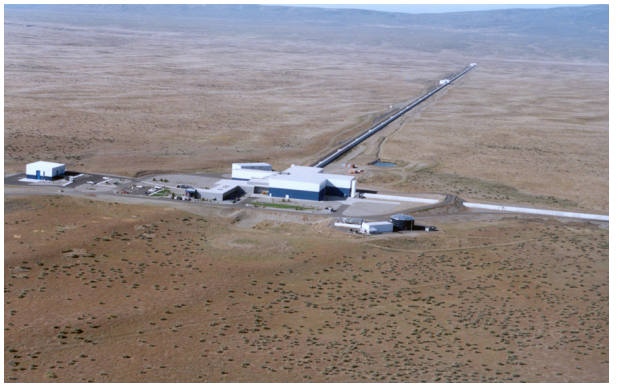
LIGO-Virgo status : O3 observing run & beyond



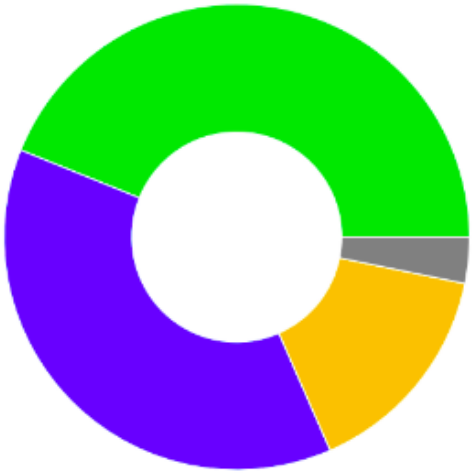


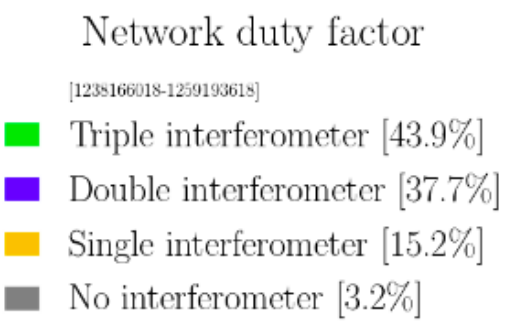
TS2020- III, 25-26 september 2019, IAP Paris

Marie Anne Bizouard, ARTEMIS CNSR/OCA, Nice

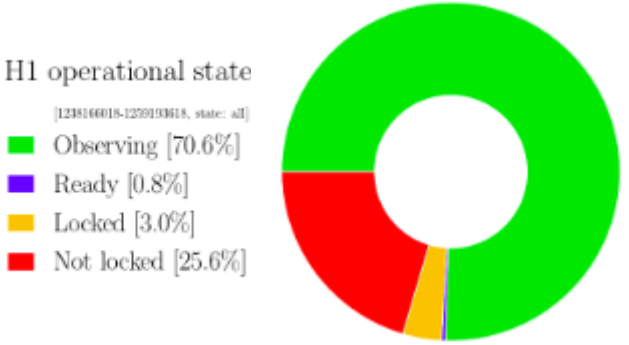
on behalf of the LIGO Scientific Collaboration and the Virgo Collaboration

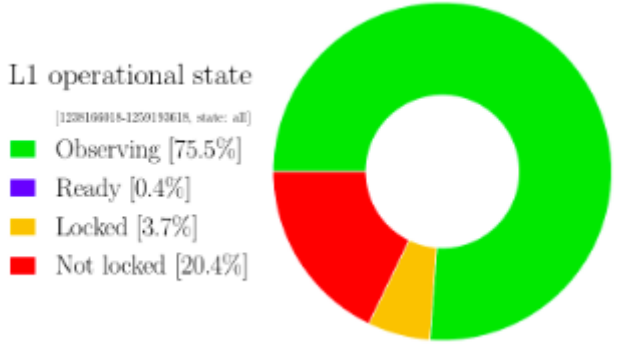
Detector Performance: O3 cumulative duty factor

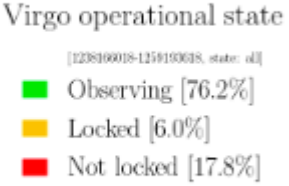




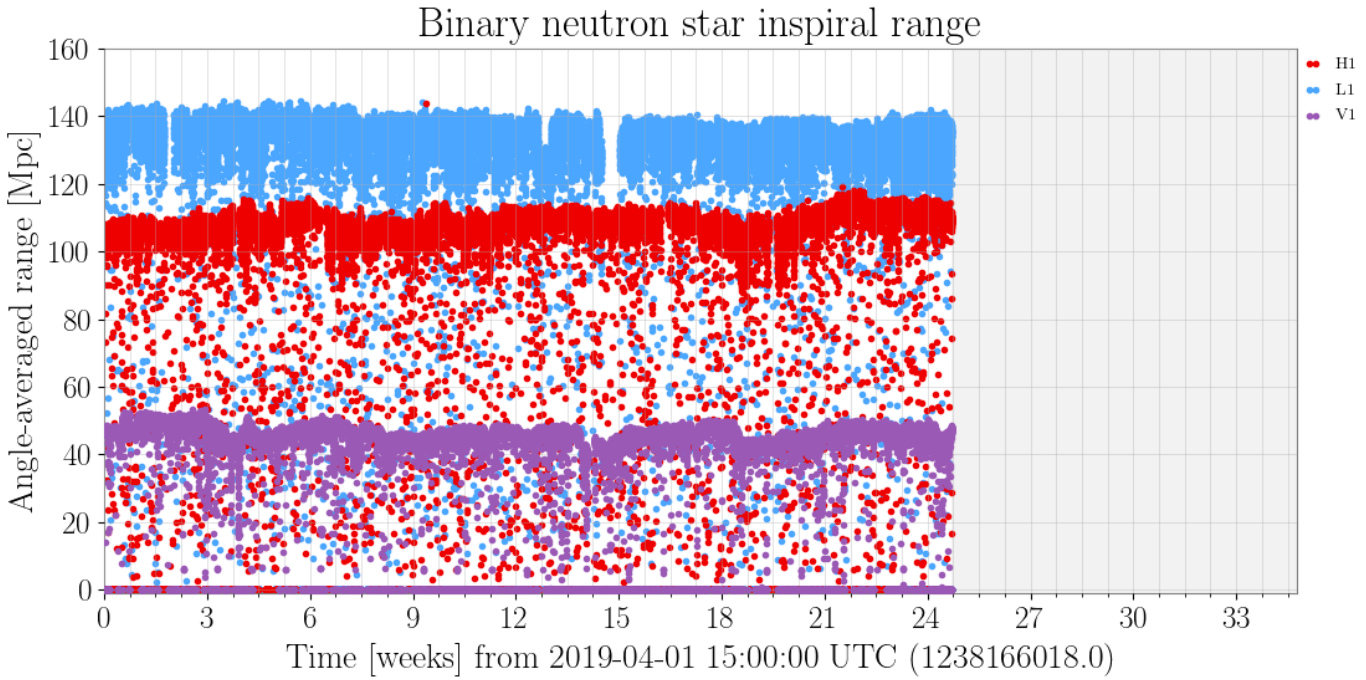
- Individual ifo ~ 75 % duty cycle
  - → Triple coincidence : 44 %
  - → Double coincidence : 80 %
- No ifo coverage : ~3 %

