Solar Radio Imaging-Spectroscopy and Heliospheric Imager

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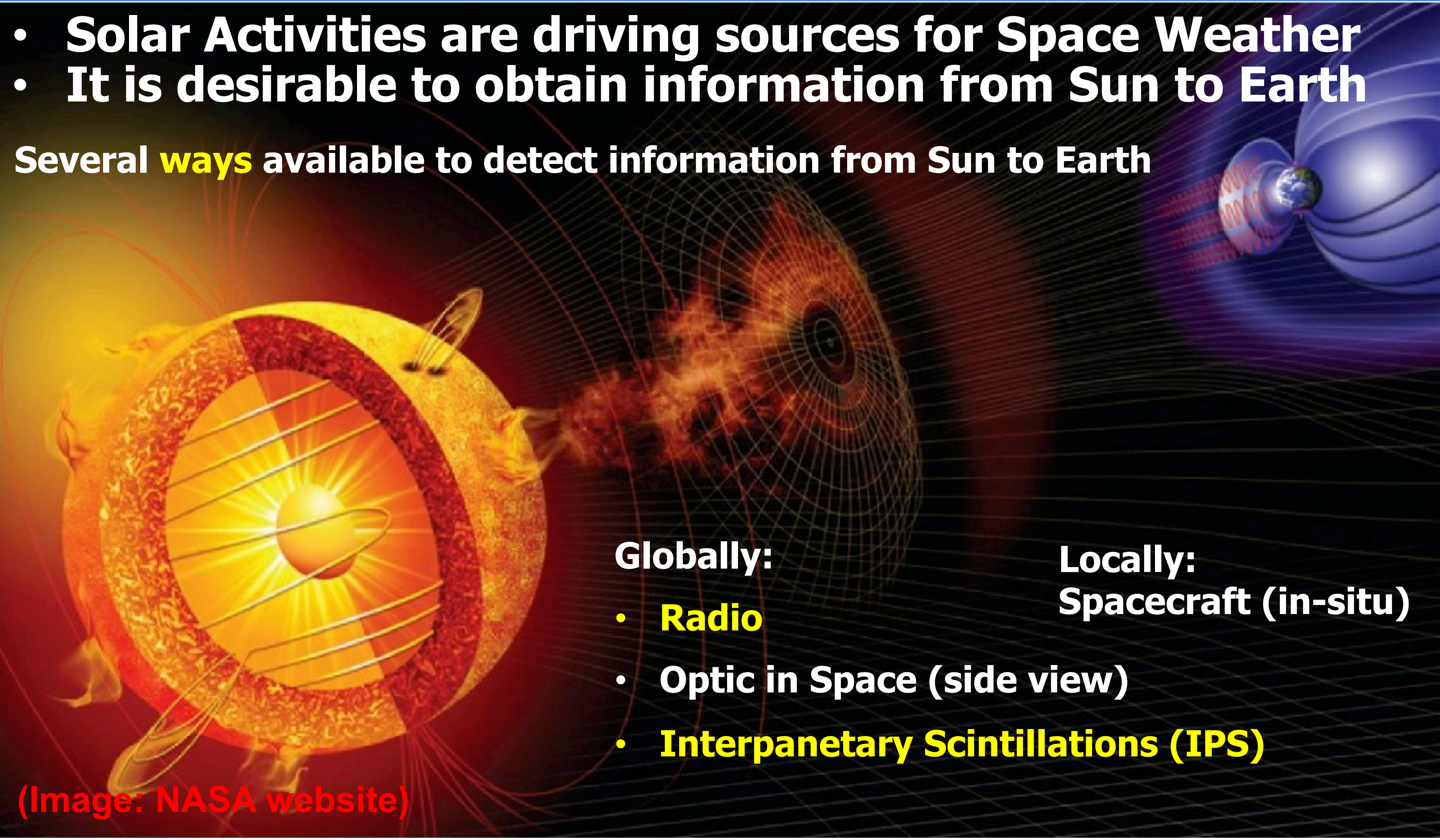
Introduction

- **Solar Activities are driving sources for Space Weather**
- **It is desirable to obtain information from Sun to Earth**

Several ways available to detect information from Sun to Earth



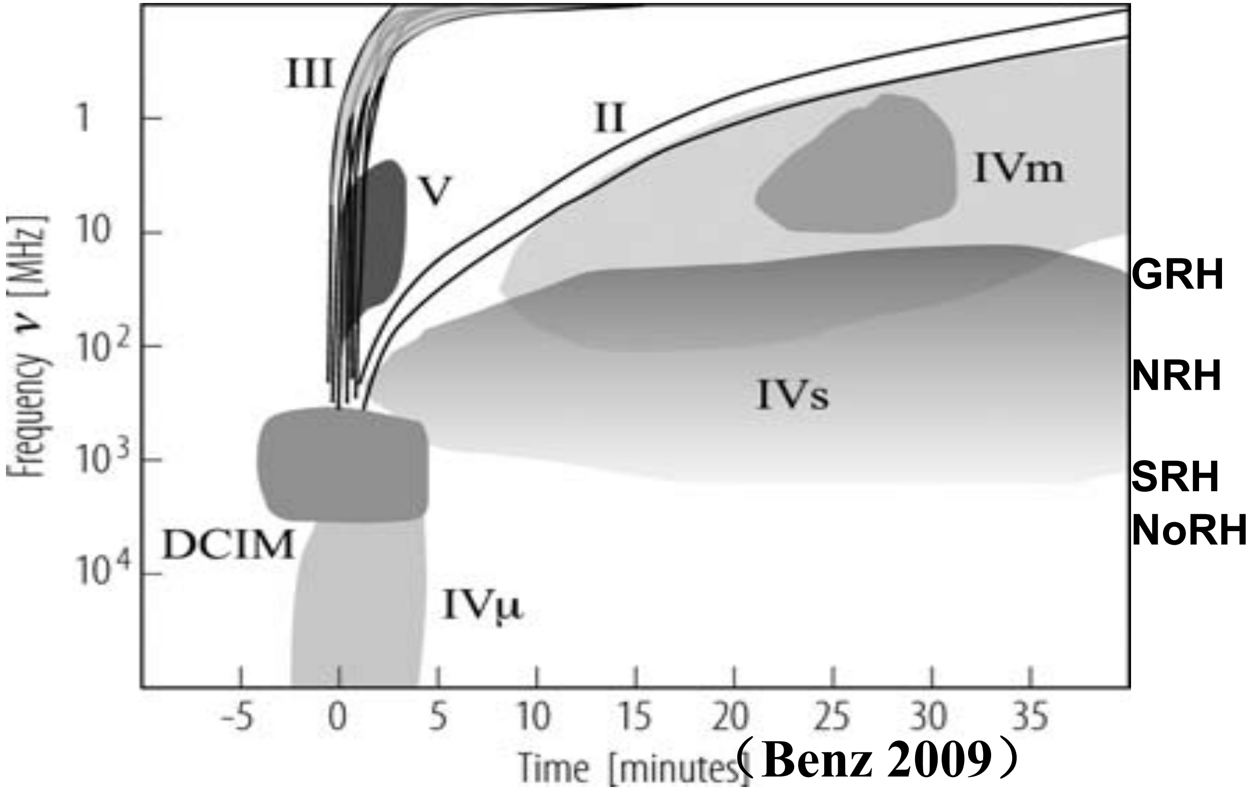
Globally:

- **Radio**
- **Optic in Space (side view)**
- **Interpanetary Scintillations (IPS)**

Locally:
Spacecraft (in-situ)

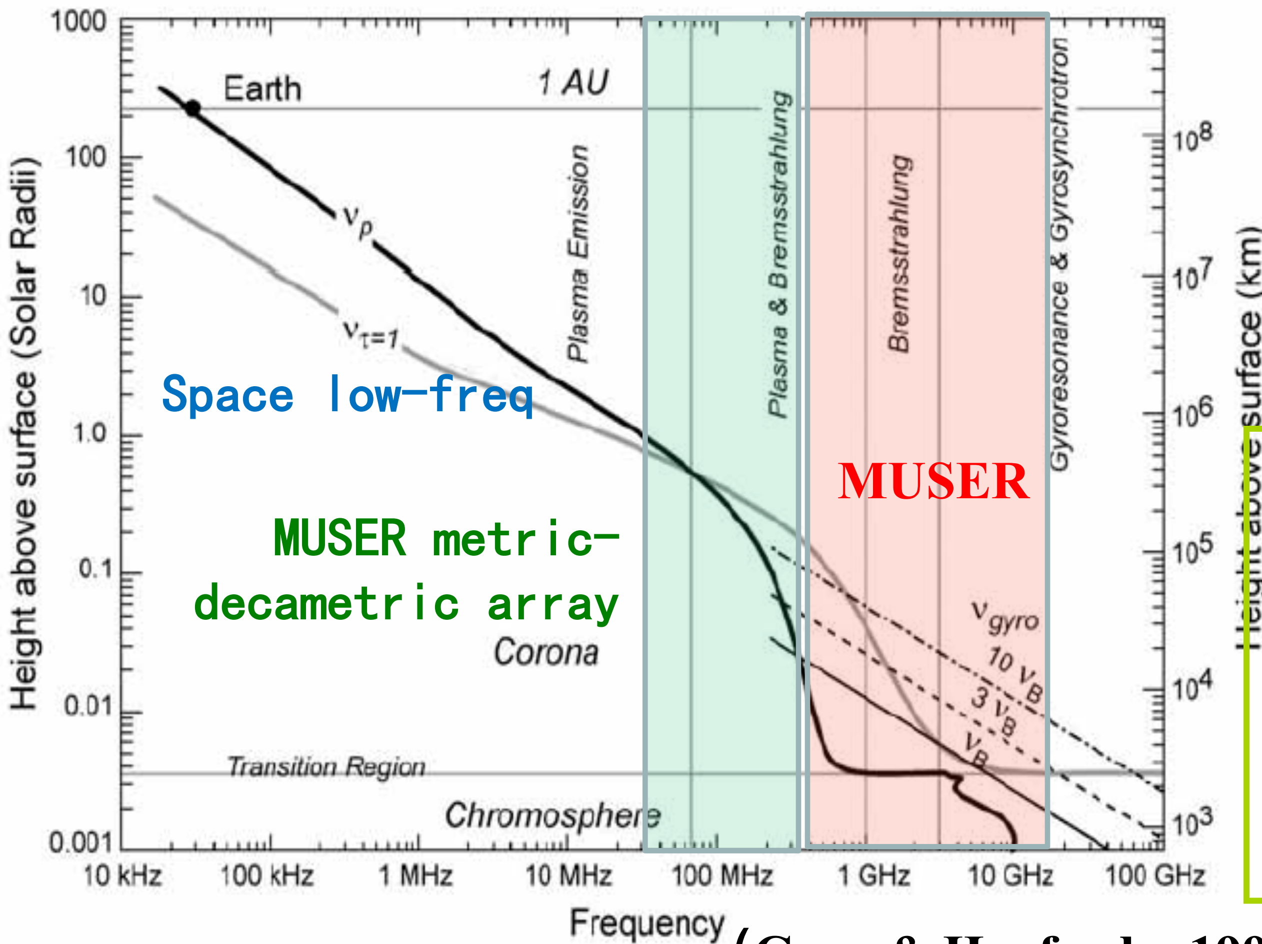
(Image: NASA website)

Introduction



(Benz 2009)

Radio bursts are prompt indicators of the various solar activities including flares, CMEs, and SEPs, etc.



(Gary & Hurford, 1999)

$$\nu_p = 8.98\times10^3\sqrt{n_e}$$

$$\nu_{\tau=1} \approx 0.5 n_e T_e^{-3/4} L^{1/2}$$

$$\nu_B = 2.8\times10^6 B$$

(1) Bremsstrahlung

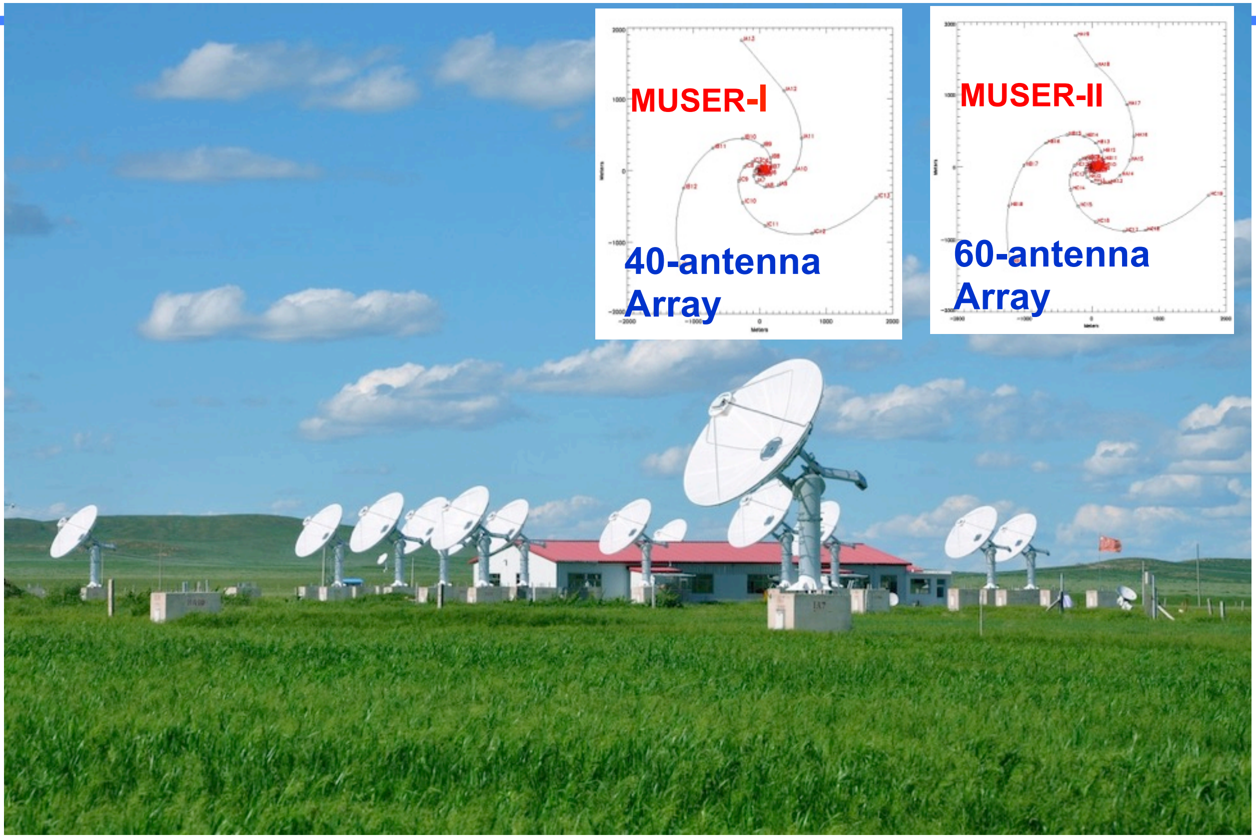
(2) Gyroresonance

(3) Coherent emission

- ★ **Plasma emission**
- ★ **ECME**

Develop imaging-spectroscopy capacity

MUSER - Mingantu Spectral Radiheliograph



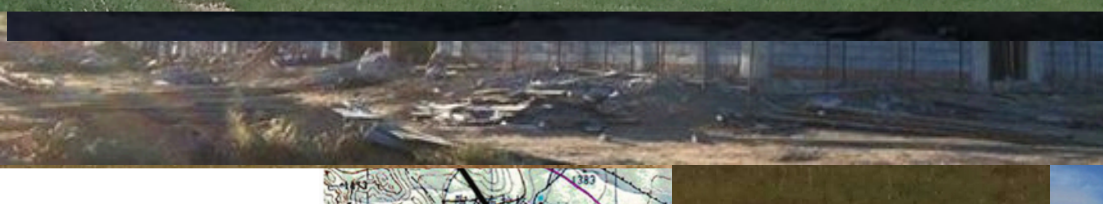
MUSER:

64 channels in 0.4-2.0 GHz & 520 channels in 2.0-15 GHz

space resolution: 1.3″-50″

time resolution: ~ 25 & ~200 ms

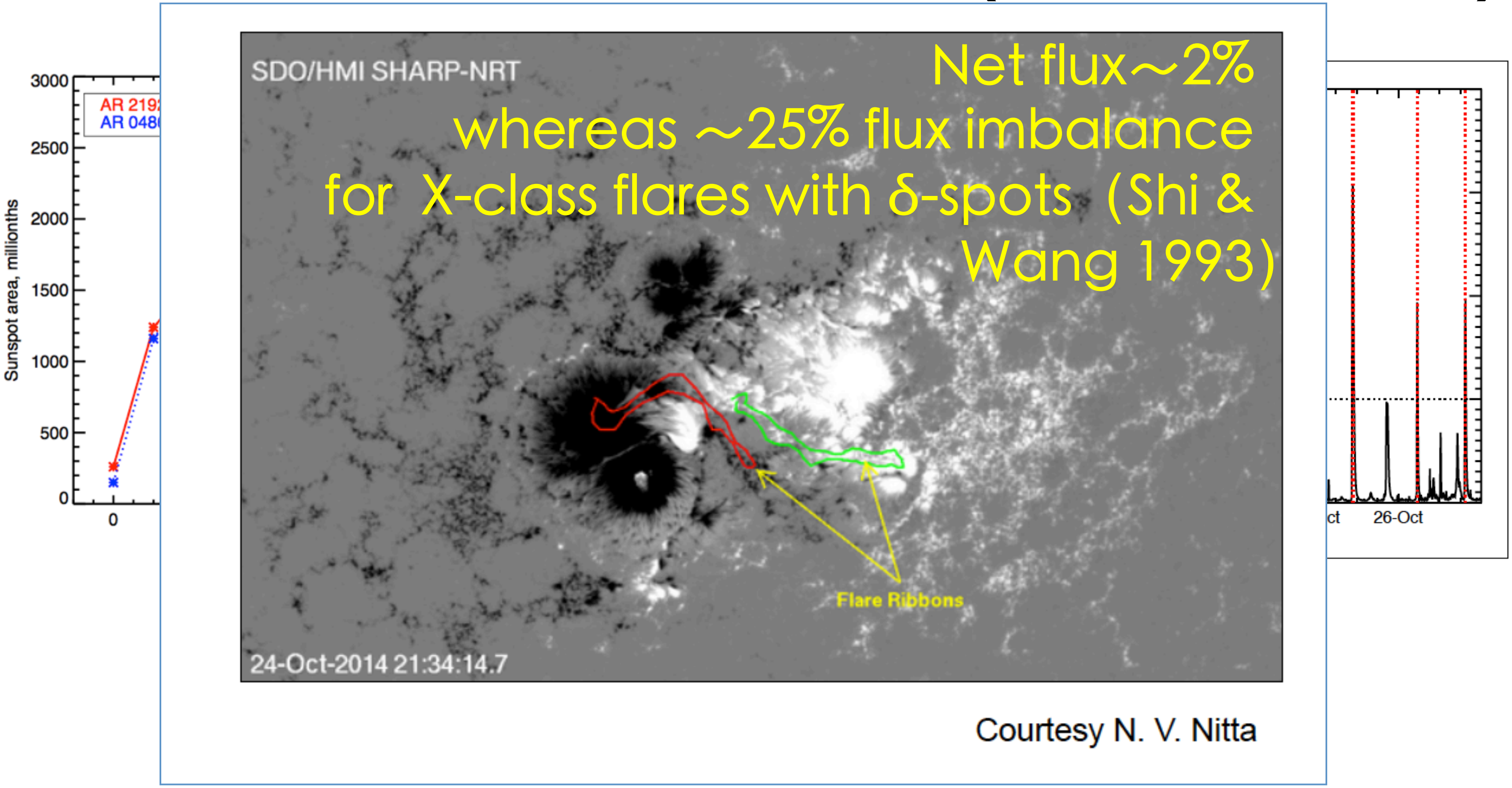
Station Construction Progress (May 2015 – Present)

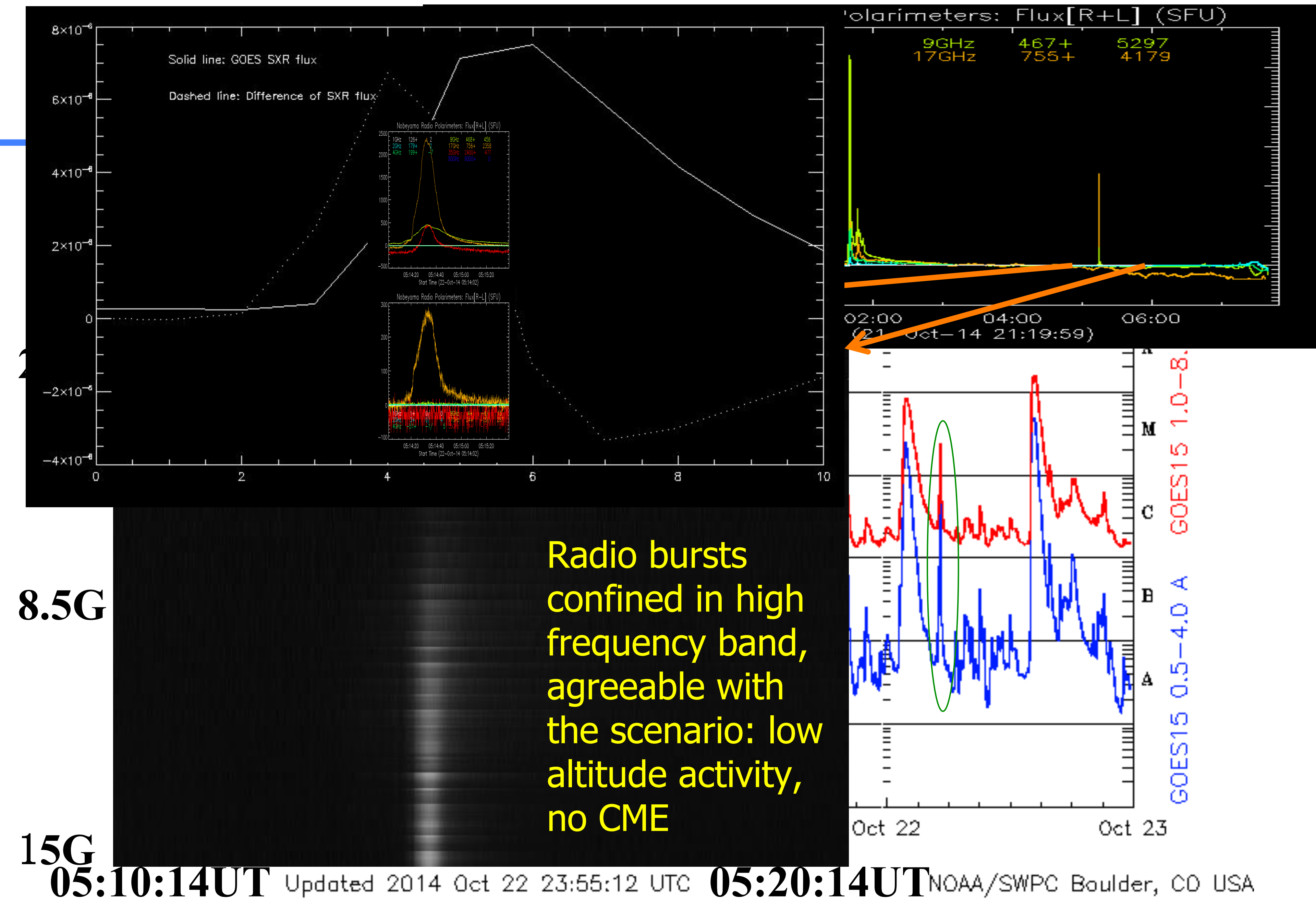


Some MUSER Observations

- burst event on 22 Oct 2014 by MUSER-II
- burst event on 11 Nov 2014 by MUSER-I
- burst event on Dec 17 2014 by MUSER-I
- quiet Sun on 7 Jan 2016 by MUSER-II
- quiet Sun on 5 Jul 2016 by MUSER-II

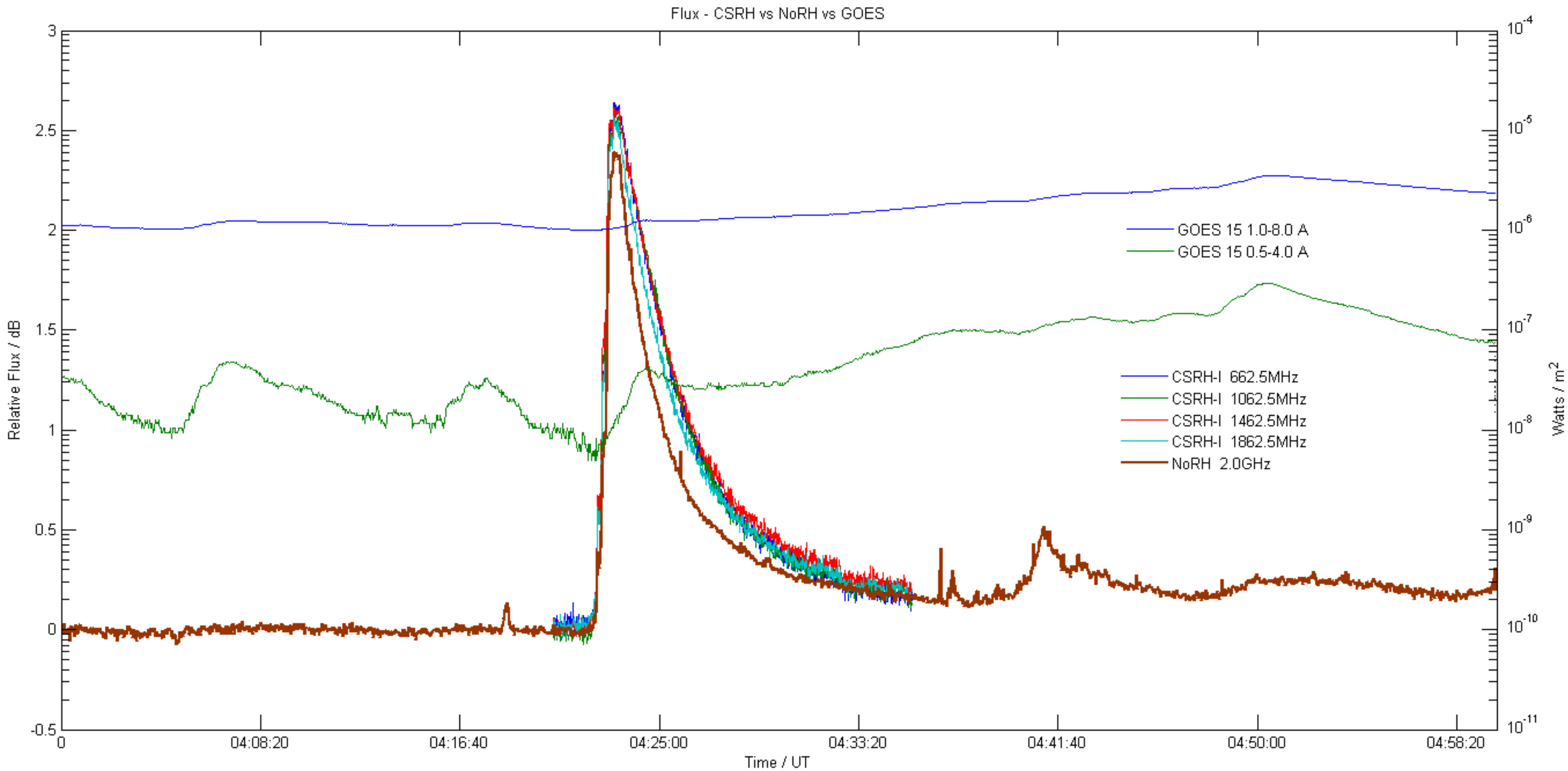
AR12129: Largest sunspot, energetic X-class two-ribbon flares, no CMEs (Hudson, 2014)



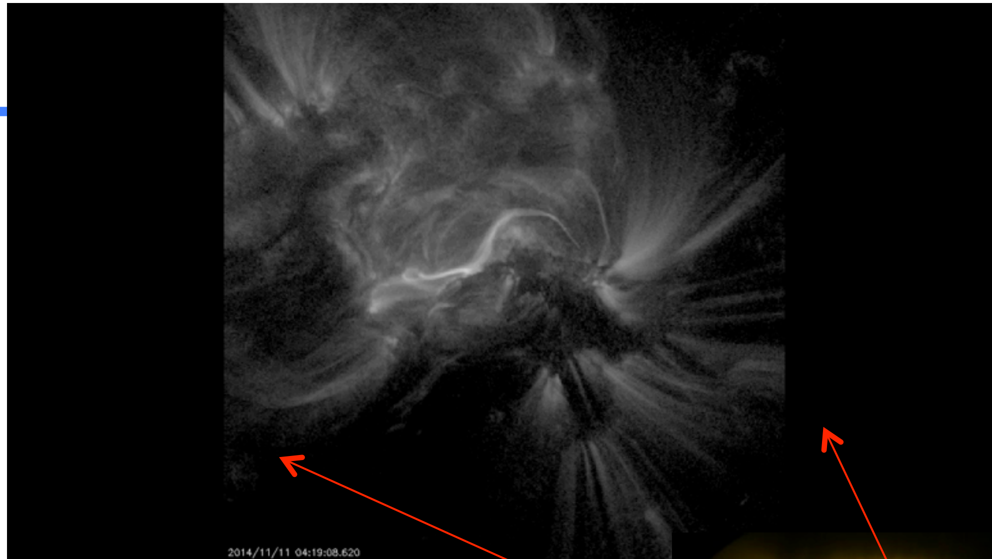


Solid line: GOES SXR flux
Dashed line: Difference of SXR flux
8×10⁻⁶
6×10⁻⁶
4×10⁻⁶
2×10⁻⁶
0
−2×10⁻⁶
−4×10⁻⁶
0
2
4
6
8
10
'olarimeters: Flux[R+L] (SFU)
9GHz 467+ 5297
17GHz 755+ 4179
02:00
04:00
06:00
Oct−14 21:19:59)
8.5G
15G
Radio bursts confined in high frequency band, agreeable with the scenario: low altitude activity, no CME
M
C
B
A
GOES15 1.0−8.
GOES15 0.5−4.0 A
Oct 22
Oct 23
05:10:14UT
Updated 2014 Oct 22 23:55:12 UTC
05:20:14UT
NOAA/SWPC Boulder, CO USA

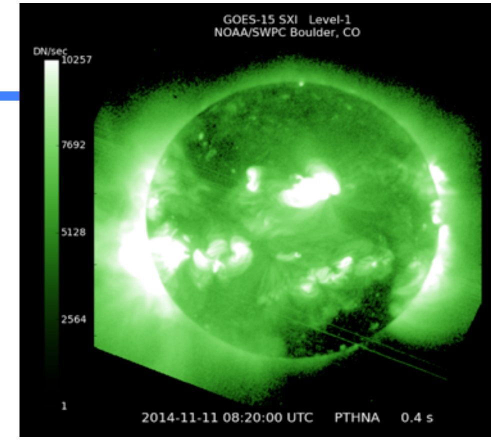
A solar flare and radio bursts on 11 Nov, 2014 (Yan et al 2016)



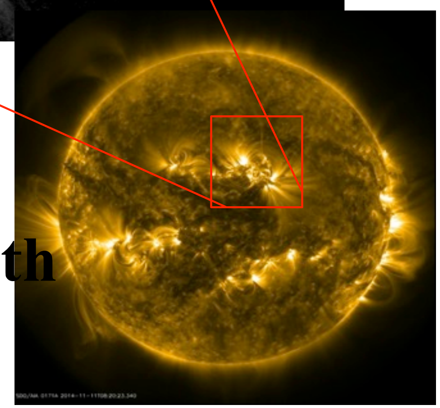
The solar flare starting at 04:22 on 11 Nov 2014



