

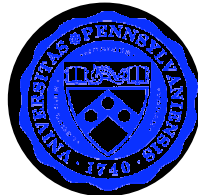
The background of the slide is a Cosmic Microwave Background (CMB) fluctuation map. It shows a complex pattern of temperature variations across the sky, with colors ranging from red (warmer) to blue (cooler). Several bright spots are visible, indicating regions of higher temperature.

ACT: The Atacama Cosmology Telescope

Raul Jimenez for the ACT collaboration

**Probing Fundamental Physics Through
Measurements of Cosmic Structure**

ACT Institutions



Penn



Princeton



U Mass



Católica



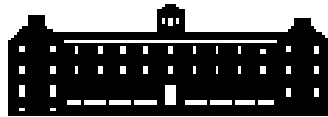
CUNY



Columbia



Toronto



Haverford

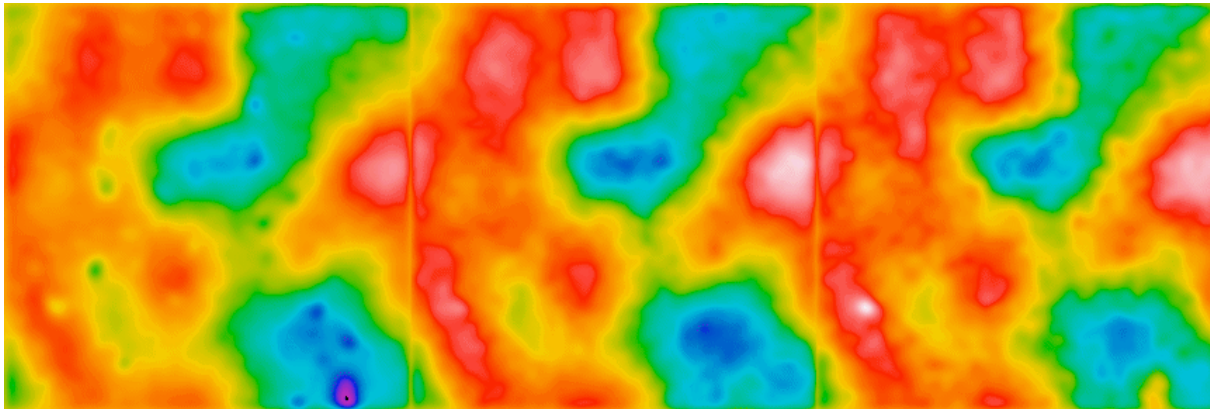


UNIVERSITY OF
KWAZULU-NATAL



ACT: The Big Picture

- Goal: high fidelity maps of $l > 1000$ CMB anisotropy
- Make mm-wave maps in 3 colors
- Survey for S-Z clusters
- Clusters followed in optical & X-ray



A Cosmic Microwave Background (CMB) fluctuation map showing temperature variations across the sky. The background is a mottled red color, with several distinct spots of higher temperature shown in yellow, orange, and green. A prominent feature is a large, elongated yellow and orange spot in the upper left quadrant. Another significant feature is a large, irregularly shaped spot in the lower right quadrant, showing a gradient from yellow to green to blue. The overall texture is grainy and noisy, characteristic of CMB data.

The Science

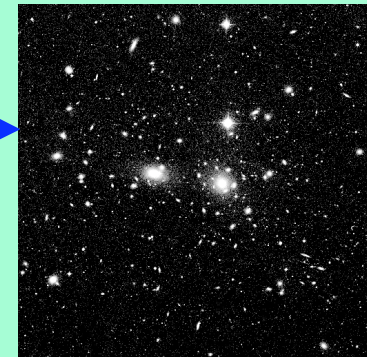
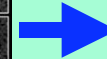
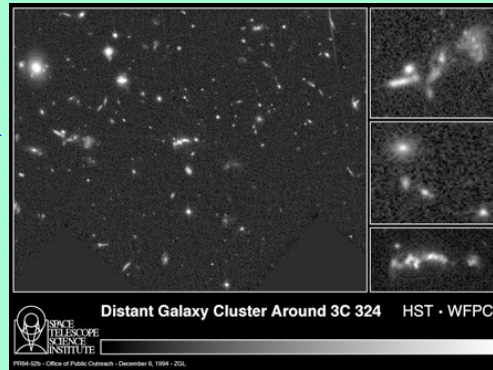
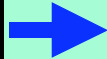
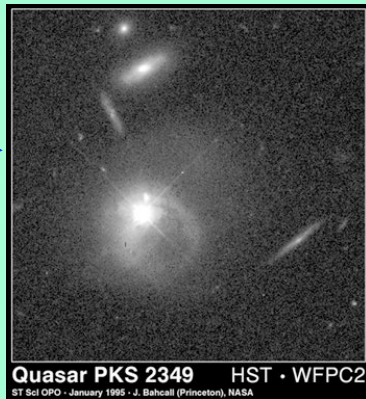
Cosmic Timeline for ACT Science



Cosmic Microwave Background



- First galaxies
- Universe is reionized
- Ostriker-Vishniac
- Diffuse thermal SZ



- Cluster formation: Sunyaev-Zel'dovich (SZ)
- Kinematic SZ
- Lensing of the CMB

- Extraction of cosmological parameters
- Initial conditions for structure formation

- The growth of structure is sensitive to w and m_n
- Rich additional science from correlations among effects



Primary CMB

OV

Diffuse Thermal SZ

CMB Lensing

Cluster Surveys

Clusters as Cosmological Probes

(cosmic structure)

Multiple observables

- SZ luminosity
- Central SZ decrement
- X-ray temperature
- X-ray luminosity
- Velocity Dispersion
- Redshift
- Lensing Mass
- Kinetic SZ amplitude

Multiple uses

- Standard candles
- Standard rulers
- Probes of volume
- Probes of velocity field

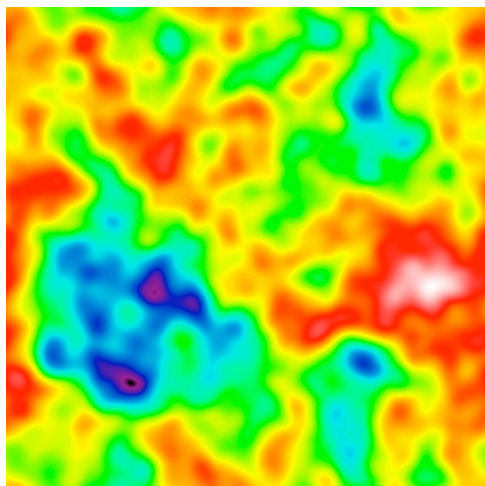
Find amplitude of fluctuations

- Gravitational lensing of CMB gives Φ
 - Kinetic SZ gives v^2
 - Cluster counts give
 - $N(M,z)$
 - $N(F_{SZ},z)$
- Low redshift counts ($z \sim 0.25$) are most useful

