# LVK Alerts Tutorial

**Mervyn Chan**
**University of British Columbia**


# Outline

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- What are LVK alerts?
- How to receive/subscribe to them?
- What do LVK alerts tell us?

# What are LVK alerts?

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    - Scalable Cyberinfrastructure to support Multi-Messenger Astrophysics (SCiMMA, https://scimma.org)
    - In real time to facilitate search for counterparts (electromagnetic waves or neutrinos)

# Types of LVK alerts

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- There are two types of LVK alerts:
  - Machine-readable Notices
  - Human-readable GCN Circulars
- They are also visible in real-time on
  - the Gravitational-Wave Candidate Event Database (GraceDB)
- A great resource is the LVK Public Alerts Userguide
  - https://emfollow.docs.ligo.org/userguide/index.html

# How to receive LVK Notices?

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## LVK Notices

machine-readable packets

available as Json, Avro, VOEvent XML, and some legacy formats*

*https://gcn.gsfc.nasa.gov/gcn_describe.html#tc7

# Kafka Notices via GCN - an example

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- Receiving LVK Notices as Kafka Notice via GCN
  - Kafka: Apache Kafka is an open-source distributed event streaming platform
    - https://kafka.apache.org/
  - One of two recommended methods (the other is Kafka Notice via SCiMMA)
  - Json serialized notices (Avro serialized notice via SCiMMA)

- Completed instructions given here:
  - https://emfollow.docs.ligo.org/userguide/tutorial/receiving/gcn.html

# Kafka Notices via GCN - an example

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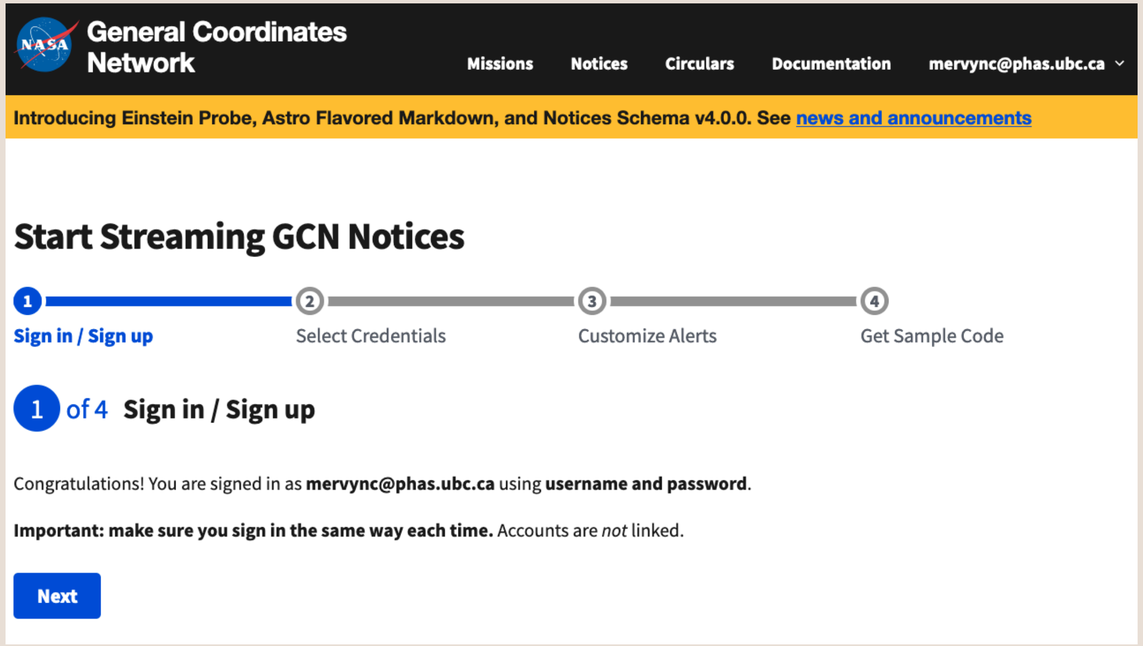


