Sunyaev-Zel'dovich Cluster Observations with APEX

Ruediger Kneissl
Max-Planck-Institute for Radio Astronomy

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Outline

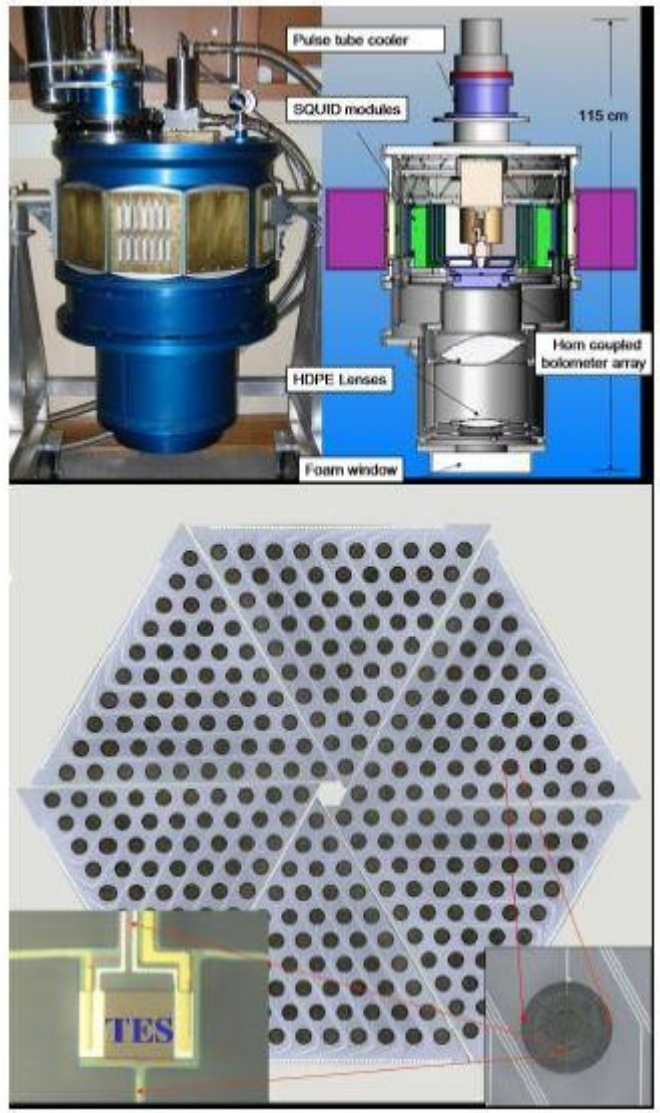
- **Instrumentation: APEX telescope, ASZCA, LABOCA**
- **Scientific goals (cf. DE), observations, analysis**
- **Targeted bright and fainter clusters**
- **Field (survey) observations**

The Atacama Pathfinder Experiment (APEX) telescope

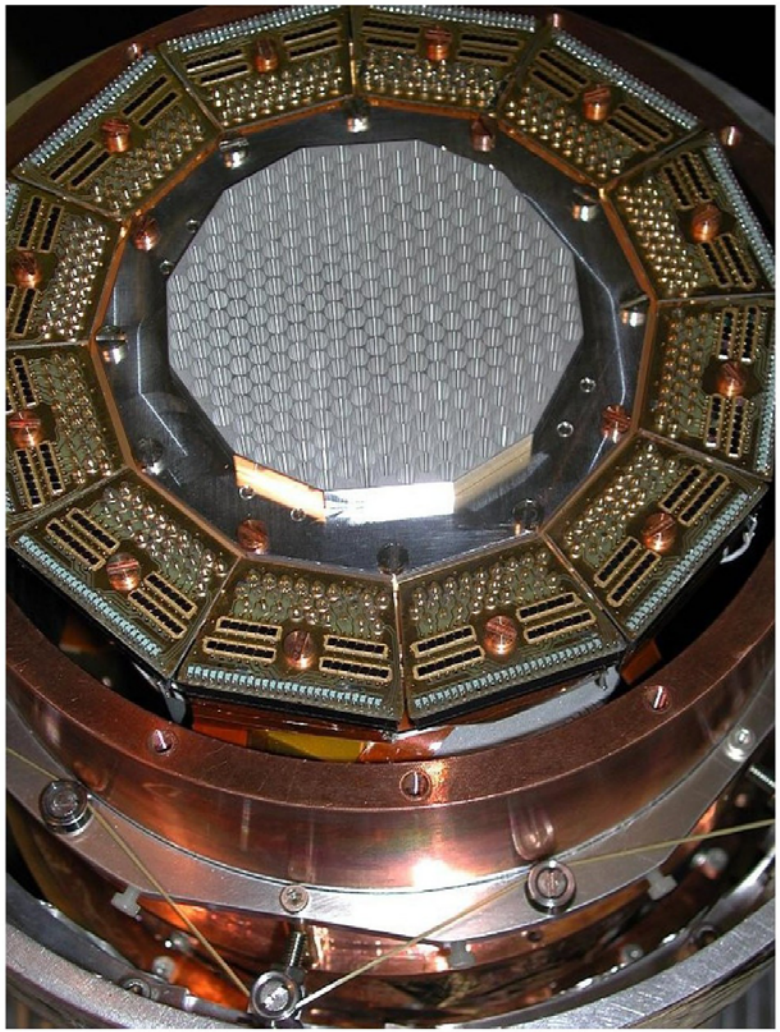
- **Modified ALMA prototype antenna by VERTEX**
- **refitted with receiver cabins**
- **12 m Cassegrain – 17” beam (850 µm), 58” beam (ASZCA)**
- **17 µm rms surface accuracy**
- **5100 m Atacama, Chile (23º S, < 0.6 mm PWV 25%)**
- **operated by MPIfR (50%), ESO (27%), OSO (23%)**
- **Bolometer cameras and heterodyne receivers**

