

# Determination of CME orientation and consequences for their propagation

Martinić K.\*, Dumbović M., Temmer M., Veronig A., Vršnak B.

correspondence: [kmartinic@geof.hr](mailto:kmartinic@geof.hr)

\*University of Zagreb, Faculty of Geodesy, Hvar Observatory, Zagreb, Croatia



- Derive the inclination of (I)CME from remote and in-situ data
- To study whether the inclination has an effect on the propagation => non-radial flows (NRF) in the sheath region

## DATA

- 63 associated CME-ICME
- 2008-2016

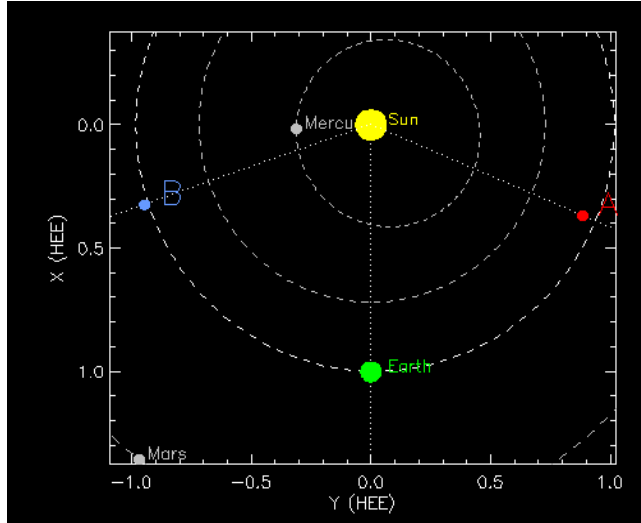
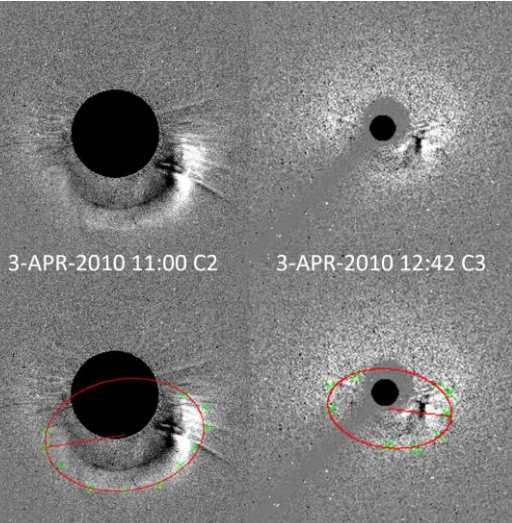
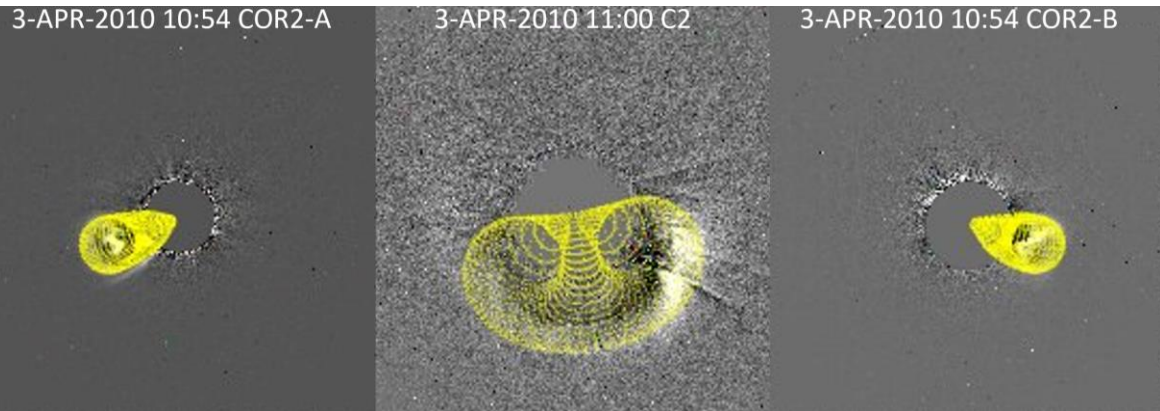
- Palmerio+2018
- Maricic+2020
- Temmer+2021
- Nitta&Mulligan+2017

