PyCBC Live

A real-time search for compact binary mergers in the advanced detector era

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in collaboration with

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3e réunion d'animation annuelle

GdR ondes gravitationnelles

Groupe de travail “analyses de données”

30 Nov 2020

PyCBC

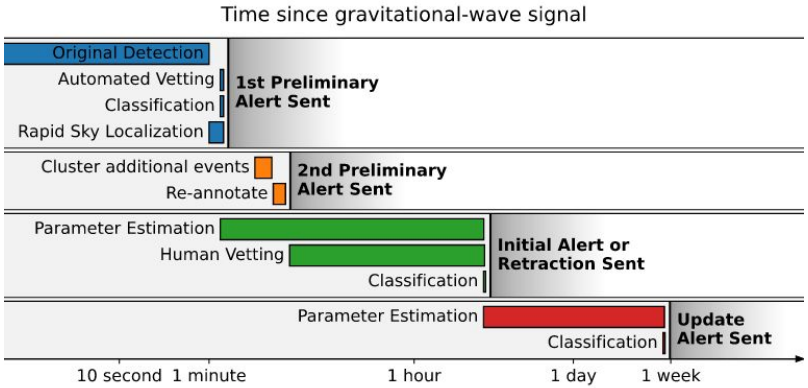
Groupement de recherche
Ondes gravitationnelles

cnrs IN2P3
Les deux infinis

Low-latency analyses of ground-based detector data

- Astrophysics
  - Rapid discovery and characterization of transients
  - Plan and start observations in other sectors
  - Examples: GW170817, GW190521

- Detector characterization
  - See what the detector is doing on an hourly time scale
  - Identify and react to problems as soon as possible
  - Maximize the amount of “good” data for later (archival) analyses
  - Improve the detectors for future runs



https://emfollow.docs.ligo.org

- Searches targeting generic transients
  - Coherent WaveBurst
- Searches targeting compact binary mergers
  - GstLAL, MBTA, **PyCBC Live**, SPIIR

Realtime frequency-domain matched filtering

Signal-to-noise ratio time series

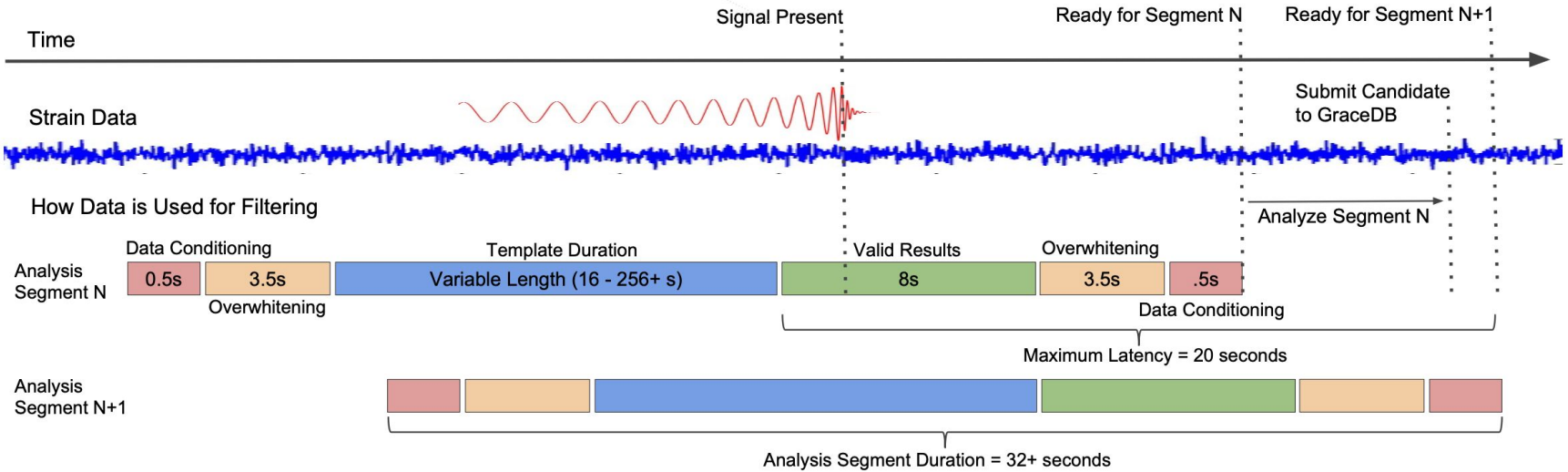
$$\rho^2(t) = \frac{4}{\langle h|h\rangle}\int_0^\infty \frac{\tilde{s}(f)\tilde{h}^*(f)}{S_n(f)} e^{2\pi i f t} df$$

