

Effective drift velocity and initiation times of interplanetary type-III radio bursts

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- We derive an “effective drift velocity” (EDV) from dynamic WIND/WAVES spectrograms of interplanetary type-III fast-drift radio bursts associated with 171 (1997-2003) near-relativistic electron events measured by ACE/EPAM at 1 AU.
- The leading edge (LE), peak (P), and trailing edge (TE) of each burst is established by a best fit of multiple time-frequency points obtained from different frequency cuts.
- Plots of inverse frequency ($1/f$) vs. time (t) produce straight lines from which we can calculate the EDVs for the LE, P and TE of each burst.
- No statistically significant correlations have been found between the EDV of the LE and the delay between the coronal origin of the type-III burst and the injection of near-relativistic electrons measured by ACE/EPAM

Near-relativistic impulsive Electron beam list.

171 events (out of 561) from
Sep 1997 – Jan 2004

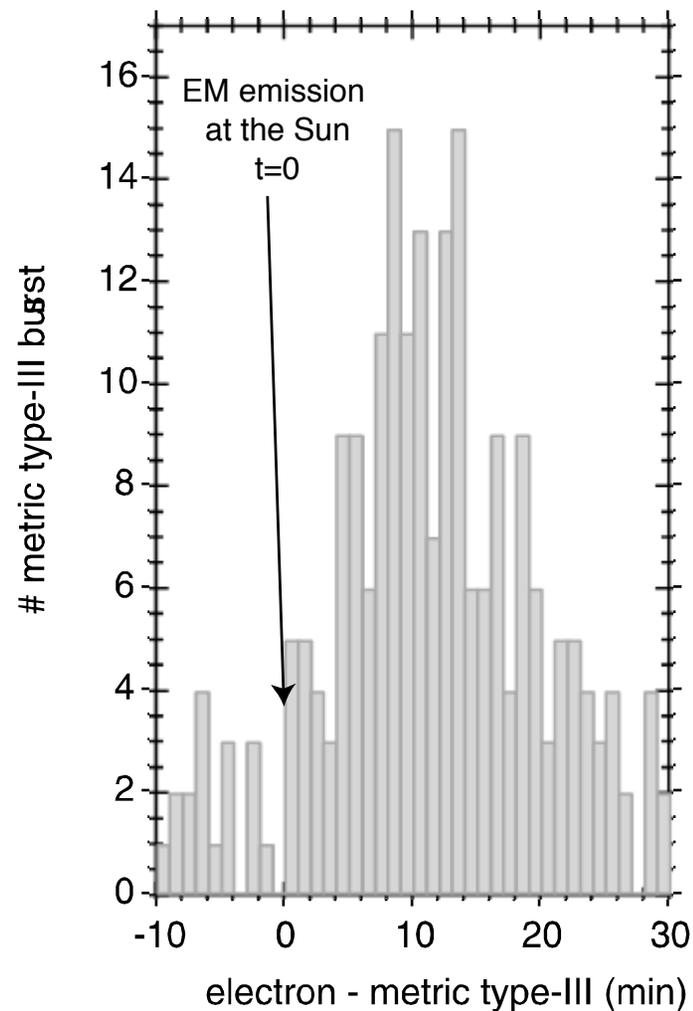
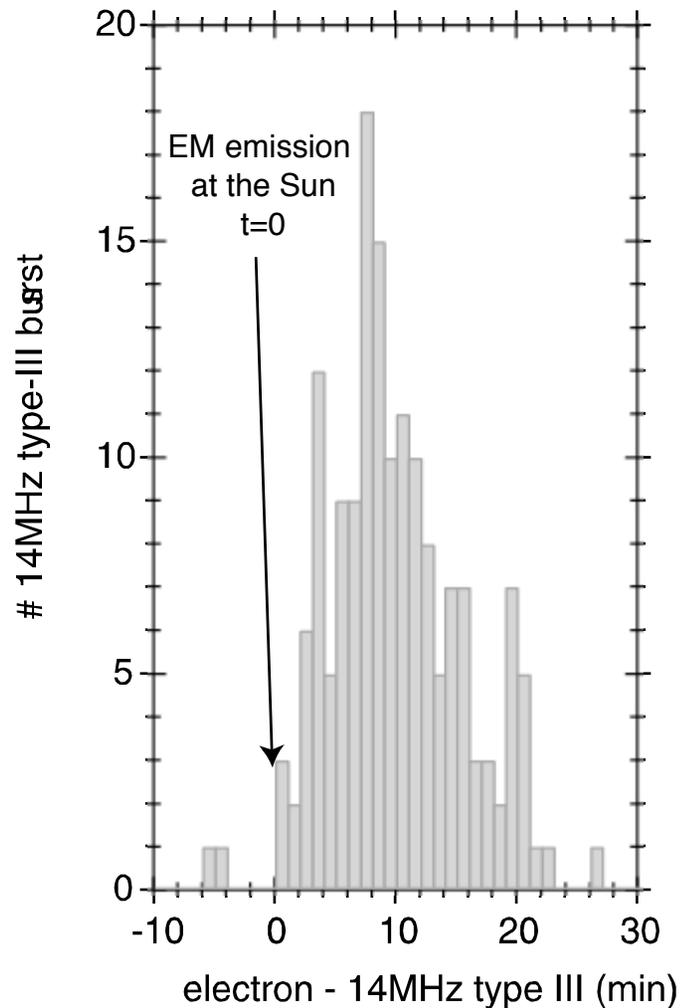
Event list located at:

<http://sd-www.jhuapl.edu/ACE/EPAM/BeamEventList.pdf>

Or from the ACE science
center

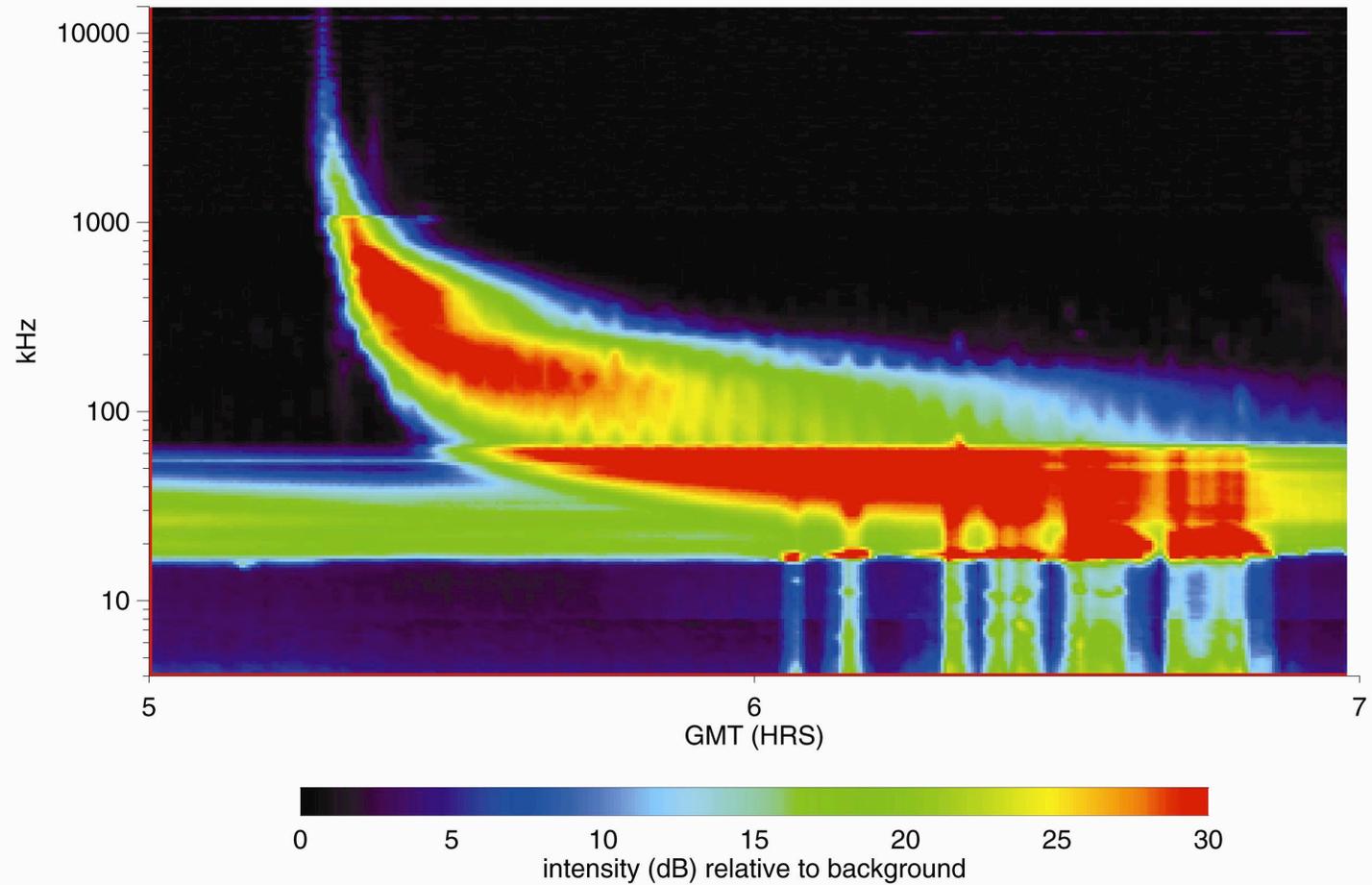
<http://www.srl.caltech.edu/ACE/ASC/DATA/level3/>

