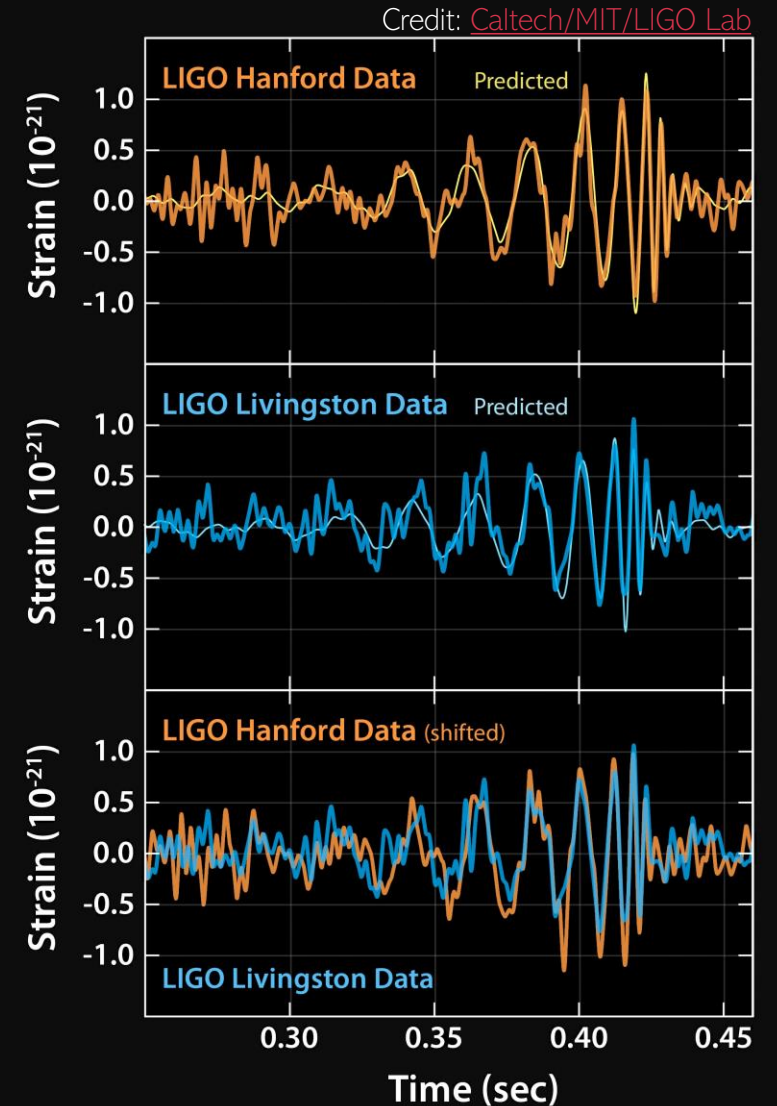


LIGO Update

Macleod and Raymond
IRIS Collaboration Meeting Dec 2024



Gravity Exploration
Institute
Sefydliad Archwilio
Disgyrchiant

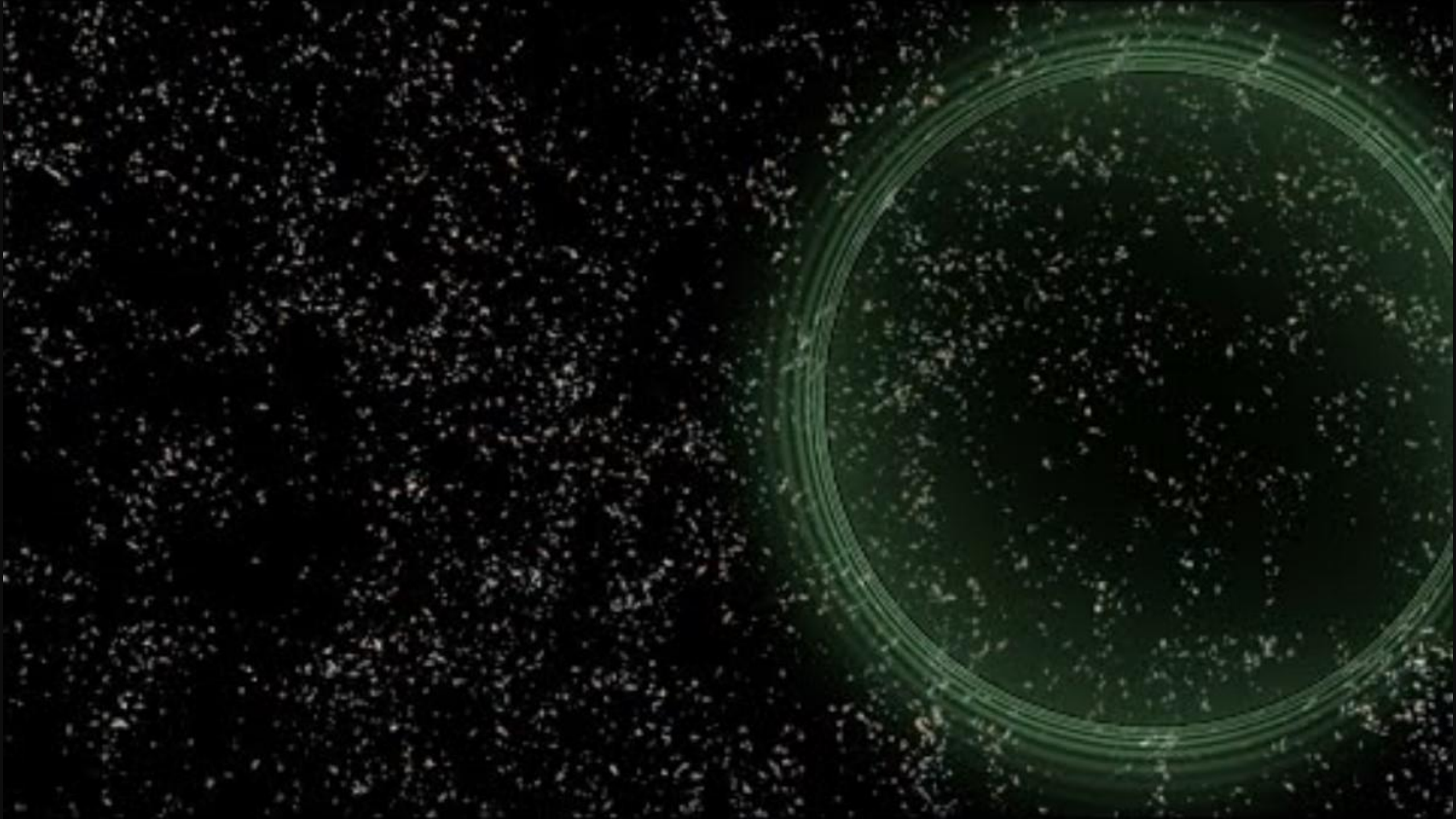


1. Introduction

