Using Type II drift rate to estimate CME-driven shock speed

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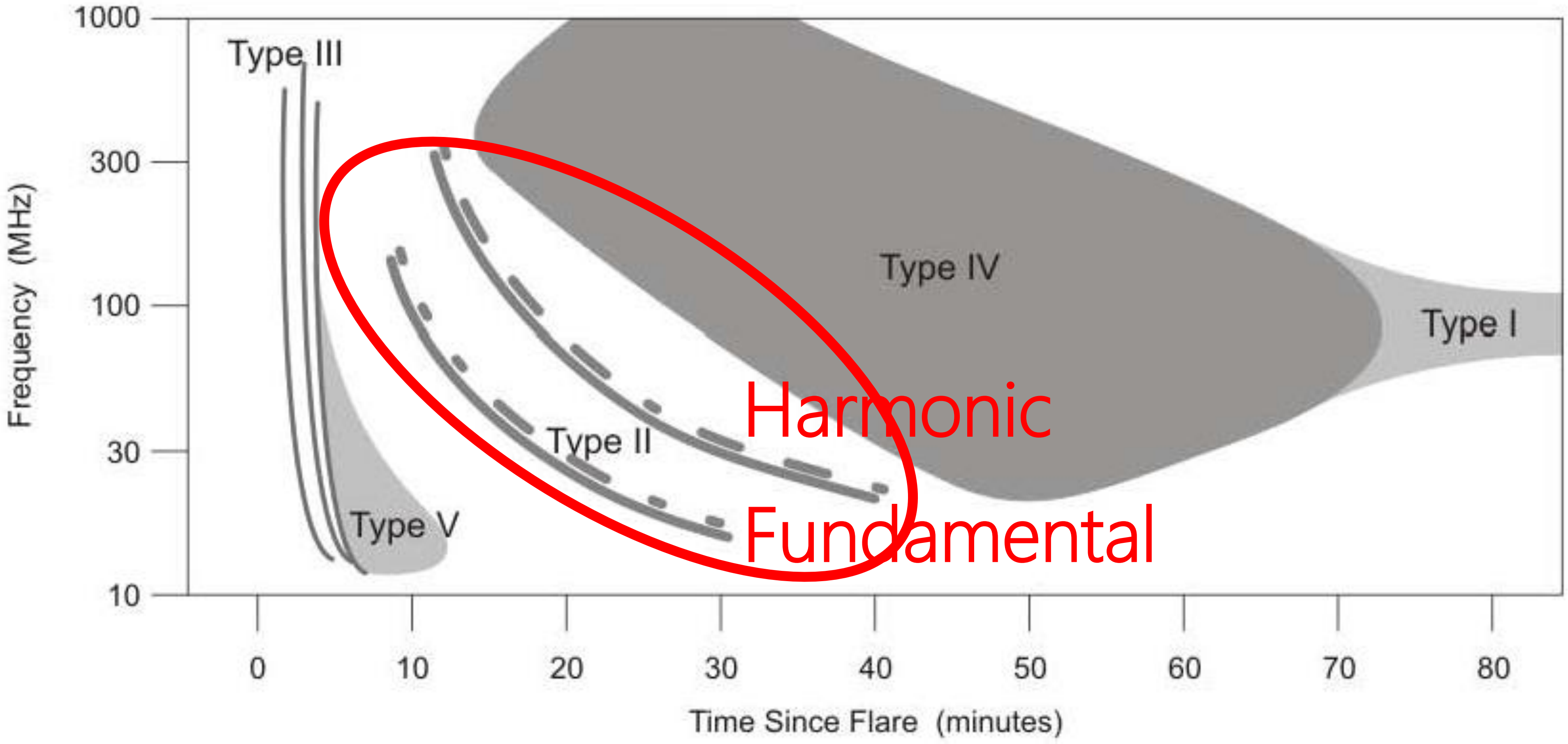
Outline

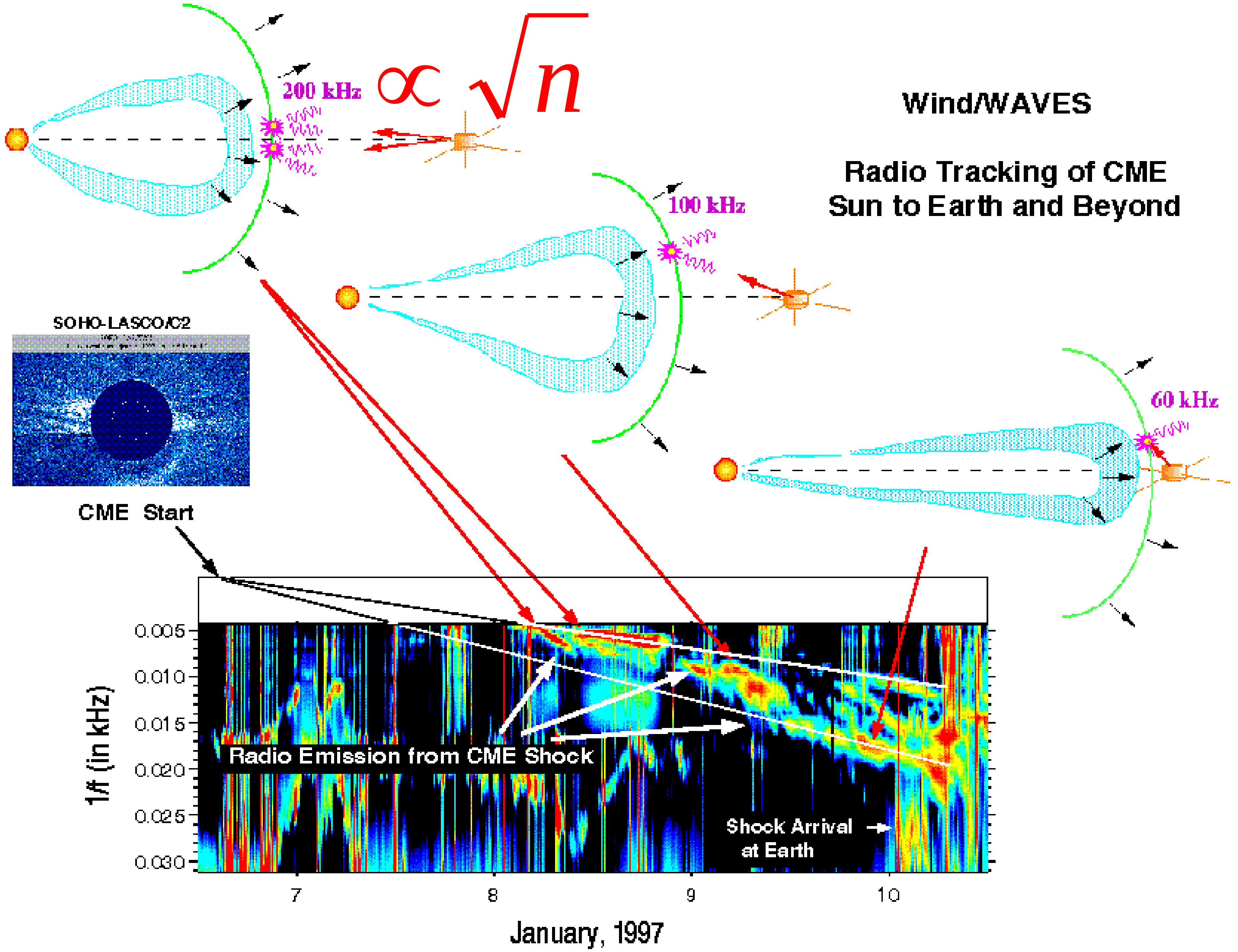
- Introduction
- Observations
- Methodology
- Events
- Summary

Introduction

This diagram illustrates all of the major burst types in a typical configuration following a large flare. It should be noted that it is **not** common for **all** of these features to be observed after a flare.

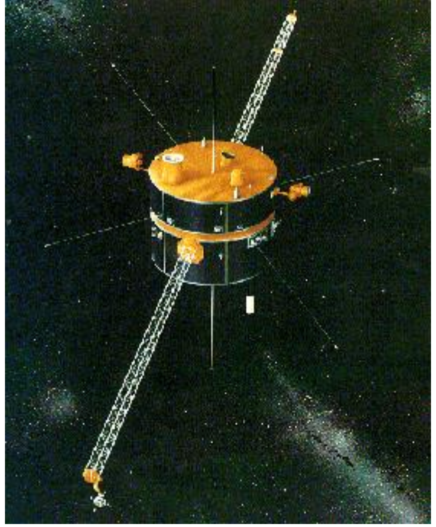


http://www.ips.gov.au/Category/World%20Data%20Centre/Data%20Display%20and%20Download/Spectrograph/Schematic%20Radiospectrogram.pdf



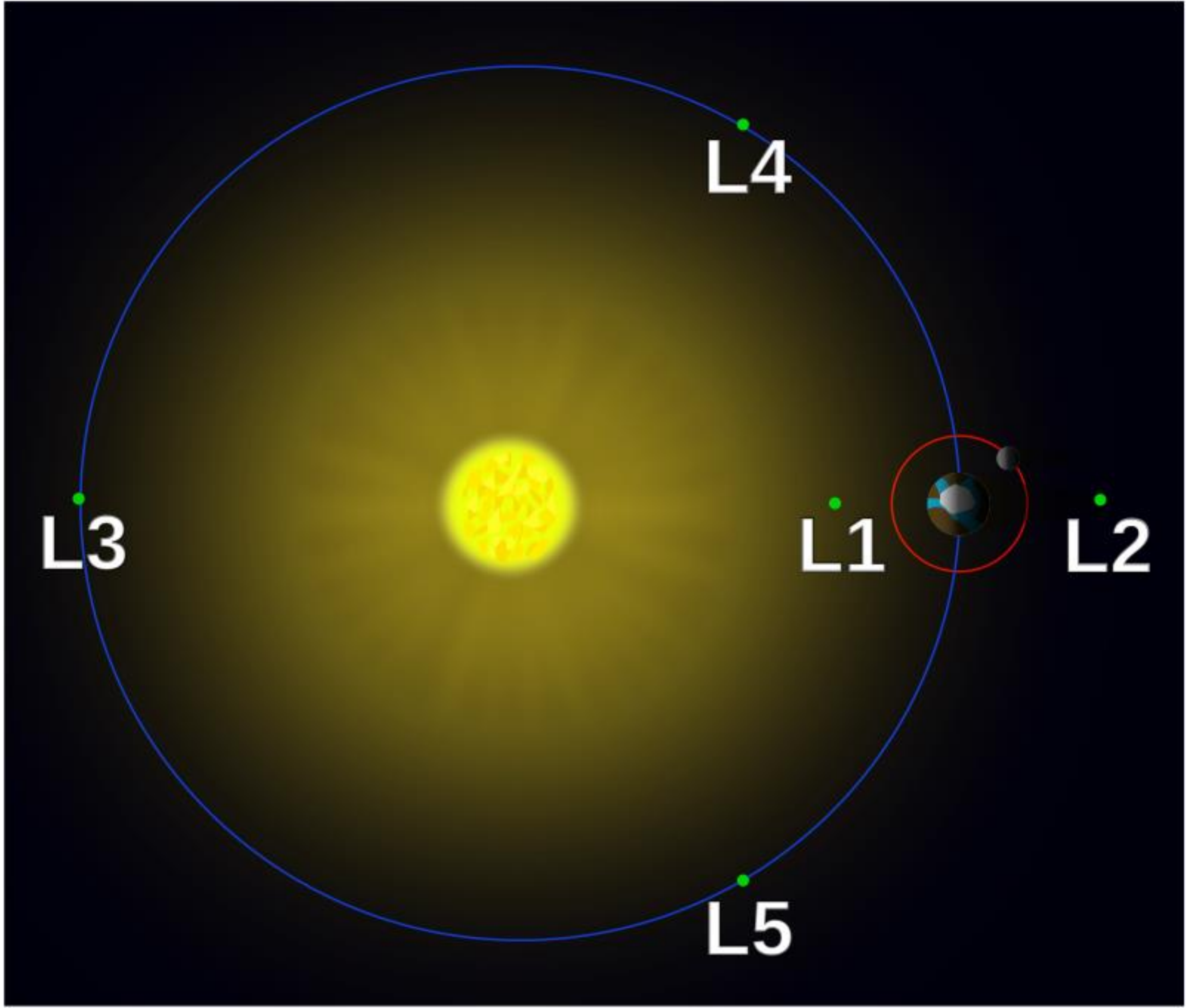
Wind/WAVES
Radio Tracking of CME
Sun to Earth and Beyond
200 kHz
$\propto \sqrt{n}$
100 kHz
60 kHz
SOHO-LASCO/C2
CME Start
Radio Emission from CME Shock
Shock Arrival at Earth
1/f (in kHz)
0.005
0.010
0.015
0.020
0.025
0.030
7
8
9
10
January, 1997

