A Tour of Lightning With HAMMA

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THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

The HAMMA Team:
Hugh Christian, Mike Stewart, Jeff Burchfield, Scott Podgorny, David Corredor,
Veronica Franklin, John Hall, and Evgeny Kuznetsov

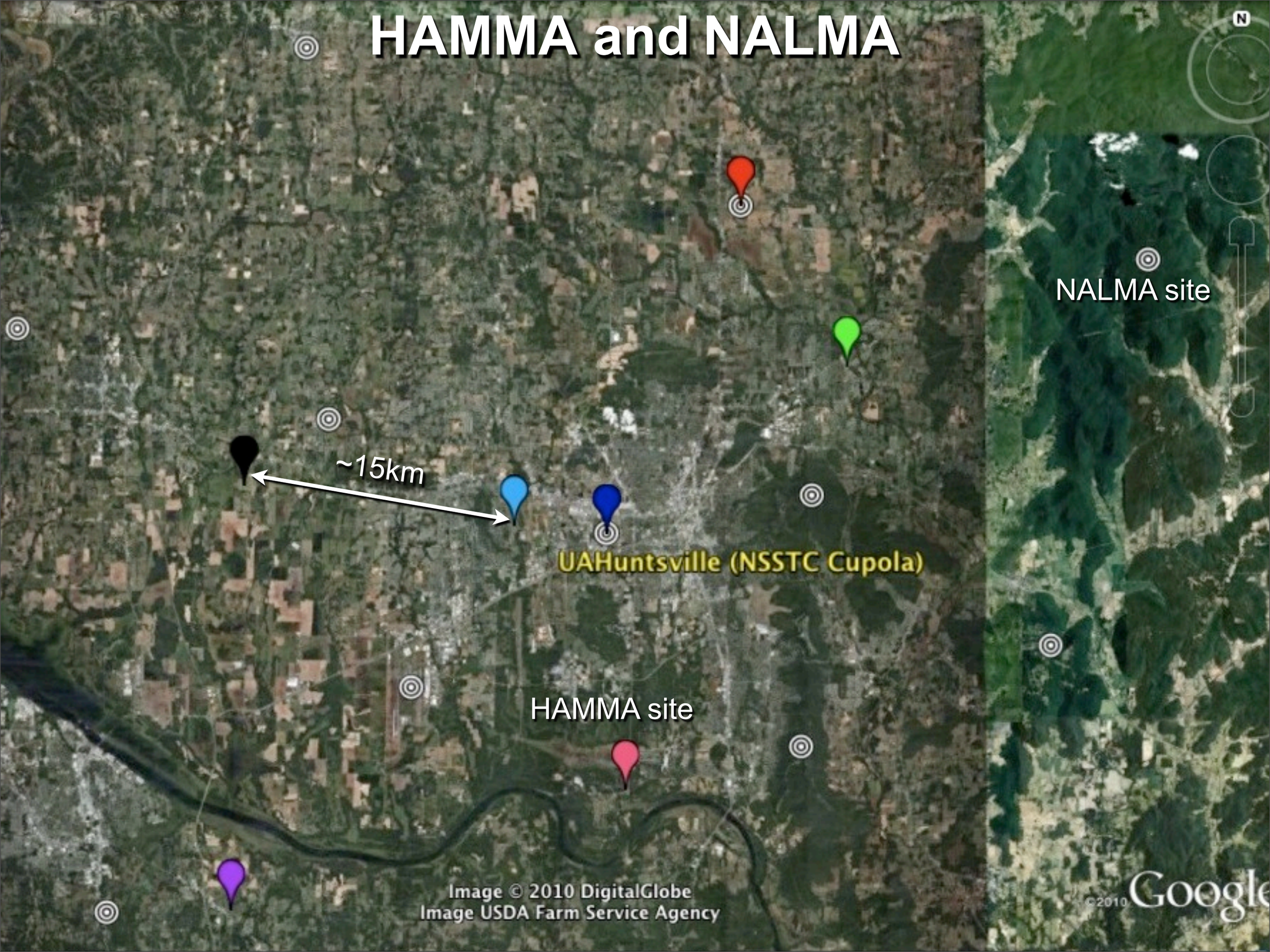
Special thanks to:
Monte Bateman and Dennis Buechler

Dan Cecil, Henry Everitt and Martin Heimbeck, Chris and Elise Schultz,
Brandon and Anne Marie Strickland, and Winfred Thomas Agricultural Research Station

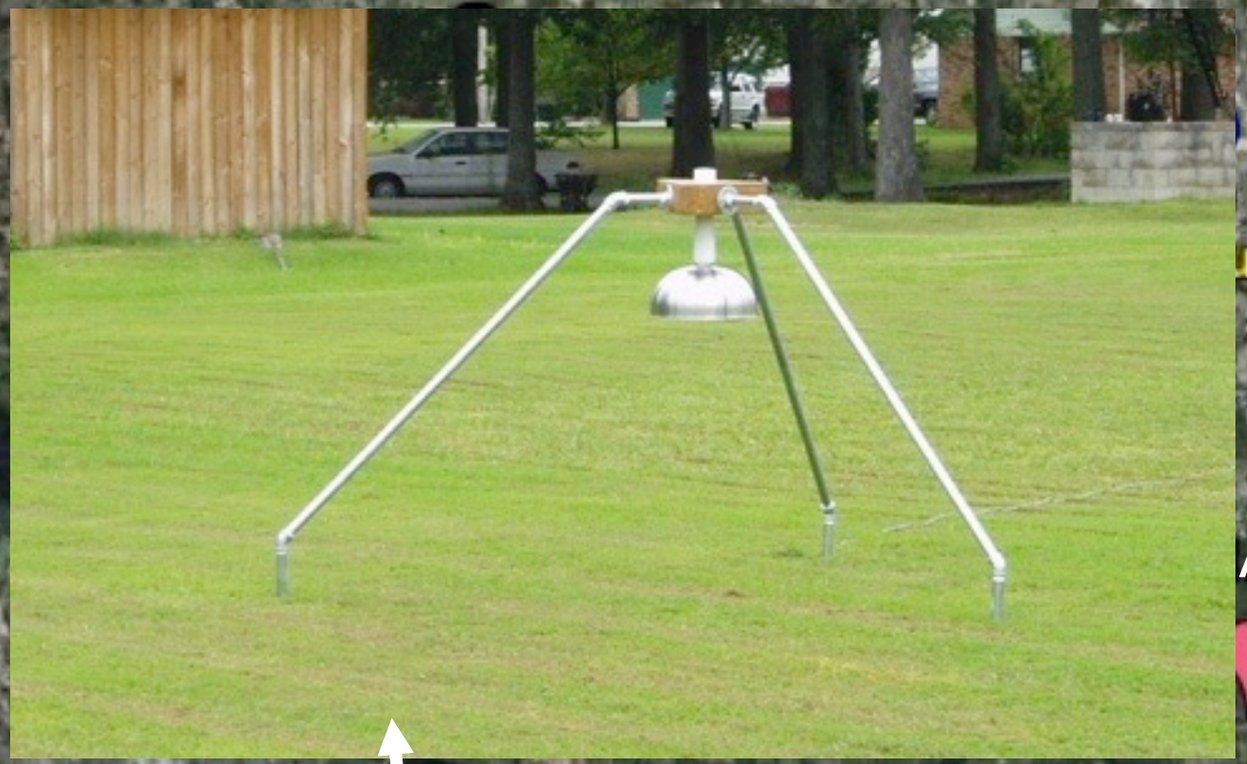
Fundamental question for *scientific* validation:

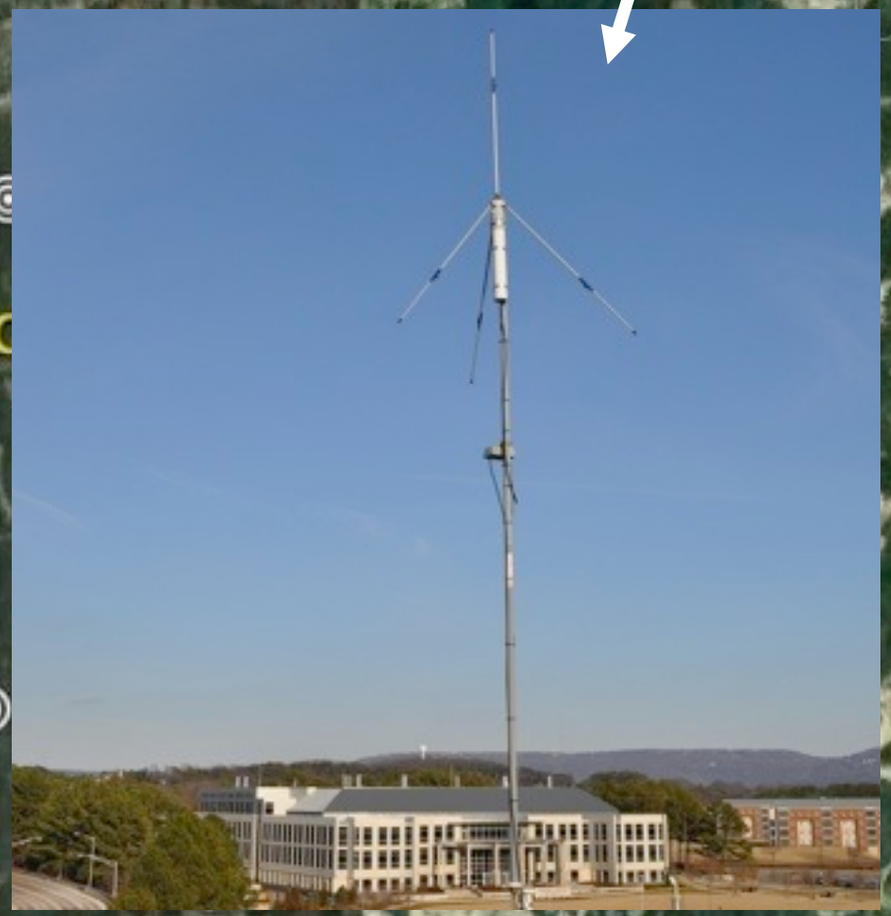
What is the best way from the ground to characterize what LIS “sees?”

HAMMA and NALMA



HAMMA and NALMA





NALMA site

A site

Image © 2010 DigitalGlobe
Image USDA Farm Service Agency

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HAMMA

Huntsville Alabama Marx Meter Array

NALMA

North Alabama Lightning Mapping Array

HAMMA

Huntsville Alabama Marx Meter Array

Wideband ~1Hz-500kHz
Sample Rate: 1MHz

NALMA

North Alabama Lightning Mapping Array

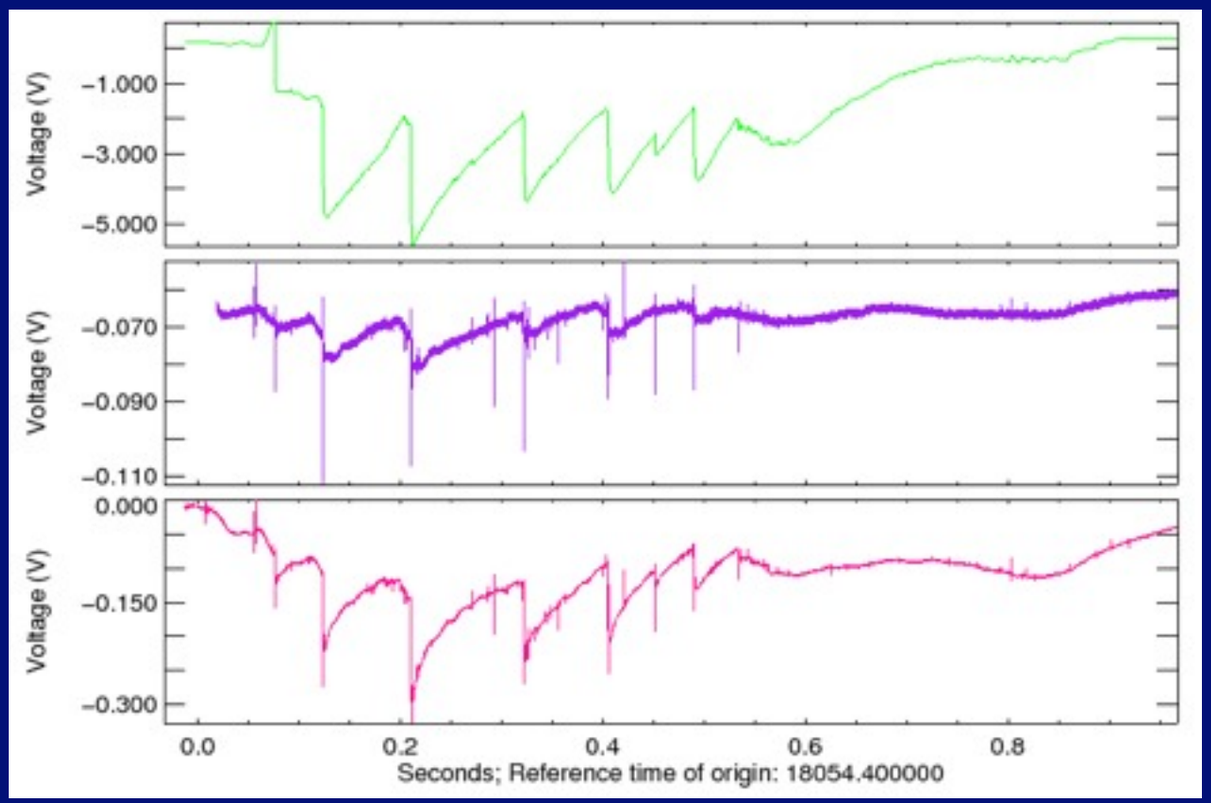
Narrowband VHF ~80 MHz
Sample Rate: 20MHz

HAMMA

Huntsville Alabama Marx Meter Array

Wideband ~1Hz-500kHz
Sample Rate: 1MHz

Can identify polarity/type of discharge

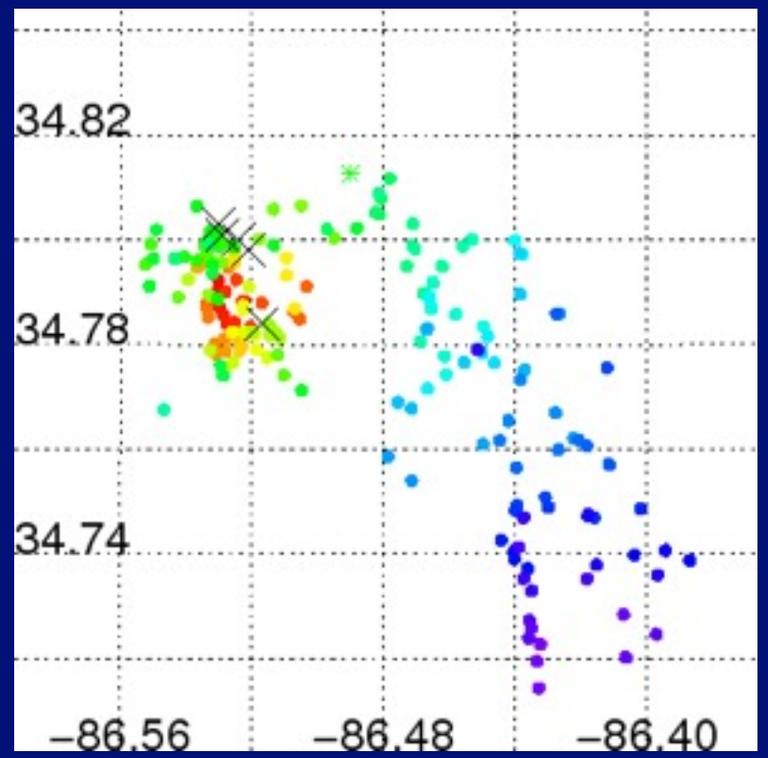


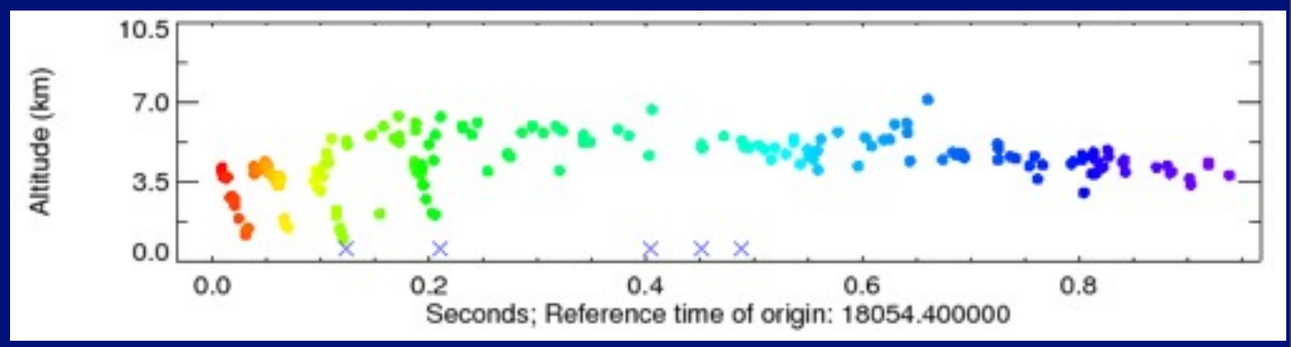
NALMA

North Alabama Lightning Mapping Array

Narrowband VHF ~80 MHz
Sample Rate: 20MHz

Provides accurate “maps” of lightning





HAMMA

Huntsville Alabama Marx Meter Array

Wideband ~1Hz-500kHz
Sample Rate: 1MHz

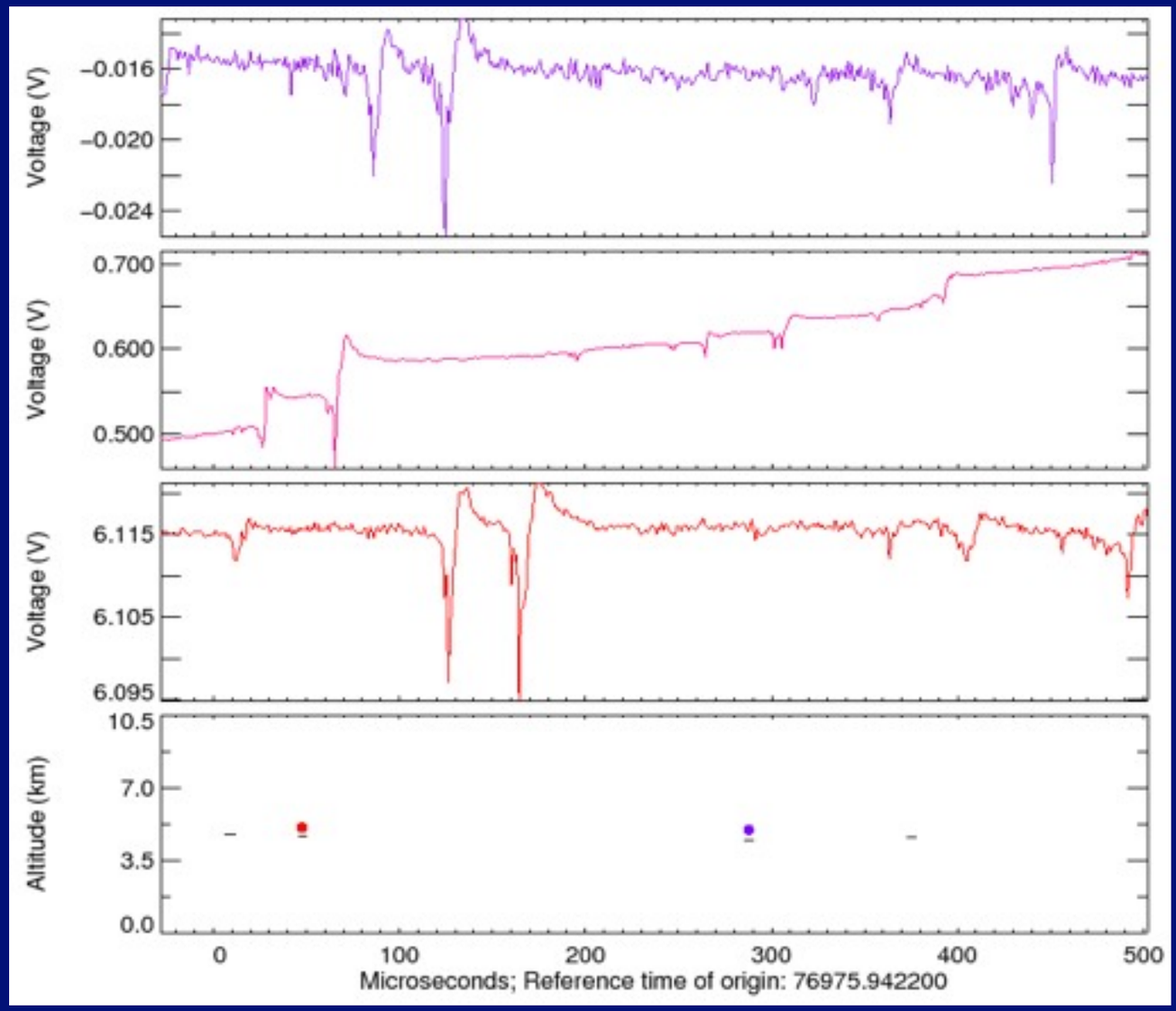
Can identify polarity/type of discharge

NALMA

North Alabama Lightning Mapping Array

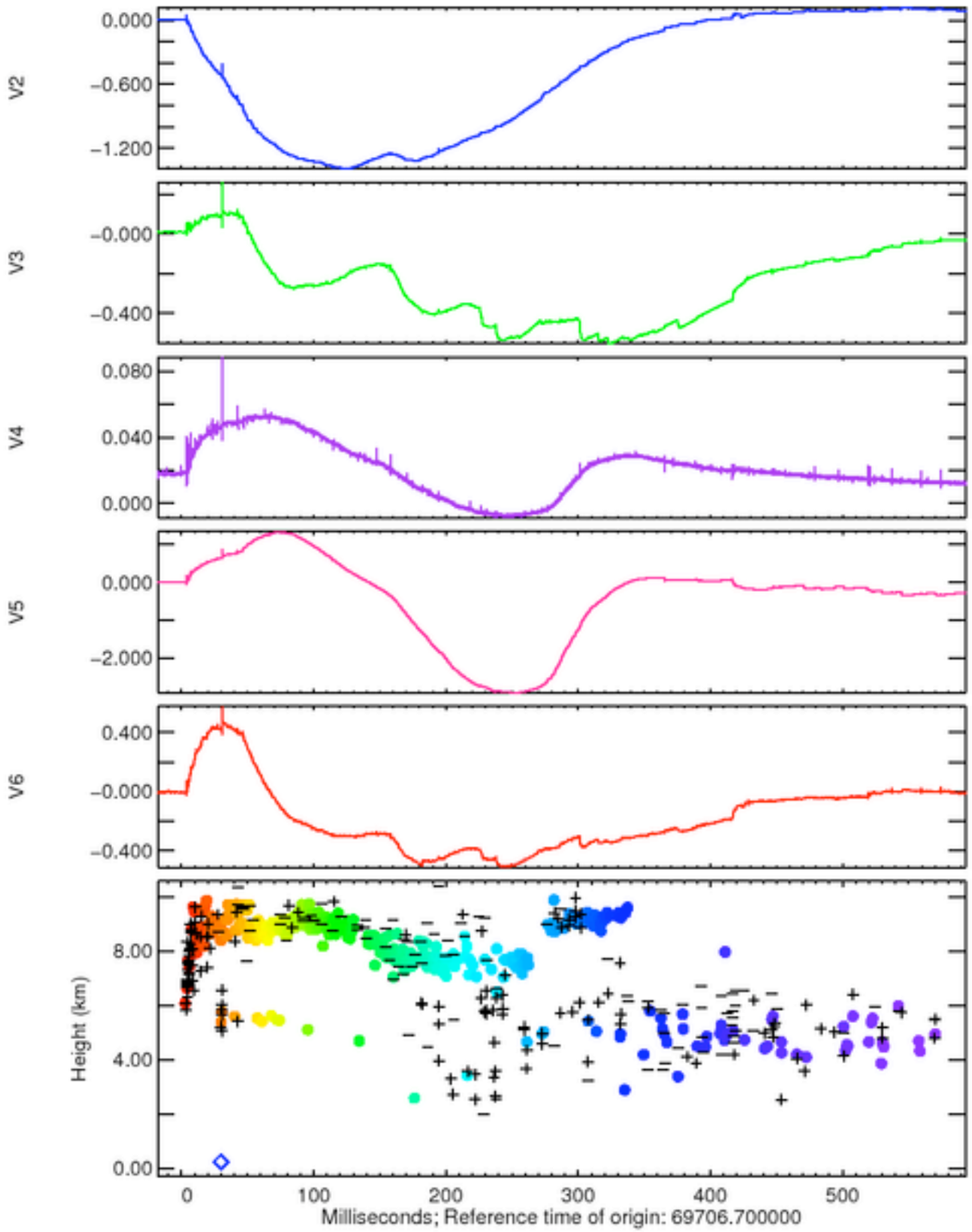
Narrowband VHF ~80 MHz
Sample Rate: 20MHz

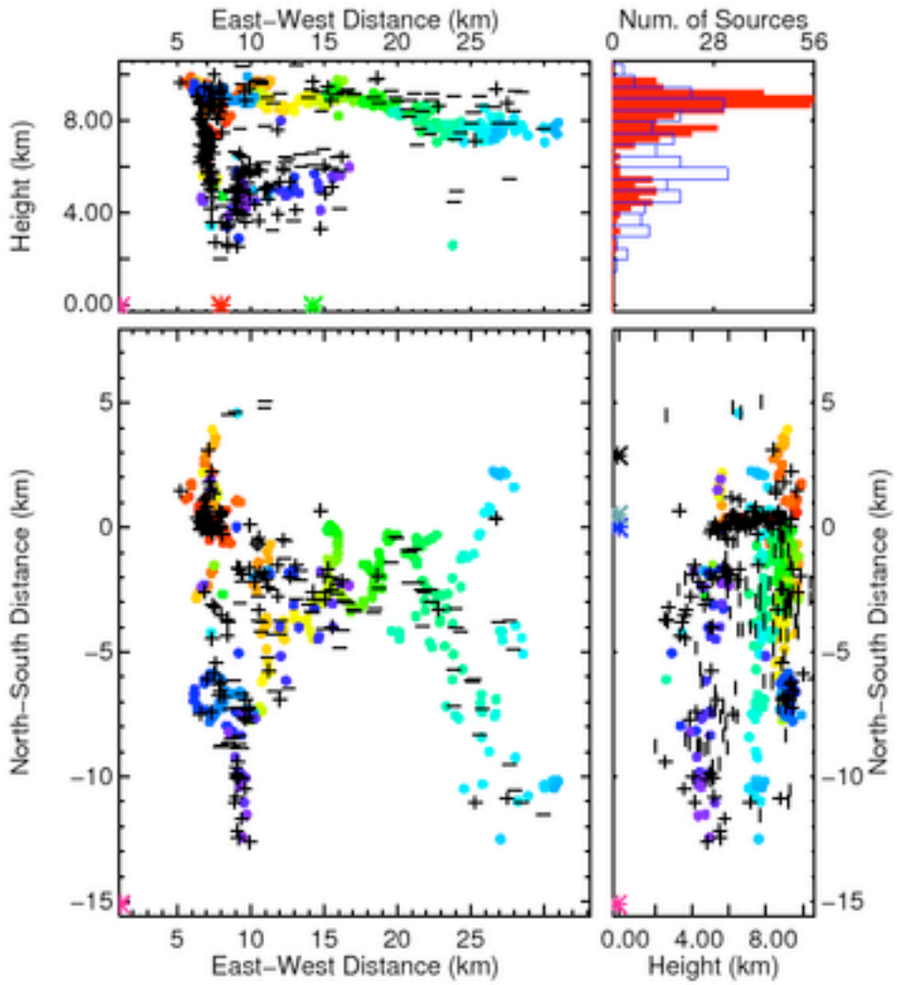
Provides accurate “maps” of lightning



Both arrays can locate sources via time-of-arrival; HAMMA can also provide energetic information

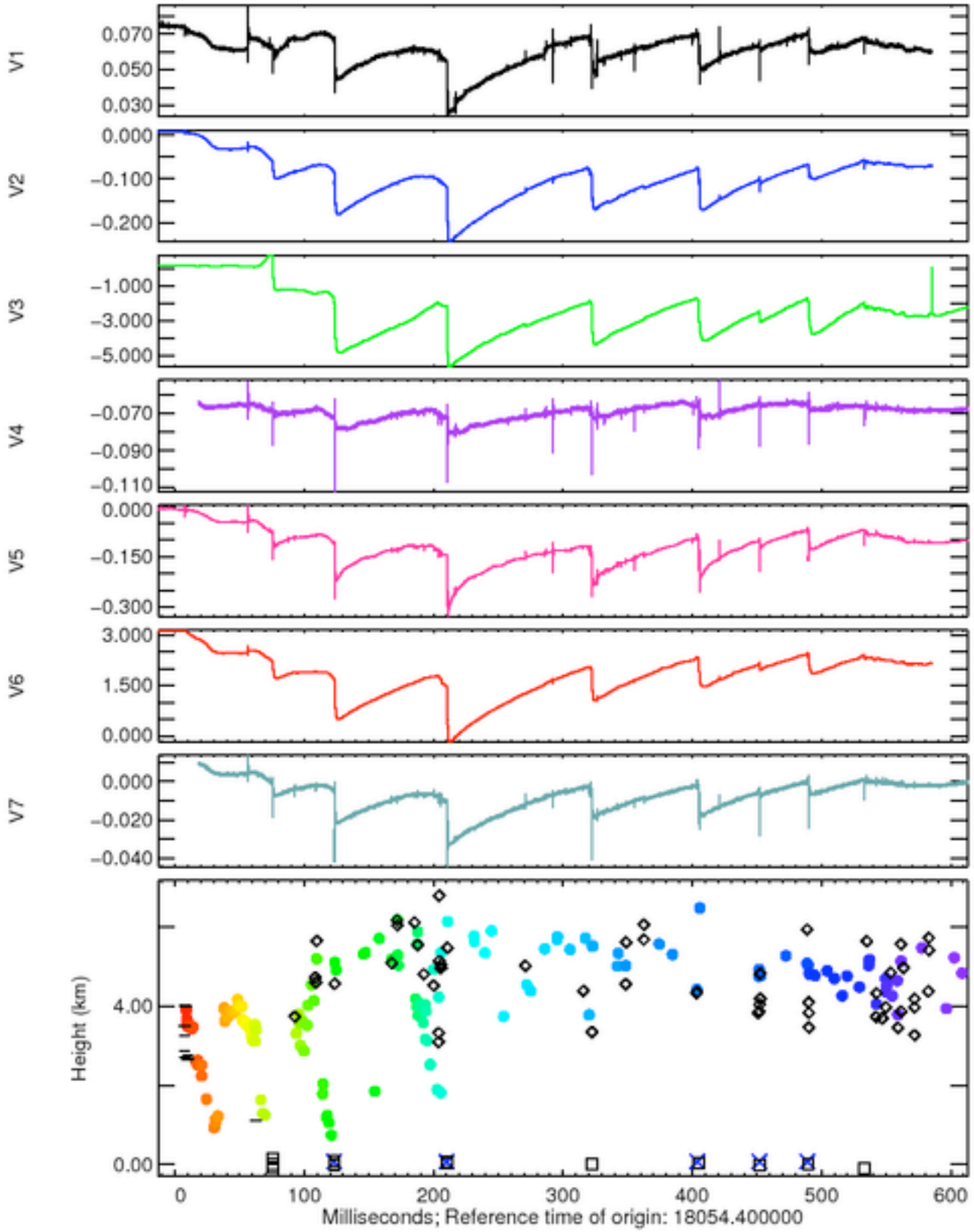
2010/06/25 19:21:46

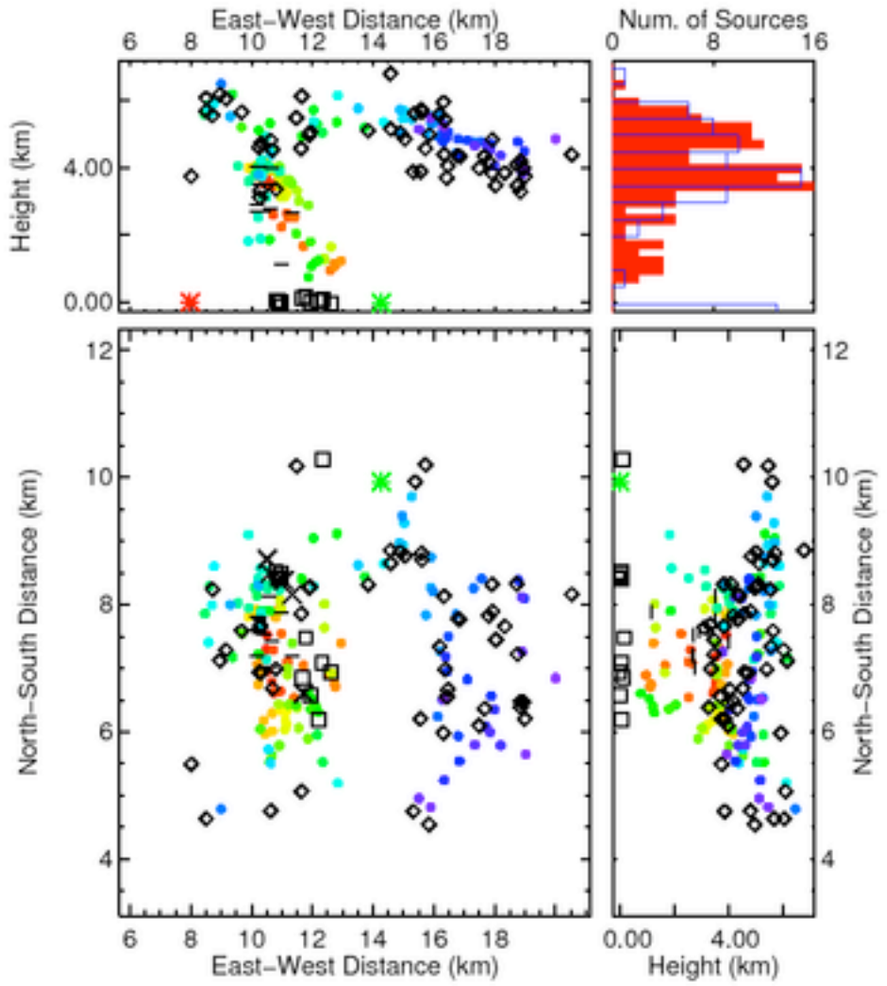




Base time:	69706.682360
Stop time:	69707.292752
Time Elapsed:	0.610392

2010/10/25 05:00:54

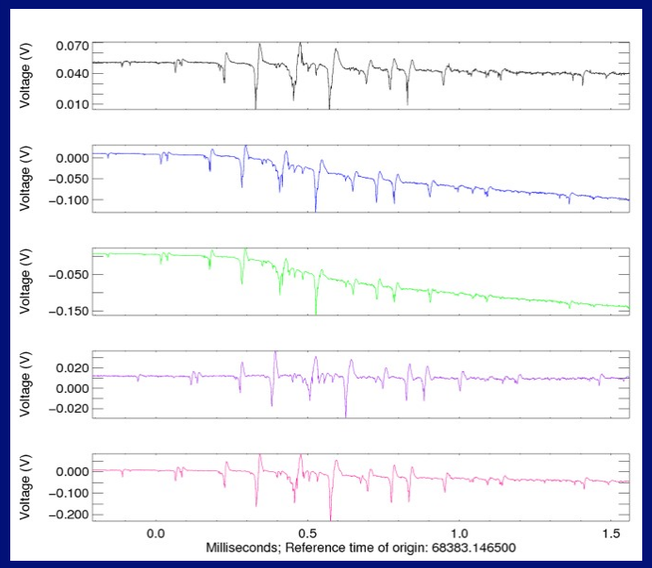


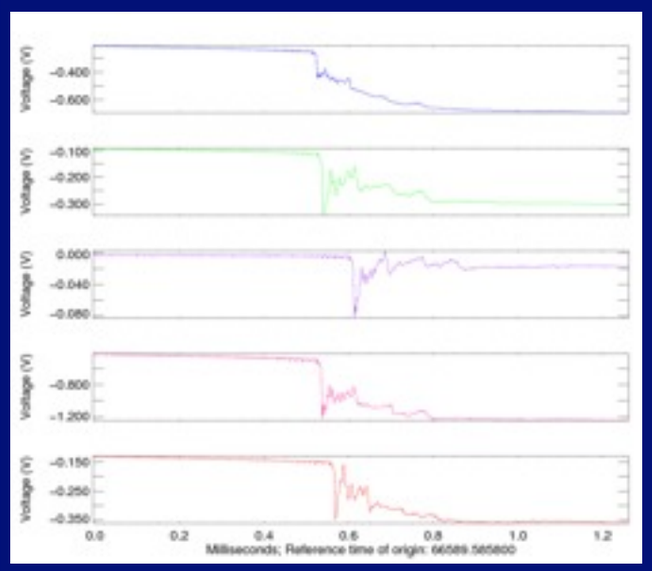


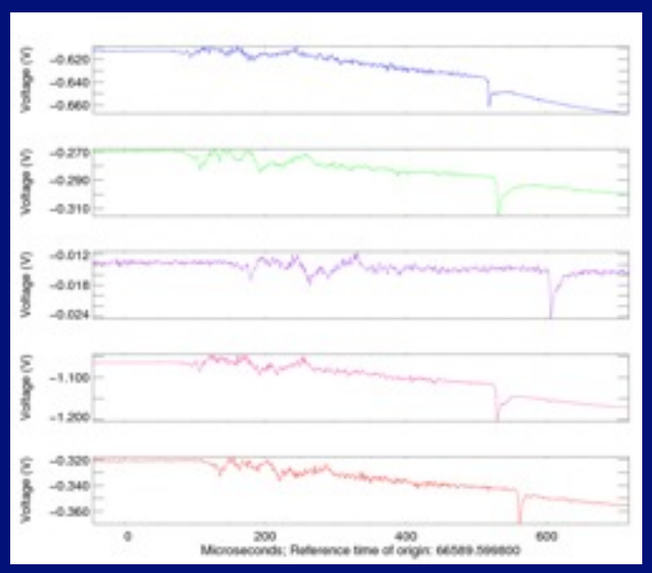
Base time: 18054.387327

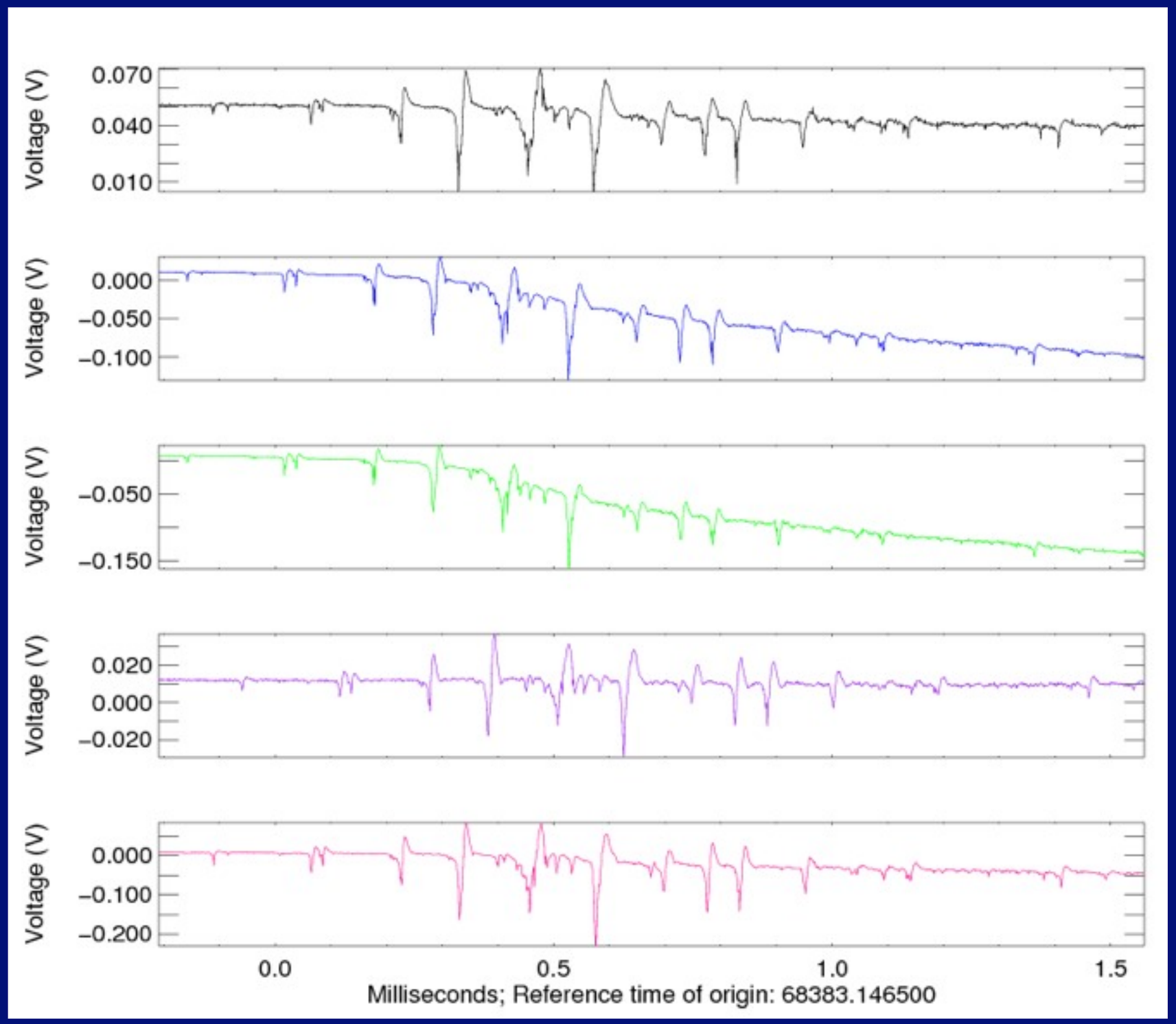
Stop time: 18055.012631

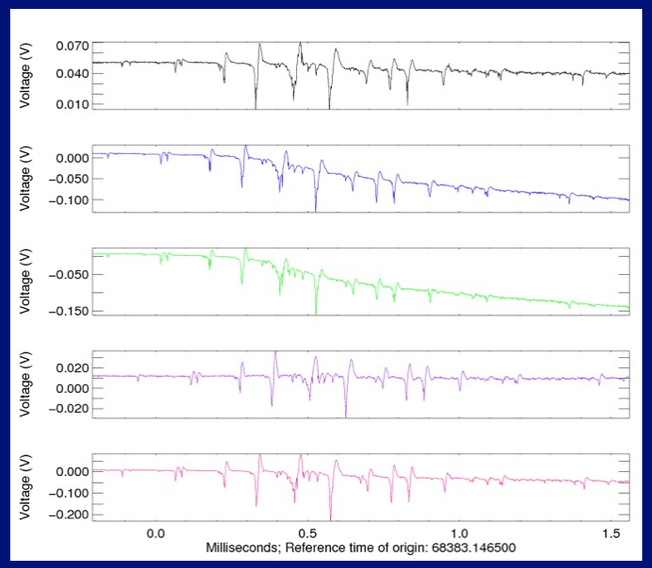
Time Elapsed: 0.625304

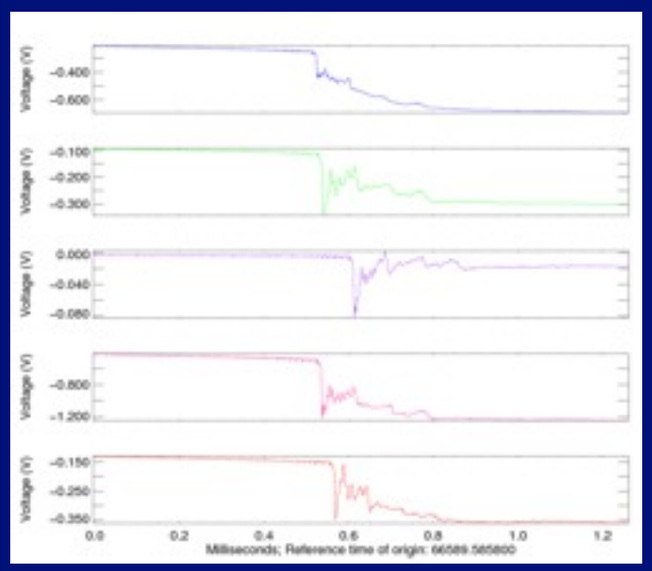

Voltage (V)
0.070
0.040
0.010
0.000
−0.050
−0.100
−0.050
−0.150
0.020
0.000
−0.020
0.000
−0.100
−0.200
0.0
0.5
1.0
1.5
Milliseconds; Reference time of origin: 68383.146500

