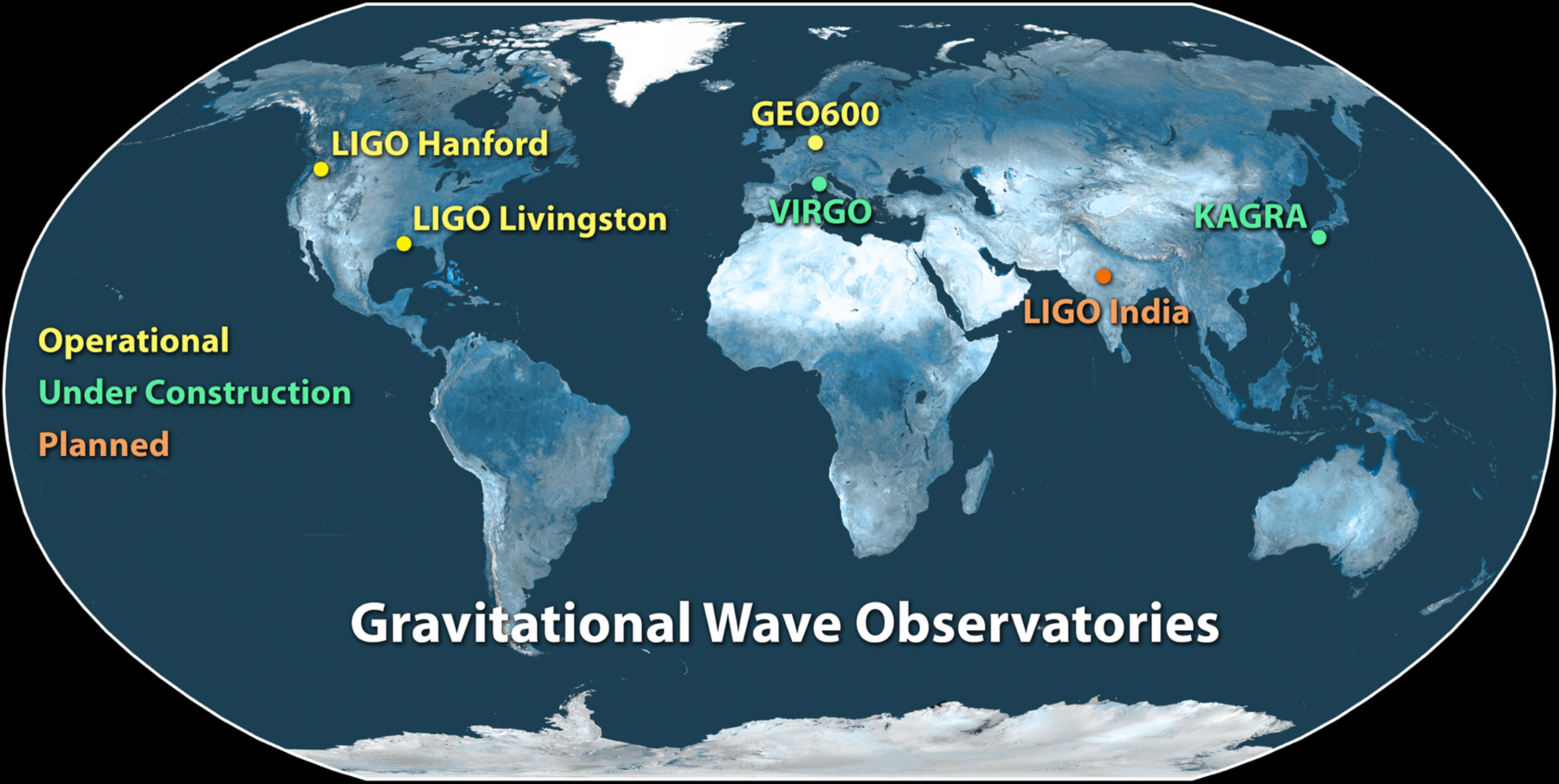
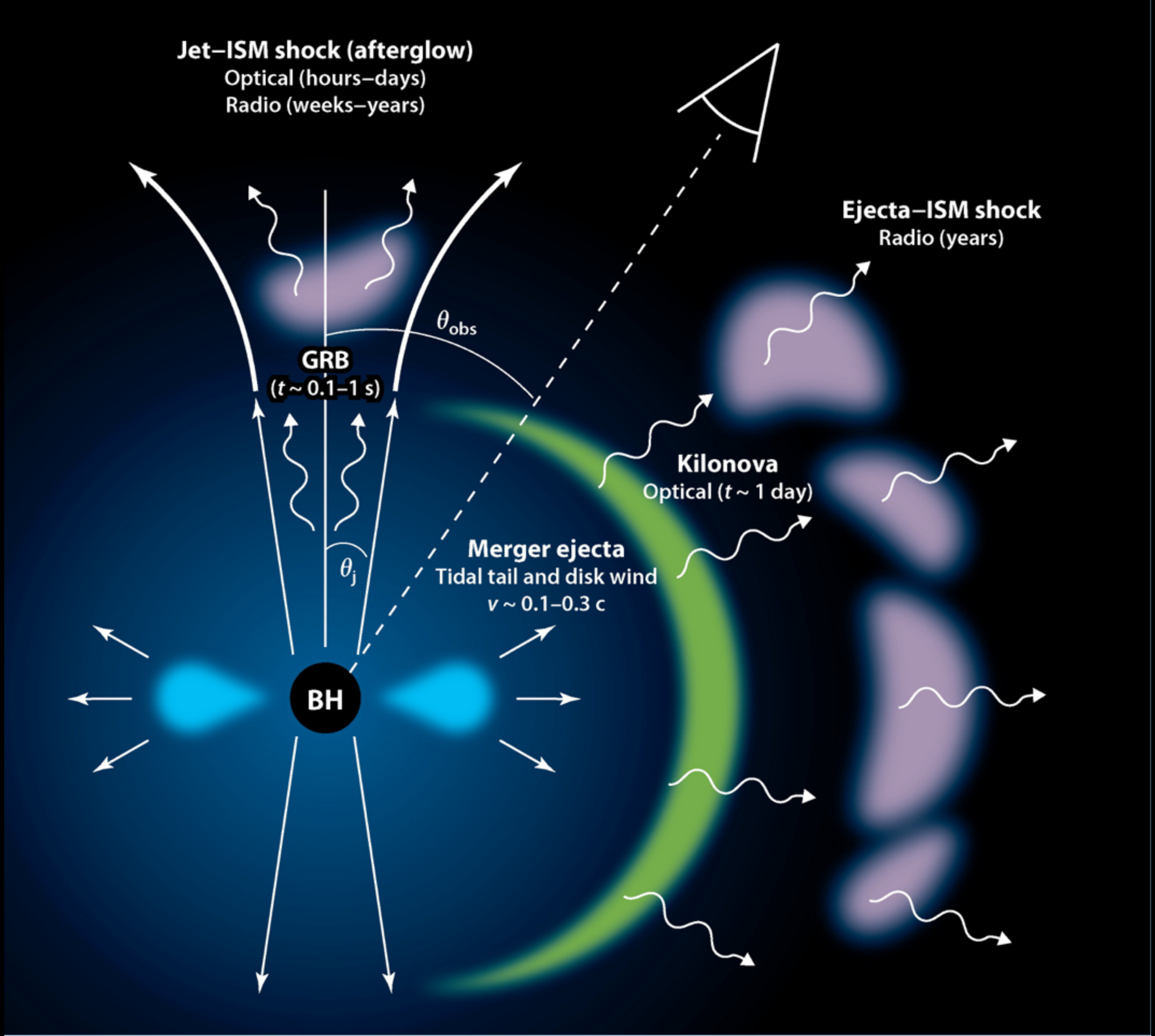
International Gravitational-Wave Projects