The APEX SZ Camera (ASZCA)

- designed and build by UC Berkeley
- 0.4 degrees Field-of View
- Spiderweb Transition Edge Sensor bolometers
- Microfabricated array of 320 elements
- Frequency multiplexed SQUID readout
- closed cycle refrigeration (no He refill)
- current observing frequency 150 GHz (2mm)



LABOCA



- designed and build by MPIfR
- 295 elements, 11’ Field-of-View
- observing frequency 350 GHz (850 µm)
- SABOCA 37 elements, 850 GHz (350 µm), TES / SQUID (IPHT Jena)

Kreysa et al. 2003, Siringo et al. 2007

APEX-SZ Collaboration

Max-Planck-Institute for Radio Astronomy:

R. Güsten, R. Kneissl, A. Kovac, K. Menten, D. Muders, F. Schuller, A. Weiss

MPE: H. Böhringer, MPA: R. Sunyaev

U Bonn: K. Basu, F. Bertoldi, G. Chon, M. Nord, F. Pacaud, R. Schaaf
OSO: C. Horellou, D. Johansson;

University of California, Berkeley:

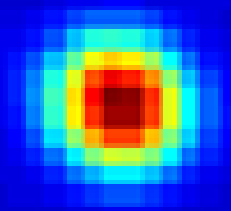
Physics Department: D. Ferrusca, W. Holzapfel, A. Lee, M. Lueker, J. Mehl, T. Plagge, C. Reichardt, P. Richards, D. Schwan, M. White, O. Zahn; LBNL: H. Spieler

U McGill: M. Dobbs

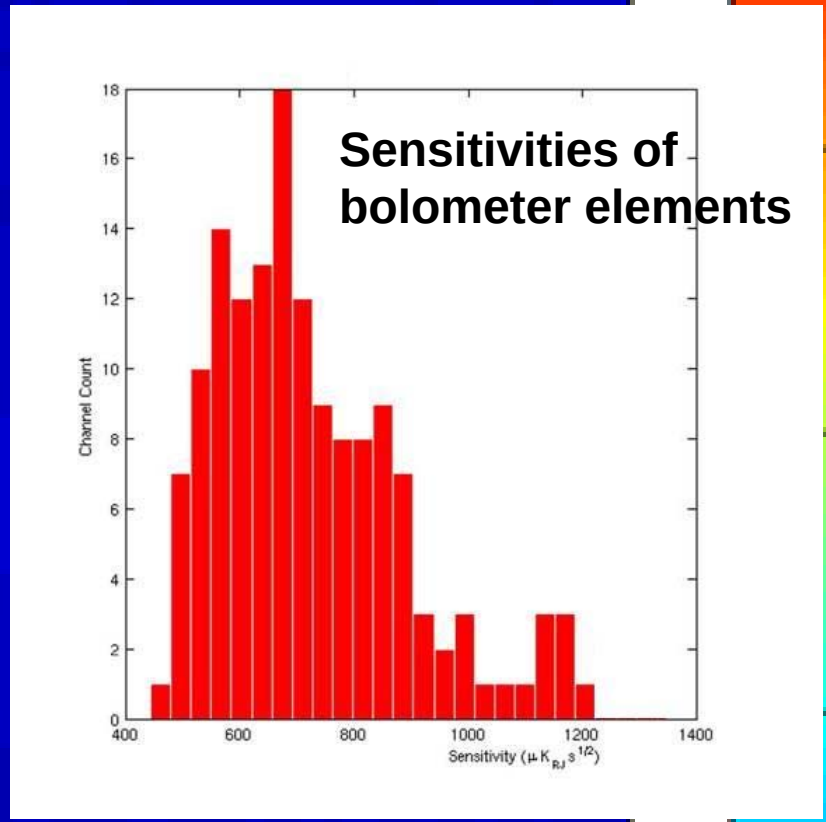
U Colorado: A. Bender, N. Halverson; NIST: S. Cho

