The Characterization of Magnetic Glitches in VSR4 data

Daniel Vander-Hyde

Friday, July 19th, 2013

CALIFORNIA STATE UNIVERSITY FULLERTON

UF UNIVERSITY of FLORIDA

VIRGO

Gravitational Physics International REU

INFN

NSF

Used Parameters

- VSR4
  - UTC time – August 2, 14:10:00 to August 7, 14:20:00 2011 (Good sensitivity)
- Sources of Initial Data:
  - OMICRON triggers (Fast Channels)
    - GPS time
    - Signal to Noise Ratio (SNR)
    - Frequency
    - Time (with respect to the beginning of the data set)
  - Infrastructure Machines Monitoring System (IMMS) (Slow Channels)

More information on OMICRON:
https://tds.ego-gw.it/itf/tds/index.php?callContent=2&callCode=9517&title=Omicron&author=Florent&startPage

Data Sample (Fast Channels)

Triggers were produced (by OMICRON) for the following channels:

CHANNEL NAME	
V1: h_4096Hz	Calibrated Interferometer Output, Dark Fringe
V1: Em_IPSCB_50Hz	Voltage Probe on IPS cable in the Central Building
V1: Em_IPSMC_50Hz	Voltage Probe on IPS cable in the Mode Cleaner
V1: Em_IPSMC_CUR1	Current Probe on IPS cable in the Mode Cleaner Building
V1: Em_IPSNE_tmp	Voltage Probe on the IPS cable in the North End Building
V1: Em_IPSWE_tmp	Voltage Probe on the IPS Cable in the West End Building
V1: Em_MABDCE02	Magnetometer in the Central Building
V1: Em_MABDMC02	Magnetometer in the Mode Cleaner Building
V1: Em_MABDNE02	Magnetometer in the North End Building
V1: Em_MABDWE01	Magnetometer in the West End
V1: Em_UPSDET01_tmp	Voltage Probe on the UPS cable in the Central Building
V1: Em_UPSMC_CUR1	Current Probe on the UPS cable in the Mode Cleaner
V1: Em_UPSMC_50Hz	Voltage Probe on the UPS cable in the Mode Cleaner
V1: Em_UPSNE_tmp	Voltage Probe on the UPS cable in the North End
V1: Em_UPSWE_tmp	Voltage Probe on the UPS cable in the West End

Data Sample (IMMS / Slow channels)

- All of the following channels are IMMS channels, plotted in time with selected triggers:

CHANNEL NAME	
IMMS_TEMC51_OUTLCW	Temperature probe monitoring water coming out of Water Chiller (part of Air Conditioning system) near the Mode Cleaner
IMMS_TEMC51_INLCW	Temperature probe monitoring water coming in the Water Chiller (part of Air Conditioning system) near the Mode Cleaner
IMMS_TENE11_INLCW	Temperature probe monitoring water coming in the Water Chiller (part of Air Conditioning system) near the North End Building
IMMS_TENE11_INLWW	Temperature probe monitoring water coming in the Water Heater (part of Air Conditioning system) near the North End Building
IMMS_TENE11_OUTLCW	Temperature probe monitoring water coming out of Water Chiller (part of Air Conditioning system) near the North End
IMMS_TENE11_OUTLWW	Temperature probe monitoring water coming out of the Water Heater (part of Air Conditioning system) near the North End Building
IMMS_TEWE11_INLCW	Temperature probe monitoring water coming in the Water Chiller (part of Air Conditioning system) near the West End Building
IMMS_TEWE11_INLWW	Temperature probe monitoring water coming in the Water Heater (part of Air Conditioning system) near the West End Building
IMMS_TEWE11_OUTLCW	Temperature probe monitoring water coming out of Water Chiller (part of Air Conditioning system) near the North End
IMMS_TEWE11_OUTLWW	Temperature probe monitoring water coming out of the Water Heater (part of Air Conditioning system) near the North End Building
IMMS_PRNE13_CA	Pressure probe monitoring the air compressor in the North End Building

Data Analysis

- With the usage of *MatLab* scripts, the following was performed between each fast channel pair:
  1. Time coincidences
  2. Plotting coincidences (SNR vs. SNR)
  3. Identifying a region of interest (ROI)
  4. Plot interesting data in time and compare with IMMS channels

```
%% Comparing A Set of Trigger Channels (Random Coincidences?)

clear all
close all

%Turning of LaTeX globally to fix subscript/underscore issue
set(0, 'DefaulttextInterpreter', 'none')

%Choosing comparison channel (ENTER IN LABEL of a single AUX or H Channel in comp_chan)
comp_chan ='Em_MABDMC02';

% Extra parameter selection
NBINS1 = 200;          % # of bins for hist1
NBINS2 = 1000;         % # of bins for hist2
time_thres = .1;       % coincidence time window threshold
snr_limit = 0;         %Set SNR limit of comparison channel (if desired)
addi = 0;              %Coin data check [illegible]
SCI_RUN = 'VSR4';
blanks = 0;

%If this is a Limiting case of the data, it will be labeled so
if snr_limit>0
   sel_name = '_sel';
else
   sel_name = [];
end
if addi>0
   add_name = '_chk';
else
   add_name = [];
end
if time_thres >=.3
   seis_name = '_seis';
else
   seis_name = [];
end
if blanks>0
   blnk = 'blank';
```

```
%% Isolating ROI

%Input desired auxilary channel
aux_chan_x = 'Em_MABDNE02';
comp_chan_y = 'h_409[illegible]Hz';

%Turning off LaTeX globally to fix subscript/underscore issue
set(0, 'DefaulttextInterpreter', 'none')

%Gives histogram of 'dt' which may help calibrate code for optimal
%threshold time (if call_dt = 1) [illegible] enter in bin_num)
call_dt = 0;
bin_num = 10000;

%INPUT ROI PARAMETERS
xi = 170; xf = 210 ; yi=6 ; yf = 14;

alltrig = dir('trig*.mat');
array = load(alltrig(1).name);
trigcell = struct2cell(array);

%Names
names = fieldnames(array);

%Compared auxilary channel (finds location of name in array)
num_comp = strmatch(comp_chan_y, names);
trig2 = trigcell{num_comp};

%Obtains array of names
names = fieldnames(array);

%Outputs the location of name in array
num_aux = strmatch(aux_chan_x, names);

if length(trig2.time)>=length(trigcell{num_aux}.time)
   [i2, i1] = coinc(trig2.time, trigcell{num_aux}.time, .1);
else
   [i1, i2] = coinc(trigcell{num_aux}.time, trig2.time, .1);
```

```
%% Periodicity Check

set(0, 'DefaulttextInterpreter', 'none')

%Name of Misc Channel and triggers that correspond
misc_name = 'MAGNETOMETER';
misc_chan1 ='Em_MABDNE01_max';
misc_chan2 = 'Em_MABDNE02_max';
misc_chan3 = 'EM_MABDNE03_max';
trig_chan = 'Em_MABDNE02';

% Name of Time variable
time = 'tsamp';

%Select appropriate number .mat file from list
dirmsel = 1;

%Loading appropriate .mat file for Misc Channel
allMAG = dir('mag*.mat');
marray = load(allMAG(dirmsel).name);
magcell = struct2cell(marray);

%Getting array of names
mag_names = fieldnames(marray);

% Getting the right indices for the names
ind_misc1 = strmatch(misc_chan1, mag_names);
ind_misc2 = strmatch(misc_chan2, mag_names);
ind_misc3 = strmatch(misc_chan3, mag_names);
ind_time = strmatch(time, mag_names);
ind_time1 = strmatch(time, mag_names);

%Plotting
figure
plot(magcell{ind_time1}/3600, magcell{ind_misc1}, 'g');
hold on
plot(magcell{ind_time1}/3600, magcell{ind_misc2}, 'k');
```

Time Coincidence

- Auxiliary Channel vs. Dark Fringe
  - PRIMARY INTEREST
  - Gives information on how often this environmental and/or instrumental glitch couples into the Dark Fringe.
- Auxiliary Channel vs. Auxiliary Channel
  - For Magnetic noise, finding coincidences between Magnetometers, Voltage Probes and Current Probes gives a good indication if a noise is produced by the VIRGO infrastructure as well as the noise path.

