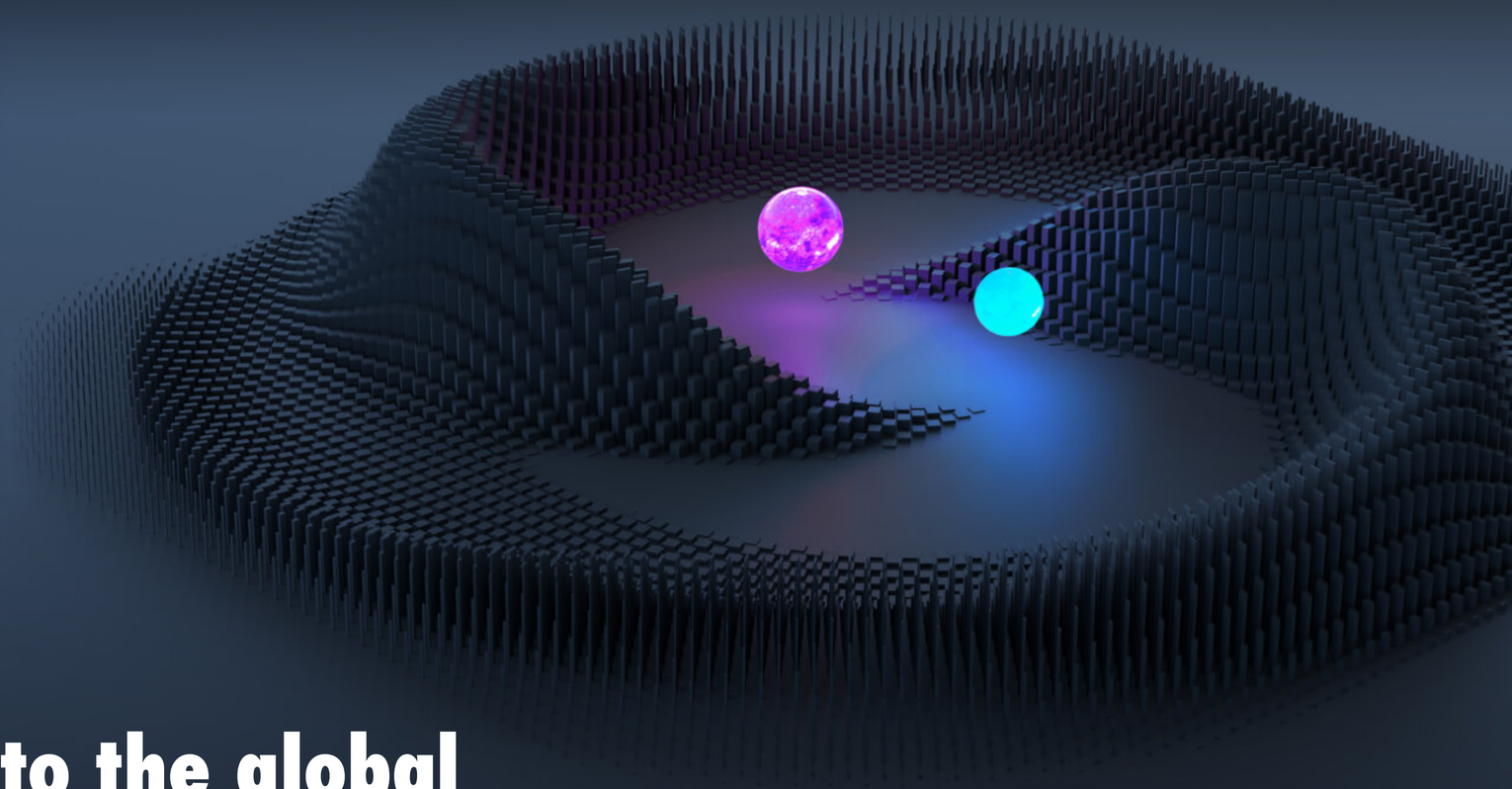


What does Australia bring to the global gravitational-wave detector network?

Ling Sun, OzGrav-ANU, 2022.12.15

Australian National University

Australian National University
Acknowledgement of Country

We acknowledge and celebrate the First Australians on whose traditional lands we meet, and pay our respect to the elders past and present.

