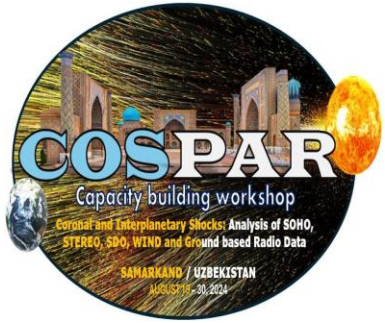
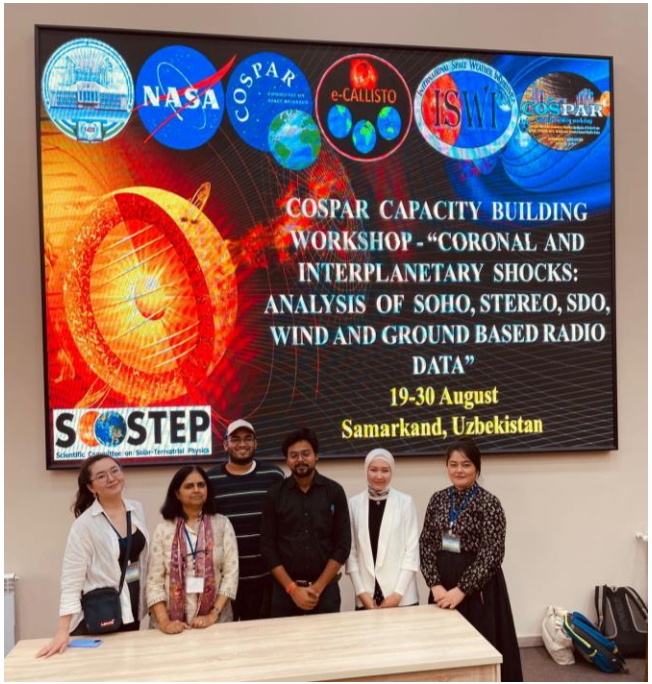


Event Analysis
23.04.2024 & 04.07.2024



Supervisor: Dr. Nandita Srivastava

Botakoz Seifullina
Munisa Boltatoshova
Mukarram Fayzullaeva
Priyank Srivastava
K.R. Arjun
Farhod

2024

Event #1: 23 April 2024

Information about the event:

Start/ Onset Time: 2024-04-23 17:33:00 UT

End Time: 17:52:00 UT

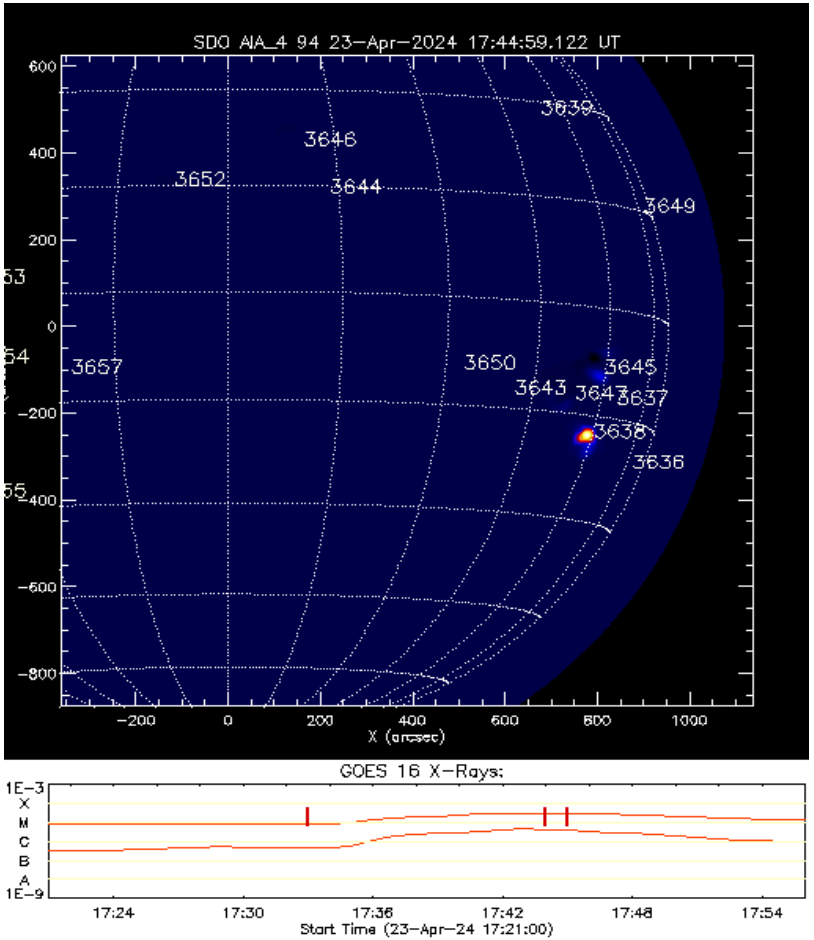
Peak Time: 17:44:00 UT

GOES M2.9 Class flare

Derived Position: S17W58 (AR 3638)

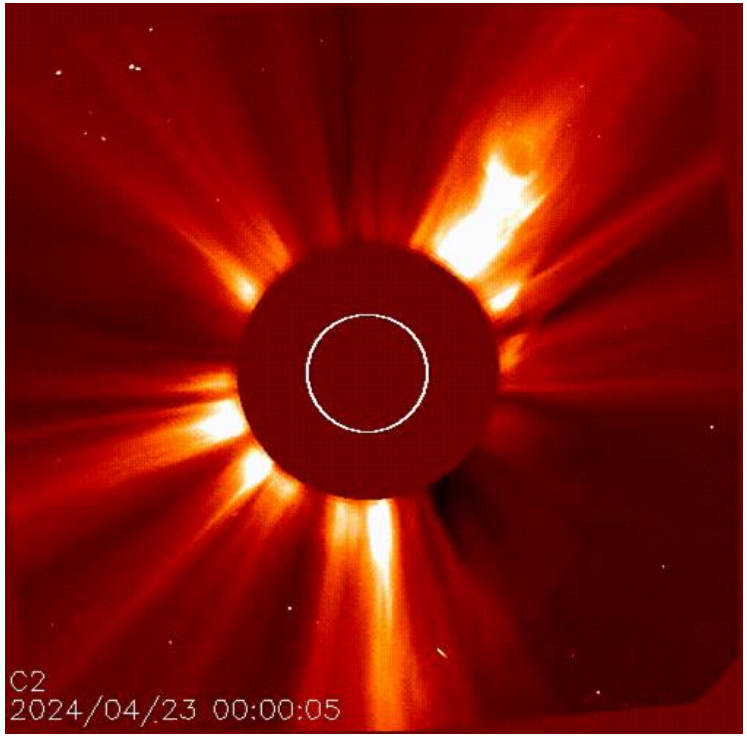
On this day several C and M class flares occurred showing that the Sun was very active.

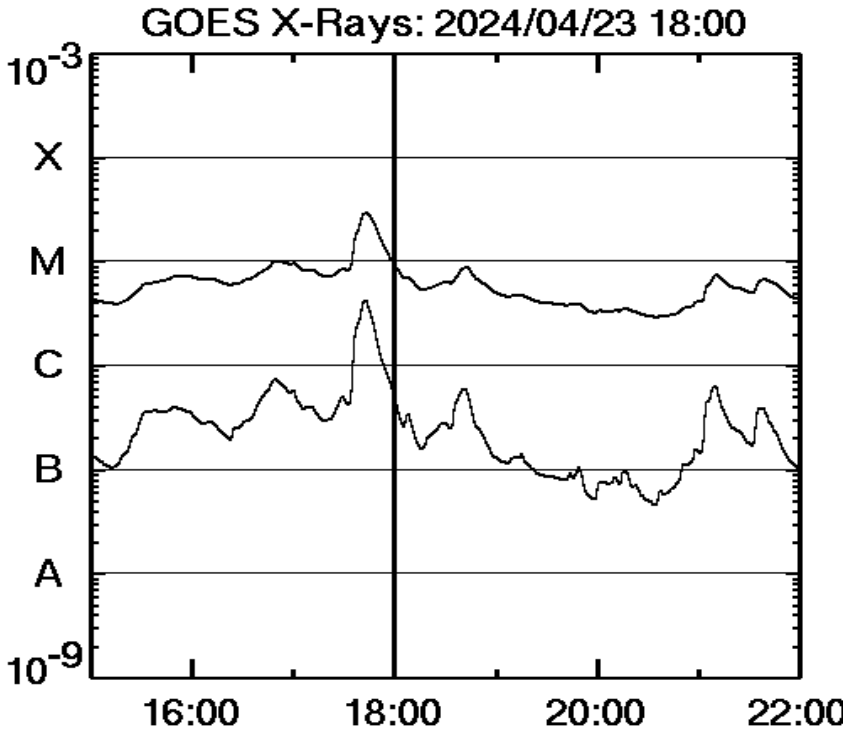
Flare Source Location



Associated CME in white light coronagraphic fov (SOHO, STEREO)

