Status of the search for GW signals from high mass compact binary coalescences in LIGO S5 data

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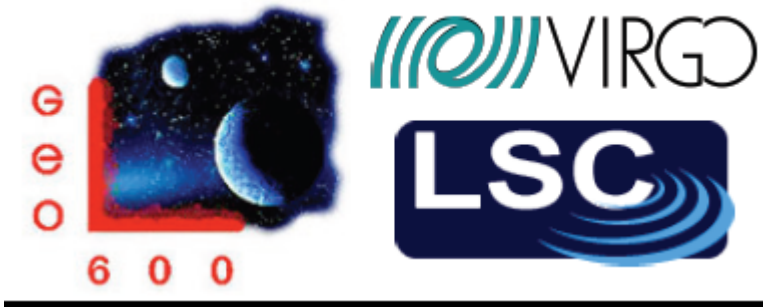


LIGO

VIRGO

Outline

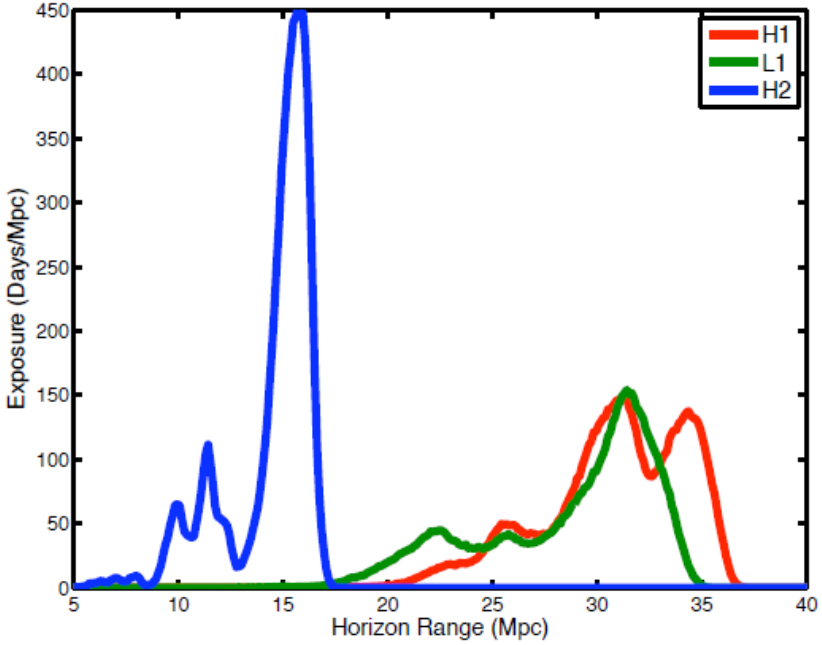
- Brief description of the data set and sources for which we are searching
- Waveform families used as search templates (EOBNR) and injections (EOBNR and phenomenological)
- Overview of the search pipeline
- Current status and improvements for future science runs

LIGO S5 Science Run

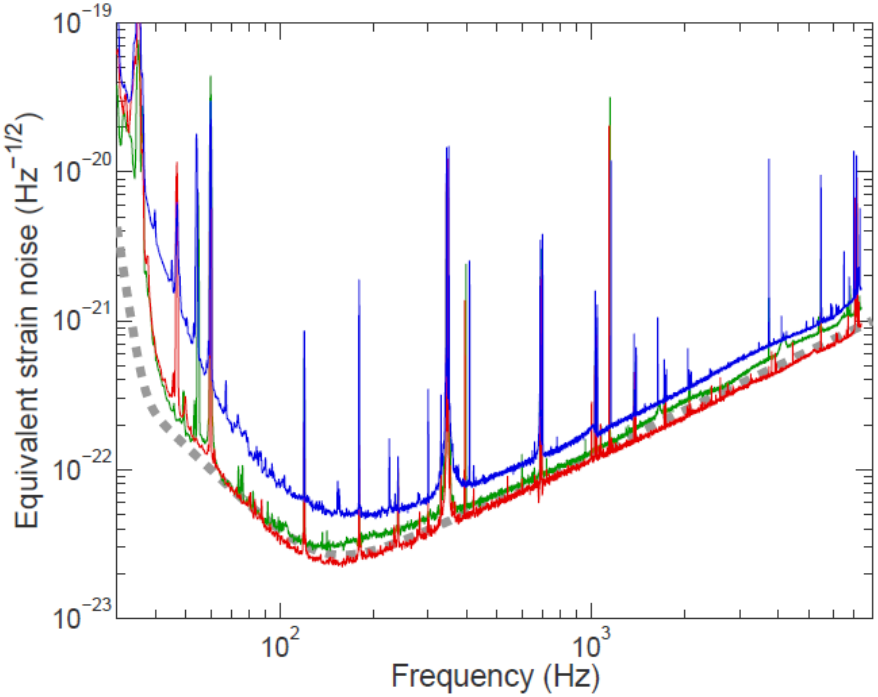
- Data taken from November 2005 - November 2007
- 3 detectors operating at initial LIGO design sensitivity
- Over a year of triple coincident data

