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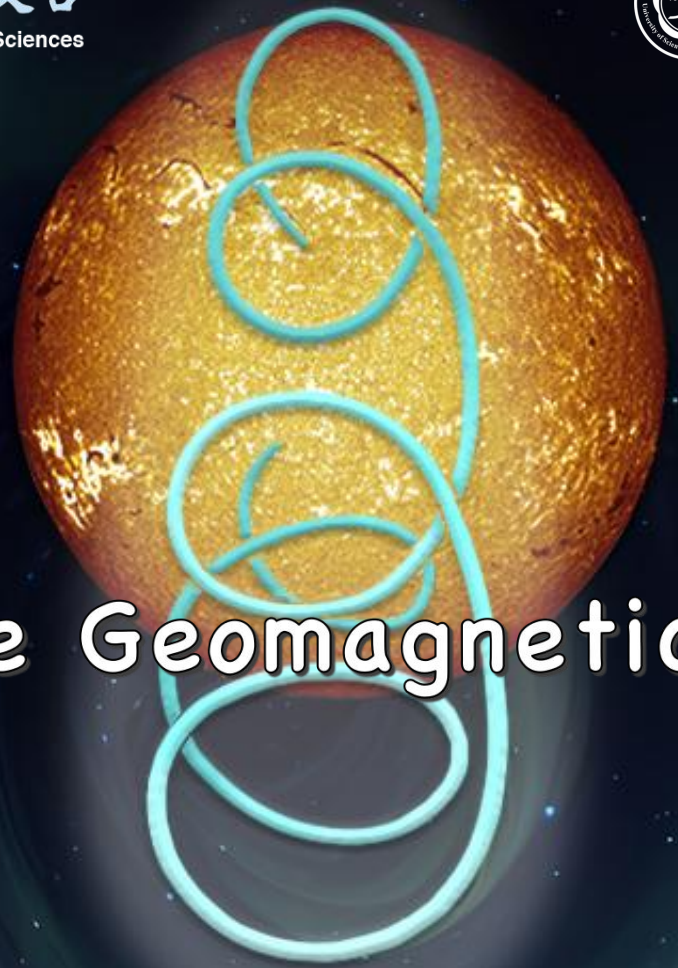


The Origin of an Unexpected Severe Geomagnetic Storm

Weilin Teng, Yingna Su, Haisheng Ji, Qingmin Zhang

Purple Mountain Observatory

EGU 2025

Geomagnetic Storm

A major disturbance of Earth's magnetosphere.

- **Main driver: Corotating Interaction Regions (CIRs),**
  Interplanetary Coronal Mass Ejections (ICMEs)

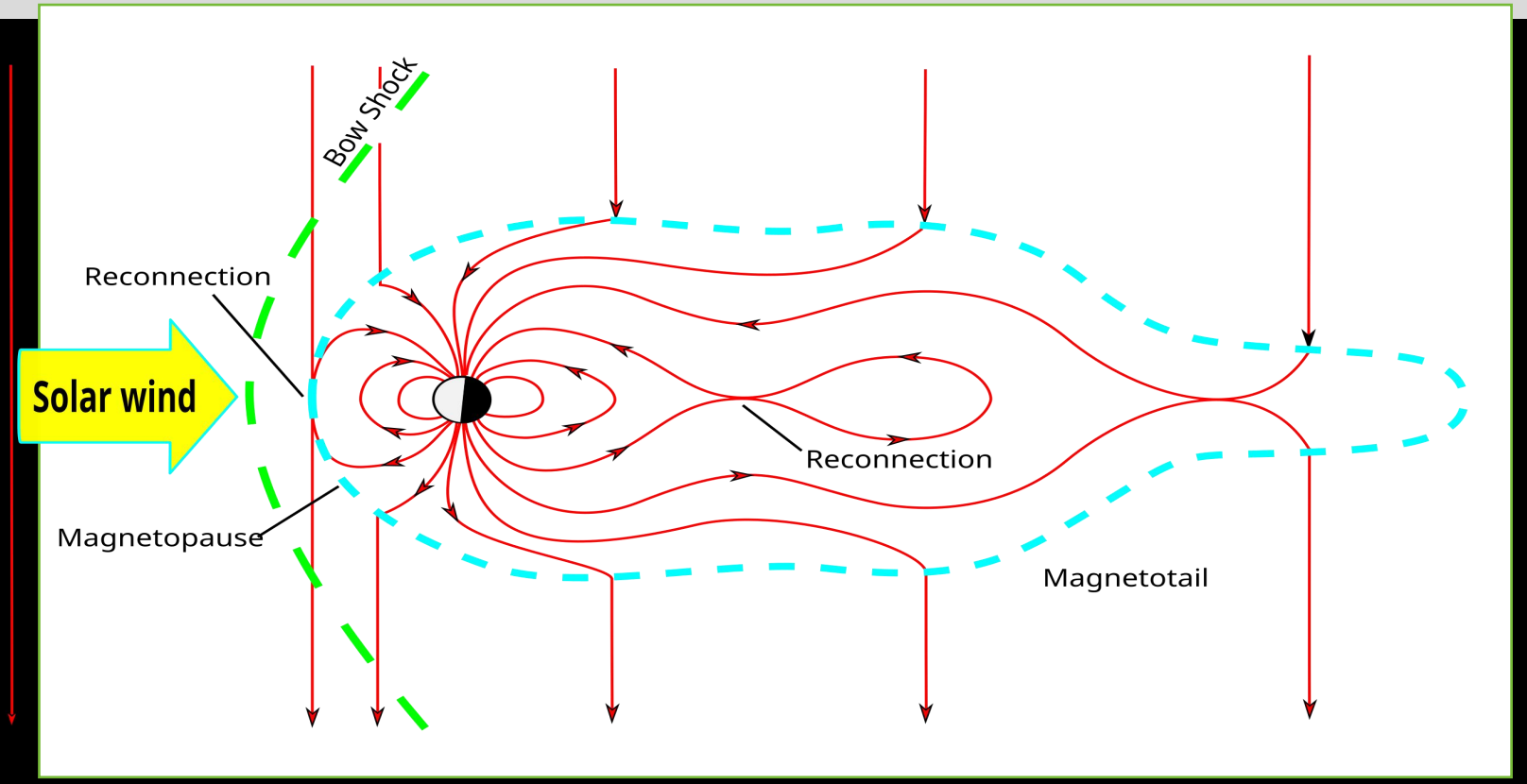
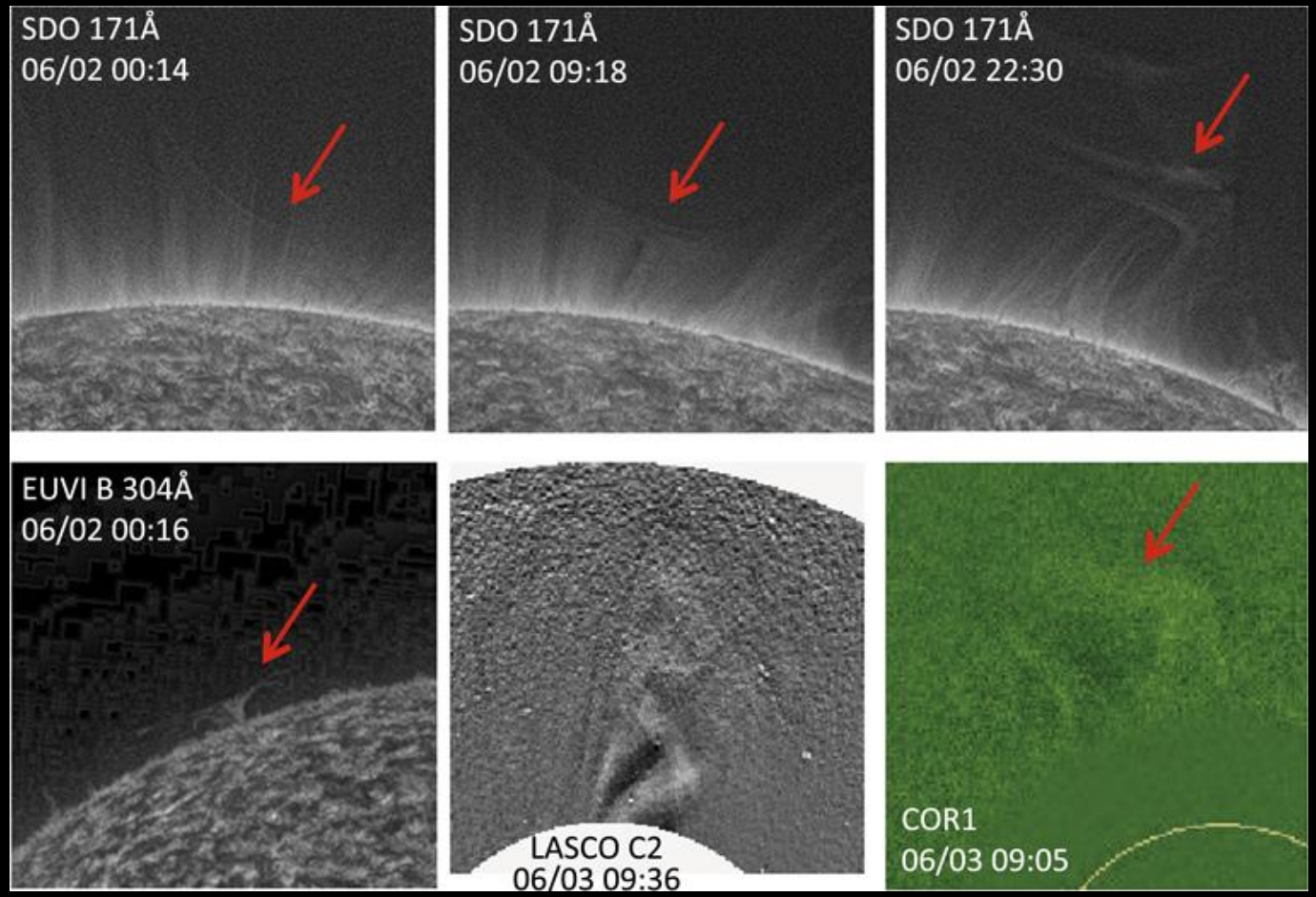


