Multi-messenger opportunities with the Einstein Telescope

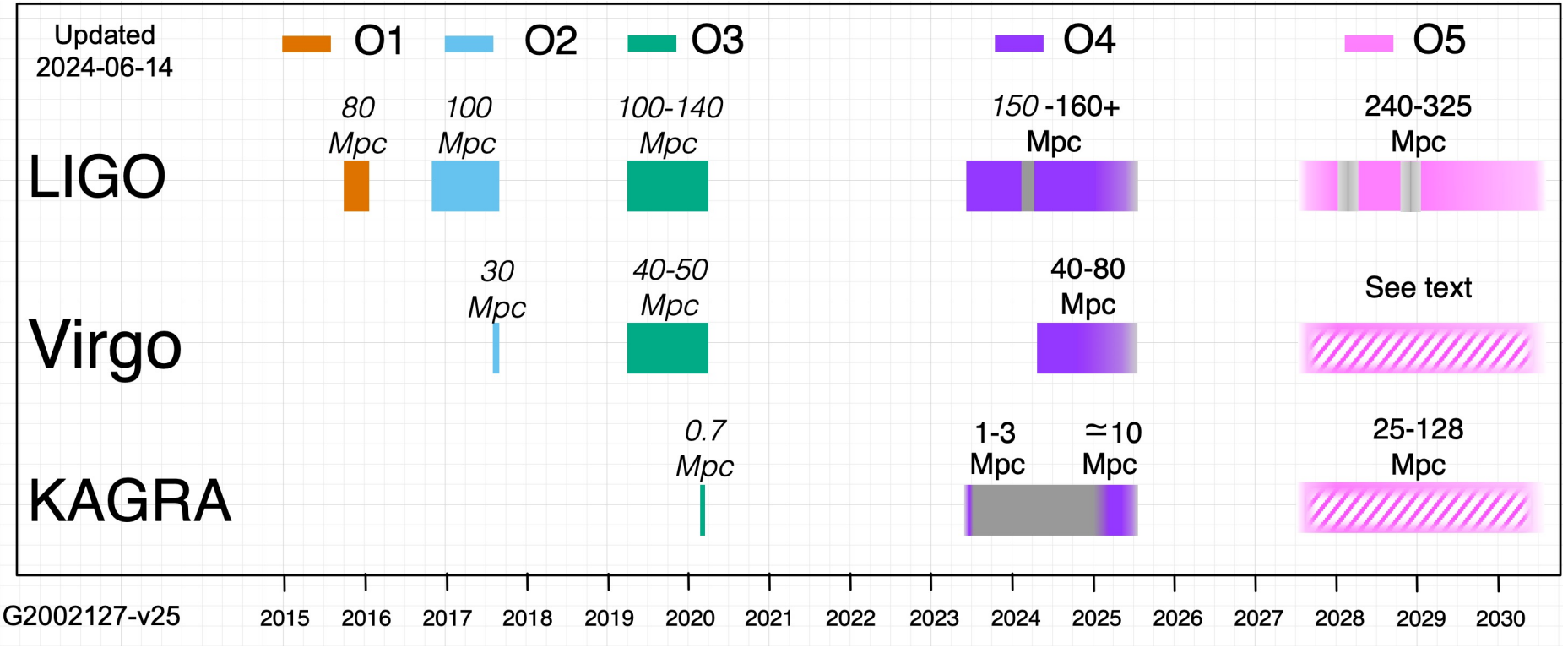
June 13 2025

Einstein Telescope, Observational Science Board (OSB), division 4

Giancarlo Ghirlanda Susanna Vergani Andrew Levan
[giancarlo.ghirlanda@inaf.it, susanna.vergani@obspm.fr, a.levan@astro.ru.nl]