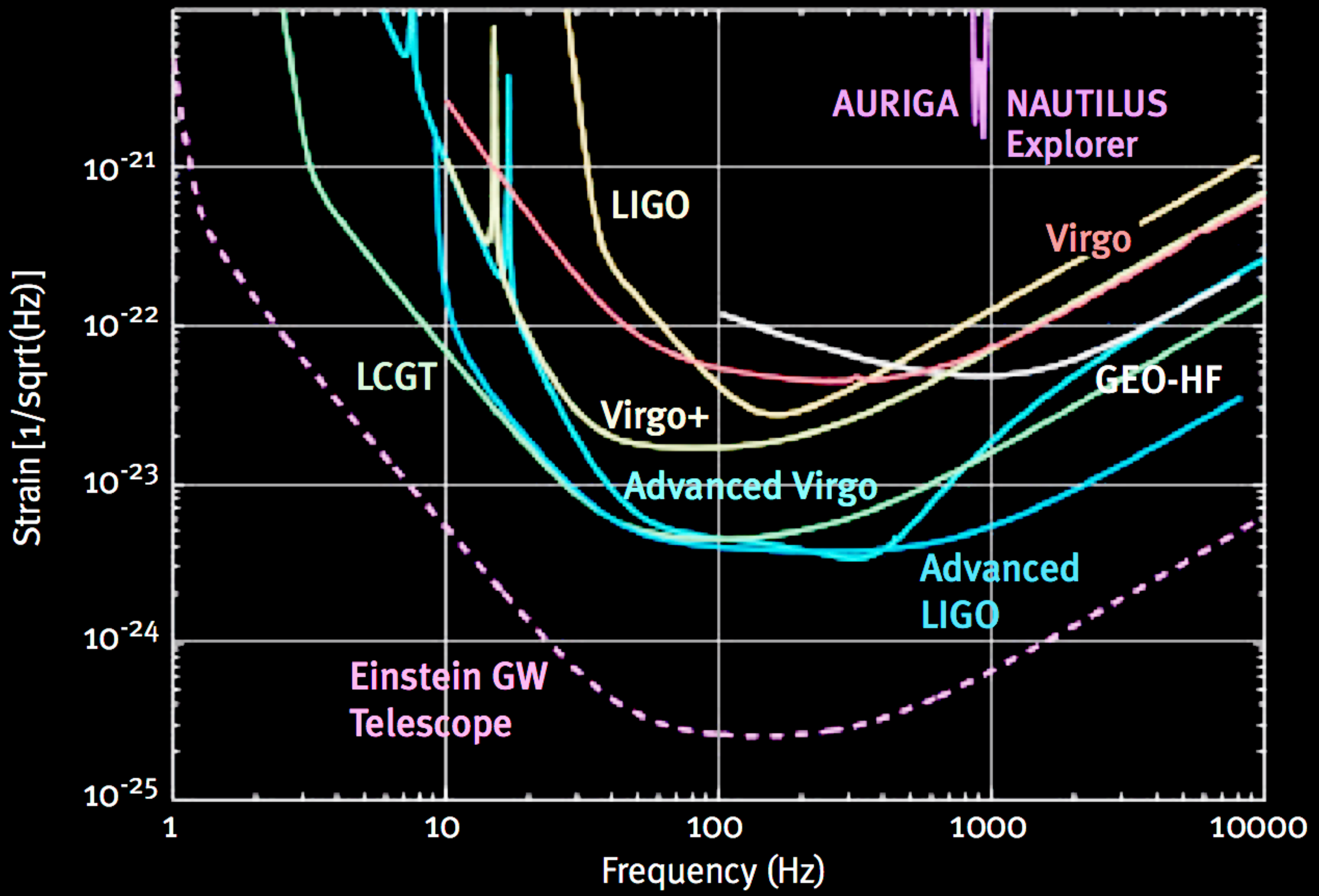
Duncan Brown
Syracuse University



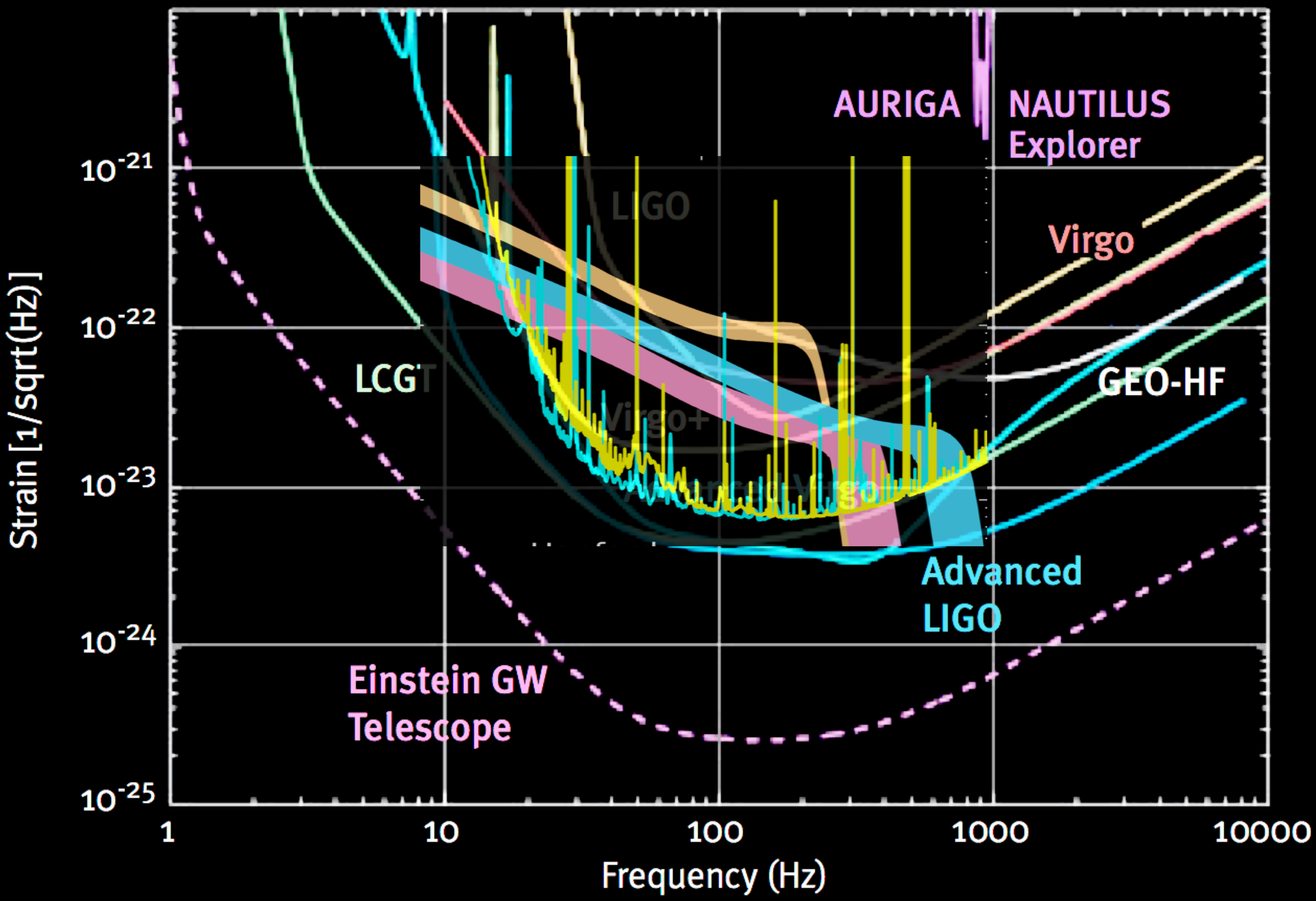
GEO600
LIGO Hanford
VIRGO
KAGRA
LIGO Livingston
LIGO India
Operational
Under Construction
Planned
Gravitational Wave Observatories



Berger E. 2014.
Annu. Rev. Astron. Astrophys. 52:43–105



https://gwic.ligo.org/roadmap/



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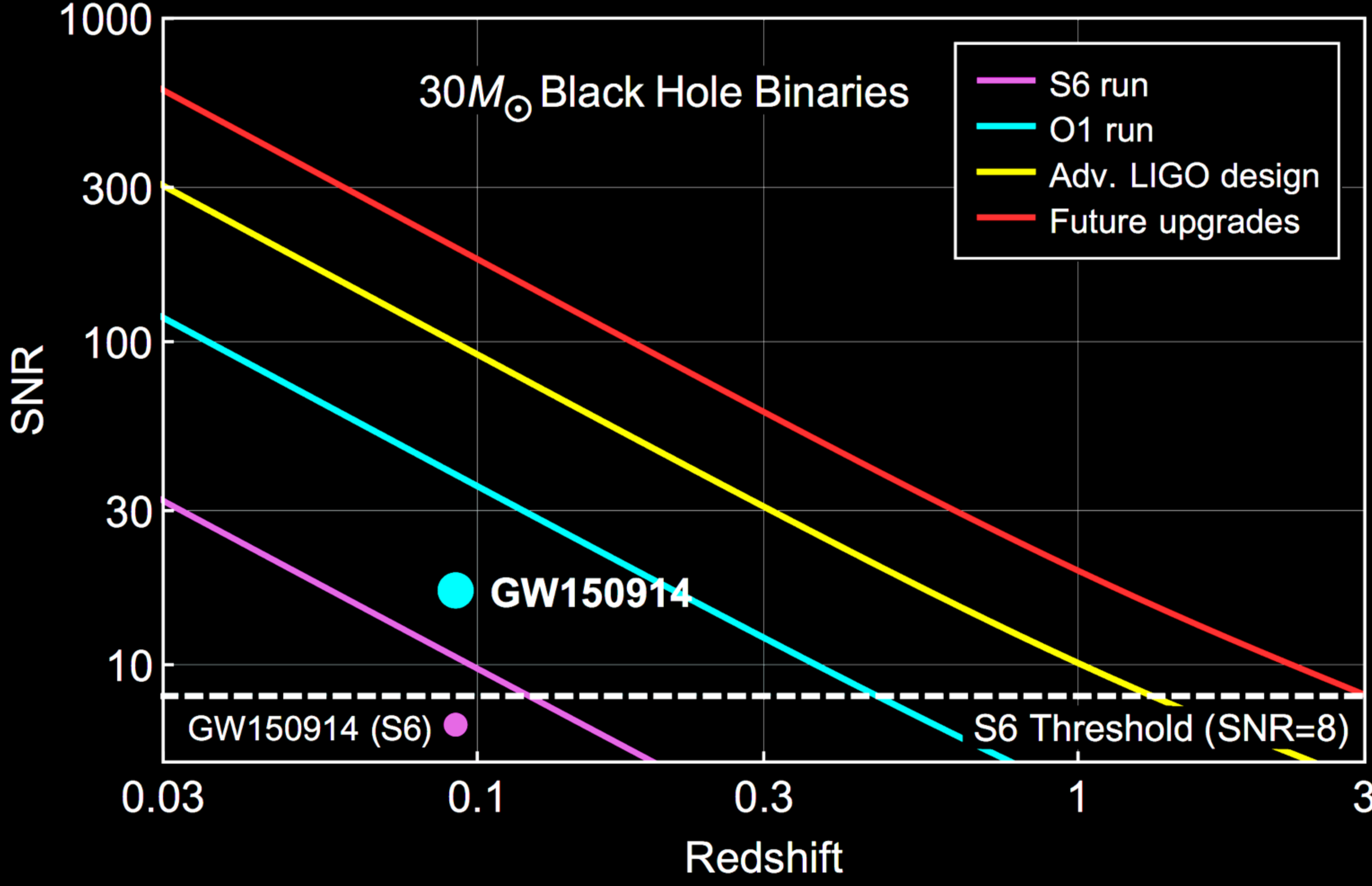

Abbott,... DAB, et al. Phys. Rev. Lett. **116**, 131103 (2016)

GEO600, Germany

- Prototype detector for testing next-generation technology
- Currently using squeezed light in regular operation

- Operates in "astrowatch" mode...
- Provide as much coverage as possible incase of nearby core-collapse supernova

Virgo, Italy

- 3km detector with technological similarities and differences to LIGO.
- Full data sharing between LIGO and Virgo collaborations

Virgo Logbook 3.13.1 LIGO logbooks: LHO LLO

Sections... Tasks...

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Displaying report 1-1 of 1.

