Study of Type III Radio Bursts from Small-scale Reconnection Events

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Nanoflares

- Impulsive energy releases due to small breaks in coronal magnetic fields that have become stressed by photospheric convection.

- Too small to be detected individually, in part due to the optically thin corona

- Several lines of evidence suggest that they may be the primary cause of coronal heating.

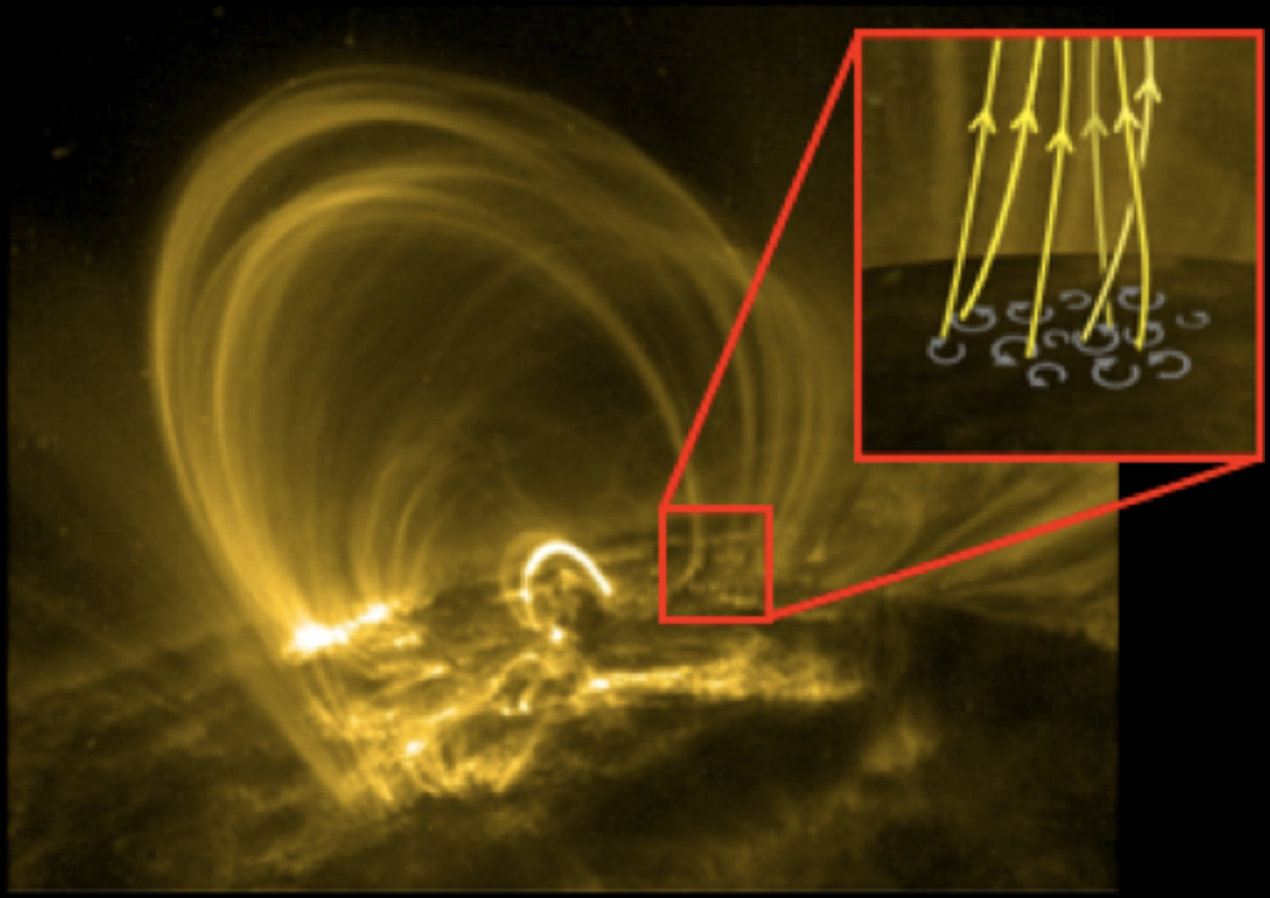
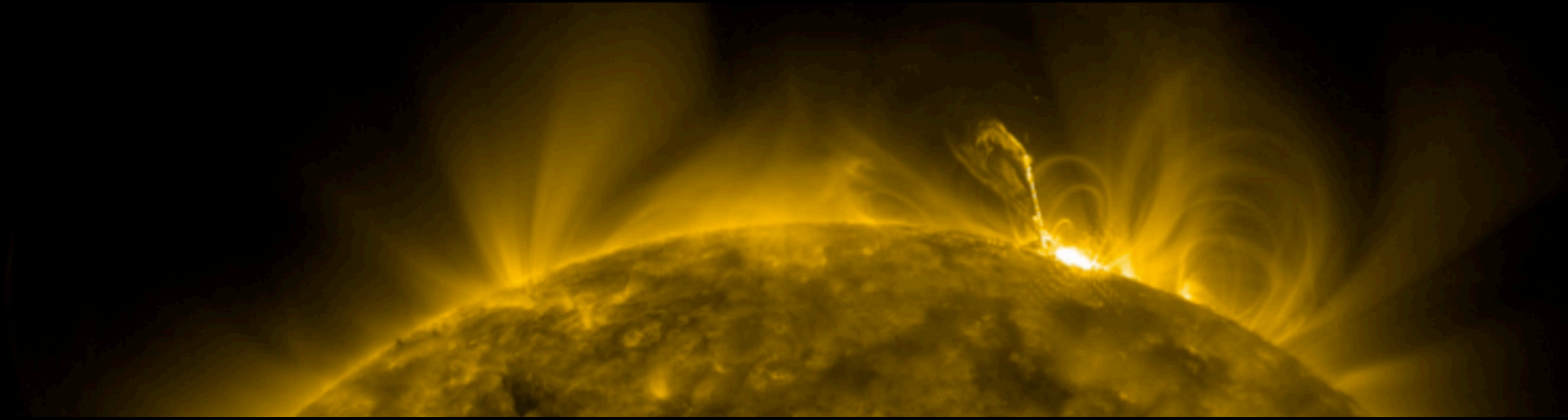


Image Courtesy: TRACE

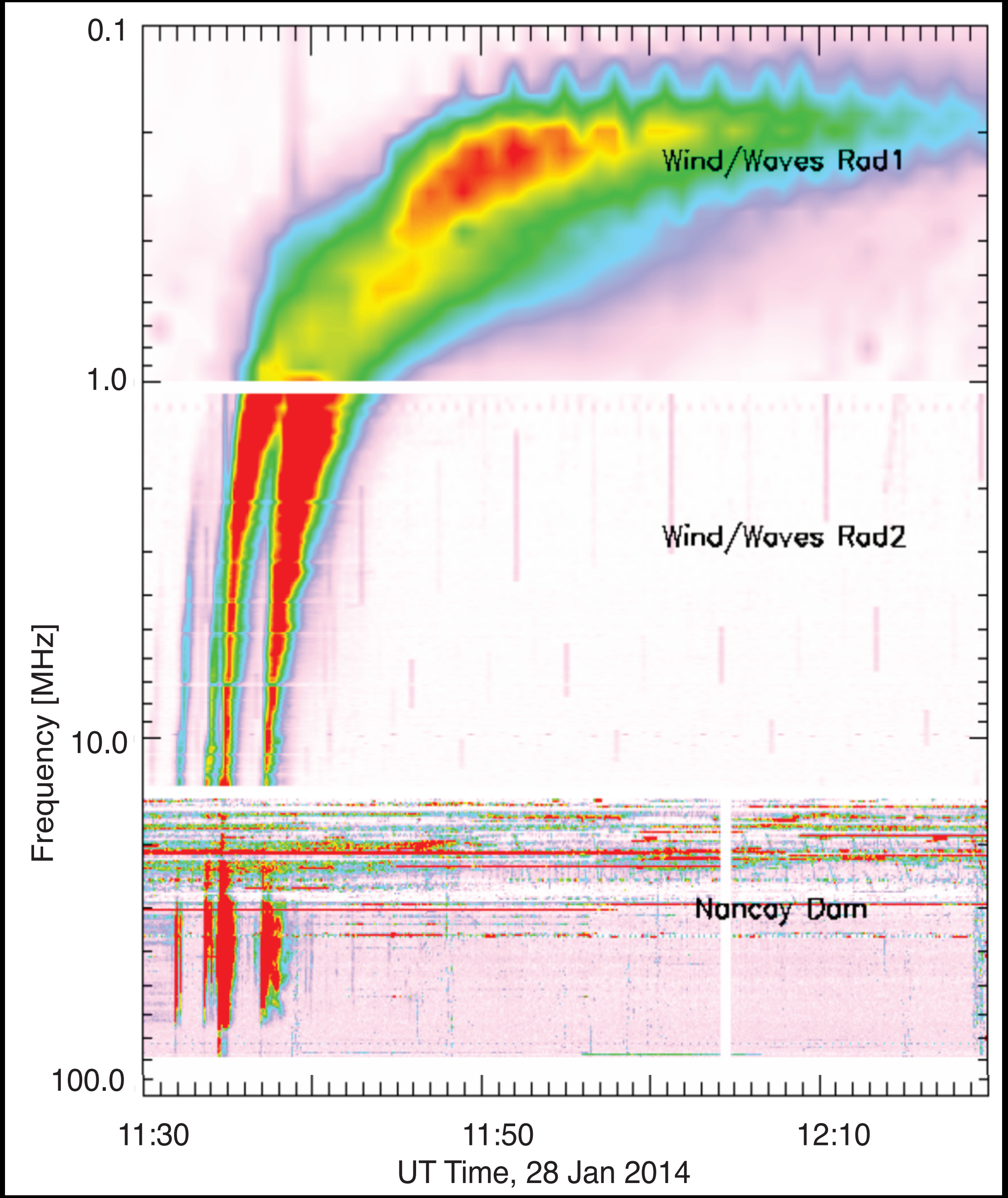
Do nanoflares accelerate particles in the same manner as full-sized flares?

If so, how efficiently?

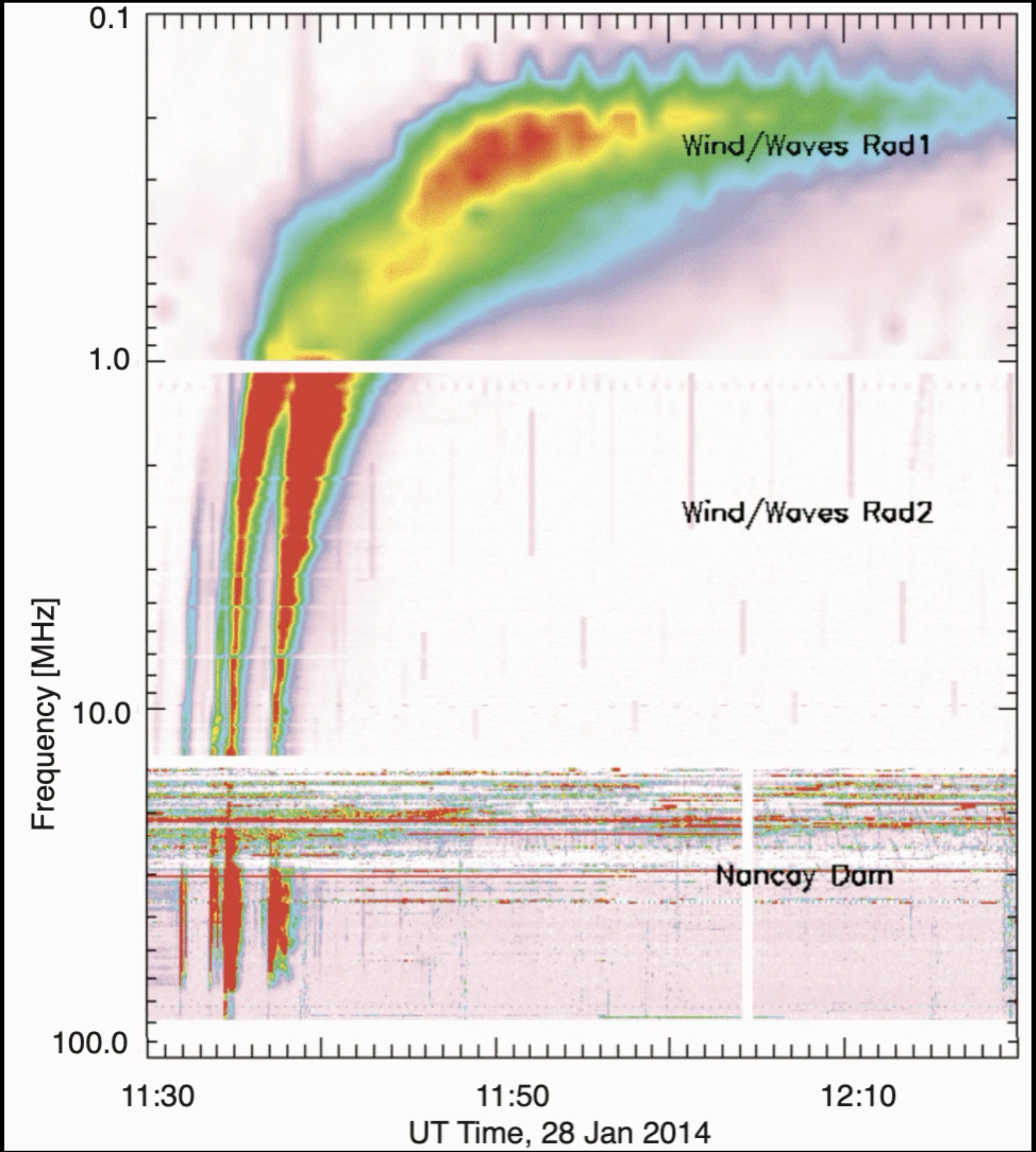


Why Type III Radio Bursts?

- Produced by propagating beams of high energy electrons
- Fast frequency drift rates



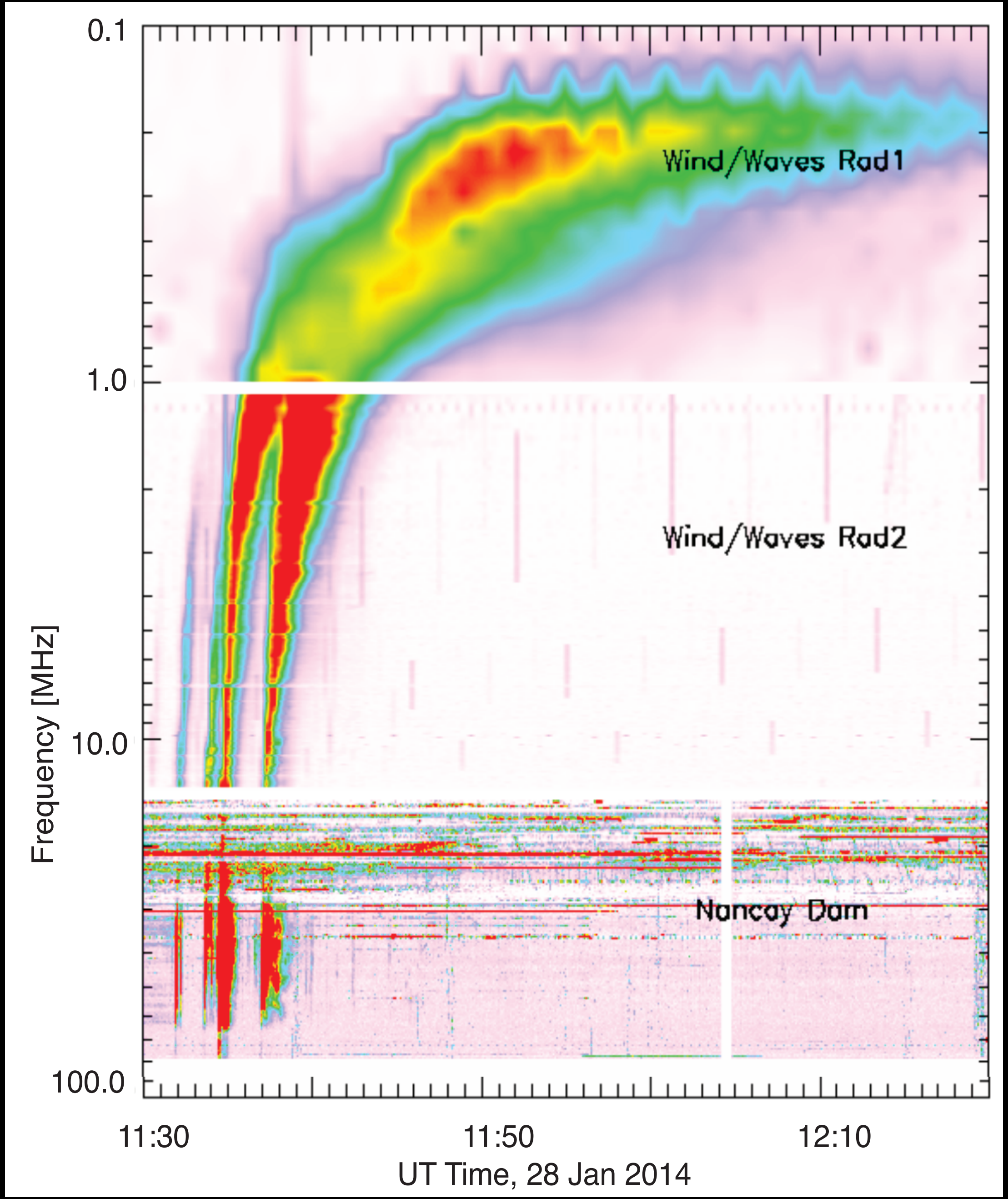
[Reid et al., 2014]



