DY11131/Brown – Responses to the report of the Referee.

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We would like to thank the referee for their careful and critical reading of the manuscript, and their constructive suggestions. The referee correctly points out that the impact of ignoring higher-order waveform multipoles in search templates might have a smaller impact on the loss in actual signal detection volume/rate than is suggested by the fitting-factors alone. While our fitting-factor study makes a more global statement about the loss in the signal-to-noise ratio for different systems, irrespective of their orientation with respect to the detector, the loss fraction is observed to be higher for sub-optimally oriented binaries to which the detector is expected to be less sensitive. We have incorporated the referee's comments in our revised manuscript. Below we address specific points raised by the referee.

Report of the Referee – DY11131/Brown

In this paper the authors study the use of standard TaylorF2 template banks in searches for gravitational waves with advanced LIGO. The paper clearly shows that these recover most signals up to total binary masses of 12 solar masses. This is not a new result, but is an important confirmation of earlier work. The authors also argue that higher modes can be neglected up mass ratios of 1.5.

I recommend this paper for publication, provided that the authors address my concerns below. My main concern is with the statments about the importance of higher harmonics.

Major Comments:

8. *This is my main concern. The study of higher harmonics does not take into account the relative SNR of signals with respect to orientation. These results provide only minimal information if this is not taken into account. It should be possible, assuming a uniform volume distribution of signals, to appropriately downweight signals that are not optimally oriented to the detector, and provide a useful estimate of the mass ratio at which higher harmonics become important. (At the moment the result is no more than a lower bound on q, and I suspect that the result with appropriately weighted signals would be much higher.)*

9. *The suppression of the inclination and polarization directions means that Fig. 5 contains very little information. One option would be to show three figures, one for optimally oriented signals, another for edge-on signals, and a third*

for signals with an inclination of 45 degrees, to illustrate the variation in results with respect to orientation.

We agree with the referee, that our results do not take the relative SNR of signals for different orientations, but make a more global statement about the fractional loss in SNR. We have added description in text (Sec.III) and plots (Fig.(6)) showing the variation of fitting-factors with respect to the inclination angle. We note that for inclinations close to parallel and anti-parallel to the line of sight, the higher harmonics do not contribute significantly to the signal, and for inclinations close to $\pi/2$ we see fitting factors as low as 0.92. This further restricts the region where including higher harmonics in templates would lead to a gain in the SNR, in detection searches. To convert the loss in SNR into averaged loss in the event observation rate, we have calculated volume-weighted fitting-factors, which weight the FFs for different binary orientations with the appropriate observable volume available to the same. This implies that systems that are unfavorably oriented to the detector, and have relatively lesser observable volume available, will downweight their loss in SNR due to the volume weighting. Thus we are able to also make a statement about the event rate loss for a population of BBHs where the inclination angle of the binary is uniformly distributed over its entire possible range, and the population is also distributed uniformly in spacial volume. We find that the actual detection rate loss for such a population does not exceed $10 - 11\%$, which is within the tolerated range.

The other angles, i.e. the sky-location and polarization angles, do not affect the fitting-factors, as they determine the relative contribution of the two orthogonal GW polarizations to the signal - which we maximize over anyway when filtering with orthogonal templates to maximize over the phase-at-coalescence parameter. These angles, (θ, ϕ, ψ) would indeed be important when one does a similar study for precessing binaries, for which these angles vary over time. In the case of non-spinning binaries, these angles remain constant throught the inspiral-merger process. Thus, if we conclude that we lose upto 8% of the *maximum possible* SNR, for systems with mass-ratio as high as 8, and inclination angles $\in [1.08, 2.02]$ radians, then this will be true for all values of the (θ, ϕ, ψ) angles.

Minor Comments:

1. *The paper provides a clear and mostly complete description of the generation of EOBNR waveforms. This is a useful resource. Could the authors also provide an algorithm for choosing initial values for integrating Eqs (6)-(9), which would complete their description?*

We agree that a description of the algorithm to calculate the initial values would make the description of the EOBNR model self contained, and so we have added a description of the equations determining motion on circular orbits, as derived in Phys.Rev.D74:104005 (2006), which are solved to get the initial conditions. We take the non-spinning limit of the results in this reference, and present the relation between the initial values of the position and momenta coordinates for the non-spinning binary, in Eq.(7)-(9).

