Science with Einstein Telescope

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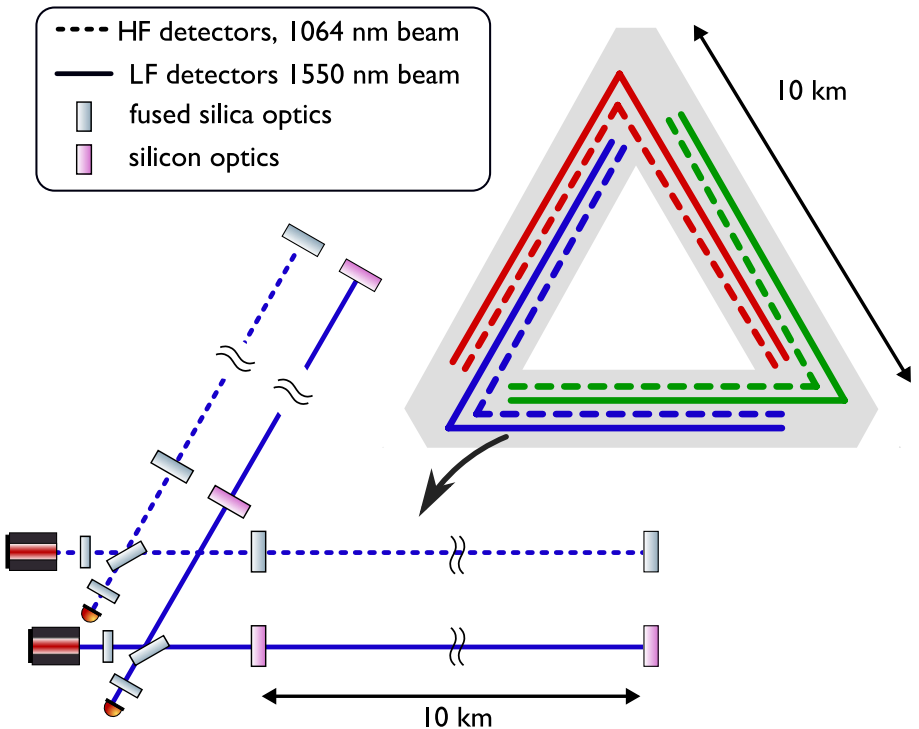
What is Einstein Telescope?

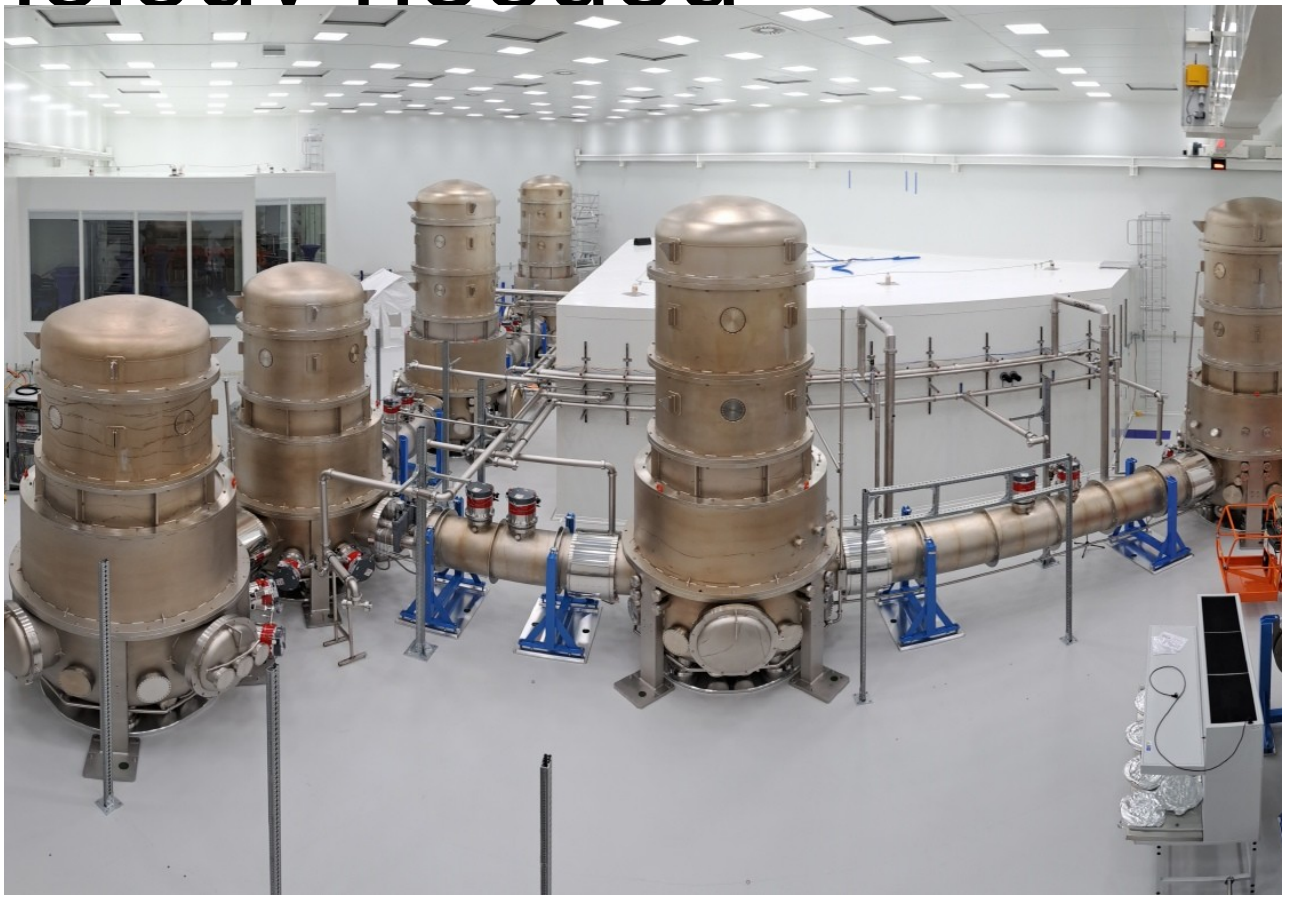
- 3rd generation gravitational wave observatory
- To be built underground
- Triangular configuration*
- 6 interferometers
- LF and HF

*) 2L also considered

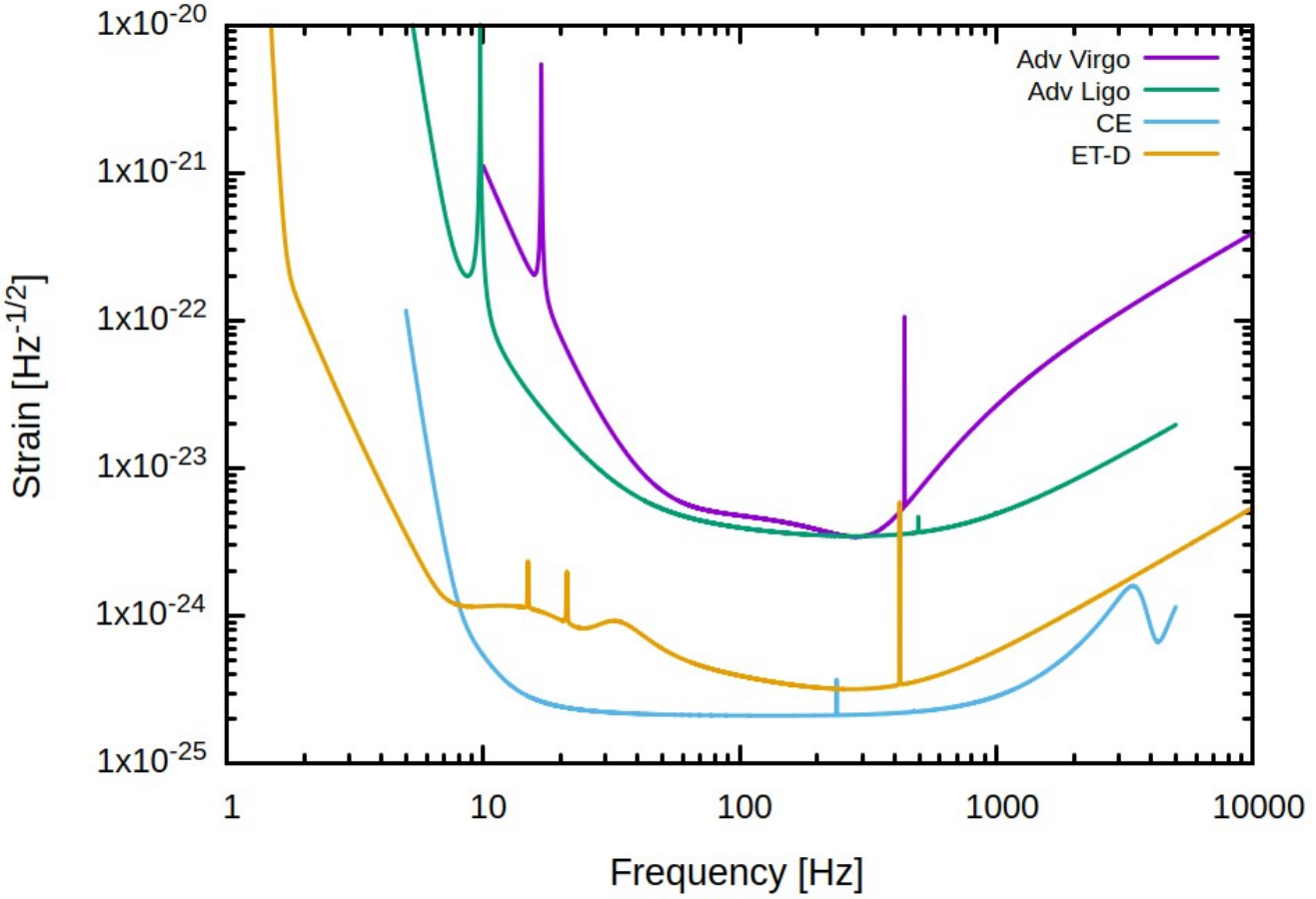


Technology needed

- Cryogenics
- High power laser
- Heavy mirrors
- New mirror technologies
- Squeezed light
-



