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

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Collaborators

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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 $\Omega_m$ 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

[Graphs showing the Sunyaev-Zel’dovich effect]

Carlstrom, Holder & Reese, ARAA, 2002
Far Future Observations: APEX

SZ Effect

Differential surface brightness is independent of redshift.

Cosmology with SZ Surveys

Nils Halverson, UC Berkeley (KITP New Cosmology Conference 8/20/02)
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 $10 \mu K_{\text{CMB}}$ 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 @ $\lambda = 2 \text{ mm}$, 6” resolution @ $\lambda = 350 \mu \text{m}$
- 0.5° maximum field of view
- To be sited at 16,500 ft in Chilean Andes
- First light mid 2003
Far Future Observations: APEX

Optimal Horn Diameter

\[ S \propto \frac{N\sigma^2}{P_{\text{photon}}} \]
\[ \propto \frac{N\sigma^2}{\eta_1 B_{\text{ext}} + (1 - \eta_1) B_{\text{tot}}} \]

Mapping speed

See also Griffin, Bock & Gear, 2002

Mapping Speed, FOV Fixed

See also Griffin, Bock & Gear, 2002
Far Future Observations: APEX

### Mapping Speed, N fixed

![Graph showing mapping speed, N fixed](image)

- Detector noise dominated (1.98Ω, max)
- Photon noise dominated, $T_{\text{phot}} = 0$ K (1.78Ω, max)
- Photon noise dominated, $T_{\text{sc}} = 12$ K, $T_{\text{phot}} = 3$ K (1.86Ω, max)

### SZ Survey Instrument Optics

- 300 element array
- 2$f_\lambda$ horn diameter
- 24' (0.4 degree) field of view
- 15 cm max array diameter $\Rightarrow$ $f < 1.75$
- Cold Lyot stop
- Cold lens

Strawman optical design
Far Future Observations: APEX

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

- 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