Comparative analysis of solar activity

Vergil Yotov

LOFAR Family Meeting 2025

Institut de Physique du Globe de Paris

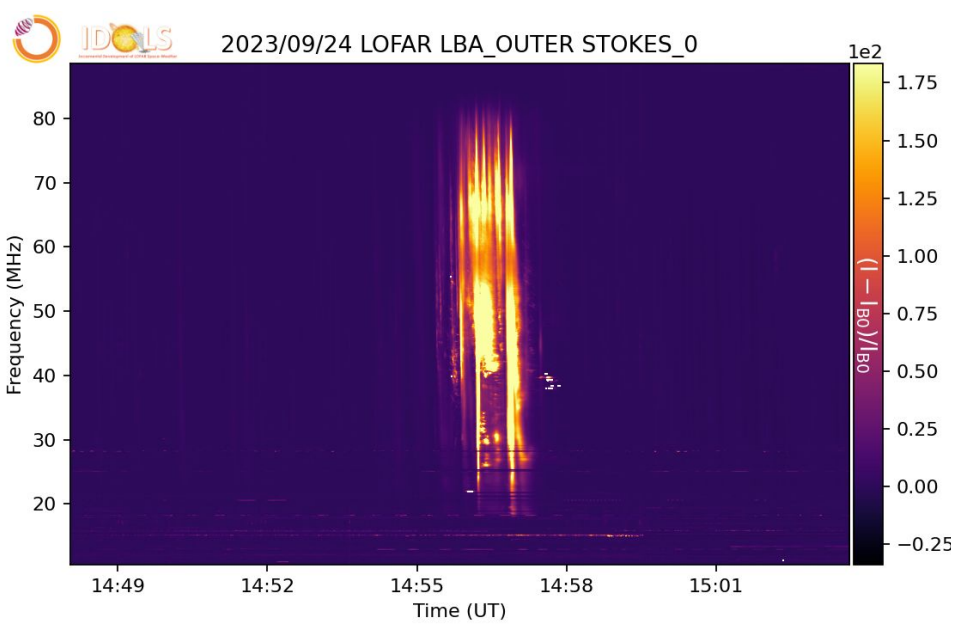
Sep 26, 2025

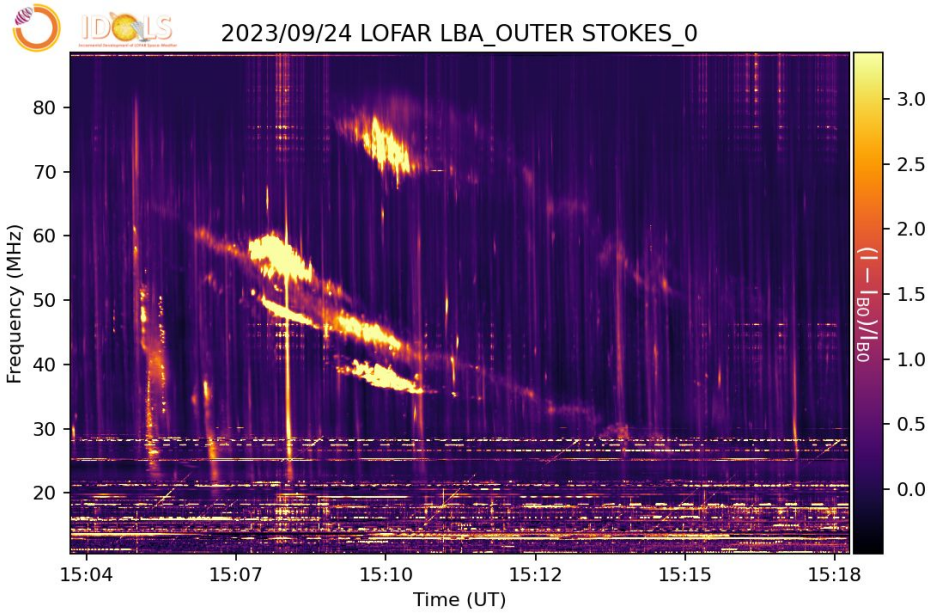

Onsala
Irbene
Birr
Dutch stations
Chilbolton
Norderstedt
Bałdy
Potsdam
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Nançay
Unterweilenbach
Medicina
Rozhen

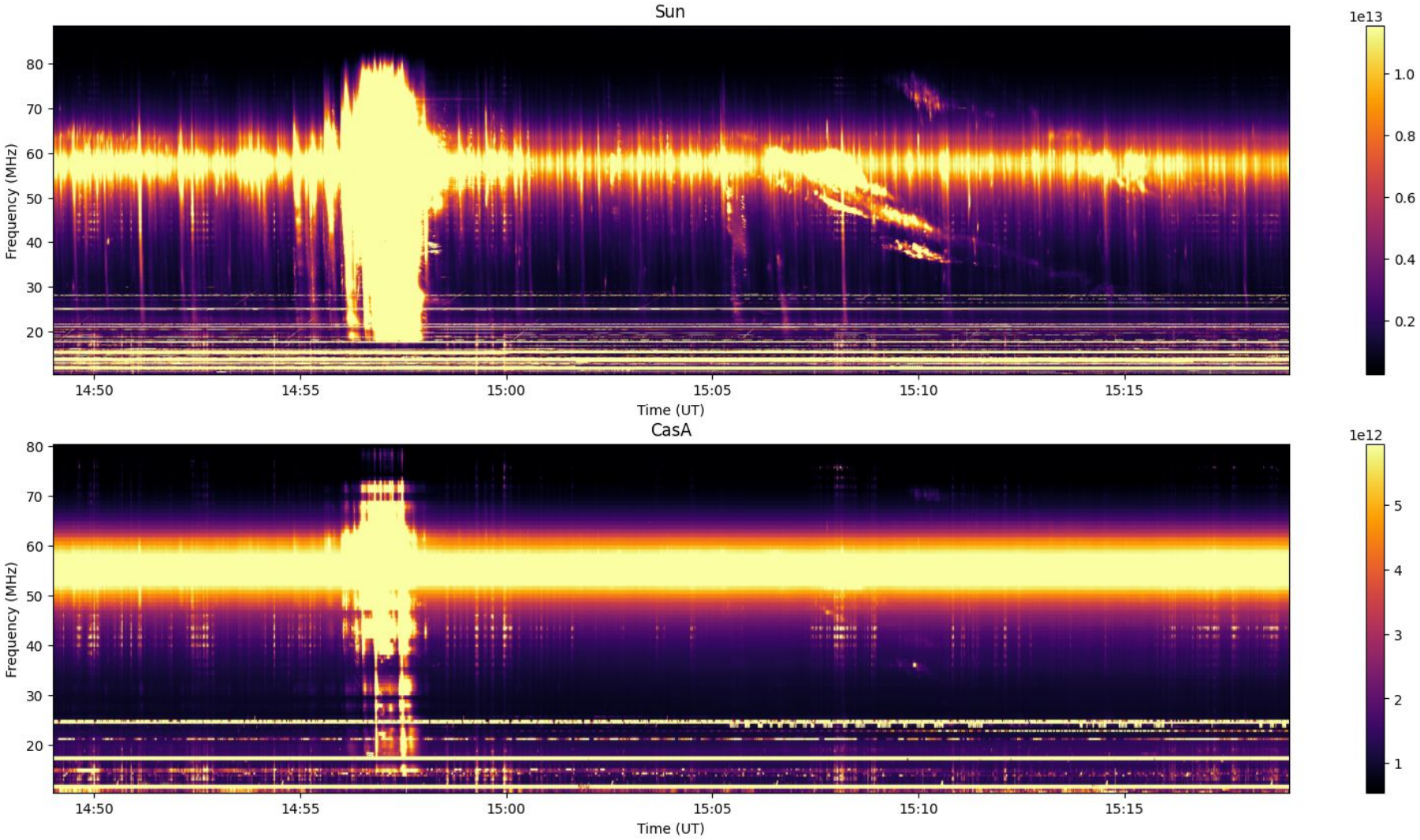
LOFAR-BG In preparation

LOFAR Data School 2024

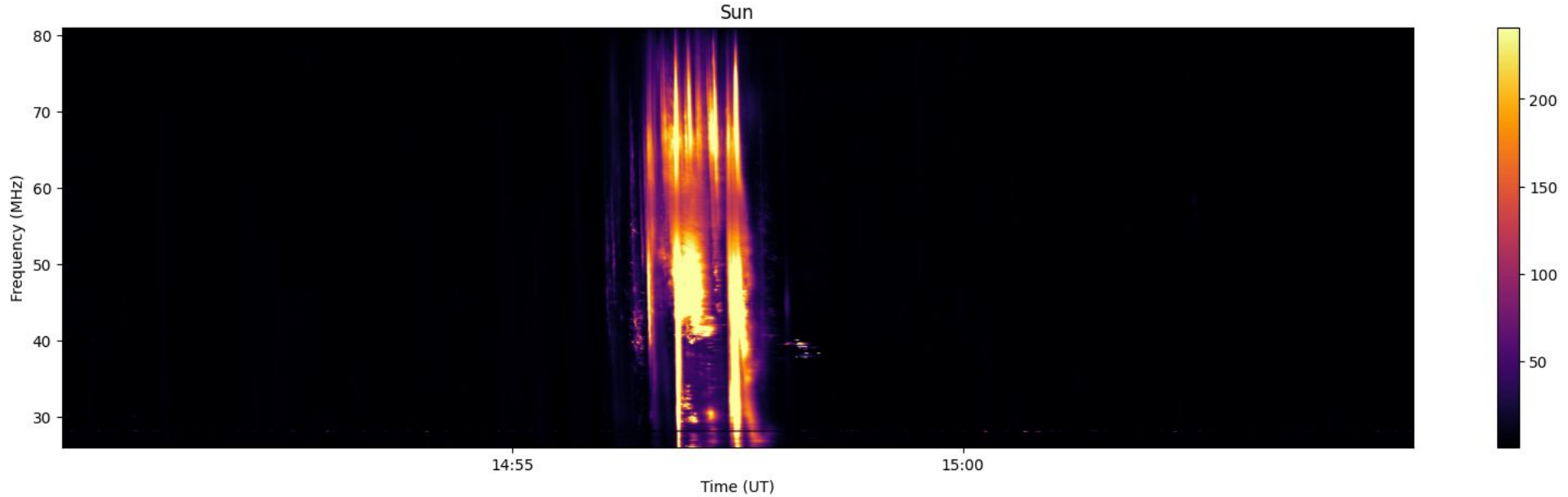
LOFAR LBA IDOLS Beamformed Observations
2023/09/24 14:48-15:18



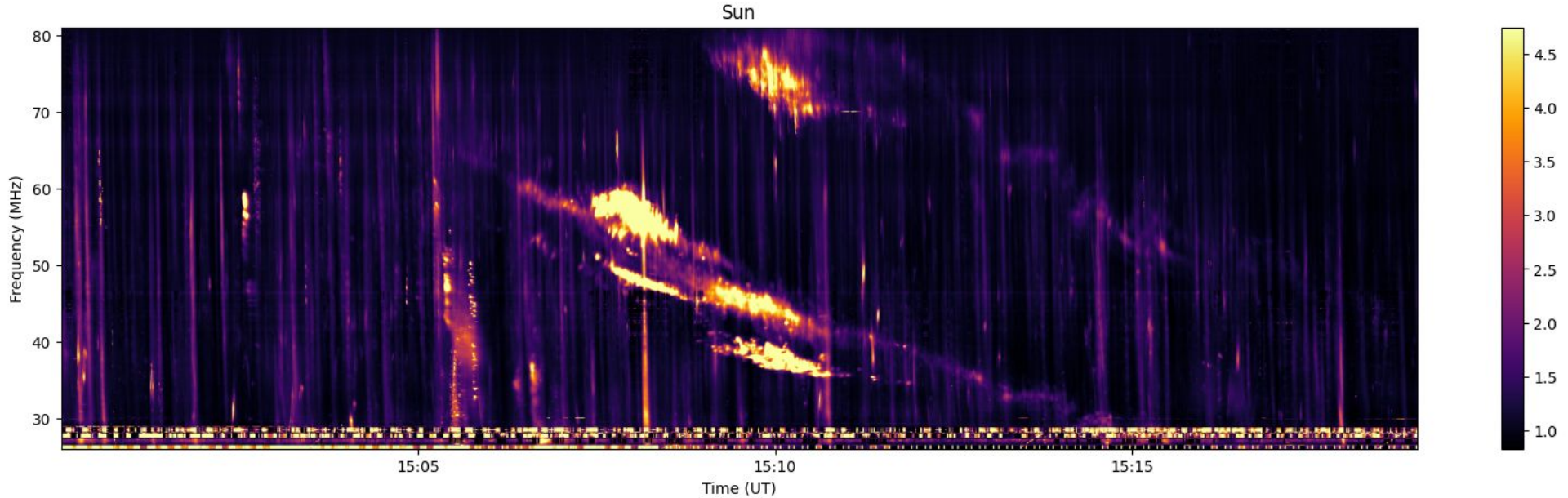



Sun
Frequency (MHz)
80
70
60
50
40
30
20
14:50
14:55
15:00
15:05
15:10
15:15
Time (UT)
1e13
1.0
0.8
0.6
0.4
0.2
CasA
Frequency (MHz)
80
70
60
50
40
30
20
14:50
14:55
15:00
15:05
15:10
15:15
Time (UT)
1e12
5
4
3
2
1

