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Cosmic Ultraviolet Emission-line Survey (CUES)

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Science Summary

Wide-field imaging observations of the Mg II λλ2796,2803 resonance line doublet in the near-ultraviolet (NUV) with sub-arcsecond spatial resolution can reveal the distribution of warm (3000-6000 K) gas in many astrophysical environments, unveiling 'missing mass' that is not seen in hotter gas tracers like optical H-recombination and forbidden emission lines, nor cold gas tracers like H_2 and CO at IR and mm/radio wavelengths. Mg II emission can trace fully radiative shocks through collisional excitation, but also, through resonant scattering, uniquely reveal significant reservoirs of freely expanding, unshocked or weakly shocked, and otherwise invisible neutral atomic gas in star-forming regions, protostellar outflows, and late-stage stellar mass-loss and explosions.

On large scales, the neutral gas at the interface of galactic disks and the surrounding halo plays a crucial role in regulating galaxy evolution and the escape of ionizing radiation from massive star-forming regions. Although this material is an important reservoir for future star formation, it is most often observed to be outflowing from star-forming systems, inspiring the ubiquitous invocation of feedback in theoretical models of galaxy formation. The physical state and kinematics of this material therefore govern the contribution of early star formation to reionization. The Mg II doublet has been exploited as a key diagnostic tracing neutral gas, as (like Lyα) it resonantly scatters photons rather than permitting them to escape as forbidden lines do.

A *Cosmic Ultraviolet Emission-line Survey* (CUES) survey of Galactic environments and global distributions in nearby galaxies will be used to connect the physics of local energy-transport to large-scale outflows and feedback observed at high redshift by large ground-based telescopes, the Hubble Space Telescope, and soon James Webb and Nancy Grace Roman Space Telescopes.

CUES Science Objectives:

- Map at sub-arcsecond scales the distribution of Mg II in nearby galaxies to assess the distribution and mass budget of warm gas, comparing to other species (e.g., Lyα, Hα).
- Conduct the first ever deep, wide-field, sub-arcsecond resolution survey of Mg II λλ2800 emission in low-excitation ISM environments to investigate the distribution of warm shocked and photoionized gas.
- Map the relationship at sub-arcsecond scales between warm (3000-6000 K) gas traced by Mg II and hotter gas traced by existing surveys in molecules, Hα (~10^4 K), [O III]λ5007 (15,000-30,000 K) and even X-rays (~10^6 K) in various environments to determine ionization fractions, shock velocities, densities, and magnetic field strengths.

Key questions:

- Does Mg II trace 'missing' mass and momentum by bridging the gap between hotter Hα-emitting material and colder molecular outflows seen at IR and mm/radio wavelengths in protostellar outflows and stellar ejecta?
- What are the physical conditions and energies of protostellar jets, evolved stellar outflows, supernova remnants and stellar outbursts, and how do these flows (through feedback) affect the ISM and future star formation?

- What is the mass and physical state of large-scale outflows from nearby galaxies, and how do these conditions relate to the escape of ionizing radiation?
- What can the Mg II emission revealed in local ISM environments and nearby galaxies tell us about the physical conditions and processes in high-redshift galaxies?

From the lunar S Pole, CUES observations will map large areas of the continuously viewable southern celestial sphere in Mg II for the first time to a sensitivity of $\sim 3\times10^{-15}$ ergs/s/cm^2/arcsec^2 at S/N > 10 in 4 hours per field, resolving sub-arcsecond structures in stellar and galactic-scale outflows. Assuming ~50 fields per lunar day, CUES can cover ~200 sq-degs/year observing every two weeks during lunar daytime. Emission-line comparisons in low-extinction regions can elucidate processes in optically obscured regions observed at longer wavelengths.

Reference Payload

The lunar surface is a stable platform from which to conduct diffraction-limited observations from smallsat-class telescopes (which the SCEM report calls “suitcase science”). The diffraction-limited spatial resolution of a 24-cm aperture working at Mg II is ~0.3”. Realizing the full potential of the optical system requires guiding to about a tenth of that, which is not a capability available with low-cost free-flying smallsat spacecraft buses. The UV-Visible Emission-line Survey Telescope (UVEST) payload uses a 24-cm aperture telescope configured to conduct wide-field (~0.6° FOV) imaging at NUV-visible wavelengths. The camera has uses a dichroic beamsplitter for simultaneous narrowband emission-line mapping and broadband continuum source identification, photometry, and tracking. The image scale is ~0.25”/pixel projected onto ‘UV-enhanced’ detectors. The telescope is steered by an alt-az gimbal, which in turn mounts to a mobile logistics package that is deployed ~0.5-1 km from the landing site by the Artemis III astronauts. (An image derotator may not be necessary at the S Pole, pending analysis.) The telescope will have an aperture cover to protect it from dust and debris during launch, landing and deployment. (Using simple dust mitigation protocols, the Chinese have demonstrated a small gimbaled Lunar-based Ultraviolet Telescope (LUT) on the Chang’e 3 mission that operated for >1.5 years on the lunar surface without performance degradation; see [1].) The total UVEST payload mass is estimated to be ~60 kg, with stowed dimensions of 0.6 × 0.7 × 2 meters.

Reference:

[1] Wang, J., et al., *Astrophys Space Sci*, **360**, 10 (2015). “18-Months operation of Lunar-based Ultraviolet Telescope: a highly stable photometric performance.”