An overview of the case-study event & coronal and IP observations of the Earth-directed CME

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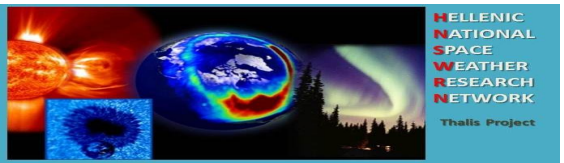


Ευρωπαϊκή Ένωση
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ
ΕΣΠΑ 2007-2013
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

7-8 March 2012: A period of intense activity in the heliosphere

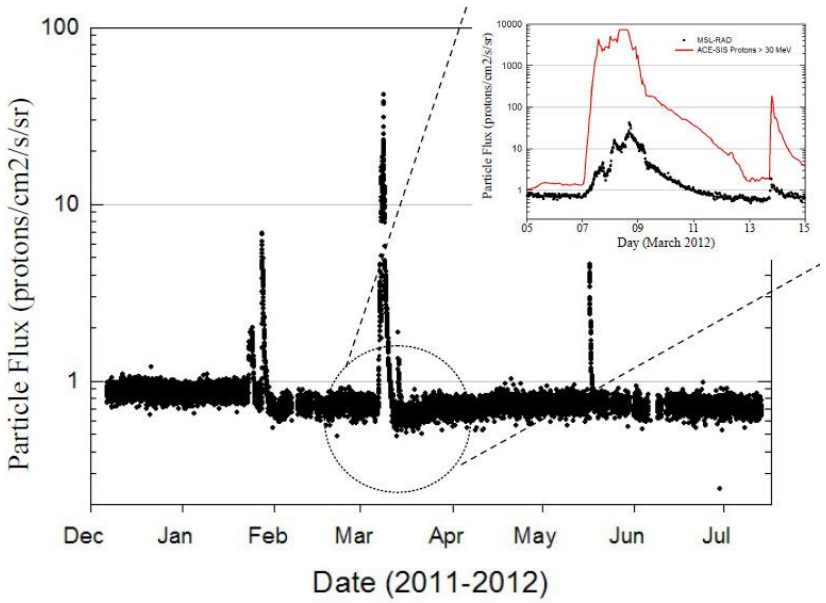
- Biggest flare of 2012 (gamma-ray flare)
- Ultra-fast CMEs (> 2000 km/s)
- Coronal and IP shock(s)

- Biggest proton event of 2012 (protons at L1 & STB)

- Biggest geomagnetic storm (min Dst ~ -147 nT) of cycle 24

Sun to Earth tracking of disturbances with SECCHI

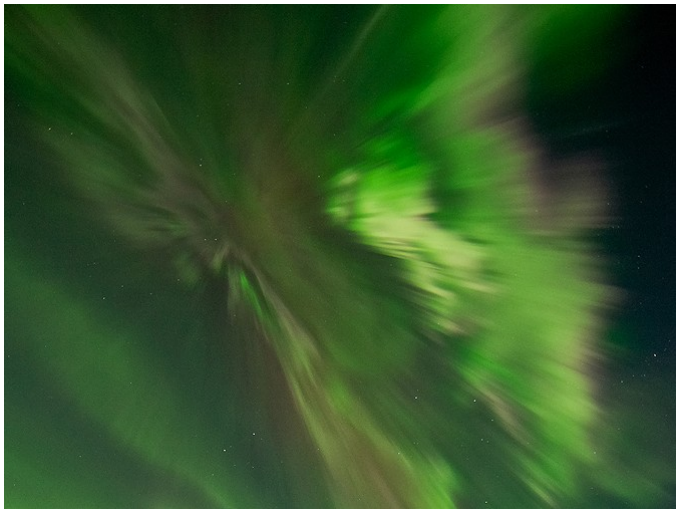
Impact of the events on various assets and bodies



