Characterization of Advanced LIGO detectors

Marissa Walker

image credit: Caltech/MIT/LIGO Lab

Marissa Walker

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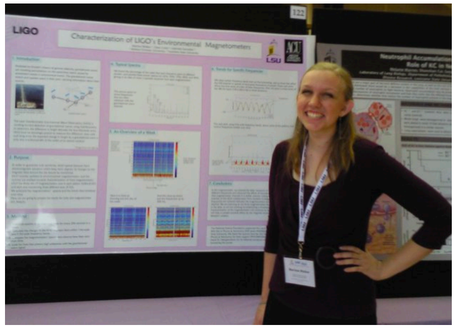
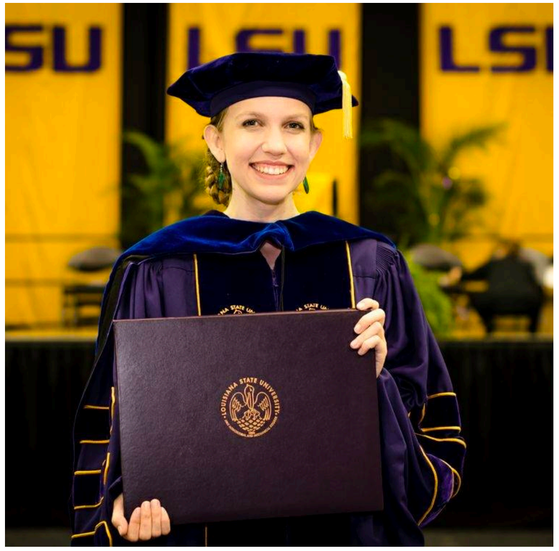
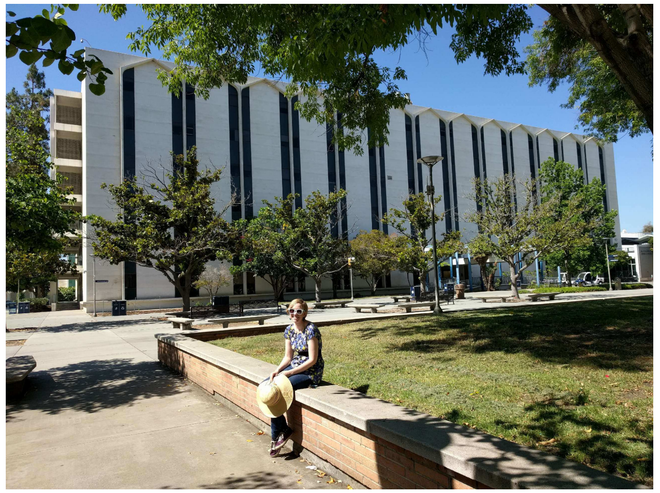
2010