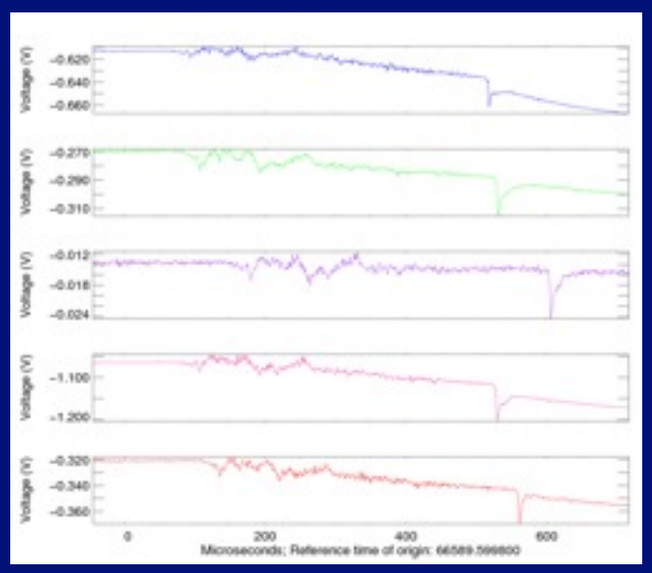

Voltage (V)
Milliseconds; Reference time of origin: 66589.565800

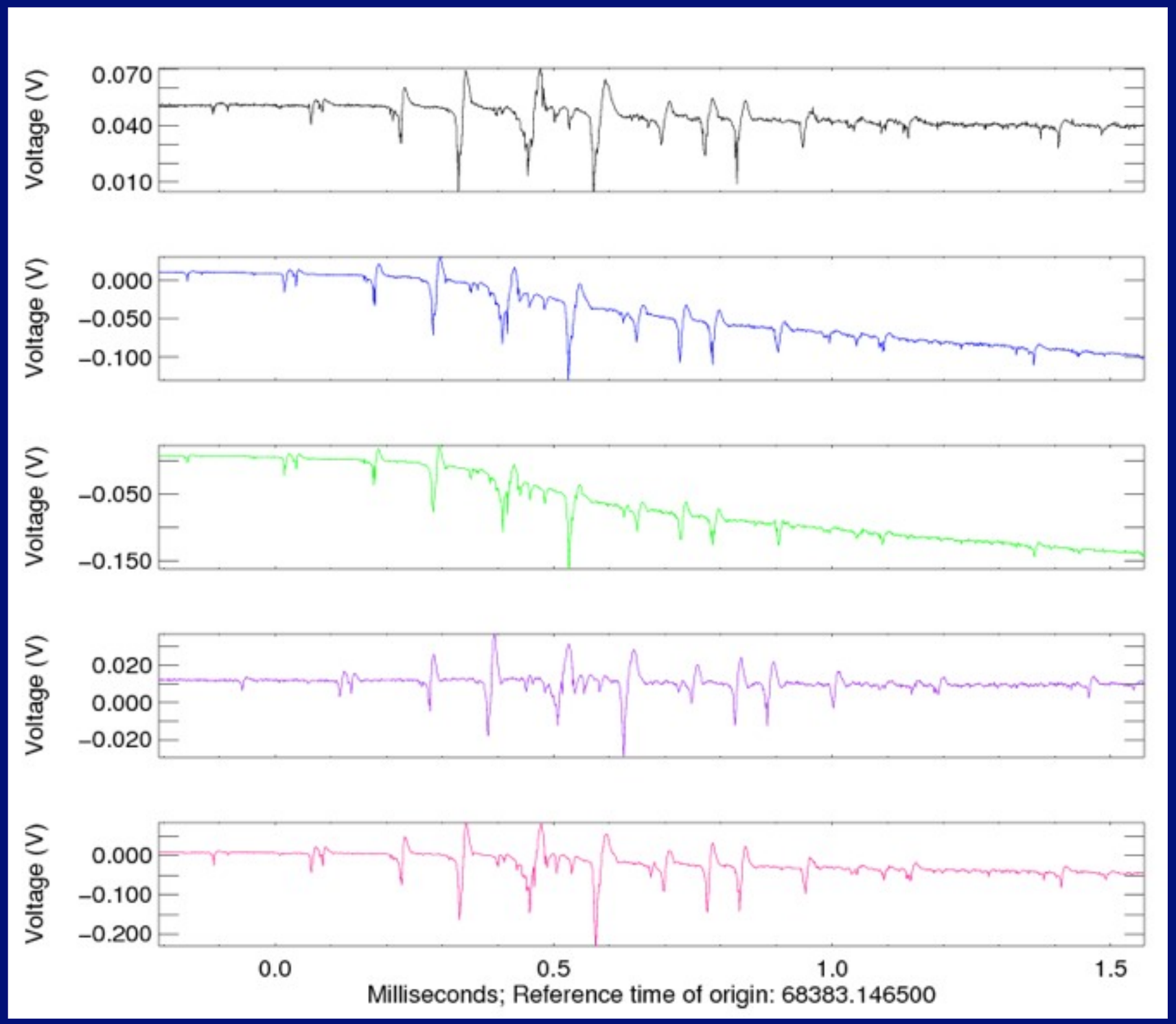

Voltage (V)
Microseconds; Reference time of origin: 66589.599800


Voltage (V)
0.070
0.040
0.010
0.000
−0.050
−0.100
−0.050
−0.150
0.020
0.000
−0.020
0.000
−0.100
−0.200
0.0
0.5
1.0
1.5
Milliseconds; Reference time of origin: 68383.146500

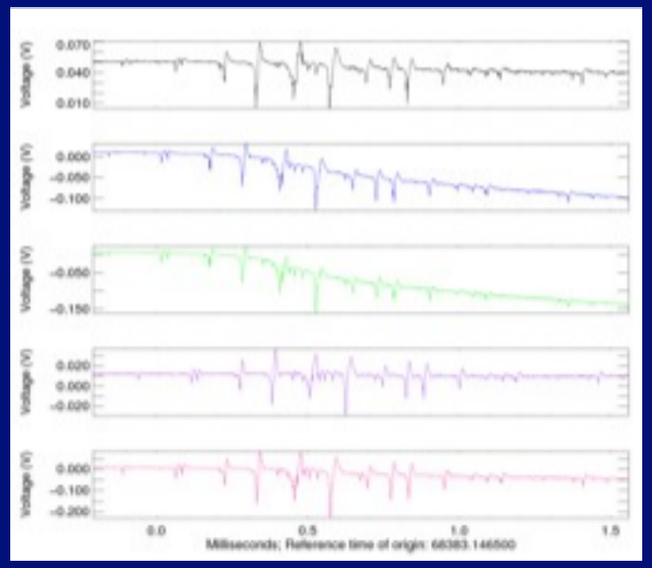


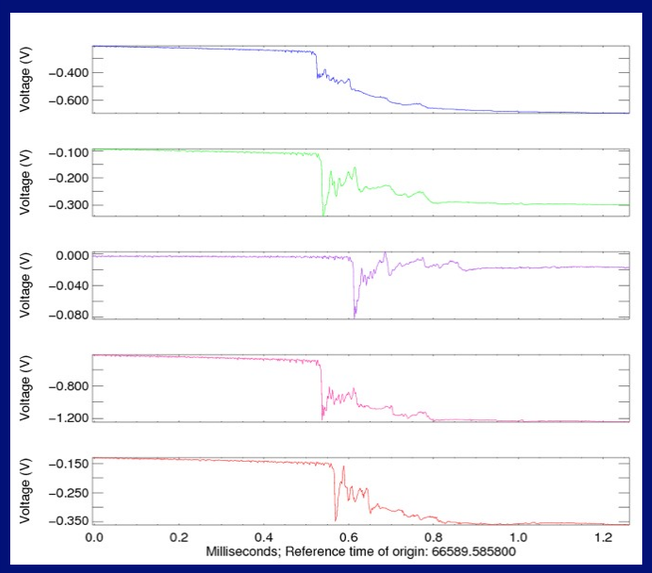


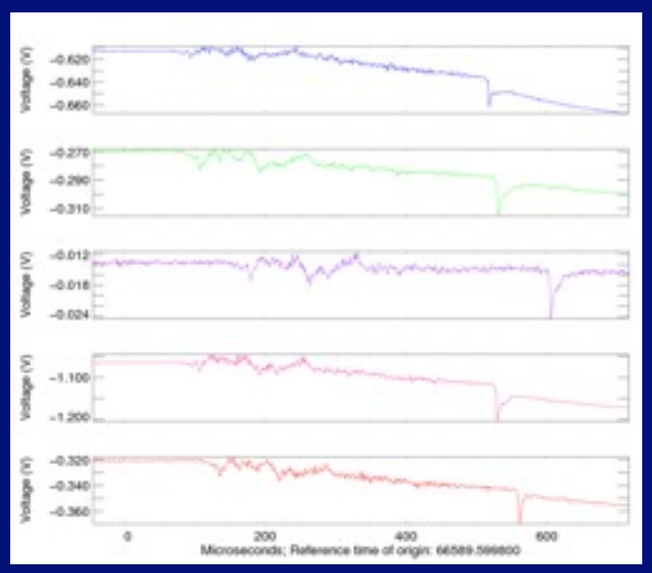


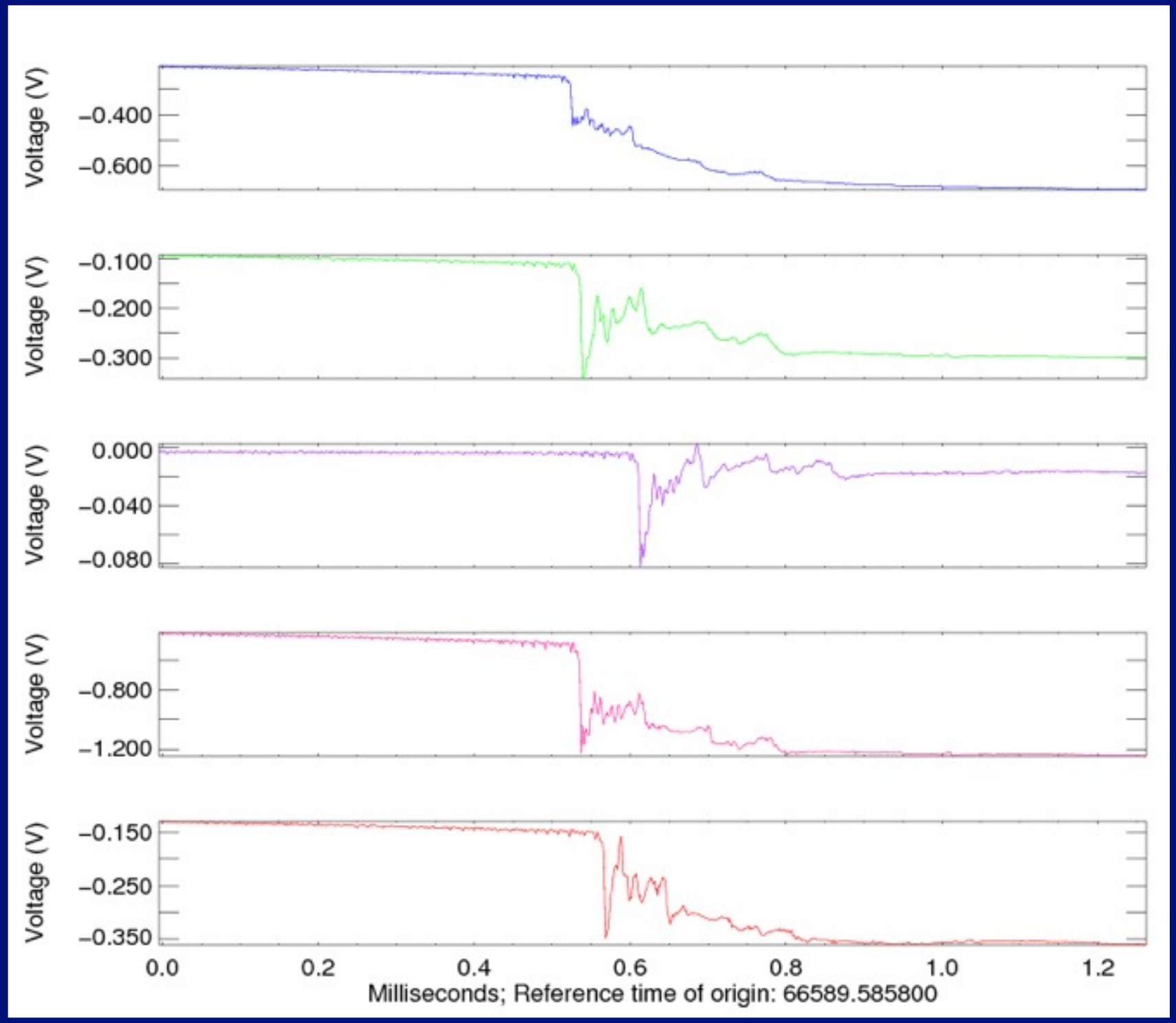


preliminary breakdown pulse train

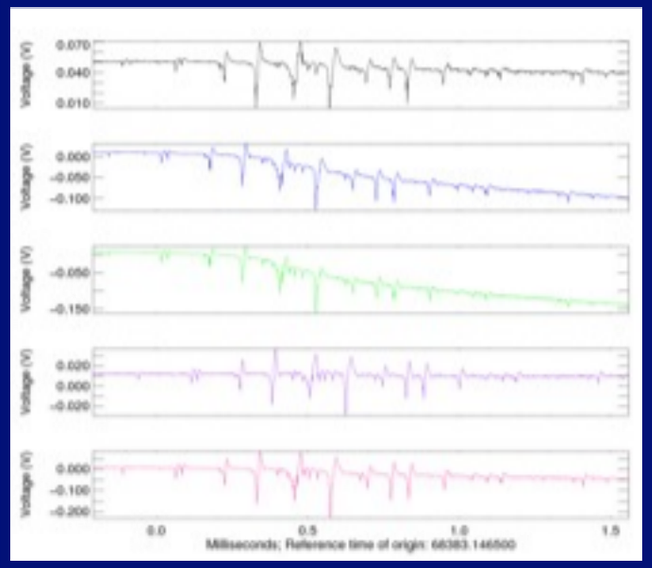


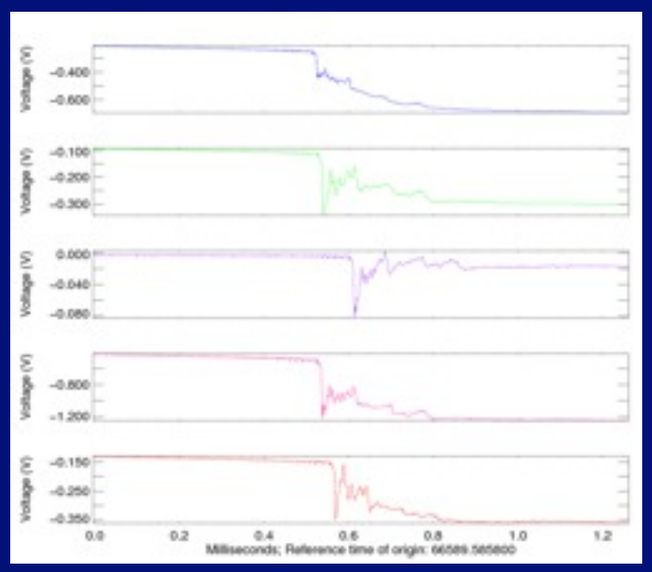


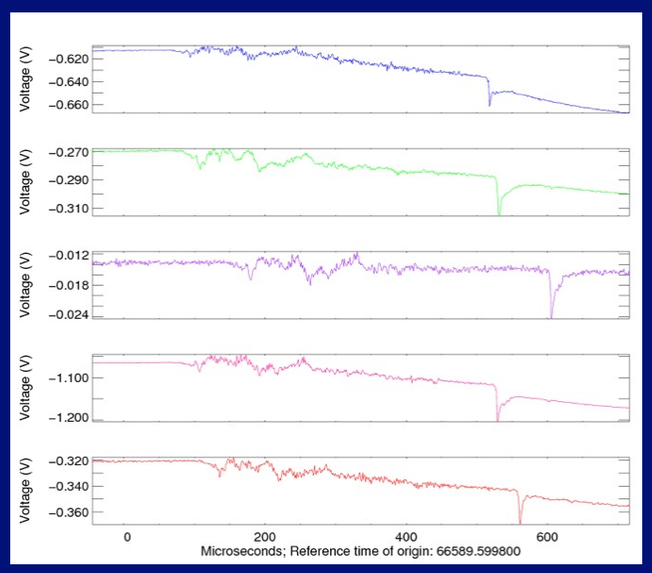


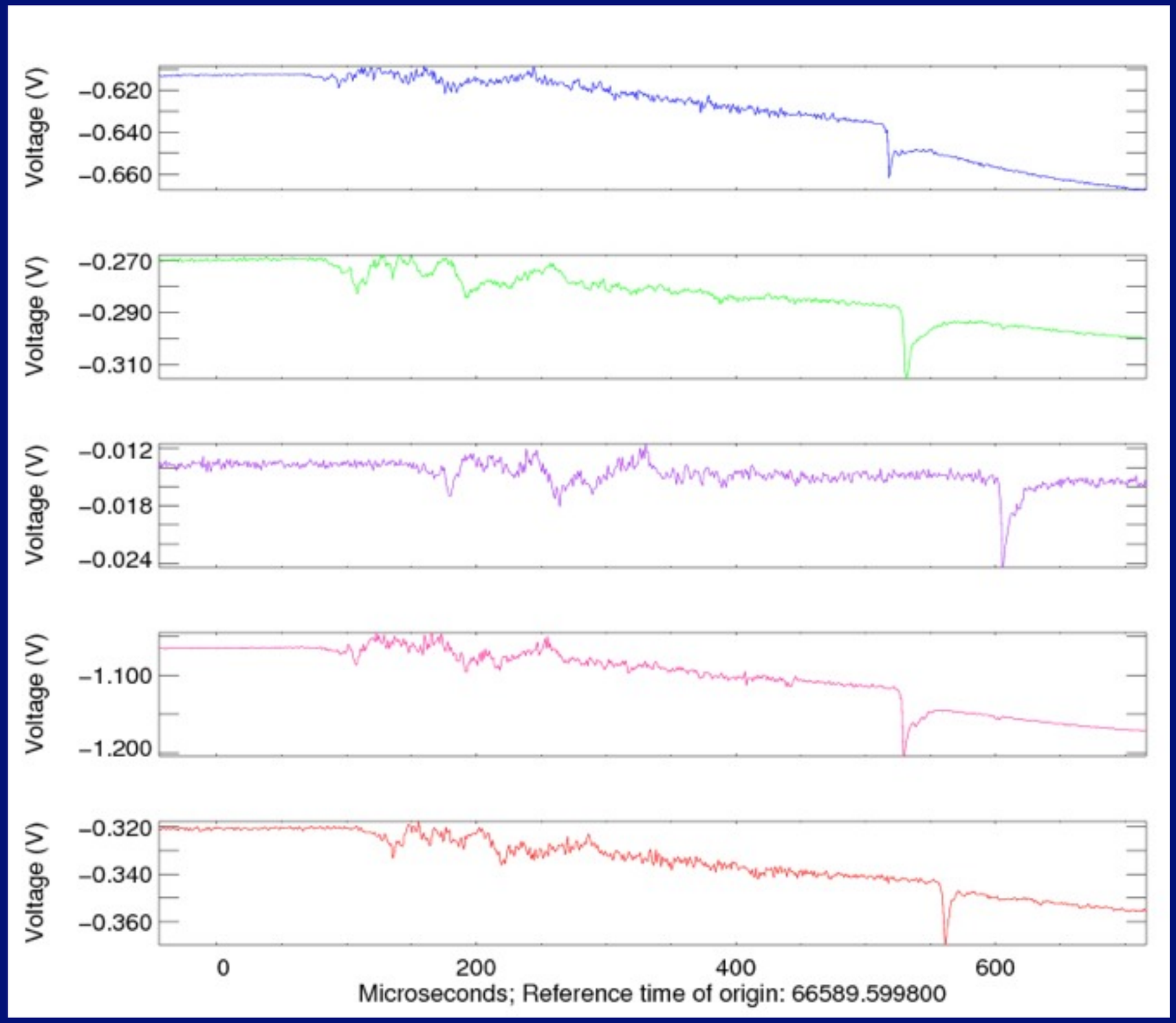


early return stroke

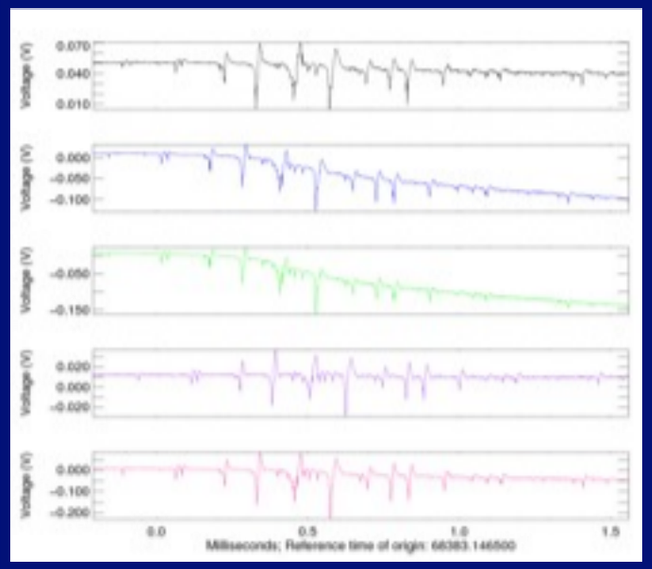


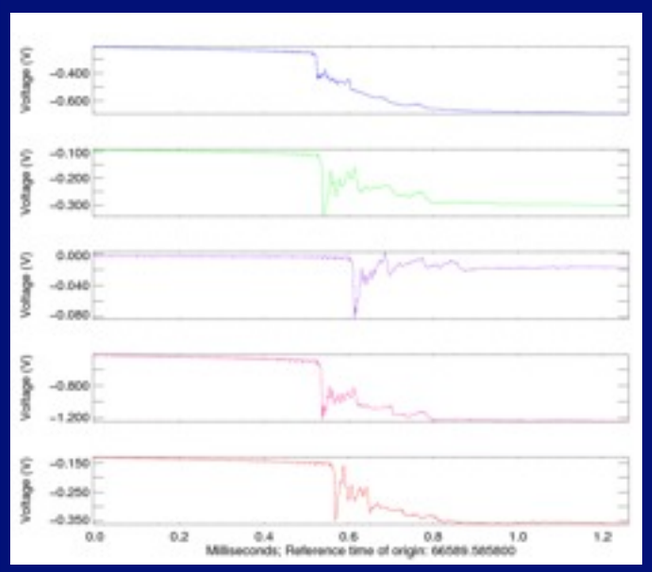


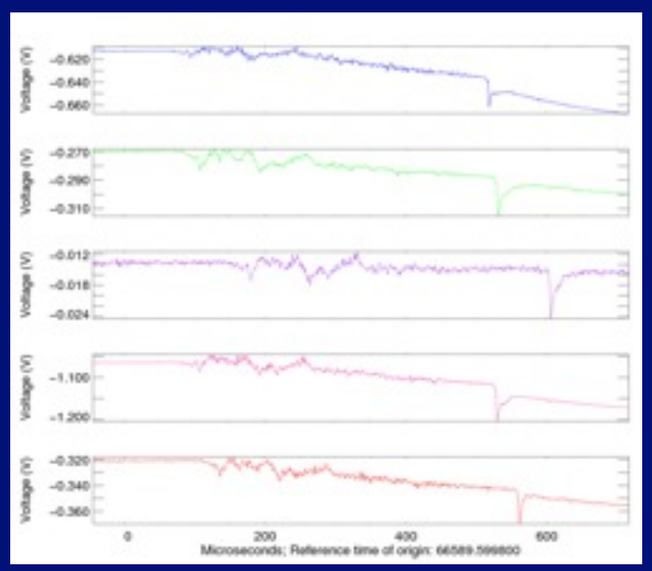




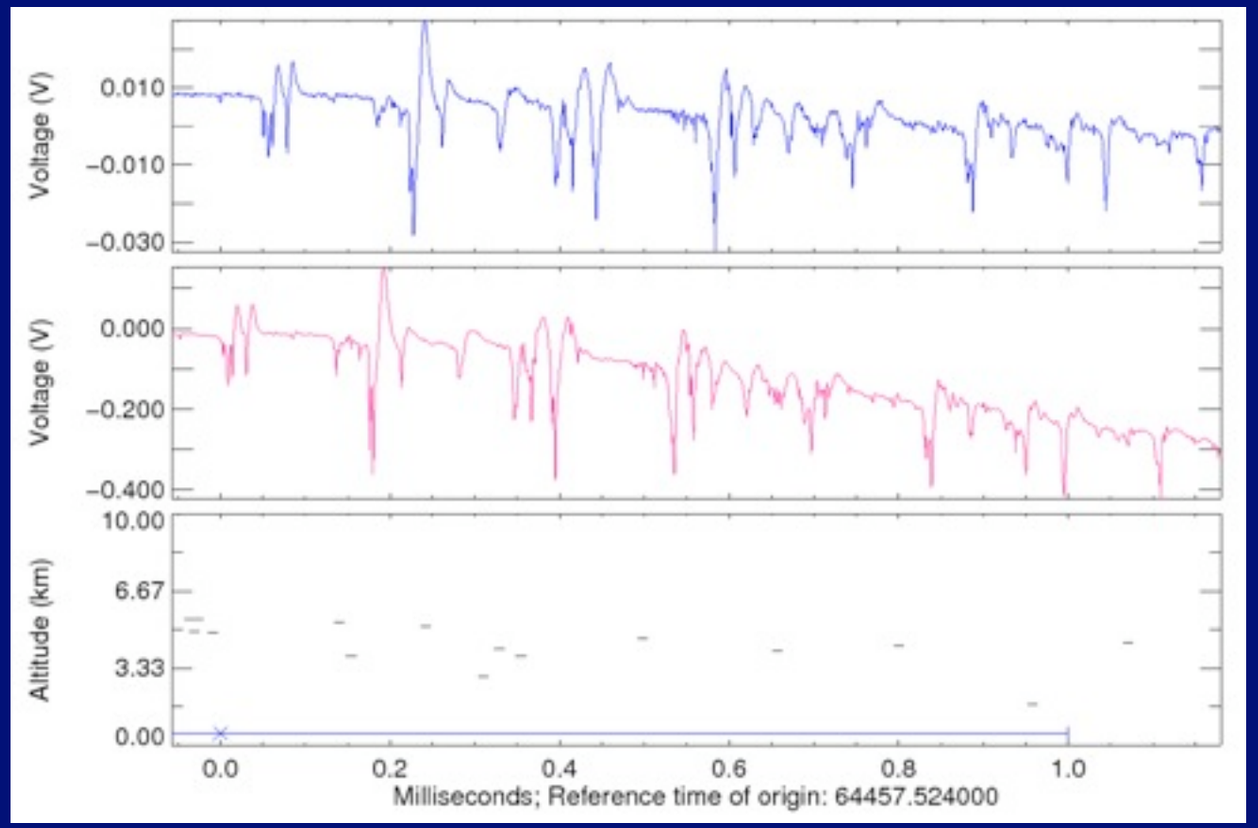
subsequent return stroke


Voltage (V)
0.070
0.040
0.010
Voltage (V)
0.000
-0.050
-0.100
Voltage (V)
-0.050
-0.150
Voltage (V)
0.020
0.000
-0.020
Voltage (V)
0.000
-0.100
-0.200
0.0
0.5
1.0
1.5
Milliseconds; Reference time of origin: 66383.146500

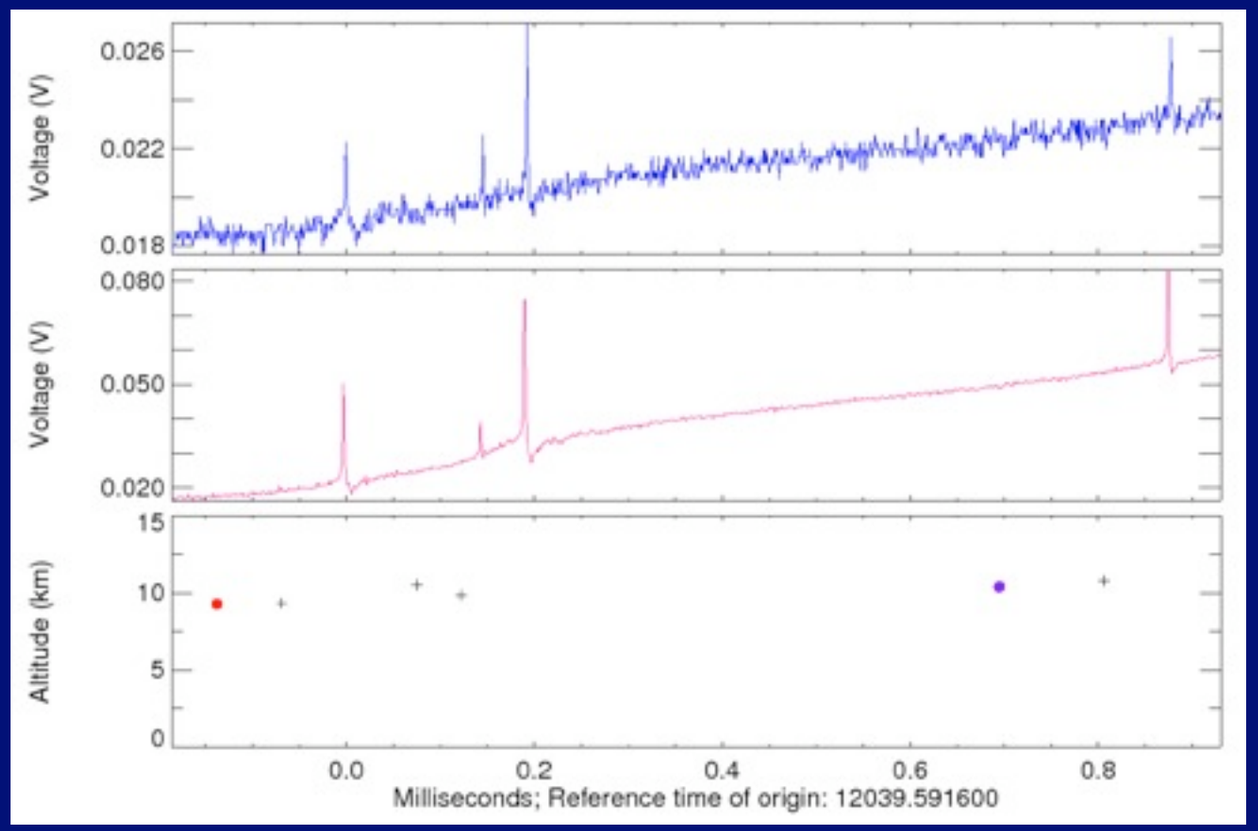

Voltage (V)
-0.400
-0.600
Voltage (V)
-0.100
-0.200
-0.300
Voltage (V)
0.000
-0.040
-0.080
Voltage (V)
-0.600
-1.200
Voltage (V)
-0.150
-0.250
-0.350
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Milliseconds; Reference time of origin: 66589.565800


Voltage (V)
-0.620
-0.640
-0.660
Voltage (V)
-0.270
-0.290
-0.310
Voltage (V)
-0.012
-0.018
-0.024
Voltage (V)
-1.100
-1.200
Voltage (V)
-0.320
-0.340
-0.360
0
200
400
600
Microseconds; Reference time of origin: 66589.599800

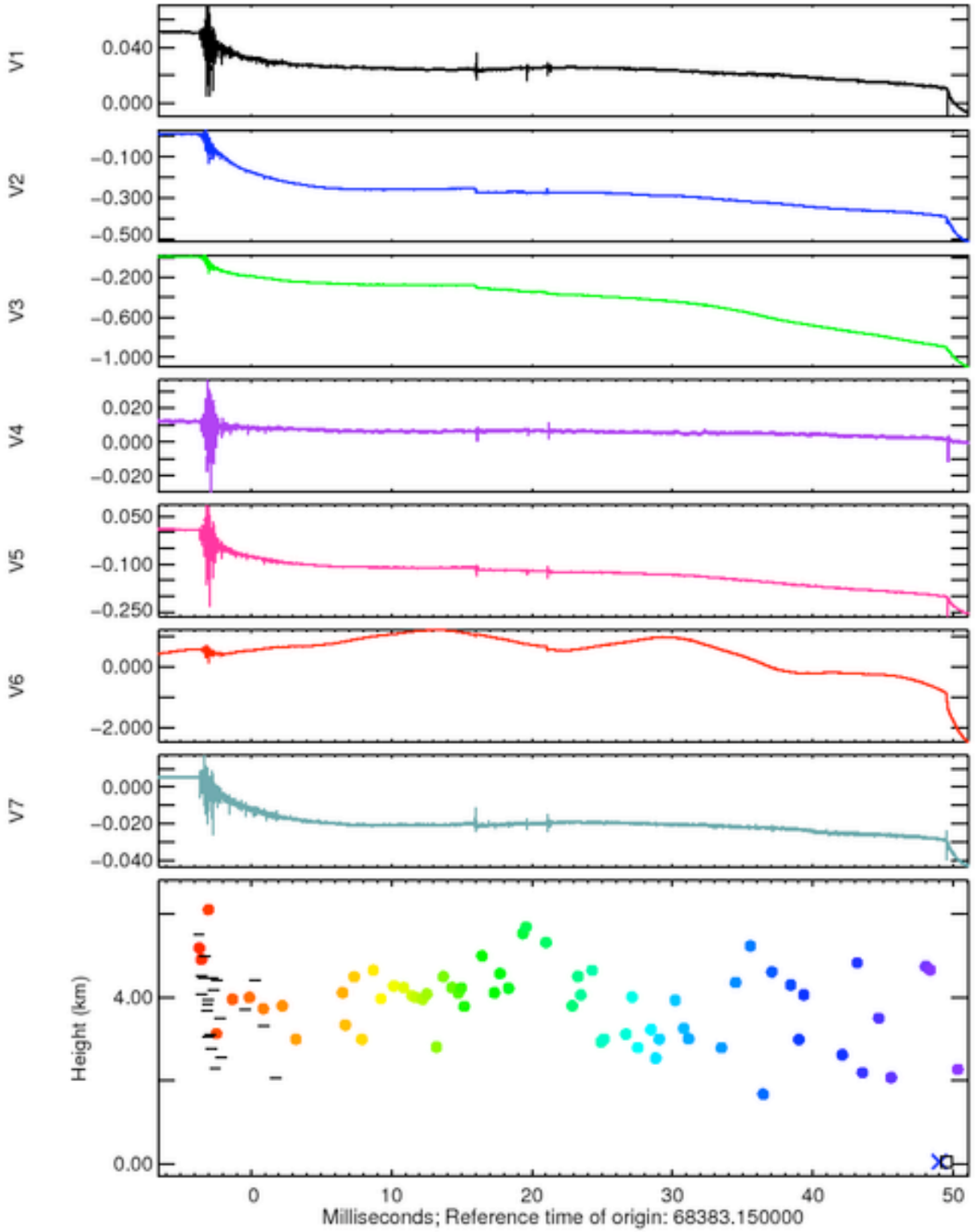
Negative CGs produce a preliminary breakdown pulse train with negative polarity pulses