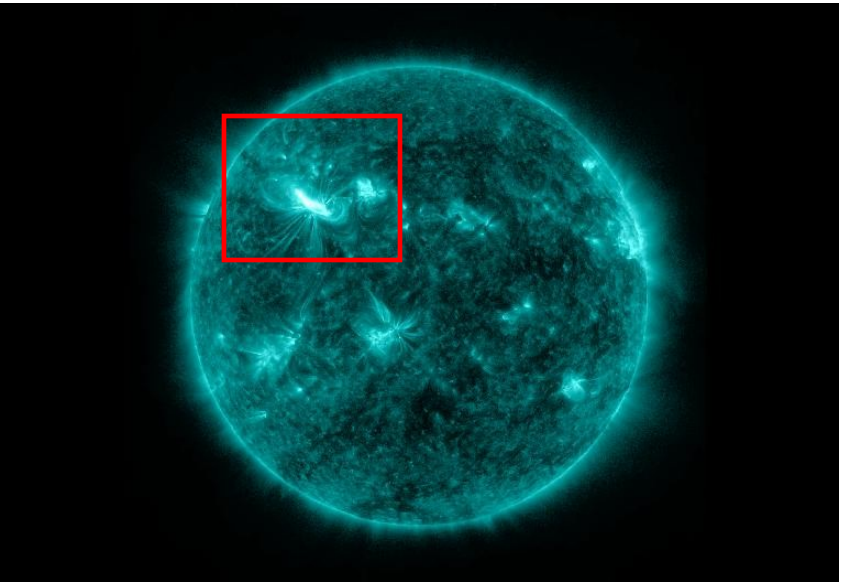
RAM measurements en-route to Mars

Curiosity rover on Mars was shut down for several hours

Aurora over Icelend

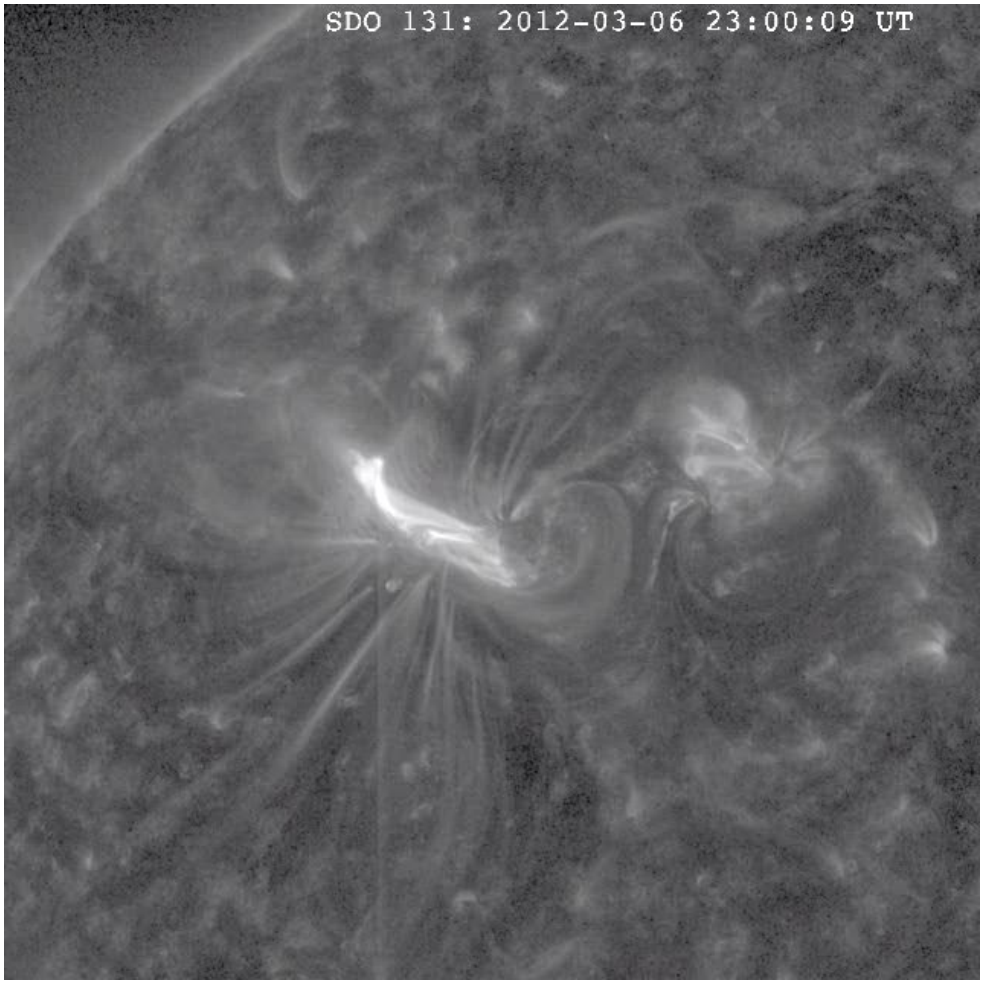


Solar sources of the disturbances



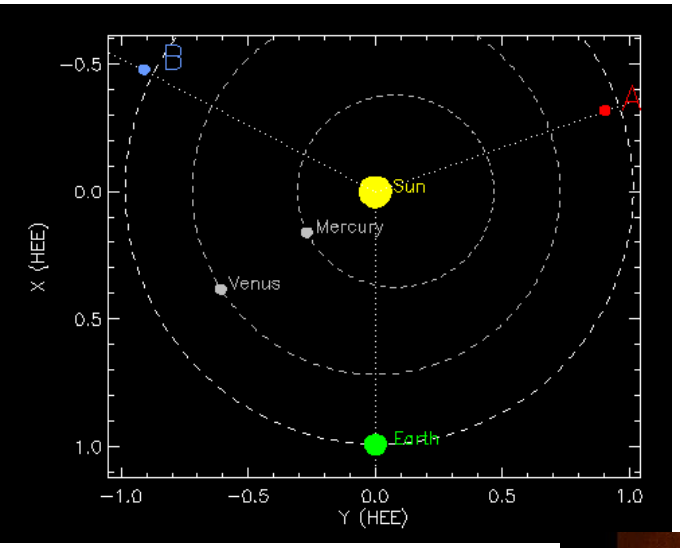
NOAA AR # 11429 (N18,E31)
CR 2121

Two eruptive X-class flares on early 7-March 2012 **within 1 hour** leading to 2 ultra-fast (>2000 km/s) CMEs (CME1 &CME2)



Event 1 NE
Event 2 SW

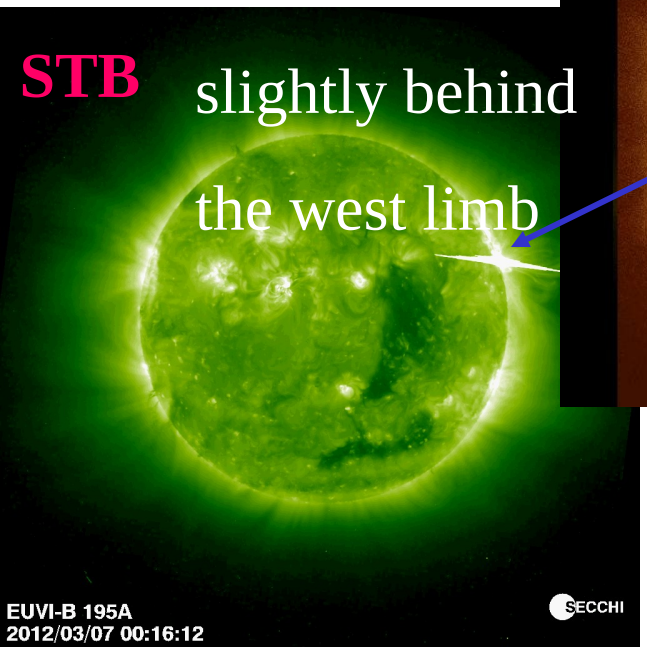
Multiple view-point observing of the event

