Preliminary Results from the SZA

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Columbia University

New Views of the Universe

Kavli Inaugural Sypmosium

Dec 11th, Chicago

Photo: Leitch

The Sunyaev-Zel'dovich Array (SZA)

Chicago: John Carlstrom, Clem Pryke, John Cartwright, Marcus Runyan Ryan Hennessy, Chris Greer, Michael Loh, Matthew Sharp

Columbia: Amber Miller, Stephen Muchovej, Tony Mroczkowski, David Tam, Ben Hooberman, Dan Harlow, Jhumki Basu (with Renaissance Charter School Students)

Caltech: David Woody, David Hawkins, James Lamb

NASA/MSFC: Marshal Joy, Georgia Richards

JPL: Erik Leitch

Photo: Leitch

Funding: NSF-ATI, NSF-KICP, McDonnell Foundation, U. Chicago, Packard Foundation

SZA Essentials

- Eight 3.5 m diameter telescopes (30 μm RMS surface, 1″ pointing)
- Close-packed configuration for high surface brightness (1.2 diameter spacings)
- 30 GHz Receivers (cluster survey)
- 90 GHz Receivers (detailed cluster observations)
- Broadband 8 GHz digital correlator (dense sampling in the Fourier plane)

- Currently taking science data

- SZA to be integrated with OVRO and BIMA telescopes (CARMA) will allow detailed imaging to ~5″

Photos: Leitch

Receiver Construction and Testing - Columbia

SZA 8 GHz, 28 baseline digital correlator

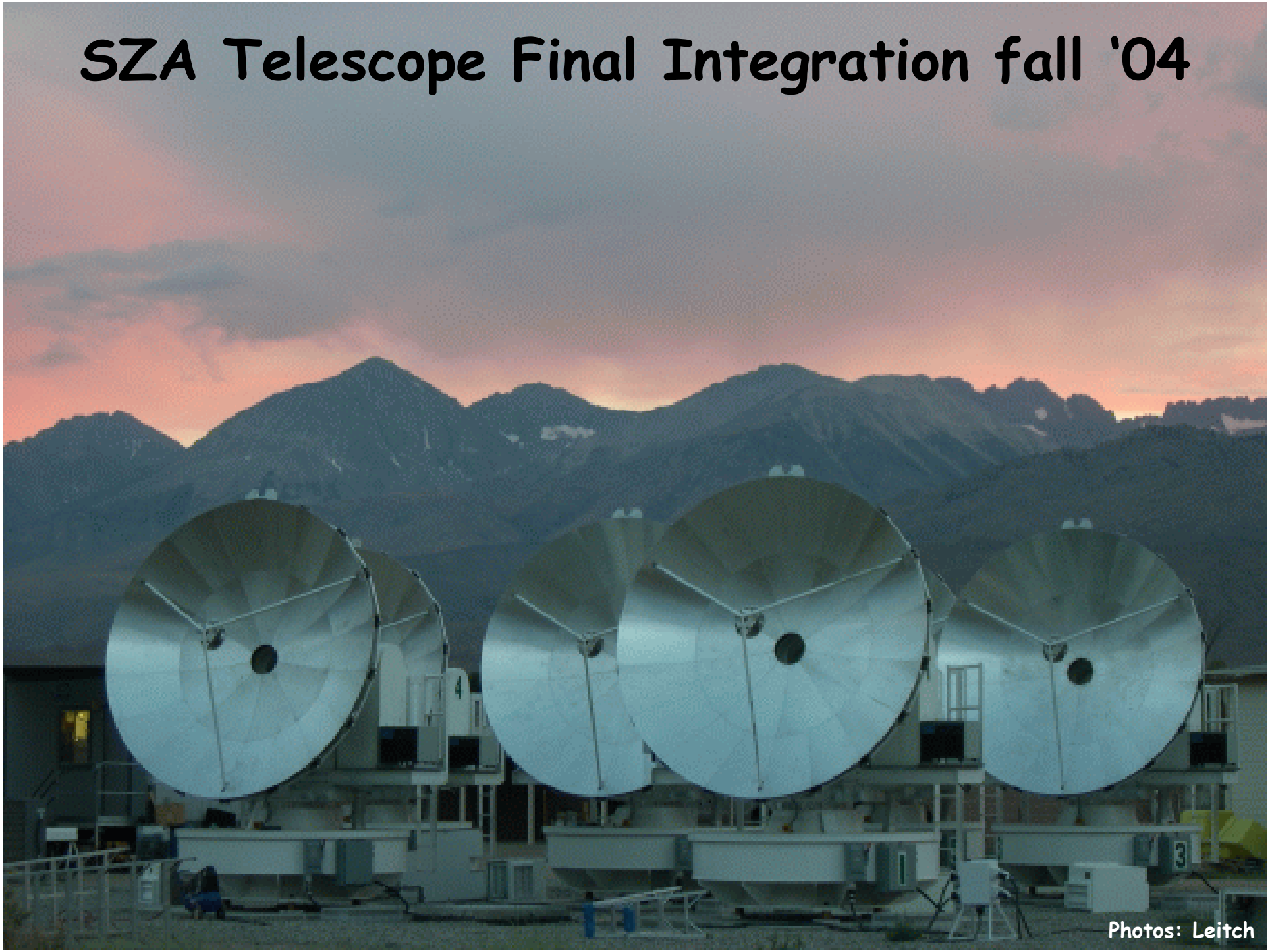
(Designed by Dave Hawkins, OVRO)

