



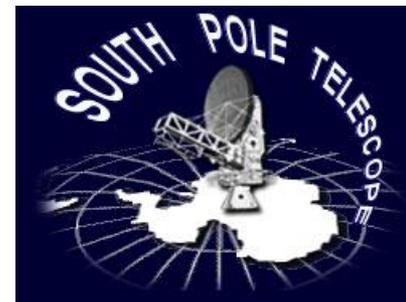
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Characterising Superconducting Detectors for the Cosmic Microwave Background

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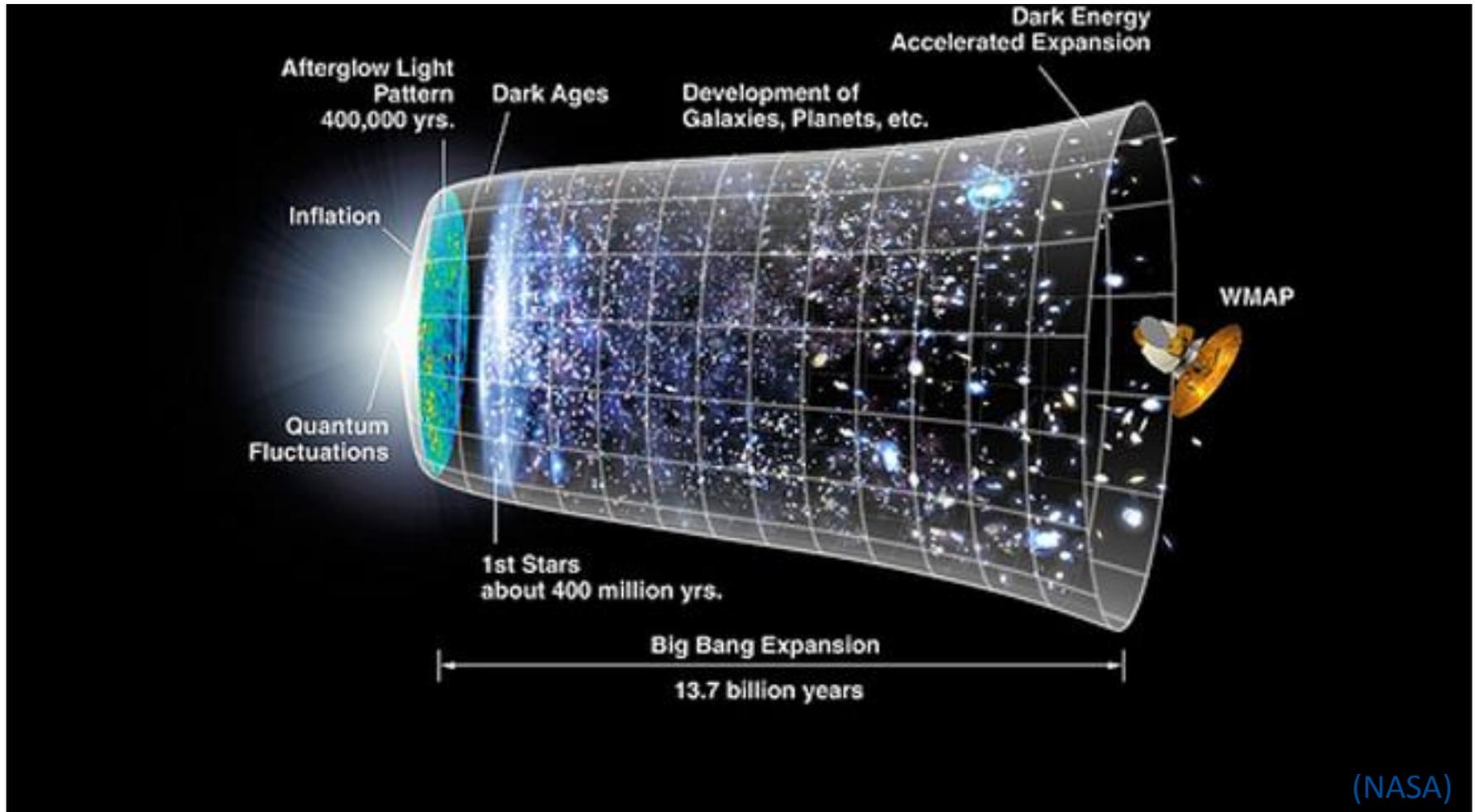
August 2015