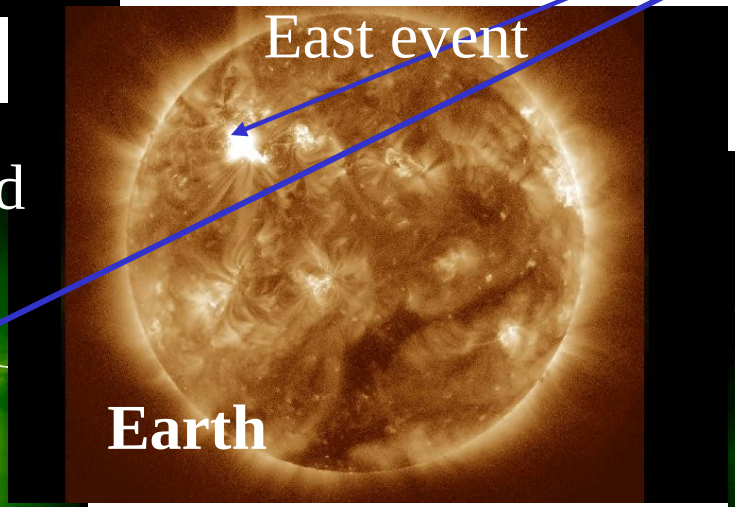


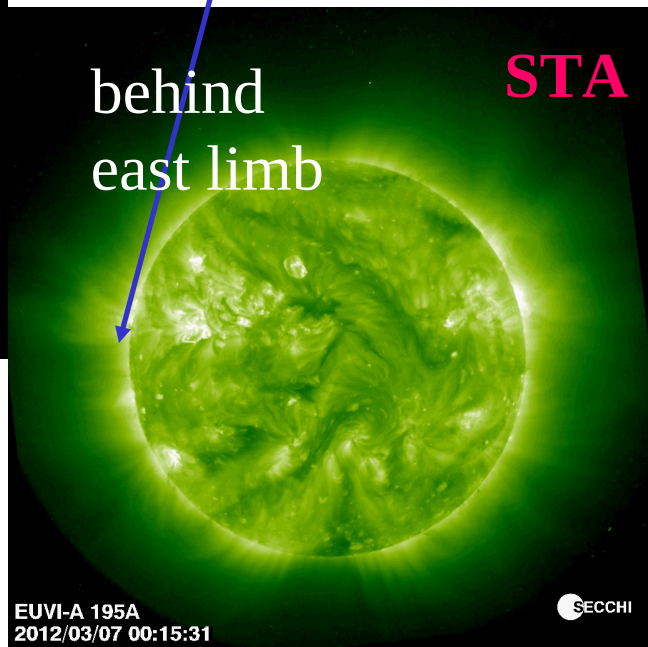
STB → 118 deg from Earth

STA → 109 deg from Earth

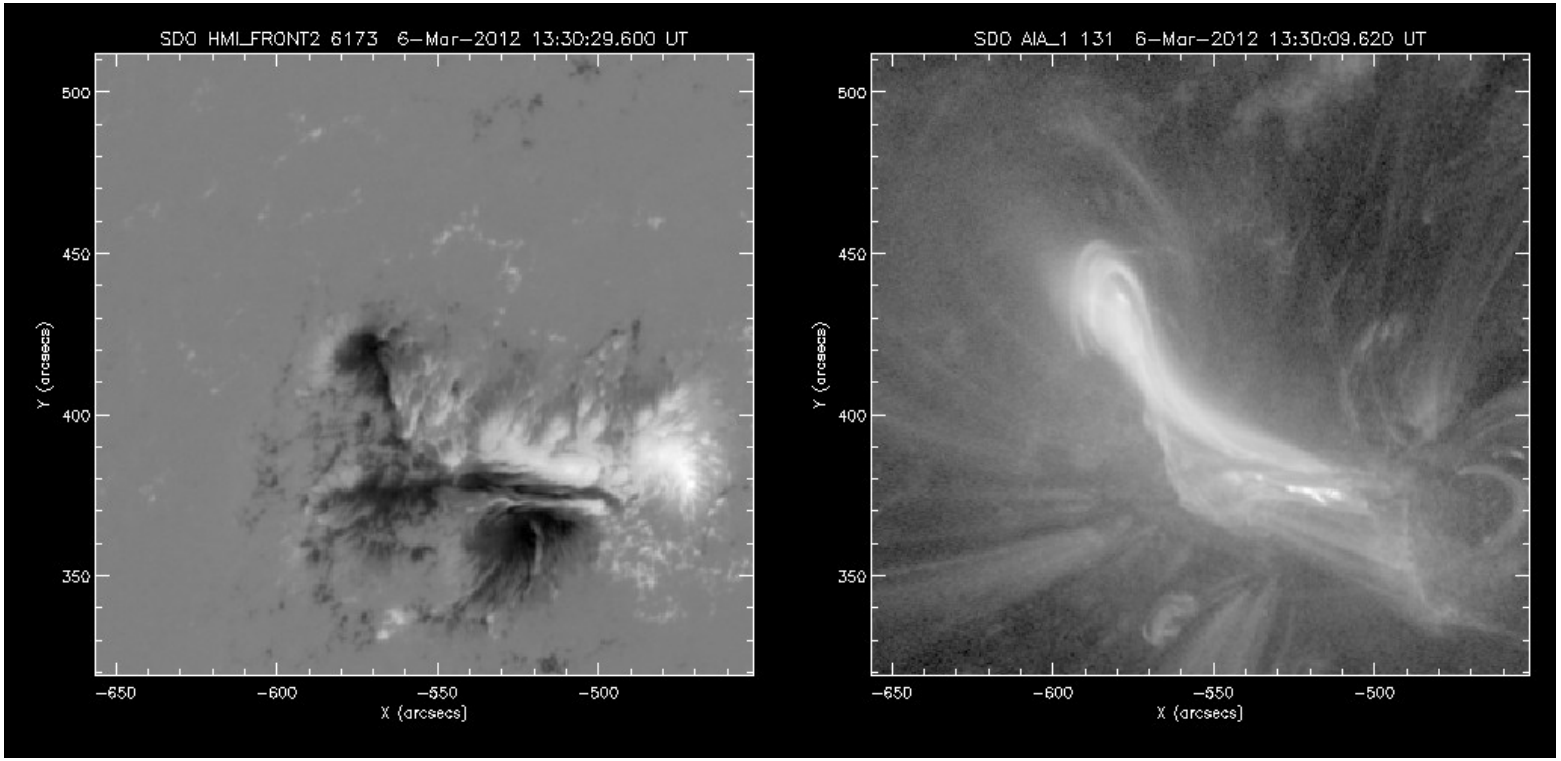
source region







Complex photospheric and coronal structures



Complex photospheric PIL

Coronal flux ropes

Major Questions

- What is the magnetic seed structure which erupted with CME1 & CME2 ? How was it formed? What triggered the eruptions? Why CME1 comes first?

