THE 15TH RUSSIAN-CHINESE WORKSHOP
ON SPACE WEATHER
September 9-13, 2024, Irkutsk, Russia

中国科学院国家空间科学中心
National Space Science Center . CAS

MUSER observation and joint study with SRH

•Chengming Tan[1] , Alexey Kuznetsov[2] , and MUSER team

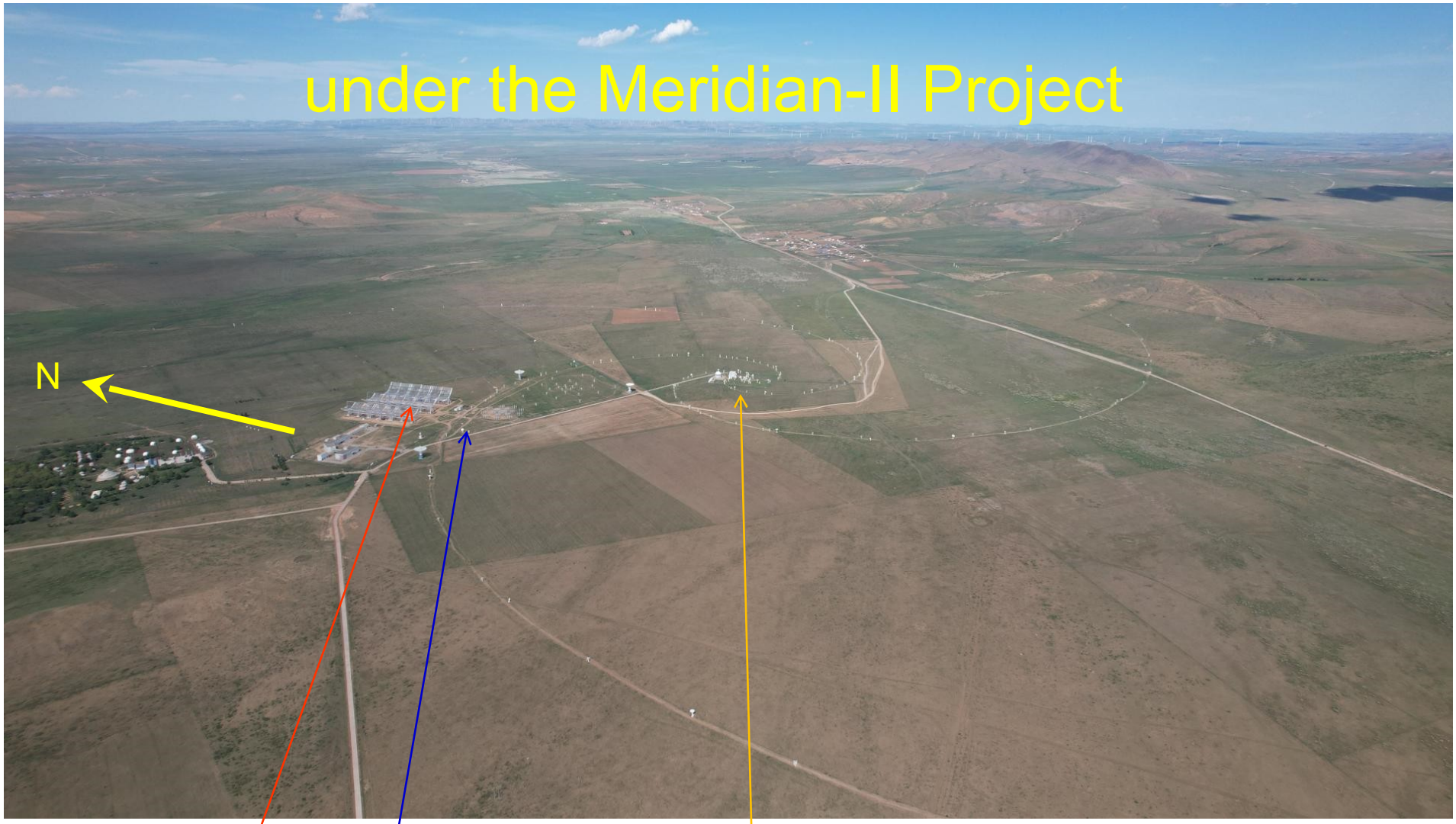
1 State Key Laboratory of Space Weather, National Space Science Center, CAS

2 Institute of Solar-Terrestrial Physics (Irkutsk, Russia)

September 11, 2024, Irkusk, Russia

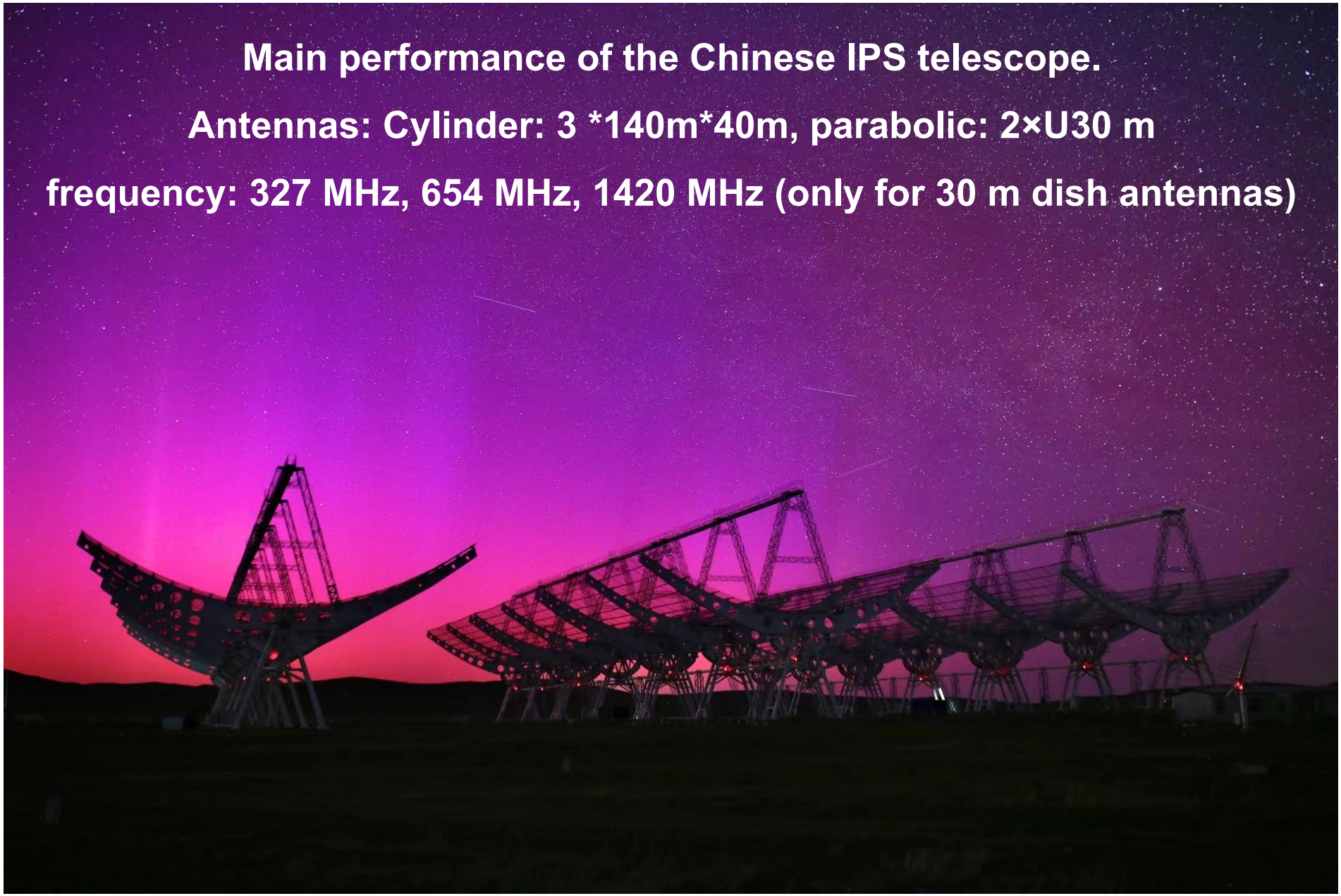
Introduction of MingAnTu Station

under the Meridian-II Project

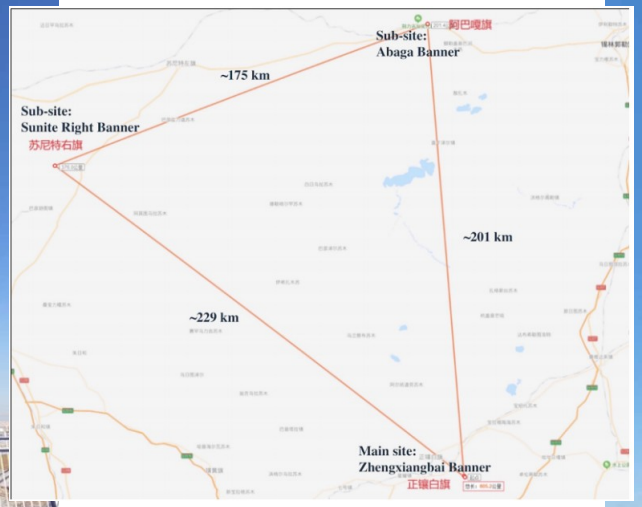


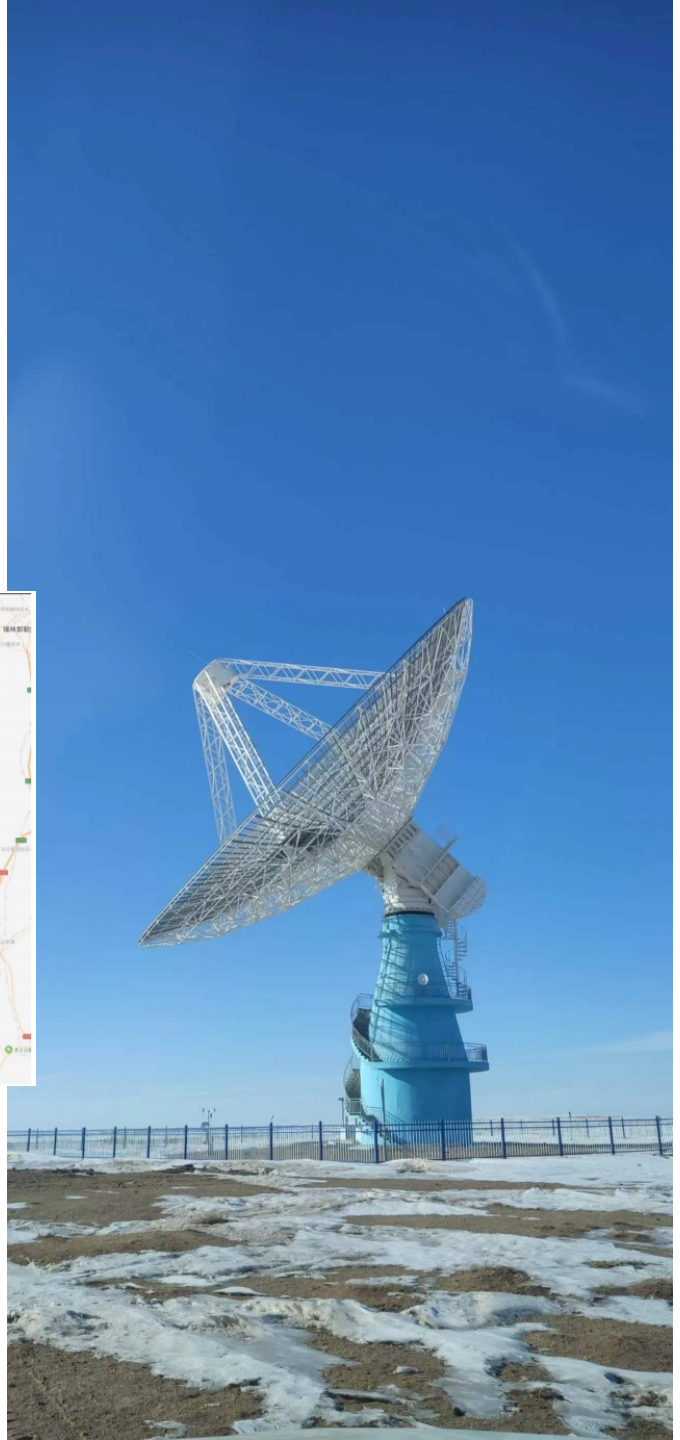
1. Interplanetary Scintillation telescope
2. MUSER-L, Meter-Decameter Spectral Radioheliograph
3. MUSER-I, Deciimeter Spectral Radioheliograph
4. MUSER-H, Centimeter Spectral Radioheliograph (to be upgrated)
5. Centimeter Spectragraph， 6.Decimeter Spectragraph

