# Future Studies of the ICM via the SZ Effect with MUSIC

Nicole Czakon, Jack Sayers, Seth Siegel, Peter K. Day, Thomas P. Downes,
Ran P. Duan, Jiansong Gao, Jason Glenn, Sunil R. Golwala, Matt I. Hollister, Henry G. LeDuc,
Benjamin A. Mazin, Phillip R. Maloney, Omid Noroozian, Hien T. Nguyen, James Schlaerth,
Anastasios Vayonakis, Phillip R. Wilson, and Jonas Zmuidzinas

## Scientific Motivation

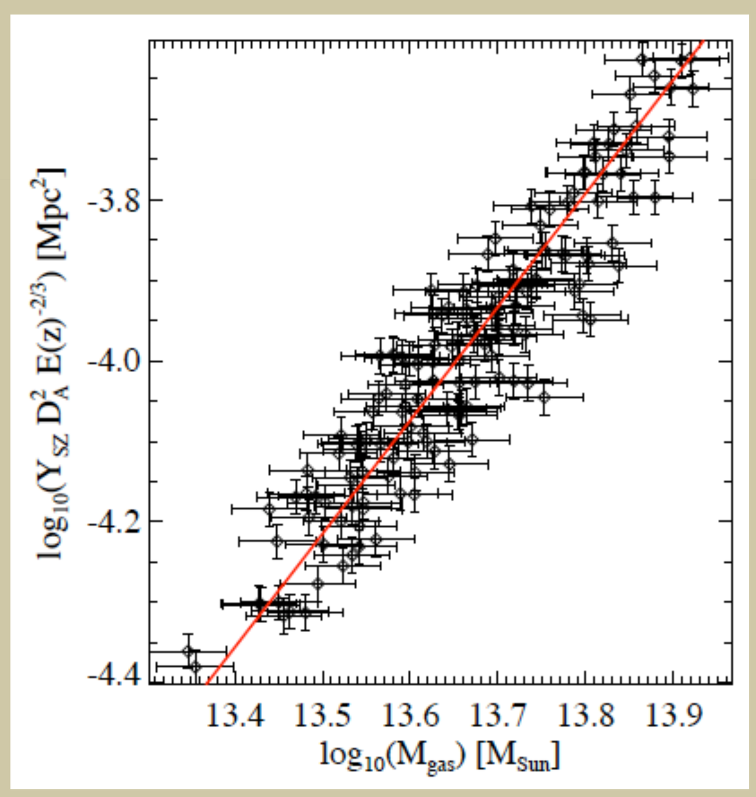
Galaxy clusters improve our understanding of both dark matter and dark energy due to their position in the mass hierarchy of cosmological structure and their complex formation histories. Scientific interpretation of the cosmological results coming out of Sunyaev-Zel'dovich (SZ) surveys, such as Planck's [1], are limited by the uncertainty in the relationship between SZ signal and cluster mass. The Multiwavelength Submillimeter Inductance Camera (MUSIC) [2], to be commissioned at the Caltech Submillimeter Observatory starting in Fall 2011, will be well suited to address this issue. MUSIC will have 576 spatial pixels, each pixel simultaneously sensitive to four bands: 1.98 mm, 1.33 mm, 1.04 mm, and .87 mm. With a 14' field-of-view, MUSIC will be able to measure resolved SZ profiles out to several factors of $r_{500}$. MUSIC's high mapping speeds will enable model-independent $Y_{SZ}$-M scaling relations for over 250 clusters in our proposed 3-year observing program.

