BRANCH **COSMOS** PRESENTS:

FIRST SUMMER SCHOOL ON SPACE RESEARCH, TECHNOLOGY AND APPLICATIONS

Report on practical session:

Sun & Space weather

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

Mohamed,
Grozdan,
Rositsa

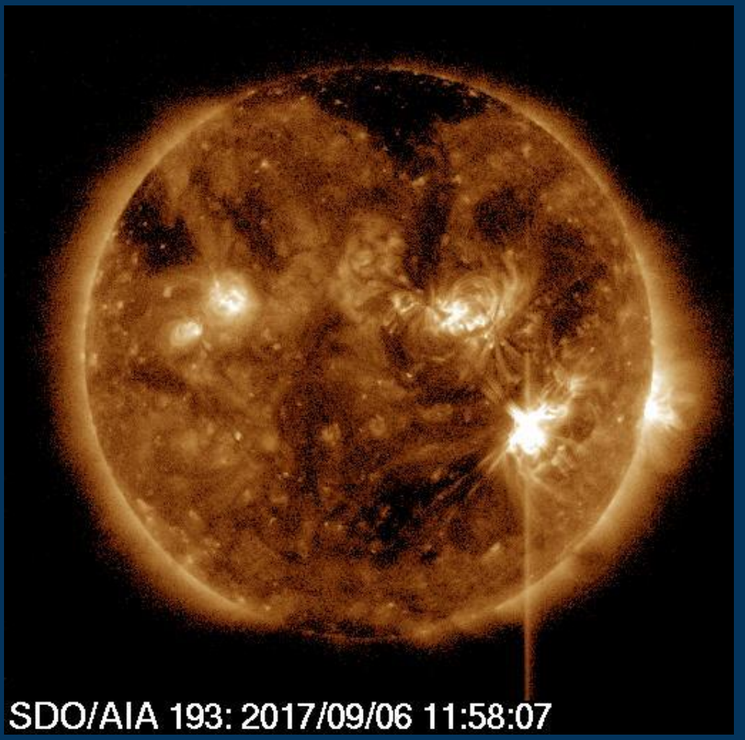
Event selection

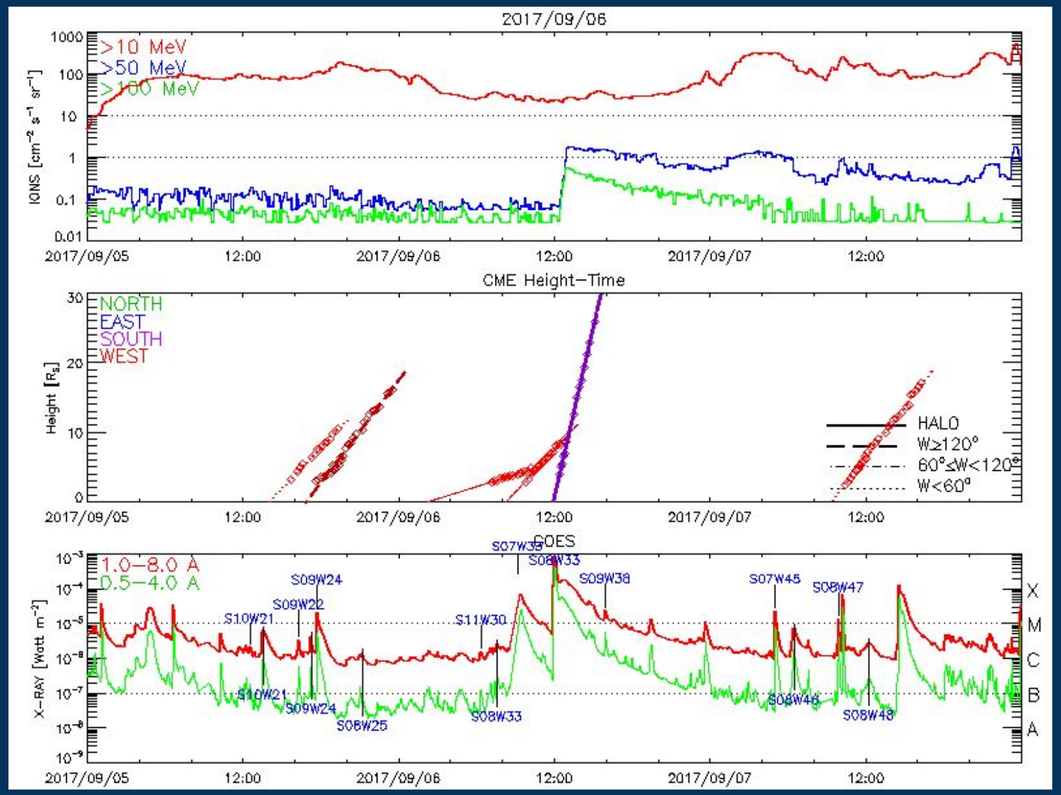
Mohamed,
Grozdan,
Rositsa

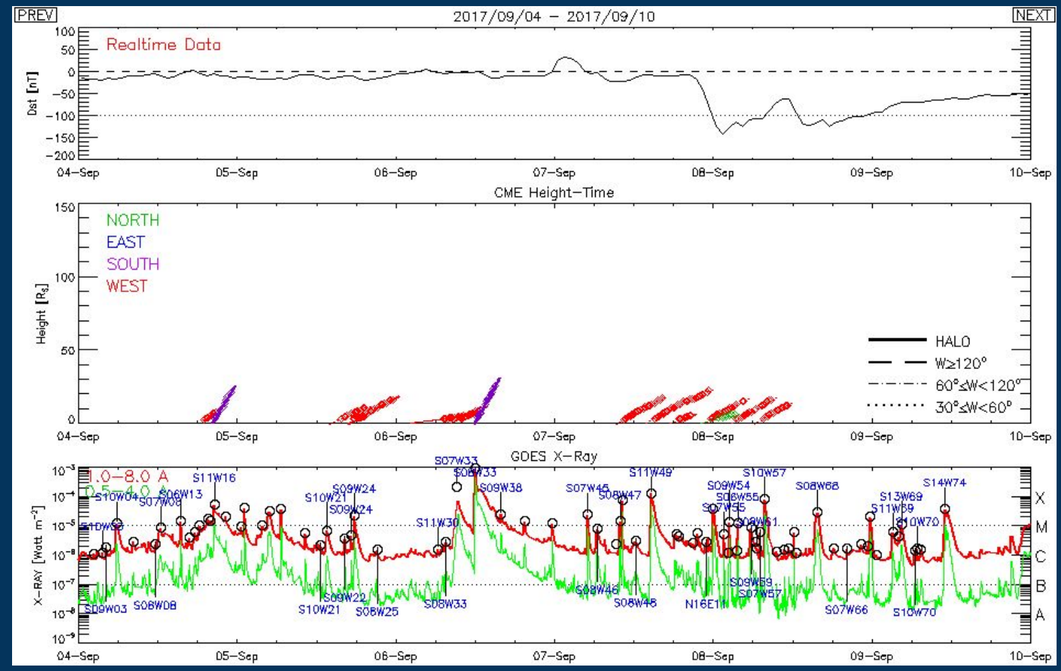