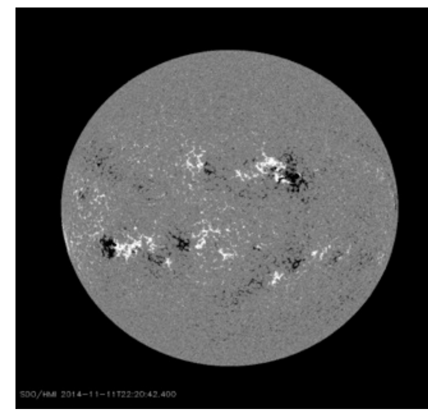
AIA131 movie



GOES SXR



AIA 171

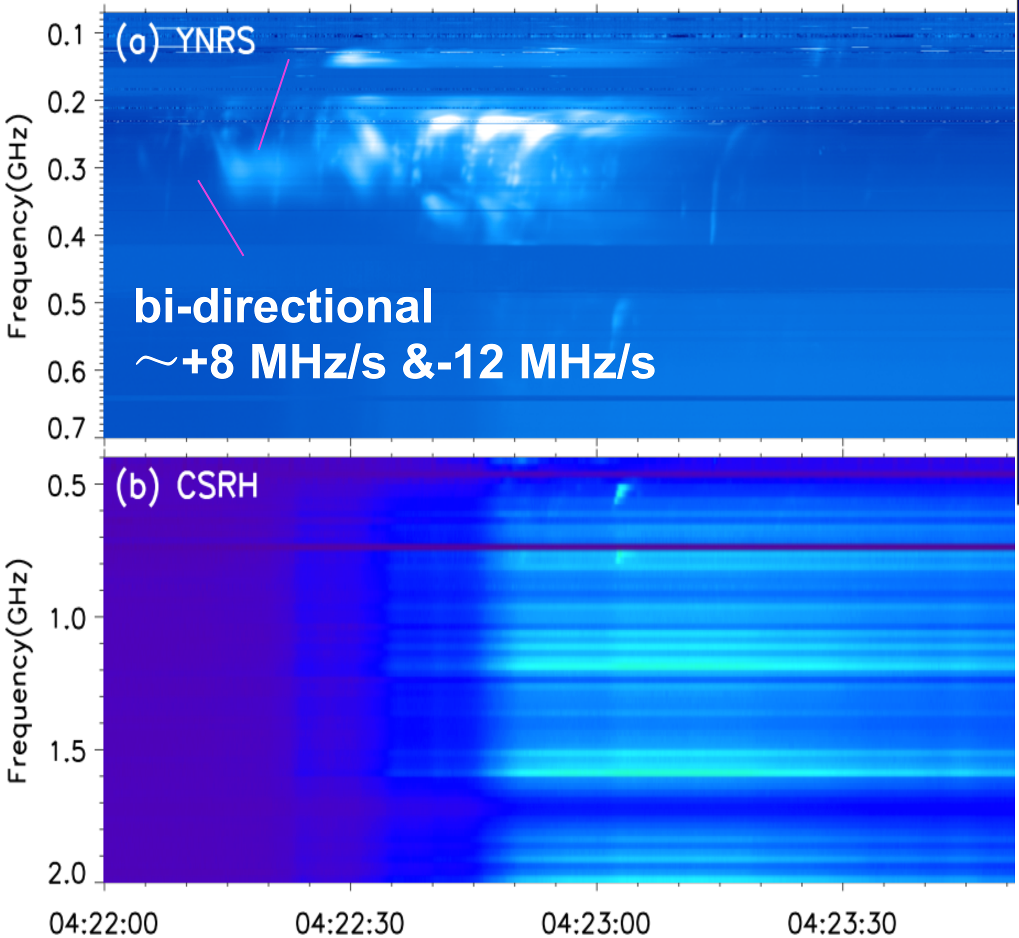


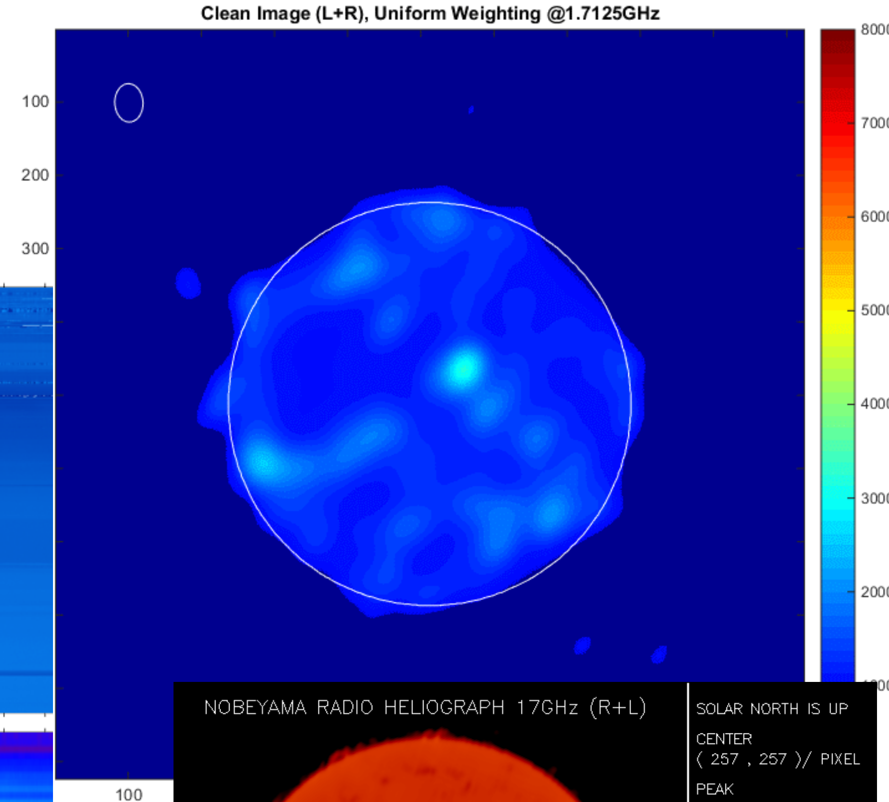
HMI / SDO

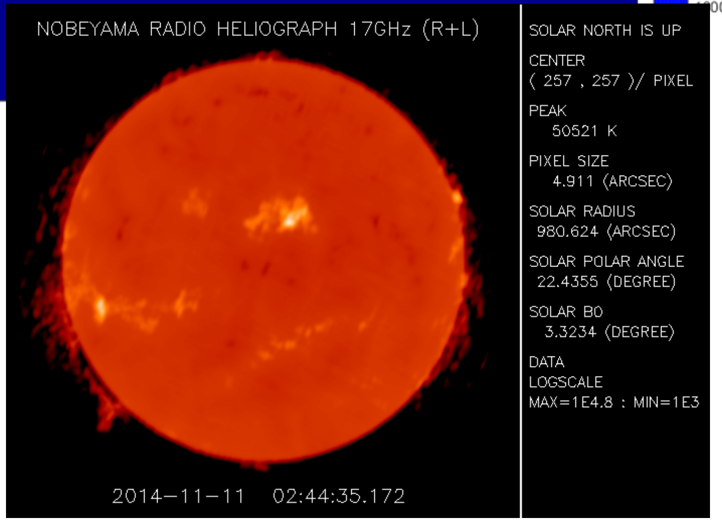
SGD associates the radio burst with the disk center flare event

200		B0422	0449	0606	LEA	1	FLA	N16W11	1F	ERU	2205
200		0422	0422	0423	LEA	G	RBR	245	730		2205
200		0423	0423	0423	LEA	G	RBR	1415	100		2205
200	+	0423	////	0424	CUL	C	RSP	018-430	III/1		2205

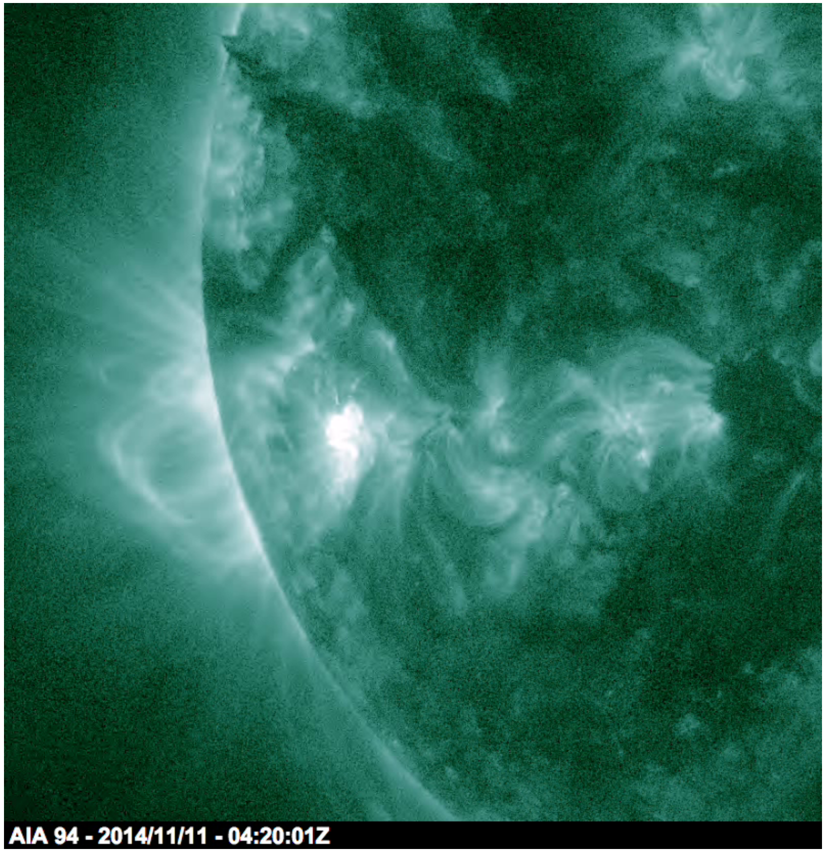
- **(L + R) polarizations (Preliminary results)**
- **04:21-04:24UT@10s interva & 3ms integral time**

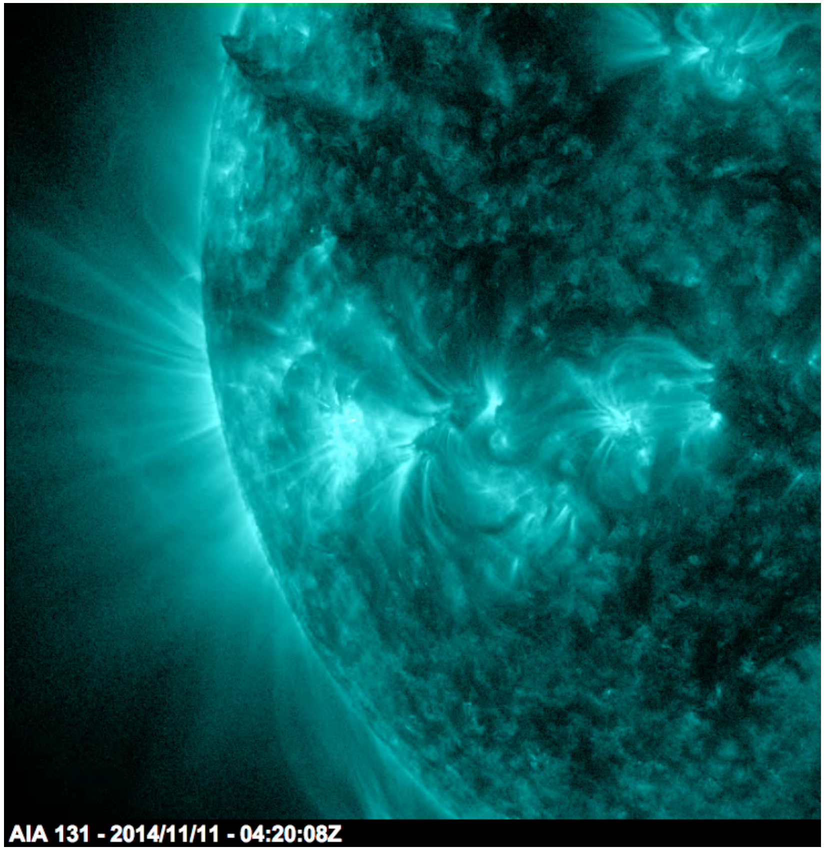




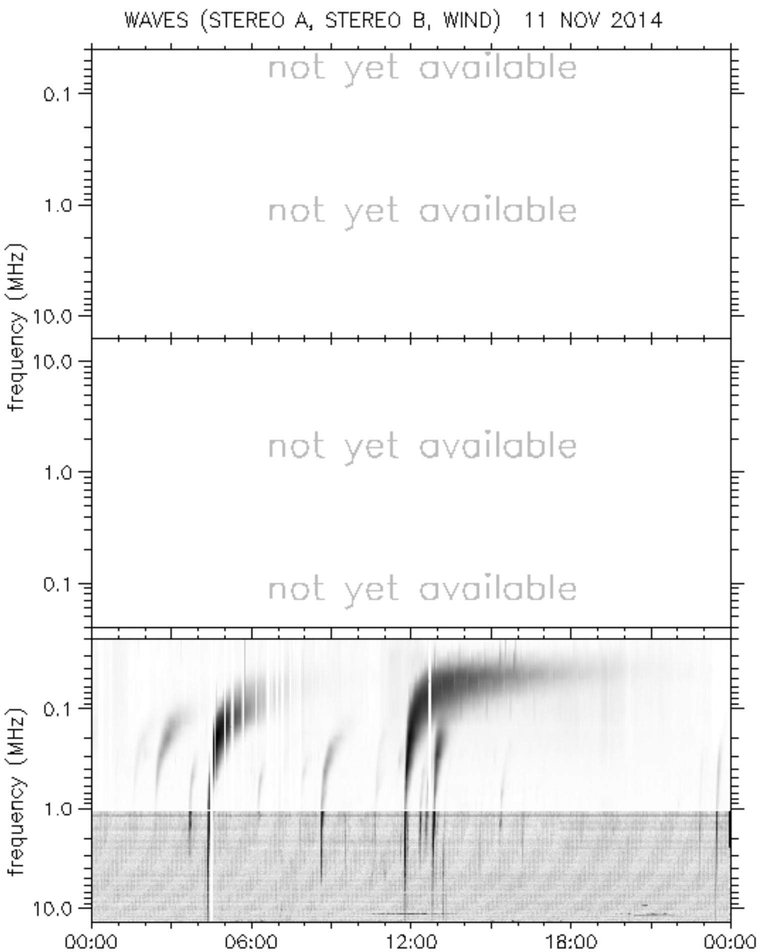


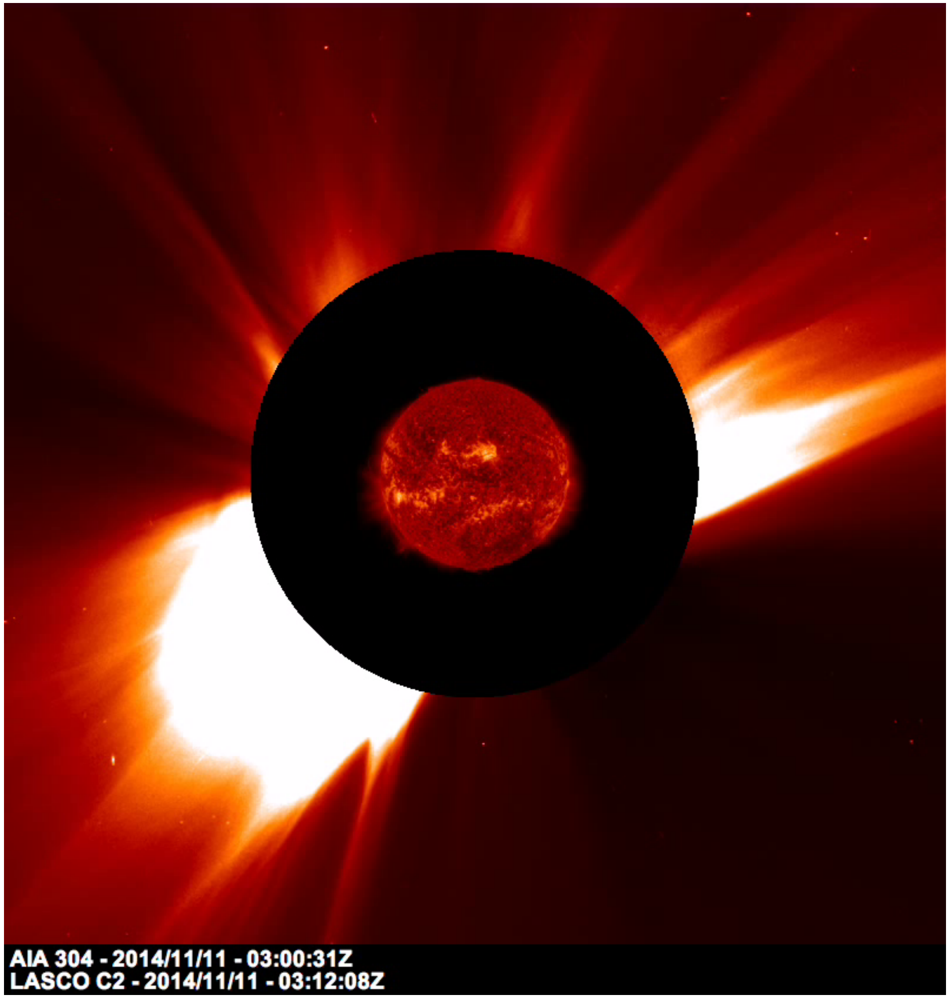
SDO/AIA observations indicate an eruptive process





LASCO / C2 & Wind radio bursts





(Solar Monitoring)

2014/11/11

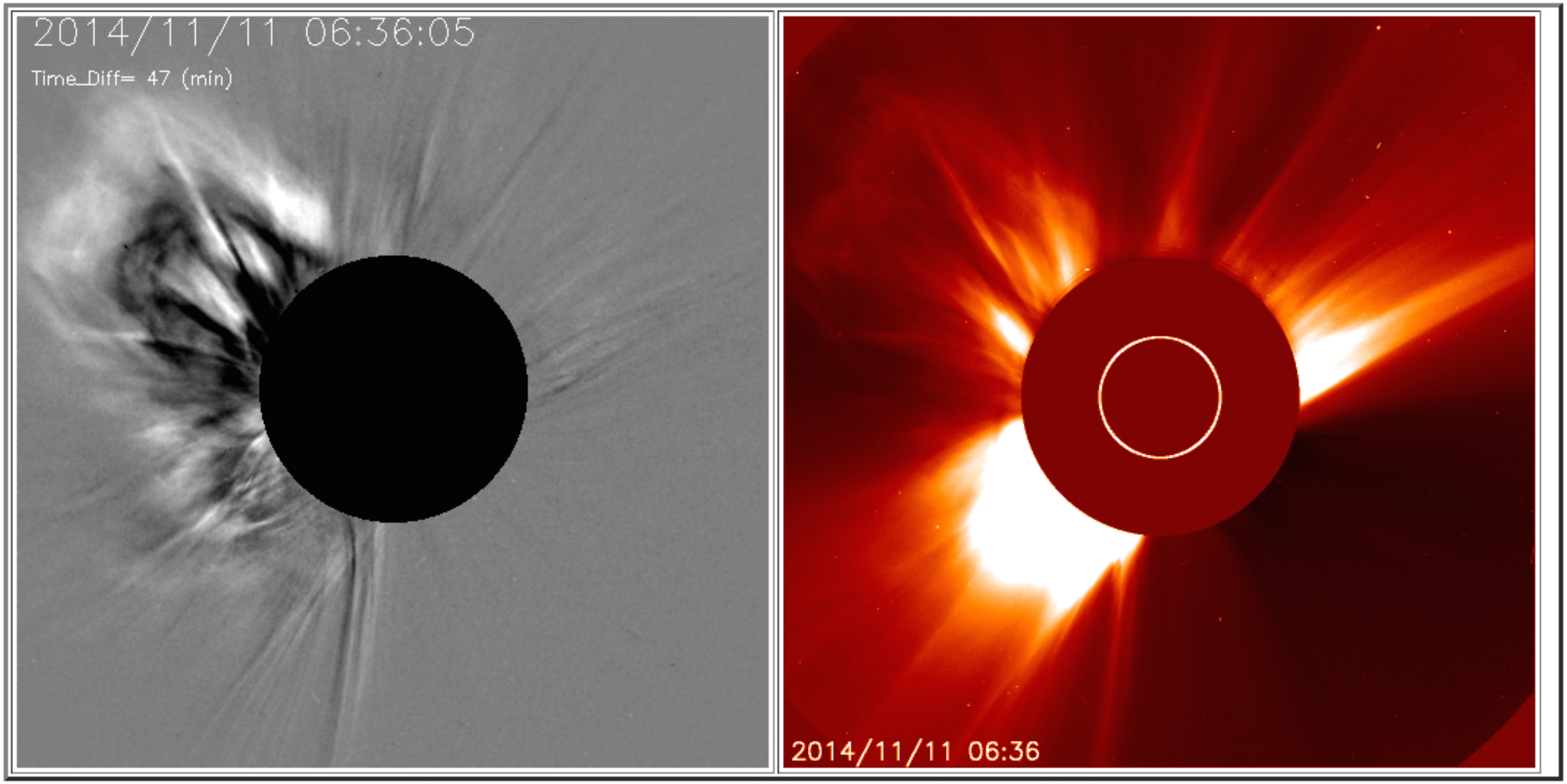


Image of the solar corona, taken by the LASCO coronagraph (C2) on the SOHO observatory

Start | Pause | Faster | Slower | Reverse | Rewind | Next | Prev.

