

Polarimeter to Unify the Corona and Heliosphere

# CME Tracking and Semi-automatic Reconstructions with PUNCH

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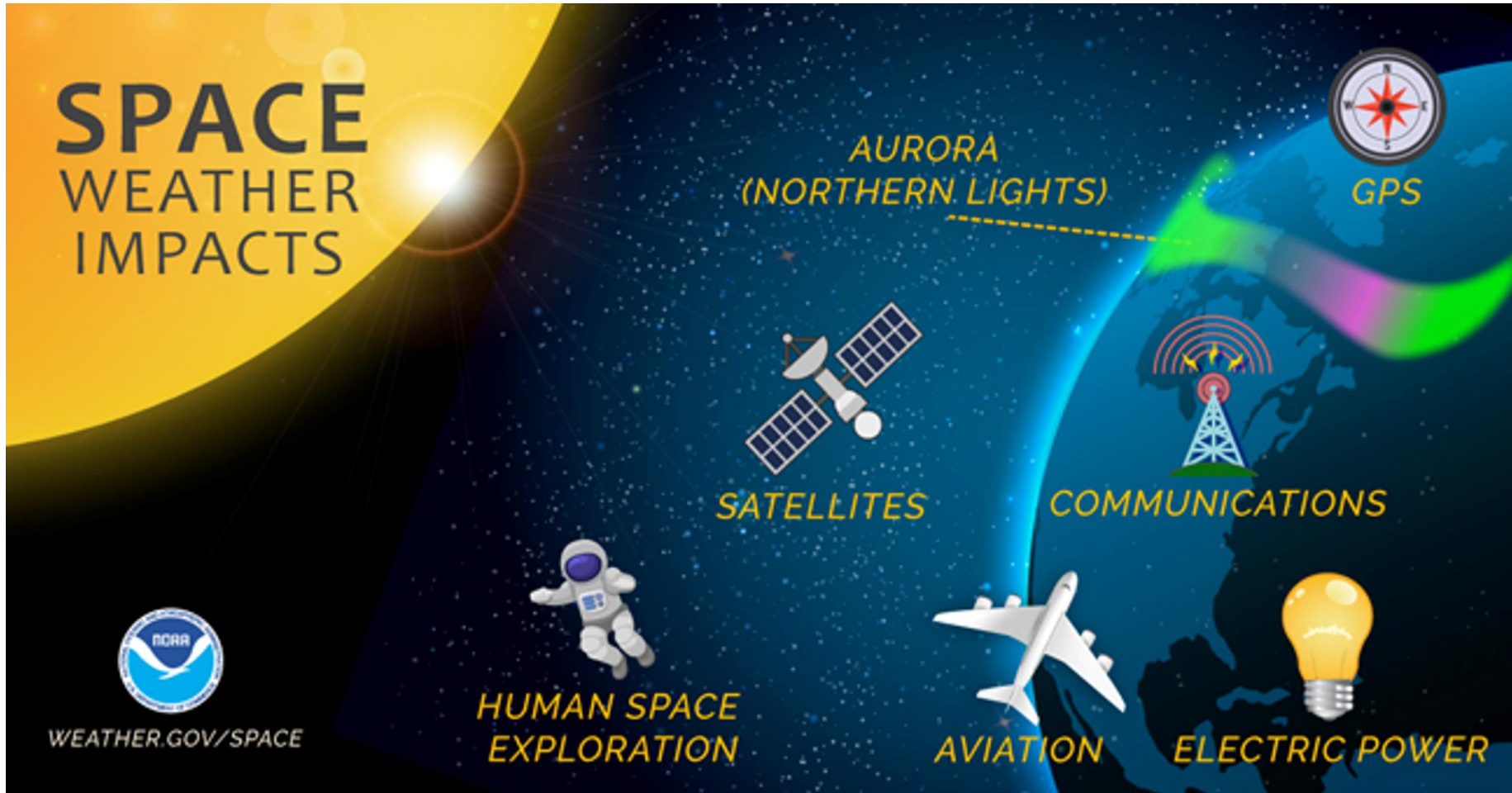
PUNCH 7 Science Meeting

May 12, 2026





# Motivation

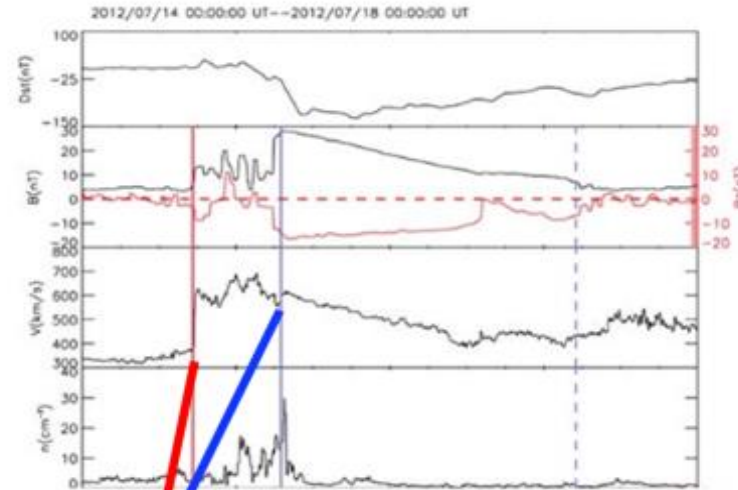
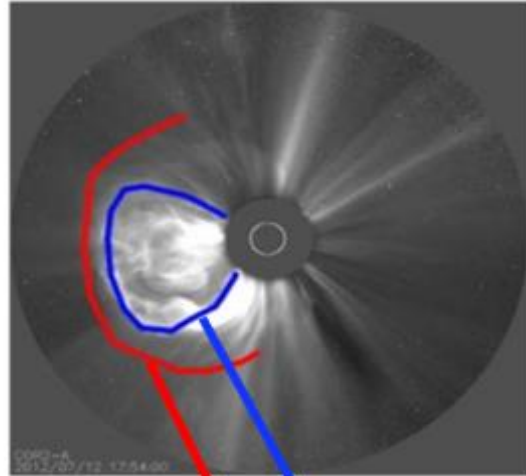


- What kind of data is needed to improve space weather predictions?
- To what heights do we need data to be able to reliably predict the CME ToA at multiple locations?
- How could the data availability affect space weather predictions?

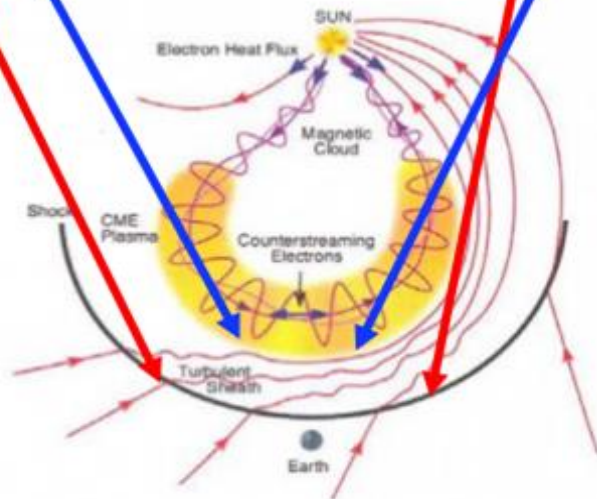


# CME Two-Front Geometric Structure

Red curve: shock  
Blue curve: ejecta



Dst index  
Solar wind magnetic field  
Velocity  
Density



Top panels: Hess & Zhang 2014  
Bottom panel: Zurbuchen & Richardson 2006

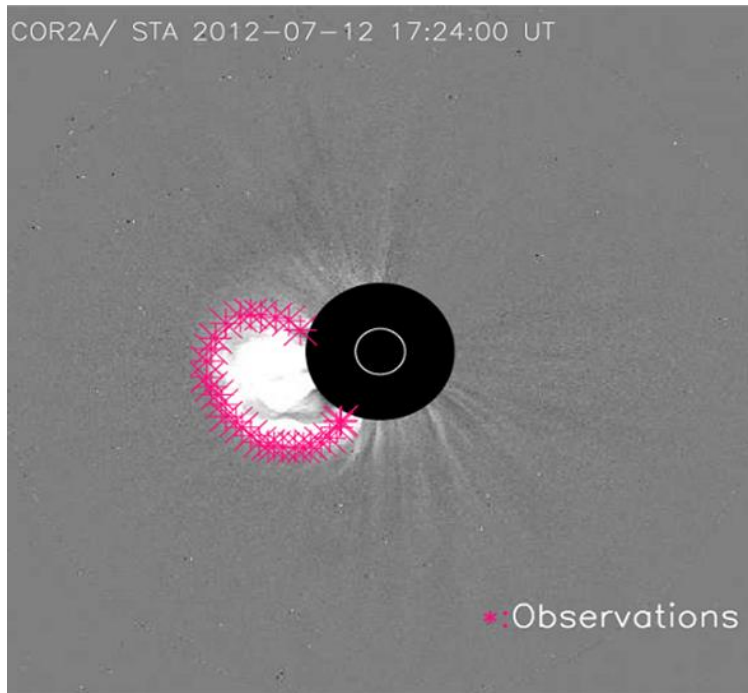
CME – ICME schematic, adapted from Zhang et al. 2021



