The SPT-SZ Cluster Survey

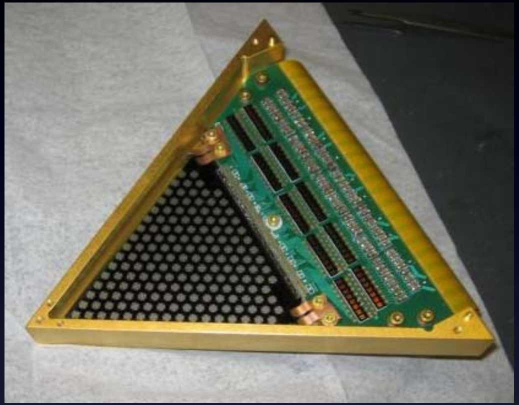
Tom Crawford (U. Chicago / KICP) for the SPT Collaboration

10m South Pole Telescope

- Big! (At least by CMB standards)
  - 10 meter clear aperture, ~7.5 meters illuminated
  - 1’ FWHM @ 150 GHz
  - 1 sq. deg. FOV
- Clean!
  - Off-axis Gregorian
  - ~20um RMS surface
  - 3 levels of shielding
    - under-illuminated primary, co-moving shields, large groundscreen (2009)
- Fast!
  - up to 4°/s scanning

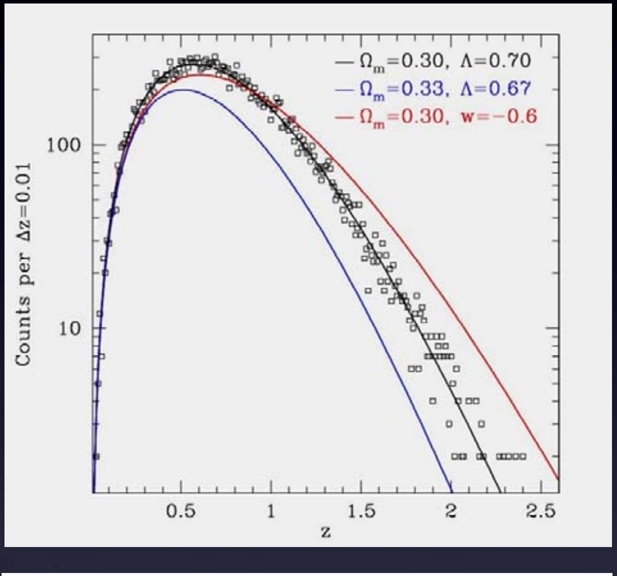
1st-Generation Camera

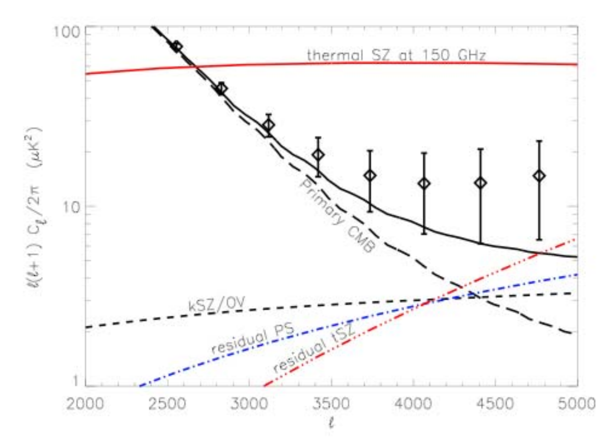
- 6 wedges of 160 bolometers each.
    - 90, 150, 220 GHz
- Cooled secondary mirror and baffles for control of loading & spillover.
- Detectors & receiver cryostat by UCB, readout by LBL, cold optics by Case/Chicago.



SPT Science Goals

Figure courtesy of G. Holder





- Find galaxy clusters through the Sunyaev-Zel’dovich Effect (SZE), constrain properties of Dark Energy.
    - 4000 sq. deg. + 10uK-arcmin = find thousands of clusters (complete to ~2.5x10^14 solar masses), measure w to ~0.1.
- Measure small-scale Cosmic Microwave Background (CMB) anisotropy.

