Extending the PyCBC offline search to a many-detector network

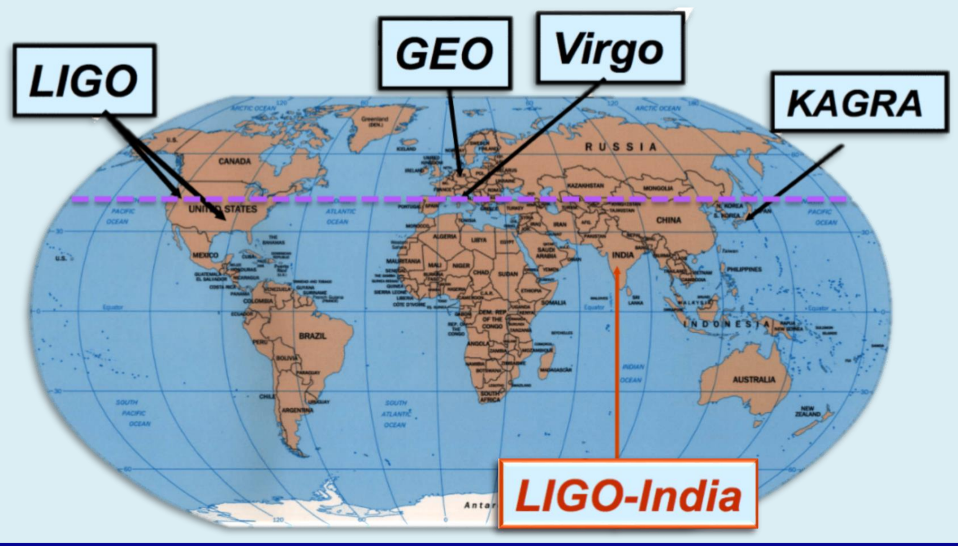
Gareth S. Davies [1], T. Dent [1], M Tápai [2], I.W. Harry [3], A.H. Nitz [4]

[1] IGFAE, University of Santiago de Compostela, [2] University of Szeged, [3] University of Portsmouth,
[4] Albert Einstein Institute, Hannover

LIGO document LIGO-G1901550

Motivation and Summary

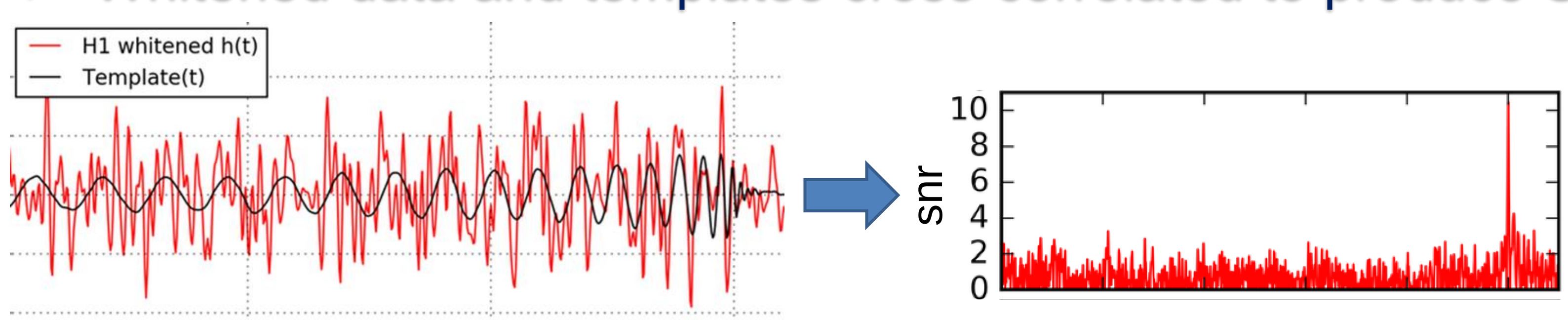
- PyCBC offline currently:
  - uses two detectors
  - requires SNR trigger in both detectors
  - ranking statistic of background rate + p/t/a consistency
- PyCBC offline multiifo:
  - SNR triggers from all combinations of two or more detectors combined
  - Updates to ranking statistic



