The South Pole Telescope

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26 June 2007

Overview

- The Antarctic Plateau is the best site on Earth for millimeter- and submillimeter-wave observations.
- AST/RO operated year-round at the South Pole for 10 years — many results in galactic astronomy.
  - Talk by Nick Tothill
- The South Pole Telescope now operational. The "cluster method" for Dark Energy will tightly constrain cosmological parameters in ways that complement other methods.

Why Antarctica?

Extraordinary atmospheric conditions:

- COLD
- DRY
- HIGH
- STABLE

Best ground-based site for measuring thermal emission at infrared to mm wavelengths

South Pole Site Testing

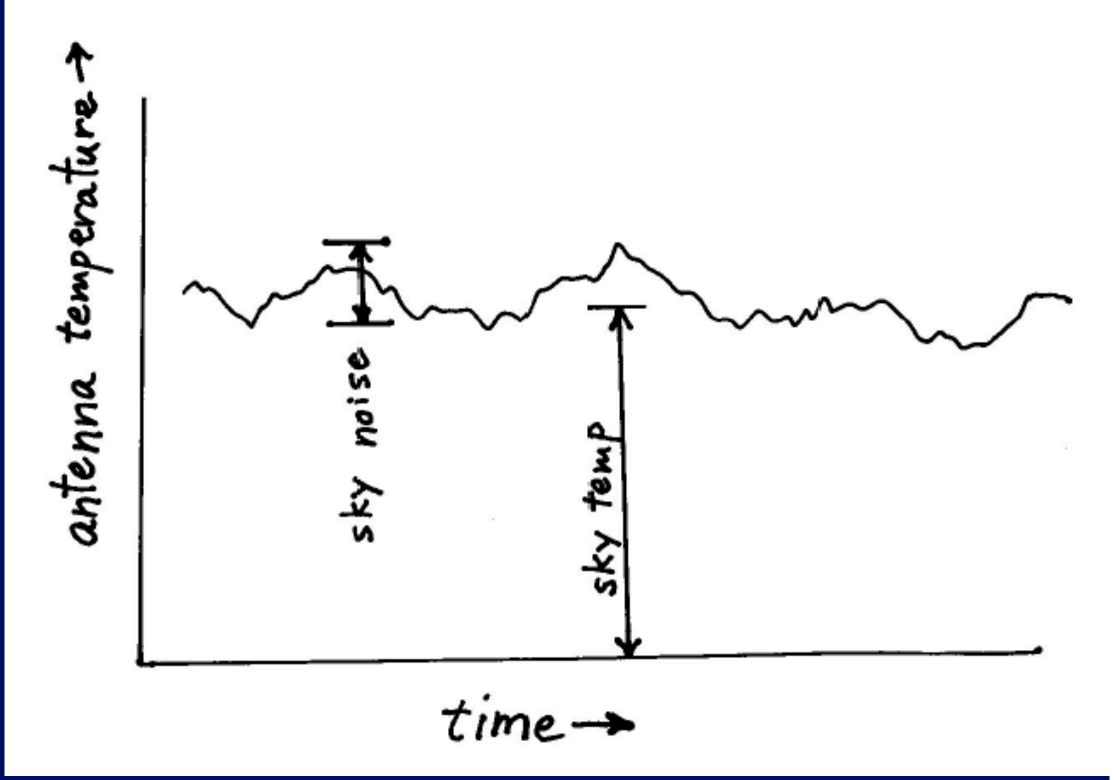
- South Pole is an excellent high-frequency radio site
- Extraordinarily low water vapor, because of cold temperatures
- Transmission is better than sites in Chile, such as the Atacama desert (Chamberlin, Lane, & Stark 1997 *ApJ* **476**, 428)
- Sky noise is 10 to 50 times better than Atacama (Lay and Halverson 2000; *ApJ* **543**, 787) ← this is a huge effect, and critical to the quality of data!

Sky Noise is more important than Sky Temperature

Sky temperature ∝ atmospheric attenuation,
but attenuation is insignificant (a few percent)
for serious millimeter-wave observations.

Sky noise may be irreducible, 1/f

Sky temperature adds to system noise



Two decades of improvements in infrastructure for science at the National Science Foundation Amundsen-Scott South Pole Station and McMurdo Sound Station…

1986: crates serve as lab space

Mark Dragovan, Bob Pernic, Martin Pomerantz, Bob Pfeiffer, Tony Stark

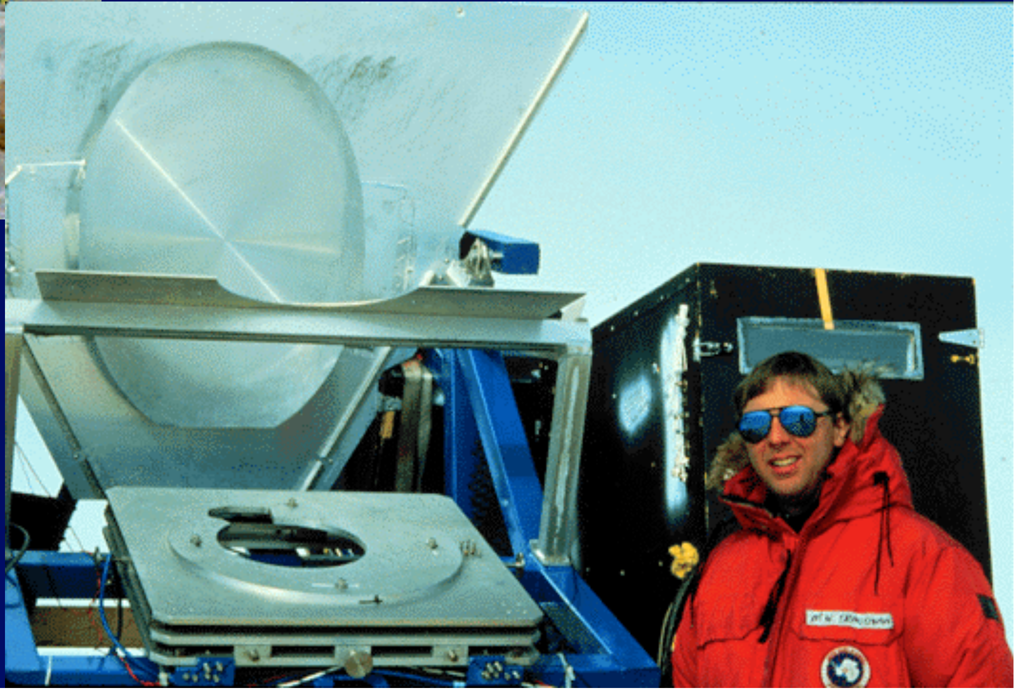
Early days for telescopes at the Pole, moving equipment, January 1987

