



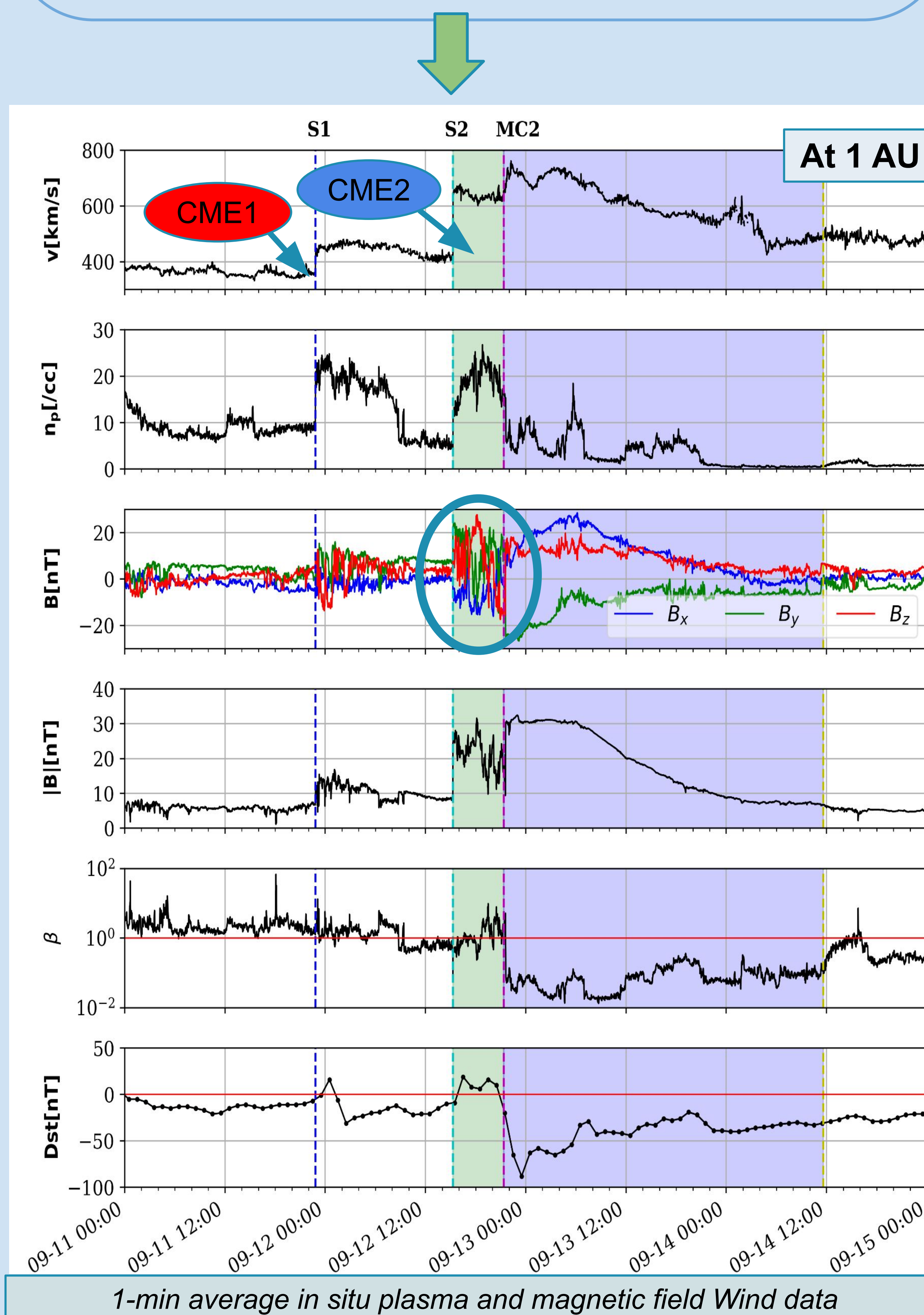
Overview

Preceding event (CME1)

[September 8, 2014] Shock is recorded at Earth. This event is not recorded in ICME catalogs.

Main event (CME2)

[September 10, 2014] Well-recorded in ICME catalogs and previously studied [Cho+2017, Kilpua+2021, An+2019].



Prediction (ISEST, VarSITI program)

CME2 to be a direct hit at Earth and cause a major storm ($Dst < -100nT$). CME1 was not considered.

