Physical Templates in the Search for Gravitational Waves from Spinning Compact-Object Binaries with LIGO

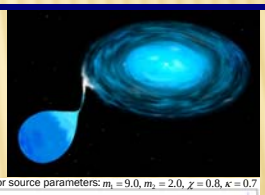
Diego Fazi - Northwestern University

LIGO-G0901044

INTRODUCTION

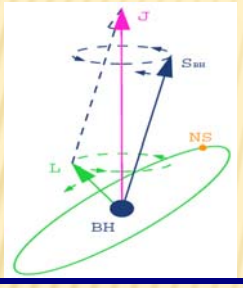
The detection of gravitational waves emitted by spinning compact-object binaries with kilometer-scale laser-interferometric detectors poses a great data analysis challenge due to the high number of parameters necessary to describe these signals. Different approaches to model the precession induced modulations using templates described by a smaller number of phenomenological parameters have been tried with little success. We present a data analysis strategy which deploys physical templates, aimed to model gravitational waves emitted by binaries with only one significantly spinning component, we show its efficiency and we assess the feasibility of a search on LIGO data.

GW GENERATION AND DATA ANALYSIS



Target Systems: Asymmetric Black Hole (BH)–Neutron Star (NS) binaries (NS's spin is negligible)

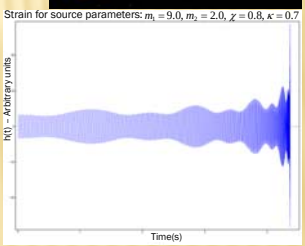
Features: Supernova explosions in close binaries: BH's spin can be significantly misaligned with respect to the orbital angular momentum.



GWs emitted: Characterized by precession induced modulations.

Data Analysis : Non-spinning templates have low efficiency in recovering single-spin signals with high mass-ratio, maximal BH spin and misalignment with the orbital angular momentum.

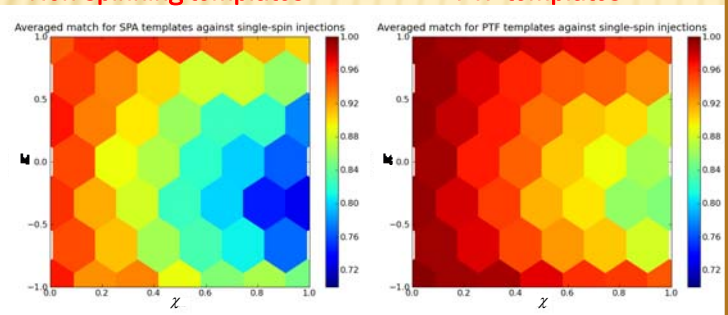
The Physical Template Family (PTF) [1] provides exact time-domain templates and allows for parameter estimation of spins as well as masses.



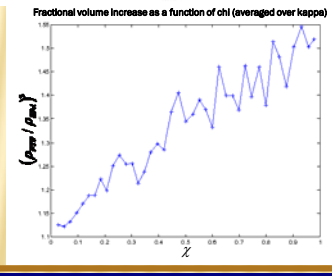
RESULTS

We plot the maximum match over the template bank as a function of BH spin magnitude $\chi = |\mathbf{S}_{BH}| / m_{BH}^2$ and orientation with respect to the orbital plane $\kappa = \hat{\mathbf{S}}_{BH} \cdot \hat{\mathbf{L}}_N$ for 4000 signals with random masses $1 \le m_{NS} \le 3, 6 \le m_{BH} \le 14$, random BH's spin magnitude and orientation, random sky location and orientation.

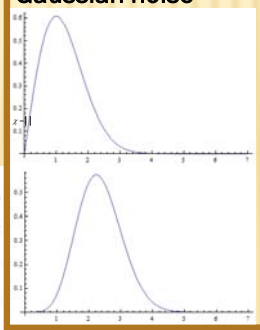
Non-spinning templates | PTF templates



The volume of accessible universe scales as the SNR cubed so, assuming the same SNR threshold, we can plot the fractional volume increase as function of the spin magnitude achieved by using PTF over non-spinning templates.



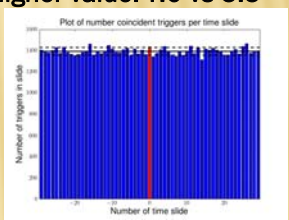
SNR distribution in presence of Gaussian noise



Non-spinning templates: 2 degrees of freedom

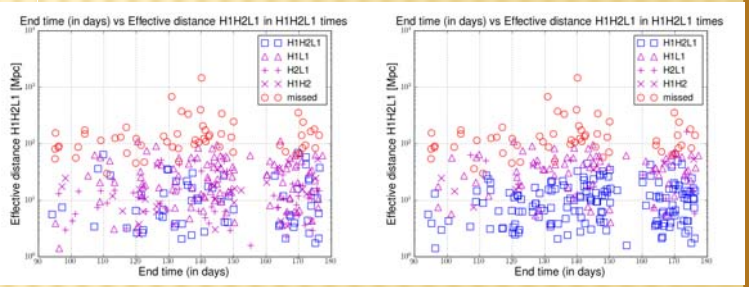
PTF templates: 6 degrees of freedom

To obtain the same background trigger rate the SNR threshold for PTF templates must be set to a higher value: 7.0 vs 5.5



~1150 signals are injected in LIGO S5 playground data and searched for in coincidence before applying signal based vetoes.

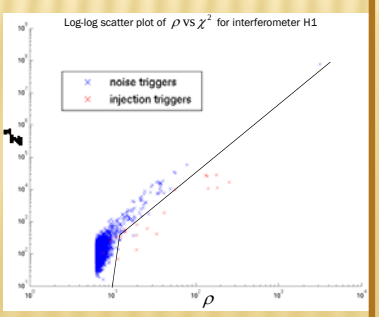
Non-spinning templates | PTF templates



Found triples: 592 | Found triples: 695

ONGOING DEVELOPMENTS

A chi-squared distributed time-frequency discriminator is under development which will allow to decrease the background trigger rate to obtain the desired false alarm rate. Here we plot chi-square vs SNR for triggers from both noise glitches and injections and show how a cut on chi-square can help discard noise artifacts.



CONCLUSIONS

Results suggest that PTF templates might be a useful tool in the search for gravitational waves from single-spin binaries. A PTF search should be targeted to the region of the parameter space where precessional effects are stronger. An alternate option would be a follow-up search to interesting triggers from the non-spinning analysis to increase detection confidence. A final assessment on which type of search is feasible will be possible once the triggers are passed through the signal based vetoes and ROC curves can be obtained to estimate the overall efficiency of the PTF template bank at multiple false alarm rates.

REFERENCES: [1] Y. Pan et al., Phys. Rev. D 69, 104017 (2004).