Planned sensitivity



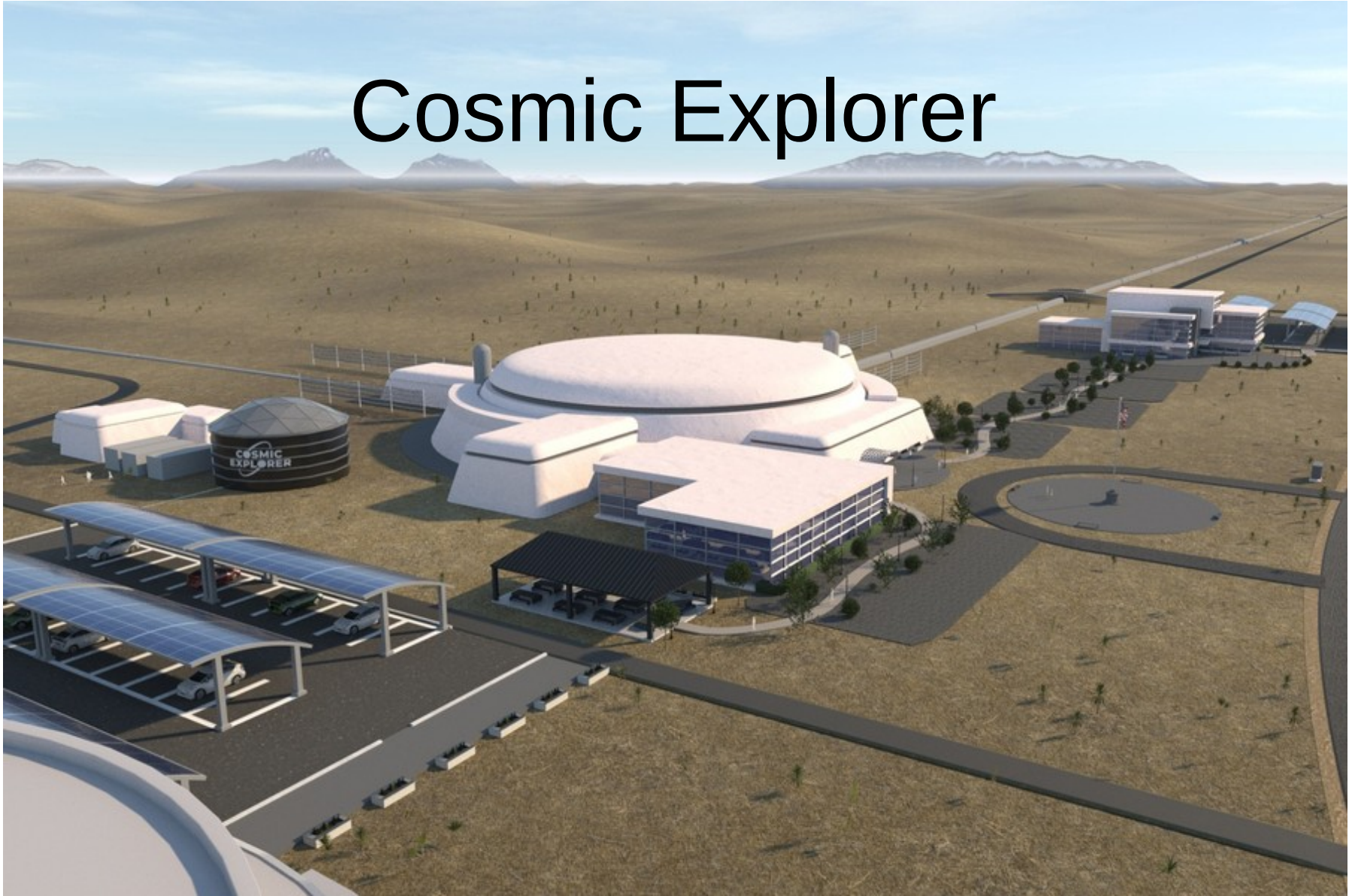
EMR site

Sos Ennatos site

ET Collaboration

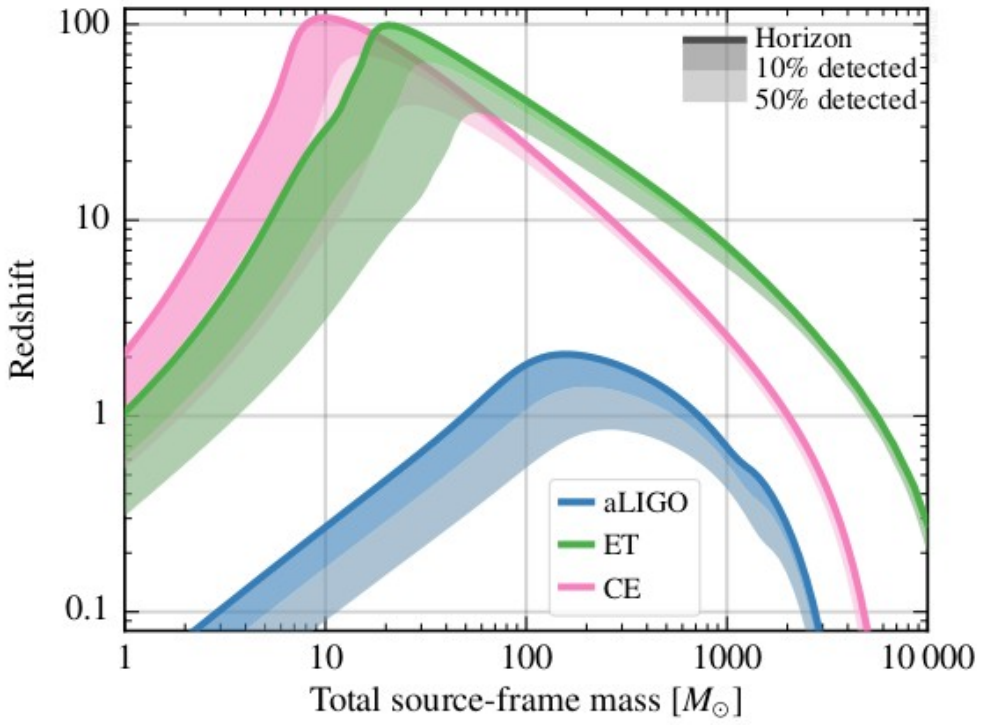
29 countries, 1730 members (yesterday

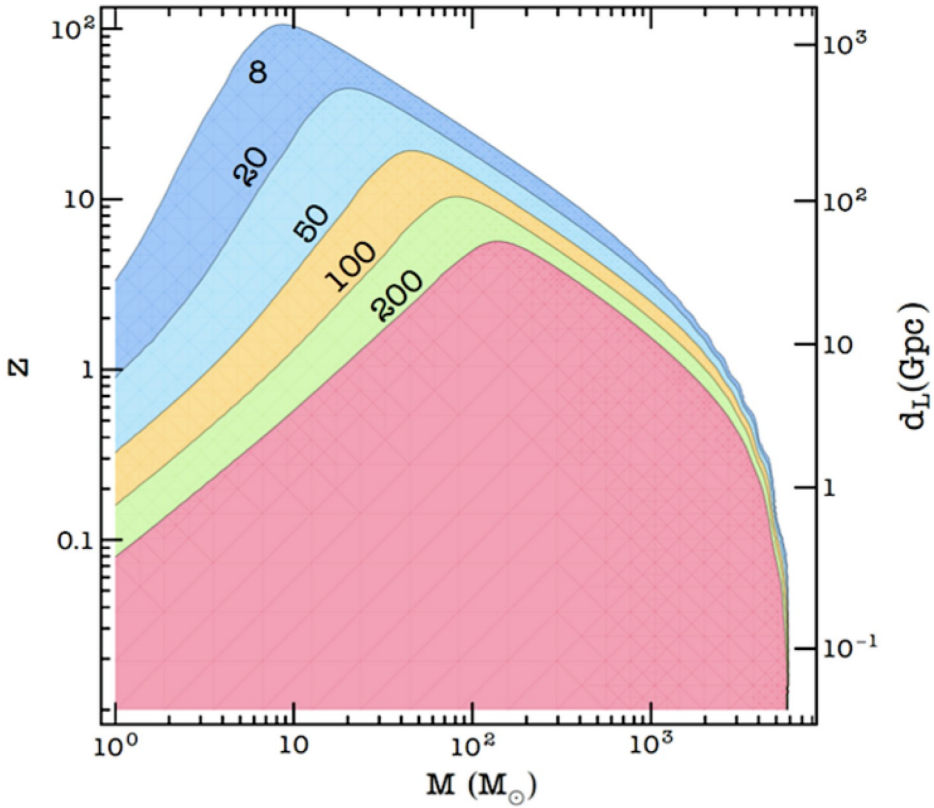
Cosmic Explorer



What do we want to achieve with the Einstein Telescope?

