MUSTANG-2

MULITIPLEXED SQUID-TES ARRAY AT NINETY GHZ

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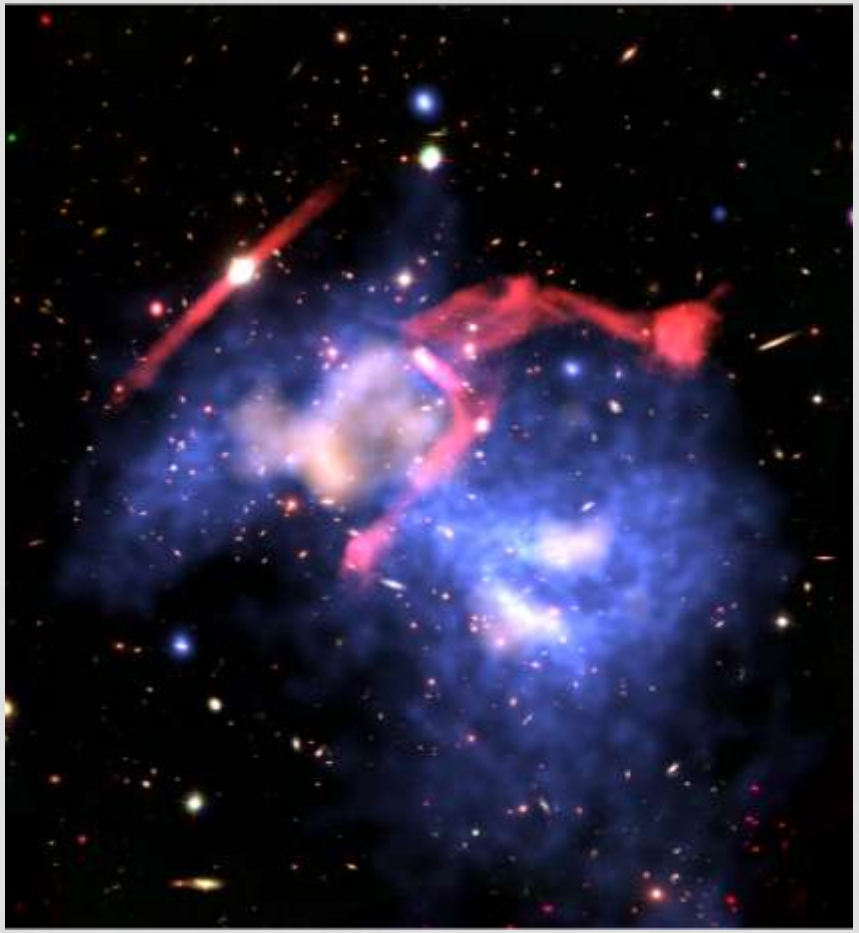
University of Pennsylvania
July 20, 2015

OUTLINE

- MUSTANG SCIENCE
- THE GREEN BANK TELESCOPE
- MUSTANG INSTRUMENT
- DETECTORS
- MULTIPLEXING
- READOUT ELECTRONICS

MUSTANG SCIENCE

- High resolution SZE imaging of galaxy clusters
- Probes density of gas in cluster
- Astrophysics
  - Mergers, AGN, star formation
- Cosmology
  - constrain SZE-mass scaling relation



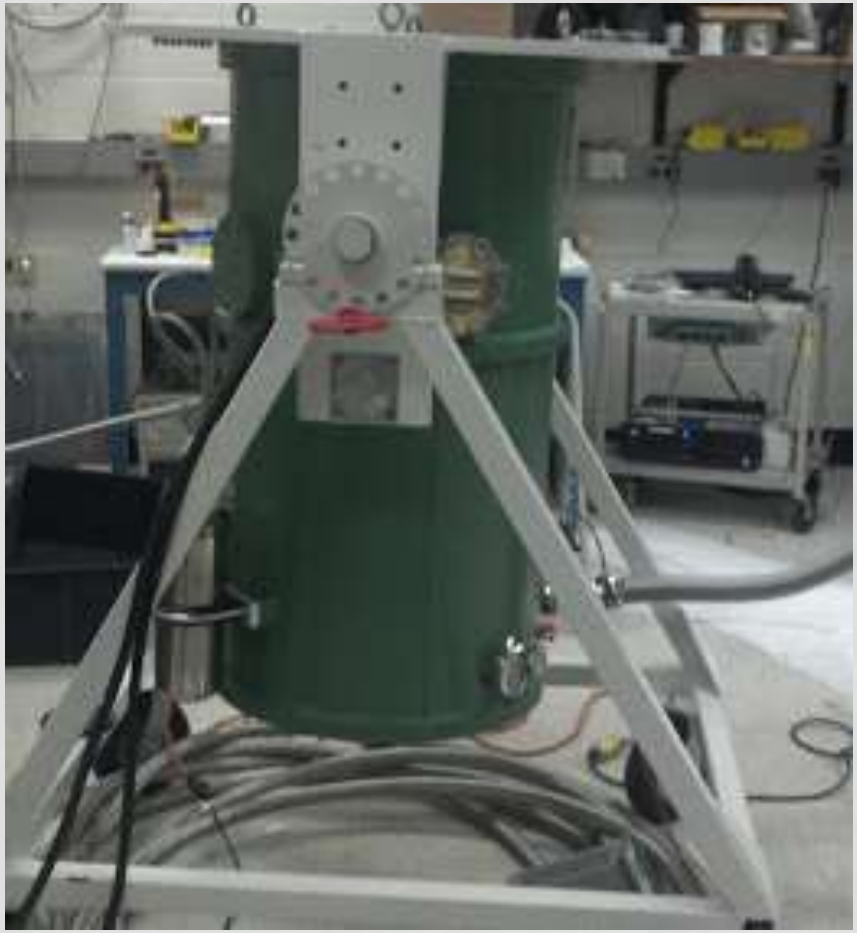
MUSTANG SZ 90 GHz Decrement, VLA S-Band (2-4 GHz), and Chandra X-ray data overlaid on HST multi-color image. Figure courtesy of Reinout van Weeren.