Data

Template waveform

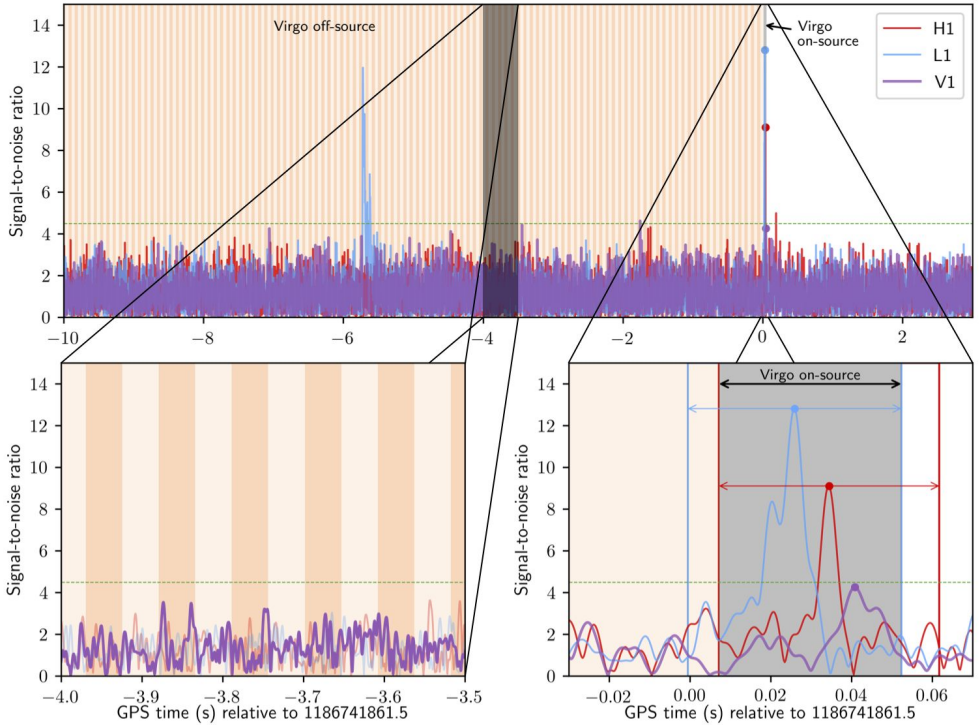
Noise power spectral density

→ Threshold and find local maxima → Candidates



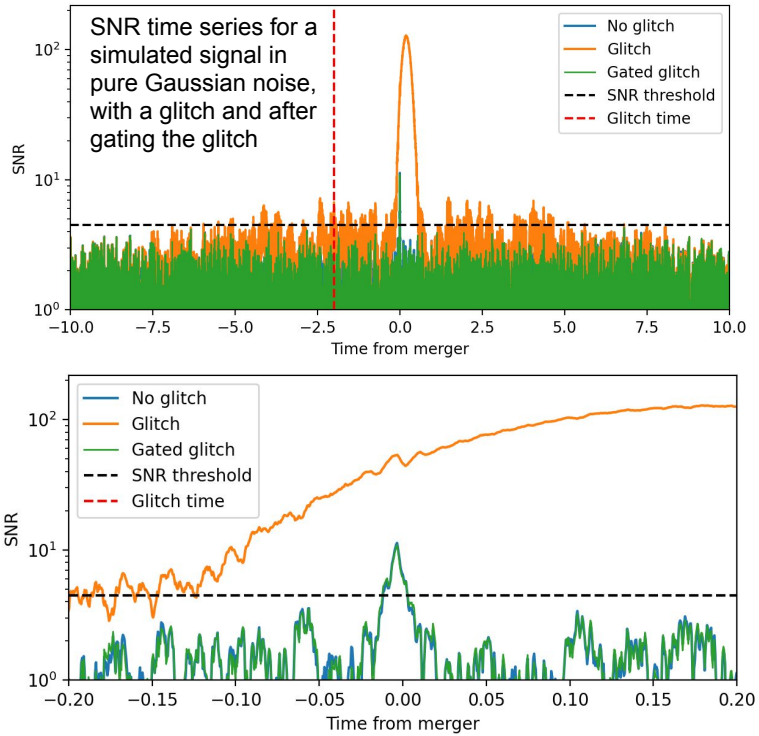
Coincidence and multi-detector significance

1. Perform matched filtering and generate single-detector candidates
2. Find two-detector coincidences, calculate FARs via time slides
3. Choose most significant coincidence
4. Followup with remaining detectors, update FAR



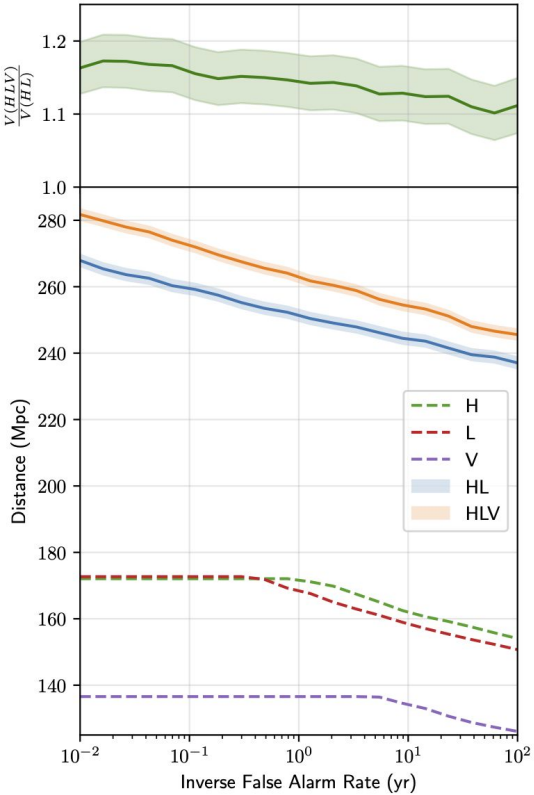
Impact and mitigation of instrumental transients

- Increased rate of non-GW candidates
  - Signal-based vetoes to down-rank the candidates
  - Astrophysical prior for the relative arrival times, phases and amplitudes at the different detectors
- Corruption of signals
  - “Gating” – replace transient with zeroes



Sensitivity to binary neutron star mergers

1. Simulate a population of BNS mergers
2. Simulate detector noise at design sensitivity
3. Add signals to noise
4. Process with PyCBC Live
5. Count how many signals are detected
    a. By each detector individually
    b. When only LIGO Hanford and LIGO Livingston observe
    c. When LIGO and Virgo observe together



