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EDITED AND REVIEWED BY
Scott William McIntosh,
Lynker Technologies LLC, United States

*CORRESPONDENCE
A. Costa,
acosta@unc.edu.ar

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Editorial: Advances on the initiation and evolution of CMEs involving remote and in-situ observations within 0.5 AU, theory, modeling, and simulations

A. Costa[1,2]*, M. Cécere[1,2,3], H. Cremades[4], R. A. Howard[5], G. Stenborg[5] and V. K. Jagarlamudi[5]

[1]National Scientific and Technical Research Council (CONICET), Buenos Aires, Argentina, [2]Institute of Theoretical and Experimental Astronomy, Córdoba, Argentina, [3]Astronomical Observatory of Córdoba, Córdoba, Argentina, [4]Group of Heliophysics Studies of Mendoza, CONICET, University of Mendoza, Mendoza, Argentina, [5]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, United States

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Editorial on the Research Topic
Advances on the initiation and evolution of cmes involving remote and in-situ observations within 0.5 AU, theory, modeling, and simulations

The advent of the latest solar missions is already imposing new constraints in both the modeling and computer simulation efforts of dynamic solar phenomena aimed at shedding light onto the physical processes at work during their origin and evolution. Their novel observations are already challenging existing models and theories, and hence demand not only the use of multi view-point observations but also the synergy provided by joint *in-situ* and remote-sensing observations. Understanding the early development of coronal mass ejections (CMEs) and their embedded magnetic flux ropes during the first few solar radii is undoubtedly decisive for their subsequent evolution, while the early stages are key for understanding the processes involved in their genesis and onset. The plethora of available data sets and the numerous open questions on their formation, triggering, and evolution demand a renewed characterization of the early development and evolution at short heliocentric distances of coronal transients and their environment, that in turn will result in the necessary addition of complexity to models and assumptions. This Research Topic brings together diverse methodologies, from observational studies to advanced numerical techniques, to provide a comprehensive view of the CME and magnetic flux rope phenomena in the solar corona.

Central to the works presented in this Research Topic is the emphasis on understanding the magnetic structures that shape CME behavior, from their origins to their trajectories in the interplanetary medium. The historical overview by Howard et al. traces the evolution of CME research, showcasing the transition from early 2D conceptions to more sophisticated 3D models. Understanding the historical sequence of scientific problems, their solutions, and discarded alternatives is important, even for scientists. It situates knowledge in its historical context, emphasizes the role of errors and revisions, helps recognize limitations and avoid repetition, and fosters a deeper understanding of the issues that shaped the discipline's current state. The observational study by Zou et al. delves into the triggering mechanisms of filaments in weak magnetic fields, demonstrating the interplay between pre-eruption reconnection and torus instability in generating CMEs. Wagner et al. complements these insights by presenting GUITAR, an advanced numerical tool designed to identify and track MFRs within complex 3D simulations, thus offering an innovative approach to understanding their destabilization and eruption processes. Meanwhile, the mini-review by Cécere et al. consolidates recent theoretical, numerical, and observational research, emphasizing the role of surrounding magnetic structures—such as coronal holes and pseudostreamers—in deflecting CMEs from their radial trajectories, a crucial factor for improving space-weather forecasting.

While the articles in this Research Topic report significant strides in understanding CMEs and MFRs, they also highlight areas that demand further exploration. Future research should aim to integrate high-resolution observational data with advanced numerical simulations that incorporate additional complexities, such as solar wind effects, multi-scale magnetic reconnection processes, and fully 3D configurations. Expanding tools like GUITAR to facilitate real-time analysis and incorporating these into broader predictive frameworks will enhance our ability to model CME initiation and evolution more accurately. Moreover, collaborative efforts between observational and modeling communities should focus on understanding the interplay between local and global solar structures. Investigating how CMEs interact with large-scale magnetic configurations will provide deeper insights into their trajectories and geoeffectiveness. This Research Topic showcases significant progress in our understanding of the early evolution of CMEs while emphasizing the collaborative potential needed to tackle unresolved challenges. By fostering synergies across disciplines, this work lays a robust foundation for developing accurate forecasting tools that safeguard technological and societal assets from the impacts of space weather.

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