LOFAR LBA 2023/09/24 14:50-15:05 – Type III burst

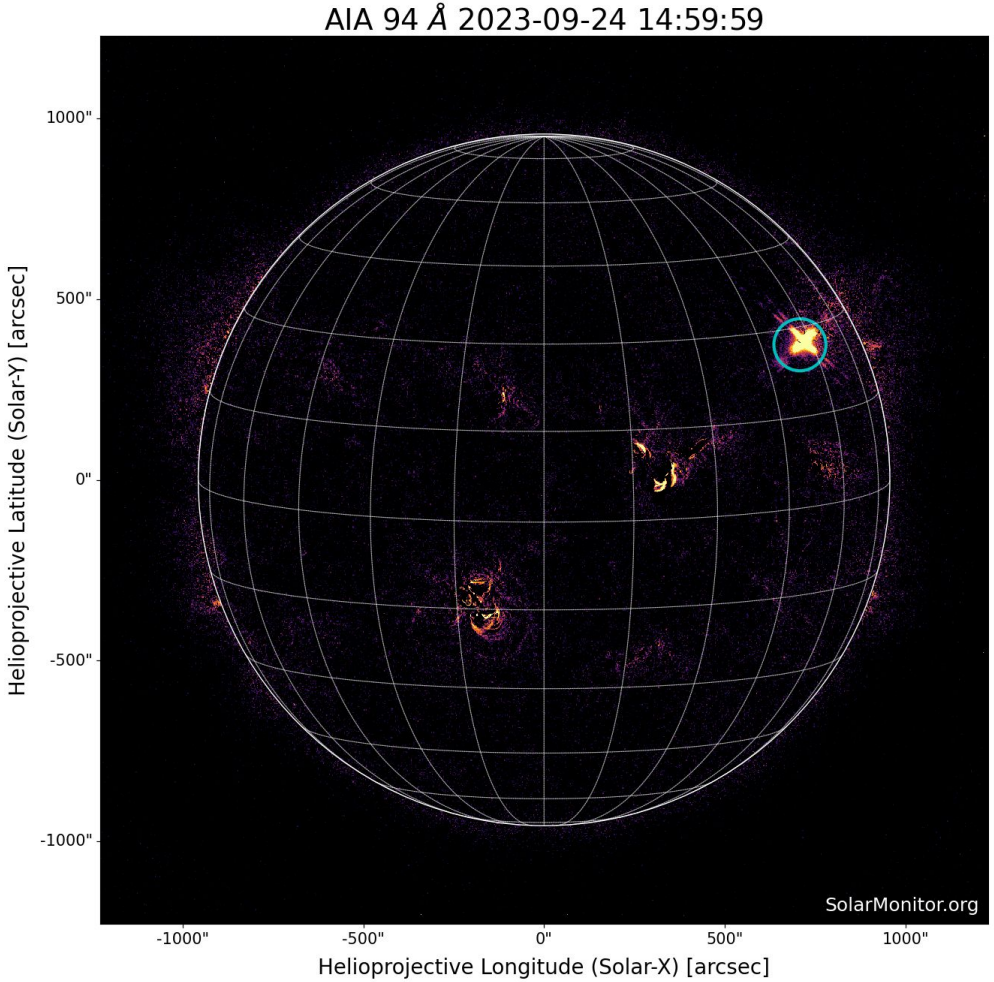


LOFAR LBA 2023/09/24 15:00-15:20 – Type II burst



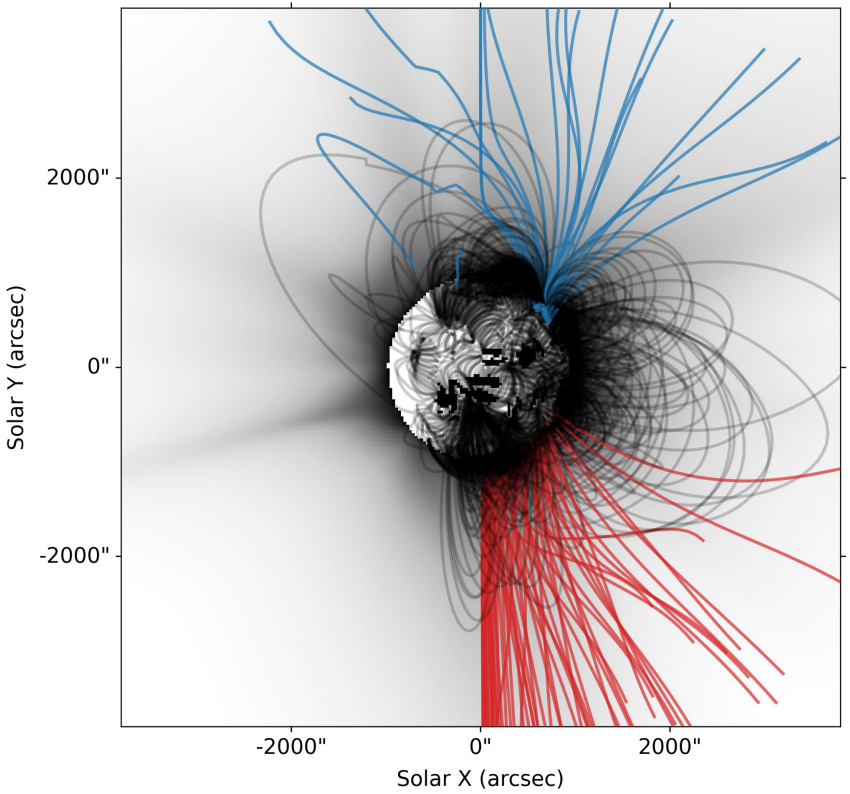
SDO/AIA 2023/09/24

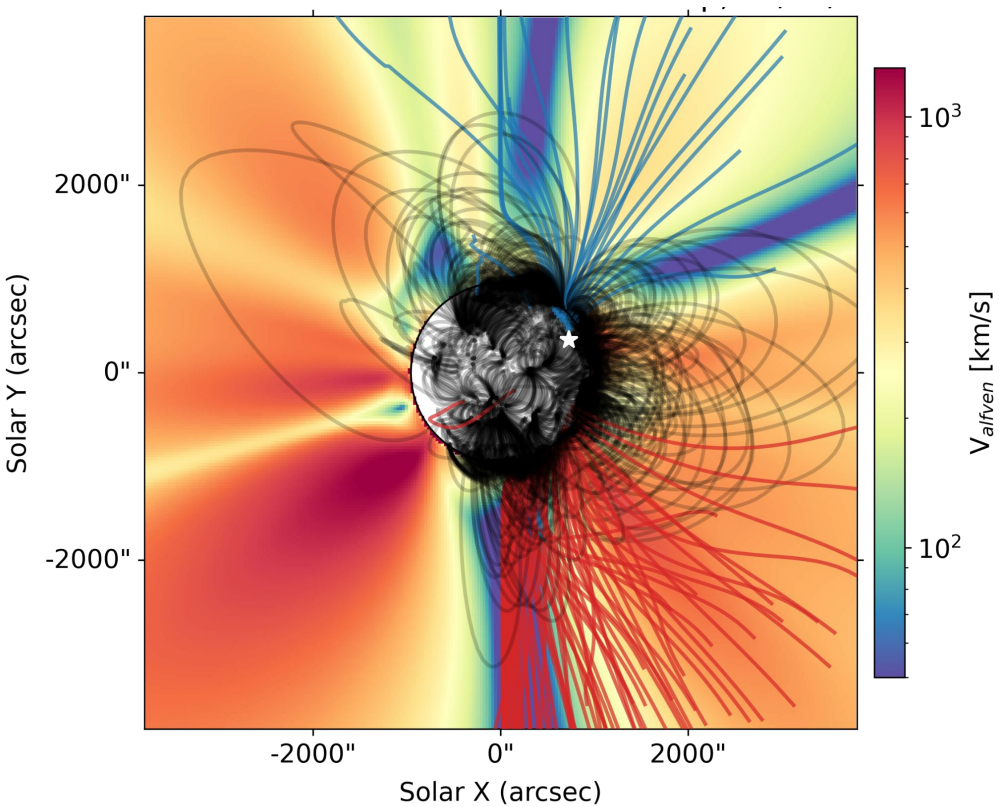
GOES Flare Class: *M1.0*
Active Region:
Flare Location (degrees): *56, 27*
Flare Location: *729.6”, 345.6”*



https://solmon.dias.ie/flare?date=2023092414&id=FL-SSWL-20230924145100

PFSS fields overlad on MHD valfen speed map 2023/09/24





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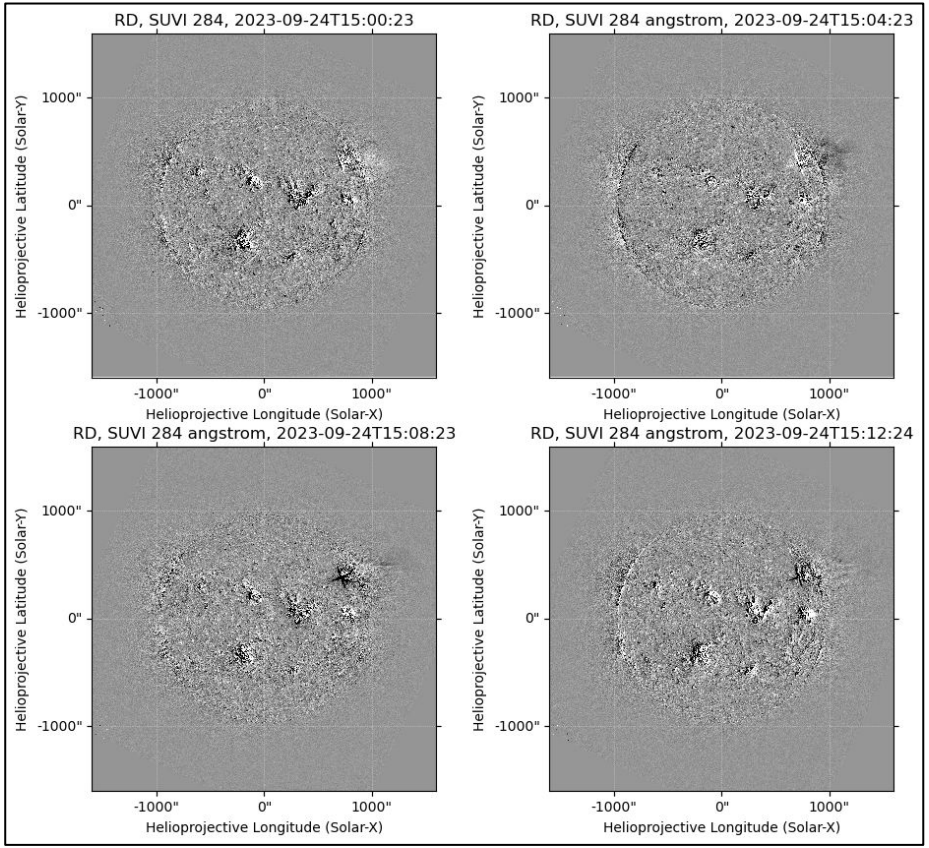
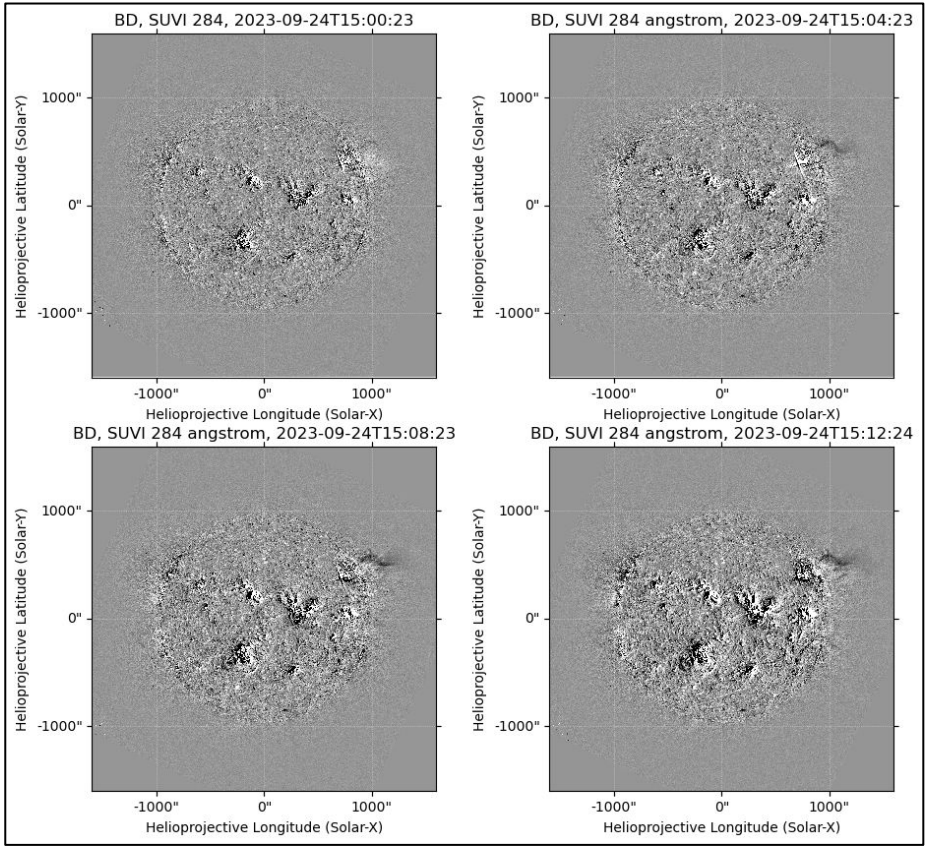
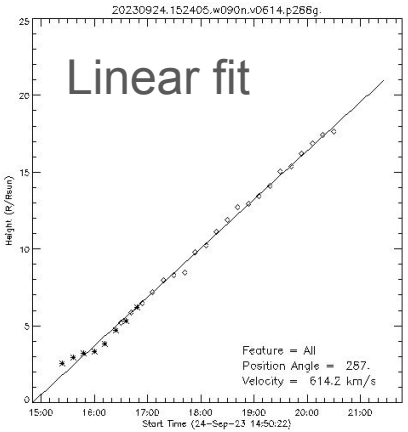
GOES/SUVI observations 2023/09/24

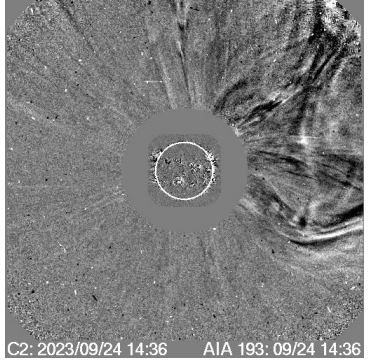


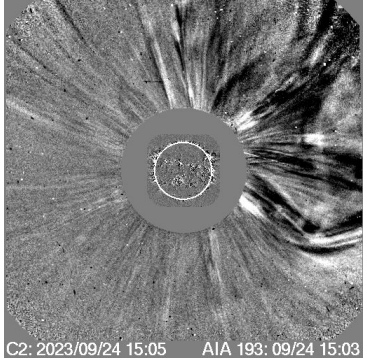


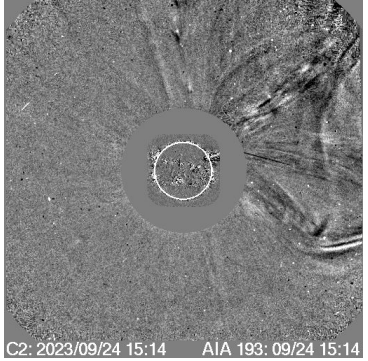
LASCO observations 2023/09/24

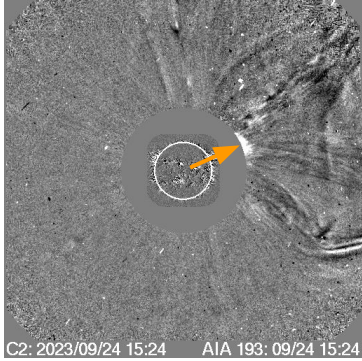


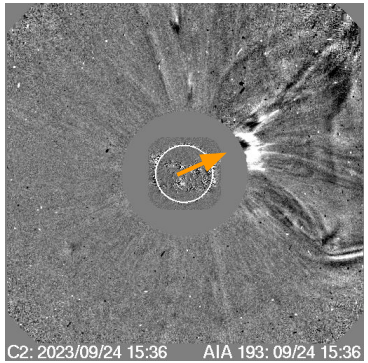
[LASCO C2 VIDEO]

