Overview of Solar Radio Bursts and their Sources

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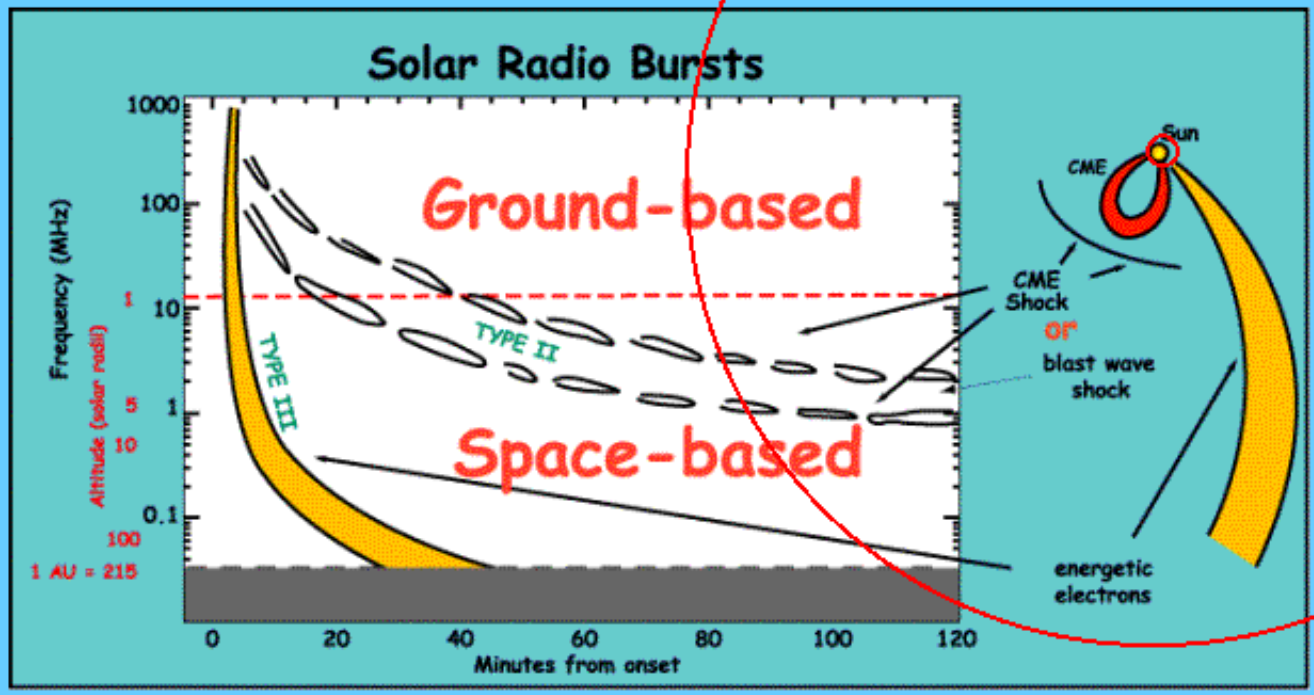
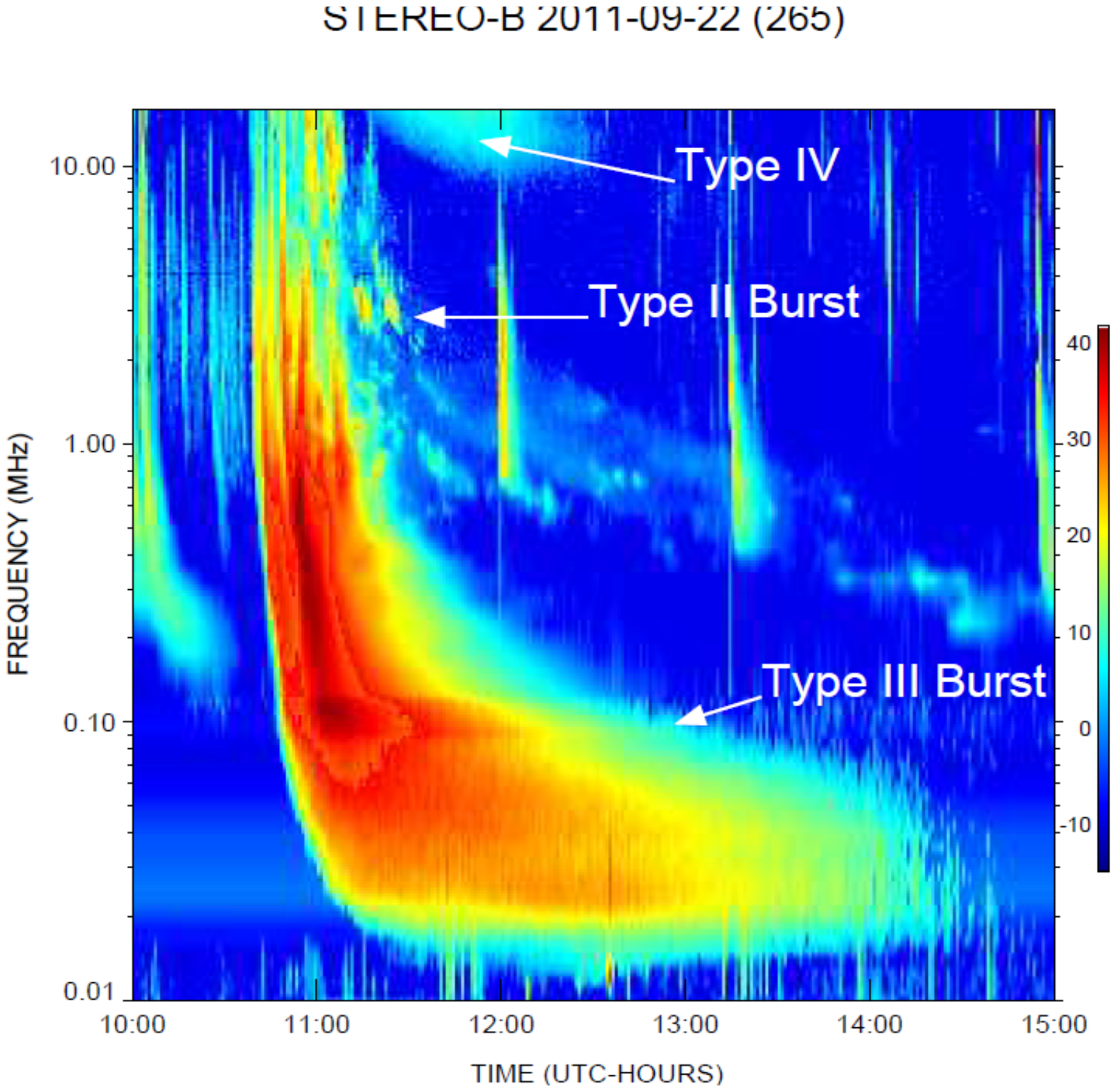
Outline