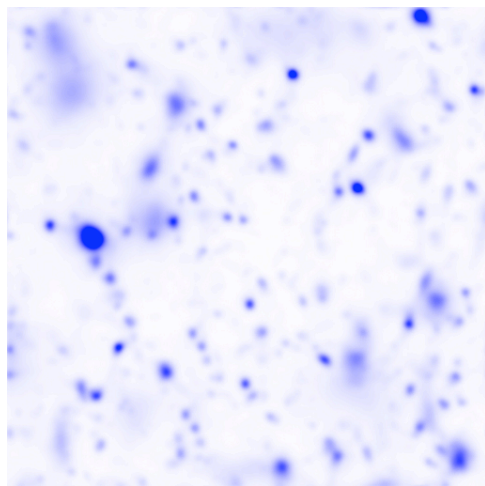
145 GHz Maps

Map Components

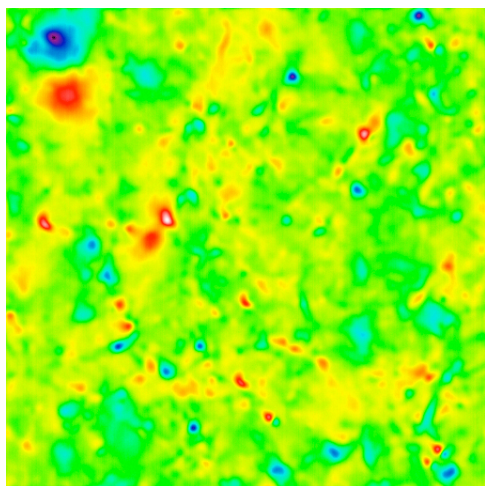
Simulations by U. Seljak



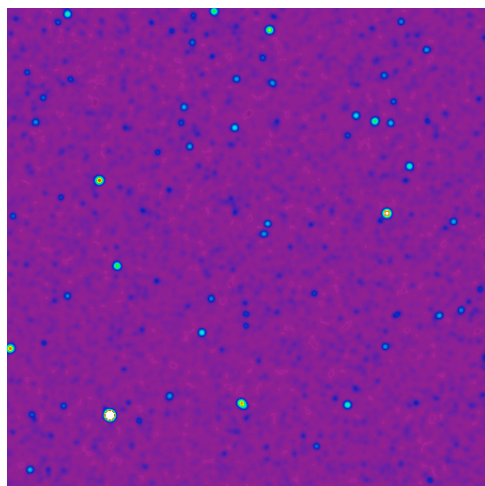
CMB



SZ

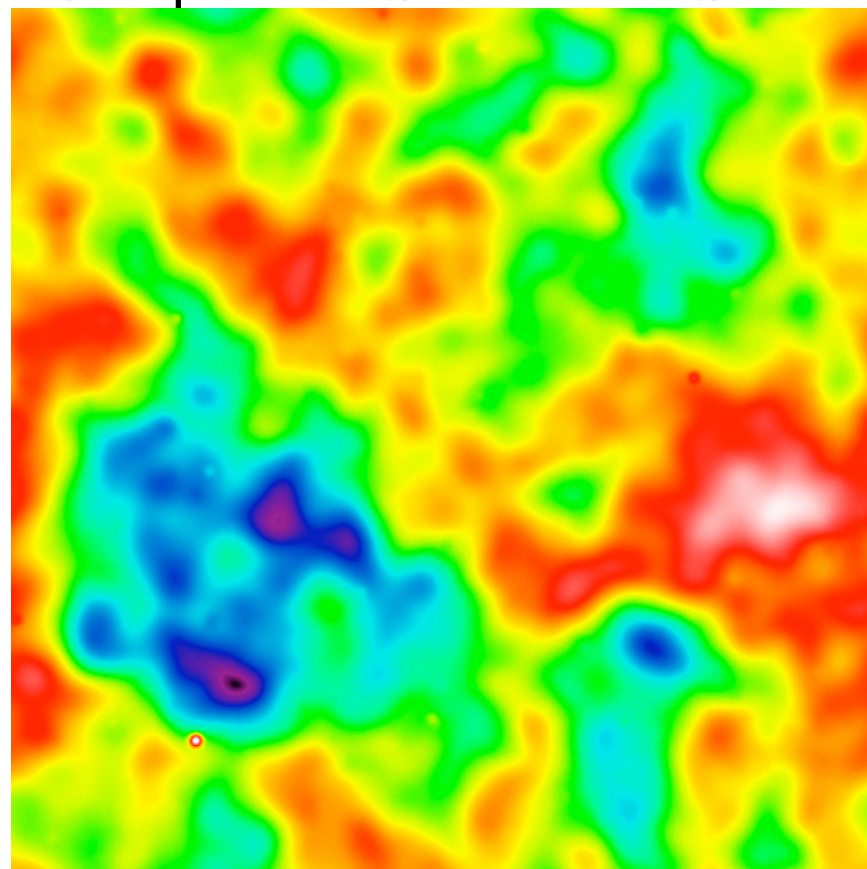


KSZ/OV



Point Sources

Components Summed to Scale

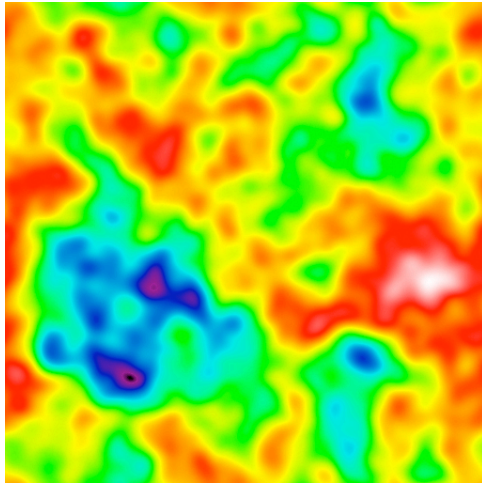


$1.4^\circ \times 1.4^\circ$

220 GHz Maps

Map Components

Simulations by U. Seljak

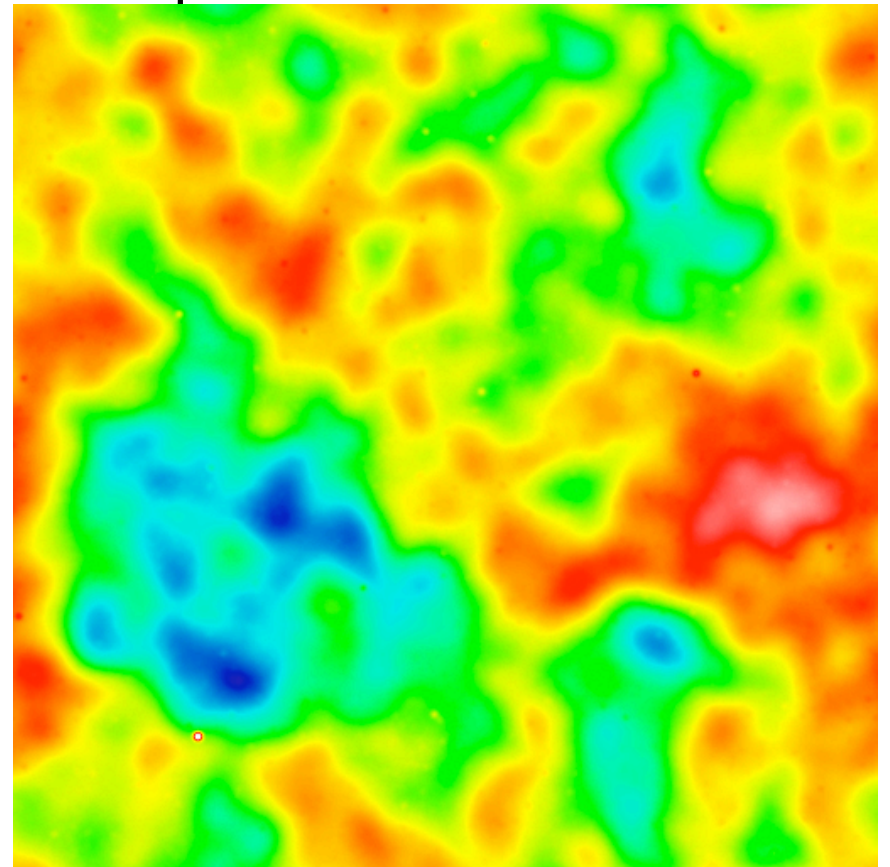


CMB

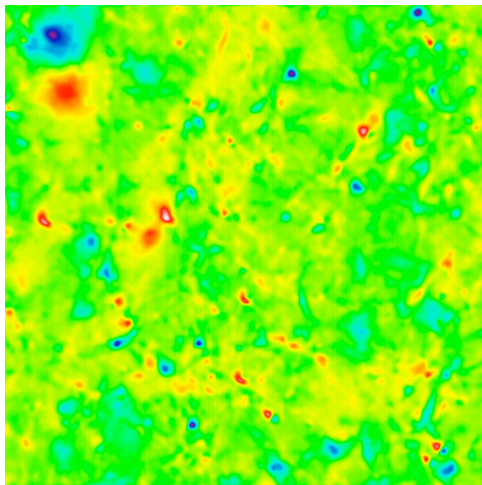


SZ

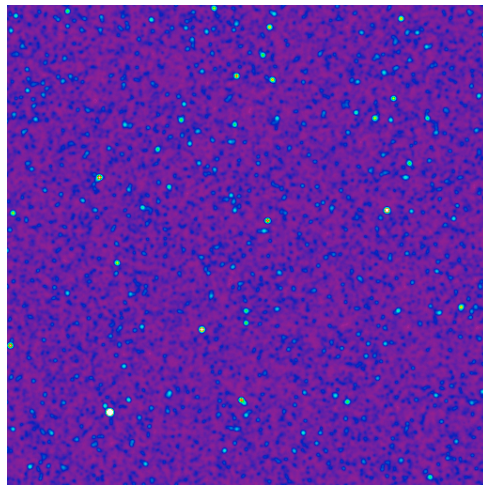
Components Summed to Scale



$1.4^\circ \times 1.4^\circ$



KSZ/OV

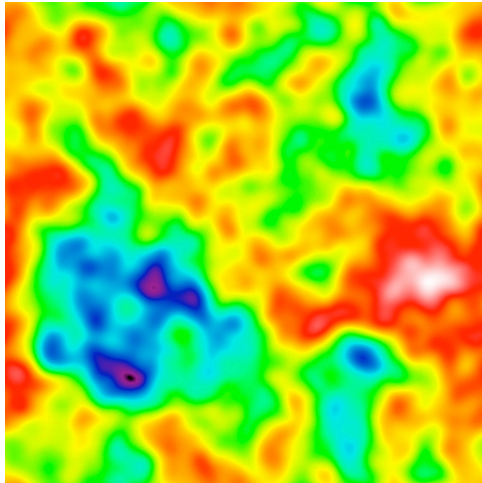


Point Sources

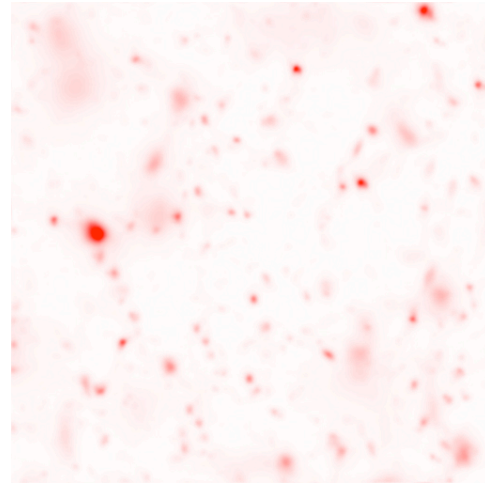
