LXVI Congresso nazionale della Società Astronomica Italiana

Multi-messenger astronomy in the Einstein Telescope era

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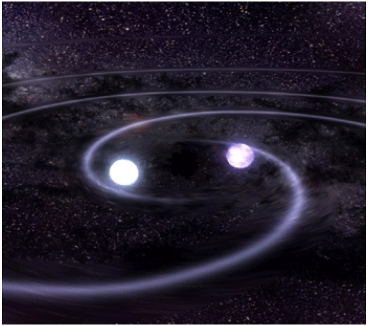
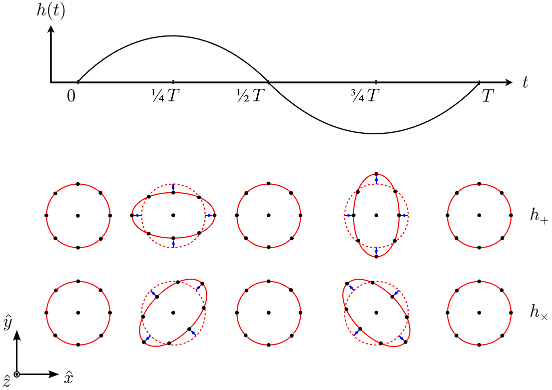
Gravitational waves

Gravitational waves



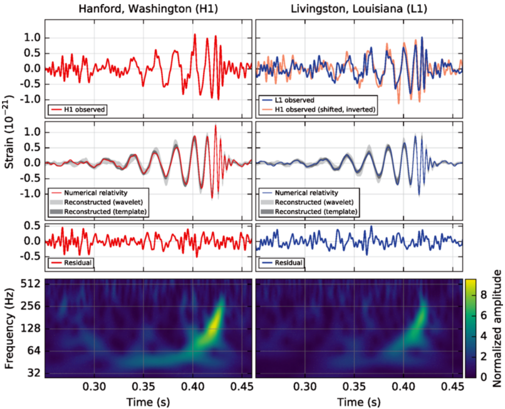
[Illustration: NASA Goddard]



[LeTiec & Novak 2017]

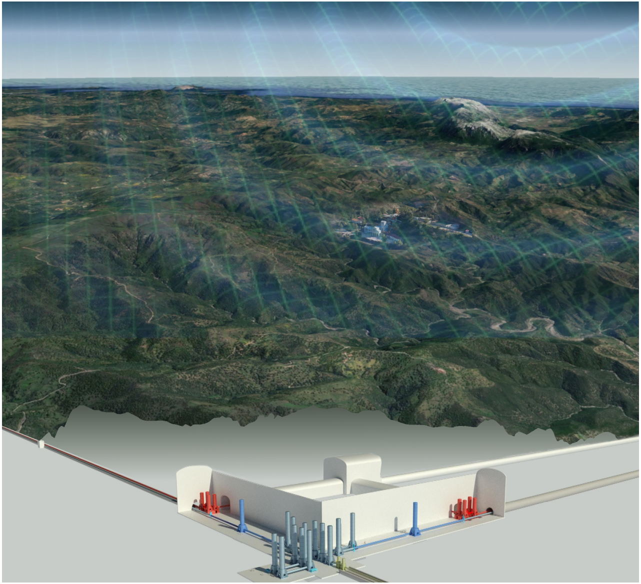
Interferometer-based GW detectors: current generation

[the Virgo detector in Cascina (PI), Italy]



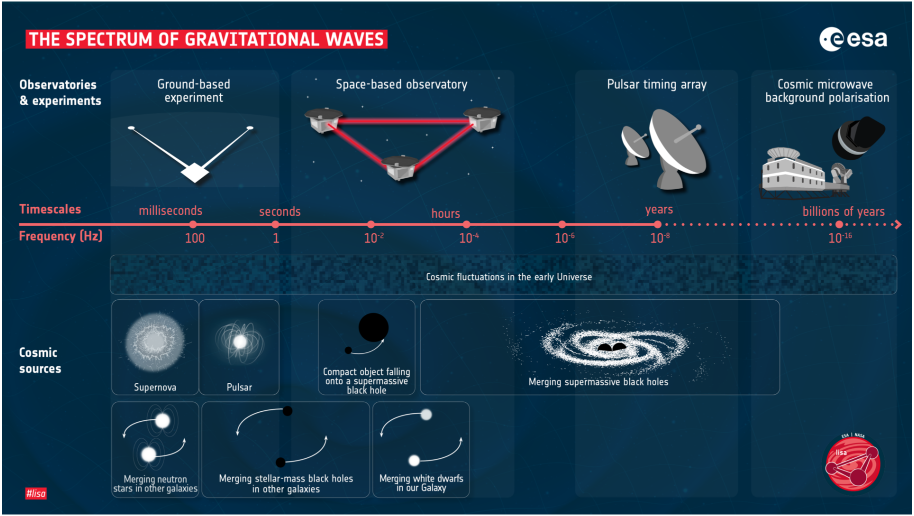
[Abbott et al. 2015]