- Brief Introduction to solar type III, type II and type IV bursts
- Some STEREO observations
- Some results from our recent paper: (1) Evidence for Spatial Collapse of Langmuir waves in Type III Bursts (Thejappa and MacDowall, 2018, ApJ, in press)

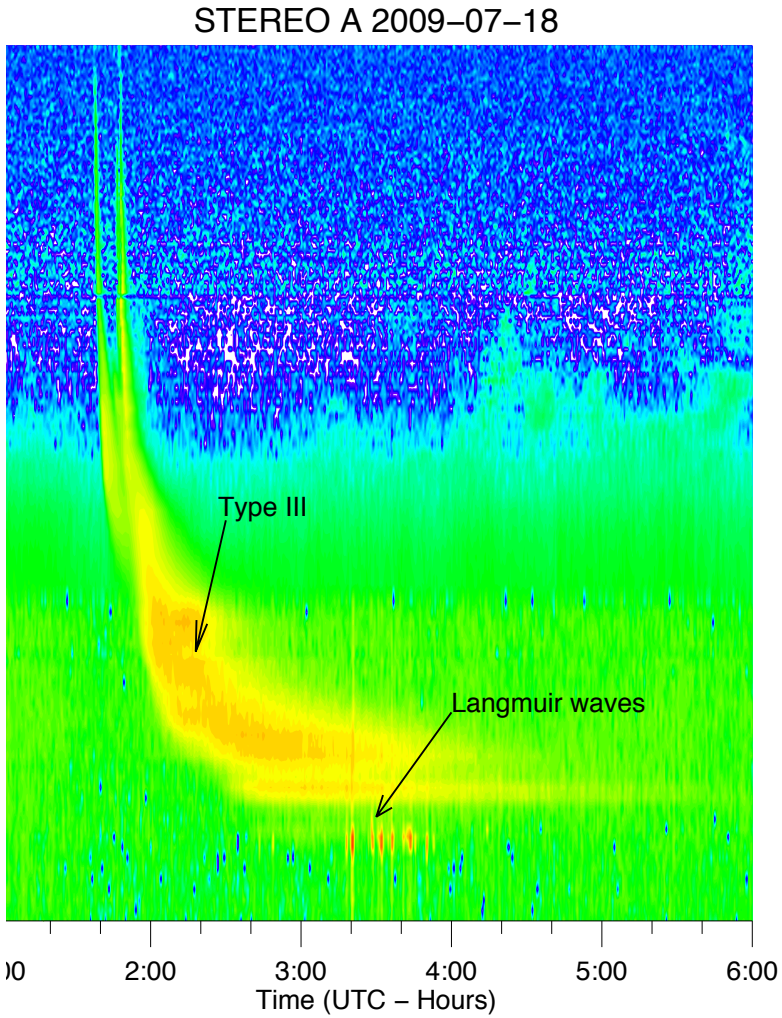
Solar Radio Astronomy

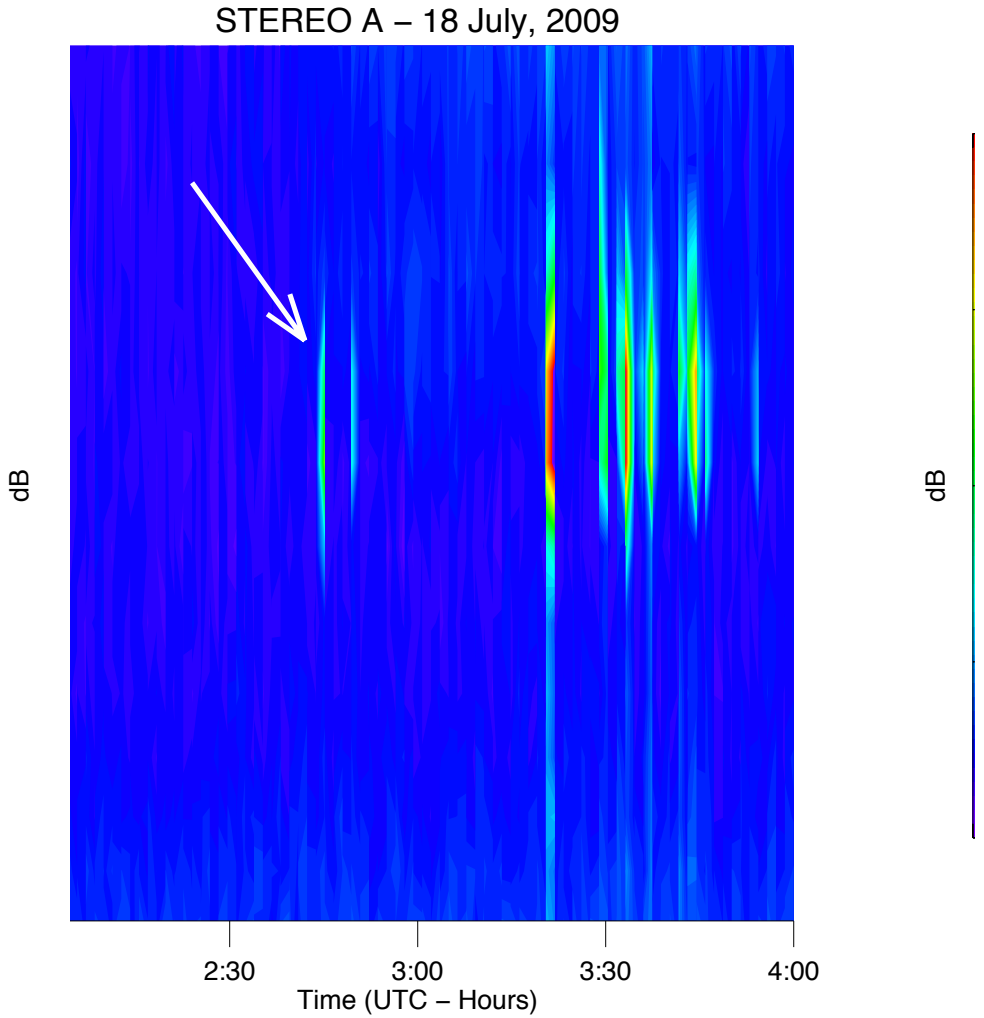
