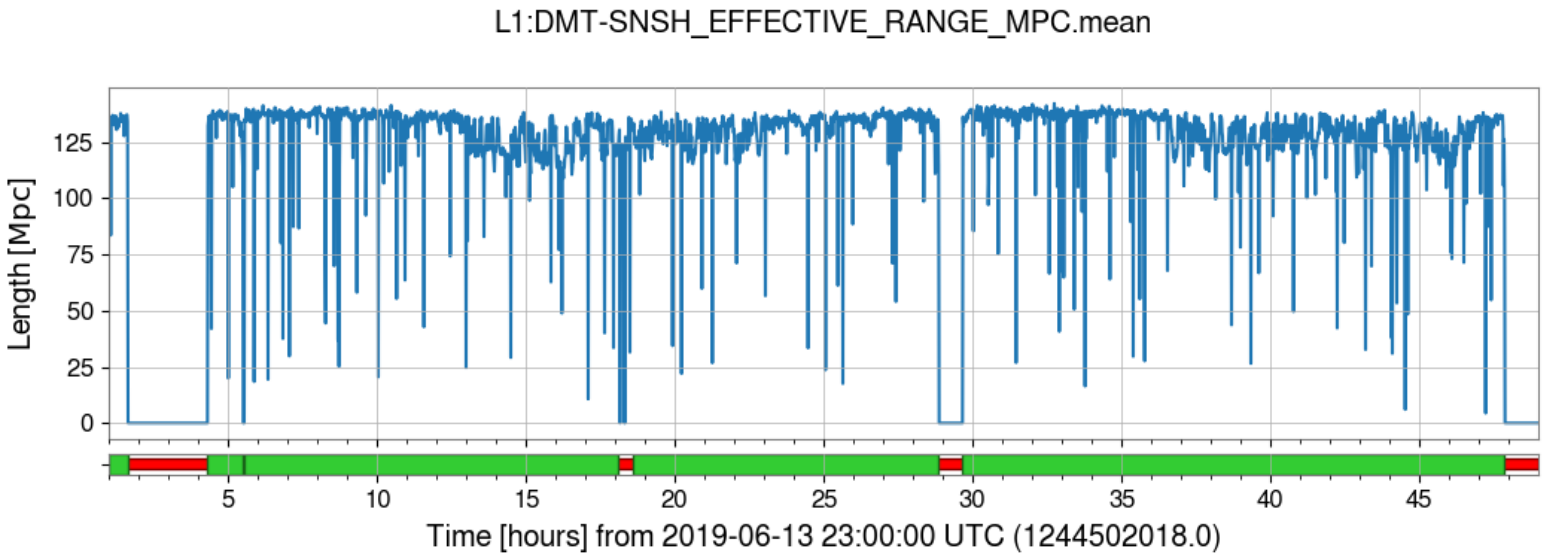
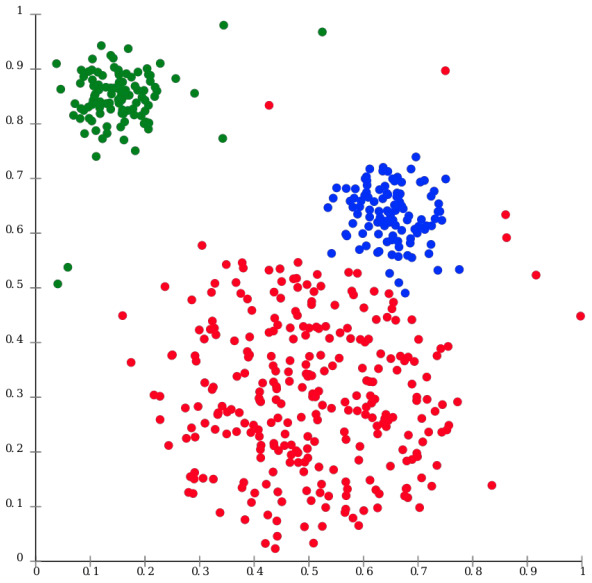
Correlation of Environmental Noise to Signals in LIGO Detectors via Clustering