The Einstein Telescope



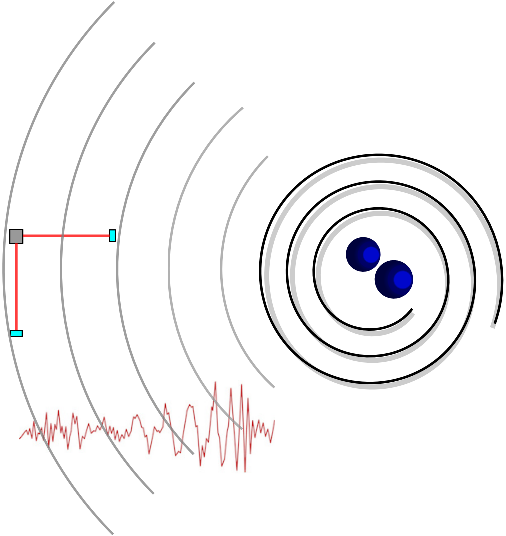
[Rendering by INFN/LNS]

GW sources



[ESA]

GW measured parameters



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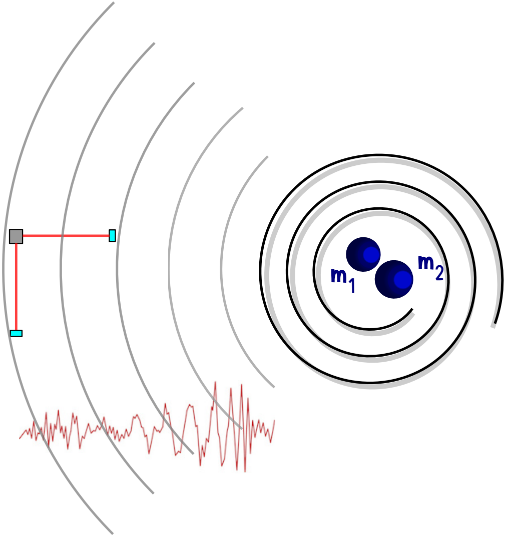
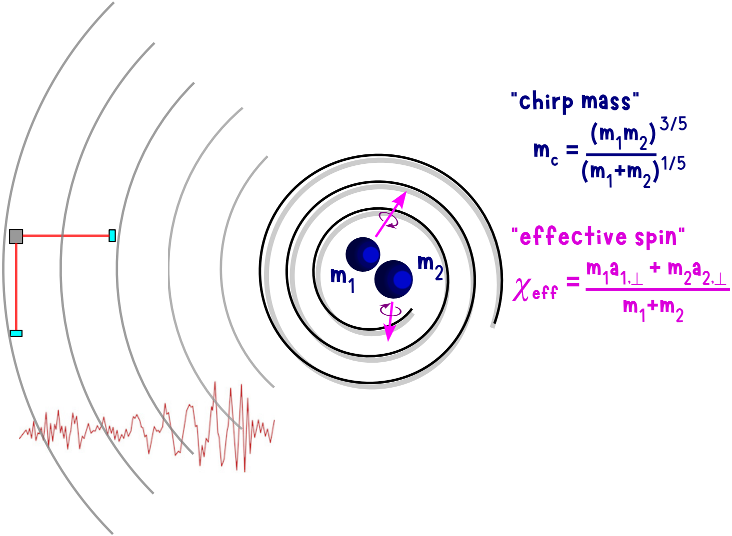


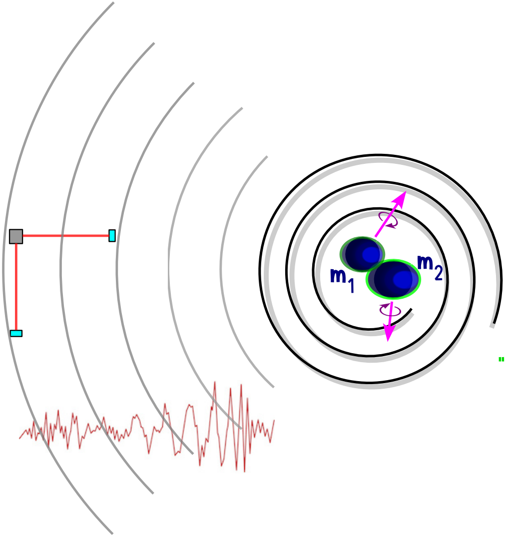
"chirp mass"

$$m_c = \frac{(m_1 m_2)^{3/5}}{(m_1+m_2)^{1/5}}$$

GW measured parameters



GW measured parameters



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$$m_c = \frac{(m_1 m_2)^{3/5}}{(m_1+m_2)^{1/5}}$$

