2G+XG Science

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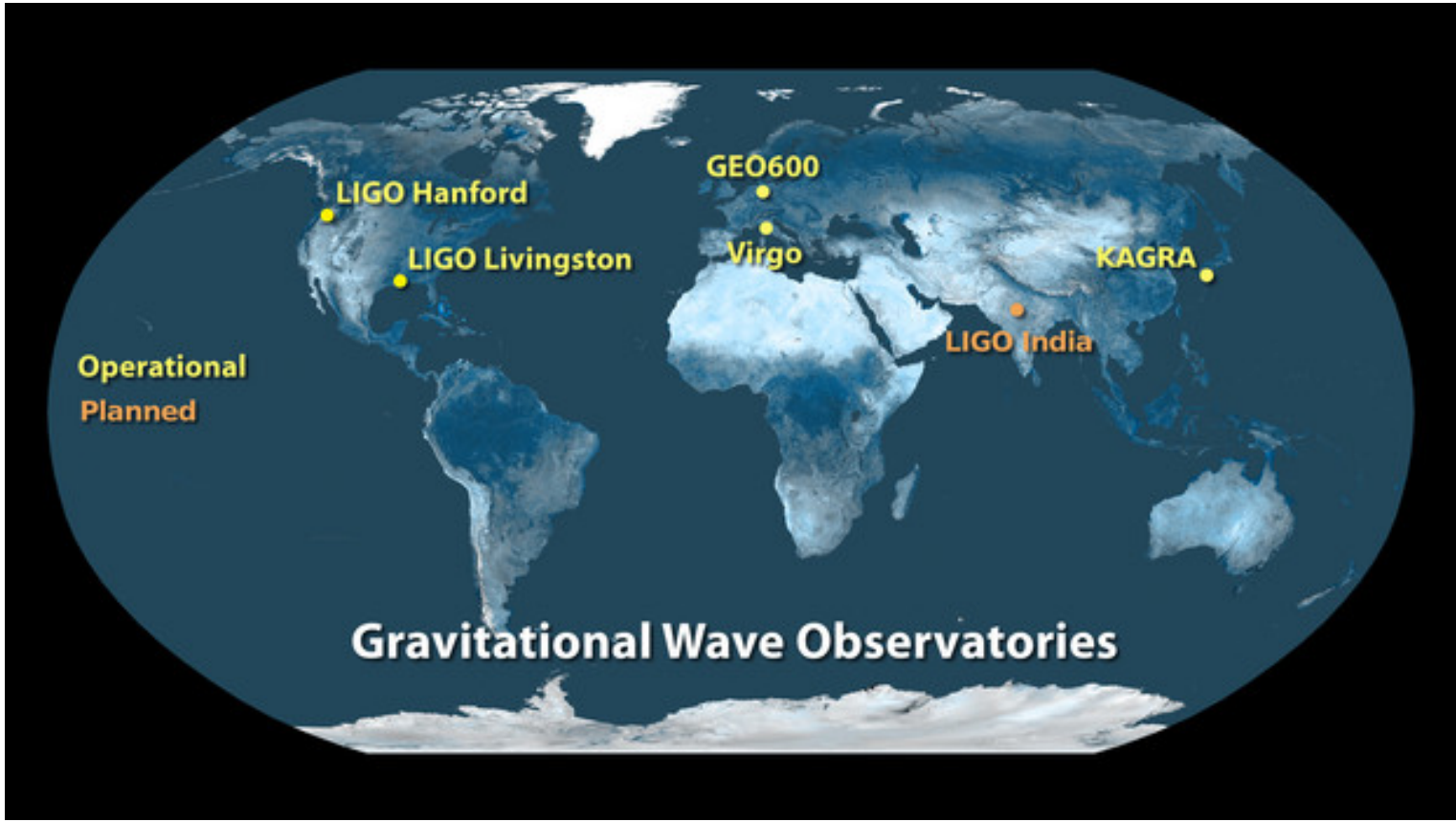
PAX X + CE, 1st July 2025

WHERE ARE WE NOW?



