From Spitzer to Herschel and Beyond
6/8/04

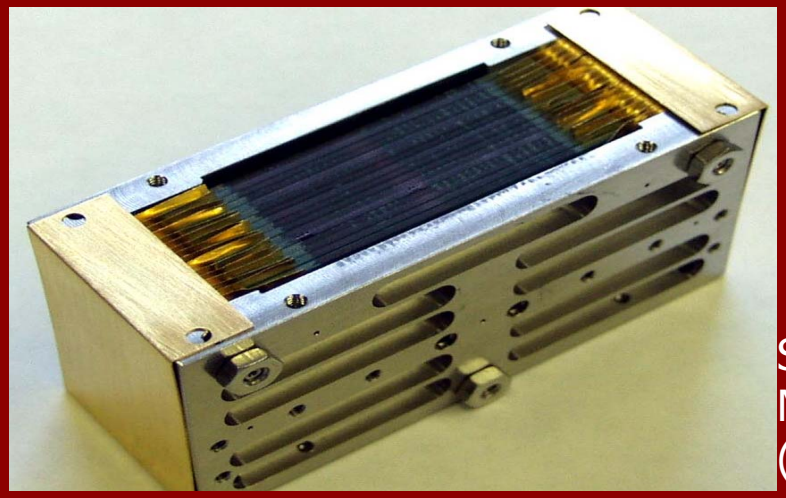
Ongoing Advances in Bolometry



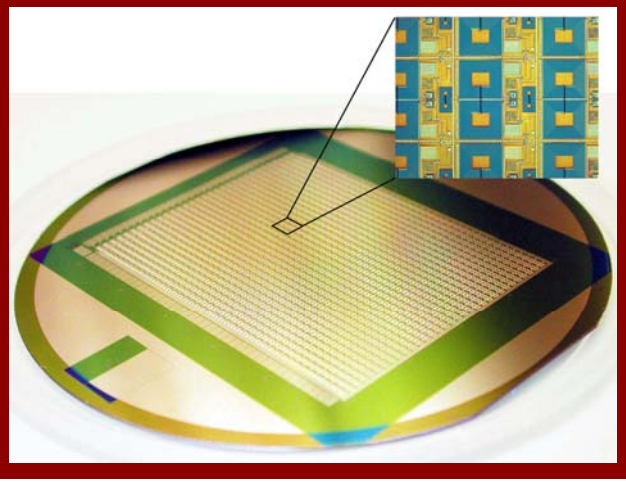
144 element BOLOCAM detector array (J. Bock)



1280 element SCUBA-2 bolometer and mux wafers (photos courtesy Kent Irwin)



SAFIR/SPIFI Mech. Prototype (H. Moseley)

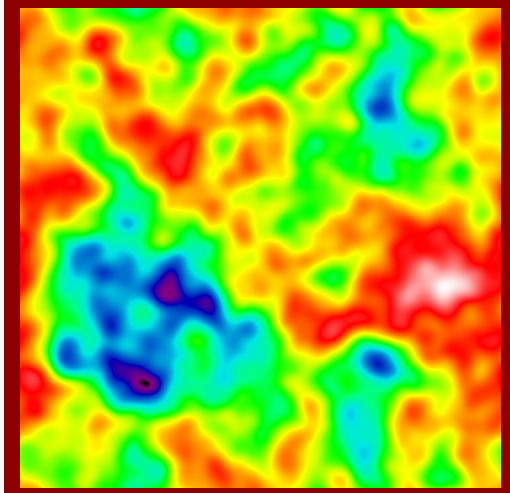


Outline

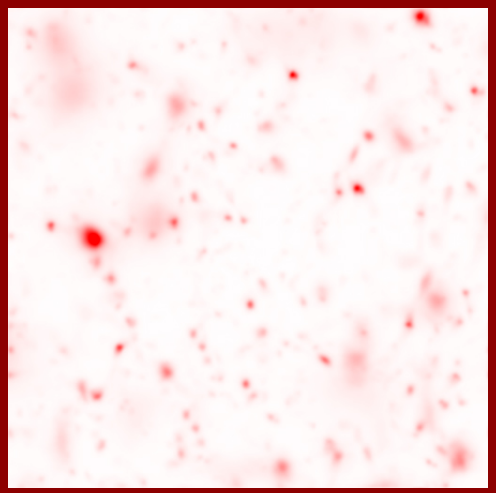
- Sources and Science at 1-3mm
- Atacama Cosmology Telescope (ACT) (and others) - 1-2′ imaging
- Large Millimeter Telescope (LMT) - 6-12″ imaging