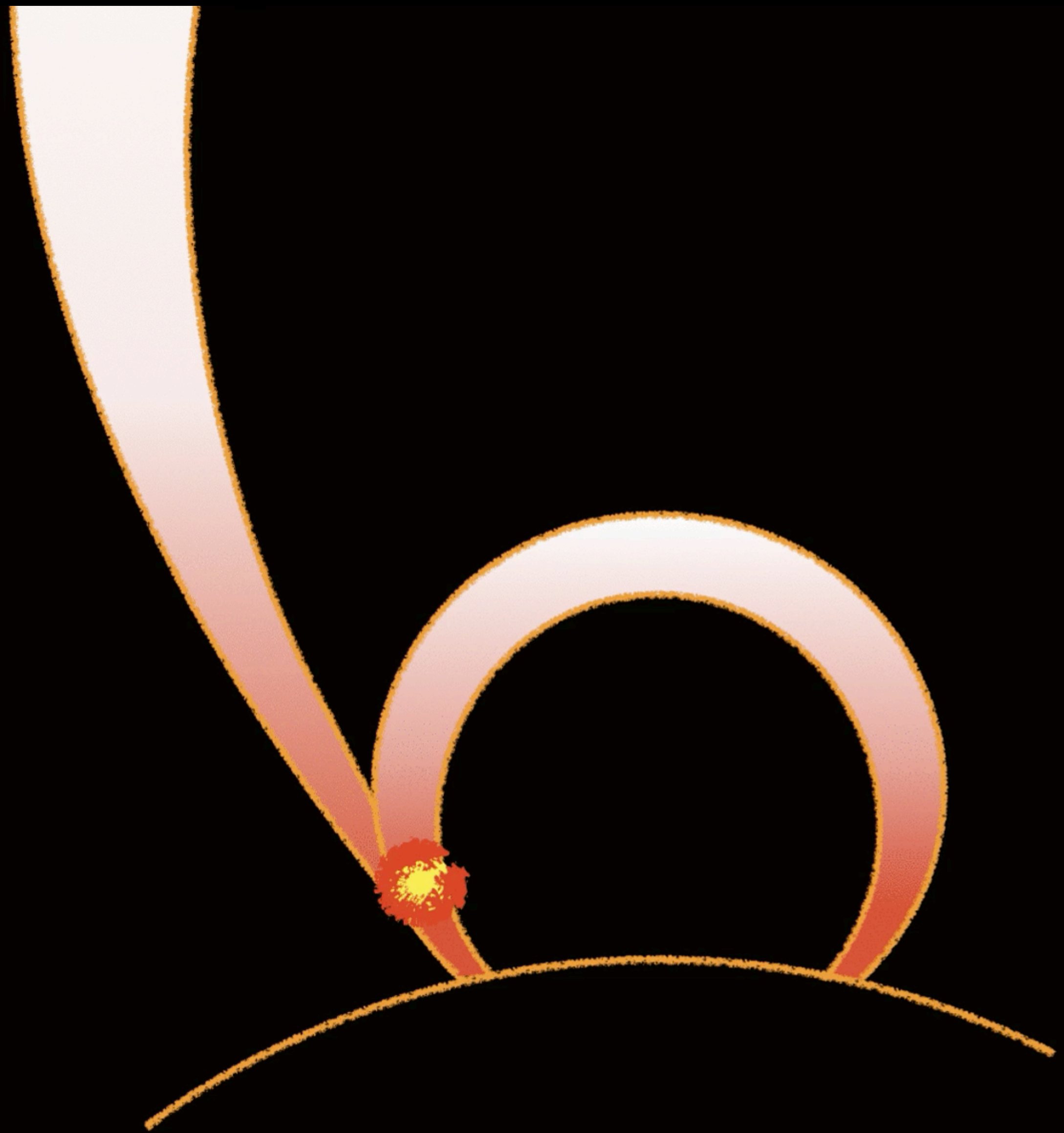
Traditional type IIIs

Why Type III Radio Bursts?

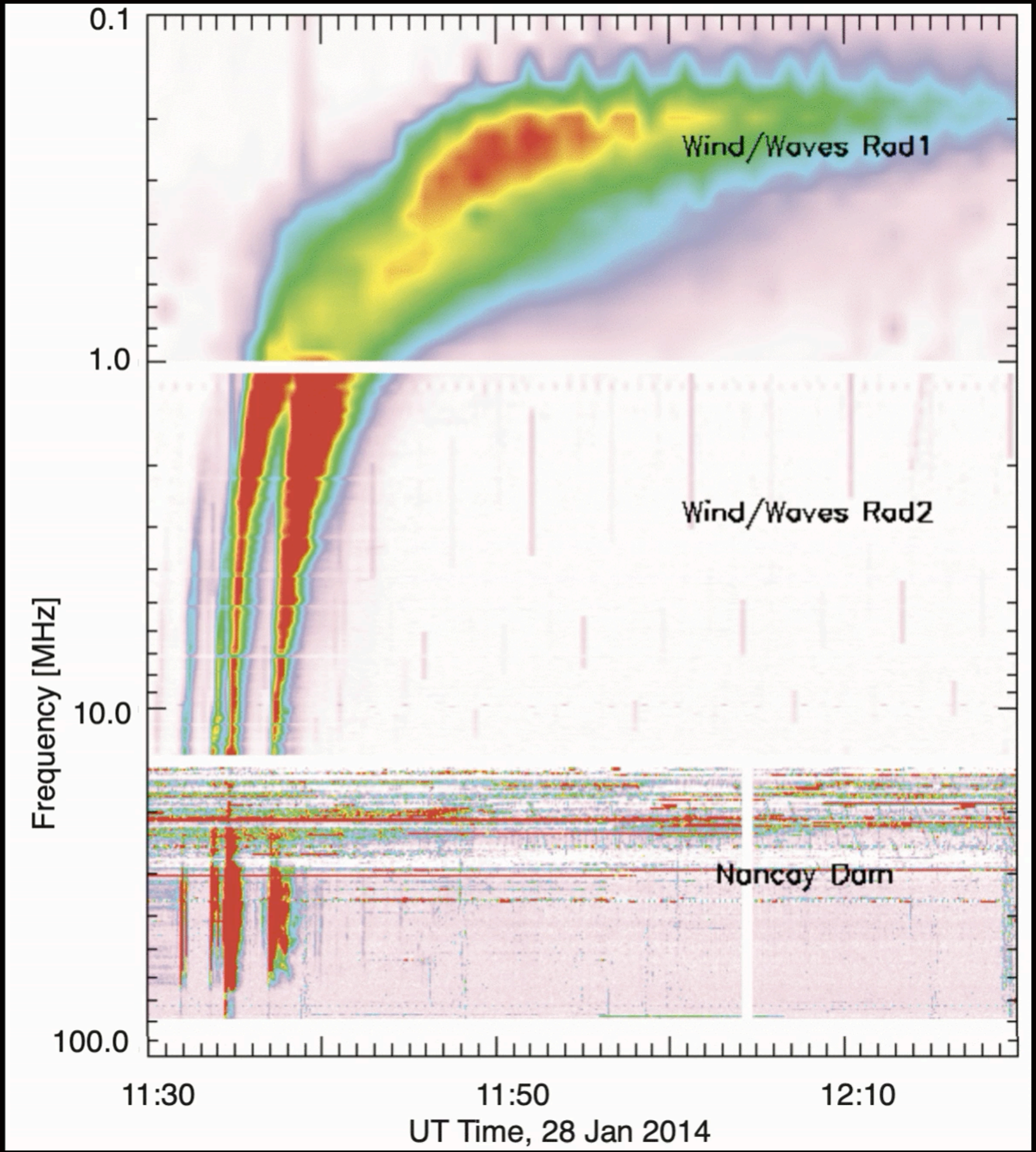
- Produced by propagating beams of high energy electrons
- Fast frequency drift rates
- Do not suffer the same limitations as hard x-ray emission or EUV



[Reid et al., 2014]

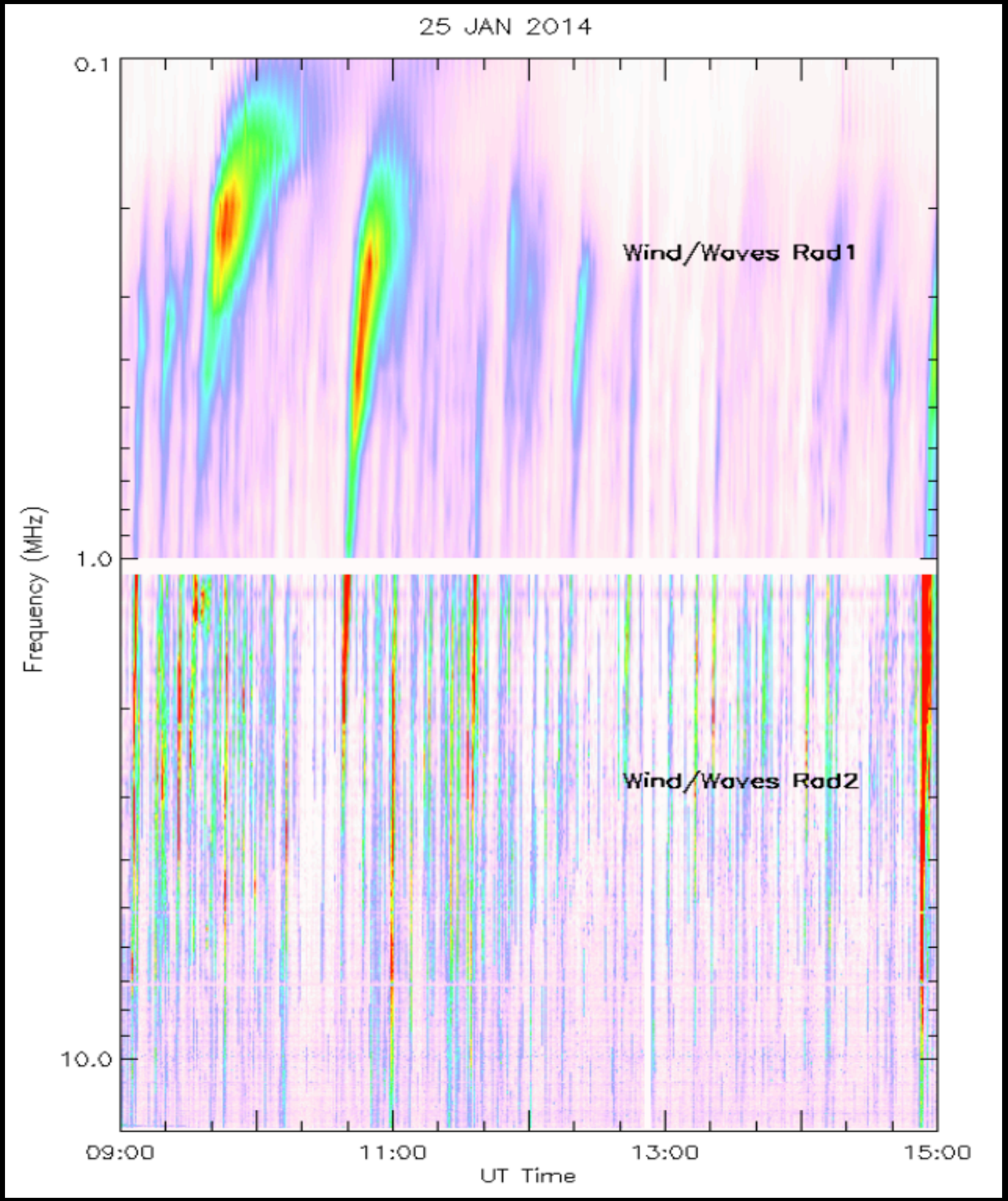


Type IIIs in closed loops



Why Type III Radio Bursts?

- Produced by propagating beams of high energy electrons
- Fast frequency drift rates
- Do not suffer the same limitations as hard x-ray emission or EUV
- Nanoflares would produce multiple overlapping Type III bursts, resulting in a “radio haze,” rather than distinct events



[Bougeret et al., 1995]

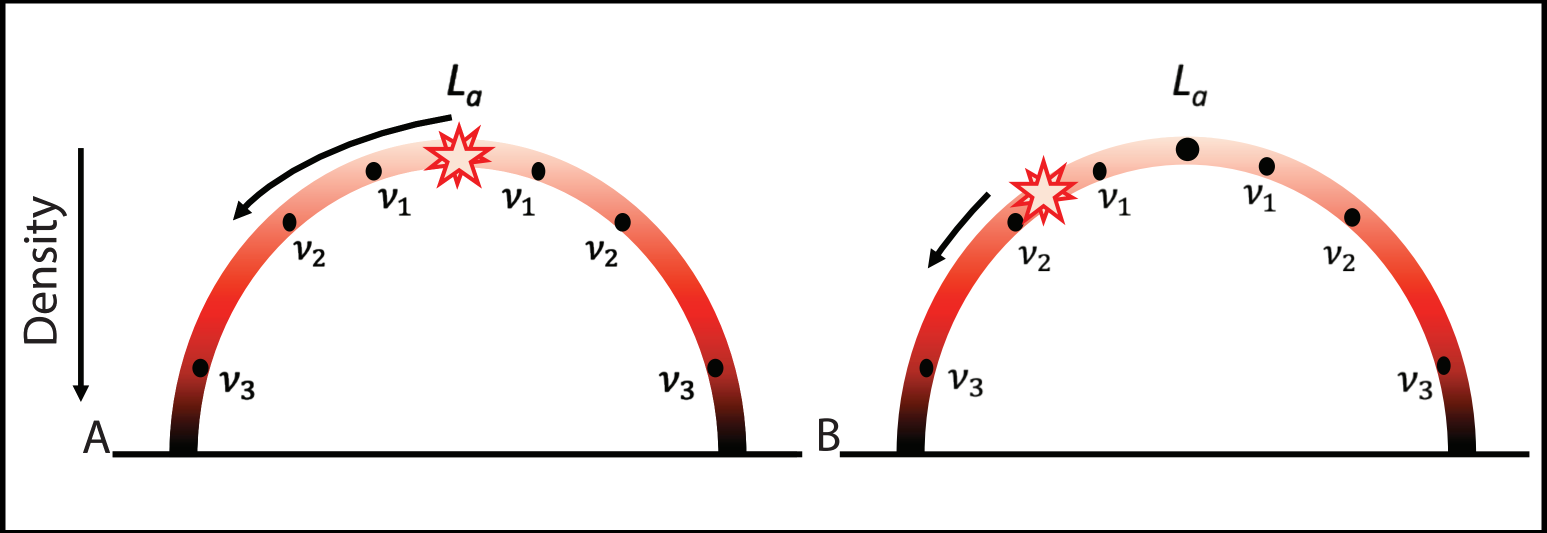
Model: Simple hydrostatic loop

Case A:

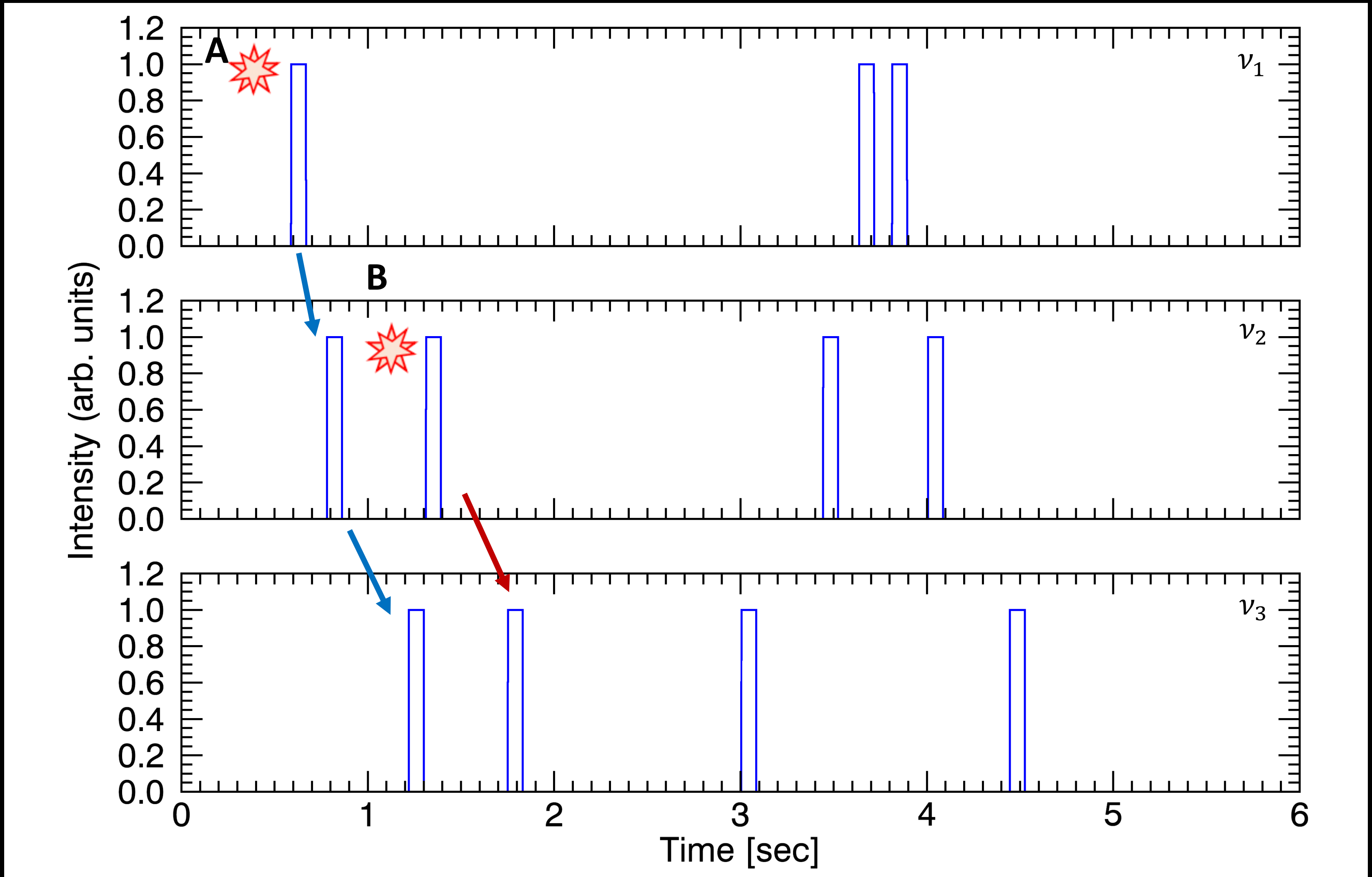
- Reconnection site: loop top
- Velocity(E = 2 keV) : Constant
- Duration of reconnection: fixed

