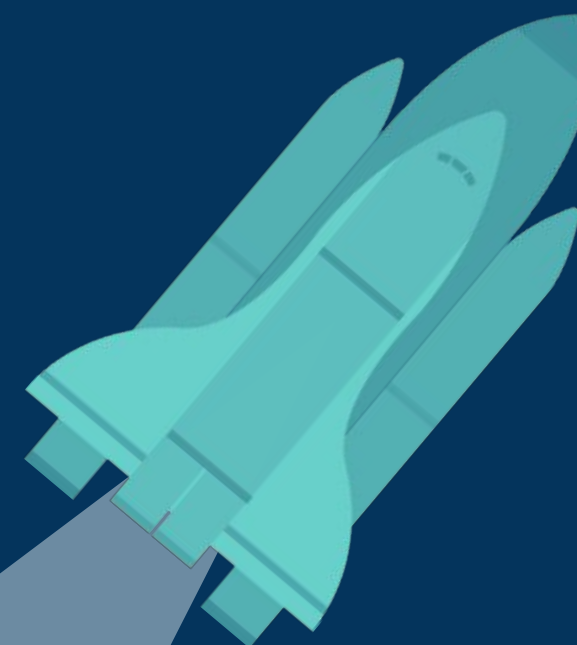


BRANCH COSMOS PRESENTS:

FIRST SUMMER SCHOOL ON SPACE RESEARCH, TECHNOLOGY AND APPLICATIONS

Report on practical session:

Sun & Space weather



AMERICA FOR
BULGARIA
FOUNDATION



Under the auspices of



REPUBLIC OF BULGARIA
Ministry of Economy



Team/Project 'Ra' (the Sun God)

Participants:

Mohamed

Grozdan

Rositsa (on-site assistant)

Mentor:

Dr. Manuela Temmer



Mohamed,
Grozdan,
Rositsa



Project objective: Forecasting CME impacts

Objective

- to forecast the arrival of CMEs at a given location in the heliosphere (e.g. Earth) in terms of its geo-effectiveness (the ability to drive geomagnetic storm)

Event selection (historical cases)

- selection of the strongest solar activity events in solar cycle (SC) 24: 2009-2019

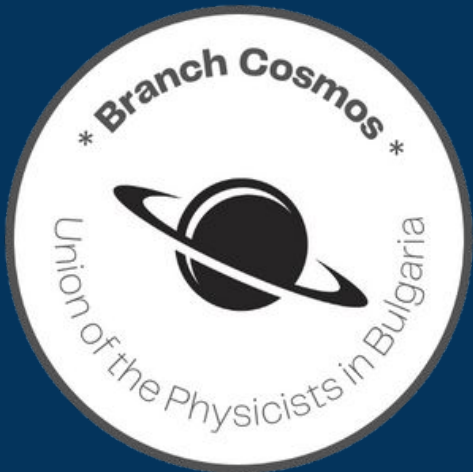
Methodology

- using remote sensing, in situ observations and transport modeling (DBEM)

Validation

- comparison of the forecasted results with in situ and ground-based measurements

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Event selection

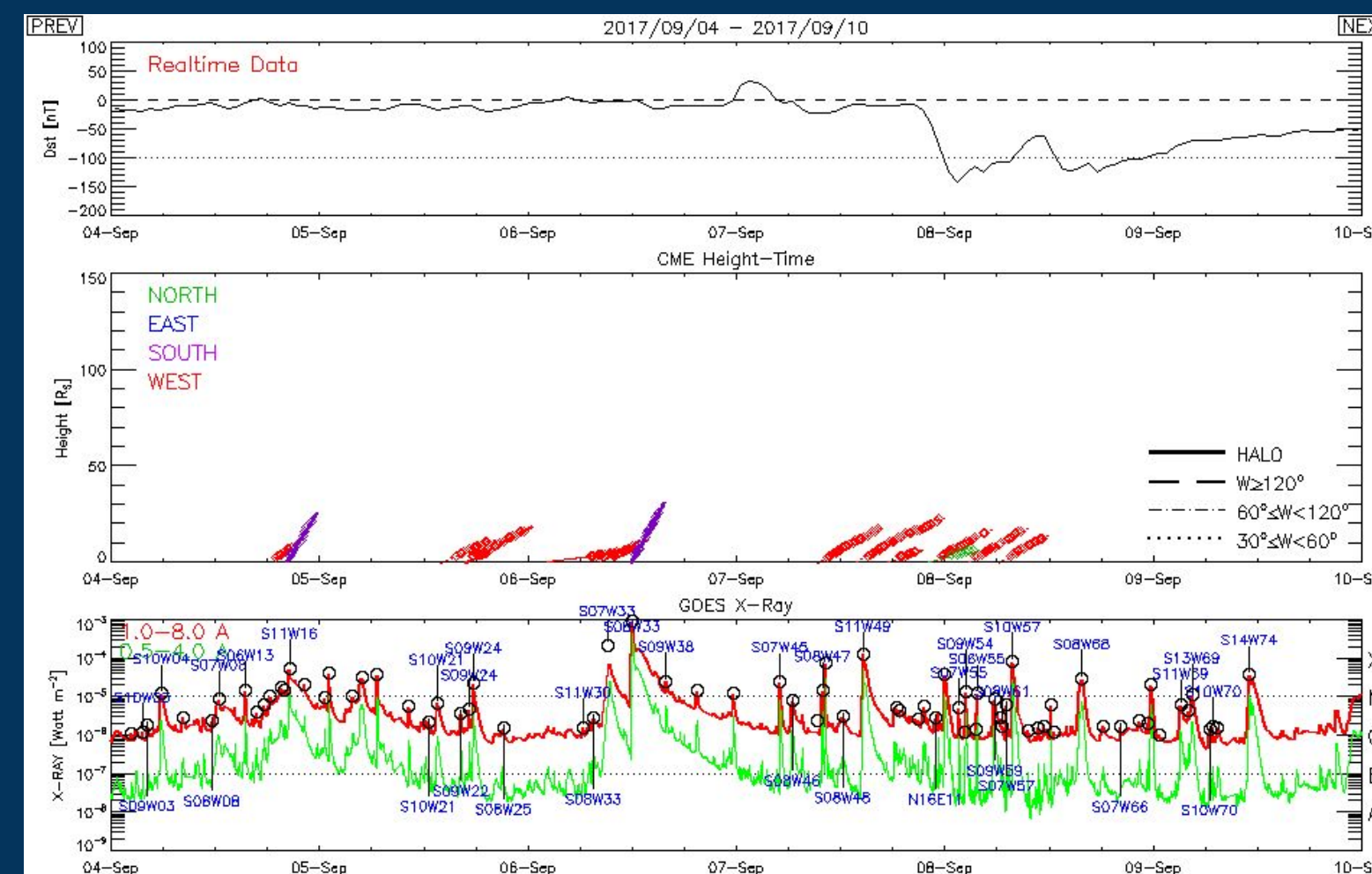
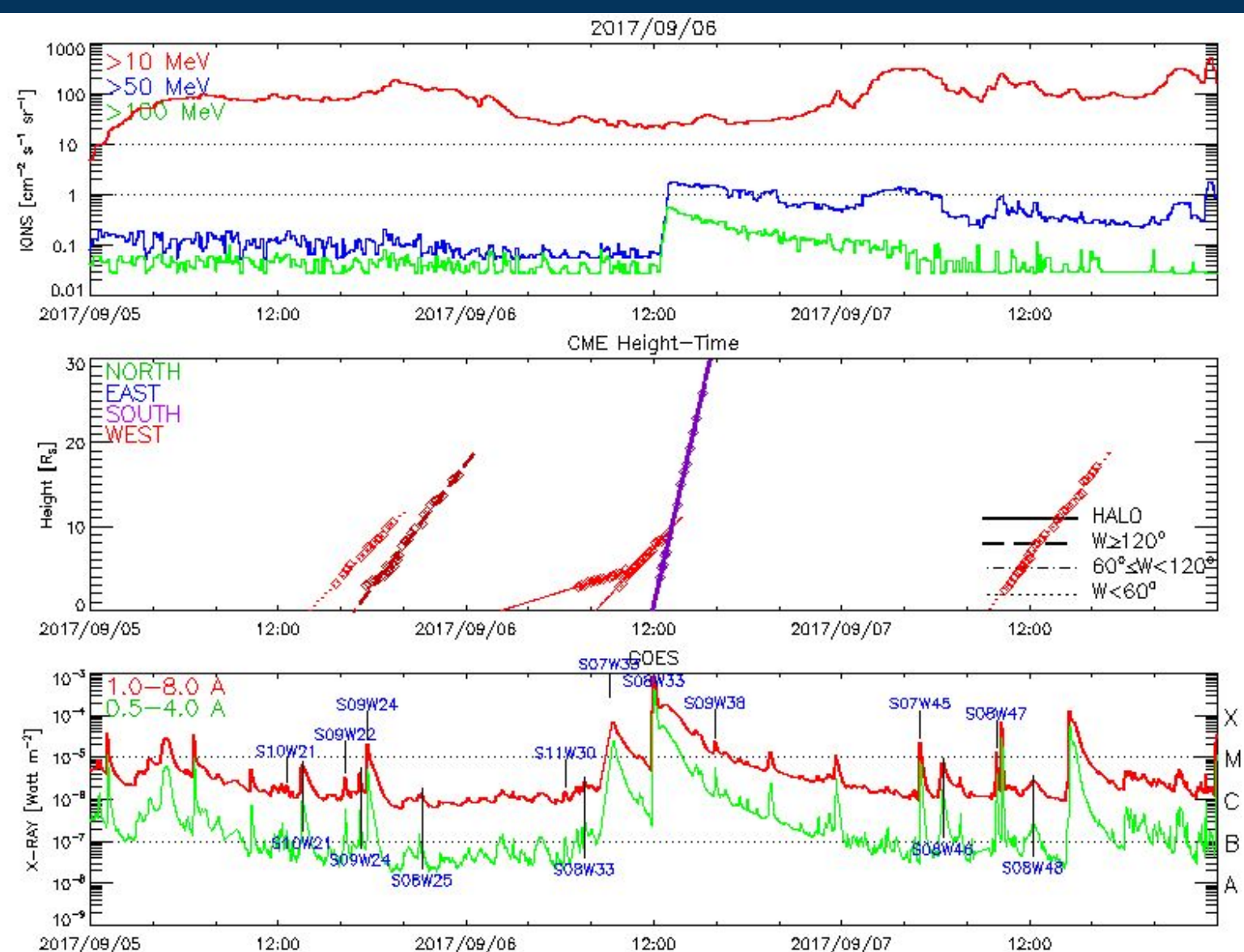
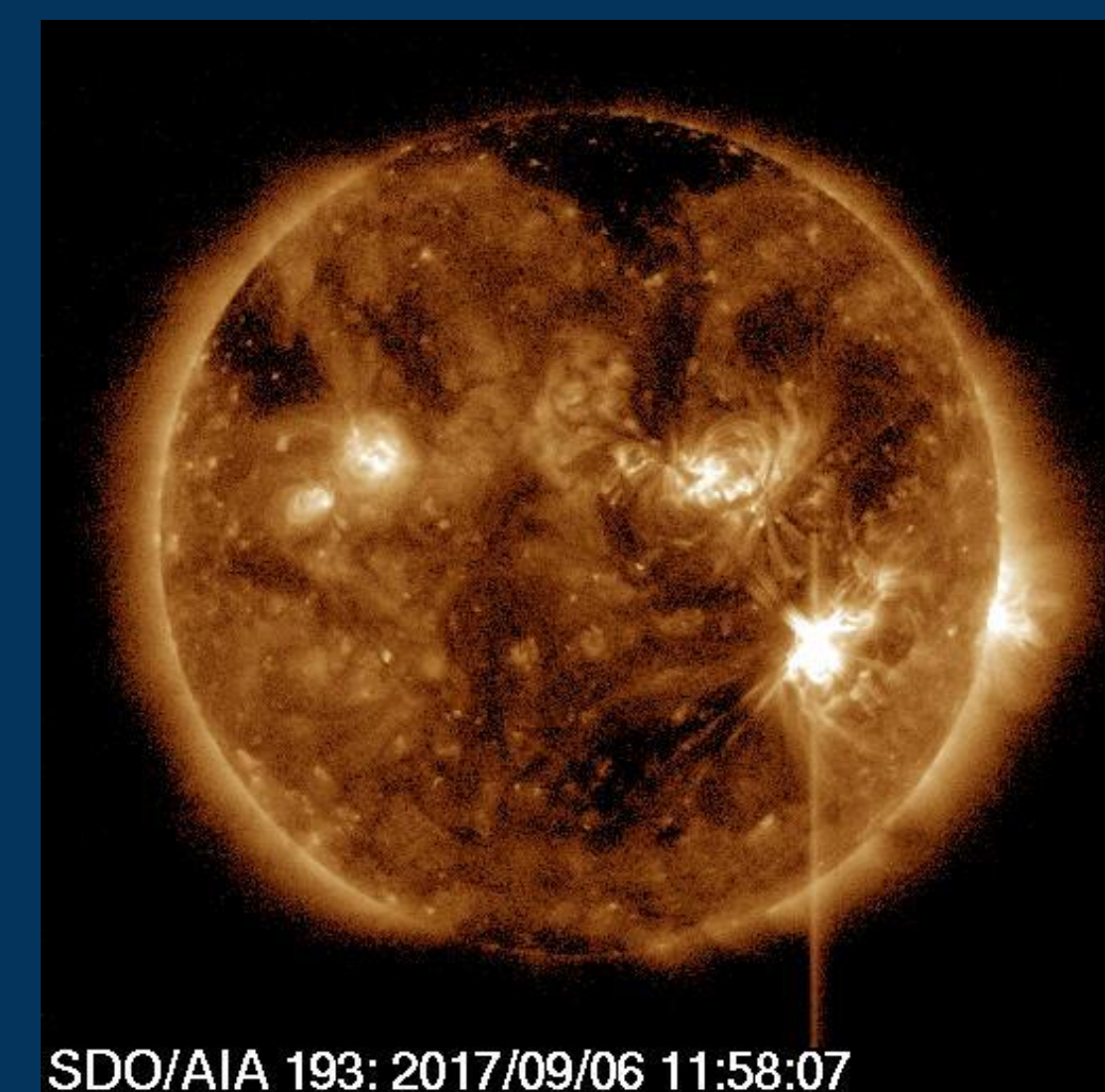
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Event selection: Solar flare