Partial Halo CME on SW limb



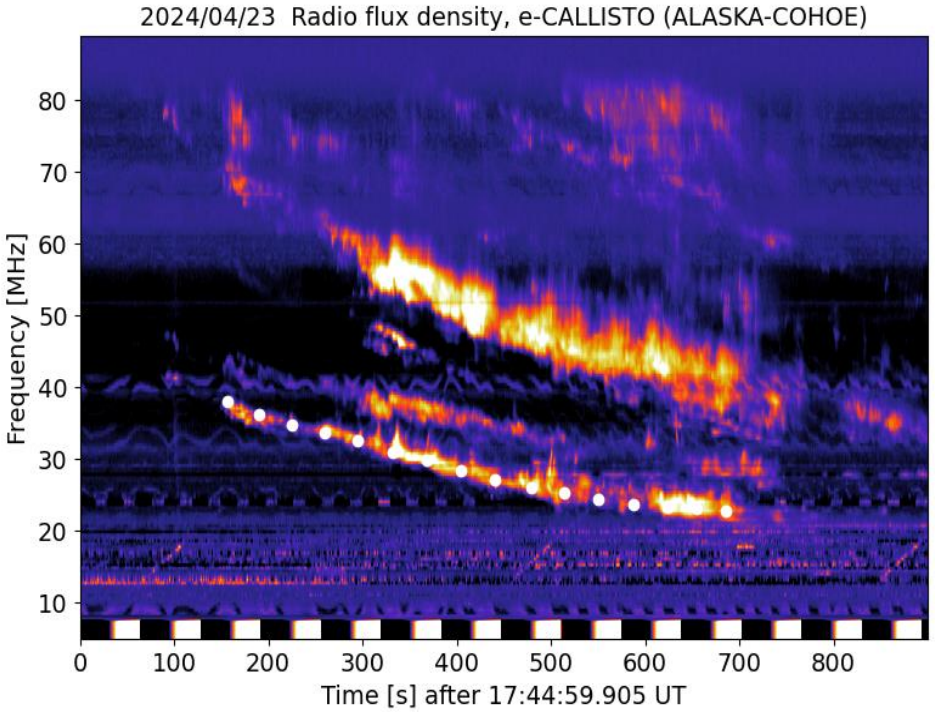


Associated Solar Bursts on 23 April 2024 during 17:33-17:52 UT

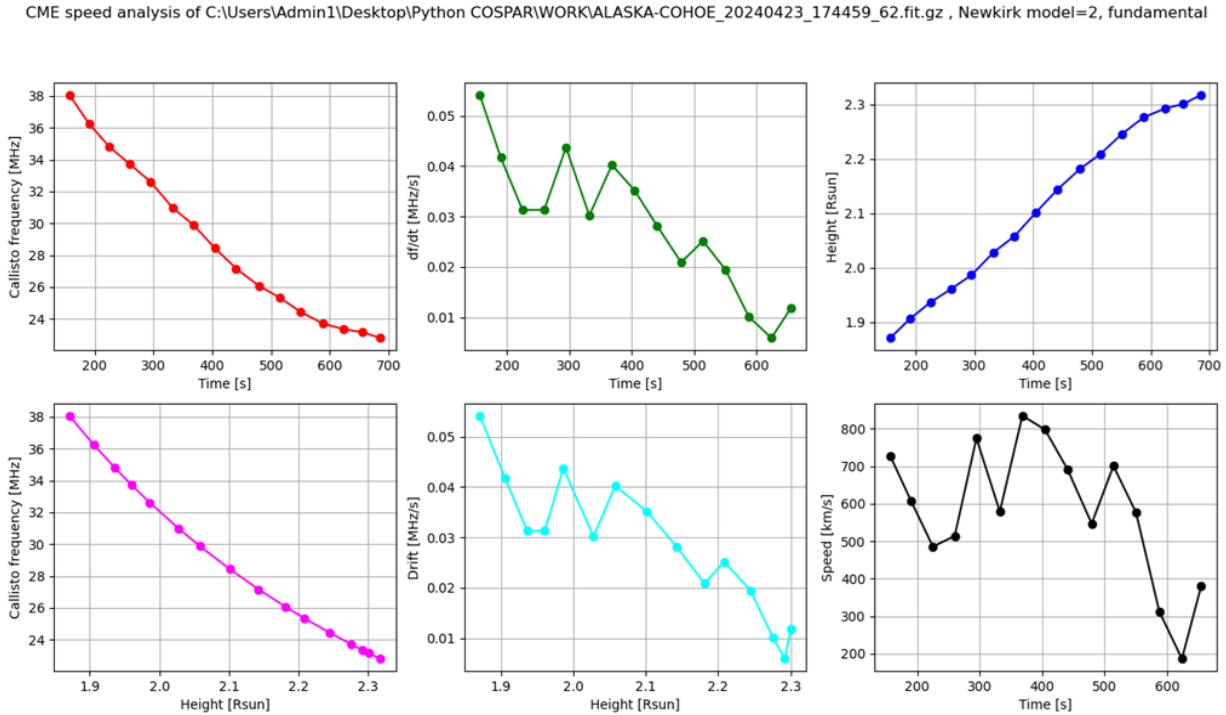
The SRB Event: 2024/04/23
Time: 17:33-17:52
Type:Type II
Stations: ALASKA-ANCHORAGE, ALASKA-COHOE, ALASKA-HAARP, BIR, GERMANY-DLR, GREENLAND, MEXART, MEXICO-LANCE, ROSWELL-NM, SWISS-HEITERSWIL, SWISS-Landschlacht, SWISS-MUHEN,
USA-BOSTON

Data chosen from the Station:
ALASKA-COHOE_20240423_174459_62.fit.gz

The figure contains a type II radio burst with a fundamental (F1,F2) and harmonic (H1,H2) with band splitting and also a second Harmonic (faint one).



Newkirk density model for the SRB Event (23/04/2024)



Statistical results for CME velocity:

Mean = 535.6 km/s

Median = 576.2 km/s

1st order = 551.7 km/s

Fundamental Band Analysis (F1 & F2):

#Table1: For the Fundamental F1 (LOWER Fl)

For Fundamental F1					
T[s]	F[MHz]	Ne[cm^-3]	Rs[Rsun]	Drift Rate (df/dt)	
159.994	37.238	17207026	1.89		
188.041	35.265	15431910	1.93	-0.036670755	
217.788	34.443	14720793	1.94	-0.031002753	
248.384	33.949	14302174	1.95	-0.031635149	**df/dt [Mean] = -0.0289 [MHz/s]**
283.23	32.634	13215377	1.99	-0.031163945	
318.076	31.483	12299654	2.01	-0.02831028	
351.222	30.168	11293369	2.05	-0.027205306	
386.069	29.017	10448093	2.08	-0.024107558	
420.065	27.701	9522319	2.12	-0.021094649	
453.211	27.044	9075535	2.15		
488.057	25.893	8319492	2.19		
528.002	25.235	7902228	2.21		**Statistical results for CME velocity:**
561.998	24.742	7596325	2.23		**Mean = 535.6 km/s**
590.045	24.084	7197848	2.26		**Median = 576.2 km/s**
624.041	23.591	6906034	2.28		**1st order = 551.7 km/s**
658.887	23.262	6714846	2.3		

#Table2: For the Fundamental F2 (UPPER = Fu)

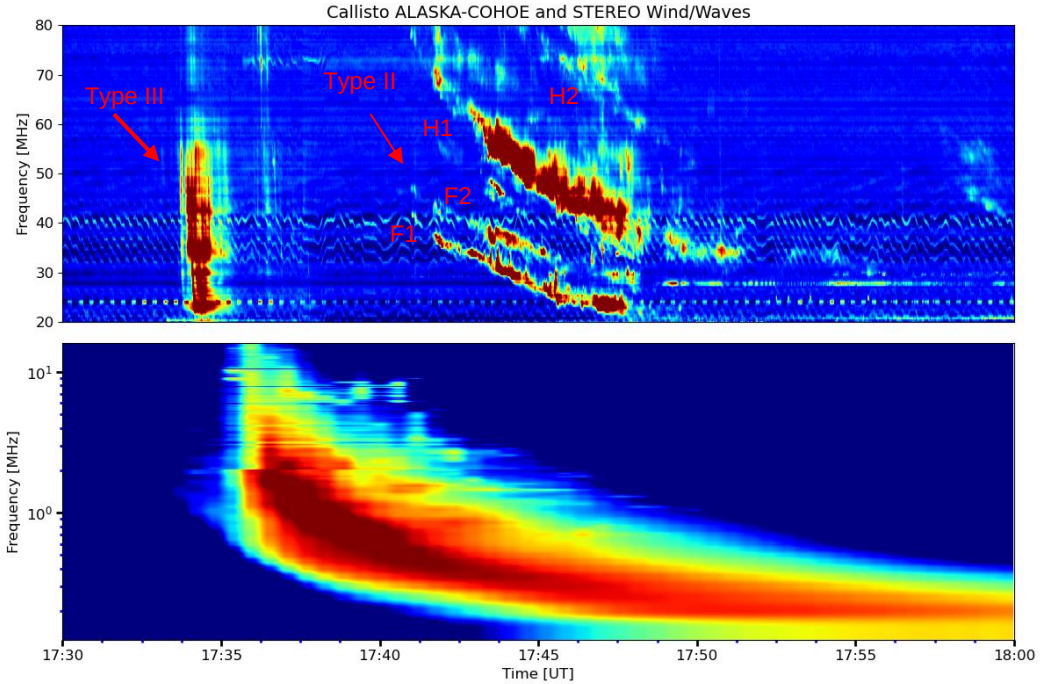
For Fundamental F2					
T[s]	F[MHz]	Ne[cm^-3]	Rs[Rsun]	Drift Rate (df/dt)	
159.994	43.157	23112055	1.79		
188.041	41.677	21554280	1.81	-0.034908769	
217.788	40.197	20050850	1.83	-0.032861938	
248.384	39.54	19400103	1.84	-0.029200537	**df/dt [Mean] = -0.0286 [MHz/s]**
283.23	38.389	18287127	1.86	-0.031167521	
318.076	36.909	16904464	1.89	-0.02831028	
351.222	36.251	16307391	1.91	-0.023576216	
386.069	35.265	15431910	1.93	-0.024107558	
420.065	33.949	14302174	1.95	-0.024632036	
453.211	32.963	13483051	1.98		
488.057	32.305	12950388	1.99		
528.002	30.825	11791144	2.03		**Statistical results for CME velocity:**
561.998	30.497	11540915	2.04		**Mean = 417.5 km/s**
590.045	30.497	11540915	2.04		**Median = 440.7 km/s**
624.041	29.674	10927082	2.06		**1st order = 426.4 km/s**
659.737	28.524	10095896	2.1		

Wind/Waves Obseravtions:
Analysis of Event 1: Type II and Type III radio bursts

2024/04/23

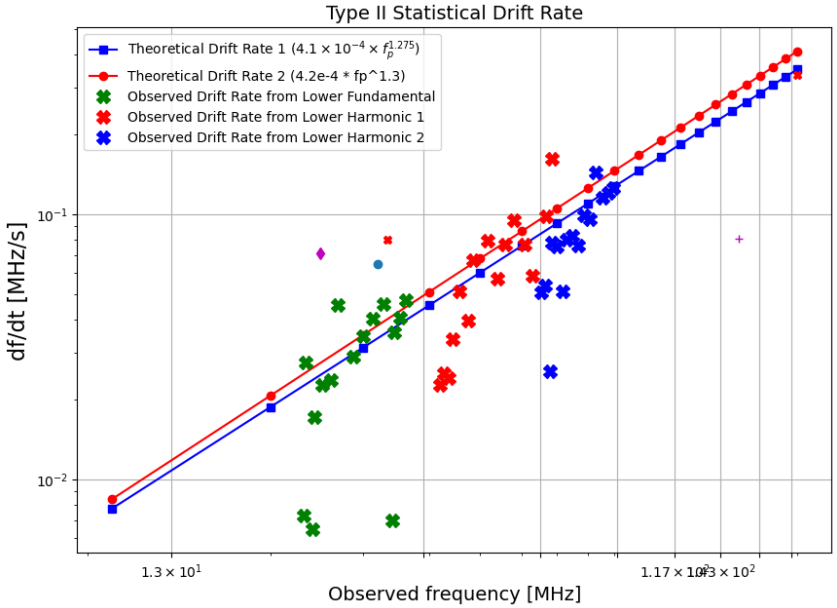
Type III radio bursts observed during the flare Onset time.