Frame: Displaying 30 of 107 Speed: 1 (frames/sec)

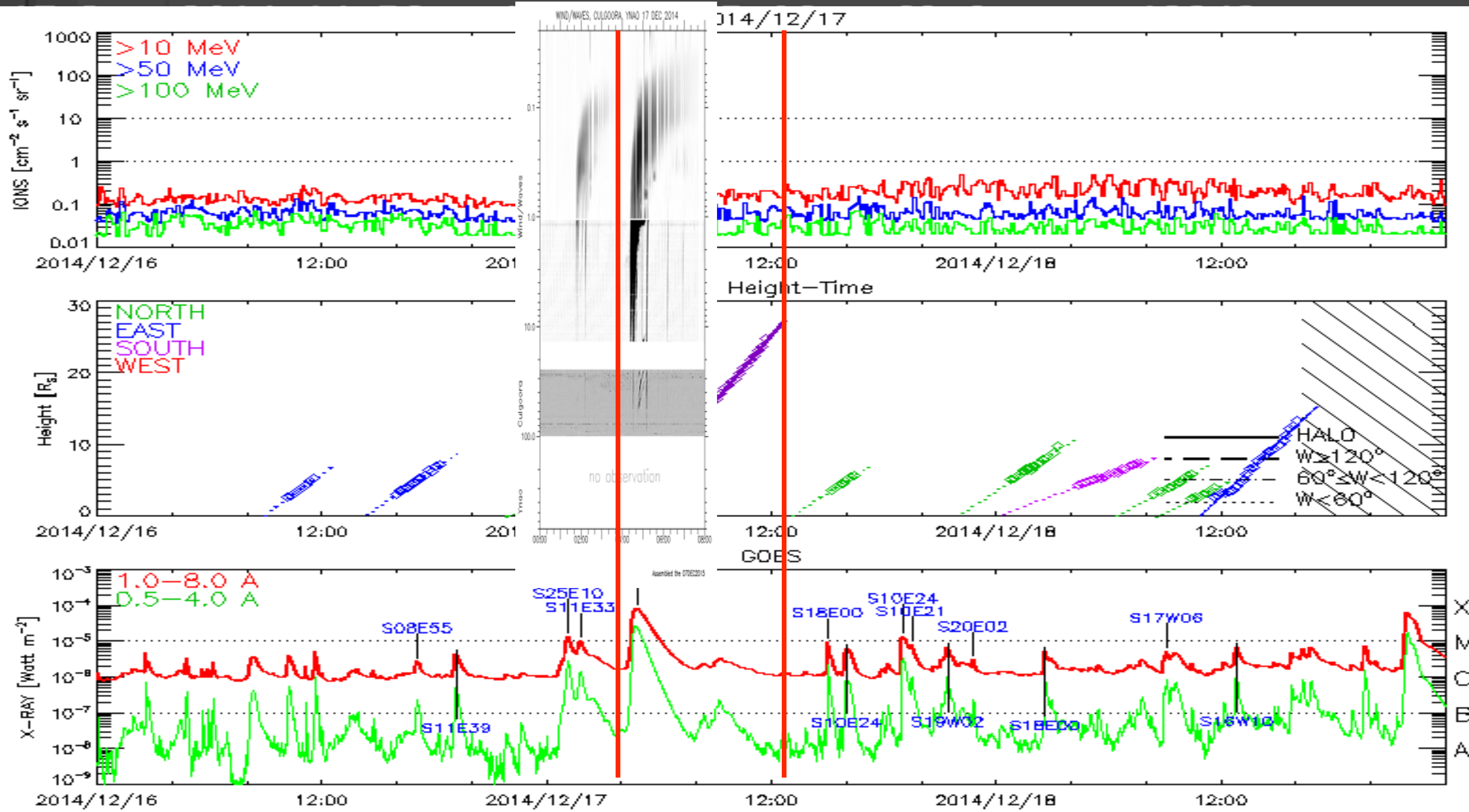
Monthly Table (2014/11)
Home

A M8.7 flare/CME event on 17 Dec 2014

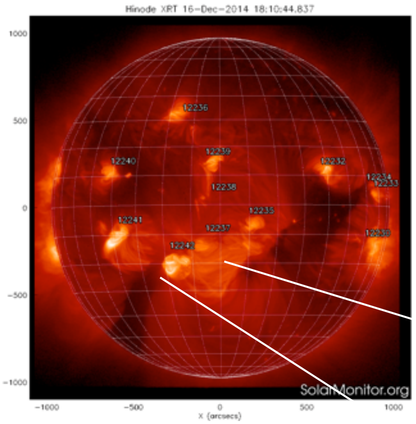
- **Coronal dimming & coronal EUV waves are usually associated with CMEs and as a signature for CME source regions (e.g.,Jin 2018).**
- **However, for this impulsive CME event, coronal dimming weak (?), coronal EUV waves not obvious (?)**

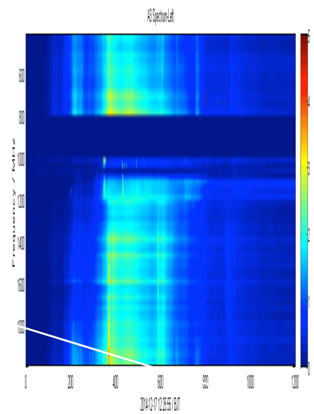
burst event on Dec 17 2014 for a M8.7 flare & CME

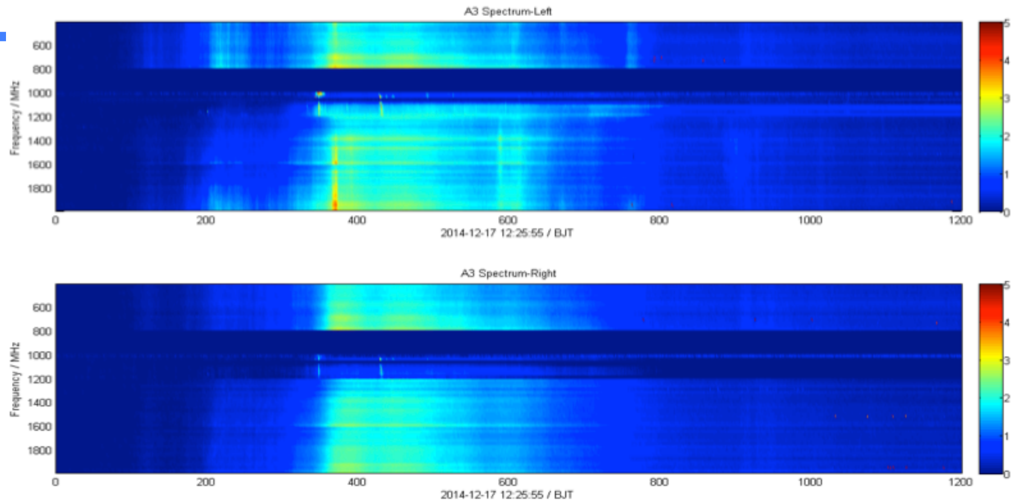
```
% GET_GEV: retrieving GEV data for 17-Dec-2014 00:00:00.000
17-Dec-2014 00:57    01:10    01:20    M1.5    S25E10    12242
17-Dec-2014 01:41    01:50    01:57    M1.1    S11E33    12241
17-Dec-2014 04:25    04:51    05:20    M8.7    S20E09    12242
```

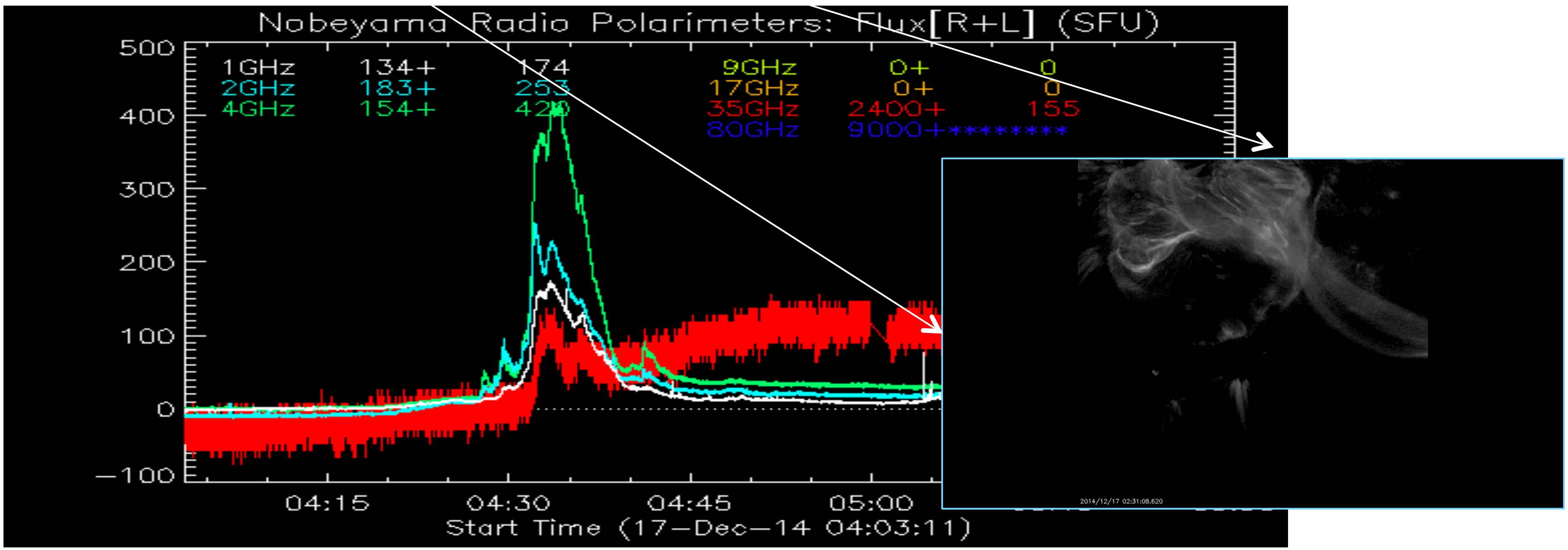


burst event on Dec 17 2014 for a M8.7 flare by MUSER-I (0.4-2 GHz)& NoRP (1,2,4,9,17,35 GHz)

