ASTHROS+: A 4-pixel ultra-broadband 1.4-2.06 THz receiver channel for the ASTHROS stratospheric balloon telescope

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Program: Strategic Initiative

Project Objective

Enormous progress have been made with data from HIFI/Herschel, GREAT/SOFIA and the Stratospheric THz Observatory (STO-2). However, the evolution of the Interstellar Medium (ISM) is not totally understood yet.

For future space missions, the goal should be to produce the first detailed and complete census of the ISM ecosystems in the Milky Way with the aim of understanding the evolution of the ISM phases and its relationship to star formation. **Even if COBE found that 50% of the total luminosity since the Big Bang is in the submillimeter range, an all-sky line survey of key species at high spectral resolution (10^6, or ~0.3 km/s) is still missing in this range.**

The main objective of this work is to develop 4-pixel ultra-broadband high-spectral resolution heterodyne receiver covering entirely the 1.38 to 2.06 THz band with just a single channel enabling the next generation of terahertz instruments. The large receiver RF bandwidth achieved with a novel concept called "on-chip diplexing" (~40%) represents an improvement of more than factor of four with regards to the previous state-of-the-art.

This revolutionary approach will allow to observe, with a single channel, most key tracers of star forming processes **The resulting new generation of large-band submillimeter-wave heterodyne instruments will offer a higher science return than any competing approach**, as envisioned by concept studies for future NASA missions.