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1	1997	09/20	263	3	48	2	70	2000	05/01	122	10	29	4	139	2002	10/21	294	4	37	3
2	1997	11/04	308	6	19	4	71	2000	06/04	156	7	17	4	140	2002	12/12	346	1	0	2
3	1997	11/13	317	21	42	4	72	2000	06/10	162	17	11	4	141	2002	12/12	346	12	54	4
4	1997	11/23	327	10	19	2	73	2000	06/15	167	19	53	4	142	2003	2/12	43	2	14	4
5	1997	11/28	332	15	31	3	74	2000	06/28	180	19	8	4	143	2003	3/17	76	10	24	4
6	1997	12/05	339	17	22	2	75	2000	07/12	194	20	22	4	144	2003	3/17	76	16	54	3
7	1998	05/06	126	8	9	4	76	2000	07/22	204	11	53	4	145	2003	3/17	76	19	13	4
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39	1999	05/09	129	18	20	4	108	2002	02/27	58	12	21	3							
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55	1999	08/07	219	17	20	3	124	2002	8/4	216	7	40	4							
56	1999	09/11	254	3	13	2	125	2002	8/14	226	2	0	4							
57	1999	09/14	257	14	45	2	126	2002	8/19	231	21	16	4							
58	1999	09/15	258	4	45	2	127	2002	8/20	232	1	56	4							
59	1999	09/15	258	9	16	2	128	2002	8/20	232	8	43	4							
60	1999	09/30	273	4	15	2	129	2002	8/24	236	1	27	4							
61	2000	01/22	22	19	23	3	130	2002	9/17	260	2	27	4							
62	2000	01/23	23	19	12	2	131	2002	9/24	267	11	27	4							
63	2000	02/18	49	9	35	4	132	2002	9/24	267	11	43	4							
64	2000	03/02	62	8	45	4	133	2002	9/27	270	0	46	4							
65	2000	03/06	66	12	27	4	134	2002	9/27	270	1	40	4							
66	2000	03/07	67	7	42	4	135	2002	10/5	278	12	27	4							
67	2000	03/07	67	12	45	3	136	2002	10/20	293	5	46	4							
68	2000	03/18	78	21	12	4	137	2002	10/20	293	11	54	3							
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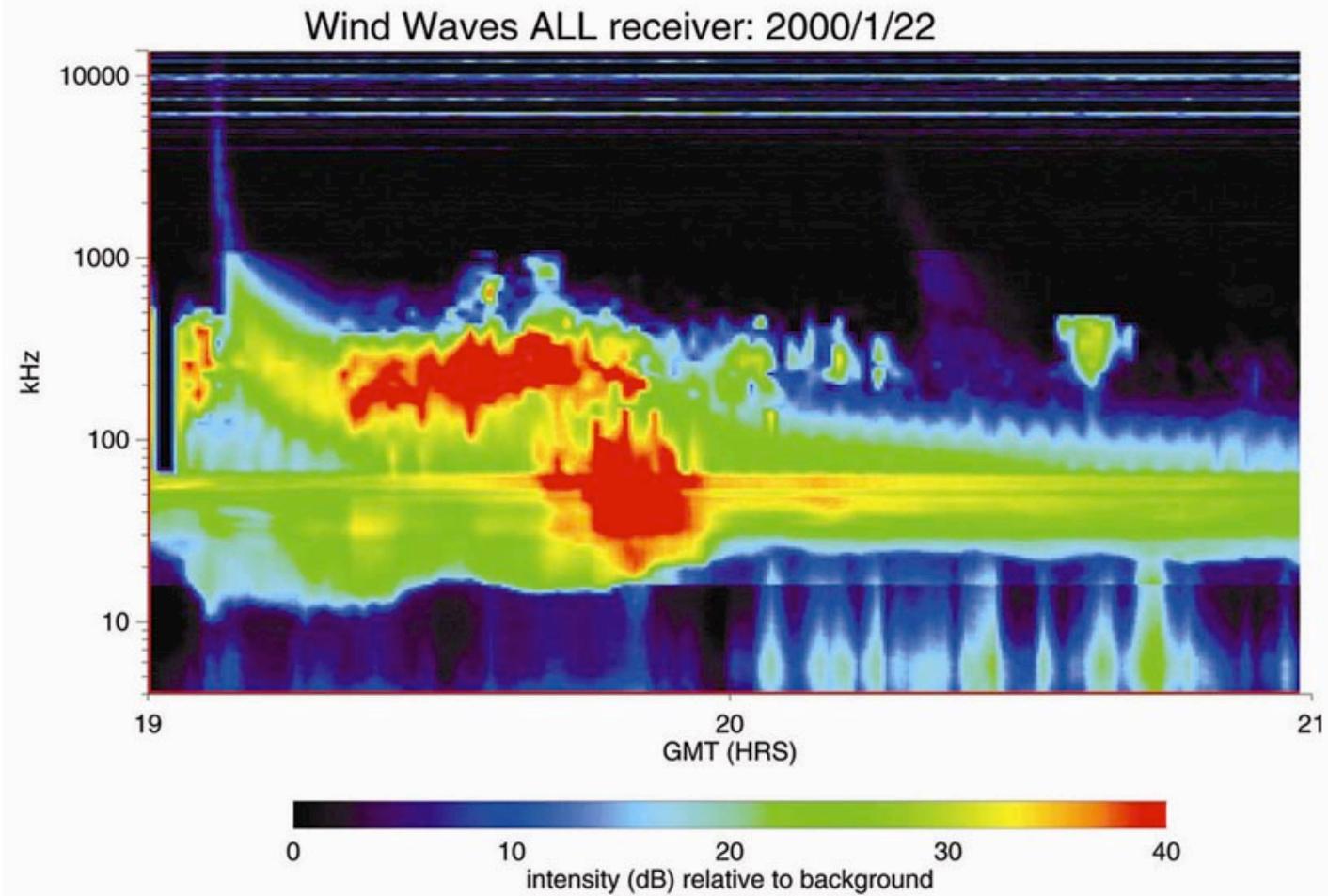


For 171 near-relativistic impulsive electron events there is a delay between the injection of the electrons and the type-III EM emission at the Sun. This delay is ~ 10 minutes and is also observed when compared to metric type-III bursts

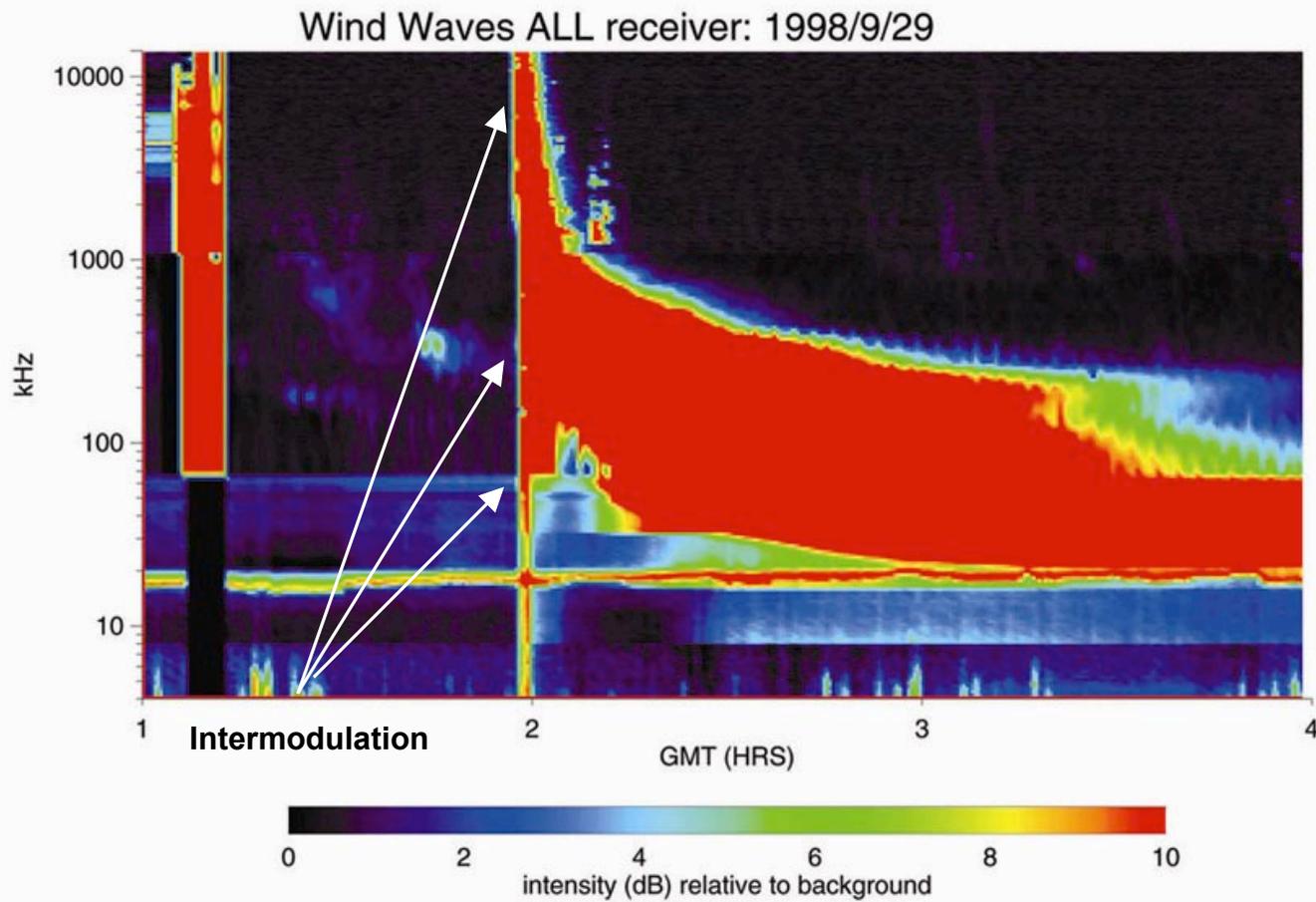
Wind Waves ALL receiver: 1999/6/13



100 of the 171 events are sufficiently “clean” to get quantitative results from frequency cuts