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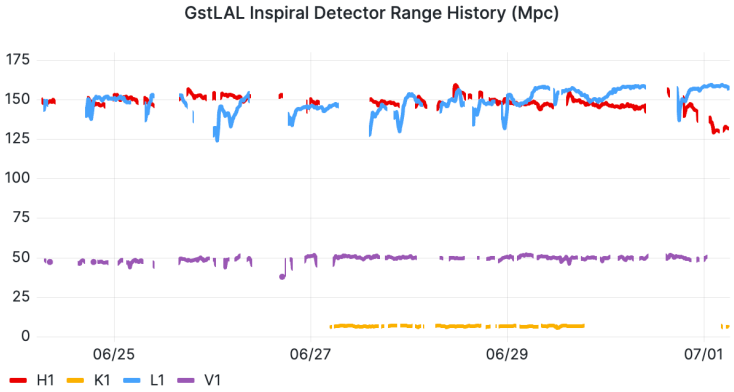
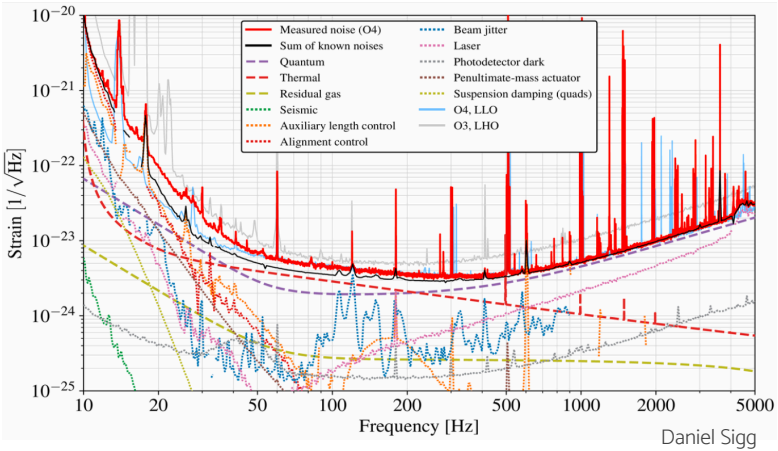
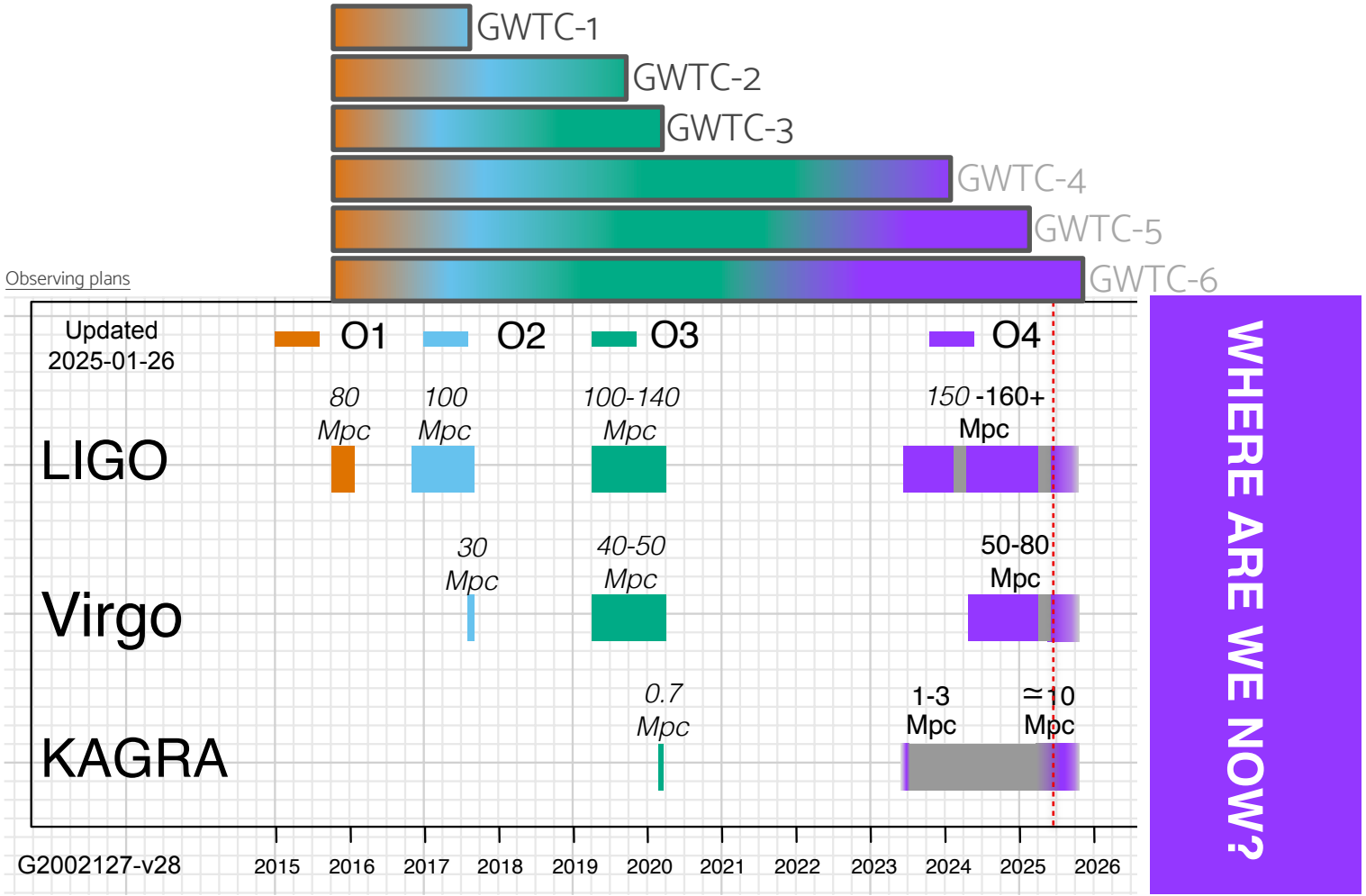


gwistat

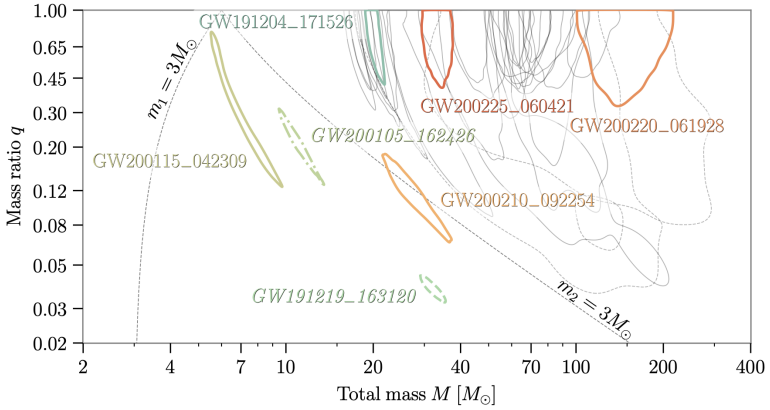


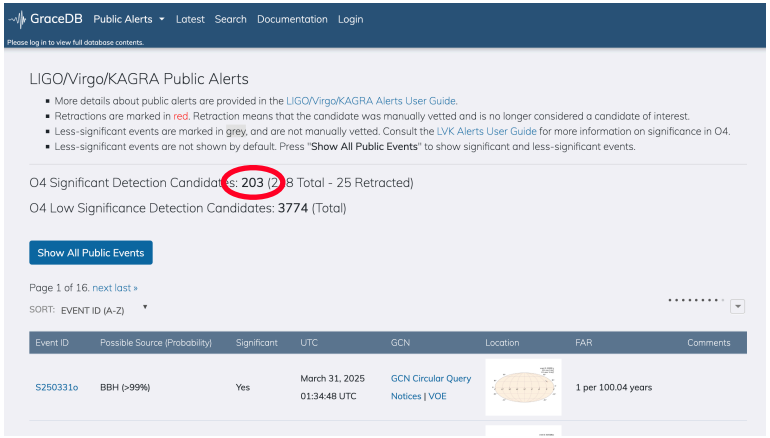
Daniel Sigg

- ALIGO detectors: dual-recycled Michelson interferometers, 4km arms, 40kg test masses, with frequency-dependent squeezing
- AdVirgo: 2km arms
- Most downtime aligned to maximise 3-detector uptime
- KAGRA: underground for lower seismic noise, cryogenic
- GEO600: used for developing and testing, and Astrowatch

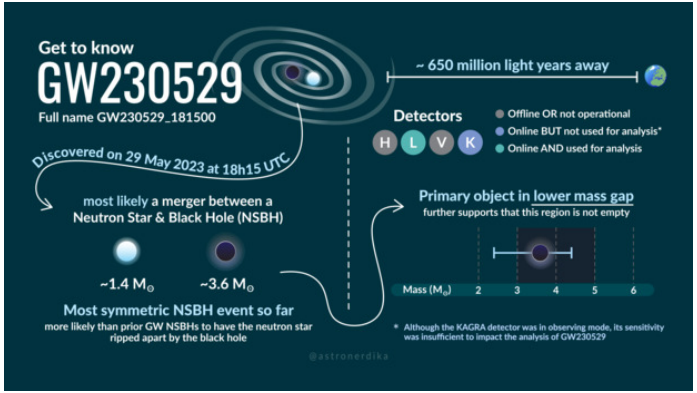

GWTC-1
GWTC-2
GWTC-3
GWTC-4
GWTC-5
GWTC-6
Observing plans
Updated
2025-01-26
O1
O2
O3
O4
LIGO
80 Mpc
100 Mpc
100-140 Mpc
150 -160+ Mpc
Virgo
30 Mpc
40-50 Mpc
50-80 Mpc
KAGRA
0.7 Mpc
1-3 Mpc
≃10 Mpc
G2002127-v28
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
WHERE ARE WE NOW?

