# MODELLING OF CORONAL MASS EJECTIONS THROUGH THE NOVEL FRi3D MODEL AND THE EFFECT OF THE TWIST PARAMETER

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## 1. STUDY MOTIVATION

FRi3D is a novel flux-rope CME model characterized by a realistic description of CME topology (Fig. 1).

FRi3D model is inserted in the space weather forecasting tool EUHFORIA. Plasma, geometrical, deformation, kinetic & magentic field parameters of the CME are necessary for modelling.

The twist ($\tau$) parameter describes the number of turns in the magnetic field from one foot point to the other.

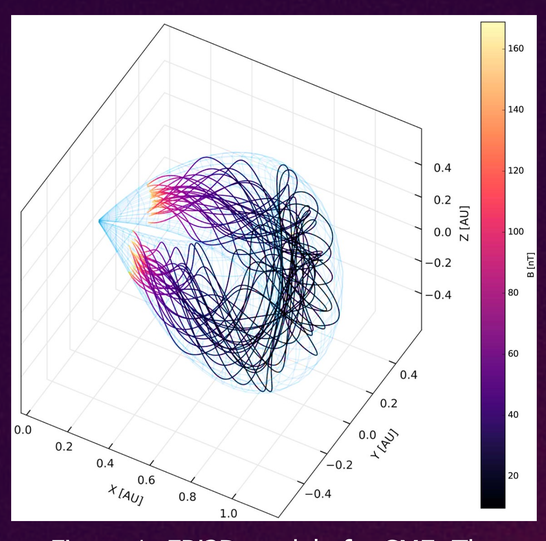


Figure 1: FRi3D model of a CME. The strength of magnetic field along each line is color-coded. Isavnin 2016.

The implementation of FRi3D to date has been conducted assuming a fixed value of twist, without considering differences beetween CME events.

Fig. 2 shows EUHFORIA simulations of a single CME event & changing twist parameter.

Results reveal the impact of twist parameter when modelling CMEs, not only in the CME arrival time but also in the strenght of the magnetic field.

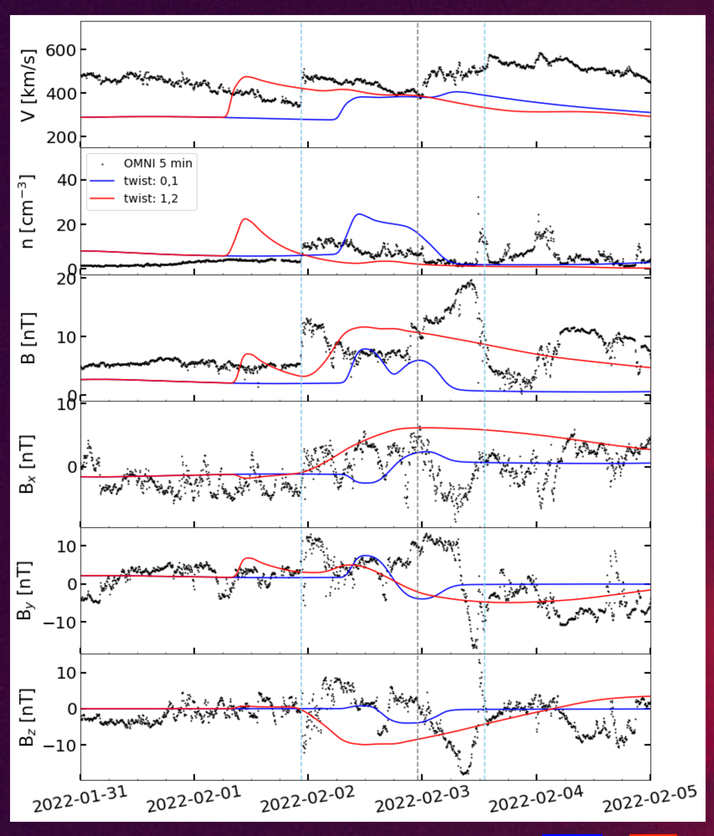


Figure 2: EUHFORIA+FRi3D simulations. Blue & red lines were obtained using $\tau$=0.1 & $\tau$=1.2, respectively.

This result motivates our work on the twist parameter constrain for CME modelling in a space weather framework.

