

Extending the PyCBC offline search to a many-detector network

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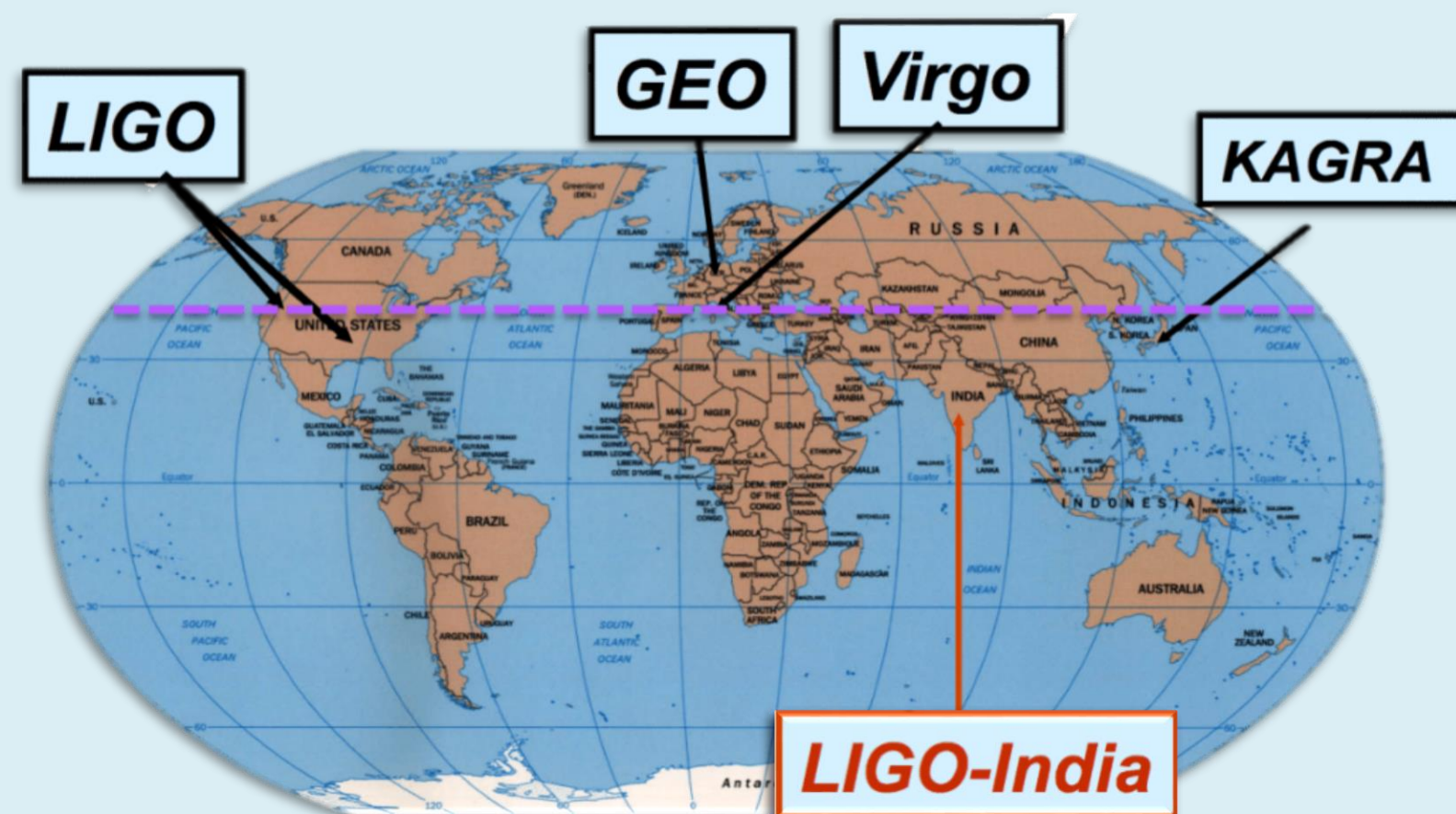
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LIGO document LIGO-G1901550

PyCBC offline currently:

- uses two detectors
- requires 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



Motivation and Summary



More detectors improves:

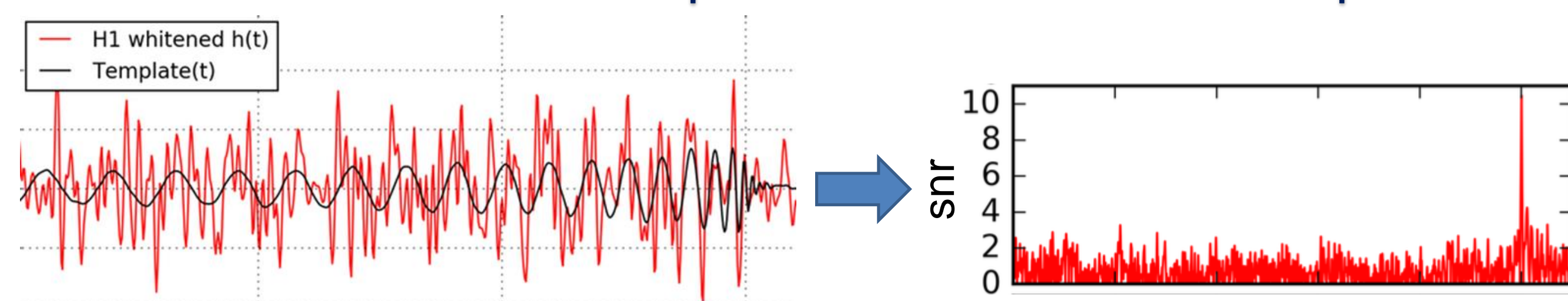
- latency
- sky localisation and coverage
- statistical confidence
- These lead to more/better detections (yay!)
- Comparison to the two-detector (two-ifo) search shows significant sensitivity improvement



PyCBC offline search: the basics

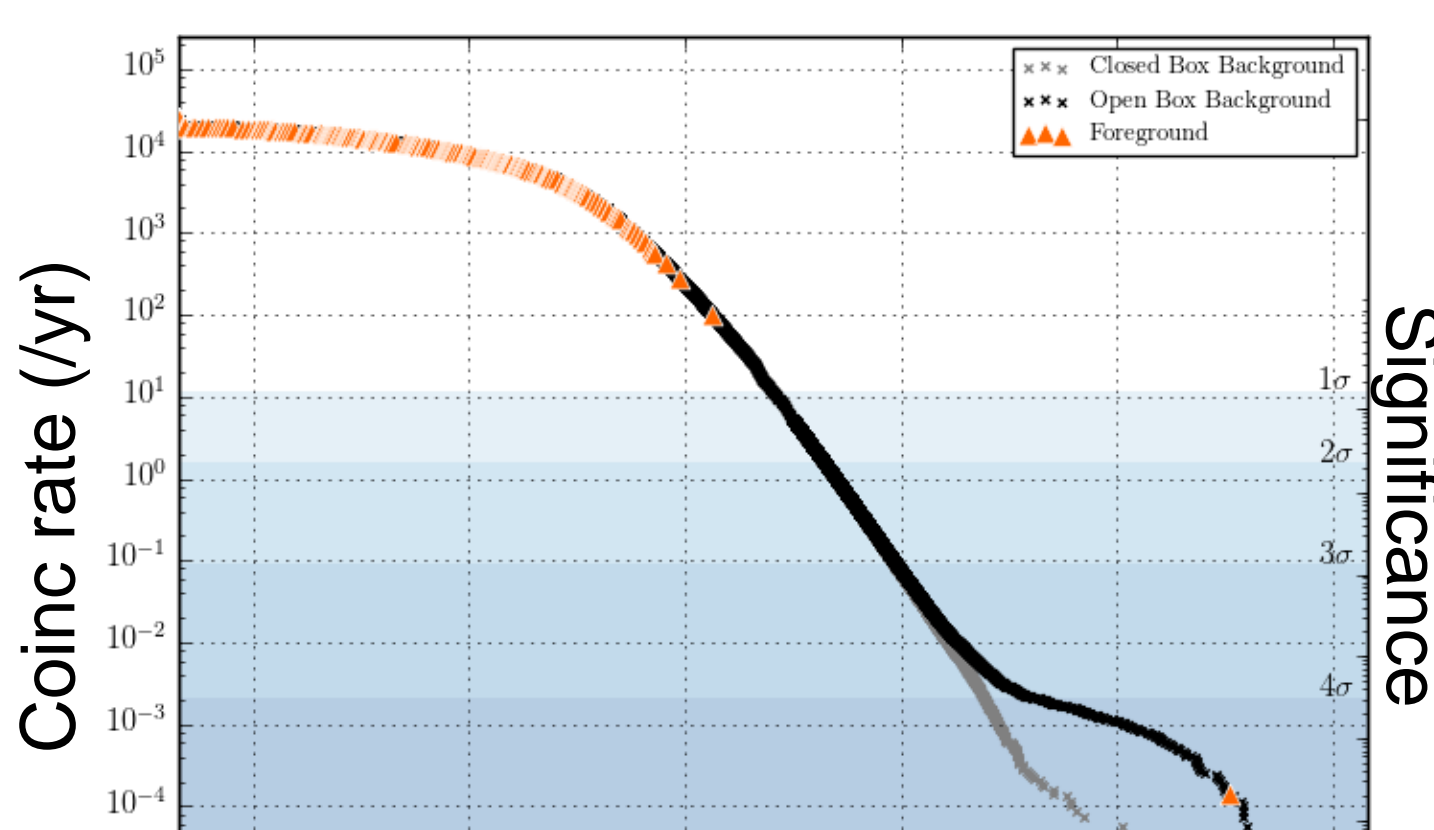
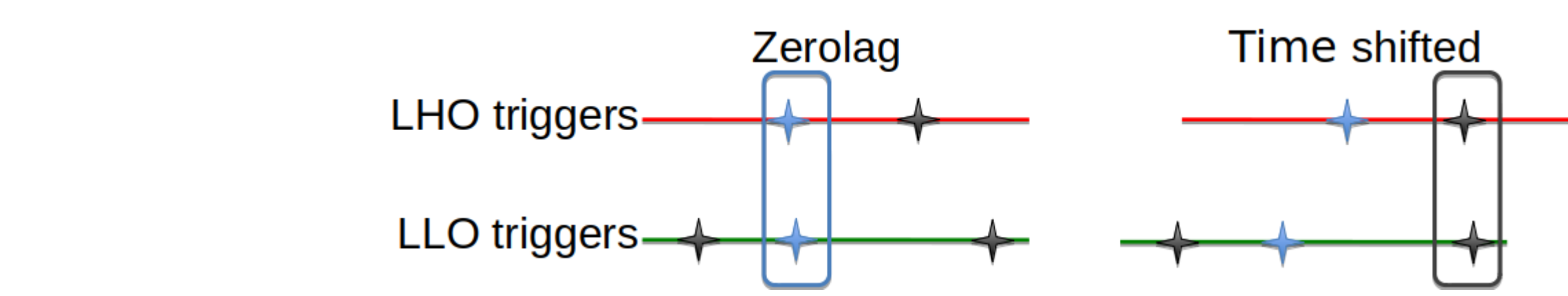
Matched Filtering