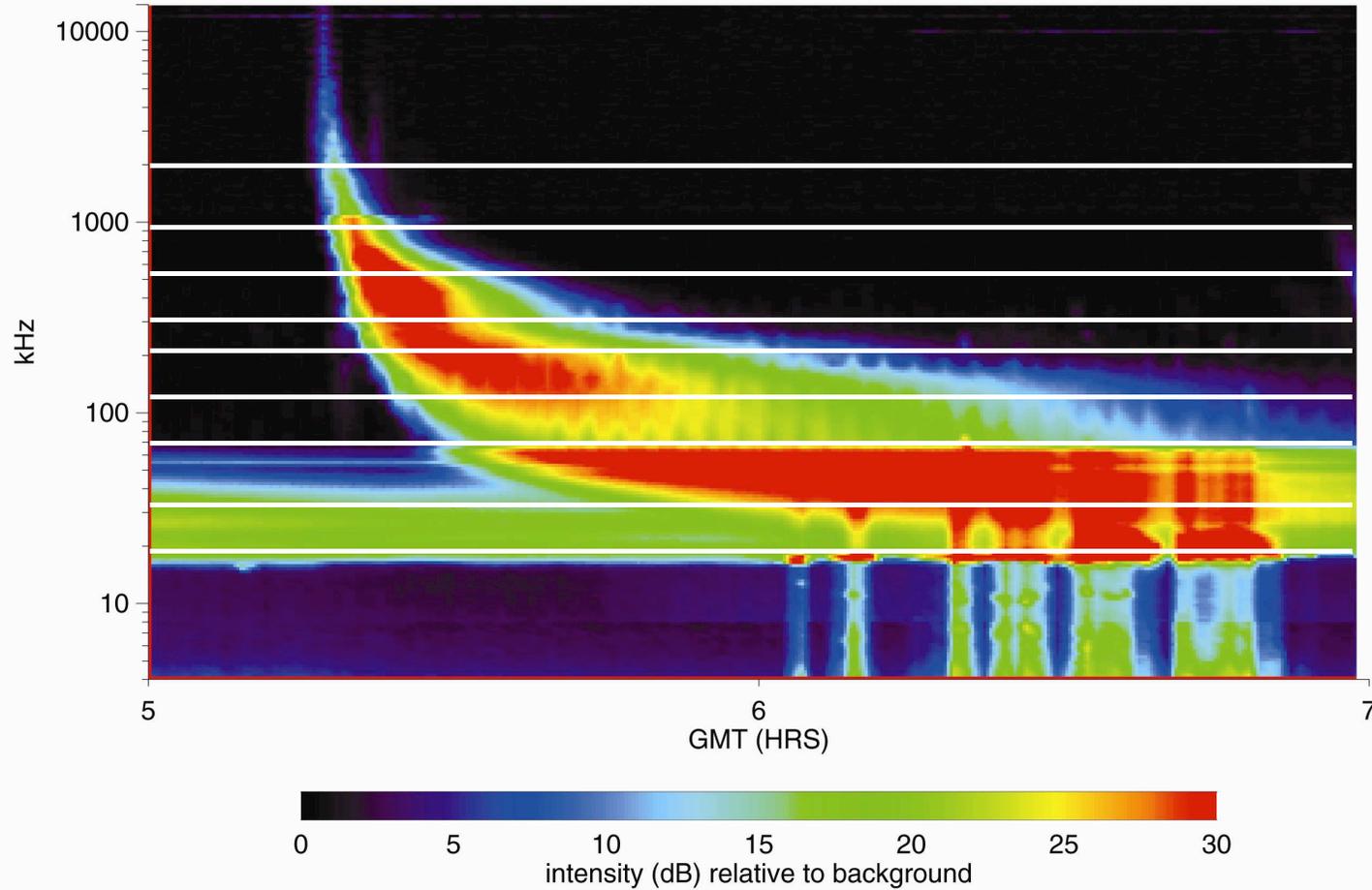


The leading edge (LE) for some events is obscured

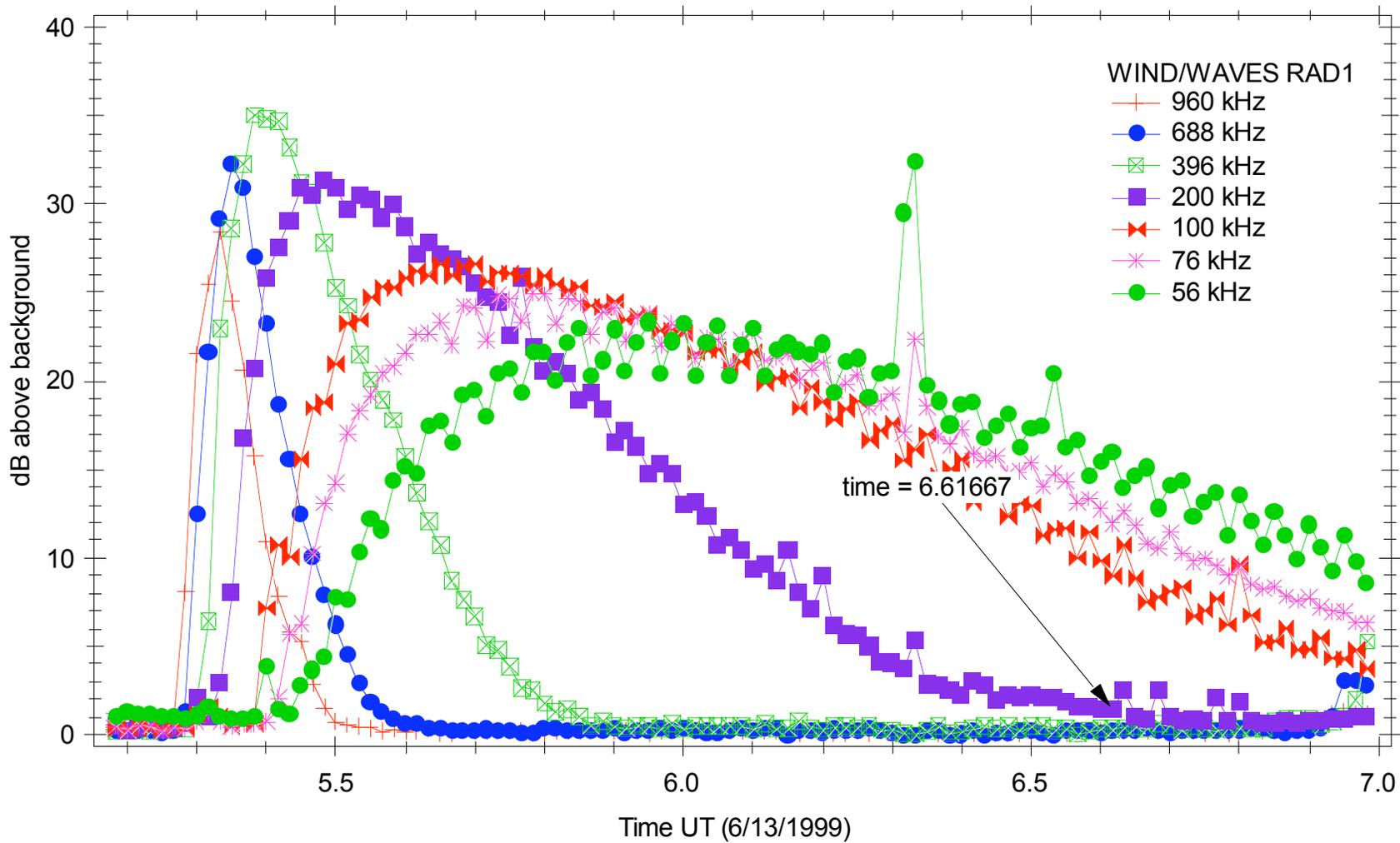


At times Instrumental effects can obscure the LE of the type-III bursts

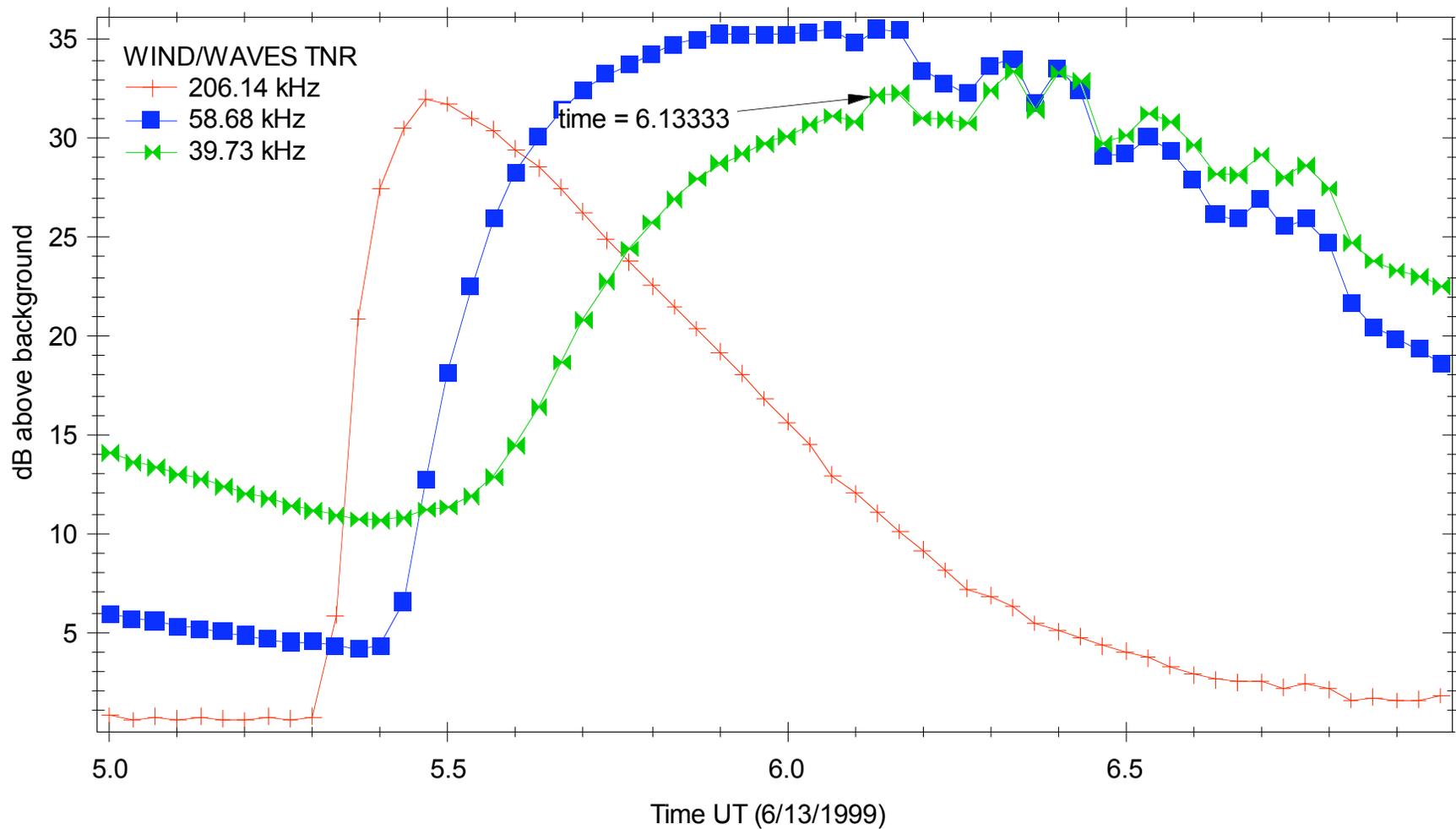
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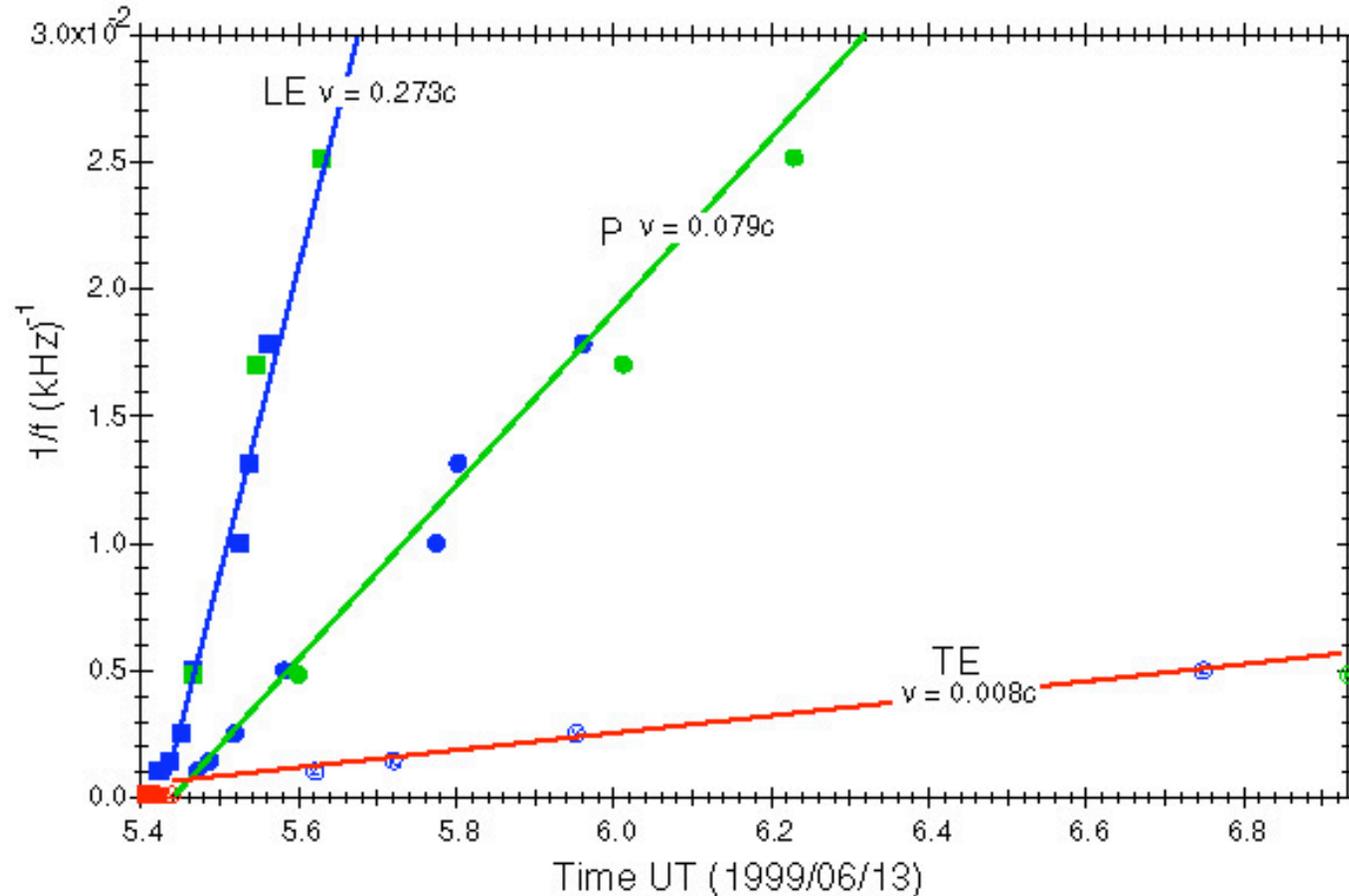
For 100 events frequency cuts of the intensity spectrogram allow an accurate determination of the LE, P, and TE



