Transient GW signals without templates

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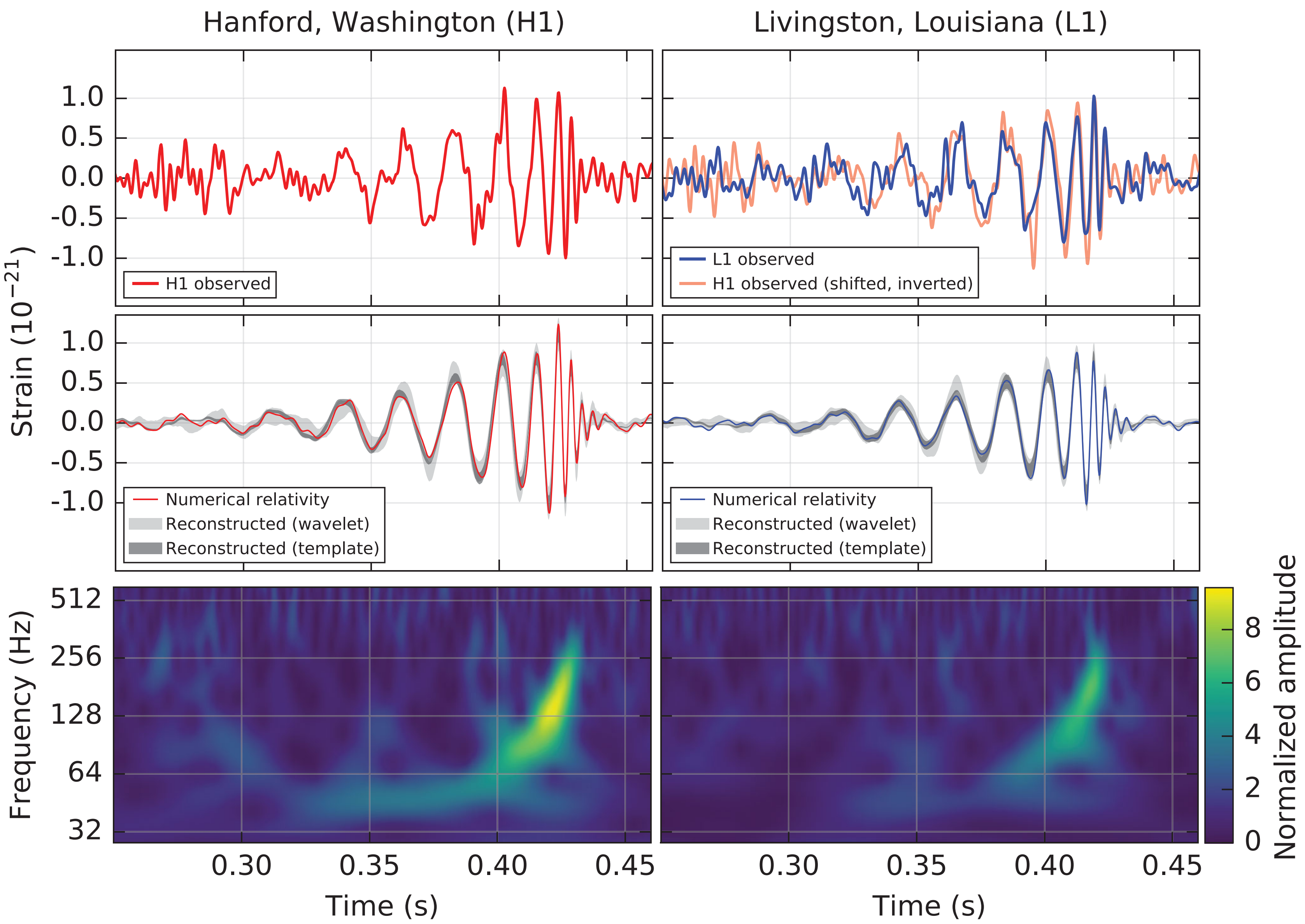
GW150914



Two main types of gravitational-wave transient signal analysis

a) templated analysis (matched filters, Bayesian computation)

b) unmodeled analysis (wavelet decomposition in the time-frequency map, likelihood maximization over sky location, coherence over different detectors)

Unmodeled analysis necessary for sources where templates are not available.

The unmodeled data analysis in this WP is carried out in the framework of the LIGO-Virgo-KAGRA collaboration.