1988: “Cucumber” experiments in Jamesway lab

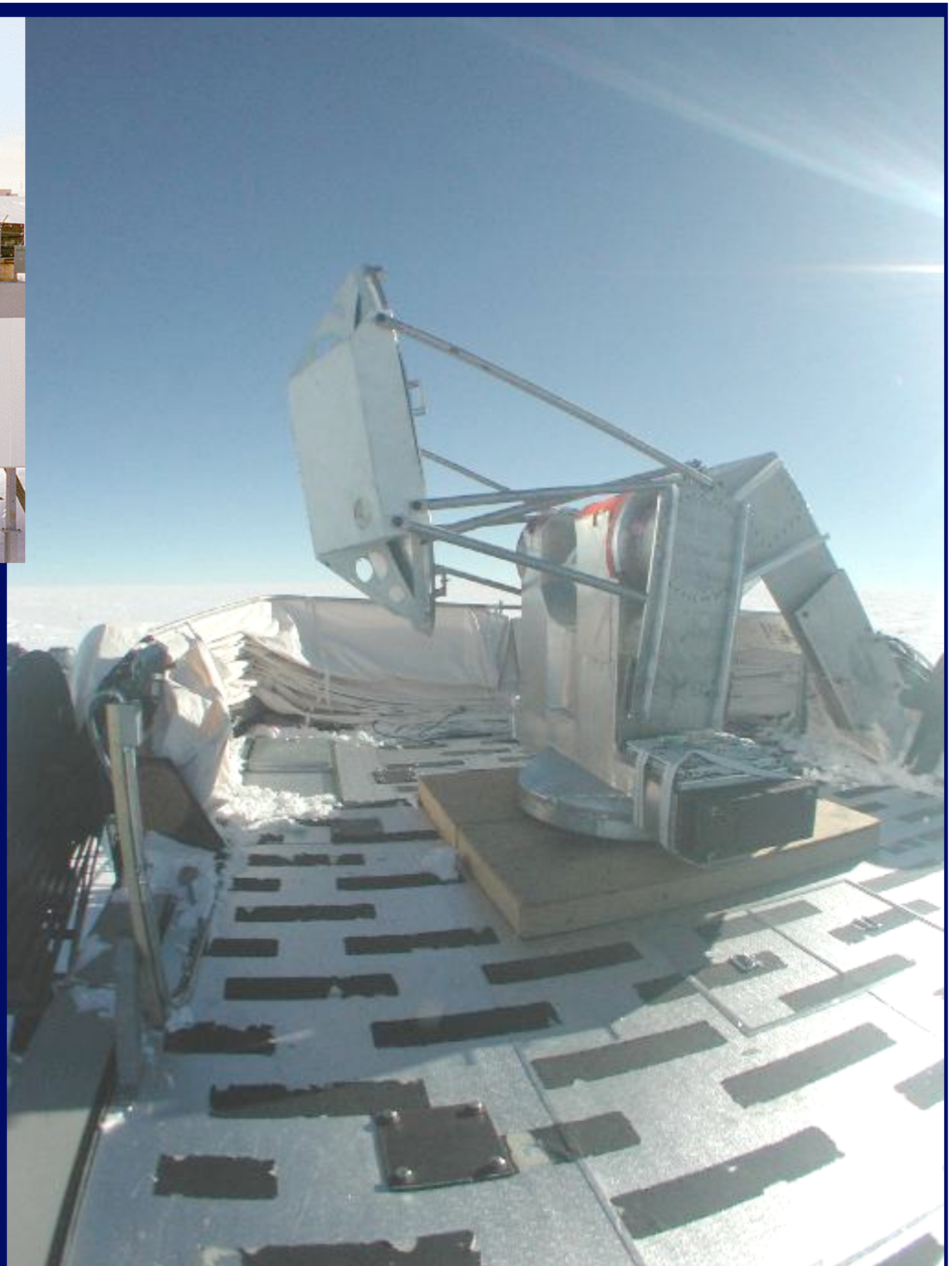
Inside Jamesway

Python CMBR telescope

Python ground shield
in front of Pomerantz Laboratory



Mark Dragovan with
Python optics



AST/RO
submm-wave Telescope

- PI Tony Stark & many collaborators
- Full suite of submm-wave receivers
- First telescope to operate through the Austral Winter