AdV-COM (AdV commissioning (1st part))

Allocca, Bersanetti, Chiummo, Mantovani, Ruggi, Swinkels - 01:57, Wednesday 22 March 2017 (36970)

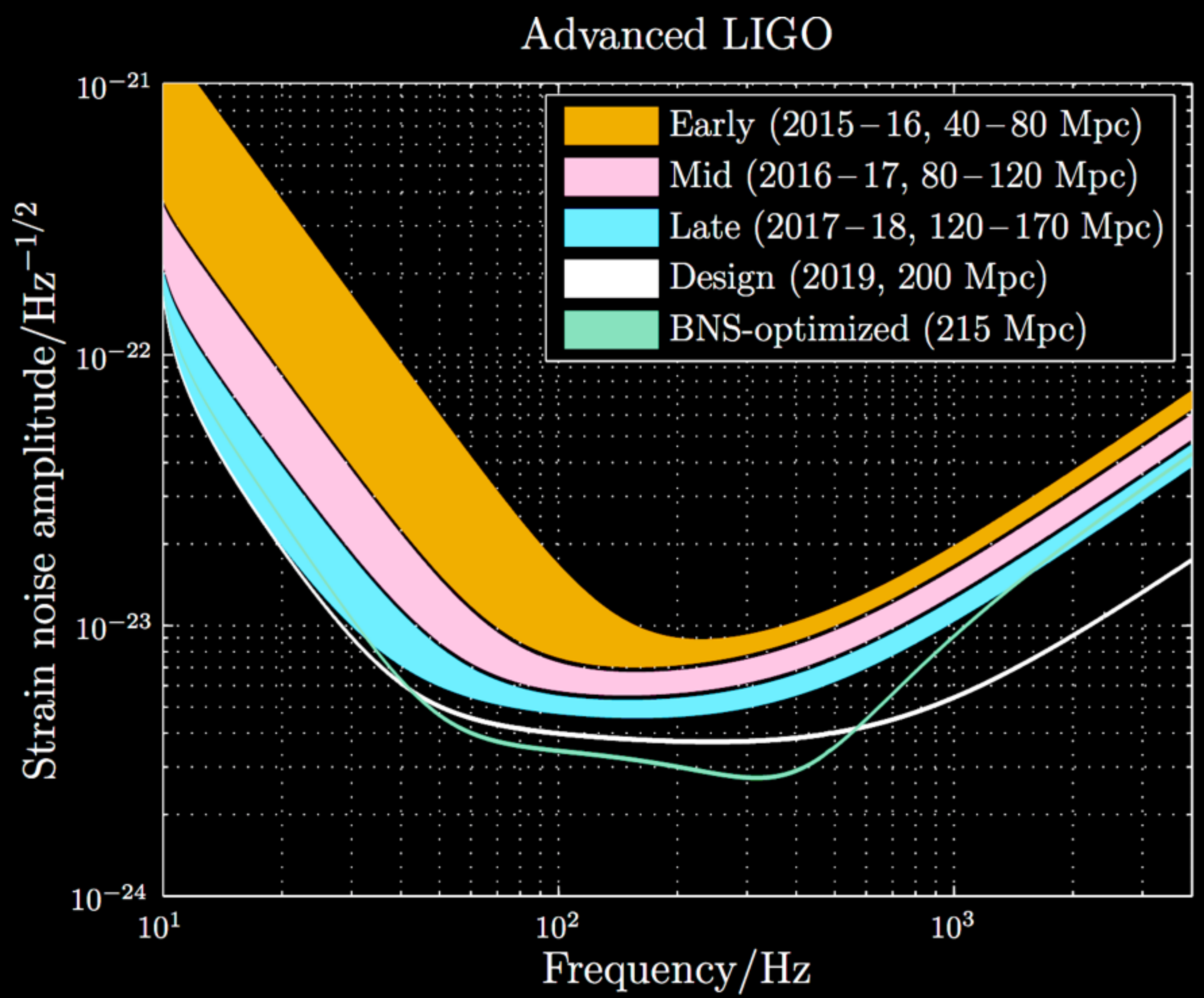
1.5 hour lock in Dark Fringe!

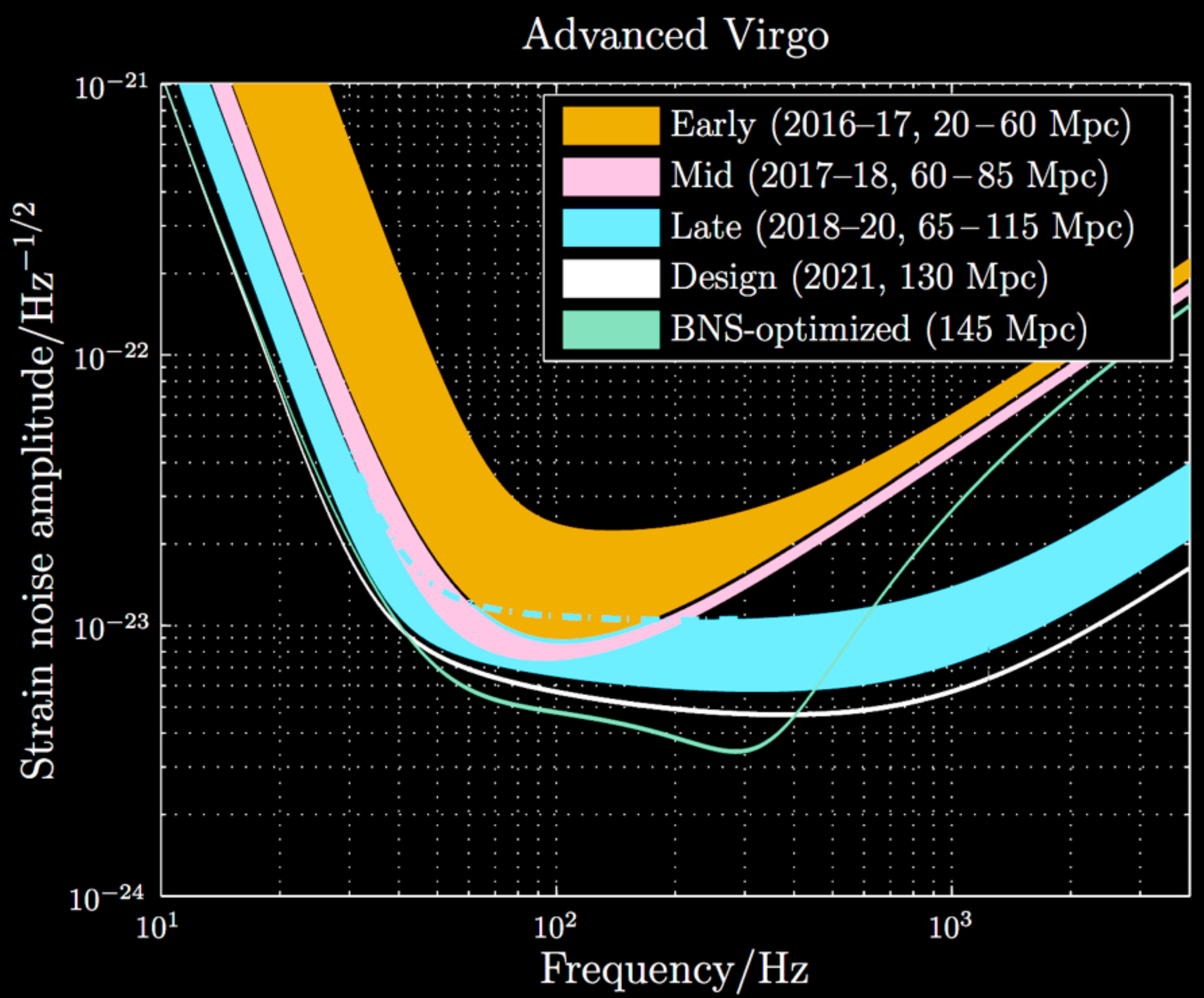
Today we could stay locked for more than one hour in Dark Fringe!

Here's the shift summary:

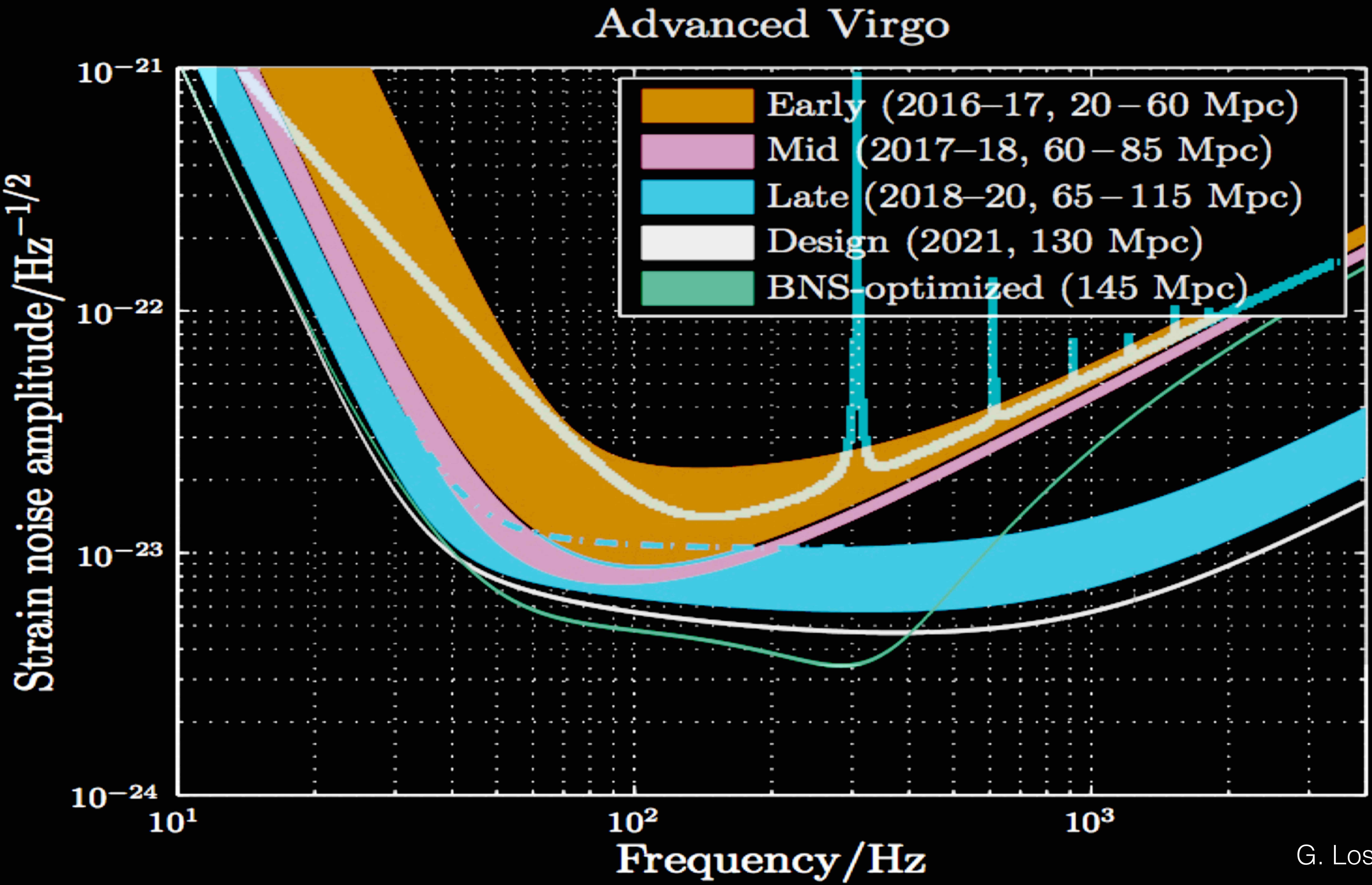
- First the DARM handoff has been performed to the B1p_56MHz_I instead of the B1p_6MHz_I. This made the DF lock m has a lower finesse and is less affected by HOMs;
- The offsets of the PR AA have been set in such a way to have a satisfying alignment (looking at the phase camera signal the lock was acquired every time. However, later on we also tried to slightly change these offsets, but the lock was acqui
- When the transition to DF was performed, the AA loop on PR was switched off. As soon as the DF lock was acquired, the zero the signals on the B1p quadrants (SDB2_B1p_QD2_H(V)_6MHz_I), which seem to work pretty well as error signals

