Development and Characterization of the POLARBEAR-2b Receiver for the Simons Array

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CMB-S4 Workshop Junior Scientist Talks
Introduction

- Graduate student at UC San Diego since 2014
- Research Advisor: Brian Keating
- Grad School Research:
  - Simons Array telescope hardware and site preparation
  - POLARBEAR-2b development and readout testing, particularly SQUID selection
  - FTS development and use
- Other Interests:
  - Project Management
  - Outreach and Mentoring
    - UCSD Cosmic Tours Portable Planetarium
    - UCSD Grad Women in Physics
    - Scientist Pen Pal
Outline

- Simons Array
- Site and telescope preparation
- POLARBEAR-2b
  - Overview
  - Lab Testing
  - Current status and future plans
Simons Array (expansion of the POLARBEAR-1 experiment)

- Located on Cerro Toco in the Atacama Desert, Chile
- Set of 3 telescopes identical in optical design to POLARBEAR-1’s Huan Tran Telescope with upgraded receivers
  - First new receiver (PB-2a) installed, assembly of second receiver (PB-2b) underway at the site
- Targeting CMB polarization measurements at \( 50 \leq \ell \leq 2000 \)
Site and Telescope Preparation

- Off-axis Gregorian telescopes with monolithic primary mirrors measuring 2.5m in diameter
- Changes to accommodate new, larger receivers:
  - Stronger receiver mount structure and hoisting system for installation
  - Upgraded receiver enclosure structure and prime focus baffle
  - Repositioning and addition of counterweights
  - Additional enclosures for room-temperature electronics
Site and Telescope Preparation

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POLARBEAR-2b (PB-2b)

~ 2 m
POLARBEAR-2b (PB-2b)

- SQUID Array Amplifiers
- Focal Plane with Multiplexing Readout Components
- Reimaging lenses
- Cryogenic HWP
- Zotefoam Window
- Millikelvin Refrigerators (not shown)
PB-2b Lab Testing

- Backend assembly and characterization
  - Millikelvin fridge testing and optimization
    [arXiv:1806.05576]
  - Dark characterization of detector modules and integration with readout system

- Integration of backend and optics tube
  - Cryogenic validation
  - Test of cryogenic half-wave plate operation
    [see upcoming presentation by Charlie Hill]
  - Optical characterization of detector modules
  - Operation of full-scale readout system
PB-2b Lab Testing - Readout System

- PB-2b’s detector/readout system includes:
  - 7 detector wafers, each containing over 1,000 optical TES bolometers
  - 30 resonator chips attached to each detector wafer, each containing 40 resonators
  - 210 SQUID array amplifiers, one for each resonator chip
  - Warm electronics implementing digital active nulling (DAN)

- PB-2b SQUID Array Amplifiers
  - Require lower input coil inductance compared to PB-1 in order to operate at higher frequencies with higher multiplexing factor
  - Options:
    - NIST SA13 design
    - Star Cryogenics E2 design
    - Star Cryogenics F2 design
    - Initial choice for PB-2b
Final in-lab run of PB-2b included a full focal plane and set of readout components, including 210 Star Cryogenics E2 SQUIDs.

Difficulties encountered:
- Unexpected increase in noise when operating detectors at high current.
- Kinks/features in the $V-\Phi$ curves of 33% of SQUIDs, with an apparent dependency on SQUID location.

Decision was made to switch to NIST SA13 SQUIDs when deploying PB-2b to the site, given this design’s demonstrated full-scale performance in PB-2a and in SPT-3G.
PB-2b Lab Testing - Readout System

- NIST SA13 SQUIDs screened in a separate cryostat after PB-2b’s last in-lab run
- Results are consistent with what we expect given experience with PB-2a
PB-2b Current Status and Future Plans

- PB-2b was disassembled and shipped to the Chilean site in early 2020, following its last in-lab run at UCSD.
- Reassembly at the site began in March 2020, with a team of SA personnel.
- Progress was halted due to Covid-19.
- Hoping to restart assembly as soon as it is safe to do so!
Thank you!

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