Martin A. Pomerantz Laboratory

Boomerang Launch from McMurdo Sound

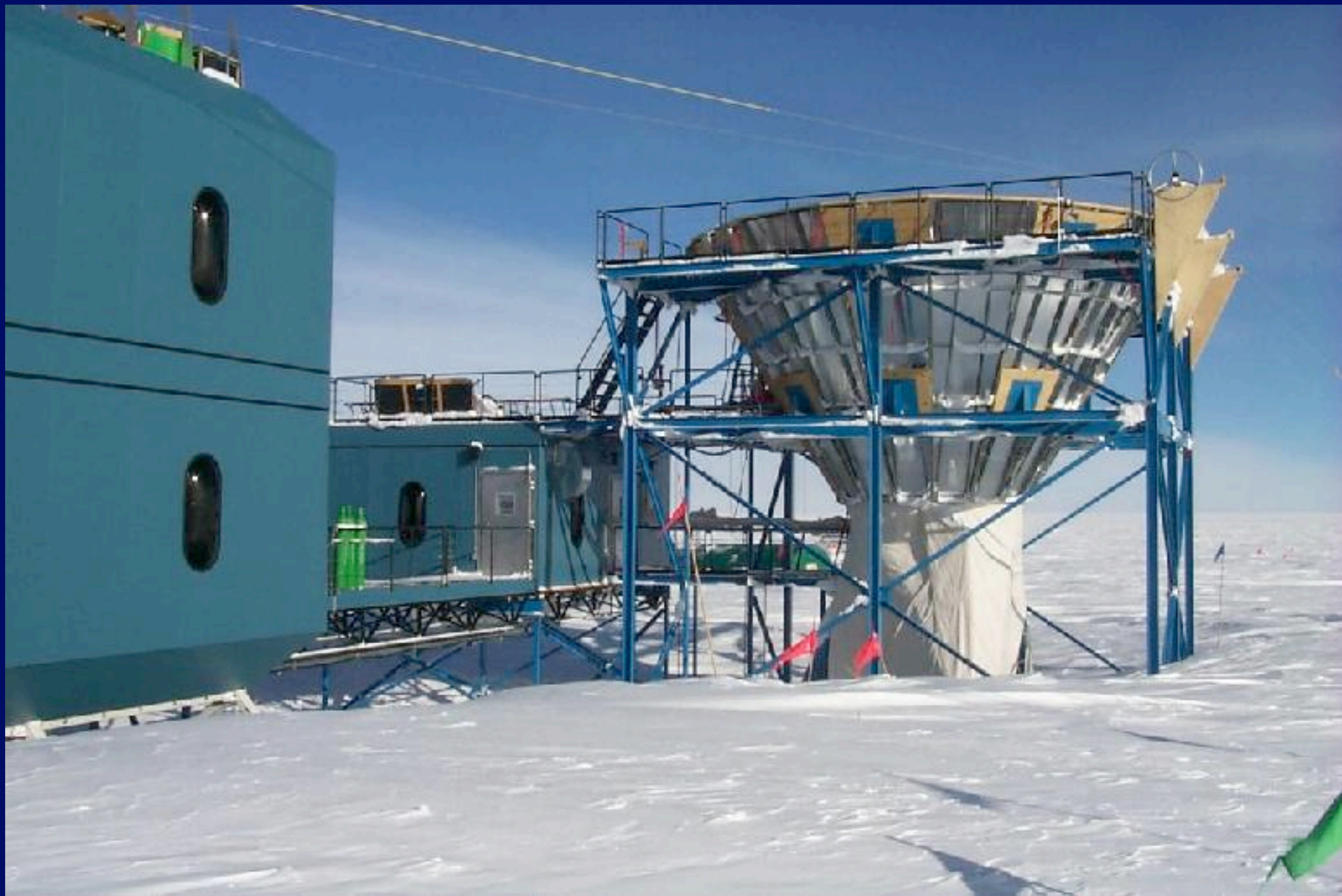
Boomerang Launch from McMurdo Sound

Boomerang Launch from McMurdo Sound

Viper Telescope at South Pole

PI: W. Holtzapfel

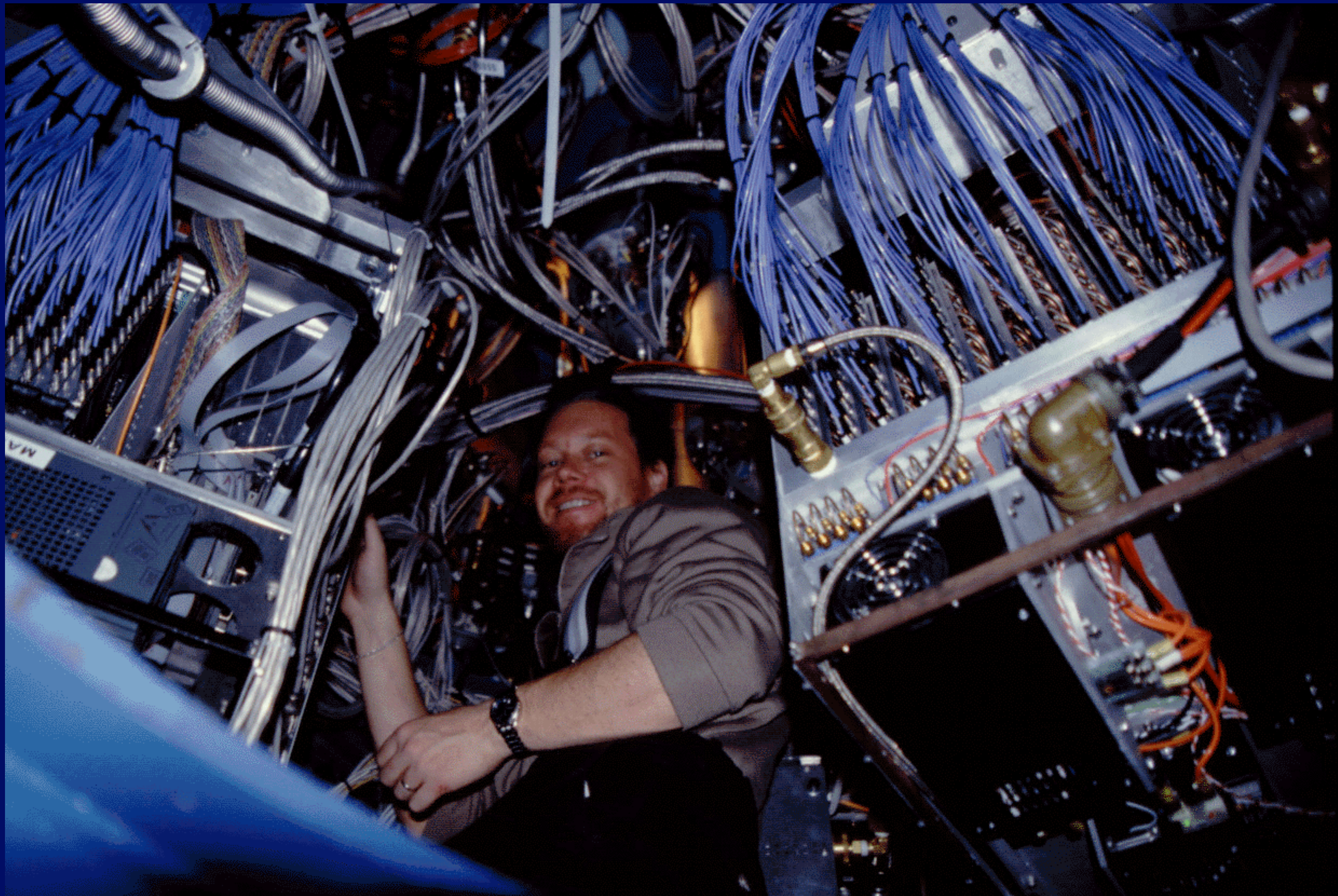
Viper's Groundshield



DASI at sunset March 2000

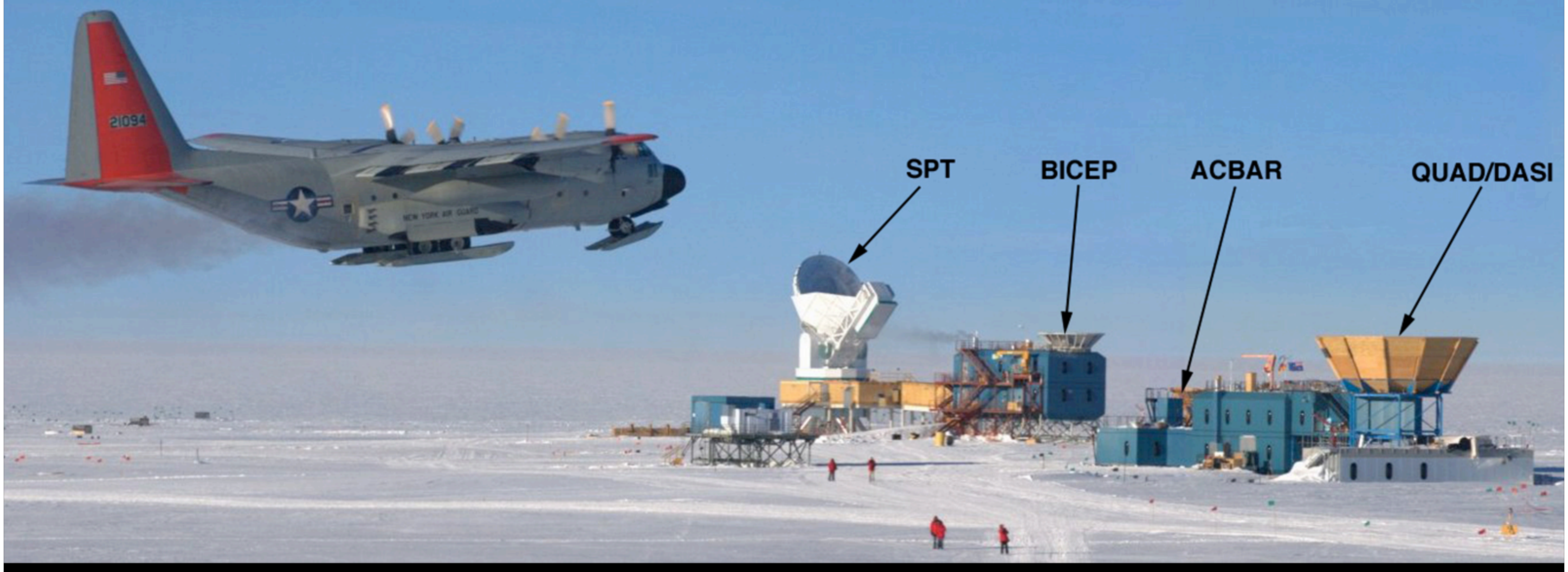
PI: John Carlstrom

Inside DASI



The South Pole Telescope, January 2007

End of austral Summer 07



The Future: SPT

- SPT is beginning to study the nature of Dark Energy, through a Sunyaev-Zel'dovich effect survey of clusters of galaxies.
- Future SPT polarization experiments may provide crucial data on Early Inflation.

SPT Collaboration

Berkeley, University of California

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

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

Cardiff University / Prifysgol Caerdydd

Peter Ade

Berkeley Lab

Helmuth Spieler

The University of Chicago
KICP – Kavli Institute for Cosmological Physics at the University of Chicago

John Carlstrom (PI)
Steve Padin (Project Manager)
Stephan Meyer
Clem Pryke
Tom Crawford
Jeff McMahon
Clarence Chang
Andrey Kravtsov
Ken Aird
Kathryn Miknaitis
Joaquin Vieira
Ryan Keisler
Lindsey Bleem
Jonathan Stricker
Wayne Hu

