Heterodyne Array Receiver Study for the FIRSST Space Mission

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***Abstract*—The Far IR Spectroscopy Space Telescope is a study to be submitted for the NASA probe mission. We are carrying out the design of a heterodyne array receiver for FIRSST to be able to observe the fundamental water lines at very high spectral resolution.**

Keywords—heterodyne receiver, far-IR, Terahertz missions, systems and instrumentation

I. INTRODUCTION

The Astro2020 decadal review has recommended that a Probe-class mission, with a cost cap of ~$1B, should be launched around 2030 in order to either carry out far-IR or for x-ray observations. The announcement of Opportunity is expected in 2023. Currently there are a number of x-ray studies under way as well as at least four studies for far-IR missions underway: A Single Aperture Large Telescope for Universe Studies (SALTUS) lead by C. Walker, the PRobe far-Infrared Mission for Astrophysics (PRIMA) led by J. Glenn and M. Bradford, the Space Infrared Interferometric Telescope (SPIRIT) by D. Leisawitz and the Far IR Spectroscopy Space Telescope (FIRSST) by A. Cooray.

II. FIRSST

FIRSST has 3 major science goals: It will accurately measure the amount gaseous material in protoplanetary disks in order to determine the maximum mass of potential planets and the timescale for planet formation. FIRSST will trace the trail of water from the interstellar medium to planets and FIRSST will study how galaxies assemble their material. FIRSST will consist of a 1.8m primary mirror actively cooled to ~20K and will have a simple, low-risk architecture. The satellite will be equipped with closed-cycle coolers to guarantee a lifetime of at least 5 years. The observatory will be equipped with two instruments: a direct detection camera with two selectable resolution modes and a heterodyne array receiver. The bolometer camera will be able to observe between 30 to 270 microns at low spectral resolving power, i.e., R~ 200, or in 4 distinct wavelength ~~frequency~~ bands between 50 and 250 microns at high spectral resolving power, i.e., R~10^5, by employing a Virtually Imaged Phased Array (VIPA) spectrometer.

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III. HETERODYNE ARRAY RECEVIER FOR FIRSST

The heterodyne array receiver for FIRSST will carry out very high resolution (R = 10^6 to 10^7) observations of the fundamental water lines at 557 GHz (ortho) and at 1113 GHz (para) as well as of water isotopes. Therefore, it has two bands: one between 550 to 750 GHz, and a second band between 950 and 1250 GHz. Each band will be covered with a small array receiver. The instrument design is based heavily on HIFI/Herschel, upGREAT/SOFIA and the recent HERO/Origins study.

As we are writing this abstract the design of the heterodyne receiver is rapidly evolving, but the design will need to be well advanced for the first satellite concurrent design lab at the end of July and nearly finished in October for the second design lab. Currently, we are focusing on cost reduction and aim to keep the receiver small, simple and low risk. Each band will see one polarization, allowing us to superimpose the two bands for simultaneous observations. We plan to use high TRL components (from HIFI or other space missions), e.g. SIS mixers for the lower band and HEB or SIS mixers for the higher band. For the water study an IF bandwidth of 6 GHz is sufficient. The IF will be amplified by either InP or SiGe amplifiers, depending on the exact array size and the available cooling power. We would detected the IF signal either by FPGA or CMOS backends. The local oscillator signal will be produced by ambient multiplier-amplifier chains, making use of the recent development for SWI/JUICE (see related papers).

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