- Which event(s) & how gave rise to the protons observed 120 degrees apart?

- Which CME was associated w/ the ICME and geomagnetic-storm? What made it so geo-effective?

EXTREMELY CHALLENGING set of events/conditions

SAME COMPLEX AR launches **TWO powerful events** within one hour

EASTERN hemisphere event

CME2 and any associated shock "see" perturbed and evacuated medium

Perturbed Geospace from previous activities (events of 5th)

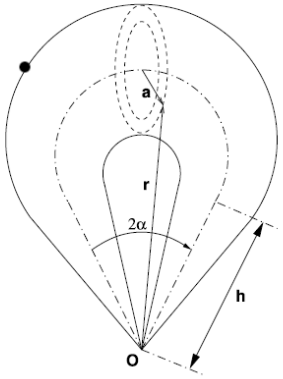
Can we tie "everything"(=Sun+IP+magnetosphere) together?

Example of coronagraphic observations of the WL CMEs and shock

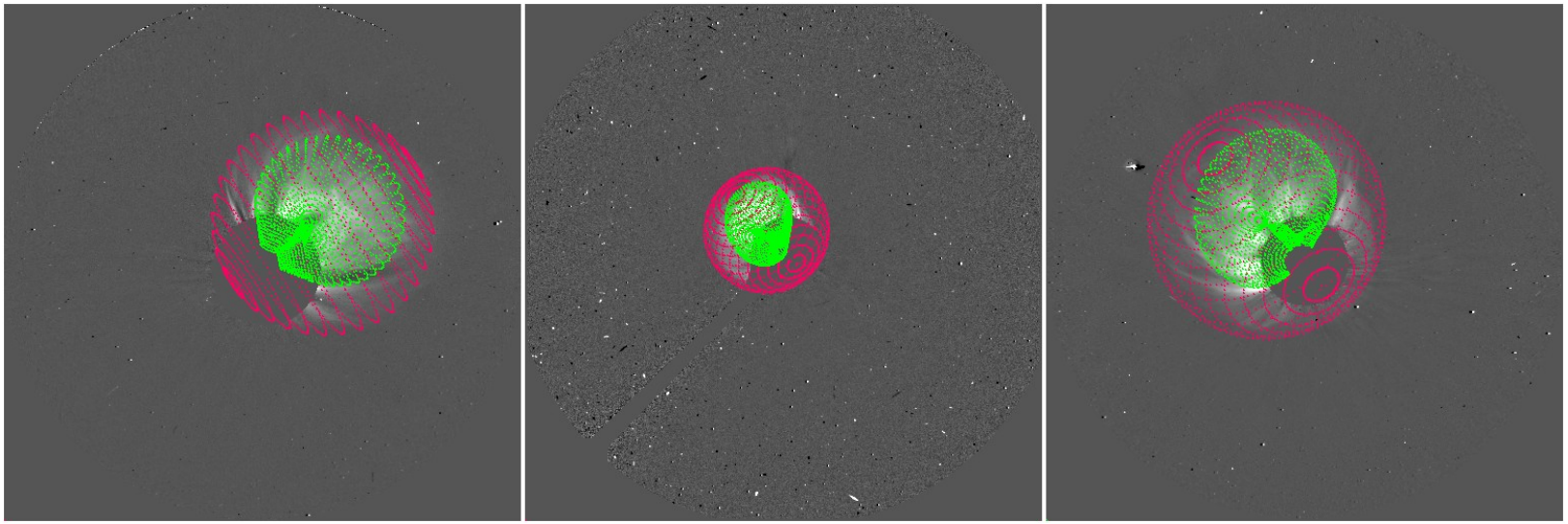
COR2A: FOV 2-15 Rs

Example of 3-ple SC WL CME fitting

CME → *Graduated Cylindrical Shell (GCS) model (= 2 conical legs + tubular section) Thernisien et al. 2006*