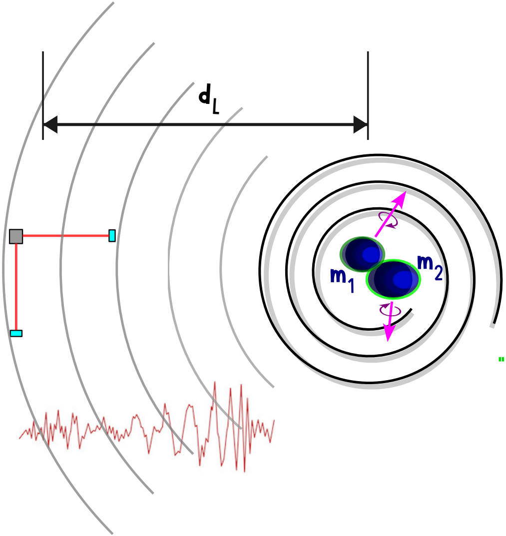
"effective spin"

$$\chi_{eff} = \frac{m_1 a_{1,\perp} + m_2 a_{2,\perp}}{m_1+m_2}$$

"dimensionless tidal deformability"

$$\tilde{\Lambda} \propto R^5$$

GW measured parameters



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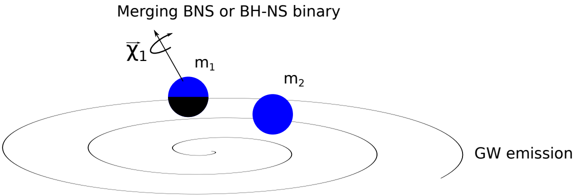
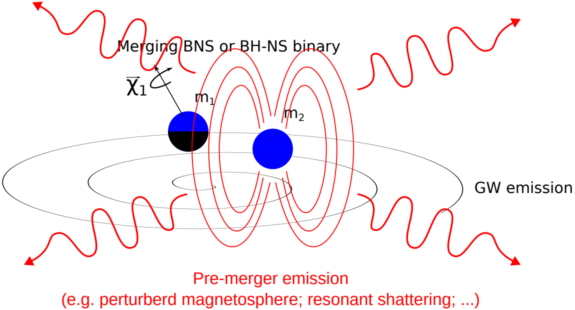
EM counterparts of BNS & BH-NS mergers



