Denoising Gravitational Waves with Deep Learning (arXiv:1901.00869)

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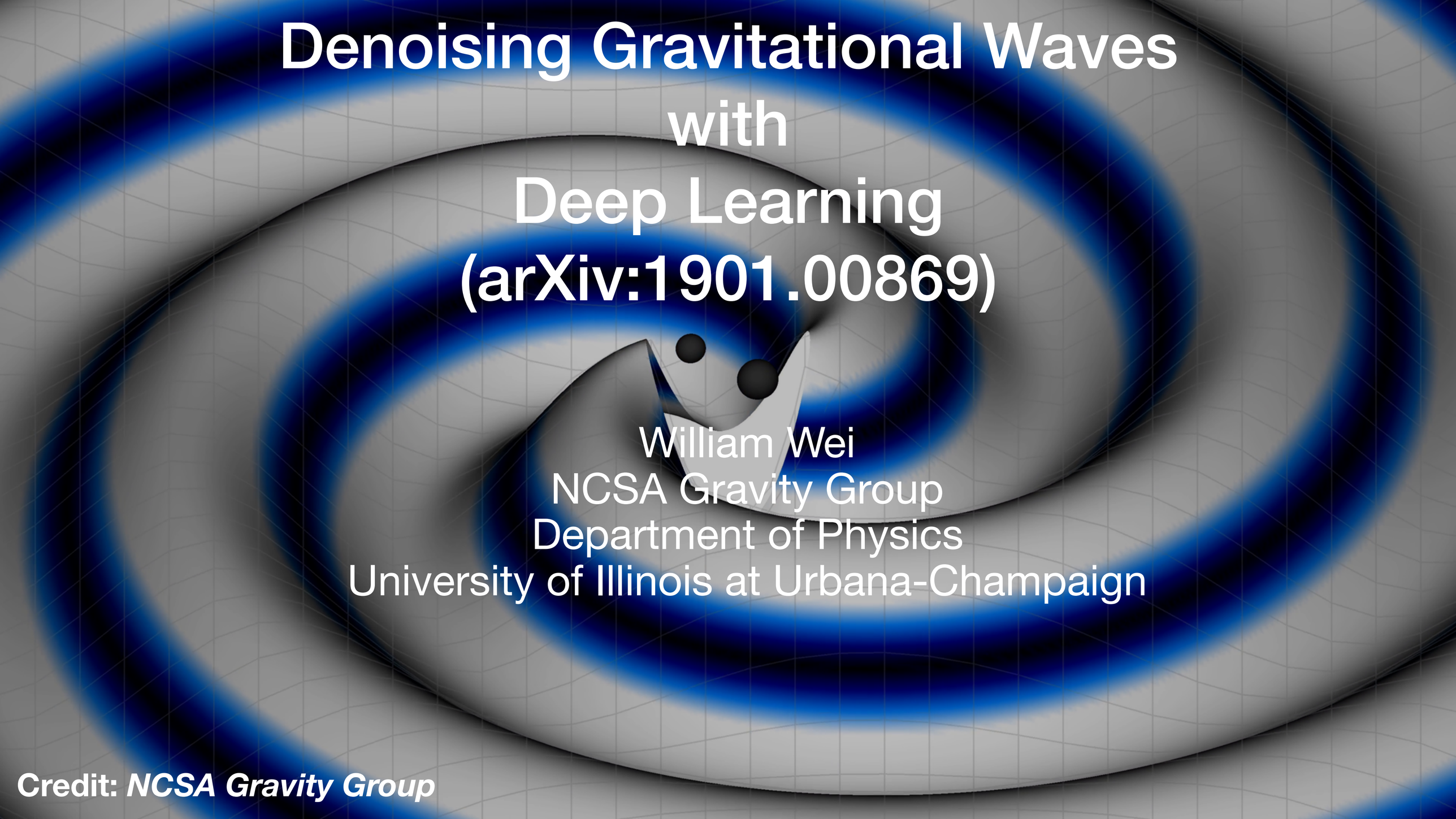


