Overview of HELCATS WP4: Verifying the kinematic properties of STEREO/HI CMEs against in-situ CME observations and coronal sources

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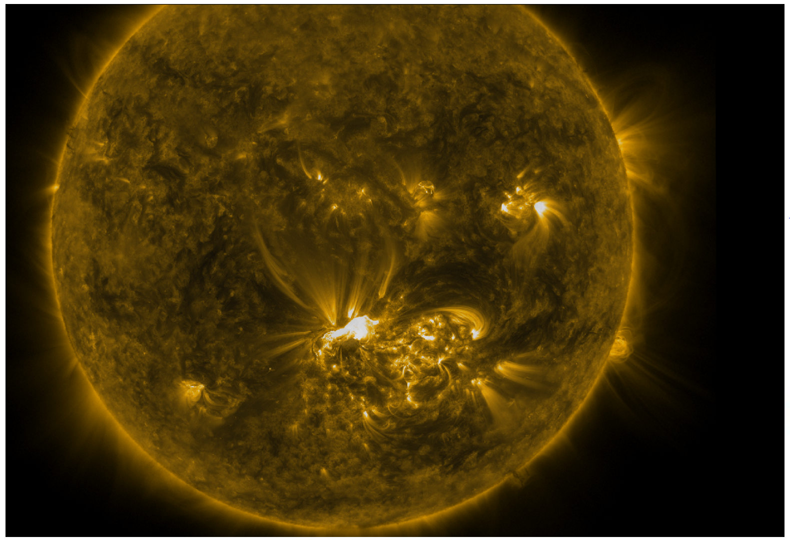
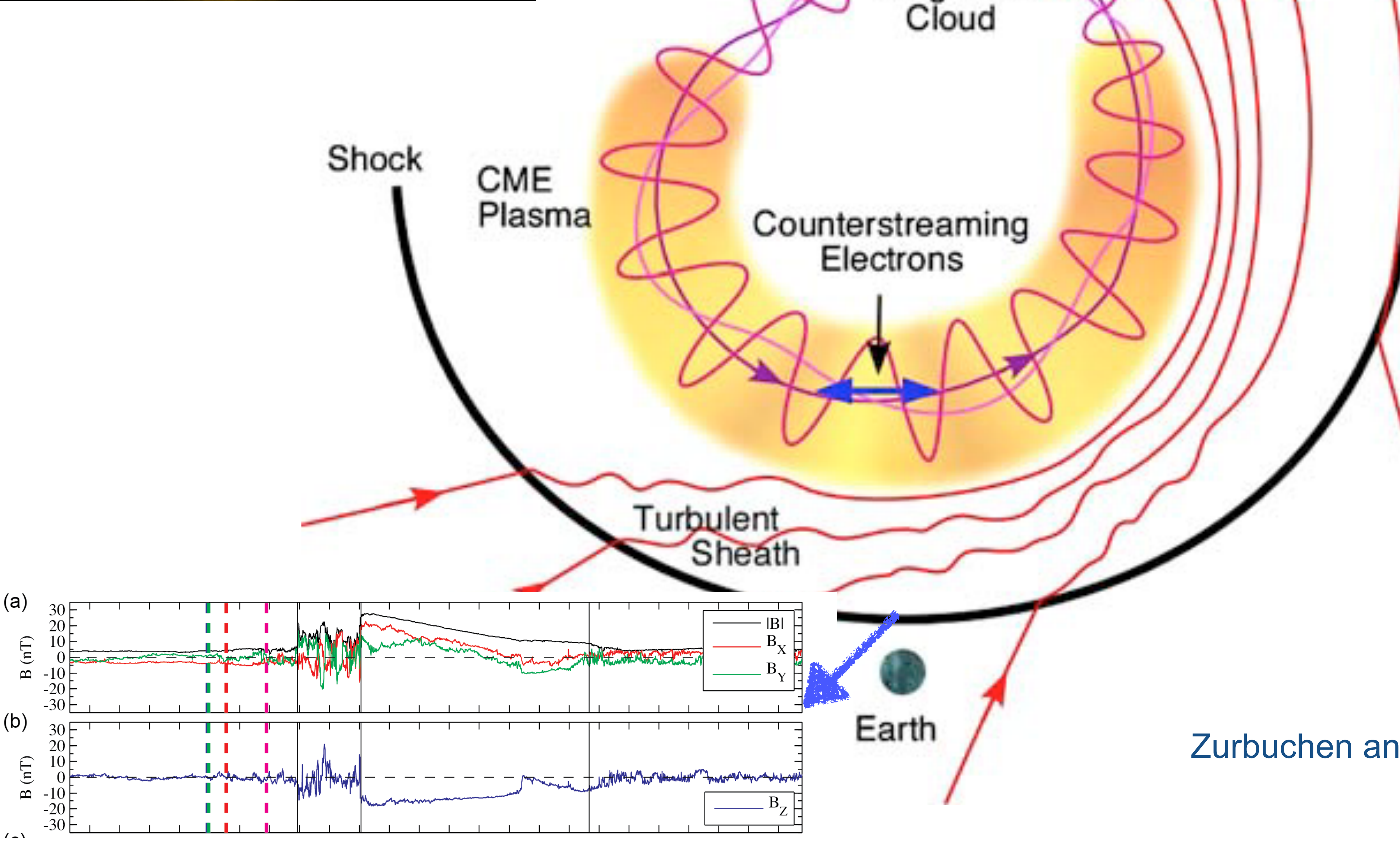
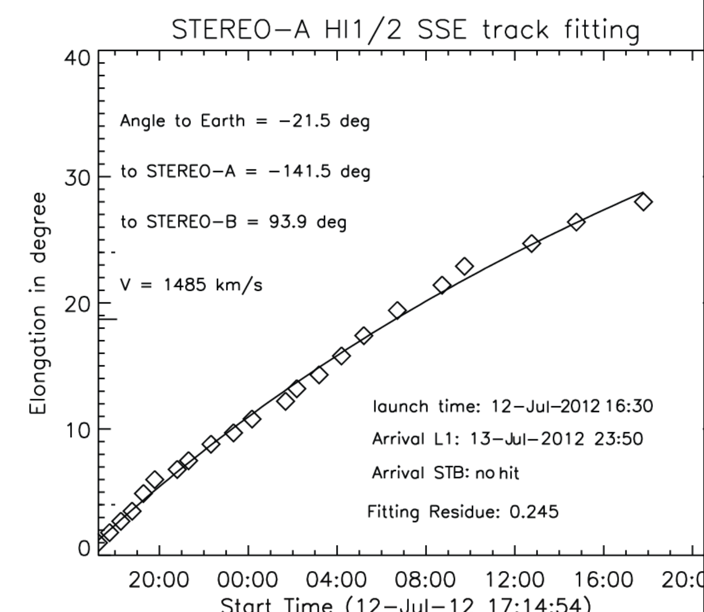
General