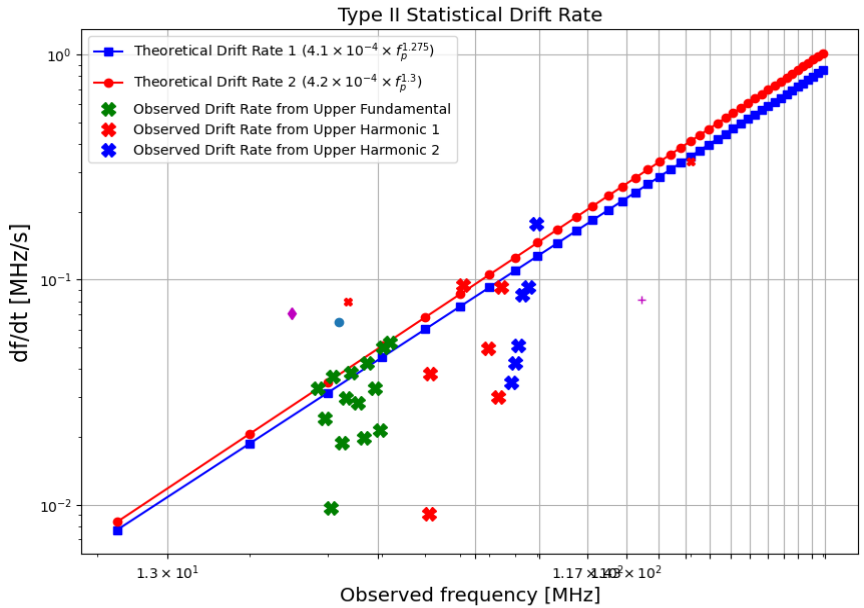
	F1	F2	H1_lower	H1_upper
Frequency	**37.24** **23.26**	**43.16** **28.52**	70.8 41.9	80.6 51
onset time	17:47	-	-	-
end time	18:21	-	-	-



Drift Rate Plots

Figure illustrates the Observed Drift Rate for both Fundamental (F1 and F2) compared with the Theoretical drift rate 1 and 2.





Lower Band df/dt: [F1, H1_1, H2_1]

Upper Band df/dt: [F2, H1_2, H2_2]

Drift Rate df/dt Estimation for different Fundamental and Harmonic bands.

	Lower Band	Upper Band
Fundamental	-0.029MHz/s	-0.0286MHz/s
Harmonic 1	-0.060 MHz/s	-0.55MHz/s
Harmonic 2	-0.078 MHz/s	-0.079MHz/s

Calculation of Alfven speed and ambient magnetic field for the SRB Event (23/04/2023)

Alfven Speed: $V_a = V_s / M_a$

(Shock Speed from the H-T measurement)

V_s = *830 km/s*

V_a = *608.06 km/s*

Mach Number (mean) = ***1.365***

B (Gauss): $B(G) = 5.1 \times 10\text{-}5.\ f_t.\ V_a$

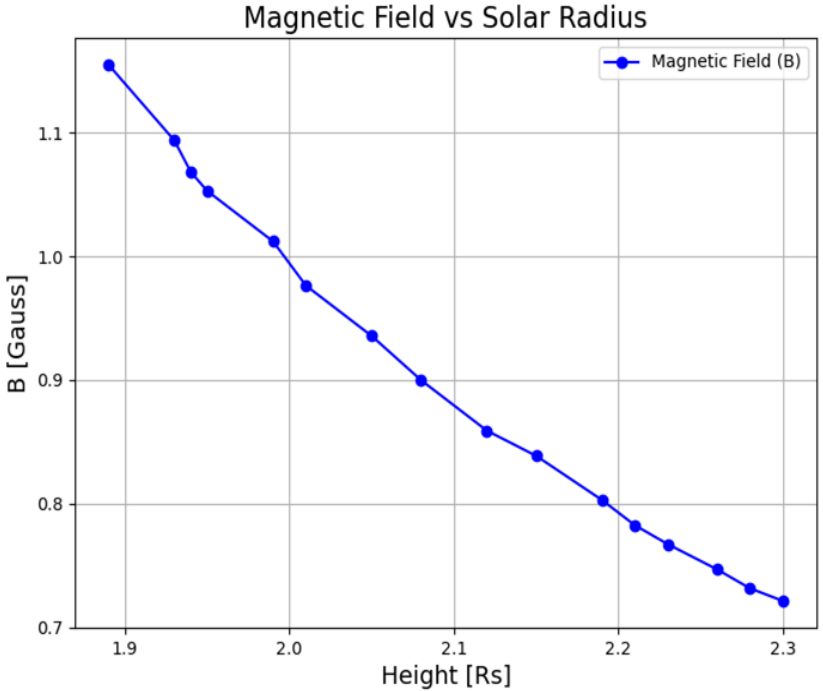
Mean $B(G) =$ ***0.903 G***

 # BAND SPLITTING:

Table3: Describes about the Fundamental (Freq. up and Freq. low), Bandwidth, Density Jump, Mach Number and Magnetic Field

Freq. up [MHz]	Freq. low [MHz]	BDW	x = sq.(BDW+1)	Mach Number (Mn)	B(G)
43.157	37.238	0.1589505	1.343166341	1.266253825	1.15479
41.677	35.265	0.1818233	1.396706401	1.309948427	1.093605
40.197	34.443	0.1670586	1.362025819	1.281563458	1.068114
39.54	33.949	0.1646882	1.356498624	1.277067607	1.052794
38.389	32.634	0.1763498	1.383798897	1.299348139	1.012015
36.909	31.483	0.172347	1.374397444	1.291654161	0.976321
36.251	30.168	0.2016375	1.443932673	1.349111445	0.935542
35.265	29.017	0.2153221	1.477007692	1.376910221	0.899848
33.949	27.701	0.2255514	1.501976293	1.398108751	0.859037
32.963	27.044	0.2188656	1.485633235	1.384212237	0.838663
32.305	25.893	0.2476345	1.556591835	1.445151707	0.802969
30.825	25.235	0.2215177	1.492105573	1.389706024	0.782564
30.497	24.742	0.2326004	1.519303836	1.412931615	0.767276
30.497	24.084	0.2662764	1.603455835	1.486299815	0.74687
29.674	23.591	0.2578526	1.58219309	1.467537629	0.731582
28.524	23.262	0.2262058	1.503580736	1.399477382	0.721379

Variation of Magnetic Field with the Height in terms of R_S



The Newkirk model is often used with typical magnetic field values:

- Near the solar surface:

$$B \approx 1-10\ B_0 \text{ Gauss.}$$

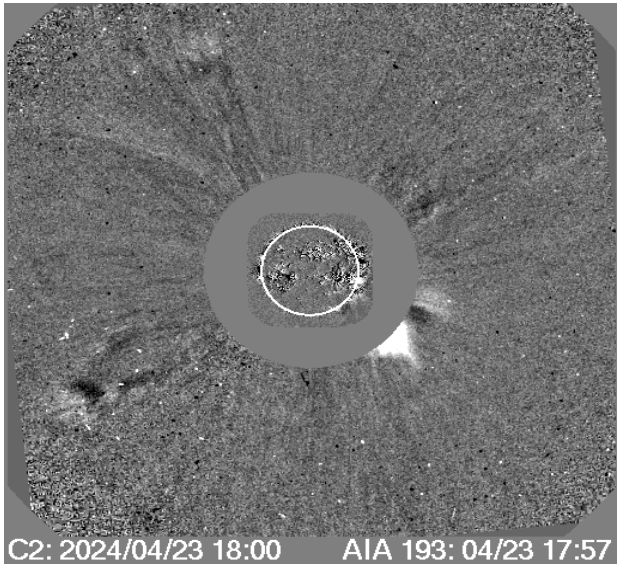
- At greater heights (e.g., 10 R_{sun}),

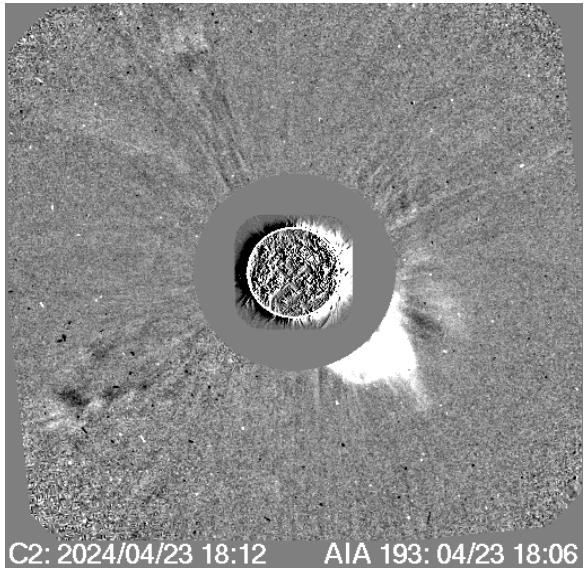
$$B \approx 0.1 B_0 \text{ Gauss.}$$

In the analysis of the SRB event (23/04/24, 17:47 UT) by the Newkirk model near the solar surface, the estimated ambient Magnetic field is :