Observations

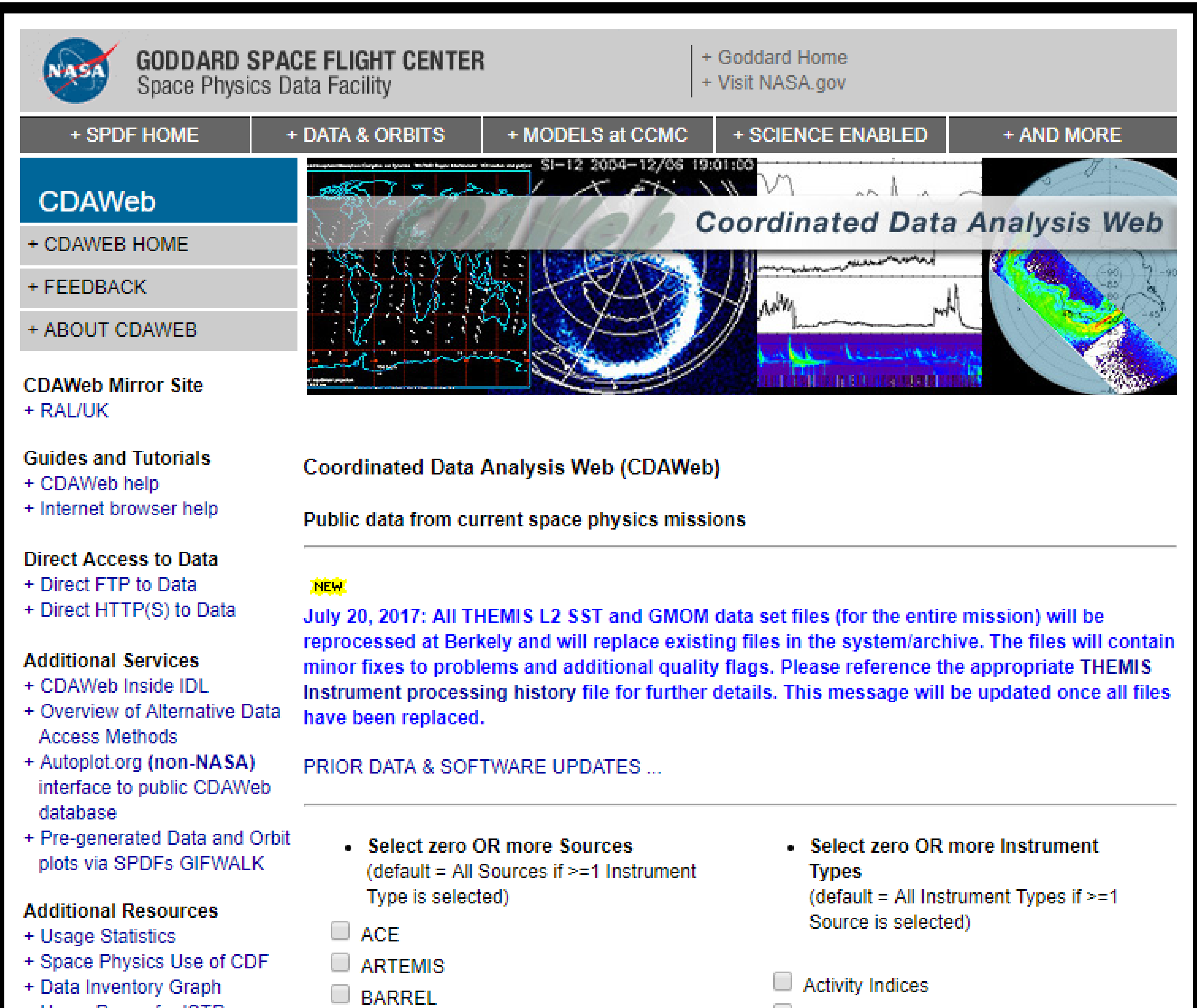


WIND/WAVES :
→around the Lagrange point (L1).

Radio Receiver Band	Frequency min (Hz)	Frequency max (Hz)	Bandwidth (Hz)
RAD1	20 k	1040 k	3 k
RAD2	1.075 M	13.825 M	20 k
TNR	4 k	256 k	400 - 6.4 k


L4
L3
L1
L2
L5

https://cdaweb.sci.gsfc.nasa.gov/cdaweb/istp_public/



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Space Physics Data Facility

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CDAWeb

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+ ABOUT CDAWEB

Coordinated Data Analysis Web

CDAWeb Mirror Site
+ RAL/UK

Guides and Tutorials
+ CDAWeb help
+ Internet browser help

Direct Access to Data
+ Direct FTP to Data
+ Direct HTTP(S) to Data

Additional Services
+ CDAWeb Inside IDL
+ Overview of Alternative Data Access Methods
+ Autoplot.org **(non-NASA)** interface to public CDAWeb database
+ Pre-generated Data and Orbit plots via SPDFs GIFWALK

Additional Resources
+ Usage Statistics
+ Space Physics Use of CDF
+ Data Inventory Graph

Coordinated Data Analysis Web (CDAWeb)

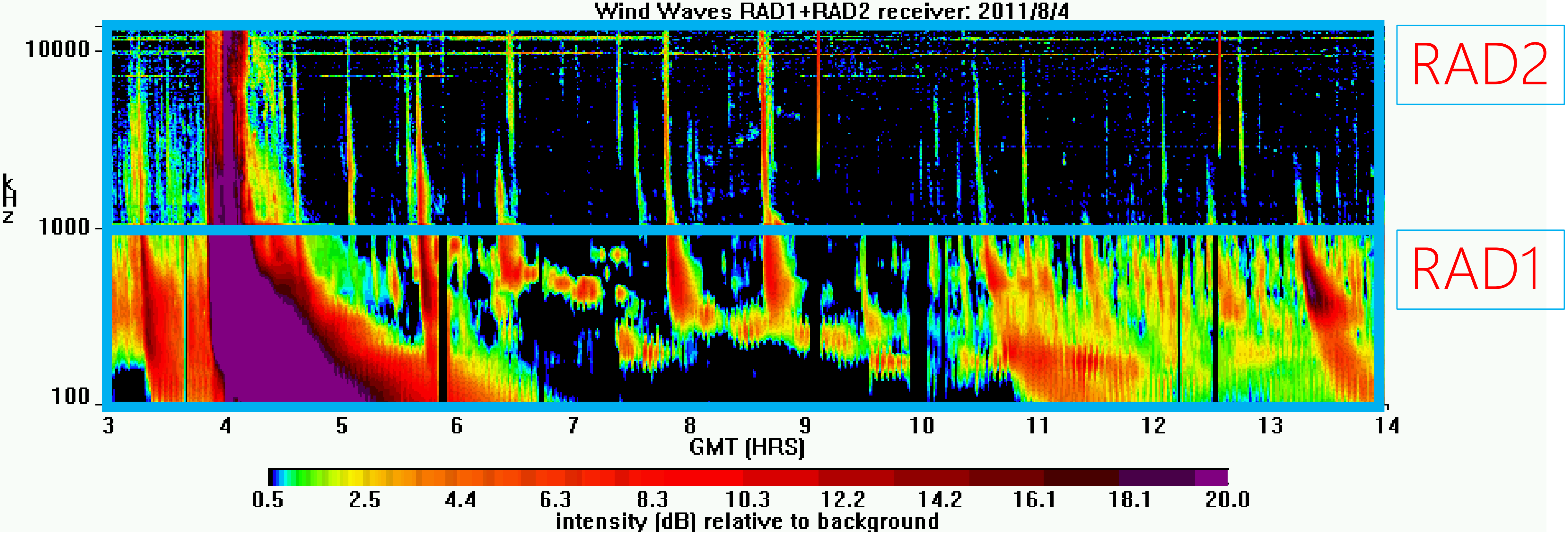
Public data from current space physics missions

NEW

July 20, 2017: All THEMIS L2 SST and GMOM data set files (for the entire mission) will be reprocessed at Berkely and will replace existing files in the system/archive. The files will contain minor fixes to problems and additional quality flags. Please reference the appropriate THEMIS Instrument processing history file for further details. This message will be updated once all files have been replaced.

PRIOR DATA & SOFTWARE UPDATES ...

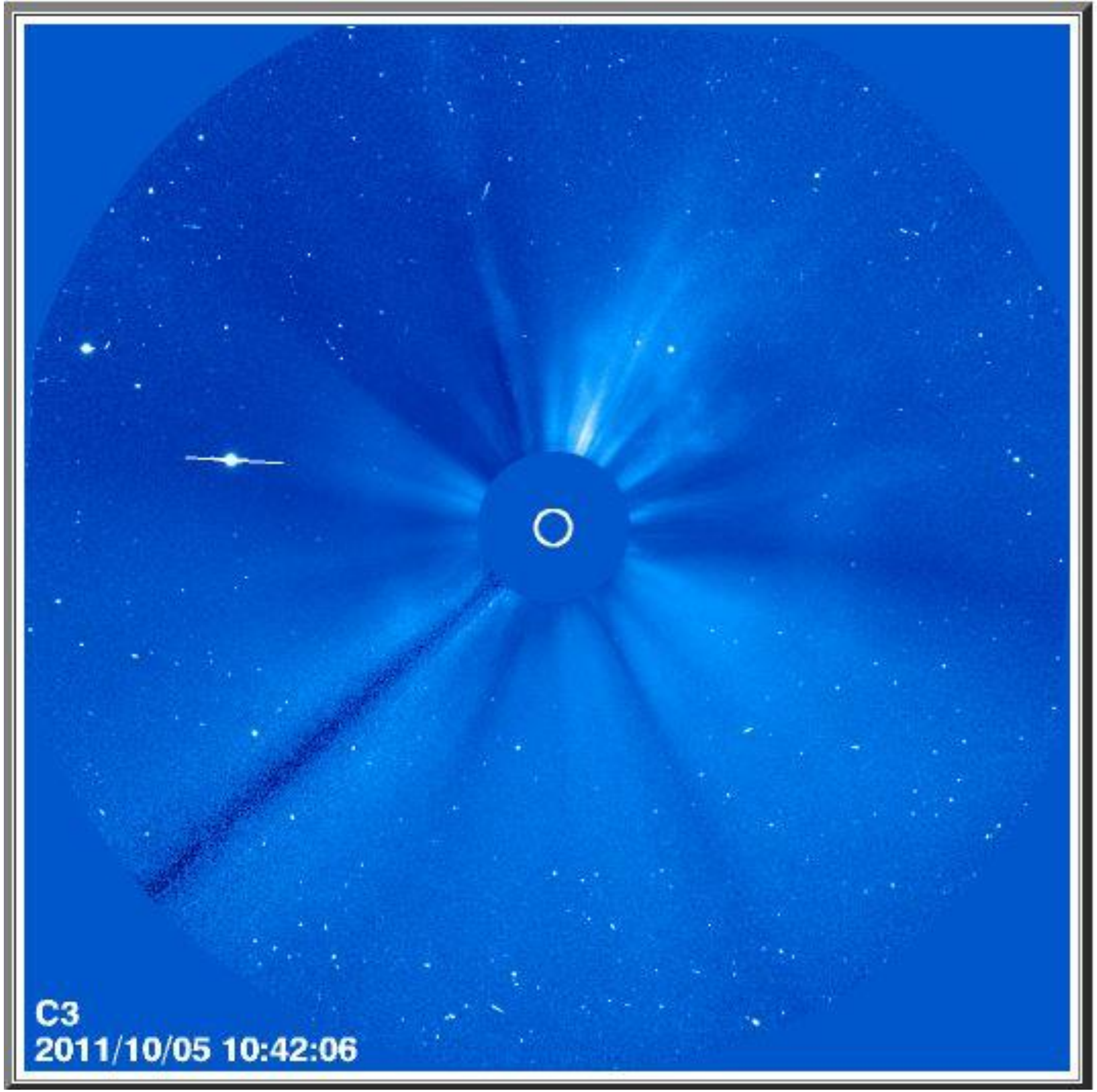
- **Select zero OR more Sources**
  (default = All Sources if >=1 Instrument Type is selected)
  - ACE
  - ARTEMIS
  - BARREL
- **Select zero OR more Instrument Types**
  (default = All Instrument Types if >=1 Source is selected)
  - Activity Indices


Wind Waves RAD1+RAD2 receiver: 2011/8/4
kHz
10000
1000
100
3
4
5
6
7
8
9
10
11
12
13
14
GMT (HRS)
0.5
2.5
4.4
6.3
8.3
10.3
12.2
14.2
16.1
18.1
20.0
intensity (dB) relative to background
RAD2
RAD1

SOHO/LASCO :
→around the Lagrange point (L1).