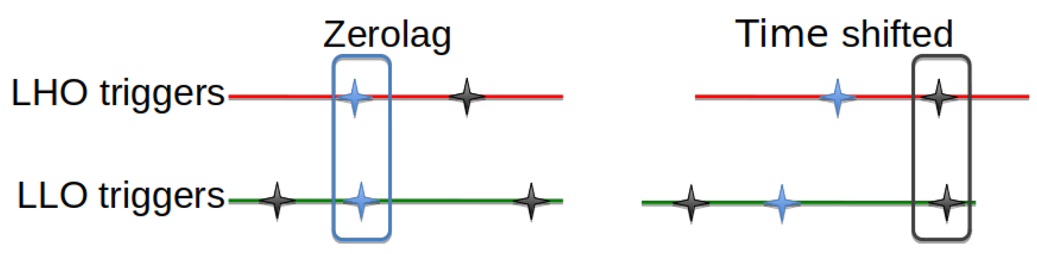
- More detectors improves:
  - latency
  - sky localisation and coverage
  - statistical confidence
- These lead to more/better detections (yay!)
- Comparison to the two-detector (two-ifo) search shows significant sensitivity improvement

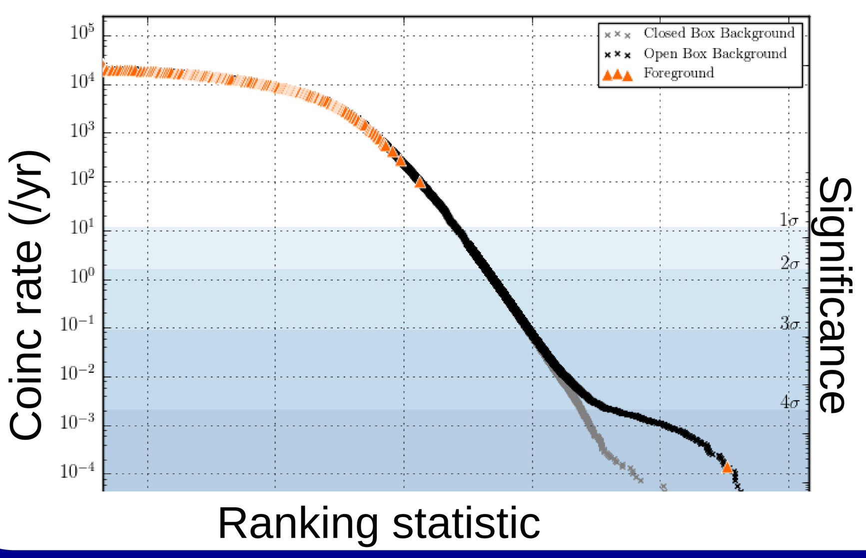
PyCBC offline search: the basics

- Matched Filtering
  - Whitened data and templates cross-correlated to produce SNR



- Coincidence (coincs)
  - Triggers (SNR peaks) from each detector compared to find coincidences in time (require same template)





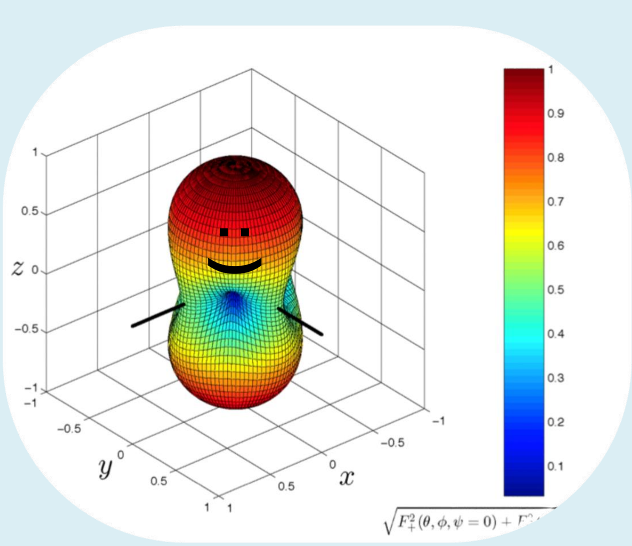
- Background & Significance
  - Time-slides performed to get noise background
  - Comparison to background → assess significance