## 2.1. TWIST CALCULATION – Previous work.

The CME twist has been analysed mainly through the reconstruction of the magnetic flux rope structure (Török et al. 2003; Kilpua et al. 2012; Hu et al. 2014; Liu et al. 2016; etc.).

J. H. Guo et al. 2021, found the twist is proportional to its ratio of axial length to minor radius, L/a, by: $|\tau| = 0.26(L/a) - 0.15$ (eq.1).

## 2.2. TWIST CALCULATION – EUV images, 2D approach.

We implement eq. 1 to calculate $\tau$, employing EUV images of the Sun to obtain the axial length and the minor radius of the CME flux rope.

This 2D approach has its limitations:
- Projection effects.
- Complexity of the region.

However, it also has its advantages:
- Availability of EUV images.
- Straightforward procedure.

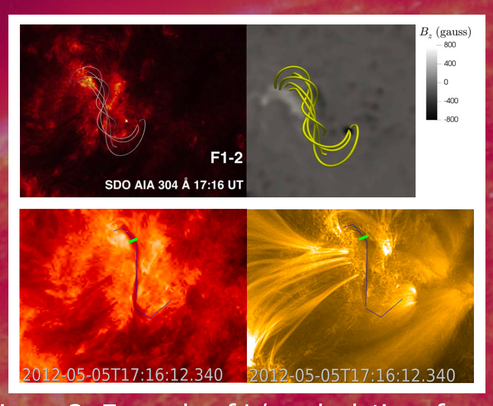


Figure 3: Example of L/a calculation: from flux rope reconstruction, J. H. Guo et al. 2021, (top) & from 2D approach (bottom).

Measurements with EUV images are performed with a conservative focus (see bottom part Fig. 3), making the use of the flux rope width more suitable than the minor radius.

## 3. DATA & METHODOLOGY

→ 12 CME events with Earth-impact component.

→ Available spacecraft with EUV instrument onboard (171 Å wavelength or close to). Used: AIA/SDO, EUVI/STEREO & EUI/SolO.
→ Measurement for each event & instrument is performed 5 times, using Jhelioviewer tool. Time used: before & close to FR eruption.

→ Coronoraph images, preferably from 2 different view points.
→ CME speed obtained from CME 3D reconstruction with GCS (Graduated Cylindrical Shape).

## 4. RESULTS

Results shown in Fig. 4 indicate a tendency of $\tau$ to be lower for faster CMEs. On the other hand, X-class flares are linked to lower $\tau$, while M-class flares are associated with higher $\tau$.