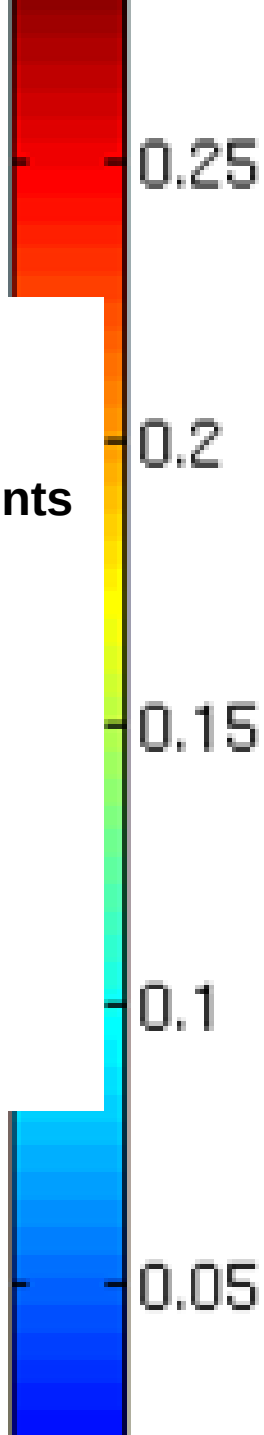
Combined Beams and Array sensitivity

Beam map of Uranus



FWHM = 58 arcsec

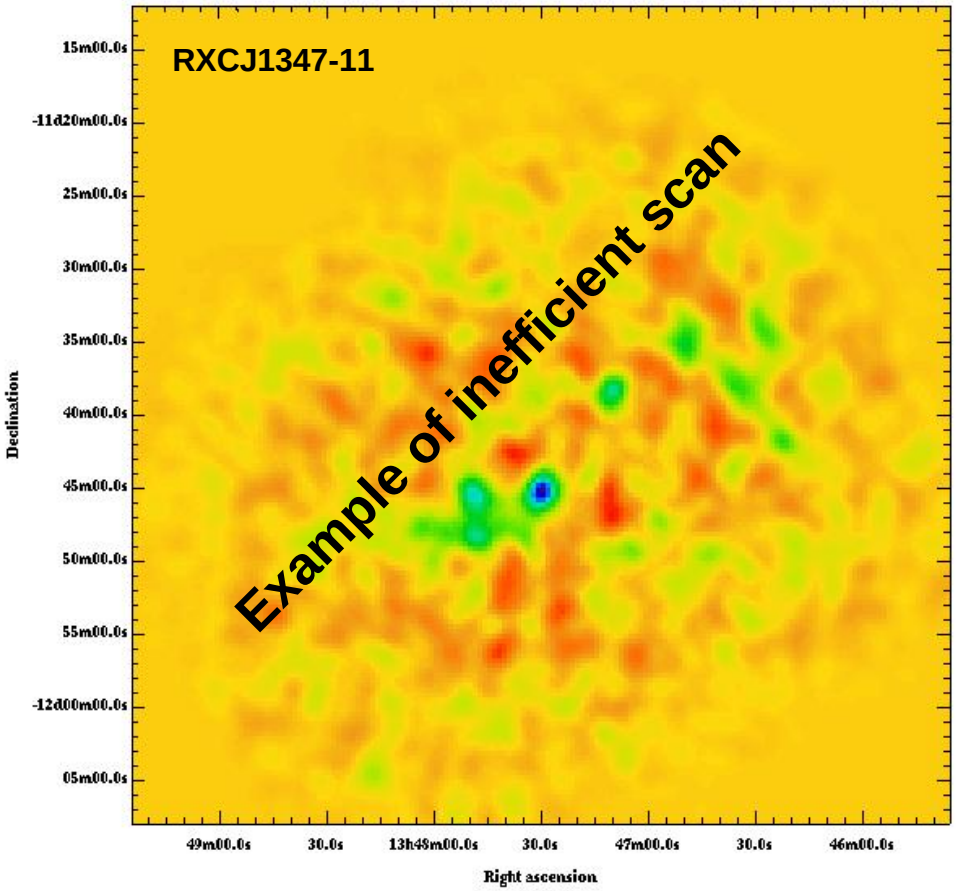


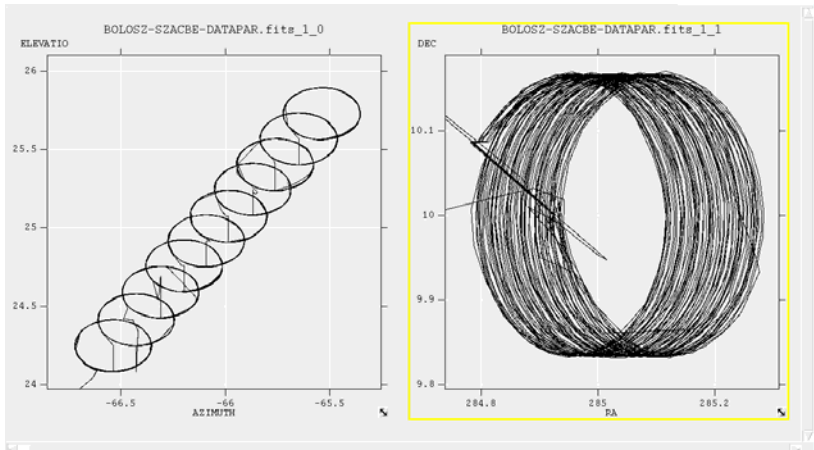


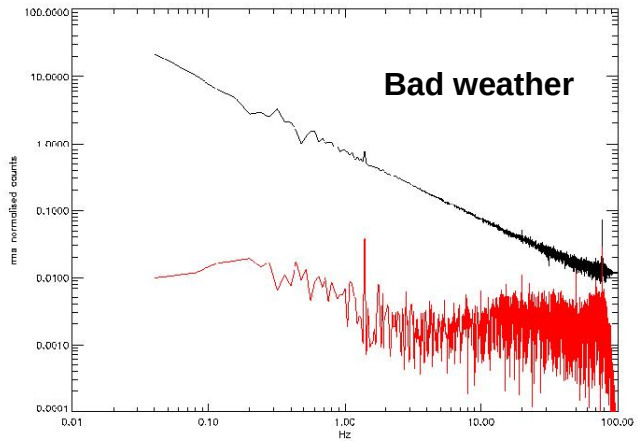
Scanning and data reduction

Circle scans allow small foot-print

<u>and</u> sky noise modulation:







Reductions include PCA and median sky noise removal, filtering and iterative signal restoration, simulated sources for evaluation.