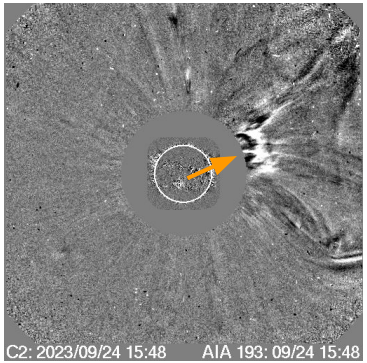


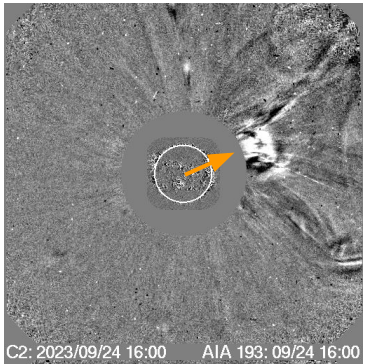


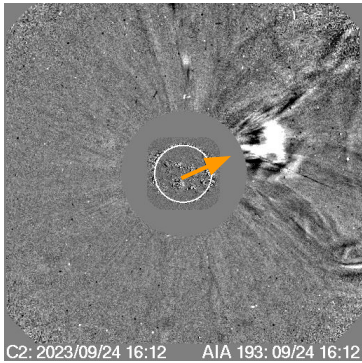


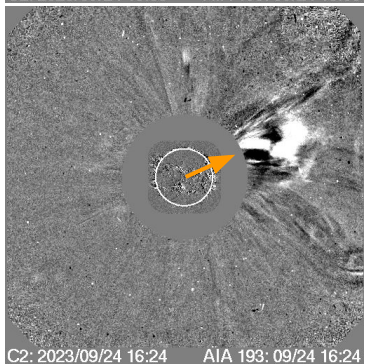


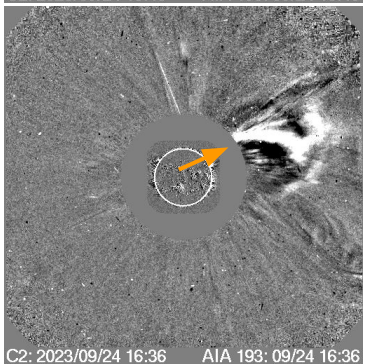


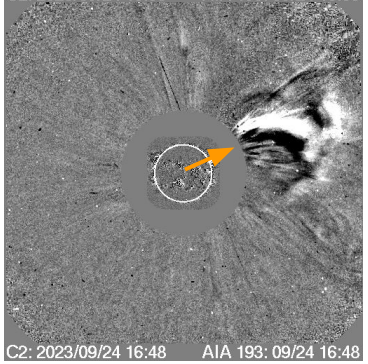


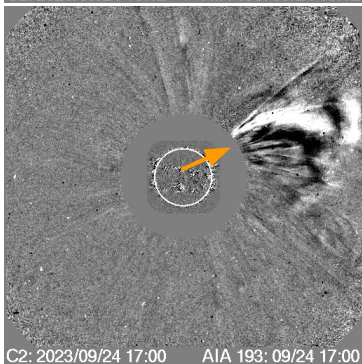




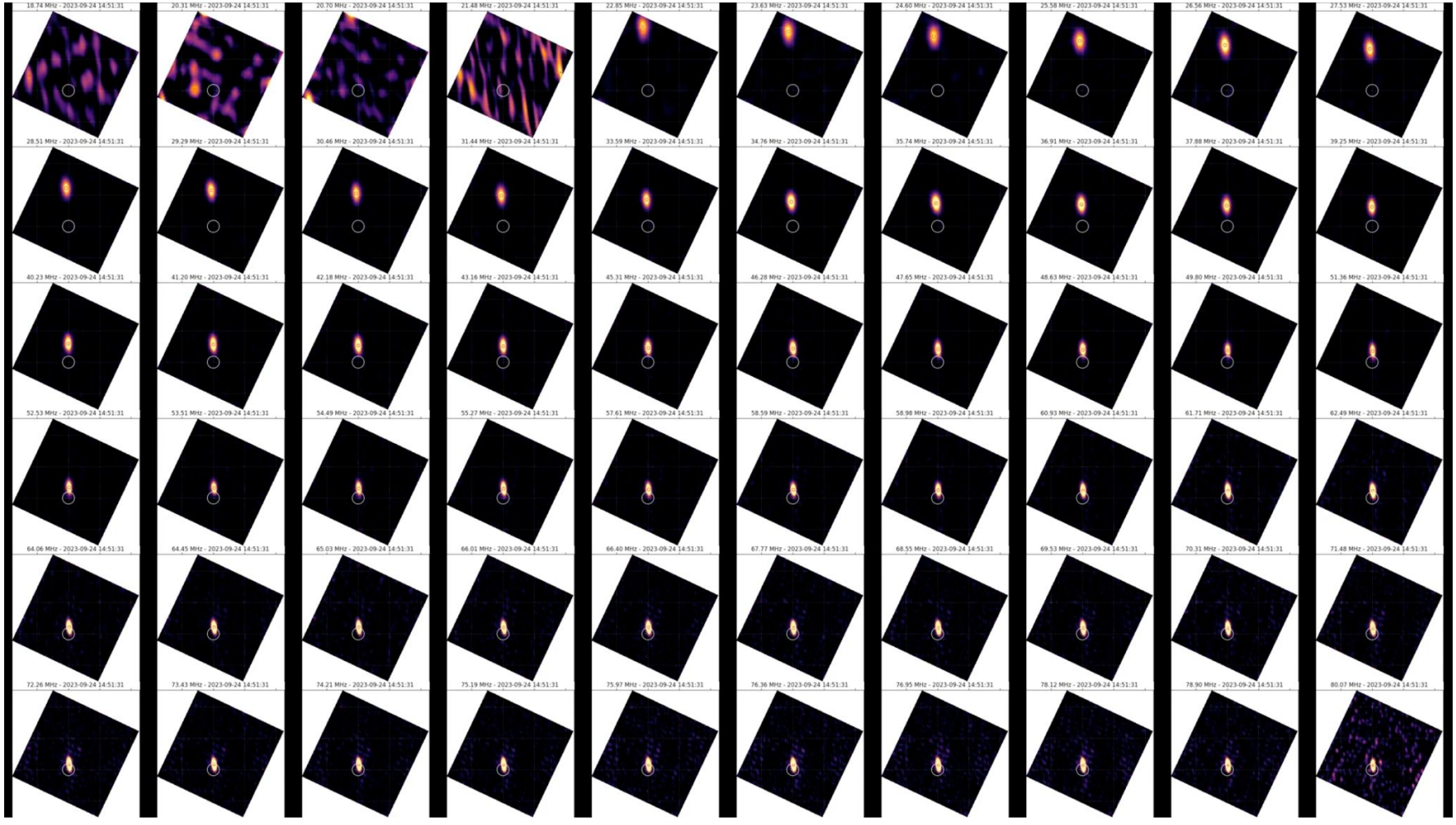




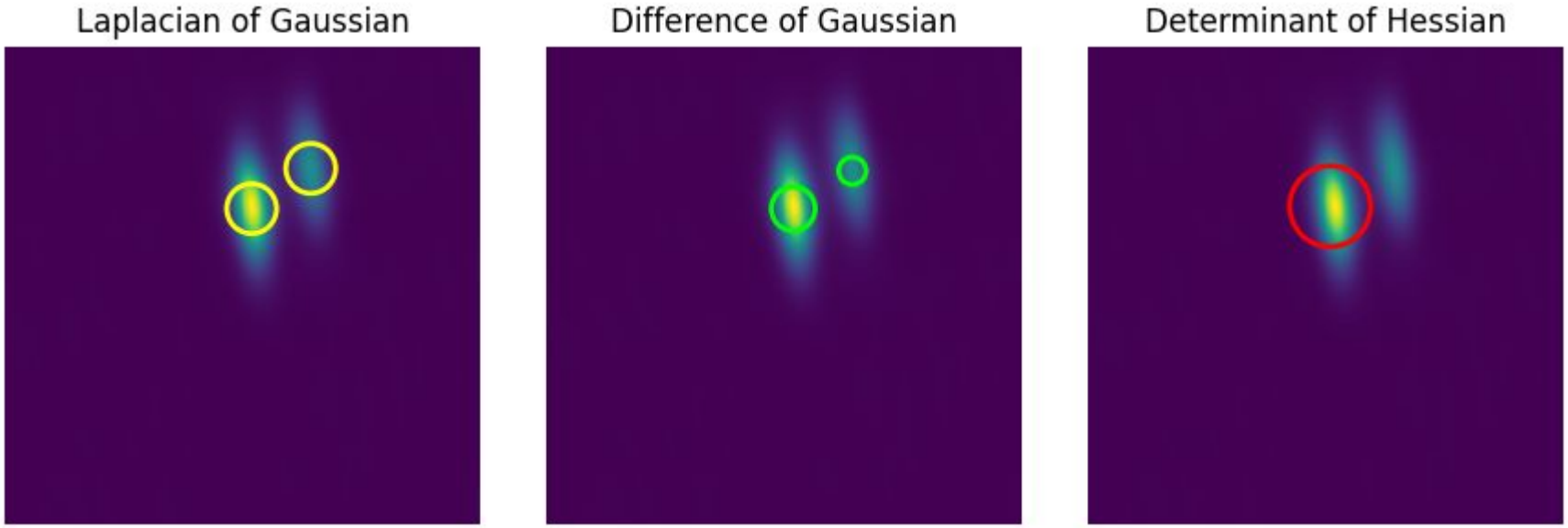




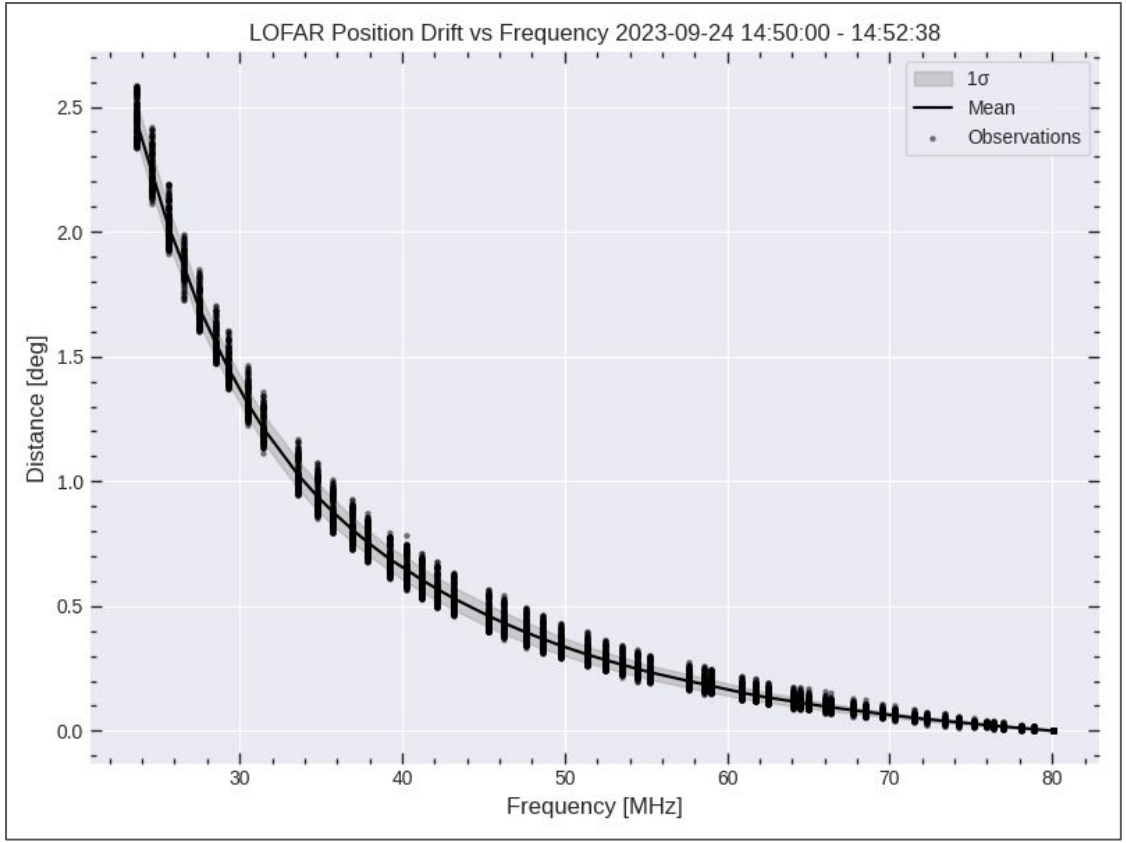
2023/09/24 Interferometry - Significant ionospheric refraction

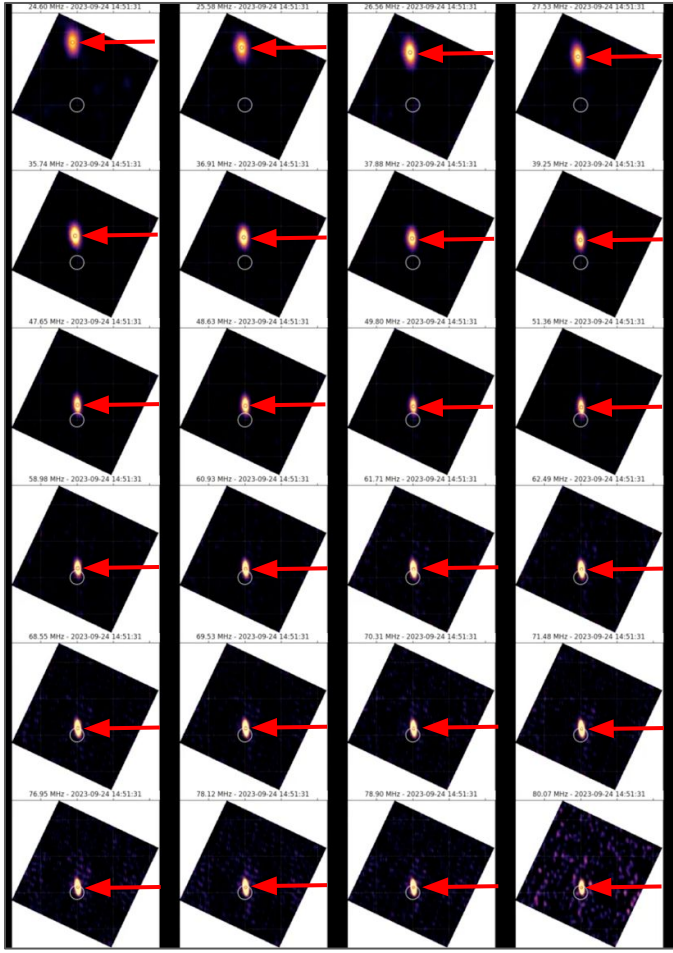


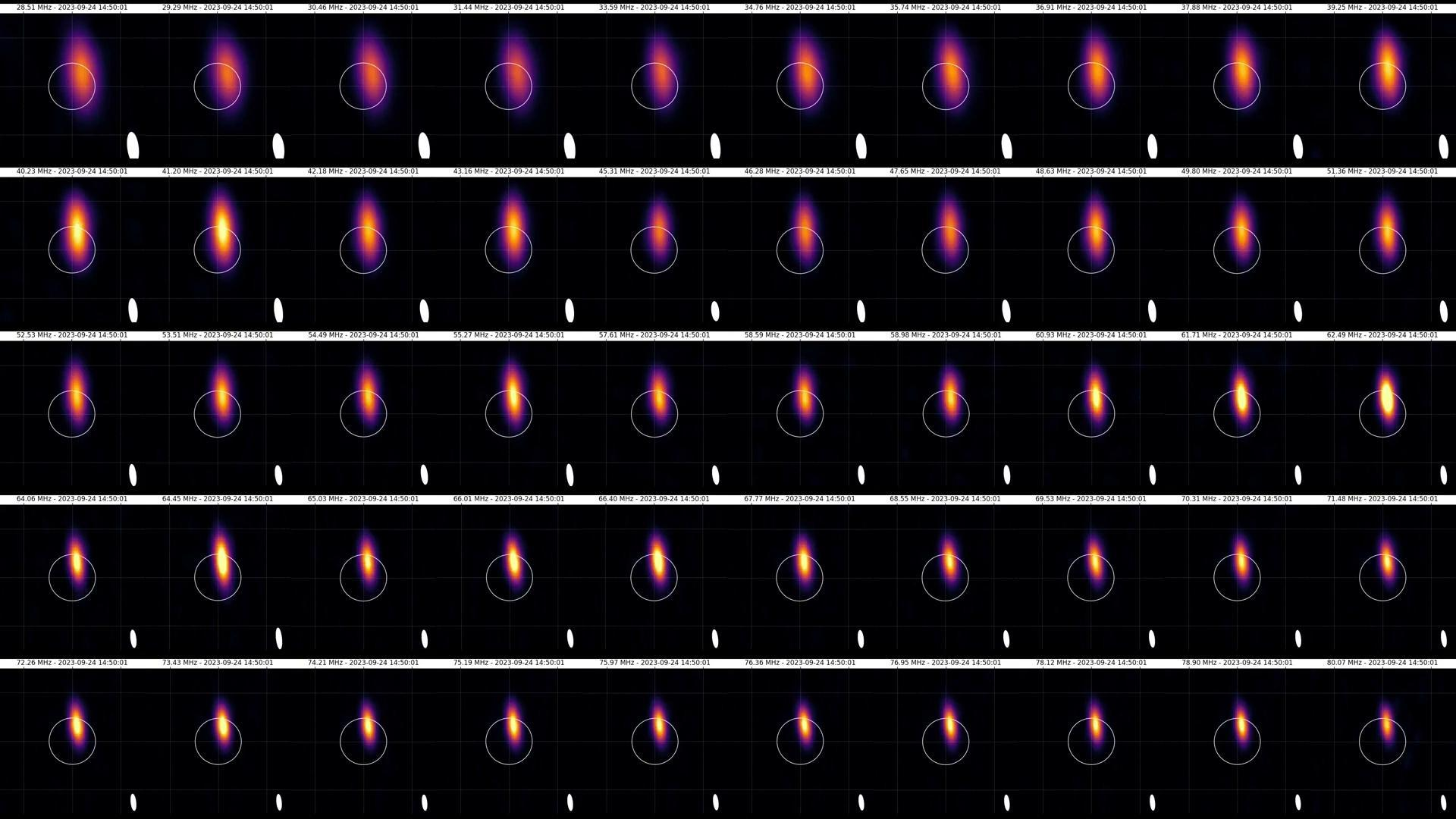
Automatic feature extraction of LOFAR Solar interferometry



