Sunyaev-Zel'dovich Observations with APEX / Planck

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Max-Planck-Institute for Radio Astronomy

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Outline

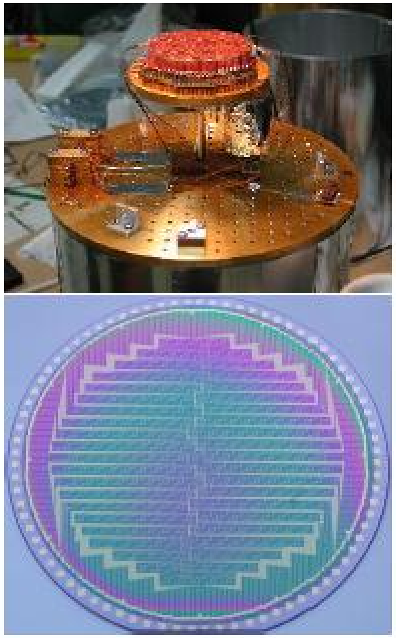
- APEX Telescope, SZ Receiver
- Observations, Analysis
- Sensitivity, Goals
- Bright and faint clusters
- Field (survey) observation
- Planck specifications
- Cluster sample properties
- Use of X-ray data

The Atacama Pathfinder EXperiment (APEX) telescope

- ALMA prototype antenna constructed by VERTEX
- refitted with two receiver cabins by MPIfR, Bonn
- 12 m on-axis Cassegrain, 17" FWHM beam (350 GHz)
- high surface smoothness (17 μm rms) for observations up to THz
- 0.75 m secondary (wobbler), tertiary optics
- high elevation (5100 m), 23°S latitude
- dry: 1/0.6 mm PWV (50/25 %), $<$ 0.3 mm in winter
- operated by MPIfR: 50%, ESO: 27%, Onsala: 23%

APEX Instrumentation

- Bolometer Cameras
  - Laboca (MPIfR), 350 GHz, 300 pix
  - Saboca (MPIfR), 850 GHz, 37 pix
  - SZ-Receiver (UC Berkeley), 150(220/90) GHz, 320 pix
  - Artemis (Saclay), 650/850/1500 GHz, 300(4000) pix
- Heterodyne Spectrometers
  - APEX-2A (OSO), 280-380 GHz, 1 pix
  - CHAMP+ (MPIfR), 600-720/790-950 GHz, 7 pix
  - FLASH (MPIfR), 460-500/780-820 GHz, 1 pix
  - CONDOR (Koeln), 1.5 THz, 1 pix
  - APEX-X (OSO): 8 bands 211-1500 GHz, 1 pix

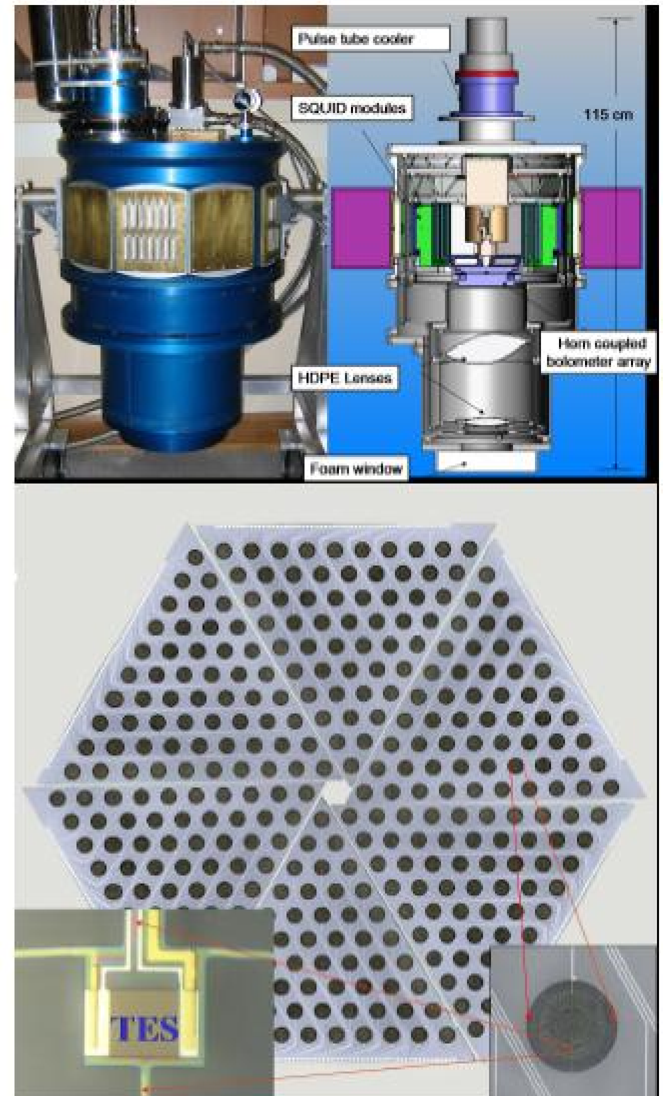


Laboca

Scientific highlights include discovery of CF^+ and extragalactic CO mapping (special issue A&A 2006)