ICMEs







Zurbuchen and Richardson, SSR, 2006

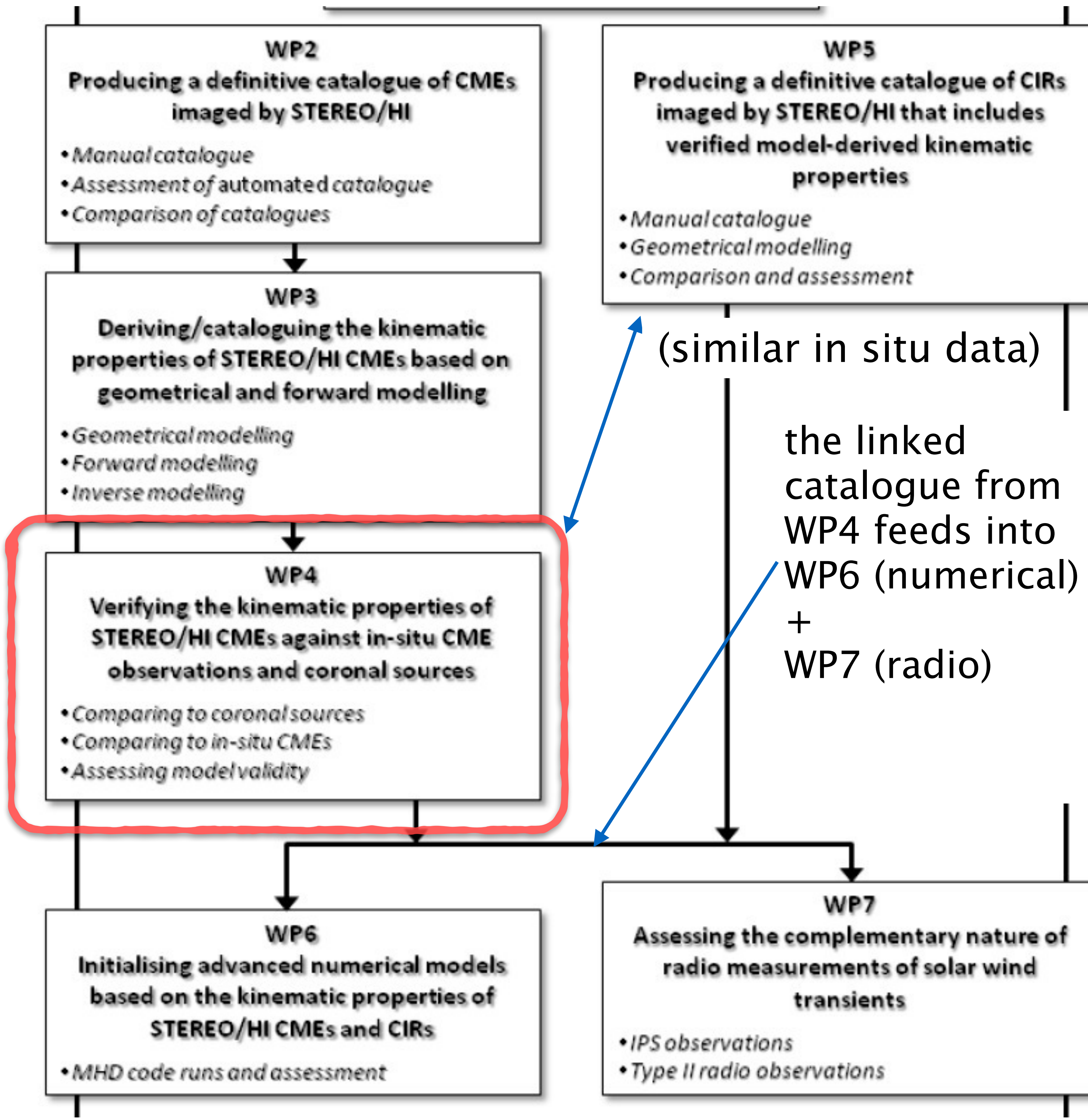
Institutes involved

Person-Months per Participant					
Participant number and short name[10]	Task1 specific effort	Task2 specific effort	Task3 specific effort	WP4 additional effort	WP4 TOTAL
1 - STFC	0.00	0.00	0.00	0.00	0.00
2 - UNIGRAZ	0.00	10.00	20.00	0.00	30.00
3 - UPS	0.00	1.00	1.00	0.00	2.00
CNRS	0.00	1.00	1.00	0.00	2.00
4 - UGOE	6.00	3.00	3.00	0.00	12.00
5 - ROB	0.00	0.00	6.00	0.00	6.00
6 - IMPERIAL	0.00	3.00	0.00	0.00	3.00
7 - UH	0.00	8.00	5.00	0.00	13.00
8 - TCD	0.00	0.00	0.00	0.00	0.00
Total	6.00	26.00	36.00	0.00	68.00

(circled) main effort in each task

Workflow

- WP4 is based on the modeled CME catalogue from WP3
- WP4 runs M10–36
- **Aim (1)** is to provide an online catalogue of linked CME obs.:
  – solar source
  – HI
  – in situ
  (M24, D4.1)
- **Aim (2)** is an analysis of that linked list (M30, D4.2)



WP4 description

To construct a community-oriented online database of in-situ CMEs, and their main parameters, **from 2007 to 2015** (minimum through maximum and early-declining phase of solar cycle 24) that fully exploits suitable currently operating heliospheric space missions.

• **To establish definitive links to coronal sources (Task 4.1) and in-situ signatures (Task 4.2) for the CMEs in the STEREO/HI catalogue (from WP2), based on the modelling results from WP3 that form the backbone that connects the HI data in space and time to the coronal data (by backward projection) and the in-situ data (by forward projection).**

• To **benchmark using HI modelling to better predict CME arrival at various heliospheric locations** using in-situ data from multiple sources, with the aim of maximizing the prediction lead time and minimizing the prediction error.

The primary goal of WP4 is to provide researchers with the ability to view and obtain the principal CME parameters (e.g. direction, speed) at a glance, following the complete chain of imaging and in-situ observations from the Sun out to 1 AU. We will bring together totally independent data sets, bridging the gap between remote and in-situ observations. The CME database will be optimized to aid the space physics community's search for clues on the origin, propagation, morphology, and planetary effects of CMEs. We will not only furnish the event catalogue with relevant parameters, but will also provide the linkage (including physical interpretations) between different CME related structures in different datasets. This resource will be useful for future missions (e.g. Solar Orbiter).

Task 4.3

Assessing the validity of the HI modelling

[Months: 10–36]

1 Jan 2007 – 31 Dec 2015

WP4 description

In Task 4.3 we statistically analyze results from Tasks 4.1 and 2, with STEREO/HI **CME parameters from WP3 forming the backbone**. The WP3 HI modeling results (over a large portion of solar cycle 24) will be assessed in terms of their reliability, in terms of connecting the different data sets, and their potential for space weather prediction. Direct comparisons between HI and in-situ data sets are possible:

(1) comparing HI-derived CME direction with spacecraft position (hit or miss predictions),
(2) comparing HI-derived CME arrival times/speeds with in-situ CME arrival times/speeds, and
(3) comparing white-light HI morphology with in-situ flux rope orientation.

Questions that can be addressed are: How can different CME substructures (sheaths, flux ropes) be identified from HI data? How well can CME arrival times/speeds be forecast using HI data, and how can this be optimized? What is the outcome of binary classifications of CME hits and misses? Are there CME, sheath or substructure properties that optimize predictive capability, and why? Moreover, comparing HI modeling and source region properties will address questions on **source position versus CME propagation direction**. To test relations for forecasting magnetic clouds, **in-situ magnetic structures will be compared with the magnetic field of their photospheric source regions**.

Role of participants:

UNIGRAZ: coordinating the analysis, comparing geometrical modeling to in-situ

UGOE: validating back-projections; comparing in-situ to solar magnetic structures;
UH: ICME inputs
UPS: CME HI in-situ substructure identification
ROB: comparing forward modelling to in situ data.