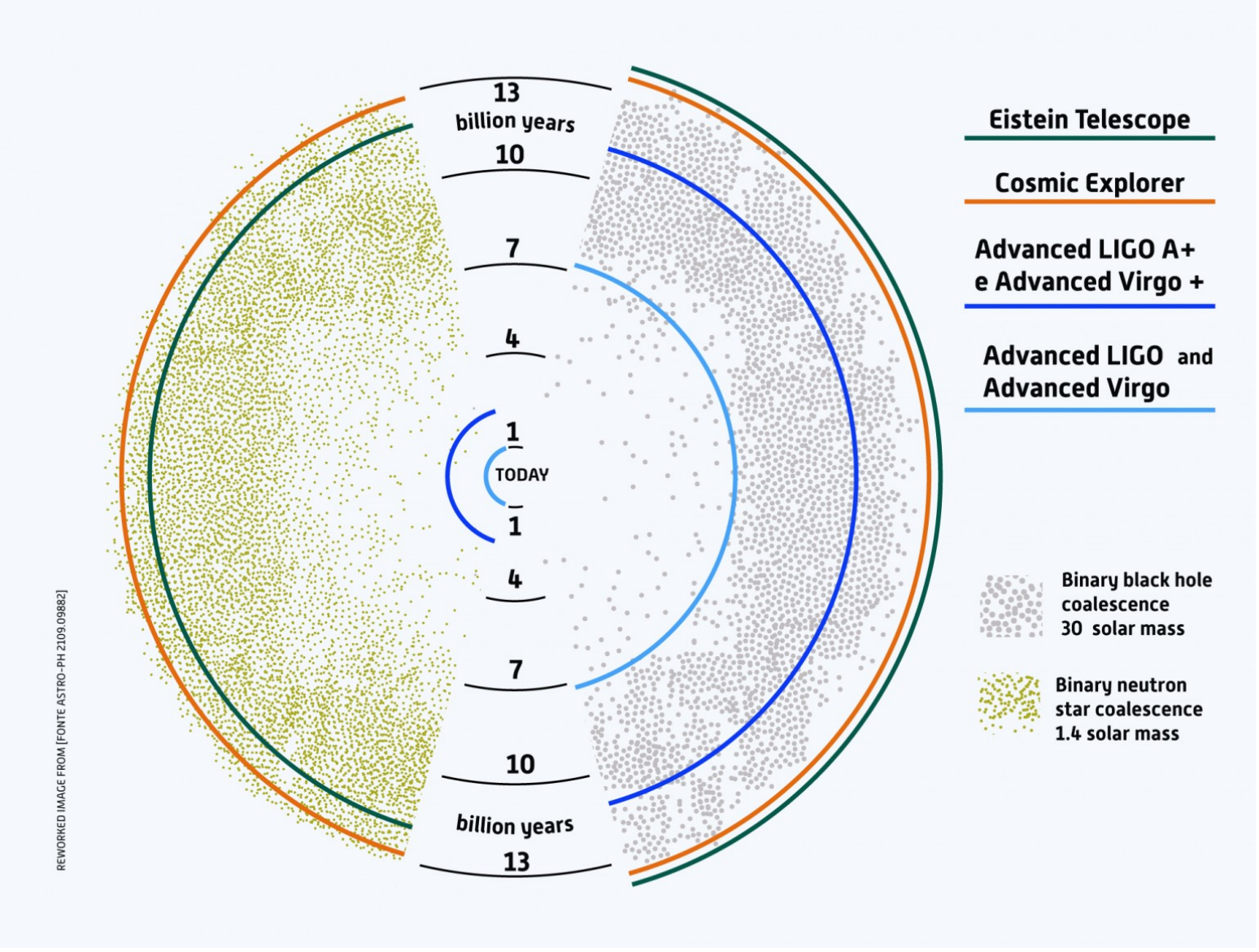
Compact object merger ranges





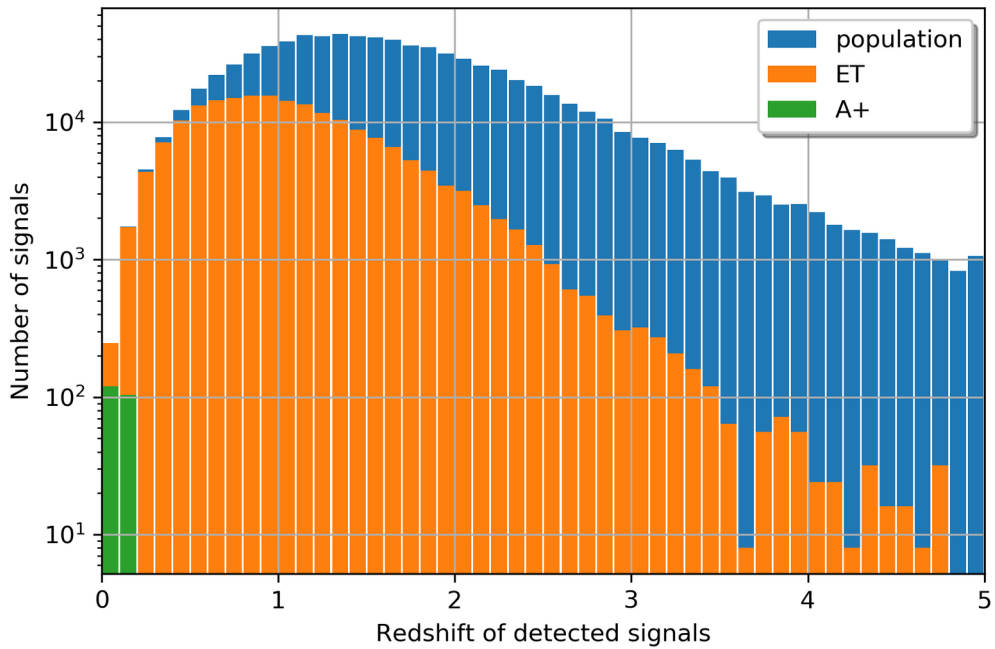
NS-NS
$10^{4\text{-}5}yr^{-1}$

BH-BH
$10^{5\text{-}6}yr^{-1}$

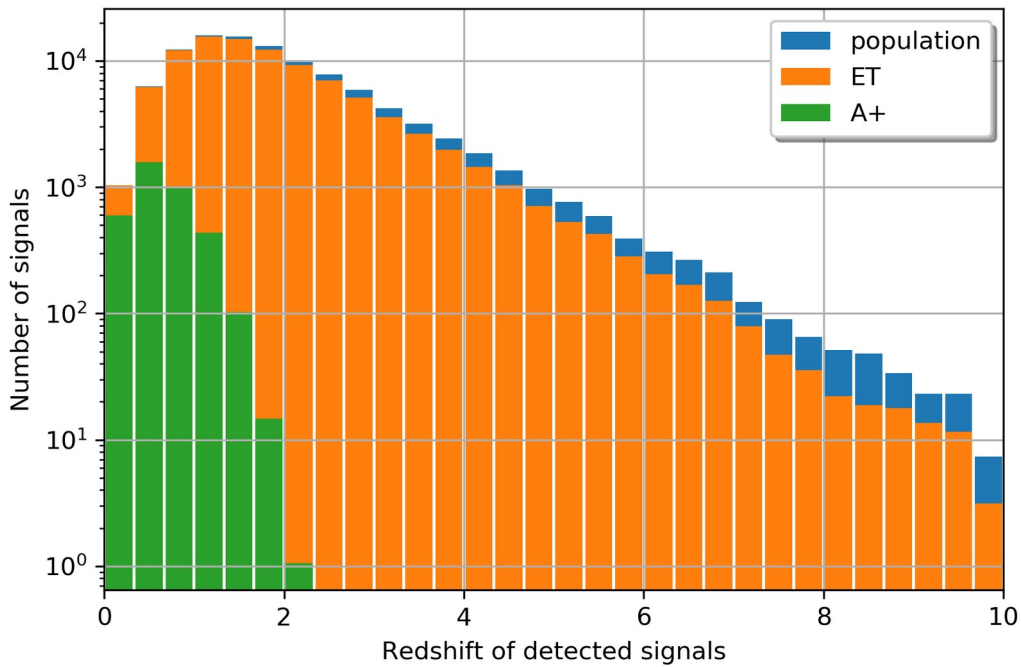


Completeness

BH BH

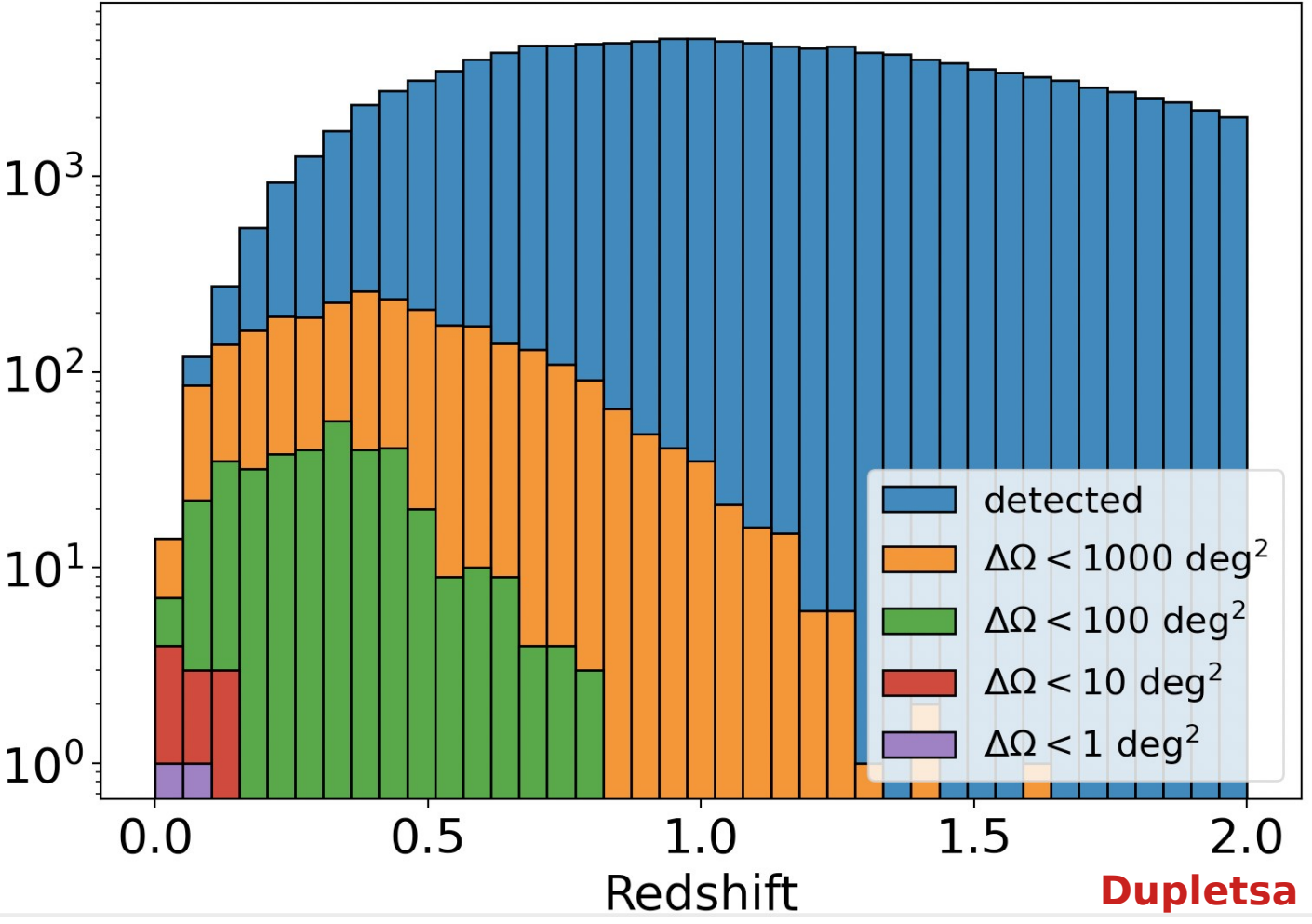


