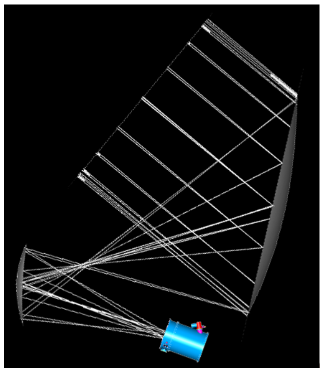
The Atacama Cosmology Telescope

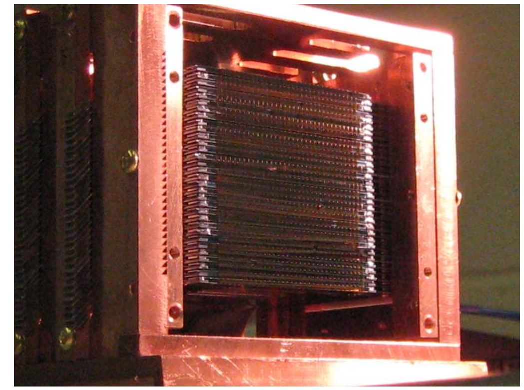
Suzanne Staggs
Santander
June 2013

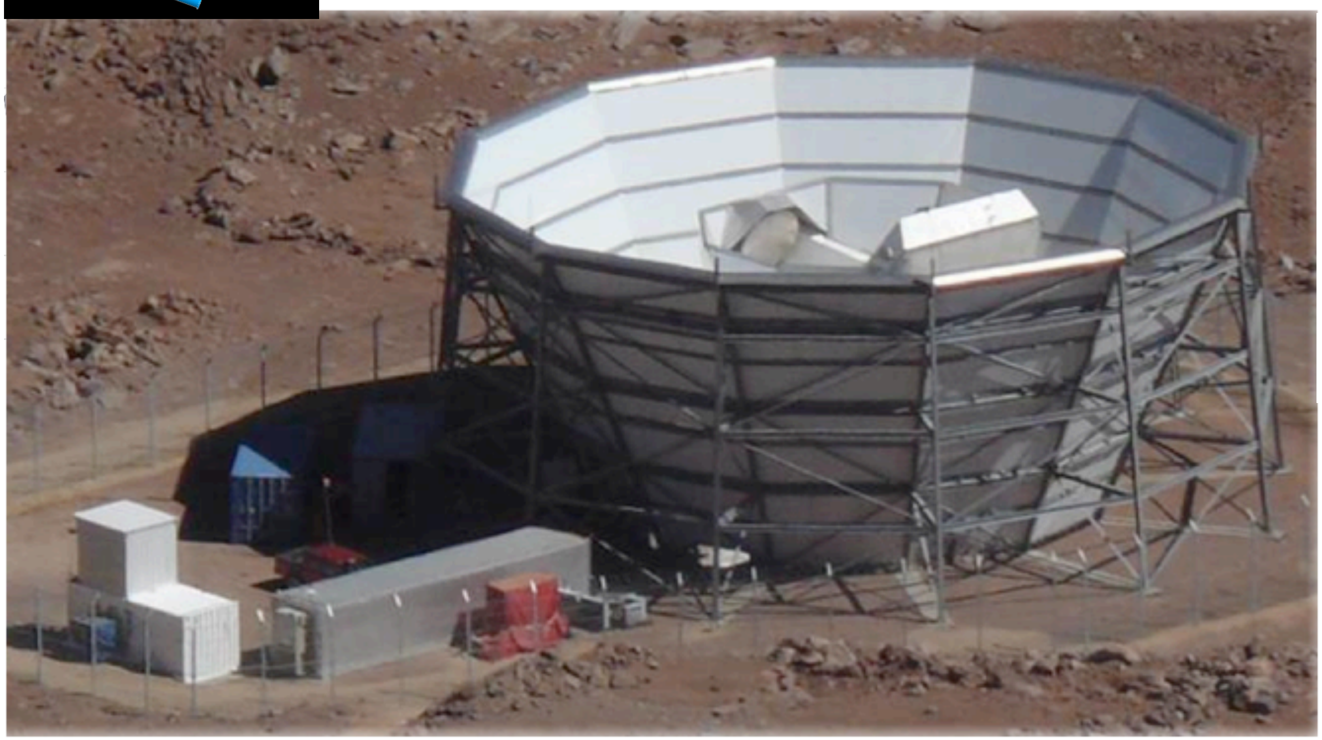
ACT

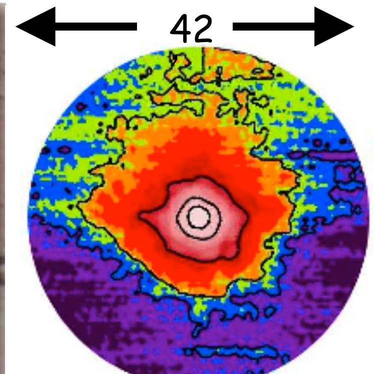
(with first receiver, MBAC)



- 6m off-axis Gregorian telescope
- Located at 5200 m (0.5 mm PWV)
- 3 arrays of 1024 TES bolometers each
- 148 GHz, 218 GHz, 277 GHz

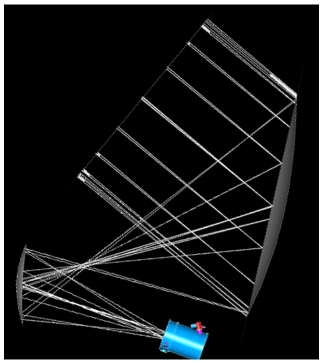




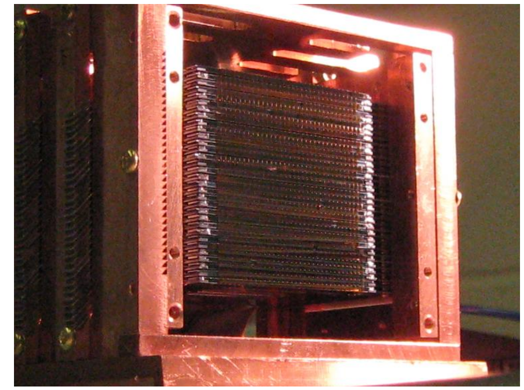


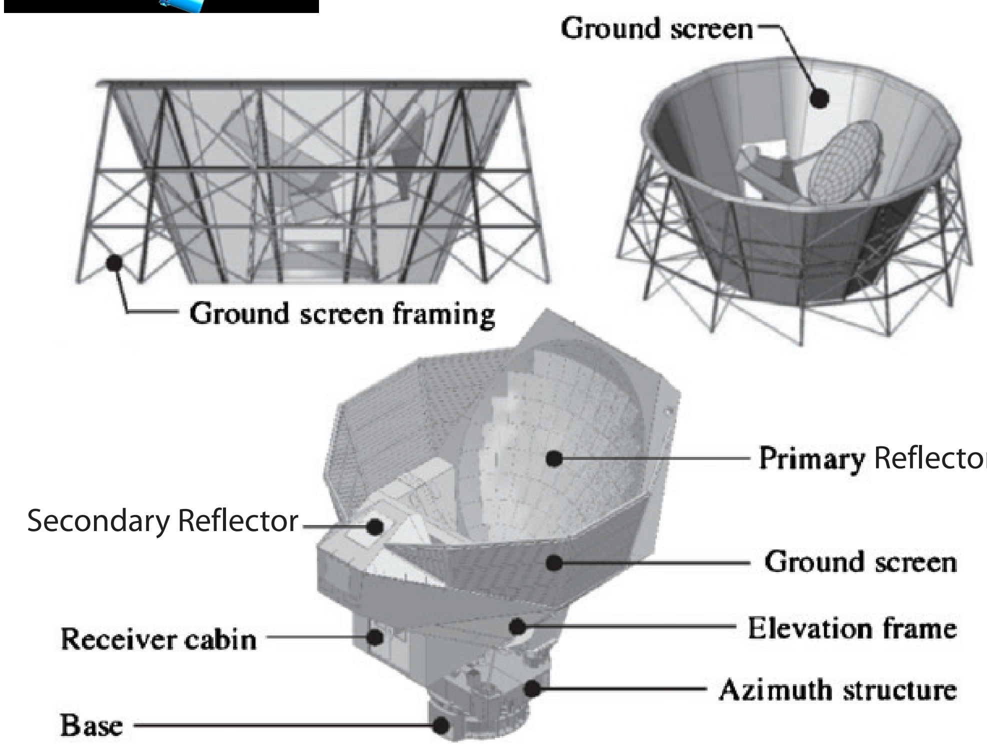
148 GHz:
1.4' resolution
30 uK-rt(s)
f_{3db} ~ 84 Hz

ACT
(with first receiver, MBAC)

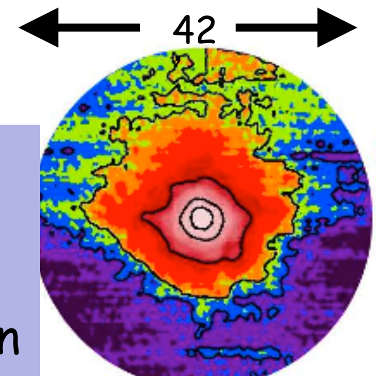


- 6m off-axis Gregorian telescope
- Located at 5200 m (0.5 mm PWV)
- 3 arrays of 1024 TES bolometers each
- 148 GHz, 218 GHz, 265 GHz





ACT ground screens: large co-moving screen and 13 m outer screen.