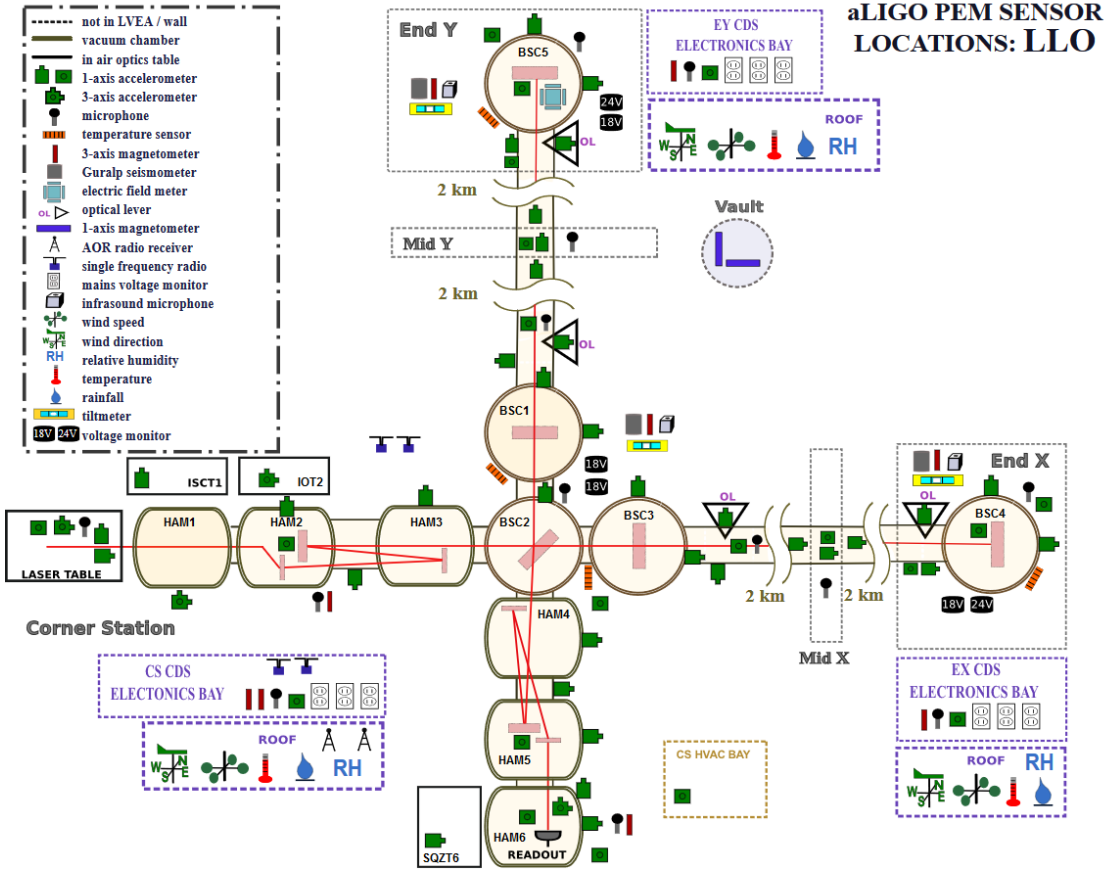
Jacob Bernhardt

Clustering


L1:DMT-SNSH_EFFECTIVE_RANGE_MPC.mean
Length [Mpc]
125
100
75
50
25
0
5
10
15
20
25
30
35
40
45
Time [hours] from 2019-06-13 23:00:00 UTC (1244502018.0)

