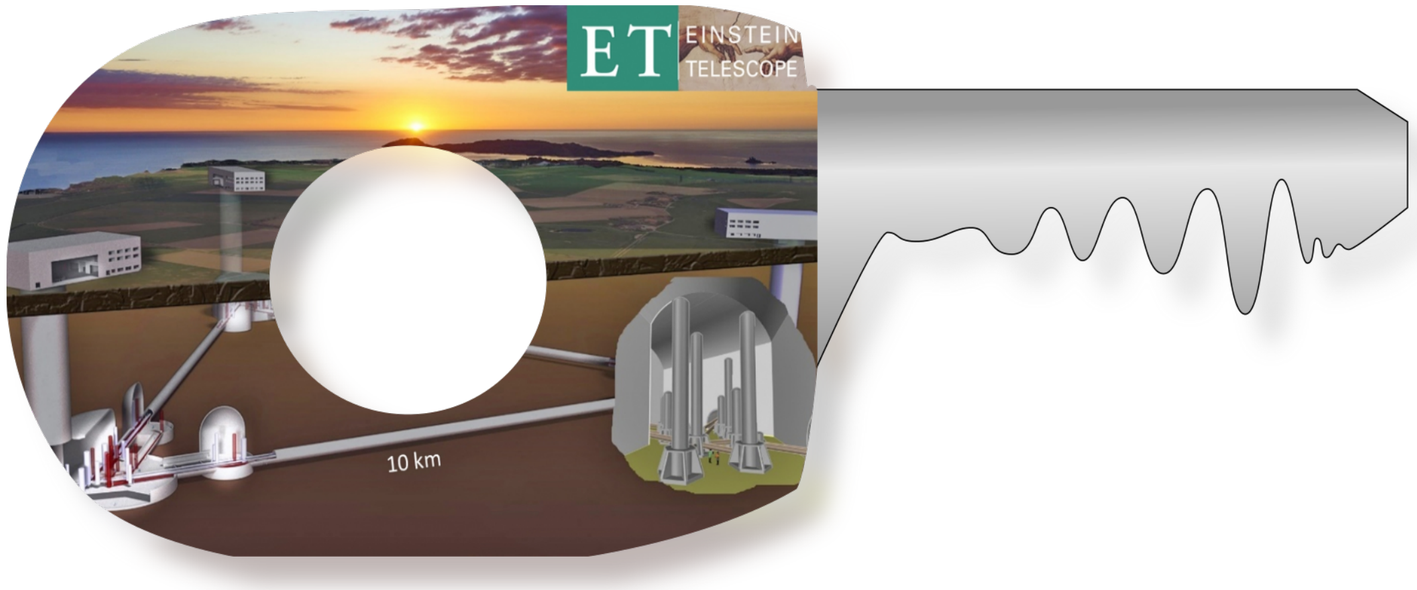
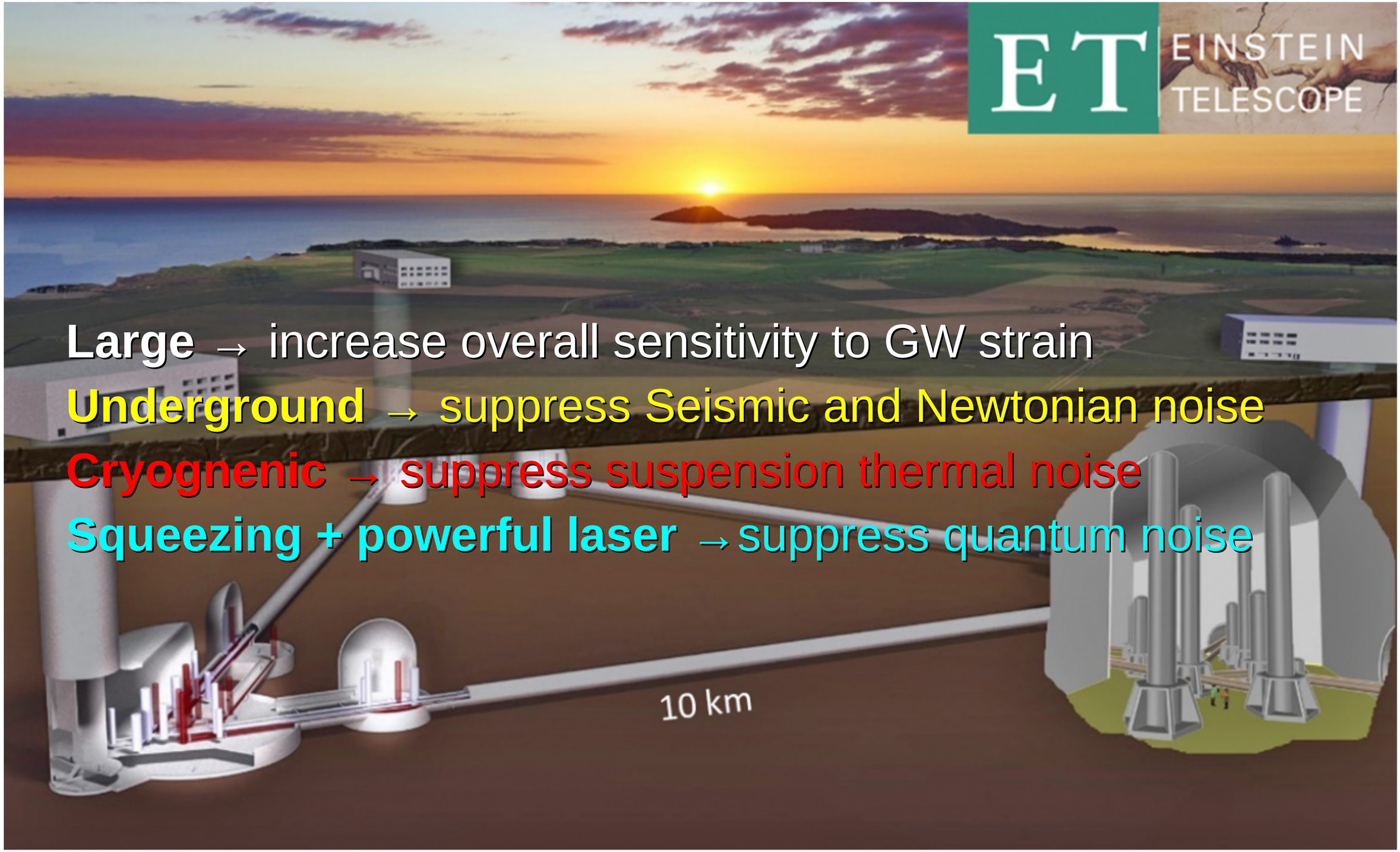
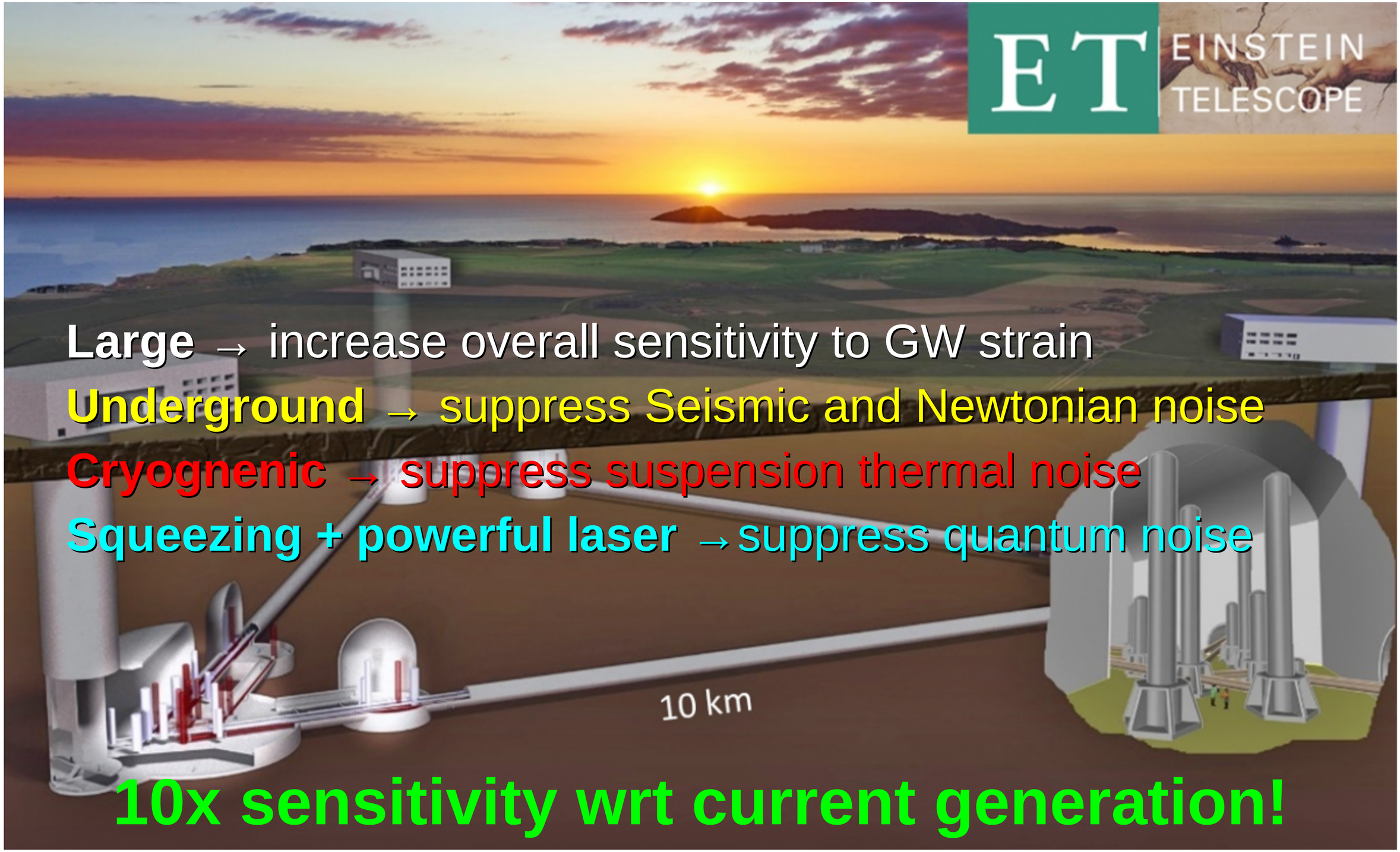
Multi-messenger observations in the Einstein Telescope era