Extragalactic sky at 270 GHz

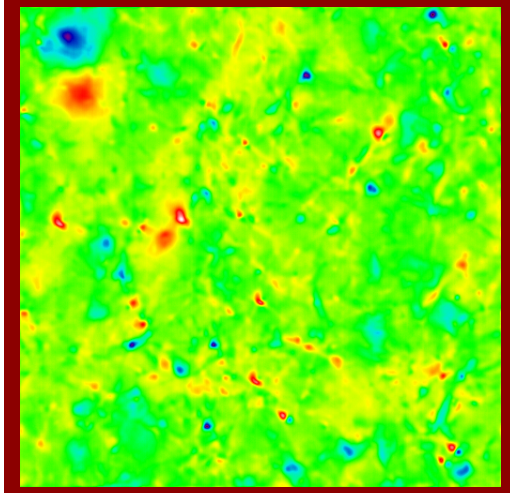
Map Components



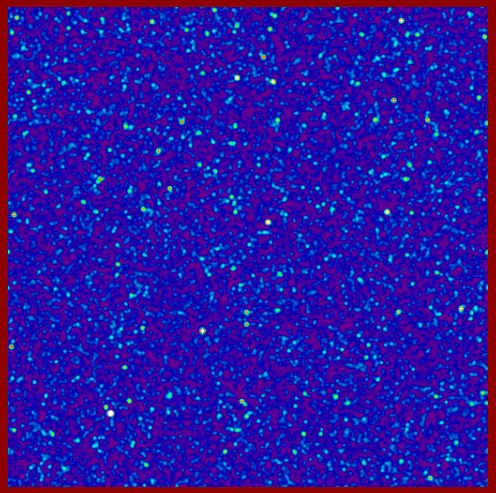
CMB



SZ

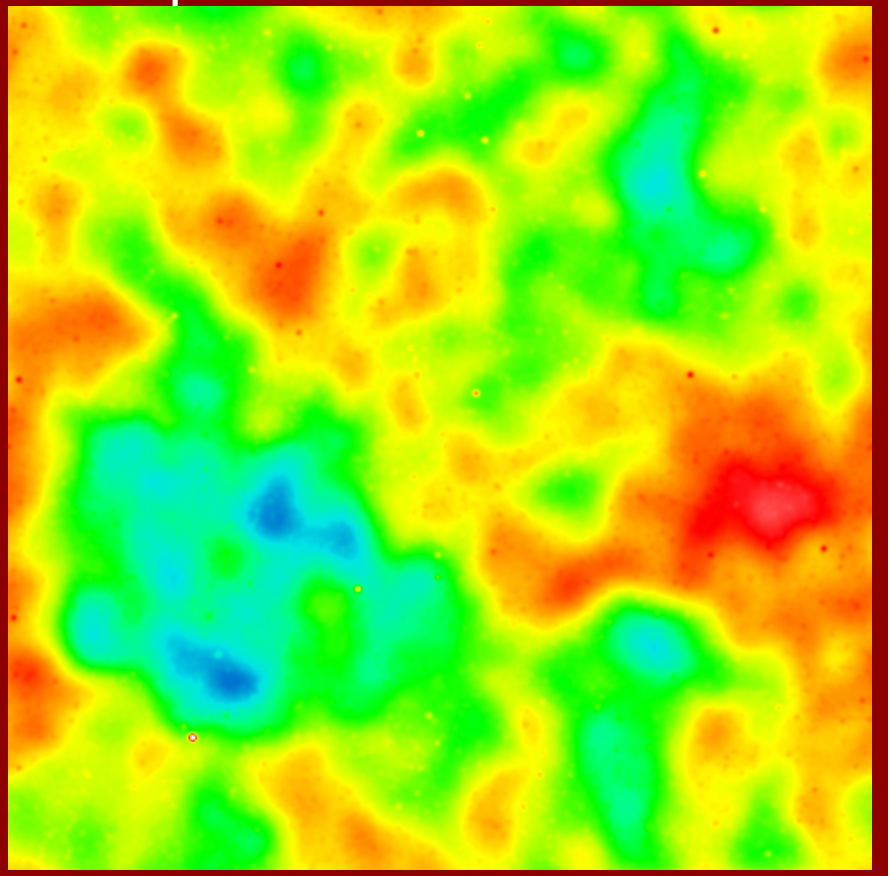


KSZ/OV



Point Sources

Components Summed to Scale

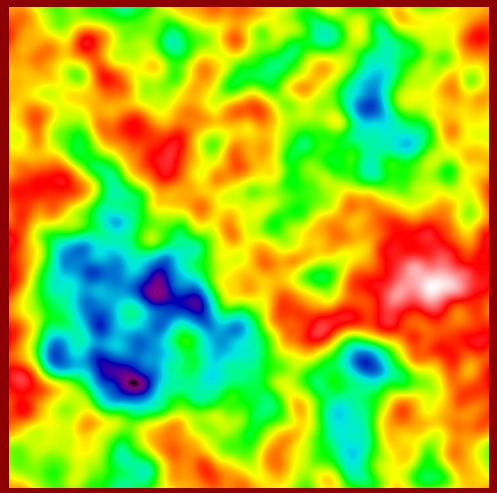


$1.4^{\circ} \times 1.4^{\circ}$

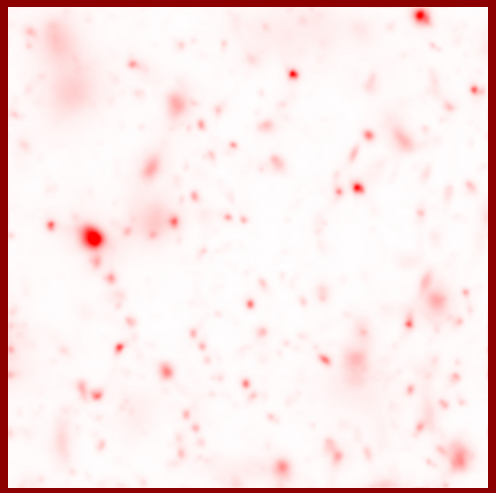
ACT Collaboration
U. Seljak

Map Components

linear physics,
lensing,
calibration



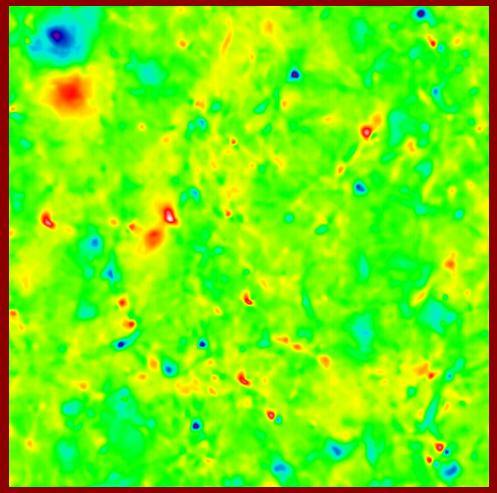
CMB



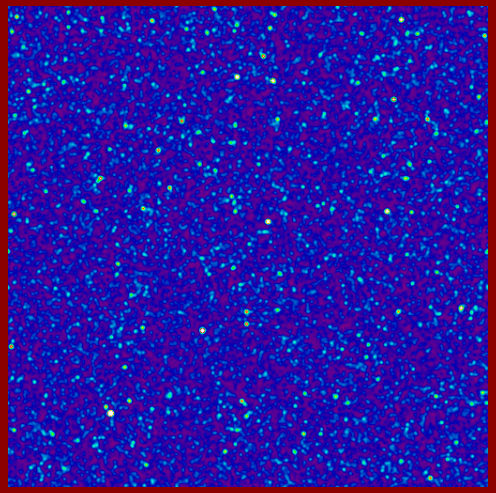
SZ

cluster catalog
↓
equation of state
neutrino mass

reionization,
large scale
matter velocity
distribution



KSZ/OV



Point Sources

bright submm
galaxy catalog
↓
star formation
history
clustering

Separating various effects requires both spectral coverage and arcminute imaging on > 1 deg scales.

