GW data analysis — Excess power methods

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Time–frequency maps

Events are often represented in time-frequency maps, as an example consider the NSBH (neutron star–black hole) event GW200105_162426, displayed in several different representations in figure 1: raw time series, whitened time series, and omega scans (a kind of spectrogram).

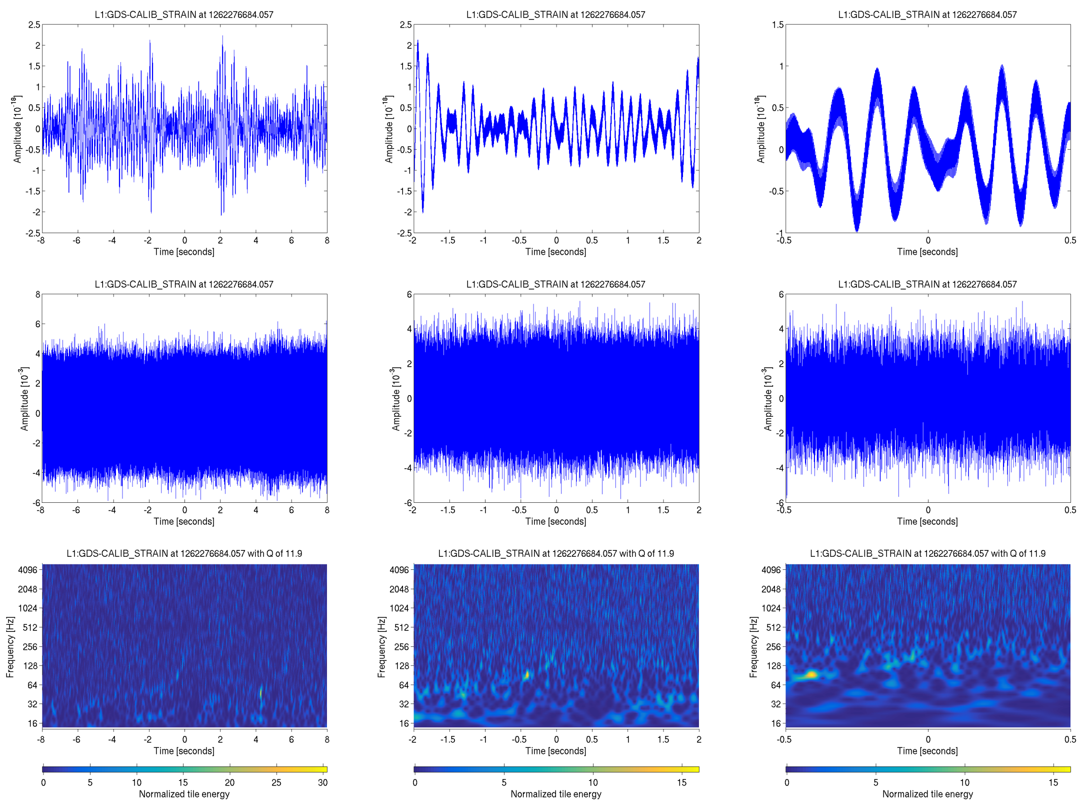

Figure 1: The GW200105_162426 event was observed by LIGO-Livingston and LIGO-Hanford. The images shown here show different representations of the signal observed by LIGO-Livingston, with different time scale ranges. First row: the raw time series; second row: the whitened time series; third row: the omega scans; note the log vertical scale in the omega scans. Data from the GraceDB database.

The omega scans display a weak time-frequency track that is typical of the coalescences of compact binary objects (CBC). The image pixels on the track have slightly more power than adjacent pixels, and the region that contains the track can be identified because it carries with it *excess power*. Methods based on excess power bear some similarity with methods based on matched filters, but they are less efficient in detecting CBC events. Detections of pipelines based on excess power also use the coherence of events in different detectors: the statistical estimators used by these pipelines take into account the presence of like pixels in the detectors' time–frequency maps.

There are several analysis pipelines based on excess power, like *coherent WaveBurst* (cWB), *BayesWave*, and *Omicron*. The first two pipelines use discrete wavelet decompositions – a highly efficient way to decompose signals in time and frequency – to produce their time–frequency maps, while Omicron uses a closely related technique, the Q-transform.

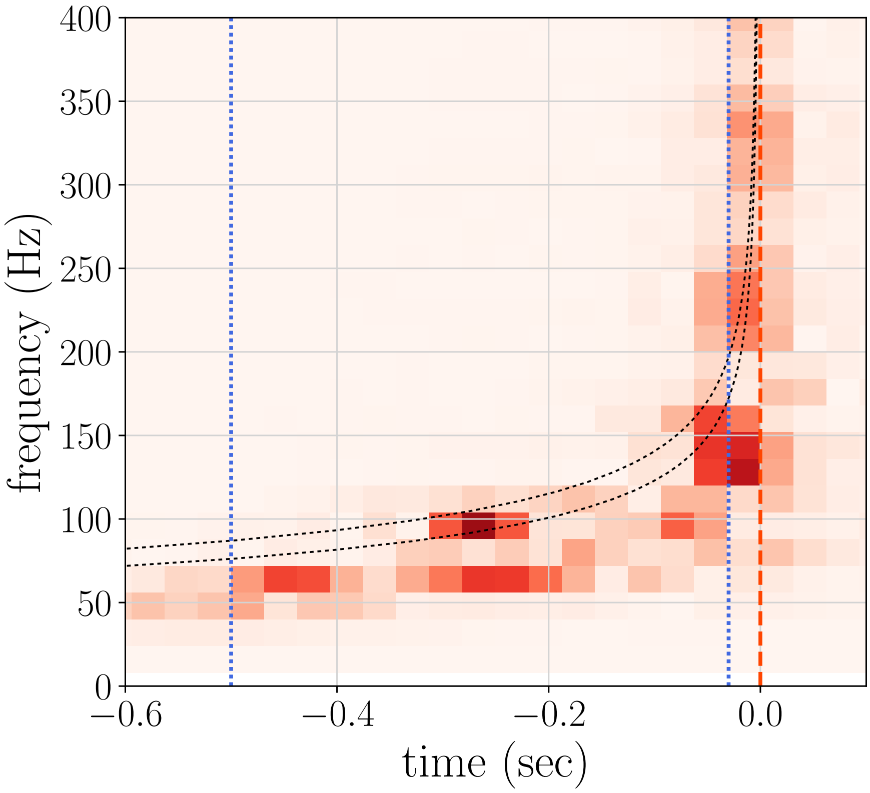

Figure 2: Time-frequency representation of the pixel-by-pixel residual energy of the GW190814 event obtained by cWB with respect to the best fitting SEOBNRv4_ROM waveform, projected into the LIGO Livingston detector using the WDM transform with resolution $dt = 1/32$ s and $df = 16$ Hz. Figure from G. Vedovato et al., *Minimally-modeled search of higher multipole gravitational-wave radiation in compact binary coalescences*, Class. Quantum Grav. **39** (2022) 045001.