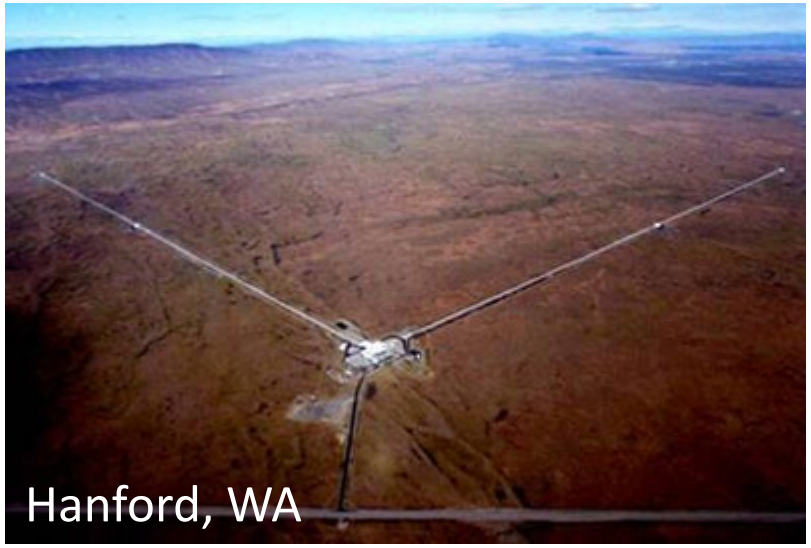
LIGO and the future of Multimessenger Astrophysics

AAAC Meeting – January 27, 2023

Laser Interferometric Gravitational-wave Observatory (LIGO)