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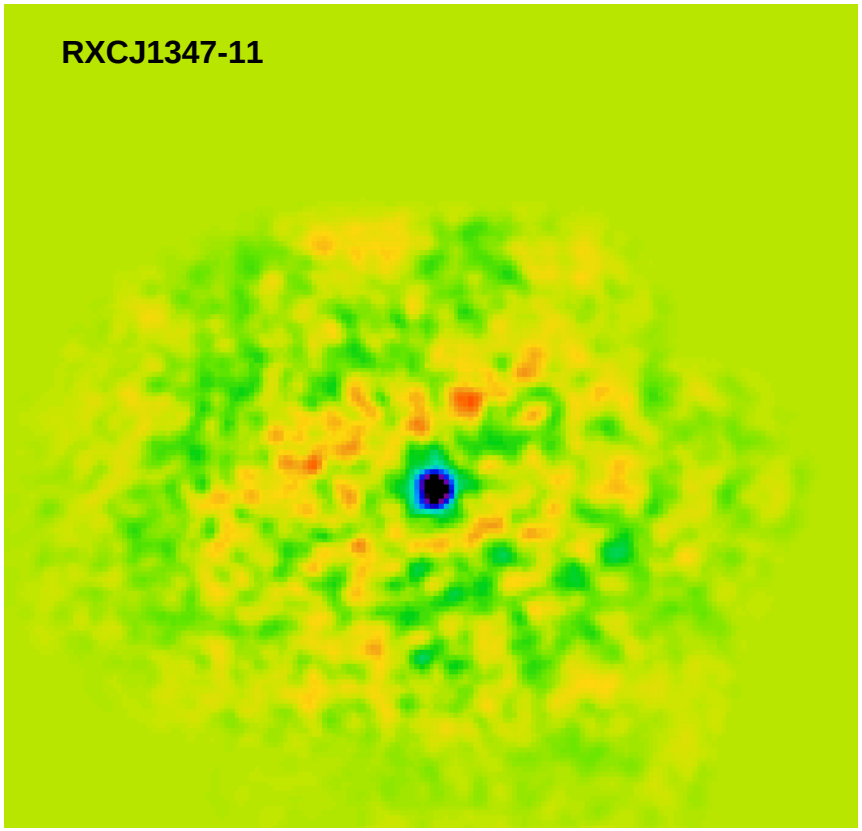