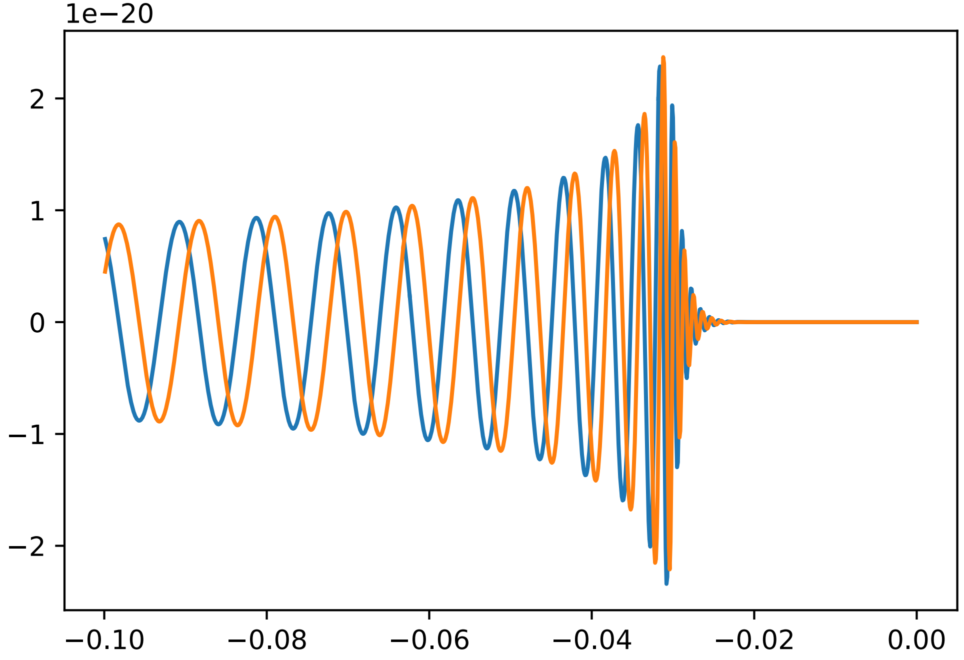
Several pipelines exist:

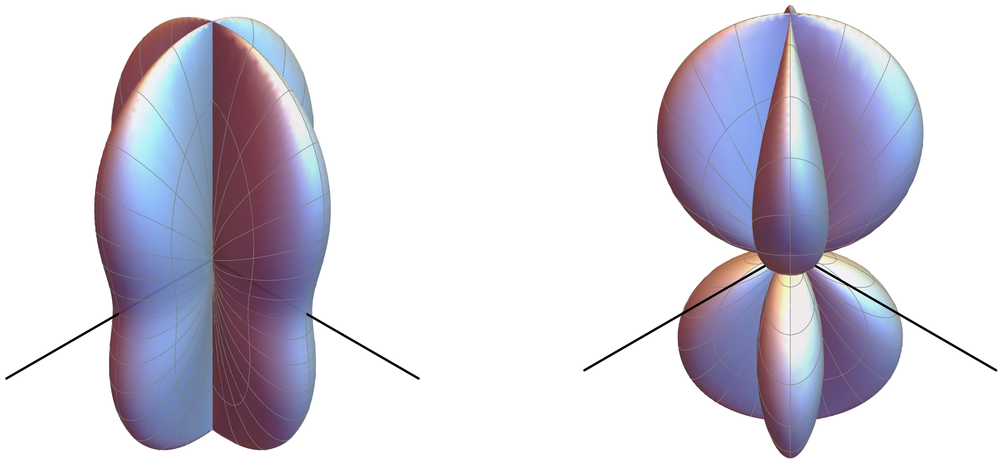
main "burst" pipelines

- **coherent WaveBurst** (in Italy: Trento, Roma, Trieste)
- **BayesWave**

other pipelines in several stages of development, all of them are going to include ML either as an essential pipeline element or as a method to enhance efficiency.

Code is written in C++ and/or Python (currently, cWB is written in C++/Root, with Python elements for online processing).





