

A short horizontal bar with a teal segment on the left and an orange segment on the right.

# Multi-messenger opportunities with the Einstein Telescope

June 13 2025

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



Giancarlo Ghirlanda

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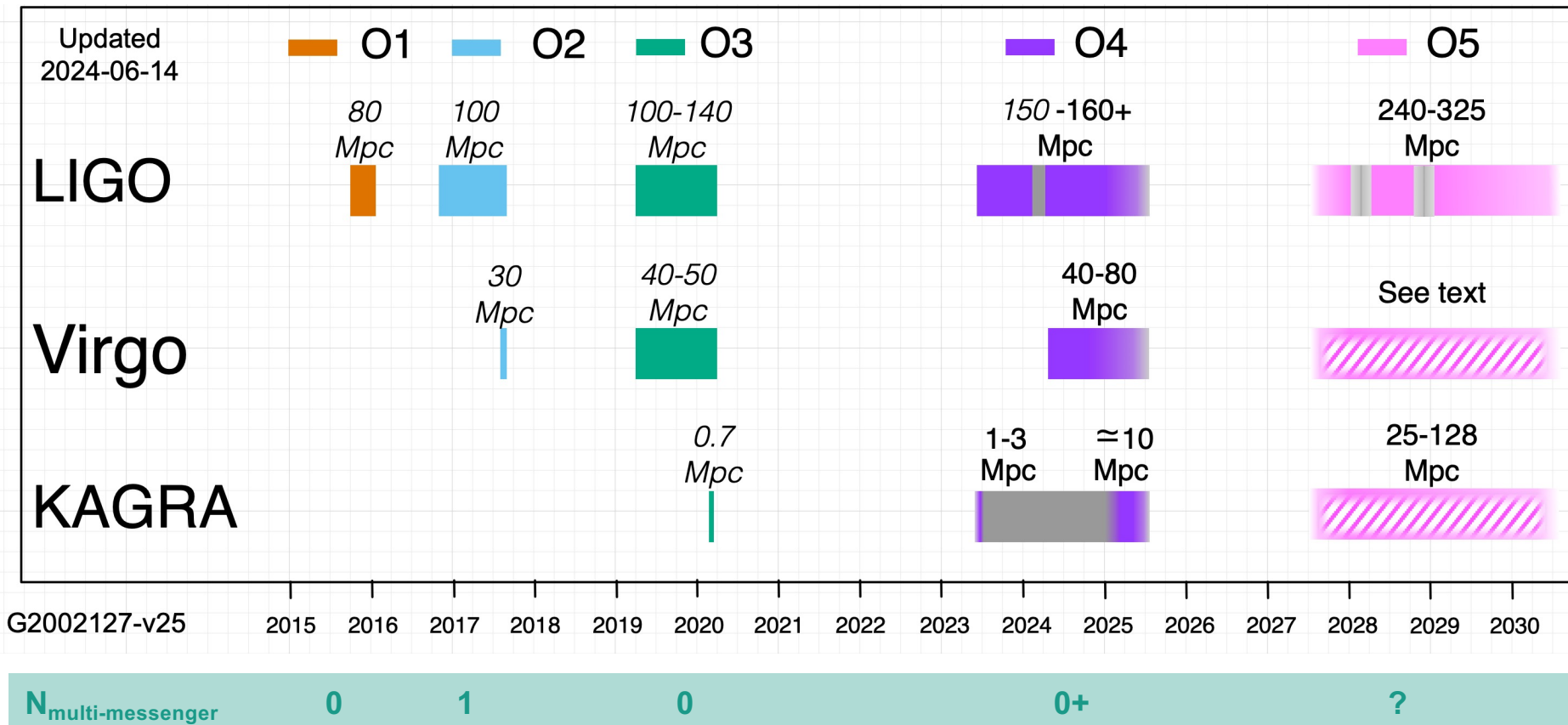
Susanna Vergani