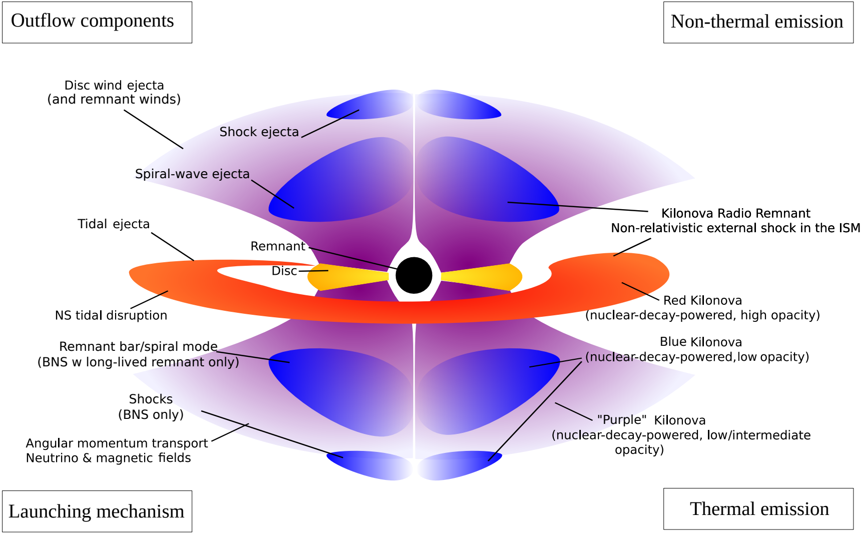
Complex, but (mostly) deterministic

EM counterparts of BNS & BH-NS mergers

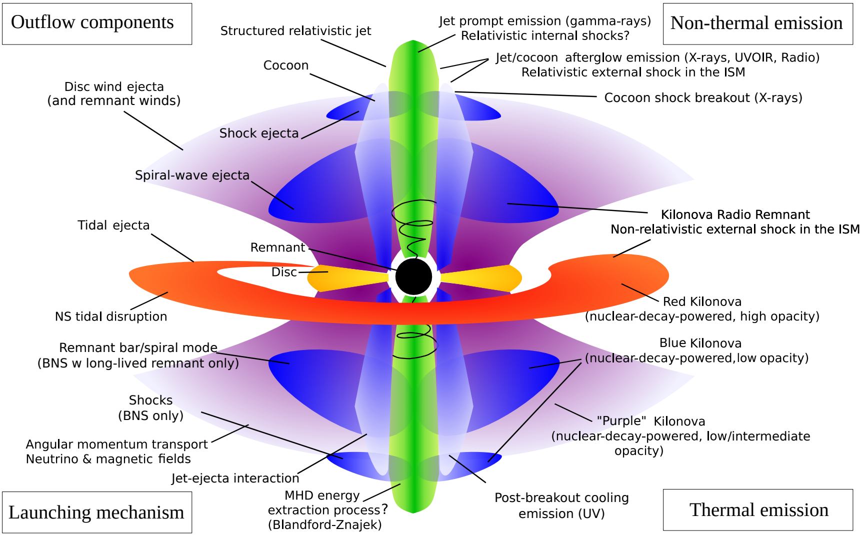


(e.g. Tsang+12,13 , Palenzuela+13, Metzger+16, Lyutikov 19, Most & Philippov 20, Pan+20, Beloborodov 21, ...)

EM counterparts of BNS & BH-NS mergers



EM counterparts of BNS & BH-NS mergers



(Adapted from Barbieri, Salafia, et al. 2019)

What can we learn?

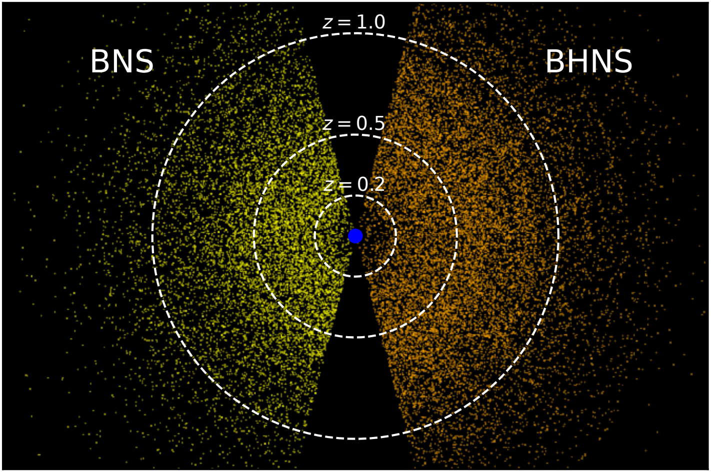
(a non-exhaustive list)

- Cosmography (bright sirens)
- Fundamental physics (GW speed; GR tests)
- Nuclear physics (NS equation of state; r-process nucelosynthesis)
- Relativistic jet astrophysics (GRB central engine; jet-launching; jet structure)
- Massive binary stellar evolution
- ...

(see also C. Ferrigno's talk!)

Accessible Universe

~10000 BNS/BHNS yr^{-1}



[Colombo, Salafia, et al. 2025]

Accessible Universe

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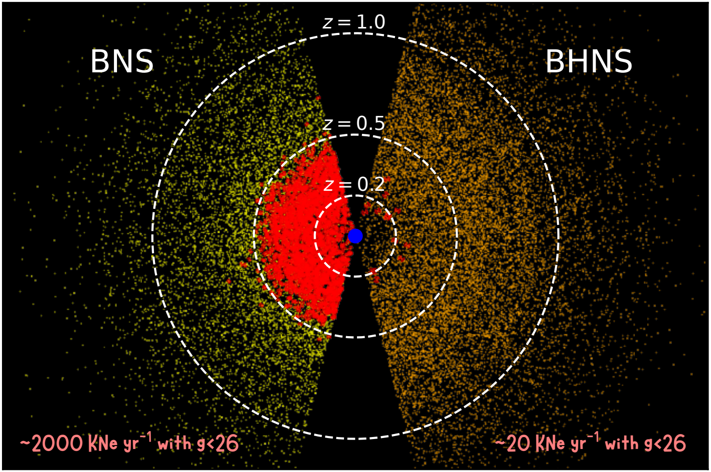

[Colombo, Salafia, et al. 2025]