WHERE ARE WE NOW?

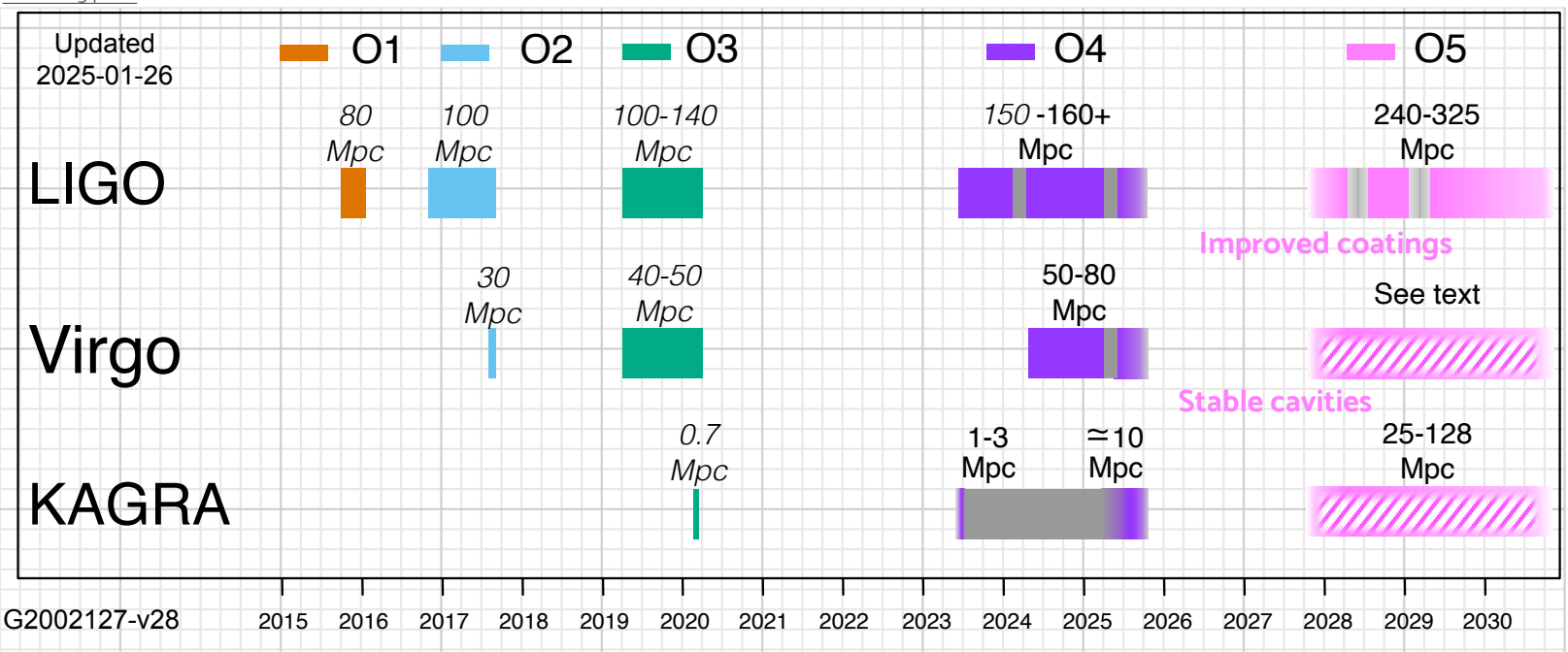




- GWTC-3: 90 confident detections
- Majority BBH mergers
- ~ a few BNS mergers, notably GW170817
- ~ five NSBH mergers, notably GW200105 and GW200115
- Some systems with masses between 3 and 5 $M_\odot$, GW190814 and GW230529