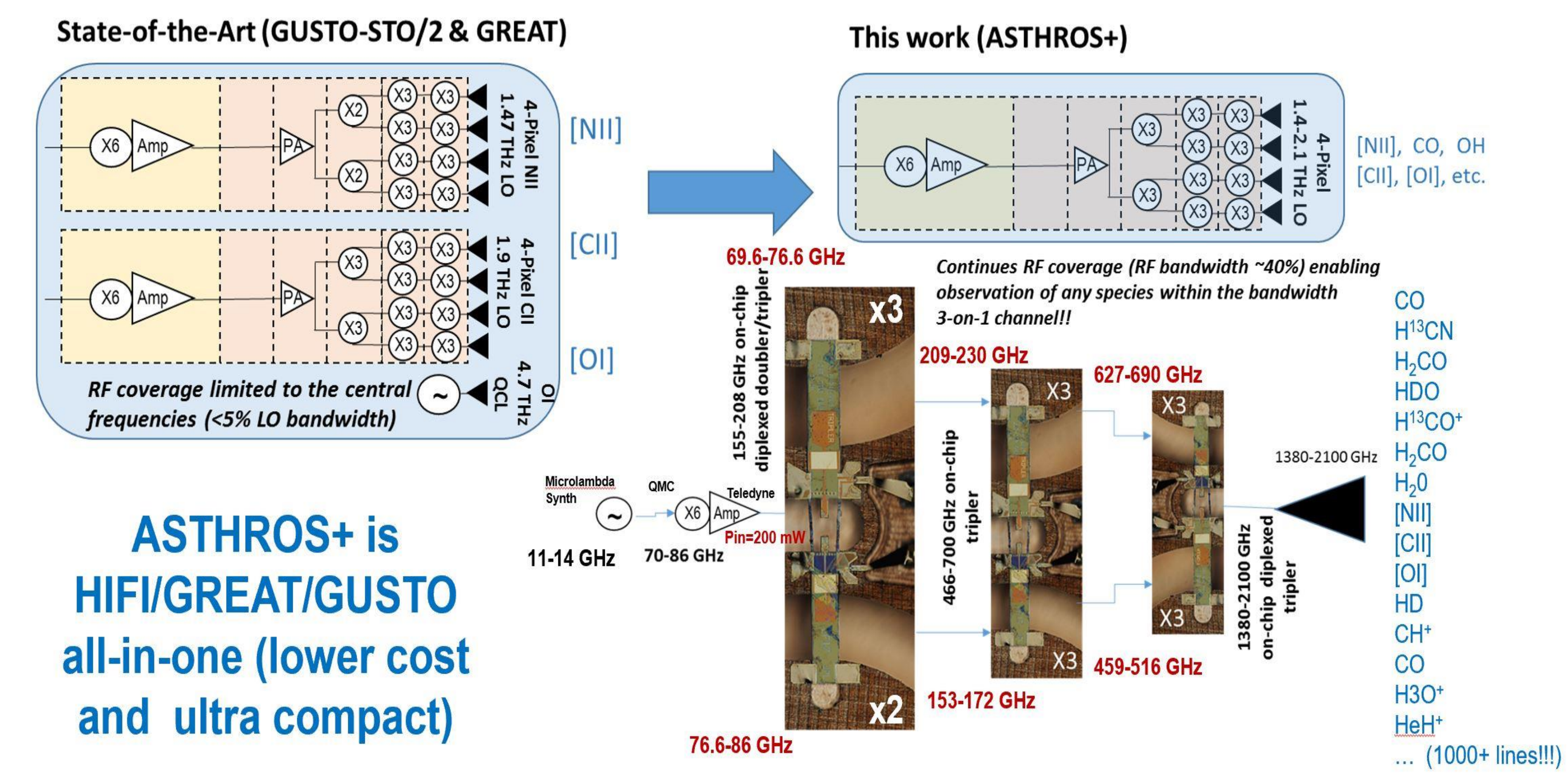


Fig.1. ASTHROS+ receiver offers continuous coverage in the 1.4-2.1 THz range, enabling observation with a single-channel of all key species of star forming cycles. Previous missions such as GUSTO/STO-2 required 3 different LO channels and with a very limited RF coverage (<5%).

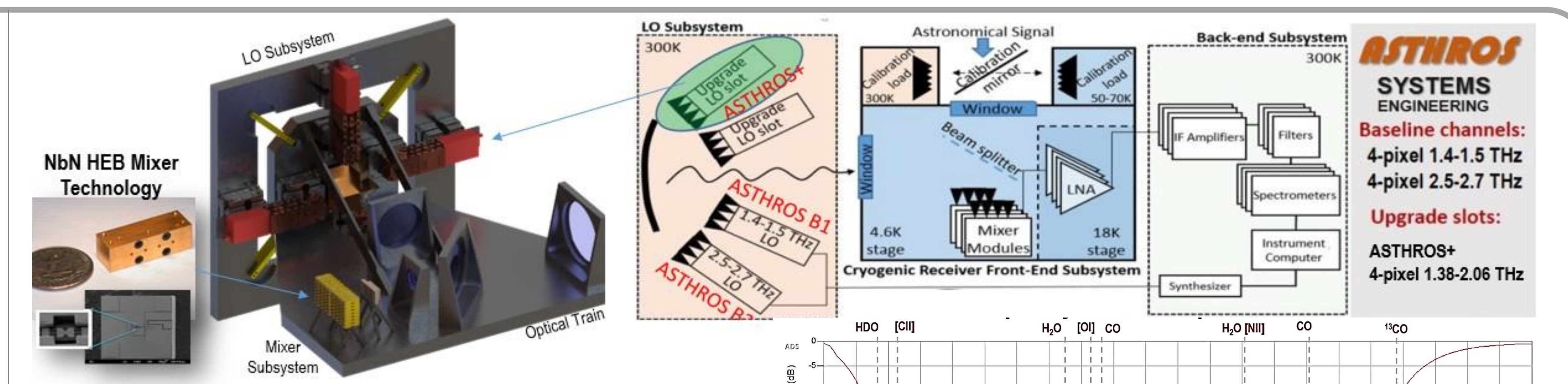
FY19 Results

The ASTHROS+ 1.4-2.06 THz heterodyne receiver consists of a Schottky diode based frequency multiplied local oscillator (LO) source and NbN Hot Electron Bolometer mixers. The mixers are inherently broadband. For the LO we use a very innovative approach consisting in diplexing 2 different bands on a single frequency multiplication stage. Starting at W-band, a first chip double or triples the input signal depending on the input frequency. The two following stages consist of triplers working simultaneously at two different sub-band (on chip-diplexing). The resulting output covers the 1.4-2.06 THz band (see Fig 2. left-center).

The multiplier chips and housing have been designed and are currently being fabricated (single-pixel version). Performance is shown in Fig 2 right. The predicted LO output power is well above the 10 μW requirement for all the key tracers to be observed.

A new broadband waveguide-based NbN HEB mixer has also been designed to operate in the 1.4-2.06 THz bands (the chip and expected performance are shown in Fig. 2 bottom left)

The ASTHROS+ receiver presented herein represents the first ever high-spectral resolution heterodyne receiver able to observe all key tracers of star formation. The architecture design is directly compatible with the ASTHROS mission architecture. Therefore, ASTHROS+ receiver could be flown in one of the upgrade slots for a TRL promotion in 2023.