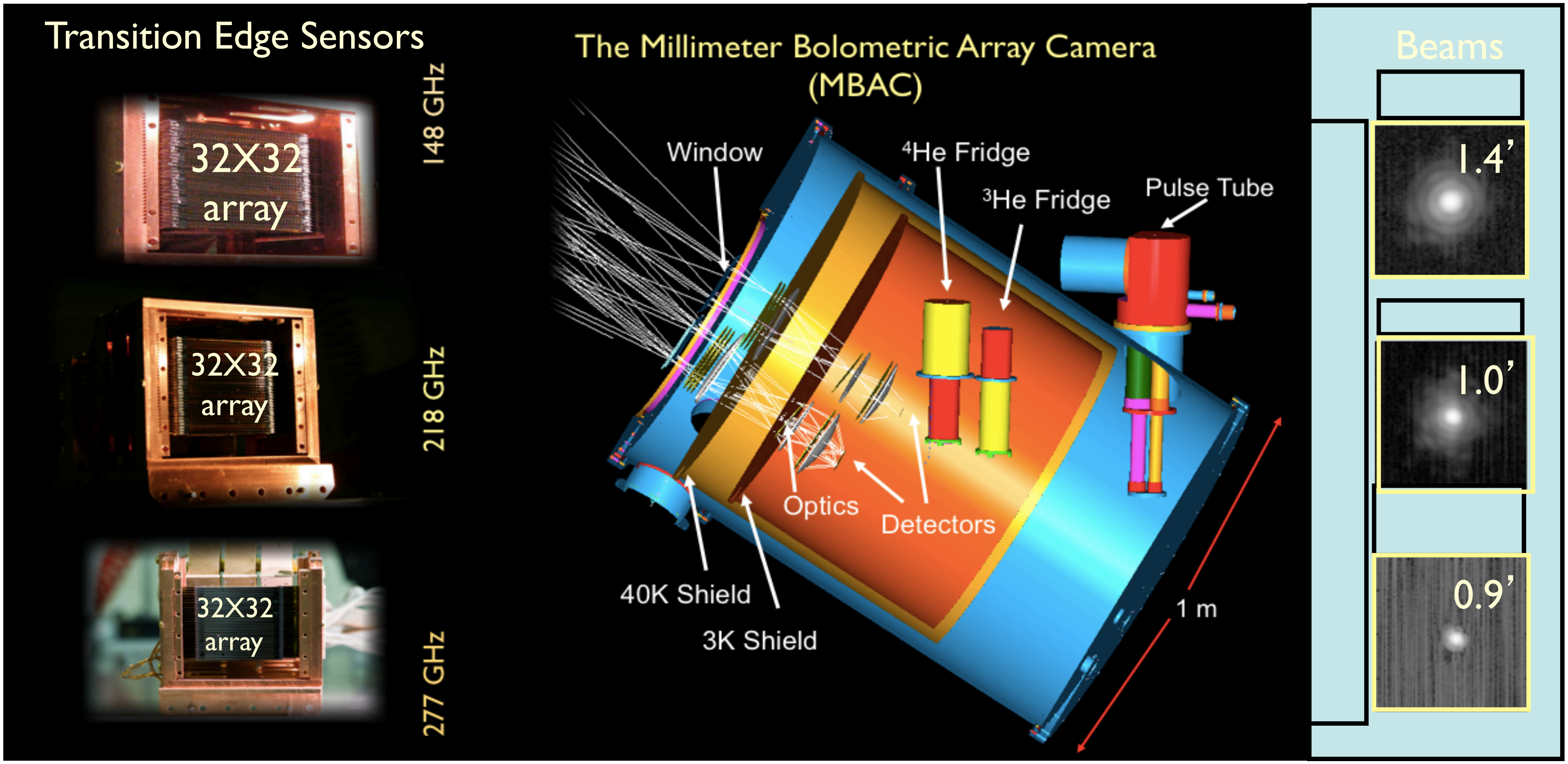


148 GHz: 1.4’ resolution

30 uK-rt(s)

f_{3db} ~ 84 Hz

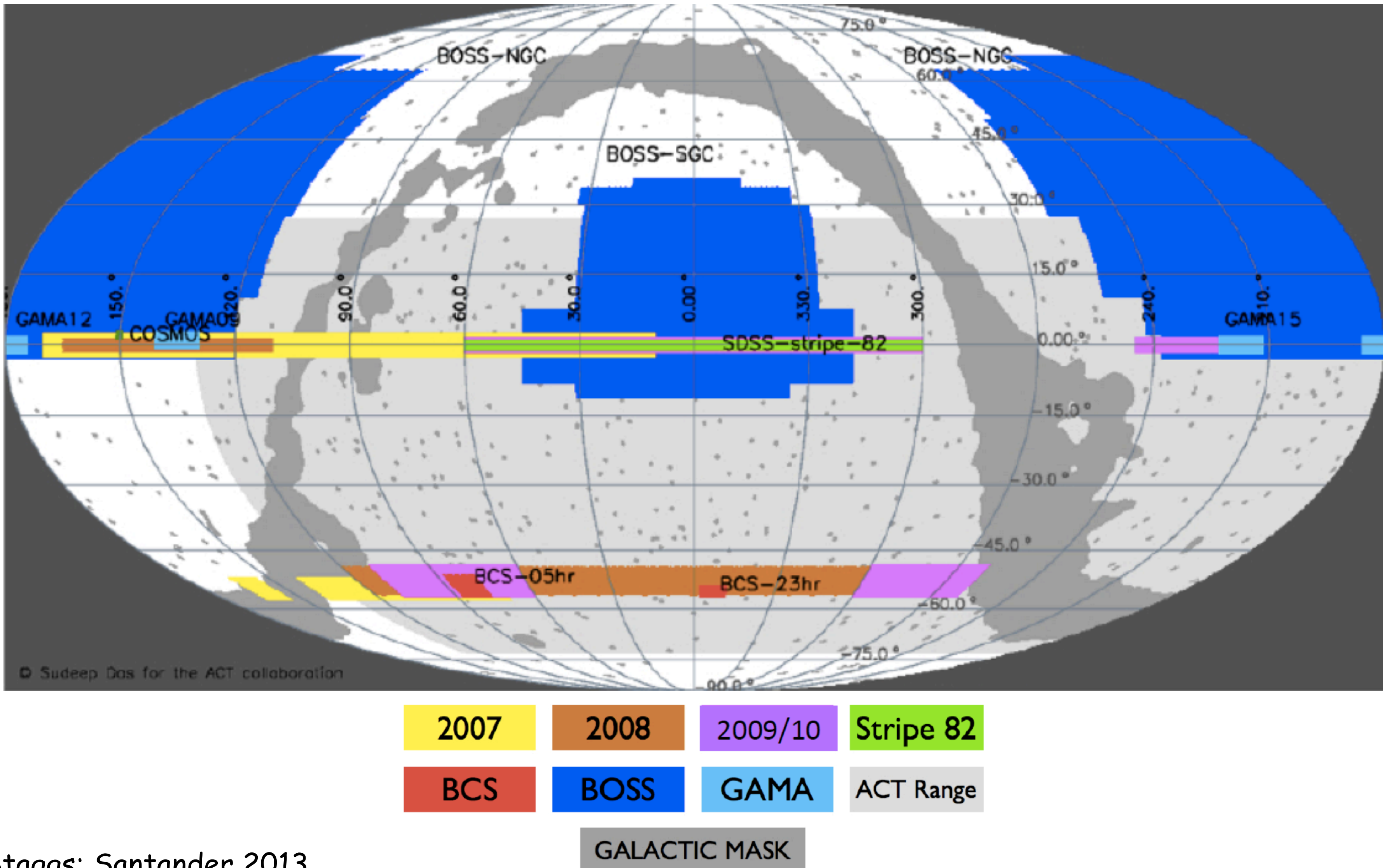
The (first) ACT Receiver



300 mK detectors; dry/closed cycle system; AR-coated silicon lenses; Lyot stop

ACT Survey Regions

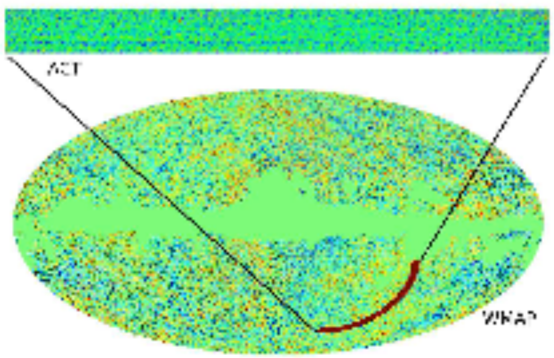
~ 100 clusters from 755 deg^2

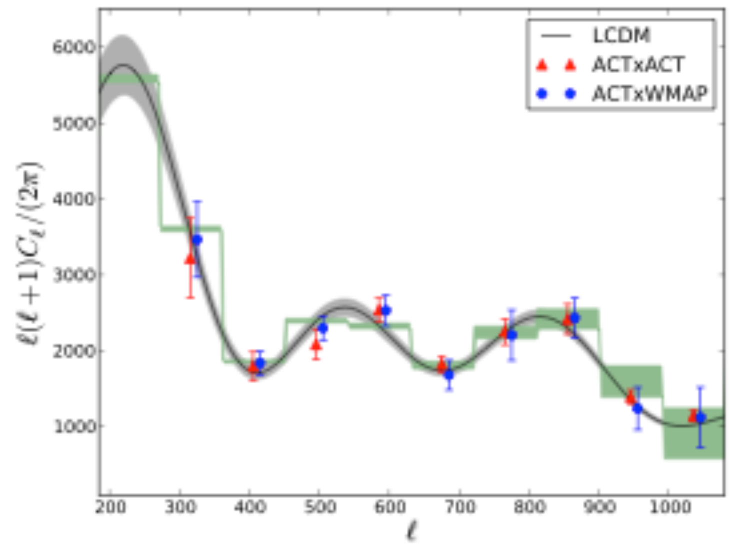


Staggs; Santander 2013

Calibrating the ACT Maps

Cross-Correlating to WMAP





(ACT at 148 GHz)

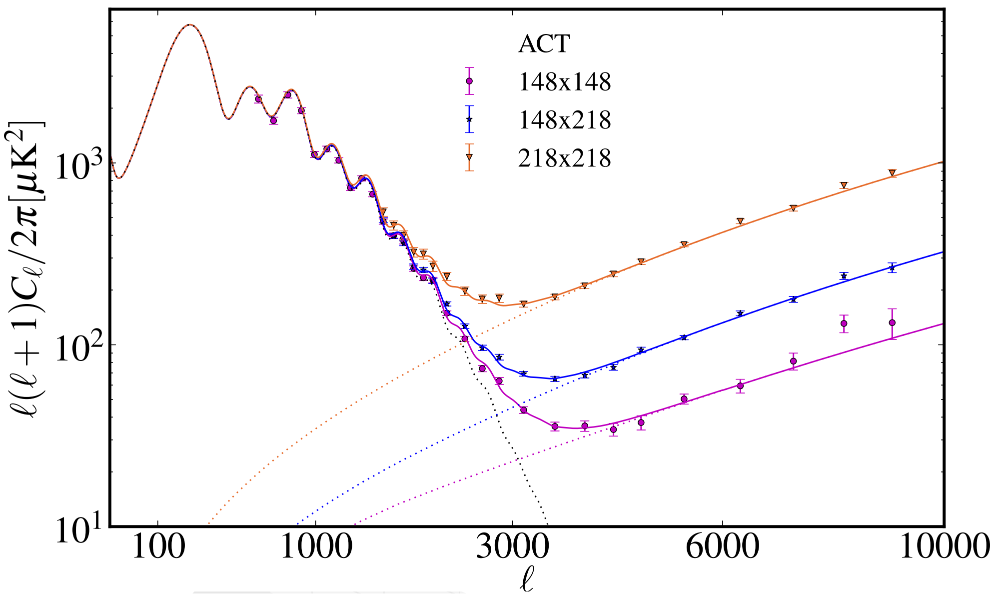
Greenish rectangles ae binned WMAP 94 GHz spectra

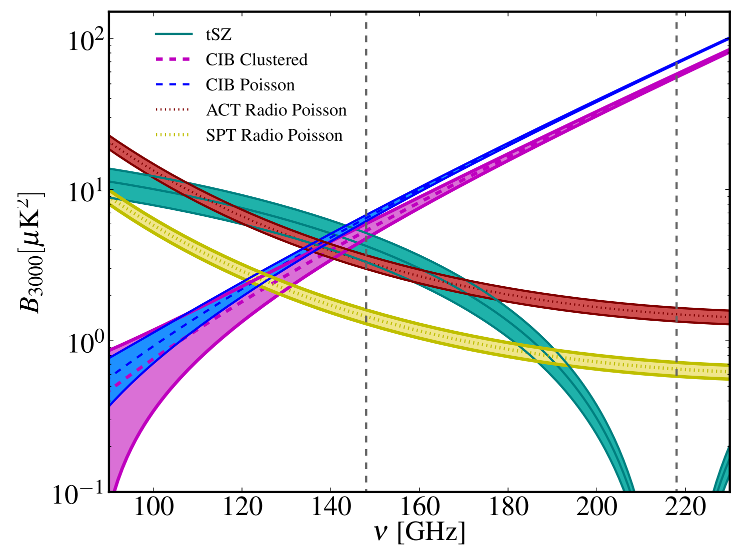
ACT maps' dynamic range permits calibration to 2% from WMAP, but ACT maps are 10x higher resolution.