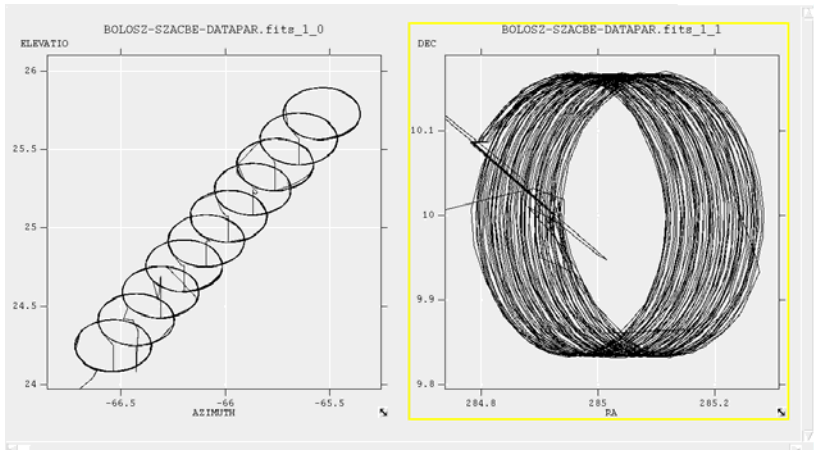

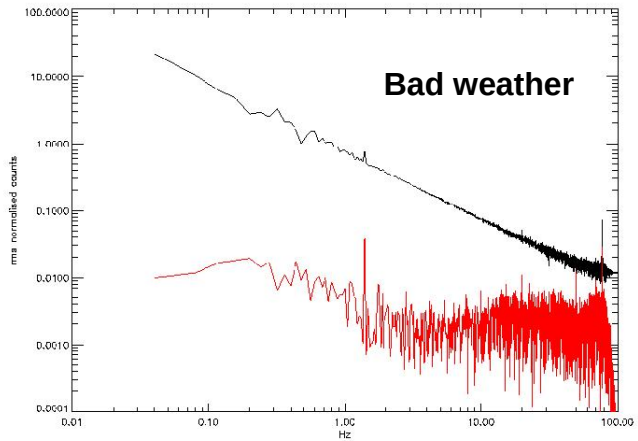

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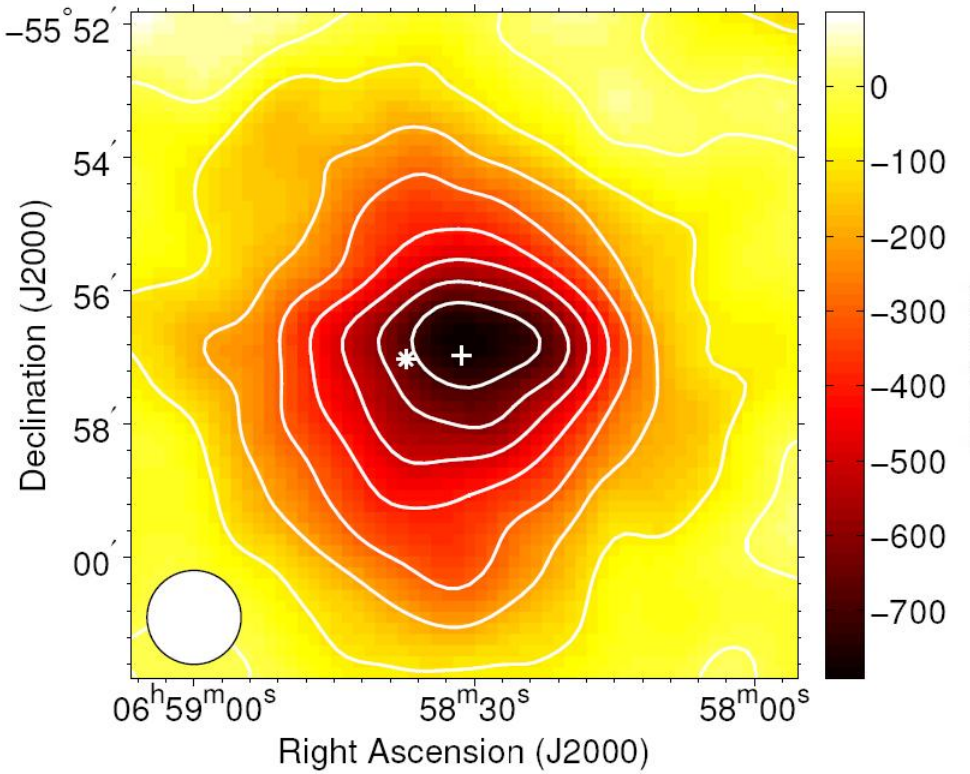
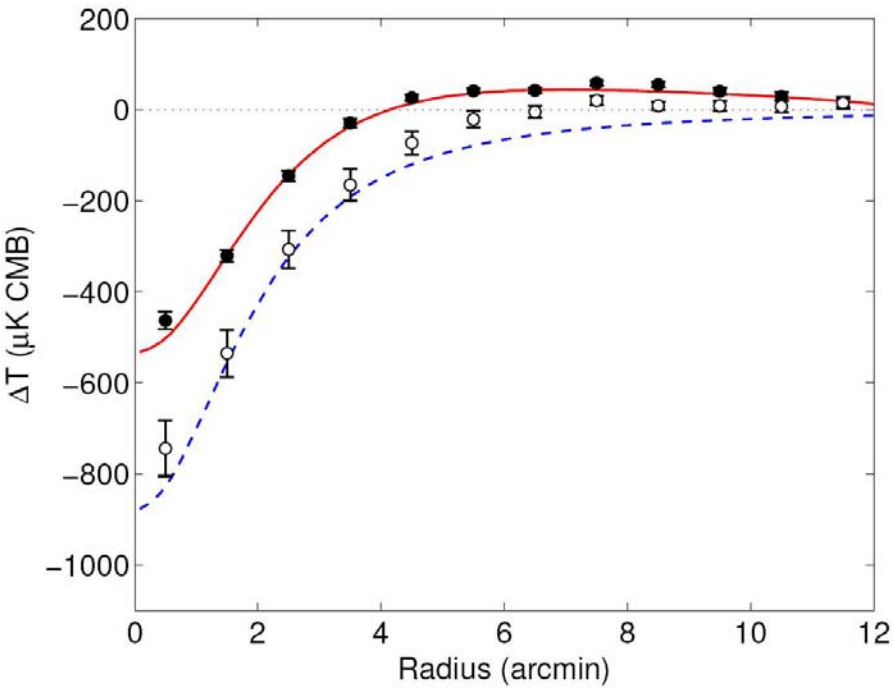
APEX-SZ: observation timeline and science goals

- Receiver cold on telescope since commissioning 03/07
- 4-6 weeks per year in 2-3 observing periods
- Optimization of scan modes and multi-beam analysis
- Good SZ image quality for individual clusters
- Allows SZ follow-up (large available sky, tracking small fields), e.g. Planck clusters, X-ray samples, to study scaling relation
- Available deep, multi-waveband fields, e.g. XMM-LSS, BCS-XMM, COSMOS, to study cluster selection and M ~ Y
- Dark energy constraints depend on accurate knowledge about cluster selection and calibration of the mass-observable relation (e.g. Weller, Battye, RK 2002)