Image Source: Wikipedia RicHard-59

"Stealthy" CMEs

- Some CMEs have **no significant low-corona signatures**.
- They are called **"Stealthy" CMEs**.
- Stealthy CMEs heading towards Earth may cause **"problem" geomagnetic storms.**



Nathalia Alzate and Huw Morgan 2017 ApJ 840 103

23-24 March, 2023
The "Dragon Day Event"

Geomagnetic Storm:

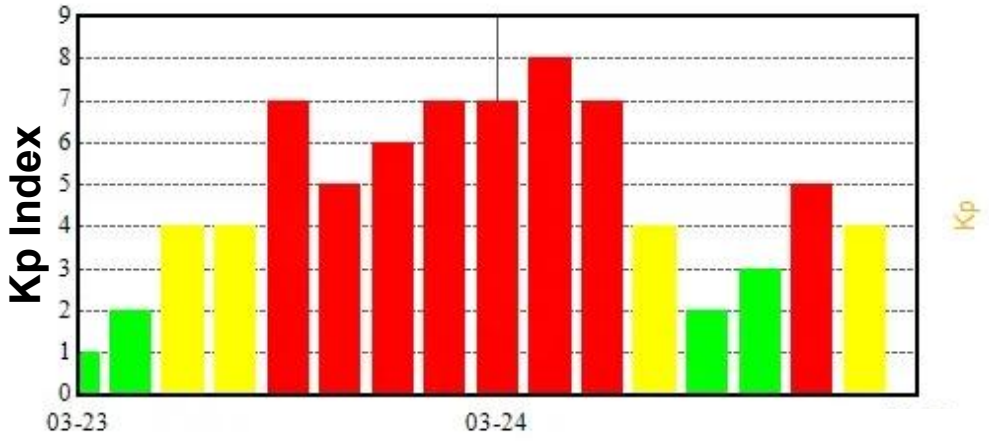
Maximum Kp=8, Severe (G4) in NOAA scale, Minimum Dst=-163 nT

Filament Eruption:

Solar Flare:

Forecast:

Video Source：Photographer @AngelAn安久

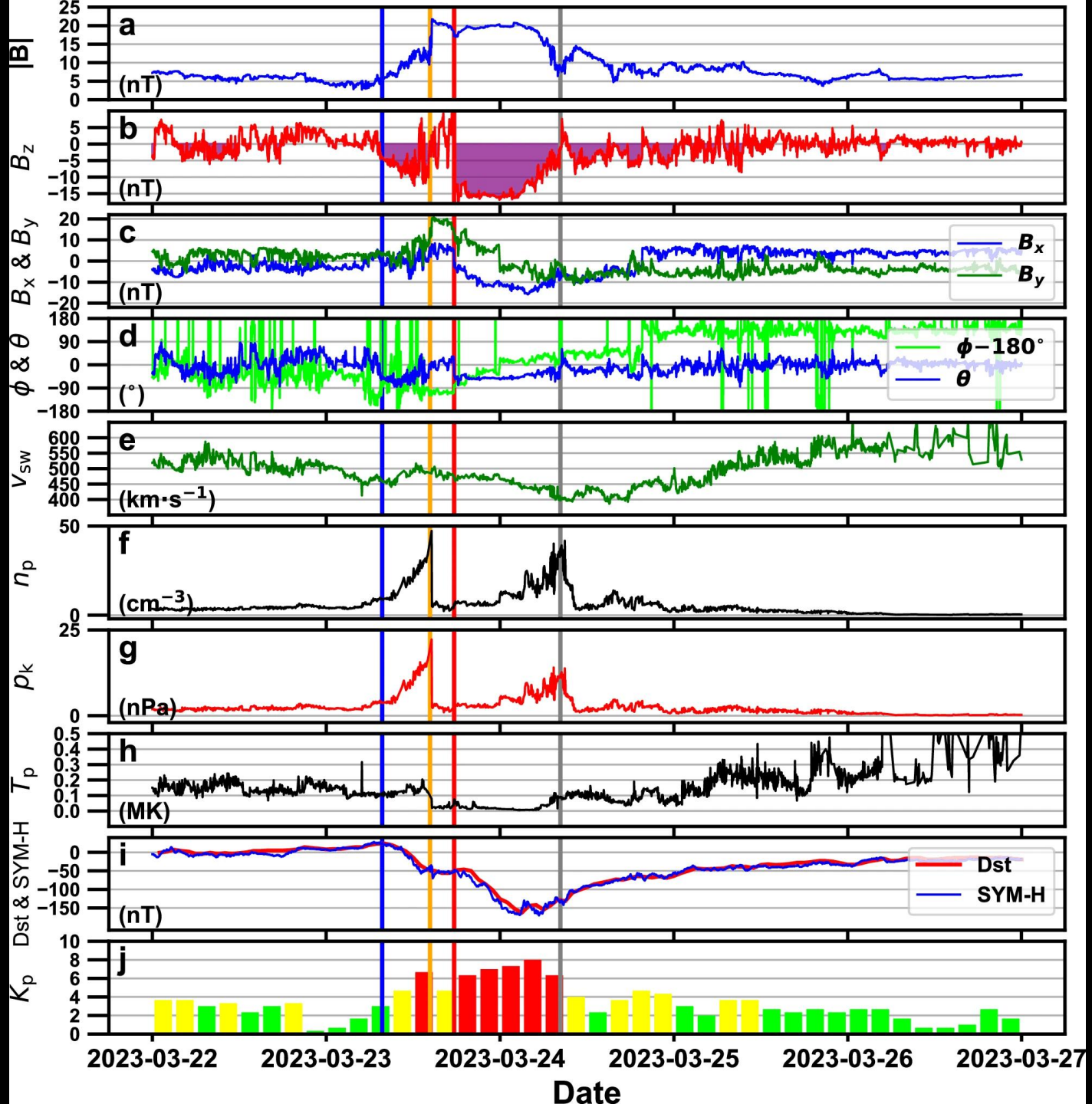


(Space Environment Prediction Center, China)

(World Data Center for Geomagnetism, Kyoto, Japan)

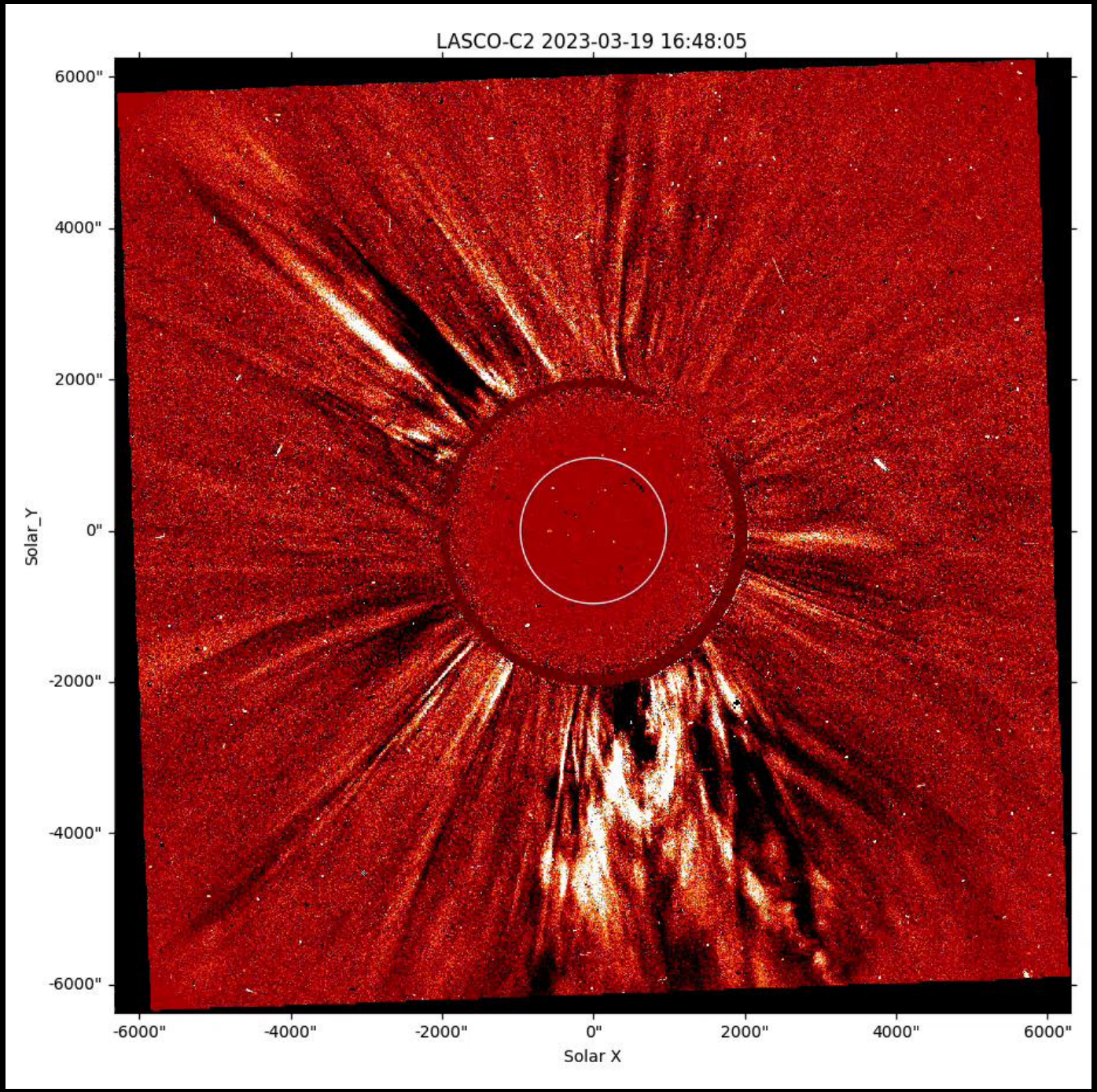
Near-Earth Space Environment

- The cause is an **interplanetary CME (ICME).**
- The inclination angle of the flux rope is -74°. **Almost perpendicular to the ecliptic plane.**
- **Sustained and strong southward magnetic field (≈ -15 nT)** near Earth.