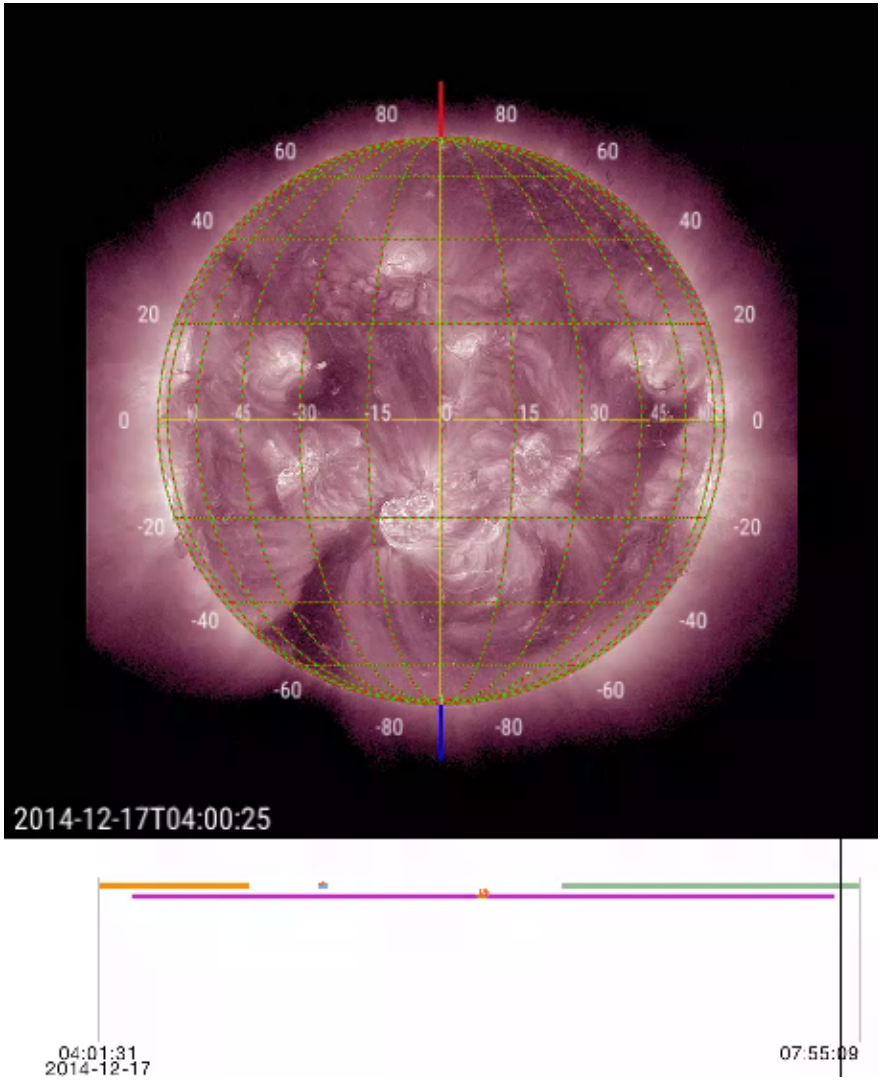


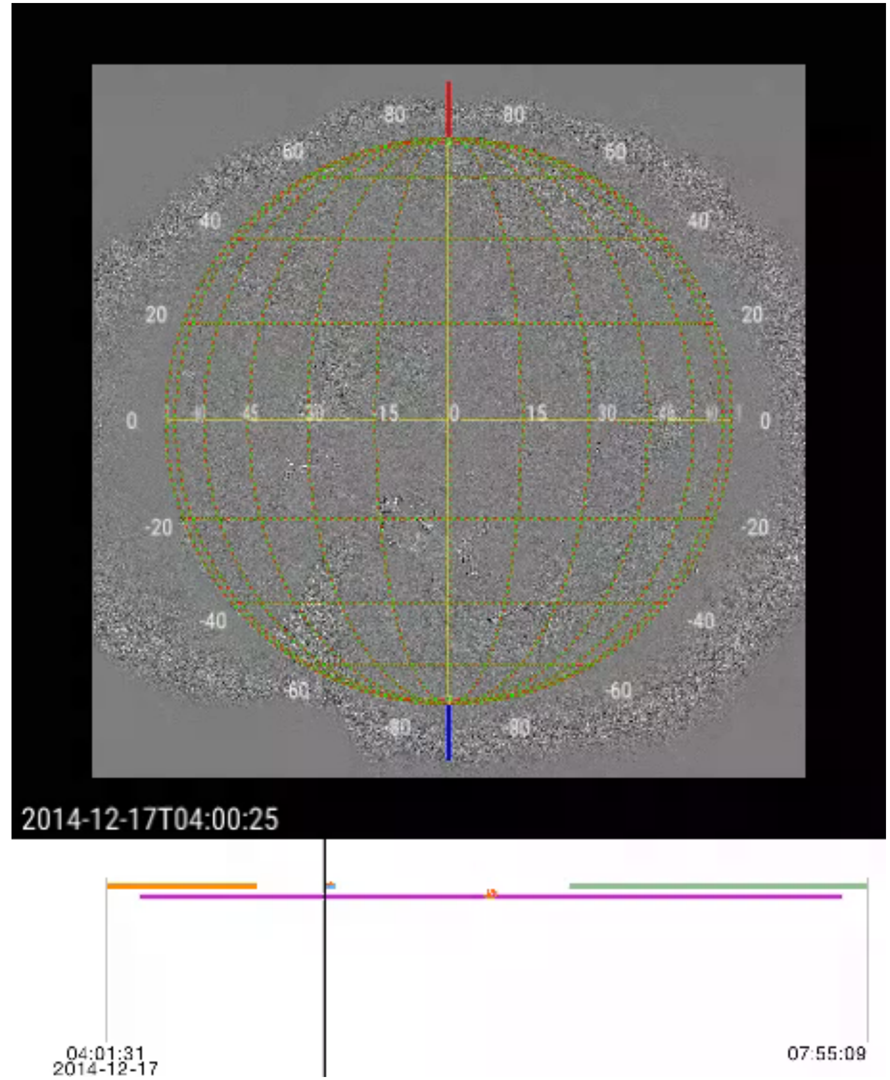




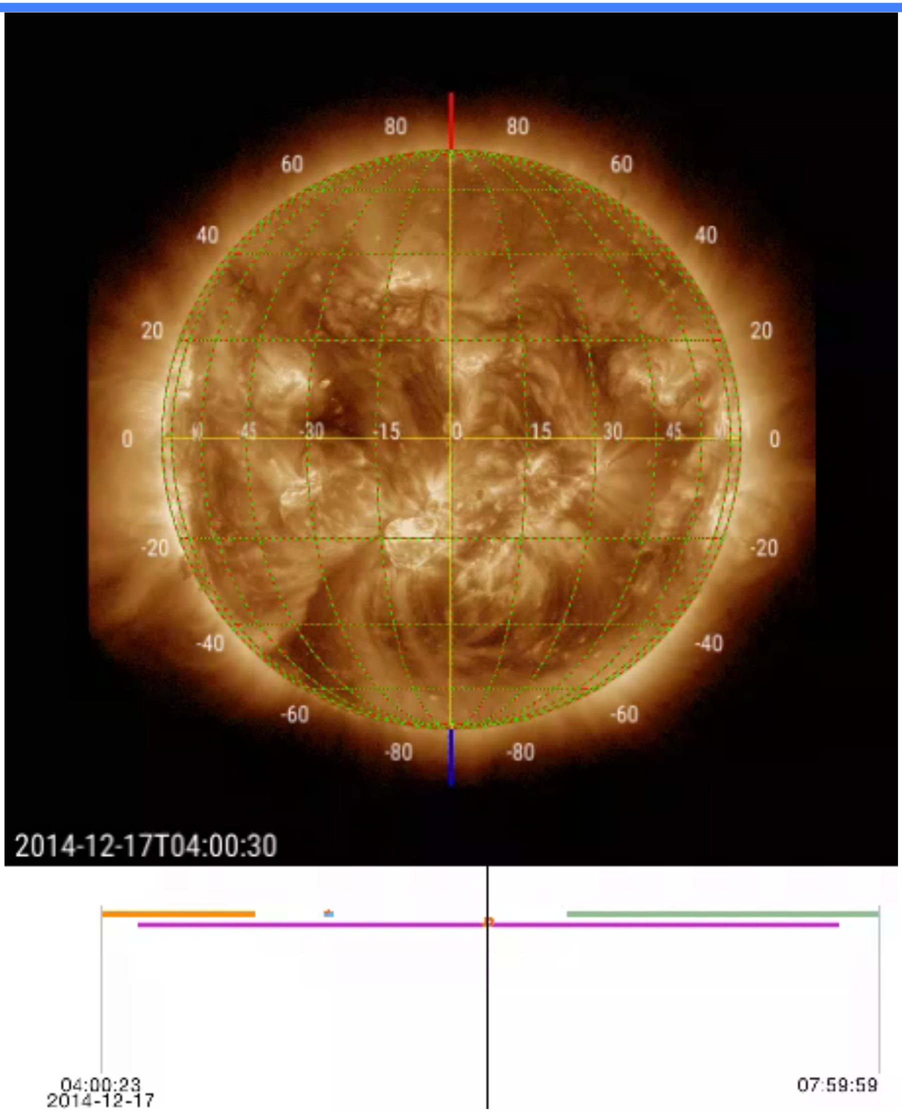


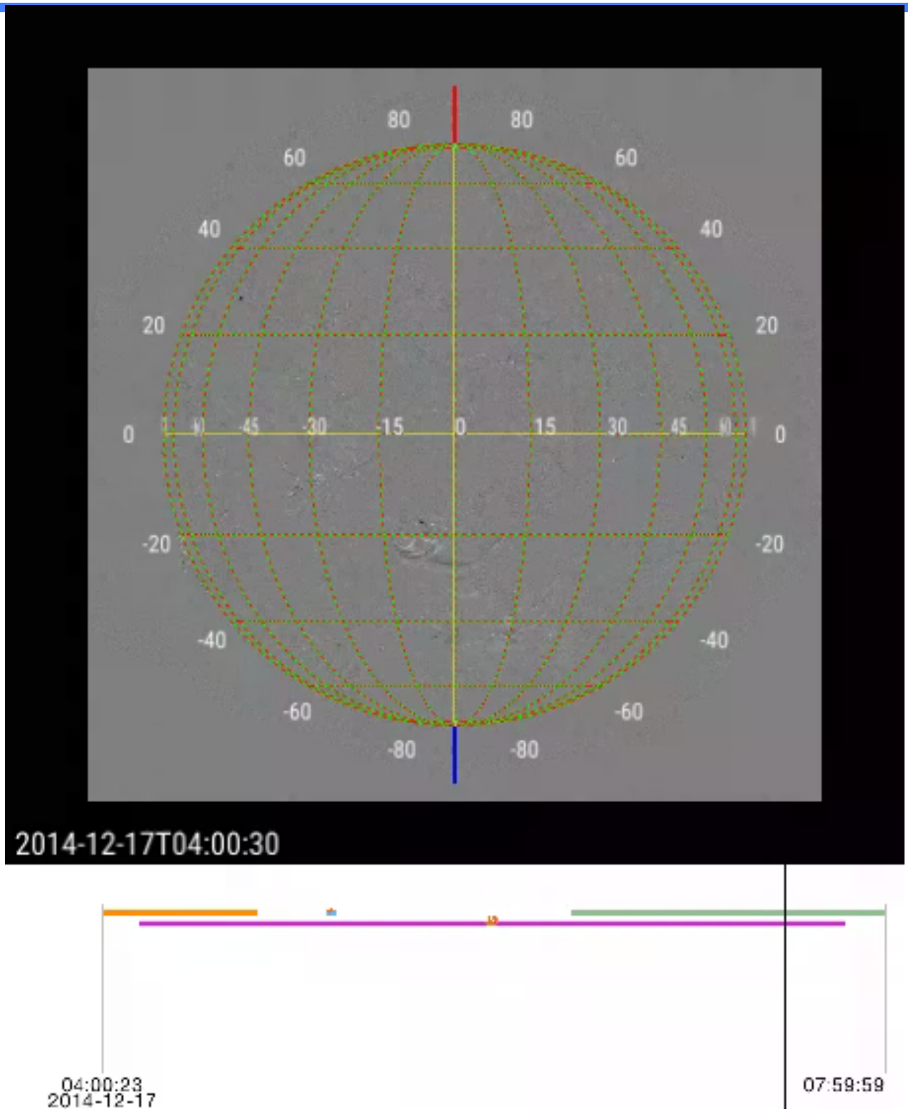
AIA/SDO 211A movie during 4-8 UT



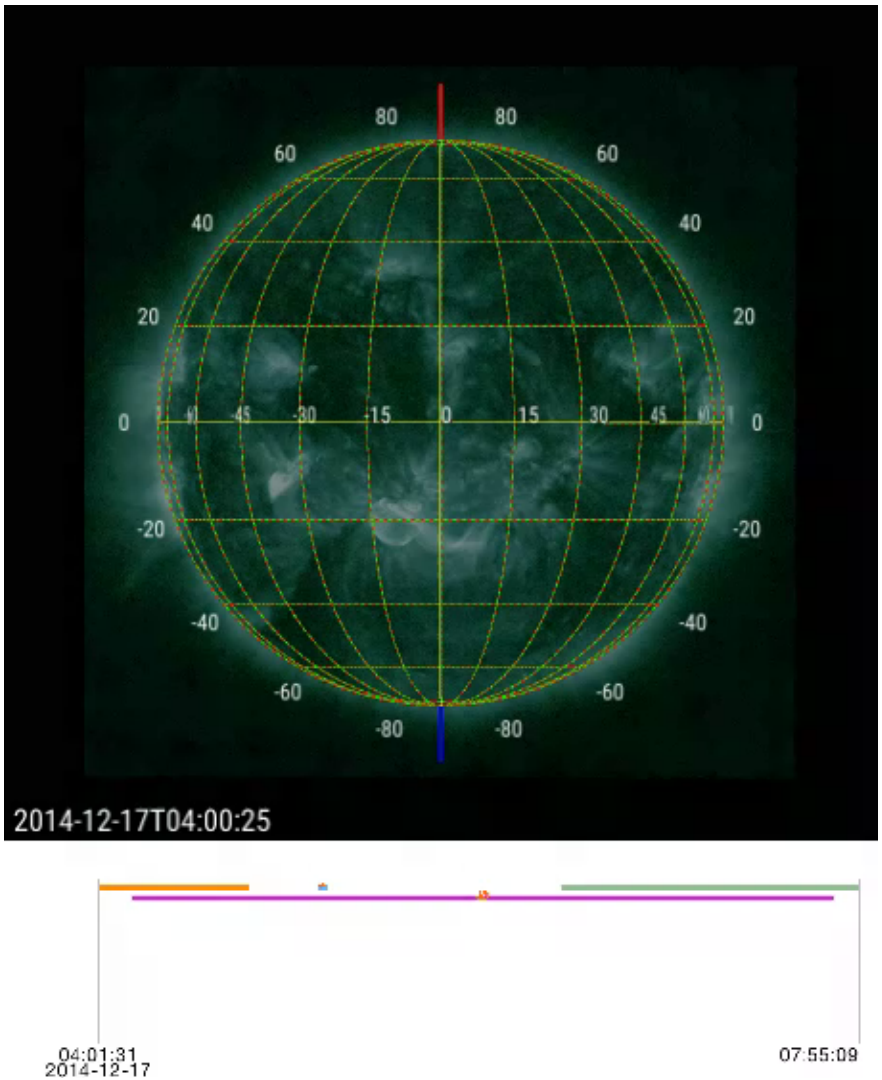


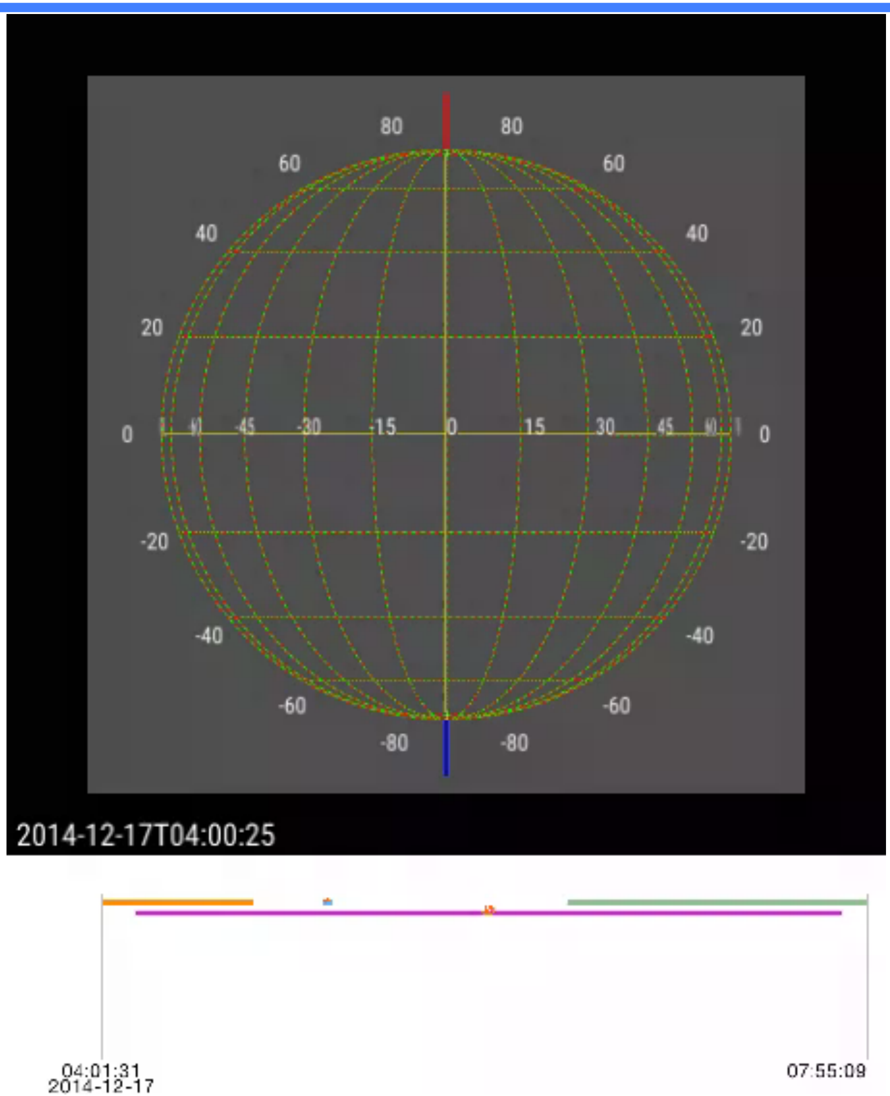
AIA/SDO 193A movie during 4-8 UT

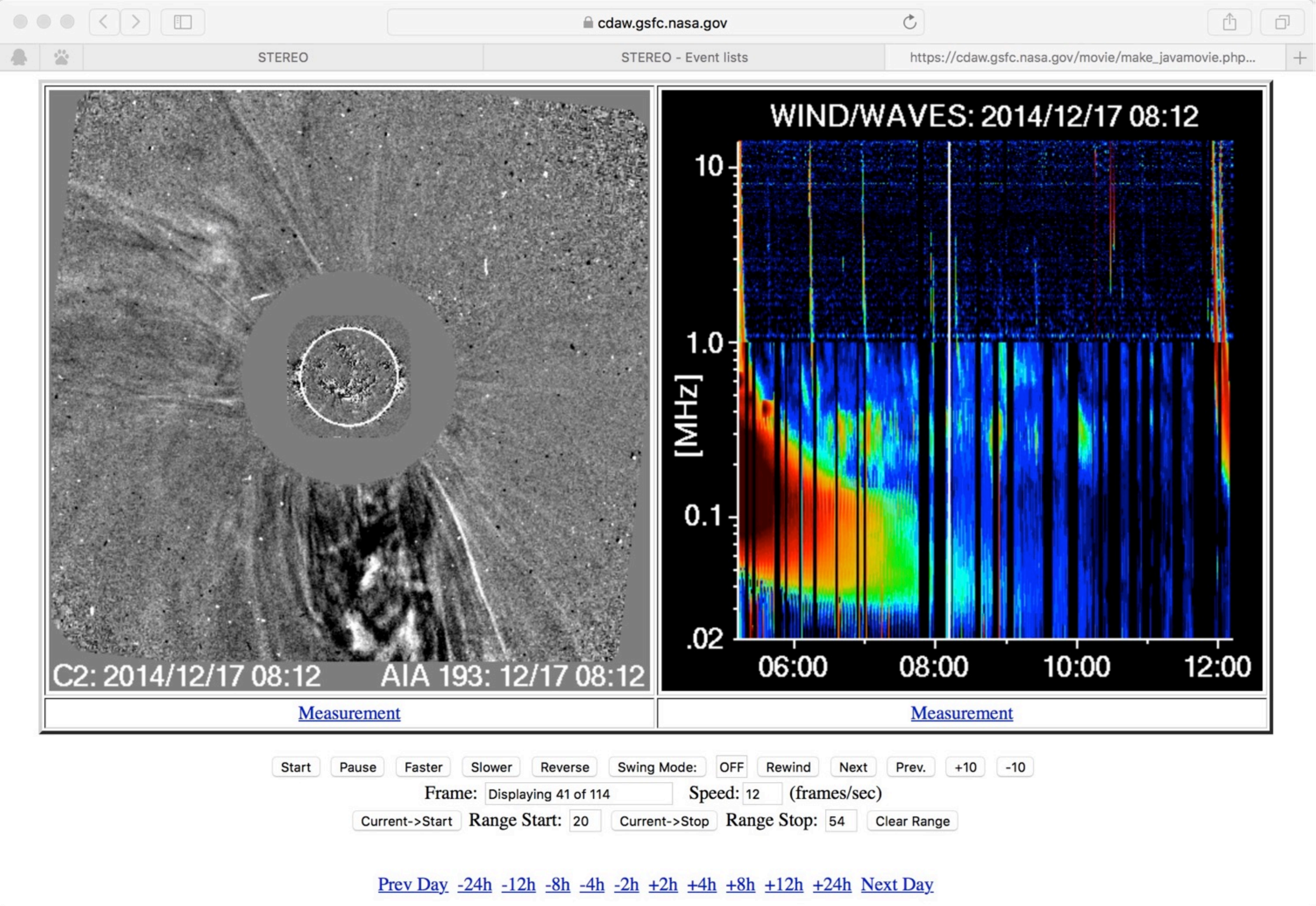


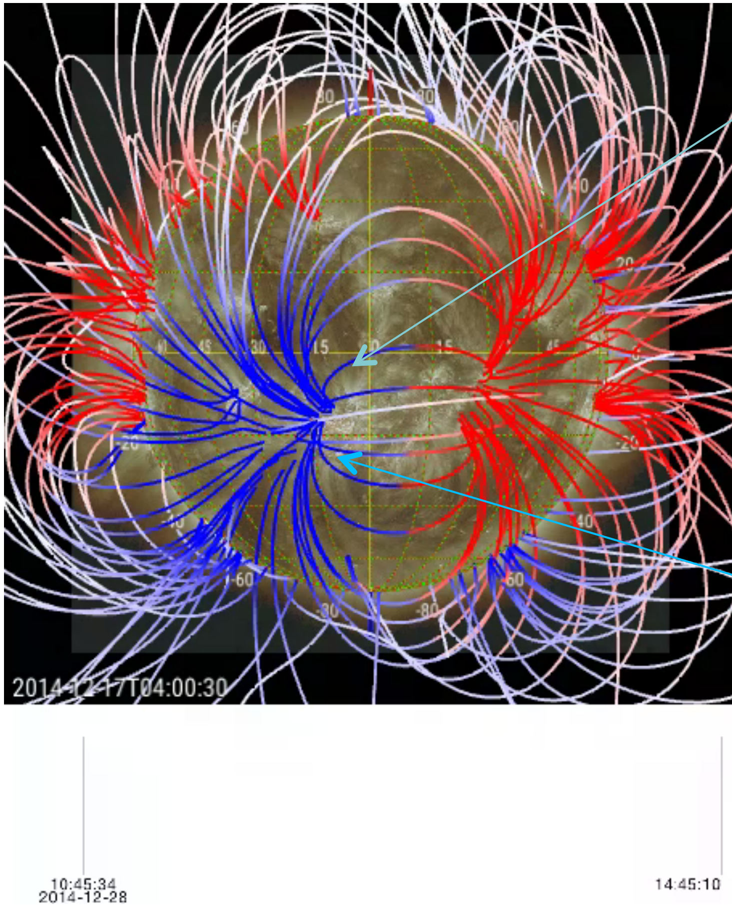


AIA/SDO 211A movie during 4-8 UT

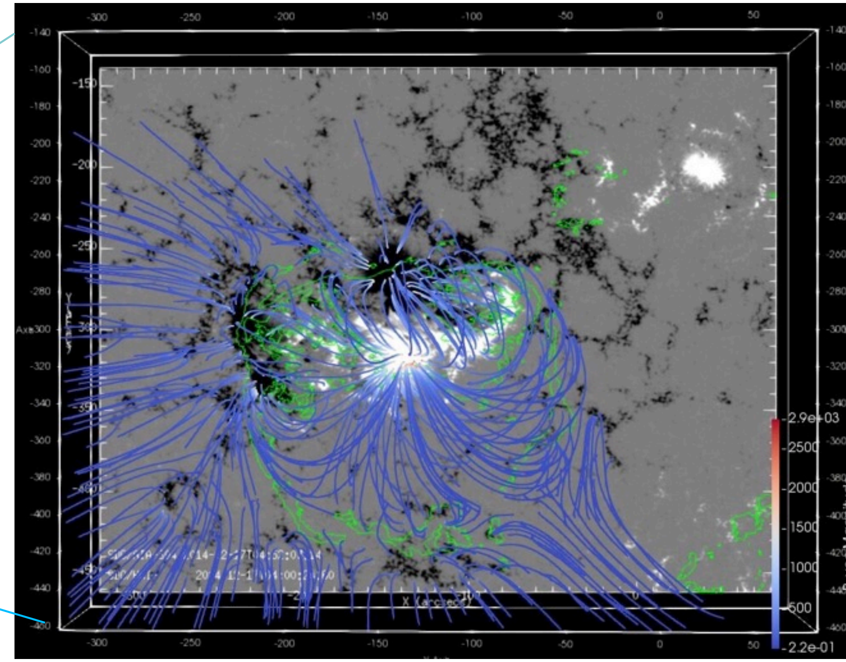





cdaw.gsfc.nasa.gov
STEREO
STEREO - Event lists
https://cdaw.gsfc.nasa.gov/movie/make_javamovie.php...
C2: 2014/12/17 08:12
AIA 193: 12/17 08:12
WIND/WAVES: 2014/12/17 08:12
10
1.0
0.1
.02
[MHz]
06:00
08:00
10:00
12:00
Measurement
Measurement
Start
Pause
Faster
Slower
Reverse