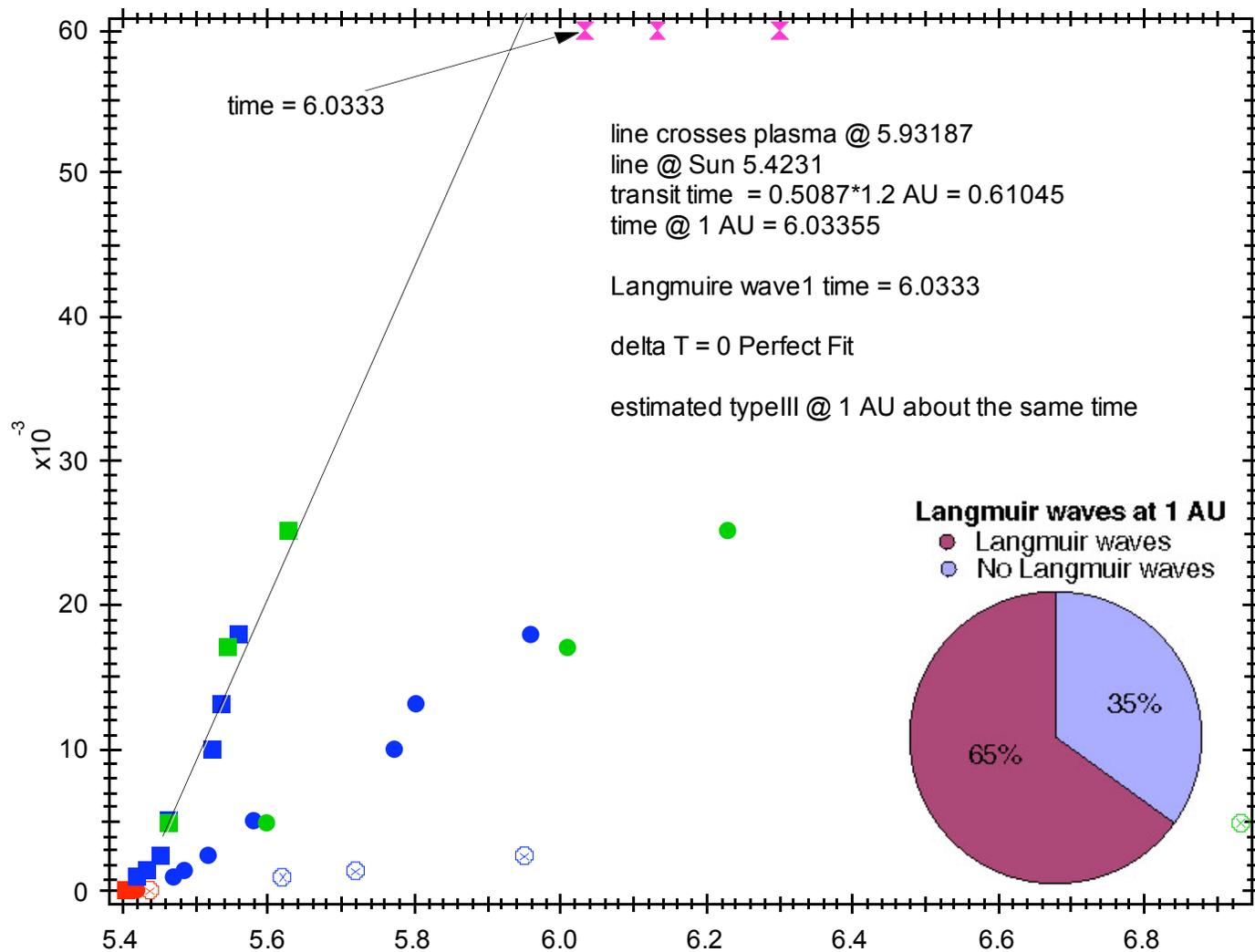
Frequency cuts through the RAD1 data (~20-1040 kHz) precisely identify the time of the onset and peak intensity for the type-III radio bursts. For some events the trailing edge can also be identified.



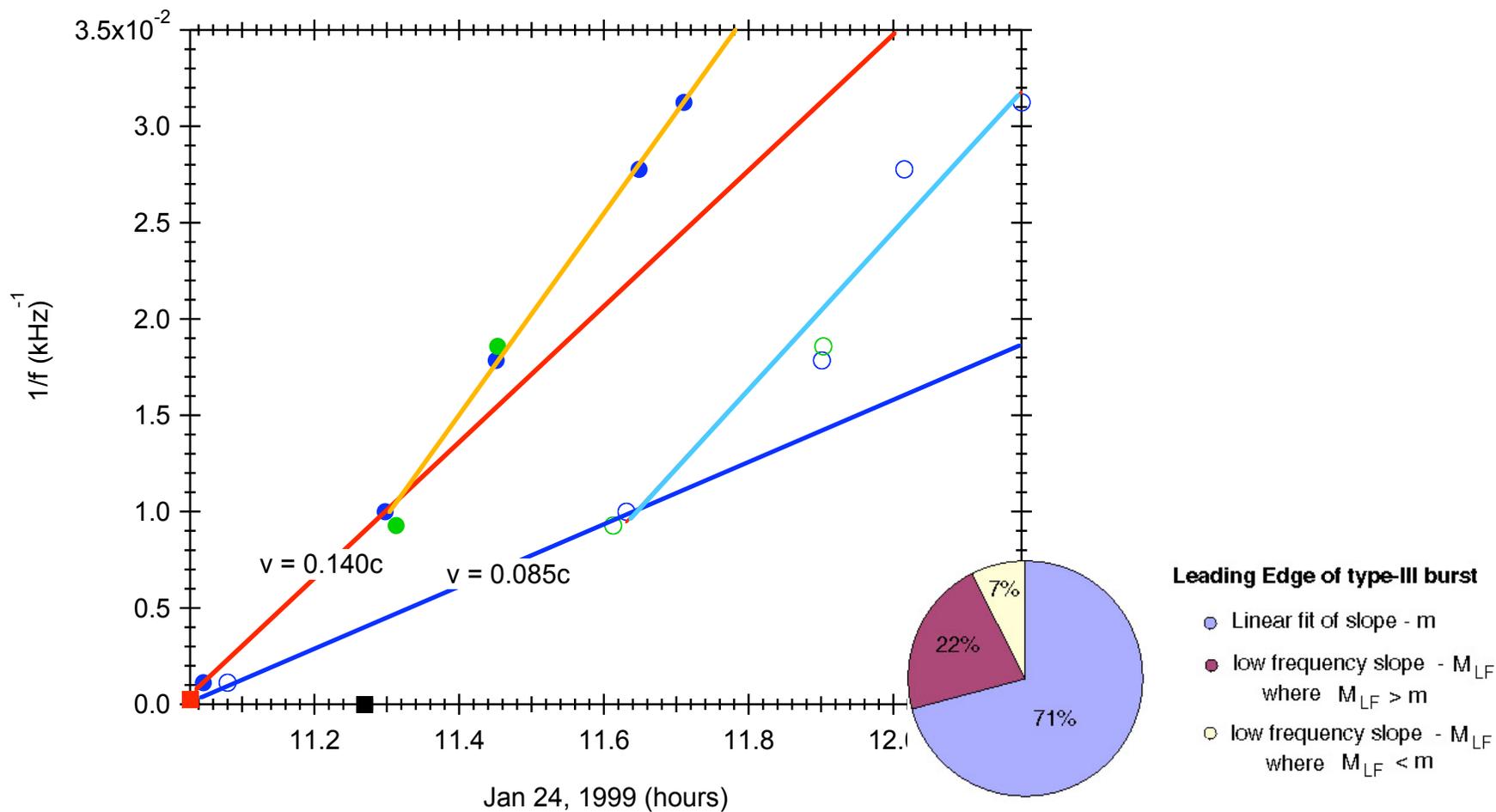
Frequency cuts through the TNR data (~4-245 kHz) show that higher frequency onset and peak times can be clearly identified but lower frequency onset and peak times are more subjective.