What are gravitational waves?

Observatory network

Observing plans



LIGO-Virgo-KAGRA network

All GW Observatories work together

Observatory network:

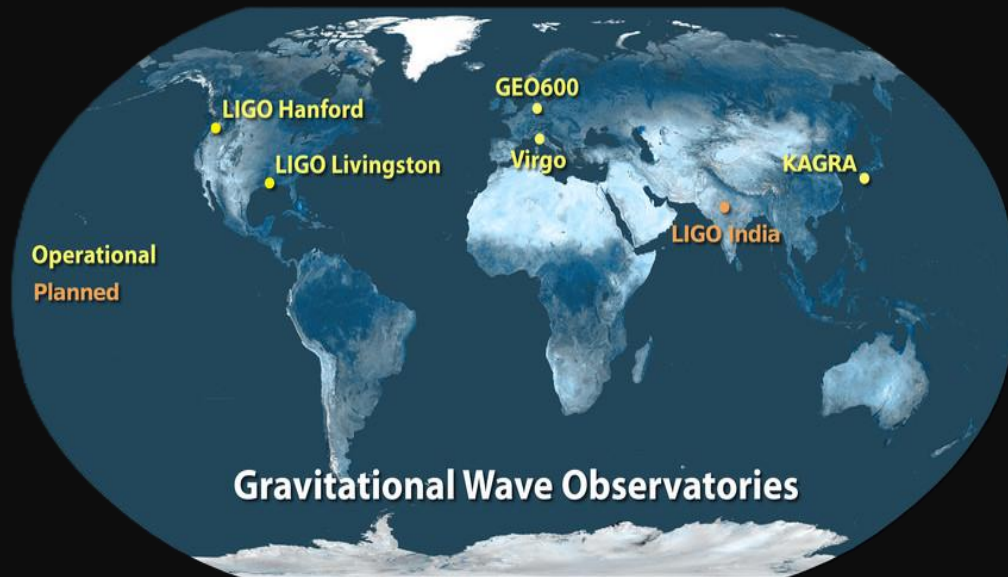
GEO (Germany)

LIGO (USA) x2

Virgo (Italy)

KAGRA (Japan)