1 minute tutorial




STEREO-B 2011-09-22 (265)
Type IV
Type II Burst
Type III Burst
FREQUENCY (MHz)
10.00
1.00
0.10
0.01
10:00
11:00
12:00
13:00
14:00
15:00
TIME (UTC-HOURS)
40
30
20
10
0
-10

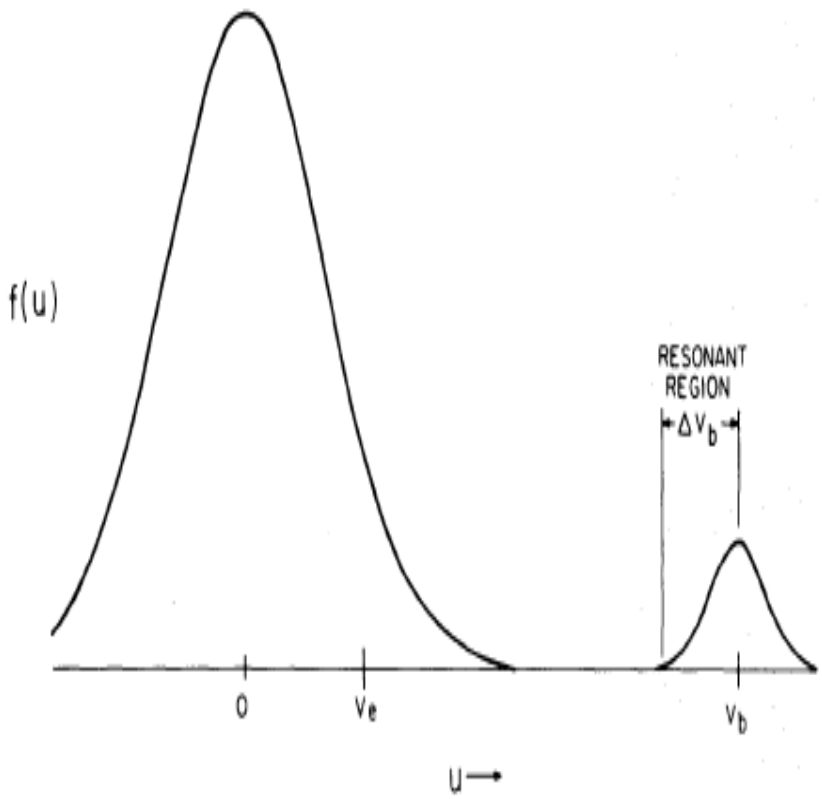
A Local Solar Type III Radio Burst

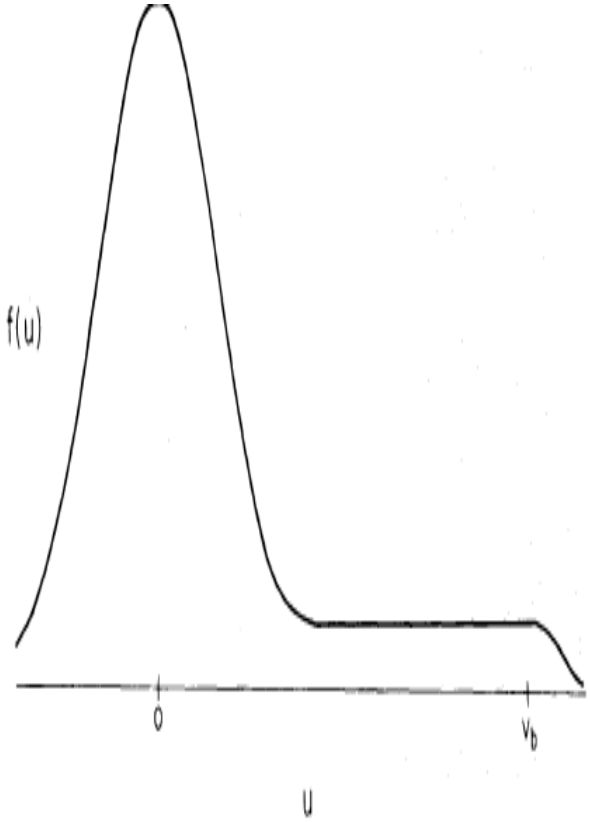




Sturrock's Dilemma

Sturrock (1964)