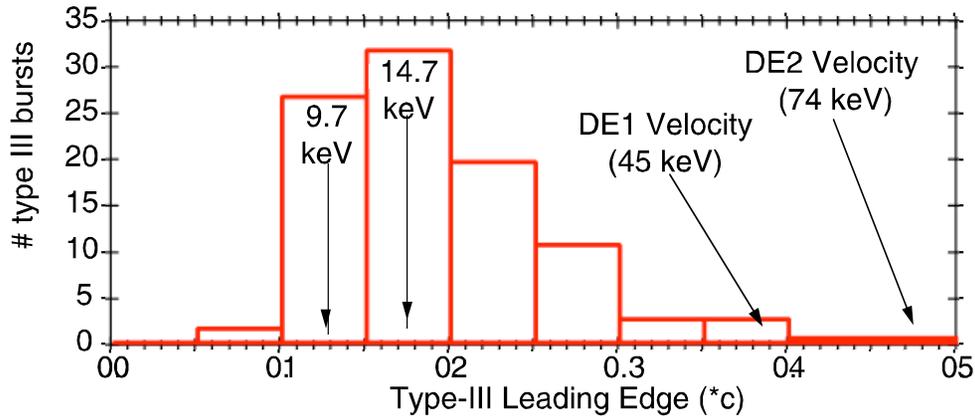
- The Leading Edge (LE, blue line), the peak intensity (P, green line), and the trailing edge (TE, red line) are found by a linear best fit of the frequency cut data.
- Assuming the electron density falls off as r^{-2} along an IMF line, $f_1/f = r/r_1$ where f_1 is the plasma frequency measured at $r_1 = 1$ AU at the onset time.
- From the slope of the fit the velocity is $v = \text{slope} * f_1 * 0.139 * c$



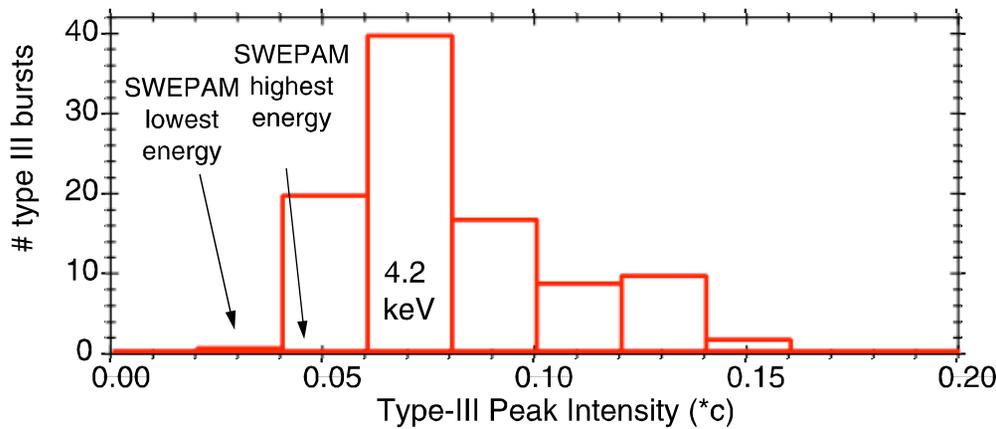
Along with the velocity of the type-III we can identify the time of the local plasma oscillations (Langmuir waves) and estimate when the type-III leading edge will arrive at 1 AU.



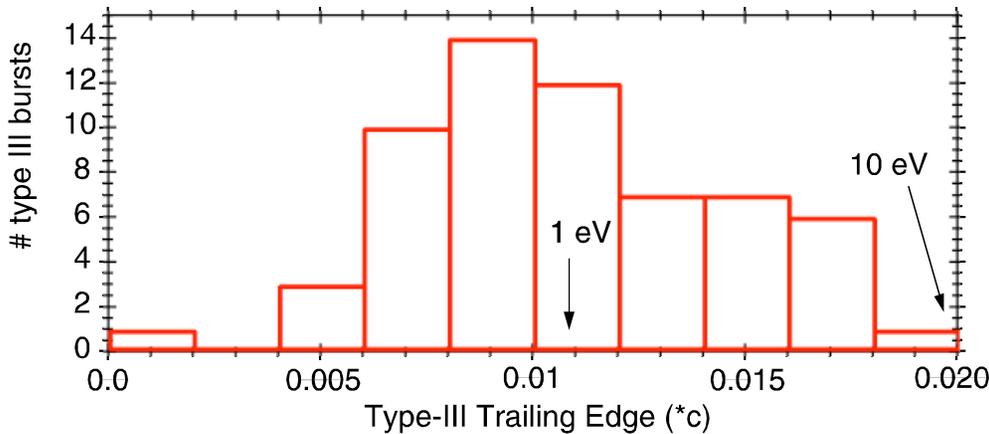
Example event showing changing slopes during event propagation For this study the higher frequency observations (closest to the Sun) were used.



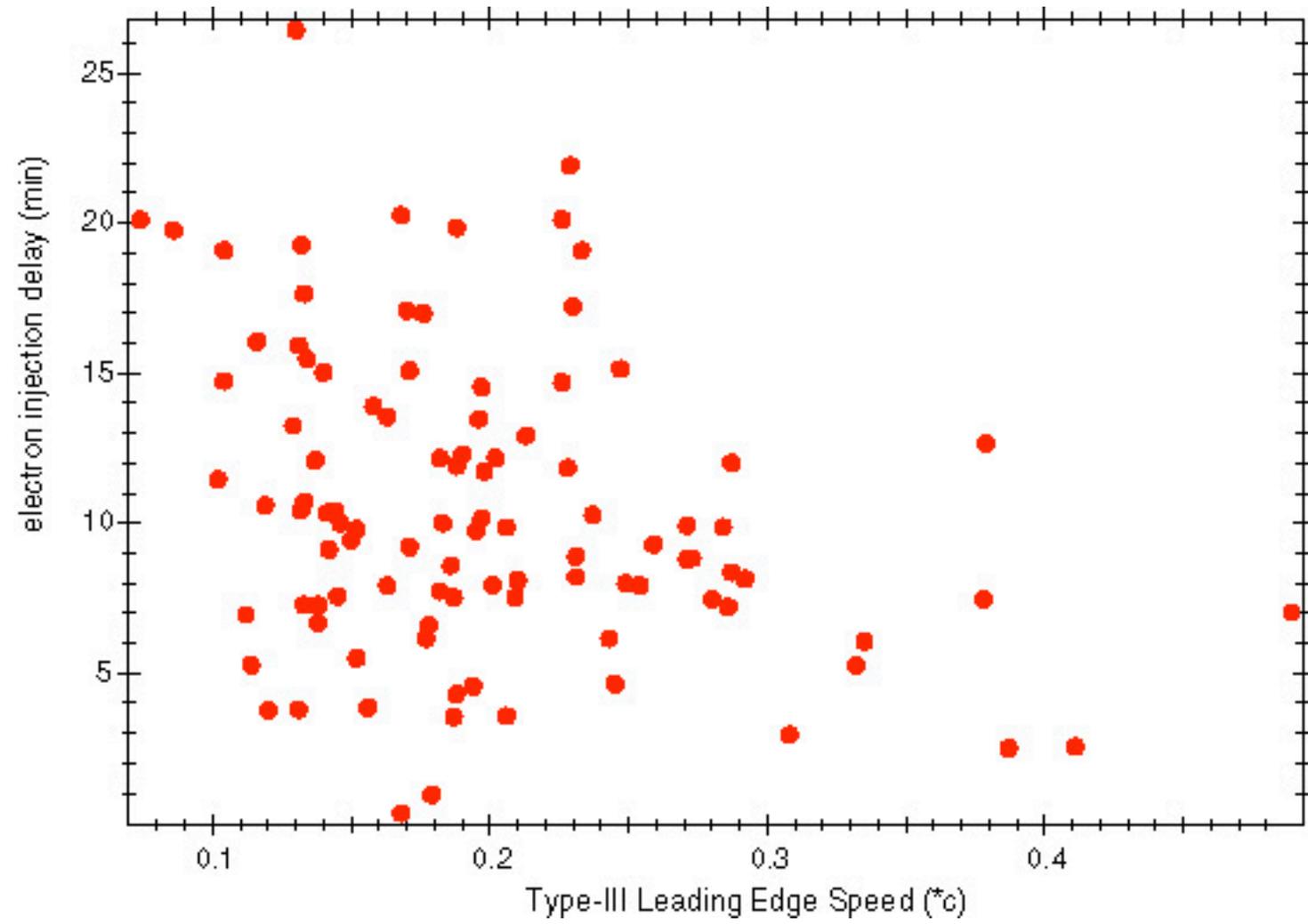
The average leading edge exciter velocity corresponds to an electron energy ~ 14 keV, implying that electrons of at least this energy contribute to the type-III emission at all radii out to ~ 0.5 AU

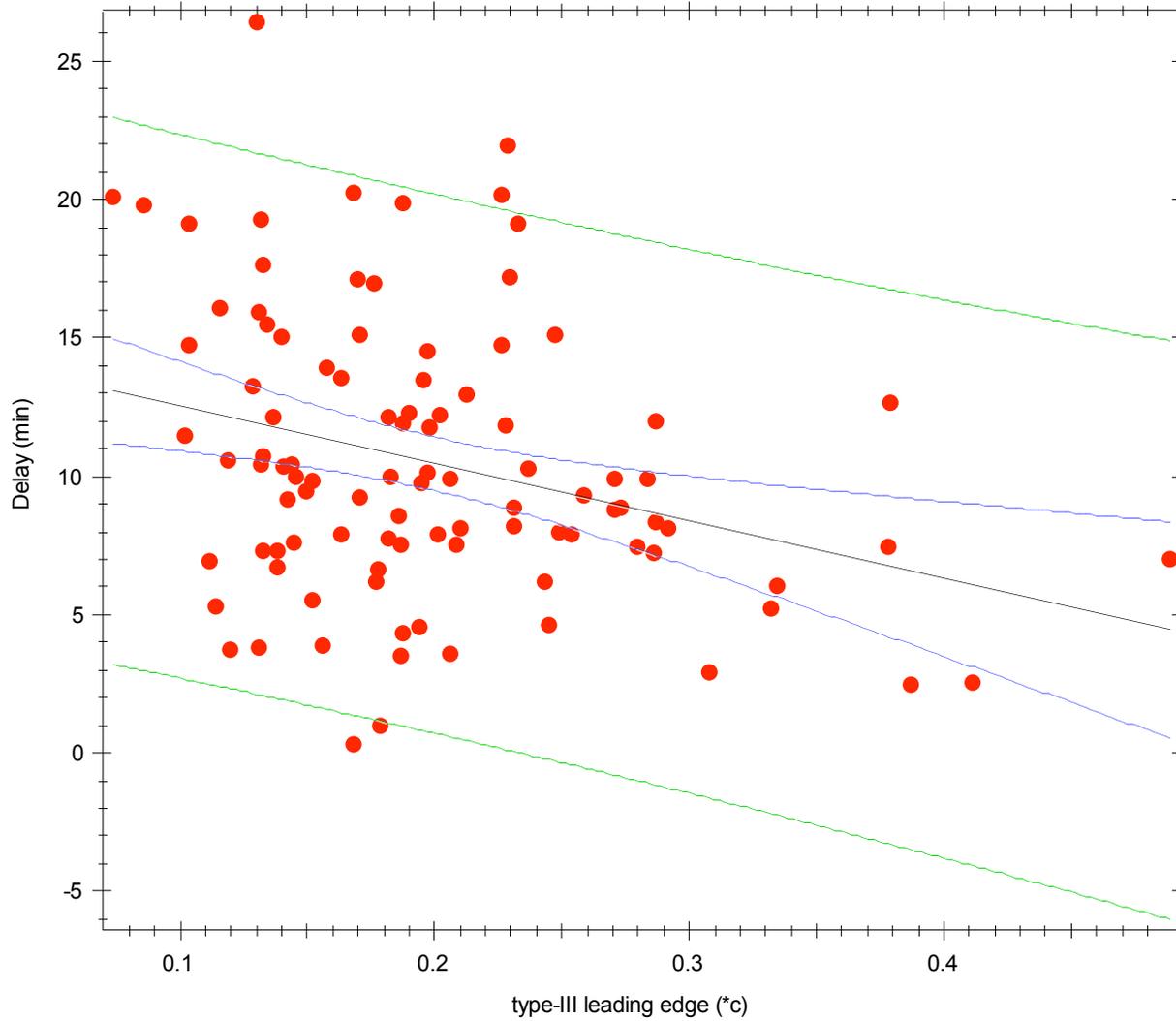


The average peak velocity corresponds to ~ 4 keV. This value agrees well with a study of the peak type-III high coronal velocities determined from the WIND/WAVES RAD2 observations at 2 and 14 MHz: (Haggerty and Roelof, *ApJ*, 2002; Haggerty, Roelof, and Simnett, *Adv. Space Res*, 2003)



The average trailing edge intensity corresponds to ~ 1 eV, so it is not to be interpreted as a propagation energy.

