The Terahertz Intensity Mapper (TIM): design and development status of a far-infrared balloon for spectroscopic galaxy evolution studies

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***Abstract*—The Terahertz Intensity Mapper (TIM) is a NASA far-infrared long-duration balloon mission, which aims to study the 3D structure of our star forming universe using far-infrared spectral lines. We will present the scientific goal of TIM, the architecture of the balloon payload and spectrometer, and reports upon the current status of hardware components.**

Keywords*—*far-infrared, balloon, grating spectrometer, intensity mapping, galaxy evolution

I. Science Goal

Understanding the formation and evolution of galaxies over cosmic time is one of the foremost goals of astrophysics and cosmology today. The cosmic star formation rate has undergone a dramatic evolution over the course of the last 14 billion years, and dust obscured star forming galaxies (DSFGs) are a crucial component of this evolution. A variety of important, bright, and unextincted diagnostic lines are present in the far-infrared (FIR) which can provide crucial insight into the physical conditions of galaxy evolution, including the instantaneous star formation rate, the effect of AGN feedback on star formation, the mass function of the stars, metallicities, and the spectrum of their ionizing radiation.

TIM, the Terahertz Intensity Mapper [1], is a NASA balloon mission that will observe the universe in the crucial gap between the spectroscopic coverage of the Atacama Large Millimeter/submillimeter Array (ALMA) in the sub/mm, and the James Webb Space Telescope (JWST) in the mid-IR; something which is impossible to do from the ground. TIM will survey two fields: ~0.1 deg^2 centered on GOODS-S and ~1 deg^2 on the South Pole Telescope (SPT) Deep Field. TIM will produce deep maps of the 3D structure of the Universe by redshift tomography ("intensity mapping") with [CI], and [CII] X [NII] cross-spectra, to constrain the cosmic star formation history at cosmic noon. In addition, it is expected to achieve spectroscopic line detections of ~100 galaxies in the atomic fine structure lines of C, N, and O, as well as establish mean galaxy properties such as star formation rate, metallicity and AGN content, using a stacking analysis of known sources and the wealth of ancillary data available in the GOODS-S and SPT Deep Field.

II. Payload & Instrument Architecture

To achieve these science goals, TIM will fly two long-slit (1 degree slit length) cryogenic grating spectrometers, which cover the 240-317 um and 317-420 um wavelength bands at R~250 simultaneously. Each of these spectrometers is serviced by a ~3600 pixel array of horn-coupled kinetic inductance detectors (KIDs), which will be read out using a Xilinx RFSoC based readout system.

The TIM gondola and cryogenic system are loosely based upon proven BLAST hardware. However, a new 2-meter low-emissivity high-throughput primary mirror will be used to achieve maximum mapping speed. This smaller mirror (compared to BLAST) has allowed the gondola design to become more compact. In contrast, the 4 Kelvin volume of the cryogenics system has grown to accommodate all optics of the spectrometers.

III. Current Status

The TIM consortium is currently receiving hardware for many of its subsystems. In particular, the primary mirror is complete and currently being shipped to the US. The detectors for the long wavelength spectrometer have demonstrated the required single pixel optical performance [2,3] and kilopixel arrays are currently under development [4]. All other major subsystems (gondola, readout, cold optics, flight software) are in their final stages of design, or have already begun fabrication. An initial full assembly of the payload is envisioned for late 2022.

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