Small Aperture Telescopes for the Simons Observatory

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Abstract

The Simons Observatory (SO) is an upcoming cosmic microwave background (CMB) experiment located on Cerro Toco, Chile, that will map the microwave sky in temperature and polarization in six frequency bands spanning 27 to 280 GHz with first light planned for 2021. SO will consist of one 6-meter Large Aperture Telescope (LAT) fielding approximately 30,000 detectors along with an array of three 0.5-meter Small Aperture Telescopes (SATs) fielding another 30,000 detectors. This synergistic combination will allow for extremely sensitive characterization of the CMB over angular scales ranging from an arcmin to tens of degrees, enabling a wide range of scientific output. Here we focus on the SAT program targeting large angular scales from ≈ 10% of the sky with successive dichroic instruments observing at Mid-Frequency (MF: 93 and 145 GHz), Ultra-High-Frequency (UHF: 225 and 280 GHz), and Low-Frequency (LF: 27 and 39 GHz). This configuration will enable maps of white noise level \approx 2 μ K-arcmin in combined 93 and 145 GHz bands, and characterization of the CMB as well as galactic foregrounds (primarily dust and synchrotron), with a primary science goal of characterizing the primordial tensor-to-scalar ratio, r, at a target level of σ(r) = 0.003.



Figure: Preliminary Site Location. SO will be located in the extremely arid Atacama Desert, at an elevation of 5190 m on the Cerro Toco mountain in the Chilean Andes. The Observatory will immediately neighbor the existing ACT, Simons Array (SA), and CLASS CMB experi-

Simons Observatory Overview



Large Aperture Telescope

Highlights:

- 6 m Cross-Dragone Telescope
- Az-El telescope with receiver co-rotator
- 2.4 m diameter cryostat receiver with 7x
 38cm optics tubes (upgradeable to 13x)
- 30,000+ detectors at 100 mK



Highlights:

- * 3x 42cm Refractive Telescopes
- * Individual 3-axis (Az-El-Boresight) mounting
- Polarization Modulation via Continuously rotating Cryogenic-Half-Wave-Plate (CHWP)
- * 30,000+ detectors at 100 mK

ments, and closely neighbor the Atacama Large Millimeter Array (ALMA) and the upcoming CCAT-prime radio telescopes, enabling SO to produce a scientific program with rich complementarity with existing and upcoming data sets.



Cold Refractive Optics: High through-put 3-lens refractor using 1 K silicon lenses imaging a 1 K Lyot stop. The optics are mounted in a cold optical assembly (COA) with extensive cryogenic baffling for spillover control.

Key Features Common to Both

Combination of Lenslet-Coupled Sinuous Detectors and Horn-Coupled OMT Detector Wafers
 3 flavors of Dichroic TES Detectors: LF 30/40 GHz, MF 90/150 GHz, HF 220/270 GHz
 -broad frequency coverage enables robust spectral separation of CMB from foregrounds
 Detectors Readout with Frequency-Domain Microwave SQUID Multiplexing (μMux)
 High-Dry Site in Parque Astronomico Atacama, Chile (elevation: 5200m) + Shared Infrastructure
 Technology, Analysis, and Science Expertise of Entire Simons Observatory Collaboration



Left: Spline feed coupled ortho-mode transducer detectors (fab by NIST). Right: Lenslet coupled sinuous antenna detectors (fab by Berkeley). Both are coupled to Transition Edge Sensor Bolometers



SAT-Receiver

• **Cryogenic Half-Wave Plate (CHWP):** A continuously rotating CHWP is mounted at

- 40K between the 1 K Lyot stop and the 300 K window. Placed as nearly the first element, the CHWP modulates the polarized signal external to the instrument, stabilizing the long-time scale (large angular scale) CMB polarization response.
- **Focal Plane Assembly (FPA):** The FPA mounts 7 detector modules at 100 mK a precise distance (<200 μm tol.) from final lens. The FPA incorporates a superconducting magnetic shield and the first stage of cold (100 mK) readout (see below), and is designed to be resistant to vibrational excitations below 100 Hz.
- Cold Readout: Mounts components of µMux readout between 4 K and 100 mK.
 Cryostat and Fridge: Cryostats (manufactured by Criotec, Impianti SpA) hold all elements of SAT, cooled by a Cryomech PT420 Pulse Tube Cooler with 50 and 4 K stages, and a Bluefors Dilution Refrigerator for continuous 1 K and 100 mK cooling.
 High Permeability Magnetic Shields: Shield SQUID readout and TES bolometers from spurious magnetic field pick up from Earth and instrument.

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- **3-axis rotation:** Az (0-360°), El (0-90°), & Boresight (Deck, ±90°)
 -Deck rotation enables additional data splits and systematic reduction
 Extensive spurious signal mitigation: from telescope, sun, and ground signal with:
 - -Forebaffle (green): mounted to receiver
 - -Comoving Shield: mounted el-stage
 - -External Ground Shield Enclosure
- Automatic sparse wire grid loader: co-mounted with forebaffle to enable periodic gain and pol-angle calibration with minimal loss of observing efficiency.

