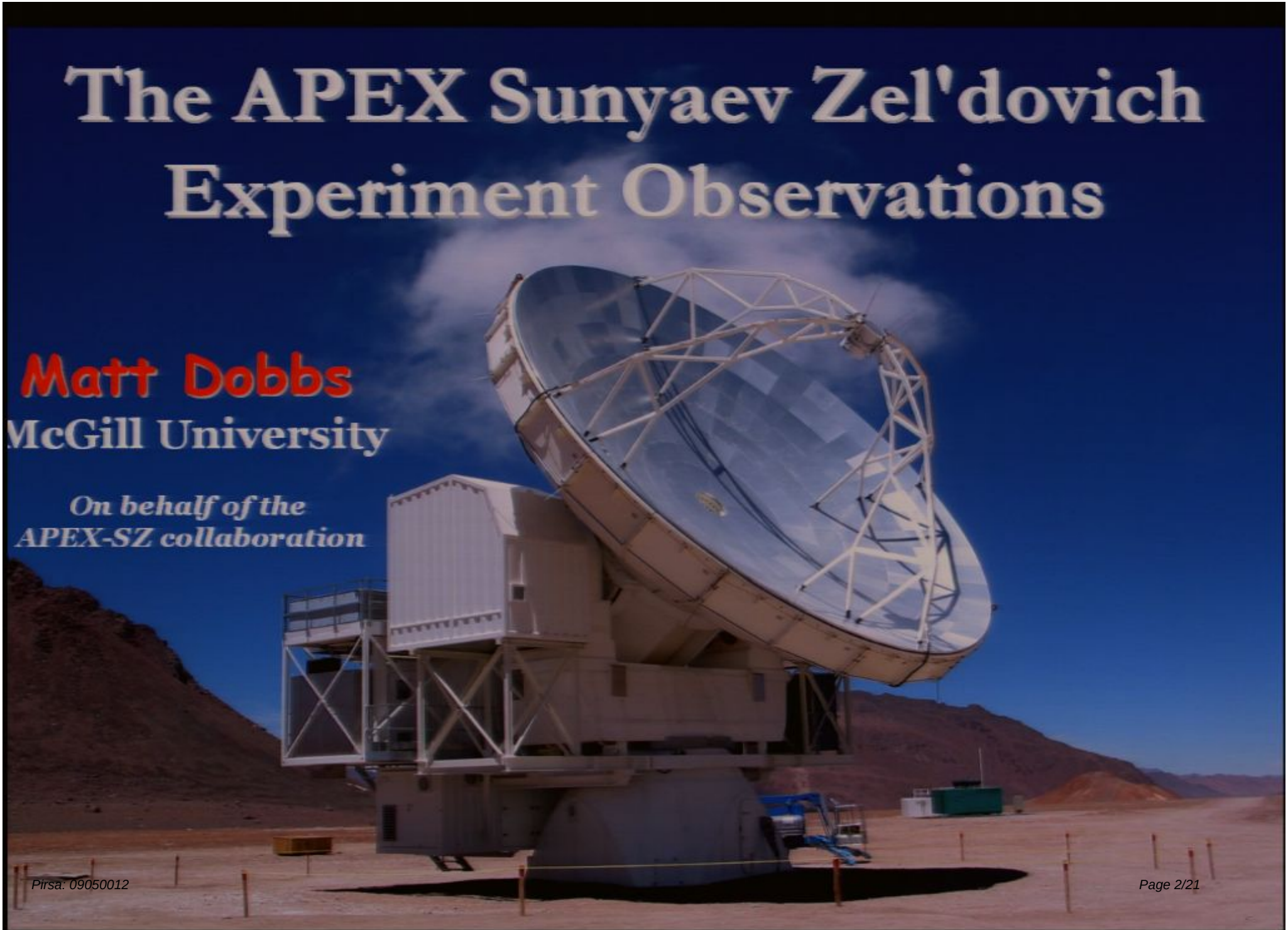
Title: The APEX Sunyaev Zel'dovich Experiment Observations

Date: May 01, 2009 09:40 AM

URL: http://pirsa.org/09050012

Abstract: The APEXÂ Sunyaev Zel'dovich experiment will be described and its performance since first light in 2006 summarized. Recent results will be presented together with plans for future observations/analysis.

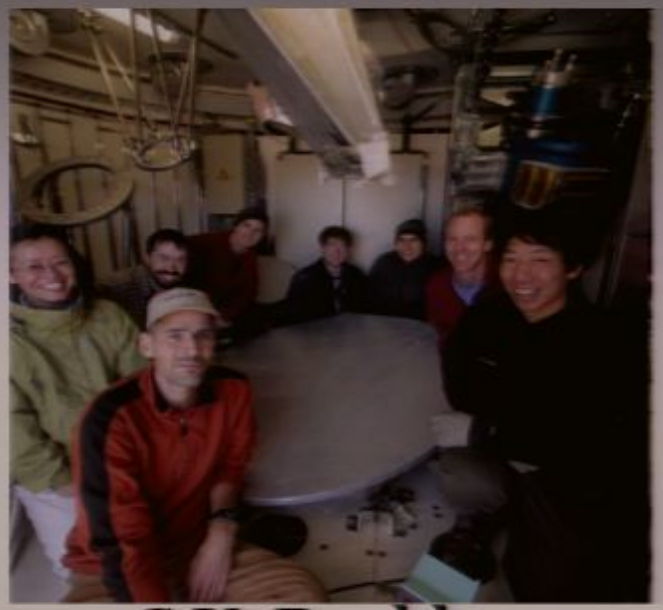
The APEX Sunyaev Zel'dovich Experiment Observations



Matt Dobbs
McGill University

On behalf of the APEX-SZ collaboration

The APEX-SZ Collaboration



U.C. Berkeley / LBNL
Brad Benson
Hsiao-Mei Cho
John Clarke
Daniel Ferrusca
Bill Holzapfel
Brad Johnson
Zigmund Kermish
Adrian Lee
Martin Lueker
Jared Mehl
Tom Plagge
Christian Reichardt
Paul Richards
Dan Schwan
Helmuth Spieler
Ben Westbrook
Martin White
Oliver Zahn

C.U. Boulder
Amy Bender
Nils Halverson

McGill University
Matt Dobbs
James Kennedy
Trevor Lanting

Onsala Space Observatory
Cathy Horellou
Daniel Johansson

Max Planck IfR
Gayong Chon
Rolf Guesten
Ruediger Kneissl
Ernst Kreysa
Karl Menten
Dirk Muders
Martin Nord
Peter Schilke

Bonn University
Kaustuv Basu
Frank Bertoldi
Florian Pacaud
Reinhold Schaaf

Cardiff
Peter Ade
Carole Tucker

APEX Telescope

- 12 m on-axis ALMA prototype built by Vertex RSI
- Sited at the Atacama plateau, Chile, elevation 16,500 ft
- Submillimeter observatory
  - 18 μm surface accuracy goal
- 1' resolution @ 150 GHz
- 0.4° field of view

Funded by:

Max-Planck-Institut für Radioastronomie

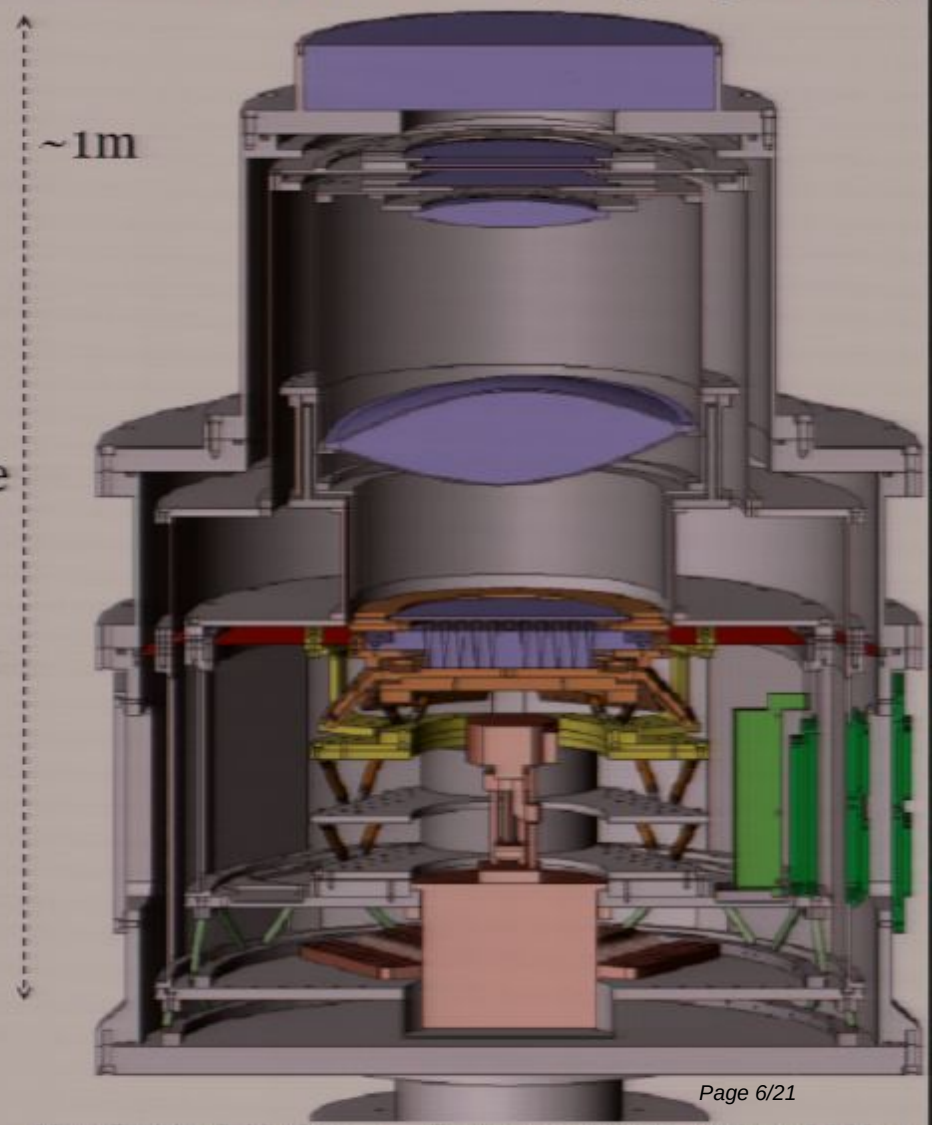
ONSALA RYMDOBSERVATORIUM CHALMERS TEKNISKA HÖGSKOLA

ESO

APEX-SZ Experiment Overview

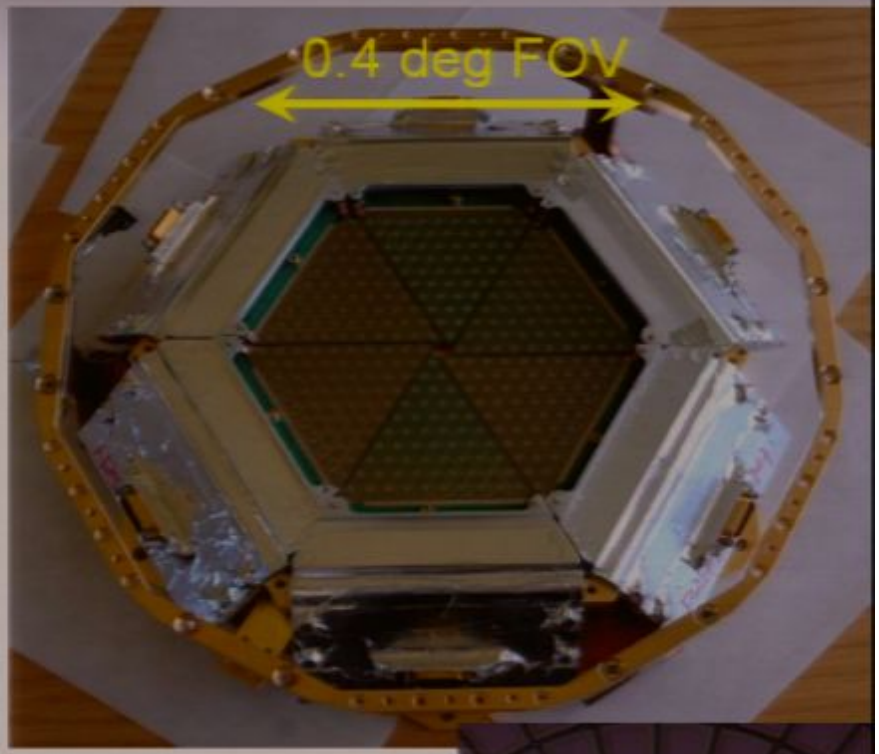
- PI instrument on APEX
- First light: December 2005
  - 55 detectors, 1 week obs
- 280 TES Bolometer channels @ 150 GHz
  - 2007, 2008 – roughly 1 month/year of which we typically get 2 weeks good observing
- Demonstrates new technologies that are scalable to other experiments, i.e., SPT
  - TES bolometers
  - Frequency domain multiplexed readout
  - Pulse-tube cooler to eliminate liquid cryogens
- Powerful camera for targeted cluster observations
  - Overlaps with northern-hemisphere multi-wavelength observations