Position drift of main emission source with frequency






28.51 MHz - 2023-09-24 14:50:01
29.29 MHz - 2023-09-24 14:50:01
30.46 MHz - 2023-09-24 14:50:01
31.44 MHz - 2023-09-24 14:50:01
33.59 MHz - 2023-09-24 14:50:01
34.76 MHz - 2023-09-24 14:50:01
35.74 MHz - 2023-09-24 14:50:01
36.91 MHz - 2023-09-24 14:50:01
37.88 MHz - 2023-09-24 14:50:01
39.25 MHz - 2023-09-24 14:50:01
40.23 MHz - 2023-09-24 14:50:01
41.20 MHz - 2023-09-24 14:50:01
42.18 MHz - 2023-09-24 14:50:01
43.16 MHz - 2023-09-24 14:50:01
45.31 MHz - 2023-09-24 14:50:01
46.28 MHz - 2023-09-24 14:50:01
47.65 MHz - 2023-09-24 14:50:01
48.63 MHz - 2023-09-24 14:50:01
49.80 MHz - 2023-09-24 14:50:01
51.36 MHz - 2023-09-24 14:50:01
52.53 MHz - 2023-09-24 14:50:01
53.51 MHz - 2023-09-24 14:50:01
54.49 MHz - 2023-09-24 14:50:01
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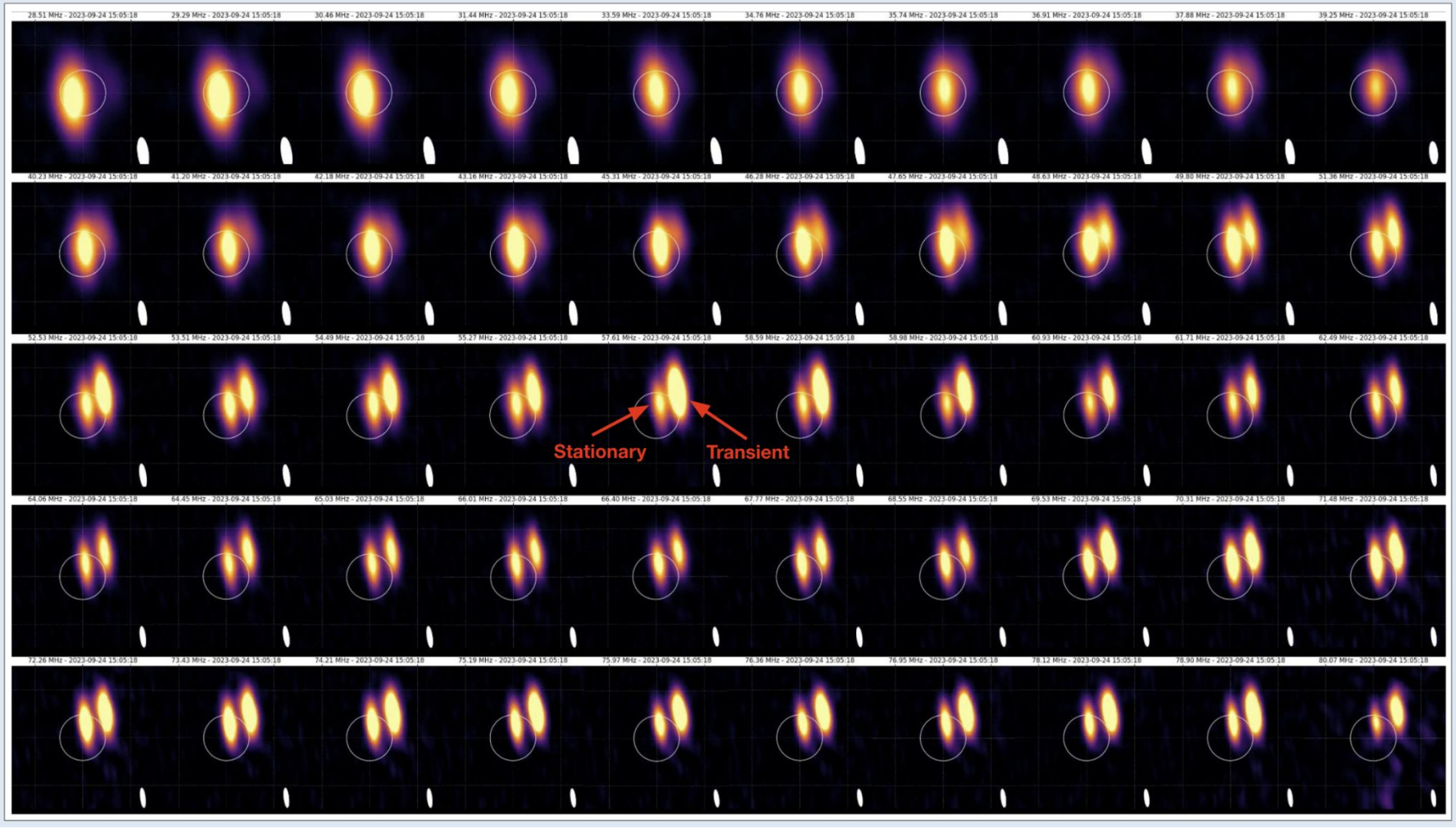
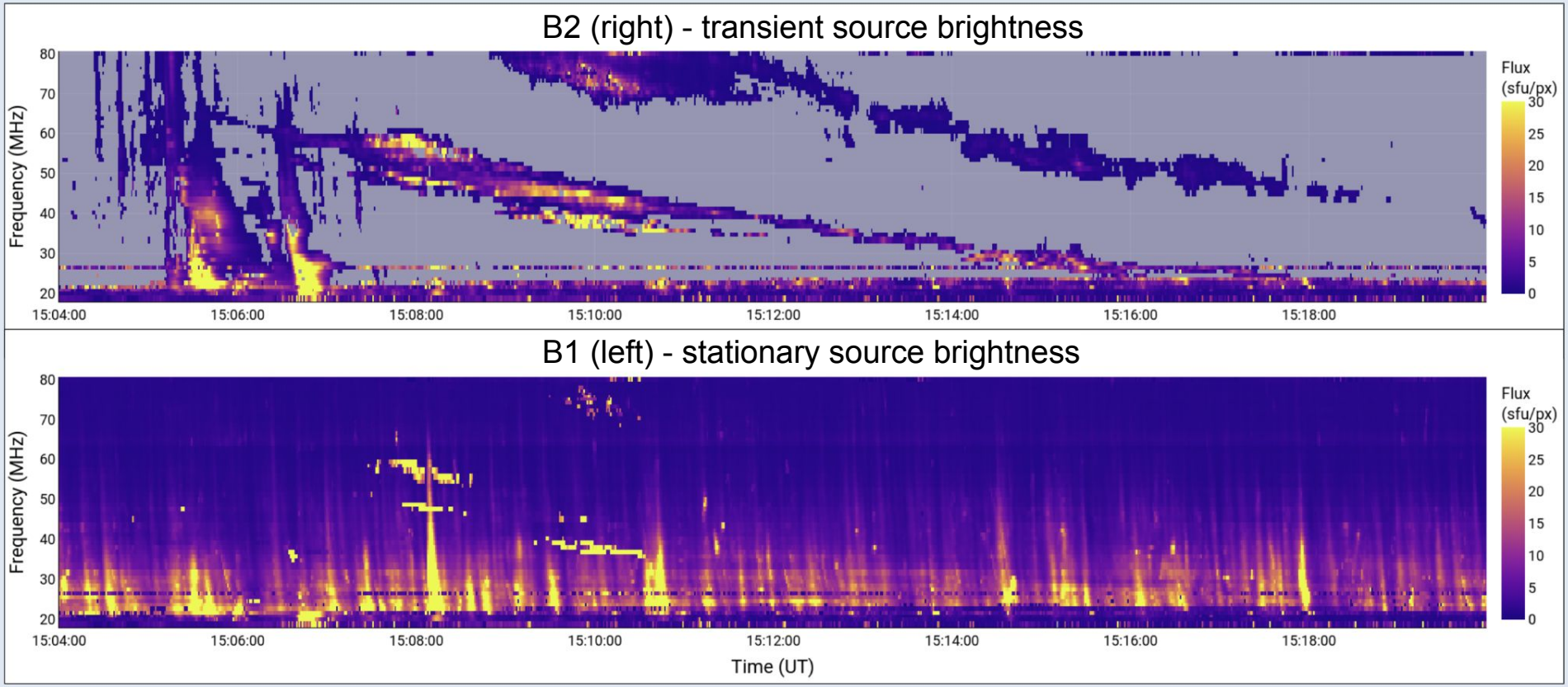
57.61 MHz - 2023-09-24 14:50:01
58.59 MHz - 2023-09-24 14:50:01
58.98 MHz - 2023-09-24 14:50:01
60.93 MHz - 2023-09-24 14:50:01
61.71 MHz - 2023-09-24 14:50:01
62.49 MHz - 2023-09-24 14:50:01
64.06 MHz - 2023-09-24 14:50:01
64.45 MHz - 2023-09-24 14:50:01
65.03 MHz - 2023-09-24 14:50:01
66.01 MHz - 2023-09-24 14:50:01
66.40 MHz - 2023-09-24 14:50:01
67.77 MHz - 2023-09-24 14:50:01
68.55 MHz - 2023-09-24 14:50:01
69.53 MHz - 2023-09-24 14:50:01
70.31 MHz - 2023-09-24 14:50:01
71.48 MHz - 2023-09-24 14:50:01
72.26 MHz - 2023-09-24 14:50:01
73.43 MHz - 2023-09-24 14:50:01
74.21 MHz - 2023-09-24 14:50:01
75.19 MHz - 2023-09-24 14:50:01
75.97 MHz - 2023-09-24 14:50:01
76.36 MHz - 2023-09-24 14:50:01
76.95 MHz - 2023-09-24 14:50:01
78.12 MHz - 2023-09-24 14:50:01
78.90 MHz - 2023-09-24 14:50:01
80.07 MHz - 2023-09-24 14:50:01


Stationary
Transient

2023/09/24 Extracted sources spectrum



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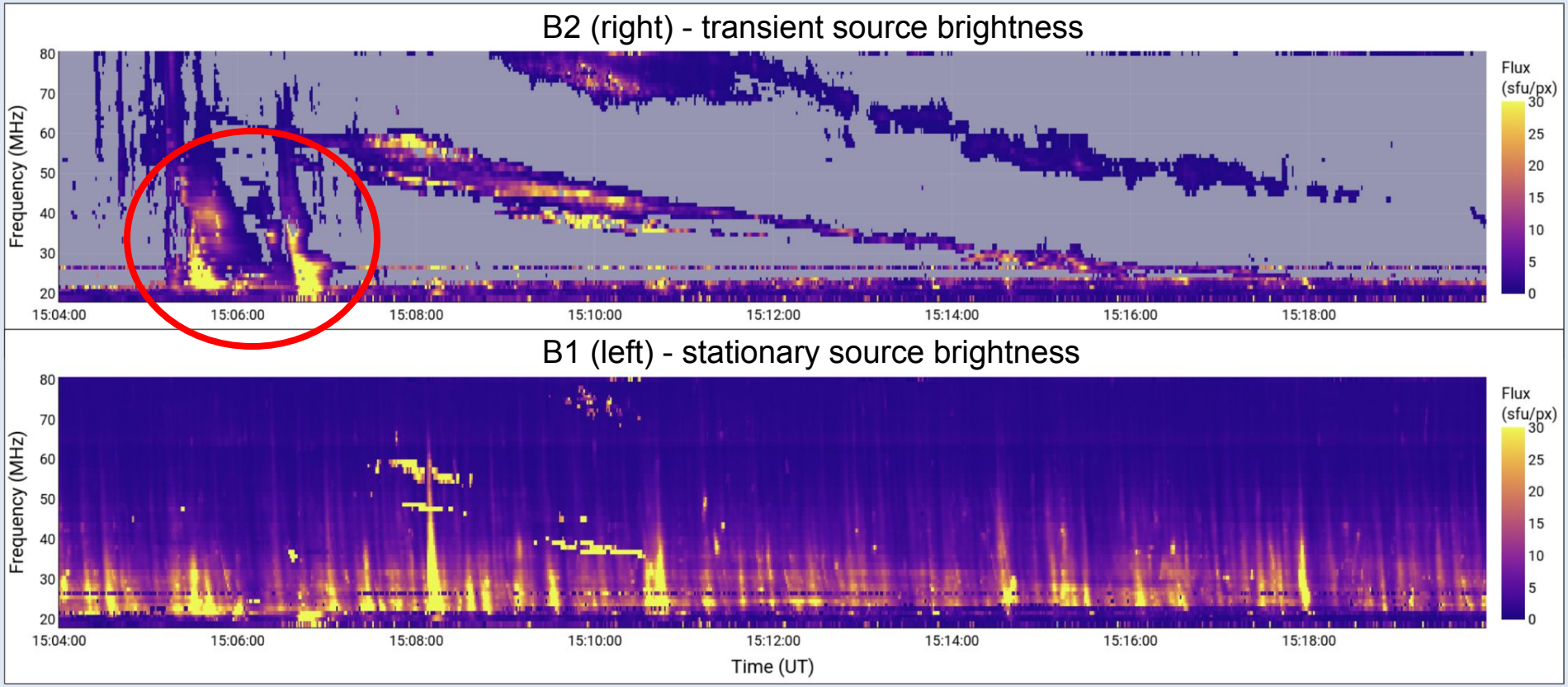
2023/09/24 Extracted sources spectrum



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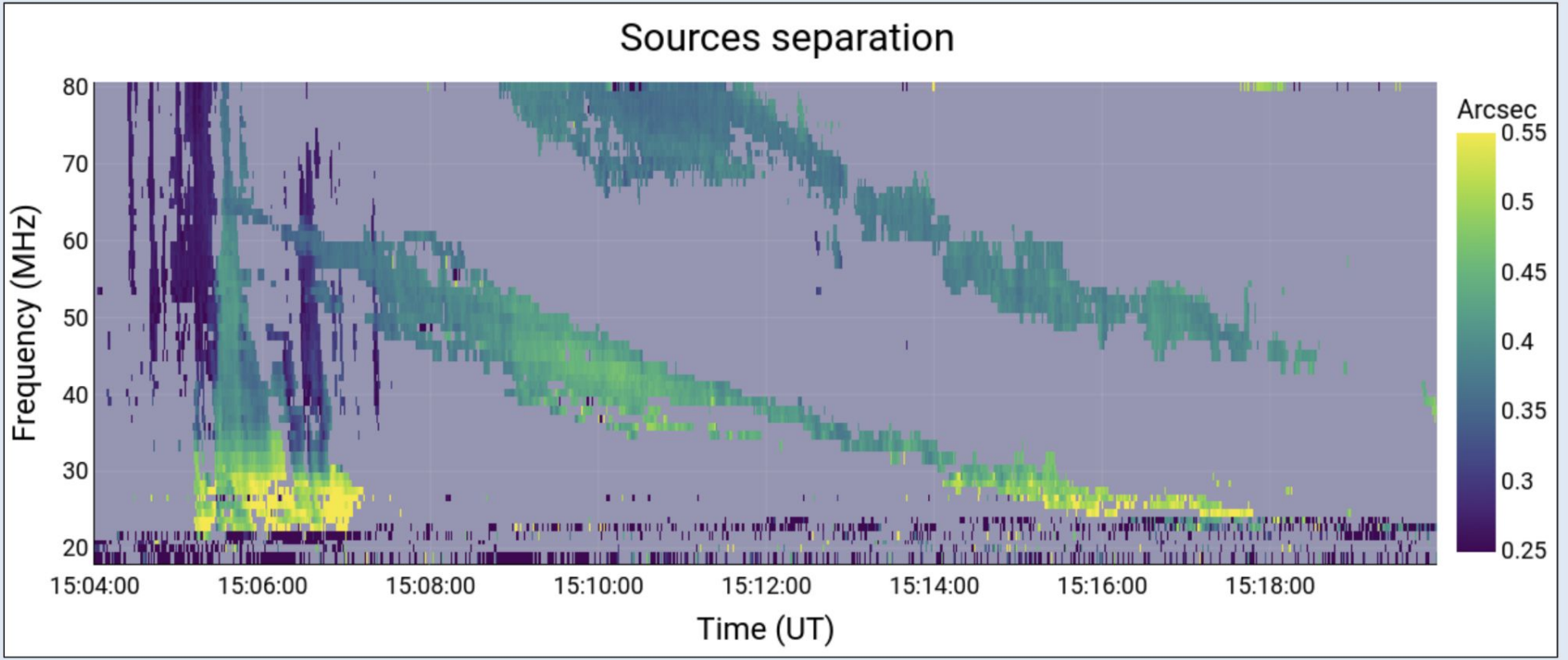
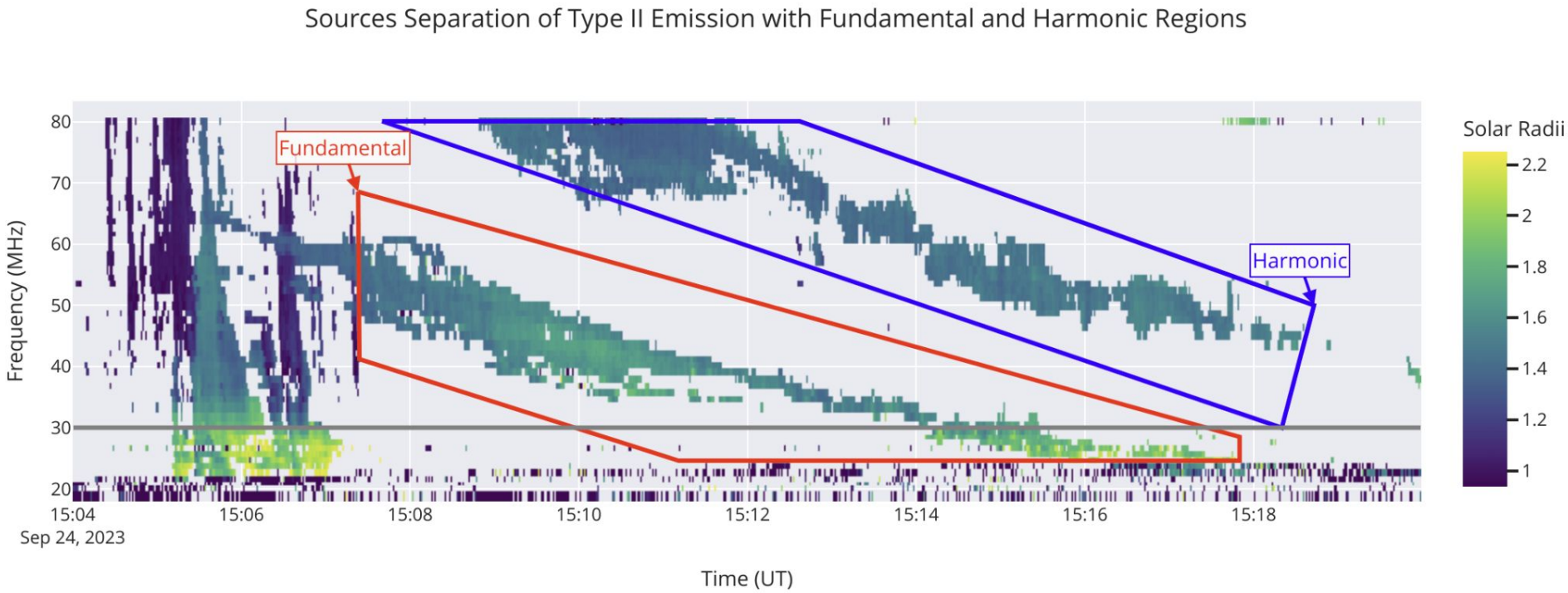