2. *The EOBNR waveforms are described in some detail, but the template placement algorithm is given only a reference. Could the authors include a description of this algorithm, and make it clear to the reader why it cannot easily be changed from a "TaylorF2 hexagonal template" to a "EOBNR hexagonal template" with gauranteed MM¿0.97 across the bank?*

The bank placement metric has a semi-analytic form when using the stationary-phase approximation to get the expression for the GW strain in the frequency domain. For the EOBNR model, however, the calculation of a similarly defined metric would involve taking numerical derivatives of functions of coordinate evolution, which themselves are obtained by numerically solving the Hamiltonian equations of motion. This could lead to numerical instabilities in the metric calculation, and we have added the description of both (Sec. IIB) to the revised manuscript.

3. *In a numerical calculation, the upper limit of Eq (17) is not infinity. What is it?*

We take the upper limit of the overlap integral, Eq (17), as the Nyquist frequency corresponding to the sample rate of $8192Hz$ at which we perform the numerical integration of the Hamiltonian equations. i.e. $4096Hz$. We have also made this information explicit in Sec. III of the revised manuscript.

4. *In Sec. III.A, why does the study stop at a maximum mass of 25 solar masses? I understand that this is the choice made in searches, but for this study it would be interesting to go to much higher masses, and determine where the hexagonal template placement algorithm really fails.*

We agree that, in principle, there is not much reason to stop at a maximum component BH mass of 25 solar masses and make a note of this in the manuscript. We are examining higher mass systems and investigating the use of hybrid/NR waveforms for detection of such systems, in addition to EOB, and this would be a separate paper.

5. *In Sec. III.B and Fig. 4, the choice of 12 solar masses seems arbitrary. It would be clearer to say "We determine the maximum total mass such that 99% [or some other choice] of signals have fitting factors above 0.97". The equivalent statement could later be said for a choice of MM of 0.99. Even better would be to provide a plot of maximum mass vs MM, such that 99% of signals have a match above 0.97.*

We have added a figure (Fig. (4)) showing the upper threshold on the total mass against the MM of the TaylorF2 bank in the region restricted to binaries with total masses below this threshold. We further require that $\geq$ 99.75% of the systems sampled in the restricted region have FFs (effectualness) with the same bank above 0.965 - to make a more precise determination of this threshold on total mass. We also do additional simulations for Sec. IIIB with 100,000 points (earlier 25,000), and find that the threshold on total mass below which the TaylorF2 bank is effectual changes from 12 to 11.4 solar masses.

6. *In Fig. 3 it is difficult to identify the general boundary between FF¿0.97 and FF¡0.97. A contour plot would be clearer.*

We have changed Fig. 3 to a contour plot, with more drastic changes in the color scale around FF= 0.97, and hope that it is clearer to read now.

7. *The MM threshold to lose no more than 10% of signals in a search is 0.965. This is usually rounded up to 0.97, but in figures like Fig. 2, the choice of 0.965 or 0.9 makes a large difference. In the second paragraph of Sec. III.B, the authors refer to matches above 0.965, but elsewhere choose 0.97. They should make a consistent choice.*

These two values of thresholds on fitting-factors (FF) have been chosen for different situations.

We have chosen 0.97 as the threshold for testing the bank placement algorithm. In section III.A, where the simulated signals and templates are obtained from the same approximant (i.e. EOBNRV2), the only loss in FF is due to the discreteness of the bank grid. We take 0.97 as the required minimal-match (MM) of the bank, and so evaluate the performance of the bank in Fig. (1) and Fig. (2), with this threshold in mind.

However, when we compute the FFs of TaylorF2 templates against signals simulated using the EOBNRv2 approximant, the deviation in FF from 1.0 is due to the combined effect of the discreteness of the template bank grid and the discrepancies between waveform models. The acceptable threshold for FF in this case is taken to be 0.965, which corresponds to: "If real signals were accurately modeled by EOBNRv2, a TaylorF2 template bank constructed with MM= 0.97 will lose no more than 10% of the events in the region where FF is below this threshold."