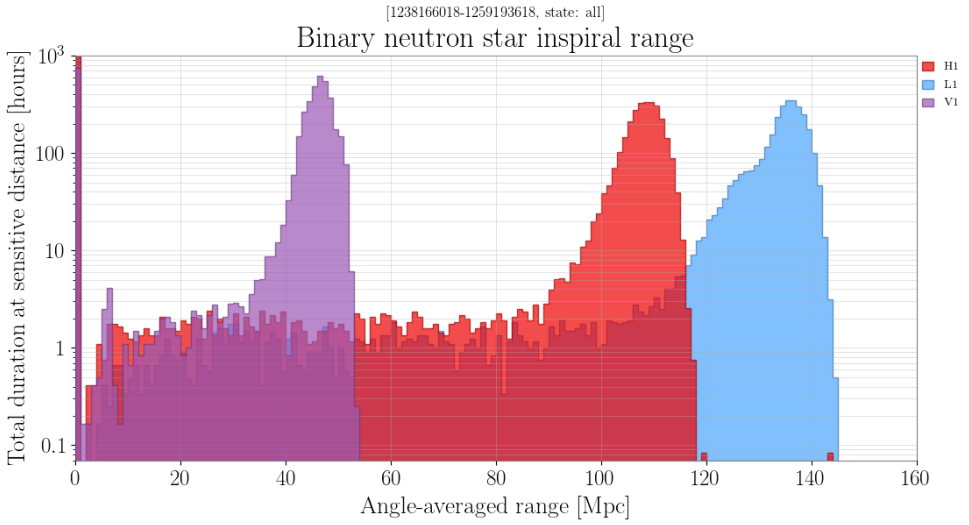


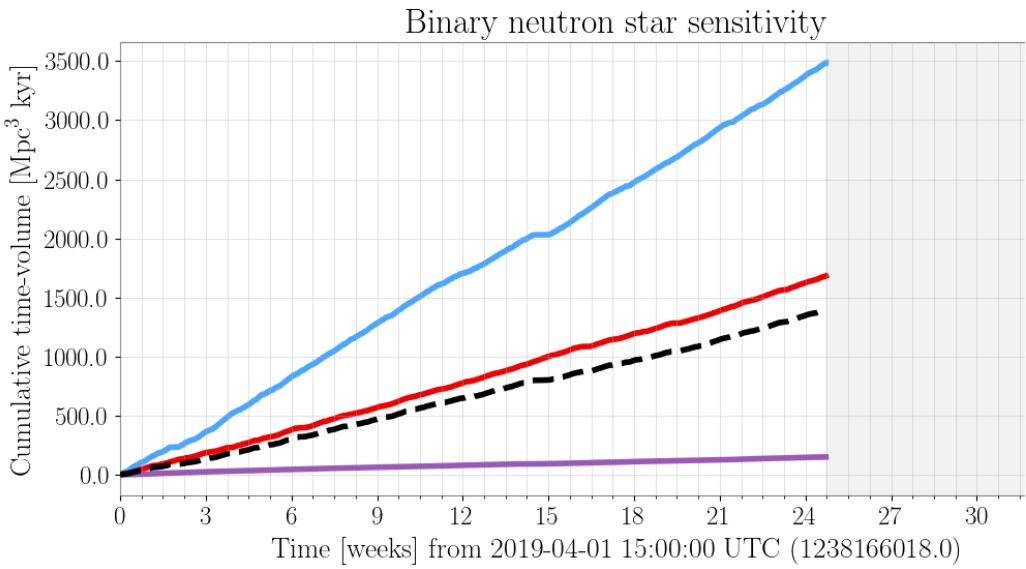




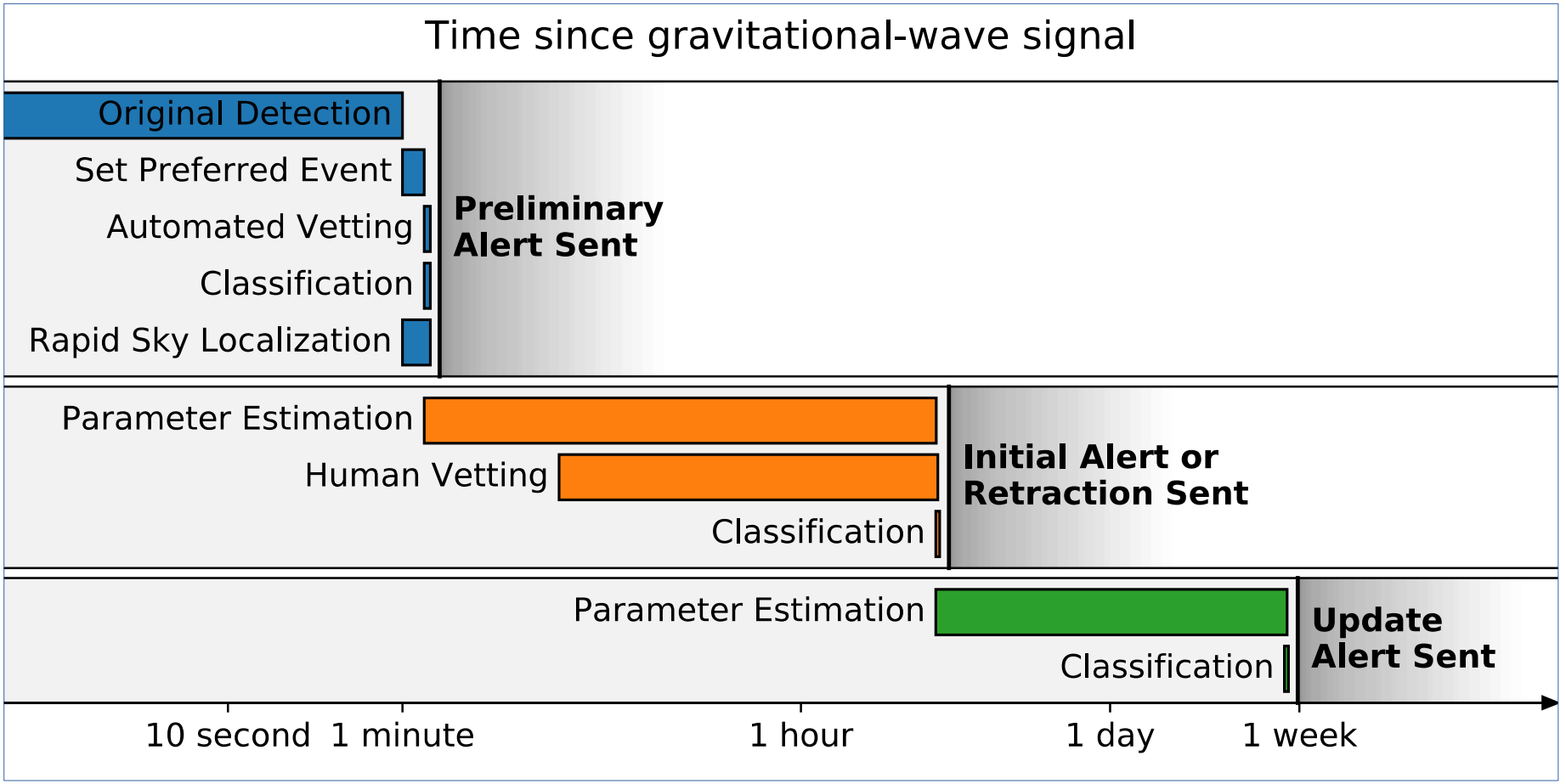
Detector Performance: BNS range







Automatic alerts during O3



Full documentation : https://emfollow.docs.ligo.org/userguide/

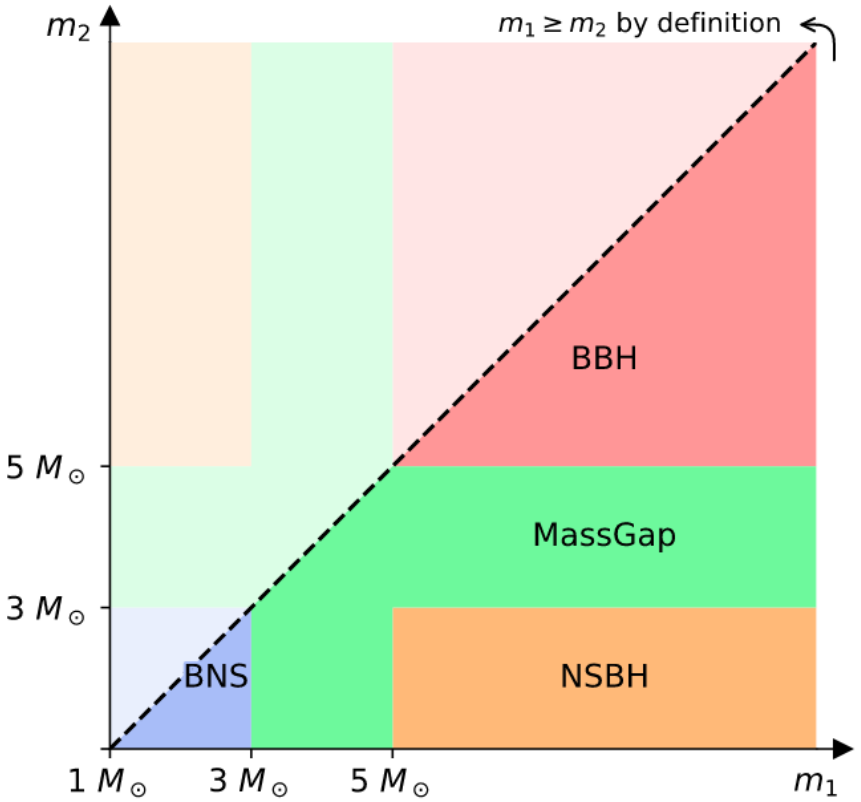
Alerts generation

- Several pipelines, each can make several detections
- Based on a given criteria, one is chosen as being the **Prefered Event** for the public alert (criteria depends on the type of search).

