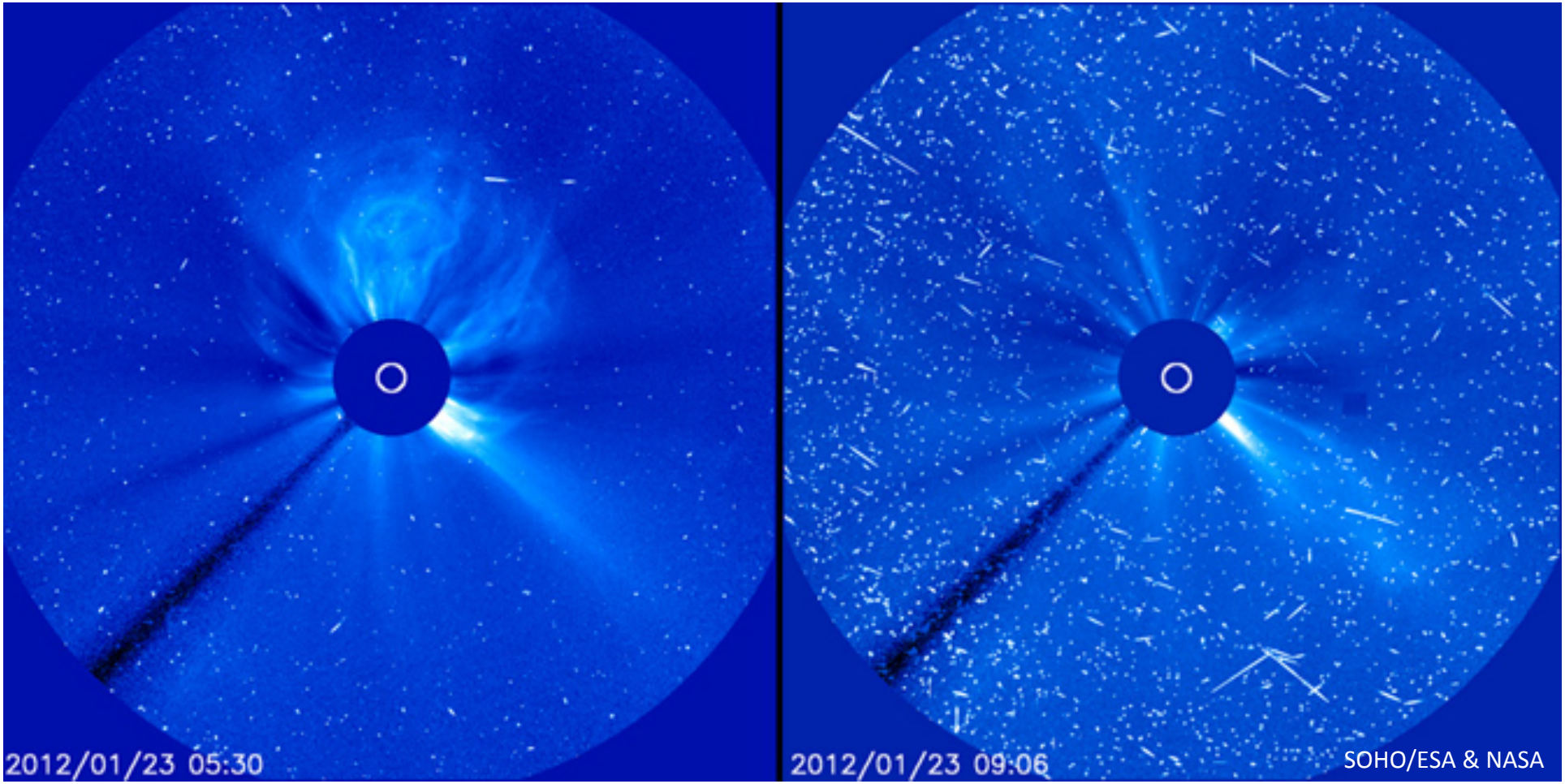


Correlating Type II and III Radio Bursts with Solar Energetic Particle Events

Kathryn Ledbetter
Mentors: Lisa Winter, Rick Quinn (AER)

Outline

- Background
  - What are Solar Radio Bursts? What is an SEP?
- Data Analysis
  - Solar radio data of all Type IIs from Wind/WAVES
  - Particle Data from GOES
- Results
  - Principal Component Analysis on radio and particle properties

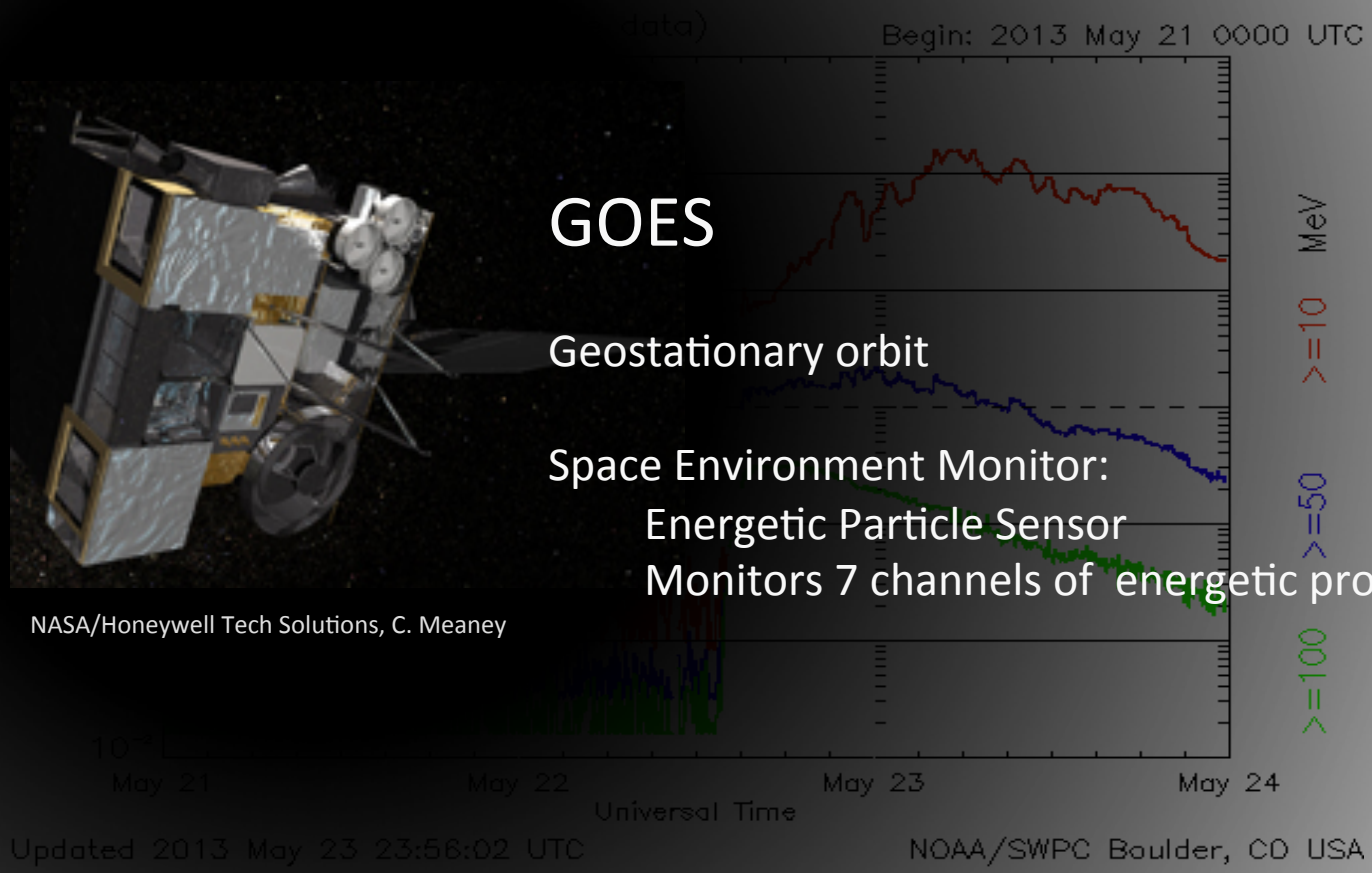
Solar Energetic Particles (SEPs)

NASA/Honeywell Tech Solutions, C. Meaney

GOES

Geostationary orbit

Space Environment Monitor:
- Energetic Particle Sensor
- Monitors 7 channels of energetic protons

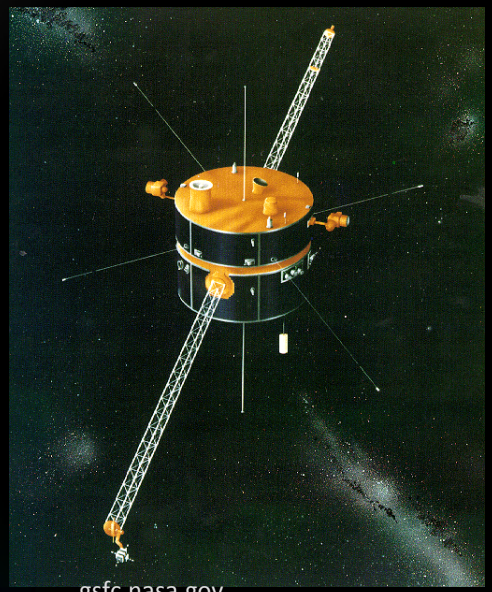


- Impulsive (flare-related) and gradual (shock wave-related)
- High energy protons can be damaging to satellites

Data

- Jan 2010-May 2013
- 123 Type II radio bursts detected by WAVES
- 24 SEP events recorded by GOES; 22 associated with a Type II radio burst
- X-ray flares detected by GOES in 2010-2012 (compiled by Alan Ling of AER)