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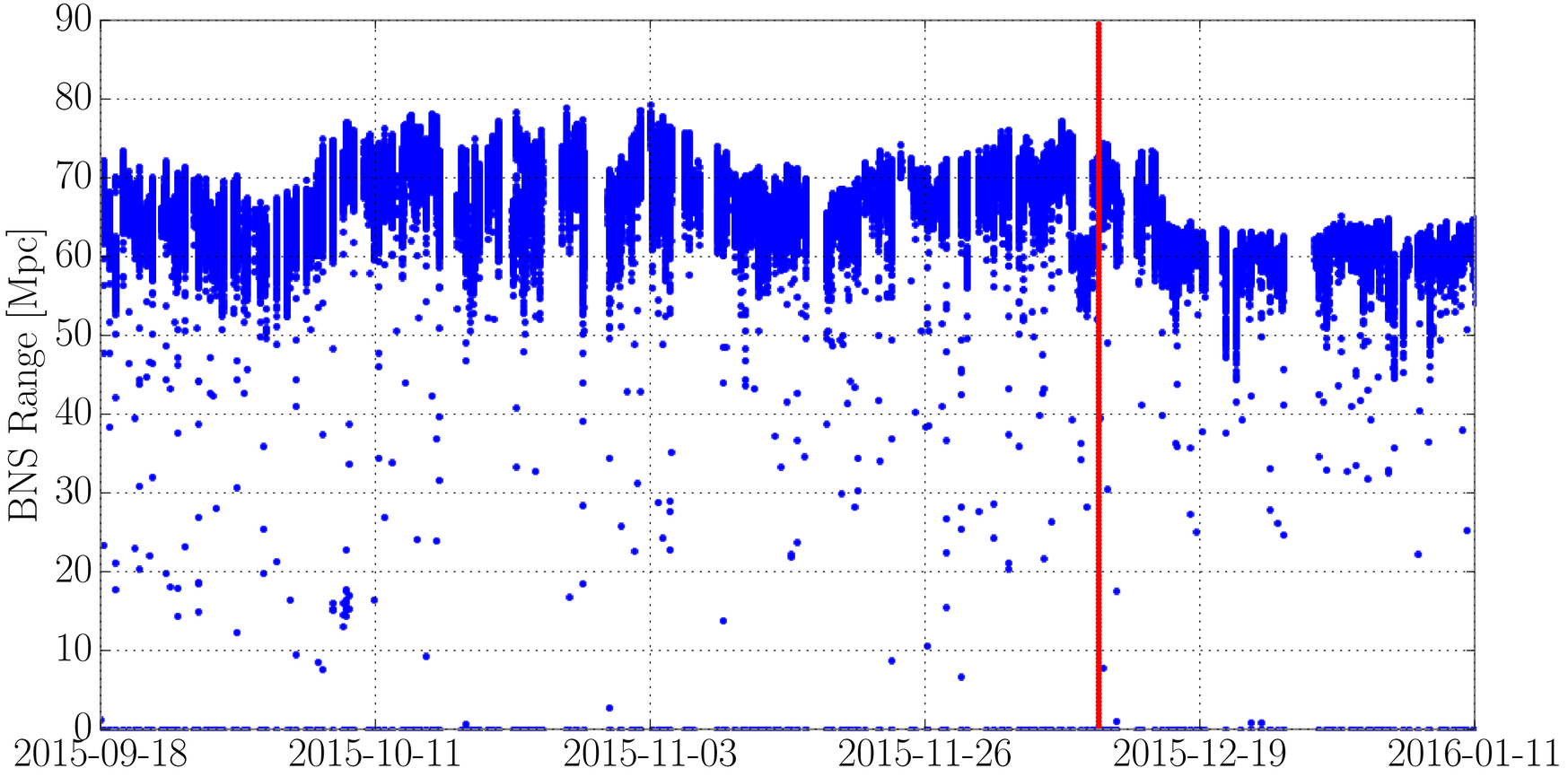
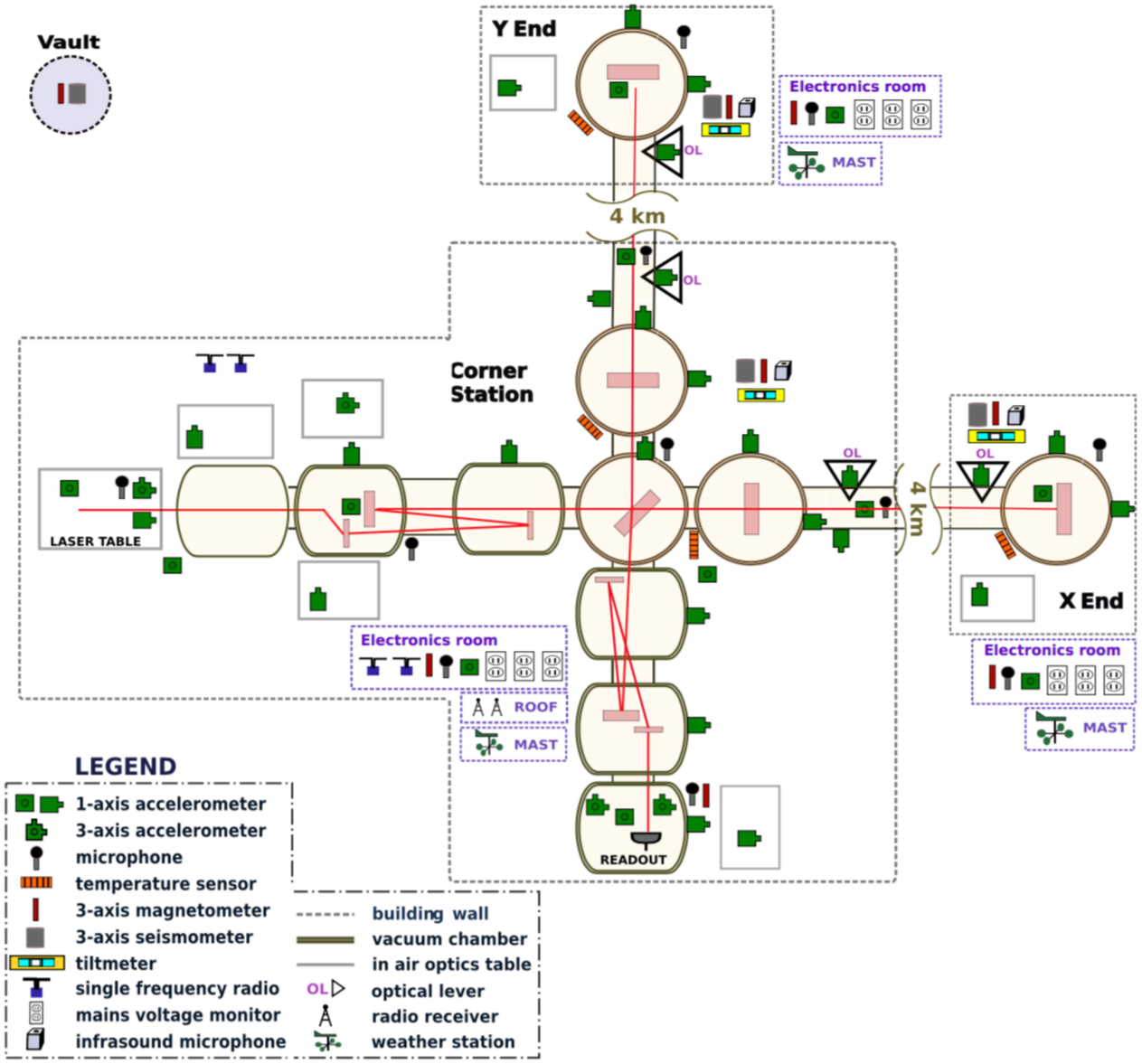
Binary Neutron Star Range in 2015-2016