2017-Sep-06 X9.3 (#1) 11:53/12:02/12:10 S08W33

https://hesperia.gsfc.nasa.gov/goes/goes_event_listings/



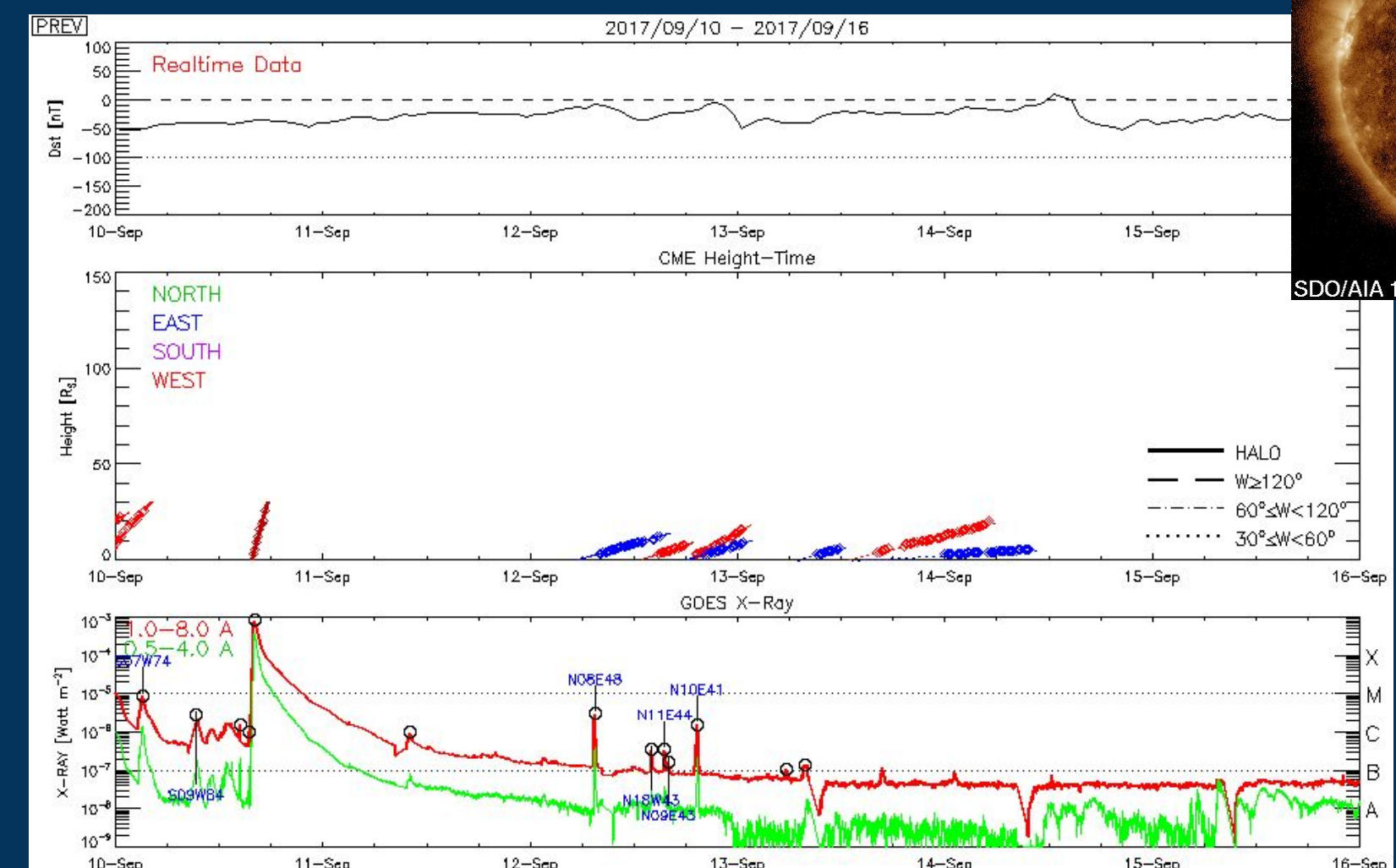
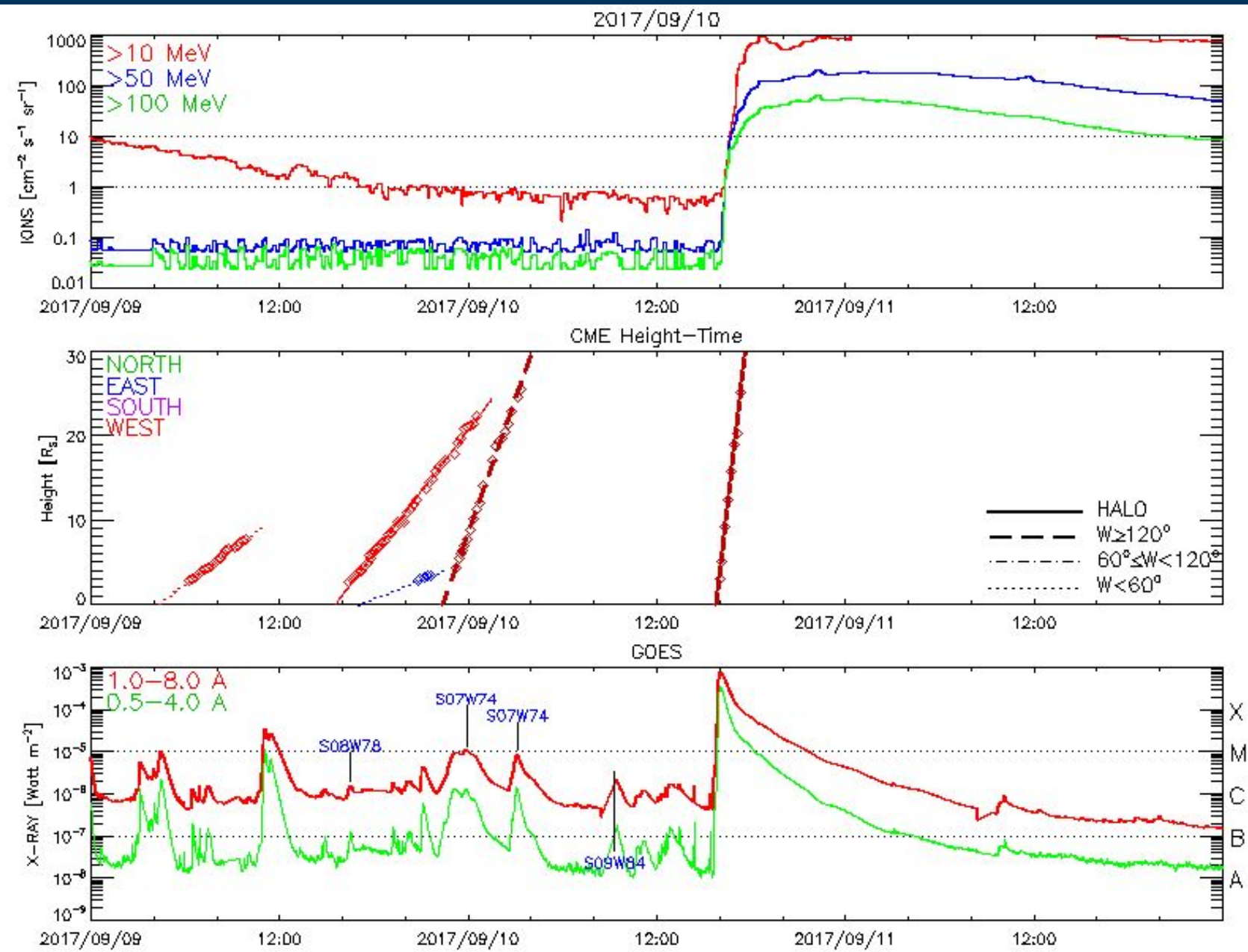
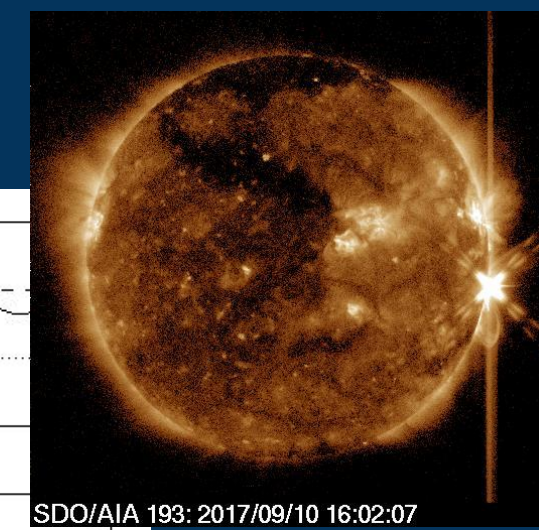
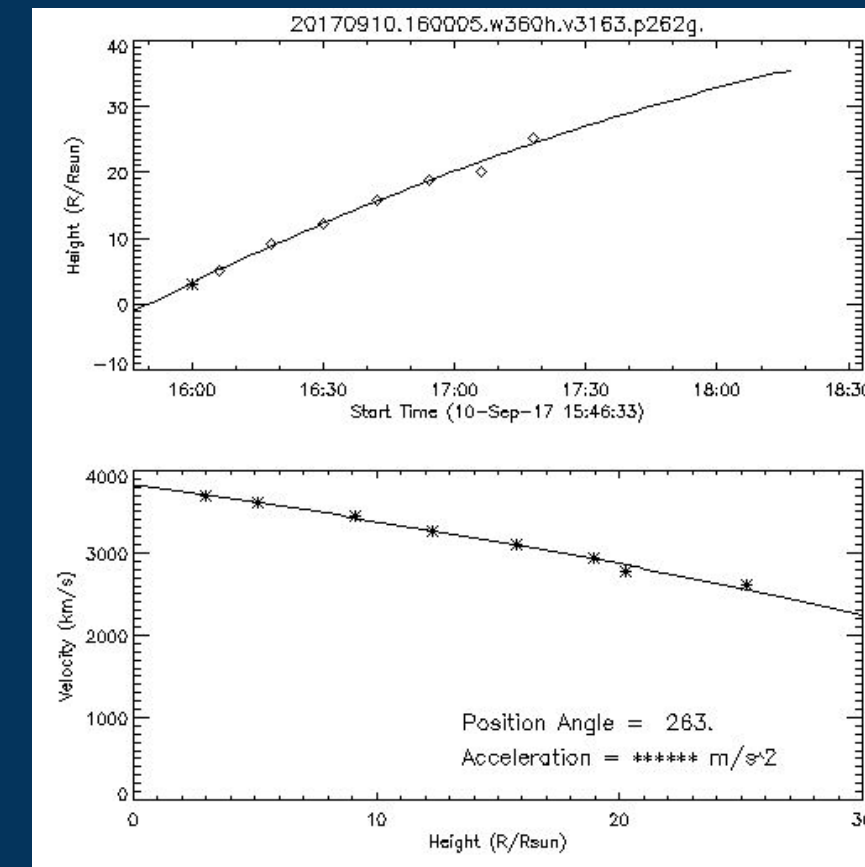
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Event selection: CME