Andrew Levan

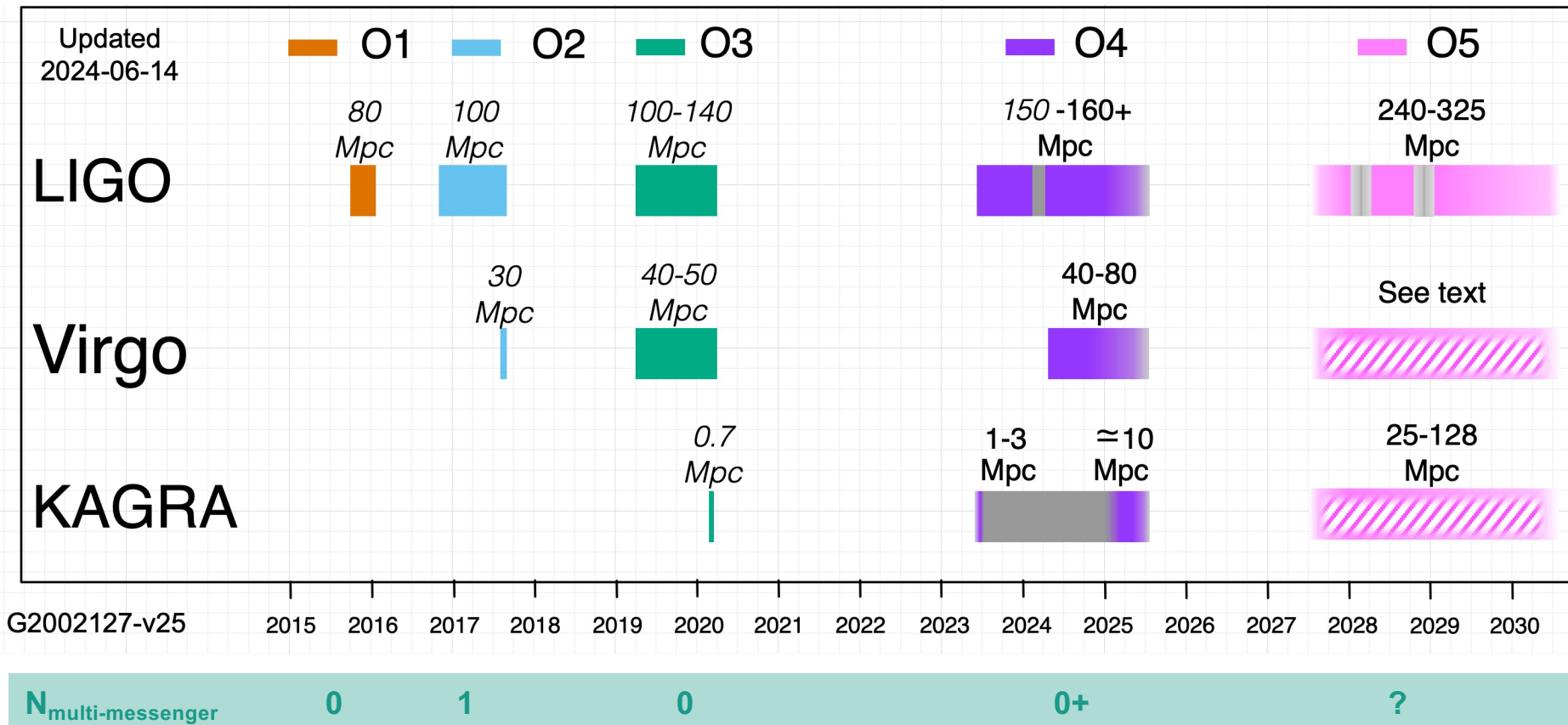
Even at O5 sensitivities  
the number of EM-bright  
detections likely to be  
modest