D. Schwan et al., in prep 2009

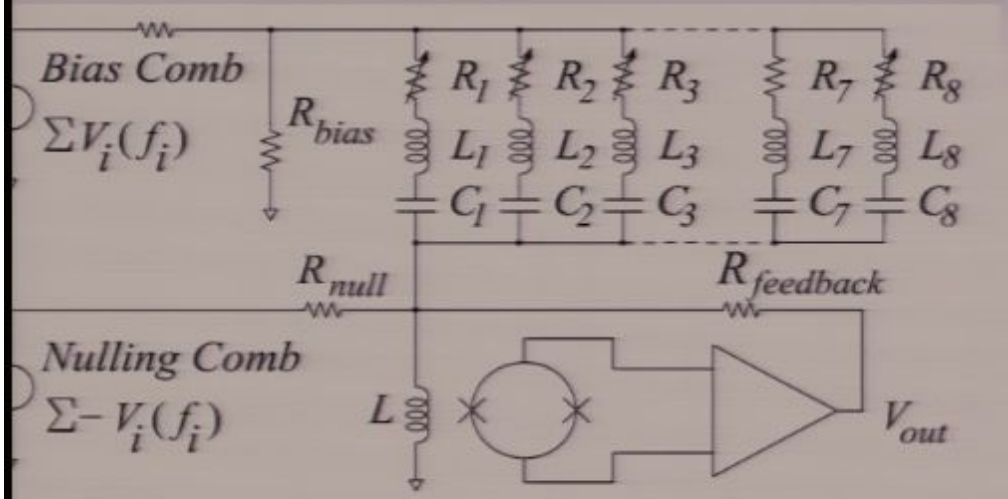


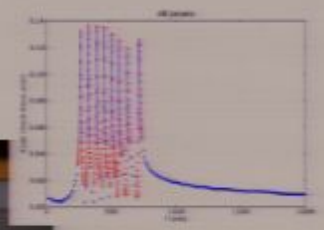
TES Detectors

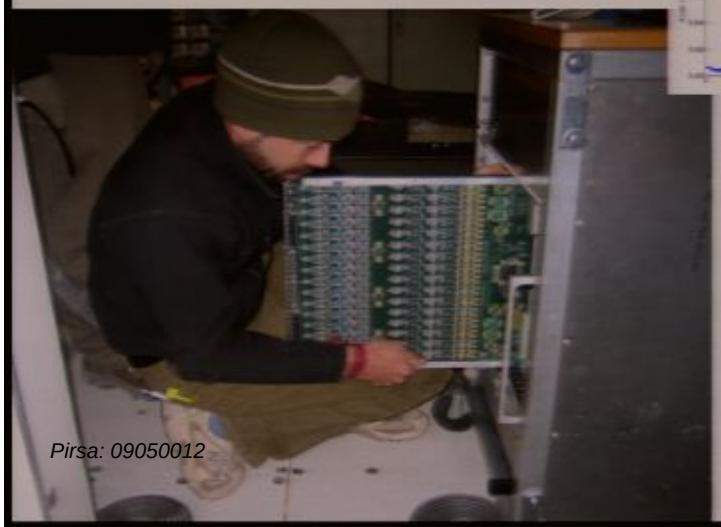
- Fabbed at UC Berkeley by Jared Mehl
- 330 element array – 280 wired
  - 6 wedges of 55 detectors
  - Science results typically use ~170 bolometers.
- March 2009: 2 wedges replaced, optimizing optical coupling, thermal conductivity, bandwidth.
  - $NET_{OLD} = 870\ \mu K_{CMB}\sqrt{s}$
  - $NET_{NEW} \approx 500\ \mu K_{CMB}\sqrt{s}$



Multiplexed Readout







- Analog frequency domain multiplexed readout
- SQUID amplifiers
- First field implementation
- Developed at LBNL/UC Berkeley/McGill
- Used on APEX-SZ, SPT
- New digital system developed for EBEX, Polarbear, SPTpol

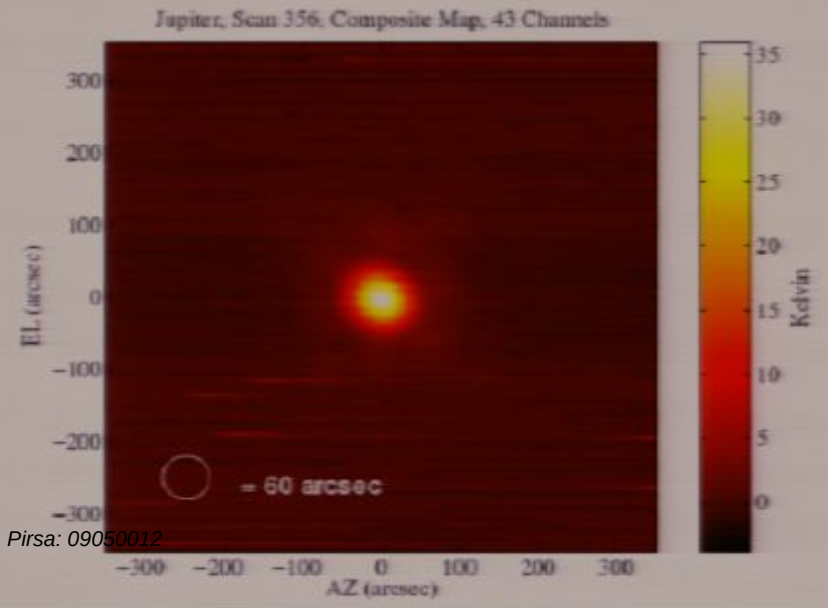
Cryogenics

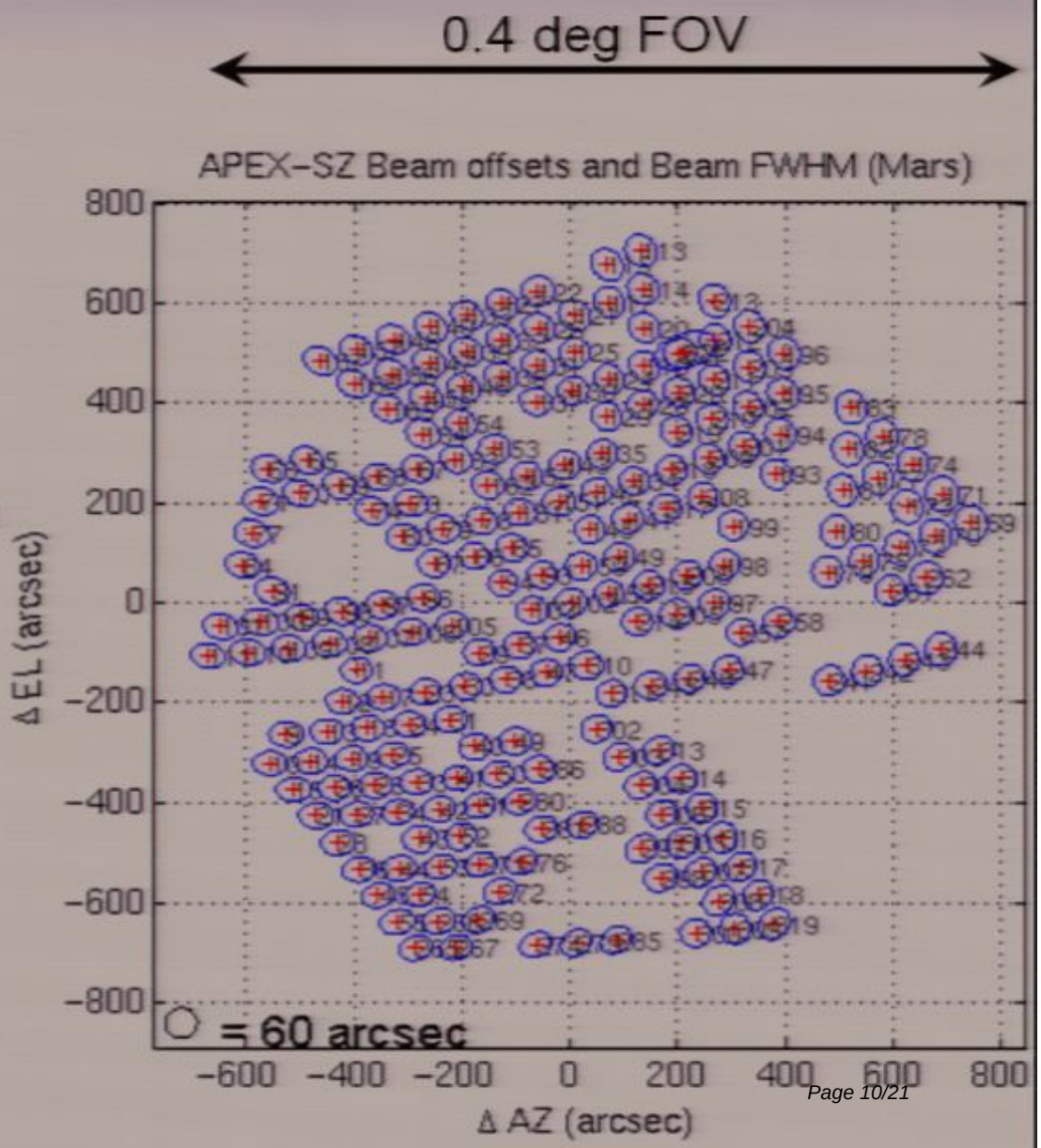
- Mechanical Pulse Tube Cooler (3-4K)
  - SQUIDs live here.
  - →No expendable cryogens
  - →No nasty fills or LHe delivery issues.
  - →Essential for remote locations
- 3 stage $He^4He^3He^3$ Absorption fridge (260 mK)
  - Detectors live here.

APEX-SZ Camera shown mounted in cabin with pulse tube lines & ballasts visible.