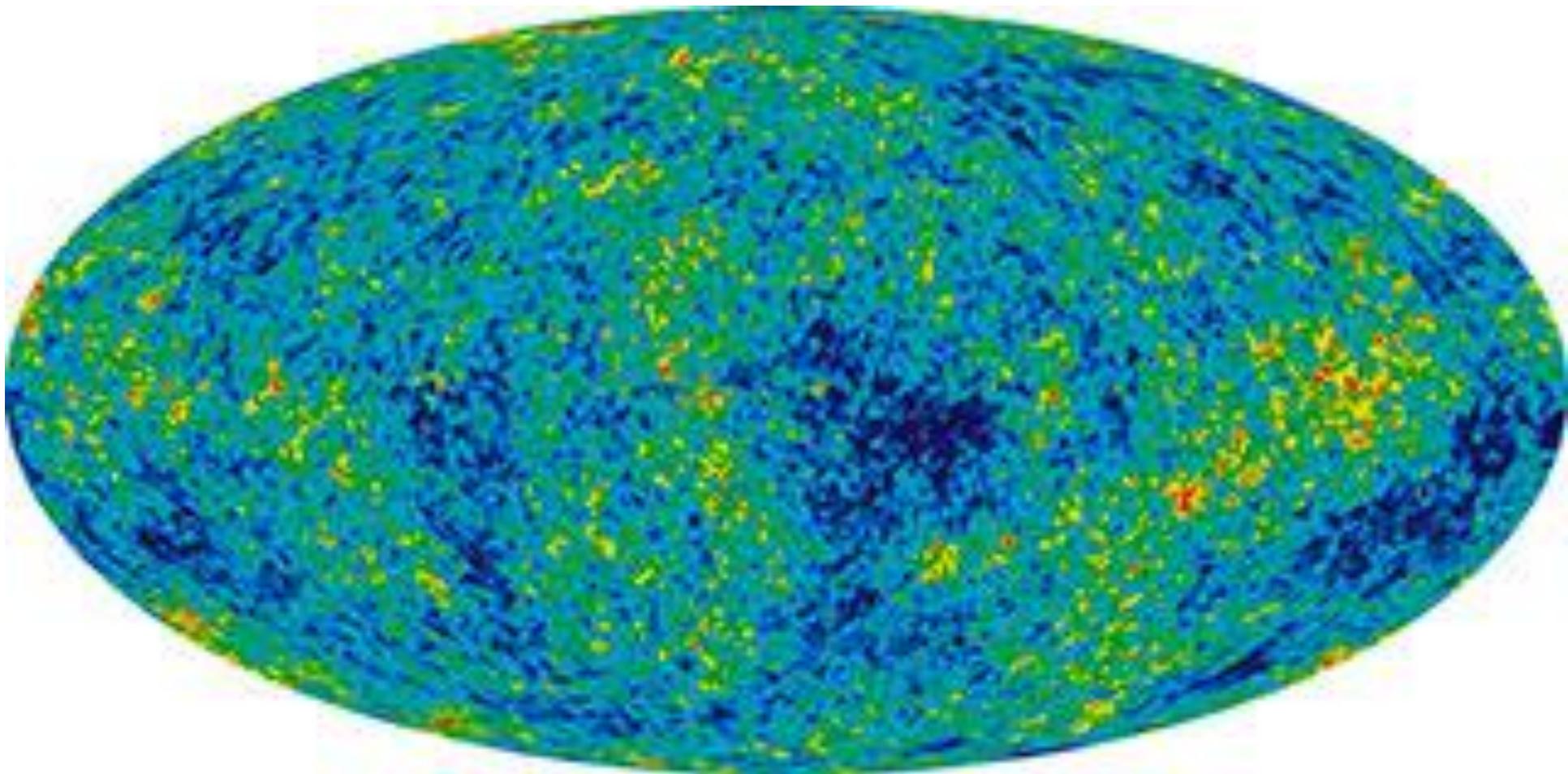
Introduction

- Background on the CMB
- The South Pole Telescope
- SPT-3G and our detectors
- Cryogenic Environment
- Blackbody Cold Load

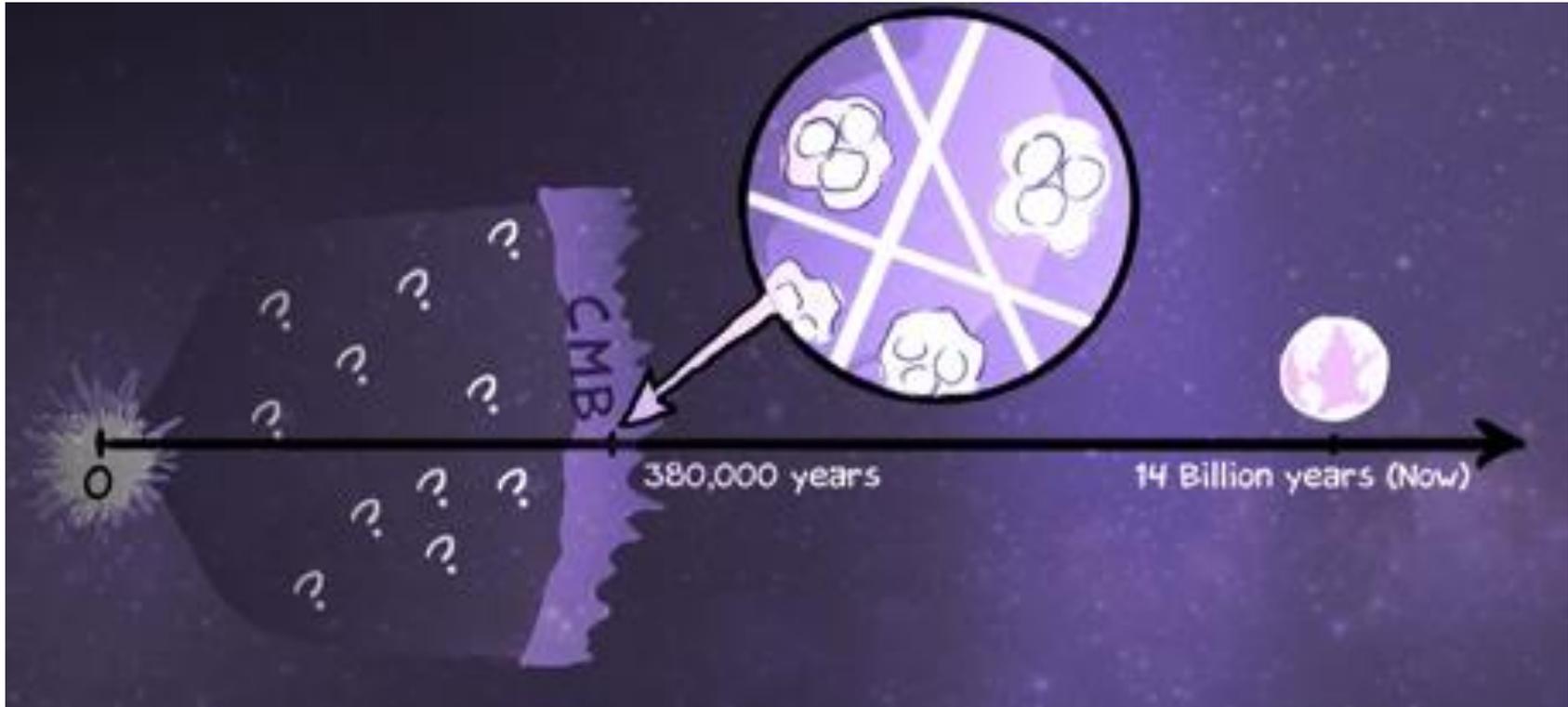
Motivation: Probing the Early Universe



The Cosmic Microwave Background (CMB)



CMB

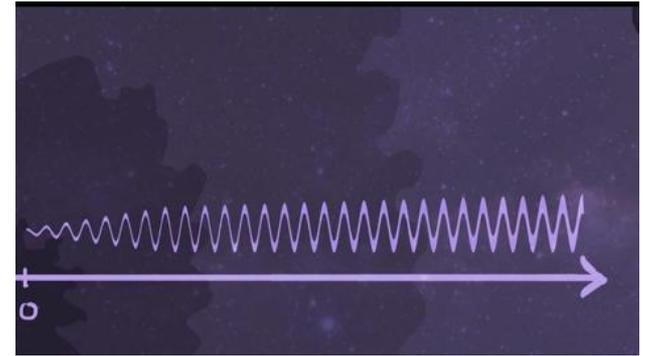


- The CMB gives us a picture of the Universe, when it transitioned from an optically-thick ionized-plasma to neutral, which occurred $\sim 380,000$ years after the Big Bang
- It is isotropic in temperature and brightness to one part in 100,000, which suggests the Universe was causally connected earlier in its history

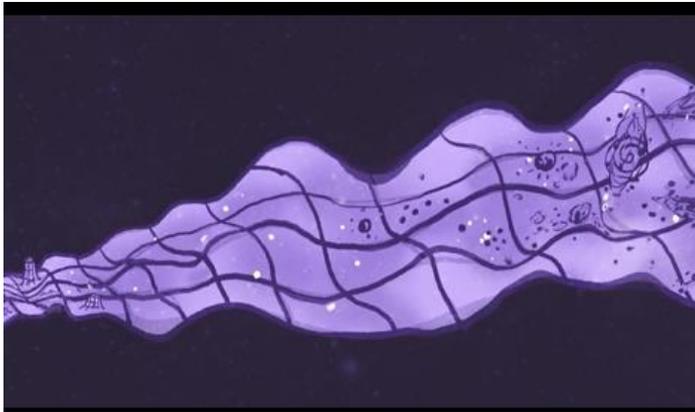
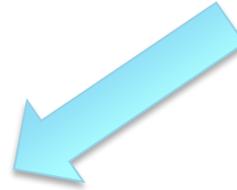
What does the CMB tell us? Inflation



