Leo P. Singer, Research Astrophysicist
NASA Goddard Space Flight Center

What constitutes an open, public alert?

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TL;DR:

We (LIGO/Virgo) will release public alerts for event candidates that we are confident about and can stand behind. They will look a lot like events in O1 and O2, except that *they will all be instantly public*.

alert ≡ O3 alert ≡ open public alert

I. Policy

We (LIGO/Virgo) will release public alerts for all event candidates in which we have a reasonable confidence and feel we can stand behind.

- For compact binary coalescences (CBCs), our goal is an *overall astrophysical purity of 90%* (e.g. at most 1 in 10 compact binary candidates on average will have instrumental or environmental rather than astrophysical origin).
- Purity of CBC *subtypes* (BNS, NSBH, BBH) may be higher or lower than 90%.
- We expect this to translate to a *false alarm rate (FAR) threshold of 1/month — 1/year*.
- There will be a separate and *more restrictive threshold for unmodeled burst sources*. Exact value is still under discussion, but will be of the order *1/10 years - 1/100 years*.
- We can elect to *promote* a candidate that does not pass our normal thresholds if it is compellingly associated with a multimessenger signal (e.g. GRB, core-collapse SN).

We will issue automated preliminary alerts, prior to vetting, with minimal latency.

- Preliminary alerts will be sent fully autonomously.
- But beware! Some preliminary alerts may be *retracted after human inspection* for data quality, instrumental conditions, and pipeline behavior.
- Candidates that are not retracted *do not necessarily qualify as confirmed detections!*
- If no counterpart is identified and the significance of the candidate does not increase in our offline analysis, then we will issue an update stating that the candidate is of no further interest because it does not meet our criteria for being a confirmed detection.

Alerts should contain all of the information that is useful for searching for a counterpart (if there is one).

- This is basically the information we provided for private alerts in O2: *significance*, *time*, GW signal *classification*, 3D sky *position* and *distance*
- We will issue a public *update* if further analysis of the GW data results in a significant improvement (criteria TBD) in the significance and/or localization of an event candidate.
- Updates of the localization will be sent up until the position is determined more accurately by public announcement of an unambiguous counterpart, at which point they stop until publication of the event

Alerts come with no strings attached regarding use or publication.

- They’re public, after all!
- (Possibly obvious) but please cite the LIGO/Virgo circular (and paper once available) for discovery of the GW signal.

https://commons.wikimedia.org/wiki/File:Original_Guy_Fawks_mask_from_V_for_Vendetta_(5400848923).jpg

We will not offer generic follow-up MOUs (as we did in O1 & O2) for triggers which do not pass our selection thresholds.

- There will be *only one kind of alert* in O3: *open, public alerts*.
- We want these alerts to provide *everyone* with *the information that they need to search for a counterpart*. (On the other hand, see E. Katsavounidis talk for science-driven MOUs)
- LSC/Virgo will consider MOUs for exchanging additional information (or low-confidence, “sub-prime” triggers) only if there is a specific science goal which requires it, and will be selective about things which are not part of the LSC/Virgo science program.

II. Anatomy of an Alert

Gamma-Ray Coordinates Network (GCN)

- LIGO/Virgo alerts will be distributed through the public *Gamma-Ray Coordinates Network (GCN)*, the alert platform used for decades by the GRB community.

- Two types of GCN alerts:

  - "*Notices*": automated, machine-readable packets. Available in many formats: VOEvent XML, binary, plain text. Listen anonymously or pre-register for connection and delivery tracking.

  - "*Circulars*": human-readable, citable, non-refereed astronomical bulletins. Pre-register in order to receive and submit by email.

Alert sequence: Preliminary

- GCN *Notice* only
- Latency: ≲ *5 min*
- Autonomous, *not vetted* by humans (caveat emptor!)
- The Preliminary notice may or may not come with a *localization*. If it does not, then it will be followed shortly by a second Preliminary notice that does contain a localization.

