Connecting remote and in situ observations of 22 coronal mass ejections from the Sun to 1 AU

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ICMEs

ICME = shock + sheath + MC/MCL/MFR/ejecta

Zurbuchen and Richardson, SSR, 2006
Geometrical modeling

Finding the direction/speed of a moving object (ball, CME)

(a)

Elongation angle

Time

goalie, Earth
striker, Sun
defender, STEREO
Geometrical modeling

FPF: Rouillard et al. 2008 GRL

HMF: Lugaz, 2010 Solar Physics


March 7–8 2012

X5.4 flare peaks March 7
2012 00:26 (EUV wave)
March 7–8 2012

STEREO separation 227°
March 7–8 2012
SolarSoft SATPLOT Software

Angle vs. Time
2012-03-07 00:00, PA 88, D 4,

track extraction

STEREO-A HI1/2 ICME HM track fitting

CME angle to Earth = -60.9 deg
to STEREO-A = -170.4 deg
to STEREO-B = 57.0 deg
V = 2717 km/s

launch time: 7-Mar-2012 00:13
Arrival ACE: 8-Mar-2012 07:07
Arrival STB: 8-Mar-2012 05:06
Fitting Residue: 0.223

fitting with geometrical models (here HMF)
March 7–8 2012

Observer

Flare pos

Sun

Mercury

Venus

Earth

FP

HM

SSE

1595 km/s

2717 km/s

2201 km/s

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March 7–8 2012

HI predictions

Wind spacecraft at L1
CME propagation speed vs. in situ speed

$V_{\text{sheath}} = 0.19956 V_{\text{CMEi}} + 335.8578$

$V_{\text{sheath}} = V_{\text{CMEi}}$

CME propagation speed to in situ observatory $V_{\text{CMEi}}$ (km/s)

ICME sheath region speed $V_{\text{sheath}}$ (km/s)

FPF
HMF
SSEF
Linear fit to SSEF
CME propagation from HI modeling and in situ (sheath region= speeds)

average speed difference to in situ ~300 km/s

average corrected speed difference to in situ ~60 km/s
Arrival times HI – in situ

Arrival time difference between HI geometrical modeling and in situ shock arrivals

Date of CME Event in the corona

- predicted arrival is earlier than observed

+ predicted arrival is later than observed

FPF, HMF, SSEF
Conclusions

- We connected 22 CMEs from STEREO/COR2 to HI to in situ observations at 1 AU
- our dataset now contains a wide range of CME speeds (400 – 2700 km/s)
- the arrival times match to within 7.5–8.8 hours, the speeds within 270–305 km/s on average (including apex/flank effects), deceleration of CMEs is clearly visible
- none of the methods is superior over the other in predicting the speeds and arrival times (surprising, giving the strong geometrical differences – geometry is not so important? none of them is a good description of ICME fronts?)
- for the ISEST goal we can provide CME propagation speeds and directions in HI1/2, as well as mostly definitive connections from the Sun (COR2) to 1 AU (in situ) – some ambiguities remain for interacting events!
- flux rope modeling at a later stage
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Sources of geomagnetic storms

Gopalswamy et al., 2005, GRL

J. Zhang et al., 2007, JGR
STEREO Heliospheric Imagers
Direction to Earth:
FPF: -8°
SSEF: -41°
HMF: -61°

Apex speeds:
FPF: 1595 km/s
SSEF: 2201 km/s
HMF: 2717 km/s

Pred. L1 speeds:
FPF: 1595 km/s
SSEF: 1264 km/s
HMF: 1320 km/s

Strong differences in direction and speed arise - the CME is fast and behind the limb - confirms theoretical expectations by Lugaz and Kintner, 2012
speed comparison HI – in situ

Difference between CME interplanetary propagation speed and ICME sheath region speed

+ HI speed is higher than in situ speed
- HI speed is lower than in situ speed
shock arrival:
March 8 2012 10:24 (Wind at L1)

Arrival times:
differences are
- 9 hours (FPF)
- 2 hours (SSEF with 45° width)
- 3 hours (HMF)
earlier than actually arrived at L1

Speeds in sheath region
(= high density visible in HI Jmap)
682 +/-30 km/s,
the predicted speeds are too high,
+600 to +900 km/s!
July 12-14 2012 coronal mass ejection
July 12–14 2012

Wind (L1) SWE / MFI 2012 July 12-14 coronal mass ejection

- Magnetic field components (B)
  - B_x
  - B_y
  - B_z

- Velocity (V_p)
- Density (N_p)
- Temperature (T_p)
- Total pressure (P_tot)

- Coronal mass ejection signature
  - Sheath
  - Magnetic cloud

- Dates:
  - 2012 Jul 13
  - 2012 Jul 14
  - 2012 Jul 15
  - 2012 Jul 16
  - 2012 Jul 17
  - 2012 Jul 18

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Transit time

CME interplanetary propagation speed versus transit time

\[ y = 9527.4x^{-0.764} \]

\[ R^2 = 0.83575 \]