Interaction between ICMEs and Forbush decrease: a case study of multiple ICME events

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United Nations/Ecuador Workshop on the International Space Weather Initiative (8-12 October 2012, Quito, Ecuador)

Summary

Three aspects:

- SEVAN network
- ICMEs interaction and arrival time calculation
- Synchronization with decrease in cosmic ray intensity and solar wind disturbances

The data set

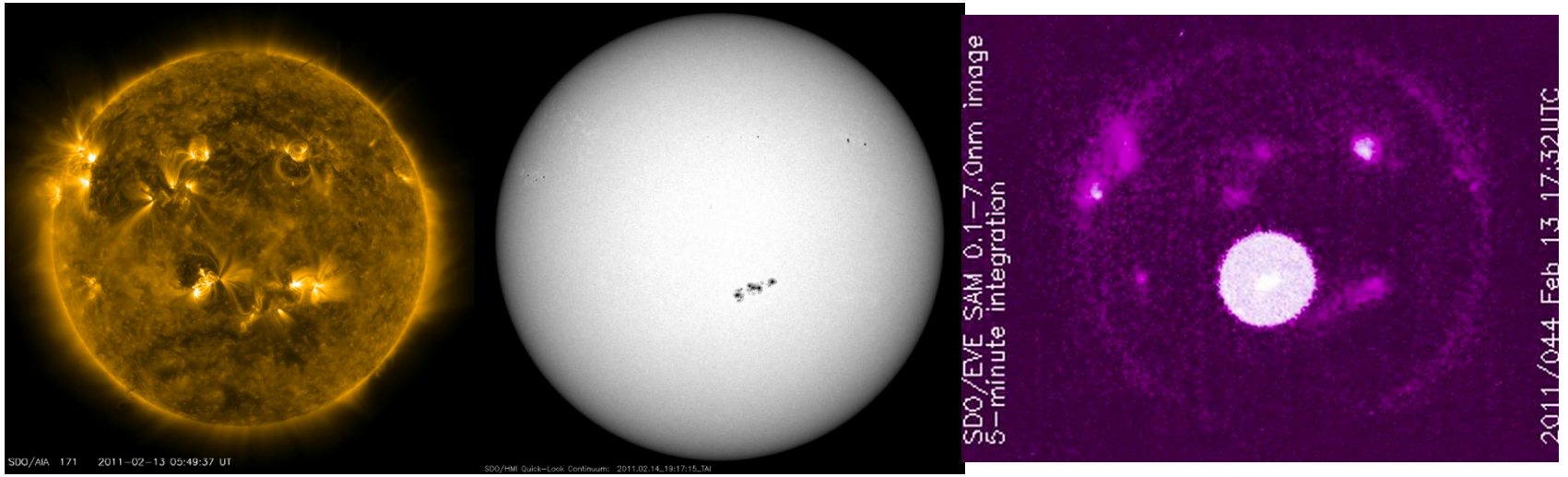
Instruments of the STEREO satellites

- SECCHI-EUVI Extreme Ultraviolet Imager (LMSAL) line of Fe xii, at 19.5 nm
- SECCHI-COR1 Inner Coronagraph (GSFC)
- SECCHI-COR2 Outer Coronagraph (NRL)
- SECCHI-HI Heliospheric Imager

For additional information we used the

- SDO Atmospheric Imaging Assembly (AIA) Fe ix 17.1 nm
- SDO/HMI Intensitigram – continuum
- SDO/EVE SAM pinchole camera
- SDO Extreme ultraviolet Variability Experiment (EVE) - SXR irradiance flux channel 0.1 – 7 nm

The data set



Accompained by

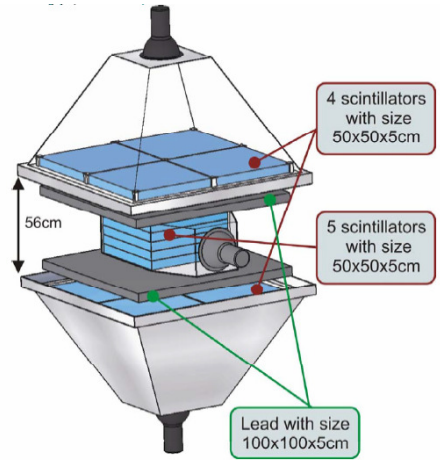
For solar wind disturbances we used the data from WIND satellite (http://wind.nasa.gov/mfi_swe_plot.php)

WDC for Geomagnetism, Kyoto Hourly Equatorial Dst index data (http://wdc.kugi.kyoto-u.ac.jp/index.html)

Space Environment Viewing and Analysis Network (SEVAN) (http://adei.crd.yerphi.am/adei/) a network of middle to low latitude cosmic rays detectors and Moscow neutron monitor (http://cr0.izmiran.rssi.ru/mosc/main.htm)

Space Environmental Viewing and Analysis Network (SEVAN)

A network of middle to low latitude particle detectors called SEVAN (Space Envirnomental Viewing and Analysis Network) - planned in the framework of the International Heliophysics Year (IHY).



100 – traversal of the low energy charged particle (~<200MeV);

010 – traversal of the neutral particle;

111 & 101 – traversal of the high energy muon (~>250MeV);

Construction of the SEVAN basic unit and possible location

Different coincidences of SEVAN detector correspond to different species of secondary cosmic rays

Space Environmental Viewing and Analysis Network (SEVAN)

SEVAN – Count Rates

SEVAN Monitor	Altitude (m)	Geographical coordinates	Rc (Gv)	Low energy particles (Coinc.100)	Simulated count rate	Neutral particles (Coinc. 010)	Simulated count rate	High energy muons (Coinc. 111 + Coinc.101)	Simulated count rate
Aragat (Armenia)	3200	40°28'N, 44°10'E	7.1	16010 ± 130	17330	2007 ± 46	1680	4056 ± 64	8051
Nor Amberd (Armenia)	2000	40°22'N, 44°15'E	7.1	11593 ± 161	10220	690 ± 27	795	4473 ± 99	5548
Yerevan (Armenia)	1000	40°22'N, 44°15'E	7.1	8862 ± 108	7202	363 ± 19	359	4337 ± 67	5477
Musala (Bulgaria)	2952	42°10'N, 23°35'E	7.1	15479 ± 136	17526	1115 ± 38	967	6315 ± 68	7136
Zagreb (Croatia)	160	45°49'N, 15°58'E	7.1	6415 ± 84	6642	316 ± 18	354	3824 ± 64	4326
Jawaharlal (India)	258	28°32'N, 77°09'E	7.1	7479 ± 106	7531	515 ± 22	534	4318 ± 78	5324
Next instalation Slovakia (Lomnicky Stit) and Germany (Khalsrue)									