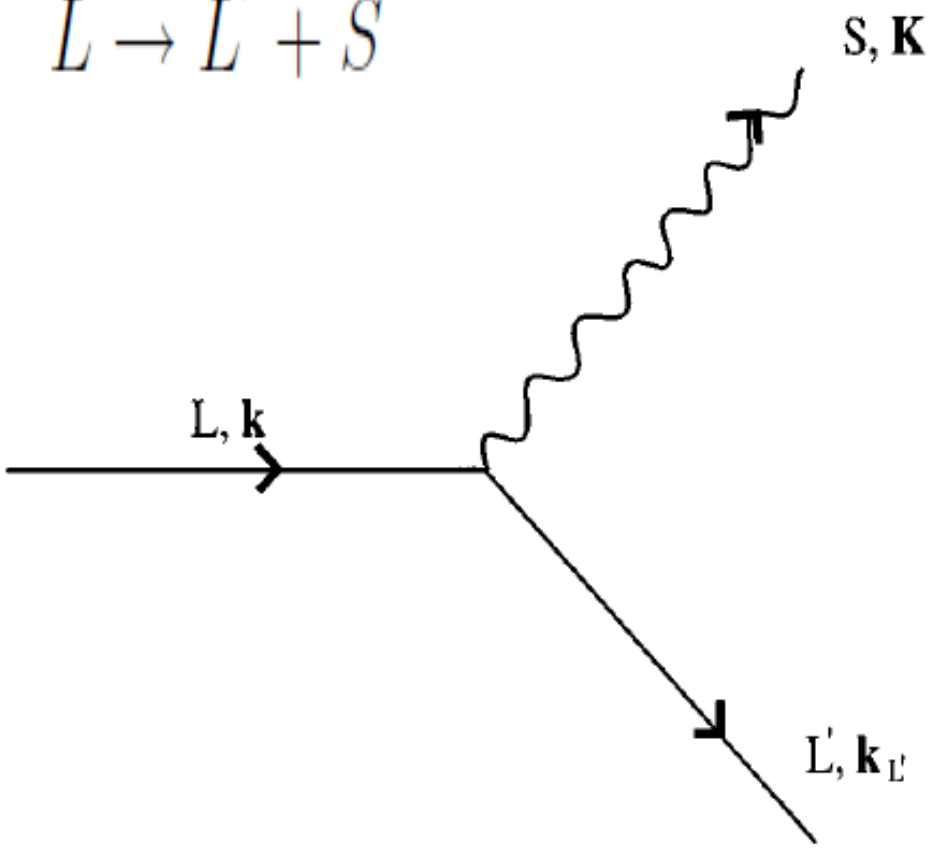


$$\omega_L = \vec{k_L}.\vec{v_b}$$

- Weak Turbulence Process (Electrostatic Decay (ESD))
- Strong Turbulence Processes (Oscillating two stream instability (OTSI), soliton formation and Langmuir collapse)

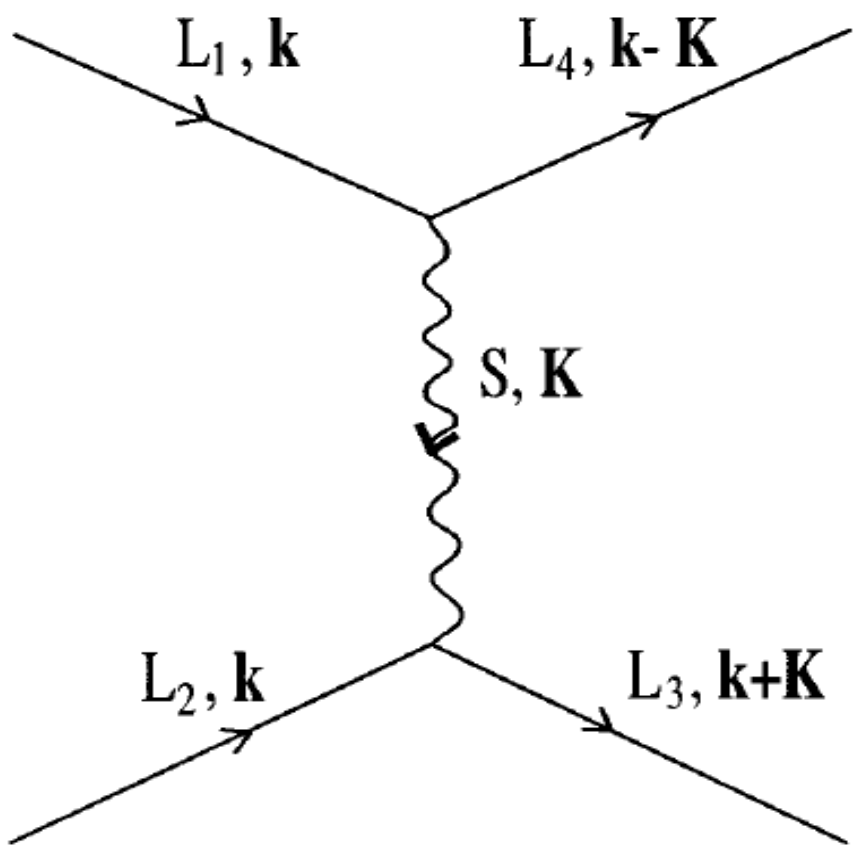
Electrostatic Decay (Three Wave interaction)