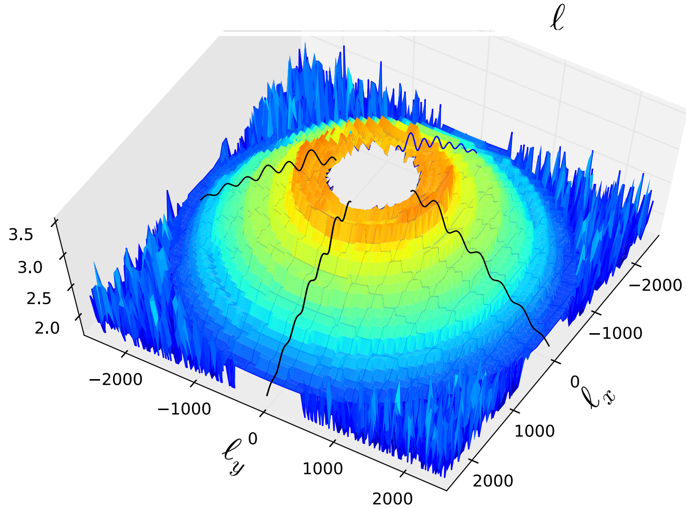
Staggs; Santander 2013

Hajian et al, 2010

The ACT Power Spectra







Power spectra from three frequency pairs, and the models for fitting them.

2d spectrum: ACT 148 GHz, equatorial region (18 uK arcmin).

Figures from Dunkley et al 2013 and Das et al 2013

Staggs; Santander 2013

TT Power Spectra

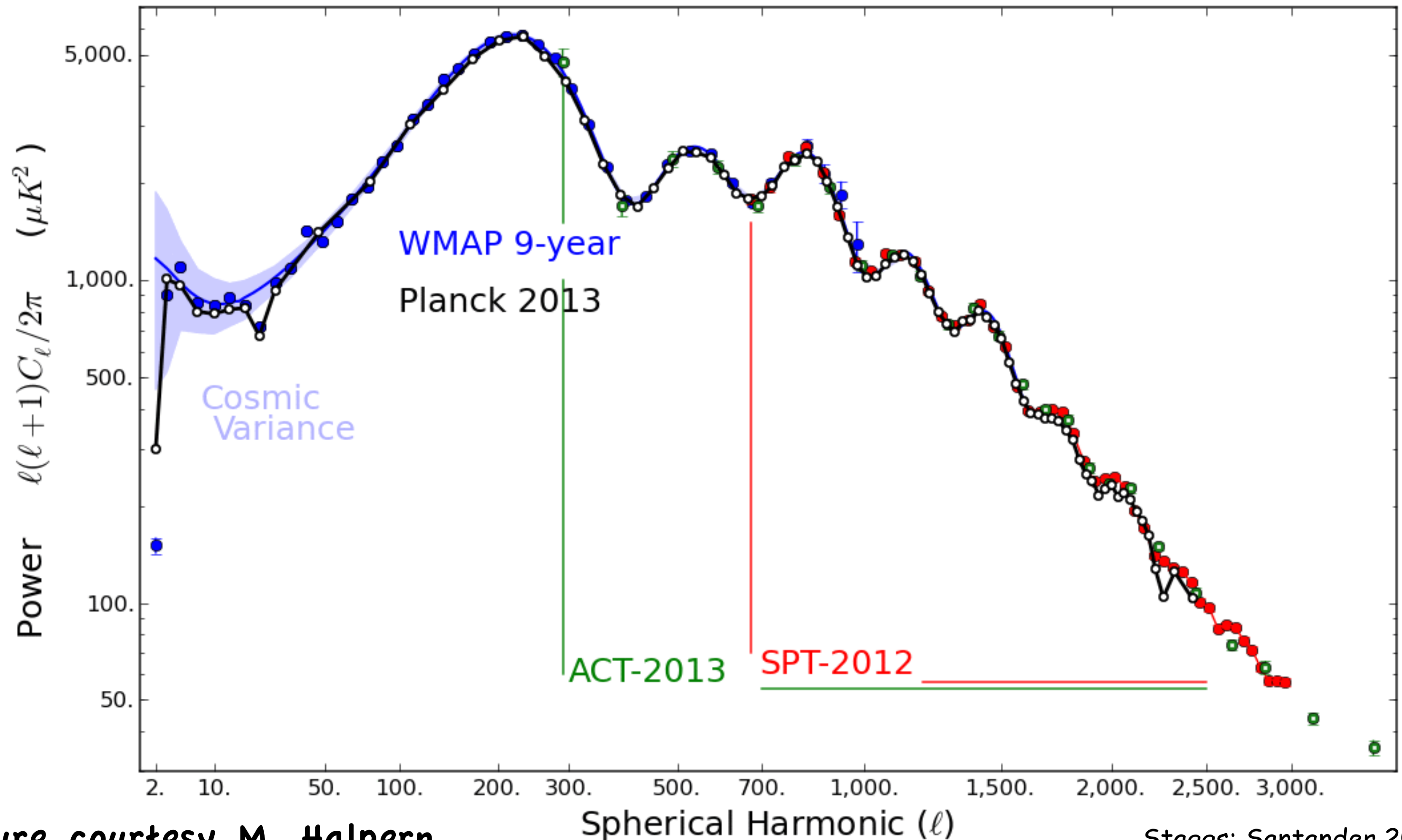
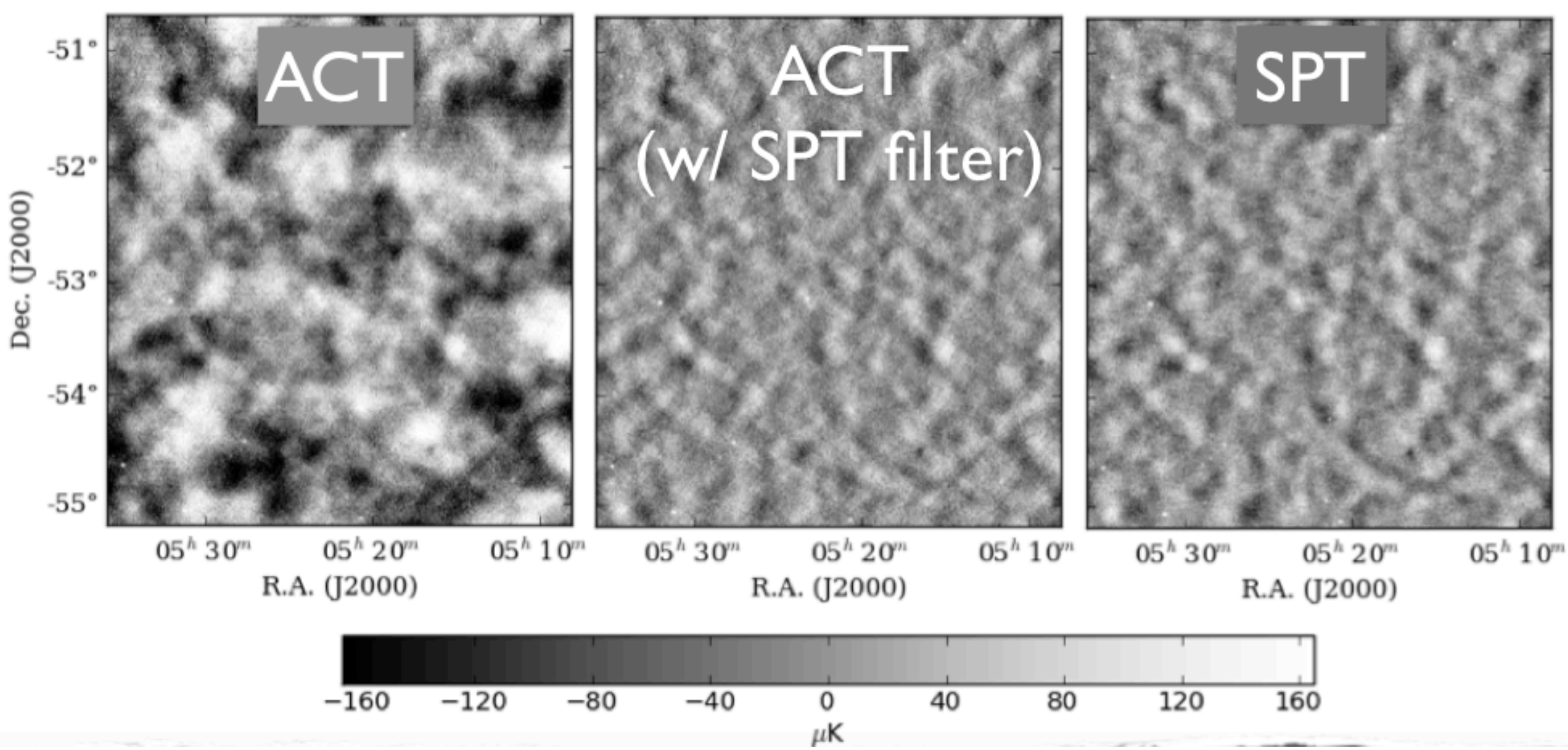