Even at O5 sensitivities the number of EM-bright detections likely to be modest

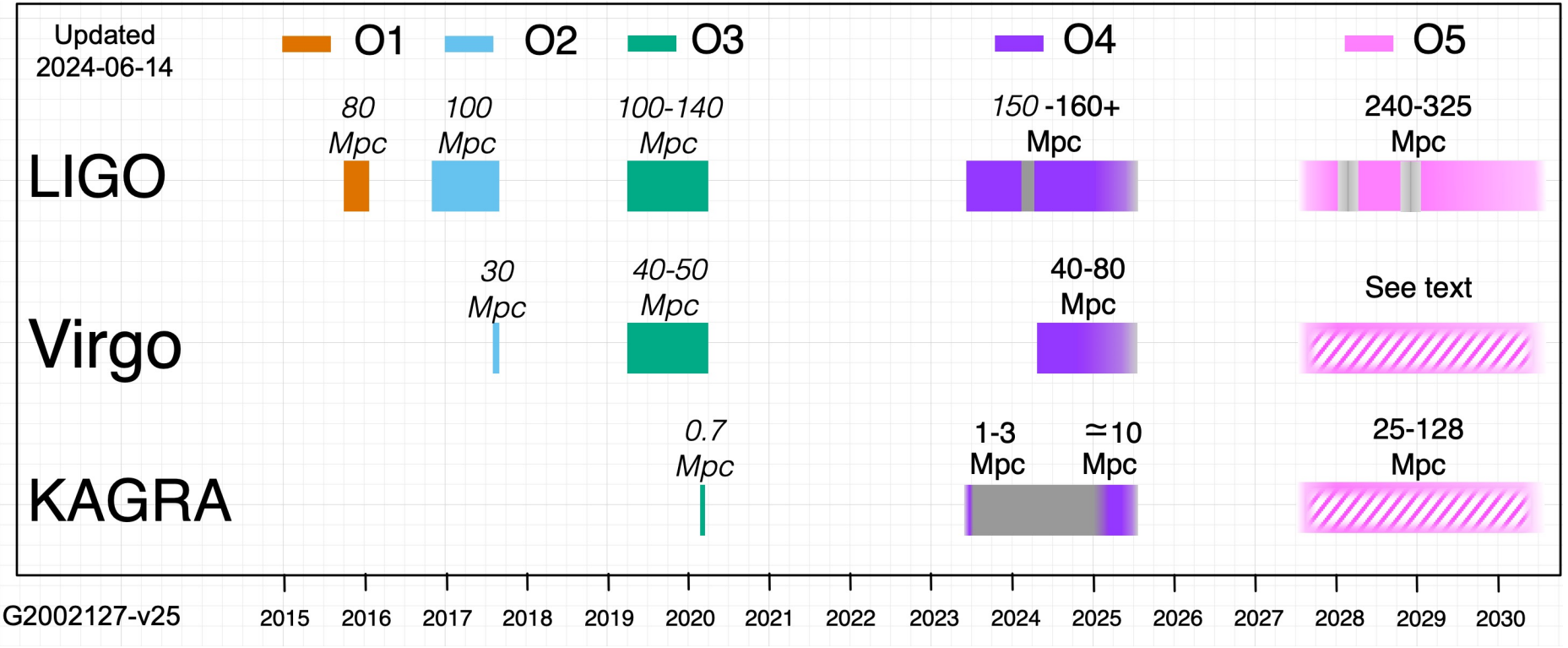
The next decade with LIGO/VIRGO/KAGRA



$N_{multi\text{-}messenger}$	0	1	0	0+	?

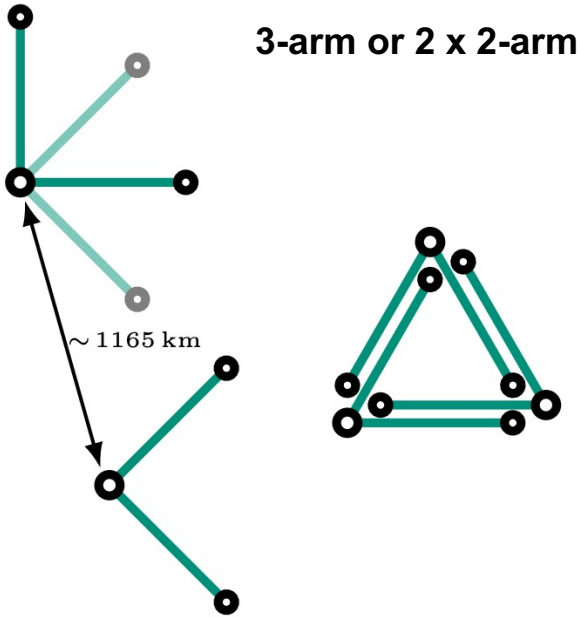
Even at O5 sensitivities the number of EM-bright detections likely to be modest

