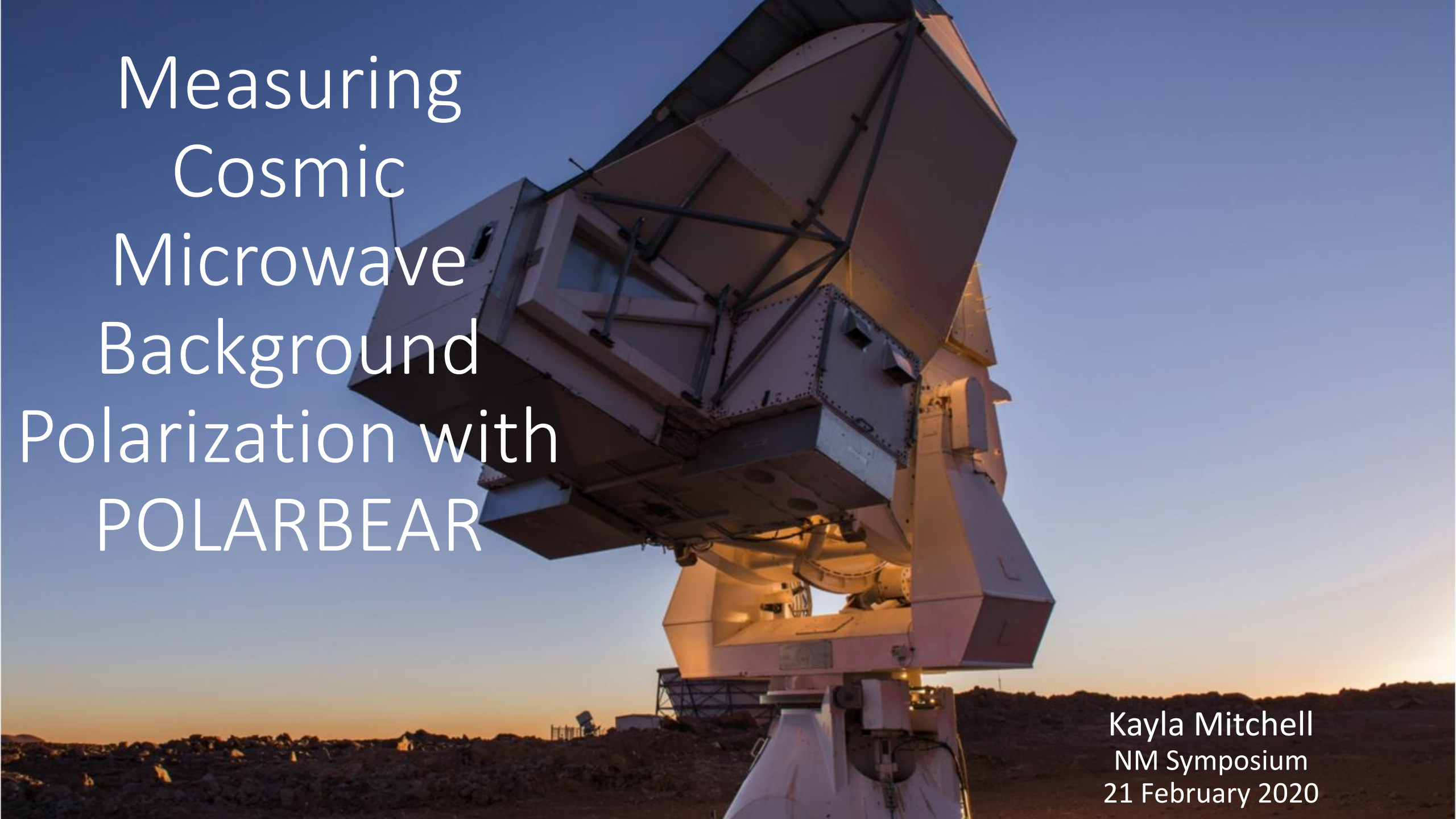
Measuring Cosmic Microwave Background Polarization with POLARBEAR



Kayla Mitchell

NM Symposium

21 February 2020

Outline

- Background on the CMB
- POLARBEAR design
- POLARBEAR-2a Commissioning
- Future of POLARBEAR