Recent ApJ paper

- Möstl et al. 2014, ApJ, 787, 119
- A first take on predicting CMEs with HI:
  coronagraph (forward modeling)
  HI (geometrical modeling)
  in situ (magnetic field and plasma parameters)
- Event list: 22 CMEs directed at STEREO and Earth between 2008-2012, tracked on average to 35° elongation from the Sun
- relationships found between interplanetary and in situ parameters
- see also Lugaz et al. 2012 (Sol. Phys.):
  STEREO directed CMEs in 2008-2010
  showed that its possible to predict CMEs which are backsided from the HI point of view

The Astrophysical Journal, 787:119 (17pp), 2014 June 1 doi:10.1088/0004-637X/787/2/119

CONNECTING SPEEDS, DIRECTIONS AND ARRIVAL TIMES OF
22 CORONAL MASS EJECTIONS FROM THE SUN TO 1 AU

C. Möstl[1,2,3], K. Amla[4], J. R. Hall[4], P. C. Liewer[4], E. M. De Jong[4], R. C. Colaninno[5], A. M. Veronig[1], T. Rollett[1], M. Temmer[1], V. Peinhart[1], J. A. Davies[6], N. Lugaz[7], Y. D. Liu[8], C. J. Farrugia[7], J. G. Luhmann[2], B. Vršnak[9], R. A. Harrison[6], and A. B. Galvin[7]
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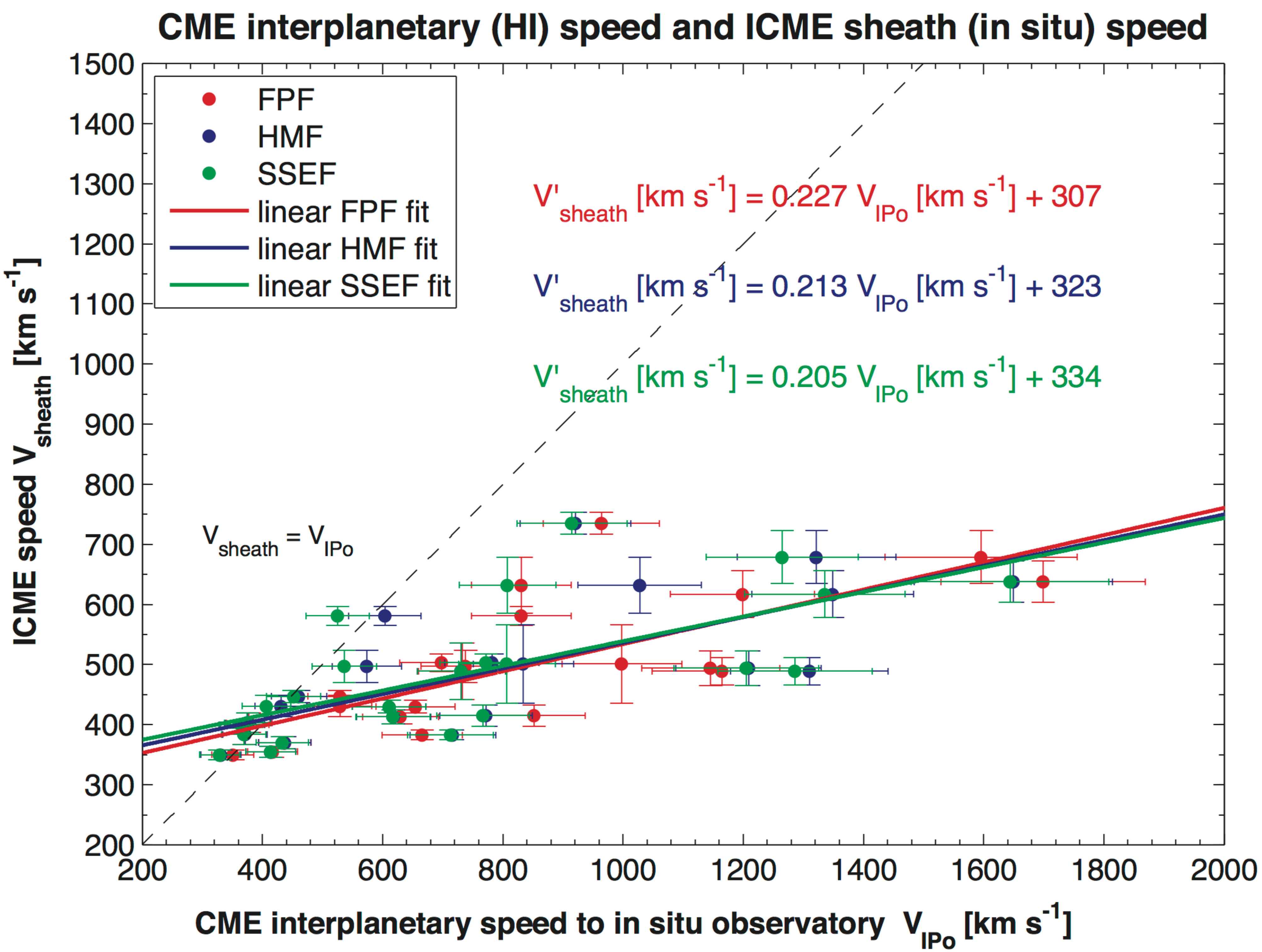
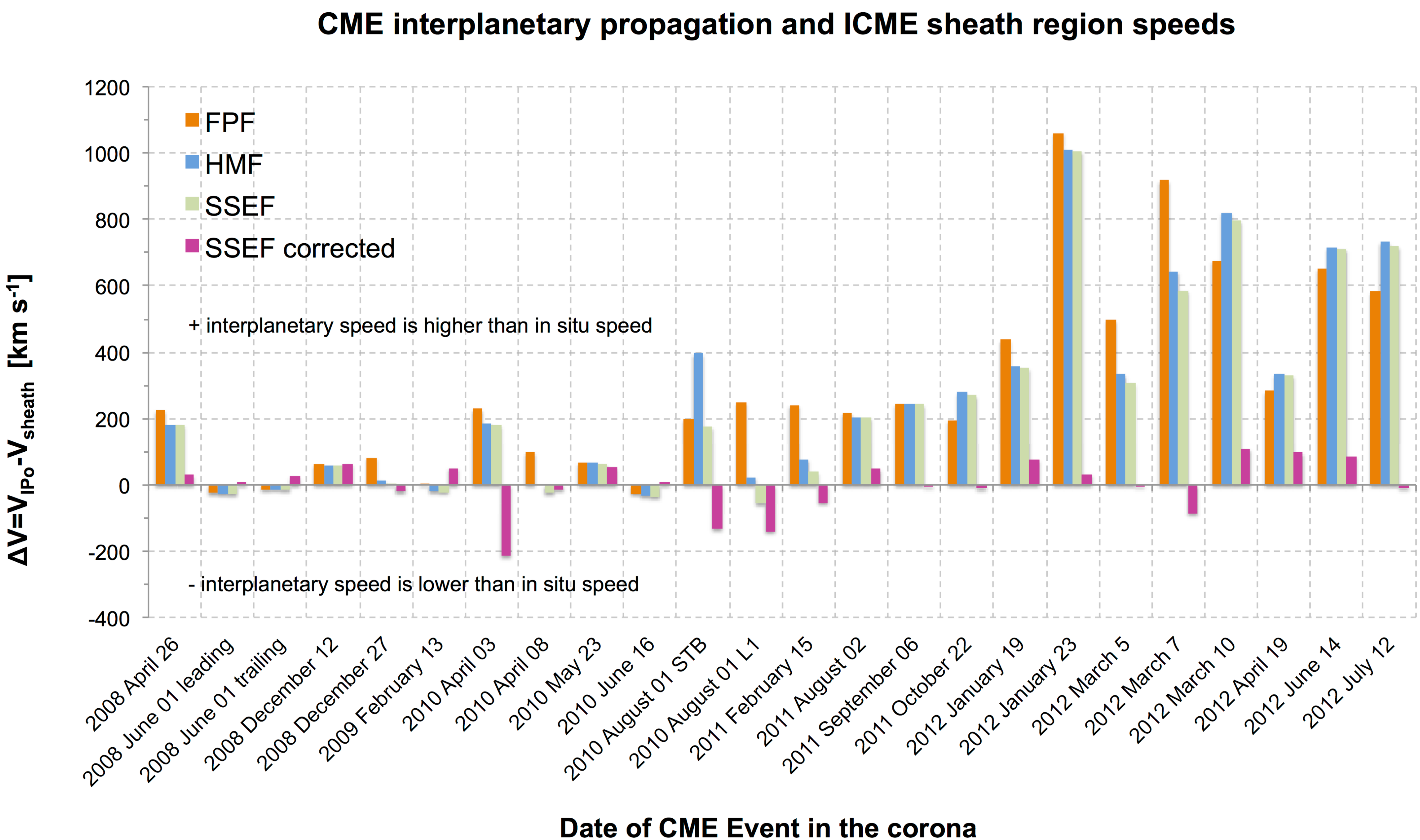
[2] Space Science Laboratory, University of California, Berkeley, CA, USA
[3] Space Research Institute, Austrian Academy of Sciences, Graz, Austria
[4] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
[5] Space Sciences Division, Naval Research Laboratory, Washington, DC, USA
[6] RAL Space, Harwell Oxford, Didcot, UK
[7] Space Science Center and Department of Physics, University of New Hampshire, Durham, NH, USA
[8] State Key Laboratory of Space Weather, National Space Science Center, Chinese Academy of Sciences, Beijing, China
[9] Hvar Observatory, Faculty of Geodesy, University of Zagreb, Kačićeva 26, HR-10000, Zagreb, Croatia