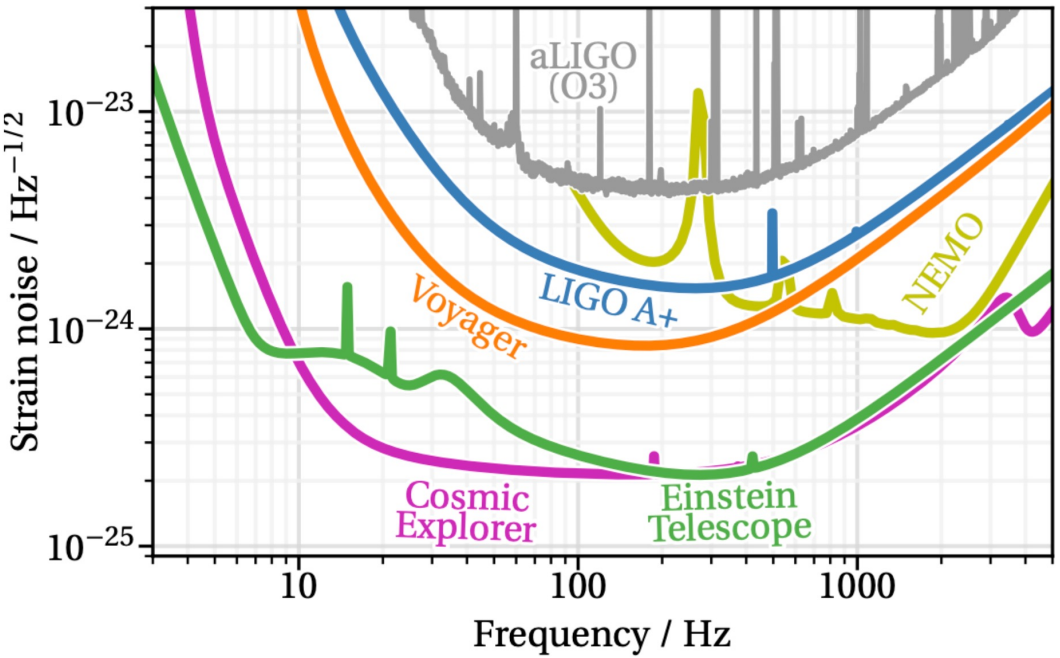
The next decade with LIGO/VIRGO/KAGRA



$N_{multi\text{-}messenger}$	0	1	0	0+	?