Livingston, LA

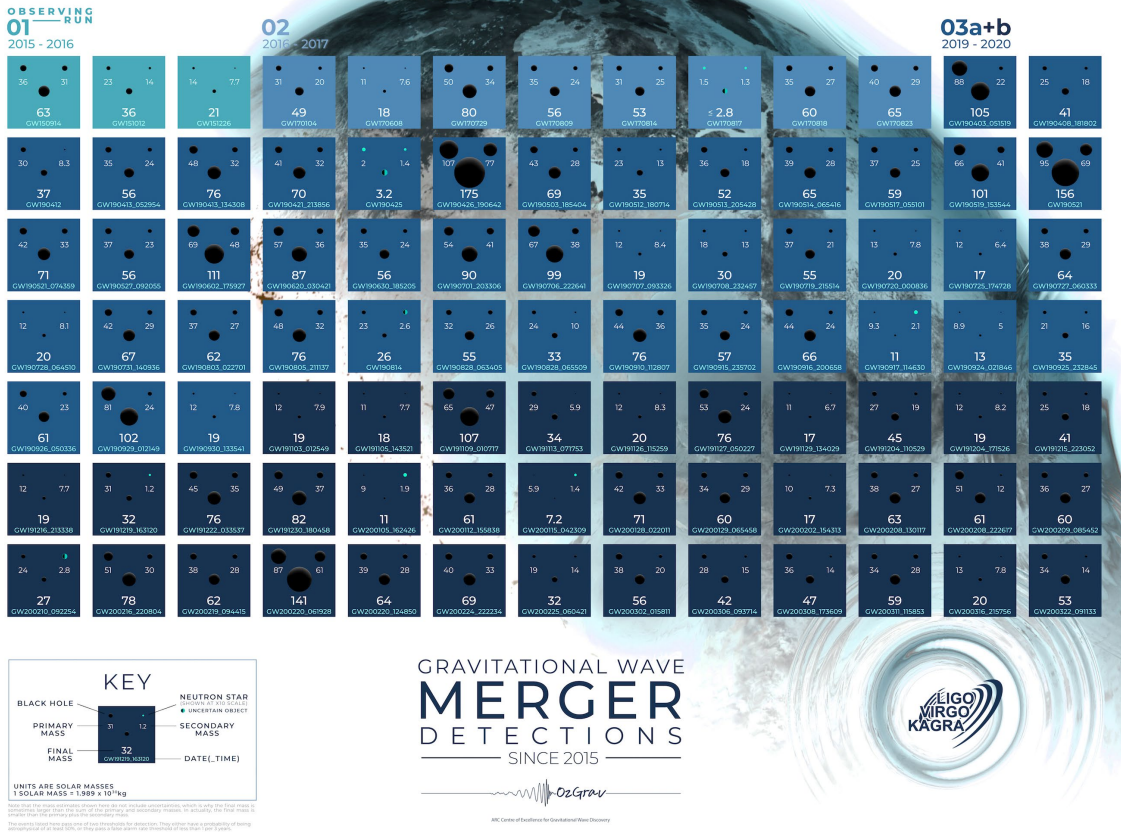

Hanford, WA

Virgo (Italy) & KAGRA (Japan)

The Observational runs of the Advanced LIGO era

LIGO-Virgo-KAGRA 3rd observational run (O3, April 1, 2019, to March 27, 2020) detected 35 new GW events. The catalog GWTC-3 (arXiv: 2111.03606) shows details of the 90 detections to date:

- 2 neutron star – neutron star mergers
- 4 black hole – neutron star mergers
- 2 black hole – uncertain objects (either BH or NS)
- 82 black hole – black hole mergers



Exceptional event: 2nd Neutron Star Merger

ApJL 892 (2020) L3 (GW190425)

No EM-counterpart detected (very distant, 500 Mly)

Total binary mass (3.4 $M_\odot$) larger than any known galactic NS binary (17 have been detected with a Maximum mass of 2.9 $M_\odot$)

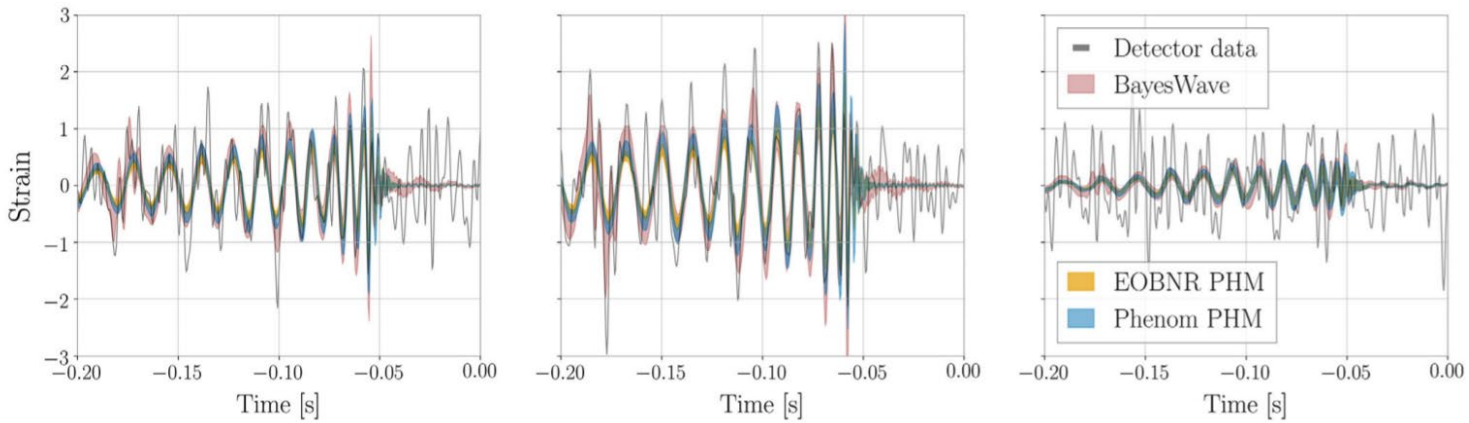
Exceptional event: Two black holes with very unequal masses