APEX-SZ Beams & Calibration

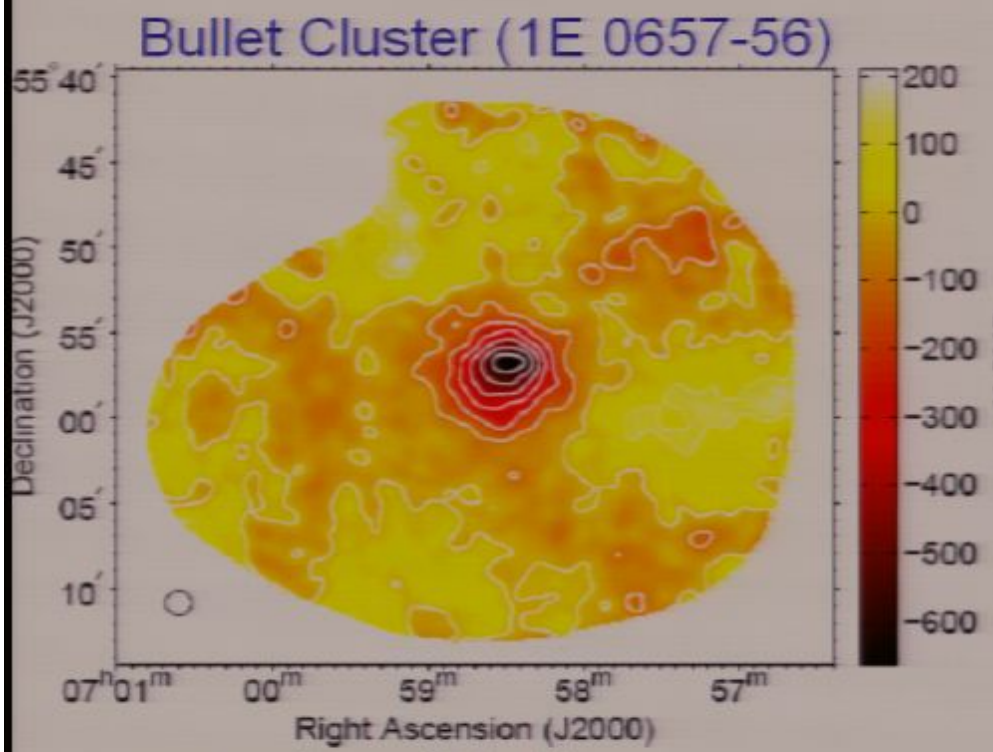
- Daily mappings of Mars
  - Calibrated against Rudy Model, updated with 1% WMAP data
- Calibration uncertainty 5.5%:
  - 4% from beam area,
  - 3% Mars temporal fluctuations,
  - 1.7% Mars temperature, ..
- Typically ~260/320 pixels active
- Beams:
  - Gaussian main lobe
  - Near sidelobes increase real beam solid angle

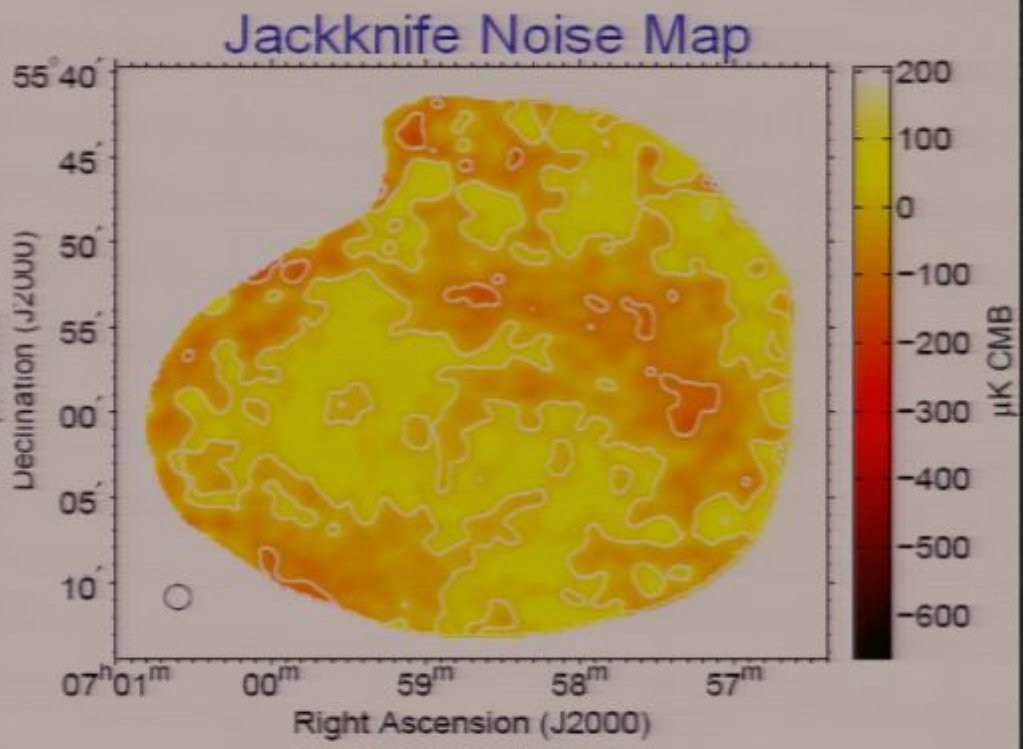




The Bullet Cluster

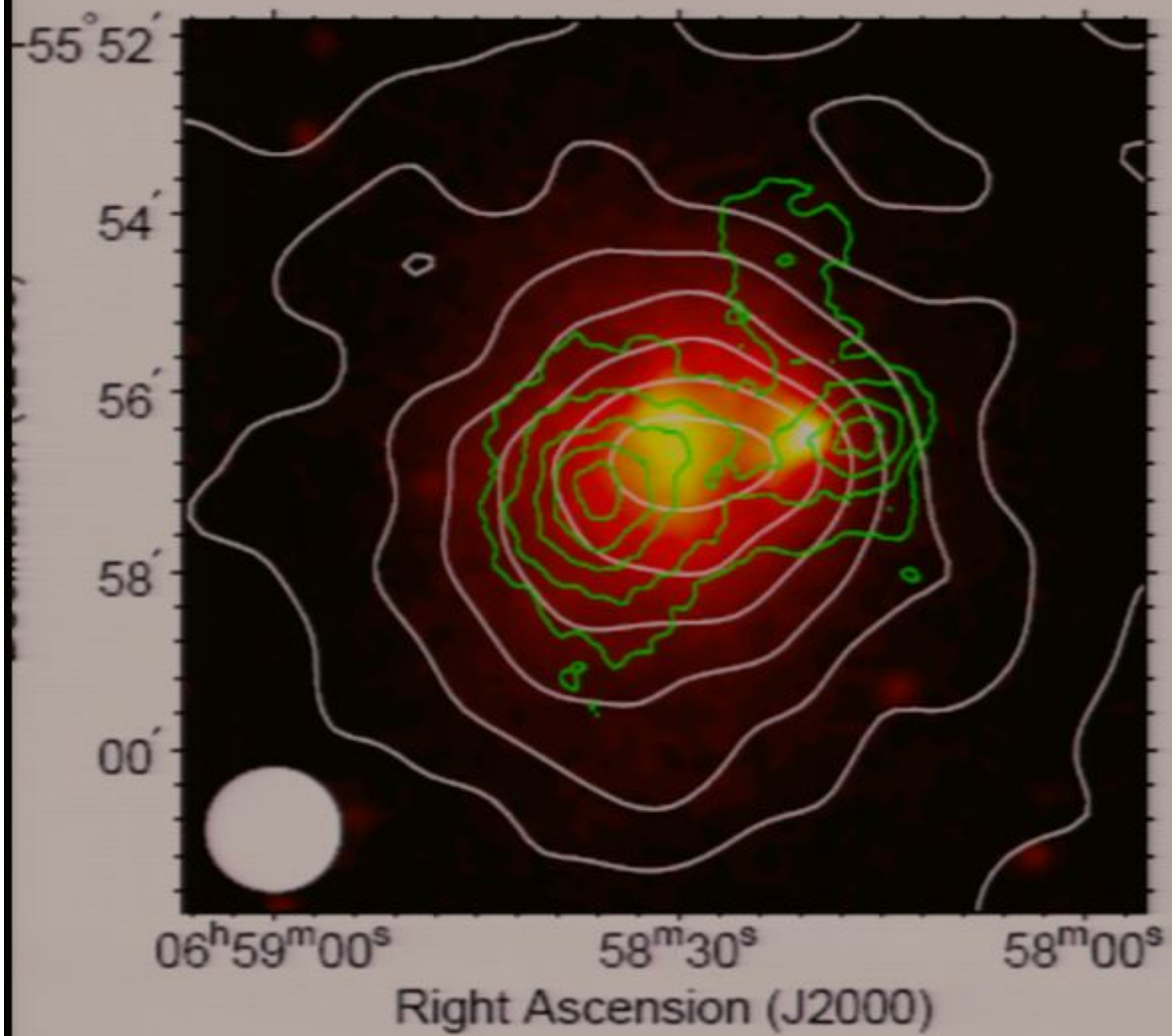
Halverson, Lanting et al., arXiv:0807.4208v1