SZA Telescope Construction – fall '03

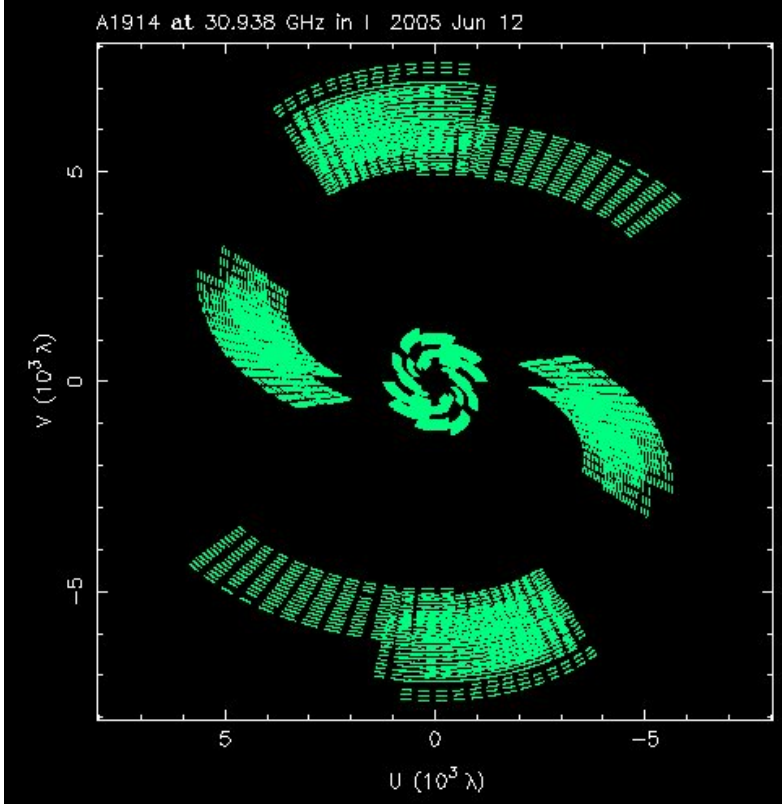
Photos: Leitch

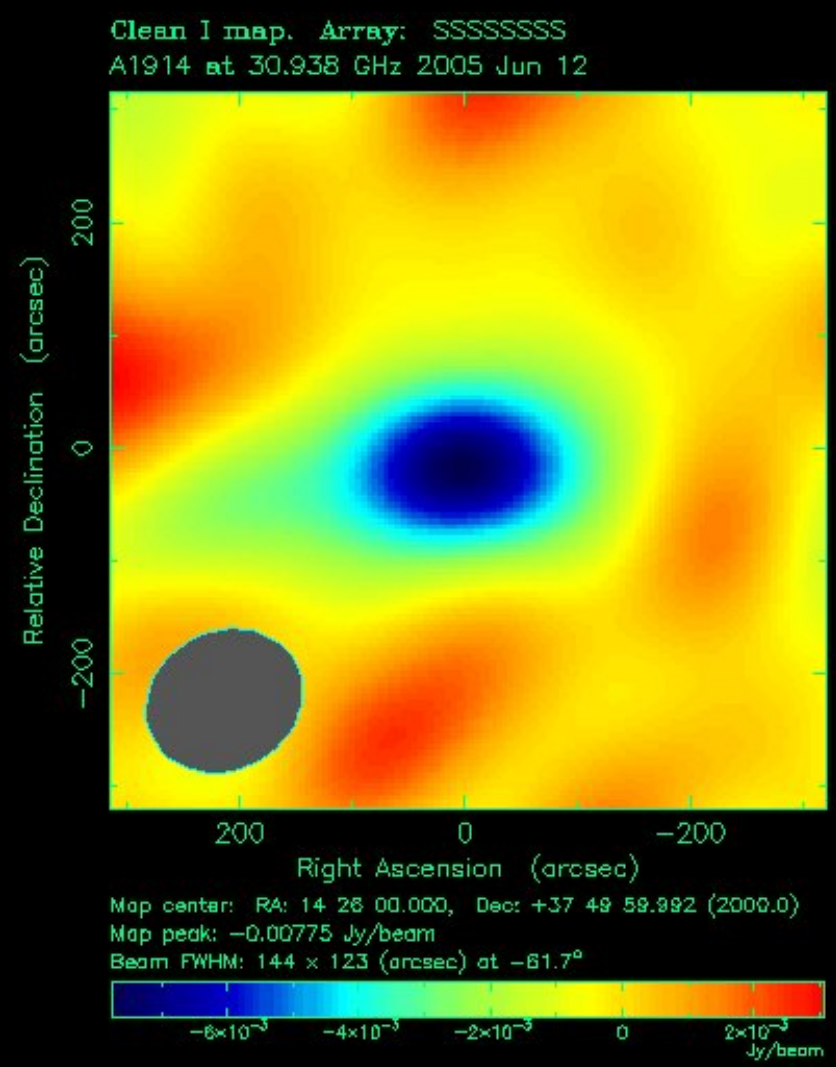
SZA Construction/Integration – winter '04

SZA Telescope Final Integration fall '04



Some Previouly Seen Clusters
1914

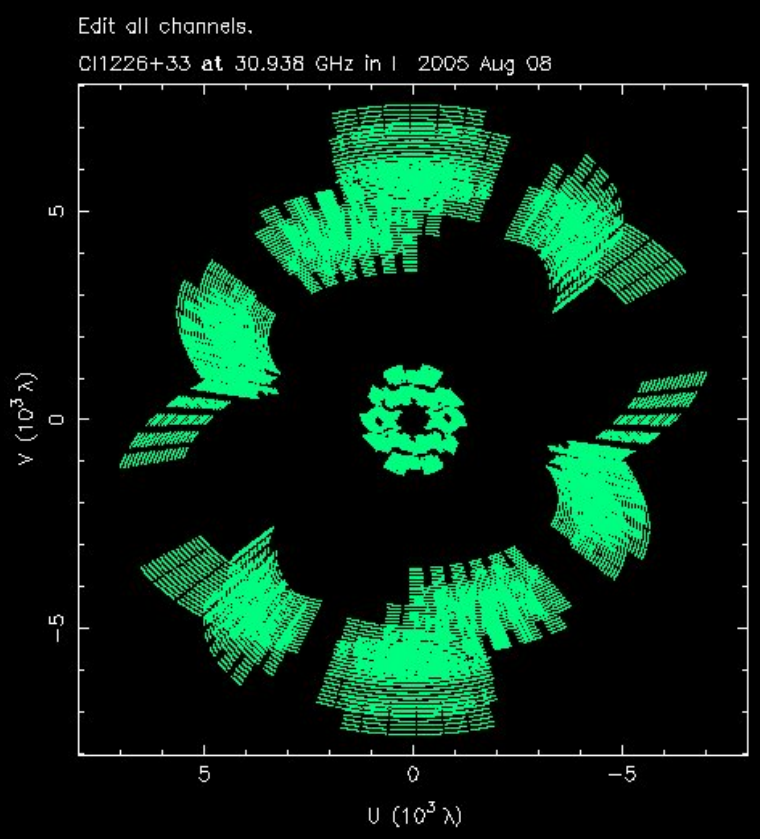


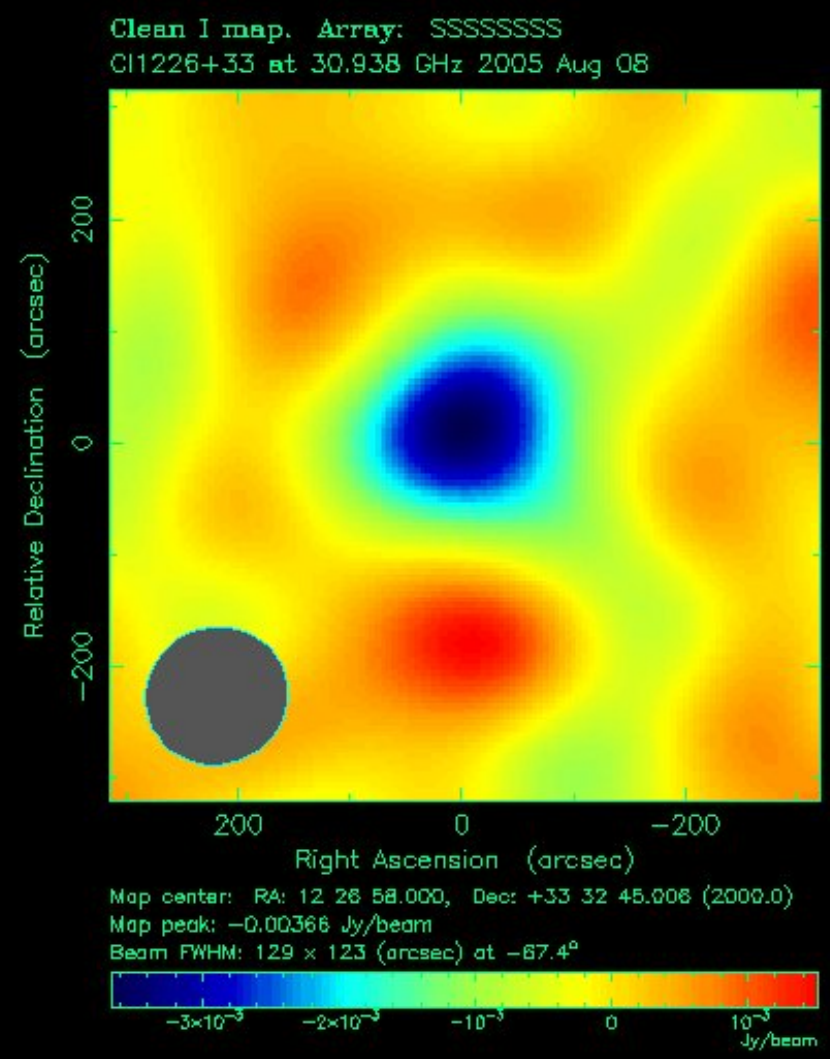


Abell 1914
~1.5 hours of data
z=0.17
(~10 sigma detection)

