# The PRIMA Probe-Class Mission Concept

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Access to the far infrared (FIR) region of the electromagnetic spectrum is essential for many areas of astrophysics research, and previous FIR space missions, most recently Spitzer and Herschel, have produced important advances in cosmology, star and galaxy formation and evolution, the development of planetary systems, and planets and small bodies in the Solar System. While previous missions have demonstrated the importance of the FIR region, they have also drawn attention to the "FIR gap" in angular resolution and sensitivity compared to facilities operating at shorter (JWST) and longer (ALMA) wavelengths. Eliminating this gap has been recognized as an objective to provide us with the tools we need to explore the multi-wavelength Universe.

The Astro2020 Decadal Review recognized that a FIR mission is needed to fill this important gap in worldwide capabilities and would advance high-priority science including "tracing the astrochemical signatures of planet formation (within and outside of our own Solar System), measuring the formation and buildup of galaxies, heavy elements, and interstellar dust from the first galaxies to today, and probing the co-evolution of galaxies and their supermassive black holes across cosmic time." It recommended that NASA implement a line of PI-led Probe-class missions, intermediate between the scale of Explorer class and Great Observatories, and that the first of these missions should be either an X-ray or a FIR observatory and be launched in the early 2030s. NASA responded promptly and positively to this recommendation with a call for Probe- class mission proposals, and following the submission and assessment of several FIR and X-Ray mission concepts, in April 2024 one mission of each kind was selected for detailed Phase-A study. These studies are now in progress with downselection of the first Probe mission foreseen in mid-2026. The FIR mission selected for study is the Probe far-Infrared Mission for Astrophysics (PRIMA), led by Dr. Jason Glenn of NASA Goddard.

PRIMA will cover FIR wavelengths between 24 and 235 μm, with a 1.8-m diameter tele- scope cooled via a combination of passive and active cooling to 4.5 K, resulting in extremely low thermal background radiation on the instruments' detectors. Its instruments will be equipped with superconducting kinetic inductance detectors (KIDs) operating at ∼100 mK, and achieving the sensitivity levels needed to take full advantage of this low background. This combination of significant aperture size and exquisitely sensitive detectors will enable PRIMA to achieve a huge leap in sensitivity over Spitzer and Herschel.

PRIMA's two scientific instruments, the Far Infrared Enhanced Survey Spectrometer (FIRESS) and the PRIMA Imager (PRIMAger), are designed to unlock the potential of the FIR spectral region to advance astrophysics over a broad range of topics spanning from galaxy and dust evolution in the early universe to the formation of planets and planetary atmospheres. FIRESS will carry out simultaneous full-band long-slit grating spectroscopy with $R \sim 100$ between 24 and 235 μm, with an optional high-resolution mode, $R = 4;400 \times (112$ μm/λ), using a Fourier transform module in series with the gratings. PRIMAger has a hyperspectral imager with $R \sim 10$ and continuous coverage from 25 to 84 μm, optimised for the detection of redshifted PAH features from distant galaxies, and a photometric and polarimetric imager with four bands from 90 to 235 μm.

Operating in a halo orbit around the second Lagrange point of the Sun-Earth system, L2, PRIMA will have a lifetime of at least five years, with observing time split between PI science programs defined by the PRIMA consortium (25%) and General Observer (GO) programs (75%) based on competitive proposals from the worldwide community. The key PI science themes, which drive the mission and instrument design are the origin of planets and their atmospheres, the co-evolution of galaxies and their central supermassive black holes, and the buildup of dust and metals over cosmic time. The PRIMA team has engaged strongly with the wider astronomy community and solicited and collected ideas for GO science, which are documented in the PRIMA GO Science Book (https://arxiv.org/abs/2310.20572), with many of them further elaborated in papers in this special section.

PRIMA's mission and instrumentation and some of its enabling technologies are described in six papers, and the remaining papers cover a wide range of science cases which can be addressed by PRIMA. An overview of

the PRIMA mission is given by Glenn et al., the FIRESS instrument, including its observing modes and scientific capabilities, is described in detail by Bradford et al., and PRIMAger is likewise presented in Ciesla et al. Key technologies, including the 100-mK cooler, KID detector architecture, post-dispersed Fourier transform spectroscopy, and the recovery of Stokes parameters from PRIMAger polarimetric mapping are described in papers by Di Pirro et al., van Berkel et al., Buchan et al., and Dowell et al. Overviews of the PI science programs are given in Pontoppidan et al. for FIRESS and Burgarella et al. for PRIMAger. The other science-focused papers, too numerous to mention individually, are by members of the international scientific community, with lead authors representing nine different countries. They serve as an illustration of the scientific promise of PRIMA, covering a great many scientific topics including cometary composition, the Galactic interstellar medium and star formation, planet-forming and debris disks, dust physics and evolution, magnetic fields in the Milky Way and nearby galaxies, the structure and evolution of galaxies over cosmic time, active galactic nuclei and their supermassive black holes, transient astronomy, and fundamental physics.

We extend our thanks to all the authors who have contributed papers, and to the expert referees for their engagement with the process and their valuable contributions to improving the clarity and quality of the papers; and we trust that this JATIS special section will be an excellent demonstration of PRIMA’s promise as a scientifically transformational mission.