NS NS



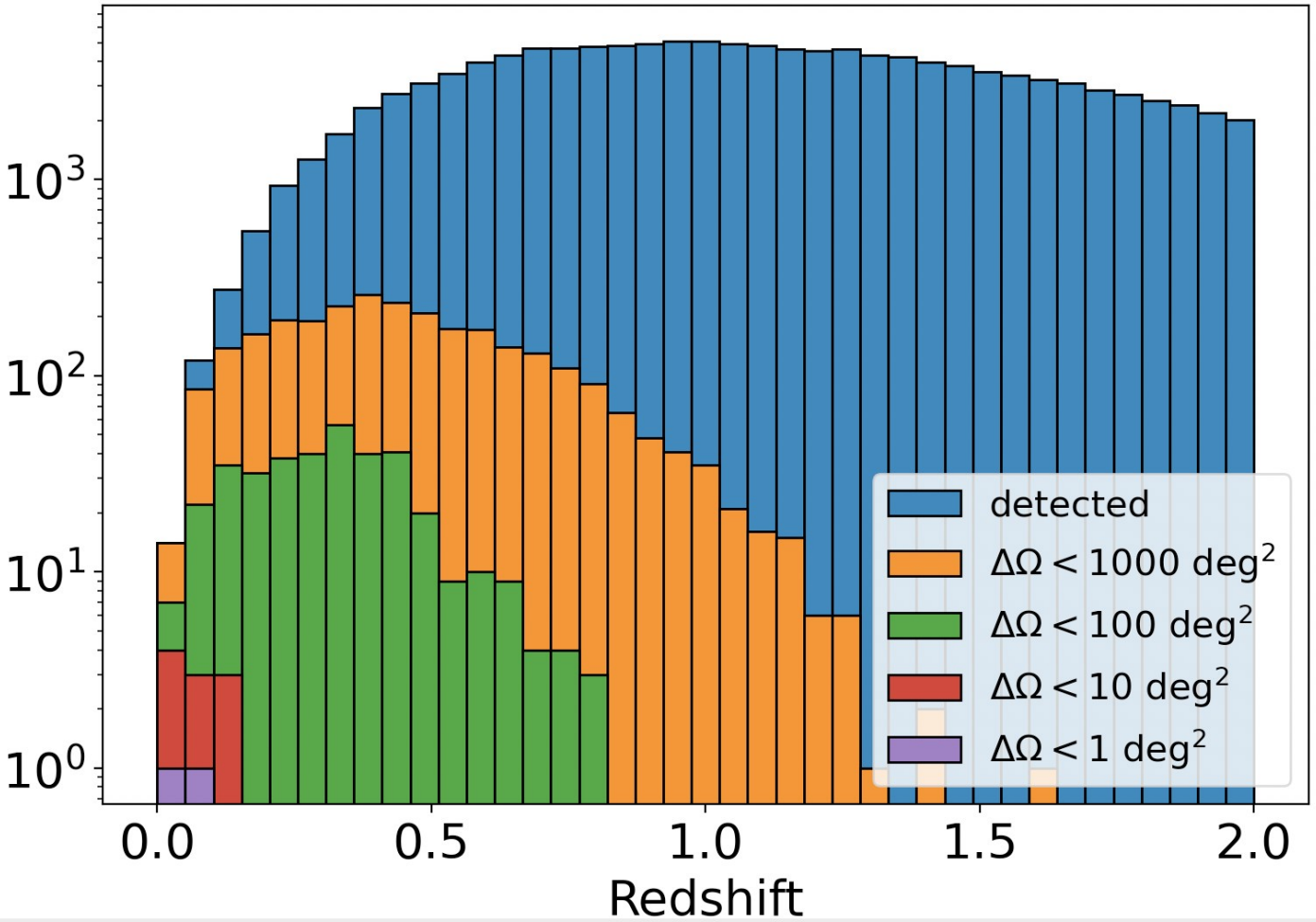
Dupletsa et al. 2023

Sky localization with ET



Dupletsa et al. 2023

Network with CE



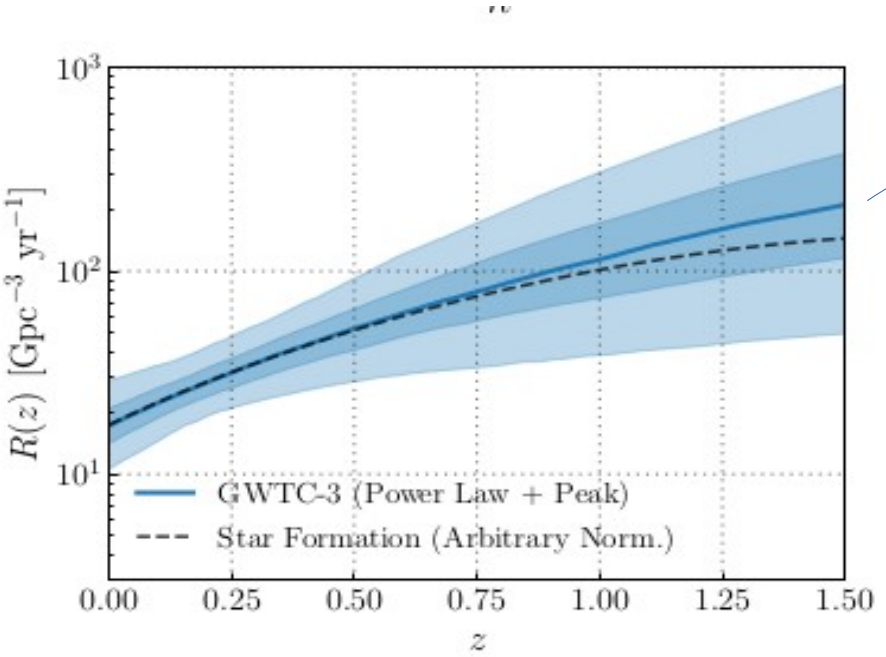
A few detections per day with localization better than 1 deg square!