Type II and III Radio Bursts

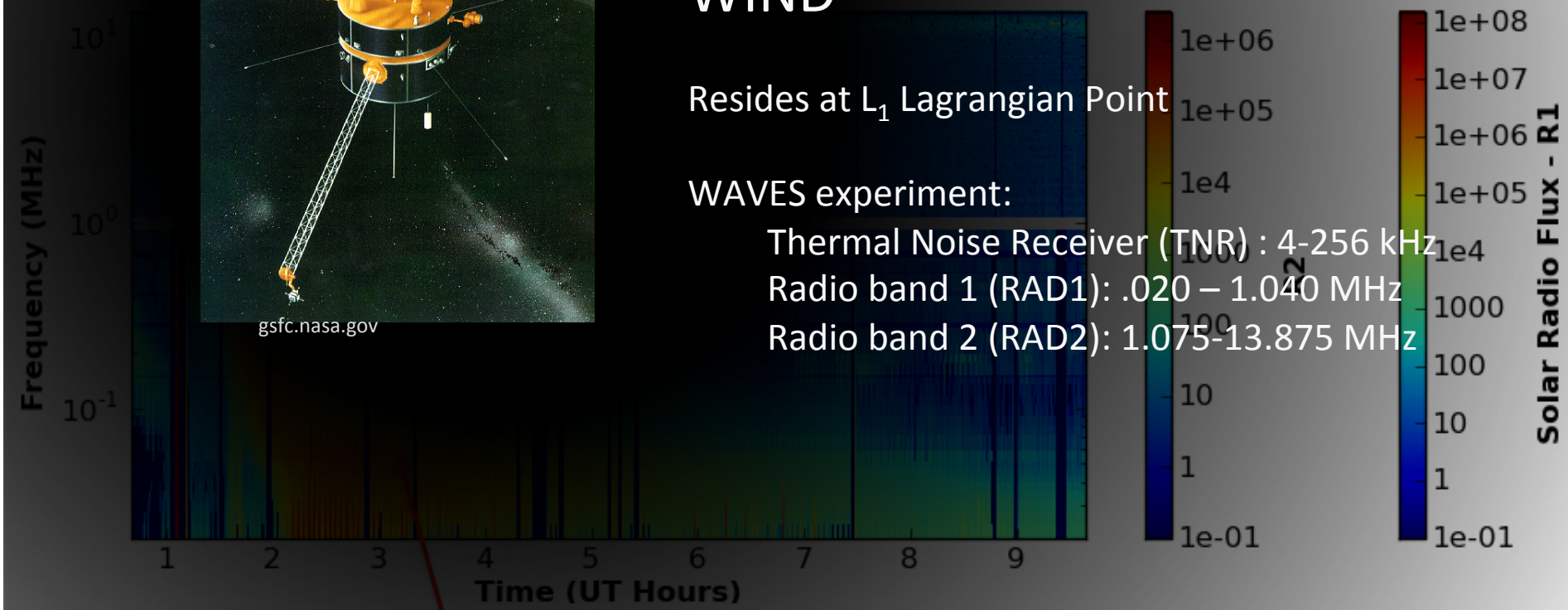


WIND

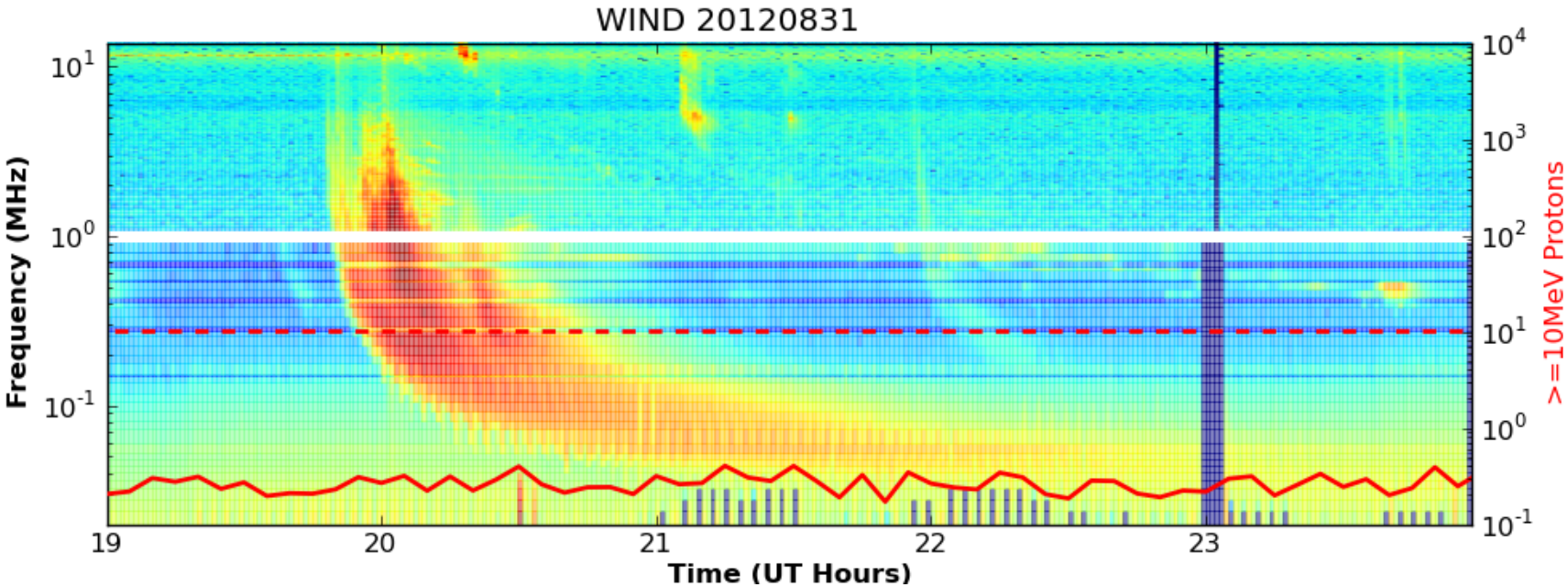
Resides at L_1 Lagrangian Point

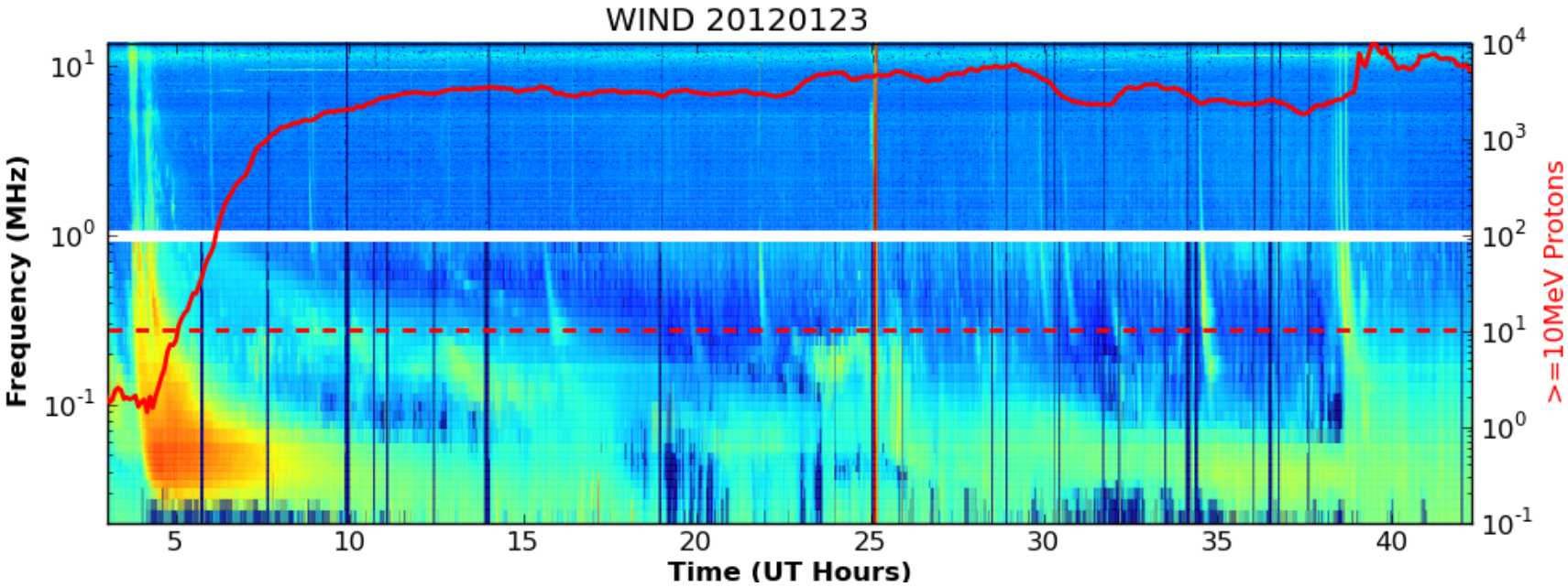
WAVES experiment:

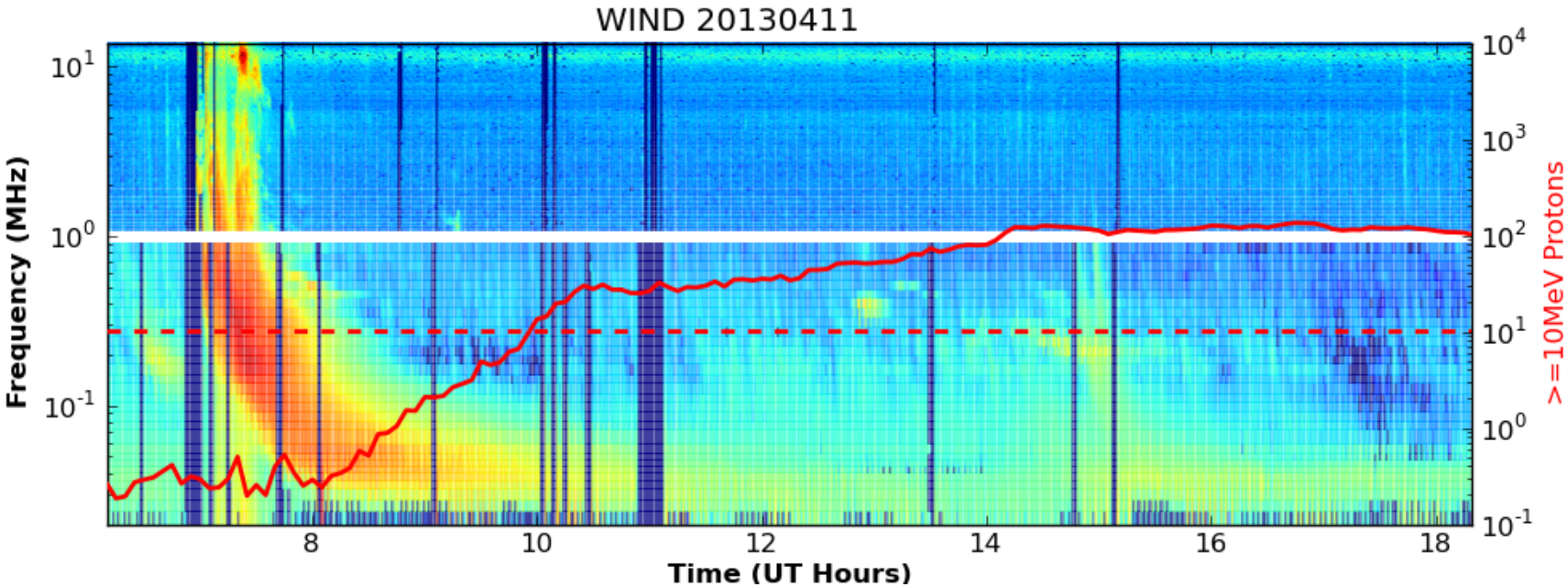
- Thermal Noise Receiver (TNR) : 4-256 kHz
- Radio band 1 (RAD1): .020 – 1.040 MHz
- Radio band 2 (RAD2): 1.075-13.875 MHz