- Advanced LIGO's sensitivity was at the upper end of that predicted for the first observing run

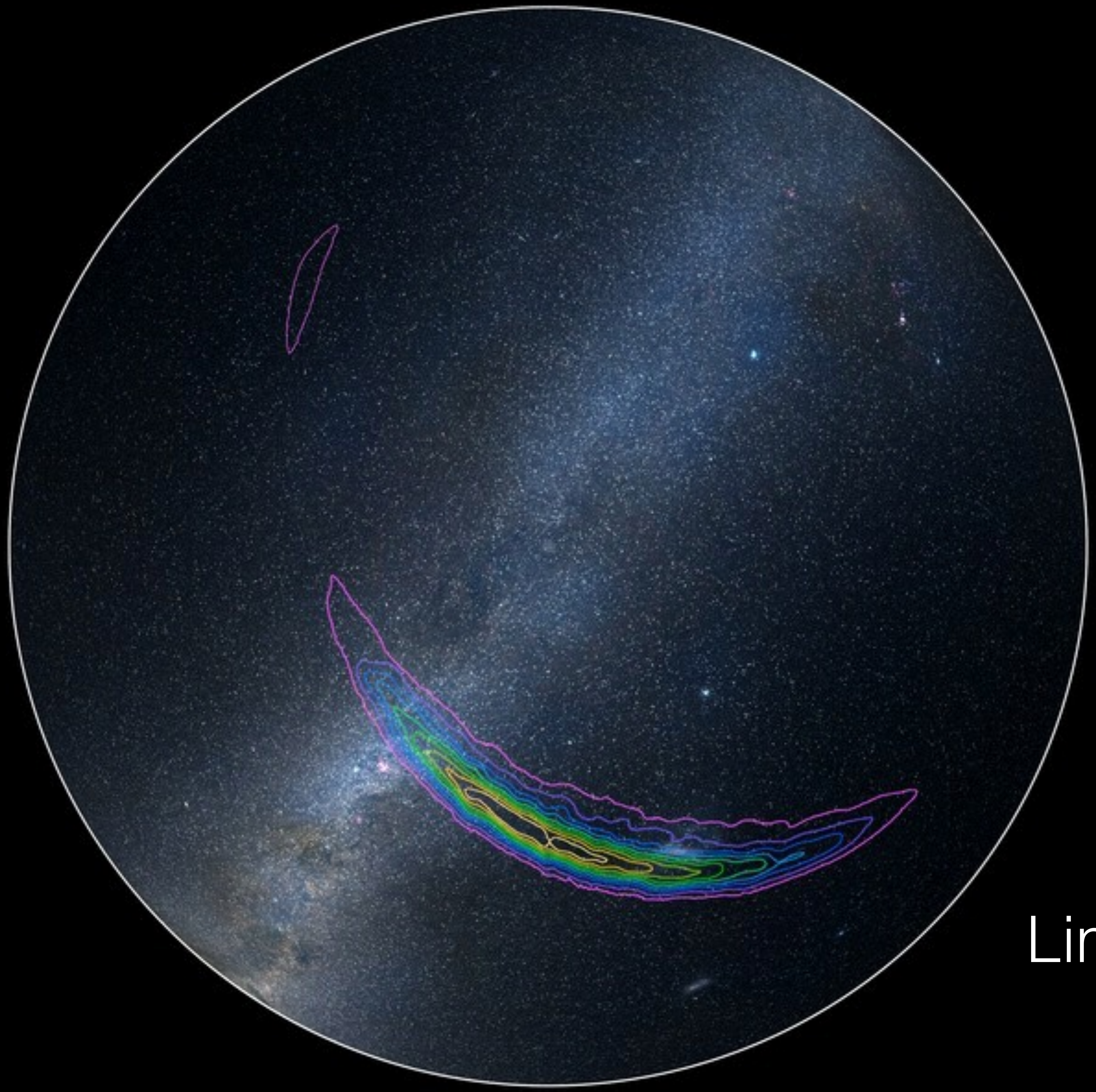




Abbott, ..., DAB, et al. Living Reviews in Relativity **19**, 1 (2016)


Advanced Virgo
Early (2016–17, 20 – 60 Mpc)
Mid (2017–18, 60 – 85 Mpc)
Late (2018–20, 65 – 115 Mpc)
Design (2021, 130 Mpc)
BNS-optimized (145 Mpc)
Strain noise amplitude/Hz$^{-1/2}$
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{1}
10^{2}
10^{3}
Frequency/Hz

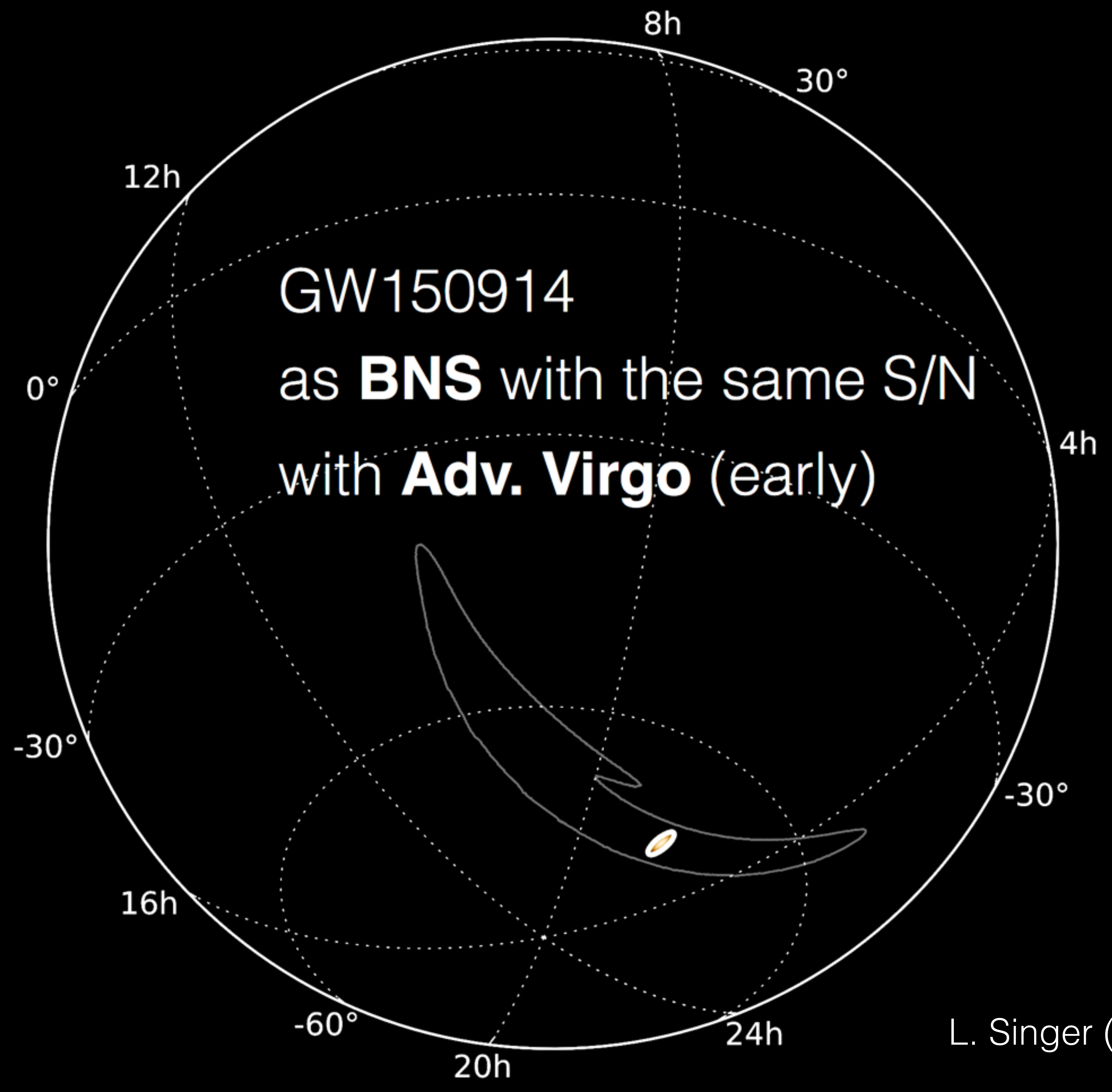
G. Losurdo



Probable location of GW150914 merger

Limited by two-detector network

Abbott, ..., DAB, et al. ApJ L **826** 13 (2016)



L. Singer (2016)

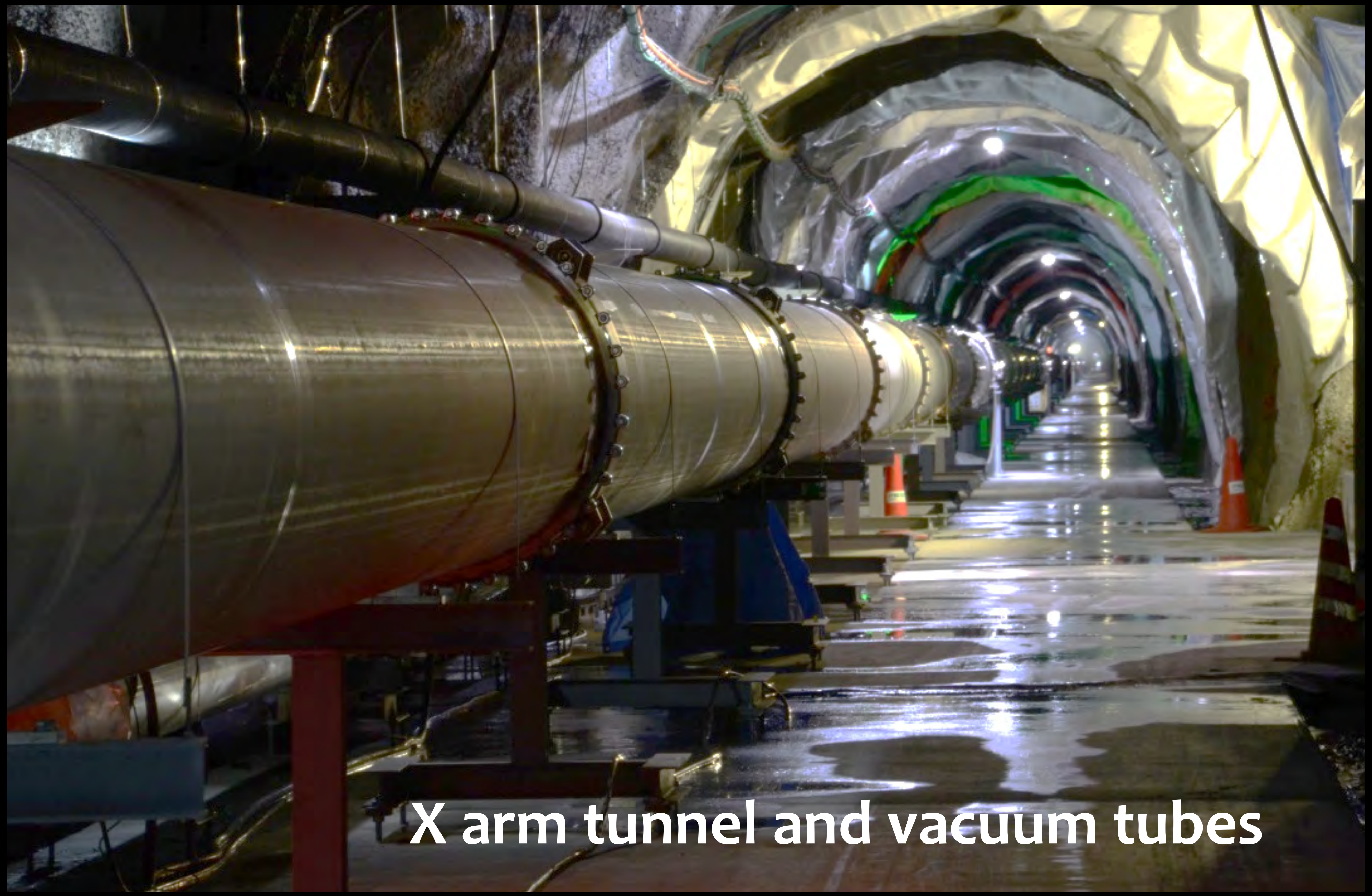
- Adding a third detector with any reasonable sensitivity significantly improves sky localization.
- If Virgo's range is 25% that of LIGO, then the LIGO-only sky localizations are reduced by ~ 60 %