A scientific treasure chest to be unlocked

Om Sharan Salafia
INAF - OAB




ET
EINSTEIN
TELESCOPE
Large → increase overall sensitivity to GW strain
Underground → suppress Seismic and Newtonian noise
Cryogenic → suppress suspension thermal noise
Squeezing + powerful laser → suppress quantum noise
10 km


ET
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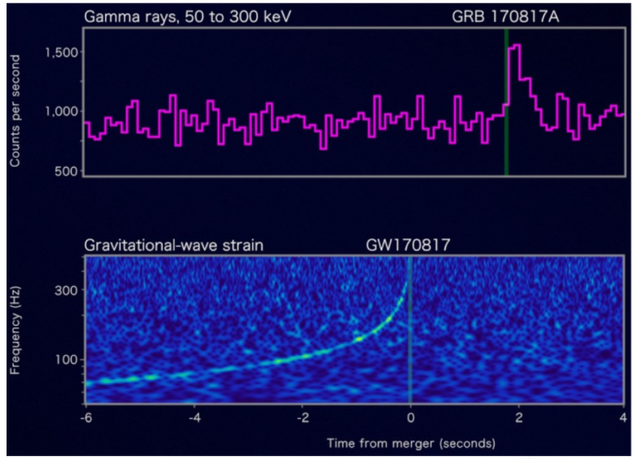
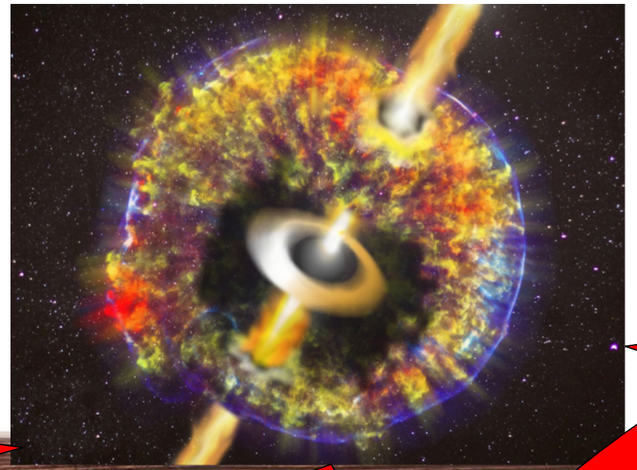
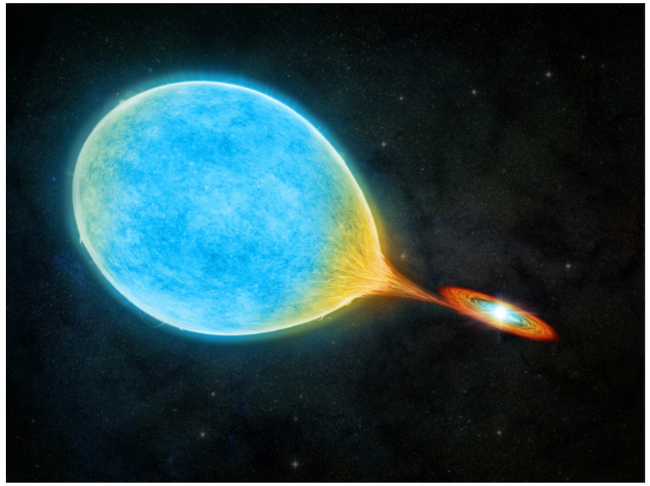
TELESCOPE
Large → increase overall sensitivity to GW strain
Underground → suppress Seismic and Newtonian noise
Cryogenic → suppress suspension thermal noise
Squeezing + powerful laser → suppress quantum noise
10 km
10x sensitivity wrt current generation!