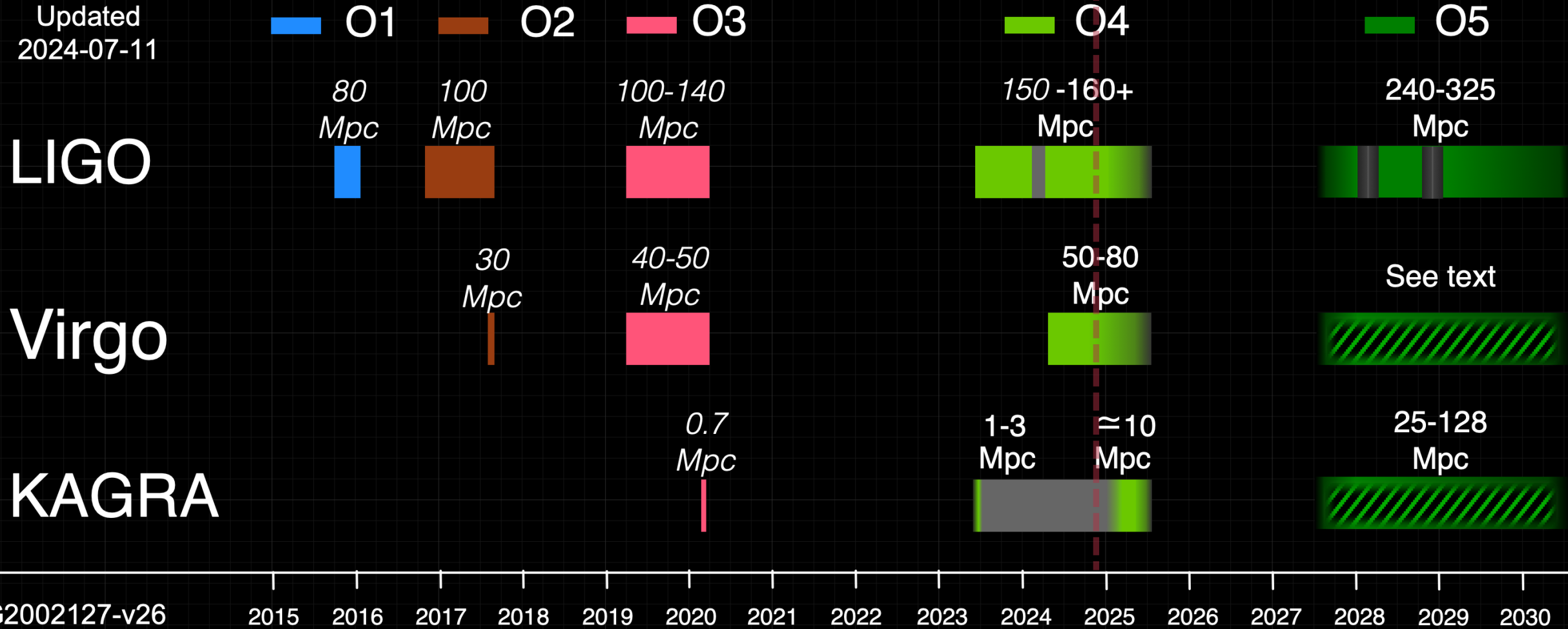
Multilateral data sharing agreement



Credit: [Caltech/MIT/LIGO Lab](#)

LVK observing plans

Updated
2024-07-11



LVK observing status



2. Data analysis

GW data processing
Low-latency alerts
Bulk analysis

GW data processing

'Multi-messenger' astrophysical events should be detected in GW **first**.

Alerts are published in 'low latency' (as quickly as possible) for EM observers to follow up.

Data recorded at each observatory in 1-second buffers

- Full data set $\sim 40\text{MB/s}$
 - Astrophysics data set $\sim 500\text{kB/s}$
-

Low-latency 'pre-processing'