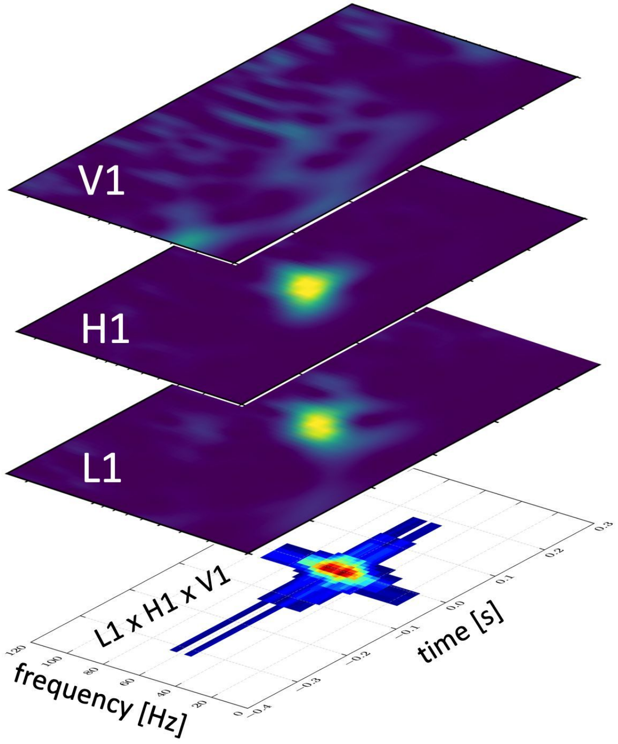
(a) Plus (+)   (b) Cross (×)

Each gravitational-wave signal is actually a linear combination between two polarizations.

Different polarizations have different spatial antenna responses (linear combinations have different coefficients for different sky locations)

Polarization disentangling becomes possible for n > 2 interferometers. Redundance needed (n > 3) to get rid of zeros that spoil the elegance of the general solution.

coherent WaveBurst (cWB)

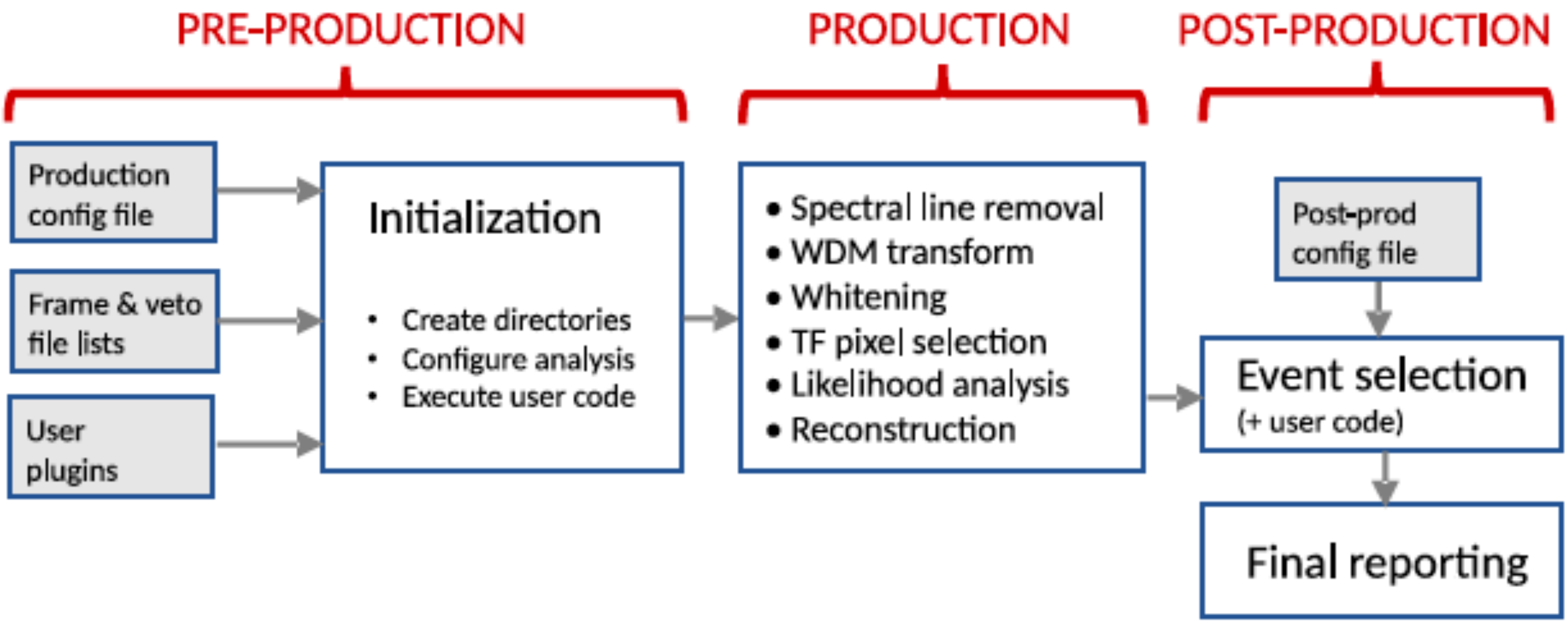


$$x(t) \xrightarrow[\text{Transform}]{\text{Wavelet}}$$

- Time-Frequency decomposition
- Cluster selection, based on black pixel probability
- Constrained Likelihood

$$\xrightarrow[\text{Transform}]{\text{Inverse Wavelet}} h(t)$$

Injected (black) vs reconstructed (red)