Colorado – University of Colorado at Boulder

Nils Halverson

JPL

Erik Leitch

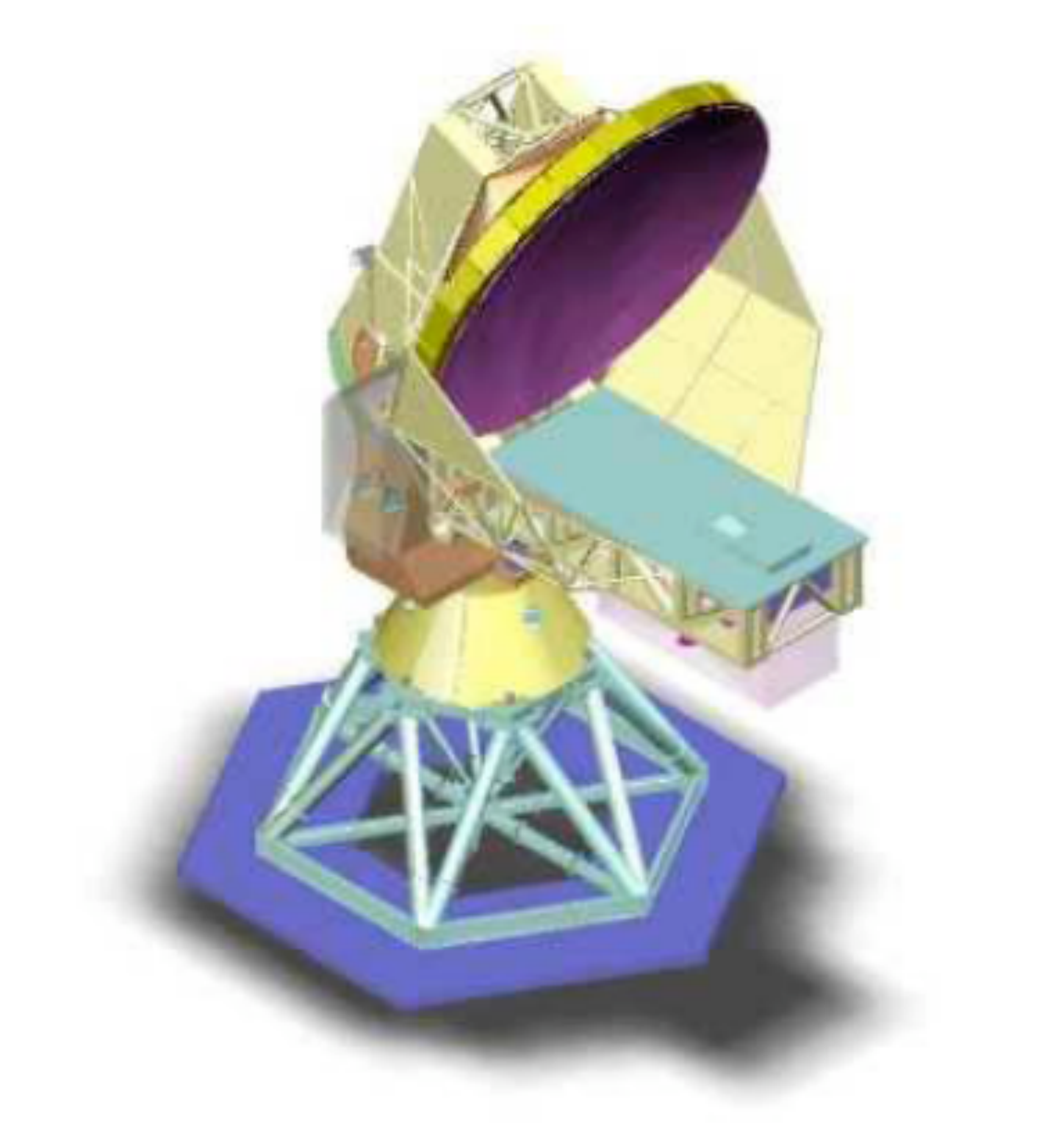
McGill

Matt Dobbs
Gil Holder
Trevor Lanting

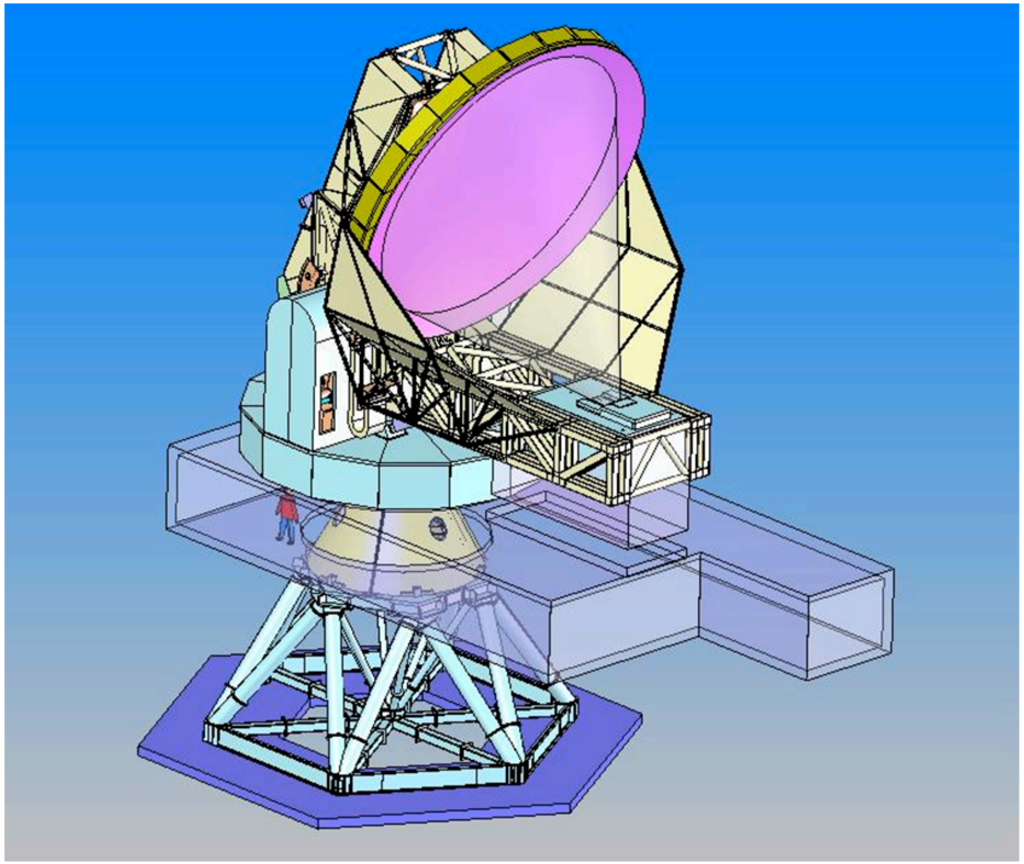
UC Davis – University of California

Lloyd Knox
Jason Dick

SPT Design



10m South Pole Telescope (SPT) and 1000 element bolometer array



Schematic of the SPT, when Telescope is 'Docked' for access to the Receiver Cabin

Low noise, precision telescope

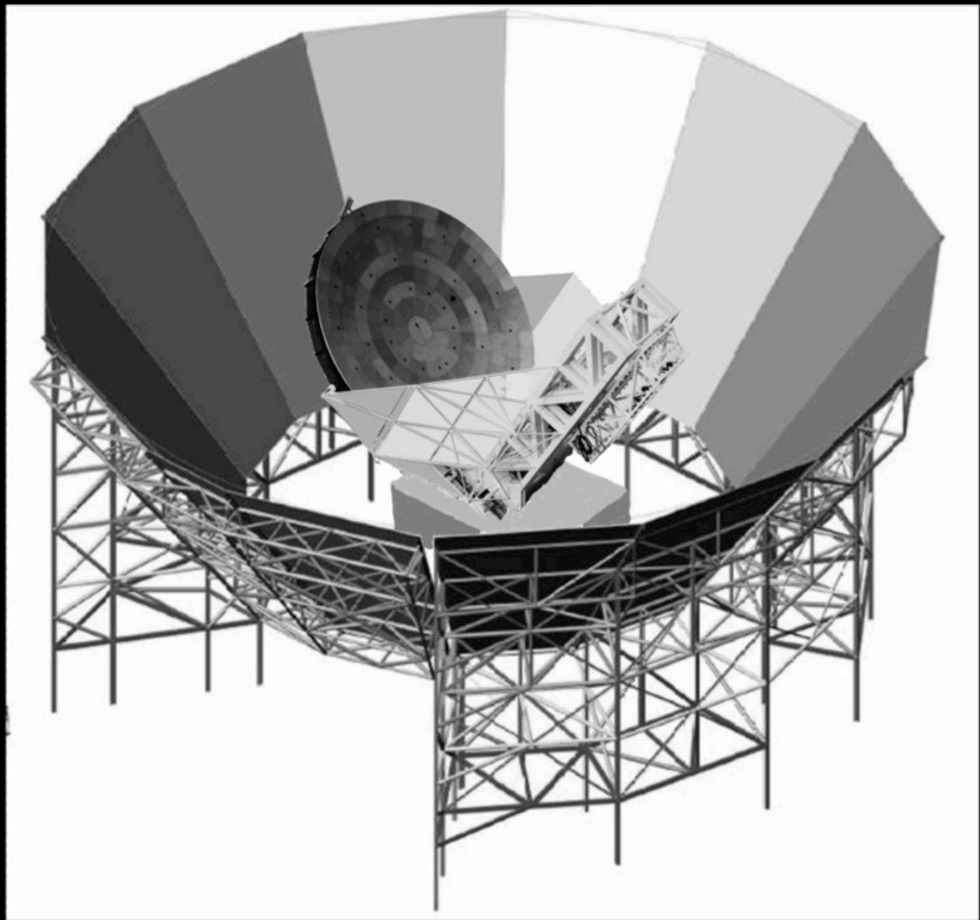
- 20 um rms surface over 10m
- 1 arcsecond pointing
- 1 arcmin resolution at 2 mm
- scan entire telescope
- 3 levels of shielding
  - 1 m radius on primary
  - inner moving shields
  - outer fixed shields

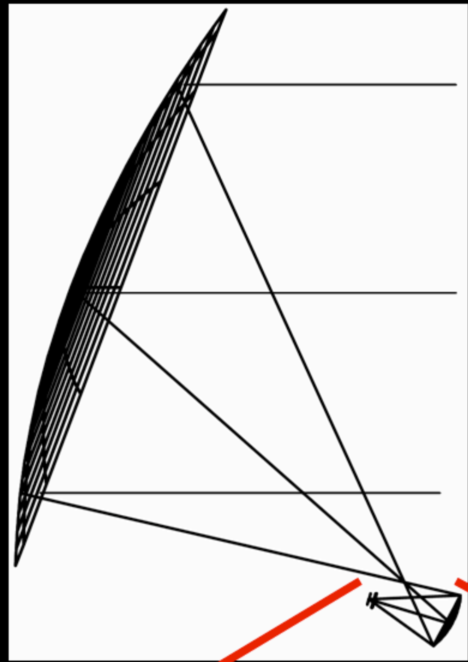
SZ-effect and CMB Anisotropy

- up to 5 bands (start w/3) 90,150, 220, 270, 350 GHz
- **4000 sq deg SZ-survey**
- deep CMB anisotropy fields
- deep CMB Polarization fields

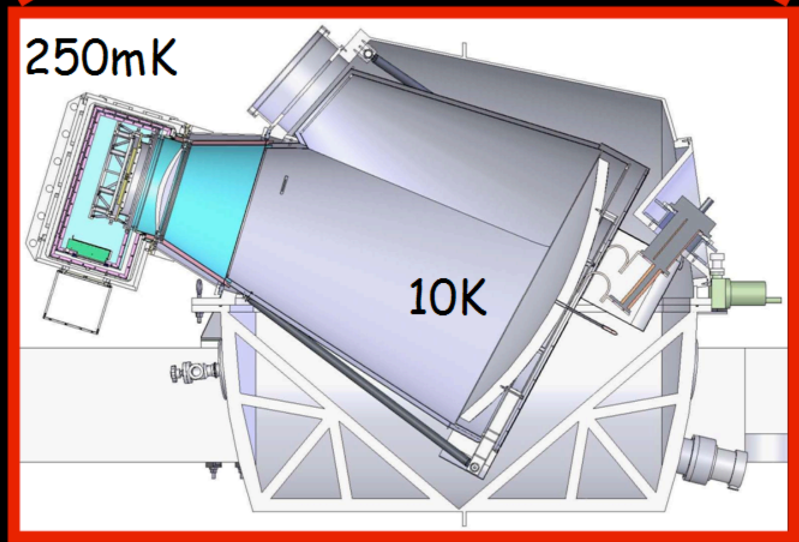
First light achieved Feb 16, 2007!

SPT - Optimal design for SZ Dark Energy experiment





- Very simple, low-noise, optical design
- 10m primary, 1' resolution at 150 GHz
- 1 sq degree field of view

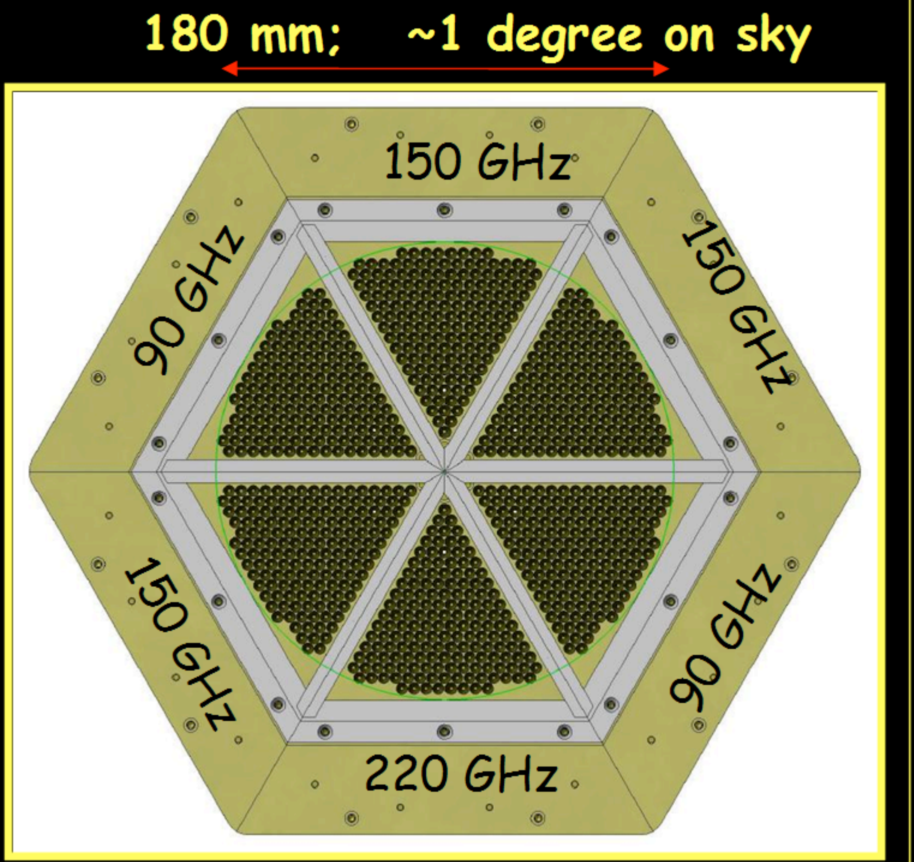


Slide: Kathryn Miknaitis

A 10-meter off-axis submillimeter-wave telescope for high sensitivity and high resolution observations of the Cosmic Microwave Background.