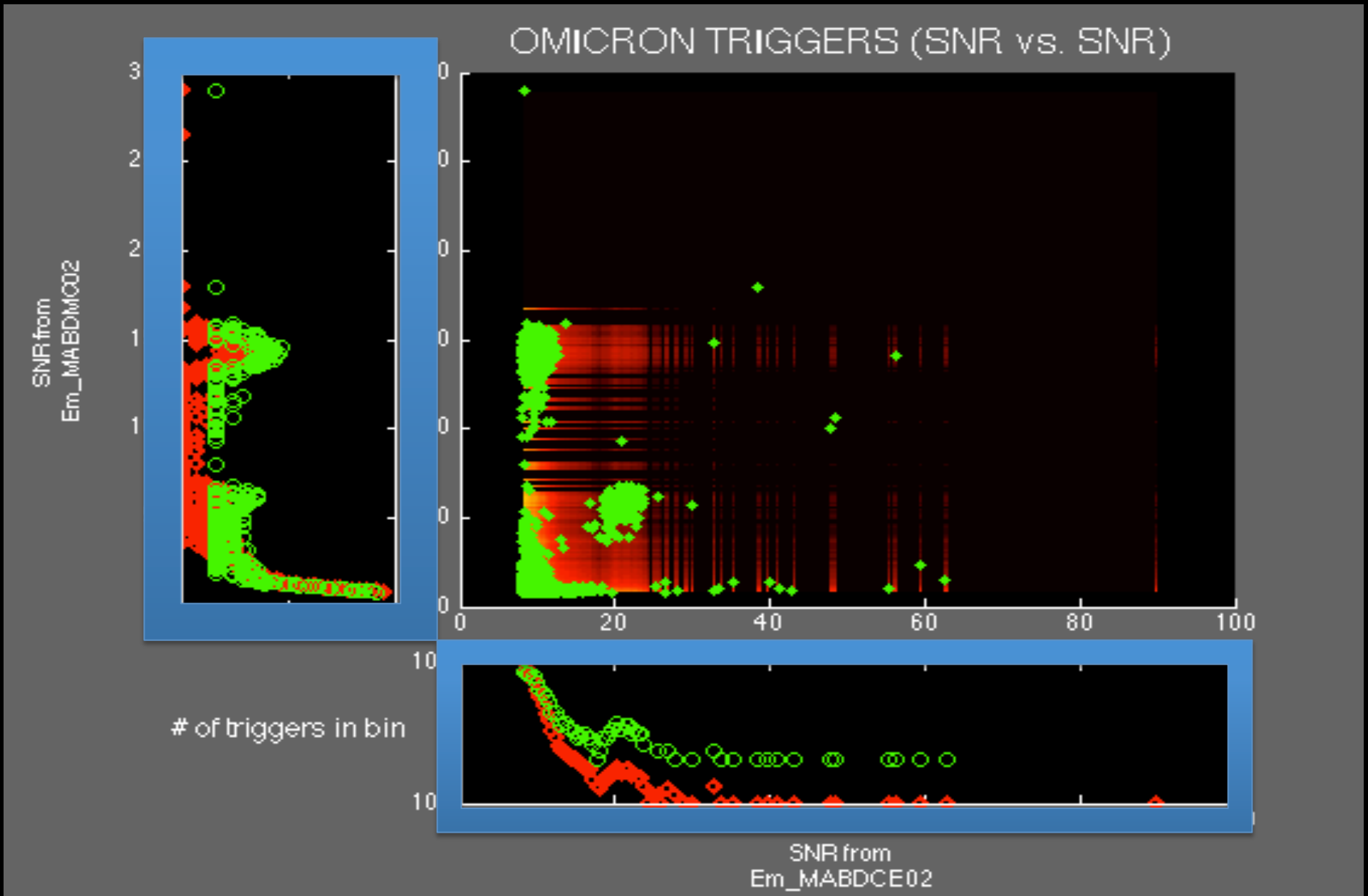
Time Coincidence

- Done through a coincidence function in *MatLab*. (Thanks, Bas)
  - [i1, i2] = coinc(t1, t2, th)
  - Where t1 and t2 are a pair of time vectors from two channels and th is a threshold window. For all of the mentioned coincidences th = .1 sec
  - The function gives back i1 and i2 which are indices that store the location of the coincident times for t1 and t2 respectively

SNR vs. SNR plot

- Use index outputs from time coincidence to create SNR vs. SNR plot.
  - Plotting one channel against another (AUX vs. H) or (AUX vs. AUX)
- These plots tend to produce trigger clusters, which have potential of revealing useful information about noise sources.
  - For high SNR events it can be easy to spot apparent clusters of data.
  - For low SNR events, it can be more difficult. Not all time coincidences can be trusted as “real coincidence”
  - Used MatLab script, with extra plotting features (i.e. visual statistics and fake time offsets) as a guide to choosing the best data.

SNR vs. SNR plot



SNR vs. SNR plot

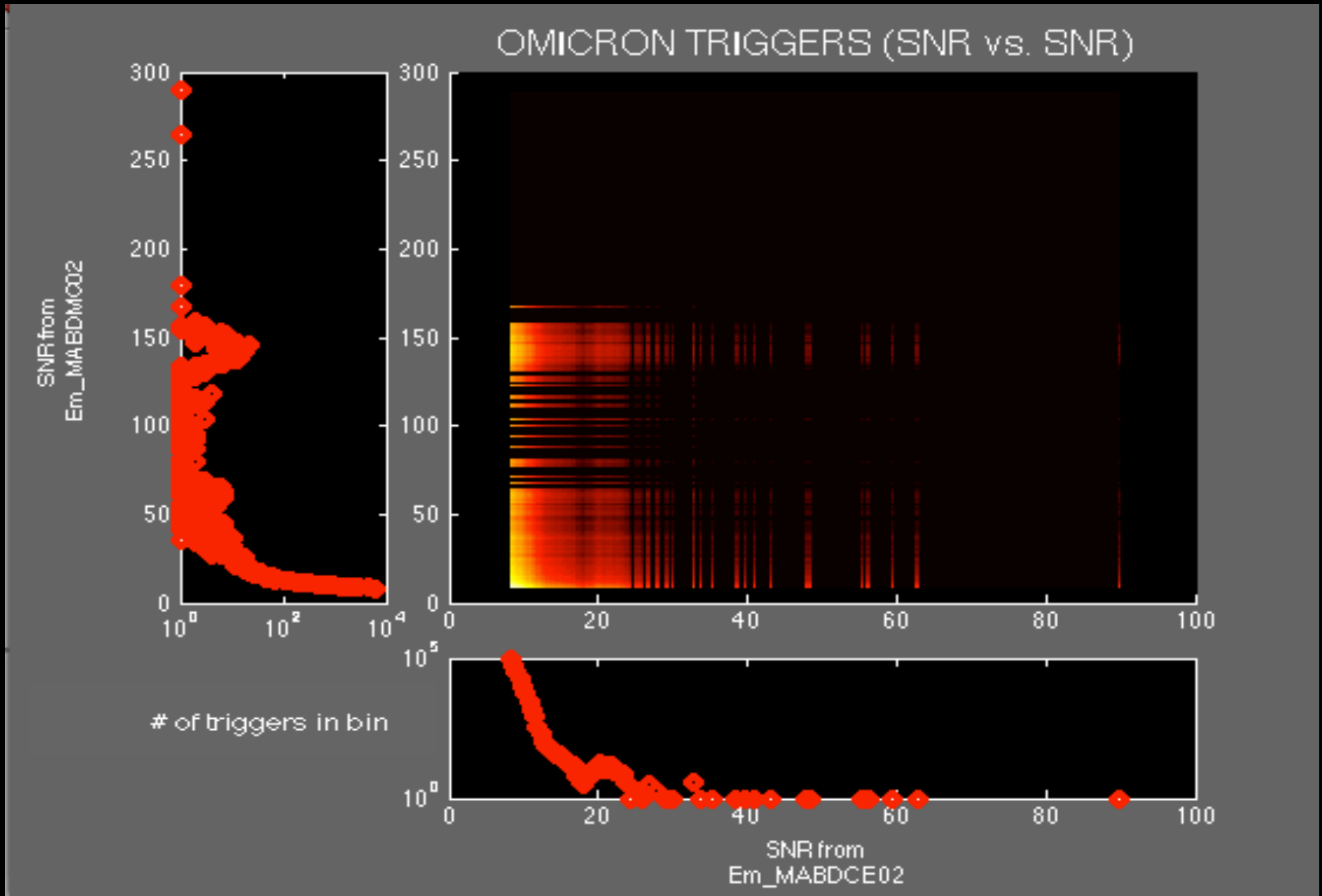
- Total of 3 subplots
- Two are along the axes of the SNR vs. SNR plot.
  - Histograms designed to display the statistical significance of coincident data.
  - The likeliness of finding a trigger in a specified bin are measured by the relative heights of the red and green dots:
    - Red (all triggers):

$$Height\ of\ Red\ dot\ =\ Number\ of\ triggers\ in\ bin$$

    - Green (coincident triggers):

$$Height\ of\ Green\ dot = \frac{Number\ of\ coincident\ triggers\ in\ bin}{\sum Coincident\ triggers} * \sum All\ the\ triggers$$