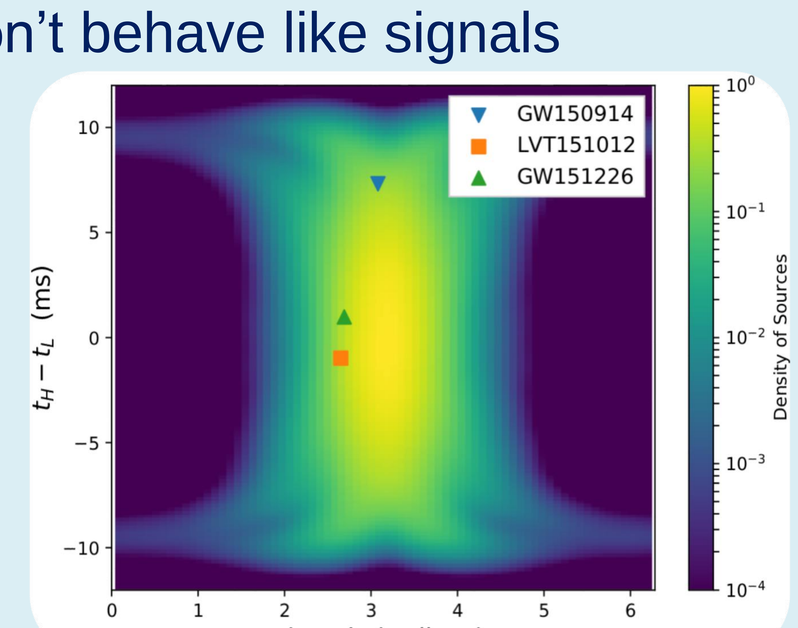
Ranking Statistic

- Method rank coincs for signal likelihood
- Optimal ranking statistic: $\log\left({}^{\mathrm{rate}_{\mathrm{signal}}}/_{\mathrm{rate}_{\mathrm{noise}}}\right)$
- Noise coinc rate estimated from individual detector trigger rates and allowed time window
- Much lower noise rates for three-ifo coincs & same signal rate → much higher rankings statistic (compared to two-ifo)
- Adjustments to rates for signal/noise consistency
- Statistics compared across coinc types for true false alarm rates

Phase-time-amplitude (P/T/A) consistency

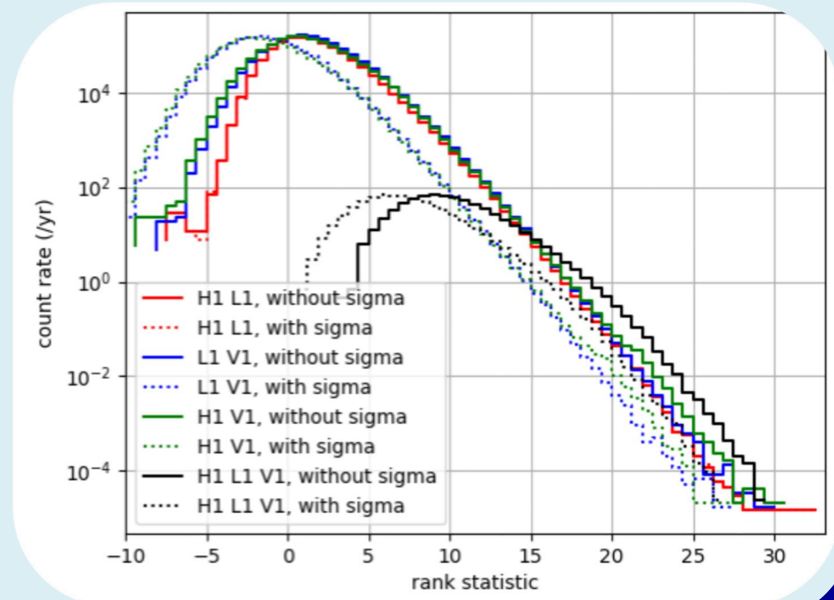
- Distributions of time- and phase-differences for coincs are different if from noise (uniform) or signals [1]
- Relative amplitudes affected by antenna patterns given direction
- Log of rates for evenly distributed, simulated signals used as priors to add to ranking statistic above
- Down-weights triggers that don't behave like signals