[Abbott et al, arXiv:0711.3041]

NS-NS Horizon Range



Detector Sensitivity



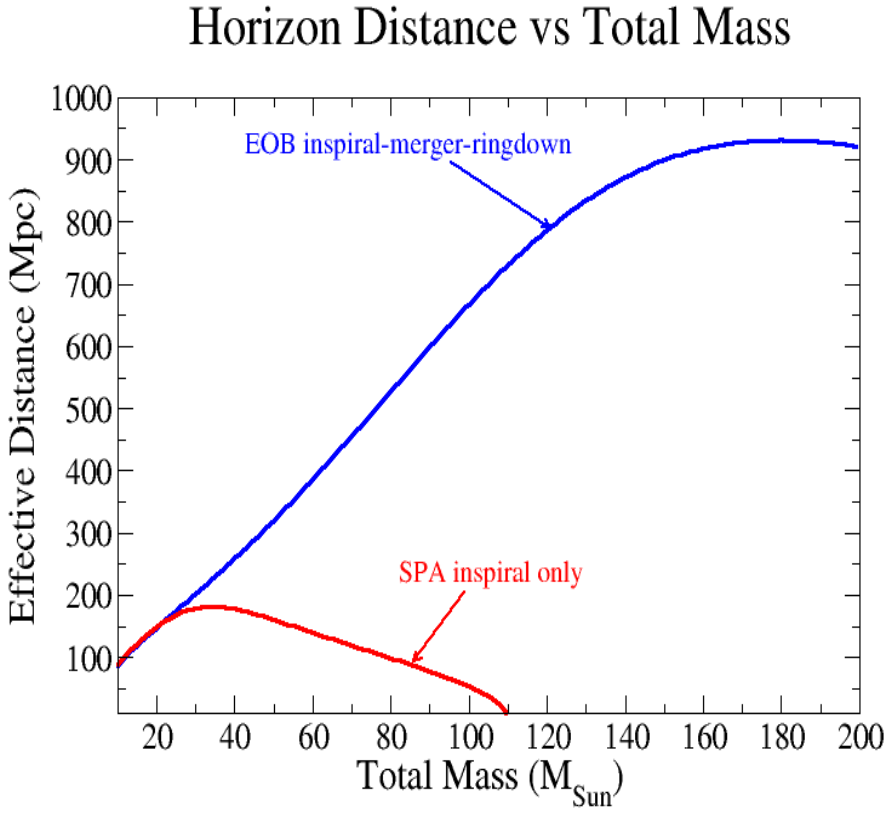
Red = H1

Green = L1

Blue = H2

High Mass Binary Inspirals

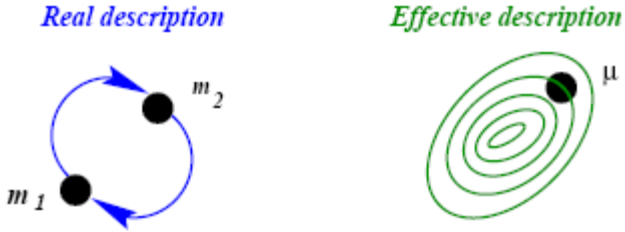
- BH-BH and BH-NS binaries
- Total mass (25 – 100) $M_\odot$ with component masses (1 – 99) $M_\odot$
- Rate of BH-BH and BH-NS merger is very uncertain, could be ~ 0.01 – 1 $MWEG^{-1}$ Myr^{-1}
- (10+10) $M_\odot$ BH binaries are detectable out to ~ 125 Mpc
- Higher mass binaries are detectable even further
- Merger and ringdown occur in the sensitive band of LIGO