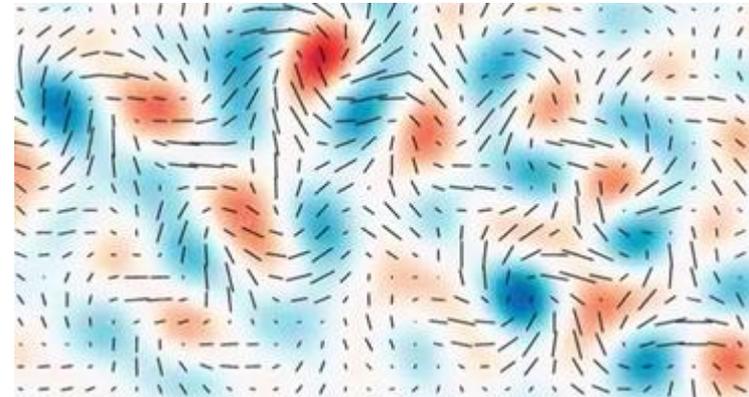
Exponential expansion after the Big Bang



Expansion of quantum fluctuations in tiny Universe

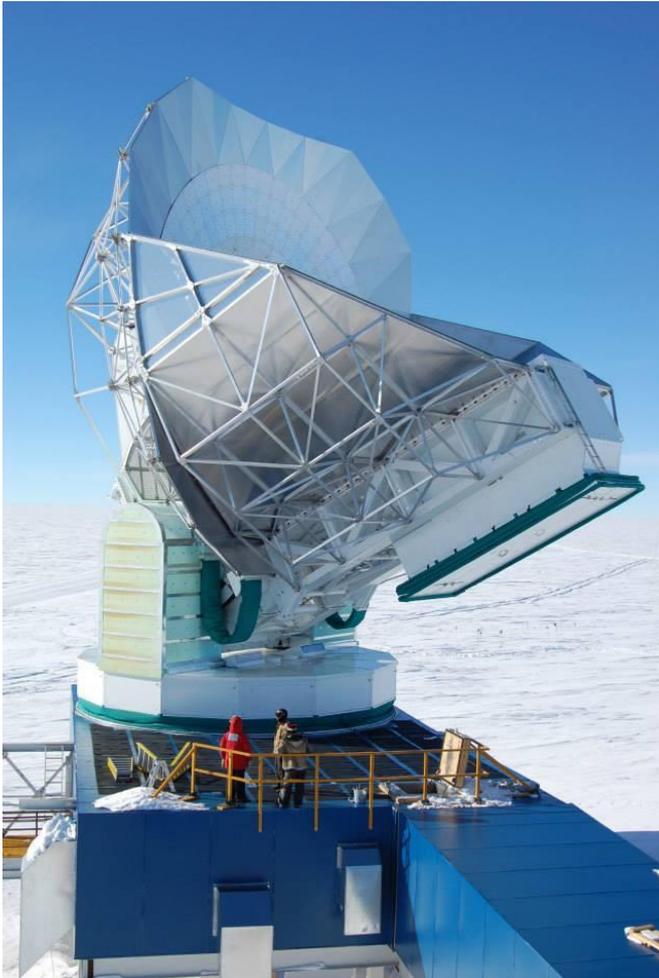


Ripples in space-time, in which matter could clump together



Induce a curl-like pattern in the CMB polarization

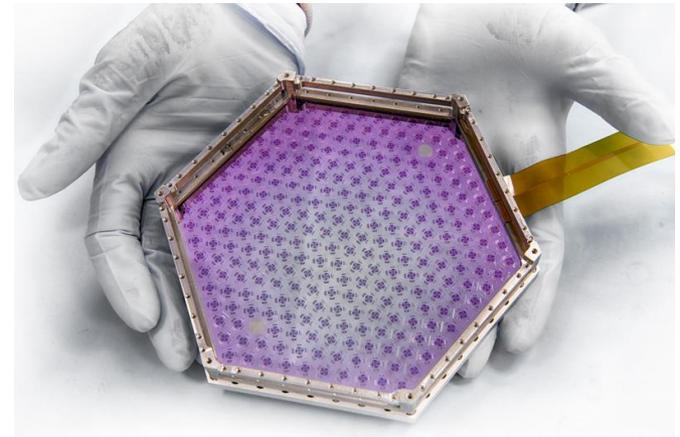
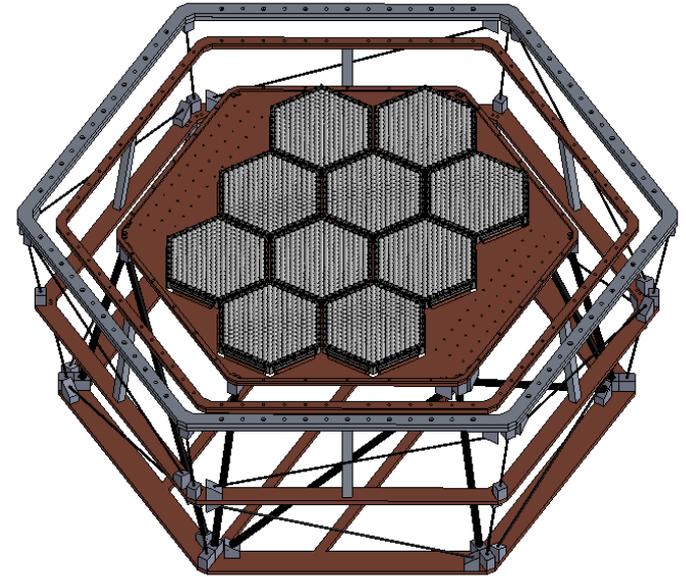
The South Pole Telescope