Event selection: Solar flare

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

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





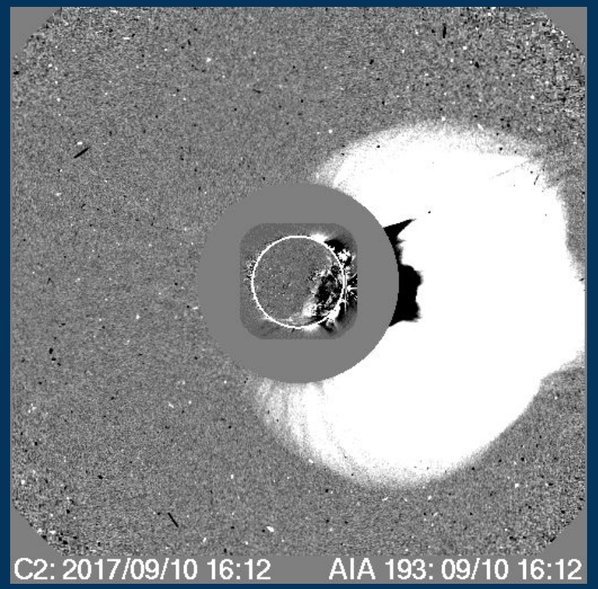


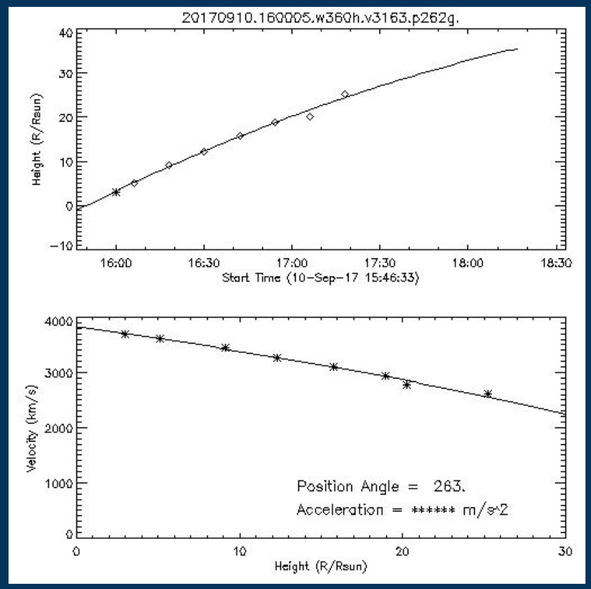
Mohamed, Grozdan, Rositsa

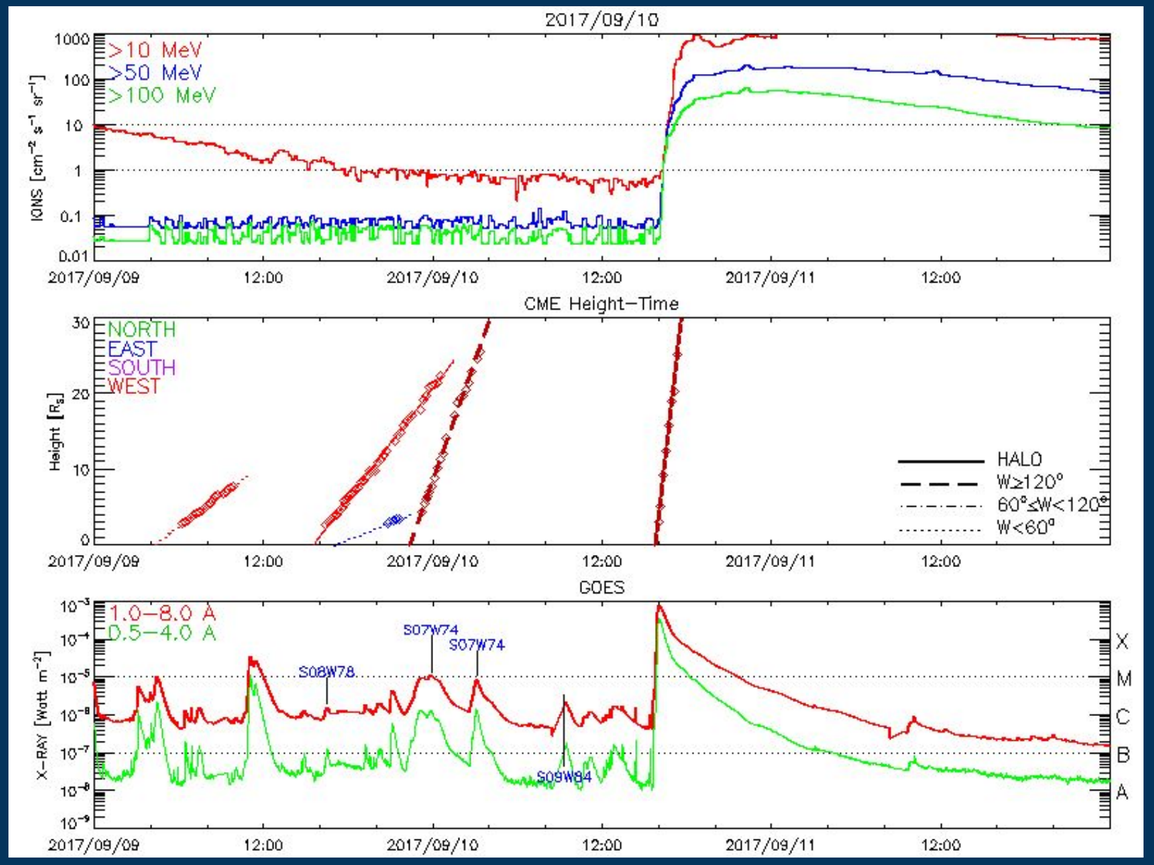
Event selection: CME

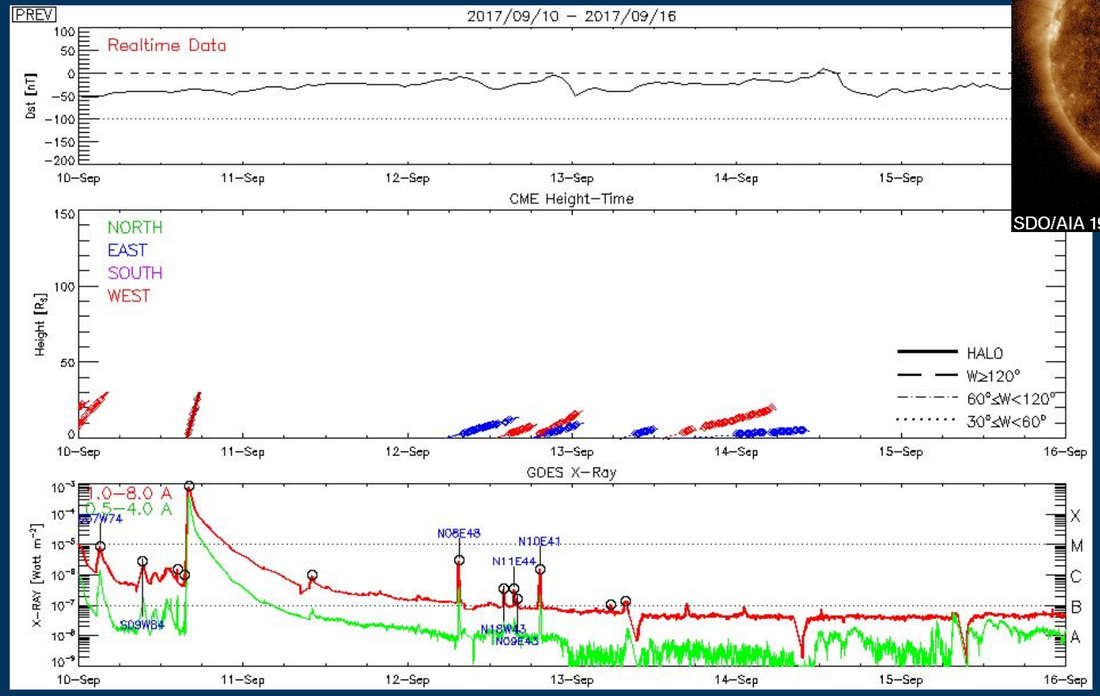
2017-Sep-10: 3163 km/s 16:00 (#1)