1. Interplanetary Scintillation telescope



30 meter
dish antennas



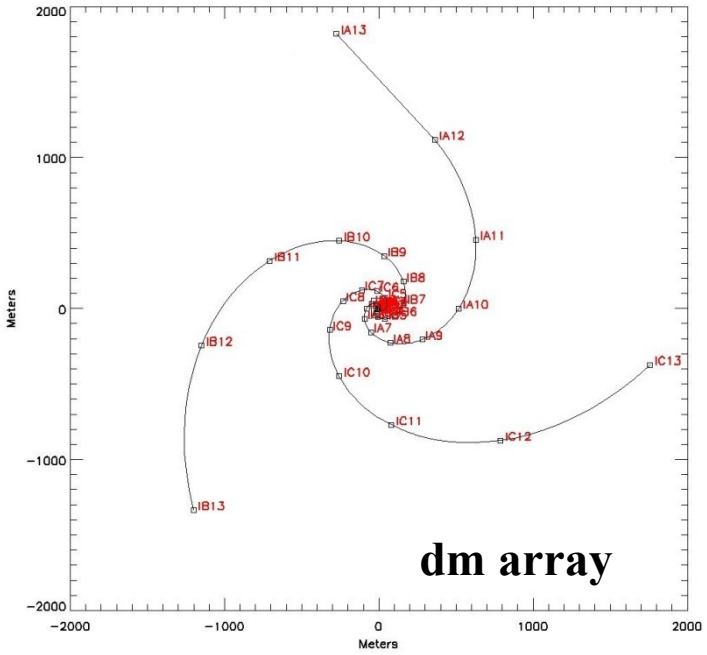


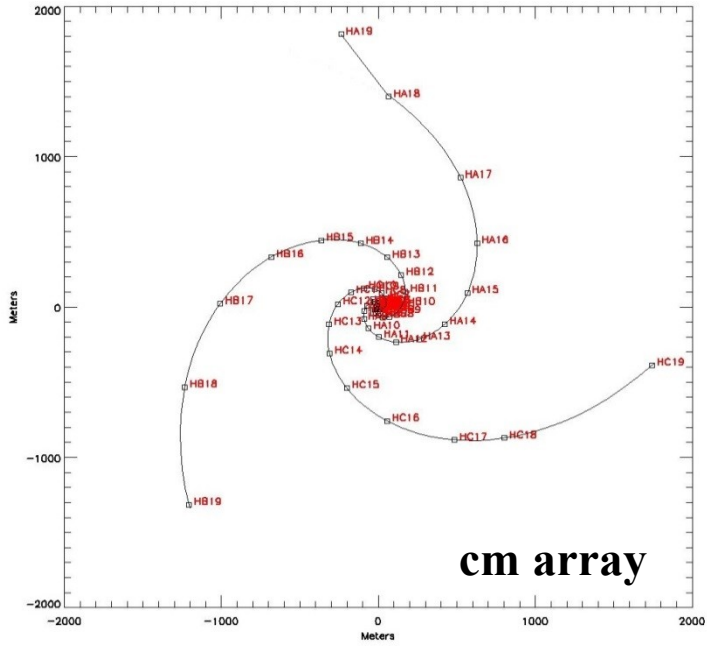
MUSER-I

Frequency：**0.4-2.0 GHz**
Antenna：Φ 4.5m×40
FOV: >2.33˚ (2 GHz)
Channel: 64
Freq. resolution：25 MHz
Cadence：25 ms
Spatial resolution：10.3"-51.6"
Image dynamic range：>25dB
polarization：R, L

MUSER-H

Frequency: **2.0-15.0 GHz**
Antenna：Φ 2.0m×60
FOV: >0.7˚ (15 GHz)
Channel: 528
Freq. resolution：~ 25 MHz
Cadence：~ 200 ms
Spatial resolution：1.4"-10.3"
Image dynamic range：>25 dB
polarization：R, L

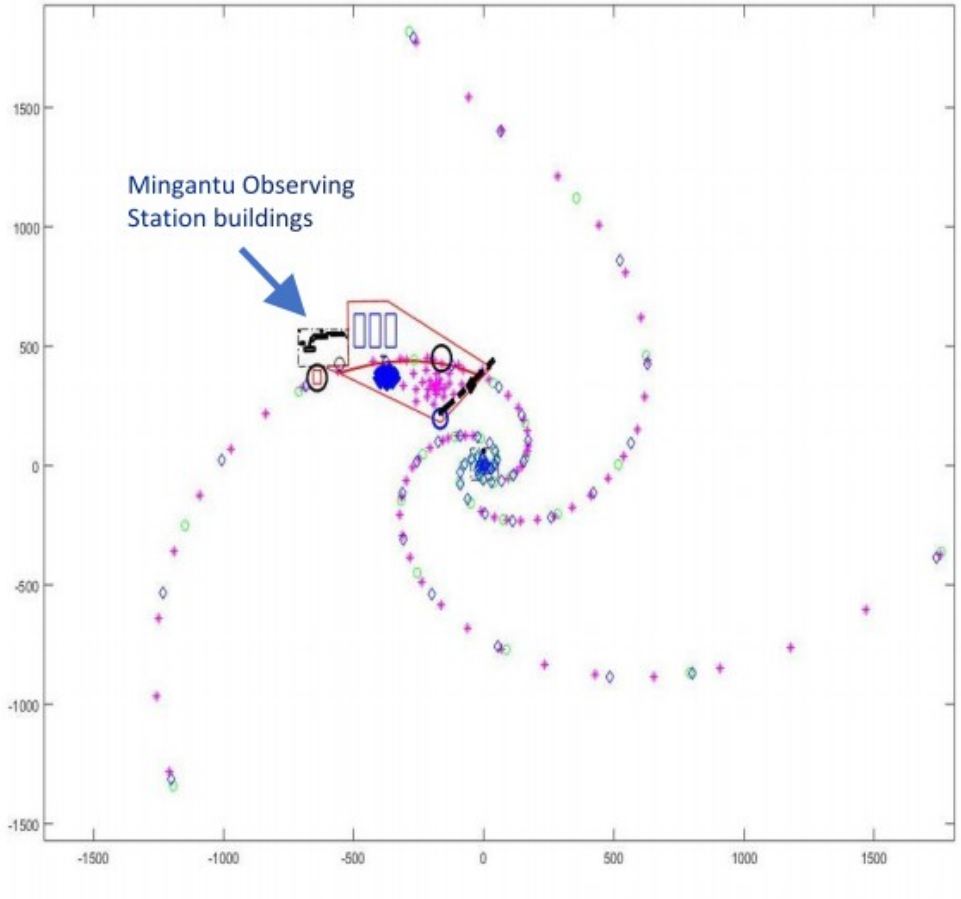


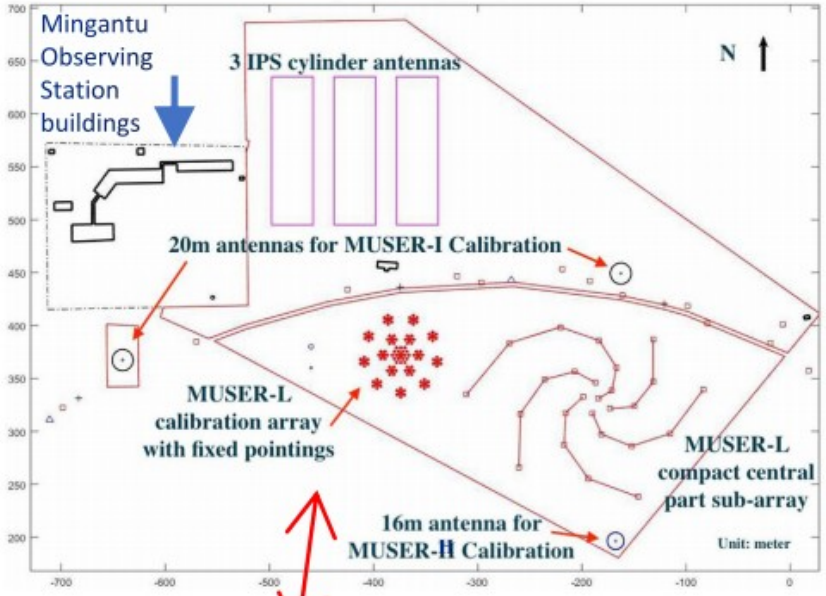


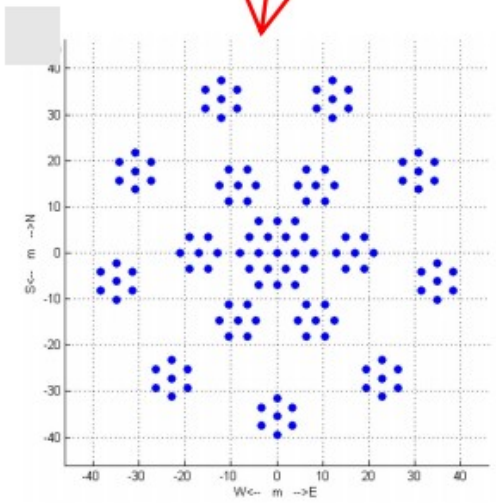
Max Baseline: **3 km**, **aperture-synthesis** technology

MUSER-L

Frequency：**30-400 MHz**	Cadence：~100 ms
Antenna： (100 + 124) ×LPDA	Spatial resolution：14′.0 –1′.0
FOV: ～ 120°	Image dynamic range：>25dB
Channel: 384	Polarization：Dual linear H, V