Modeled searches	Unmodeled searches
GSTLAL	cWB
MBTA	OLIB/BW (follow-up of cWB triggers)
PyCBC	
SPIIR	

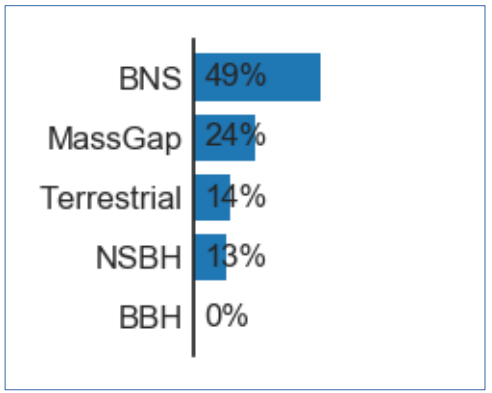
Detection FAR :
- CBC : 1 event / 2 months
- Burst : 1 event / year

Alerts classification



Classification categories :

- BNS merger
- NSBH merger
- BBH merger
- MassGap merger
- Terrestrial (glitch)



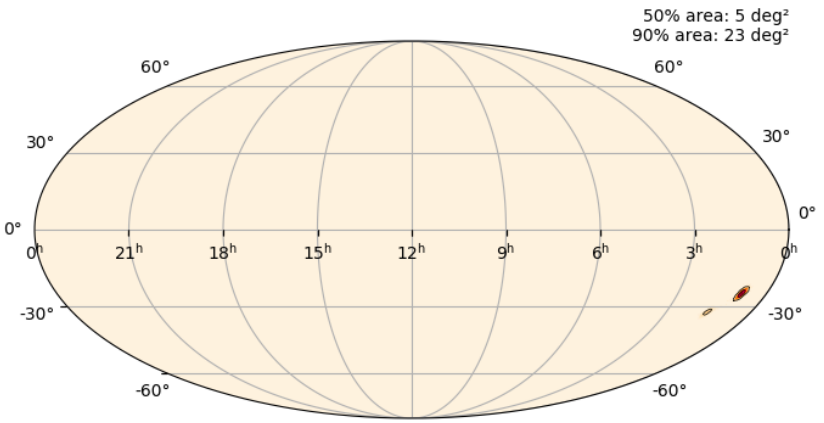
Properties :

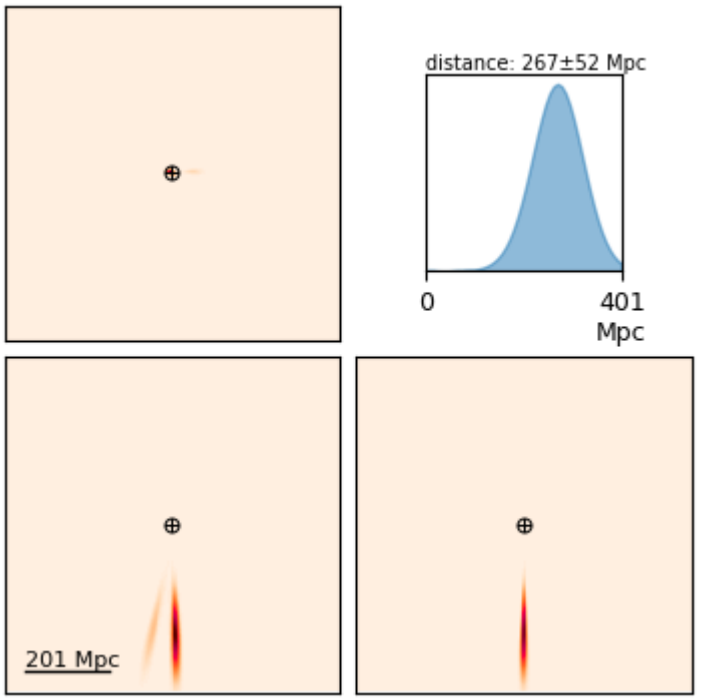
- HasNS
- HasRemnant (GRB, kilonova, ...)

  - Classification takes into consideration prior knowledge of astrophysical compact binary merger rates from previous LIGO/Virgo observations
  - Classification and Properties depend on details of neutron star physics (e.g. maximum NS mass, equation of state).

Alerts information

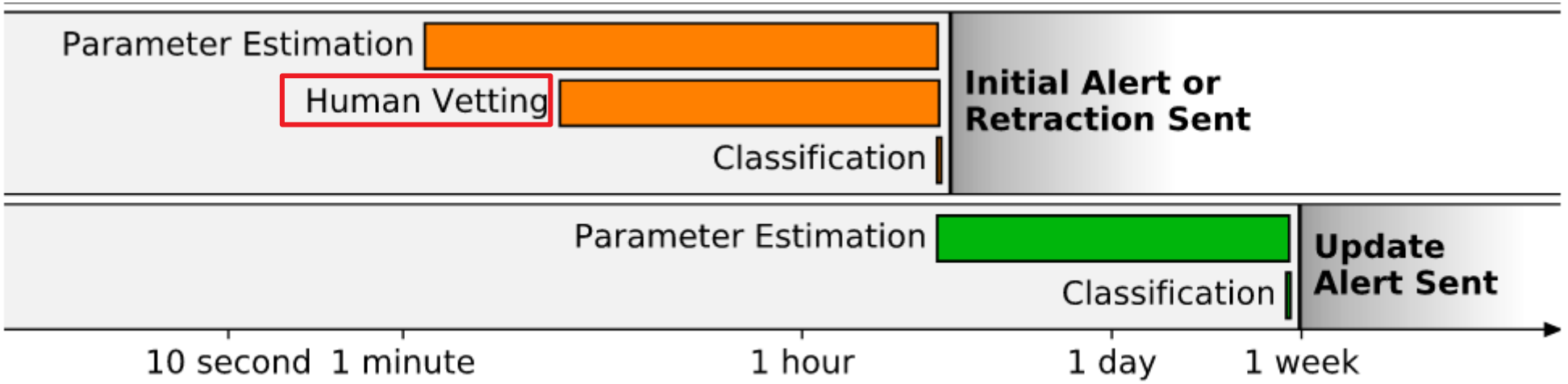
Rapid 3D Bayesian sky localization based on the trigger's matched filter time series in each detector.