The Einstein Telescope

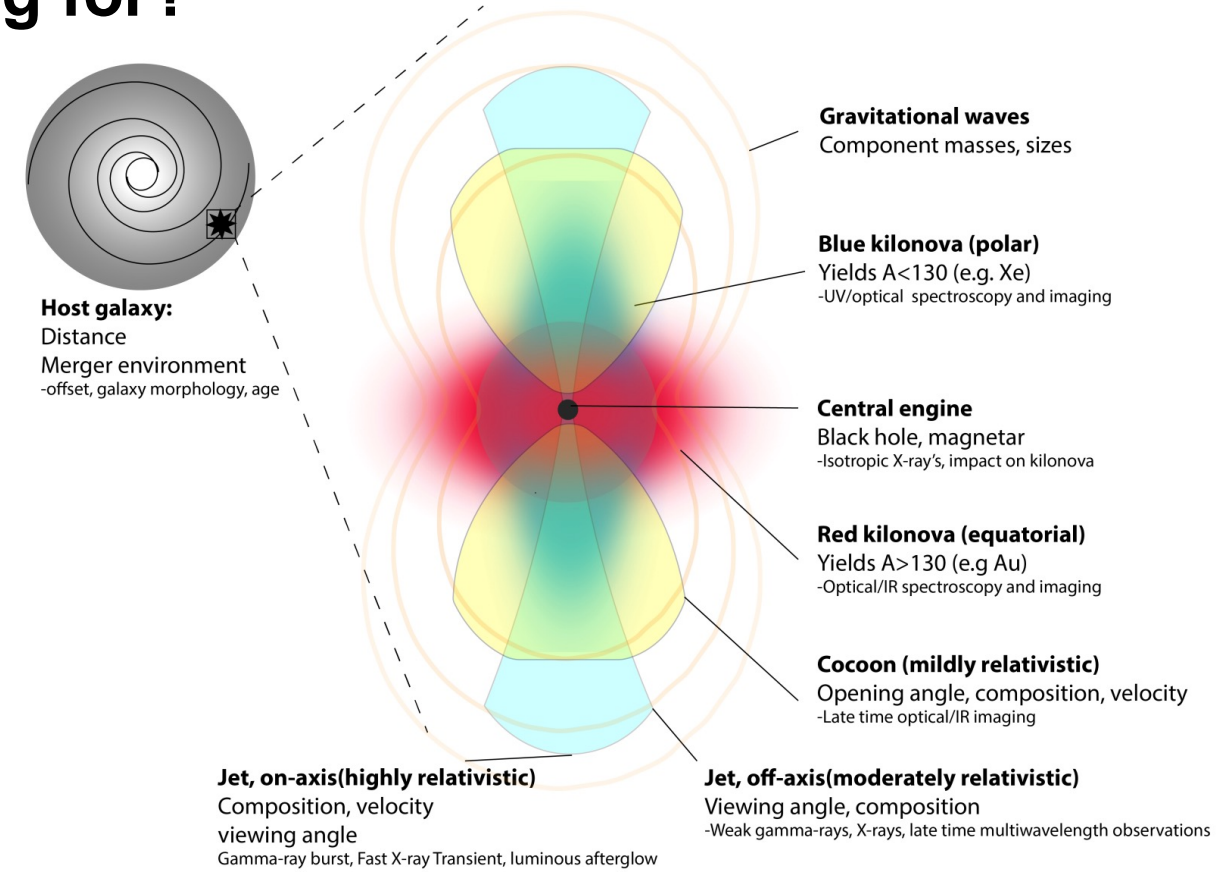




The OSB (Observational Science Board)

The OSB (Observational Science Board)

What are we looking for?