KAGRA, Japan

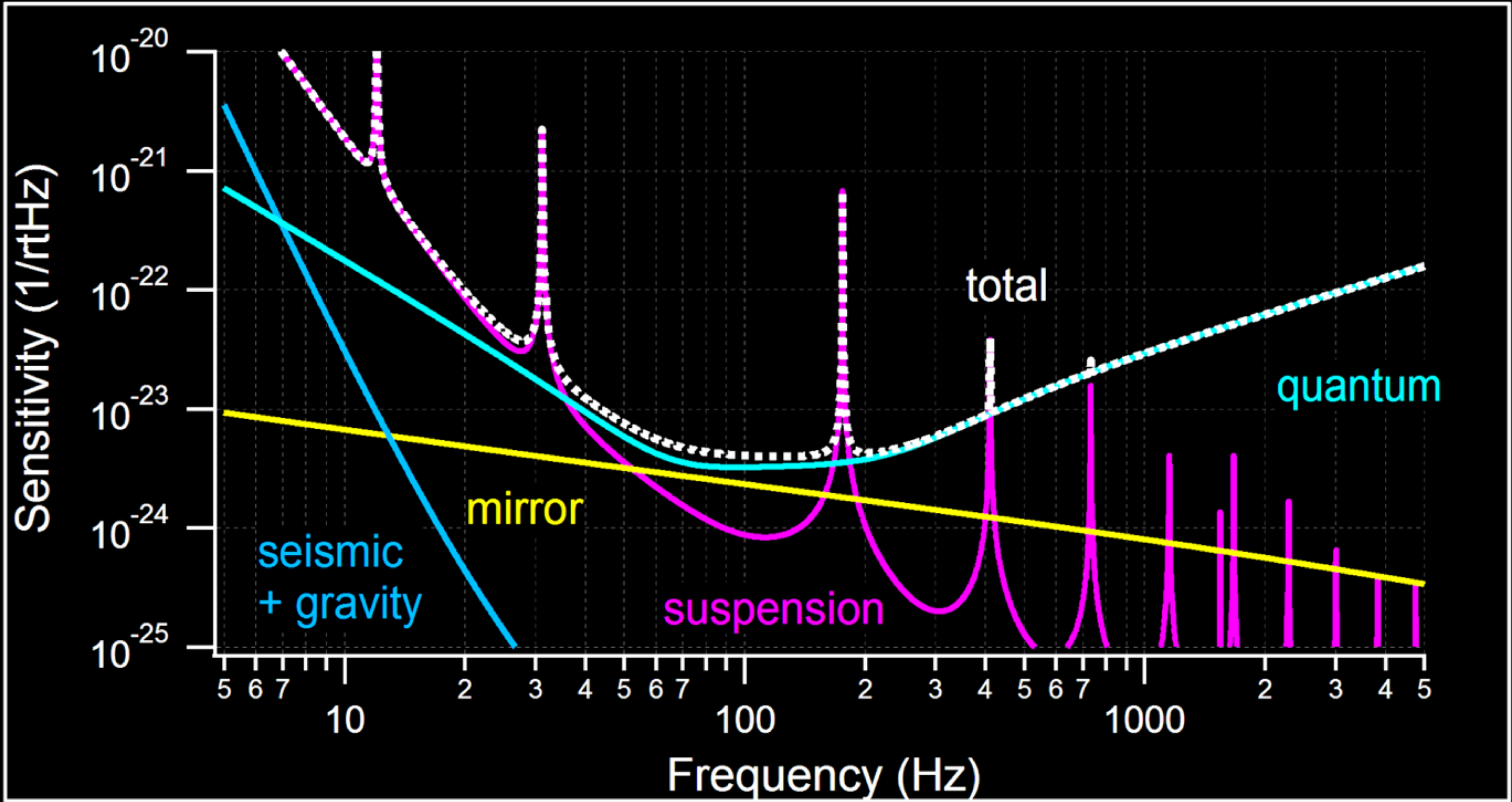
http://atc.mtk.nao.ac.jp/E/Projects/KAGRA/images/KAGRA.png

- 3km detector underground in Kamioka mine
- Similar optical layout to Advanced LIGO
- Uses cryogenic cooling to reduce mirror thermal noise

- Construction of Michelson interferometer is compete
- KAGRA have operated a 3km Michelson at room temperature
- Next stage is cryogenic operation of the 3km Michelson (early 2018)



- Sensitivity at design is ~ 140 Mpc to binary neutron stars (c.f. Virgo)



Somiya, et al. CGQ **29** 124007 (2012)

LIGO India

- A direct partnership between LIGO Laboratory and IndIGO collaboration to build an Indian interferometer
- LIGO-India would be operated as part of LIGO Global Network to maximize scientific impact
- Site selection has converged on a prime site. LIGO Lab has completed review and concurrence. Acquisition has begun.
- A project schedule has been developed by the project coordinators and the LIGO Laboratory coordinator.
- Consistent with LIGO-India observations beginning in **Jan 2024**

Status of EM Follow-up

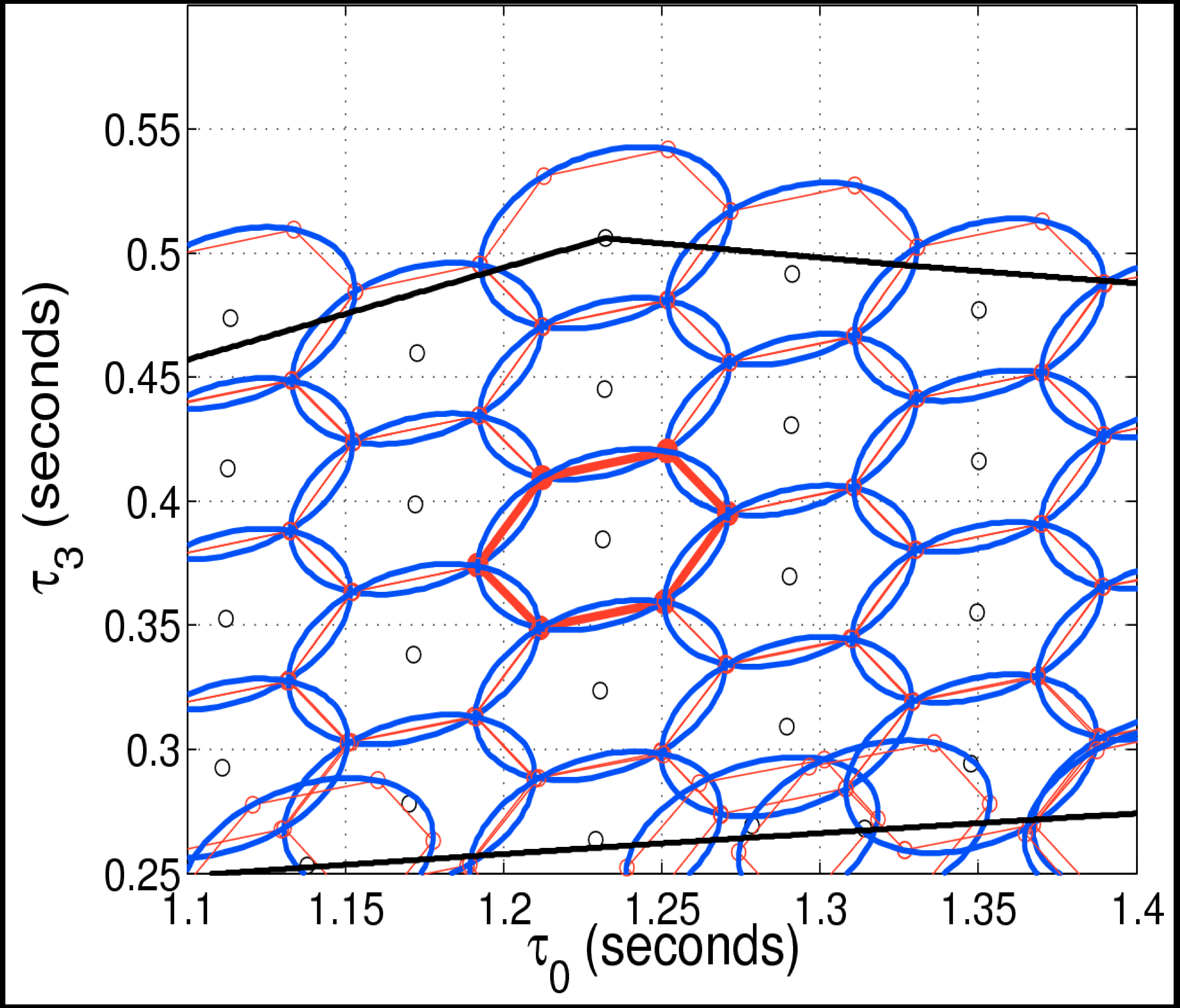
- "As of February 23, 2017, 3 event candidates, identified by online analysis using a loose false-alarm-rate threshold of one per month, have been identified and shared with astronomers."

