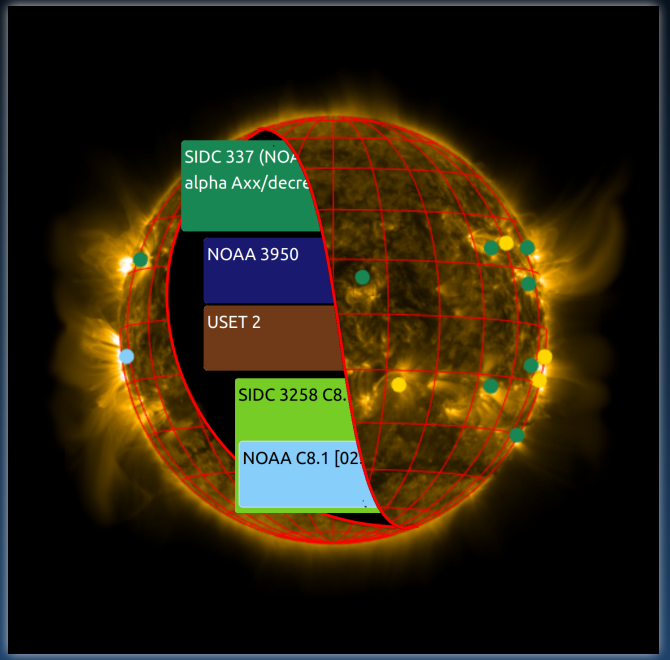
Building the Sun-to-Earth Connection

An Operational Event Chain Framework for Space Weather Forecasting at SIDC



Royal Observatory of Belgium

UKSWSE – 9 September 2025

Lukas Vinoelst, Freek Verstringe, Judith De Patoul, Daria Shukhobodskaia, Dimitrios Millas, Yana Maneva

Operational Space Weather Forecasting at SIDC

- Operational methods and data
  - Moderated analysis and classification by operators
  - Supplied with metadata
  - Near-Real-Time (daily)

→ Feed datasets that are relevant in research projects

Operational Space Weather Forecasting at SIDC

- Research on operational methods and data
  - Predictive models
  - Database optimization
  - Workflow design

→ Improve operations based on insights from research

Operational Space Weather Forecasting at SIDC

Where and how to store/capture all this operational data?

The Event Chain Database

+

Forecaster Interface

Sunspot Group

Incoming ‘Atomic’ events

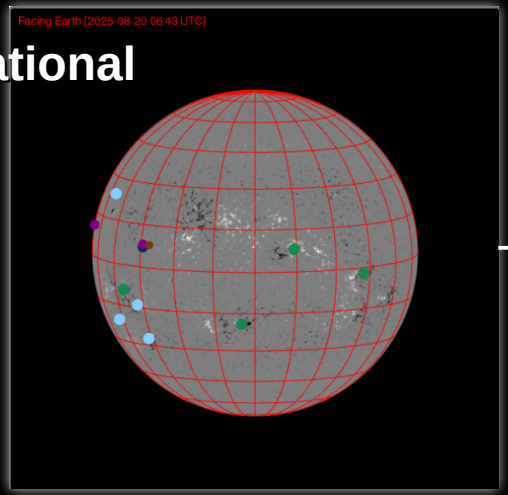
UKMO 4187 at 2025-08-20T08:35:03:

[Stonyhurst] Long : -4, Lat : -19		[Carrington] Long : 258, Lat : -19	
Number : 4187	HasDecayed : false	AreaMSH : 70	EvalTime : 2025-08-20T08:35:03
Comment : null	NSpots : 4	McIntosh : Dso	MtWilson : beta
Zurich : null	LeadingSpot : null	Growth : Stable	Provider : UKMO

USET 0 at 2025-08-20T07:15:00:

[Stonyhurst] Long : -3, Lat : -18		[Carrington] Long : -101, Lat : -18	
Number : 0	HasDecayed : false	AreaMSH : 84.31	EvalTime : 2025-08-20T07:15:00
Comment : null	NSpots : 3	McIntosh : Dsi	MtWilson : null
Zurich : D	LeadingSpot : Equal	Growth : null	Provider : USET

Observational Data



Forecaster Analysis

Consolidated Event

SIDC 605 (NOAA 4187)
(S19,E04) 08:35
beta Dso/growing
Edit

NOAA 4187
(S17,E05) 00:30

UKMO 4187
(S19,E04) 08:35

USET 0
(S18,E03) 07:15

Sunspot Group

SIDC 605 (NOAA 4187)
(S19,E04) 08:35
beta Dso/growing

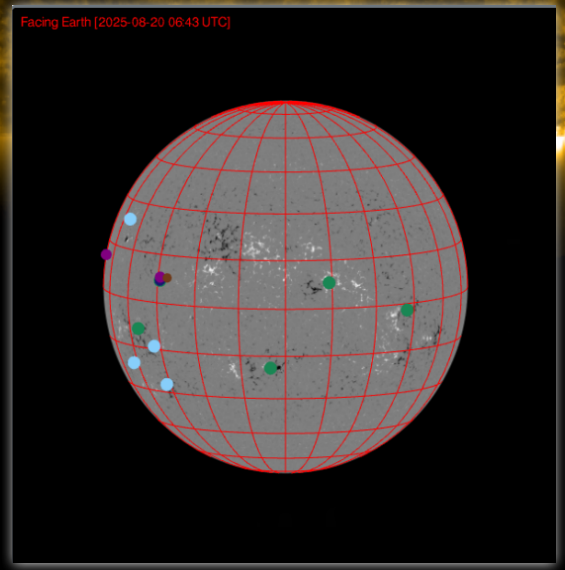
Edit

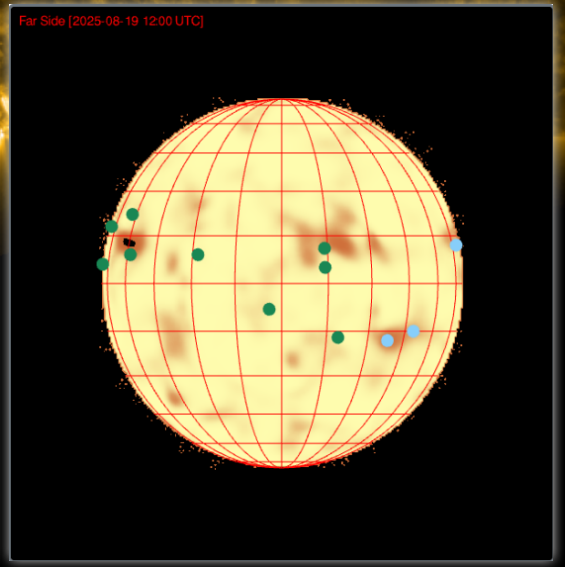
Forecaster Analysis :