Dupletsa et al. 2023

Black hole science

- Populations
  - PBHs, PopIII BHs,
  - Merger rate density as a function of redshift
  - Cosmology
- Precise waveform measurements
  - GR tests
  - Formation scenarios

Rates vs redshift



?

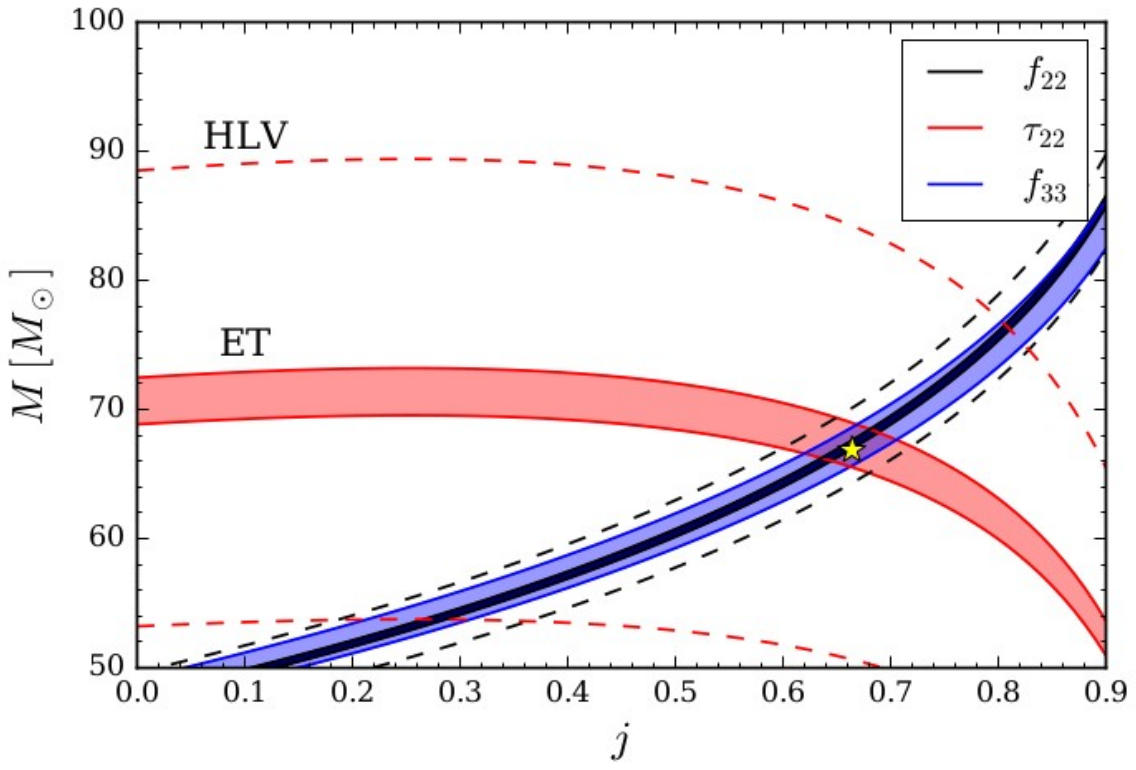
GR tests

QNM analysis with very high accuracy

No hair theorem

Alternative theories

Exotic objects



Cosmology with standard sirens

- Energy emitted E ~ M
- Timescale of merger t ~ M
- Luminosity L= E/t ~ const
- In practice using the measured M_z and amplitude we obtain d_L
- Need a separate measurement of z:
  - from known(?) mass distribution
  - from EM observation
  - From statistical considerations

Cosmology with GW - now

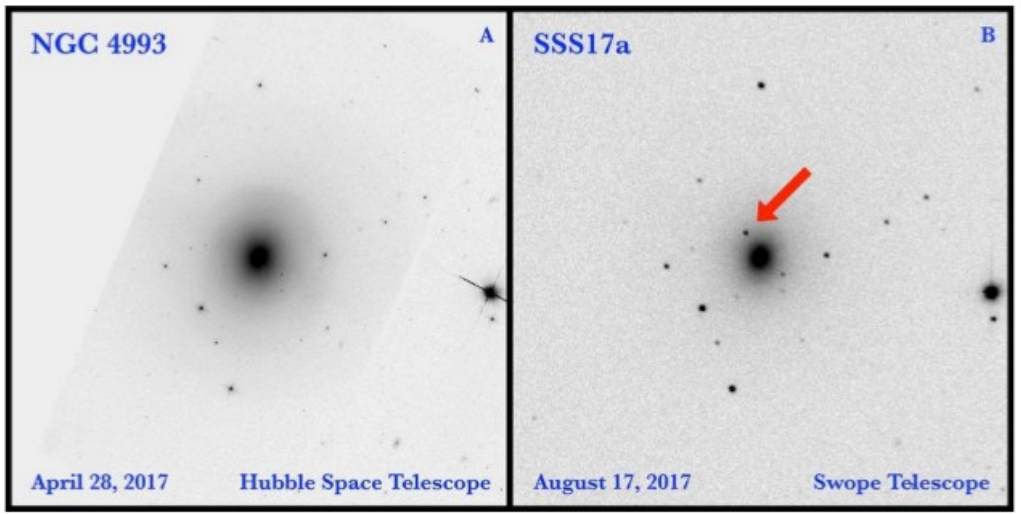
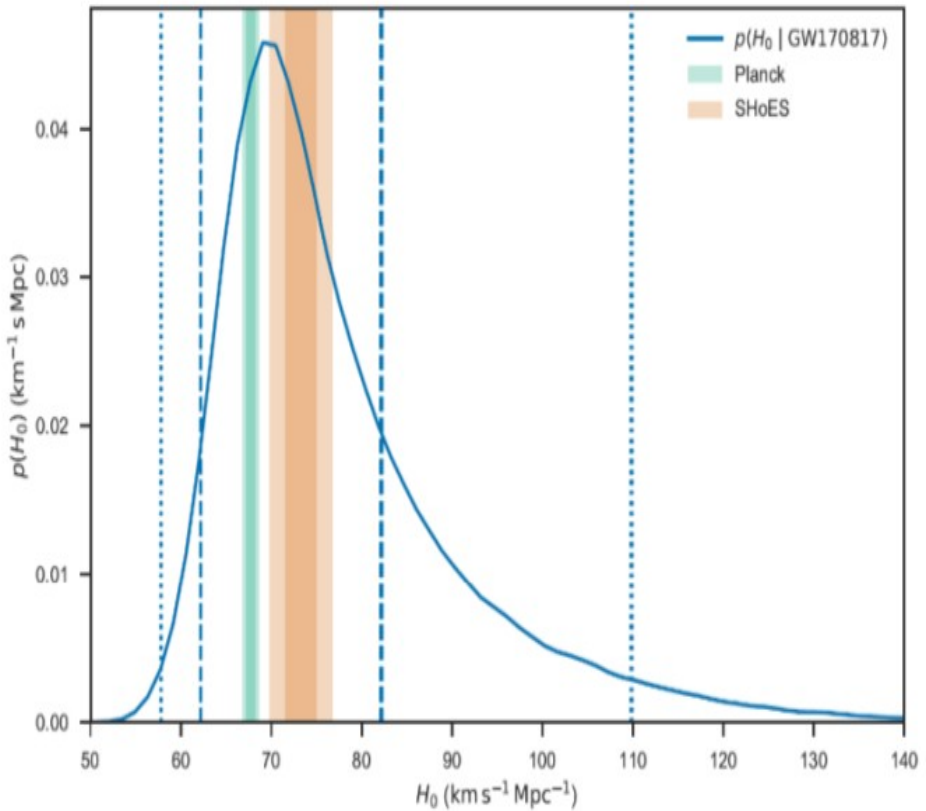