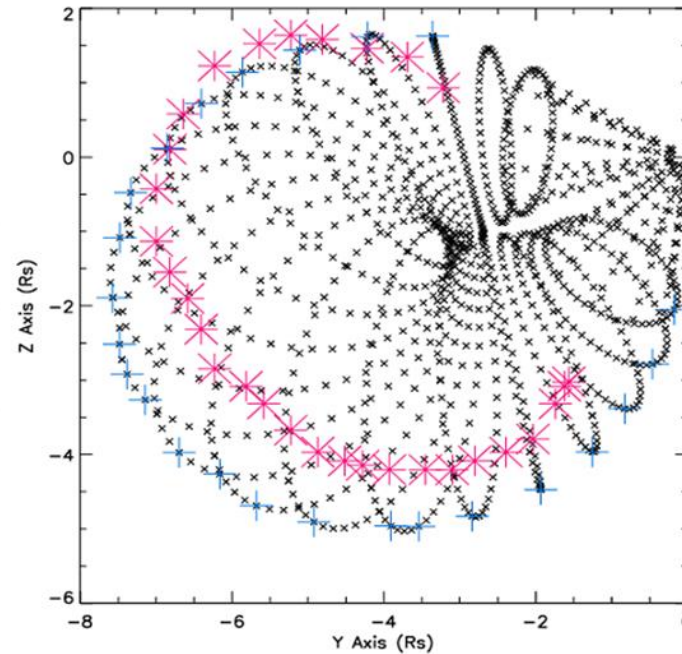
# Semi-automatic Ejecta Reconstructions

We use the semi-automatic fitting technique implemented by Nikou et al. 2025. It is a minimization based tool that uses the MPFIT IDL routine (Markwardt, C. B. 2009).

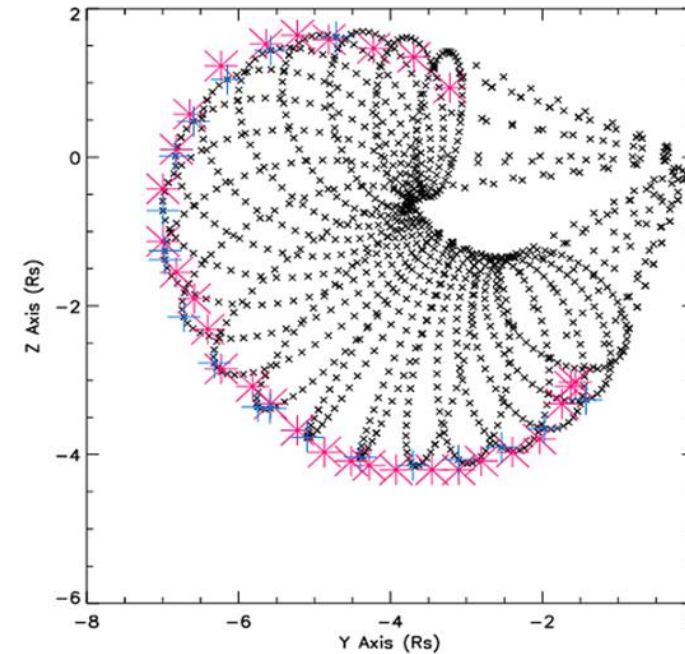
The initial implementation included only coronagraph data but it has been adapted to data from EVERY available remote sensing instrument including CCOR and PUNCH.



Step 1: Choose the leading front points



Step 2: Initial guesses of the model parameters



Step 3: Iterative fitting to minimize the  $\chi^2$  and returns (a) the best model parameters, (b) the uncertainty of each model parameter

### Pros:

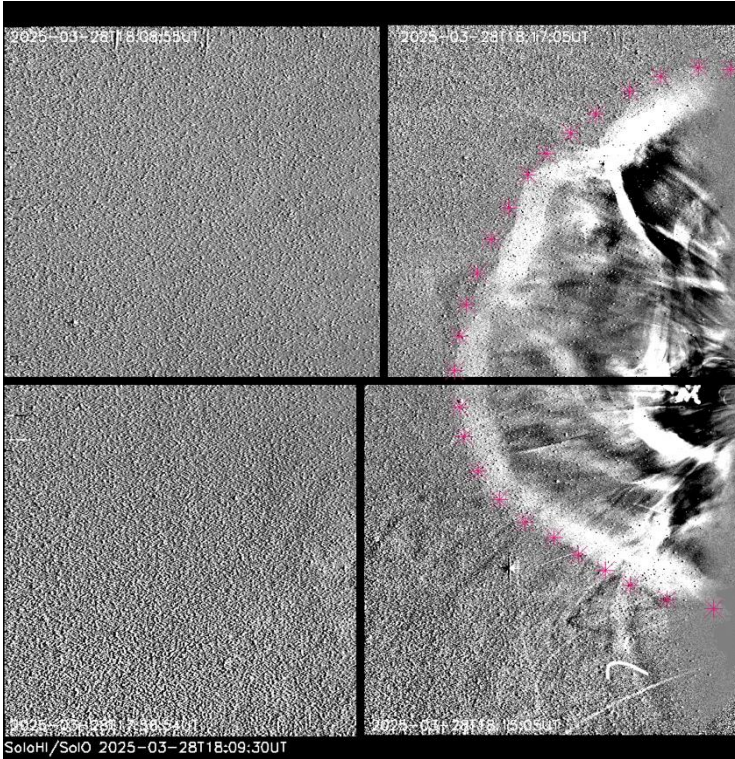
- Less human bias
- Efficient
- Provides uncertainty for each of the model parameters
- Does not rely on the user's experience

(Nikou et al. 2025)

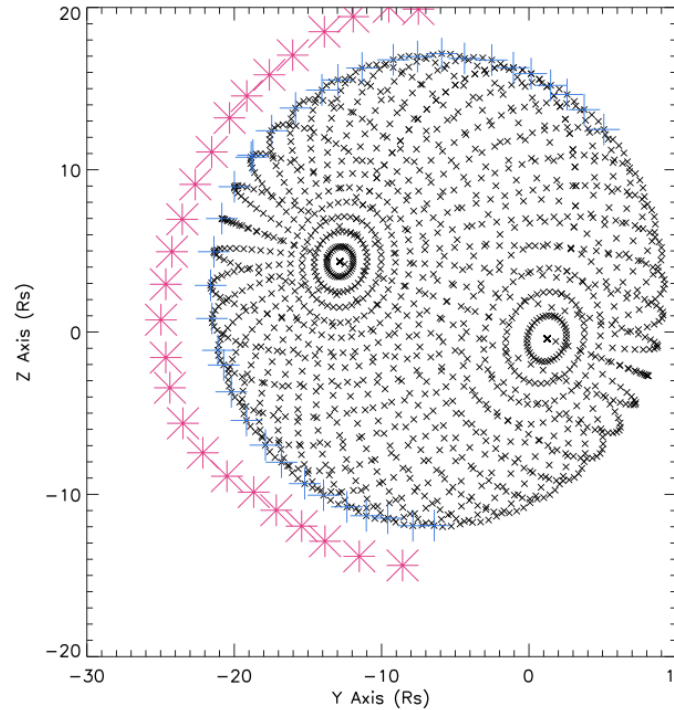
\*: Leading front points obtained by the observations  
 +: Leading front model points every 5 degrees