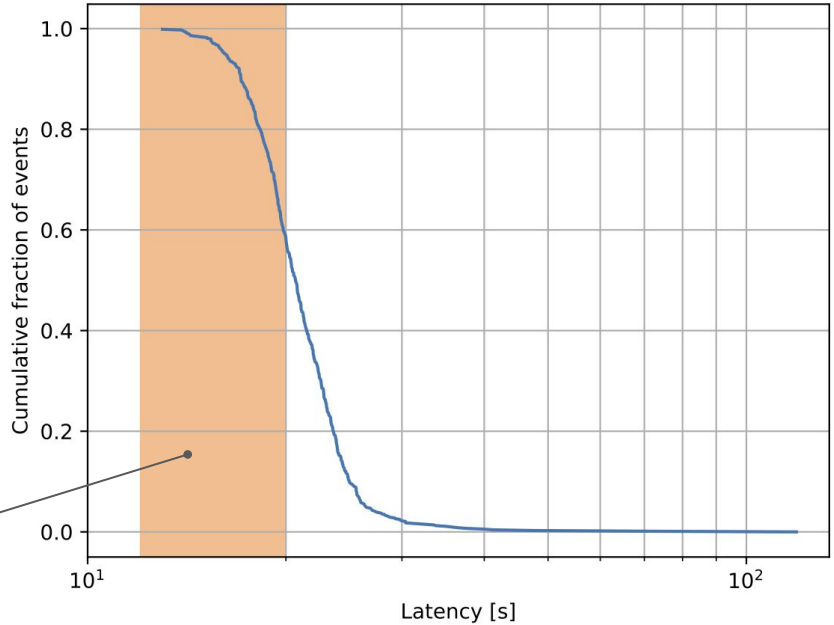
Merger latency measurement

merger latency = T_{DB} - T_{merger}

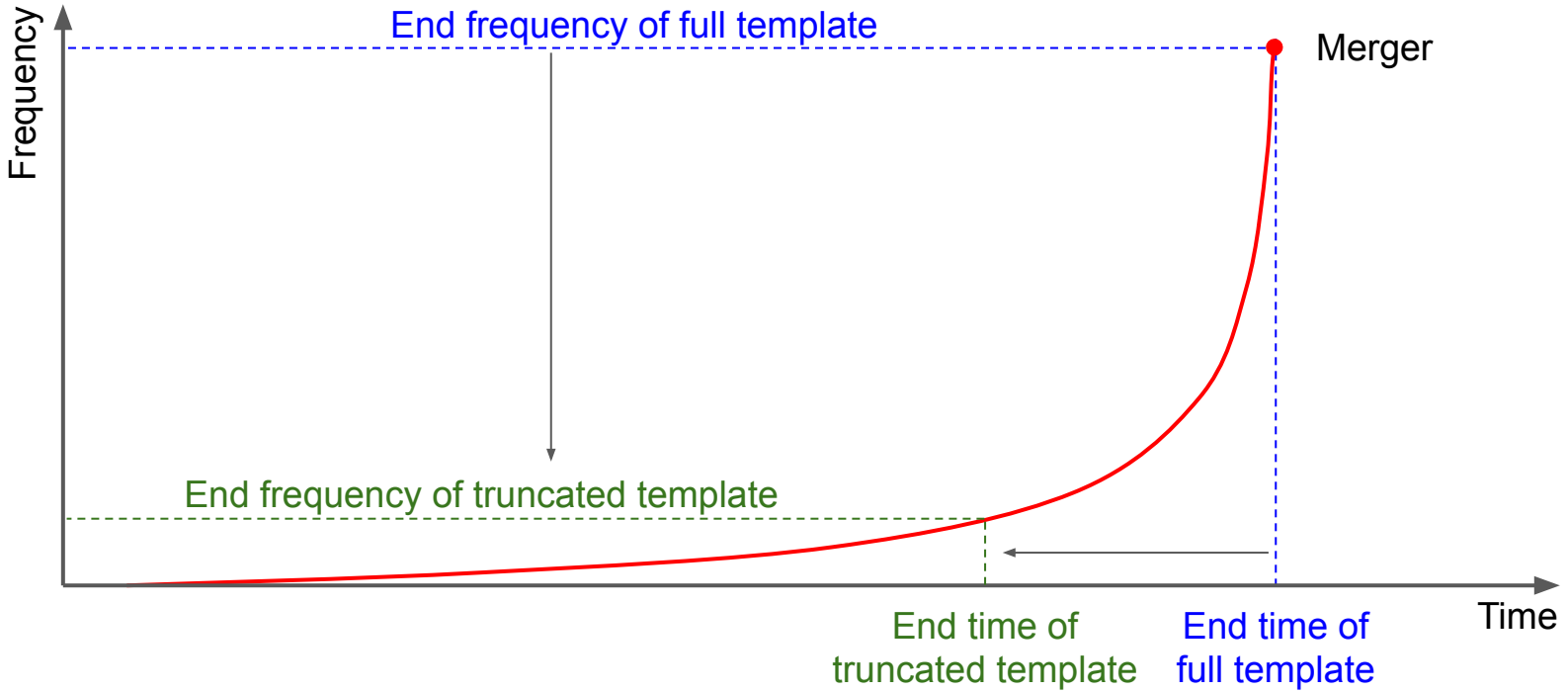
Time of candidate upload to GraceDB