- 23 sigma detection
- no evidence for significant 150 GHz emission from 13.5 mJy @ 270 GHz point source reported by Aztec.

Bullet Cluster



- Mass weighted electron temperature, using:
  - Isothermal
  - Clowe et al., 2006, Chandra

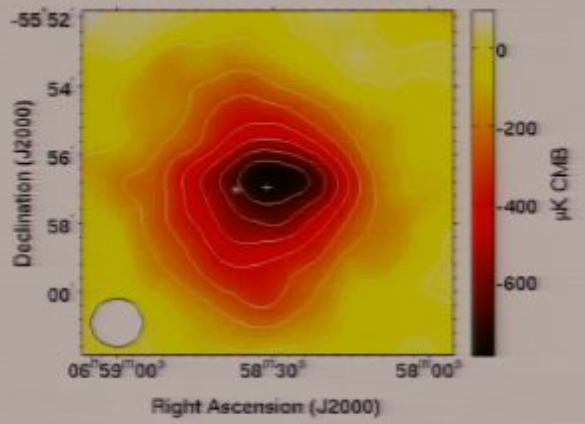
$T_E = 10.7 \pm 0.8$ KeV
($\chi^2 = 1.003$)

Xray temperatures range from 10.6 keV with XMM (Zhang et al. 2006) to 13.9 keV with Chandra (Govini et al. 2004)

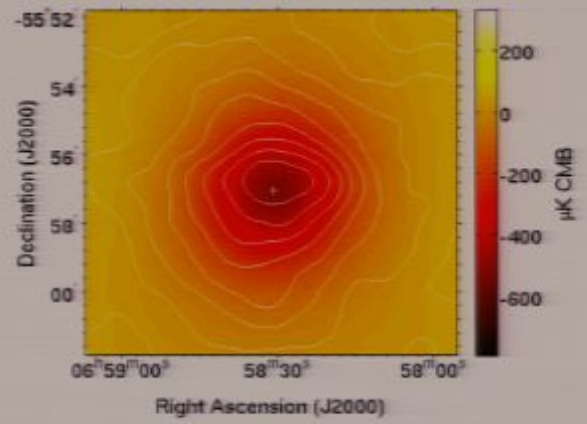
White contours: APEX SZE measurement, 100 μK contours
Green contours: weak lensing surface mass reconstruction (Clowe et al 2006)
Colormap: XMM data, 0.5-2 KeV band

Bullet Cluster

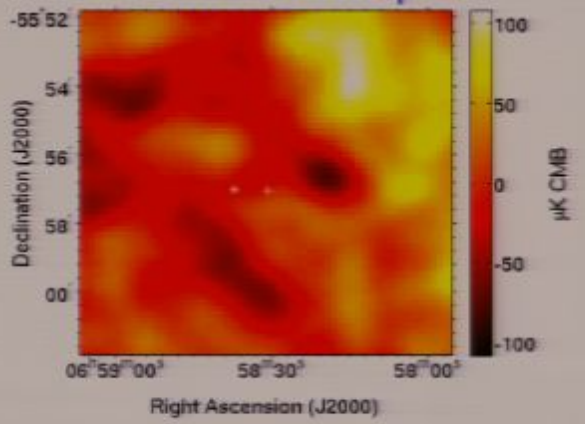
SZE Data



Best-fit Beta Model



Residual Map



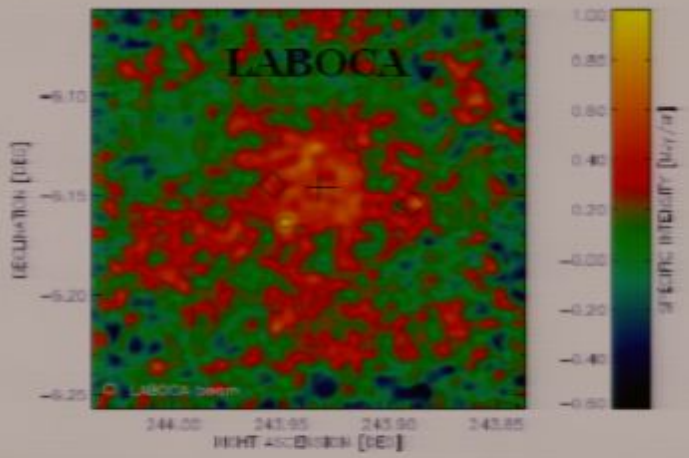
- Cluster gas profile well-fit by a isothermal elliptical beta model
  (adequate for the sensitivity and resolution of these maps – despite the complex nature of this system)
- Beta model parameters and gas-mass fraction are consistent with those derived from X-ray data

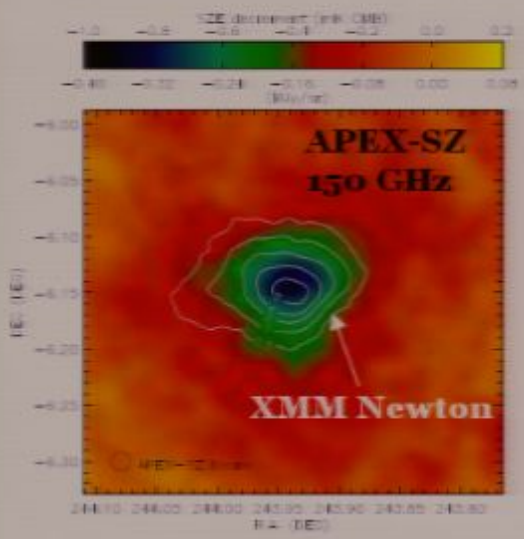
$T_e(keV)^a$	Mean Overdensity	$r_{\rm int}$ $(')^b$	$r_{\rm int}$ (Mpc)^c	Gas Mass Fraction
10.6 ± 0.2	2531 ± 236	2.18	0.580	0.208 ± 0.031
10.6 ± 0.2	743 ± 67	5.32	1.42	0.171 ± 0.034

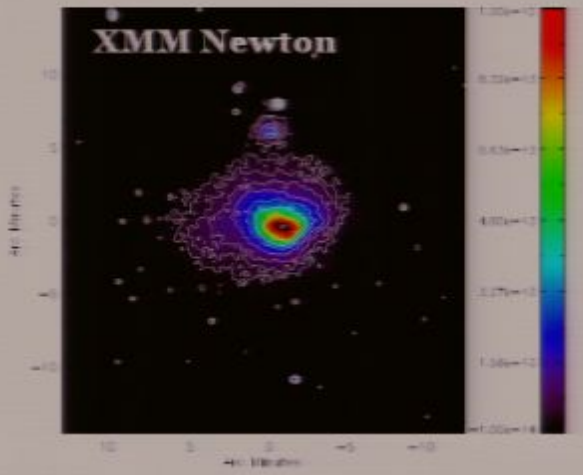
- Zhang et al (2006) $f_{gas} = 0.161 \pm 0.018$ (1.42 Mpc)
- Bradac et al (2006) $f_{gas} = 0.14 \pm 0.03$ (4.9'x3.2')