# The next decade with LIGO/VIRGO/KAGRA

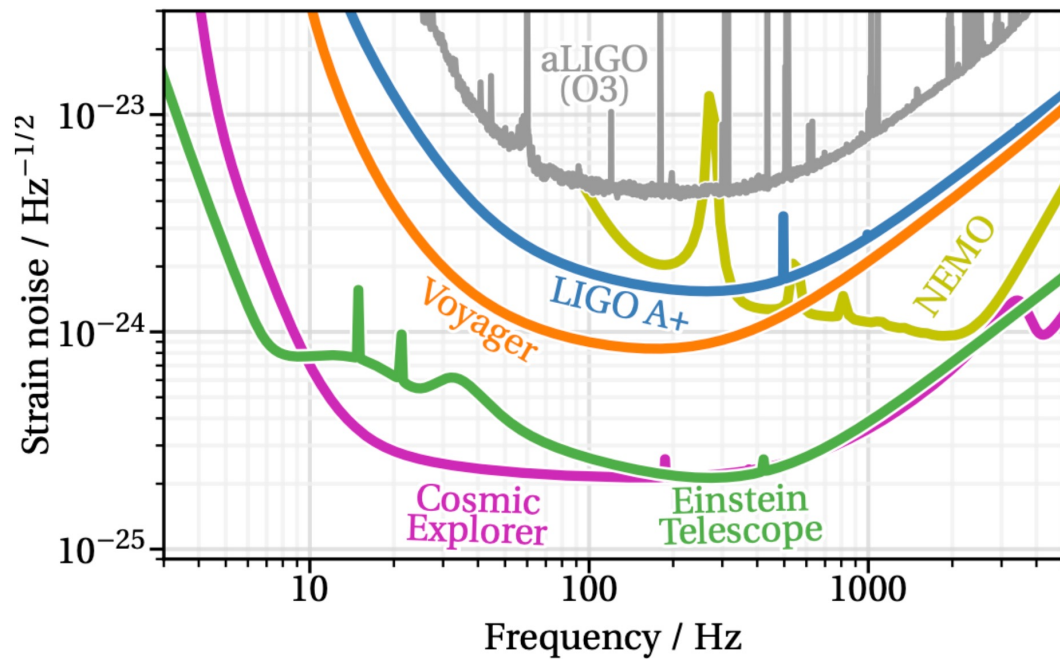
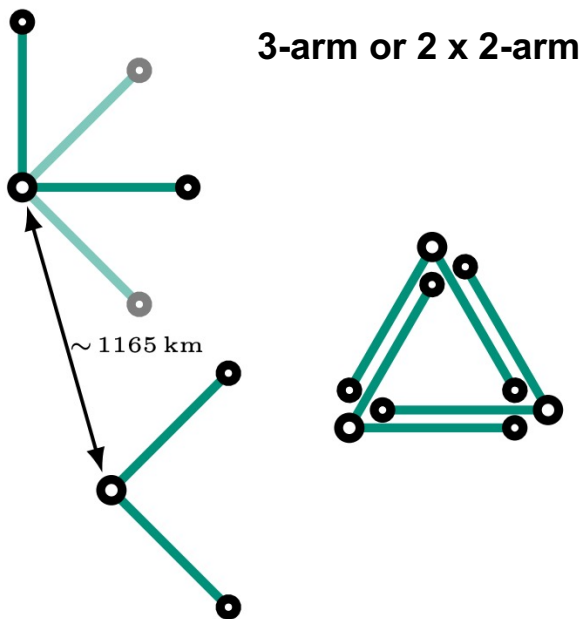


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# The next decade with LIGO/VIRGO/KAGRA



# The Einstein Telescope



# The OSB (Observational Science Board)

OSB Chairs



Michele Maggiore  
Chair



Marica Branchesi  
Chair



Archisman Ghosh  
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Fundamental Physics



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Multimessenger observations



Giancarlo Ghirlanda  
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Andrew Levan  
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Synergies with other GW observatories



Bangalore Sathyaprakash  
Synergies with other GW observatories



Nicola Tamanini  
Synergies with other GW observatories



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Synergies with other GW observatories

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Stellar collapse and isolated neutron stars



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Stellar collapse and isolated neutron stars



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Data analysis platform



Anuradha Samajdar  
Data analysis platform



Gianluca Guidi  
Data analysis platform



Elena Cuoco  
Data analysis platform

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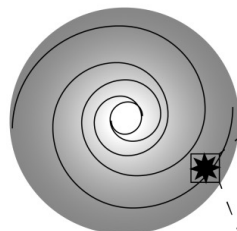


