Identifying Witnesses to LIGO Glitches Using Auxiliary Channels

Luis Gabriel C. Bariuan[1,2],
Mentors: Evangelos E. Papalexakis[2] and Rutuja Gurav[2]
[1]Massachusetts Institute of Technology, Cambridge, MA 02139
[2]University of California Riverside, Riverside, CA 92521

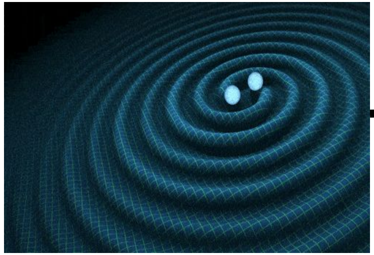
LIGO Summer Final Presentations
LIGO-T2200207
August 19, 2022
Email: lbariuan@mit.edu

Outline

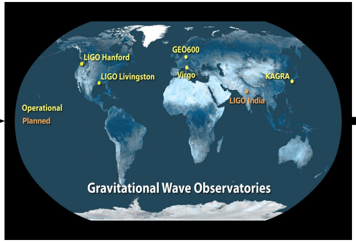
- Review basics of LIGO detectors and define glitches.
- Describe the pipeline utilized in the project.
- Describe the model.
- Present results.

LIGO is a sensitive detector of GWs

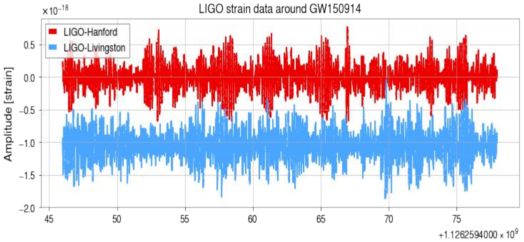
Astrophysical events generate GW



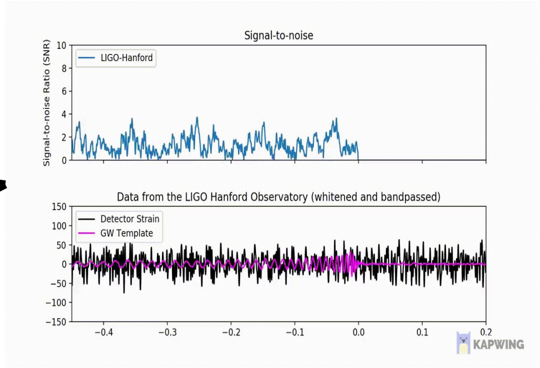
LIGO Network



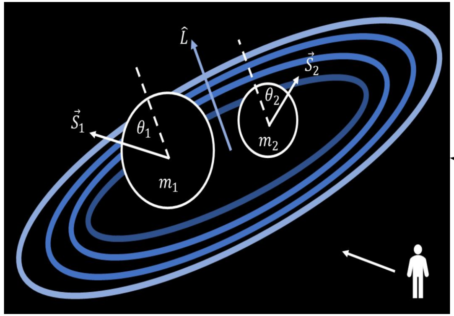
Observed Signal



GW Event Search



Astrophysical Parameter Estimation

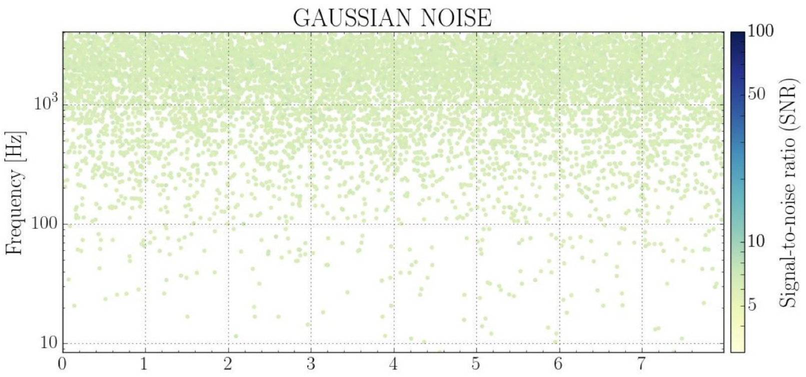


Real-time Alerts

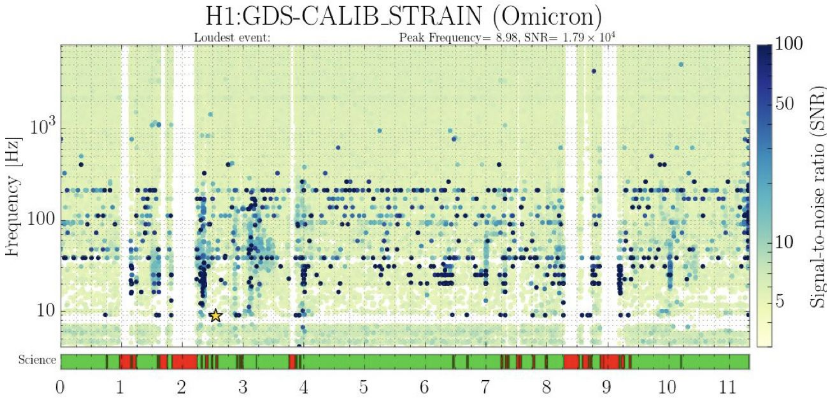
Credit: R. Gurav

Sensitivity of LIGO to faint signals makes it vulnerable to glitches

- Glitches-short-lived, noise-transients that plague the main channel.
  - Terrestrial origin.
  - Exceed Gaussian noise expectation.