Observing plans

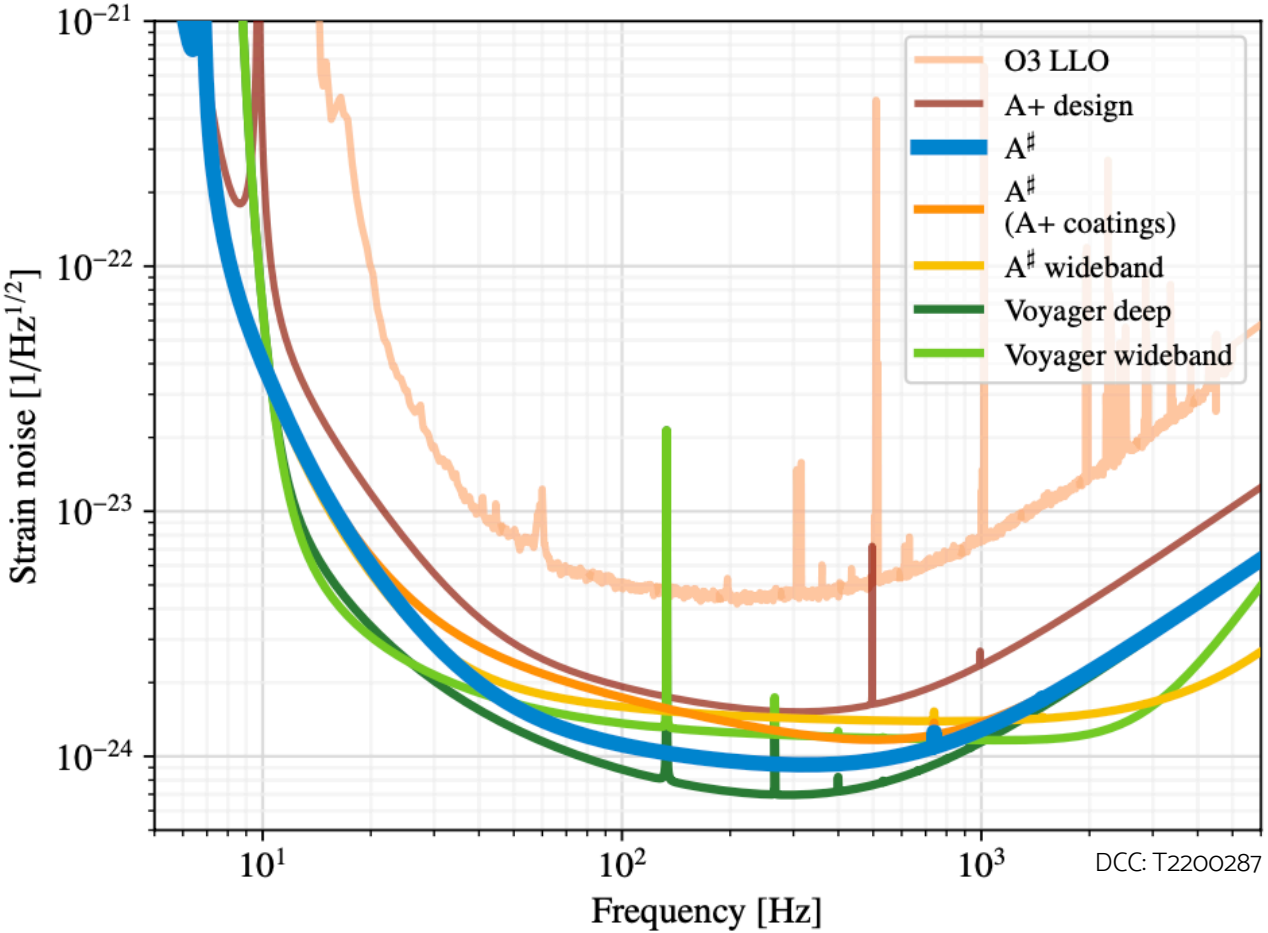


TOWARDS A+

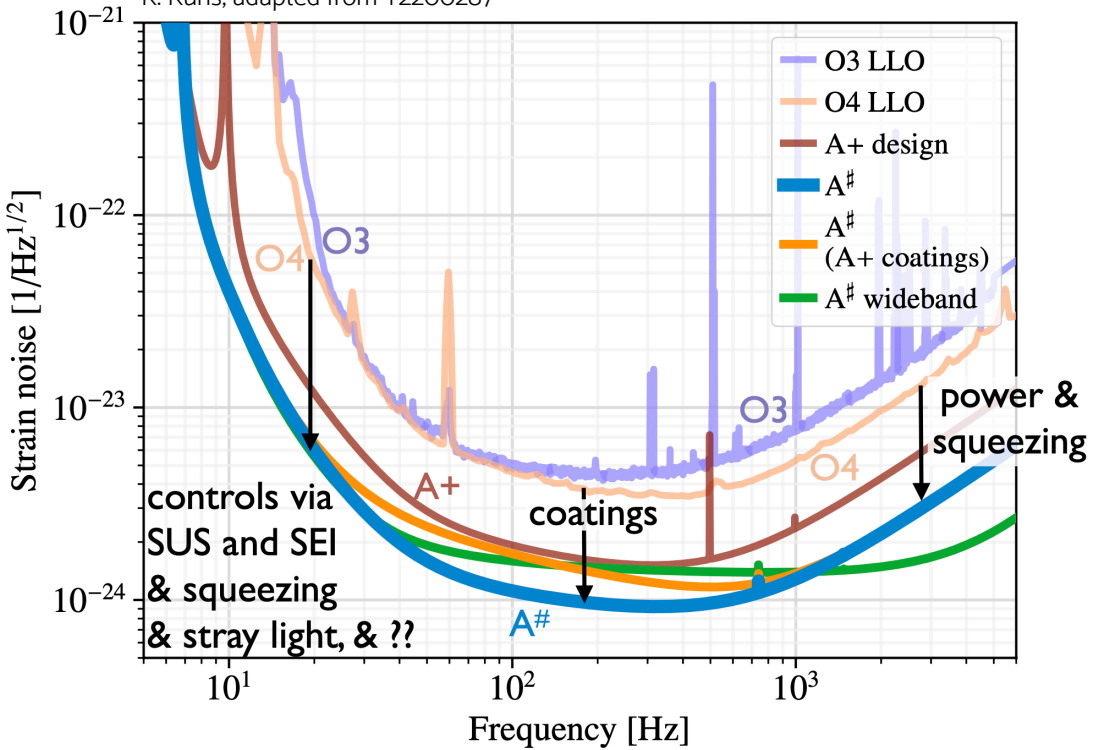
INTO THE NEXT DECADE: A#

A bridge between A+ and next-generation ground-based instruments, and a testing ground for new technologies.

See also: Virgo_nEXT, Voyager



K. Kuns, adapted from T2200287



LOW FREQUENCIES

- 100kg optics on upgraded suspensions
- Use suspension fibres at higher stress

MID FREQUENCIES

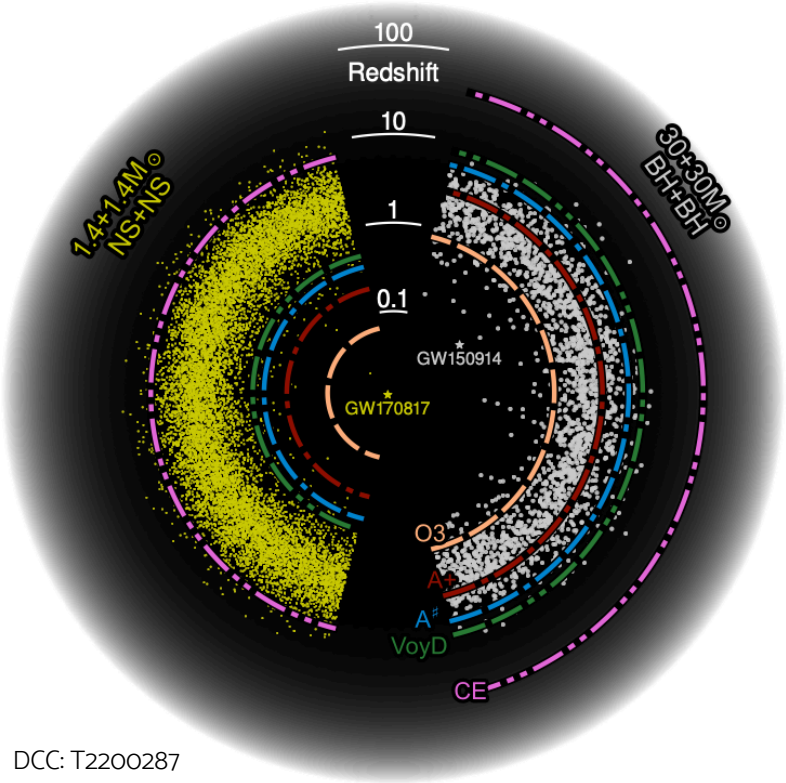
- Improve coatings for lower thermal noise