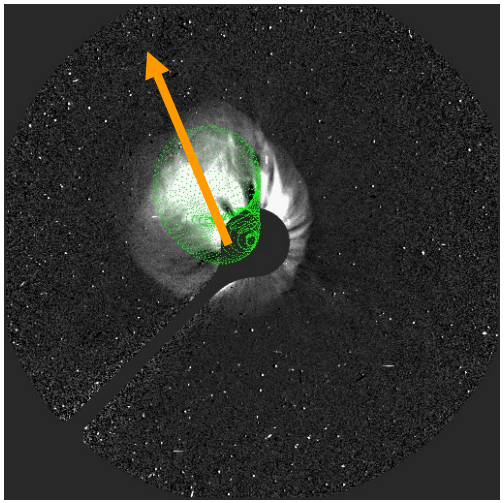


COR2B **C3** **COR2A**



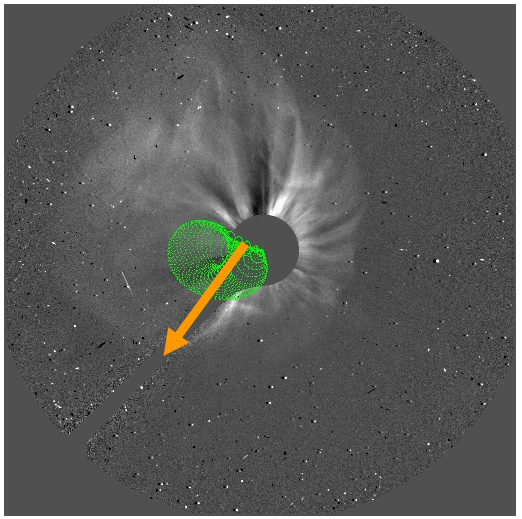
CME2 is Earth-directed

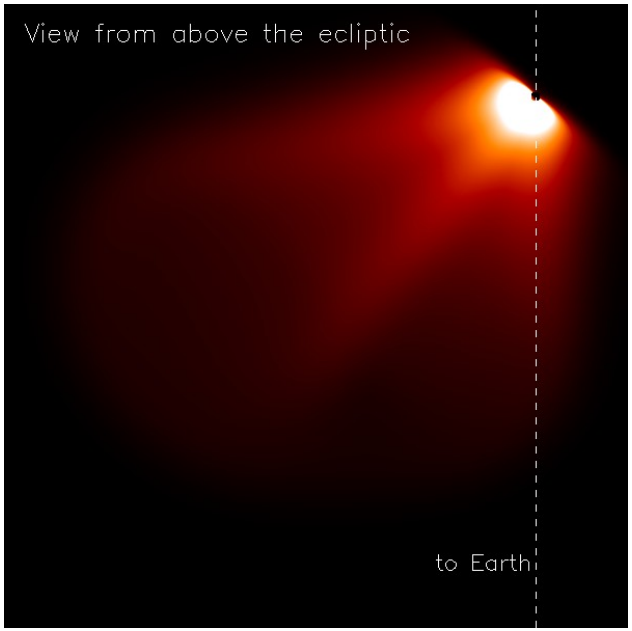
L1 views of the best-fit CMEs



CME1 → NE

CME2 → SE heading towards Earth

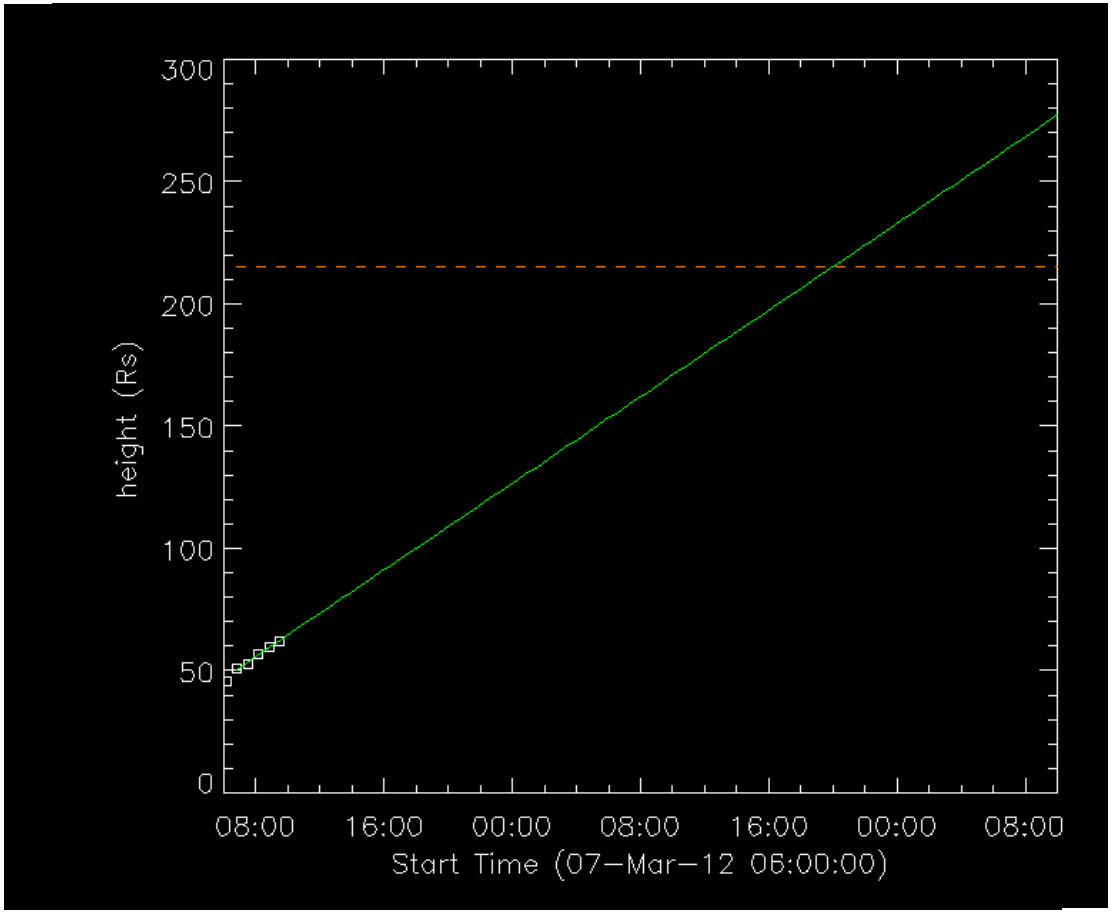




Simulated WL view of CME2 at 200 Rs from above the ecliptic

h-t of Earth-directed CME & extrapolated ICME arrival @ 1 AU

Extend to HI1 FOV: change only height of COR2-LASCO fit

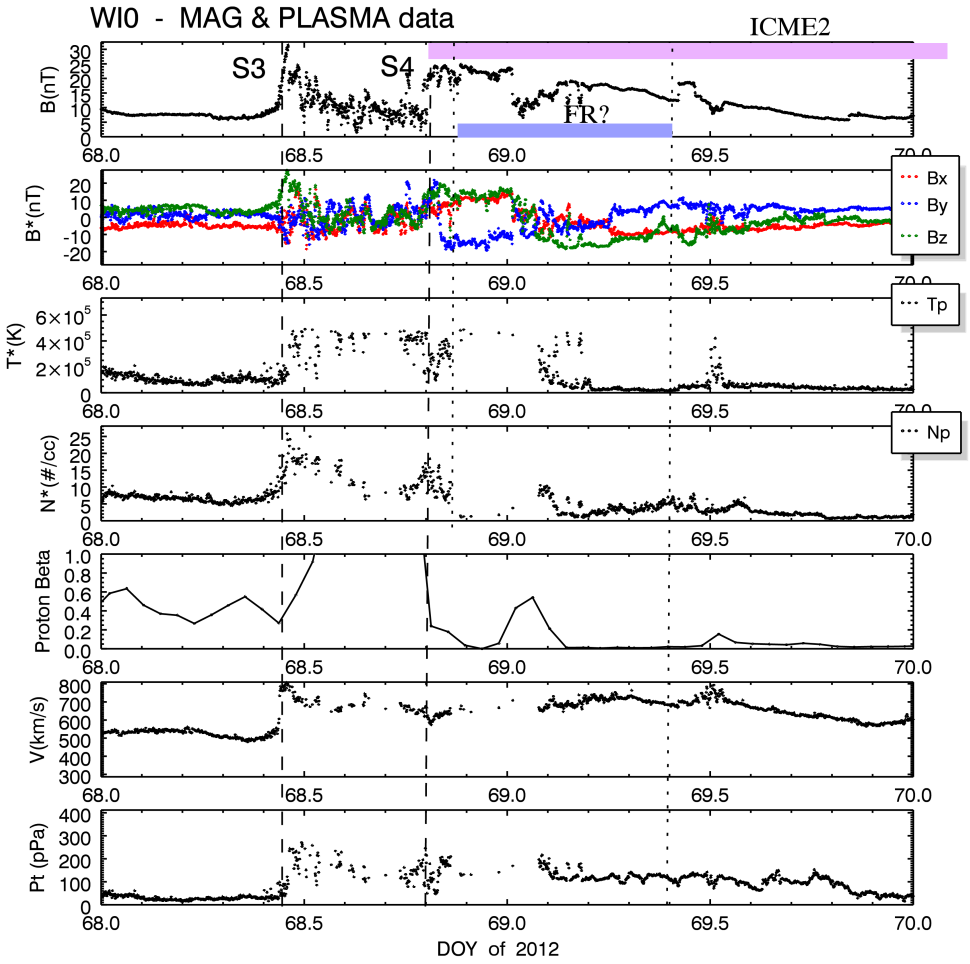