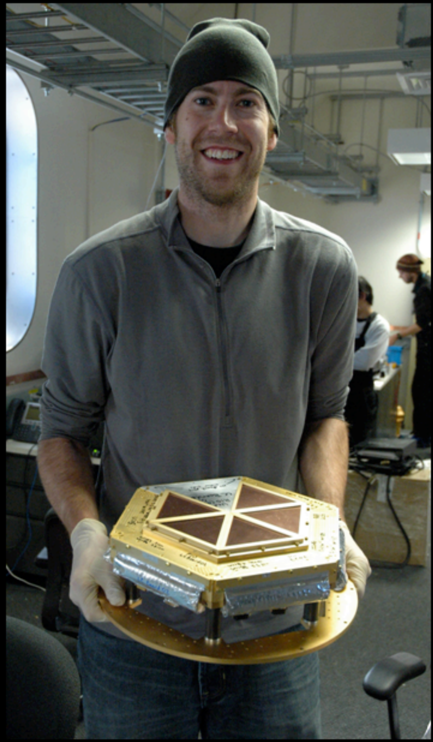
Site:	Best site on earth for CMB observations; High, Dry, Stable, Unique view of the Universe
Precision:	20 um surface accuracy (width of a human hair) Unique Carbon Fiber Reinforced Plastic back-up structure 218 reflector panels (no two alike) with 8 adjusters each (1744 adjusters)
Camera:	960 bolometric detectors cooled to 0.3 K
Data rate:	120 Gbytes/day
Weight:	600,000 lbs above the steel foundation
Number of structural bolts:	5162
Height above snow:	75 feet (~six stories)
Time to design:	2.5 years
Time to fabricate parts:	1.5 years
Time to assemble at Pole:	3 months (!)

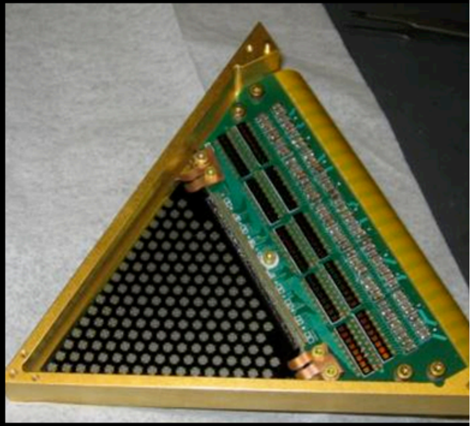
The SPT Detector Array



- 160 possible channels on each wedge
- Transition Edge Sensor bolometers with
  Tc ~ 500mK
- 8 bolometers read out by a single SQUID using frequency-domain multiplexing

(UC Berkeley)





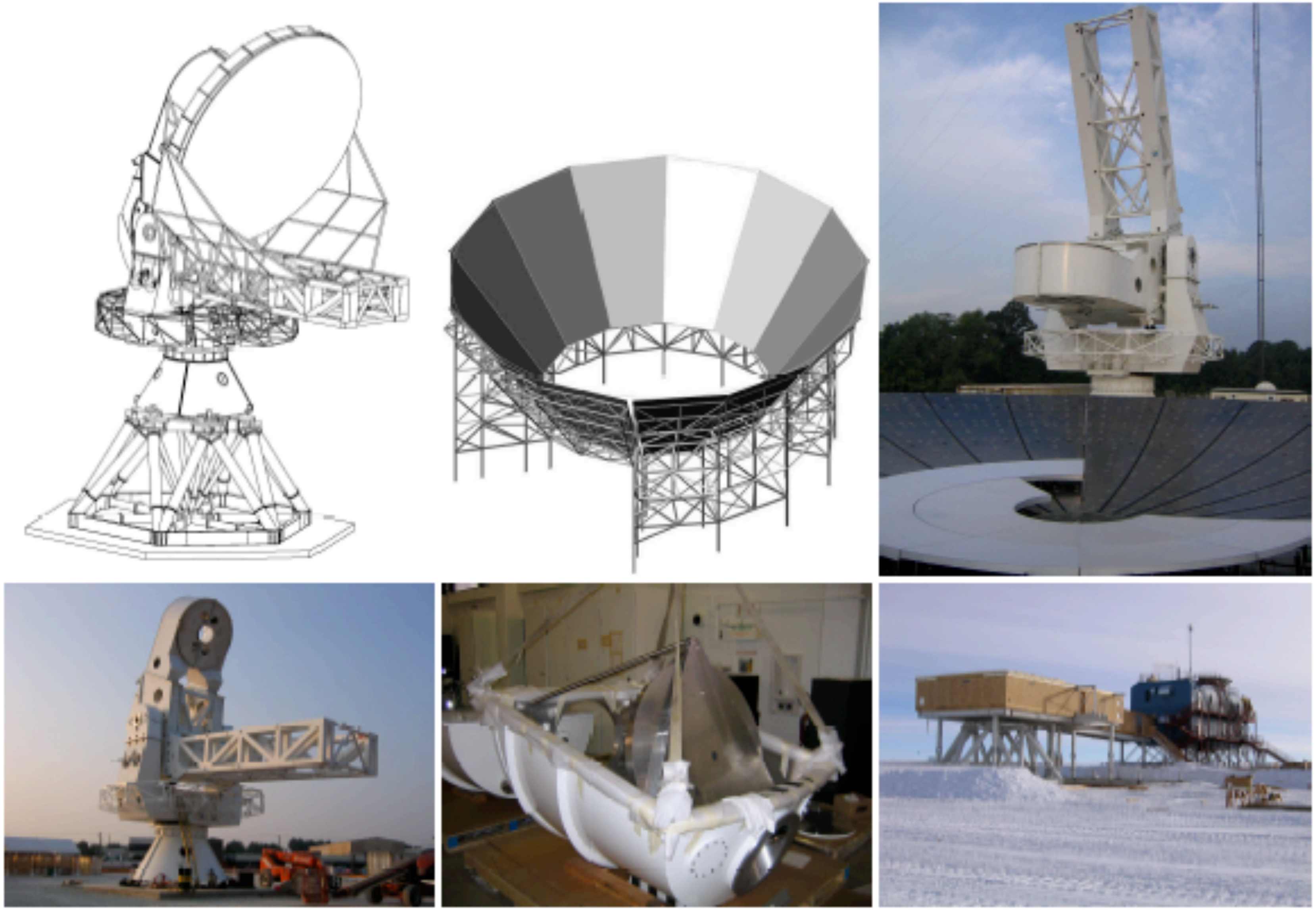
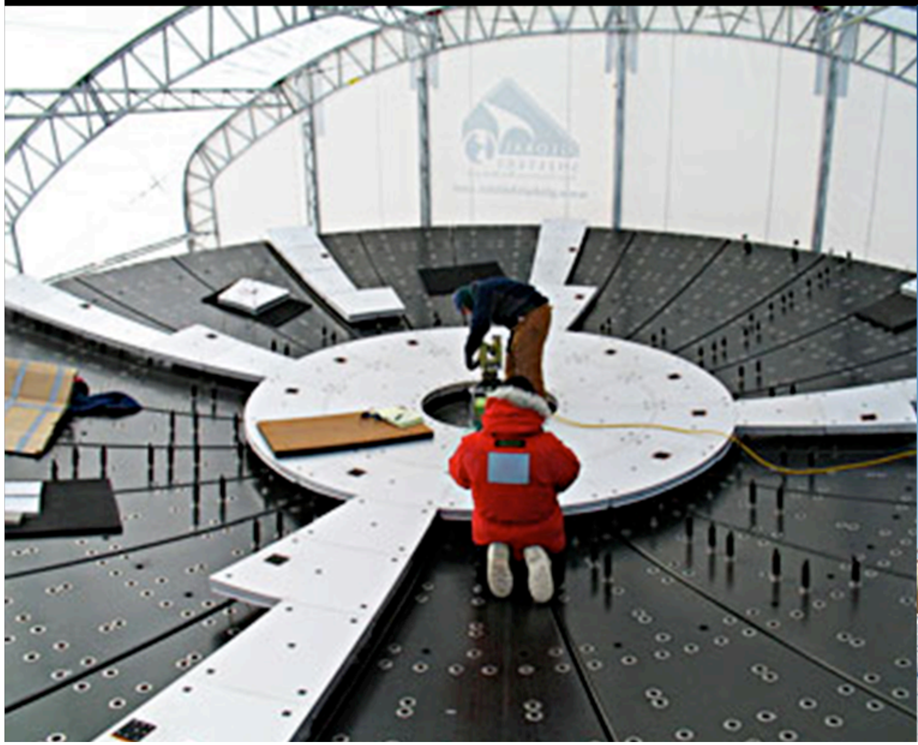


Figure 1: *Top left*: Drawing of the 10 meter off-axis South Pole Telescope pointed at horizon. *Top center*: A schematic diagram of the SPT groundshield to be installed for the second season of observations. *Top right*: The primary mirror panels being installed on the CFRP BUS. *Bottom left*: The SPT telescope without the primary reflector at the test build in Texas. *Bottom center*: Cold secondary mirror cryostat. *Bottom right*: SPT foundation and control room at the NSF Amundsen-Scott South Pole station.