Idealized Situation

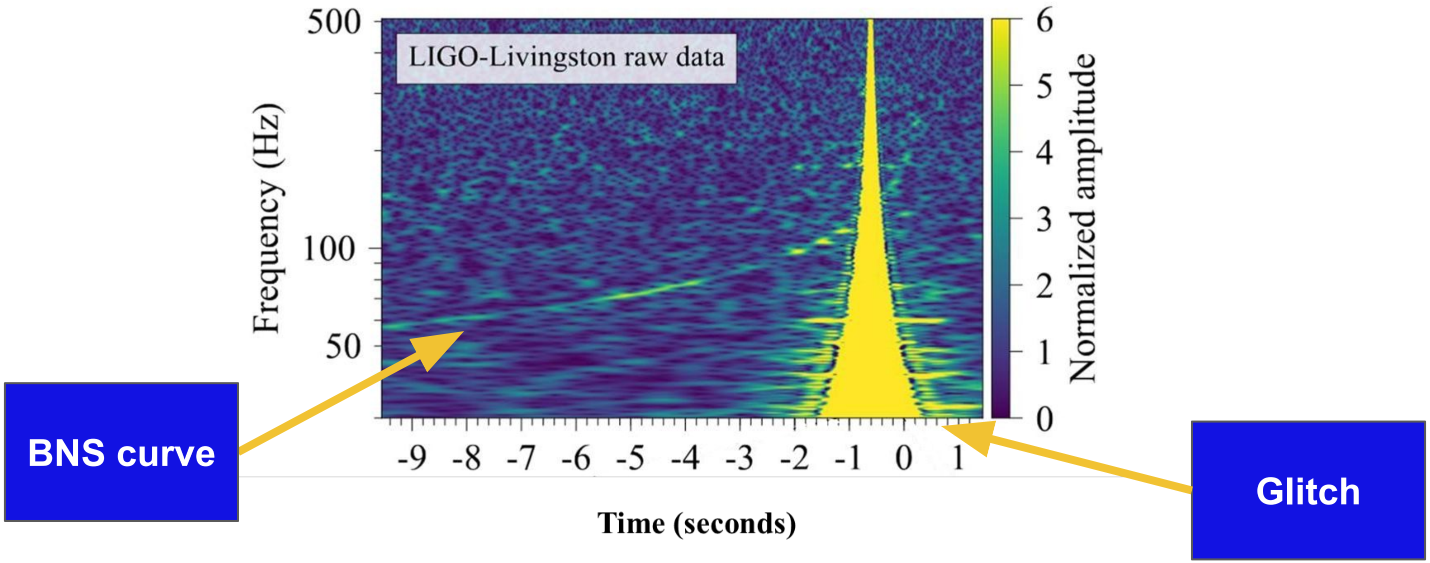


Reality

Credit: D. Davis

Glitches may mask or mimic real GW signals

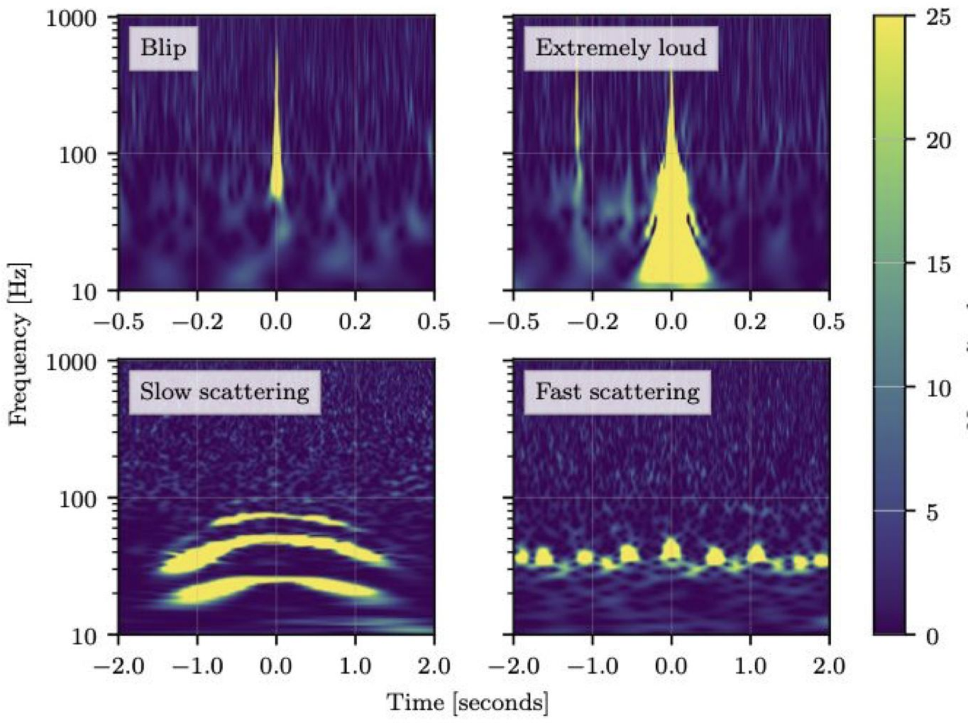
- An example GW170817 (BNS merger).
- **It is important to mitigate glitches to avoid missing real GW signals!**