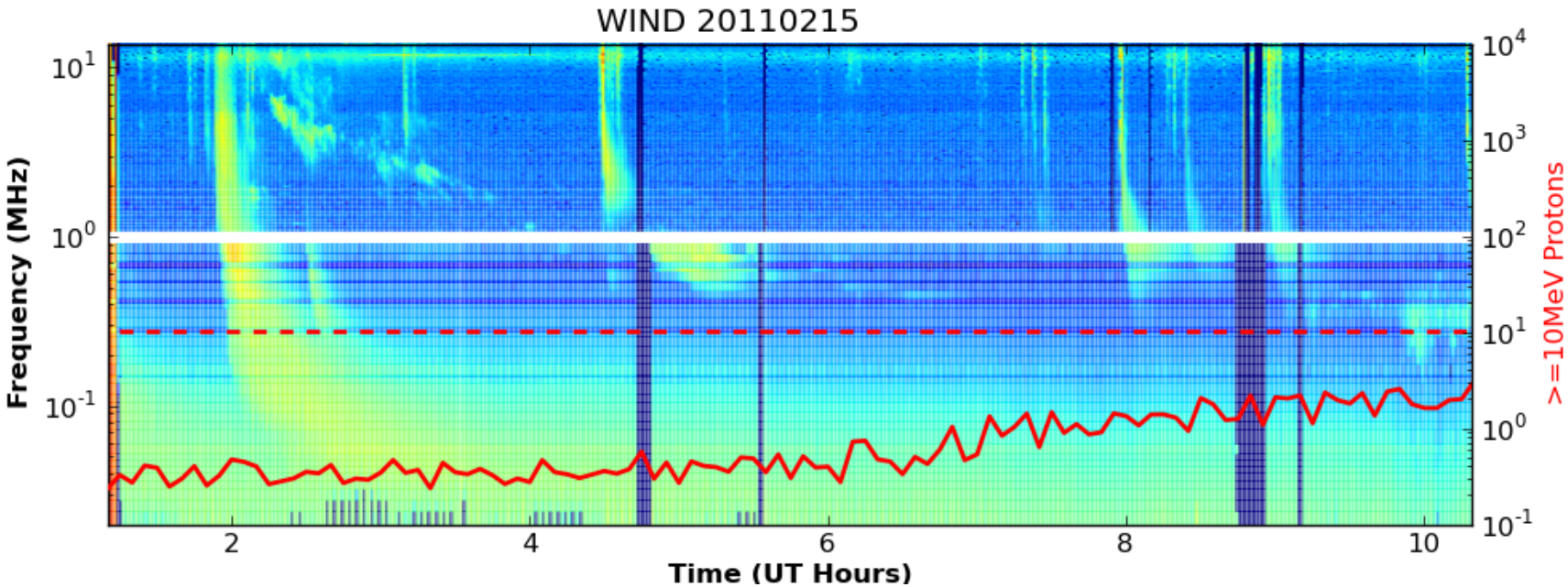


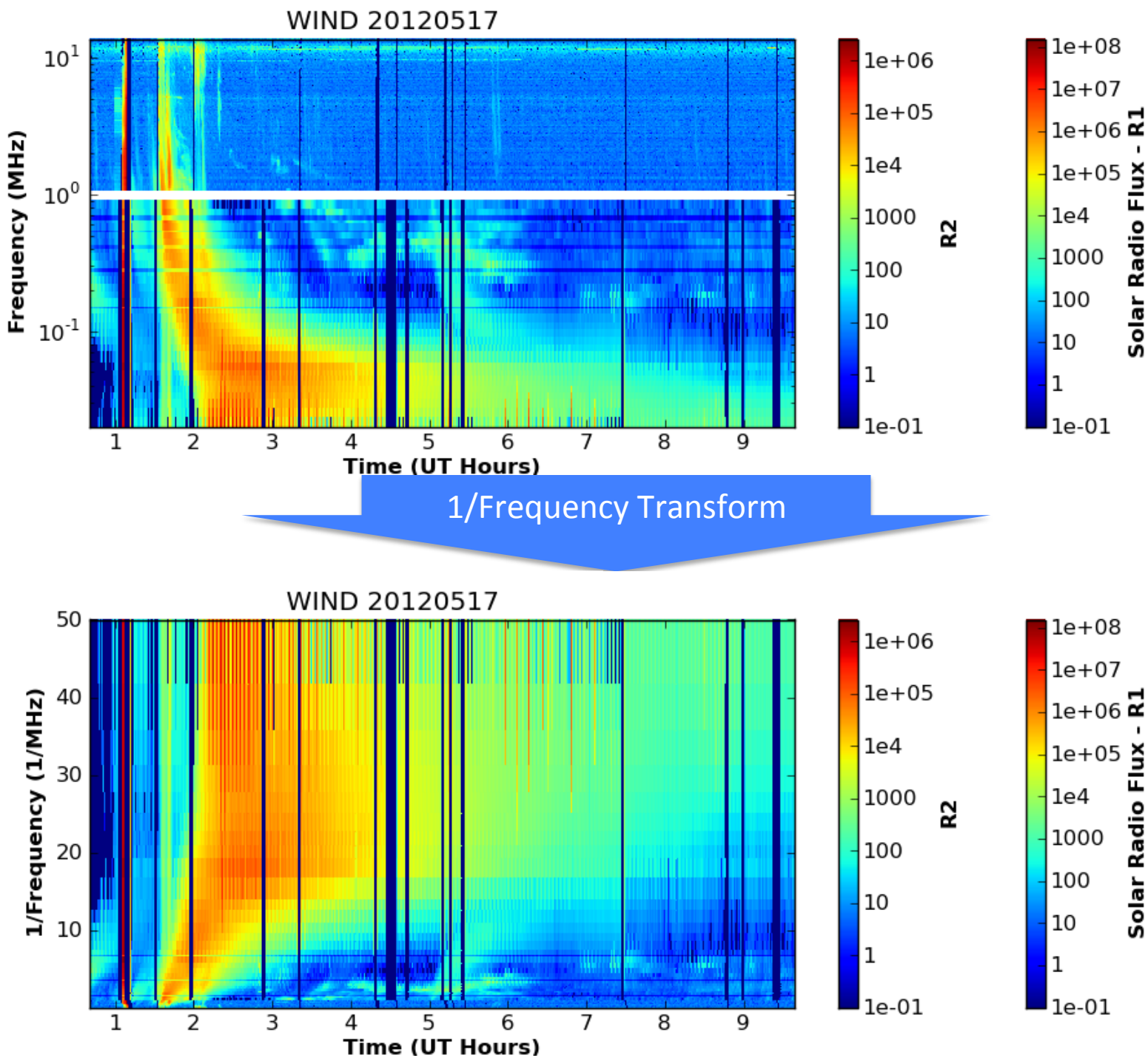
Type III Radio Burst

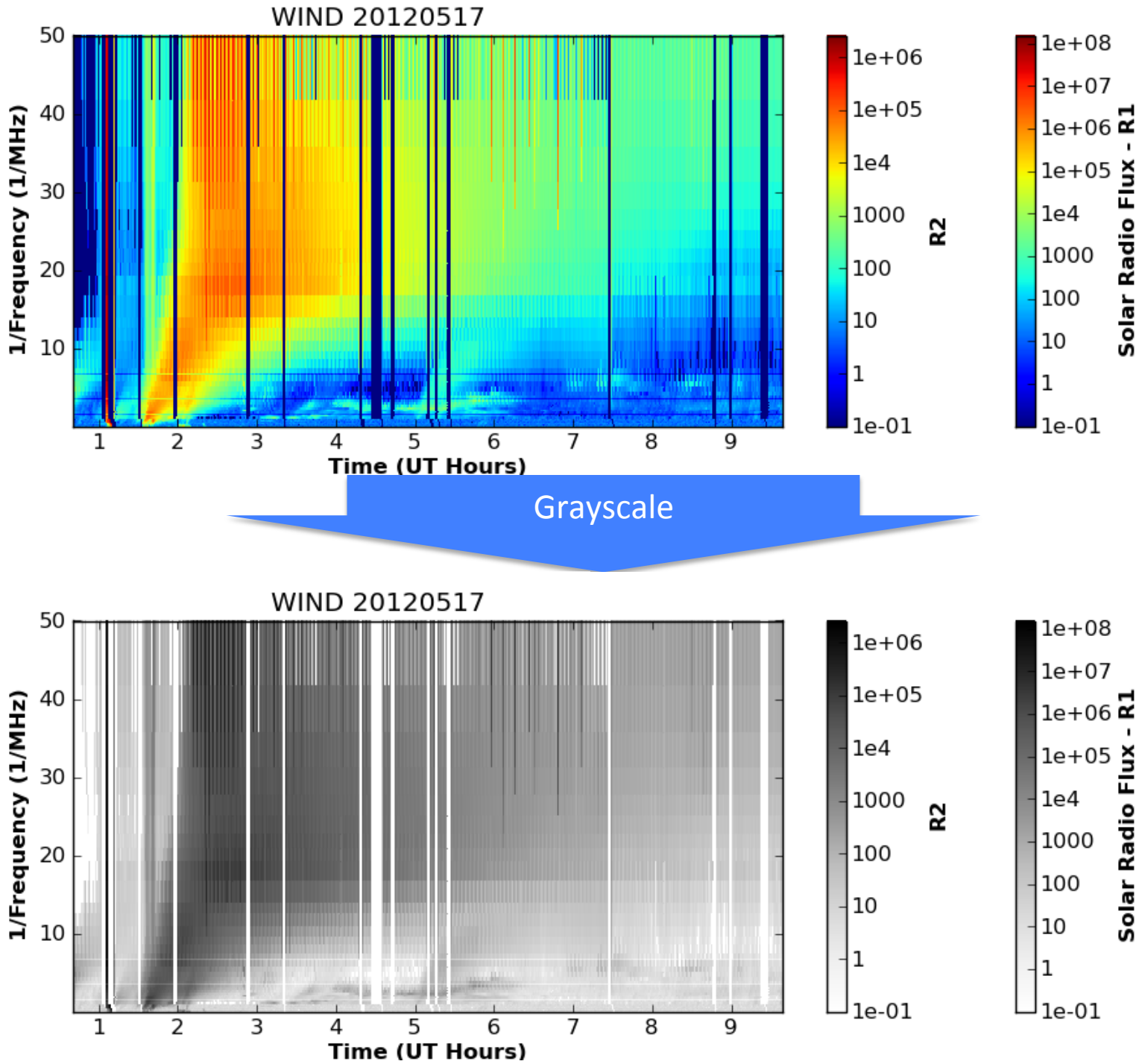

WIND 20120831
Frequency (MHz)
>=10MeV Protons
Time (UT Hours)
19
20
21
22
23

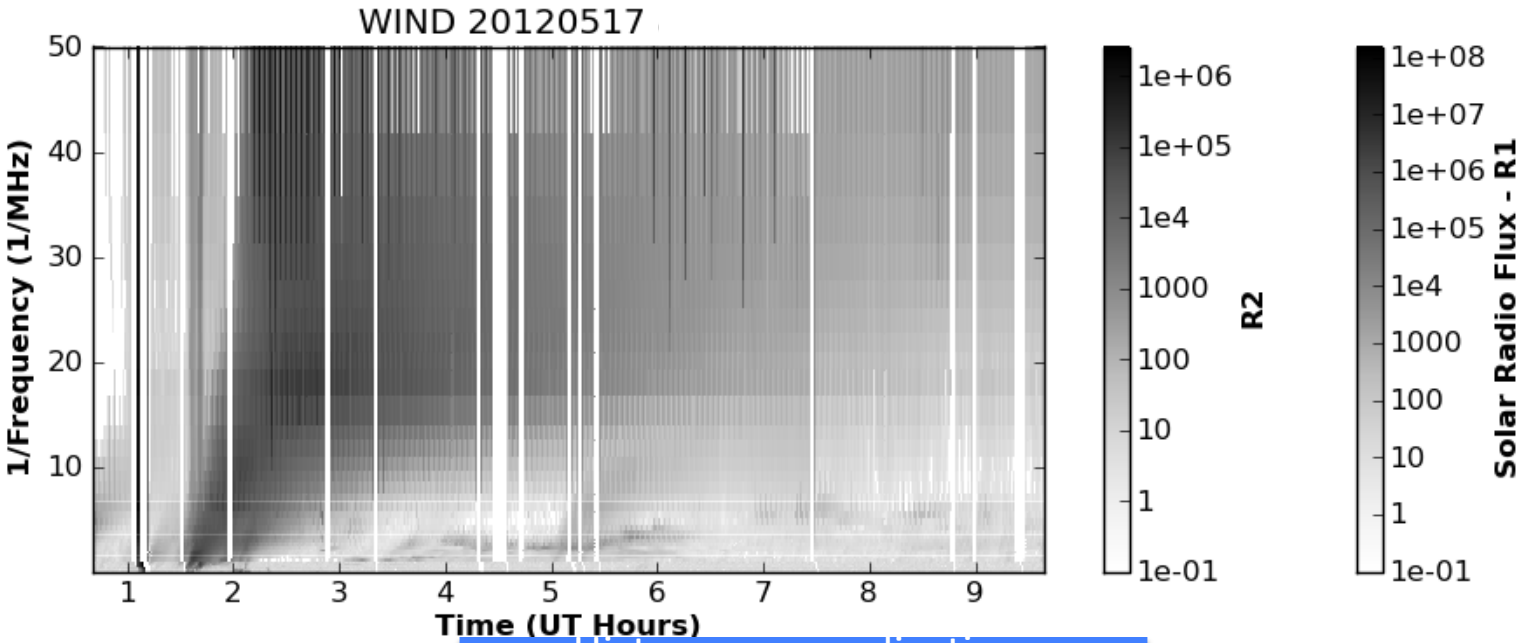

WIND 20120123
Frequency (MHz)
>=10MeV Protons
Time (UT Hours)
5
10
15
20
25
30
35
40


WIND 20130411
Frequency (MHz)
>=10MeV Protons
Time (UT Hours)


WIND 20110215
Frequency (MHz)
>=10MeV Protons
