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EDITED AND REVIEWED BY
Joseph E. Borovsky,
Space Science Institute, United States

*CORRESPONDENCE
Tommaso Alberti,
tommaso.alberti@inaf.it

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Editorial: Interplanetary medium variability as observed in the new era of spacecraft missions

Tommaso Alberti[1]*, Lina Z. Hadid[2], Valeria Mangano[1] and Beatriz Sanchez-Cano[3]

[1]INAF-Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy, [2]LPP, CNRS, École Polytechnique, Sorbonne Université, Université Paris-Saclay, Observatoire de Paris, Institut Polytechnique de Paris, PSL Research University, Palaiseau, France, [3]School of Physics and Astronomy, University of Leicester, Leicester, United Kingdom

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Editorial on the Research Topic
Interplanetary medium variability as observed in the new era of spacecraft missions

Since 1970s an increasing number of heliospheric and planetary space missions have been launched as Helios (Porsche, 1981), Ulysses (Carvell, 1986), Wind (Acuña et al., 1995), ACE (Garrard et al., 1997), MAVEN (Jakosky and Maven Science Team, 2008), Rosetta (Wood, 1987), Cassini (Prange, 1985) collected a huge amount of data to characterize the interplanetary medium variability through the Heliosphere. Nowadays, the recently launched space missions BepiColombo (Benkhoff et al., 2021), Parker Solar Probe (Bale et al., 2016), and Solar Orbiter (Müller et al., 2020) provide more accurate *in situ* measurements through high-resolution instruments for monitoring the evolution of solar wind parameters at different heliocentric distances ranging from ~0.05 A.U. to ~10 A.U., and for providing new insights into the physics of various plasma processes related to the Sun and the interplanetary medium.

The new era of spacecraft missions offers a unique opportunity to perform combined multi-point observations of the interplanetary medium variability, on one hand, to study different processes in the solar wind and their radial evolution in the inner heliosphere, such as turbulence properties, small scales structures, instabilities, waves, and dust. On the other hand, it helps to characterize large scales structures and coupling between the solar wind plasma and the different planetary environments. These observations are important for testing pre-existing theoretical models and for advancing numerical simulations to investigate various aspects of both known and unknown physical processes, moving from past accomplishments to future challenges.

The Research Topic "*Interplanetary Medium Variability as Observed in the New Era of Spacecraft Missions*" collected manuscripts on new observational findings and their theoretical counterparts coming from both single- and multi-spacecraft investigations that will help in advancing our understanding of the interplanetary medium from Mercury (~ 0.38 A.U.) up to Saturn (~ 10 A.U.):

- Investigating scaling-law behaviors, turbulence, intermittency, large-scale/inertial/kinetic physics;
- Particle acceleration, shocks, waves, and dust;
- Wave-particle interactions, solar and *in situ* magnetic structures, propagation and acceleration of energetic particles;
- Solar wind–planetary magnetosphere coupling dynamics, localized processes (e.g., reconnection and instabilities, boundaries formation and induced phenomena), cross-scale interactions and multiscale physics.

The manuscript "*Multiscale Features of the Near-Hermean Environment as Derived Through the Hilbert-Huang Transform*" by Alberti et al. proposed for the first time, the application of the Hilbert-Huang Transform (HHT) to characterize both the local and global properties of Mercury's environment as seen during two Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER) flybys. In particular, we compute the energy-time-frequency distribution of the observed magnetic field components and the reconstruction of these signals at large, magnetohydrodynamics (MHD) and kinetic scales through the empirical mode decomposition. We show that the HHT analysis allows to capture and reproduce some interesting features of the Hermean environment such as Flux Transfer Events (FTEs), Kelvin-Helmholtz vortices, and Ultra Low Frequency (ULF) wave activity. Moreover, the findings support the ion kinetic nature of the Hermean plasma structures, the characterization of the magnetosheath by anisotropic ion-kinetic intermittent fluctuations, superimposed to both MHD fluctuations and large-scale field structure. The approach considered by Alberti et al. has proven to be very promising for characterizing the structure and dynamics of planetary magnetic field at different scales, for identifying the boundaries, and for discriminating the different scale-dependent features of global and local source processes that can be used for modeling purposes.

The manuscript "*Solar Wind Plasma Properties During Ortho-Parker IMF Conditions and Associated Magnetosheath Mirror Instability Response*" by Genot and Lavraud used a solar wind plasma categorization scheme with 10 years of OMNI data to show that the fractions of the different plasma origins such as streamer-belt-origin plasma, coronal-hole-origin plasma, sector-reversal-region plasma and ejecta identified by this scheme are rather constant when expressed as a function of the IMF orientation whereas the Alfvén Mach number significantly depends on this orientation. This has a direct implication on the magnetosheath dynamics. As an example, the stability of the mirror mode in this compressed plasma is studied thanks to Rankine-Hugoniot anisotropic relations. This study sheds light on previously reported, yet unexplained, observations of a larger occurrence of mirror mode in the magnetosheath downstream of ortho-Parker IMF.

The manuscript "*BepiColombo's Cruise Phase: Unique Opportunity for Synergistic Observations*" by Hadid et al. highlighted the importance of multi-spacecraft coordinated observations during the cruise phase of BepiColombo (ESA/JAXA), with a particular emphasis on the recently launched missions, Solar Orbiter (ESA/NASA) and Parker Solar Probe (NASA). Despite some payload constraints, many instruments onboard BepiColombo are operating during its cruise phase simultaneously covering a wide range of heliocentric distances (0.28 AU–0.5 AU). Hence, the various spacecraft configurations and the combined *in-situ* and remote sensing measurements from the different spacecraft, offer unique opportunities for BepiColombo to be part of these unprecedented multipoint synergistic observations and for potential scientific studies in the inner heliosphere, even before its orbit insertion around Mercury in December 2025. The main goal of this report is to present the coordinated observation opportunities during the cruise phase of BepiColombo (excluding the planetary flybys). It reports the identified science topics, the operational instruments, the method used to identify the windows of opportunity and discuss the planning of joint observations in the future.

The manuscript "*Effect of an Interplanetary Coronal Mass Ejection on Saturn's Radio Emission*" by Cecconi et al. investigated the effects of an Interplanetary Coronal Mass Ejection (ICME) on Saturn Kilometric Radiation (SKR) in the range of a few kHz to 1 MHz. These emissions are due to electrons travelling around auroral magnetic field lines. Previous studies have shown a strong correlation between the solar wind dynamic pressure and the SKR intensity. However, up to now, the effect of an Interplanetary Coronal Mass Ejection (ICME) has never been examined in detail, due to the lack of SKR observations at the time when an ICME can be tracked and its different parts be clearly identified. This study takes advantage of a large ICME that reached Saturn mid-November 2014 (Witasse et al., J. Geophys. Res. Space Physics, 2017, 122, 7,865–7,890). At that time, the Cassini spacecraft was fortunately travelling within the solar wind for a few days, and provided a very accurate timing of the ICME structure. A survey of the Cassini data for the same period indicated a significant increase in the SKR emissions, showing a good correlation after the passage of the ICME shock with a delay of 13 h and after the magnetic cloud passage with a delay of 25–42 h.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

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