THE GREEN BANK TELESCOPE

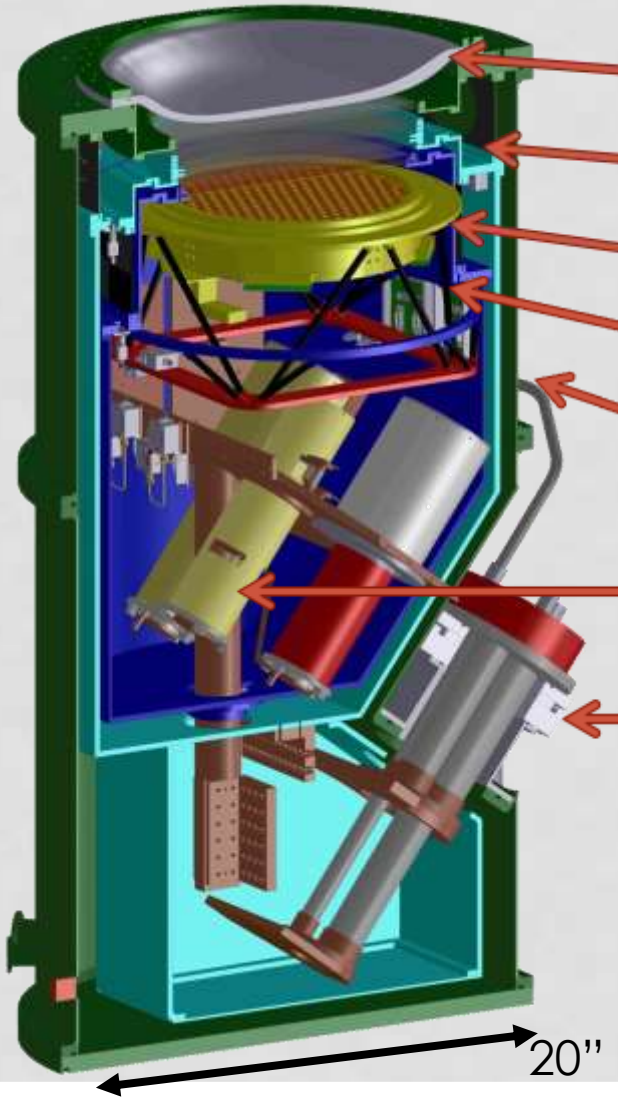
- Located in Green Bank, WV
- Operated by NRAO
- 100m single dish telescope
  - off-axis Gregorian
- 290 MHz to 100 GHz
- 2500 m^2 effective area at 90 GHz

MUSTANG-2

- 75-110GHz bandpass
- 215 element focal plane array
- Antenna coupled TES bolometers
- Frequency domain multiplexed readout
- 9” resolution
- 4’ FOV



MUSTANG 2



AR coated vacuum window

Filter Stack

Feedhorn array (300mK)