ACT Collaboration

CMB Science and New Imaging Facilities at 1-2′ scales

ACT
Atacama Cosmology Telescope

http://www.hep.upenn.edu/act

Princeton
Cardiff
Columbia
INAOE
KwaZulu-Natal, ZA
NASA/GSFC
NIST
Penn
Rutgers
U. Toronto
UBC
UMass
York College

CMB
Optical
X-Ray
Theory

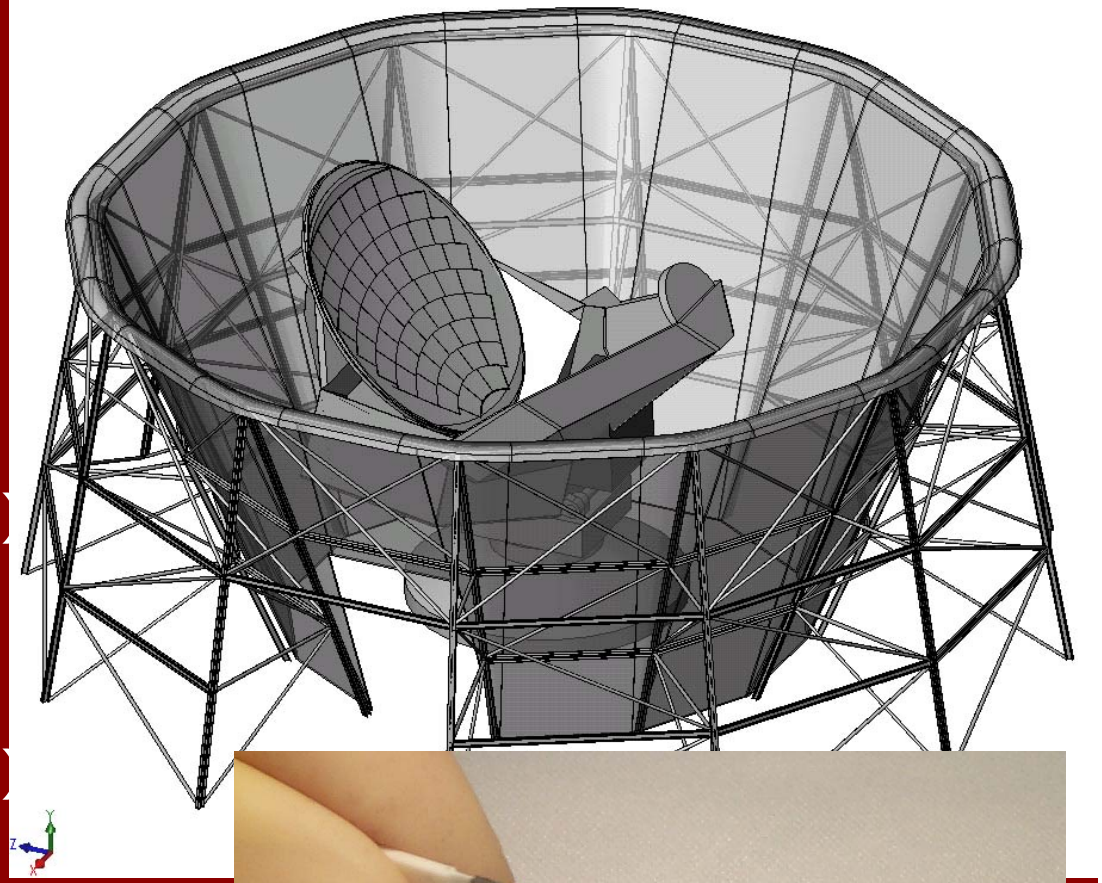
As well as:

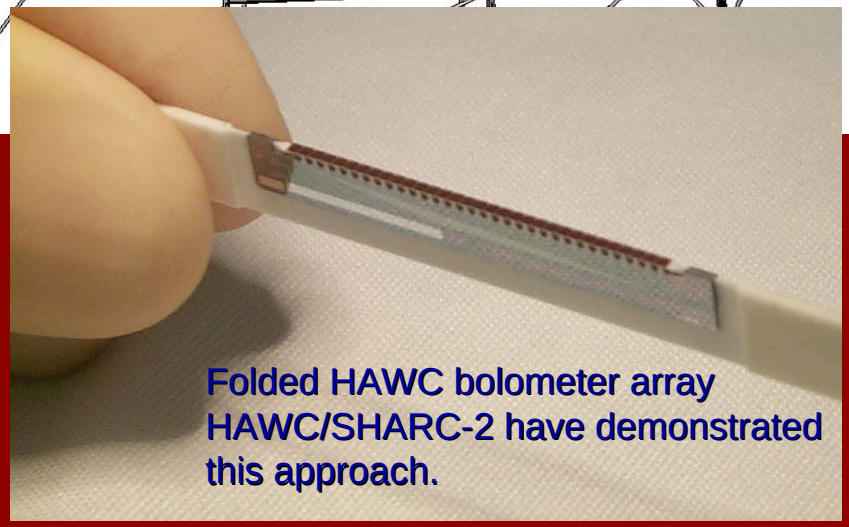
South Pole Telescope
APEX
BOLOCAM/CSO
SCUBA, SCUBA-2/JCMT

Science Goals:
- measure physical processes governing structure formation from linear to nonlinear scales
- Identify discrete and clustered structure spanning 0<z<?

ACT Specifications

- 6m telescope (AMEC)
- located near ALMA site
- CCAM (2006/2007)
    - ~128 pixels
    - TES PUDs (NASA/GSFC)
    - 145 GHz
- MBAC (2007/2008)
    - 3072 pixels
    - TES PUDs (NASA/GSFC)
    - 145, 220, 270 GHz
- 100 deg^2 map
- 1.7′ x 1.7′ pixels
- 2 μK rms at 145 GHz
- Installation mid-2006





ACT is **designed** for high sensitivity mapping of low contrast sources.