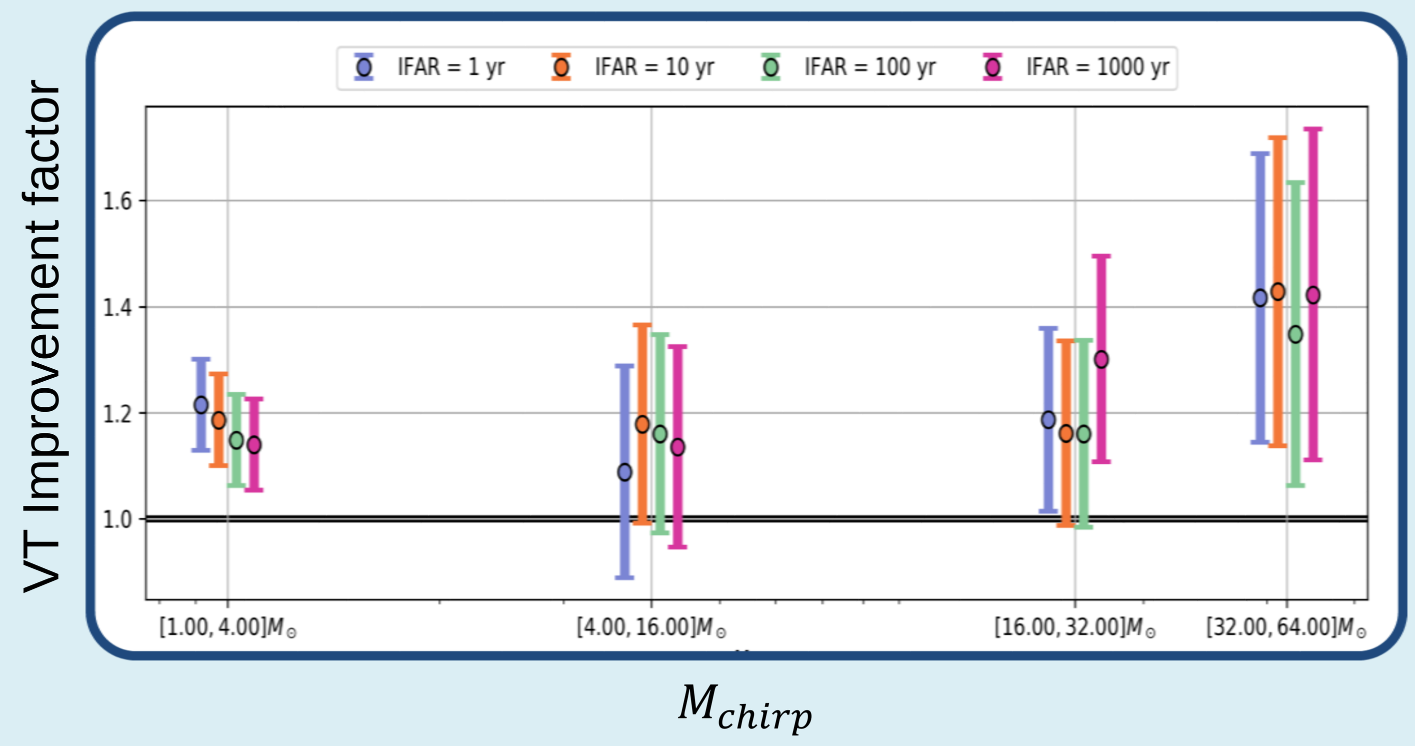
Using Network Sensitivity Information

- Each coinc made by a specific network of detectors
- Network more sensitive → more likely to detect signal → prior belief for signal increases
- Using σ^2 [2], a measure of sensitivity, for each detector in the coinc, convert to network sensitivity reweight signal rate
- Favours more sensitive times and more sensitive detector combinations



Comparison to Previous Method

- Via injections, calculate available volume×time (VT) for sources in the search
- Compare VT sensitivity between analyses
- Here compare VT of the new search in a chunk of O2 to the two-IFO search used in GWTC-1 [3]
- Some VT from extra latency → more time for coincs with 'any two from three' active detectors than requiring 'two from two'



Discussion

- VT sensitivity of search increased by factor of 1 – 1.6 (source type dependent)
- Ongoing work:
  - P/T/A consistency checks currently using two-ifo priors for three-ifo coincs, creation of three-detector priors is ongoing
  - Better fitting of background triggers for noise modelling

References

[1] Nitz et al (2017) Astrophys.J. 849 no.2, 118
[2] Allen et al (2002) Phys. Rev. D 85, 122006
[3] LIGO, Virgo et al (2018) arXiv:1811.12907