2017-Sep-10: 3163 km/s 16:00 (#1)

https://cdaw.gsfc.nasa.gov/CME_list/



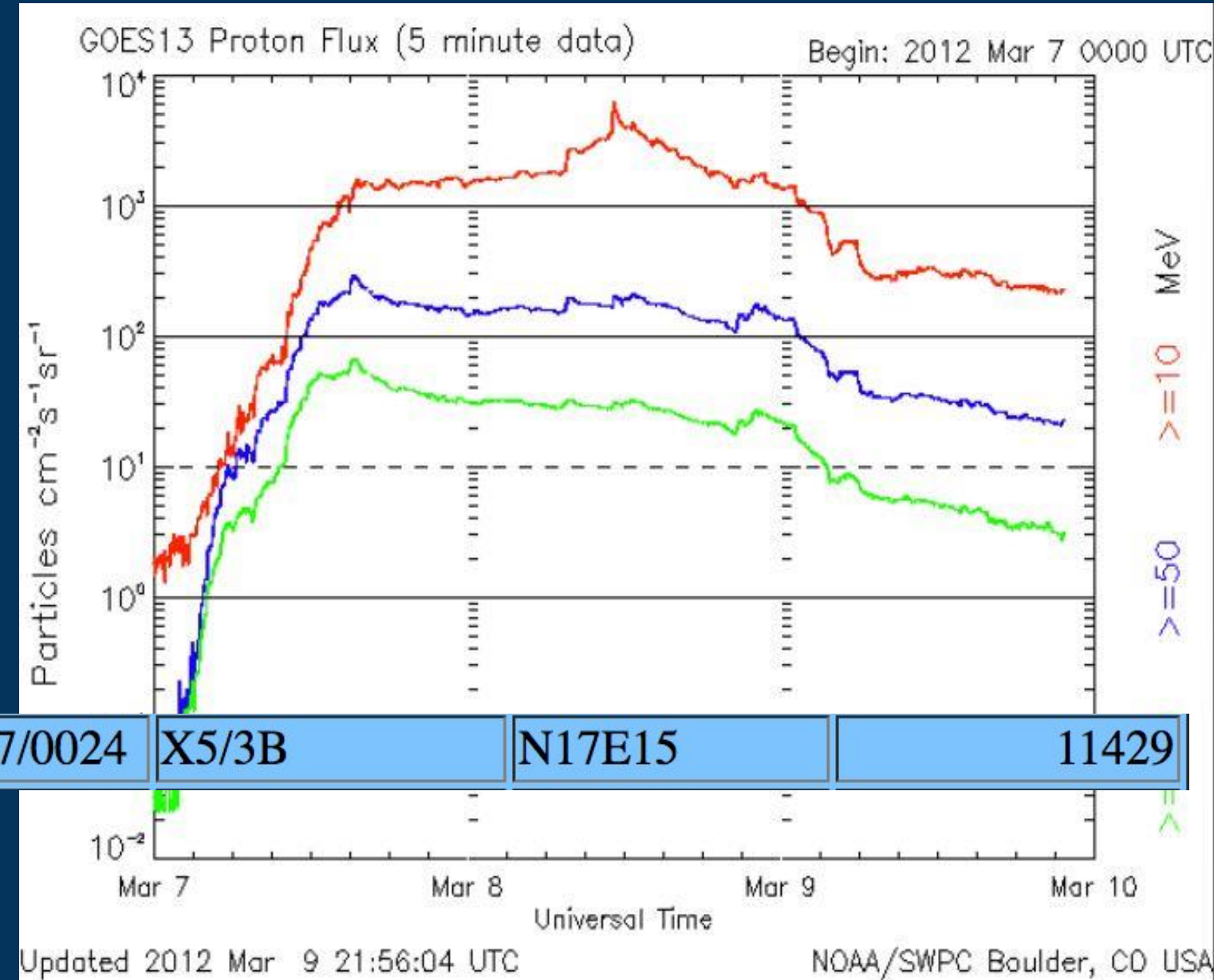
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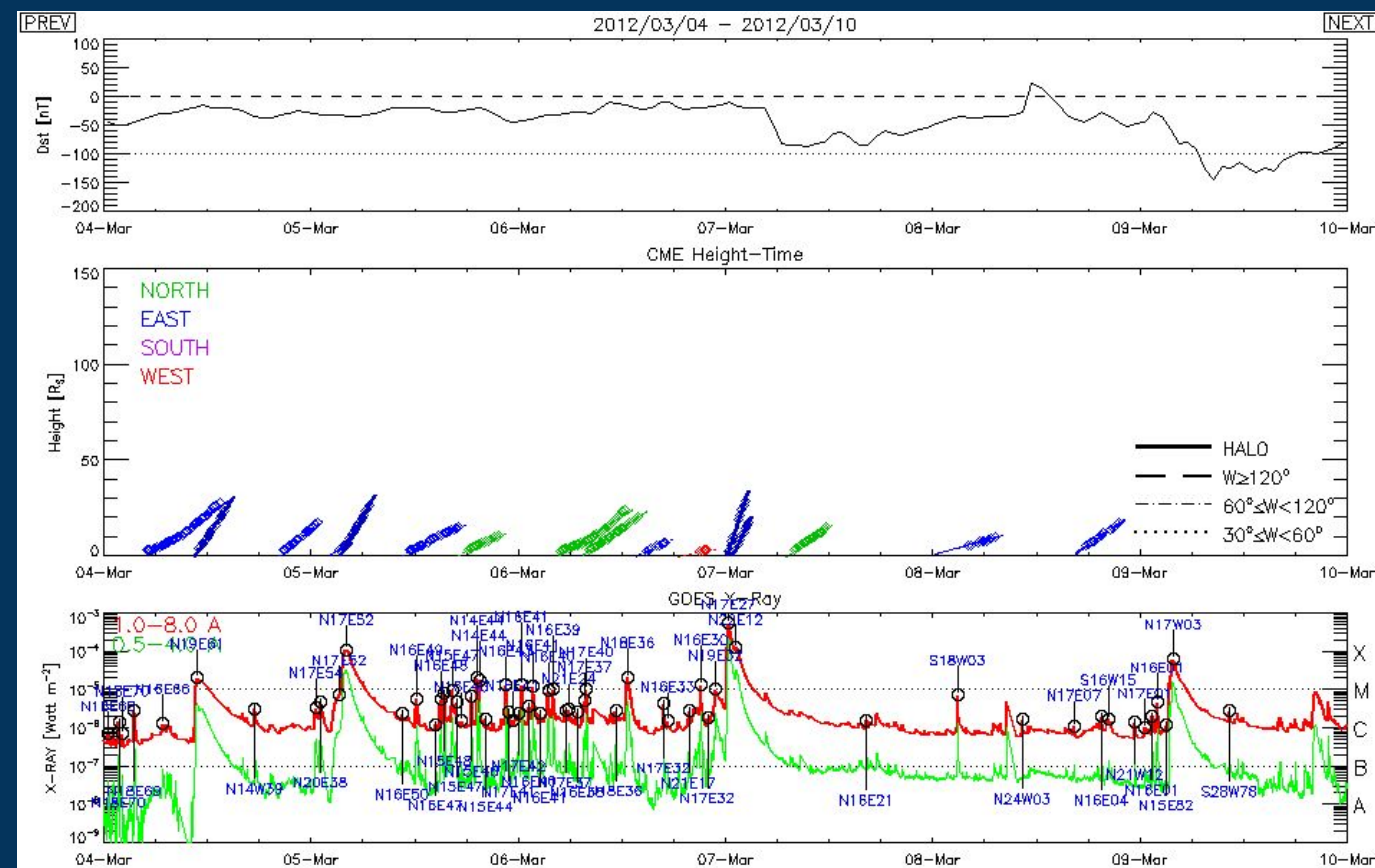
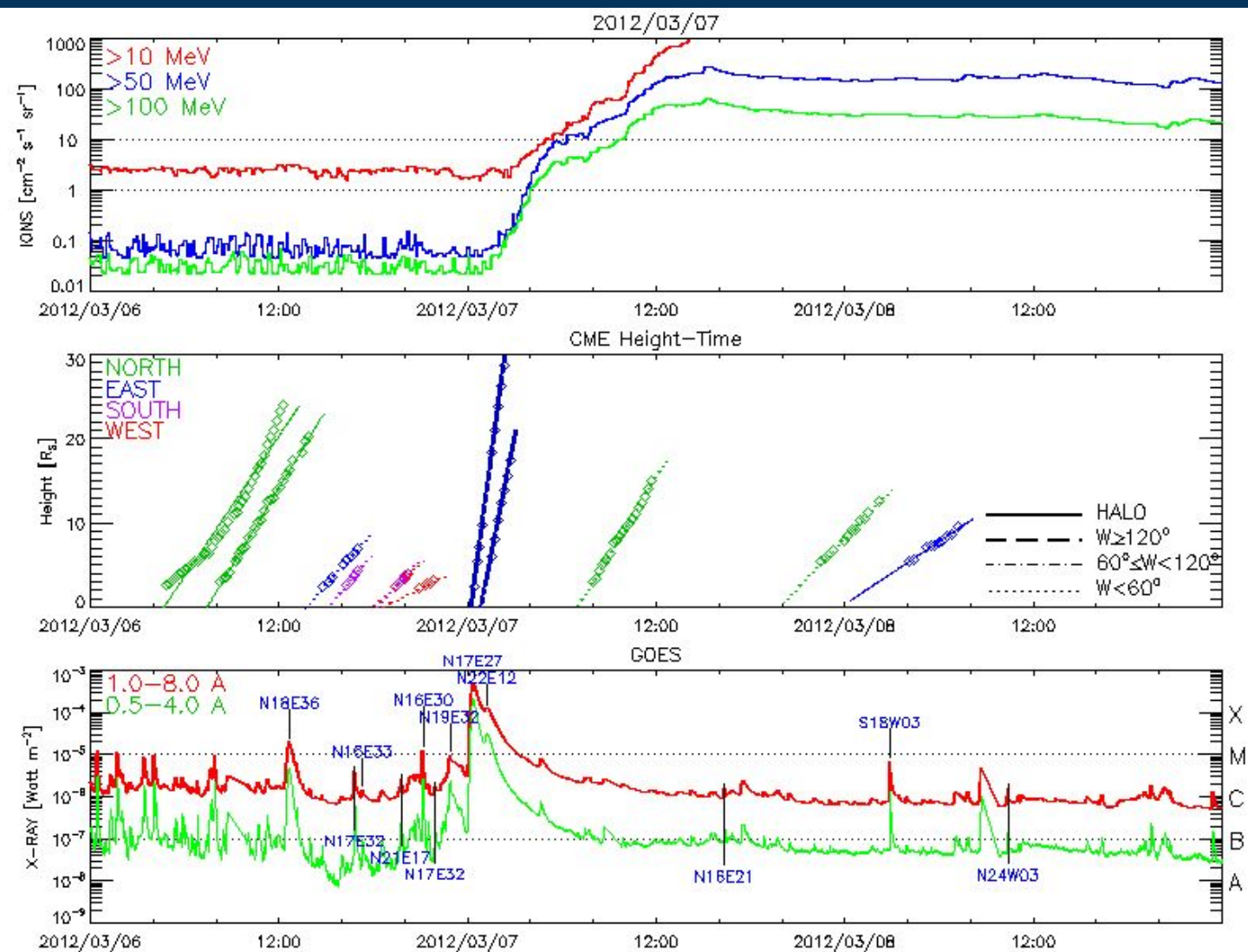
Event selection: SEP

2012-Mar-07: GOES >10 MeV: 6530 pfu (#1)