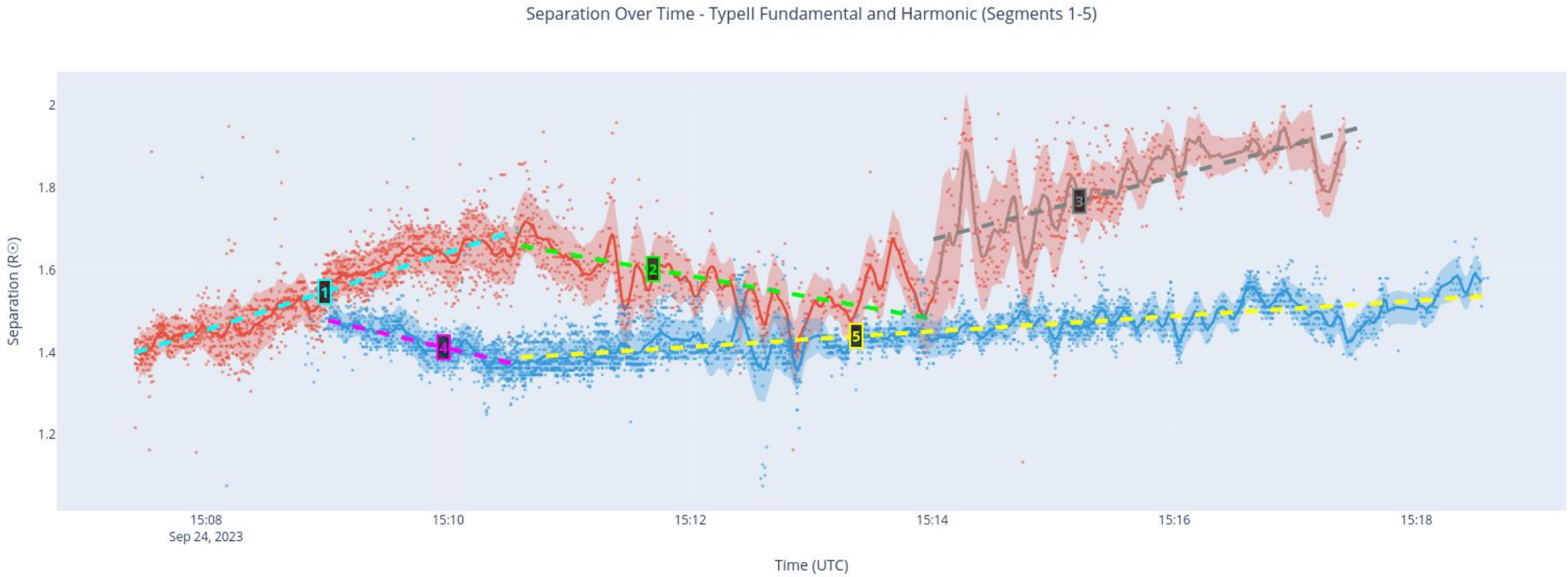
In preparation - Yotov et al

Sources separation analysis



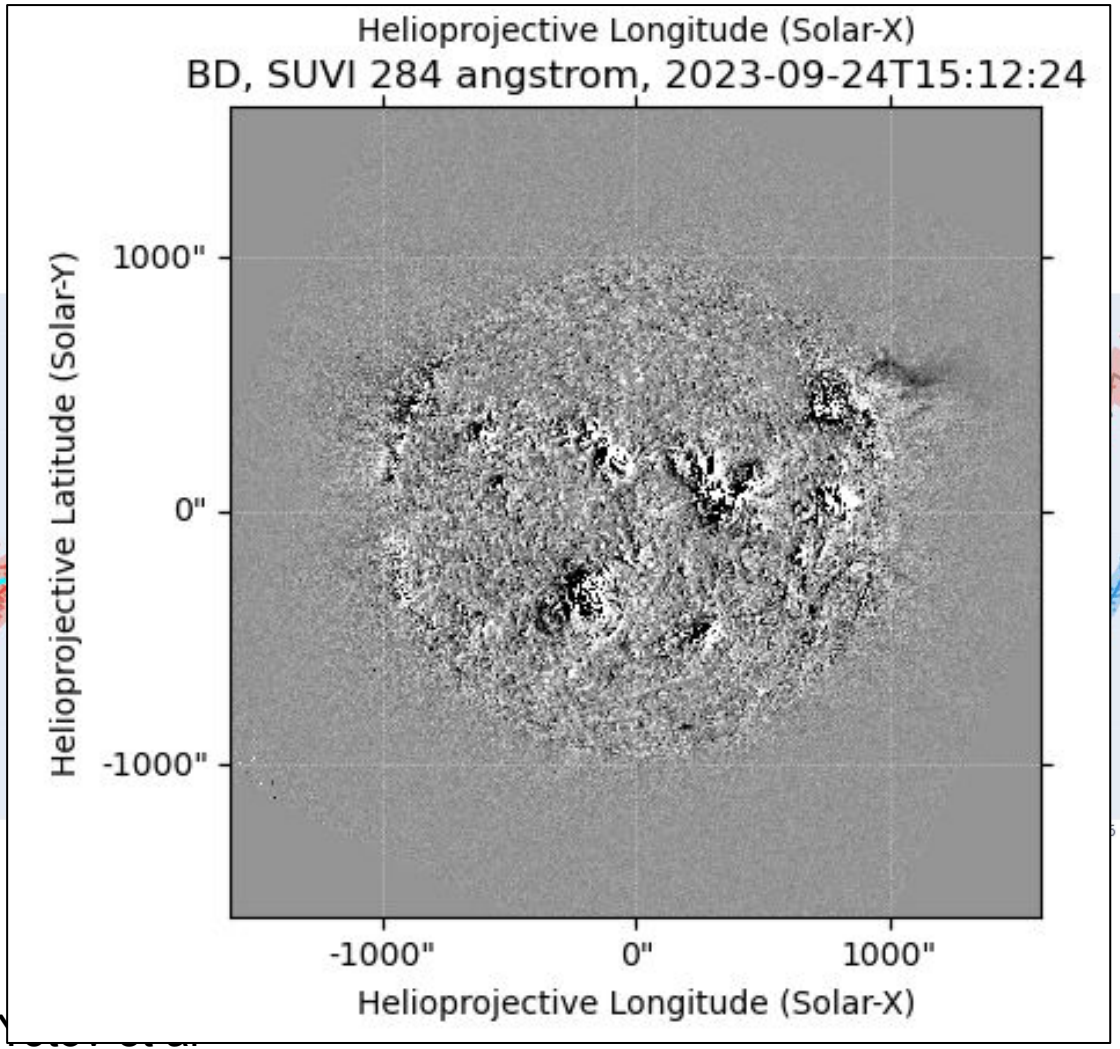
In preparation - Yotov et al

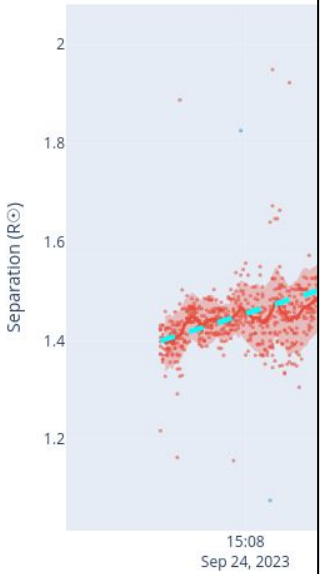
Sources separation analysis

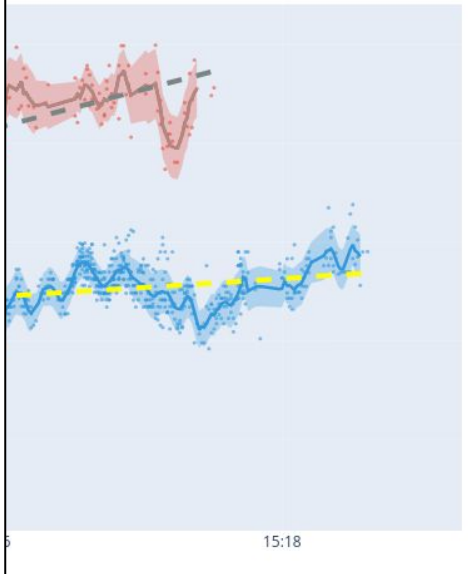


In preparation - Yotov et al

Sources







In preparation -

Velocity Segments Analysis

Segment	Time Range (UTC)	Velocity (km/s)	Duration (seconds)	MAD (R⊙)	RMS (R⊙)	Max Residual (R⊙)
1	15:07:24 - 15:10:36	1093.9 ± 311.0	191	0.0425	0.0594	0.4776
2	15:10:36 - 15:14:00	-604.1 ± 404.6	204	0.0592	0.0796	0.3784
3	15:14:00 - 15:17:31	892.2 ± 499.2	212	0.0758	0.1001	0.5990

Segment	Time Range (UTC)	Velocity (km/s)	Duration (seconds)	MAD (R⊙)	RMS (R⊙)	Max Residual (R⊙)
4	15:07:58 - 15:10:36	-796.5 ± 256.1	158	0.0289	0.0445	0.4900
5	15:10:36 - 15:18:35	217.0 ± 98.7	479	0.0340	0.0464	0.3490

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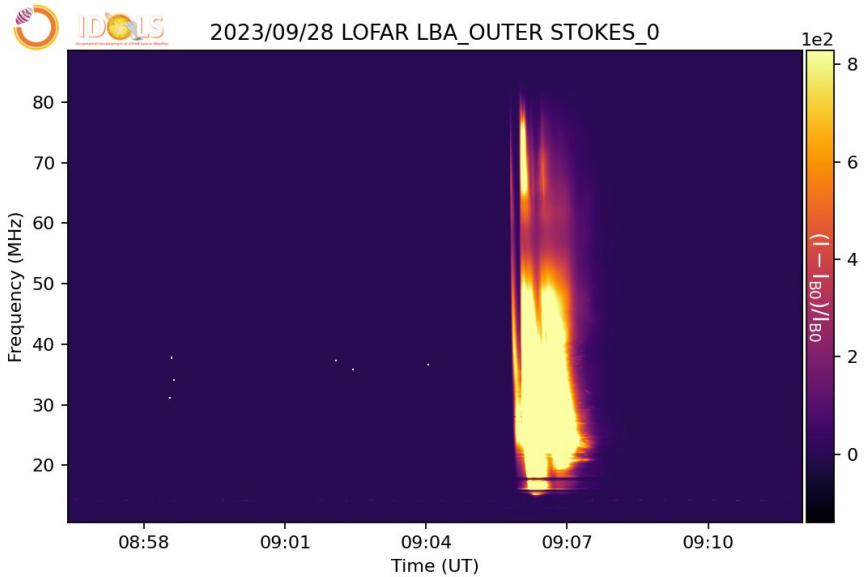
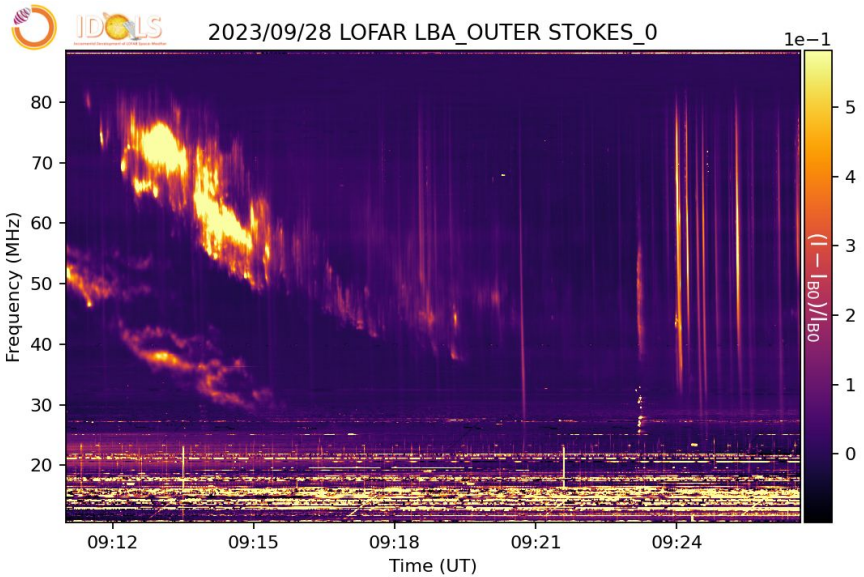
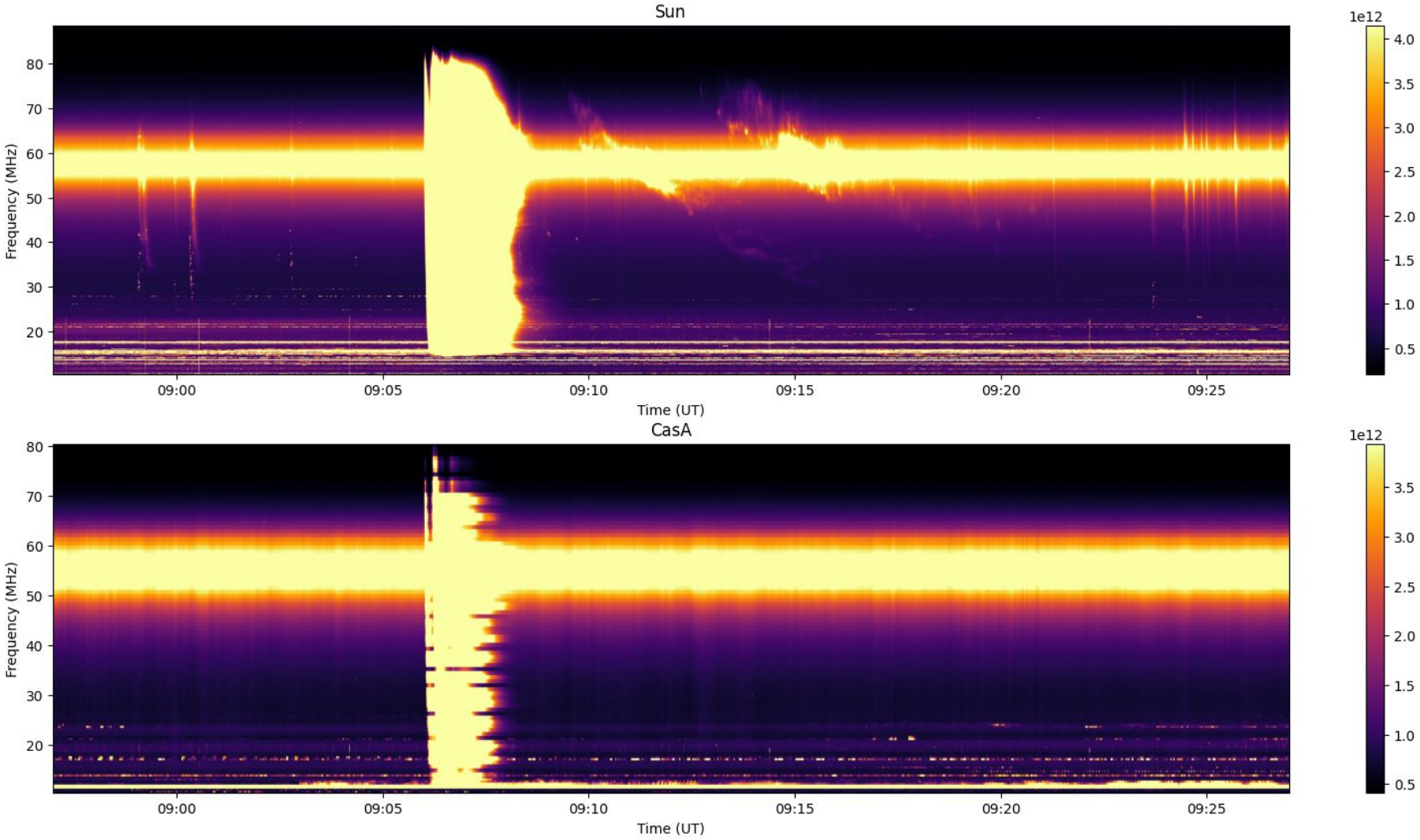
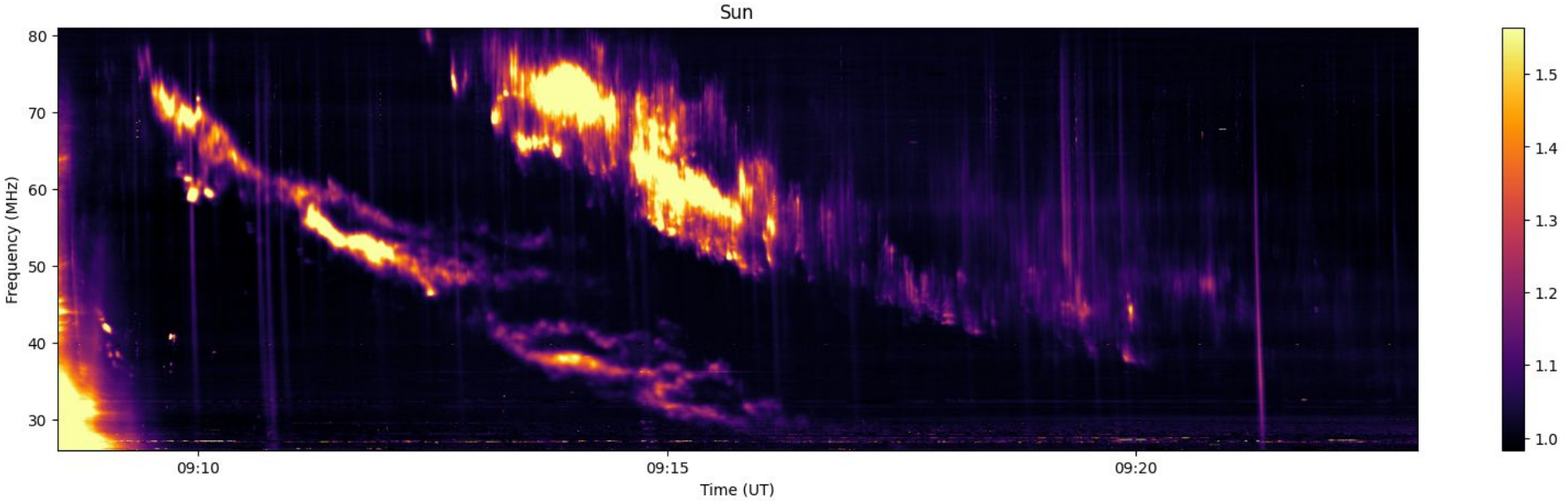
LOFAR LBA IDOLS Beamformed Observations 2023/09/**28** 08:56-09:26