Internal Tag Name	SIDC Sunspot Group Number	Evaluation Time
SIDC_SunspotGroup_Evaluation_2025-08-20_605	605	2025-08-20T09:07:10Z
Time for Location Evaluation [previously 2025-08-19T08:35:03]	Longitude [Stonyhurst, -180 deg to 180 deg]	Latitude [Stonyhurst, -90 deg to 90 deg]
2025-08-20T08:35:03Z	-4	-19
McIntosh [previously Cro]	MtWilson [previously beta]	Zurich [previously D]
Dso	beta	D
Area [MSH] [previously 10]	Number of Spots [previously 2]	Growth [suggested: Growing]
70	4	Growing
Leading Spot [previously Leading]	Decayed	
Equal	No	

Sunspot Group: Operational Monitoring

Tracking over multiple rotations:



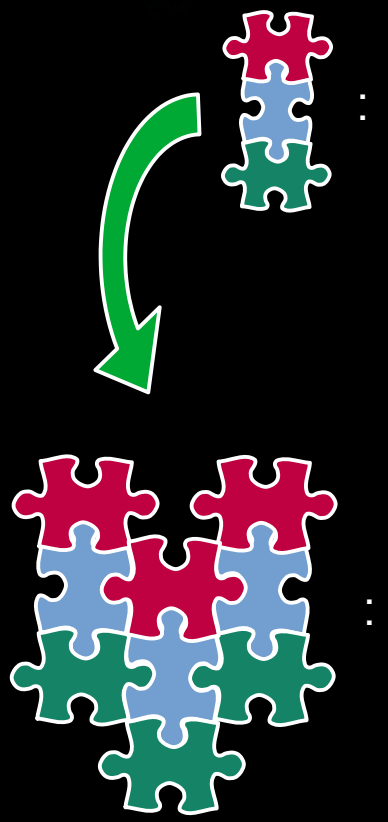


:

Daily evaluations

	Today	*Yesterday*	*Day before*
SIDC 605 (NOAA 4187) beta Dso/growing	SIDC 605 (NOAA 4187) (S19,E04) 08:35 beta Dso/growing Edit	SIDC 605 (NOAA 4187) (S18,E19) 00:30 beta Cro/stable View	SIDC 605 (NOAA 4187) (S18,E30) 08:38 alpha Axx/null View
	NOAA 4187 (S17,E05) 00:30	NOAA 4187 (S18,E19) 00:30	UKMO null (S18,E30) 08:38
	UKMO 4187 (S19,E04) 08:35	UKMO 4187 (S18,E16) 08:47	USET 2 (S17,E27) 12:00
	USET 0 (S18,E03) 07:15	USET 0 (S17,E16) 07:30	

Flare: Link to Sunspot Group



Flare

SIDC 5176 C1.2 [03:47] UTC (S02,W27)
03:47

Edit

NOAA C1.2 [03:47] UTC

Detach

solardemon [03:48] UTC (S02,W30)
03:48

View

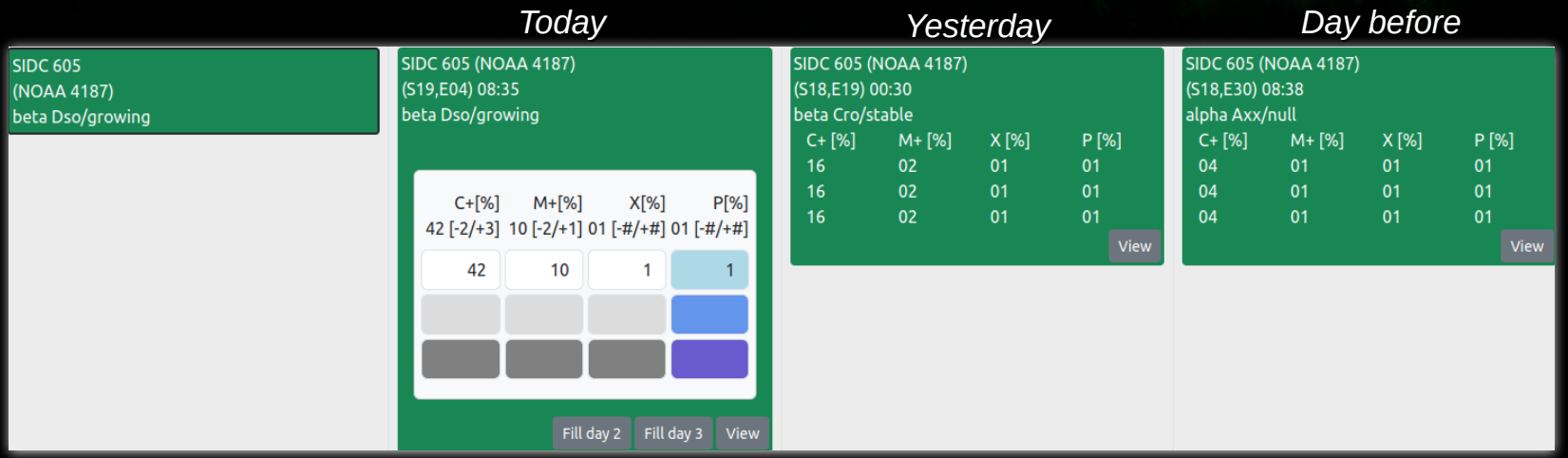
Sunspot Group

SIDC 605 (NOAA 4187)
(S19,E04) 08:35
beta Dso/growing

Edit

Today	*Yesterday*	*Day before*
SIDC 598 (NOAA 4180) (S02,W25) 00:30 beta Bxo/decreasing View	SIDC 598 (NOAA 4180) (S04,W13) 08:38 beta Cro/growing View	SIDC 598 (NOAA 4180) (S03,E02) 07:46 beta Dro/growing View
SIDC 5176 C1.2 [03:47] UTC (S02,W27) 03:47 Edit NOAA C1.2 [03:47] UTC Detach solardemon [03:48] UTC (S02,W30) 03:48 View		SIDC 5166 C3.3 [19:58] UTC (S03,W09) 19:58 View NOAA C3.3 [19:58] UTC
		SIDC 5167 C1.8 [04:11] UTC (S03,W00) 04:11 View NOAA C1.8 [04:11] UTC
+		