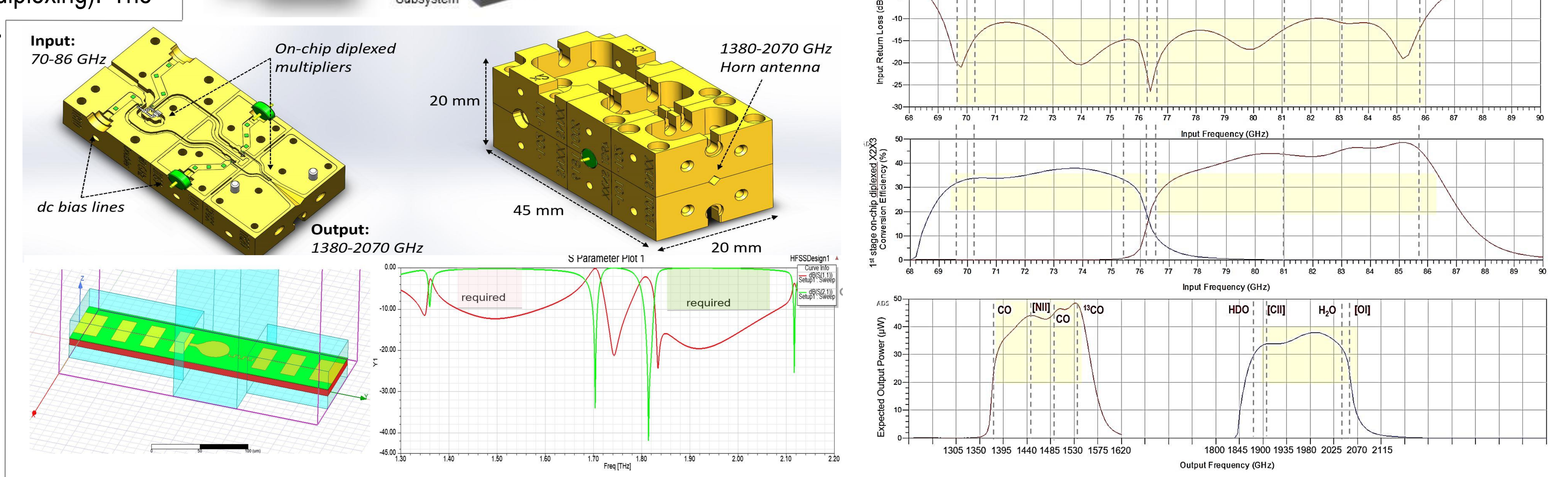


Fig.2. Accommodation opportunity for the ASTHROS+ broadband 1.38-2.07 THz channel on the ASTHROS mission (top left); overall receiver architecture for high-spectral resolution THz heterodyne receivers such as ASTHROS+ (top right). **ASTHROS+ on-chip power-combined ultra-compact 1.38-2.07 THz LO source -single-pixel version-: design (center left) and expected performance (bottom right). ASTHROS+ broadband 1.38-2.07 THz Hot Electron Bolometer mixer designed under this task: chip and expected performance (bottom left).**

Benefits to NASA and JPL

Fig.3. The innovative ASTHROS+ ultra broadband receiver will enable for the 1st time simultaneous observations of all the key tracers in the star forming cycle (left), enabling future NASA mission aimed to obtain the 1st all-sky high-spectral resolution map in the far infrared, complementing the low res. one from COBE mission (right).

Recently, NASA selected the ASTHROS balloon-borne mission, which is planned to fly from Antarctica in December 2023 days Therefore, ASTHROS offer an invaluable flight opportunity for the ASTHROS+ receiver. In fact, NASA encourages the use of these kinds of missions to include additional technologies for TRL enhancement in preparation for future space missions. ASTHROS+ will turn ASTHROS into an extremely powerful platform able to provide complete picture of the life cycle of the ISM from diffuse ionized gas to dense and warm star forming molecular gas. This is achieved by its capability to observe literally any of the key lines governing the star forming process due to the ultra-broadband tunability (see Fig. 3). Flying ASTHROS+ as part of ASTHROS will get this strategic technology ready for infusion in future suborbital (SOFIA) or space instruments (MO missions, MIDEX missions, OST, Probe missions, etc). In addition, "The Far-Infrared Astronomy Stratospheric Balloon Facility" concept submitted to the Decadal Survey on Astronomy and Astrophysics (Astro2020) would carry the ASTHROS+ instrument during at least 10 years of continued operations, if recommended.

ASTHROS+ ultra broadband high-spectral resolution receiver will be the most advanced and capable submillimeter-wave spectrometer ever built. It will be the only THz heterodyne receiver architecture able to fulfill the aggressive requirements for future missions. A successful demonstration will guarantees JPL leadership position in the field for the next decades. With this technology, JPL will be the only institution able to propose an ambitious mission aiming to produce the first high-spectral resolution all-sky map in the far infrared.

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