Coronagraph images	distance
C1	1.1 to 3 Rsun
C2	1.5 to 6 Rsun
C3	3.5 to 30 Rsun

https://lasco-www.nrl.navy.mil/index.php?p=content/lasco_desc



https://lasco-www.nrl.navy.mil/index.php?p=js_lasco1

Methodology

- Plasma frequency : $\mathbf{f} = 9\sqrt{n}$

  f : Plasma frequency(kHz)

  n : Plasma density($\frac{\#}{cm^3}$)

- Using continuity equation : $\frac{\partial n}{\partial t} + \nabla \cdot (n\vec{v}) = 0$

$\rightarrow \frac{\partial n}{\partial t} = 0$ by Steady state

$\rightarrow$Spherical coordinate : $\frac{1}{R^2}\frac{\partial}{\partial \mathrm{R}}(R^2 n\vec{v}) = 0$

$\rightarrow R_0^2 n_0 = R^2 n \quad \rightarrow R = \frac{\sqrt{n_0}}{\sqrt{n}} R_0$

$\rightarrow R \sim \frac{1}{f}$

v : solar wind speed
R : distance from sun to shock(km)
R $_0$: distance at 1AU(km)
n : Plasma density ($\frac{\#}{cm^3}$)
n $_0$: Plasma density at 1AU($\frac{\#}{cm^3}$)

Reiner et al.,1998

- Using $R \sim \frac{1}{f}$ and $R = \frac{\sqrt{n_0}}{\sqrt{n}} R_0$

$\rightarrow V = \frac{dR}{dt} = a\sqrt{n}_0 \frac{d}{dt}(\frac{1}{f})\ R_0$

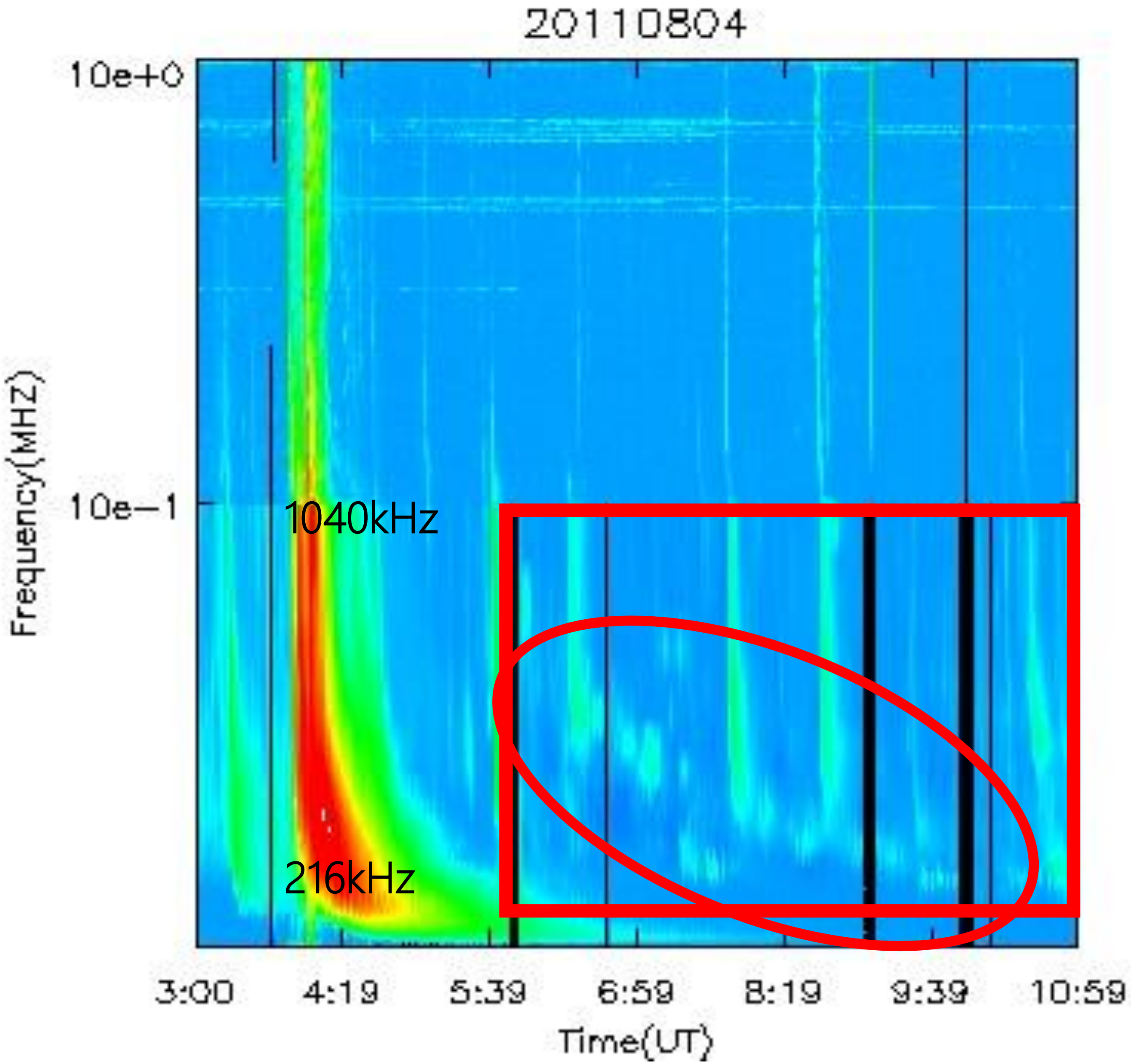
$R_0 = 1.5 \times 10^8$km $\quad n_0 = 7.2\ cm^{-3}$

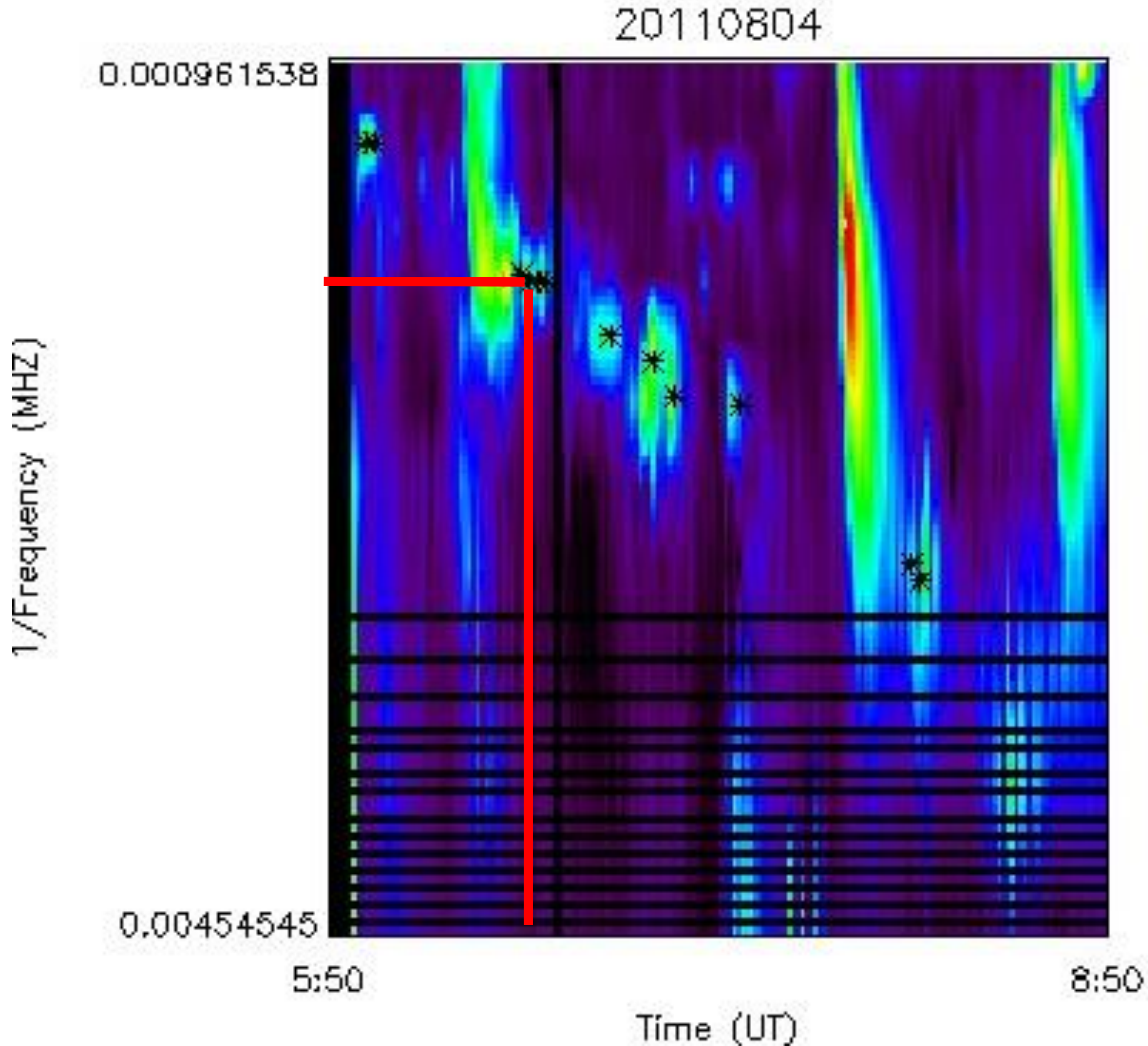
a = 9 (18) depending on whether the radio emissionis
generated at the fundamental (harmonic) of the plasma frequency

V : shock speed(km/s)