PRD 102 (2020) 043015 (GW190412)

- BHs with 30 and 8 $M_\odot$ with a mass ratio (3.75)
  Merger: 37 $M_\odot$

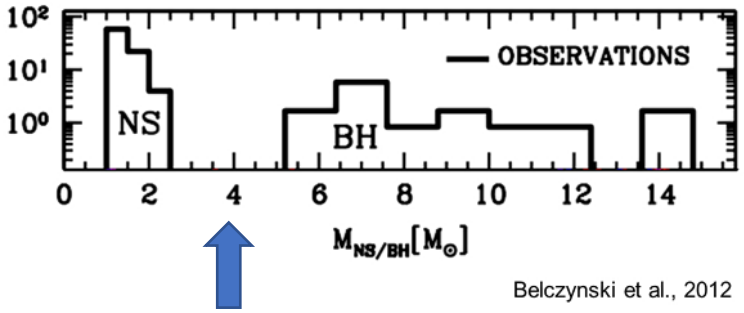
$$h_+ - ih_\times = \sum_{\ell \geq 2} \sum_{-\ell \leq m \leq \ell} \frac{h_{\ell m}(t, \boldsymbol{\lambda})}{D_{\mathrm{L}}} {}_{-2}Y_{\ell m}(\theta, \phi)$$