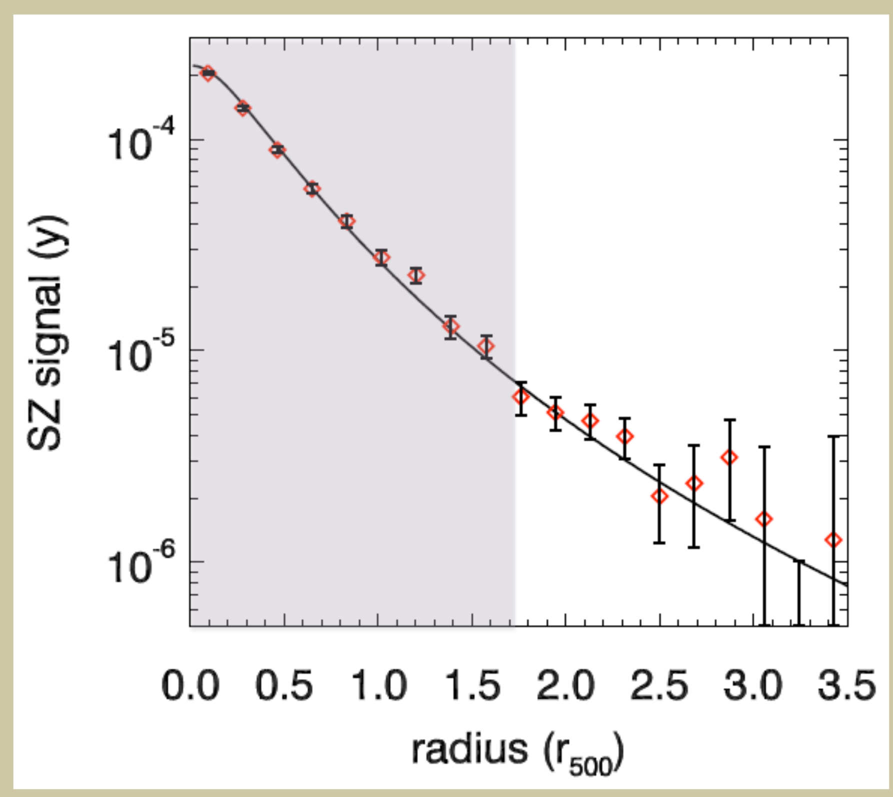
| Nominal Science Program | | | Surface Brightness RMS ($\mu K_{CMB}$-arcmin) | | | |
|---|---|---|---|---|---|---|
| | # clusters | # nights | 1.98 mm | 1.33 mm | 1.04 mm | .87 mm |
| Pointed Maps | 250 | 50 | 9.2 | 13 | 31 | 120 |
| Deep Pointed Maps | 25 | 50 | 2.9 | 4.2 | 9.8 | 39 |
| Confusion Noise | | | 4.1 | 8.8 | 19 | 42 |


| Mapping Speeds | | | | | |
|---|---|---|---|---|---|
| | | 1.98 mm | 1.33 mm | 1.04 mm | .87 mm |
| CMB | arcmin$^2$/hr/($\mu K_{CMB}$-arcmin)$^2$ | 2 | .94 | .17 | .01 |
| Galaxy Clusters | arcmin$^2$/hr/(y-arcmin)$^2$ | 1300e10 | 9e10 | 160e10 | 35e10 |

Sayers et al. 2011 (in prep)