- Binary Neutron Star (BNS) Range is a measure of how far away we could detect a BNS merger
- Varying noise in the detector causes range fluctuations
- If we can discover and eliminate where noise is coming from, we can increase our range

(1 Megaparsec = 3.26 x 10^6 light years)

Physical Environment Monitors



B.P. Abbott et al. arXiv 1602.03844

Pinpointing the sources of noise is not an easy task!

LIGO detectors have many optical components, seismic isolation systems, and control loops

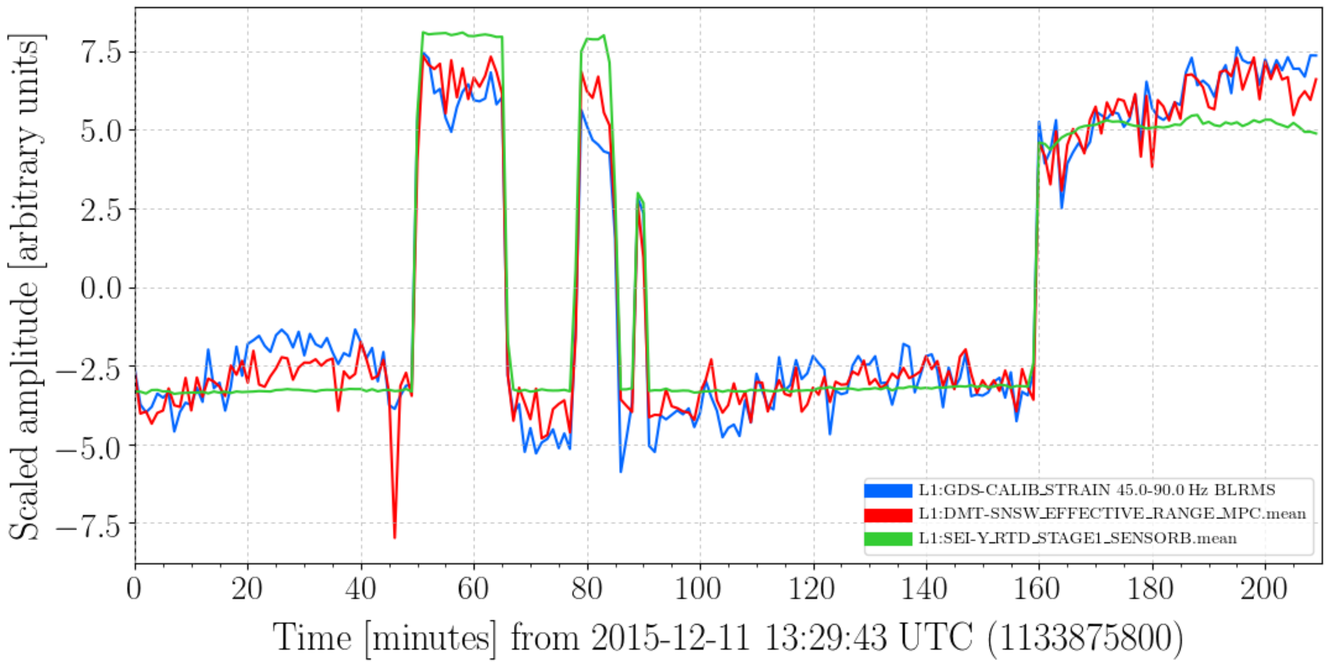
Hundreds of thousands of recorded signals - *auxiliary channels* - to search for potential noise coupling