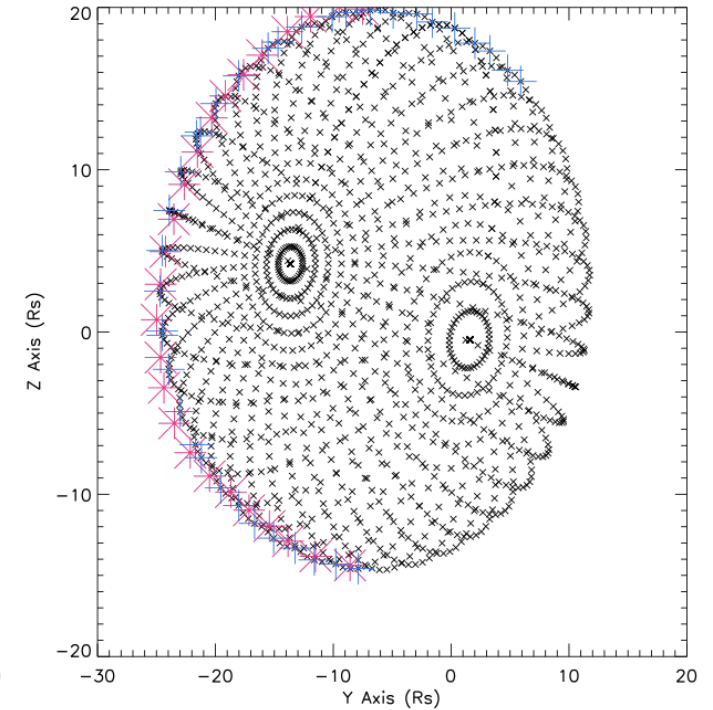
# Semi-automatic Shock Reconstructions



Step 1: Choose the leading front points



Step 2: Initial guesses of the model parameters



Step 3: Iterative fitting to minimize the  $\chi^2$  and returns (a) the best model parameters, (b) the uncertainty of each model parameter

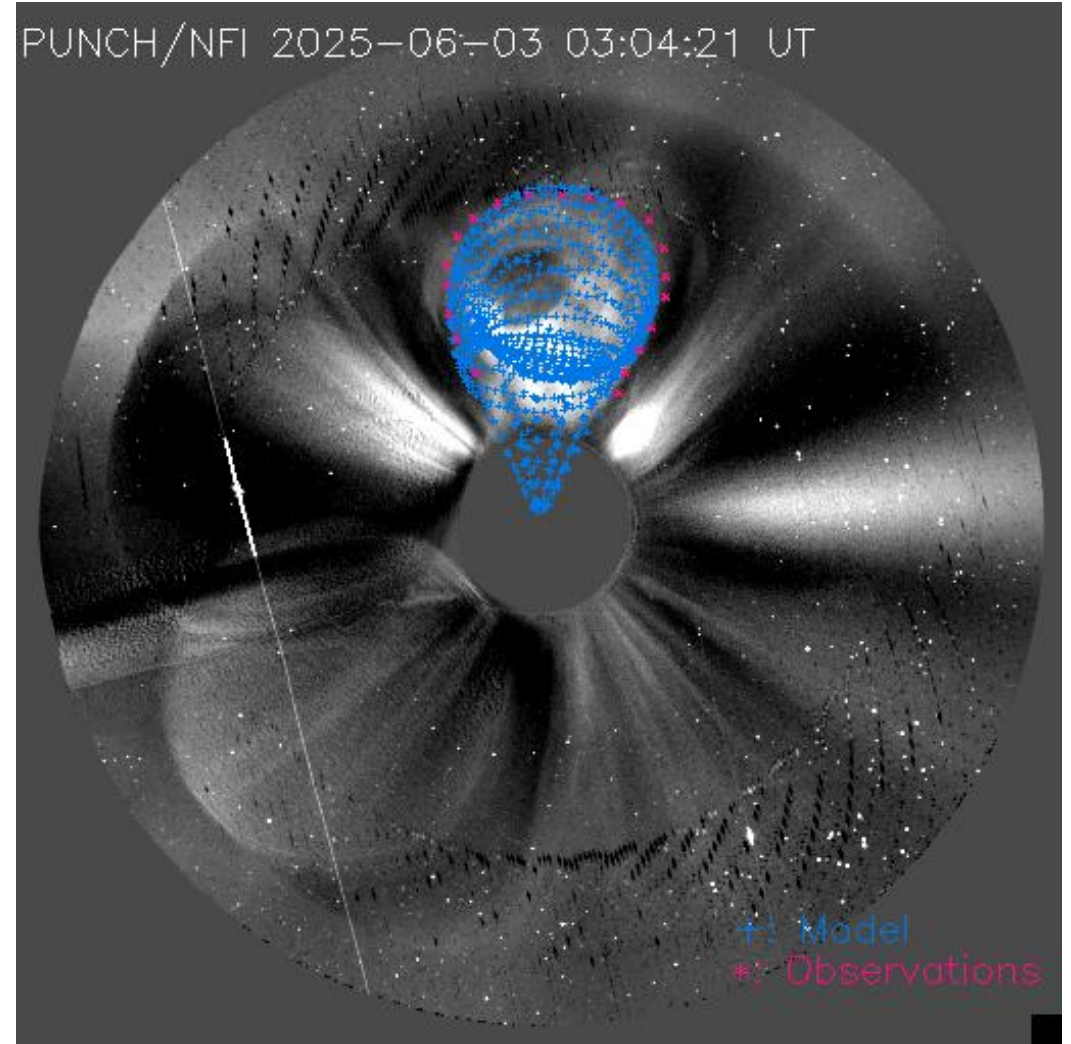
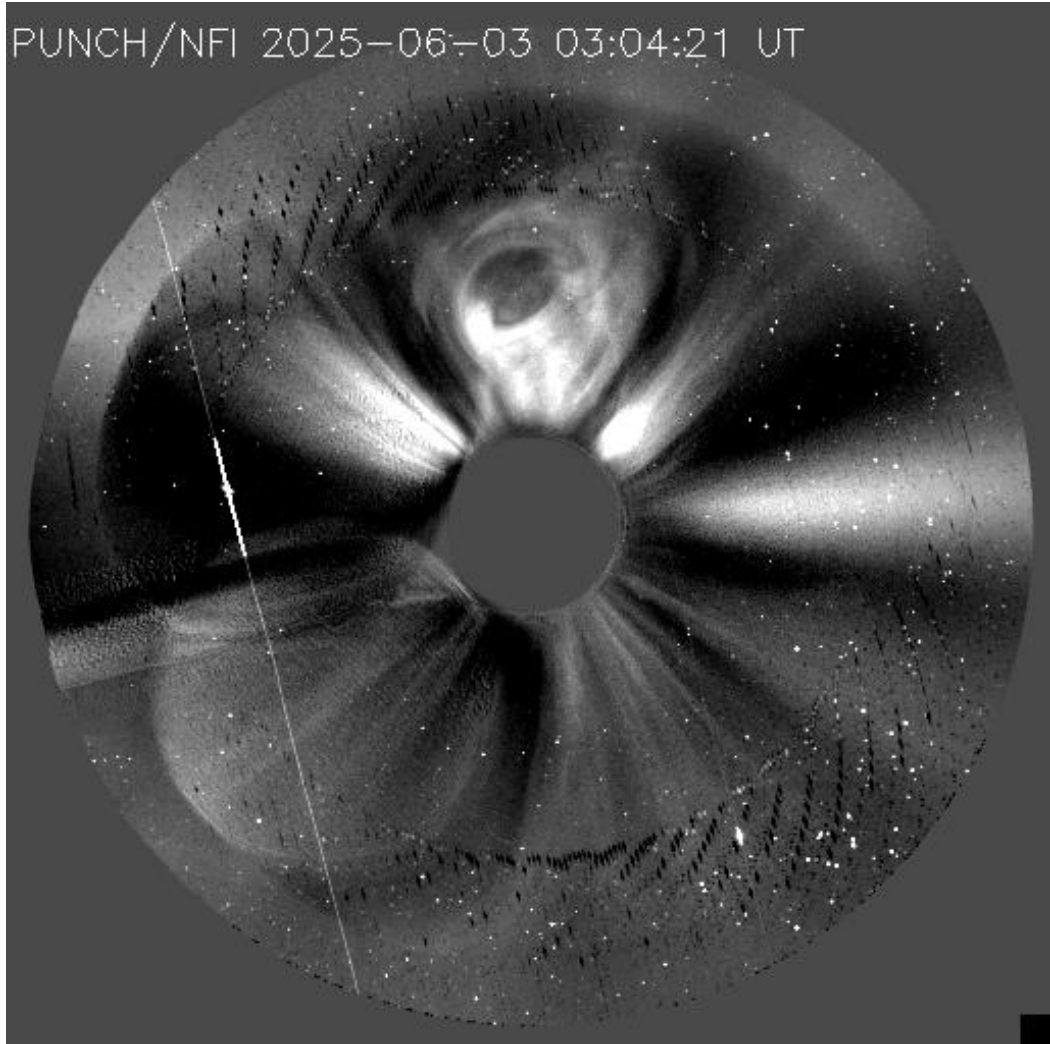
(Nikou+ 2026, to be submitted)

