IMAGING OF THE HELIOSPHERIC BOUNDARY. Pontus Brandt, Johns Hopkins University / Applied Physics Laboratory, 7-336 11100 Johns Hopkins Road, Laurel,. MD 20723.

Comparisons of astrospheres to our heliosphere provide critical information on the current evolutionary stage of stellar winds, stellar mass loss rates, and the stars' local interstellar environments. This information could help assess the habitability of extra-terrestrial solar systems.

Summary: To image the heliospheric boundaries in extreme ultraviolet (EUV) and energetic neutral atoms (ENA) from either the lunar surface or from a satellite in lunar orbit.

Value: Due to the sheer size of our heliosphere, very little is known about how it interacts with the local interstellar medium. Basic knowledge about the heliospheric boundaries is required to compare our heliosphere with astrospheres of other stellar systems. Such comparisons would provide critical information on the current evolutionary stage of stellar winds, stellar mass loss rates, give insight into the stars' local interstellar environments, and possibly assess the habitability of extra-terrestrial solar systems.

Description of science topic: The heliosphere is the three-dimensional magnetic cavity that the magnetized solar wind forms when it expands out into the denser interstellar plasma. At the heliosphere's inner interface, the solar wind plasma slows down abruptly at the termination shock, through which Voyager-1 passed recently at about 94 AU distance from the Sun. Here, it heats up, becomes relatively dense and turbulent in a region called the inner heliosheath (the thickness is most likely 10-100 AU). The heliopause separates the outermost extension of the solar wind from the region of space that is completely dominated by the interstellar plasma.

Methodology: Voyager-1 is the first spacecraft to cross the boundary of our heliosphere and Voyager-2 is soon to follow. However, the sheer size of the heliosphere leaves remote sensing as the only remaining strategy for globally imaging these enormous structures that shelter our solar system from the local interstellar medium. To date there are two promising techniques for remote imaging of the heliospheric boundary: Extreme ultra violet (EUV) and energetic neutral atom (ENA) imaging.

Hydrogen ENAs are produced in the heliosheath through charge-exchange between the shocked solar wind protons and the cold, neutral interstellar hydrogen gas. The shocked protons in this region are mostly isotropic and some fraction of the resulting ENAs will propagate radially inward, where they can be detected by Earth orbiting platforms. The most promising energy range for studying the interactions in the heliosheath is the ~0.1-6.0 keV range. Although the anticipated ENA intensity from the heliosheath is low, ENA cameras on the Interstellar

Boundary Explorer (IBEX) Mission have already been designed to meet the requirements of imaging these ENAs. IBEX is the first dedicated mission that will utilize ENA imaging to remotely probe the heliosheath structure and, thereby, infer fundamental properties of the complex interstellar interaction.

He^+ ions from the interstellar plasma emit light at 30.4 nm wavelength through excitation by the corresponding solar line, and subsequent re-emission. A large increase in number density is anticipated at the heliopause because the interstellar plasma cannot flow across this boundary. The jump in density leads to a sizeable and measurable source of this glow, which provides a way to globally map the heliopause. It has been shown that appropriately designed instruments would be capable to measure the milli-Rayleigh range intensity of the He^+ line with the high spectral resolution required to subtract other EUV contributions. In addition to the He^+ emissions from the interstellar plasma, there are also observable sources from the solar wind inside of ~20 AU from the Sun and the galactic emissions. These can be distinguished from the desired He^+ glow by their different spectral and spatial signatures [*Gruntman et al., Proceedings of SPIE, Vol. 5901, 2005*]. Due to the enormous size of the heliospheric boundary, variations in its intensity and morphology are anticipated, likely on the order of years.

Implementation: With its lack of an obstructing atmosphere, the Moon presents a desired, natural observation platform from which to observe the sky. Intensities of EUV and ENA emissions from the heliospheric boundaries are low. Long integration times and large geometrical factors are therefore strong design drivers. The variations of the heliospheric boundary are on the timescales of years and therefore long-duration observations are also required. The Moon and its associated infra structure provide a platform that fulfills the instrument requirements (in particular mass), and perhaps more important, fulfills the requirement for long-duration observations in the sense that instruments can be maintained and expanded. Observatories on the far-side of the Moon would require data downlink through a relay satellite, but would be protected from unwanted terrestrial EUV and ENA emissions. An increasingly desired location for lunar deep-sky observations is in one of the deep craters at one of poles. This location provides an acceptably quiet measurement environment while maintaining a continuous down link directly to Earth.

As with all lunar-based observations the mitigation of lunar dust deposits directly onto the instrumentation is of high priority. Since dust also scatters EUV and ENAs the spatial distribution and temporal evolution of high-altitude dust layers must be well characterized in order to assess the feasibility of a lunar based observatory. Satellite based instrumentation in Lunar orbit would benefit from avoiding the dust-related problems and a much shorter development time since it could be based on the heritage of already existing satellite missions. On the other hand, mass restrictions would be stricter, which would affect geometrical factors.

	MASS	**POWER**	**BITRATE**	**SPECTRAL RANGE**	**ANGULAR RESOLUTION**	**SPECTRAL RESOLUTION**
ENA	50-100 kg (lunar-based) 10-20 kg (satellite based)	20 W (lunar based) 5 W (satellite based)	20 kbps	0.1-10 keV	5x5 deg	$\Delta E/E$~25%
EUV	~50 kg (lunar based) 10 kg (satellite based)	~10 W	20 kbps	4 nm bandwidth centered at 30.4 nm	5x5 deg	0.005 nm

Human involvement: The deployment and installation of ground-based instrumentation would most likely depend on some kind of human presence. A significant development fraction would probably have to be devoted to achieving a dust-controlled environment. It seems likely that ENA and EUV observatories would be combined with other remote observation techniques in the same location.

Timing: In light of the technical challenges to overcome and the human presence required for a lunar-based observatory, the development of lunar based ENA and EUV observatories are feasible first after 2025, once human presence have been established to a mature level. Given the technology level of existing instrumentation satellite based ENA and EUV observations in lunar orbit can be fit into the early robotic phase (<2018).

Experiment features and benefits for future lunar exploration: No direct benefits for lunar exploration. However, there are benefits for future missions to the heliospheric boundary.