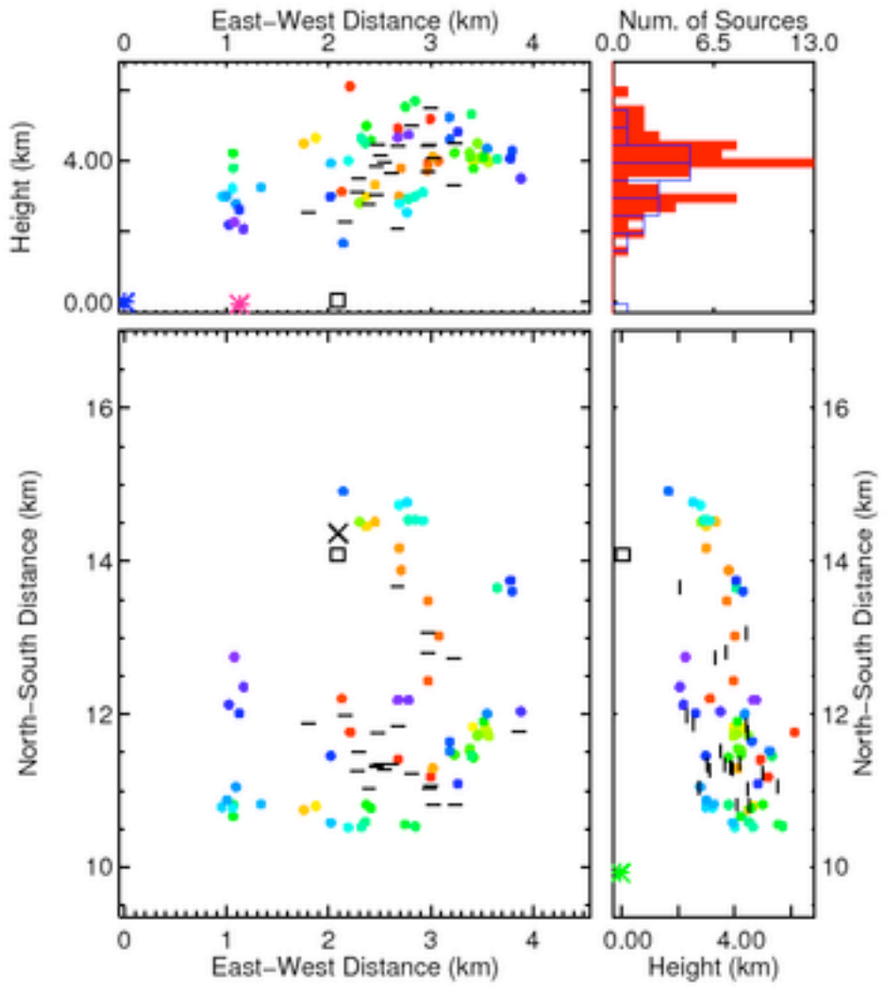


Flashes with an initial intracloud component begin with positive polarity pulses



2010/10/26 18:59:43





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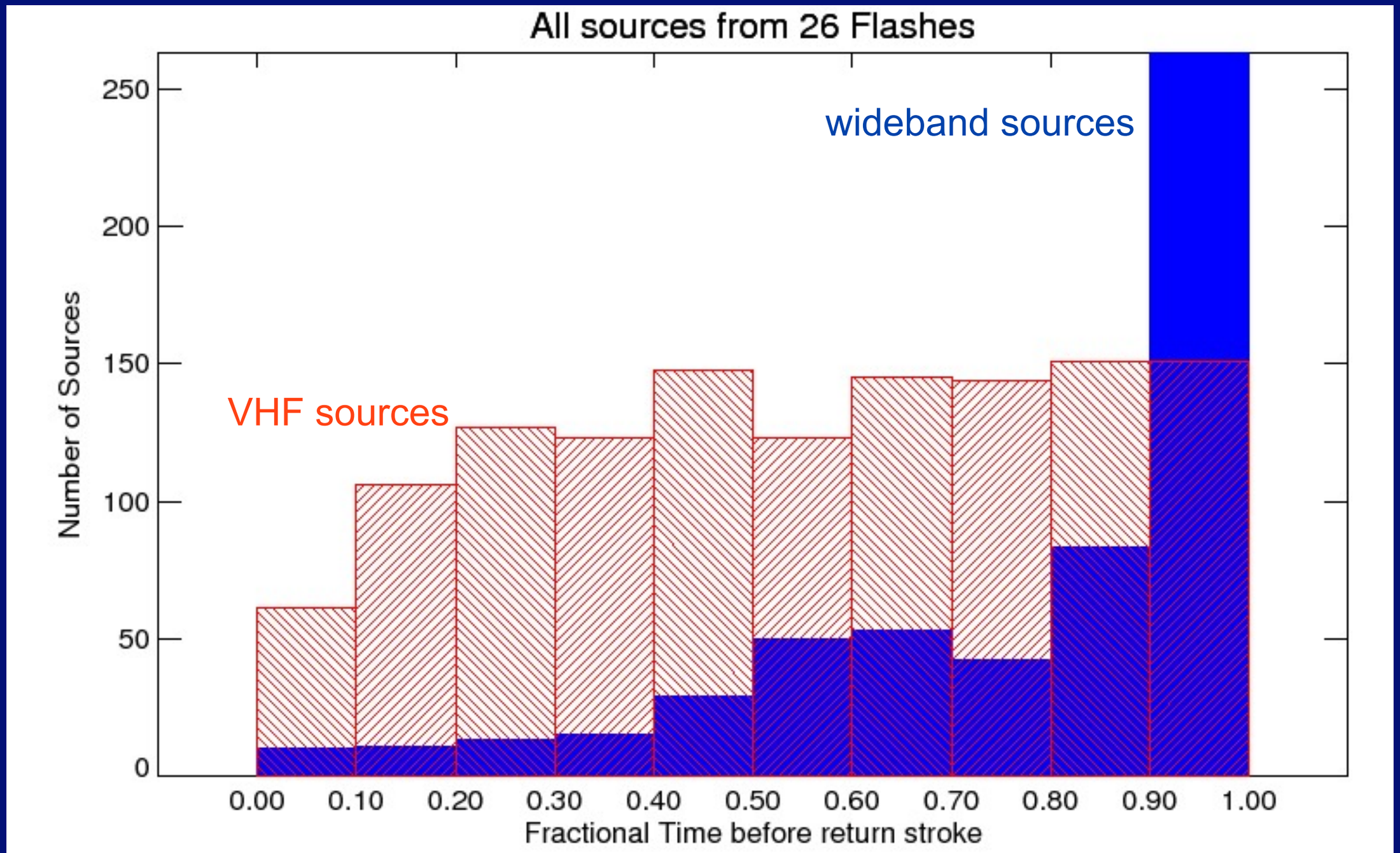
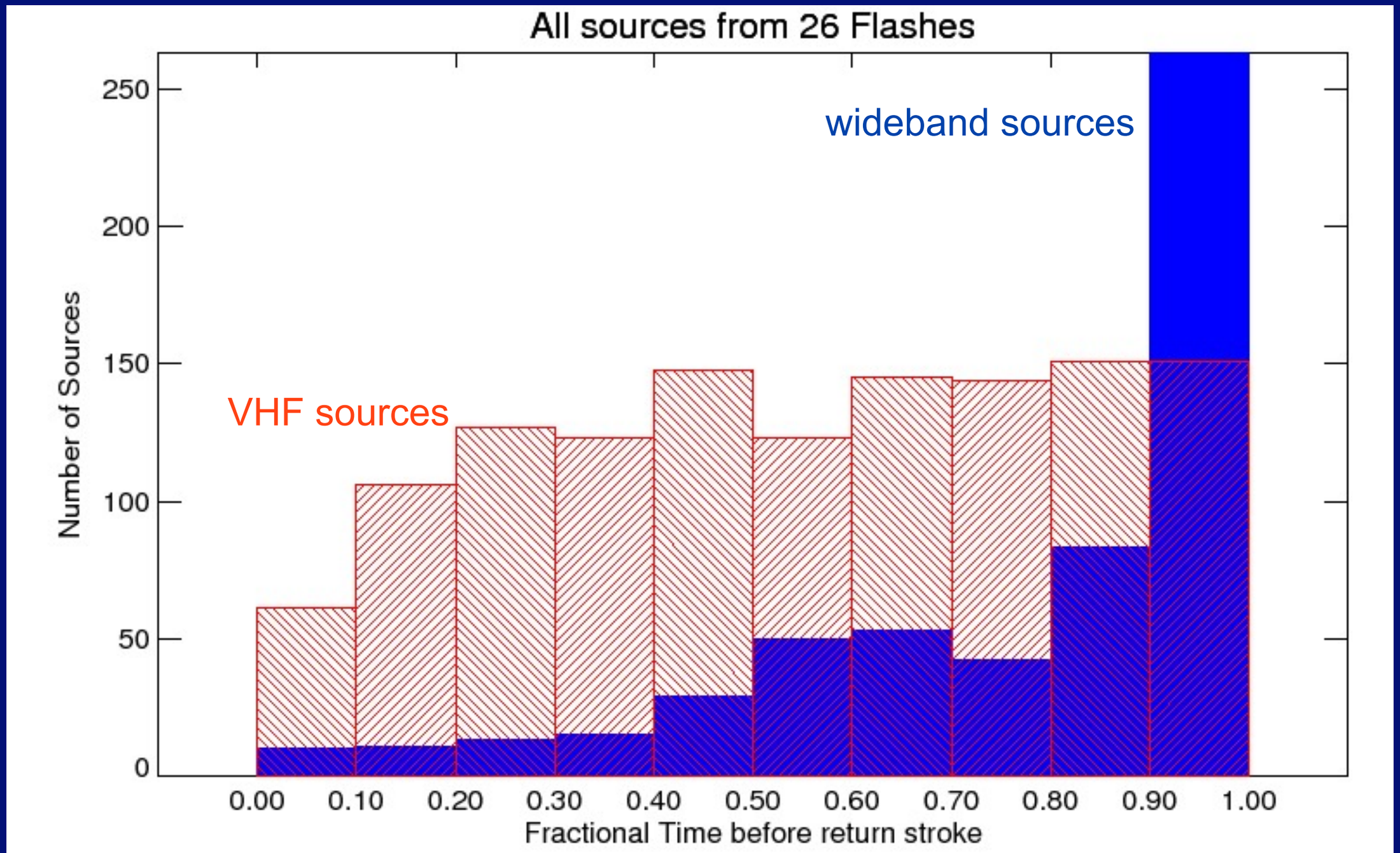
Stop time:	68383.201023
Time Elapsed:	0.057596



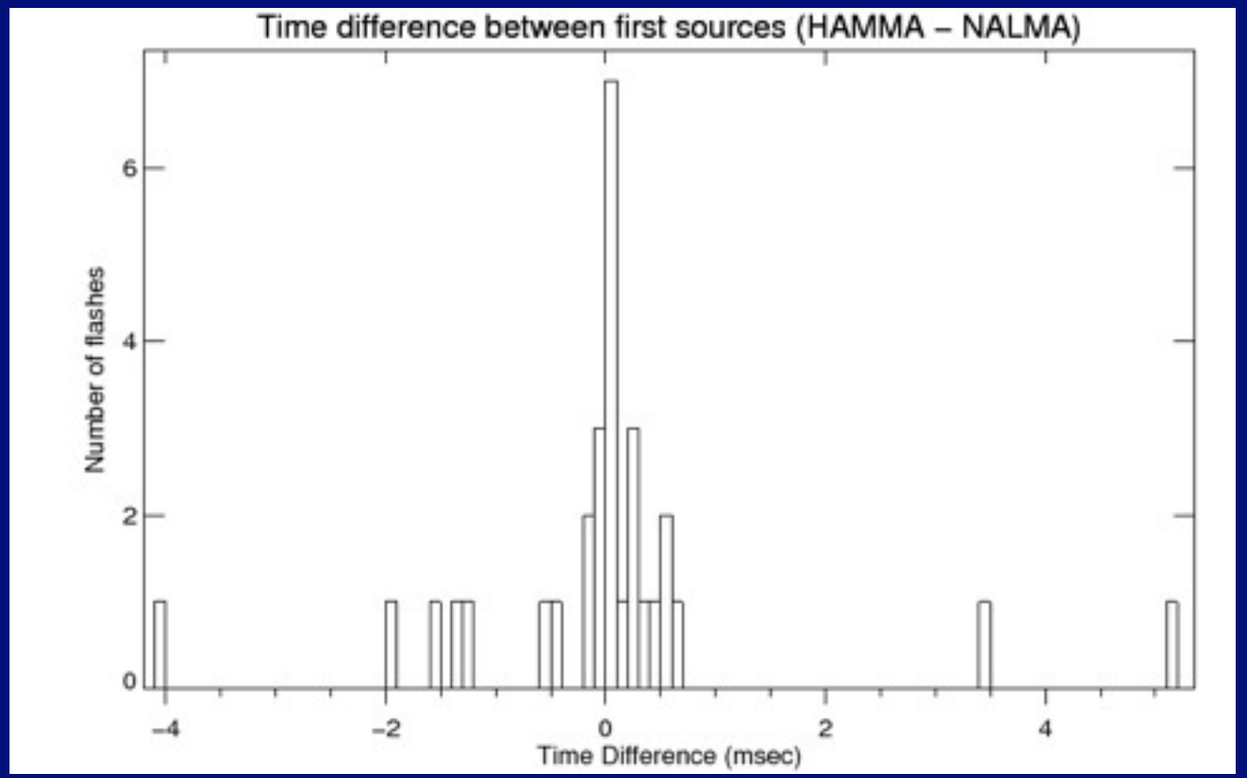
HAMMA is “very” active in the beginning of a flash

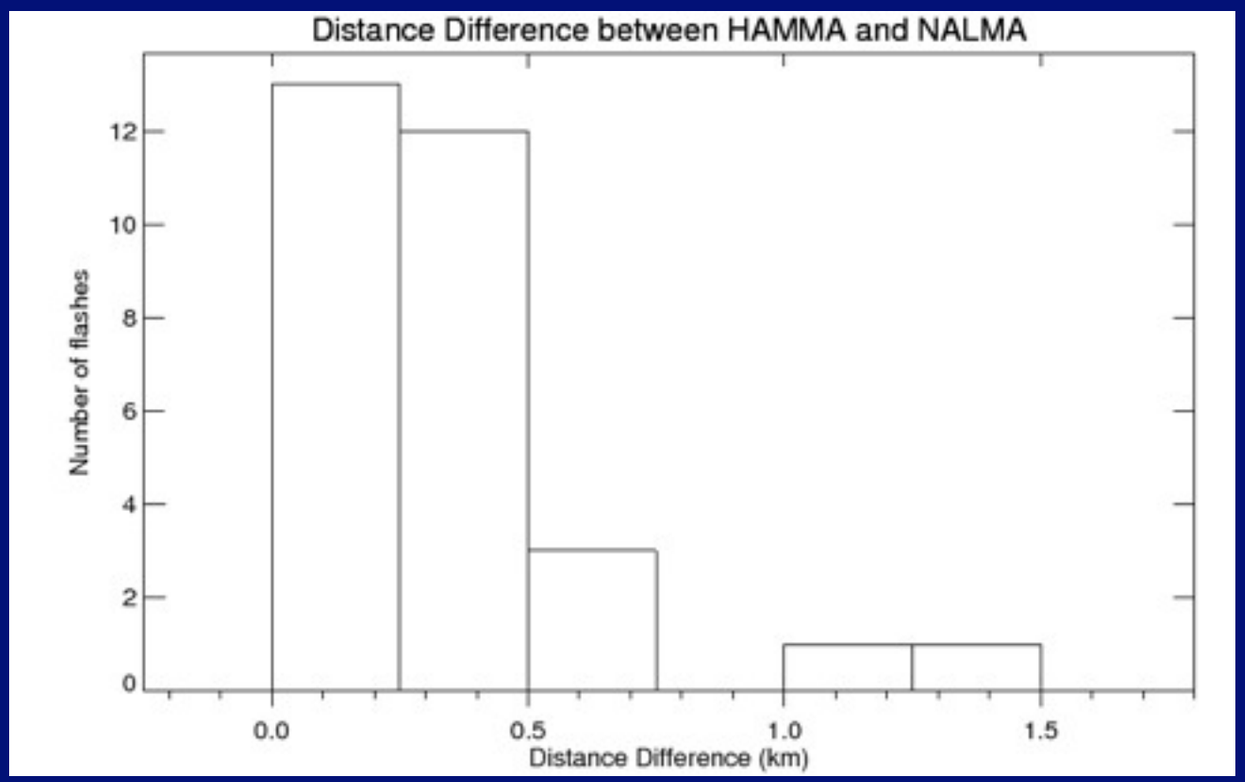


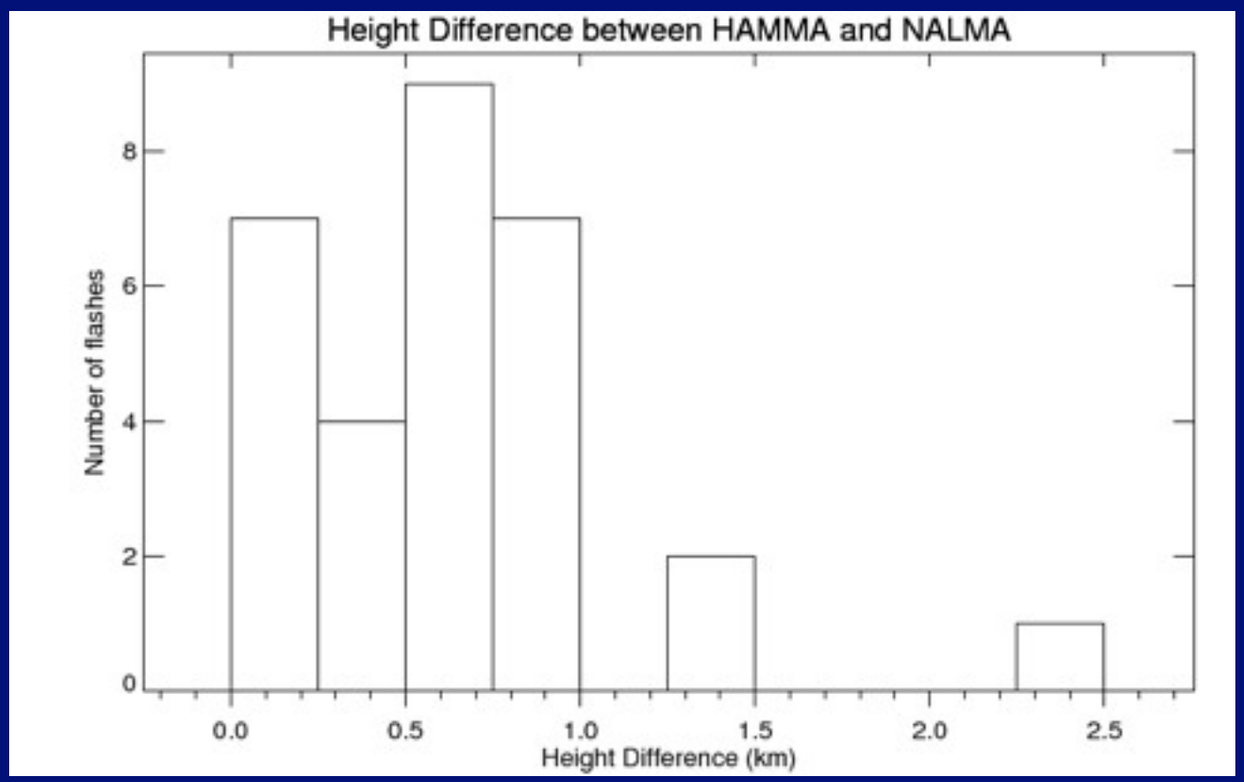
HAMMA is “very” active in the beginning of a flash

=> *wideband sources are well tuned to identify initiation*

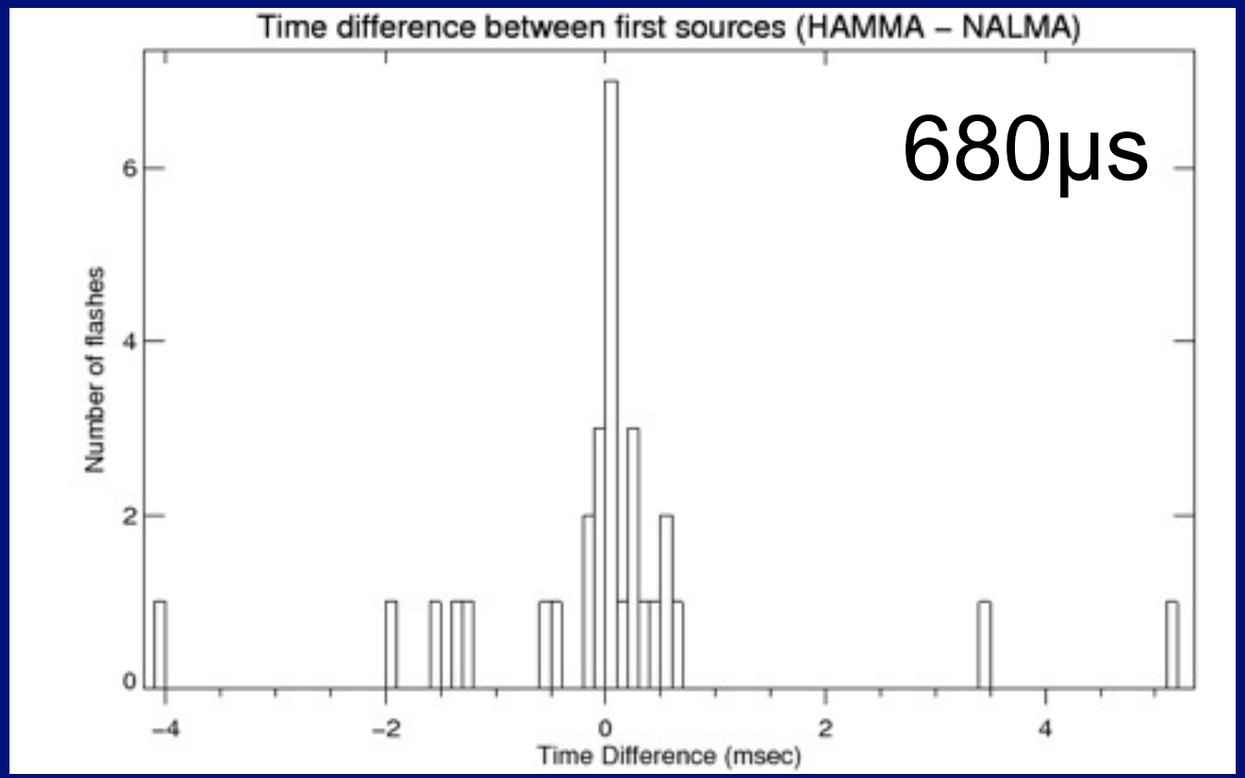
What's the difference in wideband and VHF?

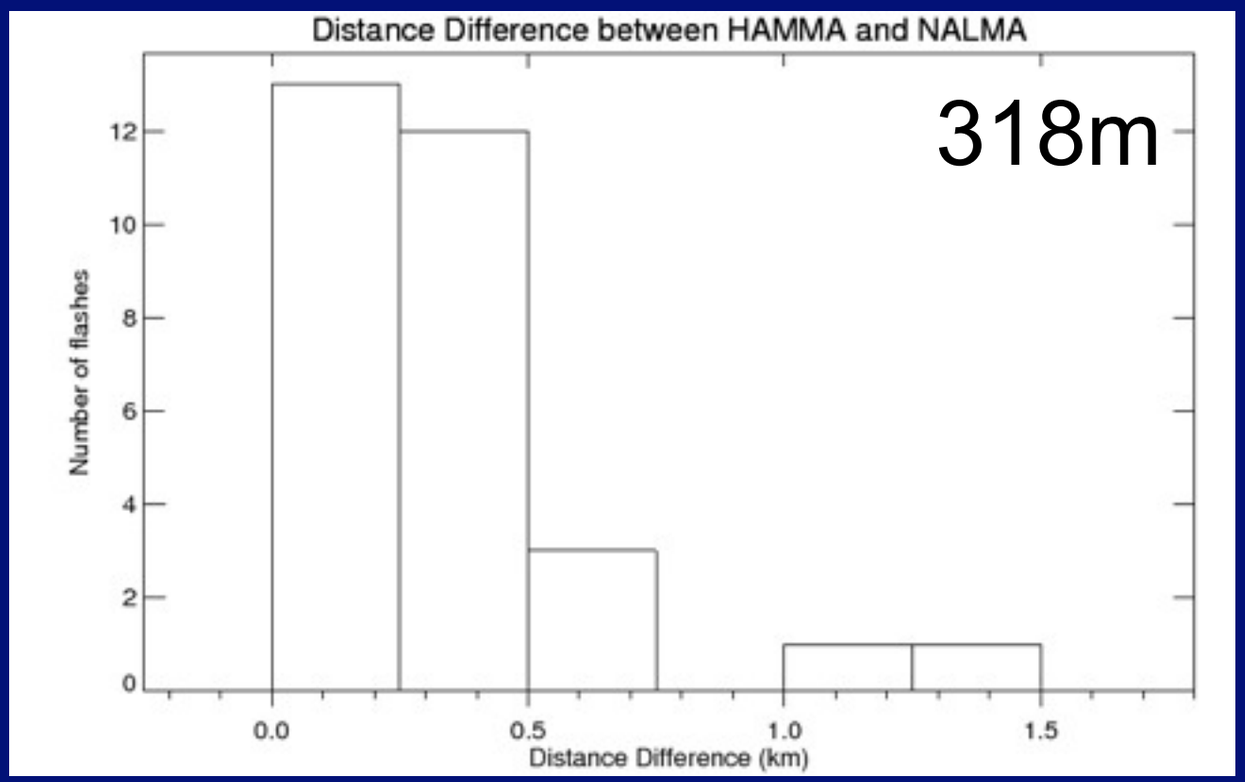


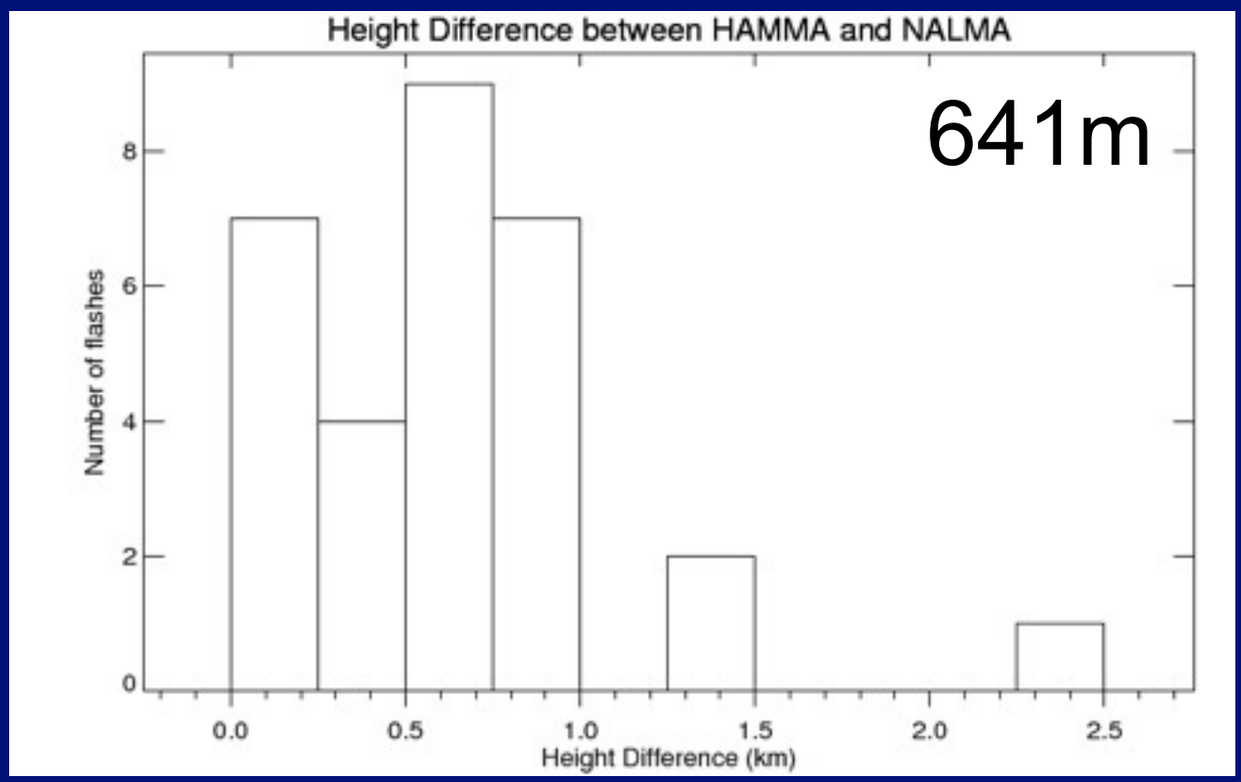


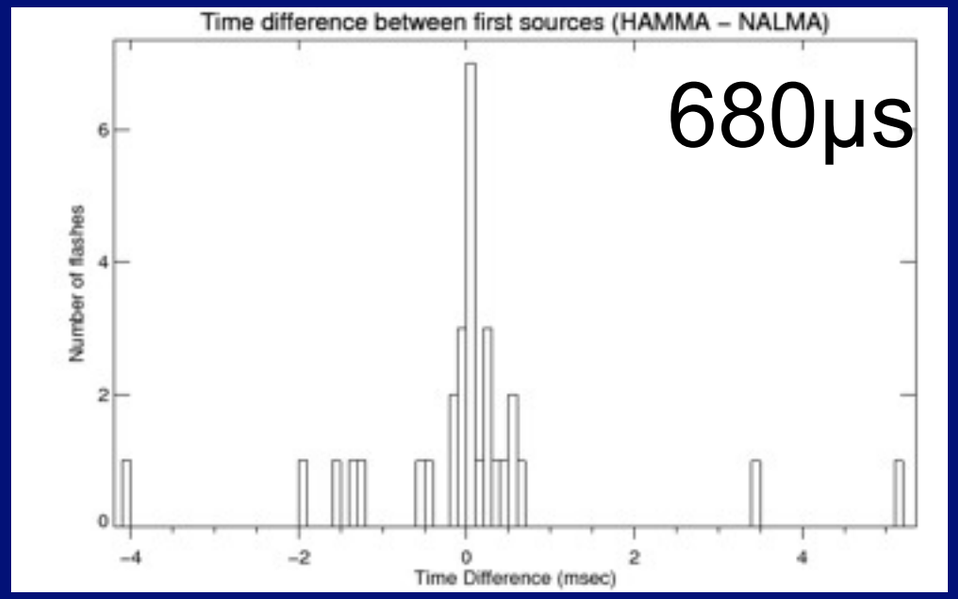


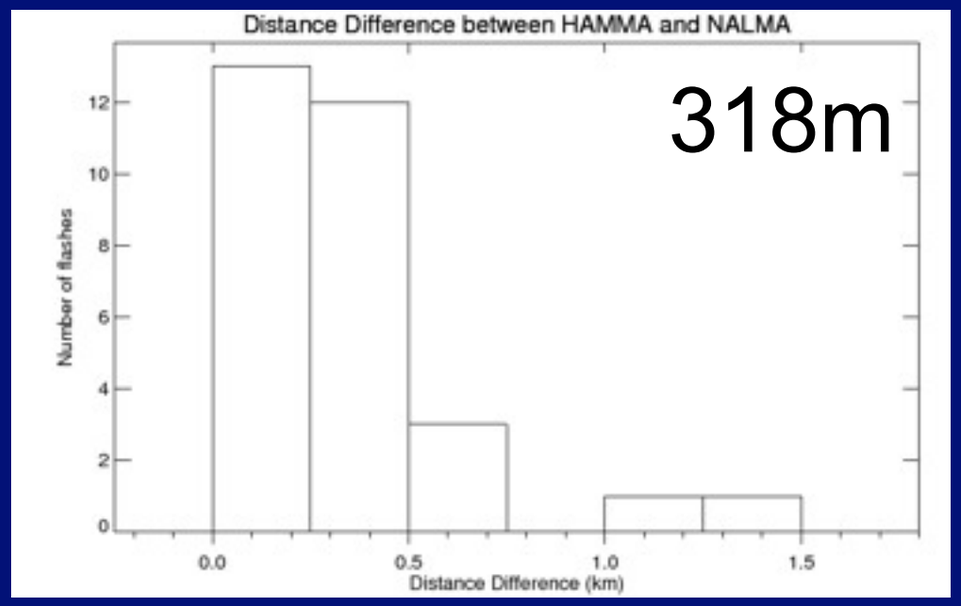
What's the difference in wideband and VHF?

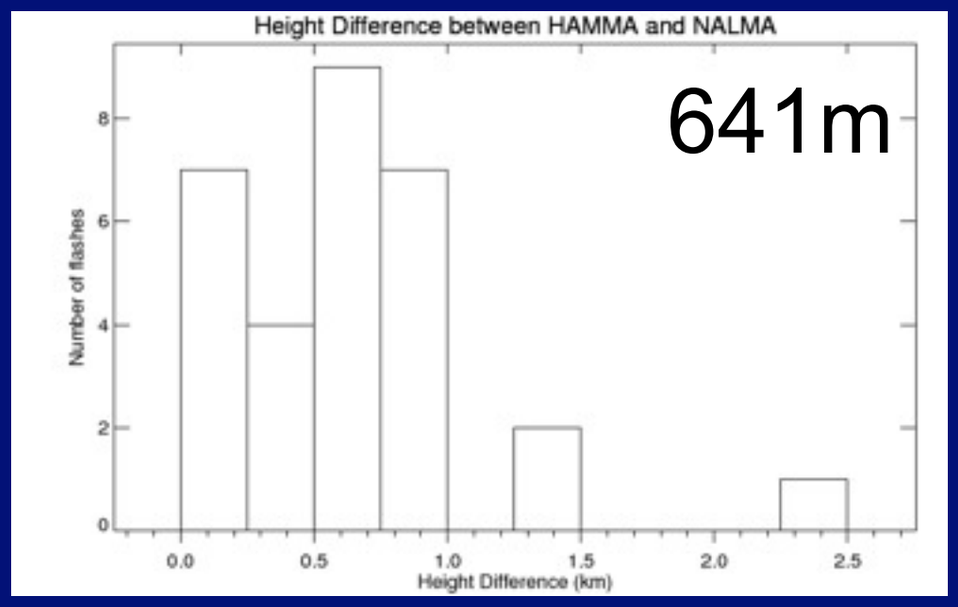


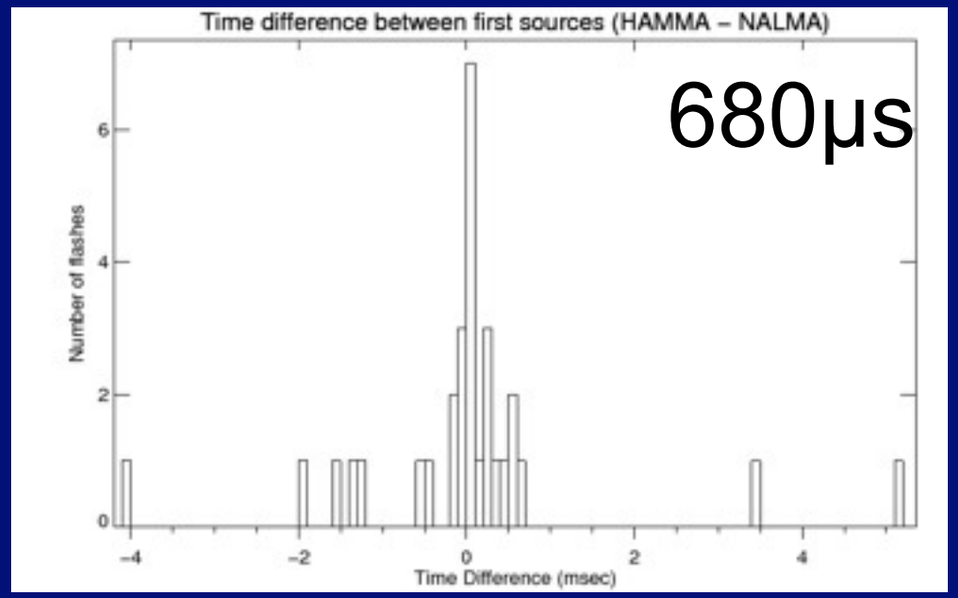


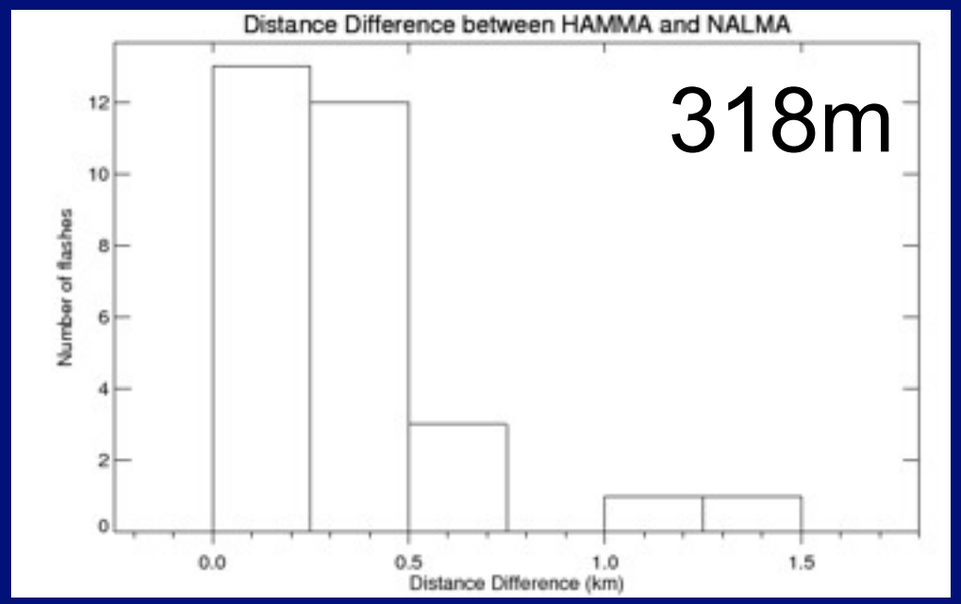


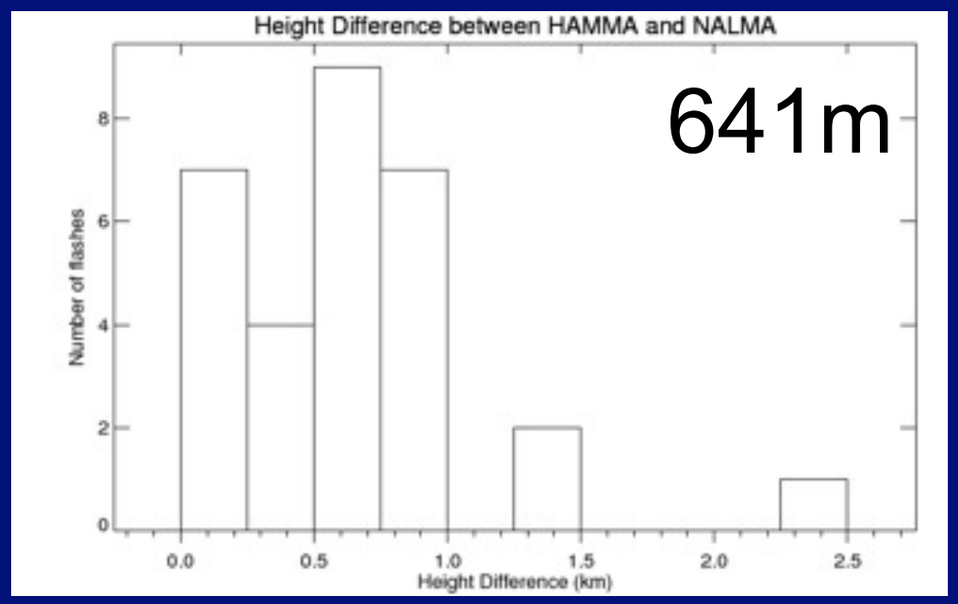

Time difference between first sources (HAMMA – NALMA)
680µs
Number of flashes
Time Difference (msec)
0
2
4
6
−4
−2
0
2
4


Distance Difference between HAMMA and NALMA
318m
Number of flashes
Distance Difference (km)
0
2
4
6
8
10
12
0.0
0.5
1.0
1.5

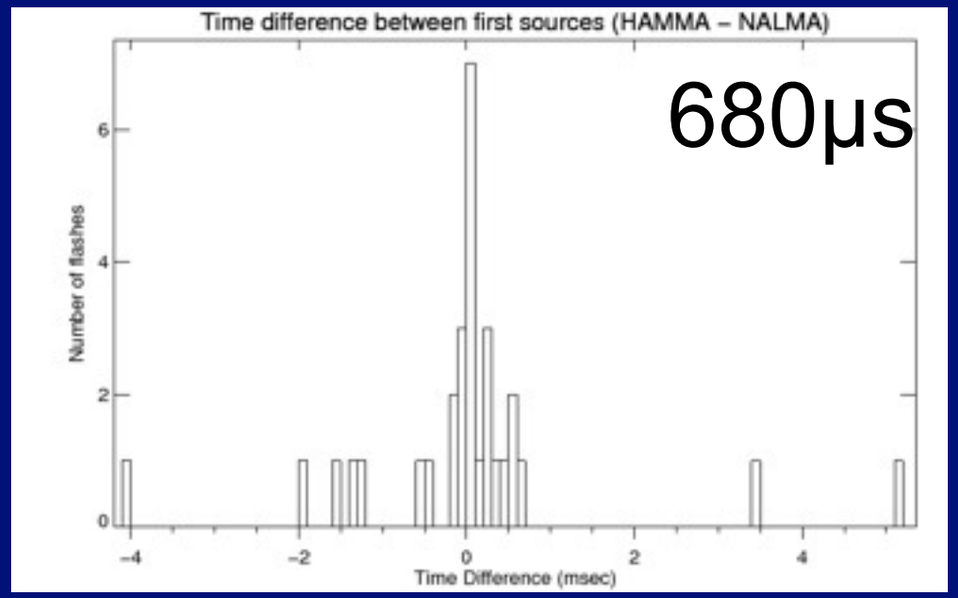

Height Difference between HAMMA and NALMA
641m
Number of flashes
Height Difference (km)
0
2
4
6
8
0.0
0.5
1.0
1.5
2.0
2.5

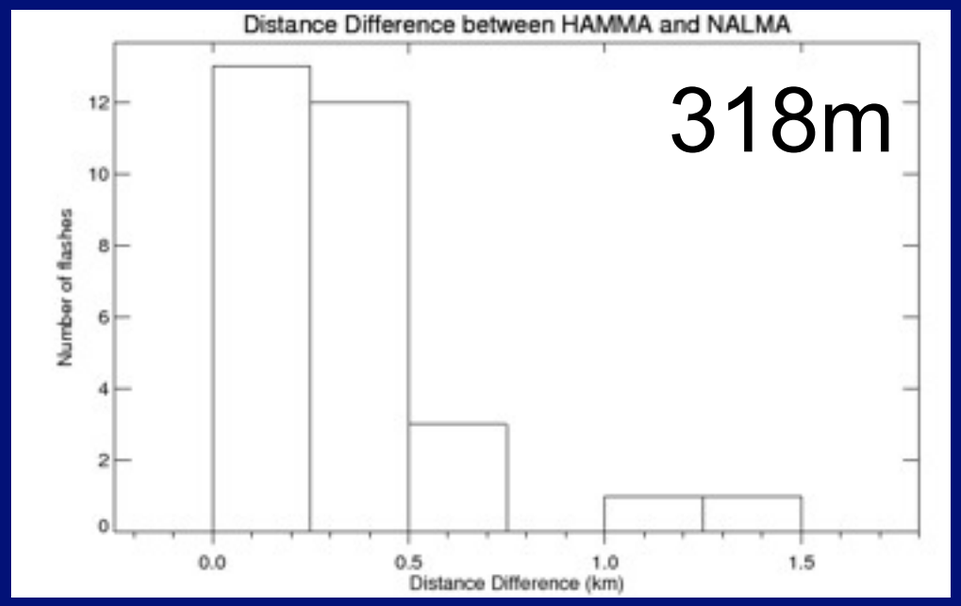


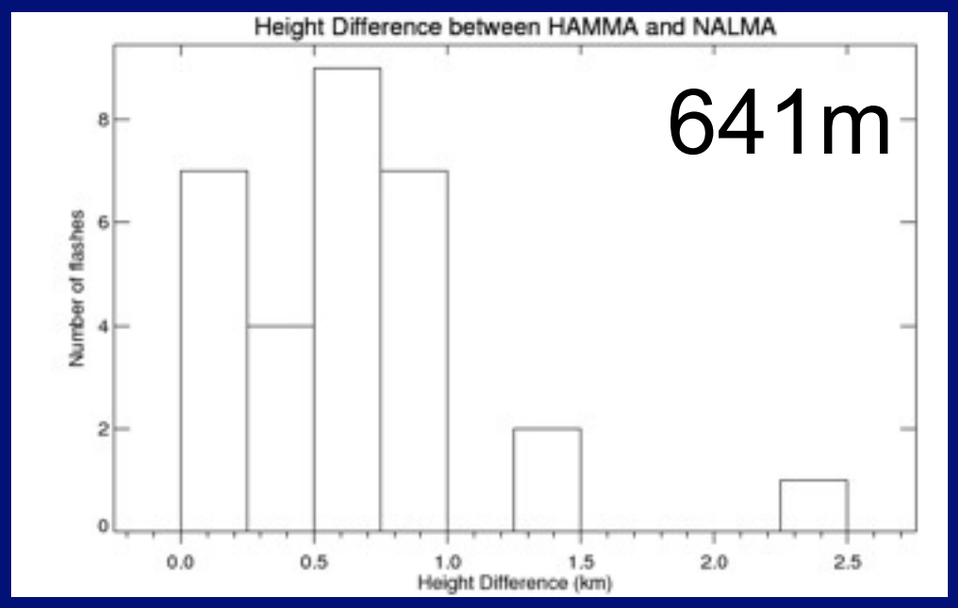




***On average**, initiation in the wideband and VHF are spatially and temporally similar…*







***On average**, initiation in the wideband and VHF are spatially and temporally similar…*

…but what does this mean for the initiation mechanism?