HIGH FREQUENCIES

- Increase circulating power to 1.5MW
- Increase squeezing up to 10dB

A# KEY UPGRADES

A# DETECTION ESTIMATES



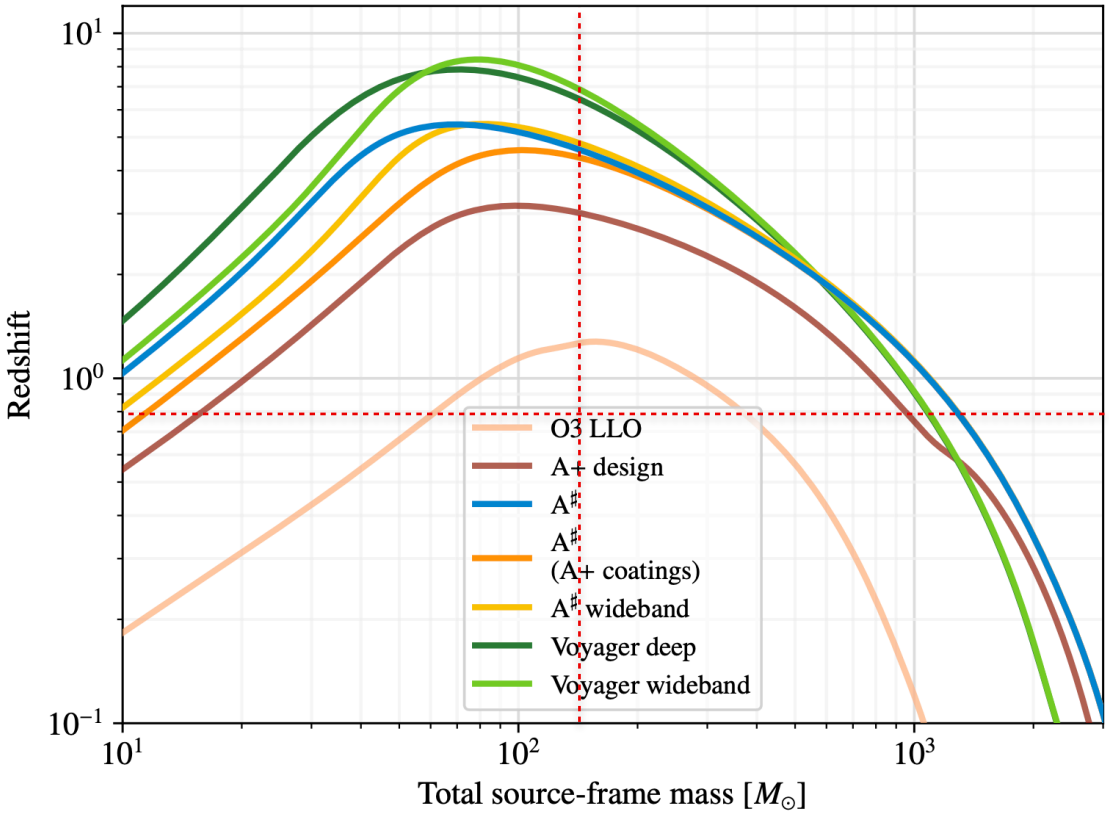
DCC: T2200287

- BNS and NSBH rate in A# more than 4 times that of A+
- Even with A+ coatings, A# still doubles BNS and NSBH rates
- BBH rate is almost 3 times with A# compared to A+

Configuration	Annual Detections		
	BNS	NSBH	BBH
A+	135^{+172}_{-78}	24^{+34}_{-16}	740^{+940}_{-420}
A♯	630^{+790}_{-350}	100^{+128}_{-58}	2100^{+2600}_{-1100}
A♯ (A+ coatings)	260^{+320}_{-140}	45^{+60}_{-27}	1150^{+1450}_{-640}
A♯ Wideband (A+ coatings)	200^{+250}_{-110}	40^{+54}_{-25}	970^{+1220}_{-540}

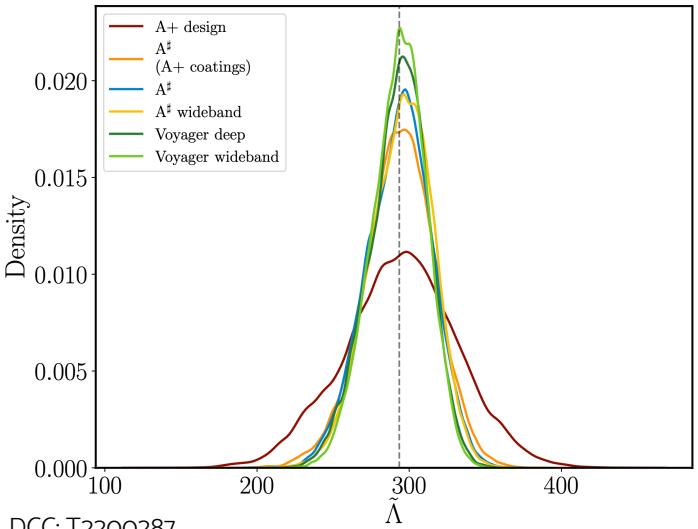
MASS AND REDSHIFT HORIZONS

- A+ will be able to see GW190521-like binaries out to z=3, and A# out to z=5
- Could see ten times heavier GW190521 at the same redshift