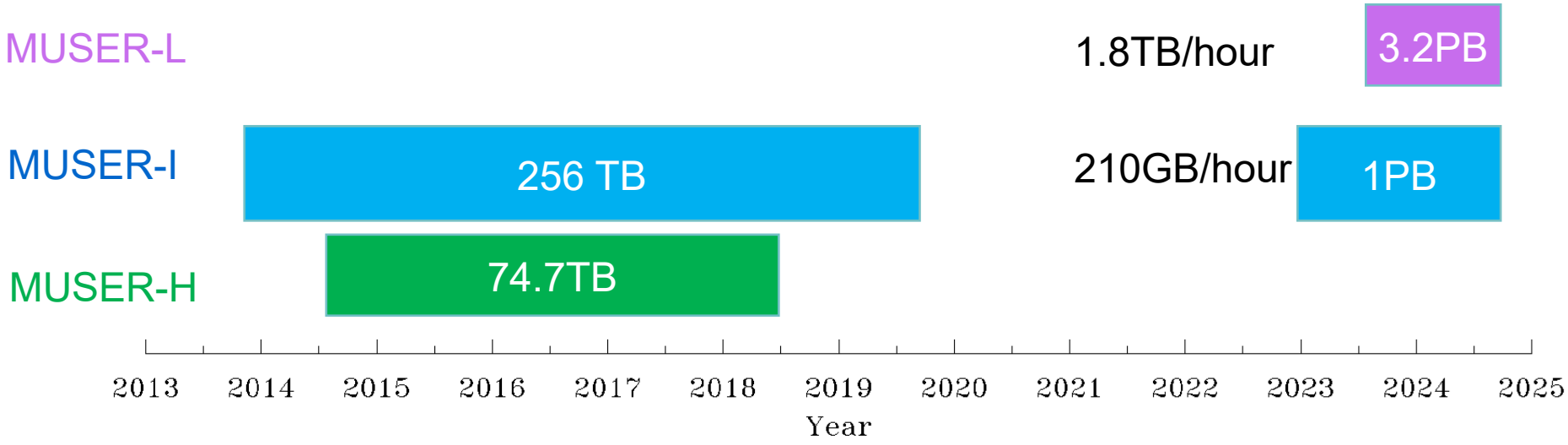




blue & green ------ MUSER-I/H

pink: -------MUSER-L

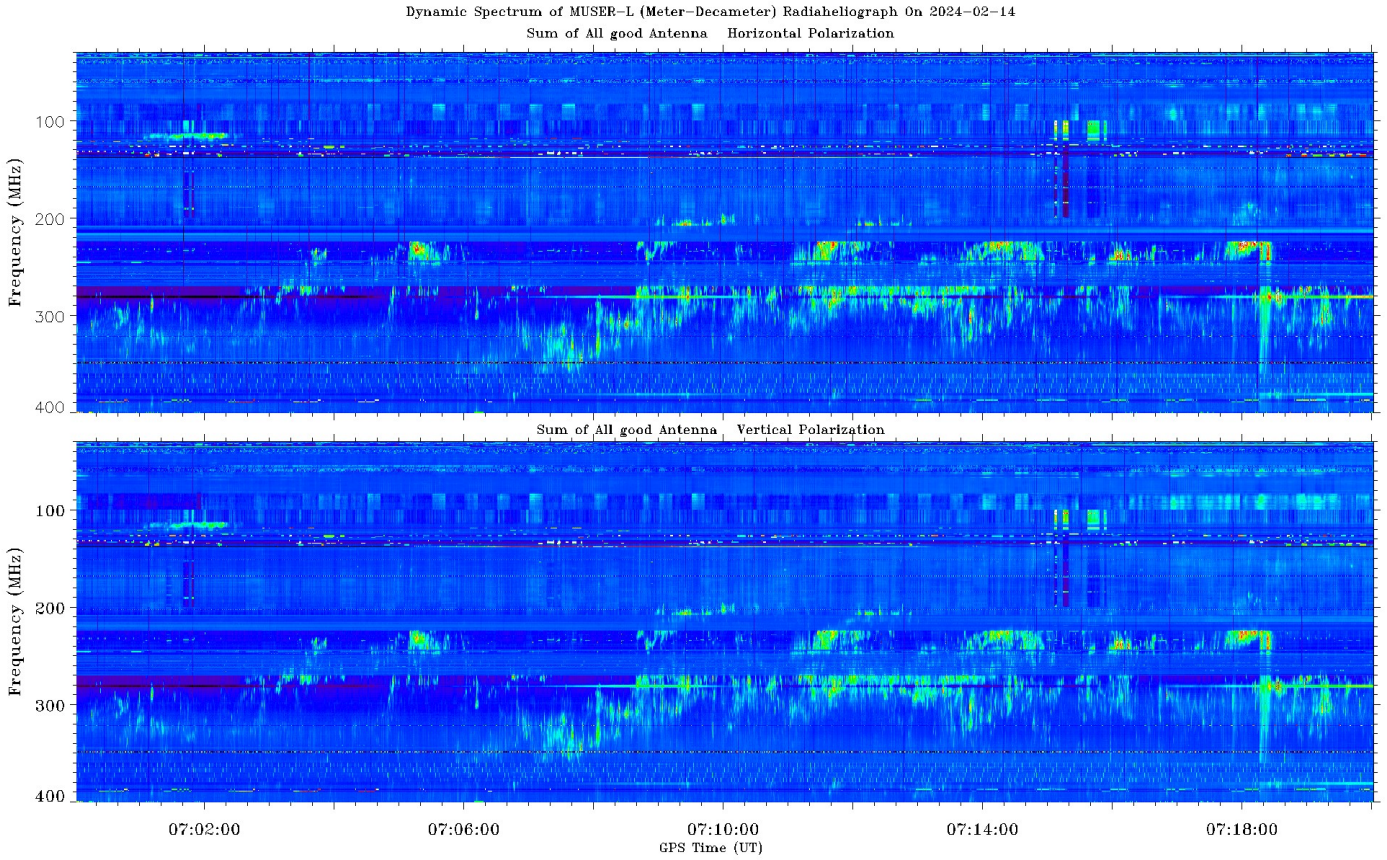
MUSER Observation

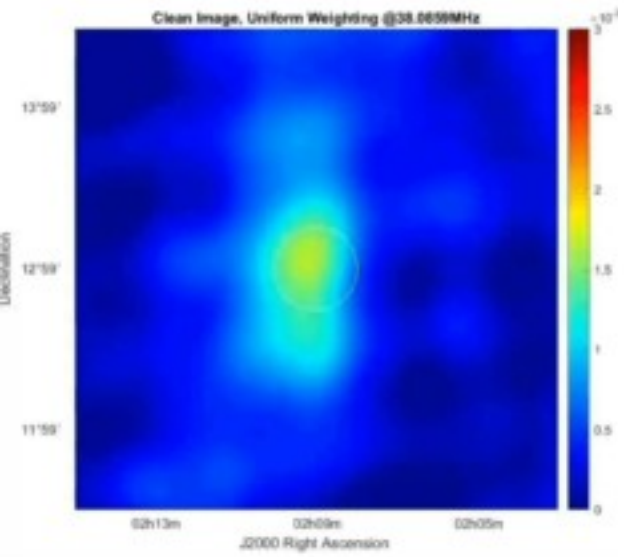


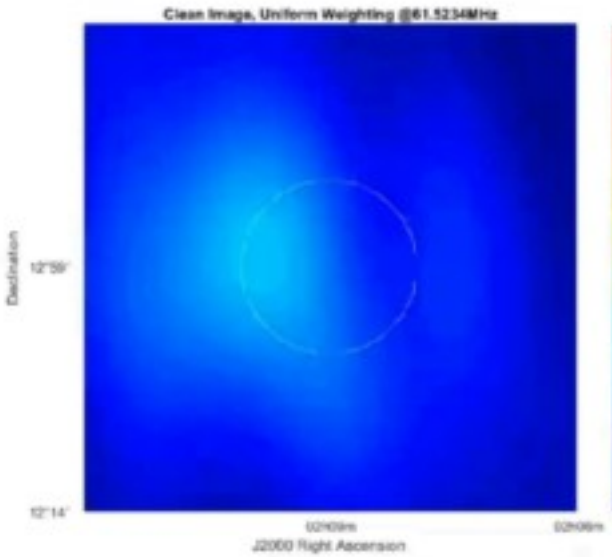
MUSER - I

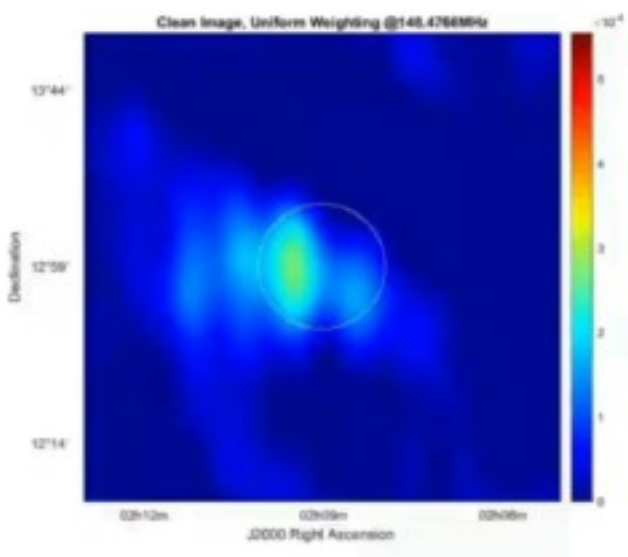
frequencyband	0.4 - 2.0 GHz	0.4 - 2.0 GHz	0.4 - 2.0 GHz	1.6 - 2.0 GHz
frequency res.	16MHz	4MHz	1MHz	16MHz
time cadence	25ms	25ms	25ms	3.125ms
polarization	L, R	L, R	L, R	L
Data	2TB/10h	8TB/10h	16TB/10h	2TB/10h

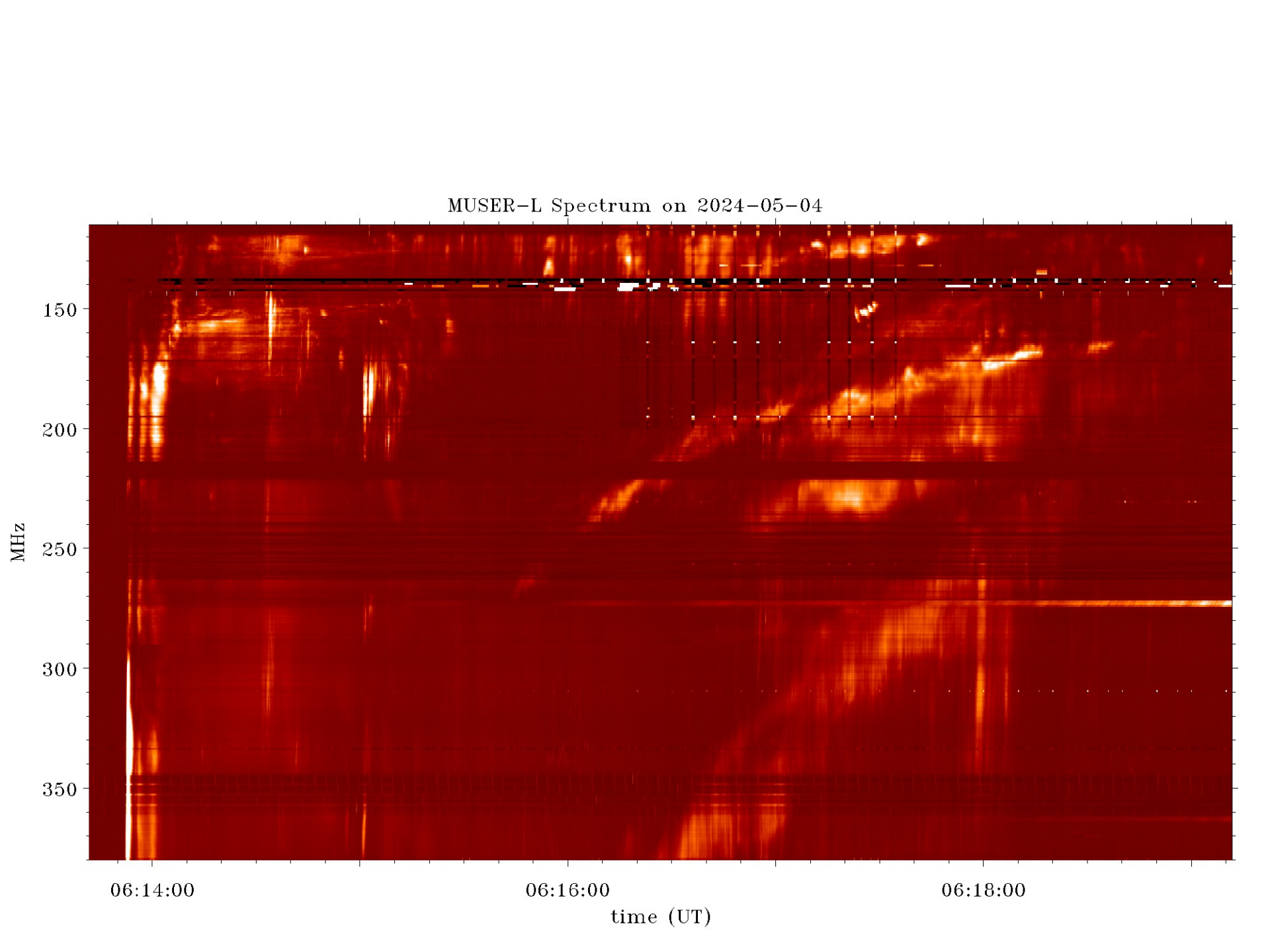
MUSER-L observation










MUSER−L Spectrum on 2024−05−04
150
200
250
300
350
MHz
06:14:00
06:16:00
06:18:00
time (UT)