\*: Leading front points obtained by the observations

+: Leading front model points every 5 degrees



# NFI - Semi-automatic Ejecta Reconstructions



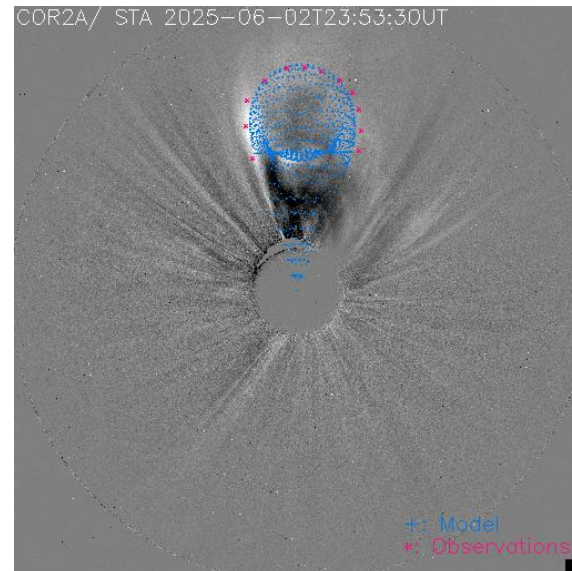
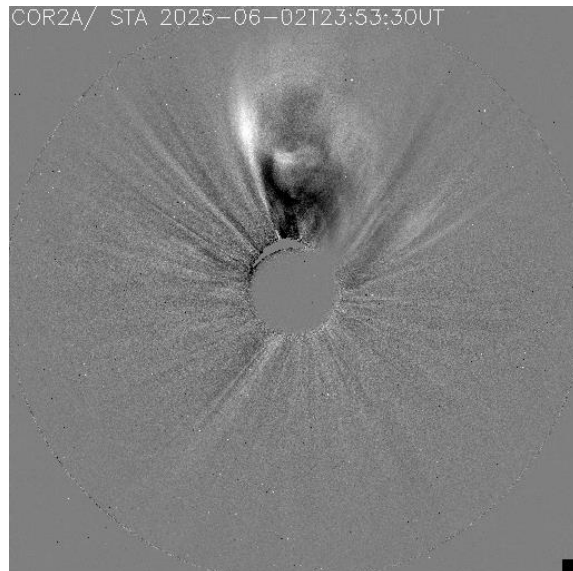
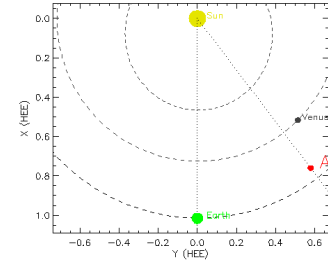
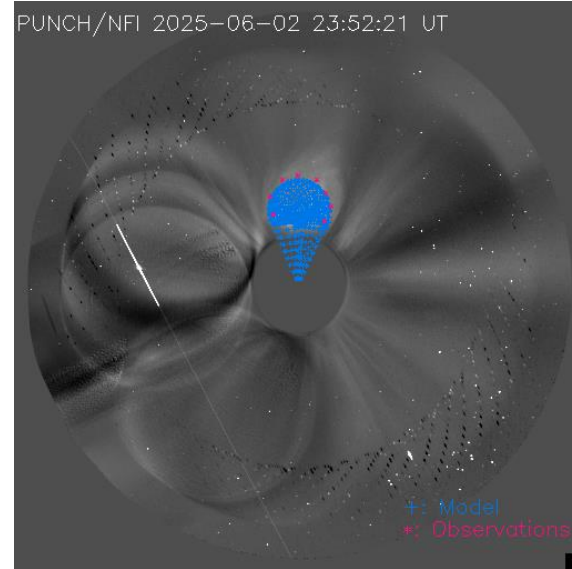
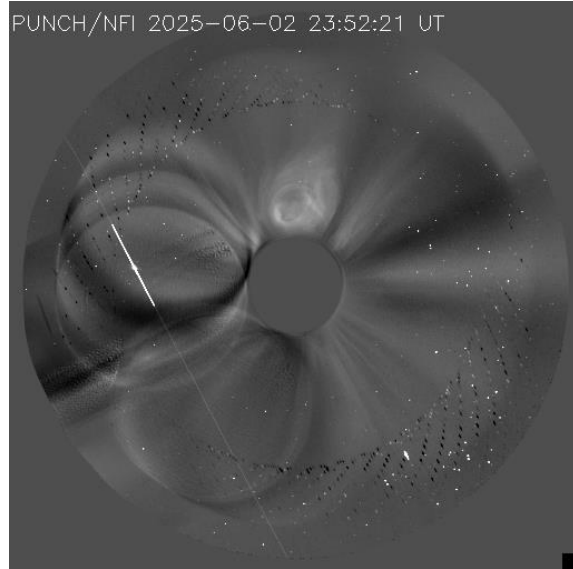
Ejecta front at  $\sim 20 R_s$

\*: Observations    +: Model



# Multi-viewpoint Semi-automatic Ejecta Reconstructions

## 2-viewpoint reconstruction (NFI – COR2A)



**\*: Observations**      **+: Model**

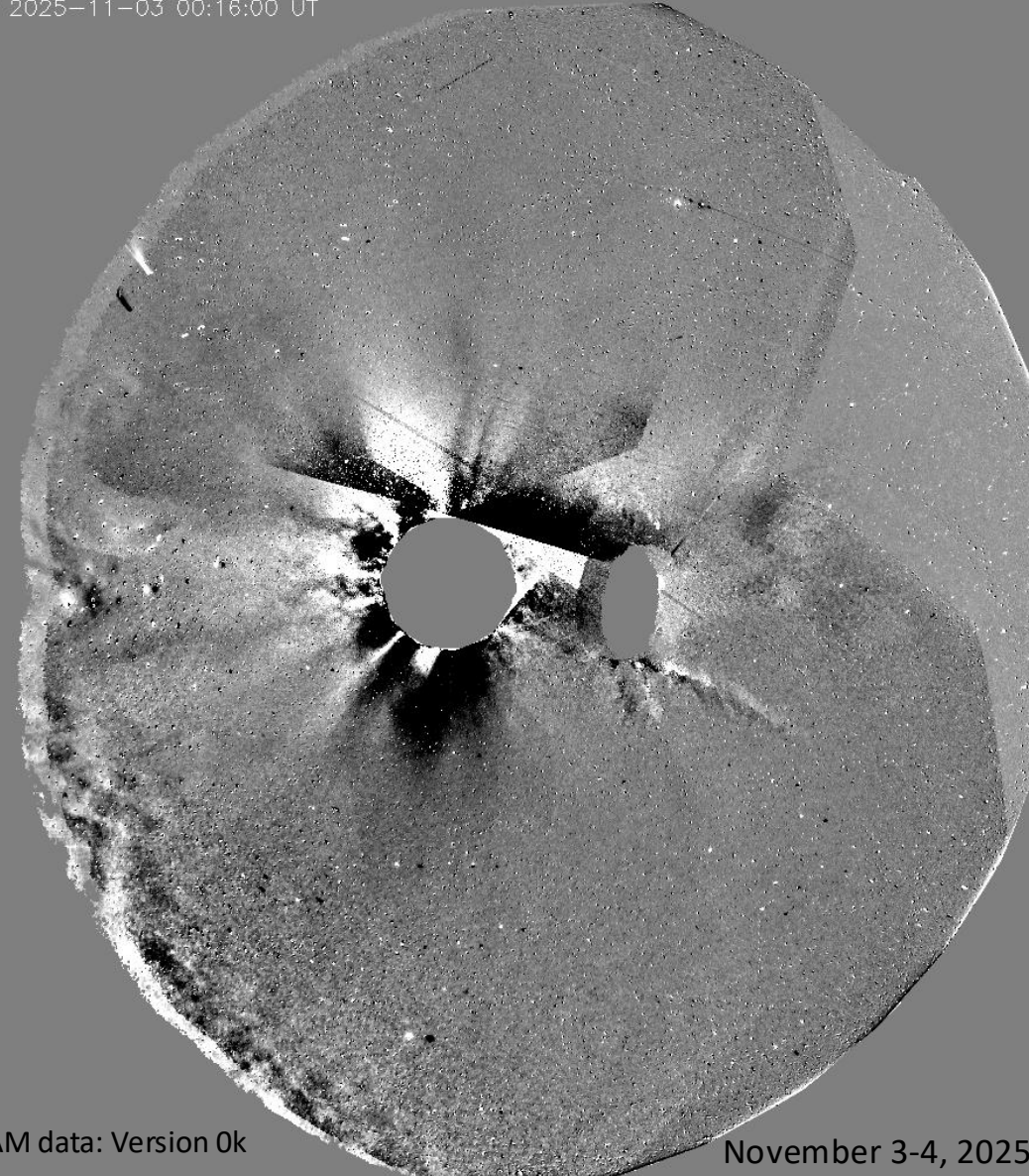
Ejecta front at  $\sim 12 R_s$



# WFI – Semi-automatic Shock Reconstructions

First time to constrain the back side of the shock in such high distances!!

