frontiers | Frontiers in Astronomy and Space Sciences

TYPE Editorial
PUBLISHED 24 April 2024
DOI 10.3389/fspas.2024.1403148

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
Julio Navarro,
University of Victoria, Canada

*CORRESPONDENCE
Joseph E. Borovsky,
jborovsky@spacescience.org

RECEIVED 18 March 2024
ACCEPTED 25 March 2024
PUBLISHED 24 April 2024

CITATION
Borovsky JE, Delzanno GL, Erickson PJ, Halford AJ, Lavraud B and Savage S (2024), Editorial: The future of space physics 2022. *Front. Astron. Space Sci.* 11:1403148. doi: 10.3389/fspas.2024.1403148

Editorial: The future of space physics 2022

Joseph E. Borovsky[1]*, Gian Luca Delzanno[2], Philip J. Erickson[3], Alexa Jean Halford[4], Benoit Lavraud[5] and Sabrina Savage[6]

[1]Space Science Institute, Boulder, CO, United States, [2]Los Alamos National Laboratory (DOE) Los Alamos, Los Alamos, NM, United States, [3]Haystack Observatory, Massachusetts Institute of Technology, Cambridge, MA, United States, [4]NASA/Goddard Space Flight Center, Greenbelt, MD, United States, [5]Laboratoire d'astrophysique de Bordeaux (LAB) Pessac, Pessac, France, [6]NASA Marshall Space Flight Center, Huntsville, AL, United States

KEYWORDS

space physics, ionosphere, magnetosphere, solar wind, solar physics, heliosphere, aurora, substorms

Editorial on the Research Topic
The future of space physics 2022

Space Physics community members have put substantial effort and ideas into white papers in participation of the U.S. Heliophysics Decadal Survey process, producing a thorough analysis of the current state of the space-physics research effort and an assessment of where future research, mission programs, and funding should focus. Simultaneously, space-physics community members in Europe and the U.S. have recently put substantial effort and ideas into papers for Vision 2050 and Heliophysics 2050. There are also other ideas in the community about the needs and focus of future Space Physics research efforts.

With this in mind, this Frontiers in Astronomy and Space Sciences Research Topic, "*The Future of Space Physics 2022,*" was created to provide a format for a reference-able, archived, accessible collection of these ideas from around the world. These ideas are now available to the research community. The Research Topic contains high-quality refereed articles on key topics across the field of Space Physics that highlight recent advances in the field while emphasizing important directions and new possibilities for future inquiries.

This Research Topic includes 64 publications that are briefly described in this editorial. The publications deal with a wide variety of space-physics topics, from the Sun to the outer heliosphere, including magnetospheres and ionospheres. The descriptions of the 64 articles are organized below into seven paragraphs that deal with 1) unsolved problems, 2) new pathways for research, 3) needed instrumentation and new approaches, 4) concepts for new space missions, 5) developing the space community including diversity, 6) data science and future computer simulations, and 7) citizen science.

Unsolved problems

Gabrielse et al. review how mesoscale phenomena in the magnetotail transition region contribute to the global response of the Earth's magnetospheric system. In a perspective article, Hwang et al. discuss the role of the Kelvin–Helmholtz instability in solar-wind/magnetosphere coupling and in solar-wind plasma transport into the magnetosphere. In a perspective article, Pettit et al. point out that the drivers and impacts of the precipitation of energetic electrons are not well-understood and that atmospheric models usually do not properly calculate energetic-electron precipitation. In a perspective article, Nieves-Chinchilla et al. discuss the need to significantly improve research on the formation and evolution of flux tubes in the heliosphere. In a perspective article, Zhang et al. discuss the outstanding Research Topic associated with the impact of greenhouse gases on the ionosphere and thermosphere. Nishimura et al. review several unsolved problems associated with the STEVE subauroral atmospheric emissions and the association with subauroral ion drifts.