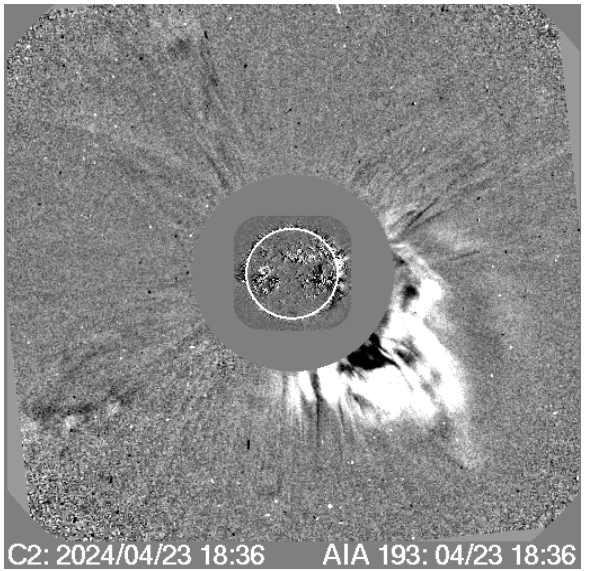
Mean B(G)= 0.903 G

CME Evolution & Propagation





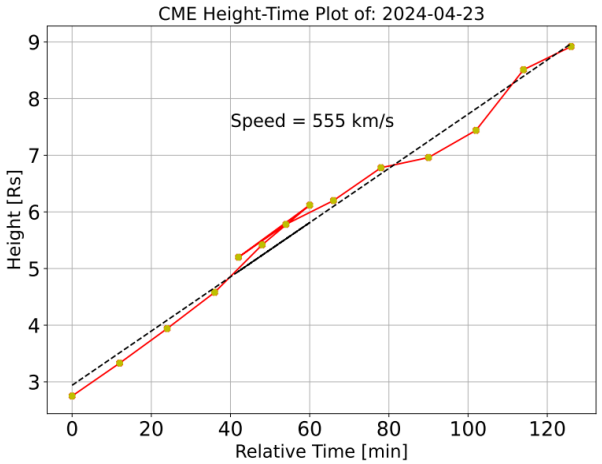
Propagating away from the S-E line



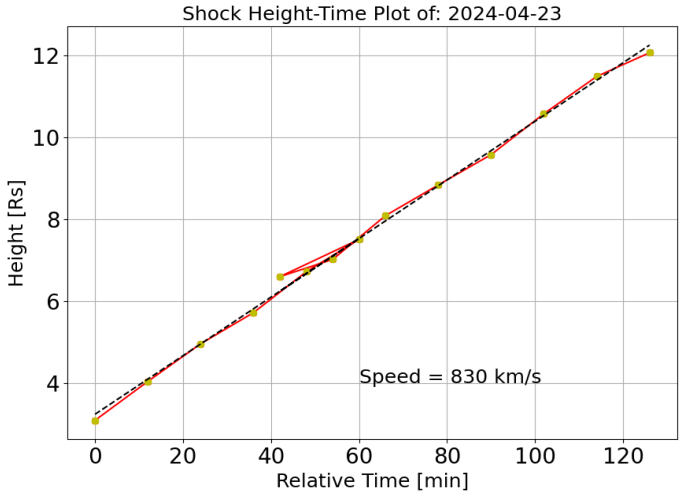
Arrival of the CME expected on 26th April 2023

Leading Edge Speed of the CME from white light observations

CME detected in the SW Limb: Not directed towards Earth



Onset Time	18:00UT
Speed	555 km/s
Position Angle	228 degree

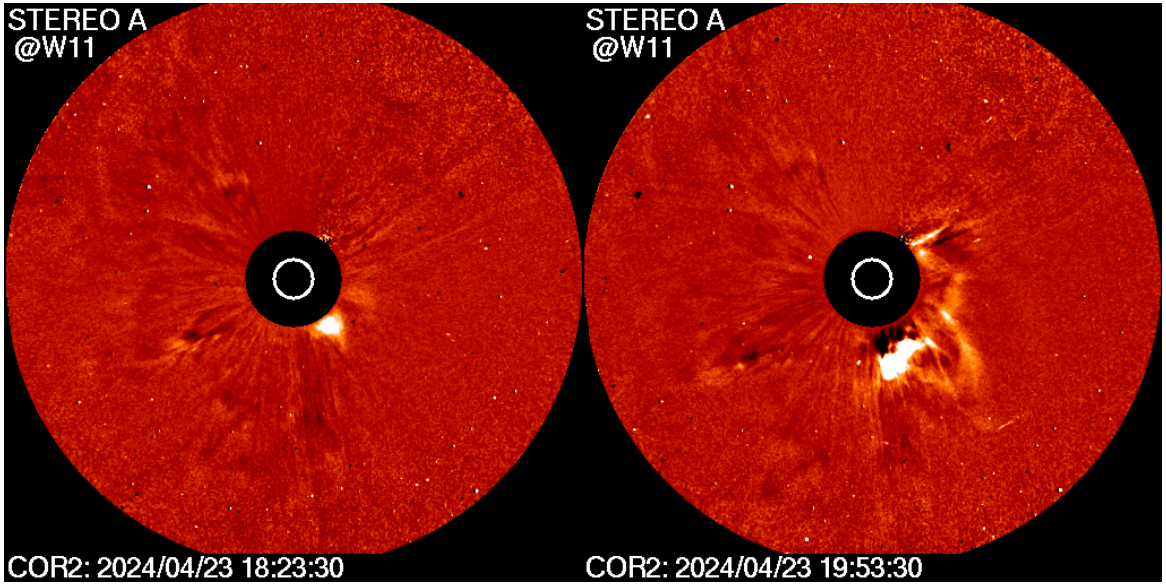


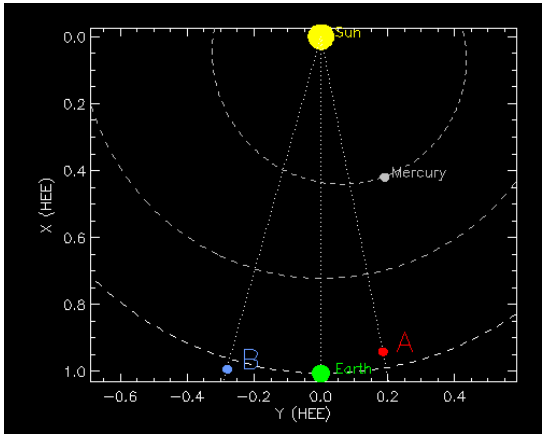
Linear fit speed is: **555 km/s** in LASCO- C2 and C3 fov

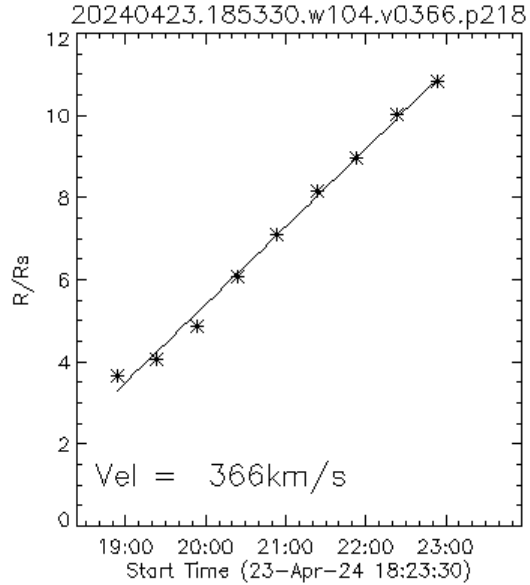
CME speed from the SOHO LASCO Catalogue:

CME (Linear Speed [km/s]) = 596 km/s

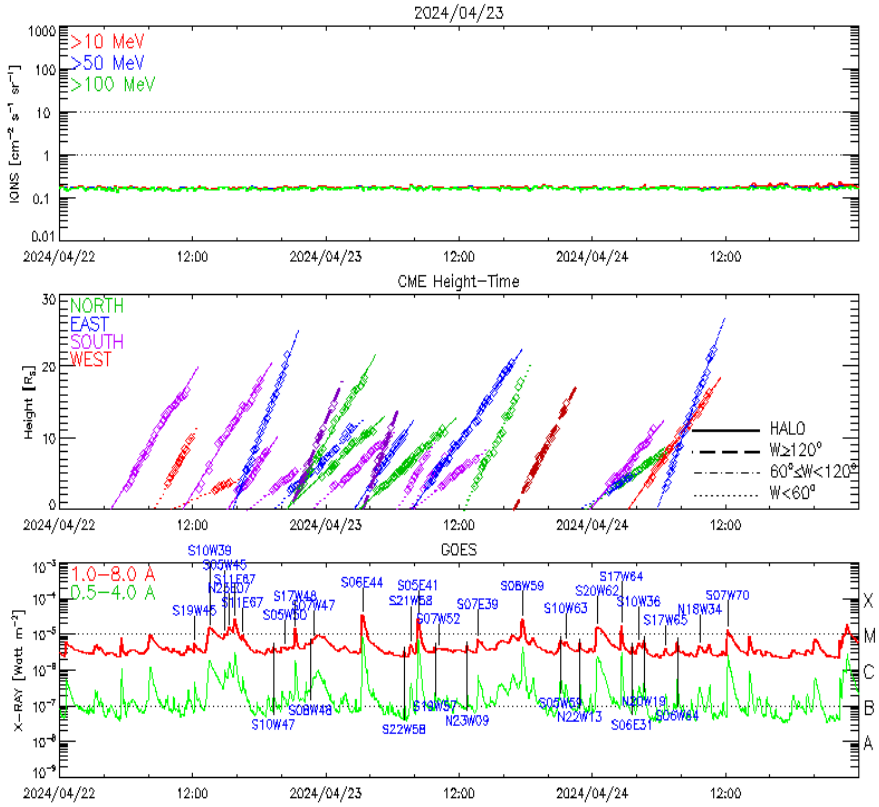
Associated CME in STEREO A/ COR2 coronagraph