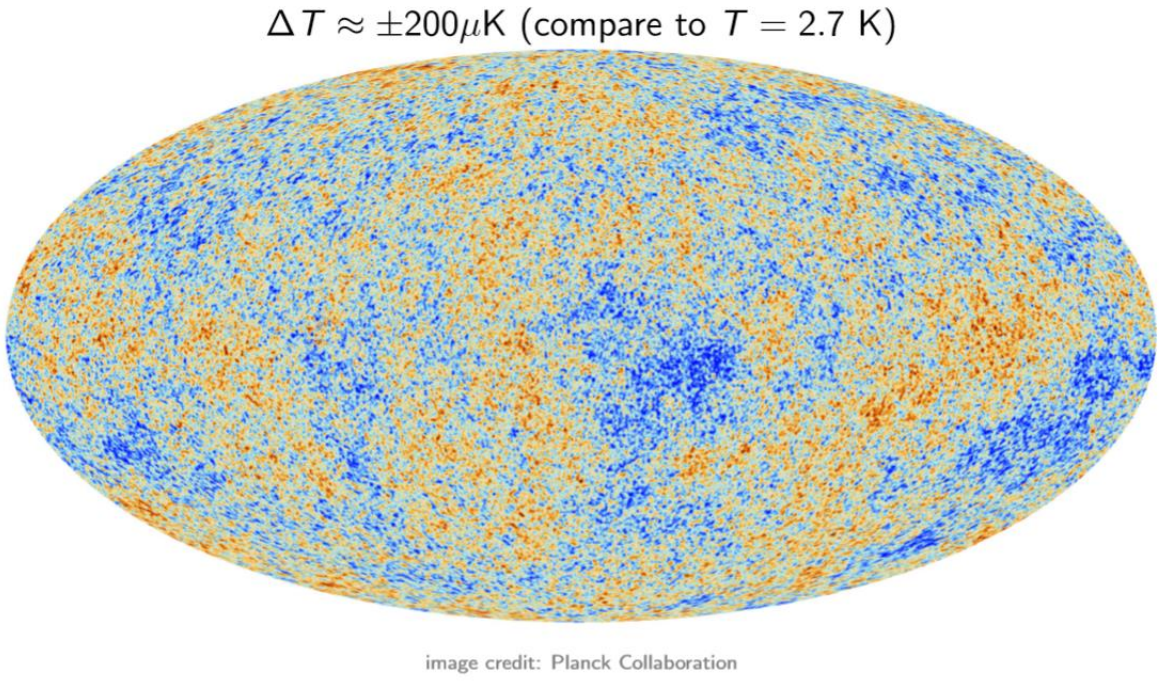
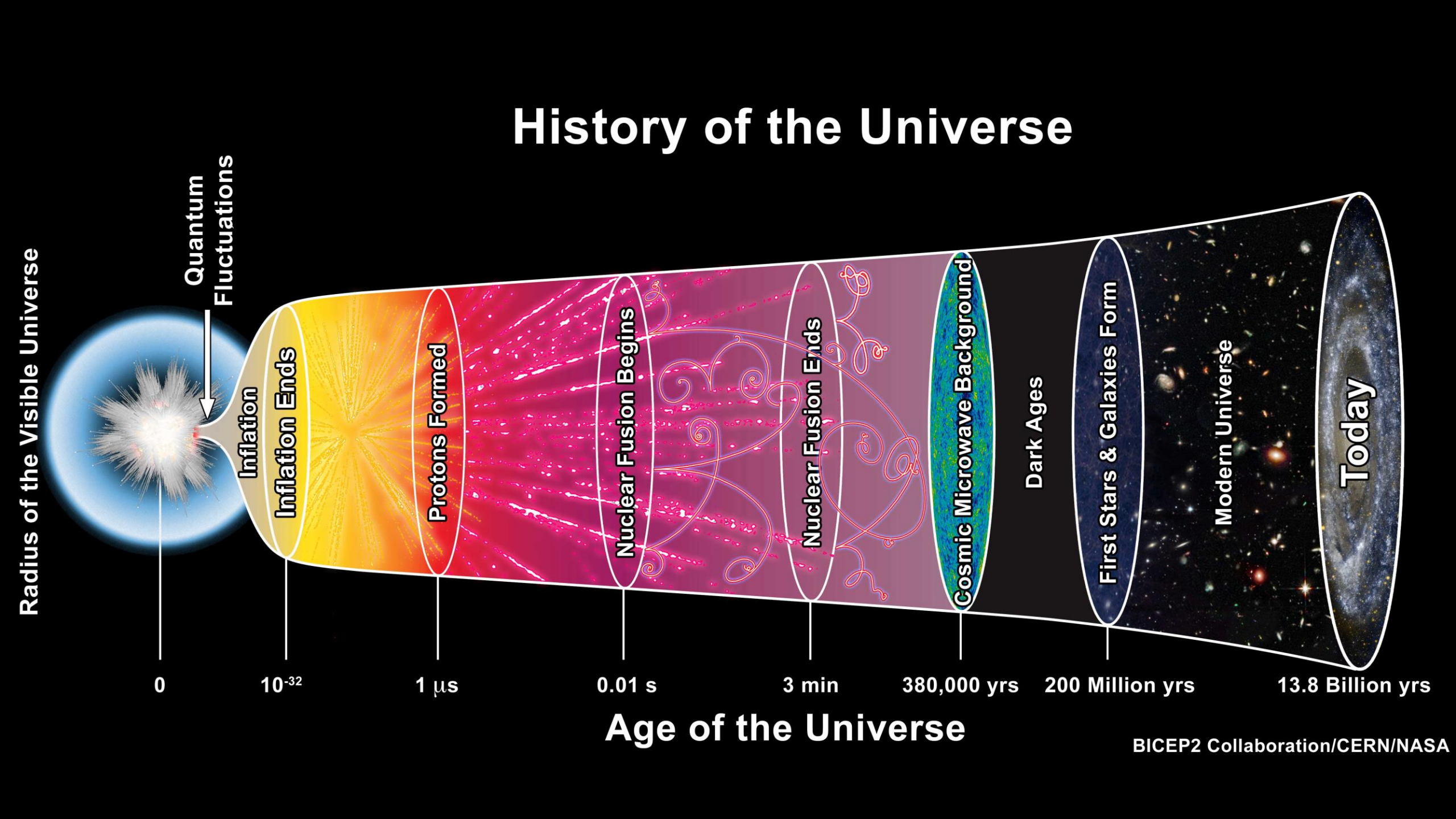
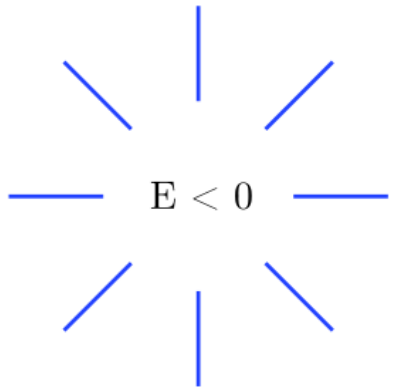


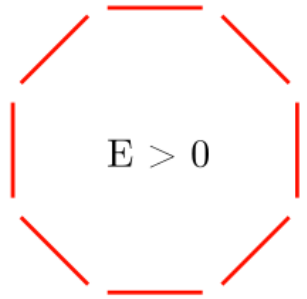
image credit: Planck Collaboration

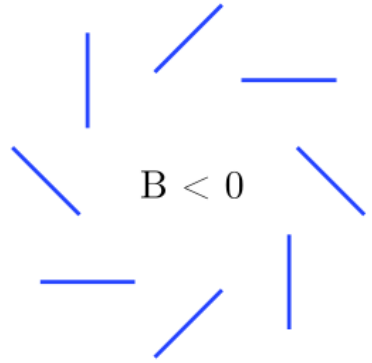

History of the Universe
Radius of the Visible Universe
Quantum Fluctuations
Inflation
Inflation Ends
Protons Formed
Nuclear Fusion Begins
Nuclear Fusion Ends
Cosmic Microwave Background
Dark Ages
First Stars & Galaxies Form
Modern Universe
Today
0
10-32
1 μs
0.01 s
3 min
380,000 yrs
200 Million yrs
13.8 Billion yrs
Age of the Universe
BICEP2 Collaboration/CERN/NASA

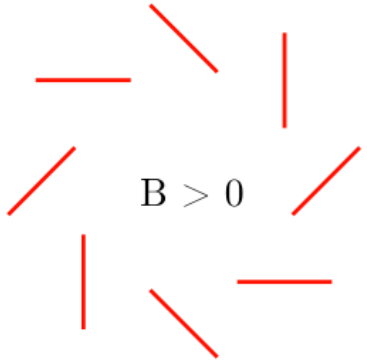
Polarization Modes

- E-modes from density fluctuations
- B-modes from:
  - Primordial gravitational waves
  - Gravitational Lensing
  - Polarized foregrounds









POLARBEAR-2 / Simons Array

- Located in the Atacama Desert in Chile at an elevation of 5200m
- Observe at 95/150/220/270 GHz
- Over 20,000 detectors cooled to 250mK