H. Xie,JOURNAL OF GEOPHYSICAL RESEARCH: SPACE PHYSICS, VOL. 118, 4711–4723, doi:10.1002/jgra.50444, 2013

$$V = \frac{dR}{dt} = 9\sqrt{n}_0 \frac{d}{dt}\left(\frac{1}{f}\right) R_0$$



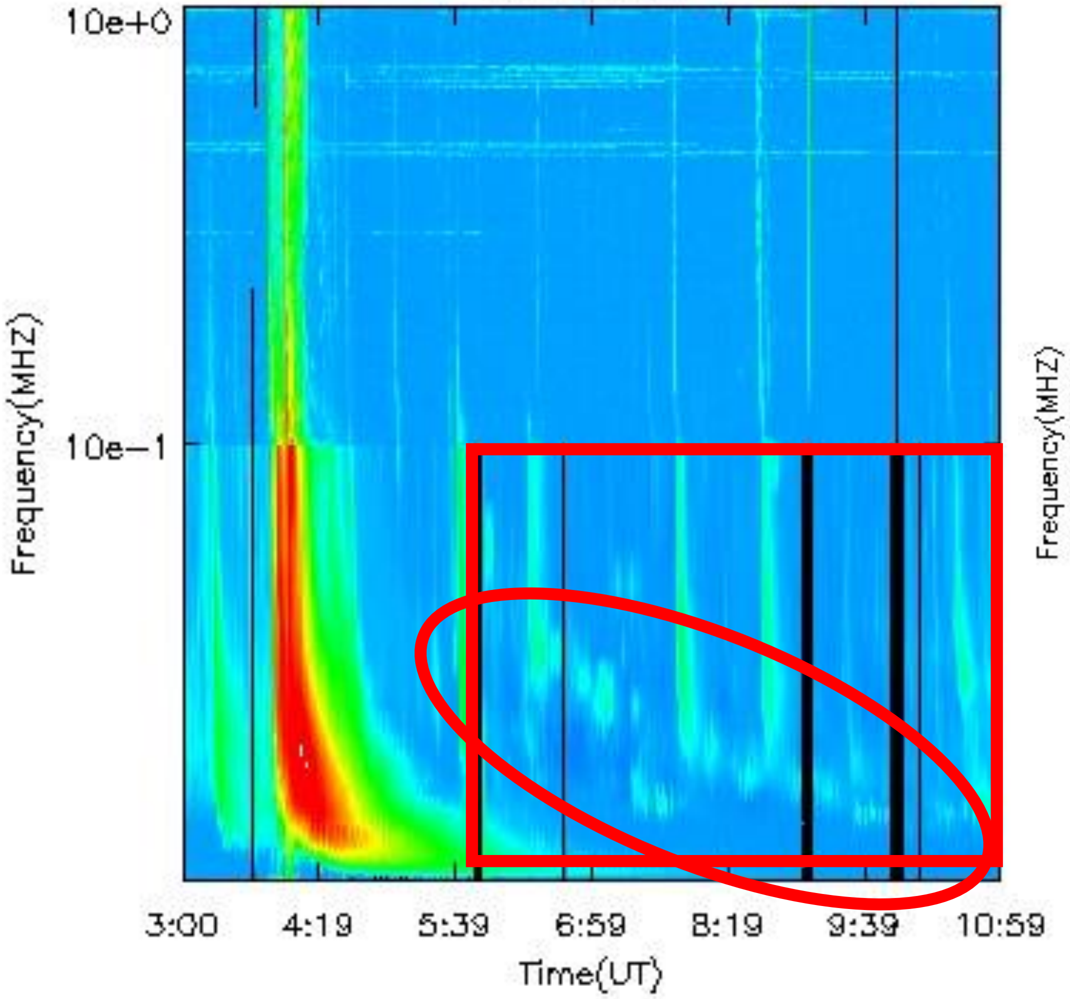


60	0.01666
↑ 20	↑ 0.00834
40	0.025
↑ 20	↑ 0.475
20	0.5

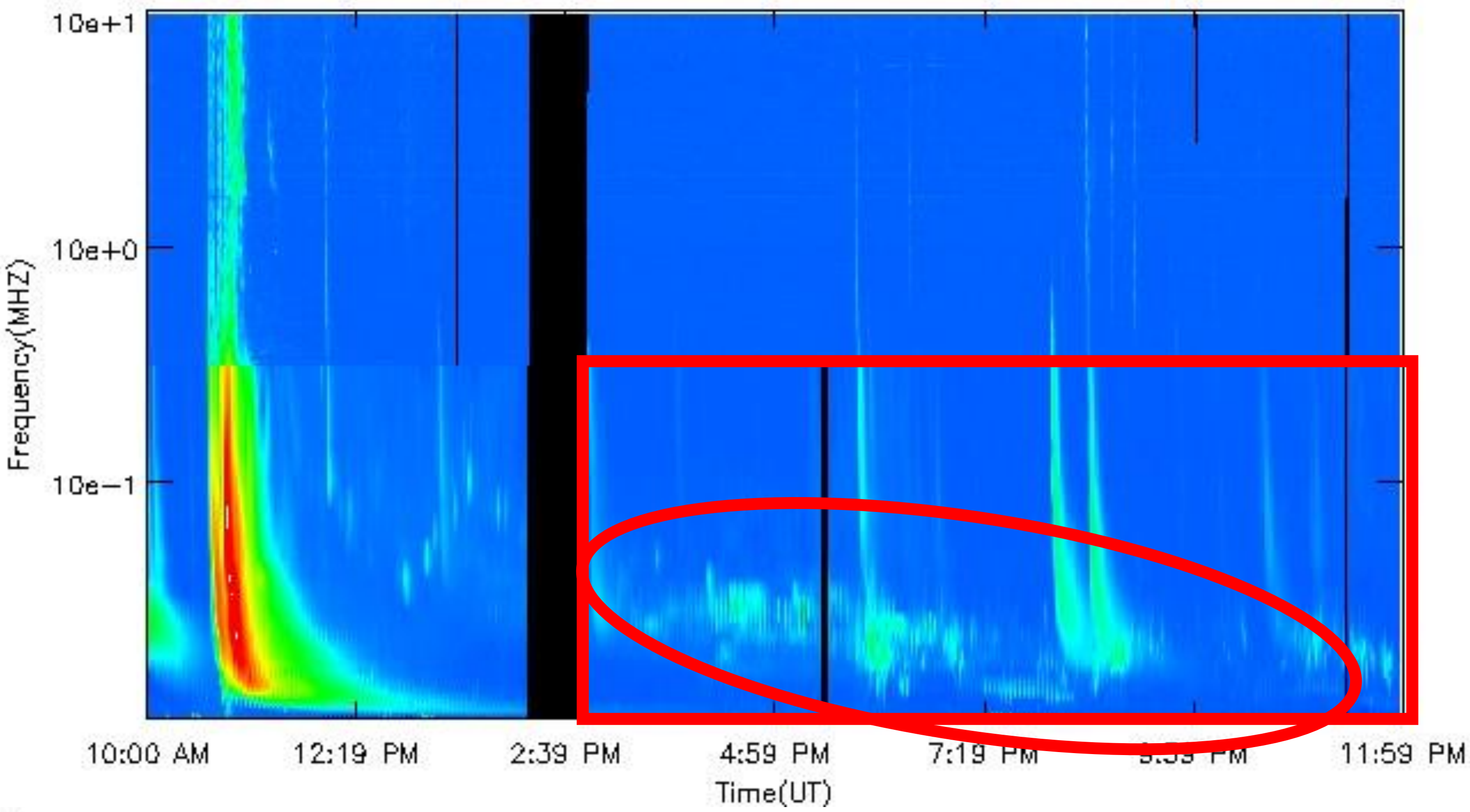
Events

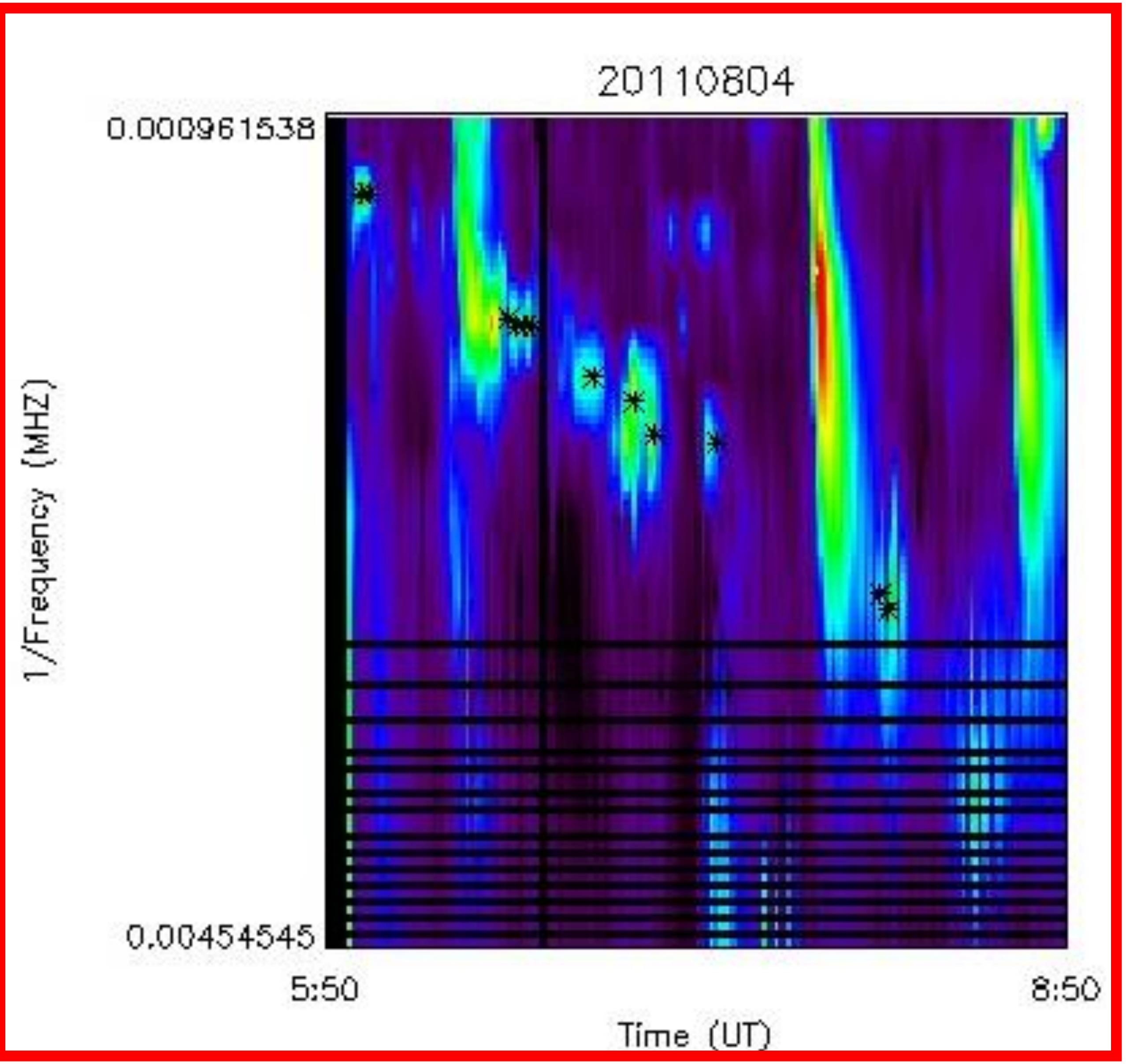
Start		End	Frequency(kHz)	Flare class
2010/08/07	18:35	19:50	700-14000	M1.0
2010/08/18	06:05	08/18 07:45	700-13000	C4.5
2011/02/15	02:10	02/15 07:00	400-16000	X2.2
2011/08/04	04:15	08/05 17:00	60-13000	M9.3
2011/09/22	11:05	24:00	70-14000	X1.4