Swing Mode:
OFF
Rewind
Next
Prev.
+10
-10
Frame: Displaying 41 of 114
Speed: 12 (frames/sec)
Current->Start
Range Start: 20
Current->Stop
Range Stop: 54
Clear Range
Prev Day -24h -12h -8h -4h -2h +2h +4h +8h +12h +24h Next Day

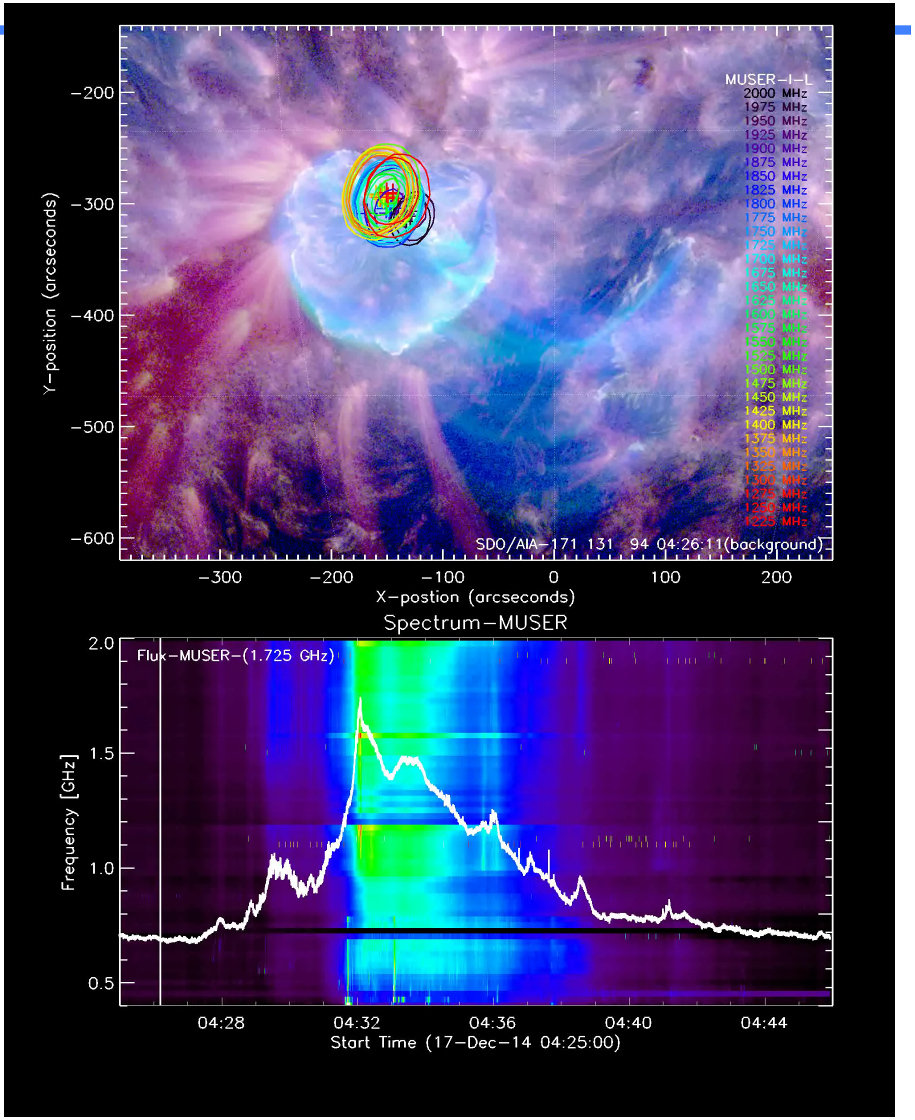

2014-12-17T04:00:30
10:45:34
2014-12-28
14:45:10

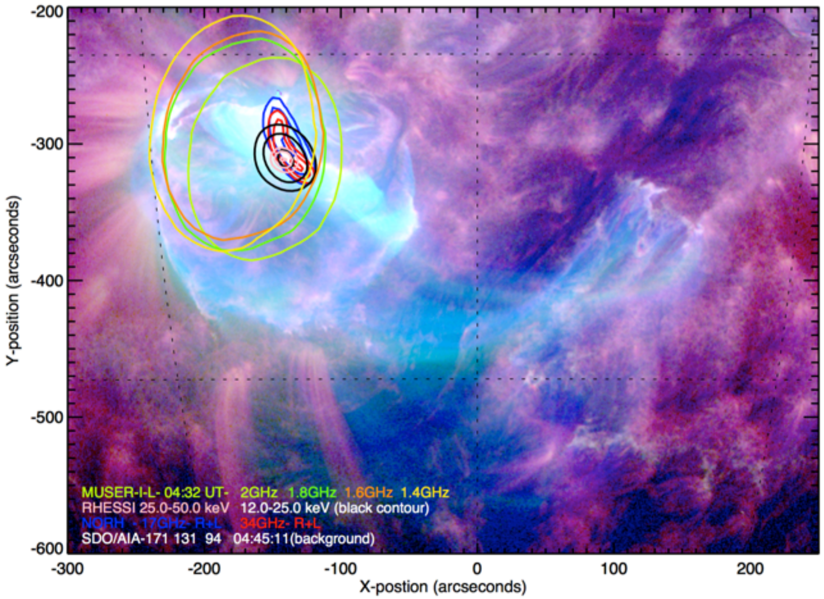
PFSS


B_vecMagnitude
2.9e+03
2500
2000
1500
1000
500
-2.2e-01

NLFFF

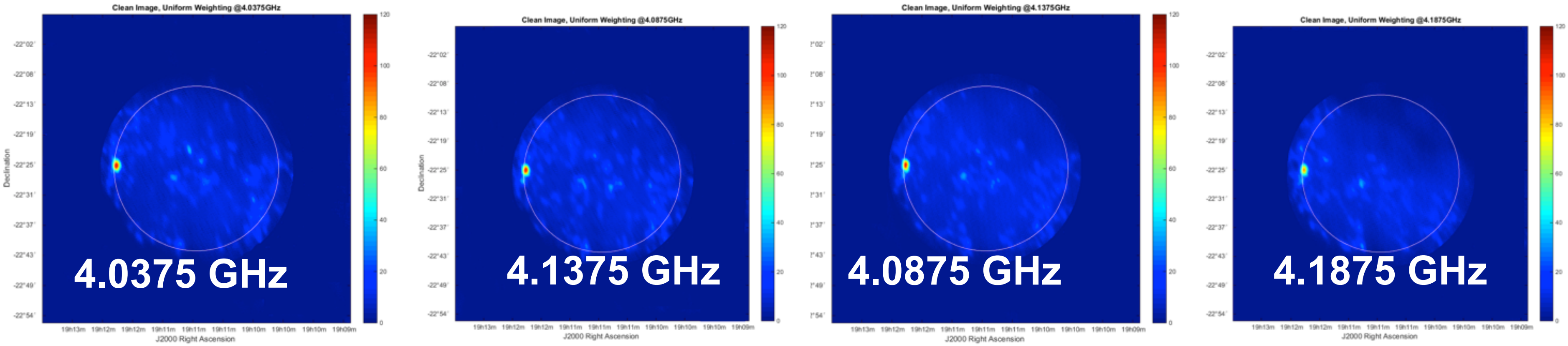
MUSER 0.4-2 GHz & RHESSI/NoRH Images



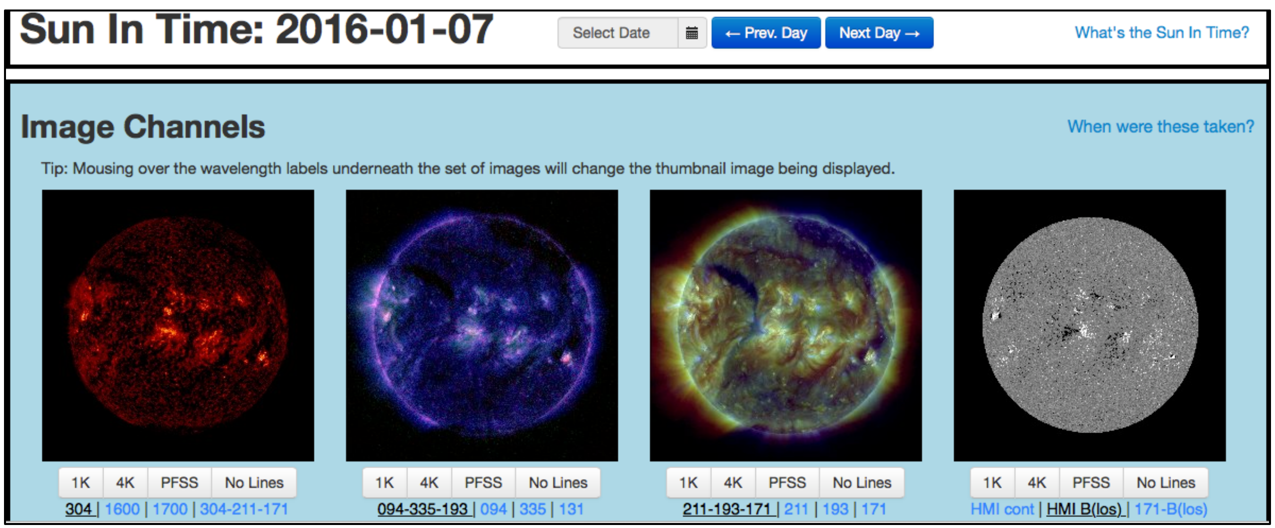


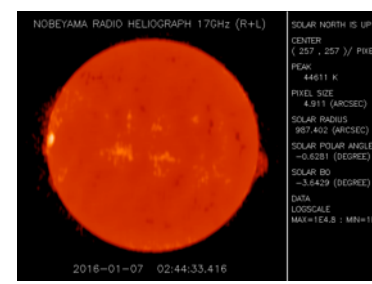
RHESSI HXR sources and NoRH 17/34 GHz sources confined at the low-lying central arcades whereas MUSER sources are extended over the doom and large-scale structures.