Clustering

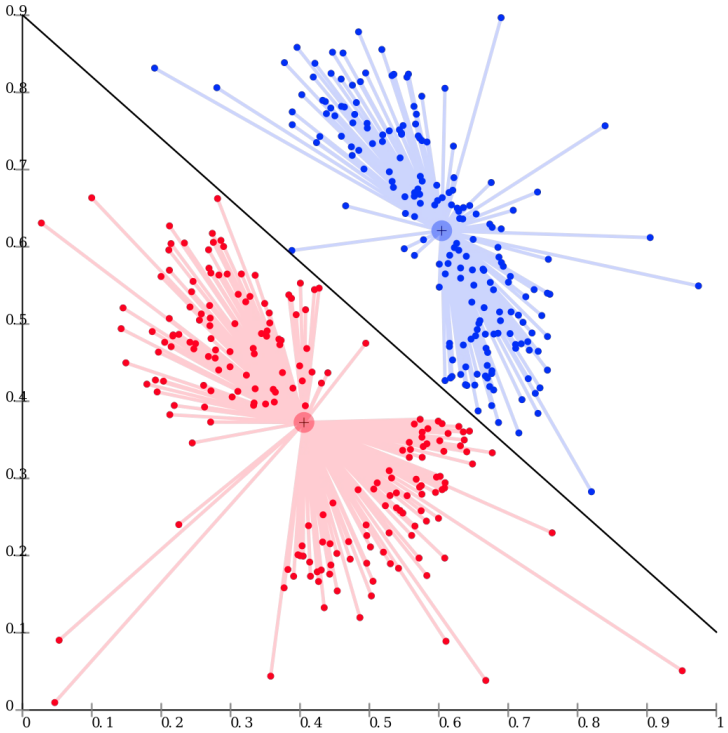

0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


aLIGO PEM SENSOR LOCATIONS: LLO
not in LVEA / wall
vacuum chamber
in air optics table
1-axis accelerometer
3-axis accelerometer
microphone
temperature sensor
3-axis magnetometer
Guralp seismometer
electric field meter
optical lever
1-axis magnetometer
AOR radio receiver
single frequency radio
mains voltage monitor
infrasound microphone
wind speed
wind direction
relative humidity
temperature
rainfall
tiltmeter
voltage monitor
End Y
BSC5
EY CDS ELECTRONICS BAY
ROOF
RH
2 km
Vault
Mid Y
2 km
BSC1
ISCT1
IOT2
HAM1
HAM2
HAM3
BSC2
BSC3
LASER TABLE
Corner Station
HAM4
HAM5
HAM6
READOUT
SQZT6
CS CDS ELECTONICS BAY
CS HVAC BAY
2 km
2 km
Mid X
End X
BSC4
EX CDS ELECTRONICS BAY

k-means with Histories

$$\left\{ s\left(t_0\right), s\left(t_{-1}\right), s\left(t_{-2}\right), \cdots, s\left(t_{-n}\right) \right\}$$

Coordinates of a point in the clustering subspace for a channel, with *s(t)* the channel amplitude time *t*.



Known States: Seismic BLRMS

Identified with "2-hour history" *k*-means over 30 days:

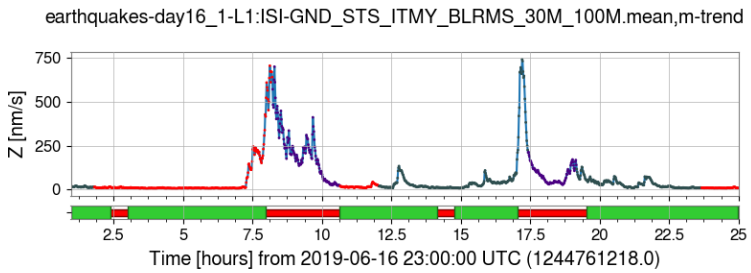
- Earthquakes (0.01 to 0.1 Hz)
- Microseisms (0.1 to 1 Hz)
- Anthropogenic noise (1 to 10 Hz)

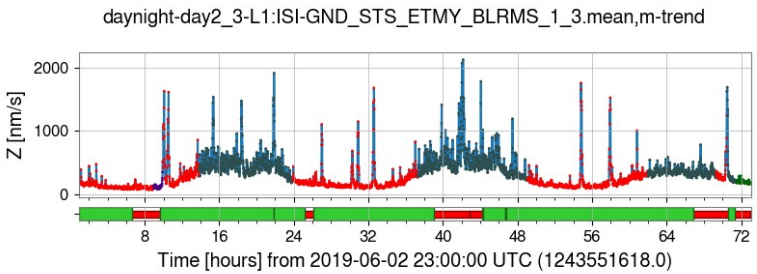
Optimized:

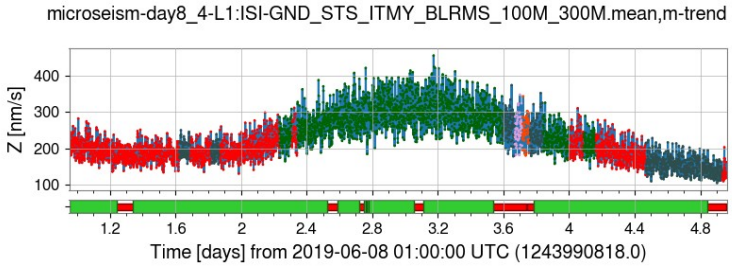
- length of history / number of clusters
- size of clustering space

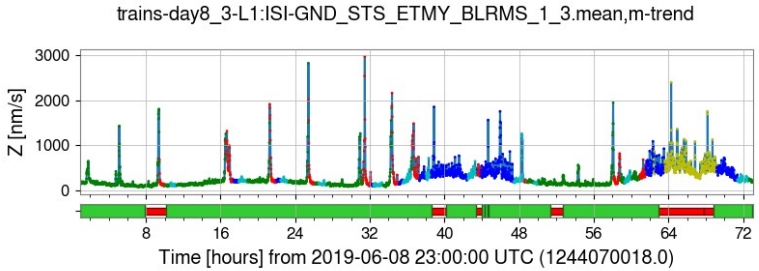
Known States: Seismic BLRMS

Hz	0.01-0.1	0.1-1	1-10
E.Q.	~100x	~10%	~0%
µSeism	~50%	~250%	~10%
Anthro	~80%	~10%	~200%