Speed of gravity

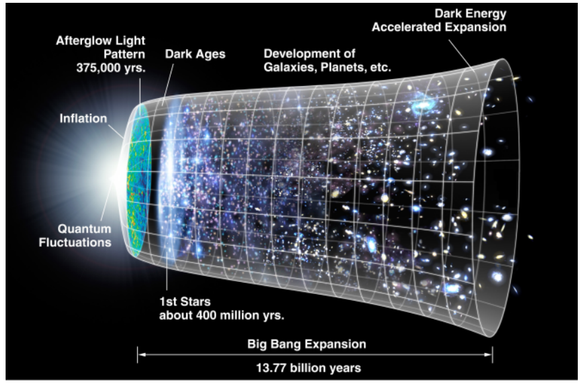


Physics of cosmic explosions



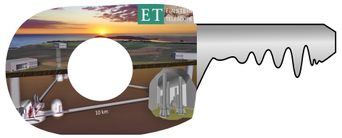


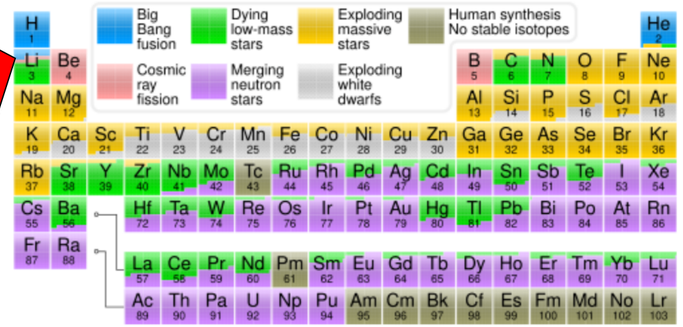
Binary stellar evolution



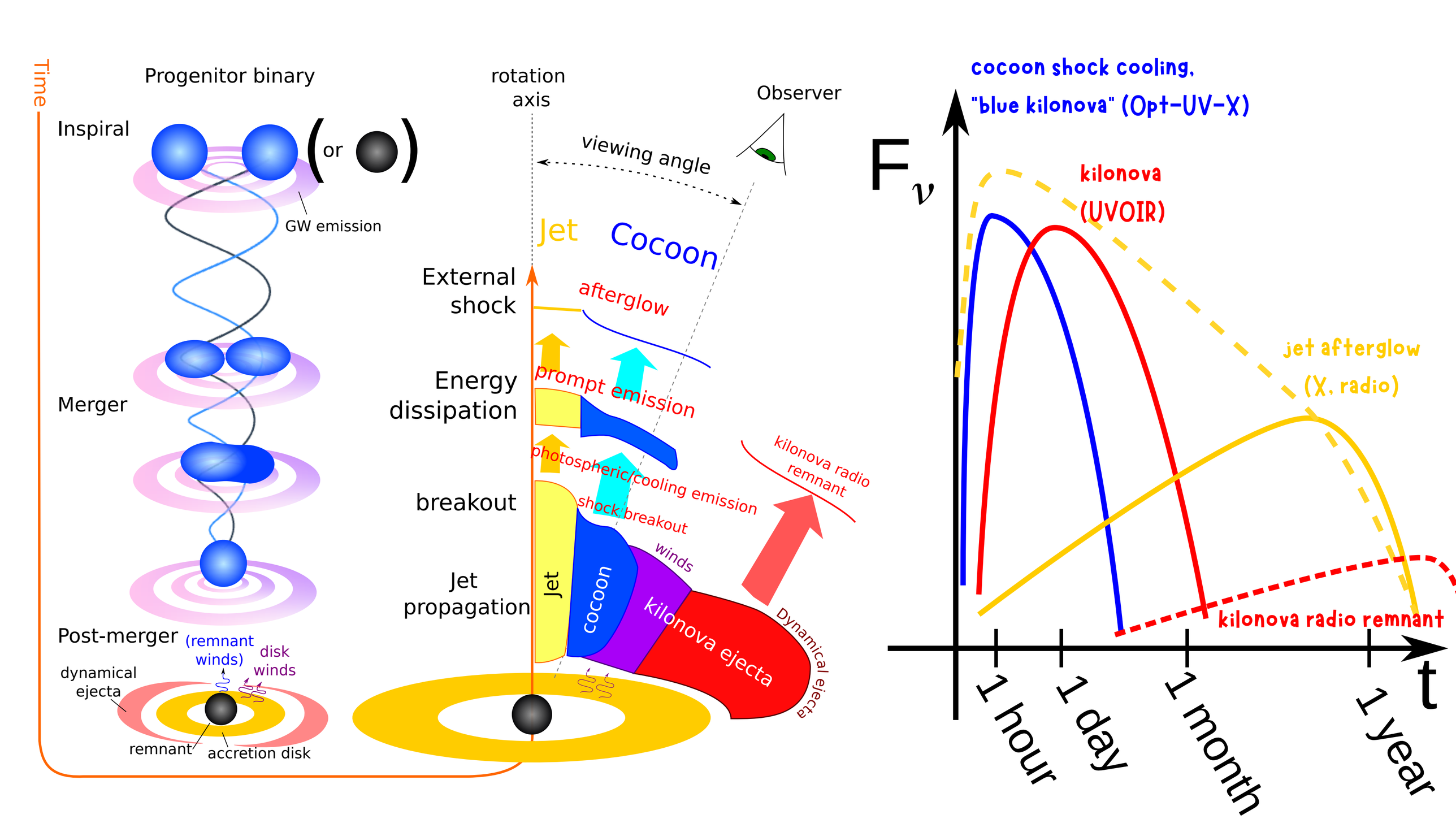
Bright siren cosmography

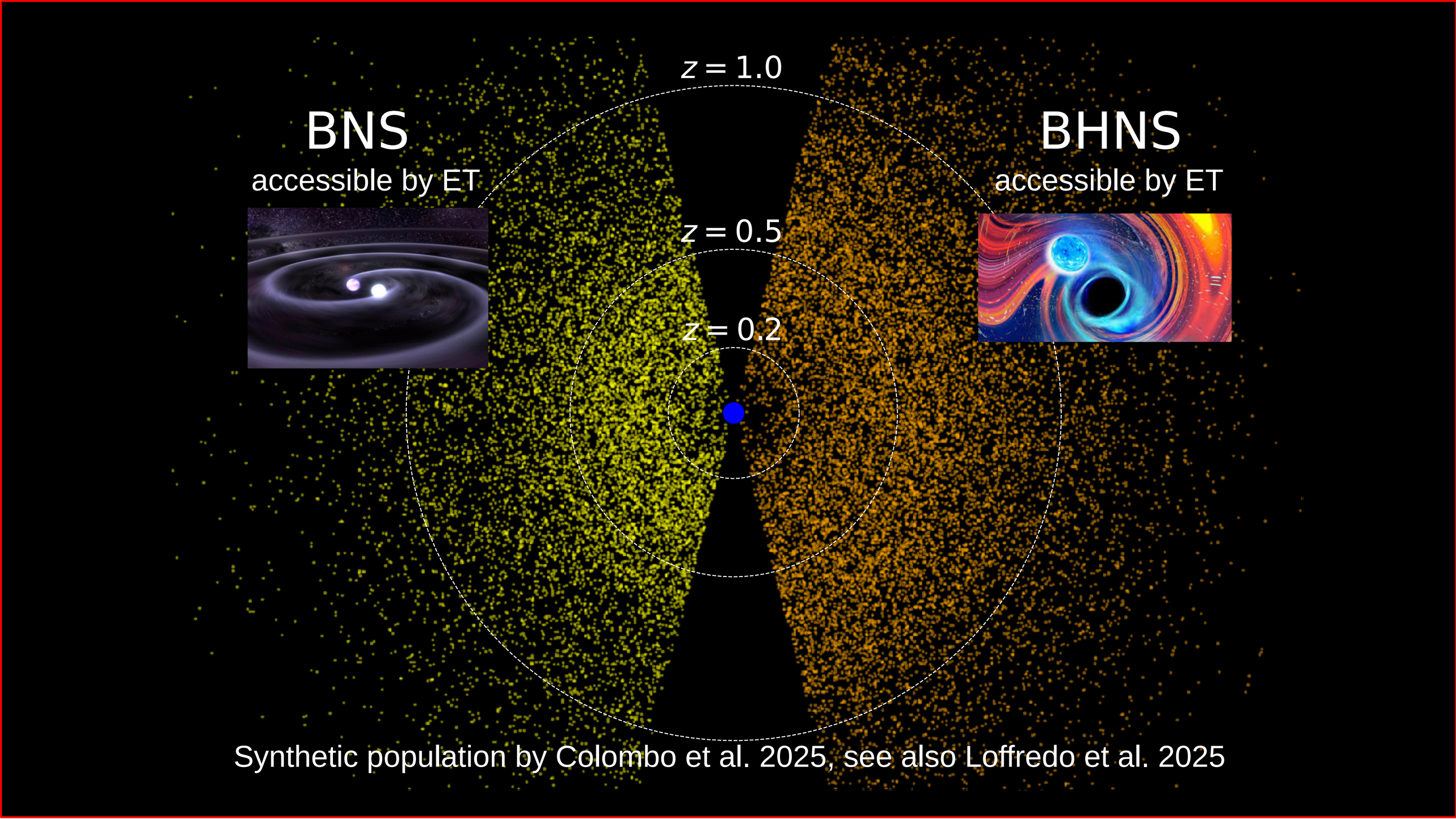
(see C. Carbone's talk)