Figure courtesy M. Halpern

Staggs; Santander 2013

ACT and SPT are Consistent



Staggs; Santander 2013

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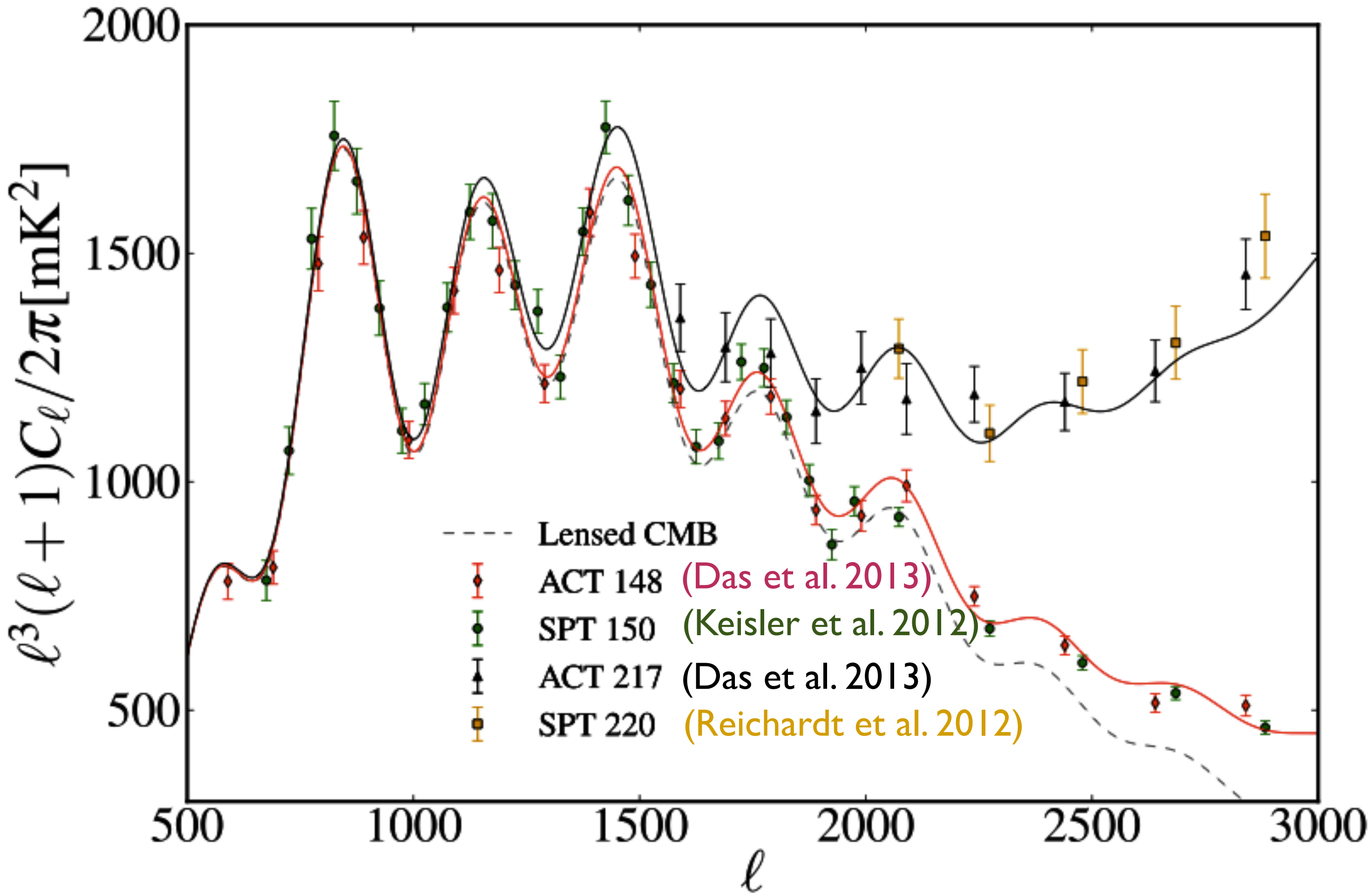
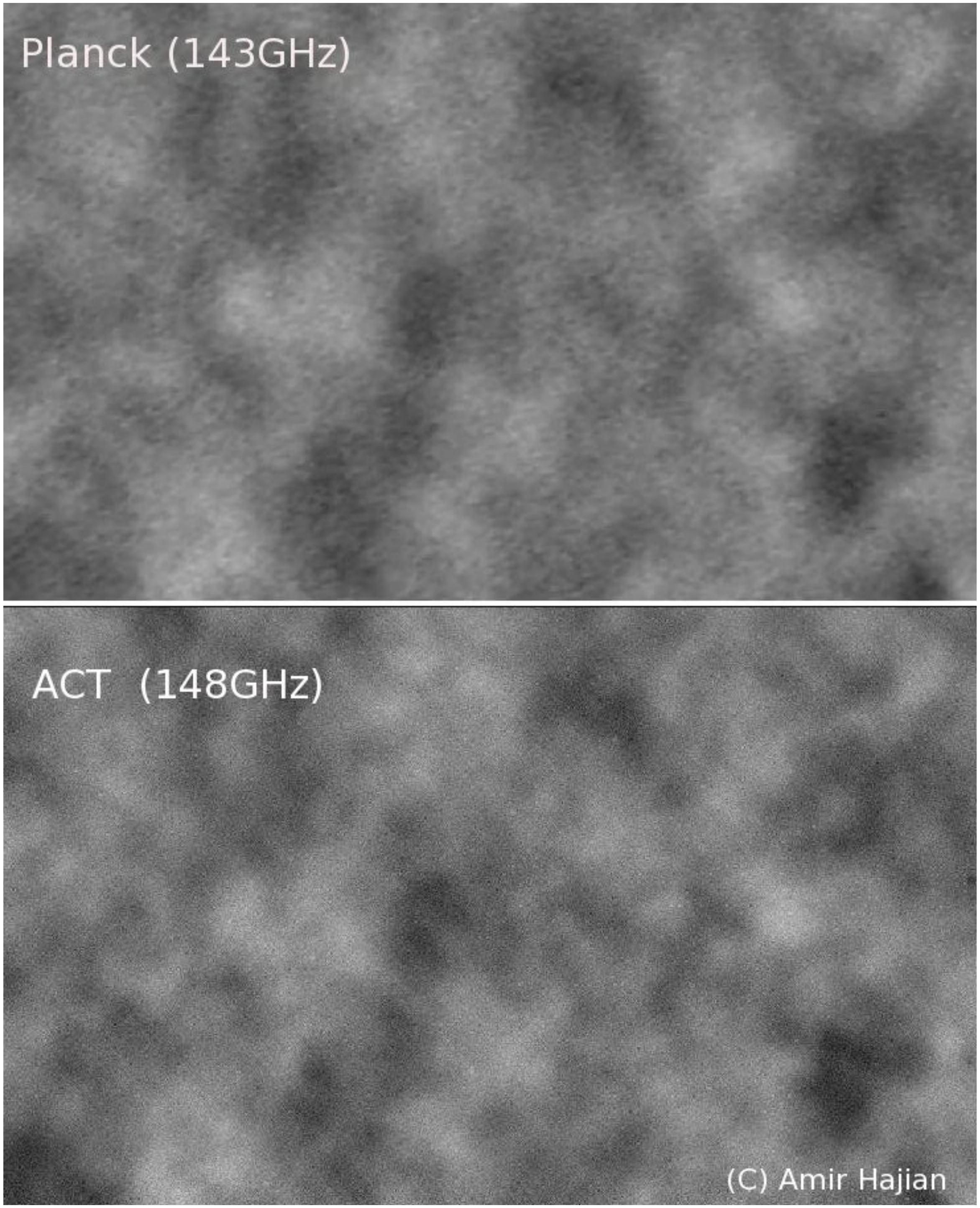


Staggs; Santander 2013

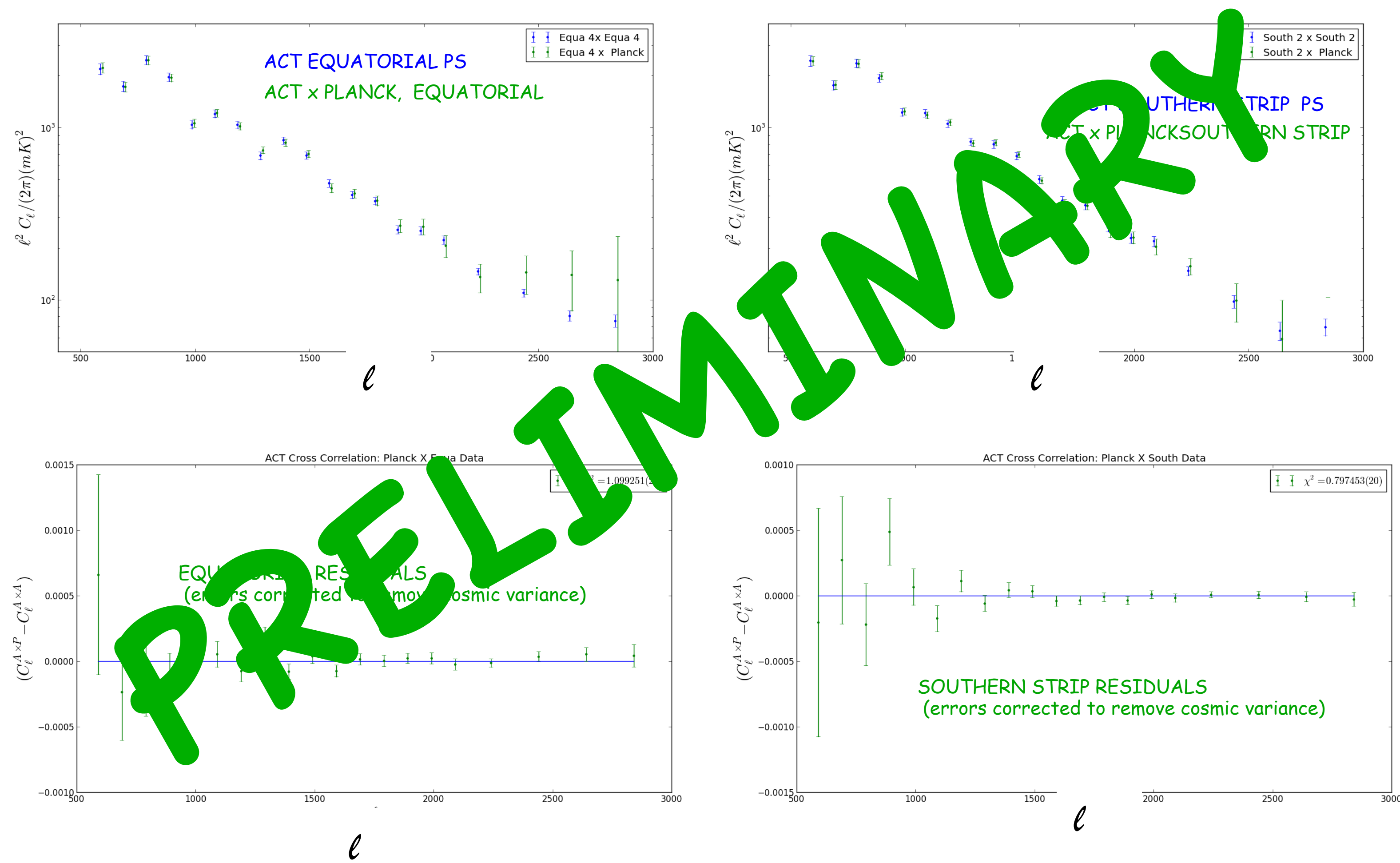


Comparing ACT and Planck

Visual comparison of maps in ~3° x 5° at equator.
Point sources are removed from ACT (only).