The SZ receiver for APEX
UC Berkeley

- Spiderweb Transition Edge Sensor bolometers
- Micro-fabricated array with 320 elements
- 0.4 degree field-of-view
- SQUID readout, frequency multiplexing
- observing frequencies (90) 150 (220) GHz



APEX-SZ Collaboration

Max-Planck-Institute for Radio Astronomy:

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U Bonn: K. Basu, F. Bertoldi, F. Pacaud, M. Nord, R. Schaaf; **MPE:** H. Böhringer

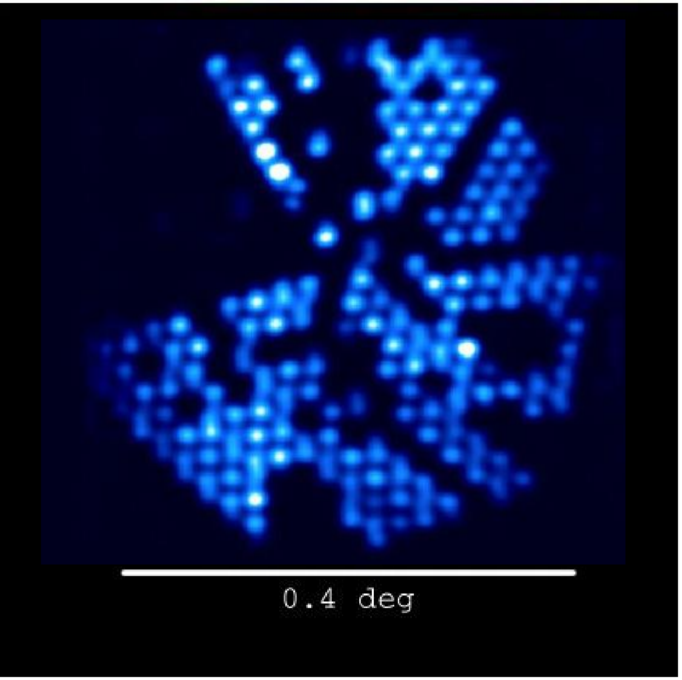
University of California, Berkeley:

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

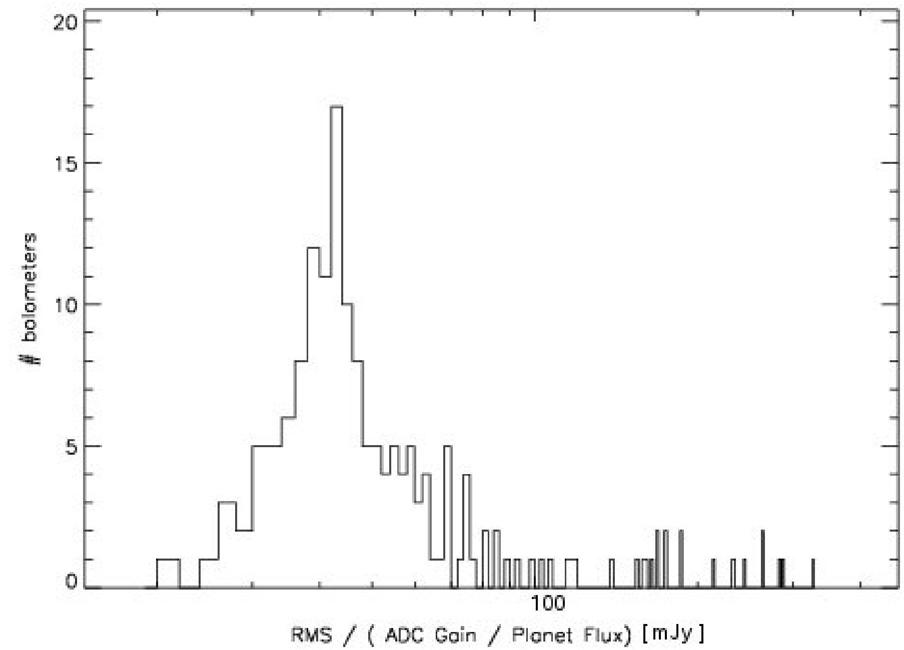
U McGill: M. Dobbs, T. Lanting

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

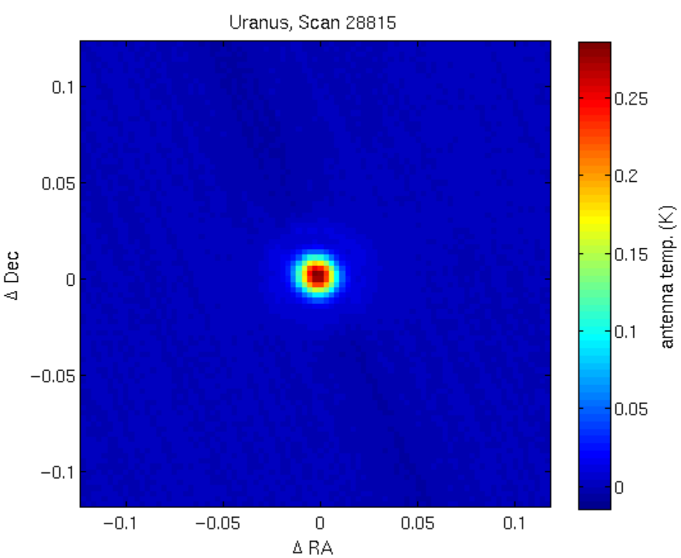
Array sensitivity



Array map of Mars



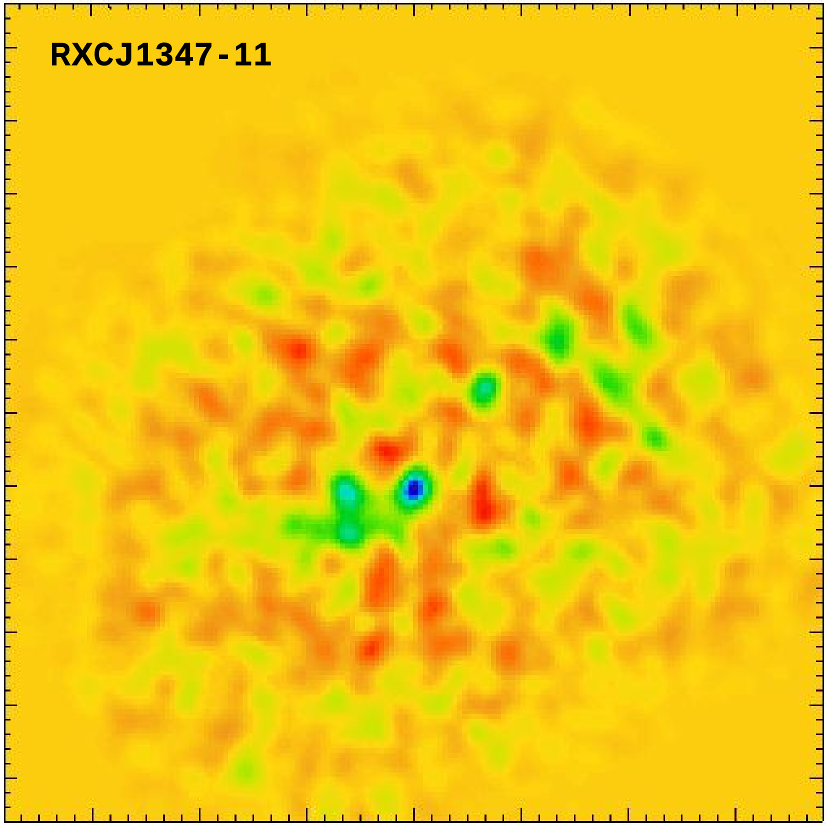
Sensitivities of bolometer elements



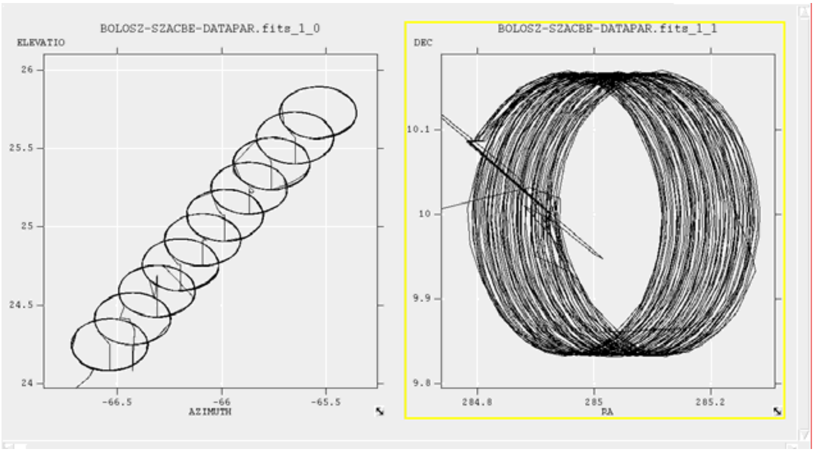
Beam map of Uranus

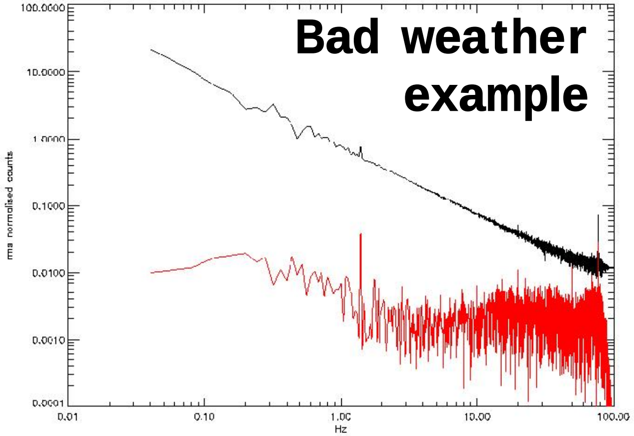
Scanning and data reduction

Linear scans are inefficient for single clusters



Circle scans allow small foot-print and sky noise modulation:





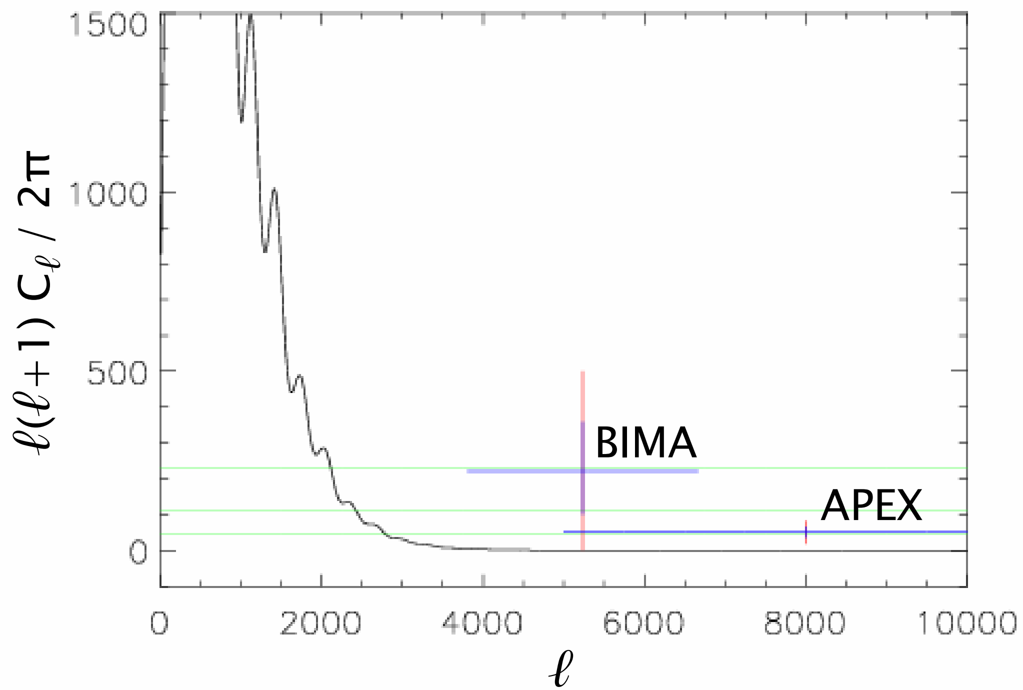
Reduction includes PCA and median sky noise removal, filtering and iterative signal restoration, simulated sources for evaluation.

APEX-SZ status and goals

- Dewar cold on telescope since commissioning 03/07
- 150-200 (/320) bolometers working
- about x2 from nominal sensitivity (noise performance)
- bandwidth smaller then expected, about 50%
- reach 10 μK map noise rms in ~24h, 0.25 deg^2 foot-print
- reduced survey area with current performance and available observing time, upgrade to full sensitivity in summer 2008
- SZ cluster physics over large range in mass and redshift
- Survey overlapping with other wavebands (XMM-LSS, BCS-XMM, COSMOS, CFHTLS, etc.)
- Cluster selection and Y – M relation
- Cosmology with targeted clusters and SZ fluctuations