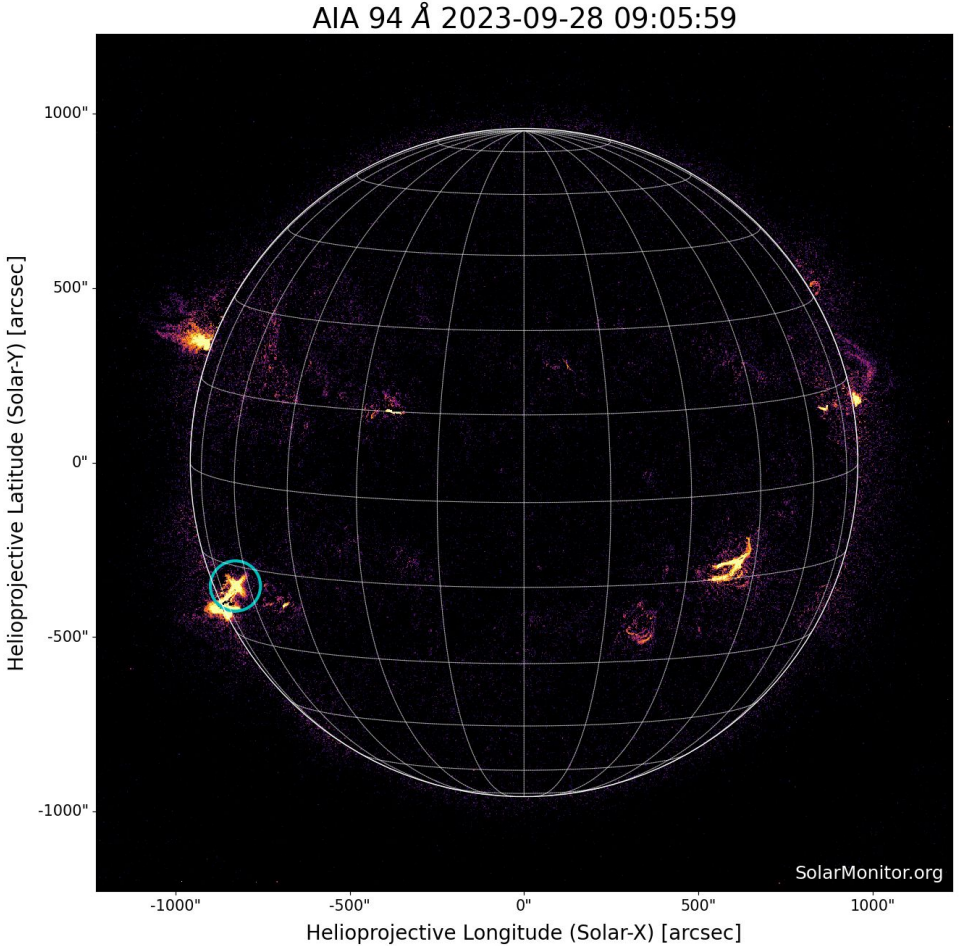

Sun
Frequency (MHz)
80
70
60
50
40
30
20
09:00
09:05
09:10
09:15
09:20
09:25
Time (UT)
1e12
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
CasA
Frequency (MHz)
80
70
60
50
40
30
20
09:00
09:05
09:10
09:15
09:20
09:25
Time (UT)
1e12
3.5
3.0
2.5
2.0
1.5
1.0
0.5

2023/09/28 Type II burst calibrated



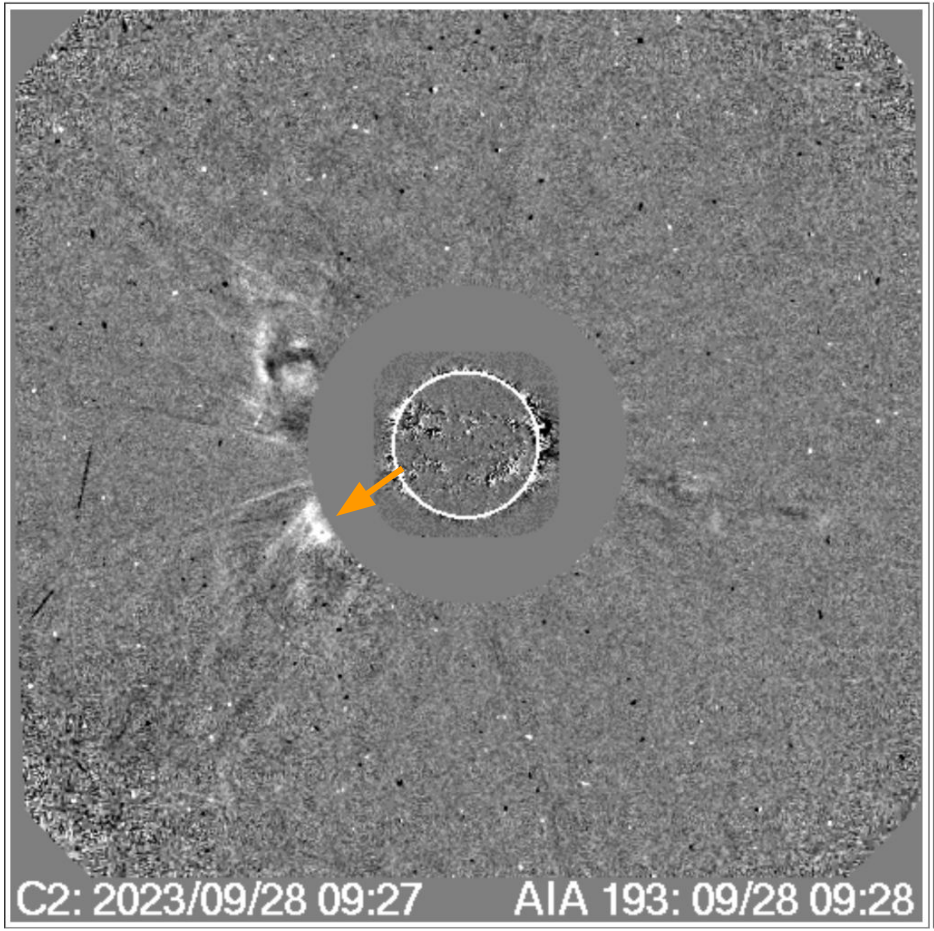
SDO/AIA observations 2023/09/28

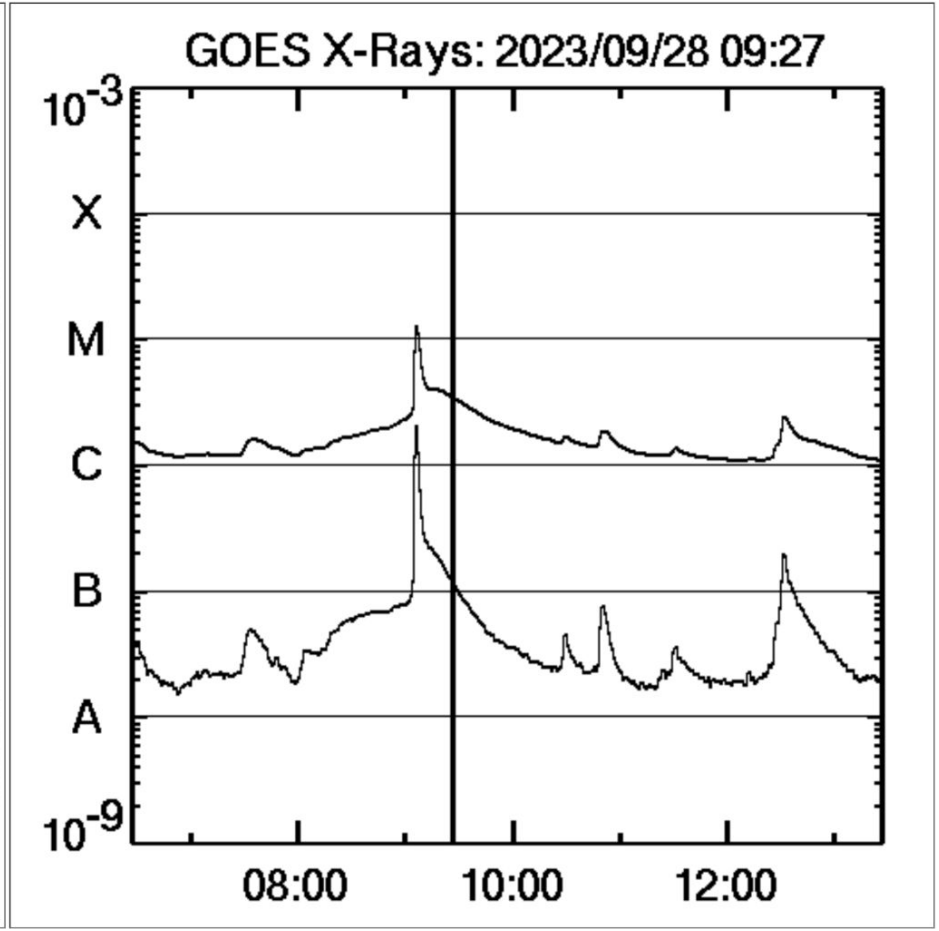
GOES Flare Class: *M1.3*
Flare Location (degrees):
-19, -66



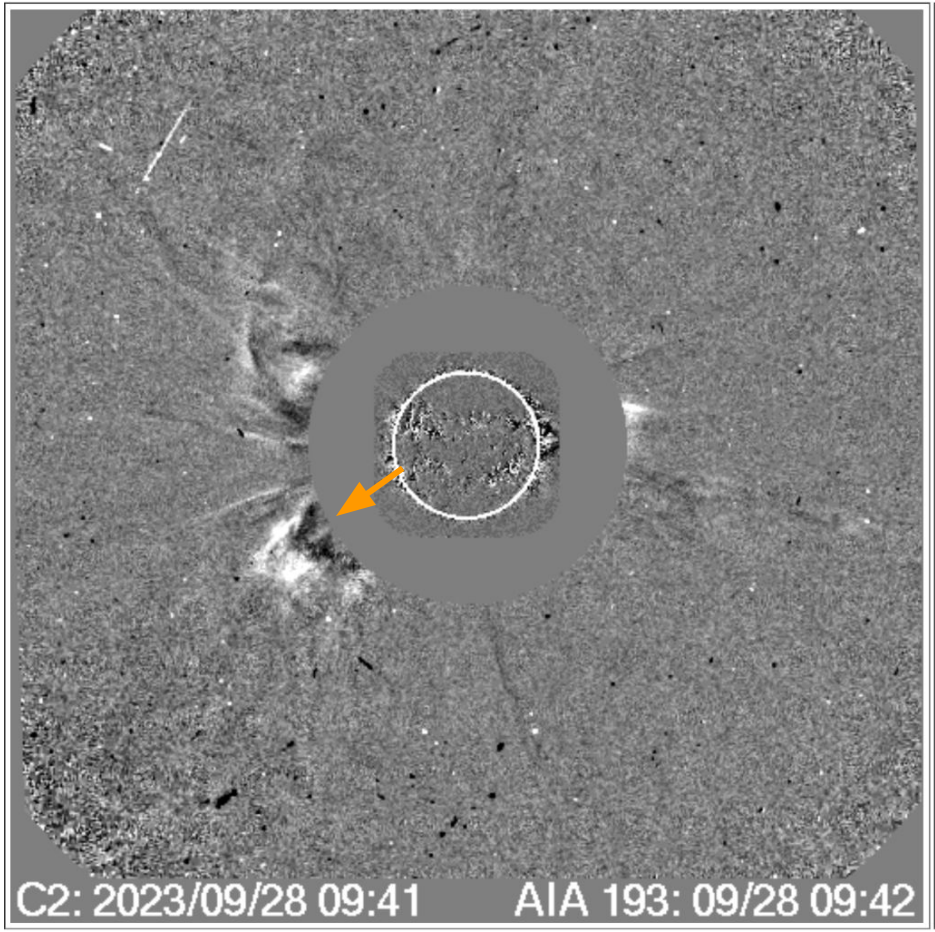
https://solmon.dias.ie/flare?date=2023092808&id=FL-SSWL-20230928085800