270 GHz Maps

Map Components

Simulations by U. Seljak

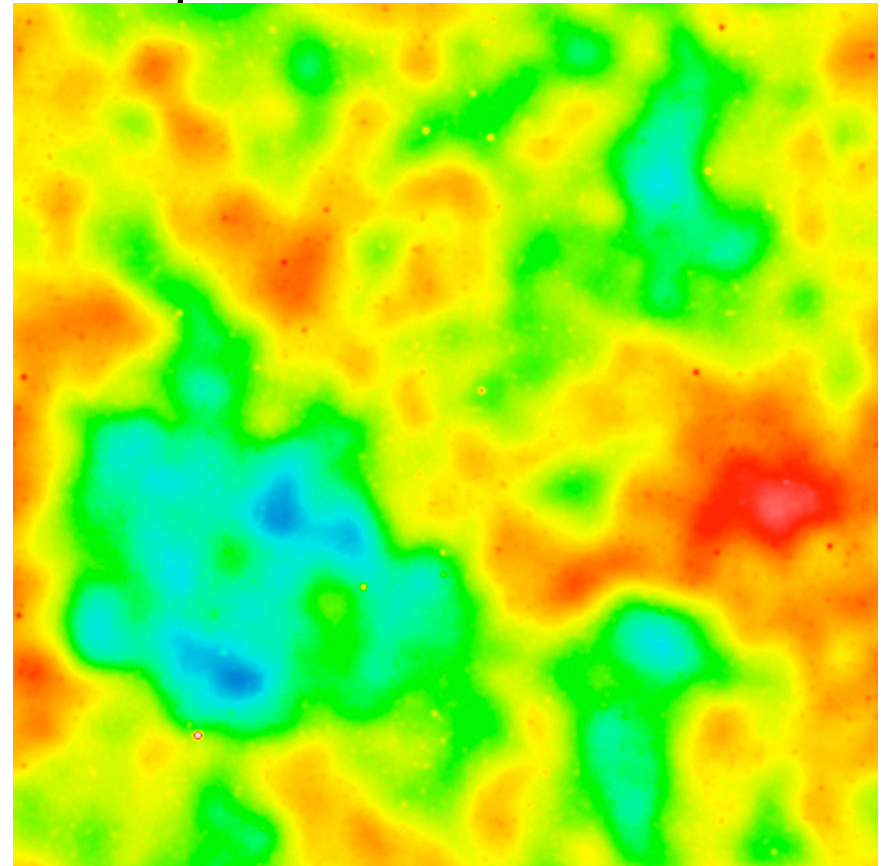


CMB

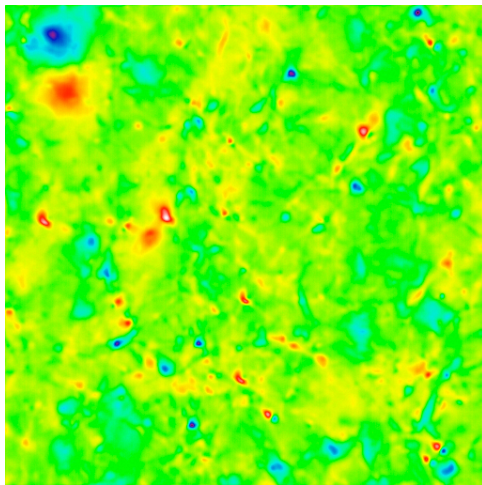


SZ

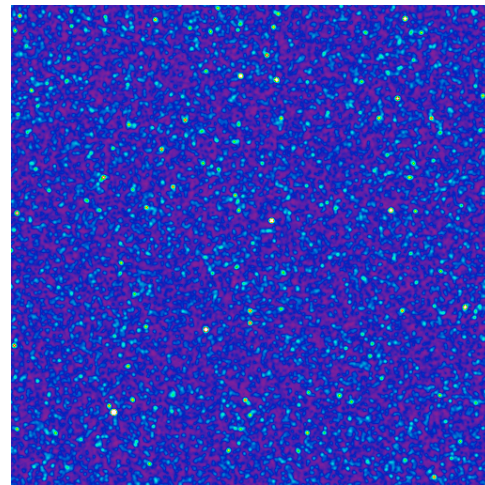
Components Summed to Scale



$1.4^\circ \times 1.4^\circ$

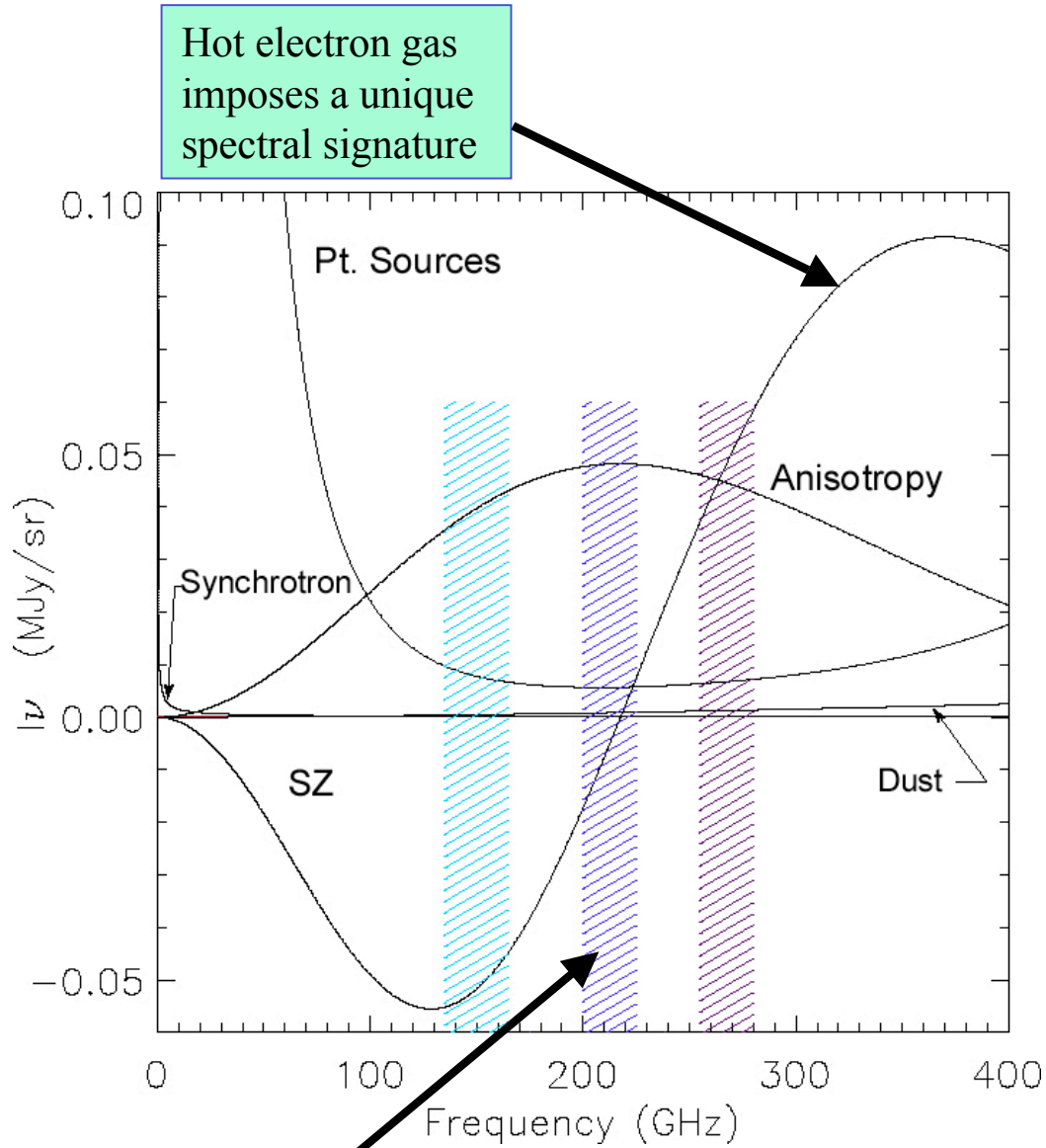


KSZ/OV

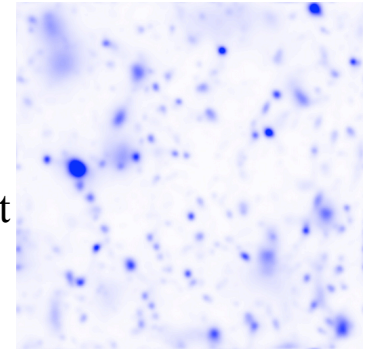


Point Sources

SZ Signature



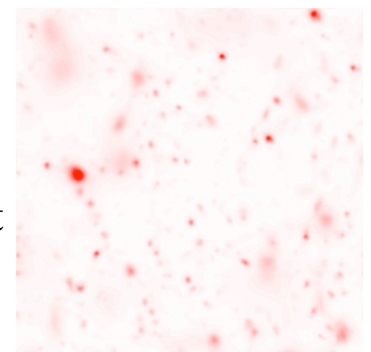
145 GHz
decrement



220 GHz
null



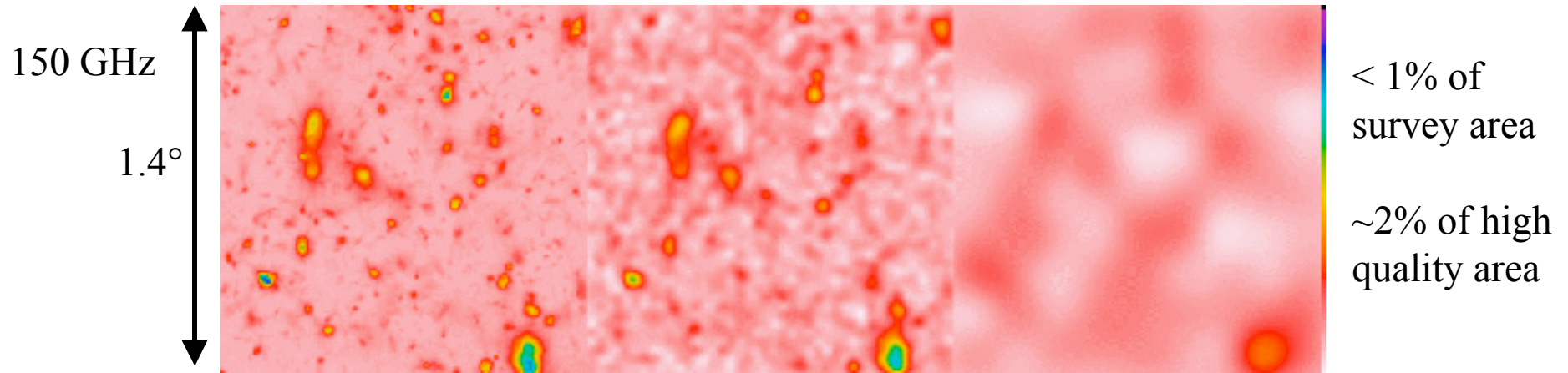
270 GHz
increment



1.4°x 1.4°

NO SZ Contribution in Central Band

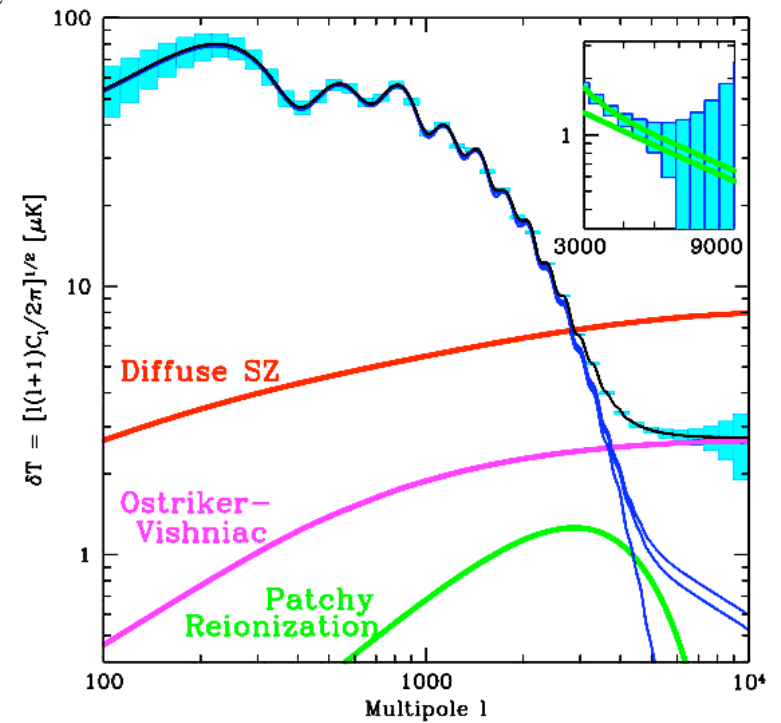
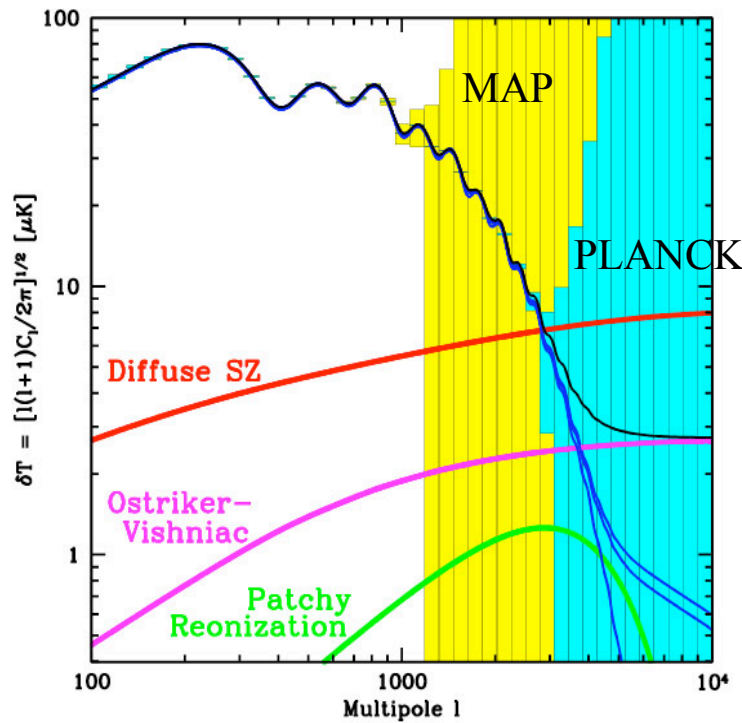
Arcminute Resolution mm-wave Observations