ACT Collaboration

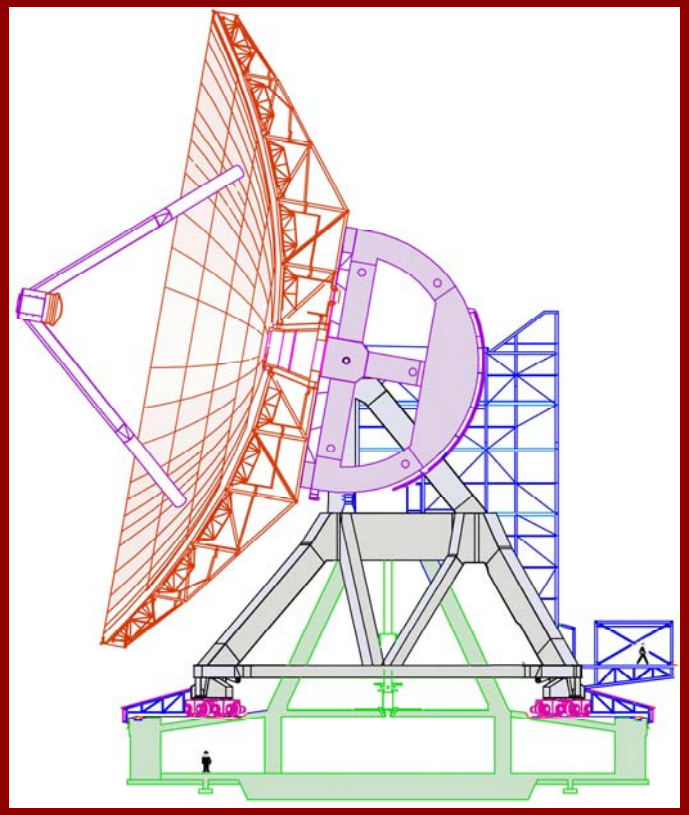
ACT Goals/Science

- Map CMB Anisotropy
  - 100 deg2 – 1.7′ x 1.7′ pixels – 2uK rms per pixel (145 GHz)
- Generate SZ selected cluster catalog
  - 200 – 2000 clusters - M > 3.10^{14} M_{sun}
  - follow-up with SALT telescope (spectroscopic z + gal. vel. disp)
  - follow-up low z clusters with X-ray obs.
- Measure *w* to +/- 0.1
- Limit or measure m_v to +/- 0.1 eV.
- Measure CMB lensing signal (probes mass distribution at 1 Mpc scales at z = 1-2)
- Detect reionization through the Ostriker-Vishniac effect in the CMB.

It's a Busy Field

- ACT – deploy in 2006, MBAC obs. in 2007
- SPT – deploy winter 2006/2007
- APEX – deployed (Berkeley bolometer array this year!)
- SCUBA-2 – at telescope at end 2005

The LMT and Science at 6-12″



LARGE MILLIMETER TELESCOPE/
GRAN TELESCOPIO MILIMÉTRICO

LMT Specifications

Antenna

Parameter	Specification	
Diameter	50 m	
Surface Accuracy	75 microns (Goal: 70)	
Pointing Accuracy	1.0 arcsec (Goal: 0.6)	
Predicted Performance		
Wavelength	3.0mm	1.2mm
Aperture Eff.	0.65	0.40
Sensitivity (Jy/K)	2.2	3.5
Beam FWHM	15"	6"

1st Generation Instruments

Continuum

BOLOCAM II
- 144 pixel bolometer array
- 1.1 mm operation

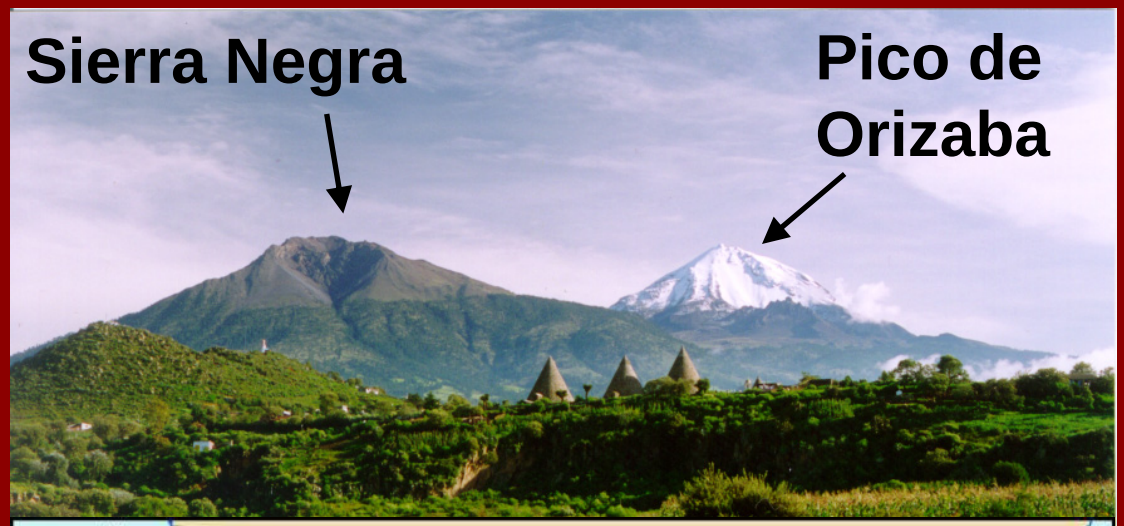
SPEED
- 4 pixel FSB array
- 2.1, 1.4, 1.1, 0.85 mm

Heterodyne

SEQUOIA – 32 pixel imaging spectrometer

1mm SIS Receiver

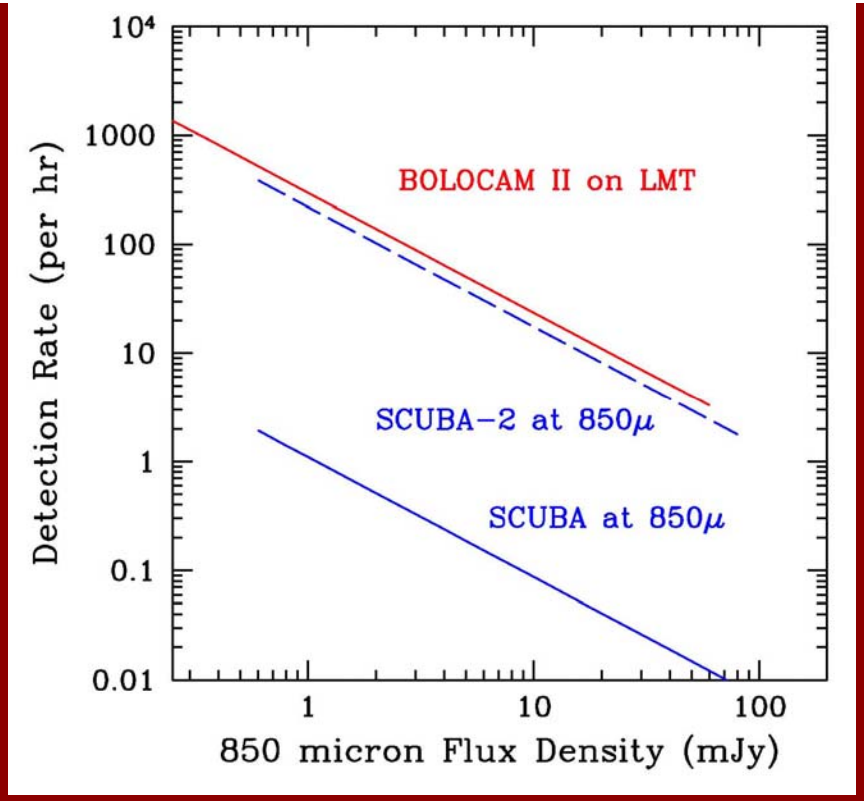
Redshift Receiver
- wide band spectrometer
- 36 GHz instantaneous bw