Time of merger estimated by search

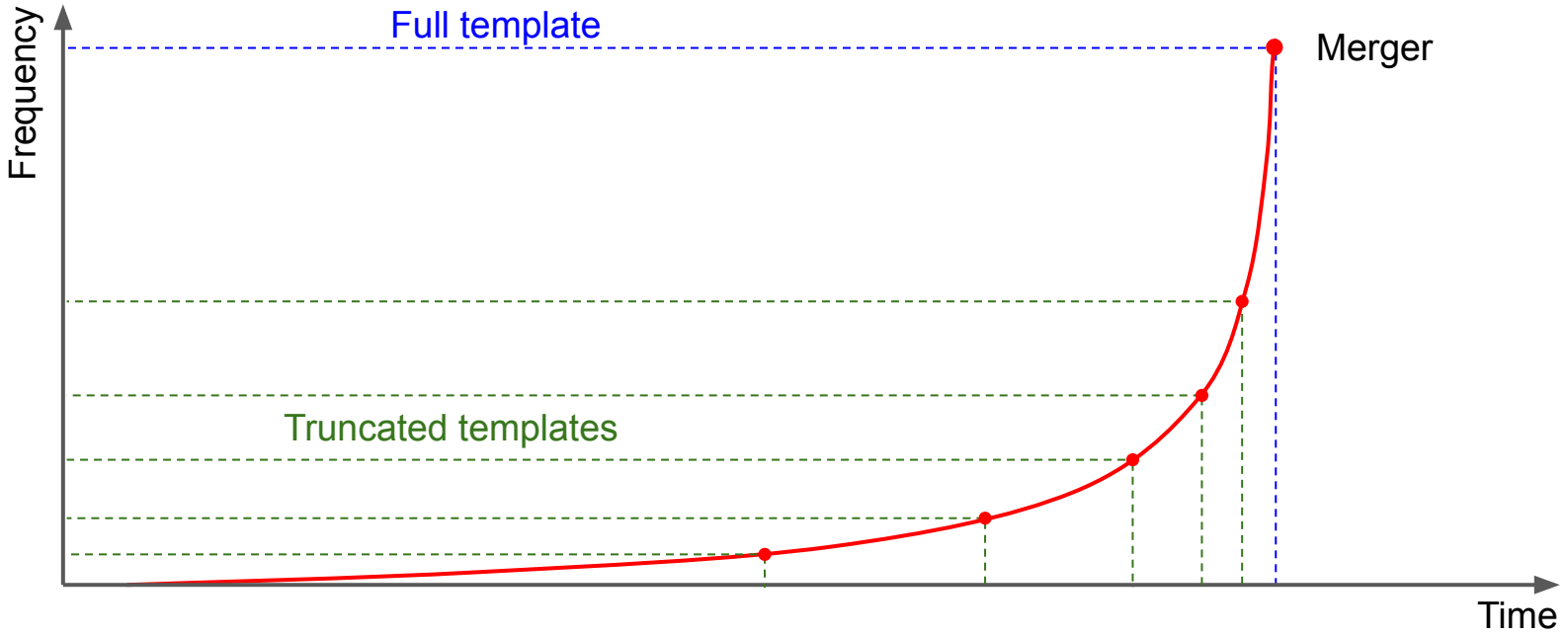
Expected latency due to the analysis (excluding generation and delivery of data)