Bullet (1E 0657-56) observation

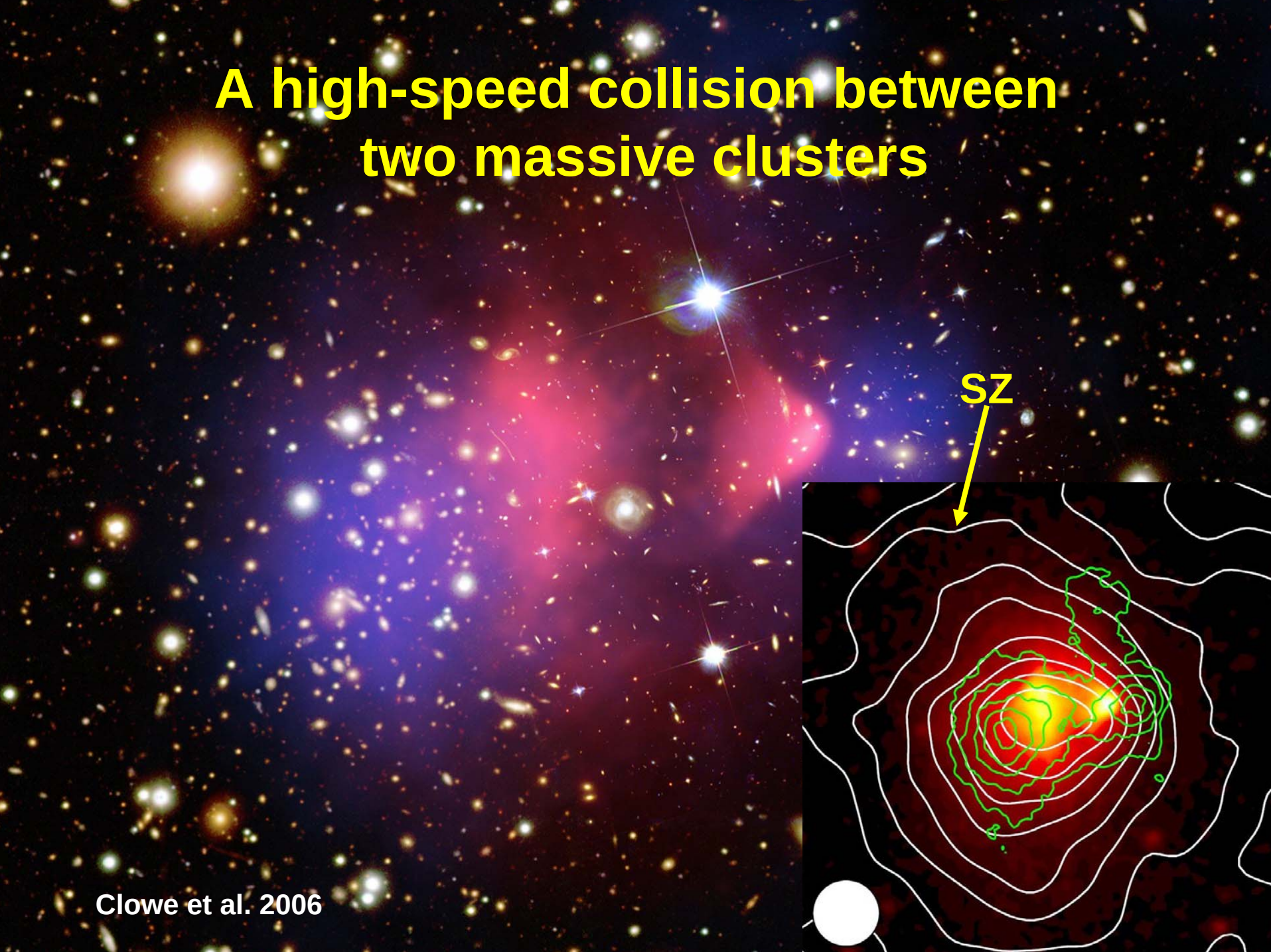




Radial Profile

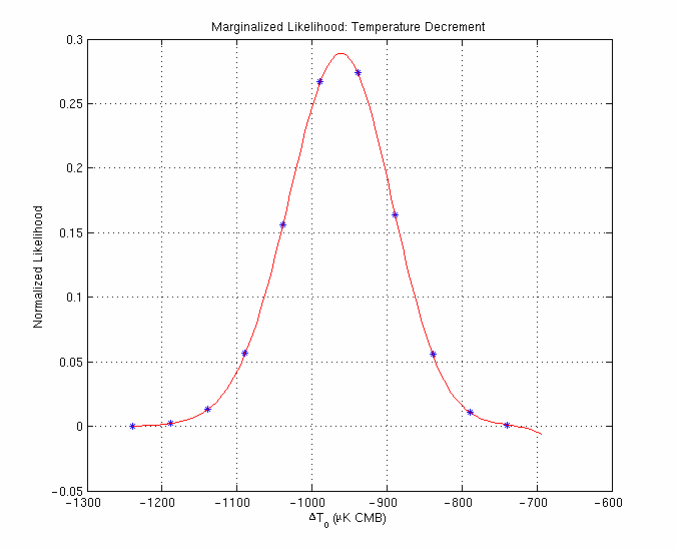
Halverson et al. 2008, [arXiv:0807.4208]

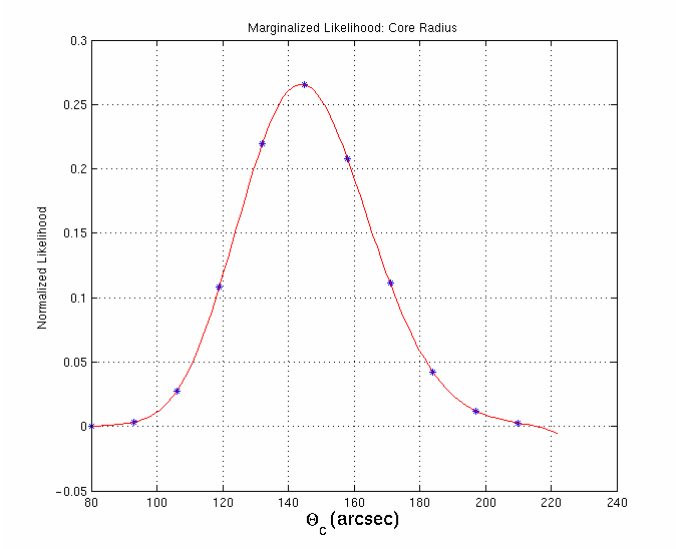
A high-speed collision between two massive clusters