- MC in-situ signatures
- GCS reconstruction,  $\geq 2$  vantage point

- 22 associated CME-ICME

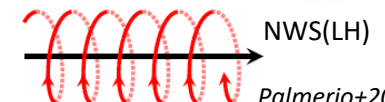
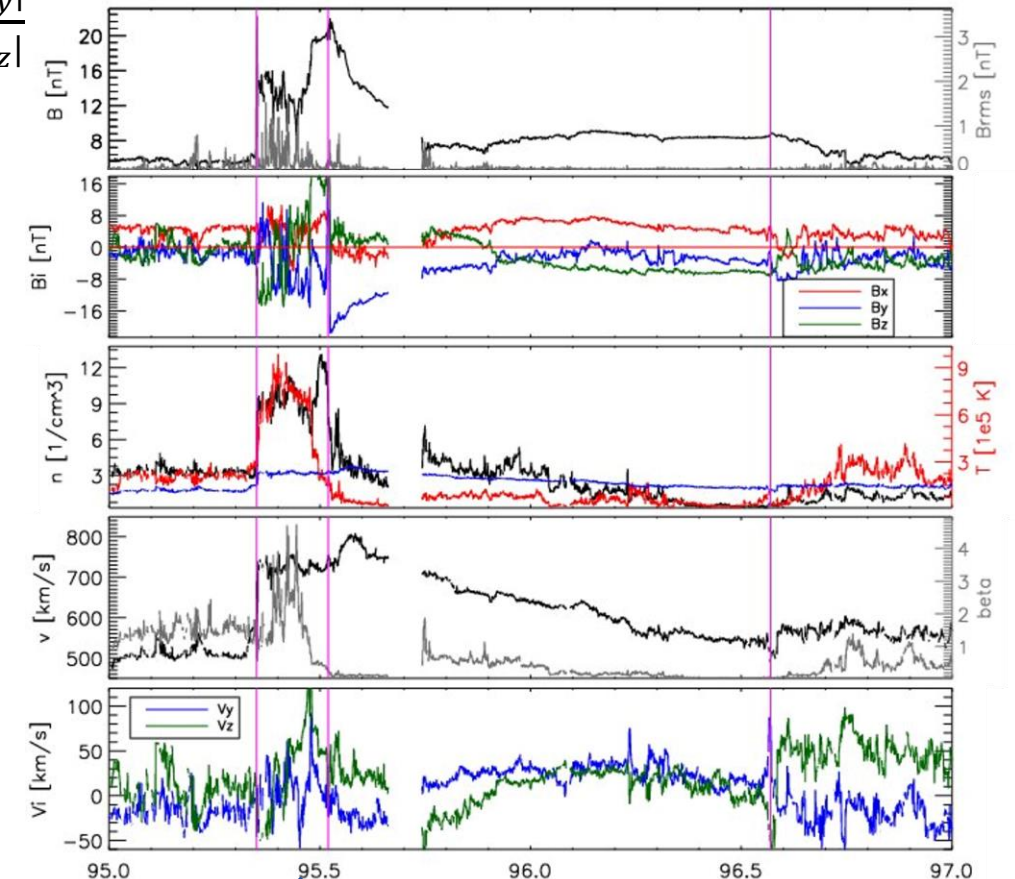
# Remote observations

- Graduated Cylindrical Shell (GCS) – 3D (croissant) geometry
- Ellipse fit – 2D (ellipse) geometry
- **Inclination** of CME axis to solar equator as measured from solar west