1 AU arrival time only ~ 40 minutes after the in-situ ICME detection!

data consistent with CME2 cruising at constant speed of ~ 900 km/s

From 50 Rs → 1 AU

ICME & MC @ L1

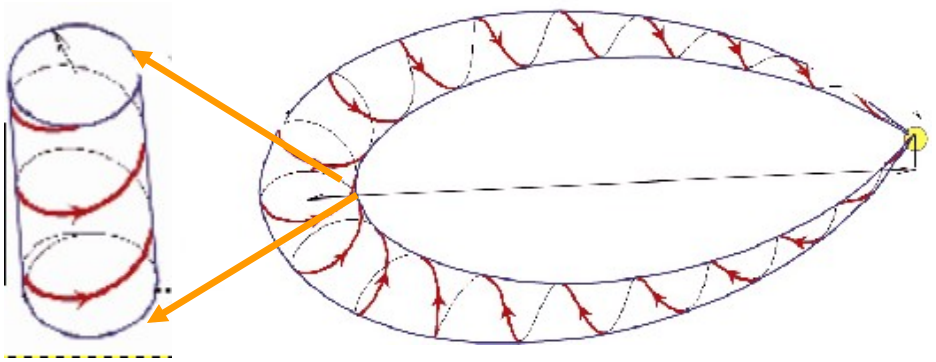


SC is within
the ICME for
longer time > B-bield
rotation interval (MC)
→ crossing flank

MC fitting results

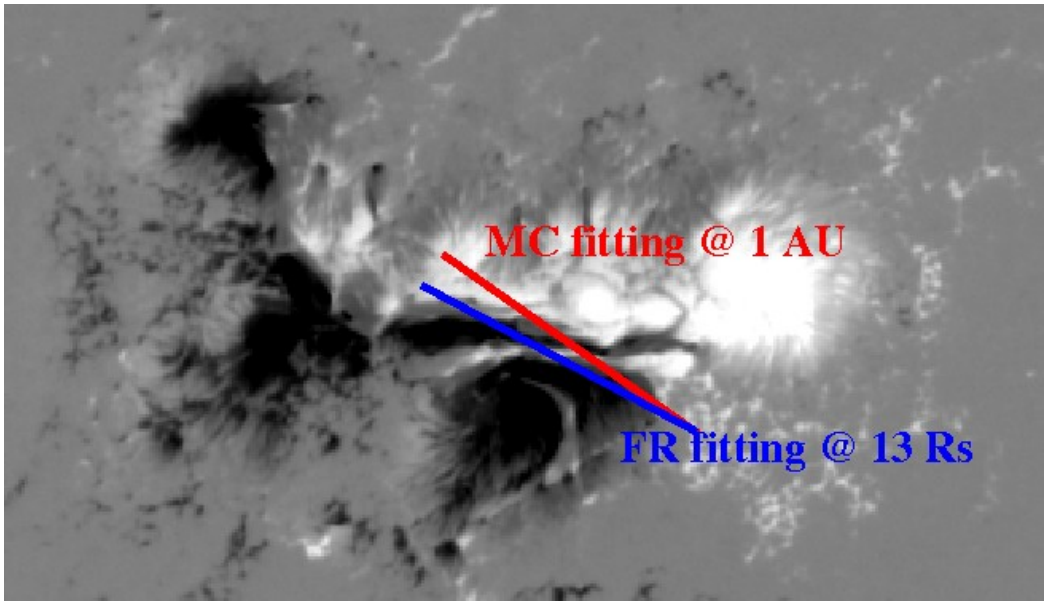
- Fit the MC b-field data w/ the Hidalgo & Nieves-Chinchilla (2012) (allowing for non-force-free & non-circular MCs)