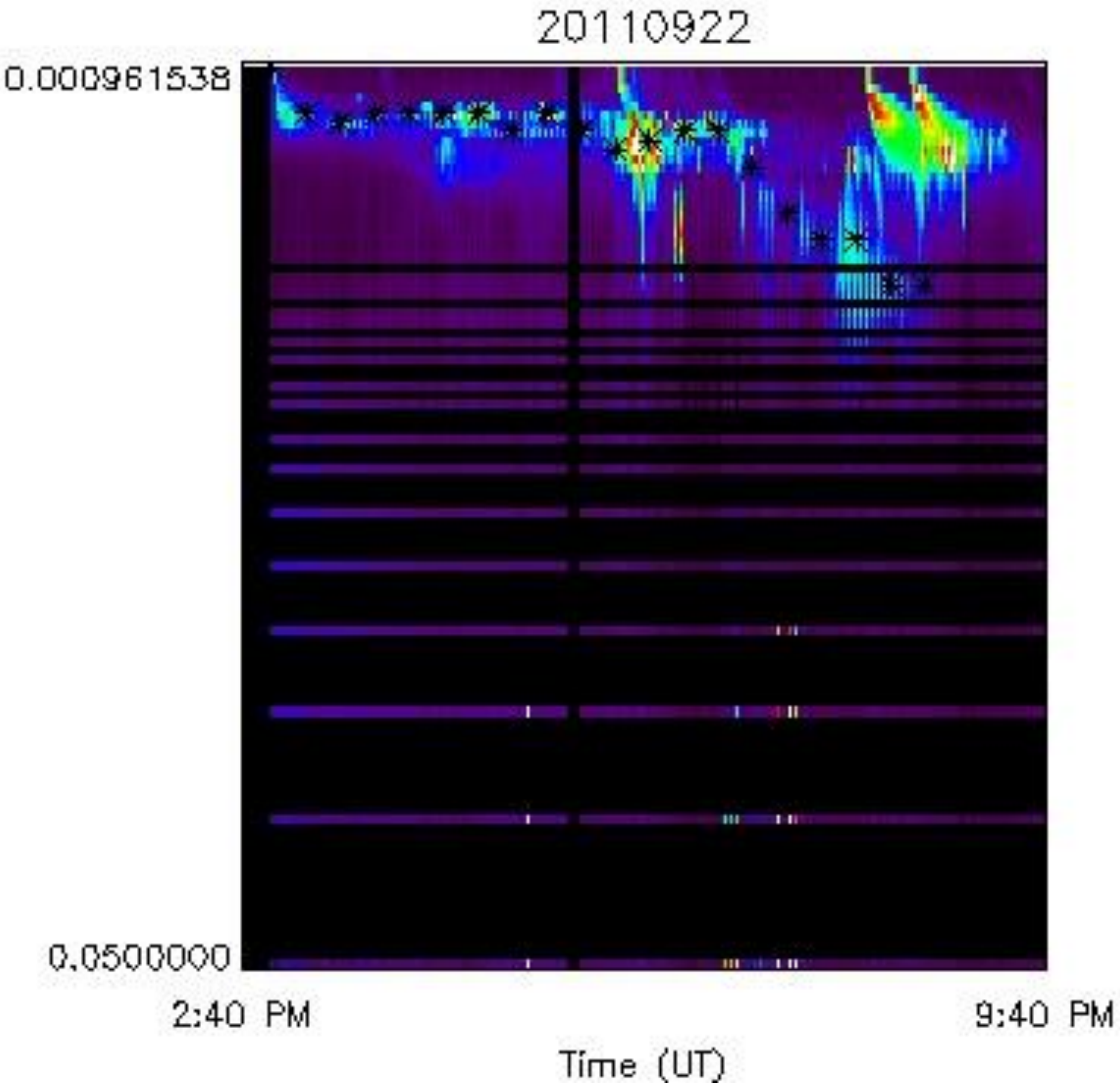
20110804



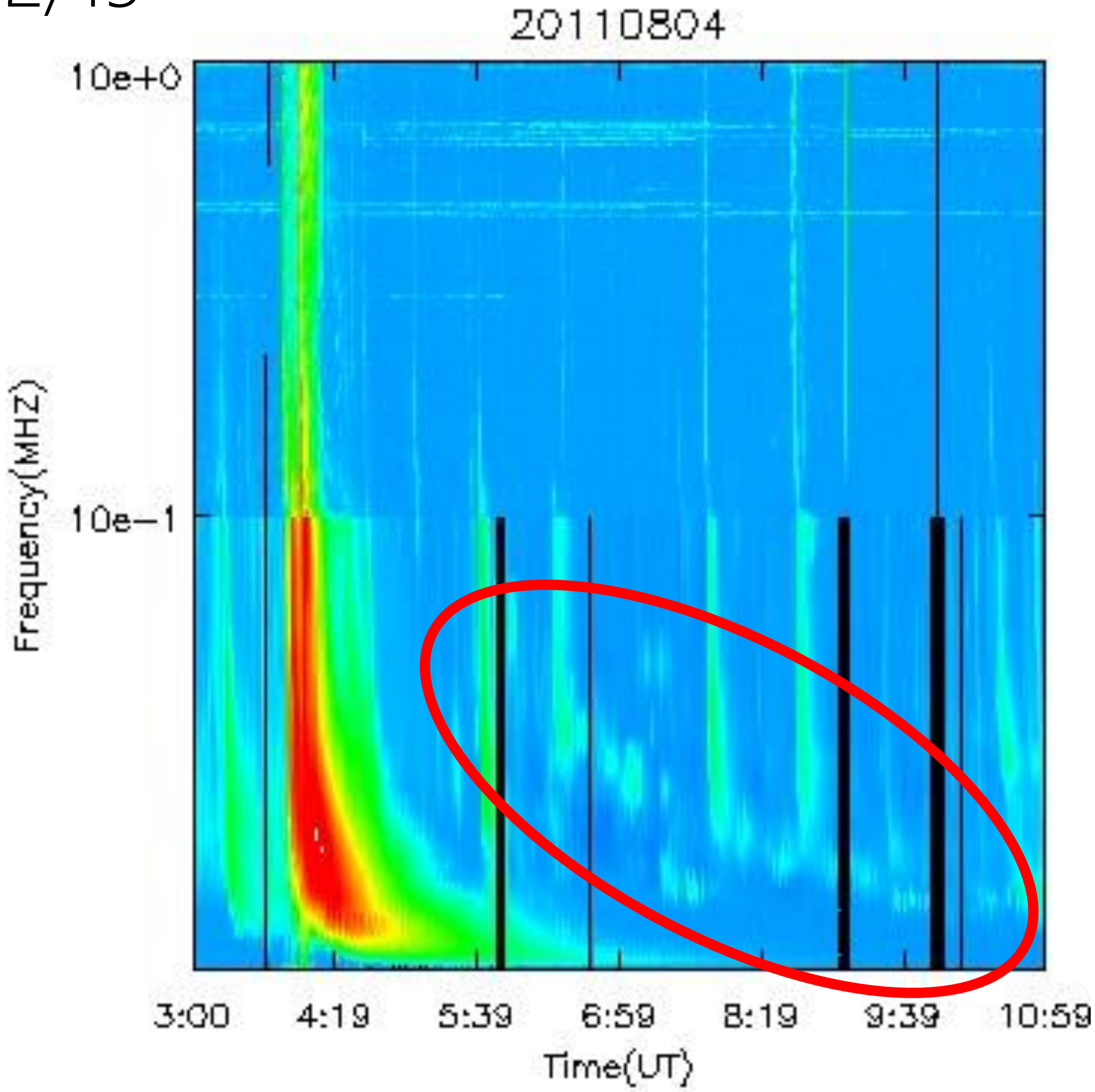
2011/09/22

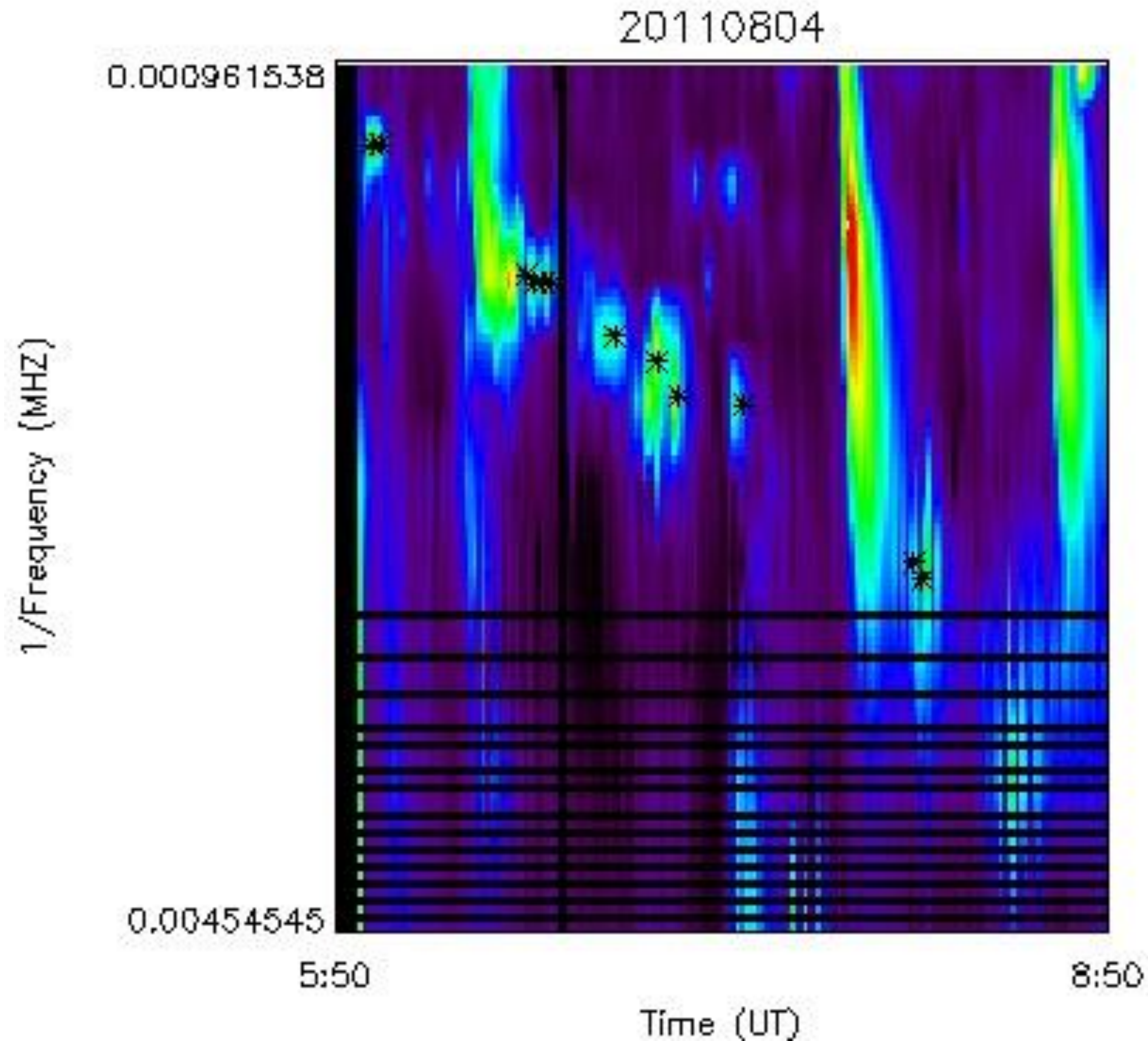



20110804
0.000961538
0.00454545
1/Frequency (MHZ)
5:50
8:50
Time (UT)


20110922
0.000961538
0.0500000
2:40 PM
9:40 PM
Time (UT)