- Detectable higher-order modes



Black Hole Mass Gaps

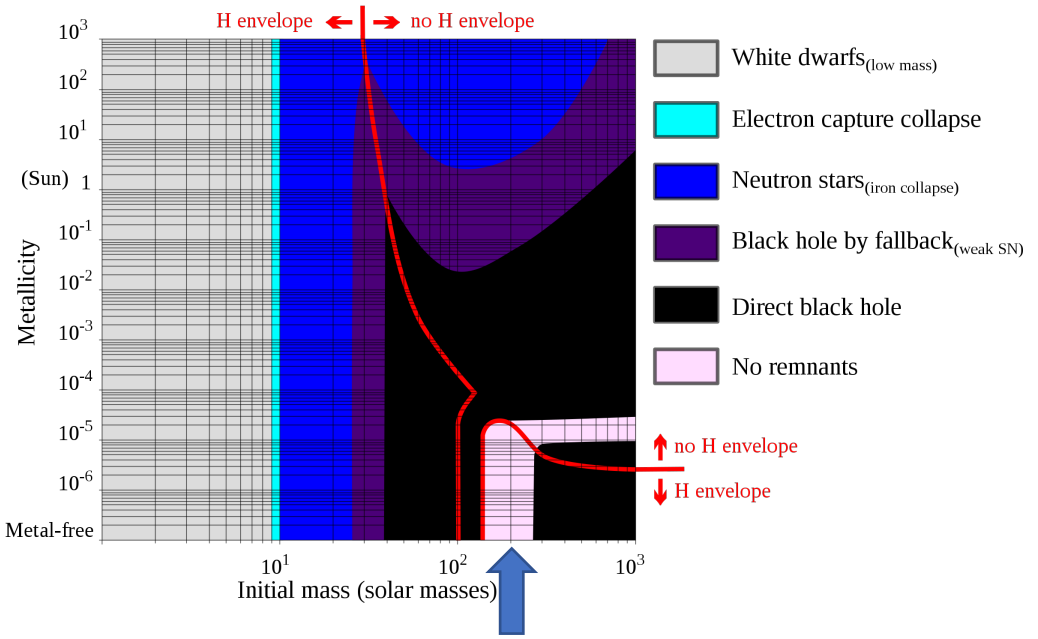
Low mass gap: ~2.5 to 5 $M_\odot$



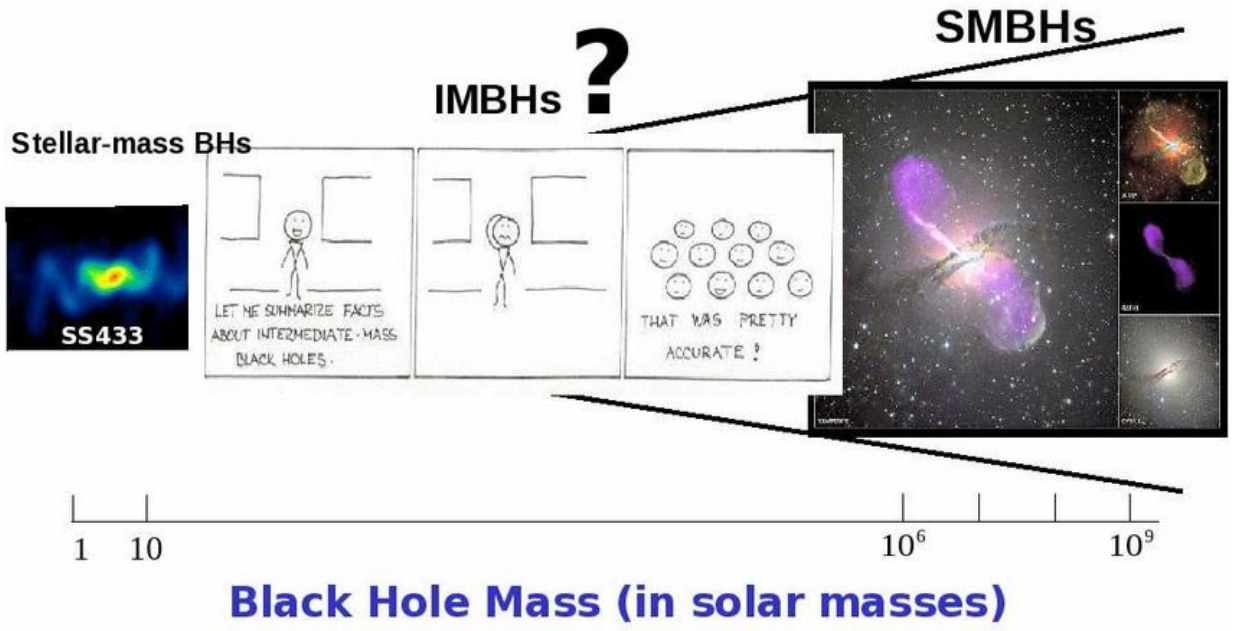
Belczynski et al., 2012

High mass gap: ~65 to 120 $M_\odot$

Remnants of massive single stars



Intermediate Mass Black Holes



Exceptional event: The Object in the “Mass gap”

ApJL 896 (2020) L44 (GW190814)

Binary with a 23 $M_\odot$ BH and a 2.6 $M_\odot$ object

The most extreme mass ratio (9!)

(No EM counterpart found)

If NS: First BH/NS detected and

Heaviest NS ever observed

If BH: Lightest BH ever observed

Either way, it falls in the low mass gap!