Cryogenic Receiver

Image: Fred Matsuda

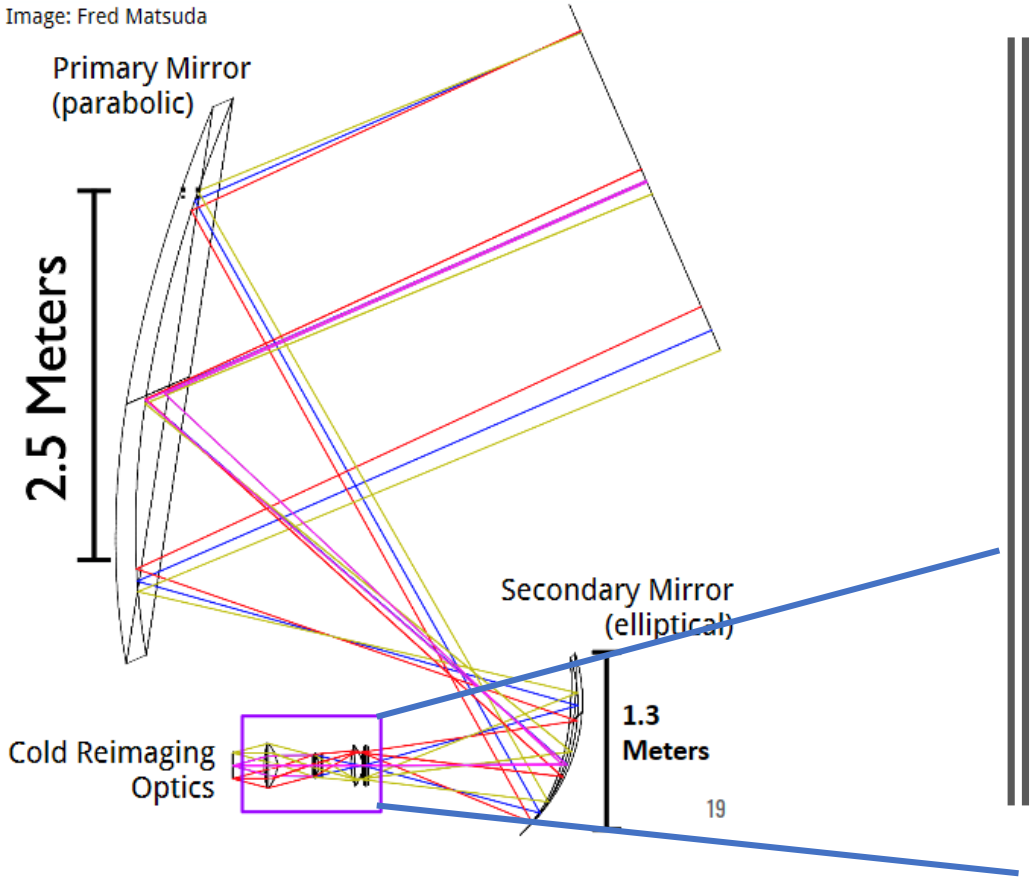
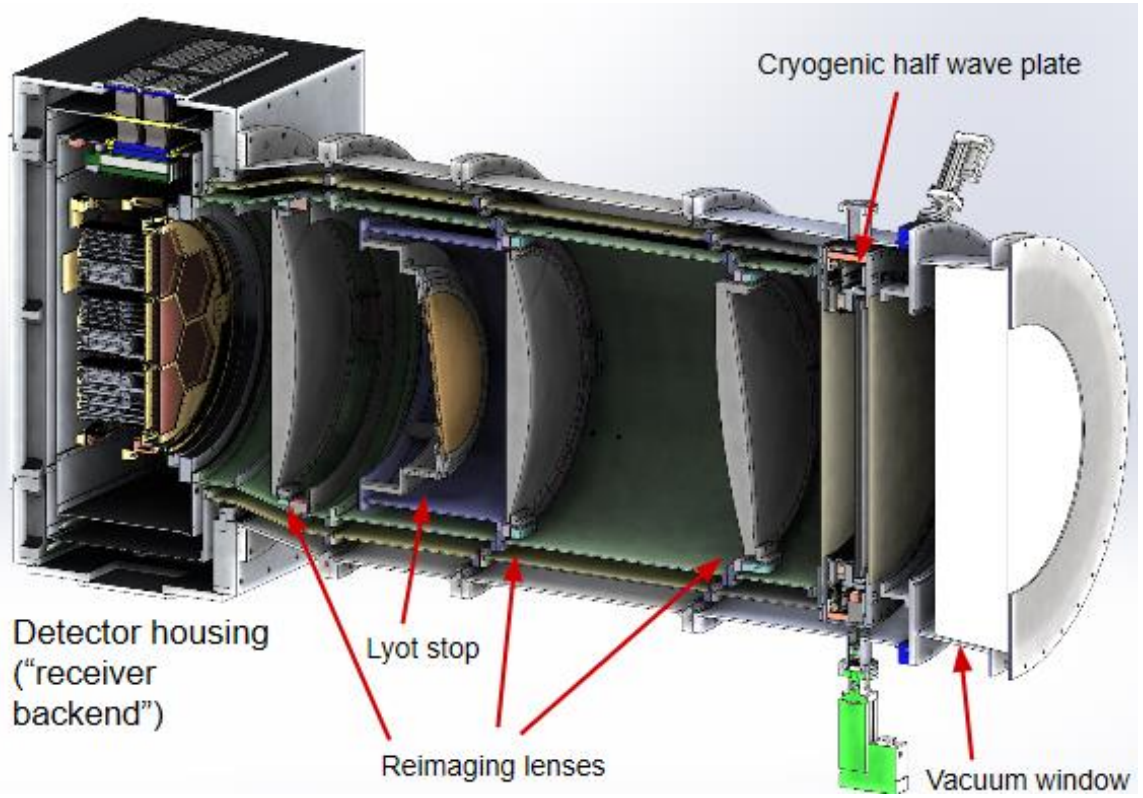


