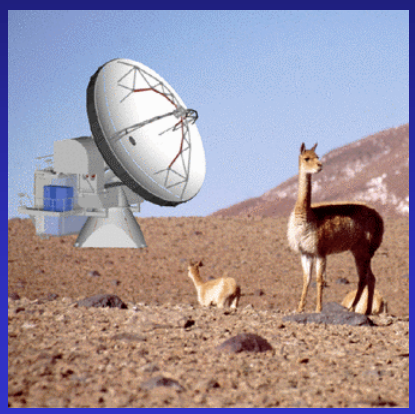
A Sunyaev-Zel'dovich Effect Survey with the APEX Telescope



Nils Halverson
U. C. Berkeley

Collaborators

U. C. Berkeley

Sherry Cho
Matt Dobbs
Nils Halverson
Bill Holzapfel
Trevor Lanting
Adrian Lee
Jared Mehl
Paul Richards
Dan Schwan
Helmuth Spieler

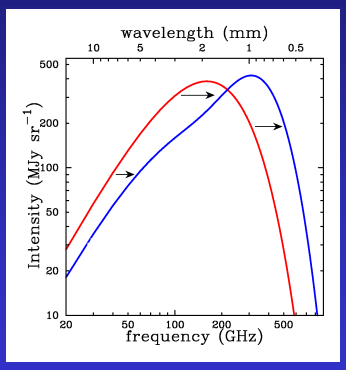
MPIfR

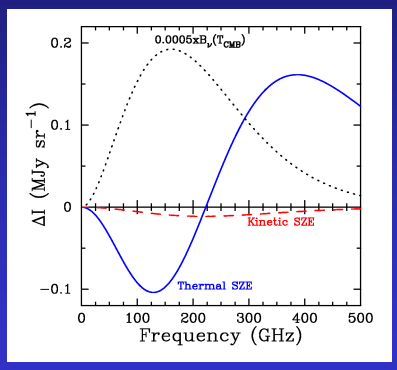
Frank Bertoldi
Rolf Guesten
Ernst Kreysa
Karl Menten
Peter Schilke

Science Goals

- Discover and catalog of order 1000 previously unknown galaxy clusters in a mass limited survey
- Observe evolution of structure, and test theories of structure formation
- Constrain mass density of the Universe Ω_m and dark energy equation of state w
- Measure Hubble constant H_0 and acceleration parameter q_0 independent of the distance ladder
- Study CMB secondary anisotropies – weak lensing, Ostriker-Vishniac effect

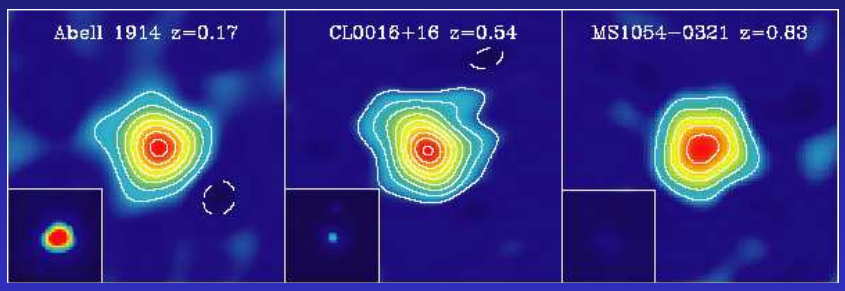
Sunyaev-Zel'dovich Effect





Carlstrom, Holder & Reese, ARAA, 2002

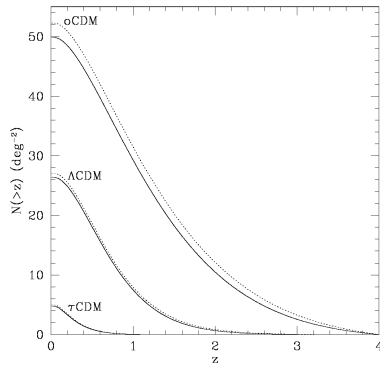
SZ Effect



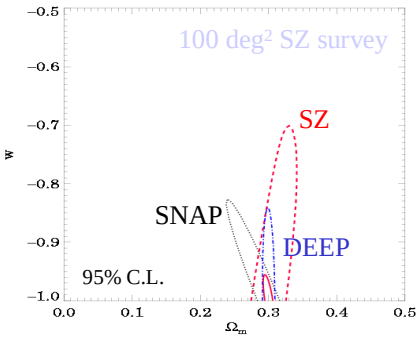
Courtesy of Carlstrom et al.