Alert sequence: Initial

- GCN *Notice* and *Circular*
- Latency: <4 hours
- Indicates that the candidate has been vetted by human instrument scientists and analysts.
- Circular will include instrument and data quality assessment, and *Retraction* if the event is rejected because the data are unsuitable.
- *Localization* estimate will be provided, even if it was already included in a Preliminary notice
- Qualitative *source classification* based on the GW signal
- This Circular is considered the first publication of a GW candidate, appropriate to cite in publications

Alert sequence: Update

- GCN *Notice* and *Circular*
- Latency: as available
- Sent whenever localization or significance accuracy improves (e.g. as a result of improved calibration, de-glitching, or computationally deeper parameter estimation)

Significance

- Event names: may use date-based designations from earliest circular (e.g. GWT 170817.529 instead of G298048) but details still under discussion

- FAR ≥ 1/100 years: number will be stated in Circulars;
  FAR ≤ 1/100 years: will be described simply as “highly significant”

- Why? FAR estimation is subject to large variation upon reanalysis or analysis by different pipelines. Values much smaller (more significant) than 1/100 years are not very meaningful (who cares whether the false alarm rate was 1/100 years or 1/10000 years?)

Source classification for CBCs

- Simple qualitative statement of whether the signal is consistent with a *BNS, NSBH, or BBH* coalescence (may be consistent with more than one source type)
- May include probability that the less massive companion has a mass consistent with NS
- May include probability that there is matter left outside of the remnant (“EM Bright”)
- May include P_{astro}, probability that the signal is astrophysical in origin accounting for both observed merger rate distribution and background distribution
- Alerts will *not* release quantitative estimates of masses and spins
- Alerts will *not* release the GW strain or the waveform regressed from the data

Data quality assessment

- Concise description of any instrument or data quality issues that affect significance estimates or parameter inference based on the GW data.
- *Unresolved* data quality issues could mean that localization estimates *may* shift after they have been mitigated, but does not mean that they will. Treat this information as advisory.
- Criteria for including such a note are TBD, but see B. O'Reilly's talk.

GCN Notices: Basic Info

	CBC	Burst
IVORN	`ivo://nasa.gsfc.gcn/LVC#{G,M}`*`nnnnnn`*`-{1,2,3}-`*`Preliminary`*`,`*`Initial`*`,`*`Update`*	
Who	LIGO Scientific Collaboration and Virgo Collaboration	
What	GraceDB ID: `{G,M}`*`nnnnnn`*	
Search group	`CBC`	`Burst`
Pipeline	`{Gstlal,MBTA,PyCBC}`	`{CWB,LIB}`
FAR	estimated false alarm rate in Hz	
Network	Flag for each detector (`LH0_participated`, etc.)	
Sky map	URL of HEALPix FITS localization file	
WhereWhen	Arrival time (UTC, ISO-8601), e.g., `2010-08-27T19:21:13.982800`	

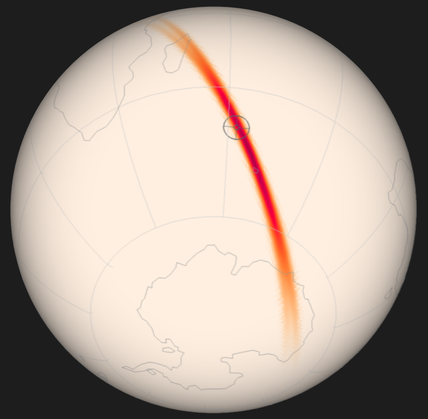
GCN Notices: Inference (CBC only)

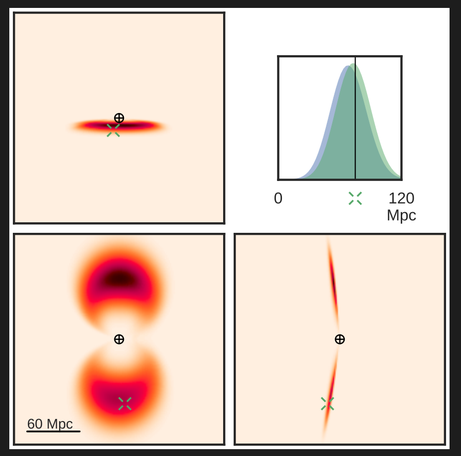
	CBC
What	GraceDB ID: {G,M}*nnnnnn*
...	...
Distance	a posteriori mean luminosity distance in Mpc
DistanceError	a posteriori standard deviation of luminosity distance in Mpc
ProbHasNS	Probability (0–1) that the less massive companion has a source-frame mass <3 M⊙
ProbHasRemnant	EMBright: Probability (0–1) that the system ejected a significant amount of NS material, as calculated by method of Pannarale & Ohme (2014)