Flare: Forecasts linked to Sunspot Group



Disk forecast from all Sunspot Groups on disk

Sunspot Groups, Flares, Coronal Holes, CMEs, Forecasts

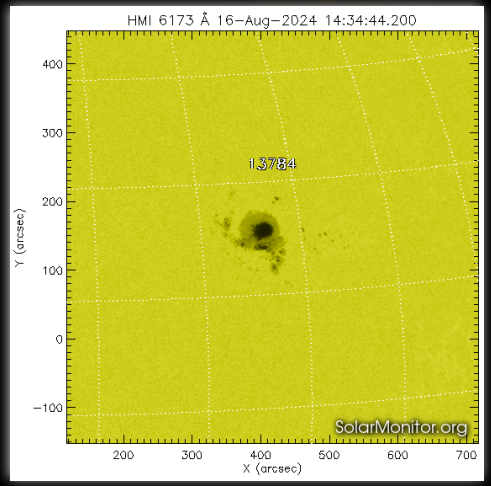
and more to come...

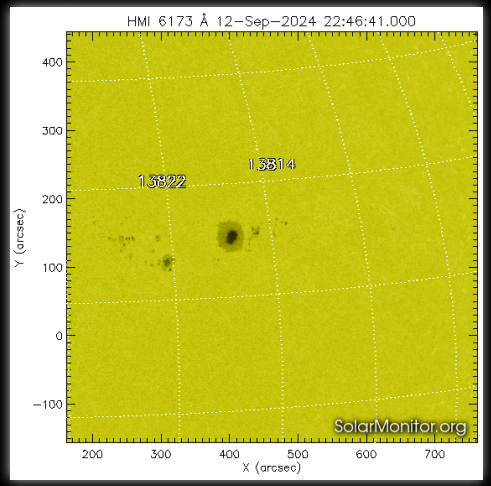
Where to find all of this?

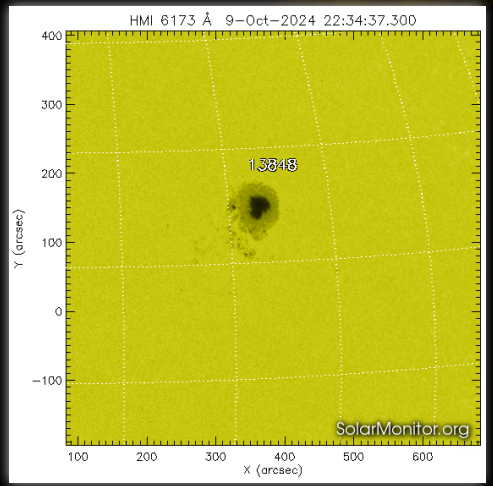
Solar Influences
Data analysis Centre
www.sidc.be

October 9th 2024

SIDC Sunspot Group 217 (NOAA 3908/3878/3848/3814/3784 multiple rotations)





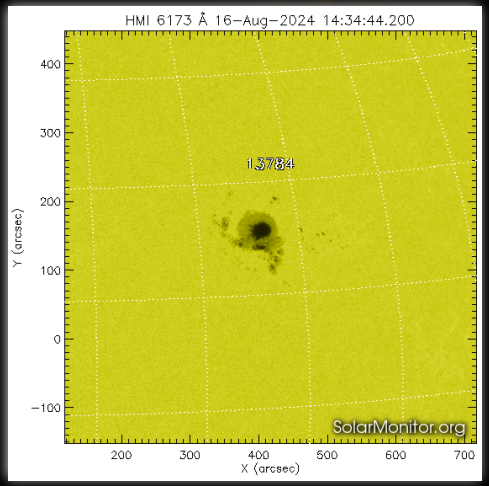


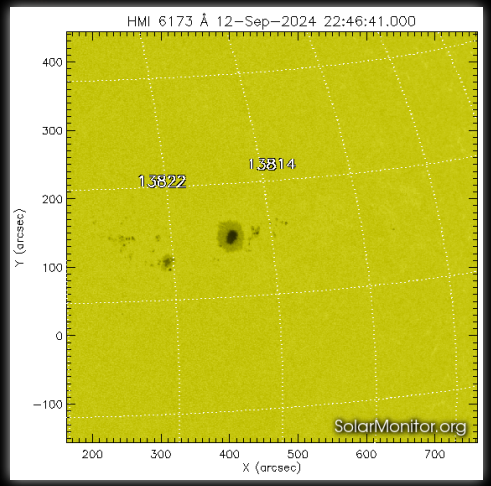
...

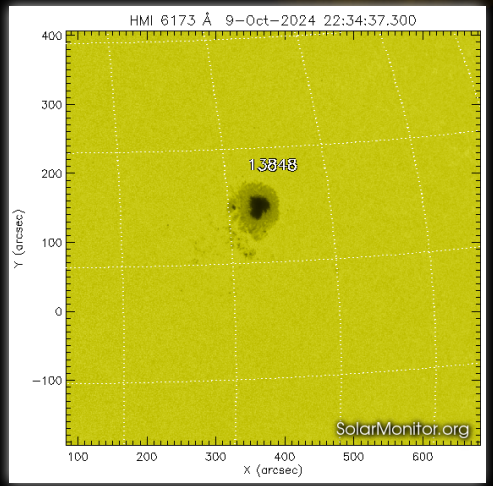
SIDC Flare 2255 X1.8 (NOAA + Solardemon) + SIDC CME 455 + Radiobursts + SEP + ...

October 9th 2024

SIDC Sunspot Group 217 (NOAA 3908/3878/3848/3814/3784 multiple rotations)







...

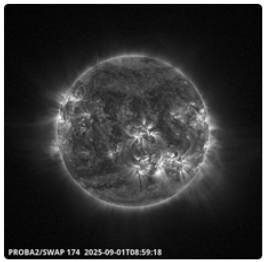
SIDC Flare 2255 X1.8 (NOAA + Solardemon) + SIDC CME 455 + Radiobursts + SEP + ...