Differential surface brightness is independent of redshift.

Cosmology with SZ Surveys



Holder et al. 2000

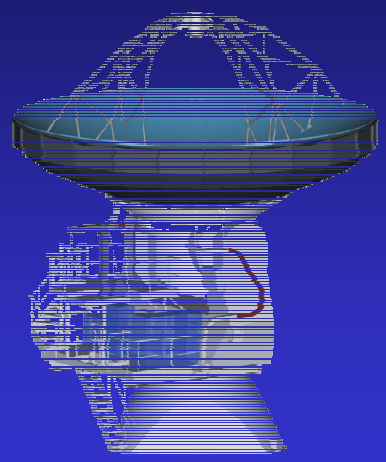


J. Newman

APEX SZ Survey Instrument

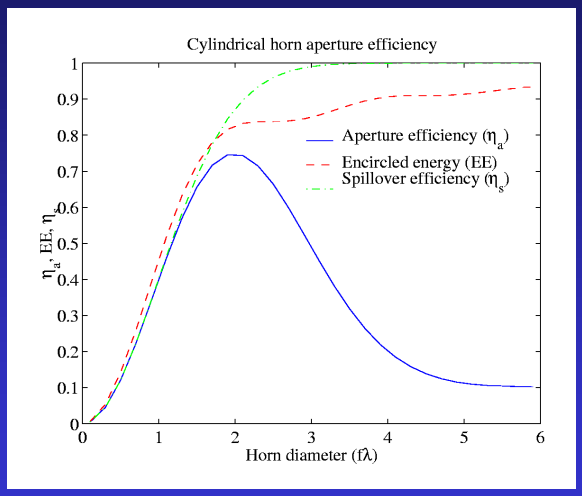
- 300 element bolometer array
- Single color observations at 2 & 1.4 mm wavelengths
- 0.4 degree field of view
- Survey 250 sq. degrees to 10 μK_{CMB} per 0.8' pixel in two seasons
- Drift scan observing strategy to reduce differential ground pickup
- Horn coupled array → RF and stray light shielding
- TES spider web bolometers, monolithic array
- Individual bolometer SQUID readouts
- Testing pulse-tube cooler to eliminate liquid cryogens

APEX Telescope



- 12 m on-axis ALMA prototype built by Vertex RSI
- Telescope fully funded by MPIfR/ESO/Onsala
- Parts under construction
- 18 μm surface accuracy goal
- 40" resolution @ λ = 2 mm, 6" resolution @ λ = 350 μm
- 0.5° maximum field of view
- To be sited at 16,500 ft in Chilean Andes
- First light mid 2003

Optimal Horn Diameter

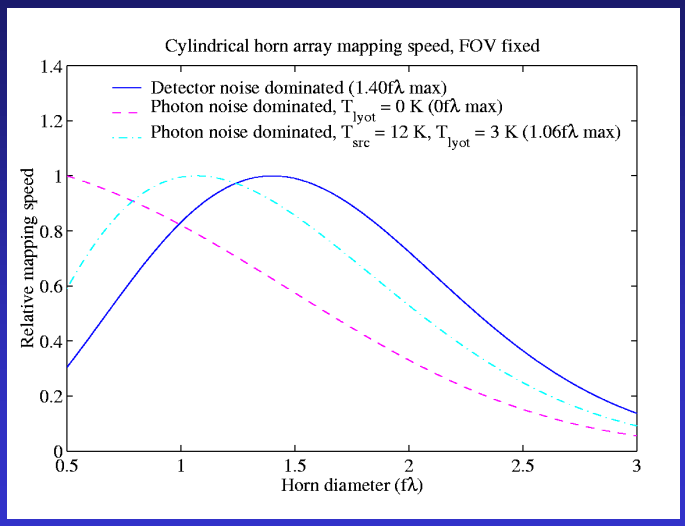


$$S \propto \frac{N\eta_a^2}{P_{\text{photon}}} \propto \frac{N\eta_a^2}{\eta_s B_{\text{ext}} + (1-\eta_s)B_{\text{int}}}$$

