Image credit: AURORE SIMONNET/LIGO/CALTECH/MIT/SONOMA STATE



Universität Zürich[UZH]

# Overview of LVK status and plans

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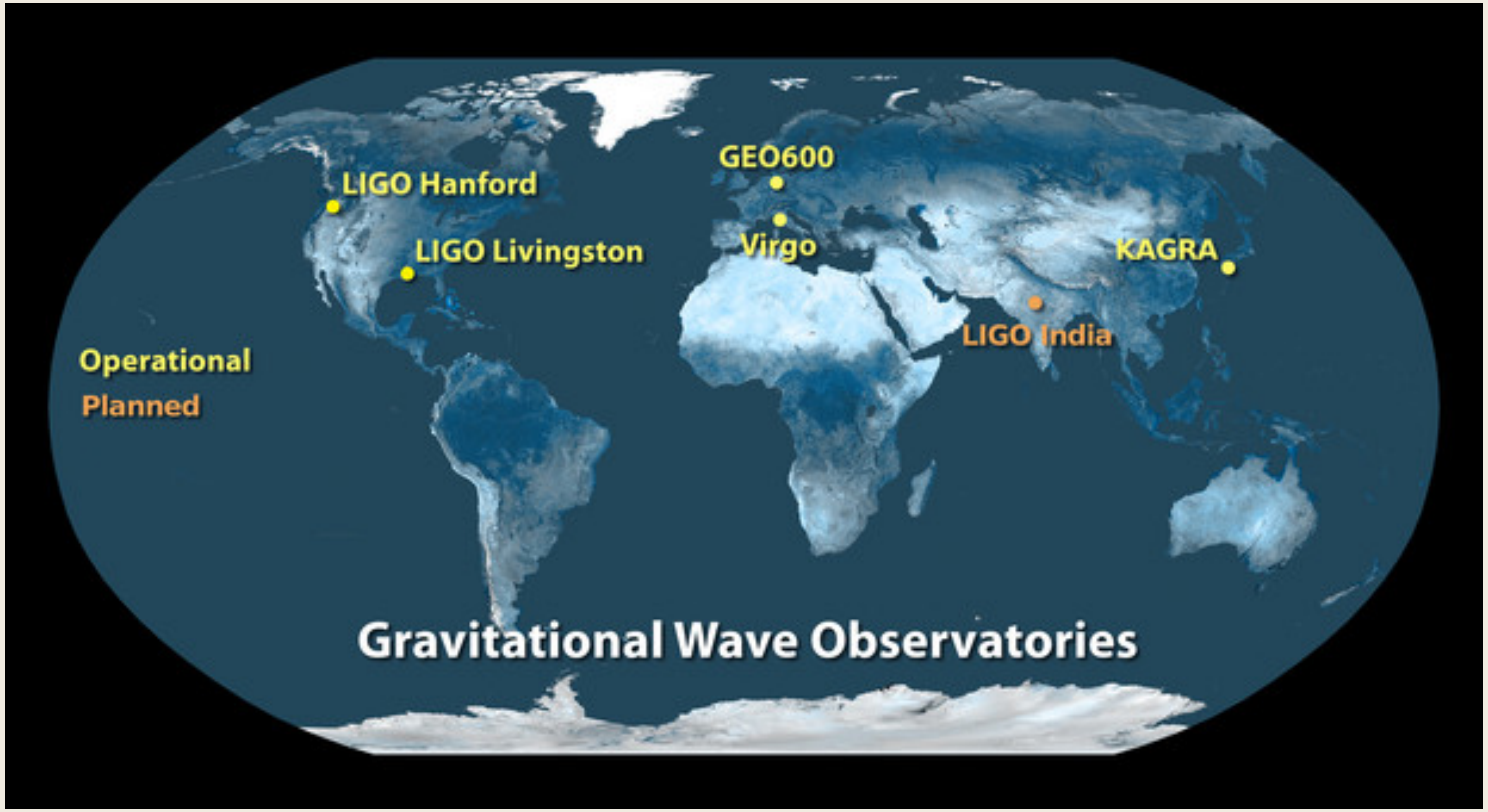
University of Zurich

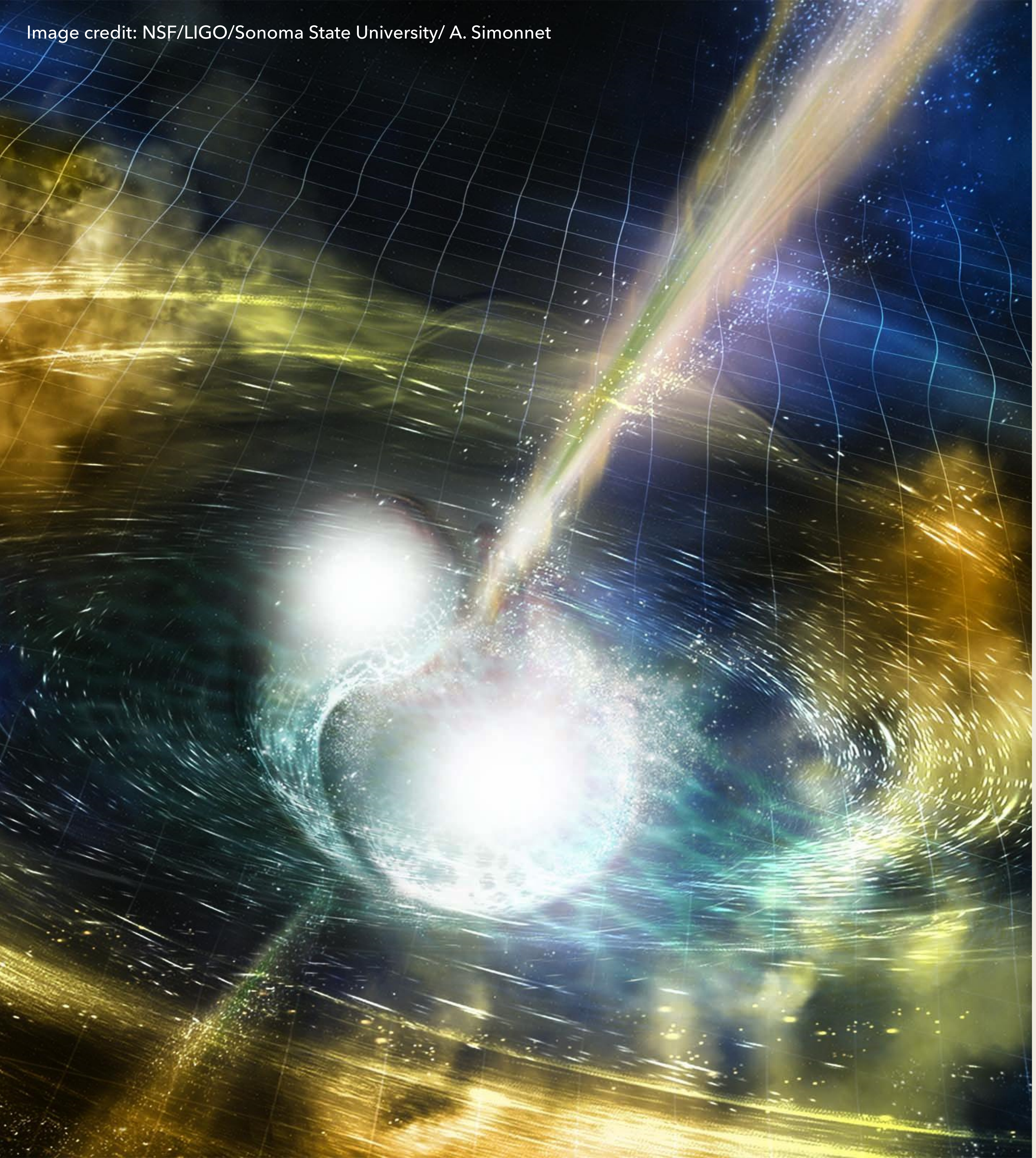
# Current generation ground-based detectors