local → global



- MC axis away from the Sun-L1 line (**flank-impact)**
- **Possitive helicity**

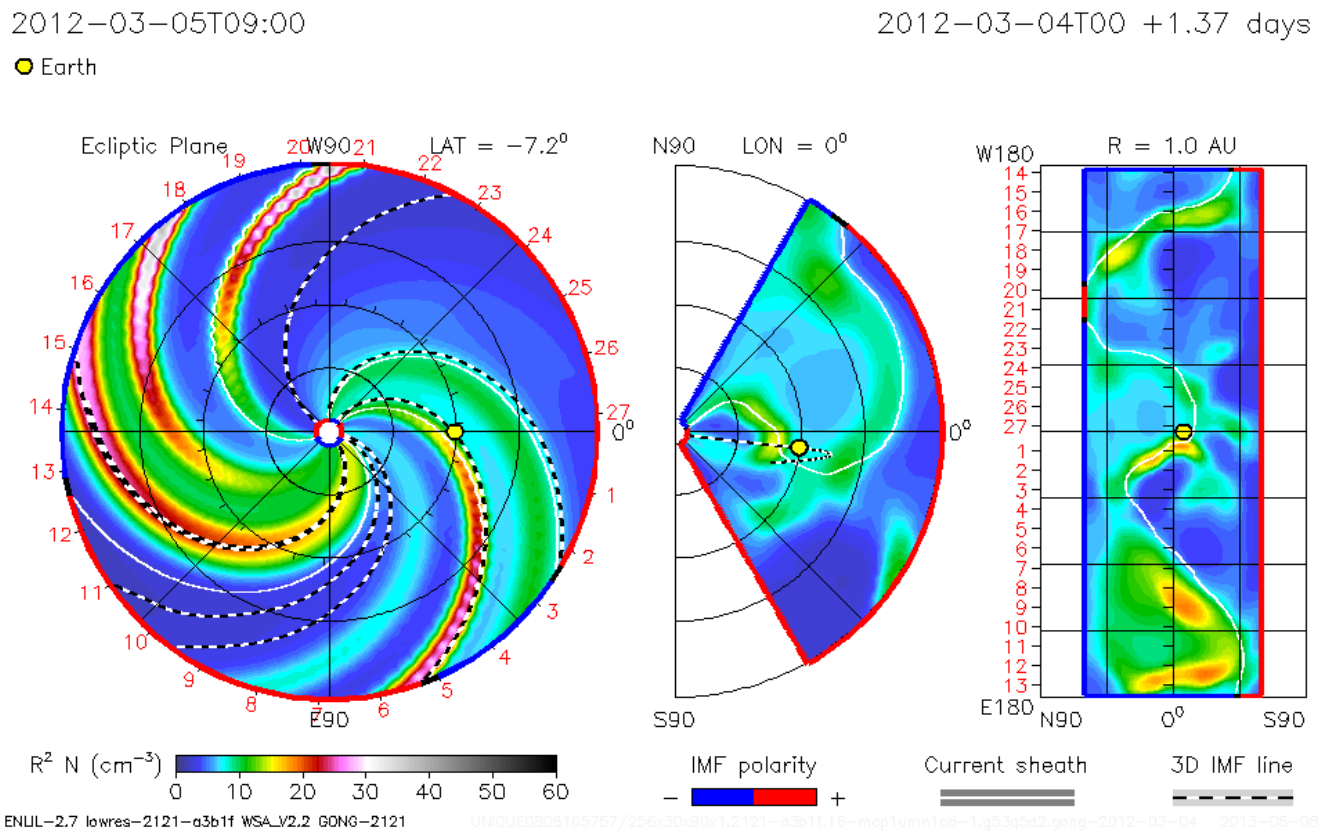
Putting WL FR & MC together



Similar tilts for FR & MC axis
& ~ EW orientation →
Φpoloidal mainly interacts w/ magnetosphere

CLOCK-WISE rotation possitive helicity

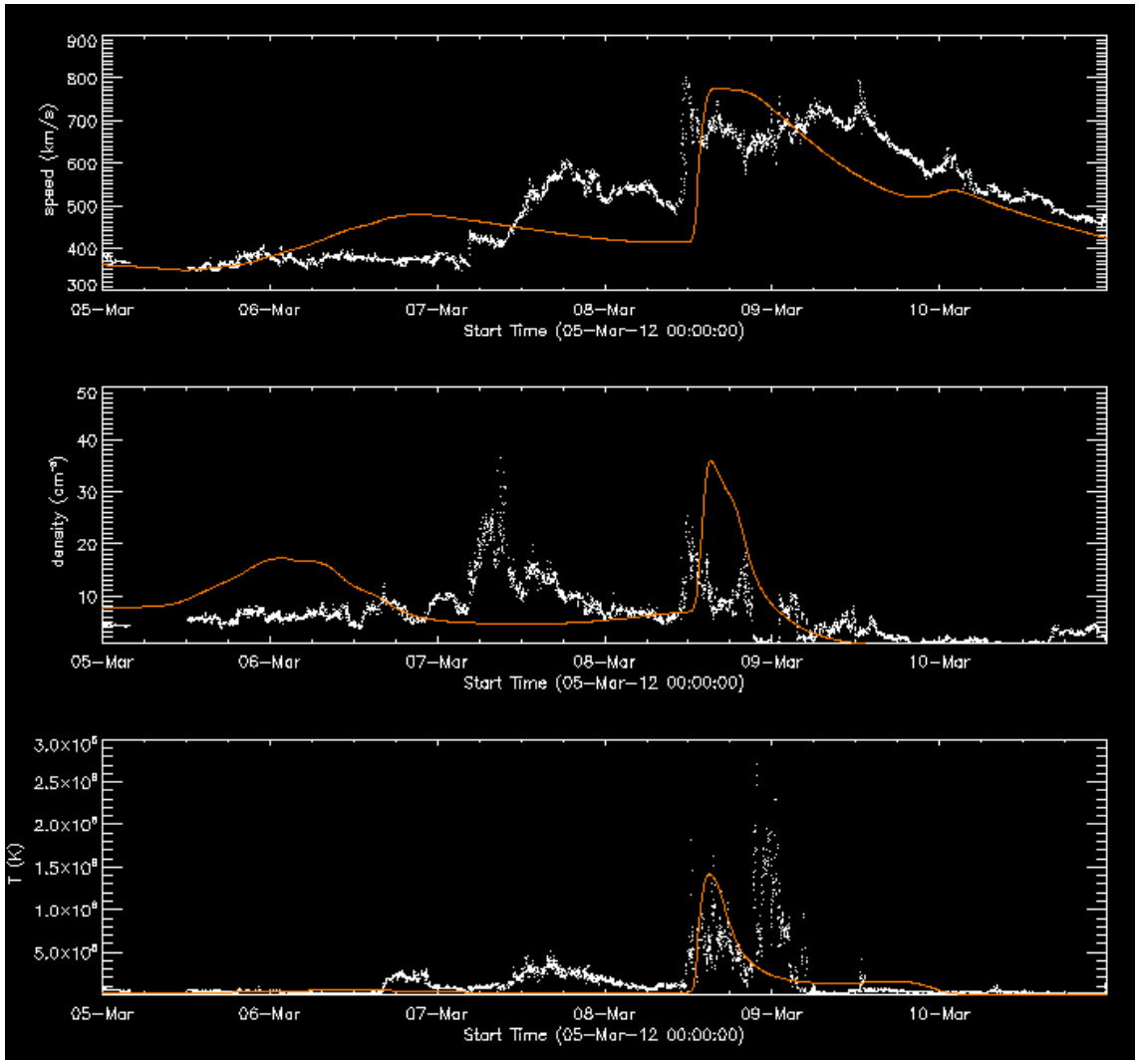
What environment does CME2 may face during IP transit ?