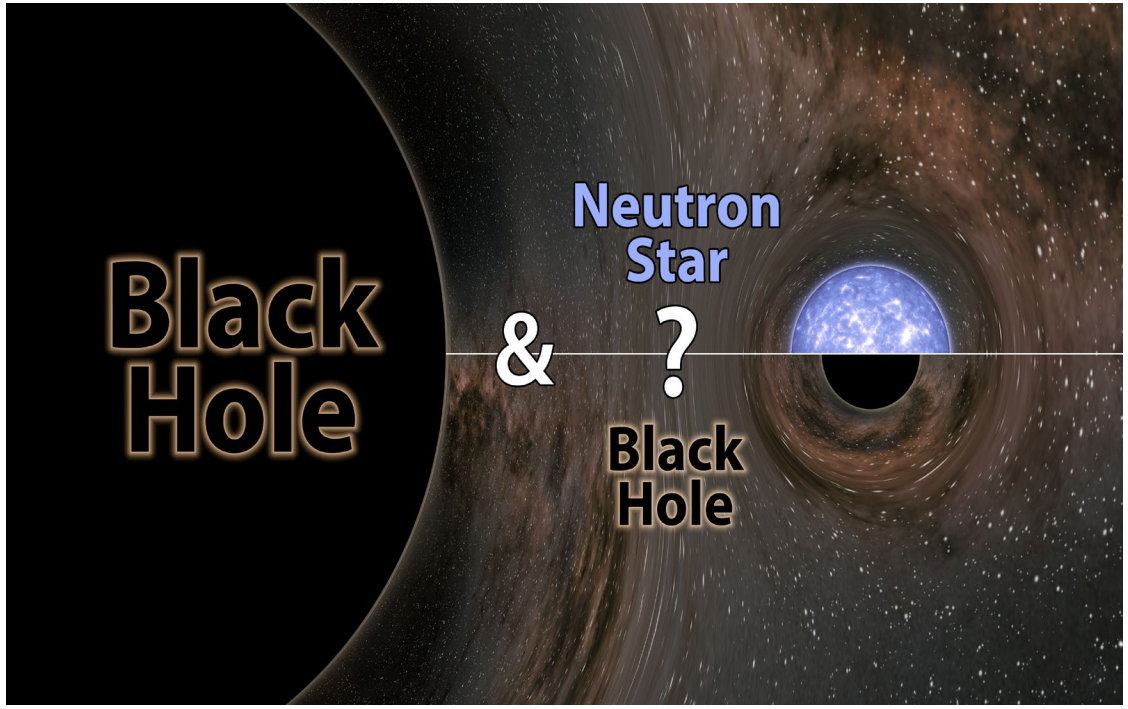


Image: LIGO.org

Exceptional event: The most massive BH binary yet

PRD 125 (2020) 101102 (GW190521)

One (two?) BH in the high mass gap

The merger created the first intermediate mass BH ever observed

The most powerful explosion detected since the Big Bang: 8 $M_\odot$!