Access through www.sidc.be

Solar Influences Data Analysis Center

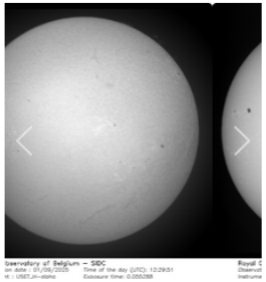
Observations

Space Based Imaging



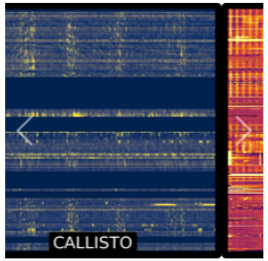
More data: SWAP, EUI

Ground Based Imaging



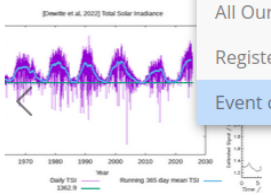
More: H-α, WL, Ca-IIK, Drawings

Ground Based Radio



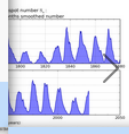
More: ARCAS+HSRS, CALLISTO

Space Based Timelines



More data: LYRA, TSI

spot



More data: SILS

Space Weather Services

Detections

Solardemon
2025-09-01 12:09 B5 flare

CACTus
2025-08-30 19:36 538km/s

Latest Alerts

Presto 2025-08-31

A full halo CME erupted on 30 August, first seen at 20:12 UT on SOHO LASCO C2. The CME was associated with an M2.7 flare from SIDC Sunspot Group 617 (NOAA 4199),

Forecasts

Flare:	M-class flares (≥50%)
Protons:	Event (10 pfu at >10 MeV)
Geomagnetic:	Major (ISES: Severe) magstorm (A>=100 or K>=7)
All quiet:	False
Provisional SSN:	183

Solar Activity

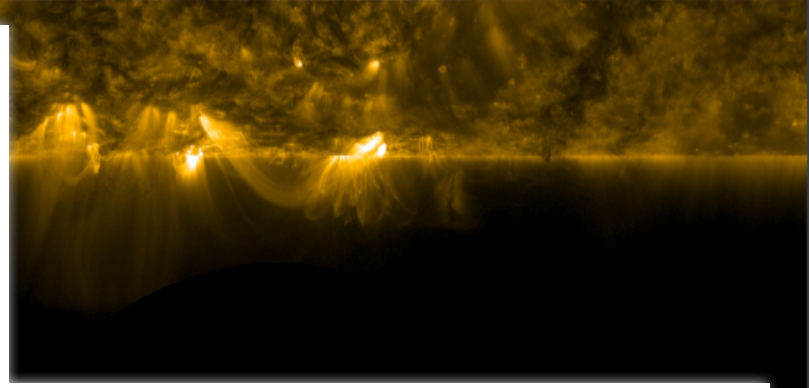
URSIgram 2025-09-01

Solar flaring activity was low over the past 24 hours. The largest flare was a C6.8 flare (SIDC Flare 5401) peaking on August 31 at 18:26 UTC, which was produced by

Solar Wind

URSIgram 2025-09-01

The geomagnetic conditions over the past 24 hours were globally and locally quiet to unsettled (Kp 1–3 & K BEL 1–3). Major storm conditions are



SIDC Sunspot Groups

Start Time: 31 / 08 / 2025 , 00 : 00
End Time: 01 / 09 / 2025 , 12 : 57

SIDC #: 217
NOAA #:

☑ USET ☑ NOAA ☑ UKMO

◉ All ○ Has ≥C flares ○ Has ≥M flares ○ Has ≥X flares

Show Table

SIDC Sunspot group 217

First time : 2024-08-08 08:10

Last time : 2024-12-01 00:00

JHelioviewer :

SIDC Eval. :

EVALUATION TIME[UTC]	NUMBER	LOCATION	AREA	GROWTH	MCINTOSH	MAGNETIC
2024-11-30 00:30	0217	N13E00	0010 MSH	Stable	Bxo	Beta
2024-11-29 00:30	0217	N13E13	0010 MSH	Stable	Bxo	Beta
2024-11-28 00:30	0217	N13E26	0010 MSH	Growing	Bxo	Beta
2024-11-27 00:30	0217	N13E40	0010 MSH	Stable	Axx	Alpha
2024-11-26 00:30	0217	N13E54	0010 MSH	NA	Axx	Alpha

October 9th 2024

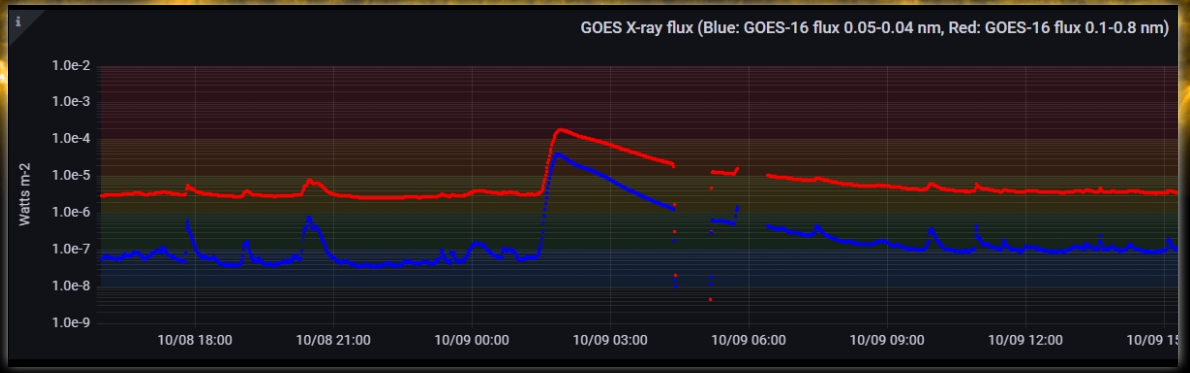
Associated Flares :

