Enhanced Detection Efficiencies and Reduced False Alarms in Searching for Gravitational Waves from Core Collapse Supernovae

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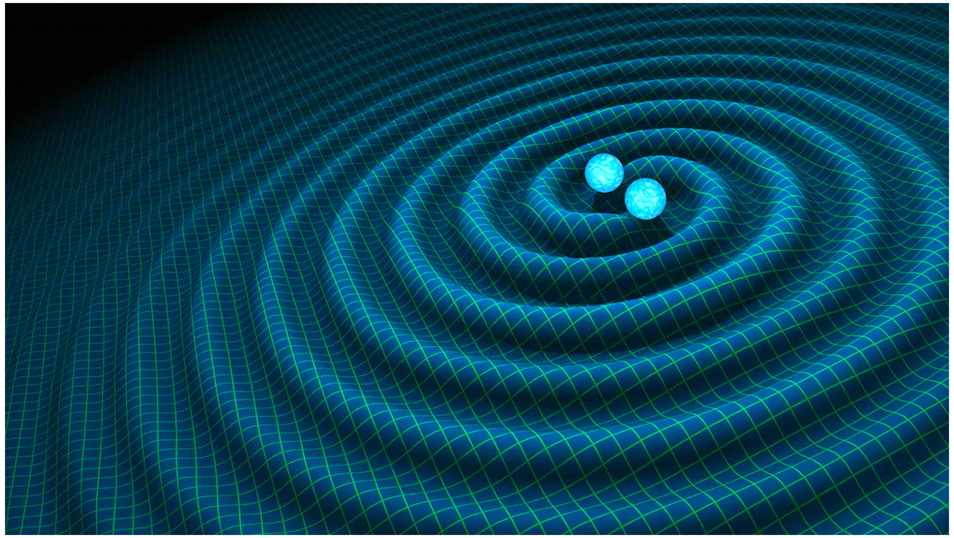
UTRGV COS ANNUAL RESEARCH CONFERENCE,
11/20/20

Outline

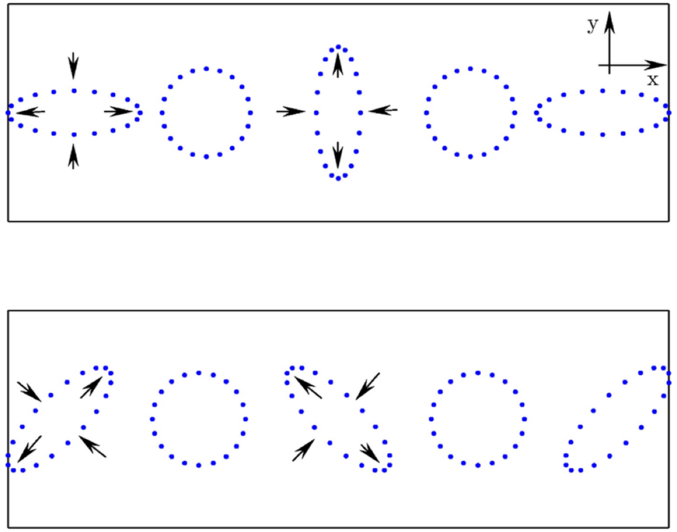
- Gravitational Waves
- Supernovae
- Detection of Gravitational Waves
- Objectives
- Proposed Method
- Results
- Challenges
- Acknowledgement

Gravitational waves

- The existence of gravitational waves was predicted by Einstein in 1916 in his general theory of relativity.
- They are an invisible ripples in space-time. Produced by movement of the massive objects.
- Gravitational waves travel at the speed of light (186,000 miles per second).
- These waves compress in one direction and stretch in perpendicular direction anything they pass by.