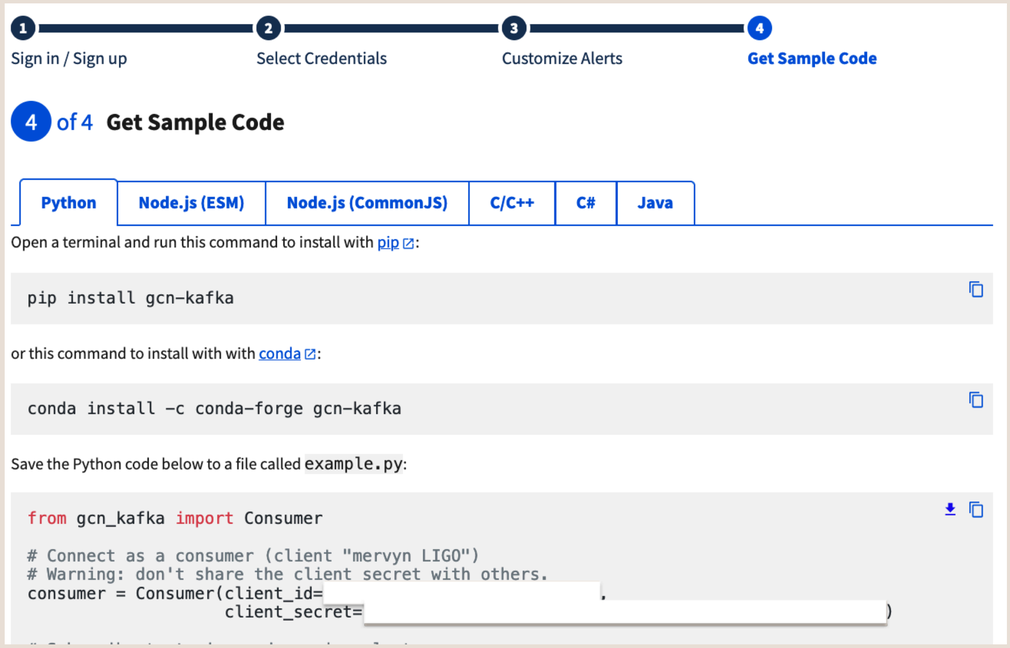


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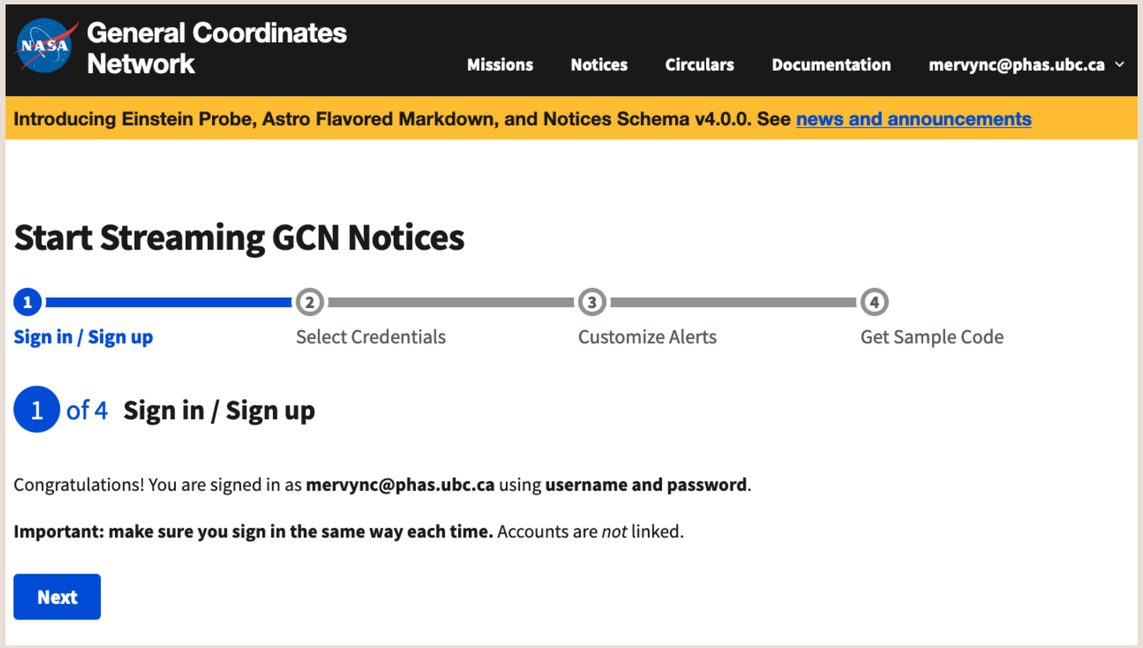