## Predicted Science

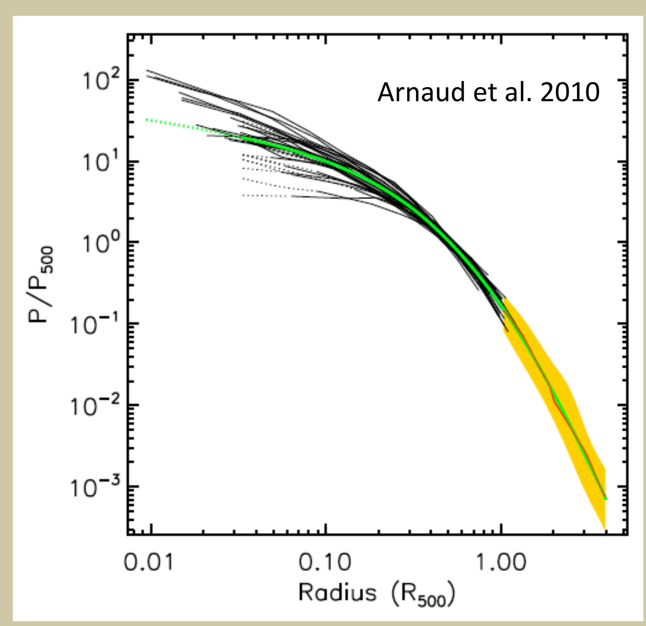


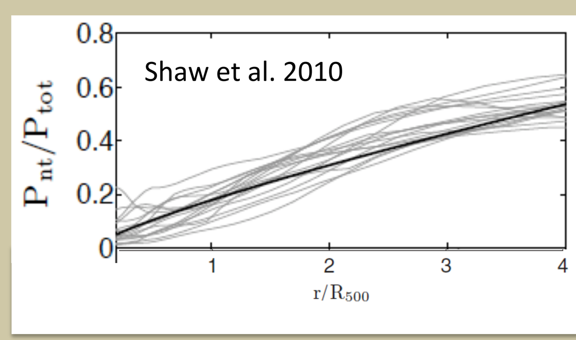

Sayers et al. 2011 (in prep)

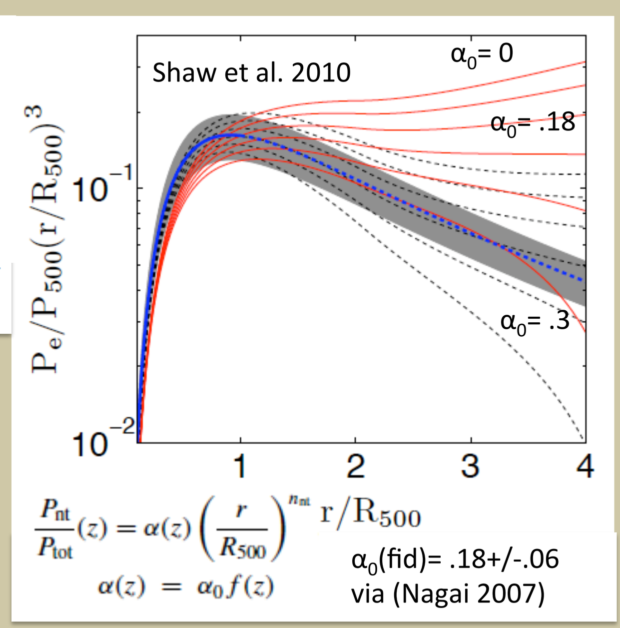
## The Need For Cluster Observations Beyond $R_{500}$

Current models used for estimating $Y_{SZ}$, such as the one on the right, are based on observational evidence out to radii of only one factor of $r_{500}$—constrained with simulations beyond [4]. By incorporating non-thermal pressure support into simulations, it has been predicted that cluster pressure profiles may vary significantly. The non-thermal pressure support fraction increases from .2-.5 beyond $r_{500}$ for a typical cluster.[5,6] The MUSIC observing program will be able to measure $Y_{SZ}$ out to several factors of $r_{500}$, as shown in the prediction above.



