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

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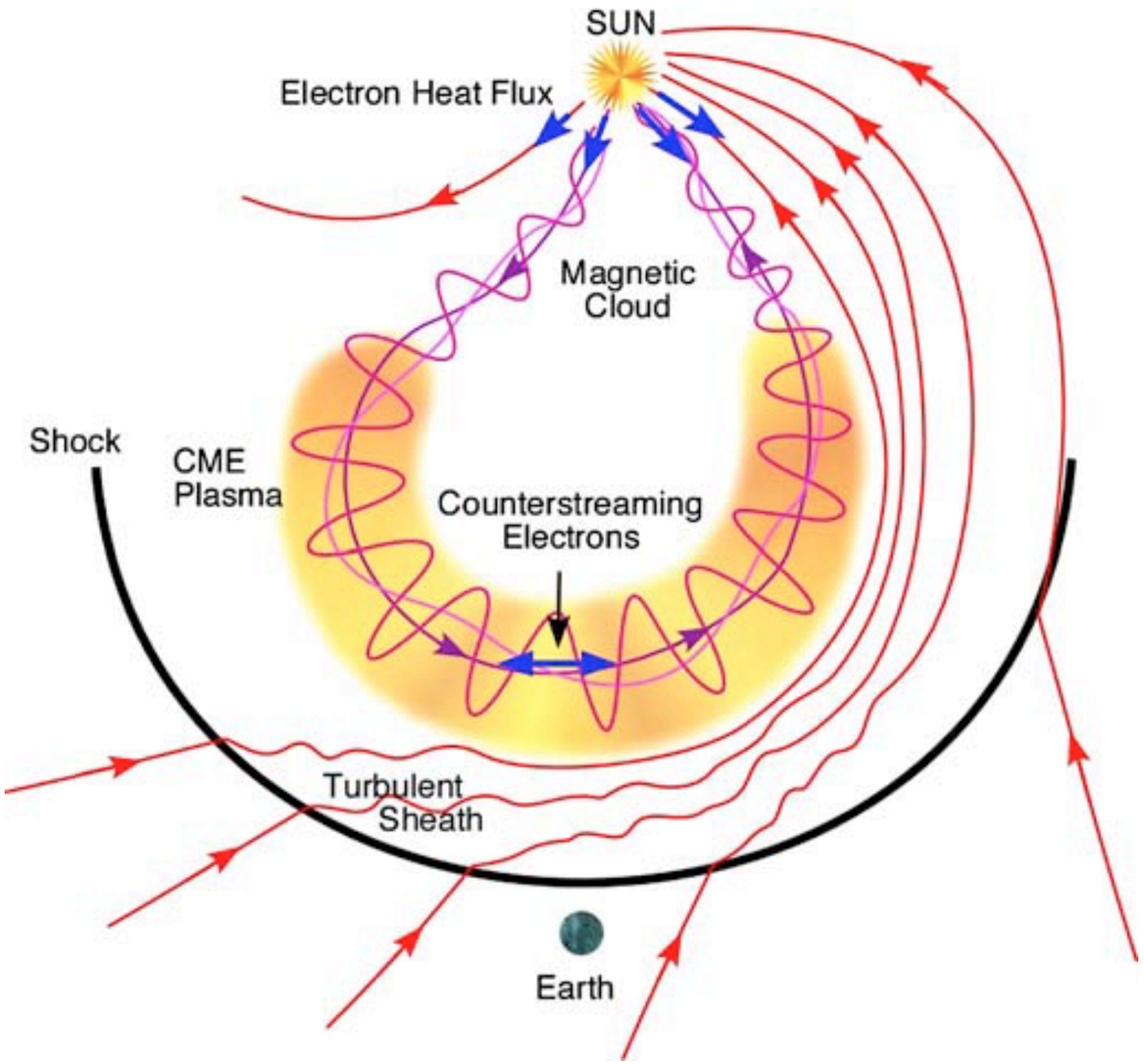
ICMEs



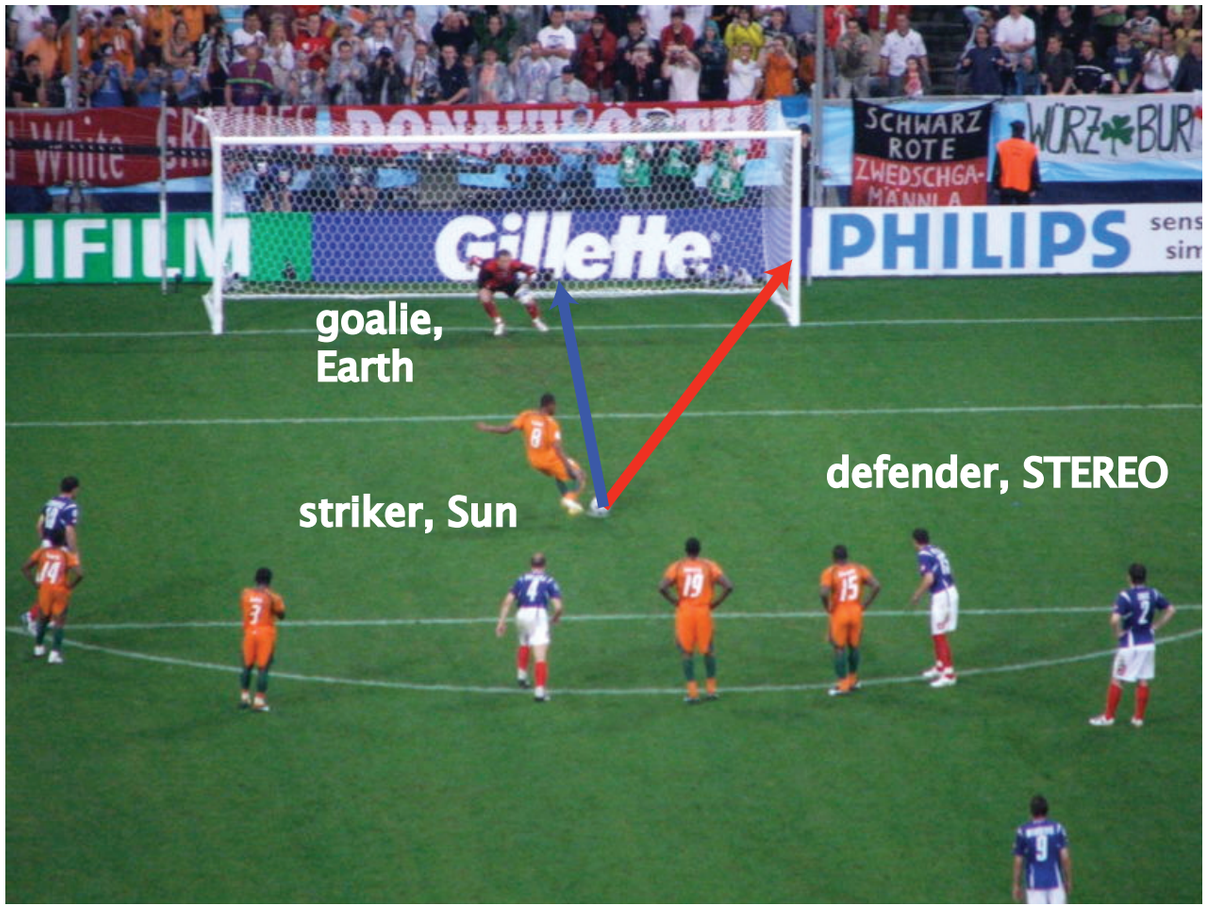
Zurbuchen and
Richardson, SSR, 2006

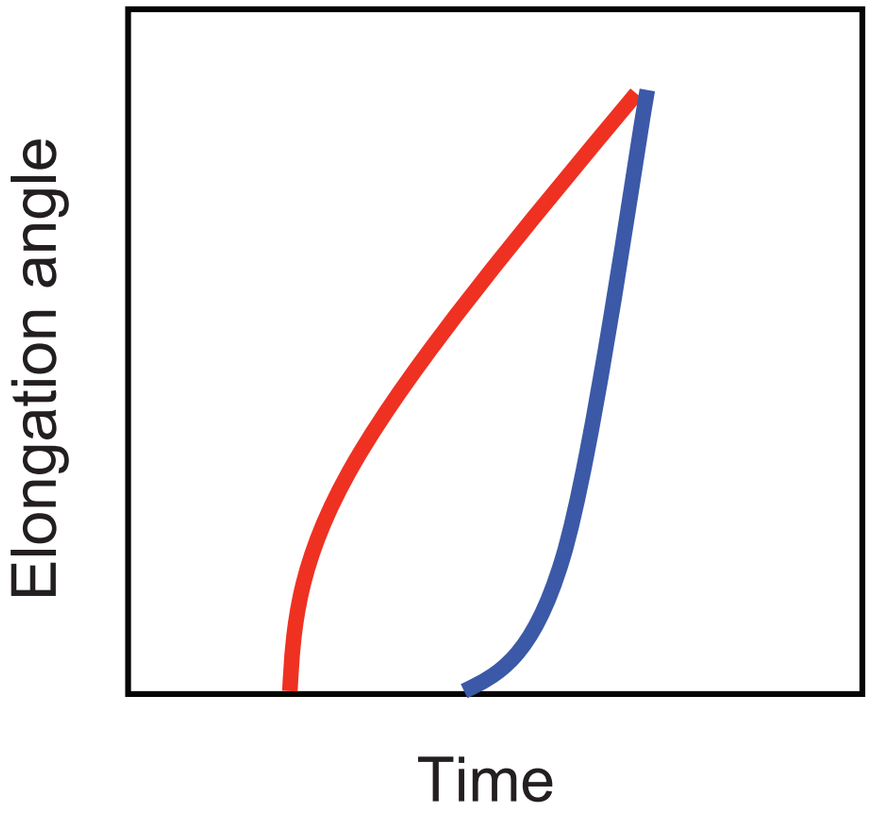
ICME= shock + sheath + MC/MCL/MFR/ejecta

Geometrical modeling

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

(a)