SPT Collaboration

Berkeley
University of California

William Holzapfel
Adrian Lee
Helmuth Spieler
Sherry Cho
Bradford Benson
Huan Tran
Martin Lueker
Jared Mehl
Tom Plagge
Dan Schwan
Erik Shirokoff

Case
CASE WESTERN RESERVE UNIVERSITY

John Ruhl
Tom Montroy
Zak Staniszewski

Harvard-Smithsonian Center for Astrophysics

Antony Stark

ASTRONOMY
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Joe Mohr

THE UNIVERSITY OF CHICAGO

John Carlstrom (P.I)
Steve Padin (Proj. Manager)

Stephan Meyer
Clem Pryke
Tom Crawford
Jeff McMahon
Clarence Chang

Kathryn Miknaitis
Joaquin Vieira
Ryan Keisler
Lindsey Bleem
Abigail Crites

Colorado
University of Colorado at Boulder

Nils Halverson

JPL

Erik Leitch

McGill

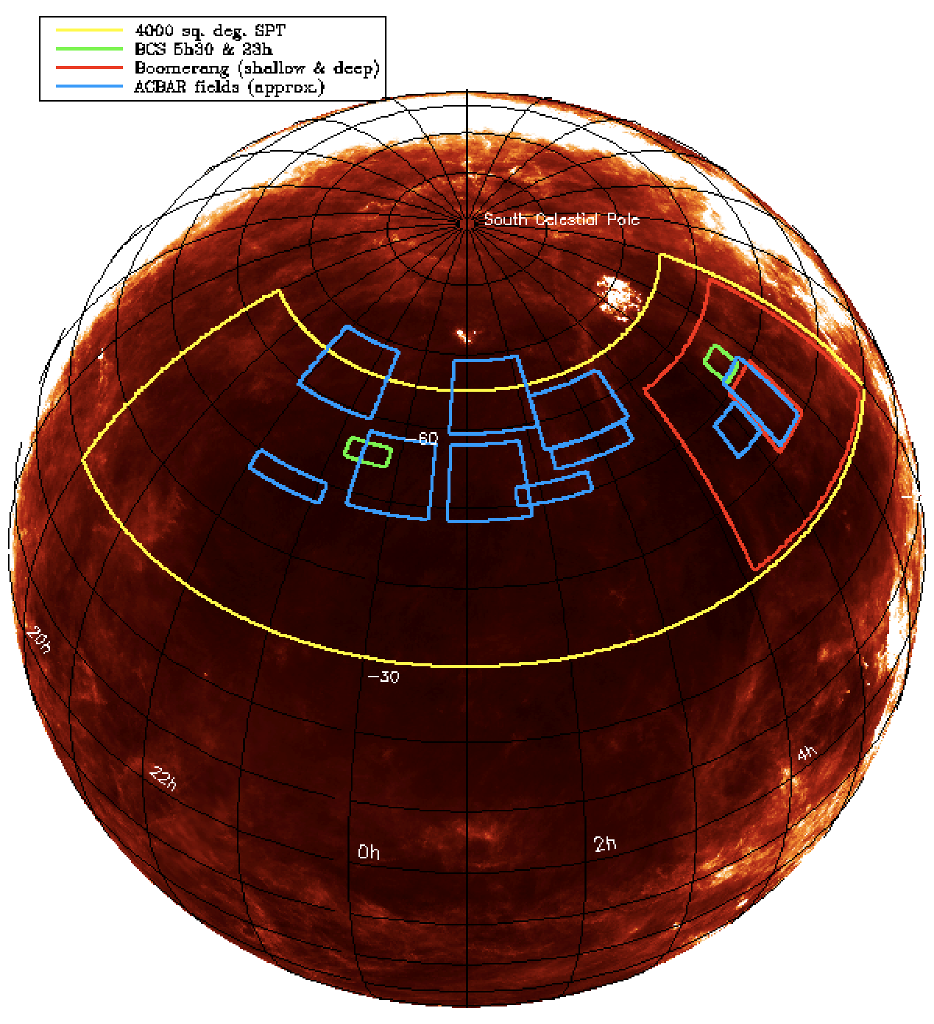
Matt Dobbs
Gil Holder
Trevor Lanting

UCDAVIS
UNIVERSITY OF CALIFORNIA

Lloyd Knox
Jason Dick

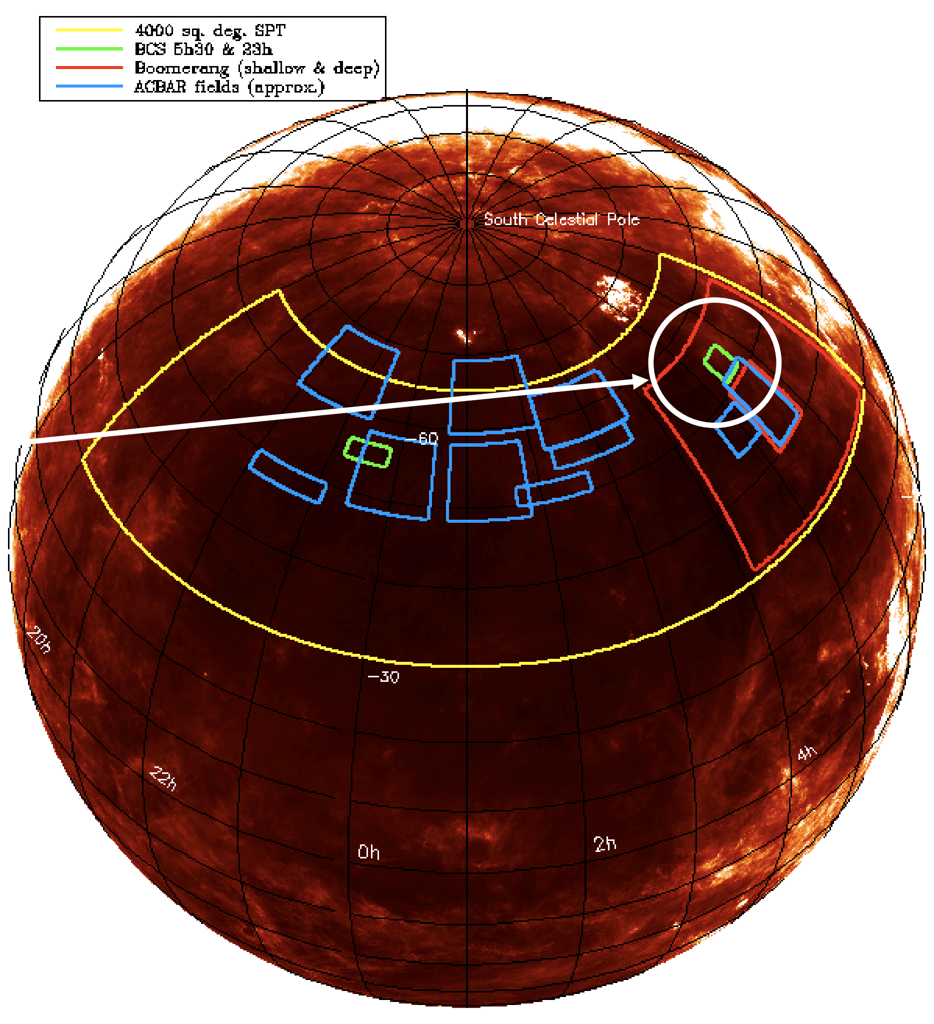
The Survey

- Limited to Southern Celestial Hemisphere.
- Galactic dust emission drives to 20h < RA < 7h.
- Atmospheric emission drives to observing elevations > 30deg.
- Leaves us ~4000 contiguous square degrees.