Time (UT Hours)

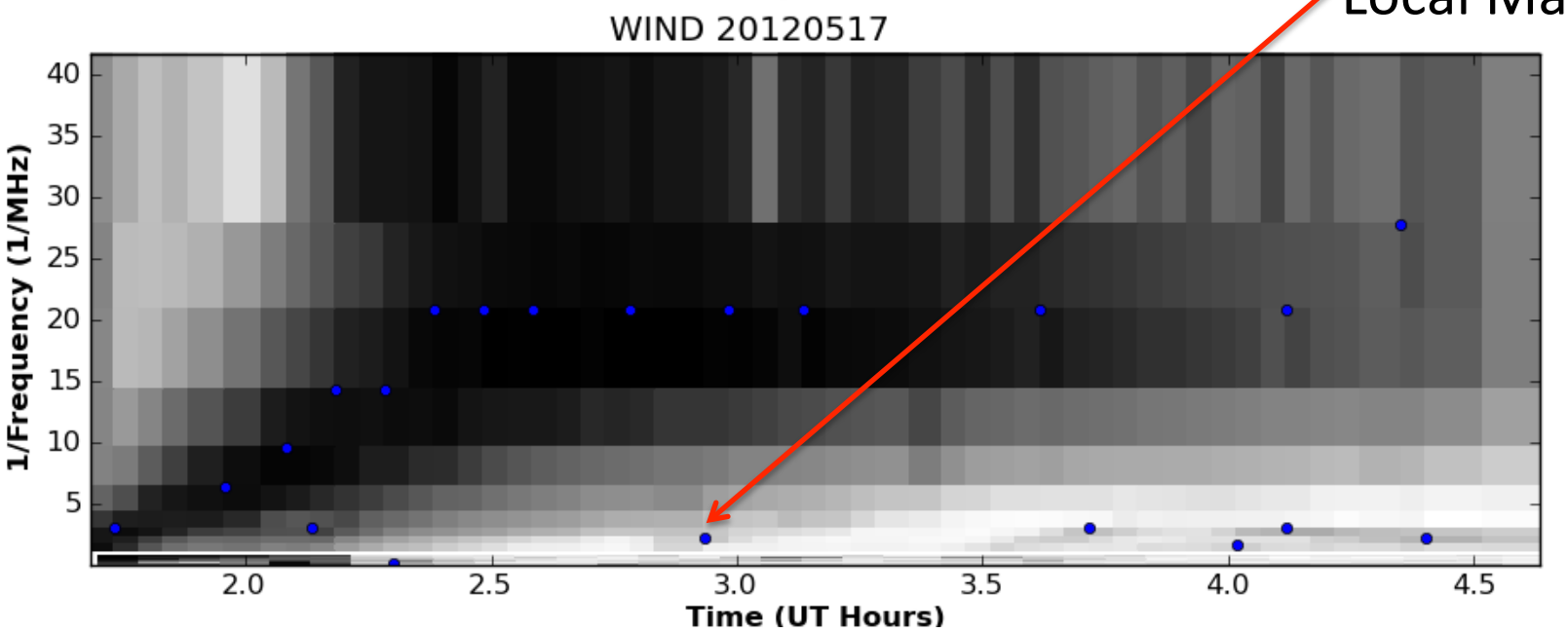

WIND 20120517
Frequency (MHz)
10^1
10^0
10^{-1}
1 2 3 4 5 6 7 8 9
Time (UT Hours)
1e+06
1e+05
1e4
1000
100
10
1
1e-01
R2
1e+08
1e+07
1e+06
1e+05
1e4
1000
100
10
1
1e-01
Solar Radio Flux - R1
1/Frequency Transform
WIND 20120517
1/Frequency (1/MHz)
50
40
30
20
10
1 2 3 4 5 6 7 8 9
Time (UT Hours)
1e+06
1e+05
1e4
1000
100
10
1
1e-01
R2
1e+08
1e+07
1e+06
1e+05
1e4
1000
100
10
1
1e-01
Solar Radio Flux - R1