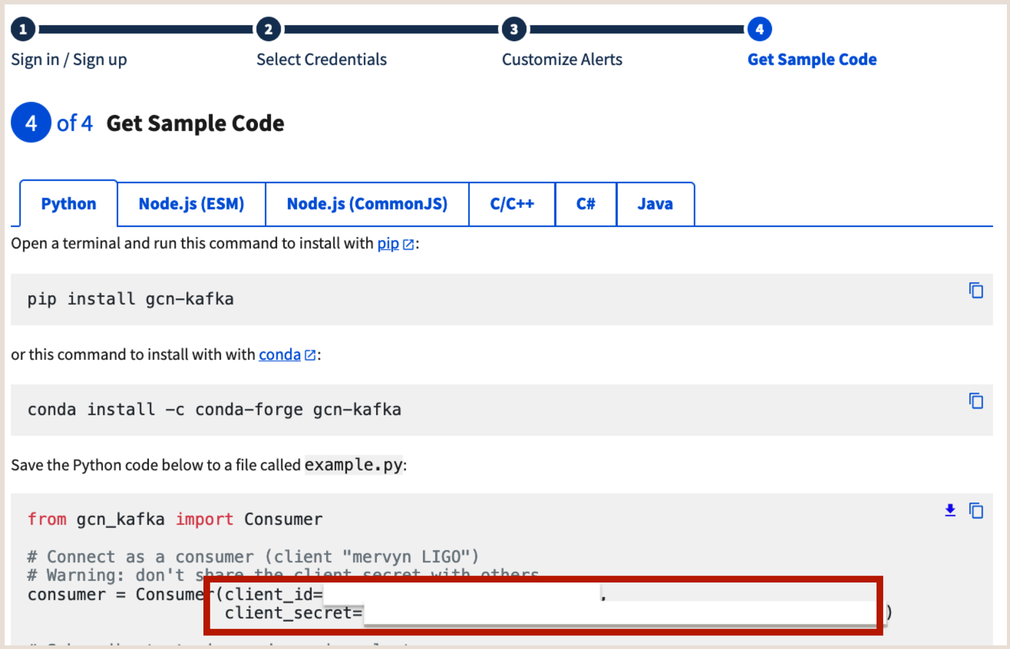


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2. Make a note of client_id and client_secret. You need them to receive LVK alerts.

- Use your client_id and client_secret to listen to LVK alerts
  - Sample code: https://emfollow.docs.ligo.org/userguide/tutorial/receiving/gcn.html

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A sky map may also be available

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# Types of Notices

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- There are five kinds of Notices:
  - Early Warning Notice
  - Preliminary Notice
  - Initial Notice
  - Update Notice
  - Retraction Notice

# Types of Notices

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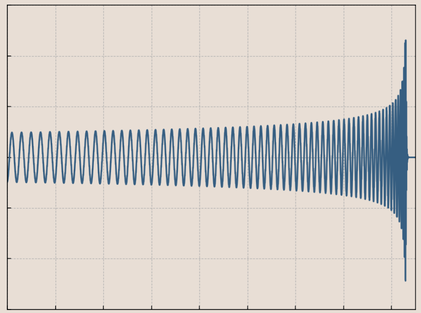
LVK Identified a gravitational wave candidate



Early Warning Notice

Preliminary Notice

Initial Notice with accompanying GCN circular

Update Notice

Retraction Notice

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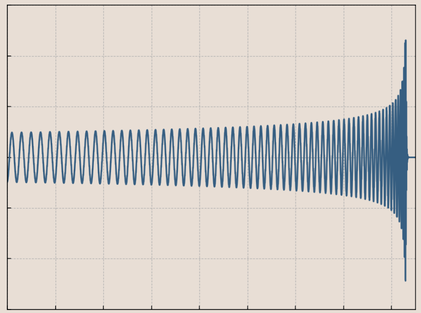

**Within minutes**

Early Warning Notice

Preliminary Notice

Initial Notice with accompanying GCN circular

Update Notice

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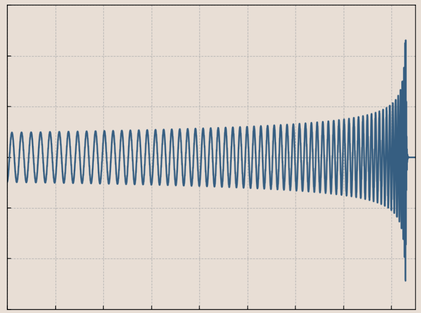
Early Warning Notice

**If the candidate passes human vetting**

LVK Identified a gravitational wave candidate



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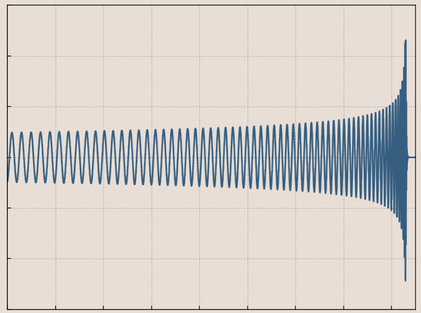
Early Warning Notice