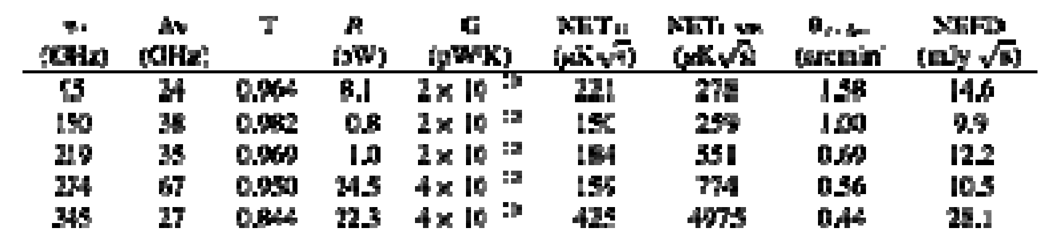


The Survey

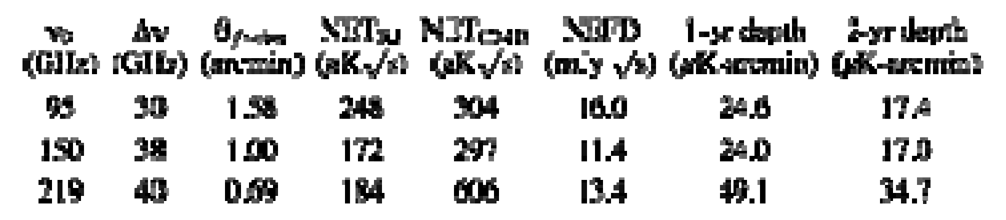
- Expected survey duration: Now - September, 2011.
- Currently going deep on 100 sq. degrees (RA=5h30, dec=-55) to check systematics. (Field includes optical and CMB “follow-up.”)
- Time available in survey for other deep fields (hint, hint).



2008 Receiver performance



ν_0 (GHz)	$\Delta\nu$ (GHz)	T	P (pW)	G (pW/K)	NET_{RJ} ($\mu K\sqrt{s}$)	NET_{CMB} ($\mu K\sqrt{s}$)	θ_{FWHM} (arcmin)	NEFD (mJy $\sqrt{s}$)
95	24	0.964	8.1	2×10^{-10}	221	278	1.58	14.6
150	38	0.982	0.8	2×10^{-12}	150	259	1.00	9.9
219	35	0.969	1.0	2×10^{-12}	184	551	0.69	12.2
274	67	0.950	14.5	4×10^{-12}	155	774	0.56	10.5
345	27	0.844	22.3	4×10^{-10}	425	4975	0.44	25.1



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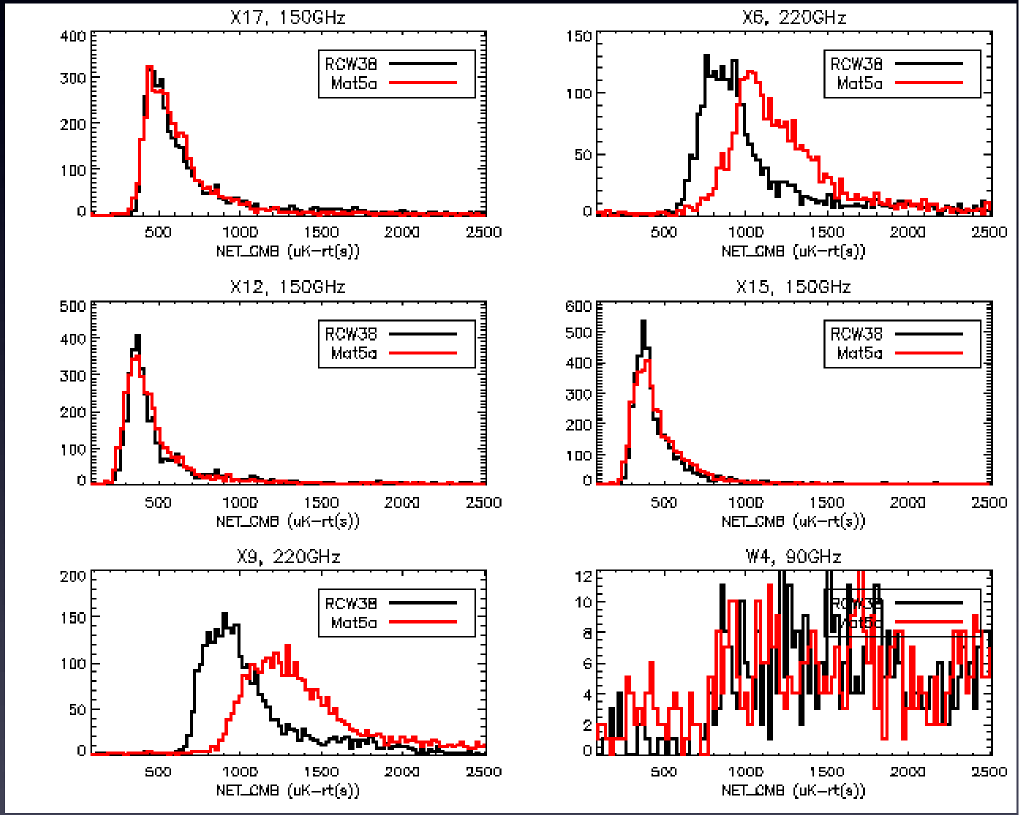
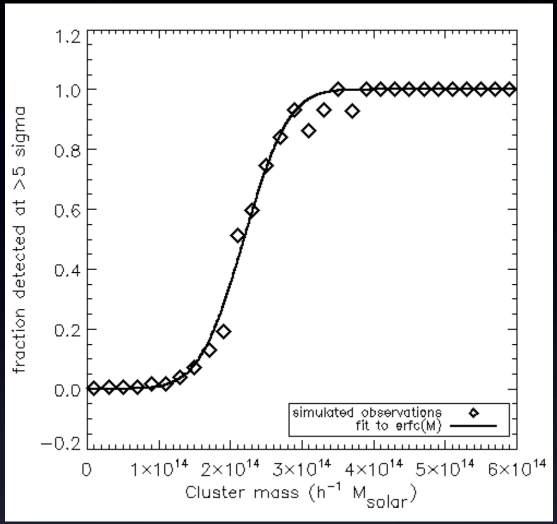
95	30	1.58	248	304	16.0	24.6	17.4
150	38	1.00	172	297	11.4	24.0	17.0
219	40	0.69	184	606	13.4	49.1	34.7