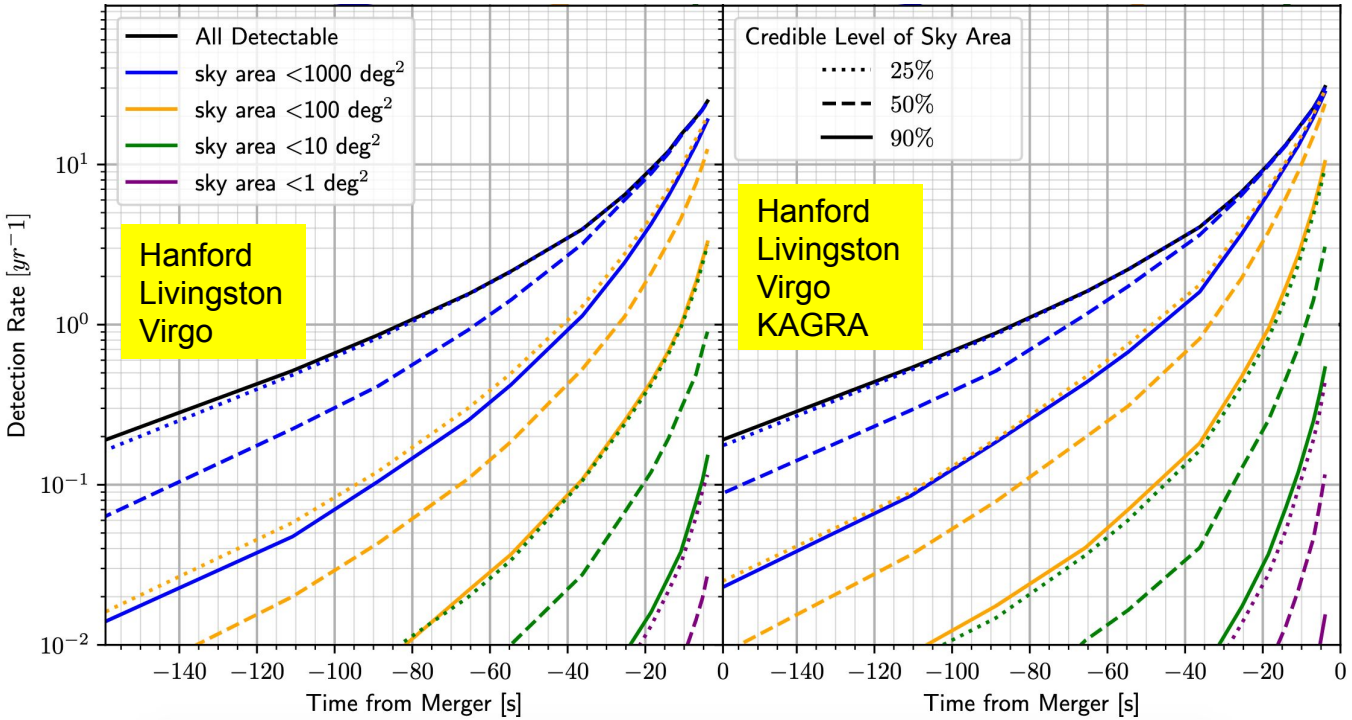
Premerger detection of binary neutron stars



