What is Heliophysics? Our Field’s Ongoing Existential Crisis

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What is Heliophysics?

NASA’s Heliophysics Division’s website says that, “The Science Mission Directorate [SMD] Heliophysics Division studies the nature of the Sun, and how it influences the very nature of space — and, in turn, the atmospheres of planets and the technology that exists there.” However, in current practice, the Divisions within SMD, the study of planetary magnetospheres and atmospheres within Heliophysics is generally confined to only those of Earth, with space plasma physics at other worlds in the solar system falling under the jurisdiction of Planetary Science and space plasma physics outside the solar system under the jurisdiction of Astrophysics. This stove-piping severely limits the broader impacts of the Heliophysics community and is detrimental to the study of space plasma physics in general.

Unfortunately, programmatic restrictions generally limit the opportunities to study the fundamental processes of greatest interest to members of the Heliophysics to relatively few targets, primarily Earth, the Sun, solar wind, and local interstellar space. However, the diverse worlds within the solar system provide crucial environments that are not replicated at Earth, but can provide deep insight into the fundamental physics that drive our local Heliophysics environment. Such shared interest in other planetary targets was emphasized in the Report of the Panel on Solar Wind-Magnetosphere Interactions (SWMI) from the 2013 Heliophysics Decadal Report:

“The magnetospheres of other planets display not only certain close similarities, such as the formation of bow shocks and radiation belts, but also many processes that are markedly different, such as the source of charged particles within the radiation belts...Both planetary and magnetospheric understanding is thus enriched by the comparative study of magnetospheres.”

This prompted the SWMI Imperative that NASA’s Heliophysics Division and Planetary Divisions partner to “ensure that appropriate magnetospheric instrumentation is fielded on missions to other planets.” Planetary Science has also highlighted the importance of comparative planetology: “Comparative planetary studies offer great potential to improve our understanding of planetary systems in general...Understanding the interactions of the solar wind at all of the planets aids in understanding the physical processes at Earth.” Despite this recognition, space plasma instrumentation is increasingly an afterthought on Planetary Science missions, if it is included at all.

Studying planetary systems with dedicated Heliophysics missions, comprehensive instrumentation, and new grant opportunities for analysis and modeling would enable novel understanding of fundamental and universal processes of space plasma physics. Such an improved, more comprehensive understanding will also enable advancement in understanding more remote astrophysical systems, including exoplanets.

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While greater collaboration between the NASA Divisions would undoubtedly increase the scientific output of NASA Heliophysics, there is yet another issue whereby Heliophysics is increasingly pigeonholed into only being important as it relates to “space weather” (i.e., the societal and technological impacts at Earth). When competing against the easily-digestible and exciting themes of other disciplines, e.g., Planetary Science (“The search for life”), Earth Science (“Understanding our home”), and Astrophysics (“Exploring the origin of the universe”) – Heliophysics has historically struggled. Often, selling Heliophysics to policymakers and the public is a challenge. Planetary missions can be seen as “boldly going” and astrophysical missions “unveil the mysteries of the universe,” yet Heliophysics missions often lack the inspirational exploration tagline. This is despite the fact that stellar and space plasmas and their processes represent some of the most genuinely universal and fundamentally important physics in the cosmos. The Heliophysics community has been hard-pressed to distill our major fundamental questions into exciting and intuitive problems that capture the public eye. We have understandably reverted to a very practical, applied definition – i.e., space weather – to justify our discipline as we advocate for our science and appeal for funding.

Space weather is a powerful practical example and something that brings home the everyday relevance of our field when speaking to the public or policymakers. Space weather has a major impact on policy both in the U.S. and worldwide. Many U.S. Congressional committees deal with issues for which space physics is relevant, including those for Homeland Security, Armed Services, Intelligence; Energy; Science; Transportation; Agriculture; Commerce; and Education.[3] Space weather is an appropriate and viable lens through which to frame the relevance of solar and space plasma physics and much success has been made over the last few years in the organization and codification of a federal strategy regarding space weather through the National Space Weather Action Plan and the PROSWIFT legislation. However, overreliance on space weather to define our field, as opposed to simply using it as a practical and relatable tool, narrows the scope of what solar and space physics is and diminishes its fundamental importance. We must realize and delicately balance the temptation to use space weather to define our science with the increasing societal relevance of space weather effects. Especially in light of humanity’s ambition to expand into the solar system (i.e., desires to establish a crewed lunar station, colonize Mars, and mine the asteroid belt), it will become increasingly critical to understand and consider space weather effects at other planetary systems as well, throughout the solar system, and such science clearly falls under the jurisdiction of Heliophysics.