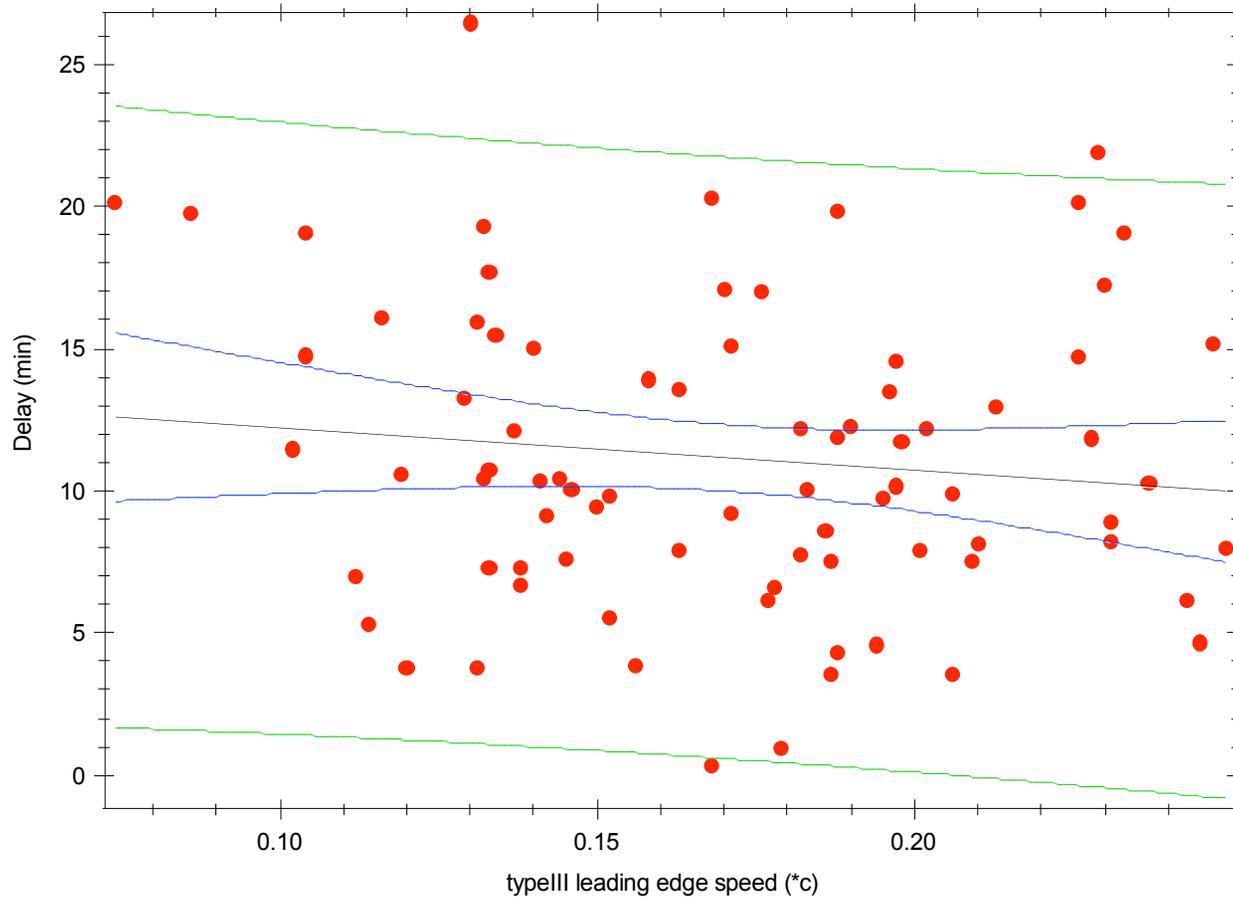




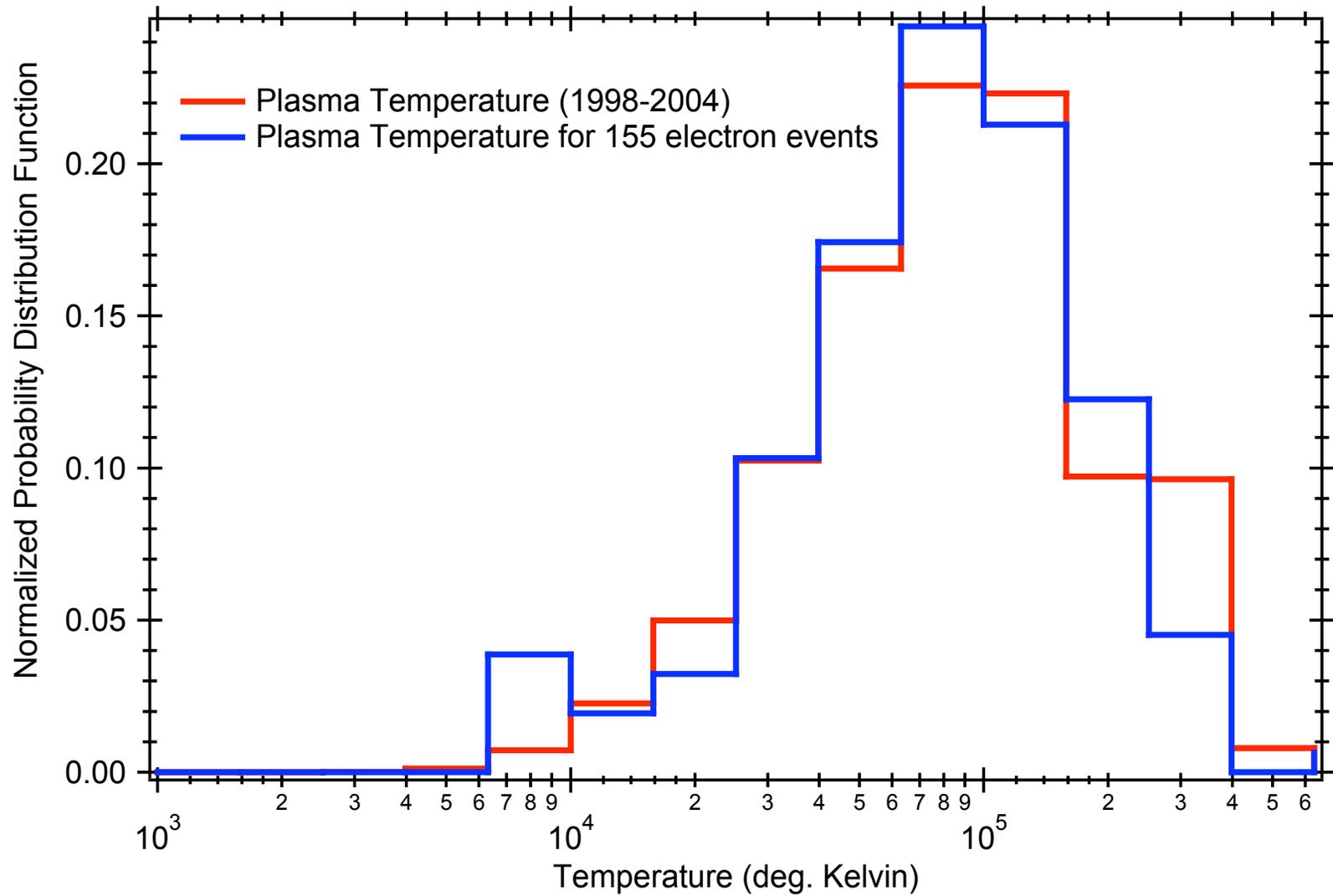
The data has a correlation coefficient of ($R = 0.3$)

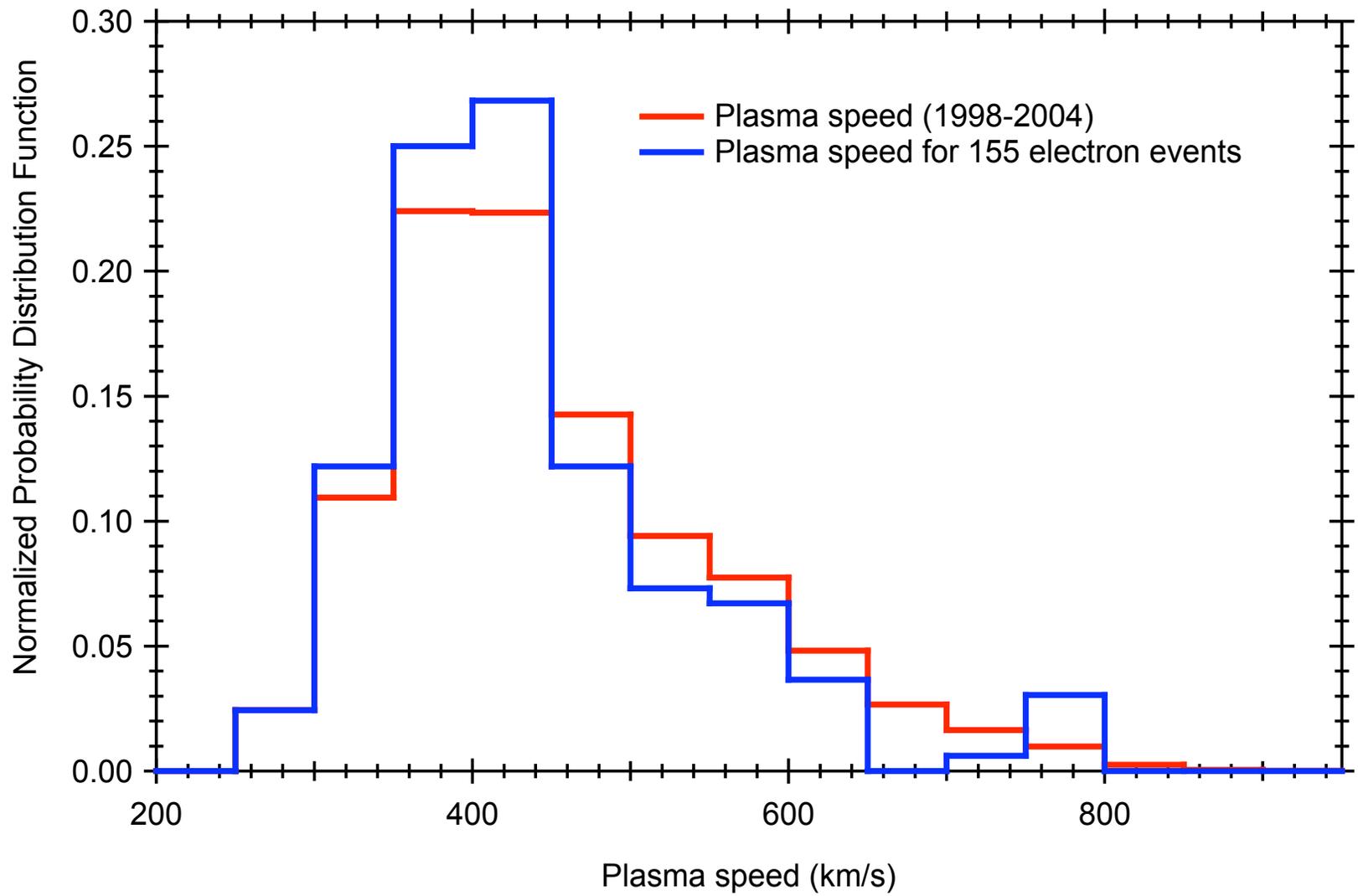
We also show the 95% confidence interval and prediction band for the validity of the fit.

