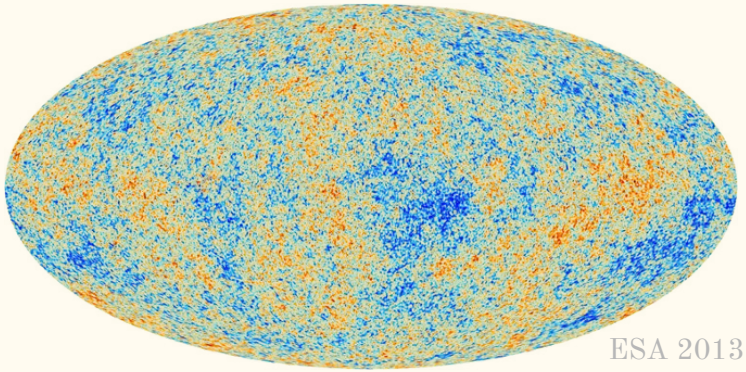
The Next Generation of Cosmic Microwave Background Experiments

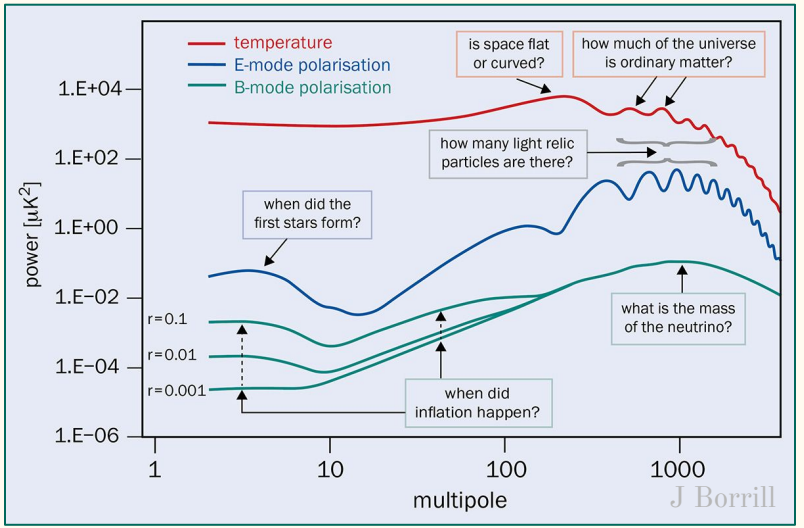
Matthew Young - New Perspectives 2023

Surveying the Cosmic Microwave Background (CMB)

- Key evidence for ΛCDM model of Universe, probe of large-scale structure growth & evolution
- Current experiments such as SPT-3G feature ~10,000 on-sky detectors
- FNAL working on 3 next-generation experiments:
  - SPT-SLIM, SPT-3G+, and CMB-S4

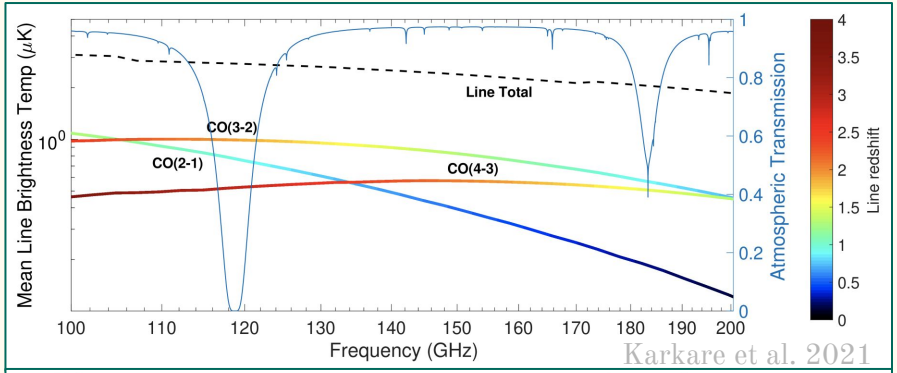


ESA 2013



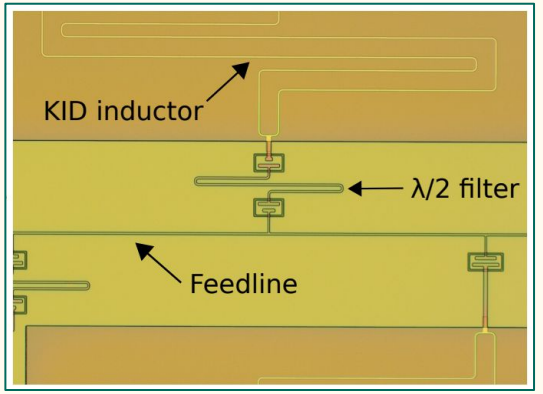
Line-Intensity Mapping (LIM) with SPT-SLIM