Gurevich (1999) predicts that initiation via relativistic runaway breakdown would produce wideband radiation prior to VHF radiation...

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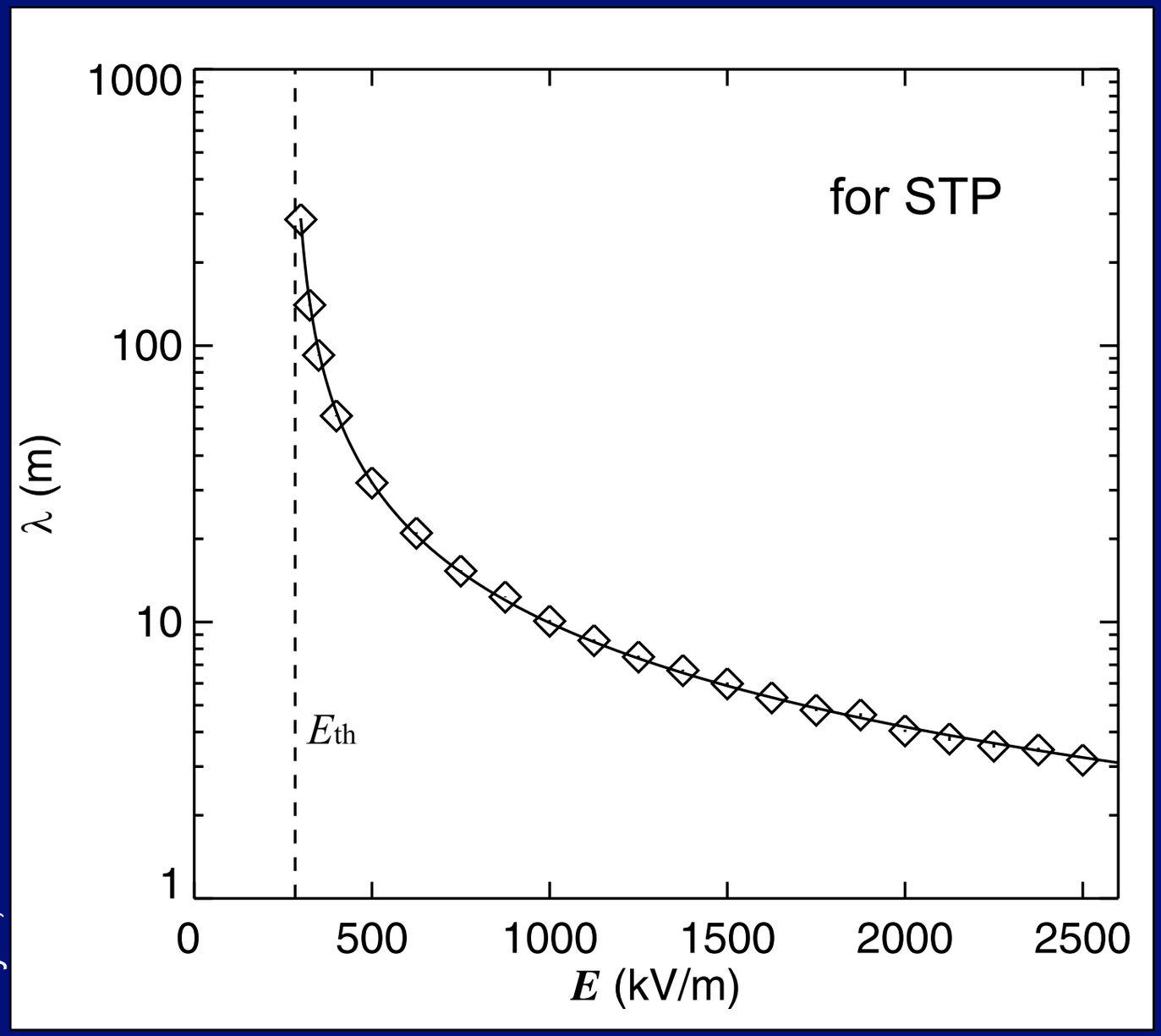

Dwyer, 2003

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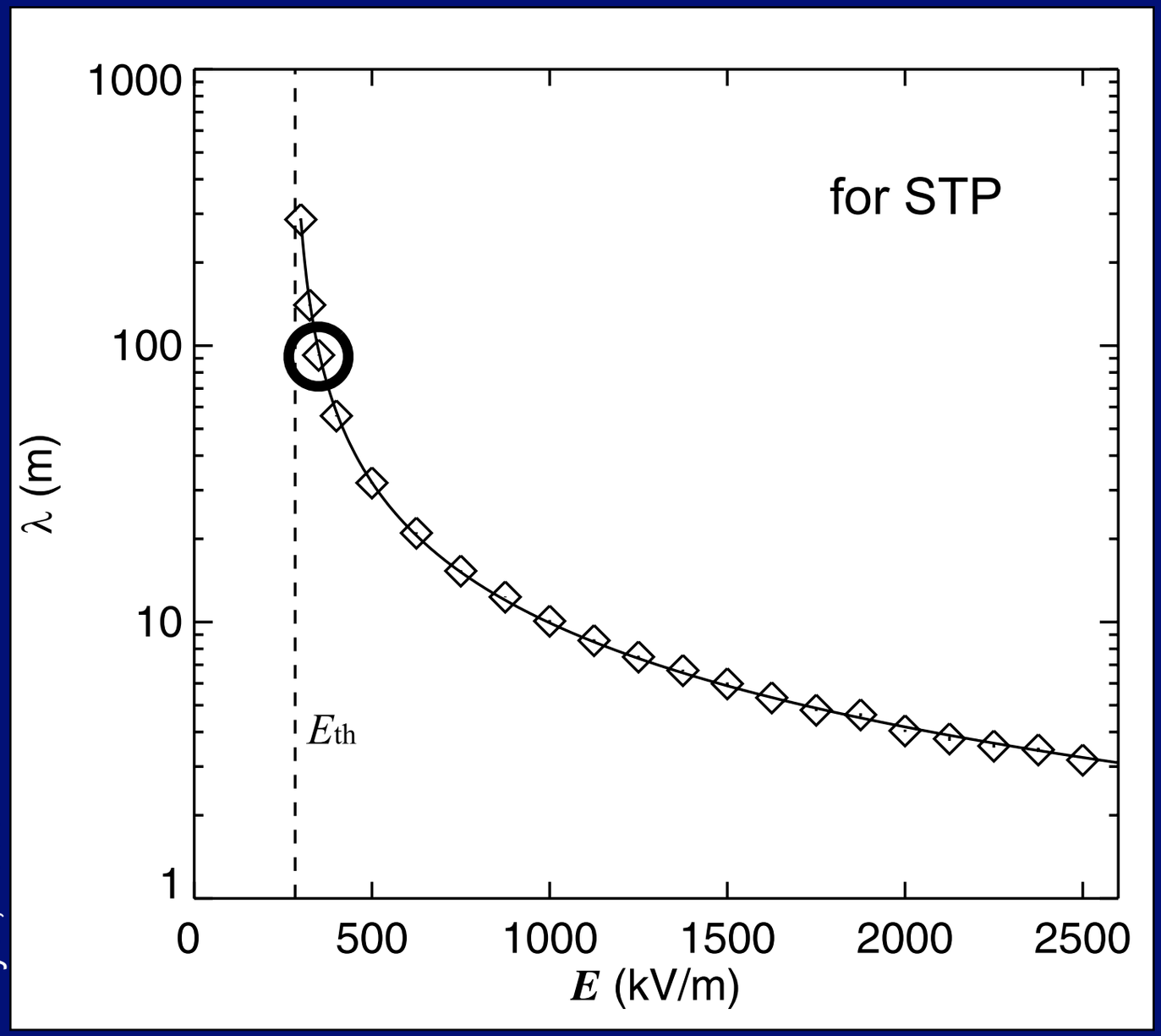

Assume:

initiation height of 6km

electric field of 175 kV/m

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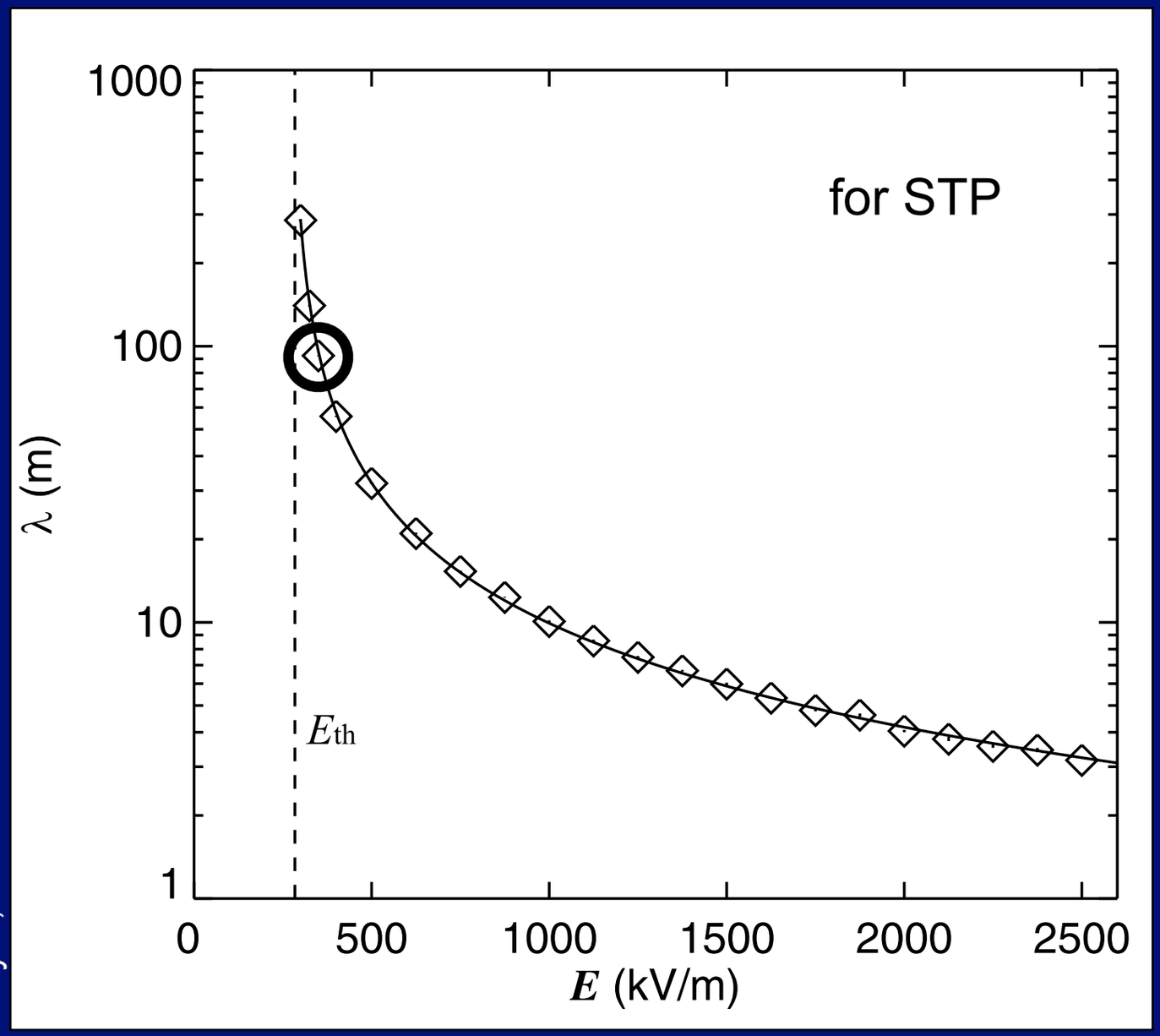

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Implies:

avalanche length is ~200m

total length of the high field region is ~2km

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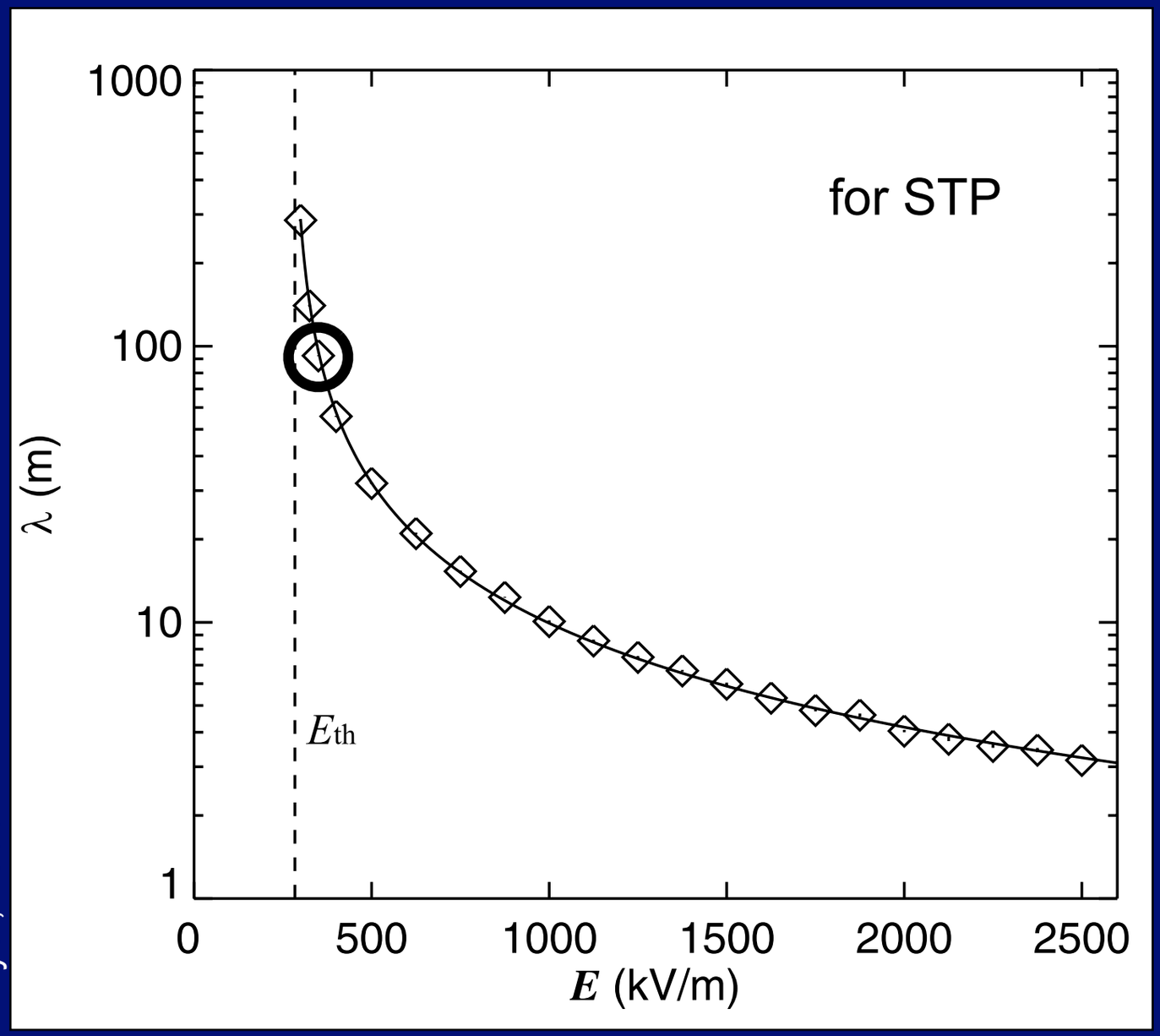

Assume:

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electric field of 175 kV/m

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total length of the high field region is ~2km

Further, Coleman and Dwyer (2006) show that the avalanche progresses with a speed of 0.89c

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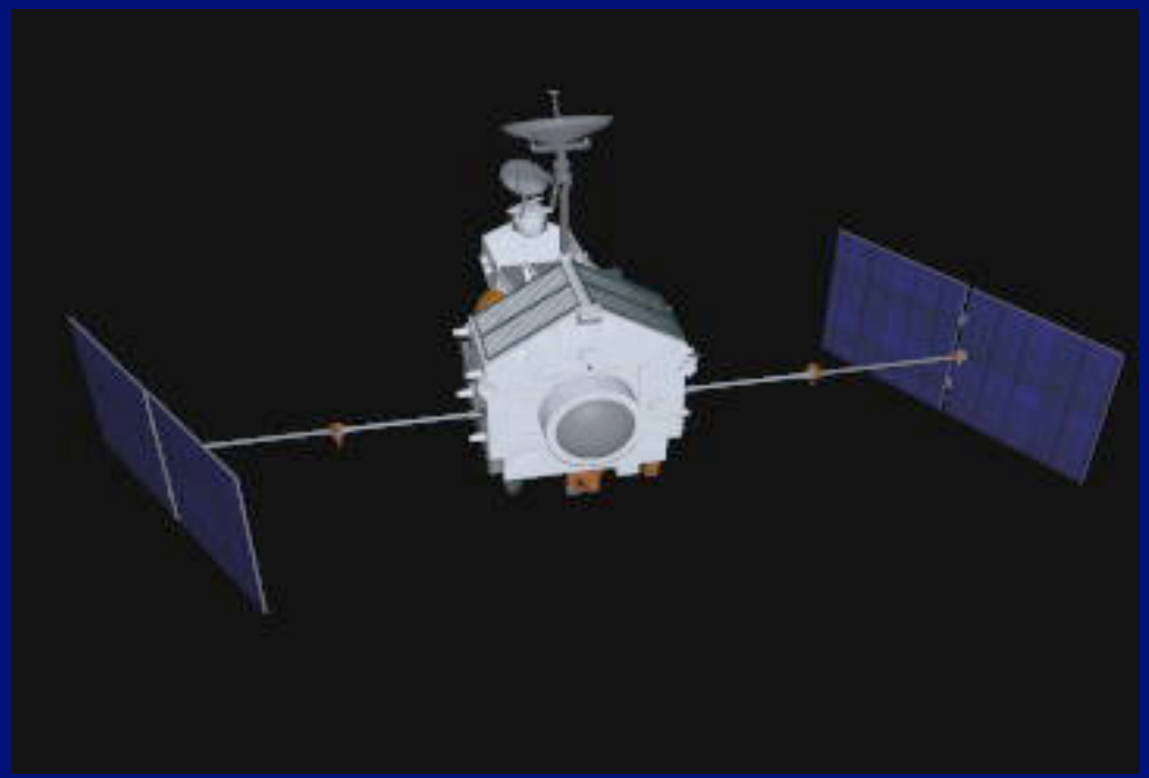
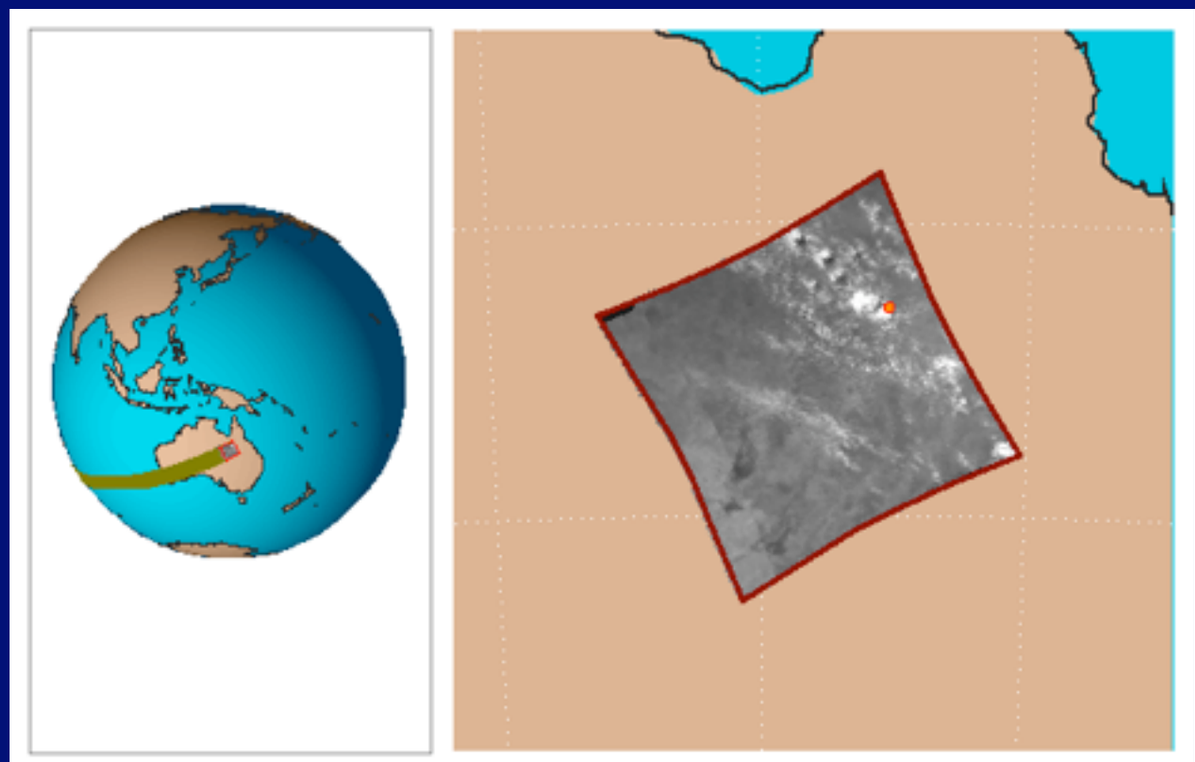
Measurements of time lag between initiation in wideband and VHF are generally incompatible with relativistic runaway breakdown!

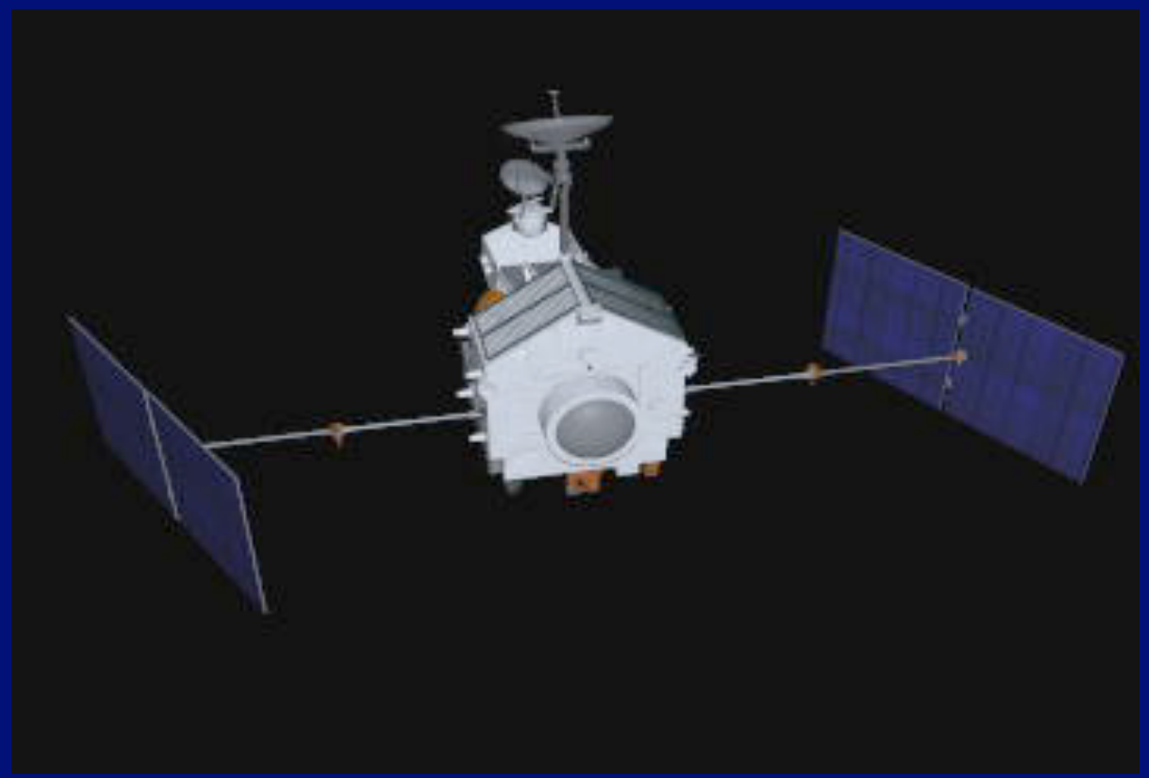
Further....
simulations (Dwyer, 2010) show the region of slow electrons is far too diffuse to yield the required conductivity.

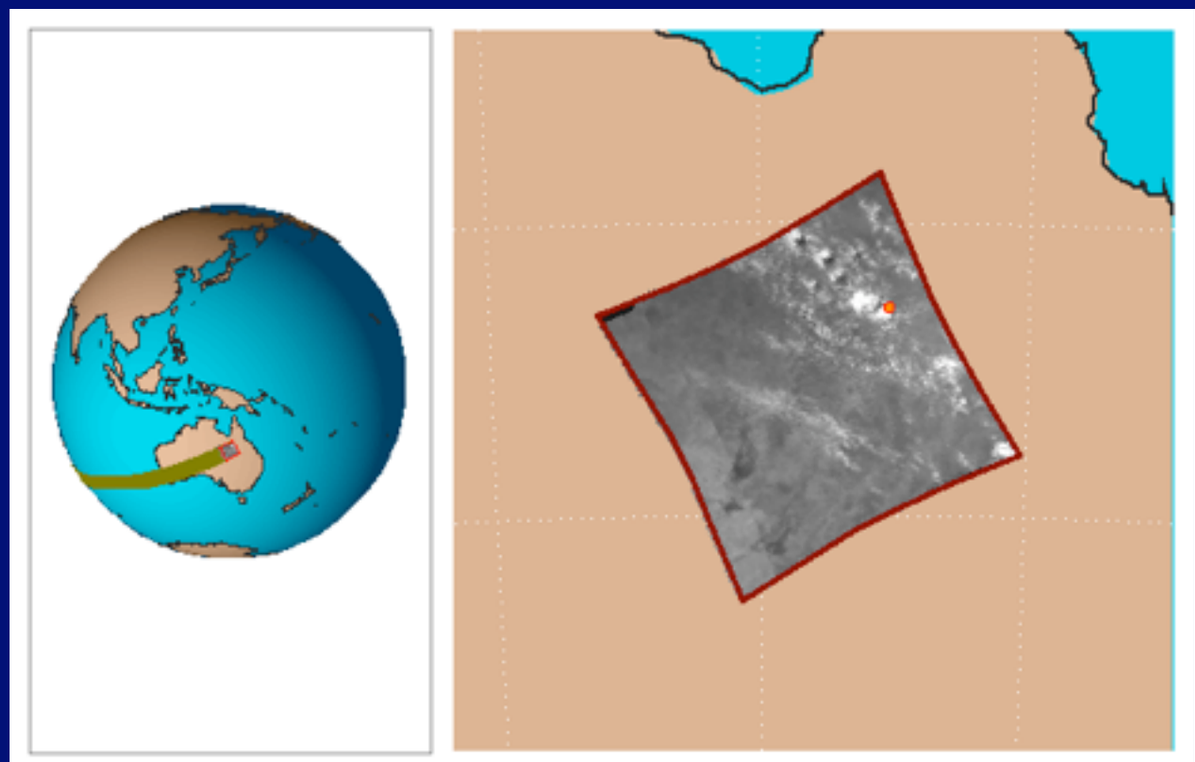
LIS (and by extension, GLM)
does not
detect *flashes...*





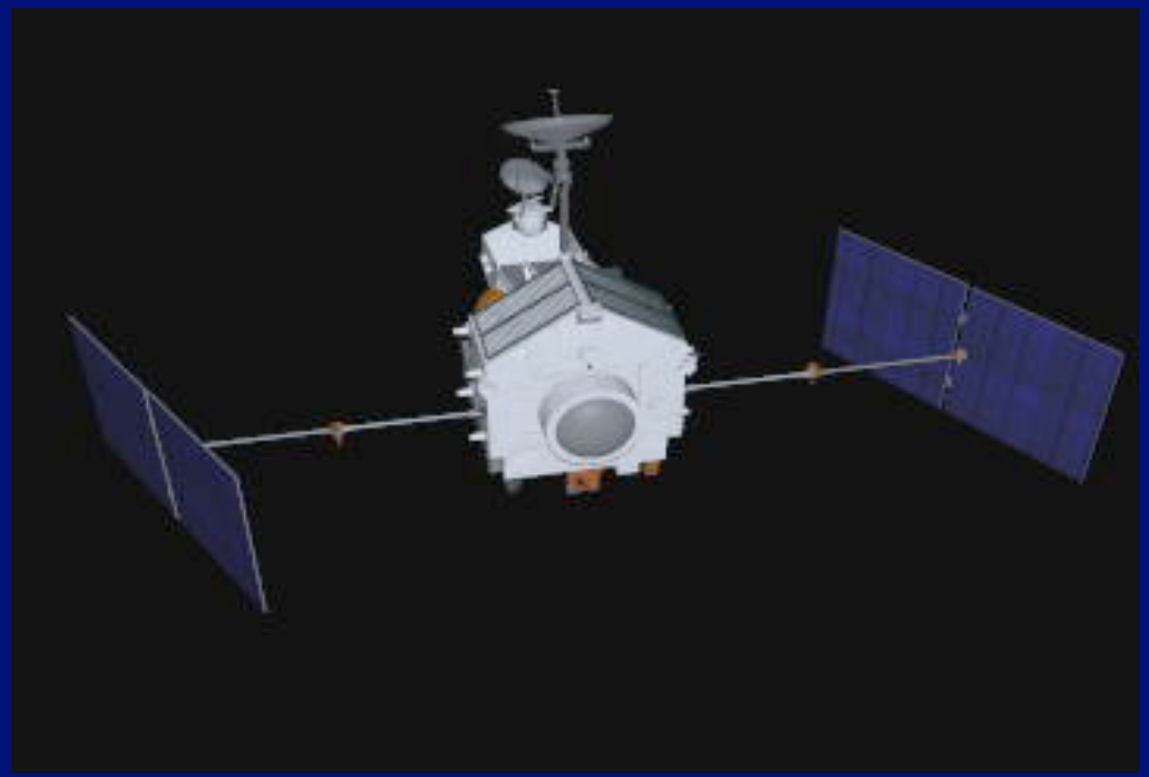
LIS is an **optical *event* detector**

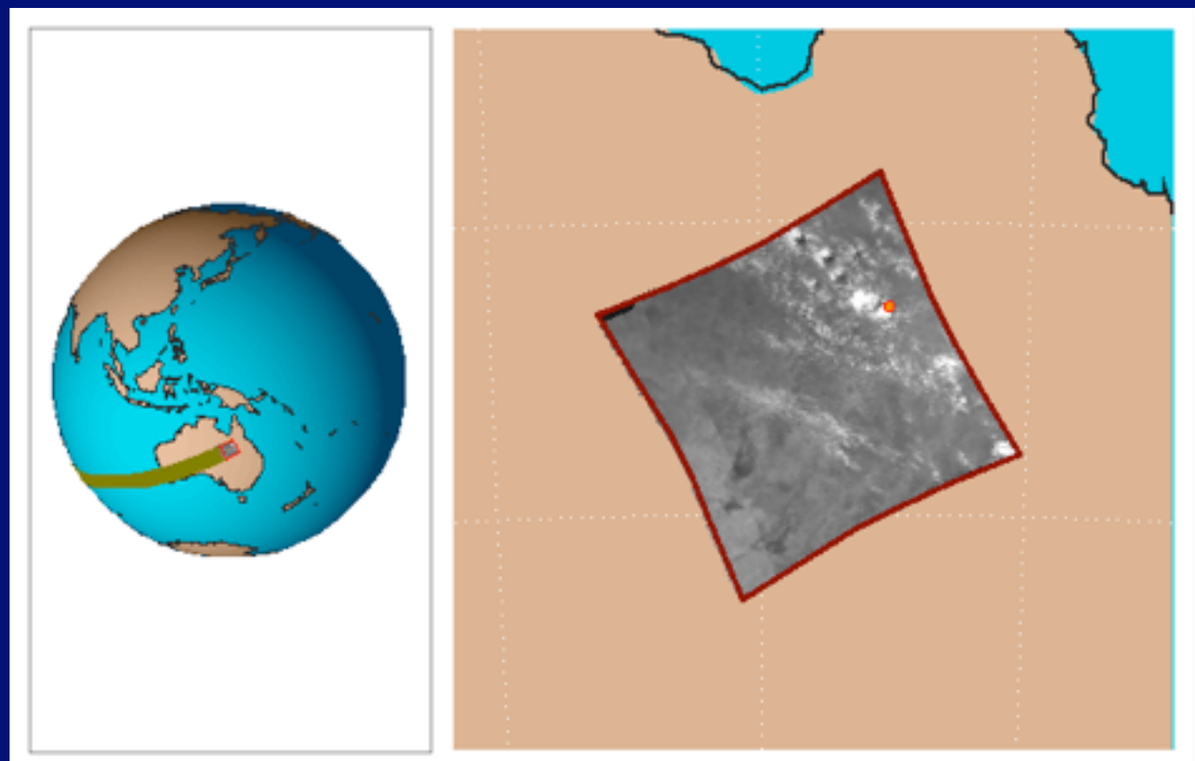




LIS is an **optical *event* detector**

These events can be classified into ~~strokes~~ groups and flashes.



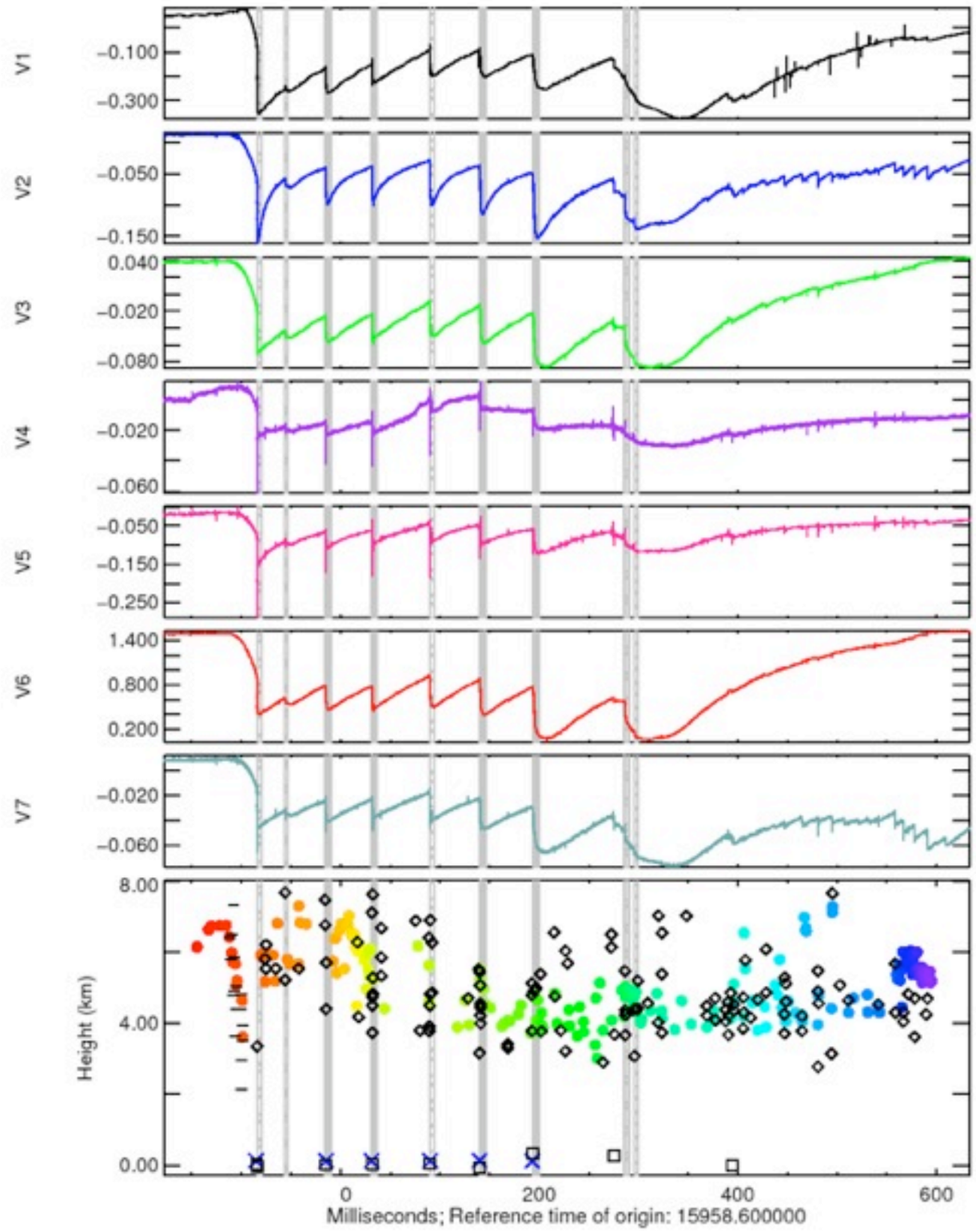


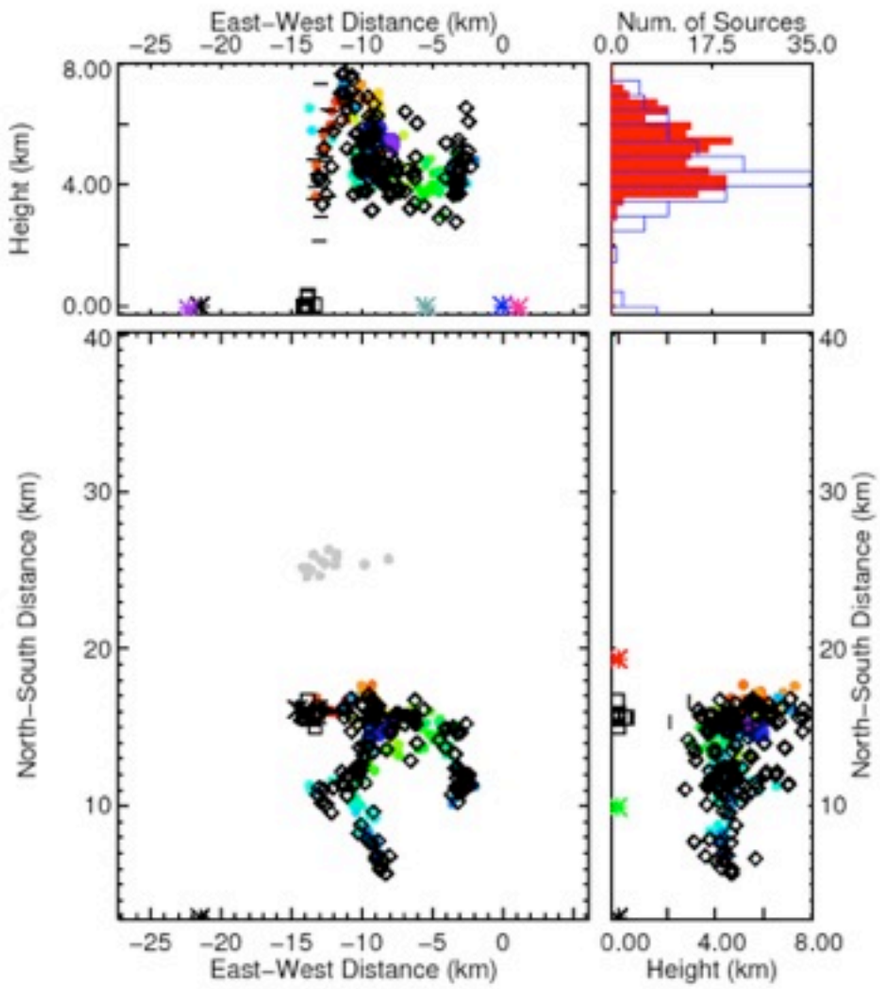
LIS is an **optical *event* detector**

These events can be classified into
~~strokes~~ groups and flashes.