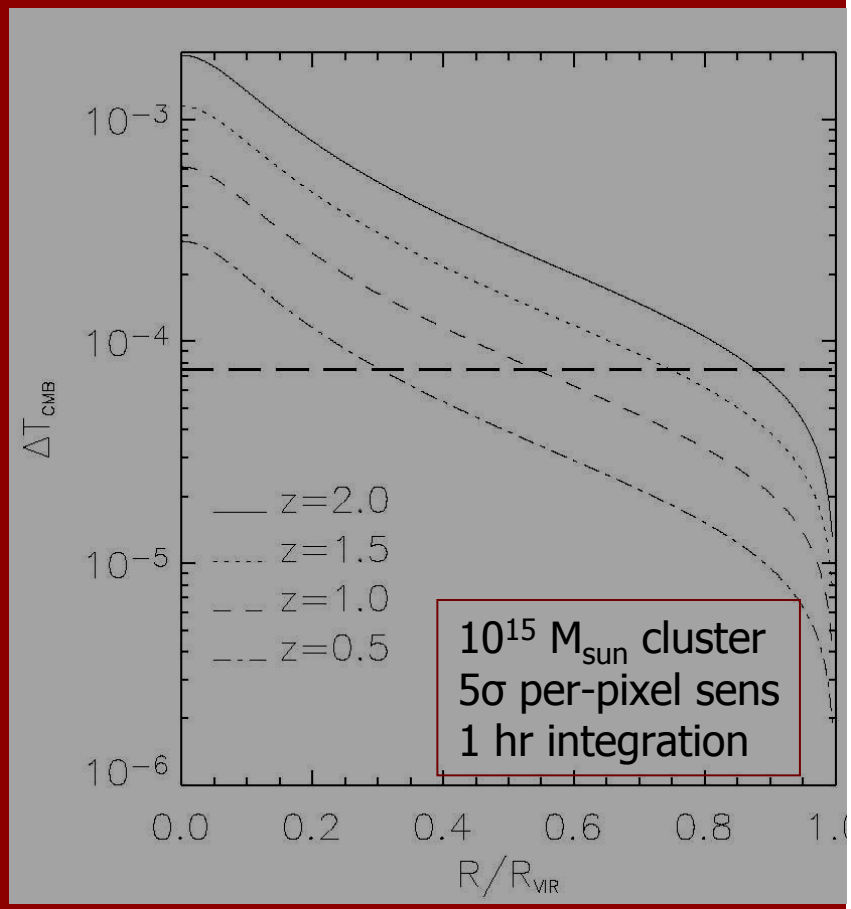
Sierra Negra

- state of Puebla, MX
- good mm-wave transmission
  - 2 mm pptH2O (median) in winter
- 4600m elevation
- 19 degrees Latitude
- Benign conditions
  - low temperature range
  - 5 m/s median wind speed

Key Extragalactic LMT Science (BOLOCAM II)



Dusty Starburst Galaxy Detection Rate
(figure courtesy M. Yun)