Speed



Möstl et al. 2014, ApJ

Speed



Möstl et al. 2014 ApJ in press

Technical issues

- **Data sources**

STEREO:	UNH and UCLA websites
ACE, Wind:	2 min, 1 min merged data; ftp at NSSDC
MESSENGER:	1 min resolution from PDS website at UCLA
VEX:	1 min res. ftp in house at SRI, Graz
ULYSSES:	1 hour res. ftp at NSSDC
MSL:	RAD from MSL notebook website

- **Availability (2007-2015)**

STEREO-A/B, L1 (ACE, Wind):	2007-	(mag and plasma)
MESSENGER:	2007-	(mag, in orbit at Mercury from 3/2011)
VEX:	2007 -	(mag)
Ulysses:	2007	(mag/plasma, last ecliptic pass)
MSL:	2012 -	(radiation experiment)

- data to plots/analysis: in **IDL** for MESSENGER, VEX, ULYSSES   to do: MSL
- data to plots/analysis: currently in **MATLAB** for STEREO, Wind -> IDL? Helsinki?

- **WP5** CIRs (Toulouse) -> similar in situ data, should aim for use of **similar software**

Data handling

- **Suggestion for WP4:**

  Plot and **analyze in situ data** (i.e. extract parameters) mostly in
  IDL SolarSoft – connection with RAL HI software straightforward, spacecraft positions easily obtainable (WCS)

  For **cataloguing** – currently I use **Excel:** easy to handle, the data is neatly arranged and can be edited in a simple way, can be saved as website + ascii output

  Further visualization and statistical analysis in **python**, some exists in **MATLAB** (for Möstl et al. 2014 ApJ)

heliocentric distance at arrival (AU)	longitude of in situ spacecraft (HEEQ)	in situ sheath speed mean (km/s)	in situ sheath speed standard deviation km/s	in situ sheath proton density mean #/ccm	in situ sheath proton density standard deviation #/ccm	maximum B (nT) in ICME (sheath+flux rope)	minimum Bz (nT) in ICME (sheath+flux rope)
1,0280	-24,02	430	11	16	6	14,0	-9,5
1,0542	-25,15	403	16	15	7	14,6	-8,6
1,0548	-25,19	384	17	13	7	12,5	-11,3
0,9840	0,0000	355	9	16	4	10,0	-7,6
1,0263	-45,49	447	10	7	3	9,5	-6,7
1,0023	-47,61	350	8	22	4	12,3	-9,4
1,0004	0,0000	735	18	10	2	21,5	-14,6
1,0021	0,0000	431	18	10	1	12,7	-8,6
1,0132	0,0000	370	10	19	4	13,7	-12,9
1,0161	0,0000	400	6	8	3	8,6	-2,8
1,0604	-70,920	632	47	4	4	33,2	-30,2
1,0146	0,0000	581	16	10	2	19,2	-11,2

Summary WP4

- WP4 runs months 10-36
- builds on WP2+3
- linked catalogue feeds into WP6+7
- **Tasks:**
  4.1 coronal sources, **Göttingen**: STEREO, SOHO, SDO, Proba2
  4.2 in situ data: **Graz, Helsinki**, Toulouse, Göttingen, Imperial
  categorization of ICMEs with WP3 results (geometrical modeling):
  STEREO, ACE, Wind, MESSENGER, VEX, Ulysses, MSL
  4.3 statistical analysis: **Graz**, Toulouse, ROB, Göttingen, Helsinki
- **Deliverables:**

  M24: Establishing an **online catalogue of potentially associated solar source and in-situ** phenomena for the timeframe 2007-2015
  (this is the first catalogue of its kind; there are many separate CME / ICME lists)

  M30: Report on **statistical analysis and comparison of HI results with coronal and in situ data**; assessment of **forecasting accuracy**.

additional slides

Task 4.1
Comparing to coronal sources
[Months: 10–36]