- Pathfinder experiment utilizing on-chip spectrometers with kinetic inductance detectors (KIDs)
- Aim to demonstrate LIM observations of CO between $0.5 < z < 2$
- Mm-wave LIM capable of competitive constraints on
  - expansion history
  - neutrinos (N_{eff} and M_{ν})
  - reionization dynamics

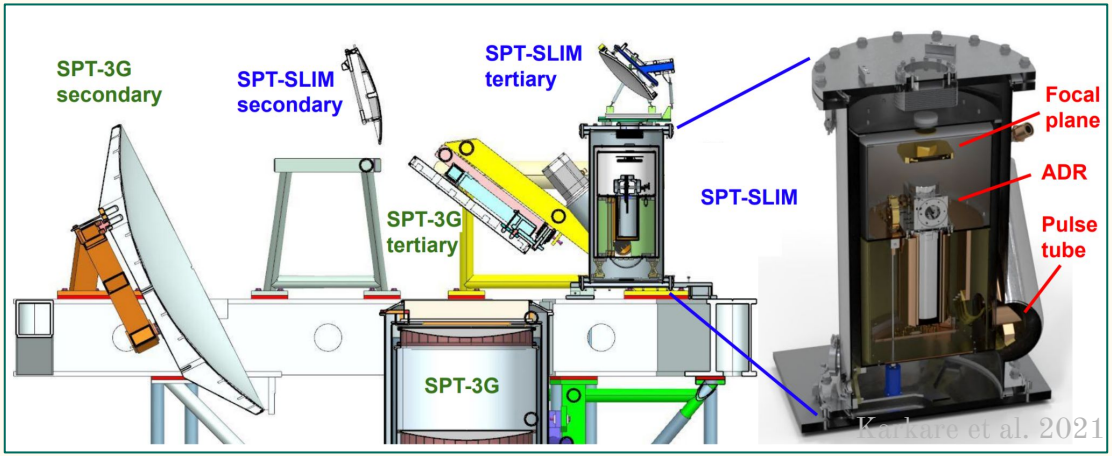


SPT-SLIM Instrument

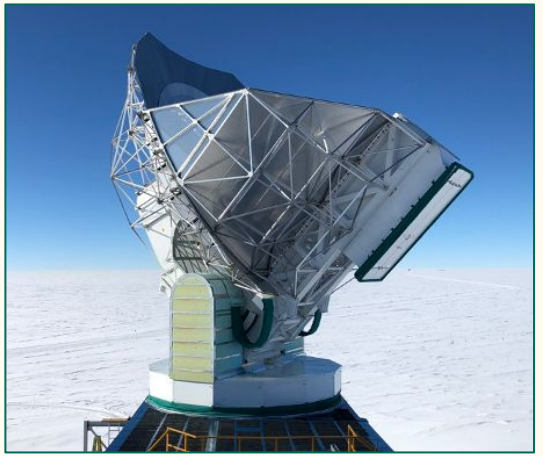
- 12x dual-polarization R=300 filter-bank spectrometers (120-180 GHz)
- ADR for 100mK operation
- Receiver to be commissioned at FNAL this summer, and deployed to the South Pole at the end of 2023