Credit: https://www.ligo.caltech.edu/image/ligo20160211c

# Gravitational wave observations


Credit: LIGO-Virgo / Aaron Geller / Northwestern University



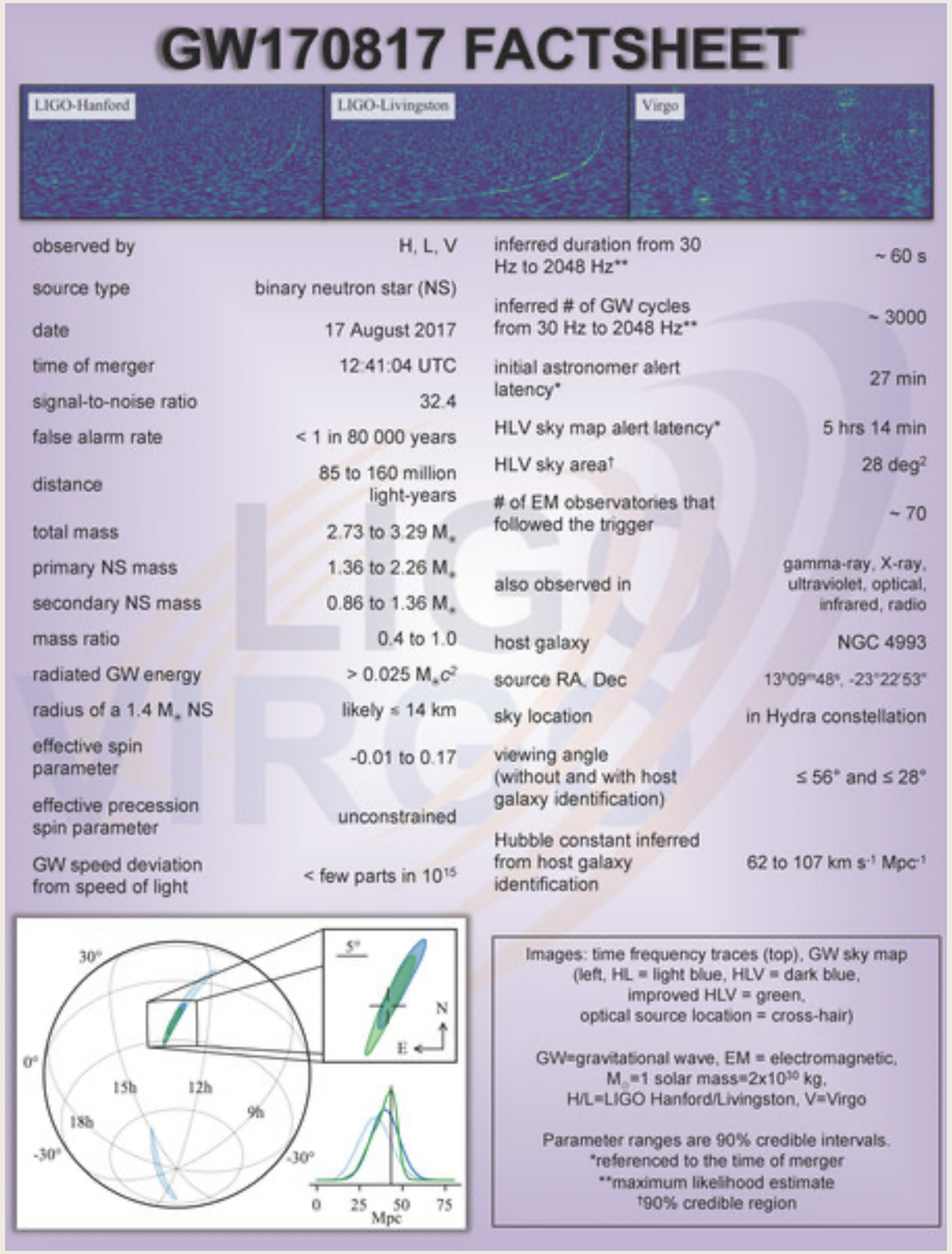



# Detection highlights

- GW170817: BNS + EM counterparts
- GW200105 and GW200115: NSBH
- GW190814: mystery mass gap object
- GW190521: first IMBH detection
- GW190412 and GW200129: spinning black holes

# GW170817: BNS + EM counterpart

- Gravitational wave signal detected strongly by LIGO but only weakly by Virgo
- Multi-messenger event very informative:
  - BNS are a source of short gamma ray bursts
  - Origin of gold and platinum