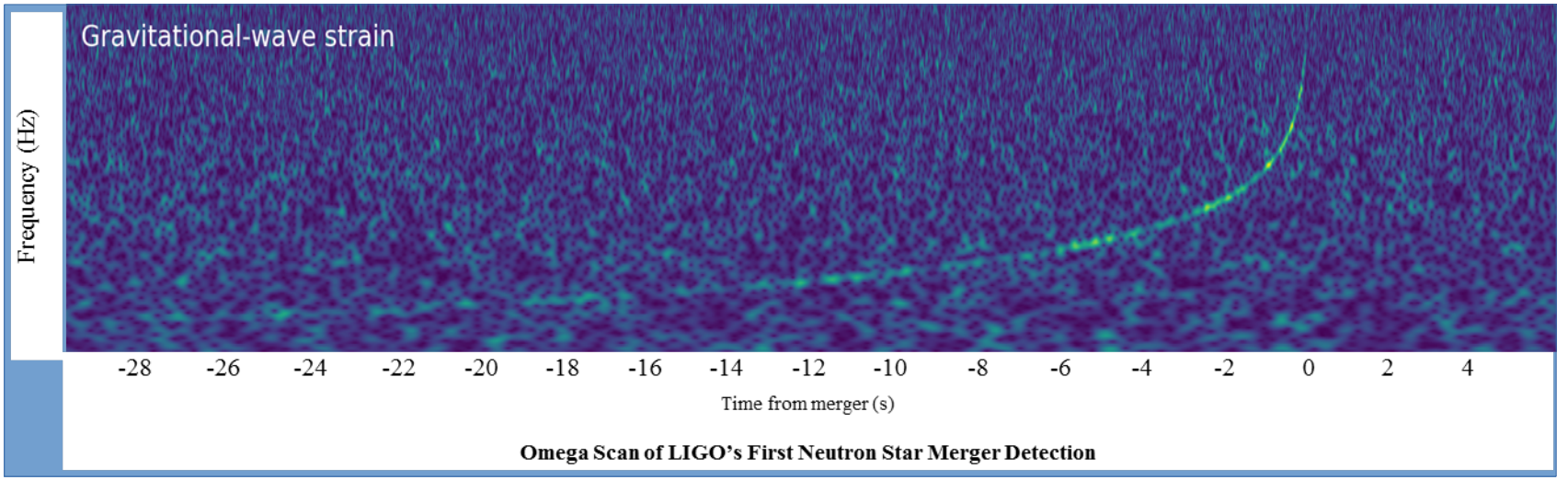


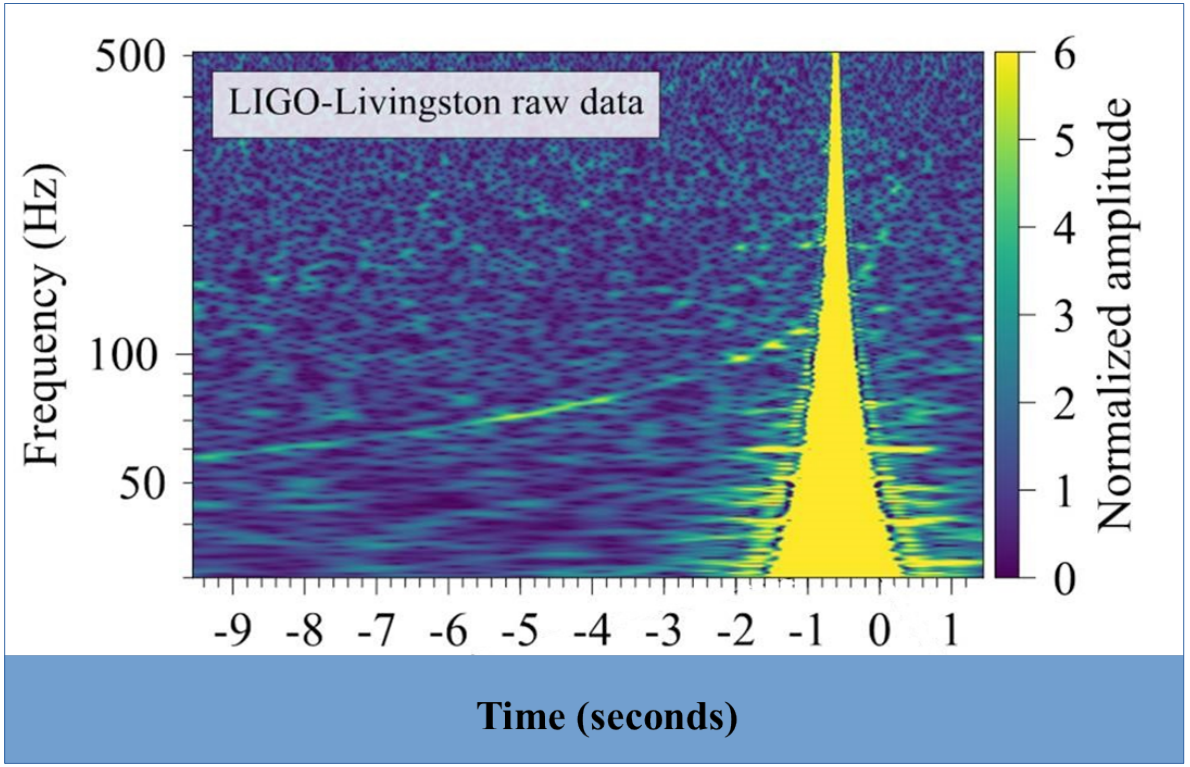
S190814bv (NSBH)