New pathways for research

Longley and Goodwin discuss using the geospace environment as a unique laboratory to study fundamental plasma physics. In a perspective article, Zawdie et al. discuss the impacts of acoustic and gravity waves on ionospheric physics and outline future studies and observations that are required. In a perspective article, de Groen points out the need to account for muons in radiation-protection calculations and models. Green et al. discuss ideas for a new initiative to calculate space weather on the surface of Mars for future human space exploration. In a perspective article, Winslow et al. point out the need to study the complexity of CME evolution as CMEs (and other solar transients) propagate out from the Sun. Garcia-Sage et al. review the research field dealing with star–exoplanet interactions and the impact of that research on heliophysics. In a perspective article, Klenzing et al. argue that a system-science approach is needed to study the problem of equatorial plasma bubbles in the Earth's ionosphere. Esman et al. explore the possibility of detecting Schumann electromagnetic resonances below the ionosphere of Mars.

Needed instrumentation and new approaches

In a perspective article, Carson et al. discuss the development of the DLITE ground-based radio-interferometer network that will be used to study solar radio bursts.Di Matteo and Sivadas argue that there is a need to quantify and correct uncertainties in solar-wind measurements upstream of the Earth to improve our ability to study solar-wind/magnetosphere coupling. Elliott et al. review the current understanding of electron microburst precipitation and outline critical knowledge gaps that need to be filled. Fraternale et al. review the current challenges of understanding turbulence in the solar wind from the Sun to the interstellar medium and discuss possible future space missions. Wilson et al. discuss the need to more accurately measure ion and electron velocity distribution functions in the solar wind. In a perspective article, Le et al. describe the need for new high-resolution magnetic-field measurements from a constellation of spacecraft in low-Earth orbit. In a perspective article, Wexler et al. describe the advantages of space-based radio–frequency fluctuation measurements of the solar corona for the study of the acceleration of the solar wind. Jones et al. highlight the need for new composition and temperature measurements in the atmosphere at heights ranging from 100 km to 200 km, which would lead to significant advances in thermosphere–ionosphere science. Huyghebaert et al. review auroral E-region plasma turbulence research and propose to expand existing ground-based radar capabilities. In a perspective article, Rivera et al. argue for future heavy-ion measurements from near the Sun out into the heliosphere to connect the study of these various regions. In a perspective article, Ugarte-Urra et al. make the scientific case for spatially resolved full-solar-disk spectral measurements of the chromosphere and the corona. Dhadly et al. review the state of knowledge of neutral winds from the mesosphere to the thermosphere and argue that critical height-resolved measurements are needed. Sarris et al. review plasma-neutral interactions in the ionosphere and thermosphere and argue for needed key measurements in the 100–200-km range of altitudes. In a perspective article, Lee et al. argue for the need for solar-wind measurements that would be relevant to studying space weather on Mars. Lavraud et al. overview current debates about the nature of the heliopause and discuss critical future measurements dealing with magnetic-field-line reconnection at the heliopause. In a perspective article, Mayyasi et al. recommend new optical measurements to diagnose the role of neutral atoms at the outer edge of the heliosphere. In a perspective article, Mrak et al. highlight the need for long-term high-fidelity measurements of ionospheric irregularities with good spatial resolution. In a perspective article, Aa et al. argue for needed imaging of the 3-D variations of the ionospheric electron density and the total electron content. Isham et al. discuss plans for new ground-based radar and radio imaging of the ionosphere above Puerto Rico. In a perspective article, Bain et al. call for key observations to be made at aviation altitudes and for advancements in space-weather modeling with a particular focus on safety for the aviation industry. Spitzer et al. argue the need for measurements in an interstellar-probe-type mission of pickup ions, interstellar neutral atoms, and cosmic rays in the heliotail.