Case B:

- Reconnection site: Random
- Preferred direction: downward



Intensity light curves at the three frequencies



Model: Simple hydrostatic loop

Case A:

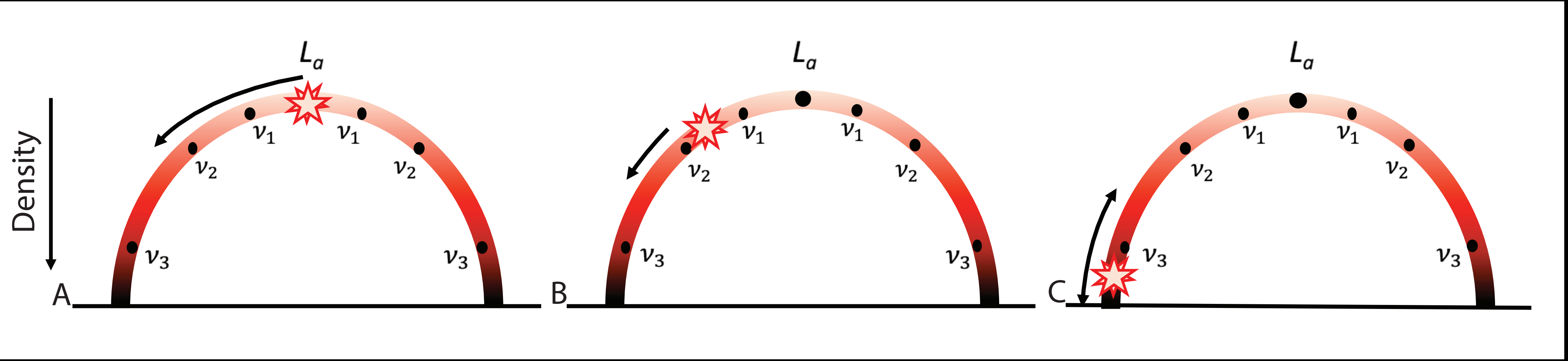
- Reconnection site: loop top
- Preferred direction: downward
- Velocity(E = 10 keV) : Constant
- Duration of reconnection: fixed

Case B:

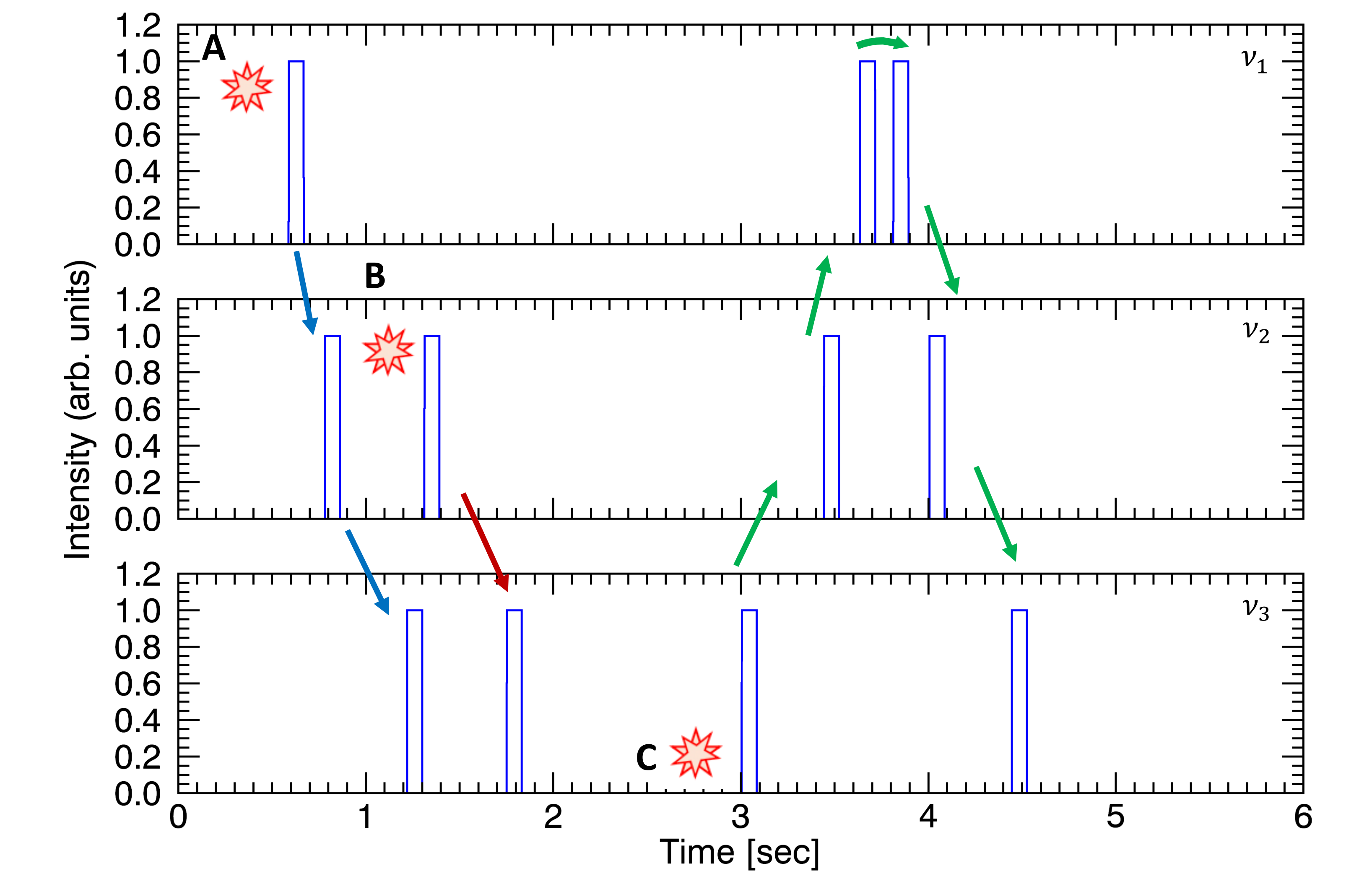
- Reconnection site: Random

Case C:

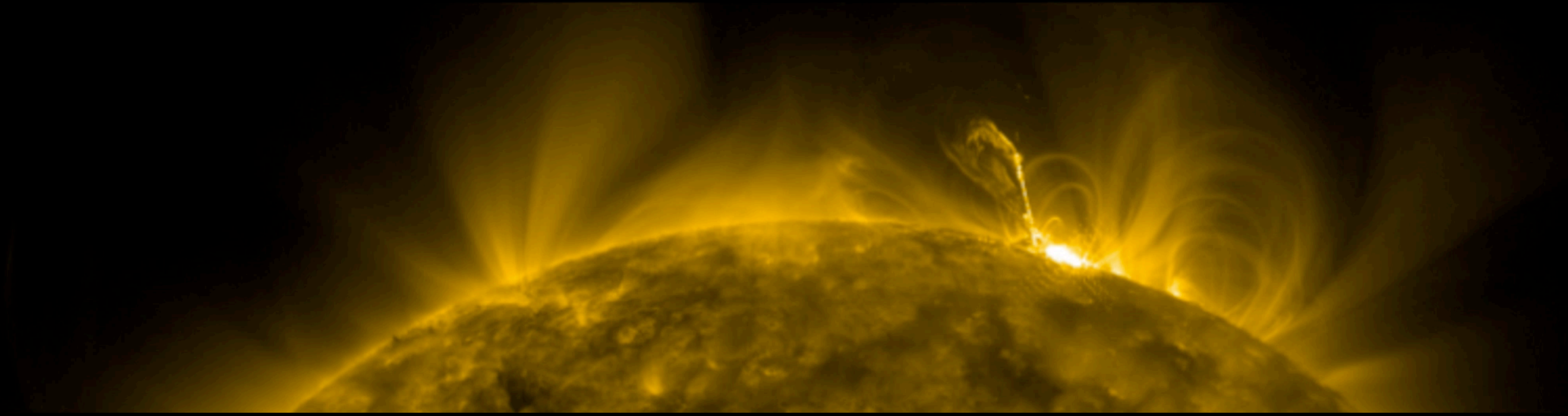
- Reconnection site: Random
- Preferred direction: Equal propagation in both directions.

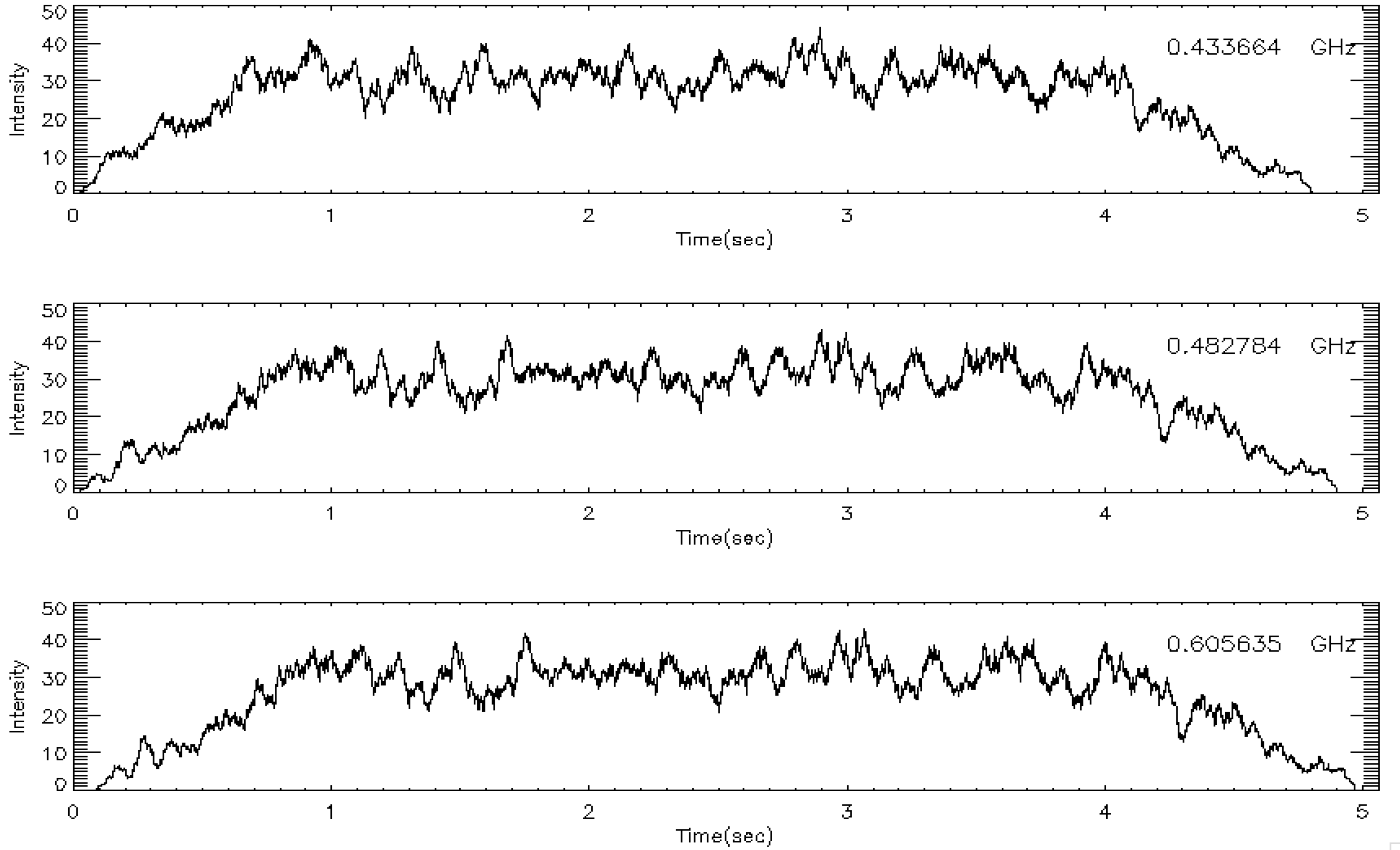


Intensity light curves at the three frequencies

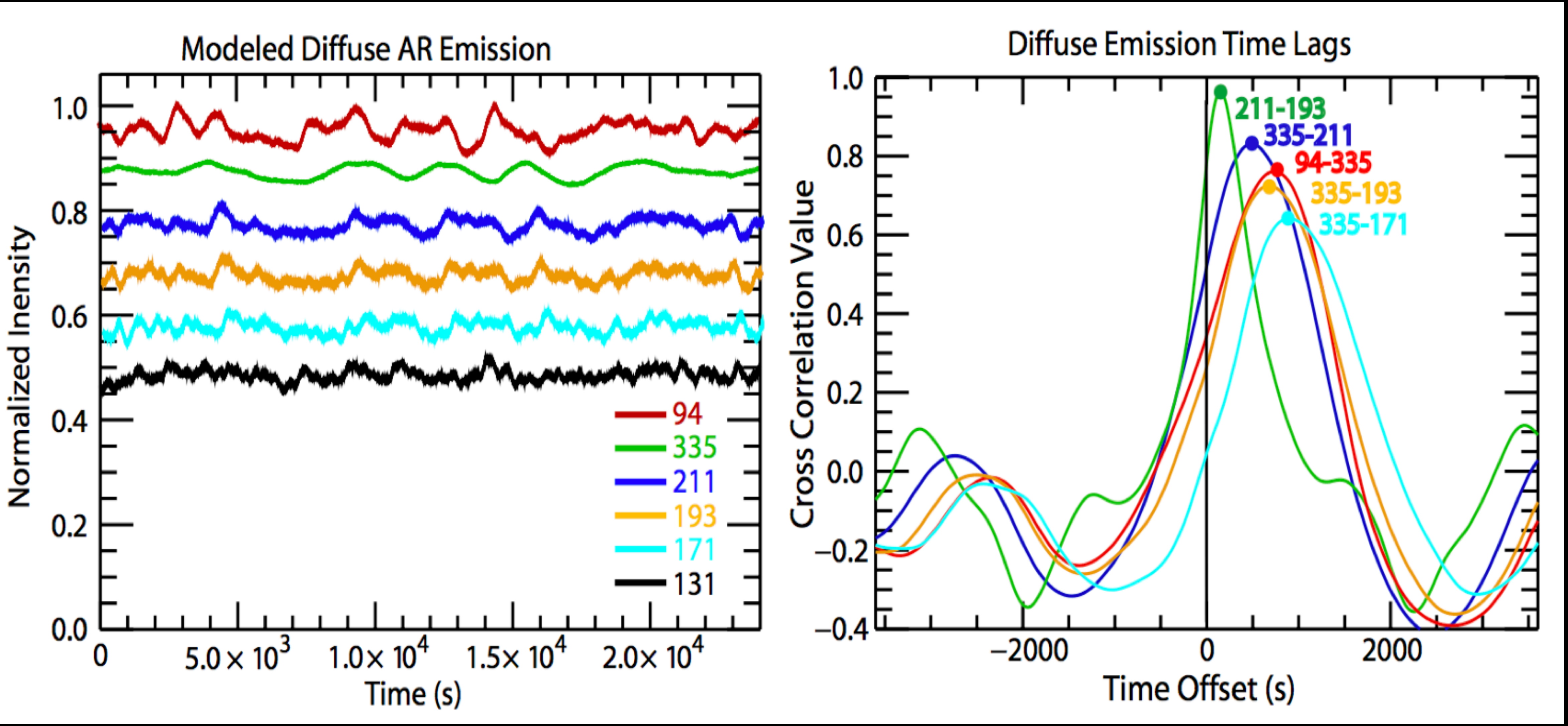


What happens when we have hundreds of nanoflares going off in a second?