<https://umbra.nascom.nasa.gov/SEP/>



Mar 07/0510	Mar 08/1115	6530	Halo /07 0036	Mar 07/0024	X5/3B	N17E15	11429
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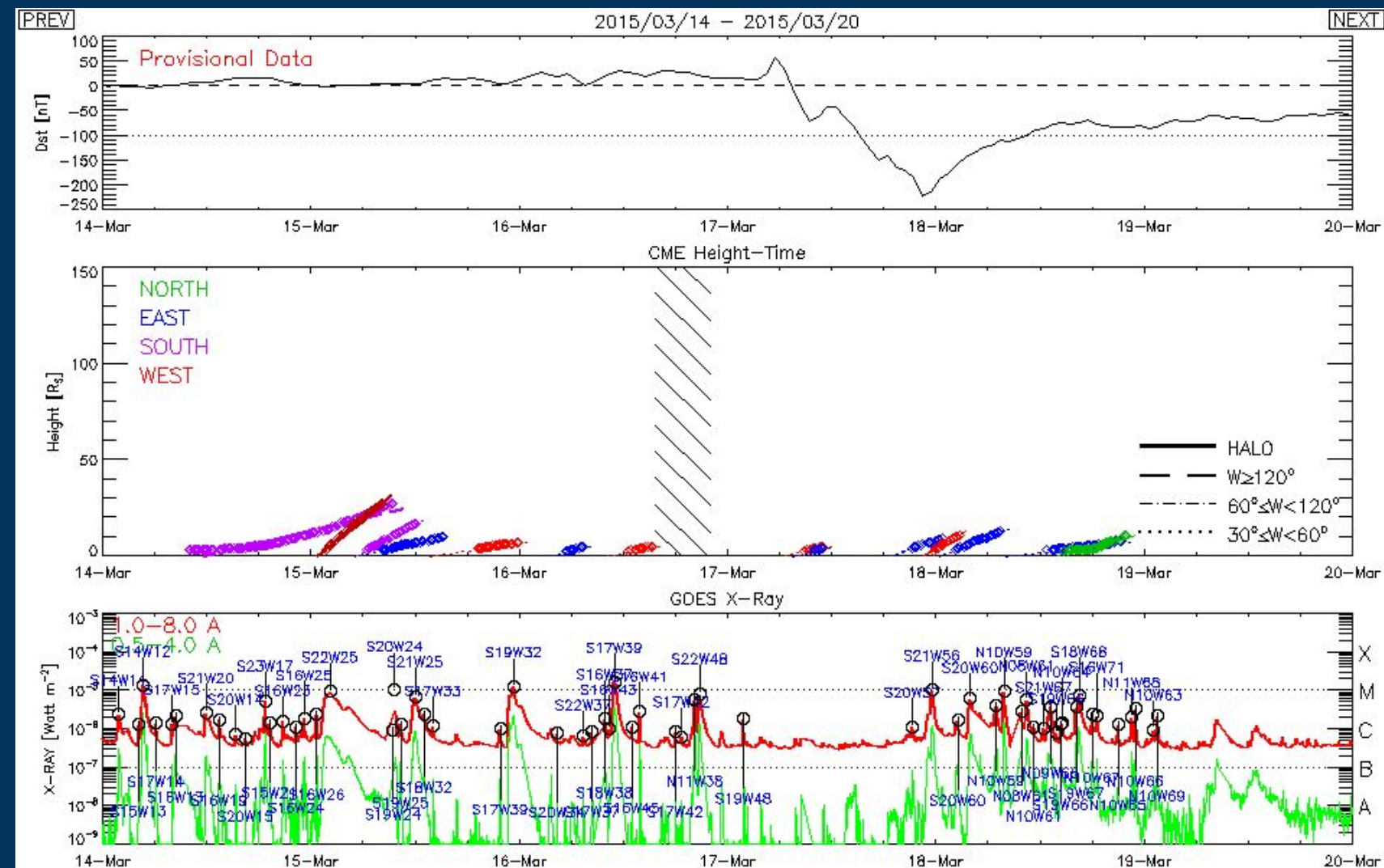
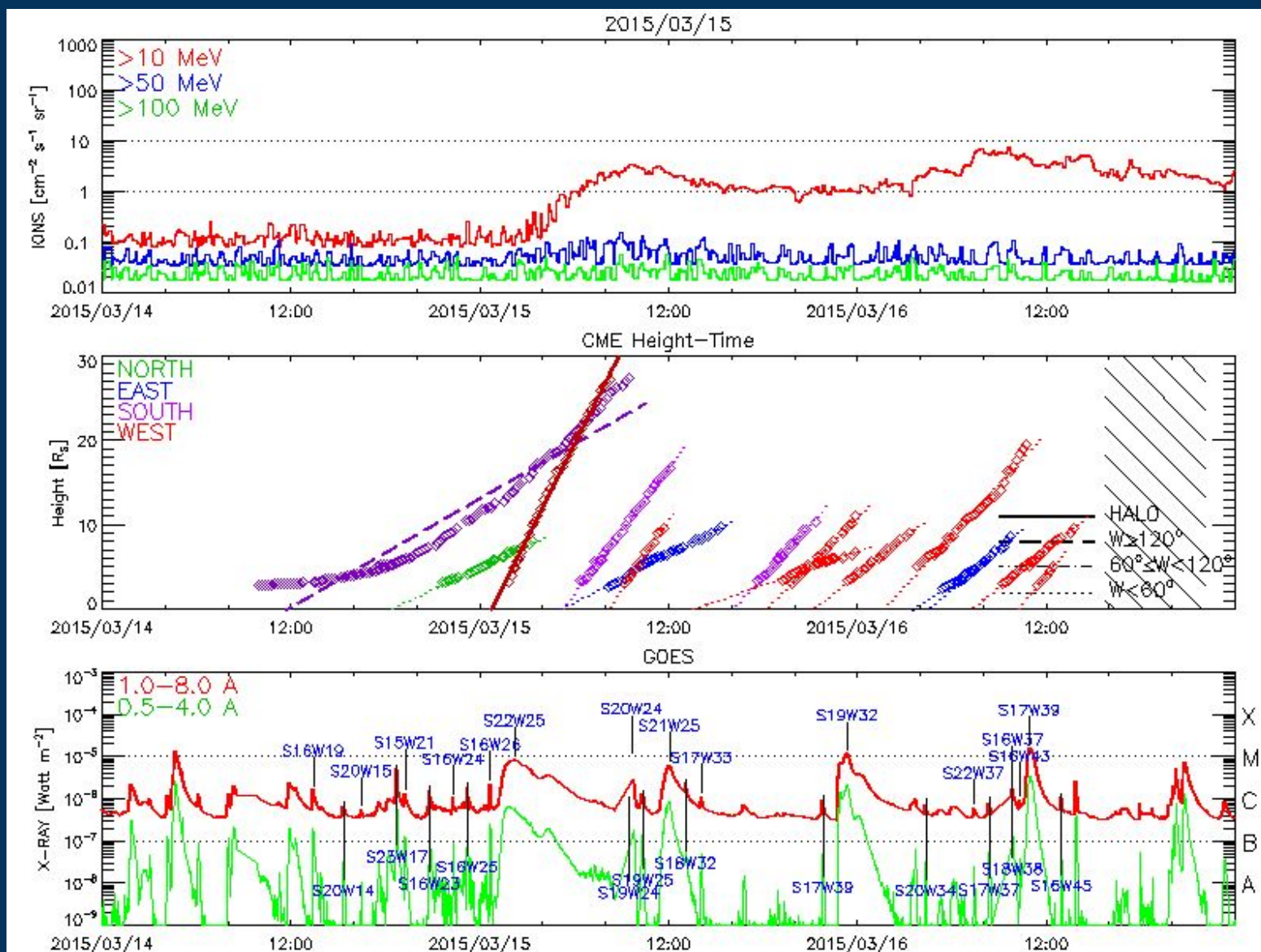
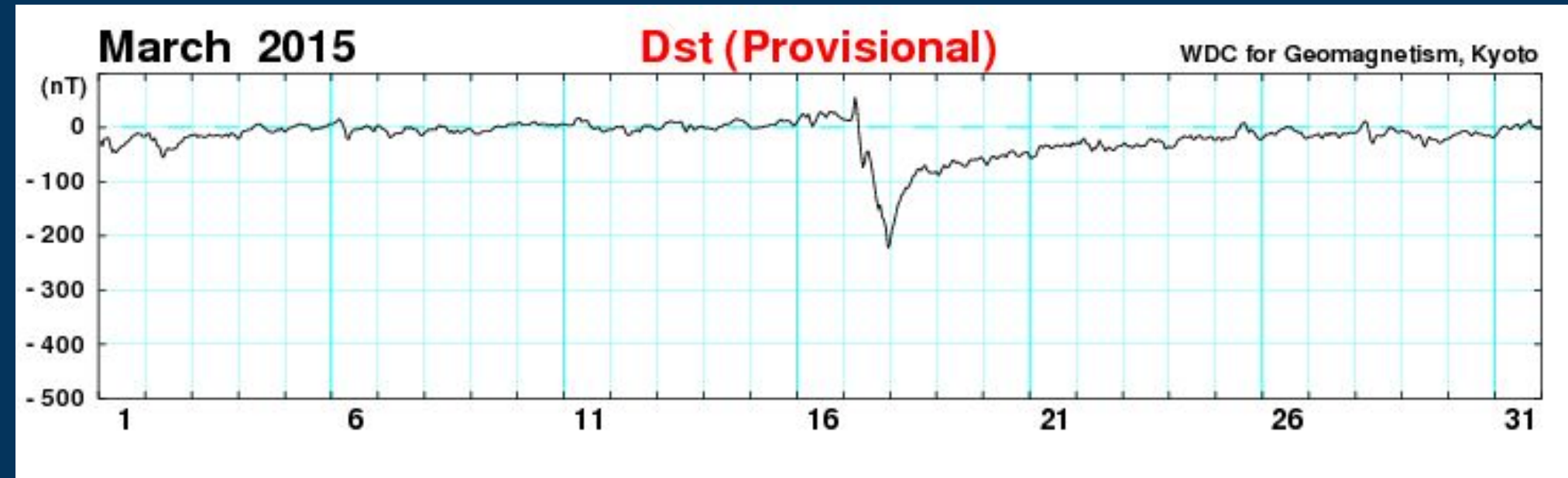
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Event selection: Geomagnetic storm

2015-Mar-17: 23:00 -223 nT (#1)

http://wdc.kugi.kyoto-u.ac.jp/dst_provisional/201503/index.html



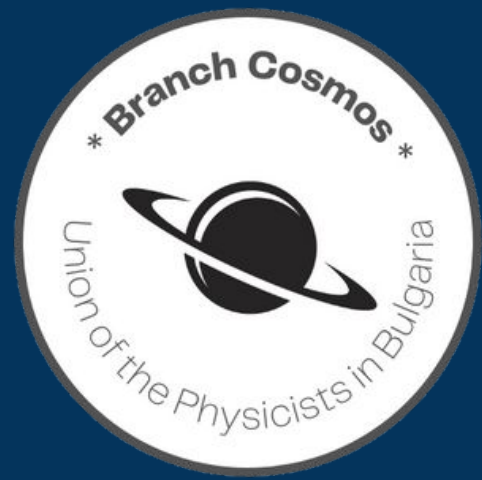
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Event properties and inter-associations

Date	Solar flare	CME	SEP	Geo-storm
2017-Sep-06	X9.3 (#1) 11:53/12:02/12:10 S08W33	1571 km/s 12:24 360/201	339 pfu 03:00+1d	-124 nT 02:00+2d (Hit)
2017-Sep-10	X8.2 15:35/16:06/16:31 [S09W84]	3163 km/s 16:00 360/262 (#1)	1139 pfu 01:00+1d	No (Missed)
2012-Mar-07	X5.4 00:02/00:24/00:40 N17E15	2684 km/s 00:24 360/57	1532* pfu (#1) 16:00 *corrected	-132 nT 14:00+2d (Hit)
2015-Mar-17	C9.1 01:15/02:13/03:20-2d S22W25	719 km/s 01:48-2d 360/240	2.78 pfu 9:00-2d	-223 nT (#1) 23:00 (Hit)

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Deducing the 3D parameters of the CMEs

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Grozdan,
Rositsa



StreoCat Analysis Tool

Image Choice Measurement Session Save URL Manual

Options

STEREO-B Behind COR2
2014-09-27T15:54:57
2014-09-27T15:54:24Z, Offset: -59438h48m56s
STEREO-B Start: COR2 Beacon

SOHO Start: C3
2021/07/09 06:30
2021-07-09T06:30:00Z, Offset: -13m20s

STEREO-A Start: COR2 Beacon
2021-07-09 06:38:54
2021-07-09T06:38:54Z, Offset: -4m26s

Start Time: 2021-06-29T06:43:19Z STEREO-B
End Time: 2021-06-29T06:43:19Z SOHO
Select Frameseries Range Pair Tolerance: 5 minutes STEREO-A

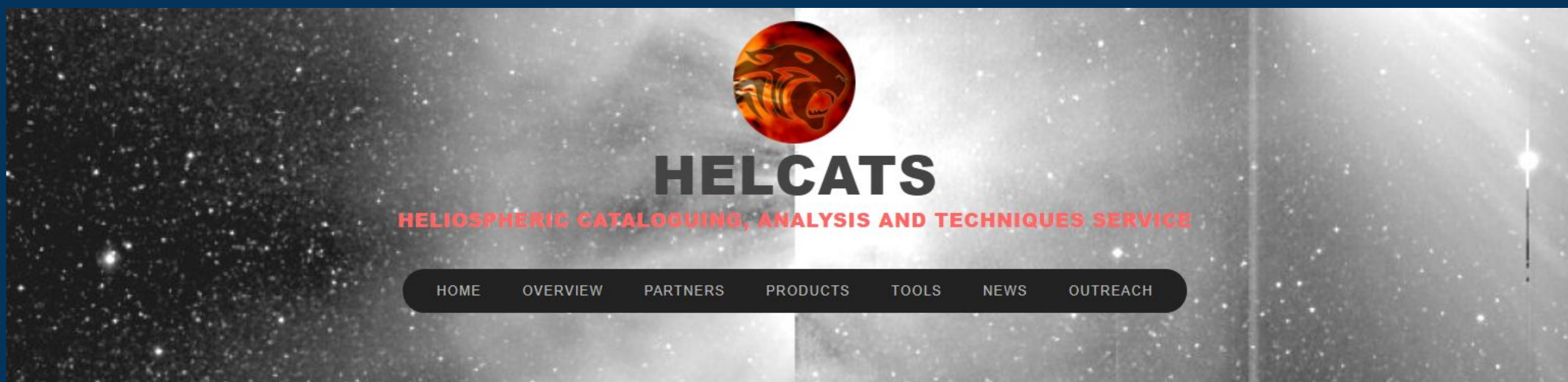
<https://ccmc.gsfc.nasa.gov/analysis/stereo/>

No available data!

Mohamed,
Grozdan,
Rositsa



HelCats Catalogue



WP3 COR2 Catalogue

[f](#) [t](#) [r](#) [Project Wiki](#) | [Contact Us](#)

CME COR2 GCS MODELLING

This catalogue builds on the work undertaken during the [EU FP7 AFFECTS project](#). The catalogue provides analysis of CME properties based on the COR2 coronagraph observations and the Graduated Cylindrical Shell model. This is a pre-release version in the context of HELCATS since the events have not yet been correlated with the released WP2 catalogue. As a result a KINCAT specific ID has been used for each event.

This is version V02 of the catalogue which extends the original pre-release catalogue with a number of additional events and provides the direct link with the other catalogues via the use of the common event ID. (DOI: *** awaiting assignment ***)

The catalogue can be downloaded in several formats ([Fixed format ASCII](#), [JSON](#), [VoTable XML](#))

Launch date range

From to

Show entries

Search:

ID	Pre-event data [UTC]	Last COR2 date	GCS HEEQ Long [deg]	GCS Carr Long [deg]	GCS HEEQ Lat [deg]	GCS Tilt Angle [deg]	GCS Aspect Ratio	GCS H Angle [deg]	GCS Apex Speed [kms-1]	GCS CME Mass [kg]
HCME_A_20070509_01	2007-05-09 02:22:00	2007-05-09 12:52:00	-116	88	1	-17	0.43	10.1	282	9.50E+15
HCME_A_20070516_01	2007-05-15 18:52:00	2007-05-16 01:22:00	-79	39	13	52	0.35	28.2	352	4.00E+15
HCME_B_20070605_01	2007-06-04 17:00:00	2007-06-05 09:23:00	111	320	-10	2	0.45	28	192	3.80E+15
HCME_B_20070608_01	2007-06-07 18:30:00	2007-06-08 03:54:00	68	240	-12	-10	0.26	17	292	1.60E+15
HCME_A_20070709_01	2007-07-08 16:52:00	2007-07-09 00:52:00	-69	55	-8	7	0.23	24.6	337	5.00E+14

https://www.helcats-fp7.eu/catalogues/wp3_kincat.html

No available data!