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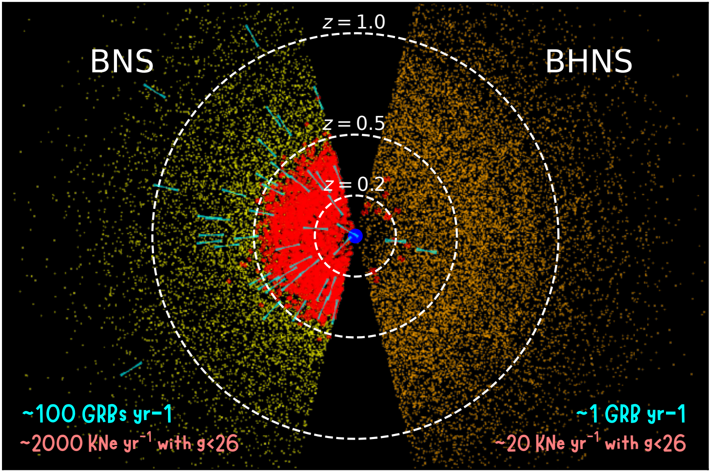
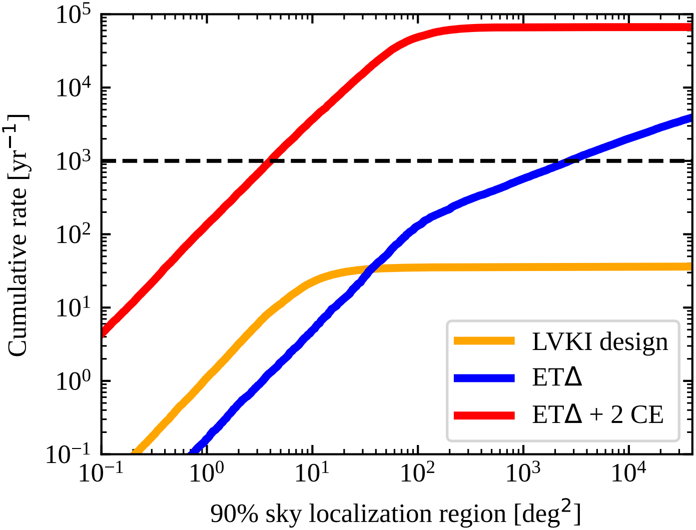


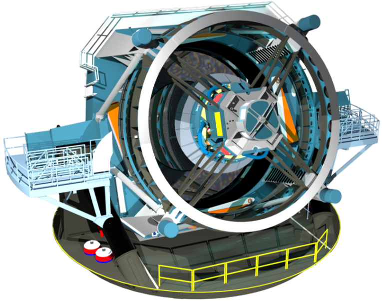
[Colombo, Salafia, et al. 2025]

Localization capabilities

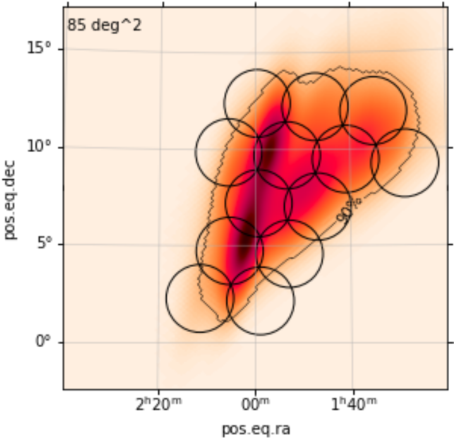


[Based on Colombo et al. 25, using GWFAST – Iacovelli et al. 22]

Observational landscape in ET era: optical imaging



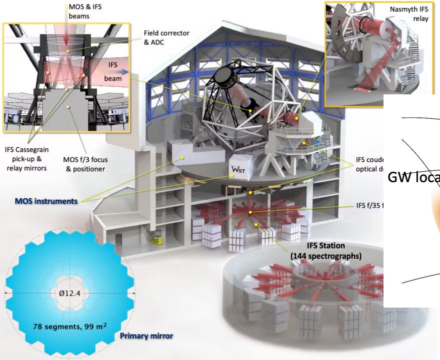
The Large Synoptic Survey Telescope
(Vera Rubin Observatory)



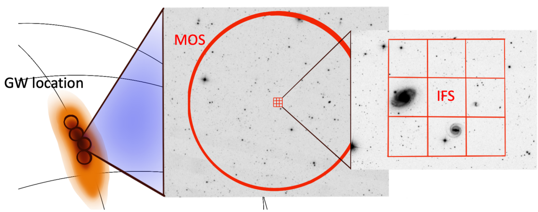
[Andreoni, Margutti, Salafia et al. 21]

(see S. Bonito's talk!)