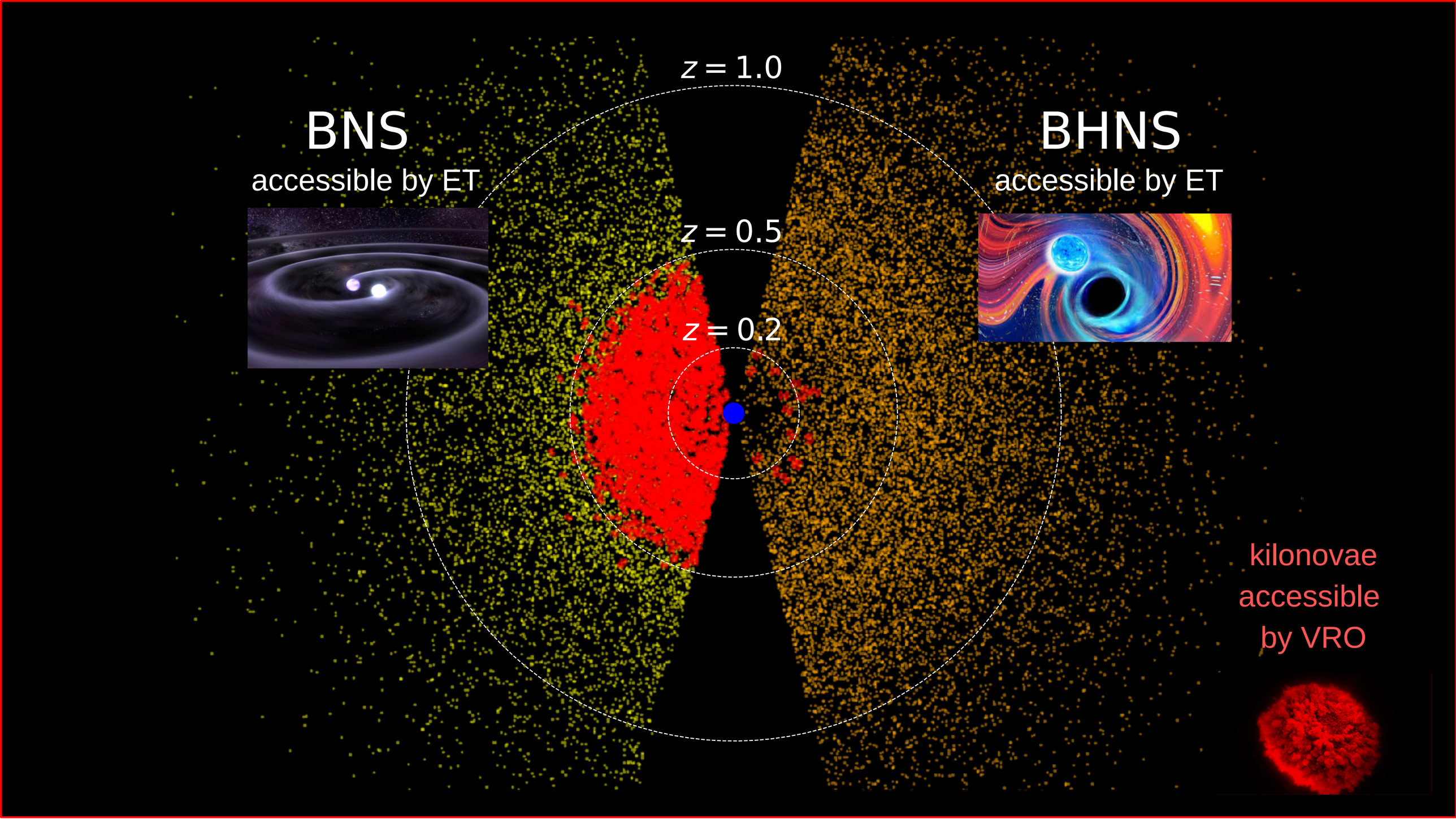


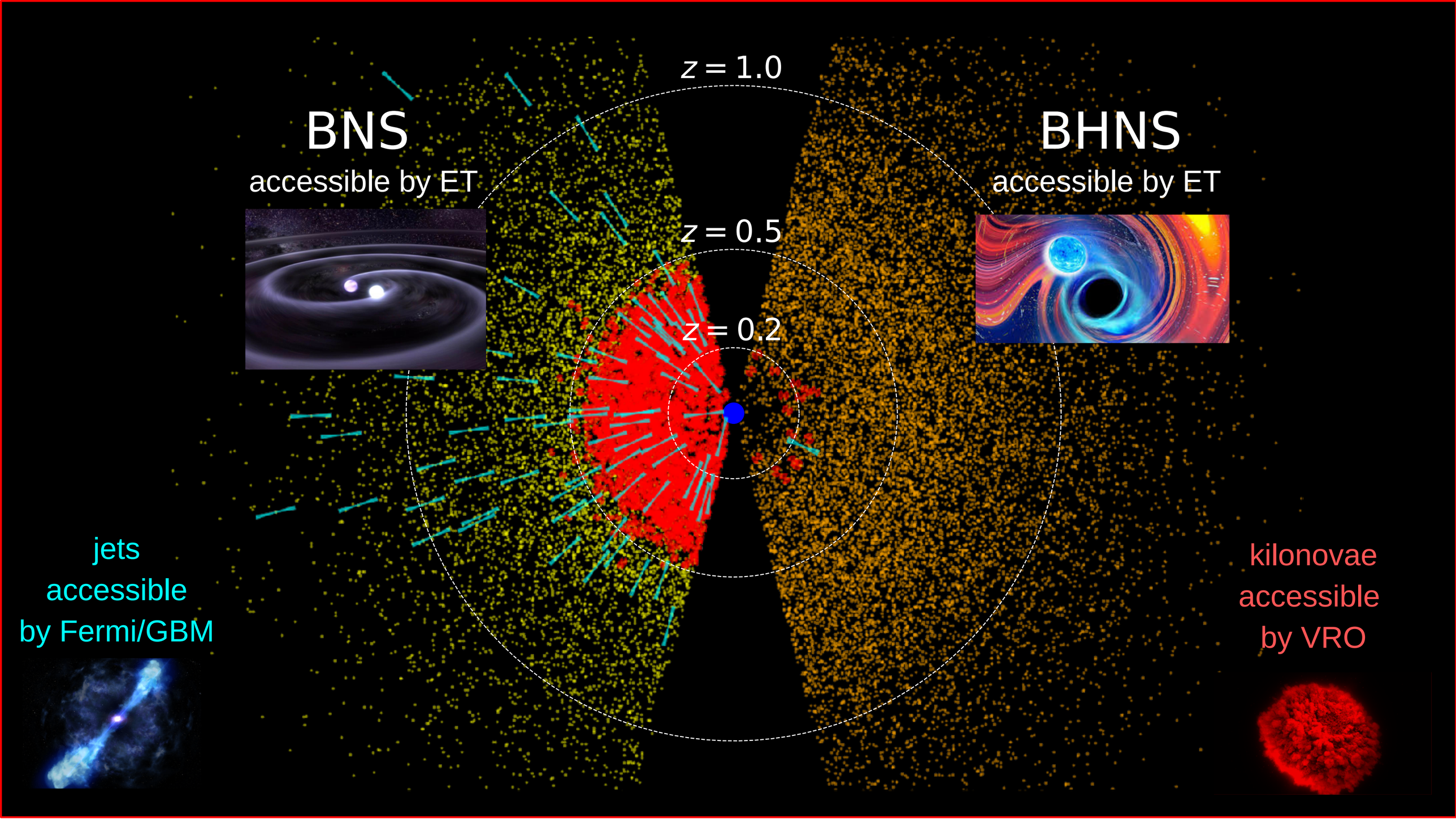


Heavy element nucleosynthesis and cosmic enrichment

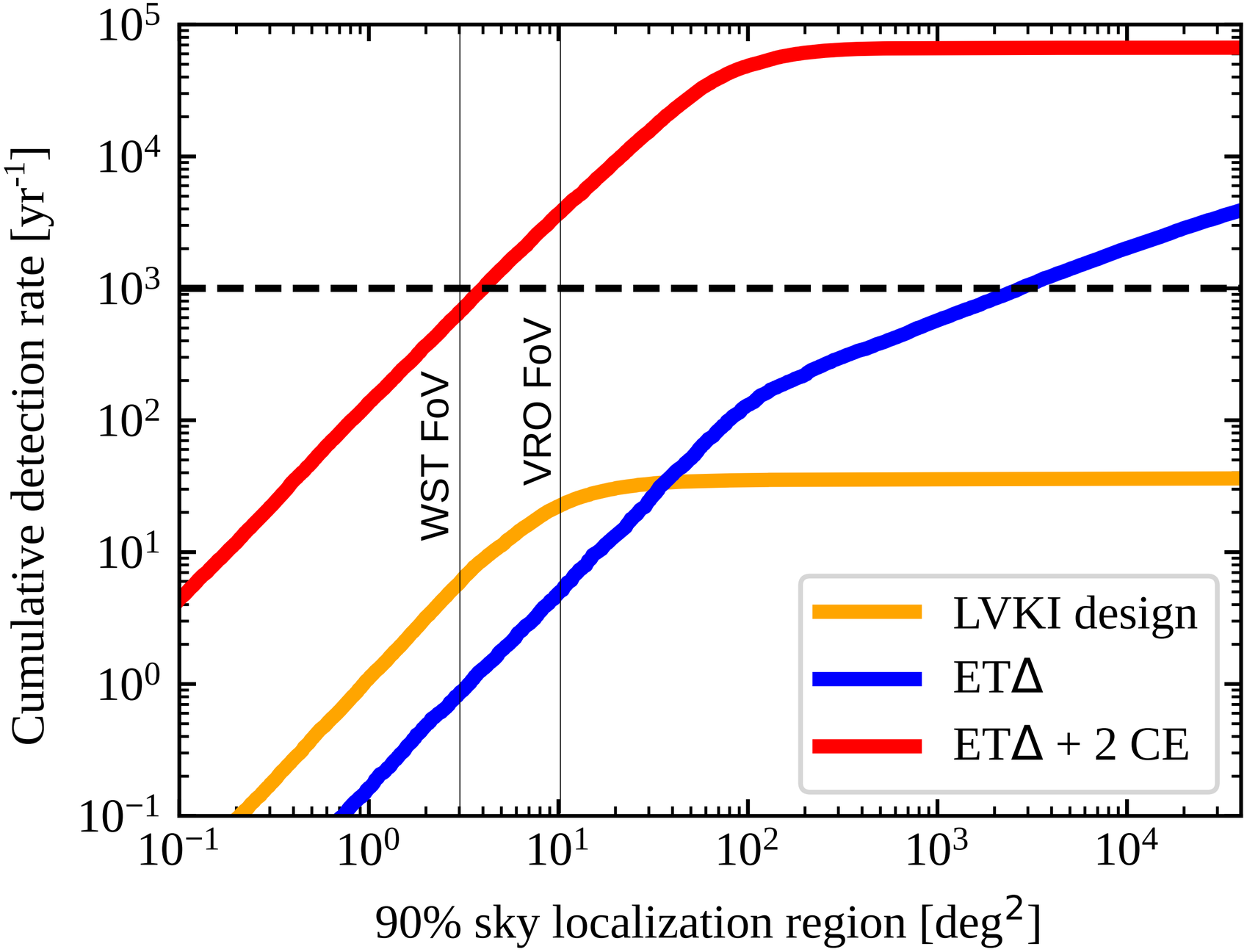

Time
Progenitor binary
Inspiral
or
GW emission
Merger
Post-merger
(remnant winds)
disk winds
dynamical ejecta
remnant
accretion disk
rotation axis
Observer
viewing angle
Jet
Cocoon
External shock
afterglow
Energy dissipation
prompt emission
photospheric/cooling emission
breakout
shock breakout
winds
Jet propagation
Jet
cocoon
kilonova ejecta
Dynamical ejecta
kilonova radio remnant
cocoon shock cooling,
"blue kilonova" (Opt-UV-X)
F_ν
kilonova
(UVOIR)
jet afterglow
(X, radio)
kilonova radio remnant
t
1 hour
1 day
1 month
1 year


$z = 1.0$
BNS
accessible by ET
BHNS
accessible by ET
$z = 0.5$
$z = 0.2$
Synthetic population by Colombo et al. 2025, see also Loffredo et al. 2025


$z = 1.0$
BNS
accessible by ET
$z = 0.5$
$z = 0.2$
BHNS
accessible by ET
kilonovae
accessible
by VRO


$z = 1.0$
BNS
accessible by ET
$z = 0.5$
$z = 0.2$
BHNS
accessible by ET
jets
accessible
by Fermi/GBM
kilonovae
accessible
by VRO

GW localization of BNS mergers

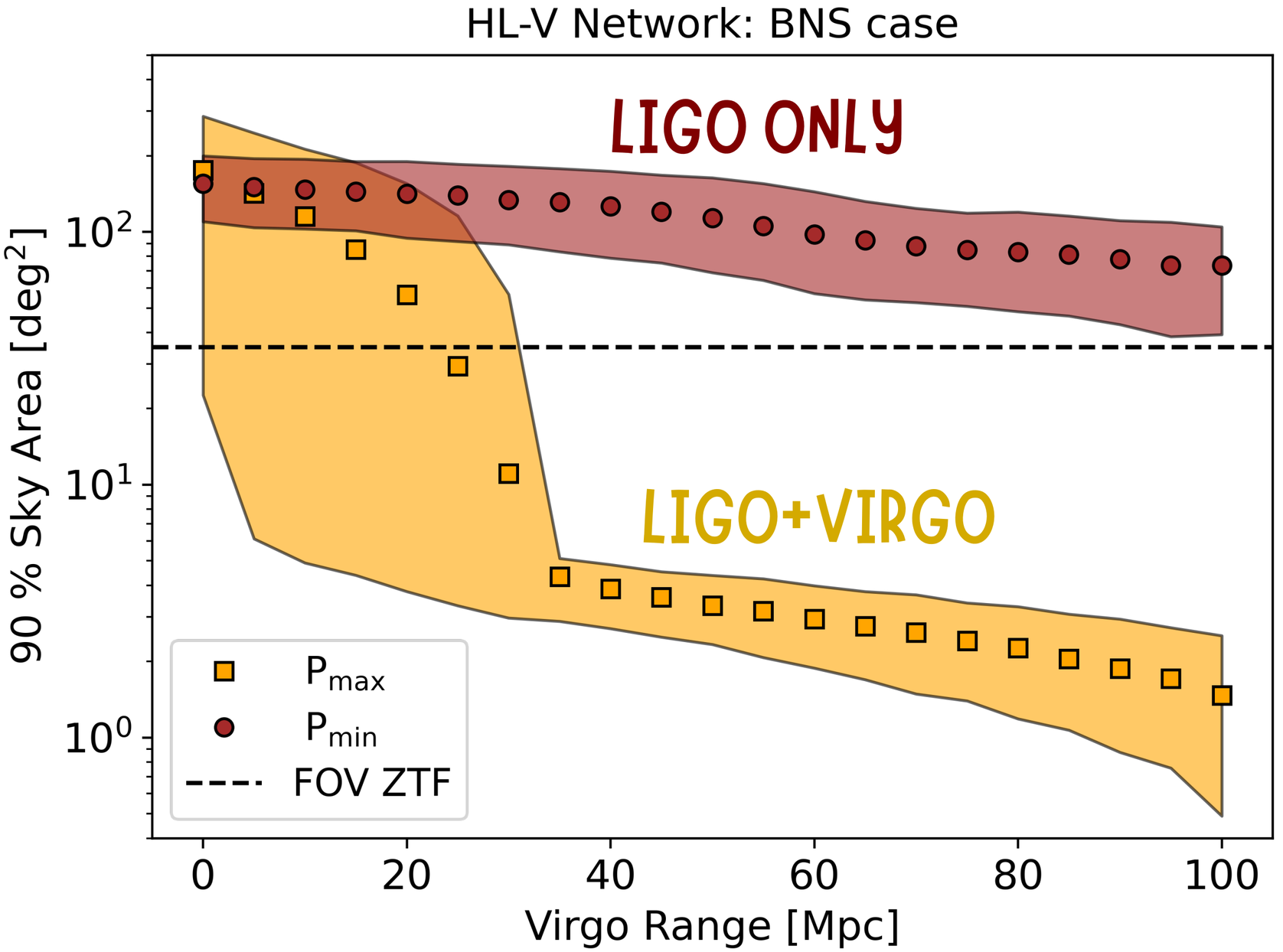


Based on Colombo+2025
PE predictions: GWFAST

See also Branchesi+2023,
Loffredo+2025,
GWFISH (Dupletsa+2022)

See Alberto Colombo's talk for more quantitative predictions!