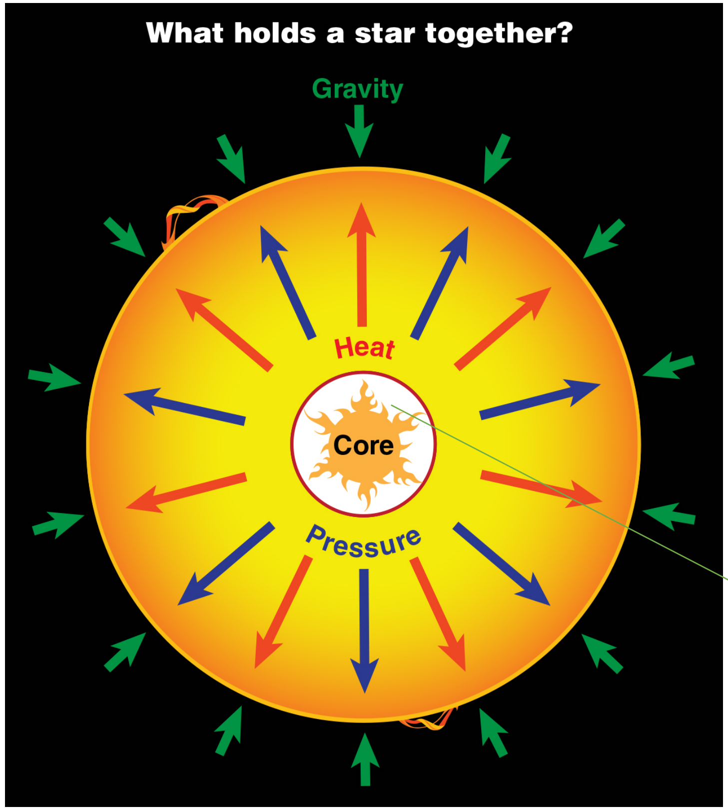
An artist's illustration of two black holes spiraling together, creating gravitational waves in the process. Image credit:©NASA



Source: https://www.researchgate.net/figure/The-effect-of-a-passing-gravitational-wave-on-a-ring-of-freely-falling-test-particles_fig18_260268927

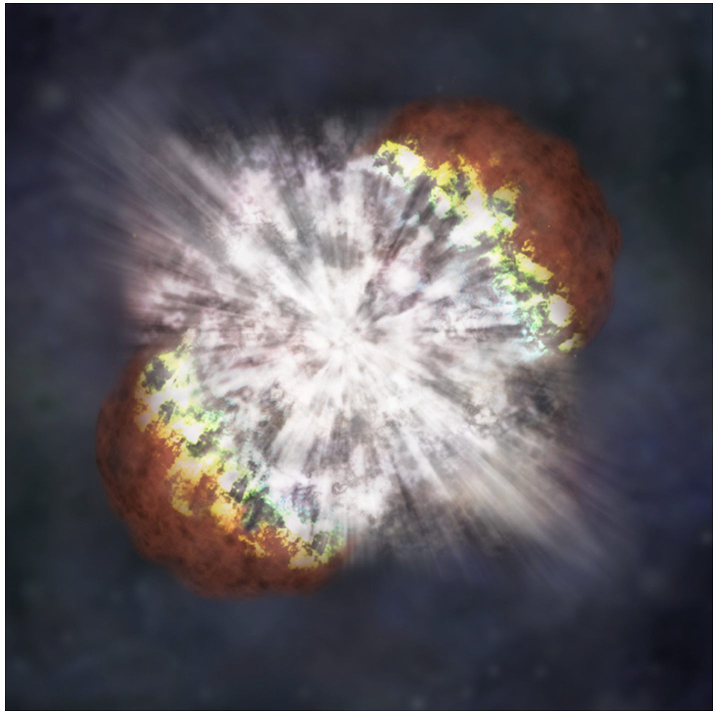
Supernovae

- Explosion of a massive star at the end of the star's life cycle.



Huge amounts of nuclear fuel

Image source: https://spaceplace.nasa.gov/supernova/en/



An illustration of one of the brightest and most energetic supernova explosions ever recorded. Image credit: NASA/CXC/M.Weiss

Detection of Gravitational Waves

- Laser interferometer
- LIGO's dual detectors
- First detection by LIGO in 2015
- Importance: Before this, everything we knew about the universe came from studying waves of light. Now we have a new way to learn about the universe—by studying waves of gravity.