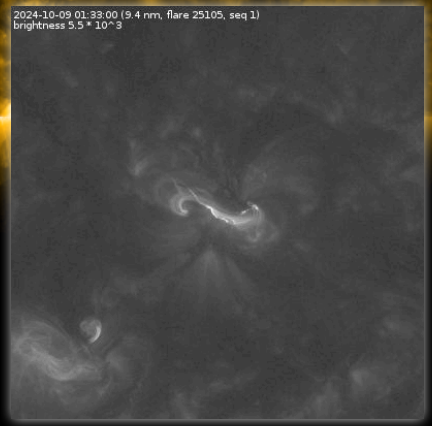
NUMBER	PEAK TIME [UTC]	GOES X-RAY CLASS	NOAA FLARES	SOLARDEMON EUV FLARES
2749	2024-11-29 04:47	C4.5	NOAA C4.5	NA
2748	2024-11-29 03:01	C5.3	NOAA C5.3	NA
2524	2024-11-06 08:50	M5.8	NOAA M5.8	NA
2500	2024-11-05 04:43	C7.4	NOAA C7.4	NA

⋮

2278	2024-10-12 03:31	C5.3	NOAA C5.3	EUV Flare [03:33 UTC]
2277	2024-10-11 23:20	C9.7	NOAA C9.7	NA
2255	2024-10-09 01:56	X1.8	NOAA X1.8	NA
2246	2024-10-07 10:28	C6.6	NOAA C6.6	NA
2214	2024-10-03 06:48	C8.6	NOAA C8.6	EUV Flare [06:51 UTC]
2049	2024-09-13 08:37	M2.9	NOAA M2.9	NA
2045	2024-09-12 21:11	C8.9	NOAA C8.9	NA
2028	2024-09-12 04:32	M1.2	NOAA M1.2	NA
2024	2024-09-11 17:52	M2.0	NOAA M2.0	NA

October 9th 2024





SIDC Flare 2255

Start time : 2024-10-09 01:25

Peak time : 2024-10-09 01:56

End time : 2024-10-09 02:43

Class : X1.8

Location : N12W12

JHelioviewer :

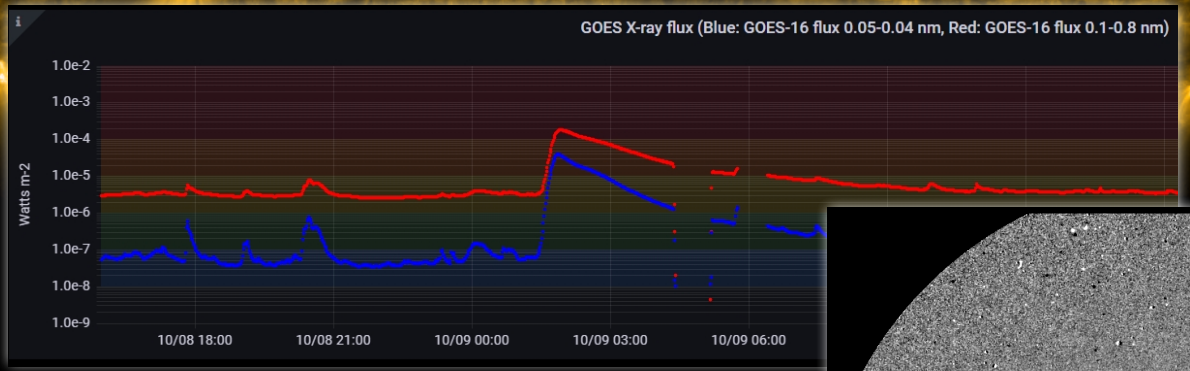
Solmon : solmon

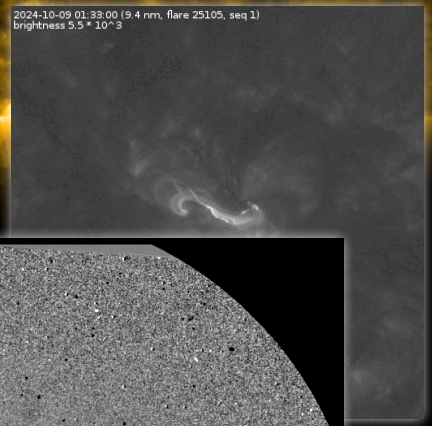
Assoc. Sunspot group : NA

Detections :

PROVIDER	START TIME	PEAK TIME	END TIME	CLASS	LOCATION
NOAA	2024-10-09 01:25	2024-10-09 01:56	2024-10-09 02:43	X1.8	N12W11
SIDC	2024-10-09 01:25	2024-10-09 01:56	2024-10-09 02:43	X1.8	N12W12

October 9th 2024

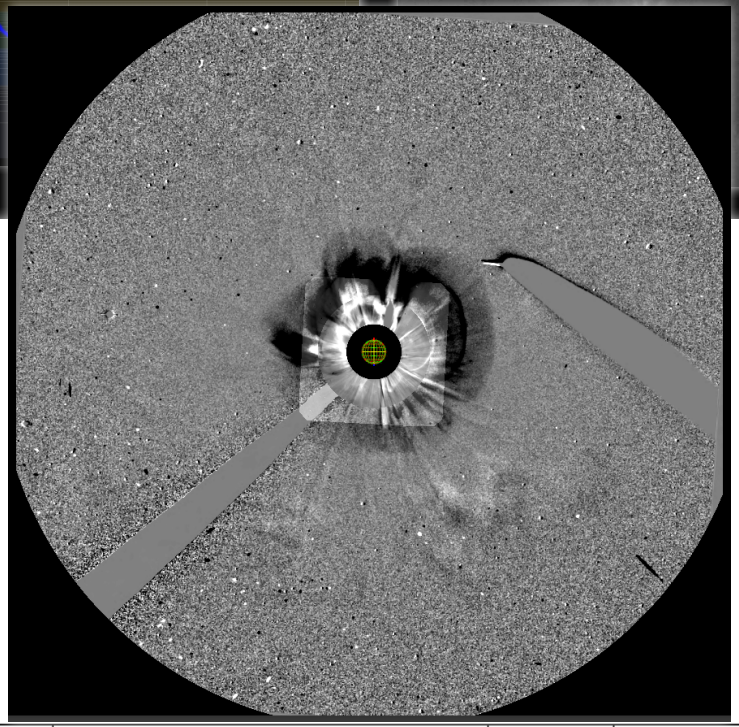




SIDC Flare 2255

Start time : 2024-10-09 01:25
Peak time : 2024-10-09 01:56
End time : 2024-10-09 02:43
Class : X1.8
Location : N12W12
JHelioviewer :
Solmon : solmon
Assoc. Sunspot group : NA