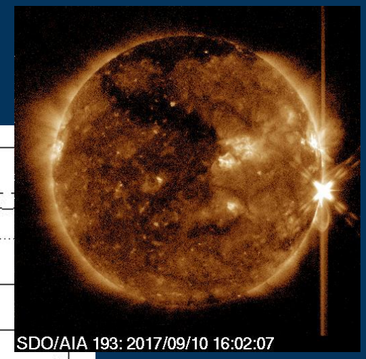
https://cdaw.gsfc.nasa.gov/CME_list/











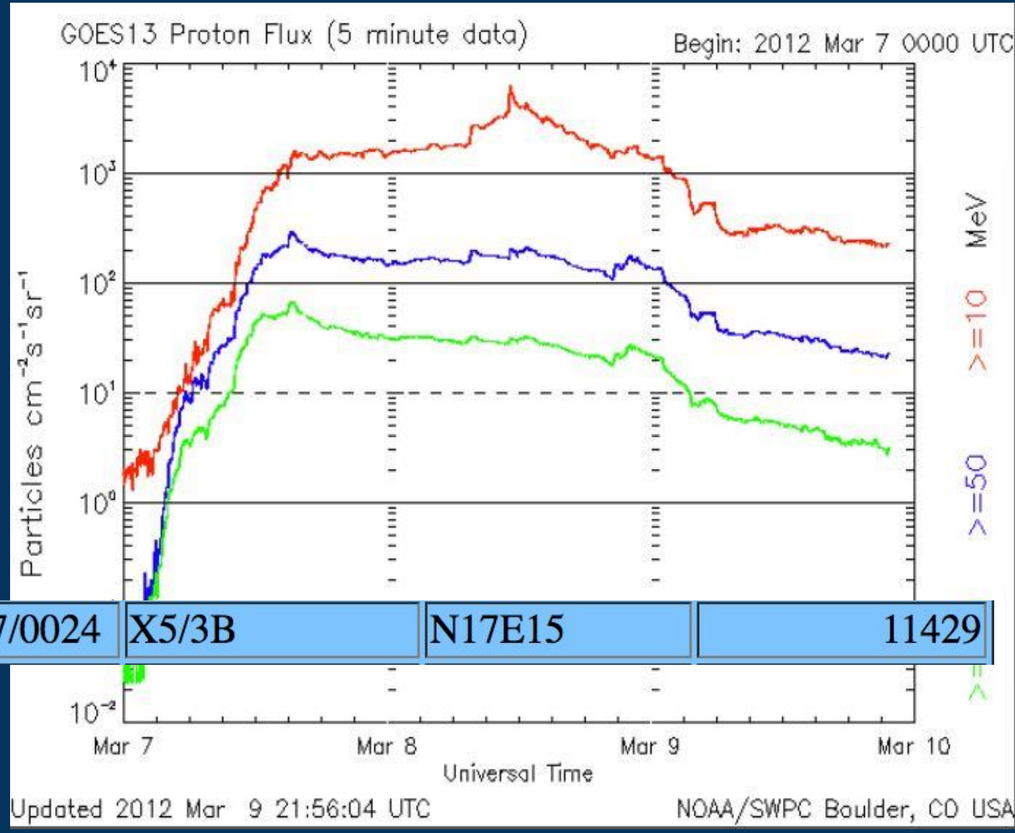
Mohamed, Grozdan, Rositsa

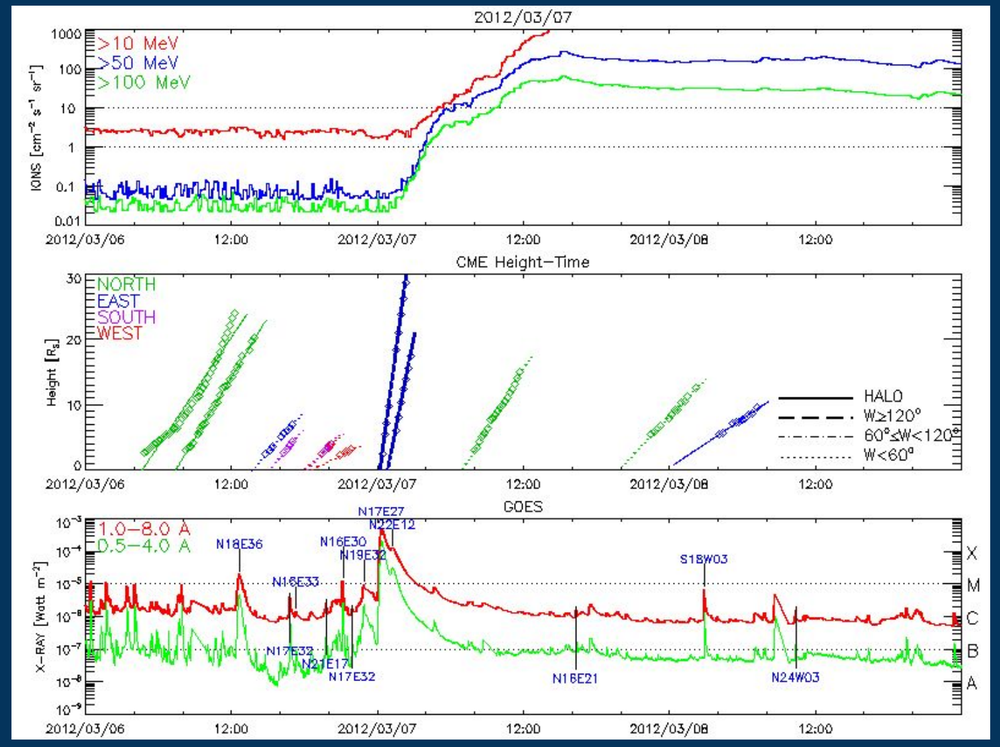
Event selection: SEP

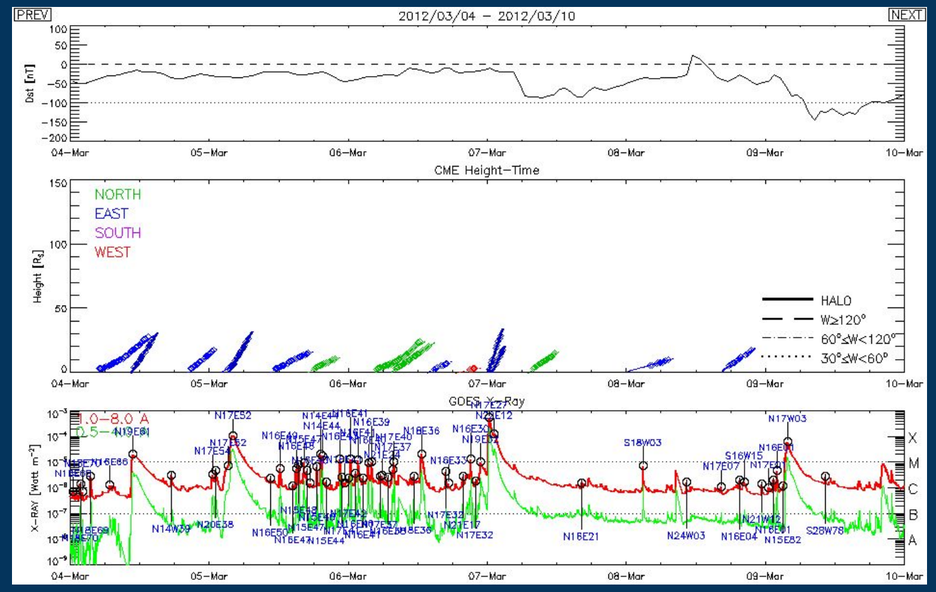
2012-Mar-07: GOES >10 MeV: 6530 pfu (#1)