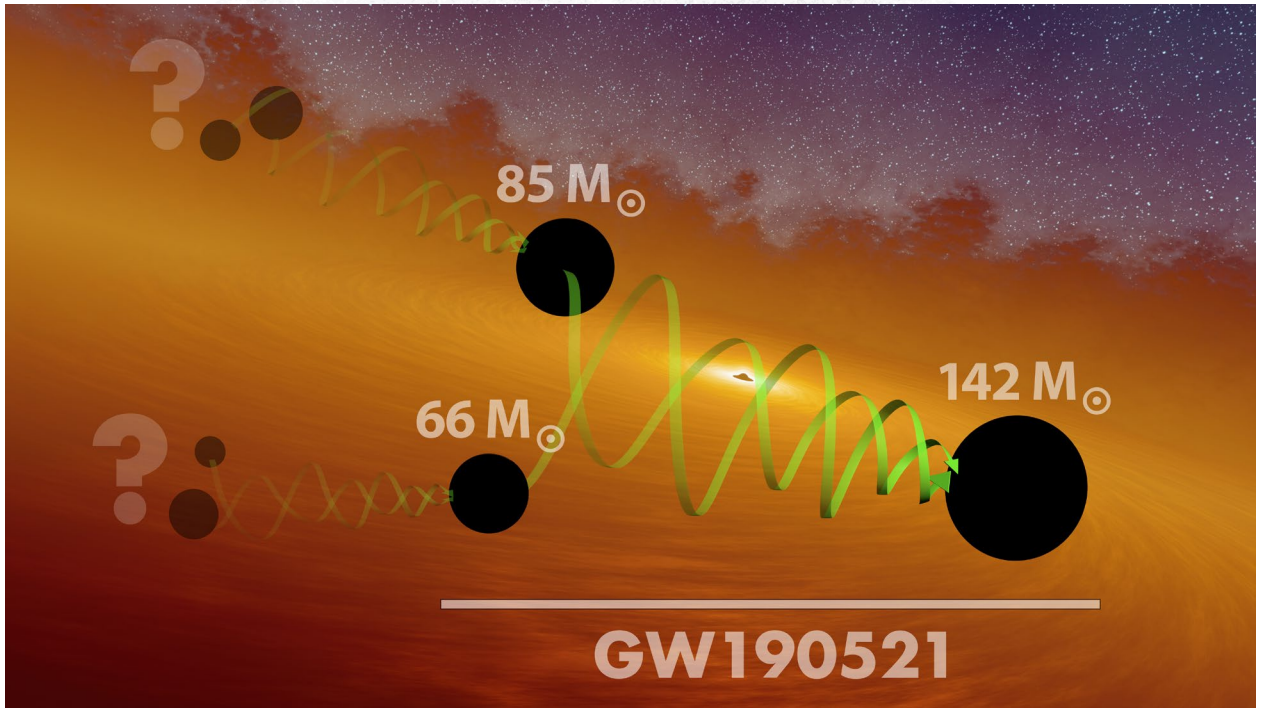


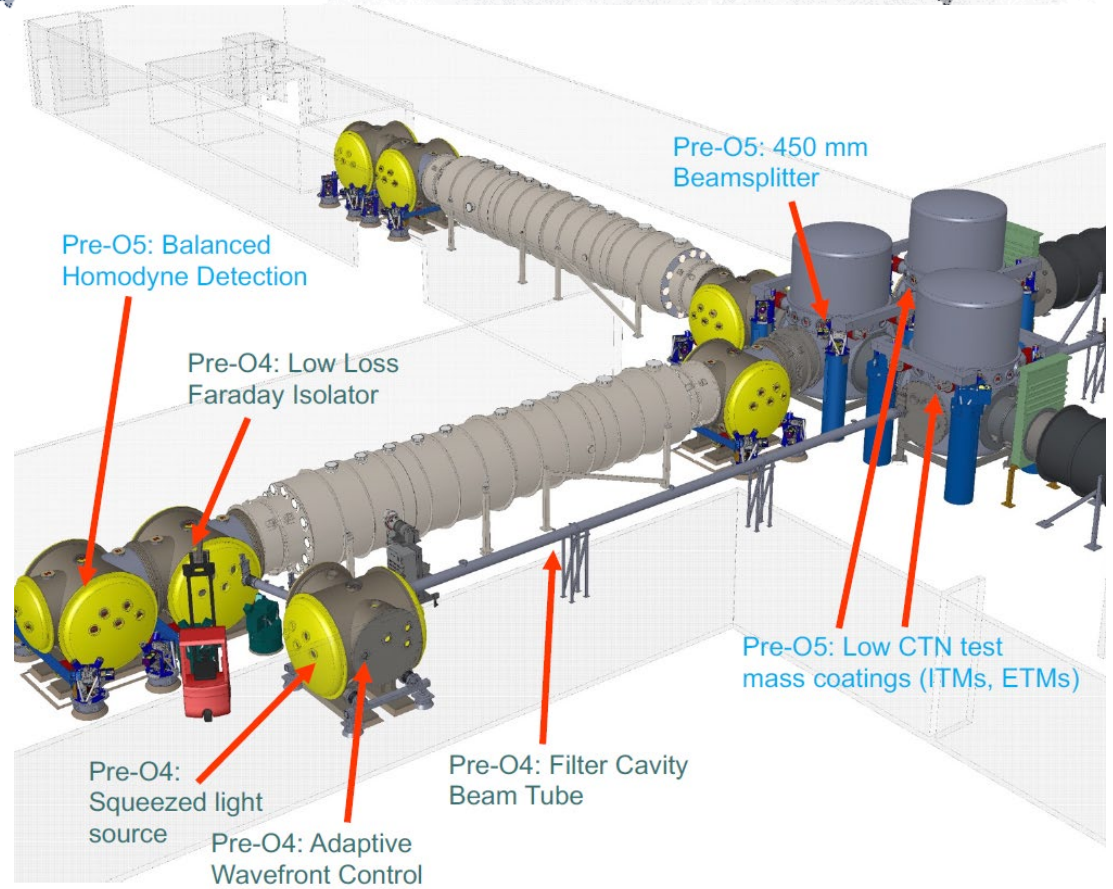
Image: LIGO.org

LIGO Upgrade A+

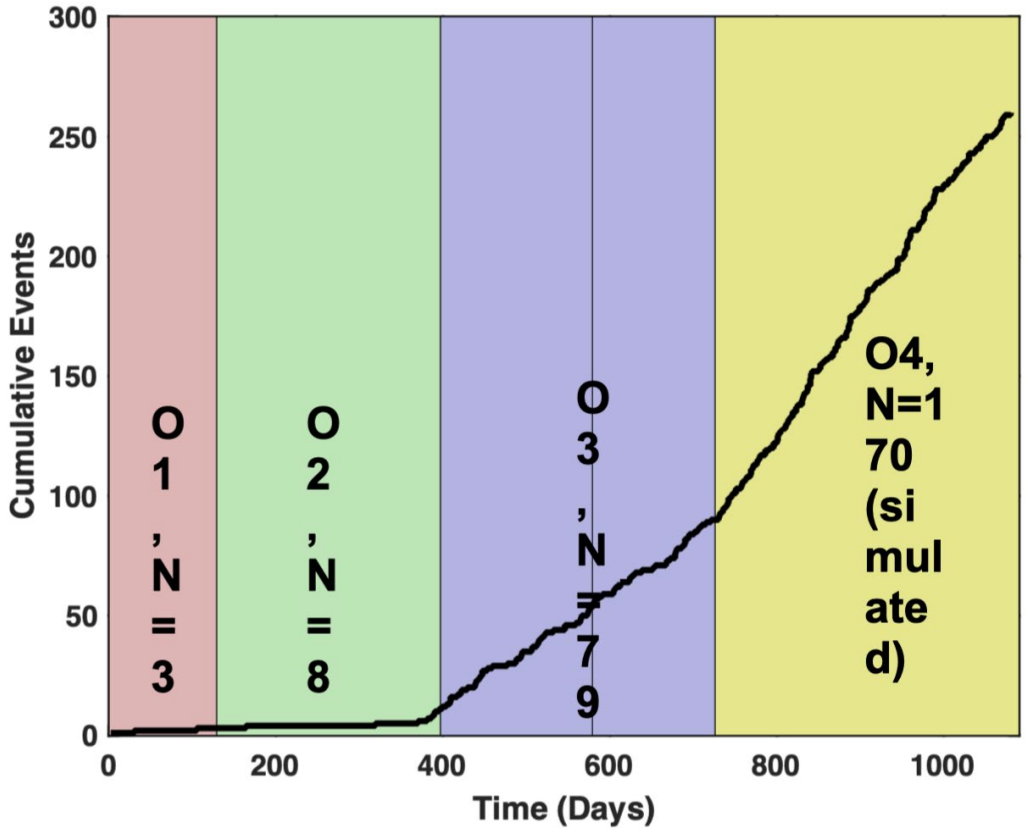
A+ is a LIGO upgrade supported by NSF, UK and Australia (NSF contributes $20.4M out of about $30M)

O4 will implement the 1st stage of A+ (frequency dependent squeezing), with BNS target sensitivity of 190 Mpc – May 24, 2023

O5 will implement the 2nd stage of A+ (new mirror coatings), with BNS target sensitivity of 325 Mpc – ~ 2026



How many events will O4 detect?