Also a CME =>



Detections :

PROVIDER	START TIME	PEAK TIME	END TIME	CLASS	LOCATION
NOAA	2024-10-09 01:25	2024-10-09 01:56	2024-10-09 02:43	X1.8	N12W11
SIDC	2024-10-09 01:25	2024-10-09 01:56	2024-10-09 02:43	X1.8	N12W12

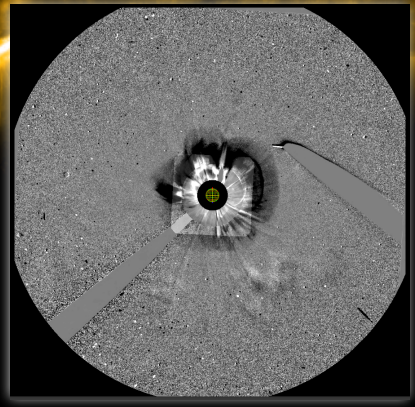
October 9th 2024

Start Time: 09/10/2024, 00:0(
End Time: 09/10/2024, 13:1(
SIDC #:

All | Has ≥C flares | Has ≥M flares | Has ≥X flares

All | Speed ≥ 600 km/s | Speed ≥ 1000 km/s

Show Table



SIDC CME 455

Launch Time : 2024-10-09T02:30:00
Issue Time : 2025-05-08T07:46:00
Backsided : No
Width : NA
Speed : NA
LAT LON : NA
Time at 21.5 $R_\odot$: TBD
JHelioviewer :

2D Detections :

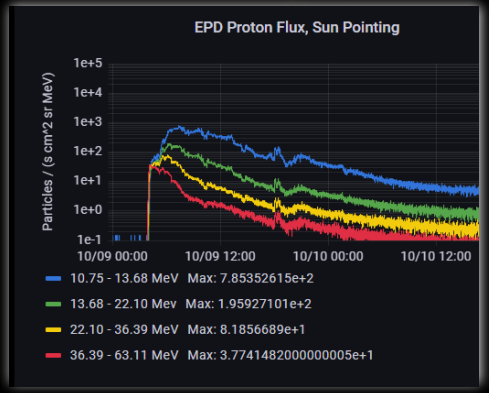
TIME [UTC]	SPEED (KM/S)	PRINCIPAL ANGLE (°)	WIDTH (°)	RADIAL DIST.	INSTRUMENT	METHOD	PROPERTIES
2024-10-09 02:30	NA	NA	NA	NA	LASCO C2	HISTORIC evaluation based on LASCO C2. [*HISTORIC_LASCO C2*]	

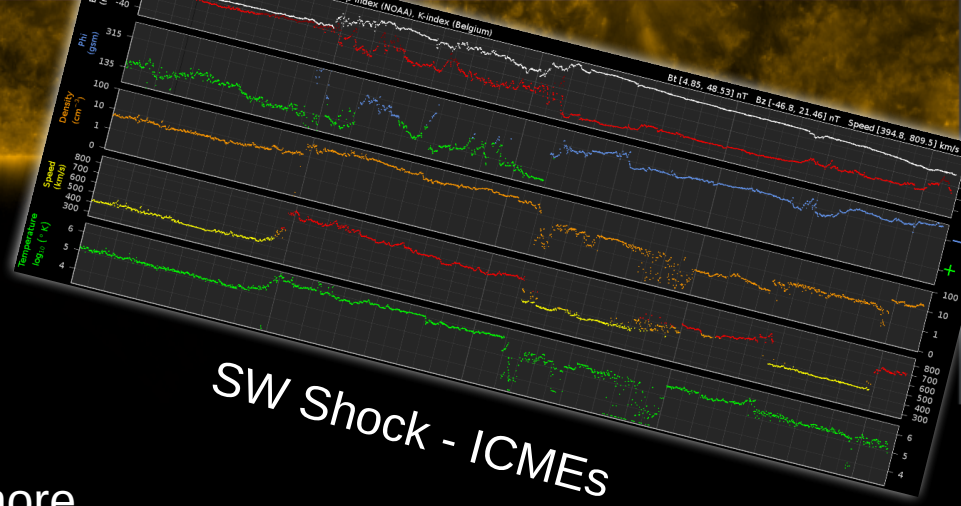
Forecasts :

ISSUE TIME[UTC]	ESTIMATED ARRIVAL TIME TIME[UTC]	CONFIDENCE (%)
2025-05-08 07:46	2024-10-10 10:00 ± 12 hours	95 %

October 9th 2024 Future prospects:

SEP-events

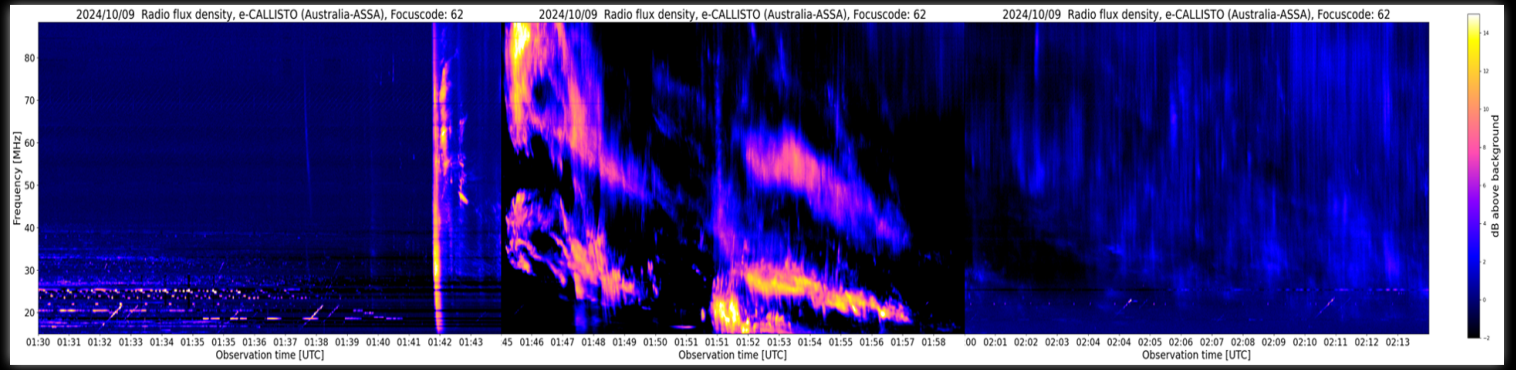




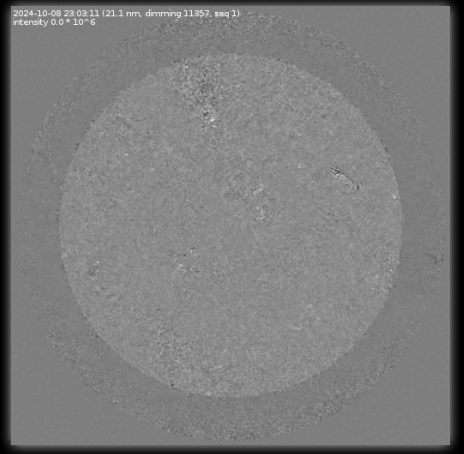
SW Shock - ICMEs

And much more...