Karkare et al. 2021

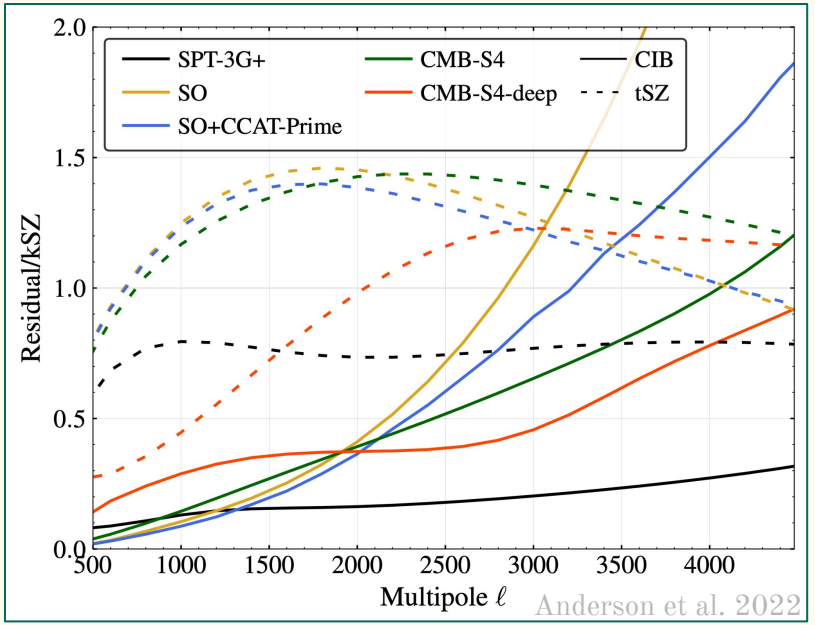


Karkare et al. 2021



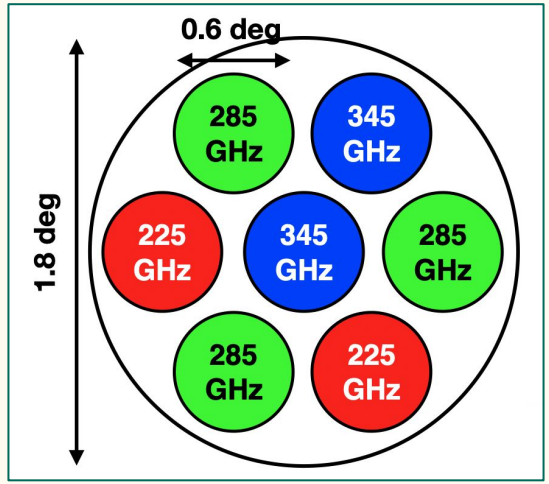
Mapping the High-Frequency CMB with SPT-3G+

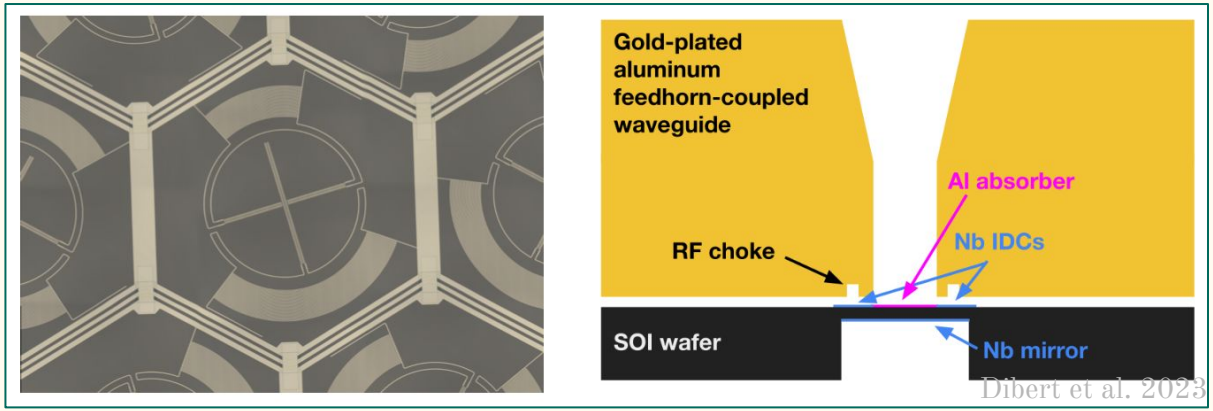
- Will survey the CMB at 220, 285, and 345 GHz with KIDs
- Enables new constraints on
  - patchy kinematic Sunyaev-Zeldovich effect (kSZ)
  - reionization optical depth τ
- Pathfinder for Rayleigh scattering detection
- Complimentary to ongoing SPT-3G survey



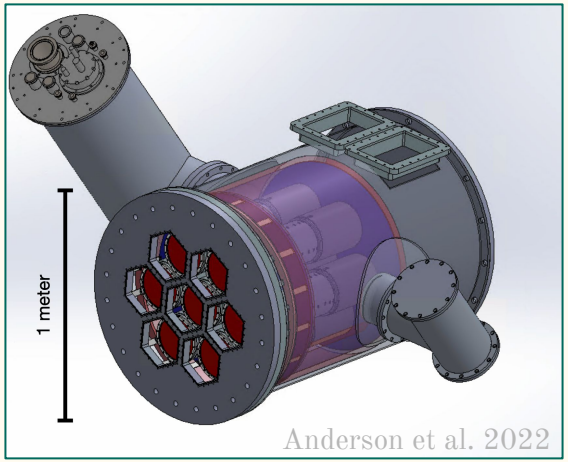
SPT-3G+ Instrument

- Focal plane to consist of ~35,000 Al/Nb MKIDs
- Dilution refrigerator for 100mK operation
- Middle stages of development, to replace the SPT-3G receiver in the next several years