Bullet (1E 0657-56) analysis

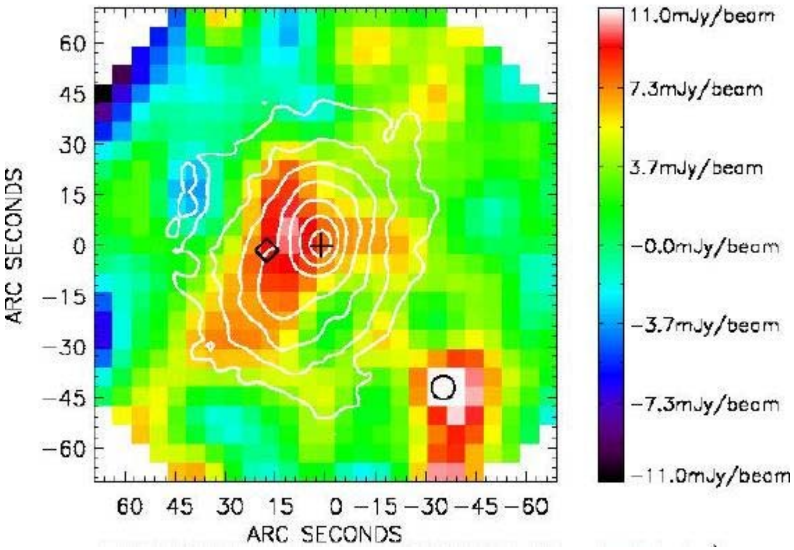
XMM-LSS-006 / SZ power spectrum



The ‘coolest’ (T < 5 keV) SZ cluster

SZ power spectrum prediction

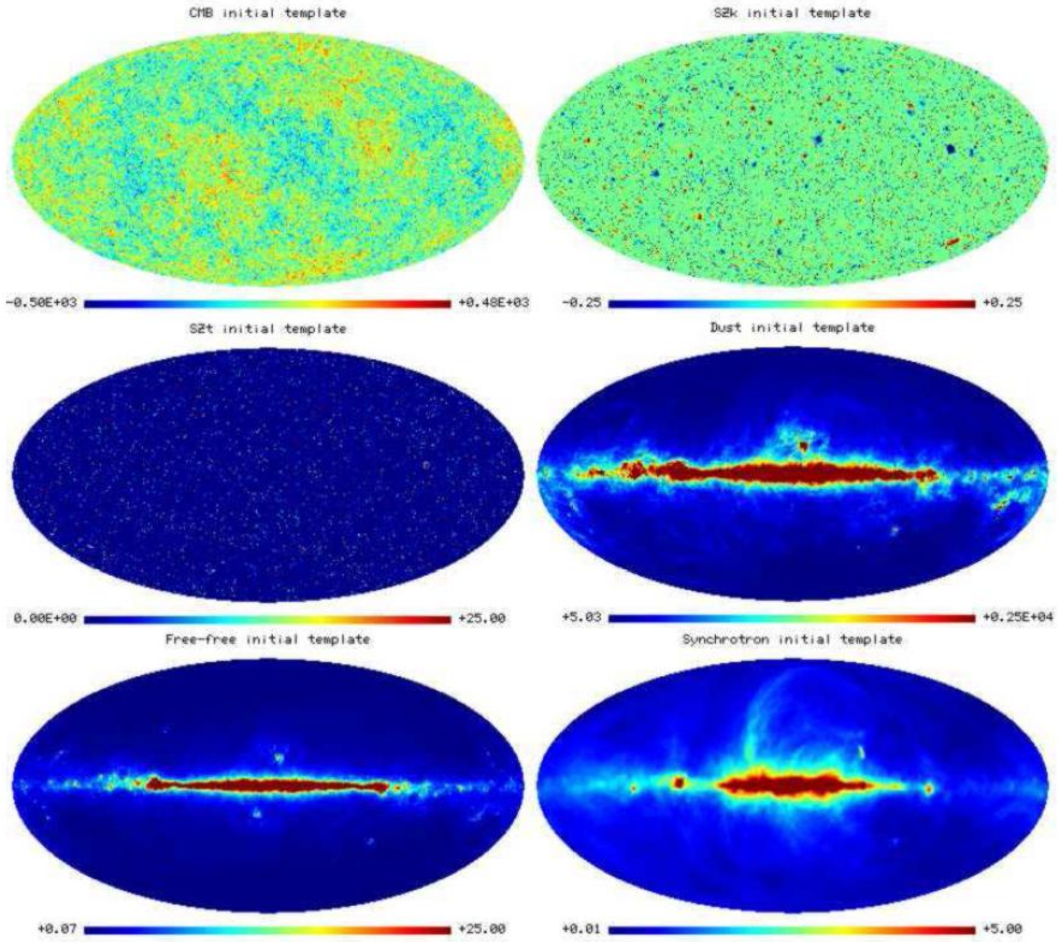
APEX / LABOCA: RXCJ1347-11



SCUBA (Kitayama et al. 2004)