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

Mar 07/0510	Mar 08/1115	6530		Halo /07 0036	Mar 07/0024	X5/3B	N17E15	11429





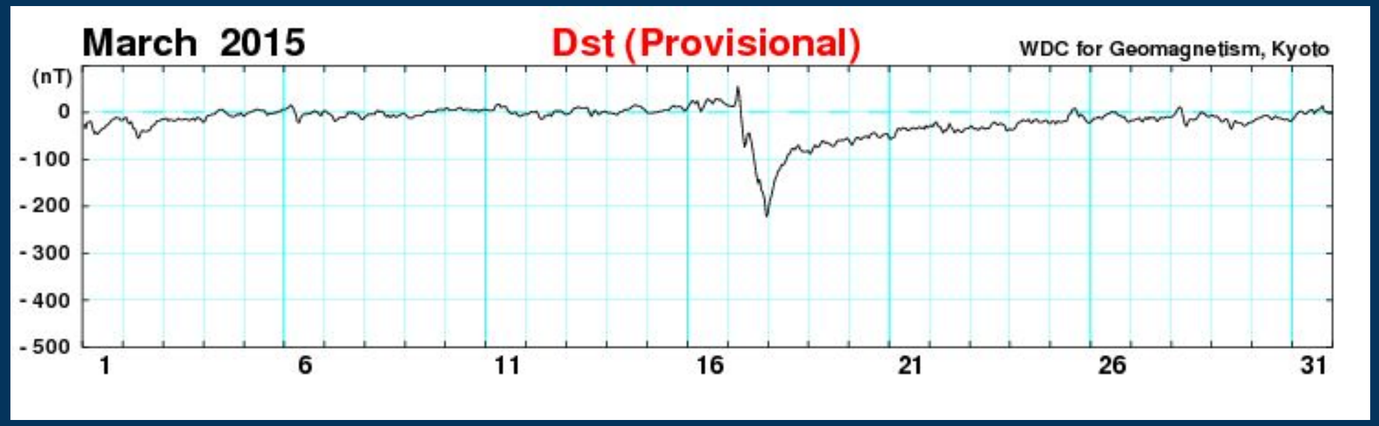


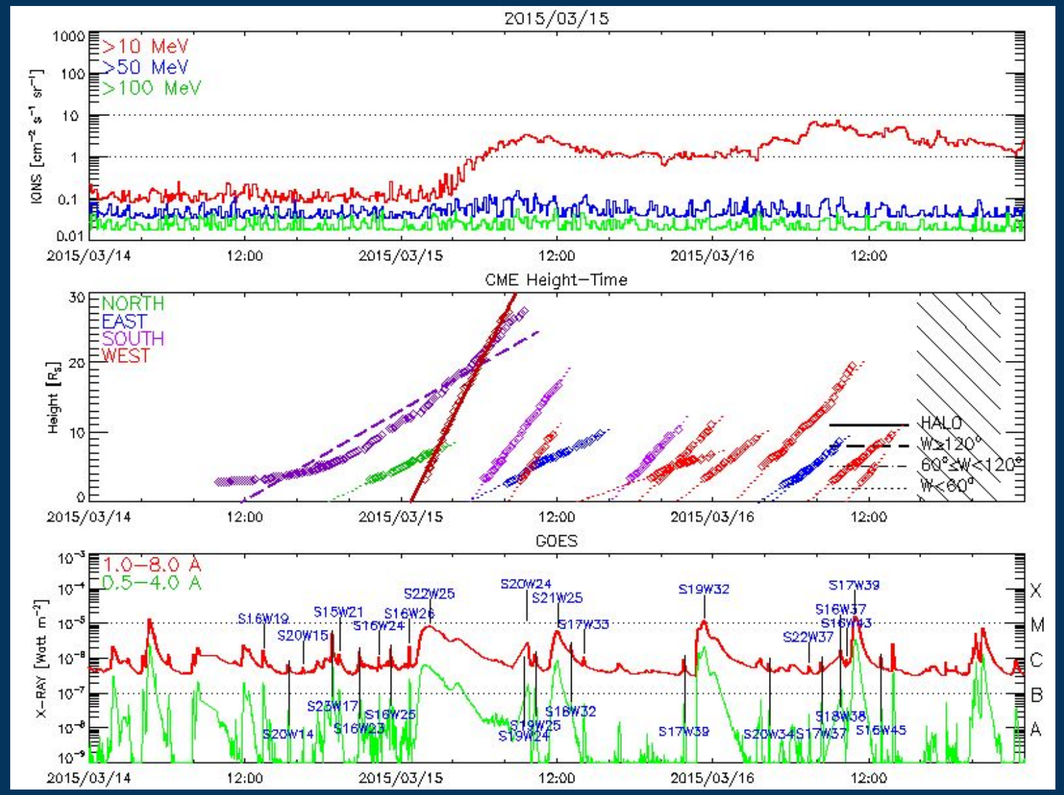
Mohamed, Grozdan, Rositsa

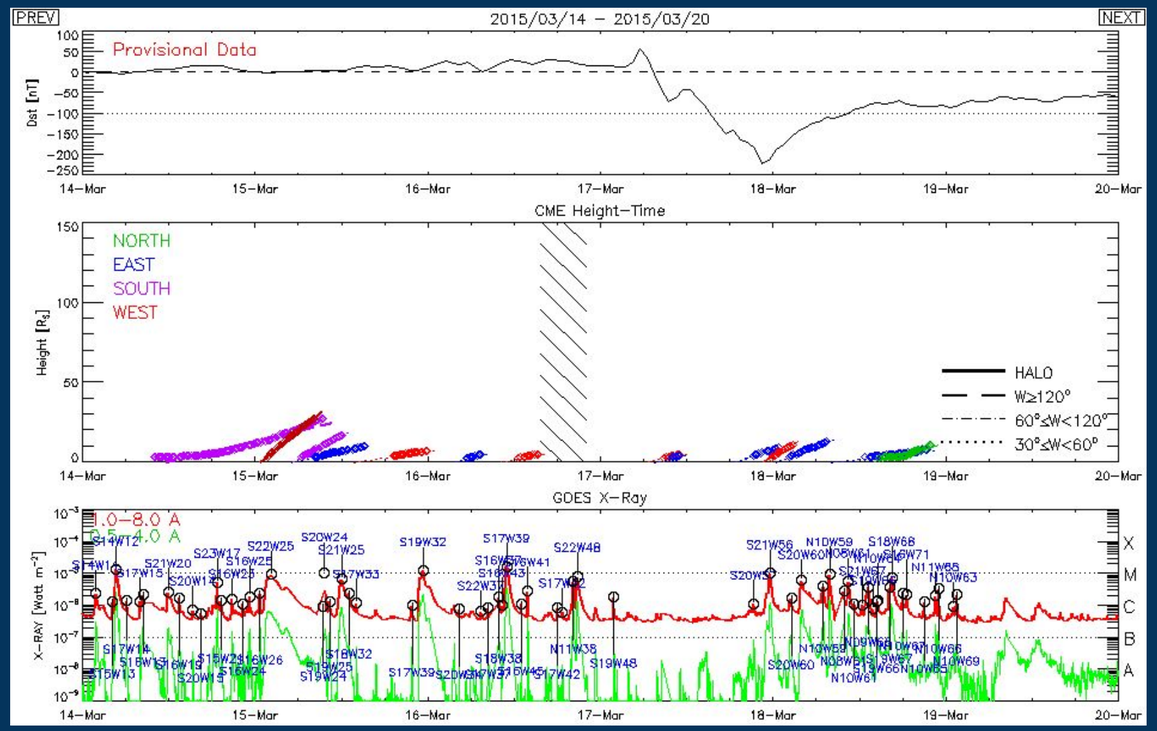
Event selection: Geomagnetic storm

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

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







Mohamed, Grozdan, Rositsa

Event properties and inter-associations

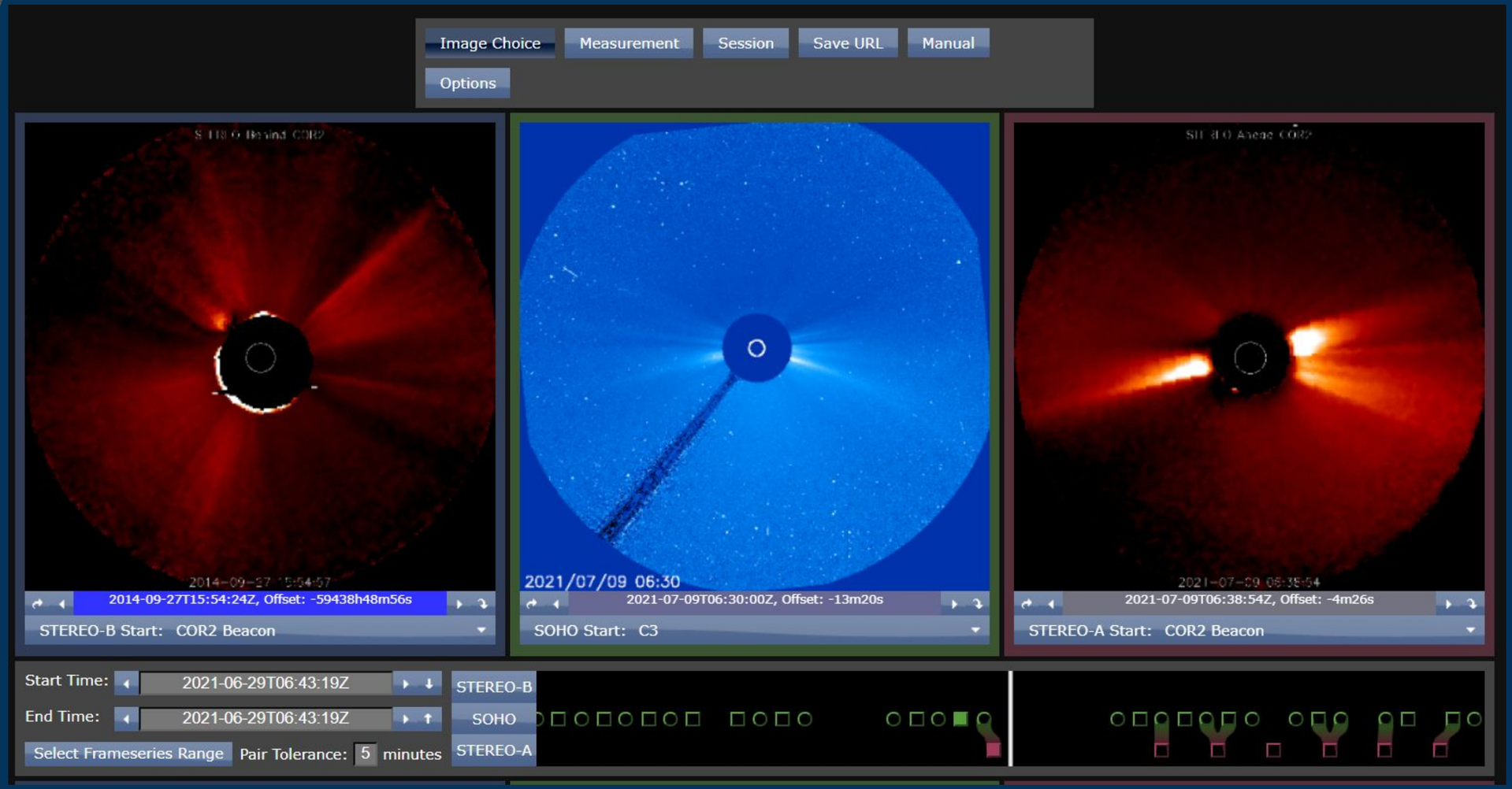
Date	Solar flare	CME	SEP	Geo-storm
2017-Sep-06	**X9.3 (#1)** 11:53/12:02/12:10 S08W33	1571 km/s 12:24 360/201	339 pfu 03:00+1d	-124 nT 02:00+2d (Hit)
2017-Sep-10	X8.2 15:35/16:06/16:31 [S09W84]	**3163 km/s** **16:00** **360/262 (#1)**	1139 pfu 01:00+1d	No (Missed)
2012-Mar-07	X5.4 00:02/00:24/00:40 N17E15	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)

Mohamed, Grozdan, Rositsa

Deducing the 3D parameters of the CMEs

Mohamed,
Grozdan,
Rositsa

StreoCat Analysis Tool

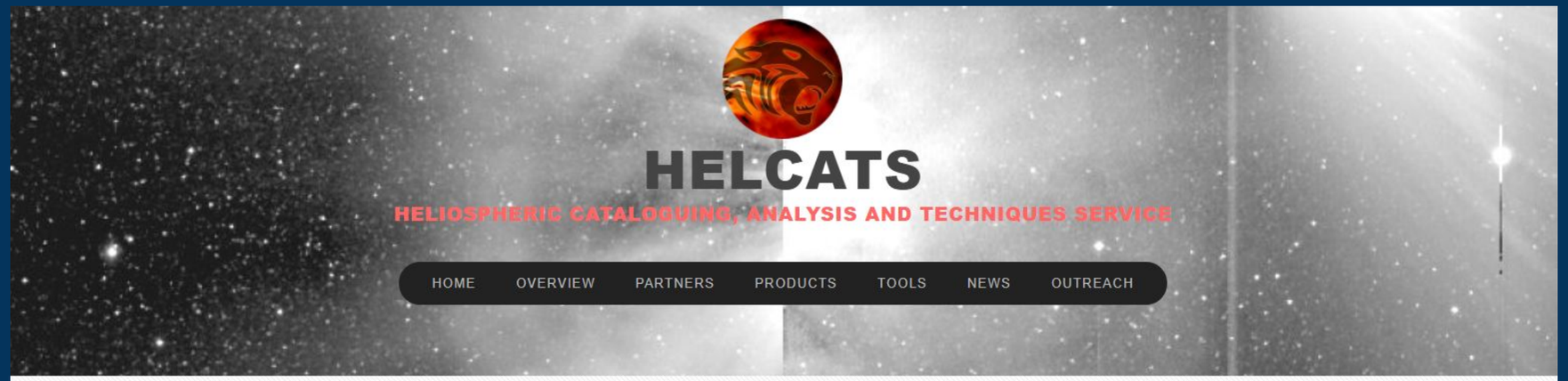


https://ccmc.gsfc.nasa.gov/analysis/stereo/

No available data!