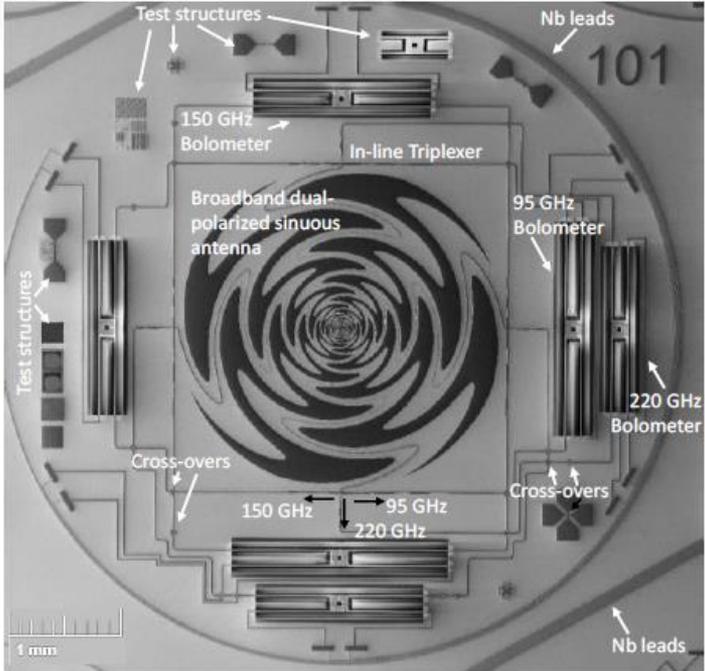
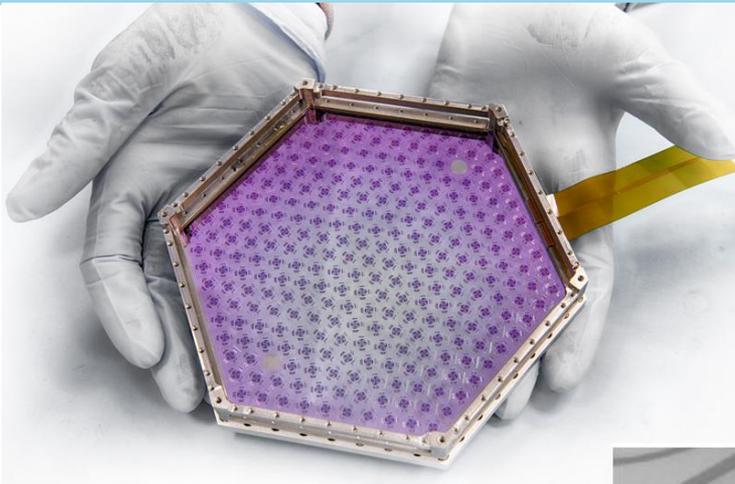
- 10 m mm-wavelength telescope
- South Pole: ideal location with high altitude and dry atmosphere
- SPT-3G third generation
- ~10x more detectors than SPT-Pol
- ~20x larger mapping speed

Detector Array

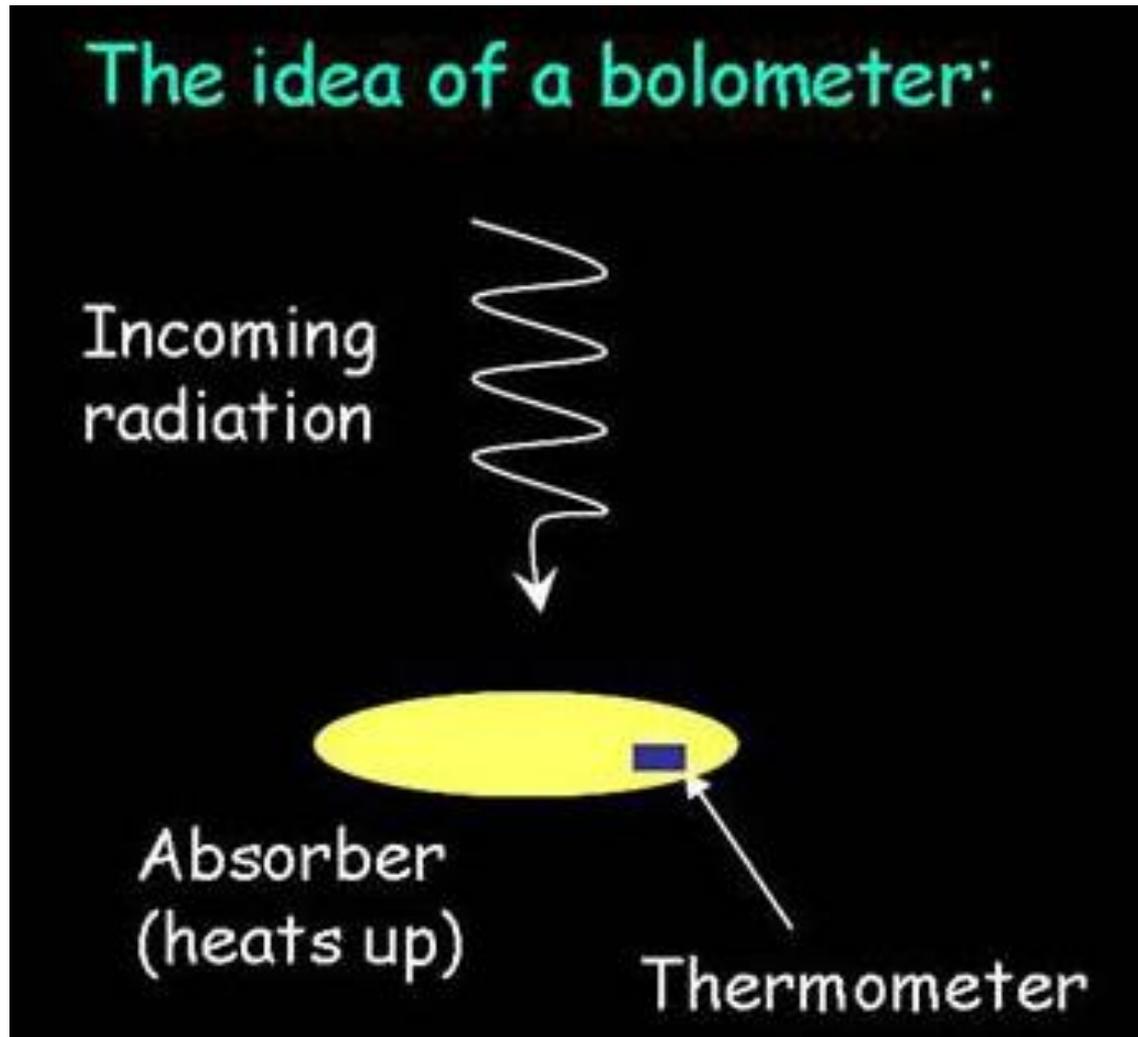
- The SPT-3G focal plane consists of 10 detector arrays.
- 271 pixels per array with 6 detectors per pixel: 16,200 detectors!!
- Each pixel measures the linear polarization in three different frequency bands at 90, 150, and 220 GHz.



Detector Design

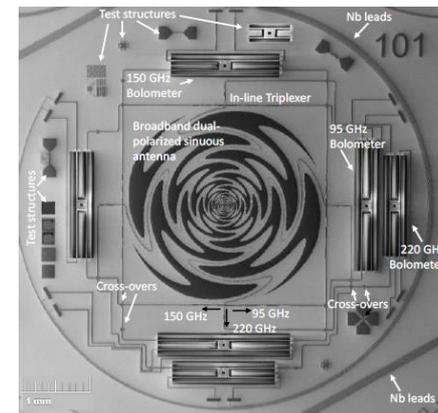
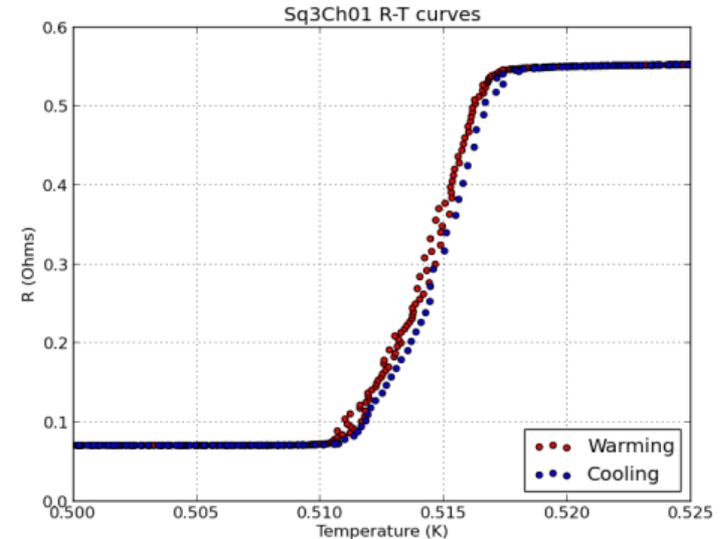