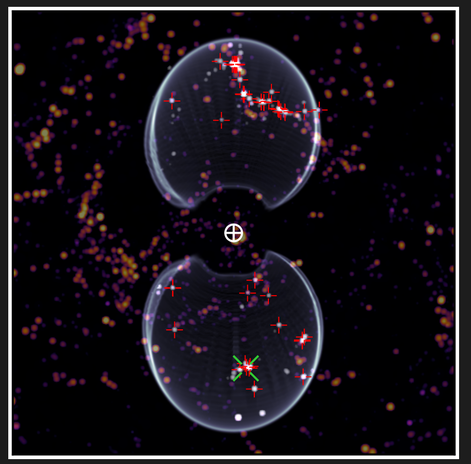
Localizations

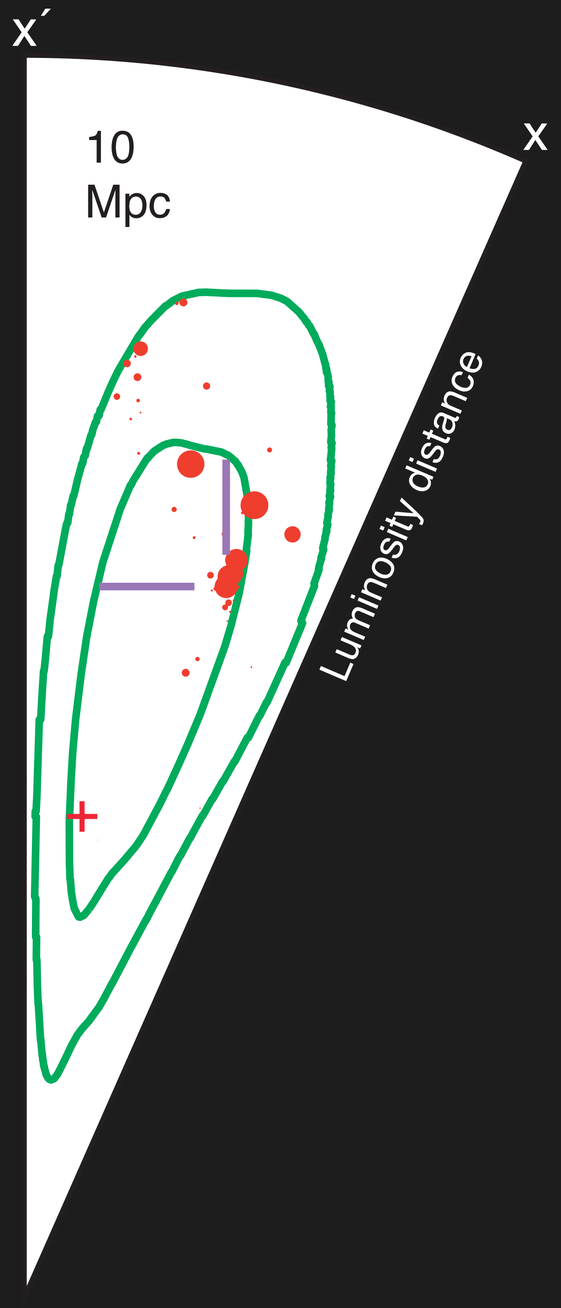
- Gzip-compressed *HEALPix* images in *FITS*
- *Sky probability* sampled in equal-area pixels
- (*CBC only*) Distance: location, scale, and normalization of an r^2 weighted Gaussian conditional distance distribution