Validation of LIS/GLM measurements
should use instruments sensitive to the part of the lightning
discharge which produces optical emission

2010/10/25 04:25:58



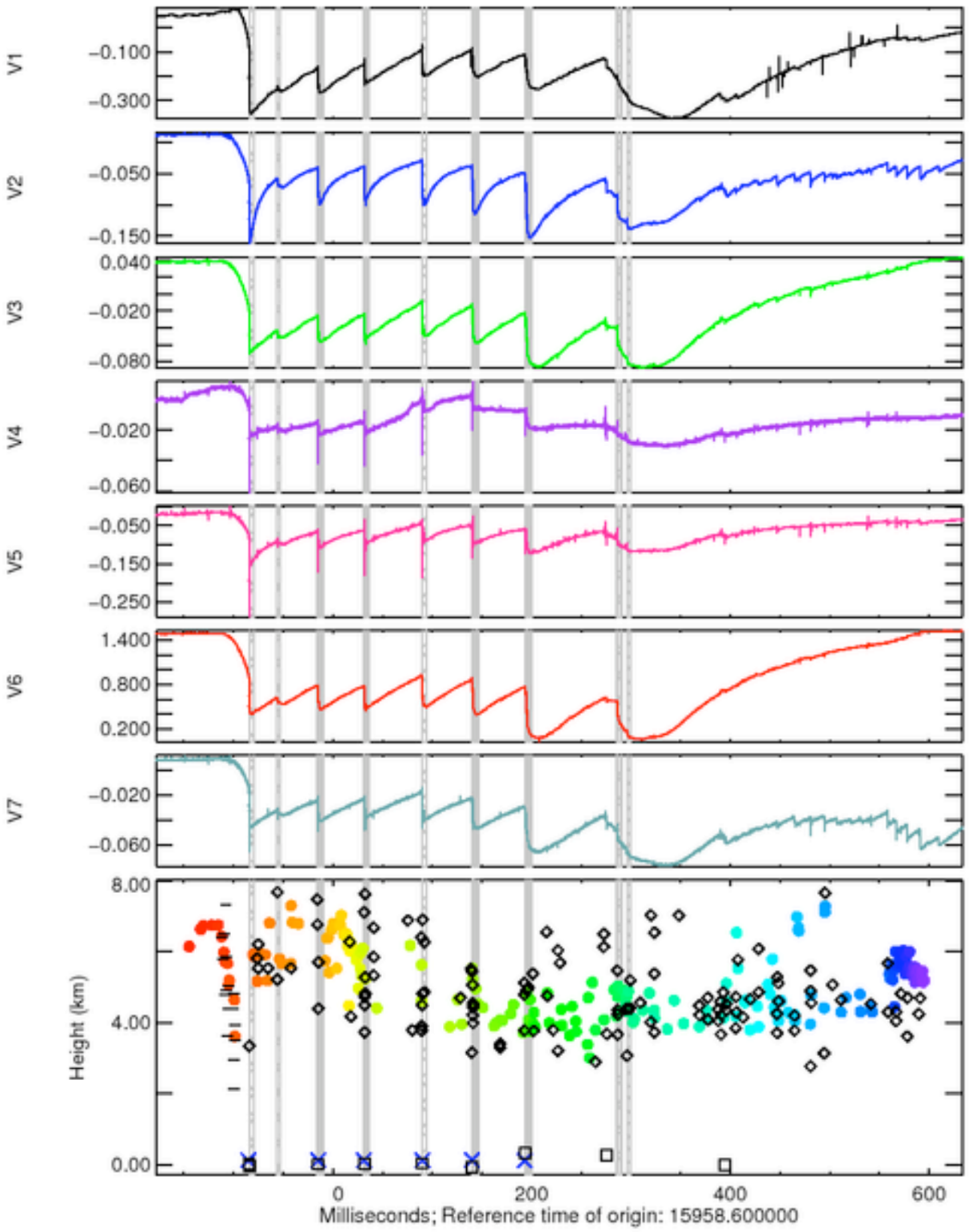


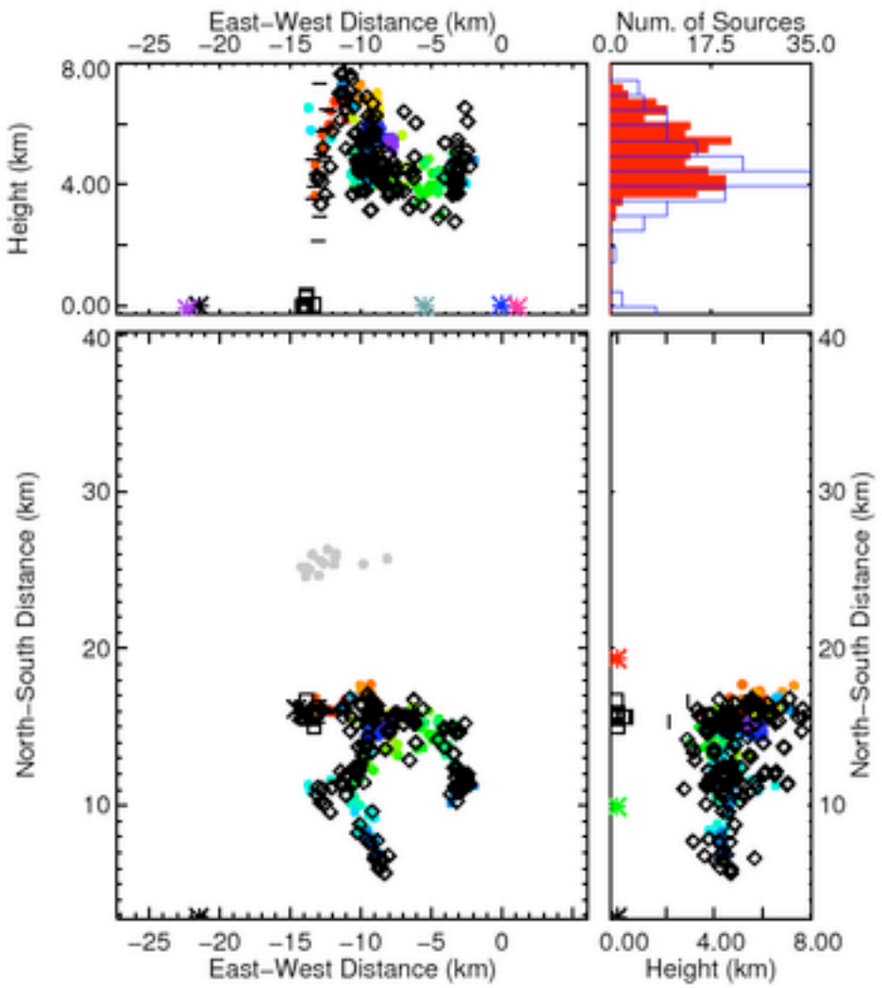
Base time: 15958.422249

Stop time: 15959.233089

Time Elapsed: 0.810840

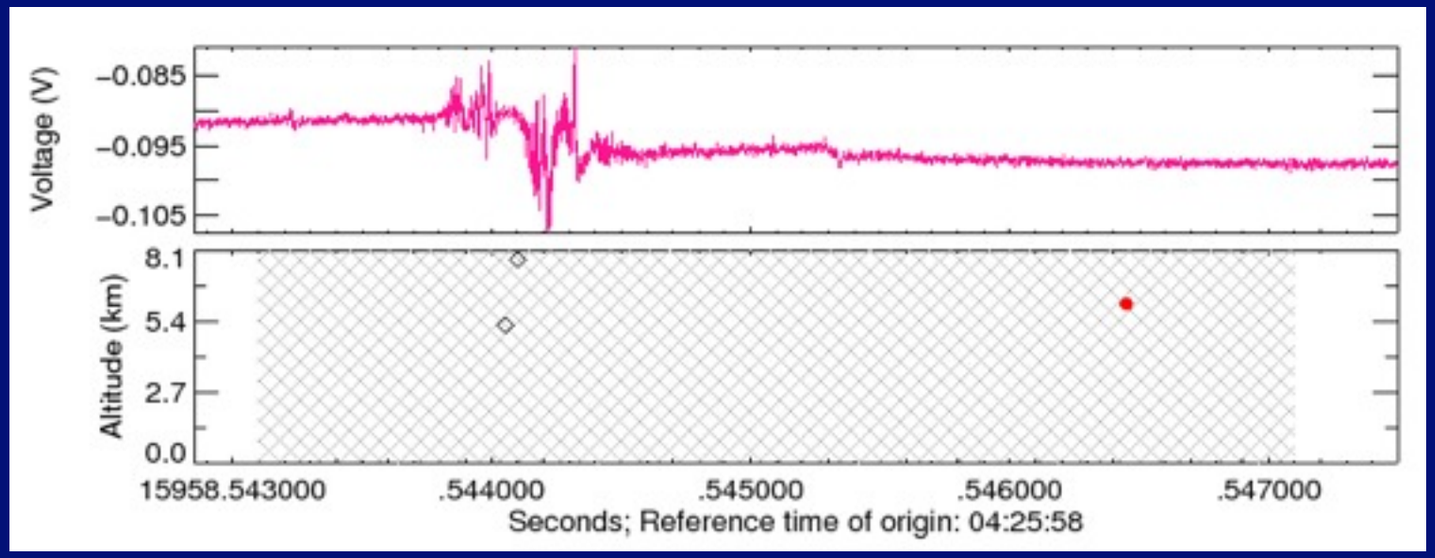
2010/10/25 04:25:58

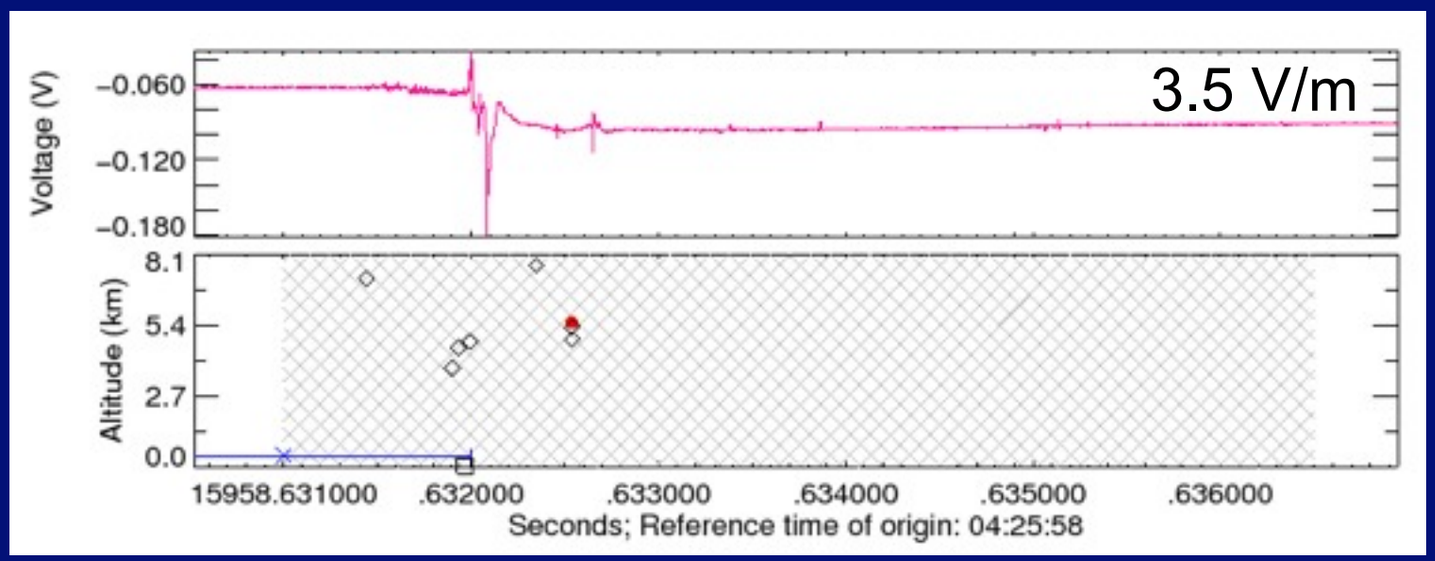


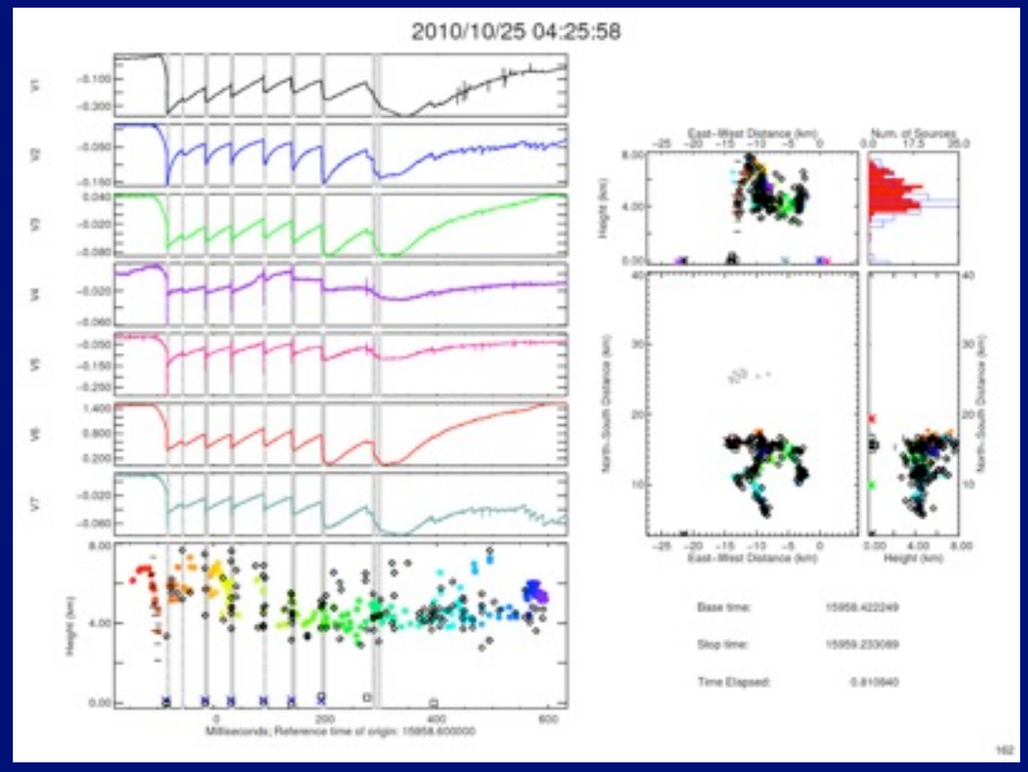


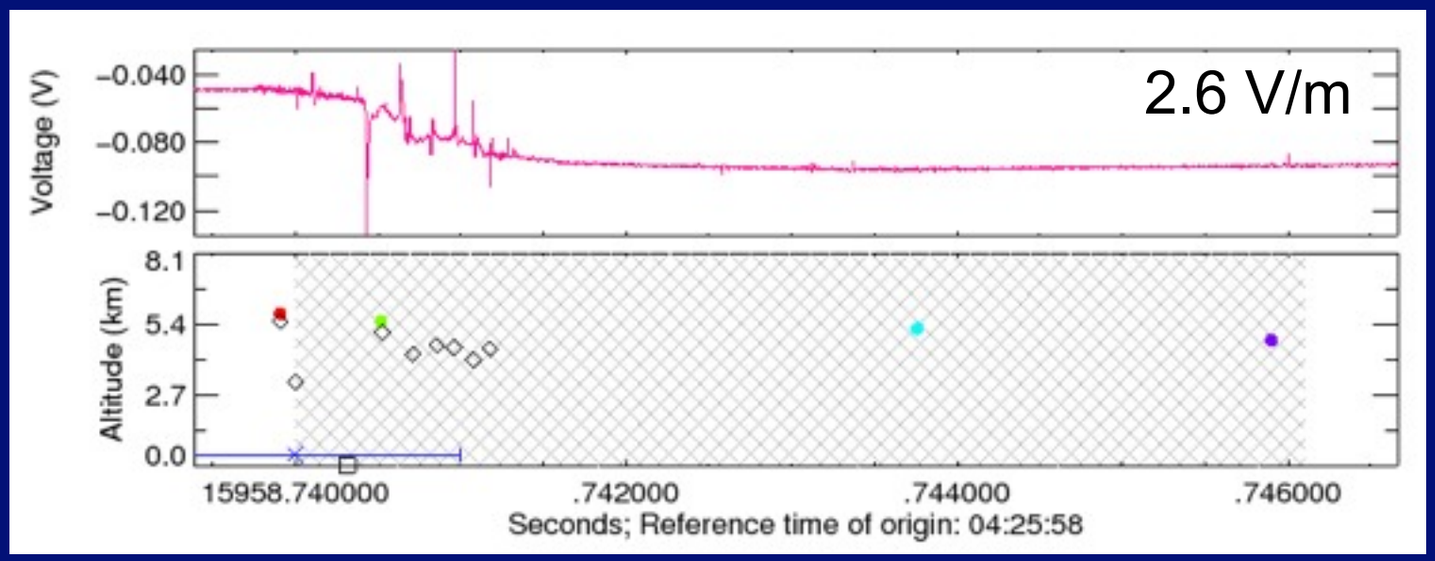
Base time:	15958.422249
Stop time:	15959.233089
Time Elapsed:	0.810840

What is a hit?


Voltage (V)
−0.085
−0.095
−0.105
Altitude (km)
8.1
5.4
2.7
0.0
15958.543000
.544000
.545000
.546000
.547000
Seconds; Reference time of origin: 04:25:58


3.5 V/m
Voltage (V)
−0.060
−0.120
−0.180
Altitude (km)
8.1
5.4
2.7
0.0
15958.631000
.632000
.633000
.634000
.635000
.636000
Seconds; Reference time of origin: 04:25:58


2010/10/25 04:25:58
East-West Distance (km)
Num. of Sources
Height (km)
North-South Distance (km)
Base time:
Stop time:
Time Elapsed:
Milliseconds; Reference time of origin:


2.6 V/m
Voltage (V)
−0.040
−0.080
−0.120
Altitude (km)
8.1
5.4
2.7
0.0
15958.740000
.742000
.744000
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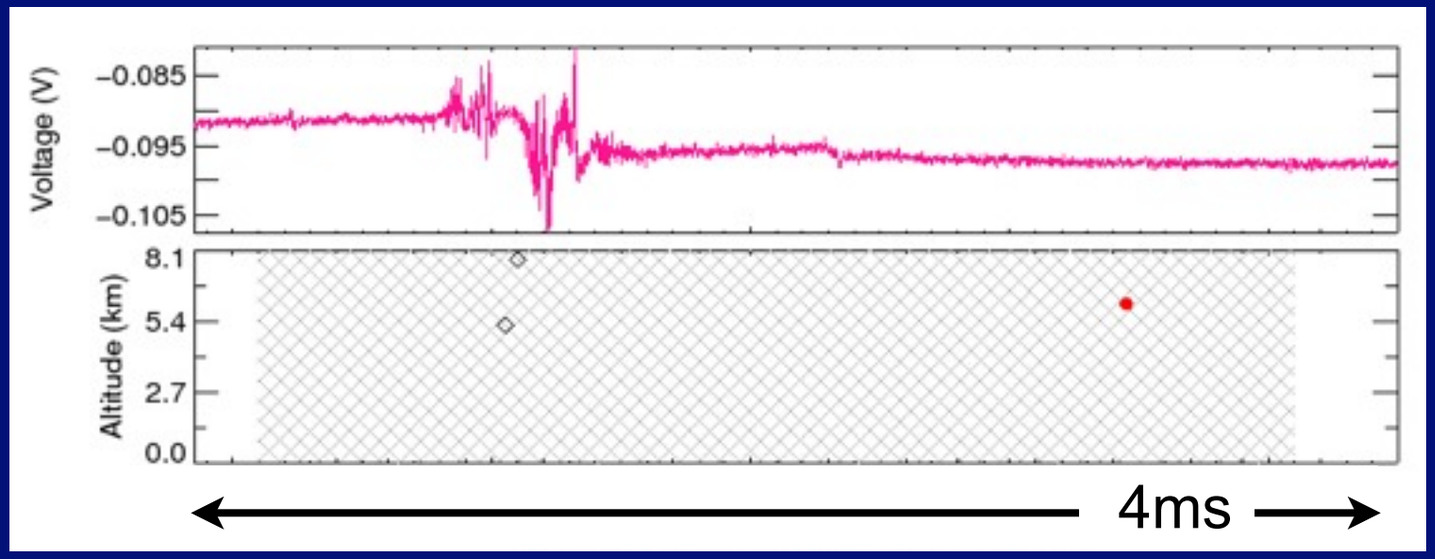
Seconds; Reference time of origin: 04:25:58

What is a hit?


Voltage (V)
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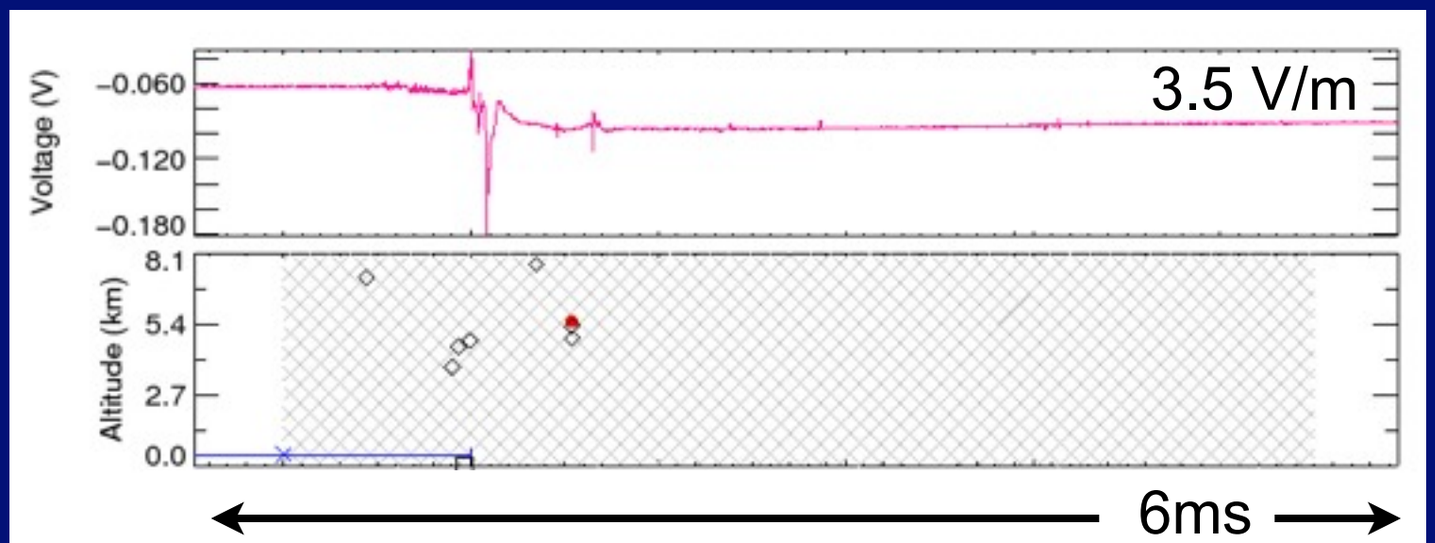
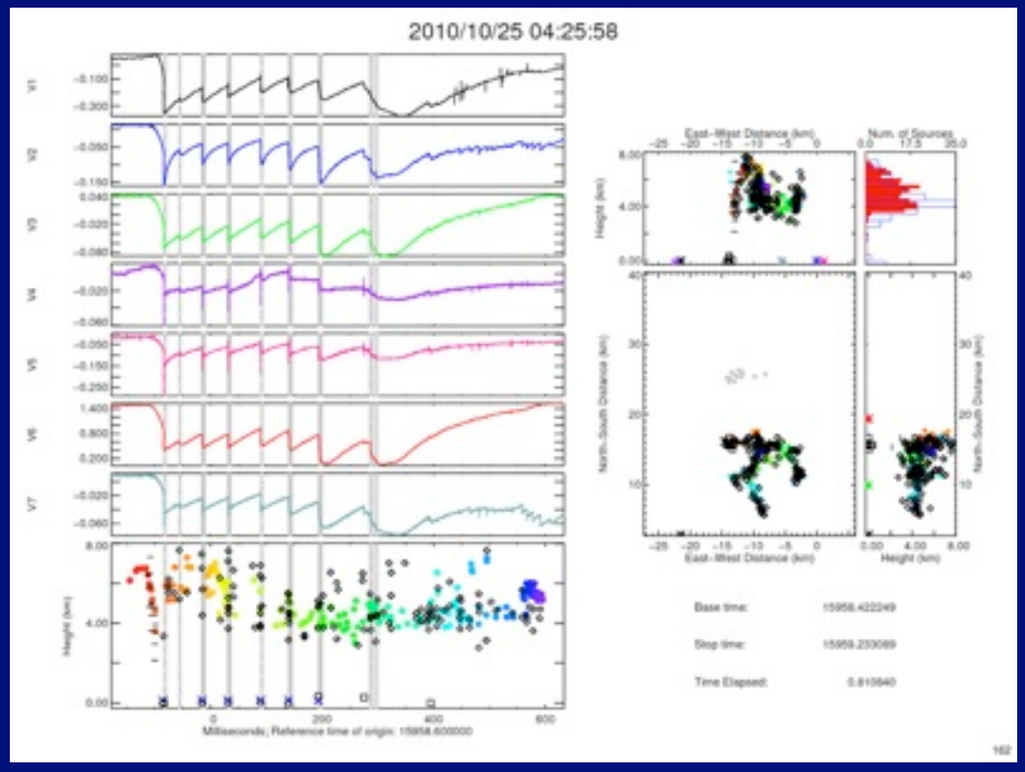
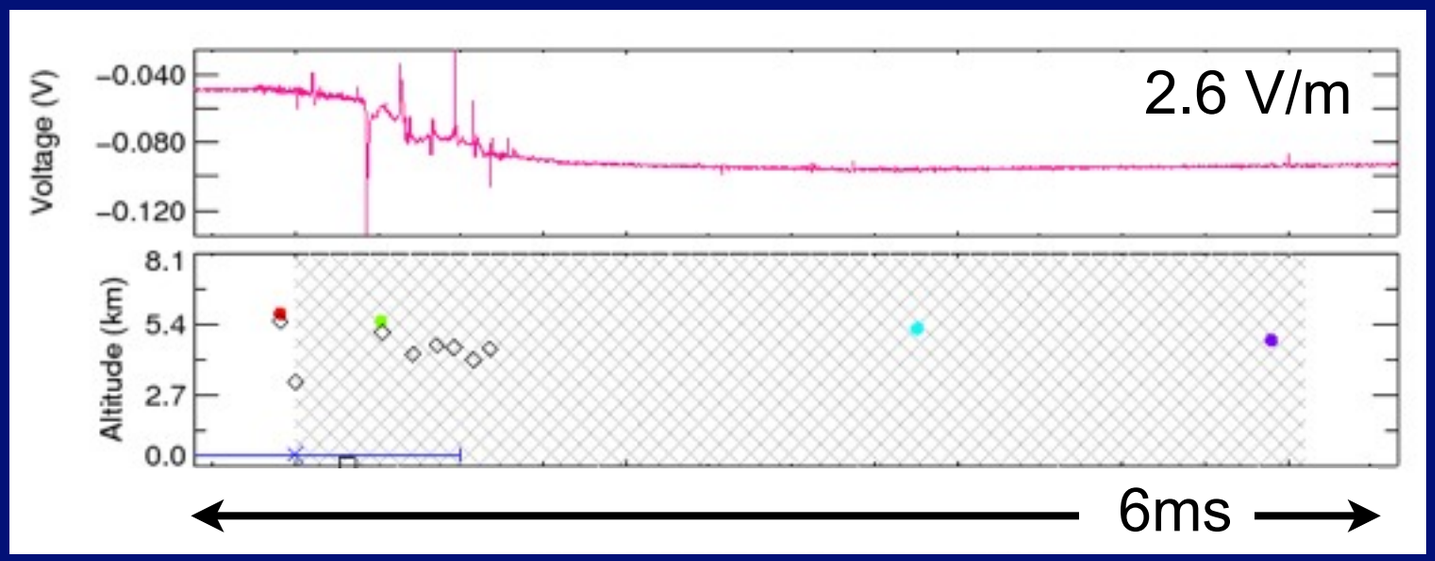
−0.095
−0.105
Altitude (km)
8.1
5.4
2.7
0.0
4ms


Voltage (V)
−0.060
−0.120
−0.180
3.5 V/m
Altitude (km)
8.1
5.4
2.7
0.0
6ms


2010/10/25 04:25:58
East-West Distance (km)
Num. of Sources
Height (km)
North-South Distance (km)
Base time:
Stop time:
Time Elapsed:
Milliseconds; Reference time of origin: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Altitude (km)
8.1
5.4
2.7
0.0
6ms

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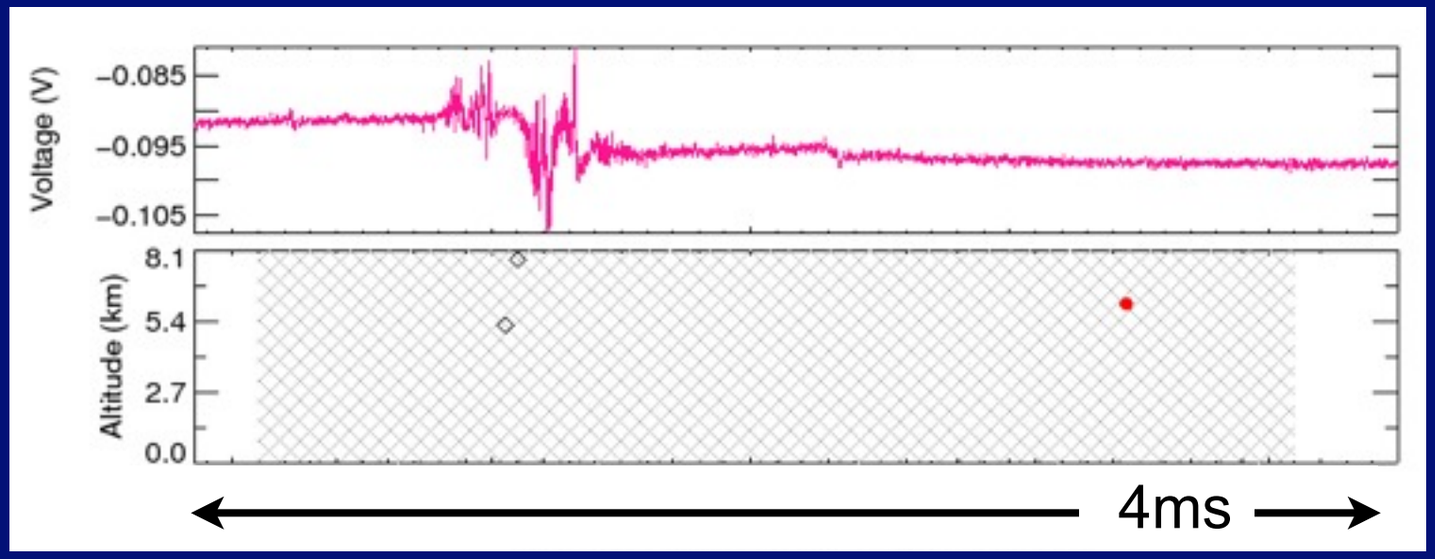
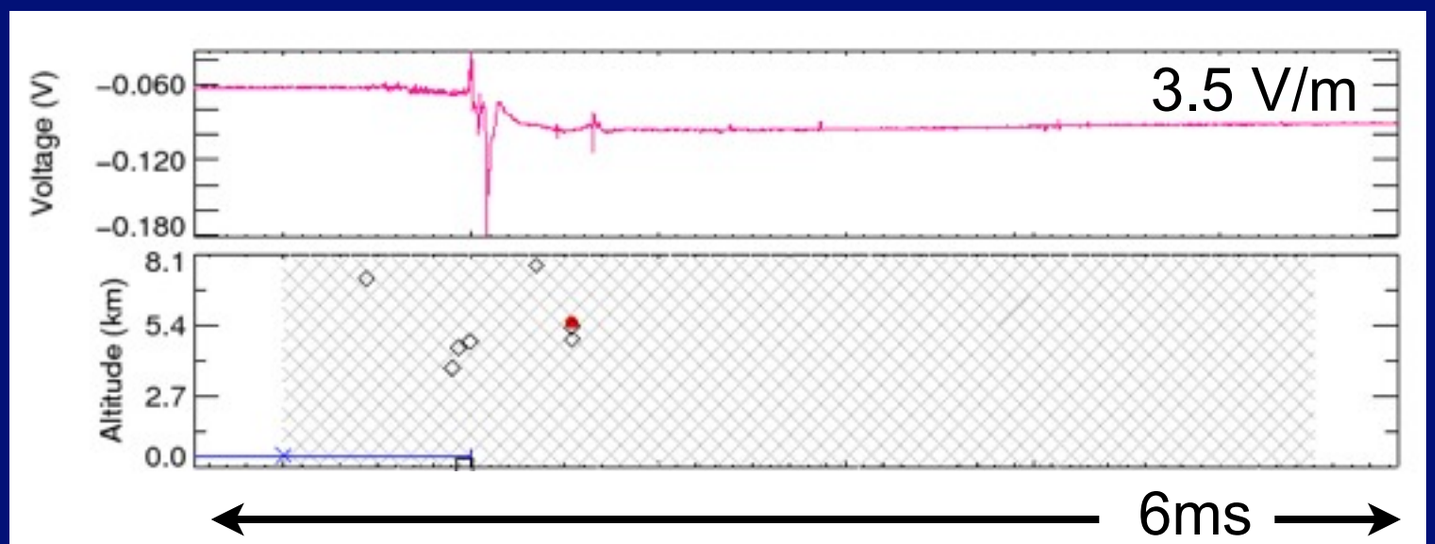
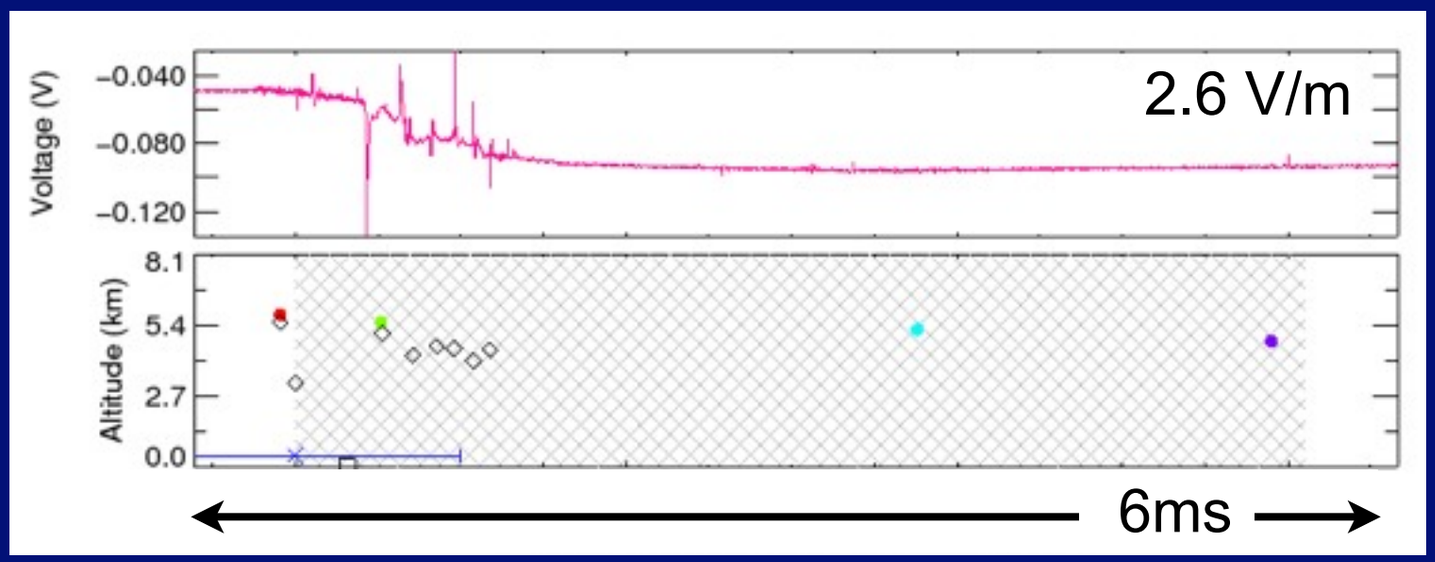
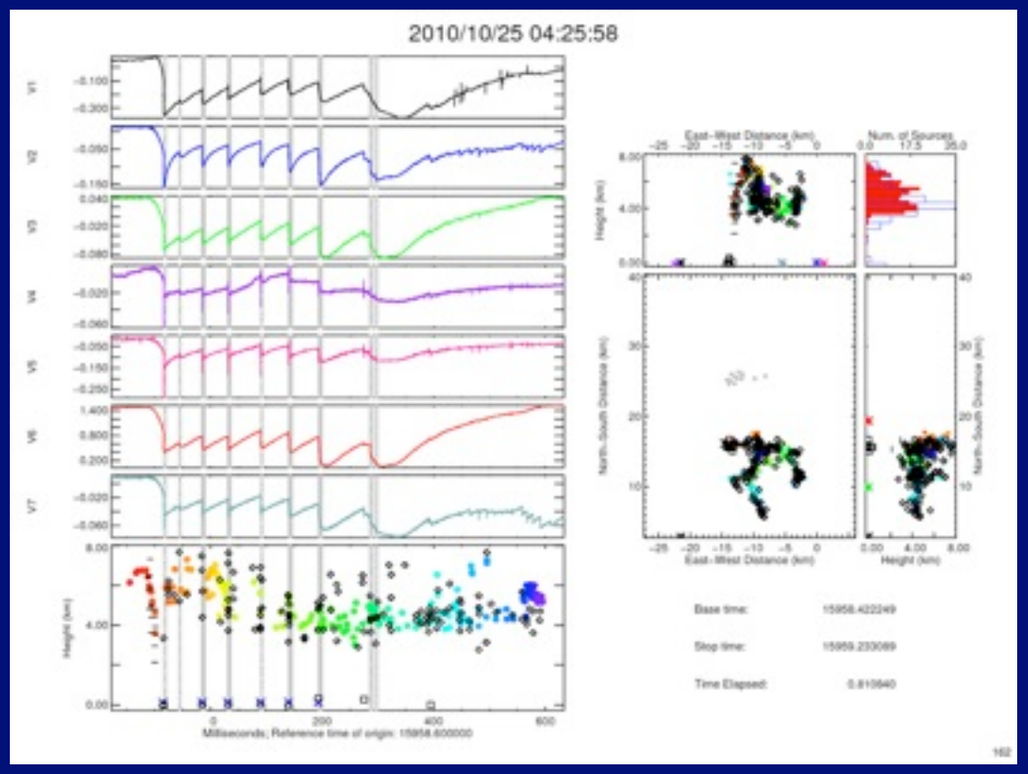