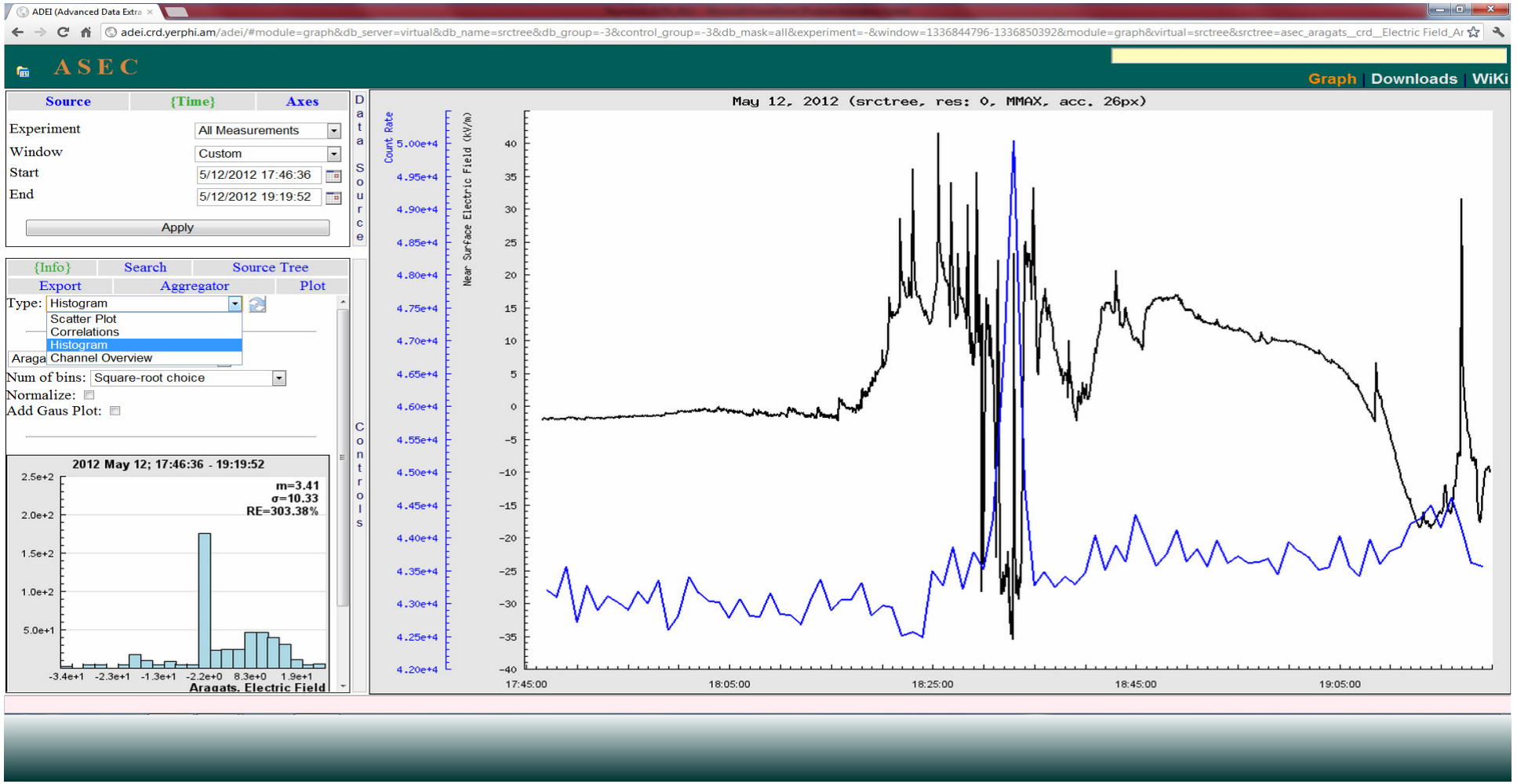
Space Environmental Viewing and Analysis Network (SEVAN)

http://sevan.aragats.am/

Space Environmental Viewing and Analysis Network (SEVAN)

Advanced Data Extraction Infrastructure (ADEI)

http://adei.crd.yerphi.am/



ICME interaction and Forbush decrease

We study propagation and space weather effects of three Earth-directed interplanetary coronal mass ejections (ICMEs), originating in the time periods:

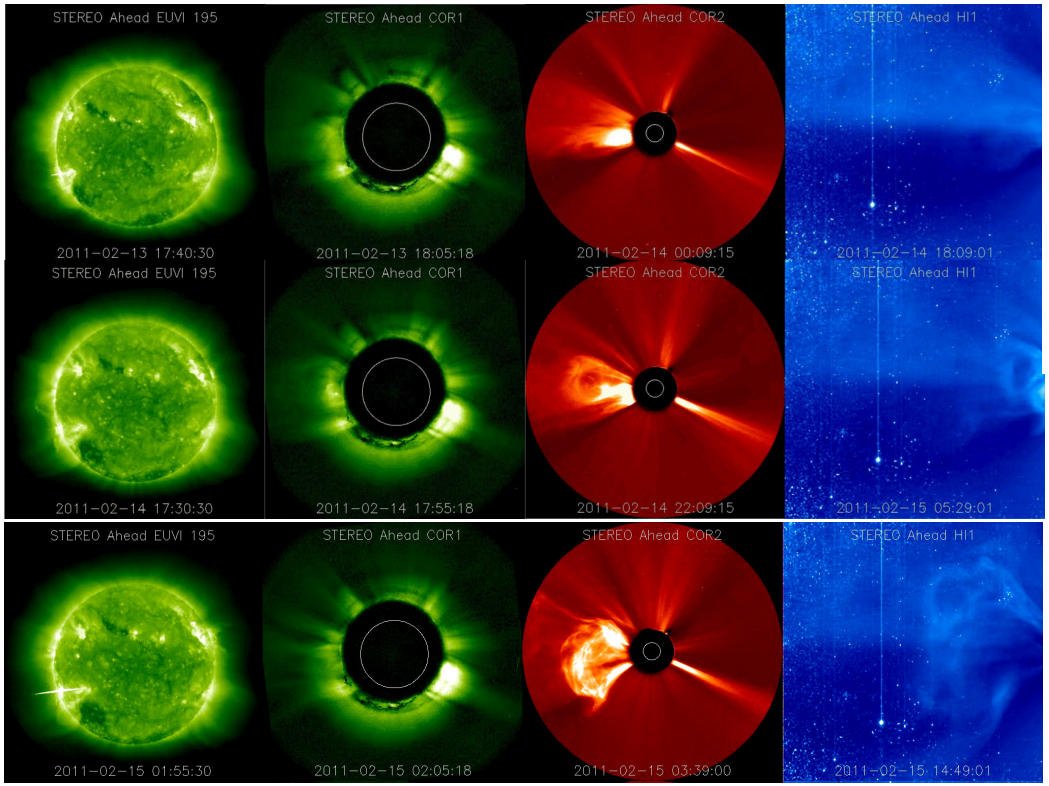
PERIODS	DATE OF THE FD
• 13^{th} – 18^{th} February 2011 ICMEs	- 18^{th} February 2011 FD
• 18^{th} - 24^{h} January 2012 ICMEs	- 24^{th} January 2012 FD
• 06^{th} - 12^{th} March 2012 ICMEs	- 8^{th} and 12^{th} March 2012 FD

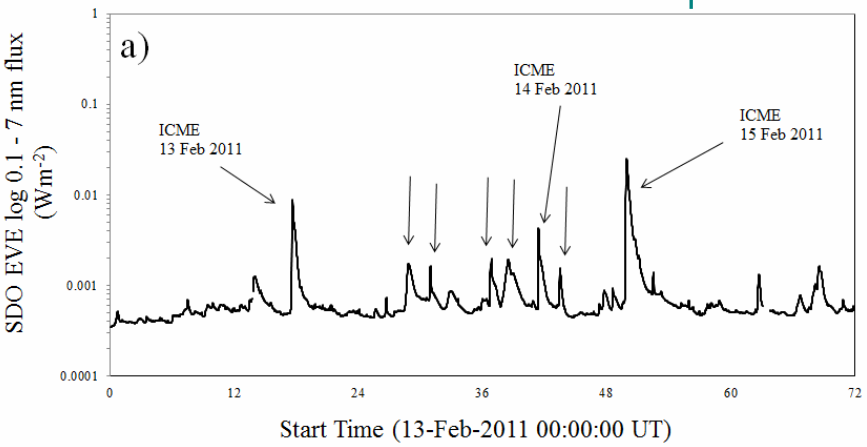
Analyze include:

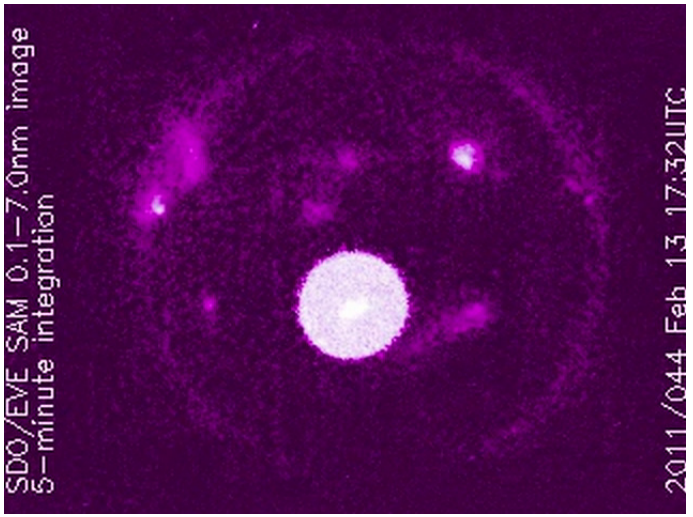
- general description of the event
- kinematic measurements
- analyze of the synchronization of ICMEs with accompanied flare energy release
- CMEs interaction on the way to Earth
- calculation of the arrival time of the ICMEs at Earth distance and
- synchronization with solar win disturbances and Forbush decrease

We present on the 13^{th} - 18^{th} February 2011

General description of the event
18th February 2011





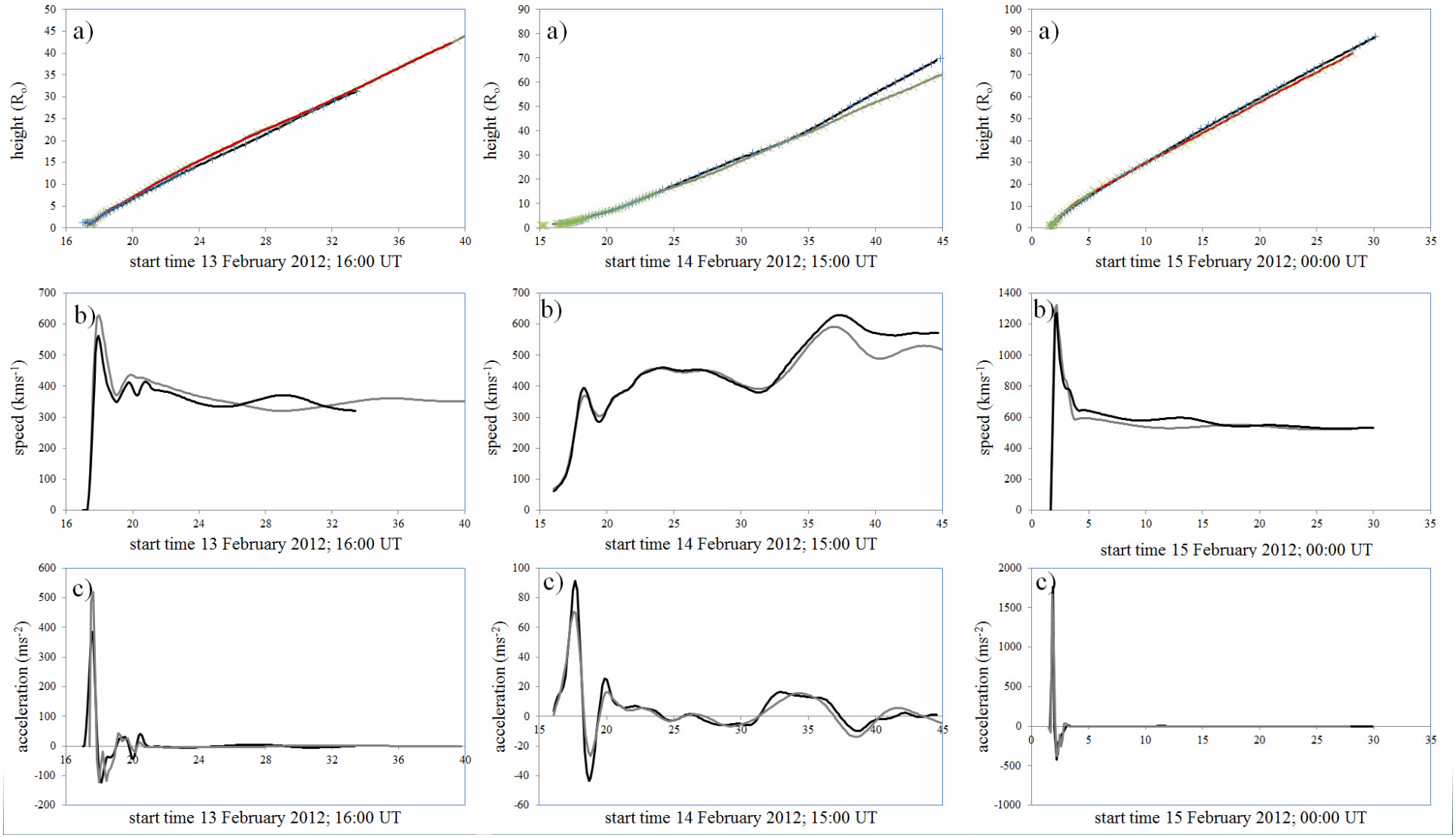


1 AU = 149597870.7 km; 18 Feb Earth at 0.988 AU
originating from the same active region AR11155
STEREO *A* and *B* was ~179° in longitude
(separation angles with Earth ~ 94° and ~87°, respectively)