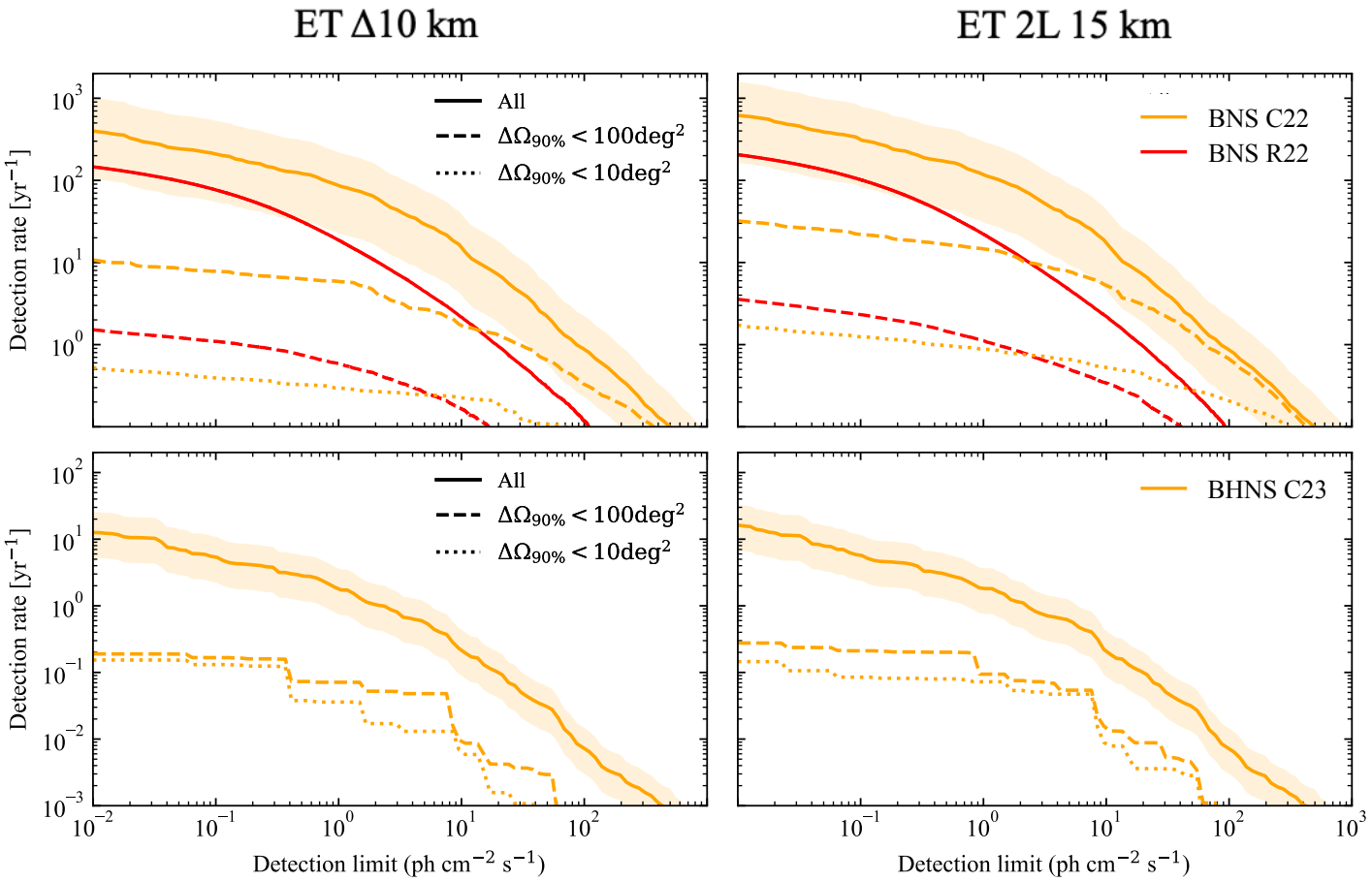


Set-up

In particular thanks to O. S. Salafia, S. Ronchini, A. Colombo, F. Iacovelli, J. Dupletsa, S. Ascenzi, E. Loffredo

