

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



Network duty factor

- Triple interferometer [43.9%]
- Double interferometer [37.7%]
- Single interferometer [15.2%]
- No interferometer [3.2%]

- 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)
РуСВС	
SPIIR	

Detection FAR :

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

Alerts classification



VIRCO

Alerts information





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





7



Alerts human vetting



Alerts and glitches









Human vetting versus glitches

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

1080Lines	1400Ripples	Air_Compressor	Blip	Chirp	Extremely_Loud	Helix
Koi_Fish	Light_Modulation	Low_Frequency_Burst	Low_Frequency_Lines	None_of_the_Above	Paired_Doves	Power_Line
Repeating_Blips	Scattered_Light	Scratchy	Tomte	Violin_Mode	Wandering_Line	Whistle



Human vetting versus glitches



Human vetting to estimate if a glitch

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

Parameter estimation





Parameter estimation



Bayesian parameter estimation Markov Chain Monte Carlo (MCMC) or Nested sampling

<u>15 parameters:</u>

- 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

<u>Several models</u> (under permanent improvement):

- Frequency domain
 - Post-Newtonian waveform
 - Phenomenological calibrated to numerical relativity
- <u>Time domain</u>
 - 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 \rightarrow update



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

		I	BBH		NSBH	BNS	Mass Gap	Terrestrial
BBH 293% Terrestrial <1% NSBH 0% MassGap 0% BNS 0% S190408 7% BBH 94% MassGap 5% S190408 7% BBH 94% MassGap 5% S190513 7% BBH 99% Terrestrial 1% NSBH 0% MassGap 0% S190602 7% RBH 99% NSBH 7% S190602 7% MassGap 0% MassGap 0% S190602 7% NSBH 0% MassGap 0%	BBH 100% Terrestrial <1% NSBH 0% MassGap 0% BBN 0% S190412m BBH 93% MassGap 2% NSBH <1% Terrestrial <1% BBH 95% S190517h BBH 5% MassGap 5% S19053b BBH 1% BBH 1% S19053ca S19063ca 3% S19063ca 3% BBH 1% S19063ca 3% S19063ca 3% S19063ca 3% S19063ca 3%	BBH 97% Terrestrial 3% NSBH 0% MassGap 0% S190421ar BBH 96% NSBH 0% MassGap 0% S190519b S190519b S190519b S190500 S190500 S19050	BBH MassGap 3% NSBH <1% Terrestrial <1% BNS 0% S190503J Terrestrial 3% NSBH 0% MassGap 0% S190706 S190705 S190705 S190705 S190705 S190705 S190705 S190705 S190705 S190705 S190	BBH 99% Terrestrial 1% NSBH 0% MassGap 0% S190512at 0% S190512at 1% MassGap 0% S190521r 0% S190521r 0% BBH 99% MassGap 0% MassGap 0% S190707g 1% BBH 99% Terrestrial 1% NSBH 0% BBH 99% Control 1% MassGap 0% BBH 99% Control 1% Standard 1% NSBH 0% BBH 90%	NSBH 599% MassGap <1% 7errestrial 0% BNS 0% BBH 0% S190814 V S190814 Terrestrial 2% MassGap 0% BNS 0% BBH 0% S190910 S190910 BNS 0% S190910 S19000 S19000 S19000 S19000 S19000 S19000 S19000 S19000 S19000 S19000 S19000 S19000 S190000 S19000 S19000 S19000 S19000 S19000 S19000 S190000 S190	BNS 299% Terrestrial <1% NSBH 0% 0% BBH 0% S190425z Terrestrial 24% MassGap 12% NSBH 0% S190426c BBH 0% S190426c BBH 0%	MassGap Terrestrial NSBH BNS BBH 0% S190924h	Terrestrial 58% BNS 42% NSBH 0% MassGap 0% BBH 0% S190510g Terrestrial 98% BNS 2% NSBH 0% MassGap 0% BBH 0% S190718y
S190720a BBH 2005 Terrestrial <1% MassGap 0% BNS 0% S190915ak	S190727h	S190728q	S190828j	S1908281	s190923y	BBH 0% S190901ap BNS 61% Terrestrial 39% NSBH 0% MassGap 0% BBH 0%		



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.

Observati Run	ion Network	Expected BNS Detections	Expected NSBH Detections	Expected BBH Detections
O3	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





Last Sensitivity (Mon Sep 2 21:04:32 2019 UTC)



Update LIGO/Virgo/KAGRA prospects



1 yr commissioning between O3 and O4 ²²

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/Telecon2019092
 6
- 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/Telecon2019092
 6
- 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.