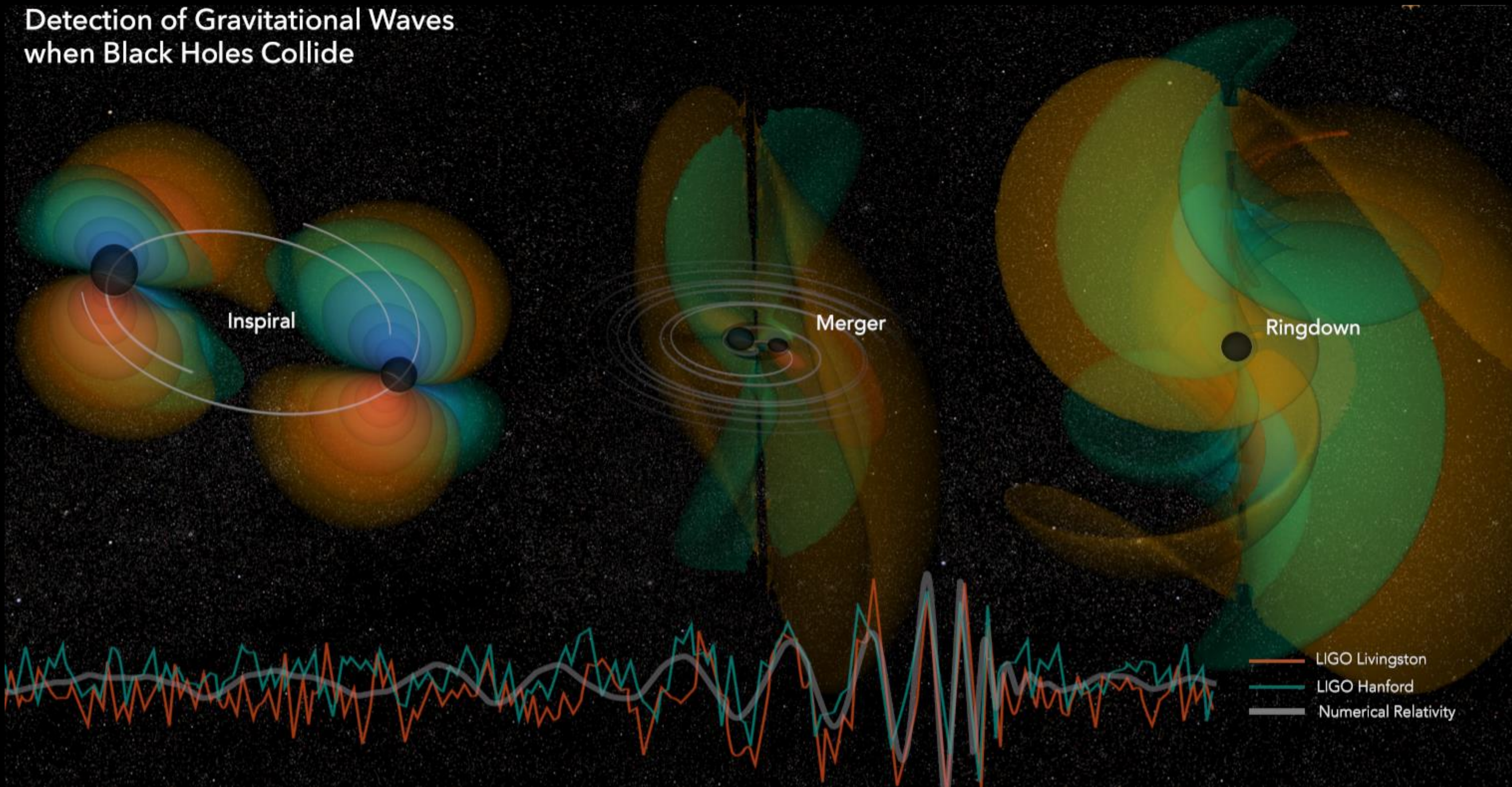

Gravitational Waves Analysis Using Machine Learning

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Gravitational Waves

- General Theory of Relativity: Space + Time = Spacetime
- Gravitational Waves -Perturbations of space-time
- Why study them? New way to explore the universe
- Dataset - Numerical Templates of gravitational waveforms generated from Binary Black Hole simulations (only 2,2 mode)