Observational landscape in ET era: optical spectroscopy

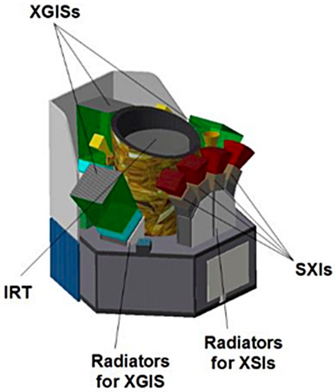


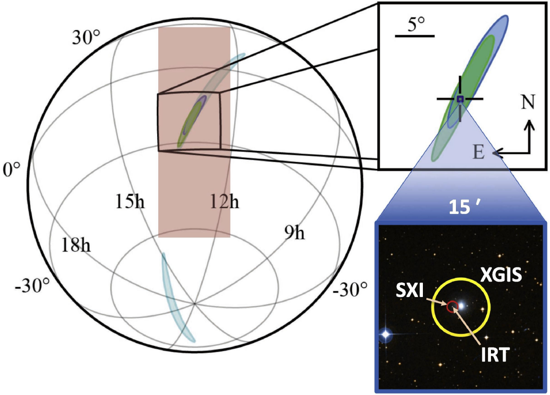
Widefield Spectroscopic Telescope



[Bacon et al. 24]

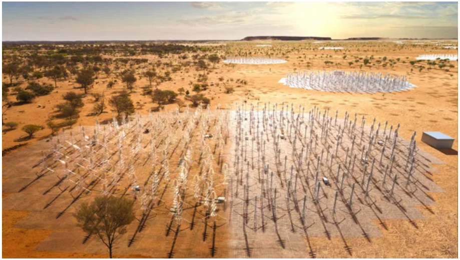
Observational landscape in ET era: keV-MeV





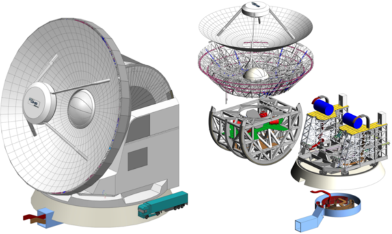
[Stratta et al. 2018]

Observational landscape in ET era: radio



[Square Kilometer Array]

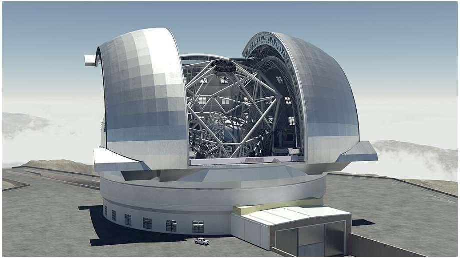
[ngVLA]



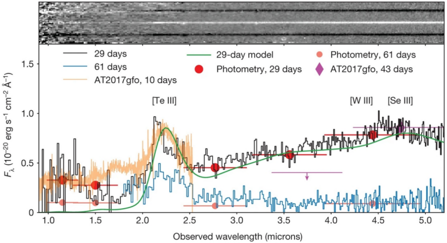
[AtLAST]

Opt-IR characterization

[JWST]



[ELT]



[Levan, ..., Salafia, et al. 23]

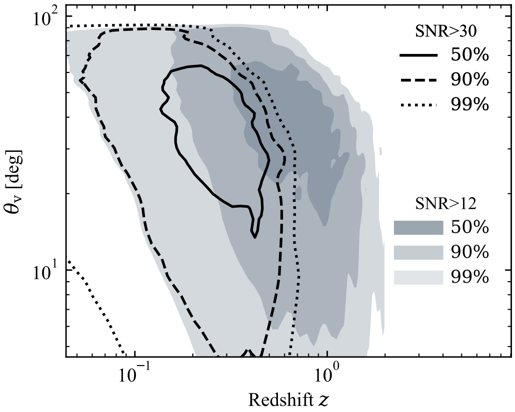
Summary

- Revolutionary potential of multi-messenger astronomy in ET era
- Several tens of BNS/BHNS merger triggers per day
- Localization crucially depends on GW detector network
- Large localization areas very challenging (despite excellent anticipated capabilities of future facilities)
- Realistically can handle few events per day (photometry, spectroscopy, multi-wavelength characterization)
- Wide-field keV-MeV monitoring is key for many science cases

Thank you!