Bolometers



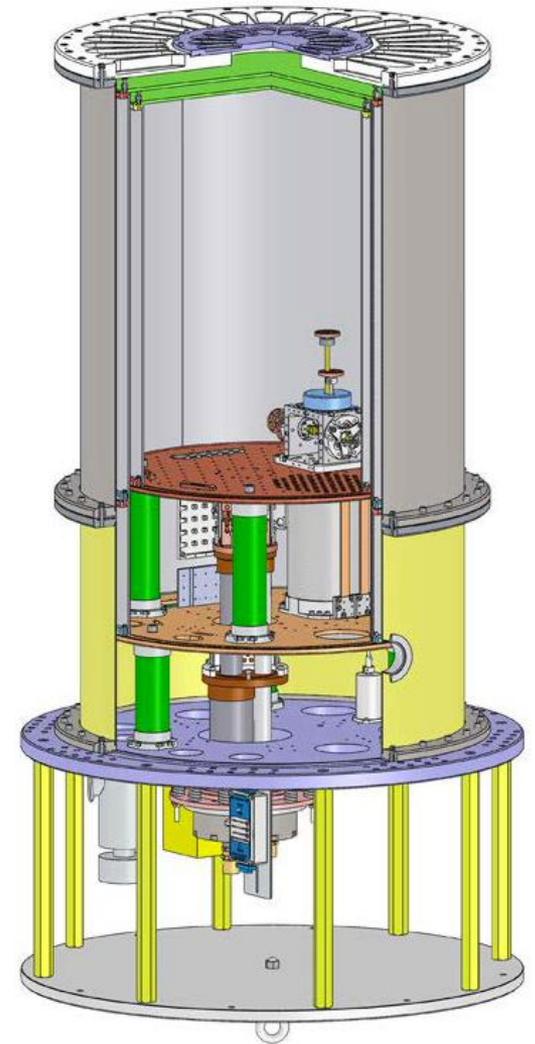
Transition Edge Sensor (TES) Bolometers

- TES on bolometer operates on its superconducting transition
- Large change in electrical resistance for small temperature change: Steepness allows high sensitivity
- 6 TES detectors per pixel for each polarization and frequency