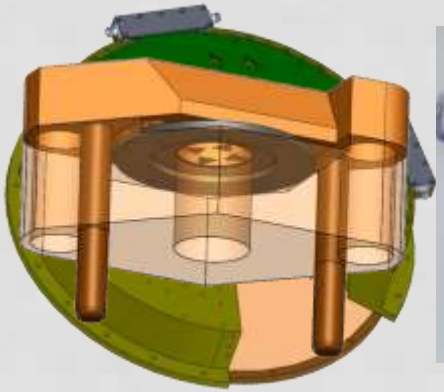
Carbon fiber supports

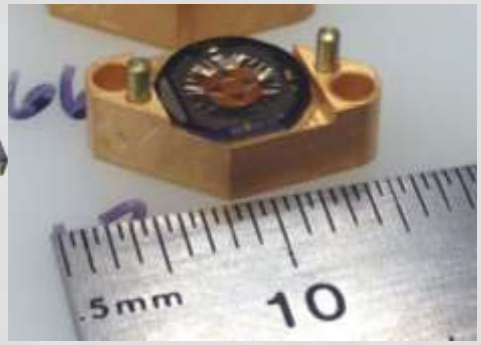
1K plate

Helium-3 sorption refrigerator

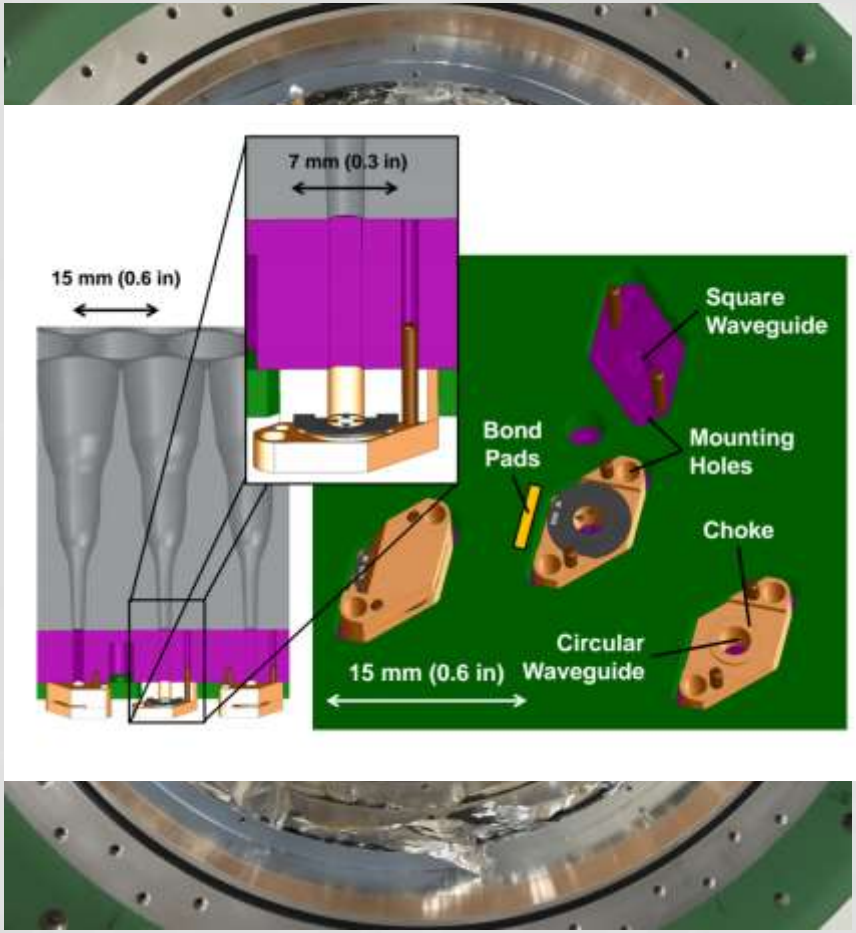
PT 410 pulse tube from CryoMech
(1W cooling at 4.2K; 30W at 40K)