WP4 description

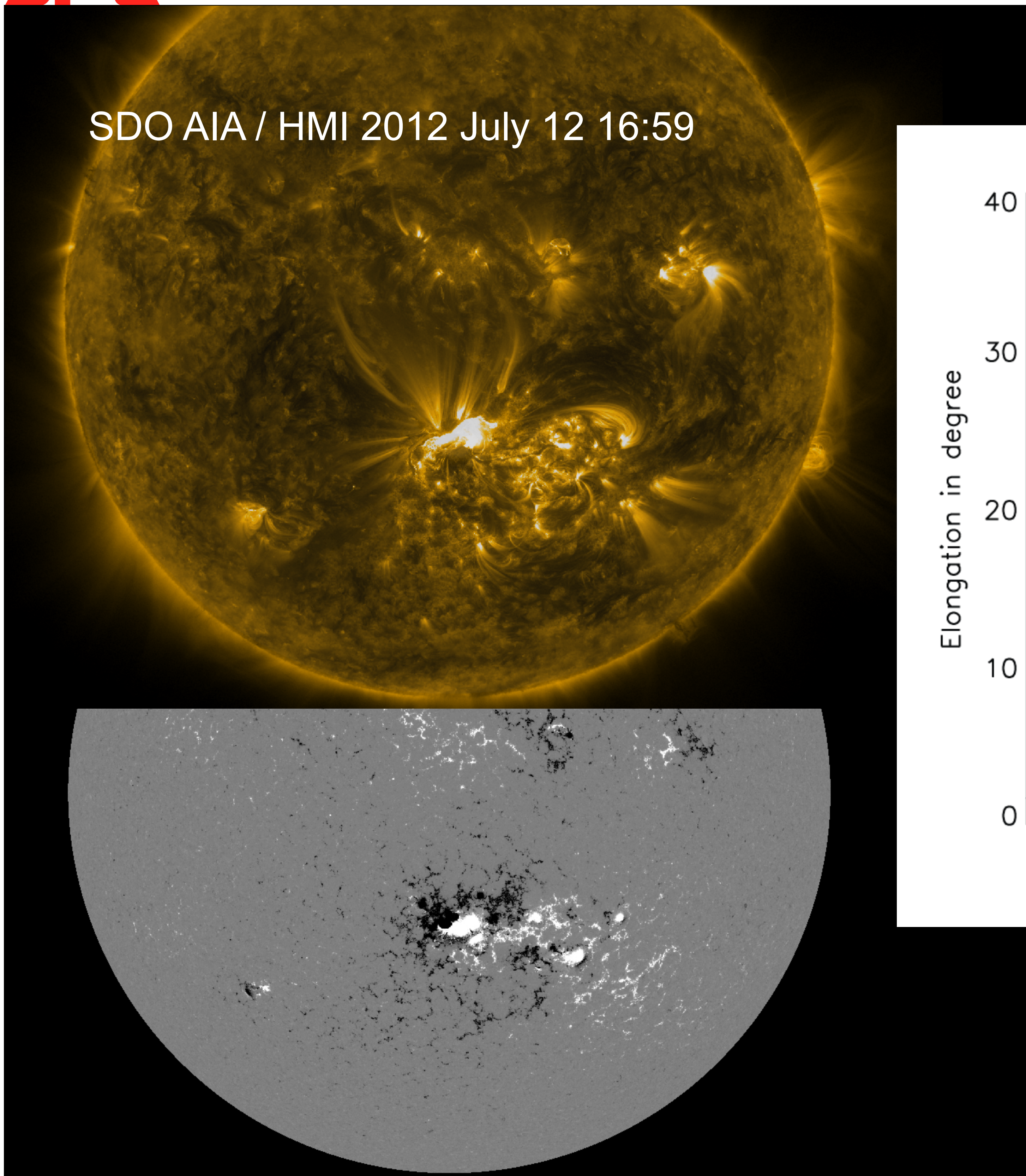
UGOE

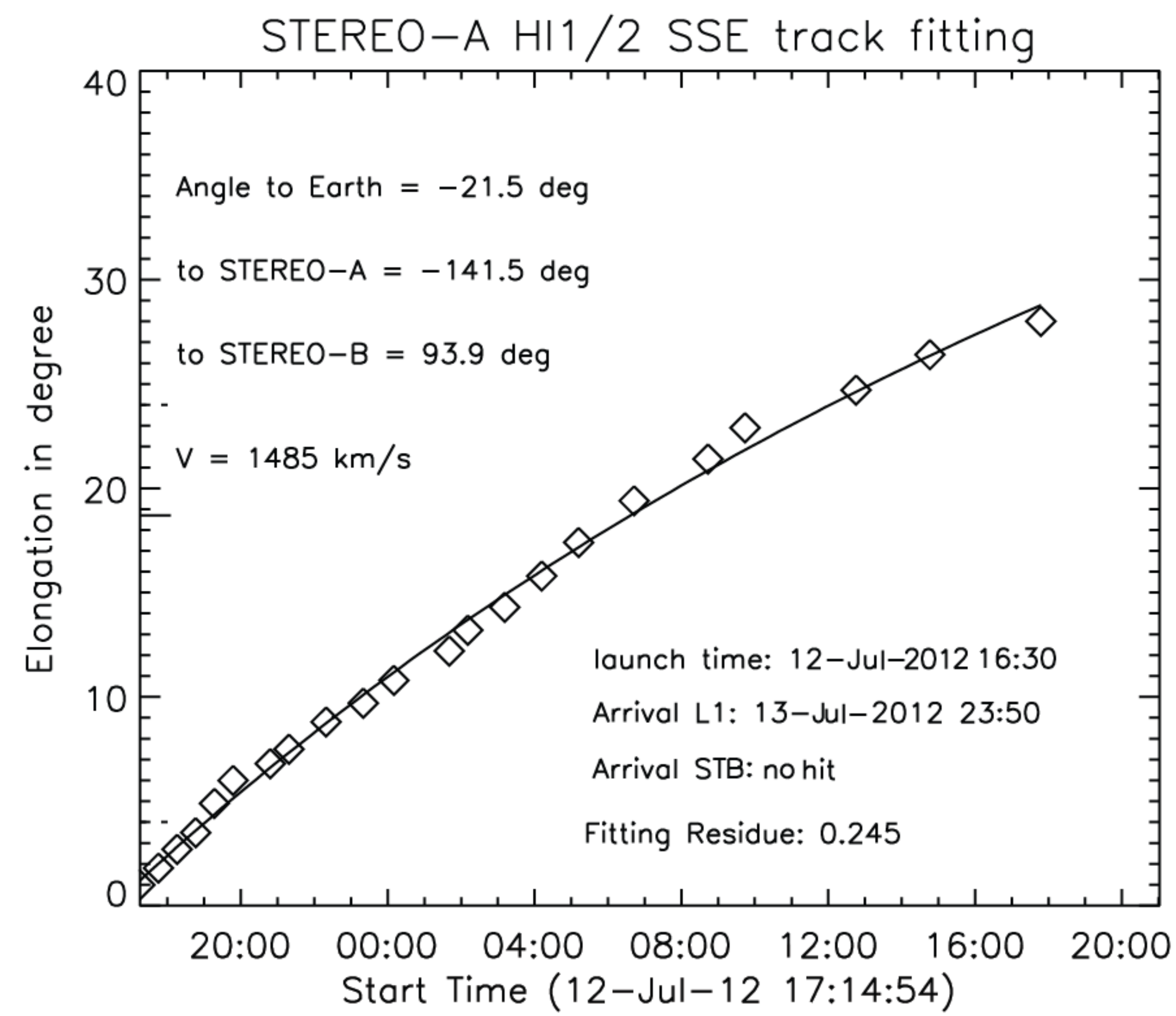
Well-established signatures of the CMEs in the STEREO/HI catalogue (WP2 and 3) will be identified in the low corona and photospheric magnetograms (flares, filaments, EUV post-eruption arcades, coronal dimmings, EUV waves, bipolar regions). The modelling methods used on HI data (in WP3) will produce windows for CME launch time and position on the solar disk, acting as proxies for identification of the sources in the low corona and photosphere.

Instruments used: STEREO/EUVI, SOHO/EIT+MDI, SDO/AIA+HMI, Proba2

Role of participants: UGOE: online cataloguing of signatures with back-projections from WP3.

Backprojection





Task 4.2
Comparing to in-situ measurements
[Months: 10-36]