Staggs; Santander 2013

PRELIMINARY
ACT:Planck Cross-Correlation

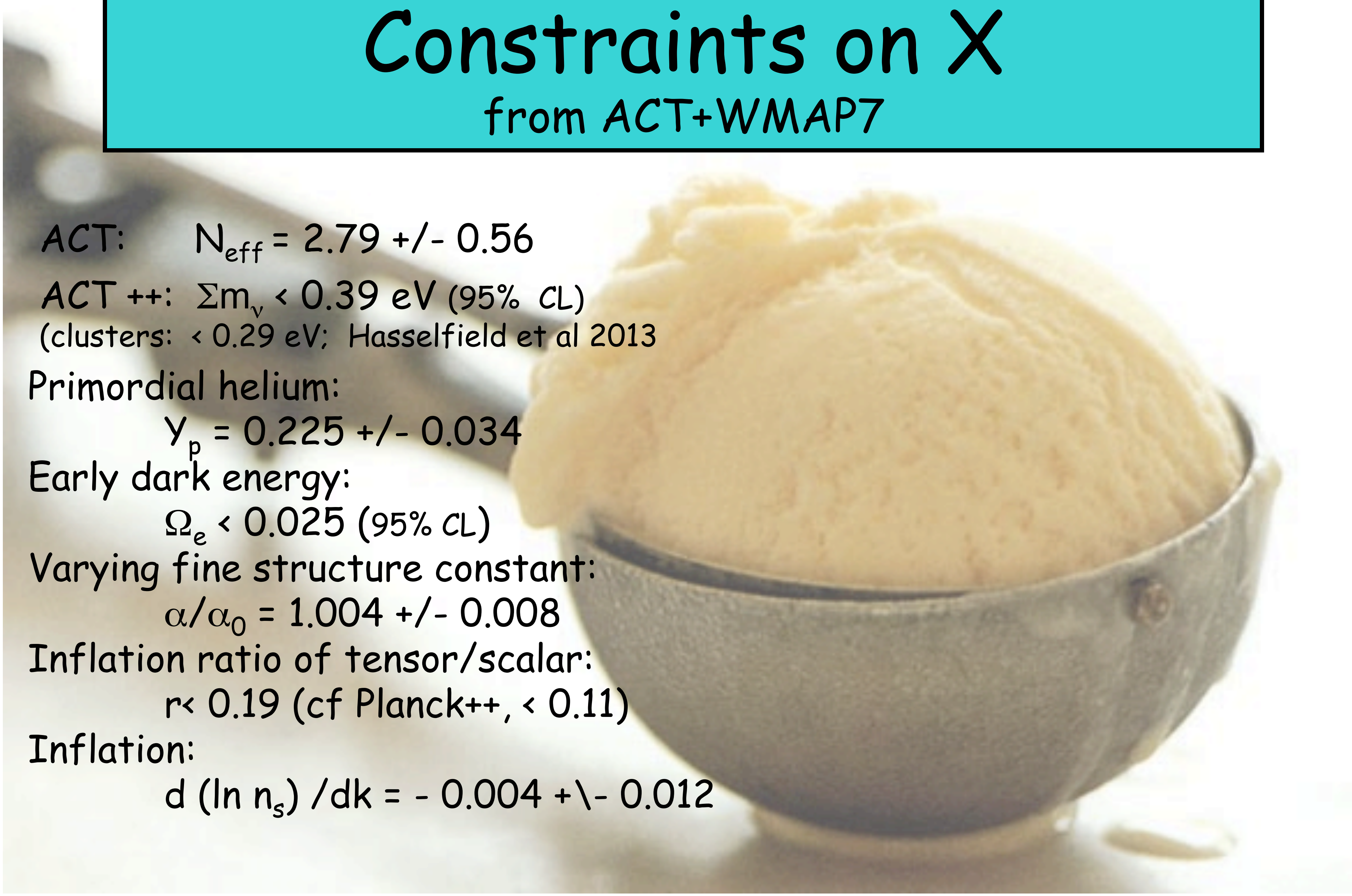


Staggs; Santander 2013

Figures courtesy T. Louis

Constraints on X

from ACT+WMAP7



ACT: N_{eff} = 2.79 +/- 0.56

ACT ++: Σm_ν < 0.39 eV (95% CL)

(clusters: < 0.29 eV; Hasselfield et al 2013

Primordial helium:

Y_p = 0.225 +/- 0.034

Early dark energy:

Ω_e < 0.025 (95% CL)

Varying fine structure constant:

α/α_0 = 1.004 +/- 0.008

Inflation ratio of tensor/scalar:

r< 0.19 (cf Planck++, < 0.11)

Inflation:

d ($\ln n_s$) /dk = - 0.004 +\- 0.012

Staggs; Santander 2013

ACT + WMAP 7 results from Sievers et al 2013; some include ACT lensing

ACT + WMAP9 Results

Calabrese et al 2013

Parameter	WMAP9 +ACT	WMAP9 +SPT	WMAP9 +ACT+SPT[a]
$100\Omega_b h^2$	2.260 ± 0.041	2.231 ± 0.034	2.252 ± 0.033
$100\Omega_c h^2$	11.46 ± 0.43	11.16 ± 0.36	11.22 ± 0.36
$100\theta_A$	1.0396 ± 0.0019	1.0422 ± 0.0010	1.0424 ± 0.0010
τ	0.090 ± 0.014	0.082 ± 0.013	0.085 ± 0.013
n_s	0.973 ± 0.011	0.9650 ± 0.0093	0.9690 ± 0.0089
$10^9 \Delta^2_{\mathcal{R}}$	2.22 ± 0.10	2.15 ± 0.10	2.17 ± 0.10
Ω_Λ [b]	0.716 ± 0.024	0.737 ± 0.019	0.735 ± 0.019
σ_8	0.830 ± 0.021	0.808 ± 0.018	0.814 ± 0.018
t_0	13.752 ± 0.096	13.686 ± 0.065	13.665 ± 0.063
H_0	69.7 ± 2.0	71.5 ± 1.7	71.4 ± 1.6
$100 r_s/D_{V\,0.57}$	7.50 ± 0.17	7.65 ± 0.14	7.66 ± 0.14
$100 r_s/D_{V\,0.35}$	11.29 ± 0.31	11.56 ± 0.26	11.57 ± 0.26
best fit χ^2	7596.0	7617.1	7640.7

[a] The combination ACT+SPT uses ACT-E data only.

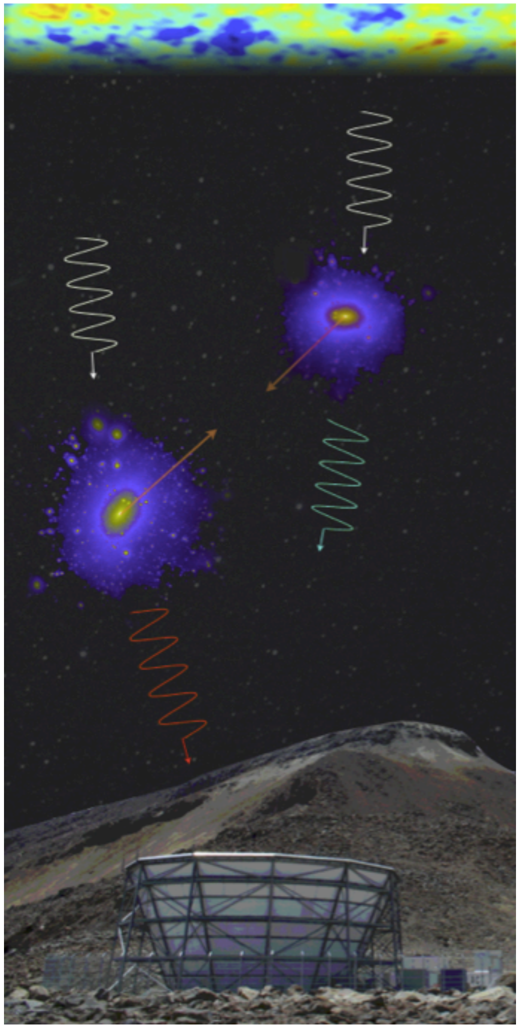
Skewness σ_8:
0.79 +/- 0.03
Wilson et al 2012

Clusters σ_8:
0.829 +/- 0.024
Hasselfield et al 2013

Staggs; Santander 2013

ACT's Clear Evidence for the Kinematic SZ Effect

Hand et al 2012



Staggs; Santander 2013

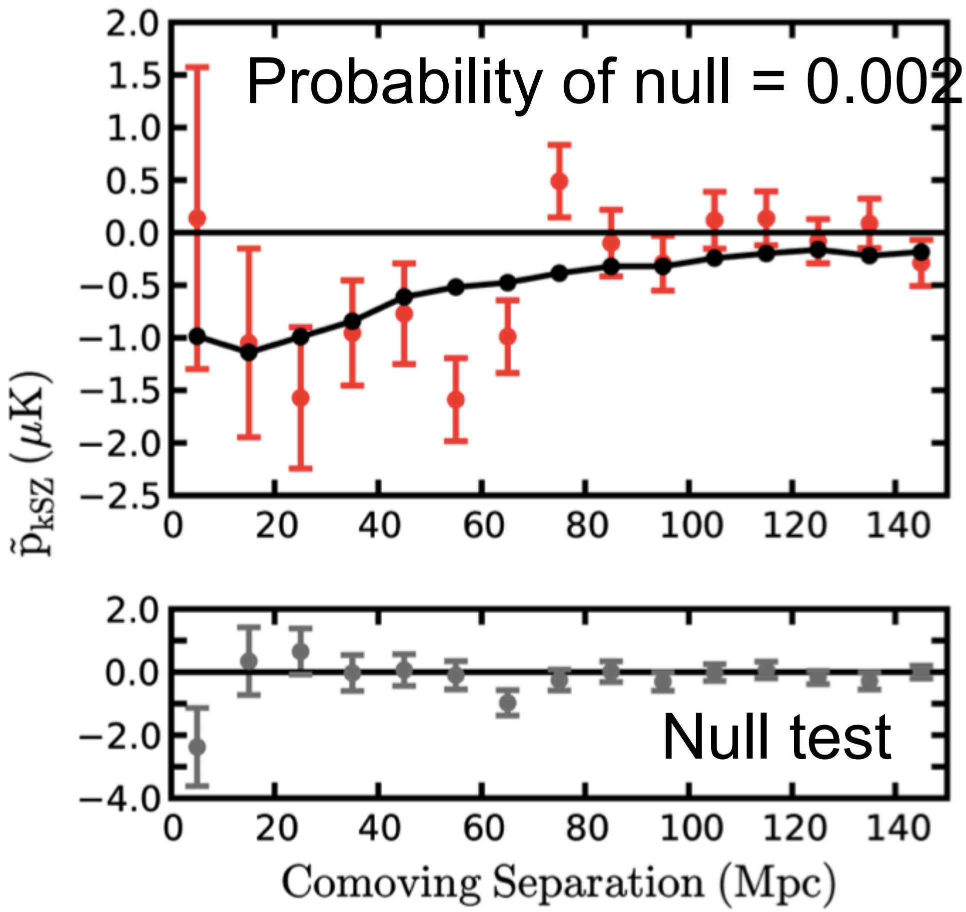
- The kSZ varies as M_e **v** and for low mass systems ($M \sim 10^{13}$ M_{sun}) is comparable in size to the TSZ effect.
- Thus ΔT_{kSZ} traces cluster momentum.
- Growth of structure imparts motions to clusters (and groups)
- In particular, cluster pairs have a slight tendency to move toward each other:

$$\langle (\mathbf{p}_i - \mathbf{p}_j) \cdot \hat{\mathbf{r}}_{ij} \rangle < 0$$

- As with pairwise velocities, one can construct line-of-sight pairwise momenta

ACT Provides the First Clear Evidence for the Kinematic SZ Effect

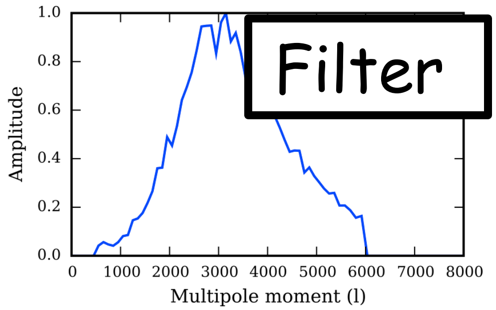
Hand et al 2012



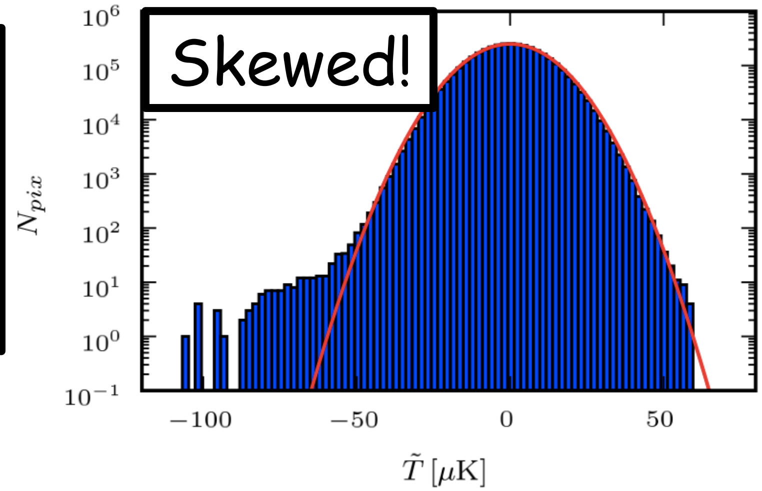
- 220 deg^2 overlap region btwn ACT and BOSS/DR9.
- LRGs locate haloes.
- Pick the 5000 brightest.
- Let the ACT 148 GHz map temperature at the position of each LRG serve as a tracer of the kSZ signal and thus the cluster LOS momentum!