General description of the event

18th February 2011

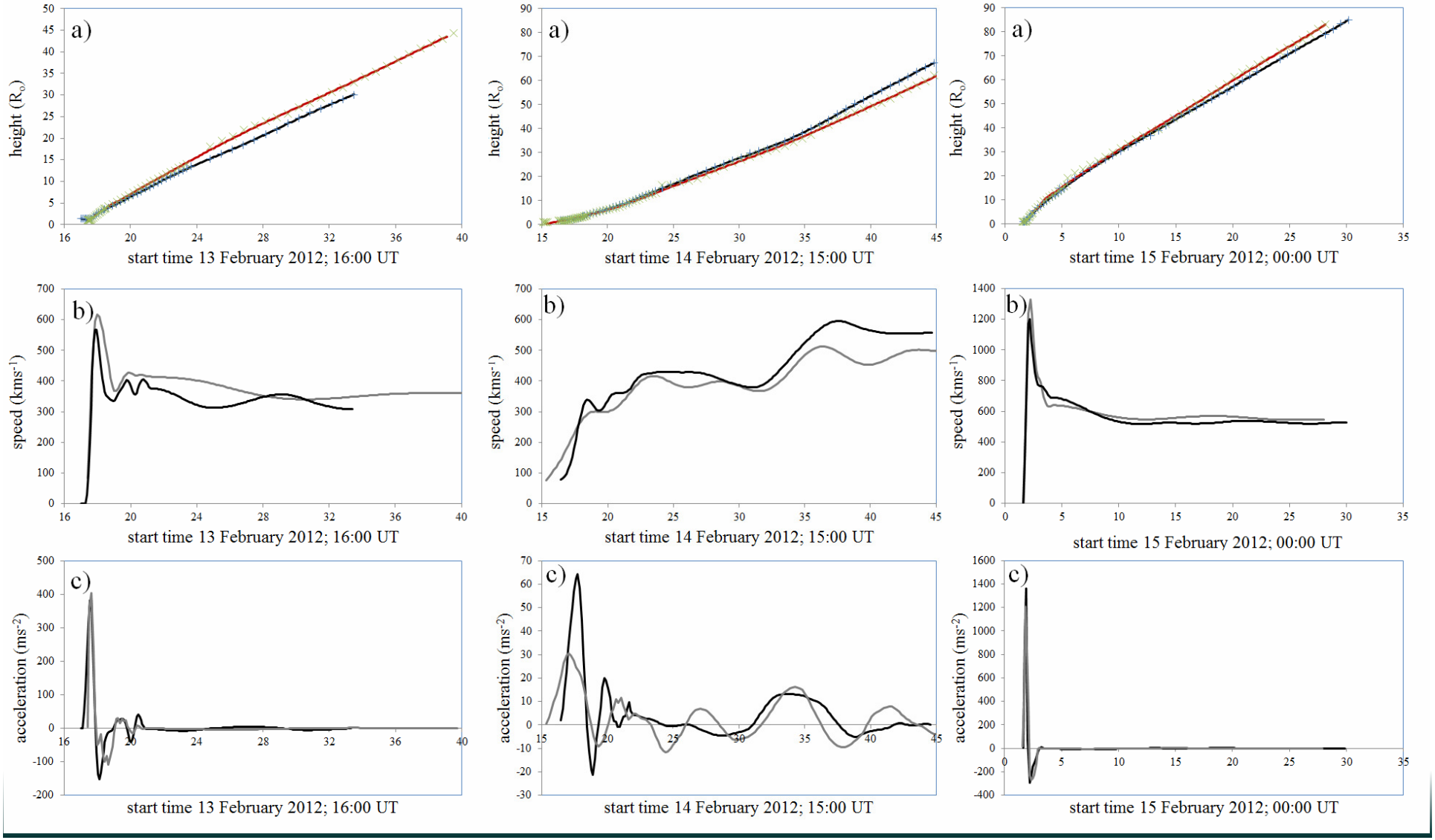
STEREO A and B data – raw data



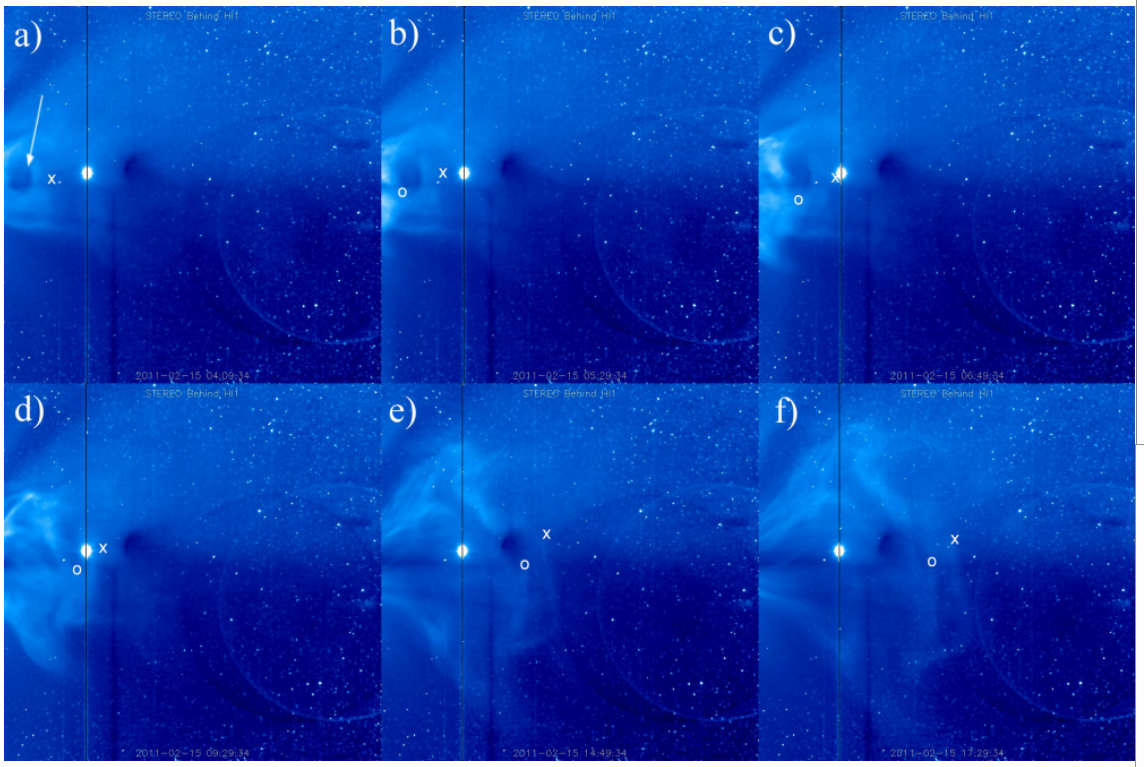
General description of the event

18th February 2011

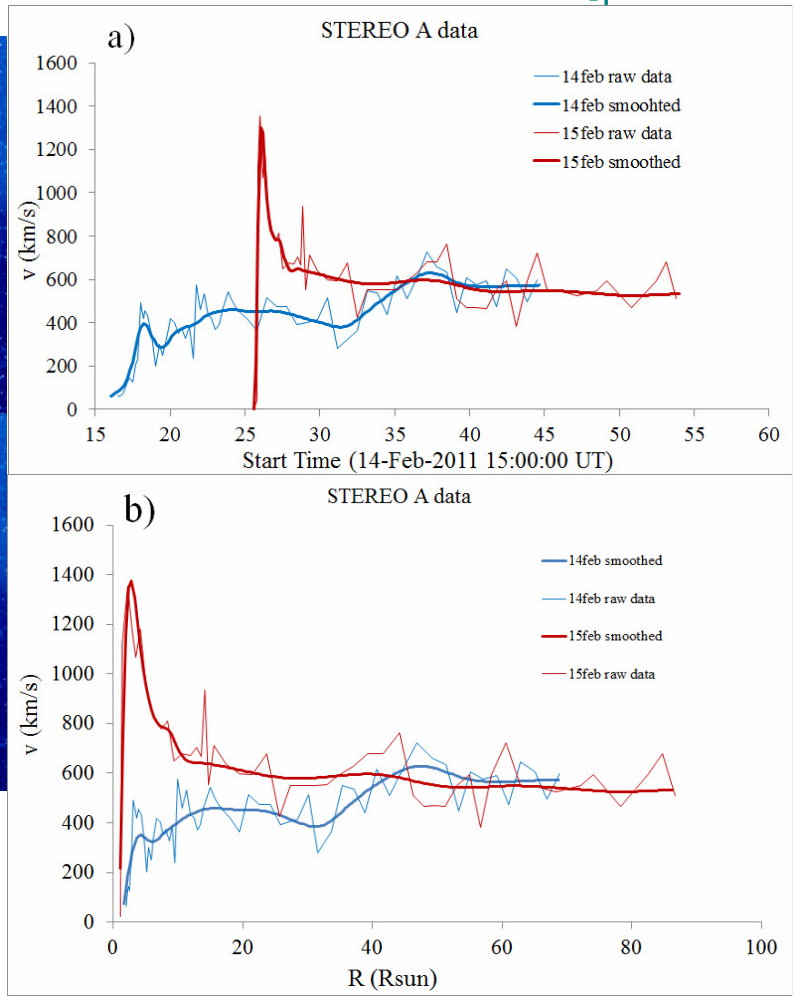
STEREO A and B data - Harmonic Mean method