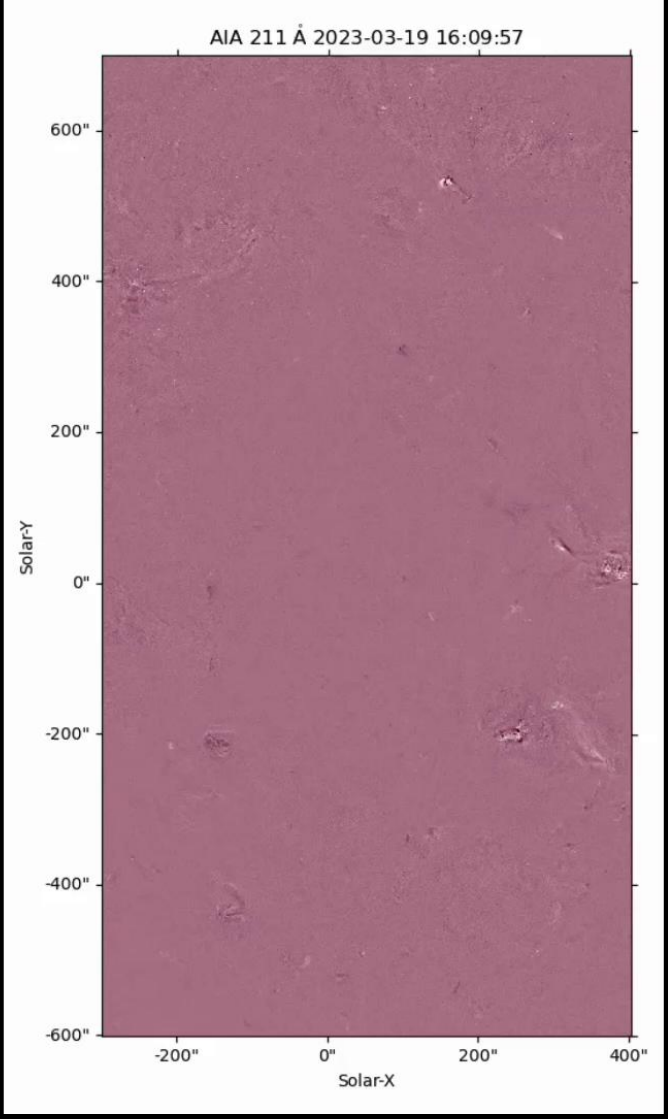


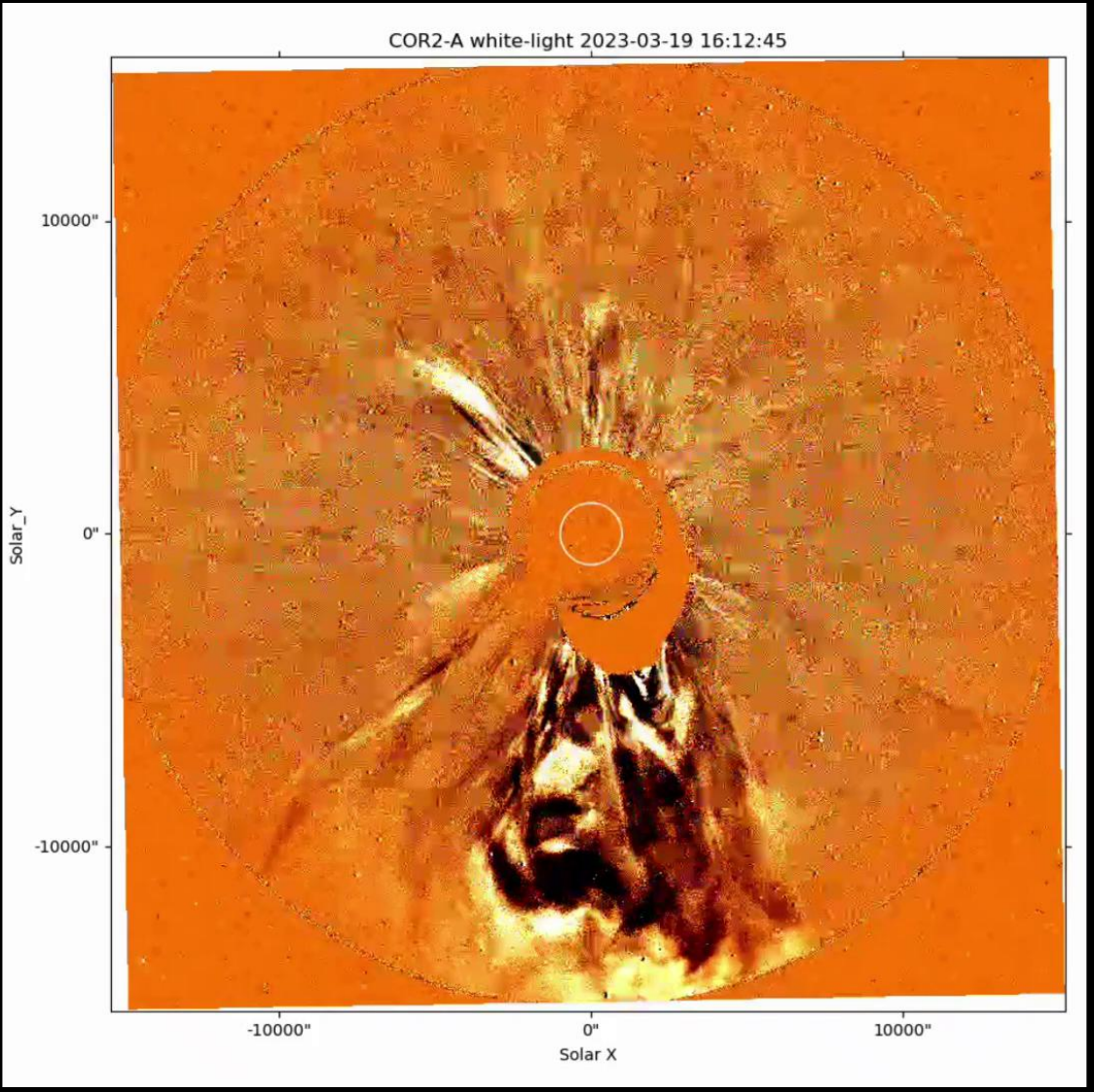
In Search of the Solar Source

- Search for **full-halo CMEs** in LASCO-C2 images before the storm.
- The only full-halo CME is a **longitudinal and lengthy CME with a faint and intermittent front**.
- It is misidentified as separate narrow CMEs in CME catalogs.



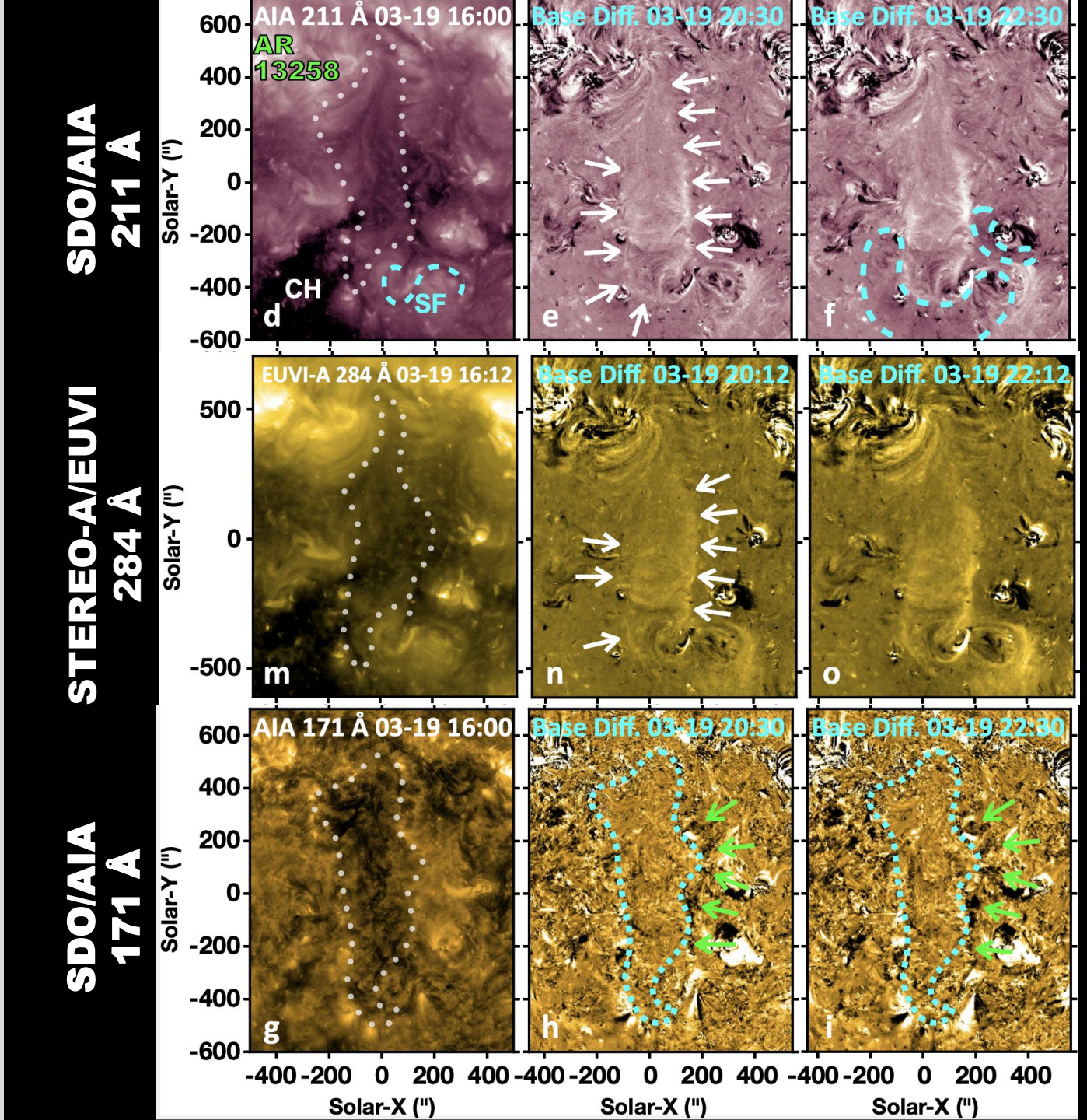
Searching the lower-corona source of the CME:
When this CME appears in the FOV of STEREO-A/cor2,
faint trans-equatorial brightening develops near the solar disk center.