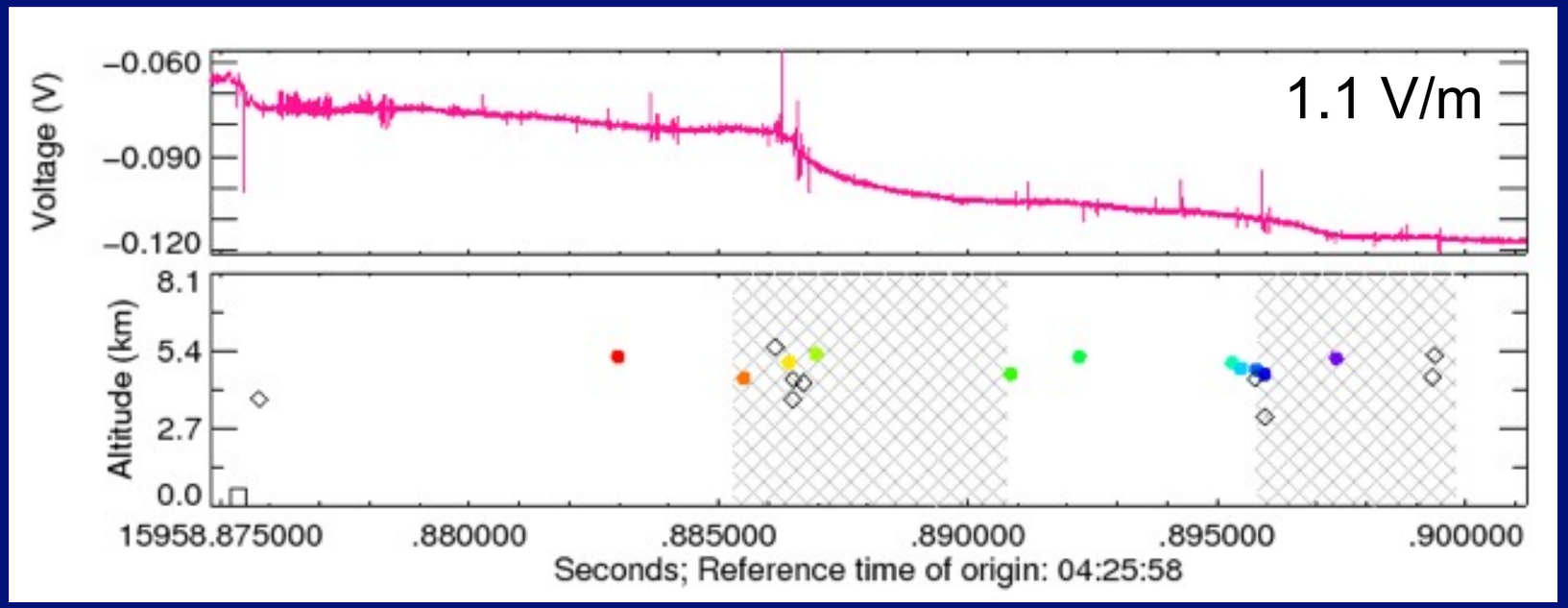


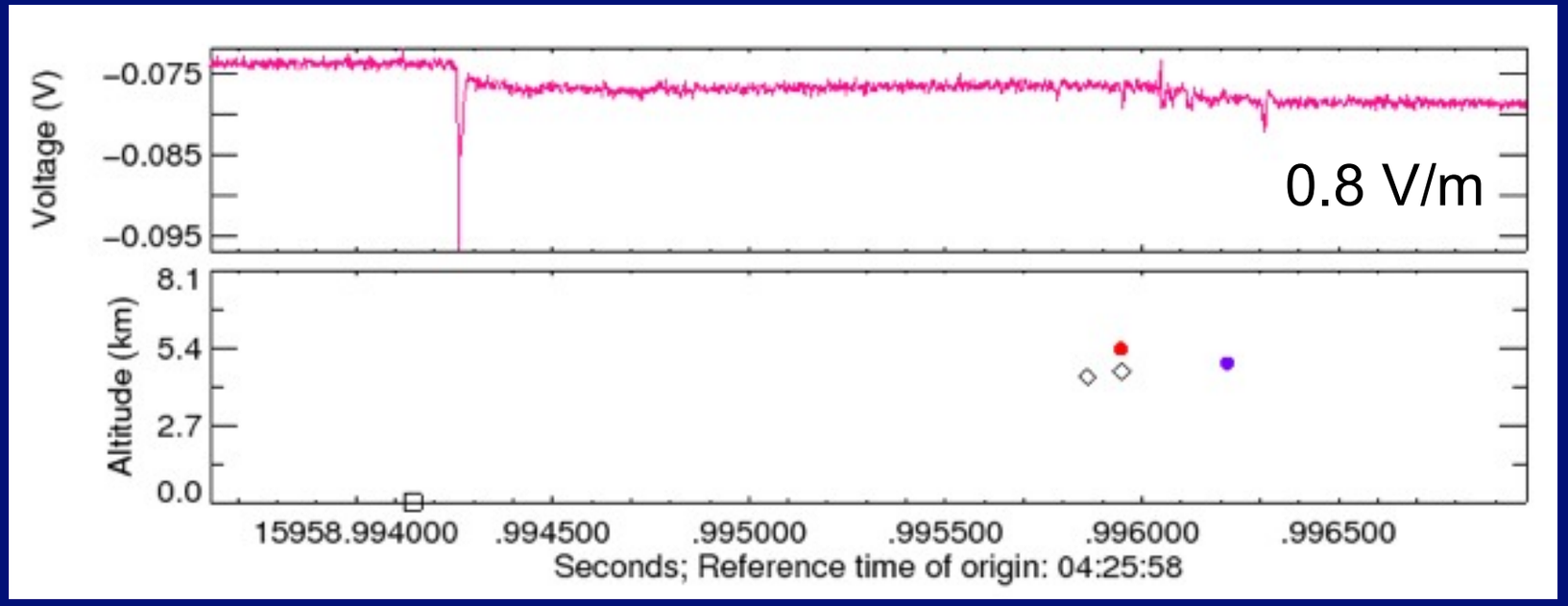




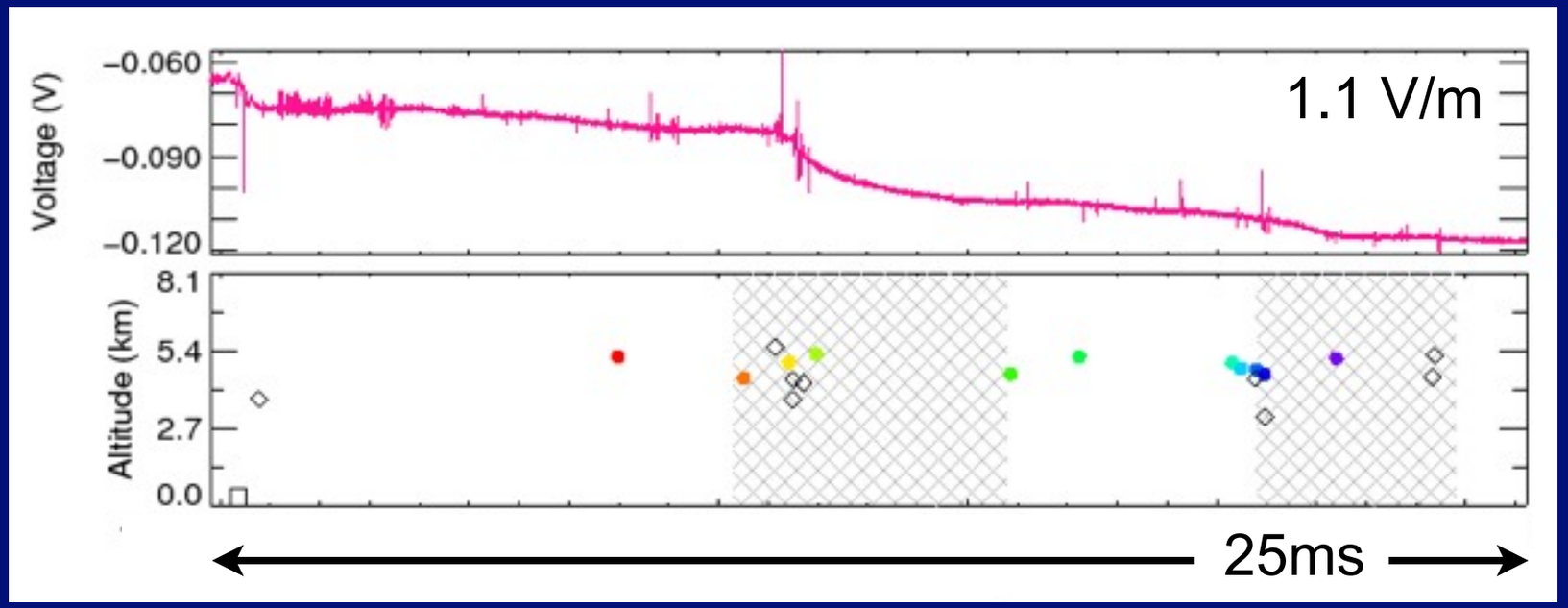
Wideband record indicates activity during LIS groups

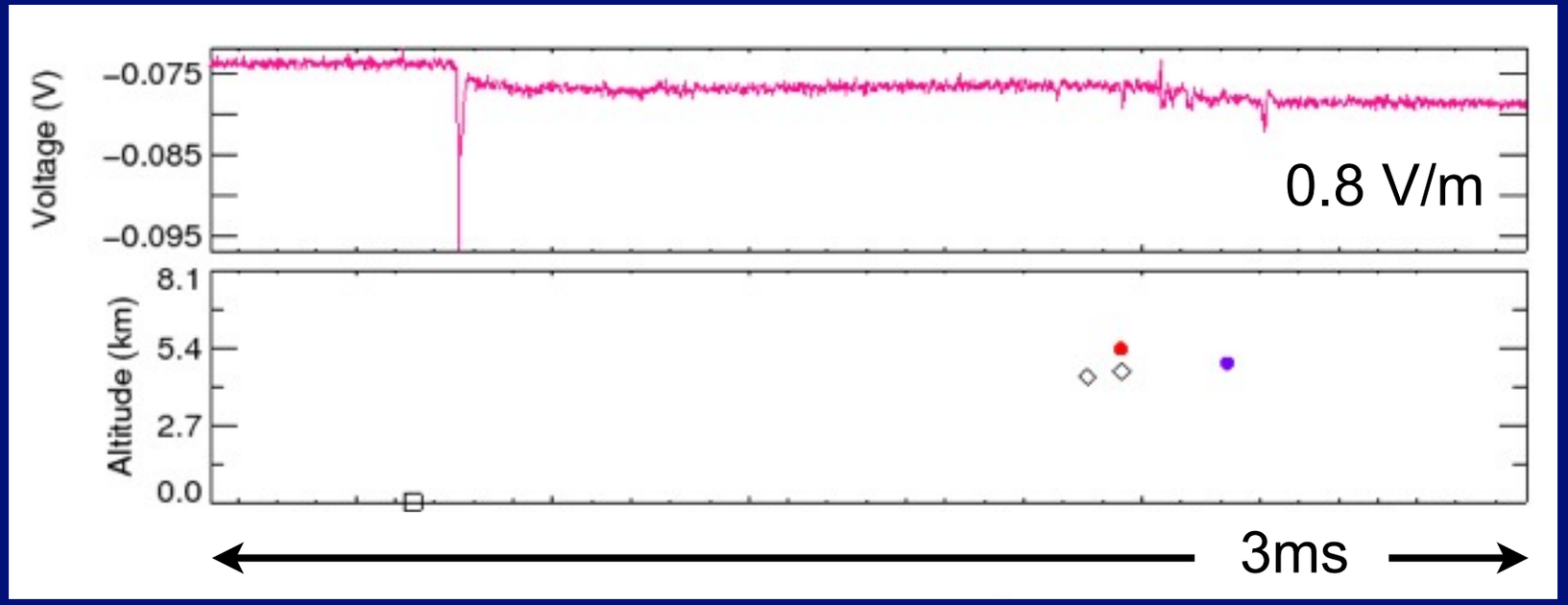
What is a miss?



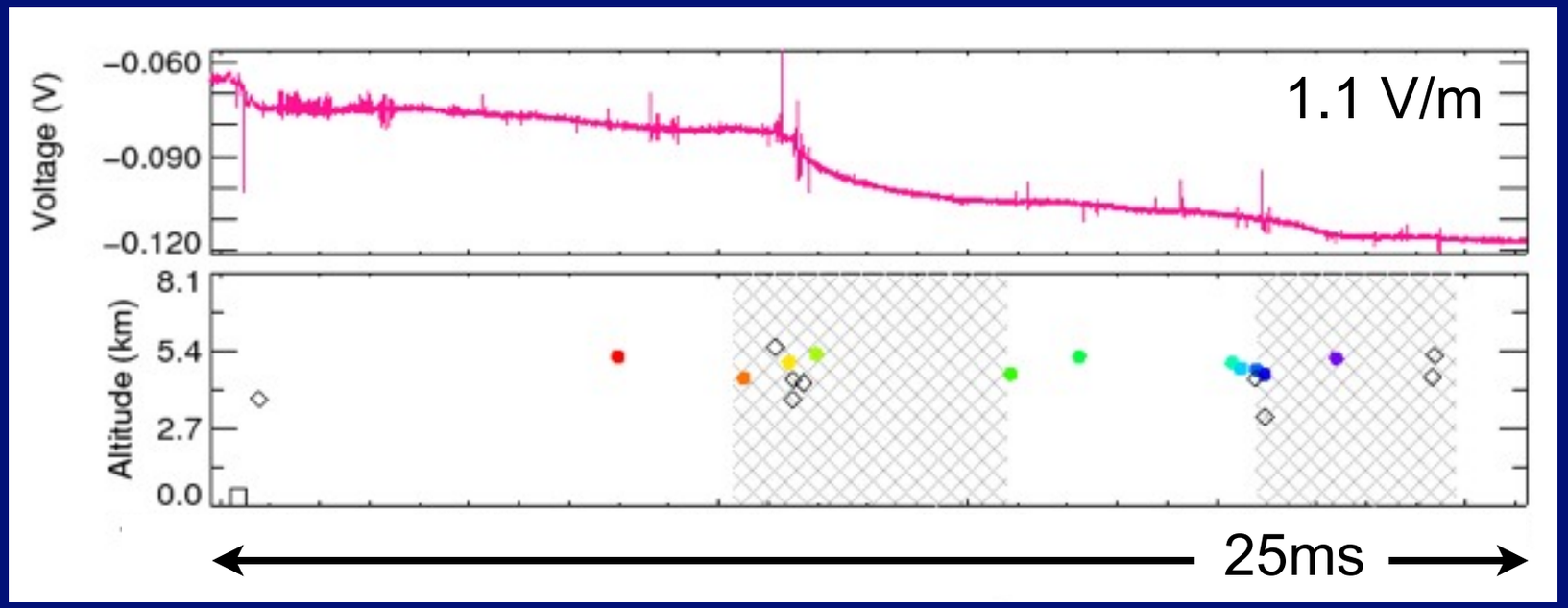


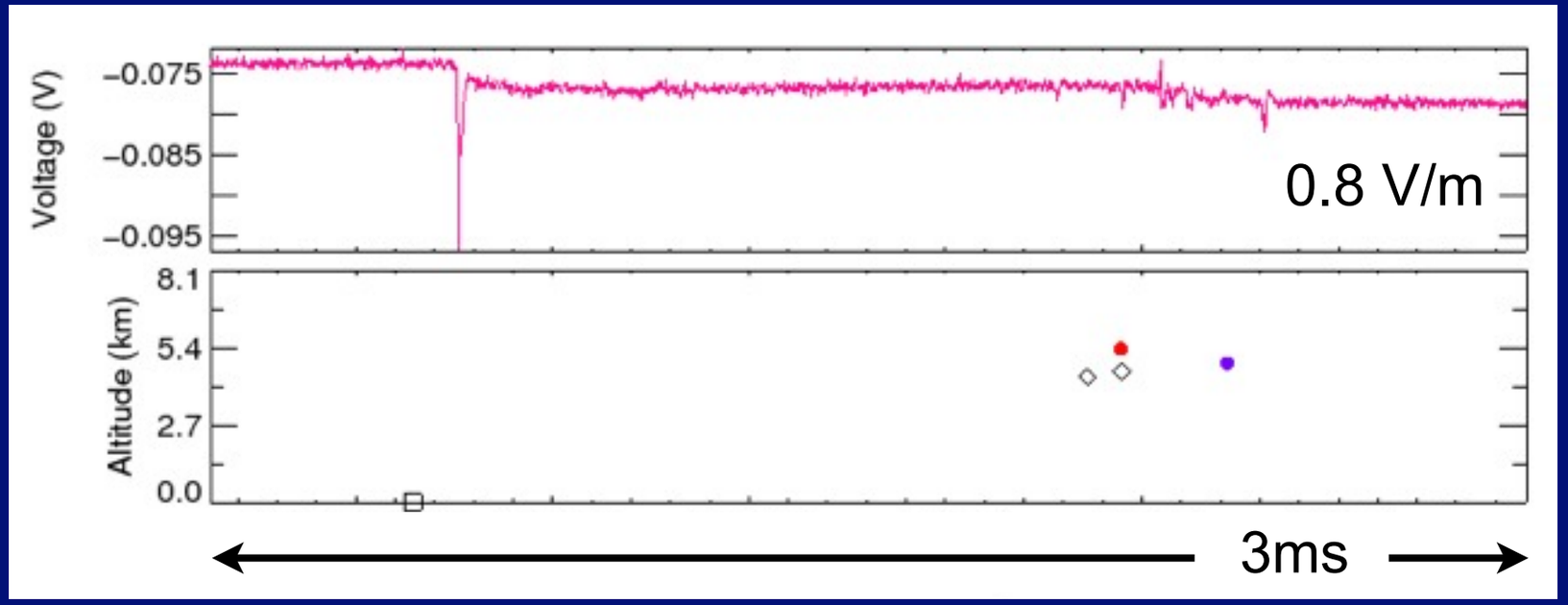
What is a miss?





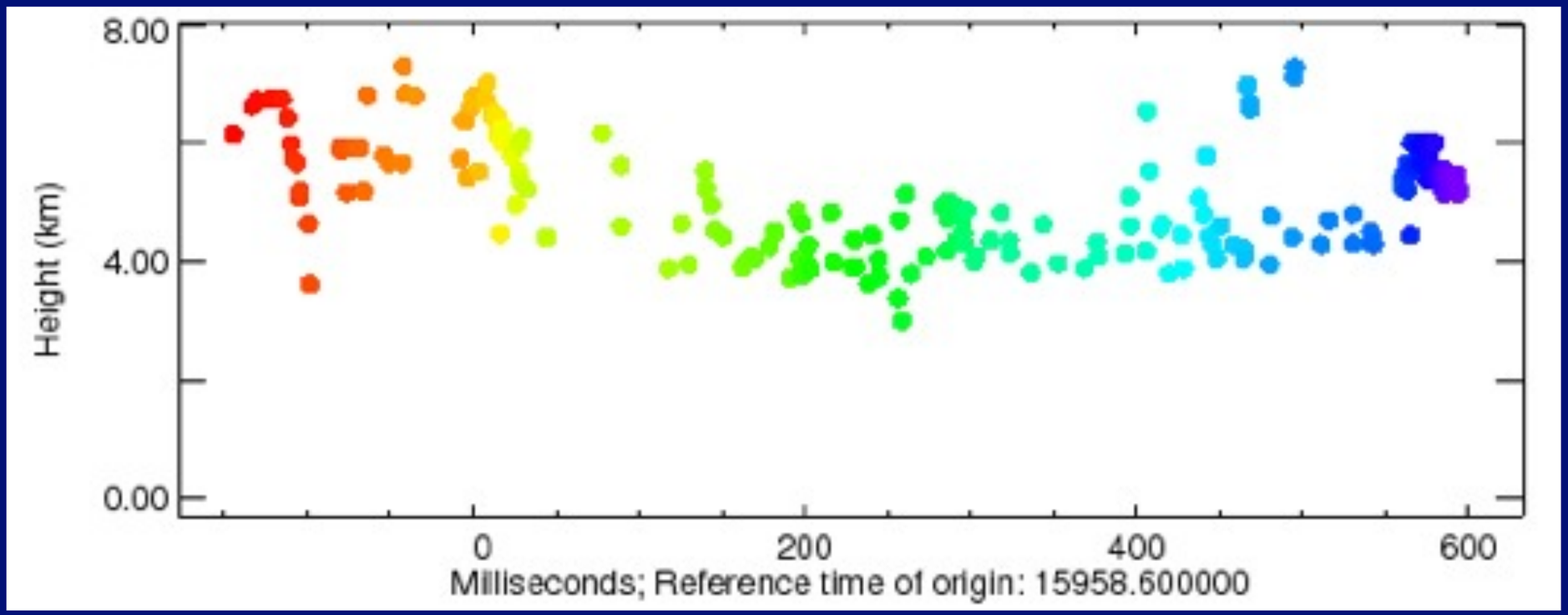
What is a miss?





Electric field measurements indicate that LIS missed these strokes because they are not very ***energetic***

What can VHF tell us?



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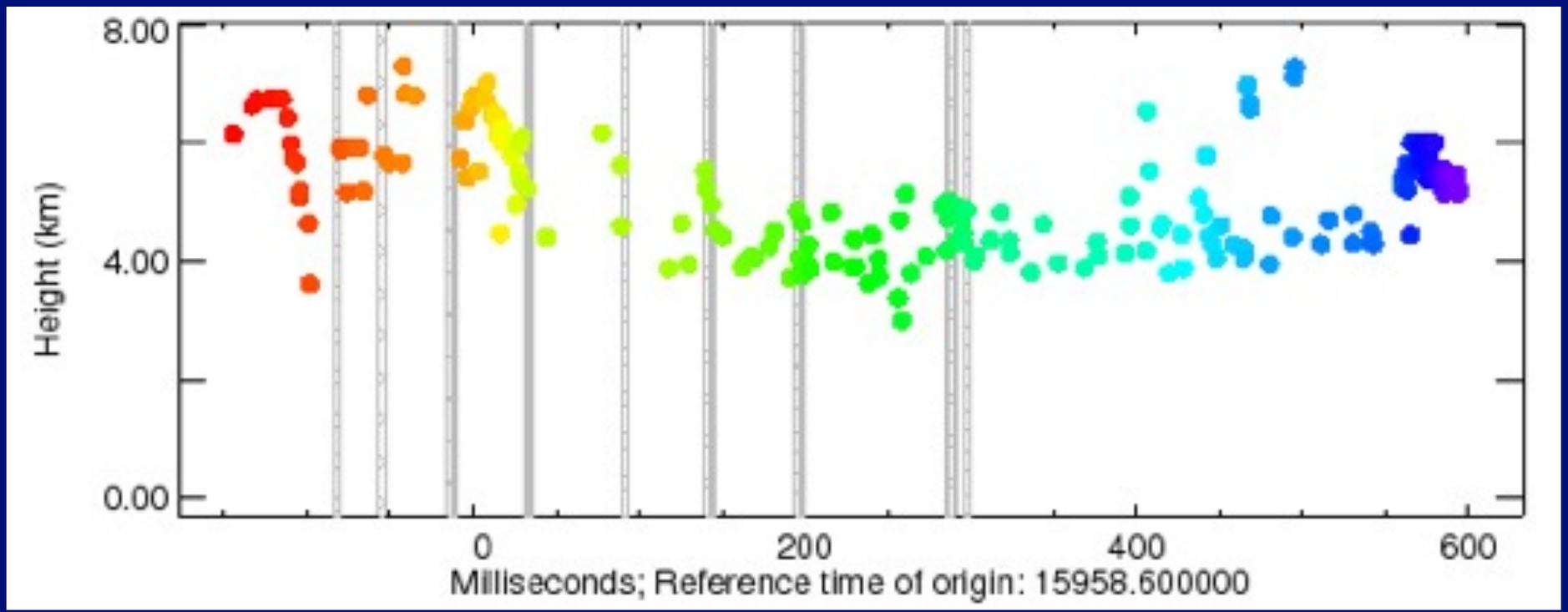

Nothing is really unique about VHF sources...

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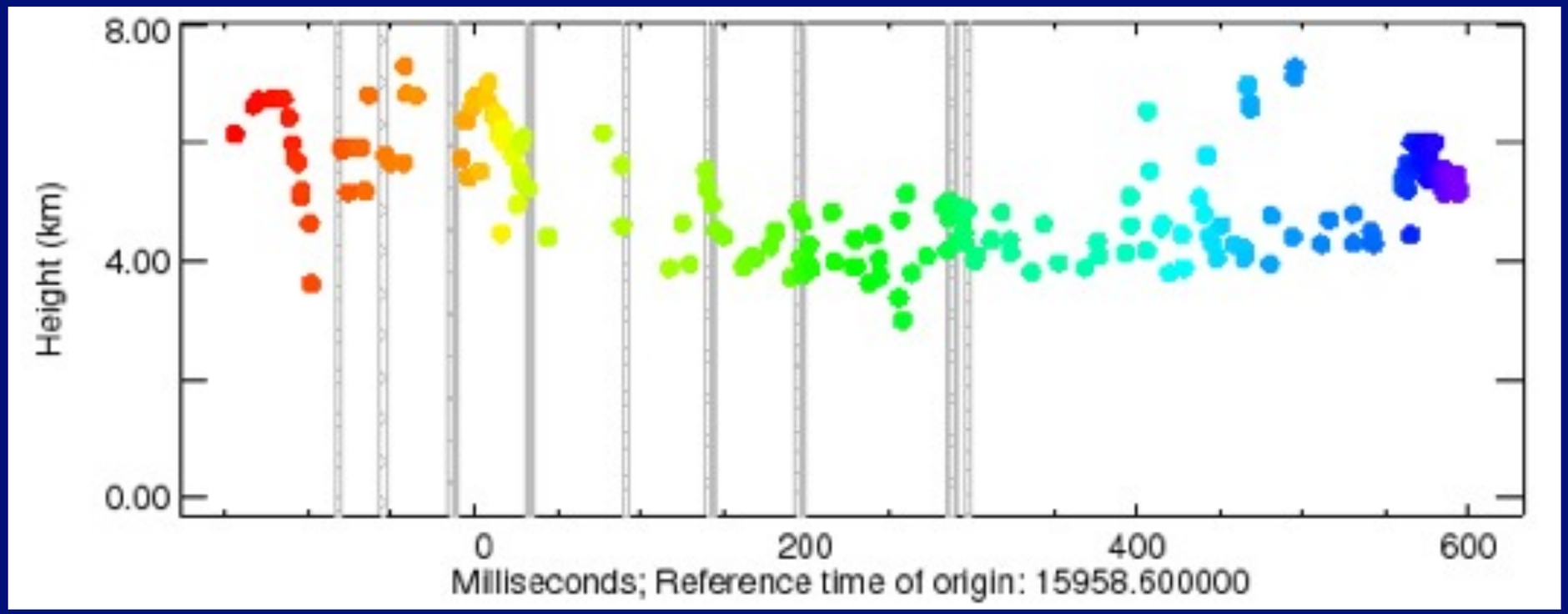

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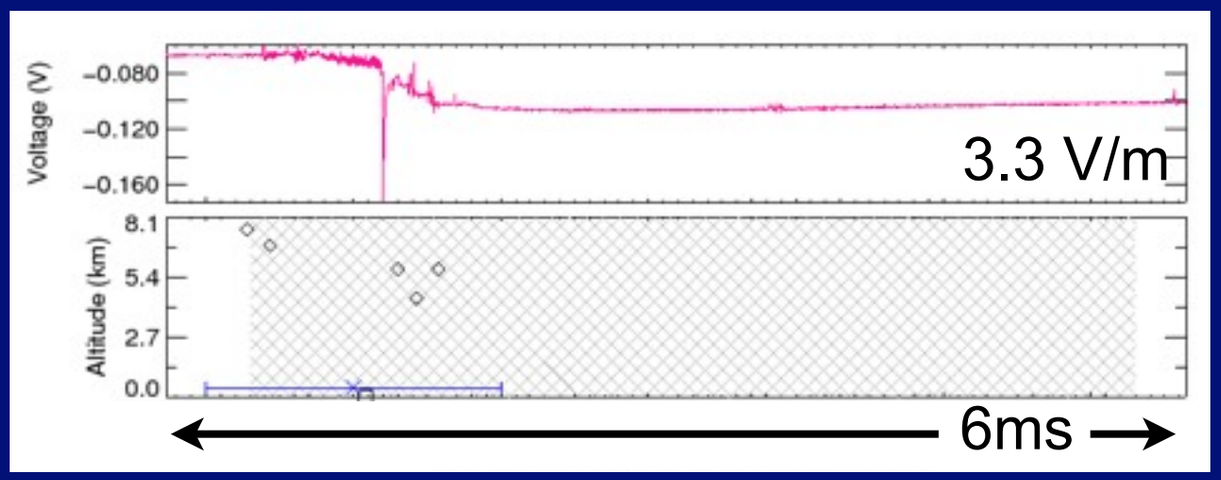

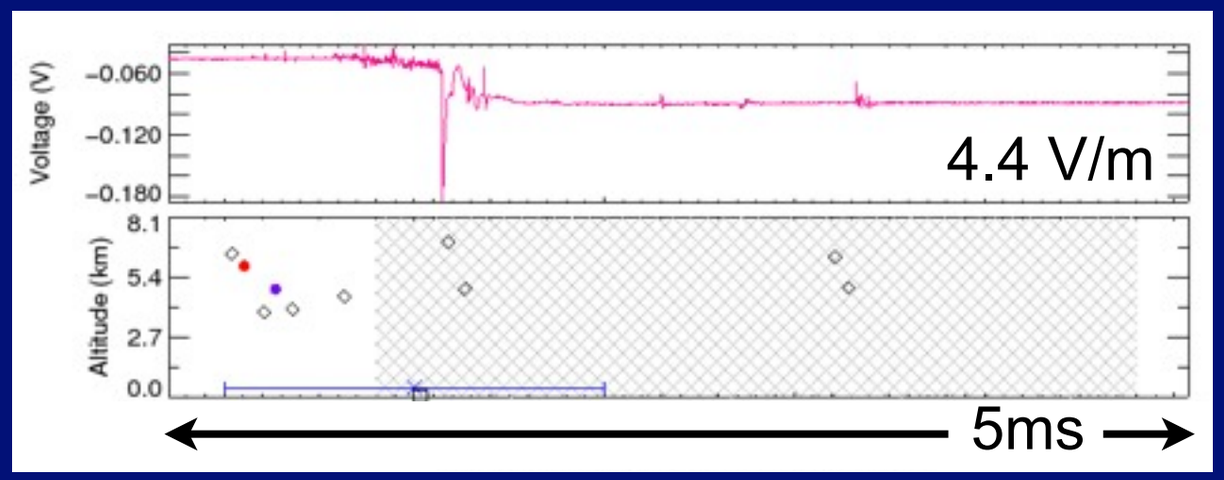

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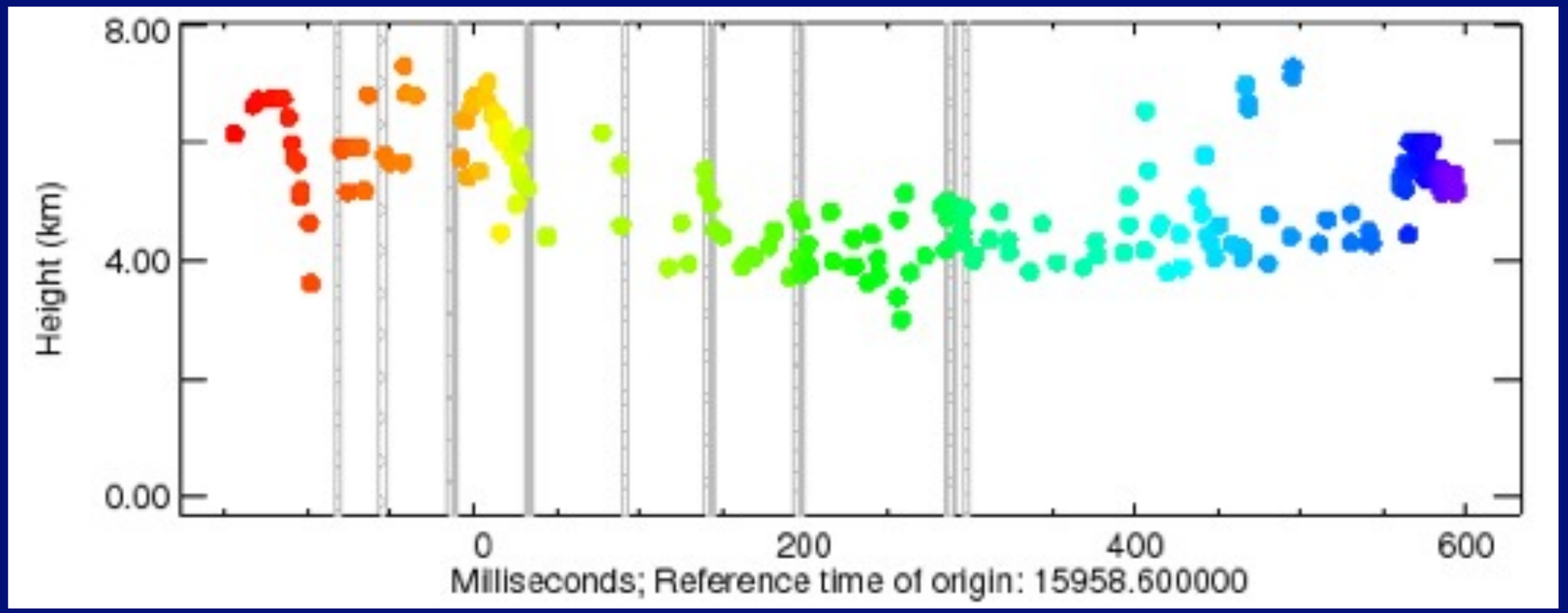

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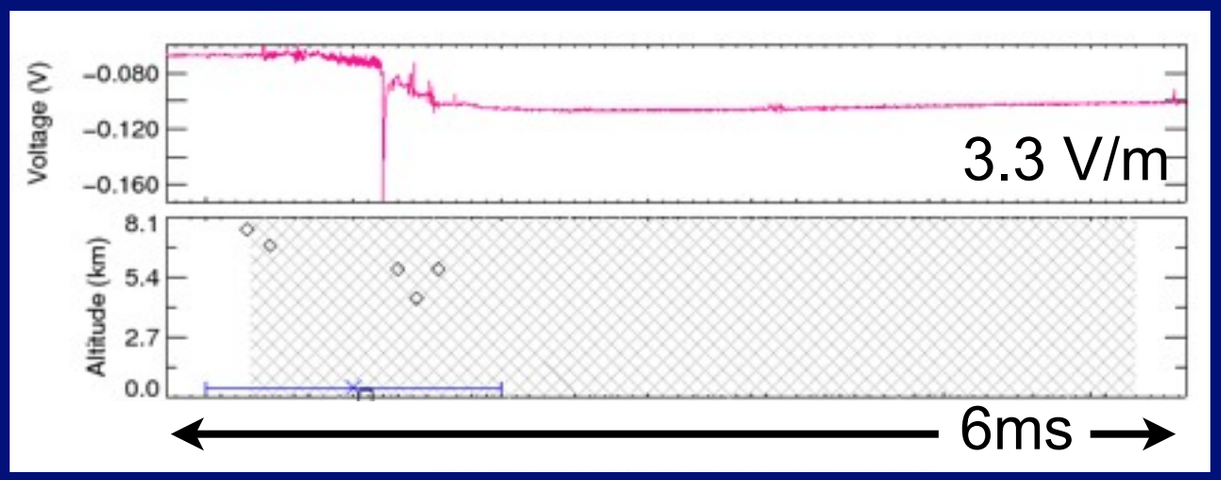
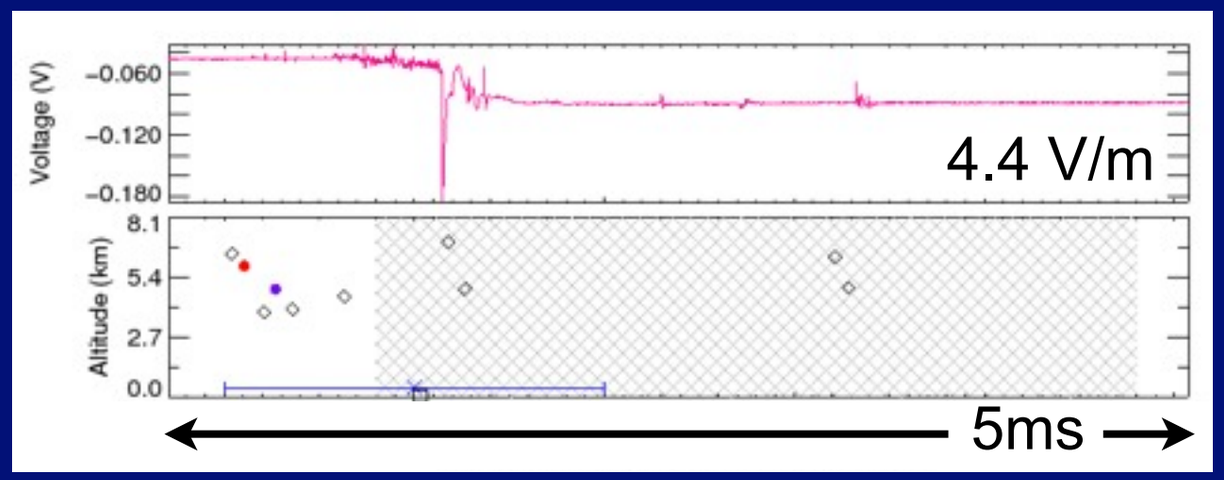
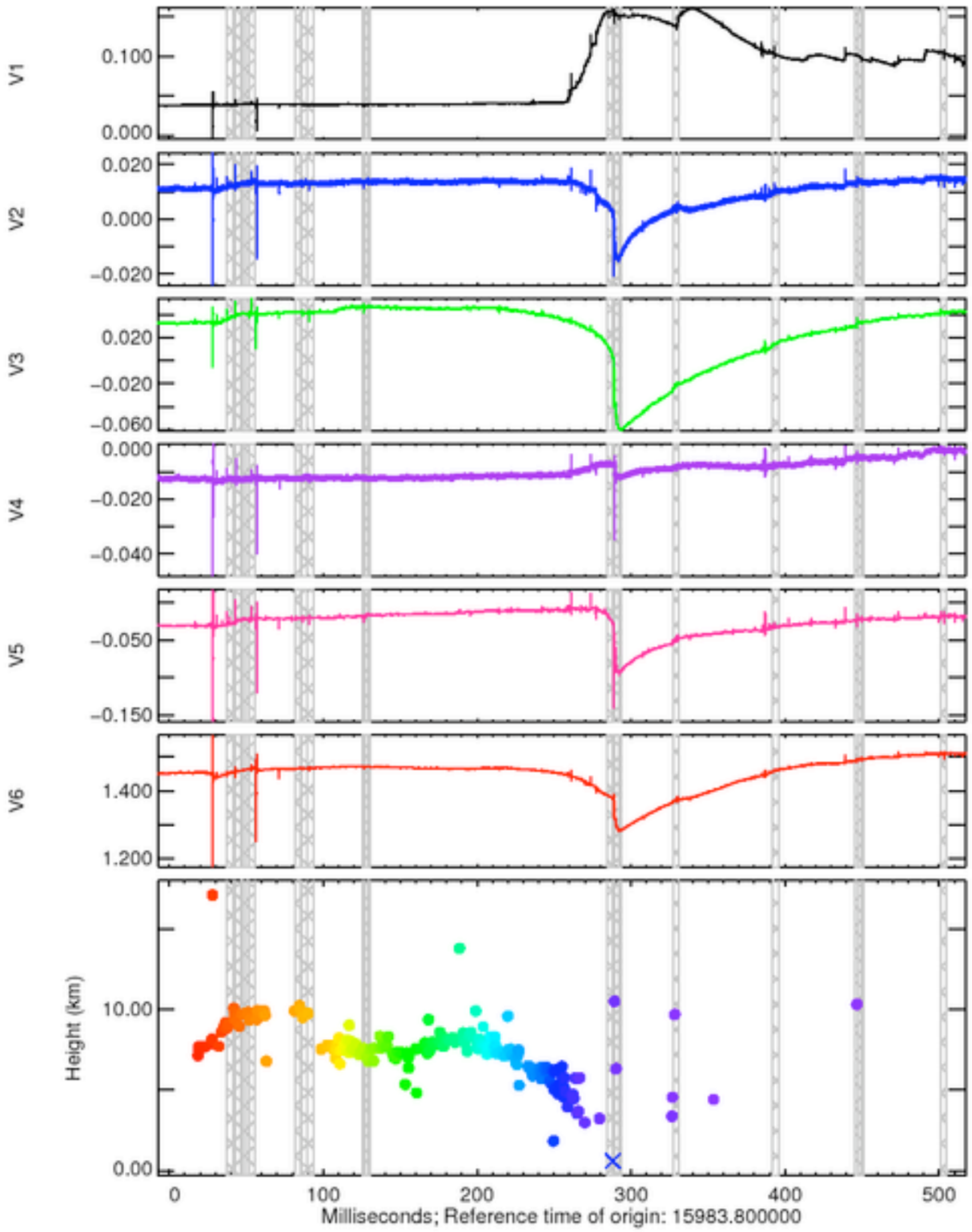
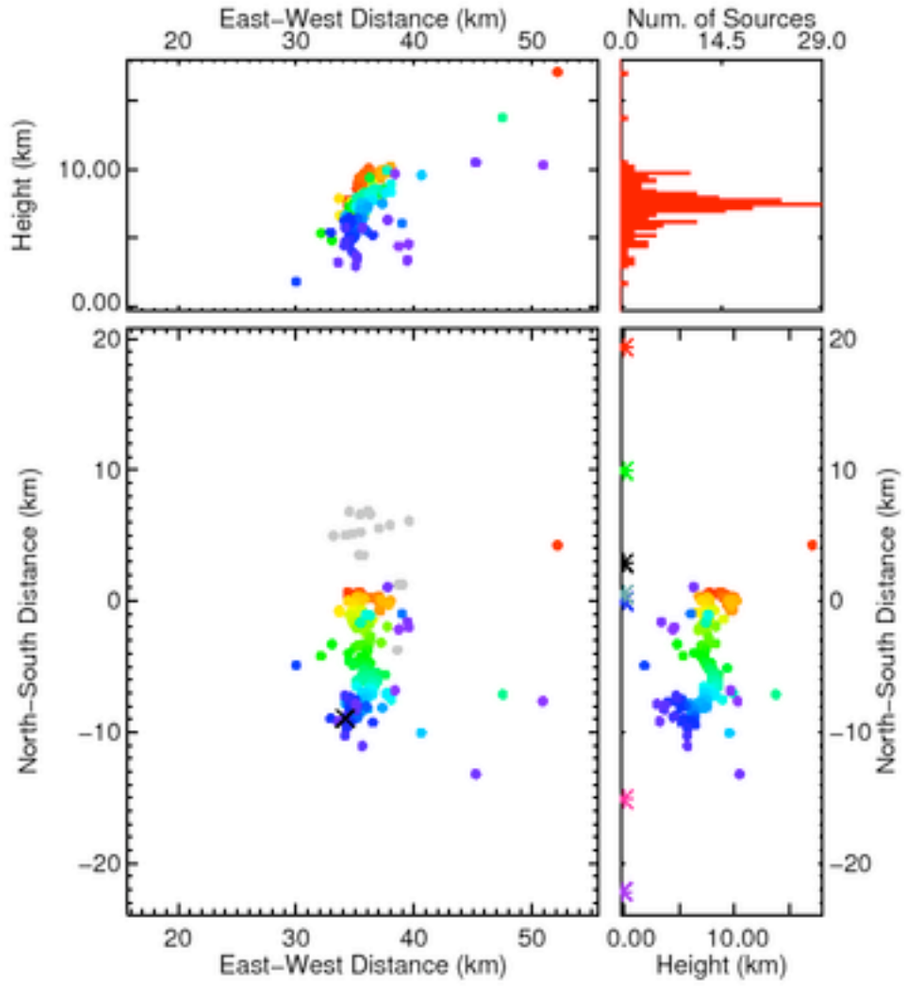




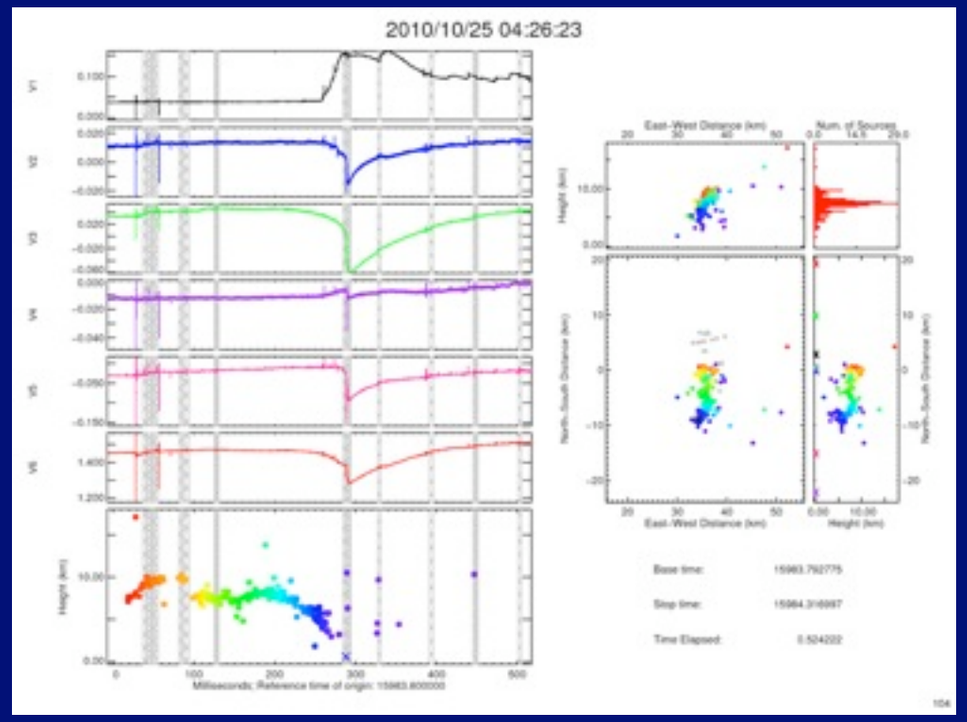
...in fact, there are LIS groups without any detected VHF sources!