FOCAL PLANE ARRAY

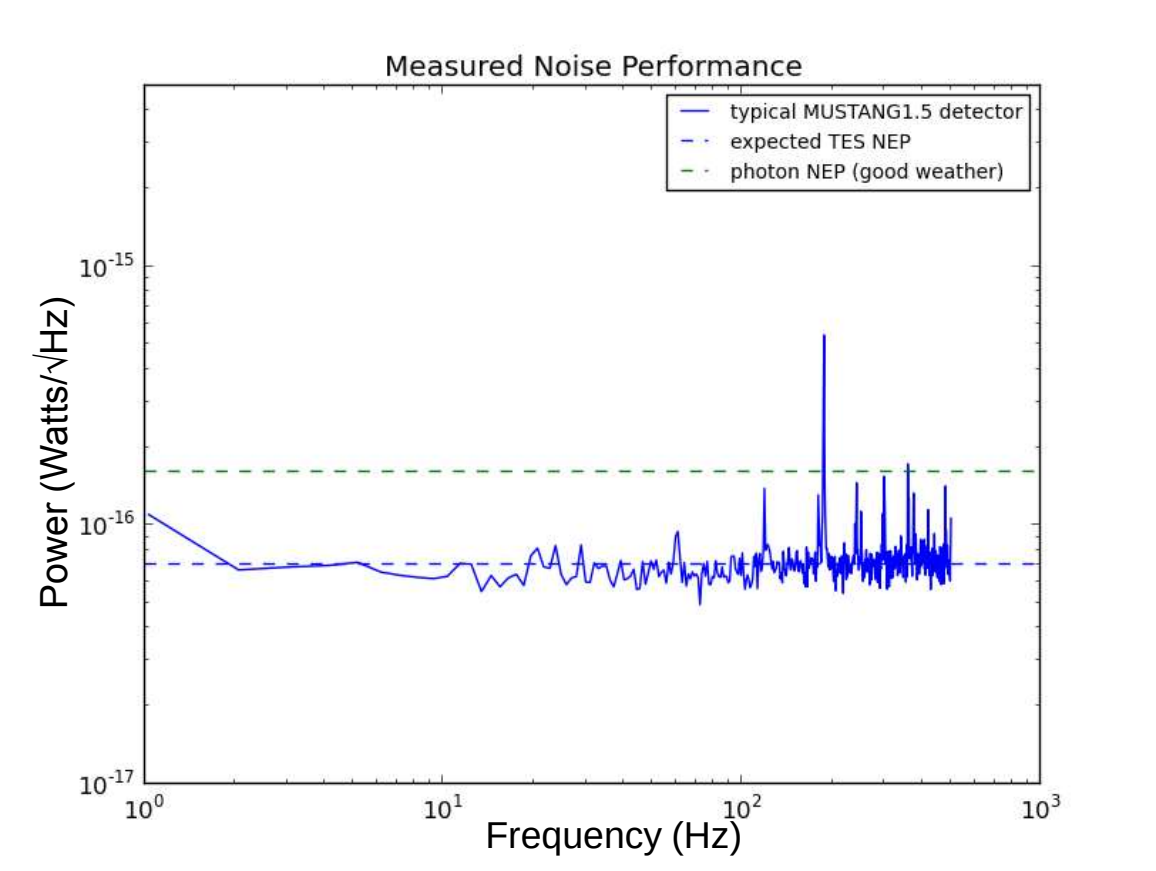




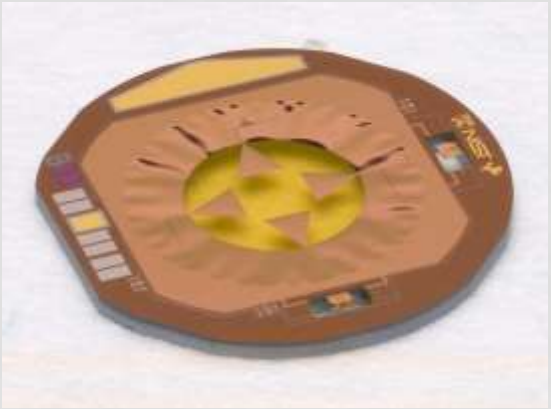
- Feeds machined out of a single block (1.9 fλ)
- Square waveguide plate
  - Provides 75GHz cutoff
- Each detector installed in a separate module
- Superconducting circuit board connects detectors to multiplexing chip



DETECTORS

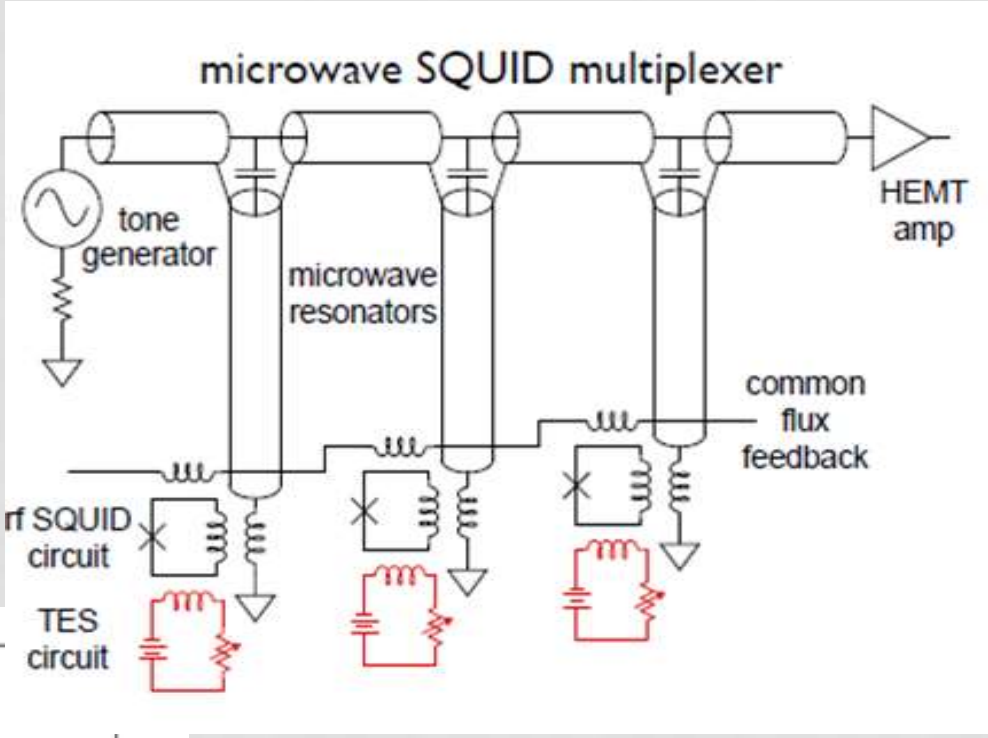


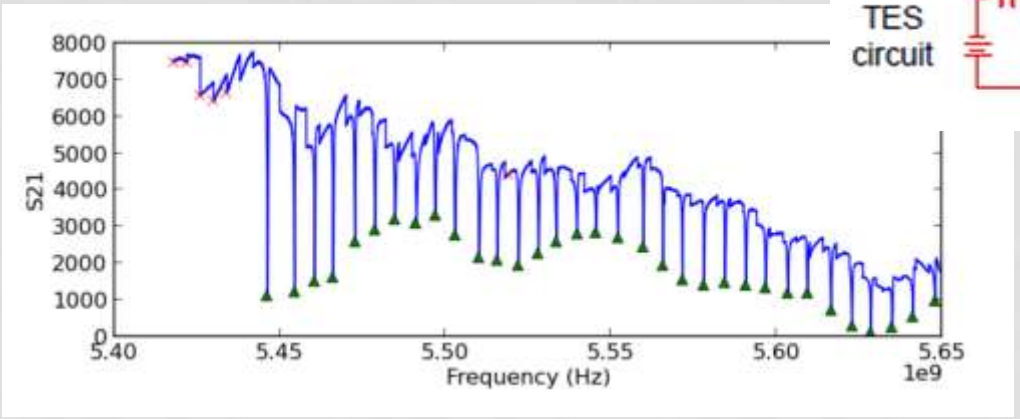
- Antenna coupled TES
- Dual polarization pixels
- Fabricated at NIST
- 480mK T_c



READOUT

- Multiplex hundreds of detectors on a single pair of "wires"
- Modified ARCONS firmware