A2163 with APEX-SZ & LABOCA

Nord, Basu, Pacaud, et al., arXiv:0902.2131



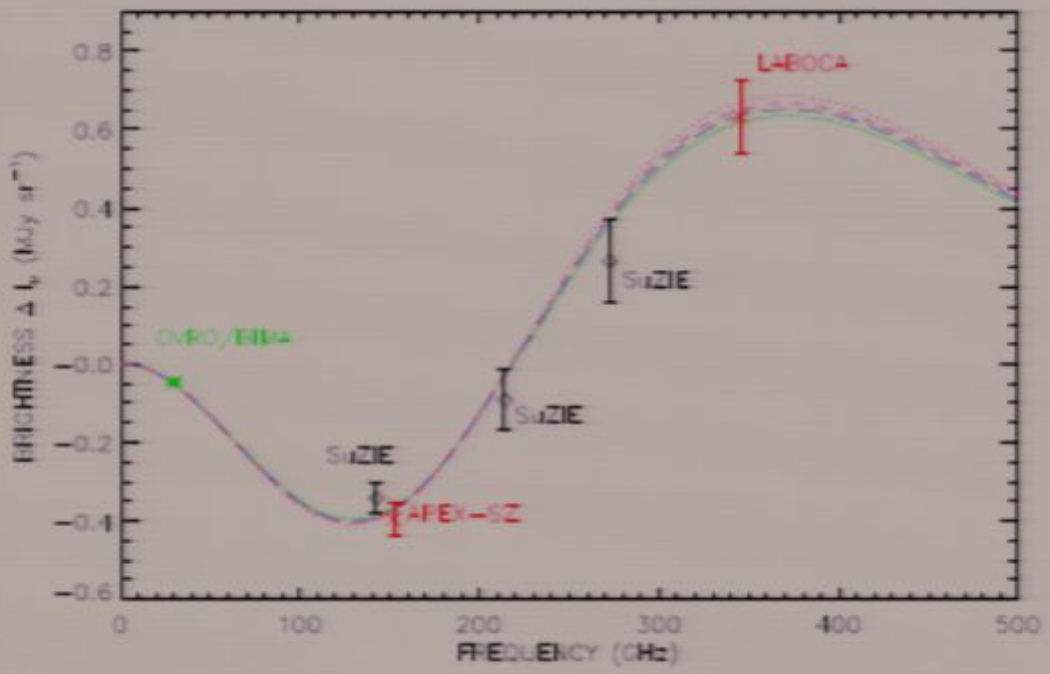


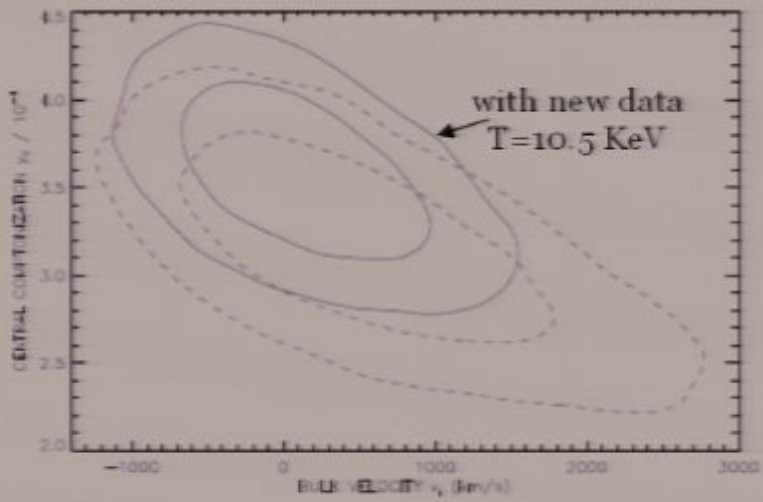


(27±9" offset)

A2163 with APEX-SZ & LABOCA

Nord, Basu, Pacaud, et al., arXiv:0902.2131





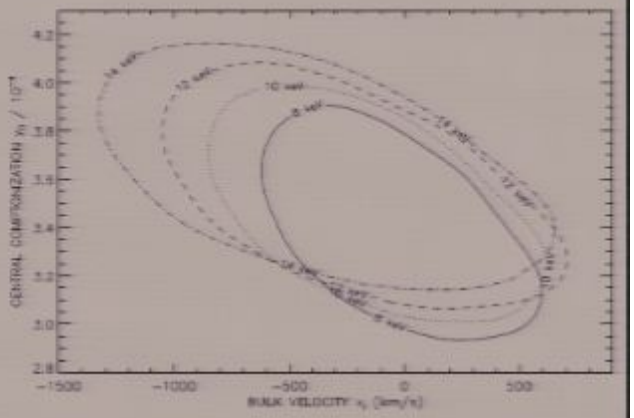
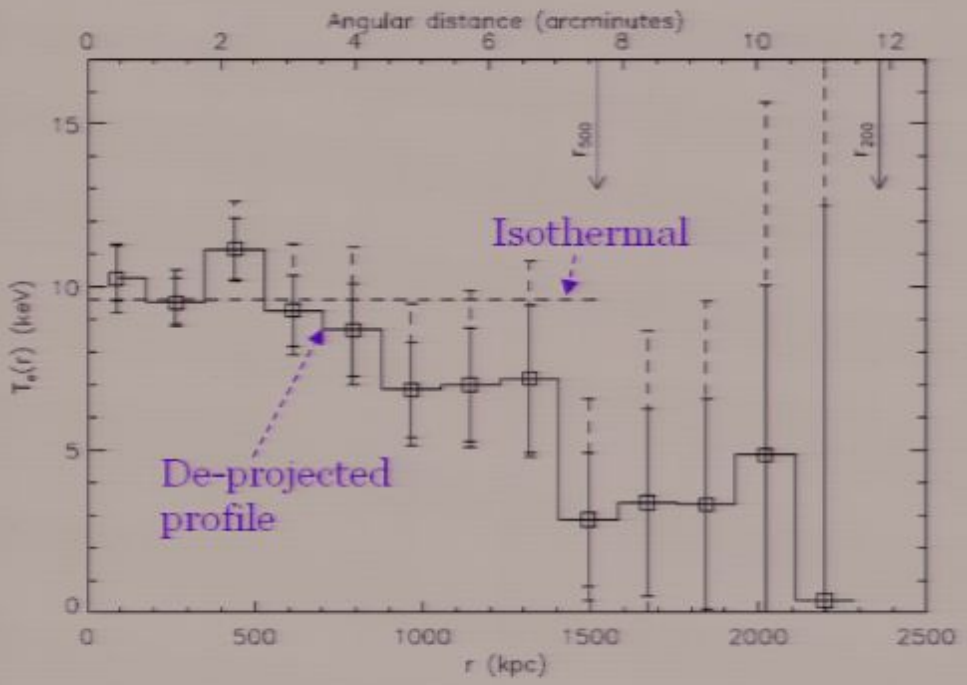