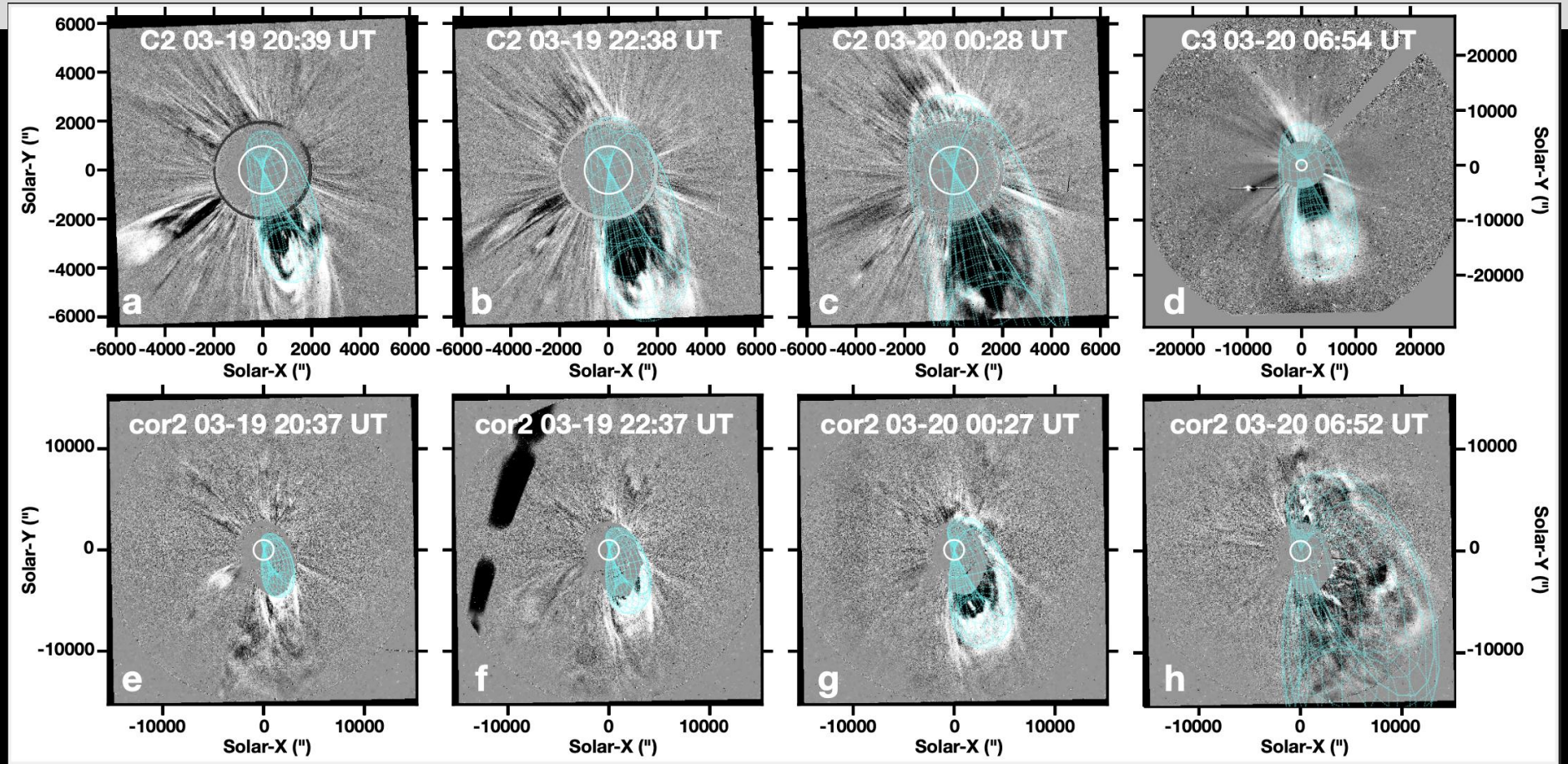
Source Region of the CME: a Trans-equatorial EUV Channel

- Before the eruption:
- **Longitudinal and lengthy** strip with **less EUV emissions** than the surroundings (named an **EUV Channel**), best seen in 171 Å.
- During the eruption:
- **Faint trans-equatorial brightening** develops and expands on both sides of the EUV channel, best seen in **211Å & 284Å**. Subsequently, the CME appears.