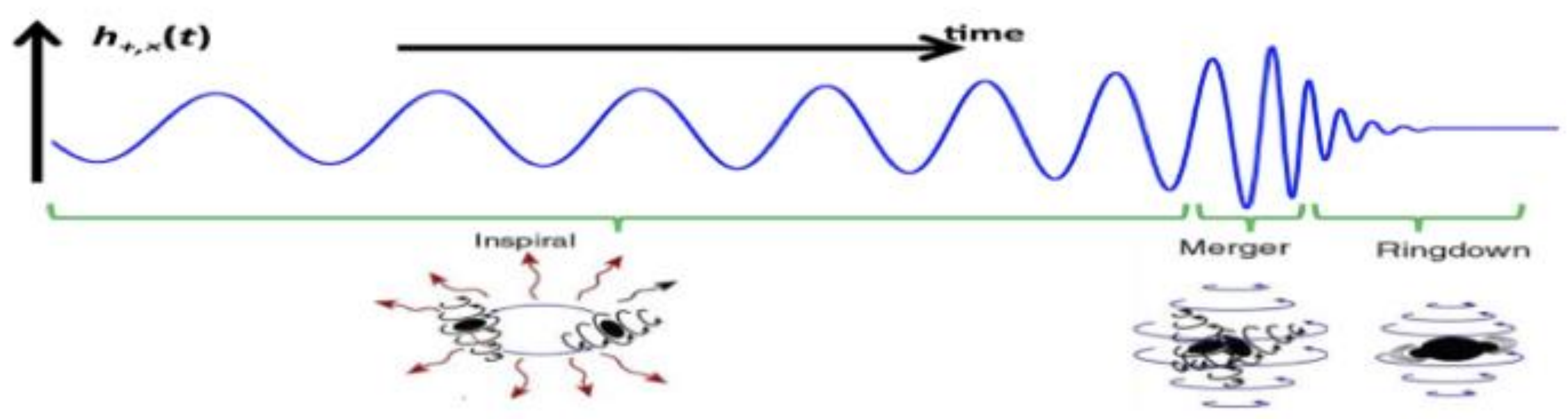