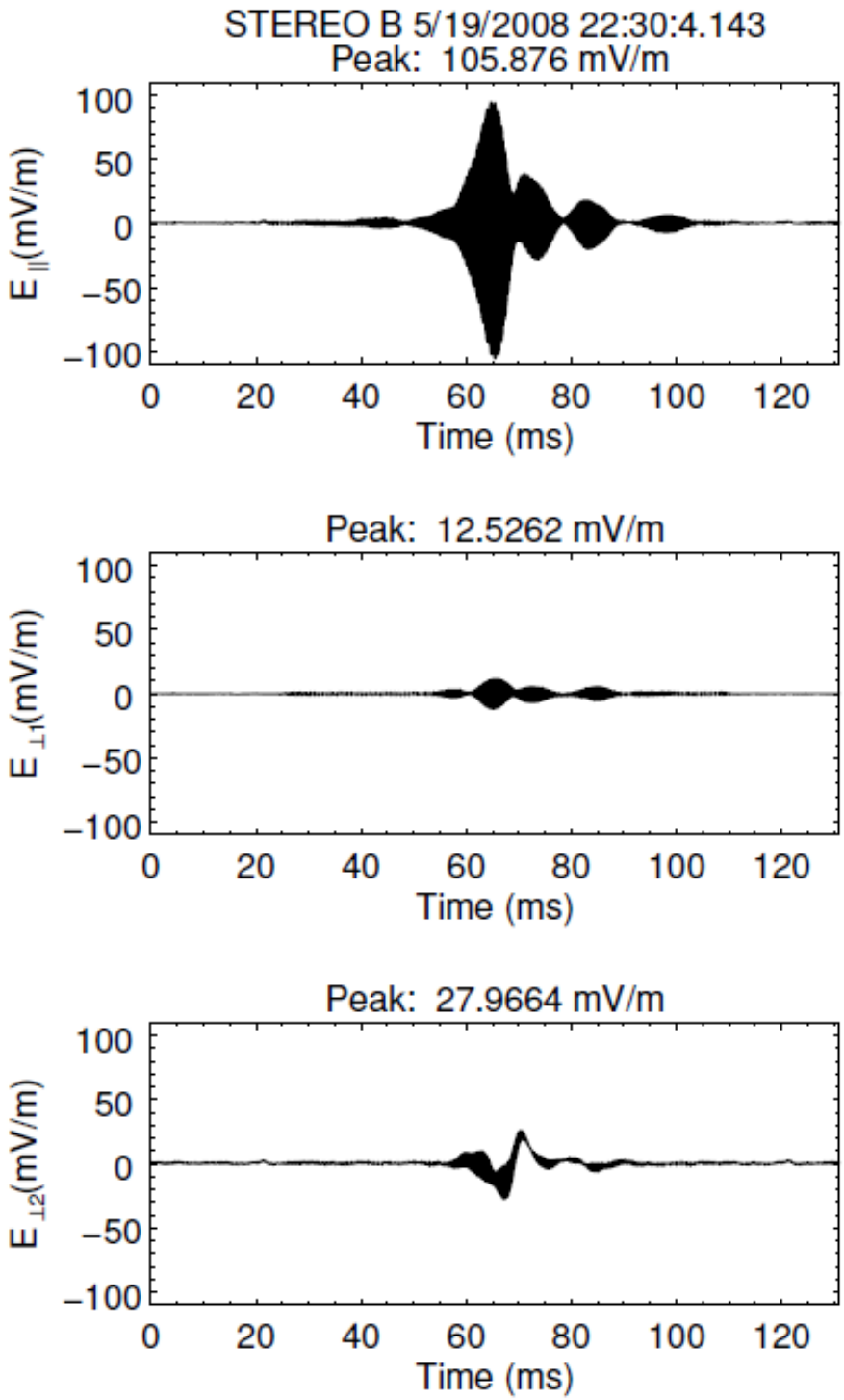
$$L \rightarrow L' + S$$

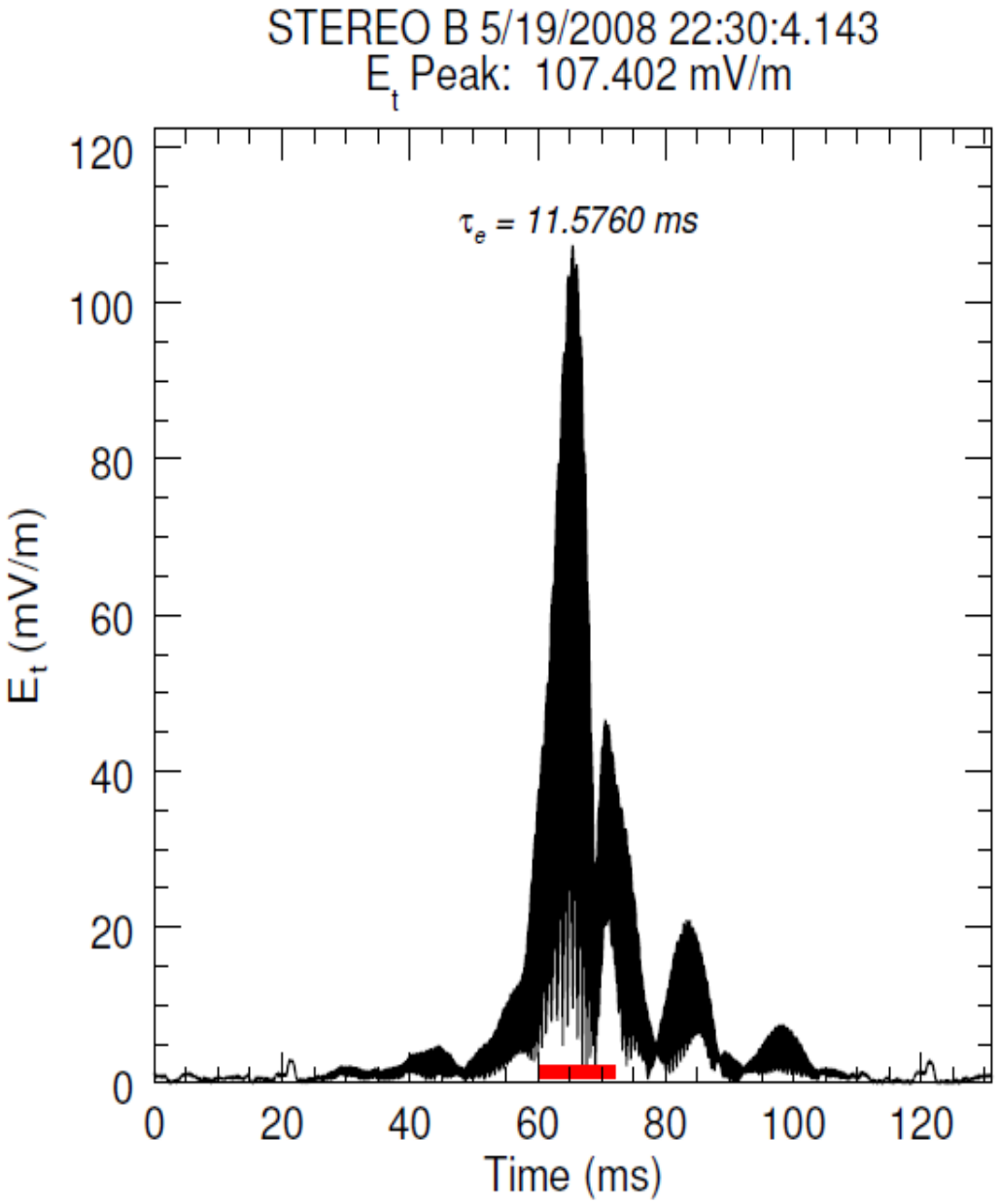


Oscillating Two Stream Instability (Four-wave Interaction)