Credit: https://www.ligo.caltech.edu/image/20171016g

# GW200105 and GW200115: NSBH systems

FACT SHEET

GW200105 GW200115

**First observation of neutron star-black hole (NSBH) binaries**

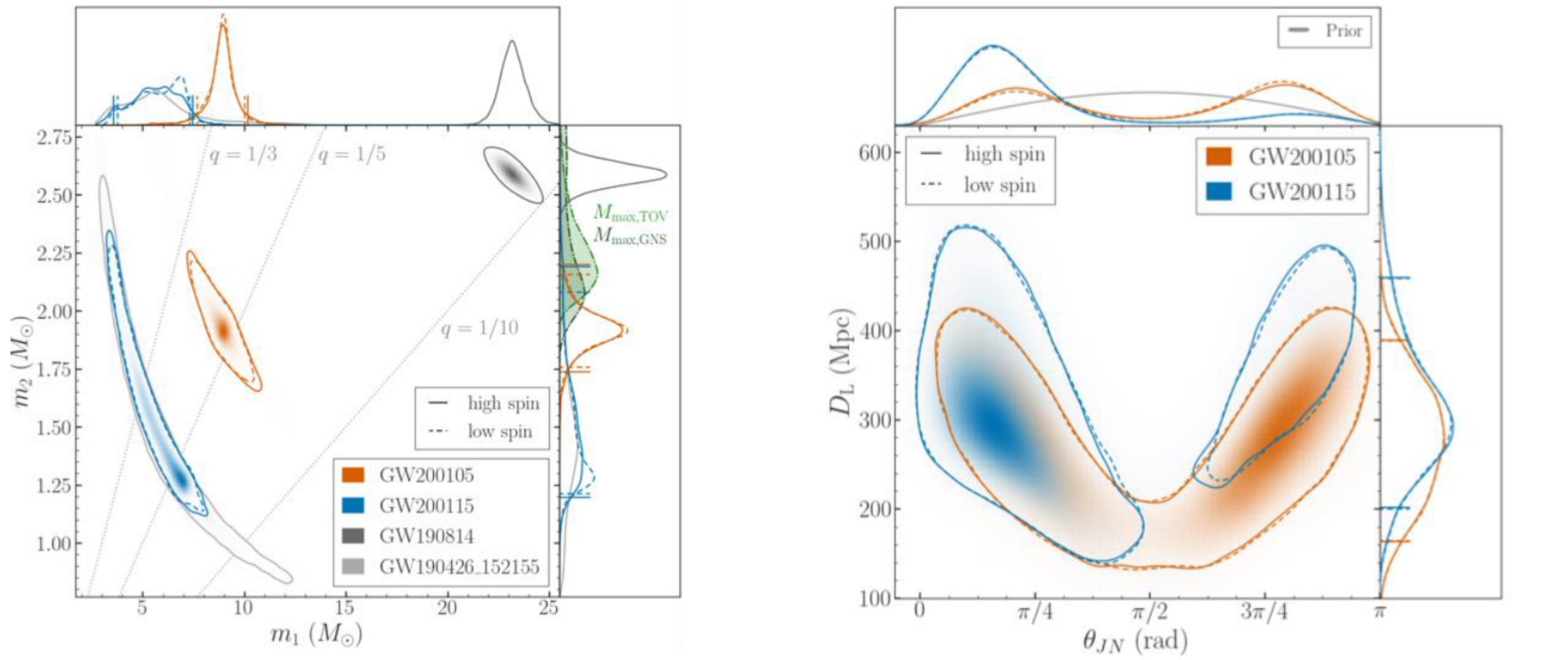
*All parameter ranges correspond to 90% credible bounds. Quoted values are for high spin (<0.99) neutron-star priors*

| | GW200105 | GW200115 |
|---|---|---|
| observed by | LIGO Livingston and Virgo | LIGO Livingston & Hanford and Virgo |
| date, time | 5 Jan 2020, 16:24:26 UTC | 15 Jan 2020, 04:23:10 UTC |
| likely distance | 170 to 390 Mpc | 200 to 450 Mpc |
| source redshift | 0.04 to 0.08 | 0.05 to 0.10 |
| signal-to-noise ratio | 13.9 | 11.6 |
| false alarm rate | < 1 in 2.8 yr | < 1 in 100,000 yr |
| Source masses ($M_\odot$) | | |
| total mass | 9.7 to 12.0 | 5.7 to 8.6 |
| primary (BH) | 7.4 to 10.1 | 3.6 to 7.5 |
| secondary (NS) | 1.7 to 2.2 | 1.2 to 2.2 |
| mass ratio | 0.18 to 0.30 | 0.16 to 0.61 |
| BH spin | 0.00 to 0.30 | 0.04 to 0.81 |
| effective inspiral spin | −0.16 to 0.10 | −0.54 to 0.04 |
| effective precession spin | 0.02 to 0.23 | 0.04 to 0.51 |

Inferred merger rate density of NSBH systems*: 12 to 120 $yr^{-1}$ $Gpc^{-3}$

* Assuming GW200105 and GW200115 are representative of the NSBH population

**Images:** companion masses (left), distance vs inclination (right), both with low (<0.05) and high (<0.99) spin priors for the neutron stars