MUSER-I observation （before 2019）

94 bursts

2014-10-22, 05:13-05:16UT, M2.7 MUSER2
2014-11-11, 04:20-04:34UT, C3.4 flare and a limb eruptions
2014-12-17, 04:25-04:45UT, M8.7, QPP and radio spike burst groups
2015-06-20, 01:24-02:29UT
2015-06-21, 01:17-03:43UT
2015-11-01, 03:35-03:44UT
2015-11-22, 04:51-04:52,up and down drift burst with C1.2
2016-07-23, MUSER2
2016-08-29, 03:44-03:48UT,C3.0
2017-02-28, 06:29:03-06:29:07,B-flare
2017-04-03, 00:45-01:30,2 groups of QPP in the rising phase of M1.2 flare
2017-05-31, 10:02-10:06,B7.0
2017-06-02, 01:31-01:50,C-class
2017-06-03, 09:37-09:38,C-class
2017-06-08, 05:46-05:47,B4.0
2017-07-03, B9.0, to be done, weak
2017-07-09, 03:40-03:43 M flare and several C-class flares
2017-07-10, 03:50-05:50,B6.0,09:48-09:55, B3.0
2017-07-13, 05:19-05:20,B5.0
2017-07-14, 01:20-04:00 M-flare
2017-07-16, 01:20-04:00 C-flare
2017-07-17, 07:24-07:26,C2.0
2017-07-31, B9., to be identify

2017-08-01, C-flare
2017-08-15, 04:30
2017-08-16, 08:27
2017-08-20, 01:45
2017-08-21, 02:30
2017-08-22, 04:00
2017-08-23, C1.4,
2017-08-24, 04:29
2017-09-04, 01:11
2017-09-05, 03:40
2017-09-06, 07:30
2017-09-07, 02:00
2017-09-08, 01:38
2017-09-09, 05:15
2017-09-10, 06:30
2017-09-12， 07:2
2017-09-26， 02:3
2018-03-30, 07:58
2019-03-08, 03:00
2019-05-05, 06:40
2019-05-06, 05:00
2019-05-07, 01:38
2019-05-09, 05:40

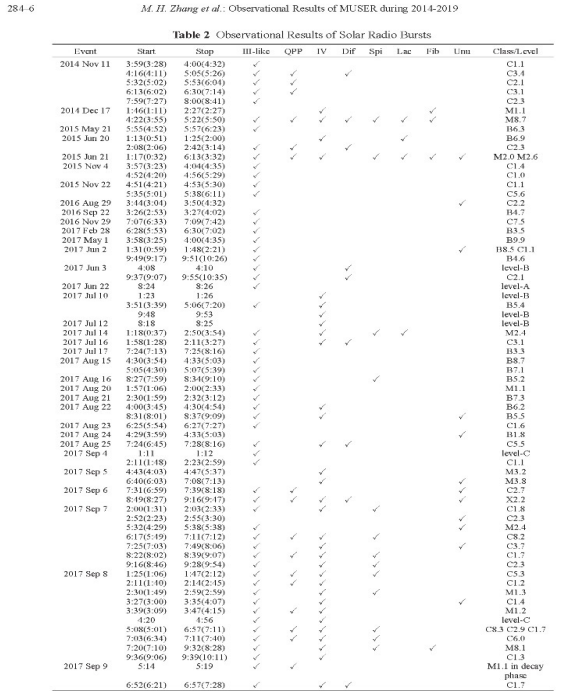

284-6 *M. H. Zhang et al.*: Observational Results of MUSER during 2014-2019

Table 2 Observational Results of Solar Radio Bursts

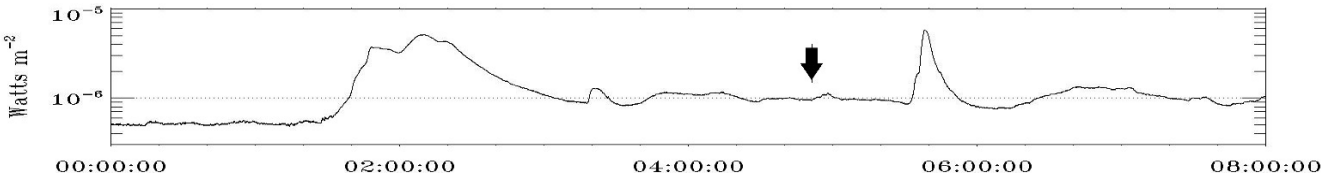
Event	Start	Stop	III-like	QPP	IV	Dif	Spi	Lac	Fib	Umu	Class/Level
2014 Nov 11	3:59(3:28)	4:00(4:32)	✓								C1.1
	4:16(4:11)	5:05(5:26)	✓	✓		✓					C3.4
	5:32(5:02)	5:53(6:04)	✓	✓							C2.1
	6:13(6:02)	6:30(7:14)	✓	✓							C3.1
	7:59(7:27)	8:00(8:41)	✓								C2.3
2014 Dec 17	1:46(1:11)	2:27(2:27)			✓				✓		M1.1
	4:22(3:55)	5:22(5:50)	✓	✓	✓	✓	✓	✓	✓		M8.7
2015 May 21	5:55(4:52)	5:57(6:23)	✓								B6.3
2015 Jun 20	1:13(0:51)	1:25(2:00)			✓			✓			B6.9
	2:08(2:06)	2:42(3:14)	✓	✓		✓					C2.3
2015 Jun 21	1:17(0:32)	6:13(3:32)	✓	✓	✓		✓	✓	✓	✓	M2.0 M2.6
2015 Nov 4	3:57(3:23)	4:04(4:35)	✓								C1.4
	4:52(4:20)	4:56(5:29)	✓								C1.0
2015 Nov 22	4:51(4:21)	4:53(5:30)	✓								C1.1
	5:35(5:01)	5:38(6:11)	✓								C5.6
2016 Aug 29	3:14(3:01)	3:50(4:32)								✓	C2.2
2016 Sep 22	3:26(2:53)	3:27(4:02)	✓								B4.7
2016 Nov 29	7:07(6:33)	7:09(7:42)	✓								C7.5
2017 Feb 28	6:28(5:53)	6:30(7:02)	✓								B5.5
2017 May 1	3:58(3:25)	4:00(4:35)	✓								B9.9
2017 Jun 2	1:31(0:59)	1:48(2:21)	✓							✓	B8.5 C1.1
	9:49(9:17)	9:51(10:26)	✓								B4.6
2017 Jun 3	4:08	4:10	✓			✓					level-B
	9:37(9:07)	9:55(10:35)	✓			✓					C2.1
2017 Jun 22	8:24	8:26	✓								level-A
2017 Jul 10	1:23	1:26			✓						level-B
	3:51(3:39)	5:06(7:20)	✓		✓						B5.4
	9:48	9:53			✓						level-B
2017 Jul 12	8:18	8:25			✓						level-B
2017 Jul 14	1:18(0:37)	2:50(3:54)	✓		✓	✓	✓				M2.4
2017 Jul 16	1:58(1:28)	2:11(3:27)	✓		✓	✓					C3.1
2017 Jul 17	7:24(7:13)	7:25(8:16)	✓								B3.3
2017 Aug 15	4:30(3:54)	4:33(5:03)	✓								B8.7
	5:05(4:30)	5:07(5:39)	✓								B7.1
2017 Aug 16	8:27(7:59)	8:34(9:10)	✓			✓					B5.2
2017 Aug 20	1:57(1:06)	2:00(2:33)	✓								M1.1
2017 Aug 21	2:30(1:59)	2:32(3:12)	✓								B7.3
2017 Aug 22	4:00(3:45)	4:30(4:54)	✓		✓						B6.2
	8:31(8:01)	8:37(9:09)	✓		✓					✓	B5.5
2017 Aug 23	6:25(5:54)	6:27(7:27)	✓								C1.6
2017 Aug 24	4:29(3:59)	4:33(5:03)								✓	B1.8
2017 Aug 25	7:24(6:45)	7:28(8:16)	✓		✓	✓					C5.5
2017 Sep 4	1:11	1:12	✓								level-C
	2:11(1:48)	2:23(2:59)	✓								C1.1
2017 Sep 5	4:43(4:03)	4:47(5:37)			✓						M3.2
	6:40(6:03)	7:08(7:13)			✓					✓	M3.8
2017 Sep 6	7:31(6:59)	7:39(8:18)	✓	✓						✓	C2.7
	8:19(8:27)	9:16(9:17)	✓	✓	✓	✓				✓	X2.2
2017 Sep 7	2:00(1:31)	2:03(2:33)	✓		✓		✓				C1.8
	2:52(2:23)	2:55(3:30)								✓	C2.3
	5:32(4:29)	5:38(5:38)	✓							✓	M2.4
	6:17(5:49)	7:11(7:12)	✓	✓	✓		✓				C8.2
	7:25(7:03)	7:49(8:06)	✓	✓	✓					✓	C3.7
	8:22(8:02)	8:39(9:07)	✓	✓	✓		✓				C1.7
	9:16(8:46)	9:28(9:54)	✓	✓	✓		✓				C2.3
2017 Sep 8	1:25(1:06)	1:47(2:12)	✓	✓	✓		✓				C5.3
	2:11(1:40)	2:14(2:15)	✓	✓	✓						C1.2
	2:30(1:49)	2:59(2:59)	✓		✓		✓				M1.3
	3:27(3:00)	3:35(4:07)	✓		✓					✓	C1.4
	3:39(3:09)	3:47(4:15)	✓	✓	✓						M1.2
	4:20	4:56	✓		✓						level-C
	5:08(5:01)	6:57(7:11)	✓	✓	✓		✓				C8.3 C2.9 C1.7
	7:03(6:34)	7:11(7:40)	✓	✓	✓		✓				C6.0
	7:20(7:10)	9:32(8:28)	✓		✓		✓		✓		M8.1
	9:36(9:06)	9:39(10:11)	✓		✓						C1.3
2017 Sep 9	5:14	5:19	✓	✓							M1.1 in decay phase
	6:52(6:21)	6:57(7:28)	✓		✓	✓					C1.7