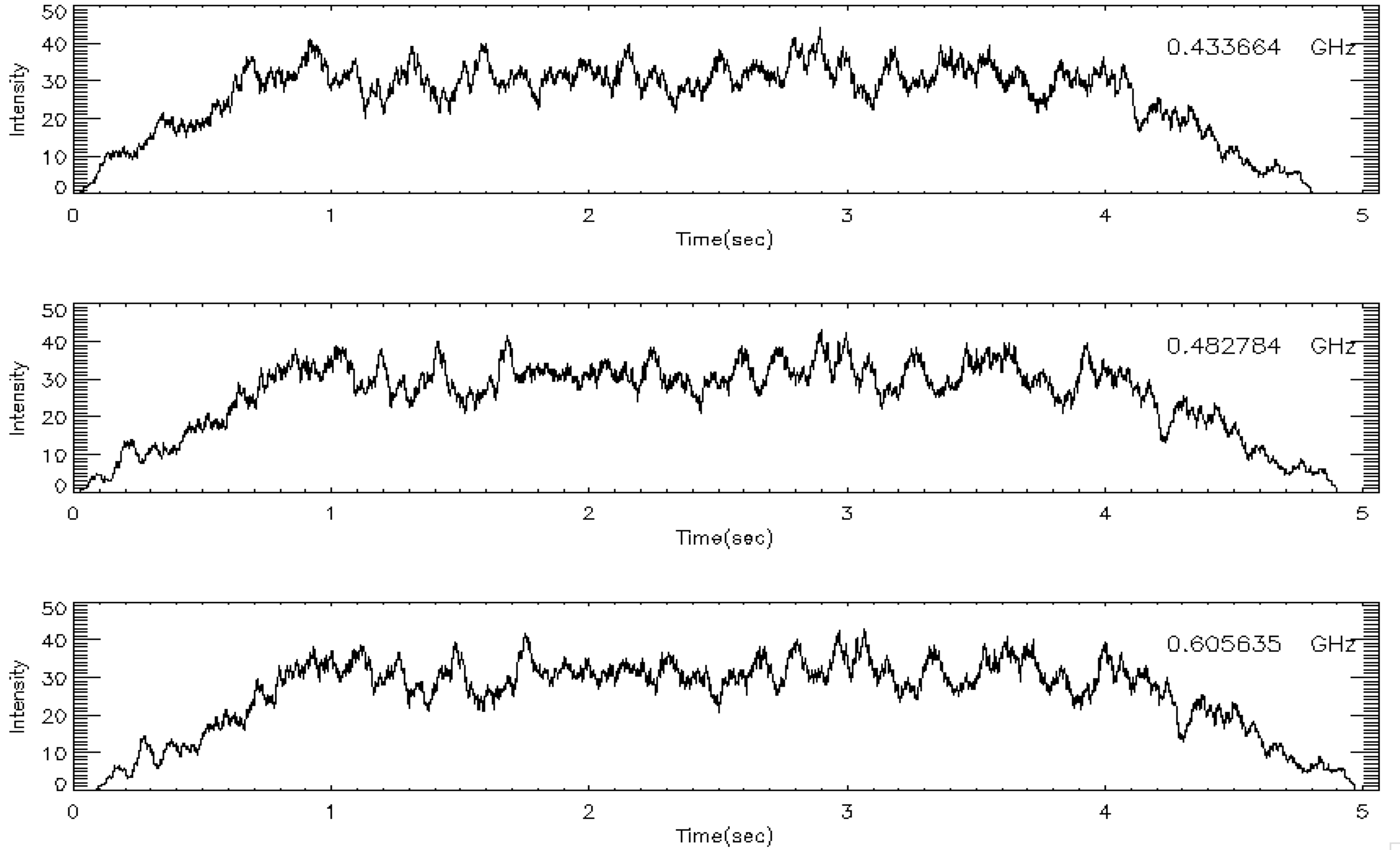



0.433664 GHz
0.482784 GHz
0.605635 GHz
Intensity
Time(sec)
0
10
20
30
40
50
1
2
3
4
5

Time – Lag Technique (simulated emission for AIA channels)



Viall & Klimchuk [2013]



Intensity
0 10 20 30 40 50
0.433664 GHz
0 1 2 3 4 5
Time(sec)
Intensity
0 10 20 30 40 50
0.482784 GHz
0 1 2 3 4 5
Time(sec)
Intensity
0 10 20 30 40 50
0.605635 GHz
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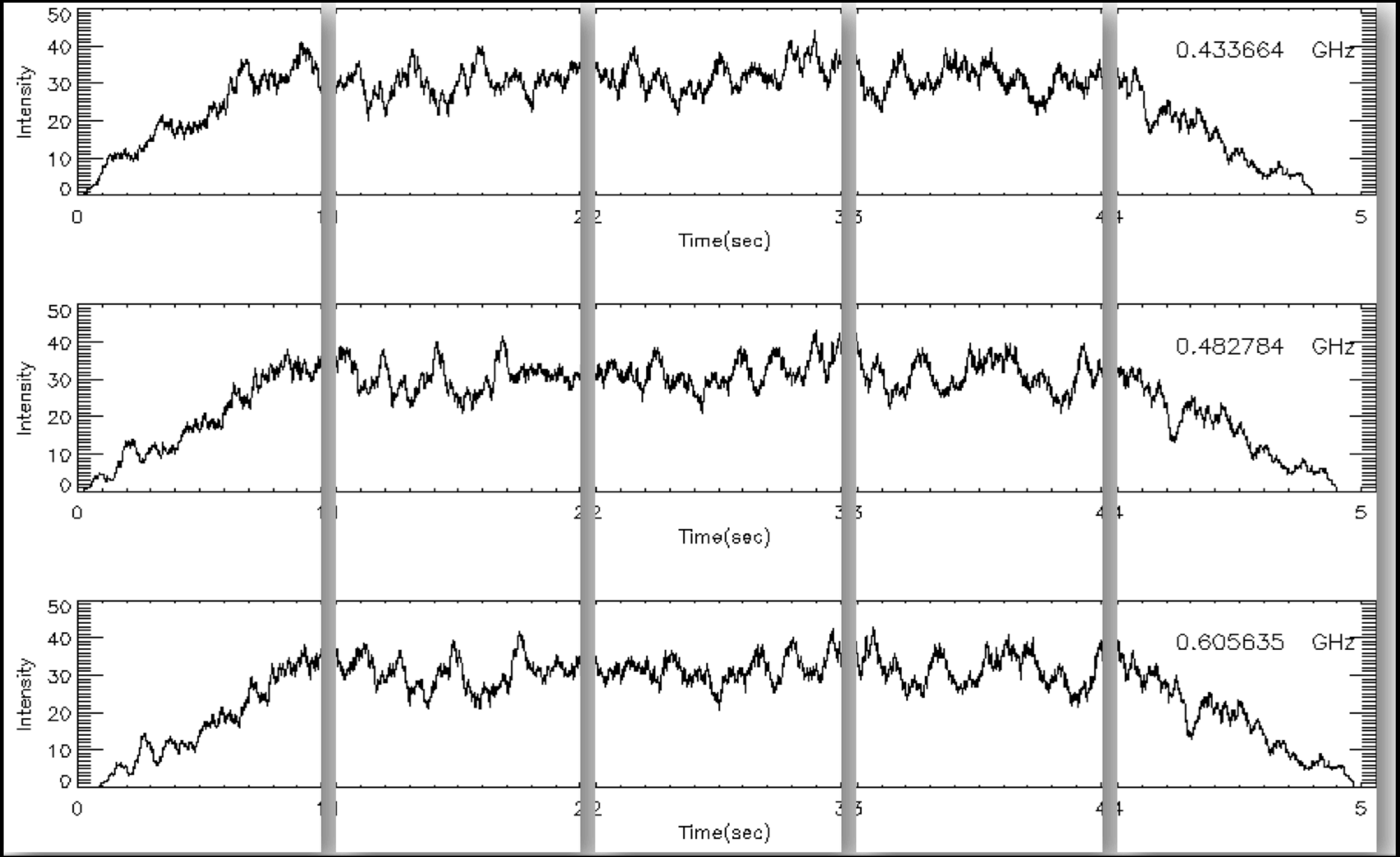
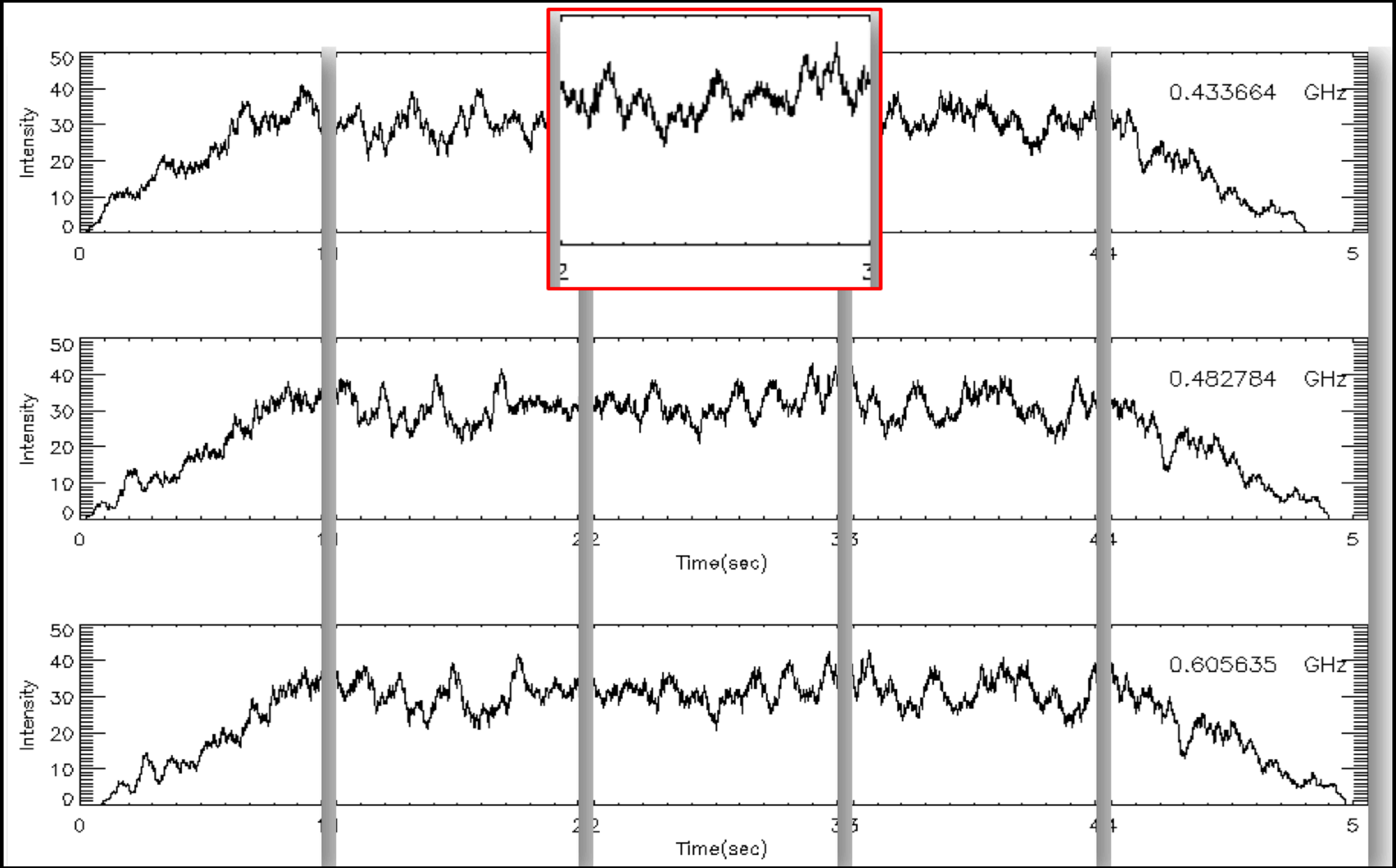
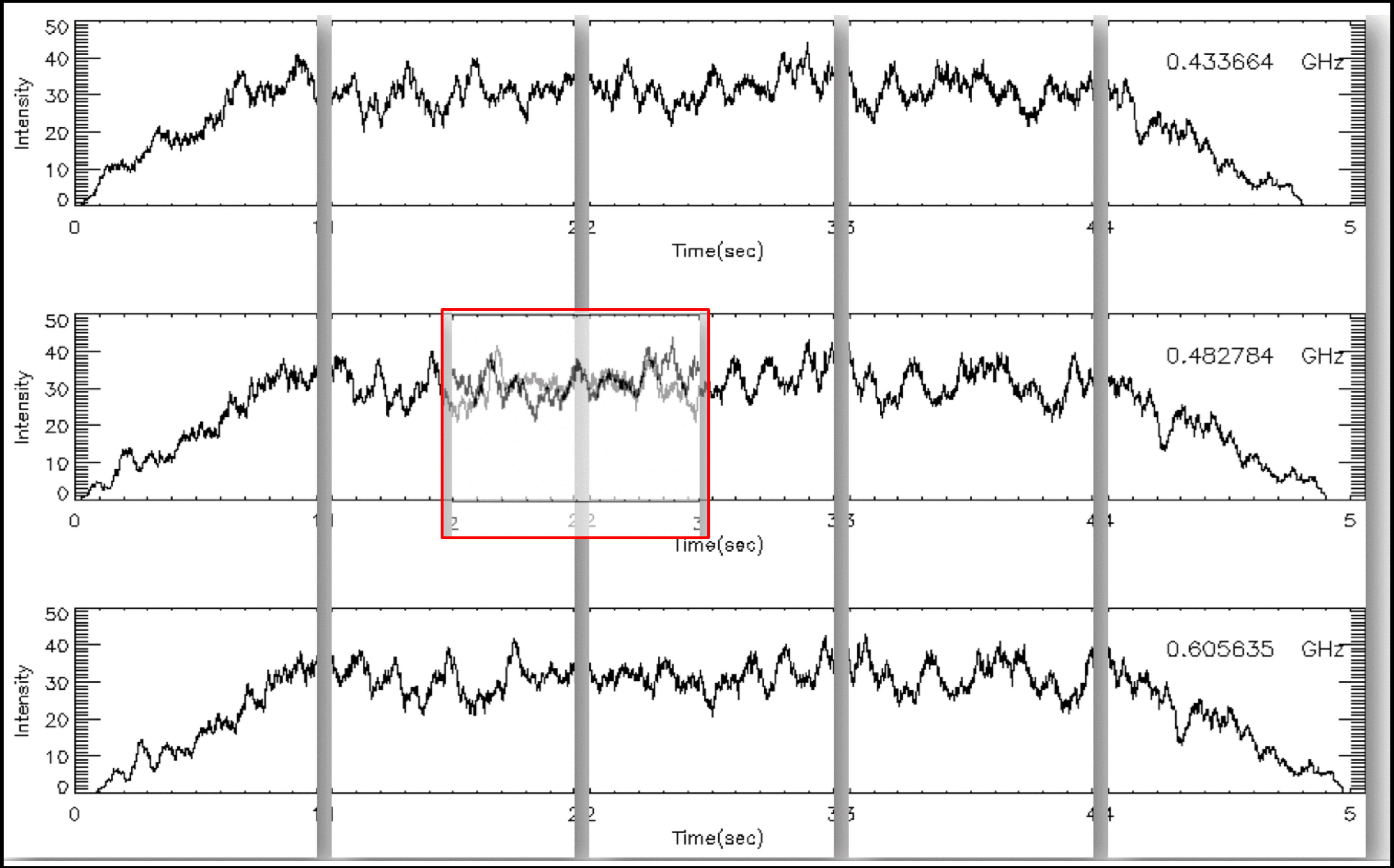
Time(sec)