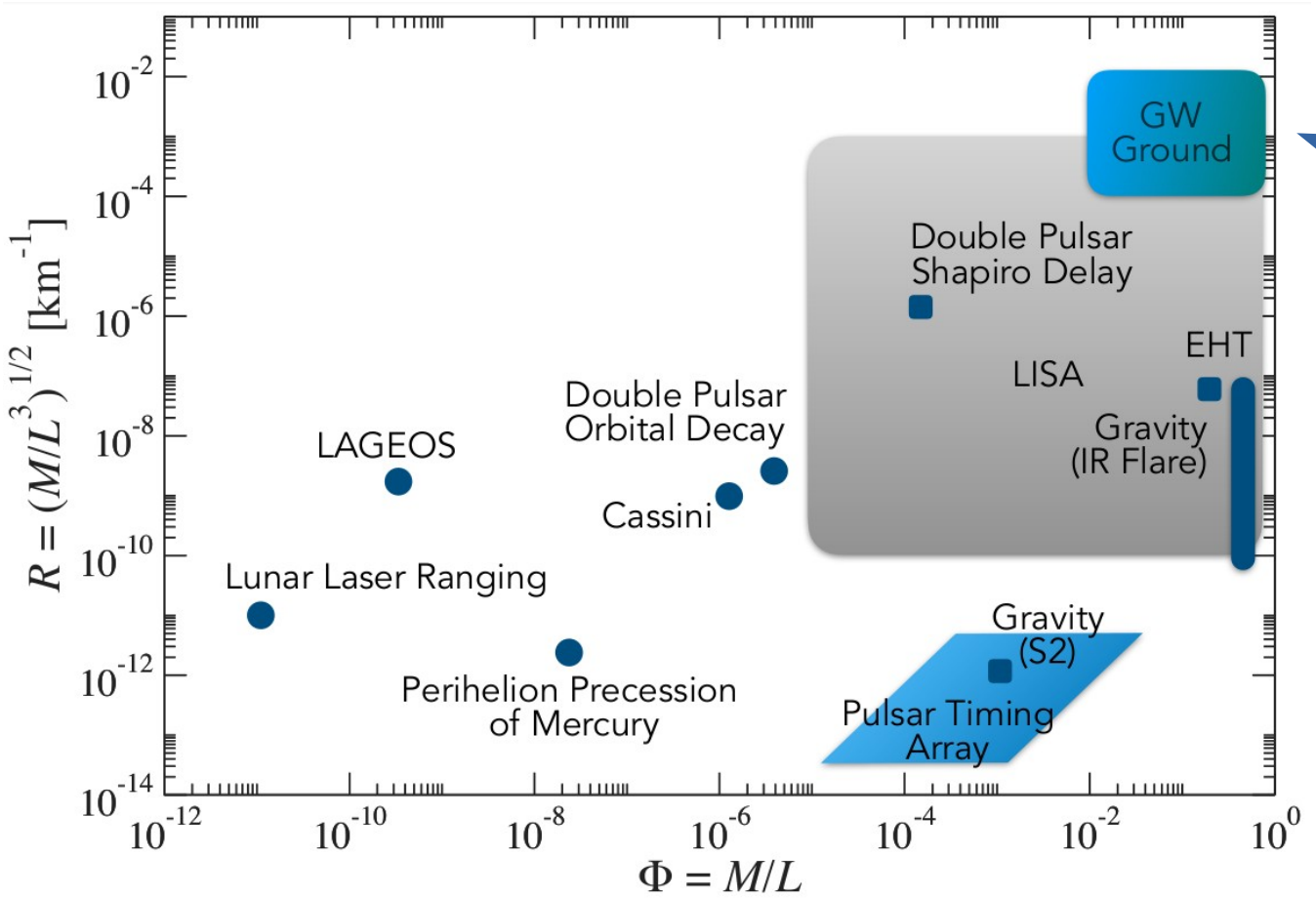
Fig. 4. 3×3 arcminute images centered on NGC 4993 with North up and East left. (A) *Hubble Space Telescope* F606W-band (broad *V*) image from 4 months before the GW trigger (*25*, *35*). (B) Swope image of SSS17a. The *i*-band image was obtained on 2017 August 17 at 23:33 UT by the Swope telescope at Las Campanas Observatory. SSS17a is marked with the red arrow. No object is present in the *Hubble* image at the position of SSS17a (*25*, *35*).



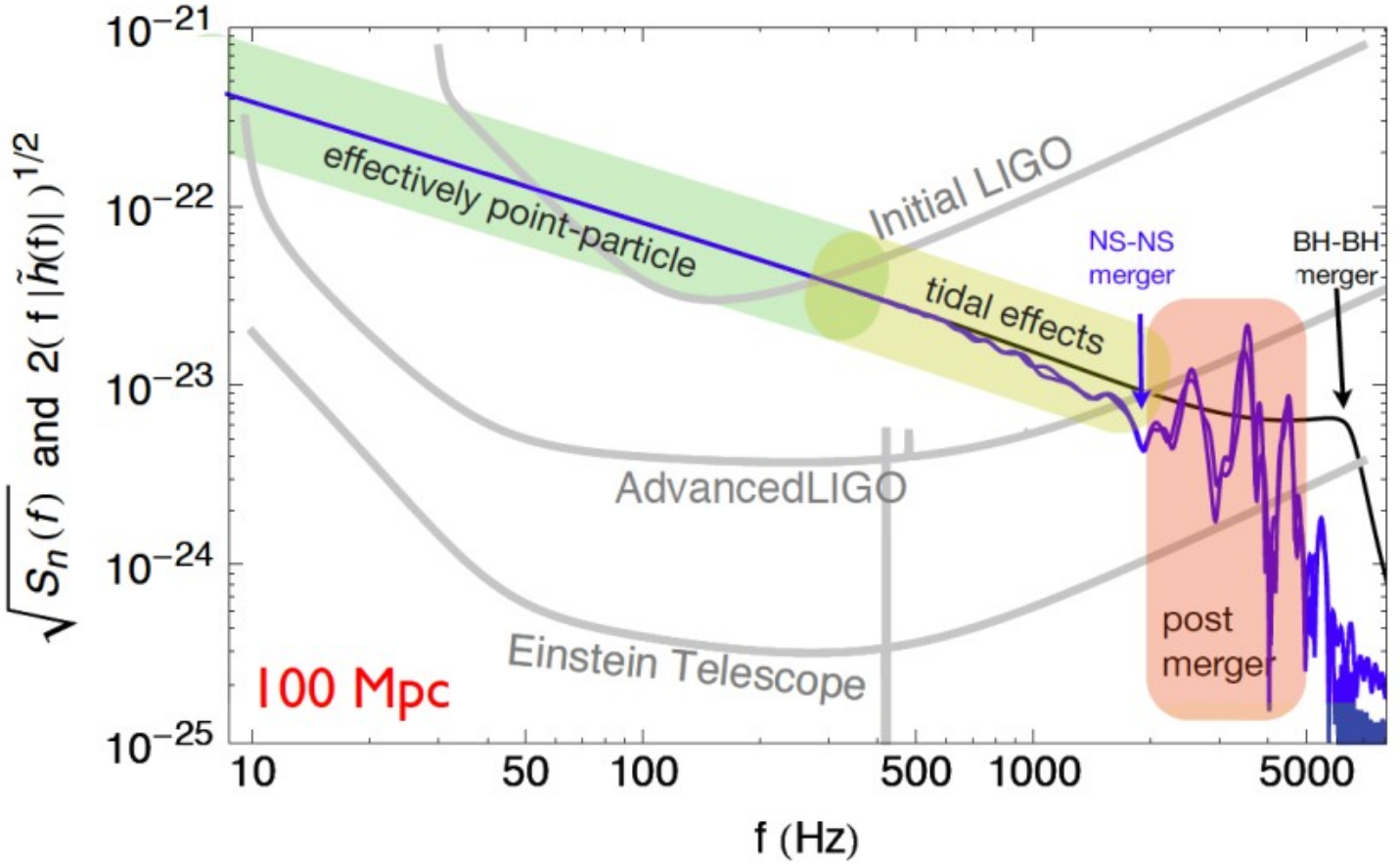
Neutron Star Mergers

- Equation of state
- Multi-messenger studies
- Early warning on mergers
- GRB connection