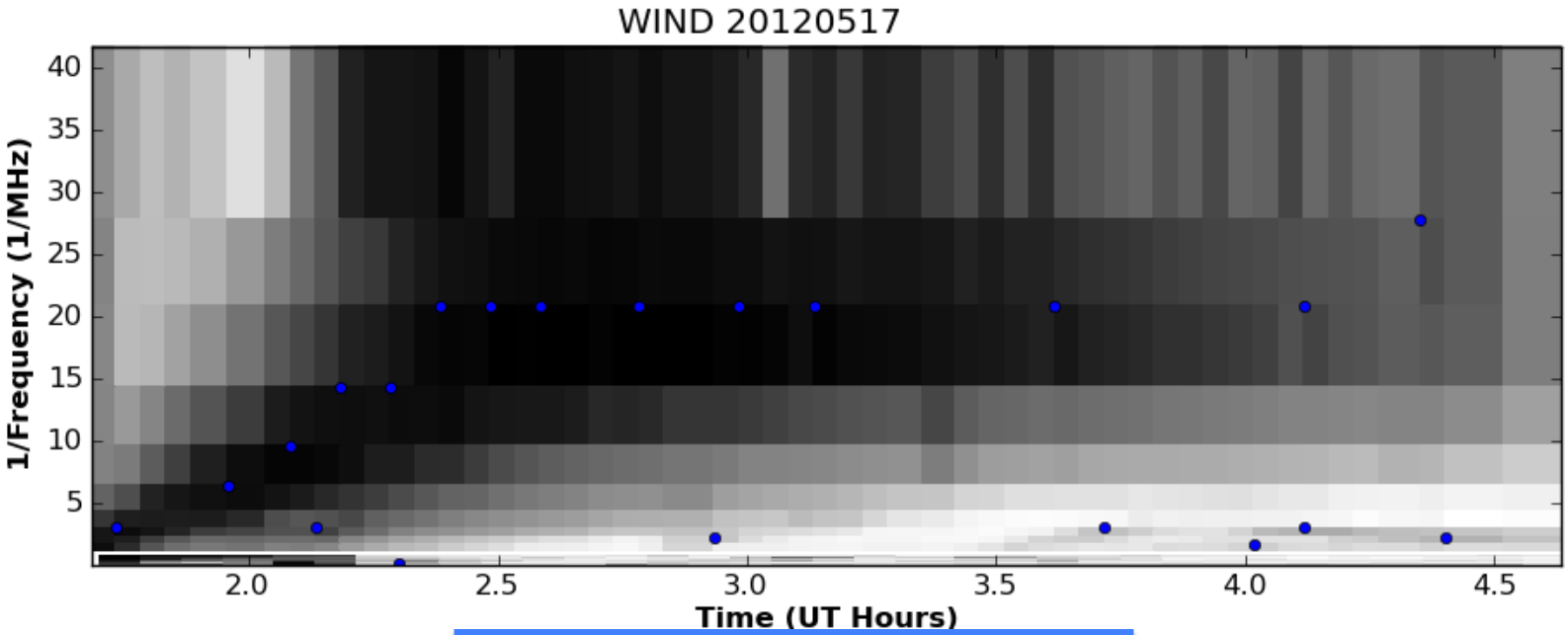

WIND 20120517
1/Frequency (1/MHz)
Time (UT Hours)
R2
Solar Radio Flux - R1
Grayscale
WIND 20120517
1/Frequency (1/MHz)
Time (UT Hours)
R2
Solar Radio Flux - R1



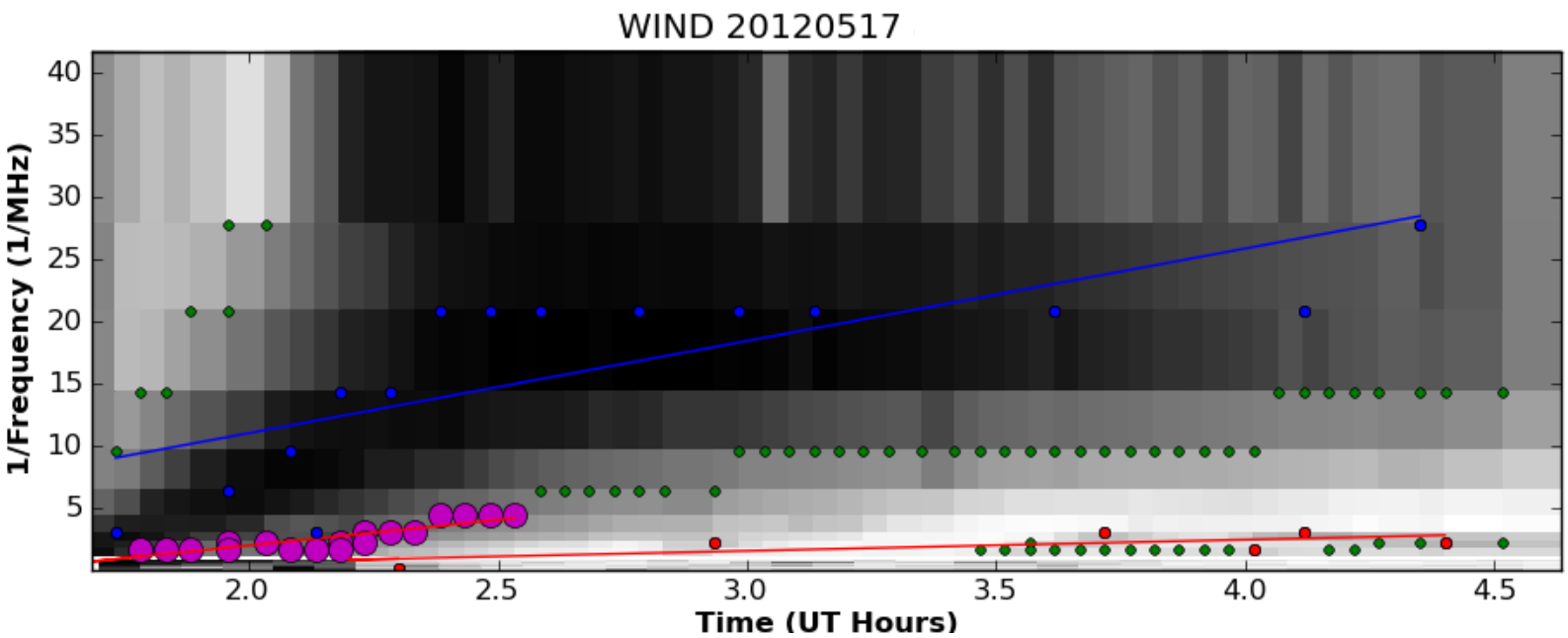
Histogram equalization, boxcar smoothing, zoom