PUNCH/WFI 2025-11-03 00:16:00 UT



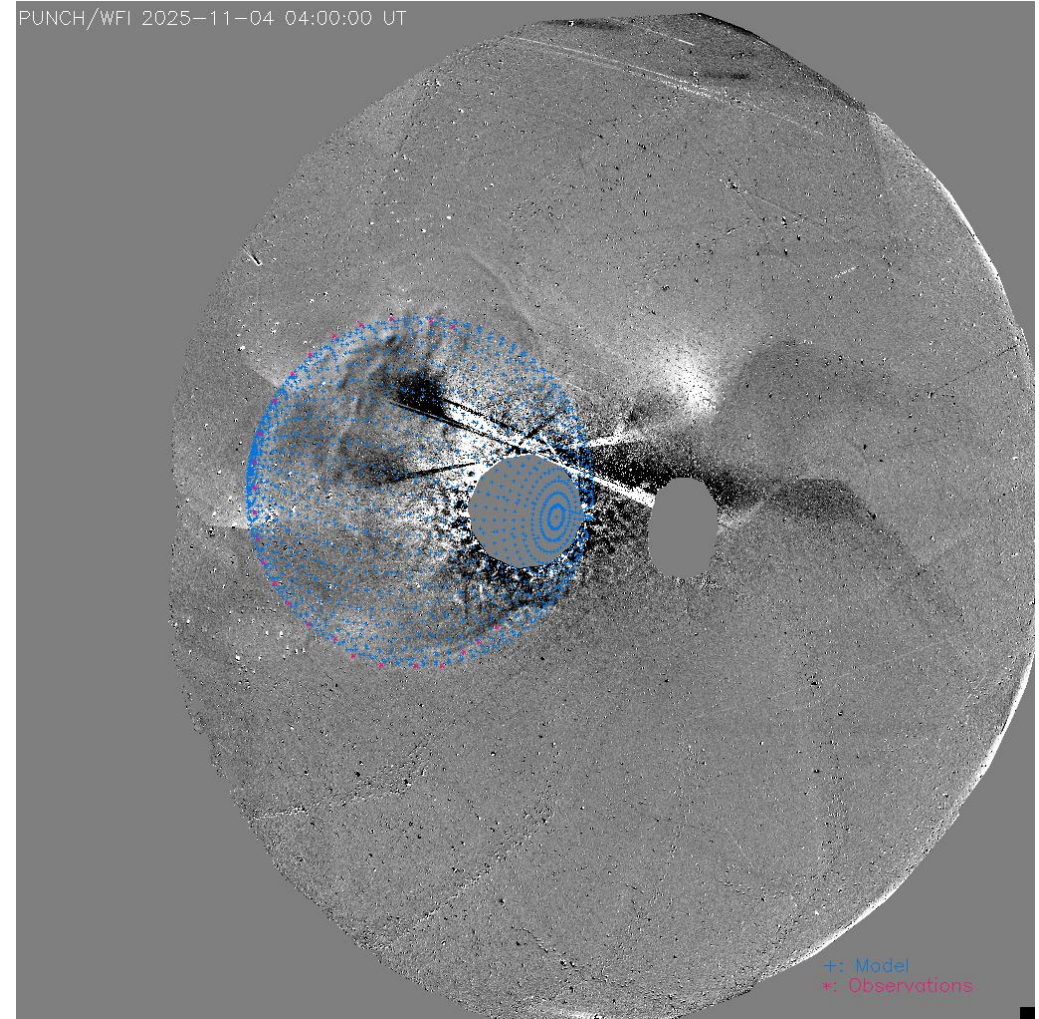
WFI L3 CAM data: Version 0k

November 3-4, 2025



# WFI – Semi-automatic Shock Reconstructions

## 1-viewpoint reconstruction



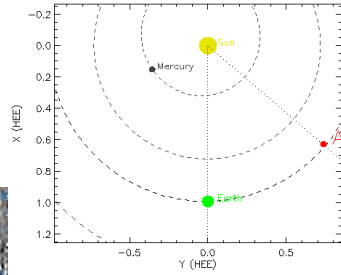
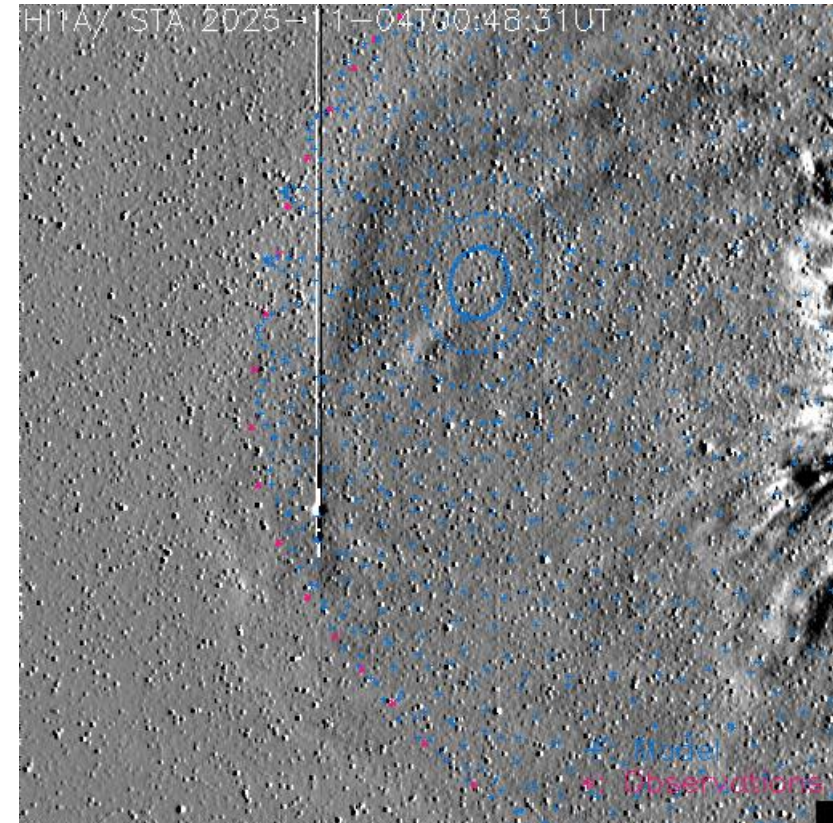
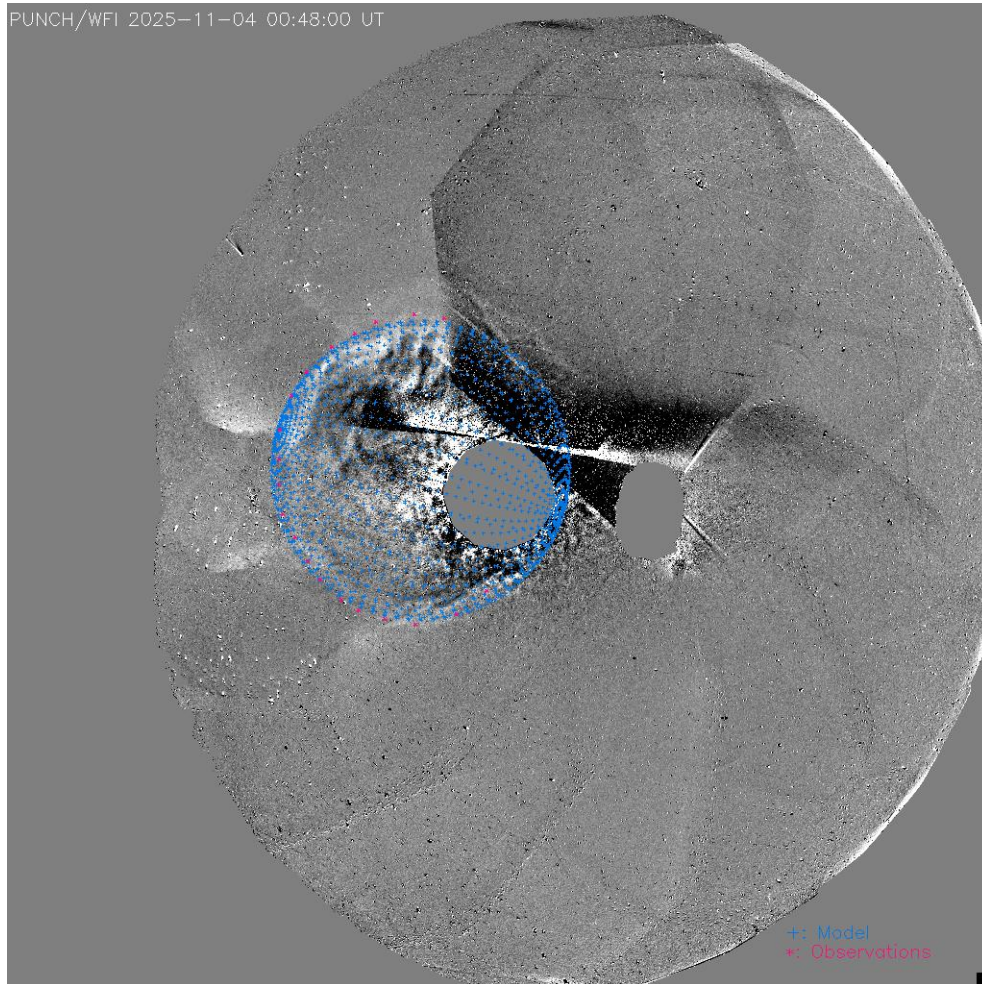
Shock front at  $\sim 90 R_s$

