Gravitational Wave alerts

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based on slides by Leo Singer for MIT & Amsterdam Town Hall

Summary

- In 2019 LIGO/Virgo will release public alerts for confident event candidates
- The alerts will be very similar to private alerts during O1 and O2
- All the alerts will be immediately public

- Principles
- Technical aspects
- Science driven MOUs

Publicité

- Page web http://gdrgw.in2p3.fr
- 8 groupe de travail
  $\Rightarrow$ Prédiction et suivi des signaux multi-messager
- 1^{ere} rencontre du GdR, Paris 18-19 Octobre 2018
- 1 heure prévue par groupe de travail
  $\Rightarrow$ quel format pour les suivi multi-messager?

Principles

What are the alerts criteria

- For compact binary coalescences (CBCs), 90% overall purity goal
  - i.e. on average 1 in 10 CBC alert will have an instrumental and not astrophysical origin
- Purity of subtypes (NS-NS, NS-BH, BH-BH) may be different from 90%
- This should correspond to false alarm rate (FAR) of 1/month – 1/year
- For unmodeled burst sources, a fixed alarm rate threshold
  - exact value under discussion in the range 1/10 years – 1/100 years
- A candidate failing these thresholds can be promoted if it is compellingly associated with a EM or neutrino signal (e.g. GRB, core-collapse SN)

Fully automated preliminary alerts

- No human intervention for preliminary alerts
- Preliminary alerts may be retracted after human inspection if there is a clear issue with data quality, instrument or analysis pipeline misbehavior
- Candidate that are not retracted are not necessarily confirmed detection
- If there is no multi-messenger counterpart and candidate not confirmed by offline analysis, then we will issue an update stating the candidate is of no further interest

Alerts should contain all information needed for followup

- Same information as provided in private alerts in O2
  - significance
  - time
  - GW signal classification
  - 3D sky position and distance
- Public updates if further analysis provides a significant improvement (critera TBD) in significance and/or localization of candidate event
- If an unambiguous counterpart with more accurate localization is found and announce public, LIGO/Virgo will stop issuing updated localizations until final event publication

Technical aspects

Gamma-Ray Coordinates Network

- LIGO/Virgo alerts are distributed through the public Gamma-ray Coordinates Network (GCN) – 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: $\lesssim$ 5 min
- Autonomous, not vetted by humans
- May or may not come with a localization. If localization not included, a second preliminary notice containing the localization will follow shortly

Alert sequence: Initial

- GCN Notice and Circular
- Latency: < 4 hours
- Candidate has been vetted by humans
- Circular include data quality assessment.
- Retraction if the event is rejected because data are unsuitable
- Localization provided even if it is already included in Preliminary notice
- Qualitative source classification based on GW signal
- This circular is the first publication of a GW candidate, suitable for citing

Alert sequence: Update

- GCN Notice and Circular
- Latency: as available (>4 hours)
- Sent whenever localization or significance accuracy improves
  - improved calibration
  - de-glitching
  - more computationally intensive parameter estimation

Event significance

- Event names
  - date-based designation under discussion
  - e.g. GWT 170817.529 instead of G298048
- Significance
  - FAR > 1/100 years: number stated in Circular
  - FAR < 1/100 years: described simply as “highly significant”
- Reason
  - FAR estimation subject to large variation between analysis
  - Values much smaller (very significant) than 1/100 years do not impact followup

Source classification for CBC

- Qualitative statement if signal consistent with NS-NS, NS-BH, BH-BH
  - may be consistent with more than one source type
- May include probability than 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 of astrophysical origin taking into account the observed merger rate and background distribution
- Alerts with not release quantitative estimates of masses and spins
- Alerts will not release the GW strain or waveform regressed from the data

Data quality assessment

- Concise description of any instrument or data quality issues that significance or parameters of event candidate
- Unresolved data quality issues may bias localization estimates.
- Exact criteria for such a note are to be determined