Backup slides

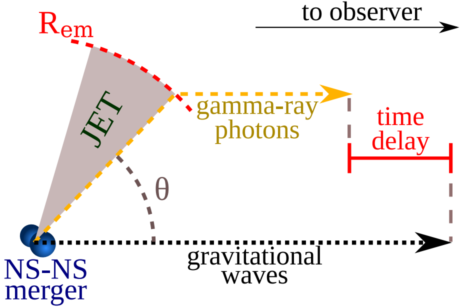
ET-accessible BNS population in (θ_v, z) space



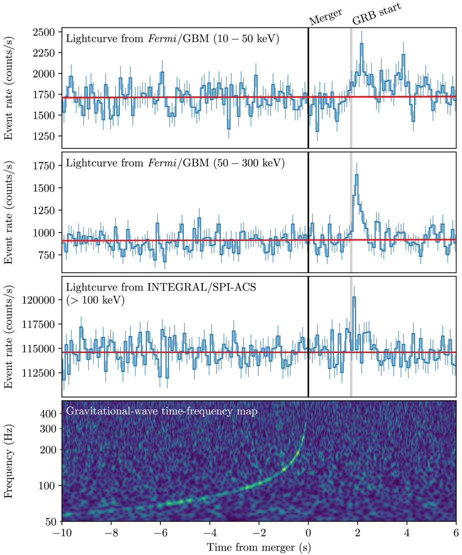
Two sub-samples:

- $30000\,\mathrm{yr}^{-1}$ with SNR>12
- $2000\,\mathrm{yr}^{-1}$ with SNR>30

GW-GRB delay: speed of gravity, GRB emission physics, ...

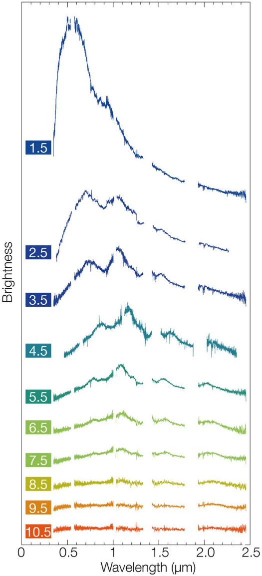


[Salafia et al. 18]

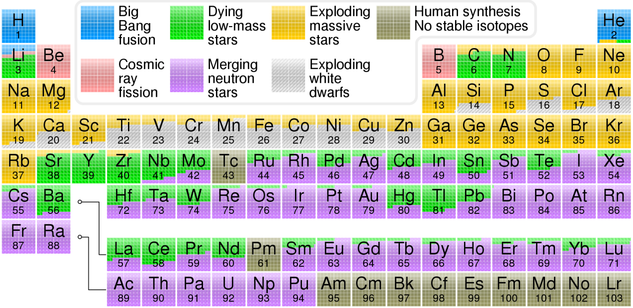


[Abbott et al. 2017]

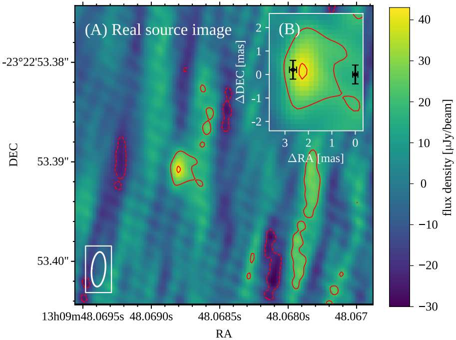
Kilonova: r-process nucleosynthesis, ...



[AT2017gfo spectra – Pian et al. 17]

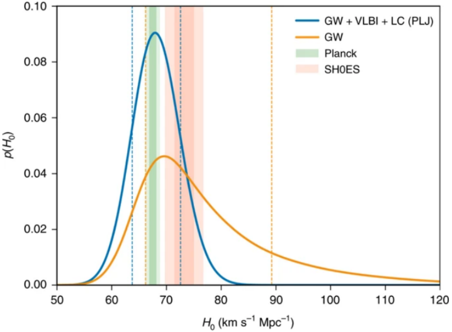


[Credit: Cmglee/Wikipedia]



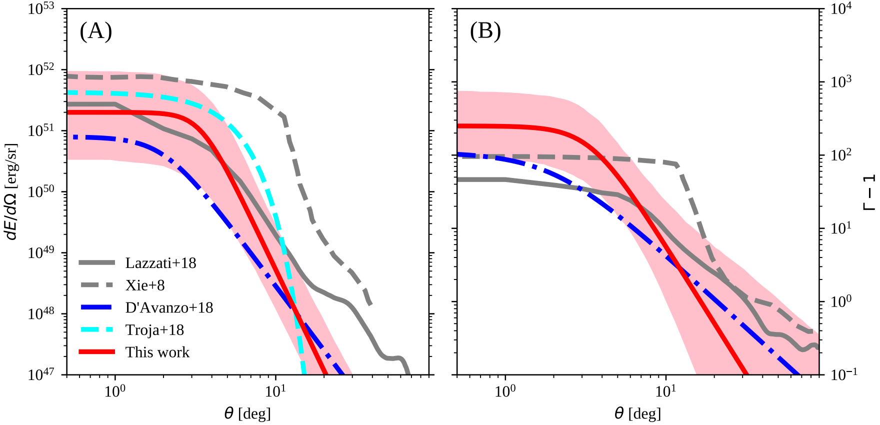
[Ghirlanda, Salafia, et al. 19]

Fig. 2: Posterior distributions for H_0.