SZ Simulation

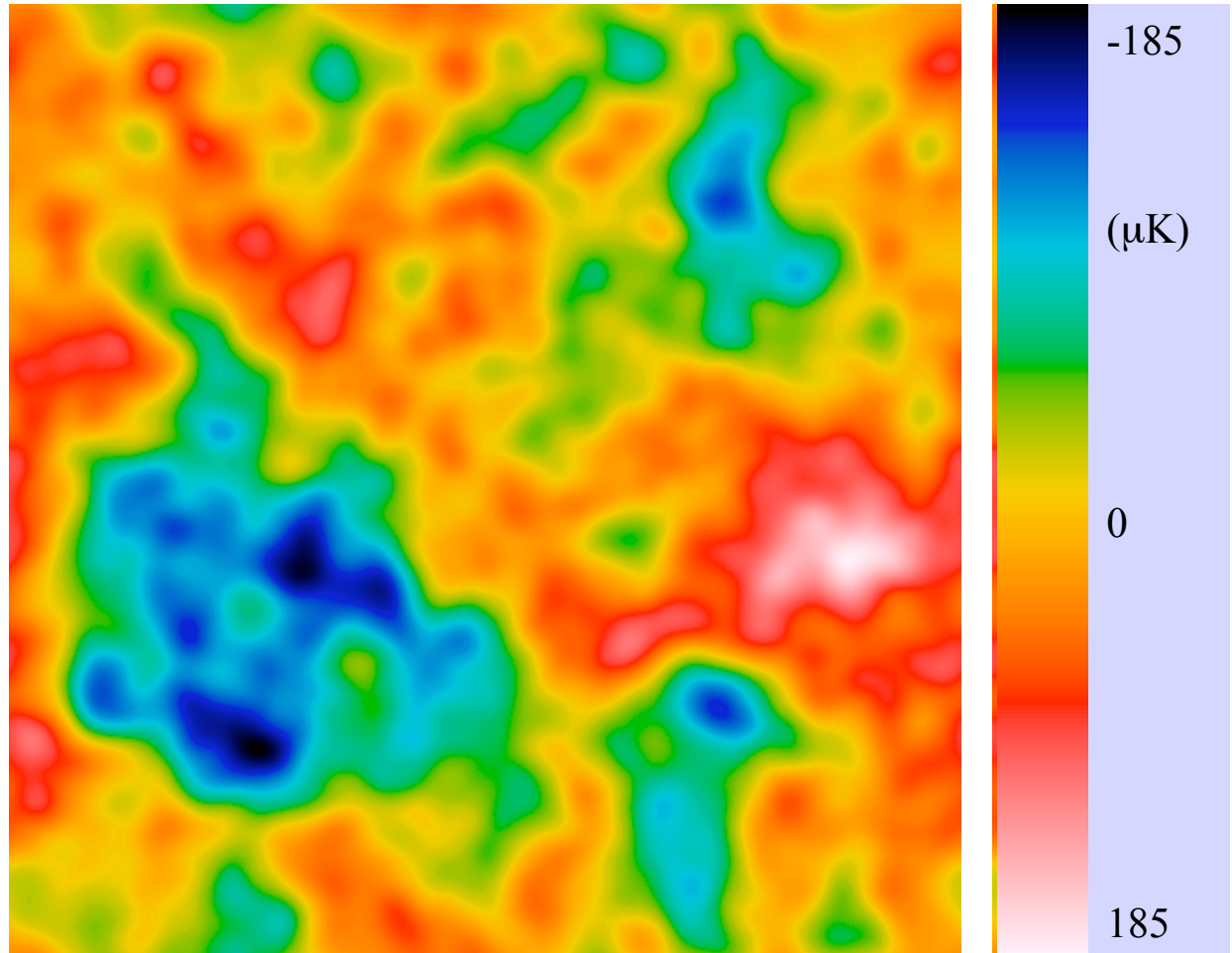
MBAC on ACT 1.7' beam w/ 2X noise

PLANCK



Lensing of the CMB

- Lensing arises from integrated mass fluctuations along the line of sight.
- The CMB acts as a fixed distance source, removing the degeneracy inherent to other lensing measurements.
- Signal at $l = 1000-3000$
- Image distortion – only a minor effect in the power spectrum.
- *Must* have a deep, high fidelity map to detect this effect.

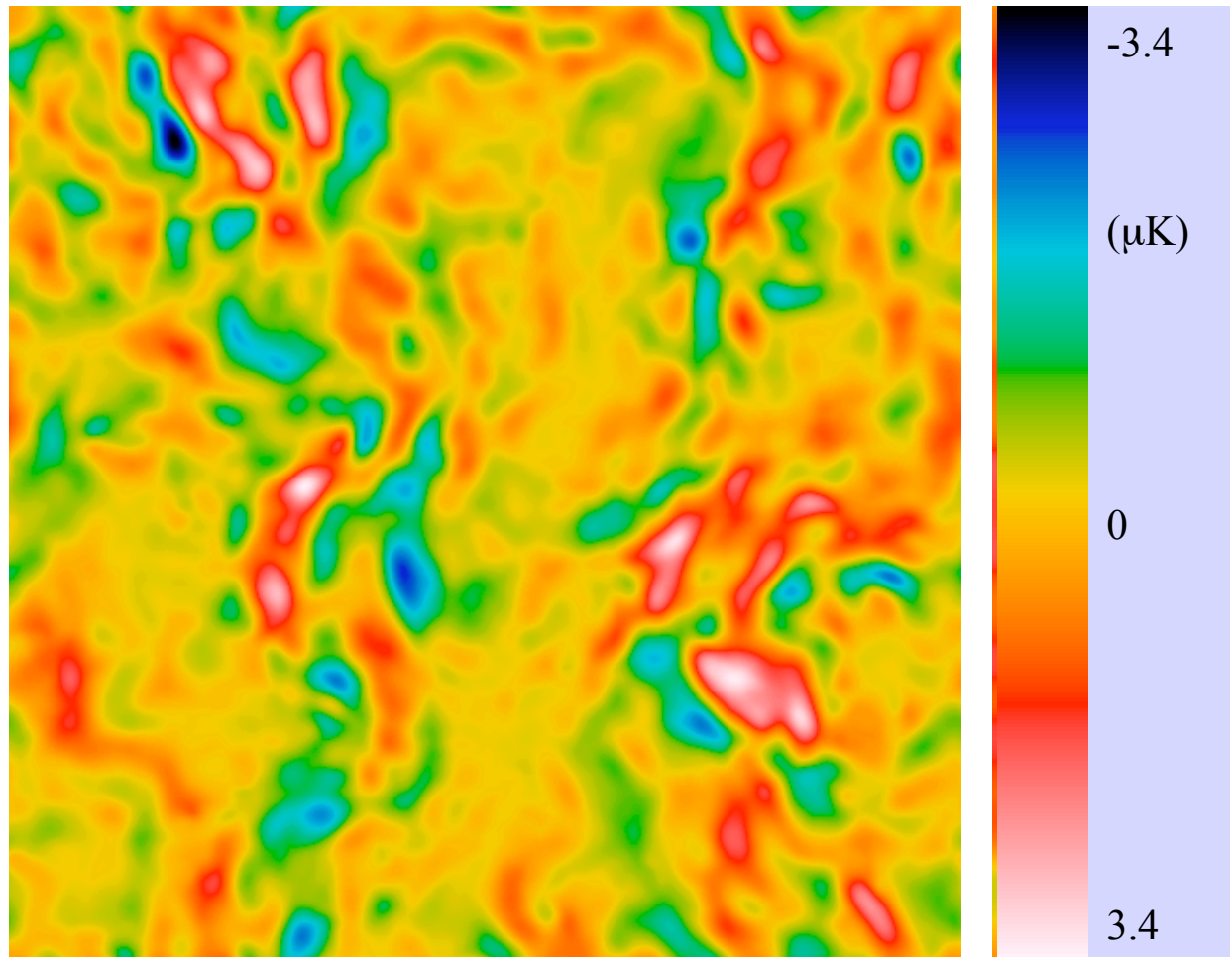


CMB

1.4°x 1.4°

Lensing of the CMB

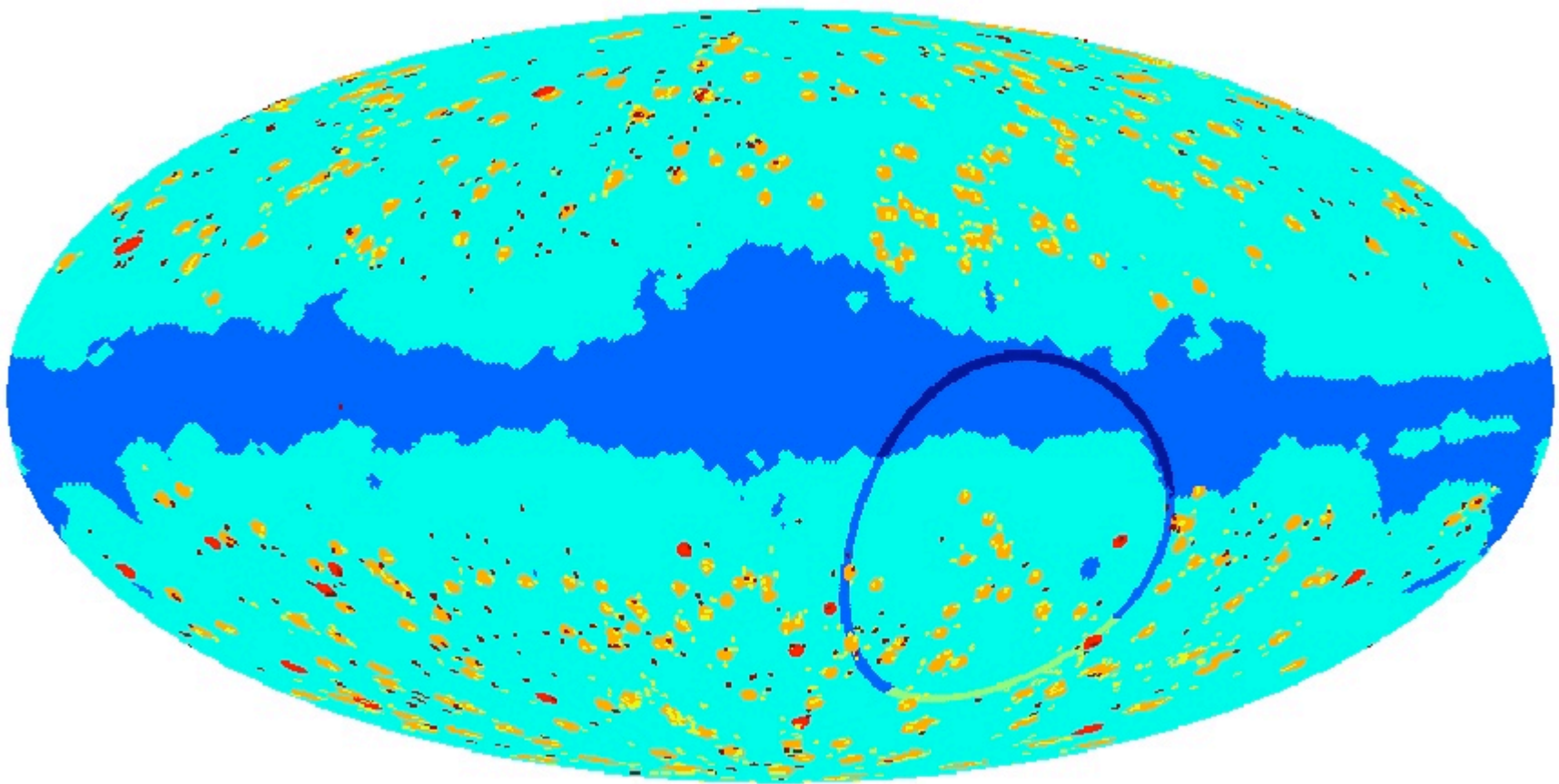
- RMS signal well above noise floor.
- Isolate from SZ and point sources spectrally.
- Identify with distinctive 4-point function.