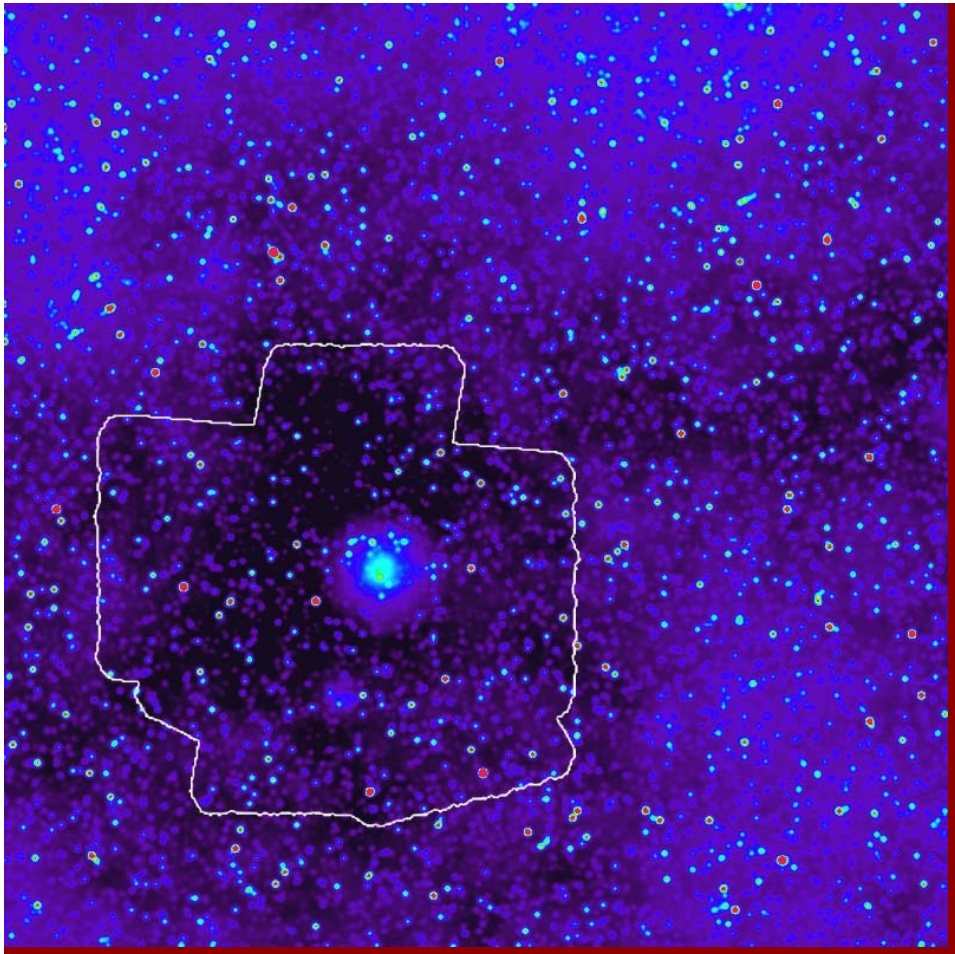


High-z galaxy surveys

- probe faint end of number counts
- detect 500-1000 galaxies per hour

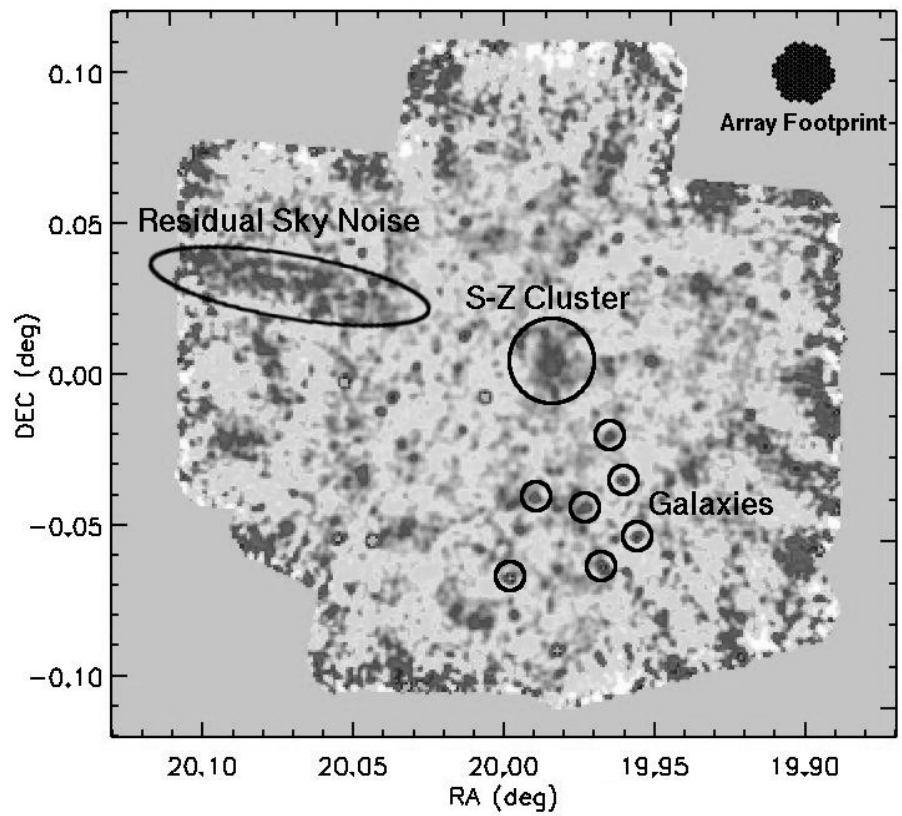
Coarse resolution cluster imaging

- test models of pressure distribution
- detect point source contamination



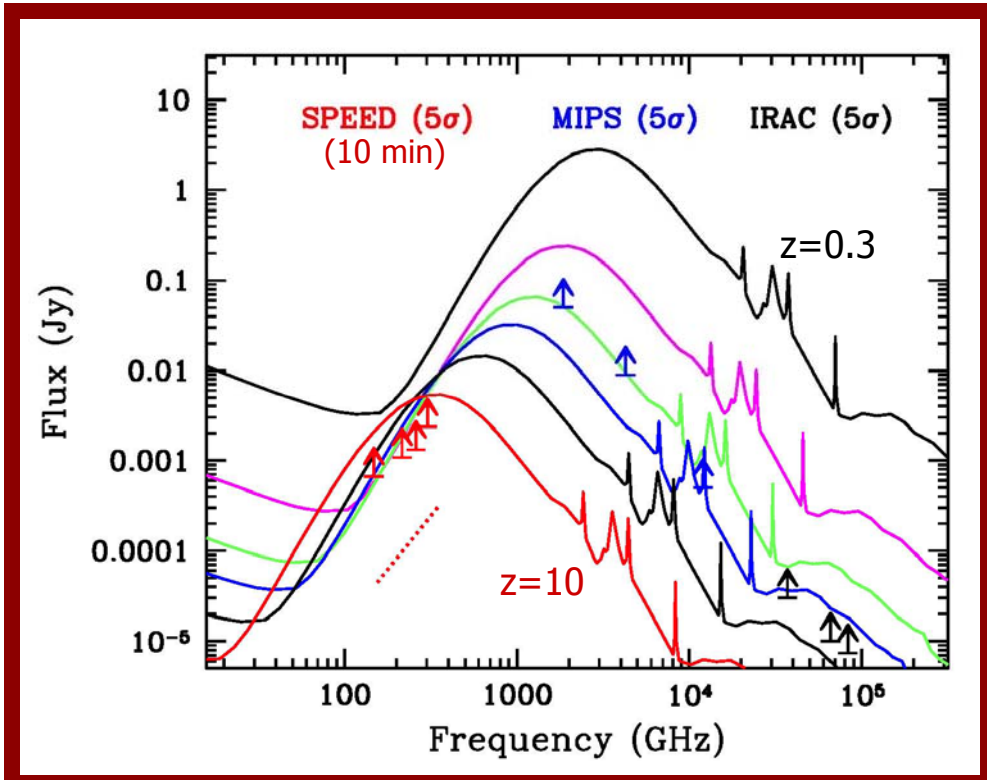
Composite idealized 1.1 mm map that includes strongly evolving high-z starburst population, a S-Z cluster, CMB, and galactic cirrus. (Simulations by Chapman & Hughes)

Ed Chapin Ph.D. thesis (INAOE-2004)