Credit: *NCSA Gravity Group*

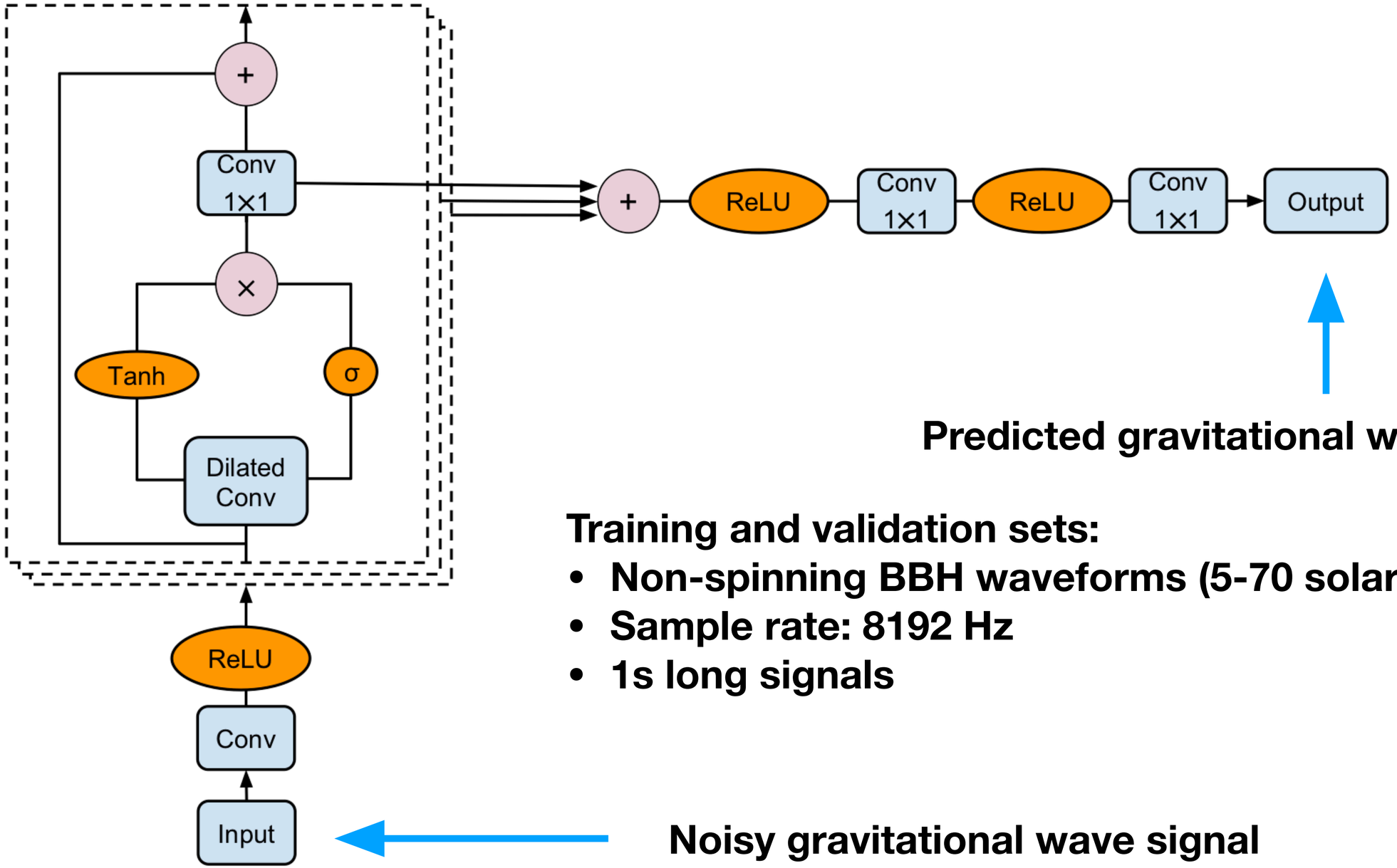
Denoising can improve data analysis for LIGO data

- Principal component analysis, dictionary learning, and deep learning, etc, have been used for denoising in the past.

- Wavenet, designed by DeepMind, can more efficiently remove noise than previous methods.

- Wavenet was originally to generate human speech, but was also applied to speech denoising later.

