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Peer Review

Review of: "Rapid Eccentric Spin-Aligned Binary Black Hole Waveform Generation Based on Deep Learning"

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Rapid Eccentric Spin-Aligned Binary Black Hole Waveform Generation Based on Deep Learning

Summary:

The article is about an AI-based surrogate model for gravitational waveforms from aligned-spin unequal-mass eccentric binary black holes. The parameter space covers mass ratios between 1 and 5, eccentricities below 0.2, and aligned spin magnitudes below 0.6. They report that the model is ~50 times faster than the waveform model it was trained on (SEOBNRE), and that the model is accurate at reproducing the base model with a mean mismatch of ~1e-3.

I think the paper was well-written and was interesting to read. The work done in this paper is a novel approach that I had not come across before for building surrogate models, and will likely be beneficial to the community in the near future. The results are interesting and I would recommend it for publishing after the following points are addressed and the suggested plots/results are included.

Essential Suggestions and Feedback:

1. In data generation, I couldn't find any information about how the amplitude and phase data pieces are aligned. Please add information about how they are aligned, perhaps the amplitudes by default are aligned in such a way that the peak is at t=0M by the SEOBNRE waveform model. Same for the phase, is it being initialized at 0 whenever the waveform starts for a given set of parameters?
2. The Conclusion and Discussion section mentions that the authors plan to work on incorporating methods for including higher modes into the model. But in equation-1, the full GW-strain (not just the quadrupolar or (2,2) mode) seems to be decomposed into amplitude and phase. I don't see any

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equation which specifies an expansion into spin-weighted spherical harmonics, and then the modes being surrogate-modeled.

3. If I understand correctly, there are 3 separate networks (for amplitude, phase and waveform duration) that are being trained independently. I couldn't find any proper mentions of what the loss function for each of them are. Please include mathematical expression the loss function for each of the 3 models: waveform duration, amp, and phase, this would help readers unfamiliar with the typical loss functions used in ML. Also I think a loss vs epochs plot for all three networks would be essential for enabling others to reproduce and validate this research, by giving some information on when the network loss saturates. I believe that such plots are typically essential for ML/DL based methods papers.
4. This is particular to the network that predicts the waveform duration (T) as a function of input parameters. I believe that a plot that shows how the error in the T affects the waveform mismatch would be a beneficial addition. Since this paper puts forth a novel waveform modeling methodology, it would be essential to have more diagnostics of the sub-models.
5. In Figure-4, there are 2 waveform generations with a 1e-4 mismatch, which I think convery the same information of the model recreating some waveforms very accurately. I believe that one of them can be replaced with a waveform with the worst mismatch to convey what the model does at its worst. Perhaps the waveform at the parameters that correspond to a mismatch of ~5e-1 (or the one corresponding to the 95th percentile in the mismatch) in the 30M violin plot in Figure-3. This information is essential because research groups who will use this model for PE will need to know what the model does when evaluated in the upper 99 percentile of errors In Figure-5, the scatter plots in each subplot are not very informative because the markers are very small to visually observe any clustering based on the colorbar. A contour plot plot instead of a scatter plot would be a much better choice.
6. Section V, "... the generation speed of a 64-core CPU is merely **twice** as a GPU. ..." -> "... the generation speed of a 64-core CPU is merely **half** that of a GPU. ...". I believe this is what the authors intended to say based on the information on timing given in Table-3

Minor Errors, Additional Suggestions and Questions:

1. Paragraph 4 line 2: IMRPhenomT is spelled incorrectly

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2. Introduction section, paragraph-4, MLP acronym used without being defined before in the paper. Preferably define this as multi-layer-perceptron before using it here.
3. “The resampled waveform is standardized to a fixed length of 1024 sampling points, which is unable to reconstruct to its original length directly.”

   This phrasing is slightly unclear. This should probably be rephrased to:

   “The resampled waveform is standardized to a fixed length of 1024 sampling points, which cannot be directly reconstructed to its original length.”
4. In Section II-B, there’s a mention of “e0-t parameter space”. This might cause slight confusion since “t” is typically an independent variable for GWs whereas the word “parameter” is reserved more for the parameters of the source CBC system.
5. In Section IVA, “... are more sensitive to the merger stage...” -> “... are more sensitive to errors in the merger stage...”. I assume this was the intended sentence?
6. In Figure-4, preferably change the symbol used for mismatch from M to something else. M can very easily be misinterpreted as total mass in the figure titles and cause confusion, even though the figure caption explicitly mentions that M stands for mismatch.
7. Are the neural network models used in the paper public (on perhaps github/bitbucket), or is there a plan to make them public eventually once the paper is published? This will help reproducibility of results.

Declarations

Potential competing interests: No potential competing interests to declare.