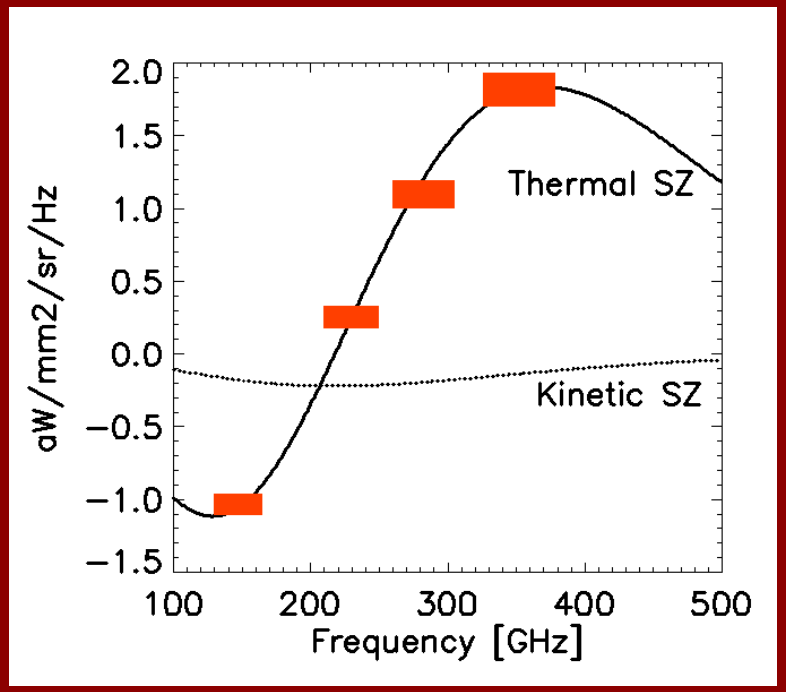


Simulation of 2 hours of Bolocam II observations with LMT on region marked on image above (simulation includes expected detector noise and mapping systematics).

Key Extragalactic LMT Science (SPEED)



SPEED starburst galaxy flux sens.
(figure courtesy M. Yun)



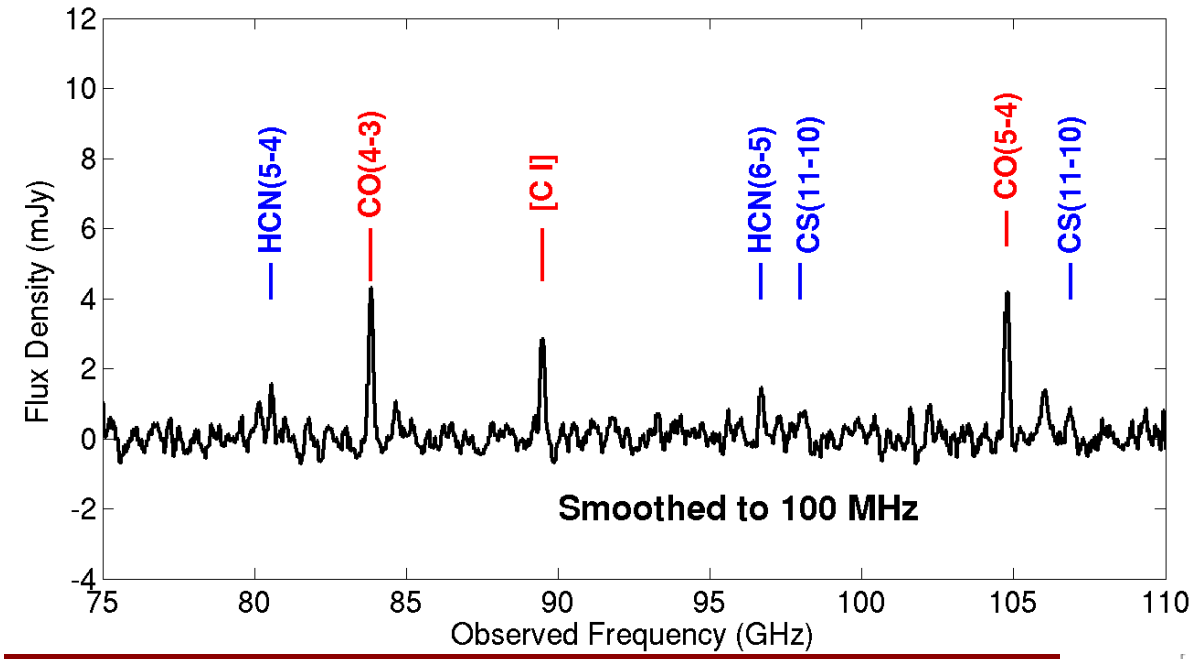
High-z galaxy photometry

- measure spectral index of bright sources at all redshifts
- determine photometric redshifts for all available Spitzer sources

SZ Photometry

- spectrally identify non-SZ flux
- spectrally clean point source contam.
- measure cluster peculiar velocity (?)

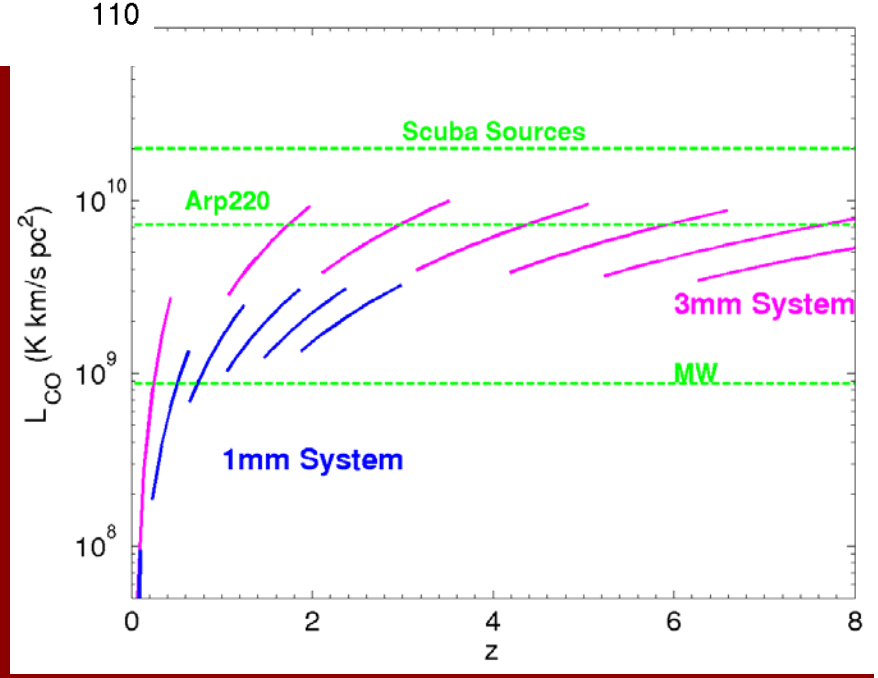
Key Extragalactic LMT Science (heterodyne)



Model spectrum of z=4.5 Arp220-like galaxy (M. Yun)

Spectroscopic Redshifts of High-z Galaxies

- 1mm receiver for z<3
- 3mm receiver for 2<z<8
- most detections with multiple lines