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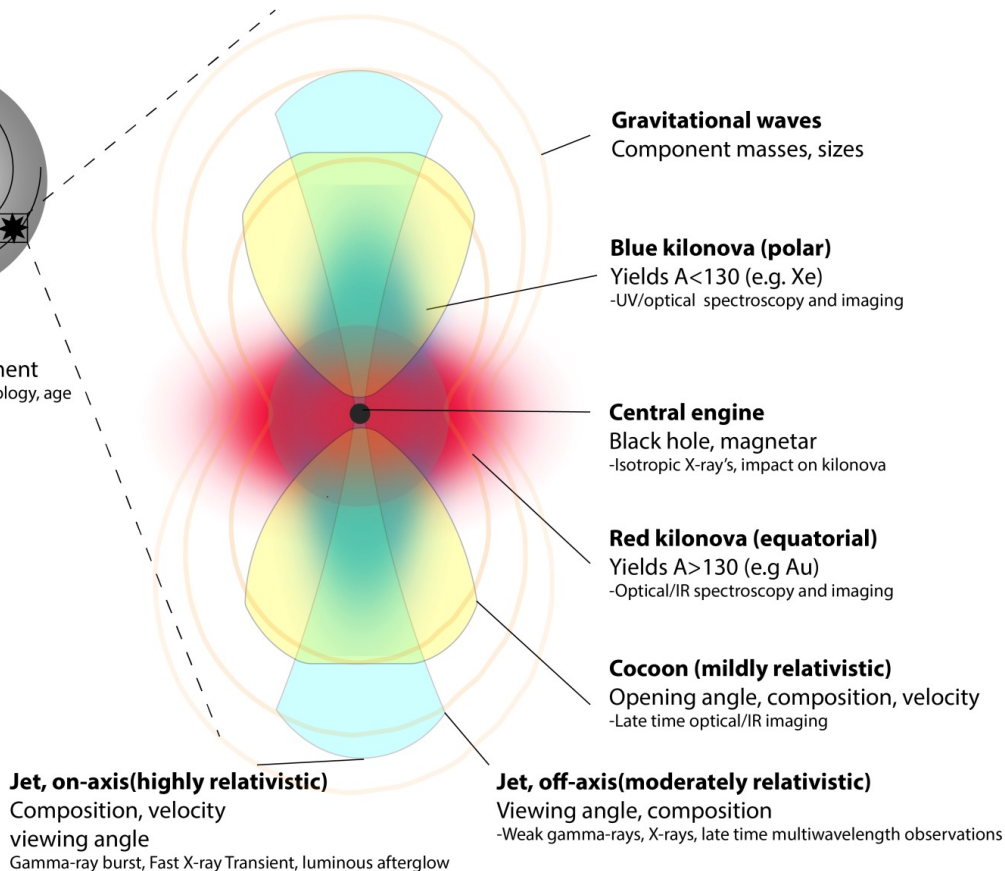
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# What are we looking for?



## Host galaxy:

Distance  
Merger environment  
-offset, galaxy morphology, age



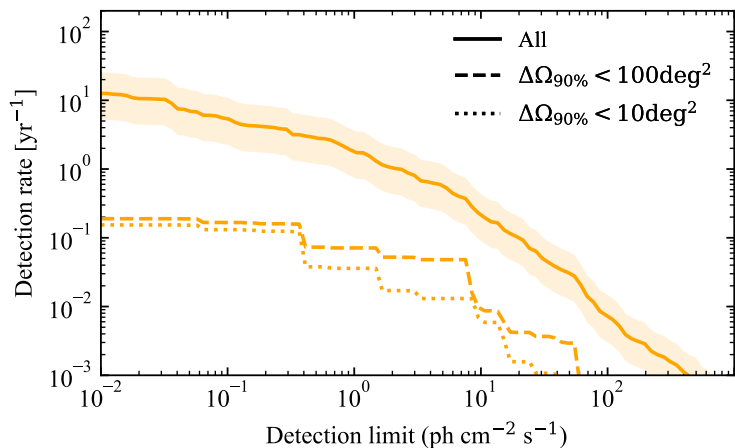
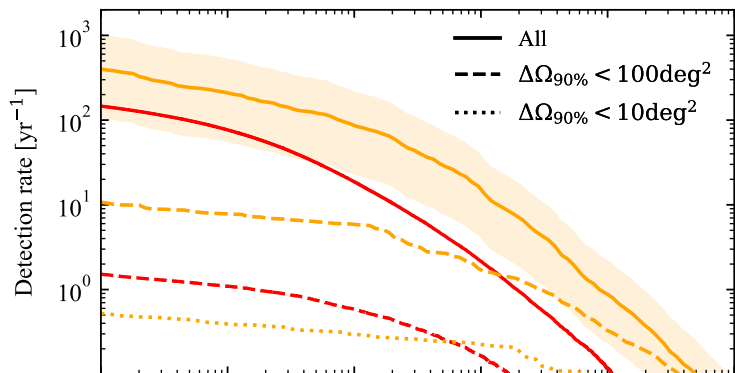
In particular thanks to O. S. Salafia, S. Ronchini,  
A. Colombo, F. Iacovelli, J. Dupletsa, S. Ascenzi,  
E. Loffredo