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	

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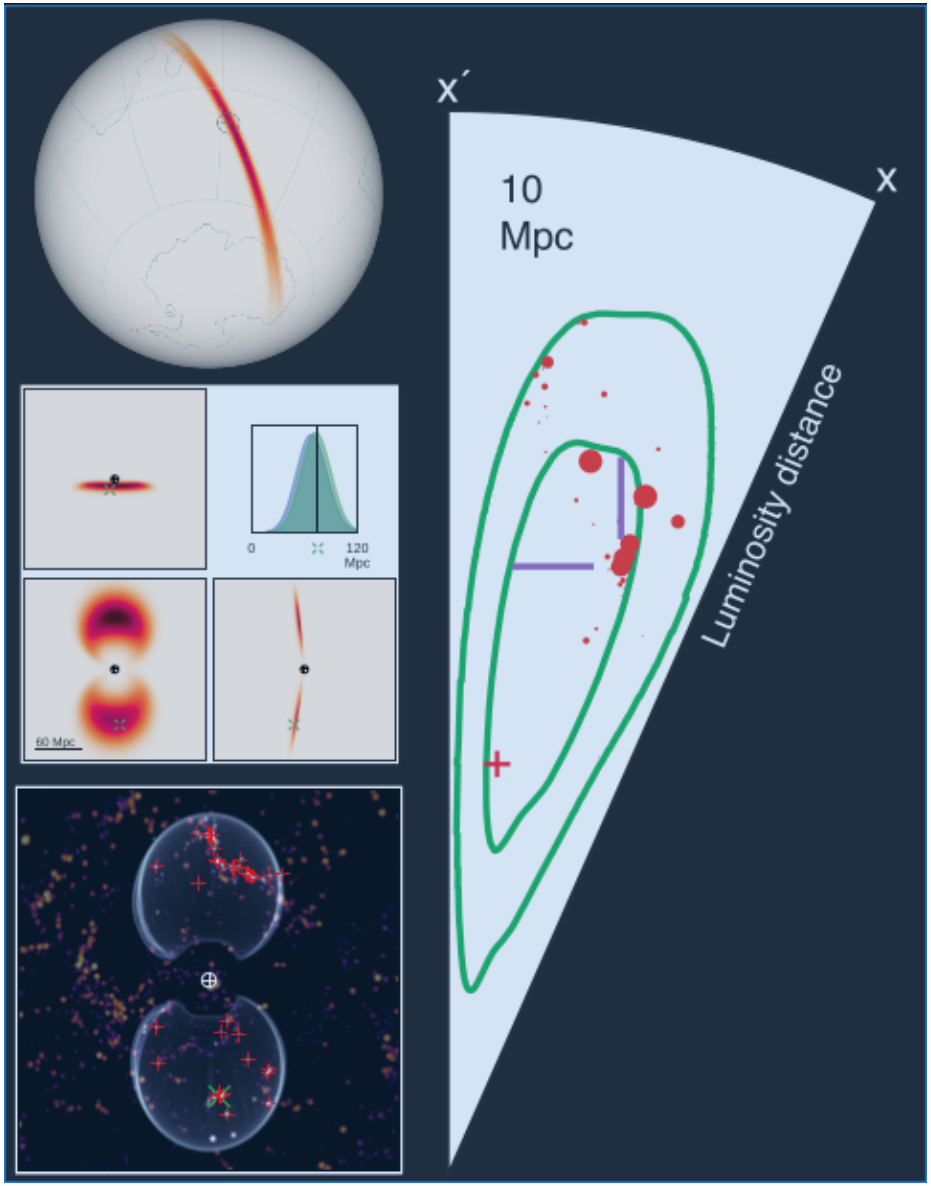
GCN Notices: Inference (CBC only)

	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)

Localization

- 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 distribution
- New for O3
  - error ellipses for well-localized events
  - multi-resolution HEALPix files for faster manipulation



Example from GW170817

- Time, source classification, significance (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...”
- Data quality assessment (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.”
- Localization distance (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 (https://gracedb.ligo.org/events/view/G298048): 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.

Science driven MOUs

Fundamentals for MOUs

- Opportunity to exchange more information than what is available in public alerts
- Goals must be part of the LIGO/Virgo science program
- Agreements should not be “exclusive” for any of the science topics pursued
- Information privacy to be maintained at all times
- Joint publication upon mutual agreement and whole LIGO/Virgo author list

Examples of MOUs

- Exchange of sub-threshold GW events & non public EM/neutrino transients for joint analysis
  - High energy neutrinos (Antares, Icecube)
  - Gamma-ray transients (Fermi/GBM)
  - Fast Radio Bursts (Green Bank, Parkes)
  - Low energy neutrinos (Borexino, Icecube, KamLAND, LVD)
  - Up to now archival (not low-latency critical) and low opportunity cost
- Non-public EM transient for GW followup
  - CCSN light curves & progenitor information (ASAS-SN, DLT40)
- GW parameters not in public alerts for joint with EM analysis
  - Inclination, individual masses and spins, tidal parameters for CBC
  - 3D localization with full degeneracies on other parameters
    $\Rightarrow$ complete galaxy catalog in that region for Hubble constant estimation from BH-BH
- Requires added value compared to public data

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