- Calibration
 - Data-quality checks
-

Low-latency detection

- Searches for GW signals
-

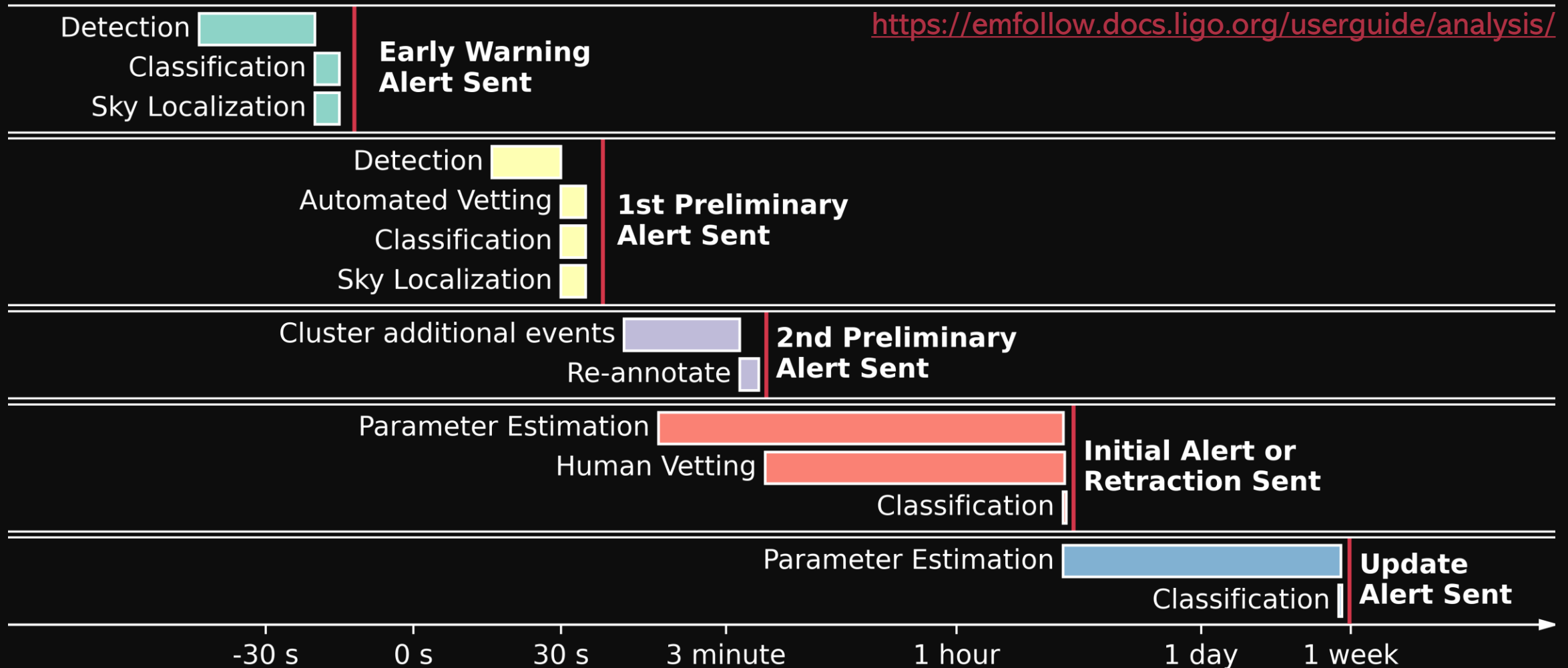
Low-latency follow-up

- Initial parameter estimation
 - Event classification
-

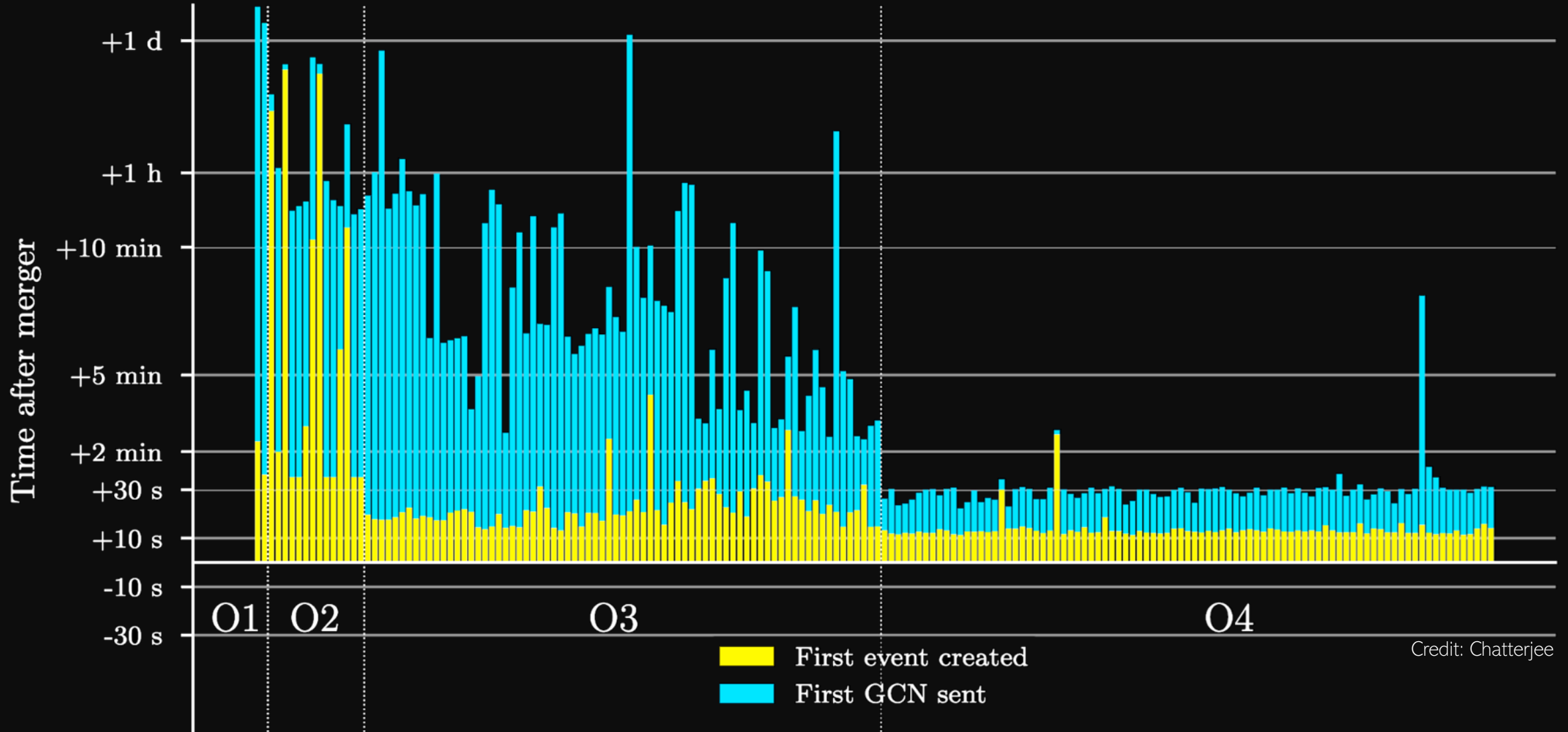
Public alerts

GW online data flow

Time relative to gravitational-wave merger



Public alert latency



Astrophysics data stored in binary files (custom format).