# Set-up

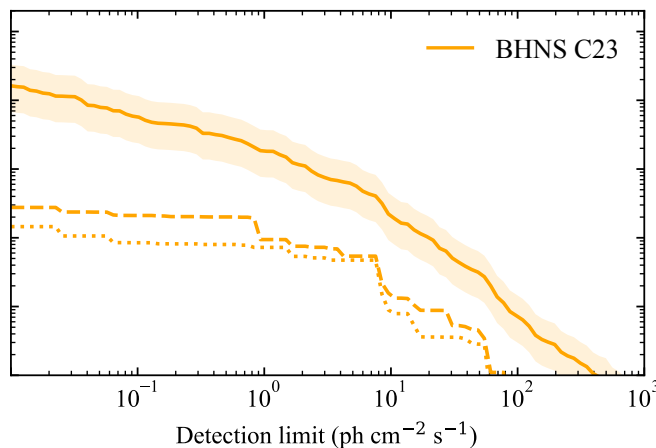
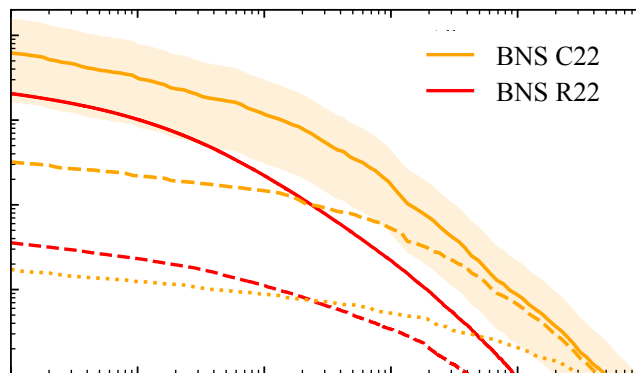
Independent routes to make KN and GRB (multiwavelength) predictions

	<b>C22</b> [7]	<b>R22</b> [8]	<b>L24</b> (add L24)	<b>C23</b> [9]
CBC System	BNS	BNS	BNS	BH-NS
CBC Pop.	R0+delayed SFR	Santoliquido+21	Iorio+23	Broekgaarden+21
$\mathcal{R}_0$ [ $\text{Gpc}^{-3} \text{yr}^{-1}$ ]	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