Image: Logan Howe



Receiver Backend

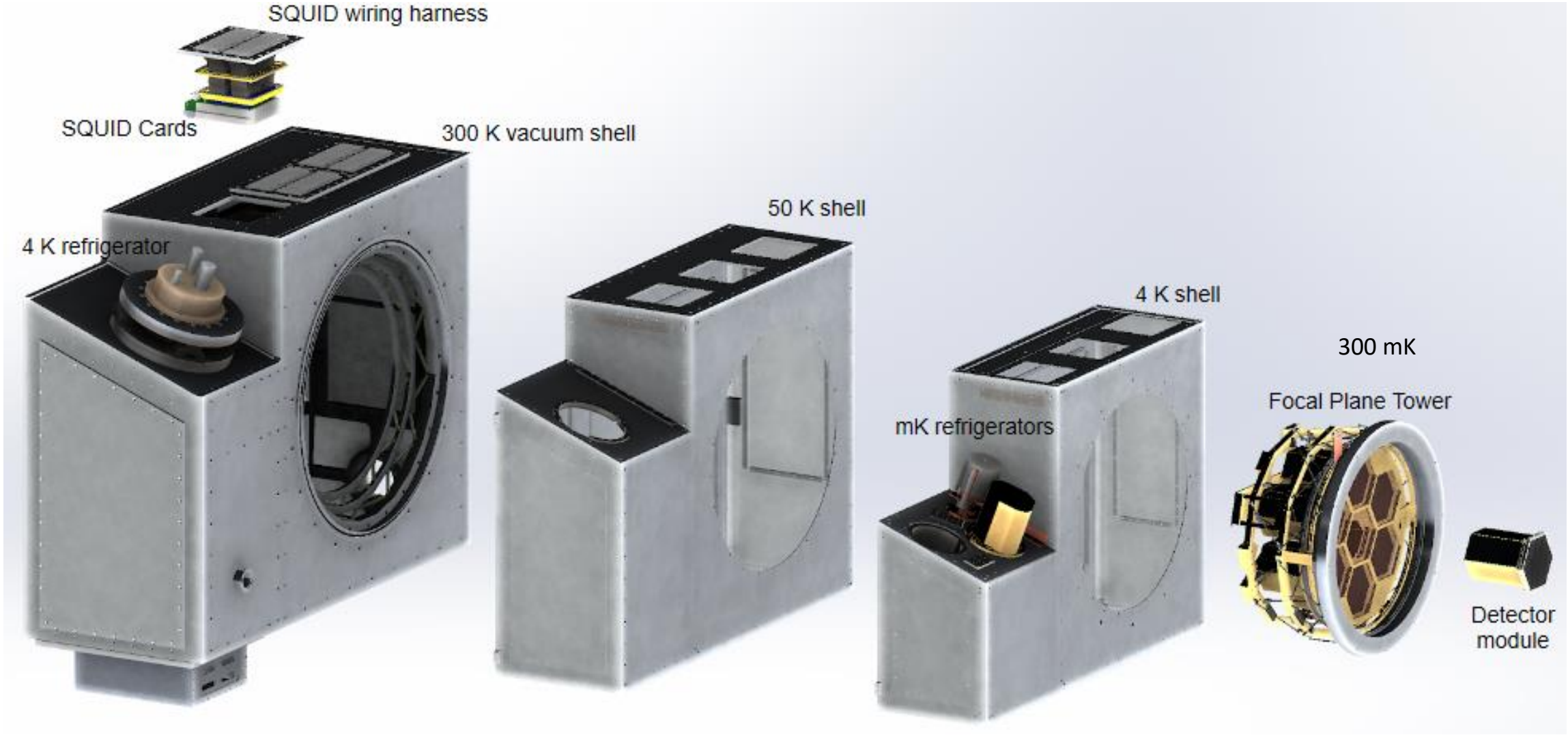
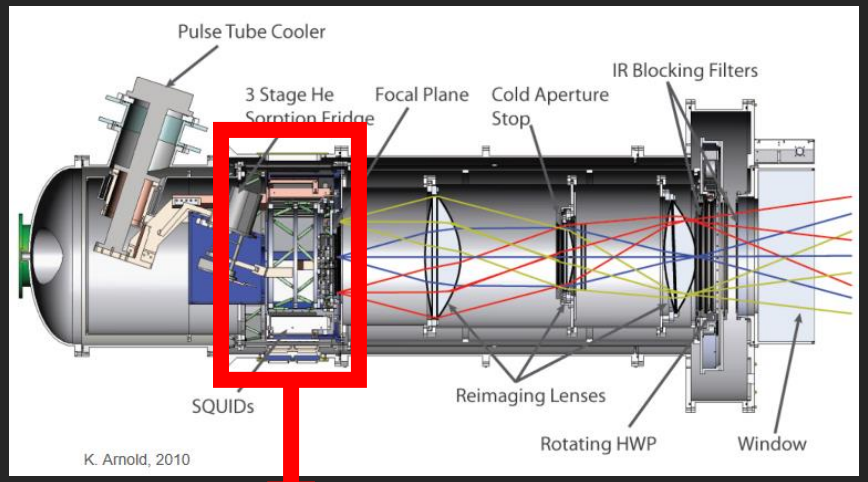


Image credit: Logan Howe

Focal Plane

- 1084 Transition Edge Sensor (TES) bolometers fabricated on each 6-inch wafer
- Coupled to anti-reflection coated lenslets
- 1897 dual-polarization dichroic pixels in focal plane



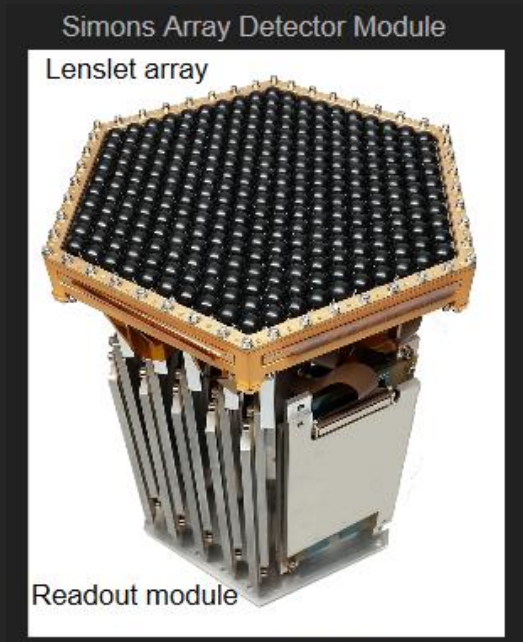


Image: Lindsay Lowry

TES Bolometers

- Polarization signals much weaker than temperature measurements – need high sensitivity, low noise detectors
- Sensitivity of each detector at 150 GHz limited to ~500 μK-sqrt(s) by photon statistics. To improve sensitivity, must add more detectors!
- Voltage bias maintains superconducting film at its transition temperature
- Small amounts of optical power slightly increase bolometer's temperature resulting in large changes in bolometer's resistance
- Due to the voltage bias, these resistance changes can be read out as changes in current through the TES

