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Heterodyne Array receivers for Space Missions

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The first heterodyne array receivers have been built and been used on ground-based telescopes, e.g., CHAMP on the CSO, HERA on the IRAM 30m telescope, SuperCAM on the HHT; on airplane observatories, e.g. upGREAT on SOFIA, and on balloon experiments e.g. on GUSTO and on ASTHROS. With the success of these array receivers, we are now designing heterodyne array receivers for space missions drawing from the heritage of these arrays, along with the single pixel HIFI/Herschel instrument.

When adapting existing arrays to a space mission great care needs to be taken to limit the required resources: cooling power, electrical power, size and weight. The largest challenge is to reduce the required cooling power to a few tens of mW for the whole array, as space-qualified cryocoolers have only very limited cooling power, that generally needs to be shared between several instruments and for the cooling of the primary mirror. To reduce the required cooling, we need to select very low power (< 2mW) first stage amplifiers, which could be InP or SiGe amplifiers and possibly place them at a slightly warmer stage. The other large challenge is to limit the required electrical power, which is dominated by the spectrometer backends and the local oscillator. New ASIC chips are being commercially developed and would be a great asset once space qualified, alternatively CHIRP spectrometers and autocorrelators (ACS) can be used. High efficiency amplifier-multiplier chains are becoming available as LO source. Quantum Cascade Lasers have been flown on SOFIA and work is being carried out to reduce their cooling requirements, so that they could be an alternative.

We have recently carried out a detailed design of such a heterodyne array receiver for the Far-IR Spectroscopic Space Telescope (FIRSST) proposal that was submitted in November 2023 in response to the NASA Astrophysics Probe Explorer call. The Probe call asks for mission concepts for a far-IR or x-ray mission with a budget between a large and a medium mission, to be launched ~2032. The FIRSST mission has a 1.8m cryogenic primary mirror and two instruments: a Direct Detection Spectrometer Instrument (DDSI) and a Heterodyne Spectrometer Instrument (HSI). HSI has 3 frequency bands covering 500 to 790 GHz, 882 to 1250 GHz and 1500 to 2000 GHz. Each band has two 5-pixel arrays, one for each linear polarization. HSI uses state of the art double sideband SIS mixers for the lower frequencies and HEB mixers for the higher frequencies. The arrays will be pumped by amplifier-multiplier LOs that reside in the warm space bus and whose signal is guided up optically via baffles and filters to the cold optical bench. The first stage InP amplfiers are physically close to the mixers, but heat strapped to the 18K stage. Up to 12 pixels can be read out simultaneously with CHIRP or ACS spectrometers. The The ICU includes hardware and software modules that control the instrument and its calibration, as well as process and transfers the data.