General description of the event
18th February 2011

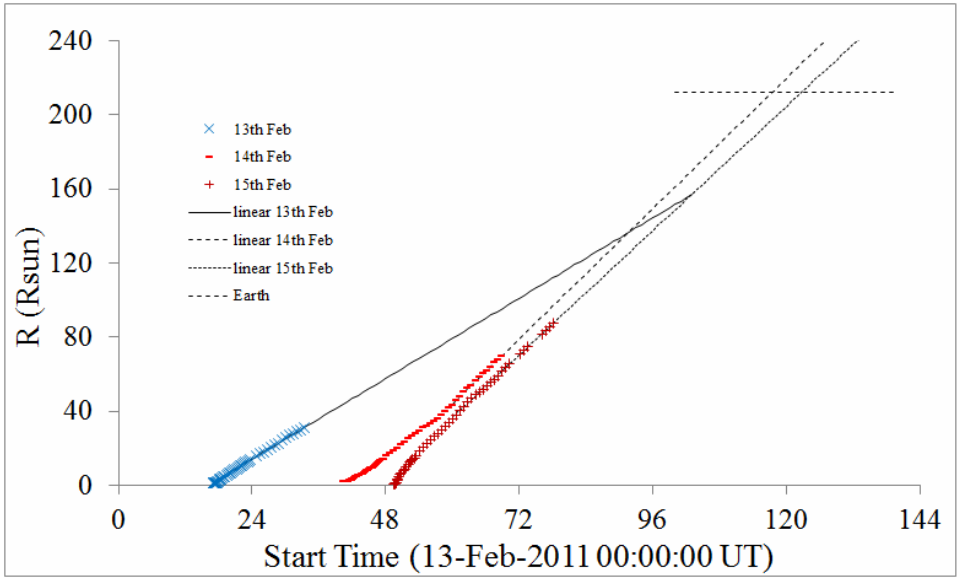


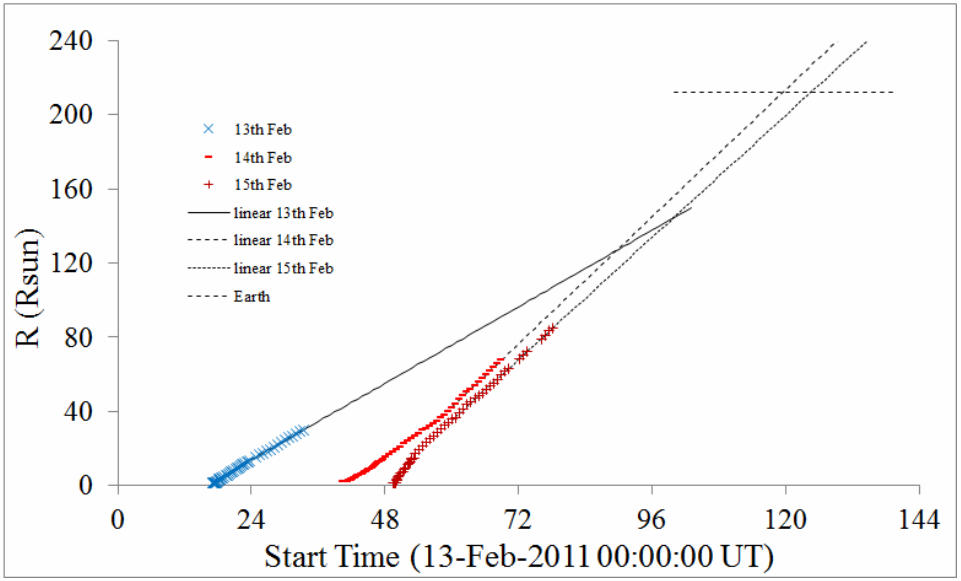
STEREO B HI I images of 14Feb and 15Feb CME-CME interaction. With x and o we denoted the measured frontal rim of 14Feb and 15Feb CMEs, respectively.



Kinematical curves for 14Feb (blue) and 15Feb (red) CMEs for STEREO A (left) measurements. On a) velocity - time plots and b) velocity - distance plots.

General description of the event
18th February 2011





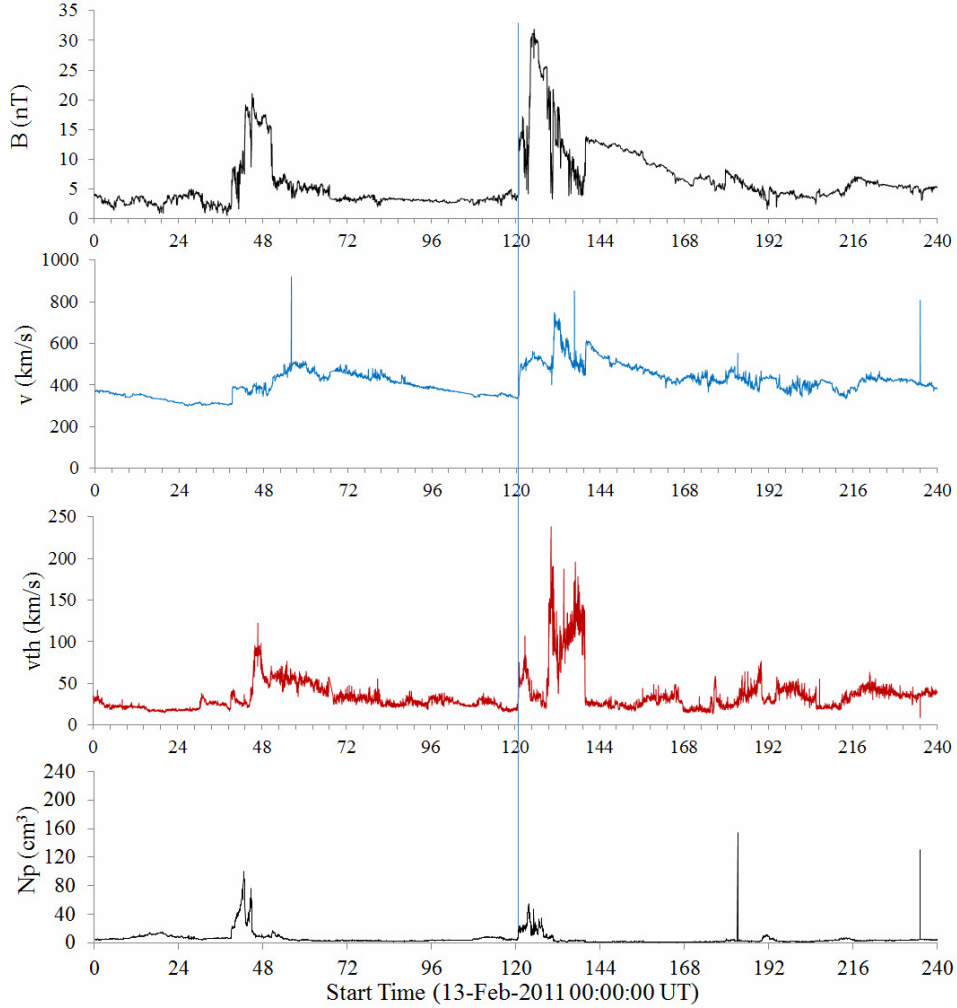
Prediction of the interaction with 13Feb CME and arrival time at Earth distance using linear fit extrapolation (left), linear fit extrapolation gained with Harmonic mean conversion (right).