http://www.ligo.org/news/index.php#O2Mar2017update

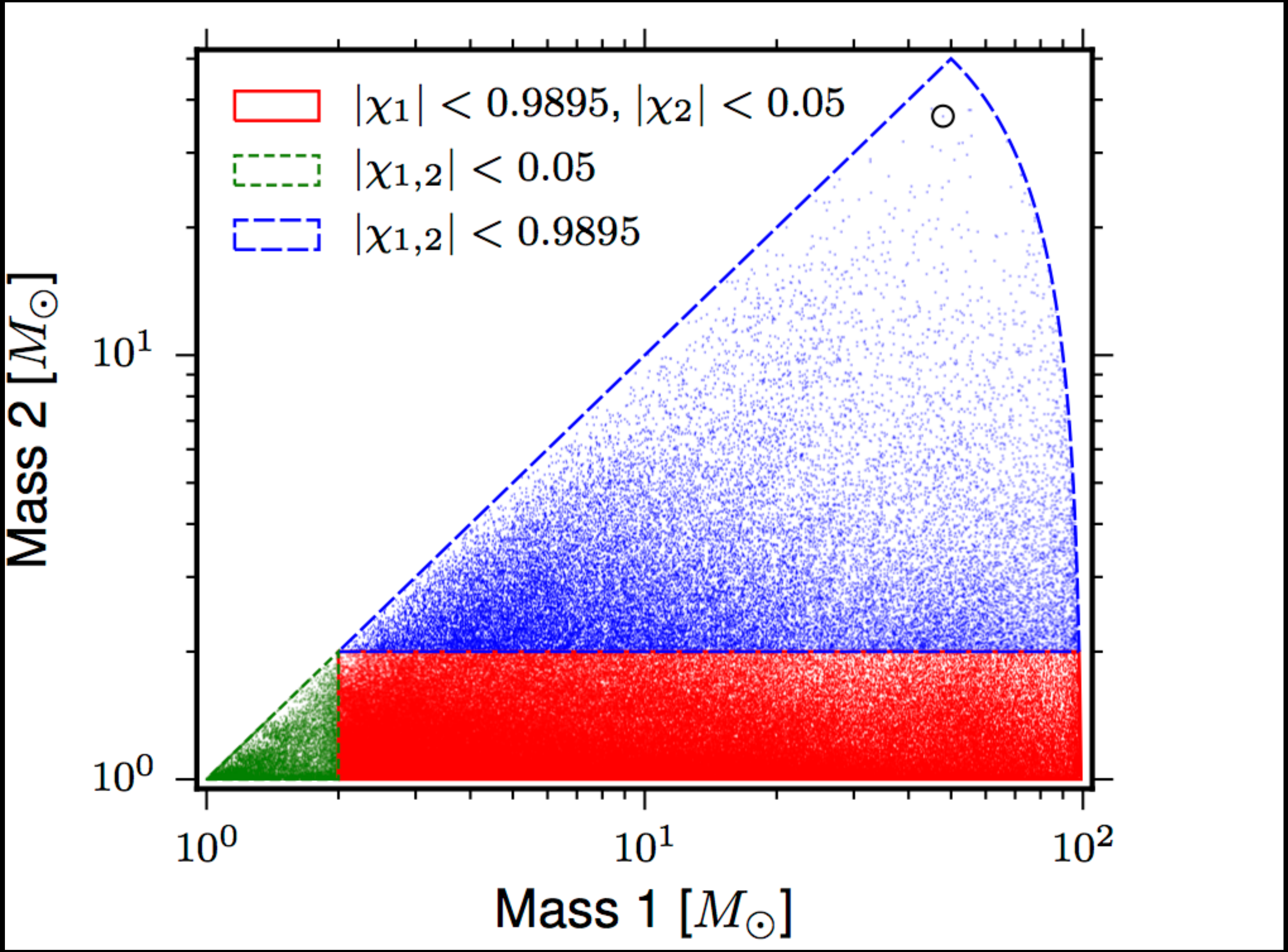
Signals are well modeled, so construct a bank of templates and matched filter for signals, with additional techniques to mitigate detector noise

$$\rho = \frac{\langle s|h\rangle}{\sqrt{\langle h|h\rangle}}$$

$$\langle a|b\rangle = 4\mathrm{Re}\int_{f_{\mathrm{low}}}^{f_{\mathrm{high}}} \frac{\tilde{a}(f)\tilde{b}(f)}{S_n(f)}\,df$$



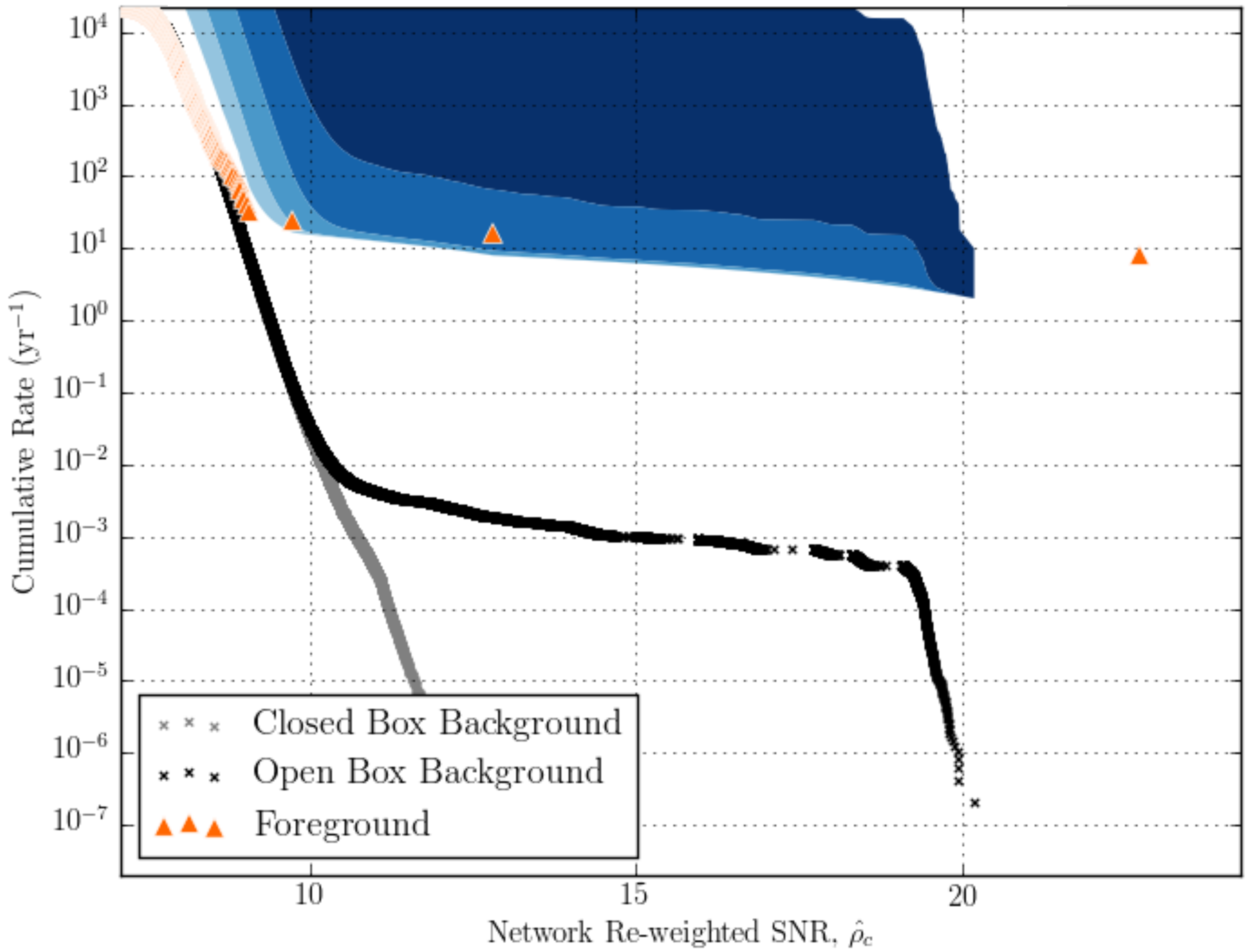
Owen and Sathya PRD 60, 022002 (1999)
Babak et al. Class.Quant.Grav. 23 5477 (2006)
Allen, Anderson, Brady, DAB, Creighton Phys Rev D 85 122006 (2012)
Babak,..., DAB, et al. Phys Rev D 87 024033 (2013)
Usman,... DAB, et al. CQG **33** 215004 (2016)

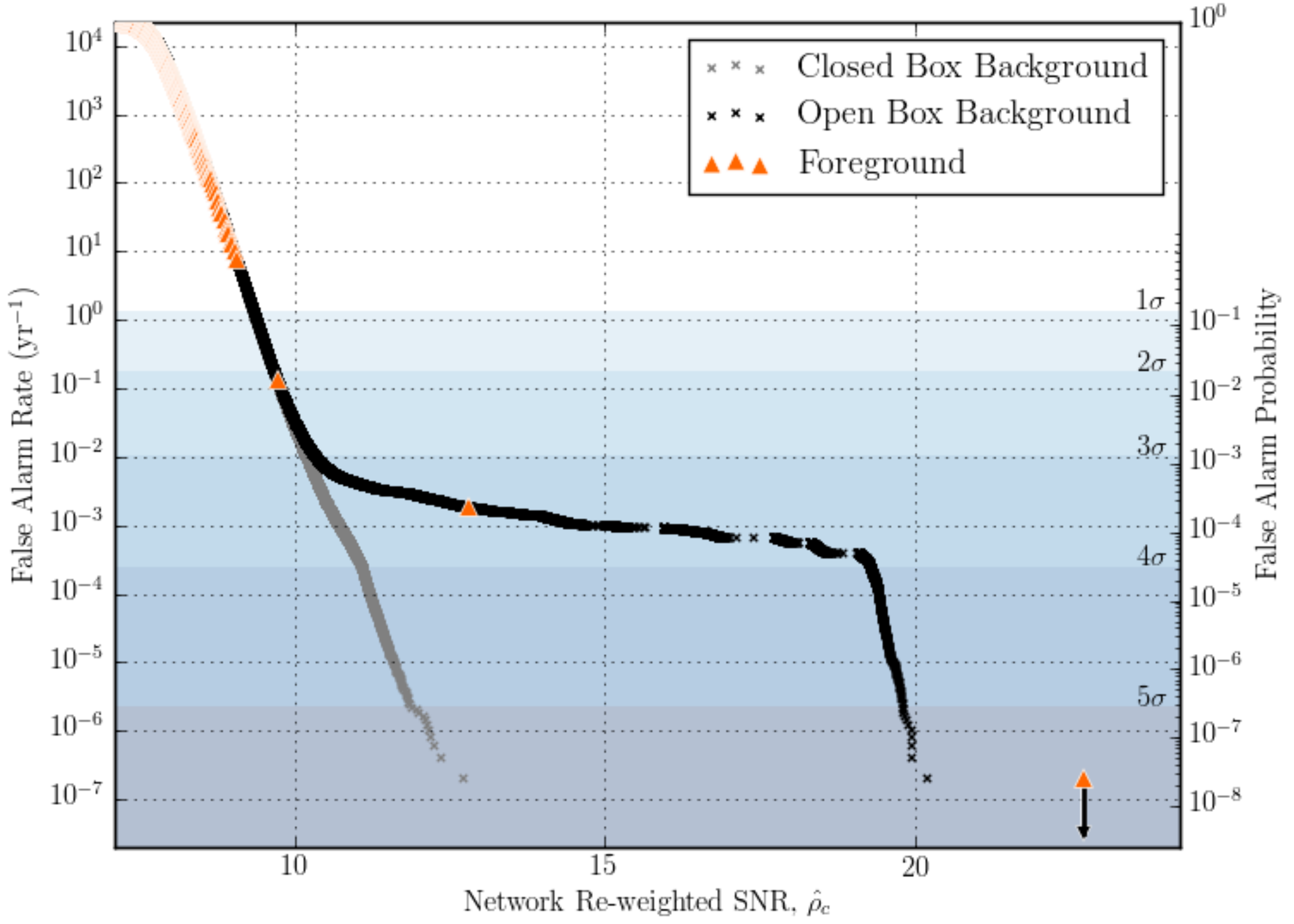


Binary coalescence searches target binary neutron stars, binary black hole, and neutron star-black hole binaries