Mohamed, Grozdan, Rositsa

HelCats Catalogue



WP3 COR2 Catalogue

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 2007-01-01 to 2015-01-01

Show 10 entries

Search: Show / hide columns

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!

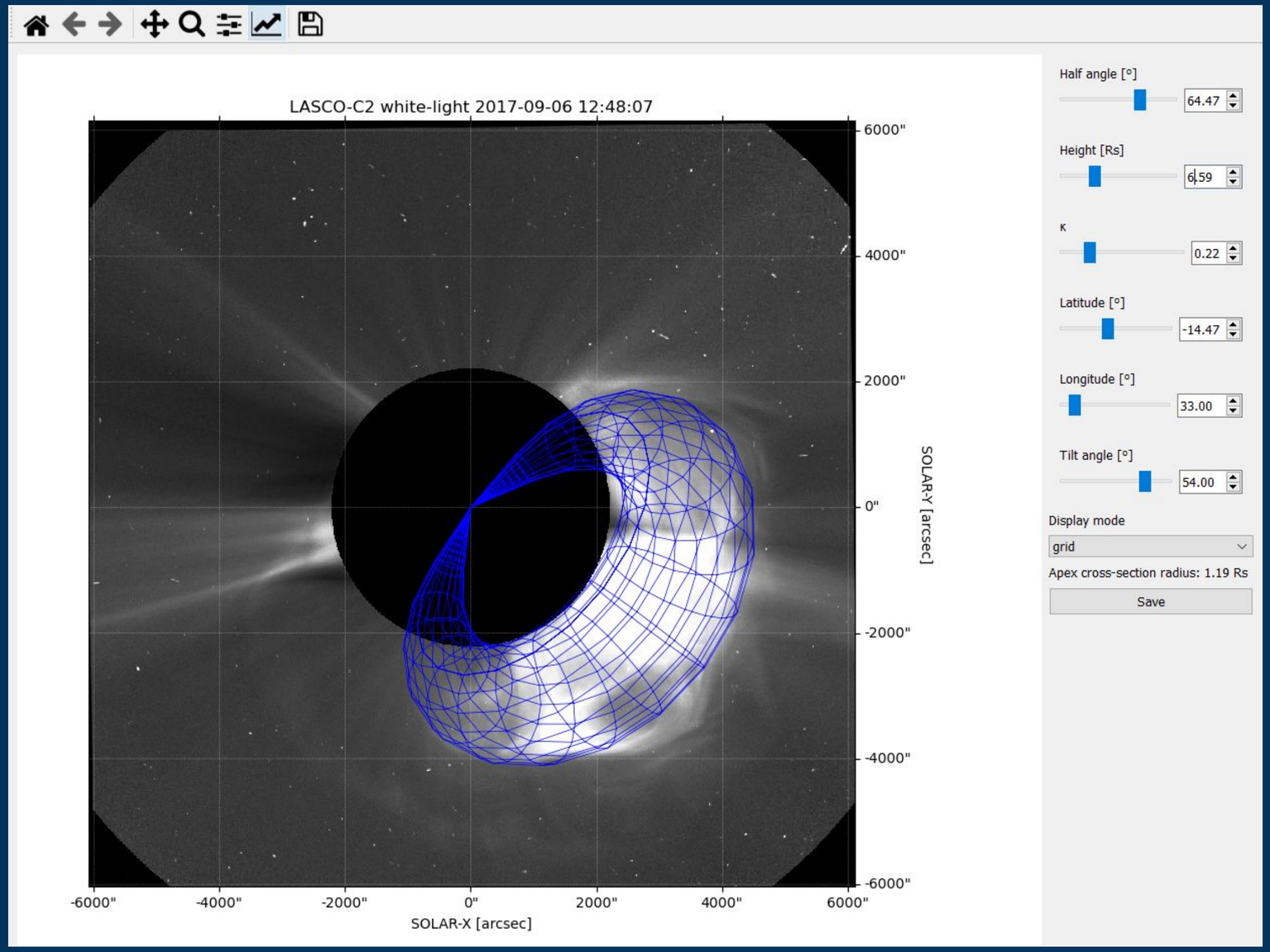
Mohamed, Grozdan, Rositsa

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

Mohamed, Grozdan, Rositsa

The Graduated Cylindrical Shell (GCS) Model



https://github.com/johan12345/gcs_python

Mohamed,
Grozdan,
Rositsa

The Graduated Cylindrical Shell (GCS) Model

Steps of estimating the CME speed from the LASCO data:

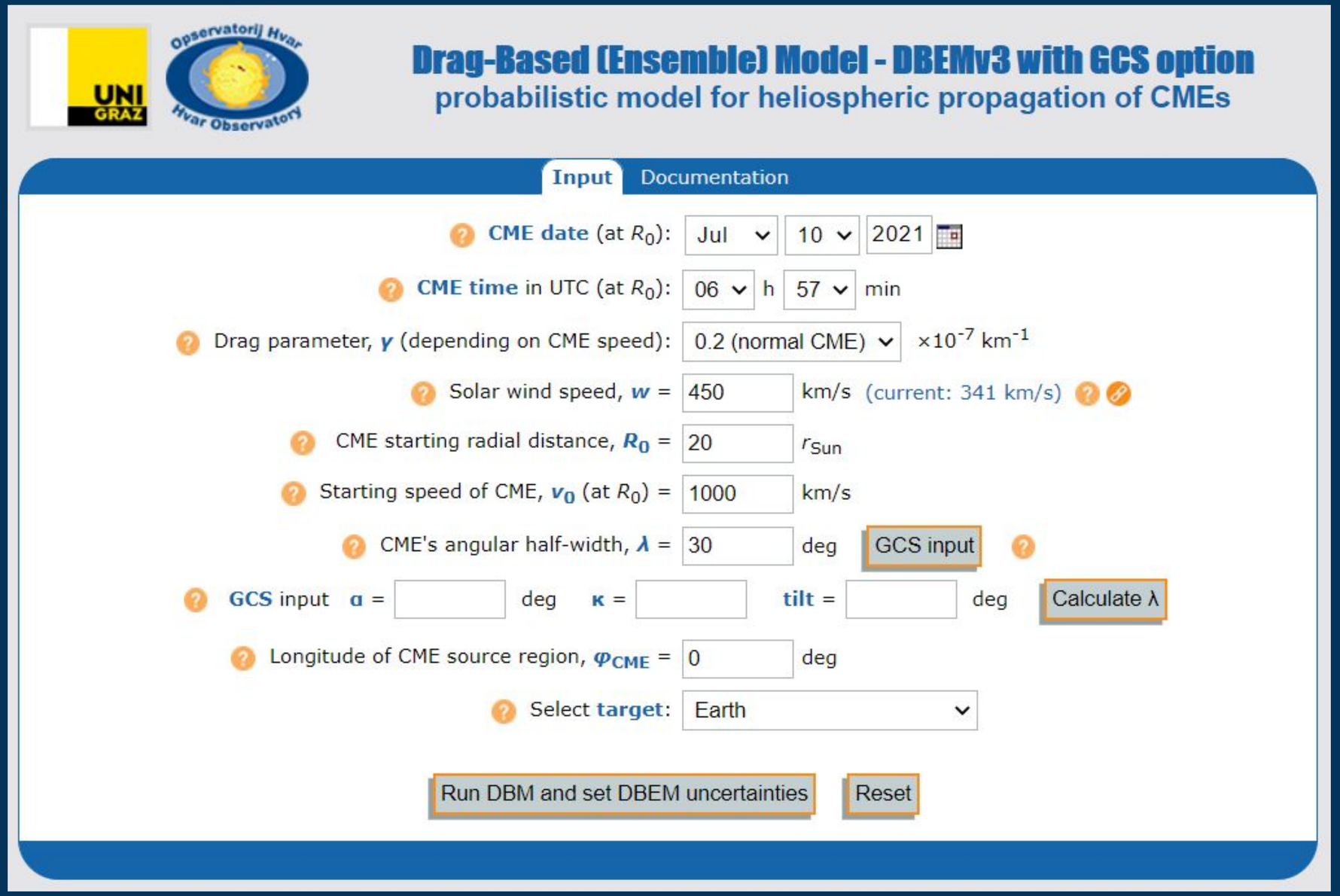
1. Fit the 3D mesh of the GCS model onto the LASCO image in the first frame in which the CME shows up, so that the upper edge of the mesh matches the leading edge of the CME
2. Repeat the same for the second frame
3. Take the difference in CME heights and times
4. Calculate the CME speed by $V = dX/dt$