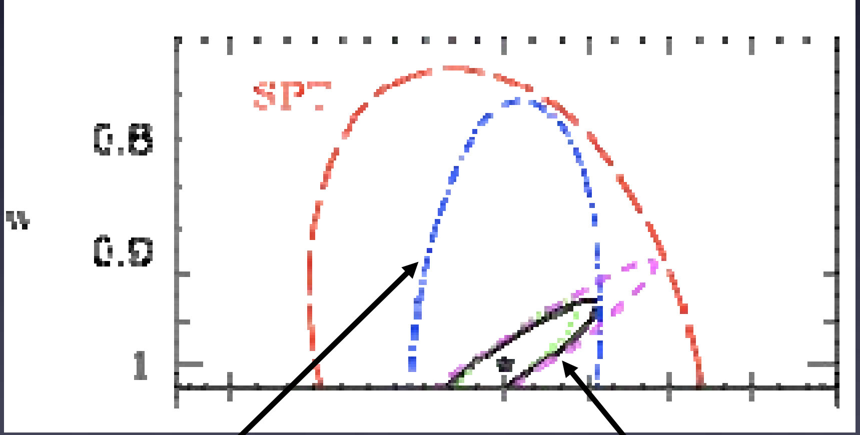
T. Crawford, SPT-SZ Cluster Survey, XMM-XXL Paris 2008

The Survey

- Simulated observations (including many levels of non-idealities) show full survey should be 90% complete at ~2.5x10^14 M_sun/h.
- BUT: Mass/SZ relation needs to be calibrated (including scatter & redshift evolution). Self-calibration methods are greatly improved by complementary mass estimates of even a small fraction of clusters.