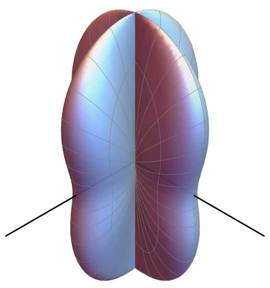


cWB algorithm optimized for n = 2 interferometers. New developments for n > 3 are welcome. Application of GPUs to inner loop would increase efficiency (**link to WP4**), especially in the Production block.

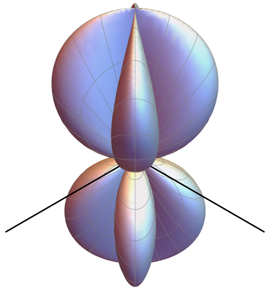
HPC architectures can also help accelerating the calculation of statistical significance of each event with the technique of time slides.

Challenges

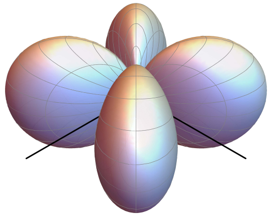
non-GR polarizations



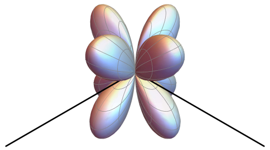
(a) Plus (+)



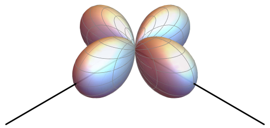
(b) Cross (×)



(c) Vector-x (x)



(d) Vector-y (y)



(e) Scalar (s)

overlaps

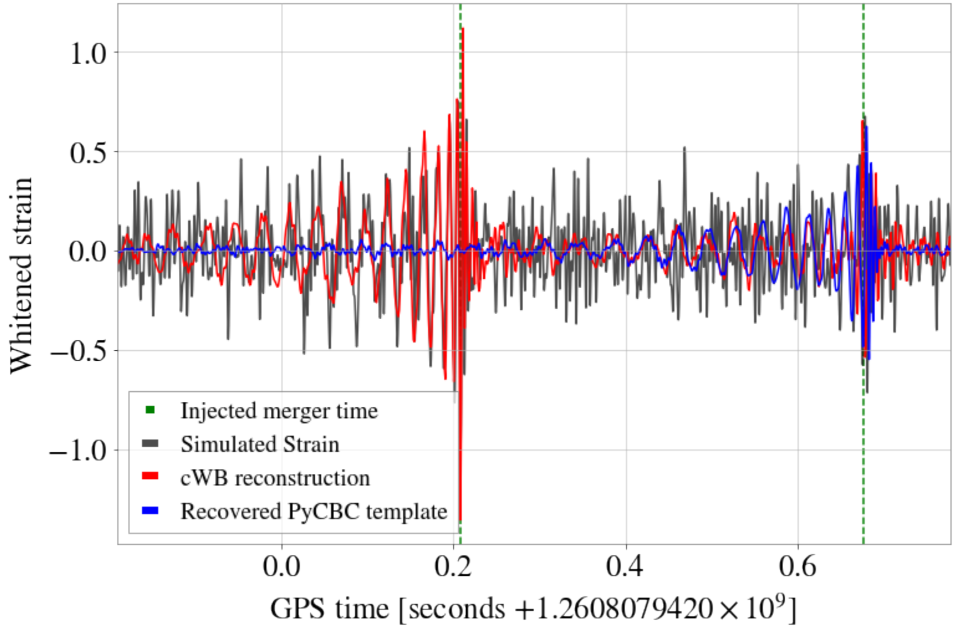


FIG. 8. A plot of whitened strain, in the LIGO-Hanford detector, for a BBH+BBH injection. The blue line shows the matched templates found by PyCBC in the PAIRS injection set. The red line is the cWB reconstructed waveform from the PAIRS injection set. The green, dashed, vertical lines indicates the injected merger times.