ET  $\Delta 10$  km



ET 2L 15 km



GRB prompt emission

## Advantages:

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

## Disadvantages:

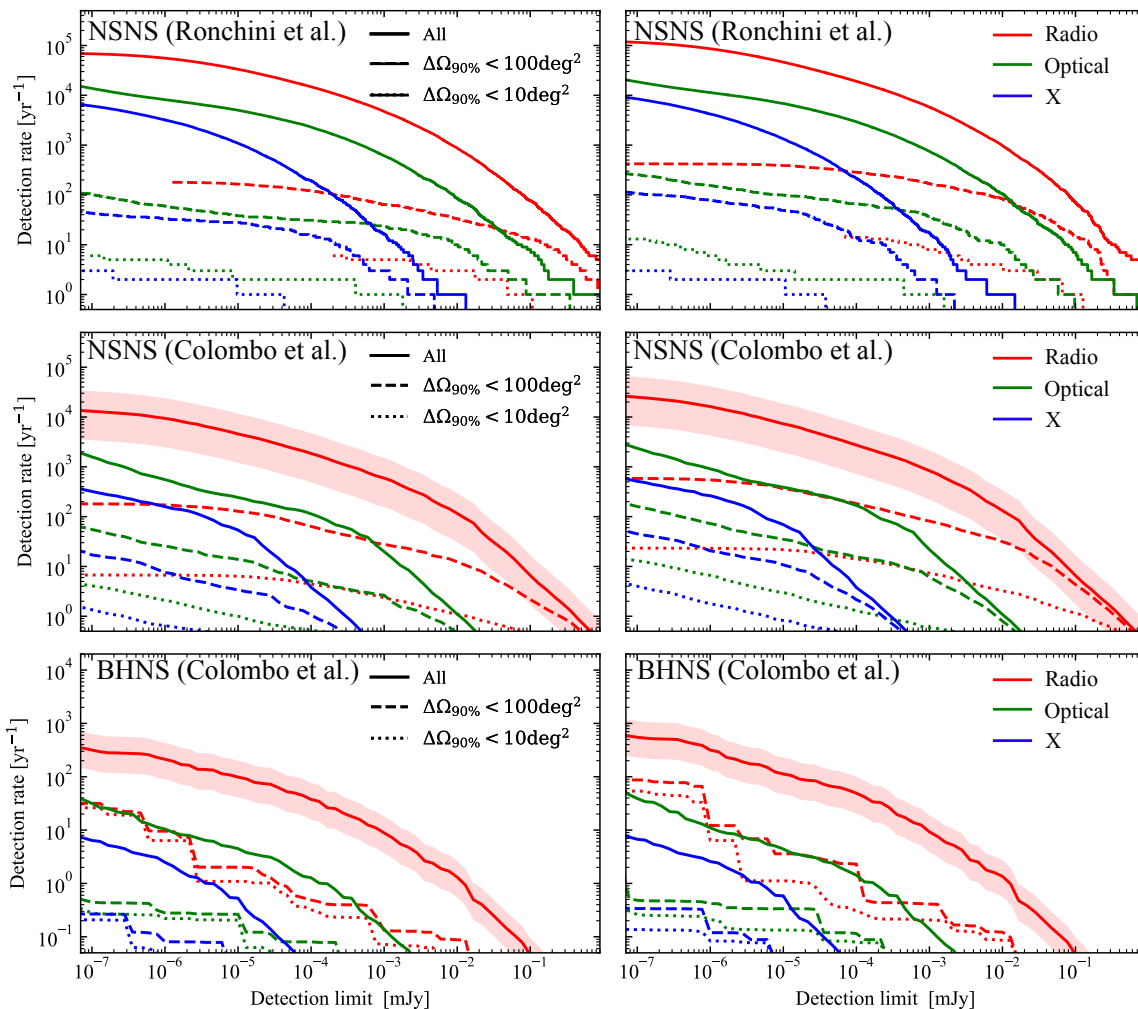
Often poor  
localisations  
(especially for all-sky  
monitors), no  
immediate host  
galaxy / redshift  
measurements  
possible.  
Most events don't  
have a GRB!

ET  $\Delta 10$  km

ET 2L 15 km



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

ET  $\Delta 10$  km

ET 2L 15 km

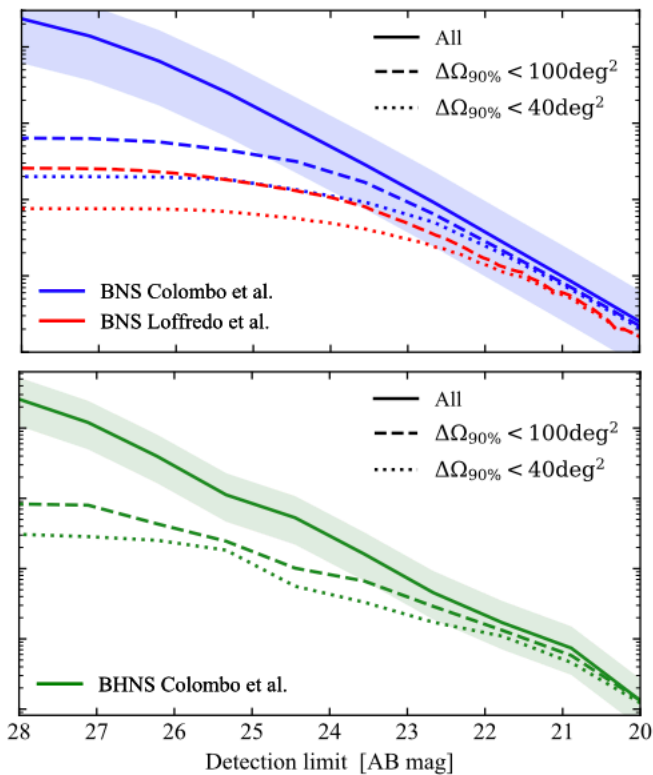
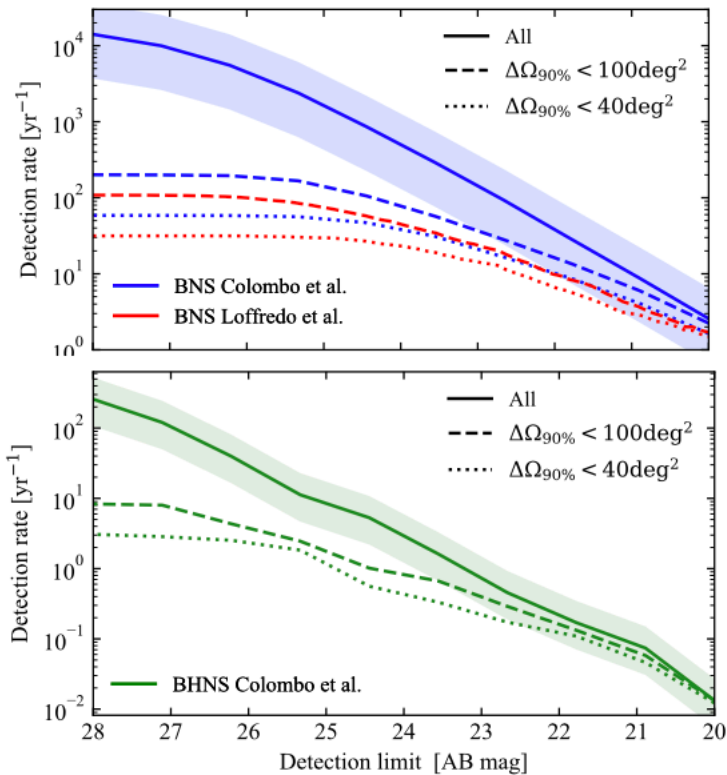
## Kilonovae