Impact of lower-sensitivity detectors on localization

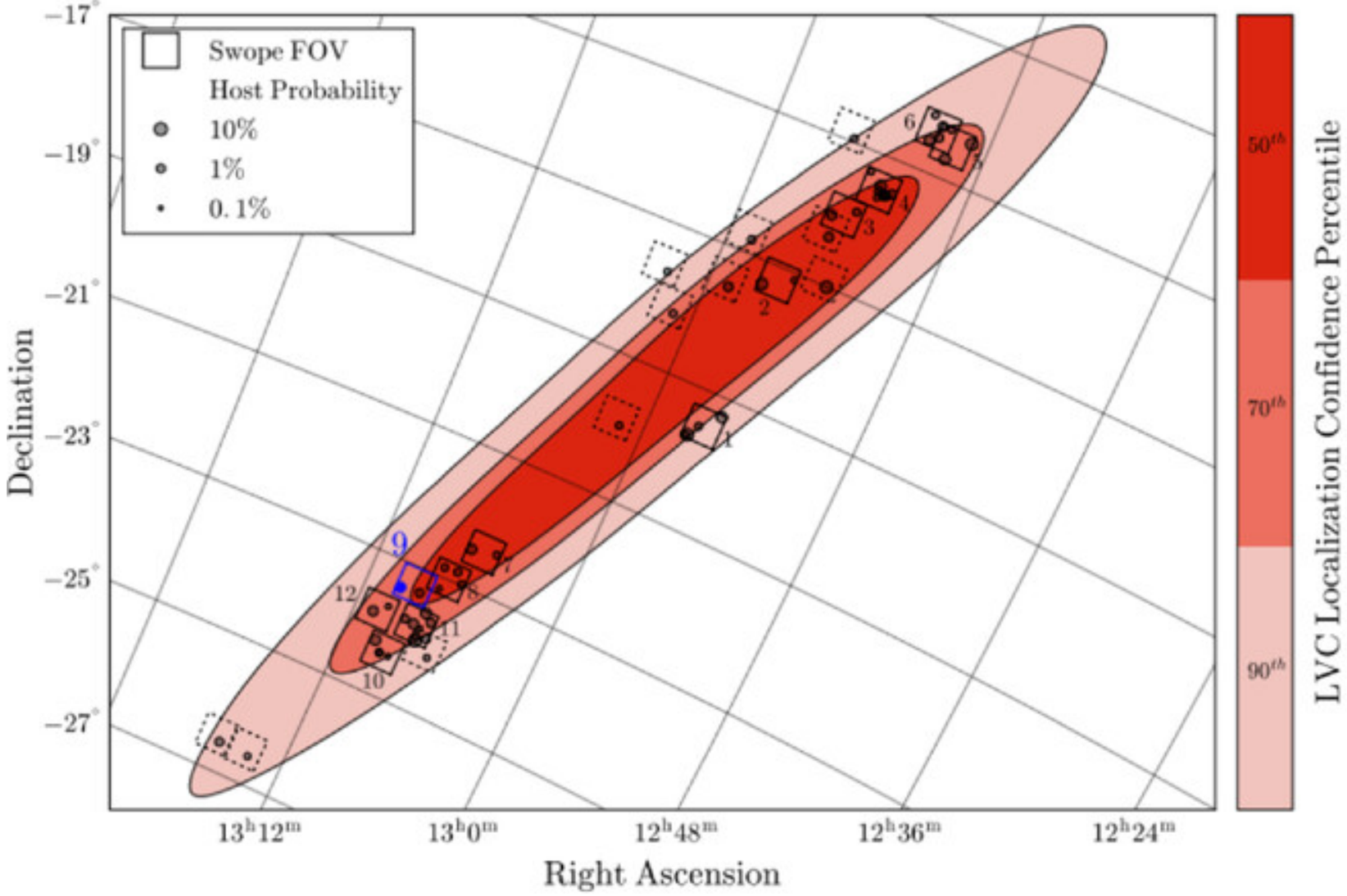


Emma+2024

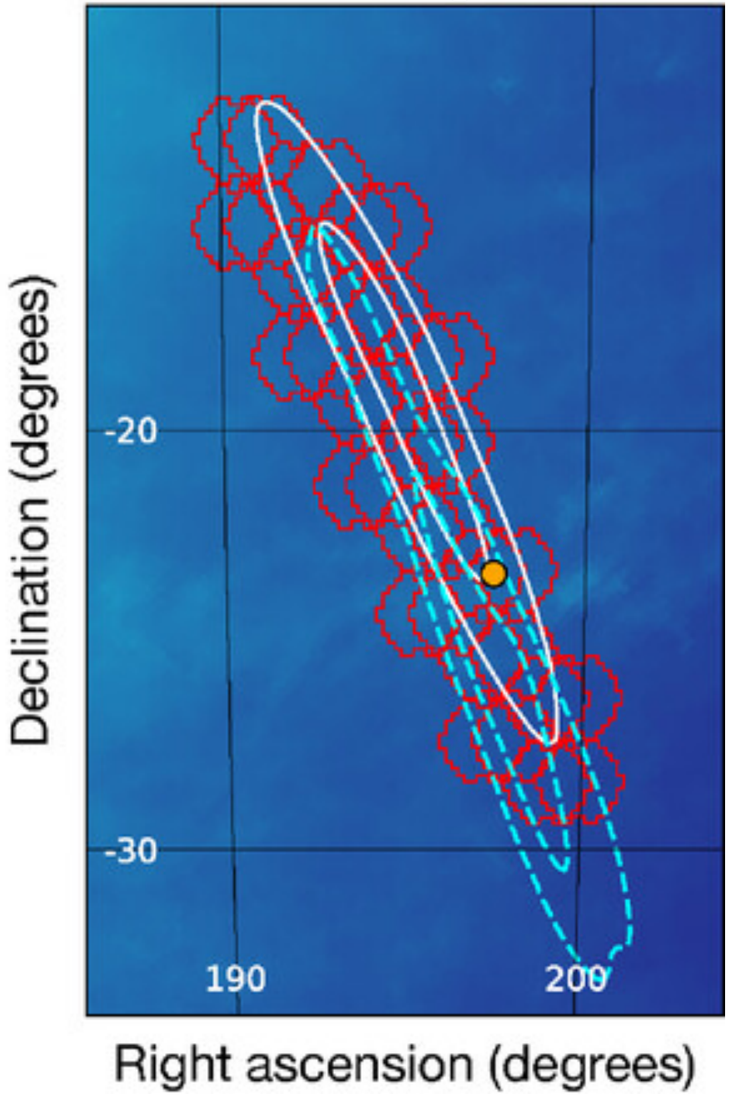
Multi-messenger community must advocate for multiple GW detectors