Cluster anaysis and images: Muchovej

CL1226

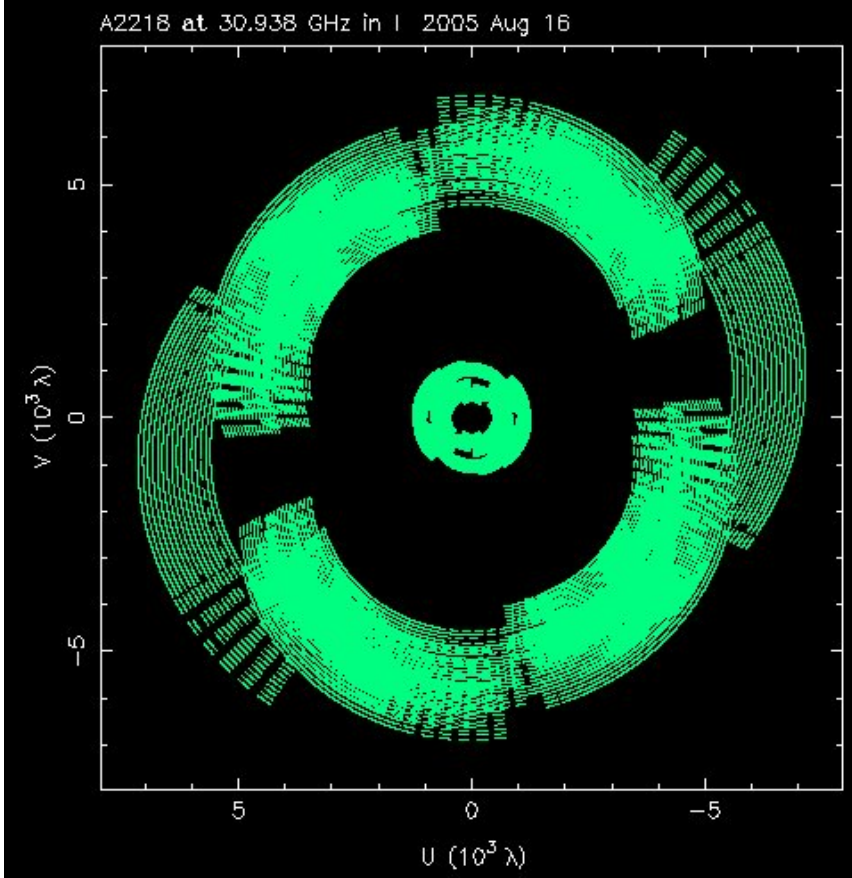


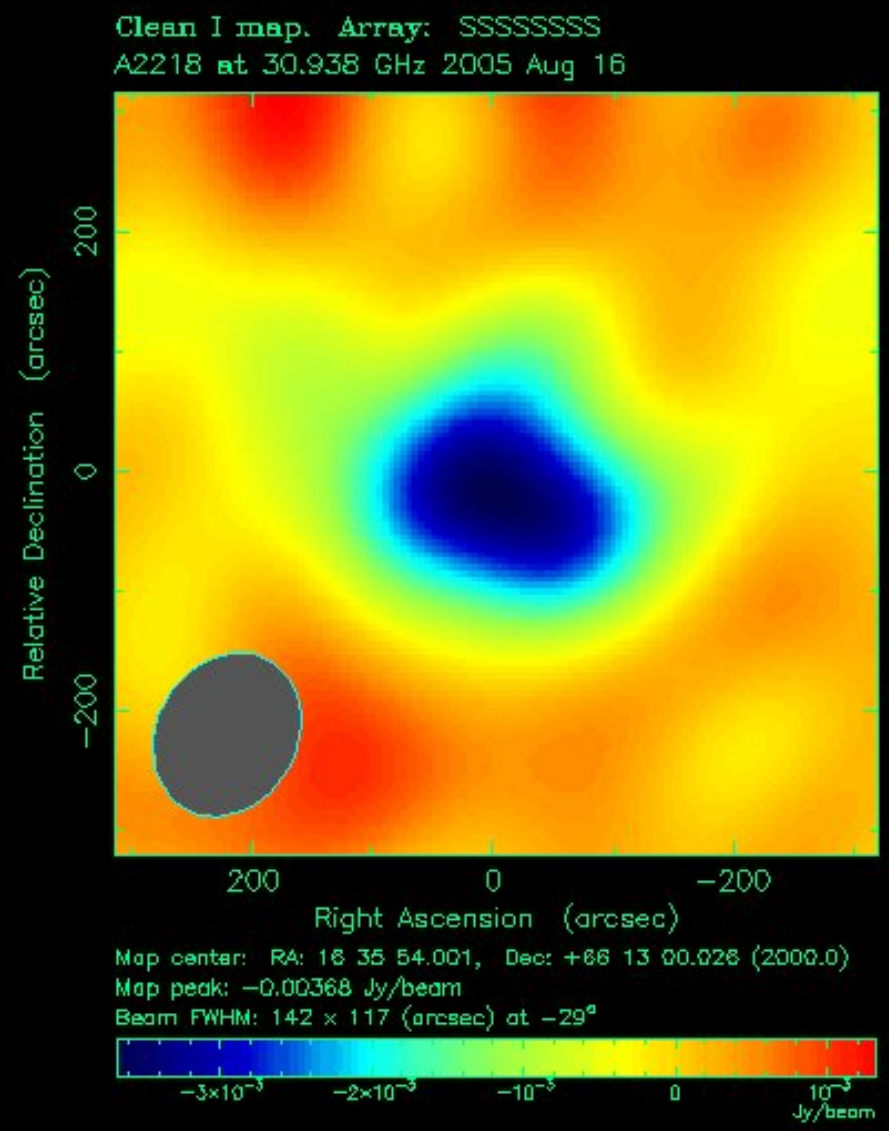


CL1226
6.3 hours of data
z=0.84
(~8 sigma detection)
1 point source removed

Cluster analysis and images: Muchovej

A2218

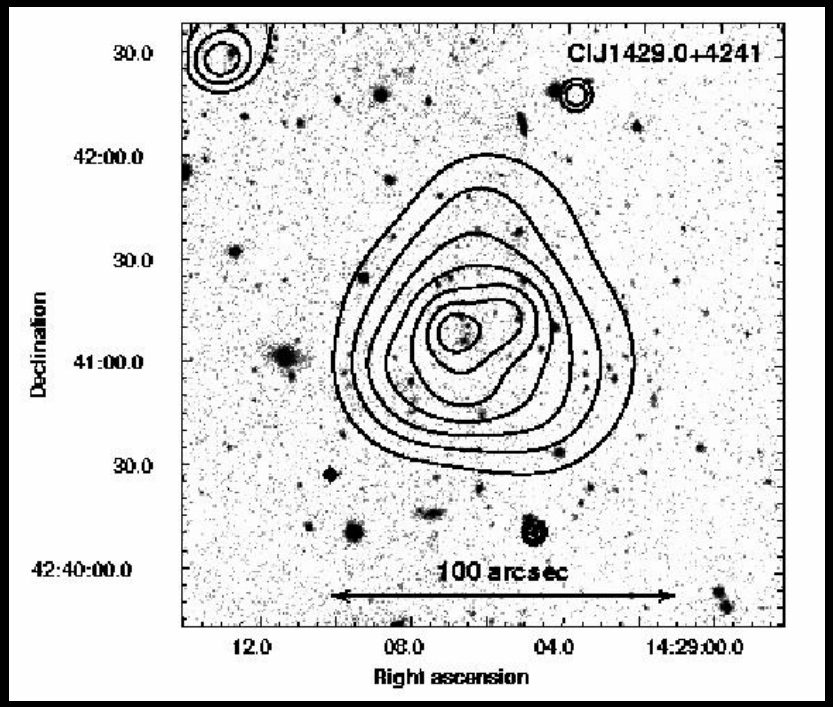




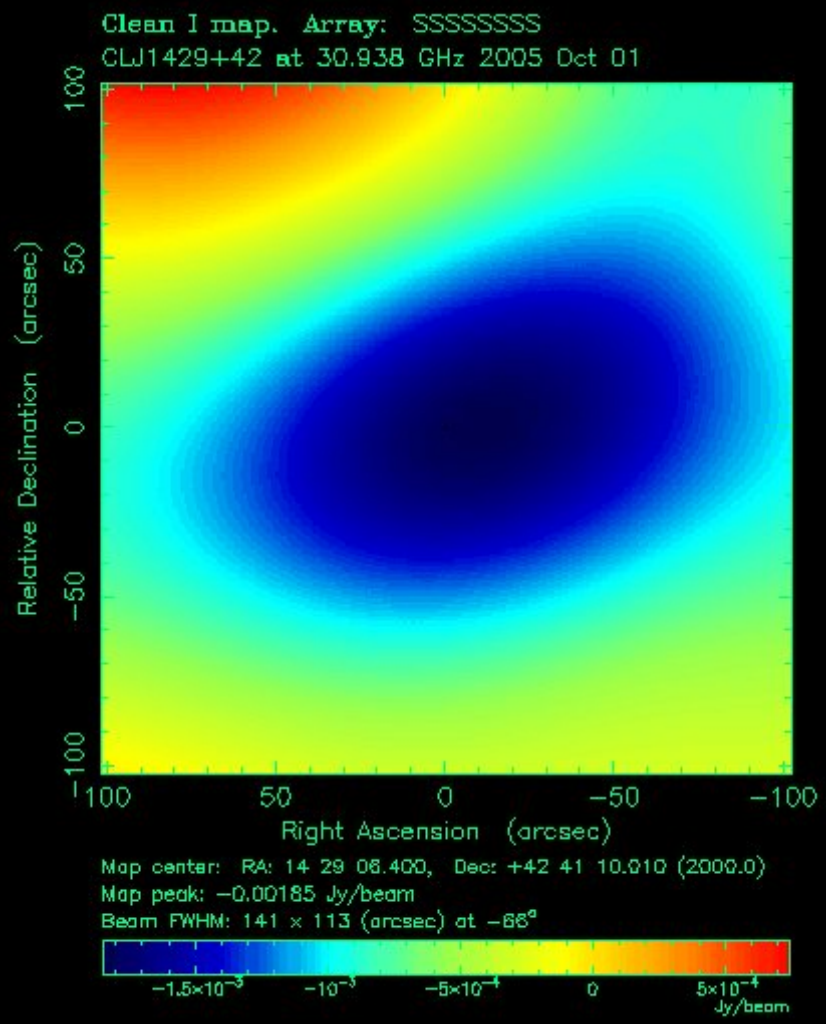
Abell 2218
9.3 hours of data
z=0.18
(~11 sigma detection)
3 point sources removed

Cluster analysis and images: Muchovej

Clusters not seen before in the SZE
CL1429 (z=0.92) $M \sim 5 \times 10^{14}\ M_{sun}$