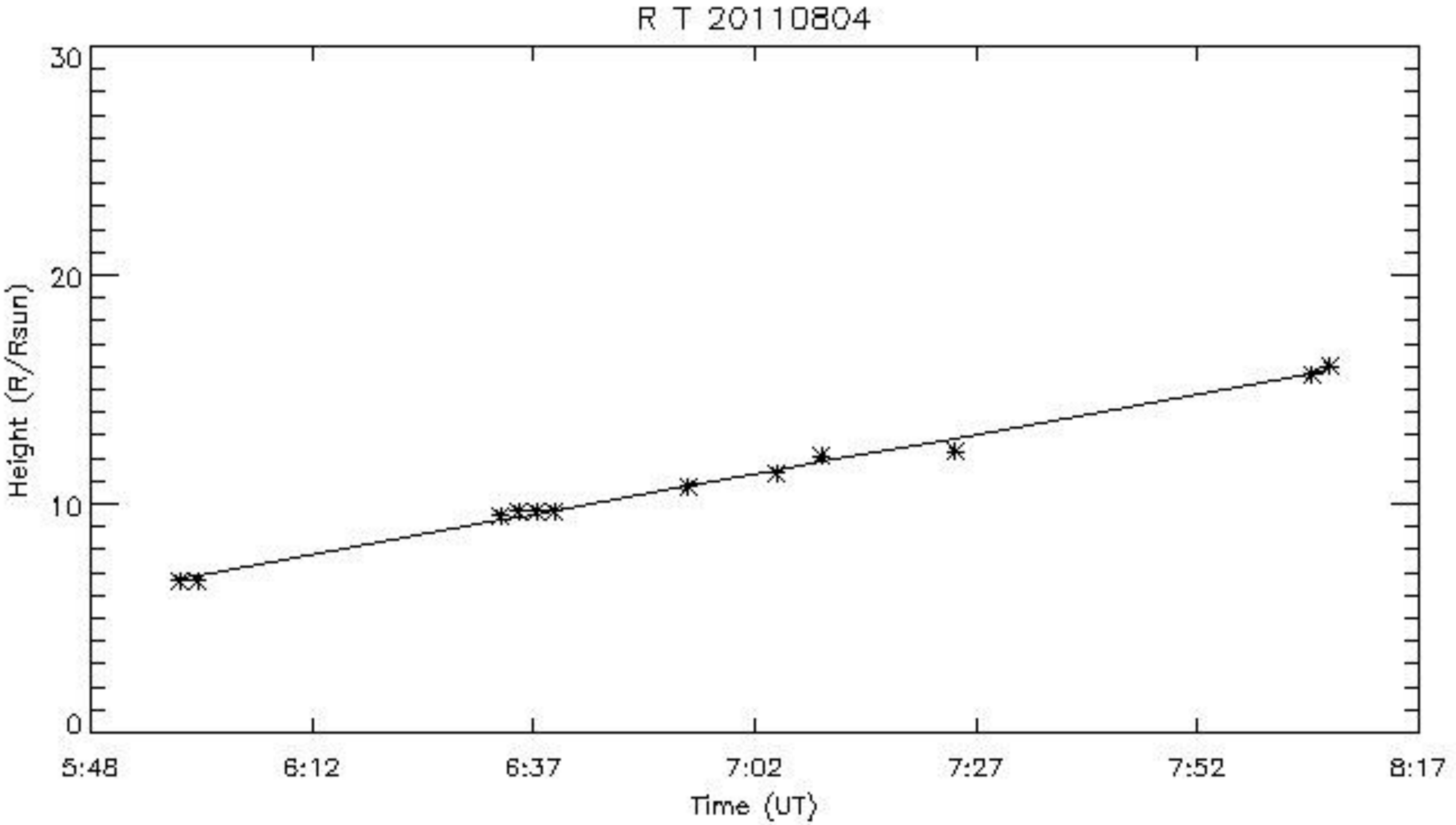
2011/08/04 02/15

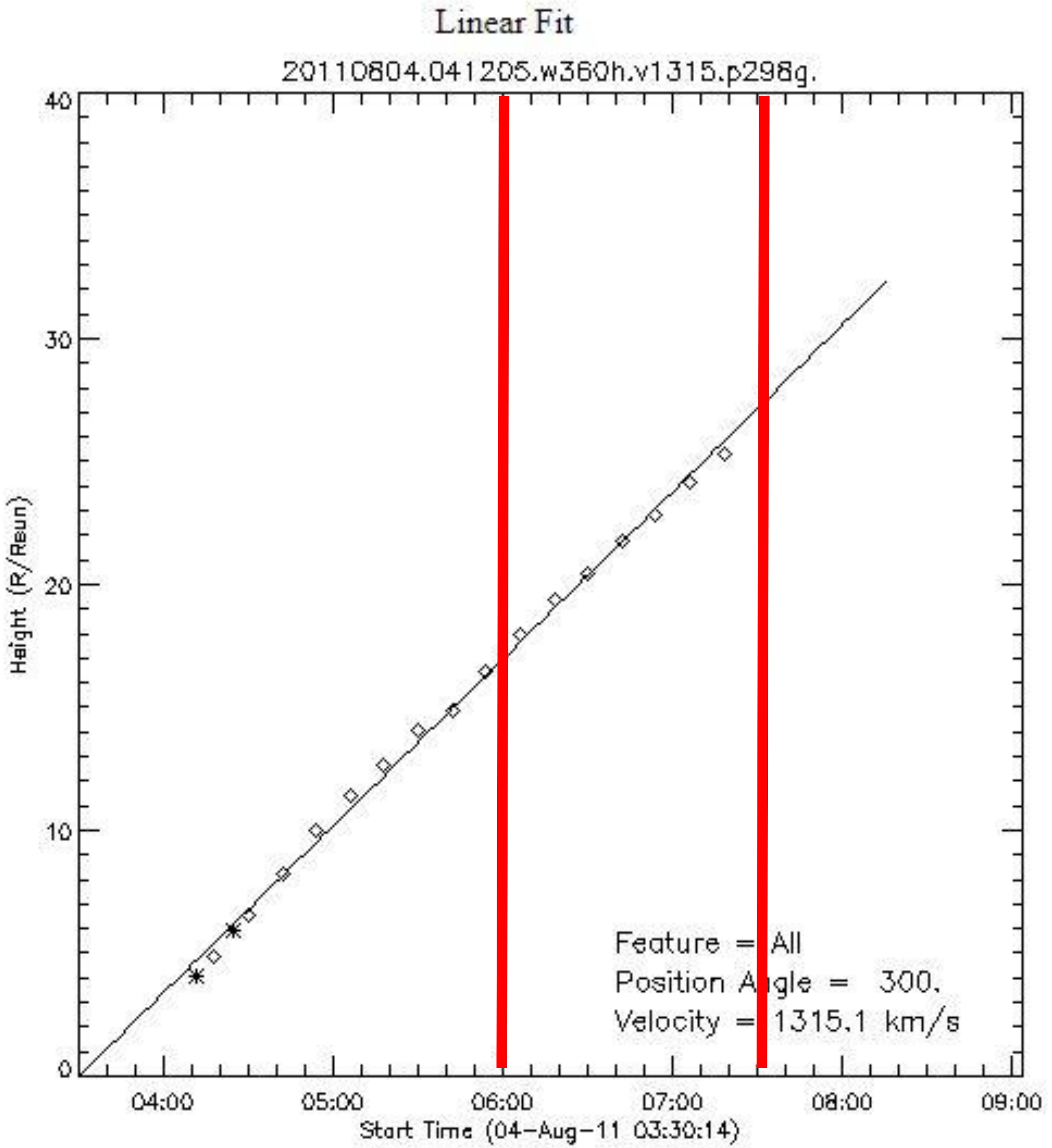




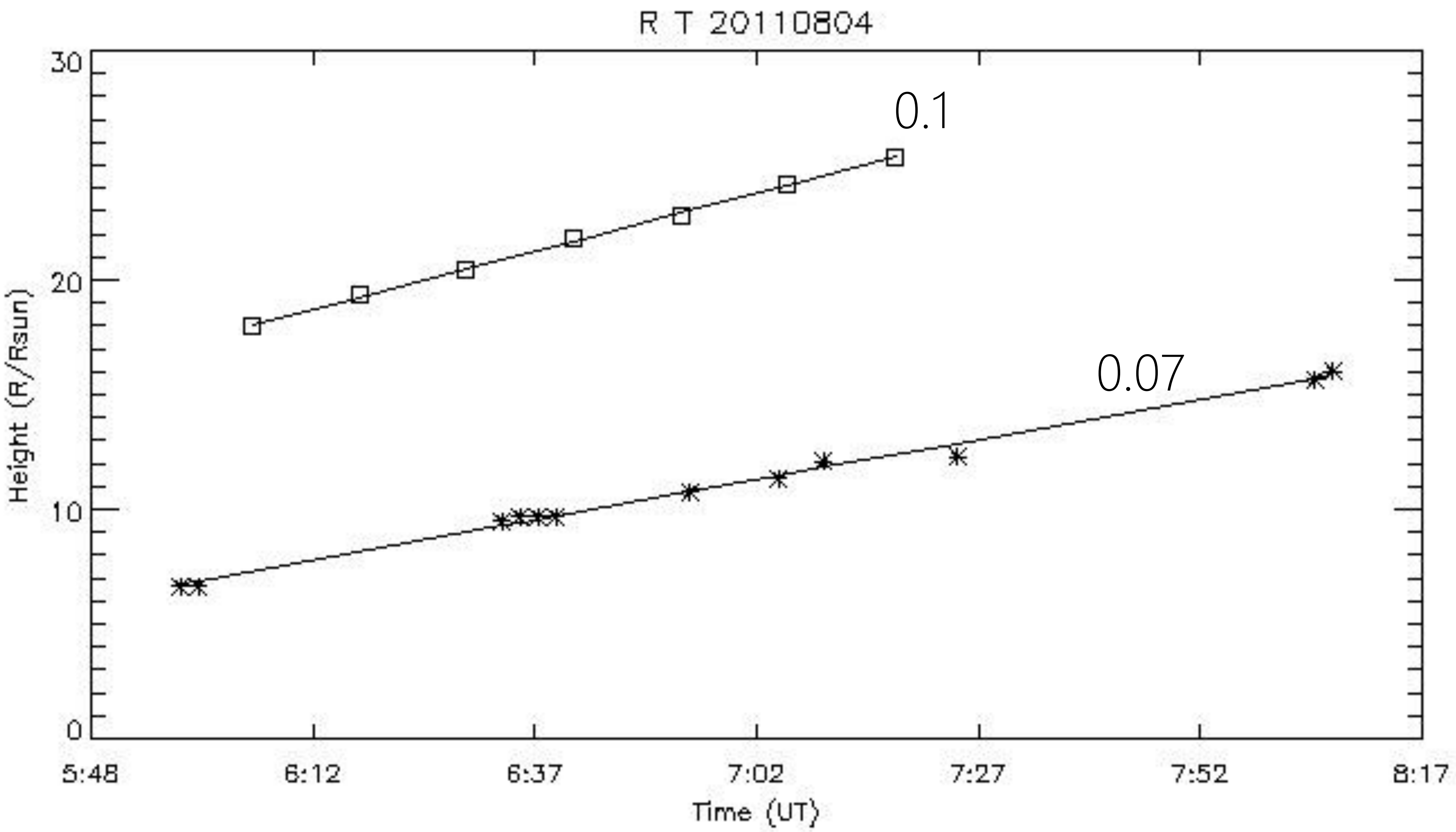
20110804
0.000961538
0.00454545
1/Frequency (MHZ)
5:50
8:50
Time (UT)