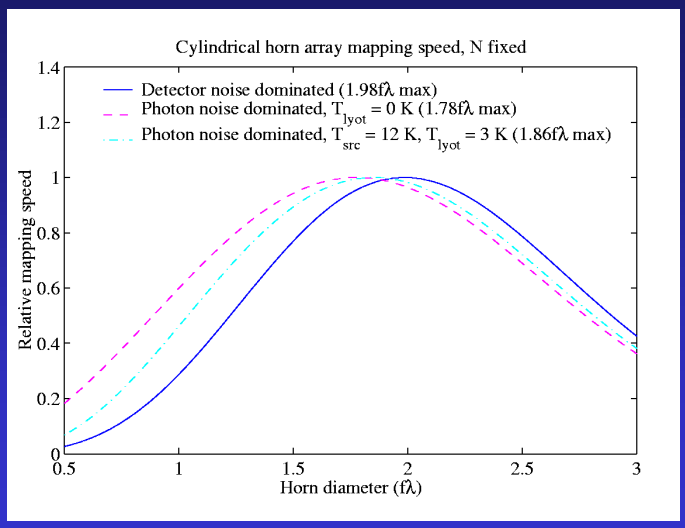
Mapping speed

See also Griffin, Bock & Gear, 2002

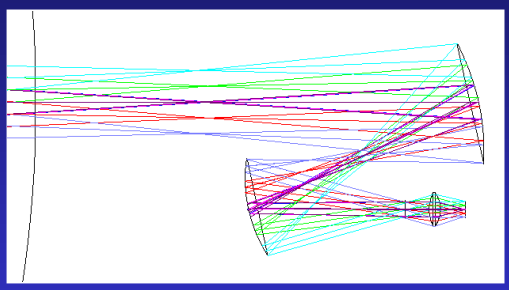
Mapping Speed, FOV Fixed



Mapping Speed, N fixed



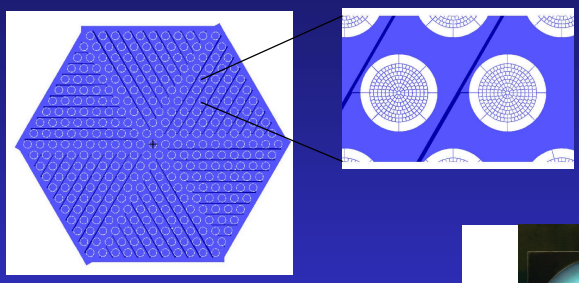
SZ Survey Instrument Optics



Strawman optical design

- 300 element array
- 2fλ horn diameter
- 24' (0.4 degree) field of view
- 15 cm max array diameter → f < 1.75
- Cold Lyot stop
- Cold lens

TES Bolometer Array

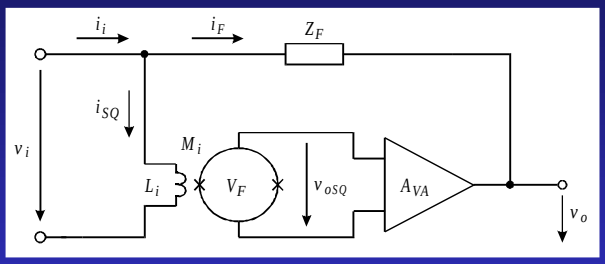


300 element mask

Spider web TES bolometer

3.5 mm

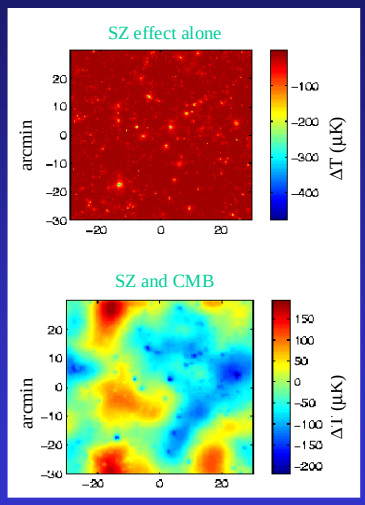
SQUID Readout Electronics



Shunt feedback SQUID amplifier

- Low input impedance to maintain constant voltage bias of bolometers
- Large dynamic range to accommodate AC bias up to several hundred kHz

Data Analysis Challenges



Simulations courtesy M. White

- Source confusion
  - CMB
  - Point sources
  - Filamentary SZ
- Completeness
- Y-distortion – mass relation
- Redshift information
- Etc …

Project Status

- Telescope under construction
- APEX-SZ receiver funded and under development
- Tertiary optics: diffraction limited designs achieved
- Cryogenic testing of pulse tube cooler and microphonics in progress
- Single TES bolometer demonstrated, array design and fabrication underway
- SQUID readout prototype fabricated and under test