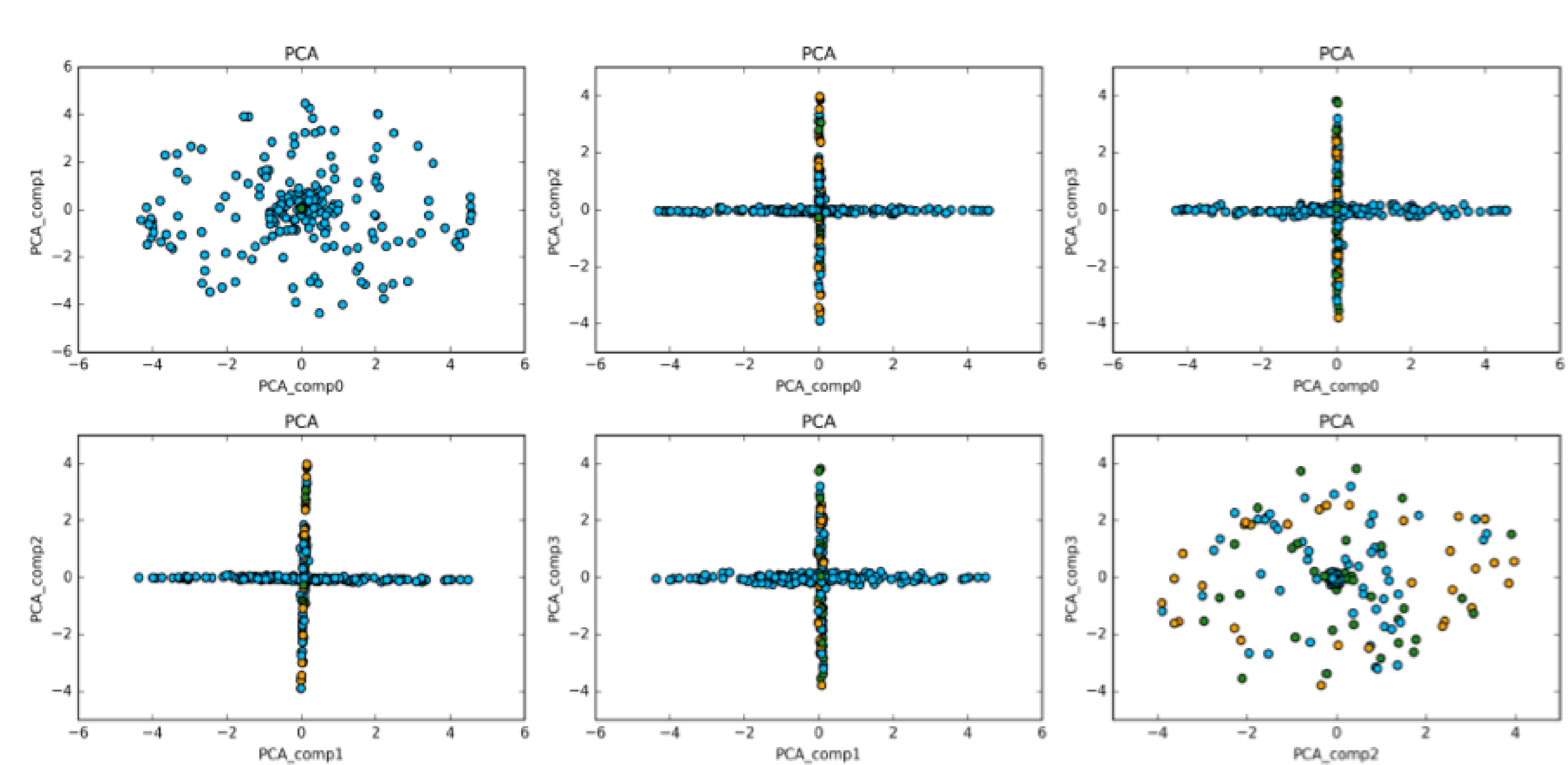