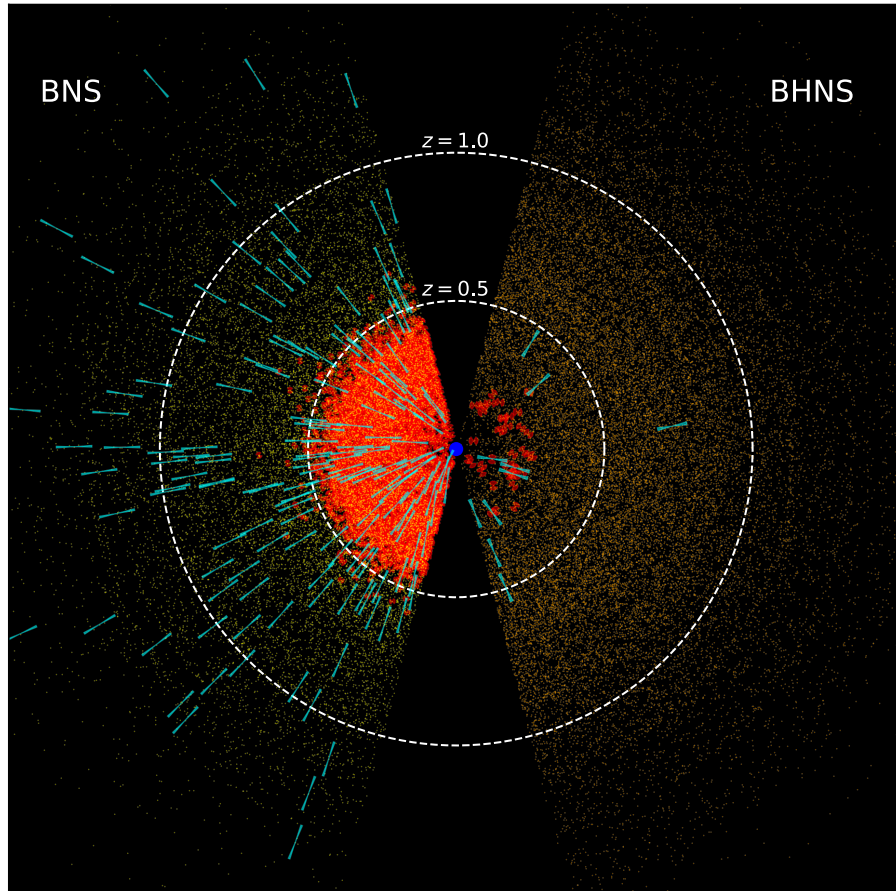
**Advantages:**

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.





### **Punchline:**

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

### **Caveat:**

Detectability is not the same as discovery

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  $\gg 10$  multi-messenger sources.

This sample size is likely required to fully investigate:

- 1) Heavy element enrichment
- 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  $\rightarrow$  If we want EM capability at the time of ET we need to ensure it is present by taking action now.