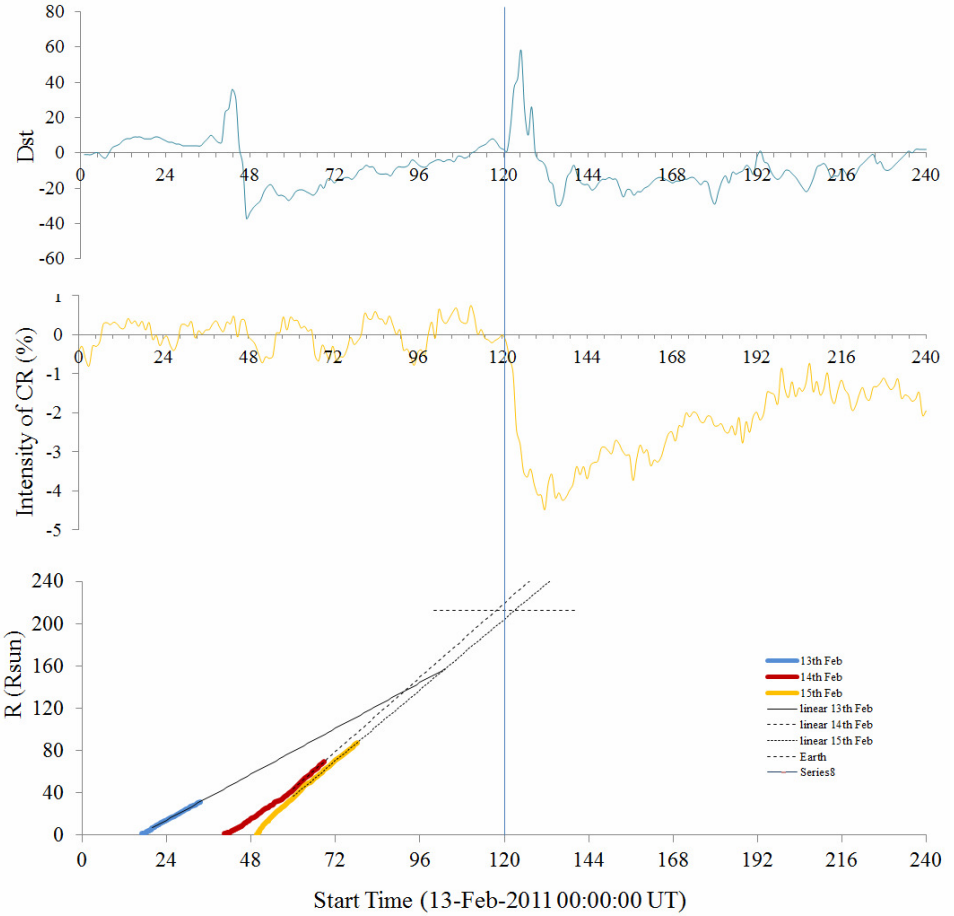
Dashed line - Earth distance on 18th February 2011.

Using extrapolated kinematics we infer that the two ICMEs reach and presumably interact with another ICME, as it originates from the same active region and propagates in the same direction (i.e. towards the Earth).