Electromagnetic counterpart search strategies

Galaxy-targeted search

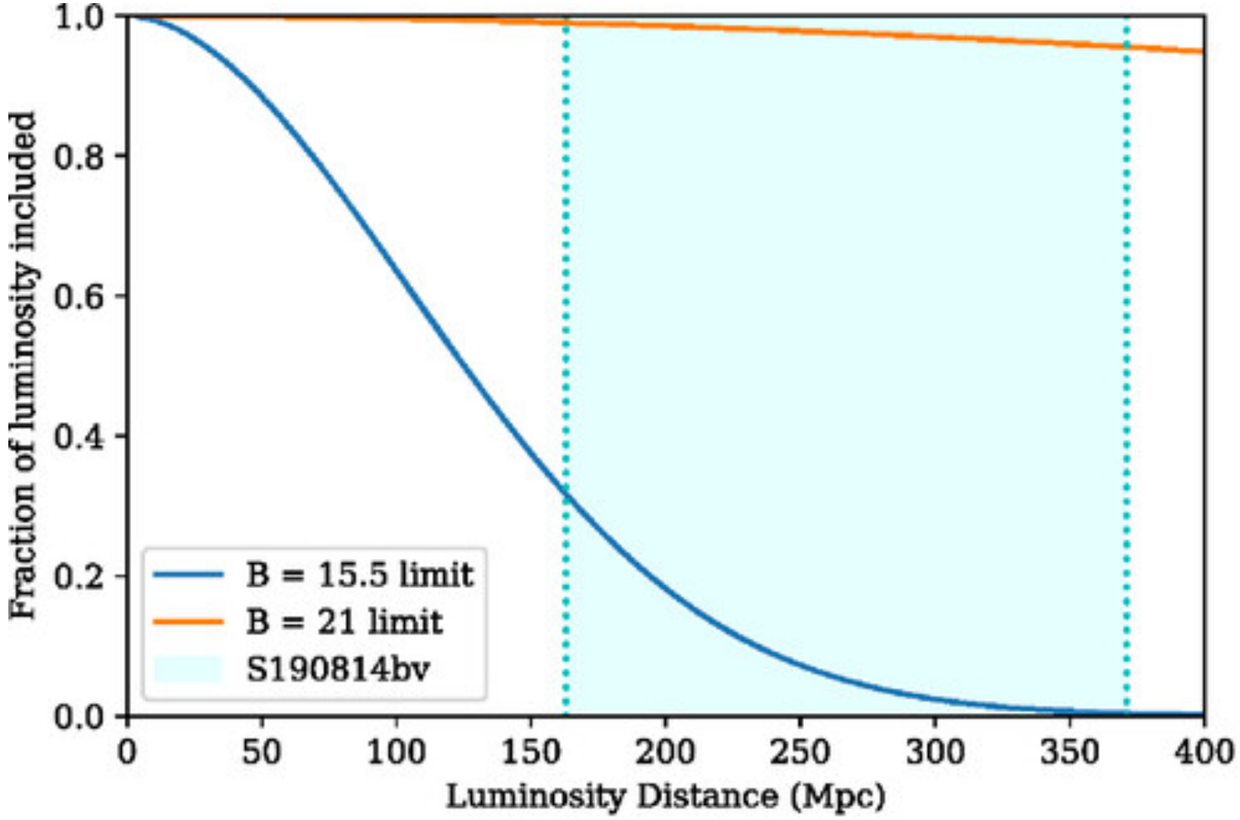


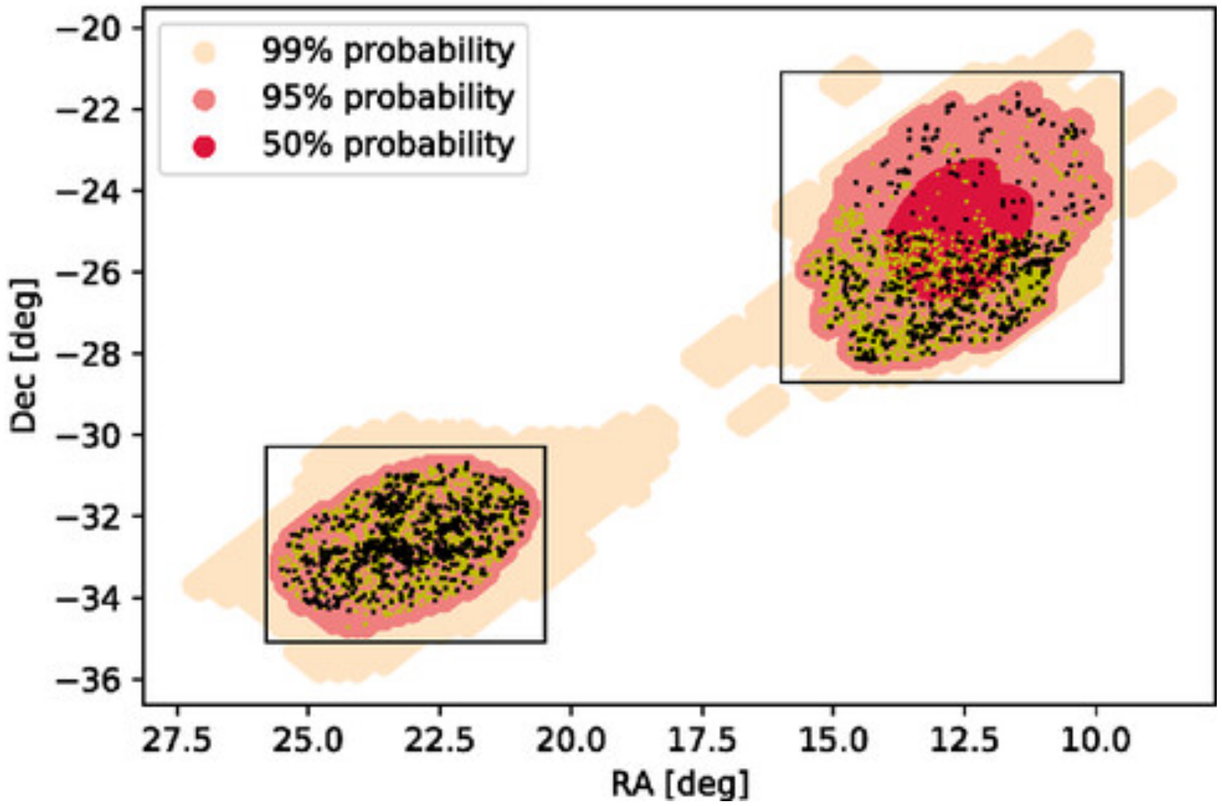
Tiling



from Nicholl & Andreoni 2025

Galaxy catalog incompleteness

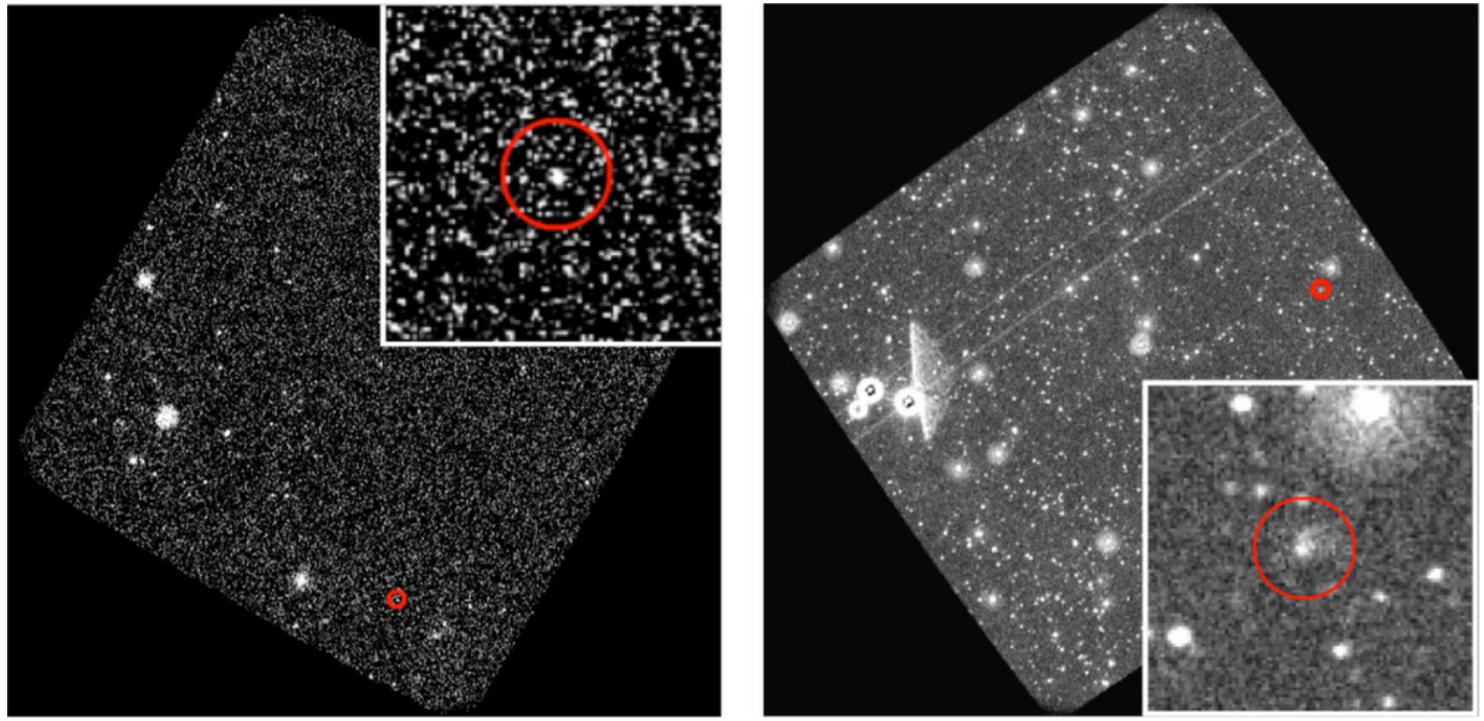




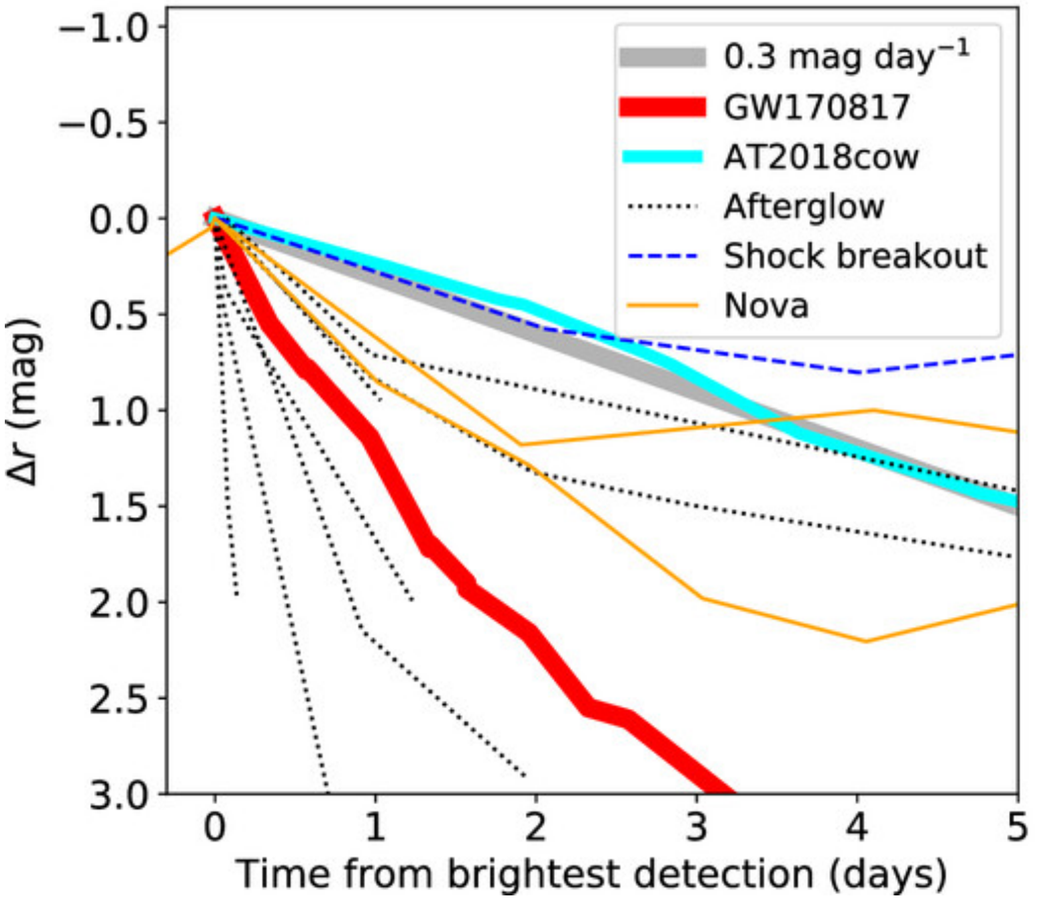
Nicholl & Andreoni 2025, Ackley+2020

Contaminants

Image subtraction artifacts



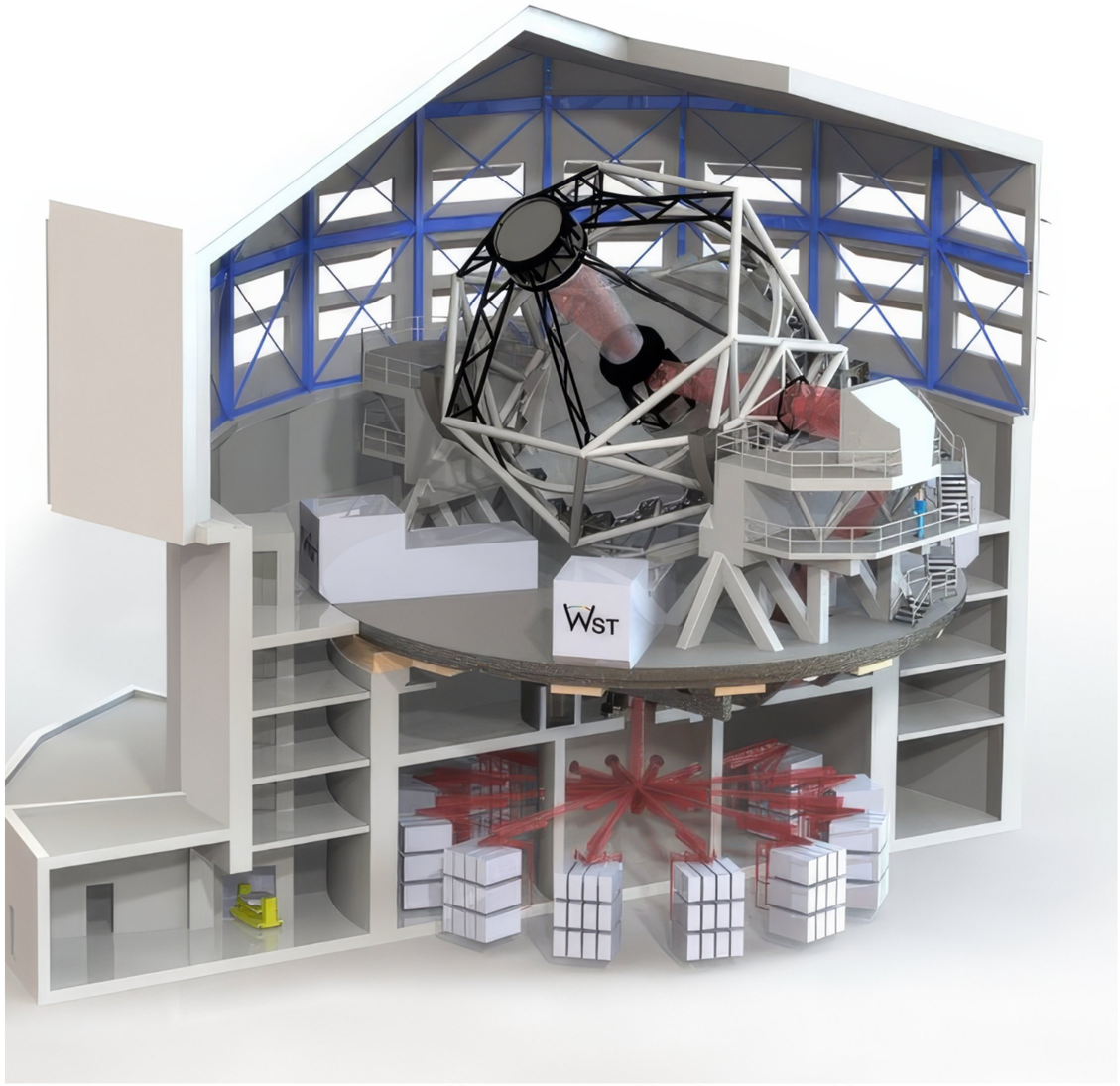
Unrelated transients