- Whitened data and templates cross-correlated to produce SNR



Coincidence (coincs)

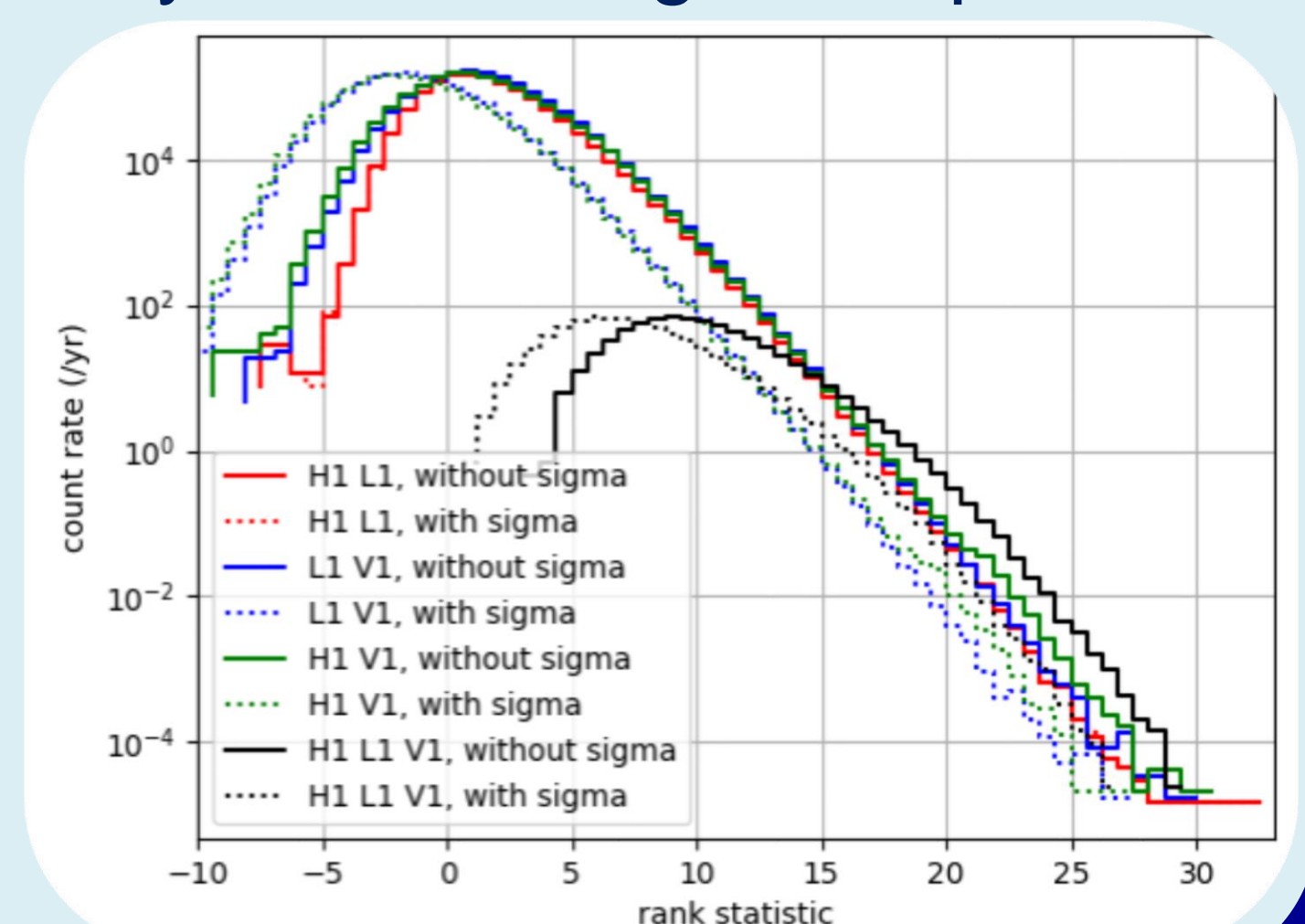
- Triggers (SNR peaks) from each detector compared to find coincidences in time (require same template)