# In-situ observations

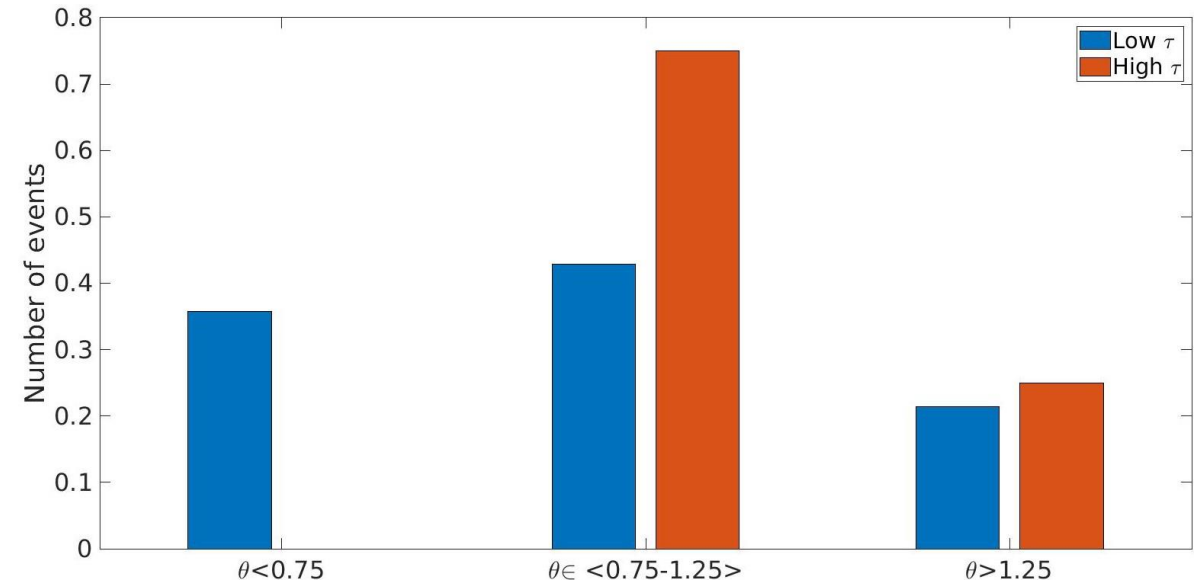
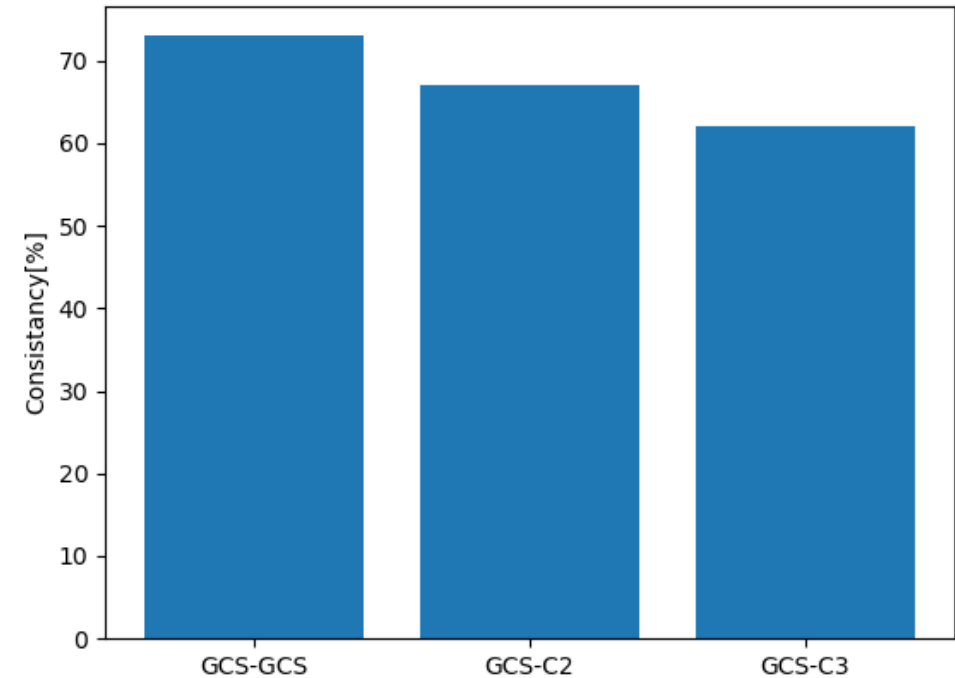
- Manual boundary detection and FR type determination=> **inclination**
- Calculation of ratio of NRF in the sheath region in y- and z- direction (GSE)
- $\theta = \frac{|v_y|}{|v_z|}$