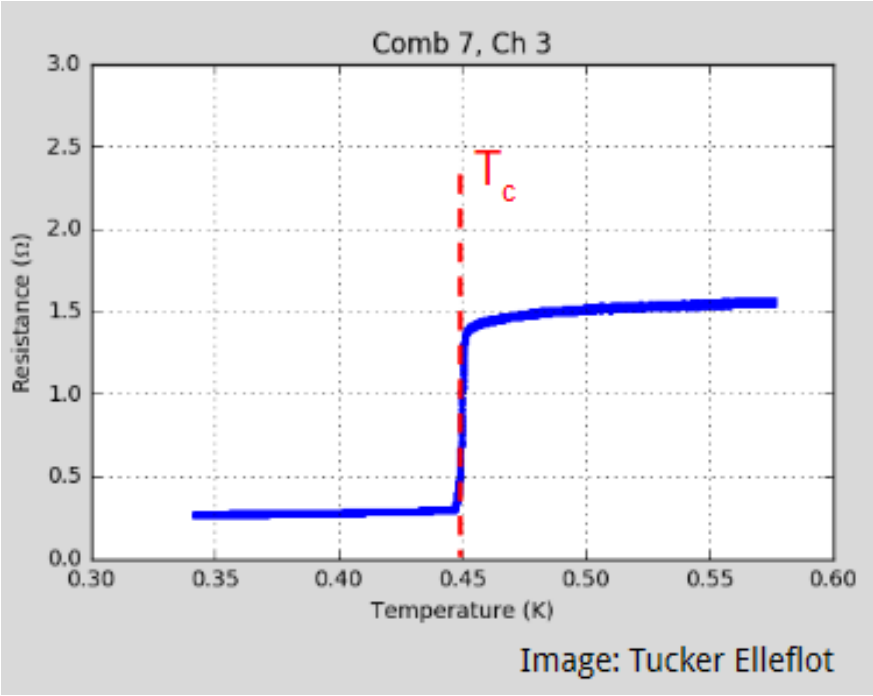
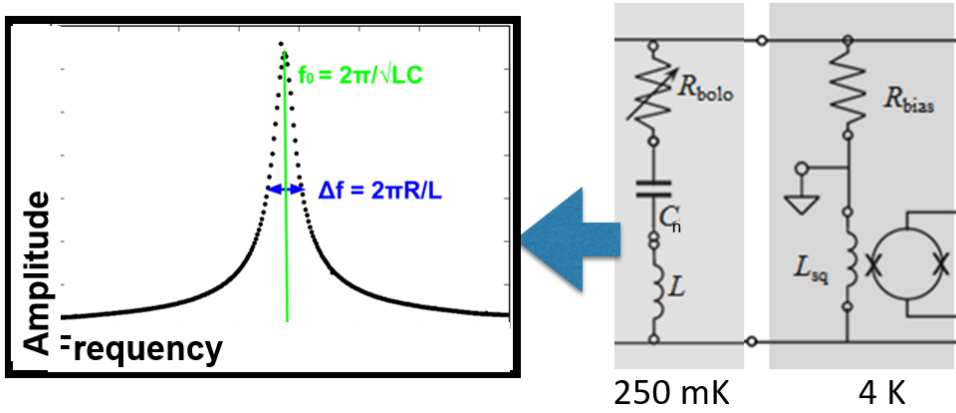
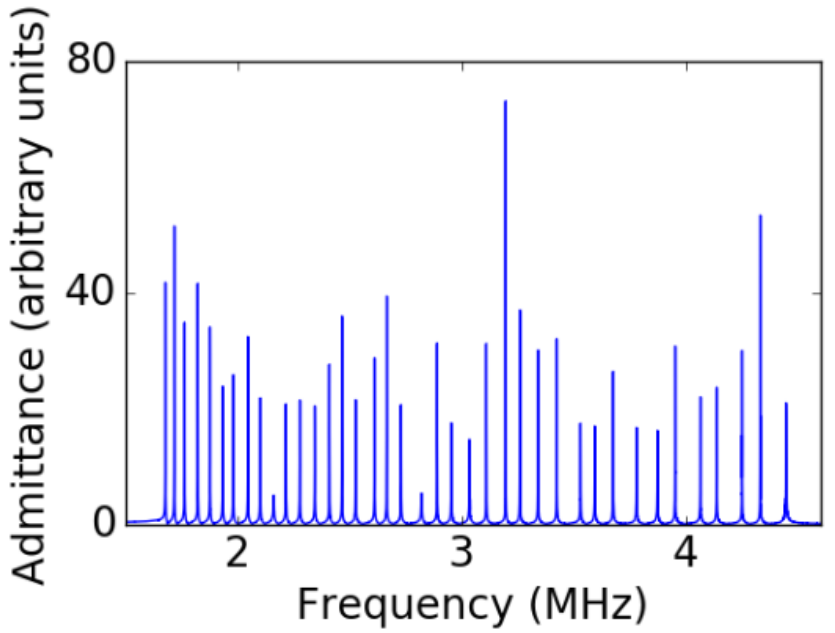


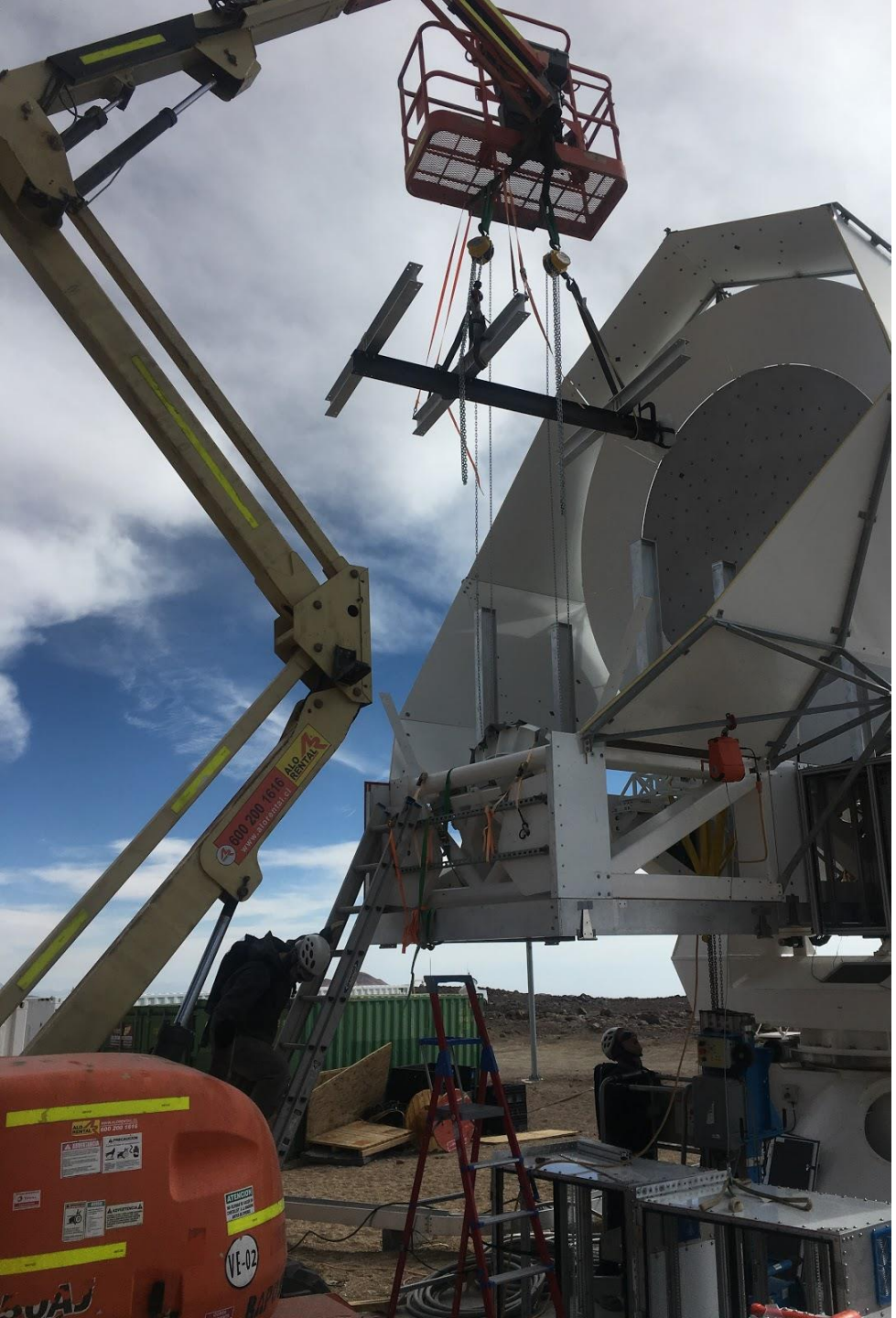
Image: Tucker Elleflot

Frequency-multiplexed Readout

- Signal from 40 detectors read out on a single pair of wires
- Achieved by placing an inductor and capacitor in series with each TES
- Signal from optical power shows up as an amplitude modulation
- All tones fed through a cold SQUID amplifier
- Demodulate signals with room temperature electronics