Deployment

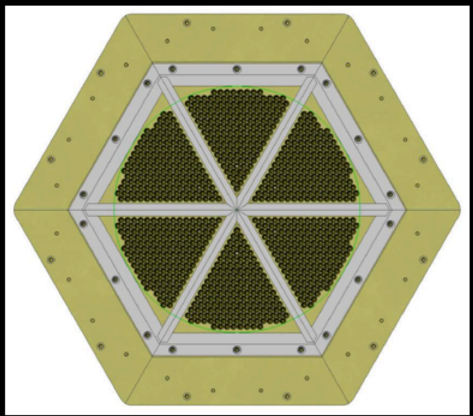


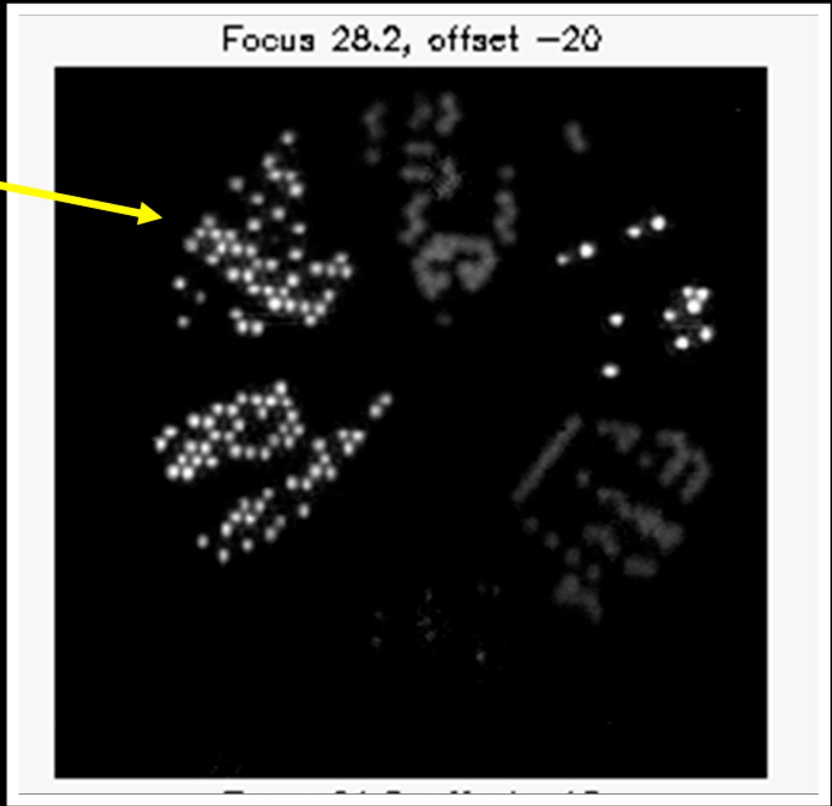
The South Pole Telescope, January 2007

First Light and Test Observations

First maps made from scans across Jupiter, Feb. 16 2007!

Scanning across Mars, without correcting for pixel offsets

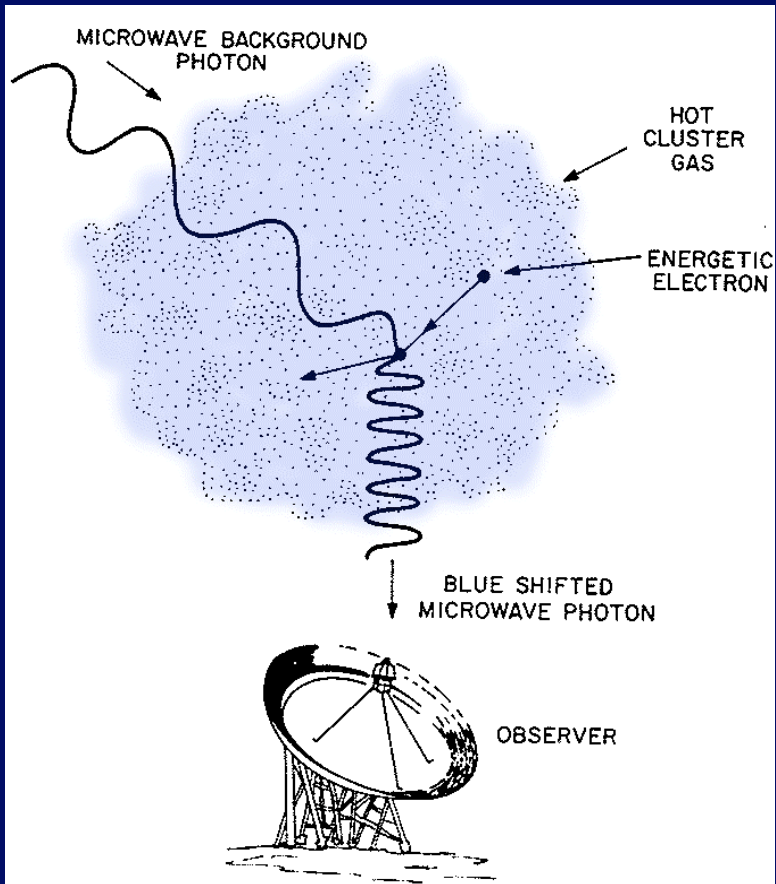




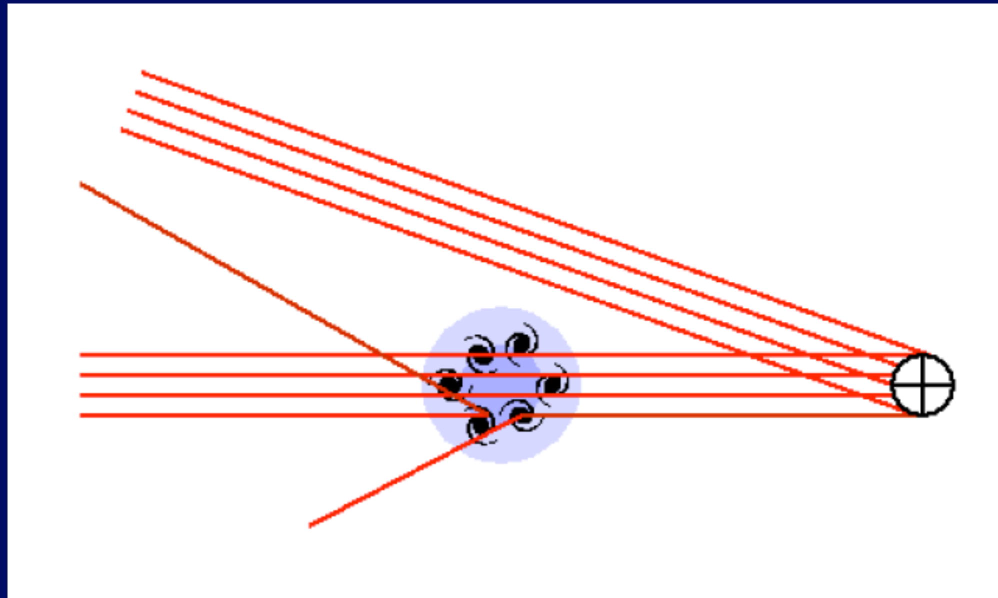
~400 detectors working

Galaxy clusters

Sunyaev-Zel'dovich Effect



Adapted from L. Van Speybroeck



Cosmic Microwave Background photons interact with hot gas in clusters of galaxies.

Low-frequency photons are kicked up to higher frequencies.