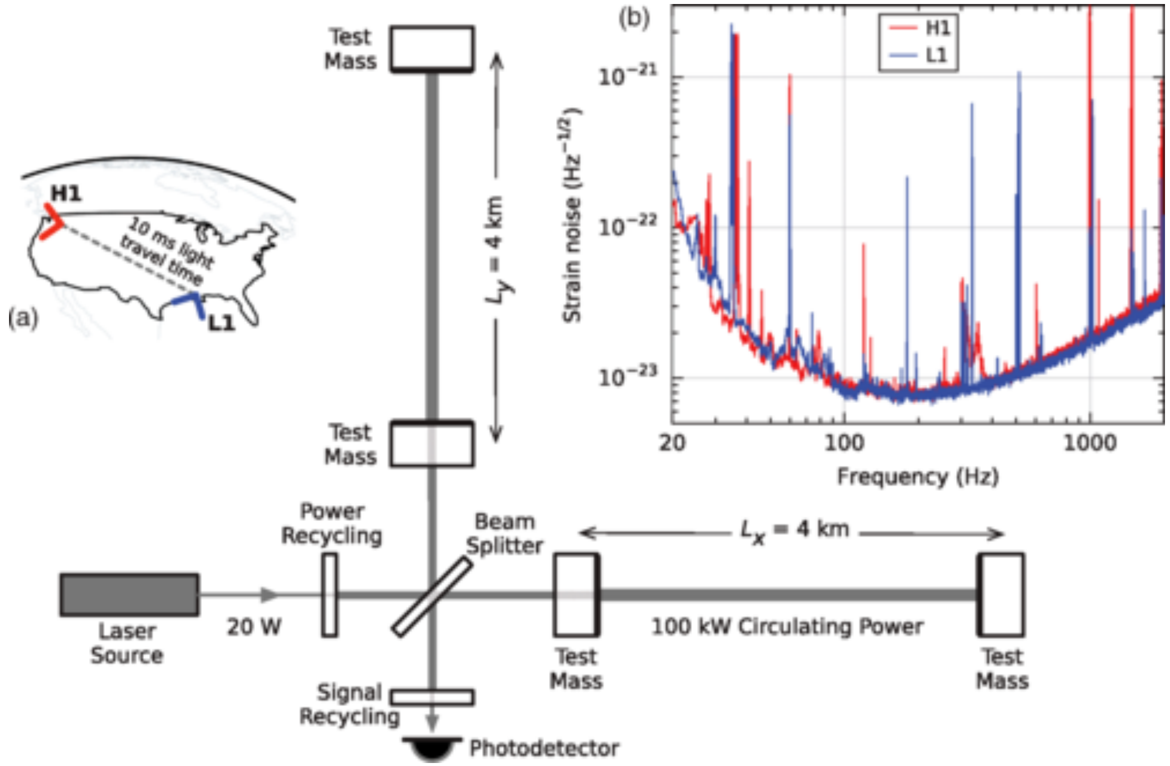
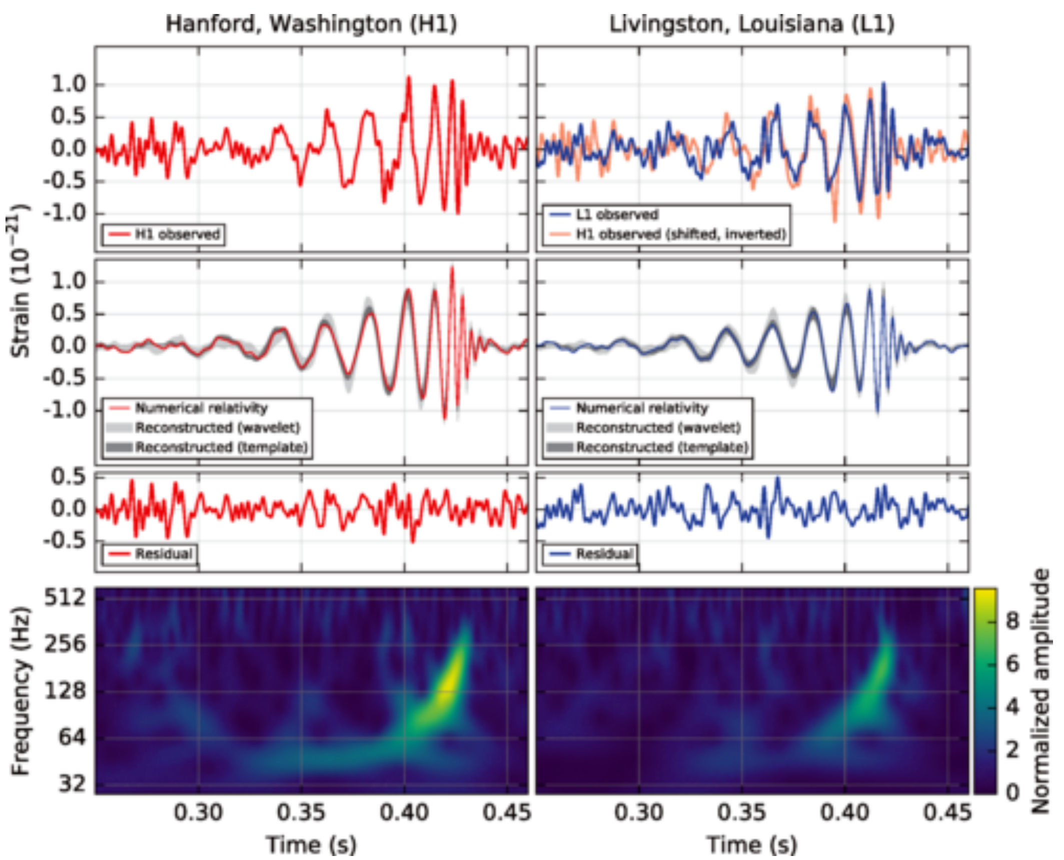