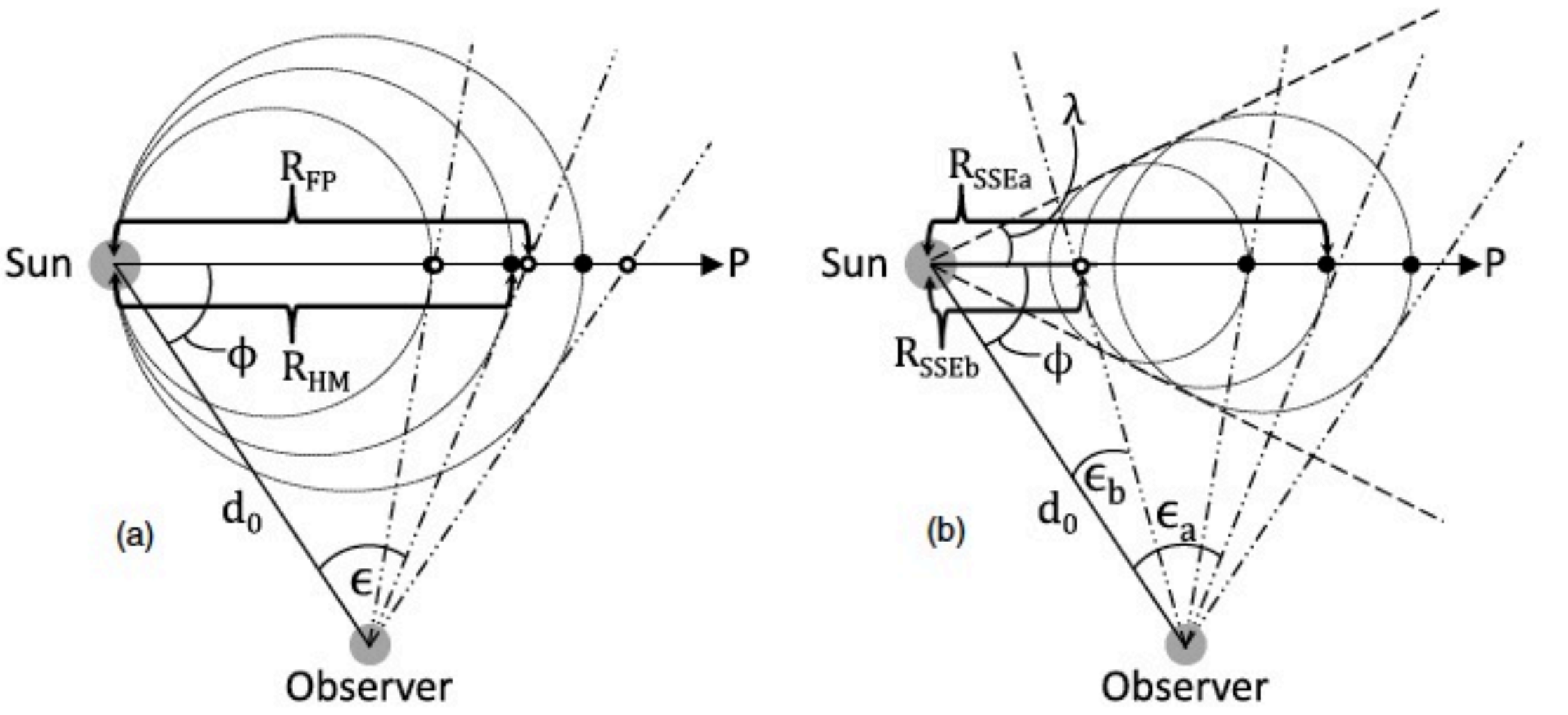


Geometrical modeling

Fixed-Phi Fitting

Harmonic Mean Fitting

Self-similar expansion fitting



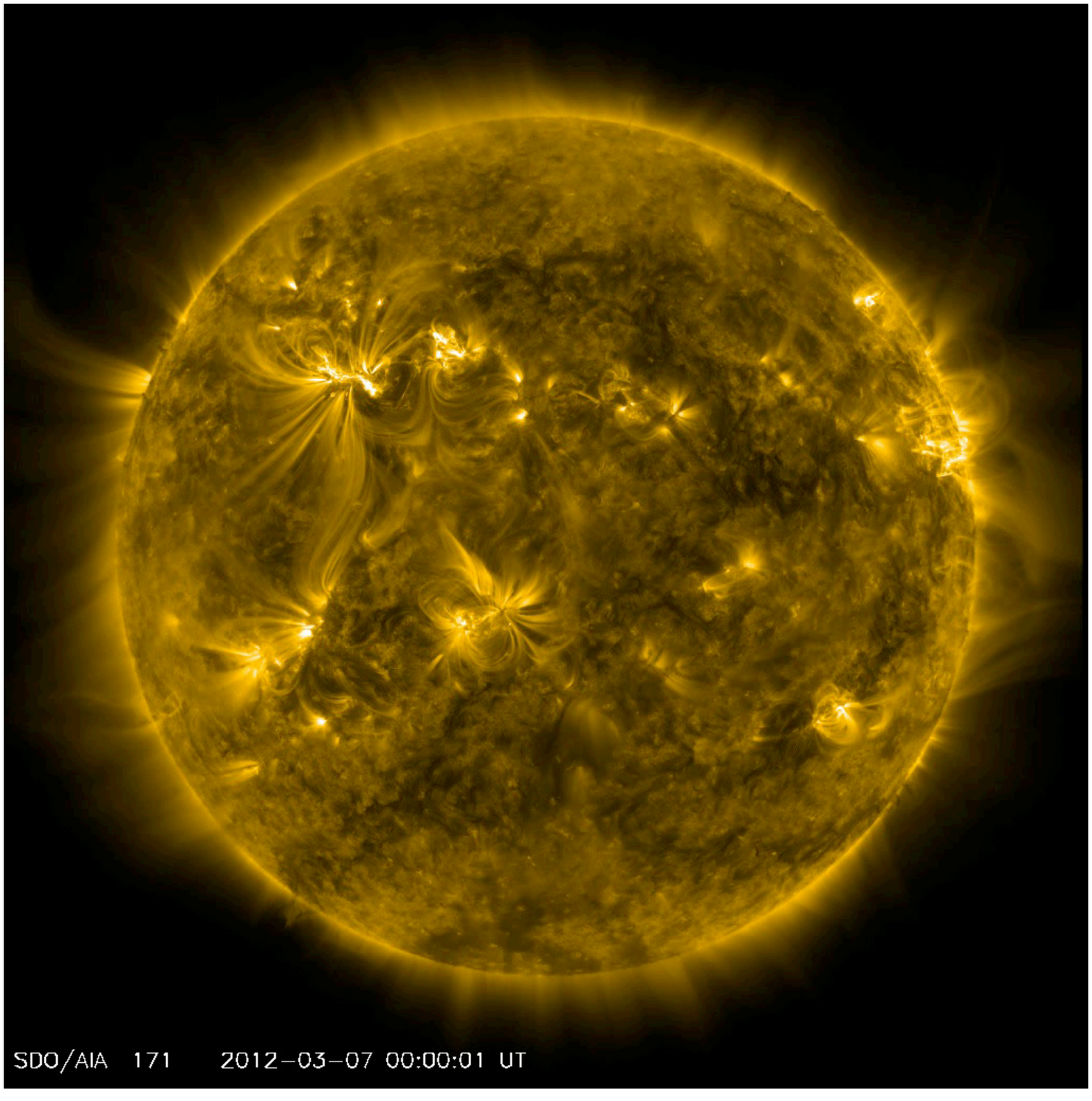
FPF: Rouillard et al. 2008 GRL

HMF: Lugaz, 2010 Solar Physics

SSEF: Davies et al., 2012 ApJ, Möstl and Davies, 2013 Solar Physics

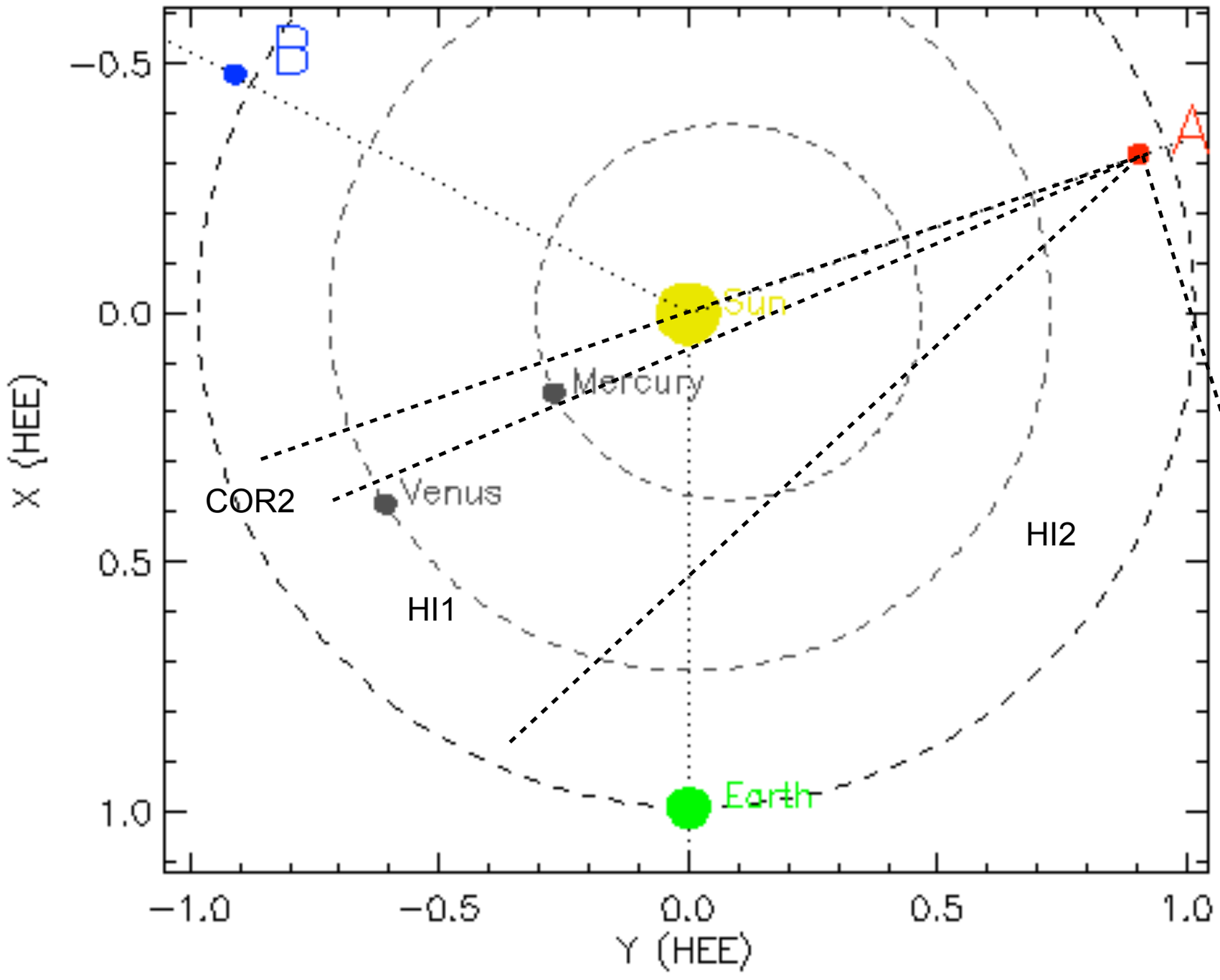
triangulation versions (two HIs): Ying Liu et al., ApJ(L) 2010-2013, Davies et al. 2013 submitted

March 7-8 2012



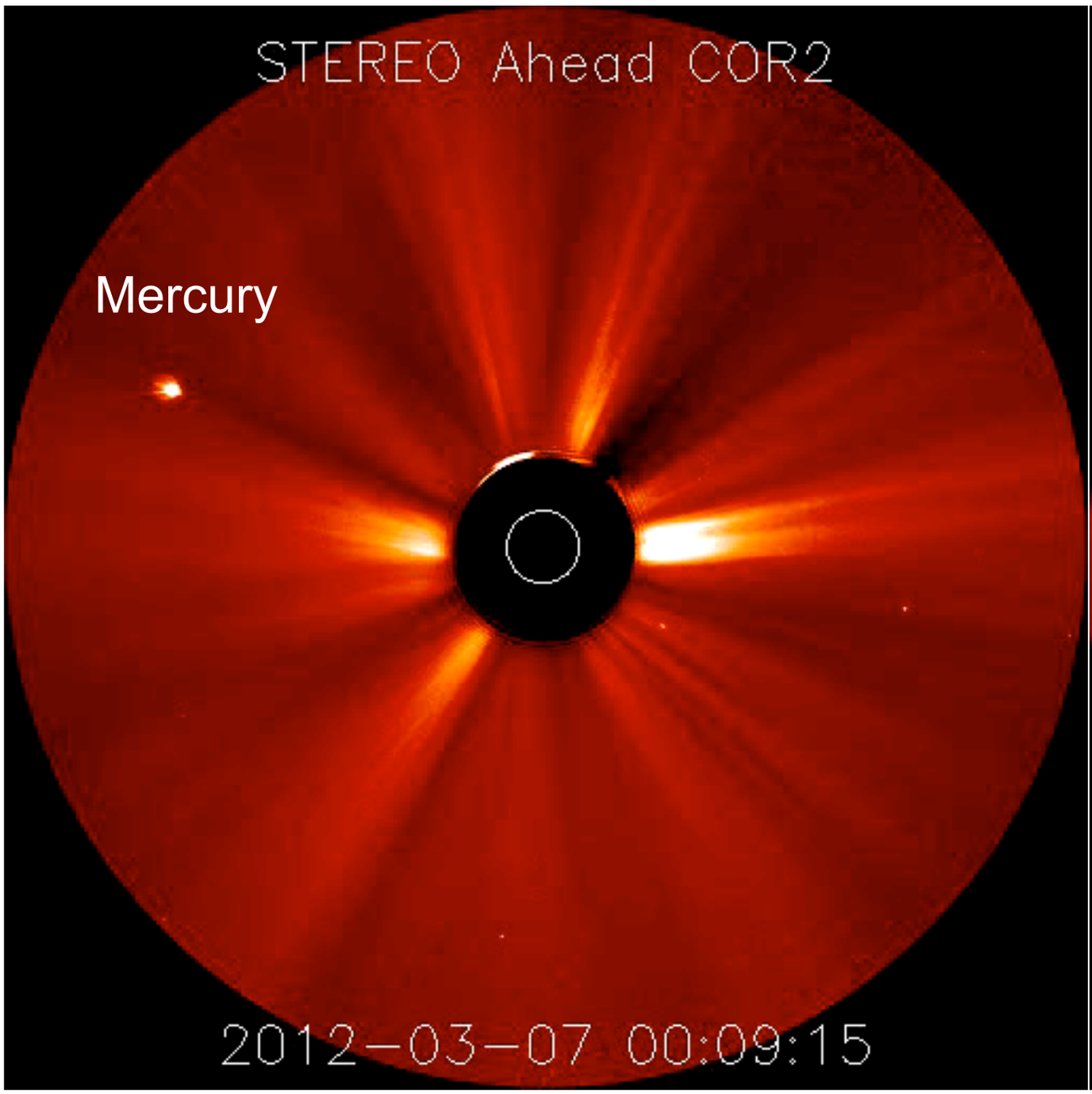
X5.4 flare peaks March 7
2012 00:26 (EUV wave)