Figure 1: Gravitational Waveform template

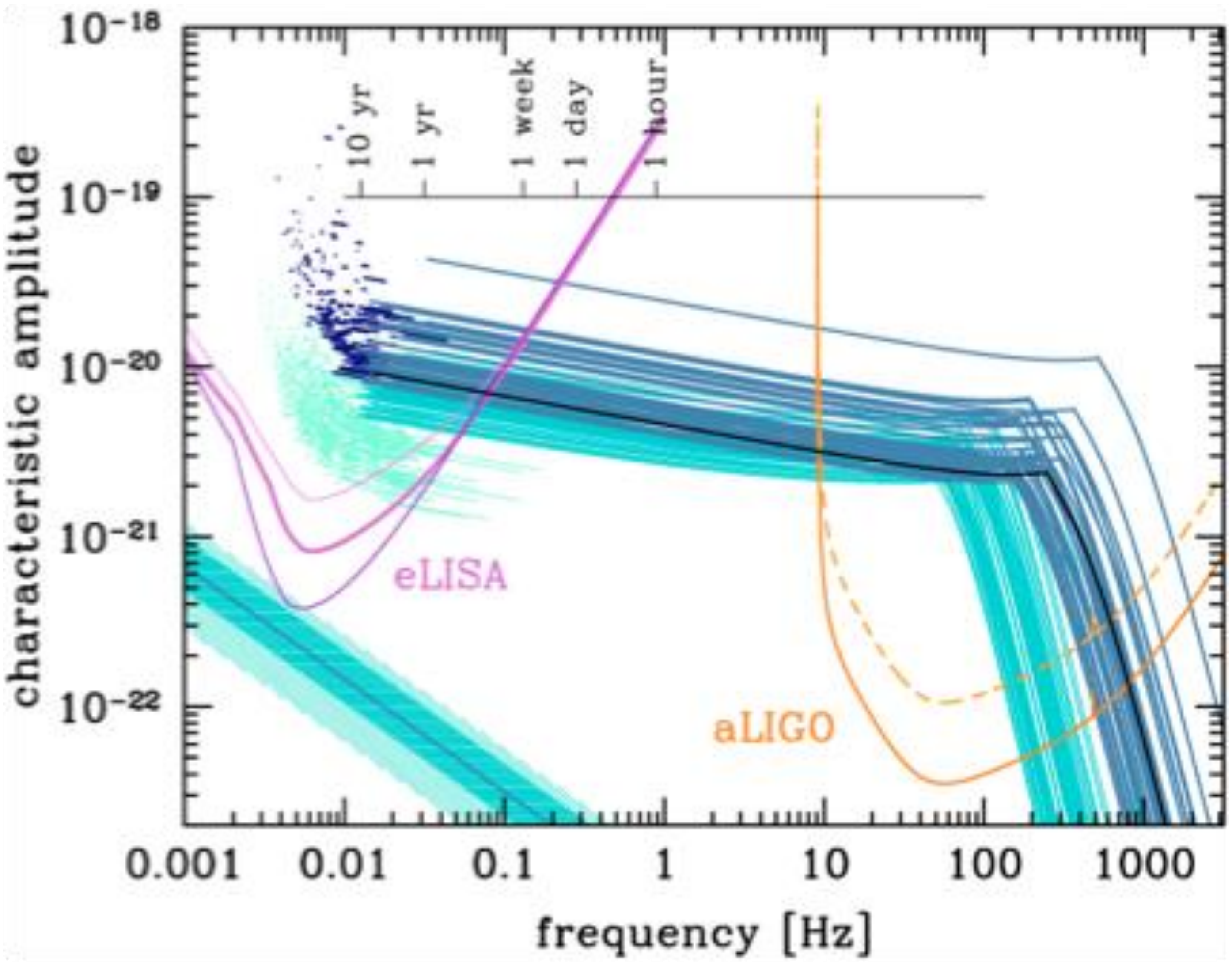
Problem and Applications

- **Problem:**
  - Distinguish between different types of black holes systems using machine learning.
  - Identify source directly from signal (without using theory).
  - Find relevant features which correspond to source properties. (spin-type and mass ratio)
- **Applications:**
  - Identifying the source from actual signals observed by LIGO.
  - Find the missing regions in parameter space where templates do not exists.
  - Developing artificial templates using Regression