Image source: B. P. Abbott Et Al. (Ligo Scientific Collaboration And Virgo Collaboration) Observation of Gravitational Waves from a Binary Black Hole Merger

Detection of Gravitational Waves



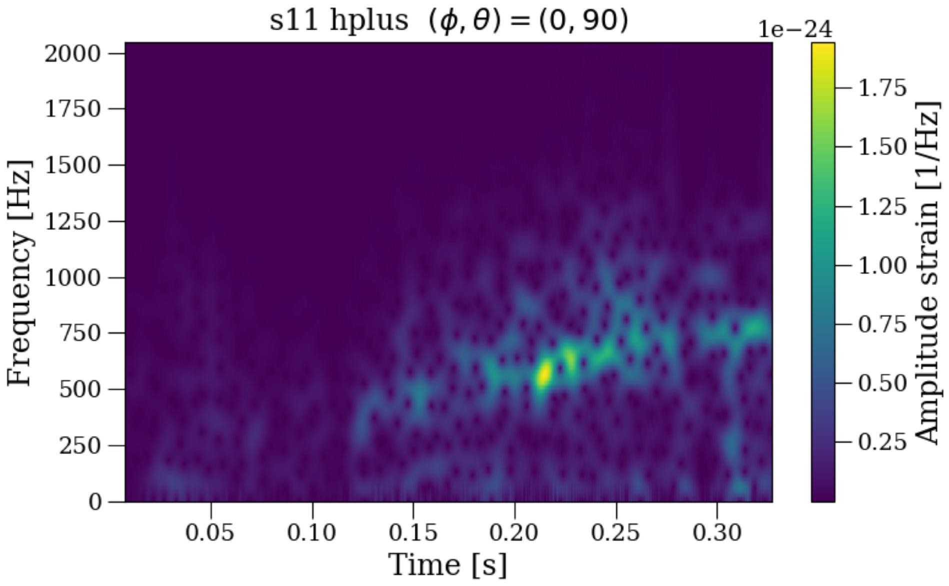
First detected gravitational waveforms from binary black holes in H1 and L1 detectors
Image source: B. P. Abbott Et Al. (Ligo Scientific Collaboration And Virgo Collaboration) Observation of Gravitational Waves from a Binary Black Hole Merger

LIGO Livingston
Image source: https://www.ligo.caltech.edu/LA/page/what-is-ligo

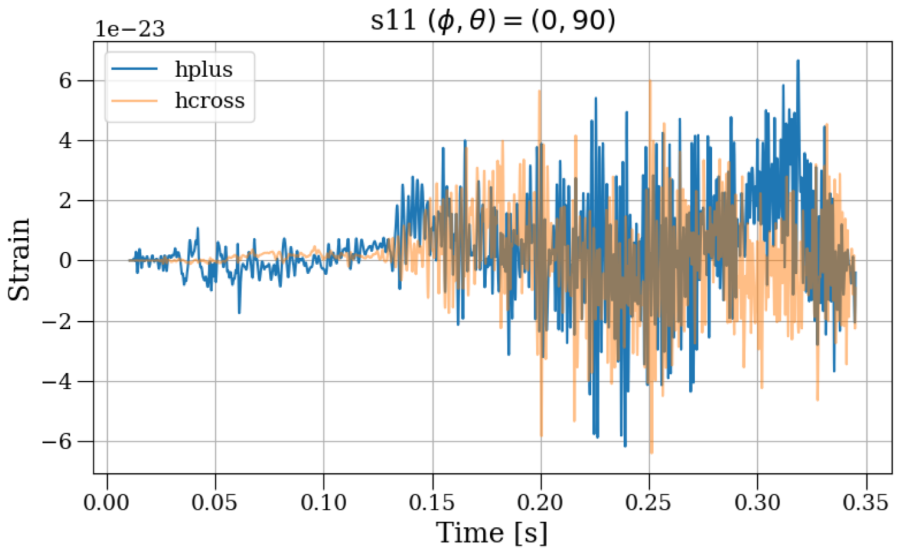
LIGO Hanford
Image source: https://www.ligo.caltech.edu/WA/#