SNR vs. SNR plot



SNR vs. SNR plot

- Central Subplot:
  - Displays "hot" color map background which visually presents the probability of finding a trigger at a (Bin_x, Bin_y) pixel via intensity. This Two-Dimensional probability is defined:

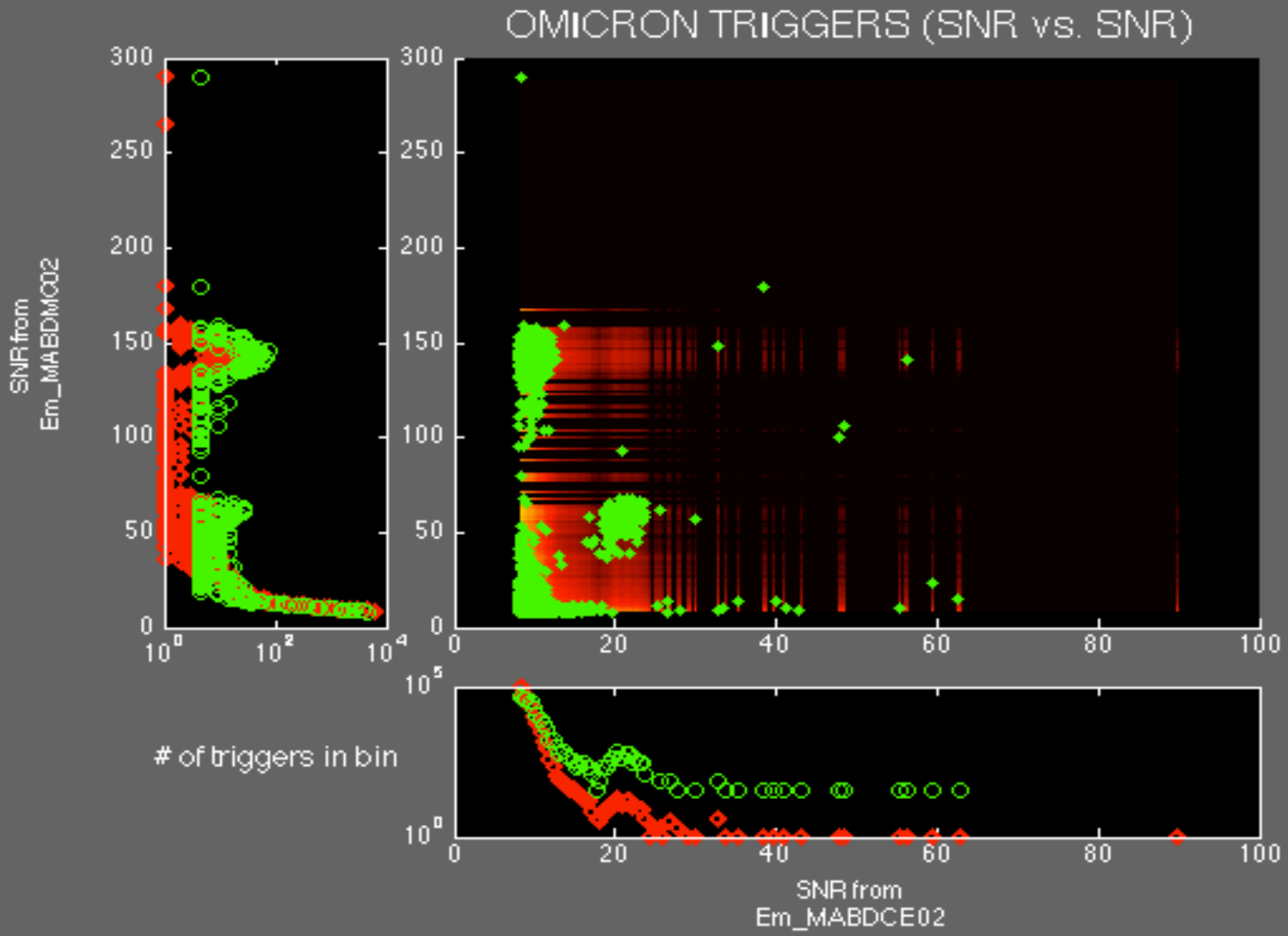
$$Chance\ of\ finding\ trigger\ at\ a\ Pixel\ = Probability_{Bin_x} * Probability_{Bin_y}$$

$$Probability_{Bin_x} = \frac{\sum Triggers\ from\ Channel\ x\ in\ Bin_x}{\sum All\ Triggers\ in\ Channel\ x}$$

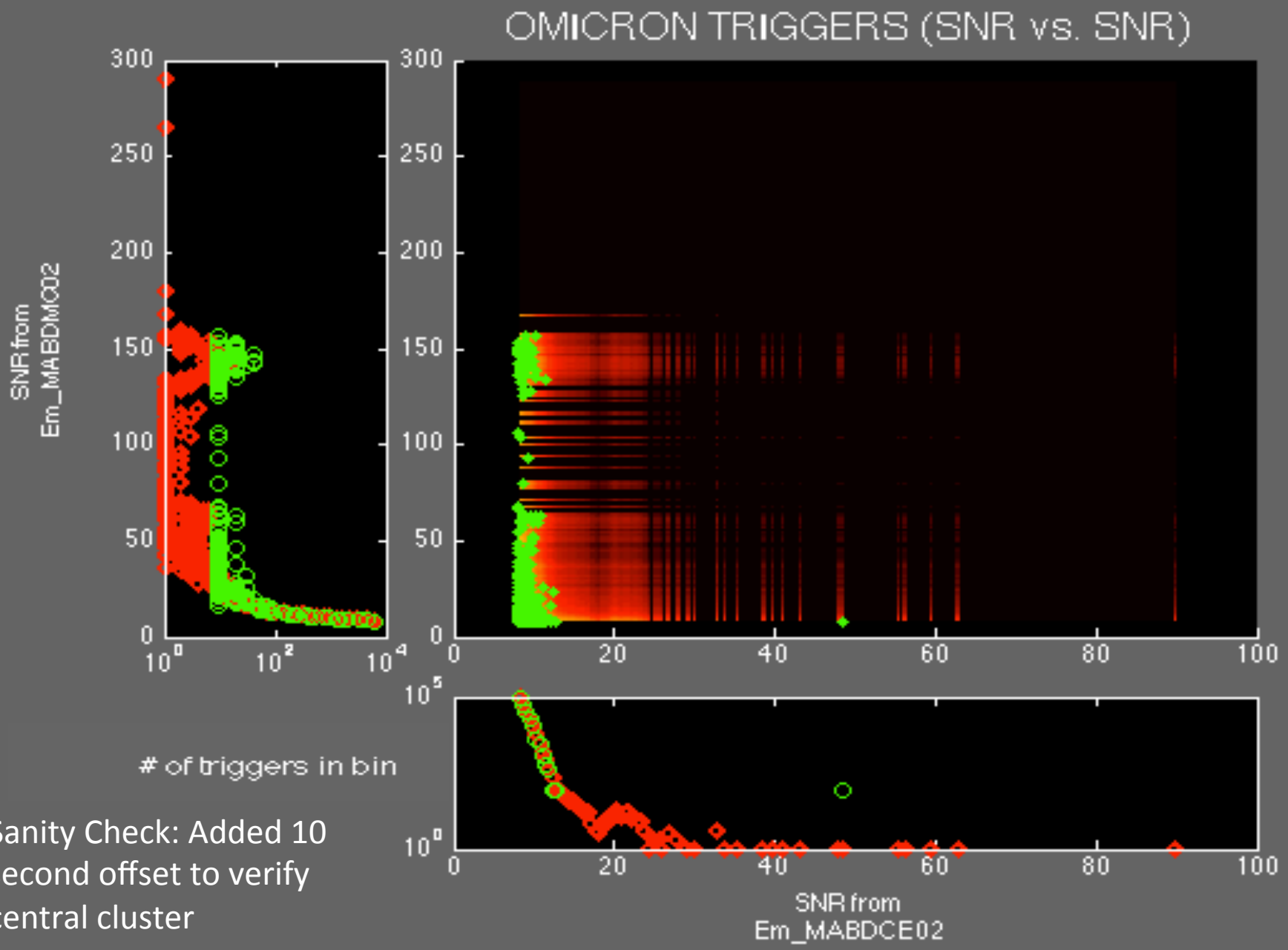
$$Probability_{Bin_y} = \frac{\sum Triggers\ from\ Channel\ y\ in\ Bin_y}{\sum All\ Triggers\ in\ Channel\ y}$$