In situ observations

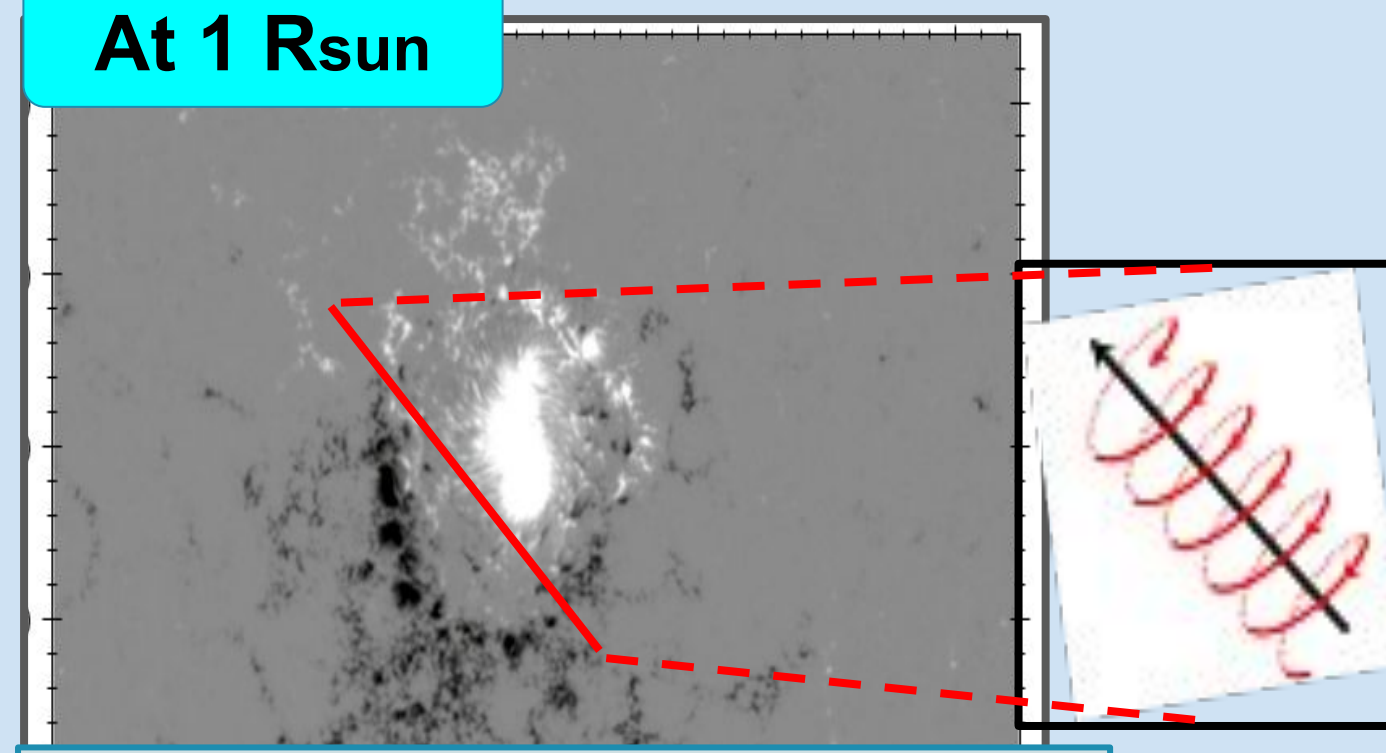
Positive B_z occurred in CME2 magnetic cloud & negative B_z in the sheath ($Dst \sim -73nT$). Geo-effectiveness of different sub-structures of the storm mis-predicted.

Objectives

1. To understand the change in orientation of CME2 (rotation OR/AND flank encounter)
2. To investigate the role of CME-CME interaction in the sheath region geo-effectiveness