WP4 description

UH, UNIGRAZ, UPS, UGOE, IMPERIAL

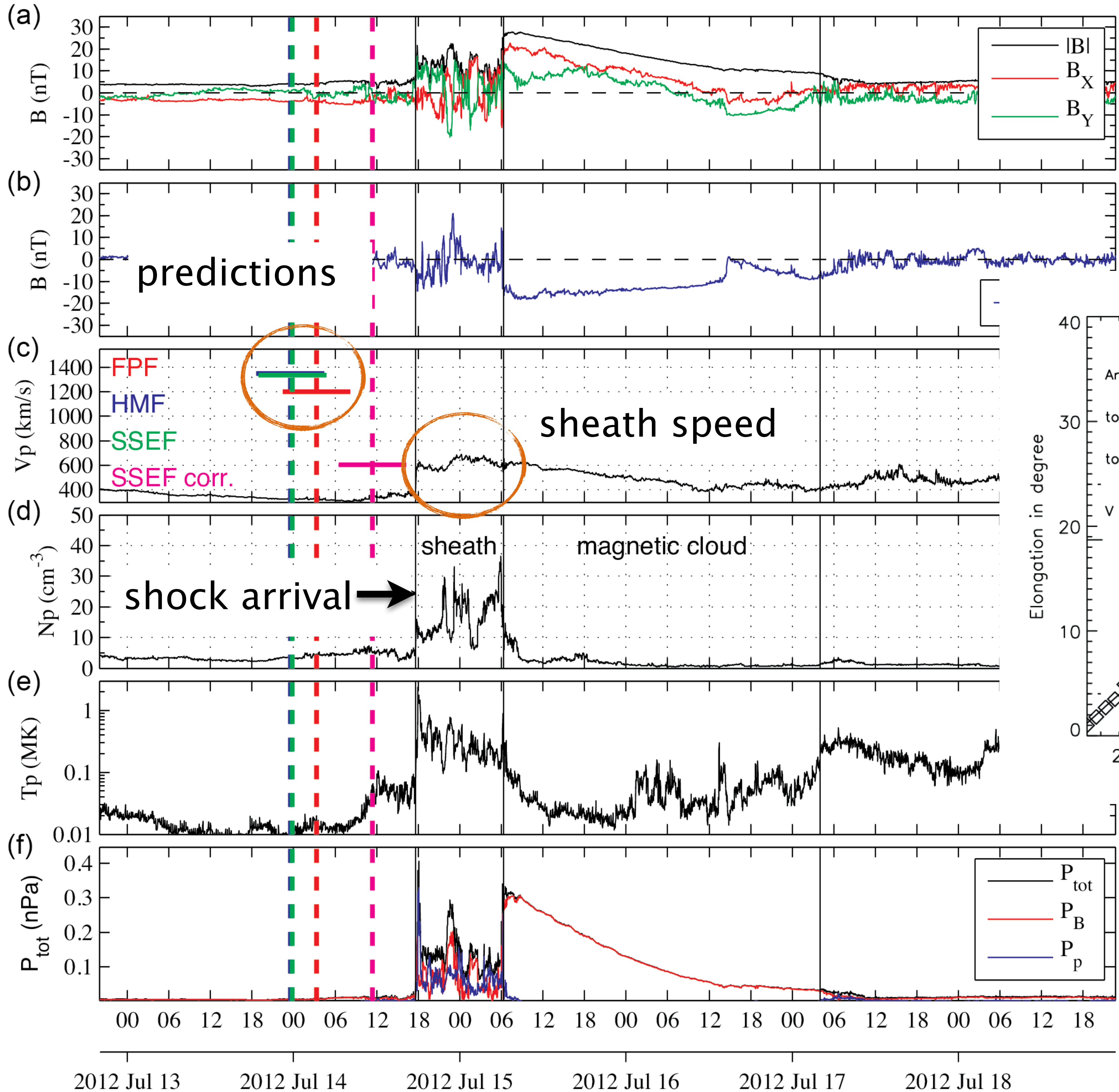
This task will combine in-situ observations from many spacecraft into a single comprehensive CME database by extensive analysis (of magnetic field, thermal plasma, suprathermal electrons and compositional data) during the estimated CME arrival times (from WP3). Use of a physics-based phenomenological characterization of CMEs and
their surrounding solar wind, which we have carefully evaluated to optimize comparison with remote observations, will maximize the benefit to us and other researchers in understanding CME effects. Task 4.2 will consist of the following:

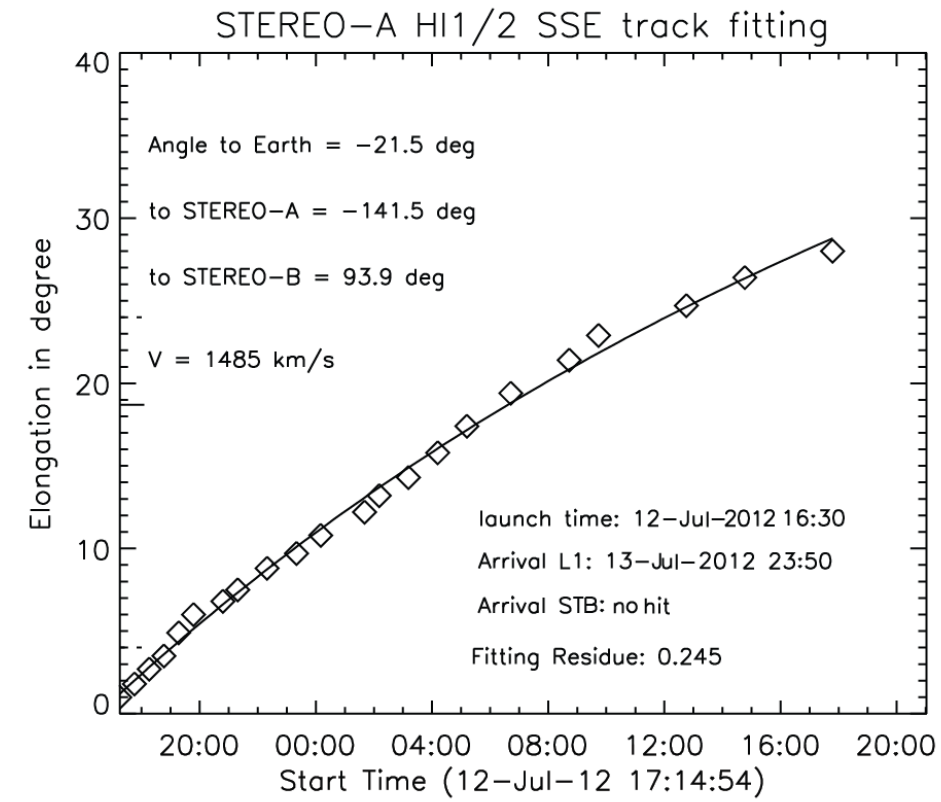
1. Categorizing CMEs based on their physical structure observed in-situ (e.g. flux rope/non-flux rope CMEs, complex CMEs, compound streams) and calculating relevant parameters (e.g. shock stand-off distance, expansion speed).
2. Modelling flux-rope CMEs using Grad-Shafranov (GS) reconstruction.
3. Categorizing CMEs based on ambient solar wind speed/interplanetary magnetic field structure.
4. Analysis of sheath/CME density substructures.