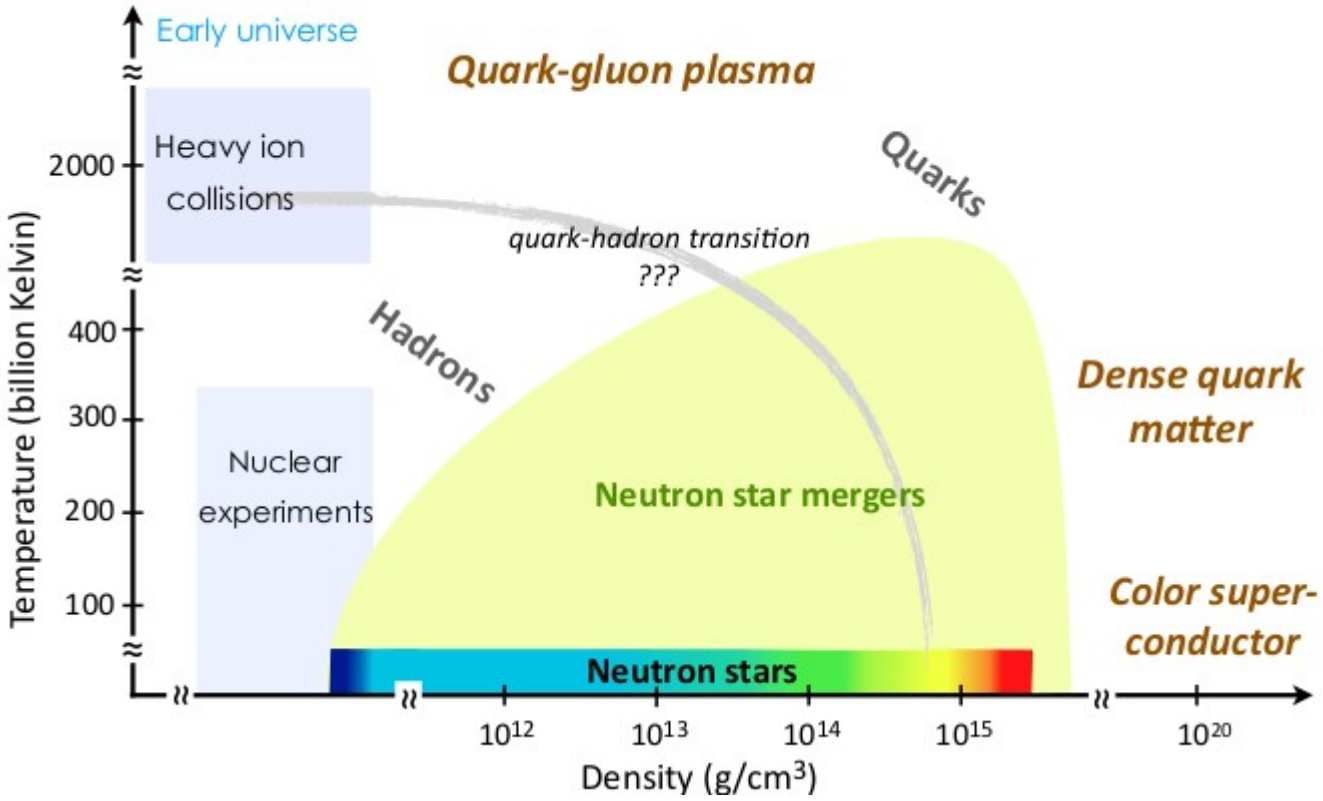
Probing gravity at extremes



ET

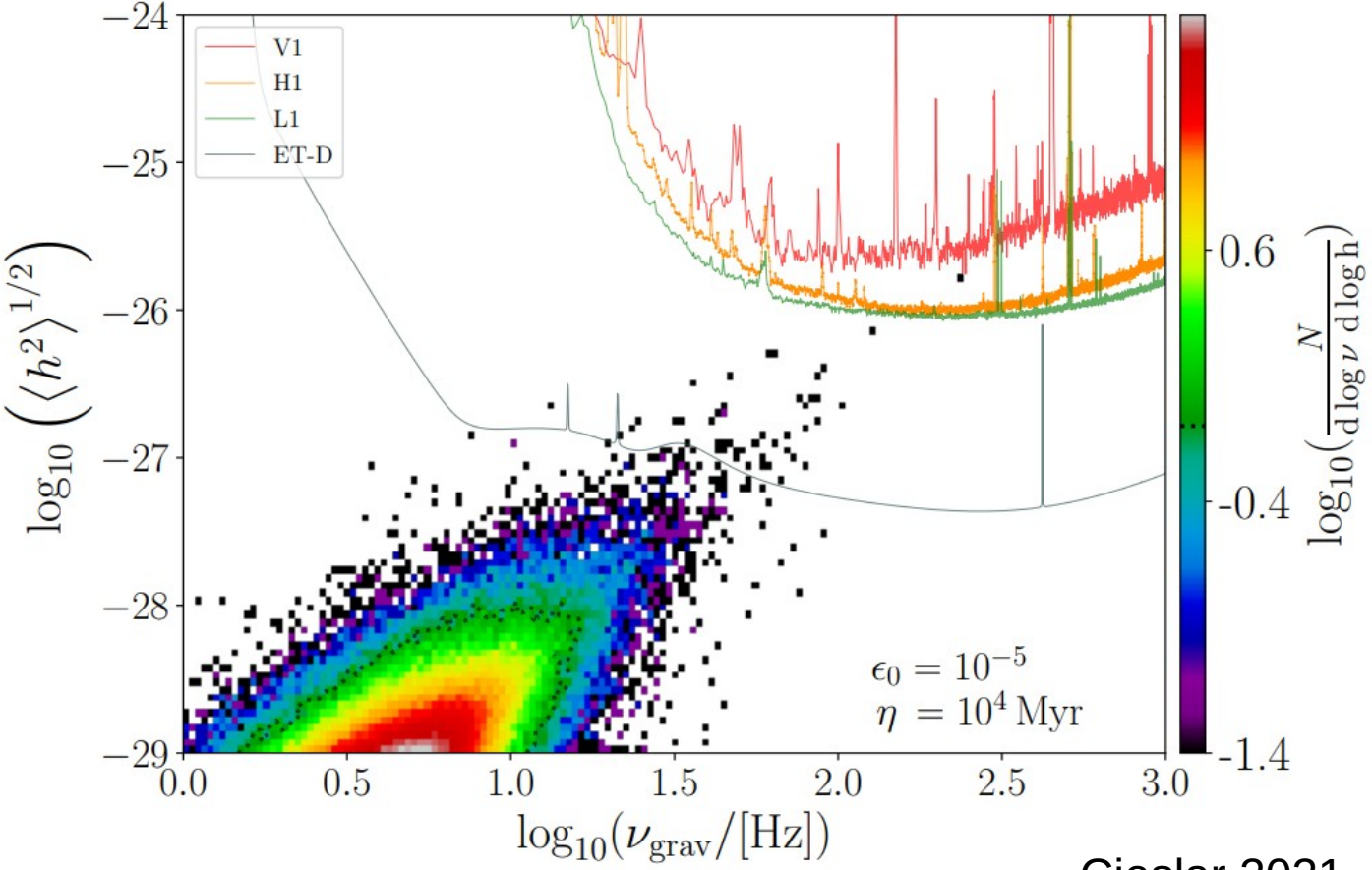

10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
$\sqrt{S_n(f)}$ and $2(f|\tilde{h}(f)|)^{1/2}$
effectively point-particle
Initial LIGO
NS-NS merger
BH-BH merger
tidal effects
AdvancedLIGO
post merger
Einstein Telescope
100 Mpc
10
50
100
500
1000
5000
f (Hz)

Dense matter parameter space



Pulsar population

Sensitivity in one year observation.