LVK Identified a gravitational wave candidate



**Within minutes**

Preliminary Notice

Initial Notice with accompanying GCN circular

Update Notice

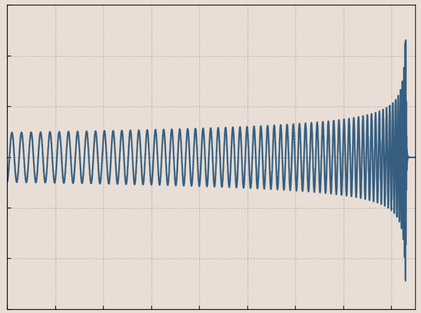
Retraction Notice

**When further analysis leads to improved estimates of the sky localization, significance, or classification**

# Types of Notices

Mervyn Chan

LVK Identified a gravitational wave candidate



**Within minutes**

Early Warning Notice

Preliminary Notice

Initial Notice with accompanying GCN circular

Update Notice

**If the candidate does not pass human vetting**

Retraction Notice

# Types of Notices - Early Warning Notice

Mervyn Chan

Image credit: LIGO/Virgo/Lovelace, Brown, Macleod, McIver, Nitz

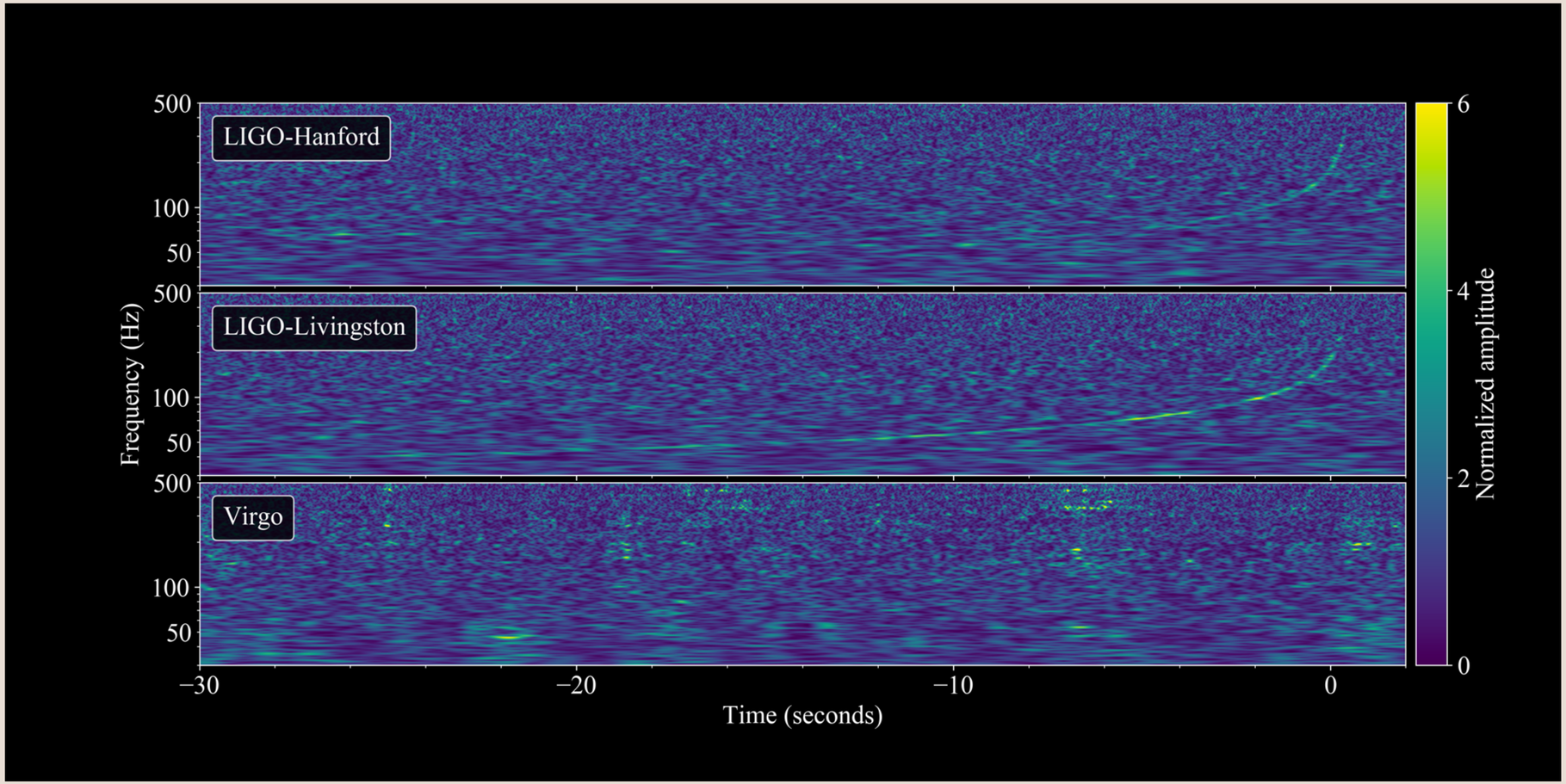


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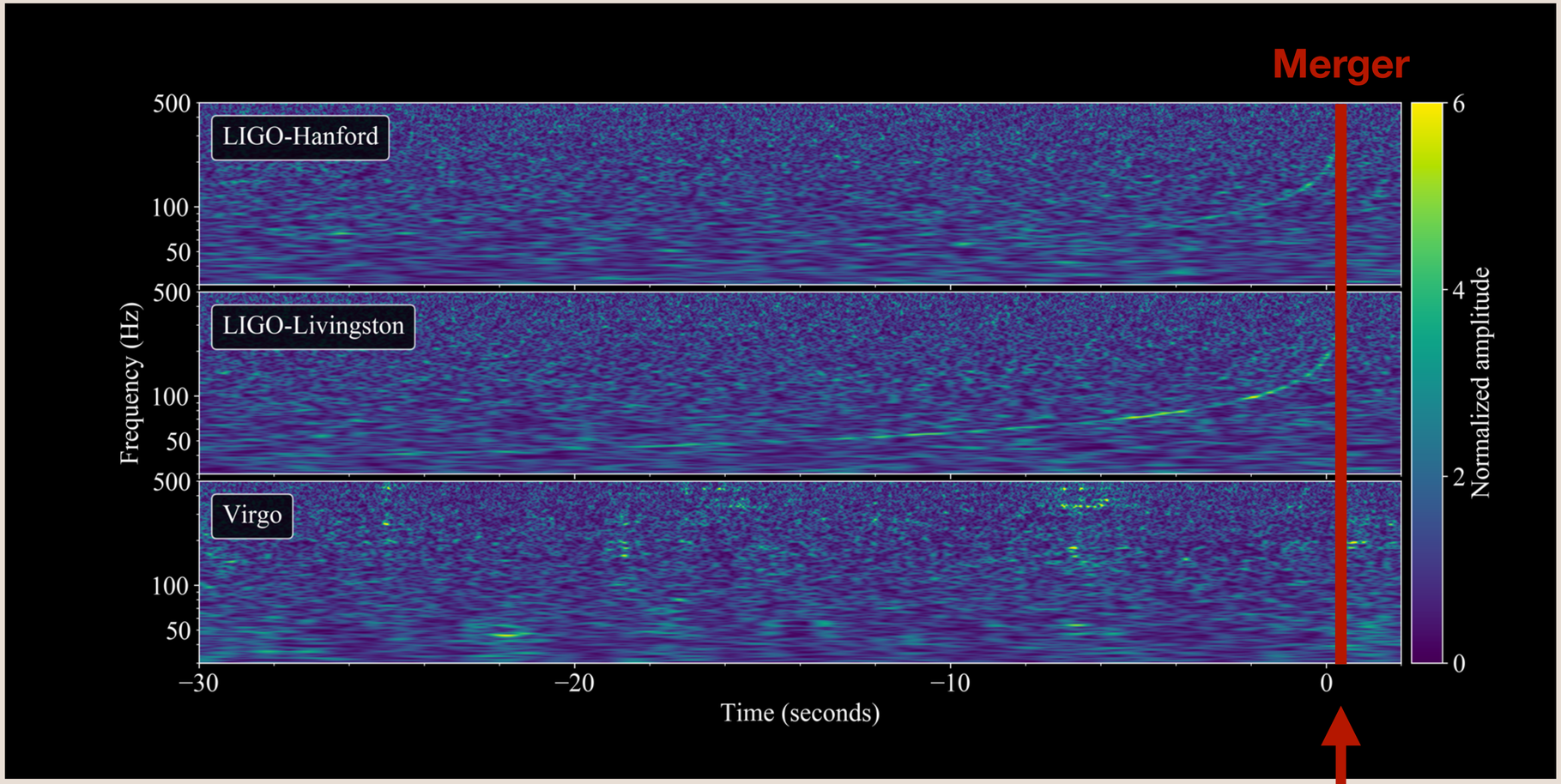
Image credit: LIGO/Virgo/Lovelace, Brown, Macleod, McIver, Nitz

