Quantifying and Reducing the Observed Ageing Effect of CMEs through Simultaneous In-situ Measurements

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Introduction

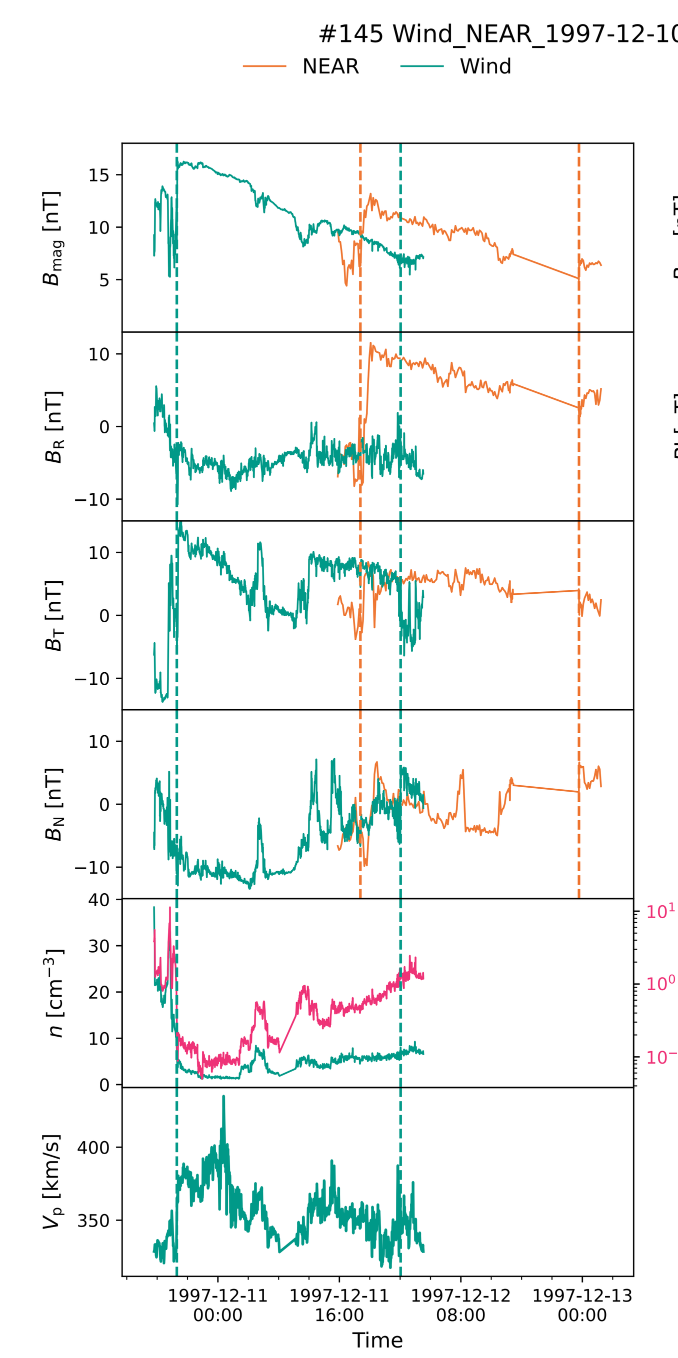
Coronal mass ejections (CMEs) can be studied using in situ measurements made by interplanetary probes. However, during the encounter with a probe, CME properties have time to evolve. The time the CME takes to pass over the probe constitutes a non-negligible fraction of its lifetime. Such **ageing effect** impacts CME features such as the asymmetry of the magnetic field profile.