$$R(t) = \frac{a\sqrt{n_0}}{f(t)} \frac{R_0}{R_{sun}}$$

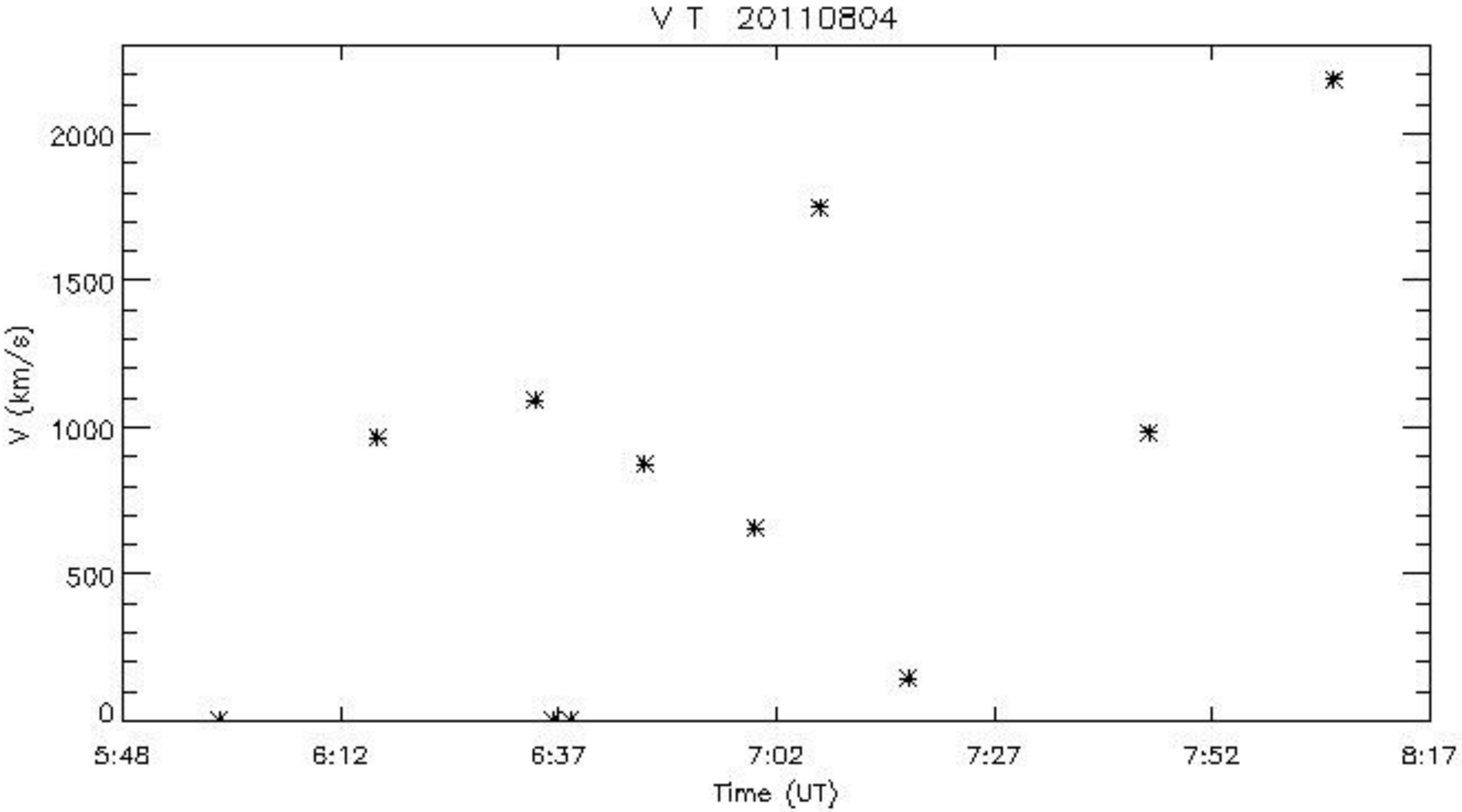




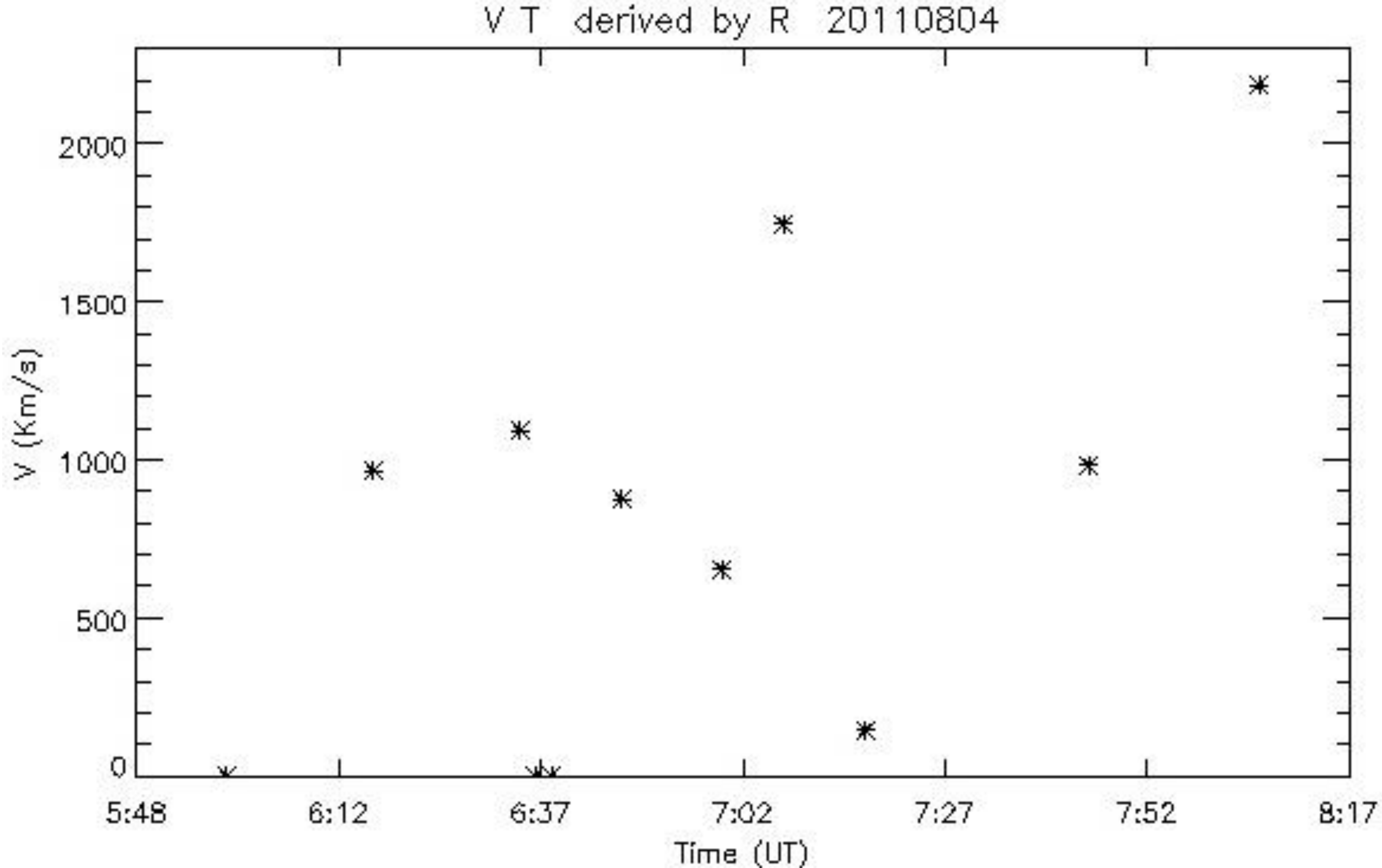
https://cdaw.gsfc.nasa.gov/CME_list/UNIVERSAL/2011_08/htpng/20110804.041205.p298g.htp.html


R T 20110804
0.1
0.07
Height (R/Rsun)
Time (UT)
30
20
10
0
5:48
6:12
6:37
7:02
7:27
7:52
8:17

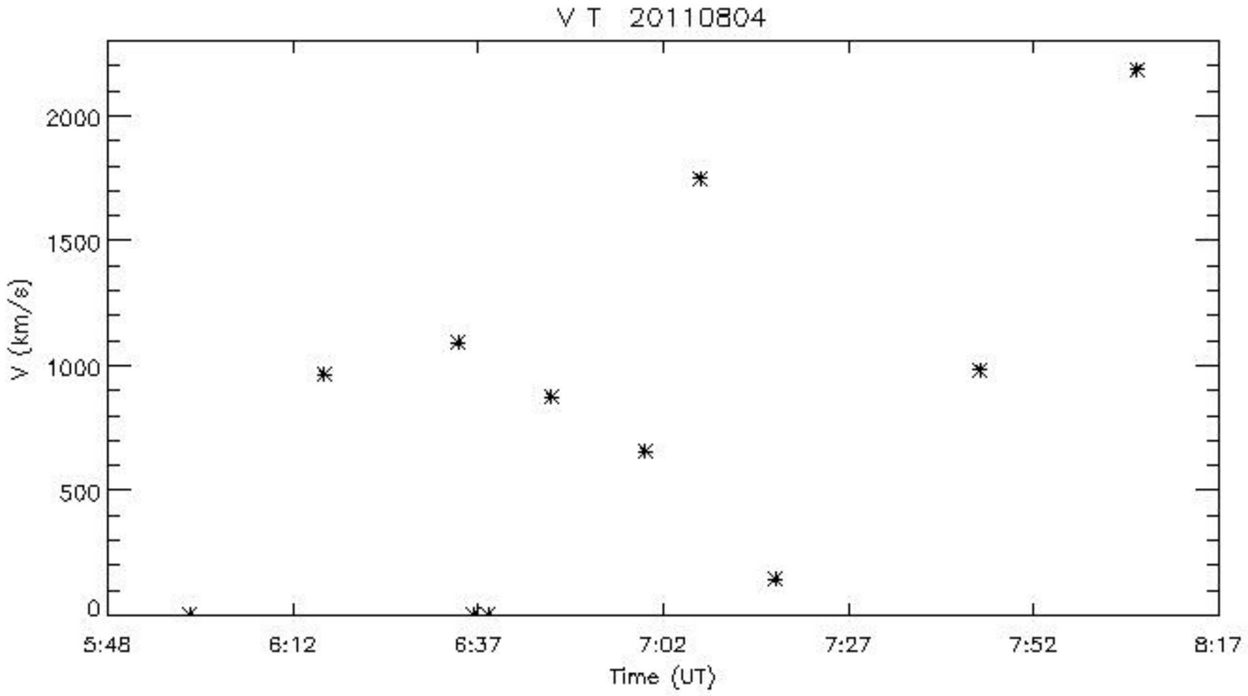
$$V = 9\sqrt{n_0}\,\frac{d}{dt}\left(\frac{1}{f}\right) R_0$$



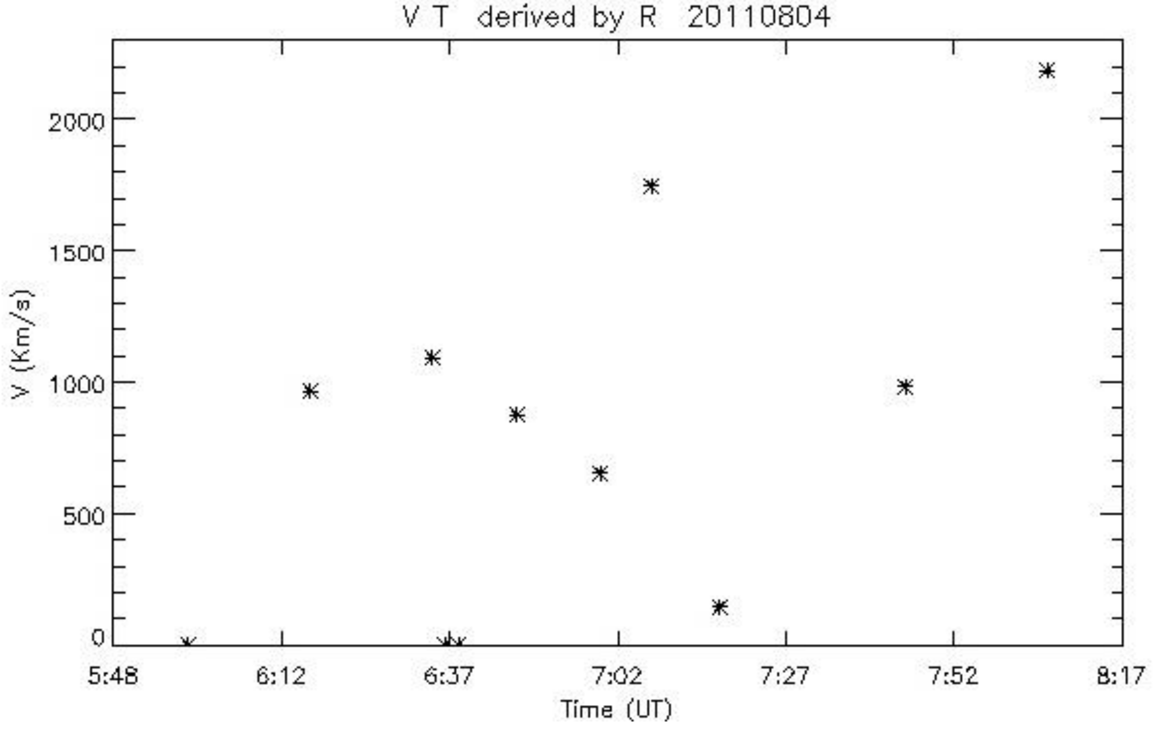
$$V = \frac{dR}{dt}$$

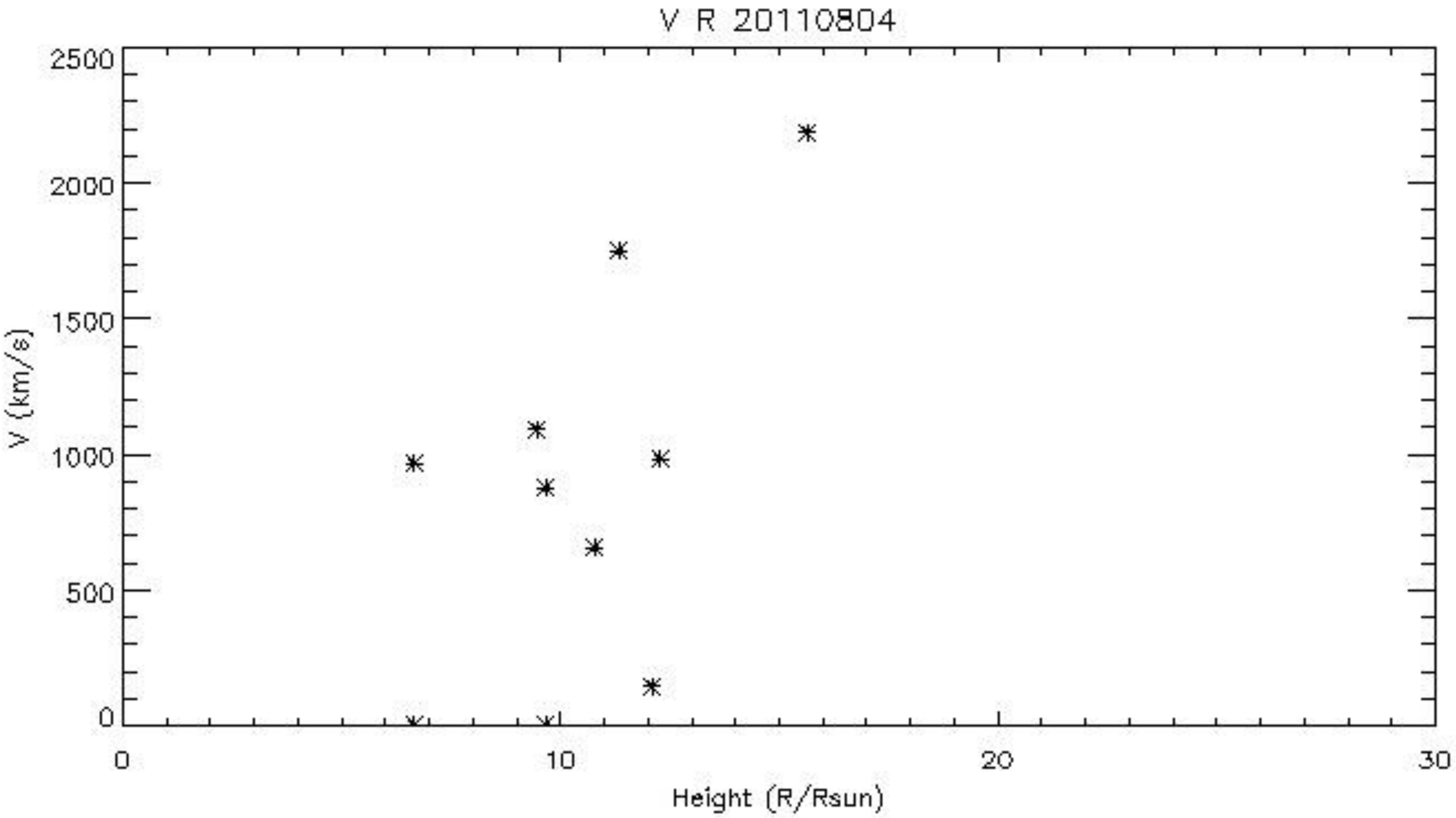

V T derived by R 20110804
V (Km/s)
0
500
1000
1500
2000
5:48
6:12
6:37
7:02
7:27
7:52
8:17
Time (UT)