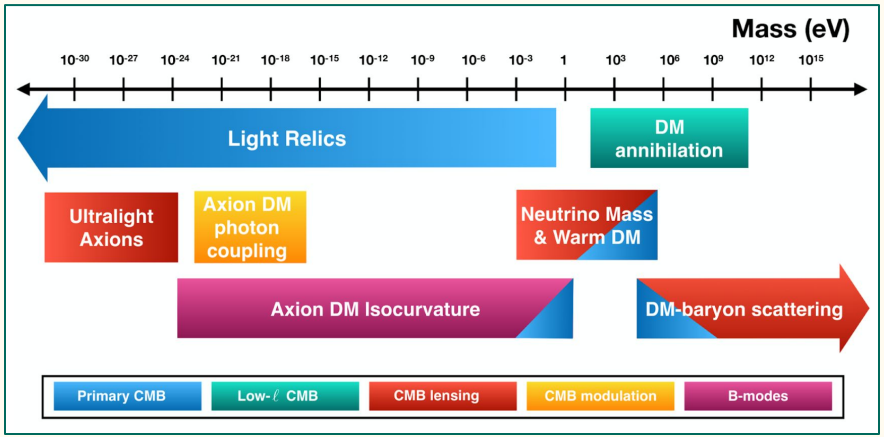
Dibert et al. 2023



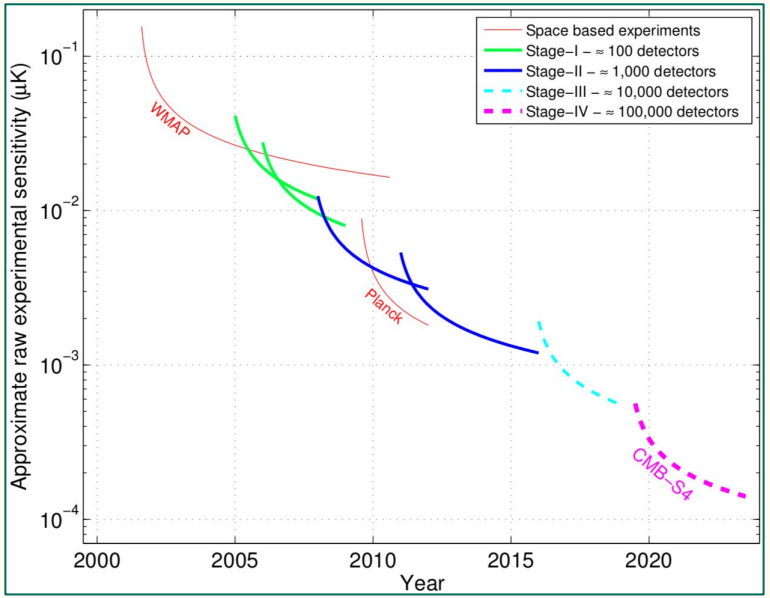
Anderson et al. 2022

Unparalleled Sensitivity with CMB-S4

- Stage-4, the largest ground-based CMB experiment to date
- Will address a broad range of fundamental physics
  - signatures of cosmic inflation
  - nature of dark matter
  - probing dark energy and neutrino masses