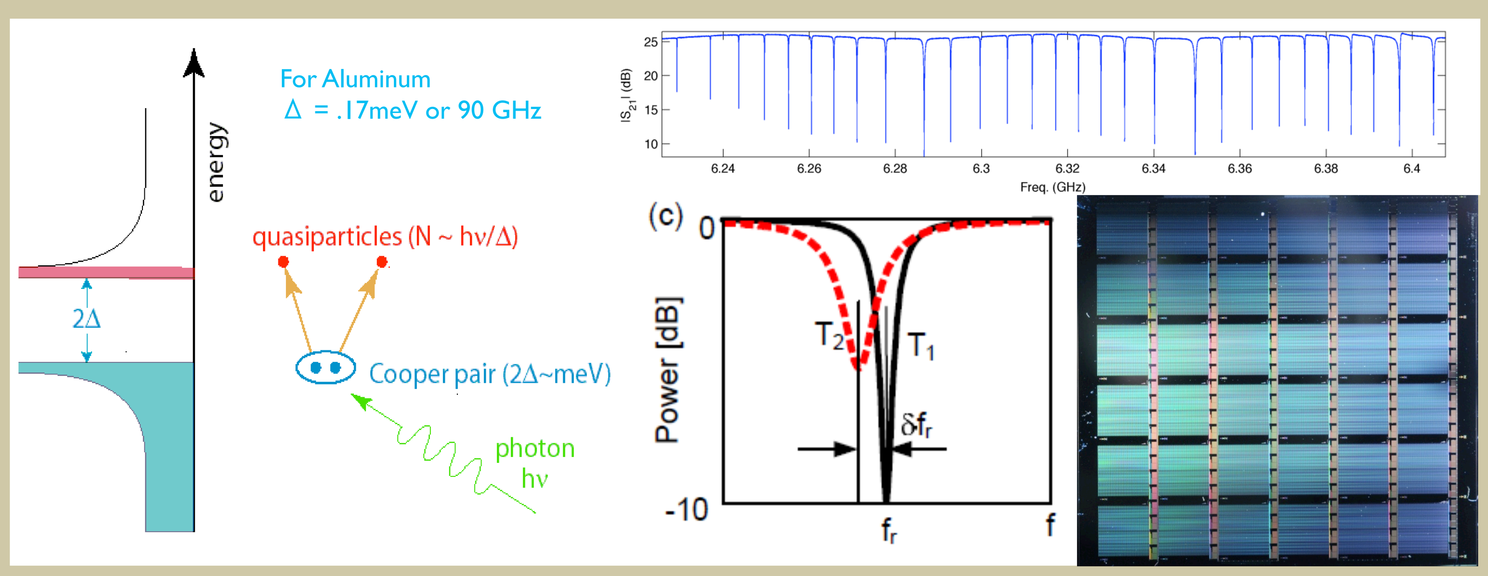

The two figures on the right show the effect of non-gravitational physics on pressure profiles. The smaller figure plots the ratio of non-thermal to total pressure for 16 cluster simulations from (Lau et al. 2009), together with the (Shaw, et al. 2010) fid. model. The figure on the right displays electron pressure profiles for different cluster masses, $M_{500}=3\times10^{14}h^{-1}M_{SUN}$ (black) and $M_{500}=3\times10^{13}h^{-1}M_{SUN}$ (red). Dark blue line: Arnaud, et al., 2010.