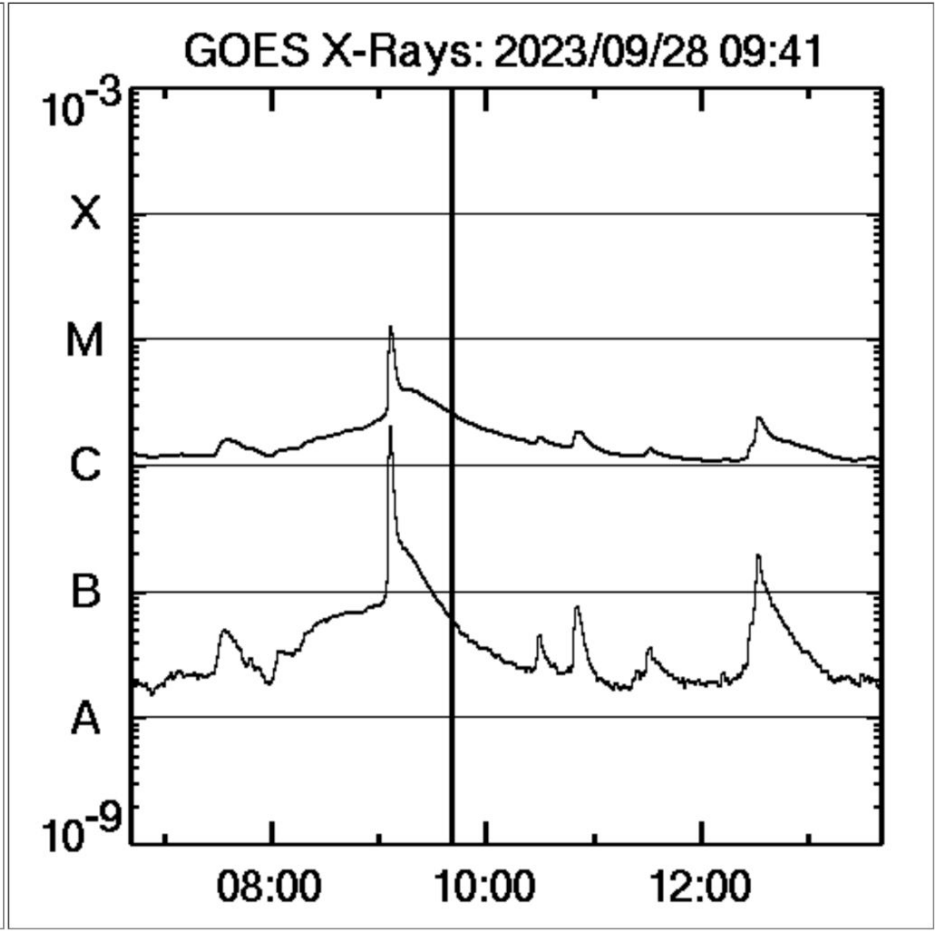
LASCO observations 2023/09/28



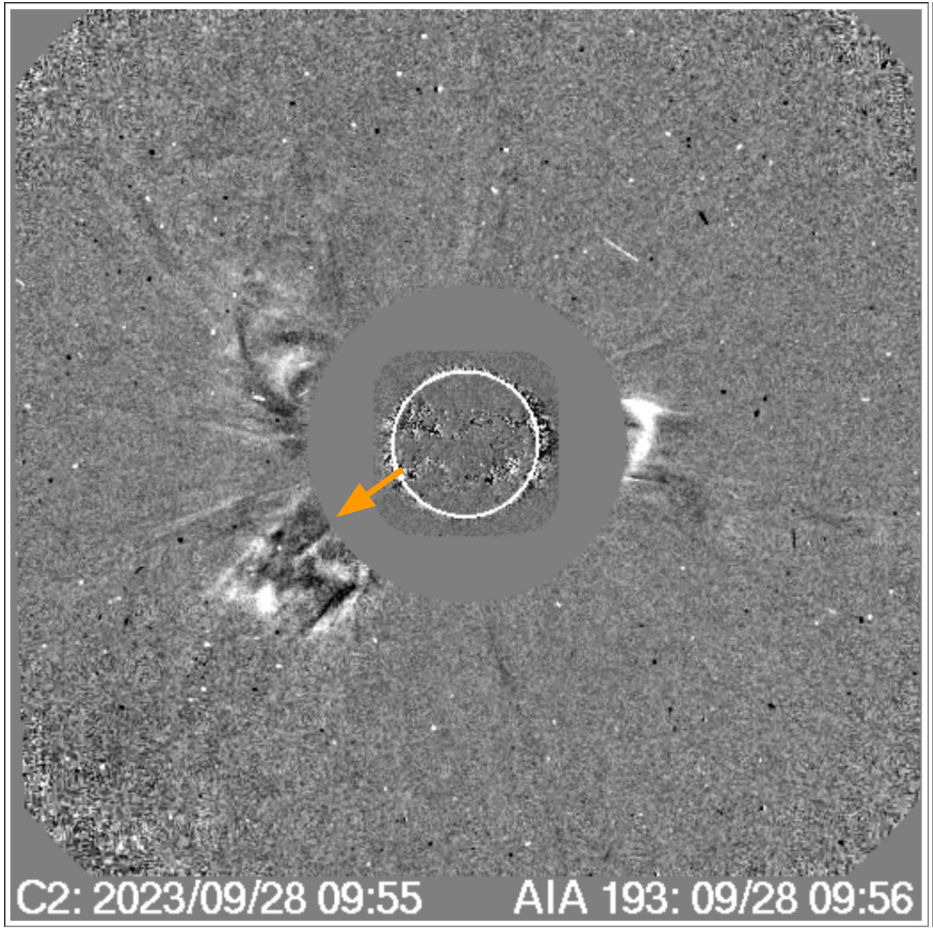


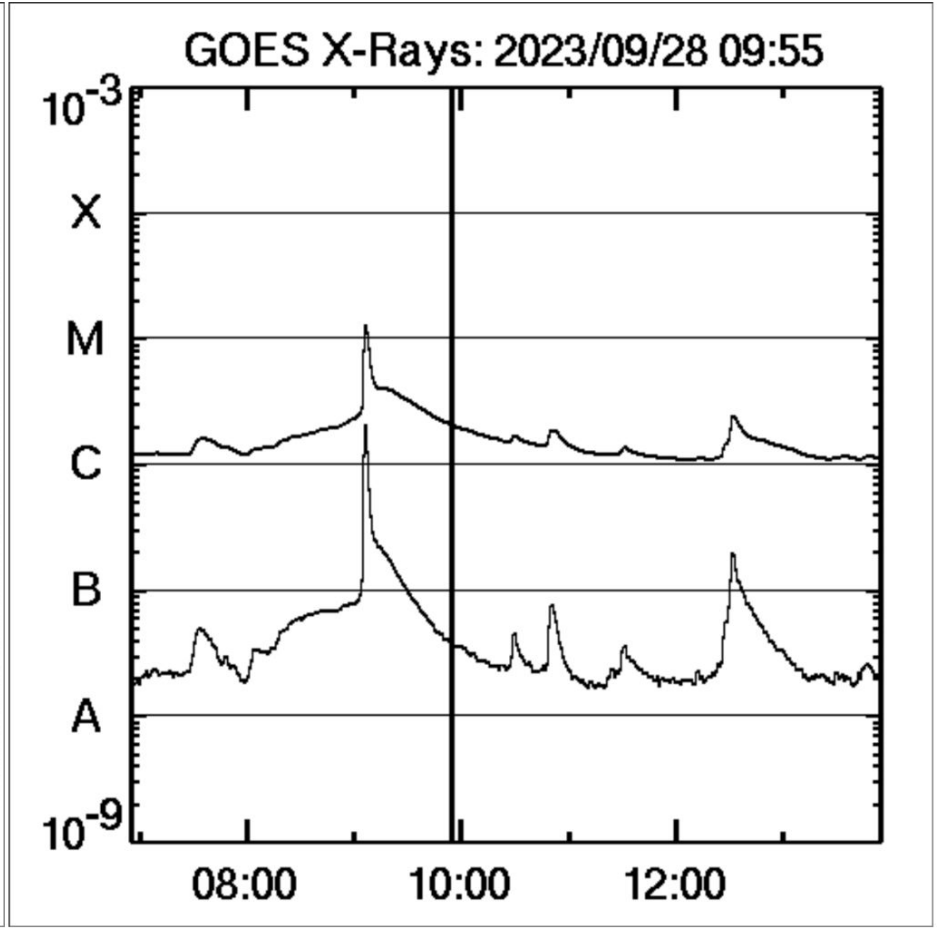
LASCO observations 2023/09/28

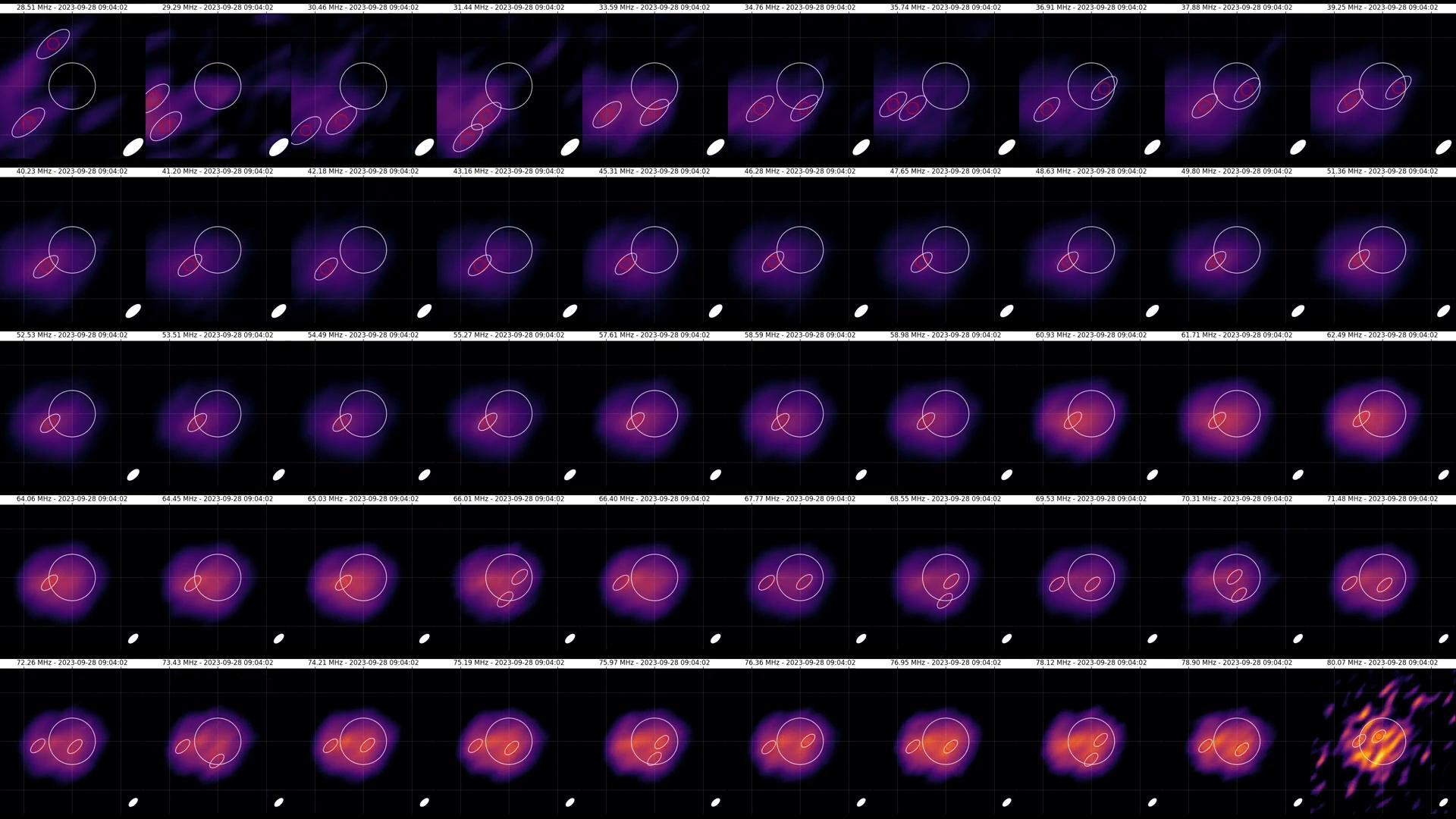




LASCO observations 2023/09/28






28.51 MHz - 2023-09-28 09:04:02
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30.46 MHz - 2023-09-28 09:04:02
31.44 MHz - 2023-09-28 09:04:02
33.59 MHz - 2023-09-28 09:04:02
34.76 MHz - 2023-09-28 09:04:02
35.74 MHz - 2023-09-28 09:04:02
36.91 MHz - 2023-09-28 09:04:02
37.88 MHz - 2023-09-28 09:04:02
39.25 MHz - 2023-09-28 09:04:02
40.23 MHz - 2023-09-28 09:04:02
41.20 MHz - 2023-09-28 09:04:02
42.18 MHz - 2023-09-28 09:04:02
43.16 MHz - 2023-09-28 09:04:02
45.31 MHz - 2023-09-28 09:04:02
46.28 MHz - 2023-09-28 09:04:02
47.65 MHz - 2023-09-28 09:04:02
48.63 MHz - 2023-09-28 09:04:02
49.80 MHz - 2023-09-28 09:04:02
51.36 MHz - 2023-09-28 09:04:02
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54.49 MHz - 2023-09-28 09:04:02
55.27 MHz - 2023-09-28 09:04:02
57.61 MHz - 2023-09-28 09:04:02
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61.71 MHz - 2023-09-28 09:04:02
62.49 MHz - 2023-09-28 09:04:02
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69.53 MHz - 2023-09-28 09:04:02
70.31 MHz - 2023-09-28 09:04:02
71.48 MHz - 2023-09-28 09:04:02
72.26 MHz - 2023-09-28 09:04:02
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74.21 MHz - 2023-09-28 09:04:02
75.19 MHz - 2023-09-28 09:04:02
75.97 MHz - 2023-09-28 09:04:02
76.36 MHz - 2023-09-28 09:04:02
76.95 MHz - 2023-09-28 09:04:02
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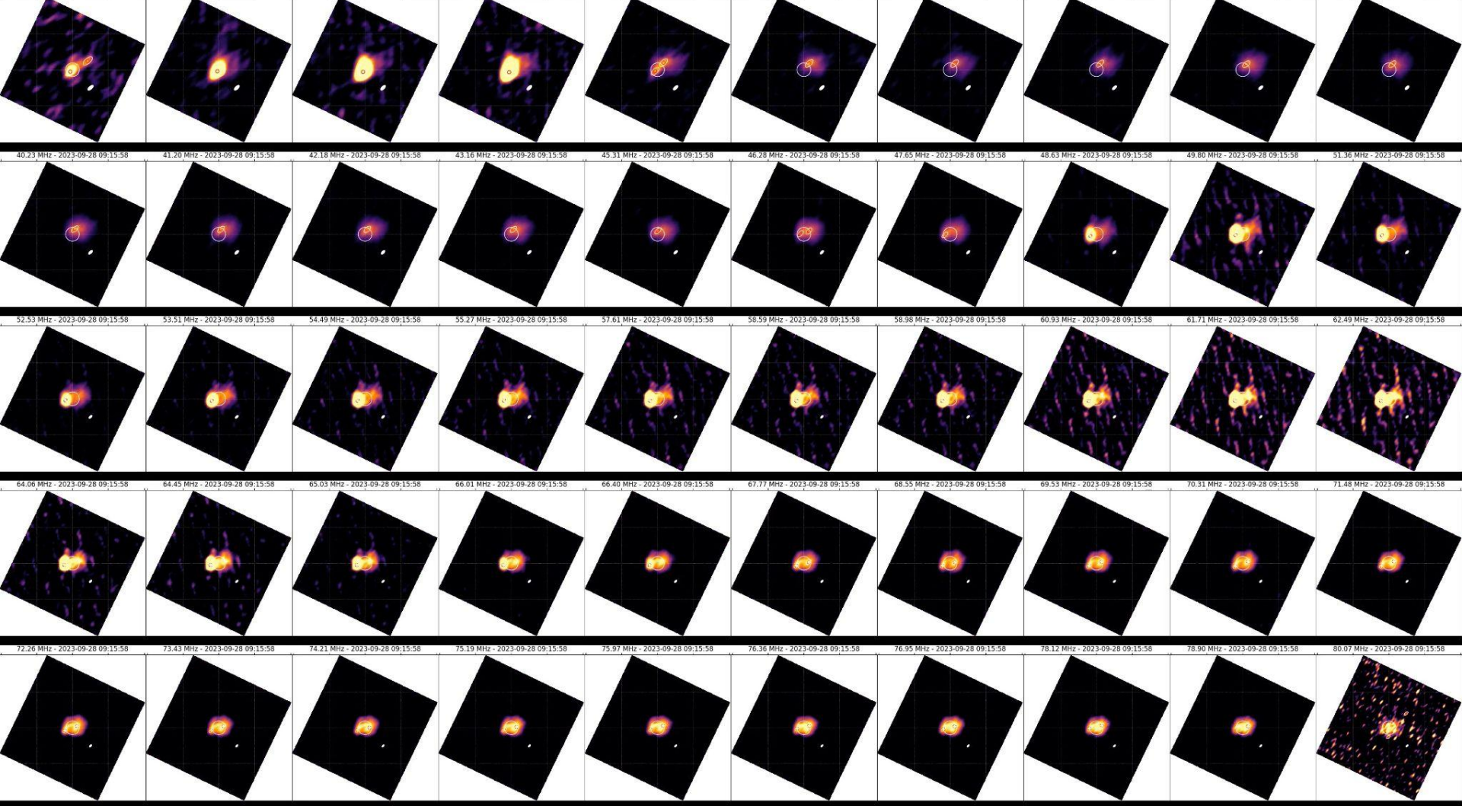
78.90 MHz - 2023-09-28 09:04:02
80.07 MHz - 2023-09-28 09:04:02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45.31 MHz - 2023-09-28 09:15:58
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48.63 MHz - 2023-09-28 09:15:58
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52.53 MHz - 2023-09-28 09:15:58
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55.27 MHz - 2023-09-28 09:15:58
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66.40 MHz - 2023-09-28 09:15:58
67.77 MHz - 2023-09-28 09:15:58
68.55 MHz - 2023-09-28 09:15:58
69.53 MHz - 2023-09-28 09:15:58
70.31 MHz - 2023-09-28 09:15:58
71.48 MHz - 2023-09-28 09:15:58
72.26 MHz - 2023-09-28 09:15:58
73.43 MHz - 2023-09-28 09:15:58
74.21 MHz - 2023-09-28 09:15:58
75.19 MHz - 2023-09-28 09:15:58
75.97 MHz - 2023-09-28 09:15:58
76.36 MHz - 2023-09-28 09:15:58
76.95 MHz - 2023-09-28 09:15:58
78.12 MHz - 2023-09-28 09:15:58
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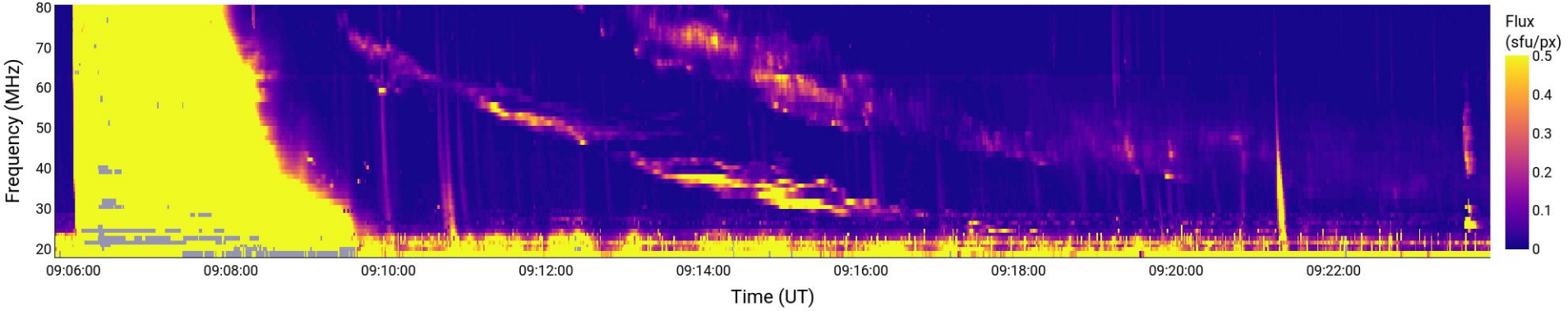
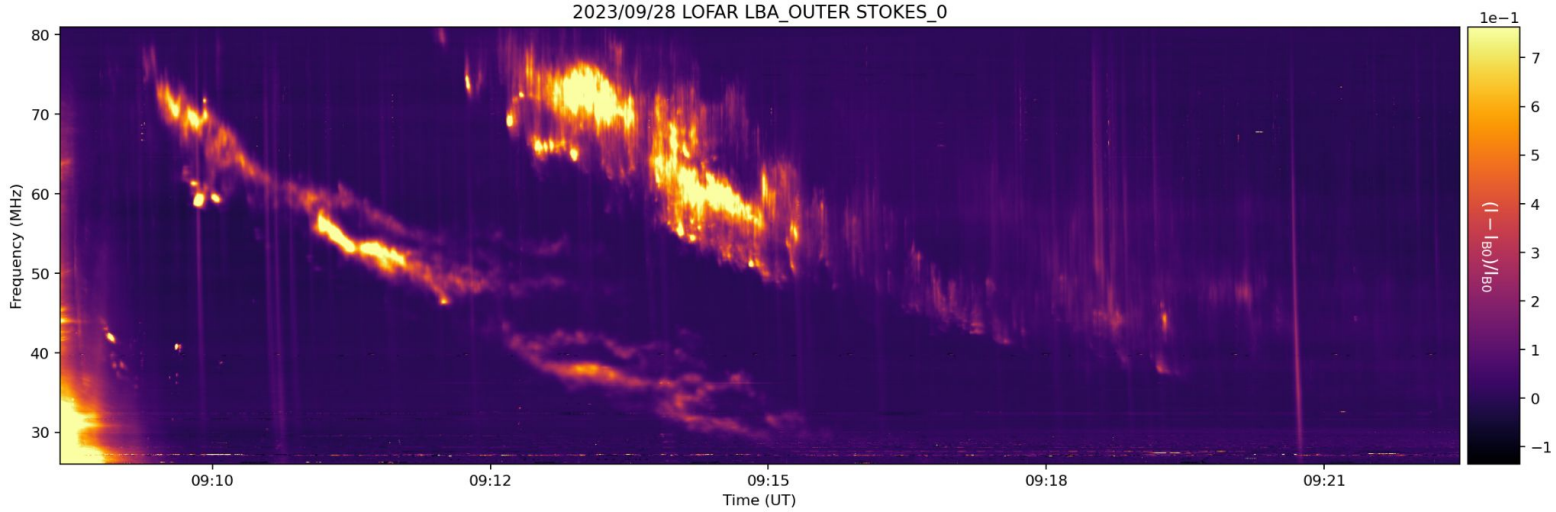
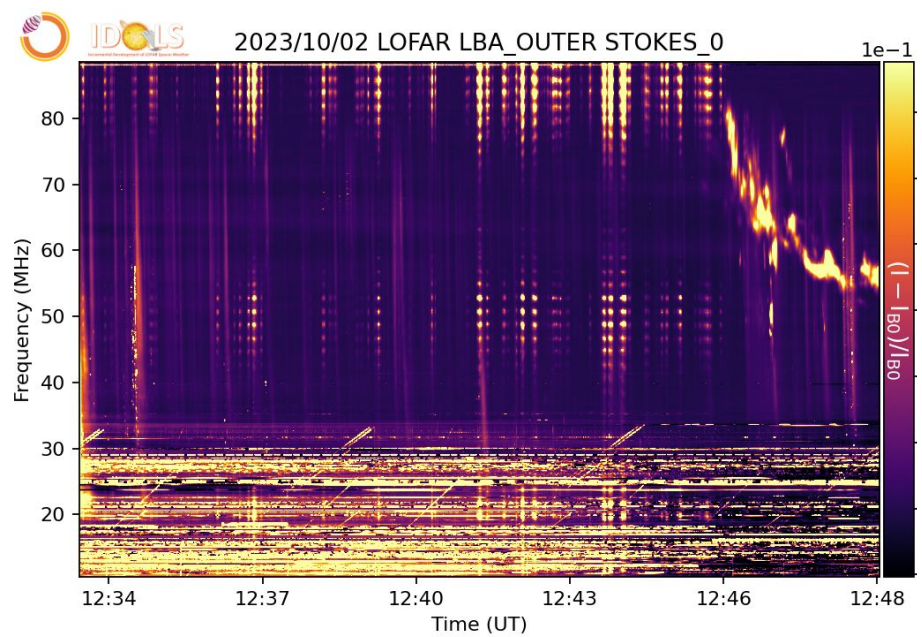
80.07 MHz - 2023-09-28 09:15:58