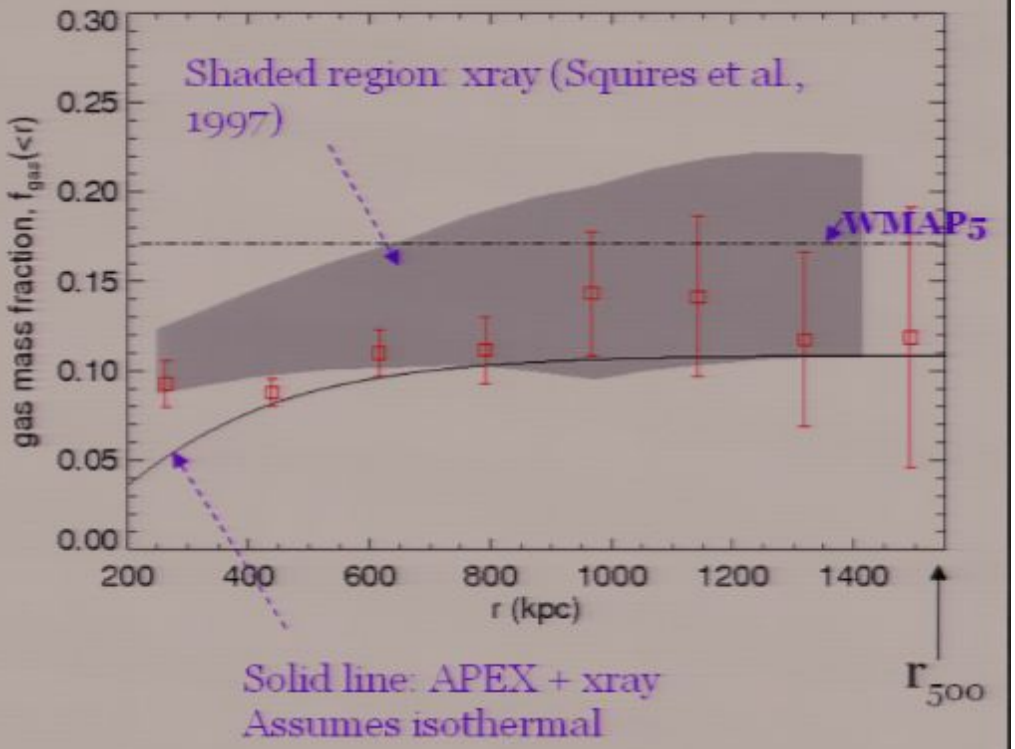
Fig. 9. SZE spectrum of Abell 2163 (points) and best-fit models using different priors on the ICM temperature: 8 keV (solid line), 10 keV (long-dashed line), 12 keV (short-dashed line) and 14 keV (dotted line).

A2163 with APEX-SZ & LABOCA

Nord, Basu, Pacaud, et al., arXiv:0902.2131

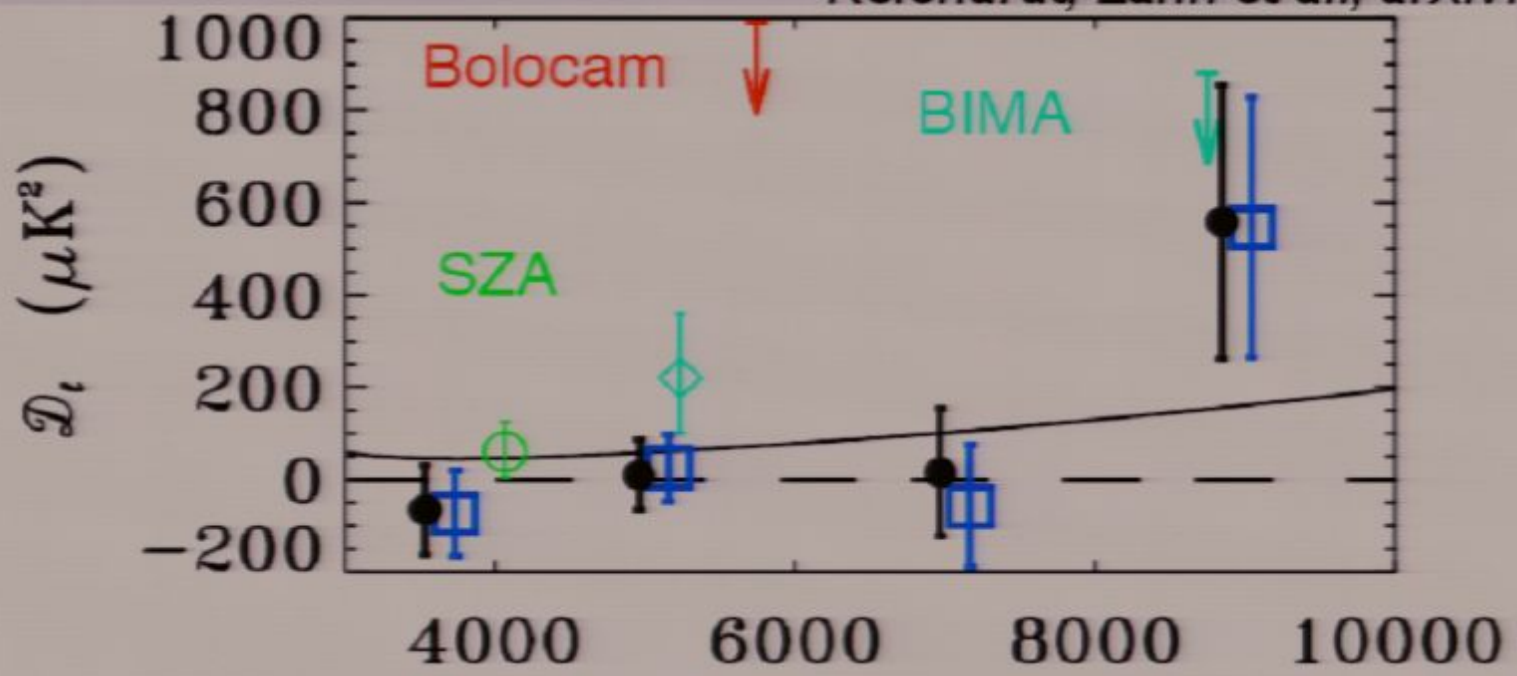


Consistent with XMM (Markevitch, Vikhlinin 2001)



APEX 150 GHz Power Spectrum

Reichardt, Zahn et al., arXiv:0904.3939



- 0.8 sq degrees at 150 GHz with 1' resolution
- 10 nights in Aug/Sept 2007, 2.9 k-bolo-hrs
- 12 μK_{RMS} per 1' pixel
- XMM LSS field, centered on XLSSU J022145.2-034614 (5 KeV x-ray cluster)

- Total Anisotropy < 105 μK^2 at 95%.
- σ_8 < 1.18 at 95%
  - Fitting for SZE & Poisson bright point source population
  - Properly accounting for non-Gaussian statistics (limit would be σ_8 < 0.94 assuming Gaussian noise only)

APEX 150 GHz Power Spectrum

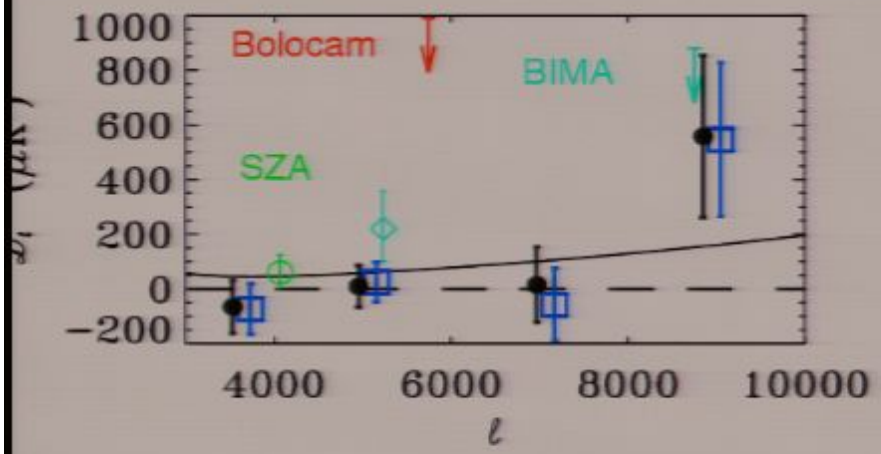


TABLE 2
POINT SOURCE POWER AND σ_8 CONSTRAINTS

	Cluster masked	Cluster + Sources masked
Zero SZE power: C_ℓ^{PS} (10^{-5} μK^2)	$1.0^{+0.9}_{-0.6}$	$1.2^{+1.9}_{-0.8}$
Fixed $\sigma_8 = 0.8$: C_ℓ^{PS} (10^{-5} μK^2)	$0.9^{+0.9}_{-0.6}$	$1.1^{+0.9}_{-0.8}$
Unconstrained σ_8: C_ℓ^{PS} (10^{-5} μK^2)	$0.9^{+0.9}_{-0.6}$	$1.1^{+0.9}_{-0.8}$
σ_8 (G) (95% CL)	0.94	0.94
σ_8 (NG) (95% CL)	1.18	1.18
Flat excess: (with $\ell_{center} = 4966$) D_ℓ (μK^2)	33^{+37}_{-24}	36^{+39}_{-26}
95% CL	97	105