Principal Component Analysis

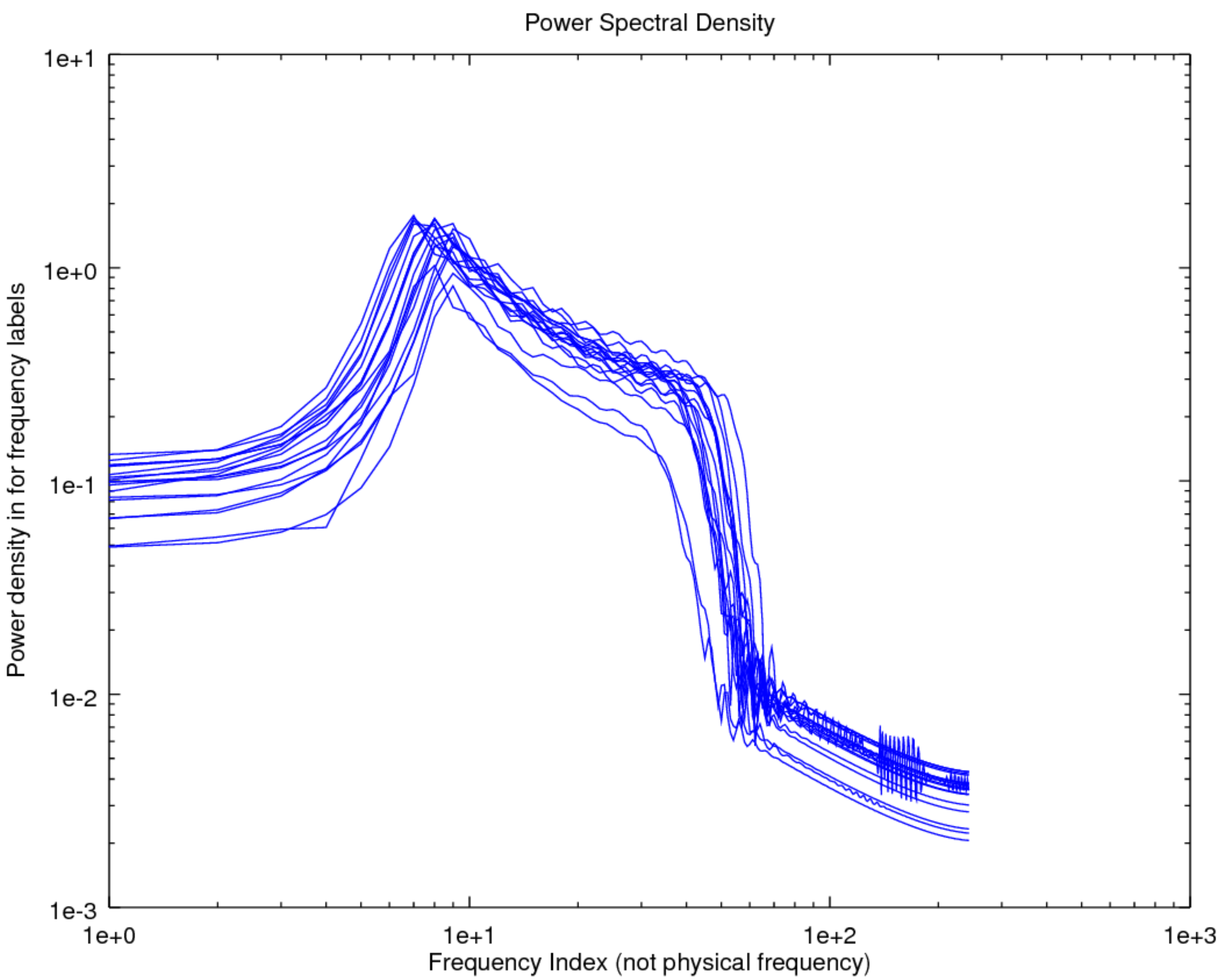


Spectral Power Density



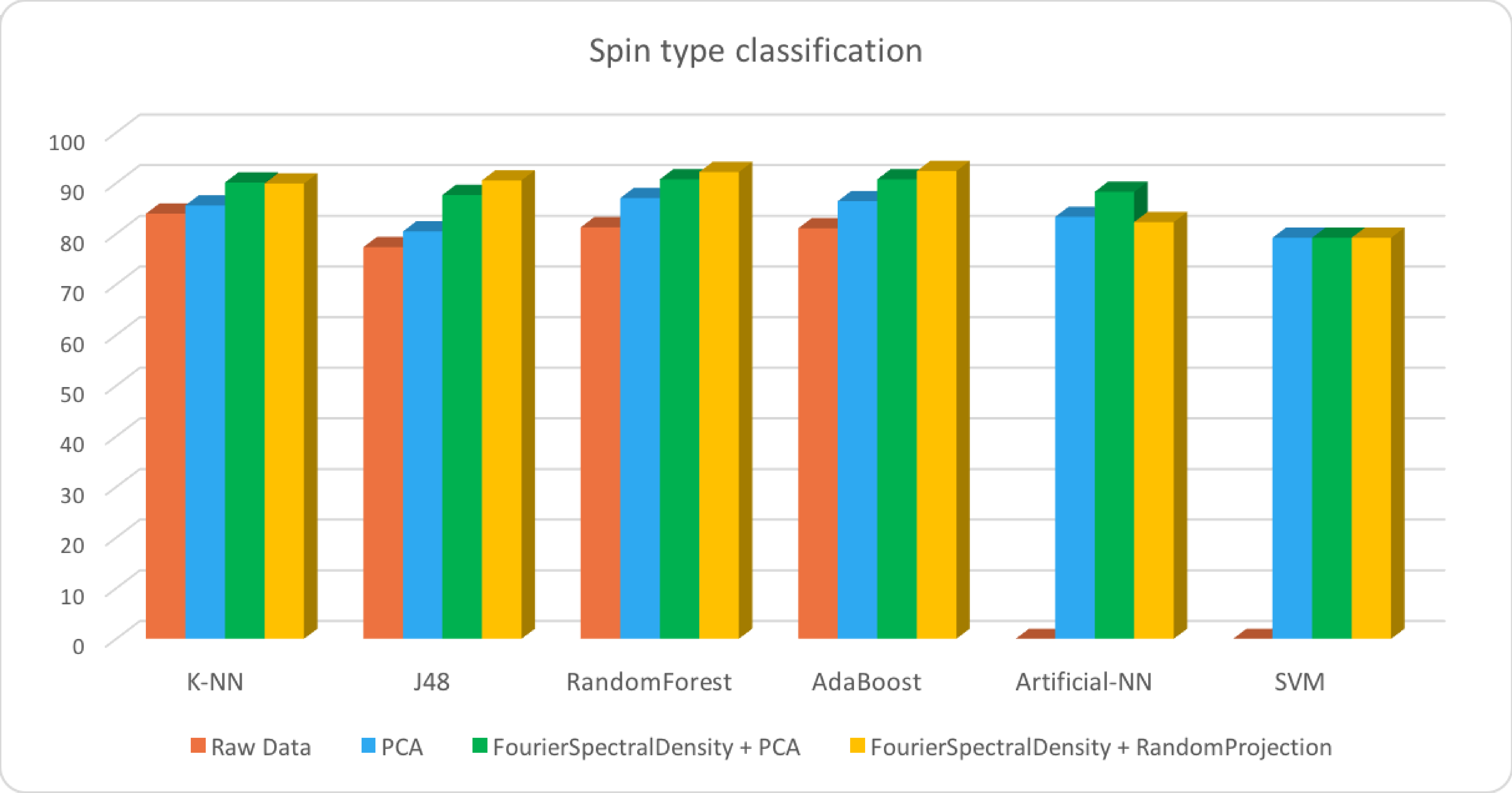
- aLIGO: Earth based Gravitational Wave Detectors with higher noise and hence all window of frequency
- eLISA: Space-Based detectors. Low noise leads to possibility of detection of low frequency sources

Spectral Power Density (our data)