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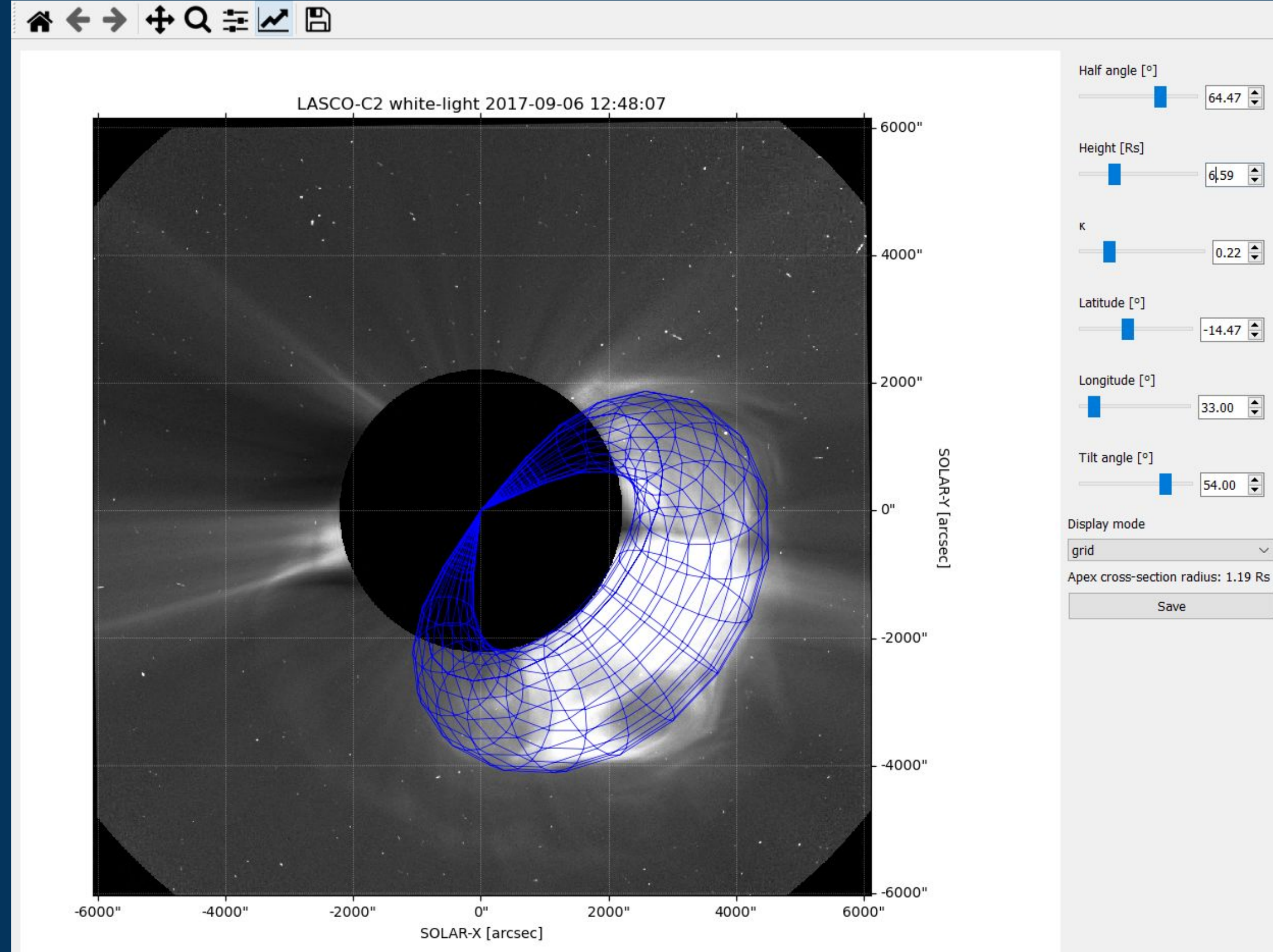


The Graduated Cylindrical Shell (GCS) Model

- During the implementation of the GCS model for estimating the 3D properties of the CMEs, **the tilt angle, aspect ratio, half-angle, latitude, longitude, and height** are assumed to be variable in order to make the best fit in the given frame of SOHO/LASCO C2
- The CME aspect ratio, latitude and longitude might differ a bit from that of the associated flare in order to fit the model
- The solar wind speed is taken as the minimum value within the day before the CME launch time



The Graduated Cylindrical Shell (GCS) Model



https://github.com/johan12345/gcs_python

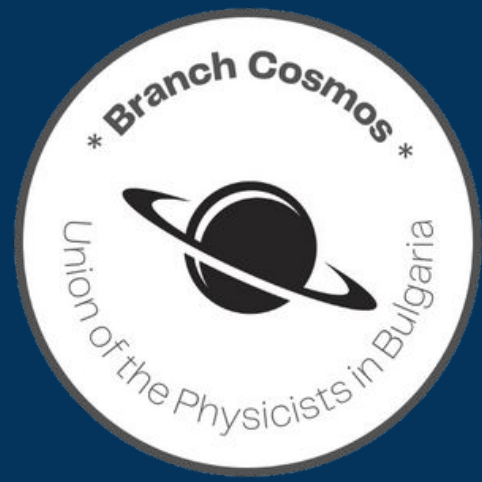
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The Graduated Cylindrical Shell (GCS) Model

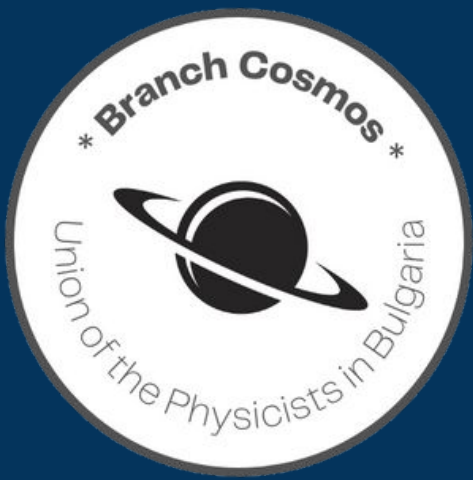
Steps of estimating the CME speed from the LASCO data:

1. Fit the 3D mesh of the GCS model onto the LASCO image in the first frame in which the CME shows up, so that the upper edge of the mesh matches the leading edge of the CME
2. Repeat the same for the second frame
3. Take the difference in CME heights and times
4. Calculate the CME speed by $V = dX/dt$



Run the model for CME propagation using the deduced inputs

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Rositsa



CME propagation using DBEM-tool

UNI GRAZ **Opservatorij Hvar** **Hvar Observatory**

Drag-Based (Ensemble) Model - DBEMv3 with GCS option

probabilistic model for heliospheric propagation of CMEs

Input Documentation

? CME date (at R_0): Jul 10 2021

? CME time in UTC (at R_0): 06 h 57 min

? Drag parameter, γ (depending on CME speed): 0.2 (normal CME) $\times 10^{-7} \text{ km}^{-1}$

? Solar wind speed, w = 450 km/s (current: 341 km/s)

? CME starting radial distance, R_0 = 20 r_{Sun}

? Starting speed of CME, v_0 (at R_0) = 1000 km/s

? CME's angular half-width, λ = 30 deg **GCS input**

? GCS input α = [] deg κ = [] tilt = [] deg **Calculate λ**

? Longitude of CME source region, φ_{CME} = 0 deg

? Select target: Earth

Run DBM and set DBEM uncertainties **Reset**

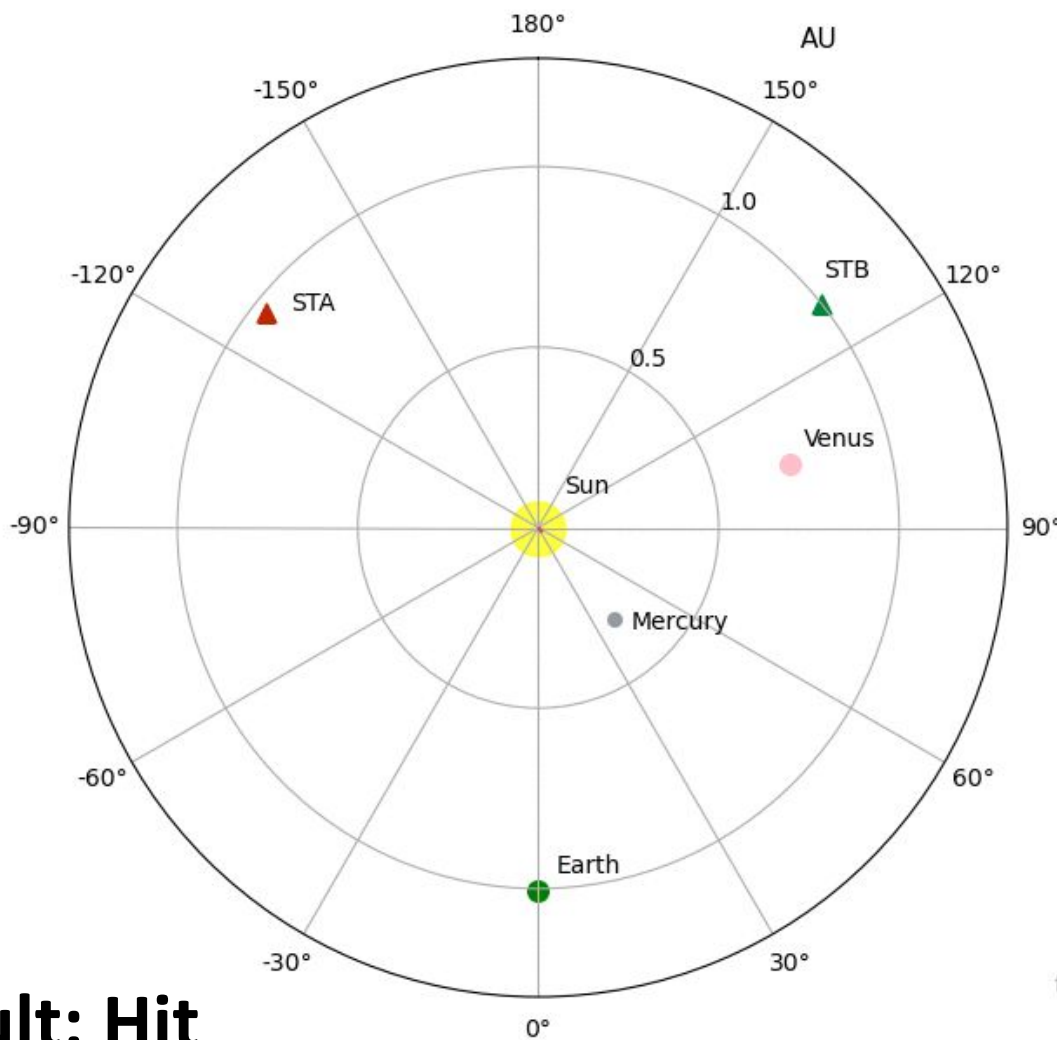
<http://phyk039240.uni-graz.at:8080/DBEMv3/dbem.php>

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Analysis: CME propagation (projected vs. 3D)

Event 1



Result: Hit

Animation info

Date: 06 Sep 2017
 Time: 12:24 h
 Transit time: 0.0 h
 Speed, v : 1450 km/s
 Distance: 0.02 AU

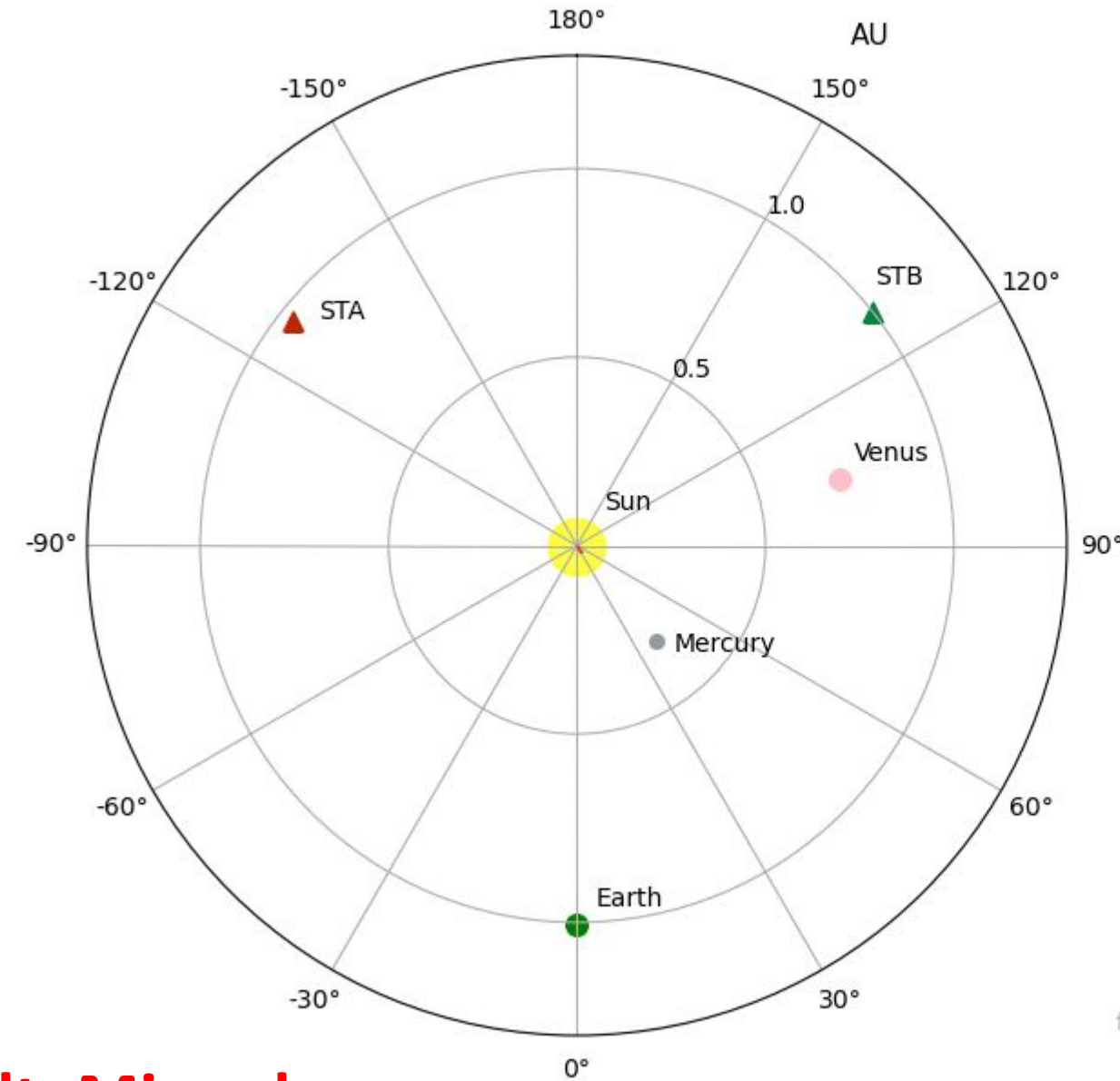
DBM results

CME arrival (at Earth)
 Date: 08 Sep 2017
 Time: 03:53 h
 Transit time: 39.49 h
 Speed at target: 821 km/s
 Distance (target): 1.01 AU

