

Note on the JPL/Caltech submission for Challenge 3.2

Michael Cohen, Curt Cutler, Ilya Mandel, Michele Vallisneri
JPL, Caltech, and Northwestern
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We briefly describe our algorithm for searching for spinning MBH signals in Mock LISA data, for Challenge 3.2. More details will be given elsewhere

I. METHODOLOGY

This brief note describes the method our JPL/Caltech group has taken in searching for spinning MHB binary inspirals in Mock LISA data. The search essentially had two parts. First, we looked for bright sources using tools we developed for non-spinning MBH searches. We did this in two ways, both described in Brown et al. [1]. We used a simple grid search on the $m1 - m2$ plane, using lowest order PN waveforms and neglecting modulations related to the source's sky position and LISA's motion, as well as higher-PN corrections. This search revealed 4 clear candidates (two of which were visible by eye in the waveform), as well as approximate values of t_c , $\mathcal{M}$ and η . We also used a time-frequency track search, tuned for non-spinning binaries, for the same purpose, and obtained consistent detections of the four candidates.

In the second stage, we used a publicly available multinested sampling algorithm called "Multinest" [2, 3] to optimize the fit search over a 12-dimensional space: all 15-dimensions except for Distance, PhaseAtCoalescence, and CoalescenceTime. (We first verified that Multinest performed well in searches for non-spinning binaries, which of course are searches in a space of significantly smaller dimension.) The optimization of these three parameters was done analytically. Essentially, we used (a version of) the F -statistic to maximize over Distance and PhaseAtCoalescence, and we used the standard Fourier-transform trick to maximize over CoalescenceTime. Neither of these analytic maximizations is quite exact though. The Fourier-transform trick is inexact because LISA is moving over the observation. In practice, we accounted for this by using a 2-step iterative scheme to maximize over CoalescenceTime, starting with an initial guess derived from the first stage of the search. And while it is approximately true that under a change in CoalescenceTime Δt_c , the Michelson variables transform as $\tilde{X}(f) \rightarrow \tilde{X}(f)e^{2\pi i \Delta t_c}$, this is not exactly true, and can fail badly at the highest frequencies for the MLDC version of the tapered ringdown. (Presumably the symmetry is actually closer to exact in reality than in the MLDC's tapered waveforms.)

Of the twelve searched-over parameters, we restricted Multinest to searching in neighborhoods of our best-guess parameters $(t_c, \mathcal{M}, \eta)$ (from the first stage), but allowed Multinest to range freely over the other nine parameters. The four searches were run on Caltech's shc cluster. We ran 4 nodes (16 cores) for about 4 days on each search.

II. WHAT WE DID NOT DO, AND FUTURE WORK

The noise for Challenge 3.2 had a spectral density that was uncertain (to participants) by 20%. Ideally we would have solved for the actual noise spectral density, but because of time limitations we ended up just assuming the standard (for these Challenges) LISA noise spectrum, including instrumental noise plus confusion noise from the undetectable WD binaries. Also, we ran four individual searches, with no attempt to best joint fit or to otherwise account for correlations between the sources. We plan to improve on these aspects of the search. Also, if not for time pressure, we would have done a follow-up Multinest run that searched over all 15 physical parameters (since again, the symmetries lying behind the analytic maximizations are not exact).

Additionally, we did not invest any significant effort in looking for the lowest SNR waveforms. This will also be a goal of future work. In principle, Multinest alone should be capable of finding all the imbedded waveforms and determining their parameters.

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- [1] D.A. Brown, J. Crowder, C. Cutler, I. Mandel, & M. Vallisneri; arXiv:0704.2447
 - [2] F. Feroz & M.P. Hobson; arXiv:0704.3704
 - [3] F. Feroz, M.P. Hobson, & and M.Bridges; arXiv:0809.3437