- *New for O3* (talk to me during the break for more info):
  - *error ellipses* for well-localized events
  - *multi-resolution* HEALPix files for *faster* manipulation









```
INDXSCHM= 'IMPLICIT'           / Indexing: IMPLICIT or EXPLICIT
OBJECT  = 'G298107 '           / Unique identifier for this event
REFERENC= 'https://gracedb.ligo.org/events/G298107' / URL of this event
INSTRUME= 'H1,L1,V1'           / Instruments that triggered this event
DATE-OBS= '2017-08-17T12:41:04.444458' / UTC date of the observation
MJD-OBS =    57982.52852366262 / modified Julian date of the observation
DATE    = '2017-08-17T16:11:42.000000' / UTC date of file creation
CREATOR = 'BAYESTAR'           / Program that created this file
ORIGIN  = 'LIGO/Virgo'         / Organization responsible for this FITS file
RUNTIME =                 15.0 / Runtime in seconds of the CREATOR program
DISTMEAN=    39.76999609489005 / Posterior mean distance (Mpc)
DISTSTD =    8.308435058808682 / Posterior standard deviation of distance (Mpc)
LOGBCI  =    13.64819688928804 / Log Bayes factor: coherent vs. incoherent
LOGBSN  =    261.0250944470225 / Log Bayes factor: signal vs. noise
VCSVERS = 'LALInference 1.9.4.1' / Software version
VCSSTAT = 'CLEAN: All modifications committed' / Software version control status
VCSREV  = 'b002970a29277aab145627f8b5eea76f3a8c5829' / Software revision (Git)
DATE-BLD= '2017-08-03T19:22:48-0700' / Software build date
HISTORY
HISTORY Generated by calling the following Python function:
HISTORY lalinference.bayestar.sky_map.localize(event=<LigoLWEvent(singles=(<Ligo
HISTORY LWSingleEvent(detector=u'H1', snr=15.745832, phase=0.59536642, time=1187
HISTORY 008882.4467773)>, <LigoLWSingleEvent(detector=u'L1', snr=24.330324, phas
HISTORY e=-3.0009944, time=1187008882.4433594)>, <LigoLWSingleEvent(detector=u'V
HISTORY 1', snr=None, phase=None, time=1187008882.4450684)>))>, waveform='o2-ube
HISTORY rbank', f_low=30, min_distance=None, max_distance=None, prior_distance_p
HISTORY ower=2, cosmology=False, method='toa_phoa_snr', nside=-1, chain_dump=Non
HISTORY e, enable_snr_series=True, f_high_truncate=0.95)
HISTORY
HISTORY This was the command line that started the program:
HISTORY bayestar_localize_lvalert
```

Example Circular

The first few Circulars for GW170817 contained all of the components I described. Let’s take a look at it.

GCN 21509

“A binary neutron star candidate was identified in data from the LIGO Hanford detector at gps time 1187008882.4457 (Thu Aug 17 12:41:04 GMT 2017). The signal is clearly visible in time-frequency representations of the gravitational-wave strain in data from H1. The current significance estimate of ~1/10,000 years is based on data from H1 alone. Information about this candidate is available in GraceDb here...”

Time, source classification, significance

GCN 21513

“Investigation of L1 data identified a noise transient from a known class of instrumental glitches during the inspiral signal. The duration of this glitch is a small fraction of a second and does not appear to affect the signal at times away from the glitch. To make an improved preliminary estimate of the sky position, we re-analyzed the data, removing the L1 noise transient at GPS time 1187008881.389 by multiplying the strain data with a Tukey window, such that the total duration of the zeroed data is 0.2 s and the total duration of the Tukey window is 1.2 s.

Data quality assessment

GCN 21513

An updated BAYESTAR sky map (Singer et al. 2016, ApJL 829, 15) that uses data from all three gravitational-wave observatories (H1, L1, and V1) is available for retrieval from the GraceDB page: bayestar-HLV.fits.gz. The centroid (maximum a posteriori) sky location is R.A.=12h57m, Dec.=-17d51m. The 50% credible region spans about 9 deg2 and the 90% region about 31 deg2. The luminosity distance is 40 +/- 8 Mpc (all-sky a posteriori mean +/- standard deviation). This is the preferred sky map at this time.

Localization, distance

IV. Event Vetting (B. O’Reilly)