Concepts for new space missions

Allen et al. describe the InterMeso multispacecraft mission concept to study mesoscale dynamical structures in the solar wind at 1 AU. In a perspective article, Kooi et al. describe the Trans-Coronal Radio Array Fleet mission concept designed to diagnose the plasma and magnetic-field structure of the Sun's corona. Borovsky et al. describe a multispacecraft mission to accurately determine magnetic-field mapping between the Earth's magnetosphere and ionosphere utilizing a relativistic-electron accelerator and ground-based optical detectors. Wimmer-Schweingruber et al. describe the STELLA mission concept to explore *in situ* the interaction between the heliosphere and the interstellar medium. Landi et al. review the COSMO visible to near-infrared coronograph mission to measure plasma thermal structure, plasma velocities, and the magnetic field of the Sun's corona. Sibeck et al. describe the single-spacecraft STORM mission concept to globally image the plasma structure of the magnetosphere as it interacts with the solar wind. Sterling et al. describe a high-resolution, high-temporal-cadence EUV imager of the Sun that could study coronal jets and smaller-scale features. Dialynas et al. describe a single-spacecraft interstellar-probe mission concept involving *in situ* particle and field measurements plus energetic-neutral-atom imaging. In a perspective article, Jensen et al. describe the FETCH instrument concept for the proposed MOST mission concept, where FETCH would measure polarization to determine the magnetic configurations of the solar wind and transient interplanetary structures. Nykyri et al. describe the Seven Sisters, a seven-spacecraft mission concept to study solar-wind physics and provide about 2 days of advanced space-weather information for the Earth. Cooper et al. describe the Lunar Solar Occultation Explorer mission concept wherein an optical telescope in space utilizes lunar occultations of the Sun to produce very-high-resolution information about the solar corona. Goodrich et al. describe the multispacecraft MAKOS mission concept, which is designed to study the physics of collisionless shock waves with observations of both interplanetary shocks and the Earth's bow shock.

Developing the space community, including diversity

Schoneld et al. argue for expanding the Deep Space Network to better support the multiple spacecraft of the Heliospheric System Observatory. In a perspective article, Klenzing et al. make the case for using the Application Usability Level framework to track the health and progress of heliophysics research. In a perspective article, Rivera et al. argue for more support of atomic and laboratory plasma physics to help advance heliophysics research. Kenny et al. discuss gender diversity in heliophysics and point out that gender demographics are changing and that it is important for organizations to ensure that early-career scientists feel accepted. Jones et al. provide targeted recommendations for bringing diversity, equity, and inclusion measures in heliophysics to the forefront. Halford et al. review several recent position papers on inclusivity in heliophysics that provide recommendations to increase inclusivity in heliophysics.

Data science and future computer simulations

In a perspective article, Halford et al. point out that the findability, accessibility, interoperability, and reusability of data are essential to heliophysics research and give recommendations to achieve this. In a perspective article, Ledvina et al. point out how open data and interdisciplinary collaborations are critical for the success of space-weather research. In a perspective article, Alzate et al. argue the need to create a system treatment of the Sun and heliosphere using data mining to analyze and model heliospheric-environment data. In a perspective article, Poduval et al. argue that AI methods could greatly help in the analysis and interpretation of the large accumulation of spacecraft measurements, and they present an action plan to make the data AI ready. In a perspective article, Karimabadi et al. discuss the need to adapt deep learning techniques to increase the efficiency and accuracy of plasma simulations. In a perspective article, Narock et al. discuss new standards for the use of artificial intelligence and how the standards present burdens to researchers who are not supported by funding agencies and institutions. In a perspective article, Harvey et al. argue that more accurate computer simulations of the mesospheric polar vortex are needed for improved understanding and predictions of the thermosphere and ionosphere.

Citizen science

In a perspective article, Ledvina et al. point out that citizen scientists are adaptable and responsive, can bring expertise from other fields, and can enhance space-physics research. Frissell et al. review the global citizen-science amateur-radio collaborations and point out open opportunities to advance heliophysics research, radio science, and space weather.