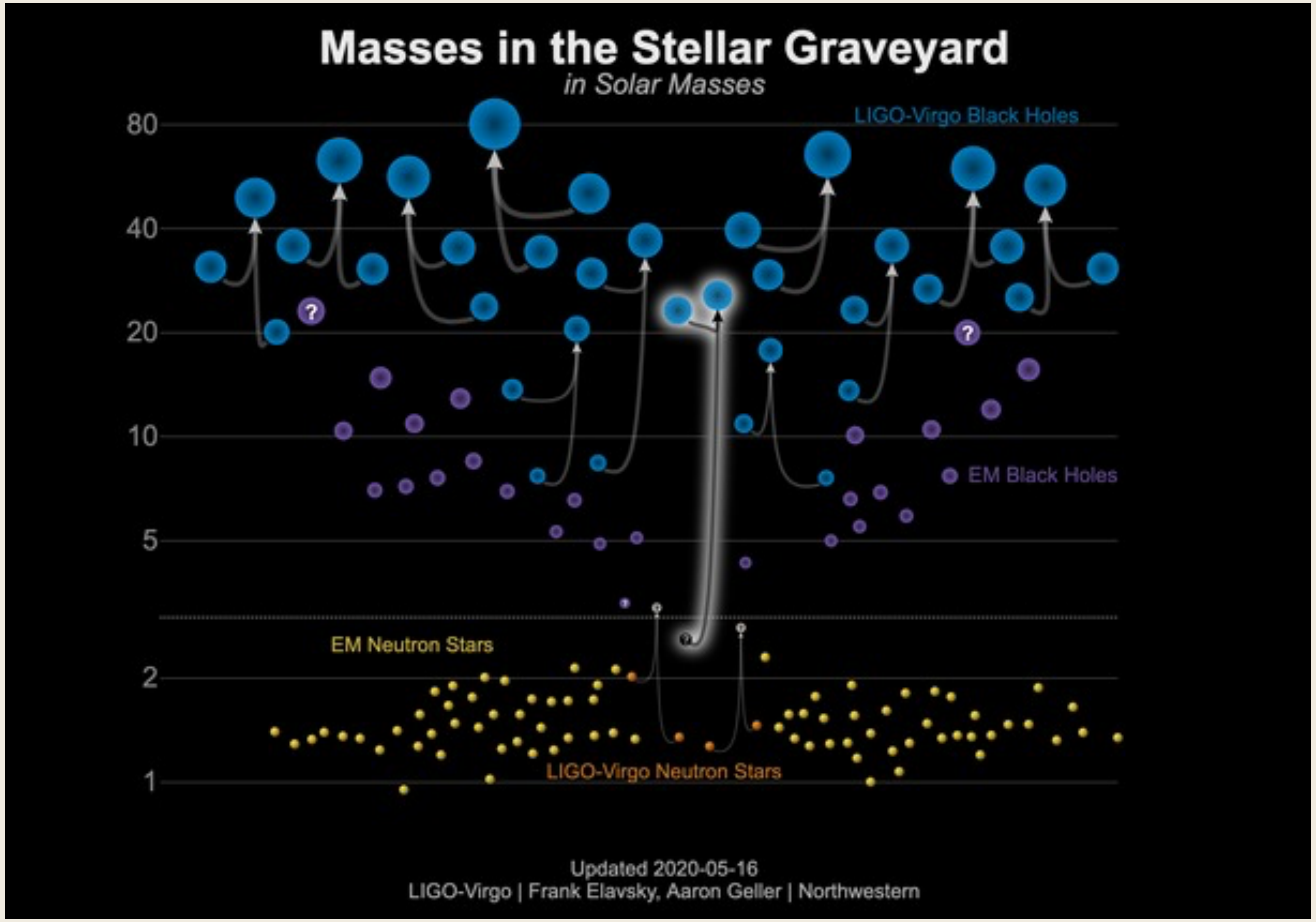

Credits: B.S. Sathyaprakash, Penn State and Cardiff University

- First ever evidence of a binary composed of a neutron star and a black hole
- No EM counterpart
- Estimated NSBH merger rate of ~1/month within 1 billion light years from Earth

Credit: B. S. Sathyaprakash, Penn State and Cardiff University

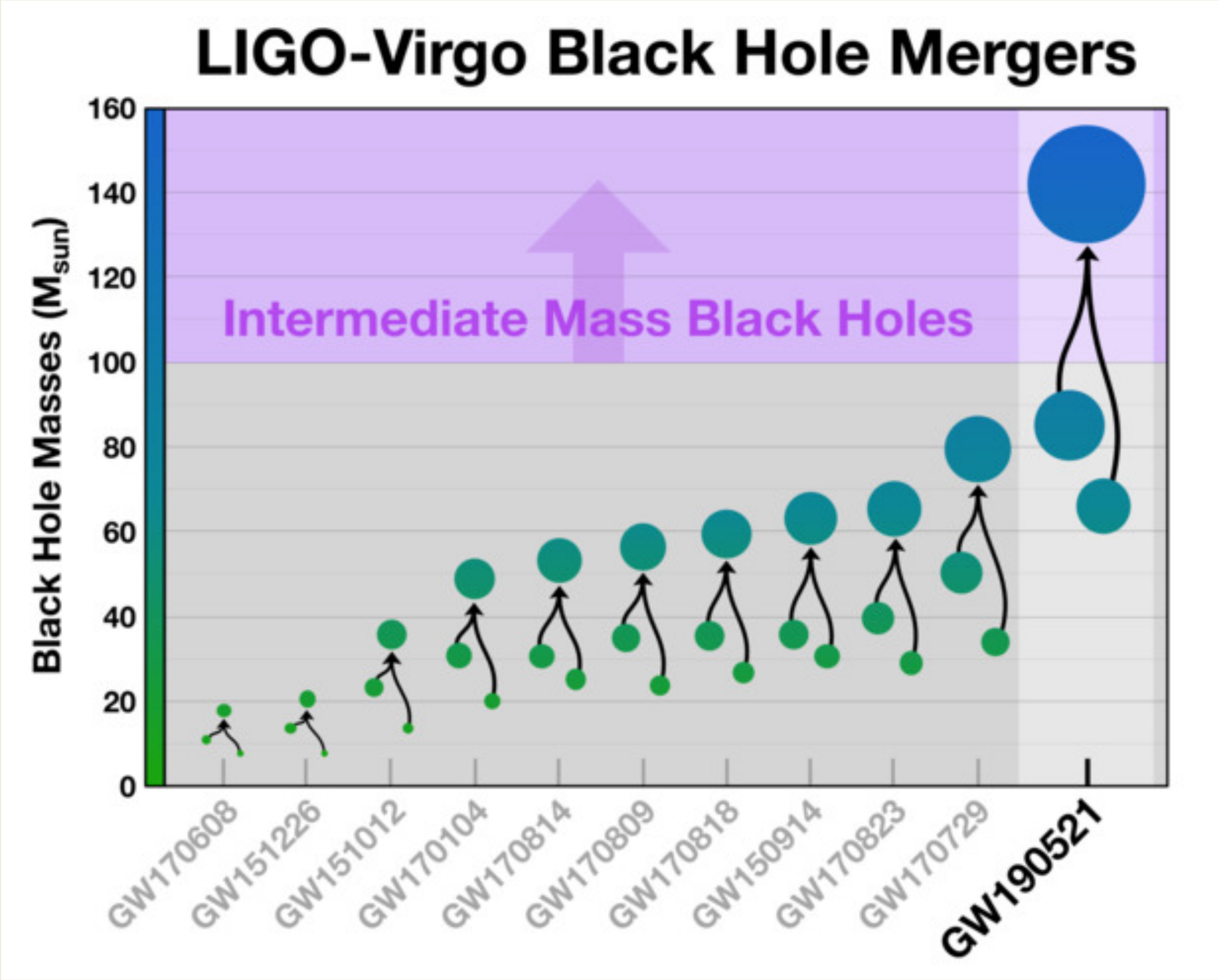
# GW190814: mystery mass gap object

- Binary contains a $23M_{\odot}$ black hole and a $2.6M_{\odot}$ object
- Nature of lighter object is unknown
- No EM counterpart