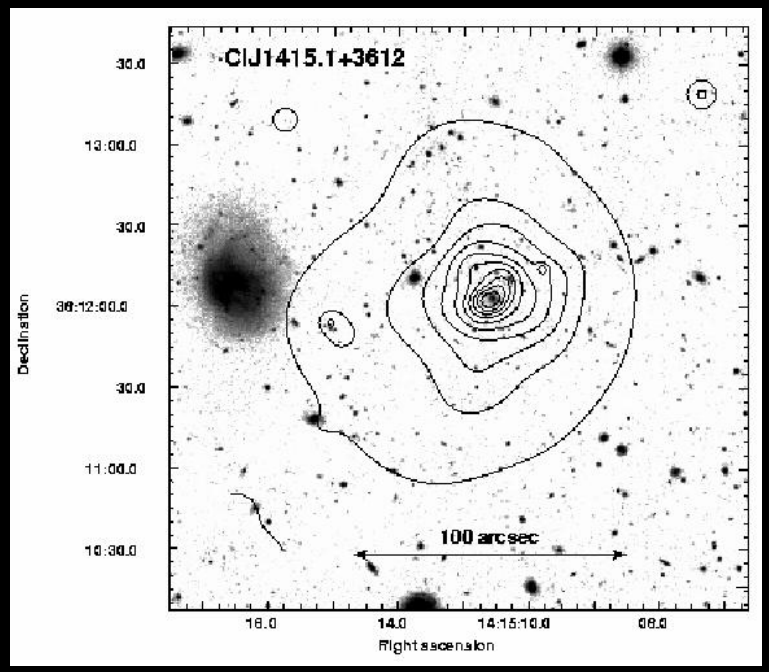
X-ray detection
Maughan et al. (and references therein) 2005

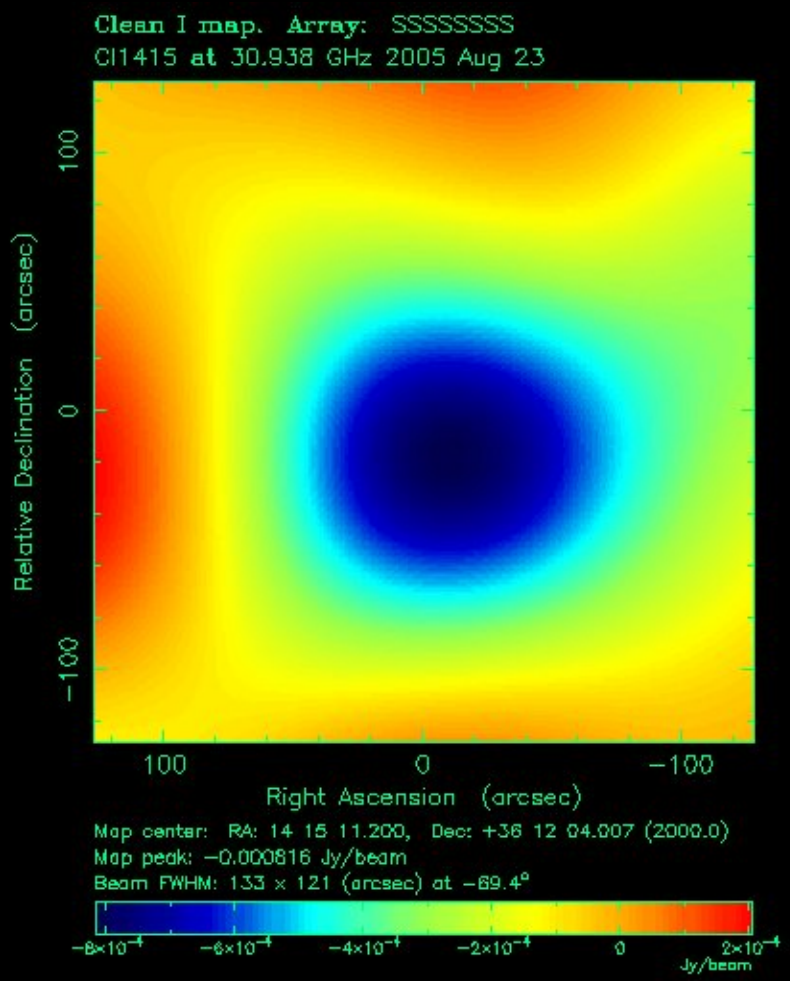


SZE detection (SZA)
1 pt source removed ~7 sigma detection 29 hours

Cluster analysis and images: Muchovej

Clusters not seen before in the SZE
CL1415 (z=1.03) $M \sim 3.7 \times 10^{14}\ M_{sun}$