Observations

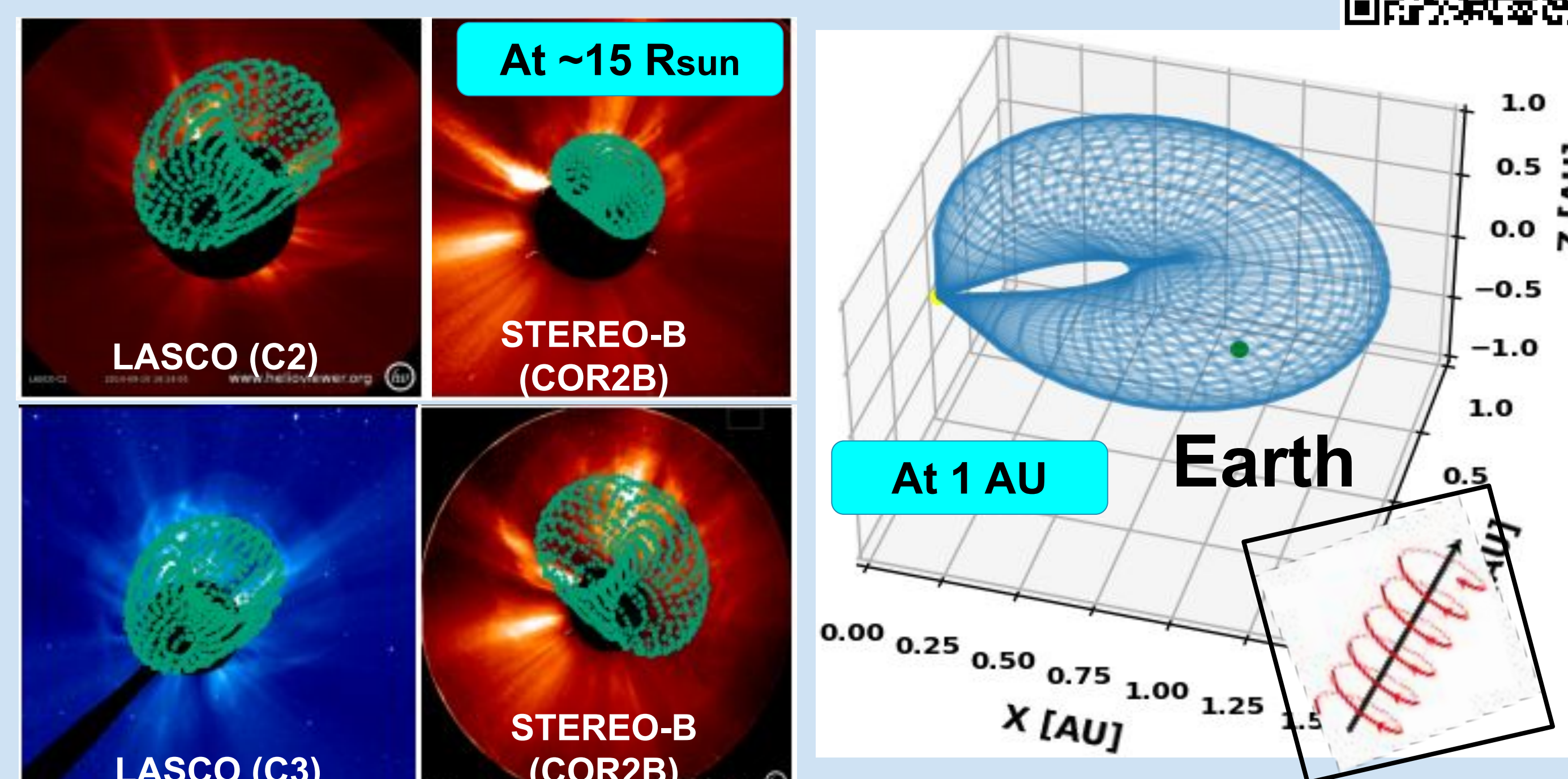
At 1 R_{sun}



AR12158: HMI magnetogram before CME2 eruption

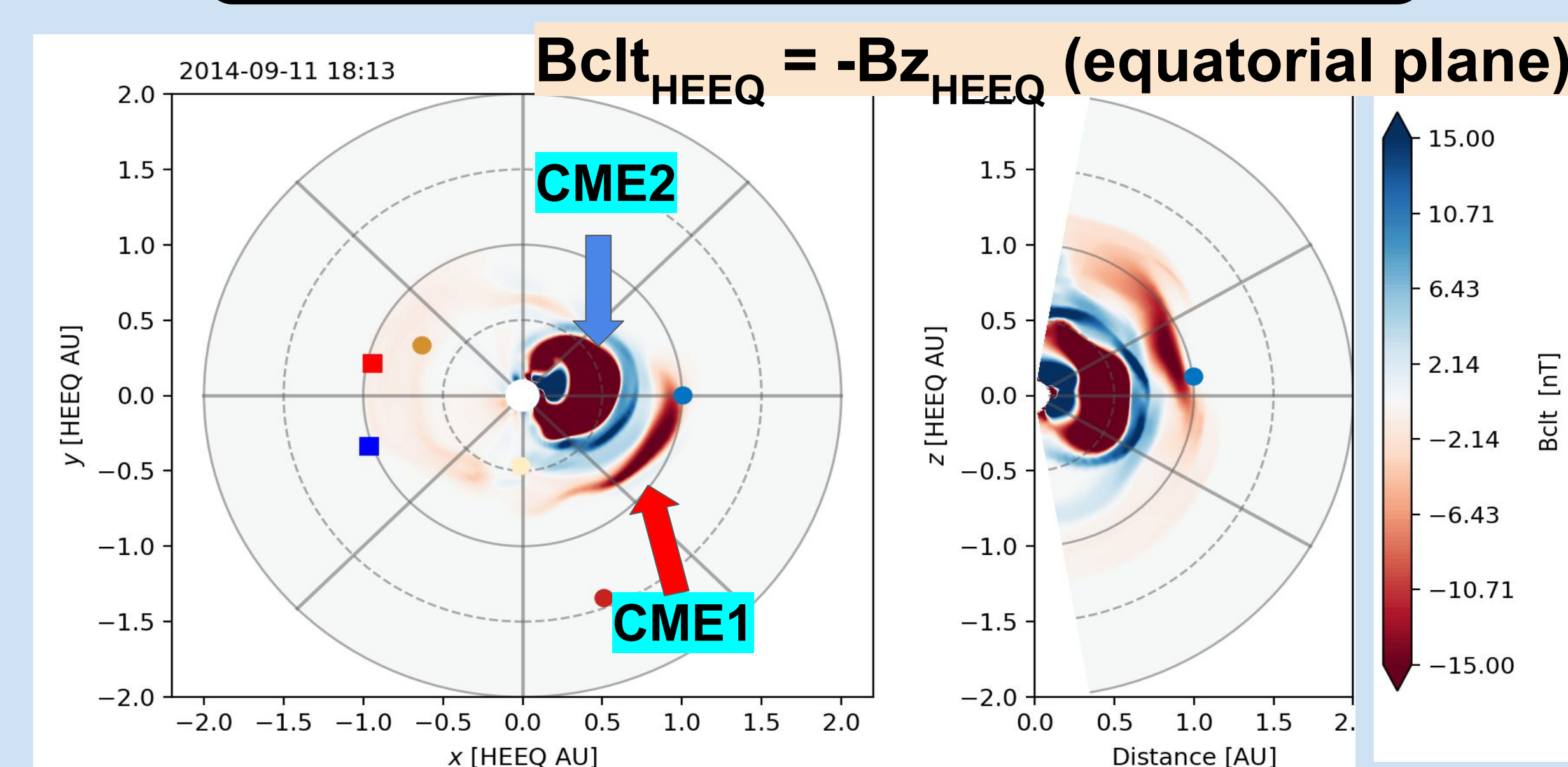
Focus is on CME2. This source region orientation does not match the ICME orientation at 1 AU

3D reconstruction with FRI3D (Flux Rope in 3D) Isavnin+2016, Maharana+2022



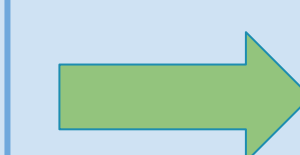
Orientation from 3D reconstruction at 15 R_{sun} implies close to flank encounter at Earth. This orientation is used to initialise the CME2 in EUHFORIA.

MHD modelling



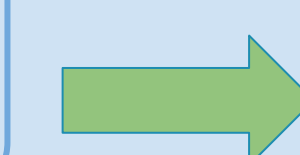
EUHFORIA (Pomoell and Poedts, 2018)