Bulk analysis

Large-scale offline analysis

Collaboration with [PATh](#) (OSG + CHTC)

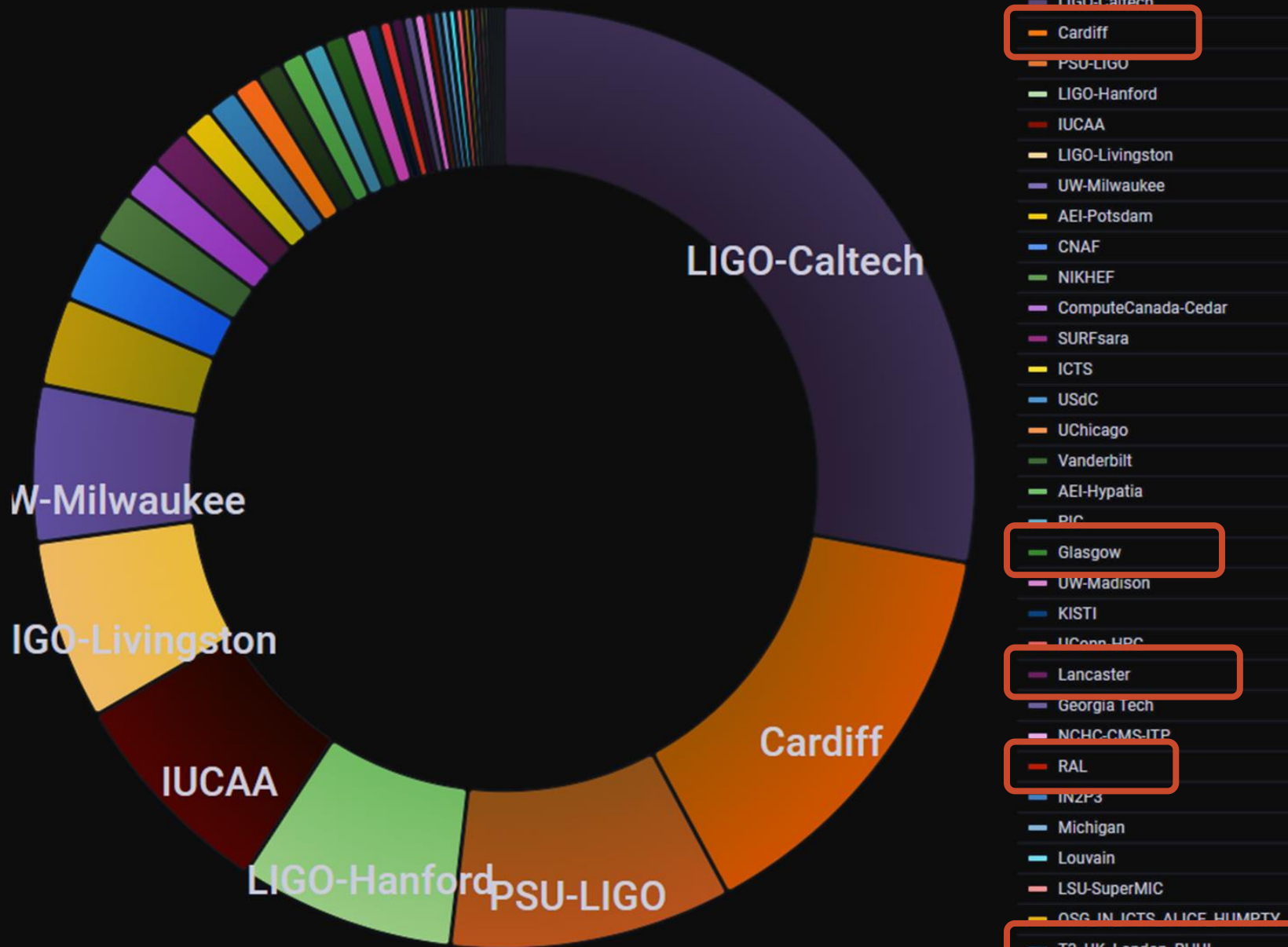
Distributed using [Pelican](#) (XRootD)

- One Origin per Observatory
 - Global cache network for efficient access
 - HTTP(S) with Bearer auth (SciToken)
-

Analysis workflows managed by HTCondor

- Pool of globally distributed resources
- Opportunistic use of any execute point resource
- Outputs available at access point