To conclude, the state of the heliophysics field is engaged. Although not every white paper was submitted to our Research Topic, many people took the time to further research, cite, and provide extended insights for this Research Topic. The engagement of this community shows a strong breadth and depth of knowledge looking at the fine details of how the star, space, and planet environments work and how to work translationally across these boundaries. The next 10 years for our community will be exciting as there is much compelling science discussed within this Research Topic as well as solutions and mitigations proposed for common roadblocks we see along the way. We hope the community finds this Research Topic useful and, in 10 years, will reflect on how far we have come.

Author contributions

JB: writing–original draft. GD: writing–review and editing. PE: writing–review and editing. AH: writing–review and editing. BL: writing–review and editing. SS: writing–review and editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. JB was supported at the Space Science Institute by the NASA LWS Program via grant 80NSSC23, by the NSF Magnetospheric Program via grant AGS-2149822, and by the NASA HERMES Interdisciplinary Science Program via grant 80NSSC21K1406.

Acknowledgments

The authors of this editorial would like to thank Xochitl Blanco-Cano, Jaroslav Chum, John Dorelli, Tzu-Wei Fang, Elena E. Grigorenko, Fan Guo, Mike Henderson, Vladislav Izmodenov, Jay Johnson, Zerefsan Kaymaz, Guozhu Li, Larry Lyons, Francesco Malara, Thomas Earle Moore, Julio Navarro, Katariina Nykyri, Daniel Okoh, Noora Partamies, Nicholas Pedatella, Mirko Piersanti, Luca Sorriso-Valvo, and Vladimi Sreckovic for their help with editorial duties, and the authors would like to thank the many reviewers of these articles Mahboubeh Asgari-Targhi, Markus Aschwanden, Stas Barabash, Chris Bard, Luke Barnard, Veronika Barta, Ciarán D. Beggan, Anna Belehaki, Paul Bernhardt, Enrico

Camporeale, Frank Centinello, Ashot Agassi Chilingarian, Debi Prasad Choudhary, Rob Ebert Giulia D'Angelo, Kshitija Deshpande, Paolo Desiati, Simone Di Matteo, Andrew Dimmock, Mourad Djebli, Alexei V. Dmitriev, Tibor Durgonics, Bengt Eliasson, Len Fisk Federico Fraternale, Silvano Fineschi, R. Gafeira, Vincent Génot, Yun Gong, Lindsay Goodwin, Jingnan Guo John Bosco Habarulema, Jiansen He, Mike Henderson, Katie Herlingshaw, Steven Hill, Lauri Holappa, Jia Huang, Joe Huba, Vania Jordanova, Stephen Kahler, Primoz Kajdic, Amy Keesee, Olga Khabarova, Maxim Khodachenko, Emilia Kilpua, Alexey A. Kuznetsov, Giovanni Lapenta, Brian Larsen, Jun Liang, Jeffrey Linsky, Jiajia Liu, Kaijun Liu, Xiao Liu, Larry Lyons,Stefano Markidis, Steve Milan, Steven Morley, Huw Morgan, Thom Moore, Hans Mueller, Masaru Nakanotani, Denny Oliveira, Sampad Kumar Panda, Athanasios Papaioannou, Dimitry Pokhotelov, Arik Posner, Shishir Priyadarshi, Tuija Pulkkinen, Dario Recchiuti, John Retterer, Jean-Francois Ripoll, Reinaldo Roberto Rosa, Raphael Rougeot, Vadim Roytershteyn, Evangelia Samara, Ludger Scherliess, Steven J. Schwartz, Joshua Semeter, Victor Sergeev, Kazuo Shiokawa, Maria Alexeevna Shukhtina, Martin Snow, Vladimir A Sreckovic, Štěpán Štverák, Yingna Su, Monika Szelag, Scott Thaller, Takayuki Umeda, Andris Vaivads, Brian Walsh, Shan Wang, Tieyan Wang, Anna Wawrzaszek, Assar Westman, Dan Weimer, Chao Xiong, Yongliang Zhang, Jie Zhang, Shufan Zhao, Xu-Zhi Zhou, and Gaeta Zimbardo.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors, and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.