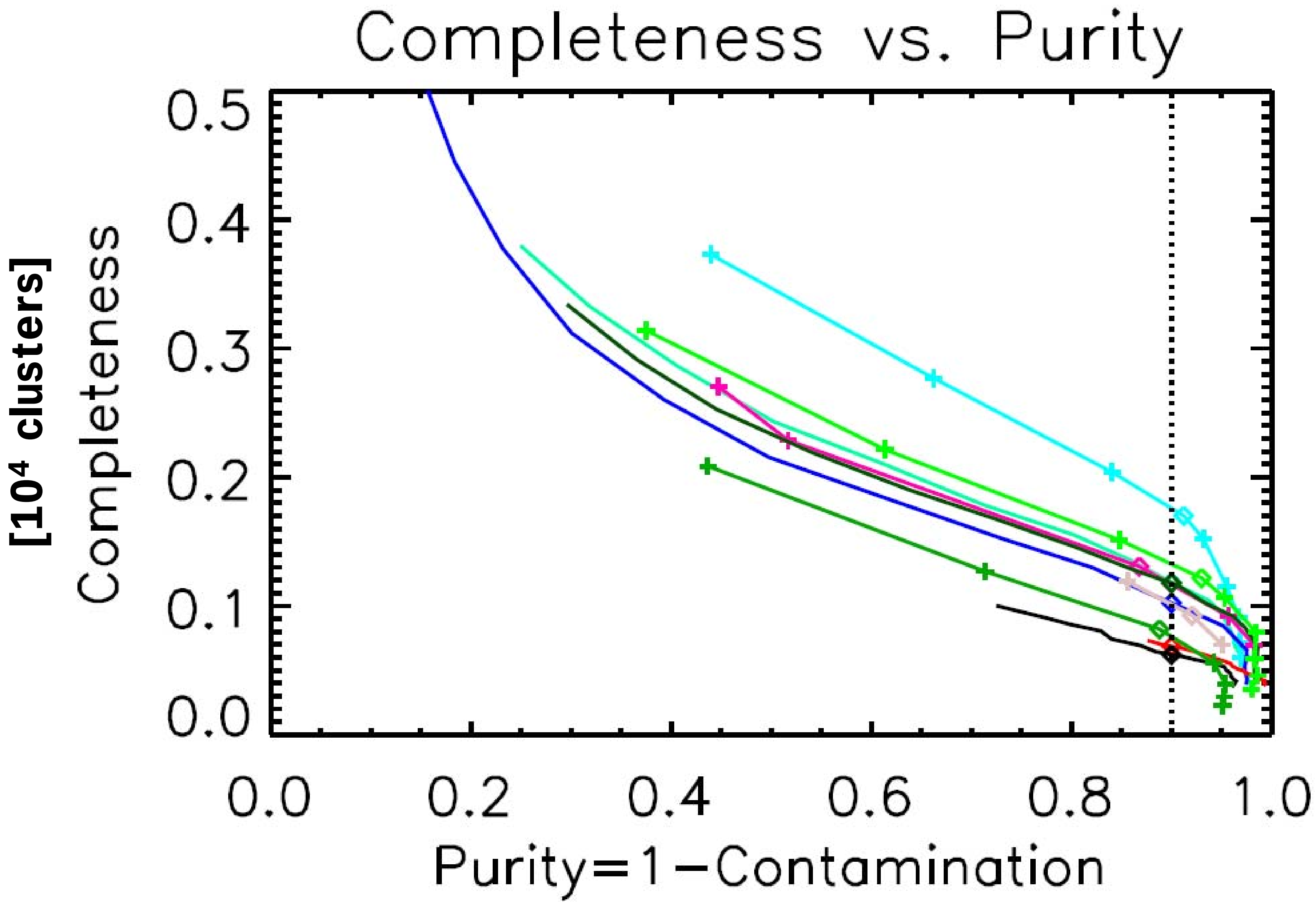
LABOCA (Kneissl et al.)