Majumdar & Mohr (2003)



No follow-up

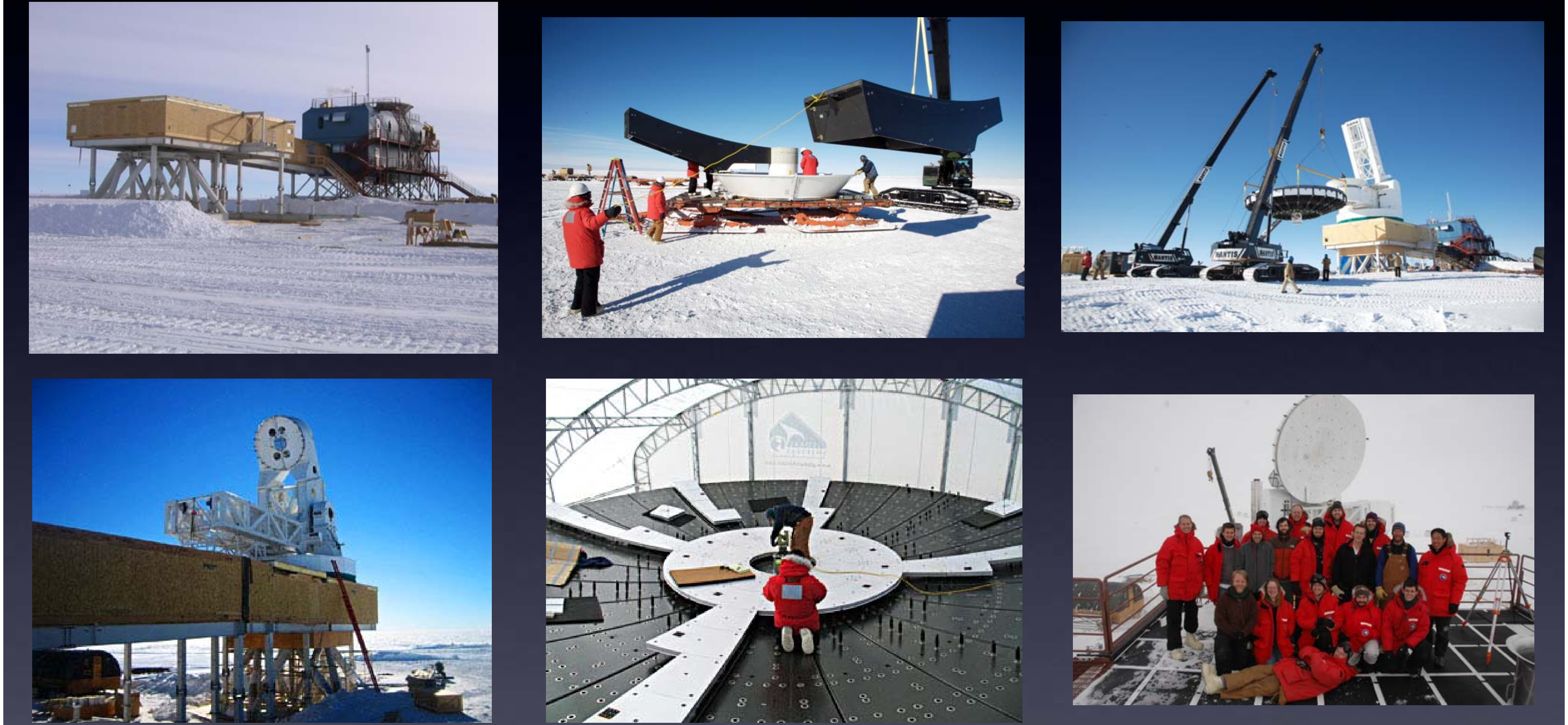
100 clusters

Summary

- 10-meter South Pole Telescope + 1st Generation Camera deployed & operating.
- >1000 sq. deg SZ cluster survey is underway.
- Survey science yield can be improved by independent cluster mass estimates from a survey such as the XMM-XXL Extragalactic Survey.