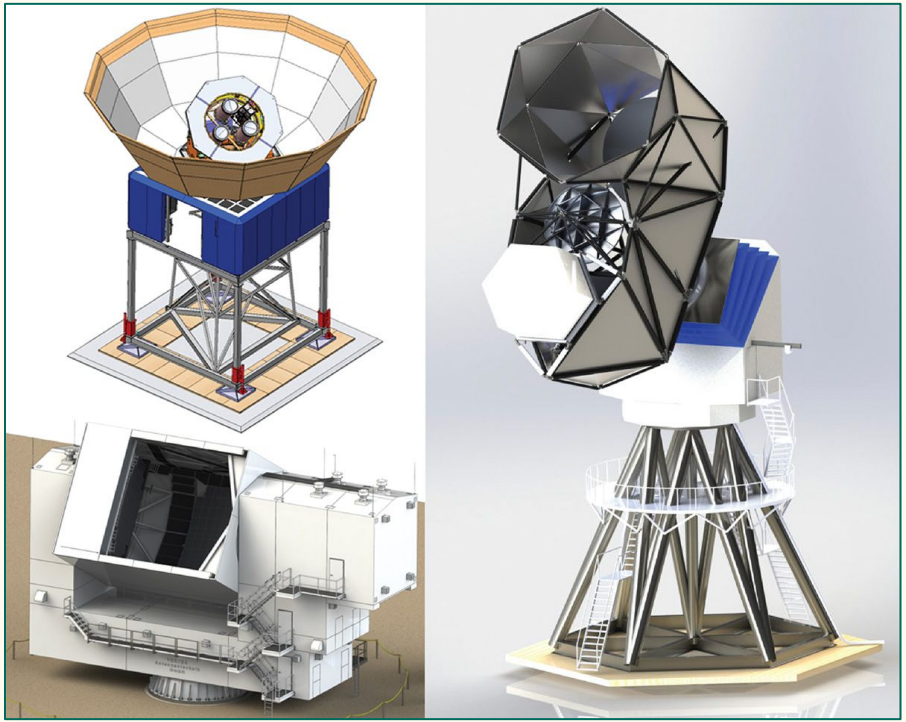
CMB-S4



Abazajian et al. 2016

CMB-S4 Experiment

- Several new telescopes
  - Atacama Desert and South Pole
  - Large and Small aperture designs
- Over 500,000 detectors
  - Time-multiplexed superconducting Transition Edge Sensors (TES)
  - 11 observing bands
  - ~500 wafers
  - 100mK operating temperature
- Science operations to begin early 2030s

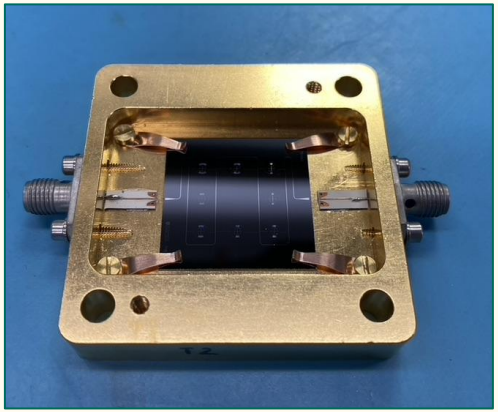


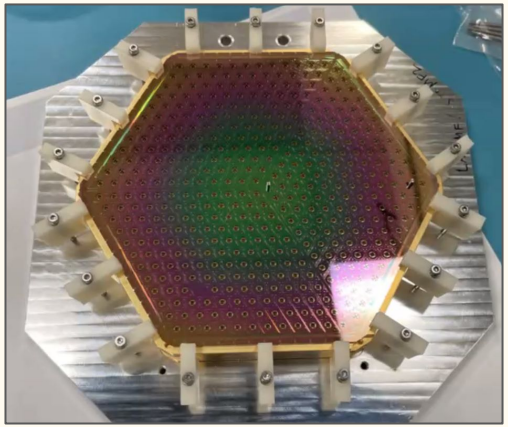
CMB-S4

CMB Experiments at FNAL

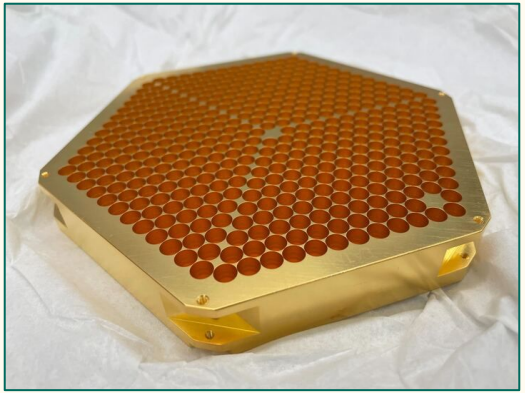
SPT-SLIM cryostat test installation

SPT-3G+ chip characterization



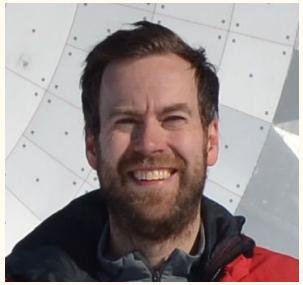


CMB-S4 module prototyping and testing



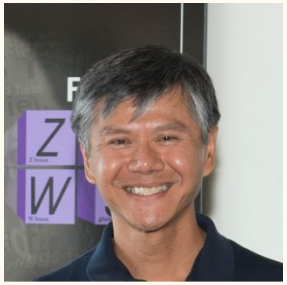
Cryostat window + IR filter for optical testing

FNAL CMB Group


Bradford Benson

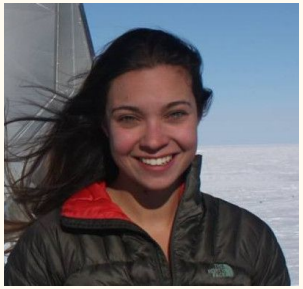

Adam Anderson


Sara Simon



Hogan Nguyen


Joshua Sobrin


Jessica Zebrowski

et al.

Thank you