New tool: Range correlations with Lasso regression

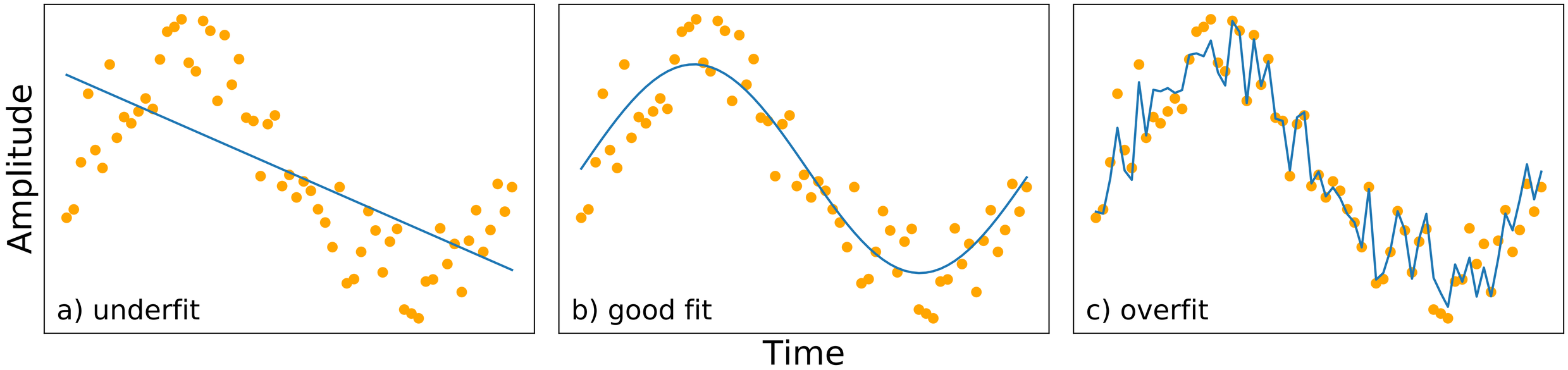
Jeff Bidler, Alex Macedo, Josh Smith, Marissa Walker
(Cal State Fullerton)

- Motivation: Understand fluctuations in range in order to improve the detectors
- Problem: With over 100,000 channels to search, how do we find the few noise sources that are most important?
- Method: Create a model of the range based on auxiliary channels to determine largest contributors

Example: a broken sensor in 2015



What is Lasso regression?



Our goal is to create a model that is a good fit to the data but is still easy to interpret

What is Lasso regression?

Linear regression:

Create a model ***y*** for the range using a combination of ALL auxiliary channels, $\mathbf{x_1, x_2, \ldots x_n}$

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \ldots + \beta_n x_n$$

Using ALL of the channels, we can create a very accurate model for a data set, but it will not be interpretable!

What is Lasso regression?