Use Wavenet to denoise gravitational waves



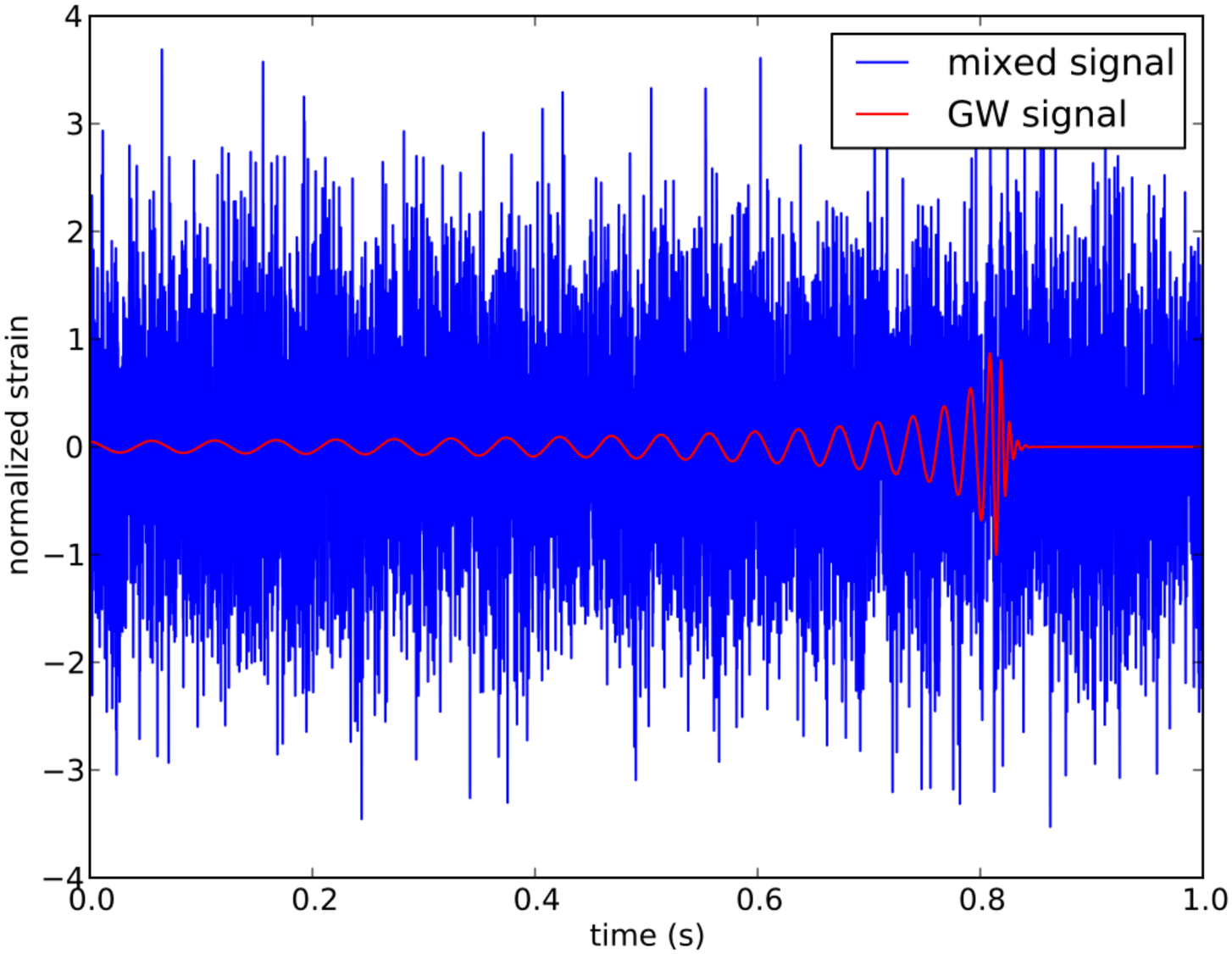
Predicted gravitational wave signal

Training and validation sets:

- **Non-spinning BBH waveforms (5-70 solar masses, q<10)**
- **Sample rate: 8192 Hz**
- **1s long signals**

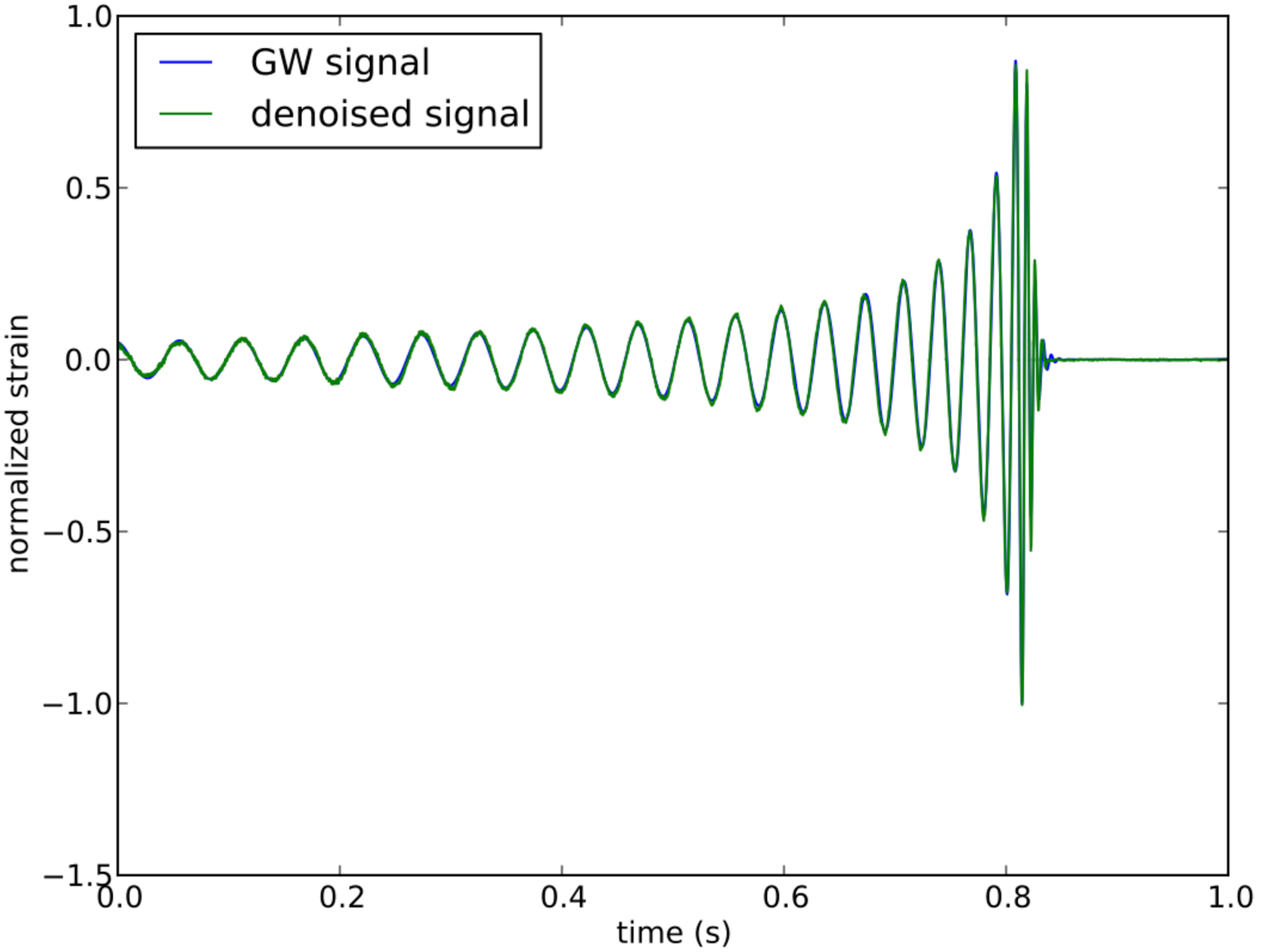
Noisy gravitational wave signal

Wavenet can effectively remove Gaussian noise (Wei & Huerta, arXiv:1901.00869)