Clowe et al. 2006

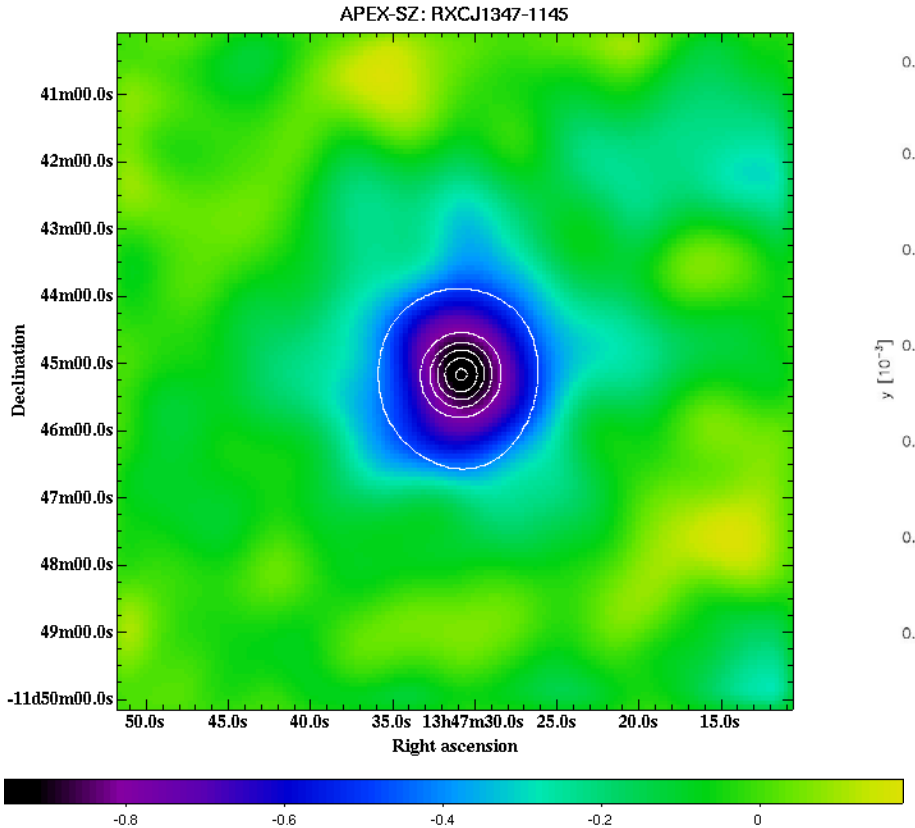
Likelihood Analysis

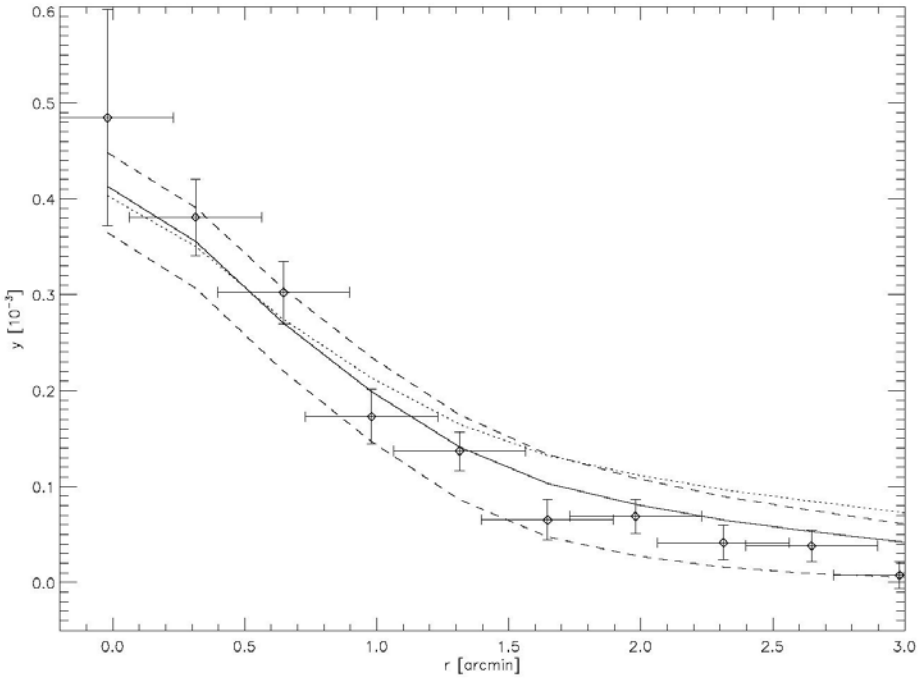




Parameter	Description	Value	Uncertainty[a]
X_0	RA centroid position	$06^{\rm h}58^{\rm m}31.41^{\rm s}$ (J2000)	$\pm 7.5''$
Y_0	DEC centroid position	$-55°56'57.9''$ (J2000)	$\pm 8.7''$
ΔT_0	Central temperature decrement	$-880\ \mu\mathrm{K_{CMB}}$	$\pm 80\ \mu\mathrm{K_{CMB}}$
y_0	Central Comptonization[b]	3.77×10^{-4}	$\pm 0.34 \times 10^{-4}$
$\theta_{\rm c}$	Core radius	$144''$	$\pm 19''$
η	Ellipse minor/major core radius ratio	0.881	± 0.086
Φ	Ellipse orientation angle	$-70°$	$\pm 20°$
β	Power-law index	1.16	± 0.12