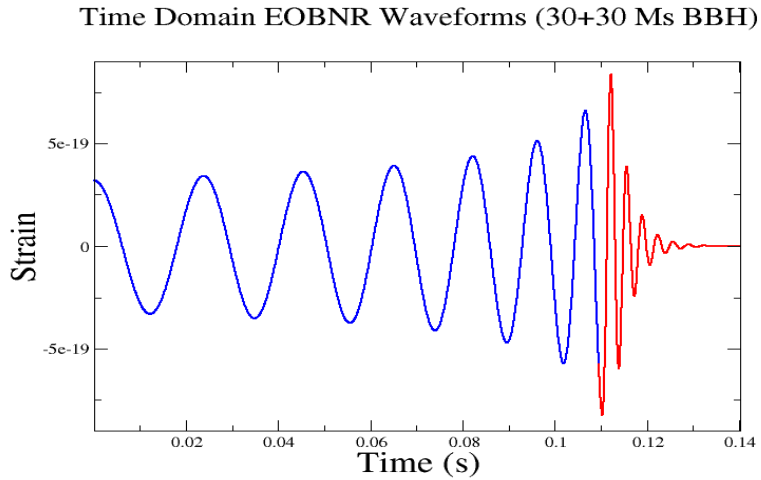
Calculated with analytic noise curve

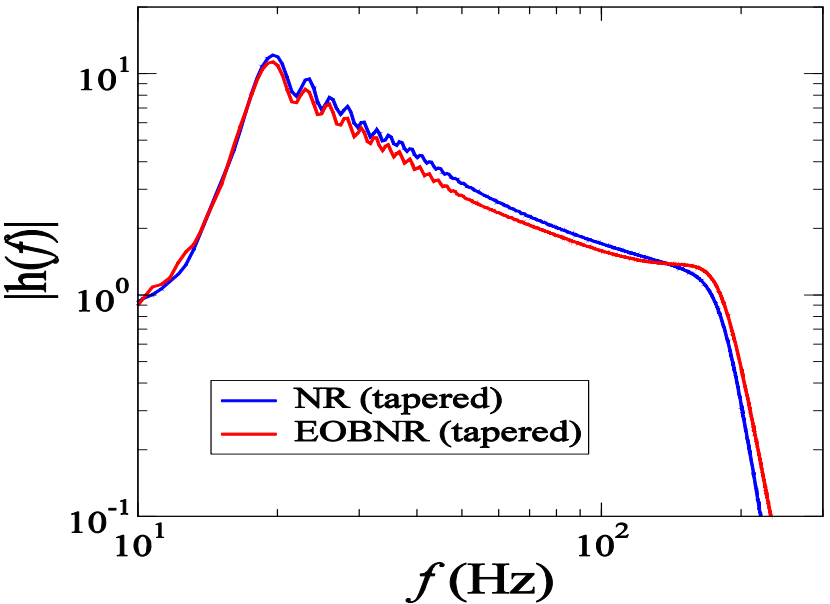
EOBNR Inspiral-Merger-Ringdown Waveforms

[Buonanno et al, PRD 2007]



- The effective-one-body (EOB) approach uses a re-summed Hamiltonian of the binary dynamics during inspiral up to the light ring
- The EOB inspiral-plunge waveform is computed along the trajectory provided by the EOB Hamiltonian
- The EOB merger-ringdown waveform is a superposition of quasi-normal modes smoothly attached near the light ring
- The model was calibrated to NR waveforms with mass ratios 1:1 - 4:1 from the NASA-Goddard group
- Used as search templates