\*: Observations    +: Model



# Multi-viewpoint Semi-automatic Shock Reconstructions

## 2-viewpoint reconstruction (WFI – HI1A)



Underconstrained shock fittings with the HIs when used as a single viewpoint since only part of the shock front is observed.

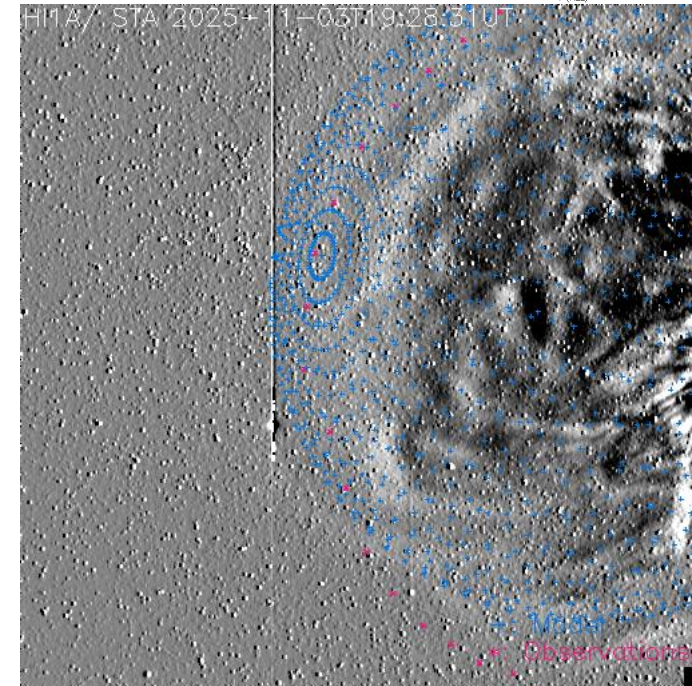
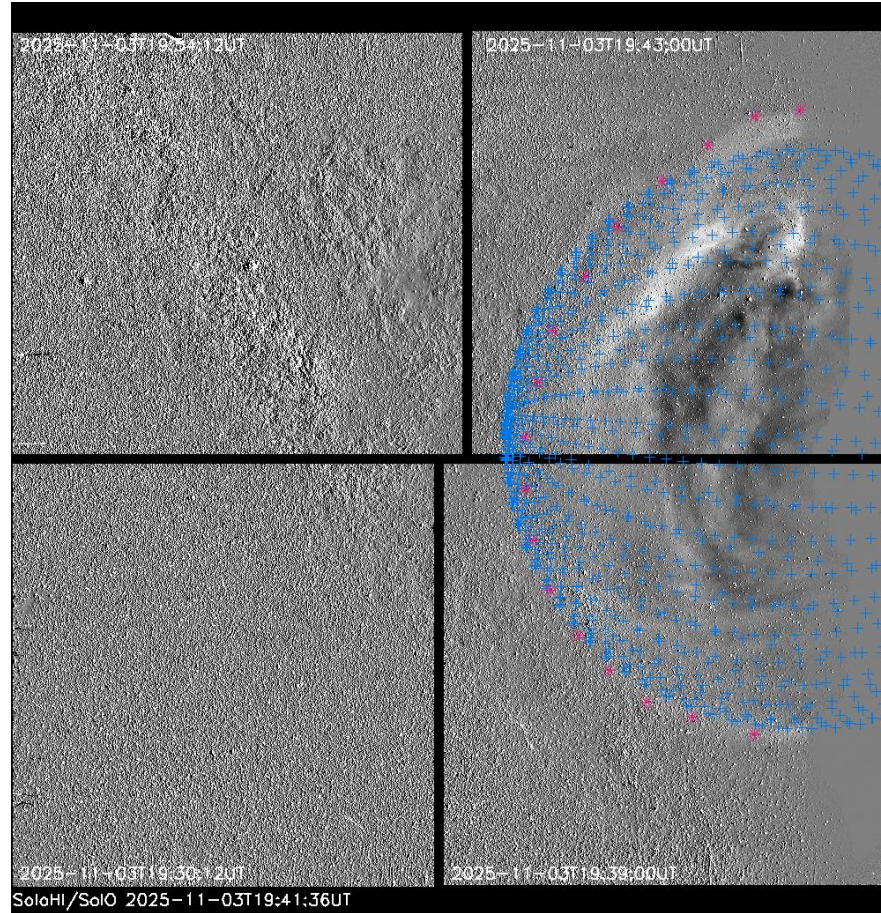
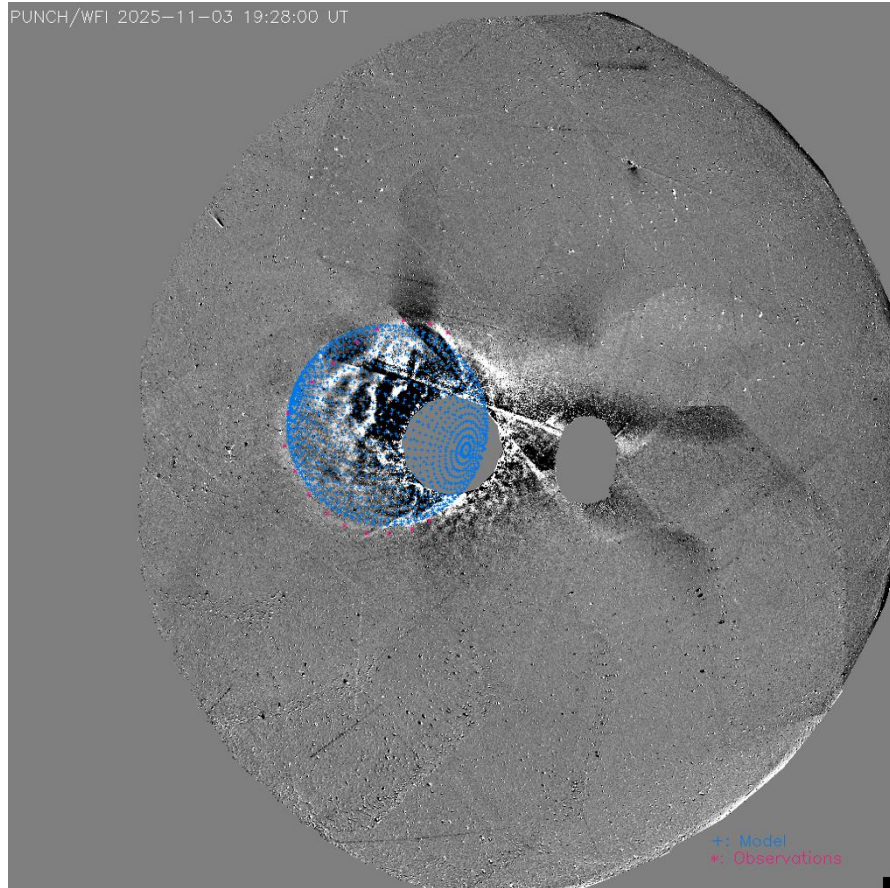
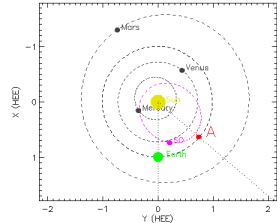
Shock front at ~80 Rs