Objectives

- Reduce false alarms rate in the data

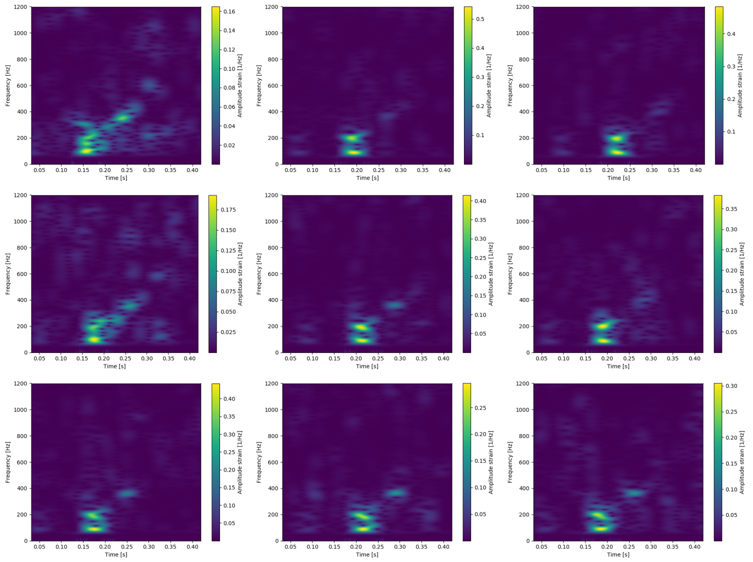


- Increase detection efficiency of core-collapse supernovae signal

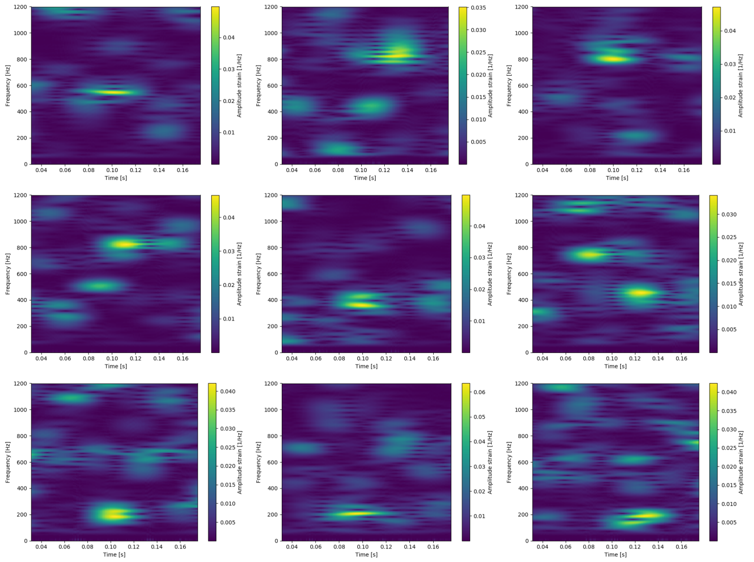


MuLaSECC pipeline

- Multi-Layer Signal Enhancement
- Train the convolutional neural network (CNN) for image classification
- Classify spectrograms of false alarms and the supernovae signal from the detector's data
- Remove classified false alarms(glitches) using method of imputation
- Apply coherent Wave Burst (cWB) pipeline for the glitch removed data