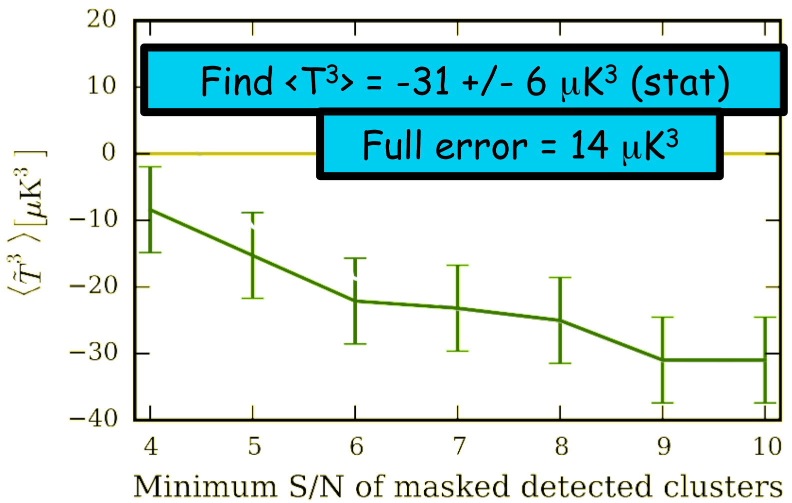
Staggs; Santander 2013

CLUSTERS REVEALED BY SKEWNESS
in the ACT equatorial maps (Wilson et al 2012)



MASK
Mask sources: 14.5% of map
Match-filter/CLEAN > 5σ from 148 GHz map
Mask dusty galaxies from 218 GHz maps (heavily)





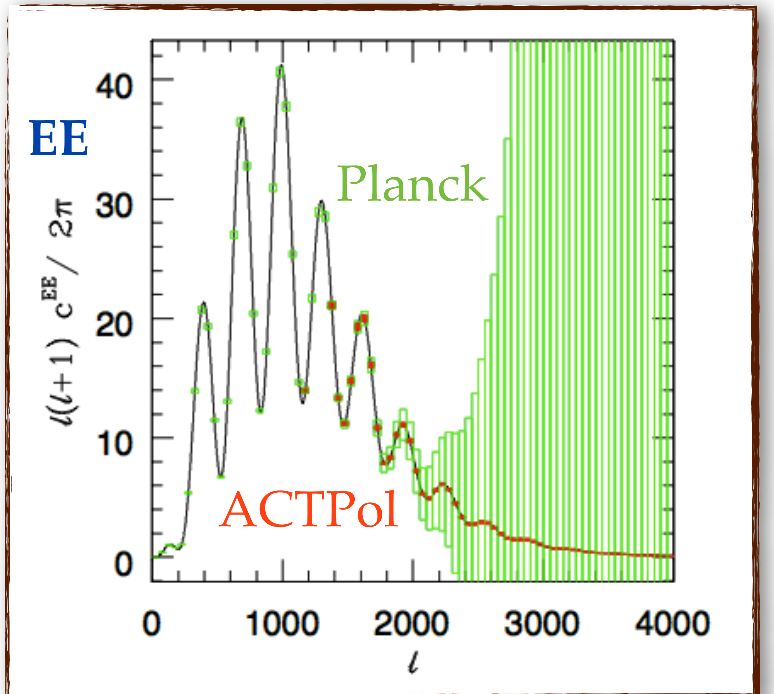
Signal diminishes as remove confirmed clusters

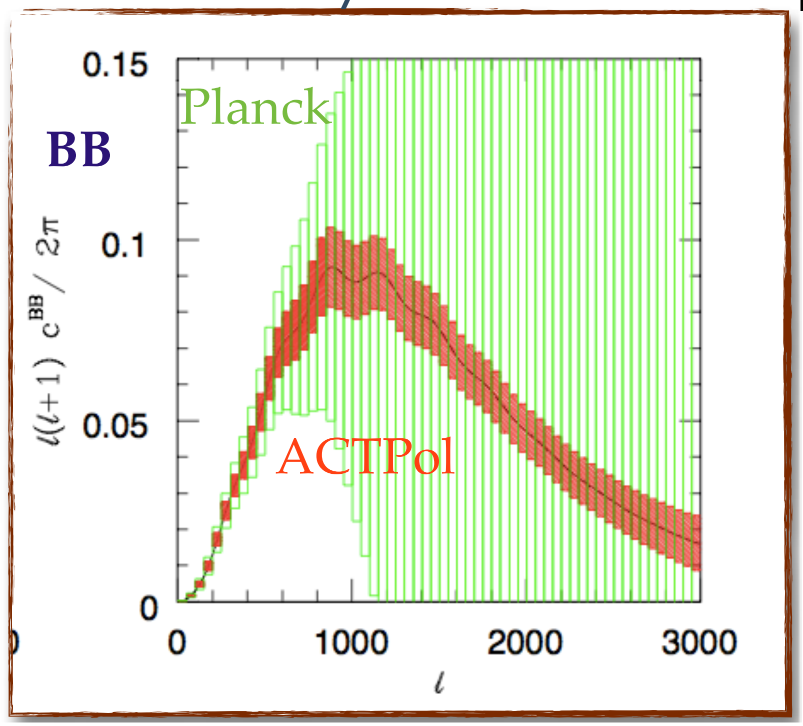
COMPLEMENTS TSZ PS DATA
1) Sources & TSZ have opposite sign; CMB, atmosphere & detector noise have no skewness
2) Probes higher mass systems fewer feedback concerns: half of PS but only ~ 20% of $\langle T^3 \rangle$ from M < $4 \times 10^{14} M_{sun}$
3) $\langle T^3 \rangle$ scales as ~ σ_8^{11} cf σ_8^{8} for PS

σ_8 = 0.78 +/- 0.03 (68% CL)

Staggs; Santander 2013

ACTPol

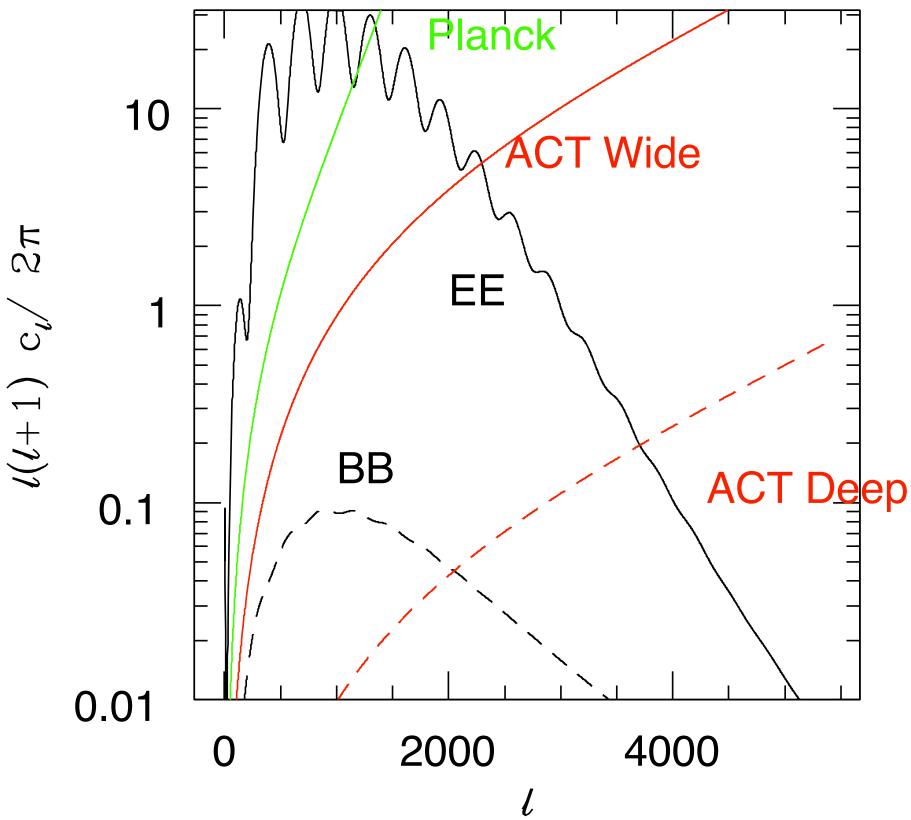




- New camera – 16x faster than MBAC
- Wide survey (~4000 deg^2)
- Deep survey (5 fields, each 25 deg^2)
- Described in Niemack et al, arXiv:1006.5049

ACTPol Science Goals in Brief

Statistical Noise Curves



Cluster Catalog -

- Overlap with existing surveys
- Complementary to SPT/Planck

Improved power spectra –

- (TT)
- TE
- E-modes
- B-modes
- Deflection field

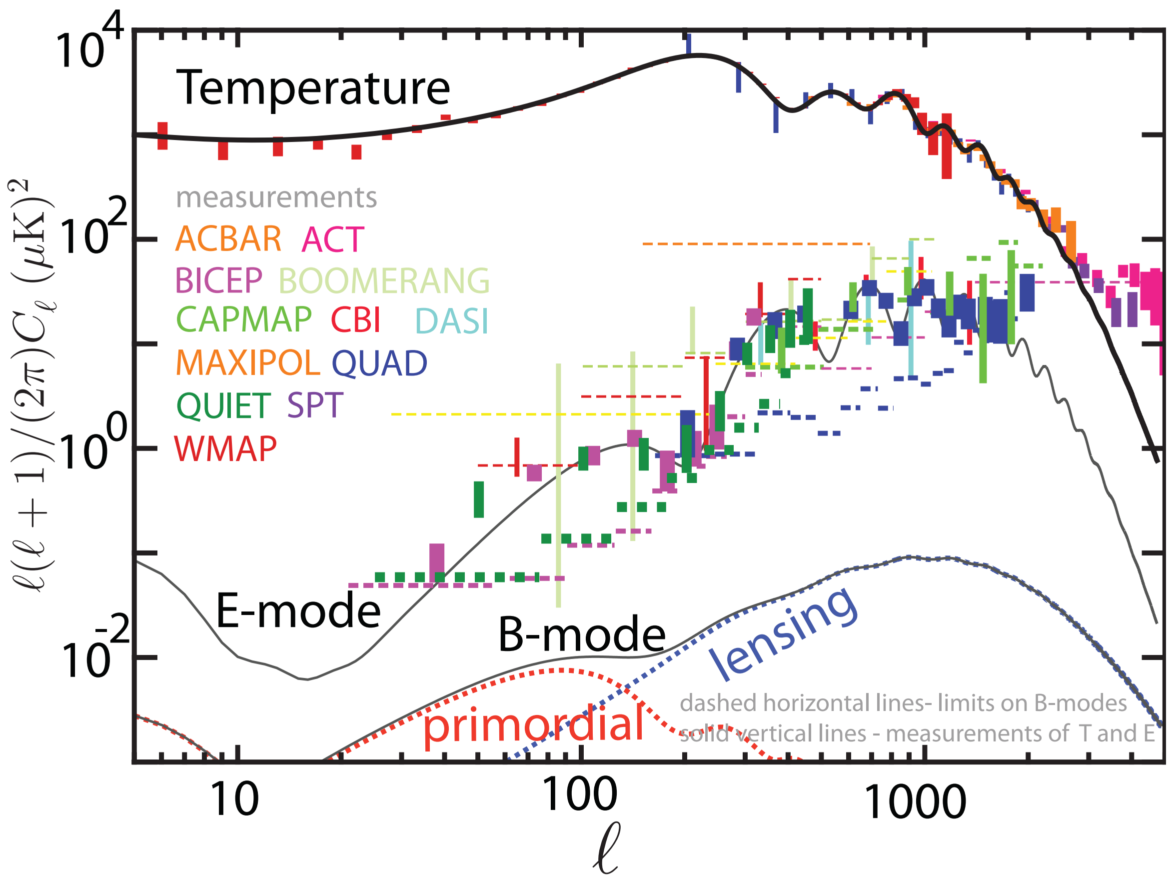
Maps –

- CMB
- Deflection field

Wide survey (~4000 deg^2); Deep survey (5 fields, each 25 deg^2)