0.433664 GHz
0.482784 GHz
0.605635 GHz
Intensity
Time(sec)
0 10 20 30 40 50
0 1 2 3 4 5

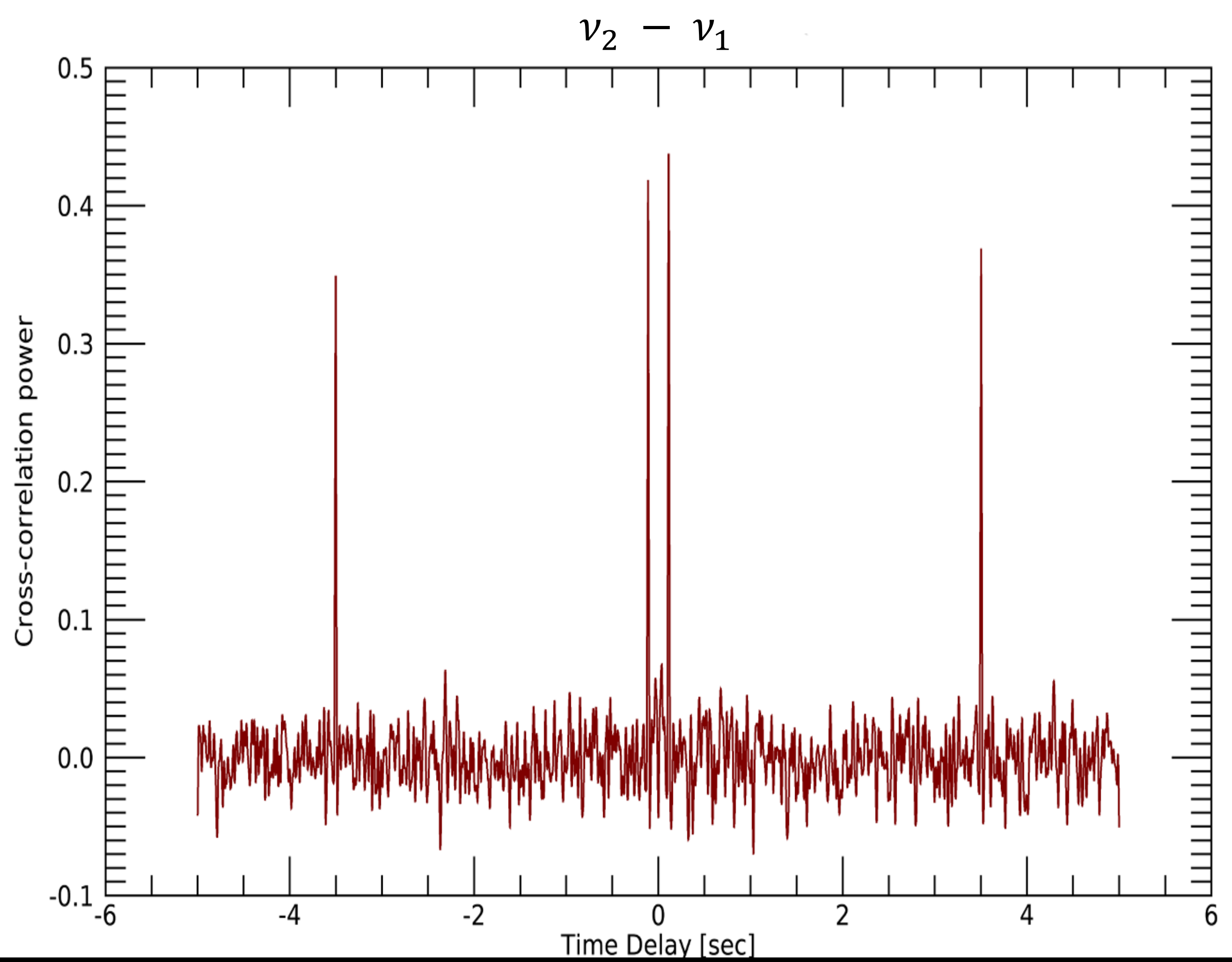


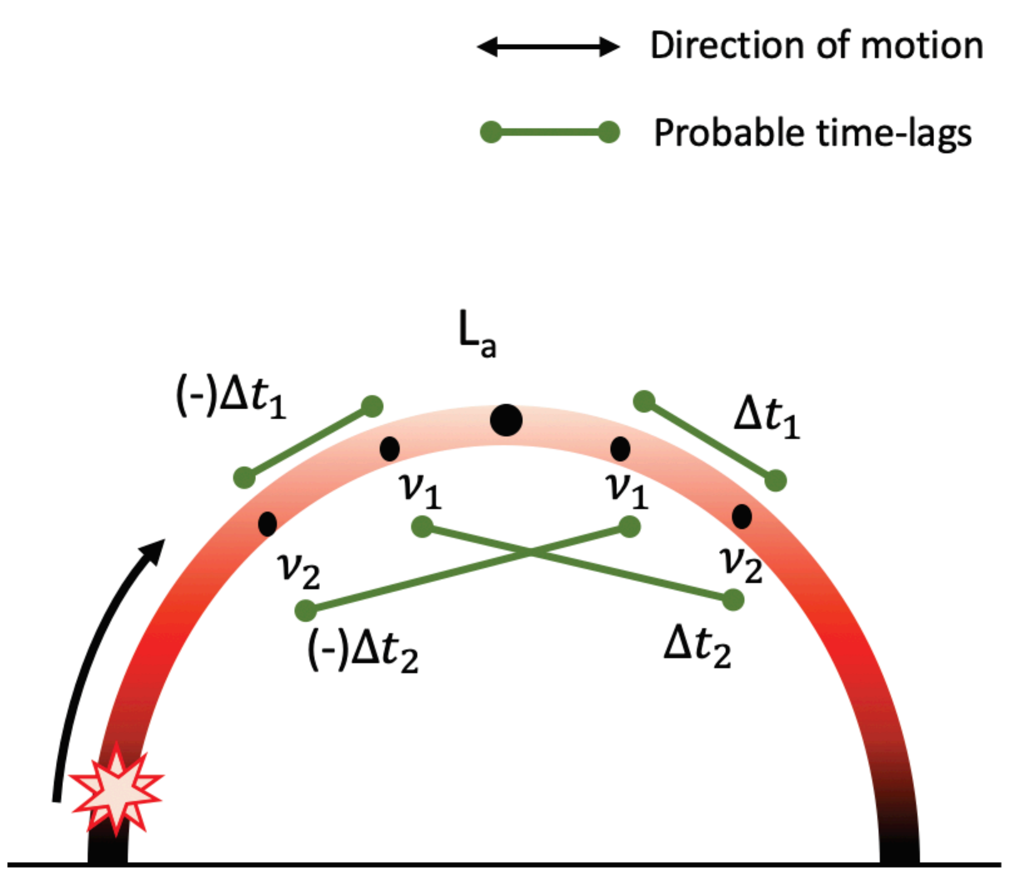
0.433664 GHz
0.482784 GHz
0.605635 GHz
Intensity
Time(sec)



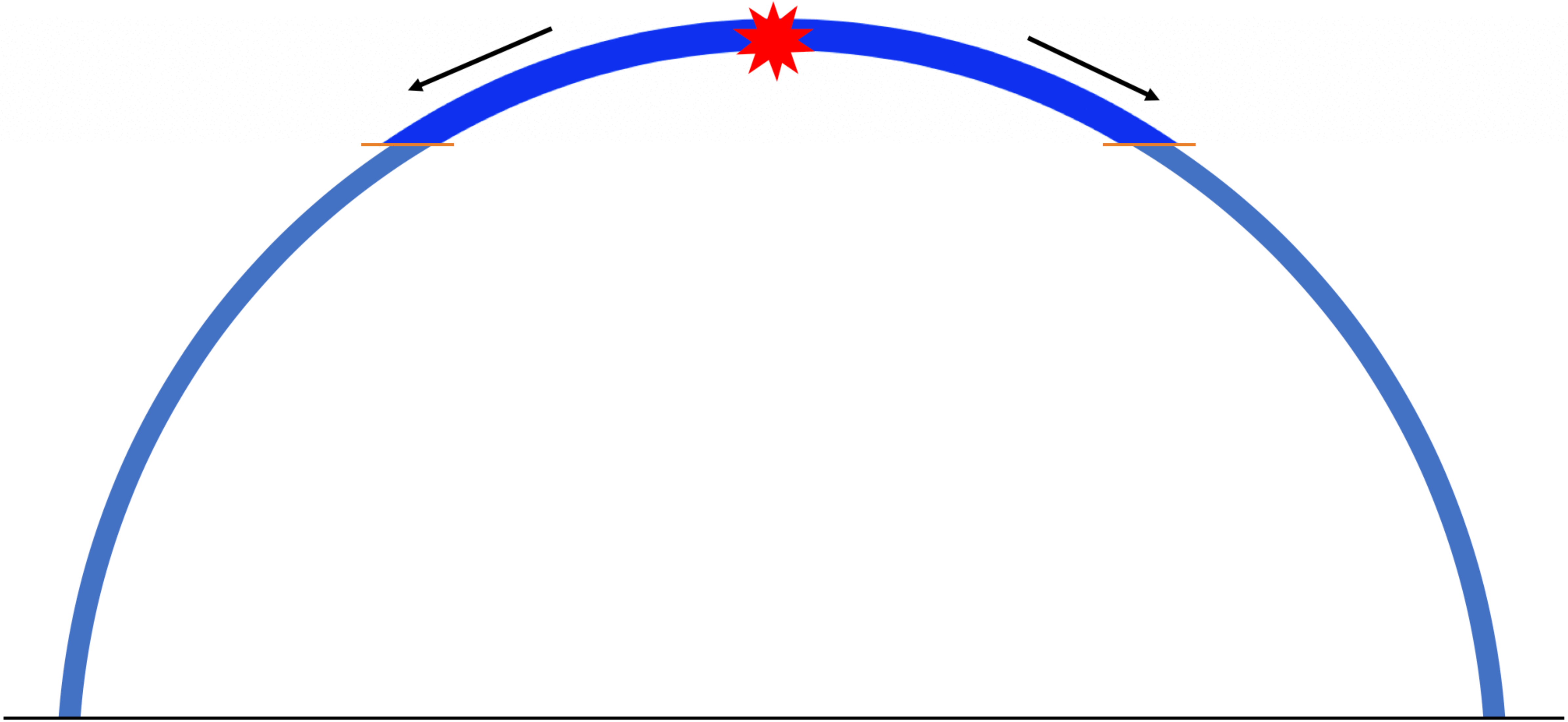
Intensity
0.433664 GHz
Time(sec)
Intensity
0.482784 GHz
Time(sec)
Intensity
0.605635 GHz
Time(sec)

Cross-correlation Power Spectrum (CCOPS)

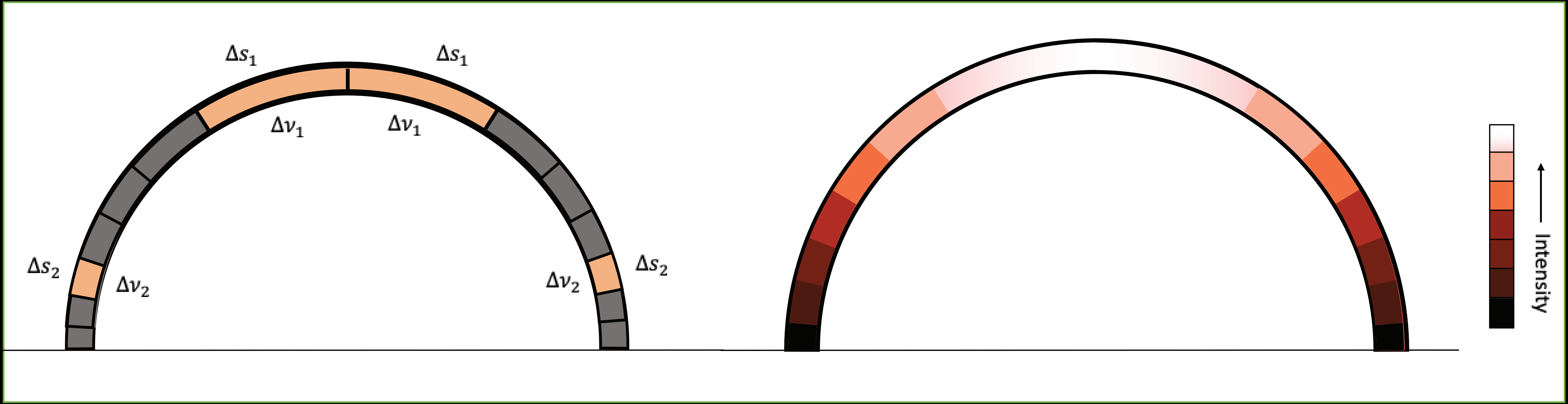




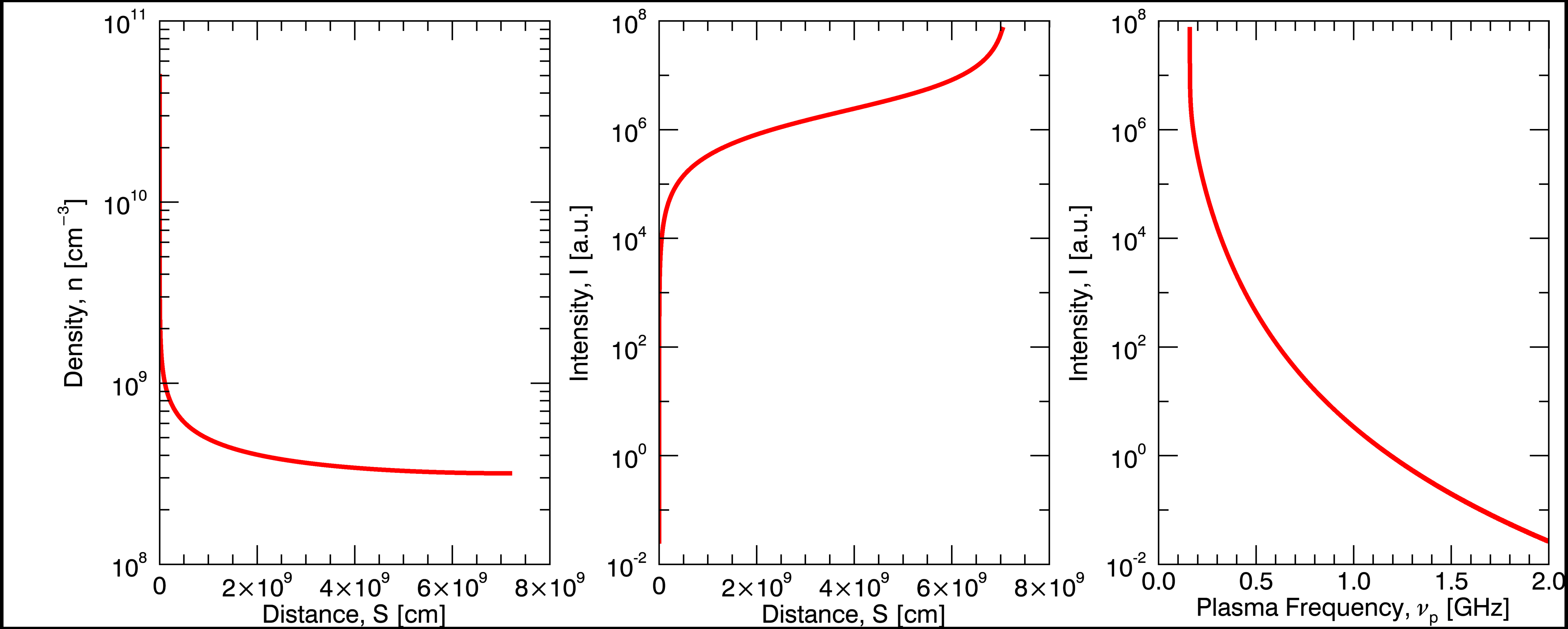
Varying Intensity as a function of $\Delta\nu$



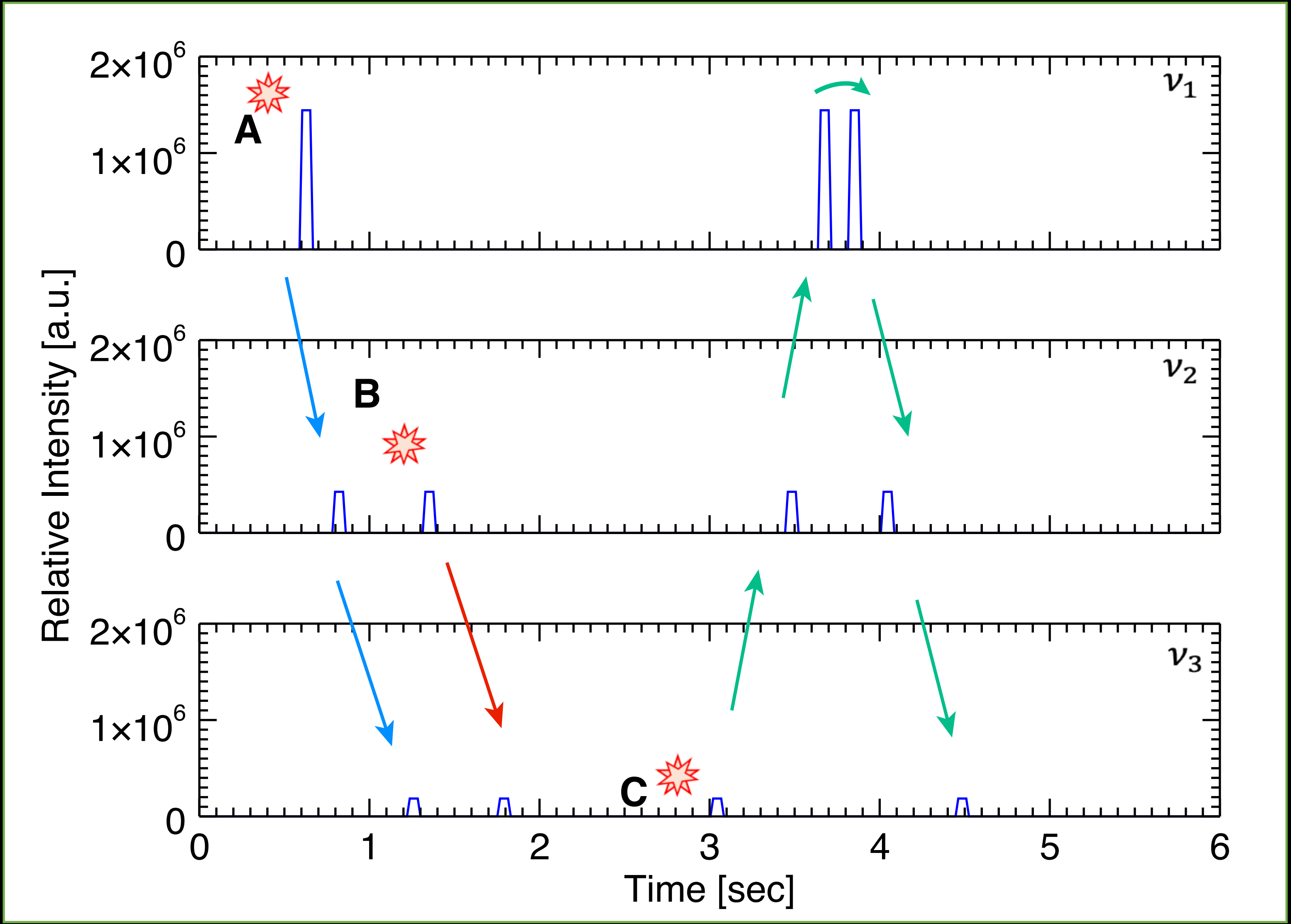
Varying Intensity as a function of $\Delta\nu$