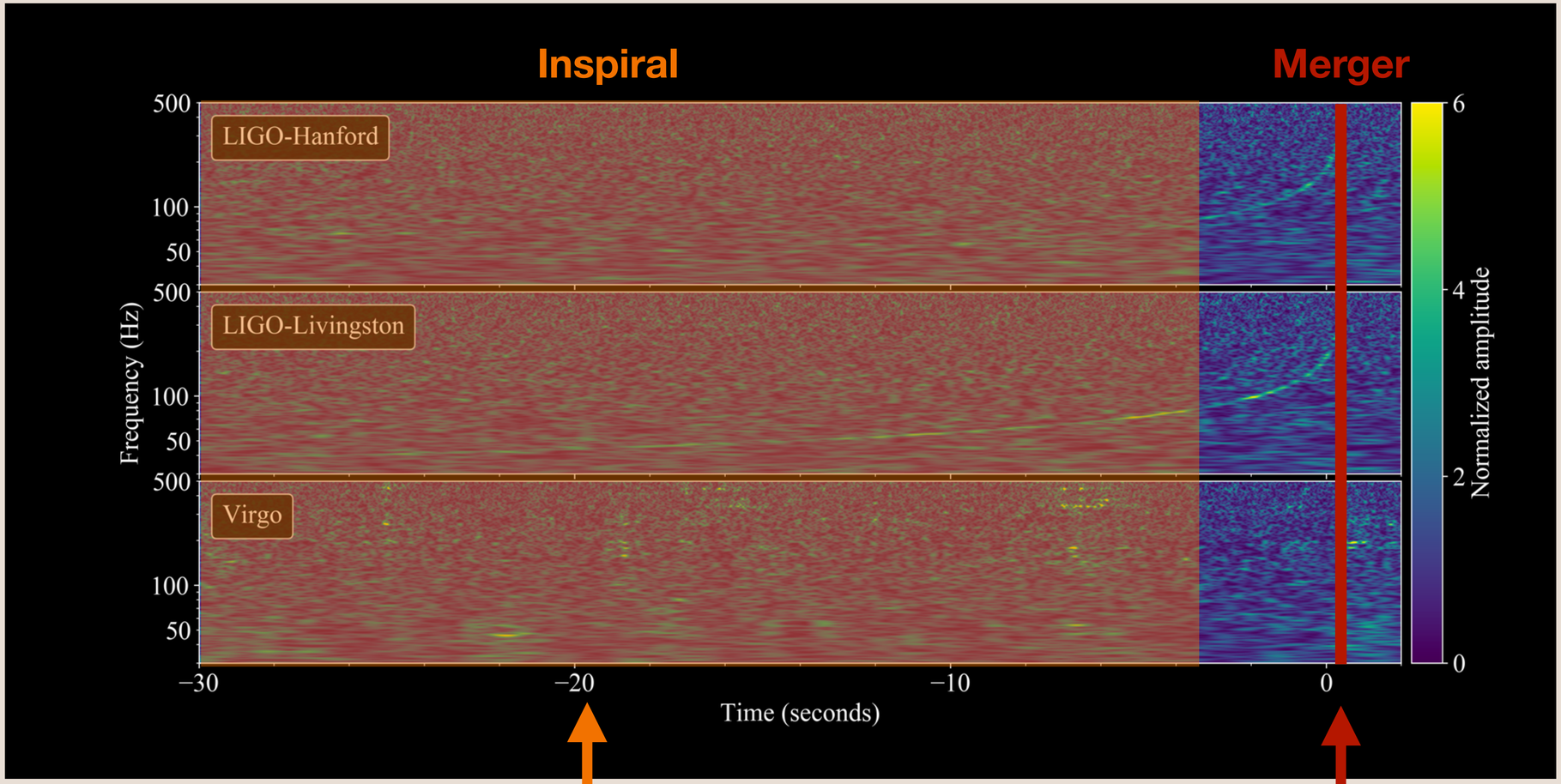



Full alert

# Types of Notices - Early Warning Notice

Mervyn Chan

Image credit: LIGO/Virgo/Lovelace, Brown, Macleod, McIver, Nitz



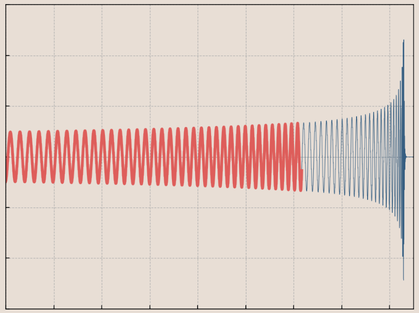

Early warning alert

Full alert

# Types of Notices

Mervyn Chan

LVK Identified a candidate where the objects have not merged



Early Warning Notice

Preliminary Notice

**If the candidate is astrophysical in origin**

Initial Notice with accompanying GCN circular

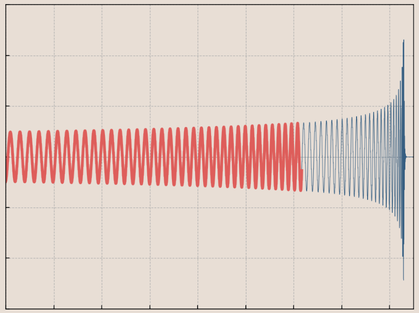
Update Notice

Retraction Notice

# Types of Notices

Mervyn Chan

LVK Identified a candidate where the objects have not merged



Early Warning Notice

Preliminary Notice

**If the candidate is terrestrial in origin**

Initial Notice with accompanying GCN circular

Retraction Notice

Update Notice

# How to receive LVK alerts - GCN Circulars

Mervyn Chan

- GCN Circulars are
  - Short human-readable astronomical bulletins (remember LVK notices are machine-readable)