Alerts human vetting



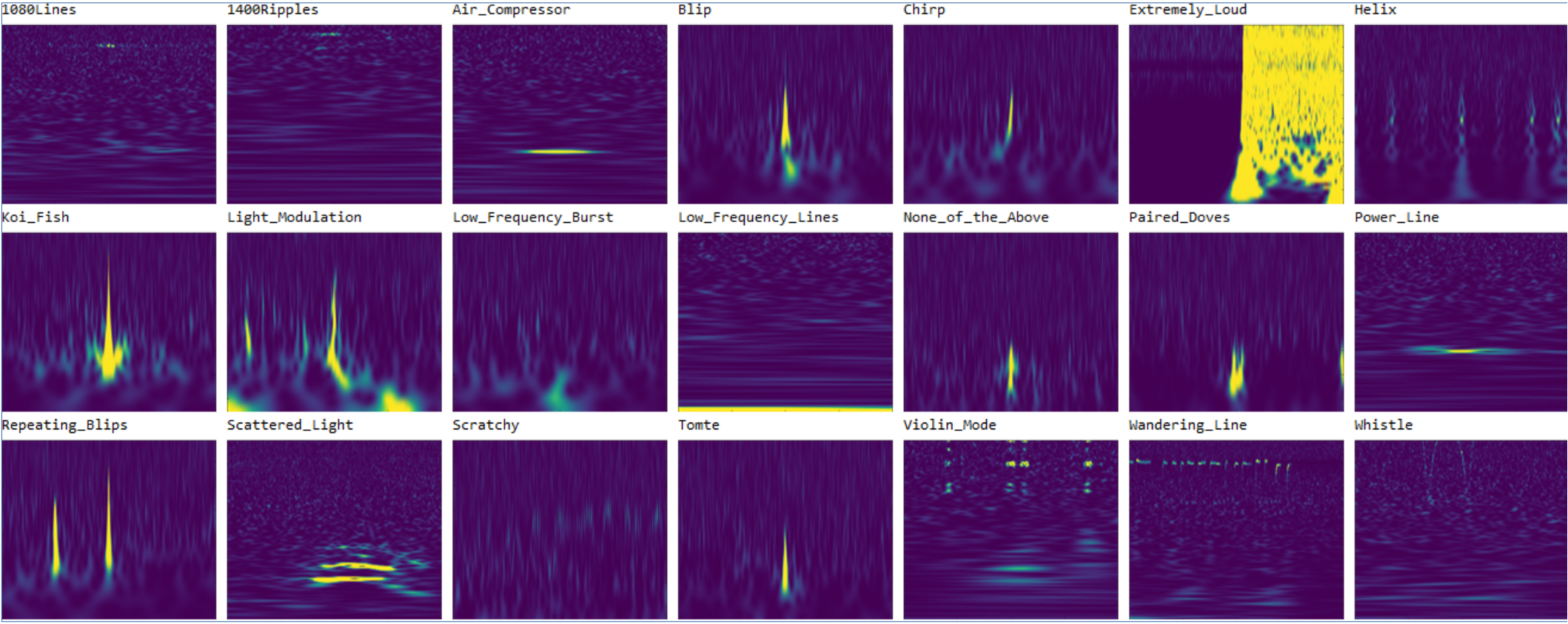
Alerts and glitches



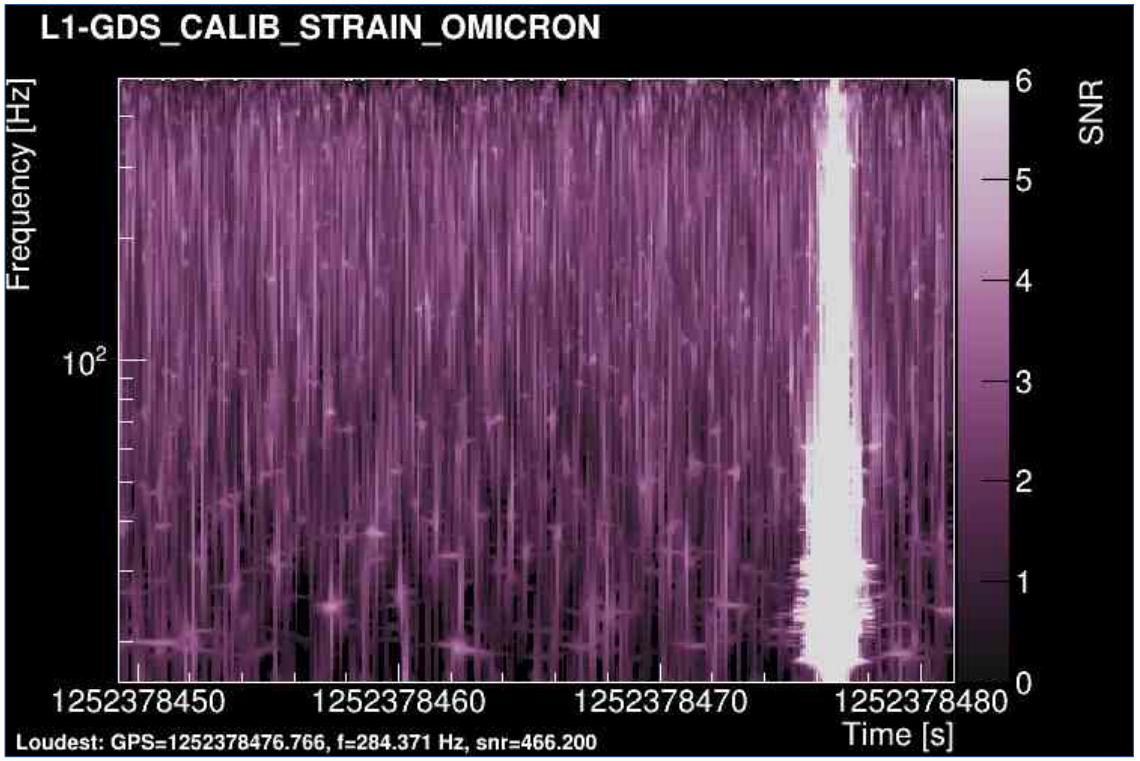


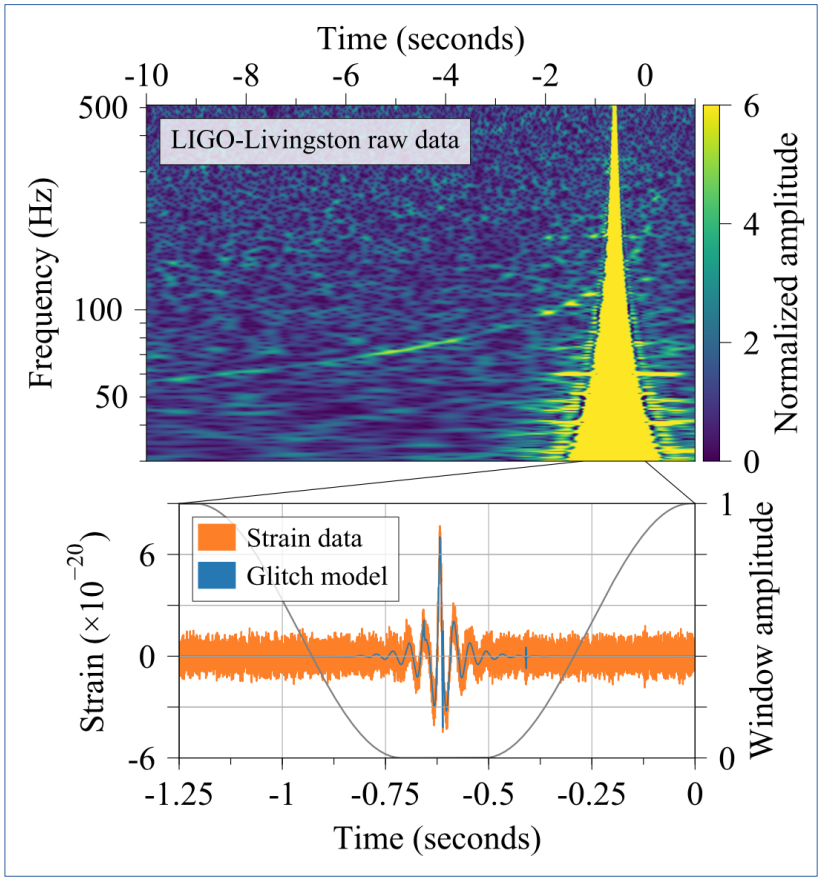
Human vetting versus glitches

Anyone can help characterizing glitches at Gravity Spy
(collaborative: provide training for IA)



Human vetting versus glitches

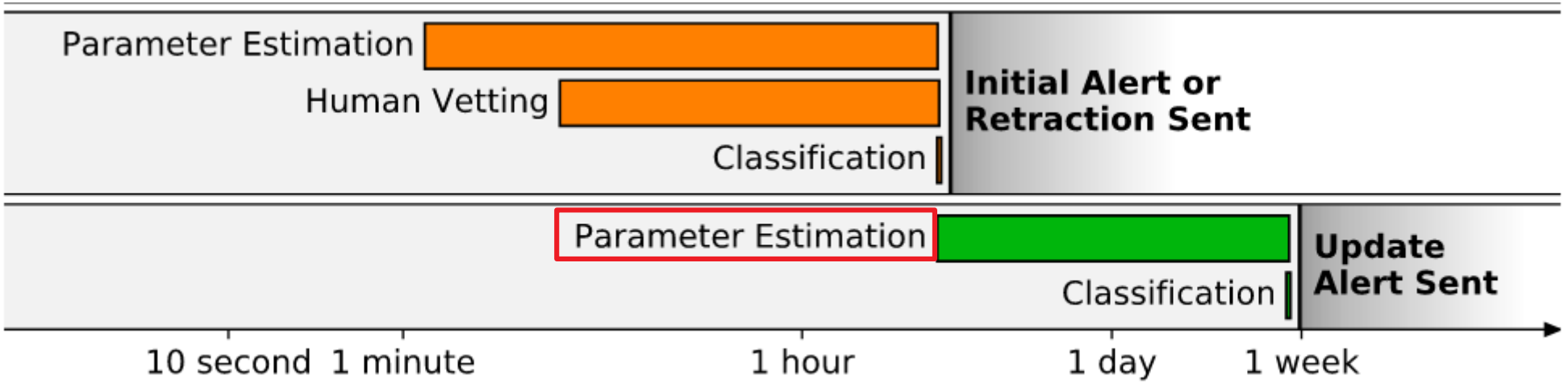




Human vetting to estimate if a glitch

- may mimic a GW candidate → alert retractation
- may biais the candidate properties → alert update

Parameter estimation



Parameter estimation

Bayesian parameter estimation

Markov Chain Monte Carlo (MCMC) or Nested sampling

15 parameters:

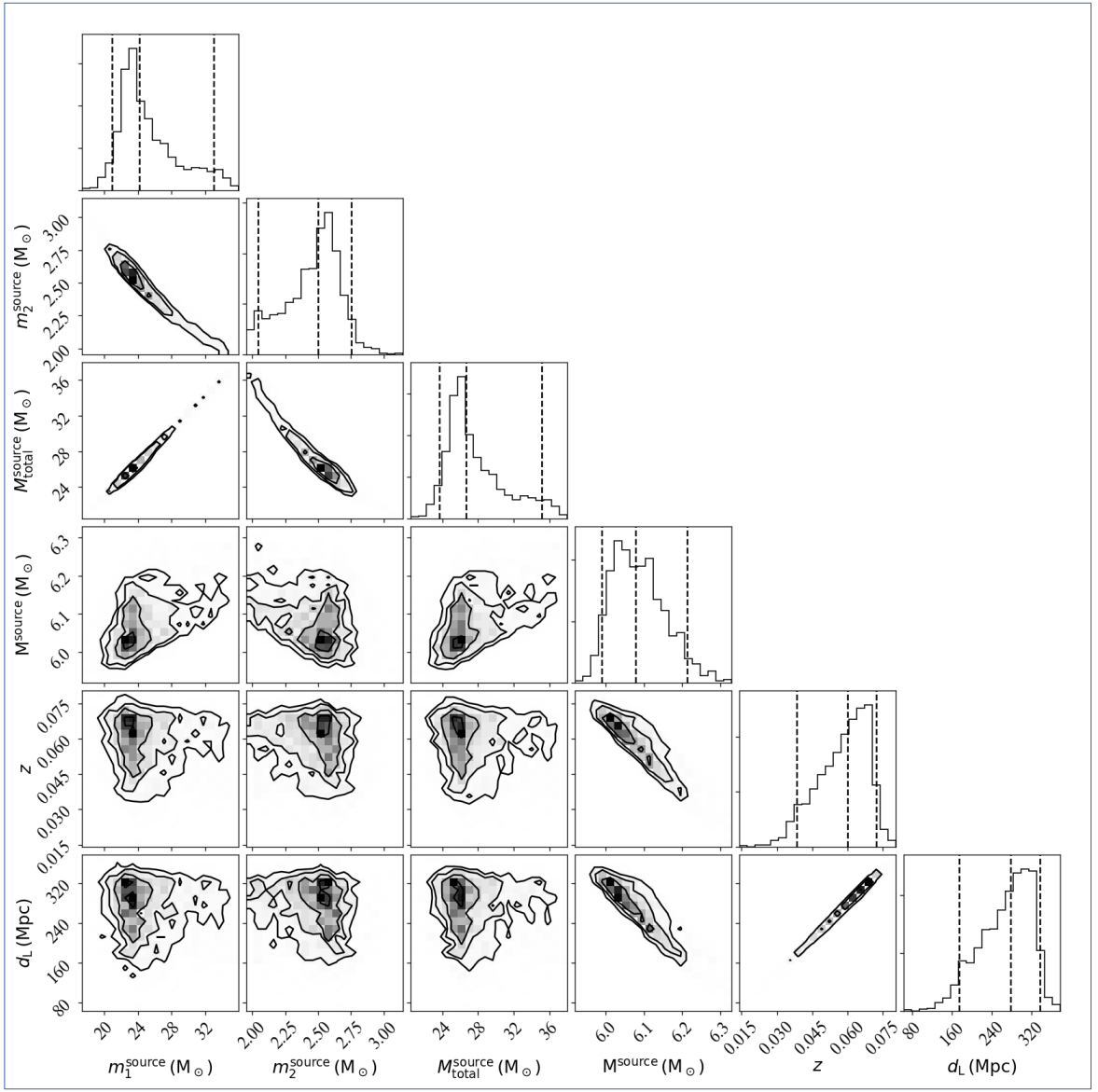
- 2 masses
- Luminosity distance
- Right ascension & declination
- Inclination angle
- Polarization angle
- Reference time
- Orbital phase at reference time
- 2 spin magnitudes
- Two angles for each spin