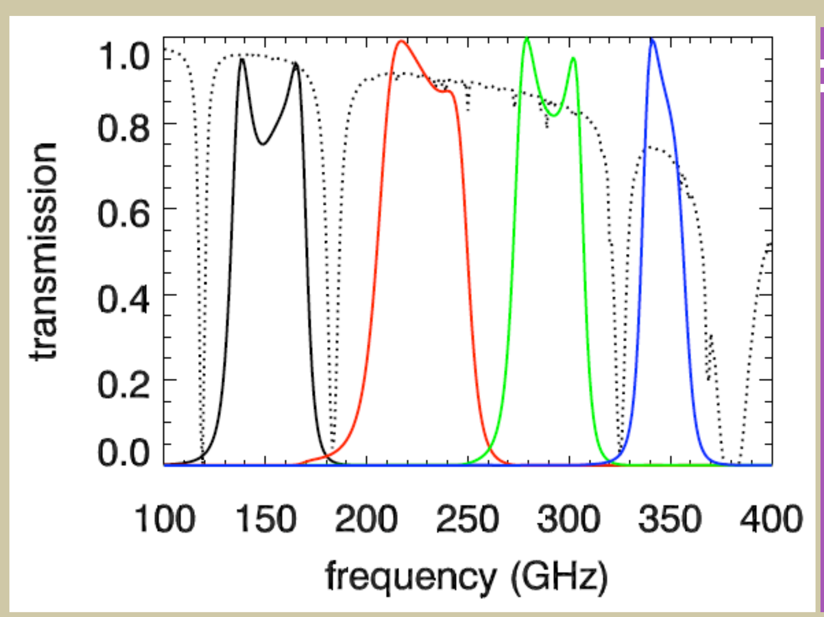


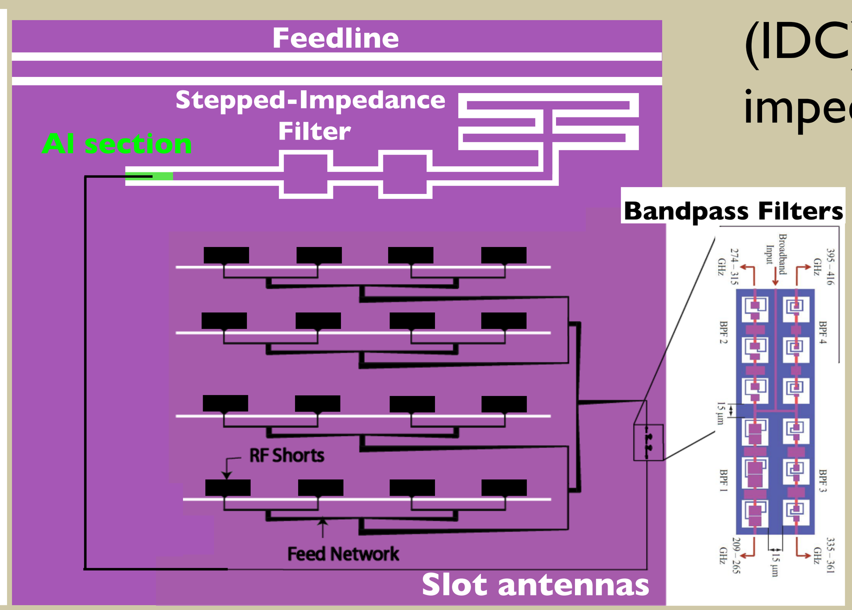




## The Focal Plane

The detecting technology for MUSIC is a microwave kinetic inductance detector (MKID) [7]. Incident submillimeter radiation breaks Cooper pairs in a superconducting strip of aluminum, changing the resonance properties of a microwave transmission line. Light is collected with slotline antennas and separated into four bands by a bank of lumped element bandpass filters. Each passband is transmitted to an individual MKID, allowing simultaneous four-color sensitivity for every spatial pixel.



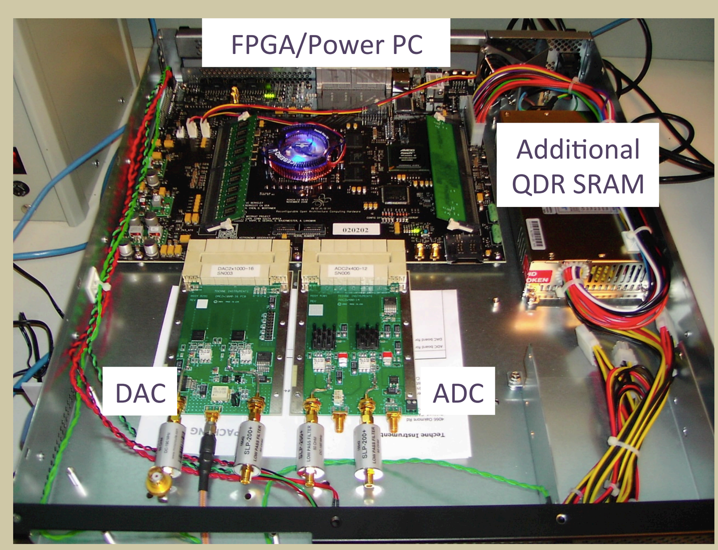




The original quarter-wave resonator design of the MKID has gone through several modifications from the original design. Most notable is the incorporation of an interdigitated coupling capacitor (IDC) to reduce the effects of two-level system noise in the phase-readout [8,9]. A stepped-impedance was incorporated to elminate any direct pickup from the IDC.