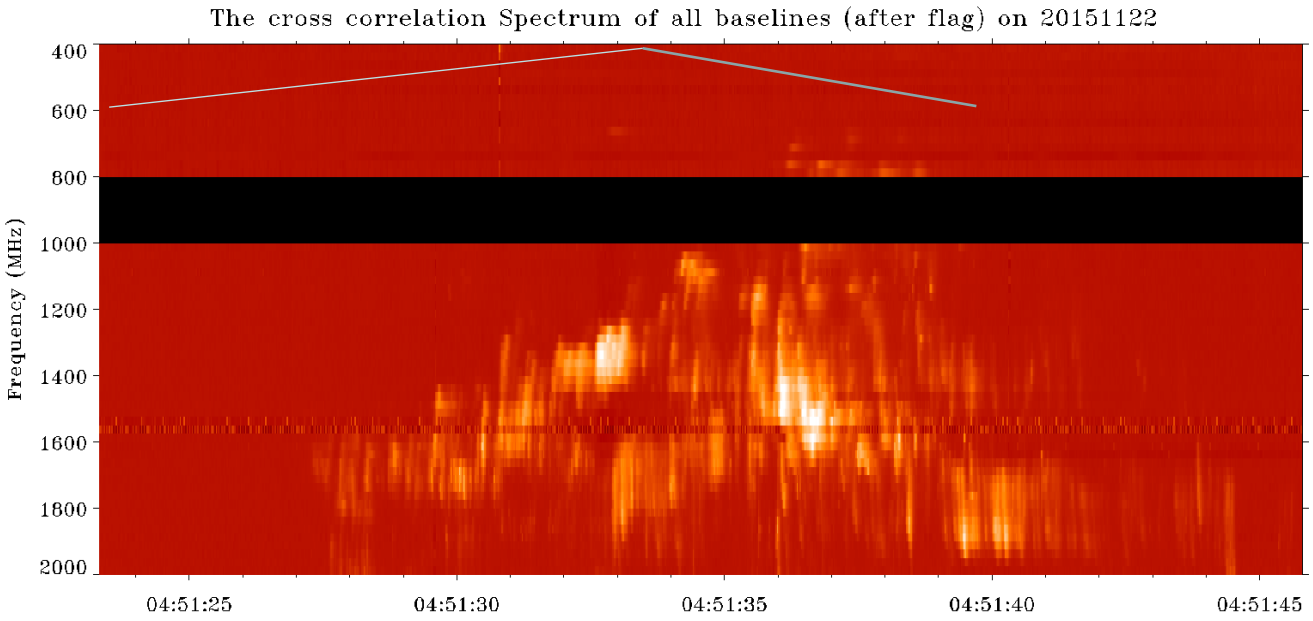
Year	2013	2014	2015	2016	2017	2018	2019	2020	Total (Tb)
Data Size(Tb)	0.14	4.4	12.2	58	152	121	~40	~5	~390

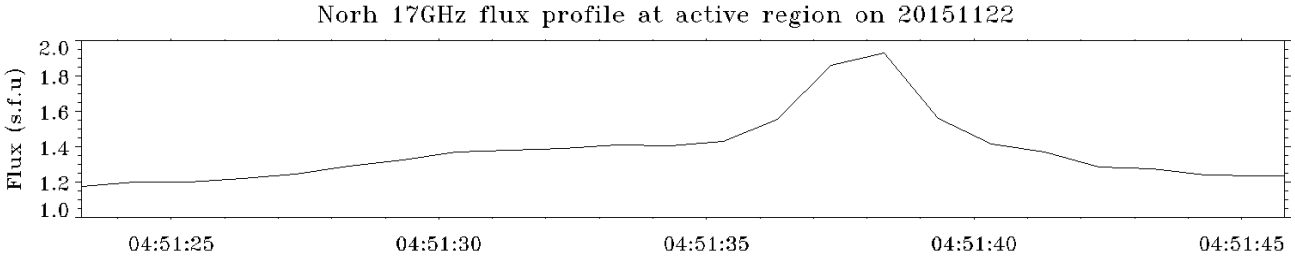
Zhang, Ming-Hui, et al, Observational results of MUSER during 2014–2019 , 2021, RAA , Vol. 21 No. 11, 284(12pp)

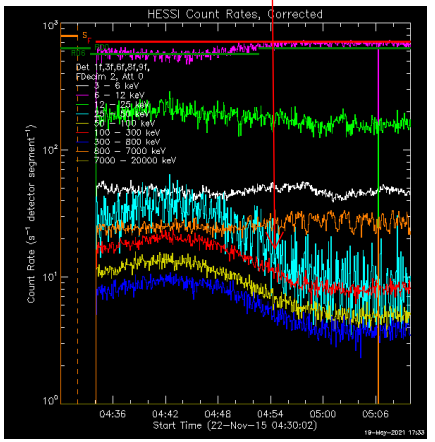
The 20151122 event

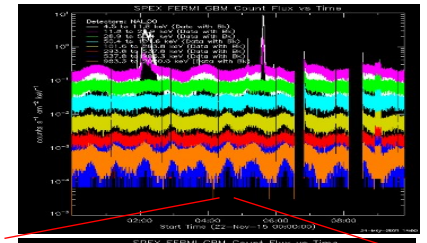
RHESSI and Fermi HXR showed no increasing