Lasso regression:

Create a simpler model ***y*** for the range using a combination of SOME auxiliary channels by setting many coefficients to zero

$$y = \beta_0 + \mathbf{0} + \beta_2 x_2 + \mathbf{0} + \mathbf{0} + \beta_5 x_5 + \ldots + \beta_n x_n$$

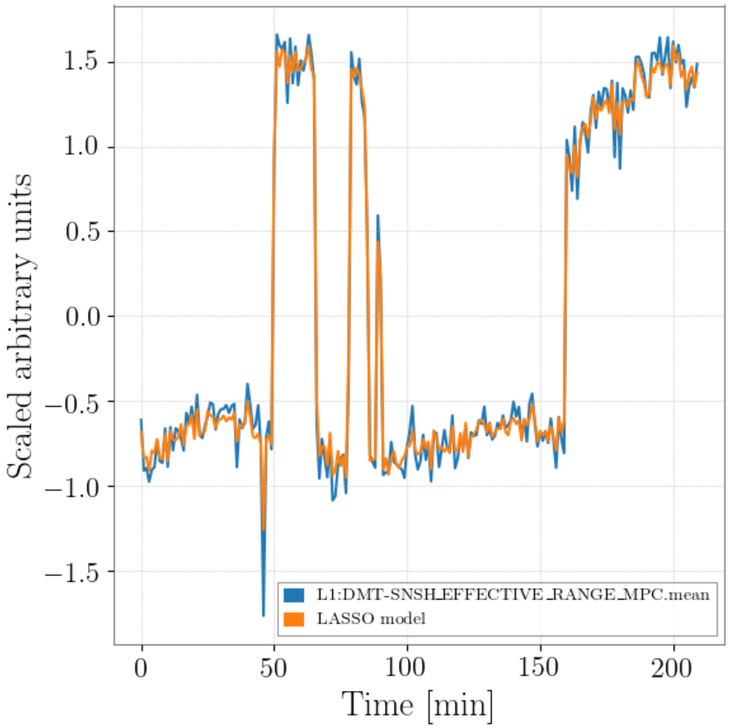
By creating a model based on only a few of the auxiliary channels, we have a better idea of what the largest noise contributors are

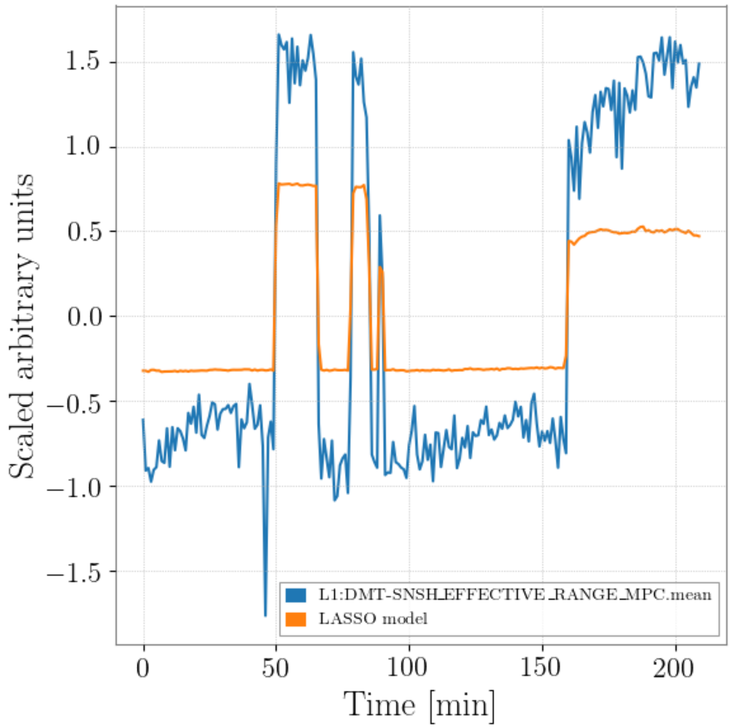
Lasso Slow Correlation Tool

- Lasso regression allows us to create a model for the range based on a subset of the most important channels
- The alpha parameter determines the complexity of the model - low alpha approaches ordinary linear regression

Low alpha (0.01)

Fits the range very closely, using larger number of channels (117)





High alpha (0.55)

Does not fit the range as well, but selects a small number of channels (2)