Initial result with MUSER-II of quiet Sun

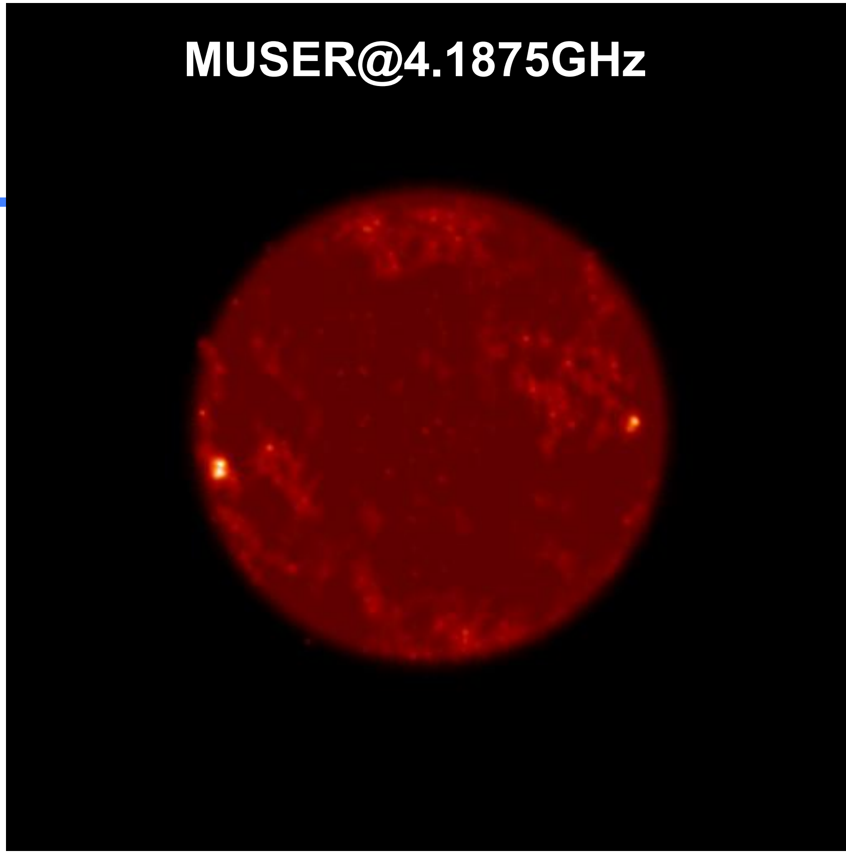


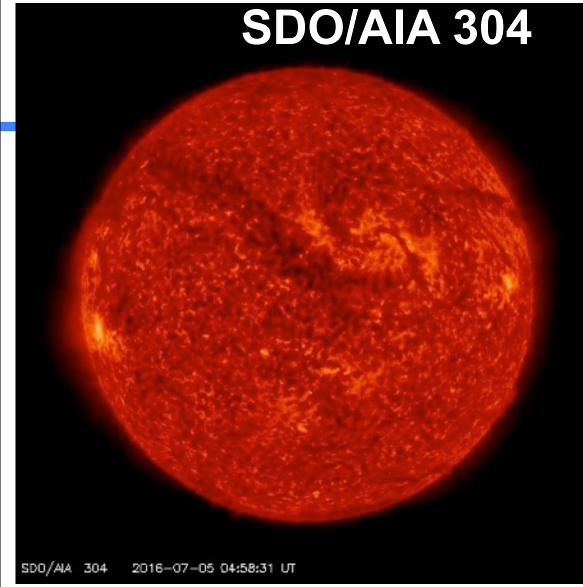
CSRH-II images @04:35 UT of the quiet Sun at 4.0375、4.0875、4.1375、4.1875 GHz and comparisons with SDO & NoRH 17 GHz observations on 7 Jan 2016.





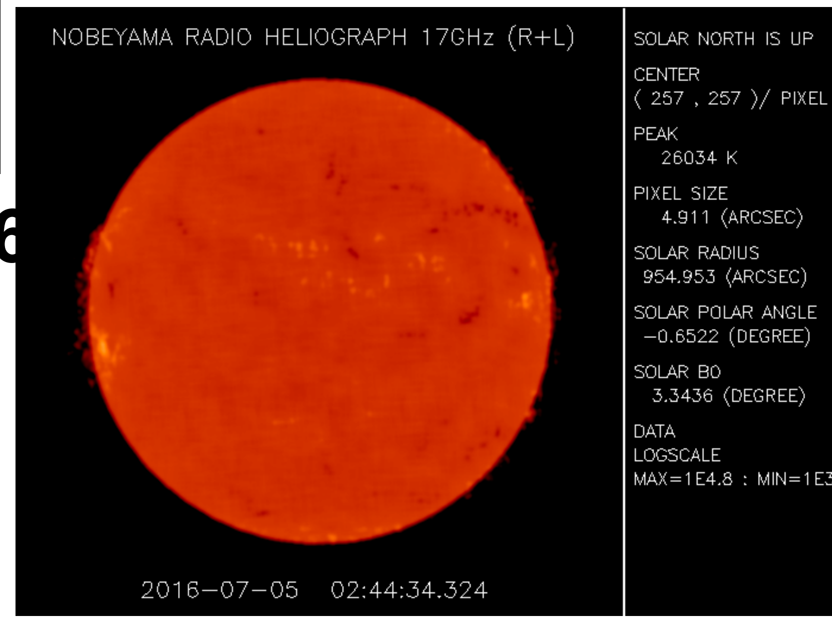
17 GHz





MUSER Data on July 5 2016

- **Quiet Sun.**
- **Time: 2 hours (3:04 – 5:04UT)**
- **Frequency: 4.1875GHz; Integration: 60ms / frame**



Meridian-II Project

National Science Infrastructure Project under "13th 5-year plan" program (2016-2020) has been approved.

Solar & Interplanetary Subsystem as a new part in Meridian-II:

- **Metric & decametric arrays in Tibetan Plateau (by NSSC) & Mingantu**
- **IPS telescope with 3 sites and 2 frequencies including major one at Mingantu**

Use 2 20 m antennas for MUSER-I Calibration

Add 2-3 ~15 m antennas for MUSER-II Calibration

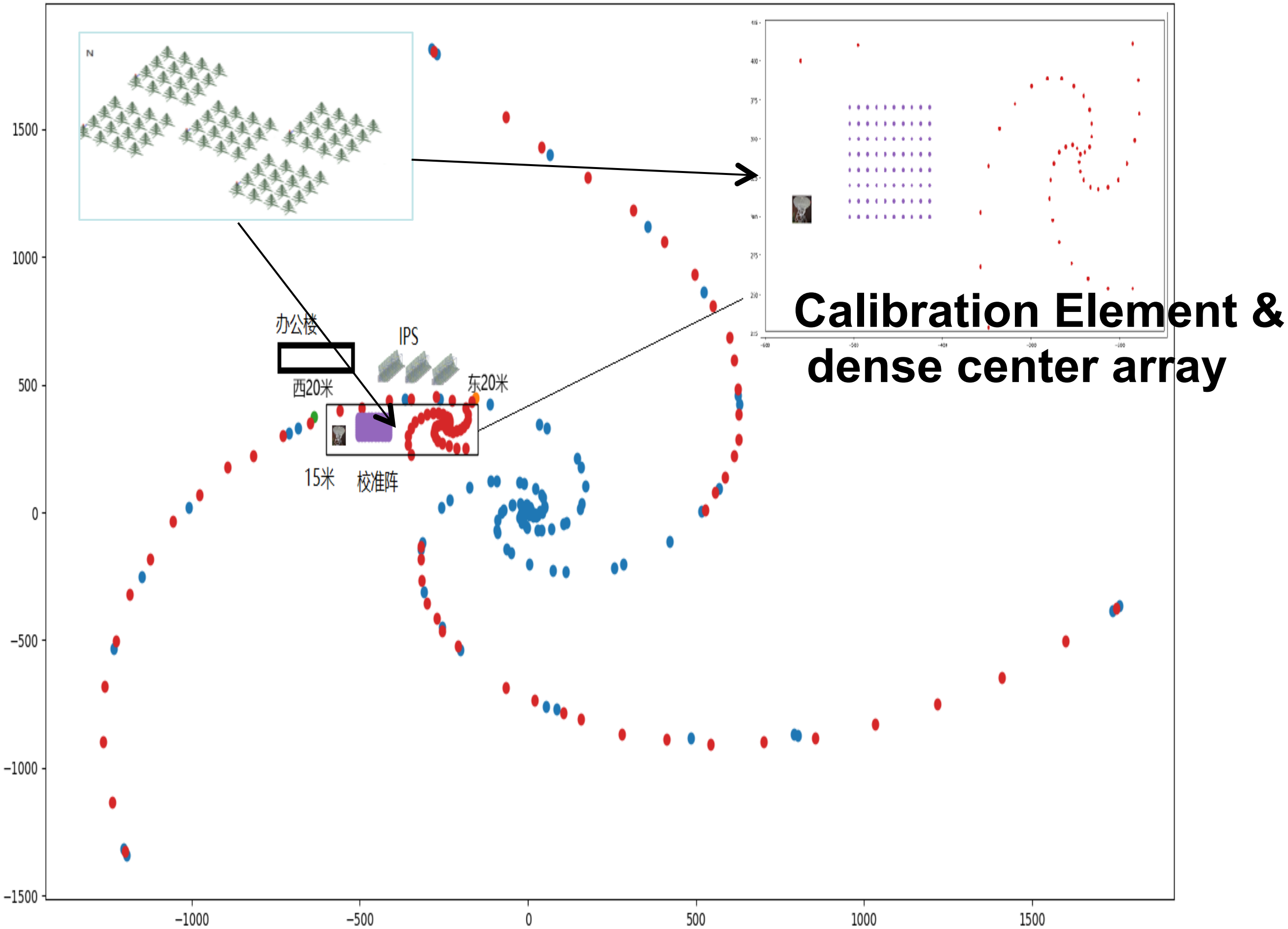
MUSER at metric & decametric wavelengths

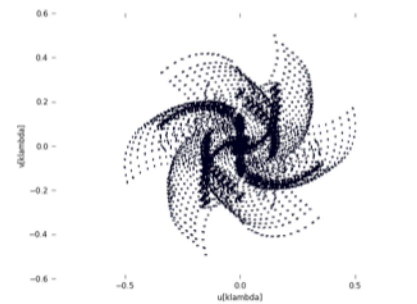
- Array of ~100 LPDA elements
- + 80 LPDA (as calibration element)
- Calibration element also use as spectrometer

Performances

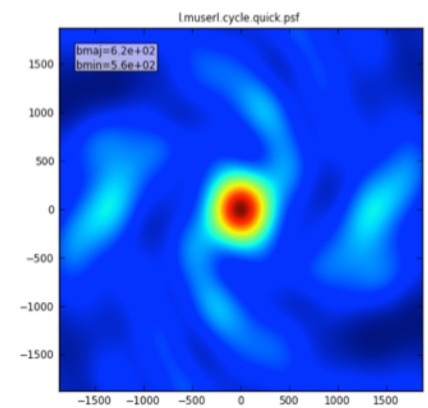
Freq range： 30 ～ 240 (400) MHz
Antennas： ～100 LPDA +
calibration element (80 LPDA)
Max baseline： ～3000 m
Δf： 1 ~5 MHz
Δt： ~100 ms
Δx： ～(1.0’) 1.7’－14’
Polarization： I、Q、U、V

MUSER at metric & decametric wavelengths





UV distribution



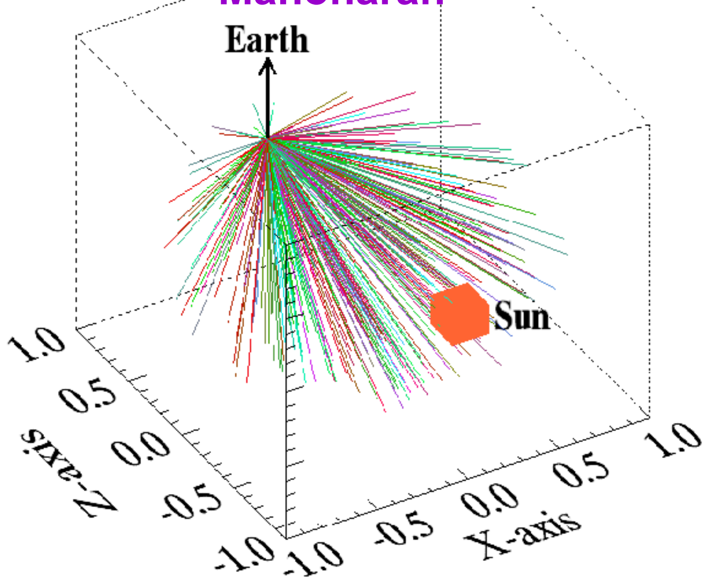
an array for heliospheric imager

Interplanetary scintillation (IPS)

Current facilities: (ORT, MEXART) 1 station with larger collecting areas
(ISEE) multiple-stations with intermediate size

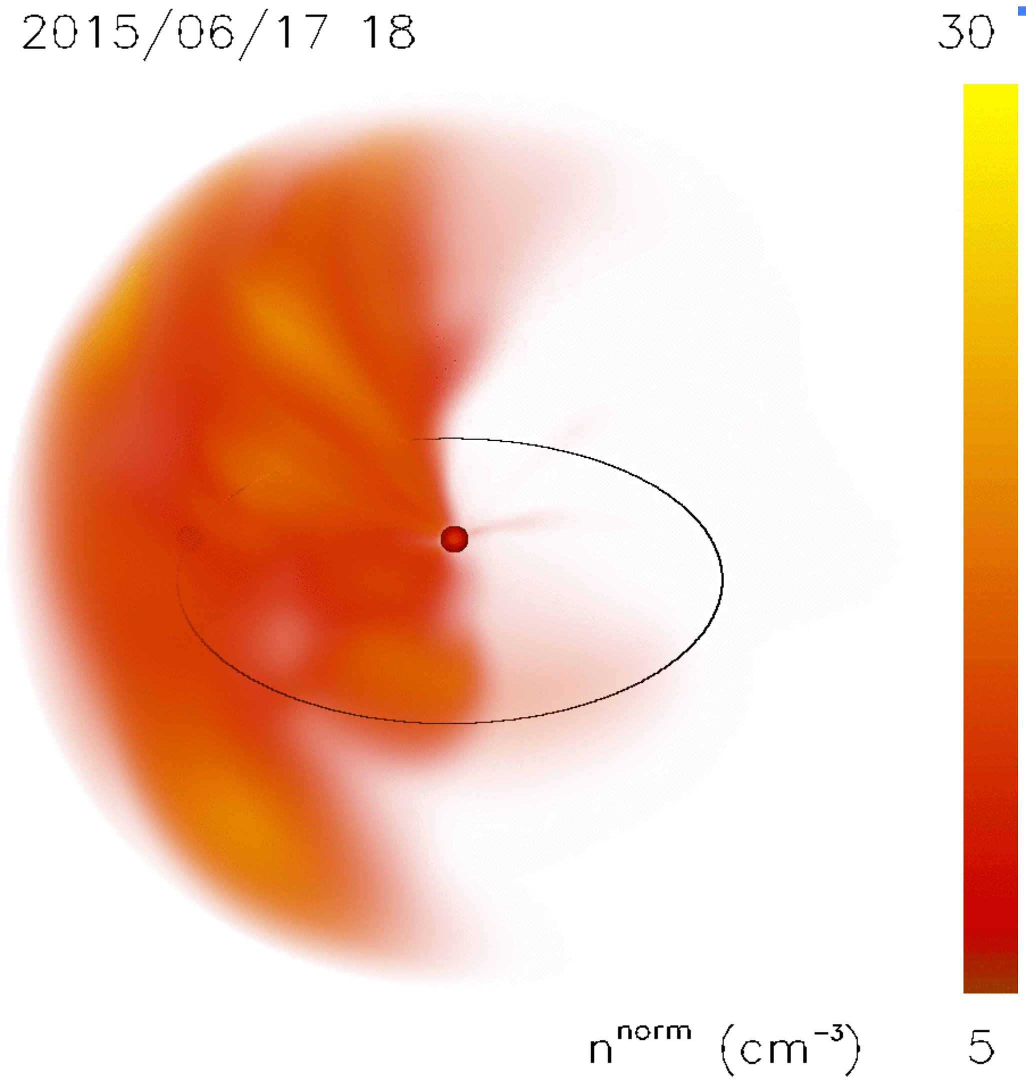
Single Station IPS	Multiple Station IPS
ORT: one 530*30 m antenna	**STEL: 3 100*20 ＋74∗27 m antennas**
~1000 radio sources	**~100 radio sources**
Vsw deduced from model	**Vsw deduced from measurement**

Lines of sight – typically observed in a day
By Ooty telescope (2-AU cube)---
Manoharan



So, IPS technique applies "CT" to reconstruct 3-d solar wind structure. It would desire to achieve direct measurements from observing more radio sources!

Ooty IPS – 3-D Reconstruction



(Courtesy of Manoharan)

Features for IPS Observation

- Larger collecting area: to observe more radio sources
- Multi-sites: to measure the projected solar wind parameters directly.
- With dual-frequency:
  1. Achieve higher accuracy in the calculation of the characteristic frequency
  2. Reduce the effects from the variation of the solar wind parameters
  3. Obtain higher sensitivity

A new Telescope Concept

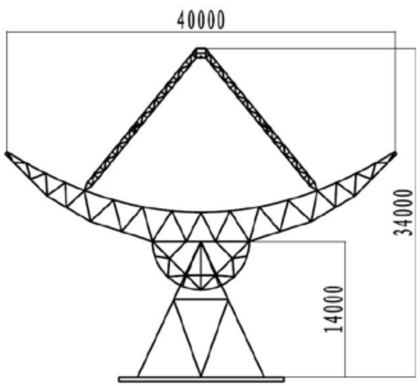
A new solution is proposed:

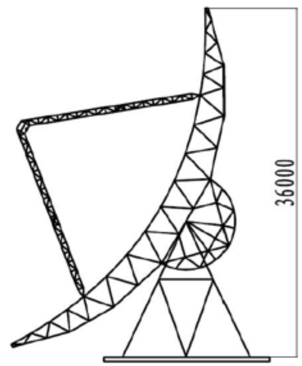
- The whole IPS telescope consists 3 sites, one main site and 2 sub-site.
- Main site: 3 cylinder antennas placed side by side, and size of each antenna is 140m in N-S direction and 40m in E-W direction; plus available 20m parabolic antenna.
- Sub site: a 15~20m parabolic antenna with cryogenically cooled receiver.