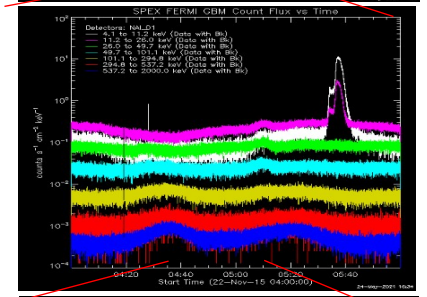


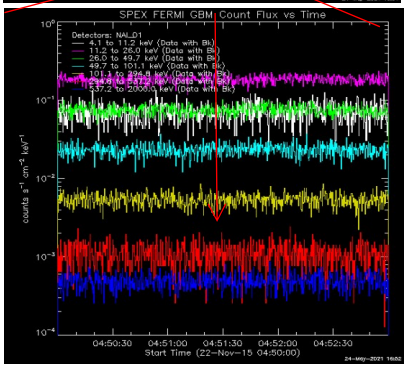






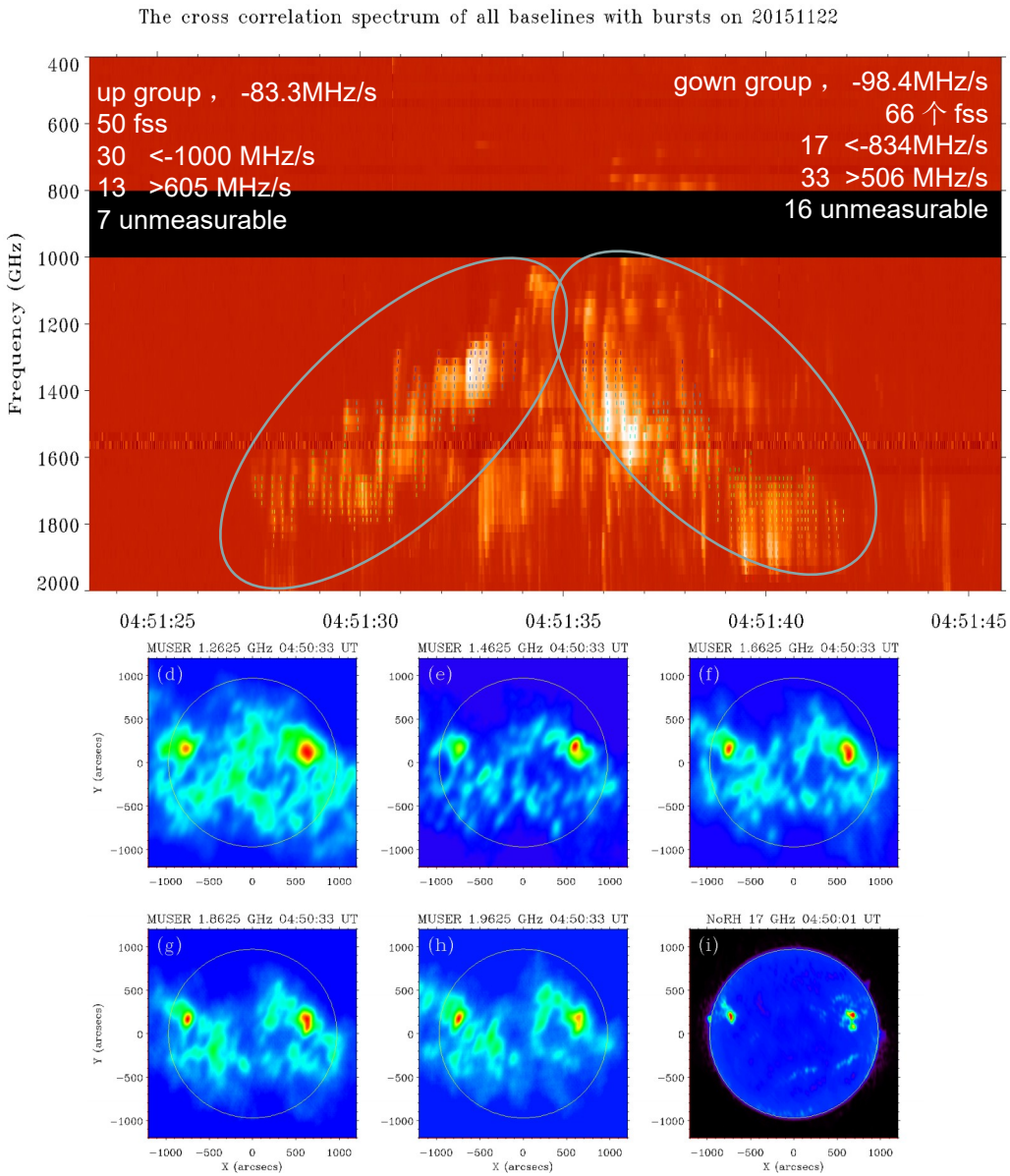


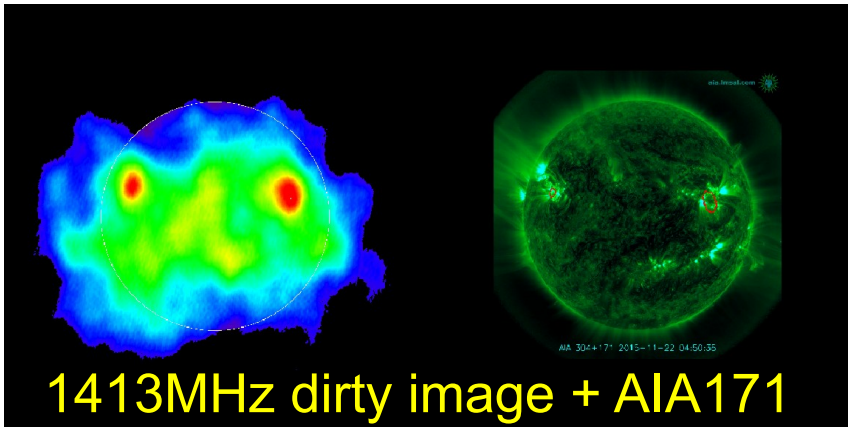


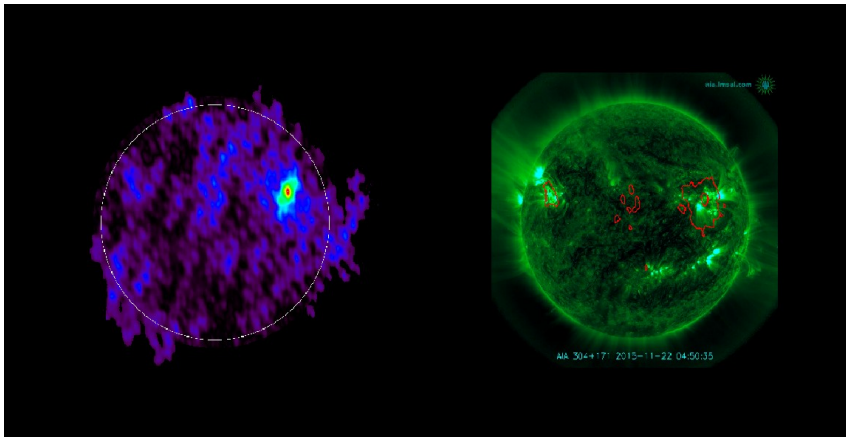


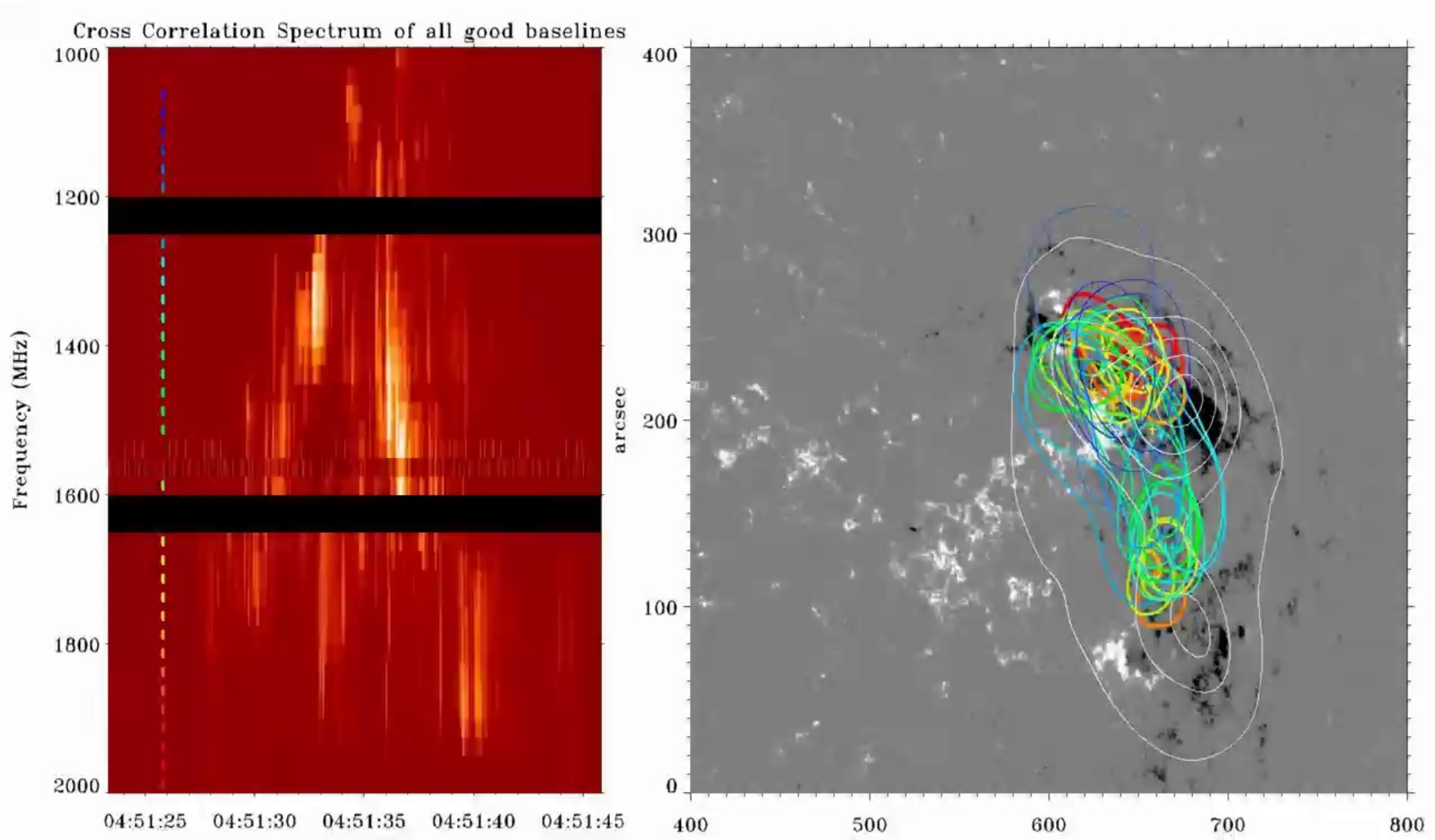
spectrum and image

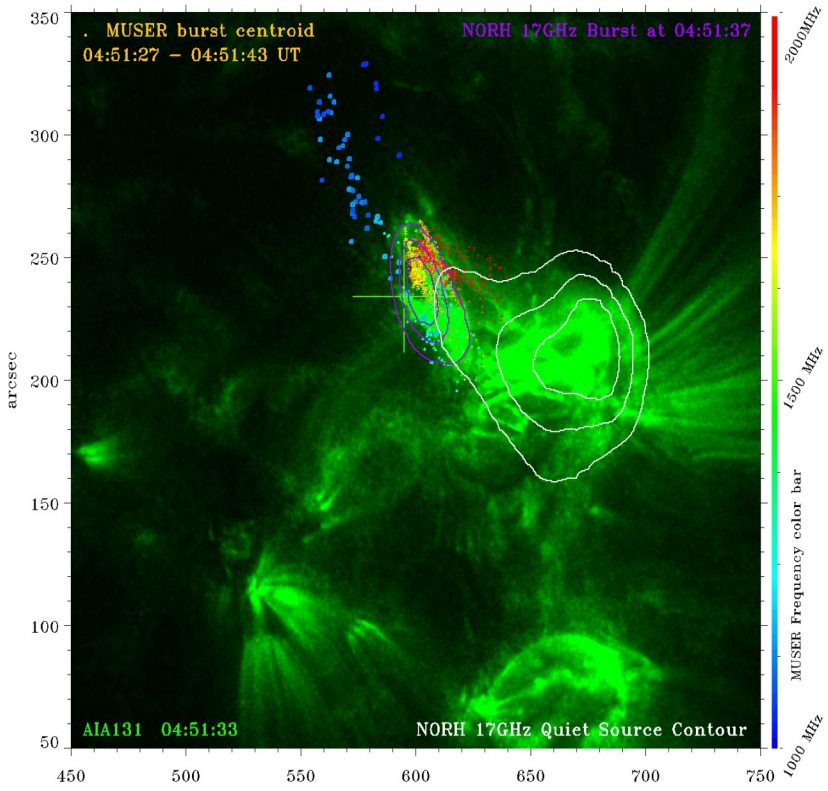
drifting

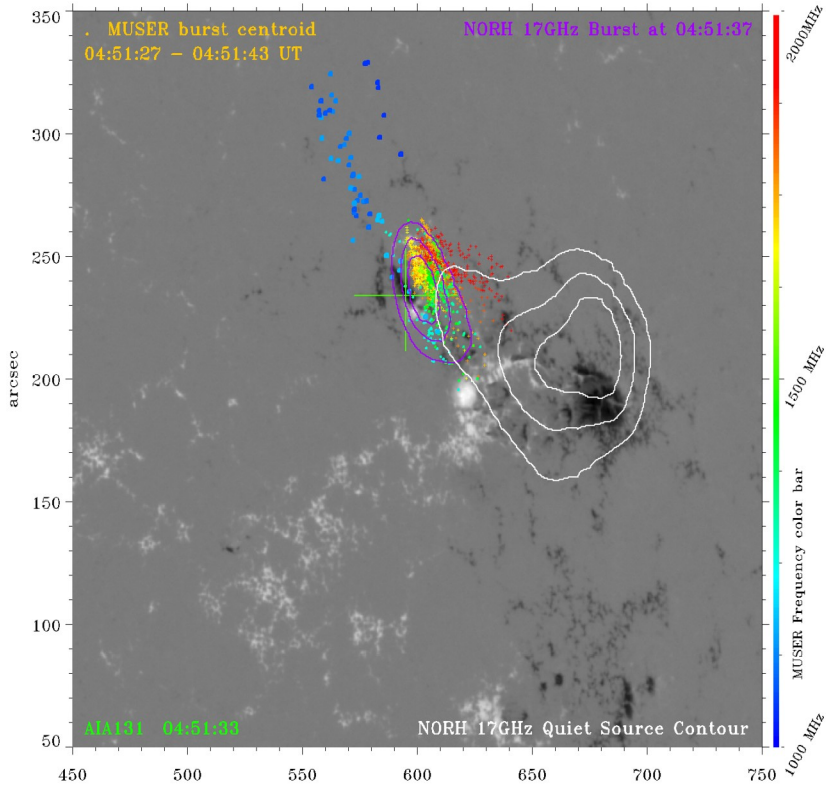


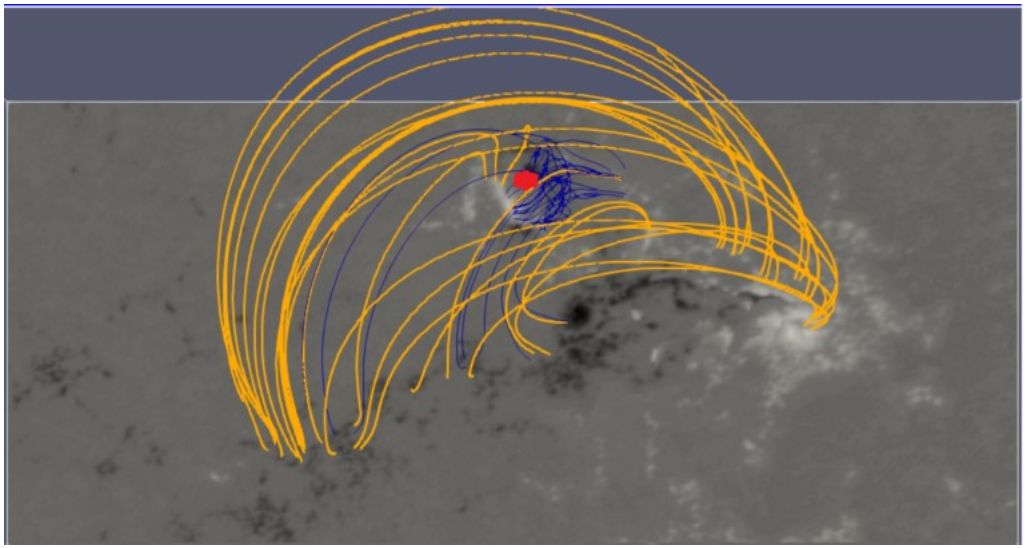




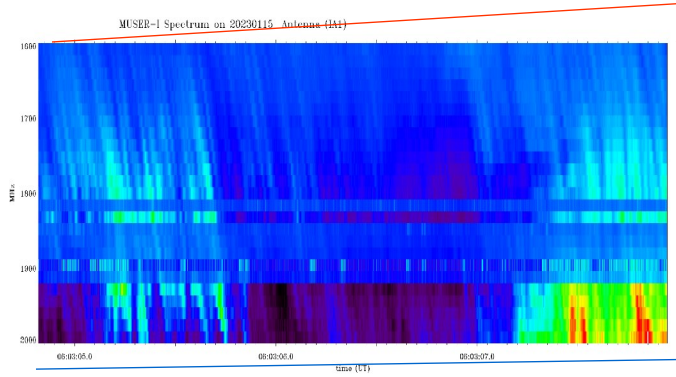

Cross Correlation Spectrum of all good baselines
Frequency (MHz)
1000
1200
1400
1600
1800
2000
04:51:25
04:51:30
04:51:35
04:51:40
04:51:45
arcsec
400
300
200
100
0
400
500
600
700
800