$$L_1 + L_2 \rightarrow L_3 + L_4$$




STEREO B 5/19/2008 22:30:4.143
Peak: 105.876 mV/m
100
50
0
−50
−100
E||(mV/m)
0
20
40
60
80
100
120
Time (ms)
Peak: 12.5262 mV/m
100
50
0
−50
−100
E⊥1(mV/m)
0
20
40
60
80
100
120
Time (ms)
Peak: 27.9664 mV/m
100
50
0
−50
−100
E⊥2(mV/m)
0
20
40
60
80
100
120
Time (ms)



$$\Delta = \tau v_{sw} \cos\theta \sim 206\lambda_{De}$$

$$v_{sw} \sim 590 \text{ kms}^{-1}$$

$$\theta = 68^{\circ}$$

$$\lambda_{De} = 12.4 \text{ m}$$

Threshold Condition for OTSI

Zhakarov (1972)

$$\frac{W_L}{n_e T_e} > \frac{m_e}{m_i} > (k_L \lambda_{De})^2$$

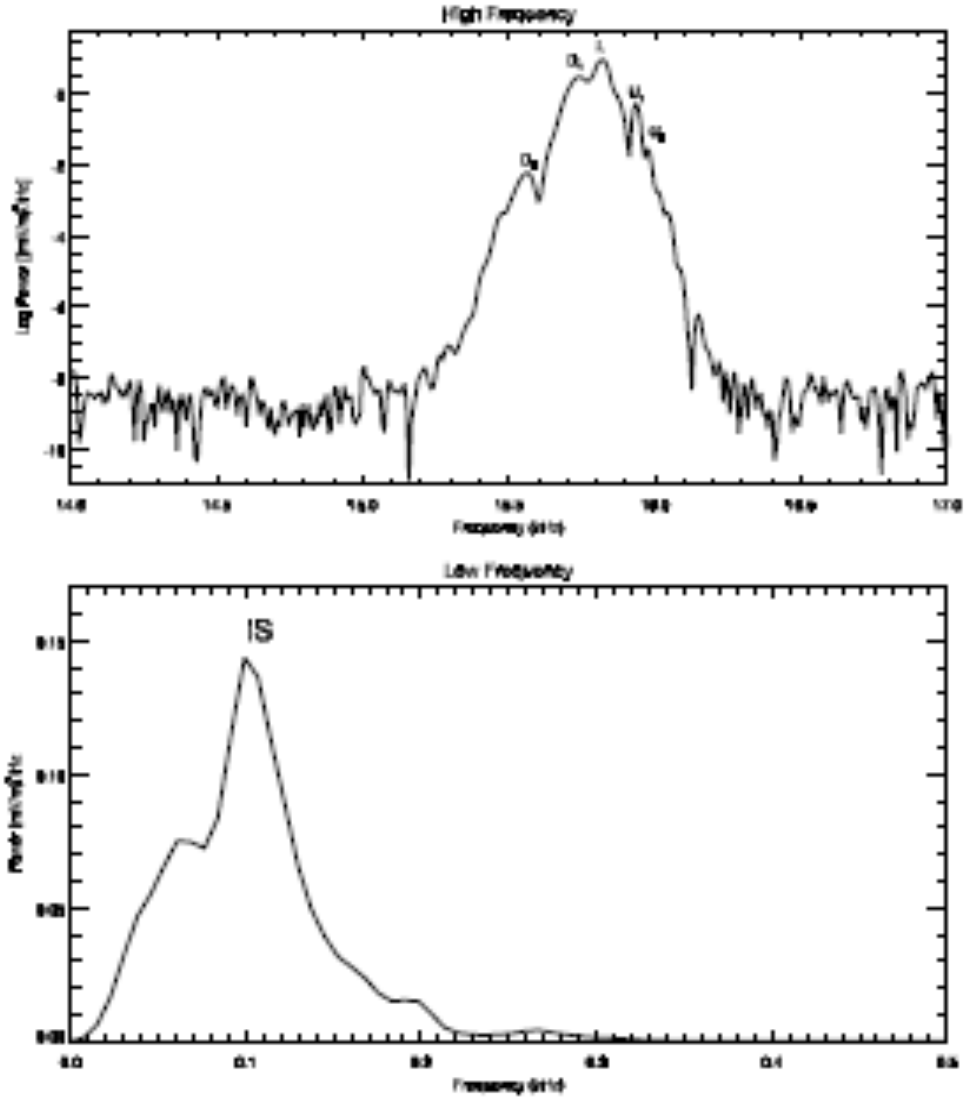
$$\frac{W_L}{n_e T_e} \sim 6 \times 10^{-3},$$

$$\frac{m_e}{m_i} \sim 5.5 \times 10^{-4}$$

$$(k_L \lambda_{De})^2 \sim 1.87 \times 10^{-4},$$

Oscillating Two Stream Instability (OTSI)