Independent routes to make KN and GRB (multiwavelength) predictions

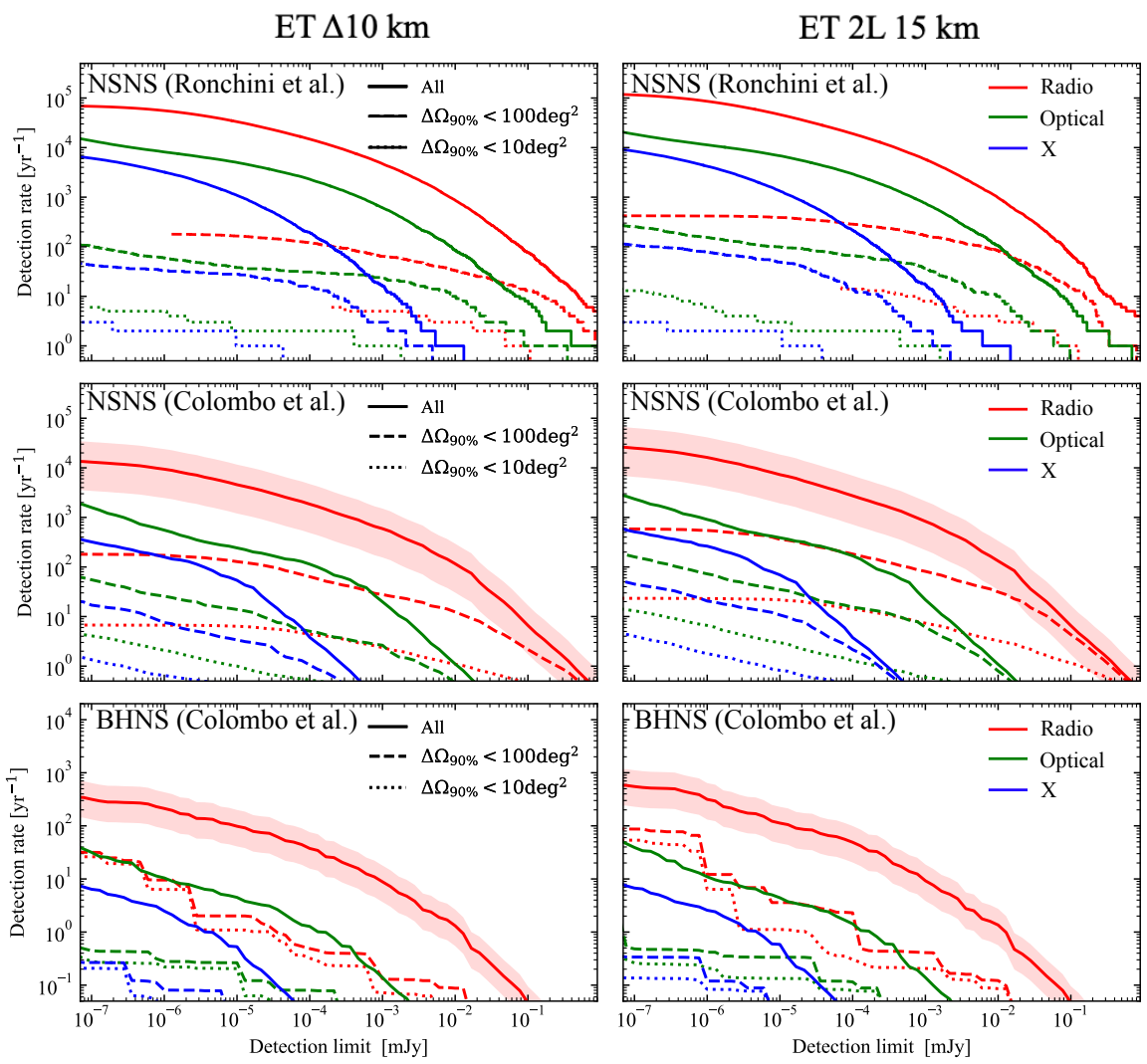
	C22 [7]	**R22** [8]	**L24** (add L24)	**C23** [9]
CBC System	BNS	BNS	BNS	BH-NS
CBC Pop.	R0+delayed SFR	Santoliquido+21	Iorio+23	Broekgaarden+21
$\mathcal{R}_0$ [Gpc^{-3} yr^{-1}]	347	365	107	149
Mass distr.	Analytic	Uniform	Gaussian	Broekgaarden+21
EOS	SFHo	–	BLh	SFHo
Fisher analysis	`GWFast`	`GWFish`	`GWFish`	`GWFast`
SNR cut	12	8	8	12
EM Transients	KN, GRB	GRB	KN	KN, GRB
KN ejecta model	[10, 11, 12]	–	[10, 12] (add L24)	[13, 12]
KN emission model	[14, 15]	–	[16]	[11, 14]
Jet launch & breakout	Yes	No	–	Yes
Cocoon Emission	Yes	No	–	No



GRB prompt emission

Advantages:
Prompt alerts
Can be all sky
GW amplitude maximized for on-axis events

Disadvantages:
Often poor localisations (especially for all-sky monitors), no immediate host galaxy / redshift measurements possible.
Most events don't have a GRB!



GRB afterglow emission

Advantages:

More slowly evolving (especially in the radio), have time to conduct the searches.