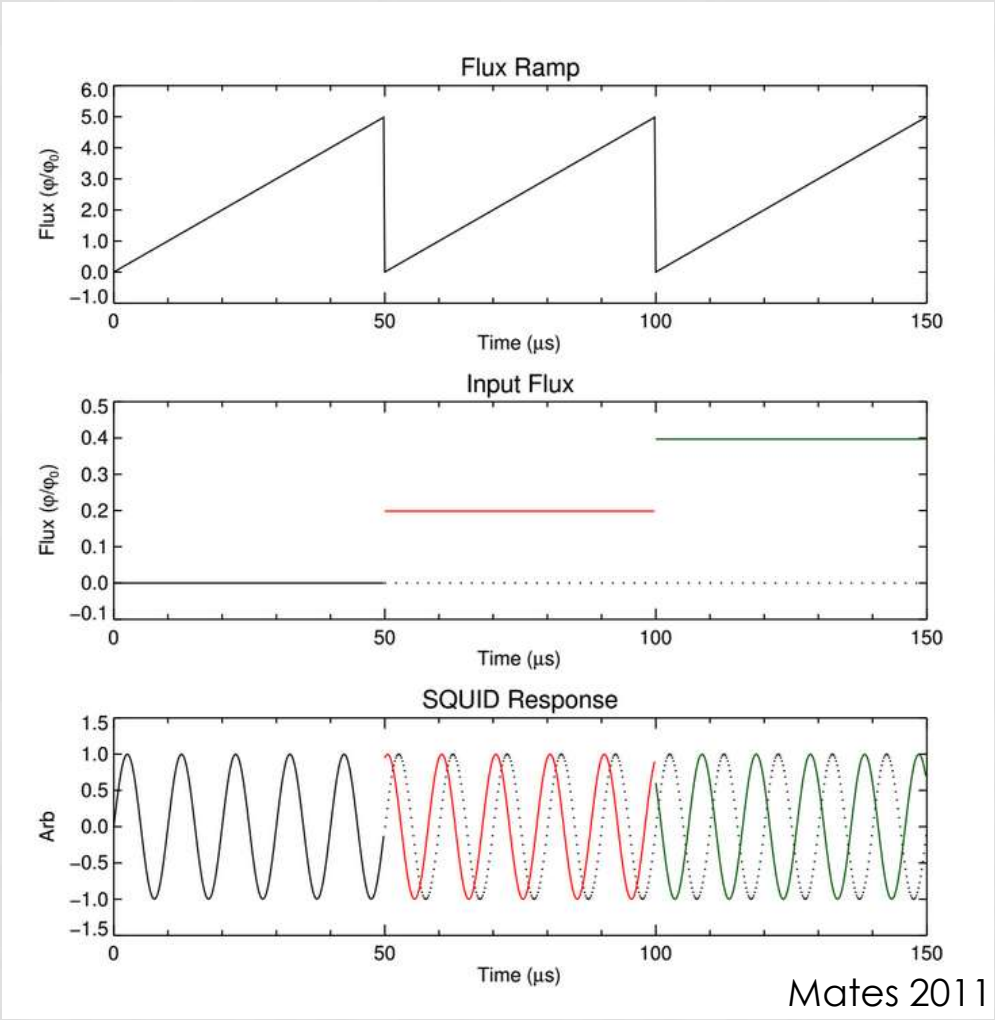




Check out Ben Mates' talk in session 3, Tuesday afternoon!