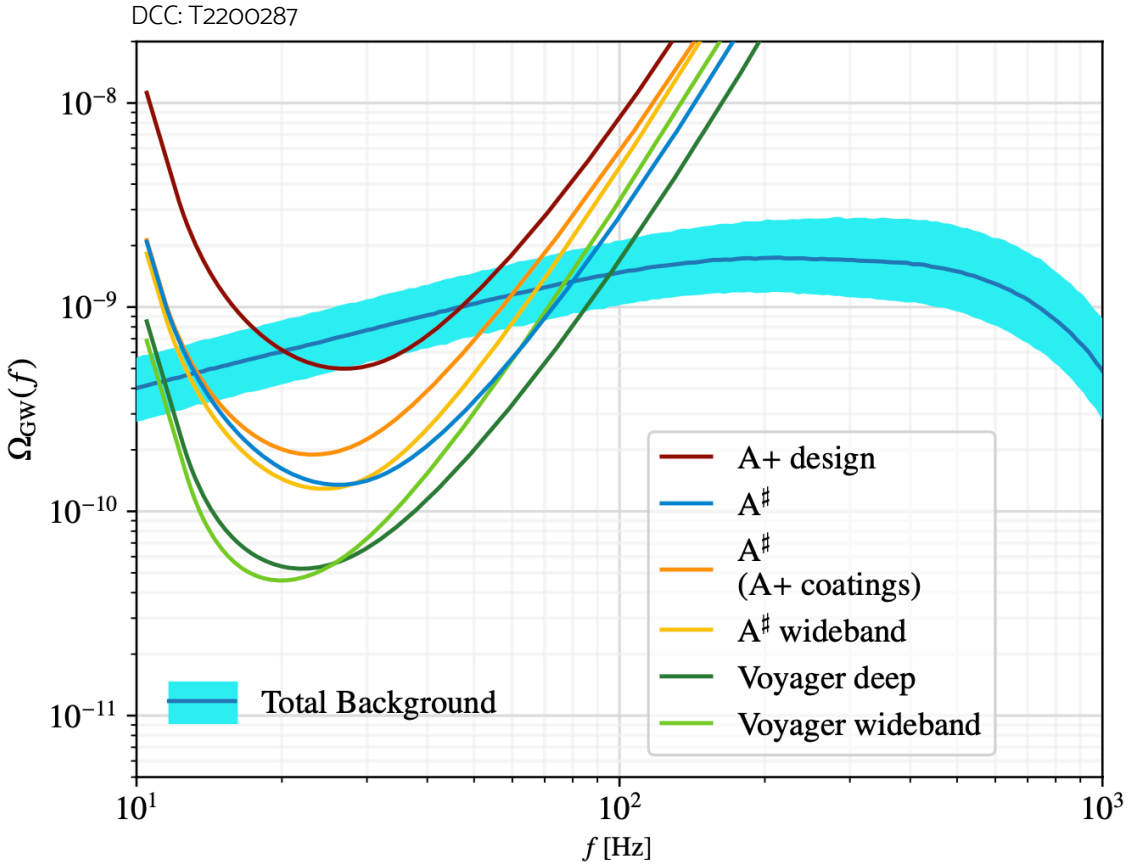
NS SCIENCE

Configuration	Range [Mpc] BNS	BBH	$t_{\rm early}$[min]	$z_{\rm max}$	Post-Merger $\rho_{\rm pm}^{(10)}$	$\rho_{\rm pm}^{(\rm max)}$
O3 LLO	130	1200	0.3	1.3	0.4	0.6
July 2022 LLO	120	1200	0.5	1.5	0.3	0.5
A+	350	2600	2.7	3.2	1.4	2.0
A+ Wideband	290	2300	3.7	3.5	2.2	2.6
A♯	600	3700	6.2	5.4	2.7	3.7
A♯ (A+ coatings)	440	3000	6.1	4.6	2.7	3.4
A♯ Wideband	490	3300	6.8	5.5	4.8	5.6



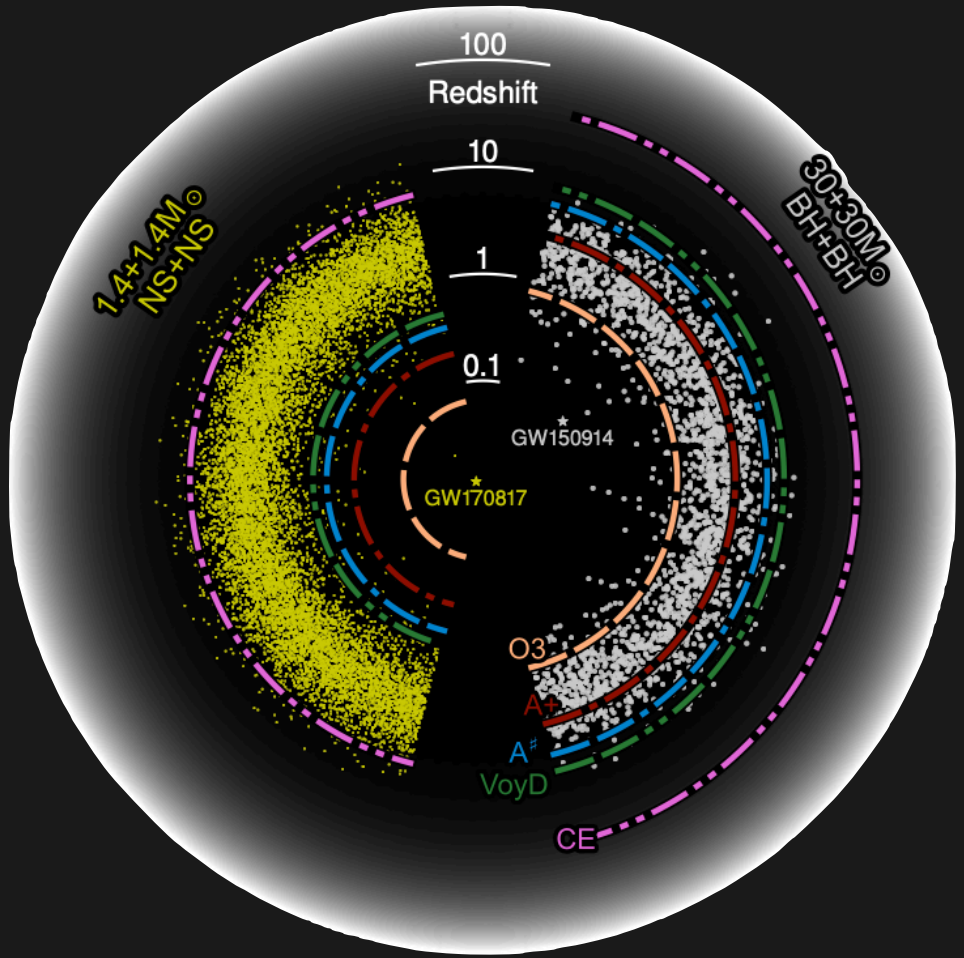
DCC: T2200287

- BNS range around 4 times further than current
- Low frequency sensitivity improvements lead to BNS early warning of six minutes
- High frequency improvements make BNS post-merger detections a tantalising possibility
- Can infer tidal parameter significantly better



- If not already detected by O5, any post-O5 upgrade will allow for the detection of an unresolved background of binary mergers