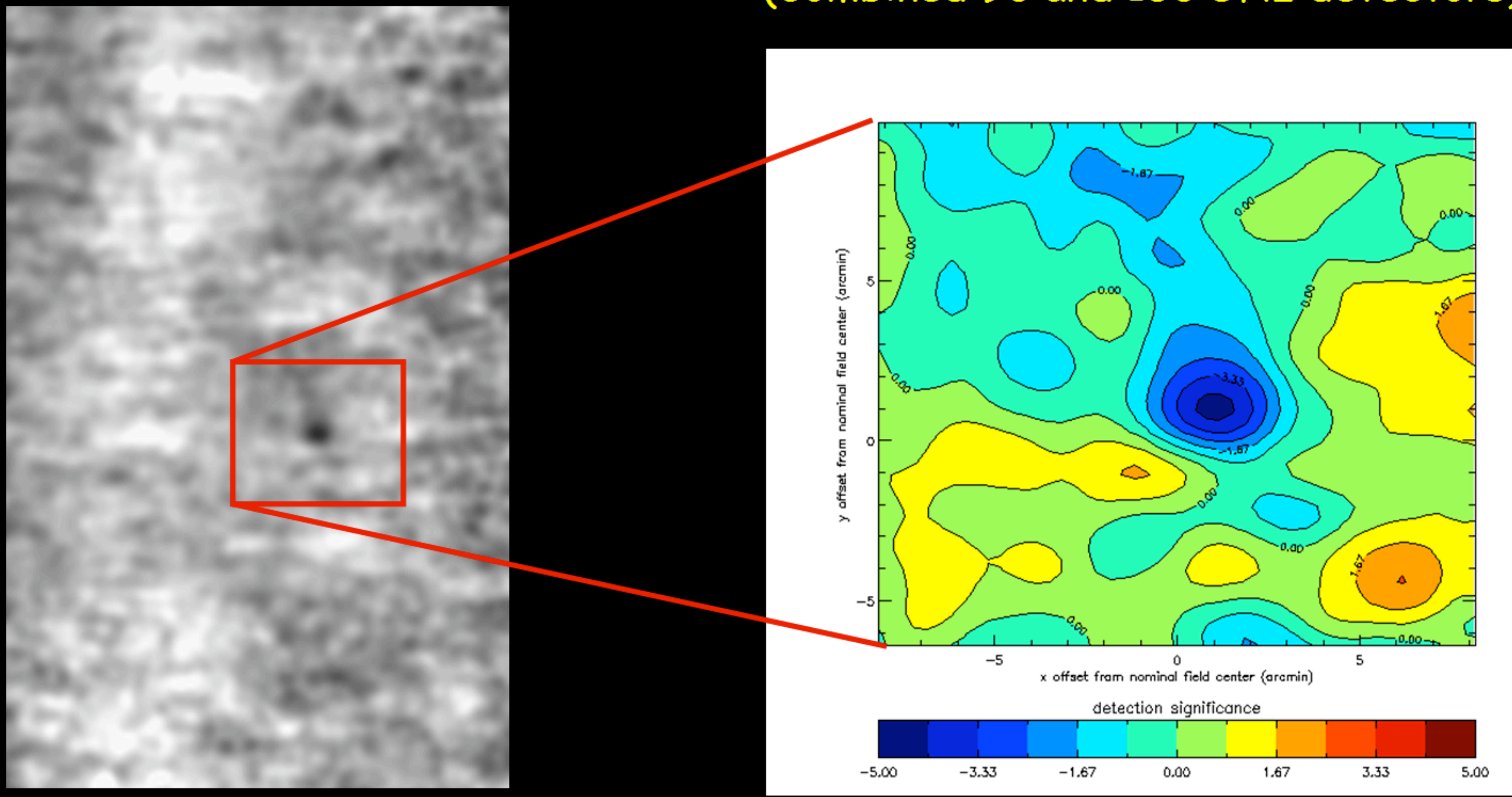
SPT-SZ Survey

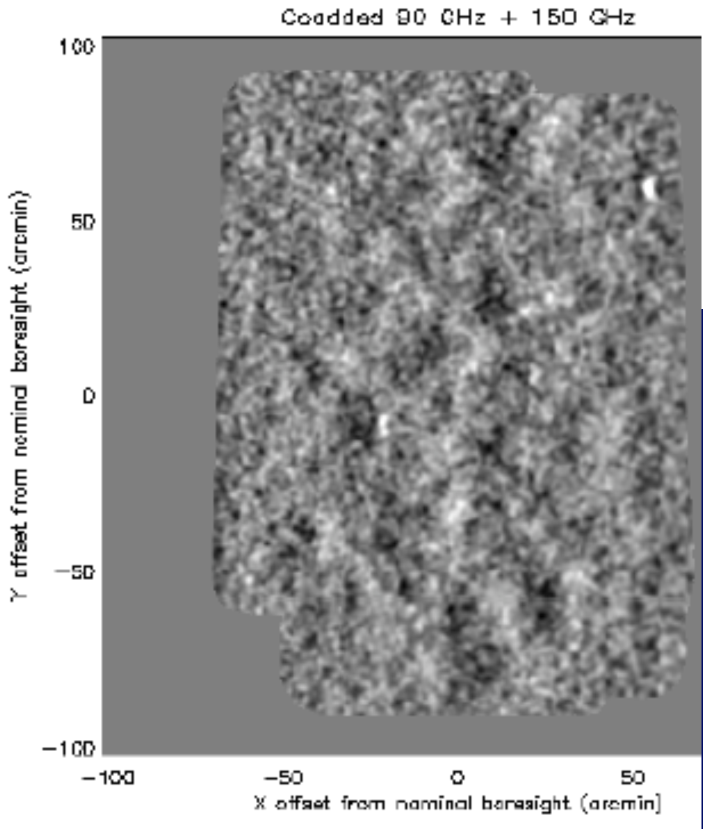
- SPT will find thousands of clusters of galaxies
- Most will have core radius ~ 1 arcminute
- Richness information from depth of SZ signature
- No redshift information (PISCO!)
- Timescale: next few years, beginning now
- "Clusters" approach to Dark Energy is complementary to Supernovae method (cf. Bob Kirshner 2 weeks ago)
- SZ, X-ray data from clusters may be comprehensible from first principles — potentially a big advantage

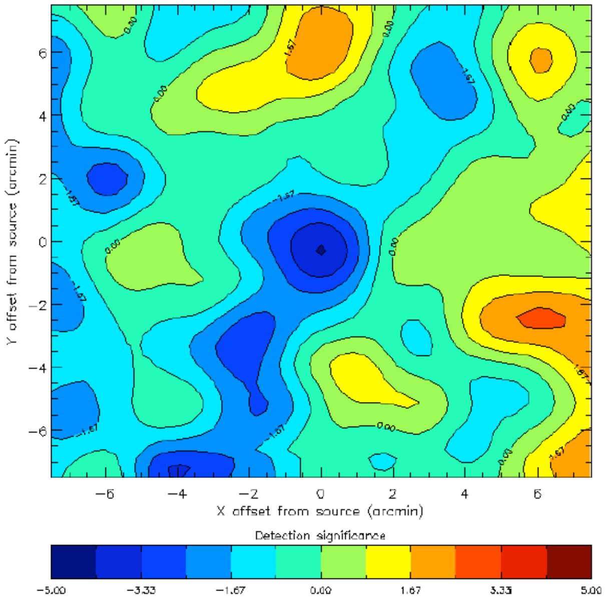
SPT's First SZ-effect Observations

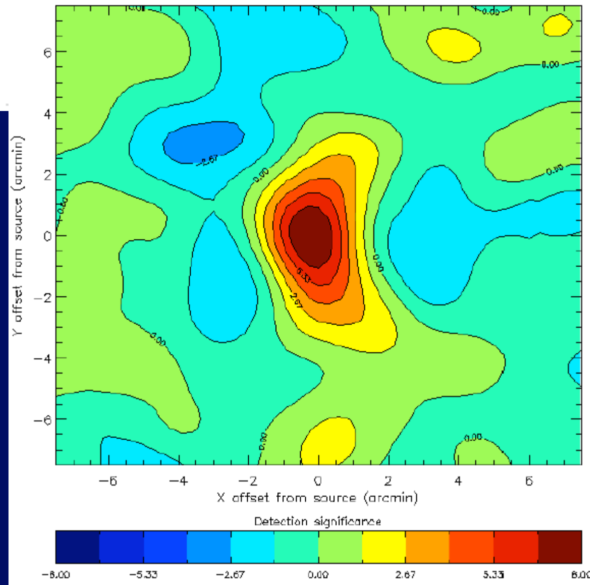
First SZ cluster observed by SPT (AS1063)

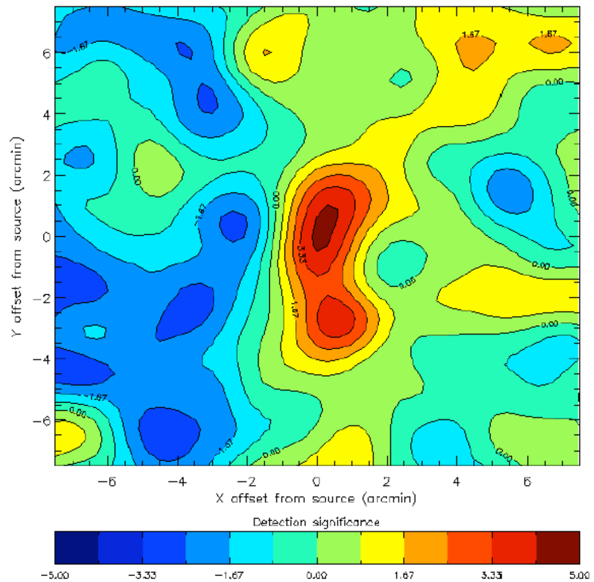
(Combined 90 and 150 GHz detectors)