Figures: Mates 2011

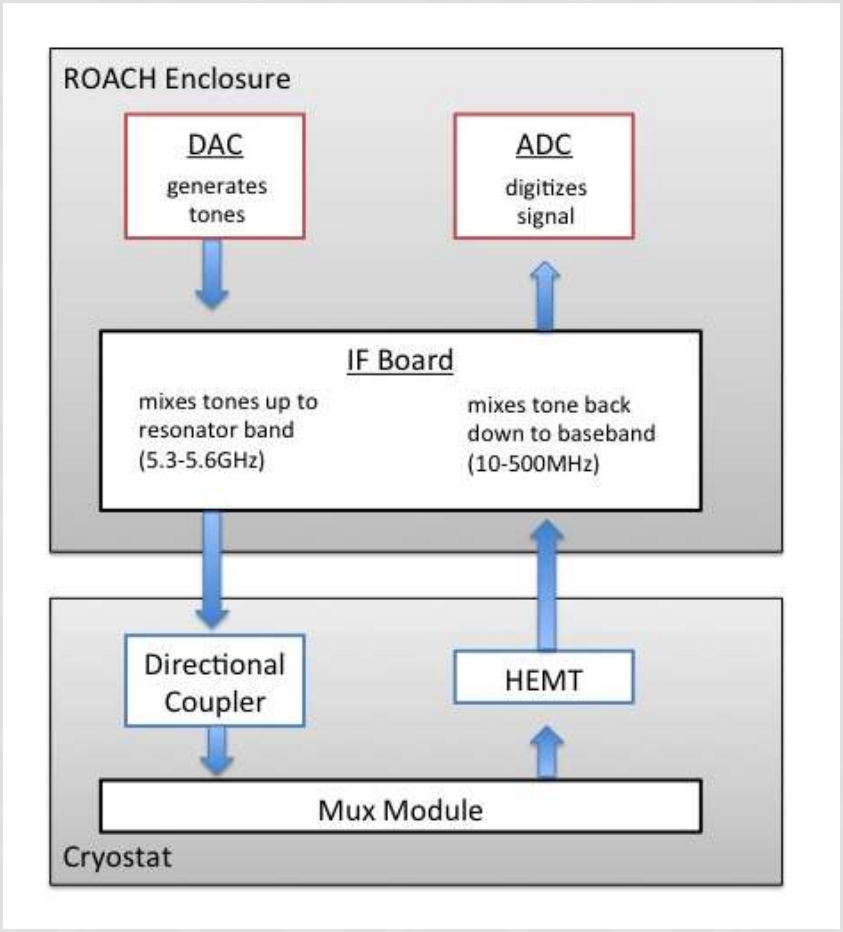
SQUID MULTIPLEXING READOUT

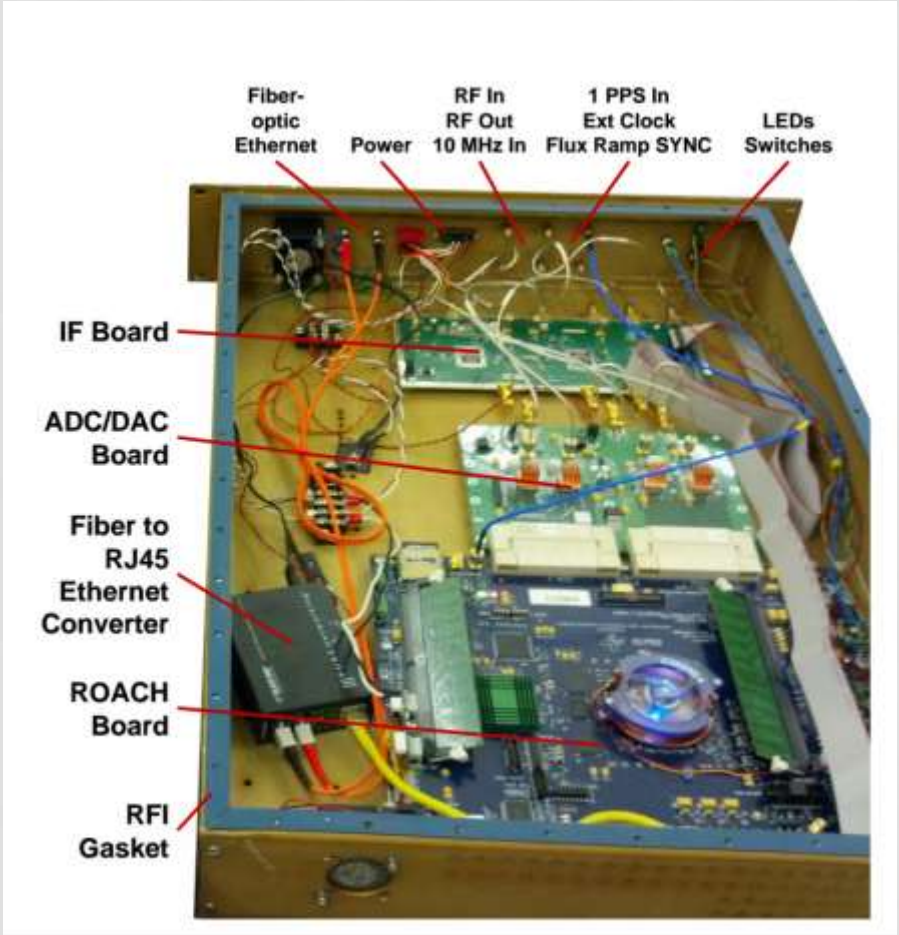


Mates 2011

READOUT ELECTRONICS

- Commercially available ROACH board – developed by CASPER





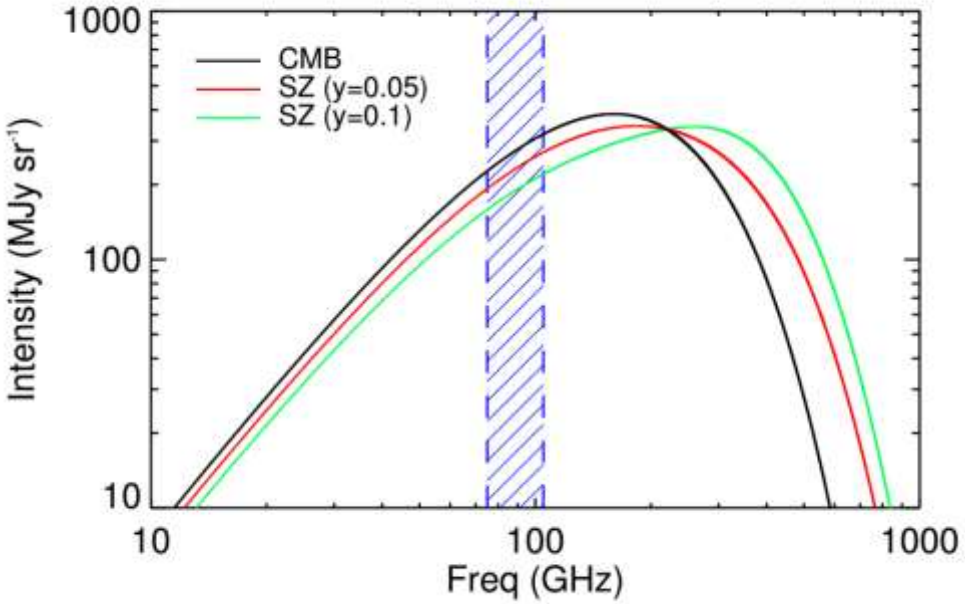
CONCLUSIONS

- MUSTANG-2 is a 215 element TES array
- Frequency domain multiplexed w/μMUX
- Facility class instrument at GBT
- Deploying early 2016