Input parameters

CME date: 06 Sep 2017
 CME time: 12:24 h
 Drag, γ : $0.1 \times 10^{-7} \text{ km}^{-1}$
 SW speed, w : 400 km/s
 Radial dist., R_0 : $3.73 r_{Sun}$
 CME init. speed, v_0 : 1571 km/s
 CME half-width, λ : 69.0 deg
 CME long., ϕ_{CME} : 39.0 deg
 Target: Earth

figure generated with DBEMv3



Result: Missed

Animation info

Date: 06 Sep 2017
 Time: 12:24 h
 Transit time: 0.0 h
 Speed, v : 843 km/s
 Distance: 0.02 AU
 Note: Shown values are for CME flank

DBM results

CME misses the target (Earth)

Input parameters

CME date: 06 Sep 2017
 CME time: 12:24 h
 Drag, γ : $0.1 \times 10^{-7} \text{ km}^{-1}$
 SW speed, w : 400 km/s
 Radial dist., R_0 : $5.42 r_{Sun}$
 CME init. speed, v_0 : 1130 km/s
 CME half-width, λ : 26.3 deg
 CME long., ϕ_{CME} : 33.0 deg
 Target: Earth

figure generated with DBEMv3

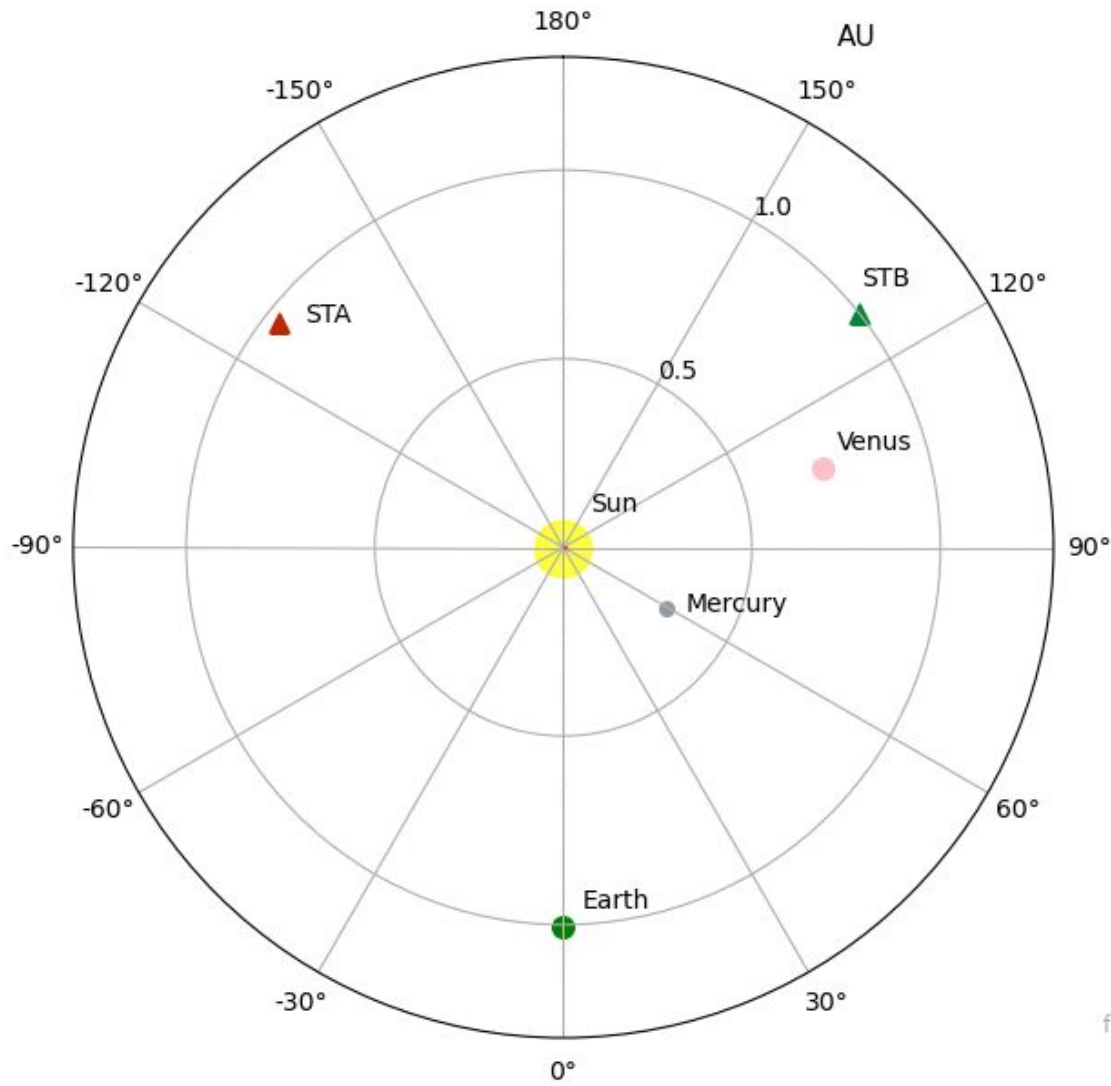
Observations: Hit

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Analysis: CME propagation (projected vs. 3D)

Event 2



Animation info

Date: 10 Sep 2017
 Time: 16:00 h
 Transit time: 0.0 h
 Speed, v : 2264 km/s
 Distance: 0.01 AU
 Note: Shown values are for CME flank

DBM results

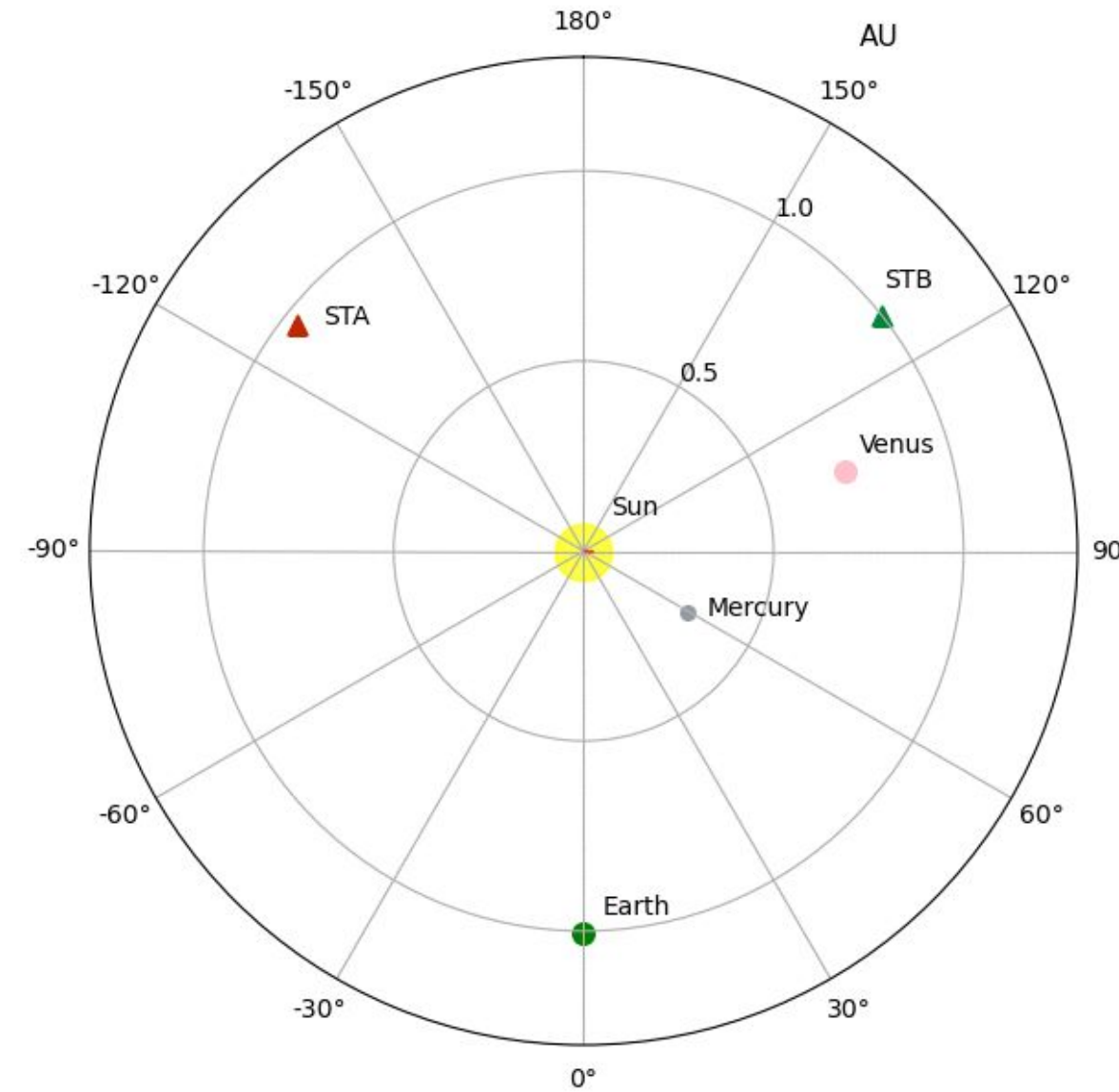
CME misses the target (Earth)

Input parameters

CME date: 10 Sep 2017
 CME time: 16:00 h
 Drag, γ : $0.1 \times 10^{-7} \text{ km}^{-1}$
 SW speed, w : 648 km/s
 Radial dist., R_0 : $2.76 r_{Sun}$
 CME init. speed, v_0 : 3163 km/s
 CME half-width, λ : 36.0 deg
 CME long., ϕ_{CME} : 75.0 deg
 Target: Earth

figure generated with DBEMv3

Result: Missed



Animation info

Date: 10 Sep 2017
 Time: 16:12 h
 Transit time: 0.0 h
 Speed, v : 2382 km/s
 Distance: 0.02 AU
 Note: Shown values are for CME flank

DBM results

CME misses the target (Earth)