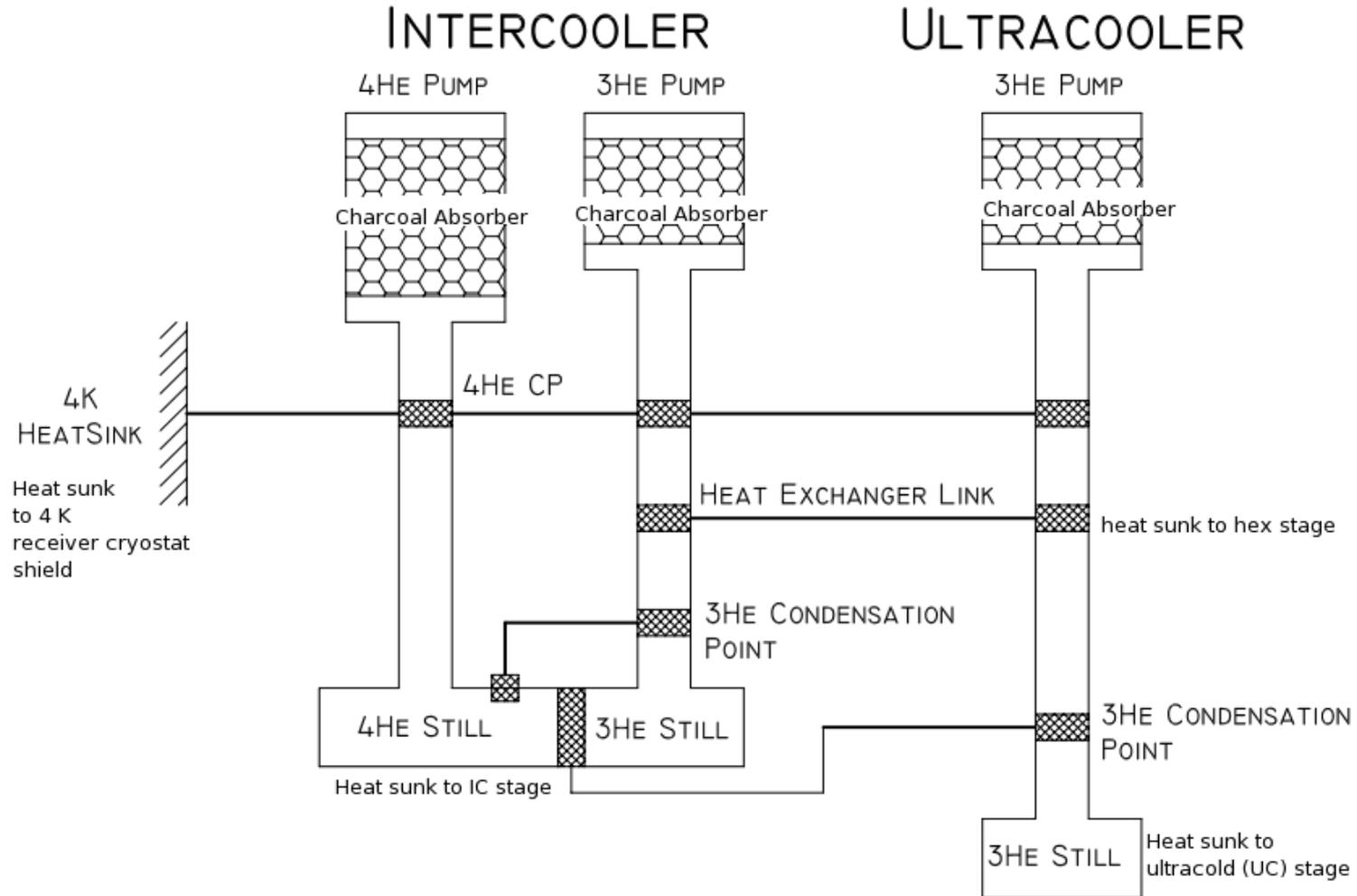


Cryogenic Environment

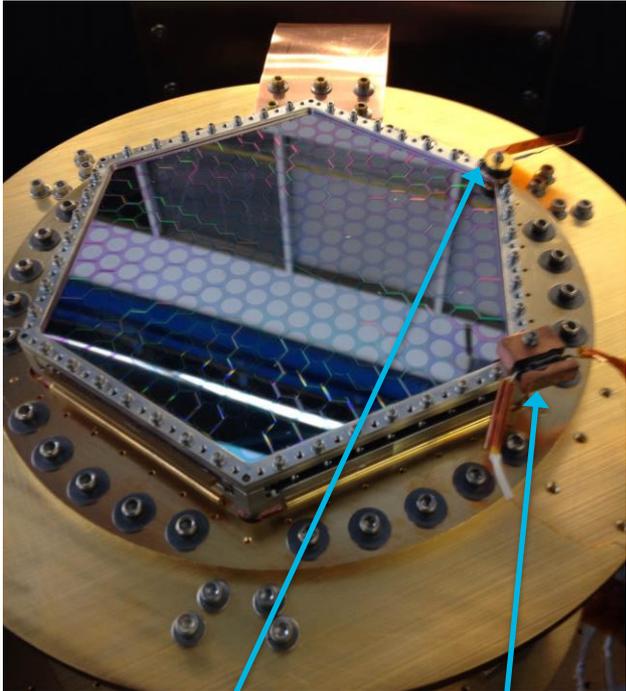
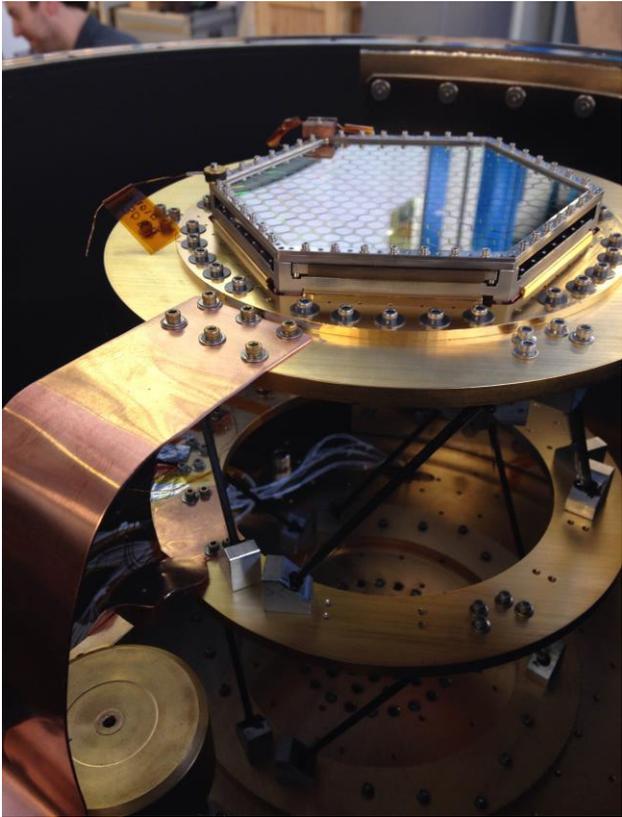
To reduce their noise, the detectors are cooled to 250 mK via a three-stage He4-He3-He3 sorption refrigerator.



He4-He3-He3 sorption refrigerator



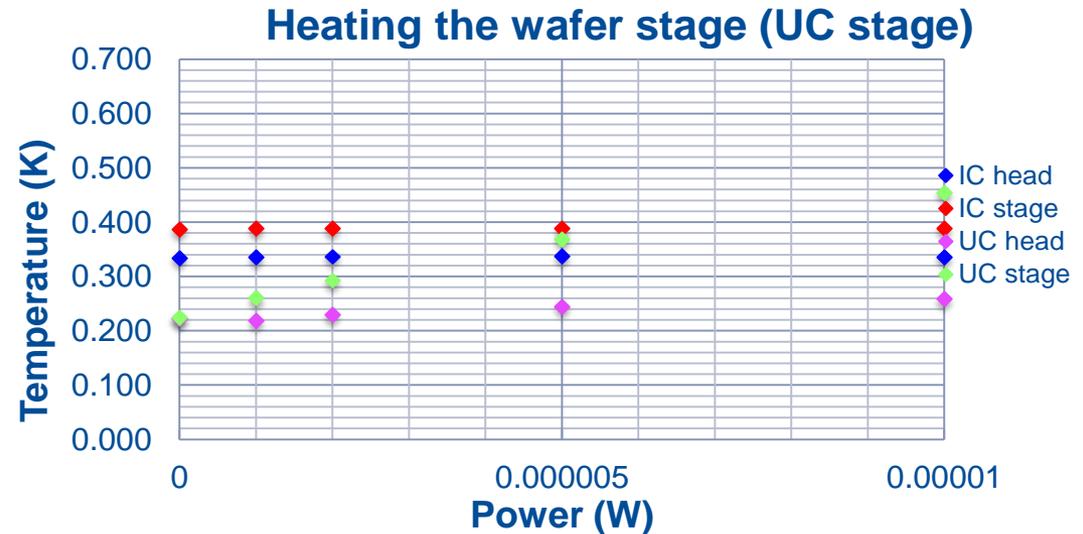
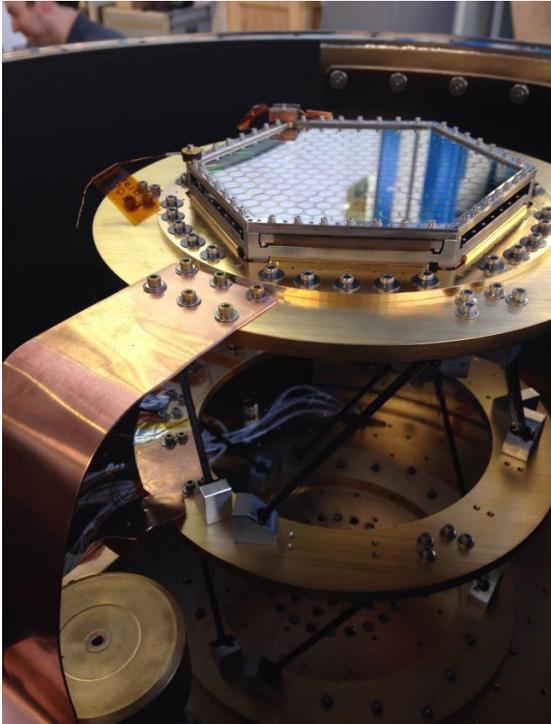
Inside the Cryostat



Temperature sensor (diode)