Credit: LIGO Caltech

The Gravity Spy Catalog aimed to classify glitches visually

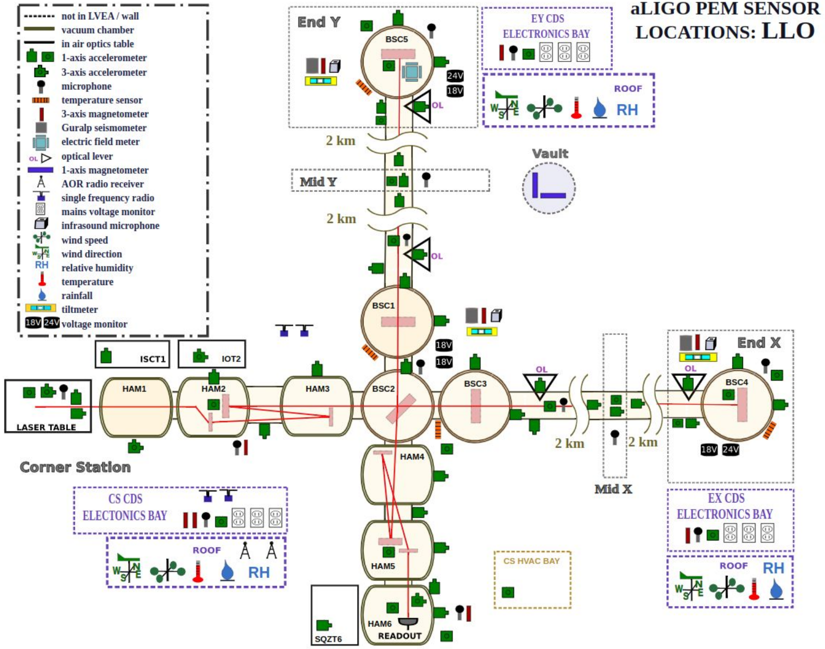
- No information about the origin of the glitches.



Credit: Davis+2021

Idea: Use LIGO’s sensor network to find glitches

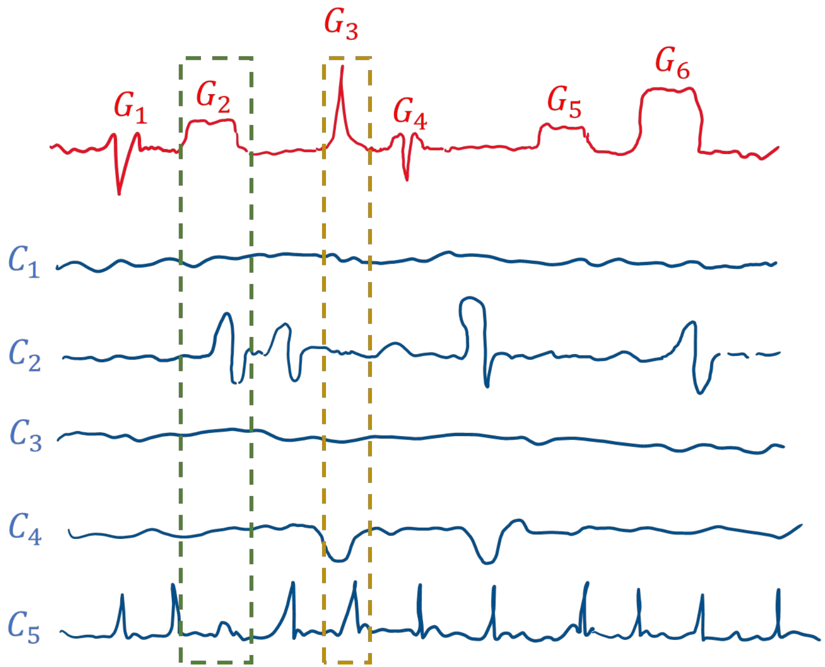
- Sensor networks monitors state of instrument and the environment.
- Capacity to record noise events.
    - May help localize origin of glitches.