RXCJ1347-11

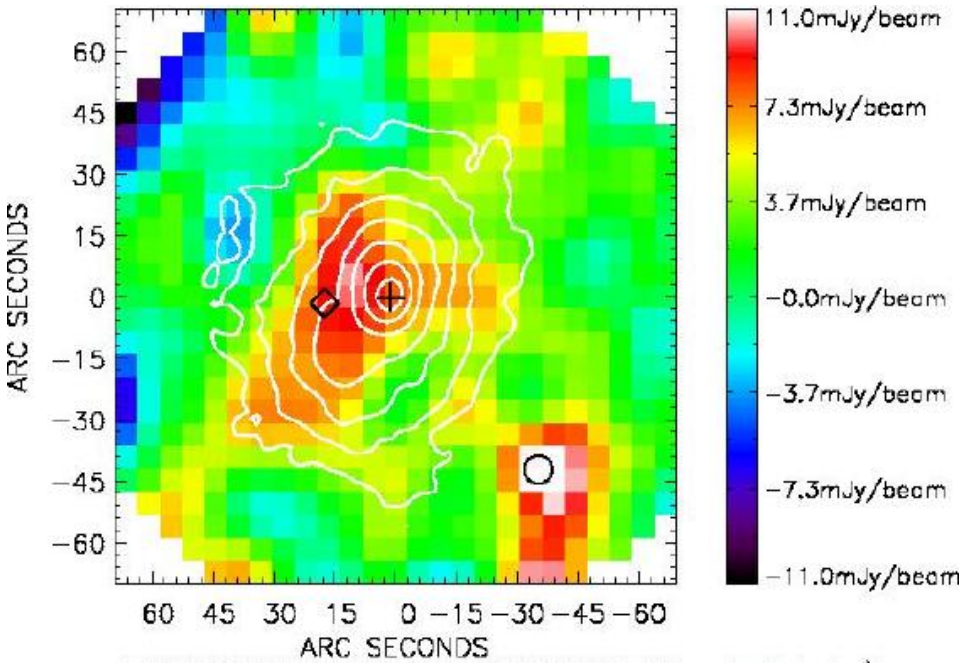




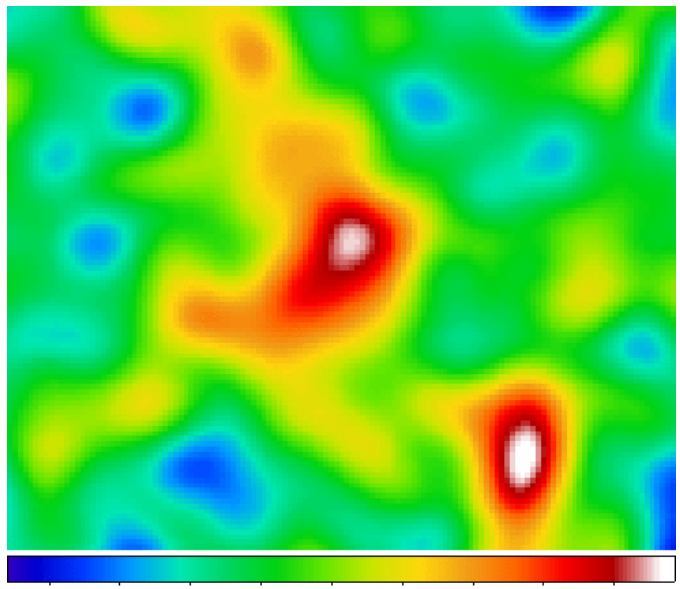
SZ vs. X-ray profiles

Kneissl et al., in prep. (w/ Suhada, Boehringer)

APEX - LABOCA: RXCJ1347-11

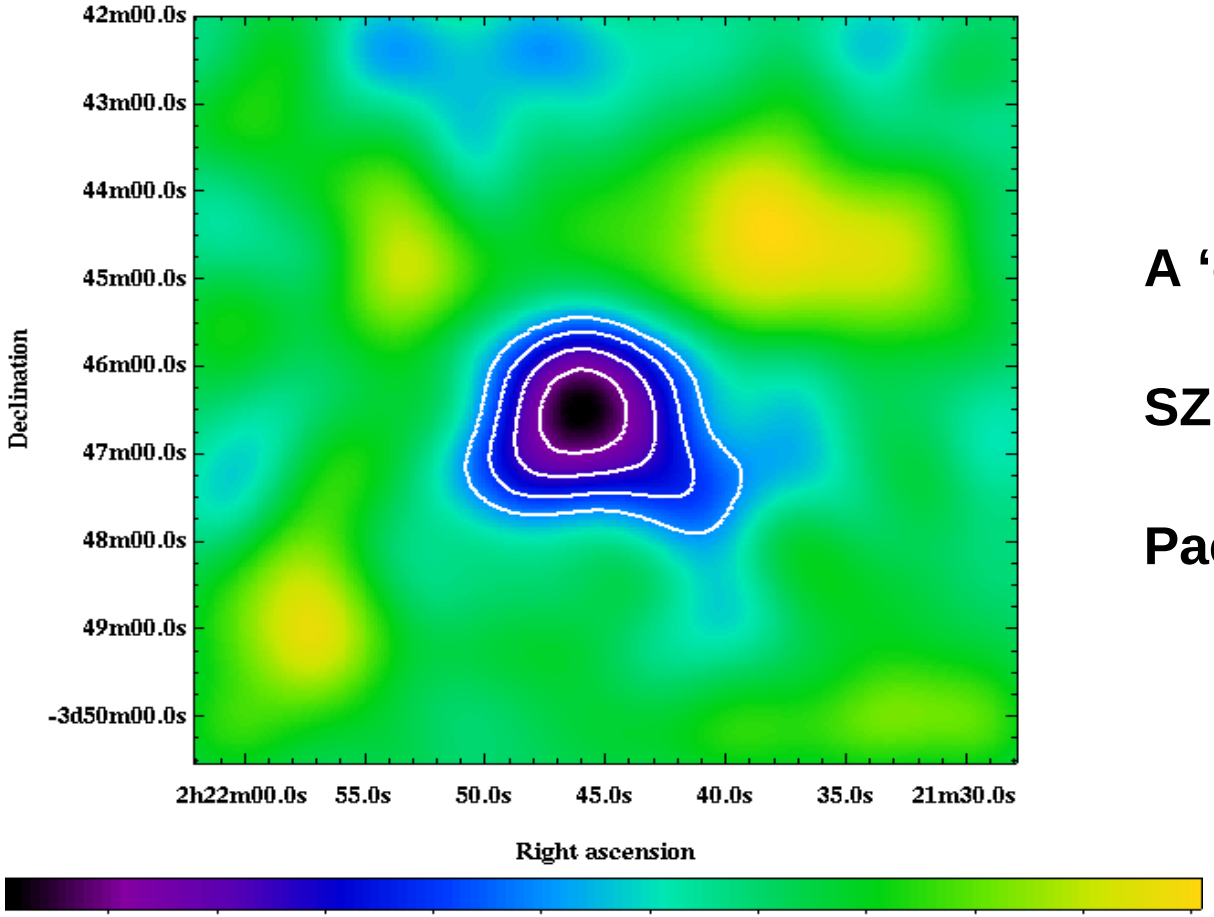


SCUBA (Kitayama et al. 2004)



LABOCA: central part of 10 x 10 arcmin^2 image; Subtraction of sub-mm sources important

XMM-LSS Field



A ‘cool’ (T < 5 keV)

SZ cluster at z = 0.43

Pacaud et al., in prep.

Conclusions

- **First published scientific result from observations with a large array of multiplexed superconducting transition edge sensor bolometers.**
- **Good quality images of bright clusters will allow new constraints on scaling relations**
- **Large available sky area and tracking scan modes ideal for cluster sample studies and deep multi-waveband fields, e.g. COSMOS**
- **Dark energy constraints possible via 'classical' cluster distances & studies to calibrate mass-observable relation, cluster selection**