General description of the event

18th February 2011



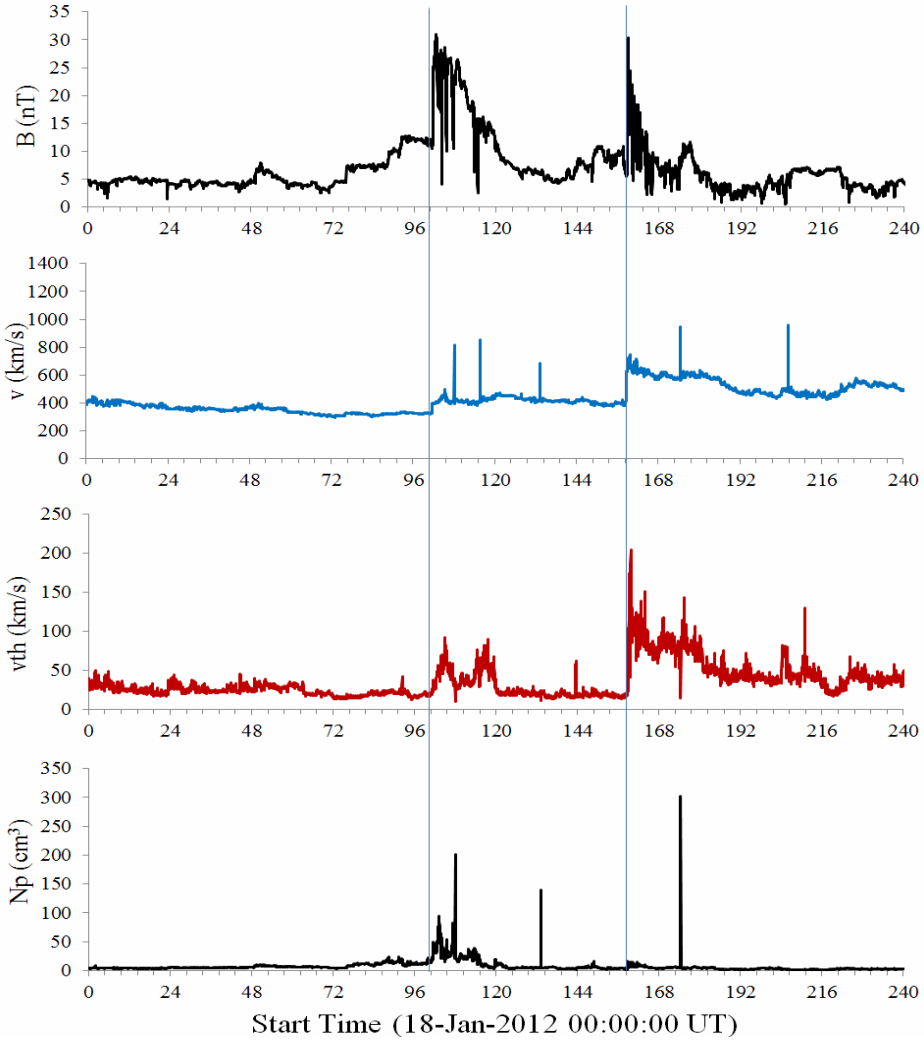


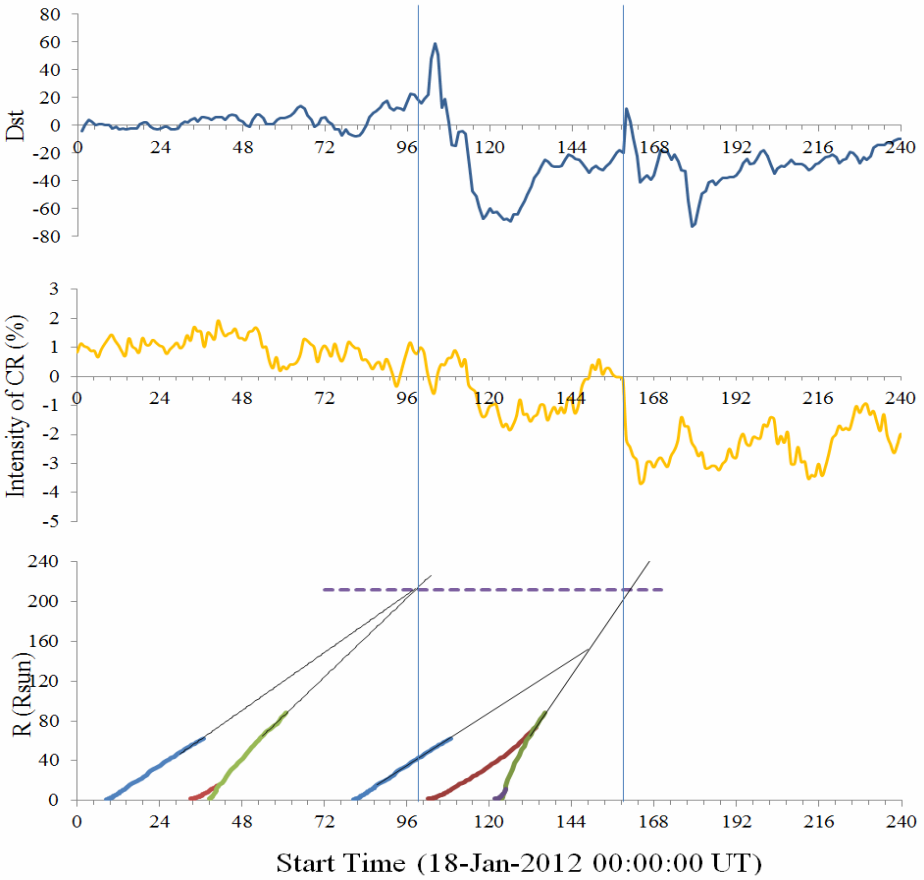
Arrival time and onset of the FD

Predicted arrival time of :			Stdev (hours)
direct measurement from STEREO A data	doy 49.11	02:50 UT 18 February 2011	± 10
direct measurement from STEREO B data	doy 49.18	04:30 UT 18 February 2011	± 10
Harmonic Mean STEREO A data	doy 49.19	04:40 UT 18 February 2011	± 10
Harmonic Mean STEREO B data	doy 49.09	02:15 UT 18 February 2011	± 10
Measured in situ onset times:			Stdev (hours)
WIND shock arrival time	doy 49.02	00:30 UT 18 February 2011	± 3
WIND ICME1 arrival time	doy 49.19	04:30 UT 18 February 2011	± 3
WIND ICME2 arrival time	doy 49.41	10:00 UT 18 February 2011	± 3
WIND ICME3 arrival time	doy 49.81	19:30 UT 18 February 2011	± 3
WIND ICME3 end time	doy 51	00:00 UT 20 February 2011	± 3
Measured CR onset times:			Stdev (hours)
onset of FD	doy 49.83	00:50 UT 18 February 2011	± 5
minimum of the FD	doy 49.56	13:30 UT 18 February 2011	± 5
end of the FD recovery	doy 53.71	17:00 UT 22 February 2011	± 5

