

The Space High-Angular Resolution Probe for the InfraRed (SHARP-IR): A Potential Far-Infrared Interferometric Probe

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The Space High-Angular Resolution Probe for the InfraRed (SHARP-IR) would extend high resolution imaging into the far IR, observing crucial atoms, ions, and molecules such as water as well as continuum sources, to enable discoveries in the areas of star and planet formation, AGN, obscured star forming galaxies at high redshifts, cool objects in general, and the outer solar system. With a cold interferometer and a baseline of 12 m, it would offer 8 times the spatial resolution of Herschel combined with superior (TBD) sensitivity. It would operate between 20 and 160 μm , filling the u - v plane in the synthetic aperture, to enable high quality imaging. This new concept is currently under development at GSFC, with a (growing) science team from multiple institutions; the mission is in the earliest stage of concept development, as the team works to identify key engineering challenges and to define the core science that would be enabled by it.

1. Science Drivers

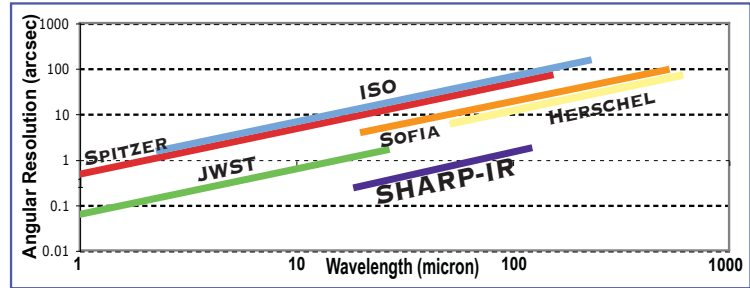
A far-infrared (FIR) space-based interferometer such as SHARP-IR would provide new capabilities for high angular resolution in the FIR; these capabilities, in turn, would enable a wide range of new scientific inquiry. While the science case for SHARP-IR is still in development, one key area will be the study of star formation. Most stars in our galaxy form in clusters of 50 or more young stars. Because of their young age, a large amount of dusty material from the original molecular cloud still surrounds these stellar nurseries, and absorbs short wavelength light to re-radiate it in the thermal infrared: that is why these regions are best studied at infrared wavelength. However, the protostars are often in close proximity, such that the long wavelength observations made with *Spitzer*, *Herschel*, and SOFIA are often confused: it is not possible to clearly identify where the far-IR emission is coming from, and this leaves key questions about the star formation process unanswered. With the angular resolution provided by SHARP-IR, it would become possible to not only measure the spectra of a large number of protostars, but it would also allow direct measurement of the shapes of the envelopes around Young Stellar Objects (YSOs). This will enable us to map the distribution of dust and help answer fundamental questions about how protostars reach their final mass in these important regions of stellar birth. In addition, SHARP-IR would enable new studies of the processes present in the hearts of active galactic nuclei, dynamics and interactions near our own galactic center, and characterization of bodies within our own solar system.

As part of the ongoing SHARP-IR study, we are looking at all of these scientific options, and are expanding the science team to explore other potentially new and interesting science.

2. Technical Capabilities

The goal of the SHARP-IR concept is to complement JWST by providing comparable angular resolution observations out to much longer wavelengths (as can be seen in the figure above). SHARP-IR will take advantage of interferometric data reduction techniques developed for radio astronomy, and will provide nearly an order of magnitude improvement in angular resolution

relative to *Herchel*, with comparable sensitivity. One activity within the current SHARP-IR study effort is the development of simulations that clearly demonstrate these capabilities.



3. New Technologies

Fundamentally, no new technologies are necessary for SHARP-IR, with the possible exception of detectors. The fast response times and high sensitivity needed from detectors are likely well within the reach of current detector development programs, but additional analysis of detector requirements will be needed as study progresses. Beyond detectors, all of the major technologies have been proven, and the BETTII balloon experiment will serve to provide a system-level demonstration of a free-flying interferometer. Further, independent of the final architecture of the FIR Surveyor, investments in technologies (e.g. cryocoolers) will likely benefit SHARP-IR; while the current state-of-the-art is sufficient for SHARP-IR, improved subsystem capabilities will reduce cost and risk.

4. Why a Probe?

There are several motivations for SHARP-IR. Scientifically, an order of magnitude improvement in angular resolution at FIR wavelengths opens a new space of discovery. But SHARP-IR would also serve as a technological pathfinder. In 2012, NASA HQ established the NASA Roadmap team, leading to the Roadmap report, *Enduring Quests – Daring Visions*. In that document, a series of missions are laid out, first in the Formative Era, to be followed by missions in the Visionary Era. Notably, “All notional missions in the Visionary Era are interferometers, and technology maturation of interferometric techniques is thus highly relevant to realizing the science vision.” The report also notes “Interferometry has historically progressed from longer wavelengths, where technological challenges are less extreme, to shorter wavelengths.”

It is possible that the FIR Surveyor could adopt an interferometric architecture; should that occur, it would have capabilities exceeding that of SHARP-IR, and would enable future interferometers working at shorter wavelengths (as per the vision of the Roadmap). If, however, the FIR Surveyor adopts a single aperture architecture, a mission such as SHARP-IR is needed to make future interferometric observatories possible.

Balloon-based experiments such as BETTII serve as an important stepping stone to future space-based missions, but limitations of flying within the atmosphere fundamentally constrain their scientific capability. Most importantly, the warm telescopes that must be used on a balloon interferometer limit the overall sensitivity, such that they can observe only the closest star formation regions.

We have also considered whether a mission similar to SHARP-IR could be developed on an Explorer budget, but previous experience with mission studies of other interferometric missions (SPIRIT, at >\$1B; FKSI, at ~\$500M in 2009 dollars) demonstrated that these small budgets are not commensurate with a scientifically capable interferometer.