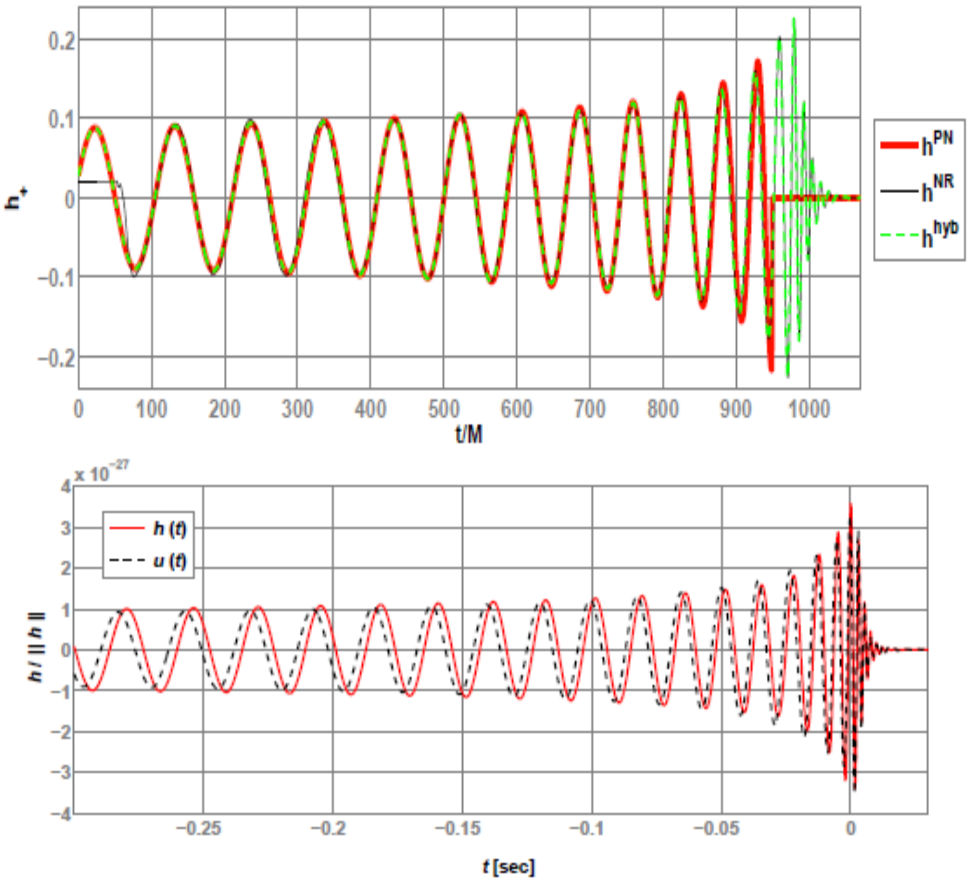


Phenomenological Inspiral-Merger-Ringdown Waveforms

- Hybrid waveforms are created by stitching PN waveforms to NR waveforms from the final few orbits

- Phenomenological waveforms are fit to the hybrid waveforms in the frequency domain
  - The inspiral waveform has the structure of stationary-phase approximation waveforms
  - The ringdown waveform decays as a Lorentzian
  - Undetermined coefficients are calibrated to match the hybrid waveforms
  - The waveforms are parameterized by the masses with no spurious degrees of freedom
  - The model was calibrated to AEI-Jena waveforms with mass ratios 1:1 – 4:1

[Ajith et al, CQG 2007]