\*: Observations +: Model



# Multi-viewpoint Semi-automatic Shock Reconstructions

## 3-viewpoint reconstruction (WFI – SoloHI – HI1A)



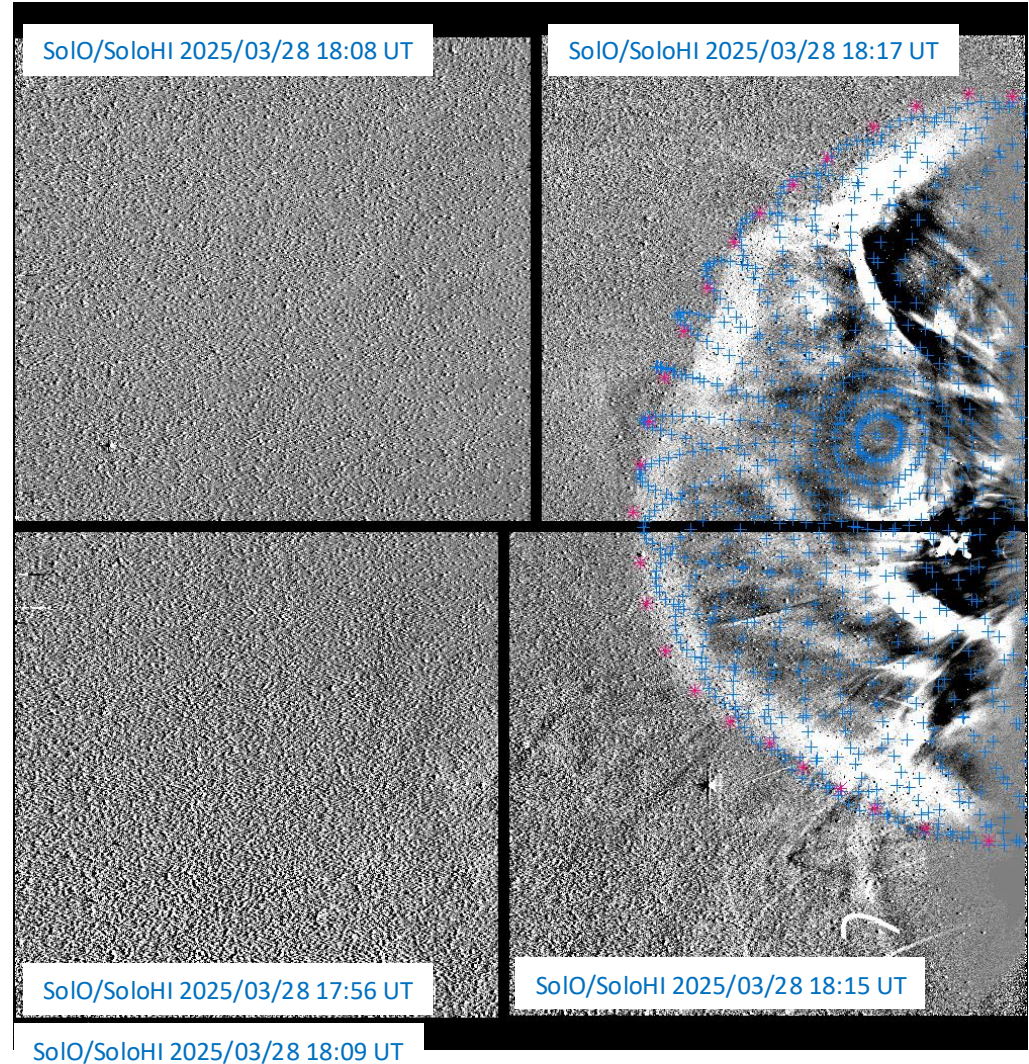
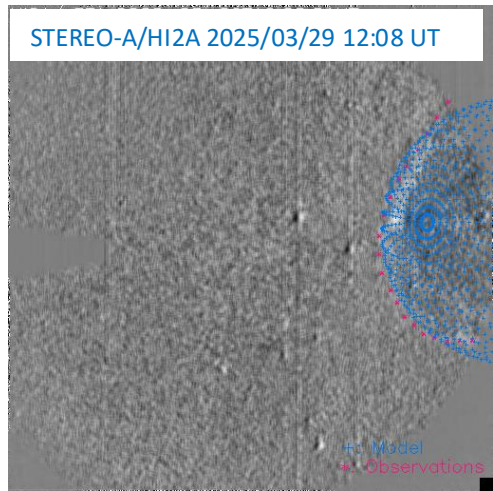
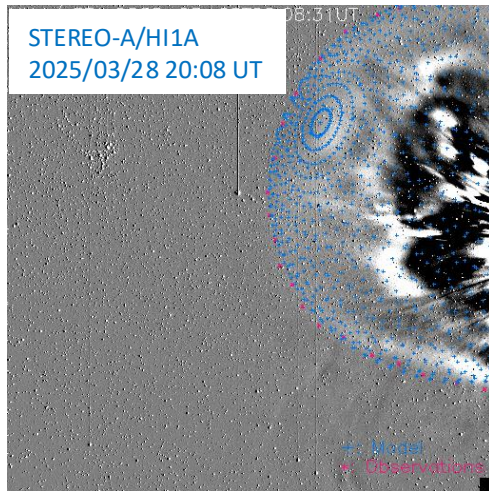
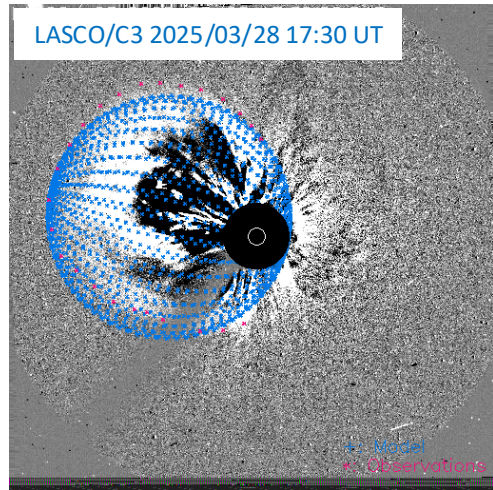
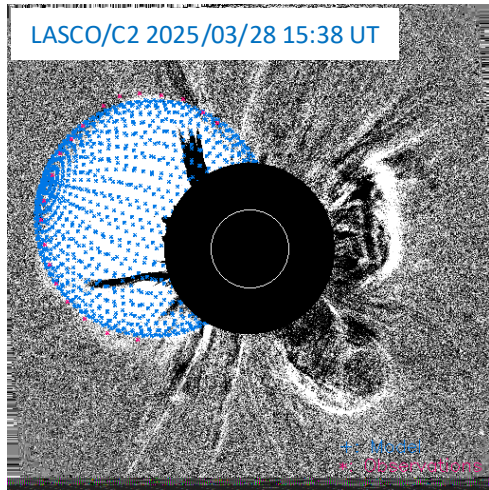
Shock front at  $\sim 65 R_s$

\*: Observations    +: Model



# PUNCH – An Asset for Space Weather Predictions at multiple locations

Example of a case study of a CME shock propagating to Mars (At the time of the CME, PUNCH data was not yet available)