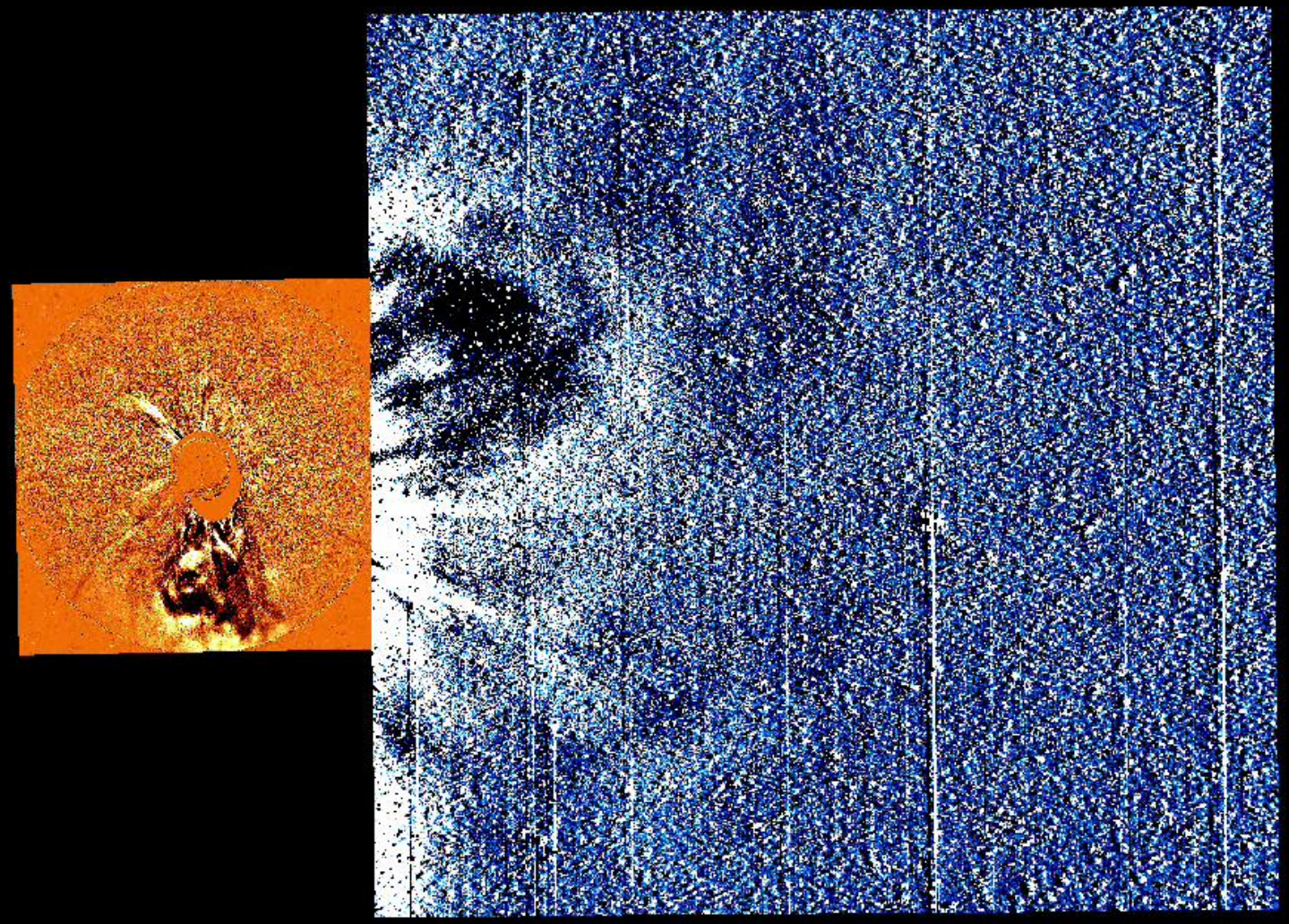
Early Propagation of the Full-halo CME

- Use **GCS model** to fit the CME observed from SOHO/LASCO-C2 and STEREO-A COR2.
- Fitting results show that the CME's apex direction is similar to the location of the EUV channel in the source region.
- **The CME propagates towards the Earth, with a high inclination angle of ~ -75°.**



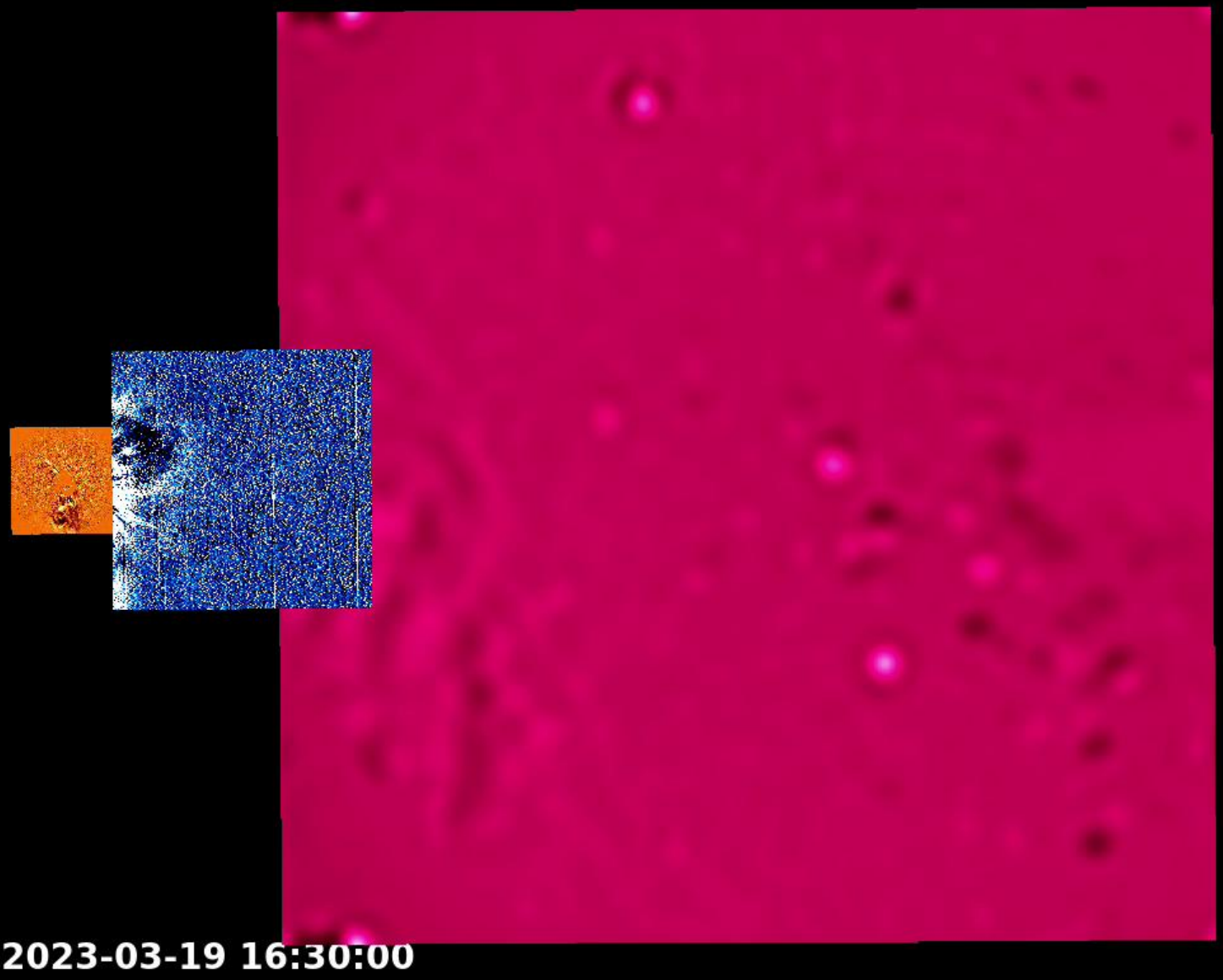
Interplanetary Propagation of Full-halo CME

STEREO-A/cor2&HI1:



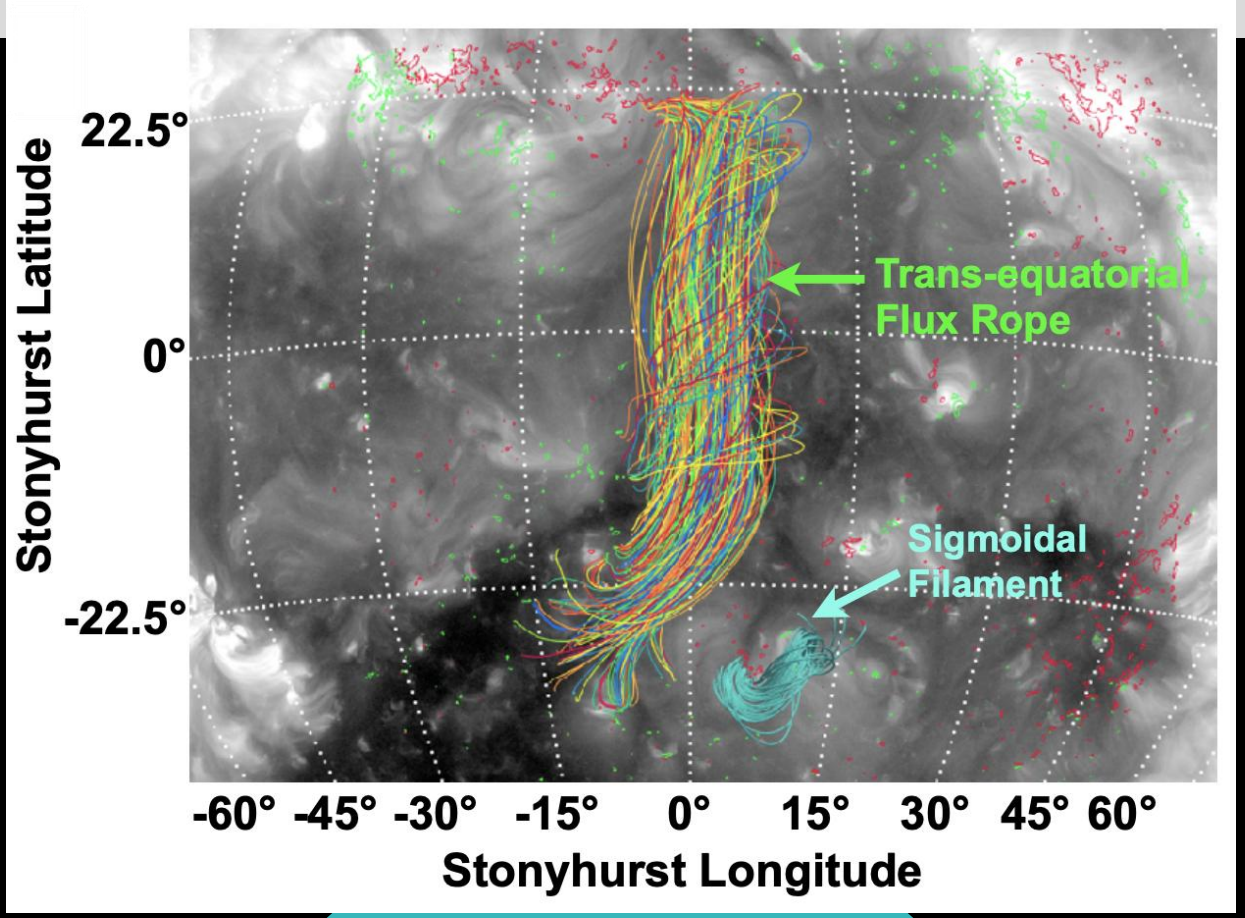
Interplanetary Propagation of Full-halo CME

STEREO-A/HI1&2:



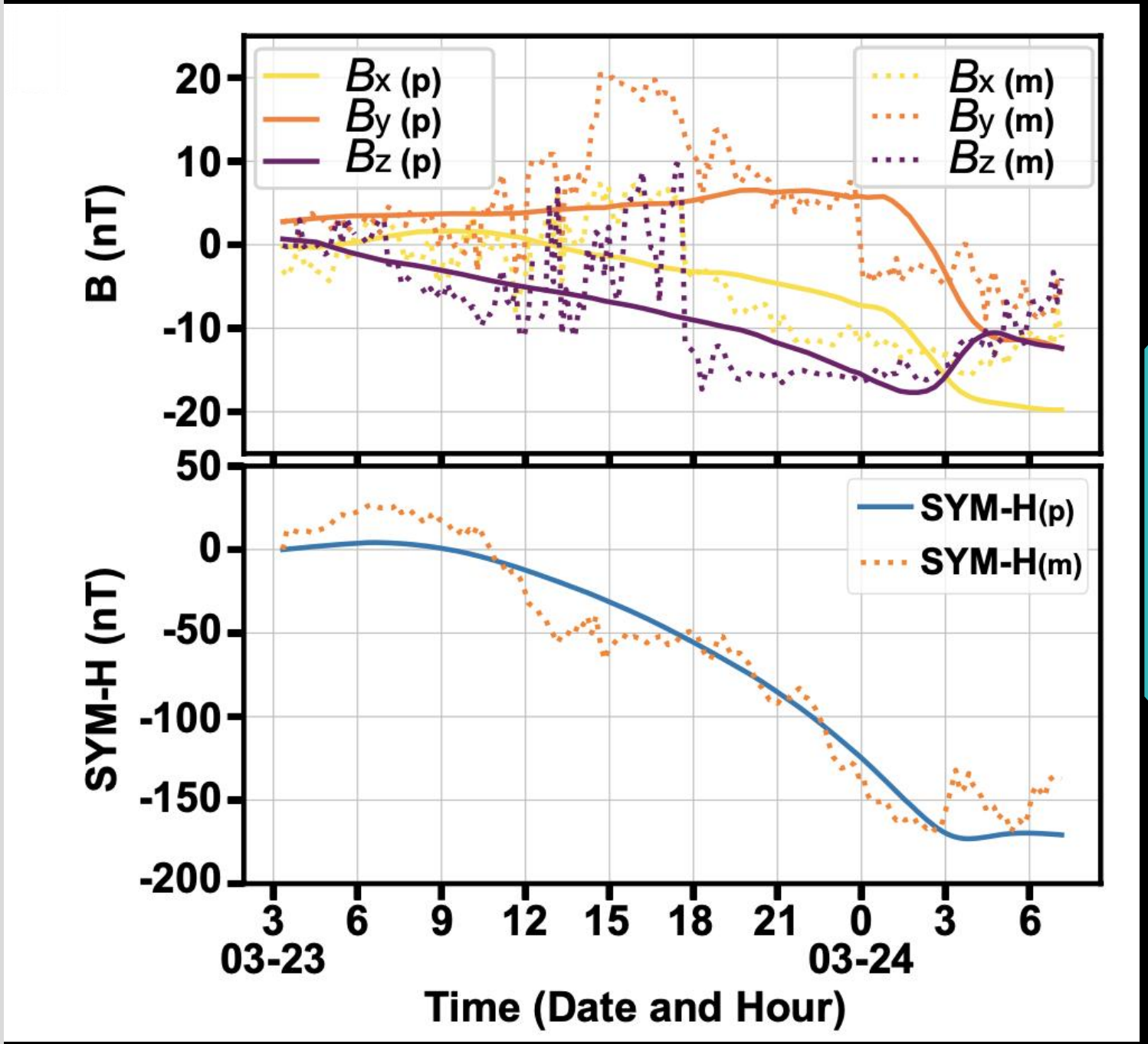
Remaining Question: The magnetic structure of the source region?

- We use the **flux rope insertion method** to reconstruct the coronal magnetic field structure of the EUV channel.
- We find that the EUV channel corresponds to a **large-scale, trans-equatorial flux rope**.