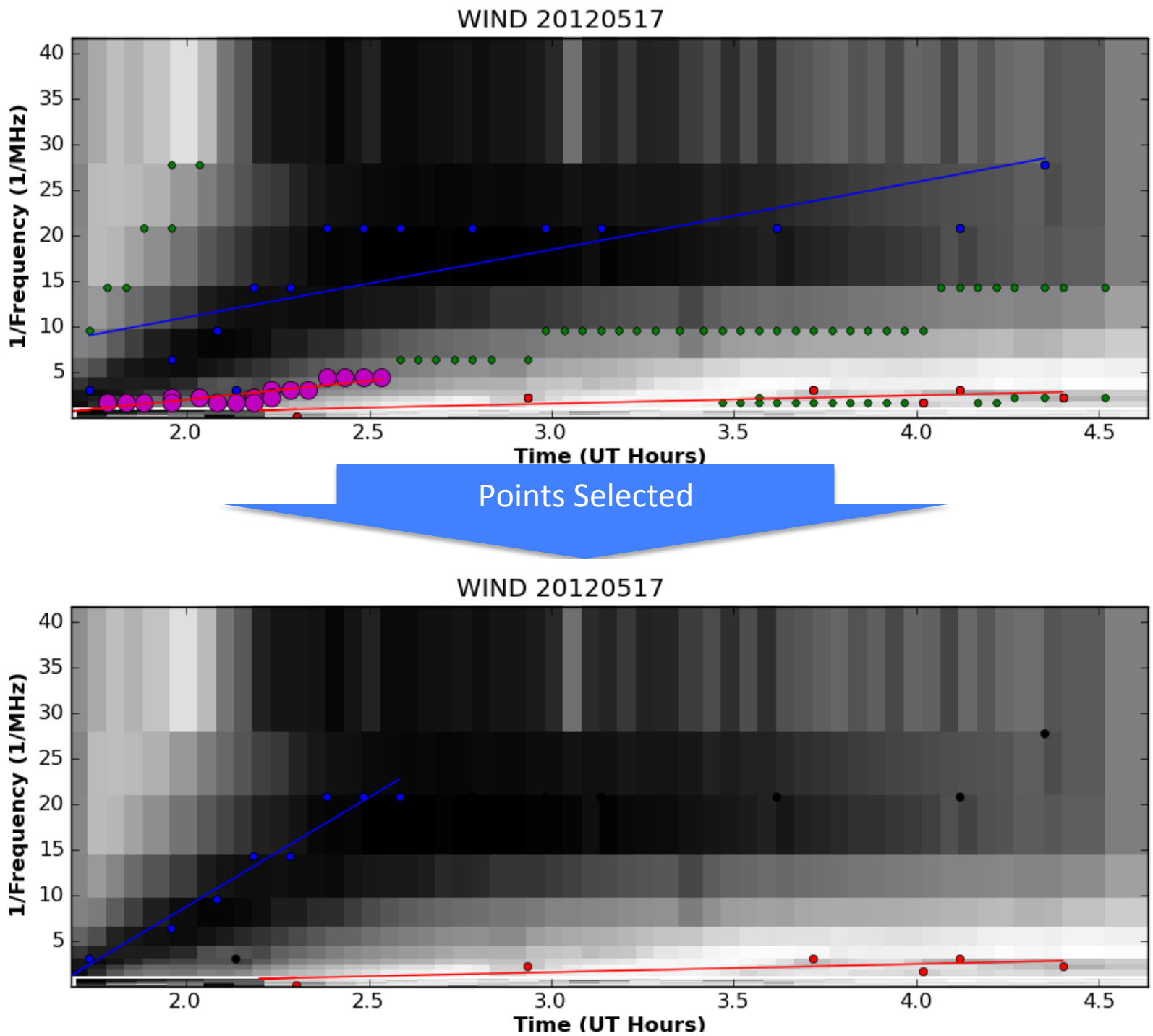
Local Maxima

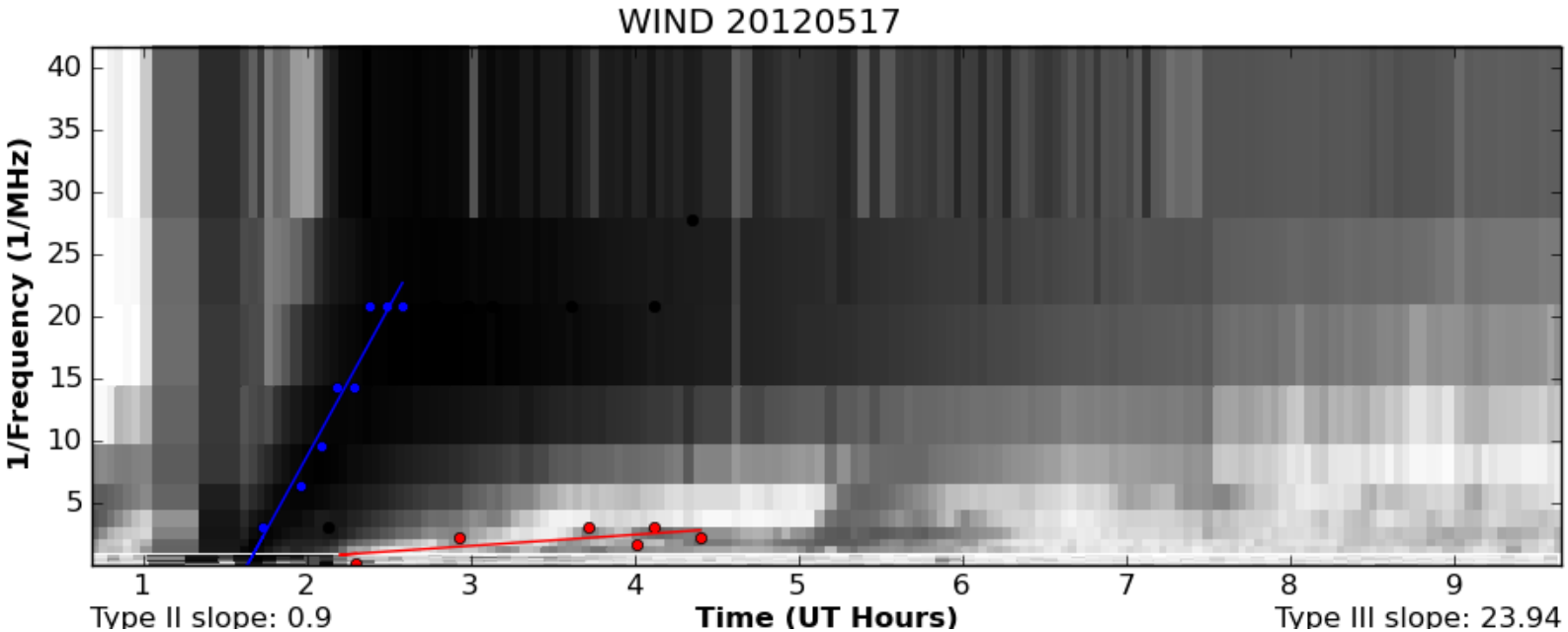




Separation along Edges




WIND 20120517
1/Frequency (1/MHz)
40
35
30
25
20
15
10
5
2.0
2.5
3.0
3.5
4.0
4.5
Time (UT Hours)
Points Selected
WIND 20120517
1/Frequency (1/MHz)
40
35
30
25
20
15
10
5
2.0
2.5
3.0
3.5
4.0
4.5
Time (UT Hours)

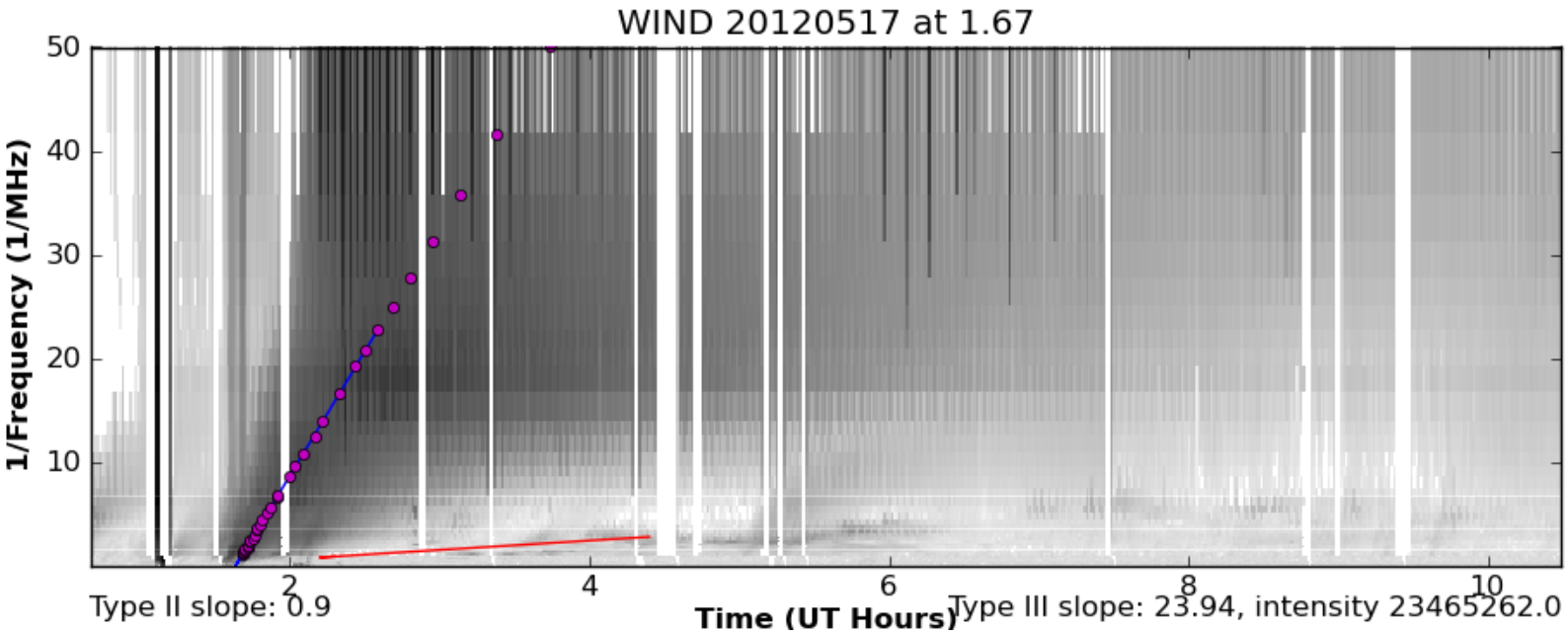


-Type II Burst Slope

-Type III Burst Slope

-Type III Burst Duration above 6 dB at 1 MHz (10 minutes is the MacDowall (2003) definition of a long-duration Type III burst)

Intensity

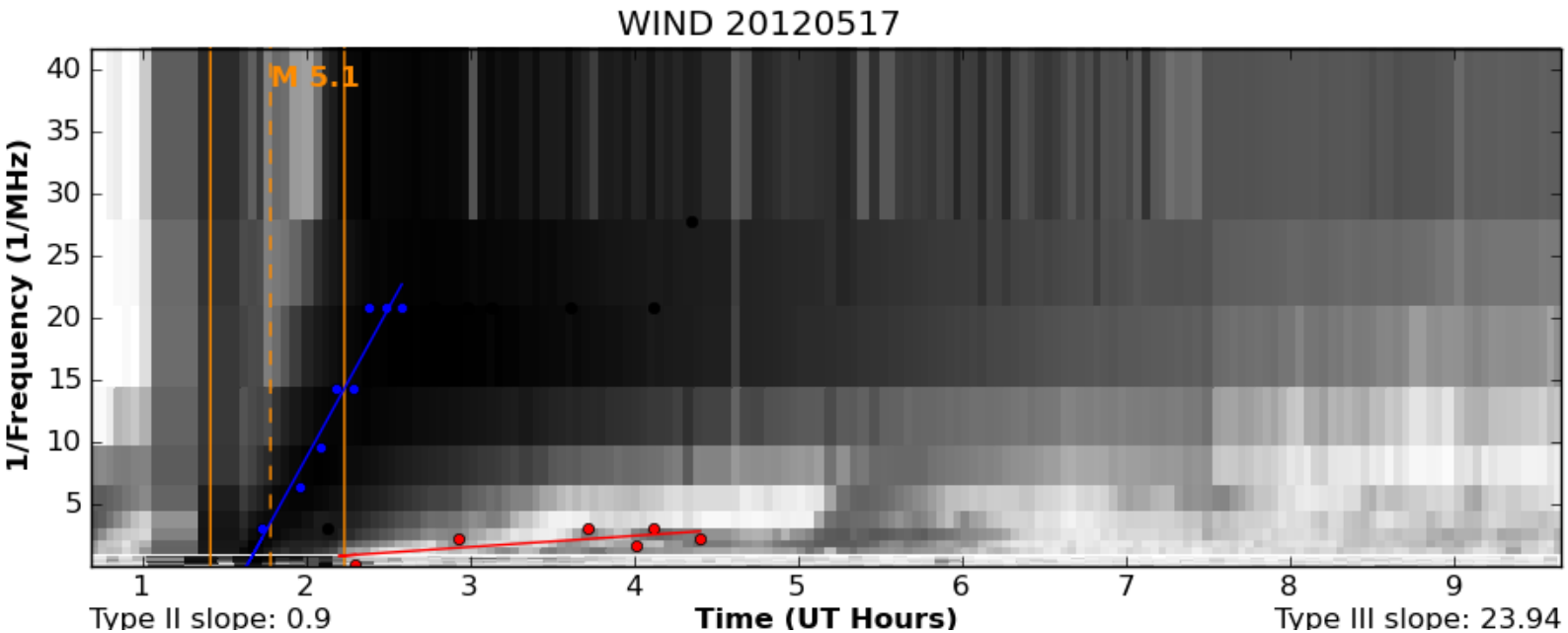


-Type III Intensity integrated along fitted line until the log(intensity) drops 15% from log(maximum)

