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APEX-SZ first light and instrument status

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Abstract

The APEX-SZ instrument is designed for the discovery and study of galaxy clusters at mm-wavelengths using the Sunyaev Zel'dovich effect. The receiver consists of 320 superconducting transition edge sensor (TES) bolometers cooled to 250 mK with the combination of a three stage He sorption fridge and mechanical pulse tube cooler. The detectors are instrumented with a frequency domain multiplexing readout system. The receiver is mounted on the 12 m APEX telescope located at 5100 m on the Atacama plateau in Chile. For the first light engineering deployment of December 2005, the receiver was configured with a 55 element wedge of the bolometers and operating in the 150 GHz atmospheric window. During the engineering run we achieved significant milestones in our instrumentation development efforts, including celestial observations with a monolithically fabricated TES bolometer array cooled with a mechanical cooler and successful implementation of a SQUID-based MHz AC-biased readout. These technology demonstrations point the way toward future large TES bolometer array instruments. Here we describe the results of this deployment and future plans for the APEX-SZ instrument.

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Contents

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1. Introduction

The APEX-SZ galaxy cluster survey instrument is a 320 element transition edge sensor (TES) bolometer array receiver designed to conduct a large mass-limited survey of galaxy clusters using the Sunyaev-Zel'dovich (SZ) effect. The instrument was deployed for an engineering run and saw first light in December 2005 on the 12 m Atacama Pathfinder EXperiment (APEX) telescope. The APEX telescope was commissioned in September 2005 at its site in the Chilean Atacama desert; see Güsten et al. (2006a); Güsten et al. (2006b) for detailed descriptions of the APEX project. The APEX-SZ survey instrument is scheduled for its first science observing run in Fall 2006.

The Sunyaev-Zel'dovich effect (Sunyaev and Zeldovich, 1970) is a distortion of cosmic microwave background (CMB) photons as they pass through clusters of galaxies. The surface brightness of this effect is largely independent of redshift, allowing detection of galaxy clusters with mm-wavelength detectors at all redshifts at which clusters are present. APEX-SZ is a powerful new SZ survey instrument, with a mapping speed significantly faster than the present generation of SZ experiments. With APEX-SZ, we will survey 100–200 square degrees to an rms of 10 μK per arcminute pixel. We expect to discover and catalog thousands of previously unknown galaxy clusters in a mass-limited survey. This will enable us to study the evolution of structure formation in the universe and constrain cosmological parameters, such as the matter density and the dark energy equation of state, that are associated with structure formation.

A description of the instrument, including the receiver, telescope, Chajnantor site, optics, detectors, and readout is given in Section 2, the instrument configuration for the first engineering run is given in Section 3, first light instrument characterization, including instrument noise characterization and optical beam parameters, are described in Section 4, we discuss the current status and plans in Section 5, and conclude in Section 6.

2. The APEX-SZ instrument

The APEX-SZ instrument is an imaging array receiver incorporating monolithically fabricated transition-edge sensor (TES) bolometers. The initial configuration of band-defining filters is tuned to an observation frequency of 150 GHz (2 mm wavelength), with possible future observations at 90 and/or 220 GHz. The bolometer array consists of six triangular wedges, each containing 55 spiderweb absorber-coupled Al/Ti bilayer TES bolometers (Lee et al., 2003). A total of 320 detectors will be instrumented in the survey configuration. The detectors are cooled by the combination of a He pulse tube cooler and a three-stage He sorption refrigerator to a temperature of 250 mK. They are AC biased and read out by SQUID-based electronics with shunt-feedback (Spieler, 2002) for low impedance and increased dynamic range. The system is being upgraded to an 8-channel frequency-domain multiplexed (fMUX) readout for the upcoming Fall 2006 science run. The instrument is mounted in the Cassegrain receiver cabin of the APEX telescope. Reimaging optics in the Cassegrain cabin allow the APEX-SZ focal plane to instantaneously image a 22′ field of view (FOV) with 60″ FWHM beams. The receiver as installed in the APEX telescope is shown in Fig. 1.

2.1. Telescope and Chajnantor site

The Atacama Pathfinder EXperiment (APEX) telescope (Güsten et al., 2006; Güsten et al., 2006) is a 12-m diameter submillimeter telescope designed for observations up to 1.2 THz (250 μm). The telescope, is located near Cerro Chajnantor at an elevation of 5100 m, on the Atacama plateau adjacent to the Atacama Large Millimeter Array (ALMA) site in northern Chile. Designed and built by Vertex RSI, the APEX telescope is a prototype ALMA antenna, with the addition of two Nasmyth cabins, and is intended for single-dish observations with a complement of both heterodyne and bolometer array receivers. The primary mirror panel alignment has been measured with holography and aligned to an rms surface accuracy of 17–18 μm. The superb optical quality, along with arcsecond pointing accuracy and secondary mirror supports designed to minimize stray light scattering, make the telescope very well suited to a mm-wavelength SZ survey instrument.

The Chajnantor site has been well characterized as part of the ALMA site testing program, and has been found to have both low levels of precipitable water vapor and very good atmospheric stability (Radford and Holdaway, 1998; Lay and Halverson, 2000), both necessary for