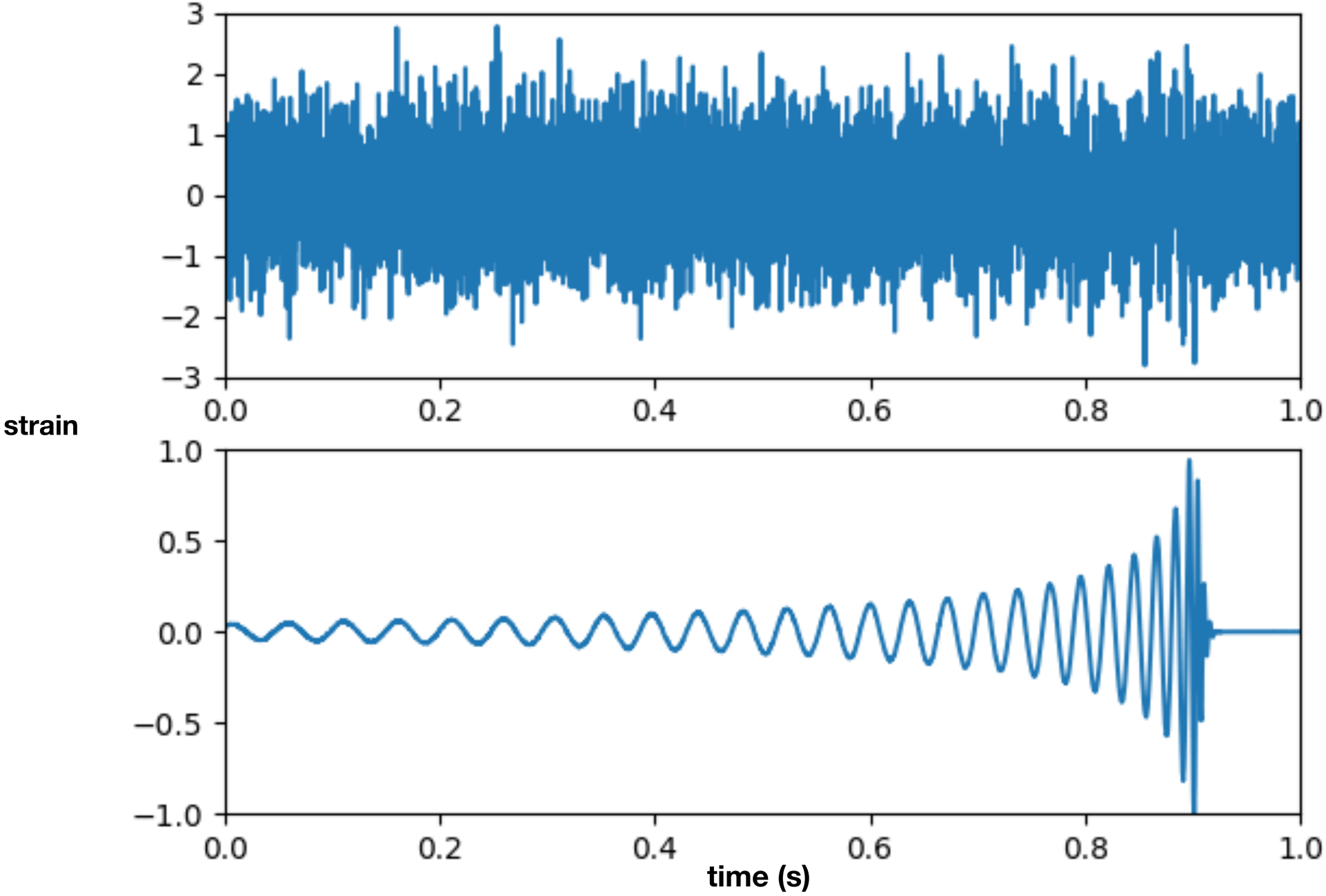
Comparison of a clean gravitation wave signal to one corrupted by Gaussian noise

Wavenet can effectively remove Gaussian noise (Wei & Huerta, arXiv:1901.00869)