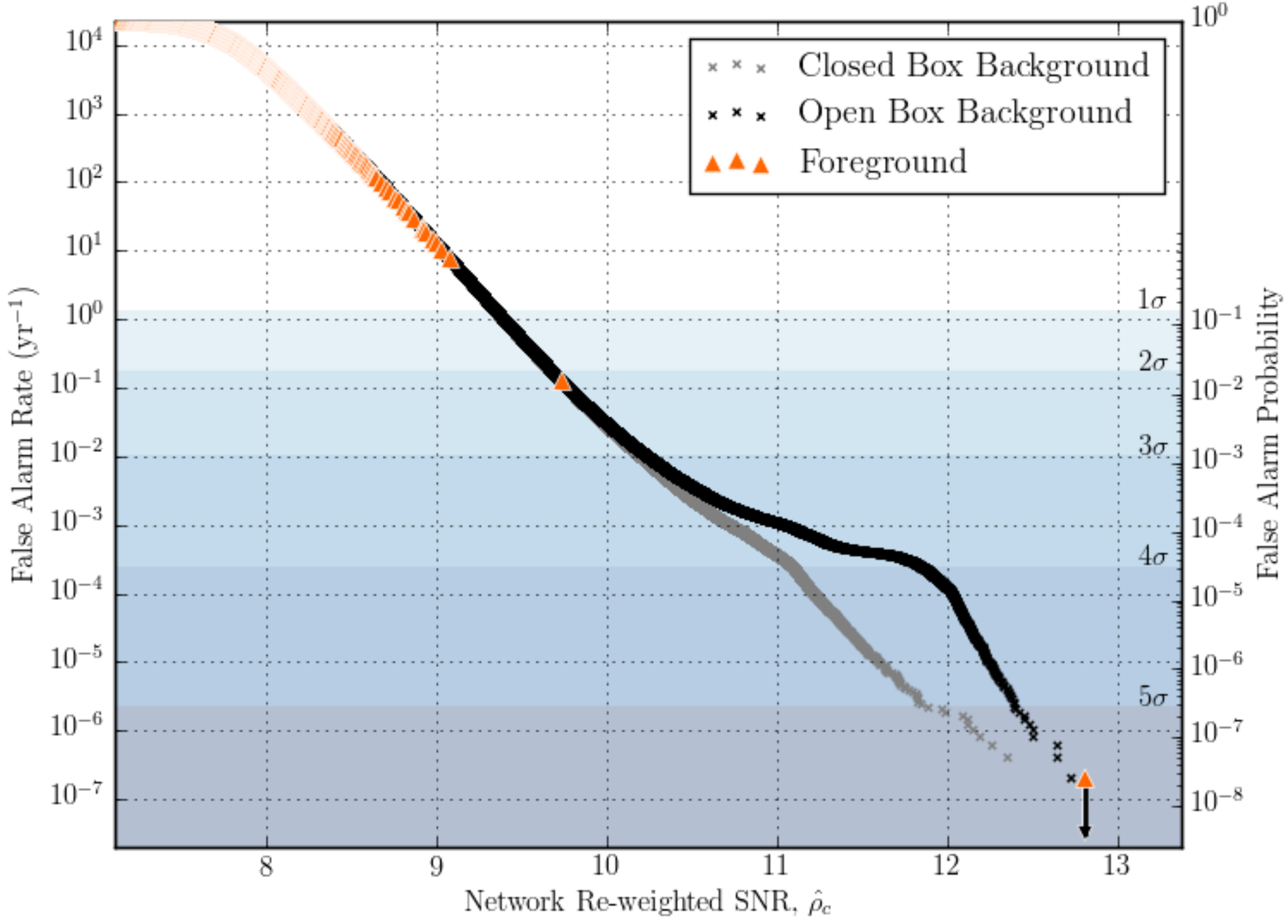
Searches assume aligned-spin waveforms which have good sensitivity to precessing signals for binary black holes

Abbott, ..., DAB, et al. Phys. Rev. D. **93** 122003 (2016)
DAB, Harry, Lundgen, Nitz, Phys. Rev. D 86 084017 (2012)
Capano, Harry, Privitera, Buonanno Phys. Rev. D **93**, 124007 (2016)

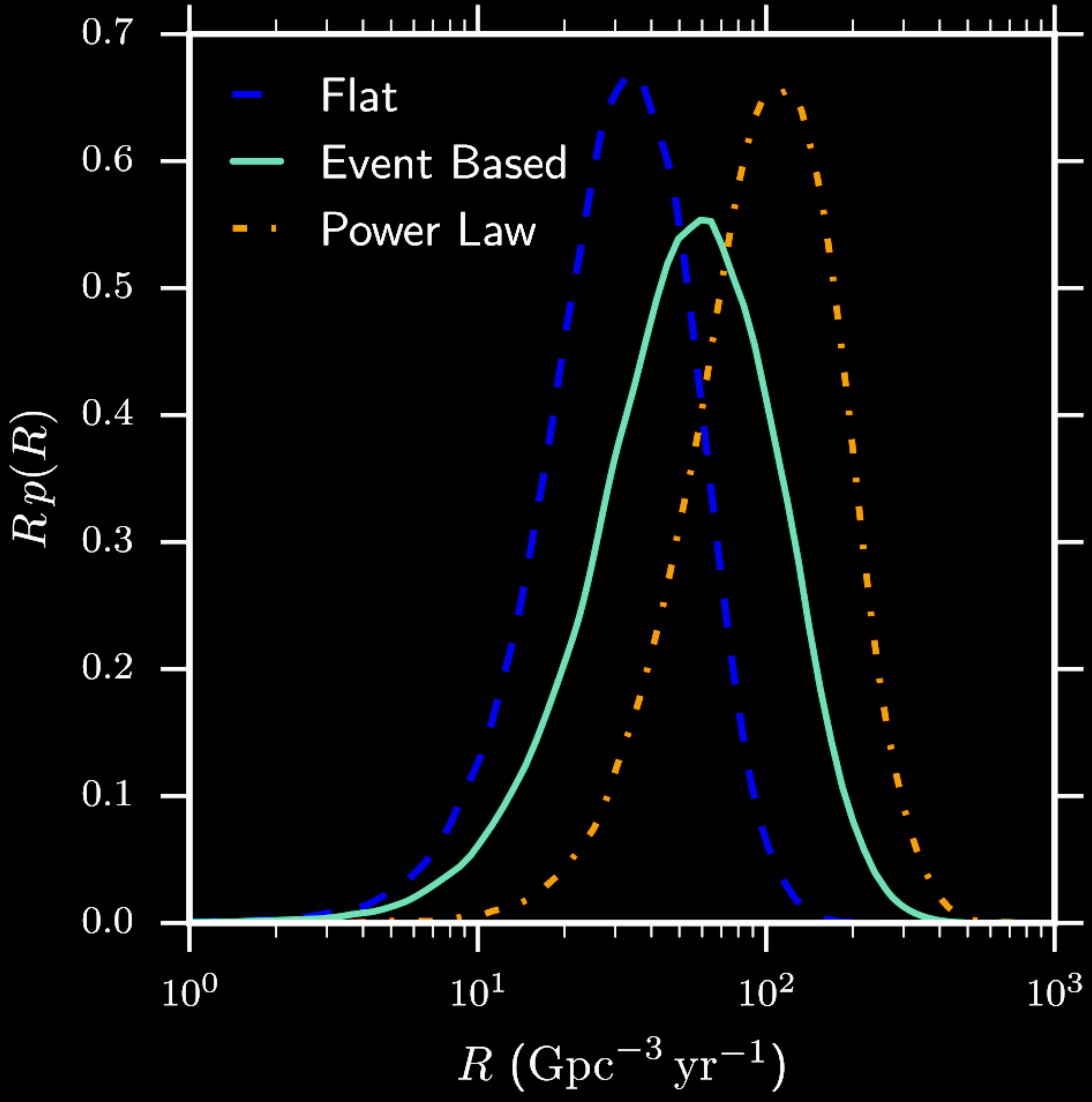

Cumulative Rate (yr^{-1})
Network Re-weighted SNR, $\hat{\rho}_c$
Closed Box Background
Open Box Background
Foreground
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10
15
20



Closed Box Background
Open Box Background
Foreground
False Alarm Rate (yr^{-1})
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
False Alarm Probability
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
1σ
2σ
3σ
4σ
5σ
10
15
20
Network Re-weighted SNR, $\hat{\rho}_c$