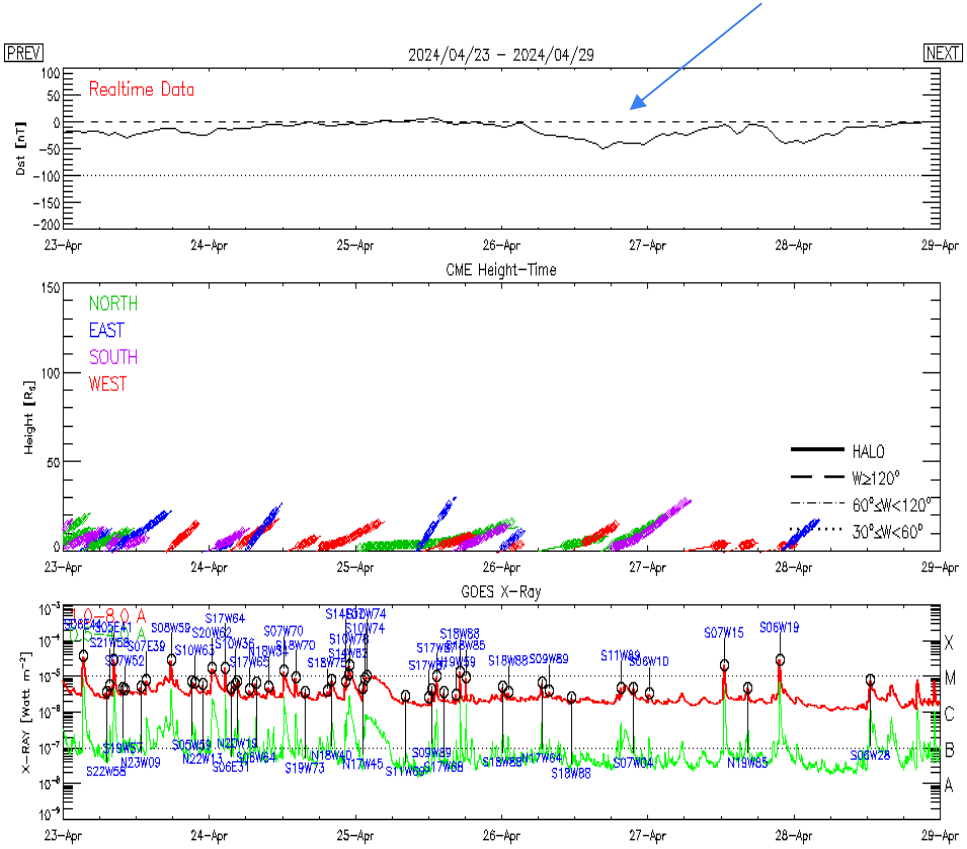




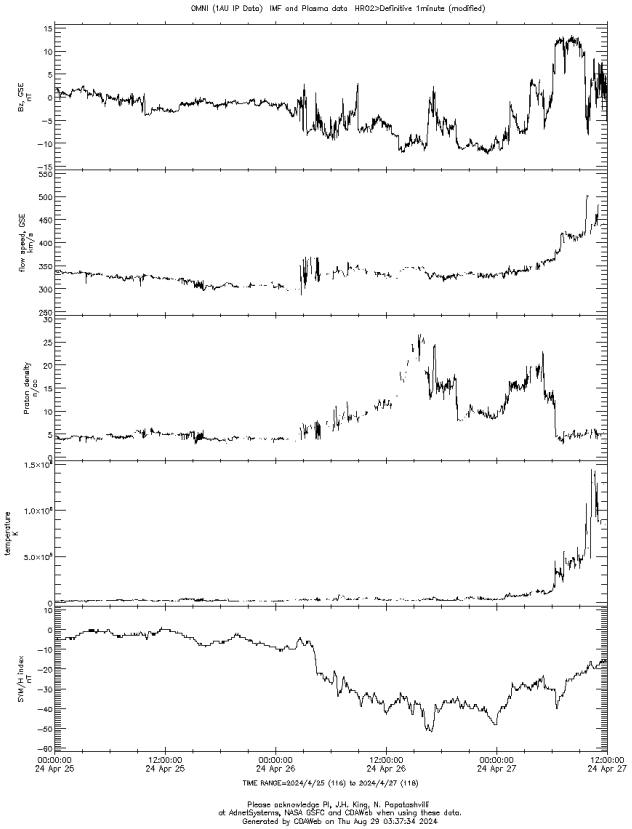
No SEP Event



Minor Geomagnetic storm (-51nT)



Insitu Observations at L1: ACE & Wind

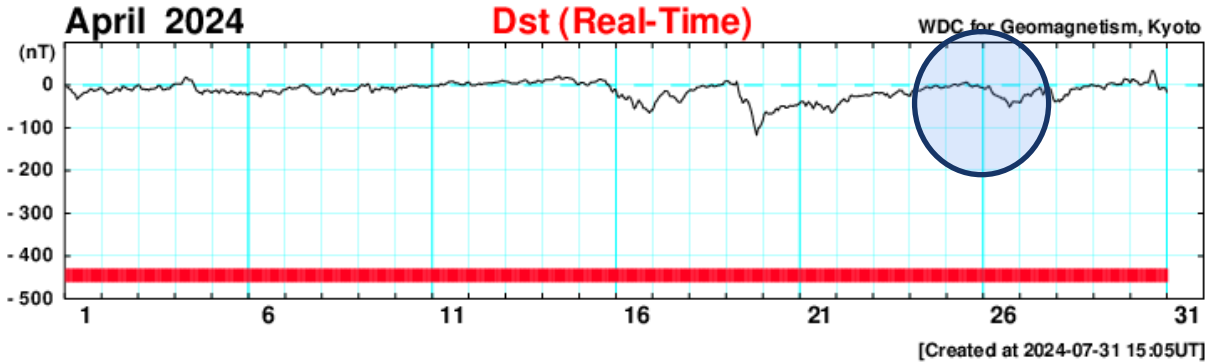


Solar wind velocity is very low < 350 km/s

No (Minor?) shock

Bz remains negative for several hours

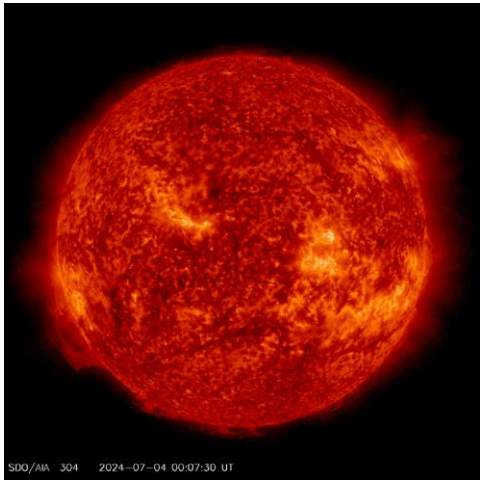
Dst index also remains negative for several hours



Summary

- The event of 24 April 2023 associated with M2.9 flare is unique in terms of radio observations. with fundamental, harmonic and a second harmonic band.
- The associated CME is partial halo, with average speed and initial propagation direction suggests that it is not a major space weather event.
- ICME observations show that CME arrives with a low speed (in a slow ambient solar wind) but Bz is negative for a long time, leading to a minor storm of -51 nT
- Further analysis required to rule out possibilities of arrival of other CME or structures which can lead to long southward Bz structure (minor storm).
- Arrival time also needs to be estimated accurately.
- STA in a better location to intercept the ICME, insitu observations analysis can help further in better understanding of the phenomena.

Event II: 04/07/2024 14:27 UT



GOES Soft X-Ray Flare Event

 # Event Date/Time: 04 July 2024 14:27

This SXR *Event is not associated with currently named NOAA regions:*

SXR Goes Class [M1.0]

1. Data collected from the website:

https://www.lmsal.com/solarsoft/latest_events_archive/events_summary/2024/07/04/gev_20240704_1406/index.html

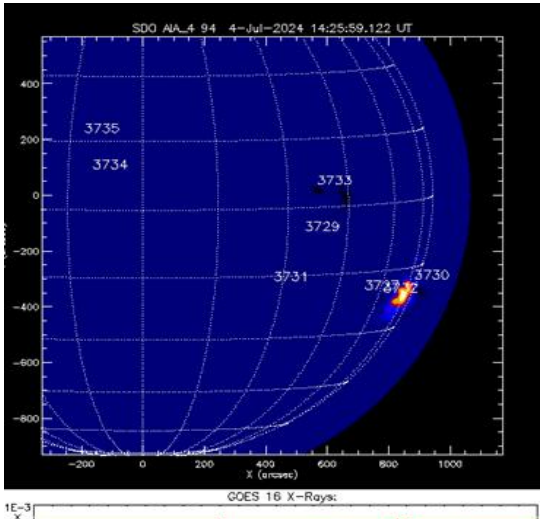
2. Information about the event:

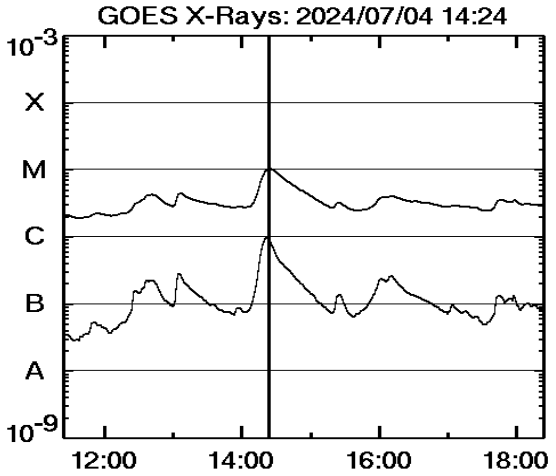
Starting/ Onset Time: 14:06:00 UT

Stopping Time: 14:42:15 UT

Peak Time: 14:25:00 UT

3. *Derived position* S21W74 **(AR)** (3732)



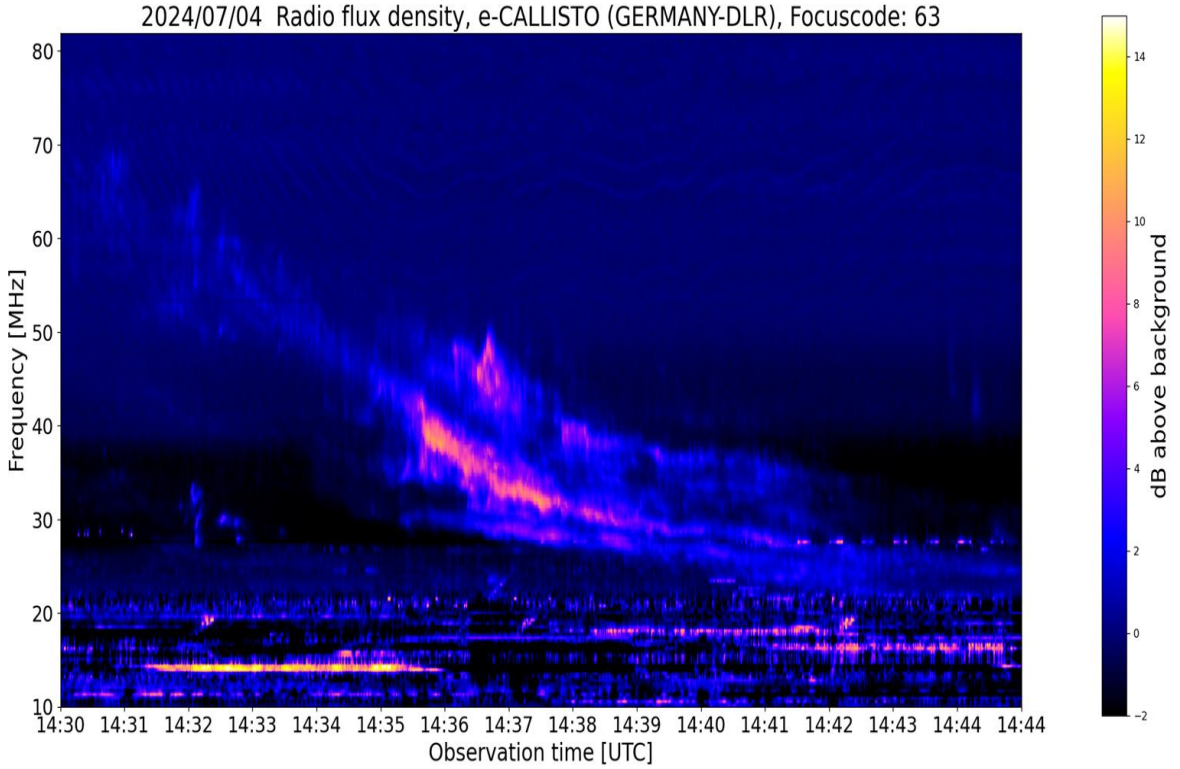


Event 2024_07_04 1427

20240704 14:27-14:44 Type II

(ALASKA-HAARP), (AUSTRIA-OE3FLB), BIR, **GERMANY-DLR**, GLASGOW, GREENLAND, HUMAIN, MEXICO-LANCE, MRO, NORWAY-EGERSUND, SWISS-HEITERSWIL, SWISS-Landschlacht, SWISS-MUHEN, USA-BOSTON