-Type II intensity peak point

-Type II Integral intensity along fitted line until 15% drop

X-Ray Flares

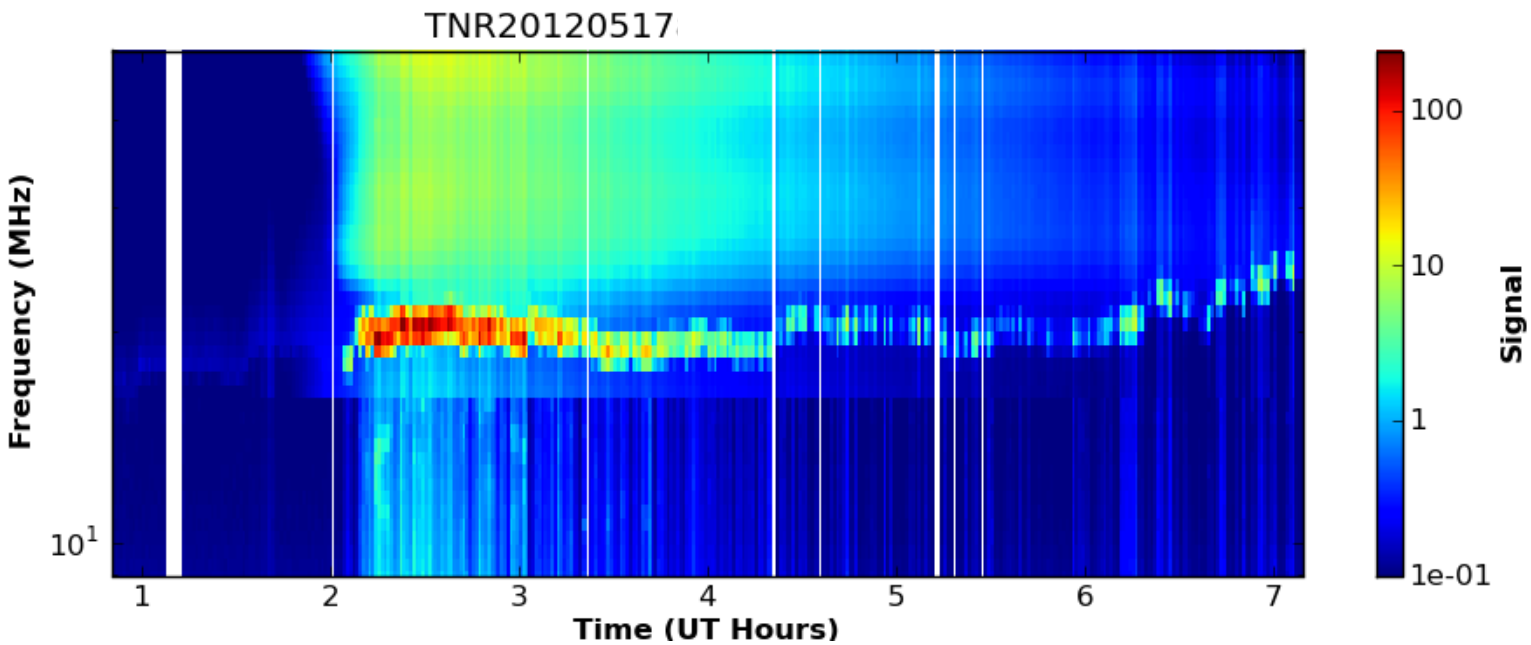


-X-ray Flares Preceding Type II Radio Burst

-X-ray Peak Magnitude

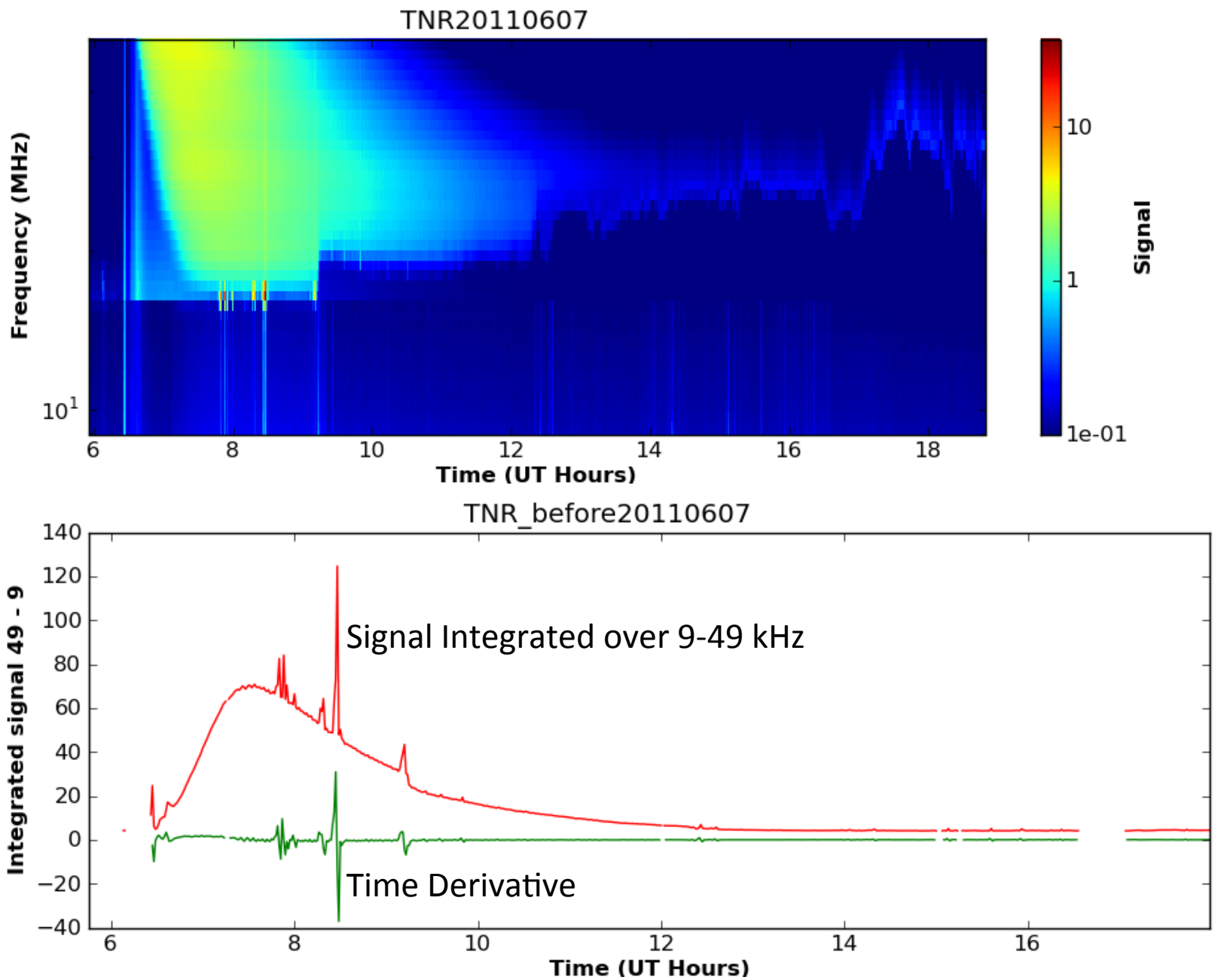
-X-ray Flare Duration

Local Langmuir Waves



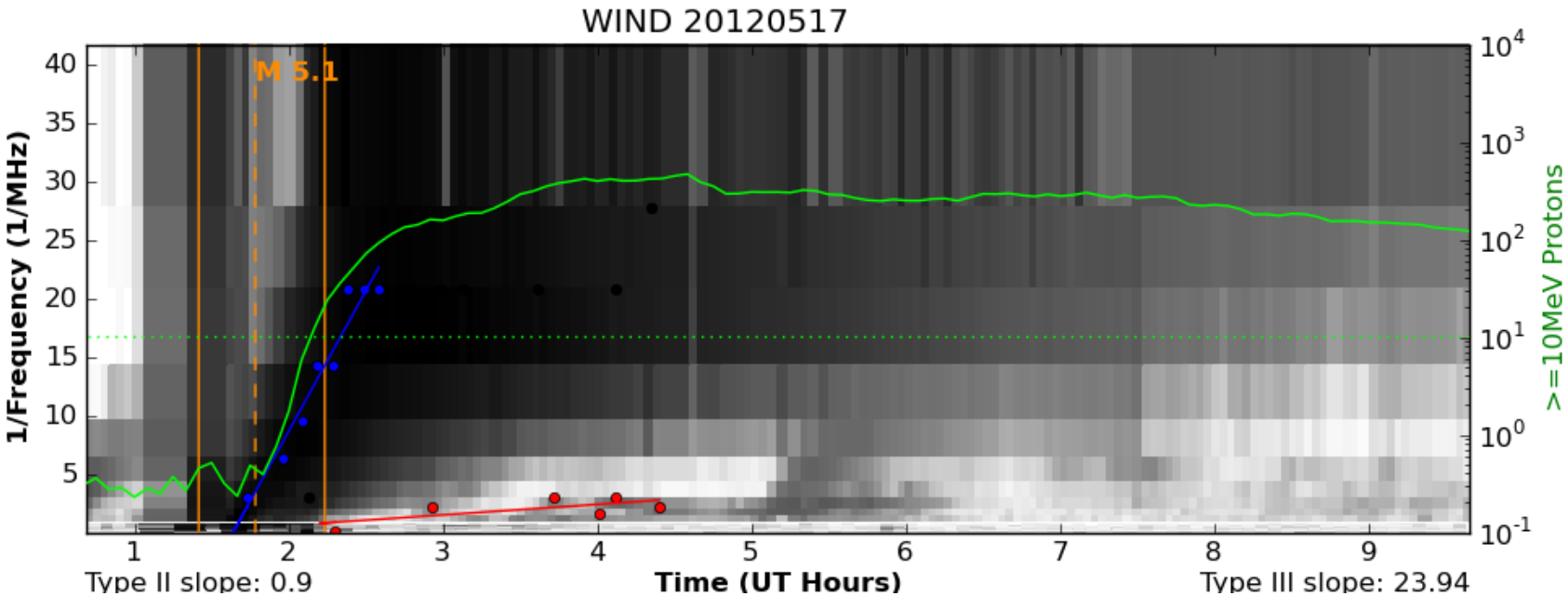
Caused by electrons passing by the satellite and radiating at the local plasma frequency

Langmuir waves are a sign that WIND is magnetically well-connected to the active region and is in the path of electrons accelerated there