    - (Where $Probability_{SNRx}$ and $Probability_{SNRy}$ are defined as the individual probabilities at a specified SNR values for the respective channels)
    - The final matrix displayed is plotted on *MatLab's* "imagesc" function as $\log_{10}$(2-D probability) for cosmetic purposes.
  - Green points are the plotted coincident triggers

SNR vs. SNR plot

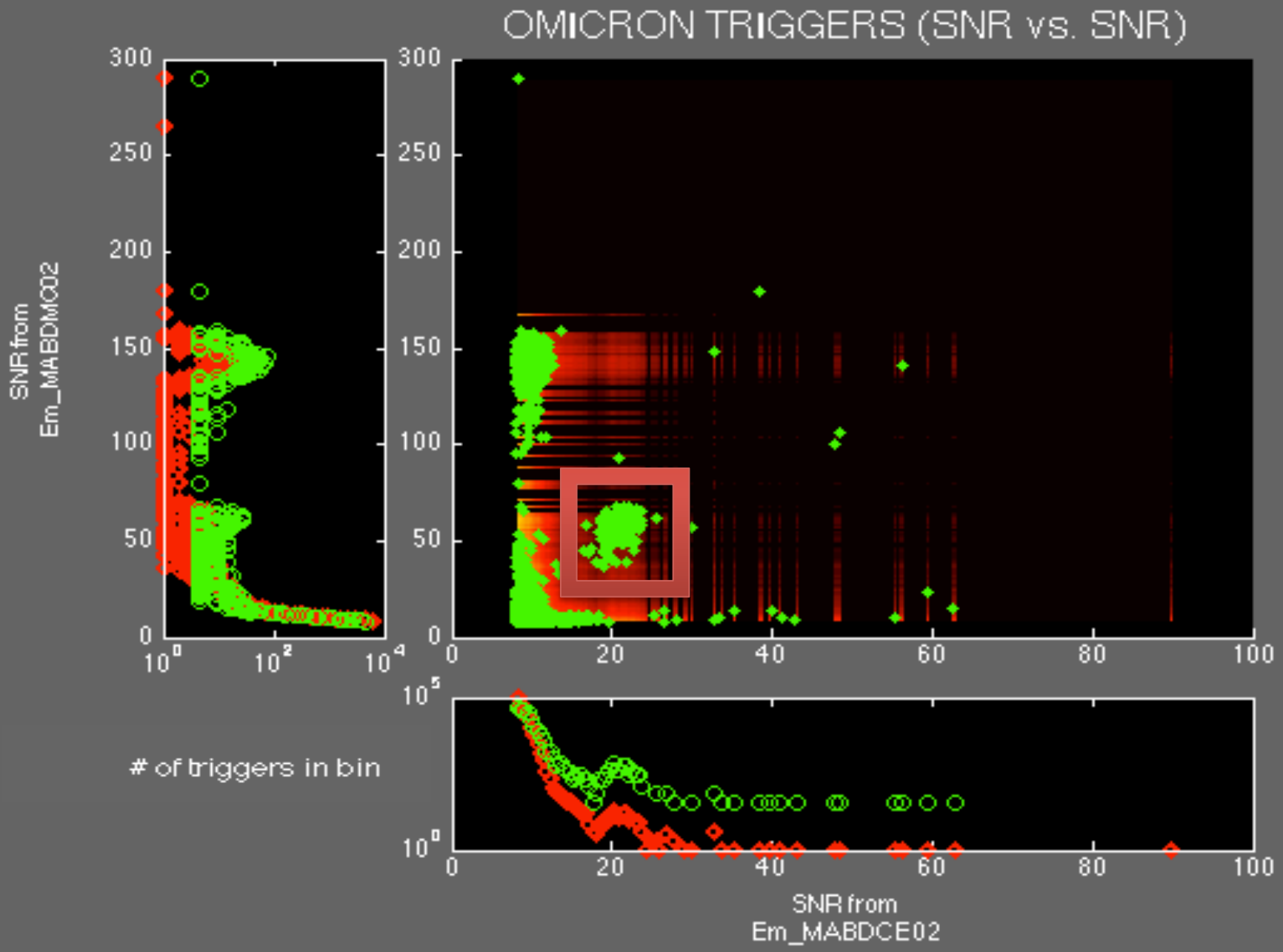


SNR vs. SNR plot



Sanity Check: Added 10 second offset to verify central cluster

Region of Interest



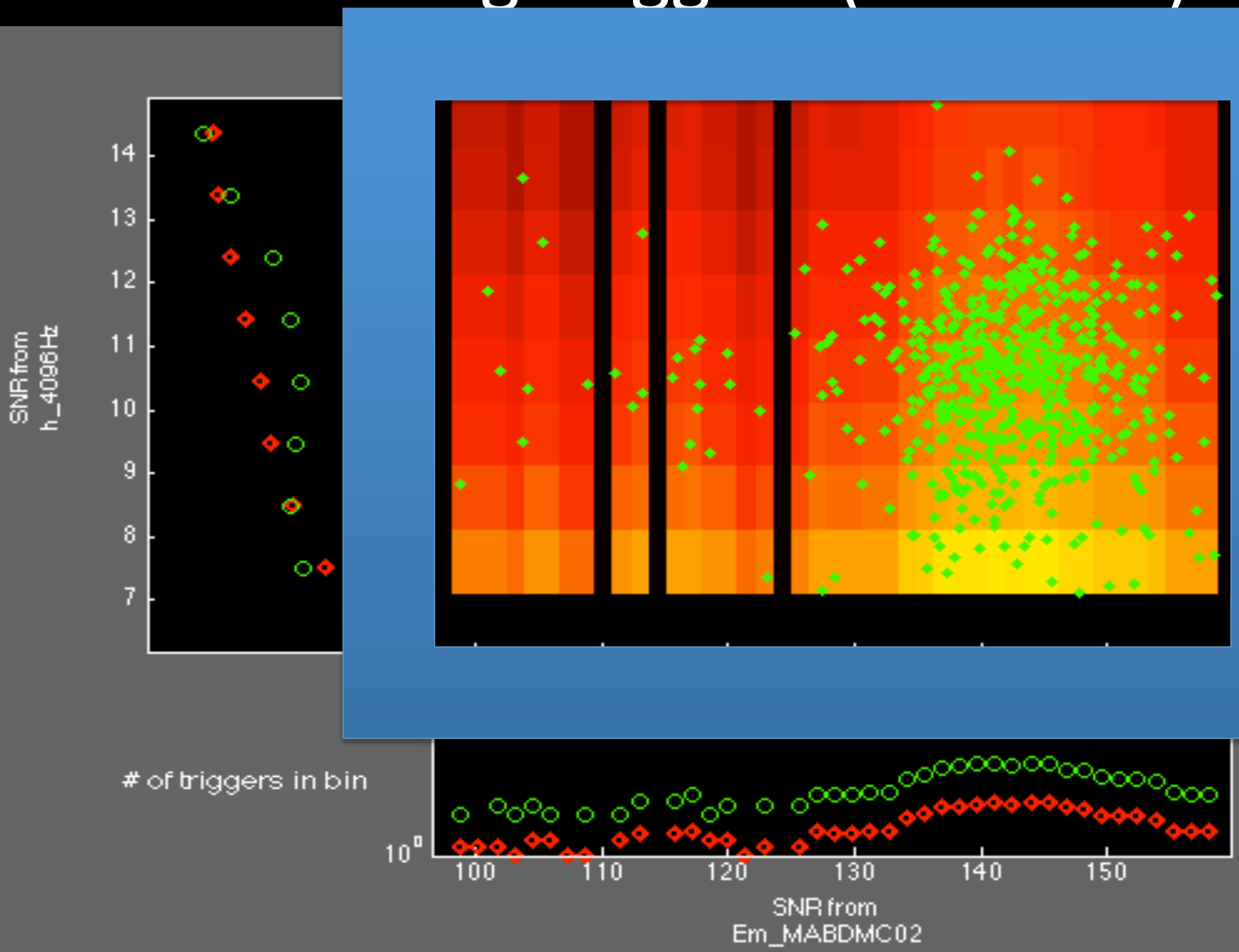
Region of Interest

- These areas are clusters of triggers that contain interesting data (reveal information about noise sources)
- A *MatLab* script stores the indices corresponding to these triggers on the workspace which will later be used to call time information and correlate with an IMMS channel