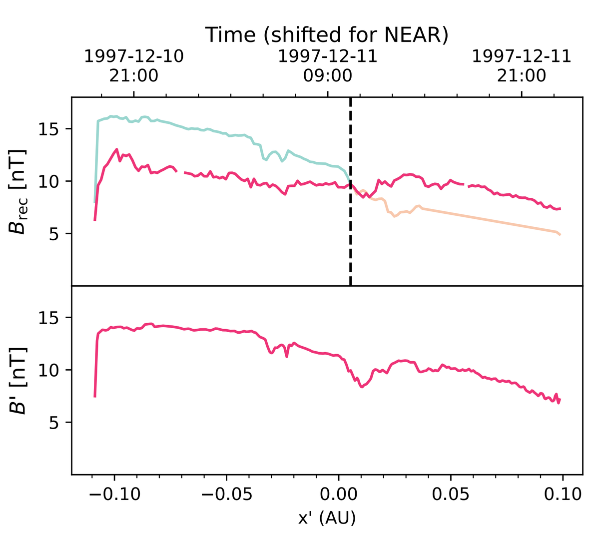
This study aims to investigate the importance of ageing. To do so, we study CMEs observed simultaneously by two or more spacecraft during what we define as a **close conjunction**. A close conjunction occurs if a CME passes over a spacecraft when another spacecraft is separated by less than **0.2 au in radial distance and 10° in azimuth**.

Using 2374 potential ICMEs spread over roughly 50 years of data acquired by 11 spacecraft, we find **19 usable close conjunctions**. All these conjunctions provide simultaneous measurements of the CMEs at two spacecraft, enabling studies of the effects of ageing, and expansion.

Case study

Figure 2 shows a close conjunction presented in Mulligan et al. 1999 and is an **almost perfect alignment** of NEAR and Wind with a separation comparable to the size of the ME. When the ME reaches NEAR, Wind is at the back of it.





Such spacecraft configuration allows us to compute a "true" front to back ratio of the magnetic field profile.

From NEAR to Wind we see a flattening of the profile.

Both reconstructed and instantaneous profiles are more symmetric than the original profiles.

Table 1 - Front to back ratios and DiP for the different magnetic profiles.

	Front-to-back ratio	DiP
NEAR	2.11	0.42
Wind	1.90	0.40
"True"	1.42	
Instantaneous	1.72	0.42
Reconstructed	1.42	0.47

Figure 2 - Left column : magnetic and plasma data of the NEAR-Wind conjunction on the 1997-12-11.
Right column : Reconstructed and instantaneous (following Demoulin et al. 2020 method) profiles.

Discrepancies in the ME properties between the two spacecraft

Figure 1 summarizes the differences in magnetic ejecta (ME) properties measured by the first and the second spacecraft to enter inside the ME.

The evolution of the magnetic field at such short lengthscales does not match well with power laws deduced from observations over wide scales. (Winslow et al. 2015; Davies et al. 2022). We find that 7 CMEs have an increasing mean magnetic field as a function of r.

The duration of 5 of the CMEs decreases by more than 10% between the first and the second spacecraft.

The distortion parameter (DiP, Nieves-Chinchilla et al. 2018) and the front to back ratio of the magnetic field are very well correlated. Thus, **the front to back ratio is a good proxy for the overall asymmetry of the magnetic field profile.**

During a close conjunction the changes between the two spacecraft are on average :