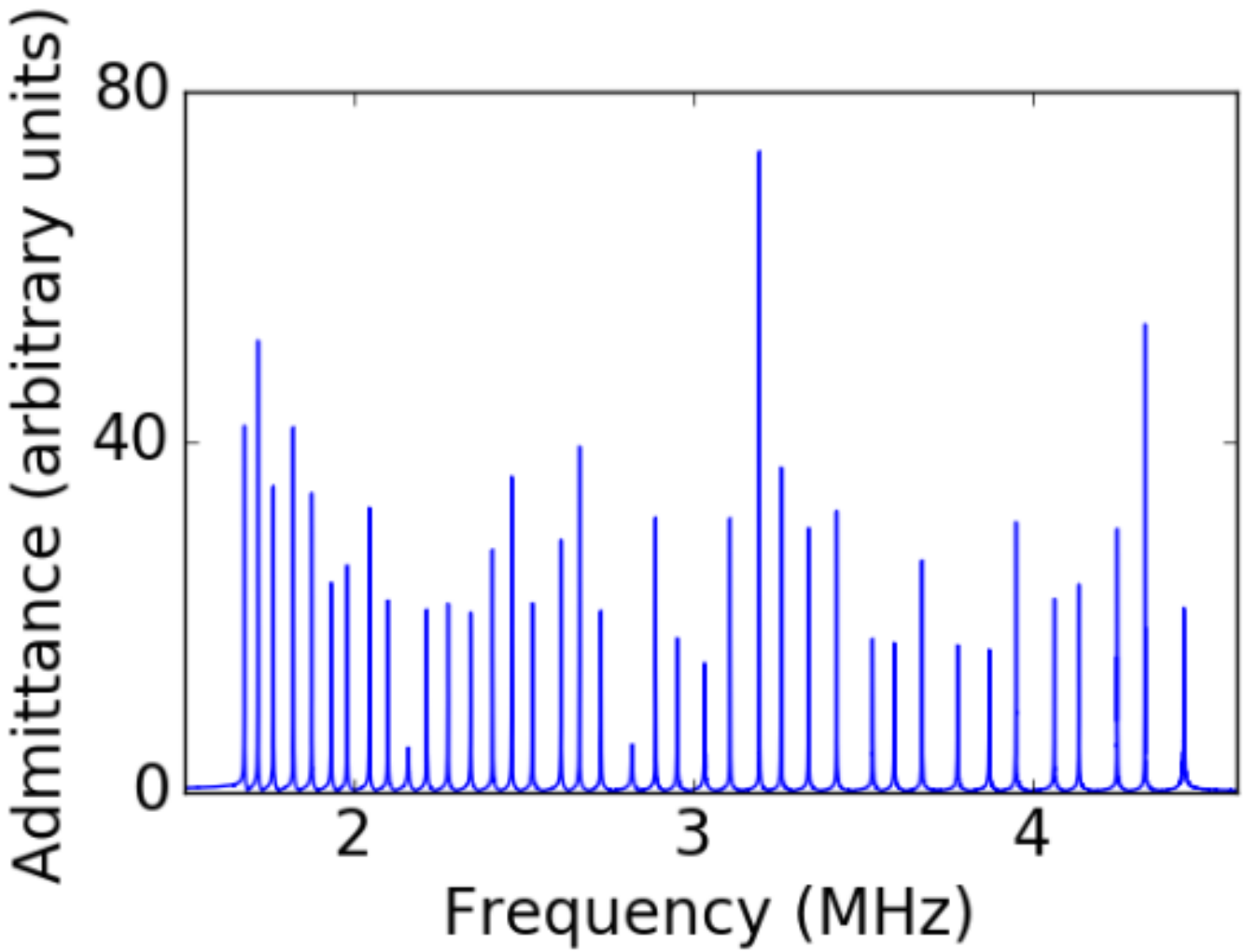
PB-2a

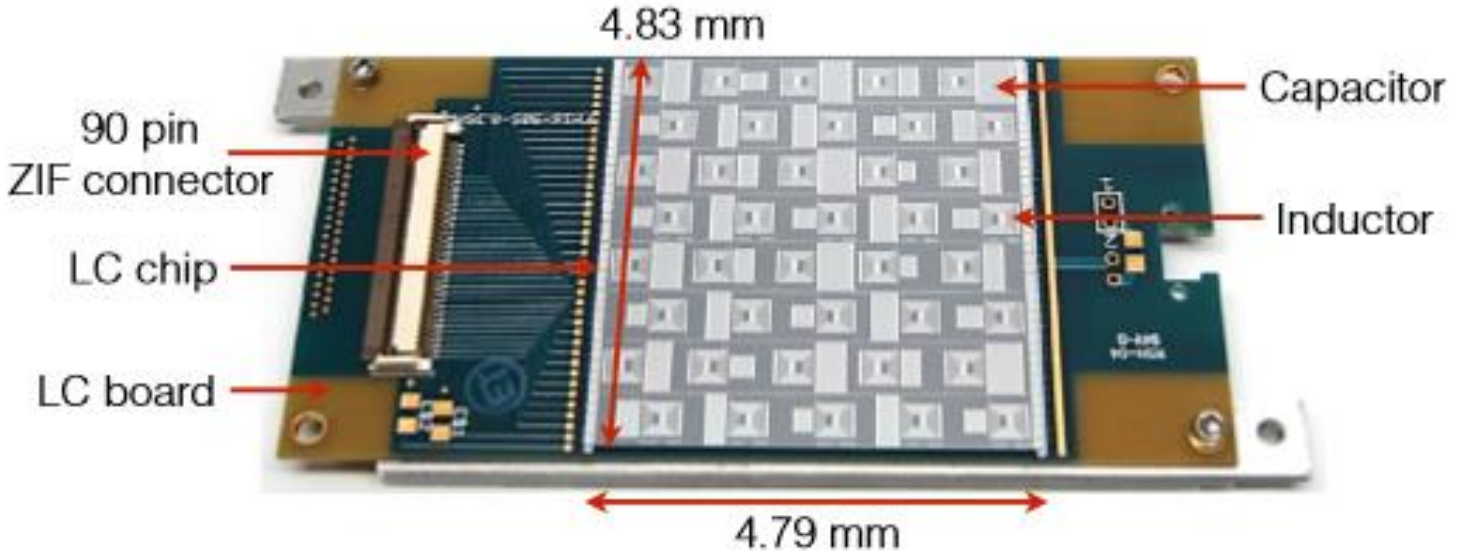
- November/December 2018 – receiver placed on telescope, cooled, and calibrated
- January 2019 – first planet observations made
- Taking network analysis data
- First commissioning season austral winter 2019