Lensing Signal

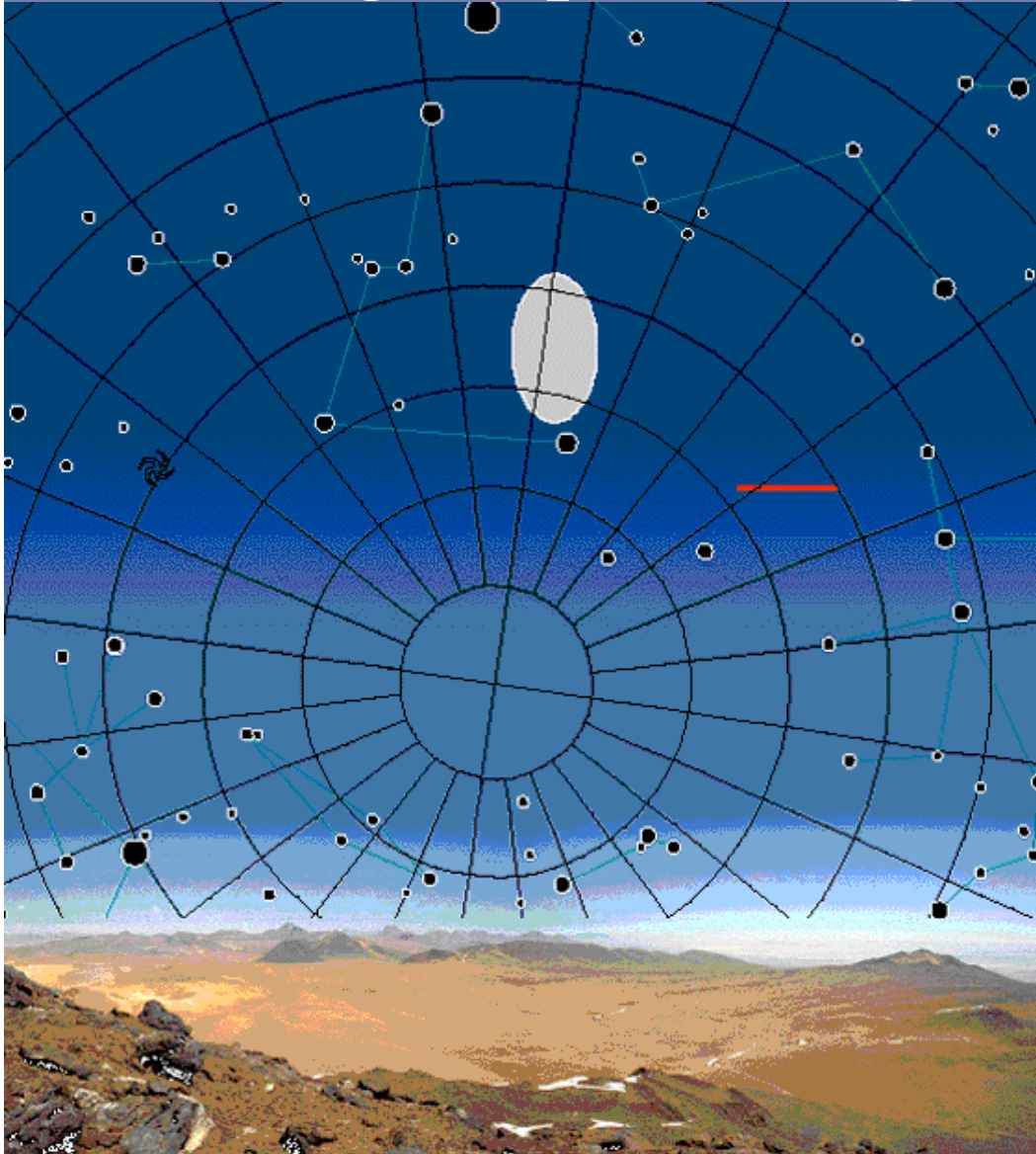
$1.4^\circ \times 1.4^\circ$

2% of CMB RMS

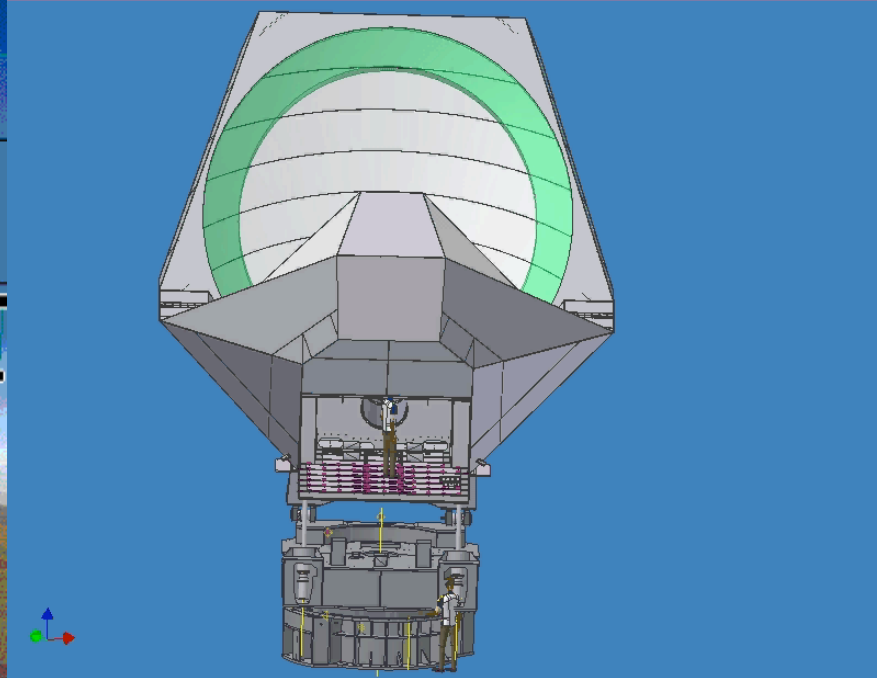


From Carlos Hernandez-Monteagudo

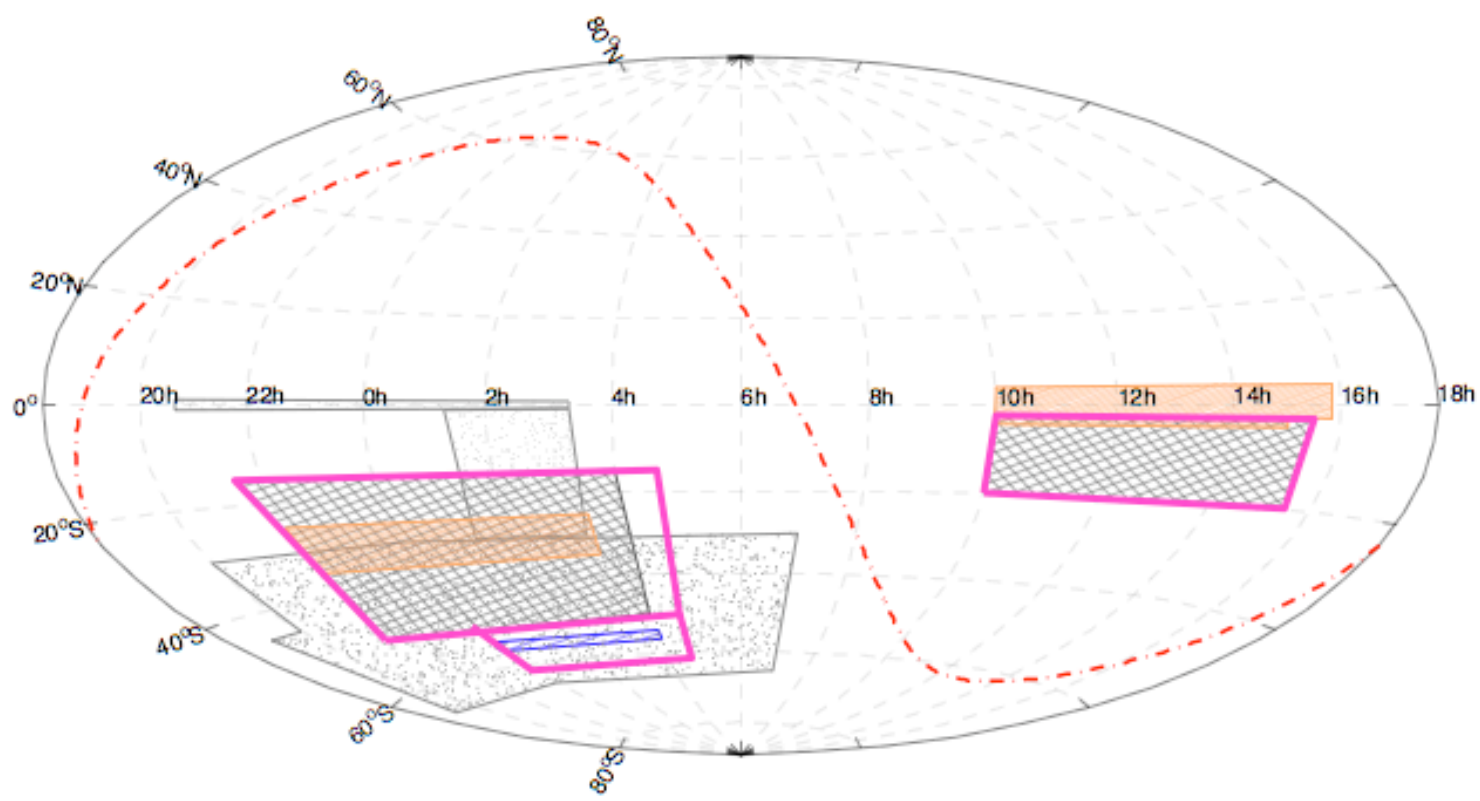
Cross Linked Scan Strategy is Crucial to Making Maps on Degree Angular Scales