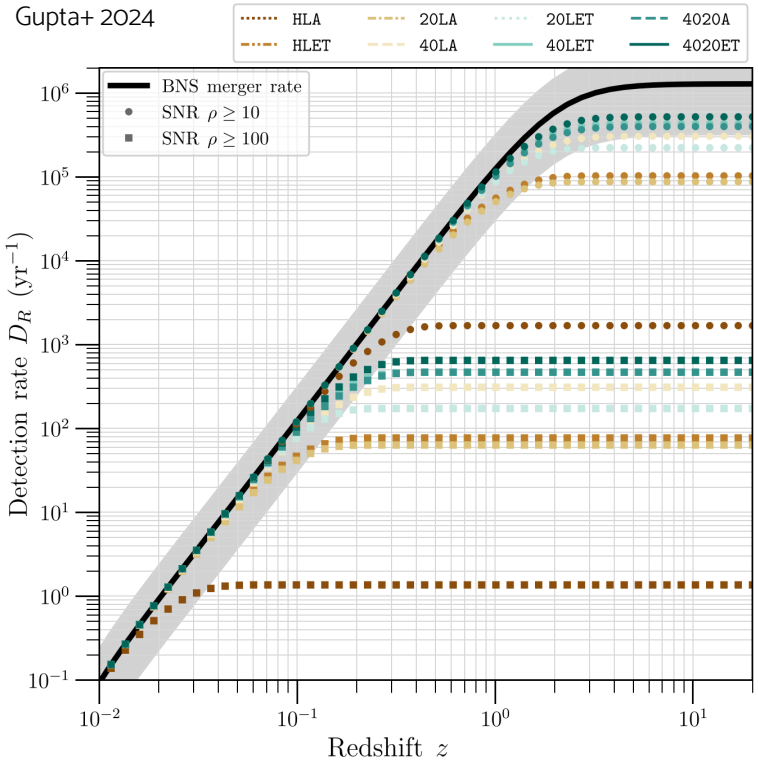
UNRESOLVED BACKGROUND



HERE COMES XG!

DCC: T2200287

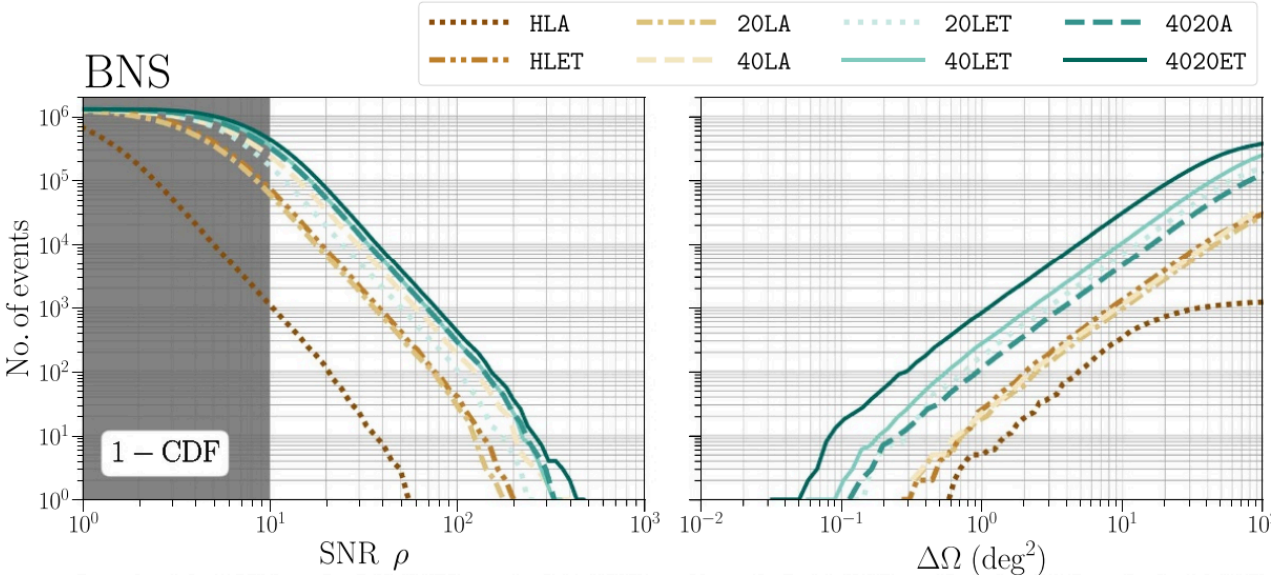
Gupta+ 2024



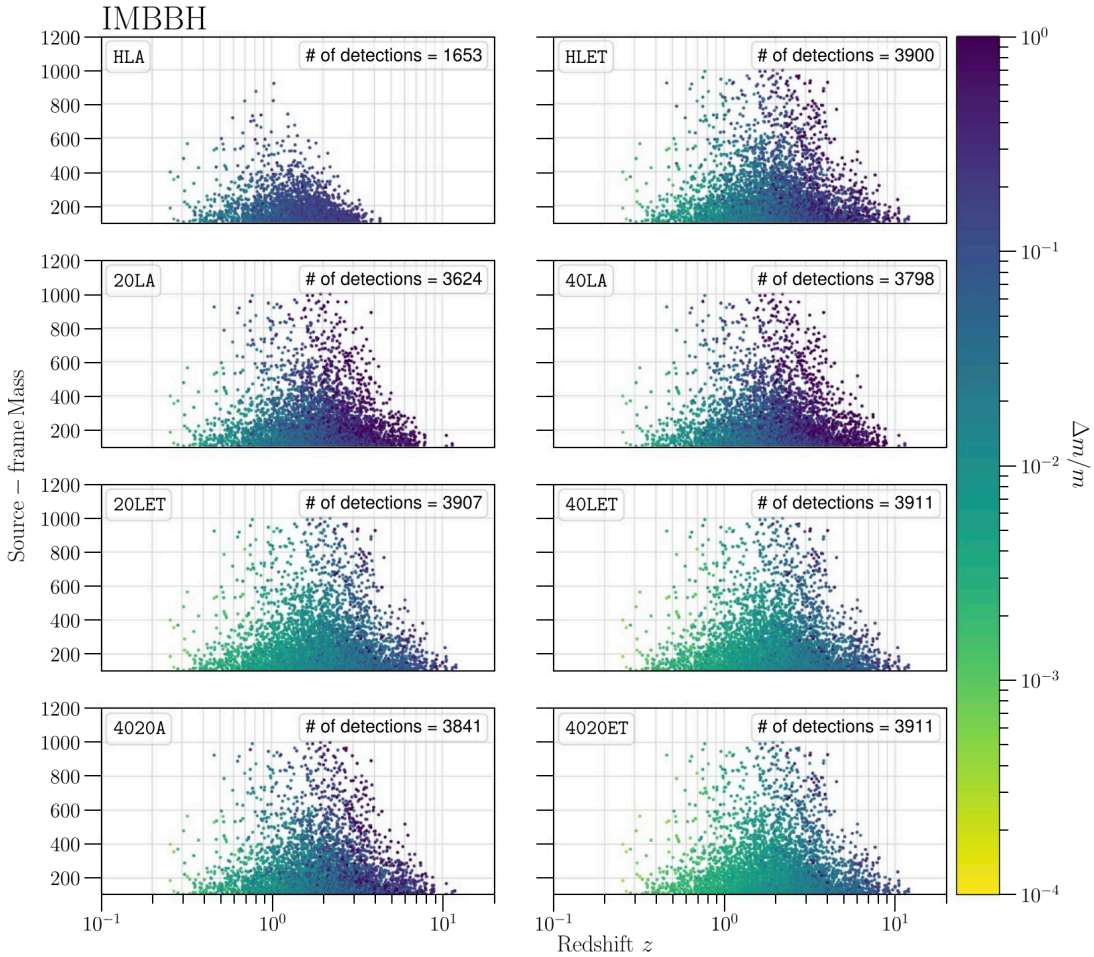
- 2G A# network will observe ~0.1%, 1% and 15% of the BNS, NSBH and BBH population respectively
- With two CEs this increases to ~30%, 66% and 95%
- At least one XG instrument required to detect BNSs up to peak star formation rate