Several models (under permanent improvement):

- Frequency domain
  - Post-Newtonian waveform
  - Phenomenological calibrated to numerical relativity
- Time domain
  - Post-Newtonian waveform
  - Effective One Body (EOB) → inspiral-merger-ringdown

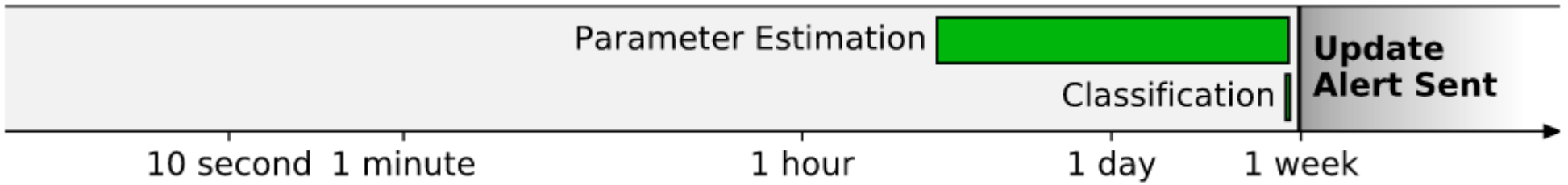
With several EOS models for BNS and NSBH

Parameter estimation

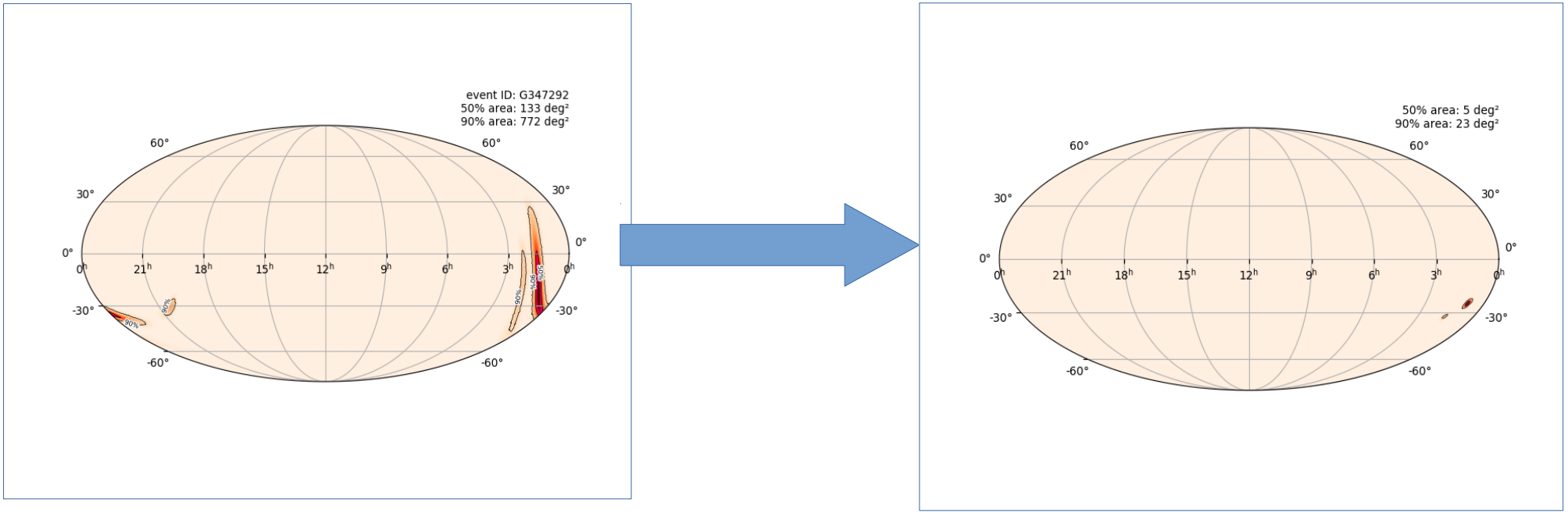


Alerts update

If better skymap and/or classification → update



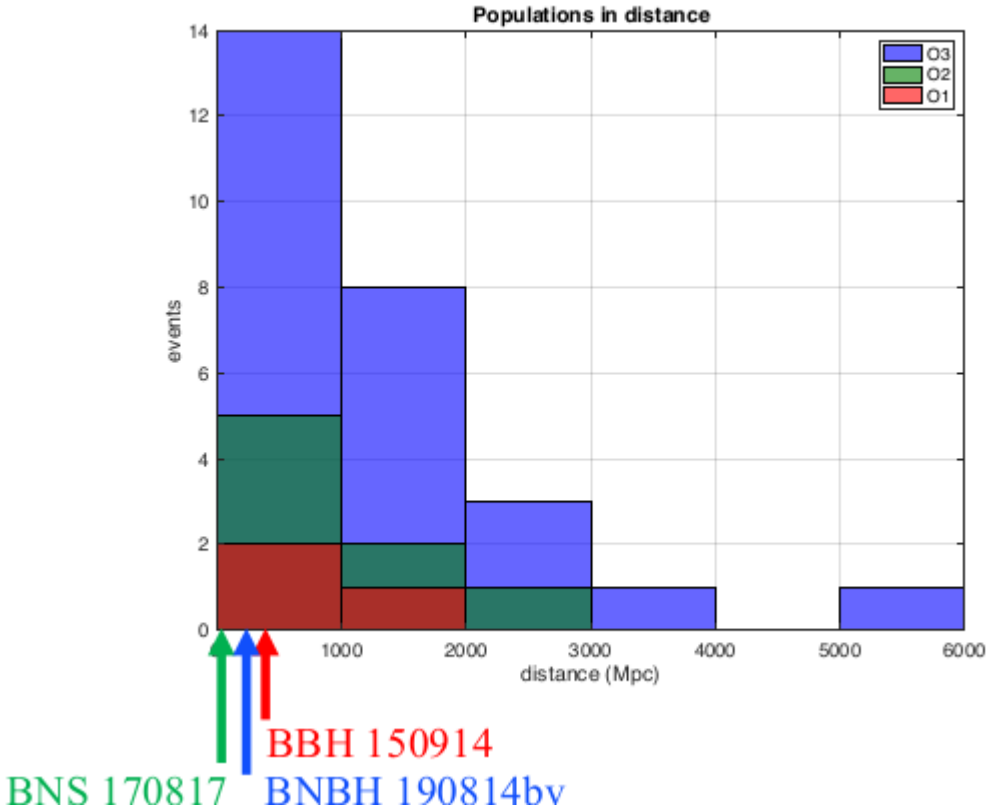
Sometimes significant improvement

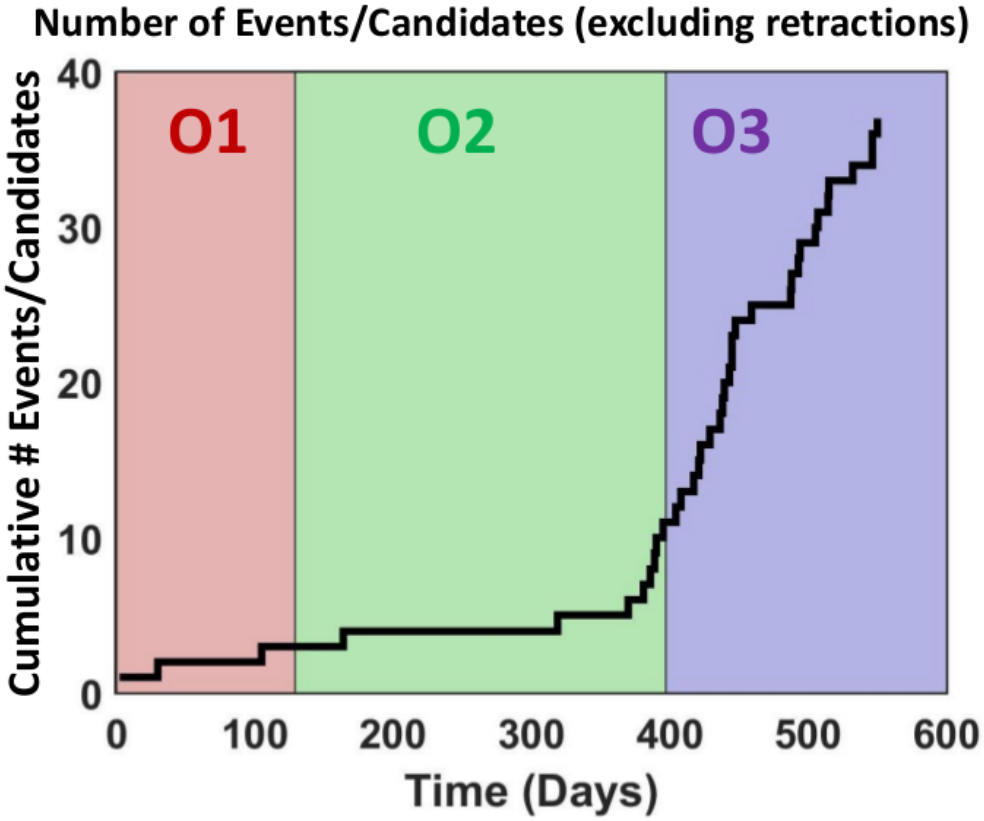


O3 alerts

~6 months of observation :