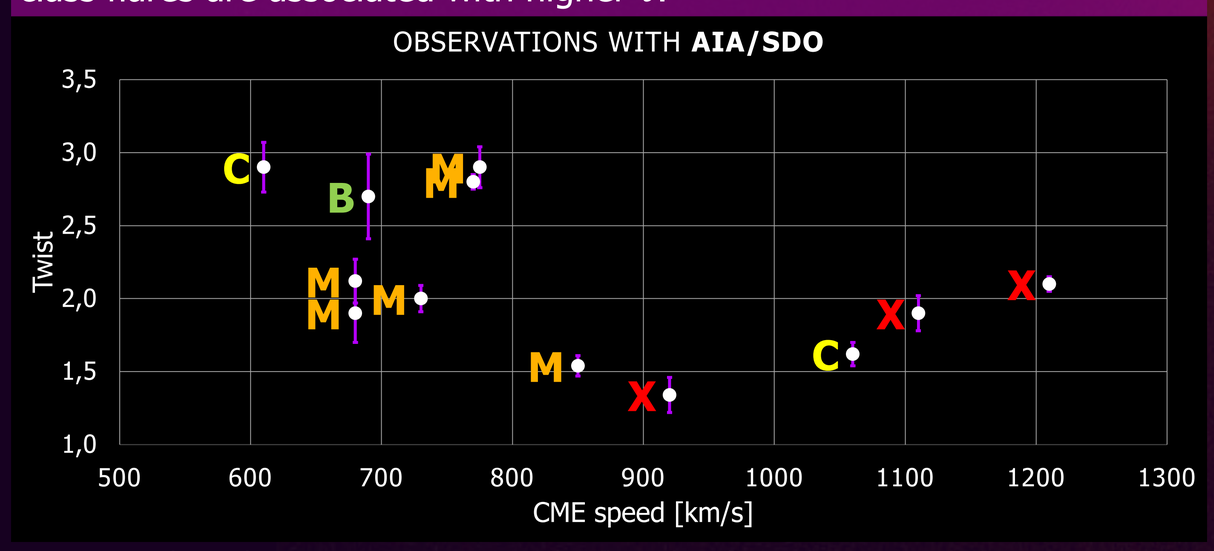


Figure 4: Relation between twist, CME speed & flare class for each event. Only for measurements with AIA/SDO.

Fig. 5 shows how the distance of the active region (AR), from the disk centre to the limb, affects the calculation of $\tau$. Closer the AR is from the east or west limb, the lower the resulted twist.

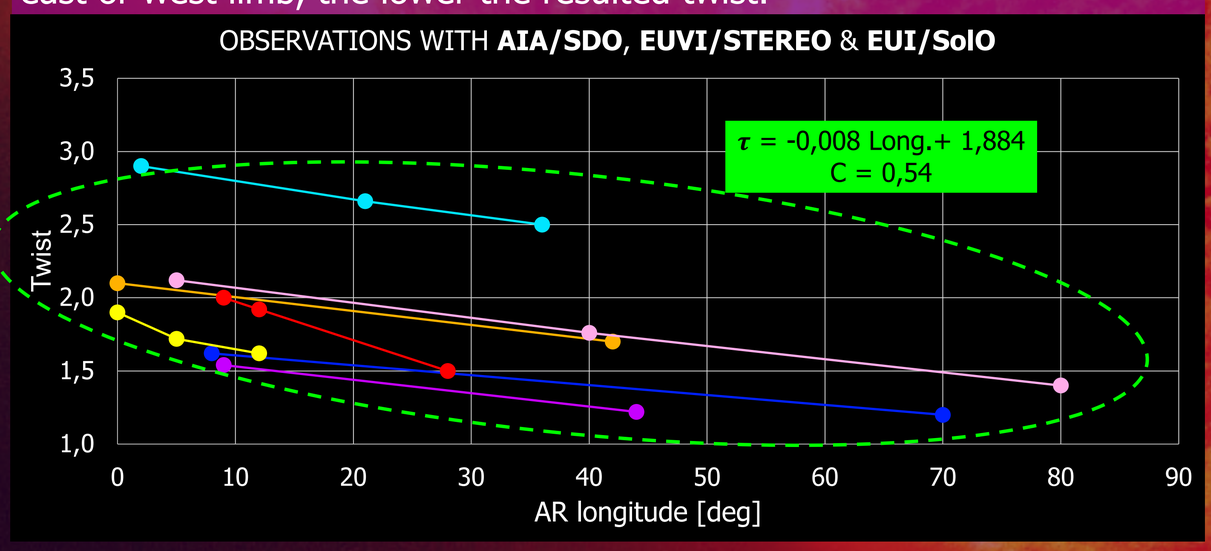


Figure 5: Twist measured from 2 or more spacecraft. CME events are color-coded. Each point represents a twist measurement from a different spacecraft for the same event.

Twist values obtained by 2D approach through EUV images are consistent with values reported in previous work.

## 5. DISCUSSION & FUTURE WORK

- EUHFORIA simulations with FRi3D model show a clear impact of twist parameter in the CME arrival time, and, most important, in the strenght of the CME magnetic field, which is currently of interest to improve for better CME forcasting.
- The 2D approach through EUV images proves to be a coherent and straightforward method for the estimation of twist parameter needed for FRi3D CME model. This will benefit the CME forecasting workflow.
- Results suggest a link between twist value & both CME speed and the flare associated to the CME event.
- Measurements of the twist for a same event with different spacecraft show a dependency of the measured value with the distance of the active region to the limb (east or west), from which a linear relation was obtained. This shows that the calculation of the twist are affected by a projection effect.
- Future work will focus on increasing the number of CME events for more robust results. Also, the application of the methodology for CME modelling with EUHFORIA+FRi3D for a thorough understanding of its impact.

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