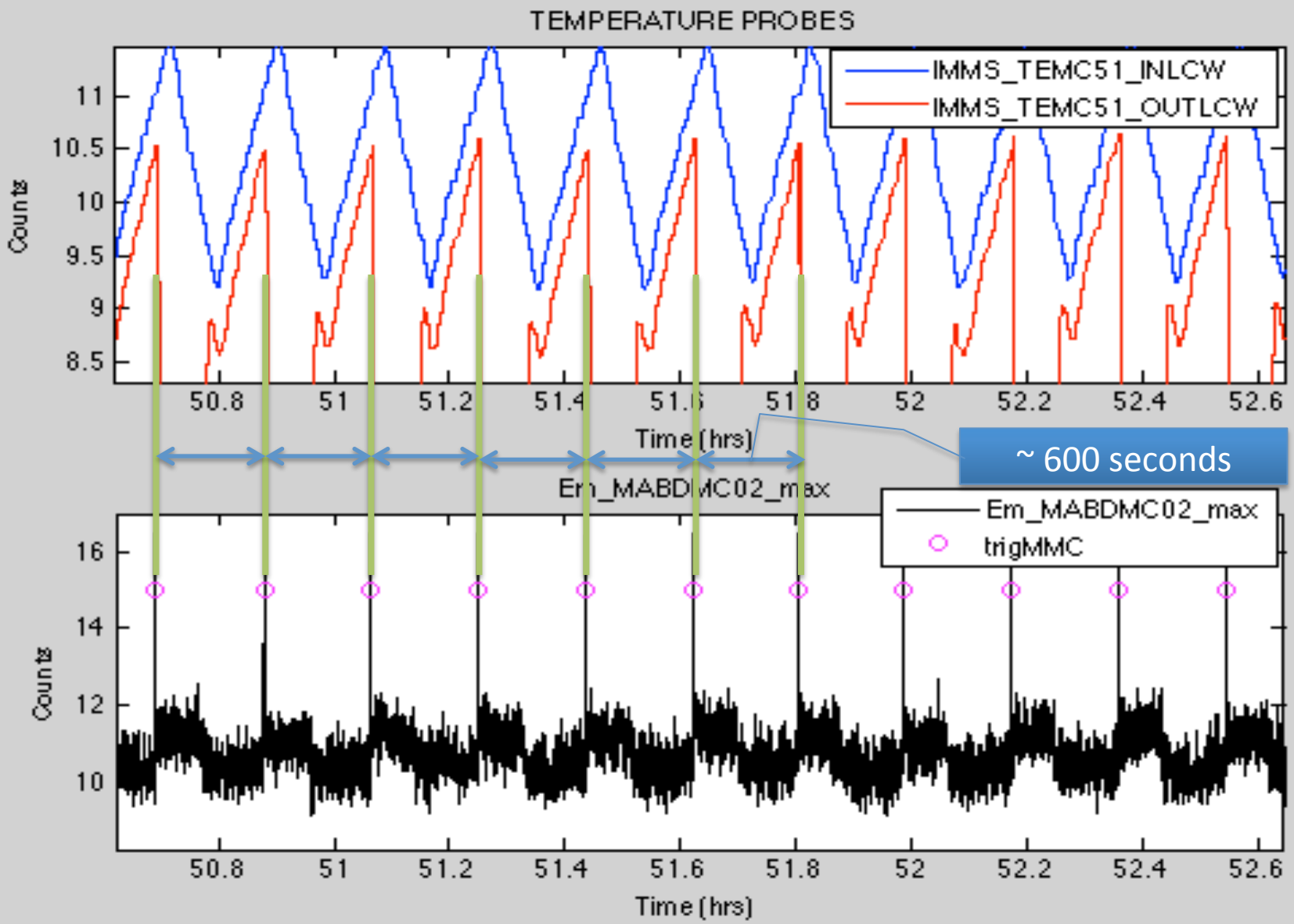
Results

- There is much evidence that supports strong magnetic activity in the Mode Cleaner (MC) which is coupling into the Dark Fringe (H).
- For documentation purposes, it is also important to note that the magnetometers in the Terminal buildings also produced a handful of interesting triggers.
- The source of these glitches can be attributed to the inrush current pulse occurring at each periodic switching on of the Air Conditioning water chiller.

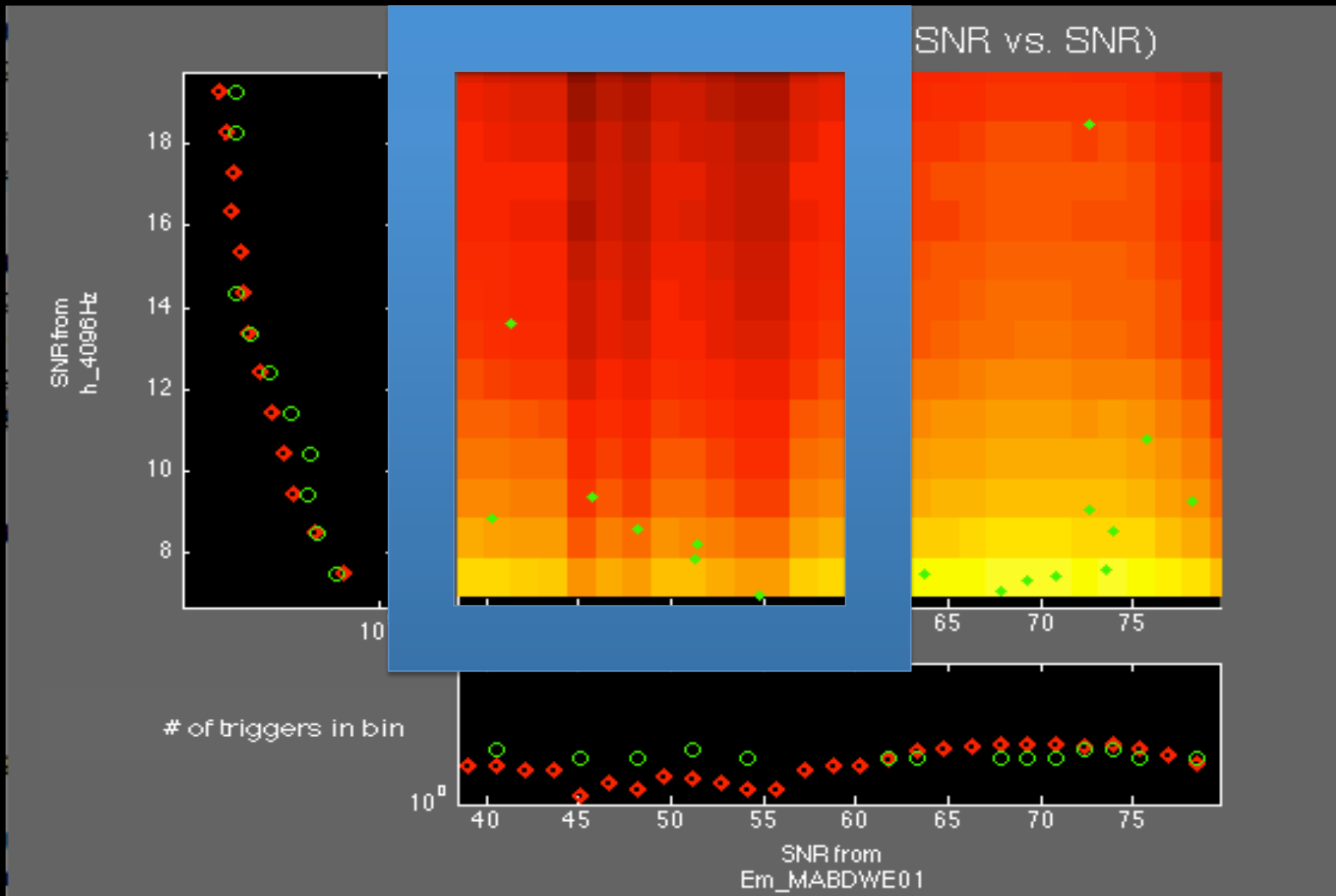
Interesting Triggers (MC vs. H)