Radiobursts

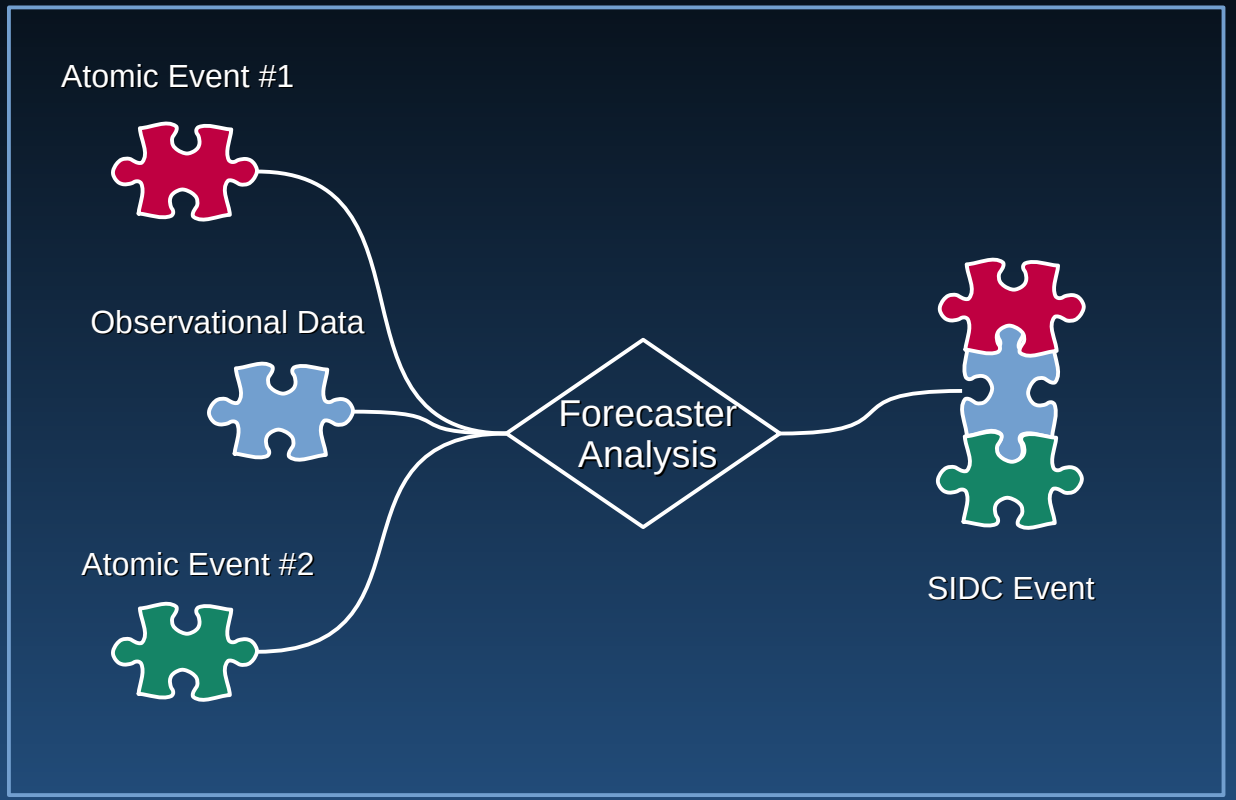


Solar dimmings

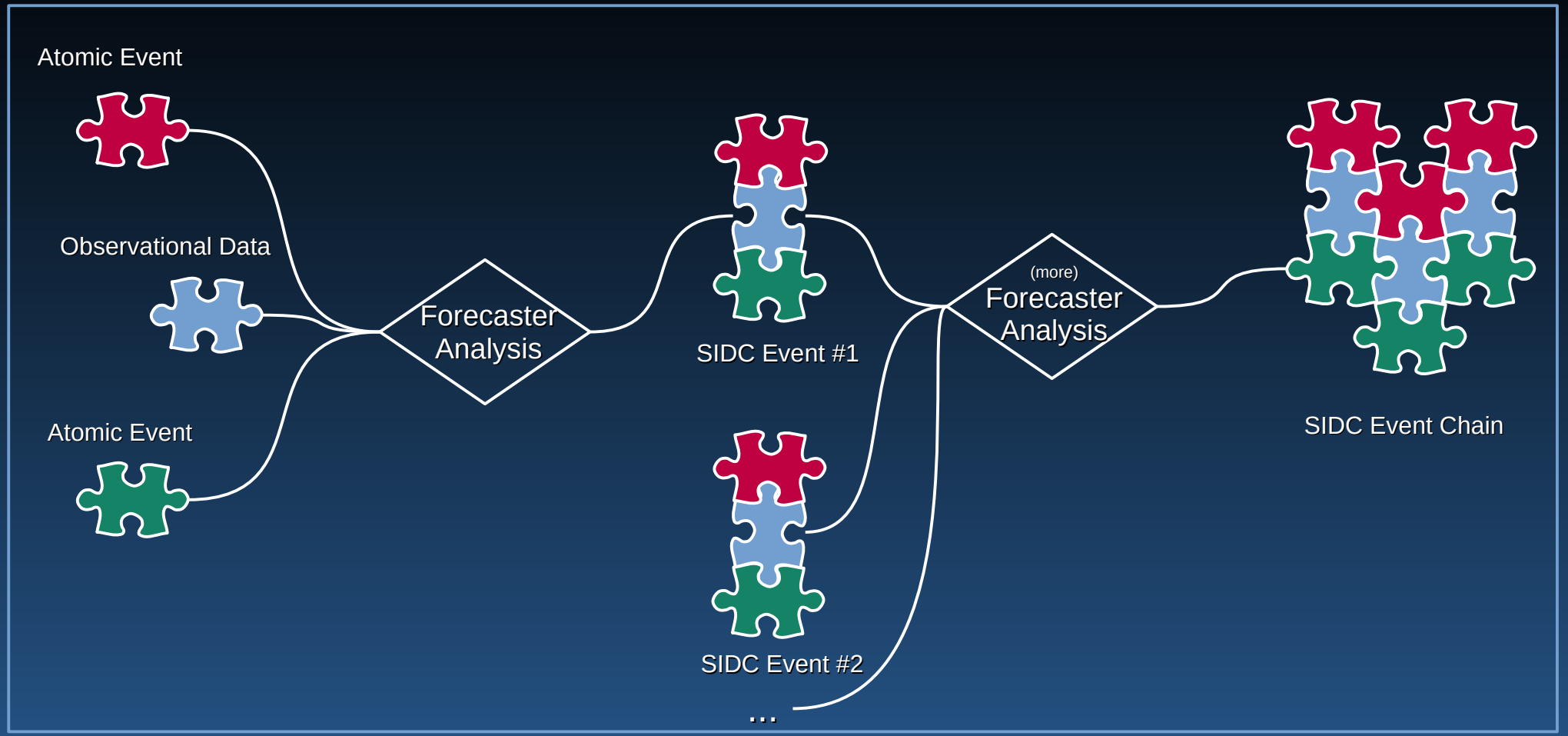


Thank you!

The Event Chain Database



The Event Chain Database



Other Events:

SIDC CME 537 [2025-08-05 17:14 UTC]

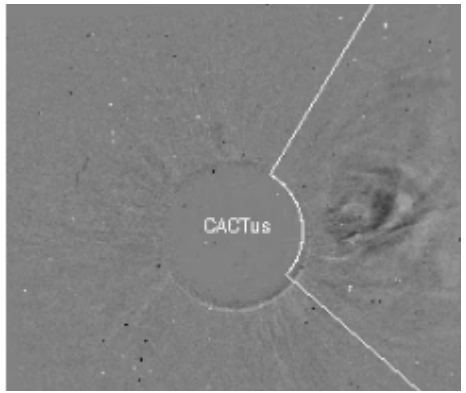
Earth Arrivals	Forecast		Observed	
ICME (Earth)	450 km/s	[2025-08-09T12:00 UTC]	580 km/s	[2025-08-08T21:00 UTC]
Geom. Impact (Earth)	Max K: 6	[2025-08-09T00:00 UTC]	Max K: 5	[2025-08-09T00:00 UTC]

Arrivals

Linked events:

SIDC Flare #	Class	Peak Time	Stonyhurst	SIDC Sunspot #	McIntosh	MtWilson
SIDC 5041	M4.4	[15:53]	(N05,W06) [15:53]	SIDC 588 (NOAA 4168)	Eac	beta-gamma-delta

Edit Links



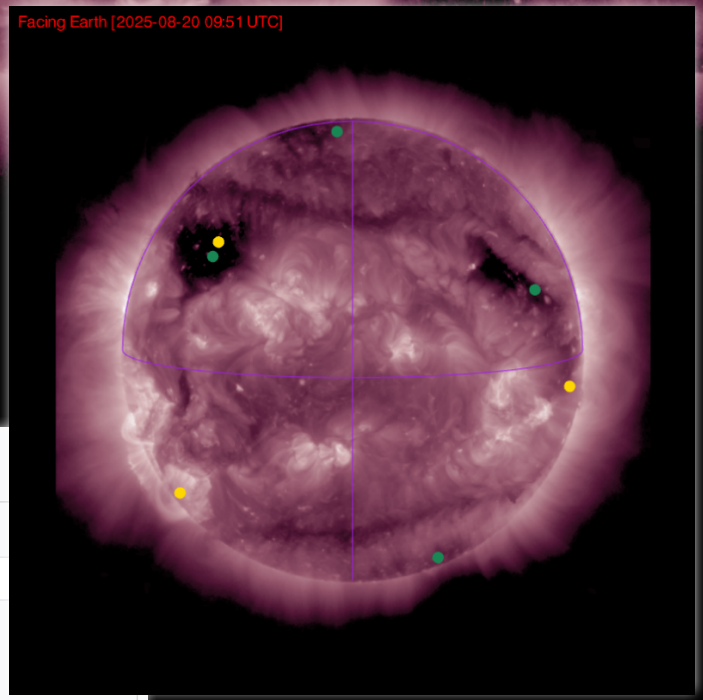
SIDC evaluation launched at [2025-08-05 17:14 UTC]			
3D Parameters:			
Direction (Stony): (N05,W30)		**Width:** 86	
Source Loc. (Stony): (N05,W05)		**Speed:** 400	
2D Detections:			
CACTUS [16:48]	**Principal Angle:** 280	**Width:** 98	**Speed:** 328
LASCO C2 [17:14]	**Principal Angle:** 280	**Width:** 100	**Speed:** 319

Send | + Forecast | + Draft

ICME Arrival Forecast	Models	Speed	Speed ±	Expected Time	Probability	Status
Earth	View	450	100	2025-08-09 12:00	95%	Sent to CCMC

Geomagnetic Impact Forecast	Models	Max K	Max K ±	Expected Time	Probability	Status
Earth	View	6	1	2025-08-09 00:00	90%	Sent to CCMC

Other Events:



Prediction of high speed stream arrival at L1

Arrival time	Uncertainty on arrival time [+/-Hours]	Probability of arrival [%]
2025-08-13T00:00:00Z	24	

Impact speed [km/s]	Uncertainty on impact speed [+/-km/s]
	100

Prediction of geomagnetic impact

Start of Storm	Uncertainty on Occurrence time [+/-Hours]	Probability of occurrence [%]
2025-08-13T00:00:00Z	24	

Maximum K [0-9]	Uncertainty on maximum K [+/-value]
	1