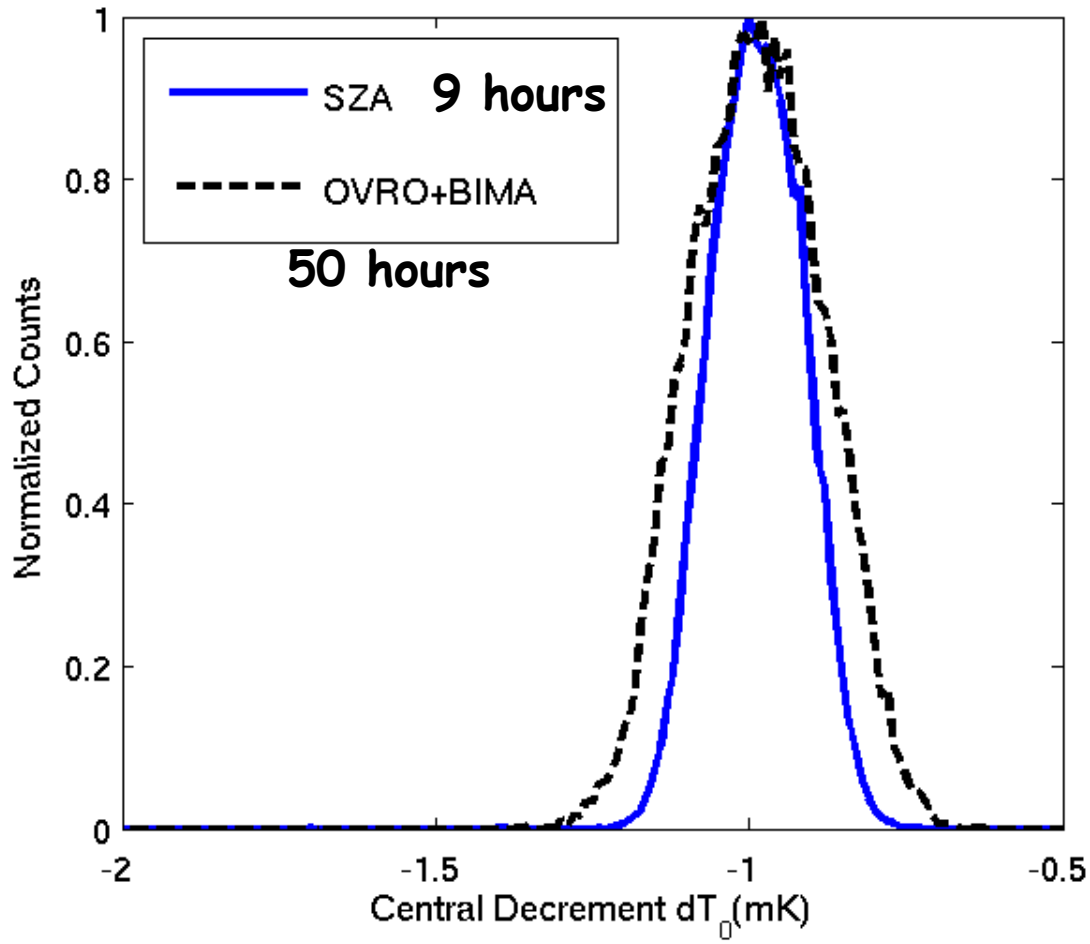


Maughan et al. (and references therein) 2005

SZE Detection (SZA)
44 hours 1 point source, 1 galaxy, ~5 sigma detection

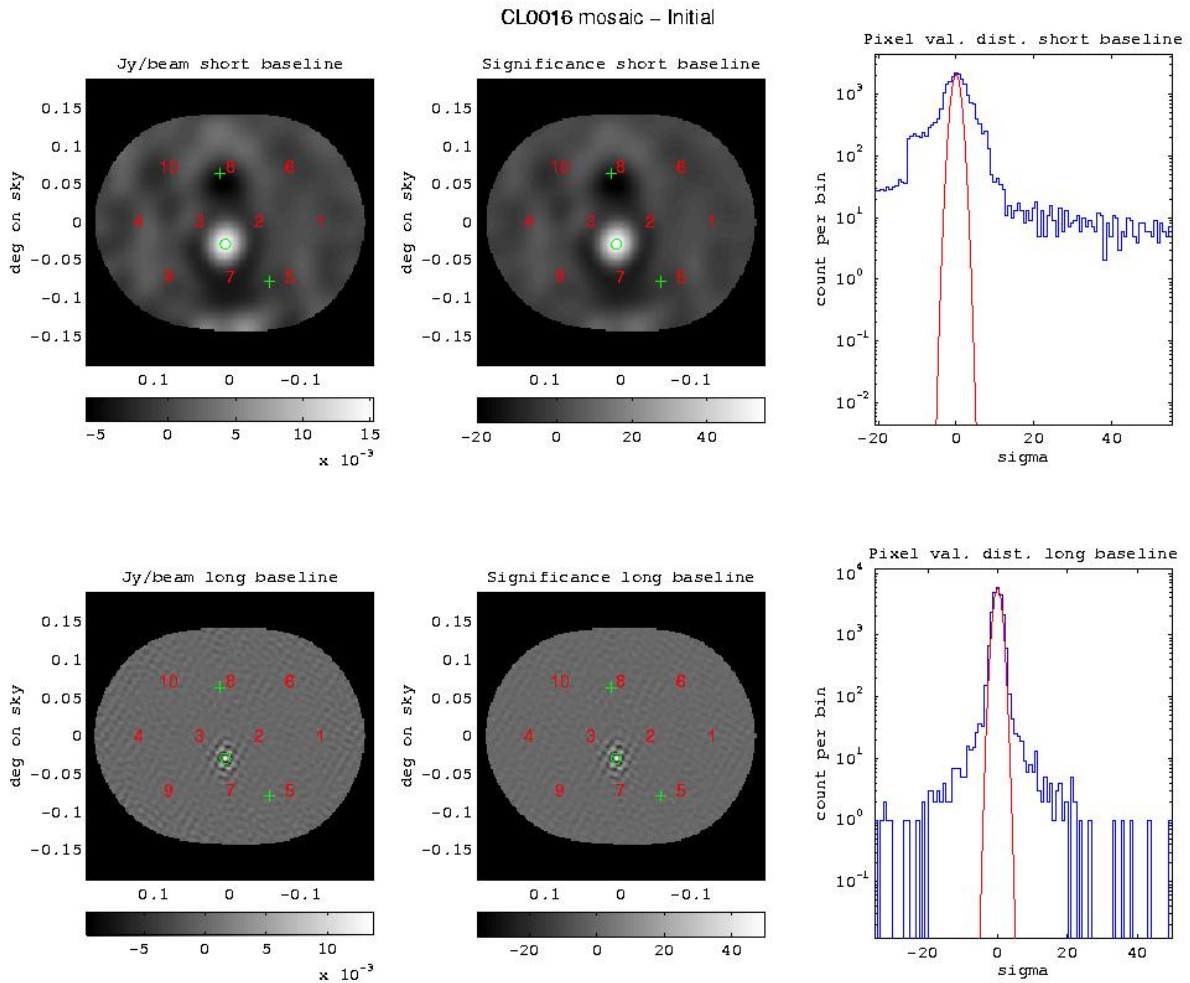
Cluster Analysis and images: Muchovej

A2218 OVRO/BIMA vs SZA



Markov code adapted from OVRO/BIMA team by Mroczkowski
Analysis Mroczkowski

Mini mosaic Test - Cl10016 Field



Verify Array Performance
Verify Survey Sensitivity
Verify Analysis Tools

pixel value distribution of significance map.
Red line is Gaussian with sigma=1 (should match observed if there are no sources in the mosaic)

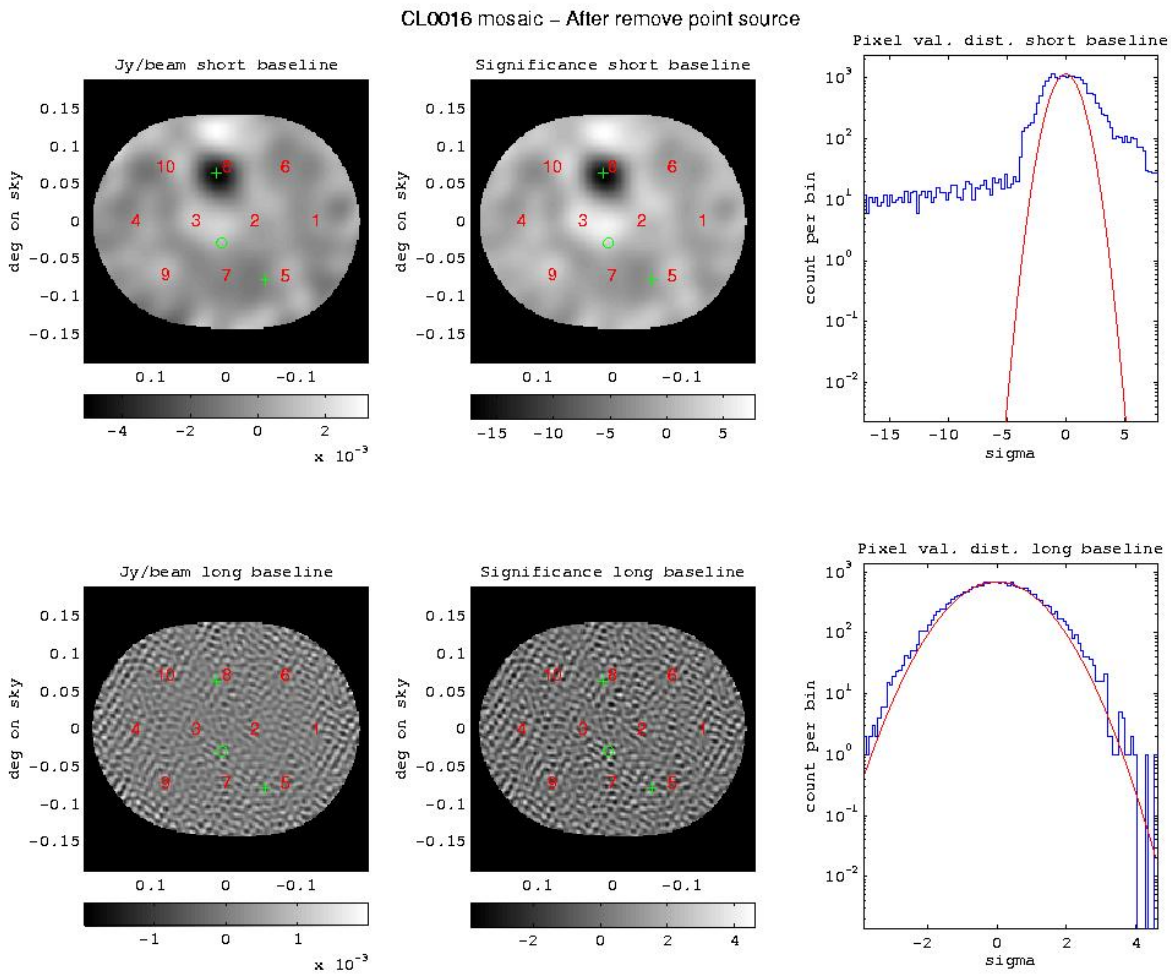
Point source shows up at ~ 50 sigma (results in highly non-Gaussian pixel value distribution).

Signal map - peak value is point source flux

Significnce map - units of detection sigma

Mosaic analysis: M. Loh

Point Source Removed (all 10 fields)