Event	Begin	Max	End	Obs	Q	Type	Loc/Frq	Particulars	Reg#
7620 +	1406	1425	1443	G16	5	XRA	1-8A	M1.0	1.6E-02	3723



The figure contains a type II radio burst with a fundamental (F1, F2)

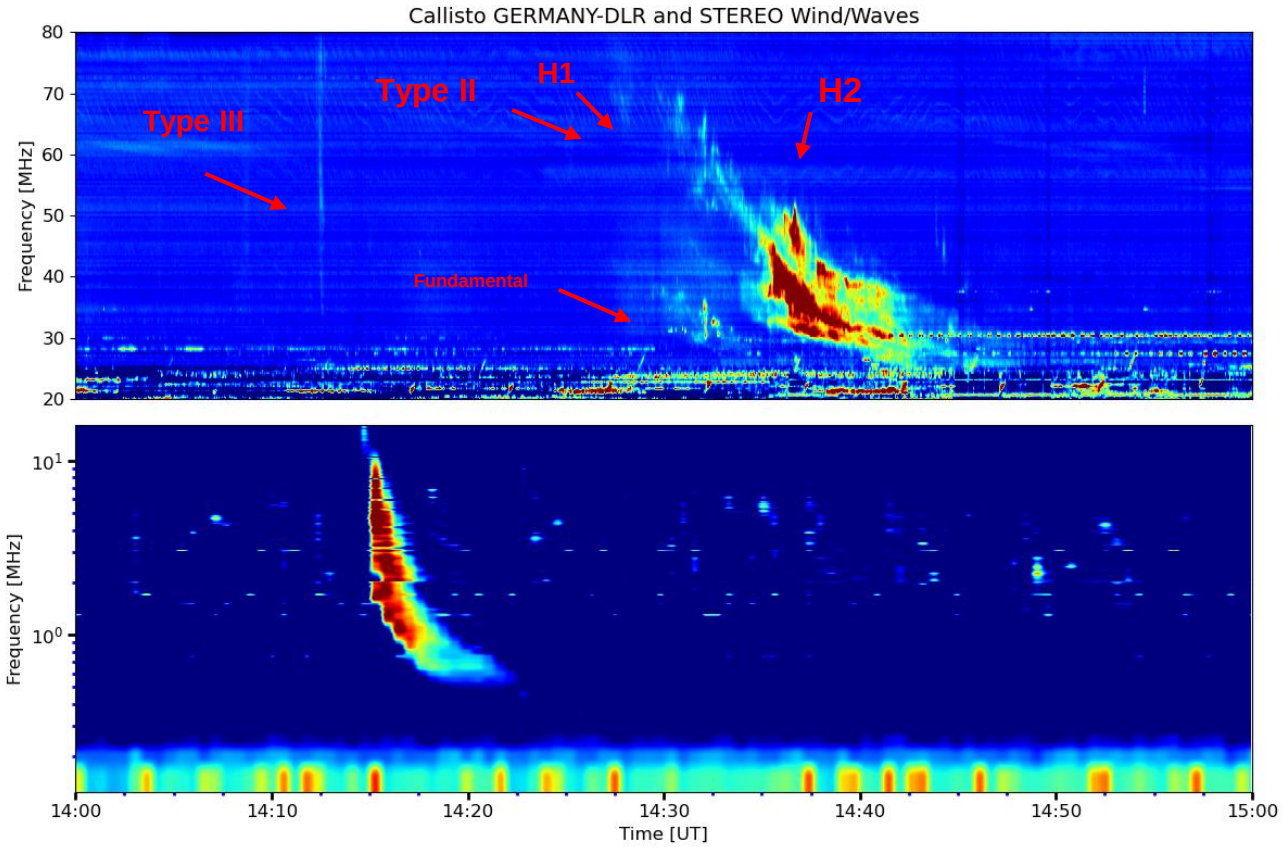
Analysis of Event 2: Type II and Type III radio bursts

2024/07/04

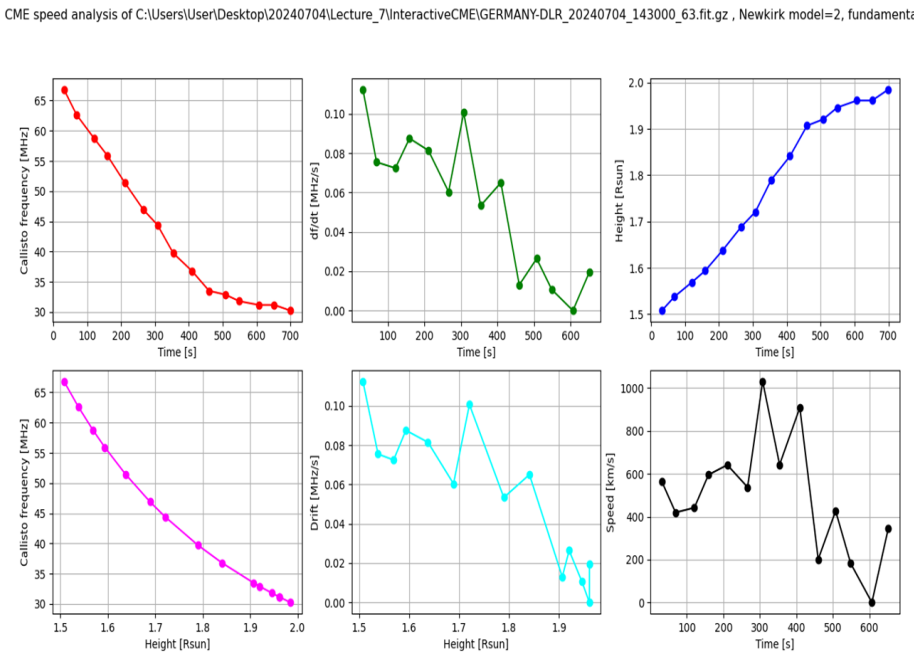
Type II radio bursts

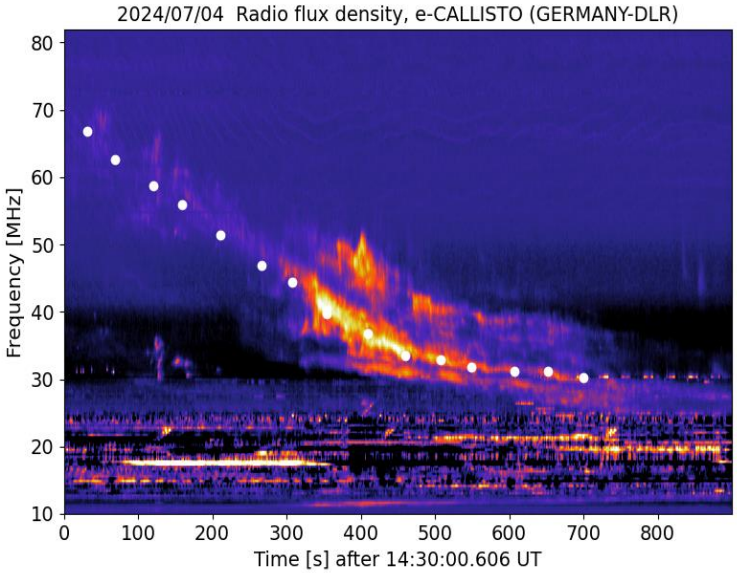
	H1	H2
Starting Frequency	24.9285	21.7365
Ending Frequency	18.3105	15.1185
start time	338.616s	338.616s
end time	609.508s	609.508s

#Due to the weak visibility of the Fundamental band, we used the Harmonic band (H1, H2) for analyzing the SRB event..



Newkirk Model for the SRB Event (04/07/2024 14:27 UT)





#The Newkirk model is typically applied for electron density measurements near the solar corona. In contrast, models such as the Saito and Leblanc models, which describe electron density as a function of solar radius, are generally used for higher coronal altitudes.

Harmonic Band Analysis (H1 & H2):

Harmonic H1					
T[s]	F[MHz]	Ne[cm^-3]	Rs[Rsun]	df/dt	
338.616	43.473	23451444	1.78		
352.805	41.916	21801567	1.81		
370.865	40.358	20211862	1.83	-0.07942	
386.344	38.801	18682330	1.86	-0.07092	df/dt = -0.0547
404.404	37.867	17793494	1.87	-0.06624	
418.593	36.777	16783897	1.9	-0.05688	
436.653	35.687	15803785	1.92	-0.05248	
456.002	34.597	14853157	1.94	-0.04511	
476.642	33.351	13802830	1.97	-0.03787	
498.571	32.417	13040356	1.99	-0.0284	
523.08	31.639	12421509	2.01		
546.3	31.016	11937263	2.03		
568.229	30.704	11698750	2.04		
609.508	30.237	11345494	2.05		

	Harmonic H2				
T[s]	F[MHz]	Ne[cm^-3]	Rs[Rsun]	df/dt	
338.616	49.857	30845049	1.7		
351.515	49.078	29889234	1.71		
369.575	47.833	28391221	1.72	-0.07306	
386.344	46.431	26751988	1.74	-0.07302	df/dt = -0.0574
404.404	45.185	25335809	1.76	-0.06982	
418.593	44.251	24298948	1.77	-0.06316	
436.653	42.694	22618984	1.79	-0.05641	
456.002	41.448	21318337	1.81	-0.04999	
476.642	40.358	20211862	1.83	-0.0426	
497.281	39.424	19286922	1.85	-0.03171	
523.08	38.49	18383645	1.86		
546.3	37.867	17793494	1.87		
568.229	37.089	17069345	1.89		
608.218	36.621	16642076	1.9		

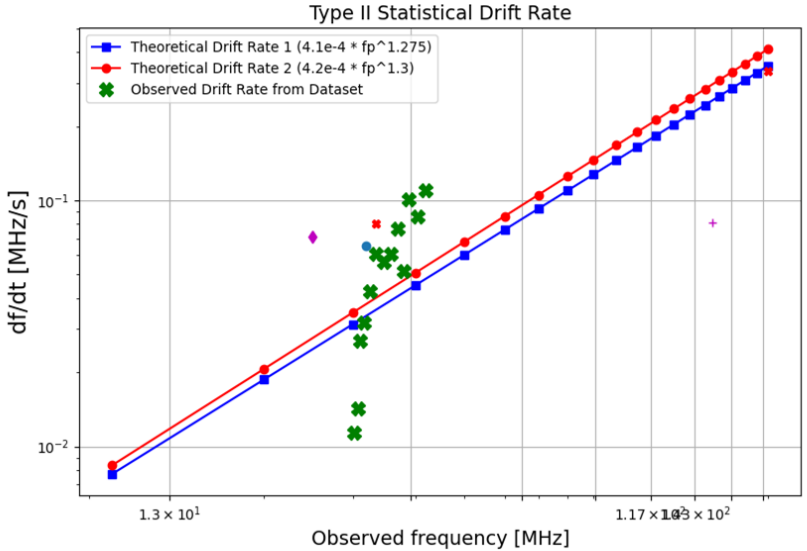
Statistical results for CME velocity from the Newkirk Model:

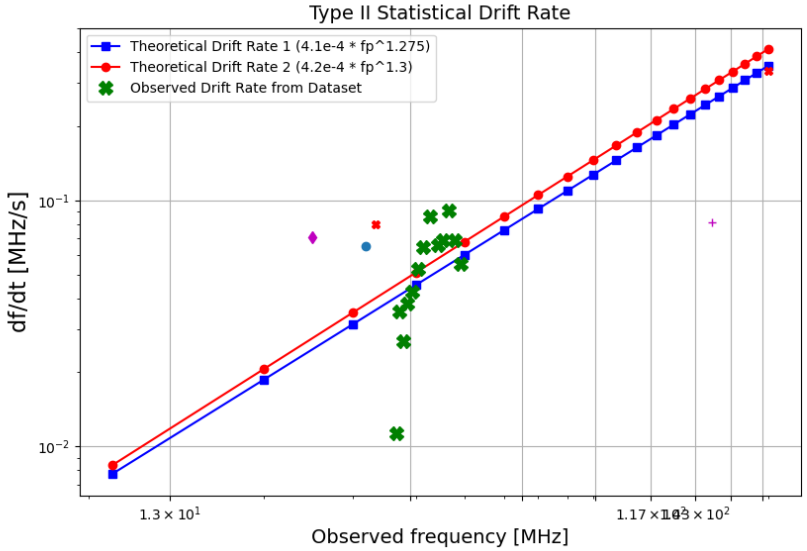
Mean = 495.8 km/ Median = 489.9 km/s 1st order = 496.9 km/s

##The CME has not yet been listed in the catalog; as a recent event of Solar Cycle 25, it requires thorough analysis.

Drift Rate Plot from the calculated data for the Harmonic[H1, H2]

Figure illustrates the Observed Drift Rate for both Harmonic band (H1 and H2) compared with the Theoretical drift rate 1 and 2.





Lower Band df/dt [H1]: -0.0547 [MHz/s]
[H2]: -0.0574 [MHz]

Upper Band df/dt

Band Splitting Analysis and calculations of certain parameters (BDW, x, M_A, v_A , B)

Bandwidth

$$BDW = \frac{F_{upper} - F_{lower}}{F_{lower}}$$

Density Jump ($x = N_2/N_1$)

$$x = (BDW + 1)^2$$

Mach Number

$$M_A = \sqrt{\frac{x(x+5)}{2(4-x)}}$$

Alfven Speed

$$v_A = \frac{v_{shock}}{M_A}$$

Ambient Magnetic Field (B):

$$B(G) = (5.1 \cdot 10^{-5}) \cdot f_l \cdot v_A$$

Calculation of Alfven speed and Ambient magnetic field for the SRB Event (04/07/2024)

Alfven Speed: $V_a = V_s / M_a$

(Shock Speed from the H-T measureme

V_s = *480 km/s*

V_a = *357.67 km/s*

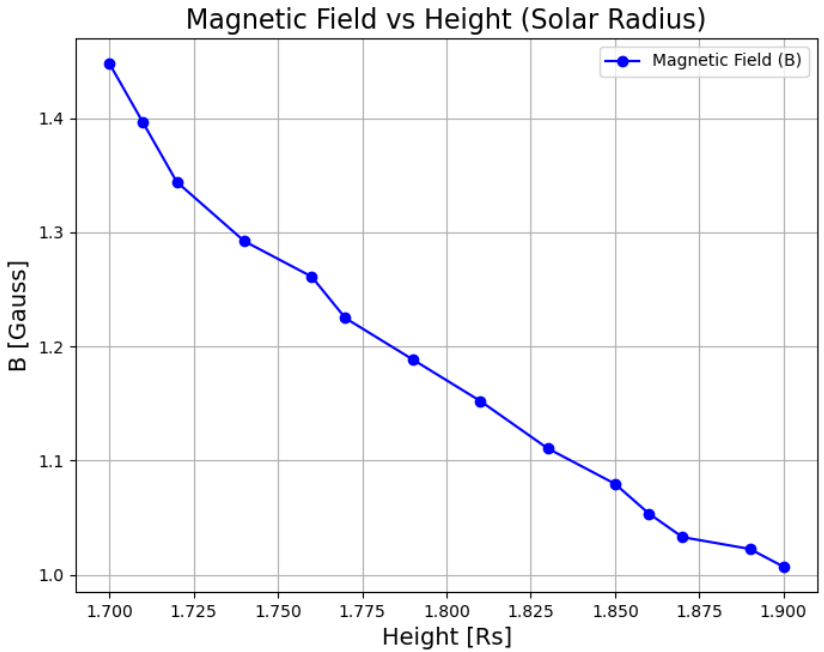
Mach Number (mean) = ***1.342***

B (Gauss): $B(G) = 5.1 \times 10\text{-}5.\ f_l.\ V_a$

Mean $B(G) =$ ***1.18 G***

Hu [MHz]	Hl [MHz]	BDW	x = sq.(BDW+1)	Mach Number	B(G)
49.857	43.473	0.14685	1.315264	1.24376	1.348144
49.078	41.916	0.170866	1.370926	1.288819	1.29986
47.833	40.358	0.185217	1.40474	1.316568	1.251544
46.431	38.801	0.196644	1.431958	1.339124	1.20326
45.185	37.867	0.193255	1.423858	1.33239	1.174296
44.251	36.777	0.203225	1.44775	1.352304	1.140494
42.694	35.687	0.196346	1.431244	1.338529	1.106692
41.448	34.597	0.198023	1.435259	1.341873	1.07289
40.358	33.351	0.210099	1.464339	1.366225	1.03425
39.424	32.417	0.216152	1.479026	1.378617	1.005286
38.49	31.639	0.216537	1.479961	1.379408	0.981159
37.867	31.016	0.220886	1.490563	1.388395	0.961839
37.089	30.704	0.207953	1.459151	1.361863	0.952164
36.621	30.237	0.211132	1.466841	1.368332	0.937681

Variation of Magnetic Field with the Height in terms of R_S



The Newkirk model is often used with typical magnetic field values:

- Near the solar surface:

$$B \approx 1-10\ B_0 \text{ Gauss.}$$

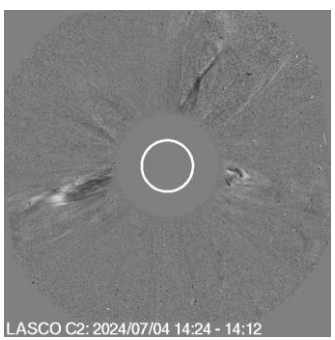
- At greater heights (e.g., 10 R_{sun}),

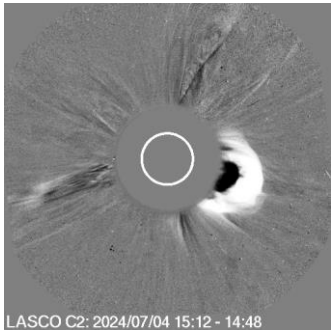
$$B \approx 0.1 B_0 \text{ Gauss.}$$

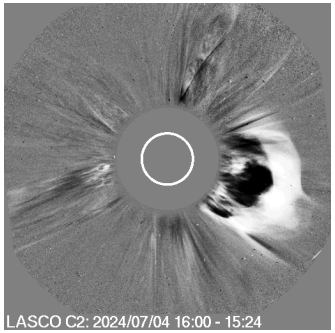
In the analysis of the SRB event (23/04/24, 17:47 UT) by the Newkirk model near the solar surface. We got the Ambient Magnetic field :