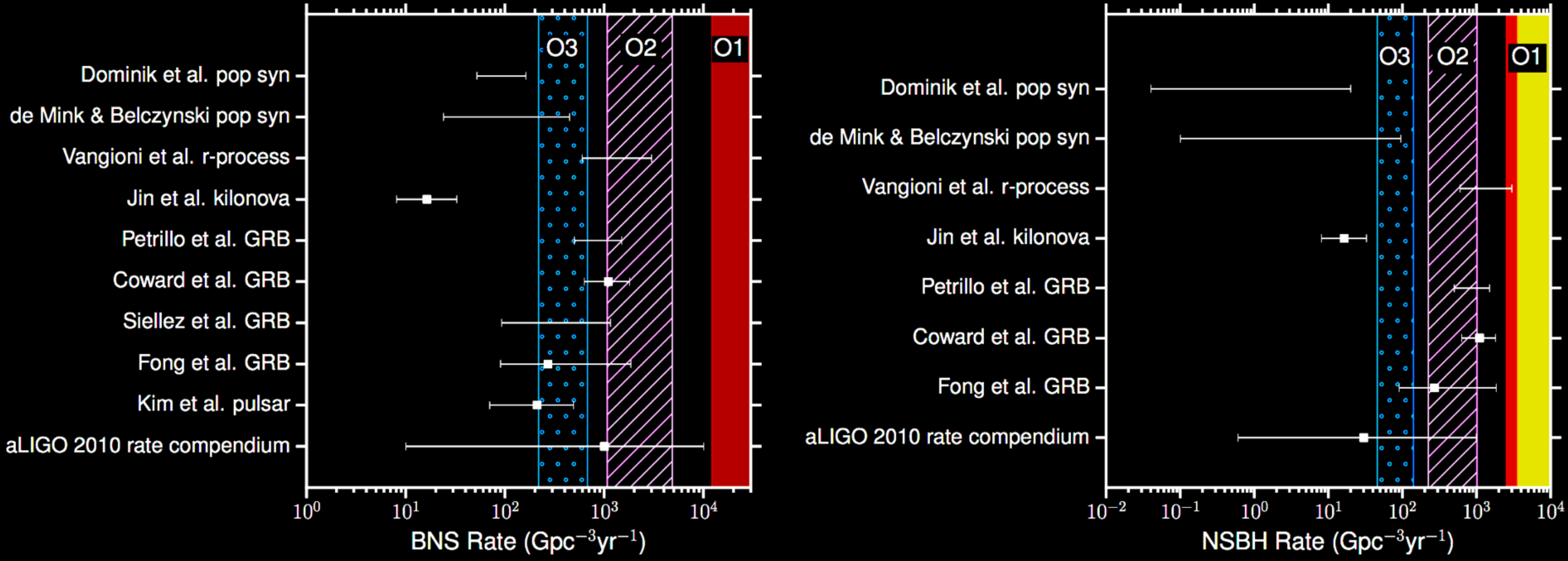
Closed Box Background
Open Box Background
Foreground
False Alarm Rate (yr^{-1})
False Alarm Probability
Network Re-weighted SNR, $\hat{\rho}_c$
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
1σ
2σ
3σ
4σ
5σ
8
9
10
11
12
13



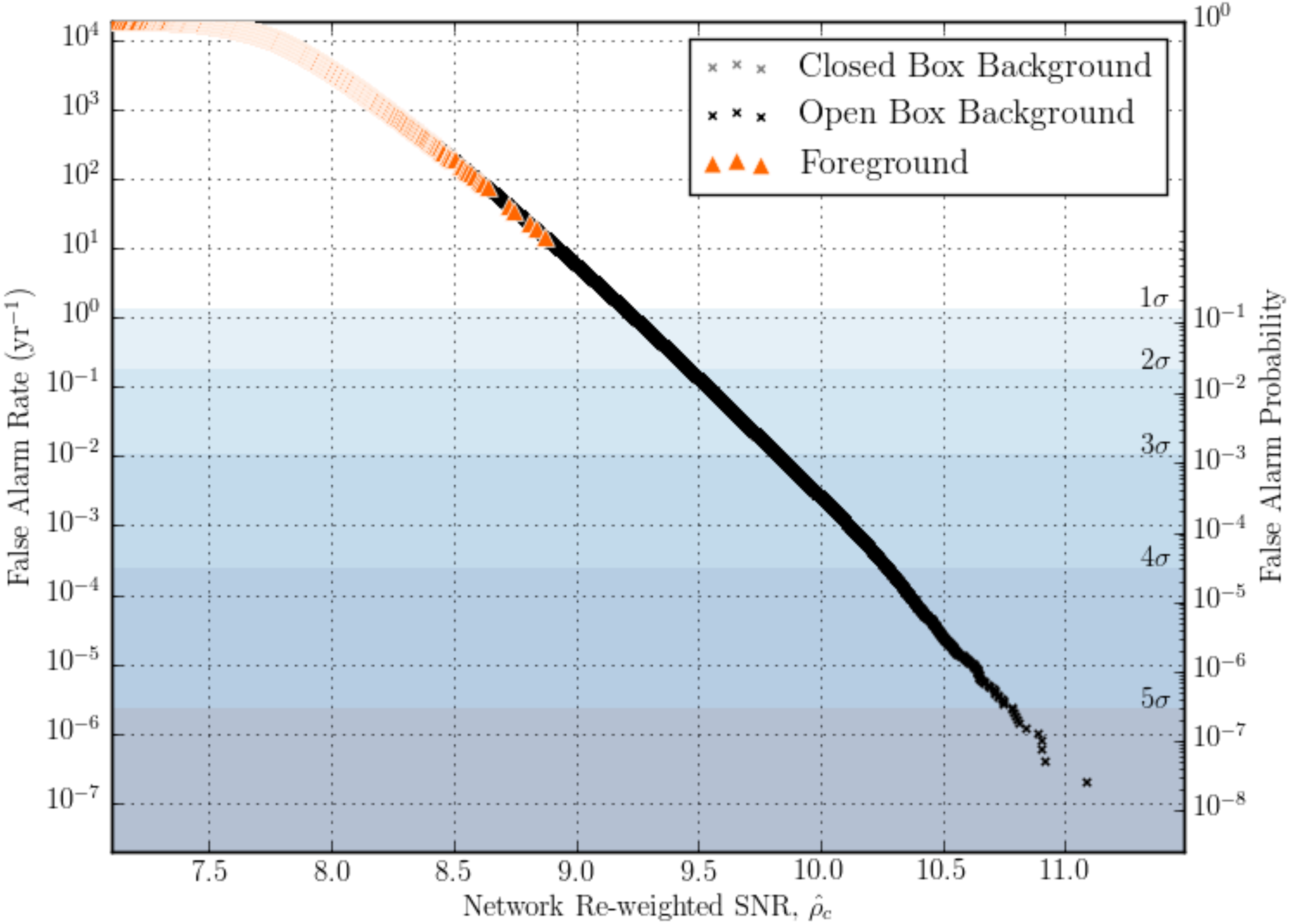
- We can use the observers BBH mergers to measure the event rate
- This rate can be used to estimate the probability that a given trigger is of astrophysical origin
- p(astro; LVT151012) = 0.87

Abbott, ..., DAB, et al. PRX **6** 041015 (2016)

No significant BNS or NSBH candidates in O1



Abbott, ..., DAB, et al. ApJ L **832** 21 (2016)



Closed Box Background
Open Box Background
Foreground
False Alarm Rate (yr^{-1})
False Alarm Probability
Network Re-weighted SNR, $\hat{\rho}_c$
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
1σ
2σ
3σ
4σ
5σ
7.5
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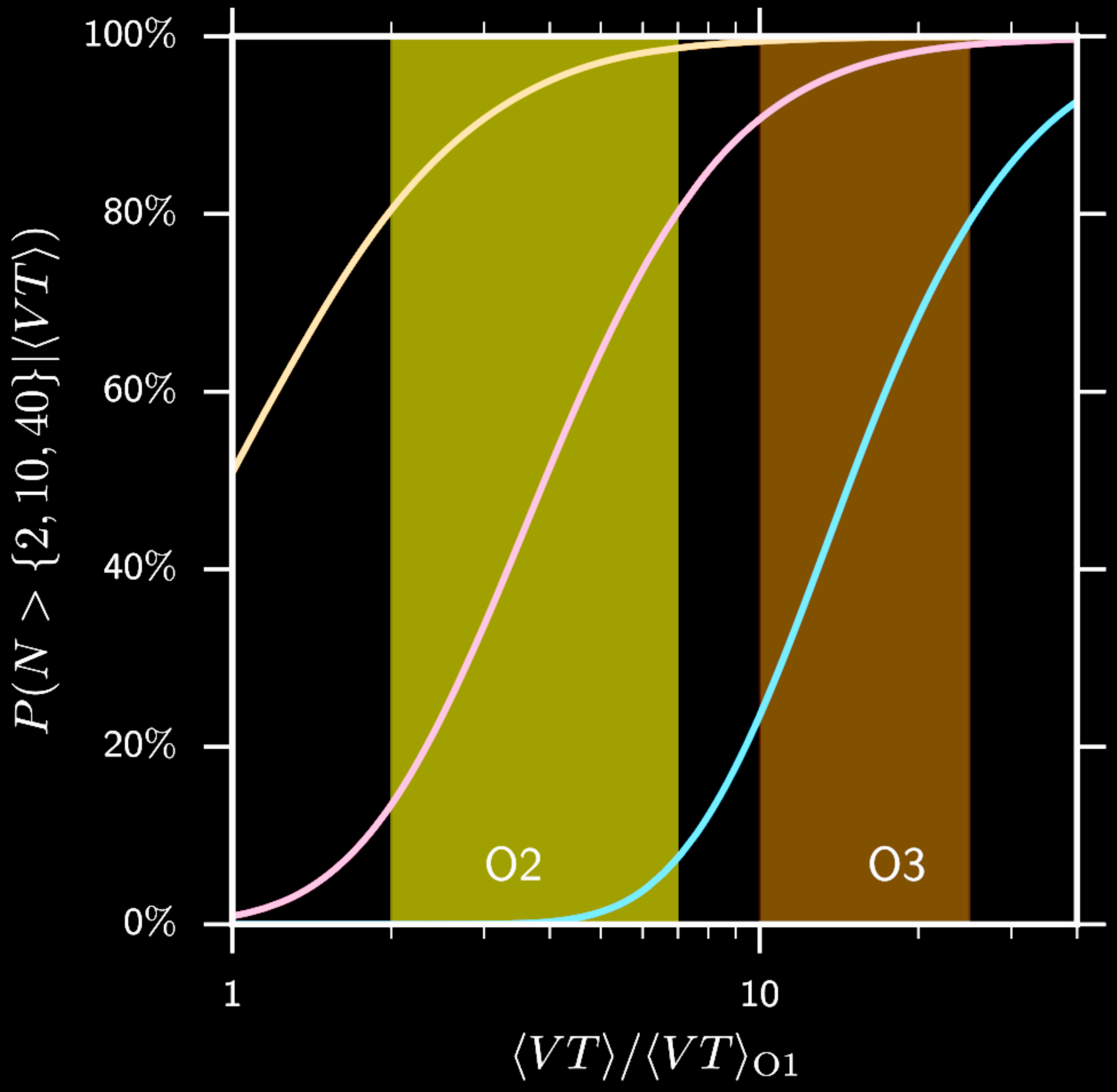
9.5
10.0
10.5
11.0



- Measured BBH coalescence rate is 9 - 240 Gpc^{-3} yr^{-1}.
- The projected detection rate assumes two-detector coincidence.
- The network range is set by the second most sensitive detector (currently Hanford).

Abbott, ..., DAB, et al. PRX **6** 041015 (2016)