- 38 LVC public alerts. Of those, 7 retracted
- 1 FermiGBM-LVC public alert for subthreshold candidate

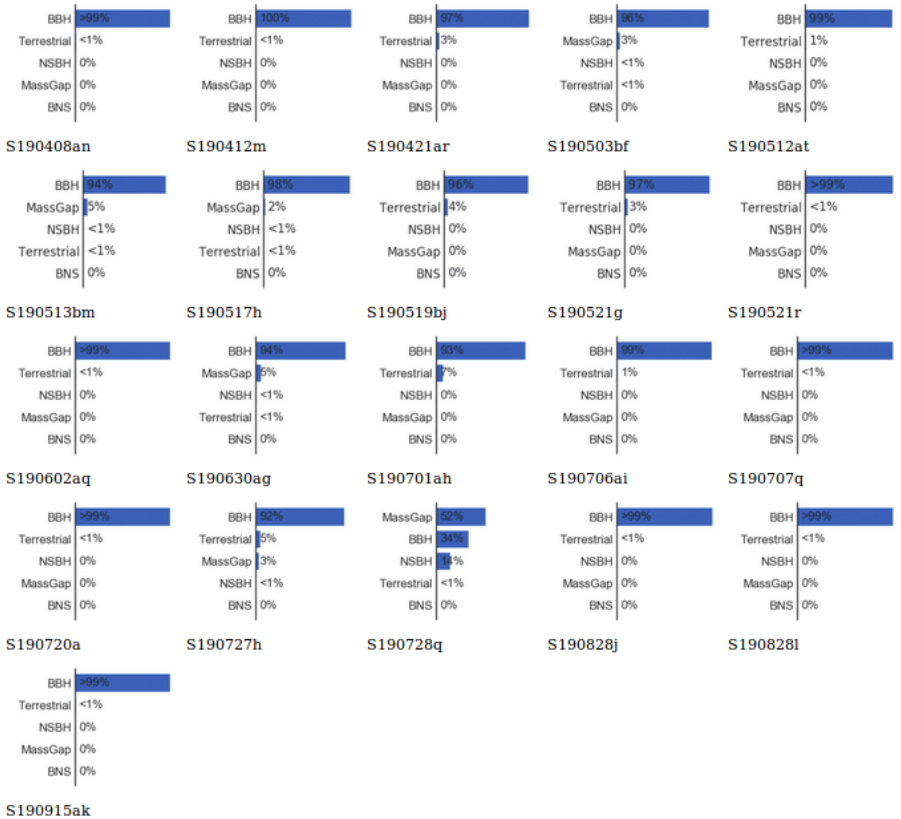


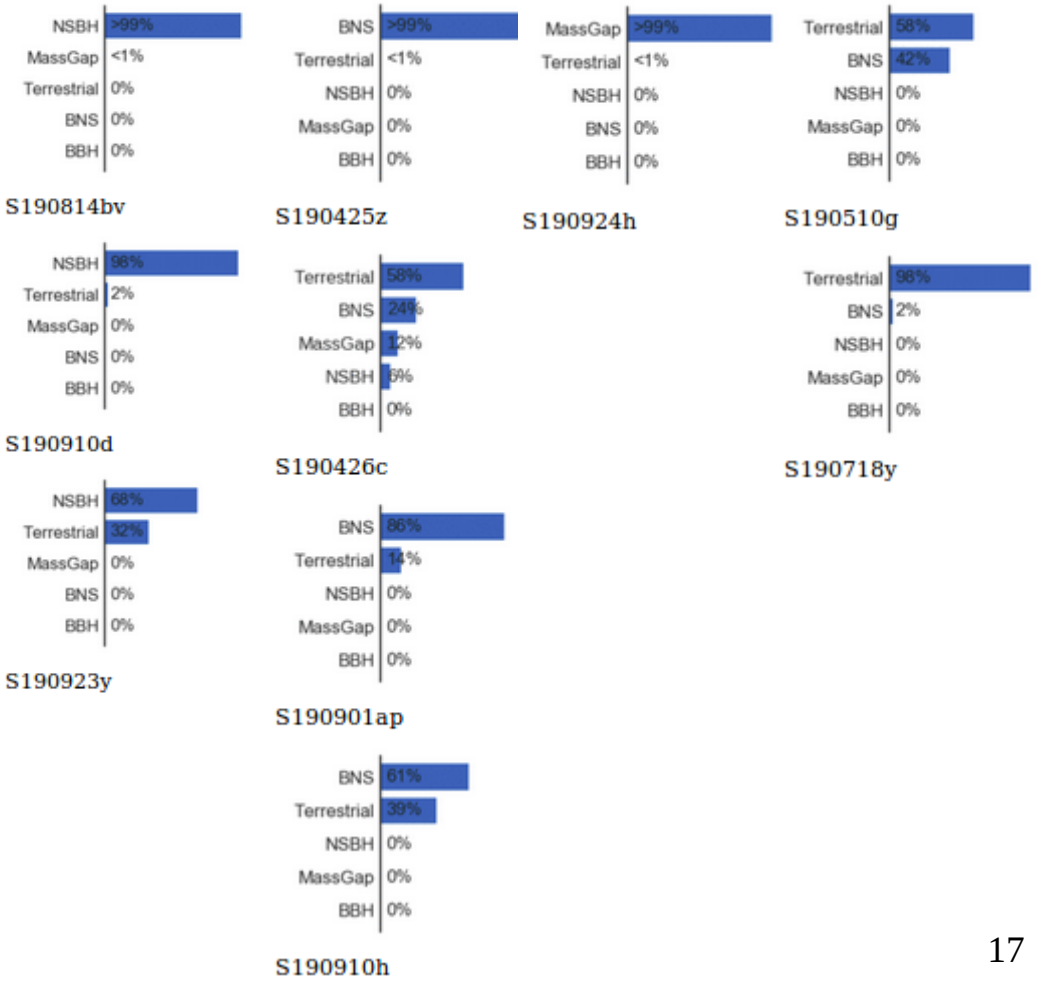


O1+O2 : 10 BBH and 1 BNS

Alerts classification

BBH	NSBH	BNS	Mass Gap	Terrestrial





Comparison with expectation

- The detection number predictions are given as detection counts including Poisson statistical variations and based on a one-calendar-year observing run.

Observation Run	Network	Expected BNS Detections	Expected NSBH Detections	Expected BBH Detections
O3	HLV	2^{+8}_{-2}	0^{+19}_{-0}	15^{+19}_{-10}
		Events after ~6 months	4	3	21

Final content of the O3 catalogue might differ !