UK/IRIS computing is critical for LVK



3. Scientific results

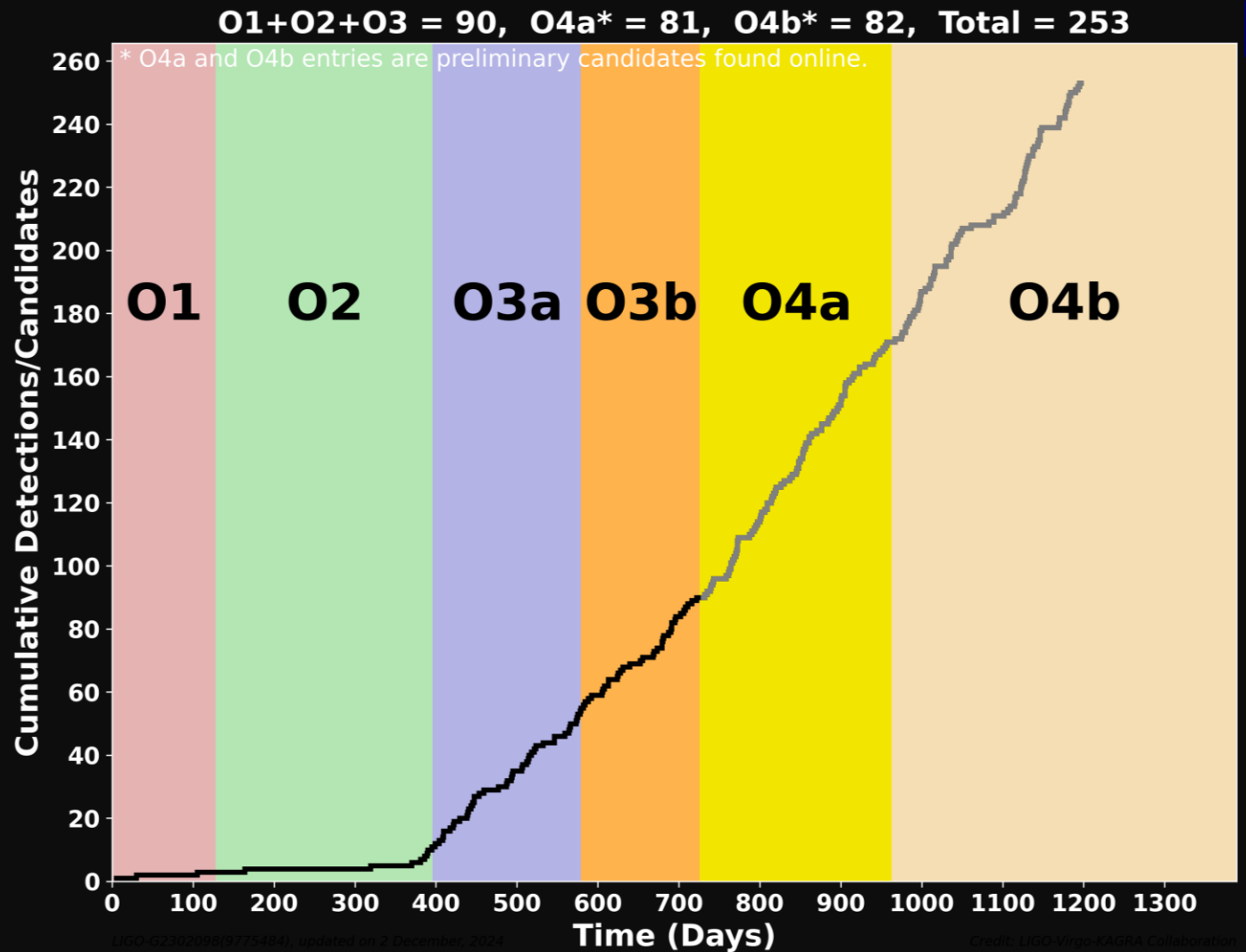
Low-latency alert statistics

O4 results highlights

O4 candidates

- **O1** (09/2015 - 01/2016)
- **O2** (11/2016 - 08/2017)
- **O3a** (04/2019 - 10/2019)
- **O3b** (11/2019 - 03/2020)
- **O4a** (05/2023 - 01/2024)
- **O4b** (04/2024 - 06/2025)

Event **rate** scales as the **cube** of the range



LIGO-G2302096v725464, updated on 2 December 2024

Credit: LIGO-Virgo-KAGRA Collaboration

<https://gracedb.ligo.org/superevents/public/O4/>

LIGO/Virgo/KAGRA Public Alerts

- More details about public alerts are provided in the [LIGO/Virgo/KAGRA Alerts User Guide](#).
- Retractions are marked in **red**. Retraction means that the candidate was manually vetted and is no longer considered a candidate of interest.
- Less-significant events are marked in **grey**, and are not manually vetted. Consult the [LVK Alerts User Guide](#) for more information on significance in O4.
- Less-significant events are not shown by default. Press "Show All Public Events" to show significant and less-significant events.