- 1.1 nT for the mean B
- 0.04 for the DiP
- 2.6 hours for the duration

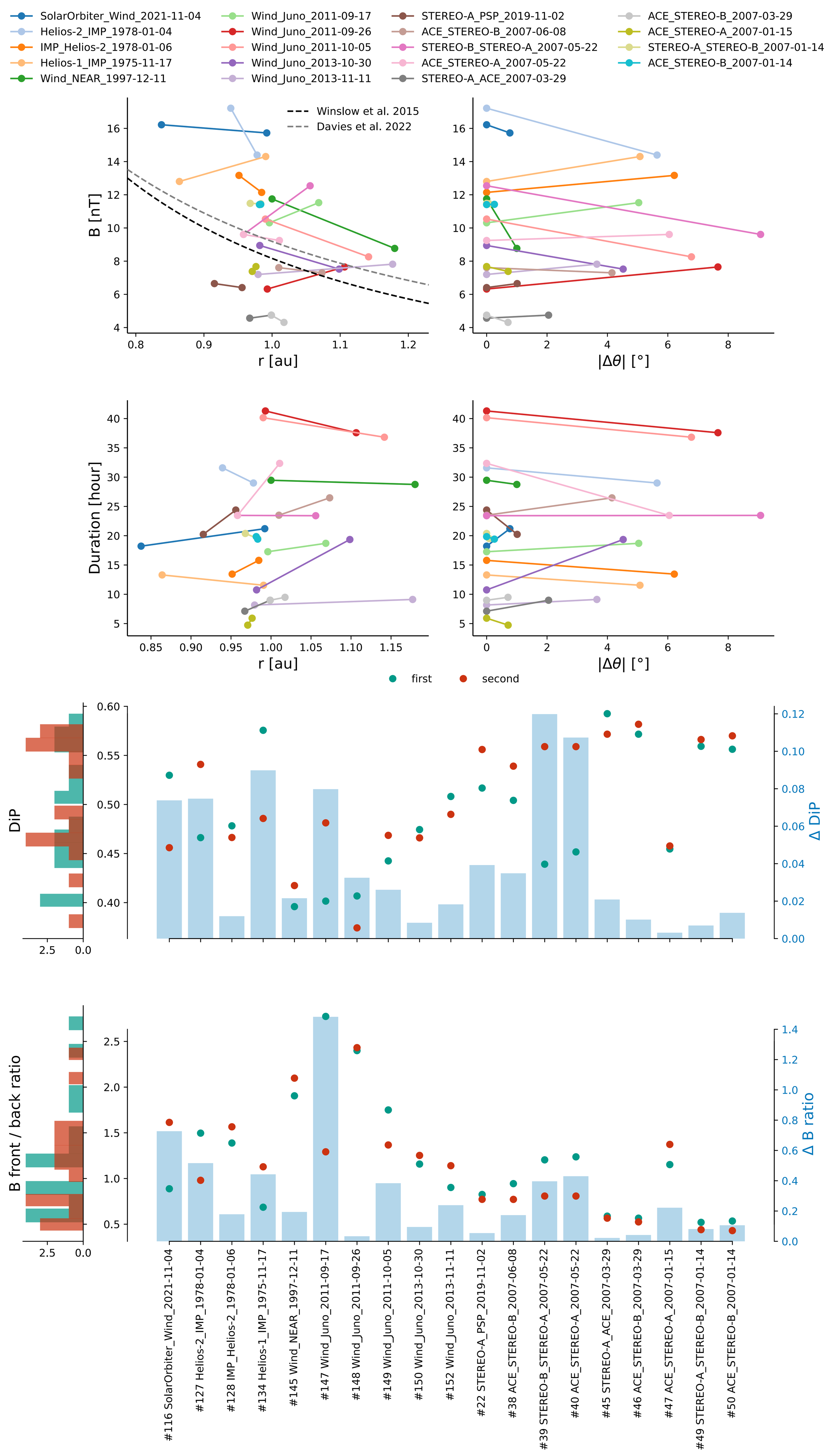


Figure 1 - Summary plot of the close conjunction catalog.

This gives information about the typical change of those parameter for simultaneous measurements by two spacecraft with small angular and radial separation (±10° and 0.2 au)

Conclusion / Discussion

Ageing effect is not only linked to expansion, other processes (like internal reconnection or interaction with the solar wind) can locally change the ME properties. These processes have not been well studied given the current fleet of spacecraft.

The use of simultaneous measurements of CMEs during a close conjunction is a very powerful tool to study some of the different **physical processes possibly at heart of the discrepancies highlighted by Figure 1** but also to **constrain even more models** widely used to describe the ME magnetic structure.

Figure 3 summarizes the main possible configurations during a close conjunction. **Radial alignement would allow us to study the ageing processes** while **an azimuthal alignment would allow us to test the axis invariance** (redundant assumption of flux ropes) but also the effect of the impact parameter on ME properties.