-Langmuir Wave Maximum Intensity

SEPs



-Point of Increase

-Peak

-Cross of 10 pfu threshold

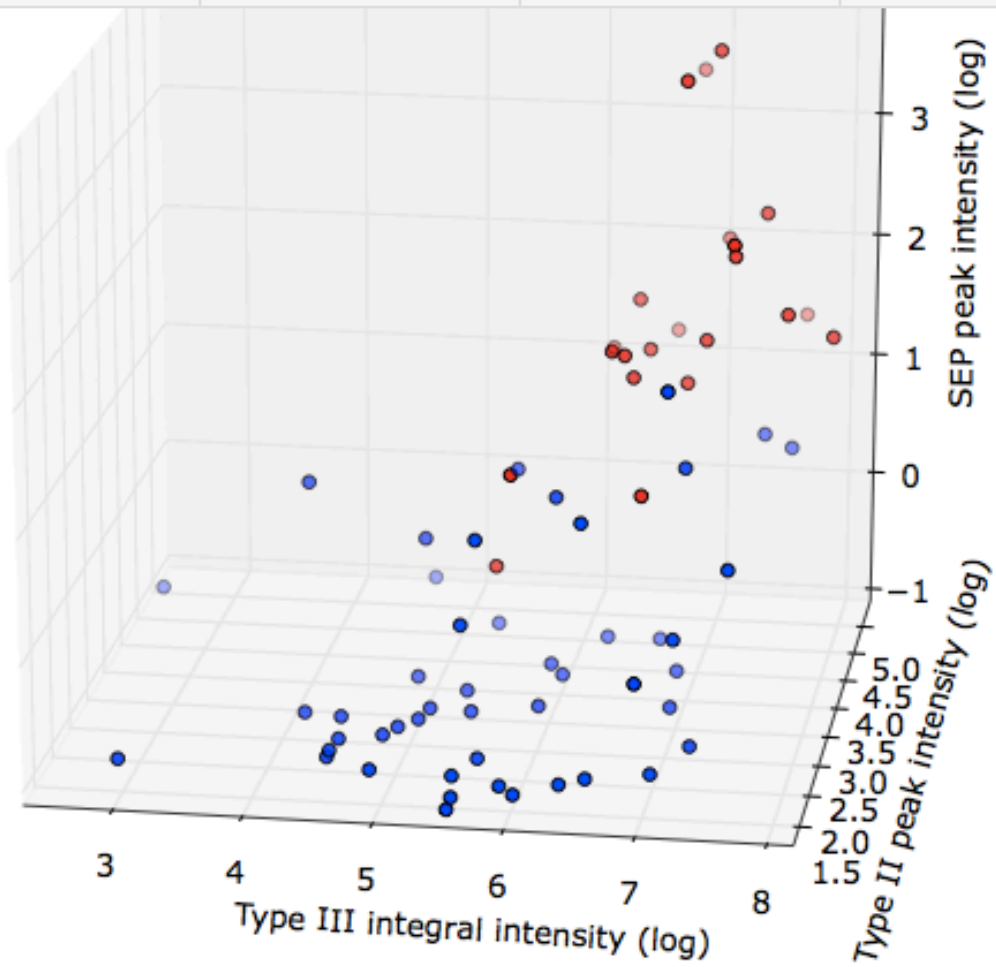
Variables Overview

Type II Radio Bursts	**Type III Radio Bursts**	**X-ray Flares**	**Local Langmuir Waves**	**Solar Energetic Particles**
Duration	Duration at 1MHz	Peak Intensity	Peak Intensity	Increase Time
Frequency Range	Slope	Duration		Peak Time
Slope	Integral Intensity			Peak Intensity
Peak Intensity				
Integral Intensity				

94 usable data points—29 Type II bursts were either not visible to WIND or overlapped too closely to be characterized (none of these discarded bursts were associated with an SEP event).

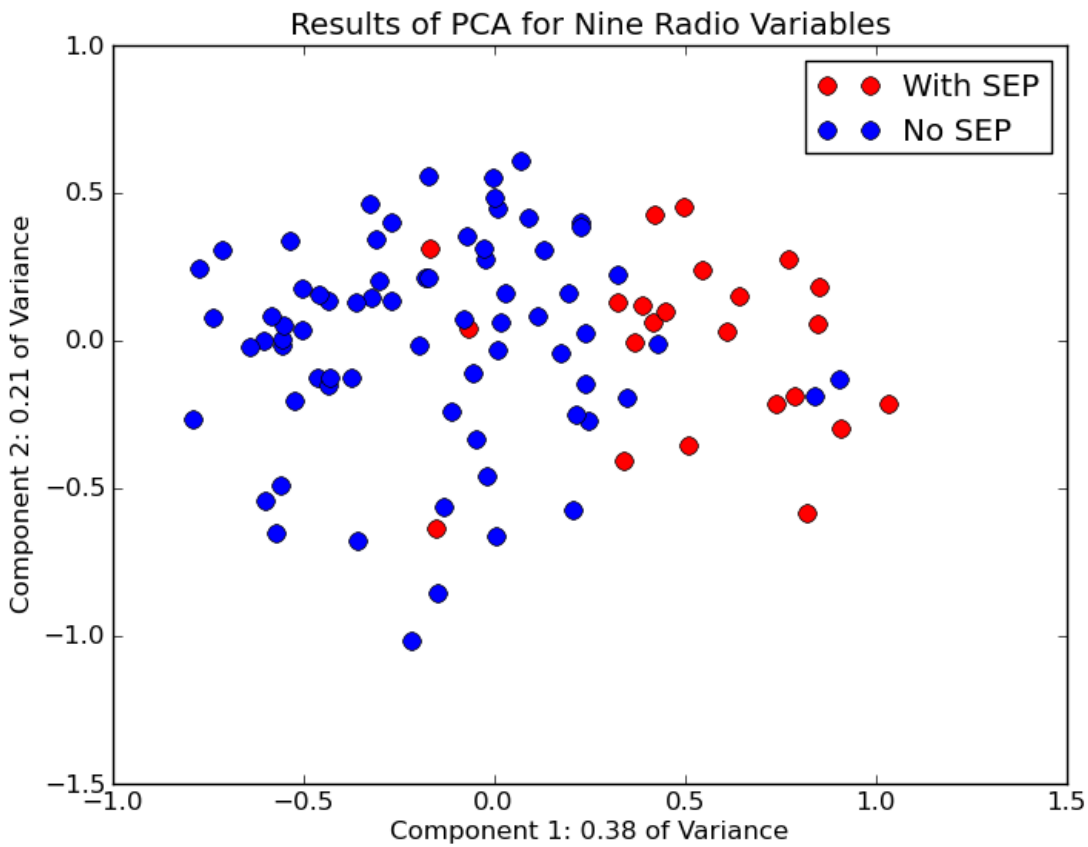
Principal Component Analysis

SEP Peak Intensity	Type II Peak Intensity	Type II Integral Intensity	Type III Integral Intensity	X-ray Peak Intensity	Langmuir Peak



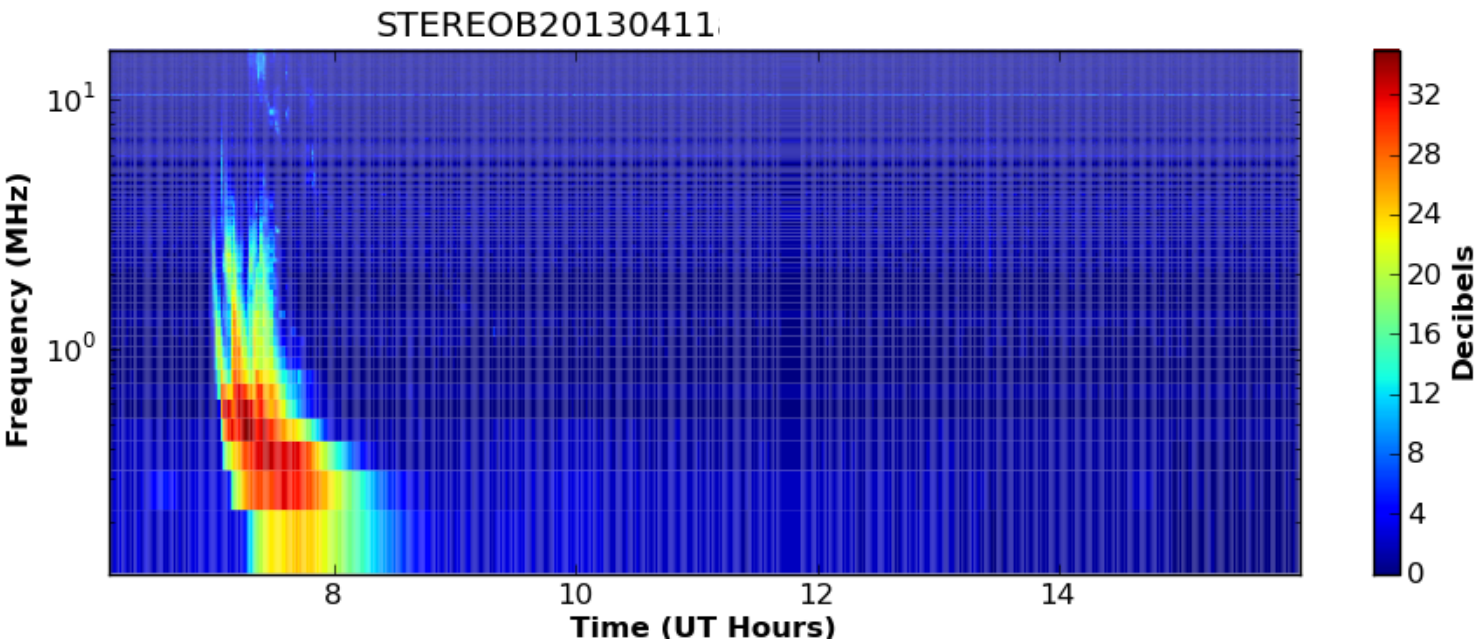
Type III duration at 1MHz	**Type II Peak Intensity**	**Type III Integral Intensity**	**Langmuir Peak Intensity**

Type II Duration	**Type II Frequency Range**	**Type II Slope**	**Type II Integral Intensity**	**Type III Slope**



19/22 SEPs predicted
5 false alarms

Future Work



- Present work at Fall AGU and AER
- Extend to STEREO archived data, as well as beacon data for real-time predictions
- Automate characterization of SEP peaks
- Include X-ray variables in PCA

Acknowledgements and Citations

Mentors: Lisa Winter and Rick Quinn (AER)

Langmuir Waves: David Malaspina (LASP)

X-Ray Data: Alan Ling (AER)

Lobzin, V et al. (2010). Automatic recognition of coronal type II radio bursts: The automated radio burst identification system method and first observations. The Astrophysical Journal Letters, (710), L58-L62. doi: 10.1088/2041-8205/710/1/L58.

MacDowall, R. J. (2003). Long-duration hectometric type III radio bursts and their association with solar energetic particle (SEP) events. Geophysical Research Letters, 30(12), 8018. doi: 10.1029/2002GL016624.