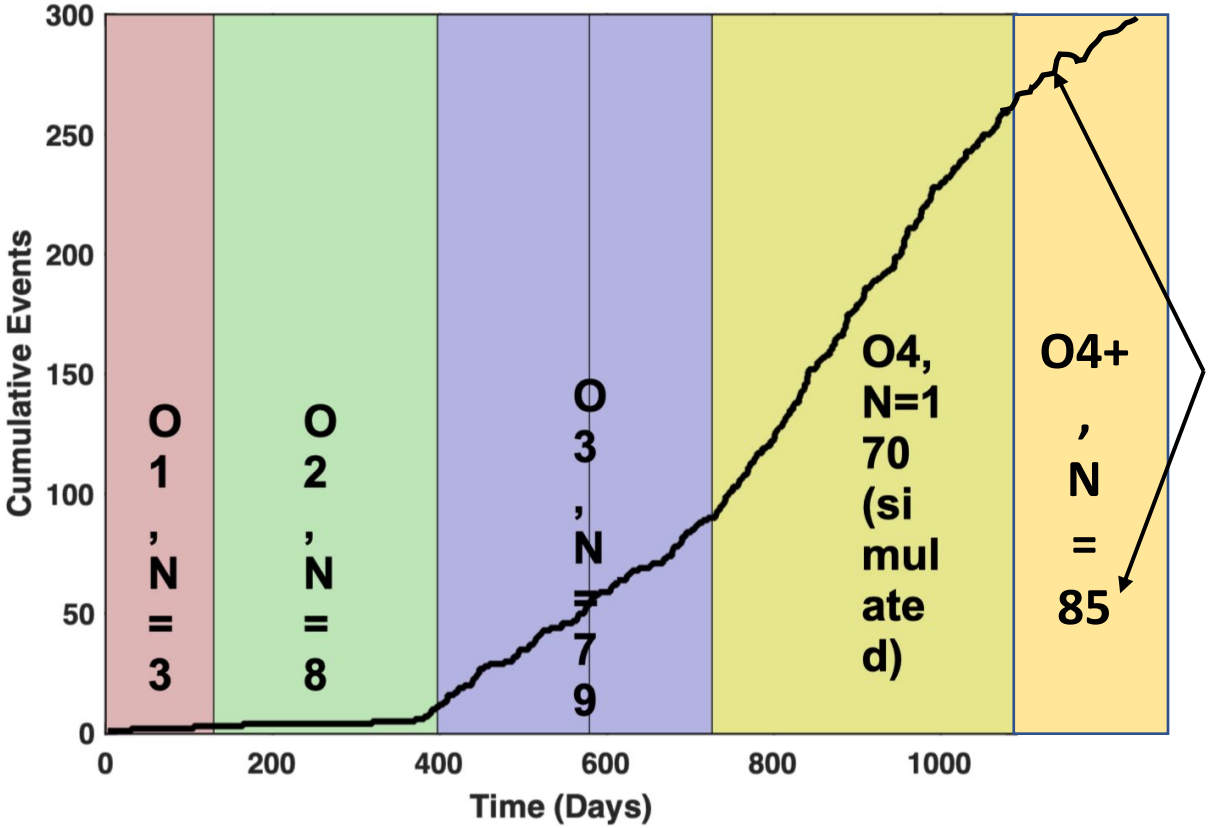


Interactions with the greater Astronomical Community

LVK-EM

Monthly virtual town hall meetings between LIGO-Virgo-KAGRA and the astronomical community (https://wiki.gw-astronomy.org/OpenLVEM)

At the request of the EM community, LIGO-Virgo-KAGRA agreed to extend the duration of O4 from 12 to 18 months, with the possibility of 24 months.



Windows on the Universe

Since 2019, the WoU program supports proposals in any area of research supported through the participating divisions that address at least one of the following criteria:

- ***Coordination*** of observations involving more than one messenger
- ***Observations*** of potential sources of more than one messenger
- ***Interpretation*** of observations of astrophysical objects that are sources of more than one messenger

This could be the last year of Windows on the Universe (renewal is currently under consideration)