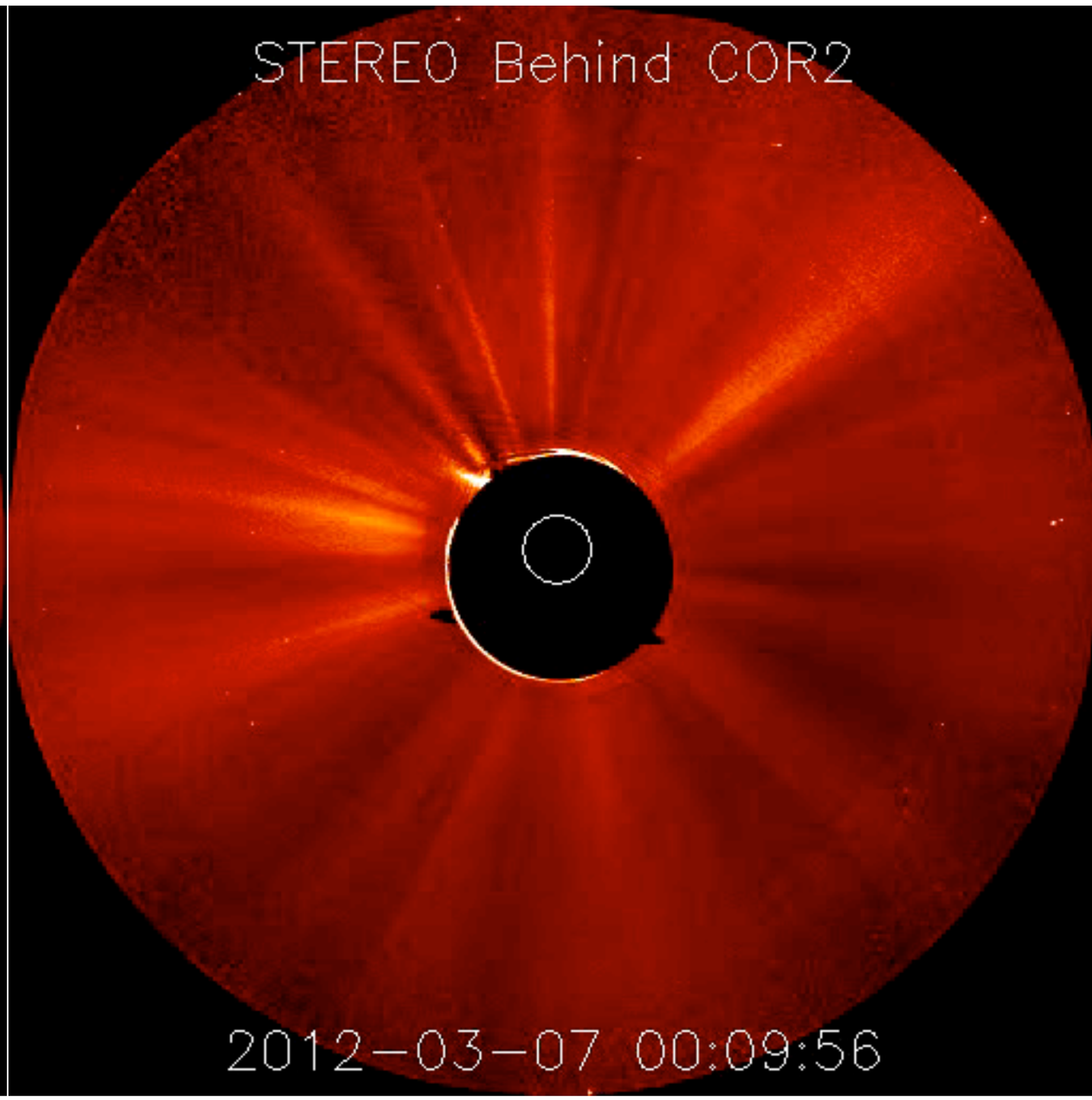
March 7-8 2012



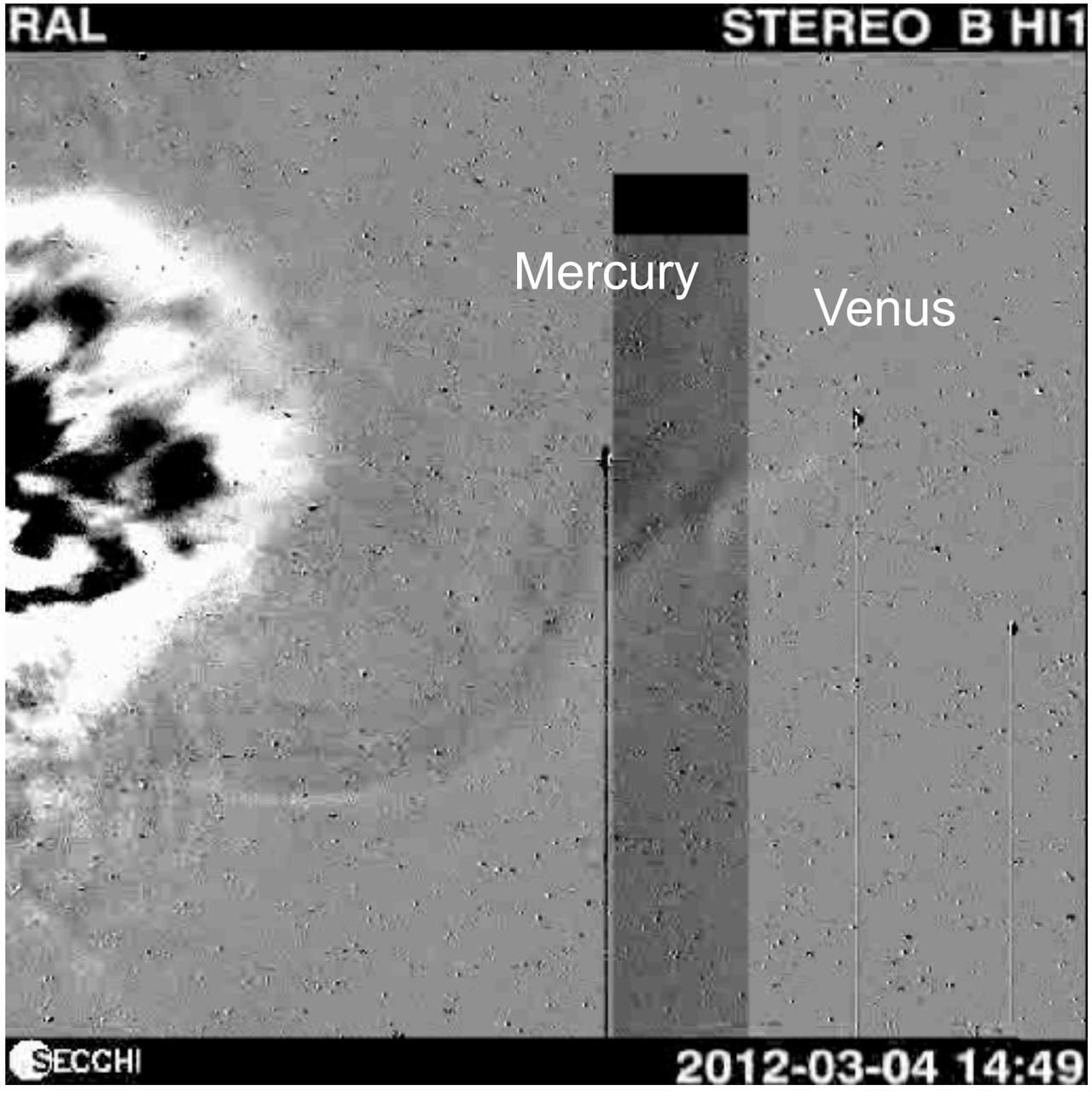
STEREO separation 227°

March 7-8 2012

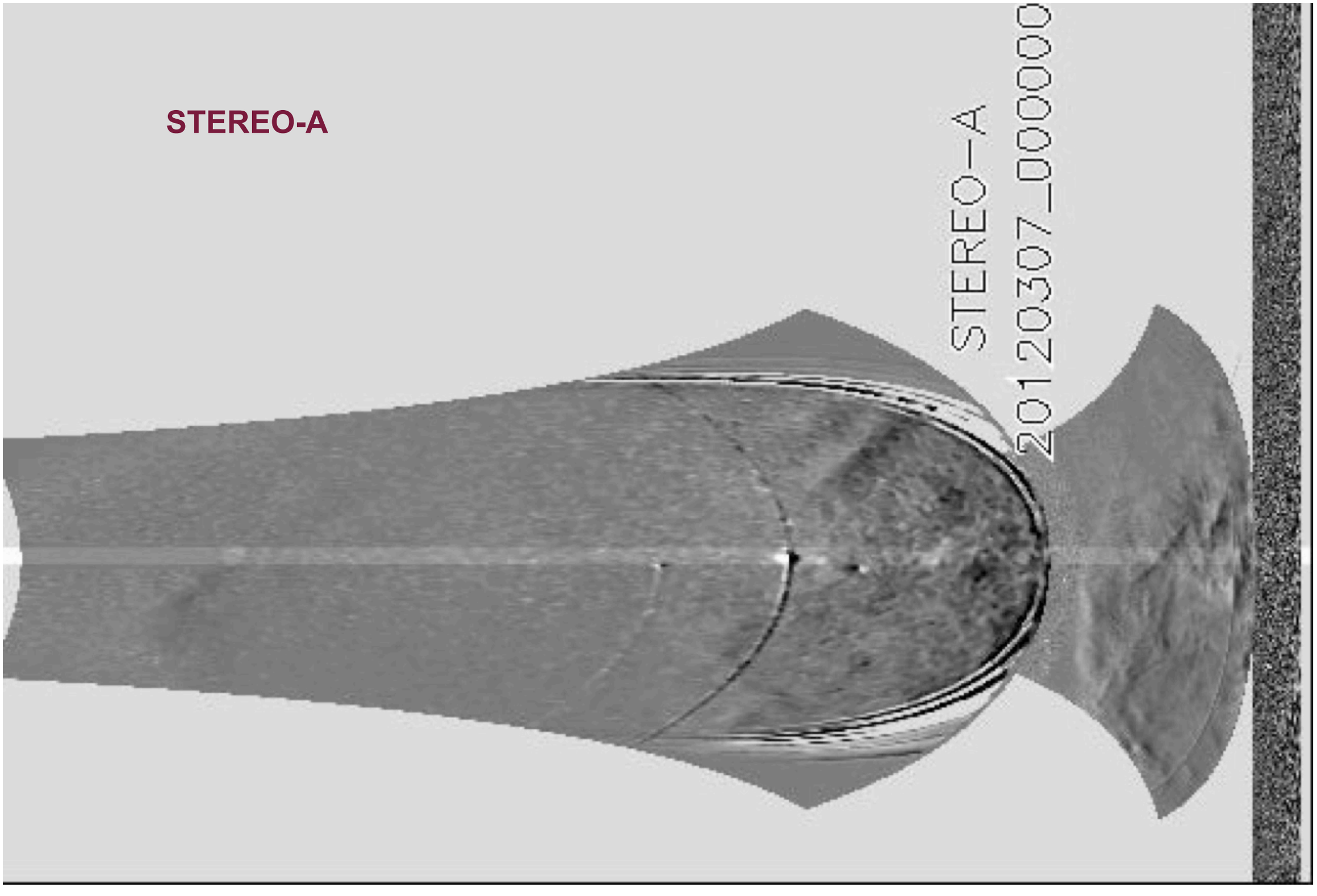