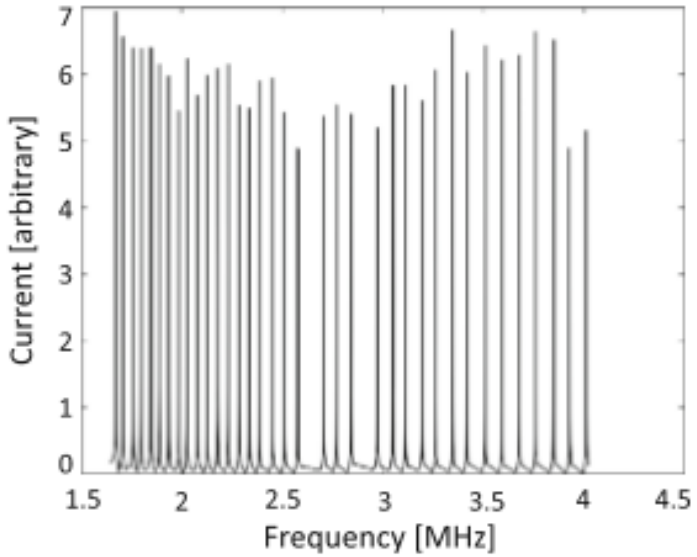
Image: Lindsay Lowry

Network Analysis Data

Peaks at resonant frequencies







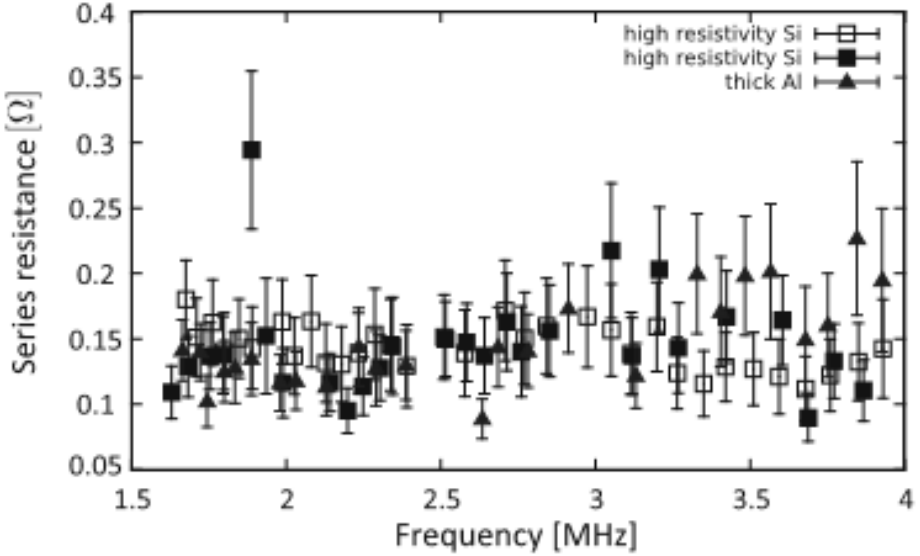
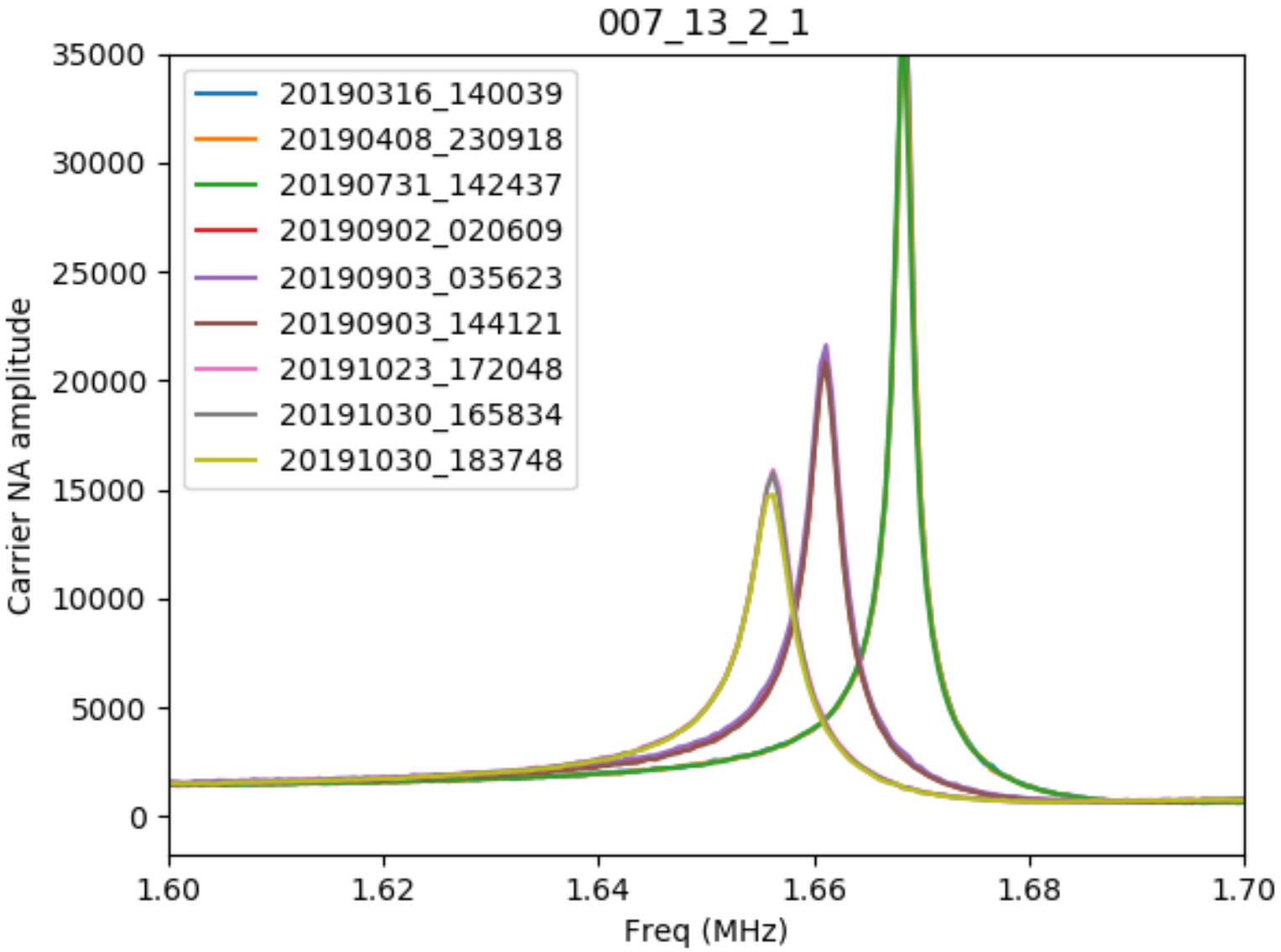


Fig. 3 *Left* Network analysis of a 40× LC filter. *Right* Plot of series resistance versus frequency for interdigitated capacitors. Three measurements are displayed using a 30 Ω·cm resistivity Si substrate. *Solid and empty square* 1000 Å Al layer. *Solid Triangle* 3000 Å Al layer