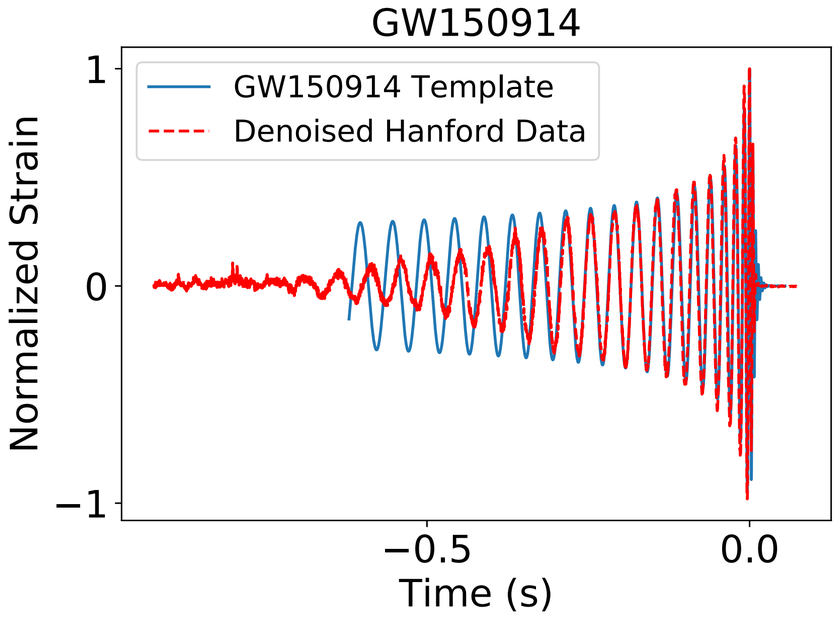


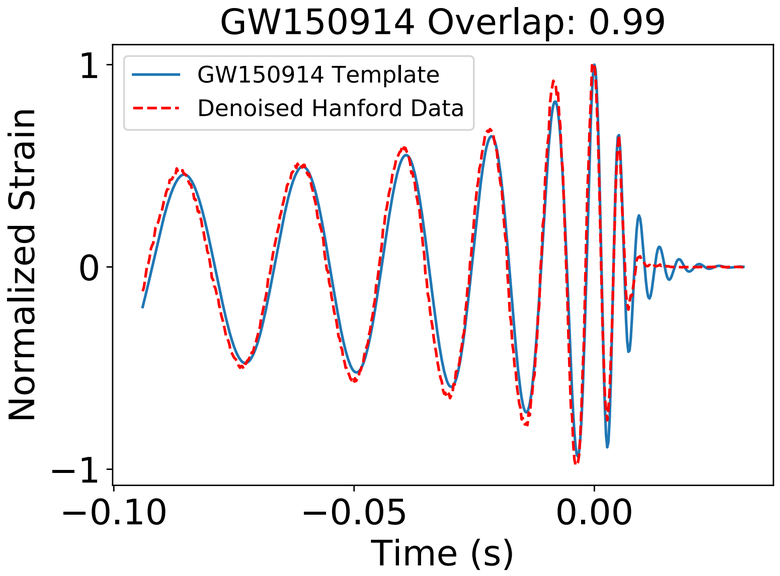
Comparison of a clean gravitation wave signal to the reconstructed signal

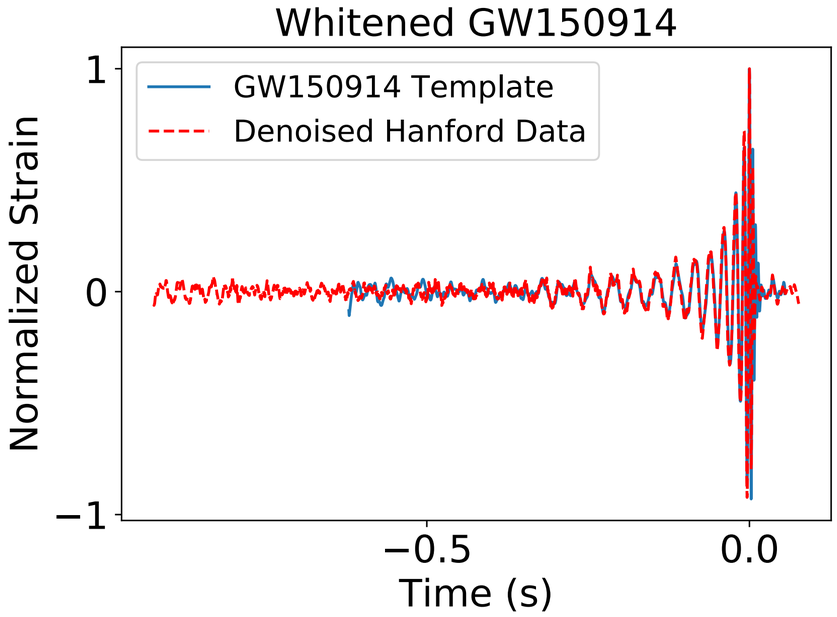
Wavenet can effectively remove Gaussian noise (Wei & Huerta, arXiv:1901.00869)