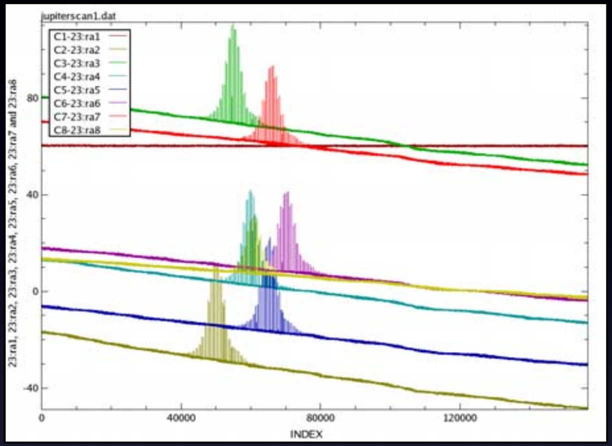
Fin

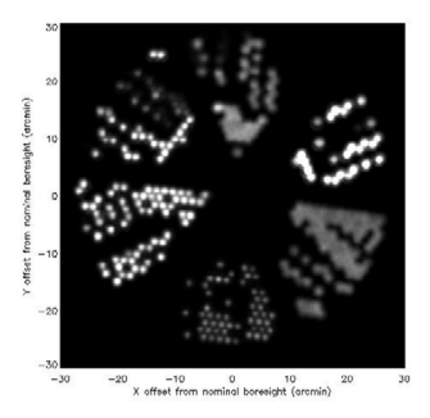
Deploying the SPT

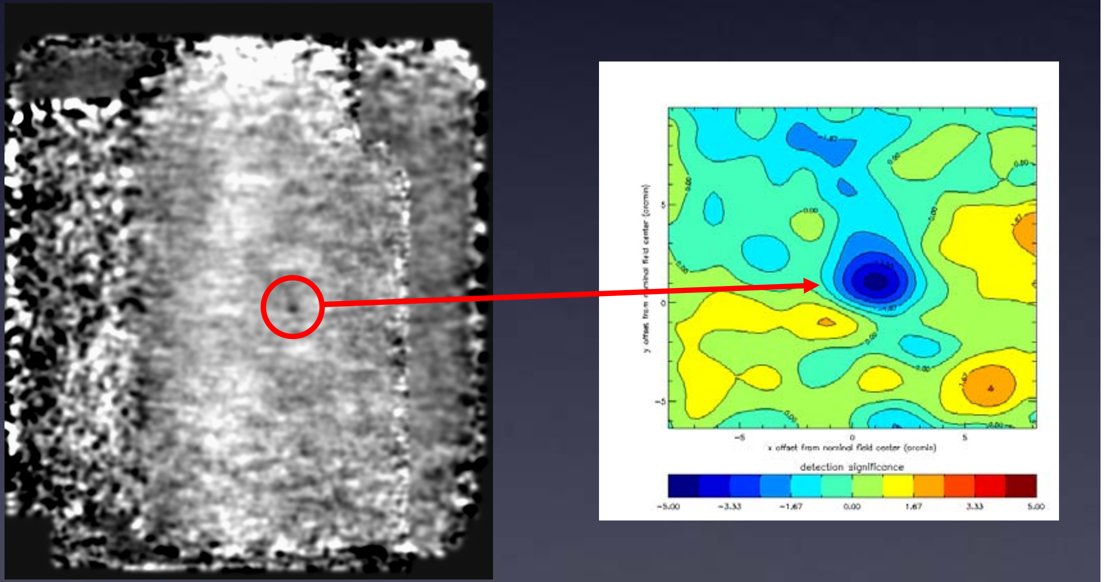


First Light / Early Observations

- First Light February 16, 2007, scans across Jupiter.
- Detector positions & beams characterized, focus found with planet scans (Jupiter & Mars).
- Abell cluster AS1063 observed (>5σ decrement in ~1hr).
- Rest of season: survey of tens of sq. deg. on fields with optical/X-ray/IR coverage.







Scan Strategy: Why does it matter?

- Efficiency:
  - finite acceleration -> finite time spent “turning around.
  - - holds for single-pixel and array instruments.
  - uniformity of coverage:
  - - array instruments have non-uniform borders.
- Matching signal spectrum to instrument noise or response:
  - e.g., 1/f noise in detectors or amplifiers, finite detector response time.