A New Heliophysics for 2050

Moving forward, hopefully starting with the next Decadal Survey and certainly by 2050, the solar and space physics community should focus emphasis on the general and fundamental importance and excitement of its science with a new mindset:

Heliophysics is a fundamental science discipline that is interwoven with planetary science, astrophysics, geoscience, and laboratory plasma physics. It is the study of the very nature of plasmas throughout space, originating with our own Sun and heliosphere and extending to planetary atmospheres and magnetospheres, stellar atmospheres and atmospheres, interstellar space, and more exotic magnetized plasma regimes like pulsars, black holes, and supernovae.

When people ask “What is Heliophysics?” the answer should speak to the fundamental understanding of the very nature of interplanetary, interstellar, and intergalactic space itself (i.e., plasma: by far the most common state of matter in the universe). It

should encompass, in both name and practice, stellar-planetary and moon-magnetosphere interactions across the solar system, galaxy, and cosmos. By its very nature, Heliophysics is in-situ astrophysics, studying the only star and atmosphere to which we have direct access.

Heliophysics is and will continue to be many exciting things. Today, it’s the amazing photographs of auroral displays seen from the ground and the International Space Station. It’s the discovery of the mysterious “STEVE” (Strong Thermal Emission Velocity Enhancement) emissions in the sky by amateur citizen scientists. It’s exploring the intense radiation belts around Earth with NASA’s Van Allen Probes. It’s using large-scale advanced ground-based solar telescopes, like NSF’s Daniel K. Inouye Solar Telescope to probe the detailed dynamics of the outer regions of the Sun. It’s the hypnotizingly complex videos of the Sun’s boiling plasma surface and corona by NASA’s Solar Dynamics Observatory. It’s developing advanced computer simulations of the environments in near-Earth space, the Sun, and interplanetary and interstellar space. And it’s launching a spacecraft like NASA’s Parker Solar Probe to touch our Sun.

By 2050, Heliophysics should also be exploring the induced magnetosphere of Venus to determine how small rocky bodies without internal magnetic fields interact with their host star. It should be flying into the heart of Jupiter’s intense radiation belts to understand the fundamental acceleration processes at play there. It should be exploring the complex and unusual magnetospheric configurations and dynamics of the Ice Giants, Uranus and Neptune. It should be comparing and contrasting other magnetospheres to Earth’s and extrapolating to other, more extreme astrophysical magnetospheres. This can be achieved either by bold new standalone Heliophysics-dedicated missions to other planets or through greater collaboration with other Divisions.

Our scientific community needs to be bold and unabashed in our definition of Heliophysics and its big questions. By 2050, we hope that Heliophysics at NASA will be unbound from its current confinement to the Sun-Earth line and expanded to studies of space plasma physics to more systems throughout the solar system and greater cosmos.

**Empowering Heliophysics Through Advocacy**

Such a fundamental redefinition of Heliophysics and the resulting ambitious Heliophysics program of science missions and discovery will require a correspondingly ambitious budget, coupled with strong support within the White House Office of Science and Technology Policy, the Office of Management and Budget, and Congress.

Unfortunately, despite the fundamental nature of solar and space plasma physics and space weather’s importance to human society and the national interests of the United States, Heliophysics receives the lowest funding amongst the primary Divisions (Planetary Science, Earth Science, Heliophysics, Astrophysics) within the NASA Science Mission Directorate and is at constant risk of further budget reductions.

To counteract this recent funding trend and enable new, innovative, and inspiring solar and space plasma physics missions throughout the solar system and into local interstellar space, the Heliophysics community needs to be actively engaged in advocacy for our field. Armed with bold ideas and exciting ambitions, inspiring stories, impressive visuals, and accessible language, Heliophysics researchers need to unapologetically promote their fundamental and practical research and the genuinely universal scope of Heliophysics to the public and policymakers. Celebrating research successes is a necessary public service in the best interest of the Heliophysics community overall.