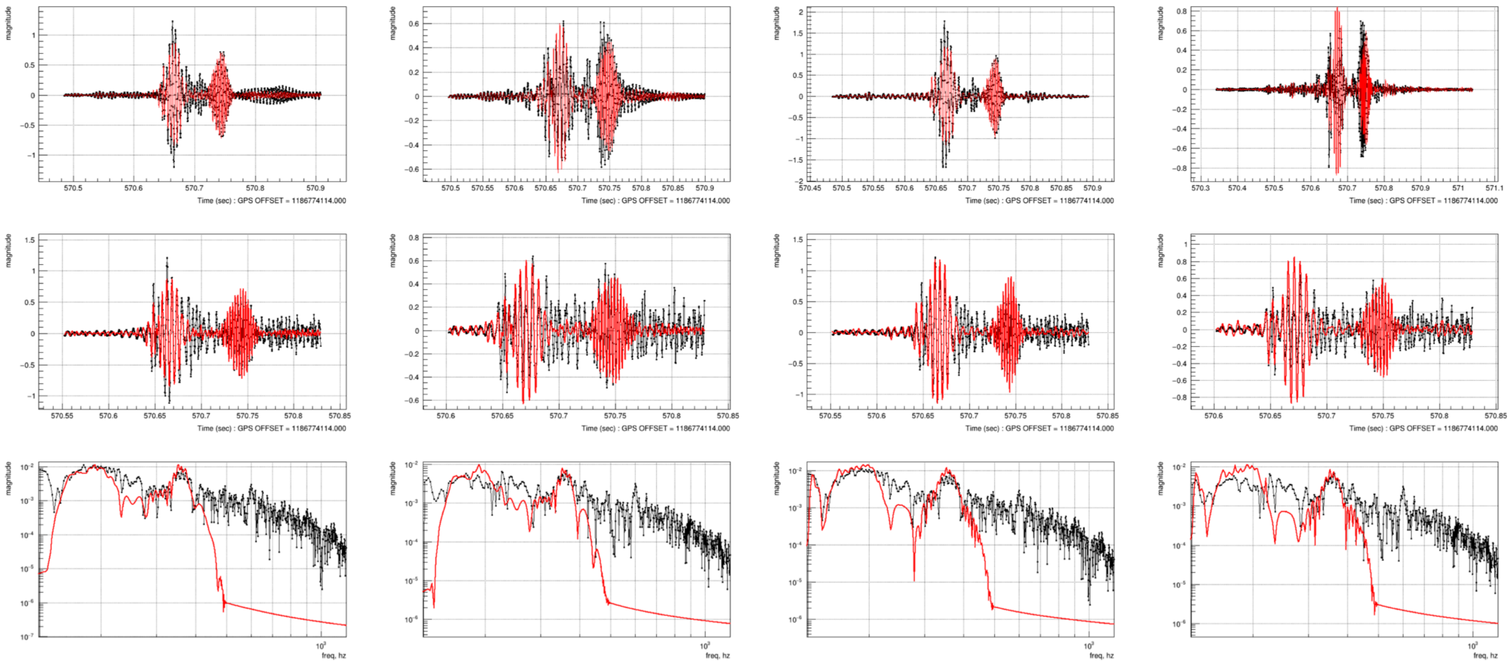


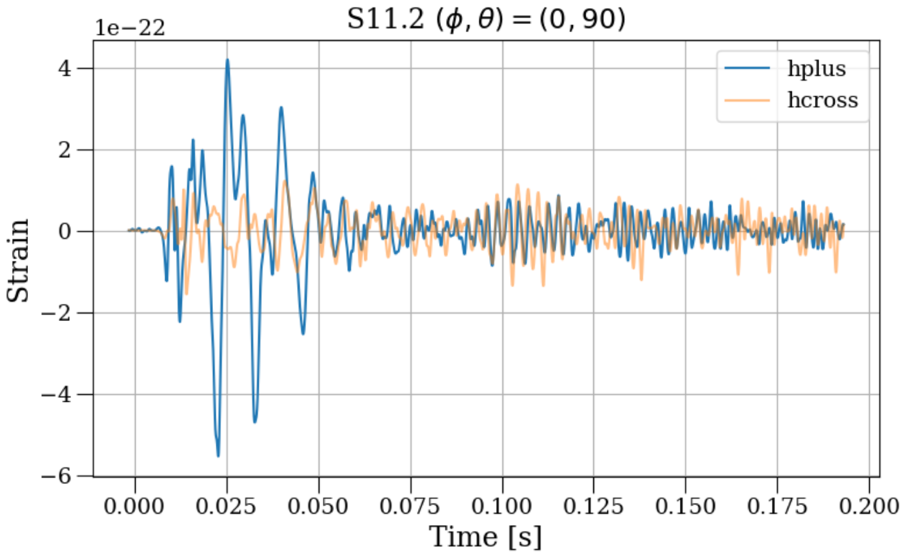
Spectrograms Kuroda 2017 s11 waveform

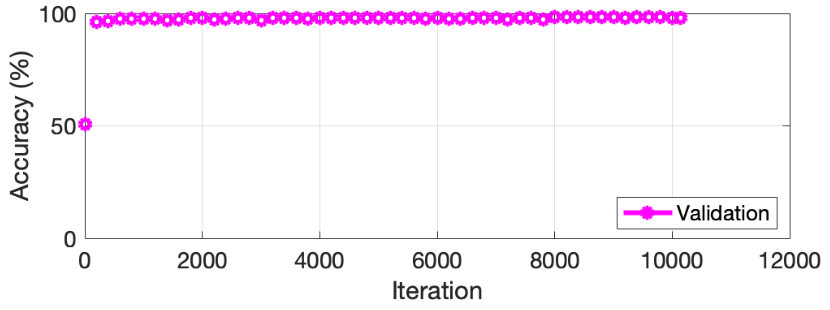


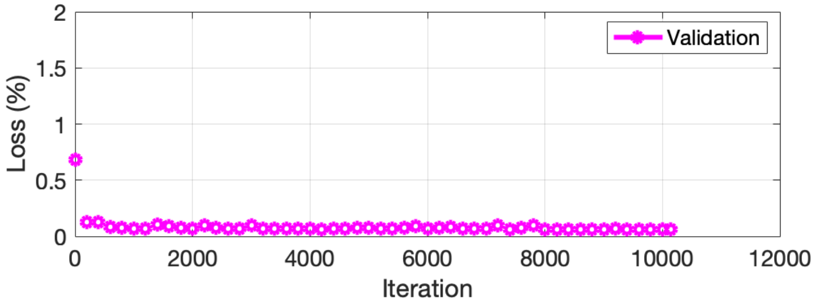
Spectrograms of the false alarms

Results







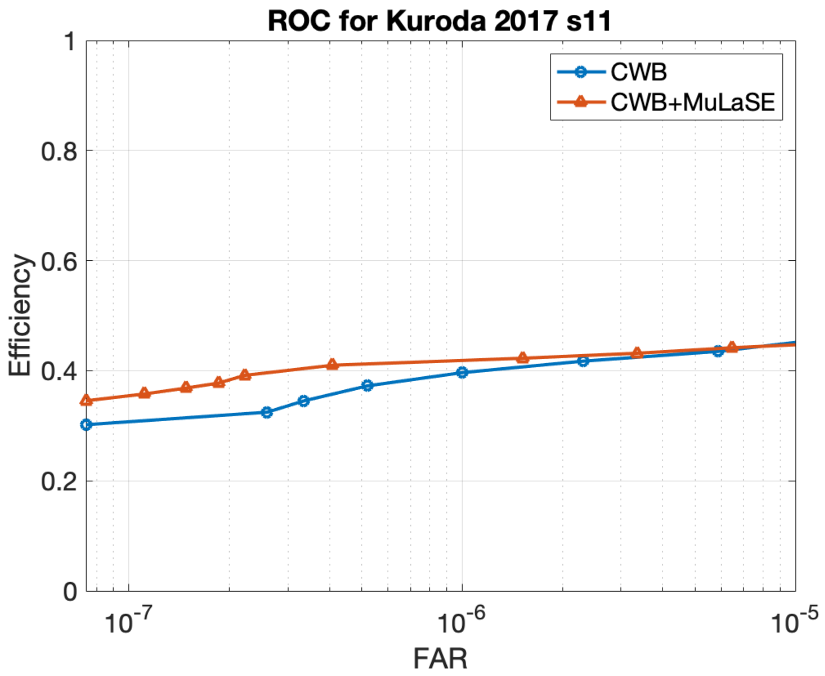


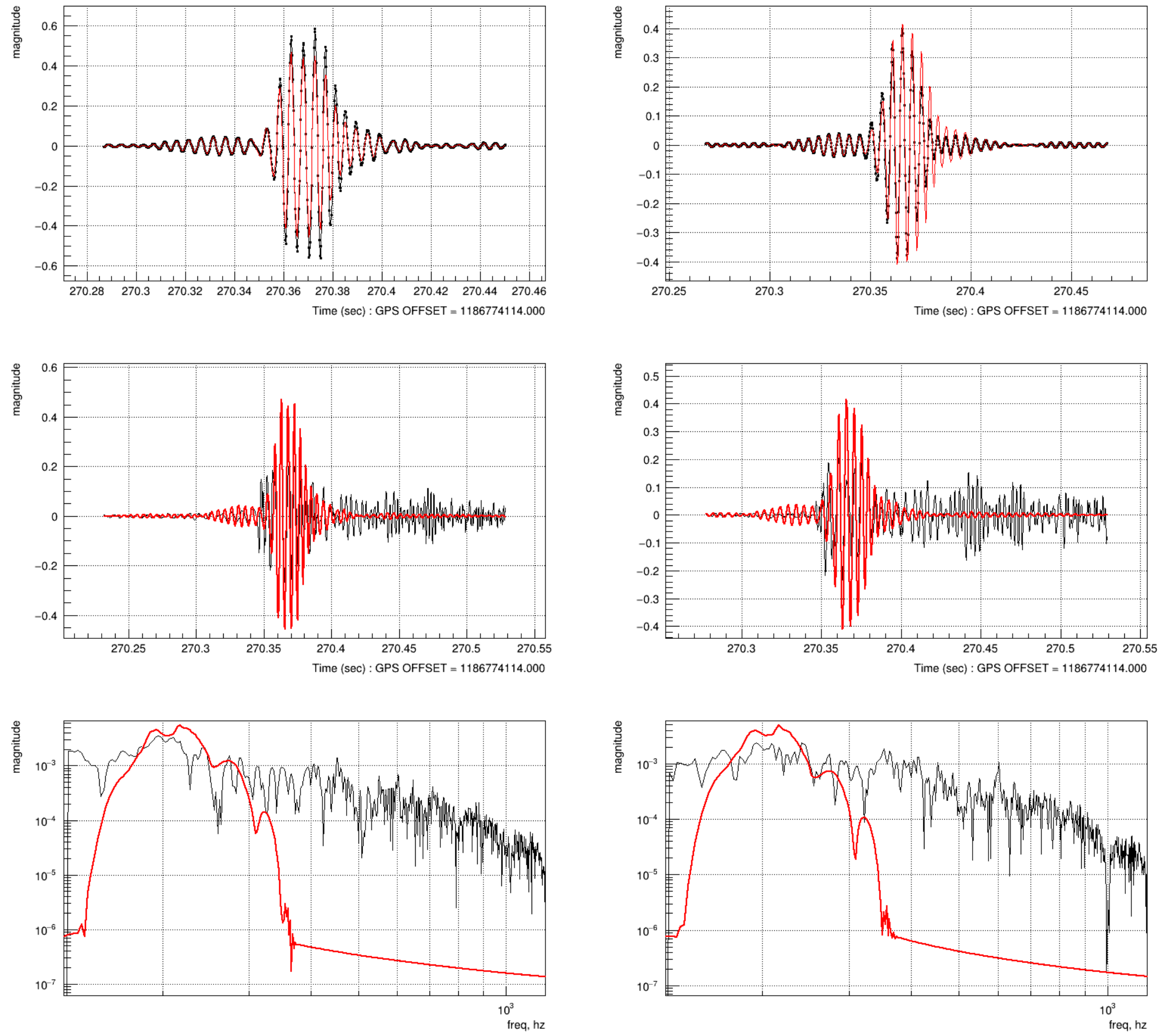
Reconstruction of the Kuroda 2017 s11 waveform at snr = 20 for L1 H1 detectors

Results

Reconstruction of the Kuroda 2017 s11 waveform at snr = 6 for L1 H1 detectors using MuLaSECC

No signal was reconstructed at snr=6 by cWB





Challenges and perspectives

- Producing dataset for the CNN needs to be optimized
- Training CNN for more supernovae waveforms
- Glitch removal method needs to improved
- Producing results for other core-collapse supernovae waveforms
- Prepare MuLaSECC pipeline for the online production mode
- Paper is coming soon

Acknowledgement

- Thanks to Oscar Valdez and Dr. Soma Mukherjee in UTRGV research group
- Supernovae research group from LIGO Scientific Collaboration

Thank you!