Mohamed,
Grozdan,
Rositsa

Run the model for CME propagation using the deduced inputs

Mohamed,
Grozdan,
Rositsa

CME propagation using DBEM-tool

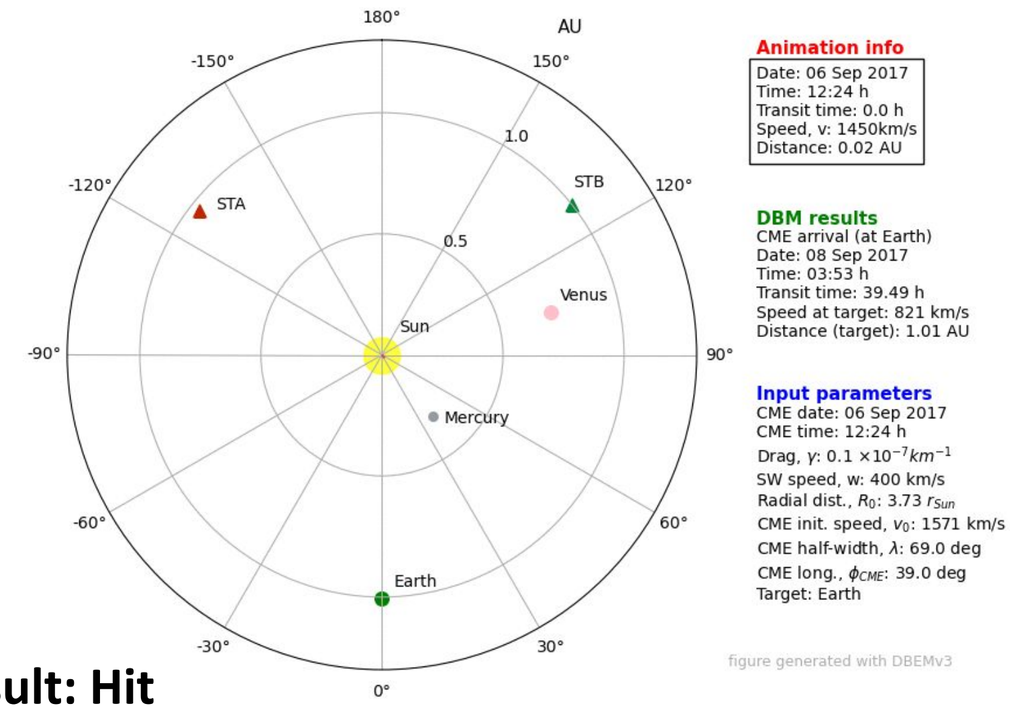


http://phyk039240.uni-graz.at:8080/DBEMv3/dbem.php

Mohamed,
Grozdan,
Rositsa

Analysis: CME propagation (projected vs. 3D)

Event 1



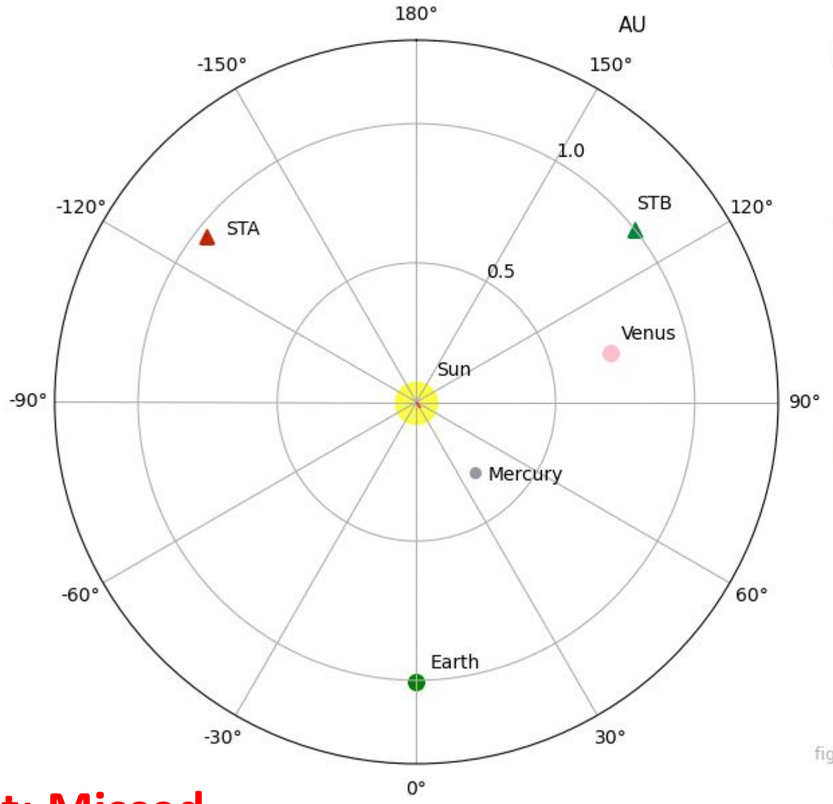
Animation info
Date: 06 Sep 2017
Time: 12:24 h
Transit time: 0.0 h
Speed, v: 1450km/s
Distance: 0.02 AU

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 $\times 10^{-7} km^{-1}$
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: Hit



Animation info
Date: 06 Sep 2017
Time: 12:24 h
Transit time: 0.0 h
Speed, v: 843km/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 $\times 10^{-7} km^{-1}$
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

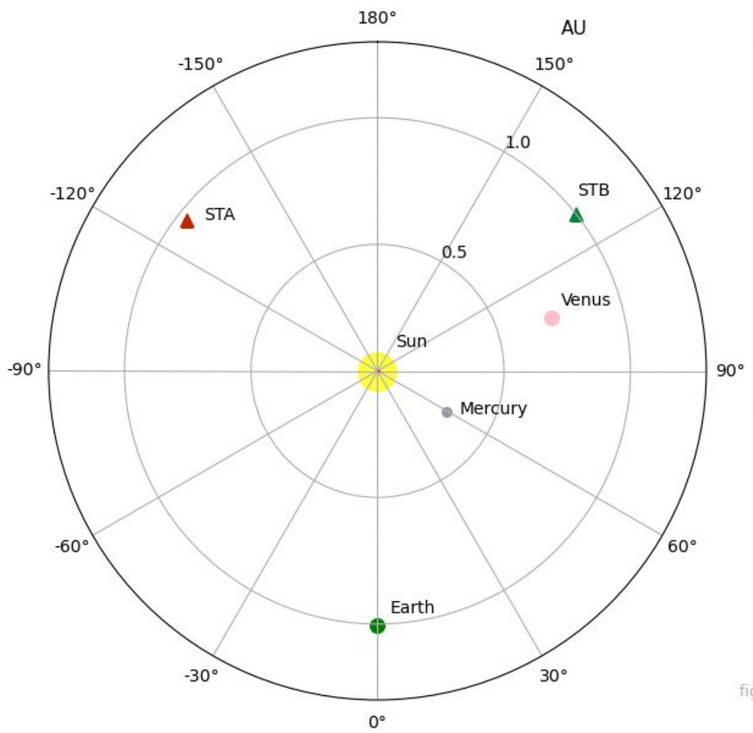
Result: Missed

Observations: Hit

Mohamed,
Grozdan,
Rositsa

Analysis: CME propagation (projected vs. 3D)

Event 2



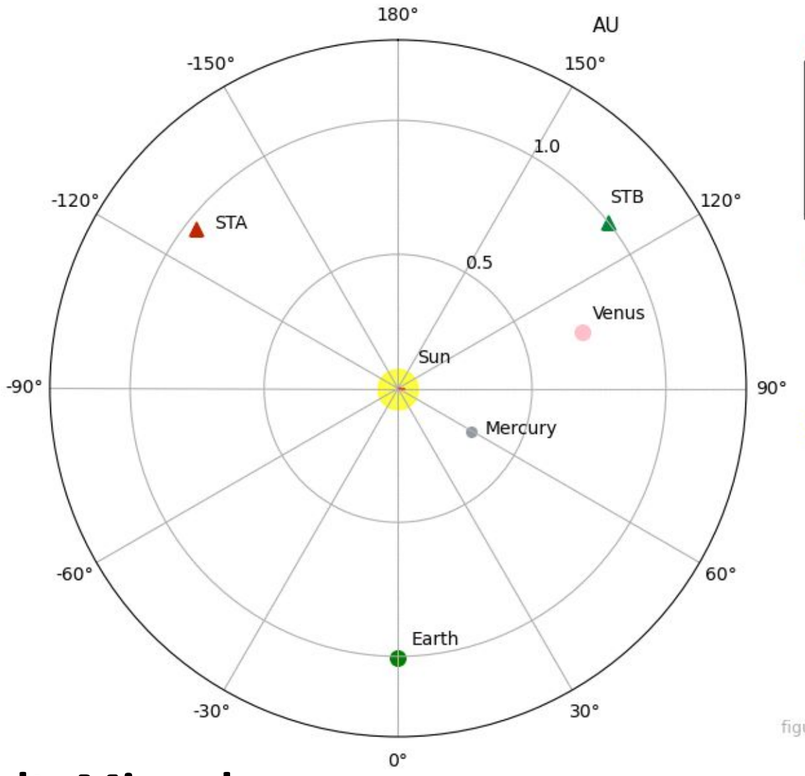
Animation info
Date: 10 Sep 2017
Time: 16:00 h
Transit time: 0.0 h
Speed, v: 2264km/s
Distance: 0.01 AU
Note: Shown values are for CME flank

DBM results
CME misses the target (Earth)

Input parameters
CME date: 10 Sep 2017
CME time: 16:00 h
Drag, γ: 0.1 $\times 10^{-7} km^{-1}$
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: 2382km/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 $\times 10^{-7} km^{-1}$
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