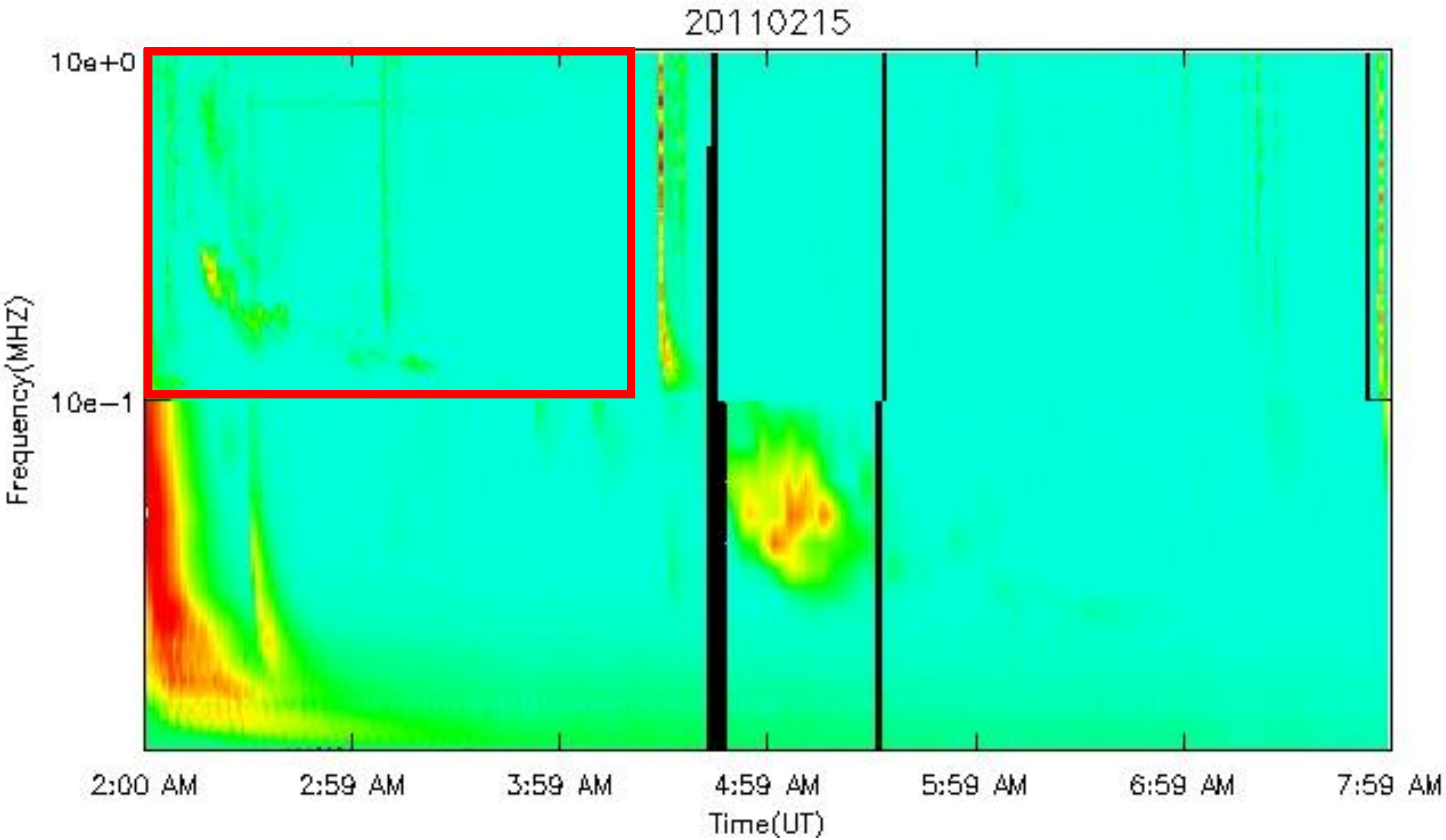
$$V = 9\sqrt{n}_0 \frac{d}{dt}\left(\frac{1}{f}\right) R_0$$

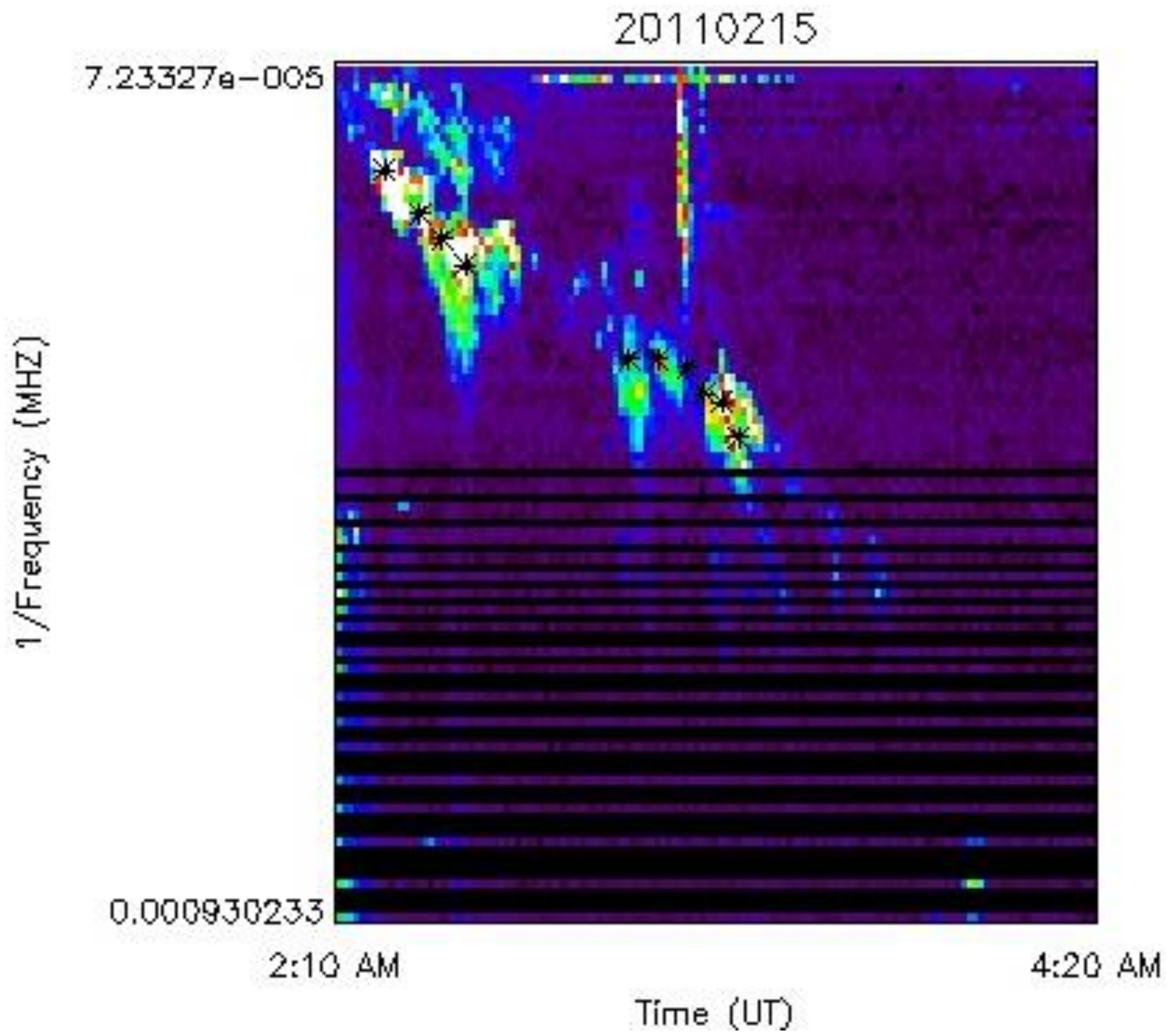


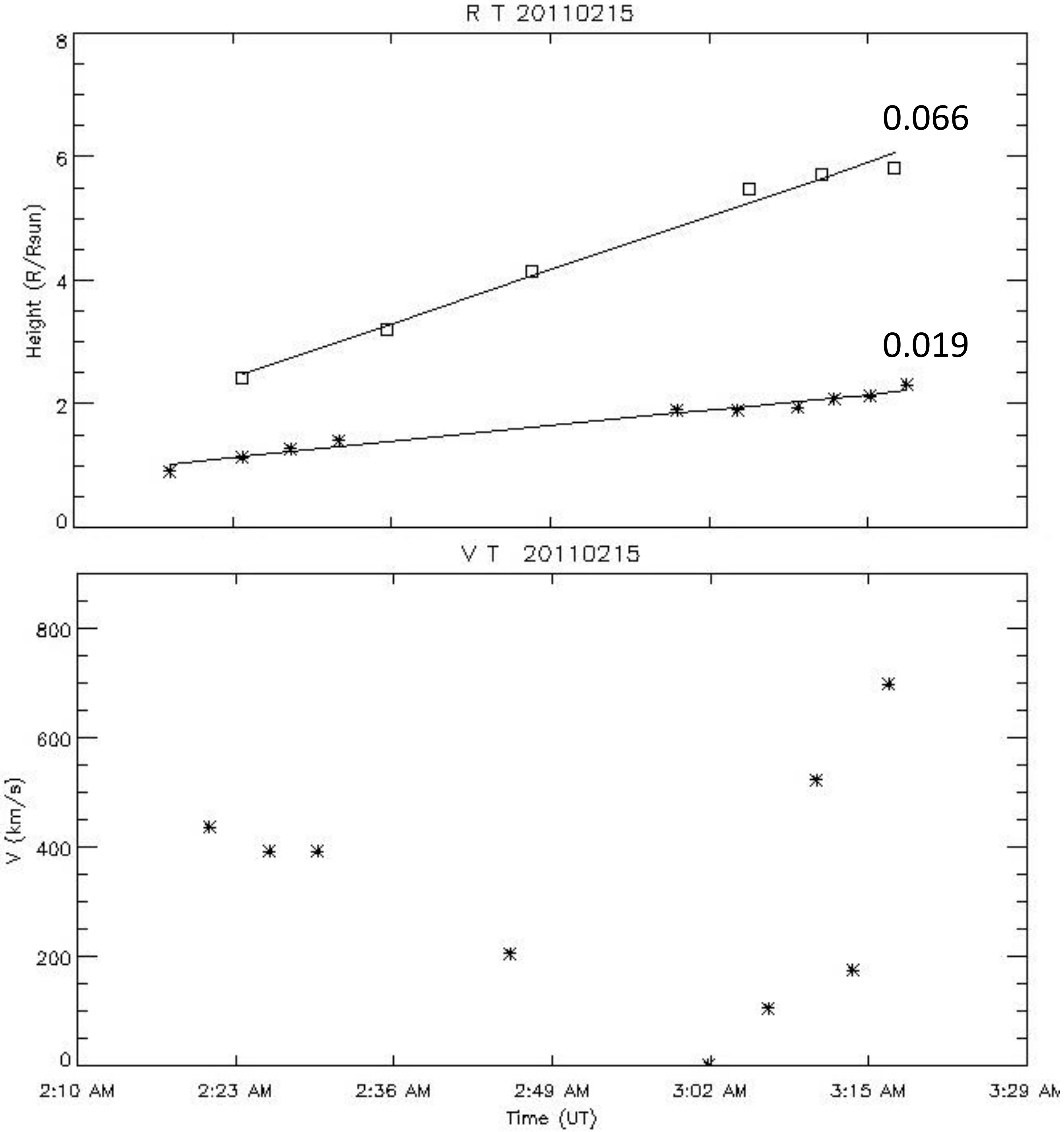
$$V = \frac{dR}{dt}$$




V R 20110804
2500
2000
1500
1000
500
0
V (km/s)
0
10
20
30
Height (R/Rsun)


20110215
10e+0
10e−1
Frequency(MHZ)
2:00 AM
2:59 AM
3:59 AM
4:59 AM
5:59 AM
6:59 AM
7:59 AM
Time(UT)


20110215
7.23327e-005
0.000930233
1/Frequency (MHZ)
2:10 AM
4:20 AM
Time (UT)


R T 20110215
Height (R/Rsun)
0.066
0.019
V T 20110215
V (km/s)
2:10 AM
2:23 AM
2:36 AM
2:49 AM
3:02 AM
3:15 AM
3:29 AM
Time (UT)

Summary

- The shock speed derived from low-frequency range is similar to the observation (e.g., 20110804).
- The large inconsistency between shock and CME heights may come from the simple assumptions in the calculation.
- The harmonic Type II burst event can be included in a future study.