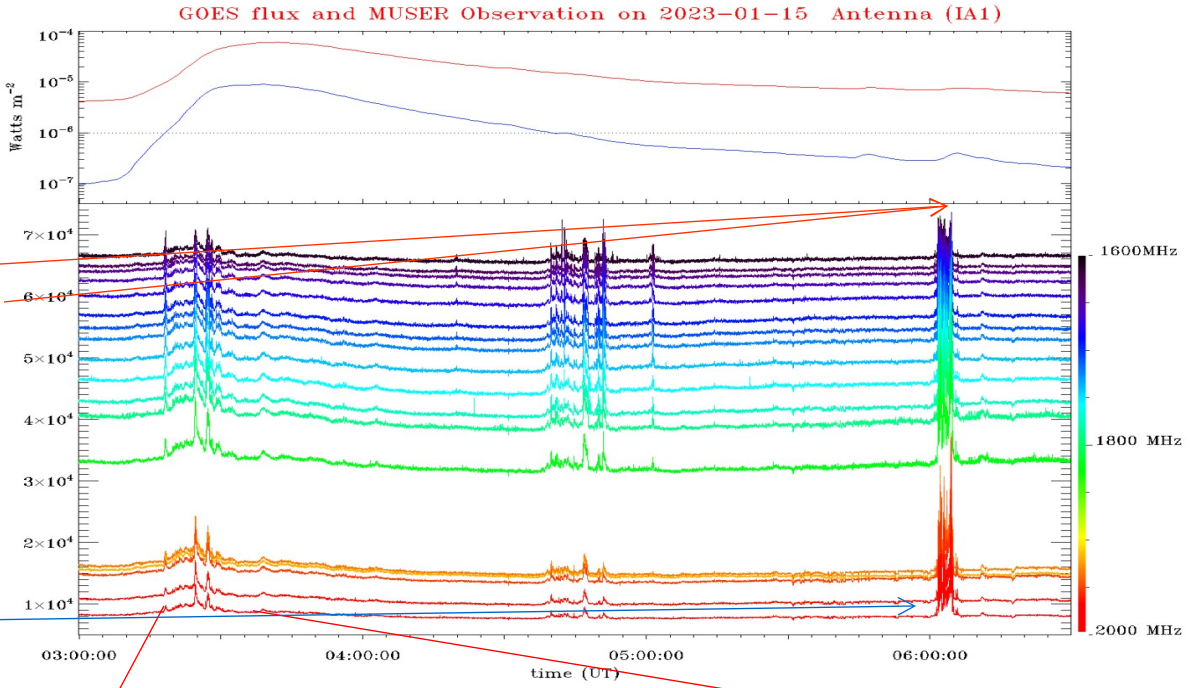

. MUSER burst centroid
04:51:27 – 04:51:43 UT
NORH 17GHz Burst at 04:51:37
AIA131 04:51:33
NORH 17GHz Quiet Source Contour
arcsec
MUSER Frequency color bar
2000MHz
1500 MHz
1000 MHz


. MUSER burst centroid
04:51:27 – 04:51:43 UT
NORH 17GHz Burst at 04:51:37
AIA131 04:51:33
NORH 17GHz Quiet Source Contour
arcsec
MUSER Frequency color bar
2000MHz
1500 MHz
1000 MHz

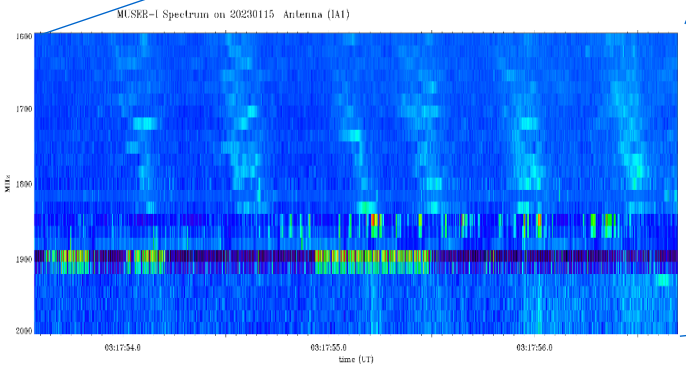


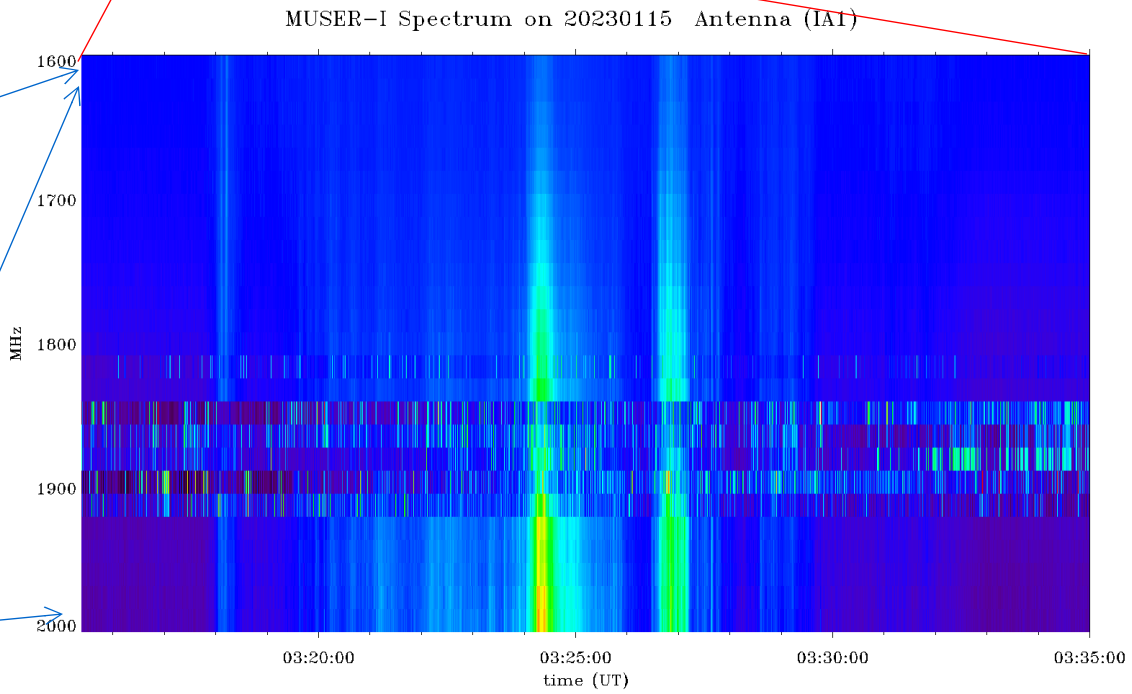
MUSER-I upgrade

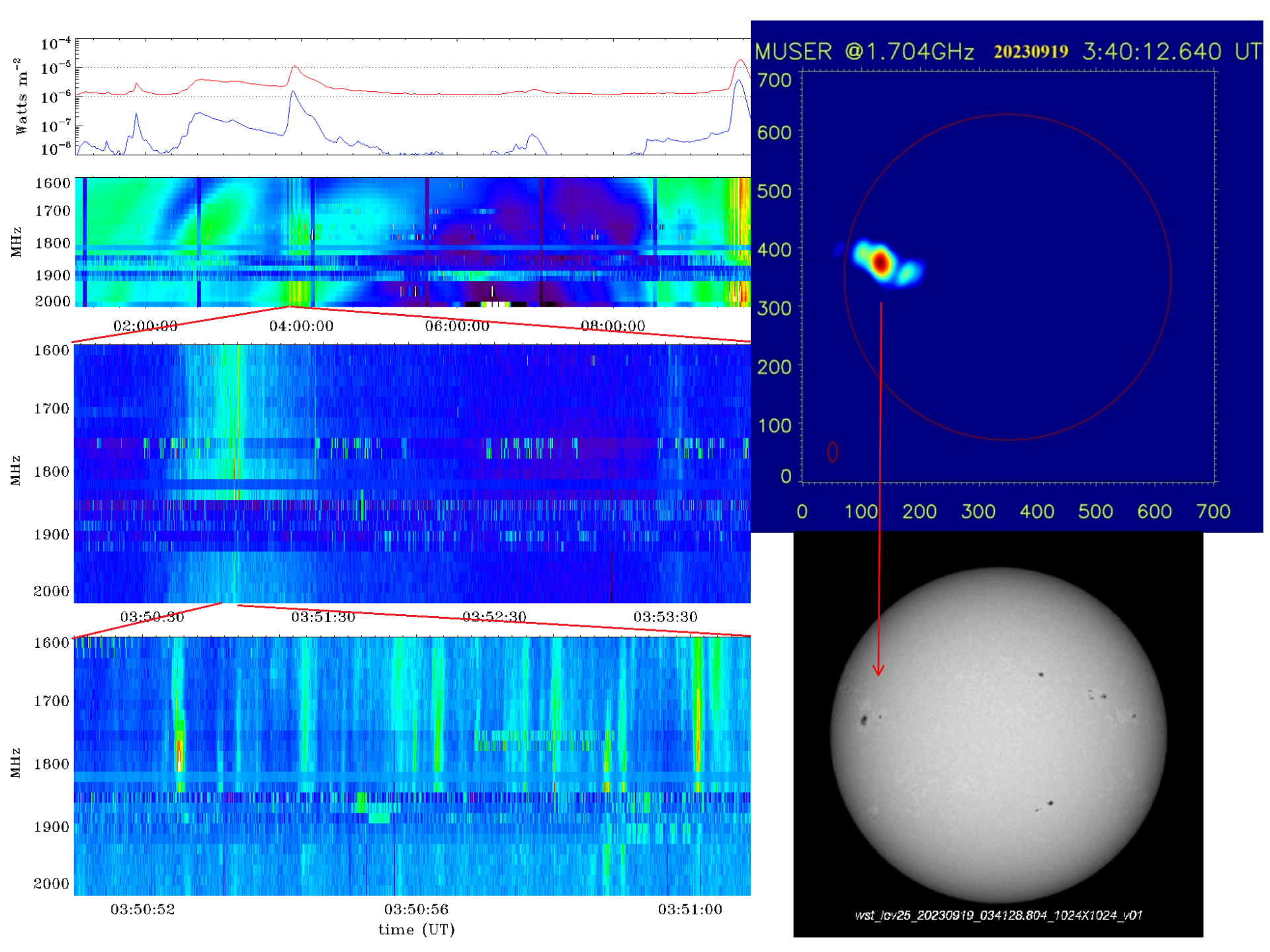




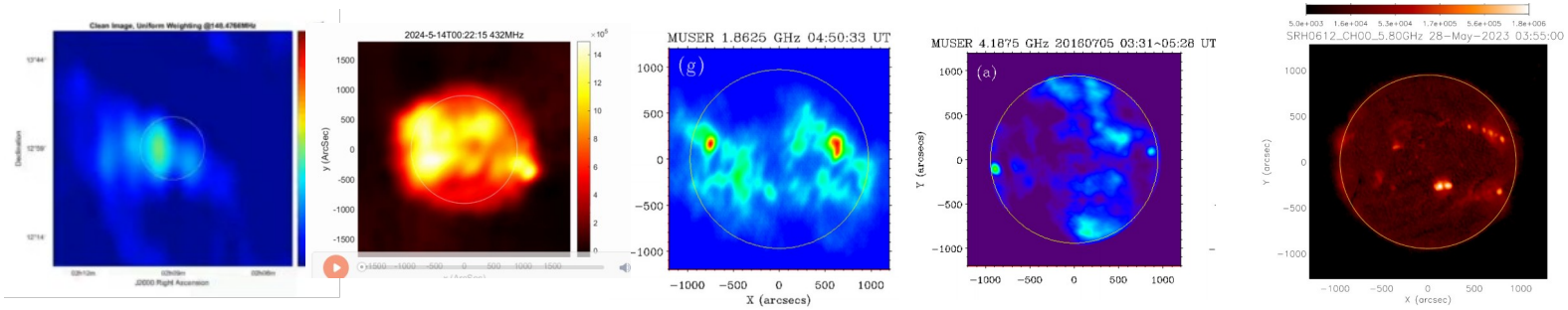
fiber burst






Watts m^{-2}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
MHz
1600
1700
1800
1900
2000
02:00:00
04:00:00
06:00:00
08:00:00
03:50:30
03:51:30
03:52:30
03:53:30
03:50:52
03:50:56
03:51:00
time (UT)
MUSER @1.704GHz 20230919 3:40:12.640 UT
0
100
200
300
400
500
600
700
wst_lcv25_20230919_034128.804_1024X1024_v01