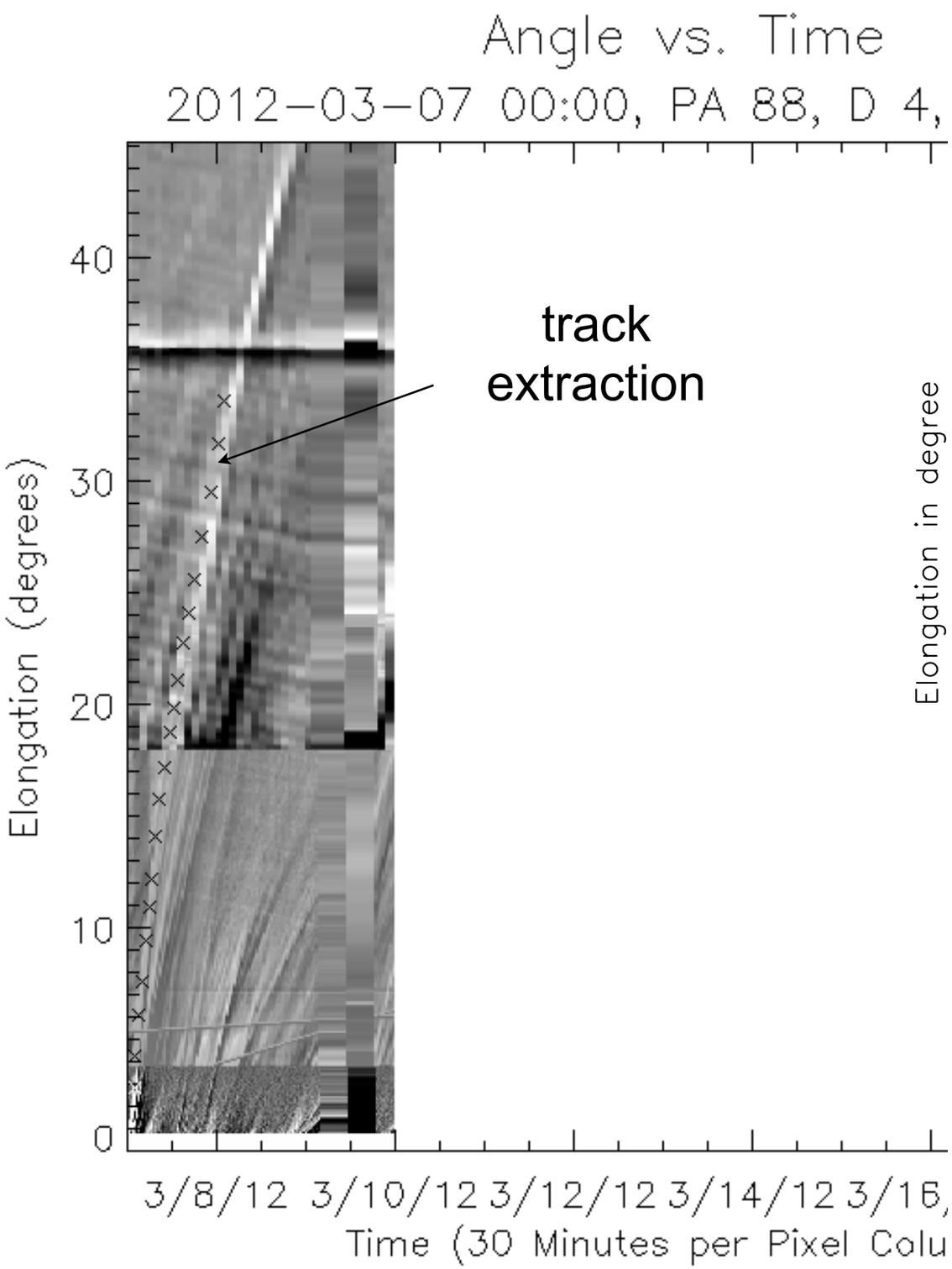
March 7-8 2012

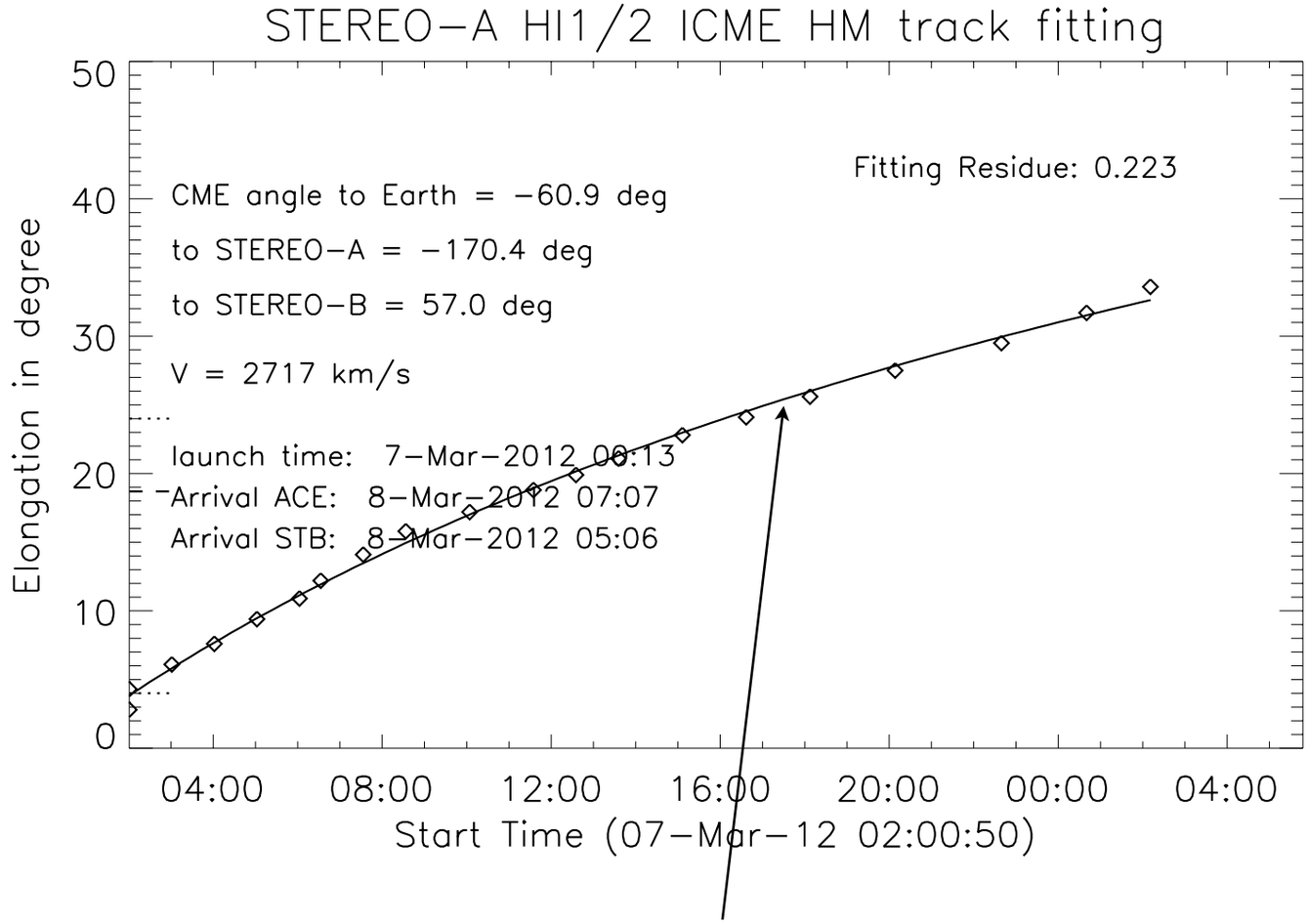


March 7-8 2012



SolarSoft SATPLOT Software





fitting with geometrical models (here HMF)