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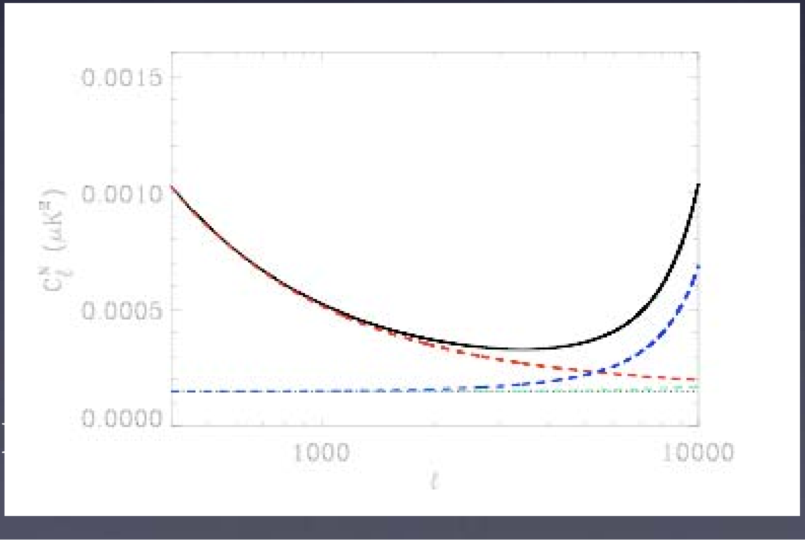
- Scan strategy maps noise(f) into noise(vector(k)) - exact and analytically tractable for some scans.
  - e.g., for raster-scanning, $f(\boldsymbol{k}) = \left|\frac{k_x v_s}{2\pi}\right|$ (astro-ph/0702608)
- average appropriately to get noise(scalar(k))
- Place signal in sweet spot:



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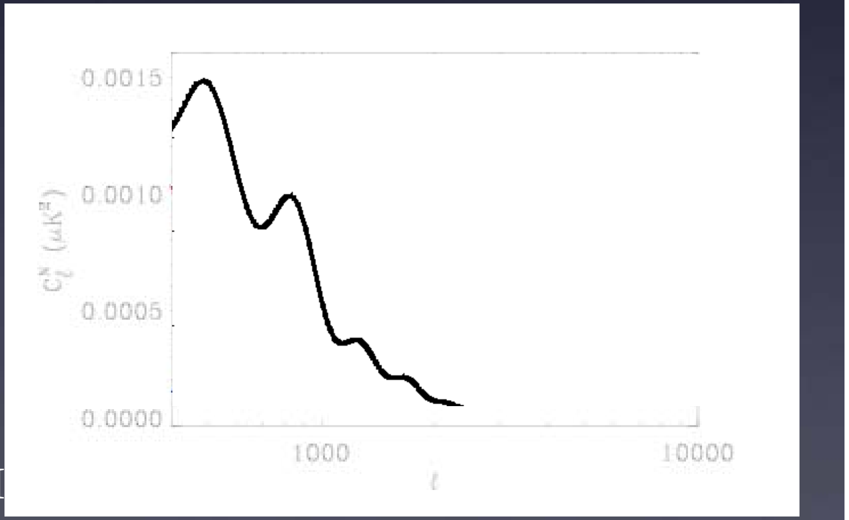

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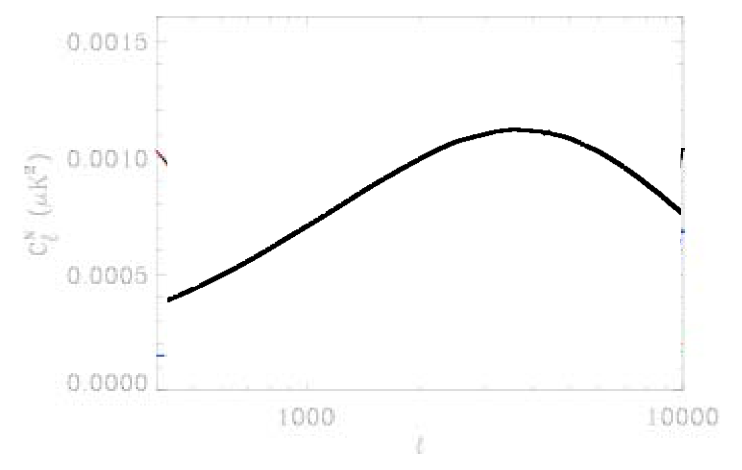

Implications for Mapmaking

- Can make naive maps with well-understood noise properties.
- Can investigate benefits of more complicated scan strategies, e.g. cross-linking.