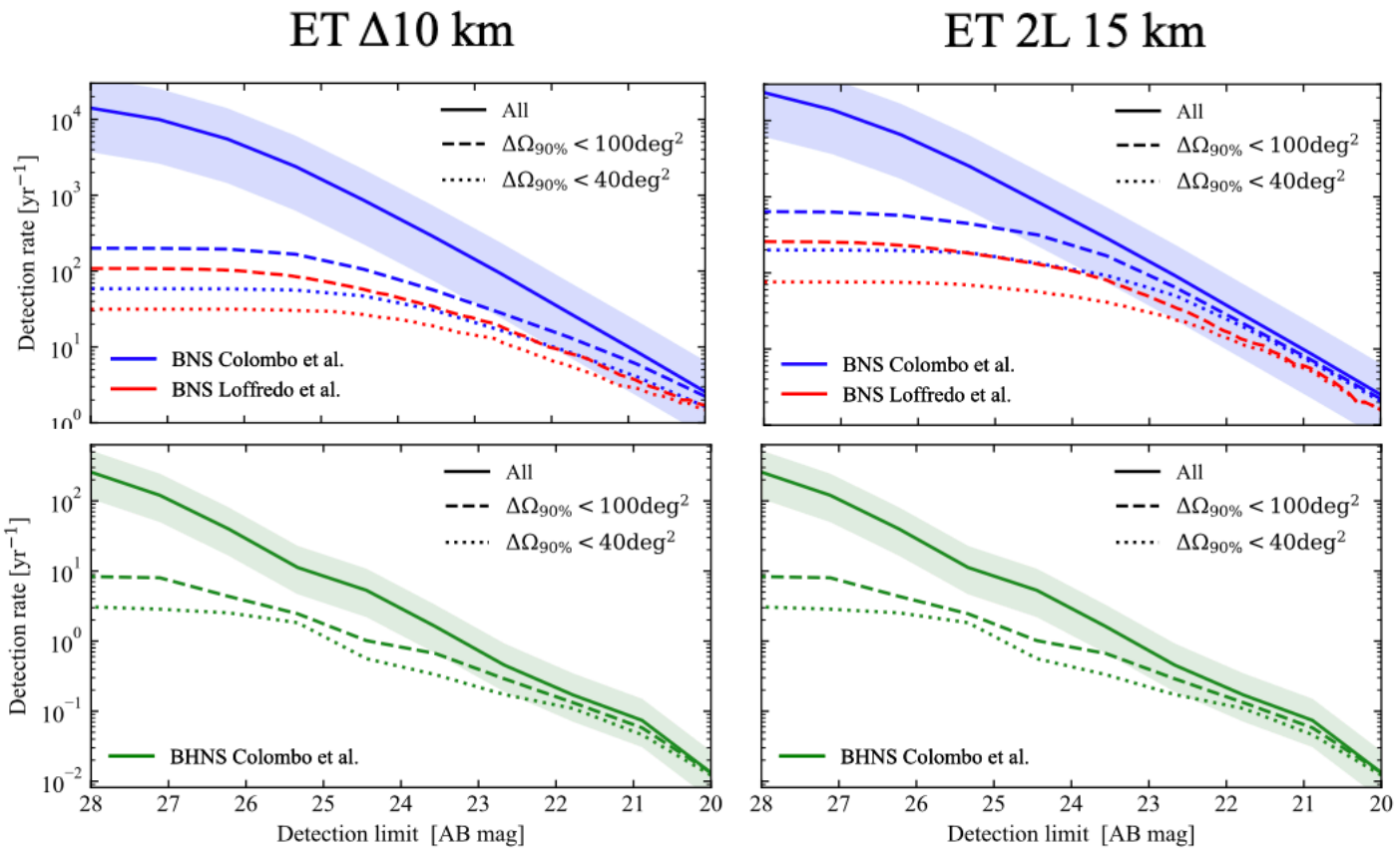
Precise localization possible.