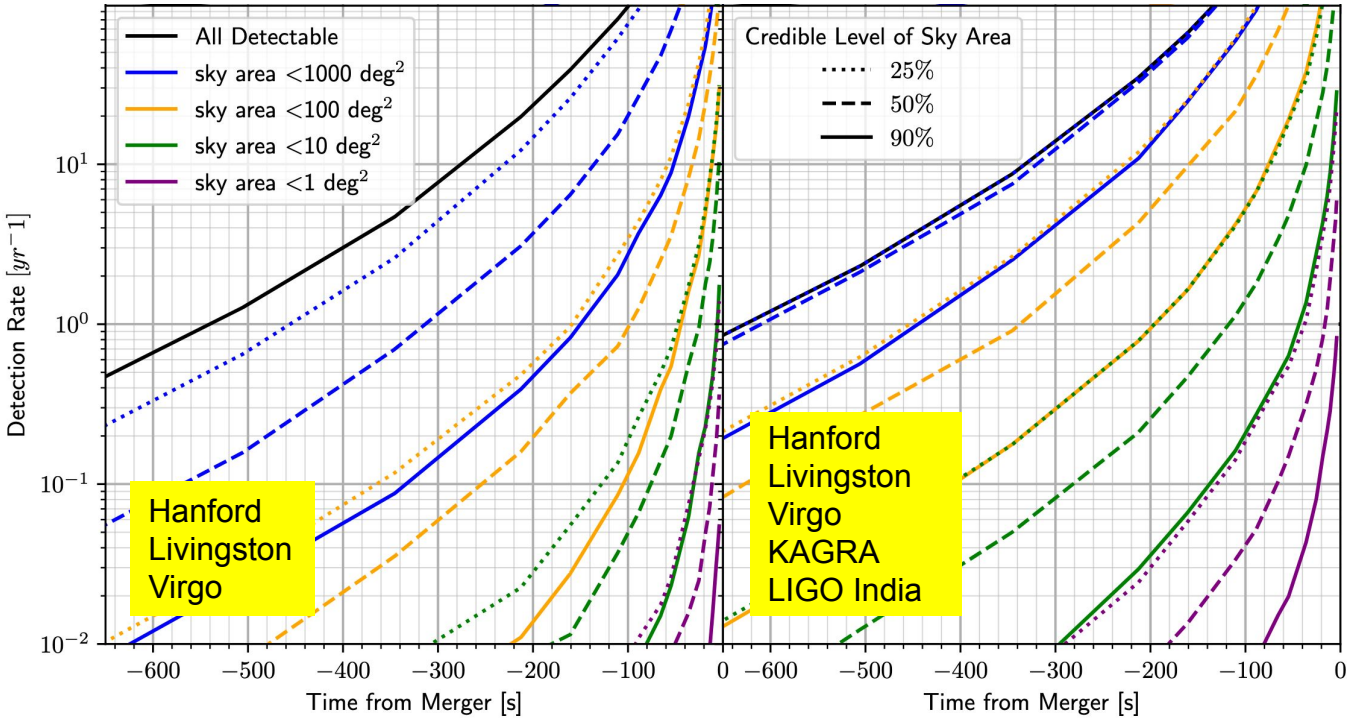
Premerger detection of binary neutron stars



Prospects for premerger detection – “design” era



Prospects for premerger detection – “Voyager” era



Conclusion and links

- Important component of public alerts and data-quality monitoring in O3
  - First search to produce an alert for GW190521
  - Only a single alert was retracted
- Open development on GitHub
  - https://**github.com/gwastro/pycbc**/blob/master/examples/live/run.sh
- Publications
  - Nitz et al 2018 – arXiv:1805.11174
  - Dal Canton et al 2020 – arXiv:2008.07494
  - Nitz et al 2020 – arXiv:2009.04439

Thank you!