Signal map - peak value (negative) is cluster flux

Significnce map - units of detection sigma

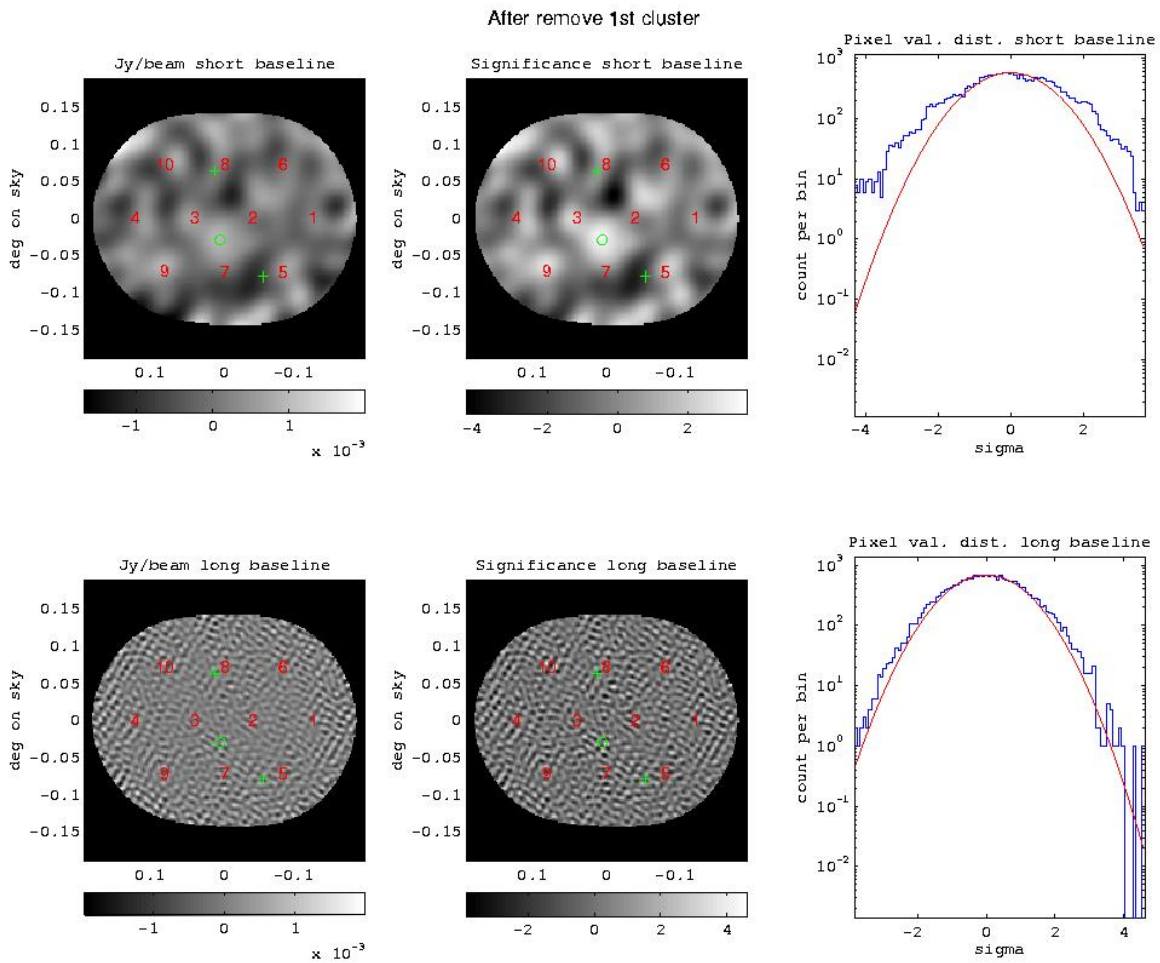
Multi-pointing data fit to a point source model (initial location chosen by peak in long baseline map but allowed to float)

Beam modeled as truncated Gaussian (reasonable match to real beam)
Green + indicates x-ray cluster position
SZA cluster shows up at ~17 sigma

Note long tail in short baseline pixel value distribution (cluster decrement)

Mosaic analysis: Loh

Main Cluster Removed (all 10 fields)



Multi-pointing data fit to a cluster model (visibility amplitude exponential with baseline length, and exp width free). Spectral shape is fixed at that expected for SZE

Beam modeled as truncated Gaussian (reasonable match to real beam)

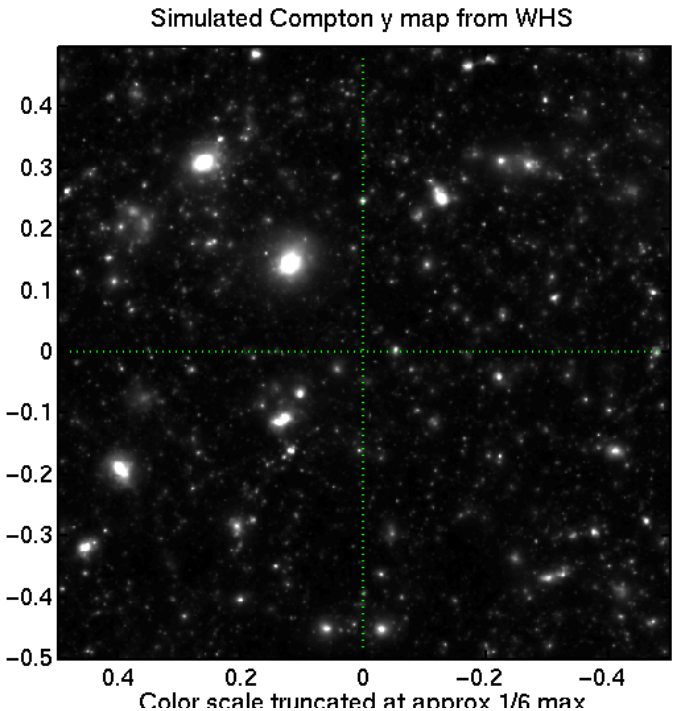
Signal map - peak value (negative) is cluster flux

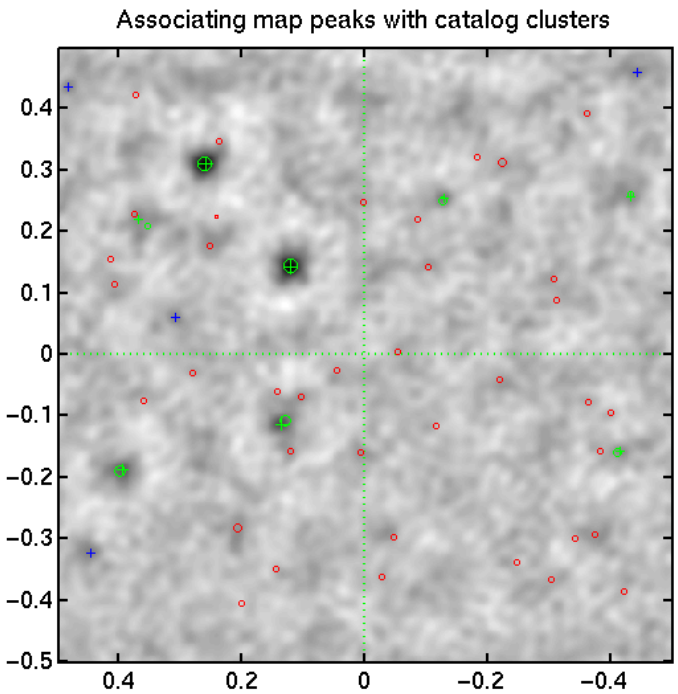
Significnce map - units of detection sigma

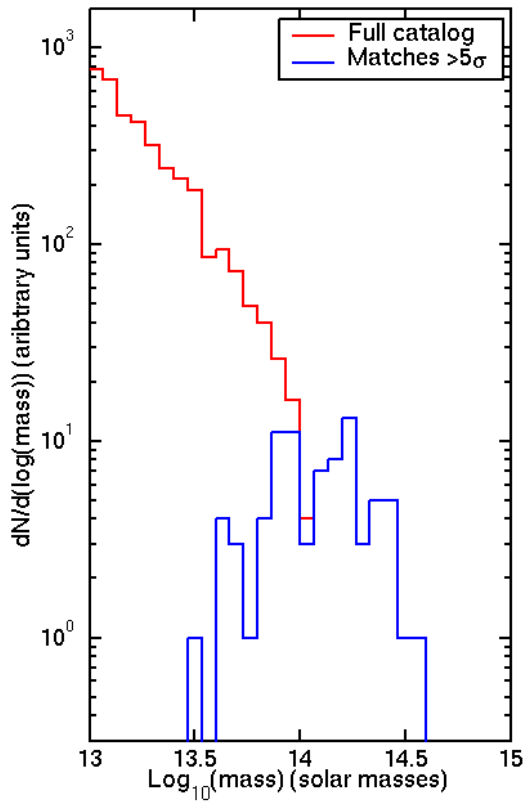
Mosaic analysis: Loh

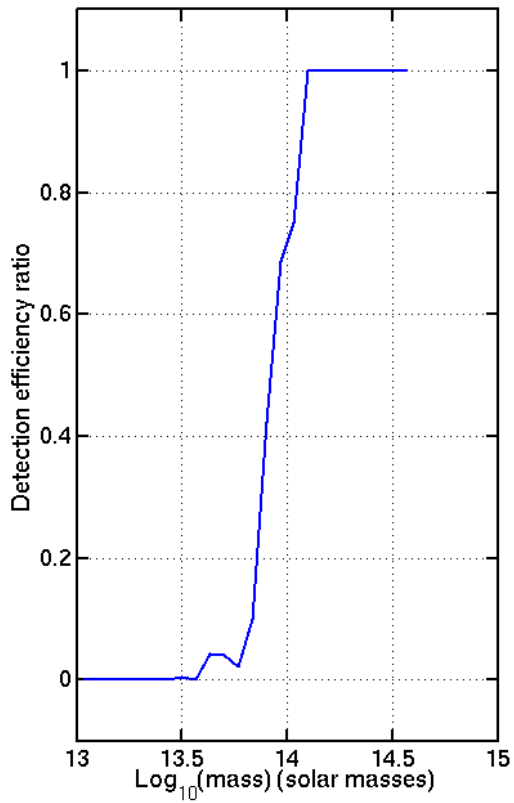
SZE Blank Field Survey for Cosmological Measurements (dN/dz)