Planck specifications and cluster prospects



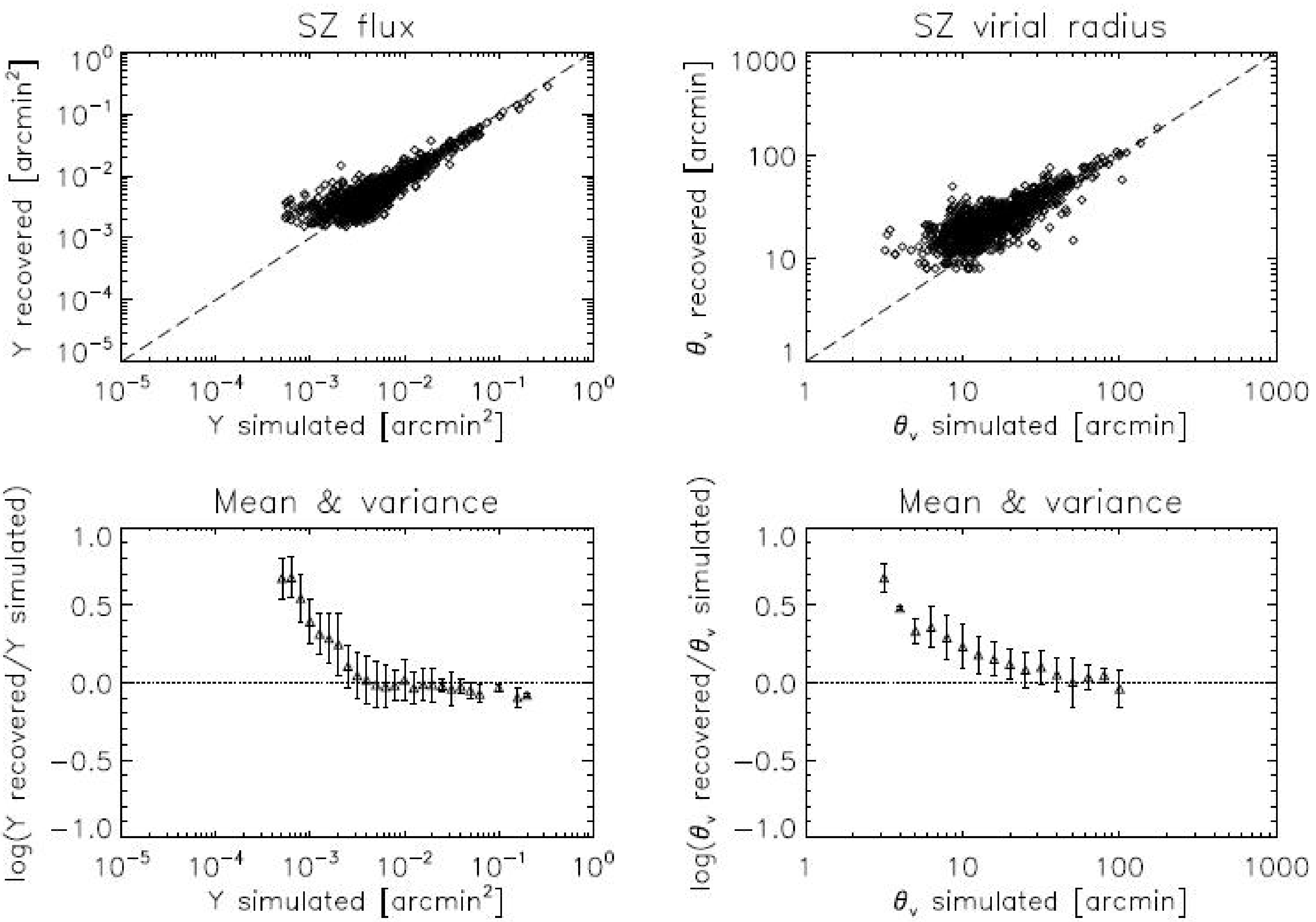
- Large beams (≥ 5 arcmin)
- 9 frequencies (30-900 GHz)
- No atmosphere
- all-sky, few μK

Planck Cluster Extraction Challenge



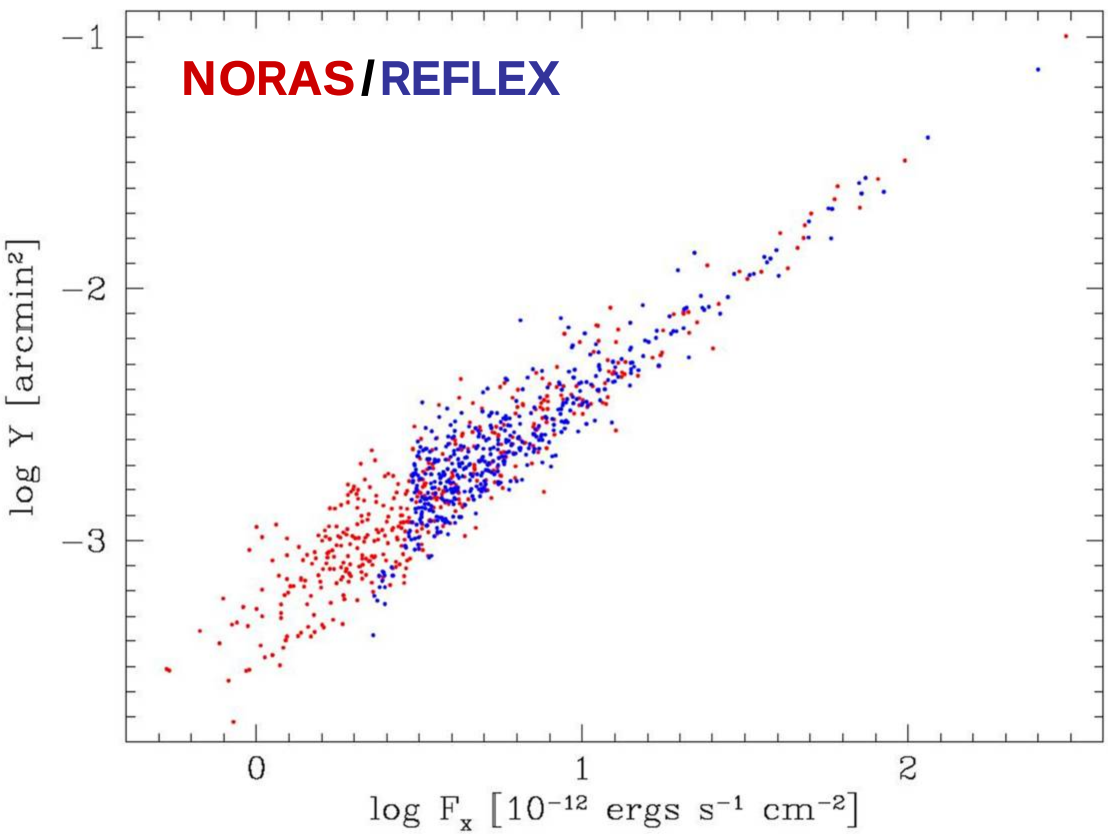
J.-B. Melin et al.