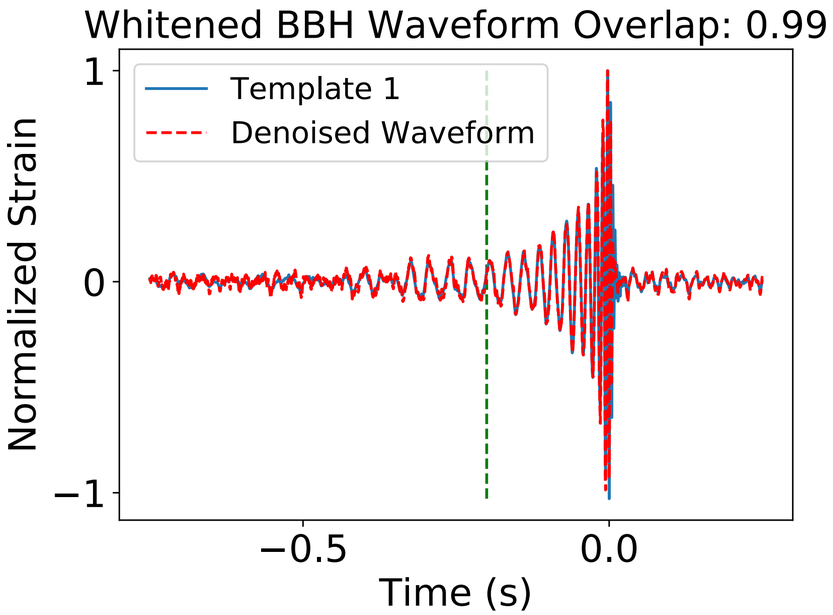
Denoising GW150914

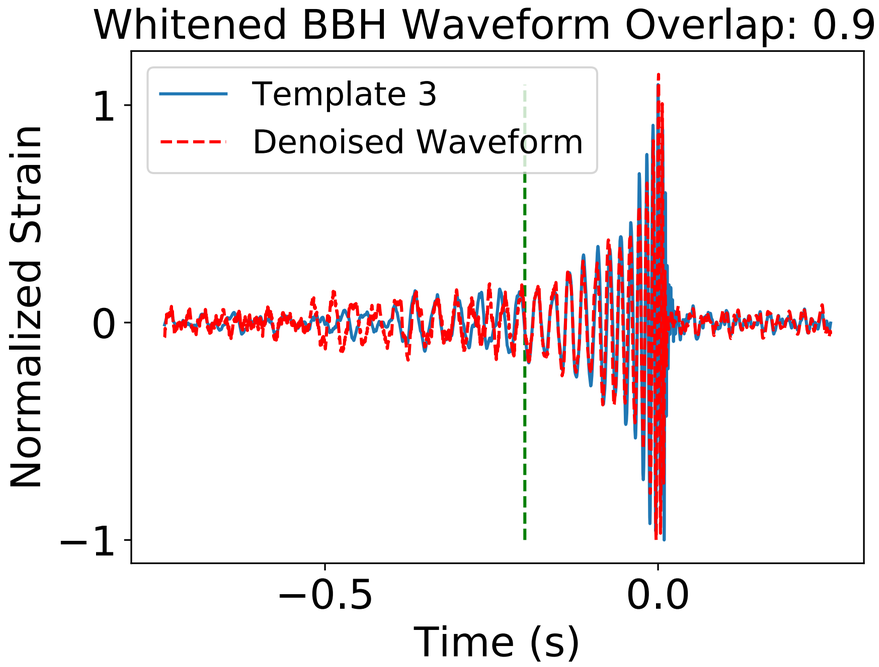


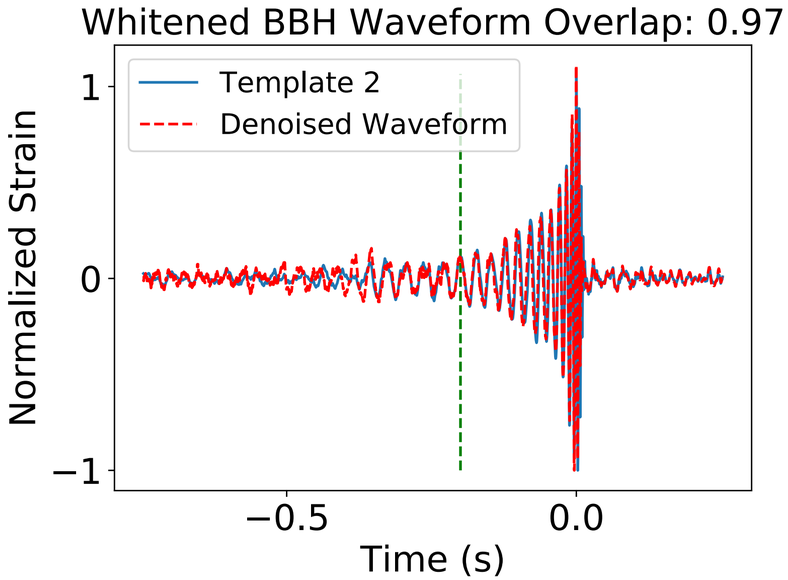




Denoising spin-precessing BHH signals contaminated by GW150914 noise







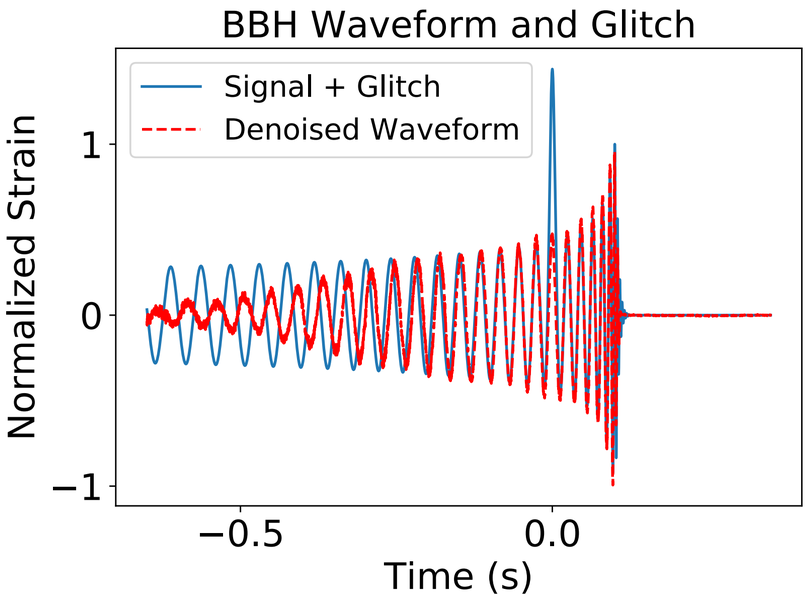
Total mass: 70 solar masses, mass ration: 4/3

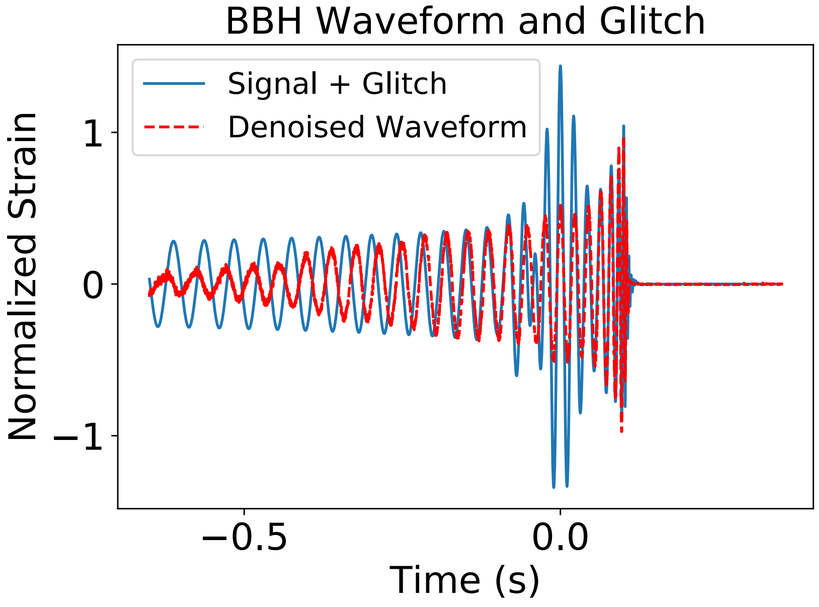
Case 1: $\mathbf{s_1} = (0.2, 0.3, 0.5)$ $\mathbf{s_2} = (0.3, -0.4, 0.5)$