First Pass
Testing mass limit with mock SZA survey (Pryke)



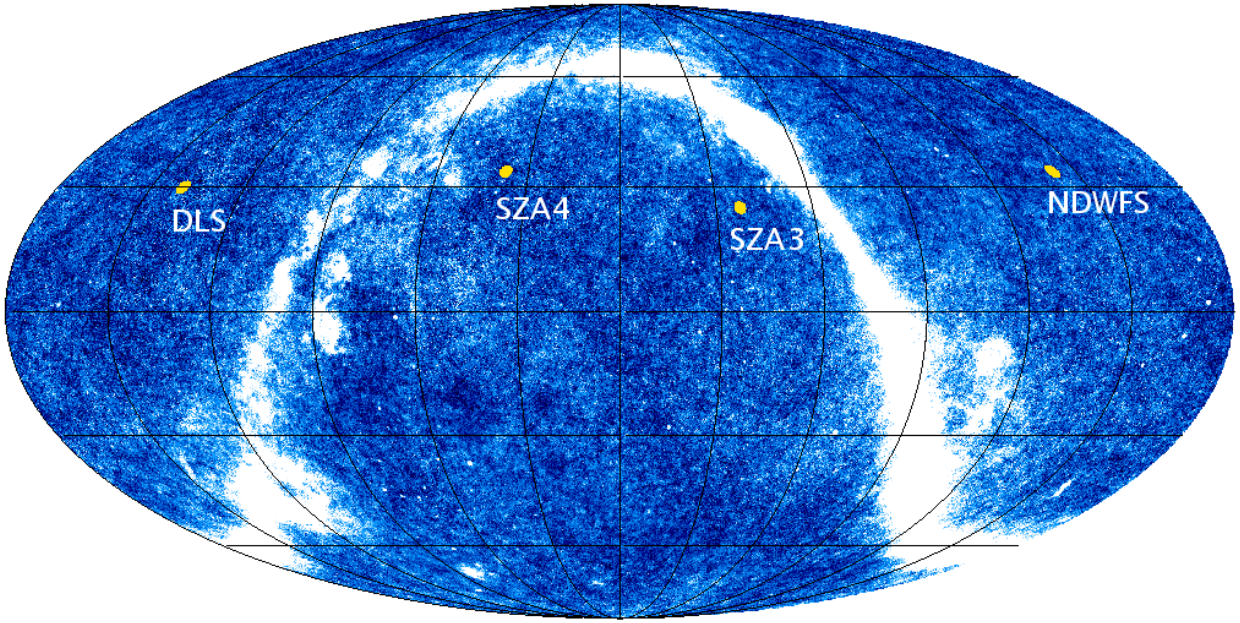






White, Hernquist, Springel, (WHS) 15 of 1 deg x 1 deg images from hydro sims.

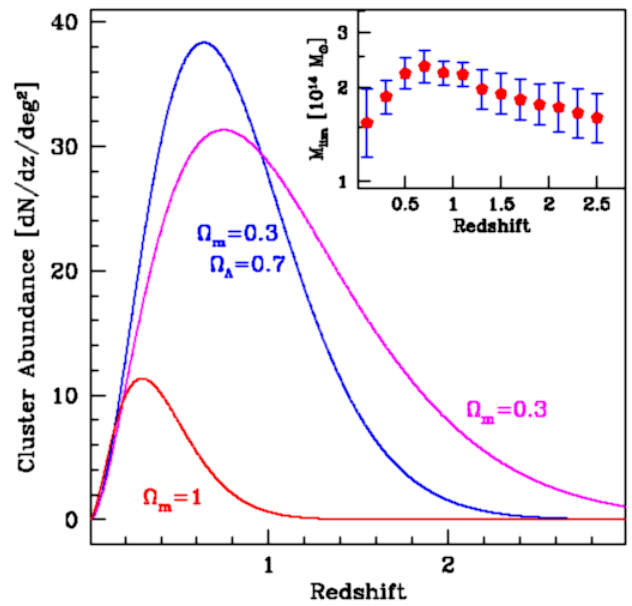
SZA survey (12 square degrees) - in progress

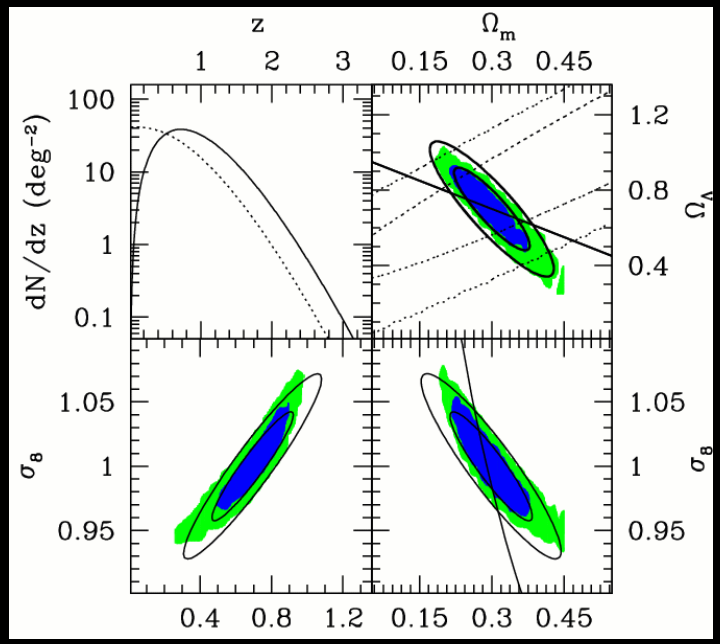


- four fields (each roughly three square degrees equally spaced in RA)
- expect ~100 clusters (survey designed for sensitivity to clusters and secondary CMB anisotropy)
- science requires photometric redshifts (requires imaging in several bands including near IR)
- fields need to be selected in order to
  - be properly spaced in RA to allow survey observations 24 hours/day
  - be properly positioned in declination (near zenith at transit) so as to minimize atmospheric contamination and to optimize imaging
  - minimize foregrounds (WMAP Ka band map)
  - to take advantage of as much publicly available optical data as possible for for redshift information - two fields overlap with existing optical data

Survey Science

- Cluster Abundance dN/dz
- Determine σ_8 to 5%
- Tests of Non-Gaussianity
- Spatial power spectrum, P(*k*)