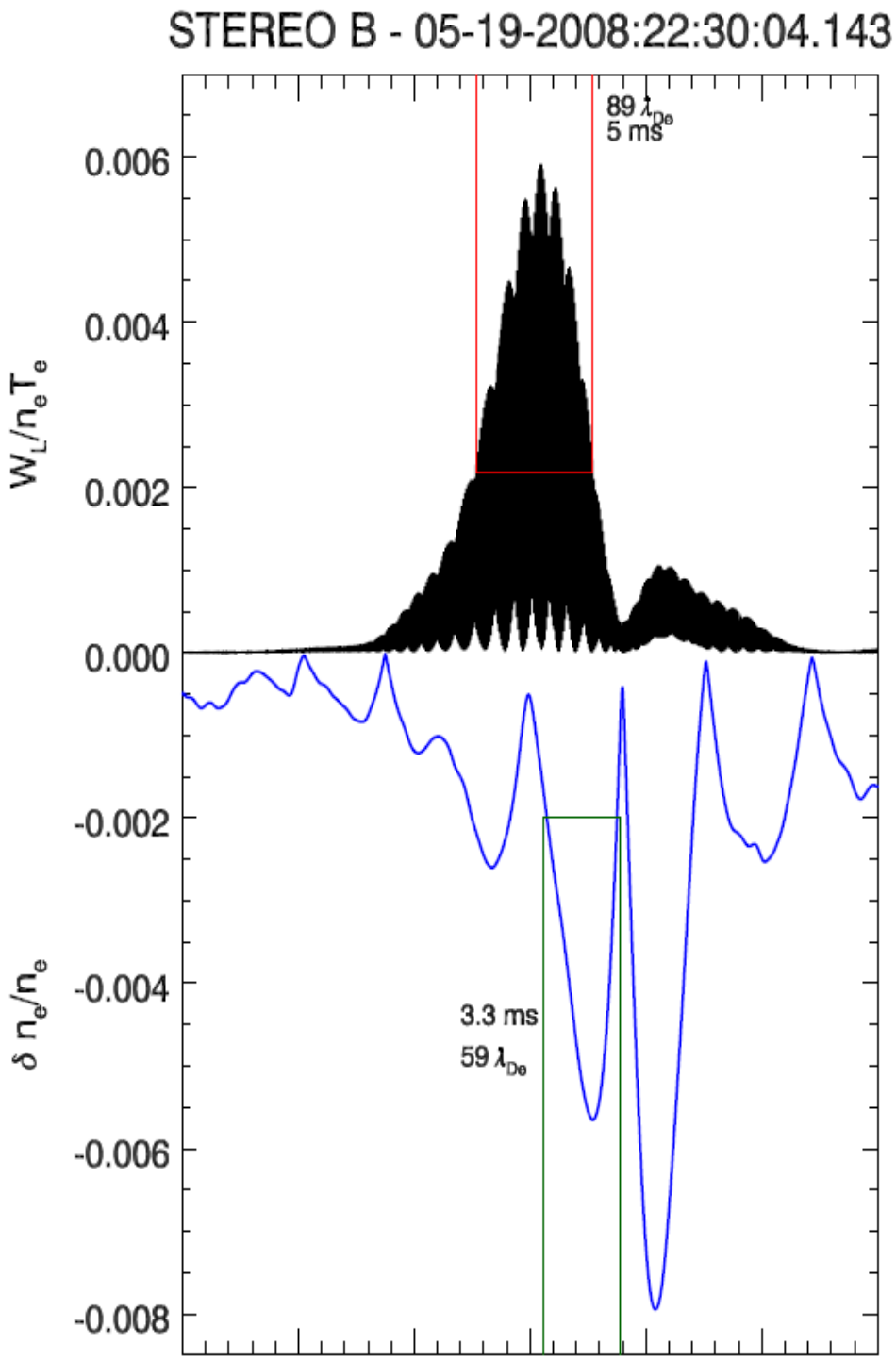
STEREO B 20080519 22:30:04.143

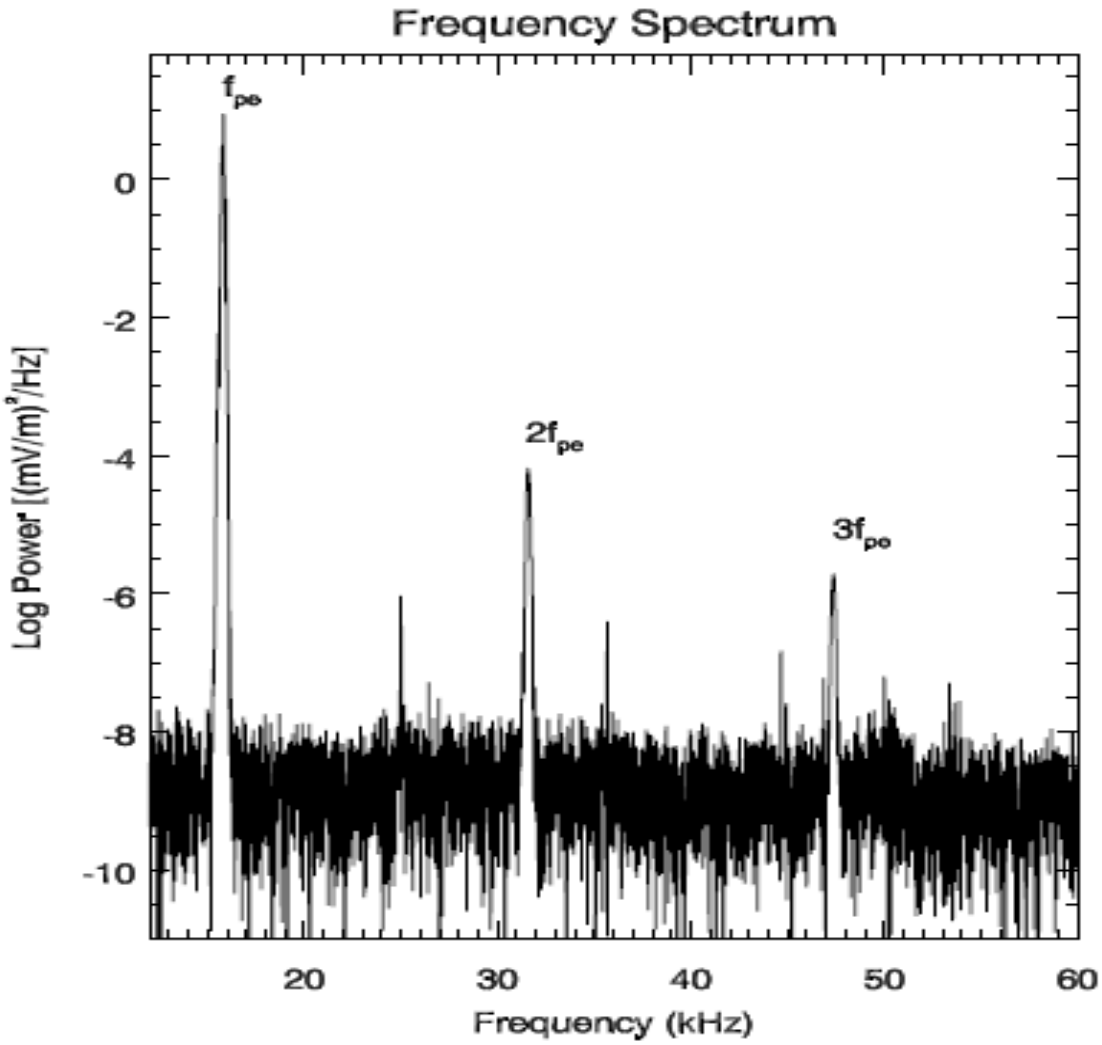


$$L_1 + L_2 \xrightarrow{S} U_1 + D_1$$

$$f_{D_1} = f_{pe} - \Omega \qquad k_{D_1} = k_L - q$$

$$f_{U_1} = f_{pe} + \Omega \qquad k_{U_1} = k_L + q$$


STEREO B - 05-19-2008:22:30:04.143
89 λDe
5 ms
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
WL/neTe
δ ne/ne
3.3 ms
59 λDe