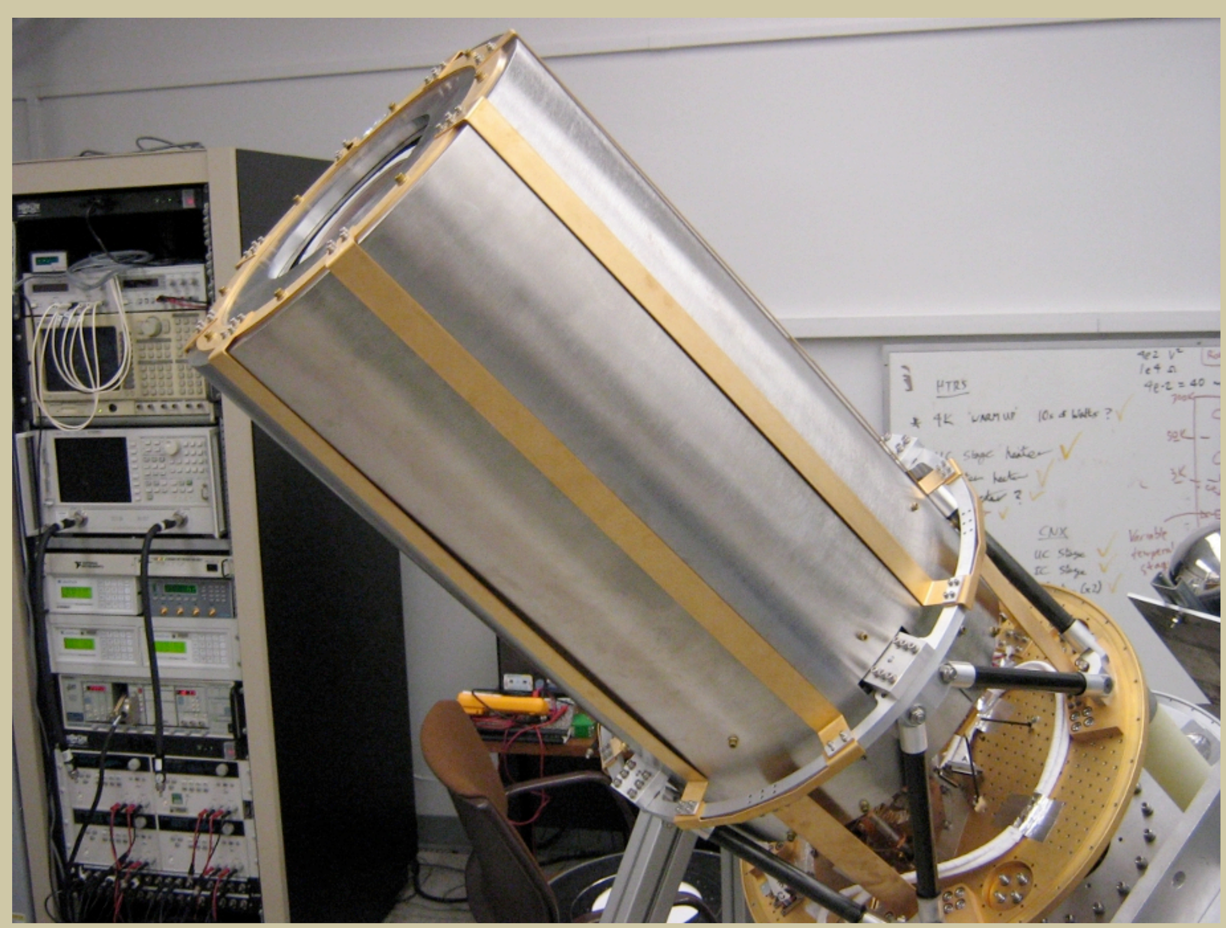
## FPGA-Based Readout

One of the primary advantages of MKIDs is that they allow large focal planes to be read out by only a few microwave transmission lines. Complex readout electronics can be transferred to room temperature. A full FPGA-based readout system has been developed, based on the CASPER-ROACH board. [10]




## Status of the Instrument

All of the cold hardware has been designed and installed for the MUSIC cryostat [11]. The focal plane will have sixteen detector tiles, such as the one in the figure above. A demo camera has been built to test one such tile at a time. Lower noise performance has been achieved by driving detectors with large powers [12]. In May of 2010, an observing run was made at the CSO with the demo camera. Sensitivities were measured between .25-.50 mJy $\sqrt{s}$, although background-limited performance was prevented primarily by low-frequency readout noise. Since then, a redesign of the ADC/DAC heat sinking has reduced the low-frequency contribution to the noise by about 10 dB, and an additional order of magnitude improvement is expected with closed-loop feedback of the amplifier bias supplies. Commissioning is expected to begin at the CSO in the Fall 2011.



## References

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