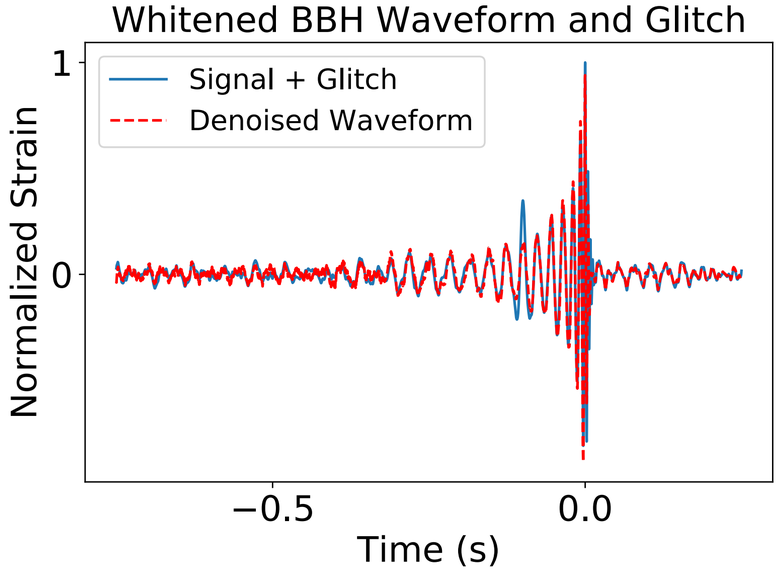
Case 2: $\mathbf{s_1} = (0.4, 0.6, 0.8)$ $\mathbf{s_2} = (0.4, -0.6, 0.7)$

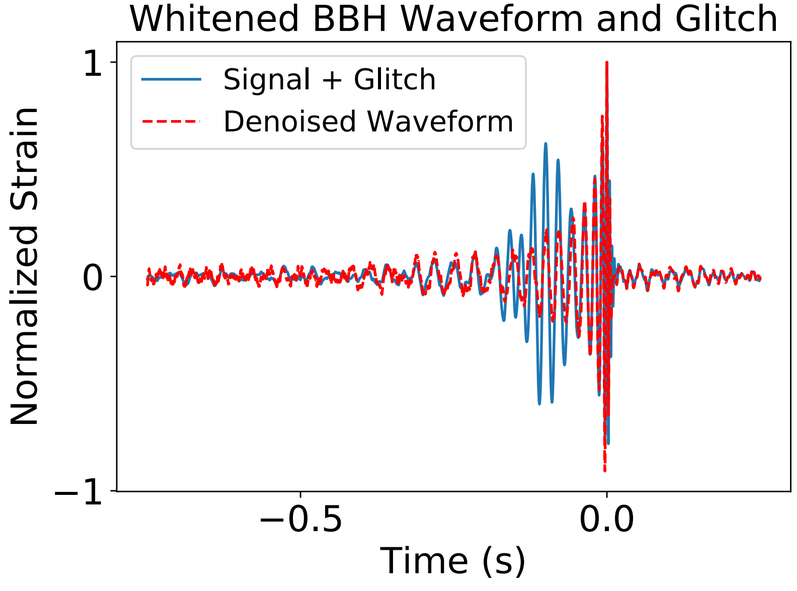
Case 3: $\mathbf{s_1} = (0.8, 0.8, 0.9)$ $\mathbf{s_2} = (0.8, -0.8, 0.9)$

Denoising non-spinning BHH signals contaminated by GW150914 noise and glitches (Total mass: 64.5 solar mass, mass ration: 1.24)