More information / EM connection

- LIGO-Virgo candidates currently generate ~50% of GCN circular traffic
- Vanilla BBH candidate typically generates 15-20 GCN circulars
- S190425z (BNS) and S190814bv (NSBH) generated ~120 circulars
- S190426c and S190510g (BNS then terrestrial) generated ~ 60-70 circulars
- S190728q (MassGap then BBH) generated ~40 circulars
- Fermi GBM-190816 generated ~20 circulars

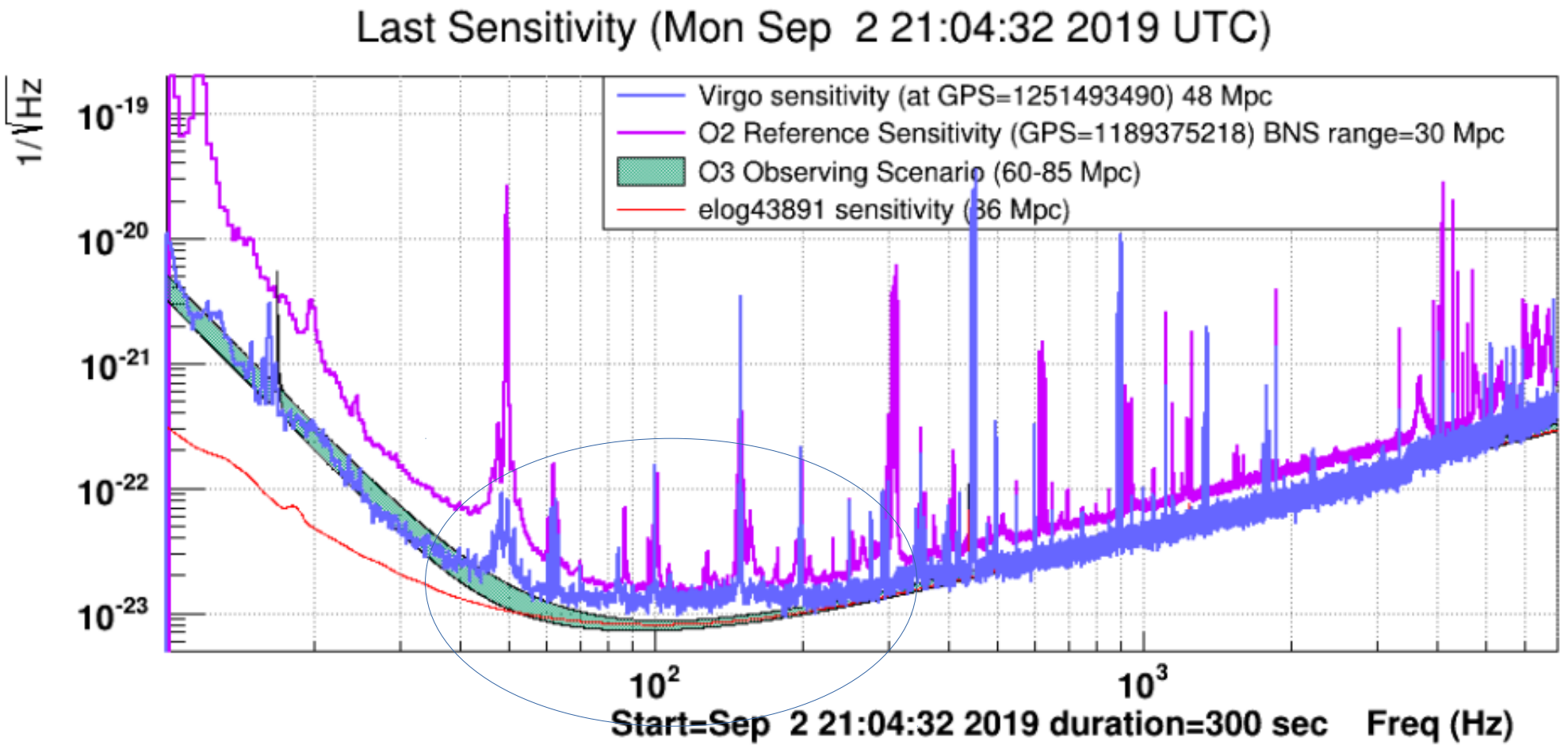
O3 commissioning break and future

- Commissioning break scheduled Oct 1@1500 UTC – Nov 1@1500 UTC

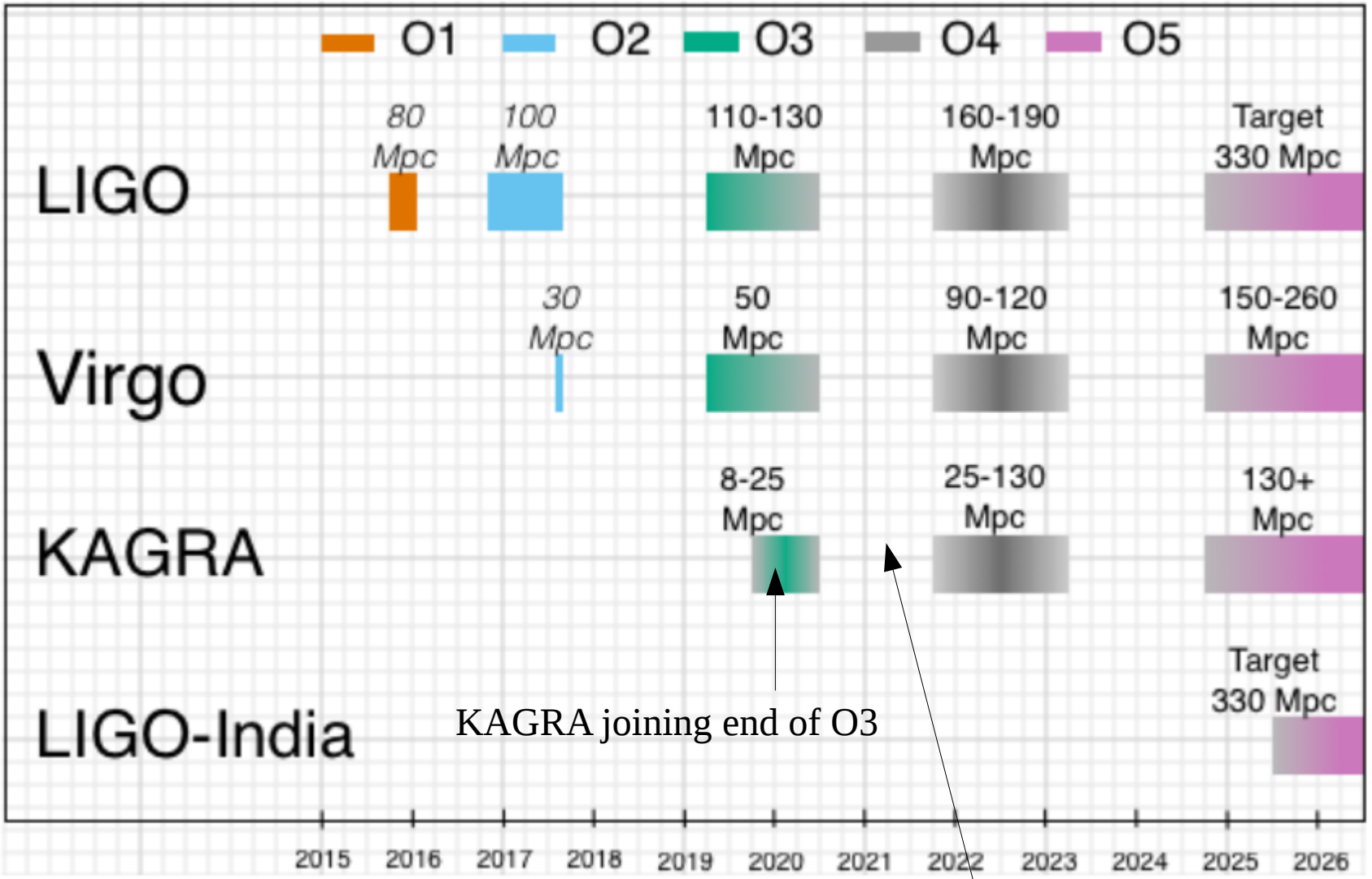
  (see below for the Virgo program!)
- O3 expected to continue through at least the end of April 2020 (at least one year of data taking)

Sensitivity + stability	• Investigate/recover slow decrease of laser power
Duty cycle	• Increase dynamics of laser power stabilization to mitigate "fast unlocks" issue
Glitchiness + sensitivity	• Investigate/mitigate scattered light from injection system
Sensitivity	• Investigate "flat" mystery noise in 80-200 Hz band

O3 Virgo commissioning break program



Update LIGO/Virgo/KAGRA prospects



That’s the end

- All public O3 events can be found on GraceDB: https://gracedb.ligo.org/superevents/public/O3/
- Tutorials and software open source on GWOSC (Gravitational Wave Open Science Center): https://www.gw-openscience.org/about/
- Next LV-EM Open Forum Telecon - Thursday, September 26, 2019 @14:00 UTC
- https://wiki.gw-astronomy.org/OpenLVEM/Telecon20190926
- Papers in preparation (among others):
  - S190425z (BNS). Paper in preparation.
  - S190521g (BBH). Paper in preparation to be released early 2020.
  - Gravitational-wave Transient Catalog update based on O3a, plus companion papers. Release target April 2020.

- LV-EM Open Forum Telecon - Thursday, September 26, 2019 @14:00 UTC
- https://wiki.gw-astronomy.org/OpenLVEM/Telecon20190926
- S190425z. Paper in preparation with release target in October.
- S190521g. Paper in preparation to be released later in 2019 or early 2020.
- Gravitational-wave Transient Catalog update based on O3a, plus companion papers. Release target April 2020.