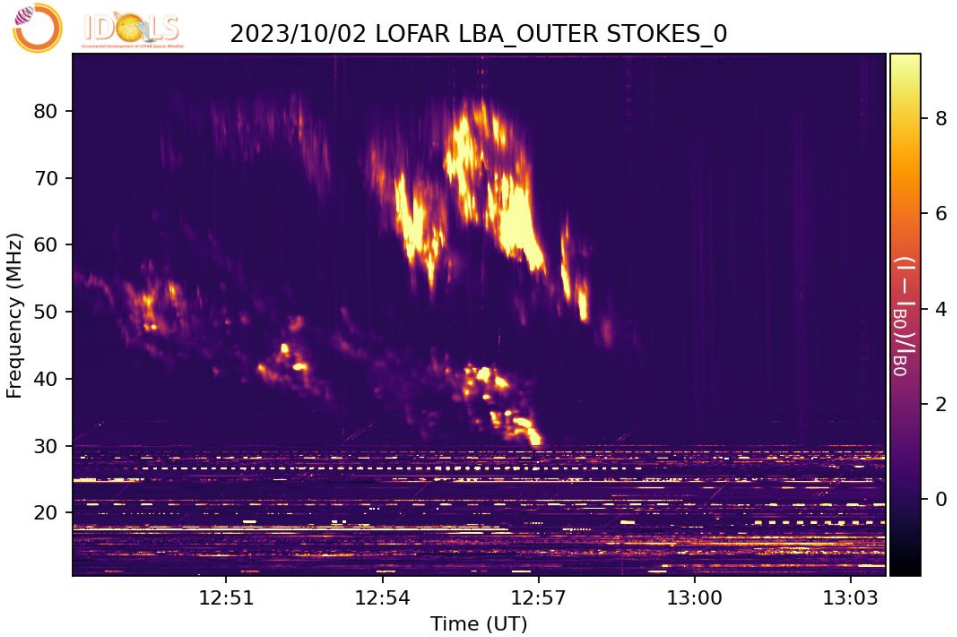
2024/10/02 12:45-13:05 Type II burst source extraction

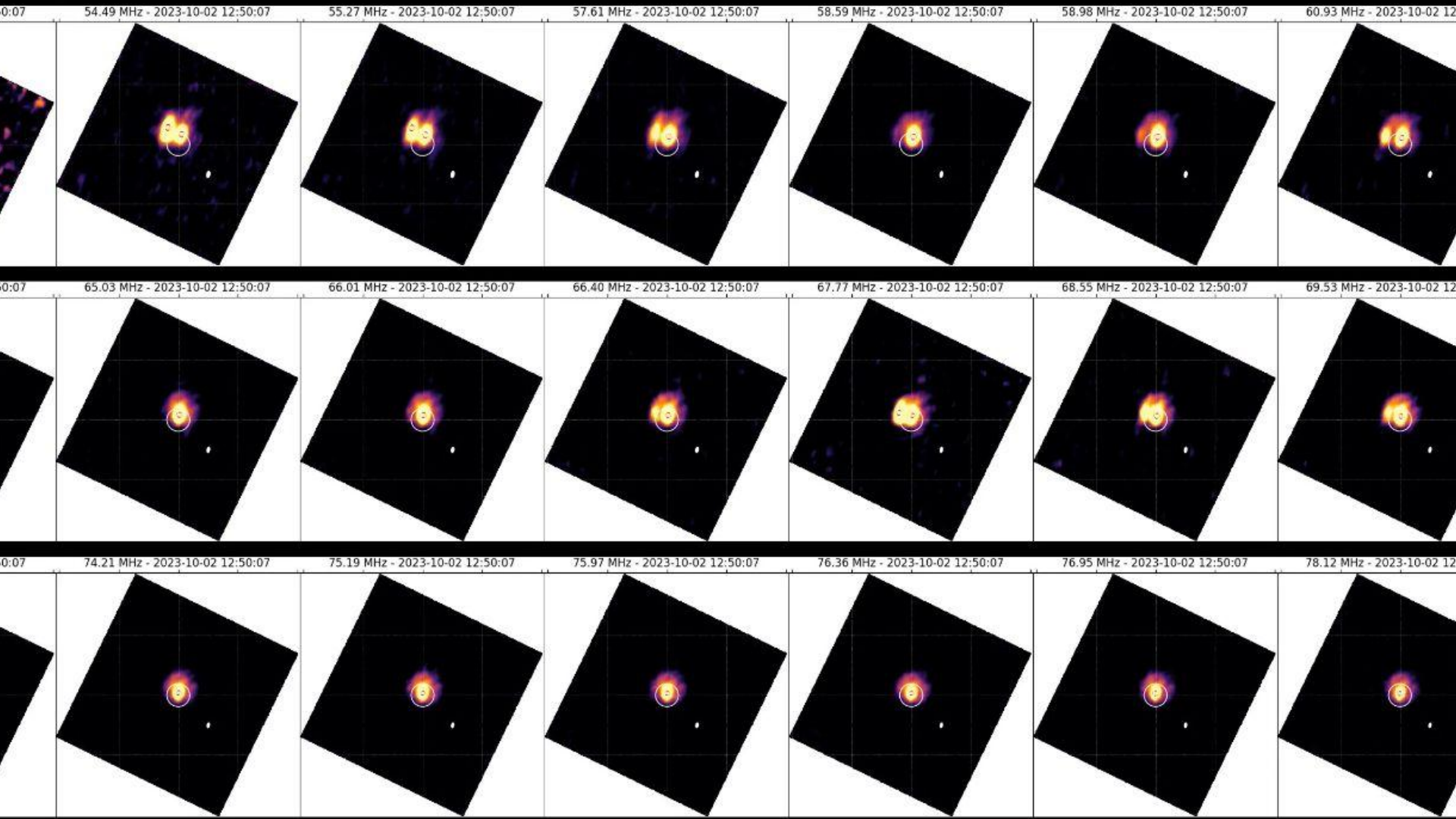




2024/10/02 12:45-13:05 Type II burst



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57.61 MHz - 2023-10-02 12:50:07
58.59 MHz - 2023-10-02 12:50:07
58.98 MHz - 2023-10-02 12:50:07
65.03 MHz - 2023-10-02 12:50:07
66.01 MHz - 2023-10-02 12:50:07
66.40 MHz - 2023-10-02 12:50:07
67.77 MHz - 2023-10-02 12:50:07
68.55 MHz - 2023-10-02 12:50:07
69.53 MHz - 2023-10-02 12
74.21 MHz - 2023-10-02 12:50:07
75.19 MHz - 2023-10-02 12:50:07
75.97 MHz - 2023-10-02 12:50:07
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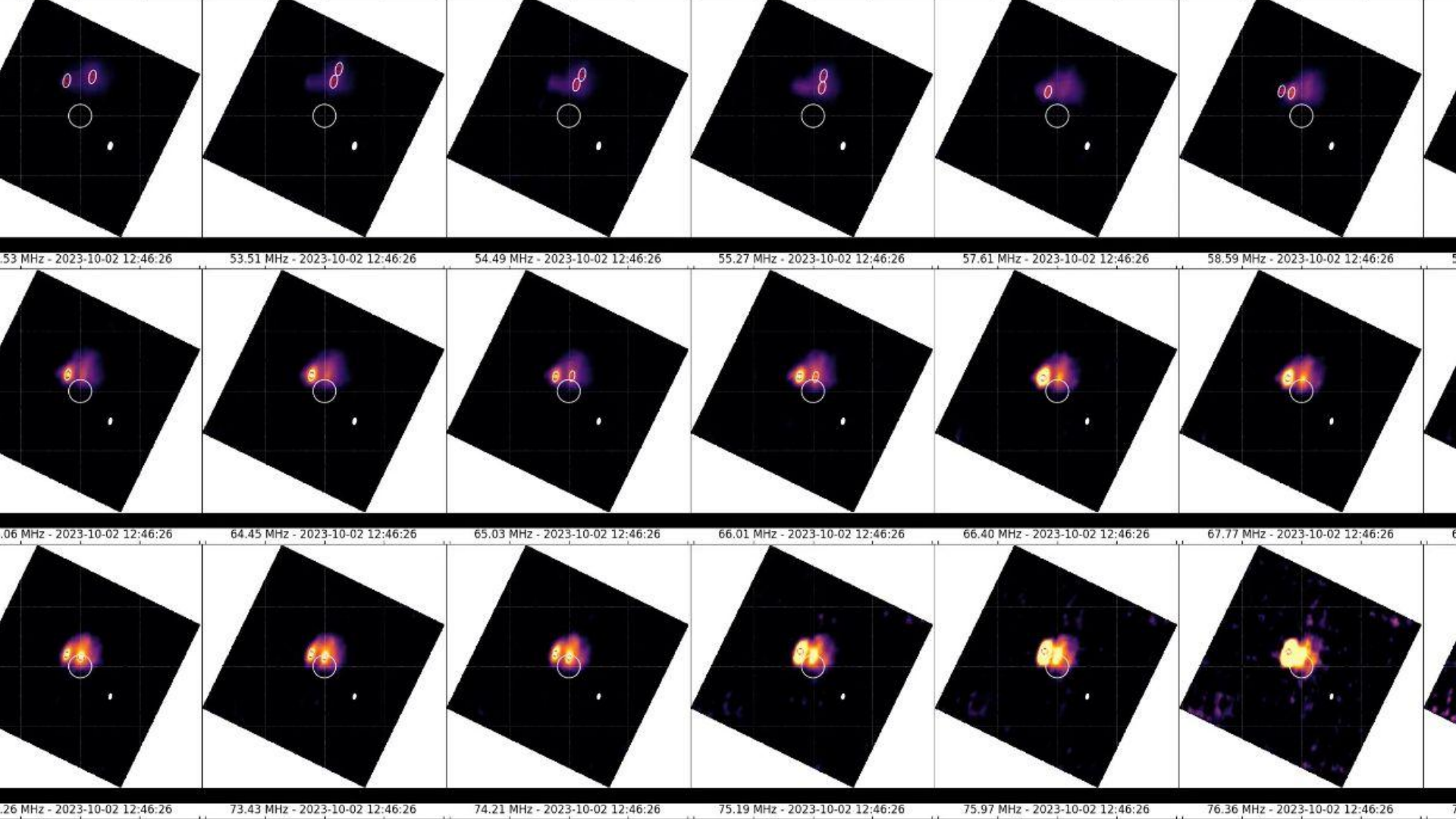
78.12 MHz - 2023-10-02 12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54.49 MHz - 2023-10-02 12:46:26
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58.59 MHz - 2023-10-02 12:46:26
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64.45 MHz - 2023-10-02 12:46:26
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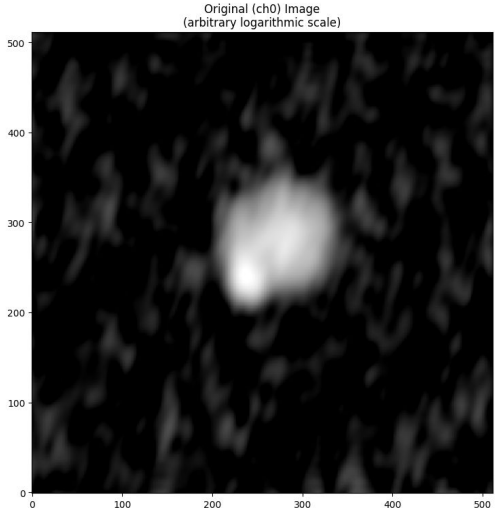
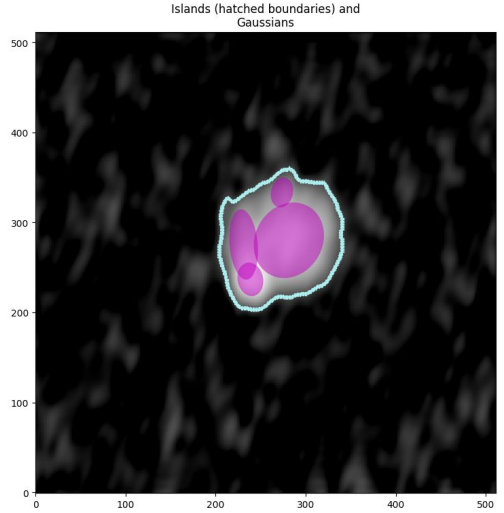
66.01 MHz - 2023-10-02 12:46:26
66.40 MHz - 2023-10-02 12:46:26
67.77 MHz - 2023-10-02 12:46:26
.26 MHz - 2023-10-02 12:46:26
73.43 MHz - 2023-10-02 12:46:26
74.21 MHz - 2023-10-02 12:46:26
75.19 MHz - 2023-10-02 12:46:26
75.97 MHz - 2023-10-02 12:46:26
76.36 MHz - 2023-10-02 12:46:26

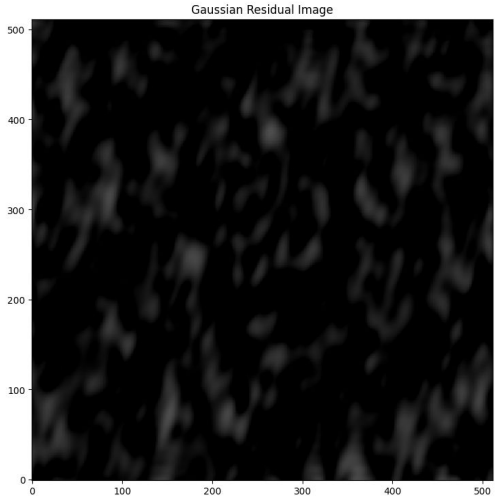
PyBDSF source extraction from interferometry snapshots

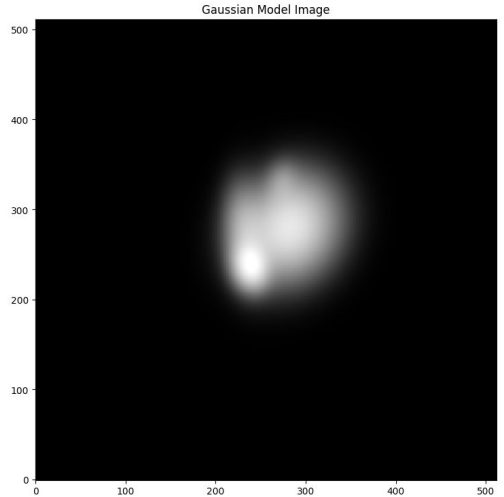




Challenges:

- Source tracking
- Stability
- Processing time





2023/09 24th vs 28th Comparison

- Similar solar context
- Significant ionospheric refraction on the 24th
- Different sources dynamics observed in interferometry
- LoG source extraction implementation useful only for brighter emissions
- Main dynamic region associated with type II in both
- Additional activity present during the events

Team effort

- Kamen Kozarev
- Pietro Zucca
- Mattia Mancini
- Mohamed Nedal