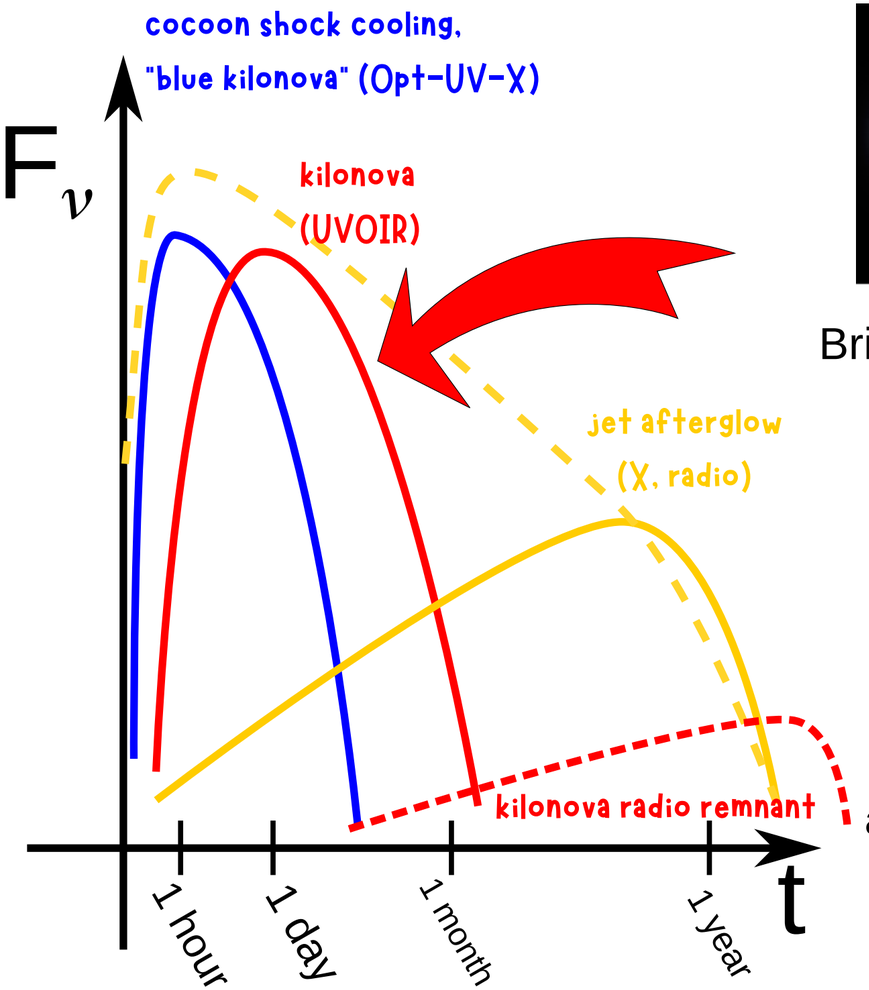
Realistically 10-100 unrelated triggers per search, per night

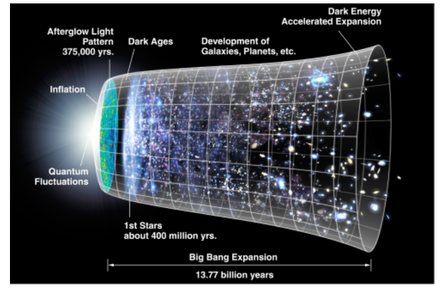
Oates 2025

WST

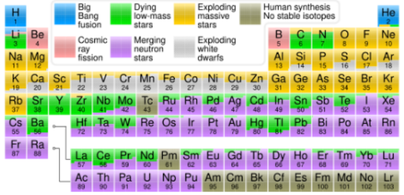


See Sofia Randich's talk





Bright siren cosmography
(also dark siren)

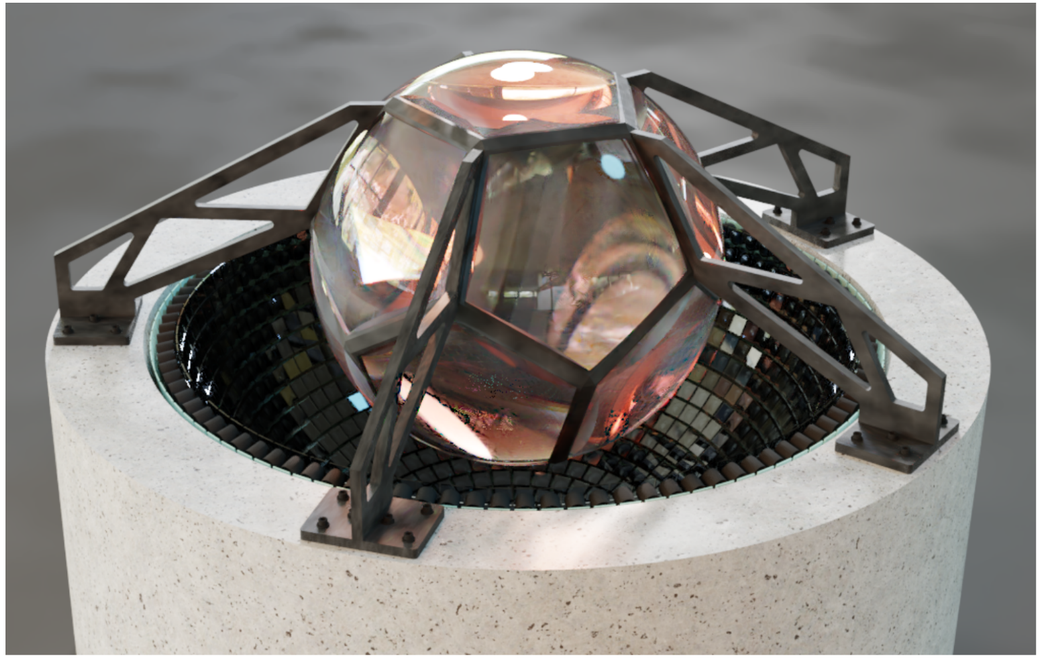


Heavy element
nucleosynthesis
and cosmic enrichment

- Relatively wide-field (3 deg^2) with fibre-fed Multi-Object Spectrograph
- Integral-Field Spectroscopy (3x3 arcmin^2)