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

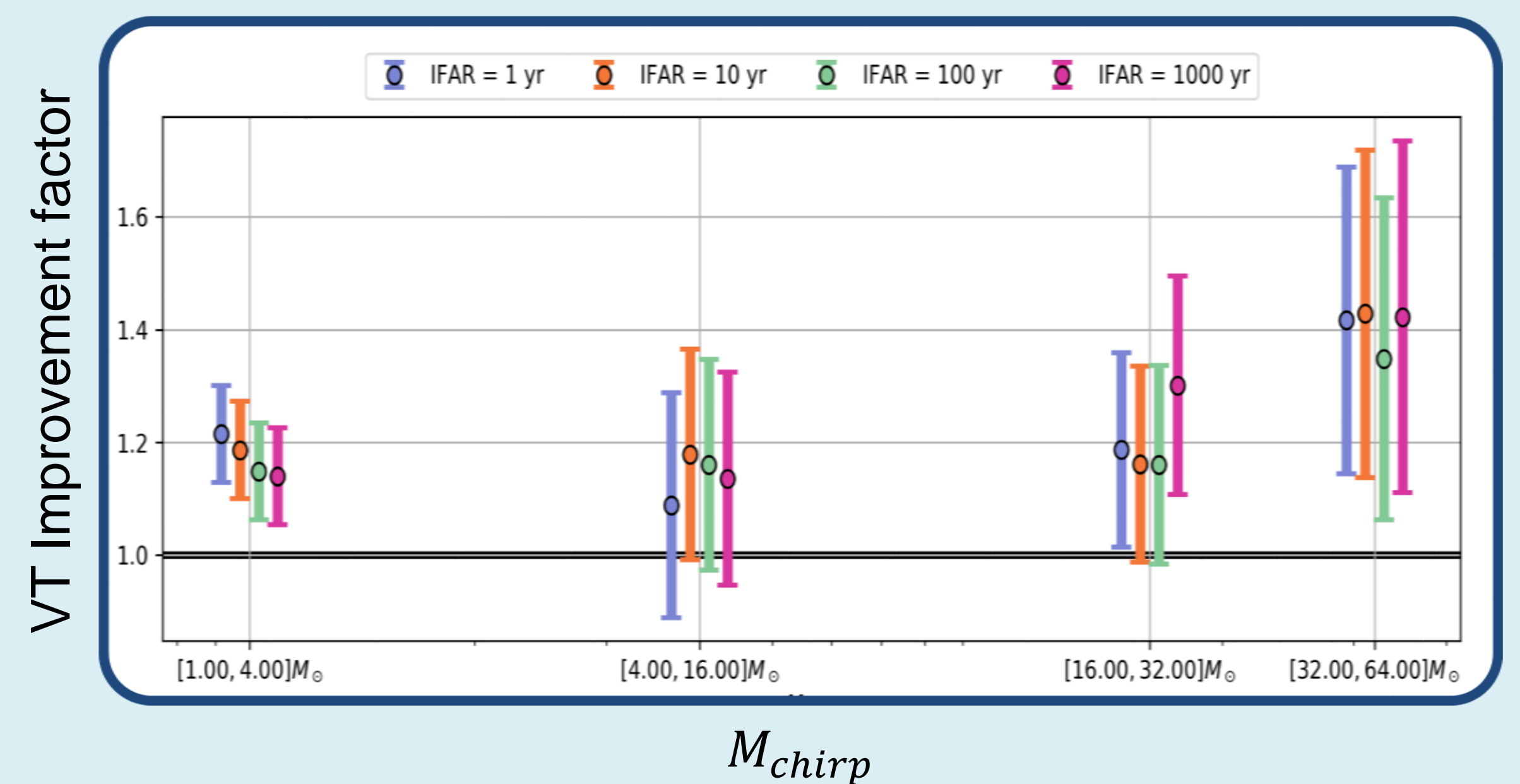
Using Network Sensitivity Information

- 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 volumetime (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 coins with 'any two from three' active detectors than requiring 'two from two'