O4 Significant Detection Candidates: **164** (183 Total - 19 Retracted)

O4 Low Significance Detection Candidates: **2766** (Total)

Show All Public Events

Page 1 of 13. [next](#) [last](#) »

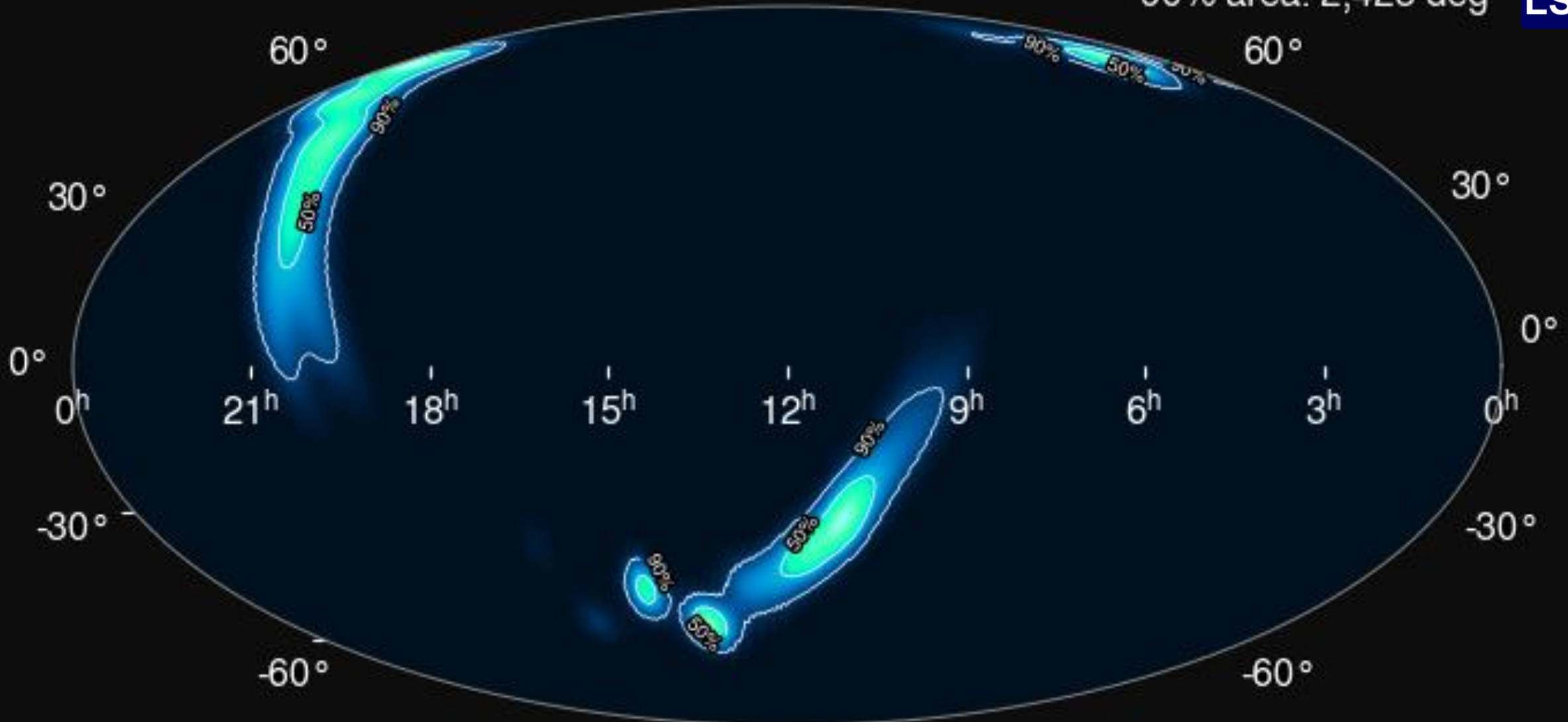
SORT: EVENT ID (A-Z) ▾

Event ID	Possible Source (Probability)	Significant	UTC	GCN	Location	FAR	Comments
S241129aa	BBH (>99%)	Yes	Nov. 29, 2024 02:18:32 UTC	GCN Circular Query Notices VOE		1 per 7.9146e+11 years	
S241127aj	BBH (>99%)	Yes	Nov. 27, 2024 06:10:08 UTC	GCN Circular Query Notices VOE		1 per 4.8758e+30 years	