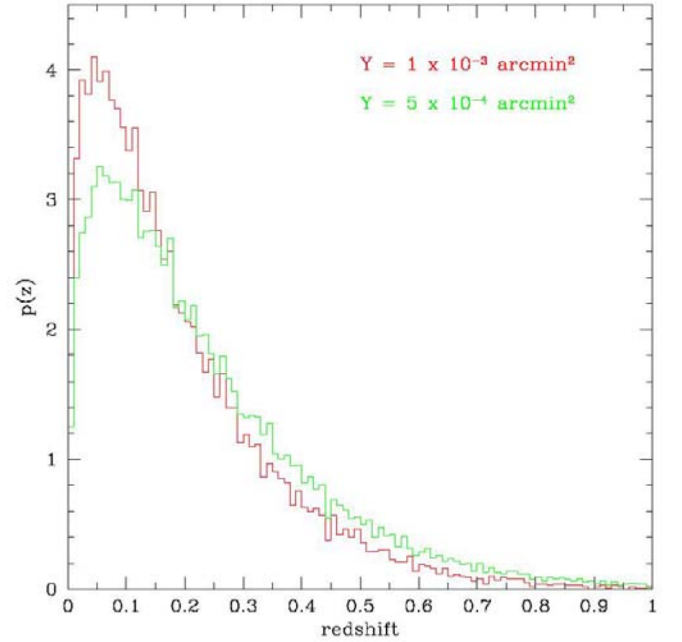
SZ Photometry

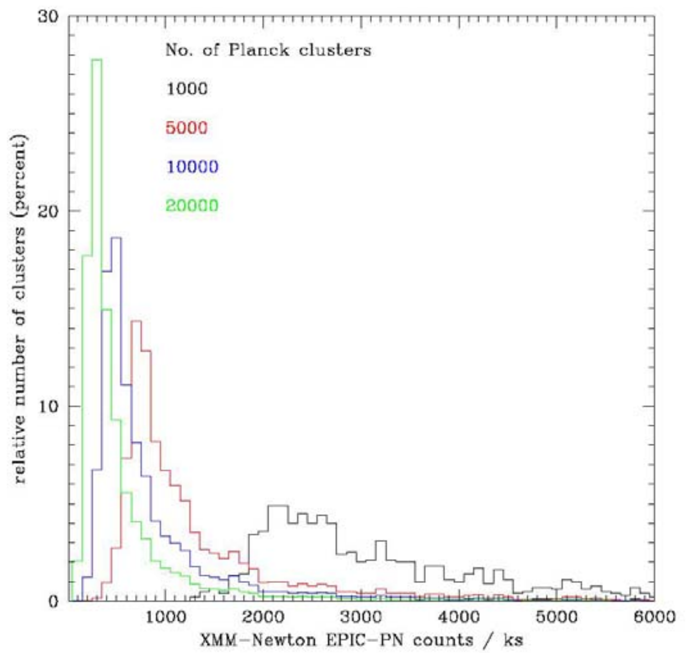


G. Chon, MPIfR

X-ray properties of Planck Clusters







What X-ray data would we like to use ?

- Large overlap between SZ and X-ray to constrain selection and Y - M

- Best overlap depends on SZ survey type, sensitivity, etc.

- APEX-SZ can overlap with existing X-ray fields, Planck provides sample ($z = 0.5-0.8$) for X-ray follow-up

- High redshift clusters ($z > 1$) also need dedicated follow-up (low mass and distant):

  - Important for cluster physical evolution and cosmology

  - Bracket trends in scaling relations

  - Dark energy - need to consider evolution of EoS: $w \neq 1$, $w(z)$

  - High-z gives leverage and inflexion point of expansion