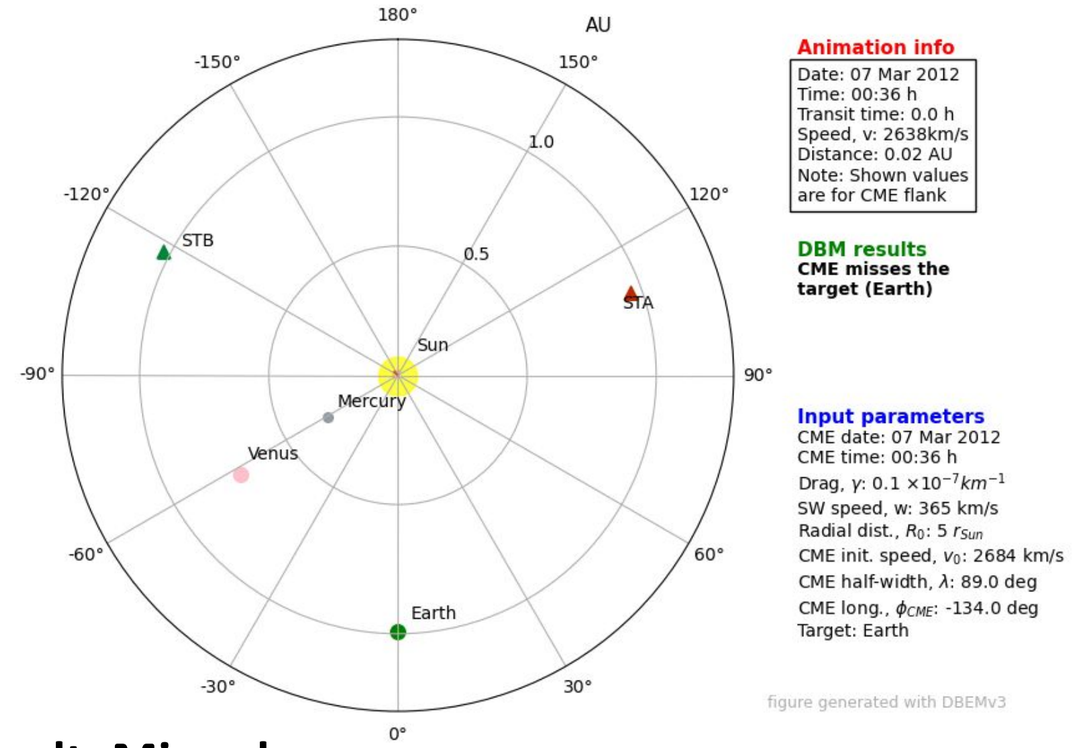
Result: Missed

Observations: Missed

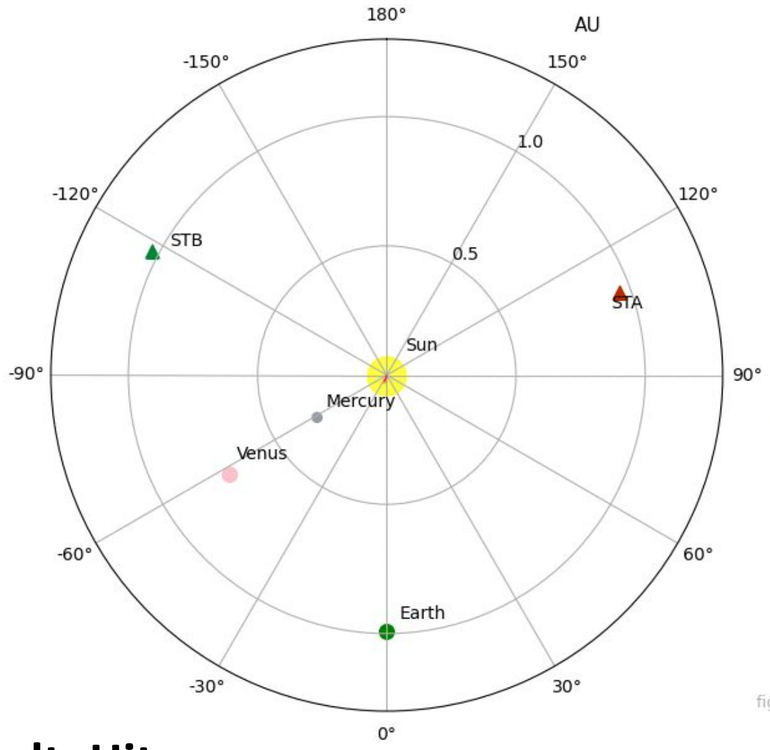
Mohamed, Grozdan, Rositsa

Analysis: CME propagation (projected vs. 3D)