Credit: LIGO-Virgo / Frank Elavsky & Aaron Geller (Northwestern)

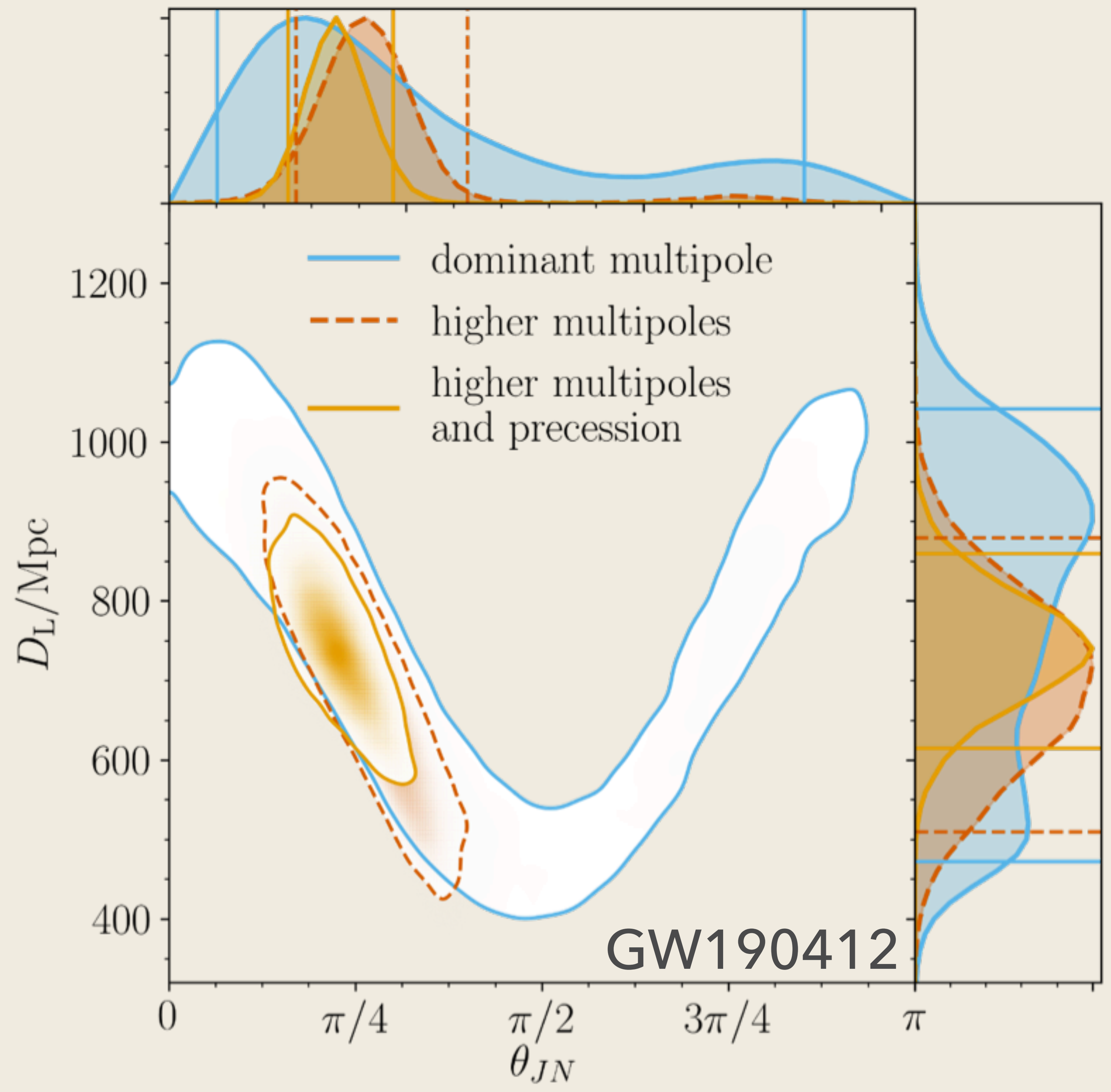
# GW190521: first IMBH detection




Credit: LIGO/Caltech/MIT/R. Hurt (IPAC)

- First ever detection of an intermediate mass black hole
    - $m_1 = 85M_\odot$; $m_2 = 66M_\odot$, $m_1 = 142M_\odot$
- Extremely short (burst-like) signal

# GW190412 + GW200129: spinning black holes




Credit: Abbott, R., et al. "GW190412: Observation of a binary-black-hole coalescence with asymmetric masses." *Physical Review D* 102.4 (2020): 043015.

- GW190412:
  - Asymmetric masses allow for detection of higher harmonics
  - $S_1 = 0$ excluded at 90% confidence