THANK YOU

- MUSTANG COLLABORATION:
  - Ade Peter A., Cardiff University
    Aguirre James, UPenn
    Brevik Justus A., NIST
    Cho Hsiao-Mei, Stanford University
    Datta Rahul, University of Michigan
    Devlin Mark J., UPenn
    Dicker Simon R., UPenn
    Dober Bradley, UPenn
    Egan Dennis, NRAO
    Ford Pam, NRAO
    Hilton Gene, NIST
    Hubmayr Johannes, NIST
    Irwin Kent D., Stanford University
    Marganian Paul, NRAO
    Mason Brian S., NRAO
  - Mates John A.B., NIST
    McMahon Jeff, University of Michigan
    Mello Melinda, NRAO
    Mroczkowski Tony, US Naval Research Lab
    Romero Charles, University of Virginia
    Stanchfield Sara, UPenn
    Tucker Carole, Cardiff University
    Vale Leila, NIST
    White Steve, NRAO
    Whitehead Mark, NRAO
    Young Alexander H., UPenn

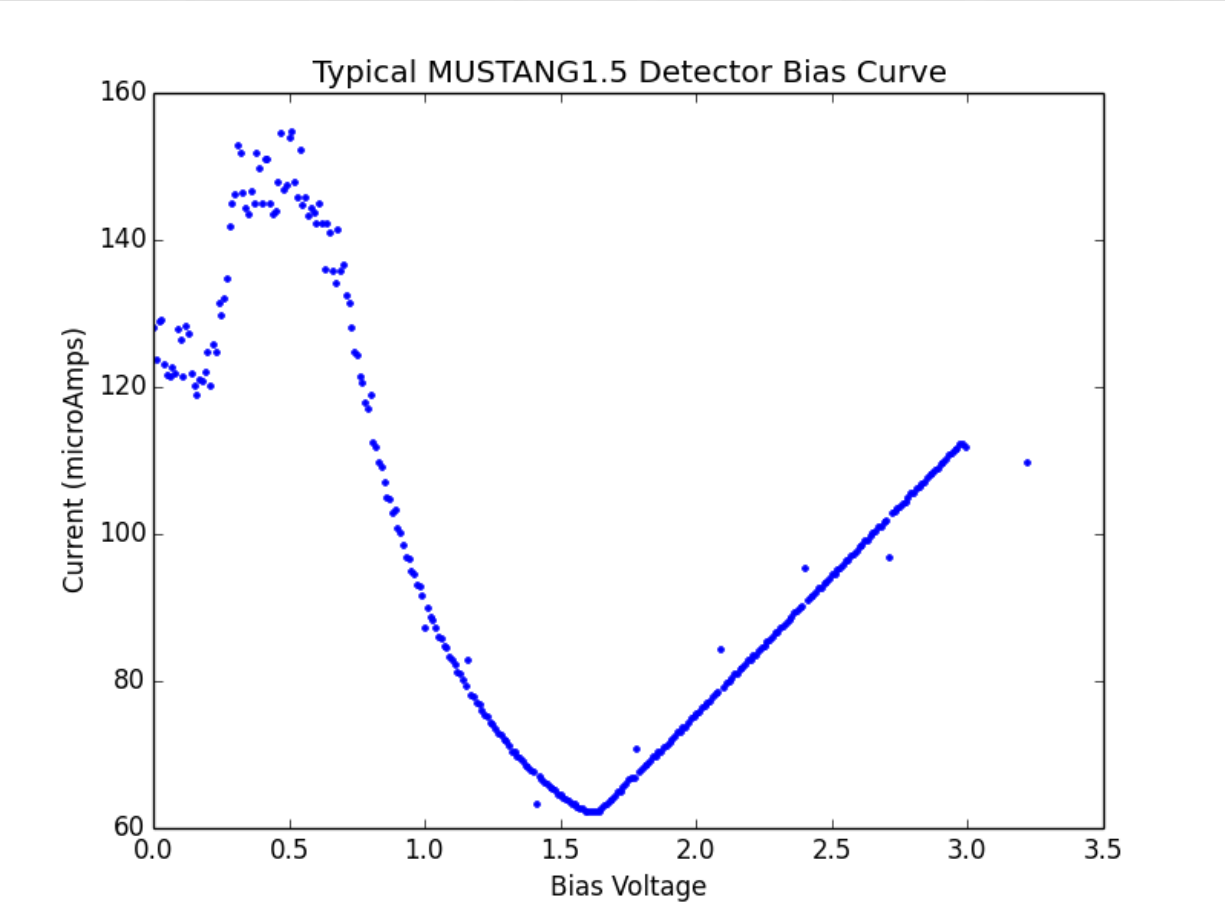
THE SUNYAEV-ZEL'DOVICH EFFECT



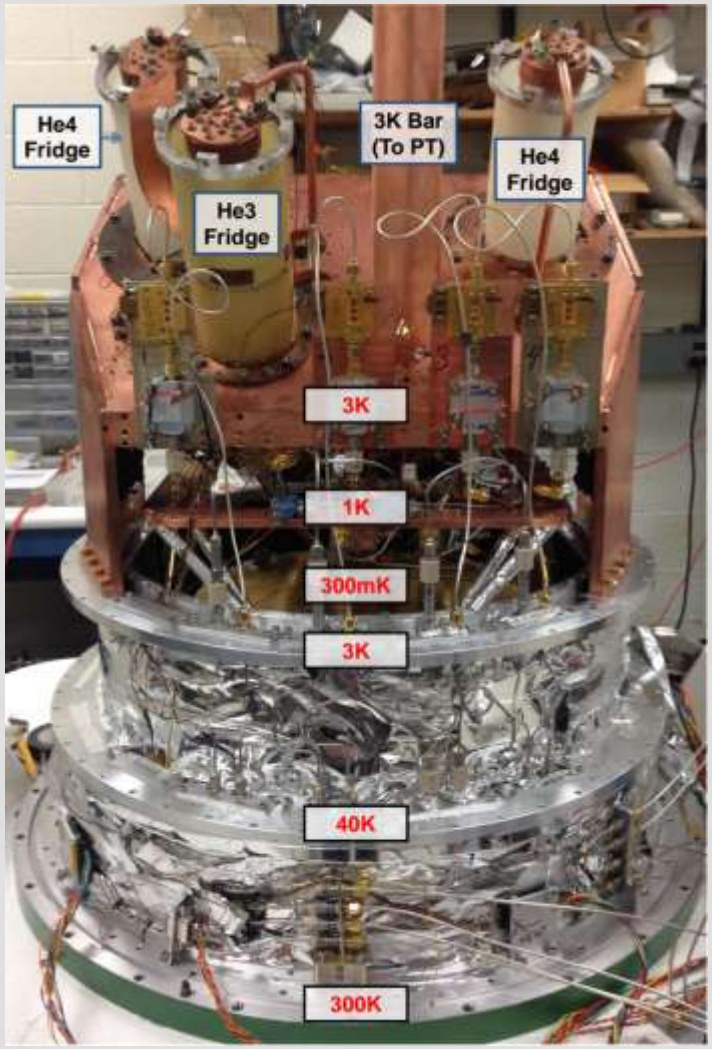
- CMB photons inverse scatter off energetic electrons in the ICM
- Magnitude of the distortion in CMB intensity is proportional to the Compton-y parameter:

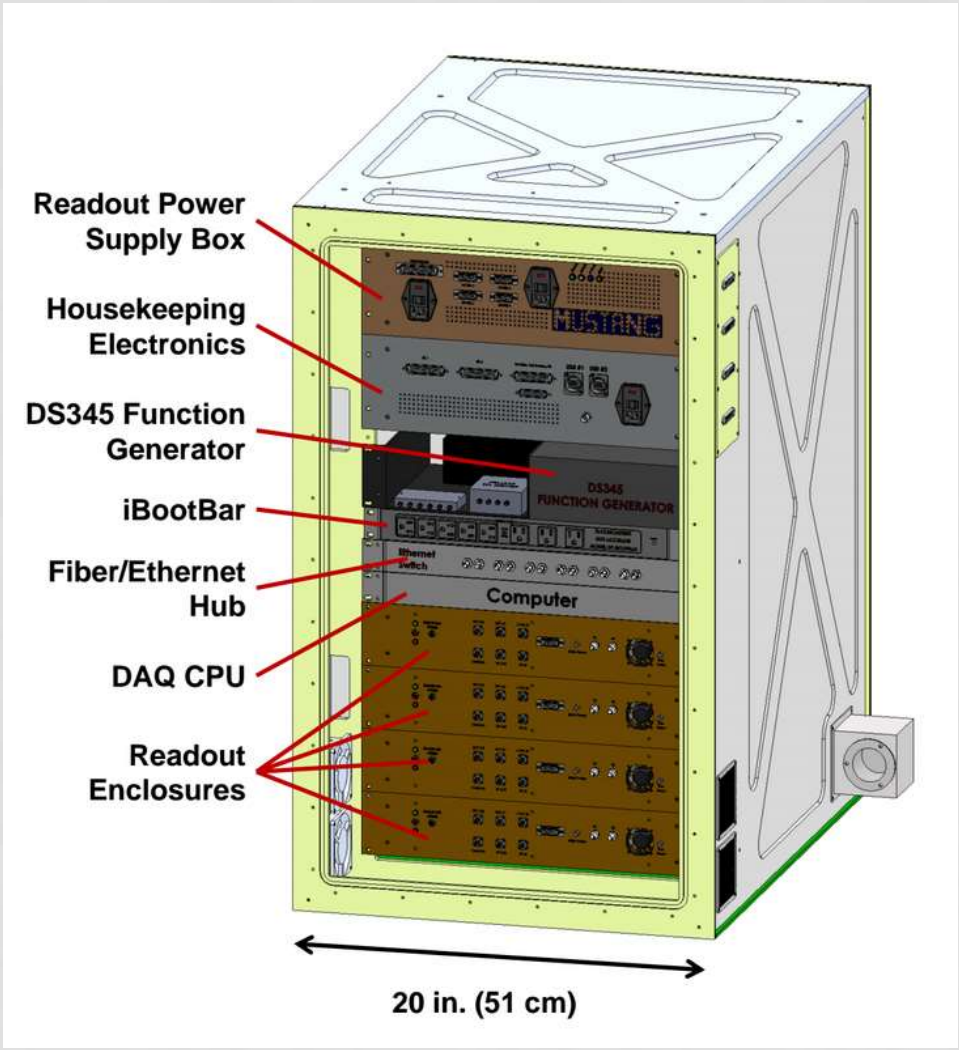
$$\Delta I_{SZE} \propto y \equiv \int P_e d\ell,$$

DETECTORS


Typical MUSTANG1.5 Detector Bias Curve
Current (microAmps)
Bias Voltage
160
140
120
100
80
60
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

MUSTANG2


He4 Fridge
3K Bar (To PT)
He4 Fridge
He3 Fridge
3K
1K
300mK
3K
40K
300K


Readout Power Supply Box
Housekeeping Electronics
DS345 Function Generator
iBootBar
Fiber/Ethernet Hub
DAQ CPU
Readout Enclosures
DS345 FUNCTION GENERATOR
Computer
20 in. (51 cm)

SQUID MULTIPLEXING READOUT