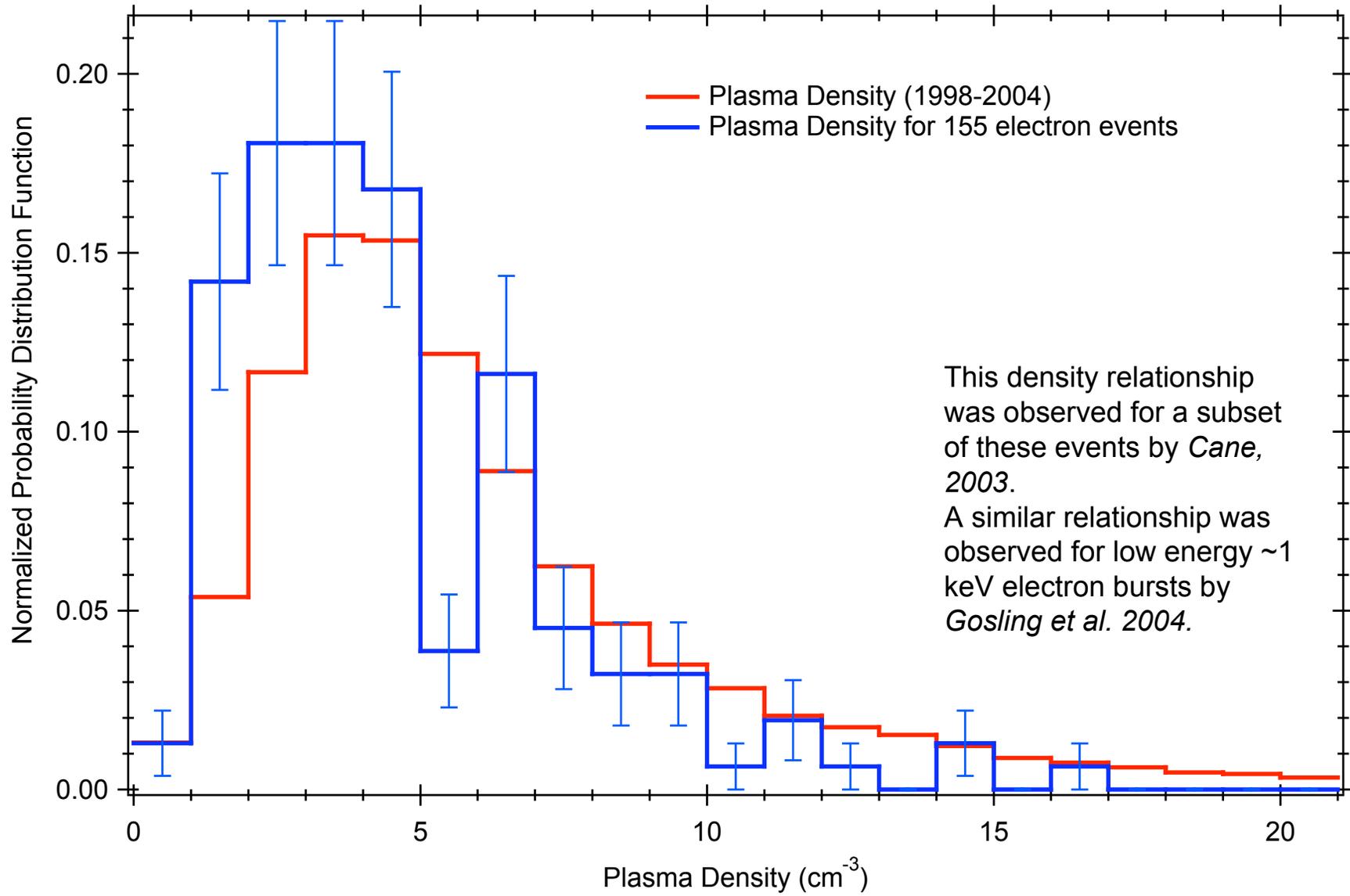
There is a small group of fast type-III events ($V > 0.25c$) that clearly stand apart from the majority of events analyzed in this study

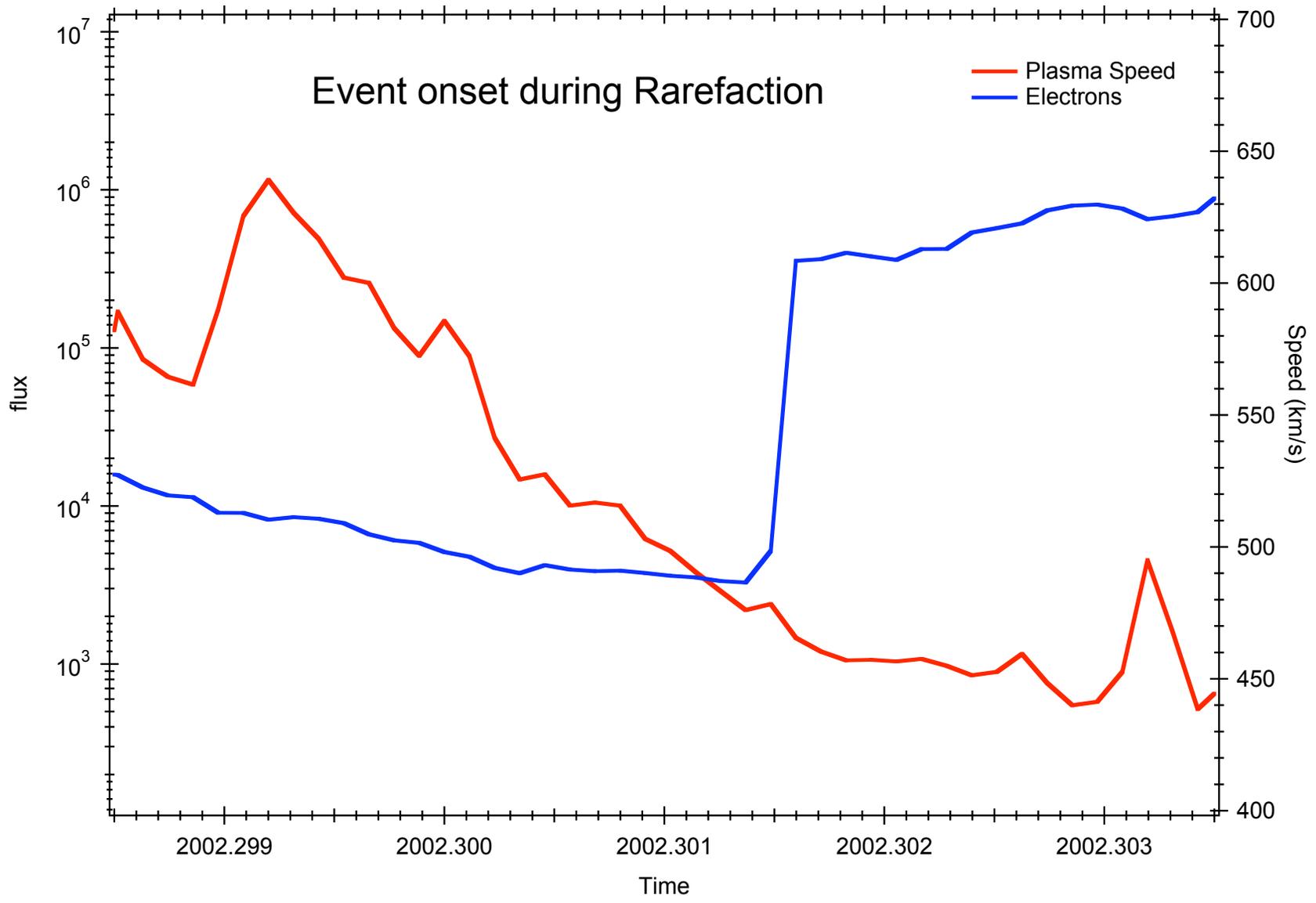


With this fast group of type-III bursts removed there is no significant correlation between the velocity of the leading edge of the type-III bursts and the delay observed between the near-relativistic electron injection and the type-III events observed at 14 MHz ($\sim 2R_s$)