Input parameters

CME date: 10 Sep 2017
 CME time: 16:12 h
 Drag, γ : $0.1 \times 10^{-7} \text{ km}^{-1}$
 SW speed, w : 648 km/s
 Radial dist., R_0 : $5.81 r_{Sun}$
 CME init. speed, v_0 : 3010 km/s
 CME half-width, λ : 18.3 deg
 CME long., ϕ_{CME} : 84.0 deg
 Target: Earth

figure generated with DBEMv3

Result: Missed

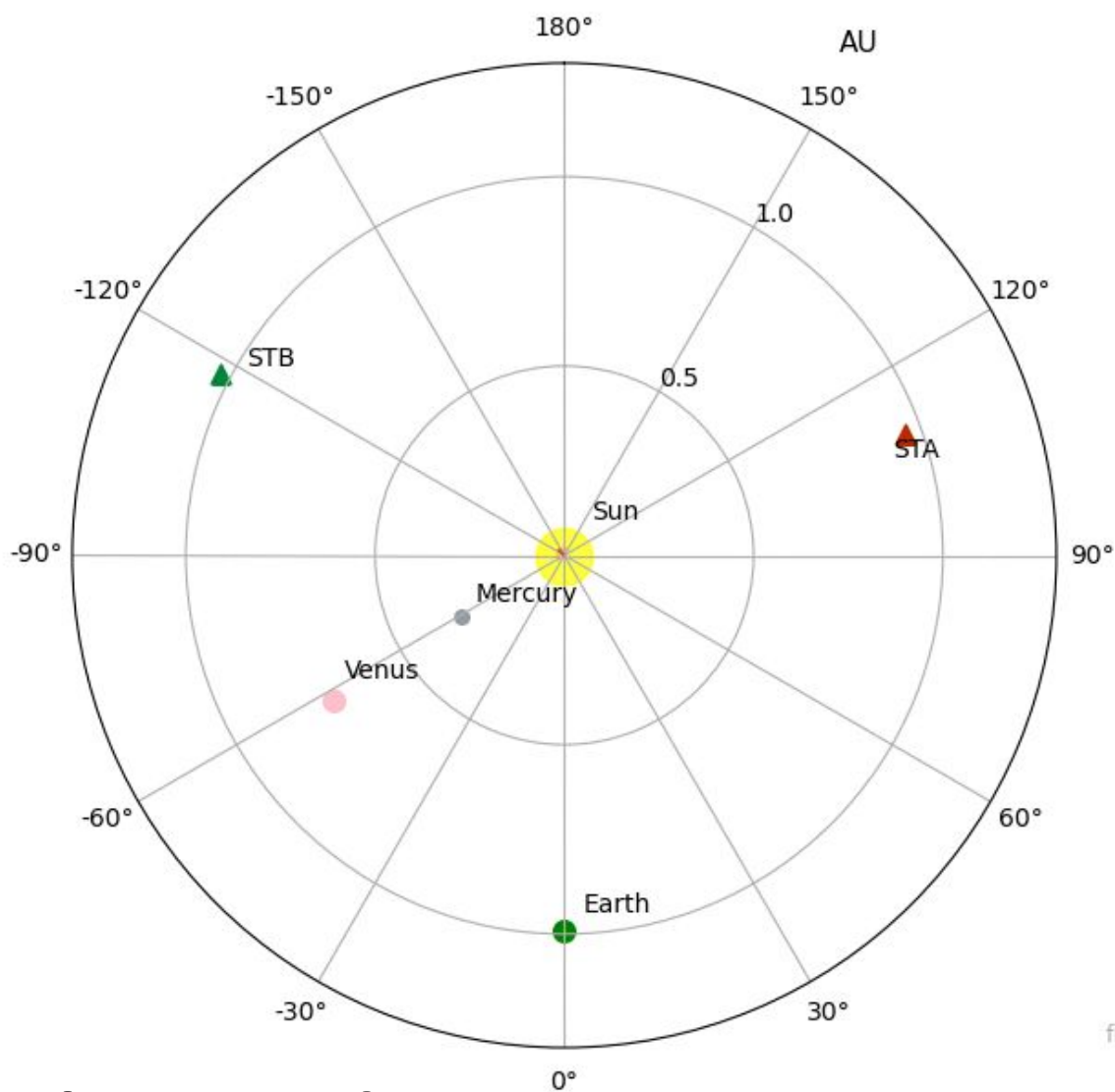
Observations: Missed

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 Rositsa



Analysis: CME propagation (projected vs. 3D)

Event 3



Animation info

Date: 07 Mar 2012
 Time: 00:36 h
 Transit time: 0.0 h
 Speed, v : 2638 km/s
 Distance: 0.02 AU
 Note: Shown values are for CME flank

DBM results

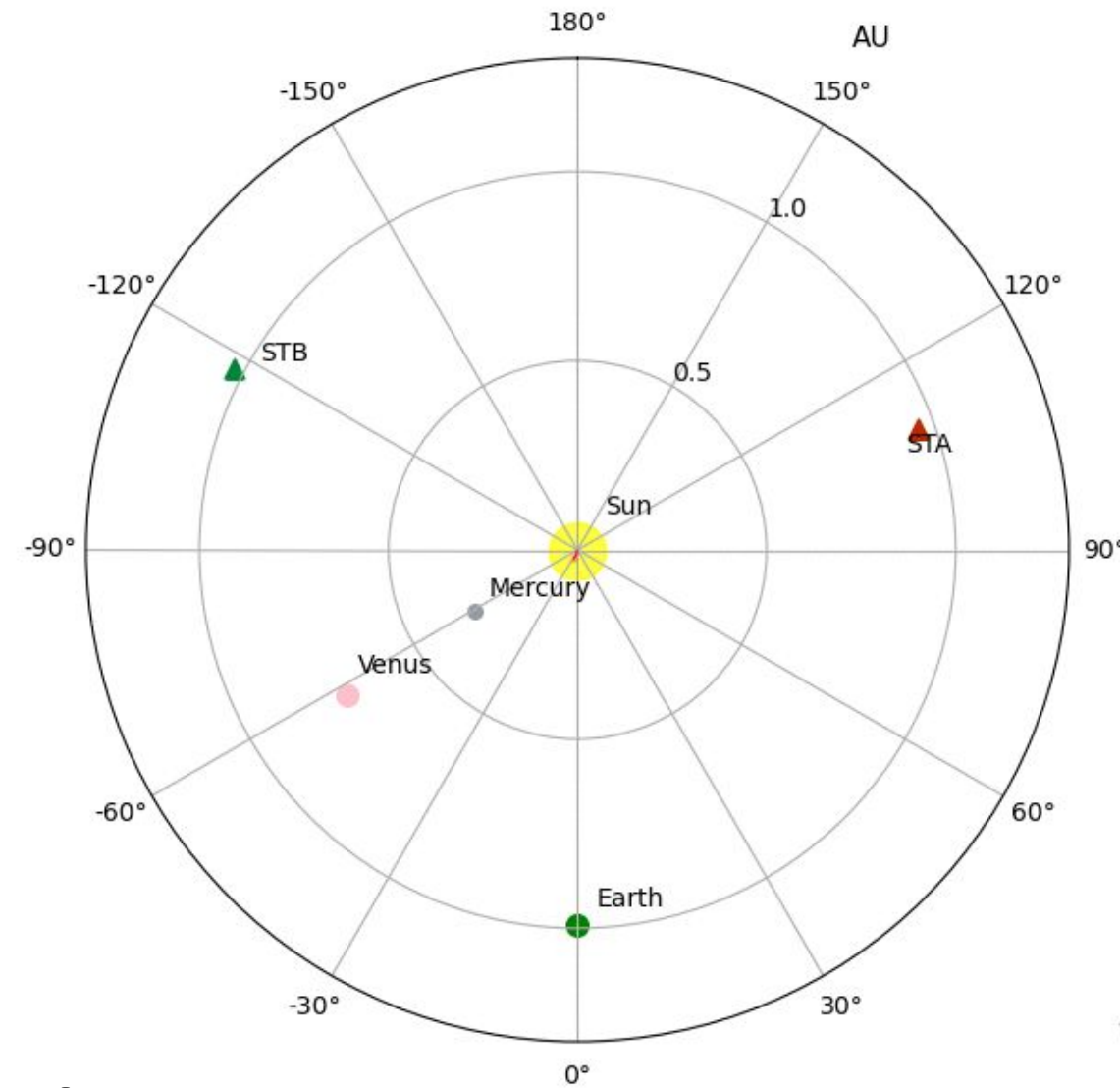
CME misses the target (Earth)

Input parameters

CME date: 07 Mar 2012
 CME time: 00:36 h
 Drag, γ : $0.1 \times 10^{-7} \text{ km}^{-1}$
 SW speed, w : 365 km/s
 Radial dist., R_0 : $5 r_{Sun}$
 CME init. speed, v_0 : 2684 km/s
 CME half-width, λ : 89.0 deg
 CME long., ϕ_{CME} : -134.0 deg
 Target: Earth

figure generated with DBEMv3

Result: Missed



Animation info

Date: 07 Mar 2012
 Time: 00:36 h
 Transit time: 0.0 h
 Speed, v : 2143 km/s
 Distance: 0.03 AU

DBM results

CME arrival (at Earth)
 Date: 08 Mar 2012
 Time: 05:50 h
 Transit time: 29.24 h
 Speed at target: 984 km/s
 Distance (target): 0.99 AU

Input parameters

CME date: 07 Mar 2012
 CME time: 00:36 h
 Drag, γ : $0.1 \times 10^{-7} \text{ km}^{-1}$
 SW speed, w : 365 km/s
 Radial dist., R_0 : $8.04 r_{Sun}$
 CME init. speed, v_0 : 2699 km/s
 CME half-width, λ : 20.8 deg
 CME long., ϕ_{CME} : -19.0 deg
 Target: Earth

figure generated with DBEMv3

Result: Hit

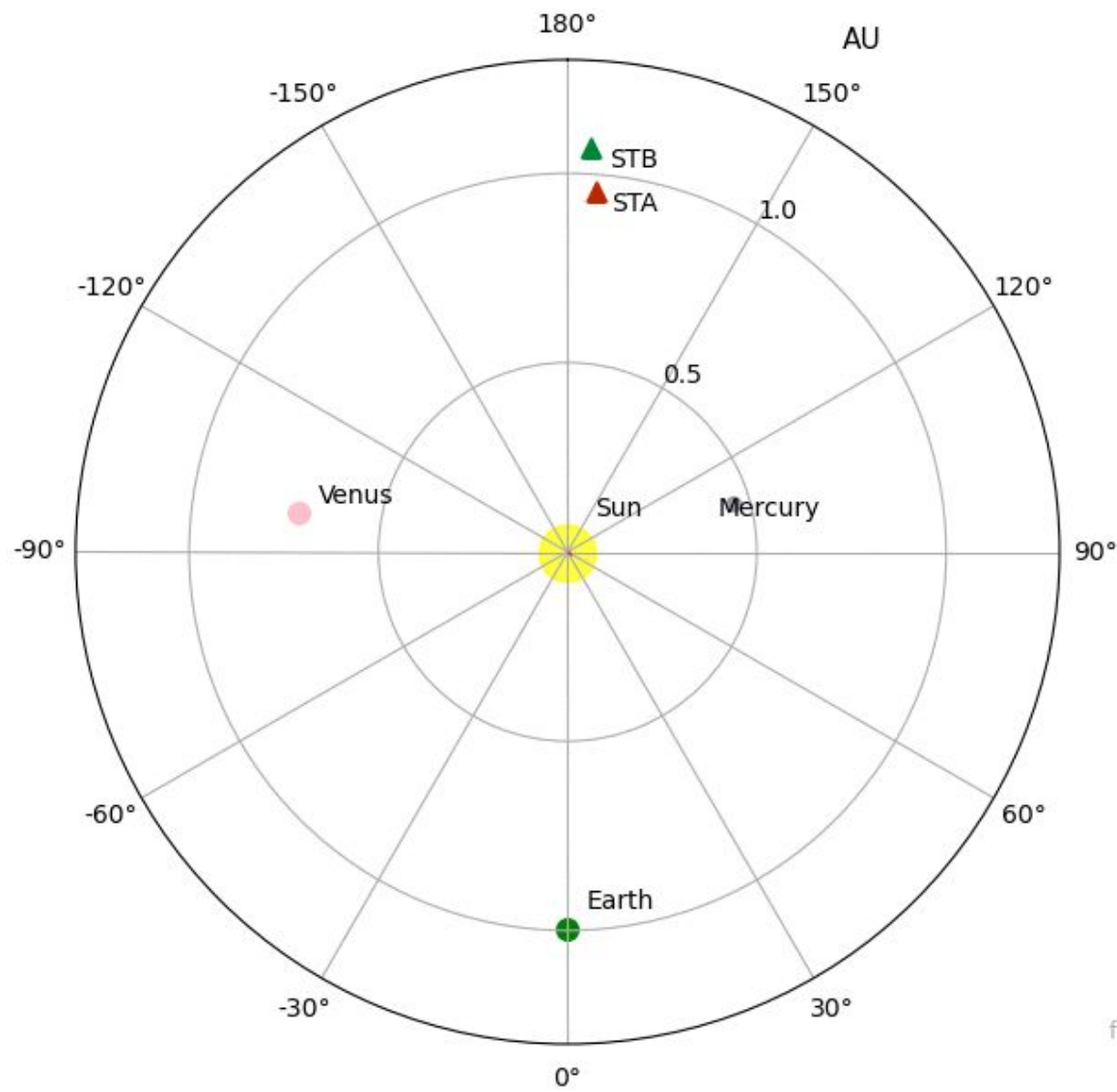
Observations: Hit

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 Rositsa



Analysis: CME propagation (projected vs. 3D)

Event 4



Animation info

Date: 15 Mar 2015
 Time: 01:48 h
 Transit time: 0.0 h
 Speed, v : 511 km/s
 Distance: 0.01 AU
 Note: Shown values are for CME flank