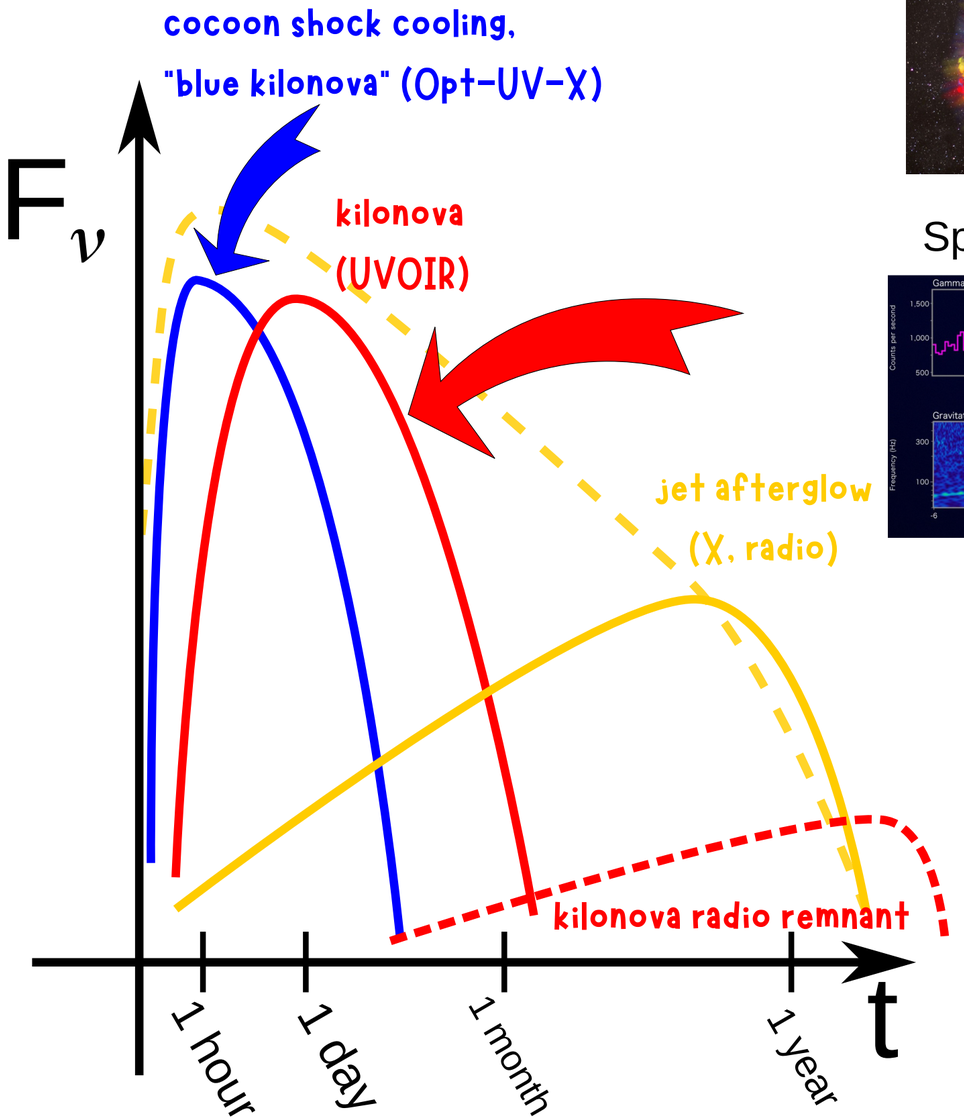
Killer facility for best localized GW events

Very-wide-field, very high cadence optical monitoring?

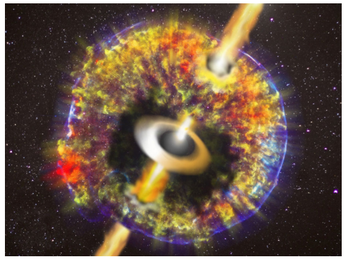


High cadence solves localisation problem by temporal association

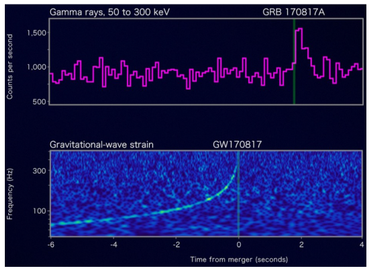
See Gor Oganesyan's talk



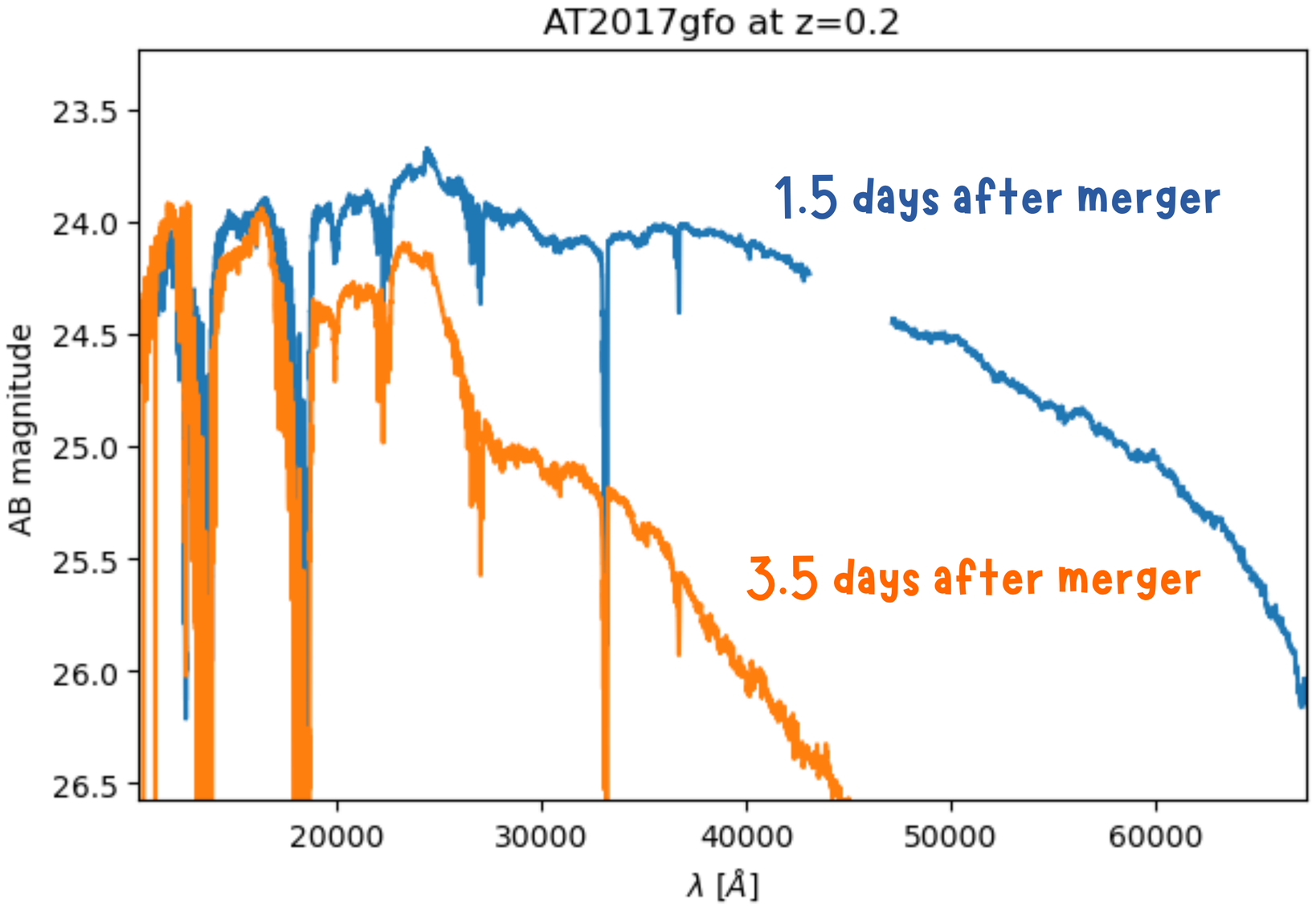
Physics of cosmic explosions



Speed of gravity



Characterization



Spectroscopy from ground requires ELT-like for most events but the nearest ones.

A dedicated JWST-like or Roman-like space telescope would make the difference for good characterization

Summary

- Einstein Telescope and Cosmic Explorer will deliver many high-significance BNS and BHNS triggers per day (let alone binary black holes)
- The localization of these sources is critical for multi-messenger science, and it depends strongly on the availability of multiple detectors in the network
- Even in case the localisation is very good, the characterization of most sources will be challenging
- High-cadence "all-sky" optical monitoring, if sensitive enough, can have big impact on localisation, and also characterization of short-lived emission components

See Ines Francesca Giudice's talk for more science cases