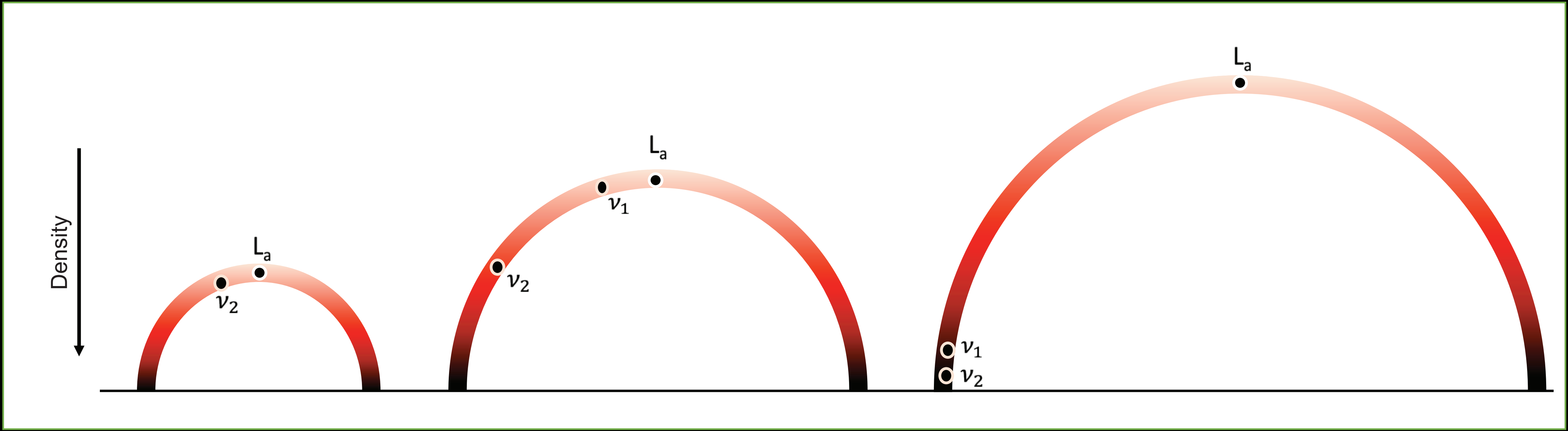
Varying Intensity



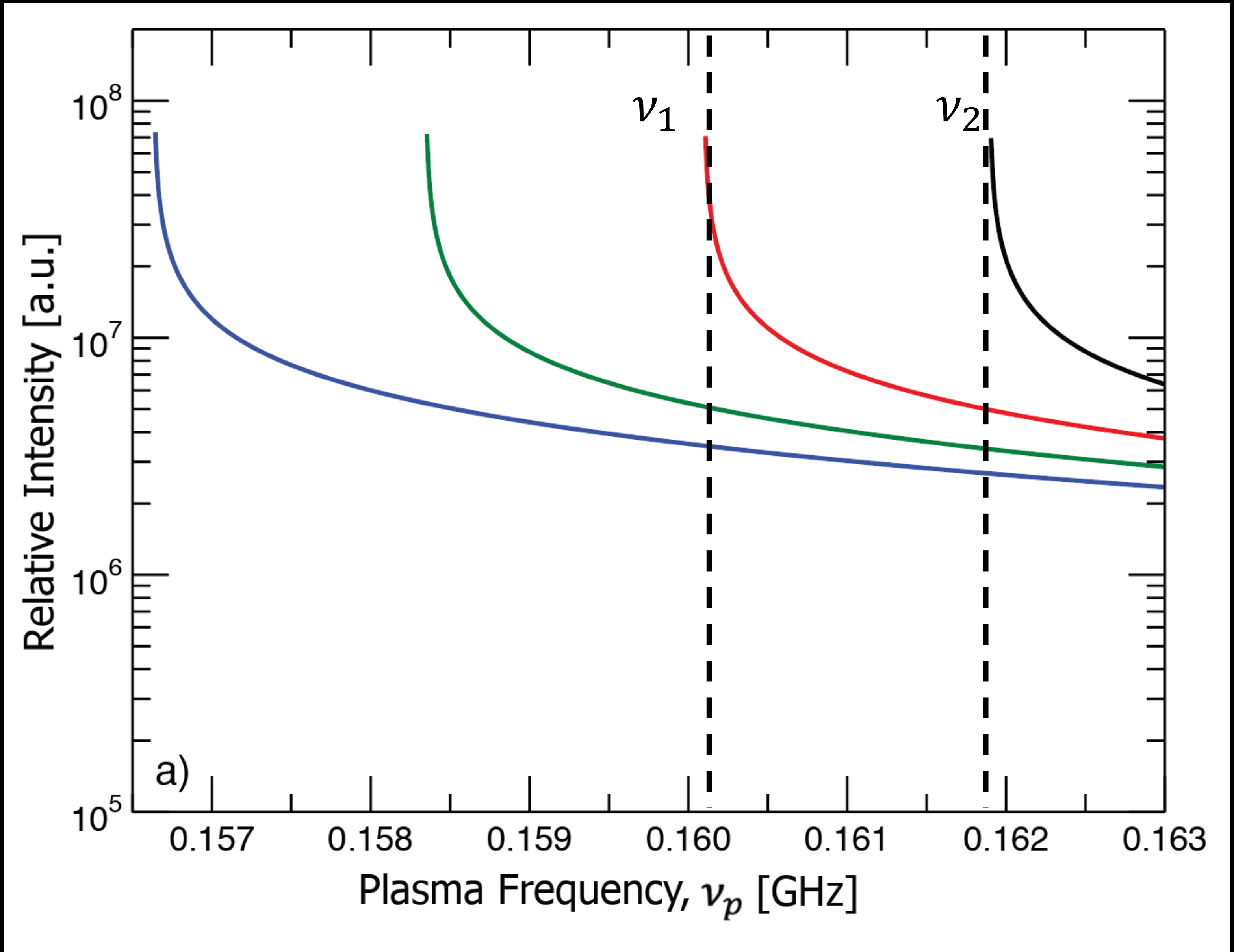
Intensity light curves after applying Intensity Variation



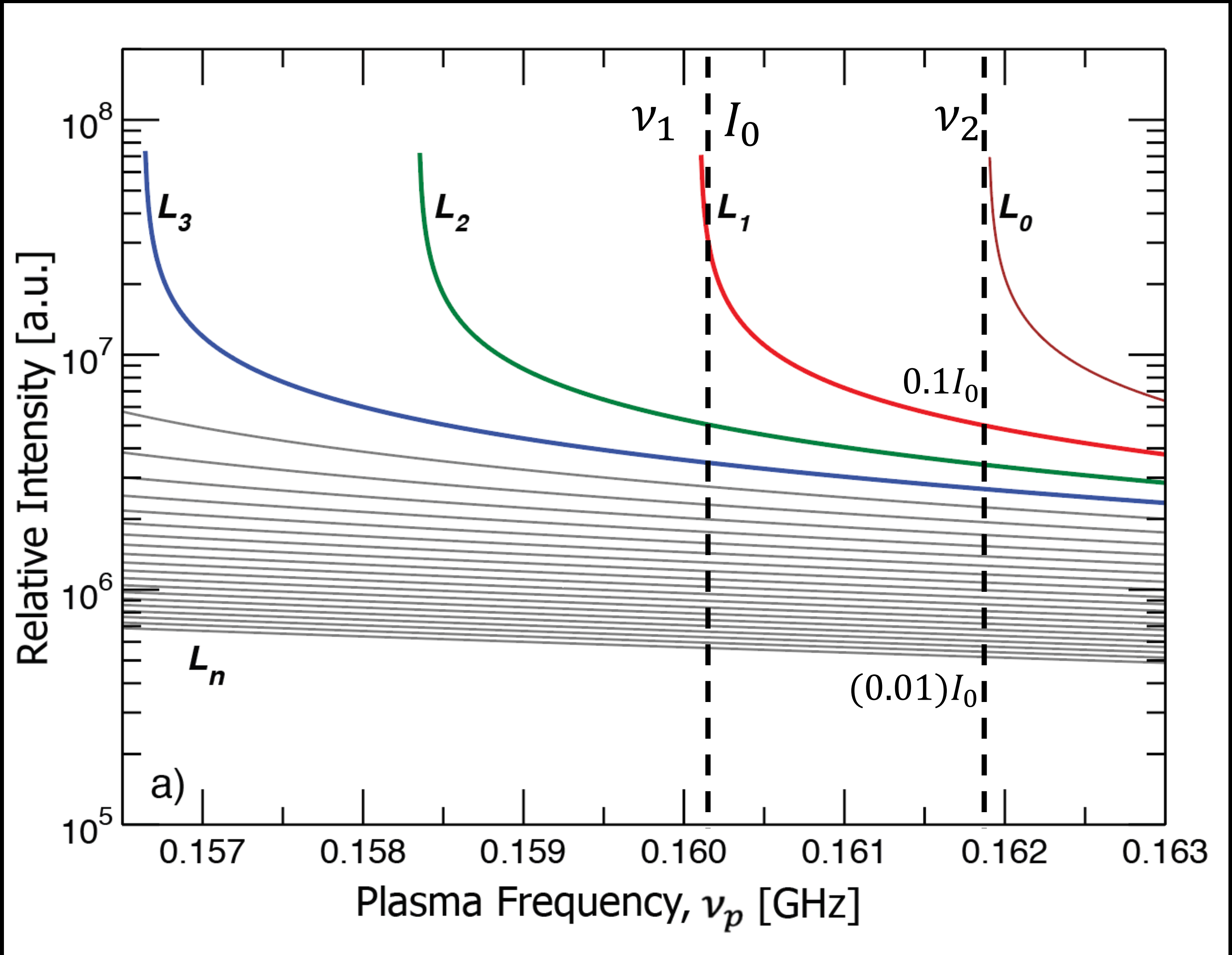
Multiple Loops: Choice of Loop Distribution and Frequencies