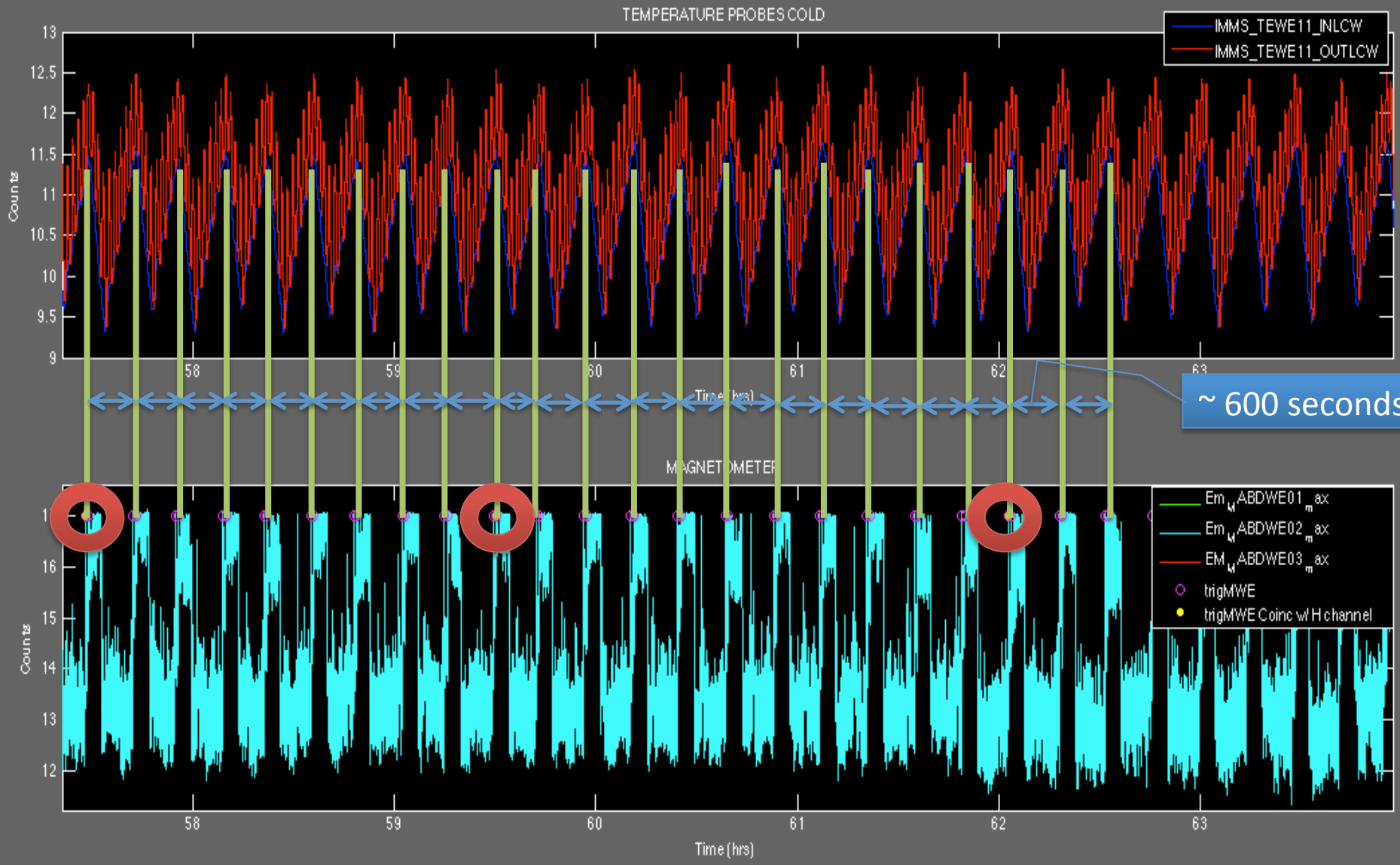
Periodicity Check



Interesting Triggers in Terminal Buildings

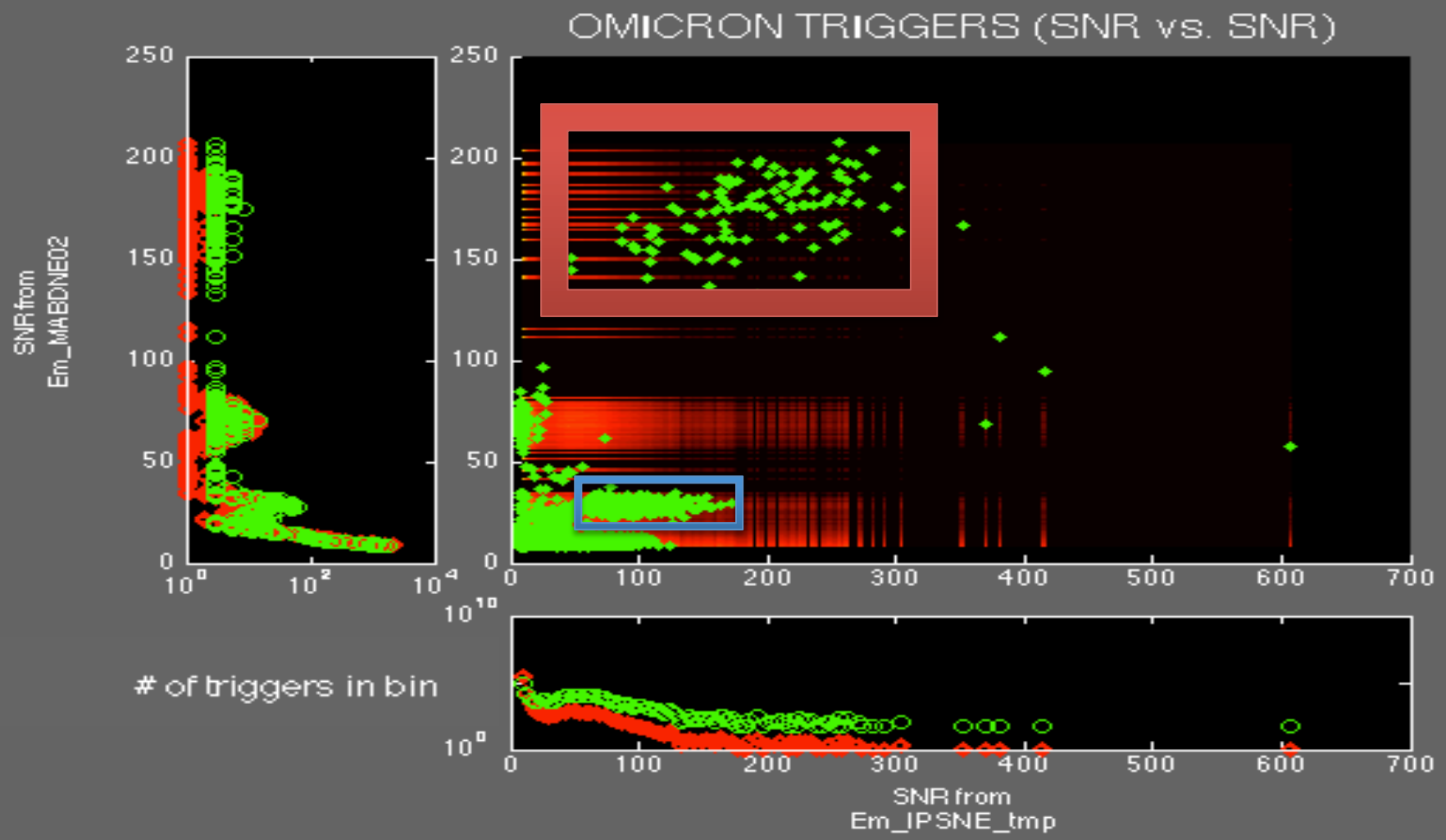


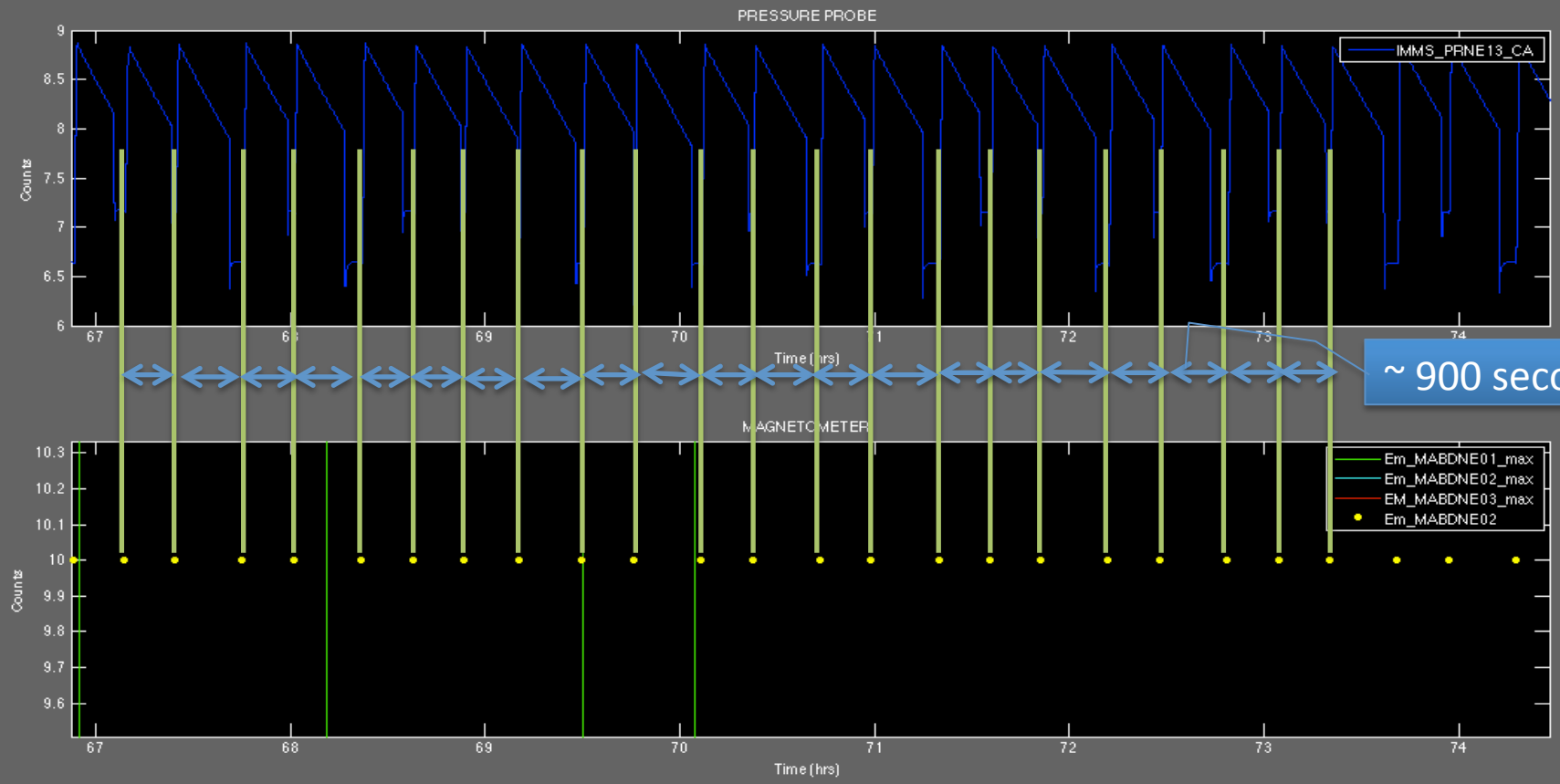
Periodicity Check (West End)



Other Sources?

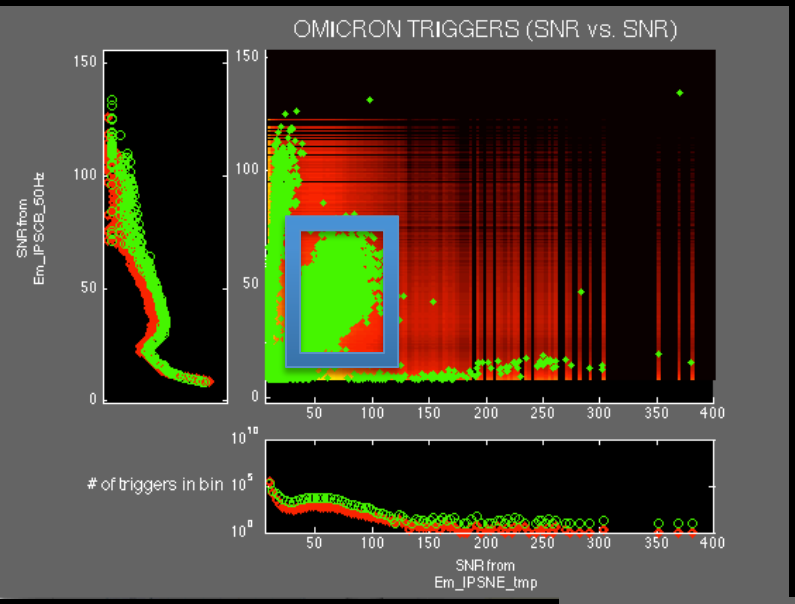