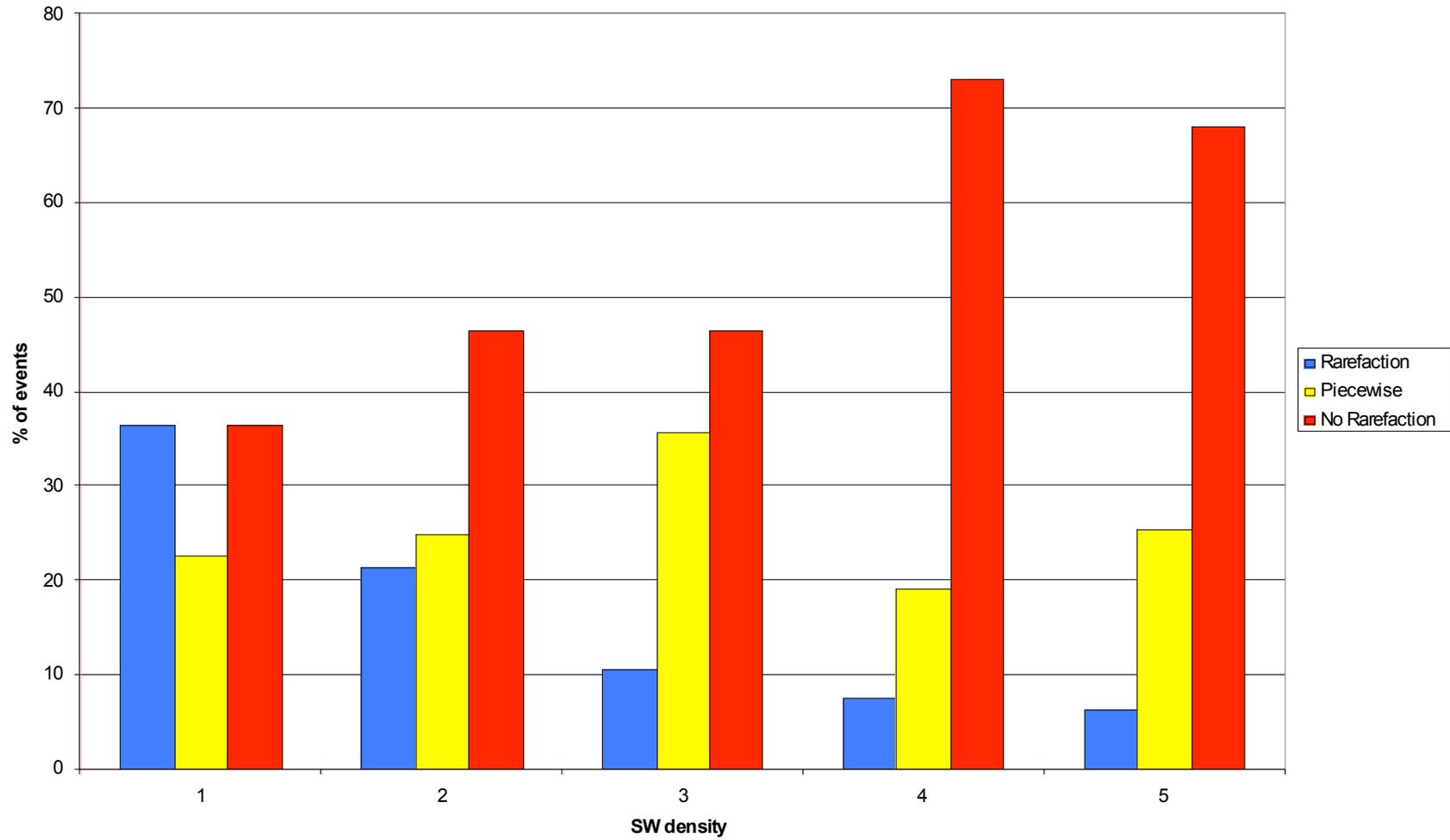




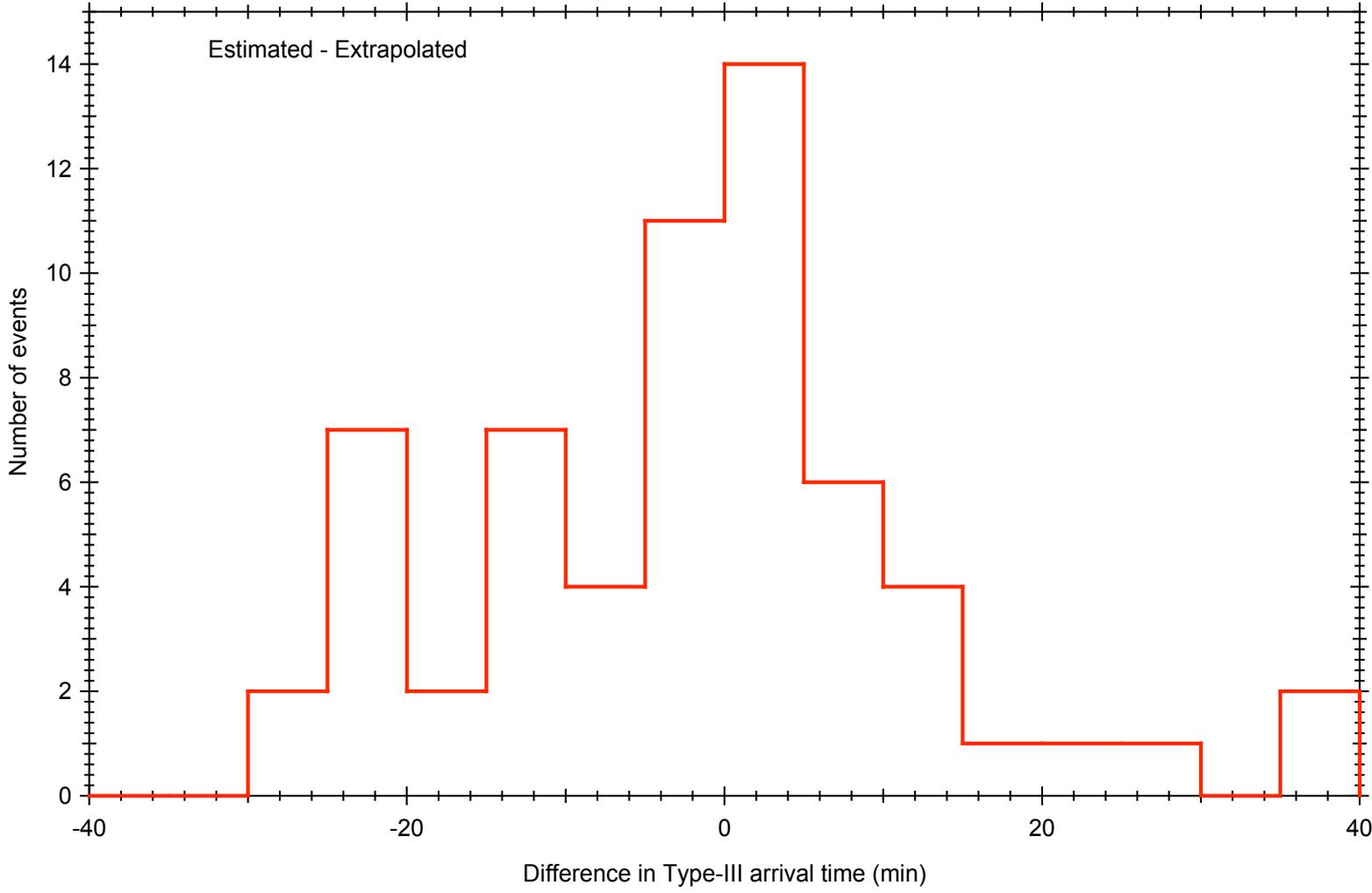




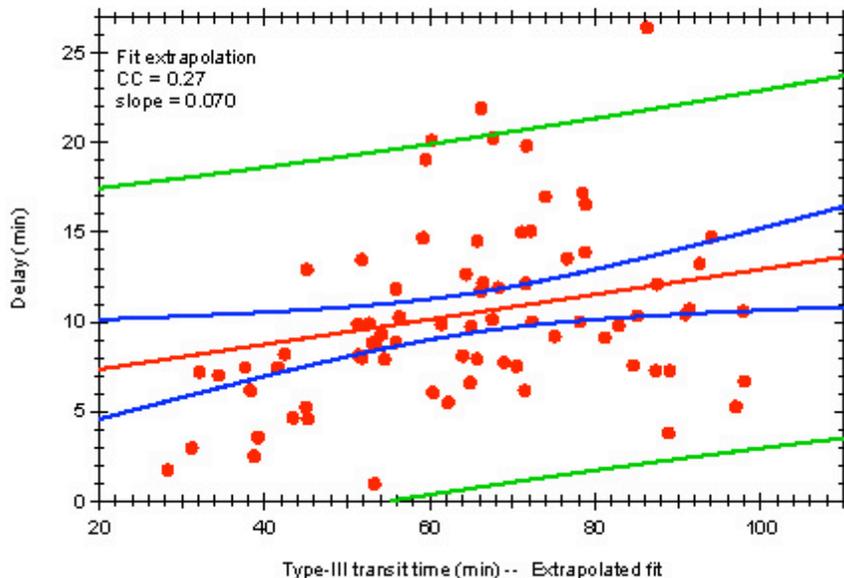
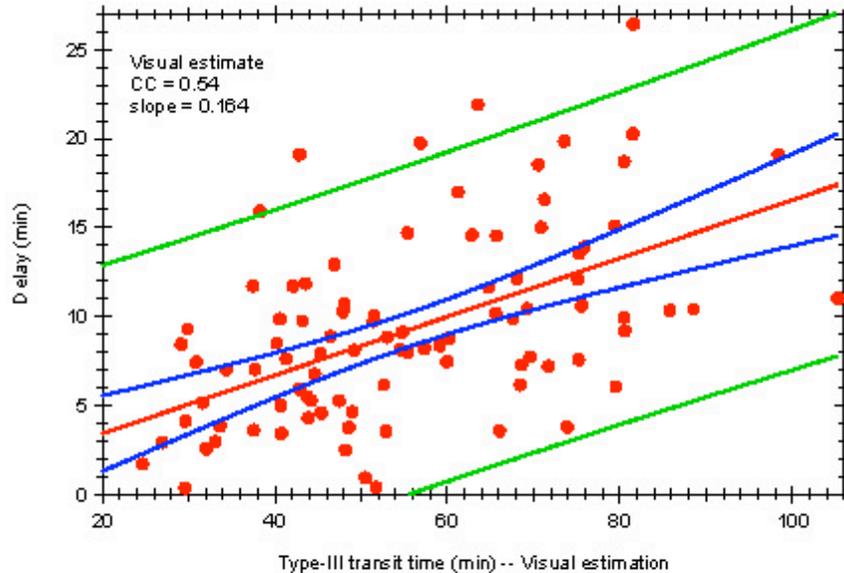
Solar Wind Structure in electron events



Comparing techniques for estimating the 1 AU arrival time for type-III bursts



Technique Comparison



When using the visual estimate technique to establish the type-III 1 AU onset time, then comparing the type-III “radio drift time” to the delay in the near-relativistic electron injection, I get very similar results to that published by *Cane 2003*. A reasonable correlation coefficient (0.54) and strong trend.

When using the fit extrapolation to establish the type-III 1 AU onset time, then the same comparison, I get a significantly reduced correlation coefficient (0.27) and much less of a trend.

Conclusions

- Frequency cuts through the WIND/WAVES data followed by linear fits of the data permit a clear identification of the leading edge and peak velocity of 100/171 (58%) of the type-III bursts in this study.
- The velocity of the leading edge exciter for 100 type-III bursts is $v = 0.17c \pm 0.10c$ (~14 keV) .
- The velocity of the peak intensity of 100 type-III bursts is $v = 0.07c \pm 0.02c$ (~4 keV).
- The trailing edge of the type-III bursts is broadly distributed around $v = 0.001c$ (we currently make no specific interpretation of this observation).
- There are Langmuir waves observed at 1 AU for 65% of these events. These Langmuir waves are associated with the type-III burst arriving at 1 AU, not with the arrival of the near-relativistic electrons.
- A linear fit through the frequency cuts matches the data well for ~70% of the events implying that the type-III burst propagates at a constant velocity through at least the first 0.5 AU.
- For 30% of the events a linear fit to the frequency cuts does not match the data well. For these events we used the linear fit from the higher frequencies to determine the speed and arrival time of the type-III bursts.

Conclusions

- The temperature and speed of the plasma at the time of the near-relativistic event onset does not differ statistically from the temperature and speed observed through the mission.
- Although near-relativistic electron events are observed at all plasma densities there is a clear excess observed during low density times as first reported by *Cane 2003*.
- We attribute this “low density” observation directly to the fact that a significant number of events observed in the low density plasma were also observed within a solar wind rarefaction region. These regions are well known to have a lower density plasma. These regions also tend to contain a quiet magnetic field that can be cleanly mapped back to the Sun.
- We used two different techniques to estimate when the type-III burst reaches 1 AU, the visual inspection of the WAVES spectrograms and the extrapolated fit. A comparison of these two methods yields a histogram peaked at zero but skewed towards the extrapolated fit coming later than the visual inspection. The histogram has a FWHM of ~40 minutes. These two techniques yield vastly different results when compared to the injection of the near-relativistic electrons.
- When we used the visual inspection technique we get results that are nearly identical to the results of *Cane 2003*, when we use the extrapolation technique we get a very poor correlation.
- There **are** a few “fast” type-III bursts that are associated with “small-delay” electron events.
- For the vast majority of the type-III bursts there is no association between the velocity of the leading edge and the observed delay of the near-relativistic electrons.