Event 3



Result: Missed



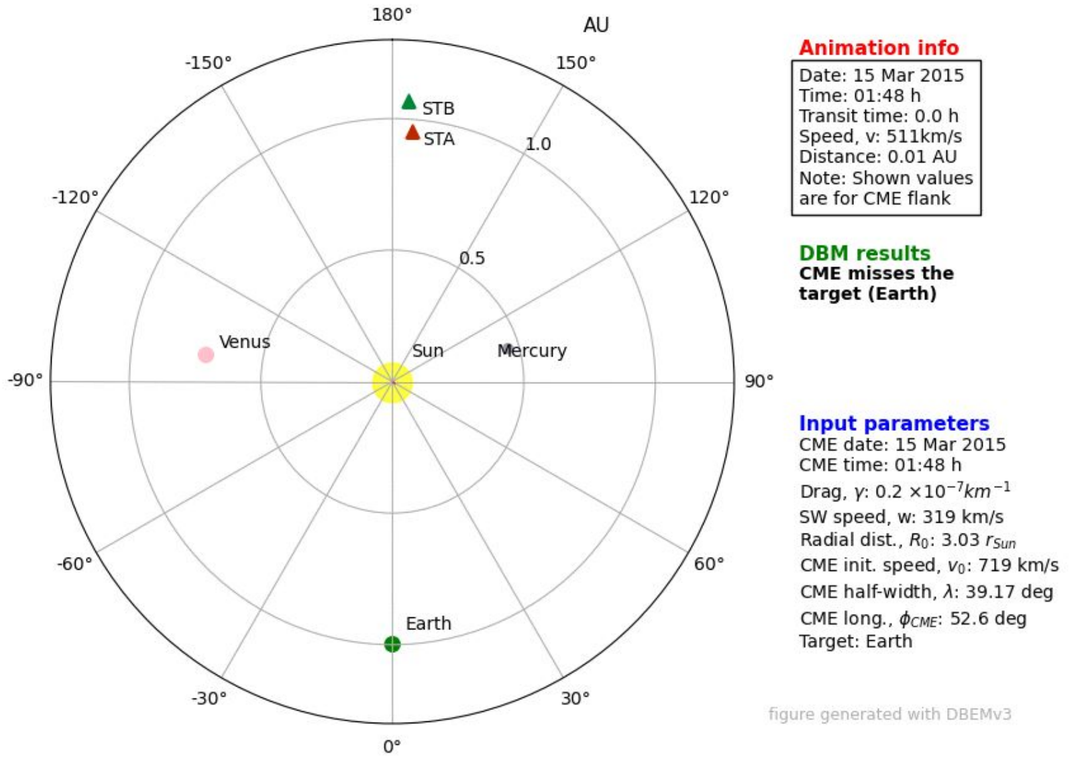
Result: Hit

Observations: Hit

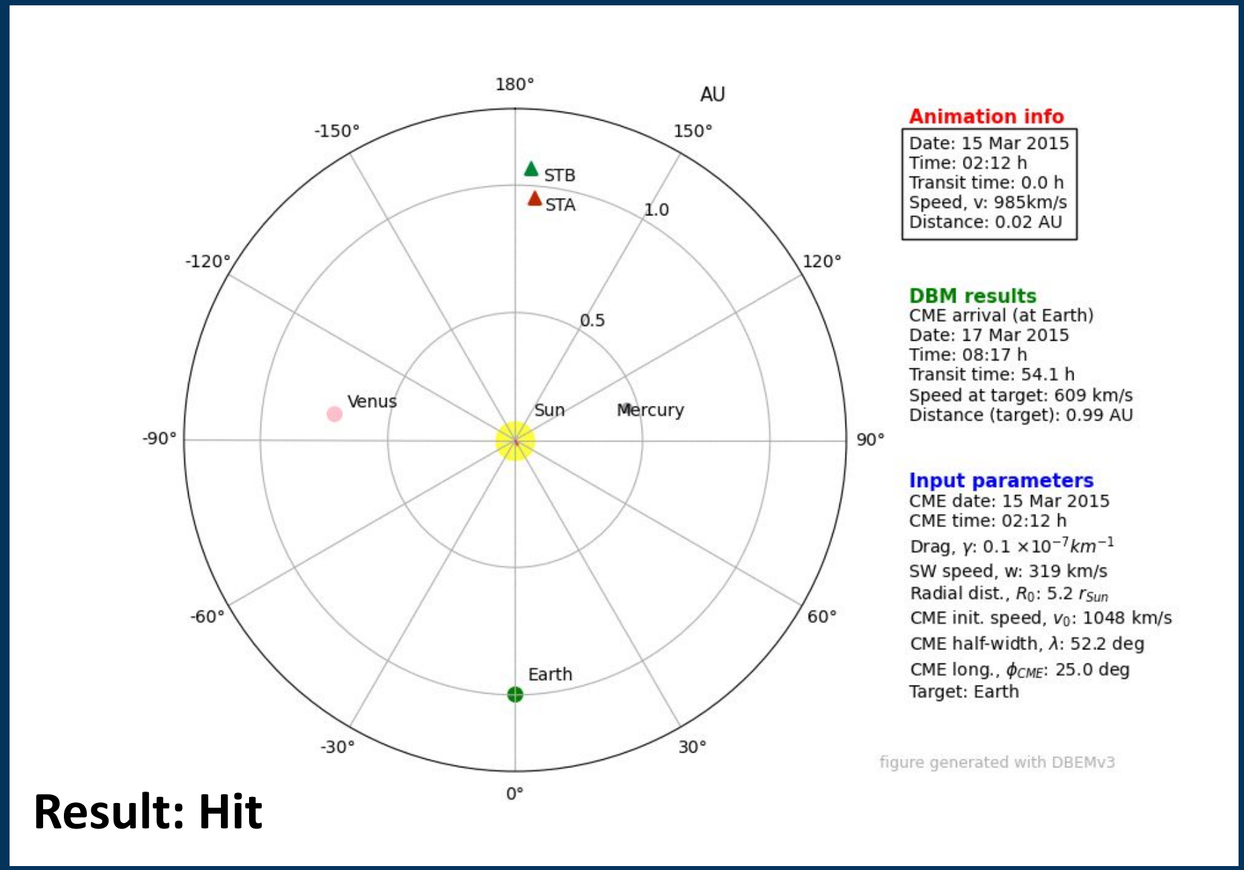
Mohamed, Grozdan, Rositsa

Analysis: CME propagation (projected vs. 3D)

Event 4



Result: Missed



Result: Hit

Observations: Hit

Mohamed, 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

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

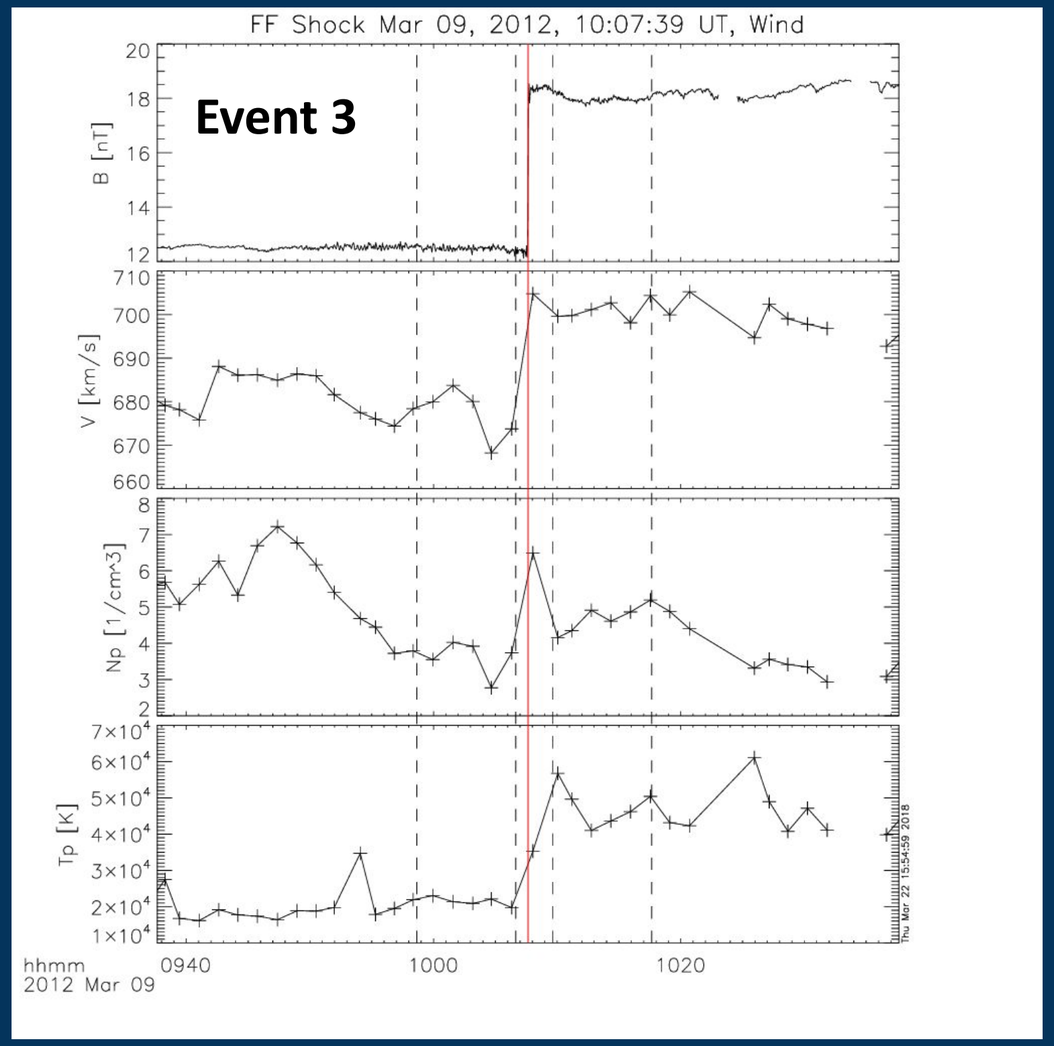
No ICME reported

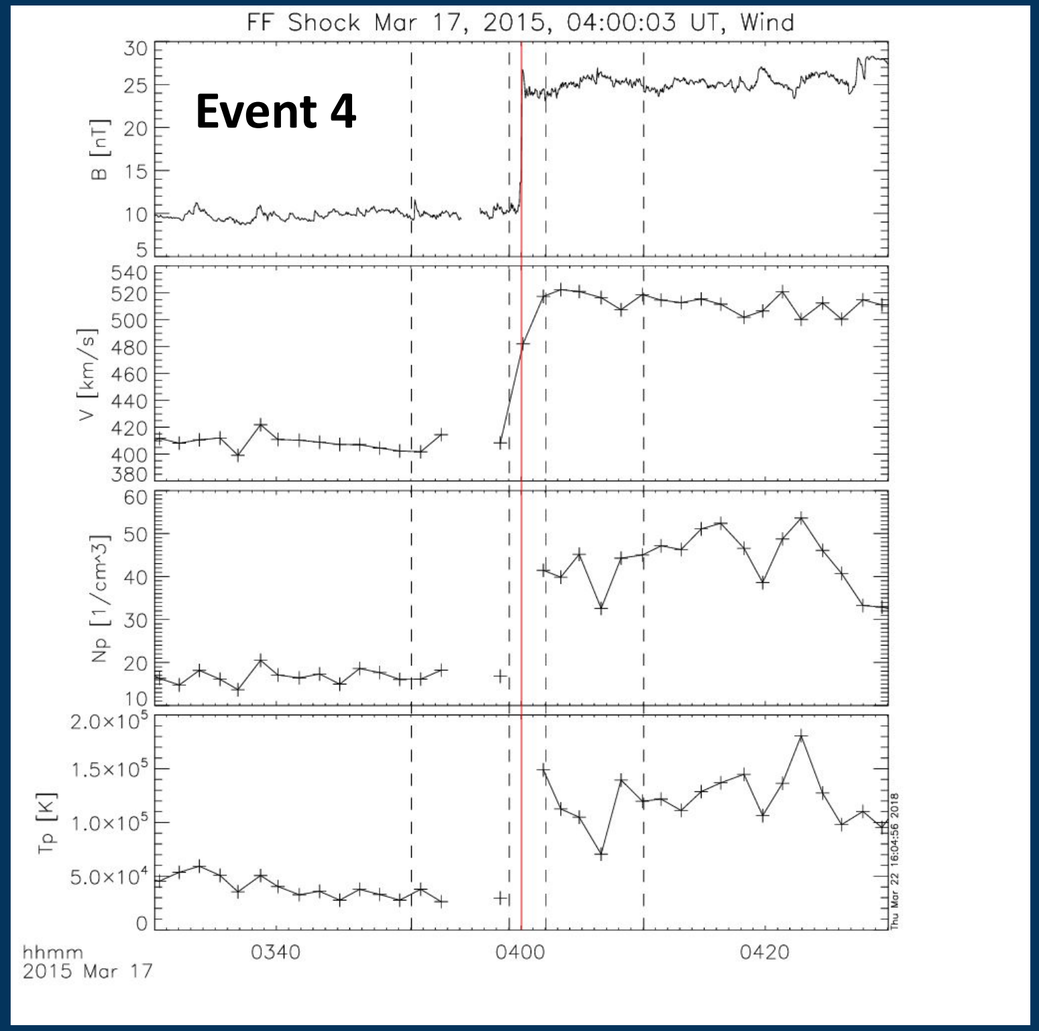
Mohamed, Grozdan, Rositsa

Comparison with in-situ observations

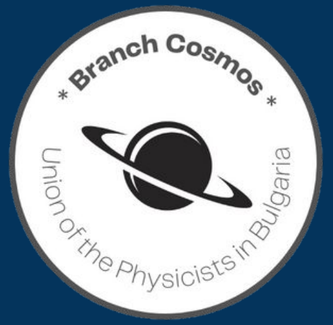
IP shocks at Earth database

http://ipshocks.fi/database





Mohamed, Grozdan, 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

Mohamed, Grozdan, Rositsa

Thank you

Mohamed,
Grozdan,
Rositsa