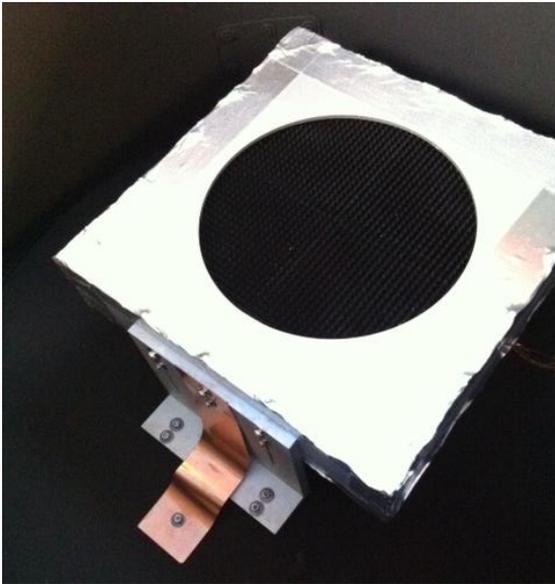
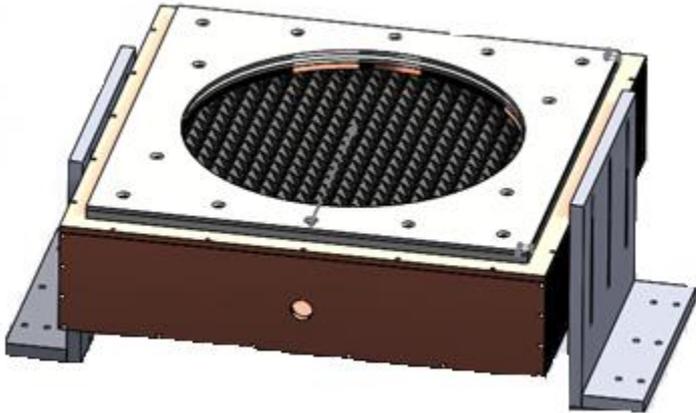
Heater (resistor)

Characterising Thermal Properties of Wafer



- Heater power increased on stage and temperature monitored
- Characterize thermal gradient between detector wafer and ultra cold (UC) head

Blackbody Cold Load

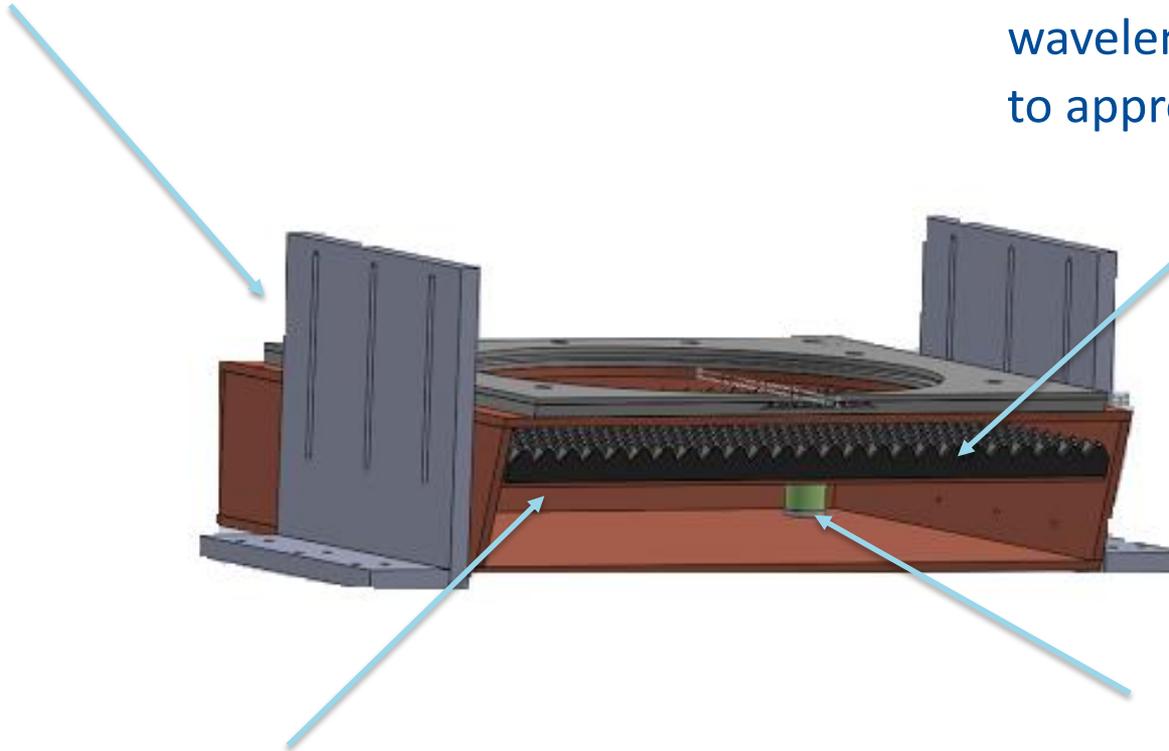


- Blackbody Cold Load designed to imitate CMB radiation
- Held below wafer in cryostat
- Characterize the efficiency of the detectors to absorb mm-wavelength radiation.

Blackbody Cold Load Design

Support legs attached to 4K stage of cryostat, to hold the blackbody source half an inch below the detectors.

Pyramidal **black polypropylene** acts as a blackbody source at mm-wavelength wavelengths, to approximate the CMB.