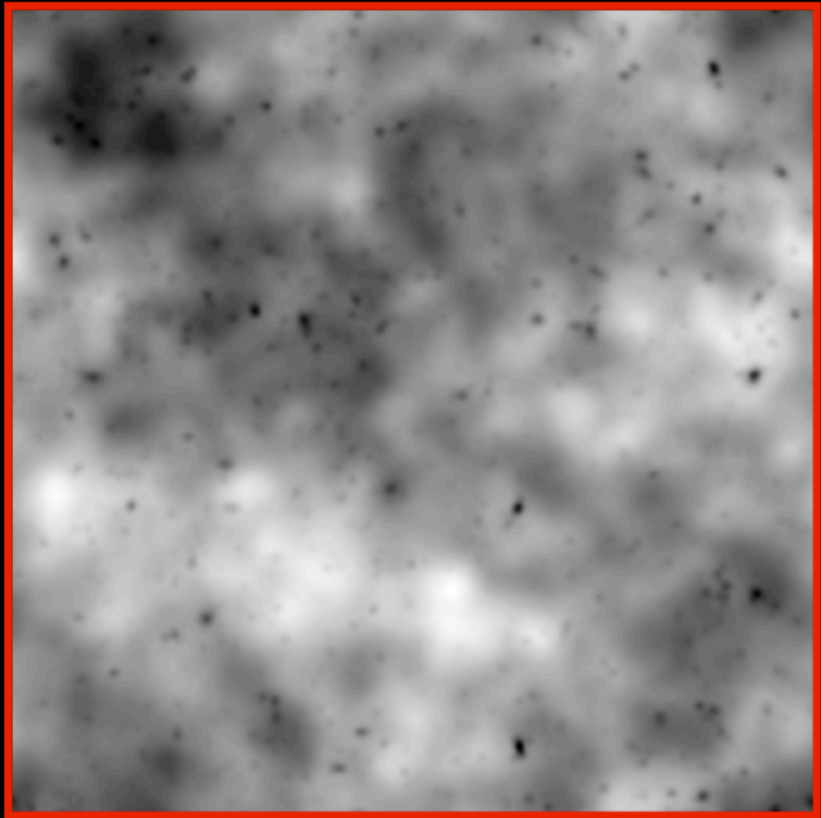

Coadded 90 GHz + 150 GHz
Y offset from nominal boresight (arcmin)
X offset from nominal boresight (arcmin)
100
50
0
−50
−100
−100
−50
0
50


Y offset from source (arcmin)
X offset from source (arcmin)
Detection significance
−5.00
−3.33
−1.67
0.00
1.67
3.33
5.00


Y offset from source (arcmin)
X offset from source (arcmin)
Detection significance
−8.00
−5.33
−2.67
0.00
2.67
5.33
8.00


Y offset from source (arcmin)
X offset from source (arcmin)
Detection significance
−5.00
−3.33
−1.67
0.00
1.67
3.33
5.00

Simulation of 10 sq degree patch of microwave sky



Simulations provided by M. White

Cluster yields for SPT 4000 sq degree SZ-Survey

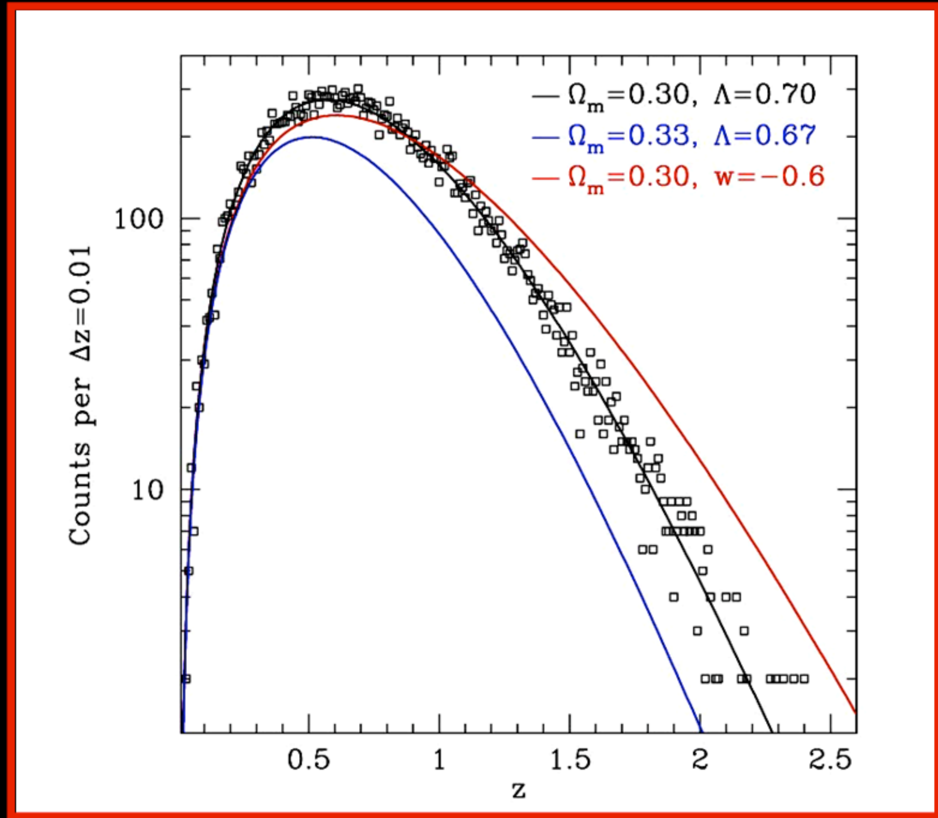


Table 2: Expected Uncertainties on Cosmological Parameters for the SPT-SZE Galaxy Cluster Survey

Surveys	Datasets Dates	Scale	#	Planck priors Ω_{DE}	Ω_k	w_p	w_a	WMAP3 priors Ω_{DE}	Ω_k	w_p	w_a
SPT-SZE+BCS	'05–'07	100 deg^2	140	0.057	0.021	0.22	2.31	0.062	0.059	0.64	5.01
SPT-SZE+KIDS	'07–	400 deg^2	640	0.038	0.007	0.10	1.61	0.047	0.020	0.17	2.49
SPT-SZE+PISCO	'07–'09	pointed	3000	0.026	0.006	0.070	1.11	0.029	0.019	0.13	1.49
SPT-SZE+DES	'09–	4,000 deg^2	6400	0.019	0.004	0.041	0.84	0.021	0.015	0.10	1.12

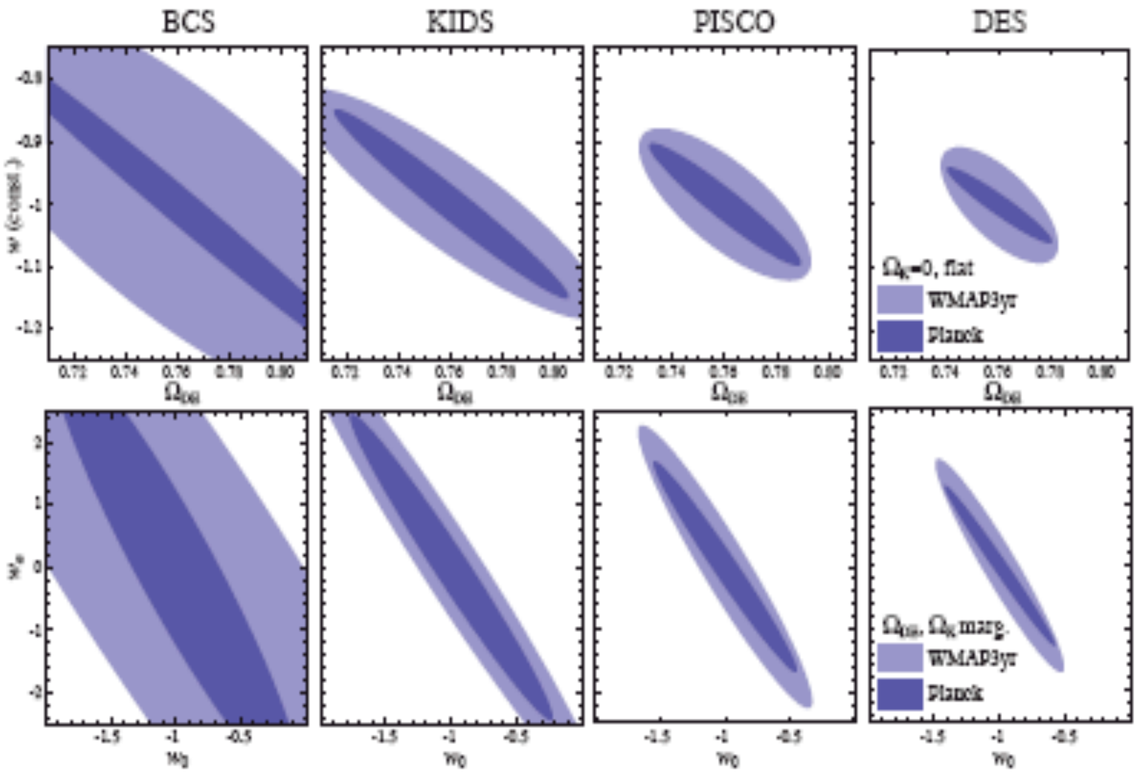


Figure 2: 68% confidence regions of $\Omega_{\rm DE}$ versus w in a flat constant w parameter space (top row) and w_0 versus w_a with $\Omega_{\rm DE}$ and Ω_K marginalized (bottom row) for the four stages of SPT-SZE optical followup. Forecasts are calculated with WMAP3 (light blue, Spergel et al., 2006) and Planck priors (dark blue). The parameters $\Omega_b h^2$, $\Omega_m h^2$, A, τ and n_s are marginalized over in all cases. BCS, KIDS, PISCO and DES details and fully marginalized constraints appear in Tab. 2; there w_p is $w(z_p)$, the equation of state at the pivot redshift where the constraints are the strongest.

THE END

http://www.tonystark.org