Thesis notebook

Thesis: Suzanne Lexmond

Daily supervisor/First examinor: Maria Haney
Second examiner: Andreas Freise

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1 Daily log

1.1 13/03/2024

- I generated a small dataset of 10 eccentric waveforms within the range of $e = \{0.01, 0.02, \ldots 0.1\}$. I noticed some interesting things in $\Delta\phi$. Note on eccentricTD that the phase drops (it starts below zero) at the start of the time-domain. Probably caused by time-derivatives in the phase calculations. This only happens for eccentric cases. No problems found in the non-eccentric case. I've corrected this by adding the lowest starting value to the original phase which translates it back to start at zero. $\phi_{trans} = \phi + \phi_0$. Before the drop, the first value was still zero so reset the first value back to zero.

- Also there seem to be some time-array differences for different eccentricities. Higher eccentricities cause longer inspiral periods, so the length of the phase-arrays will differ. To compensate I've cut off the first part of the array to set all waveformlengths equal to the shortest waveform (e = 0.1)

1.2 14/03/2024

- The drop was a bit more complicated than I thought. At first it seemed to drop at one timestep after t[0], but it was a larger area including more than 1 timestep (fig. 1). The amount of timesteps in this area seems to vary for different eccentricities so it's a bit more difficult to just add some constant value. I decided to not only cut off the first few cycles from the longer waveforms but to also cut off the front area of the shortest waveform.

1.3 15/03/2023

- Now that all waveforms have equal size I build a dataset of 10 waveforms with $0.01 \leq e \leq 0.1$ with a stepsize of 0.01. All data ($\Delta\phi$, Δamp and tM) got written into a txt file to save generation-time for further work. Fig. 2 shows the results for the 10 dimensional dataset. It can be noticed they all have the same length and there seems to be a clear pattern for increasing eccentricity.

1.4 18/03/2023

- Now that I've build a small dataset I'd like to determine the overlap error of the waveforms. This could be useful to determine the best size for the actual dataset. The overlap error is the first step in building the reduced basis. In thought of generation-time efficiency you'd prefer a dataset that can produce an surrogate algorithm with a reasonable accuracy, however you'd also

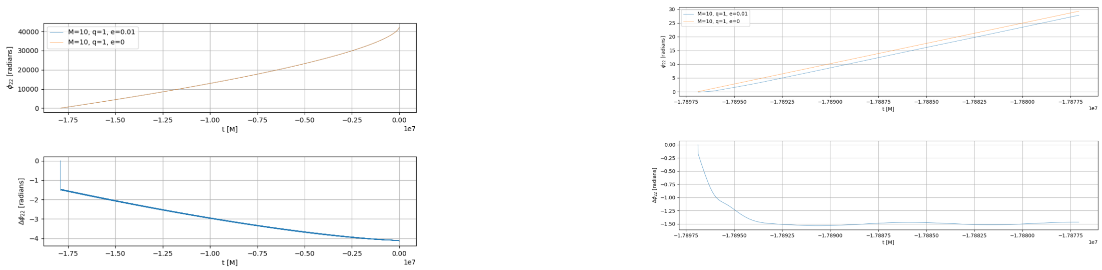

Figure 1: Small drop in $\Delta\phi$. From the left figure it only seems to be the first timestep however it concerns (right) an area of faulty data. Most likely caused by time derivatives in the calculation of the phase.

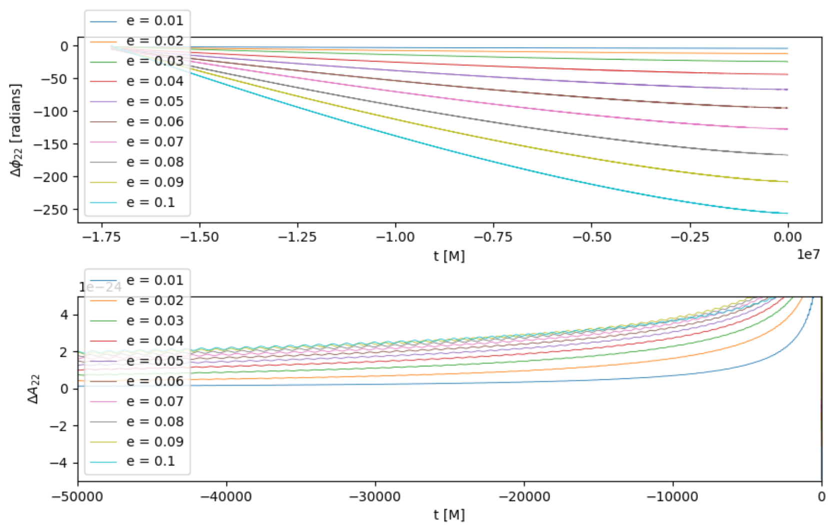

Figure 2: $\Delta\phi$ and Δamp for 10 different eccentricities in the range of $0.01 \leq e \leq 0.1$. There seems to be a clear pattern of increasing eccentricity. The first few timesteps of very waveform have been cut to make all waveforms of equal length.

prefer to do this with the least possible amount of waveforms. To look at the overlap error within our 10 dimensional dataset we can reason if the dataset is large enough for a reasonable testrun.

1.4.1 How to build a reduced basis including greedy error

A reduced basis is a low dimensional subspace that best approximates a larger function space. In this case the reduced basis is a set of m waveforms given m parameter points $\{\Lambda_i\}_i^m$,

$$\{h_i(t; \Lambda_i) : \Lambda_i \in \mathcal{T}\}, \tag{1}$$

where $\mathcal{T}$ represents a compact parameter domain. For the 10 dimensional testset $\mathcal{T} = \{0.01, 0.02, \ldots 0.1\}$. Based on the reduced basis, every waveform in the training set can now be approximated by

$$h(t; \lambda) \approx \sum_{i=1}^{m} c_i(\lambda) e_i(t), \tag{2}$$

where $\{e_i\}_i^m$ is the reduced basis.

2 Milestones

Deadline	**Task**
End Dec	Getting familiar with the literature and software used to generate eccentric gravitational waves.
End Feb	Develop and implement methods for measuring gauge invariant eccentricity in gravitational waveforms.
End April	Building a preliminary surrogate for the eccentric TD waveform model on a sparse dataset.
End June	Compile a comprehensive dataset of waveforms for optimized performance/ accuracy in eccentric parameter space.
End Aug	Train the model using the prepared dataset and develop a 1D surrogate model for eccentric waveforms of equal mass ratio.
If Extra Time	Begin exploring the possibility of building a surrogate model for 2D parameter space (eccentricity, mean anomaly) waveforms for equal mass systems.