

2.3. Improving Detection of Gravitational Waves with Topological Data Analysis. The interaction between black holes in the universe creates “chirps” in space-time known as gravitational waves. Their detection is an important problem in physics, and a difficult one at that, because the signals one is looking for are buried in background noise. In this project we will investigate how topological methods can improve the detection of said signals, and in particular, what kinds of learning models on persistence diagrams are most effective.

We will follow the paper by Bresten and Jung where the authors generate a large data set of gravitational waves of non-spinning binary black hole merges, embedded in Gaussian noise (see Figure 1) and use features derived from the persistence diagrams of their sliding window point clouds as input to a Convolutional Neural Network (CNN). Their work shows that including topological features leads to vast improvements in the detection of gravitational waves. In this project we are particularly interested in determining if:

- (1) The topological features proposed by Bresten and Jung have the most expressive power, or if other topological features (e.g., using template functions, etc) lead to better classifiers.
- (2) If the CNN, which can be costly to train, is really necessary or if better features with a simpler classifier (e.g., SVM, random forest, etc) is still competitive.

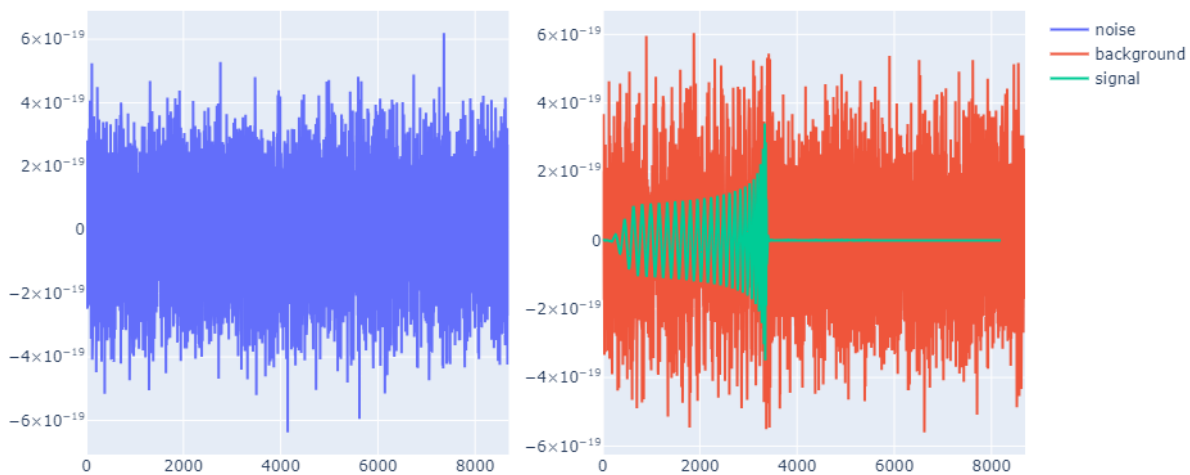


FIGURE 1. Examples of signals in the Bresten-Jung data set

A place to start:

- (1) Read the paper by Bresten and Jung to get a sense of how topological methods are being used.
- (2) Use the giotto-tda library to reproduce (i.e., run on your computer) their tutorial on gravitational wave detection.
- (3) Compare these results to other feature extraction methods (e.g., using template functions) and other models.

References.

- (1) Detection of gravitational waves using topological data analysis and convolutional neural network: An improved approach, C. Bresten and J. Jung, <https://arxiv.org/pdf/1910.08245.pdf>
- (2) Giotto-TDA tutorial on gravitational wave detection, https://giotto-ai.github.io/gtda-docs/0.3.0/notebooks/gravitational_waves_detection.html
- (3) Giotto-TDA library, <https://github.com/giotto-ai/giotto-tda>