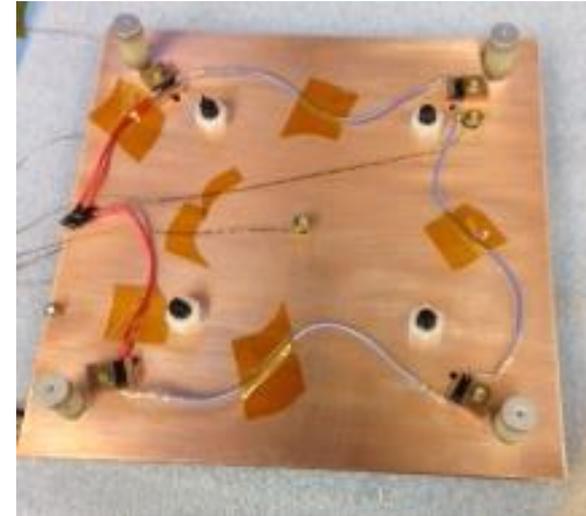


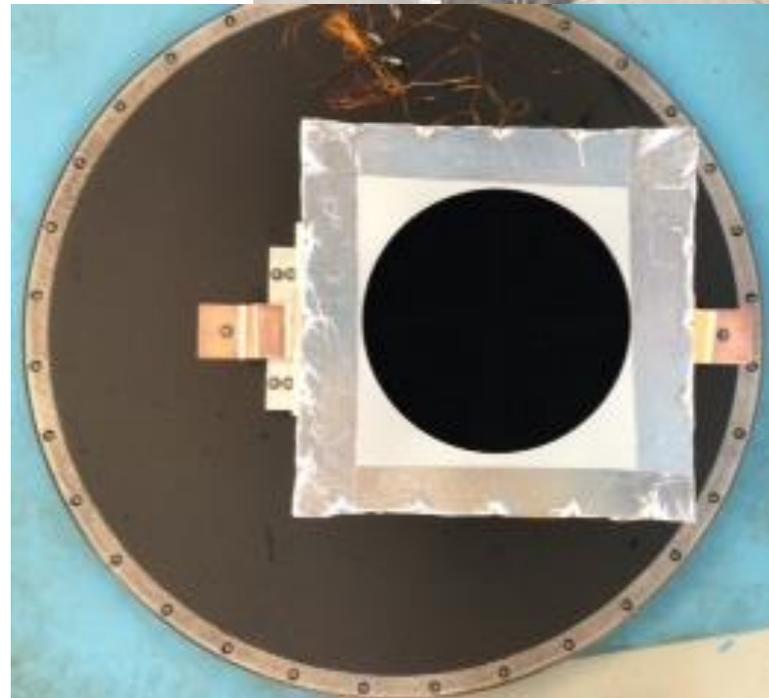
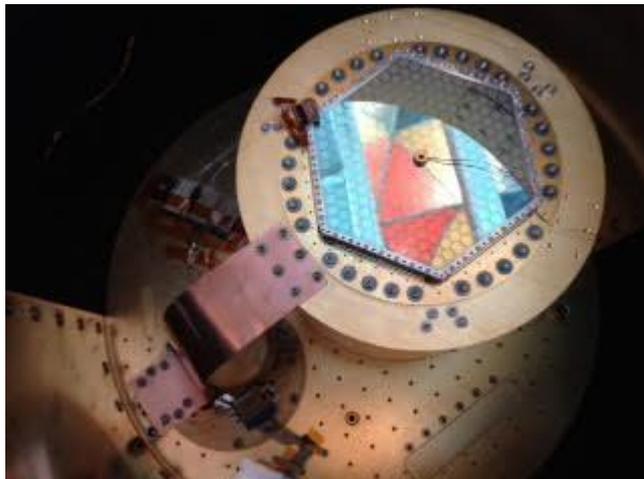
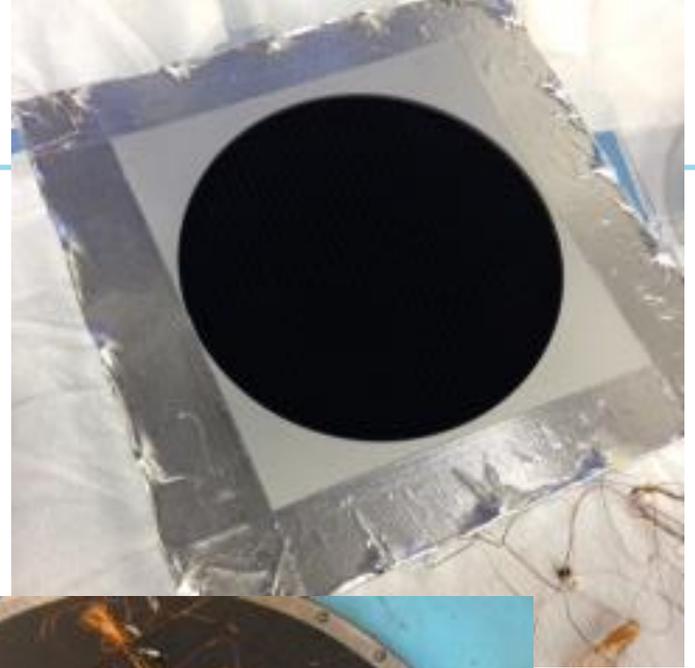
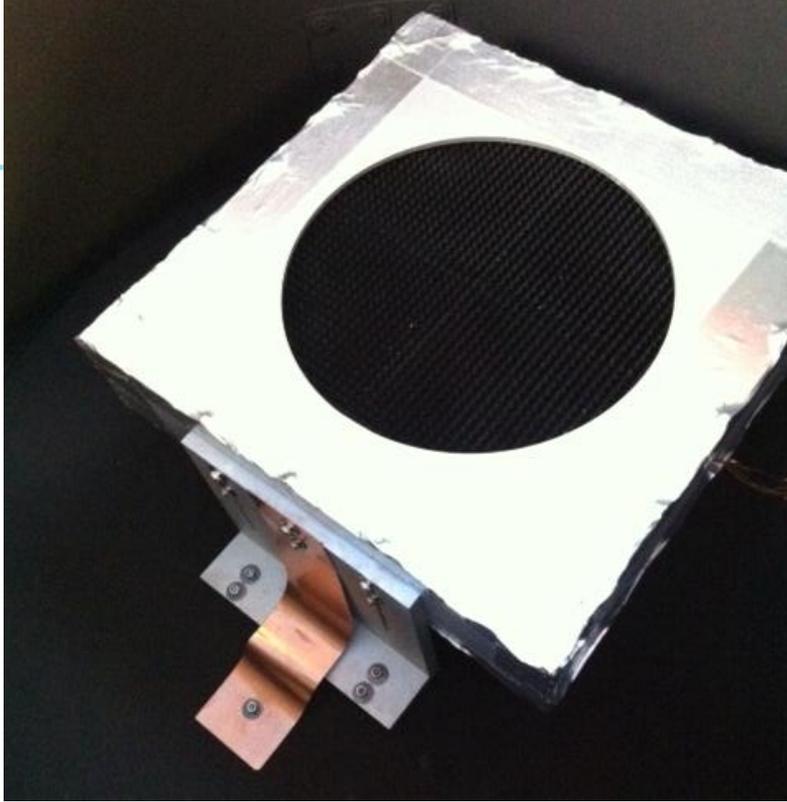
Copper plate

G10 legs: insulate copper plate from aluminum box and for stability.

Heaters

- 4 x 1.4kOhm resistors to give a maximum power output of $\sim 70\text{mW}$.
- Generate radiation from the black polypropylene such that it reaches the wafer at $\sim 25\text{K}$.
- This corresponds to the temperature of the CMB as seen by SPT due to atmospheric and telescope optics increasing the loading from 2.7K .





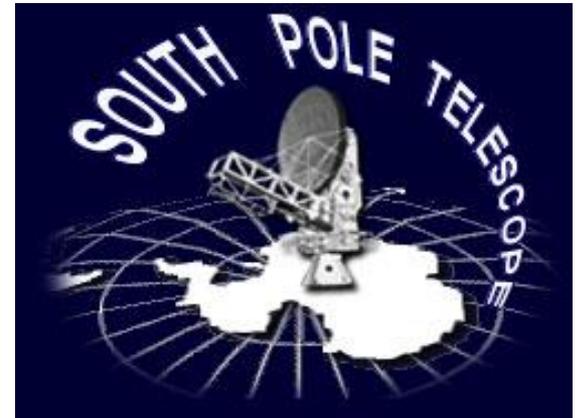
Next Steps..

- Basic temperature measurements of blackbody within cryostat: Cooling down currently.
- Testing of detectors inside cryostat using blackbody source.
- Eventual deployment of detector array to the South Pole.



What have I learnt?

- Hands on experimental physics work: from soldering tiny cryowires, to using machines and learning the cryostat
- Interfacing hardware to a computer with some python programming
- Working in a small research group as part of a large collaboration



ON THAT SIGNAL IN THE SKY,
WE CAN TRACE OUR ORIGIN:

WE WERE LIGHT ONCE.

THEN WE WERE RIPPLES
IN TEMPERATURE THAT
BECAME STARS...

GALAXIES, MATTER...

...AND LIFE.