- Found another region of interest when comparing auxiliary channels

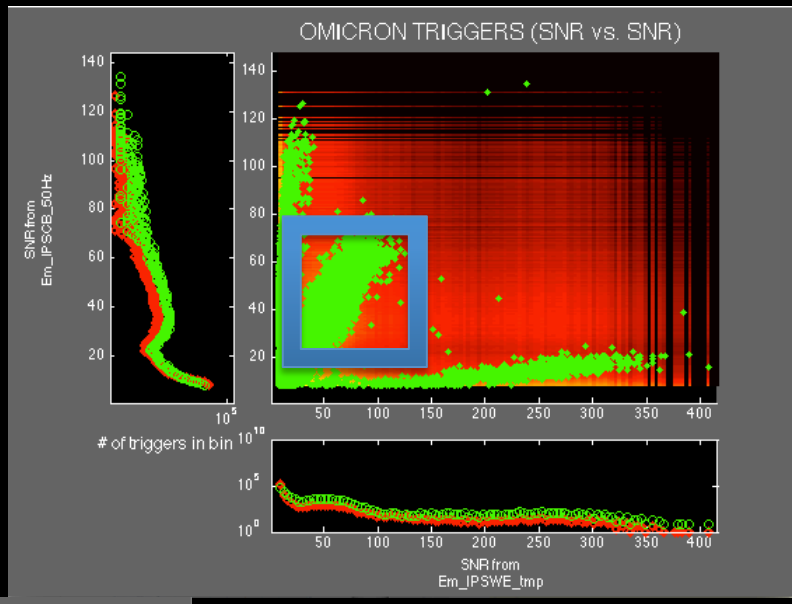


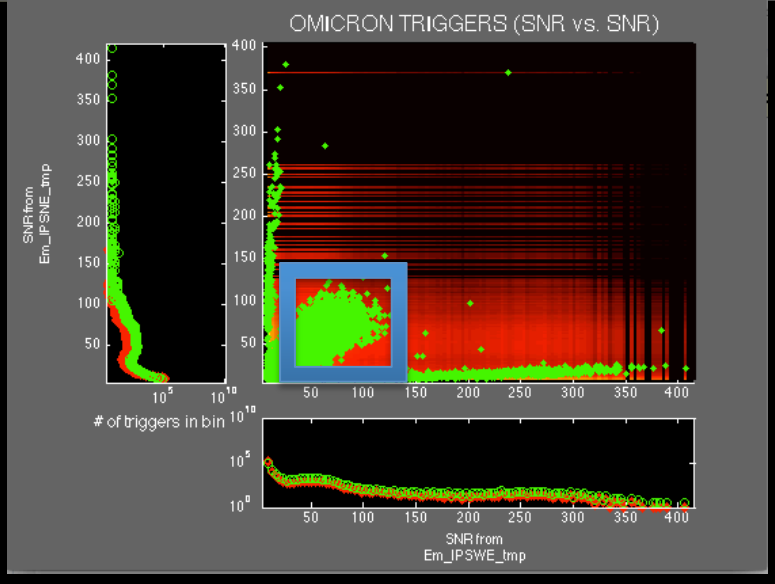


- The switching on and off of Air Compressor (again causes inrush current)
- Activity is monitored by pressure probe (Em_PRNE13_CA)
- These triggers do not show in the Dark Fringe