\*: Observations    +: Model

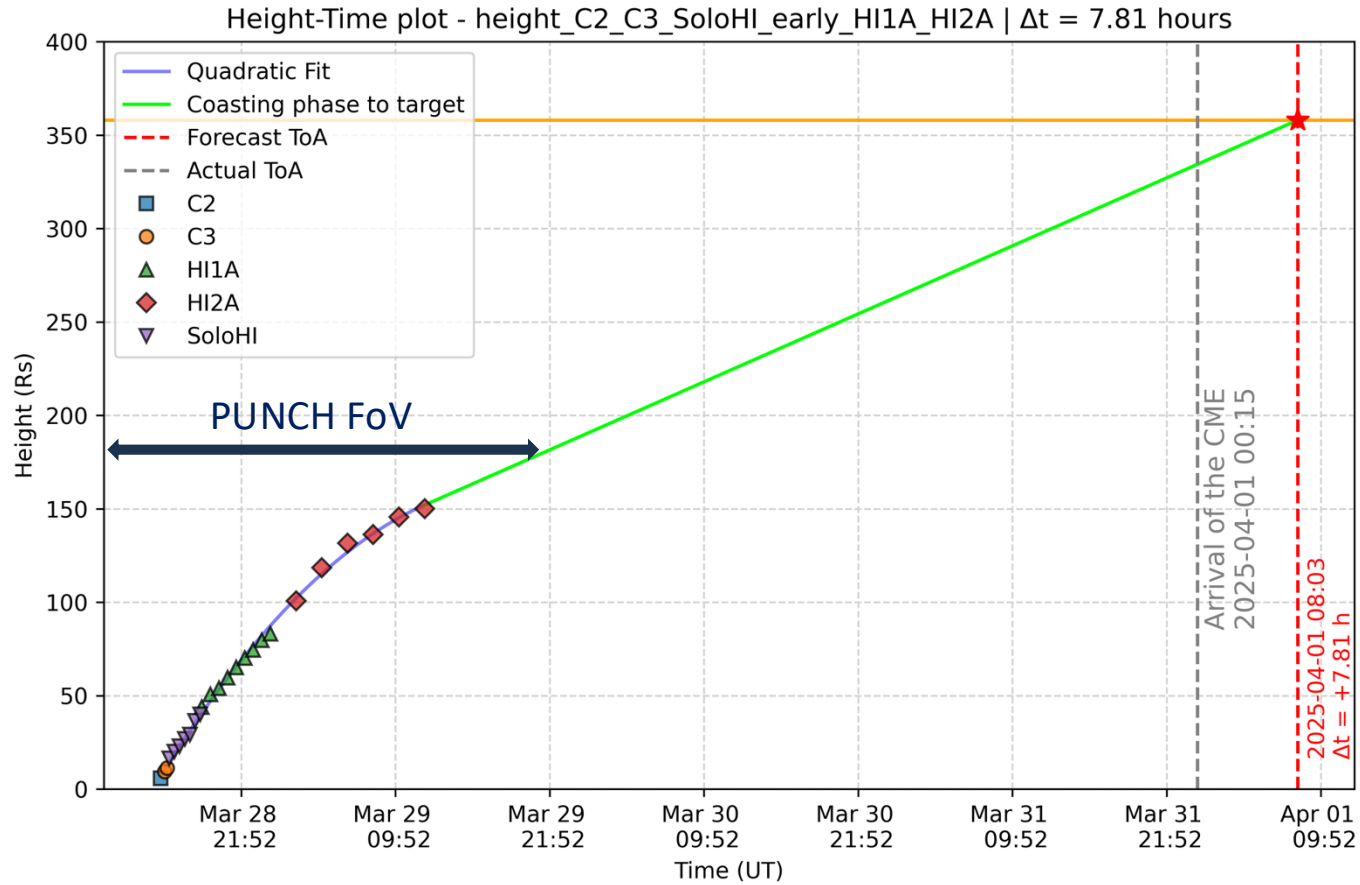
(Nikou+ 2026, to be submitted)

**Important Note:** The results rely only on one viewpoint fittings! 12



# ToA Prediction Results at Mars

Deceleration happened inside the PUNCH FoV



Predicted ToA: 2025-04-01 08:03 UT

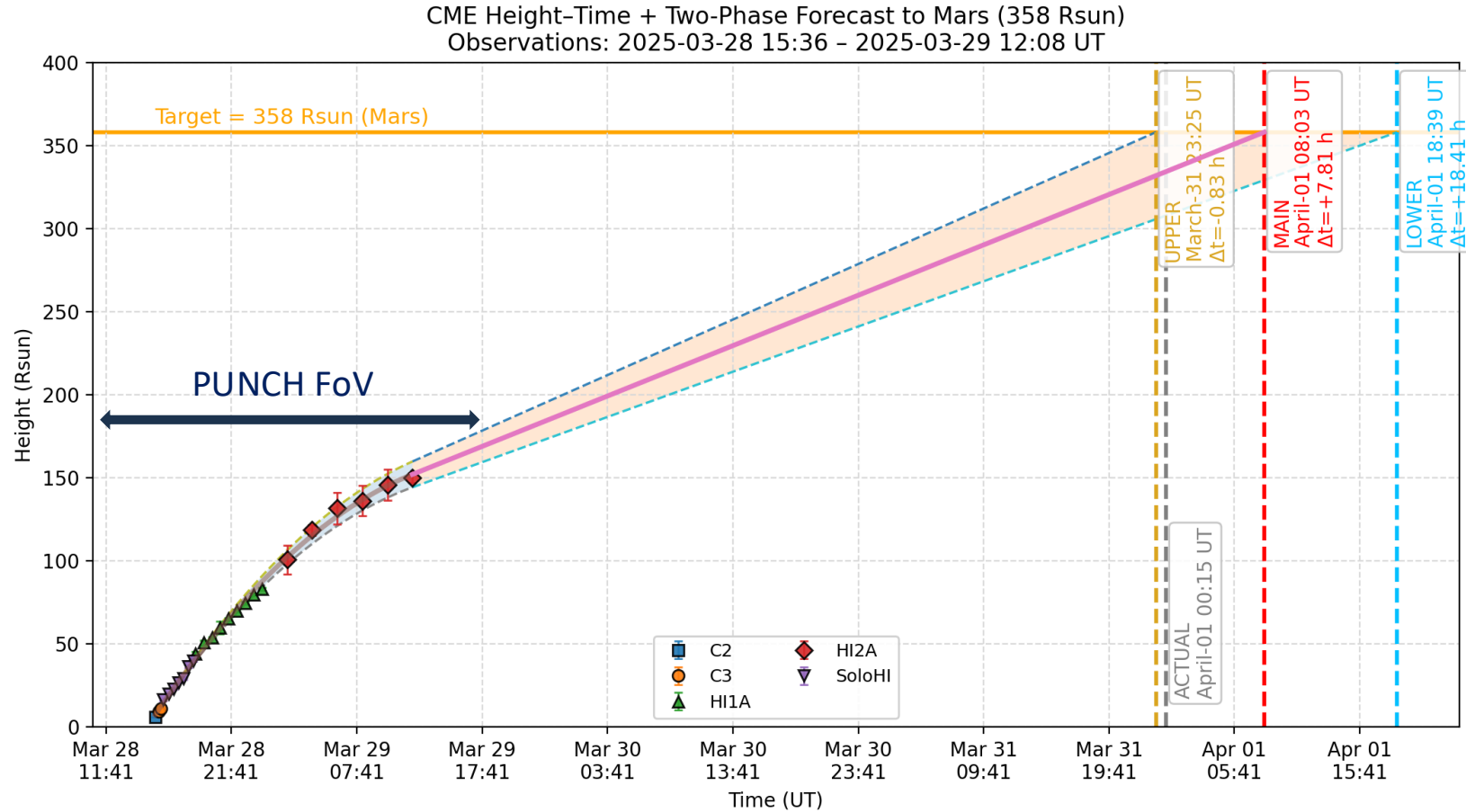
Observed ToA: 2025-04-01 00:15 UT

(Nikou+ 2026, to be submitted)



# What is the role of the Height Uncertainties in Space Weather Predictions?

The semi-automatic fitting technique provides event specific uncertainties and it sensitive to the viewpoint used as well as the type of CME studied.



(Nikou+ 2026, to be submitted)



# Discussion & Conclusions

- Semi-automatic reconstructions reduce user bias, a major source of error in CME reconstructions. Currently we can reconstruct any CME from every available viewpoint and their combinations.
- Observations from larger solar distances are crucial to better predict the ToA of CMEs at multiple locations. In the case study presented, observations from lower heights were not enough to capture its deceleration phase, resulting in early predictions.
- PUNCH will allow for uninterrupted tracking and reconstructions in higher heights that would play a key role in improving space weather predictions in multiple locations.
- Being able to constrain the back side of the shock in the PUNCH FoV of CMEs close to the limb will lead to improved height reconstructions and uncertainty estimations.
- We are also looking forward to using PUNCH's polarimetric capabilities that would help us better constrain the CME envelope and lead to more reliable reconstructions and space weather predictions in multiple locations.

We are working on making the fitting tool available to the community in IDL.



**Thank you!**