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Editorial: Flux rope interaction with the ambient corona: From jets to CMEs

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Editorial on the ResearchTopic
Flux rope interaction with the ambient corona: From jets to CMEs

Eruptive events within the Sun's corona occur across a broad range of scales, from abundant small-scale jets to highly energetic coronal mass ejections (CMEs) (e.g., Webb and Howard, 2012; Raouafi et al., 2016; Kumar et al., 2021). Flux ropes have been understood to be a fundamental constituent of CMEs for many years, but it has only been more recently that their role in smaller eruptive events has become more appreciated (e.g., Sterling et al., 2015; Wyper et al., 2017). The key to understanding the differing morphology and nature of eruptions on these vastly differing scales is to understand the nature of the interaction between the flux ropes involved and the magnetic field of the surrounding corona. This Research Topic invited perspectives on (and examples of) flux rope eruptions across this broad range of scales, from formation to ejection, with the aim of highlighting commonalities and differences to aid in ultimately building a common framework for their understanding. Starting at the smallest scales, Schmieder presented a historically ordered review of jets and surges. The parallel improvements in instrumentation, physical insight and numerical simulations over time were highlighted along with the ways in which improvements in one area led to developments in another. Overall, jets of all forms are presented as the result of magnetic reconnection between two magnetic domains, with the reconnection involving a null point, bald patch separatrix or quasi-separatrix layer. In particular, jets with observed rotational motions often involve the transfer of twist from a small-scale filament or flux rope by reconnection across the separatrix.

Twist transfer *via* flux rope reconnection is also known to occur in larger events, such as circular ribbon flares. Lee focused on such an event which had both a circular ribbon flare and CME. The novel diagnostic capability of microwaves was discussed and used to show that breakout reconnection above the flux ropes involved was the likely trigger of this event. Yurchyshyn et al. employed non-linear force-free field extrapolations to study the magnetic configuration throughout a similarly complex slow-rise flare and fast CME from an overall bipolar active region. They too find multiple flux rope structures are present before the eruption and that the surroundings also strongly influence the direction of CME flux rope propagation. In this case they note that the decay index calculated along an oblique path (Kliem et al., 2021) proved useful in explaining the CME's initial non-radial ejection.

Flux rope deflection and coronal reconnection also played a major role in the events studied by Pal et al., who analysed a series of three sequential, slow eruptive transients that ultimately resulted in a classic 3-part streamer-blowout flux rope CME. The eruption of the first narrow, unstructured CME appears to remove the outer layers of helmet streamer flux from above an energised multi-polar topology, triggering the sympathetic eruption of the next two CMEs. Furthermore, the final, well-structured CME was encountered by Parker Solar Probe (PSP) which revealed the draping of the heliospheric current sheet/plasma sheet around the CME and their dynamic interaction, resulting in magnetic reconnection eroding the interplanetary flux rope ejecta as it travelled. Finally, Rice and Yeates performed a comprehensive parameter study to investigate the eruptivity of translationally-symmetric (2.5D) bipolar helmet streamer configurations using magnetofrictional simulations. Their simulations produced both partial, streamer-detachment transients as well as larger and more complete streamer-blowout flux rope CME eruptions. Interestingly, the authors find that the recently developed eruptivity index (e.g., Pariat et al., 2017) does not appear to be particularly well-suited for predicting magnetofrictional flux rope CME eruptions from these helmet streamer configurations.

So what does this Research Topic tell us about eruptions across different scales in the solar corona? It is clear that coronal reconnection plays a key role in shaping solar eruptions, particularly in smaller scale jets (Schmieder) and confined events (Lee). While larger-scale events are also strongly influenced by flux rope expansion and deflection. The latter of which can be predicted to a certain extent by either the decay index along different paths (Yurchyshyn et al.), or somewhat equivalently by identifying nearby regions of lower magnetic field strength/energy (Pal et al.). However, despite their similarities it is clear there is still a long way to go to be able to reliably predict eruptions at different scales, even in idealised configurations (Rice and Yeates).

Encouragingly, there has never been a better time to study these fascinating events. We are entering an new era of solar and heliospheric physics where coordinated *in-situ* and remote sensing observations, driven for example by the latest results from the PSP and Solar Orbiter missions, can be contrasted against increasingly sophisticated data-driven and idealised magnetohydrodynamic models being run on ever more powerful high-performance computing platforms and resources. This Research Topic represents the type of cross collaboration—between theory, modelling, and observations, and between different fields and disciplines—that will almost certainly result in important progress toward understanding the fundamental physics of energetic transient and eruptive phenomena that occur over a vast range of spatiotemporal scales in the solar atmosphere and their resulting heliospheric consequences.

Author contributions

PW drafted the manuscript. PK and BL contributed to proof reading and editing.

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References

Kliem, B., Lee, J., Liu, R., White, S. M., Liu, C., Masuda, S., et al. (2021). Nonequilibrium flux rope formation by confined flares preceding a solar coronal mass ejection. *ApJ.* 909, 91. doi:10.3847/1538-4357/abda37

Kumar, P., Karpen, J. T., Antiochos, S. K., Wyper, P. F., DeVore, C. R., Lynch, B. J., et al. (2021). From pseudostreamer jets to coronal mass ejections: Observations of the breakout continuum. *Astrophys. J.* 907, 41. doi:10.3847/1538-4357/abca8b

Pariat, E., Leake, J. E., Valori, G., Linton, M. G., Zuccarello, F. P., Dalmasse, K., et al. (2017). Relative magnetic helicity as a diagnostic of solar eruptivity. *Astron. Astrophys.* 601, A125. doi:10.1051/0004-6361/201630043

Raouafi, N. E., Patsourakos, S., Pariat, E., Young, P. R., Sterling, A. C., Savcheva, A., et al. (2016). Solar coronal jets: Observations, theory, and modeling. *Space Sci. Rev.* 201, 1–53. doi:10.1007/s11214-016-0260-5

Sterling, A. C., Moore, R. L., Falconer, D. A., and Adams, M. (2015). Small-scale filament eruptions as the driver of X-ray jets in solar coronal holes. *Nature* 523, 437–440. doi:10.1038/nature14556

Webb, D. F., and Howard, T. A. (2012). Coronal mass ejections: Observations. *Living Rev. Sol. Phys.* 9, 3. doi:10.12942/lrsp-2012-3

Wyper, P. F., Antiochos, S. K., and DeVore, C. R. (2017). A universal model for solar eruptions. *Nature* 544, 452–455. doi:10.1038/nature22050