- launch a hydrodynamic pressure pulse at 20 Rs constrained by the shock (associated with CME1) fittings (speed, angular extend) → evolve MHD to 2 AU

courtesy NASA/CCMC

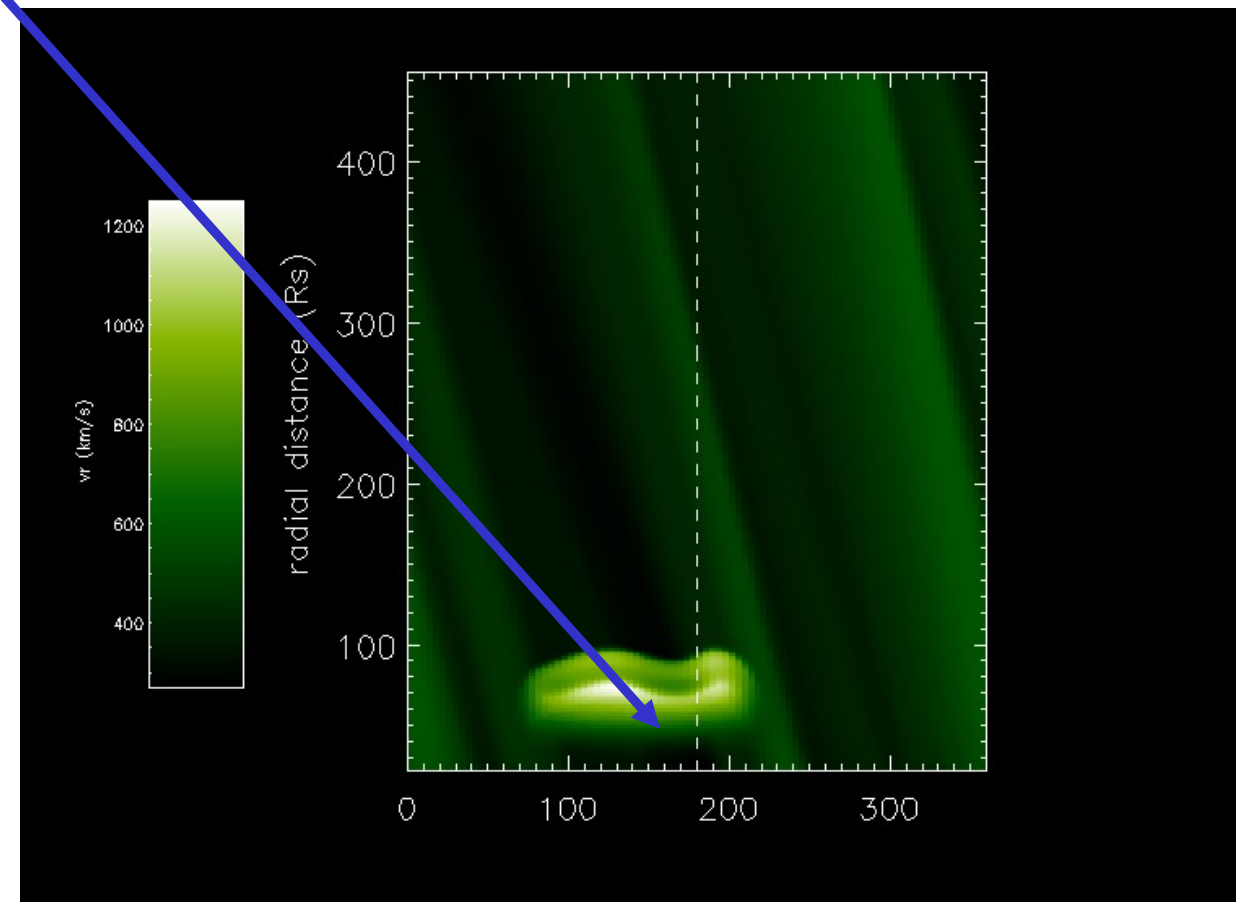
Simulated and observed shock at 1 AU



ballpark agreement between
simul & obs shock → delayed shock
onset and density offset

Upstream conditions for CME2

‘Shock’ due to CME1 ahead of CME2



CME2 “sees” high (several 100 km/s) speed solar wind → would try to adjust to this elevated speed and NOT the “canonical” sw

Conclusions

- First steps of a **synergistic effort** into understanding & combining a complex stream of solar & heliospheric data **asssociated with extreme Space Weather conditions**

- Source: **two eruptive flares** from **two different parts** (NE first & SW) of the *same AR within an hour*

- **CME2 is Earth-directed**

- **ICME flank impact at Earth:** consistent orientations of FR and MC → possitive helicity

- ICME arrival time at 1 AU consistent with cruising at constant speeed from 50 Rs to 1 AU → modulation of CME kinematics by upstream shock(s)?

Future work

- Tie **CME-ICME h-t & b-field measurements** WITH **magnetospheric response**

- e.g.: Bflux + Helicity budgets at the Sun *before eruption during eruption* ($\Phi_{poloidal}$; reconnection) and *at 1 AU* (MC fitting)

- e.g.: Extrapolate CME b-field & v at 1 AU and work out magnetospheric response

- e.g.: Determine how shocked upstream SW modulates ICME propagation