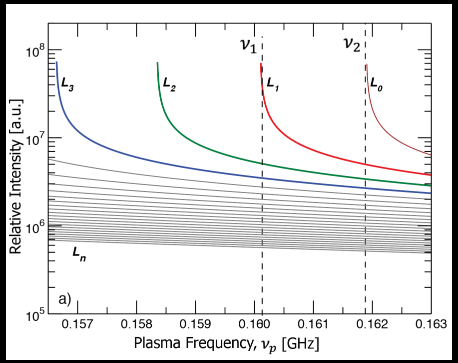
Low-Density Loop Distribution

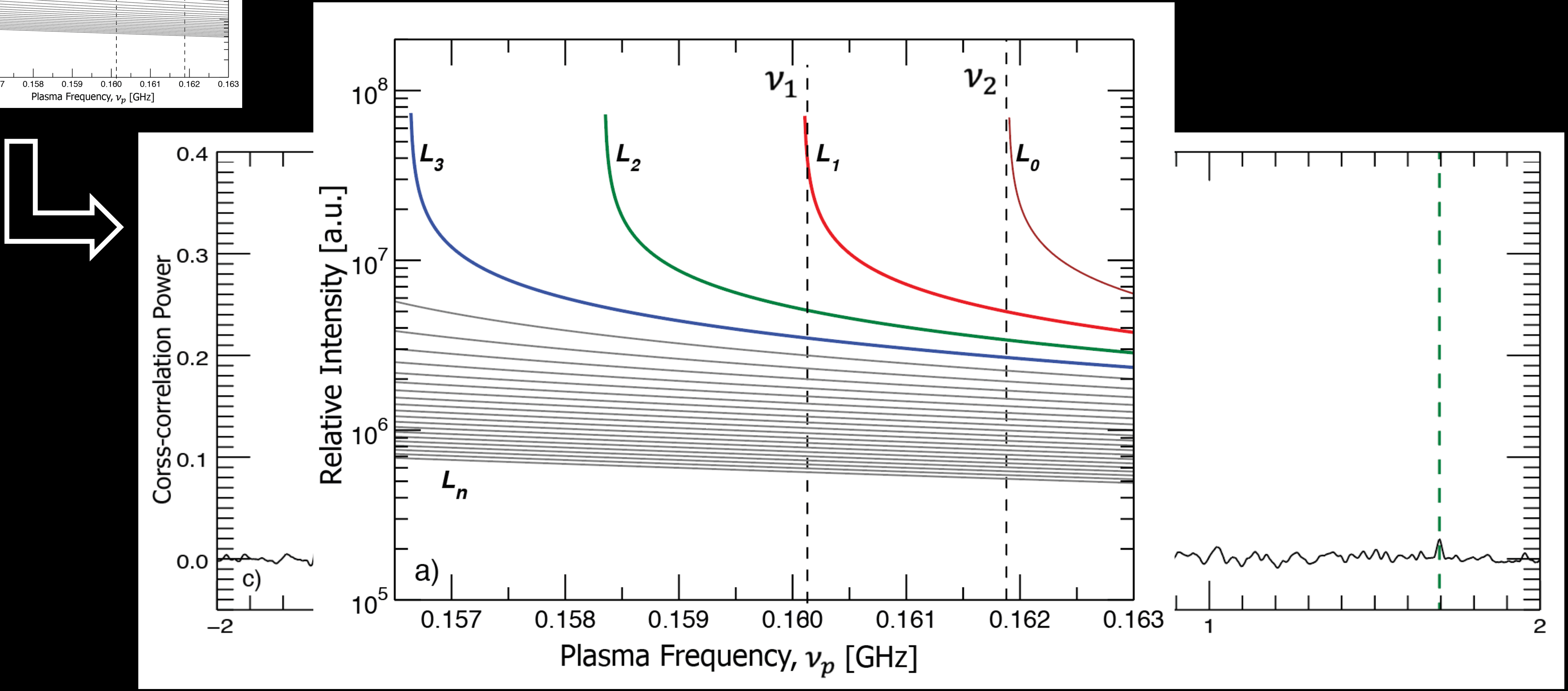


Low-Density Loop Distribution

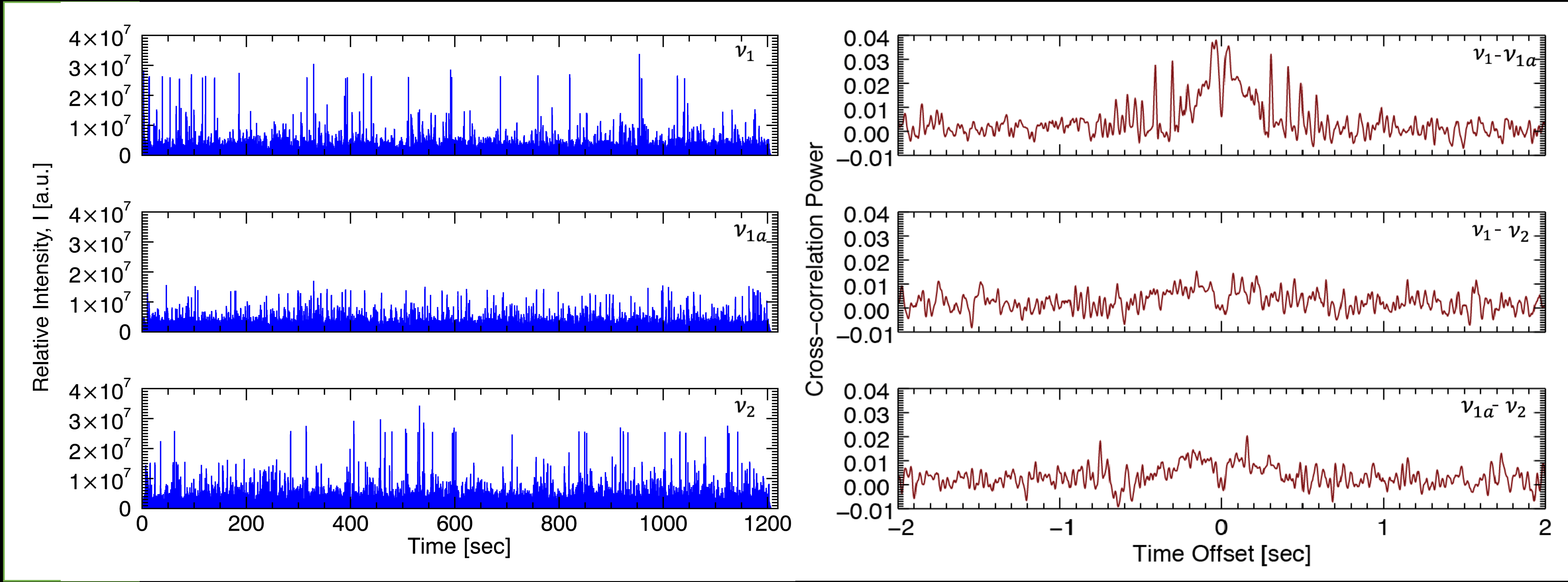


CCOPS for Low-Density Loop Distribution

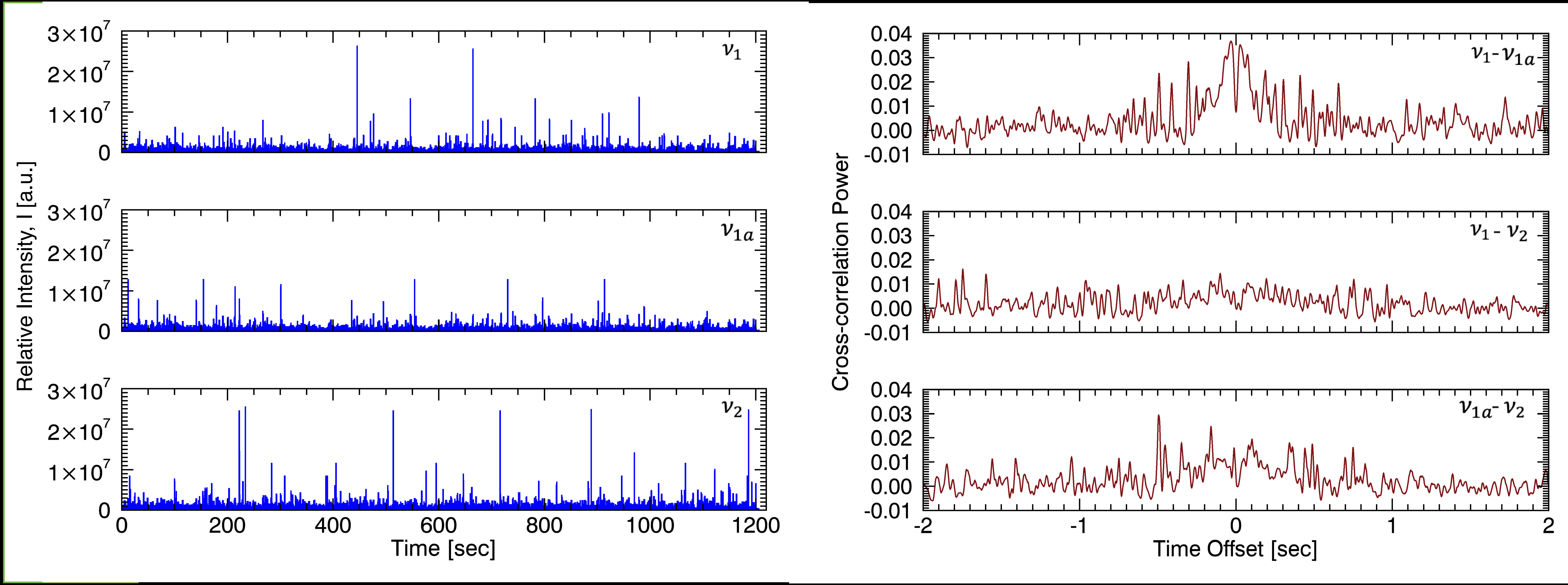




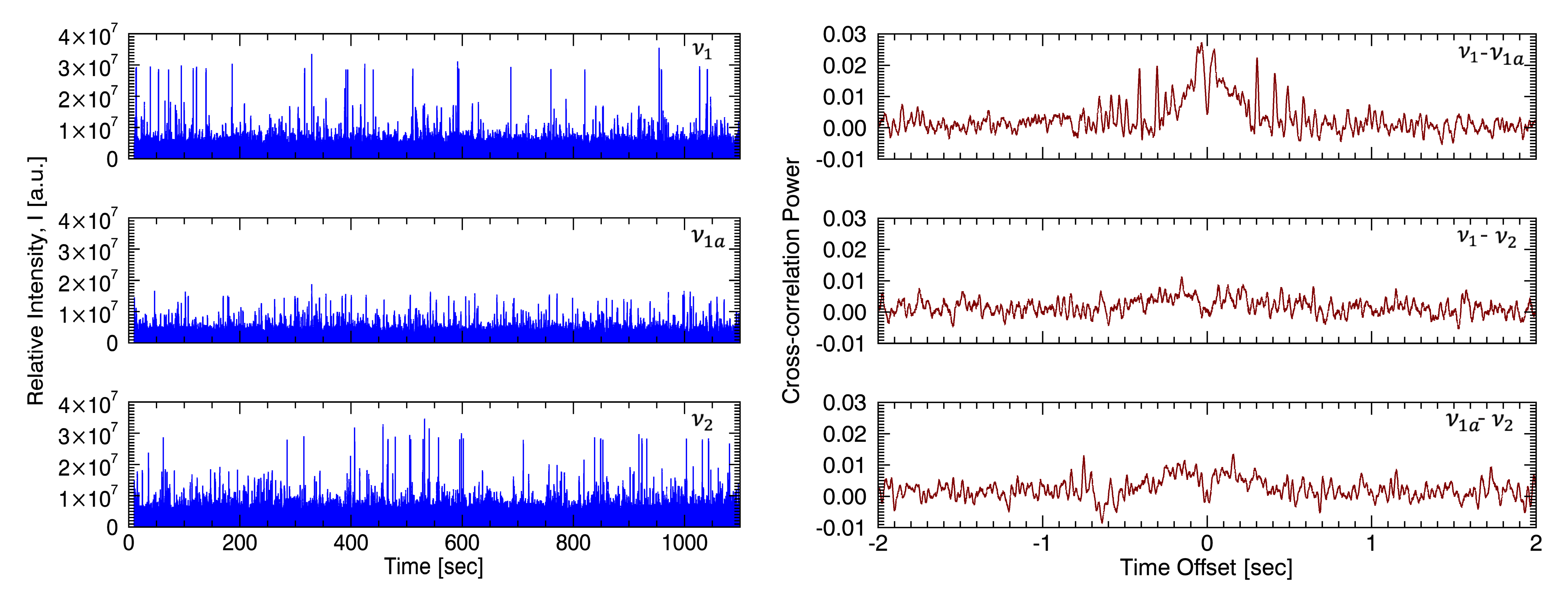
Light curves & CCOPS for a quasi-continuous distribution of loops



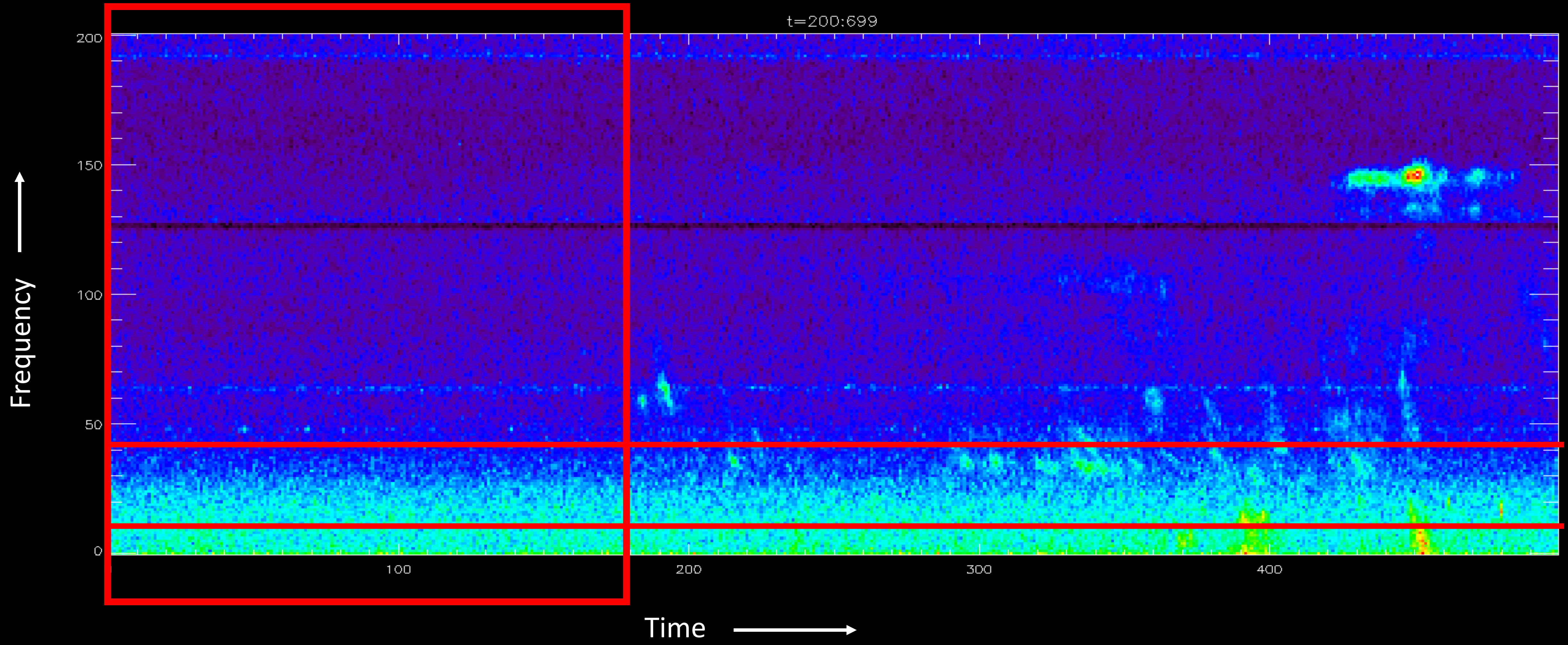
Quasi-continuous distribution of loops: Low burst-frequency

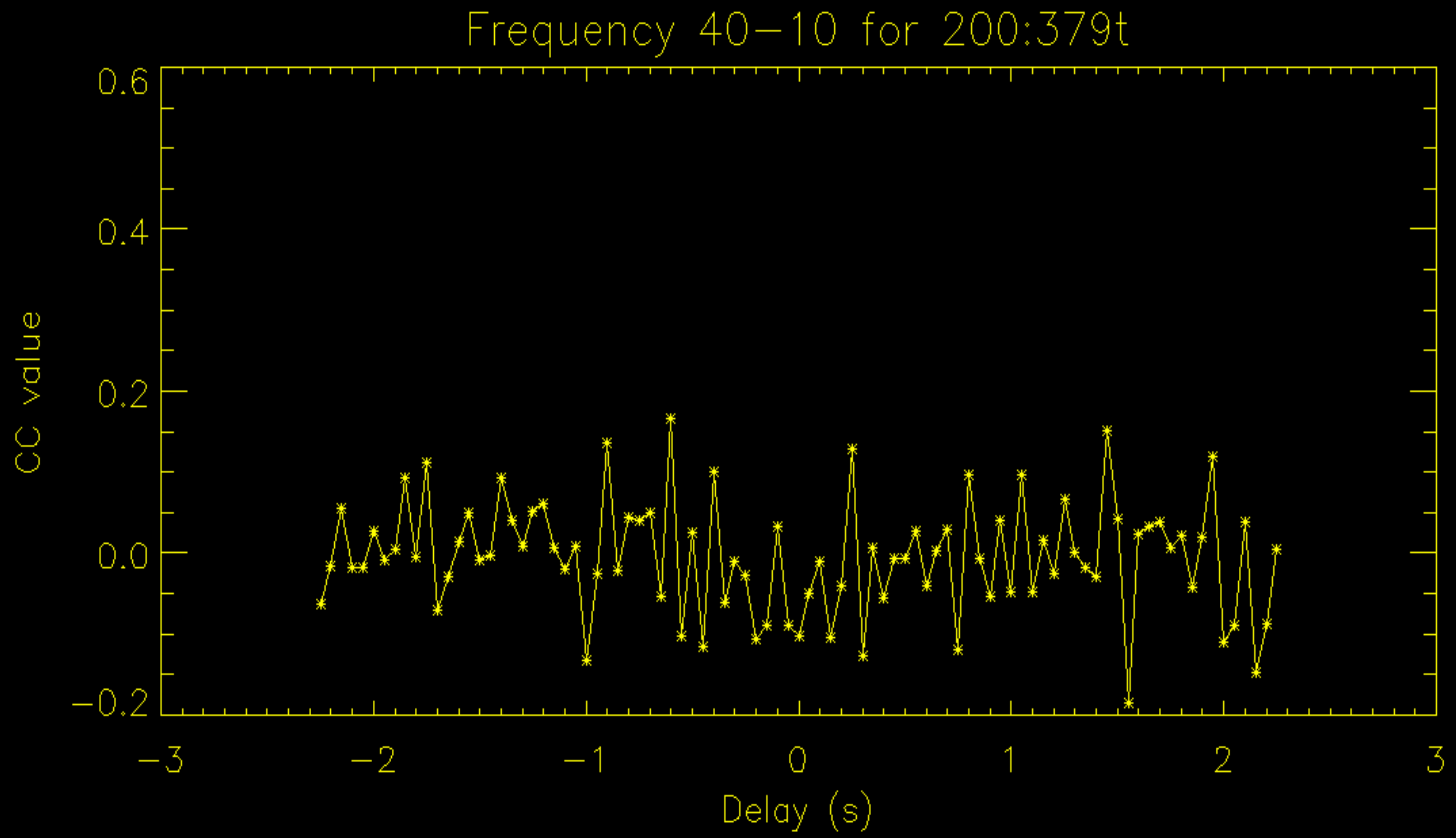


Quasi-continuous distribution of loops: The role of Noise

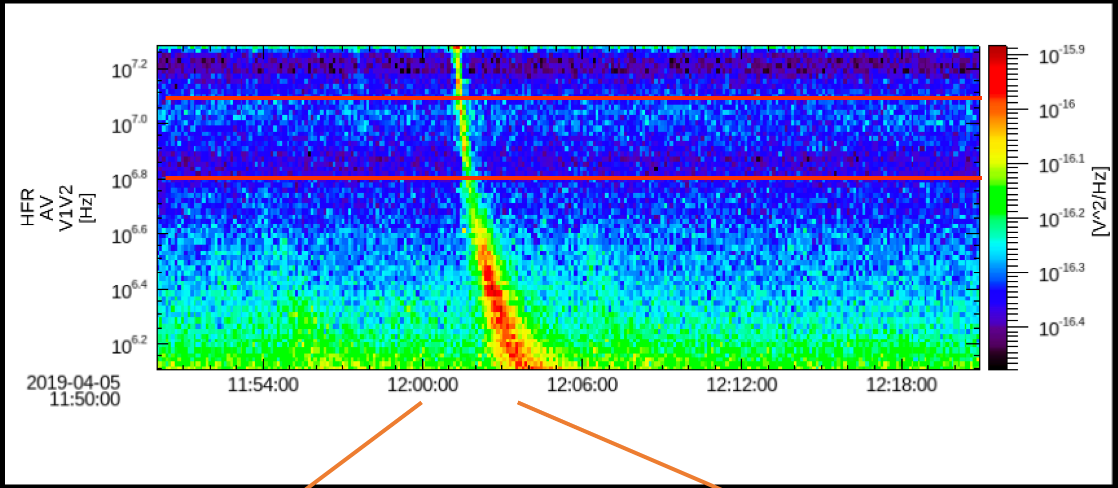


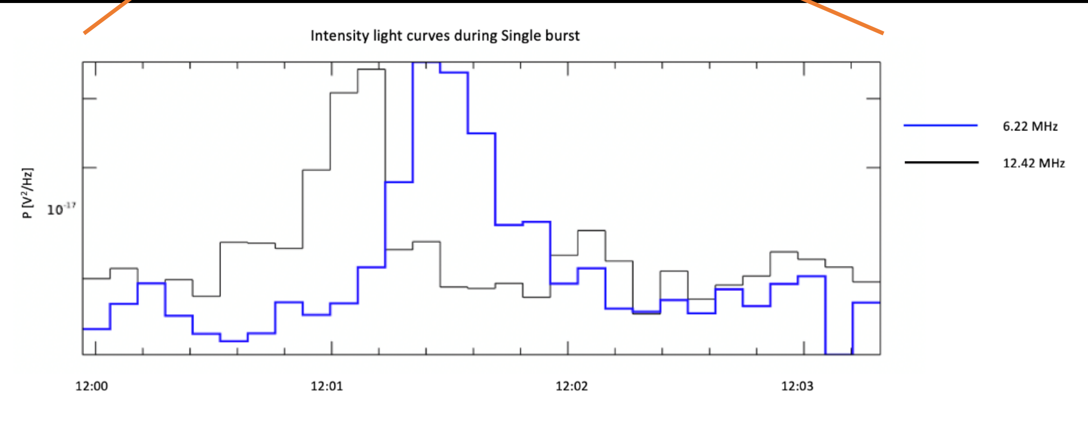
Data : VLA Dynamic Spectrum for April 25th 2013

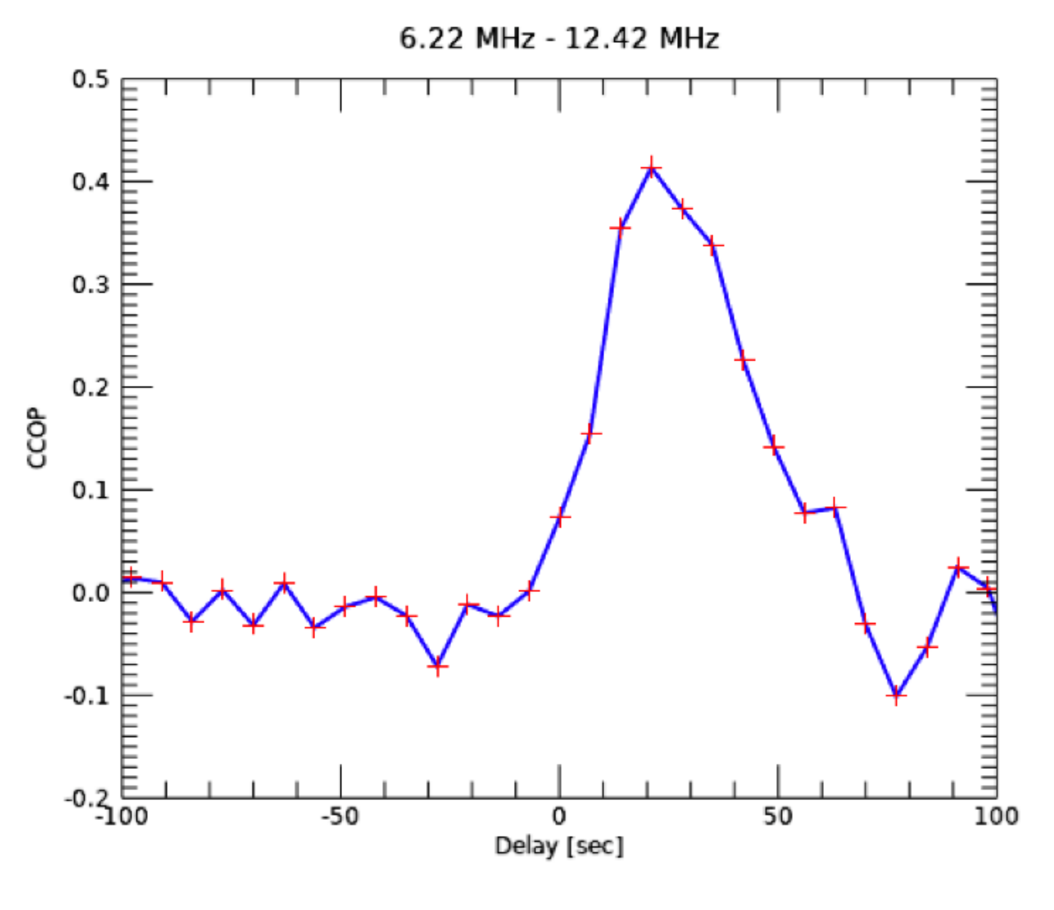



Frequency 40-10 for 200:379t
0.6
0.4
0.2
0.0
-0.2
CC value
-3
-2
-1
0
1
2
3
Delay (s)