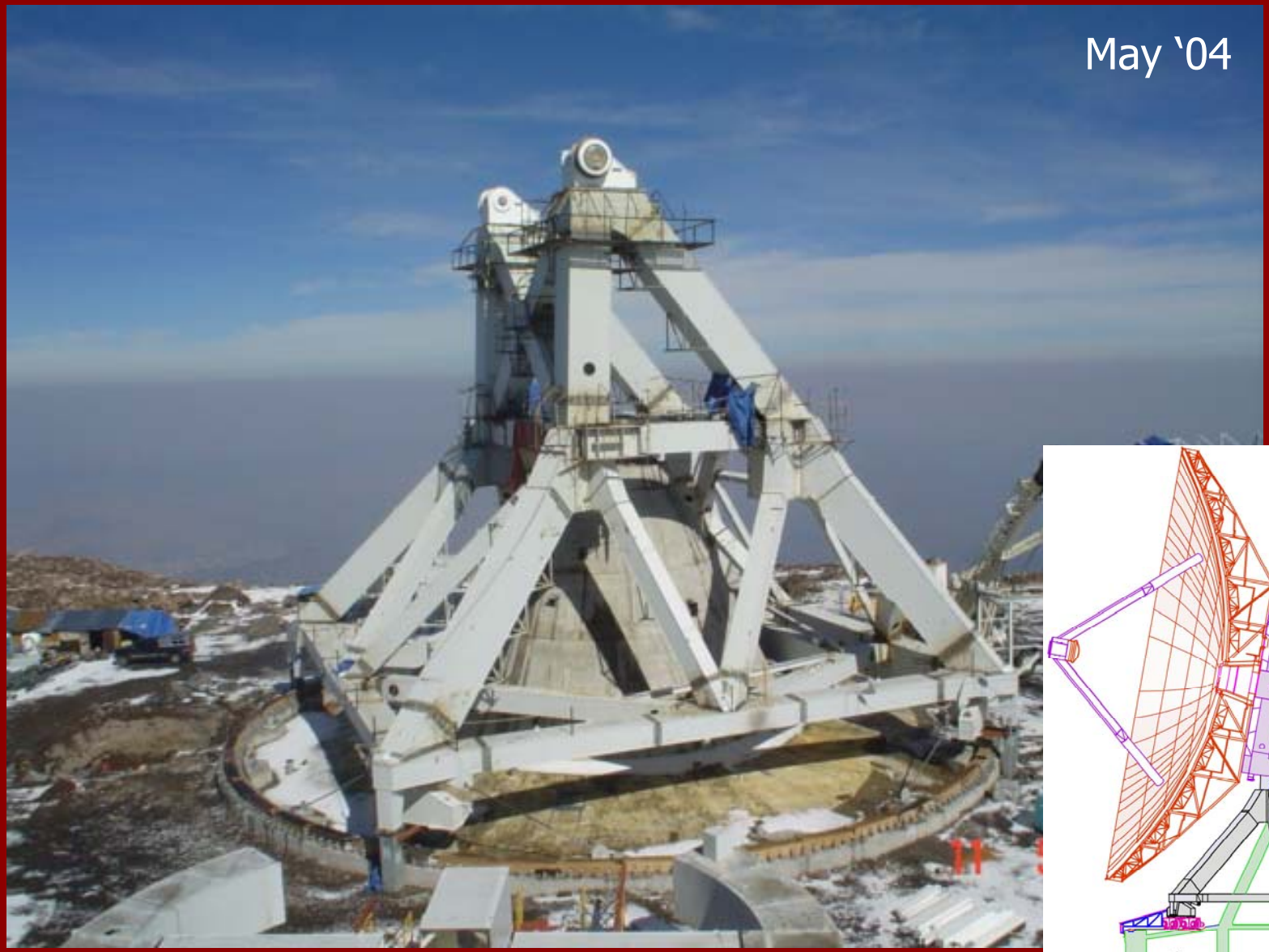


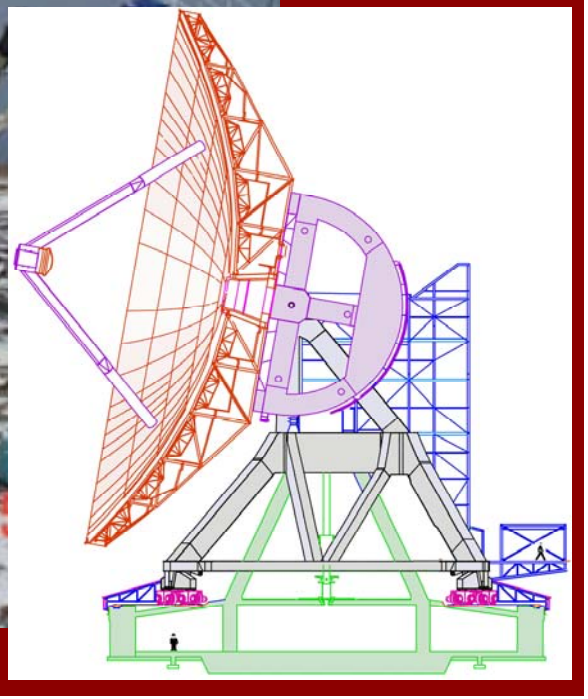
Expected sensitivities after 1 hr integration

LMT Instrument Status

- All 1st generation instruments to be commissioned on telescopes pre-LMT and potentially used in LMT commissioning
- SEQUOIA complete and operating at FCRAO 14m
- BOLOCAM II, SPEED, Rx Receiver to be deployed 2005 on existing telescopes

Telescope Construction Status





Telescope Construction Status

LMT Timeline

Steel Assembly Complete	end 2004
Surface Panel Fabrication	2004-2006
Surface Panel Installation	2005-2006
Commissioning	2005-2007

Notes:

1) telescope is designed to work at 3mm early

2) telescope should work well at 1-2mm early in benign conditions

Conclusions

Next 5 years of continuum observations should bring …

- Large format bolometer arrays integrated with large telescopes
- CMB mapped to l~7000 (linear to nonlinear regime)
  - Cluster catalogs with 10^4 SZ selected clusters at all z
  - Equation of state measured to better than 0.1
  - Tomography of large scale structure
- 3-d catalogs of high-z galaxies spanning all redshifts
  - Redshifts determined photometrically and/or with new heterodyne capabilities
- High resolution SZ imaging of clusters and cluster assembly