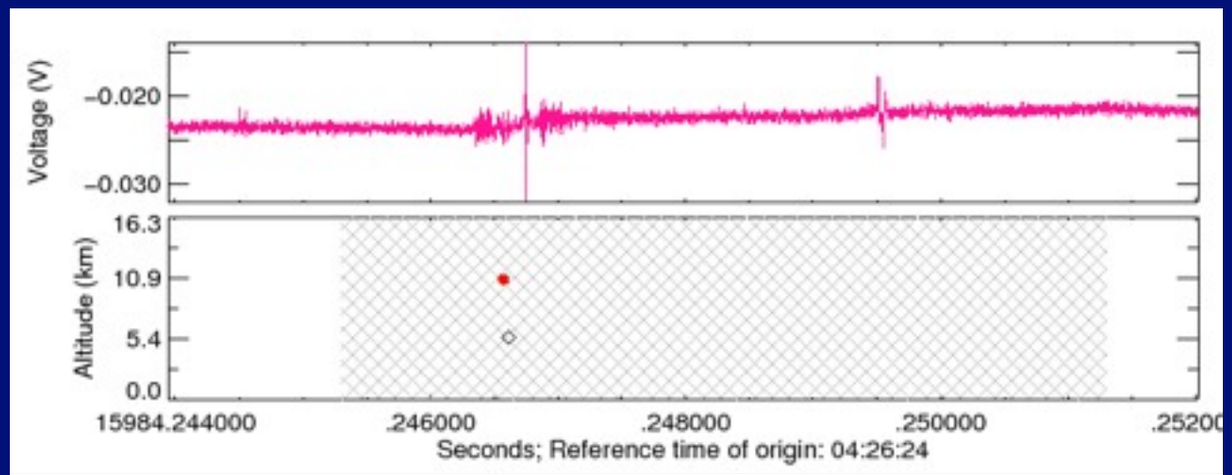
2010/10/25 04:26:23

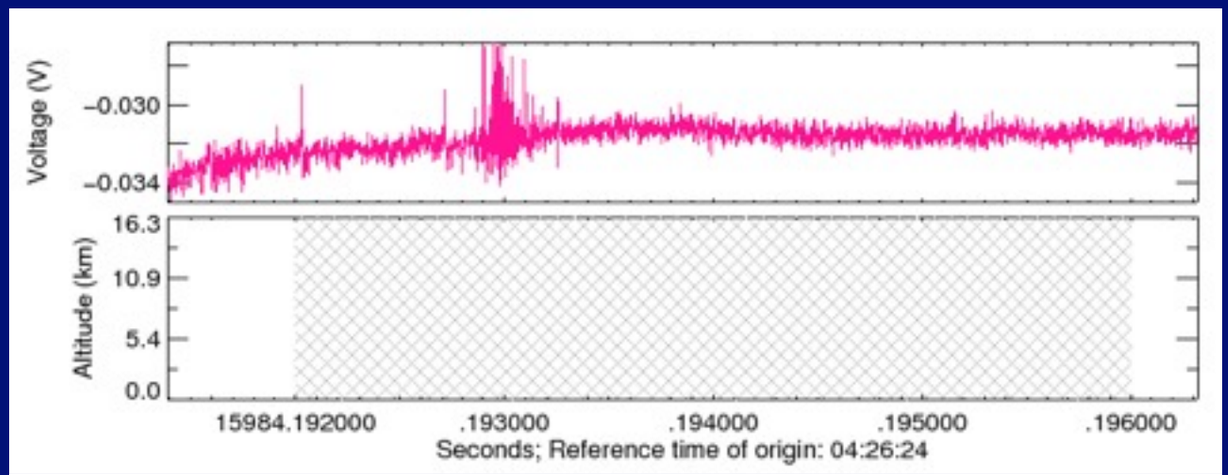


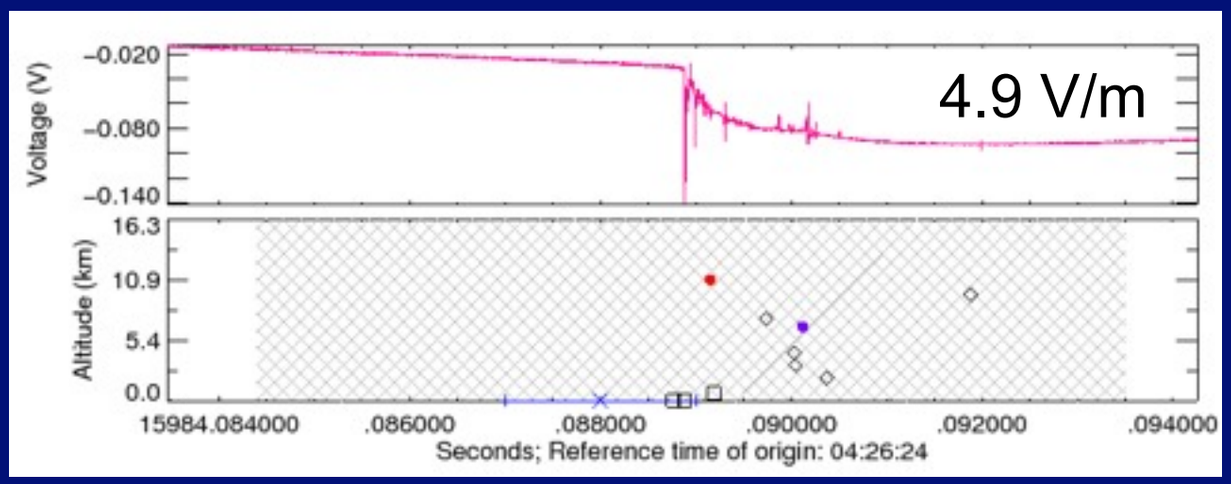


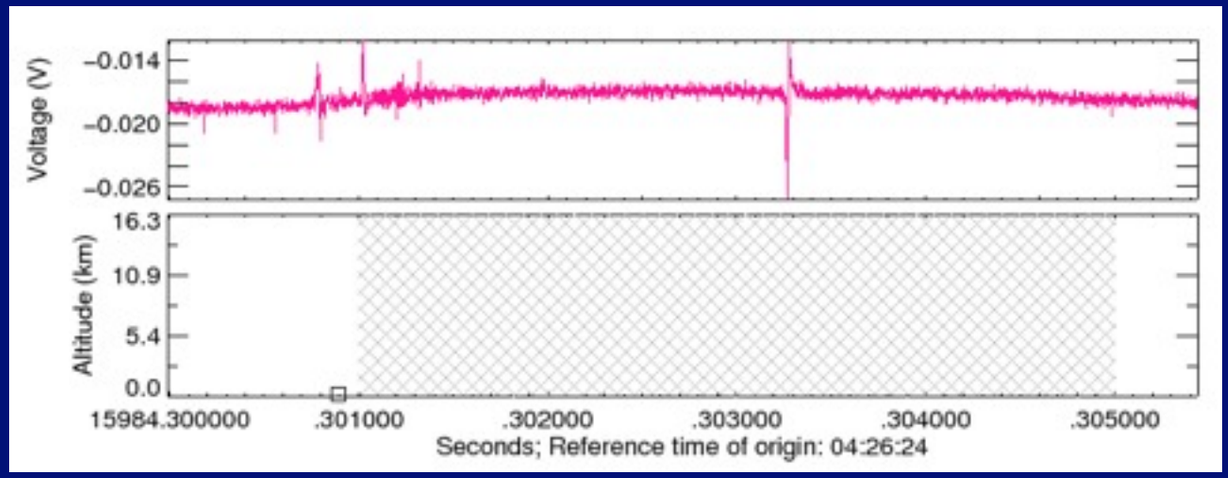
Base time:	15983.792775
Stop time:	15984.316997
Time Elapsed:	0.524222

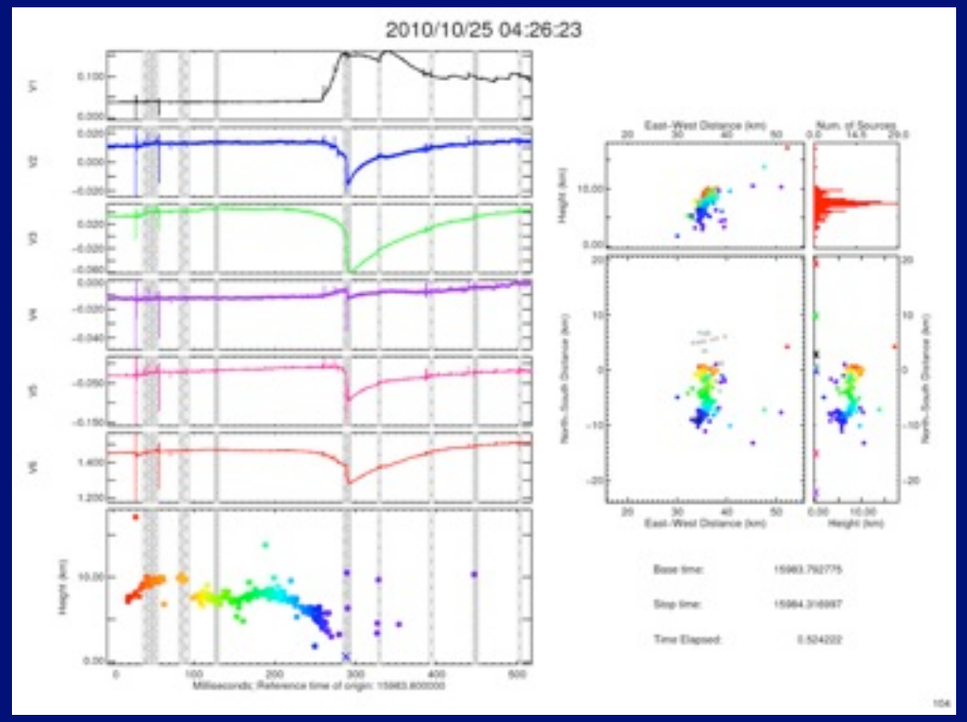

2010/10/25 04:26:23
East-West Distance (km)
Num. of Sources
Height (km)
North-South Distance (km)
Base time:
Stop time:
Time Elapsed:
Milliseconds; Reference time of origin:

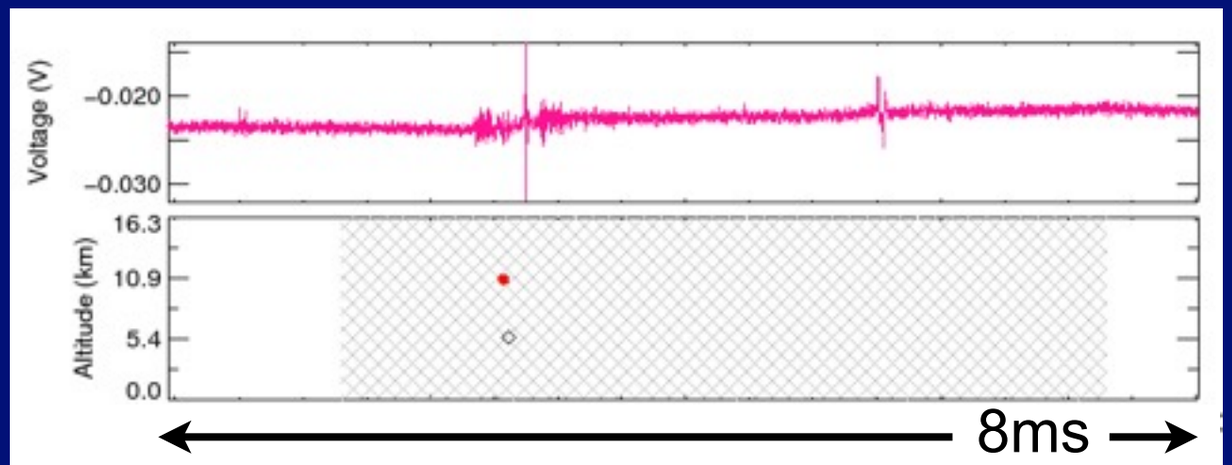

Voltage (V)
-0.020
-0.030
Altitude (km)
16.3
10.9
5.4
0.0
15984.244000
.246000
.248000
.250000
Seconds; Reference time of origin: 04:26:24

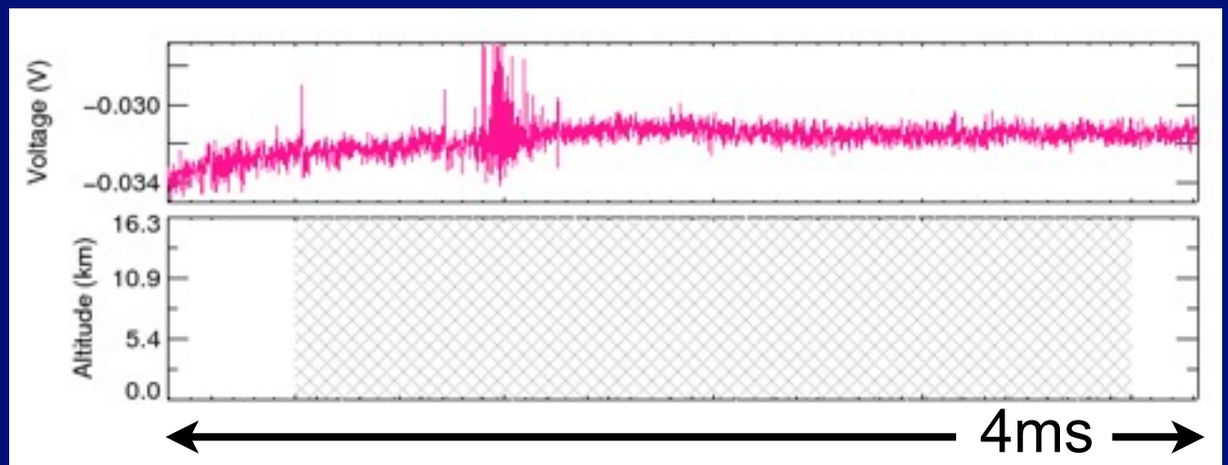

Voltage (V)
-0.030
-0.034
Altitude (km)
16.3
10.9
5.4
0.0
15984.192000
.193000
.194000
.195000
.196000
Seconds; Reference time of origin: 04:26:24

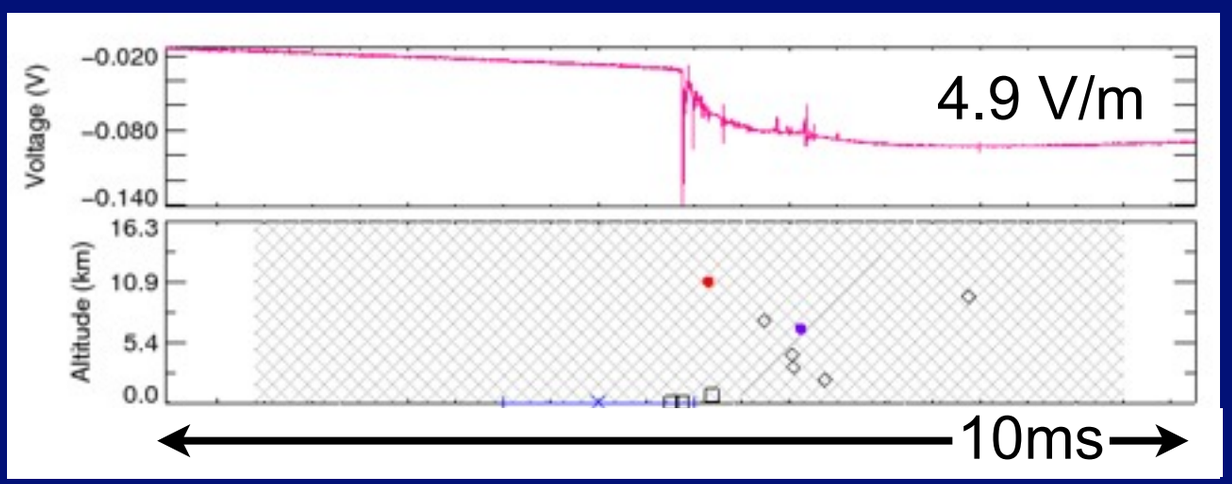

4.9 V/m
Voltage (V)
-0.020
-0.080
-0.140
Altitude (km)
16.3
10.9
5.4
0.0
15984.084000
.086000
.088000
.090000
.092000
.094000
Seconds; Reference time of origin: 04:26:24

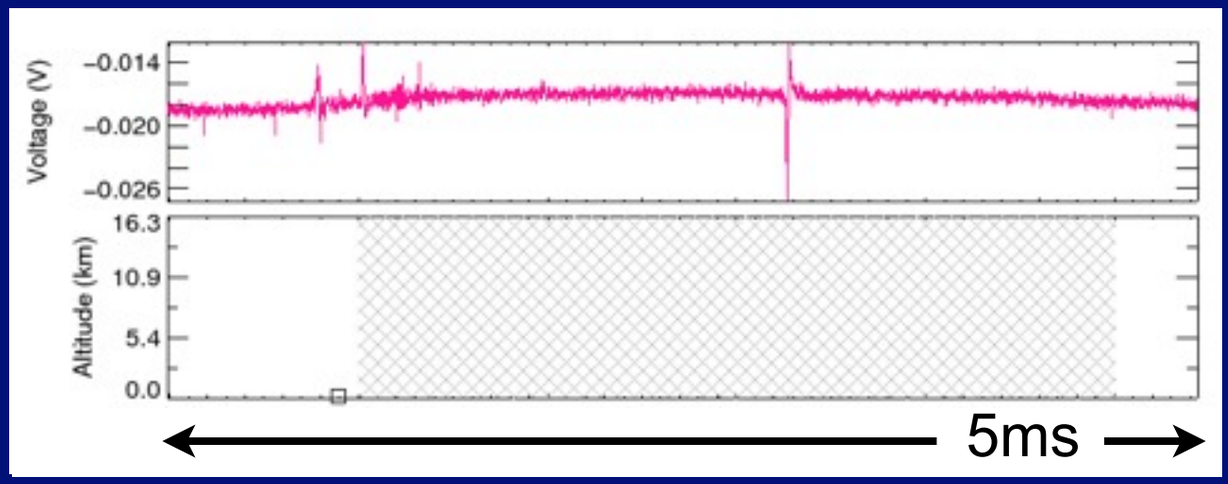

Voltage (V)
-0.014
-0.020
-0.026
Altitude (km)
16.3
10.9
5.4
0.0
15984.300000
.301000
.302000
.303000
.304000
.305000
Seconds; Reference time of origin: 04:26:24

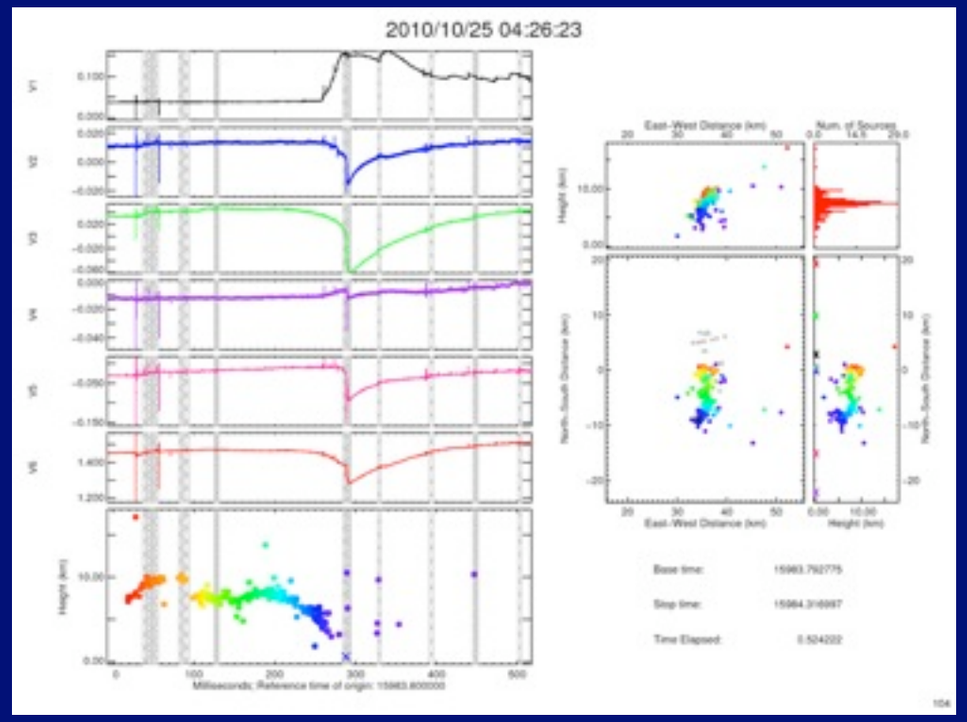

2010/10/25 04:26:23
East-West Distance (km)
Num. of Sources
Height (km)
North-South Distance (km)
Base time:
Stop time:
Time Elapsed:
Milliseconds; Reference time of origin:

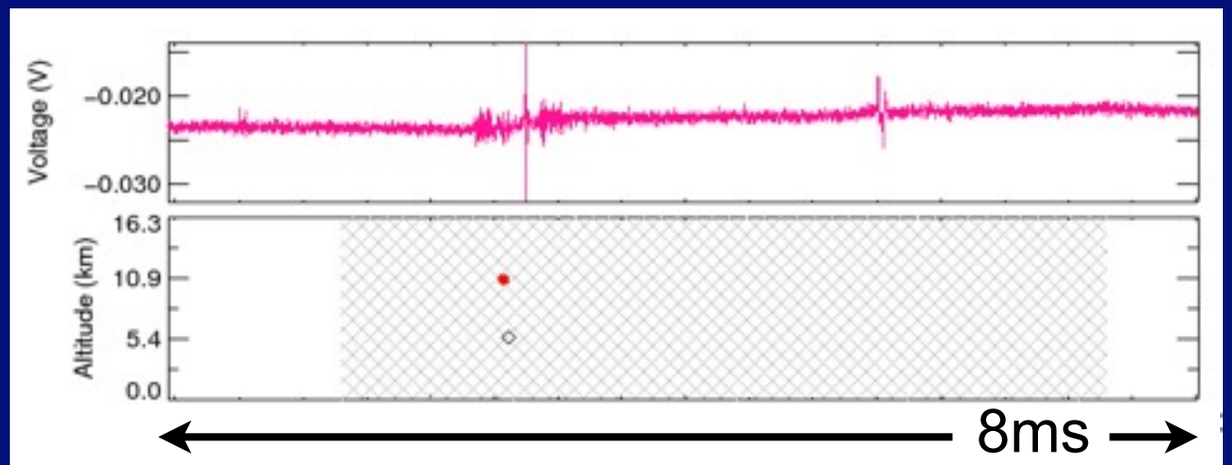

Voltage (V)
-0.020
-0.030
Altitude (km)
16.3
10.9
5.4
0.0
8ms

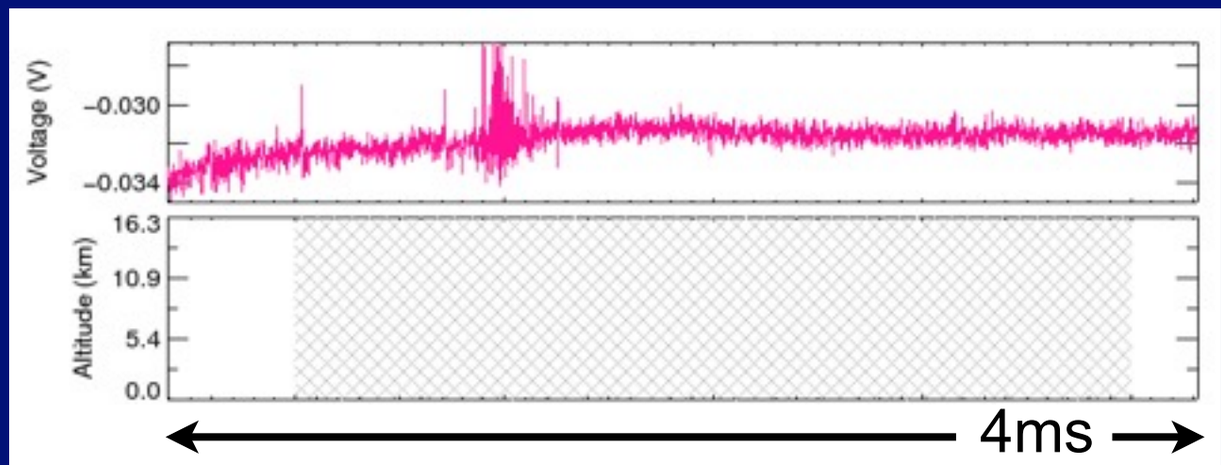

Voltage (V)
-0.030
-0.034
Altitude (km)
16.3
10.9
5.4
0.0
4ms

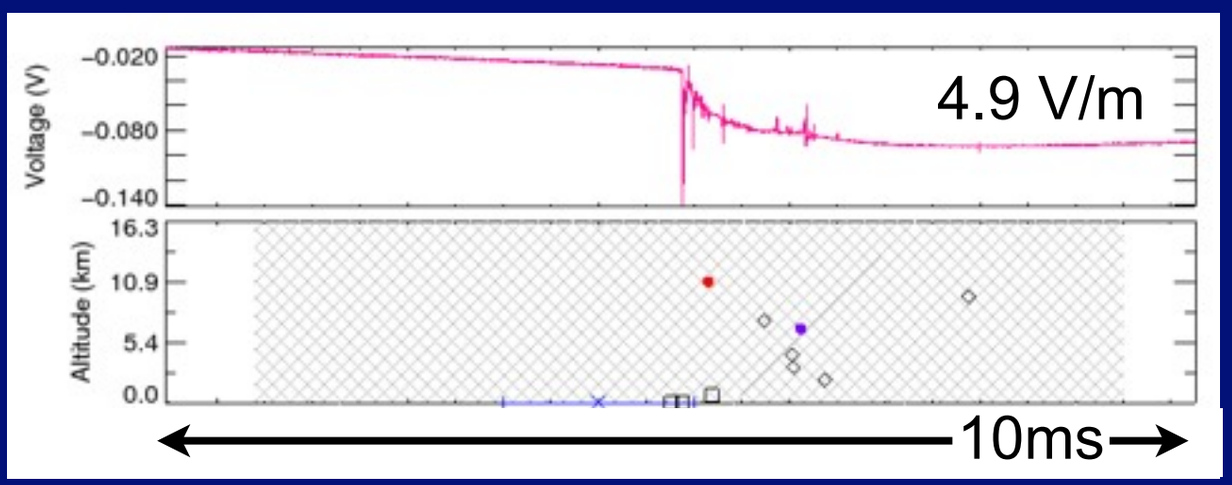

Voltage (V)
-0.020
-0.080
-0.140
4.9 V/m
Altitude (km)
16.3
10.9
5.4
0.0
10ms

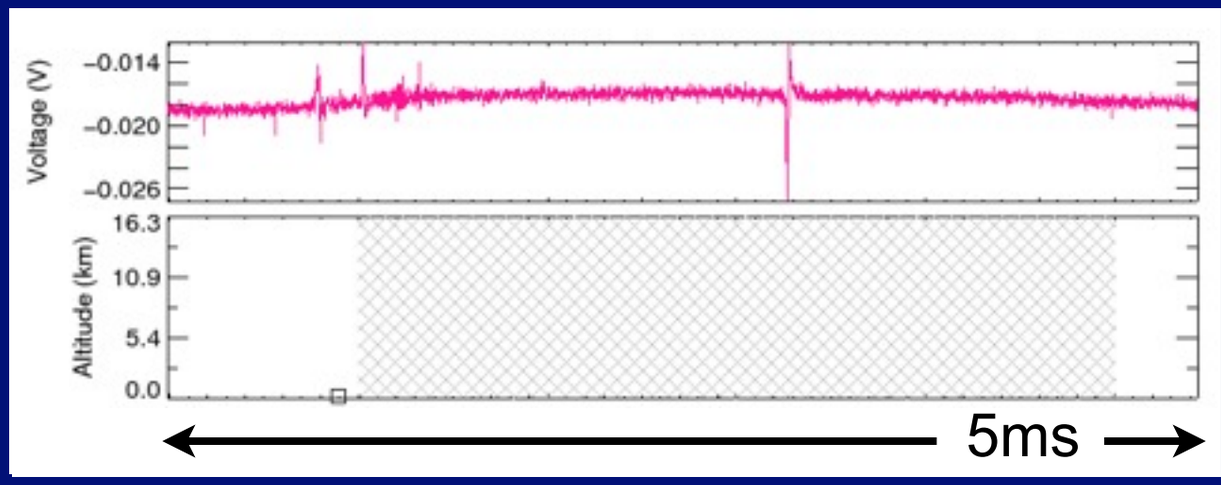

Voltage (V)
-0.014
-0.020
-0.026
Altitude (km)
16.3
10.9
5.4
0.0
5ms



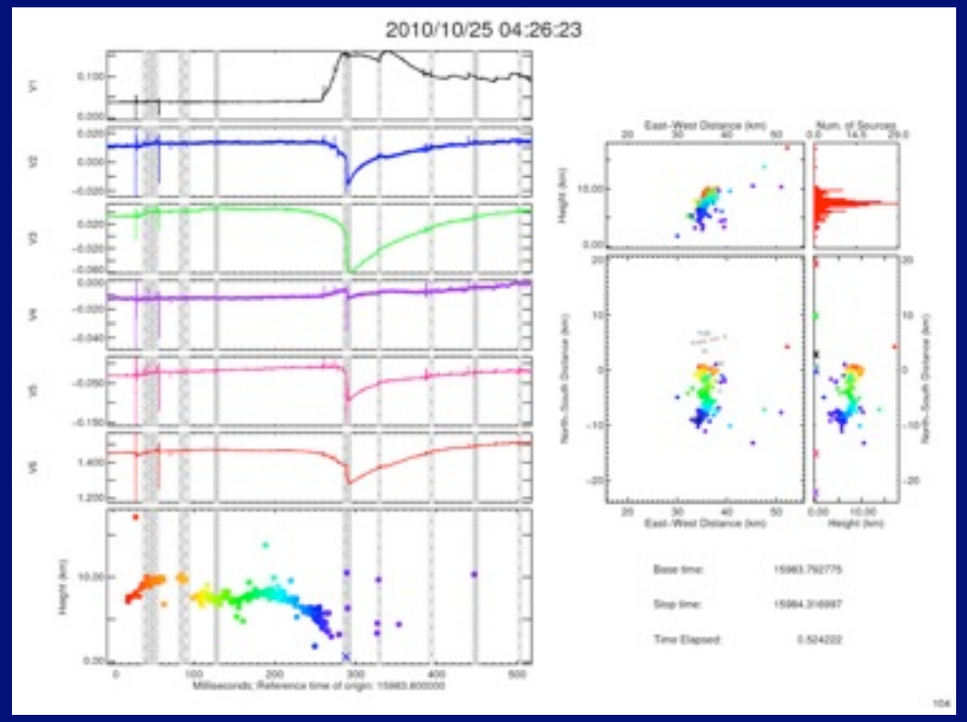


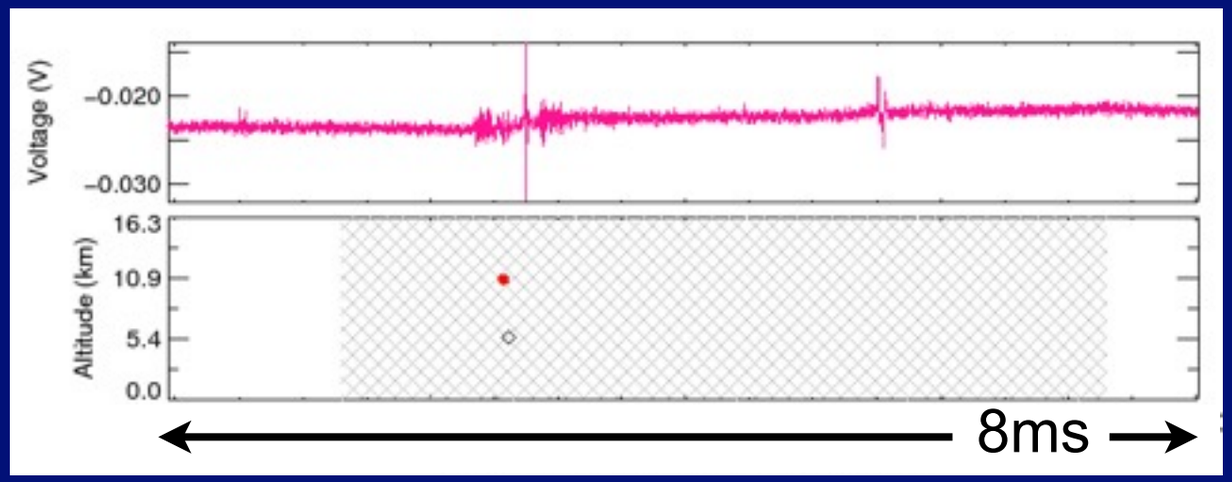


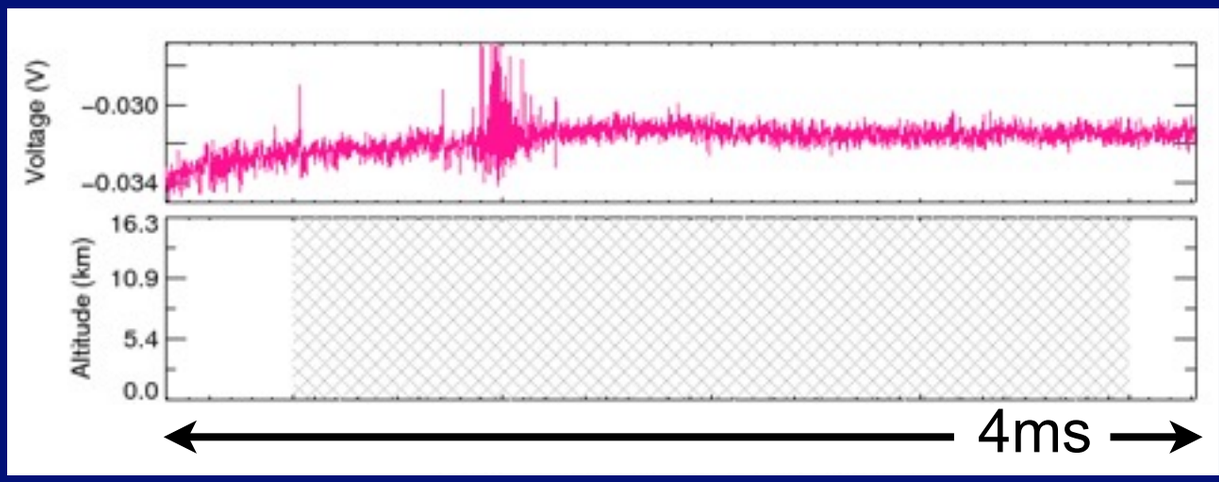


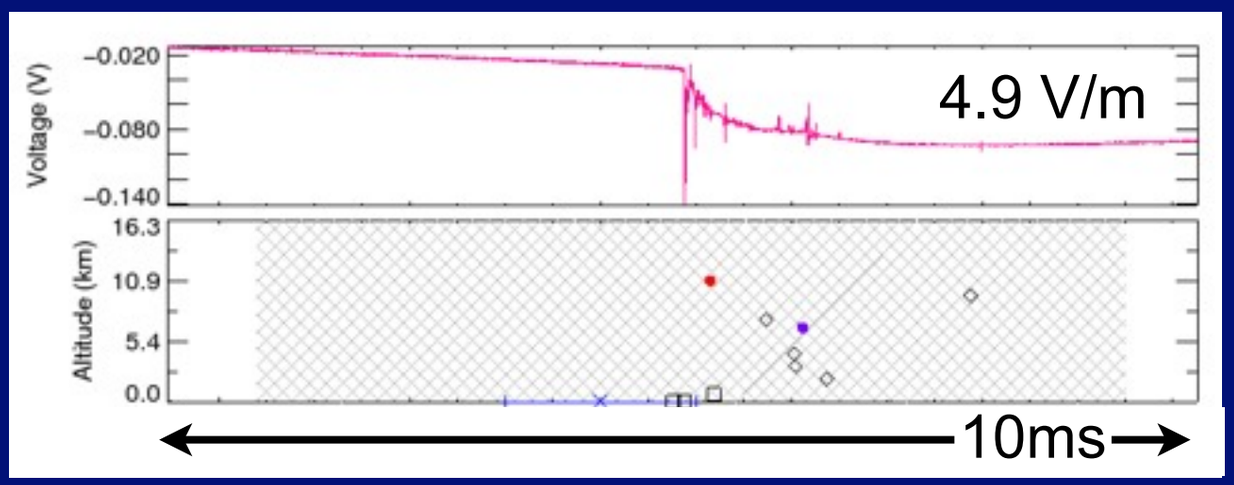


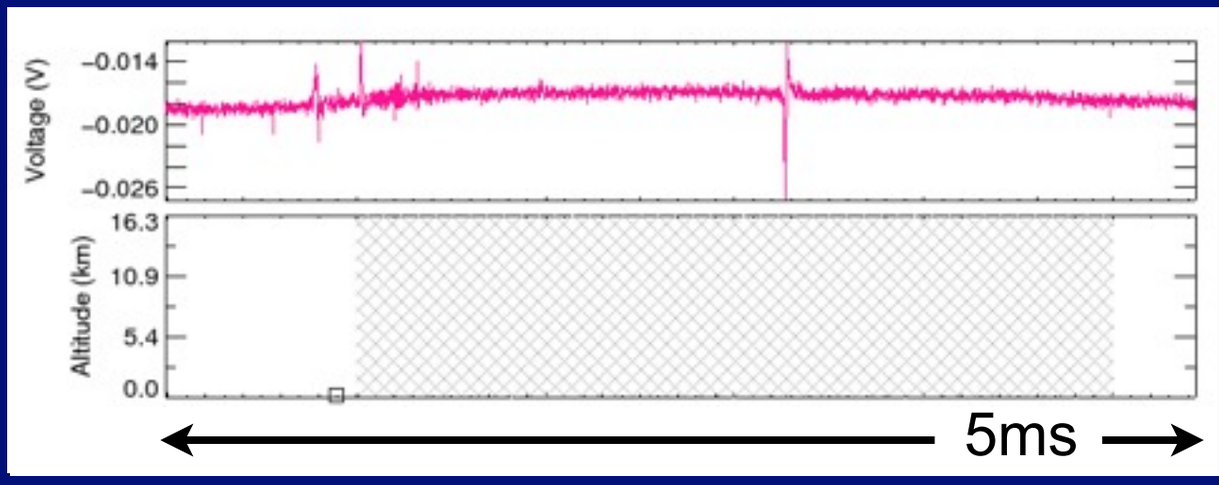
Again, the wideband record is active...











Again, the wideband record is active...

...and there are LIS groups without detected VHF sources.