Credit: R. Gurav

Auxiliary channels can witness glitches

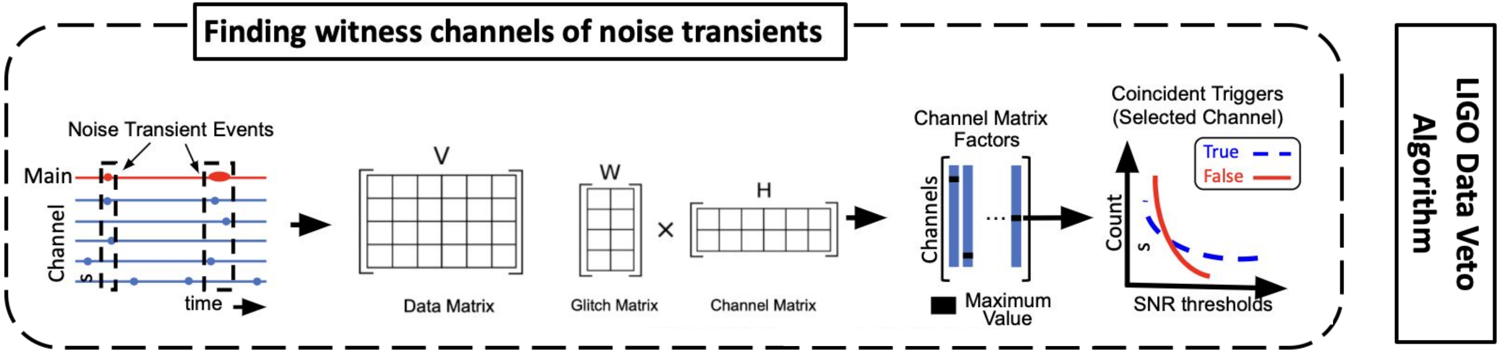
- Loud triggers in auxiliary channels can coincide with glitches in the main channel.
- Use “safe” channels to remove glitches
    - “Safe”-not witness real signals.
    - Channels that remove data
        - **Veto generators**



Credit: R. Gurav

Previous works aimed to mitigate glitches using auxiliary channels

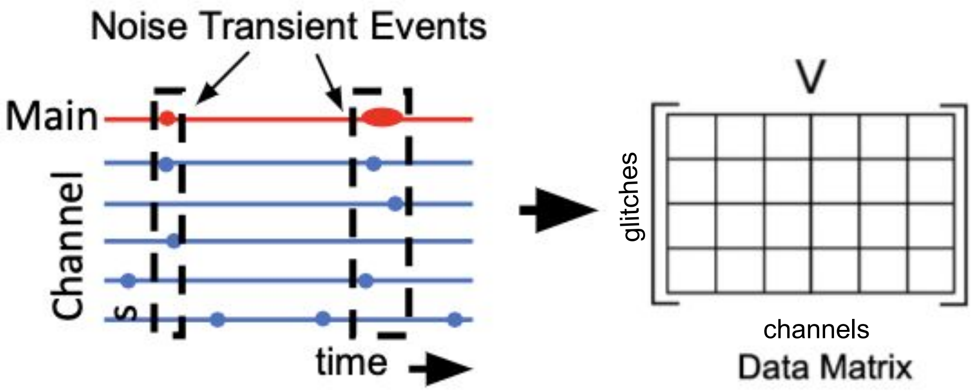
- Algorithms such as hveto and UPV searched for veto generators.
- iDQ calculates $P(\mathrm{glitch}|\mathrm{aux})$ using supervised ML.
- **We use an unsupervised ML pipeline:**
  - **"all-at-once" fashion.**
  - **Data Collection -> Dataset Creation -> Modelling -> Evaluation**



Credit: R. Gurav

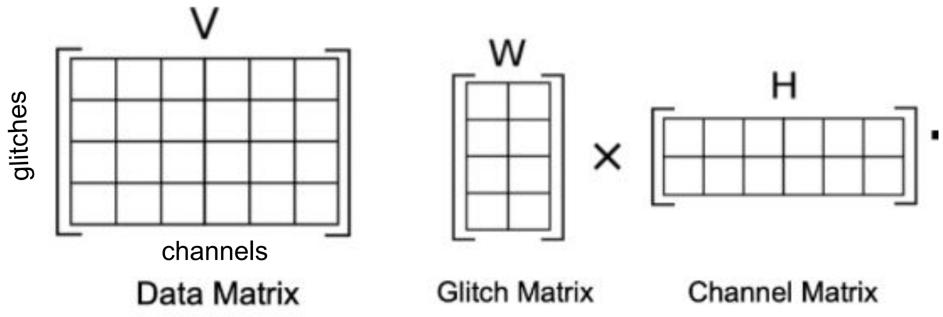
We collect data from the first week of O3b

- Obtained list of glitches.
- Collected coincident triggers from a set of auxiliary channels.
- Create a data matrix:
  - Encodes presence or absence of loud triggers coincident with glitches.