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  - Short human-readable astronomical bulletins
- You can
  - subscribe to GCN Circulars to receive them by email
    - https://gcn.nasa.gov/docs/circulars/subscribing

## Subscribing to Circulars

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   >
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   >
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2. **Go to Email Notifications Settings**

   Once you are signed in, open the user menu in the navigation bar and go to Email Notifications.

3. **Turn your Subscription On or Off**

   Toggle the "On/Off" button next to Circulars to enable or disable GCN Circulars by email.

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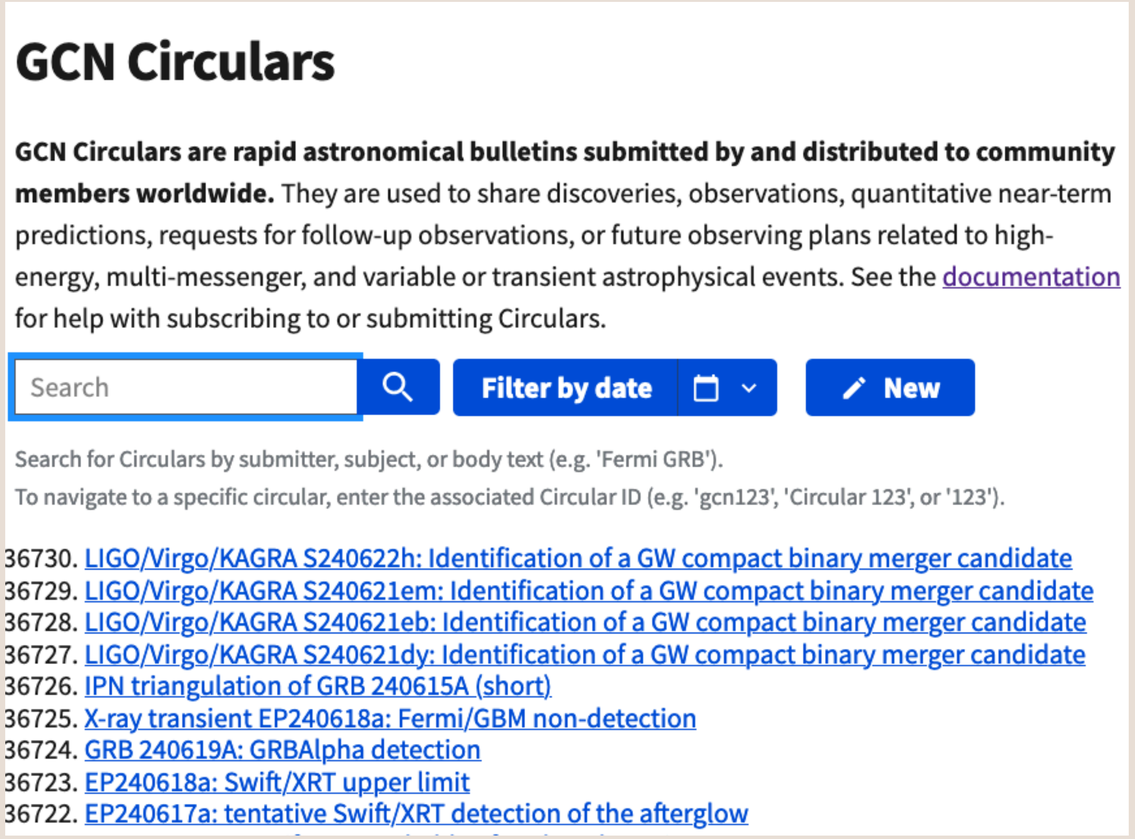

## GCN Circulars

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To navigate to a specific circular, enter the associated Circular ID (e.g. 'gcn123', 'Circular 123', or '123').