Off-axis afterglows discoverable for events initially not detected as GRBs (more counterparts).

Disadvantages:

Most events still don't have an afterglow.

Off-axis events faint

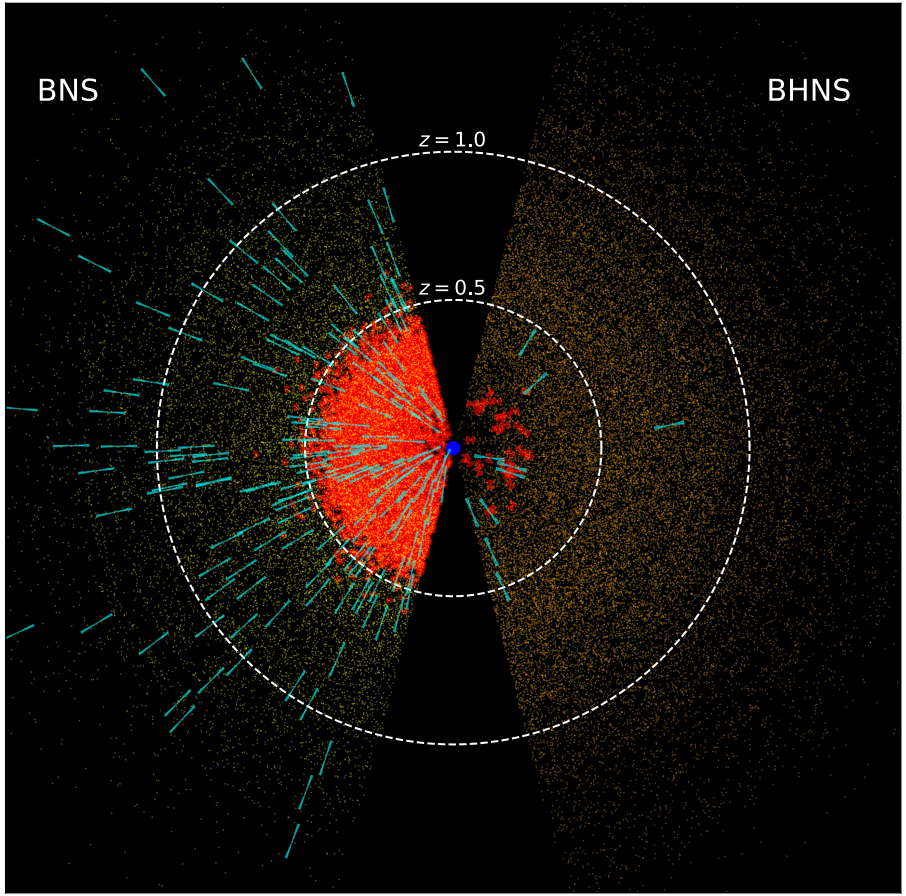


Kilonovae

Advantages:
Visible from all angles (but emission still likely directional).
Visible for days
Offer additional science returns (in particular origin of heavy elements).

Disadvantages:
Faint, many more unrelated supernovae in a typical GW error localization.

Div4 - Multi Messenger Observations



Punchline:
There will be hundreds of mergers with detectable EM emission per year

Caveat:
Detectability is not the same as discovery

Div4 - Multi Messenger Observations

Facilities with required sensitivity to detect kilonova and GRB emission at ET distances are large (~ €1 billion), c.f. many follow-up resources for LVK (e.g. BlackGEM, GOTO, ZTF etc, c. €10 million).

TAKEAWAYS

It is likely that we will need to wait for the ET era to have samples >>10 multi-messenger sources.

This sample size is likely required to fully investigate:

1) Heavy element enrichement
2) The Hubble tension
3) GW-EM as probes of extreme physics (NS EOS, LIV etc).

More distant events are more difficult to study (EM $1/d^2$ makes things more difficult than GW $1/d$)

Large scale facilities will be necessary to fully study these events -- scale of Fermi+/ELT/JWST

Such facilities have long lead times → If we want EM capability at the time of ET we need to ensure it is present by taking action now.