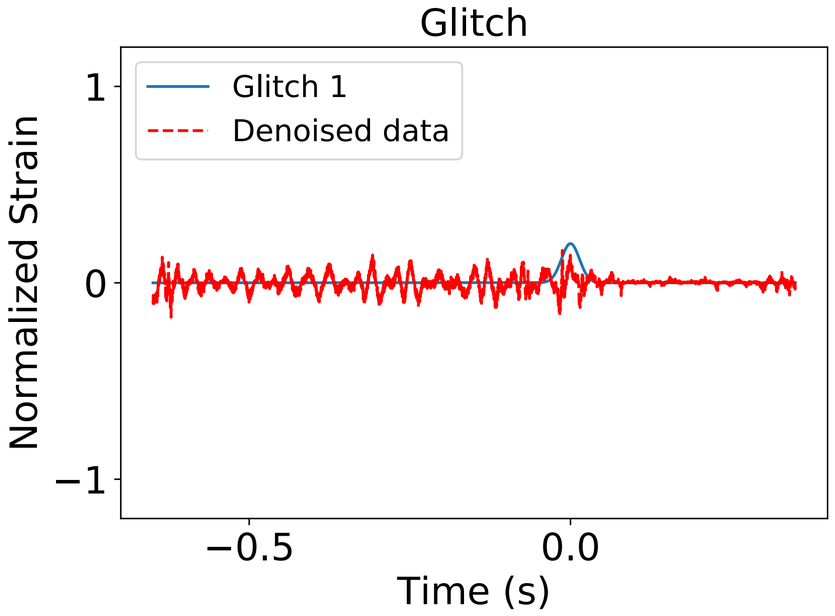


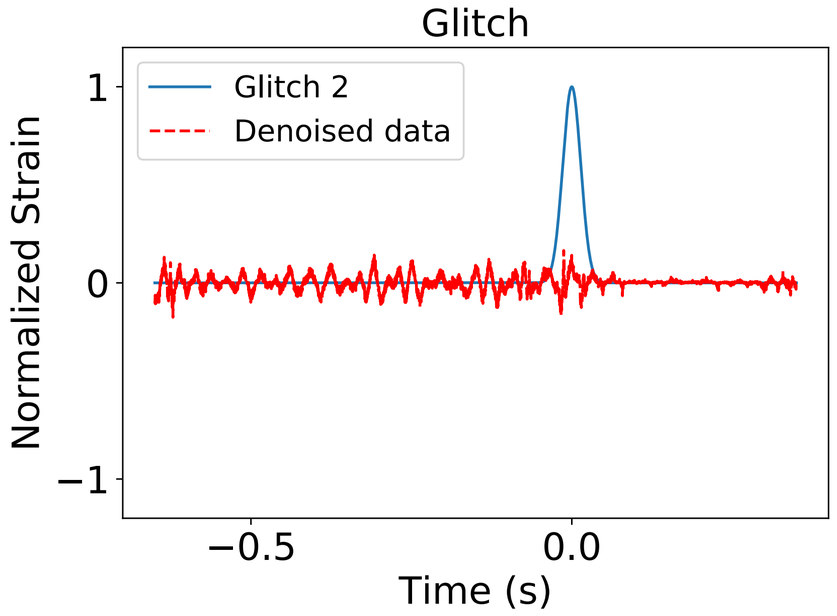


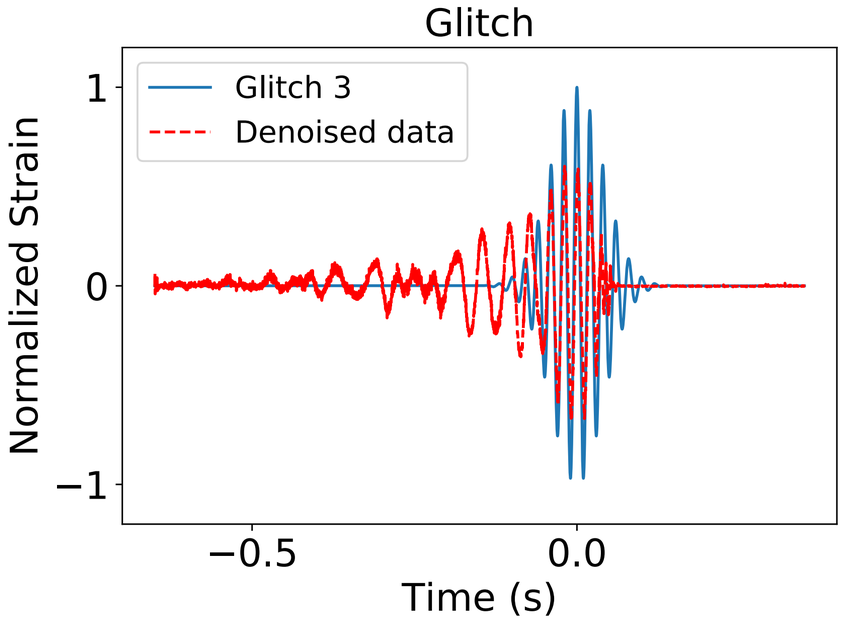


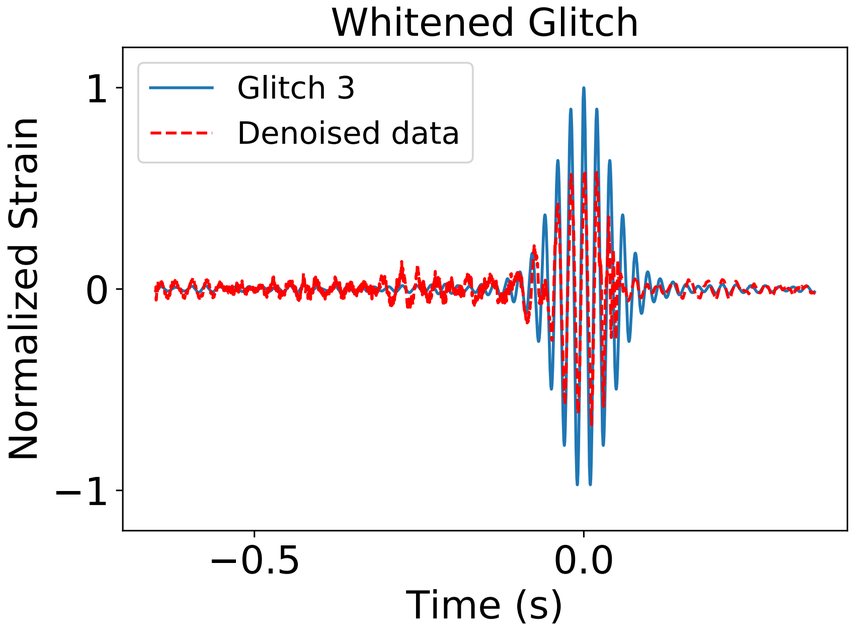


Denoising glitches









Conclusion

- **Denoising with deep learning requires fewer resources and is less time consuming**
- **The reconstructed signals are consistent to those inferred by matched-filtering pipelines.**
- **It can be used to preprocess raw data and accelerate the pipelines for gravitational wave data analysis.**