2G+XG DETECTIONS

BNS AND LOCALISATION



- 2G detectors ~a few sources less than 1 deg^2, one CE improves this by ~an order of magnitude
- Lots of sources less than 100 deg^2 (note for later)
- Both 3 XG and 2 XG detectors will be able to measure $\Delta\iota \leqslant 0.01$deg for about 100 sources, infer angle of relativistic jet



IMBBH POPULATIONS

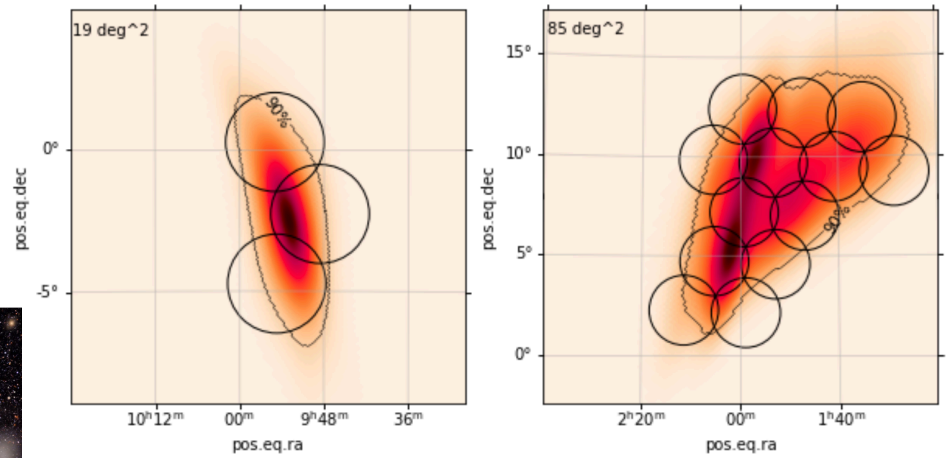
- A# detects only 40%, but XG networks over 90%
- Maximum redshift from z~3 to z>10

Gupta+ 2024

FOLLOW-UP WITH RUBIN

NSF–DOE Vera C. Rubin Observatory

Andreoni+ 2022



- Rubin first light!
- ToO observing scheduler for followup of potential multi messenger events is being tested
- NS Gold < 100 deg^2, there will (hopefully) be lots!
- 2G detector uptime when XG instruments are down?

SOME QUESTIONS

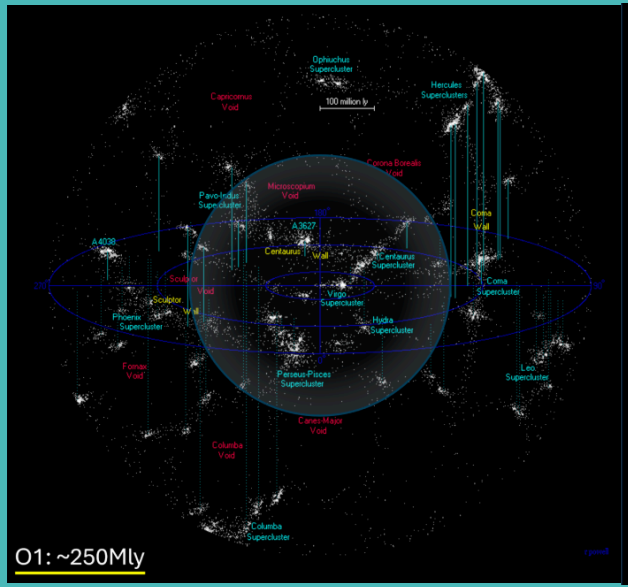
- How should we prioritise detector up time in a network of XG and 2G instruments?
- What will the impact of further detectors (NEMO) be in this future network?
- How competitive will a 2G+XG network remain for how long, and when will we require full XG synchronisation?
- … and more…

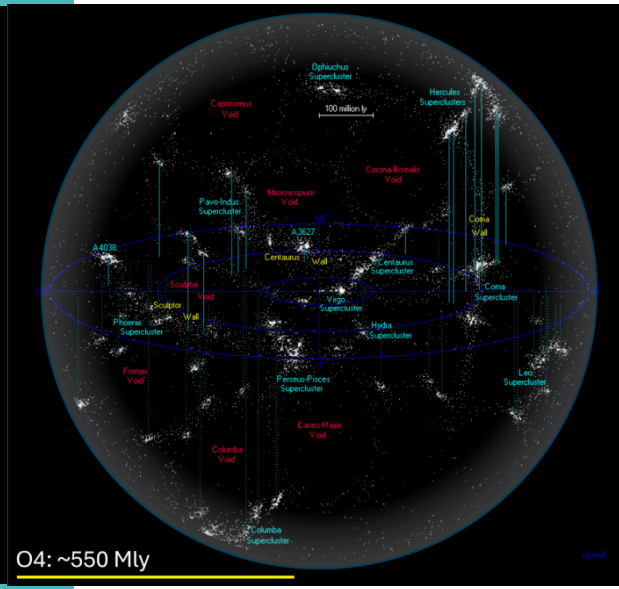
Come to the panel discussion after the coffee break! Share your opinions (the more controversial the better!) and questions

MIT/Caltech/LIGO Lab/Kim Burtnyk

SUMMARY

- A+ is only three years away, and A# in the early 2030s will provide significant science benefits
- Upgrades will lead to many more detections, including heavier BBHs, better NS constraints and an unresolved background of merging binaries
- XG will be another dramatic shift in performance, what will the value of 2G detectors be in a XG+2G network?
- Come to the panel discussion!





THANK YOU!