Instruments used: STEREO, Wind, ACE, Venus Express, MESSENGER, Ulysses, MSL

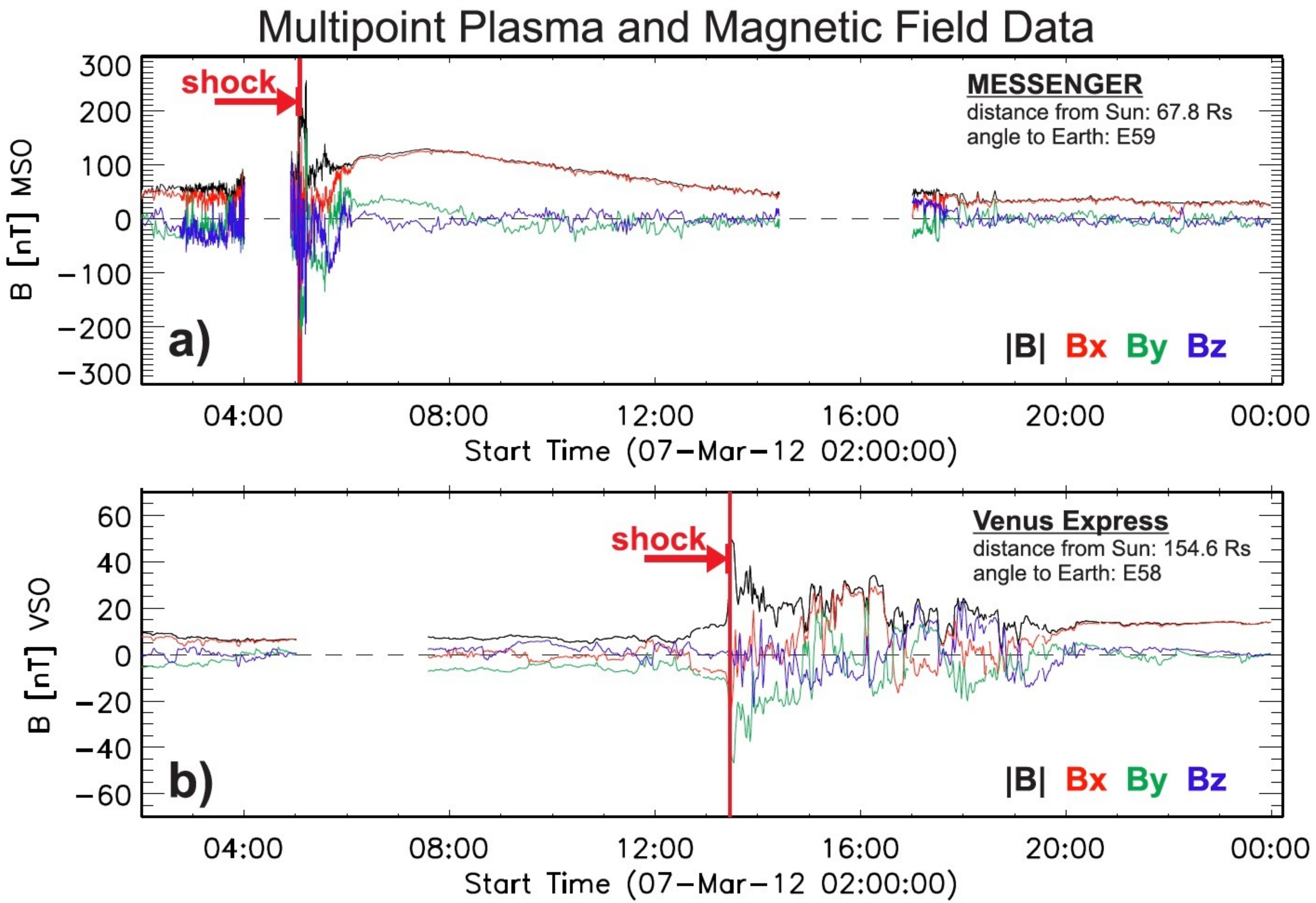
Role of participants: UH: CME categorization/cataloguing (L1 & STEREO in-situ data); UNIGRAZ: CME categorization/cataloguing (other data), GS reconstruction, multi-point heliospheric analysis; Imperial: multi-point
L1 analysis; UPS: sheath/substructure analysis; UGOE: Minimum Variance Analysis (MVA)

