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GUEST EDITORIAL

Special Section Guest Editorial: The Line Emission Mapper X-ray Observatory

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The Line Emission Mapper (LEM) is a mission concept developed in response to the NASA 2023 Astrophysics Probe Explorer (APEX) Announcement of Opportunity (AO). The 2020 National Academies Decadal Survey on Astronomy and Astrophysics recommended that NASA develop a new mission class to be called "Probes'' between the flagship missions and the Explorer missions with a cost cap of ∼$1.0 billion and a cadence of one mission per decade. The Decadal review went further to specify that the first Probe mission should be a far infrared (IR) or X-ray probe. LEM is an X-ray mission concept submitted in response to this AO.

The 2020 Decadal review identified three broad themes that are ripe for progress in the coming decade, one of which is the study of cosmic ecosystems. The Decadal survey noted: "A major advance in recent years has been the realization that the physical processes taking place on all scales are intimately interconnected, and that the universe and all its constituent systems are part of a constantly evolving ecosystem." The report stated that a key discovery area for understanding cosmic ecosystems is the mapping of the circumgalactic (CGM) and intergalactic medium (IGM) in emission. The X-ray bandpass is particularly attractive for the study of such emission given that all of the astrophysically abundant elements from C to Fe have strong emission lines in the X-ray energy range. The efficient mapping of X-ray emission lines from the CGM and IGM requires an instrument and telescope combination with large collecting area (>1200 cm^2 at 0.5 keV), large field-of-view (FOV, diameter ∼30 arcmin), high spectral resolution (1.3-2.5 eV), and moderate angular resolution (∼15 arcsec). The LEM mission concept was optimized for grasp (the product of effective area and FOV) in the 0.2-2.0 keV band while providing unprecedented spectral resolving power for diffuse emission to separate the line emission from the galactic foreground from the extragalactic emission as described in Ref. 1. This powerful combination of capabilities will also allow discoveries in other areas of astrophysics, such as diffuse emission in the Milky Way, planetary science, heliophysics, supernovae and supernova remnants, star-forming regions, habitability of exoplanets, clusters of galaxies, transient sources, X-ray binaries, and active galactic nuclei.

The demanding requirements of the LEM mission necessitated the development and maturation of new technologies. The large collecting area and imaging requirements of the X-ray mirror are met by the Si meta-shell optics under development for the past decade at GSFC.[2] The high spectral resolution and large detector format requirements are met by the X-ray microcalorimeters under development at GSFC for the previous 30 years.[3] The articles in this section focus on the unique challenges posed by the requirements of the LEM mission: high sensitivity and spectral resolution in the 0.2-2.0 keV band, large format detectors (∼14,000 290 μm pixels covering a 38 mm diameter focal plane), hybrid arrays combining pixels with a single absorber readout by a dedicated transition-edge sensor (TES) and "Hydra" pixels in which four absorbers are readout by a single TES, an operating temperature of 40 mK, stable and well-characterized background, time-division multiplexing (TDM) readout electronics, and high X-ray transmission through the optical and IR blocking filters.

In this special section, Patnaude et al. present an overview of the LEM mission concept, outlining the science goals based on the Decadal report, specifying the mission requirements, and describing how the mission will achieve those goals. Bandler et al. present an overview of the LEM Microcalorimeter Spectrometer (LMS) instrument, including the focal plane assembly, the detection chain, the mechanical and thermal design, the cooling system, the mass, the power, and the technology readiness level (TRL). Smith et al. report a detailed energy resolution budget and expected count rate capabilities for the LMS and the design of the anti-coincidence detector. Wakeham et al. present the characterization of the first 1000 pixel hybrid arrays built for LEM of single-absorber and multi-absorber pixels which demonstrated a spectral resolution of 0.90 ± 0.02 eV for the single-absorber pixels and 1.92 ± 0.02 eV for the four-absorber pixels. Sakai et al. discuss the design of the detector readout, including the mass, power, and volumes of the components that are currently at TRL-6. The design of the continuous adiabatic demagnetization refrigerator (CADR) that provides the temperature control for the focal plane is discussed in Jahromi and Shirron. The CADR is composed of two modules, a high temperature module with interfaces at 4 K and 350 mK and a low temperature module with interfaces at 350 mK and 40 mK, that allow continuous operation of the focal plane at 40 mK. Finally, Osborne et al. describe the dewar design that uses a four-stage pulse tube cryocooler providing the 4 K interface for the CADR.

The LEM mission is only now possible given the progress in the key technologies described in this section that allow the ambitious performance goals of the mission to be met. The capability of high-resolution spectroscopy for diffuse and extended emission with high sensitivity, in essence an Integral Field Unit for X-ray astronomy, makes the breakthrough science of the LEM mission possible. Many decades of research and development were necessary to advance the technologies to the point that a mission like LEM is viable.

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References

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