This work: We explore other factorization models

- Previous work:
  - Non-Negative Matrix Factorization (NMF).
  - Analyzed O2 data.
- **This work:**
  - **Boolean Matrix Factorization (BMF).**
    - **Simpler-only encodes presence or absence of glitches.**
- Use channel matrix to find witness channels.

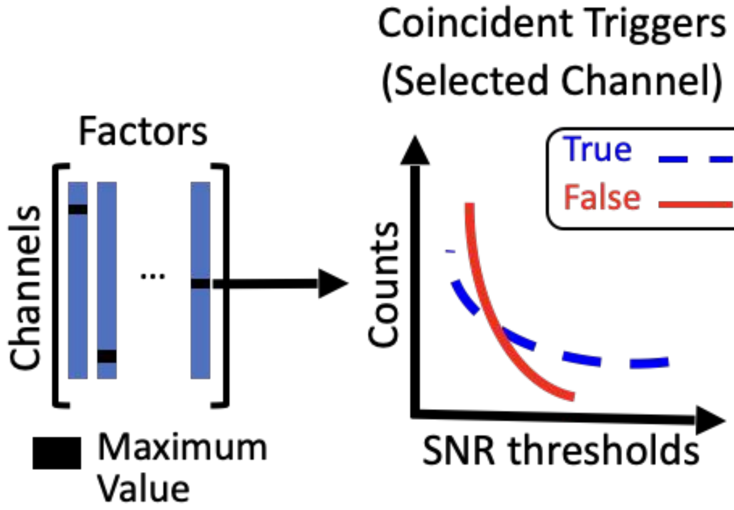


x	**y**	**x ∨ y**	**x ∧ y**
0	0	0	0
0	1	1	0
1	0	1	0
1	1	1	1

Credit: Wikimedia

Use the channel matrix to find possible witness channels

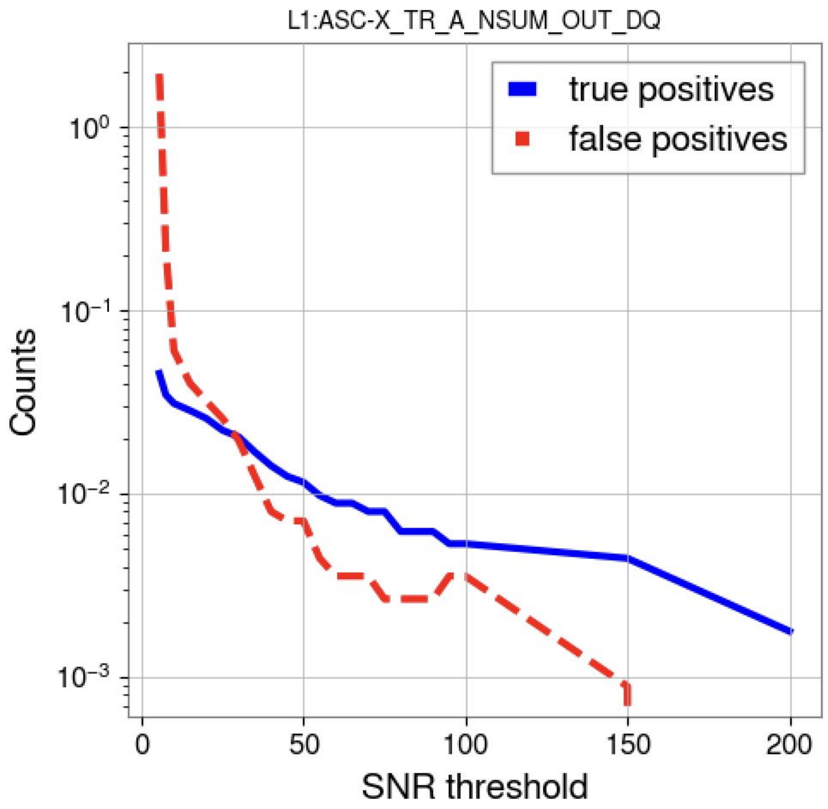
- *Evaluation* on a test dataset using the witness channels obtained from *training.*
- Plot the True Positive/False Positive curves versus SNR.
  - **True Positive (TP) -** $N_{\text{witnessed}}/N_{\text{total}}$
  - **False Positive (FP) -** $N_{\text{not witnessed}}/N_{\text{total}}$
- Criteria for a good veto generator:
  - TP must surpass FP curve at a given SNR value.