Cieslar 2021

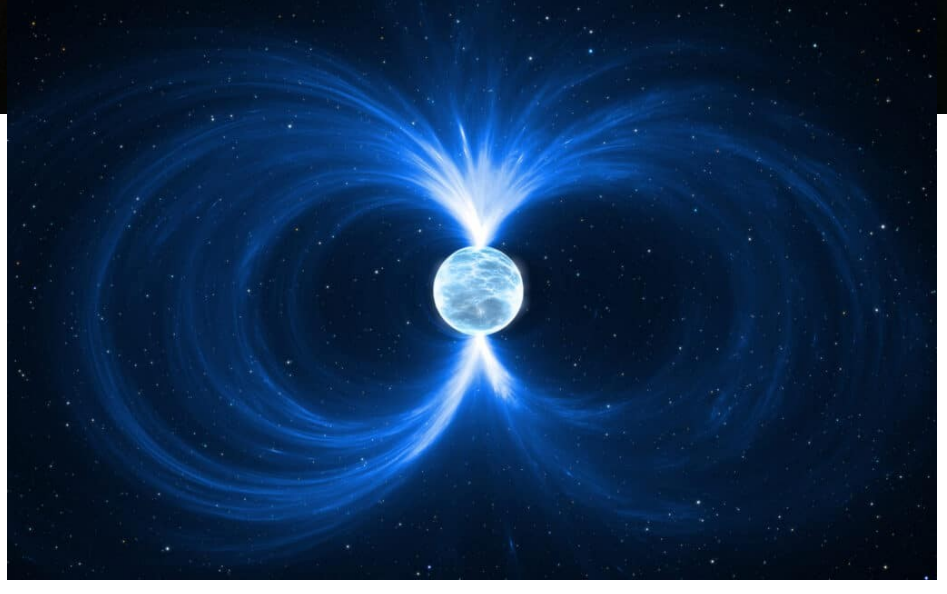
Bursts

Supernovae

Fast radio bursts

Magnetars

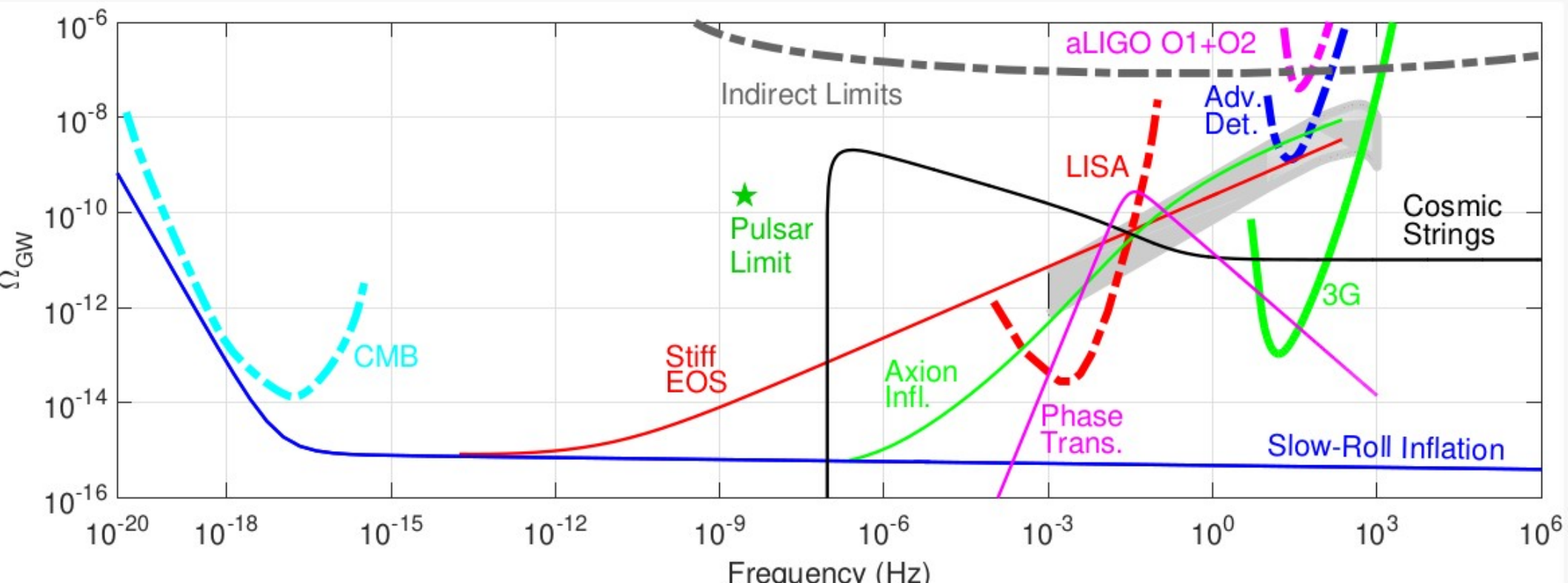
Many other



Ability to subtract binary foreground

Backgrounds

Three (x2) interfermeters, independent noise.



ET Science in a nutshell

ASTROPHYSICS

- **Black hole properties**
  - origin (stellar vs. primordial)
  - evolution, demography
- **Neutron star properties**
  - interior structure (QCD at ultra-high densities, exotic states of matter)
  - demography
- **Multi-band and -messenger astronomy**
  - joint GW/EM observations (GRB, kilonova,...)
  - multiband GW detection (LISA)
  - neutrinos
- **Detection of new astrophysical sources**
  - core collapse supernovae
  - isolated neutron stars
  - stochastic background of astrophysical origin

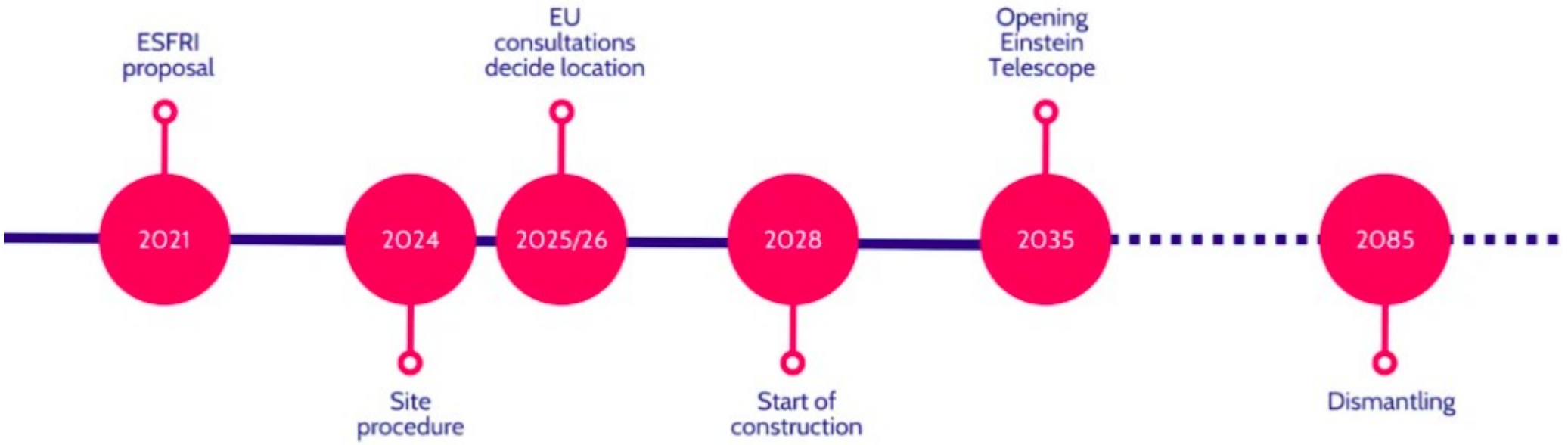
FUNDAMENTAL PHYSICS AND COSMOLOGY

- **The nature of compact objects**
  - near-horizon physics
  - tests of no-hair theorem
  - exotic compact objects
- **Tests of General Relativity**
  - post-Newtonian expansion
  - strong field regime
- **Dark matter**
  - primordial BHs
  - axion clouds, dark matter accreting on compact objects
- **Dark energy and modifications of gravity on cosmological scales**
  - dark energy equation of state
  - modified GW propagation

Stochastic cosmological backgrounds

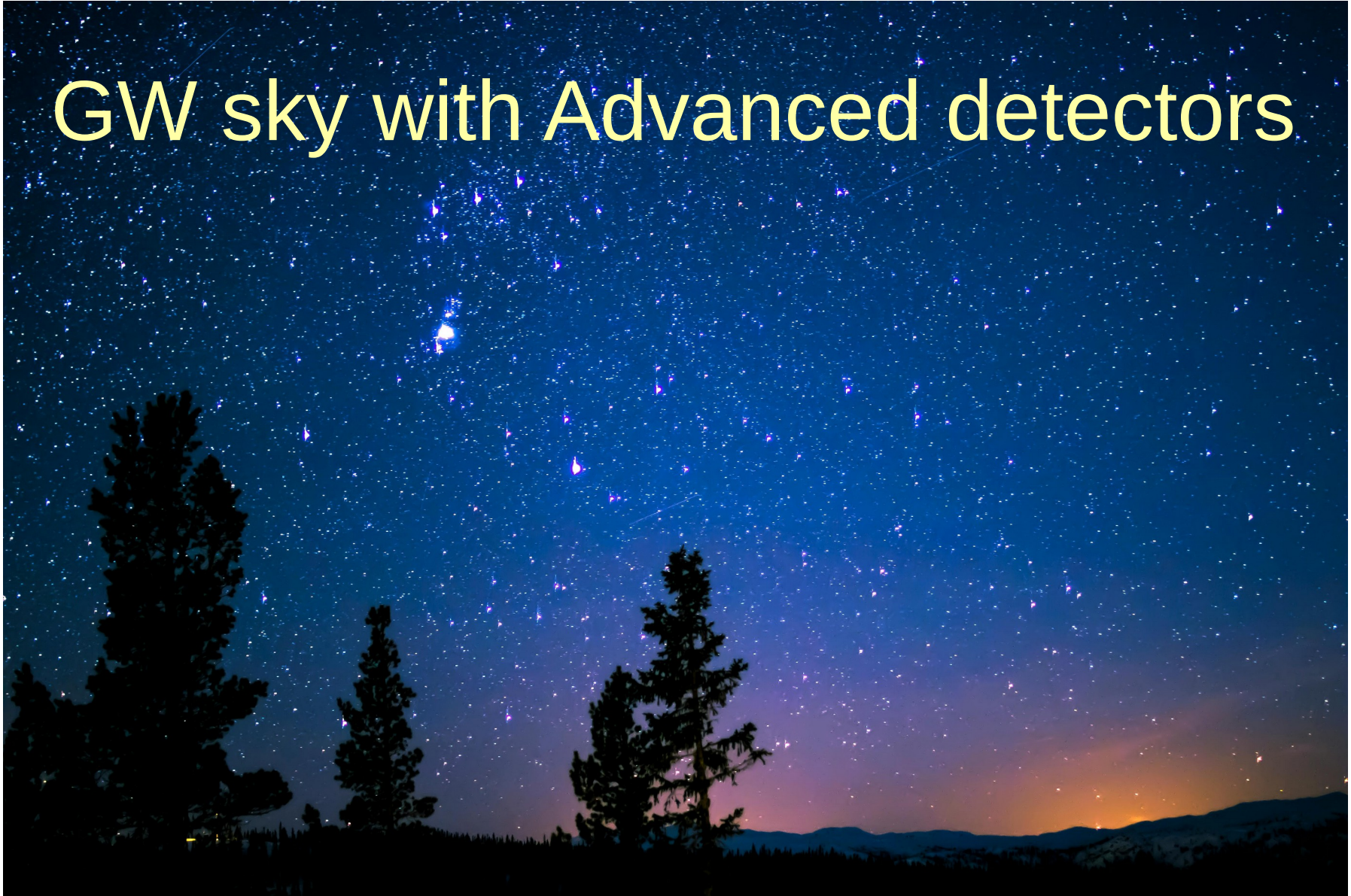
- inflation, phase transitions, cosmic strings

Timeline


ESFRI proposal
2021
2024
Site procedure
EU consultations decide location
2025/26
2028
Start of construction
Opening Einstein Telescope
2035
2085
Dismantling


GW sky few years ago

GW sky with Advanced detectors



GW sky with ET

Present and future GW astronomy