- 240 square degrees in circle
- 100 square degrees for CMB
- Connect to WMAP satellite for calibration
- Rich Galactic data set



ISW@VST Survey



xxx ATLAS ■ KIDS — ACT ::: DES — ISW@VST - - - Milky Way

Using the KSZ signal

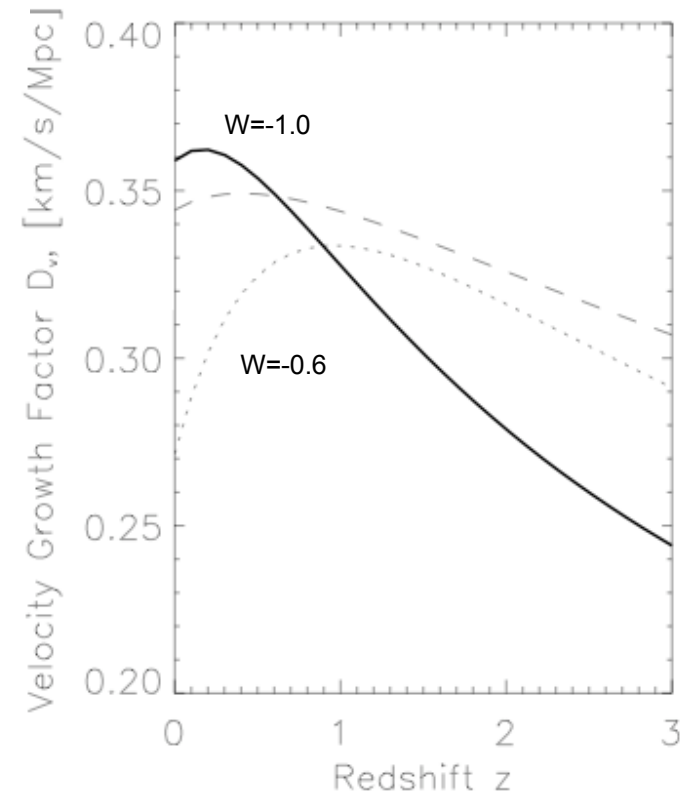
(Hernandez-Monteagudo, Verde, RJ, Spergel 2005)

The peculiar velocity field is sensitive to the onset of the late acceleration of the Universe.

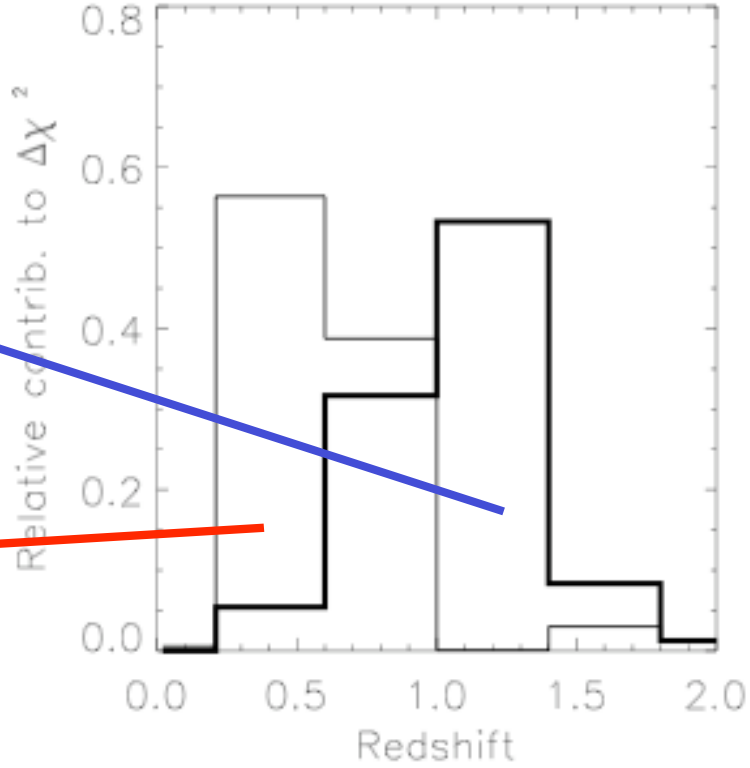
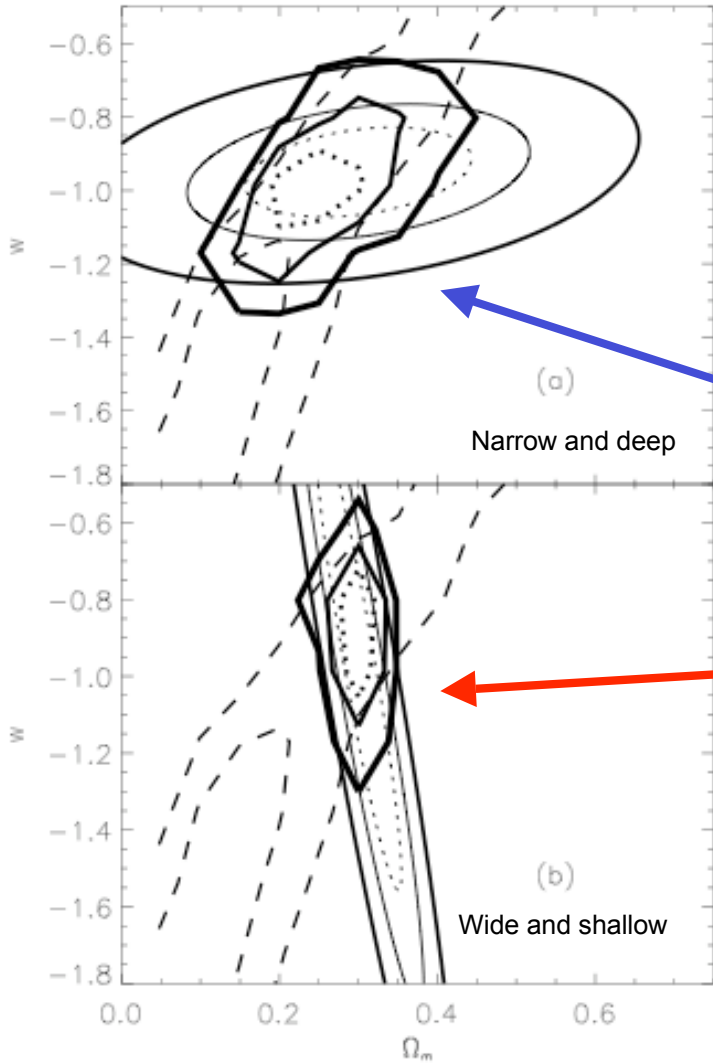
Recall that KSZ $\delta T_{kSZ} \propto n_e \mathbf{v}_e \cdot \mathbf{n}$

The power spectrum of the velocities is

$$P_{vv}(k) = \left(H(z) \left| \frac{dD_\delta}{dz} \right| \right)^2 \frac{P_m(k)}{k^2} = D_v^2 \frac{P_m(k)}{k^2},$$



KSZ sensitivity to w



(from Hernandez-Monteagudo et al.2005)⁸

Technology

The Millimeter Bolometric Array Camera: 3000 Detectors

Tricolor:

145, 225, & 265 GHz

3 independent 32x32 arrays

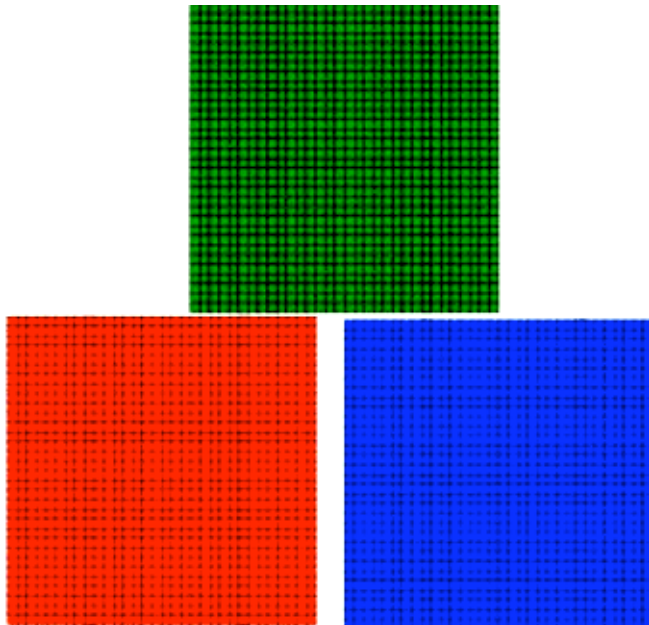


TES PUDs from GSFC

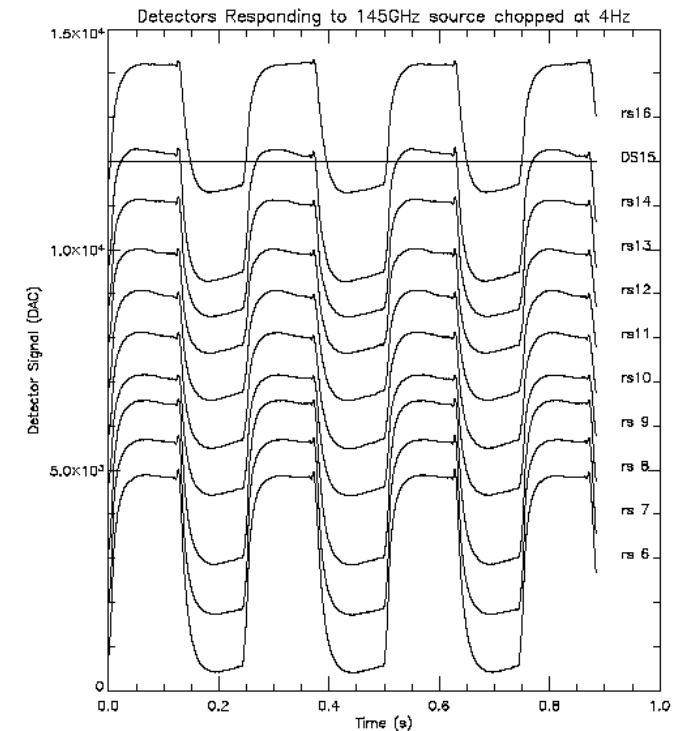
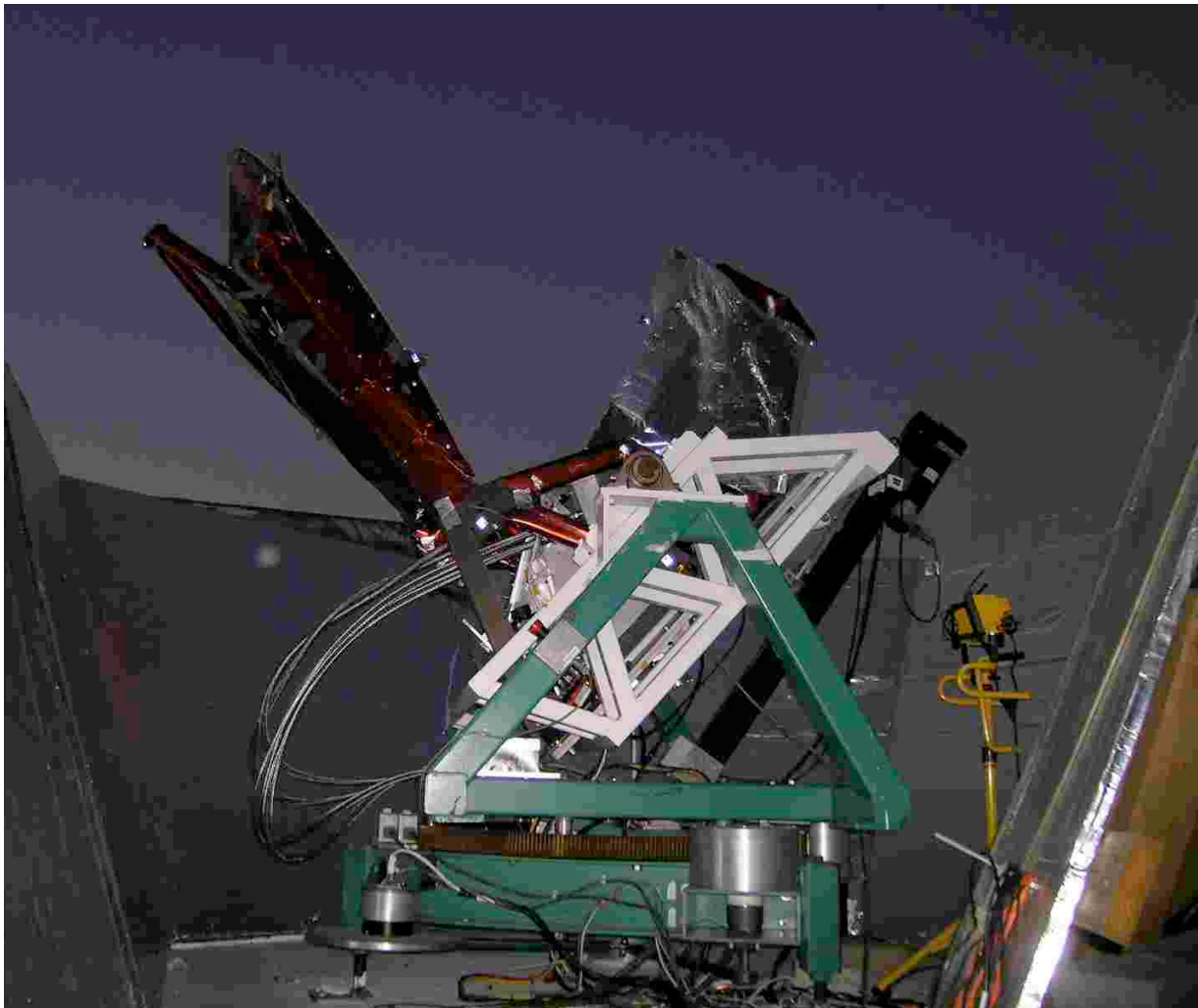
- PUDs = Pop-Up Devices
- TES = Transition Edge Sensor
Each pixel: 1 mm x 1 mm

Multiplexing from NIST + UBC

- 2-stage 1x33 mux chips (followed by Series Array SQUIDs)
- Nyquist inductors
- Room temp electronics & DAQ from UBC (based on NIST & SCUBA)

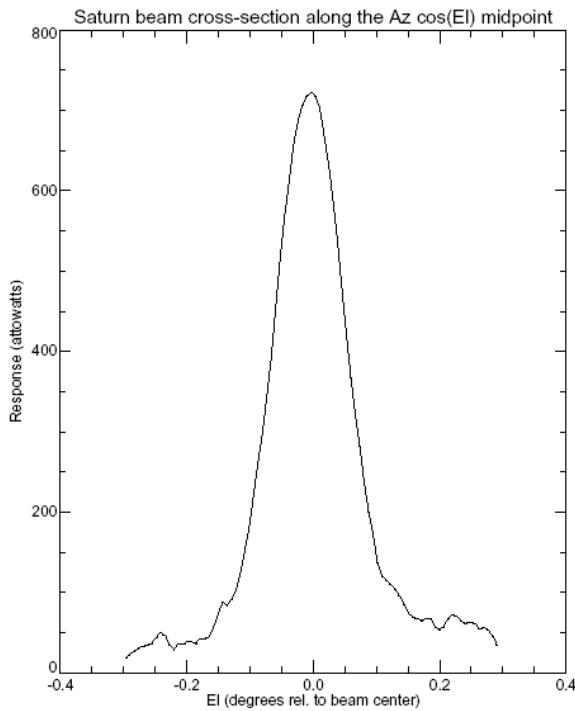


Detectors Coupled to WMAP Primary



- Mars, Saturn and the moon observed with *multiplexed* ACT detectors
- Used multiple high-index lenses.
- No excess noise, sufficiently fast time constant.

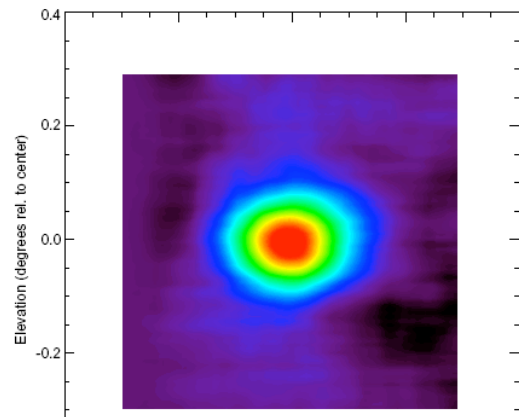
Measurements of Saturn



CCAM Princeton observation of Saturn (attowatts) 11x attenuation

-70 61 194 327 459 592 725

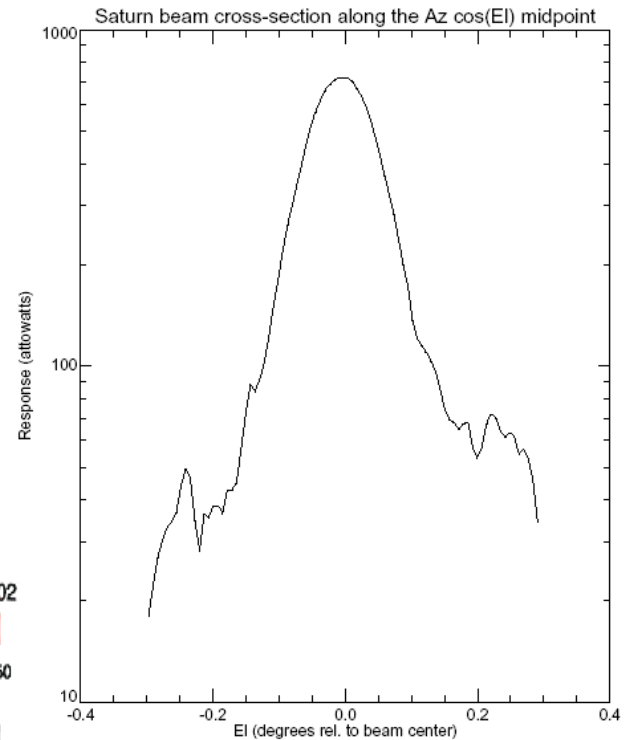
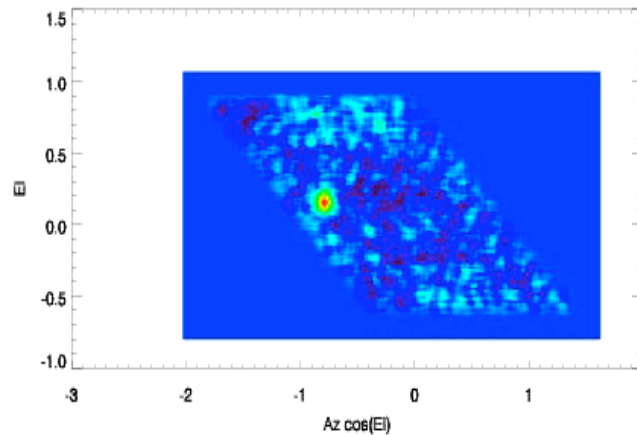
This color scale represents the intensity of the CCAM Princeton observation. The values range from -70 to 725, with a color gradient from dark purple to bright red.



CCAM Princeton observation of Saturn, 11x attenuation, (attowatts) RS02

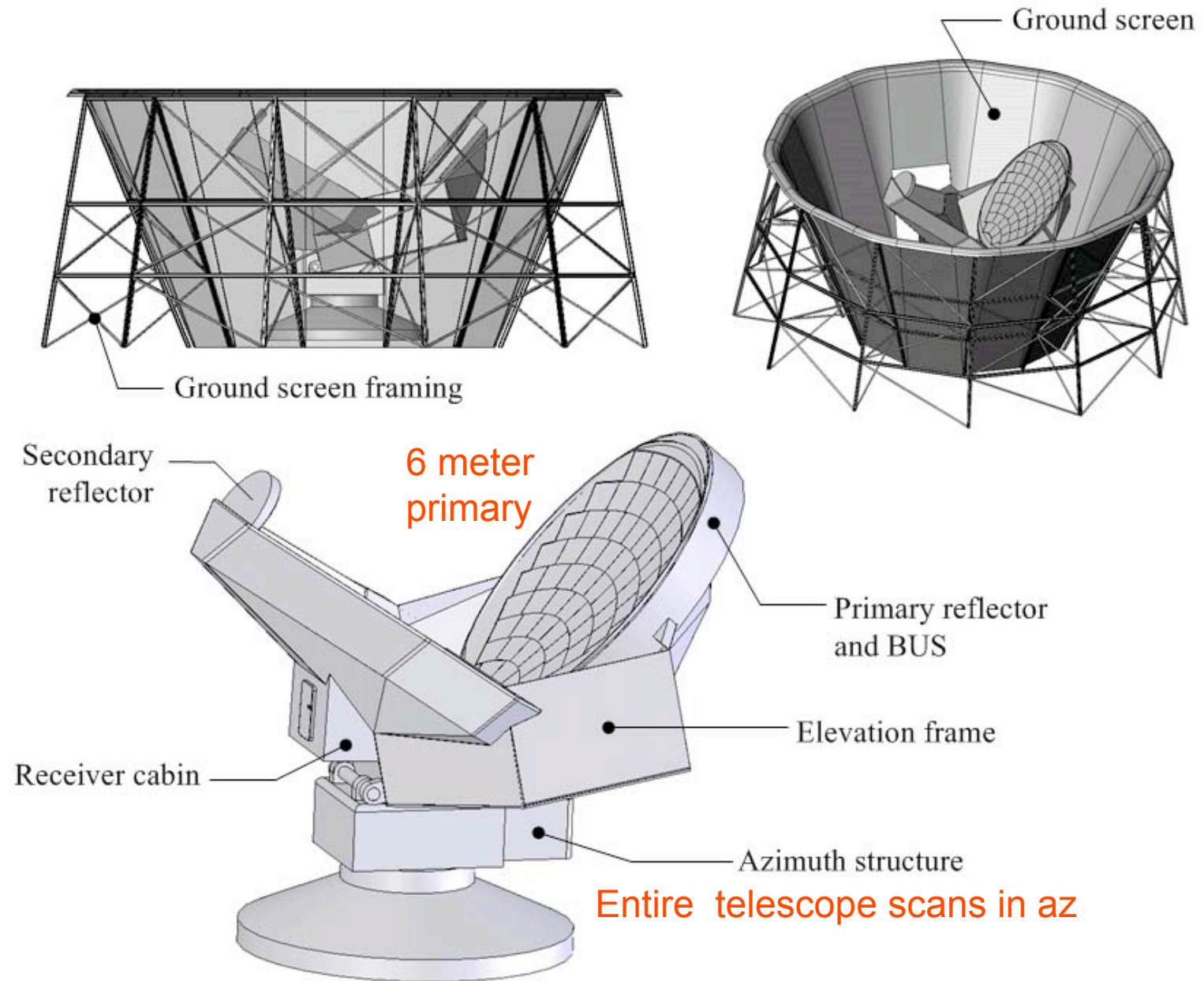
-340 -142 56 254 453 651 850

This color scale represents the intensity of the CCAM Princeton observation (RS02). The values range from -340 to 850, with a color gradient from dark purple to bright red.