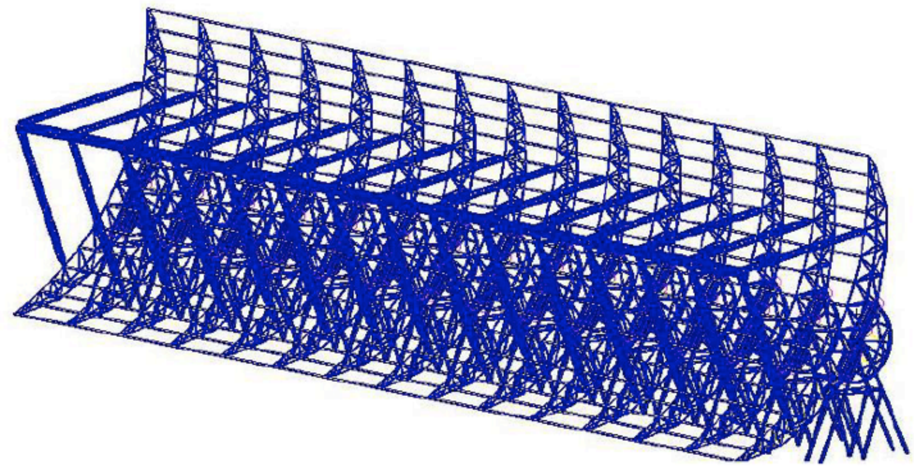
Specification

Antenna	Main site: 140m*40m*3 cylinder, 20m dish Sub site1: 16m, dish Sub site2: 16m, dish
Frequency	327MHz, 654MHz,1420MHz (for dishes)
System temperature	Main site: 110K Sub site1: ~120K Sub site2: ~120K
Antenna Effiency	Main site: ~65% Sub site1: ~70% Sub site2: ~70%
Sensitivity	~4.4mJy@1s, ~167 mJy@1s, ~261 mJy@1s
Band Width	40MHz (adjustable)

Three Station Chinese IPS Telescopes







- **Mingantu IPS Main Station:** **3 * 140 m (NS) * 40 m (EW) cylinders with collecting area ~> Ooty telescope**
  + Φ20m steerable parabolic antenna （available）
- **Sub-stations:** **Φ15~20m steerable parabolic antenna**

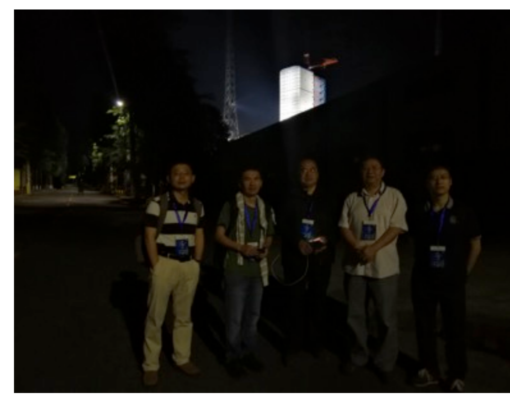
(Profs. Ramesh and Manoharan are gratefully acknowledged for comments and suggestions to improve the design for Chinese IPS telescope)

Array arrangement

NCLE on Chang'E-4 Relay Satellite

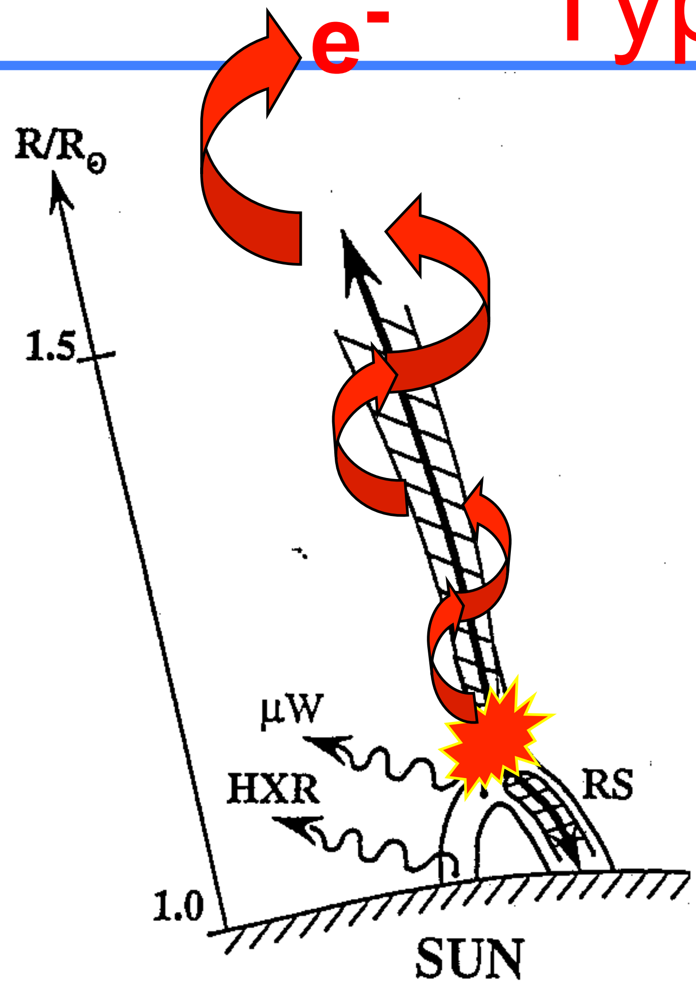
80 kHz - 80 MHz

NCLE team after launch

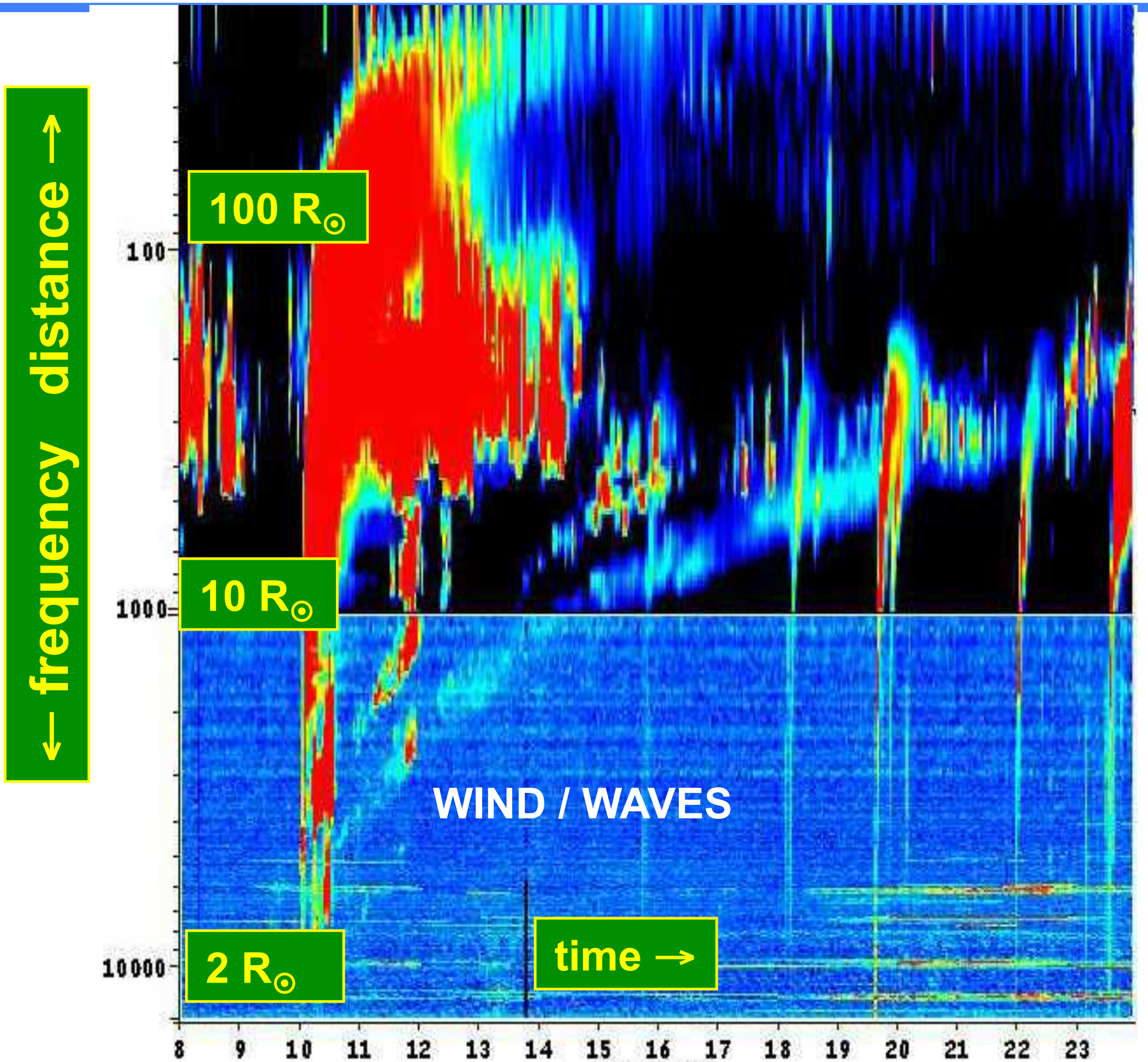


Chinese team before launch

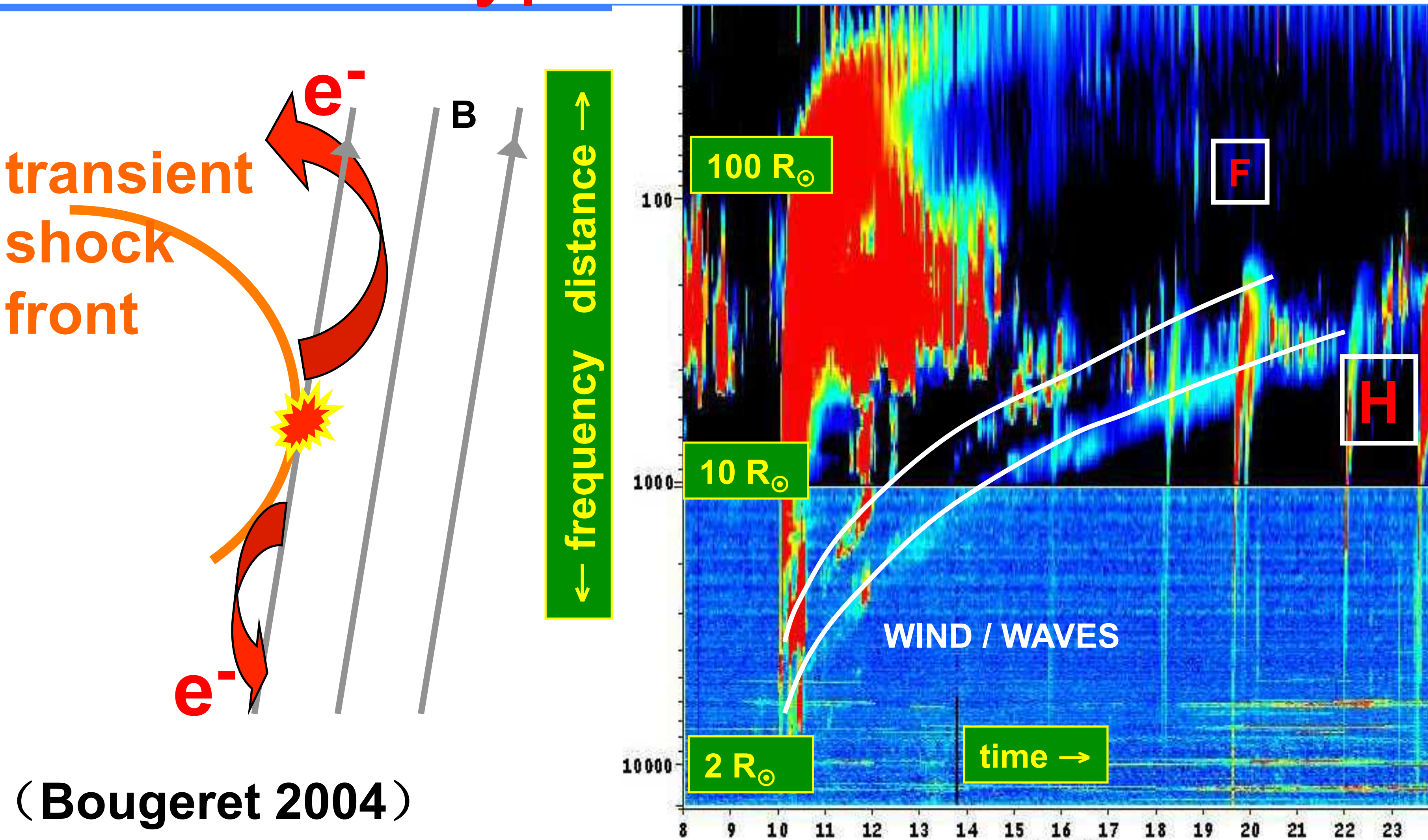
Type III Bursts



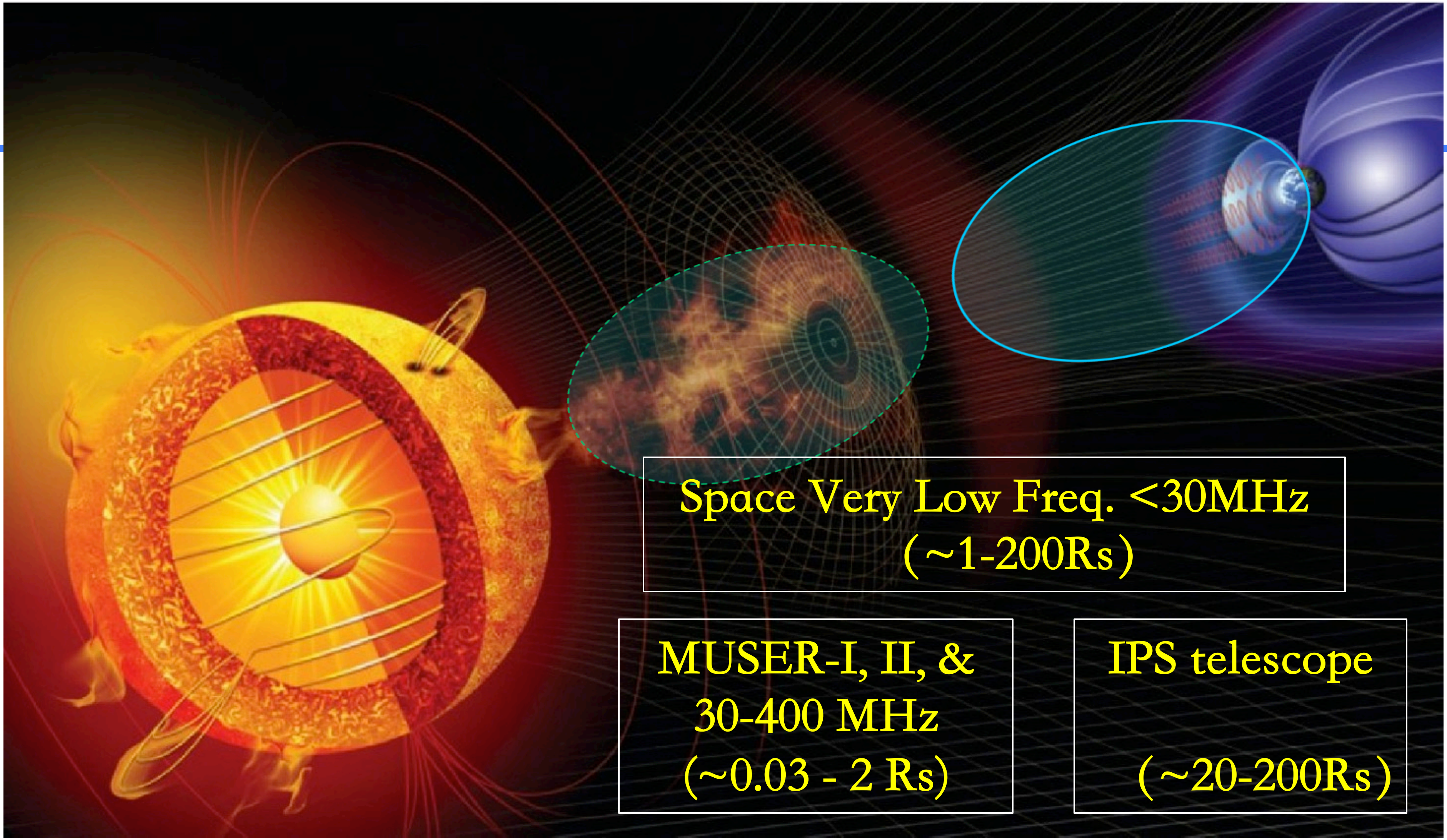
(Bougeret 2004)



Type II Bursts



(Bougeret 2004)



Complementary observations with PSP, Solar Orbiter

Summary

- Solar & Interplanetary sub-system has been included in Meridian-II project
- Solar Radio observing facilities will play important role in future space weather studies and monitors. Observations with PSP, Solar Orbiter
- A part of WIPSS

The Workshop on Solar Radio and IPS Data Analysis, Tongliao, Inner Mongolia, China, 15-18 October 2018.
(http://wsrips2018.csp.escience.cn/dct/page/1)