36730. LIGO/Virgo/KAGRA S240622h: Identification of a GW compact binary merger candidate
36729. LIGO/Virgo/KAGRA S240621em: Identification of a GW compact binary merger candidate
36728. LIGO/Virgo/KAGRA S240621eb: Identification of a GW compact binary merger candidate
36727. LIGO/Virgo/KAGRA S240621dy: Identification of a GW compact binary merger candidate
36726. IPN triangulation of GRB 240615A (short)
36725. X-ray transient EP240618a: Fermi/GBM non-detection
36724. GRB 240619A: GRBAlpha detection
36723. EP240618a: Swift/XRT upper limit
36722. EP240617a: tentative Swift/XRT detection of the afterglow

TITLE: GCN CIRCULAR
NUMBER: 36689
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FROM: simon.maenaut@kuleuven.be

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For further information about analysis methodology and the contents of this alert, refer to the LIGO/Virgo/KAGRA Public Alerts User Guide https://emfollow.docs.ligo.org/.

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The preferred sky map at this time is bayestar.multiorder.fits,2. For the bayestar.multiorder.fits,2 sky map, the 90% credible region is 5360 deg2. Marginalized over the whole sky, the a posteriori luminosity distance estimate is 7841 +/- 2600 Mpc (a posteriori mean +/- standard deviation).

For further information about analysis methodology and the contents of this alert, refer to the LIGO/Virgo/KAGRA Public Alerts User Guide https://emfollow.docs.ligo.org/.

[1] Klimenko et al. PRD 93, 042004 (2016) doi:10.1103/PhysRevD.93.042004
[2] Tsukada et al. PRD 108, 043004 (2023) doi:10.1103/PhysRevD.108.043004 and Ewing et al. (2023) arXiv:2305.05625
[3] Aubin et al. CQG 38, 095004 (2021) doi:10.1088/1361-6382/abe913
[4] Rose et al. (2022) arXiv:2201.05263 and Pankow et al. PRD 92, 023002 (2015) doi:10.1103/PhysRevD.92.023002
[5] Chatterjee et al. ApJ 896, 54 (2020) doi:10.3847/1538-4357/ab8dbe
[6] Singer & Price PRD 93, 024013 (2016) doi:10.1103/PhysRevD.93.024013

TITLE: GCN CIRCULAR
NUMBER: 36689
SUBJECT: LIGO/Virgo/KAGRA S240618ah: Identification of a GW compact binary merger candidate
DATE: 24/06/18 08:06:03 GMT
FROM: simon.maenaut@kuleuven.be

The LIGO Scientific Collaboration, the Virgo Collaboration, and the KAGRA Collaboration report:

We identified the compact binary merger candidate S240618ah during real-time processing of data from LIGO Hanford Observatory (H1) and LIGO Livingston Observatory (L1) at 2024-06-18 07:16:27.151 UTC (GPS time: 1402730205.151). The candidate was found by the CWB [1], GstLAL [2], and MBTA [3] analysis pipelines.

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# The Gravitational-Wave Candidate Event Database

Mervyn Chan

- LVK Public Alerts are also visible on GraceDB
  - https://gracedb.ligo.org/
- Contain
  - Information available in Notices and GCN Circulars
  - Extra information
    - Total number of LVK alert and retractions so far

O4 Significant Detection Candidates: **112** (127 Total - 15 Retracted)

O4 Low Significance Detection Candidates: **2068** (Total)

# The Gravitational-Wave Candidate Event Database

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    - Per-pipeline Event information

Per-Pipeline Event Information

| UID | Group | Pipeline | Search | gpstime | FAR (Hz) |
|---|---|---|---|---|---|
| G495360 | CBC | MBTA | AllSky | 1403041259.706 | 1.104e-05 |
| G495359 | CBC | gstlal | AllSky | 1403041259.721 | 6.752e-08 |
| G495362 | CBC | CWB | BBH | 1403041259.723 | 5.722e-08 |

# Summary

- LVK alerts of gravitational wave candidates include
  - **Notices**
    - NASA's General Coordinates Network (GCN, https://gcn.nasa.gov)
    - Scalable Cyberinfrastructure to support Multi-Messenger Astrophysics (SCiMMA, https://scimma.org)
    - 5 types of Notices
    - Machine-readable
    - Sky map may be available
  - **GCN Circulars**
    - Human readable
    - Can be subscribed to using emails
- Both include similar basic information about particular gravitational wave candidates
- GraceDB
  - Contains all the information available in Notices and GCN Circulars
  - Extra information such as the total number of gravitational wave candidates and per-pipeline table
- The LVK Public Alerts User Guide is a great resource
  - https://emfollow.docs.ligo.org/userguide/