Mean B(G)= 1.18 G

LASCO/C2 – While light CME as Partial Halo at SW limb



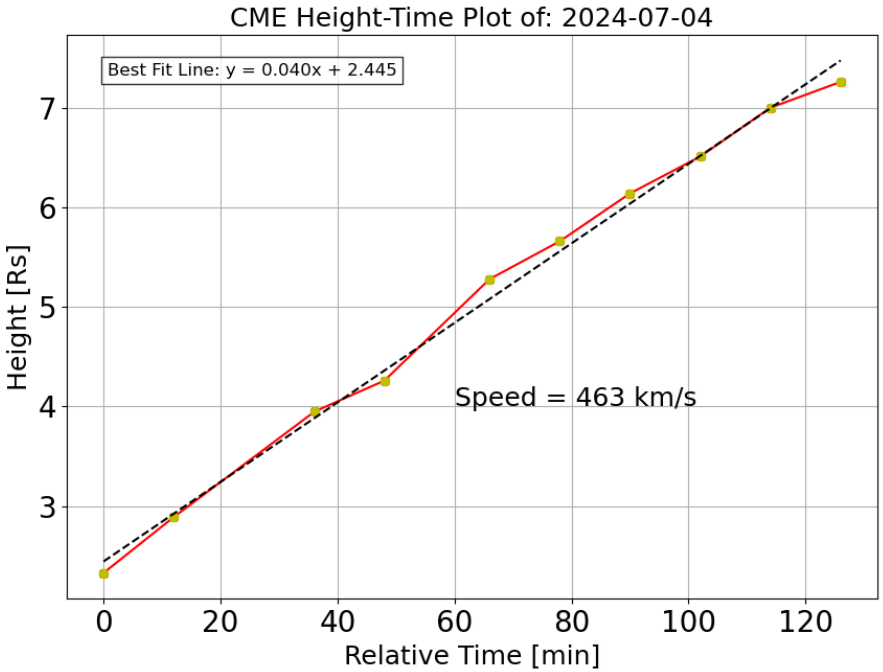


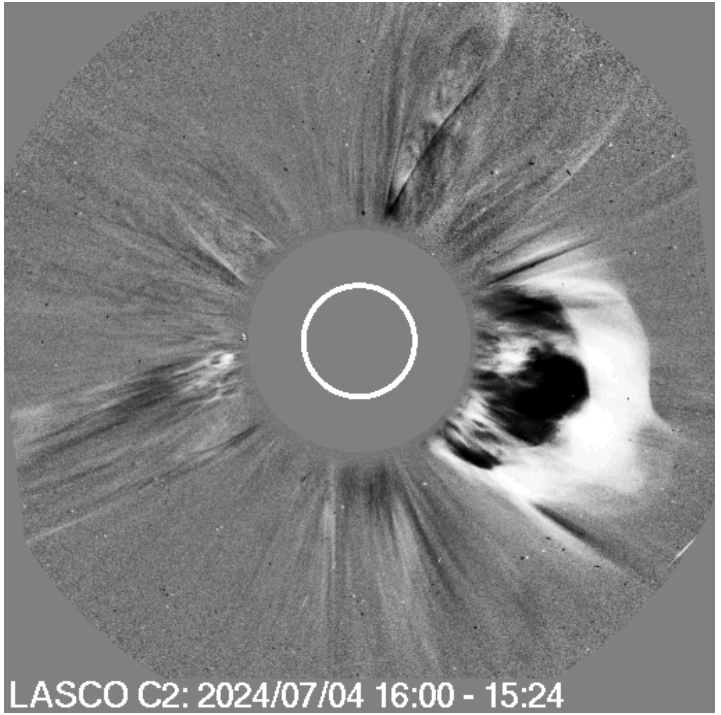


The running difference images of CME showing its propagation

White light CME observations analysis

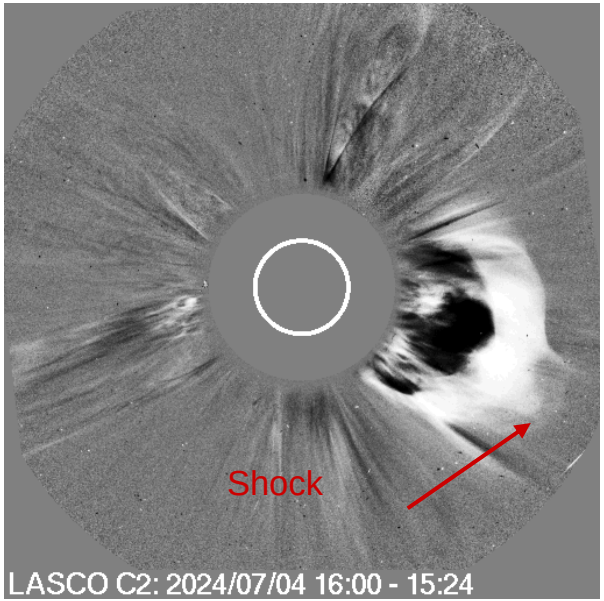
***White-light coronagraph always moves outward from the Sun into the heliosphere over a time-scale of several hours to ~ days.**

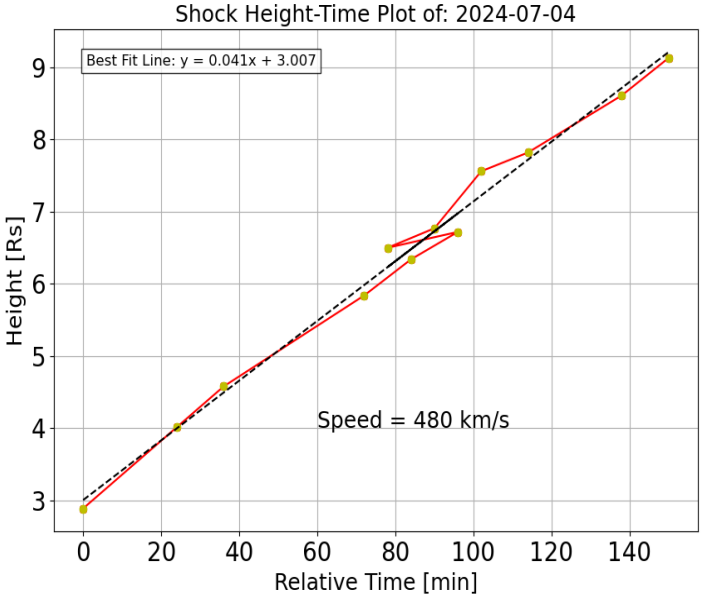




1st order CME speed from the Newkirk model: 496.9 km/s

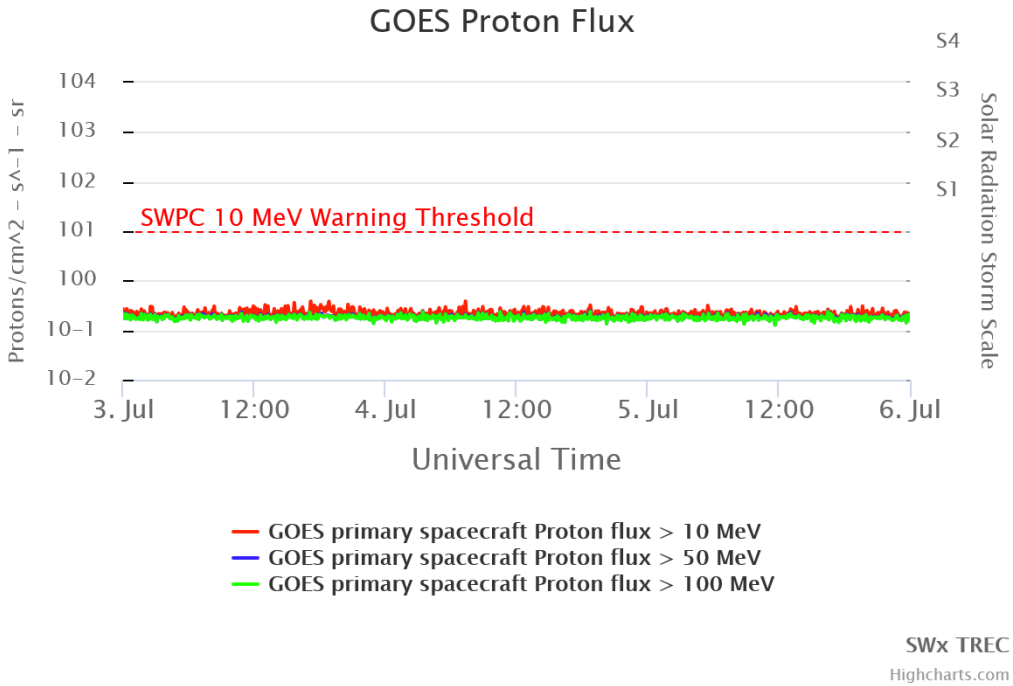
Shock speed analysis for Event II (04/07/2024)





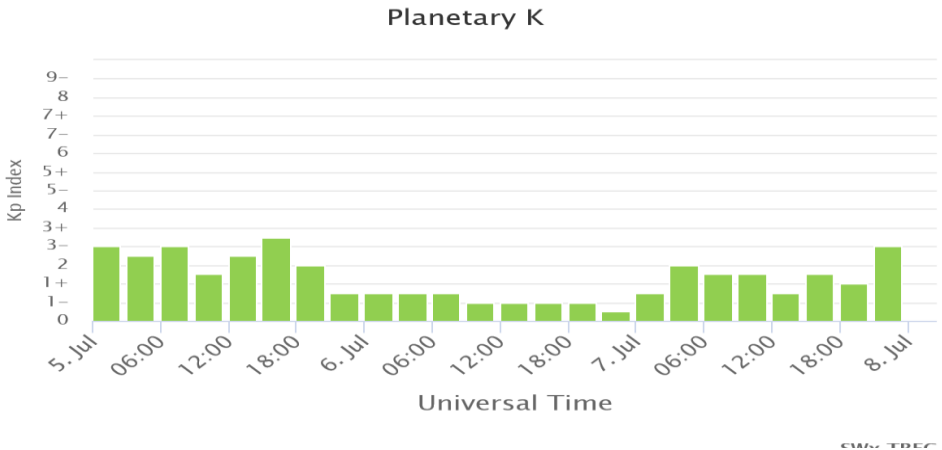
- Shock Speed from the Height-Time measurement from LASCO C2: 480km/s
- A shock is detected at ~ 241 degrees, but it is not a prominent one near the CME evolution boundary.

No SEP (Solar Energetic particle) event association with Event II (04/07/2024)



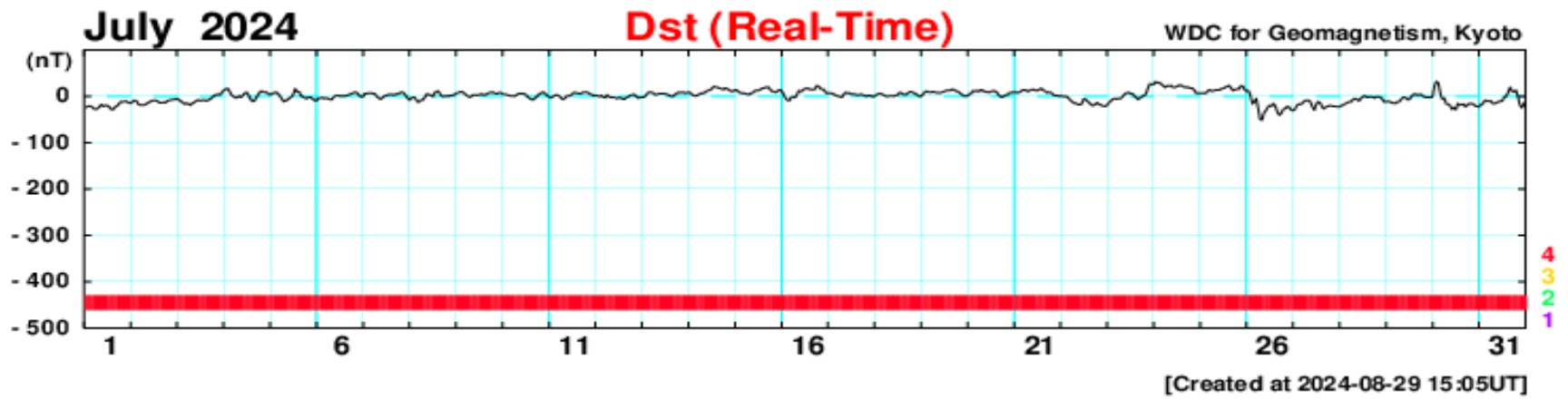
- No significant proton flux (pfu) increase was detected for the Event II (04/07/2024).
- Solar Radiation Storm indicator (< S1 type) concludes the absence of any geoeffectiveness.

Geomagnetic storm Index (Dst and Kp) for Event II (04/07/2024)



For the event II (04/07/2024):

- Kp < 4 (after 3 days)
- **No geomagnetic storm**



Summary

- The event of 4 July 2024 is associated with an M1.0 class flare and a partial halo, with average speed approx. 400 km/s and was not directed towards the Earth.
- Harmonic bands are prominently seen as compared to the fundamental and used for the drift -rate analysis.
- The CME shock is very weak.
- No SEP or geomagnetic activity associated with this event.
- The event has not been listed in the LASCO catalog and further details are to be studied.