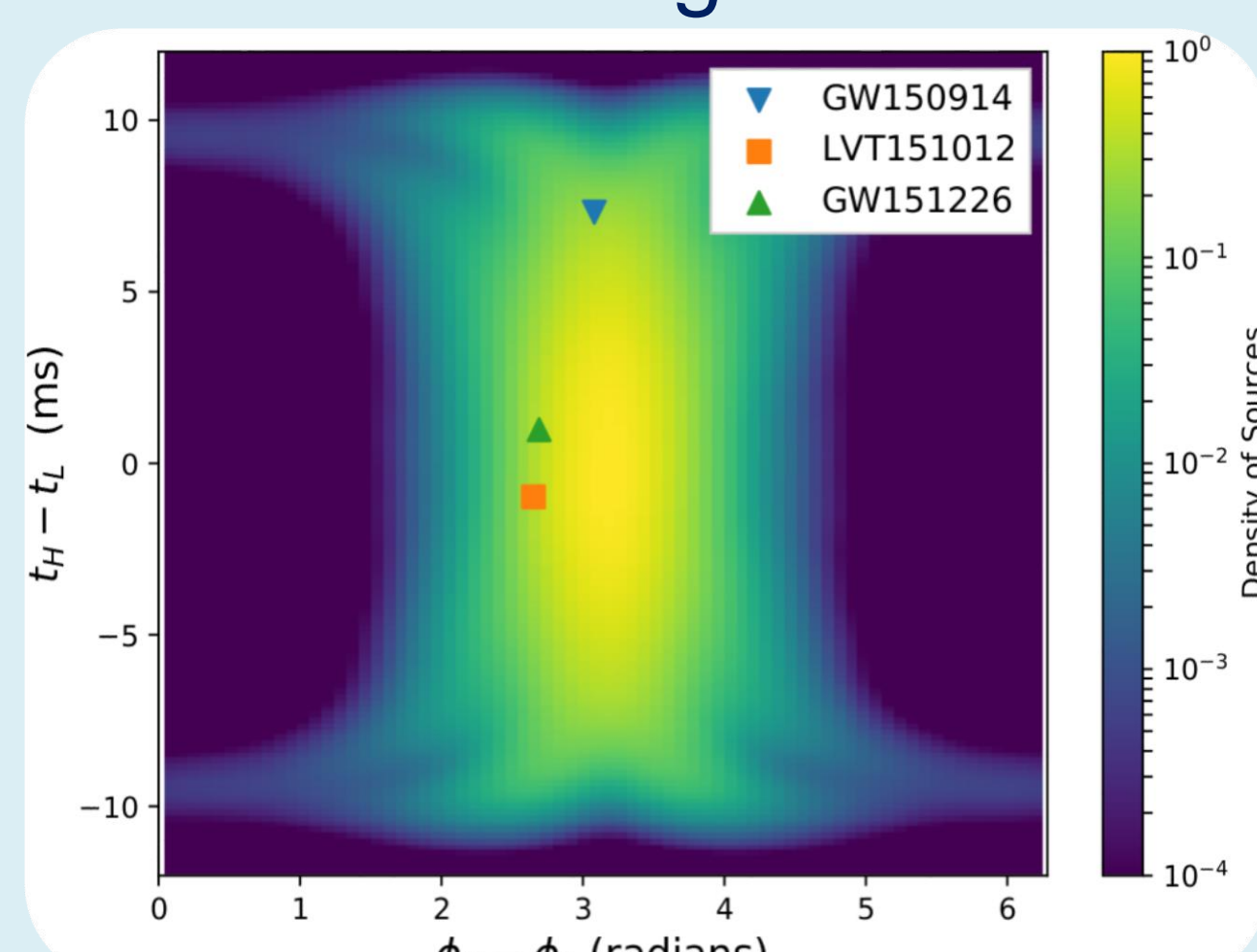
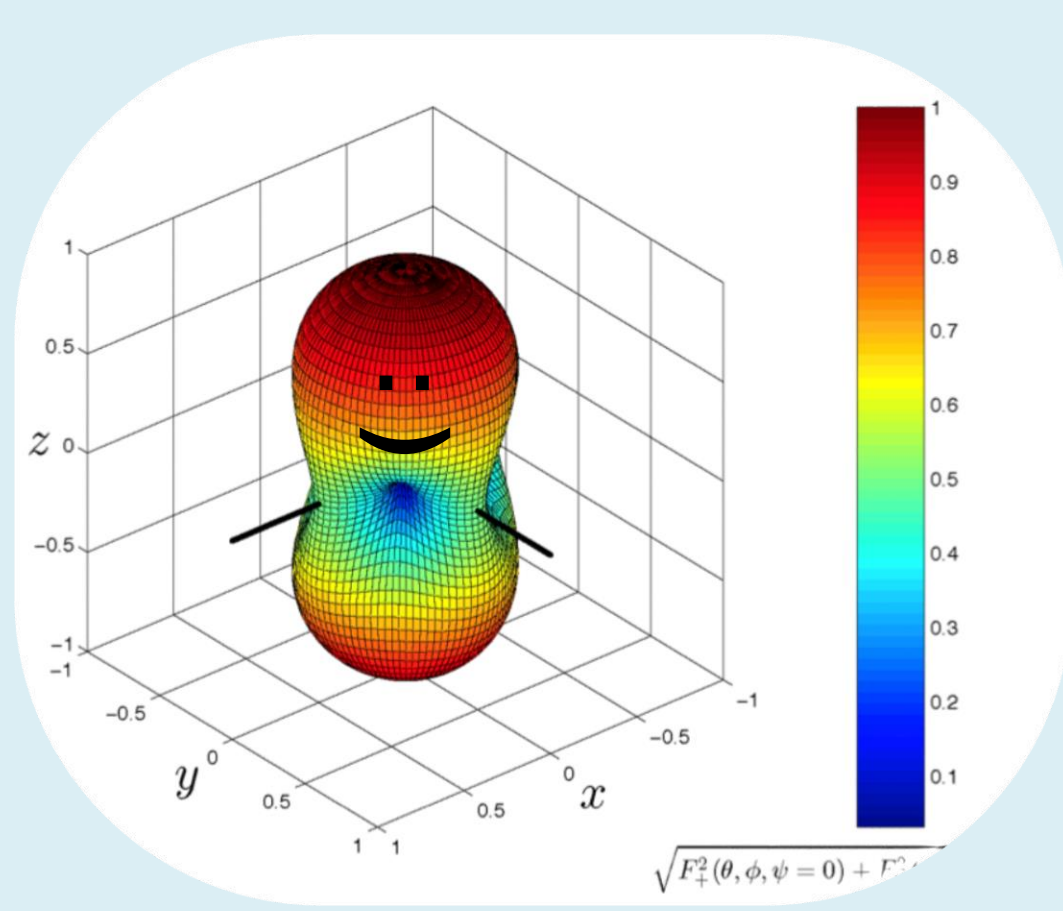
God Tier

Ranking Statistic

- Method rank coins for signal likelihood
- Optimal ranking statistic: $\log\left(\frac{\text{rate}_{\text{signal}}}{\text{rate}_{\text{noise}}}\right)$
- Noise coinc rate estimated from individual detector trigger rates and allowed time window
- Much lower noise rates for three-ifo coins & 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 coins 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



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 coins, 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 65, 122006
- [3] LIGO, Virgo et al (2018) arXiv:1811.12907