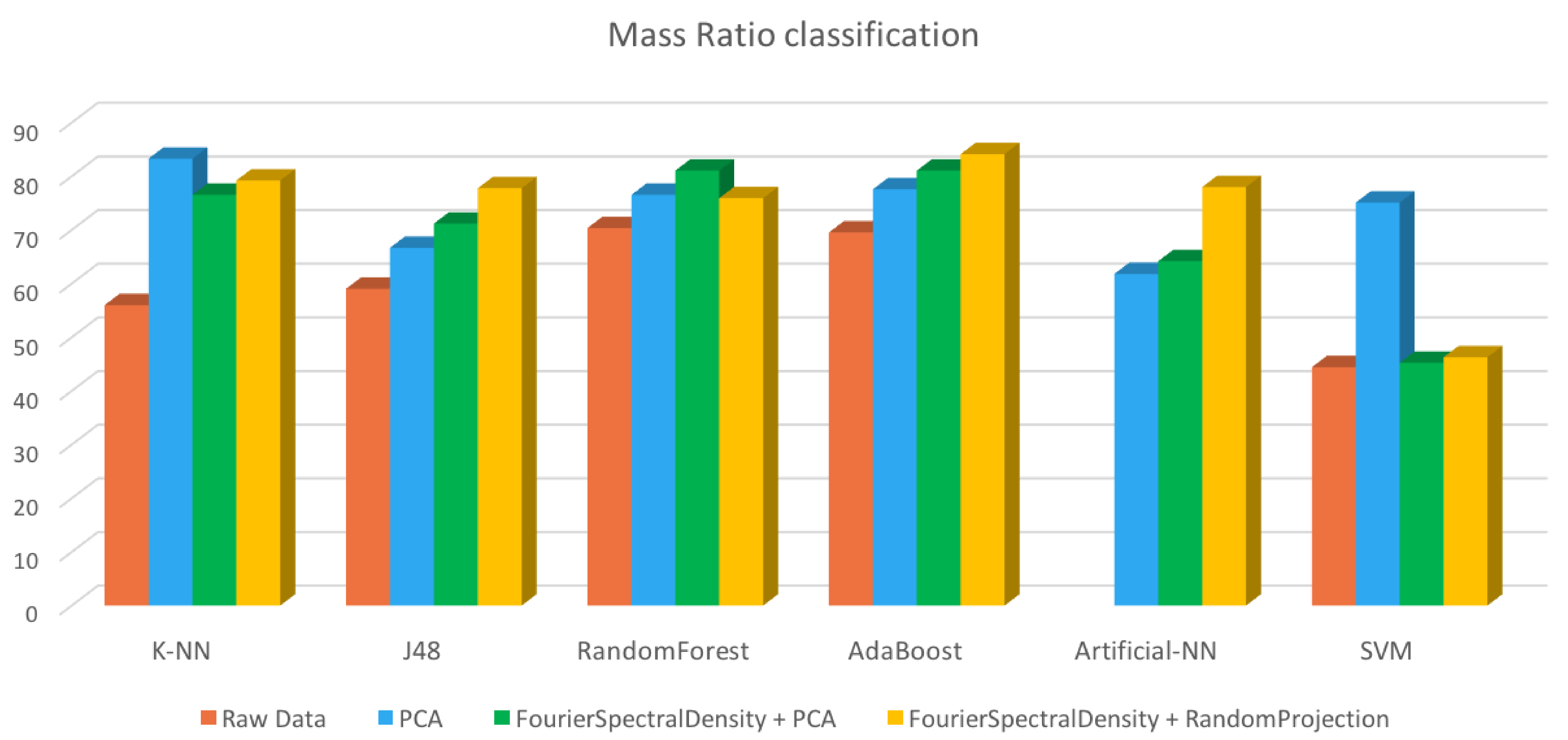


- Discrete Fourier Transform of the raw data
- FT is a good way to capture the dynamics of a physical system
- Has the information in most relevant form
- This method gives te best classification accuracy for all classifiers

Supervised Machine Learning - Spin Type



Supervised Machine Learning - Mass Type



Conclusions

- Classification of waveforms based on spin type and mass ratio
- Dimensionality Reductions using PCA and Fourier Transforms
- In Spin-Type case, Random Forest and AdaBoost performed fairly well.
- In Mass Ratio case, classification accuracy was lower - Possible due to lack of higher order modes in data.
- Future Work -
  - Include Higher order modes for mass ratio studies.
  - Find the initial spin and mass ratio using regression models.

References

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