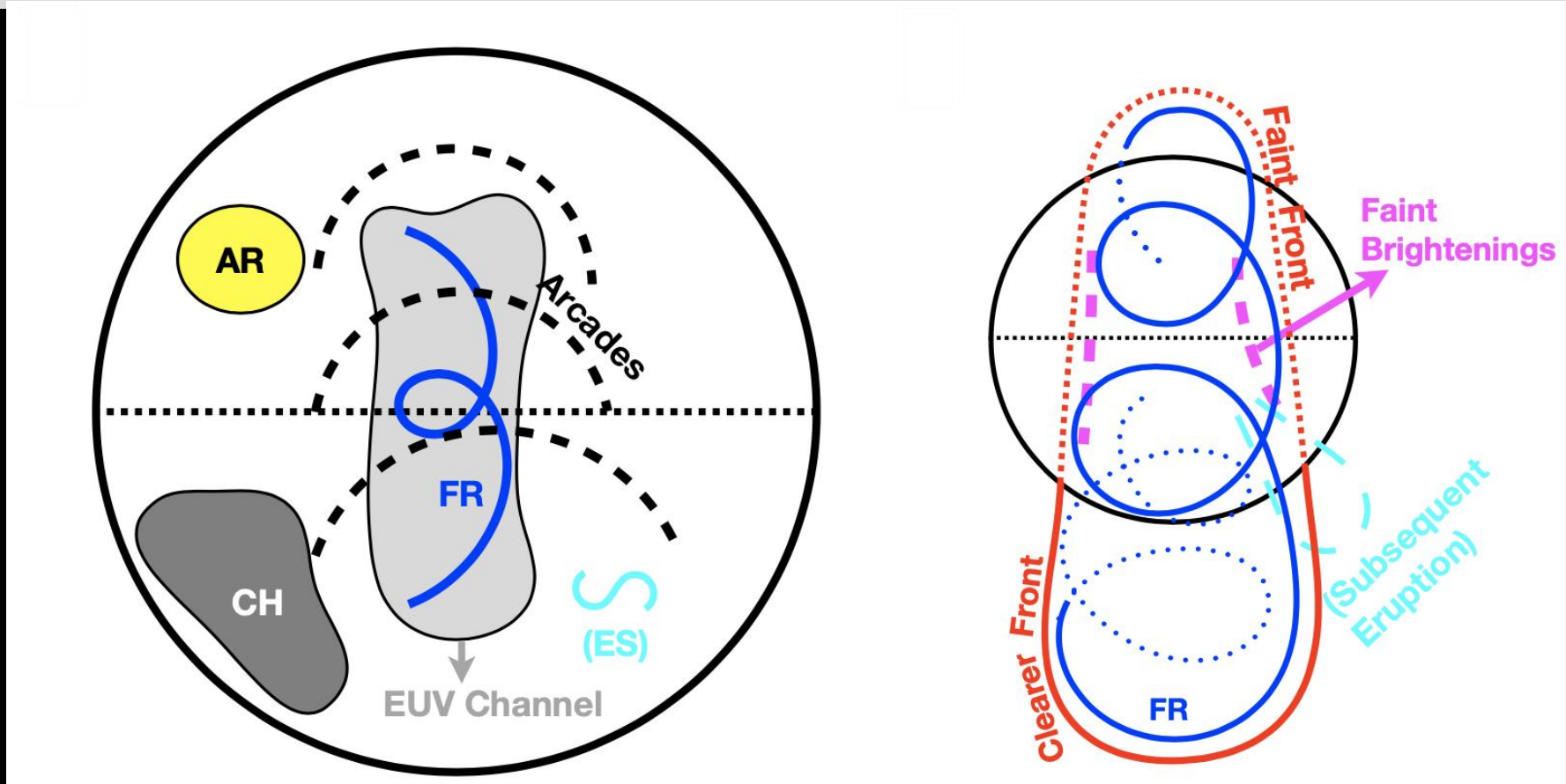
Prediction of Near-Earth IMF

- Then, we **predict the near-Earth IMF** provided by the flux rope from the model.
- According to the southward magnetic field, we **predict the SYM-H** index using the Burton's equations. The major geomagnetic storm is re-produced.
- The **axial magnetic field** of the flux rope **provides the sustained southward IMF** near-Earth, causing the geomagnetic storm.



Characteristic observational signatures of similar eruptions

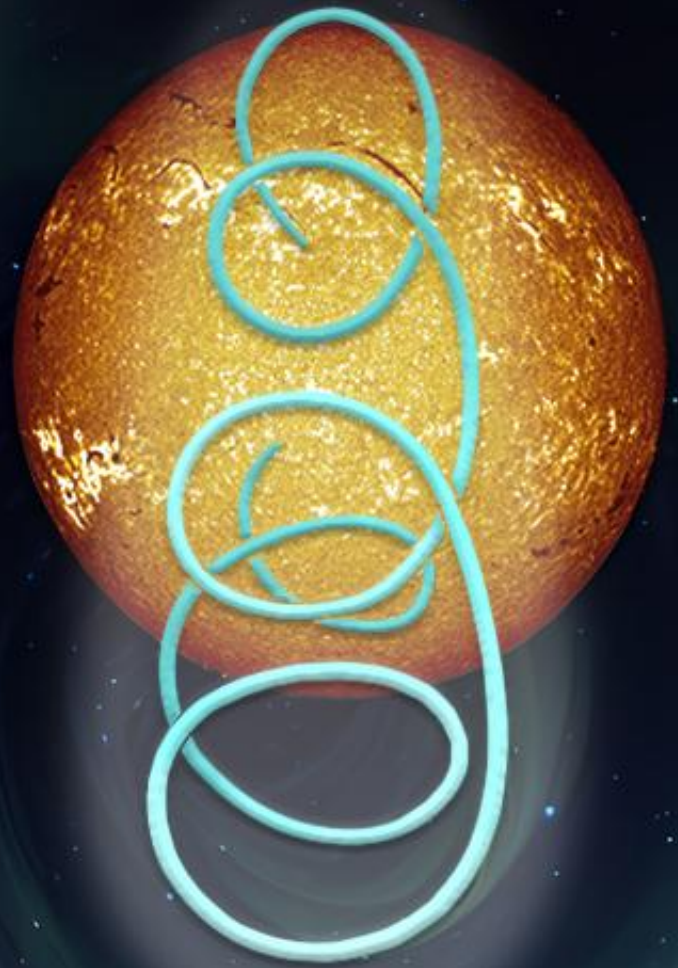
- A **trans-equatorial EUV channel** near the solar disk center. Physically a **low-density trans-equatorial flux rope**. (Before Eruption)
- **Faint trans-equatorial brightenings** on both sides of the EUV channel. (Erupting)
- A **longitudinal and lengthy CME with faint and intermittent front**. If it propagates more northwards/southwards, its nothern/southern part may be brighter due to the superposition effect, and may be identified as a narrow non-halo CME. (After Eruption)



Summary

- The eruption of a low-density **trans-equatorial flux rope** can cause a **major geomagnetic storm** in a very **stealthy** way.
- Due to the lack of filament eruption, the gentleness of the eruption, and the faintness of the CME, this event is extremely stealthy.
- The **axial field** of the erupted flux rope provides **sustained strong southward IMF near Earth**, resulting in the geomagnetic storm.
- This is the **stealthiest** CME reported causing a **G4 (severe)** storm.
- **Characteristic observational signatures of similar eruptions** are proposed to help in future forecasts.

Article



ResearchGate

Thanks