Joint study with SRH and CBS



DSRT

SRH-L SRH-M SRH-H

MUSER-L MUSER-I MUSER-H (TBU)

100 Frequency(MHz) 1000 10000

CBS

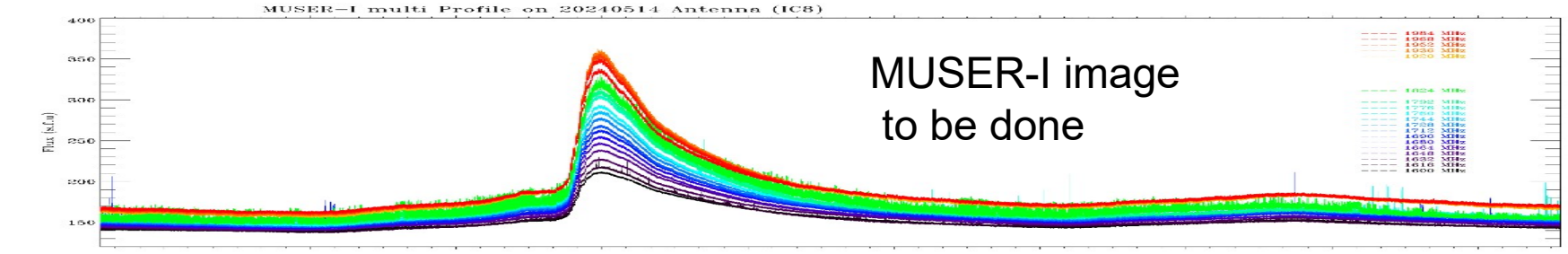
CBS

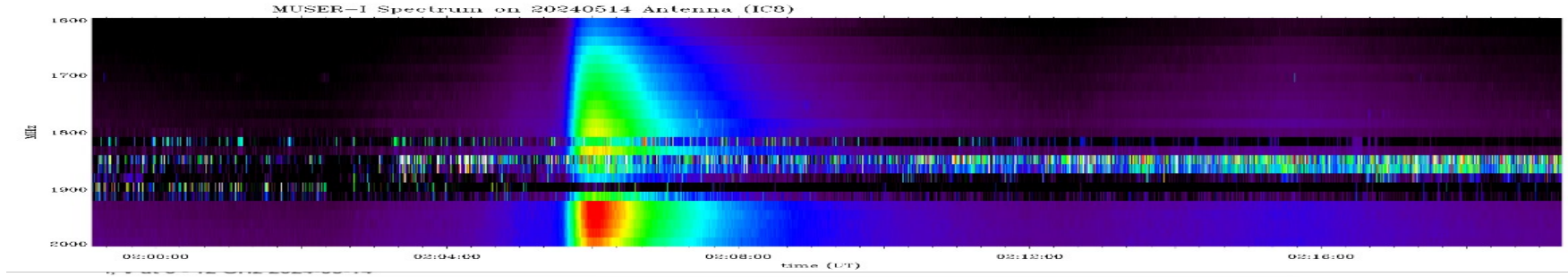
event list

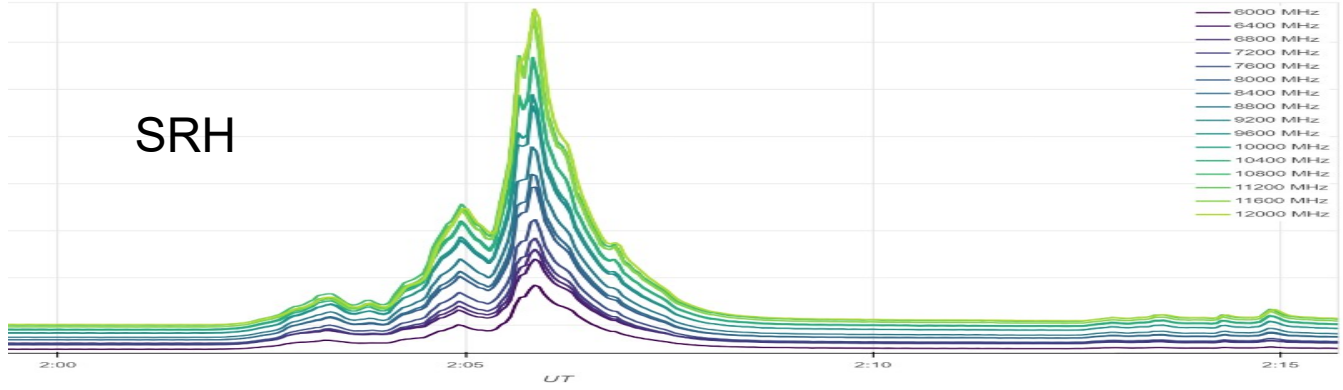
20230111， 0140-0220UT,
20230112, 0335-0350UT
20230115, 0310-0400UT， 0430-0500UT， 0550-0610UT
20230208, 0251-0254UT
20230209， 0245-0300UT （weak），0715-0717UT （ffs）
20230210， 0240-0310UT， 0730-0830UT

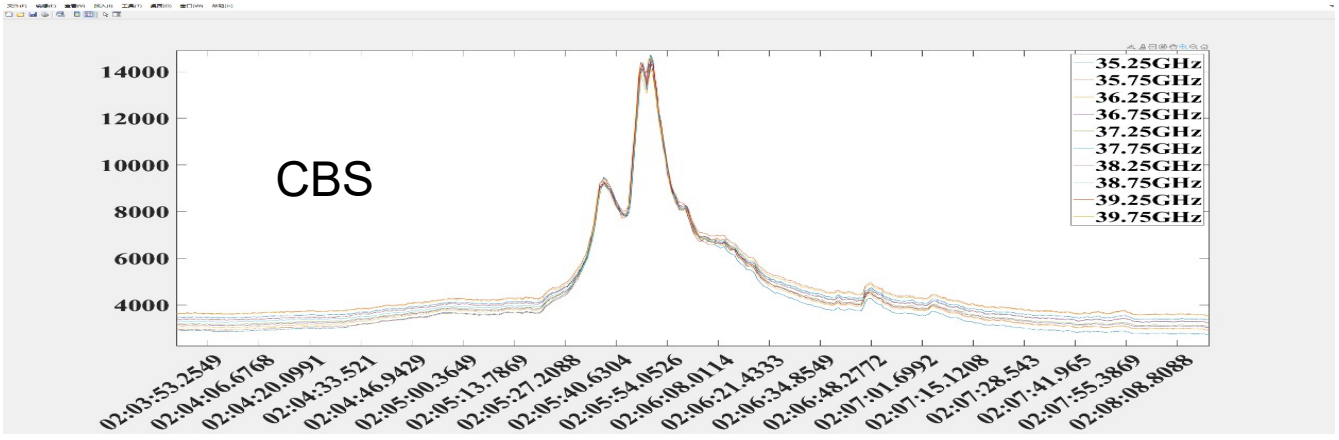
.....

SRH event Time	GOES	Location	Other data	Notes	MUSER-I	MUSER-L
2024-01-23 03:30	M5.1	[-270, 576]	KW	short, classical light curve	yes	no
2024-01-23 07:15	C9.6	[600, -213]		long rise phase	yes	no
2024-01-29 04:25	M6.8	[883, 422]	KW	~1 h, classical	yes	yes
2024-02-06 03:00	M4.3	[720, -560]		very long and complicated event (up to 3 peaks)	yes	yes
2024-02-07 03:40	M5.2	[730, -576]	DSRT, CSO	~1 h, classical	yes	no
2024-02-09 07:31	C9.4	[-228, -150]		very short, classical, late time	yes	yes
2024-02-10 03:40	M3.4	[-50, -100]	DSRT, CSO	~30 m, classical + secondary event	yes	no
2024-02-12 03:45	M6.5	[422, -115]		short, classical	yes	yes
2024-02-16 06:55	X2.5	[890, -340]	KW	short, classical; late time	yes	yes
2024-02-22 06:40	X1.7	[570, 350]	KW	~30 m, classical	yes	yes
2024-02-24 06:31	M4.5	[-190, 422]		short, classical, late time	yes	yes
2024-03-17 05:40	C3.8	[-883, 345]		~30 m, classical (+ a sympathetic weaker flare)	yes	yes
2024-03-20 07:40	M7.4	[-720, -192]		~1 h, classical + secondary event, late time	yes	yes
2024-03-23 01:30	X1.1	[-192, -115]		long and complicated event, early time	no	no
2024-03-23 07:10	M2.5	[-192, -115]		short, classical + secondary event	yes	yes
2024-03-24 06:05	M2.2	[38, -115]		very short, classical	yes	yes
2024-03-25 06:45	M4.4	[120, -120]	KW	extremely short, classical	yes	yes
2024-03-26 00:35	M1.8	[500, -110]	KW	extremely short, early time	yes	no
2024-03-28 06:30	M7.1	[730, -192]		~30 m, classical	yes	?
2024-03-29 02:20	M3.2	[810, -190]		short, classical	yes	yes
2024-04-01 01:30	M3.9	[850, 255]		very short + long secondary	yes	no
2024-05-14 02:09	X1.7	[S17W89]			yes	no


MUSER-I multi Profile on 20240514 Antenna (IC8)
Flux (s.f.u)
MUSER-I image
to be done


MUSER-I Spectrum on 20240514 Antenna (IC8)
MHz
time (UT)


SRH
6000 MHz
6400 MHz
6800 MHz
7200 MHz
7600 MHz
8000 MHz
8400 MHz
8800 MHz
9200 MHz
9600 MHz
10000 MHz
10400 MHz
10800 MHz
11200 MHz
11600 MHz
12000 MHz
UT


CBS
35.25GHz
35.75GHz
36.25GHz
36.75GHz
37.25GHz
37.75GHz
38.25GHz
38.75GHz
39.25GHz
39.75GHz

Summary

- MUSER had recoreded a huge amount of data (>4PB). The event list and figure would be organized. It will promote the joint study with SRH.
- We have started the data analysis for one candidate event. The joint analysis will be done in detail for several common view solar flares, and determining the radio flux, peak frequency, spectral or spatial characteristic. It will trace the source and process of energy release and particle acceleration.
- The spectral and spatial analysis will be helpful in the study of Solar-Terrestrial space weather in wide radio spectral range of 30MHz - 40GHz.

Спасибо !