General description of the event

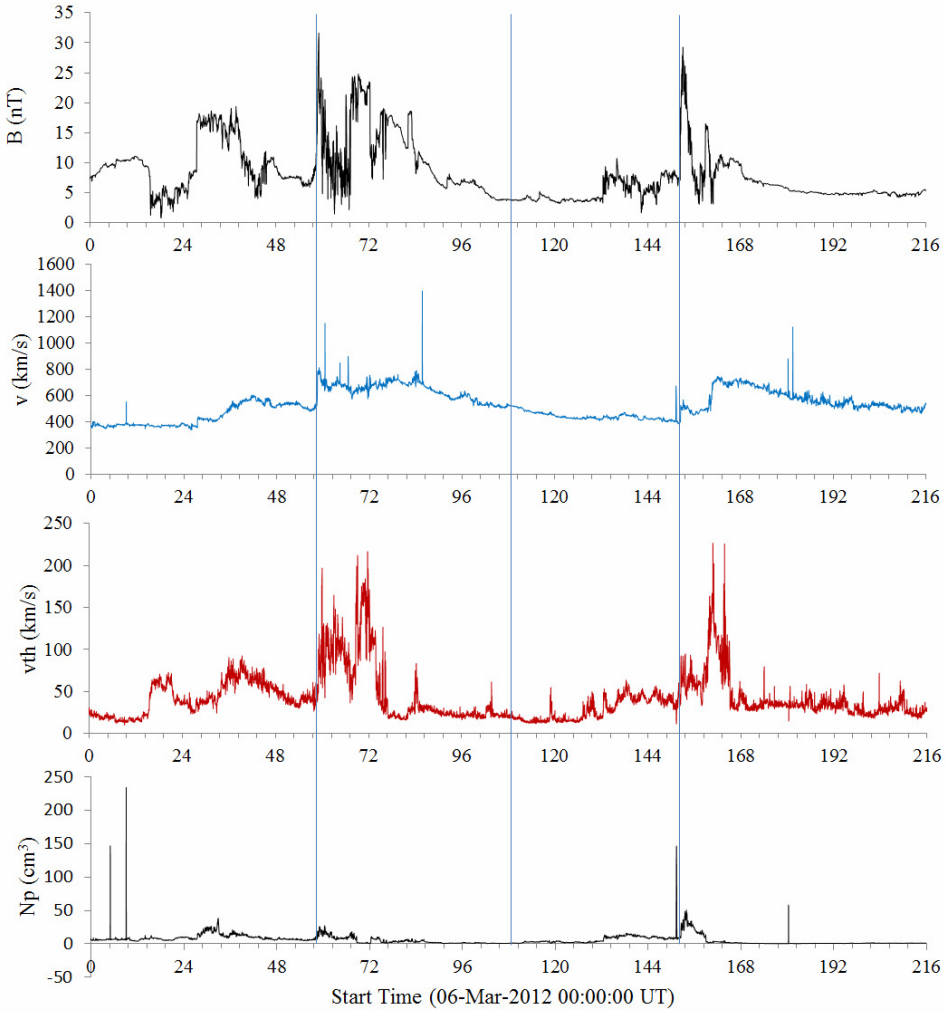
24th January 2012

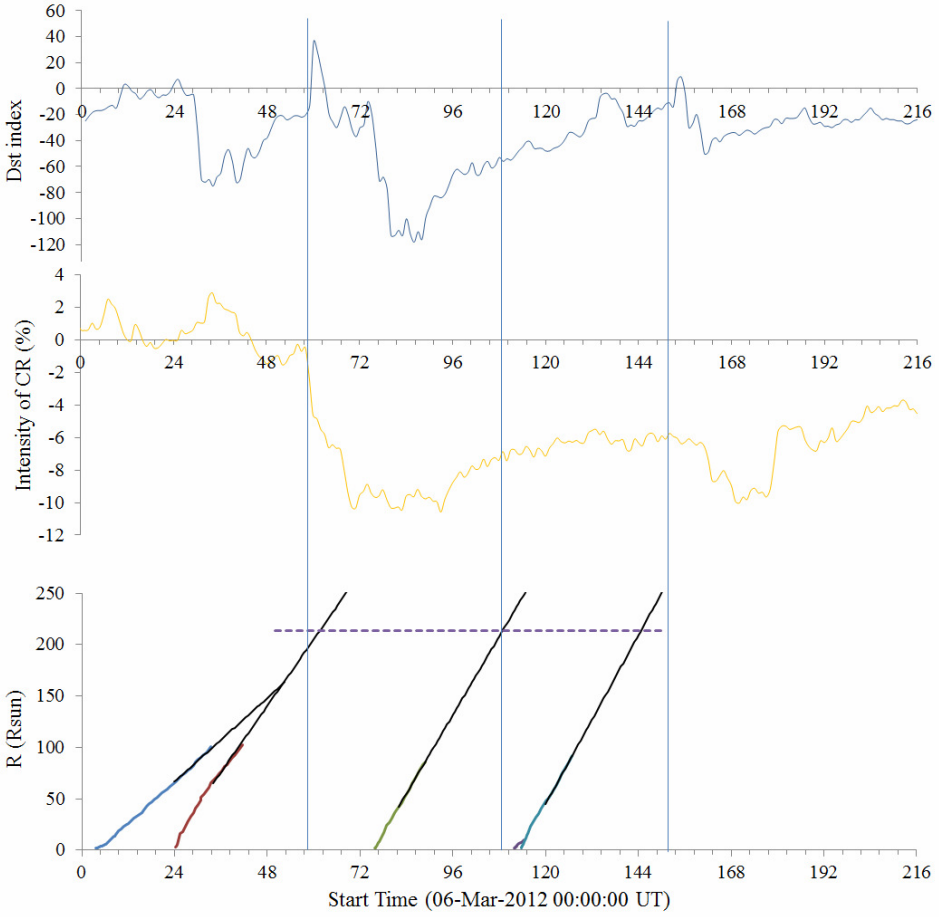




General description of the events

8th and 12th March 2012





Conclusions

- From kinematics analysis and in situ observations we infer that the ICMEs interact on their way to Earth, arriving together at Earth distance as a complex structure.
- Furthermore, as seen from the ground based cosmic ray observations, this complex structure produced a single cosmic ray event, i.e. Forbush decrease (FD).
- ICMEs interaction is not a rare phenomena.
- It seems that decreases in galactic cosmic rays flux >3% are mostly caused by ICMEs interaction.
- In future, with the results of this case study we can get better insight in the understanding of ICME interactions, consequently leading to improved space weather forecasting.

Conclusions

Remote satellite data from STEREO and SDO spacecrafts were used to identify, characterize and obtain kinematical data for three Earth directed CMEs from the same active region (AR11155).

From kinematics analysis and in situ observations we infer that the ICMEs interact on their way to Earth, arriving together at 1 AU as a complex structure.

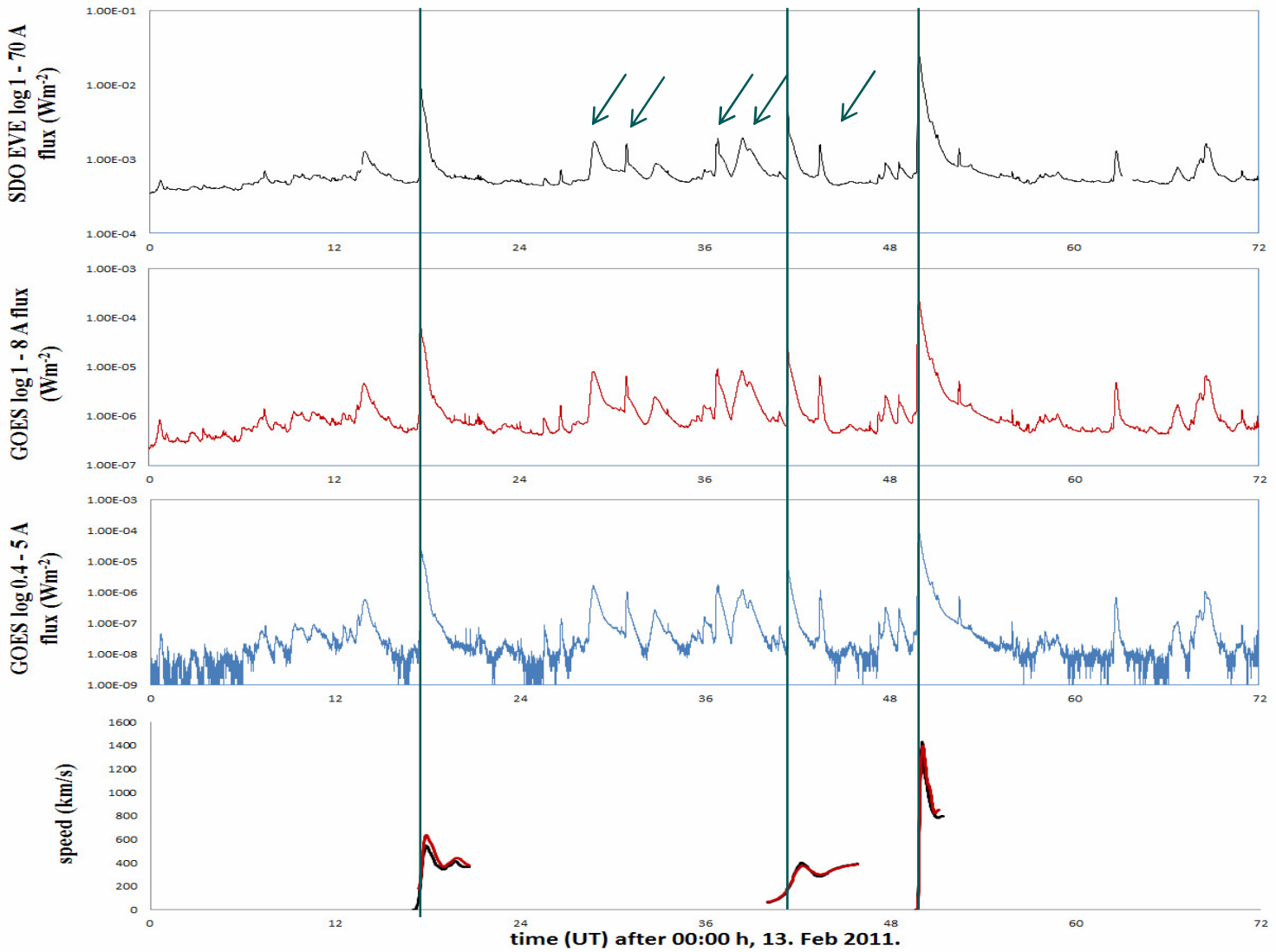
Furthermore, as seen from the ground based cosmic ray observations, this complex structure produced a single cosmic ray event, i.e. Forbush decrease (FD).

Two of them interacted in the STEREO coronagraphs field of view, providing the opportunity to directly observe an ICME-ICME interaction.

From the kinematical data we conclude that the ICMEs undergo nondisipative collision with a momentum transfer, as the shock of the trailing ICME passes through the leading ICME and the two continue propagating together.

Furthermore, from extrapolated kinematics we derive approximately the arrival time at L1 and associate these events with in situ complex ICME event, consisting of a shock sheath region and three ICMEs. We find that the three ICMEs identified at L1 match three ICMEs observed in HI1, with ICME1 and ICME2 partly merged as they undergo magnetic reconnection at their interface.

Synchronization of ICMEs and flare energ. release



Space Environmental Viewing and Analysis Network (SEVAN)

One of the major advantages of multiple-particles detectors is probing of the different populations of primary cosmic rays, initiated particle cascades in terrestrial atmosphere. With basic detector of SEVAN network we are measuring fluxes of neutrons and gammas, of low energy charged component and high energy muons. This diversity of information obtained from SEVAN network will give possibility to estimate the energy spectra of the highest energy SCR and distinguish very rare events of direct solar neutron detection.

Probe different populations of primary cosmic rays with rigidities from 7 GV up to 20 - 30 GV.

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