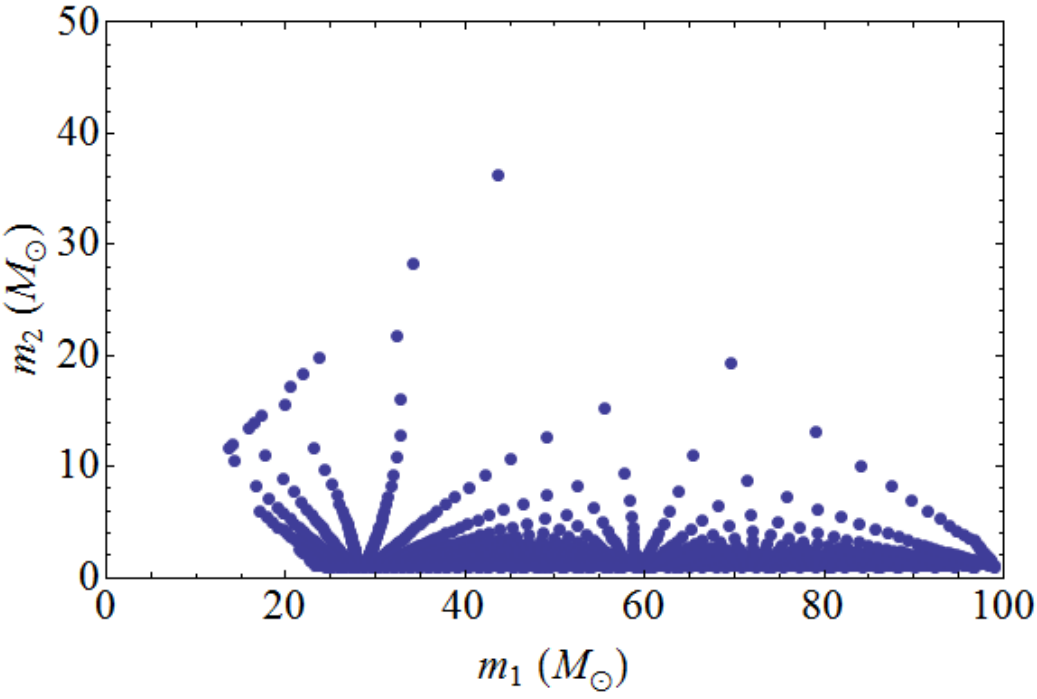


- Used as injection waveforms

Matched Filtering Pipeline

- A matched filtering approach is used to find potential signals buried in noise
- A template bank is laid out to cover the mass range so that adjacent templates nominally have an overlap > 0.97
- The data are filtered against each template
- Any triggers are tested for coincidence with other detectors
- A second coincidence test is performed with signal-based vetoes such as χ^2 applied to significantly reduce triggers due to noise

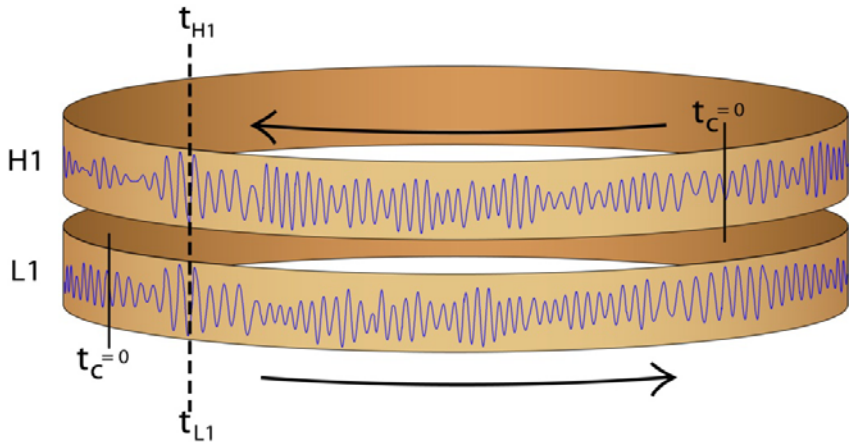
Template Bank in Mass Space



Typically ~2000 templates

Matched Filtering Pipeline

- Analysis split into chunks of approx 2 months duration
- The loudest coincident triggers in each chunk are subjected to further scrutiny
- Upper limit will be set on the rate of binary coalescences in this mass range (subject to various caveats…)



- Time slides are used to estimate the rate of background triggers
  - Repeat the analysis, but slide the data from each site relative to one another
  - Any coincident events between sites must be accidental
- We also inject waveforms to test our efficiency at recovering signals
  - Inject EOBNR waveforms over full mass range
  - Inject phenomenological waveforms with mass ratios up to 10:1

Future Improvements

- S6/VSR2 science runs will begin this summer
  - Goal is that “Enhanced” LIGO will be about twice as sensitive
  - The observable volume of the universe will be about 8x larger
- EOBNR and phenomenological waveforms will be improved by calibrating them to more accurate NR simulations as they become available
- Inspiral-merger-ringdown waveforms with spin effects and higher harmonics are also being developed
- Improve template placement at higher masses
  - Current placement depends on same metric as low mass search
  - In the future we will explore using a metric specifically for IMR waveforms

Summary

- In the S5 run, we are searching for BH-BH or BH-NS binaries with total mass 25-100 $M_\odot$ with inspiral–merger–ringdown templates
  - The LIGO interferometers operated at design sensitivity providing over a year of triple coincident data
  - The first GW search with complete I-M-R templates!
- The data analysis is nearing completion
- We expect to have public results later this year
- In S6 we will have more sensitive instruments and improved data analysis techniques
- The waveforms used for the search will also be improved as more NR simulations become available