Test cases for Lasso

Broken sensor

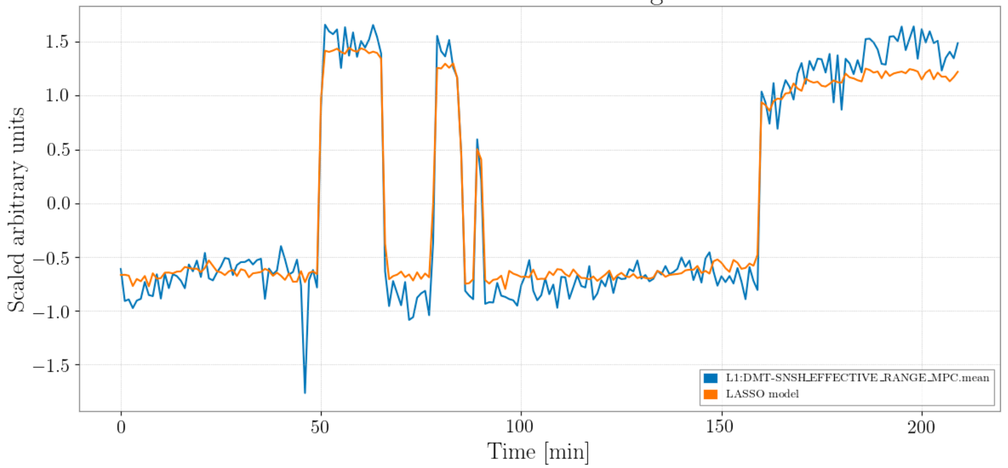
- One main noise source contributing to dramatic range jumps
- Lasso easily finds the broken sensor, creating a model based on only a few channels

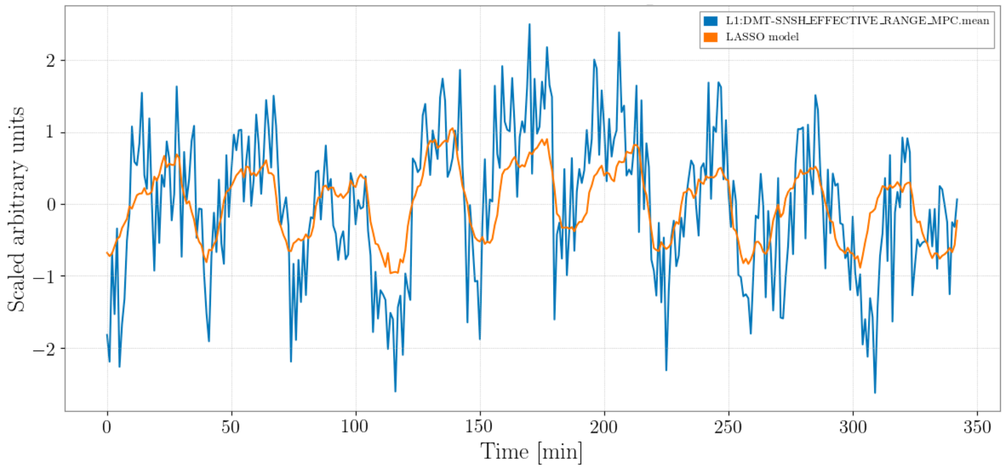
Y-end scattering

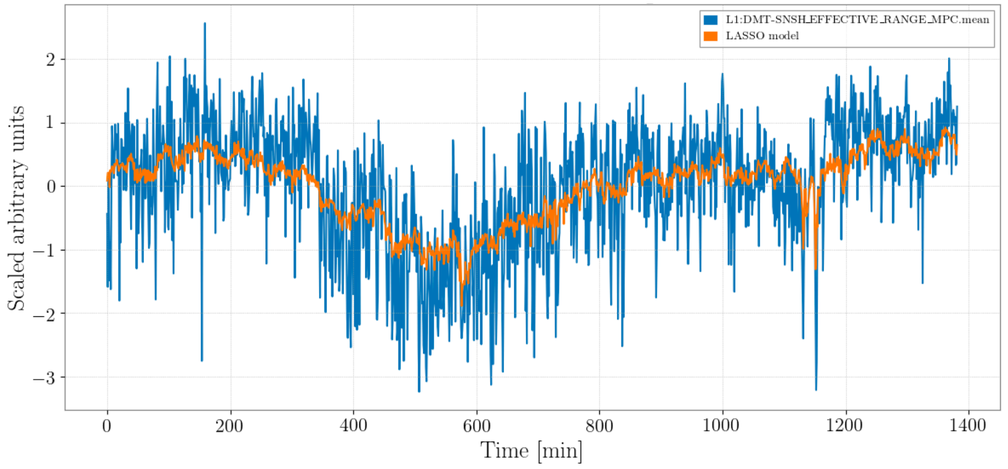
- Seismic motion in the Y-end drives noise variation through light scattering
- Lasso picks out a group of channels related to Y-end motion

24 Hours

- More subtle variations in the course of a typical day, without any single obvious noise source
- Lasso selects a larger group of channels for its model - some potential places to start follow-up investigations







Paper link: https://arxiv.org/abs/1807.02592