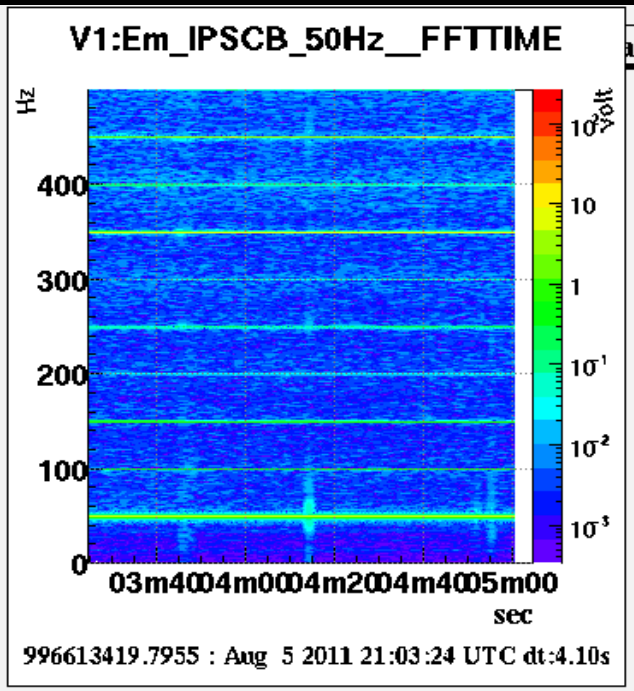
“Global” noise

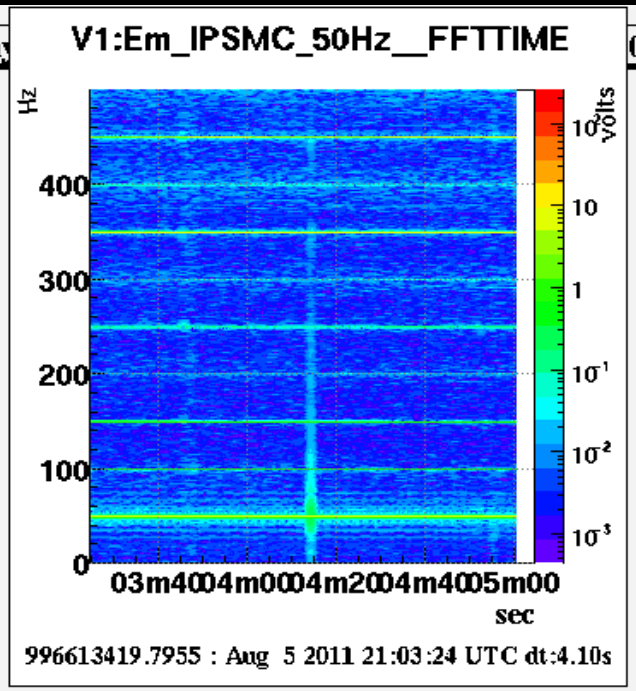


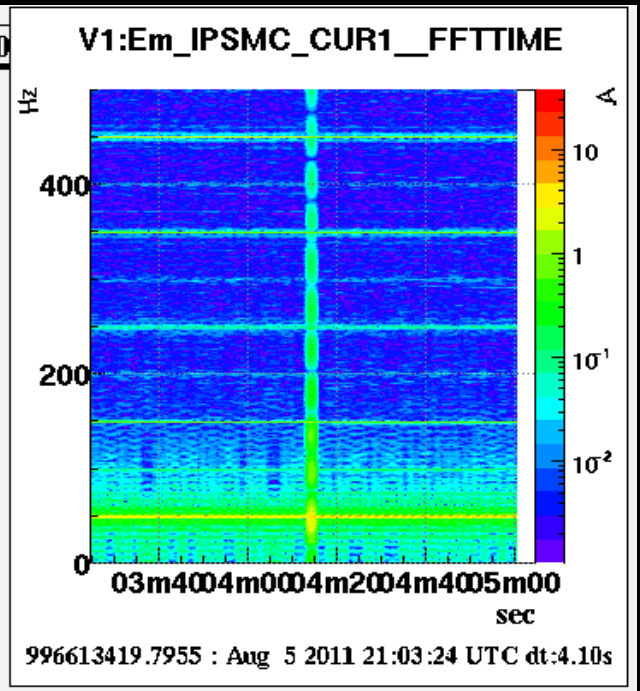


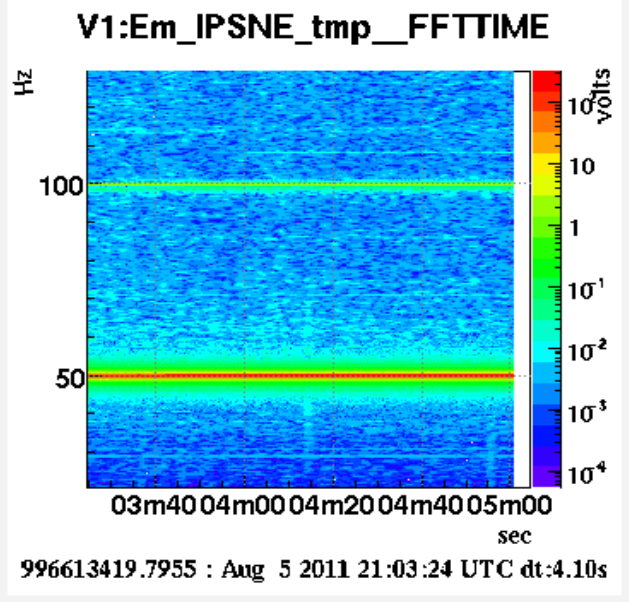


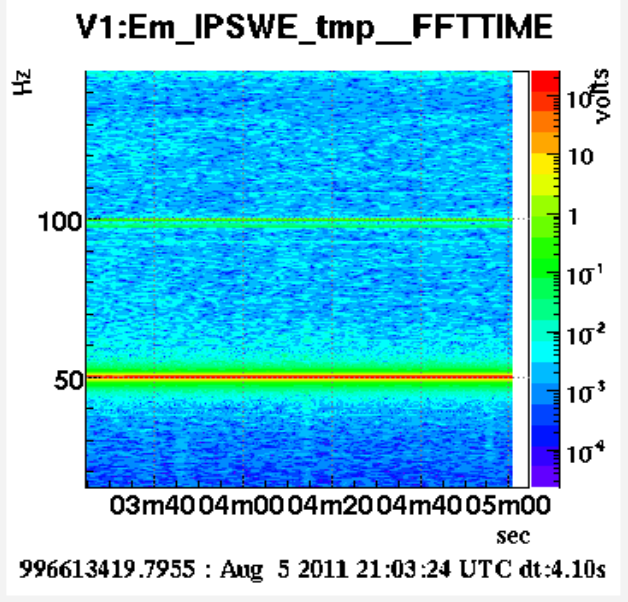
“Global Noise”

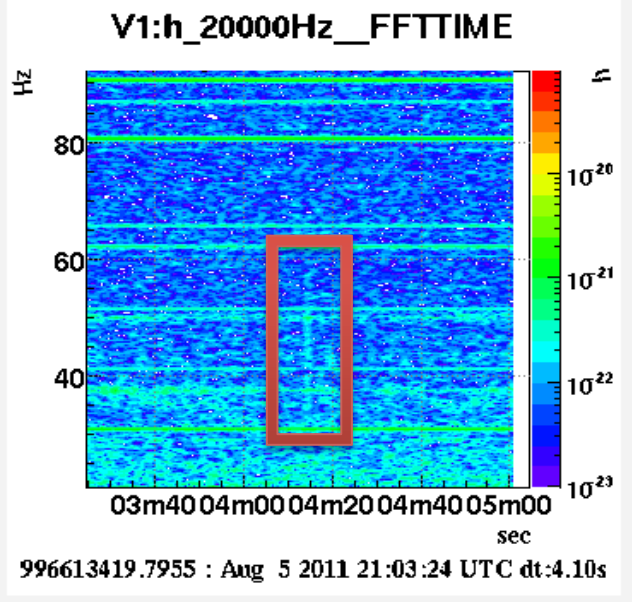












Conclusion

- Verified:
  - Chiller glitches in Mode Cleaner are largely present in Calibrated Interferometer Output Channel.
  - Chiller glitches are also present in Terminal Buildings due to North and West end chillers, but not nearly as much concern as those in the MC
  - Air compressor glitches are a common noise source among auxiliary channels but not apparent in DF channel
  - Voltage probes among buildings seem to give evidence that there is some site-wide activity
    - Still to be investigated more thoroughly
- SNR vs. SNR plots (with visual statistical analysis) along with other follow up checks help to identify and understand the physical phenomena behind these magnetic noise sources.

Acknowledgements

- Big Thanks to:
  - Dr. Bas Swinkels for the ideas behind this analysis.
  - Dr. Irene Fiori for the mentoring and introduction to Data Analysis for Detector Characterization.
  - Dr. Joshua Smith for his continued mentorship
  - Dr. Florent Robinet for providing the OMICRON triggers which made this data analysis possible