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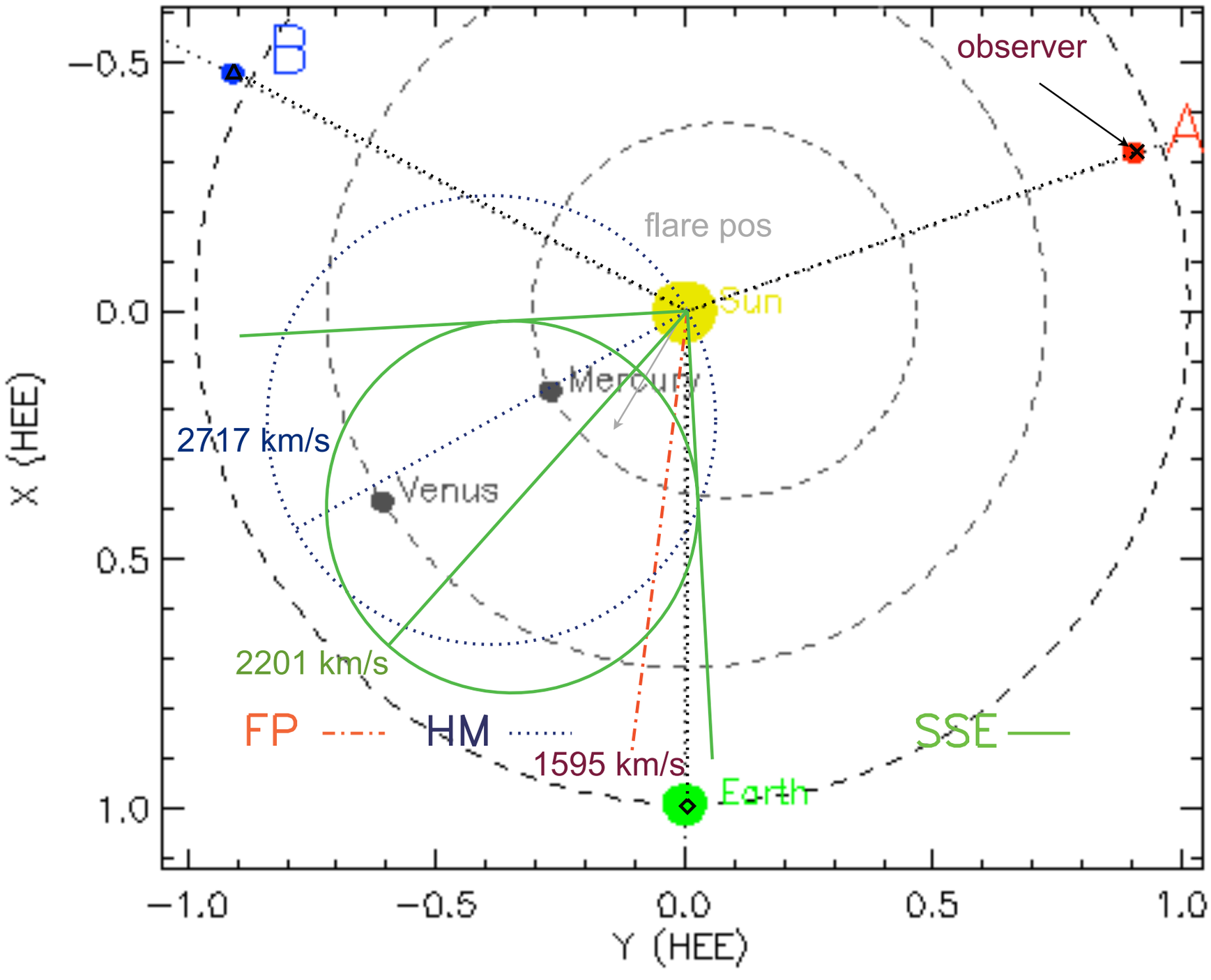
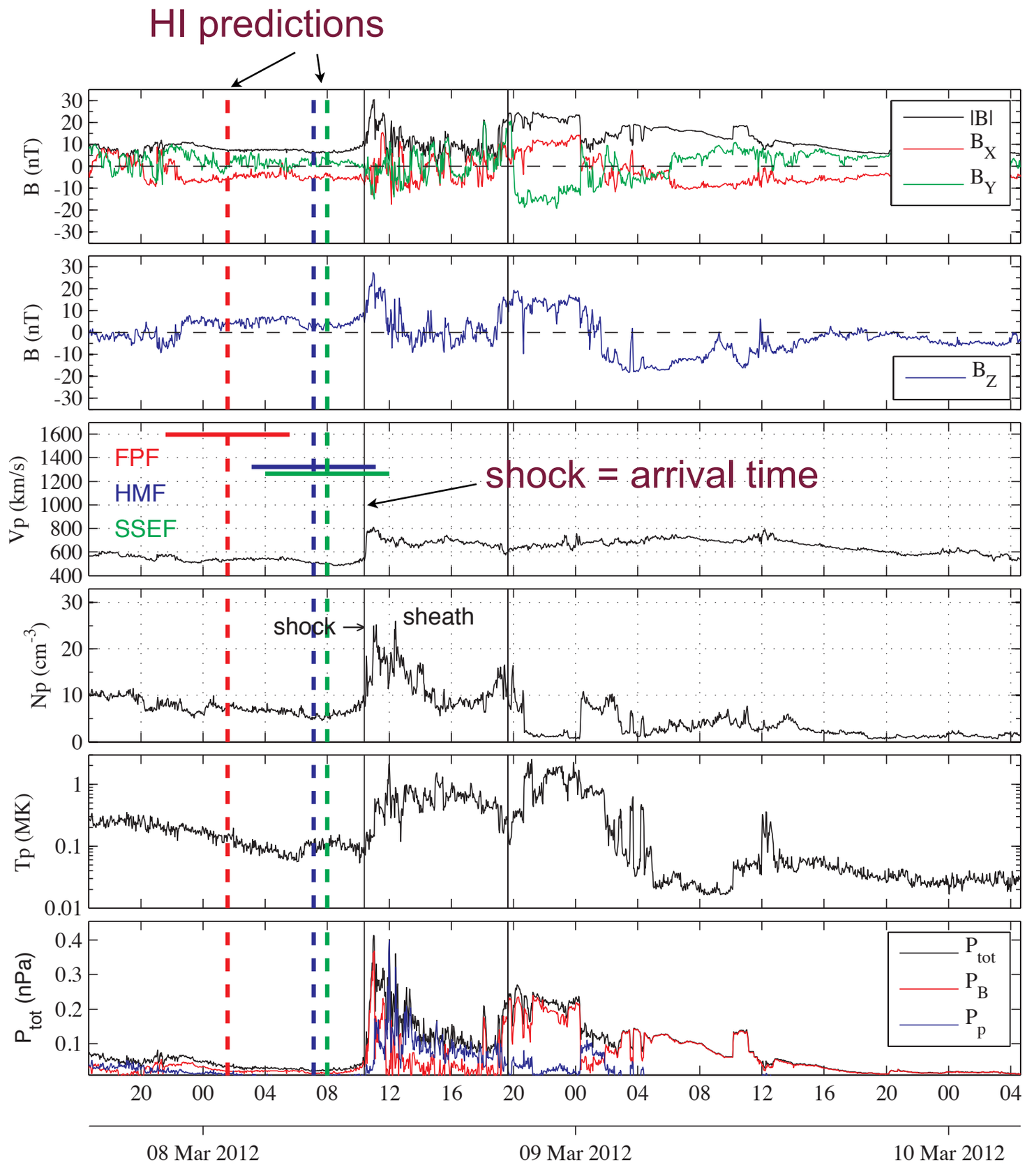
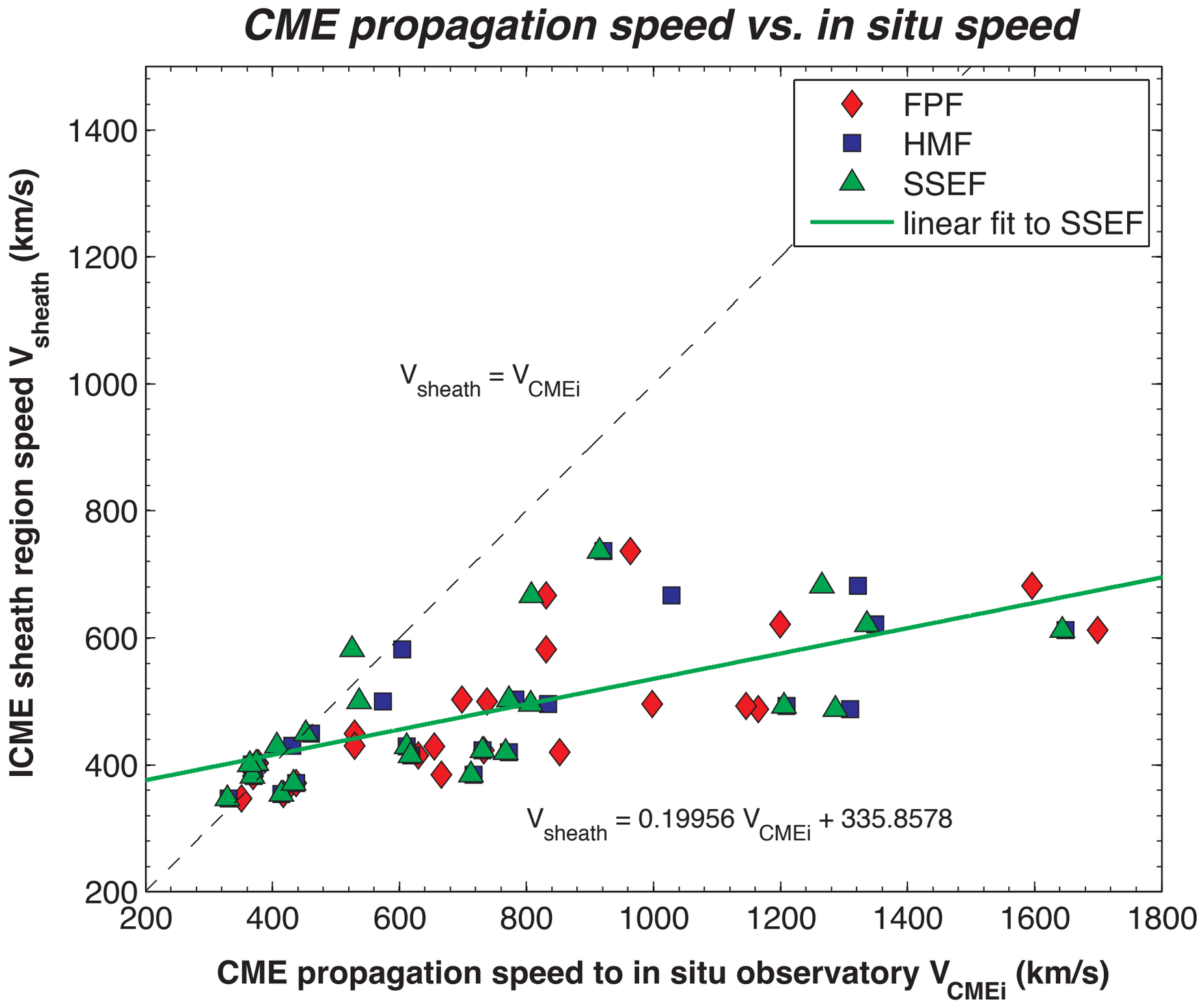