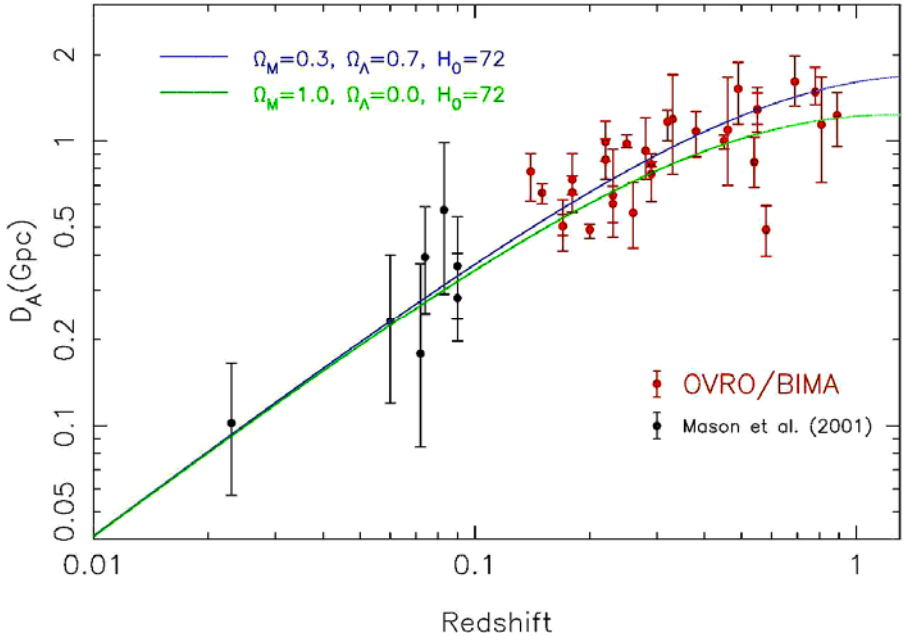


Carlstrom, Holder, Reese, 2002, ARAA V40

Survey Science

Combining with X-ray observations

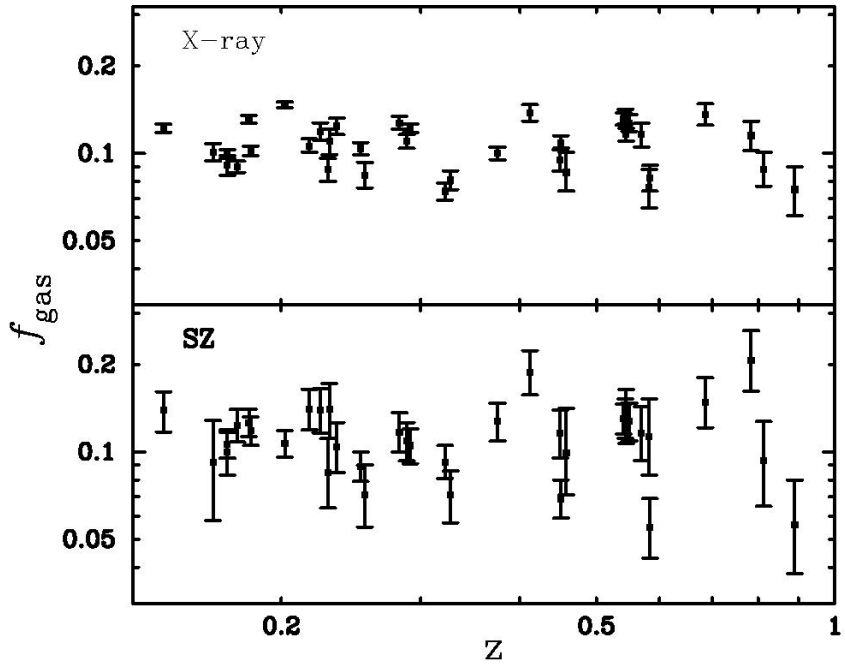
- Angular Diameter distance/Hubble Constant
- gas mass fractions
- Scaling Relations



Massimilliano et al (BIMA/OVRO SZE team), 2005

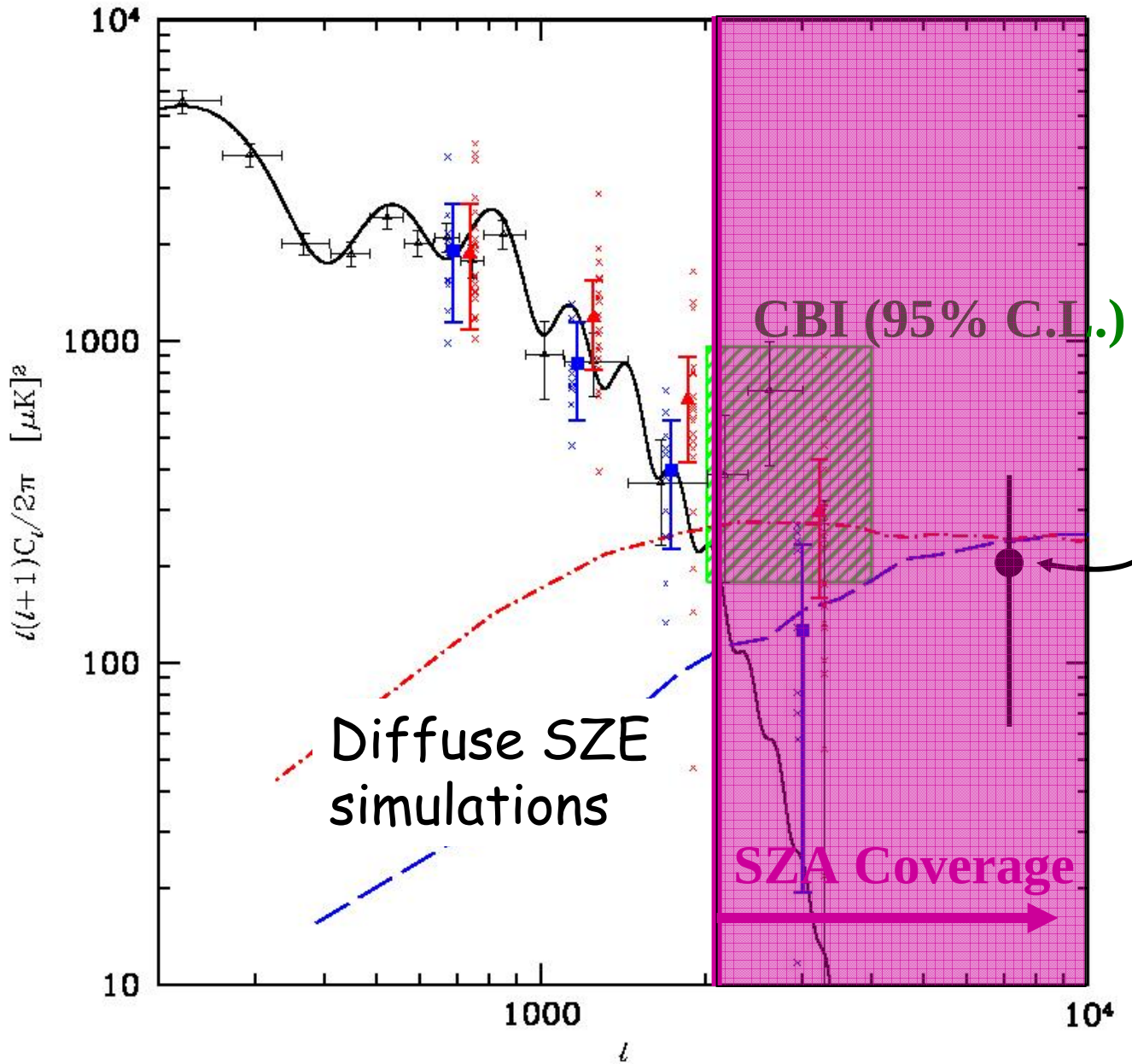
Ho=77.3 ±4 ±7 km s-1 Mpc-1 (LCDM)

fg(x-ray) = 0.109±0.003
fg(SZE) = 0.115±0.005



LaRoque et al 2005, LaRoque PhD thesis

Secondary CMB Anisotropy Measurements



$C_l(SZ) \propto (\Omega_b h)^2 (\sigma_8)^7$

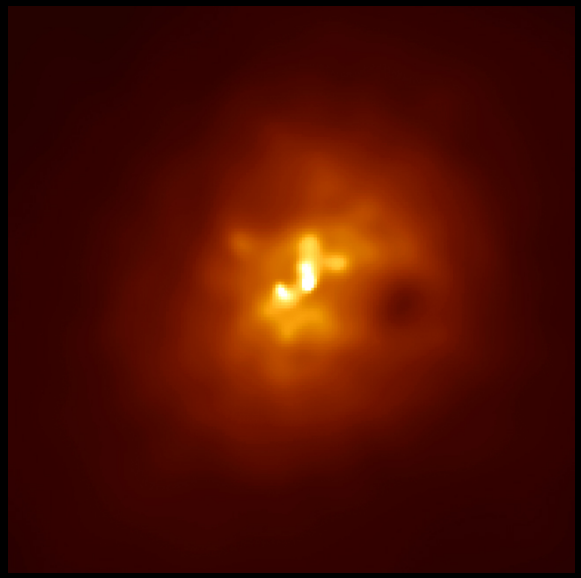
Komatsu & Seljak astro-ph/0205468

BIMA (68% C.L.)
10 "blank" fields
0.1 sq deg

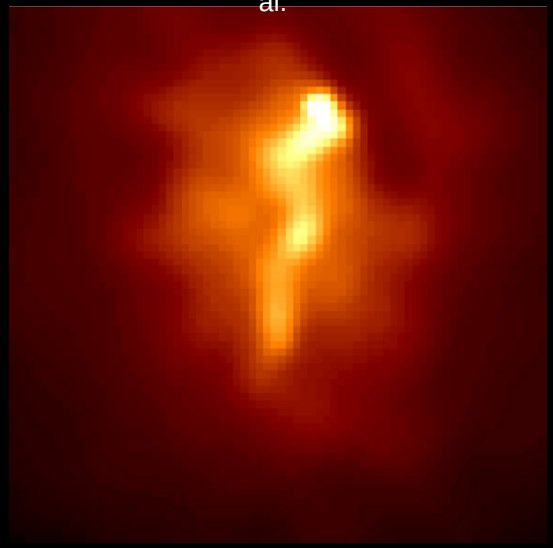
CBI & sims: Bond et al. 2002
BIMA: Dawson et al. 2002

Pointed Cluster Observations

- SZE + X-ray + optical + cluster simulations comparison of individual objects → study how various effects impact cosmological parameter determination
  - scatter in observables due to projection effects, ellipticity
  - uncertainty in gas density profile, cluster structure
  - cluster evolution
  - cooling cores, cold fronts, shock fronts, evacuated cavities
  - merger history, current dynamical state, relationship of intra-cluster gas to stellar population
- Study proto-cluster candidates



Abell 2597: NASA/CXC/Ohio U/B.McNamara et al.



Abell 1785: NASA/IoA/AC Fabian et al.

Conclusions

- The SZA is up and running, taking science data
- Performance has been verified (individual cluster observations, mosaic observations)
- 12 deg^2 survey currently in progress
- The team is analyzing data
- Stay tuned for exciting science results coming soon to a neighborhood near you…