DBM results

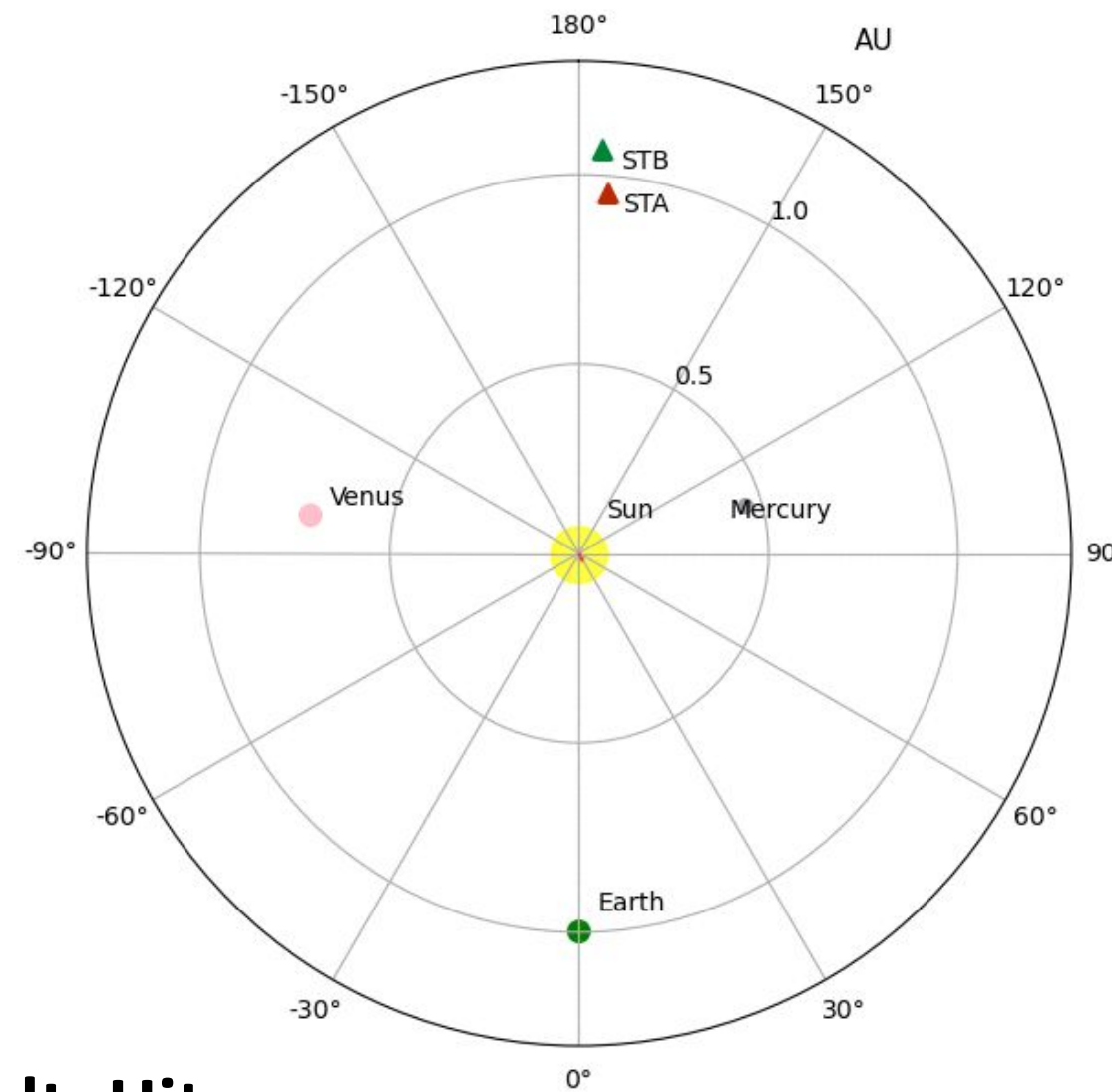
CME misses the target (Earth)

Input parameters

CME date: 15 Mar 2015
 CME time: 01:48 h
 Drag, γ : $0.2 \times 10^{-7} \text{ km}^{-1}$
 SW speed, w : 319 km/s
 Radial dist., R_0 : $3.03 r_{Sun}$
 CME init. speed, v_0 : 719 km/s
 CME half-width, λ : 39.17 deg
 CME long., ϕ_{CME} : 52.6 deg
 Target: Earth

figure generated with DBEMv3

Result: Missed



Animation info

Date: 15 Mar 2015
 Time: 02:12 h
 Transit time: 0.0 h
 Speed, v : 985 km/s
 Distance: 0.02 AU

DBM results

CME arrival (at Earth)
 Date: 17 Mar 2015
 Time: 08:17 h
 Transit time: 54.1 h
 Speed at target: 609 km/s
 Distance (target): 0.99 AU

Input parameters

CME date: 15 Mar 2015
 CME time: 02:12 h
 Drag, γ : $0.1 \times 10^{-7} \text{ km}^{-1}$
 SW speed, w : 319 km/s
 Radial dist., R_0 : $5.2 r_{Sun}$
 CME init. speed, v_0 : 1048 km/s
 CME half-width, λ : 52.2 deg
 CME long., ϕ_{CME} : 25.0 deg
 Target: Earth

figure generated with DBEMv3

Result: Hit

Observations: Hit

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 Grozdan,
 Rositsa



Comparison with in-situ observations

IP shocks at Earth database

<http://ipshocks.fi/database>

Event 1

No IP shock reported?

Event 2

No IP shock reported

ICME database

<http://www.srl.caltech.edu/ACE/ASC/DATA/level3/icmetable2.htm>

ICME reported

No ICME reported

2017/09/07 2302	2017/09/08 1100	2017/09/10 2100
-----------------	--------------------	--------------------

V_ICME (km/s) (i)	V_max (km/s) (j)	B (nT) (k)	MC? (l)	Dst (nT) (m)	V_transit (km/s) (n)	LASCO CME Y/M/D (UT) (o)
590	800	7	1	-124Q	1210	2017/09/06 1224 H

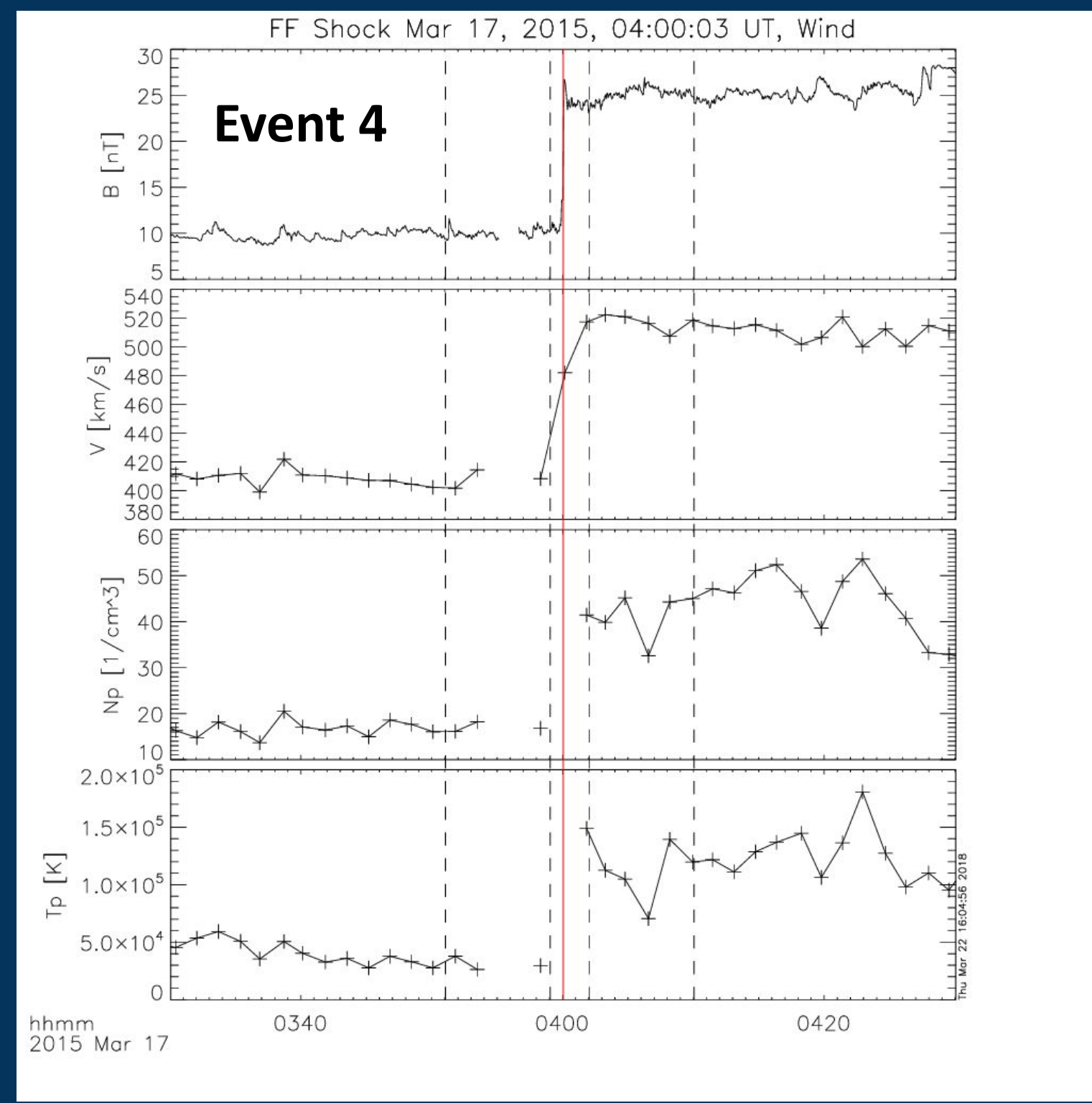
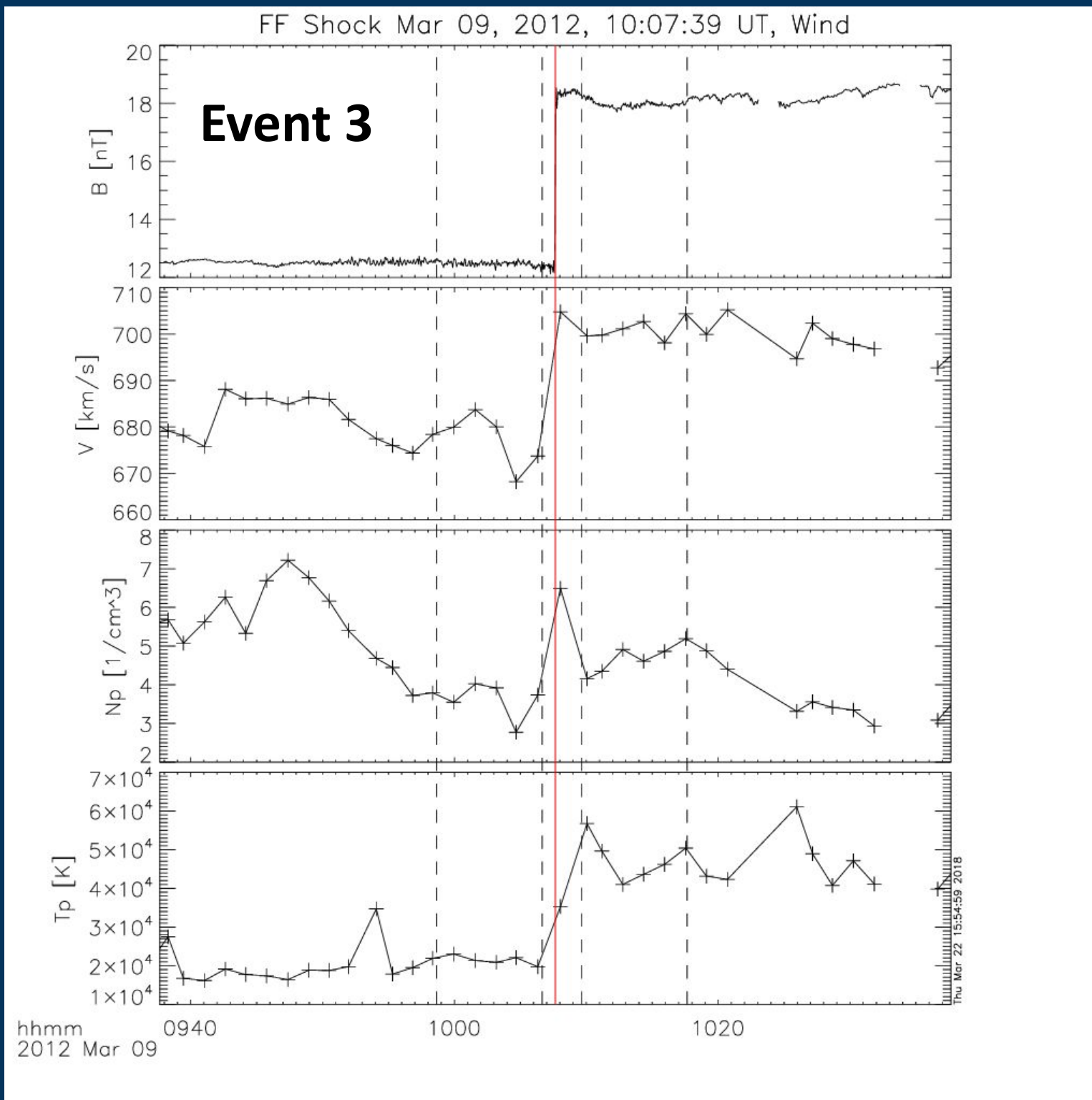
Mohamed,
Grozdan,
Rositsa



Comparison with in-situ observations

IP shocks at Earth database

<http://ipshocks.fi/database>

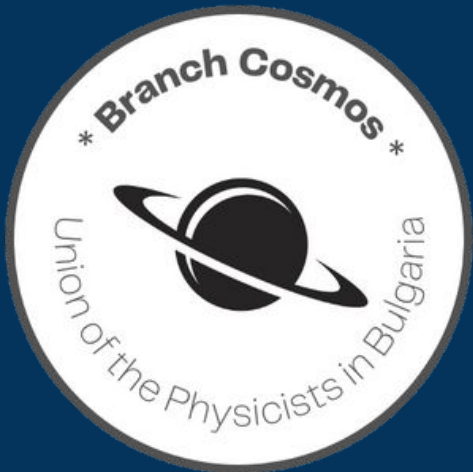


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Rositsa



Conclusions

- Utilizing the freely available data and tools for making fast predictions of the CMEs
- De-projection efforts are needed
- Stereoscopic views are crucial for Earth-directed events - take into consideration another point of view while estimating the 3D CME properties to constrain the parameters and get more accurate estimations
- Important CME parameters:
 - direction
 - width
 - speed
- Direction and spreading of the CME are more important than the propagation speed



Thank you

Mohamed,
Grozdan,
Rositsa