event ID: G527793

50% area: 688 deg²

90% area: 2,423 deg²



<https://gracedb.ligo.org/superevents/S241125n/>

event ID: S241127aj
50% area: 15 deg²
90% area: 105 deg²



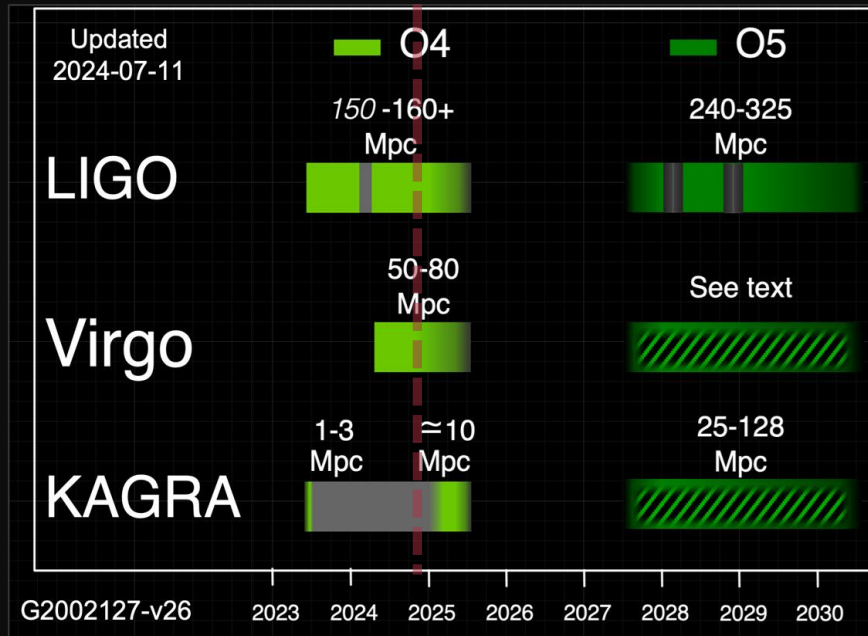
<https://gracedb.ligo.org/superevents/S241127aj/>

4. Future plans

Observing run 5

The next-generation detector network

Observing run 5



<https://observing.docs.ligo.org/plan/>

O4 will end in **June 2025**

O5 due to start **~Q3 2027**

Expect increase of **~75%** in range

~x5 increase in event rate

~x2 increase in compute need

- CPU **optimisation**
- Accelerator **porting**
- **New methods** (ML/AI)

Next generation

2030+



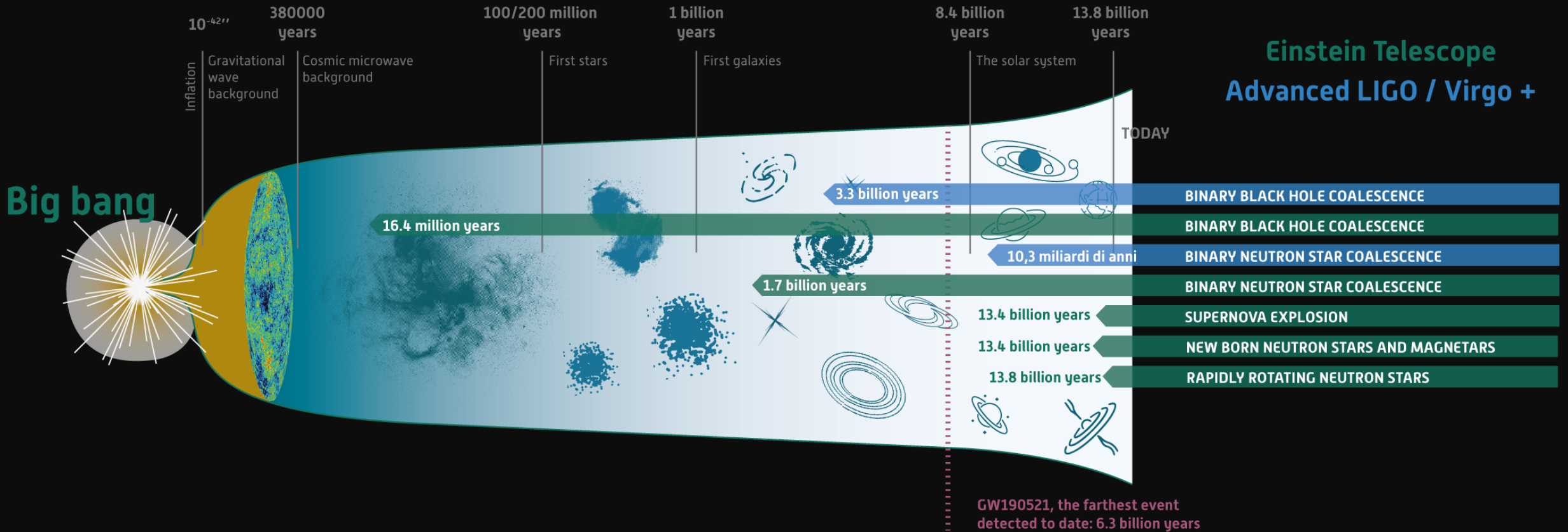
Current-generation (2G) observatories are reaching facility limits.

Next-generation (3G) projects are in design phase, with **initial funding**.

Expected **x1000 increase** in event rate.

Need improved waveform models and computational methods.

Dedicated STFC funding spread across UK-GW groups.



End

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raymondv@cardiff.ac.uk

Links

Live network status:

<https://online.ligo.org>

Latest events:

<https://graced.ligo.org/superevents/public/O4/>

LVK Observing plans

<https://observing.docs.ligo.org/plan/>

LIGO Data Management Plan:

<https://dcc.ligo.org/LIGO-M1000066/public>