Images: Rotermund et al 2016

My Work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20190316_140039
20190408_230918
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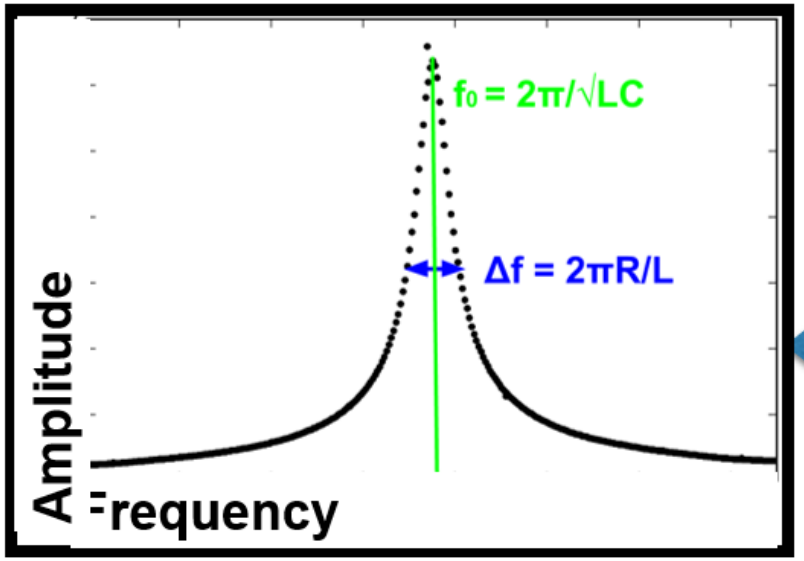
20190902_020609
20190903_035623
20190903_144121
20191023_172048
20191030_165834
20191030_183748
Carrier NA amplitude
35000
30000
25000
20000
15000
10000
5000
0
1.60
1.62
1.64
1.66
1.68
1.70
Freq (MHz)

Kinetic Inductance

- Expect resonant frequencies to be set by geometry
- Changing frequencies could be explained by additional *kinetic* inductance
- Kinetic inductance comes from inertia of charge carriers
- In a superconductor with finite temperature, not all electrons are paired up as Cooper pairs
- Leads to kinetic inductance effects that depends on temperature and other factors
- Effect is exploited to make kinetic inductance detectors, tunable resonators



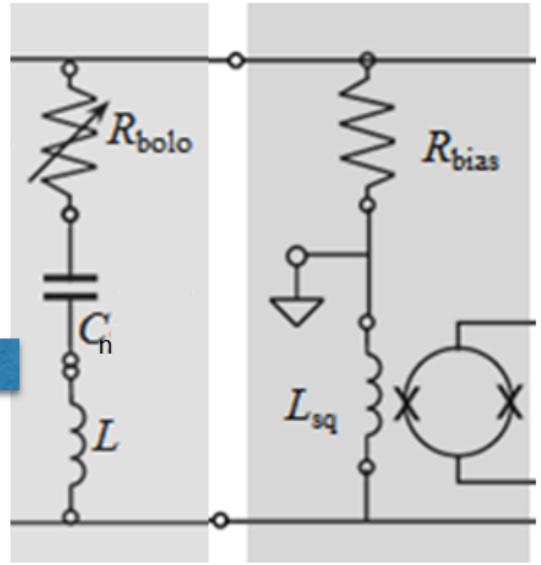


Image credit: Barron, D.

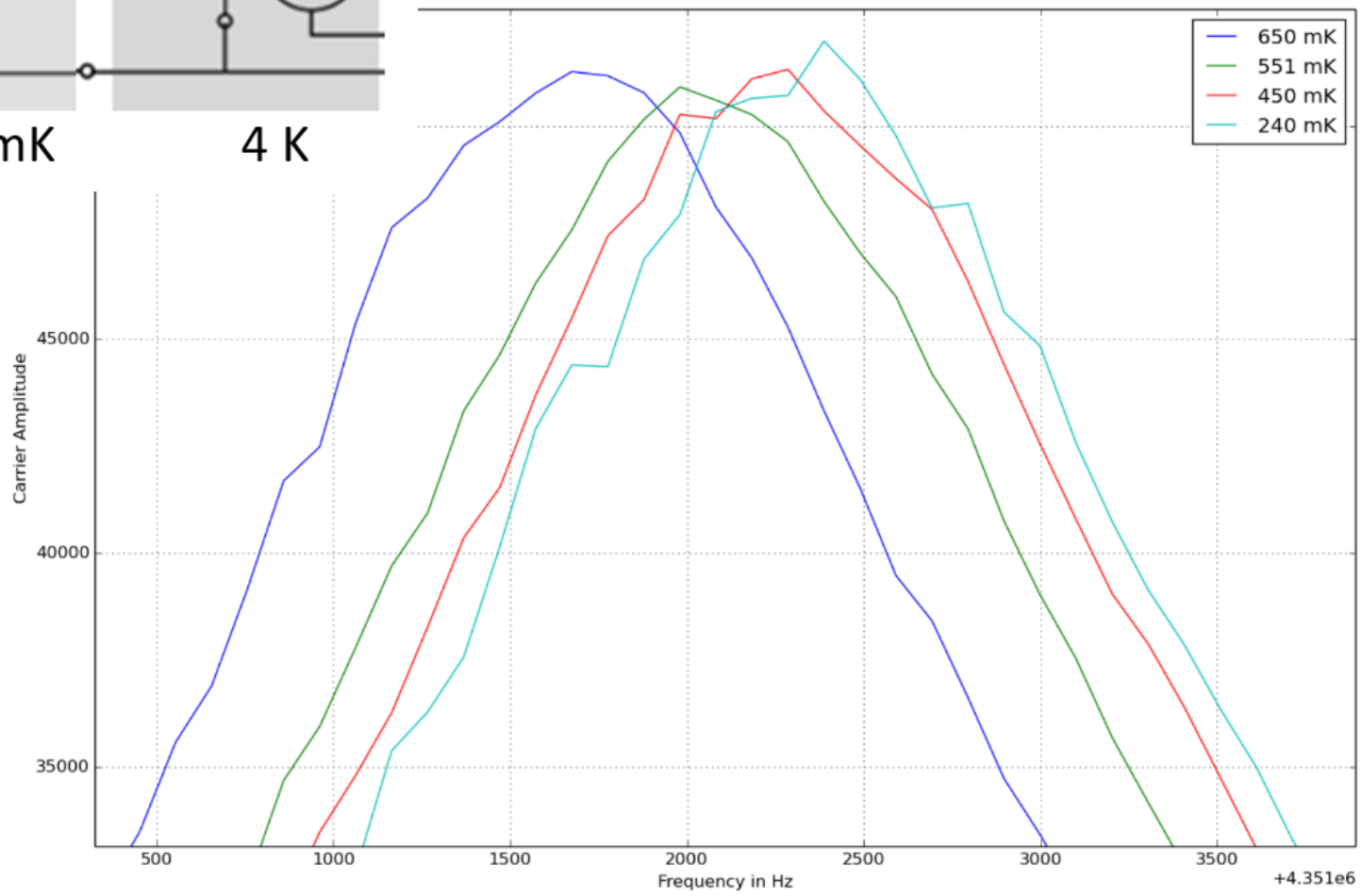


Image credit: Wang, G. 2016.

Current Status

- PB2b receiver is on boat to Chile now, commissioning this austral winter
- Comparing network analysis data and readout performance from PB2a and PB2b, for submission to Applied Superconductivity Conference this summer
- At UNM:
  - Will be setting up new cryostat
  - Will be used for development/testing of detectors
  - Currently working on all-sky IR camera to monitor polarized clouds at site

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