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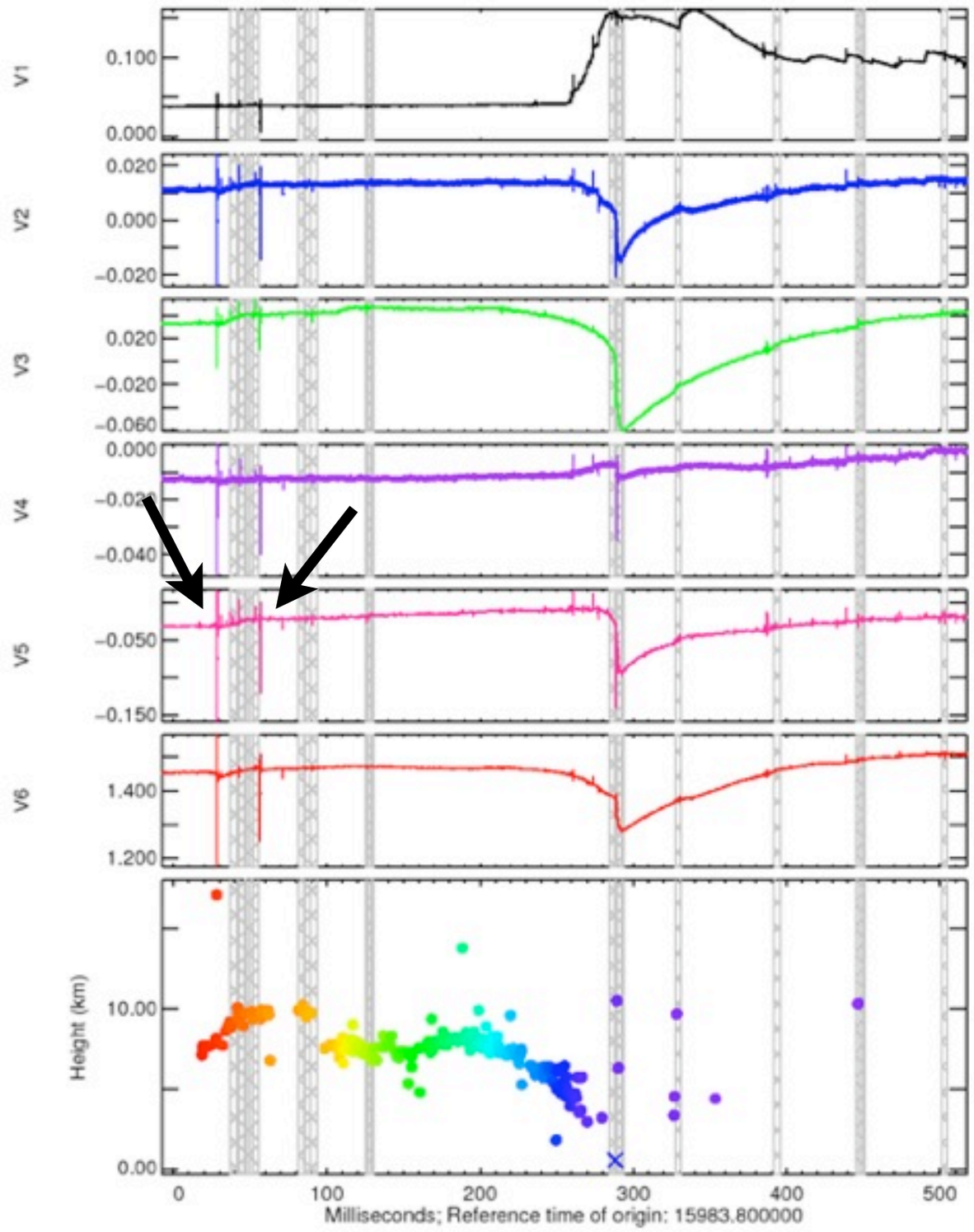
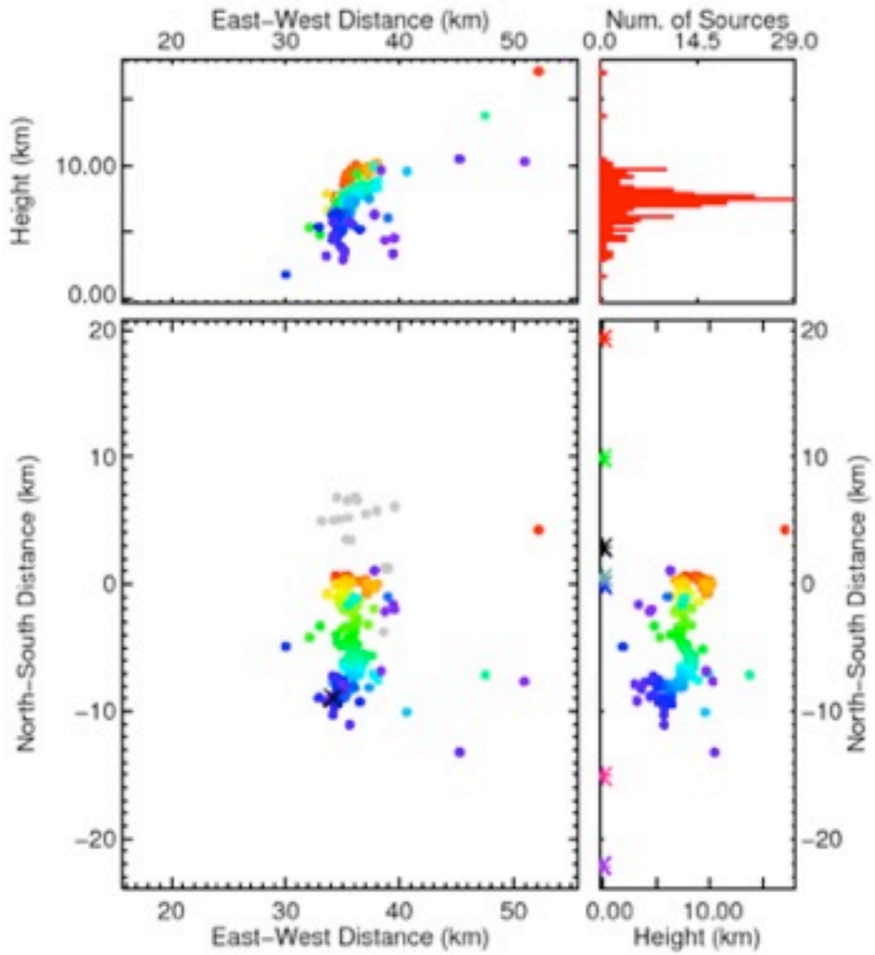
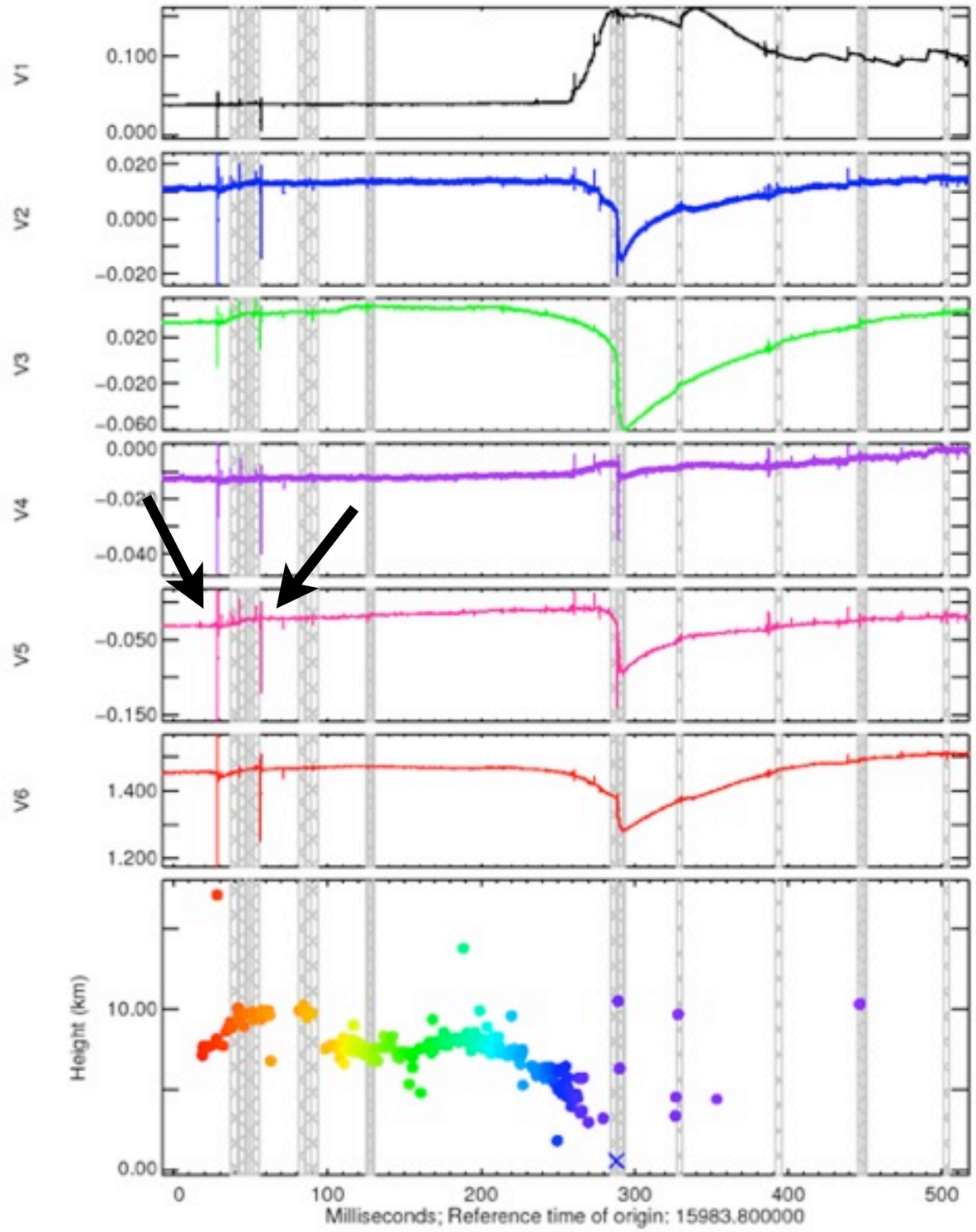


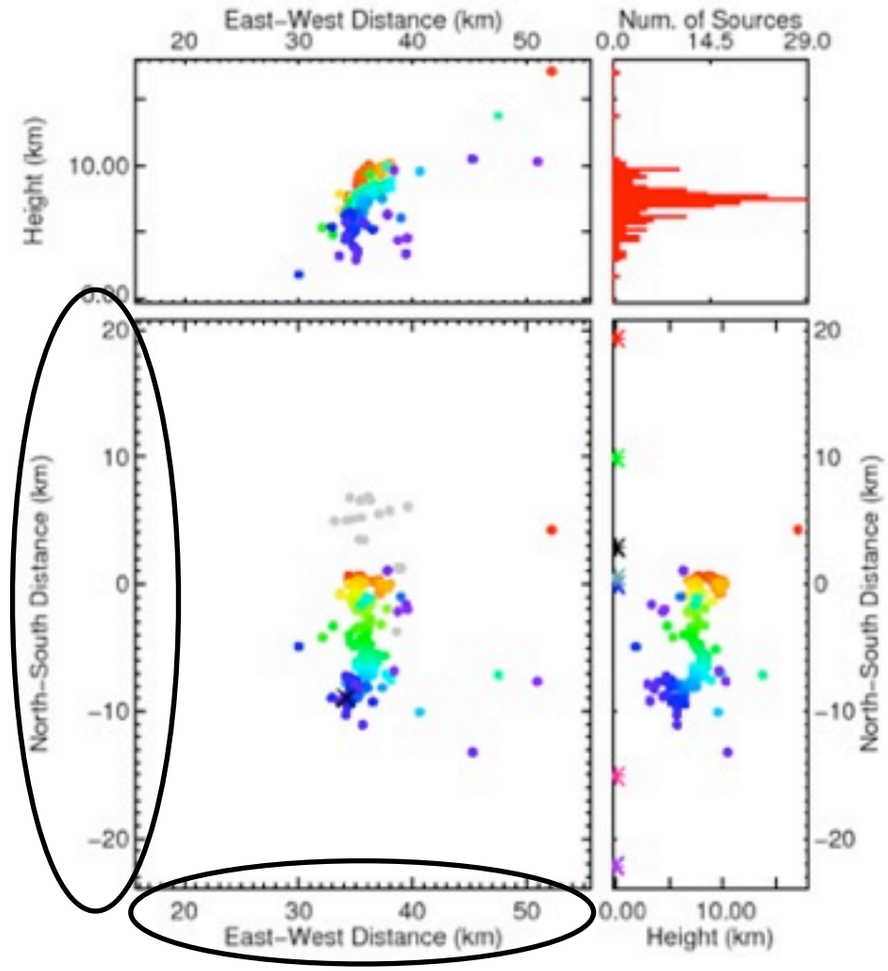


Base time:	15983.792775
Stop time:	15984.316997
Time Elapsed:	0.524222

104

2010/10/25 04:26:23

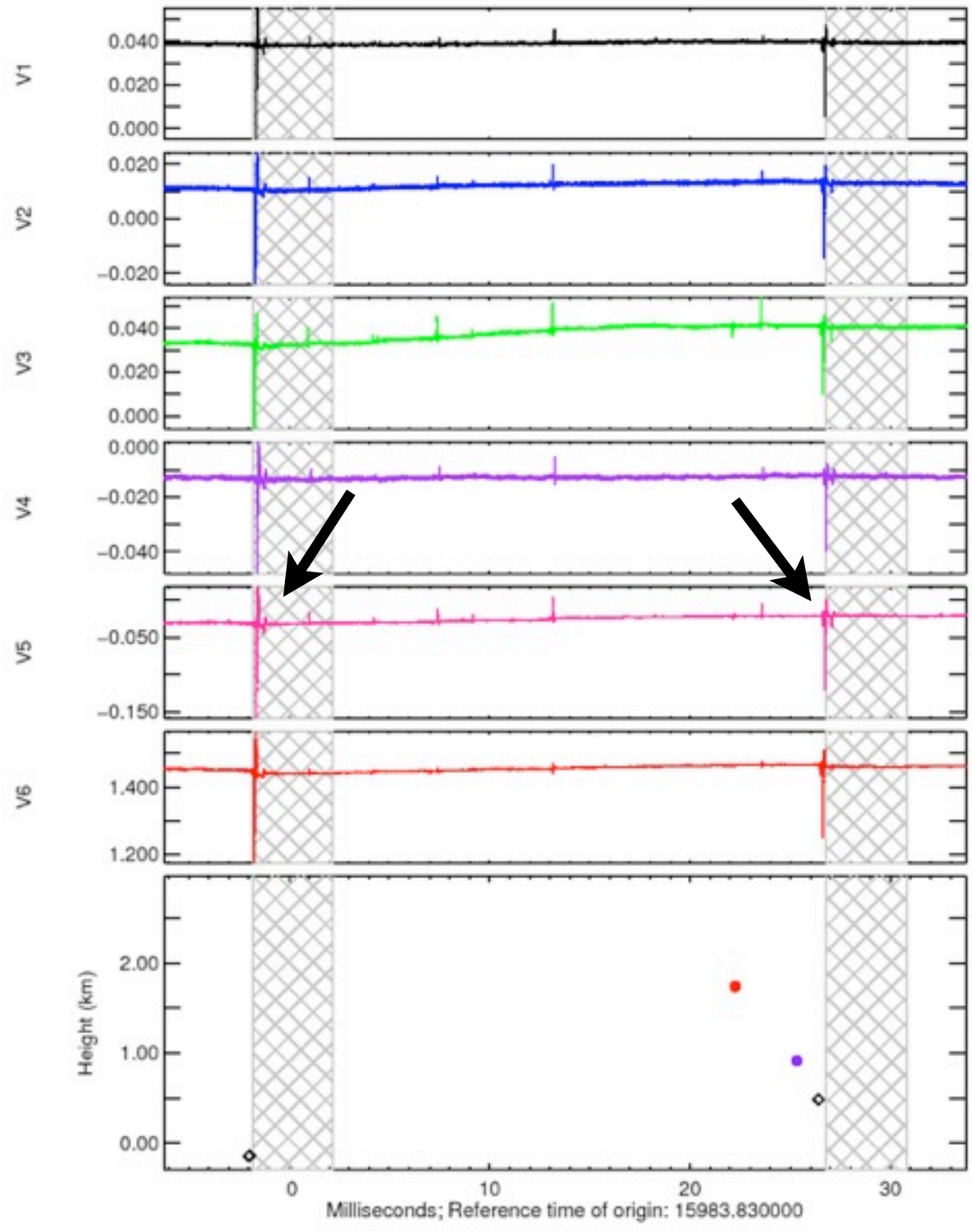


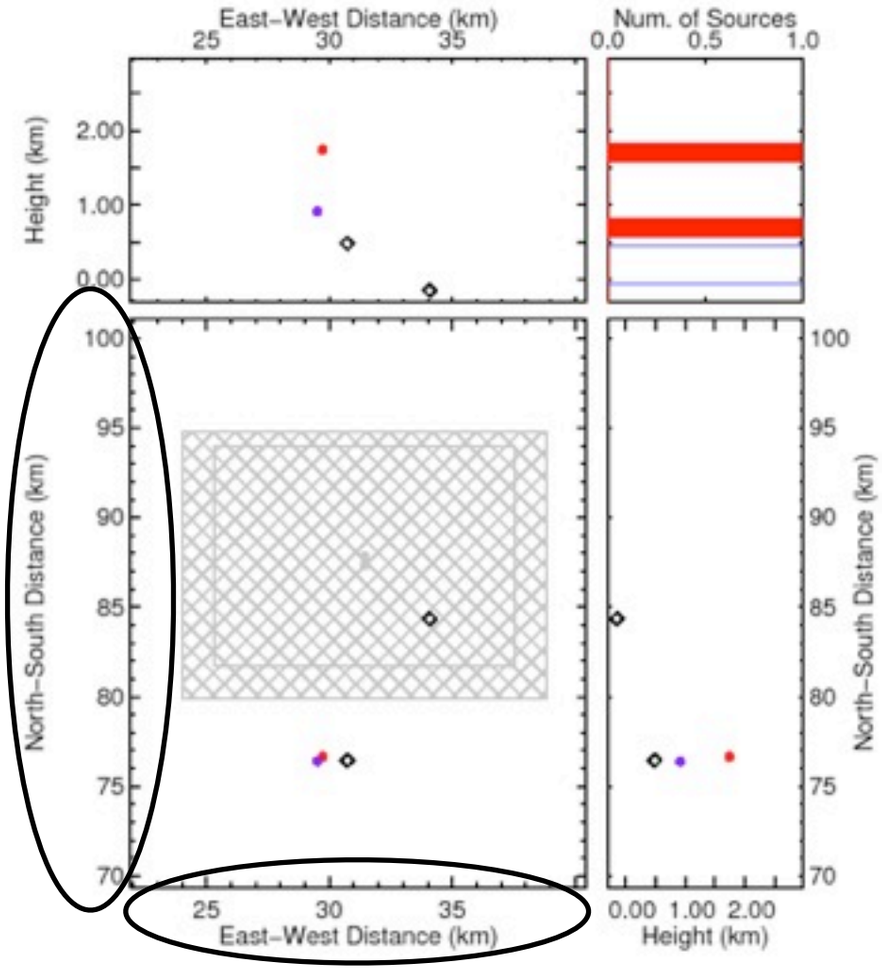


Base time:	15983.792775
Stop time:	15984.316997
Time Elapsed:	0.524222

104

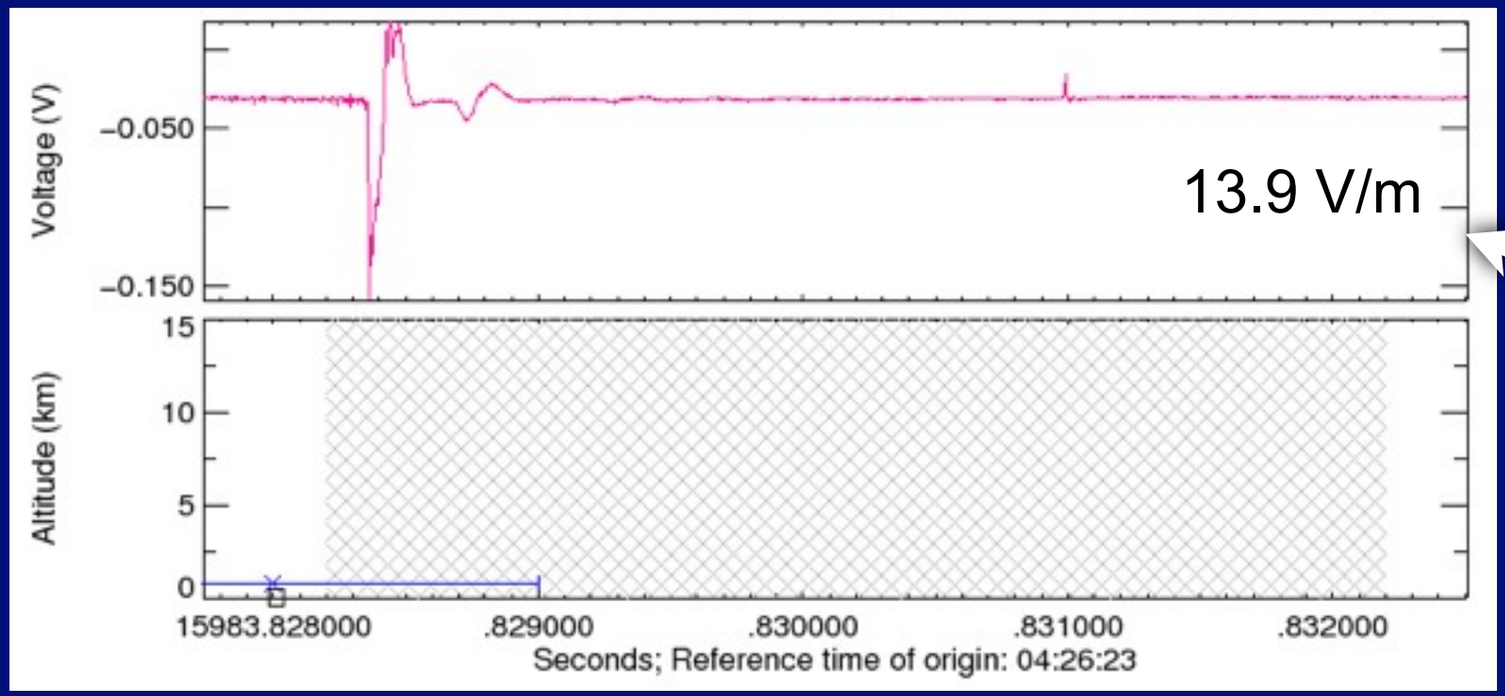
2010/10/25 04:26:23



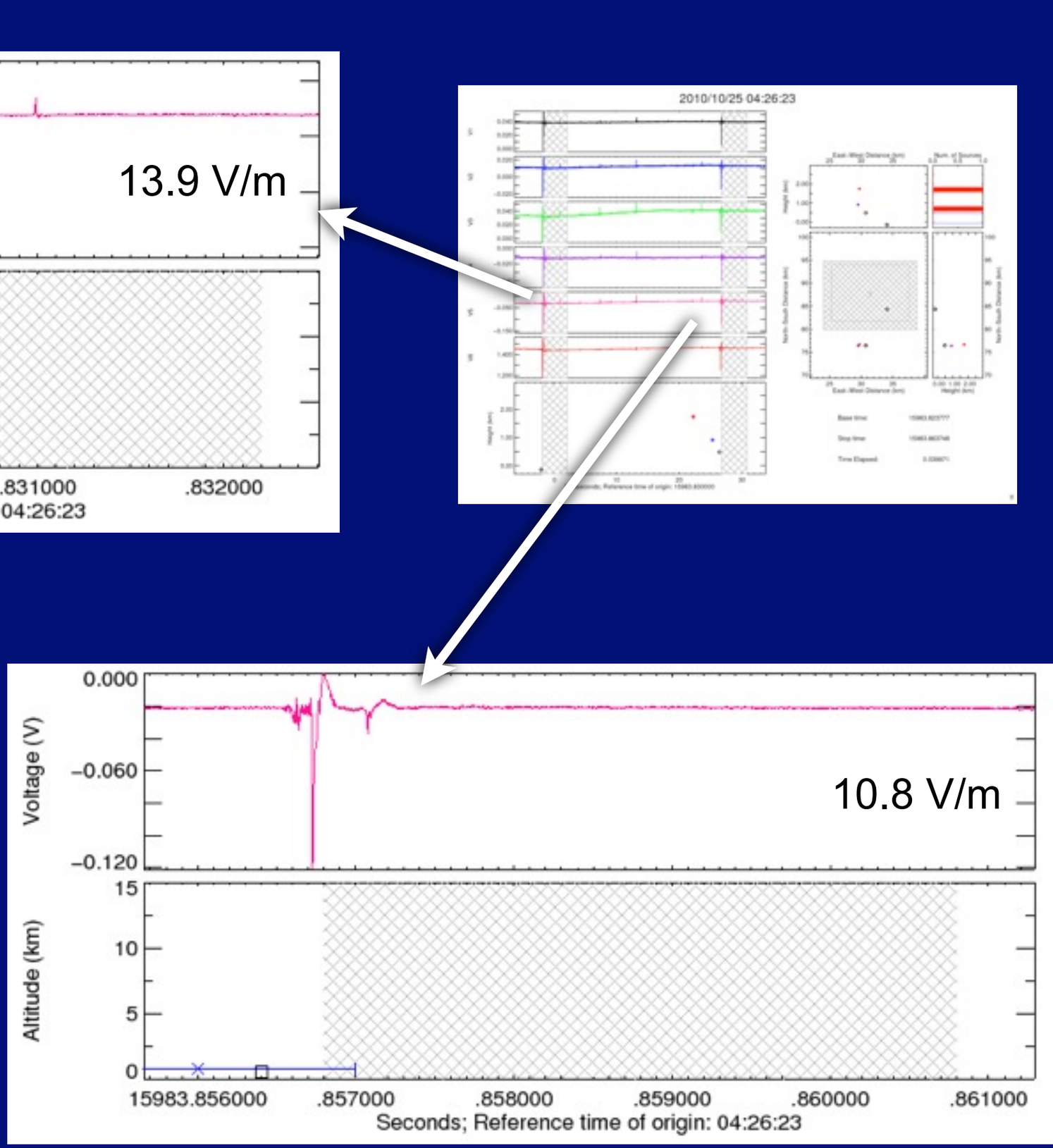


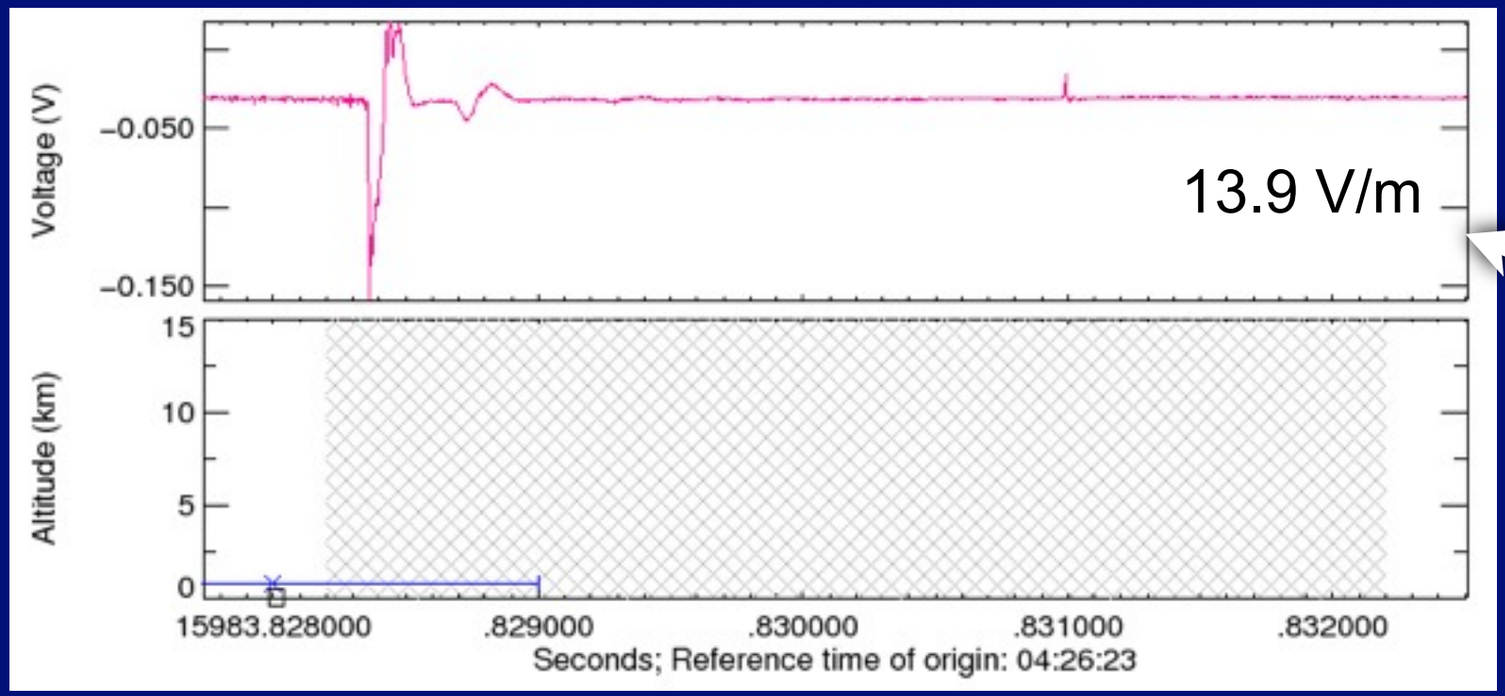
Base time:	15983.823777
Stop time:	15983.863748
Time Elapsed:	0.039971

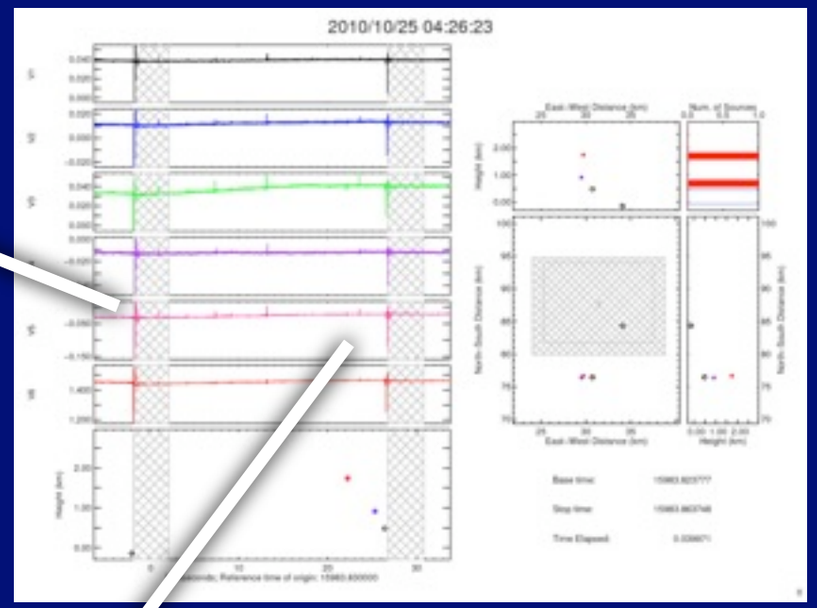
0


Voltage (V)
−0.050
−0.150
13.9 V/m
Altitude (km)
15
10
5
0
15983.828000
.829000
.830000
.831000
.832000
Seconds; Reference time of origin: 04:26:23

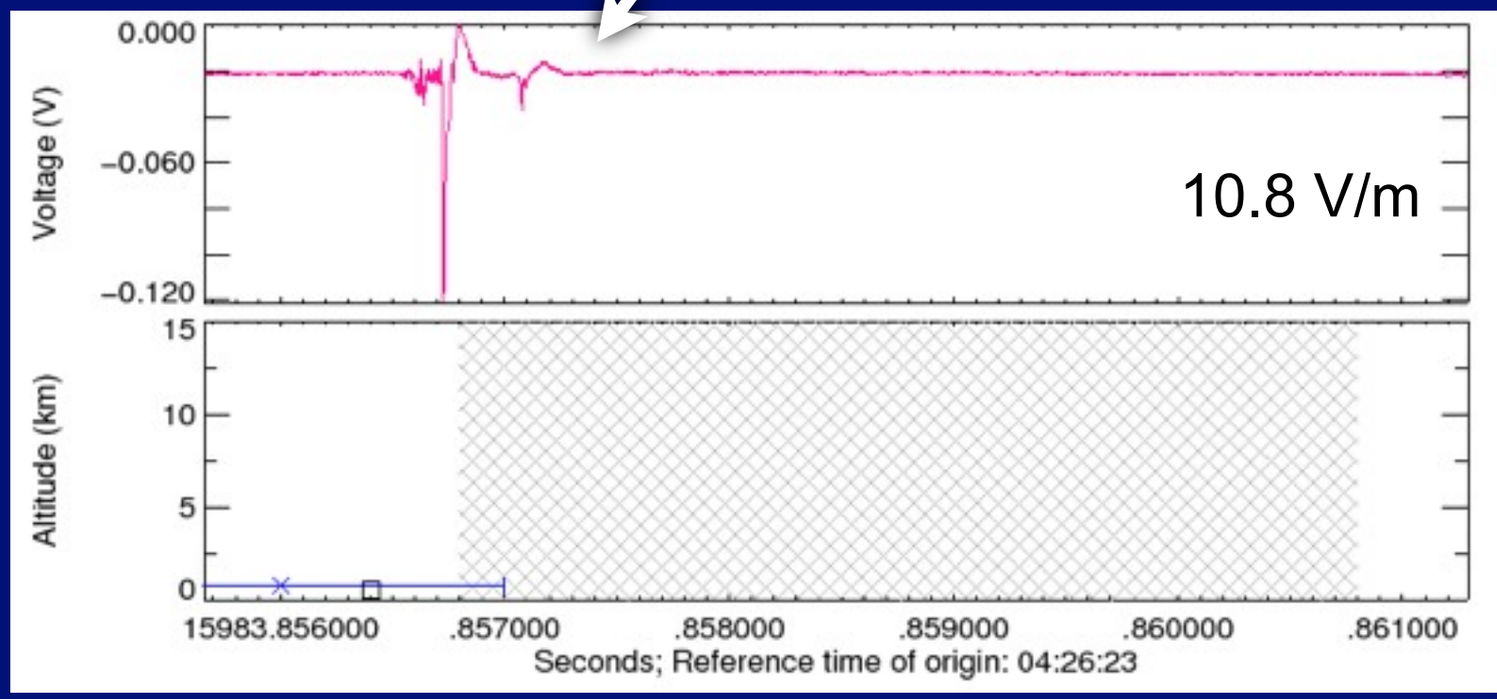
2010/10/25 04:26:23


Voltage (V)
0.000
−0.060
−0.120
10.8 V/m
Altitude (km)
15
10
5
0
15983.856000
.857000
.858000
.859000
.860000
.861000
Seconds; Reference time of origin: 04:26:23





Without an array of wideband sensors, these might have been misinterpreted as “misses”



Since LIS/GLM does not detect "flashes,"
we must find a way to validate what
LIS/GLM does detect.

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Clearly, wideband measurements are
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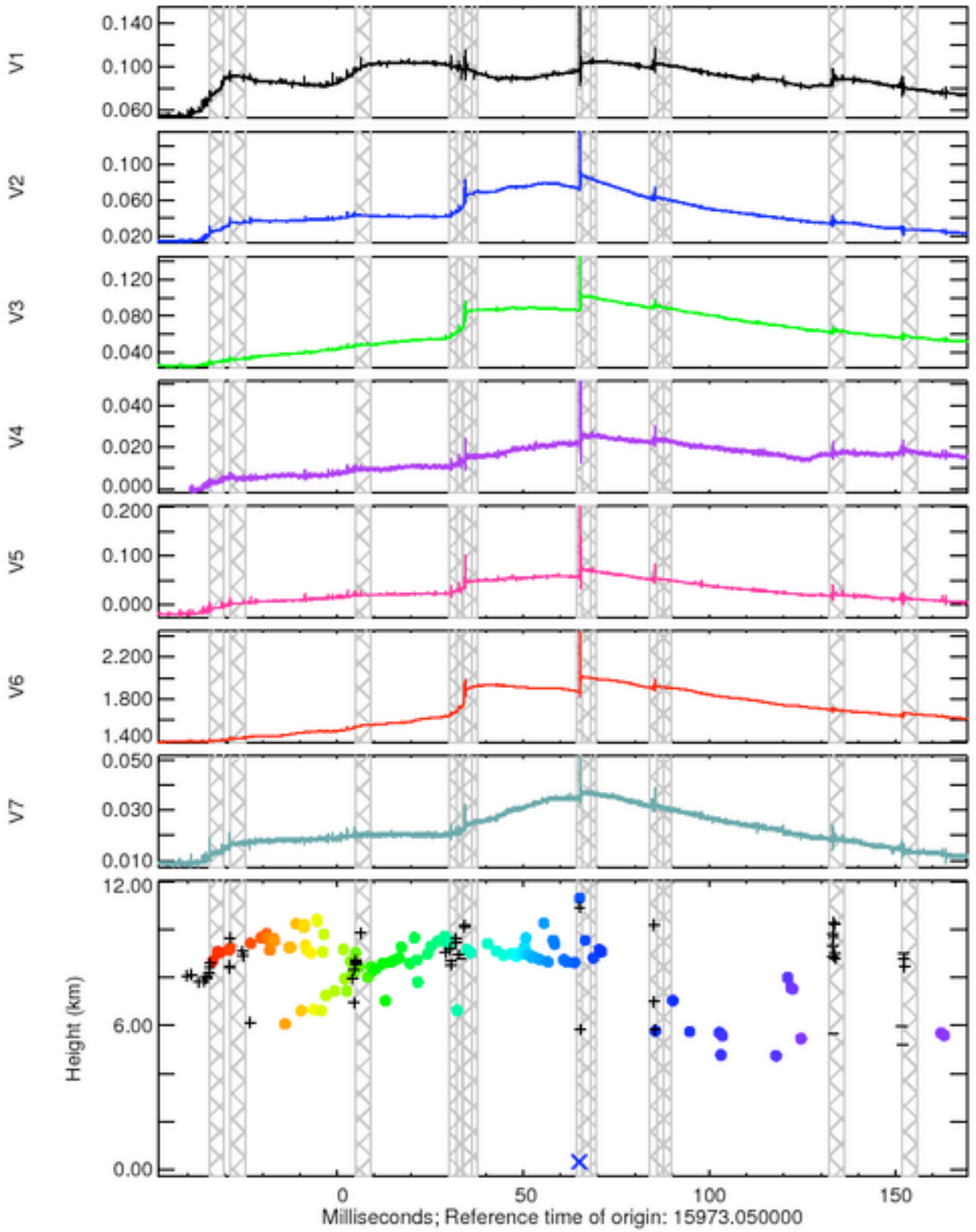
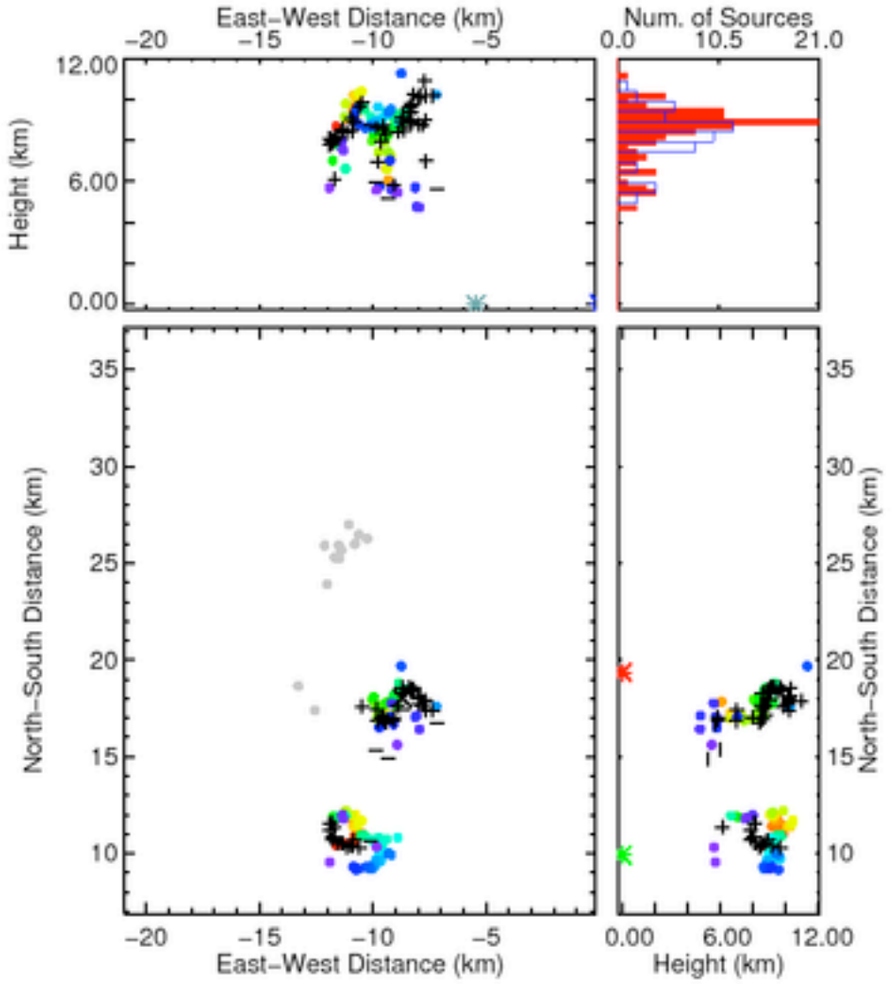
we must find a way to validate what
LIS/GLM does detect.

Clearly, wideband measurements are
better correlated to these optical events...

and even suggest there is a
lower limit to what LIS can detect!

2010/10/25 04:26:13





Base time:	15973.002030
Stop time:	15973.219127
Time Elapsed:	0.217097

Fundamental question for *scientific* validation:

What is the best way from the ground to characterize what GLM “sees?”

Fundamental question for *scientific* validation:

What is the best way from the ground to characterize what GLM "sees?"

Wideband measurements are ideally suited to the processes in lightning that produce optical emission