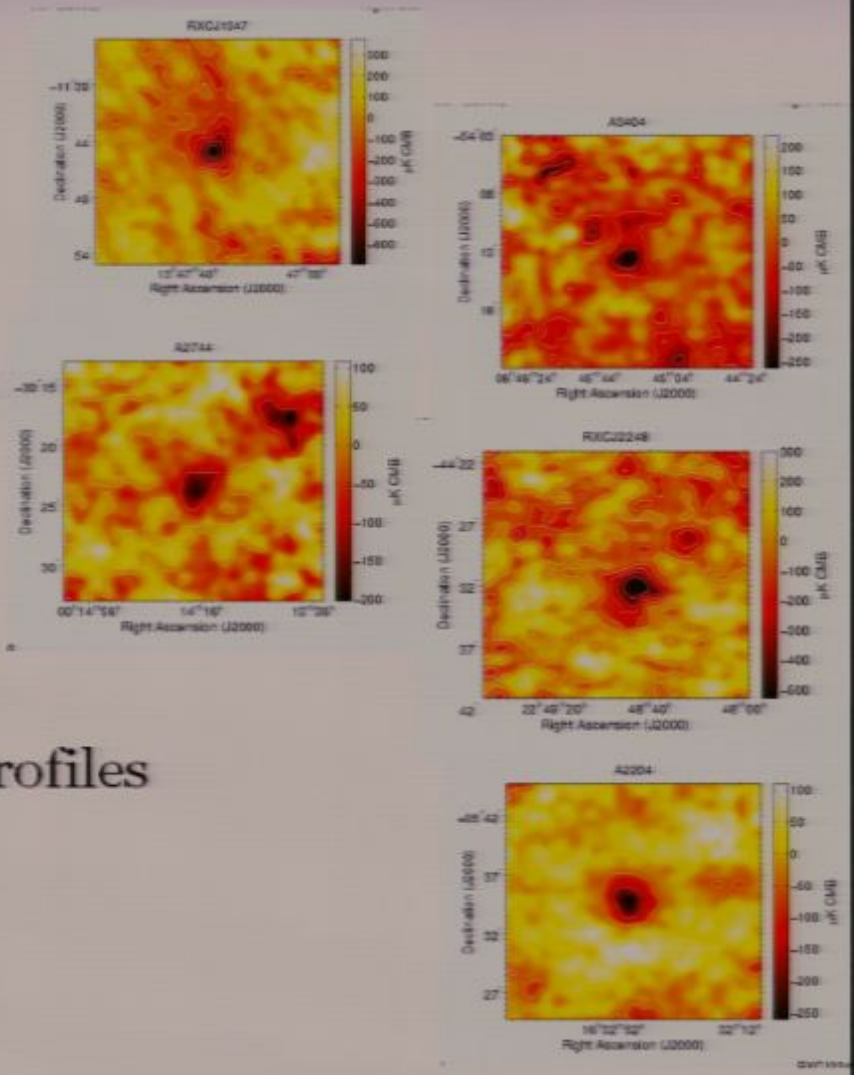
Point Source Power

- At 150GHz, expect significant power from distant dusty galaxies
  - Expect 20x less power from radio sources
- Negrello *et al.* (2007) model predicts 1.1×10^{-5} μ K^2 in the absence of clustering.

- $C_l^{PS} \approx 1 \times 10^{-5}$ μK^2
  - Nearly independent of flux cut for masking point sources
- With BLAST 600 GHz data → spectral index $\alpha = 2.64^{+0.4}_{-0.2}$.
  - Agrees with MAMBO/SCUBA index, 2.65 Greve et al. (2004)
  - Knox et al., 2004.
- *Dusty galaxies account for most power in APEX-SZ maps.*

What's Next?

- Couple dozen clusters in the can
- Gas mass fraction vs. radius
  - Constrain H_o , w
- Scaling relations: (Amy Bender)
  - Redshift evolution – good overlap with multi-wavelength data
    - Including high-Z clusters
  - Relaxed vs. complex systems
- Constraints for cluster simulations
  - Isothermal vs. universal temperature profiles
  - Radial profiles
  - Extended cluster emission
    - widen scan strategy to get beyond r_{virial}

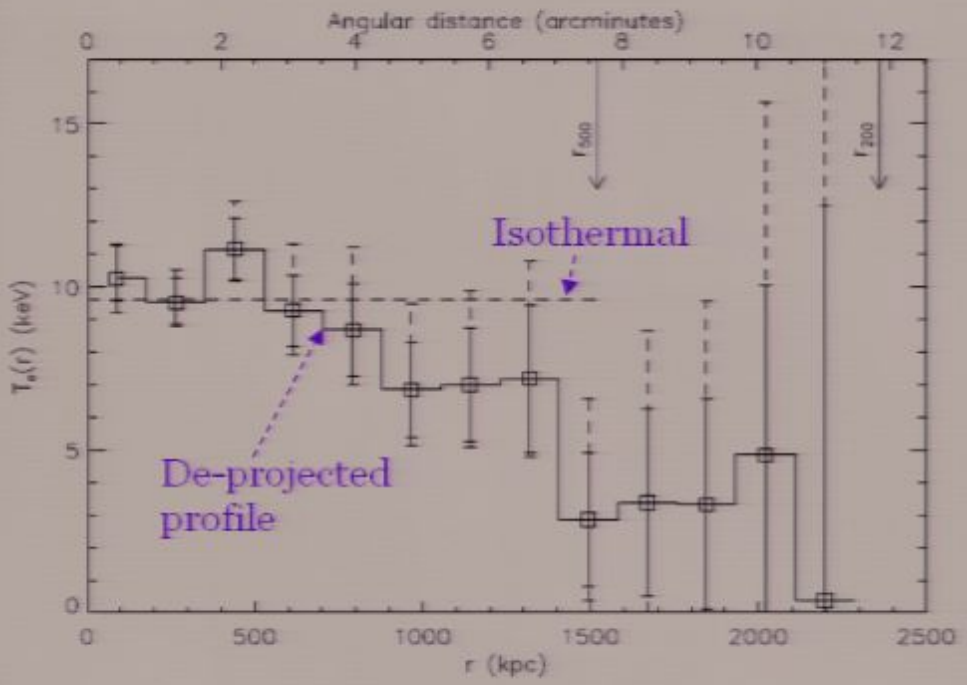


Summary

- APEX-SZ is a 280 element 150 GHz bolometer array operating on the 10m APEX telescope
  - Technology pathfinder role: 280 element TES bolometer array, multiplexed readout, no expendable cryogens.
- New SZ observations of the Bullet and A2163
  - General consistency with expectations from x-ray.
- Power spectrum is consistent with WMAP5, with majority of power from dusty galaxies.
  - $\sigma_8 < 1.18$ at 95%

A2163 with APEX-SZ & LABOCA

Nord, Basu, Pacaud, et al., arXiv:0902.2131



Consistent with XMM (Markevitch, Vikhlinin 2001)