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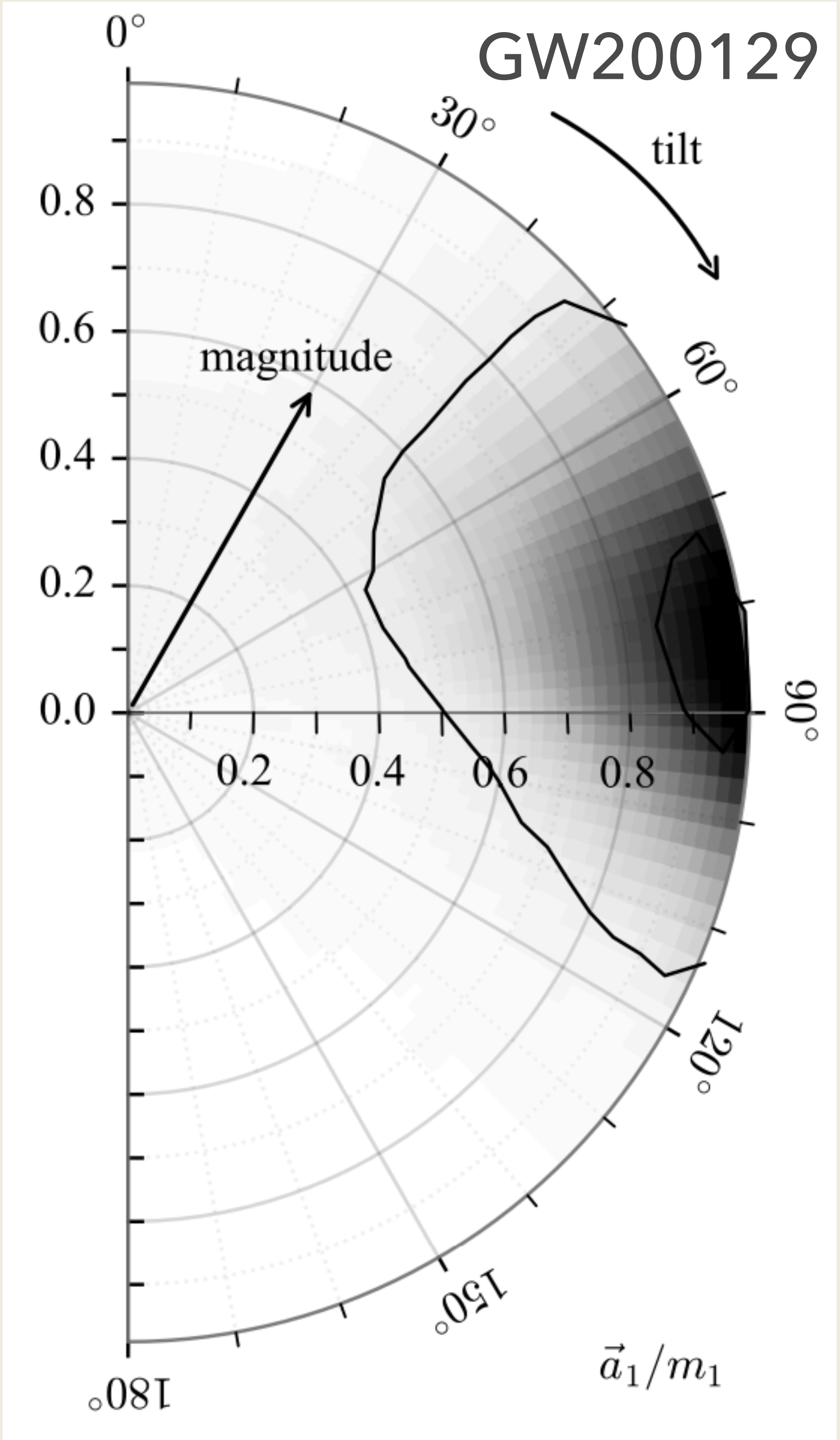
- GW200129
  - Possible first detection of precession
  - Data quality issues at time of event

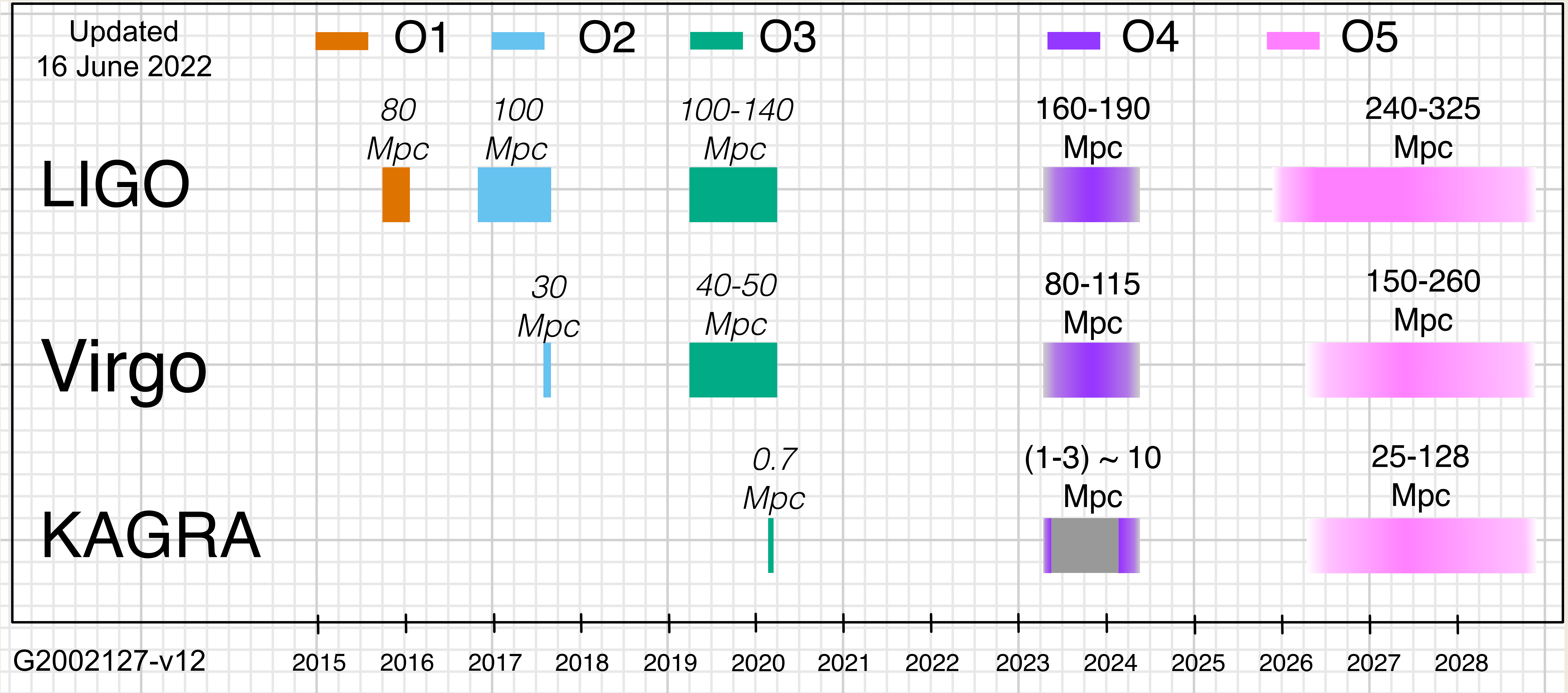



Credit: Hannam, Mark, et al. "Measurement of general-relativistic precession in a black-hole binary."