Frequency Spectrum
f_{pe}
$2f_{pe}$
$3f_{pe}$
0
-2
-4
-6
-8
-10
Log Power [(mV/m)²/Hz]
20
30
40
50
60
Frequency (kHz)

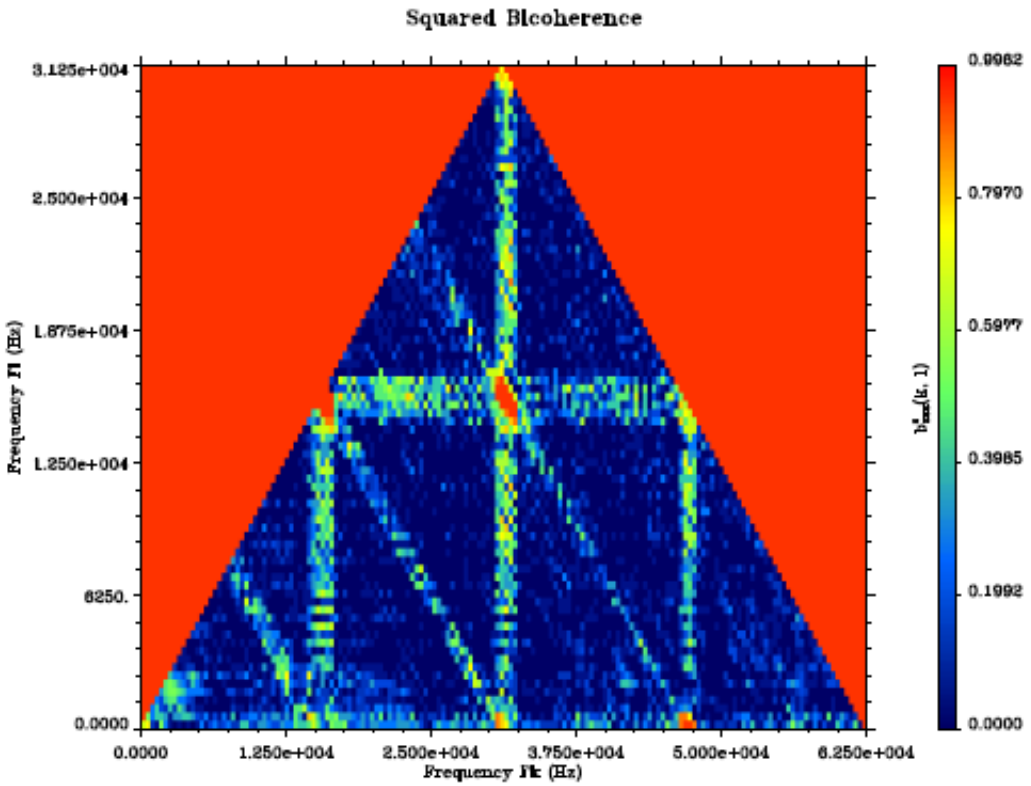
Three Wave interactions

$$L + L^{'} \rightarrow T_{2f_L}$$
$$L + T_{2f_L} \rightarrow T_{3f_L}$$

Resonance Conditions

$$f_L + f_{L'} = f_{T_{2f_L}}$$
$$k_L + k_{L'} = k_{T_{2f_L}}$$
$$\phi_L + \phi_{L'} = \phi_{T_{2f_L}}$$

$$f_L + f_{T_{2f_L}} = f_{T_{3f_L}}$$
$$k_L + k_{T_{2f_L}} = k_{T_{3f_L}}$$
$$\phi_L + \phi_{T_{2f_L}} = \phi_{T_{3f_L}}$$


Squared Bicoherence
3.125e+004
2.500e+004
1.875e+004
1.250e+004
6250.
0.0000
Frequency f1 (Hz)
0.0000
1.250e+004
2.500e+004
3.750e+004
5.000e+004
6.250e+004
Frequency f2 (Hz)
0.9962
0.7970
0.5977
0.3985
0.1992
0.0000

Threshold for Nucleation Instability

Cairns and Robinson (1992)

$$E_t \geq \sqrt{\frac{100 n_e k_B T_e}{\epsilon_0}} \frac{\lambda_{De}}{\Delta} \sim 33.7 \text{ mVm}^{-1} \qquad \delta n_b < \delta n_e$$

$$E_t \geq \sqrt{\frac{100 n_e k_B T_e V_s}{\epsilon_0 V_{Te}}} \sqrt{\frac{\lambda_{De}}{\Delta}} \sim 88 \text{ mVm}^{-1} \qquad \delta n_b > \delta n_e$$

$E_t \sim 107.4 \text{ mVm}^{-1}$ $\Delta_e \sim 206 \lambda_{De}$, $V_s = 4.1 \times 10^4 \text{ ms}^{-1}$ $V_{Te} \sim 1.23 \times 10^6 \text{ ms}^{-1}$

- Spatial collapse can also occur through nucleation

Conclusions

- The STEREO/WAVES detected the most intense 1D magnetic field aligned wave packet in a type III burst
- This wave packet for the first provides evidence for spatial collapse of Langmuir waves, where the route to collapse probably is through OTSI
- These observations also provide evidence for excitation mechanisms of the second and third harmonic EM waves.
- The OTSI and spatial collapse probably play critical roles in the beam stabilization as well as conversion of Langmuir waves into electromagnetic waves.

Thank You Very Much!