Wind July 12–14 2012





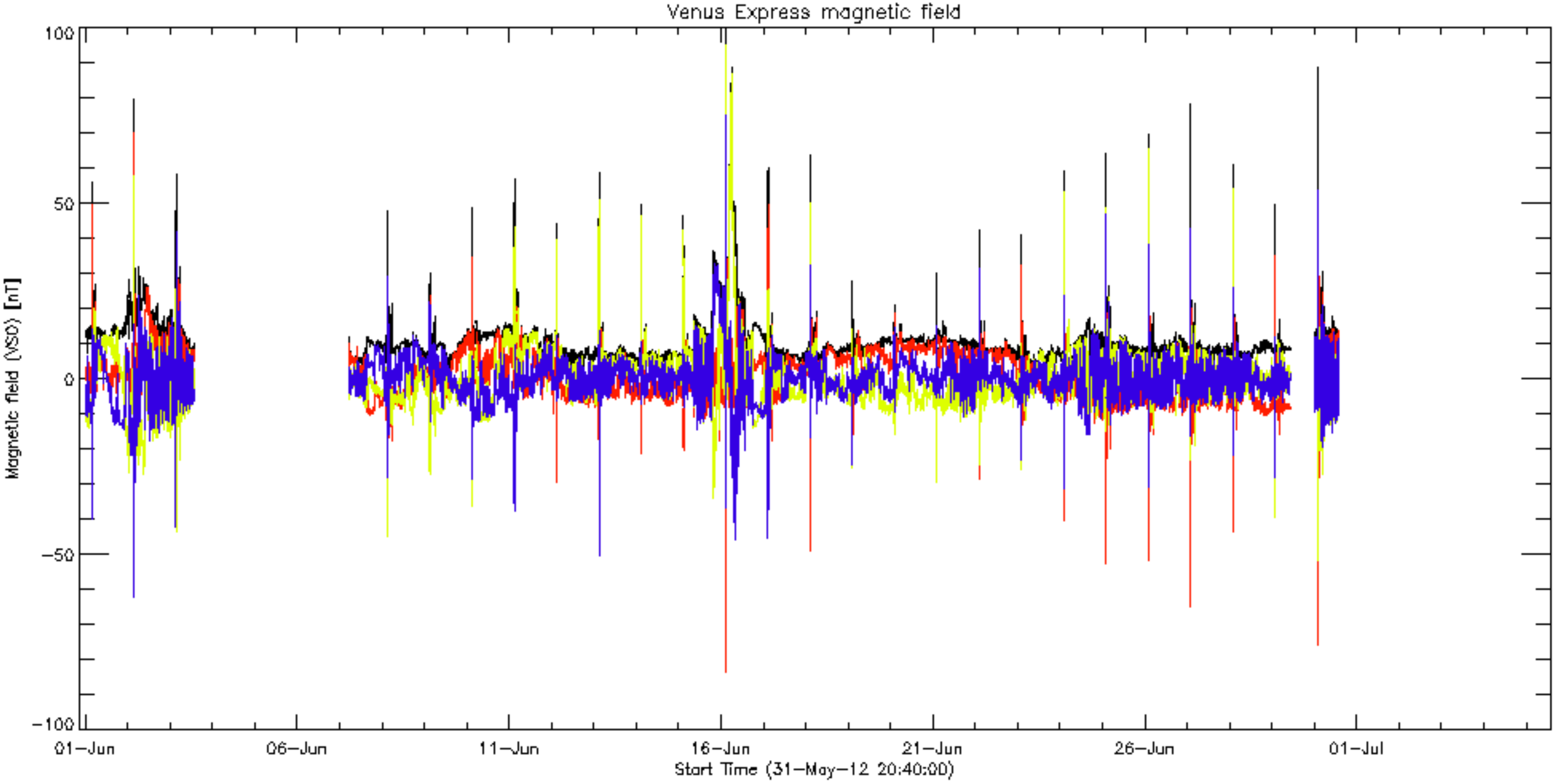
MESSENGER and VEX



Rollett et al. 2014 ApJL in revision

Venus Express

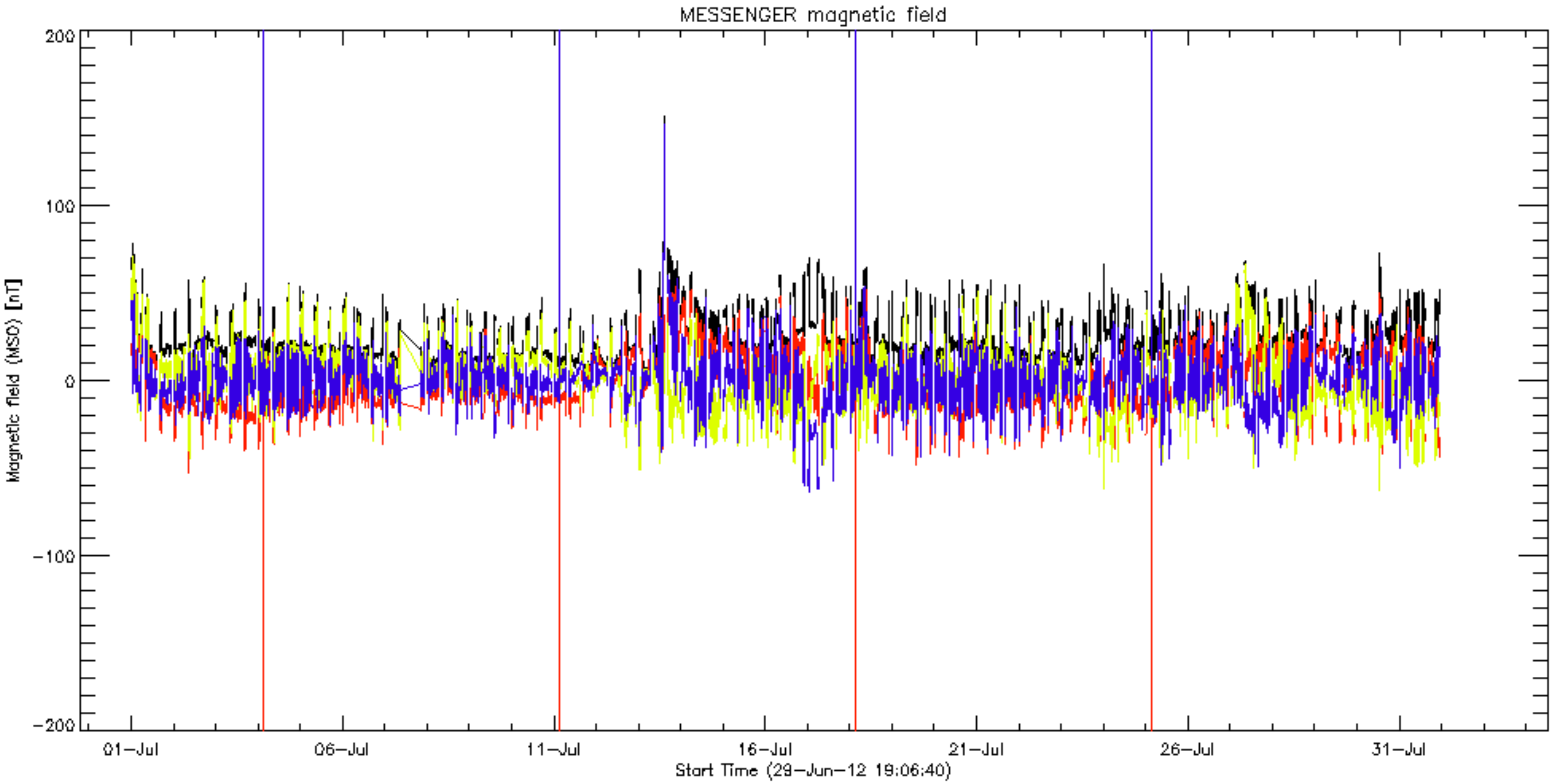
June 2012



- need to exclude intervals inside magnetopause

MESSENGER

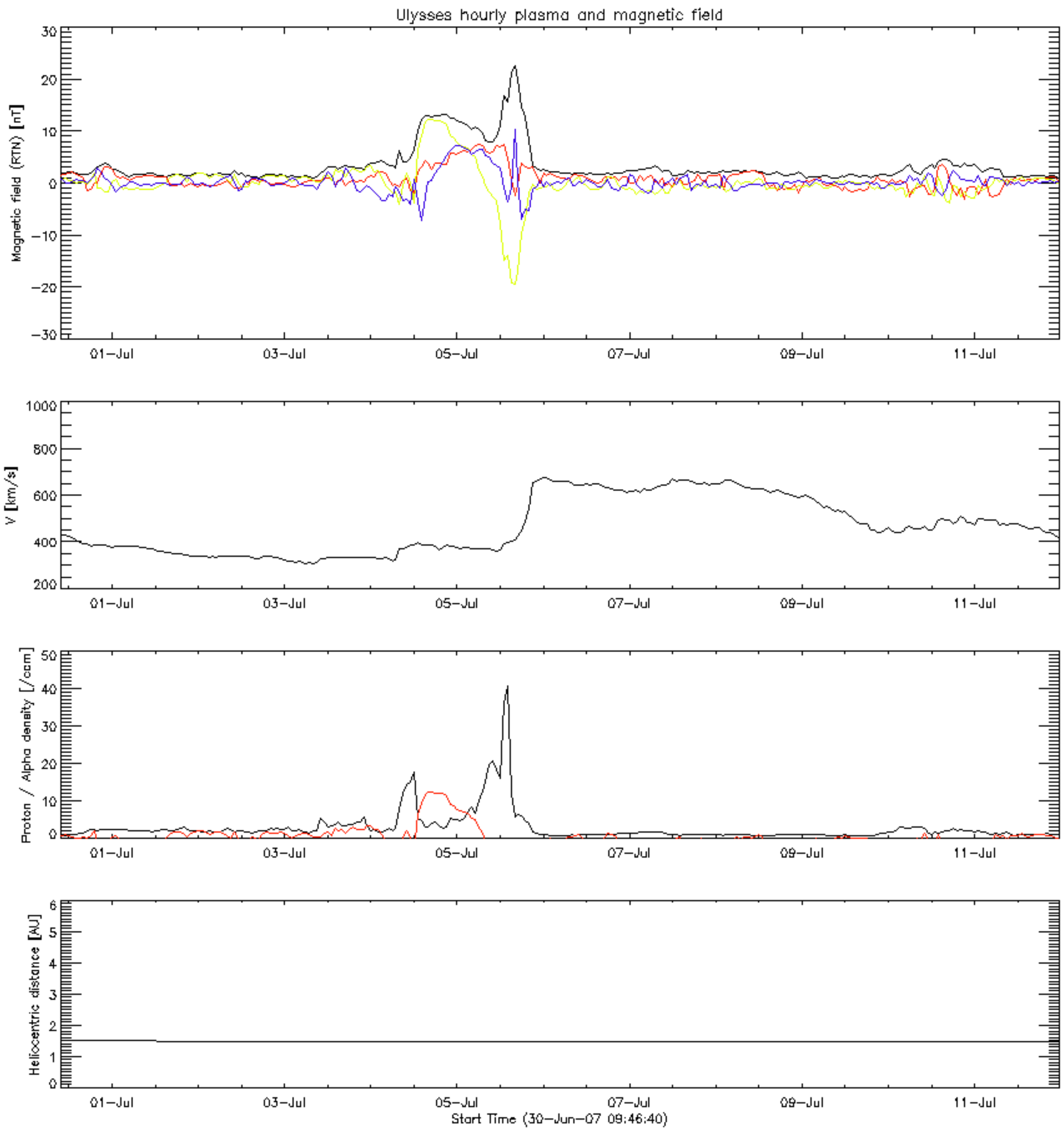
July 2012



- need to exclude intervals inside magnetopause

Ulysses

- Ex



Ulysses hourly plasma and magnetic field
Magnetic field (RTN) [nT]
V [km/s]
Proton / Alpha density [/ccm]
Heliocentric distance [AU]
01–Jul
03–Jul
05–Jul
07–Jul
09–Jul
11–Jul
Start Time (30–Jun–07 09:46:40)

Mars Science Laboratory