Palmerio+2018

# RESULTS

- GCS and ellipse fit are equally good in determining the ***dominant inclination*** of the event, high or low inclination
- The majority of events (66%) have consistent dominant inclination in the near Sun environment (GCS) and in the near Earth environment (in-situ)
- The majority of events have a  $\Theta$  ratio close to 1, regardless of their dominant inclination
- There is no high inclination event with an  $\Theta$  ratio smaller than 0.75. Also, the number of events with a high  $\Theta$  ratio is higher for high inclination events than for low inclination events.
- High inclination events have more pronounced NRF in the y-direction, while low inclination events have more pronounced NRF in the z-direction

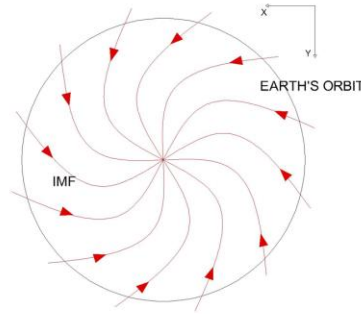


relative number of events (i.e., occurrence frequency) separately for high (orange) and low (blue) inclination events, with respect to the calculated  $\Theta$  ratios.

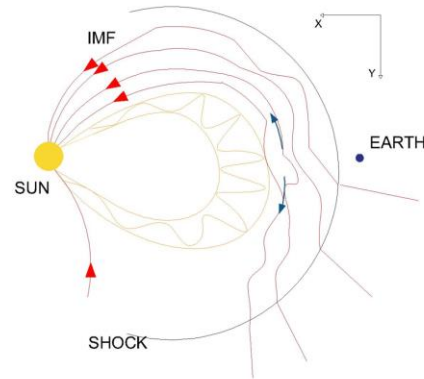
# INTERPRETATION

Ecliptic plane

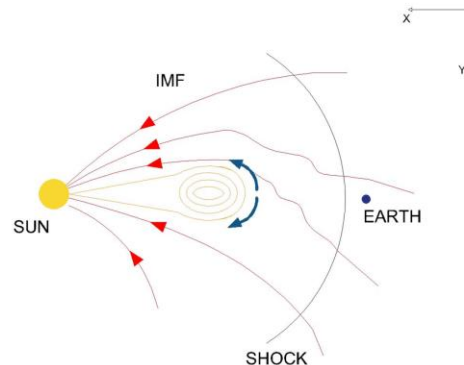
Idealised  
IMF



Low  
inclination



High  
inclination



- **Axial curvature** due to the rooting of the footpoints of the CME at the Sun => toroidal extent
- **Cross-sectional curvature** due to internal magnetic field structure => cross-sectional extent
- Low inclination CME: ambient plasma to be more easily deflected in the north-south (z-) direction where the CME extent is smaller, that is we might expect  $\Theta < 1$  ( $v_z > v_y$ )
- High inclination CME: ambient plasma to be more easily deflected in the east-west (y-) direction where the CME size is smaller, that is we might expect  $\Theta > 1$  ( $v_y > v_z$ )





**Thank you for your attention!**



## CONCLUSION

- The majority of events have consistent tilt as observed remotely and in-situ
- NRF for ***low inclination*** events are more pronounced in the ***N-S direction***
- NRF for ***high inclination*** events are more pronounced in the ***E-S direction***
- There might be a relation between the inclination and propagation
- GCS and ellipse fit methods give equally good tilt estimations which will allow us to improve the sample size when considering the whole Soho era