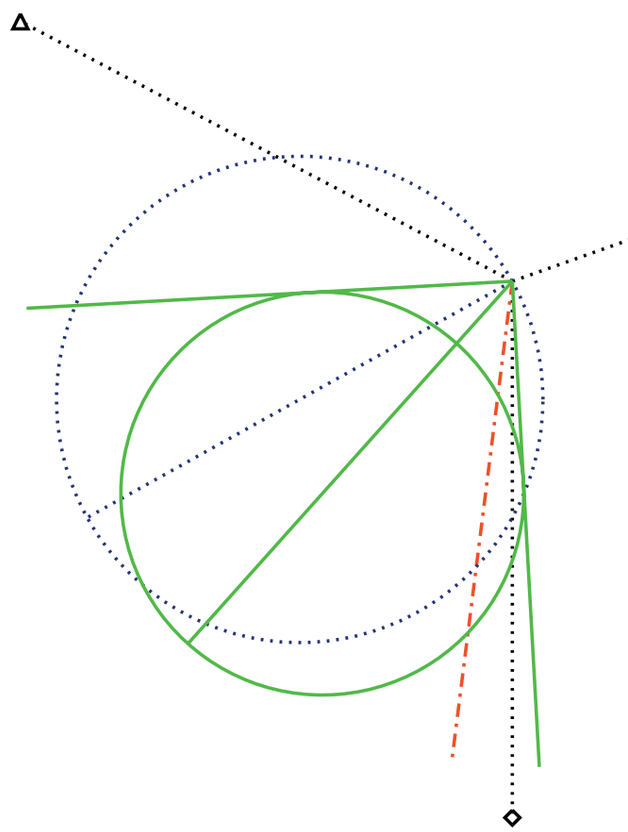
March 7-8 2012

Wind spacecraft at L1

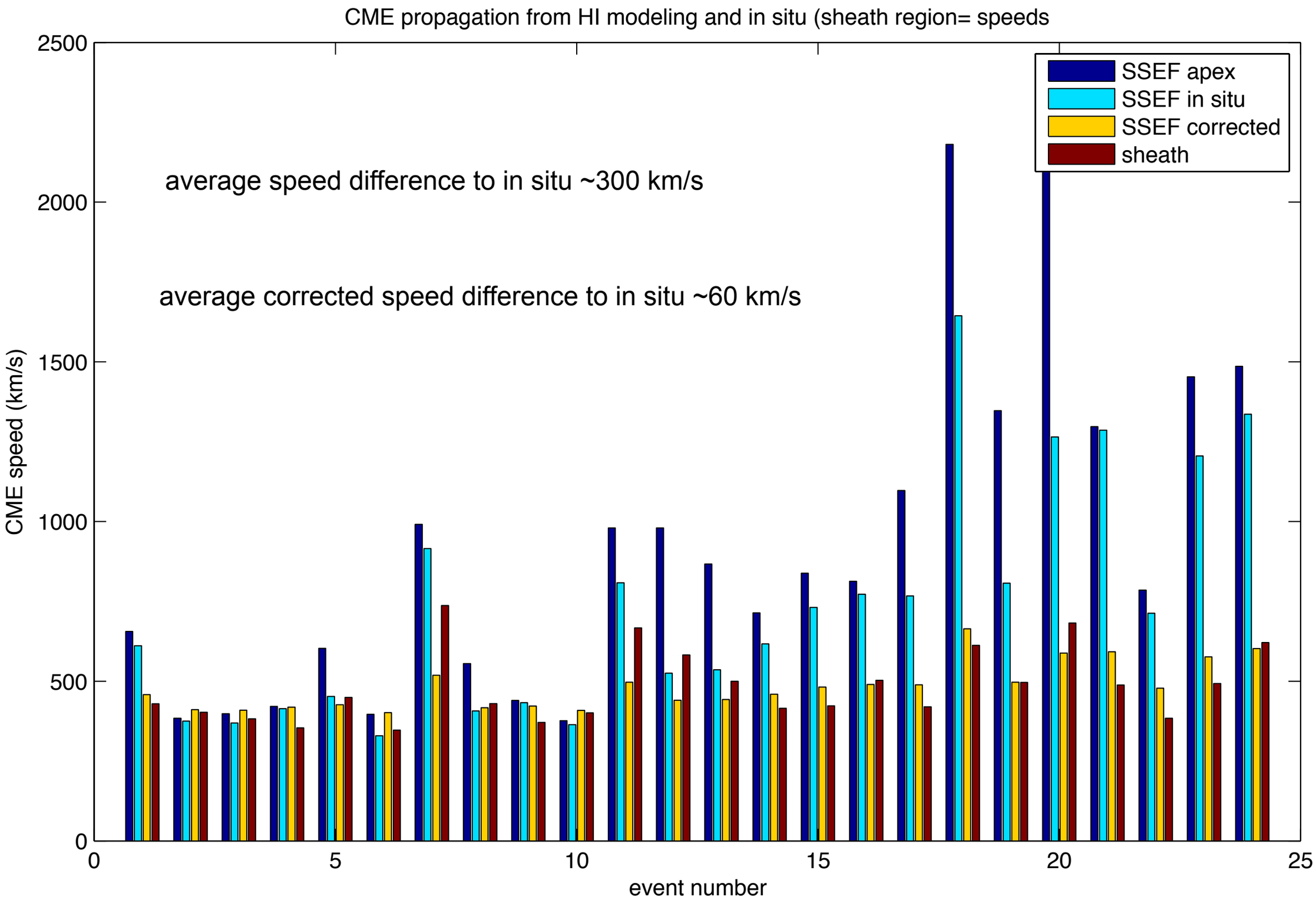


speed comparison HI – in situ

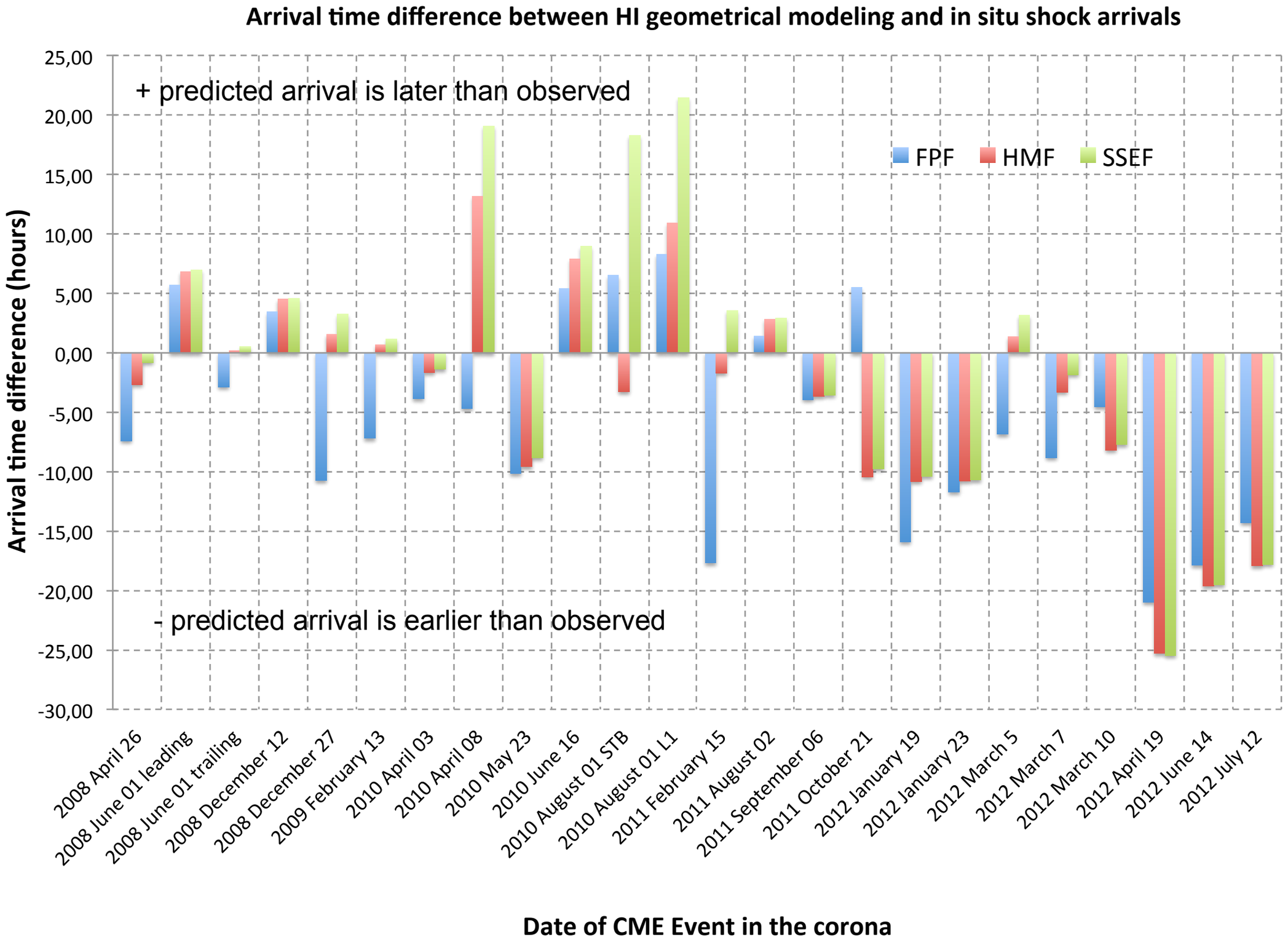




corrected HI speed – in situ



Arrival times HI – in situ



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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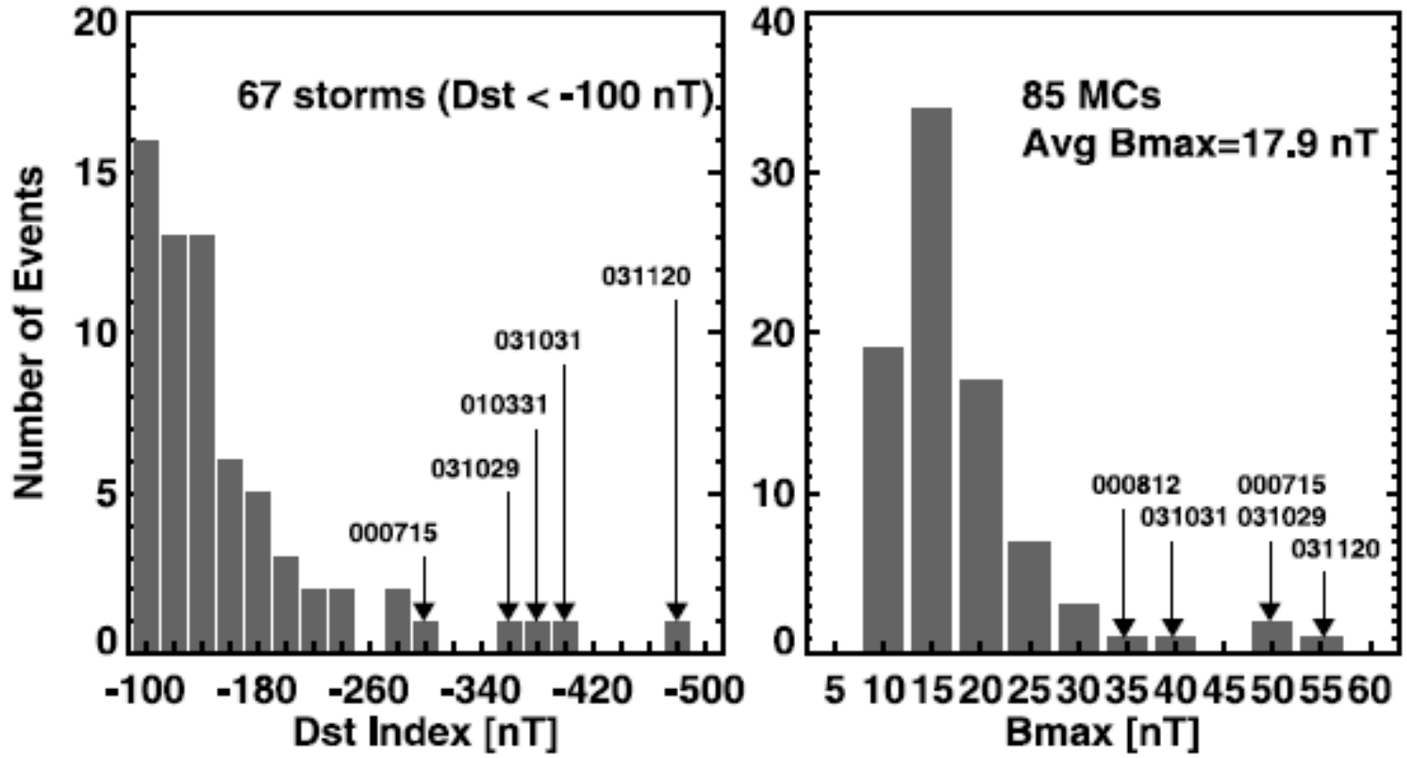
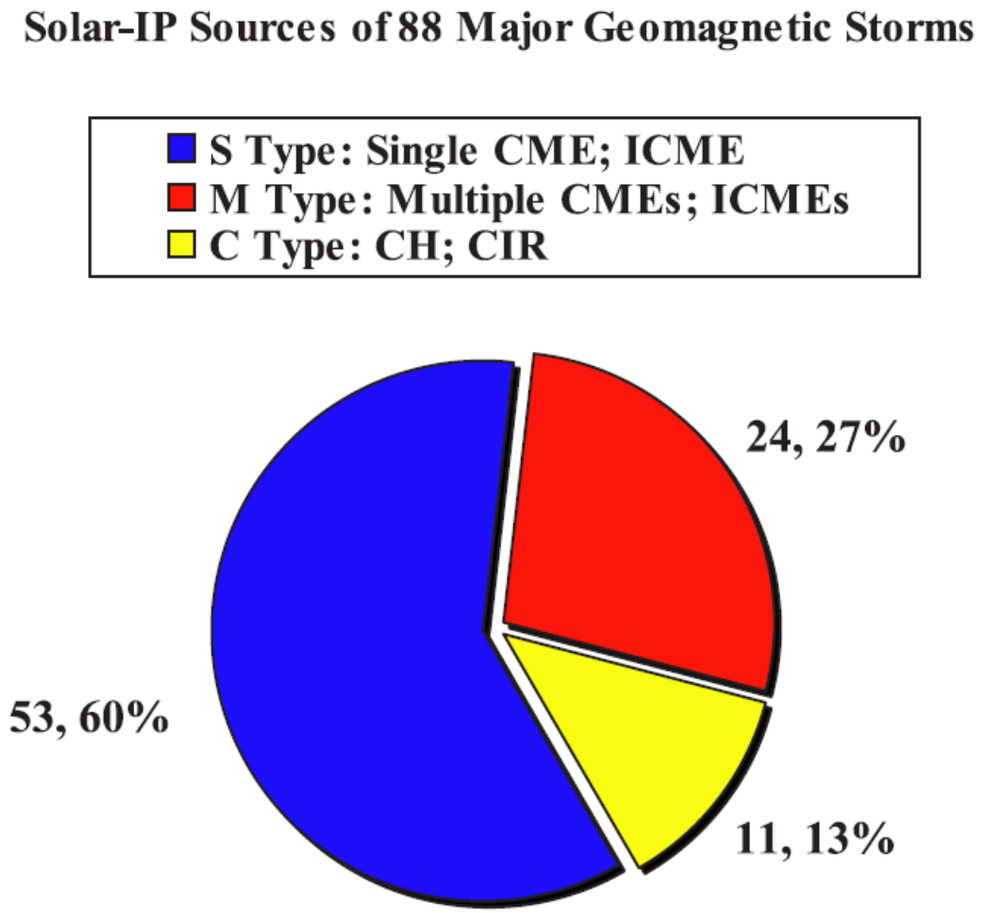
.... and it would have been entirely impossible without the dedicated people working on all those instruments! Thanks!