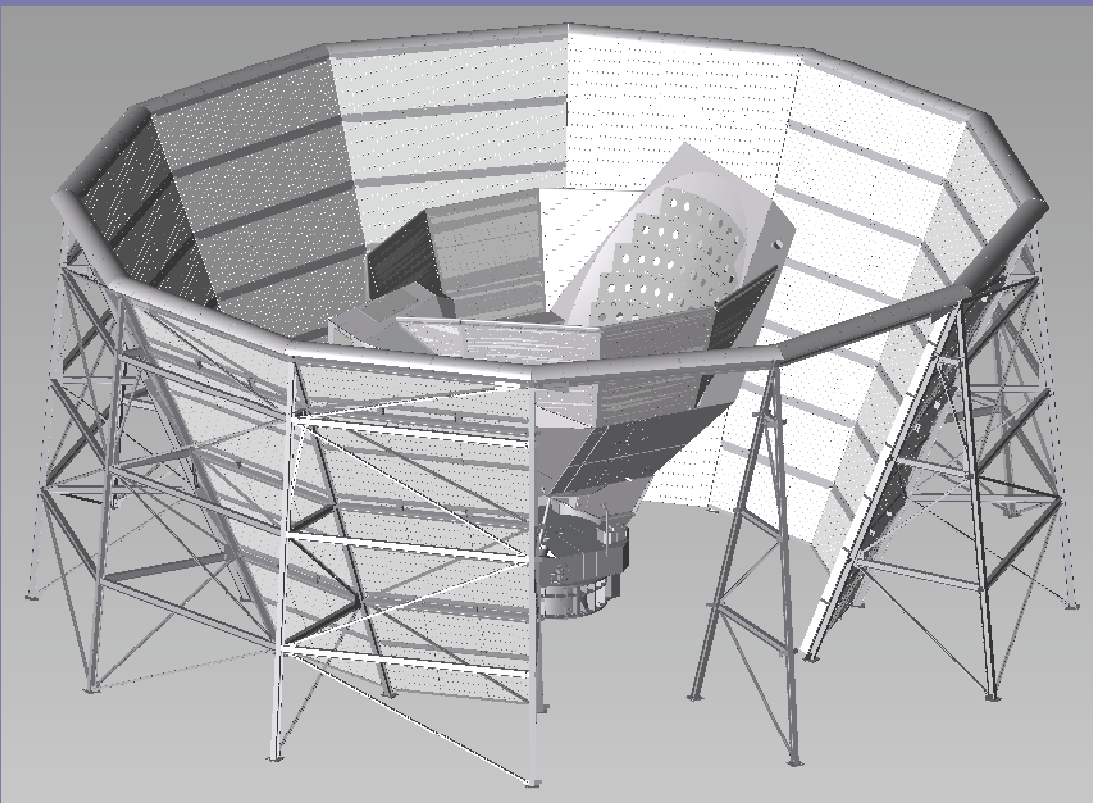
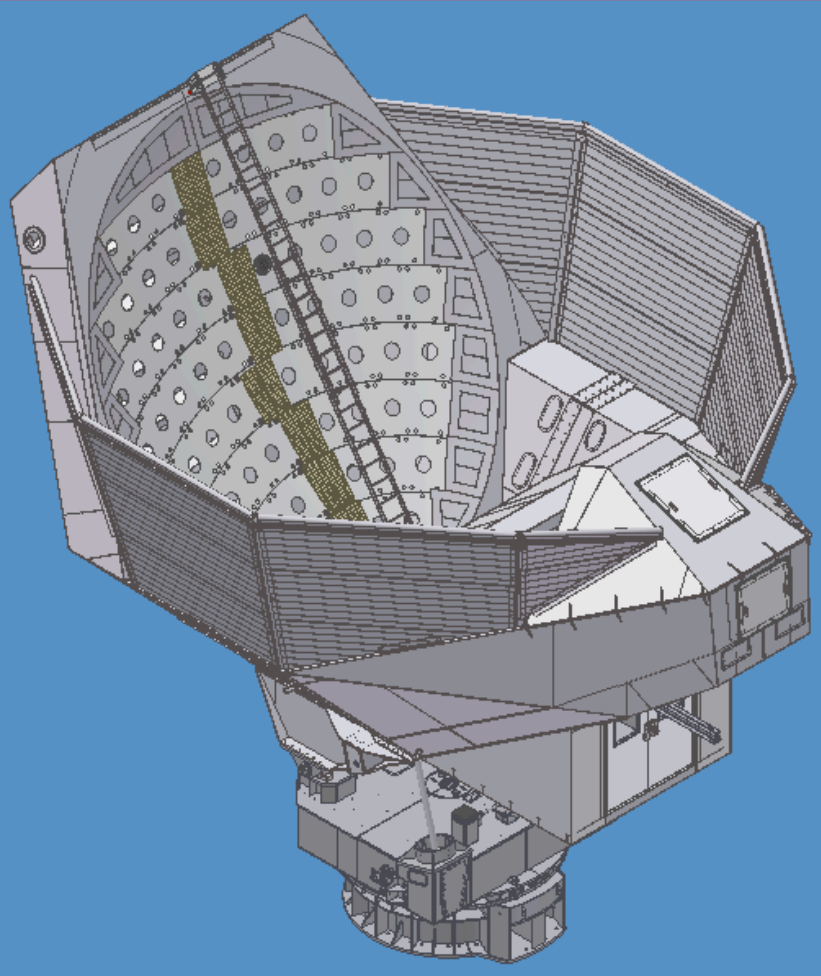


“Real-time” scan using
Multiple MULTIPLEXED
TES detectors.

ACT Telescope



Low Ground Pickup





Chilean Atacama Desert



Cerro Toco,
5200 m site

~45 minute
drive from
San Pedro de
Atacama





APEX

ALMA Support

Devlin

ACT -
5200 meters

Cerro Toco

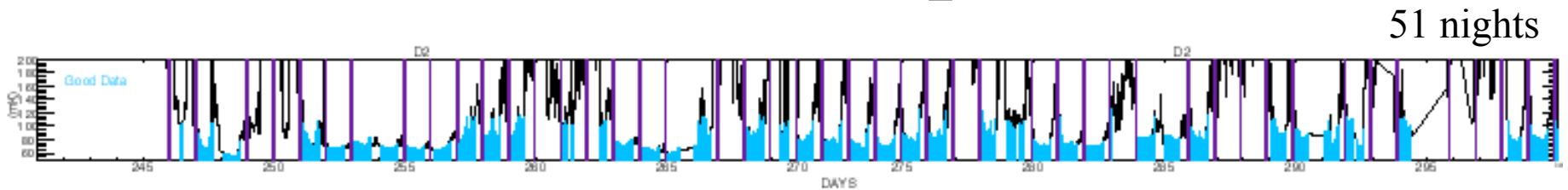
ALMA

TOCO Site

ACT -
5200 meters

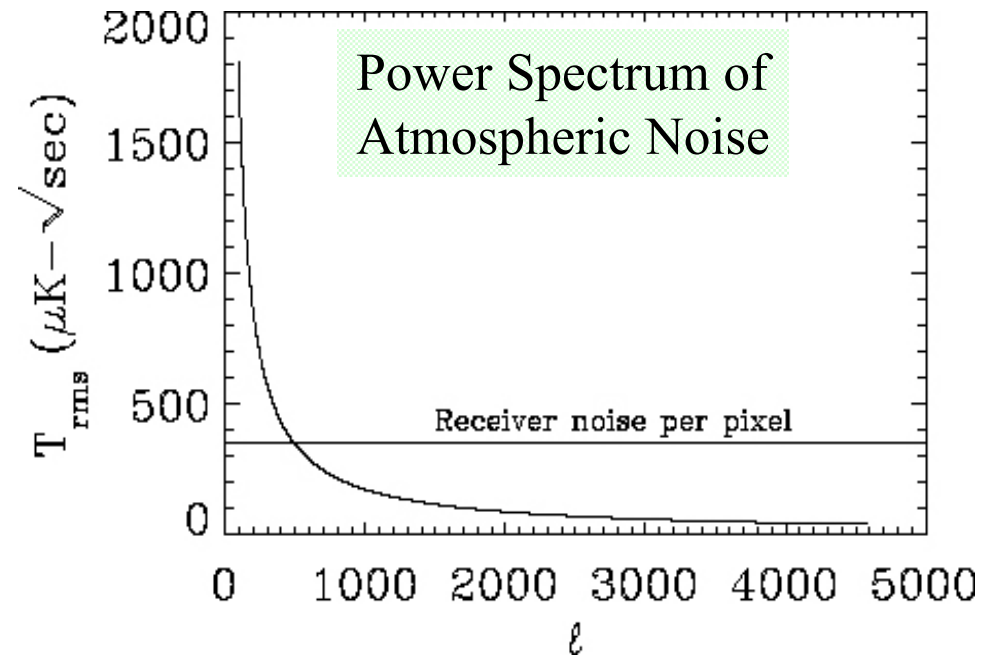


What Atmosphere?



Measured: 65% of the nights exceed the most stringent requirements.

- Only 65 nights required
- The atmospheric noise is below instrument noise ($l > 600$)
- All of our critical science is at $l > 600$



(based on Lay & Halverson)

The atmosphere is essentially featureless for $l > 1000$.

For $l < 1000$ solve for atmosphere with swept, over-sampled, filled array.

ACT Schedule

- Assemble telescope at factory: 4/15/06
- Install MBAC and test telescope: 5/1/06 – 6/16/06
- Factory Acceptance: 6/20/06
- Disassemble (3-4 parts) and ship to Chile: 7/20/06
- Assemble in San Pedro: 8/06 – 9/06
- Install at site – 9/06 – 10/06
- Site Acceptance Test: 10/06
- Install receiver and first light: 11/06



END