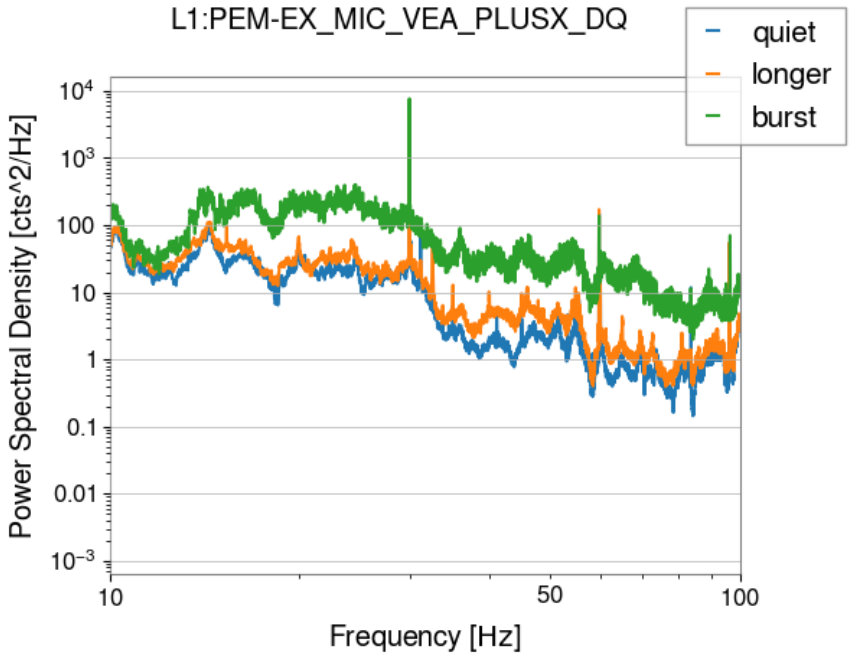




Acoustic States

BLRMS:
10-28
28-32 (HVAC)
32-50
50-70
70-100
100-200

Hz	10-28	28-32	32-50
LVEA	109%	95%	176%
PLUSX	87%		89%
PLUSY	131%	83%	165%



Longer (hours) cluster, less loud, locked times

Quick loud burst cluster @ lock-losses

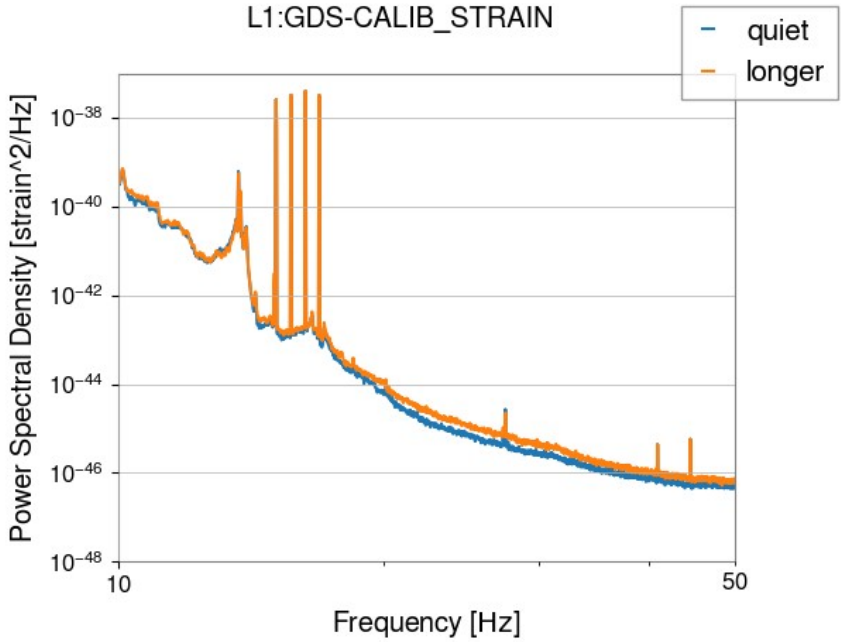
Hz	32-50	50-70
LVEA	1112%	890%
PLUSX	1183%	1034%
PLUSY	1100%	

Clustering with DARM

DARM BLRMS*:
10-13
18-22
22-27
27-29
29-40
40-54
54-65
65-76
75-115
115-190
190-210
210-290
290-480
526-590
590-650
650-885
885-970
1110-1430