Credit: R. Gurav

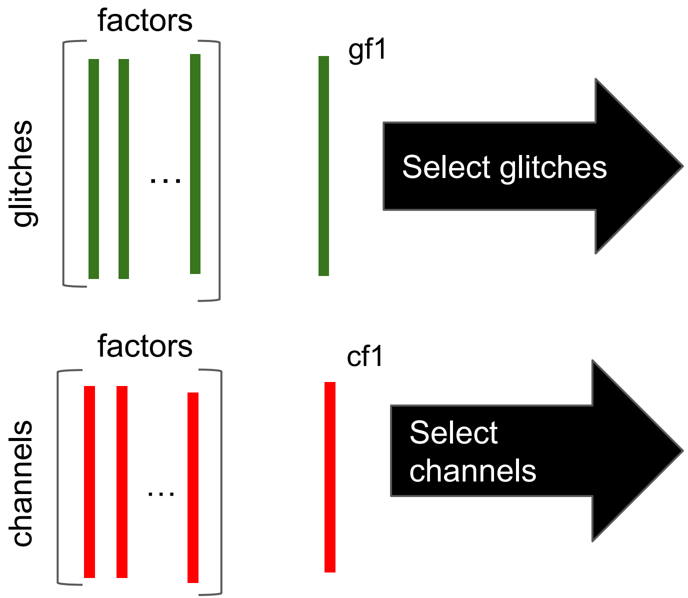
BMF is comparable to NMF in finding veto generators

- Apply both NMF and BMF:
    - 20 candidate channels.
    - BMF finds the same witness channel as NMF despite binarizing the data.



Advantage of this method is the ability to correlate glitches with channels

- Subset of channels witnessing subsets of glitches.
- Experts can use information to localize the origin of glitches as opposed to Gravity Spy.



Glitch Indices	159, 234, 327, 415, 504, 638, 697, 740, 793, 973, 1031, 1180, 1226, 1341, 1385, 1558, 1743, 1752, 1909, 1965, 2000, 2222, 2320
Associated Witness Channels	'L1:HPI-HAM4_BLND_L4C_VP_IN1_DQ' 'L1:HPI-HAM4_BLND_L4C_RX_IN1_DQ'

We explored BMF as a model for identifying glitch witnesses and clustering

- Simpler but remains comparable to NMF despite binarization in finding veto generators.
- **Advantage of pipeline: allows for co-clustering to determine associations between glitch events and channels.**
  - Can be used in conjunction with current LIGO tools to mitigate glitches.
- **Information about glitch events and their witness channels can be relayed to domain experts who can localize and fix the glitches at their source!**

In the future, we can:

- Use our approach to determine whether a Gravity Spy glitch class is a true class.
- Explore other factorization models.
- Explore using more channels for the analysis.
- Explore using other features of the triggers.

Acknowledgements

L.B. was supported by the LIGO SURF program. The LIGO SURF program is funded by the National Science Foundation.

L.B. would also like to thank Prof. Vagelis Papalexakis, Rutuja Gurav, Prof. Jon Richardson, mentors, LIGO SURF program, Caltech, UCR, and fellow students for their support in this program.

L.B. utilized the LDG and LIGO Compute Resources for this project.