### TO DO:

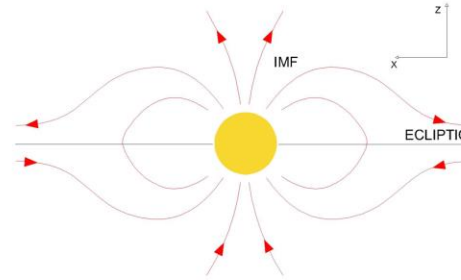
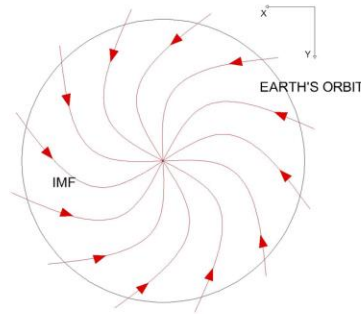
- Increase the event sample (SOHO era, ellipse fit)
- Check the transit time and gamma parameter

# INTERPRETATION

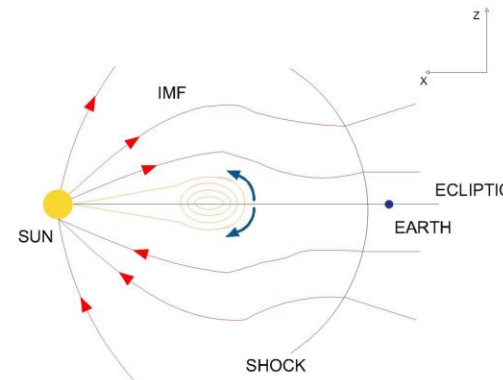
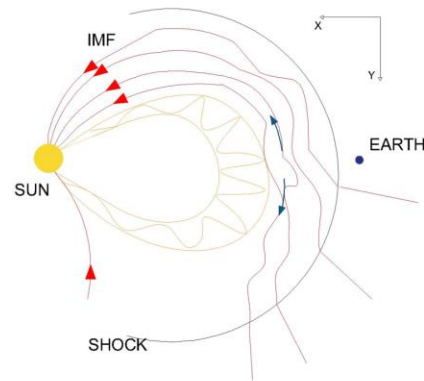
Ecliptic plane

Meridional plane

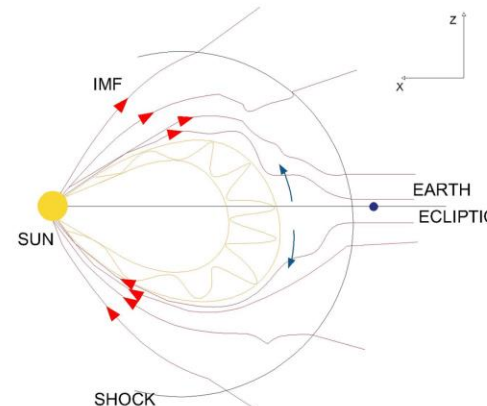
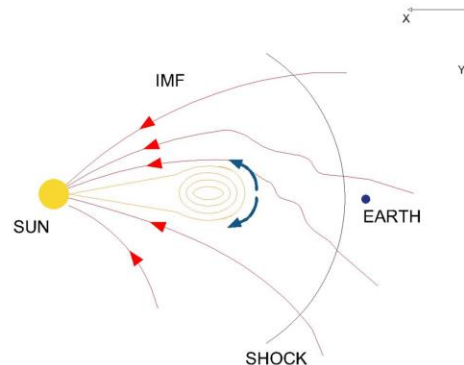
Idealised  
IMF



Low  
inclination



High  
inclination



- **Axial curvature** due to the rooting of the footpoints of the CME at the Sun
- **Cross-sectional curvature** due to internal magnetic field structure.
- Low inclination CME: ambient plasma to be more easily deflected in the north-south direction where the CME extent is smaller, that is we might expect  $\Theta < 1$  ( $v_z > v_y$ )
- High inclination CME: ambient plasma to be more easily deflected in the east-west direction where the CME size is smaller, that is we might expect  $\Theta > 1$  ( $v_z < v_y$ )