[Hotokezaka et al. 19]

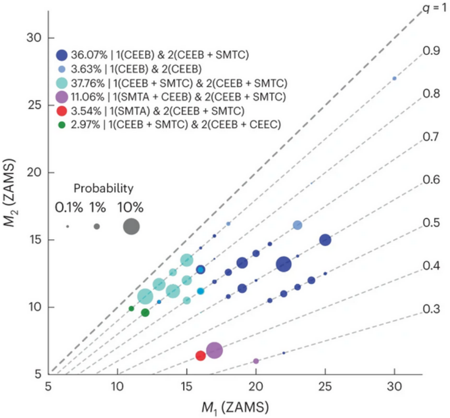
Jet afterglow: ..., jet structure, ...



[Ghirlanda, Salafia, et al. 19]

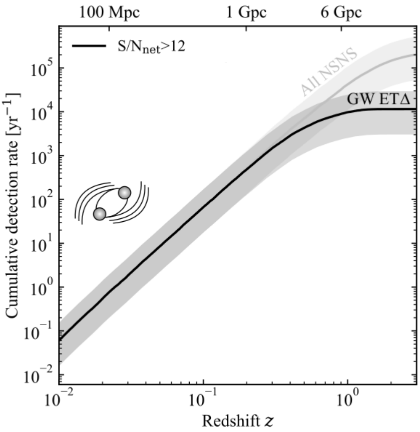
Host galaxy: massive binary stellar evolution, ...

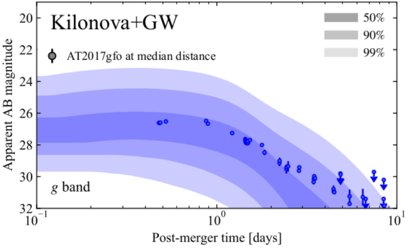
[HST view of NGC4993 – NASA & ESA]



[Stevance et al. 23]

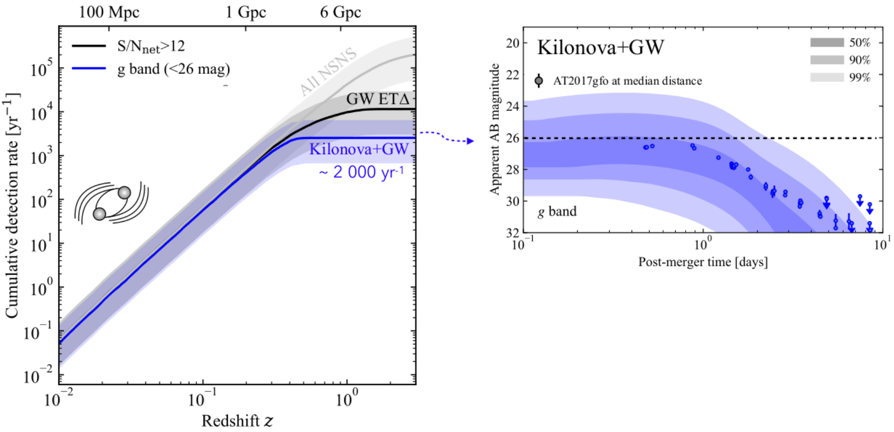
Detection rate predictions





[Colombo, Salafia, et al. 25]

Detection rate predictions



[Colombo, Salafia, et al. 25]

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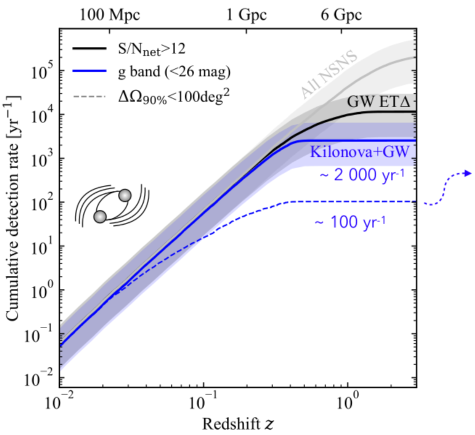

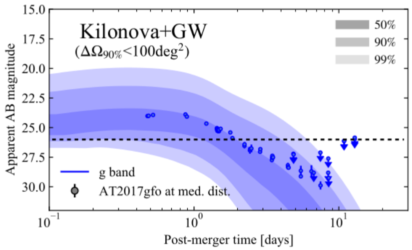

[Colombo, Salafia, et al. 25]