Semi-empirical WSA model



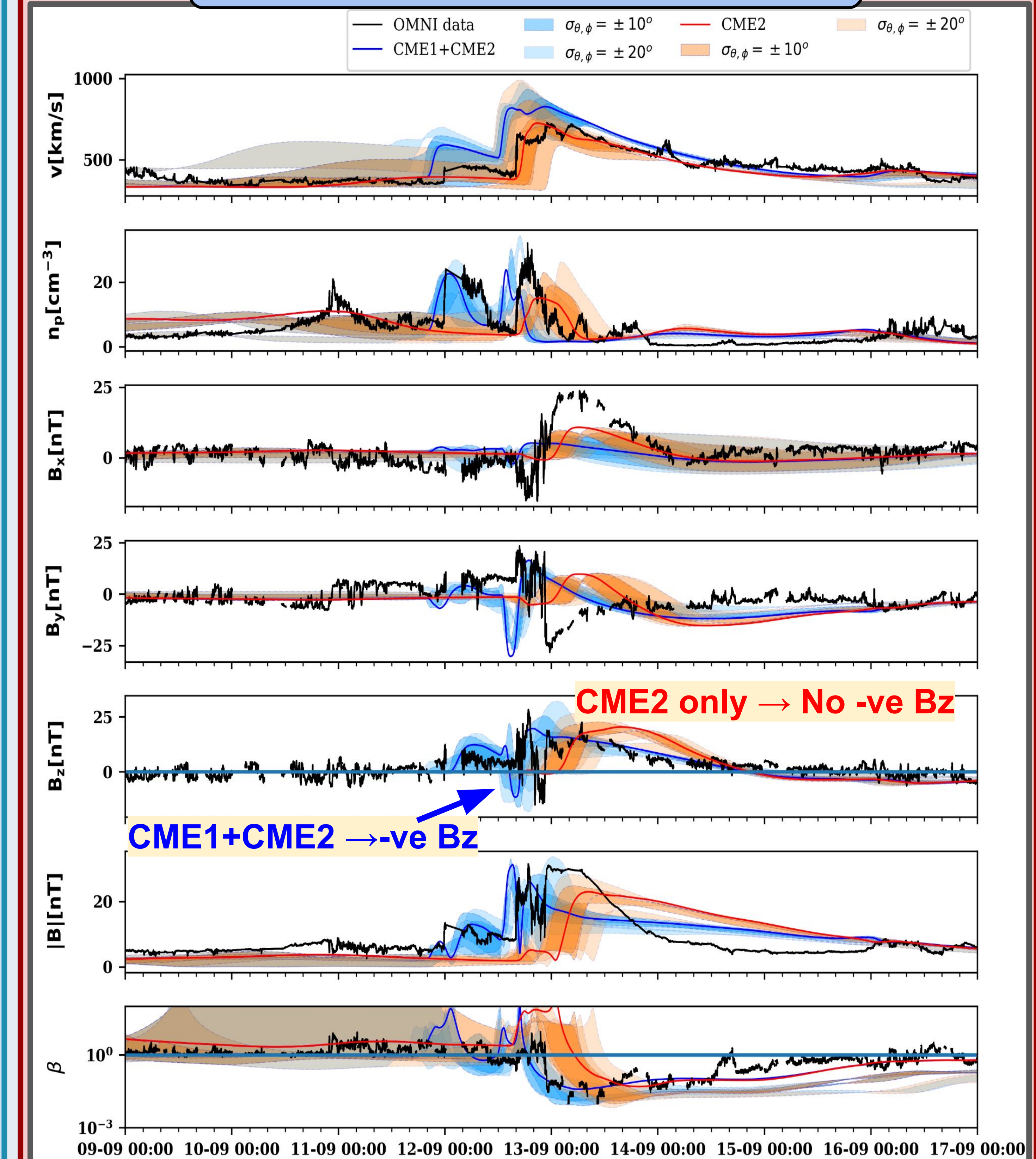
Solar wind MHD parameters at 0.1 AU

FRI3D CME model



To improve modelling of CME2 hit at Earth

Results



EUHFORIA simulation results plotted in red (CME2 only) and blue (CME1+CME2) compared with in-situ Wind data

- \rightarrow Modelling both the CMEs with spheromak could not reproduce the observations.
- \rightarrow Using FRI3D for CME2, the magnetic cloud B_z and negative B_z in the sheath were reproduced.
- \rightarrow Negative B_z is formed due to the trailing negative B_z ejecta of CME1 being compressed by the sheath ahead of CME2.

Outlook

- \rightarrow Unexpectedly, in this event, the orientation observed from the 3D reconstruction at $\sim 15 R_{sun}$ is different from that observed at the source region of the eruption.
 - \rightarrow CMEs must be initiated in simulations with the orientation obtained from 3D reconstruction close to the inner boundary.
 - \rightarrow Understanding geo-effectiveness of different sub-structures in case of CME-CME interaction, requires MHD CME evolution models like EUHFORIA.
 - \rightarrow Global CME models like FRI3D can improve prediction of non-head-on encounters.
- Maharana et al., in prep.