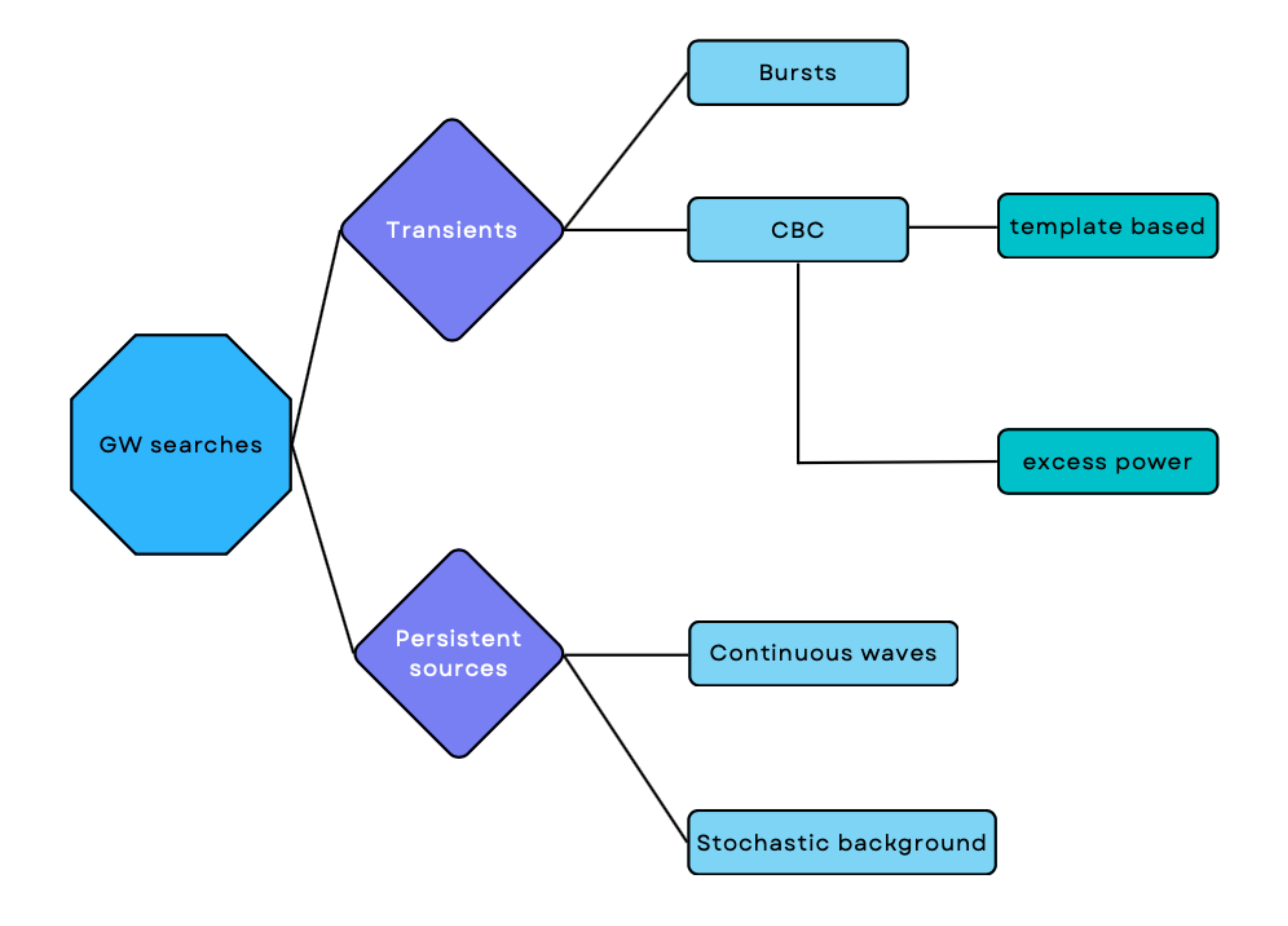

# Short term future plans

# O4 plans

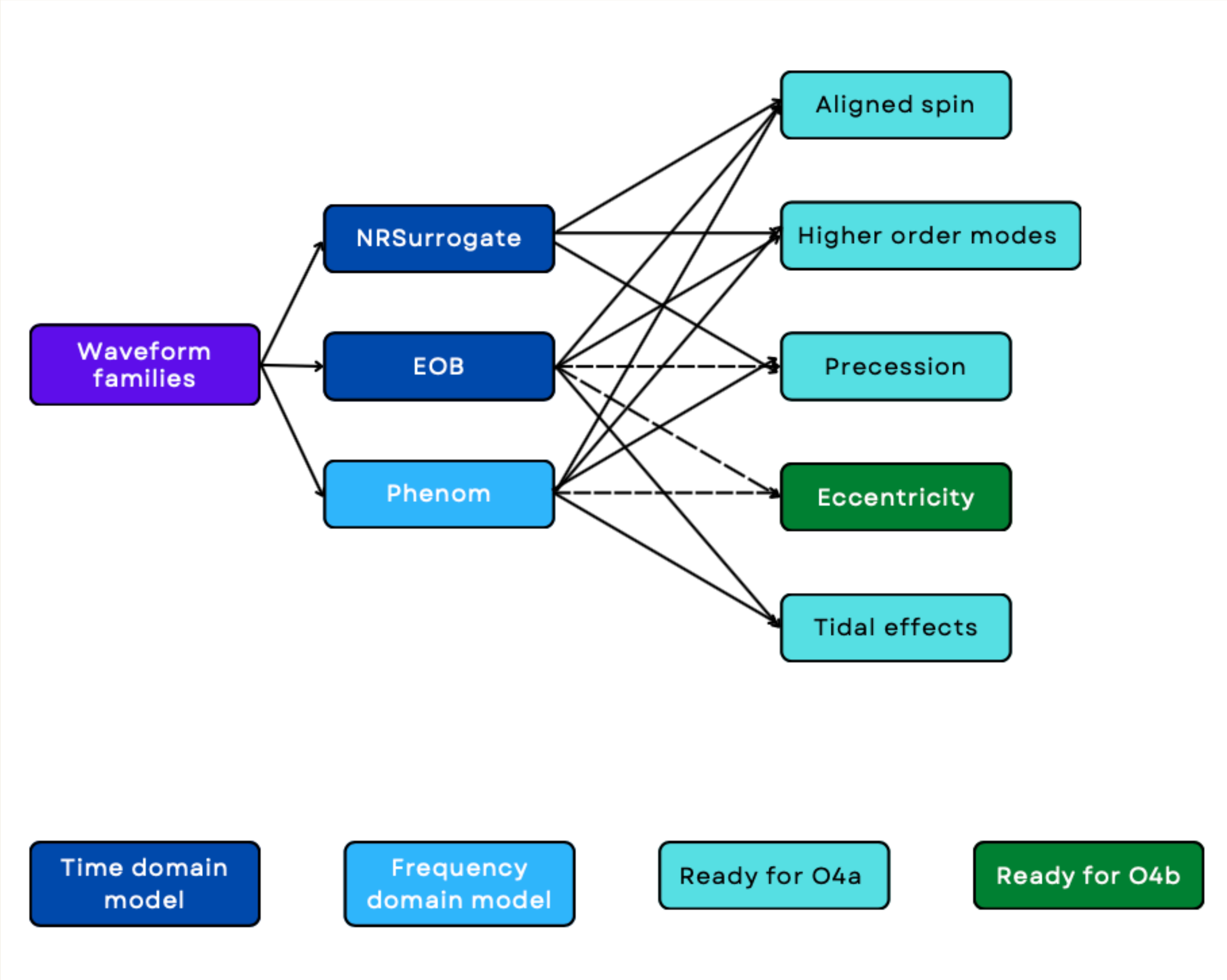


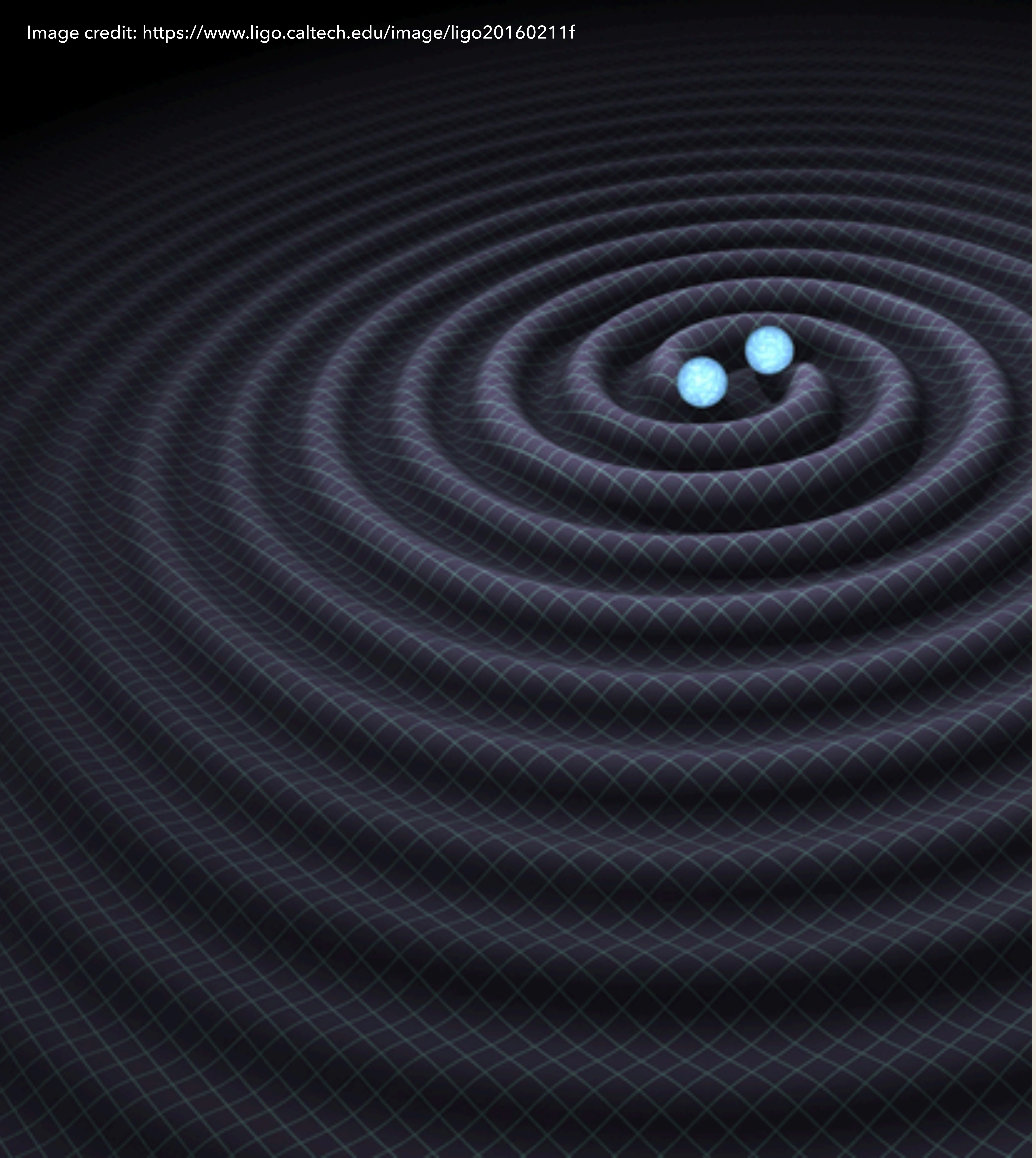

Observing scenario timeline. Credit: https://dcc.ligo.org/LIGO-G2002127/public

# GW searches


GW searches
Transients
Persistent sources
Bursts
CBC
template based
excess power
Continuous waves
Stochastic background

# GW modelling








# Conclusions

- O4 projected to being in March 2023
- 4 detector network
- Detectors will have greatly improved sensitivity
- Expect many more varied GW detections