Staggs Santander 2013

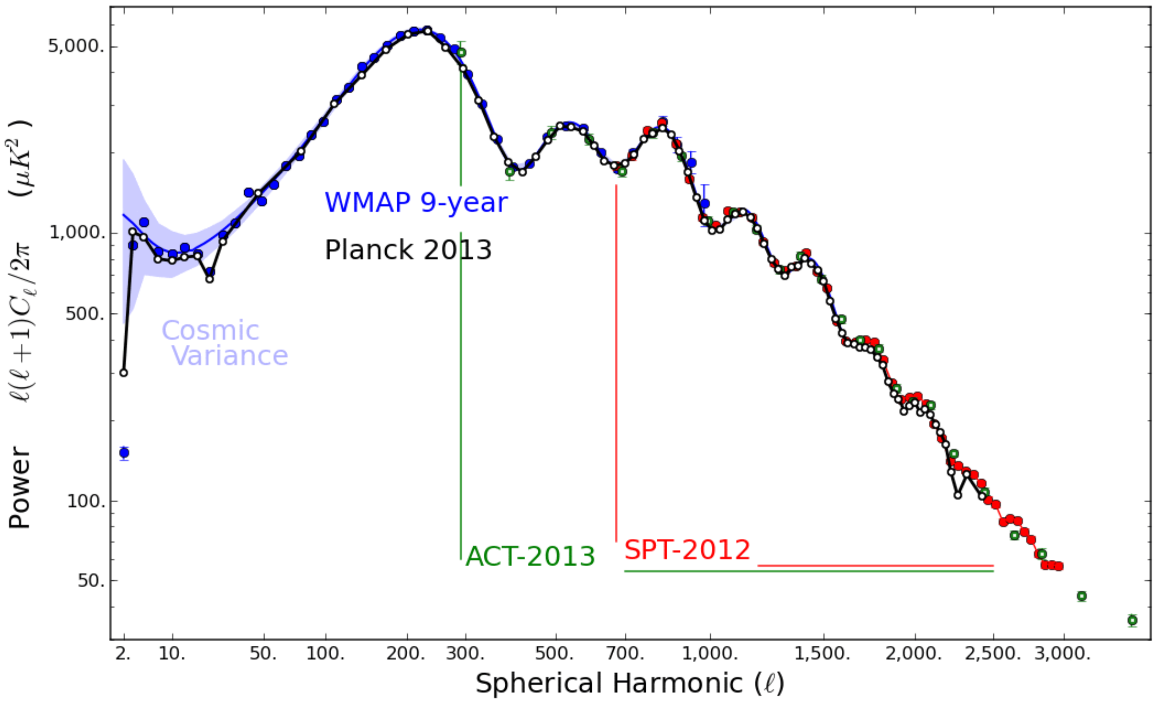
Primordial B-modes



Primordial B-modes peak at even larger angles than TT! ($c > c/3^{1/2}$)

Staggs Santander 2013

Primordial B-modes



Primordial B-modes peak at even larger angles than TT! ($c > c/3^{1/2}$)

ACT has leading-edge dynamic range (cross-linking, ML maps → little filtering) ... nonetheless ACTPol's first targets will be lensing B-modes.

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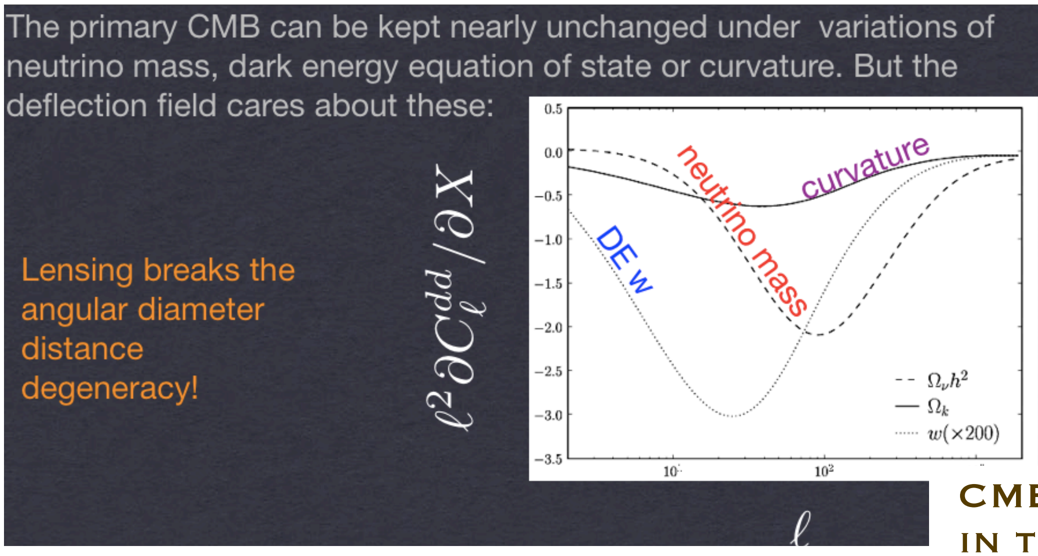
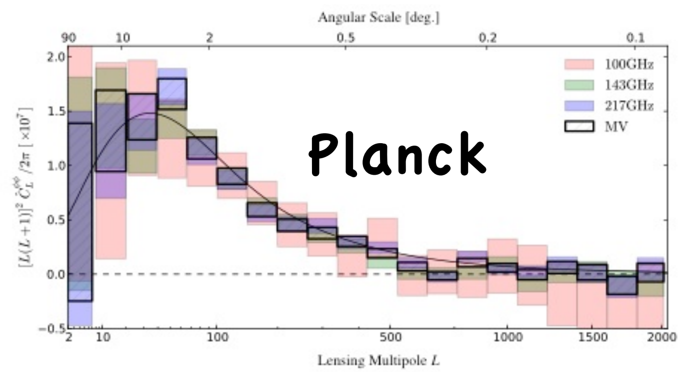
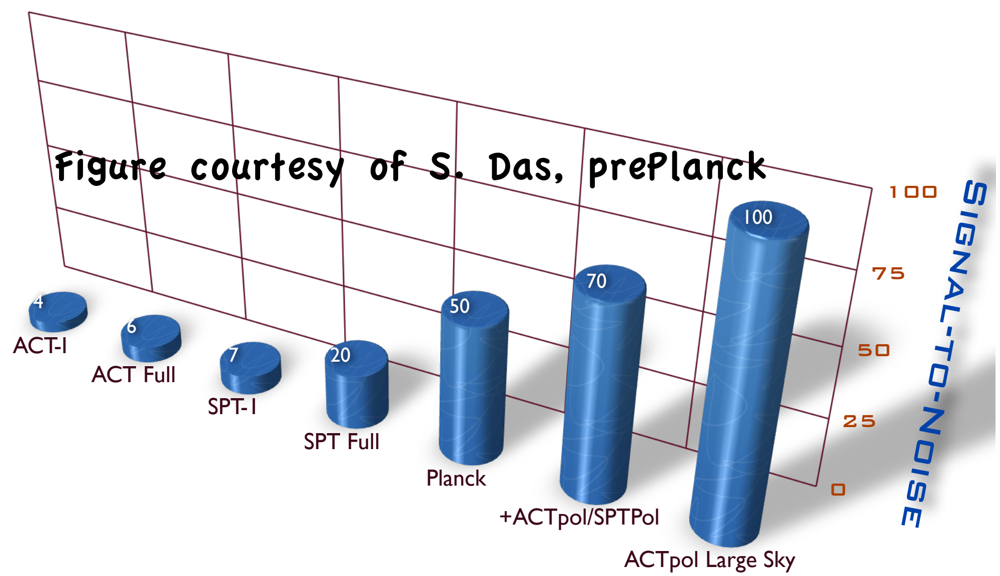
ACTPol, Lensing and the CMB





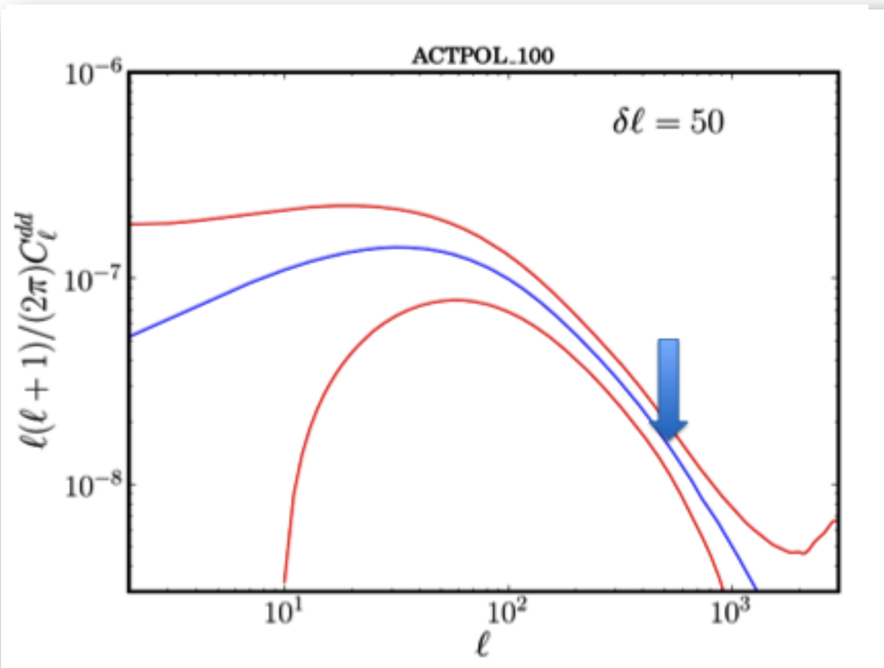
CMB LENSING IS GOING TO EXPLODE AS A FIELD IN THE NEXT FEW YEARS



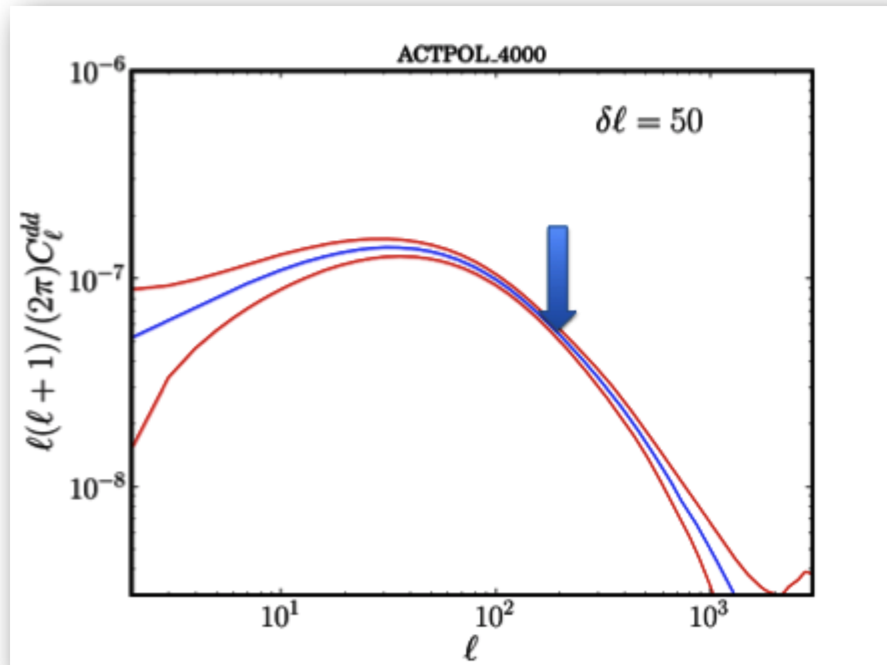
Plot from Smith, Cooray, Das, Dore et al, 2009 White Paper.