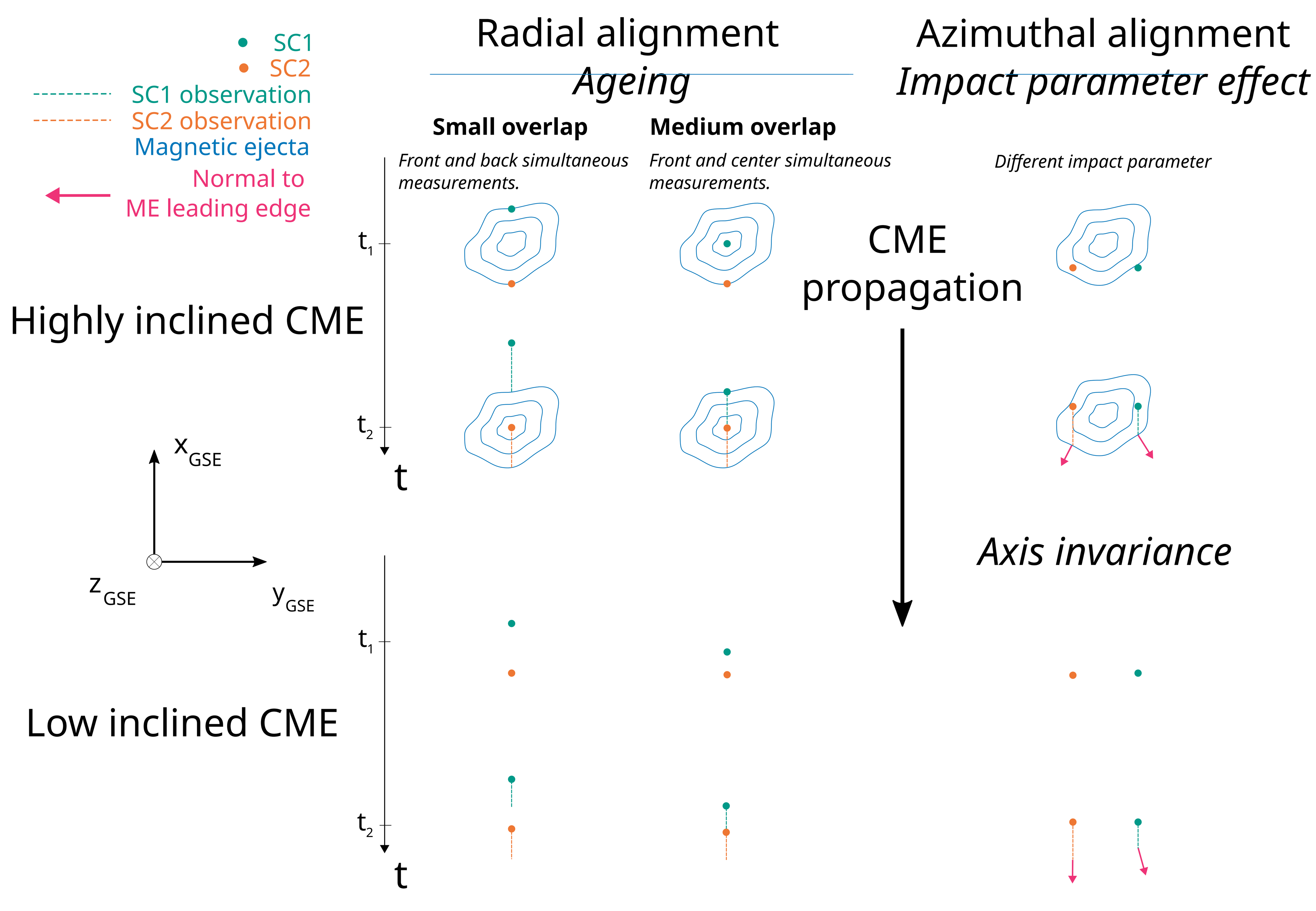


Figure 3 - Schematic of the different possible spacecraft configurations during a close conjunction.

Online version

References

Regnault et al. 2022 (submitted)
Démoulin et al. 2020
Lugaz et al. 2018
Osherovich et al. 1993

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