Longer (hours) cluster, less loud, locked times

Hz	22-27	27-29	29-40
GDS-CALIB_STRAIN	1%	3%	1%



*aLIGO LLO Logbook entry 45 374 by Gabriele Vajente

Accelerometer States

BLRMS:
1-4
4-10
10-28
28-32
32-48
48-60
60-80
80-118
118-122
122-200

Infrequent burst

BSC focus

Hz	4-10
EX BSC4 X	427%
EX BSC4 Z	884%

Hz	48-60	60-80	80-118
MY VEA BTUBE	256%	259%	123%
EY BSC5 Z	108%		

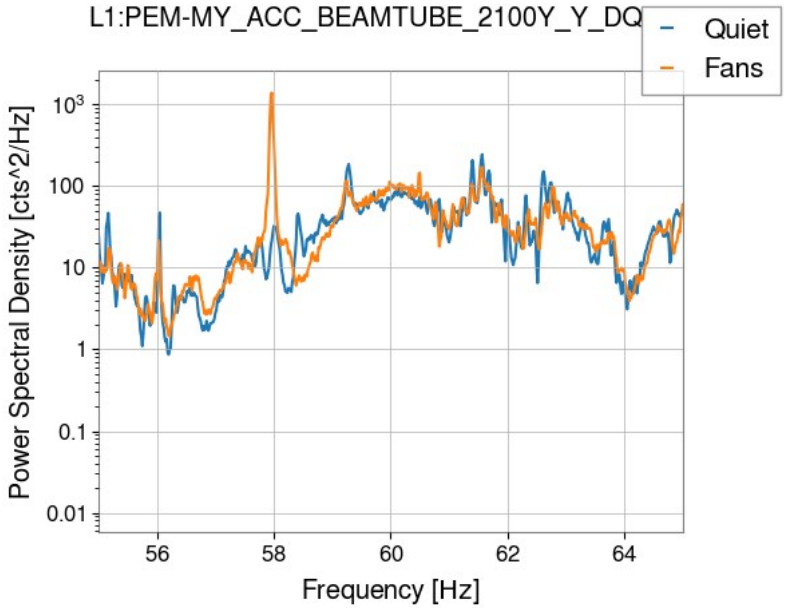
~1/2 day

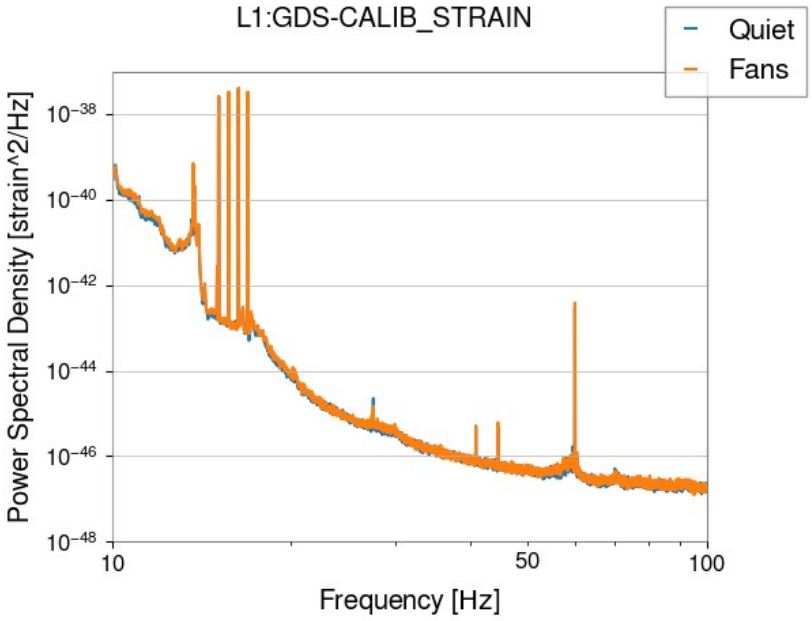
Beamtube focus

Hz	48-60
MY 2100Y BTUBE	618%

Clustering with DARM

Hz	48-60	54-65
MY 2100Y BTUBE	618%	
GDS-CALIB_STRAIN		38%





Next Steps

- Focus on DARM
  - Try clustering only observing times
- More small PEM subsets
  - Many channels in few bands
  - Many bands in few channels
  - Target new sensors

Acknowledgments

Special thanks to:

Anamaria Effler

Rana Adhikari

All LLO Staff

Alan Weinstein & the coordinators of SURF

LIGO

Appendix