Sources of geomagnetic storms

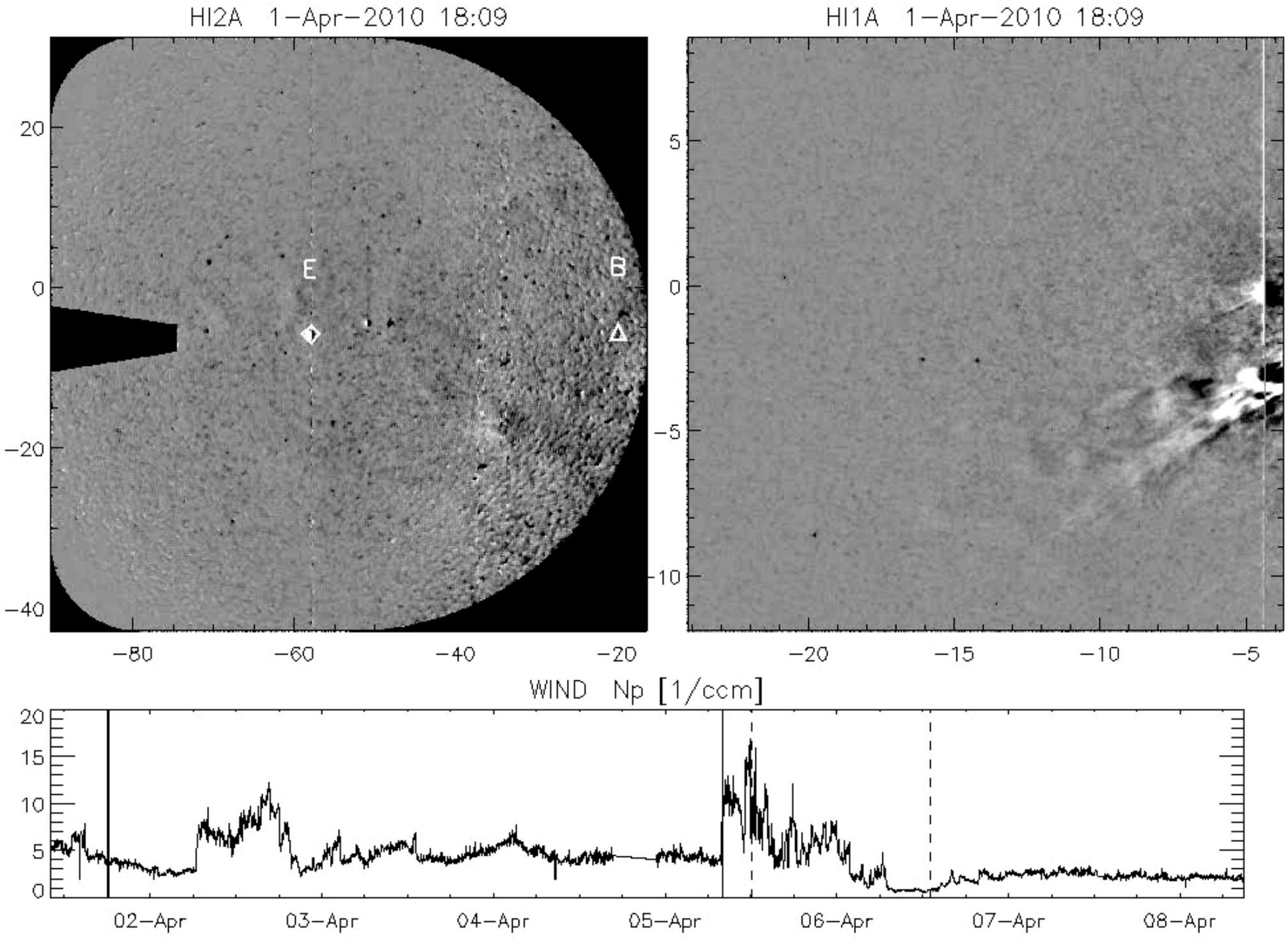


Gopalswamy et al., 2005, GRL



J. Zhang et al., 2007, JGR

STEREO Heliospheric Imagers



March 7-8 2012

- Direction to Earth:

FPF: -8°

SSEF: -41°

HMF: -61°

- Apex speeds:

FPF: 1595 km/s

SSEF: 2201 km/s

HMF: 2717 km/s

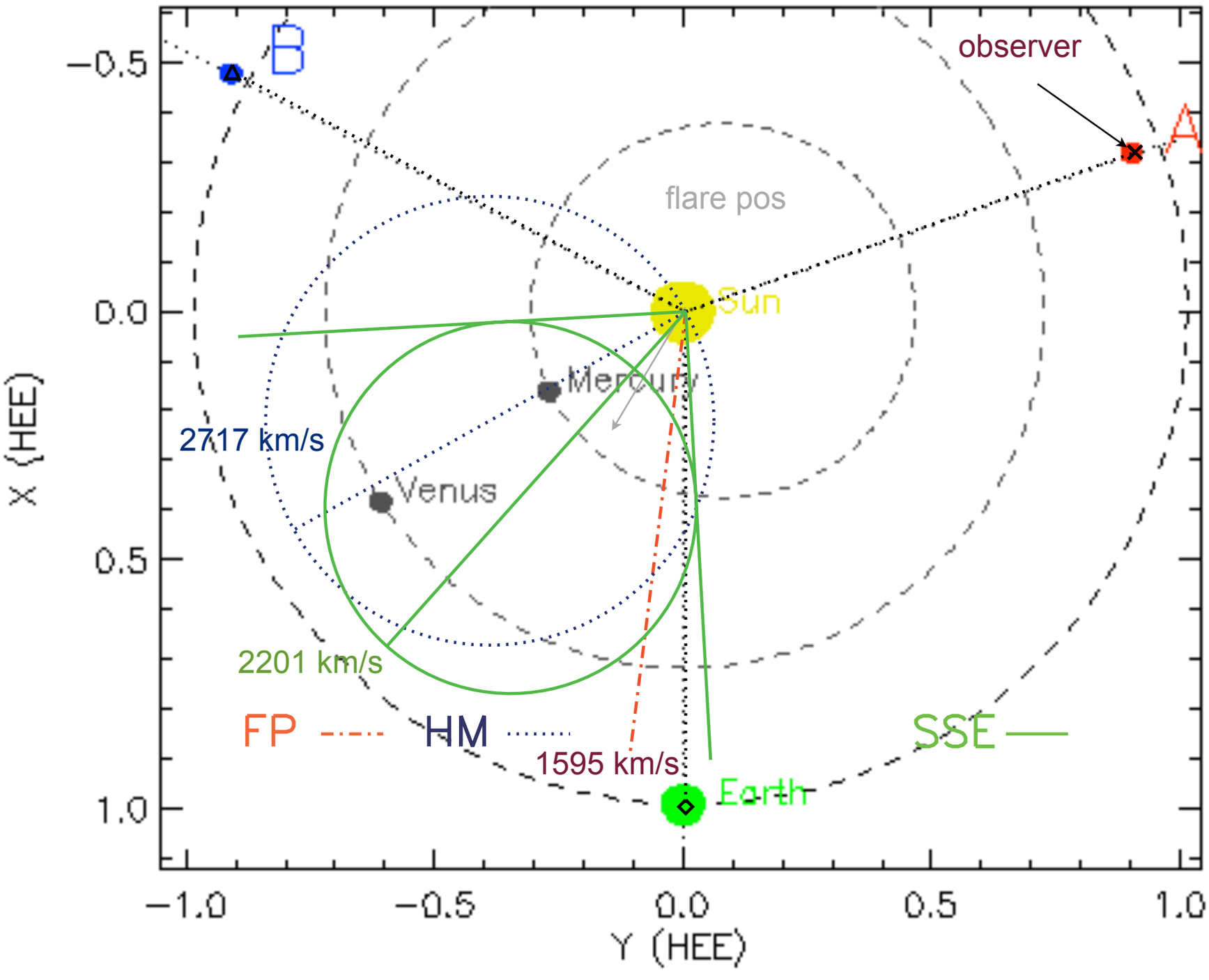
- Pred. L1 speeds:

FPF: 1595 km/s

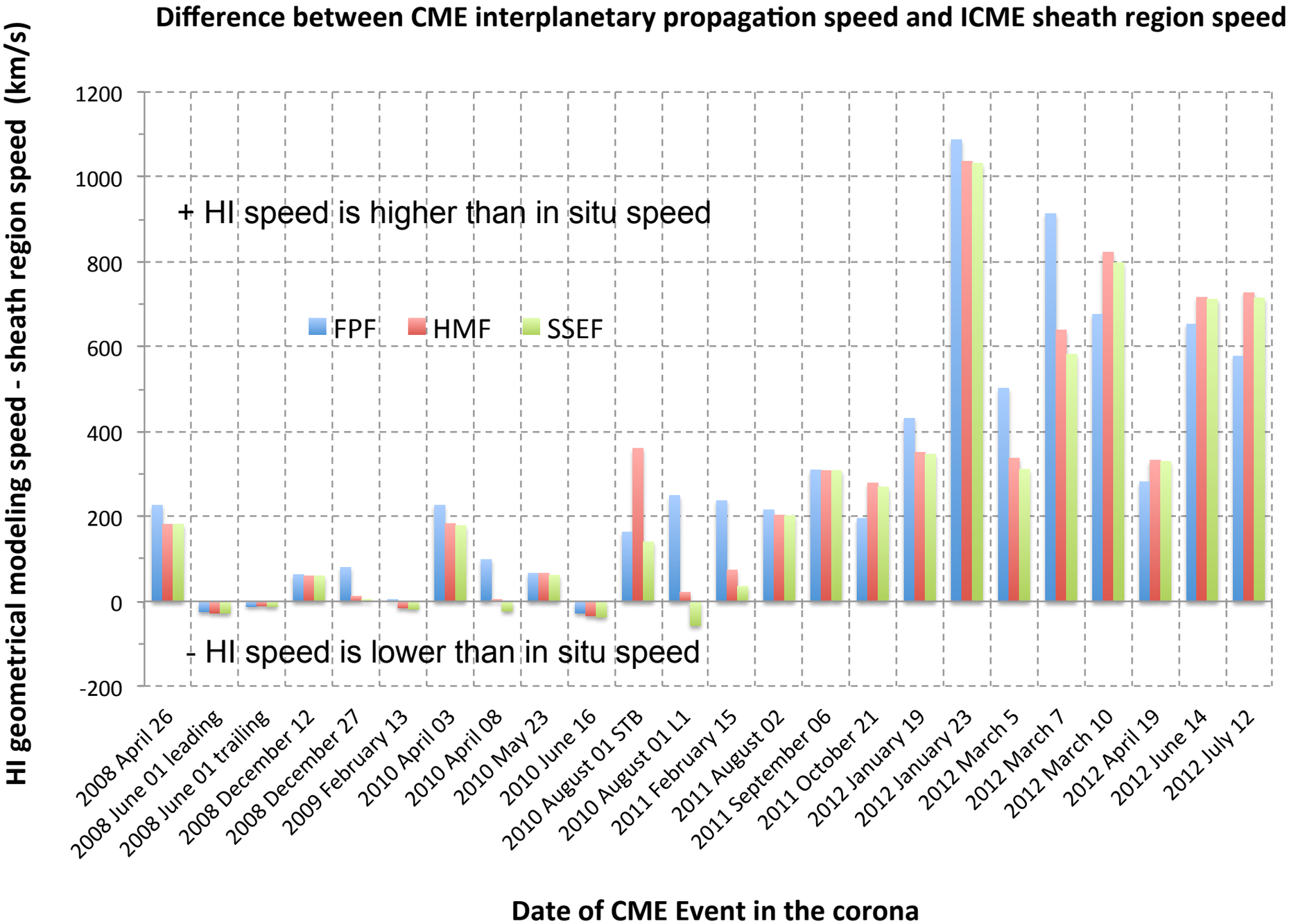
SSEF: 1264 km/s

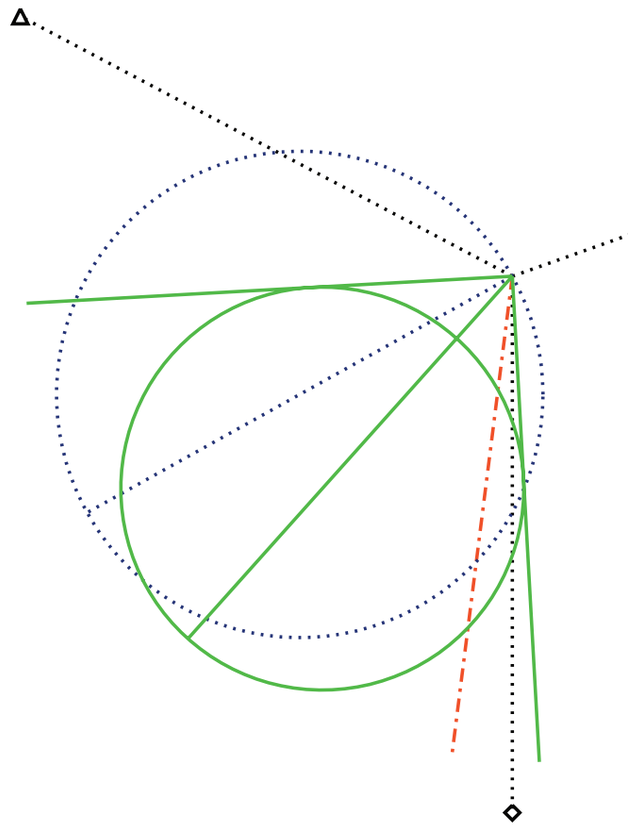
HMF: 1320 km/s

- 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





March 7-8 2012

- 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

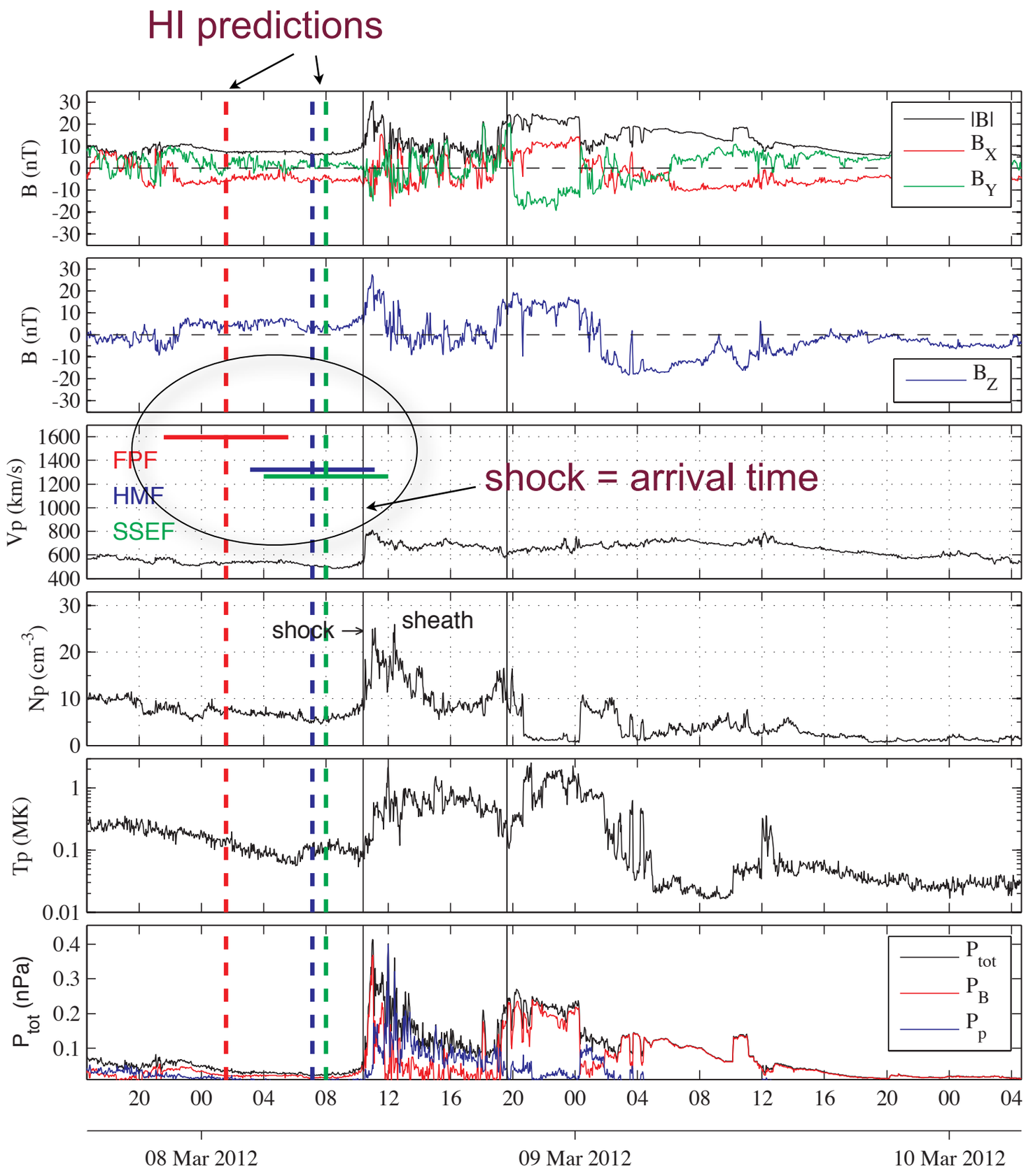
- **Speeds** in sheath region

(= high density visible in HI Jmap)

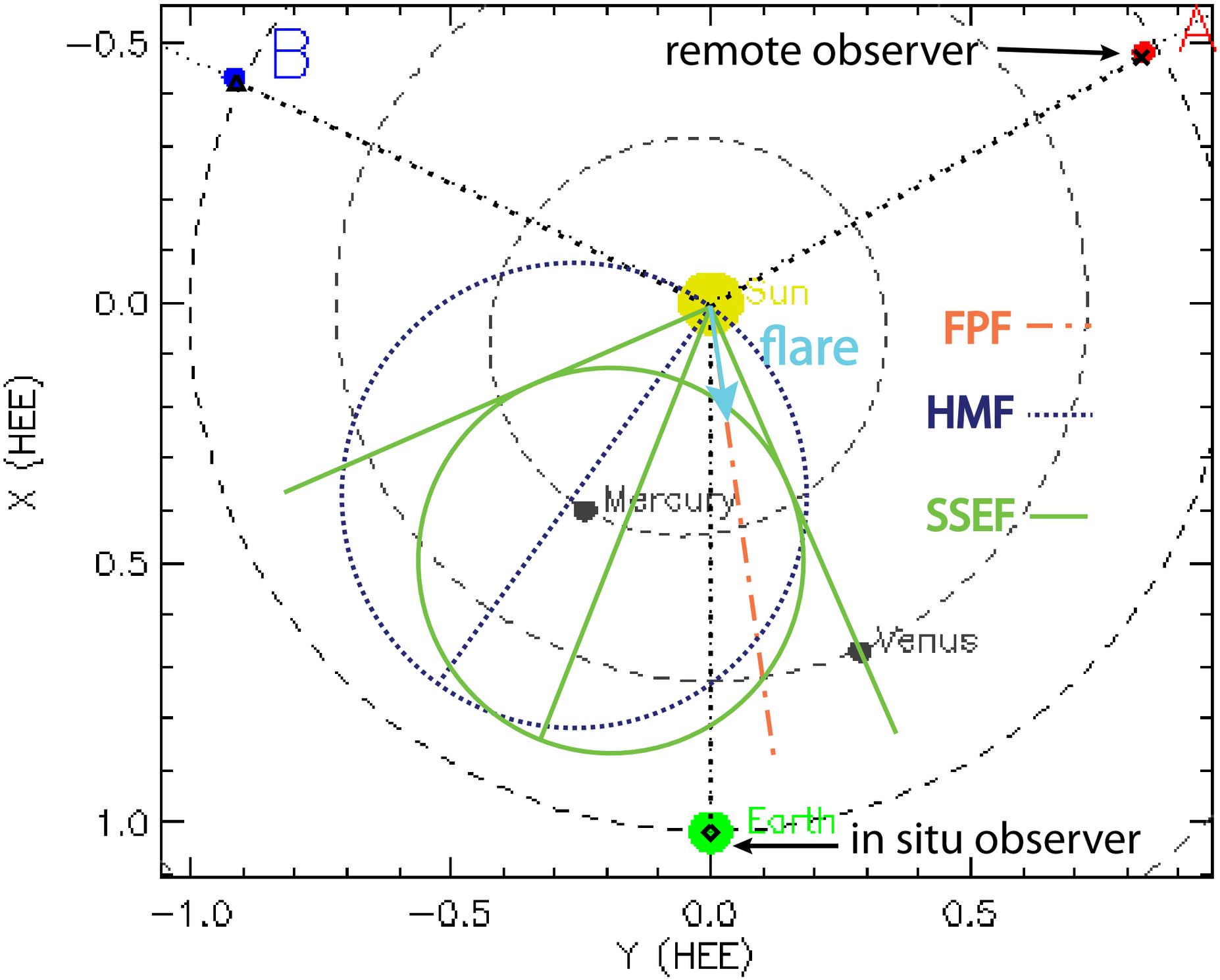
682 +/-30 km/s,

the predicted speeds are too high,

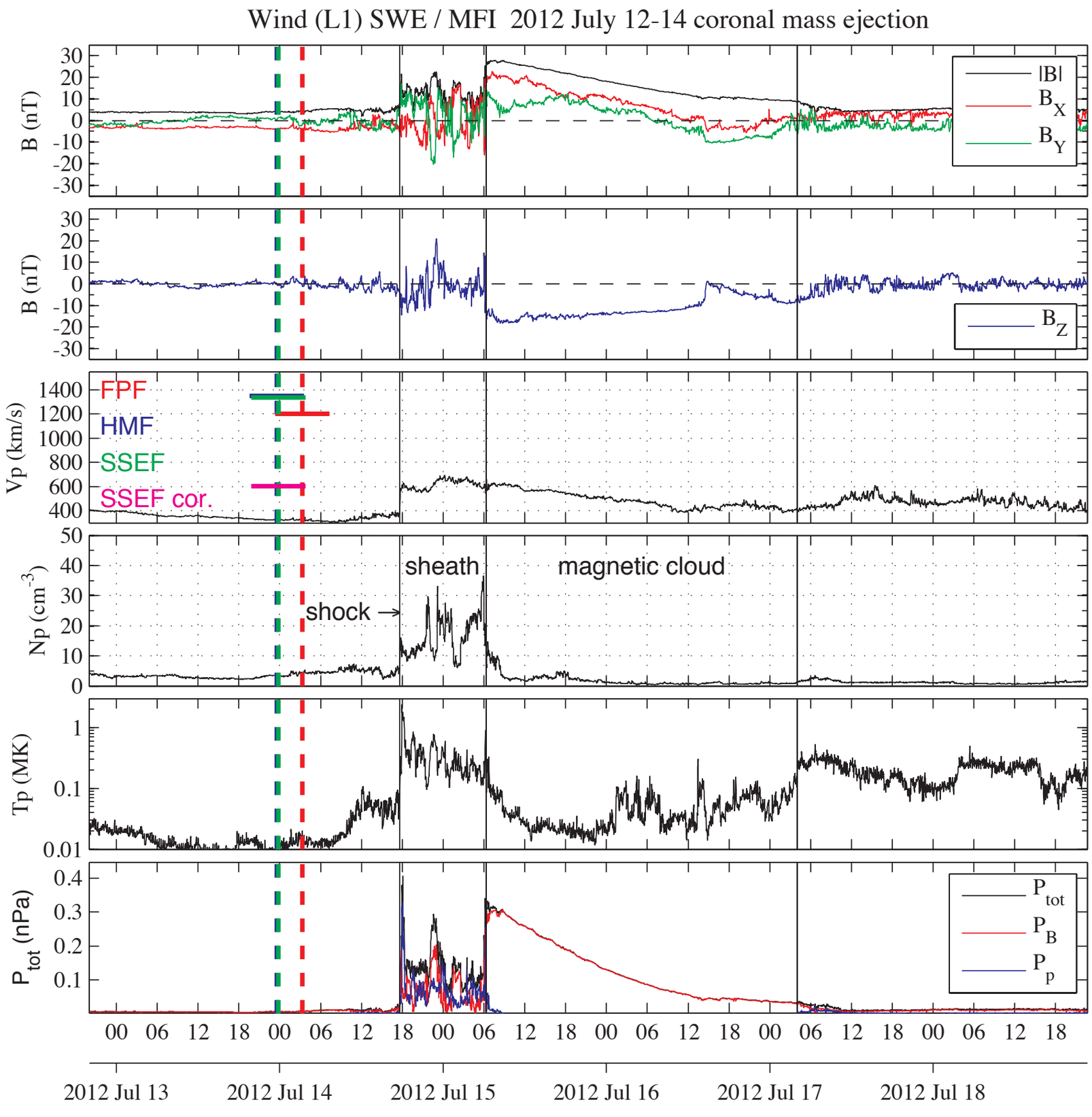
+600 to +900 km/s!



July 12-14 2012 coronal mass ejection



July 12–14 2012



Transit time