ACTPOL Lensing Forecasts

Assuming no systematics other than instrumental noise, these plots show the signal and noise power spectra for the Deep and Wide configurations.



ACTPOL-DEEP:
150 sq-deg @ 3 μK-arcmin (temp)
and 5 μK-arcmin (pol)

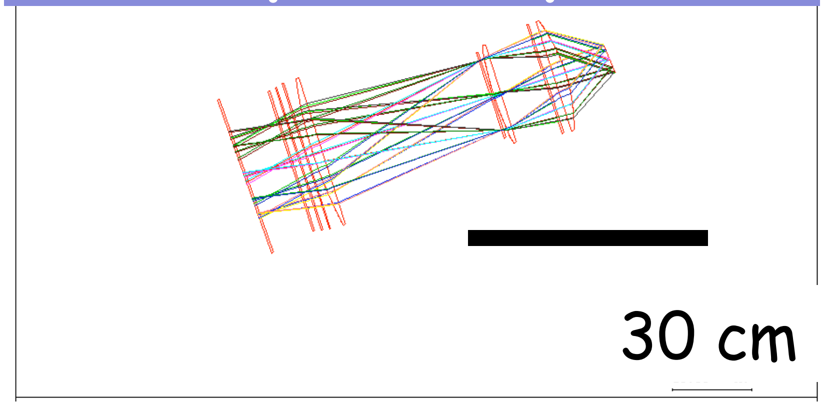


ACTPOL-WIDE:
4000 sq-deg @ 20 μK-arcmin (temp)
and 28 μK-arcmin (pol)

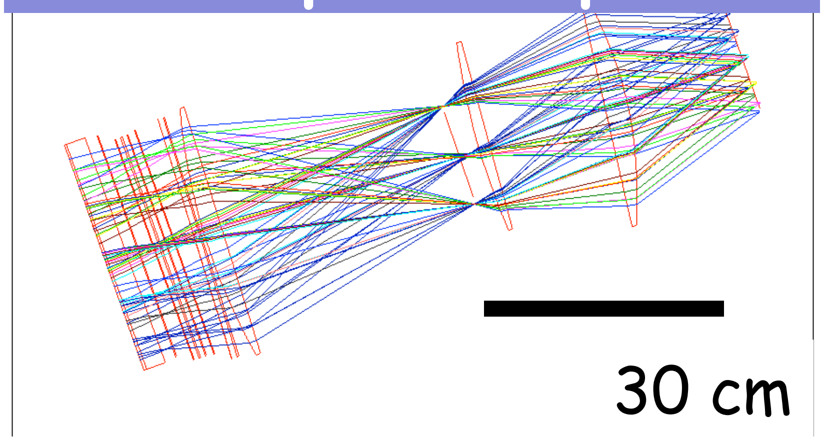
ACTPol Instrument

- Increased throughput optical design (M.Niemack)
- Wideband silicon lenses (J. McMahon)
- Feedhorn-coupled polarization arrays of TES bolometers from NIST (TRUCE)
- 2 arrays at 150 GHz;
- 1 at 100/150 GHz
- 100 mK cryogenics

Old optical path



New optical path



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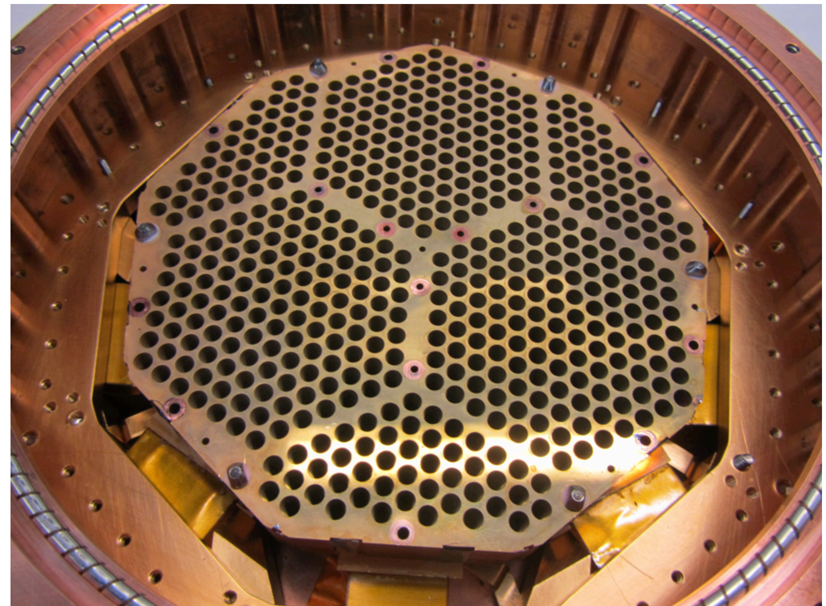

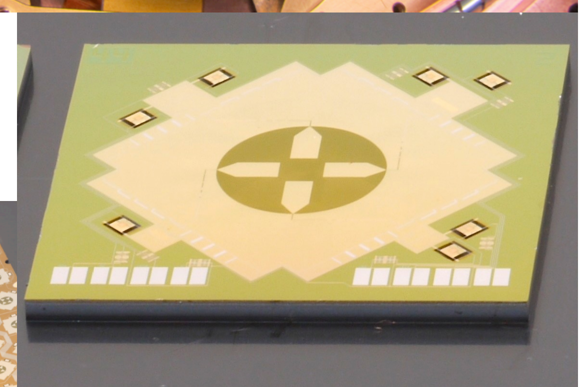

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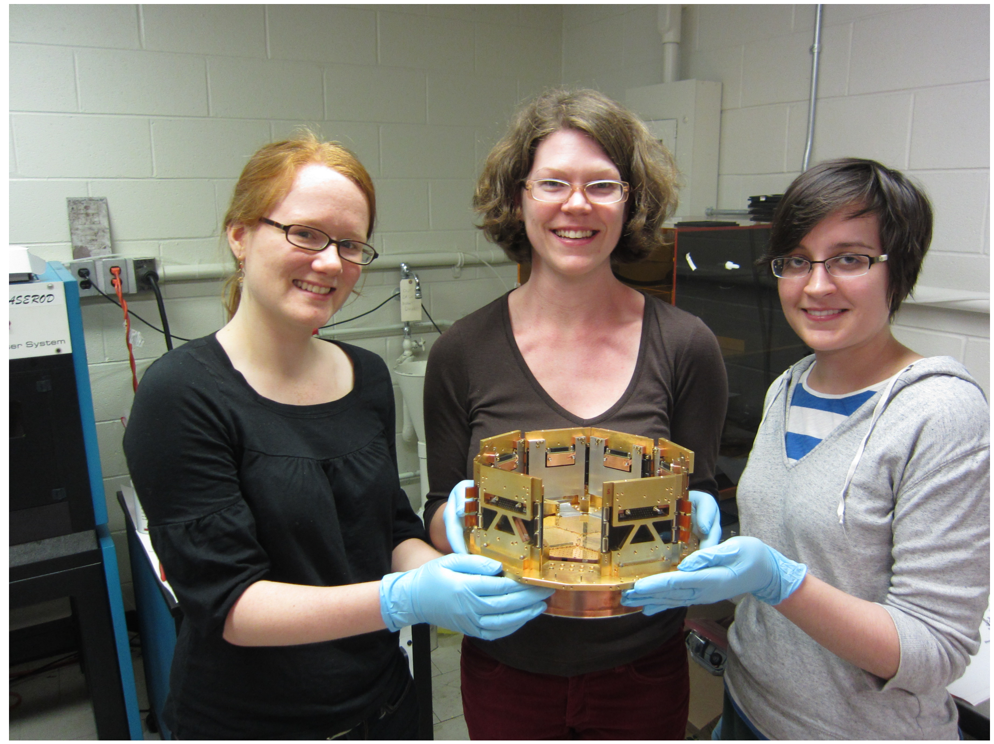
ACTPol Instrument

- Completion of the assembly, test, and full assembly of the first array of detectors!
- The first 150 GHz array is in Chile now.
- Second and third arrays in progress with special thanks to NIST team.



Special thanks to graduate students Emily Grace and Christine Pappas with postdoc Laura Newburgh, and to Ben Schmitt, Marius Lungu and Pato Gallardo (not shown) for field deployment with Masao Uehara.

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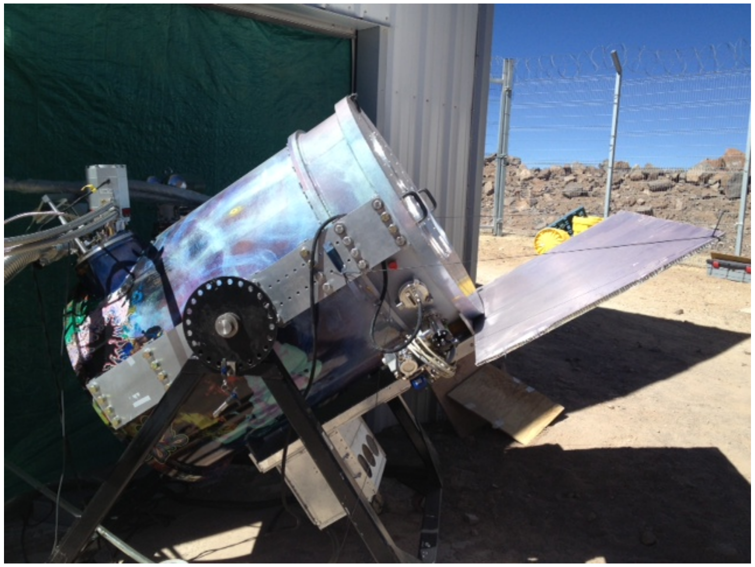
ACTPol Receiver Deployment



Observing the sky with the receiver at 17kft

Putting the receiver into the telescope cabin 2 weeks ago!

Special thanks to graduate students Ben Schmitt and Marius Lungu in the field with Pato Gallardo and Masao Uehara

THE END