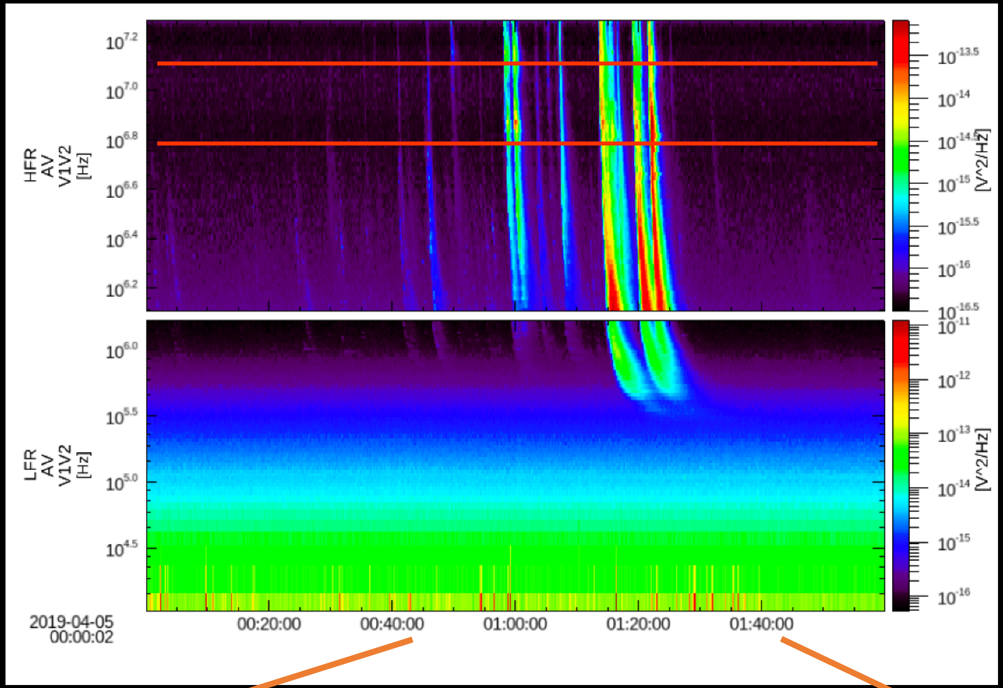
Parker Solar Probe: Single Burst

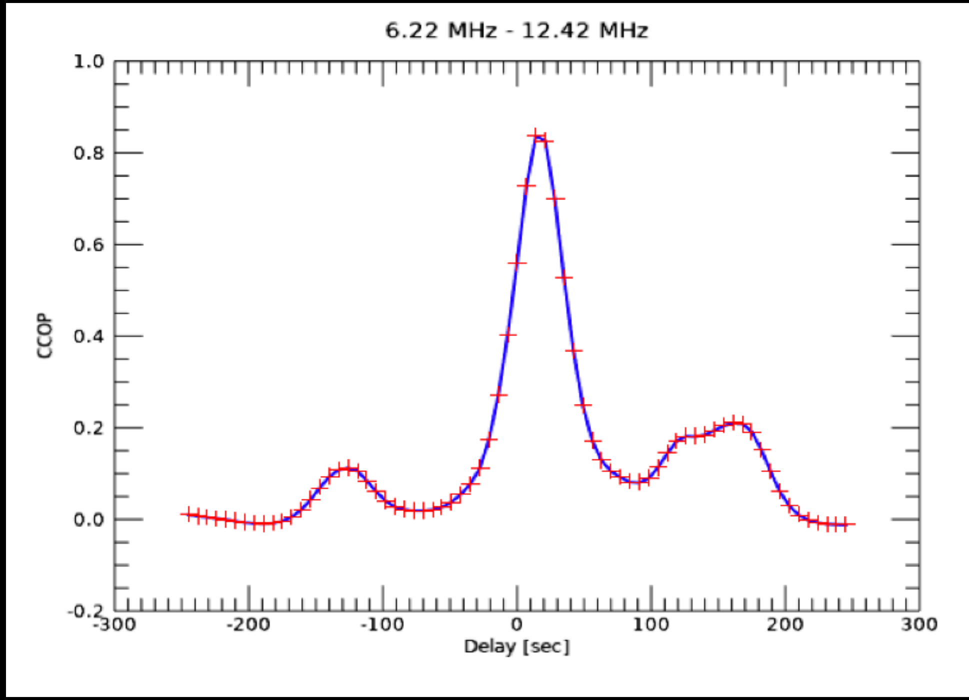


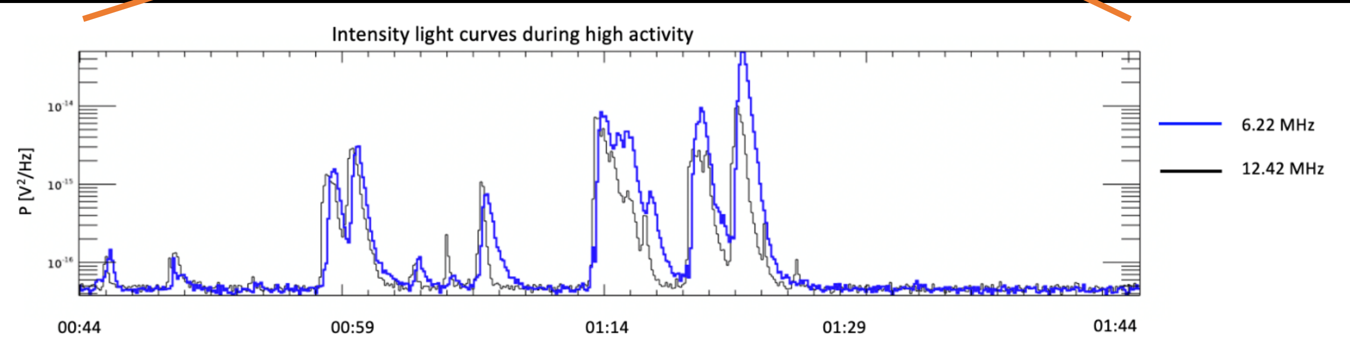




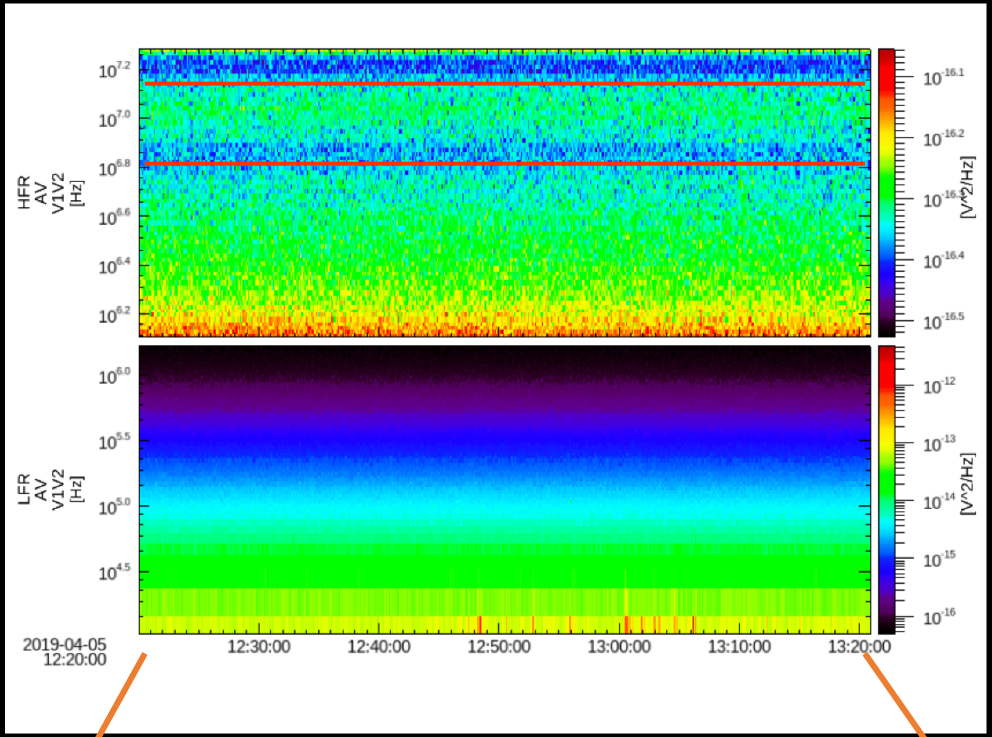
Type III Storm (E2)

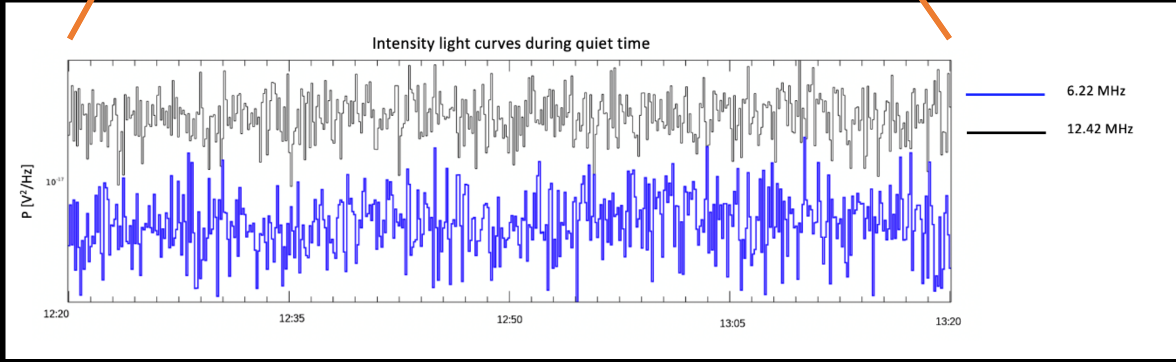


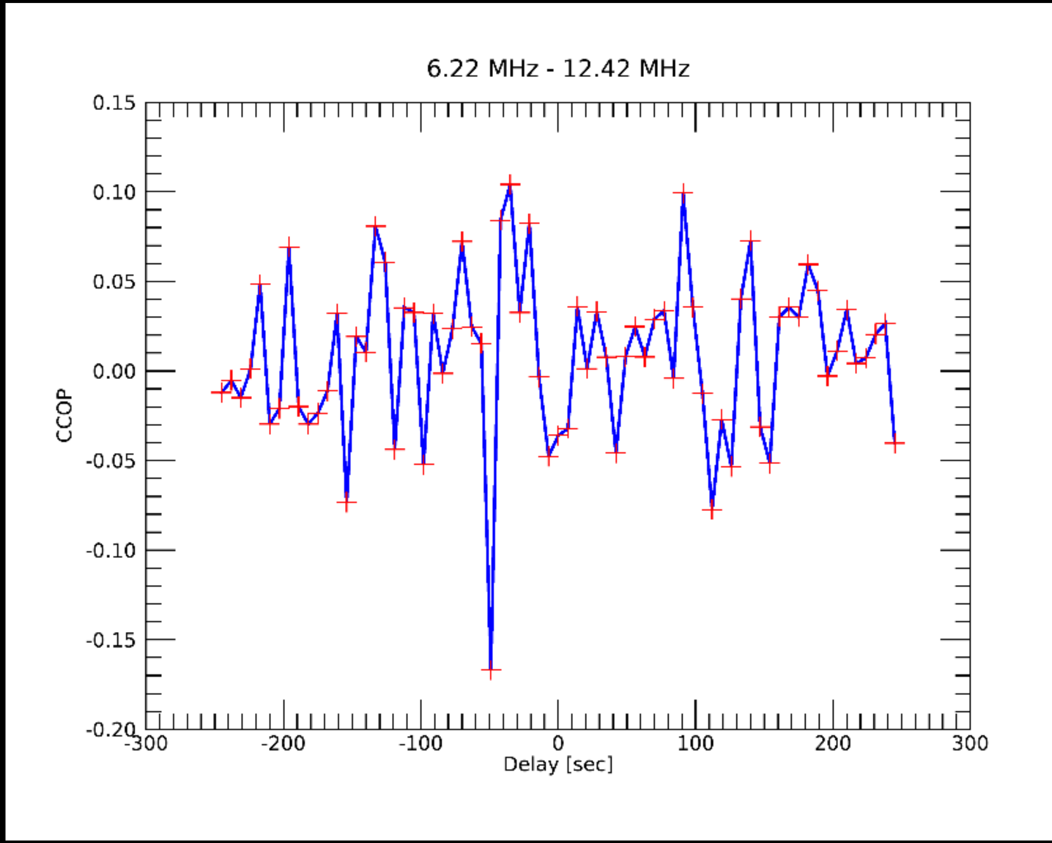




Quiet Period







Summary…

- Model: Despite the additional noise and hundreds of overlapping bursts, we are still able to identify the signature of type III bursts
  - The frequencies closer together show better results

- DATA (Preliminary Results)
  - VLA shows no signature of type IIIs
  - **Similar results are seen in PSP. The technique is able to detect time-lags in noise storms and also identifies periodicities (may be psuedo)**
    - Low-sensitivity of the instrument makes it difficult to see any fainter type III or lack thereof.

Currently Exploring…

- New data from Encounters 3,4 & 5 of Parker Solar Probe (PSP)
- Getting an upper limit on nanoflares per second that can be explained by VLA and PSP observations.
- High resolution data from LOFAR that offers much higher sensitivity
- Properties of high intensity emission from loop-top positions that may manifest as Type I bursts in a dynamic spectrum.

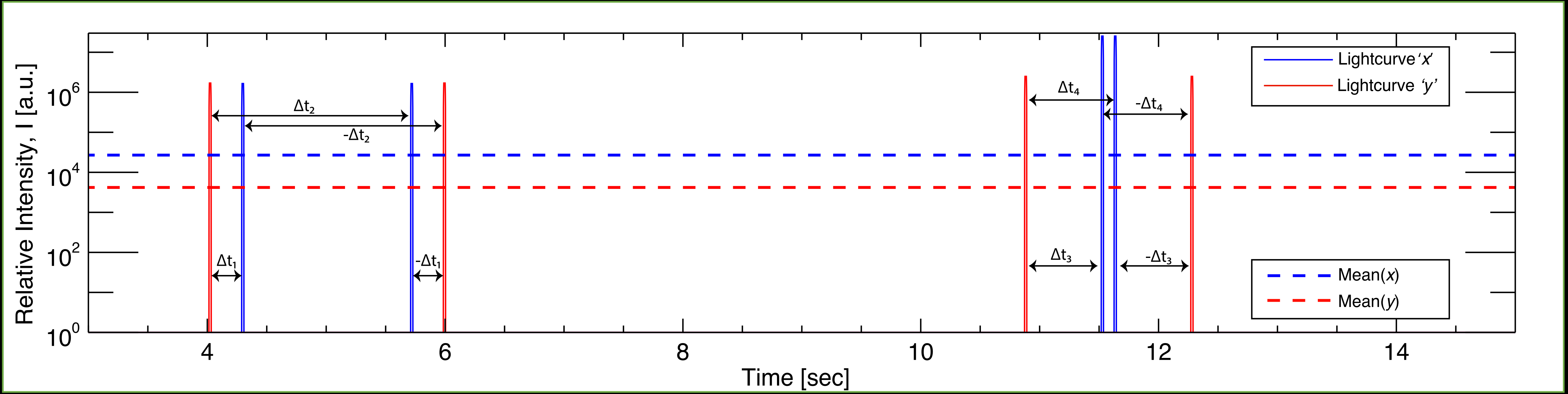
Thank you for your attention !!!

Questions?

Factors Affecting the CCOPS

$$P(l<0) = \frac{\sum_{k=0}^{N-|l|-1}(x_{k+|l|} - \overline{x})(y_k - \overline{y})}{\sqrt{\sum_{k=0}^{N-1}(x_k - \overline{x})^2 \sum_{k=0}^{N-1}(y_k - \overline{y})^2}}$$

$$P(l>0) = \frac{\sum_{k=0}^{N-l-1}(x_k - \overline{x})(y_{k+l} - \overline{y})}{\sqrt{\sum_{k=0}^{N-1}(x_k - \overline{x})^2 \sum_{k=0}^{N-1}(y_k - \overline{y})^2}}$$



Factors Affecting the CCOPS