The Ripple Effect: Rippling Out by Wurundjeri artist Judy Nicholson

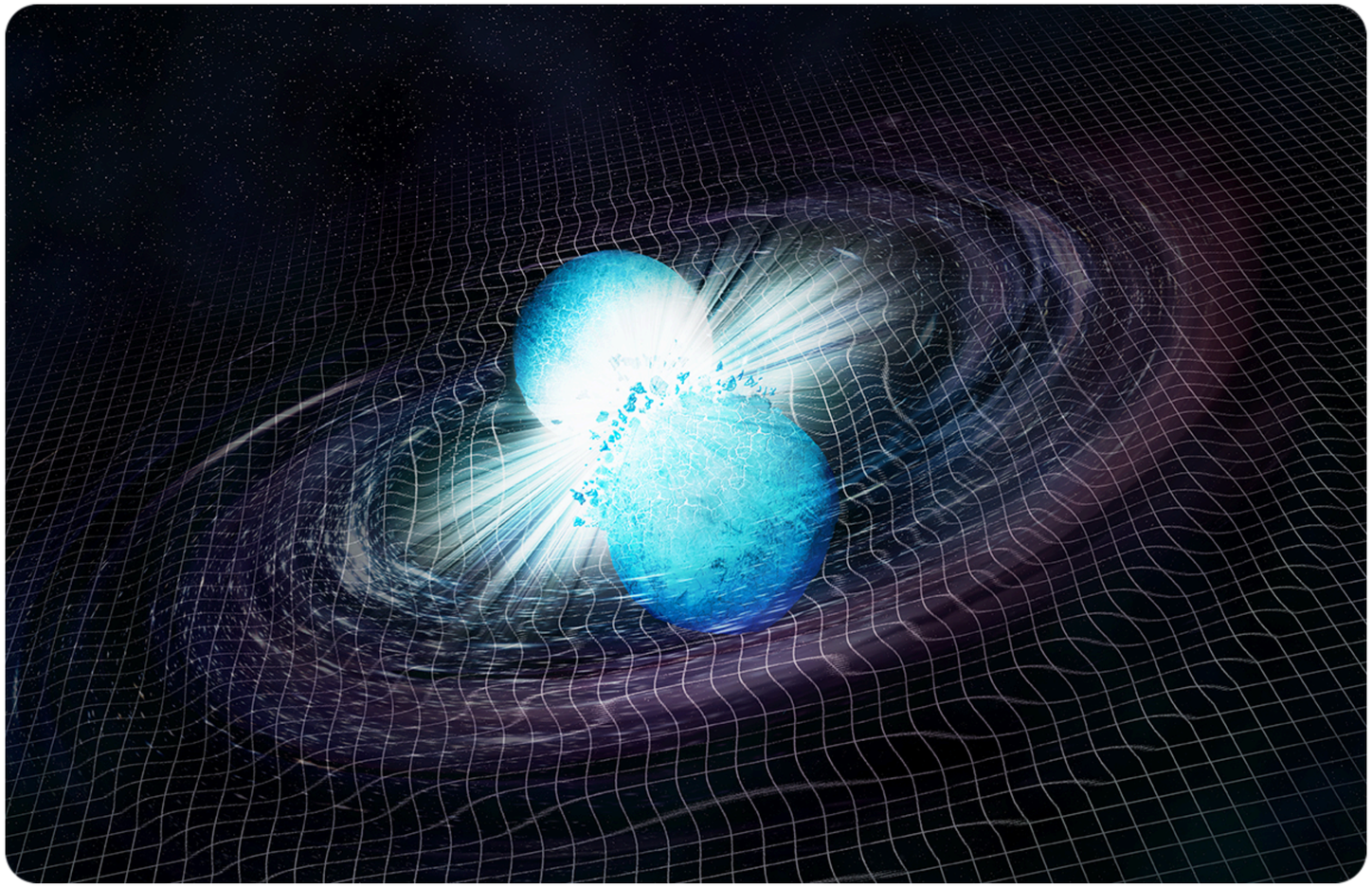
OzGrav

ARC Centre of Excellence for Gravitational Wave Discovery

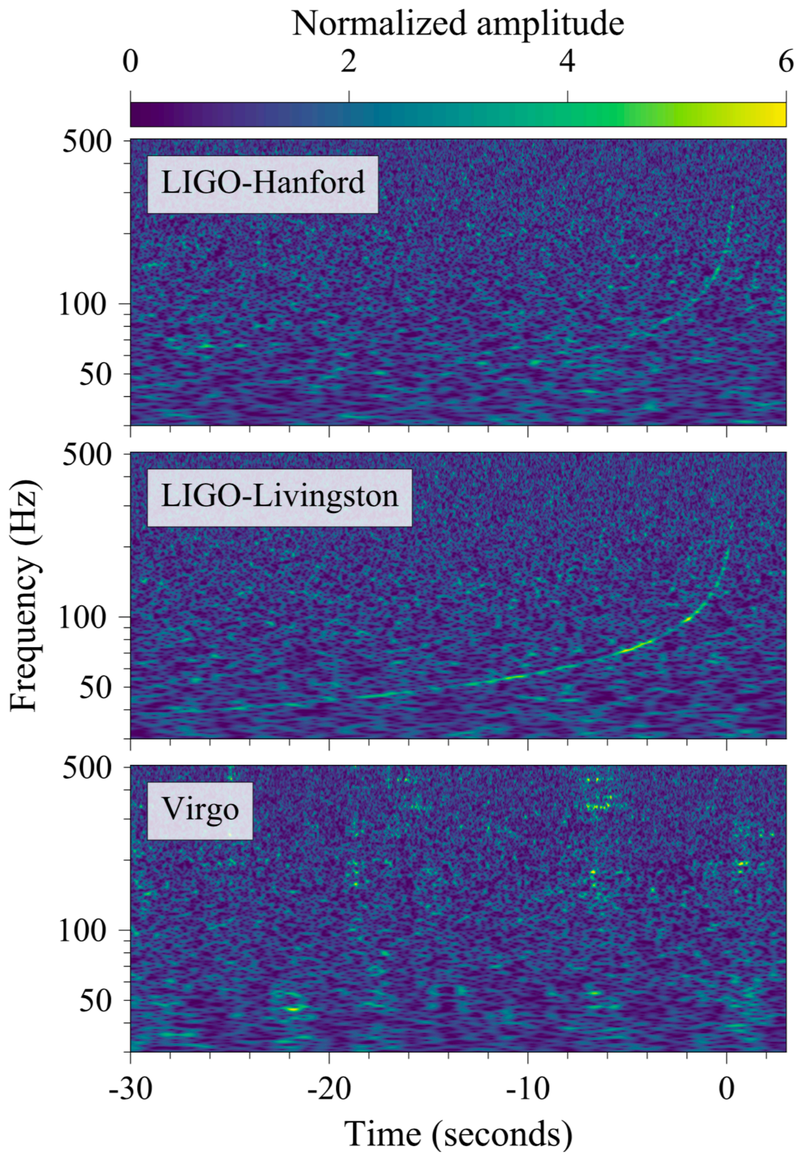
Outline

- *Binary neutron star mergers & multi-messenger astronomy*
- *Current and next generation ground-based detector networks*
- *What will an Australian detector bring us?*

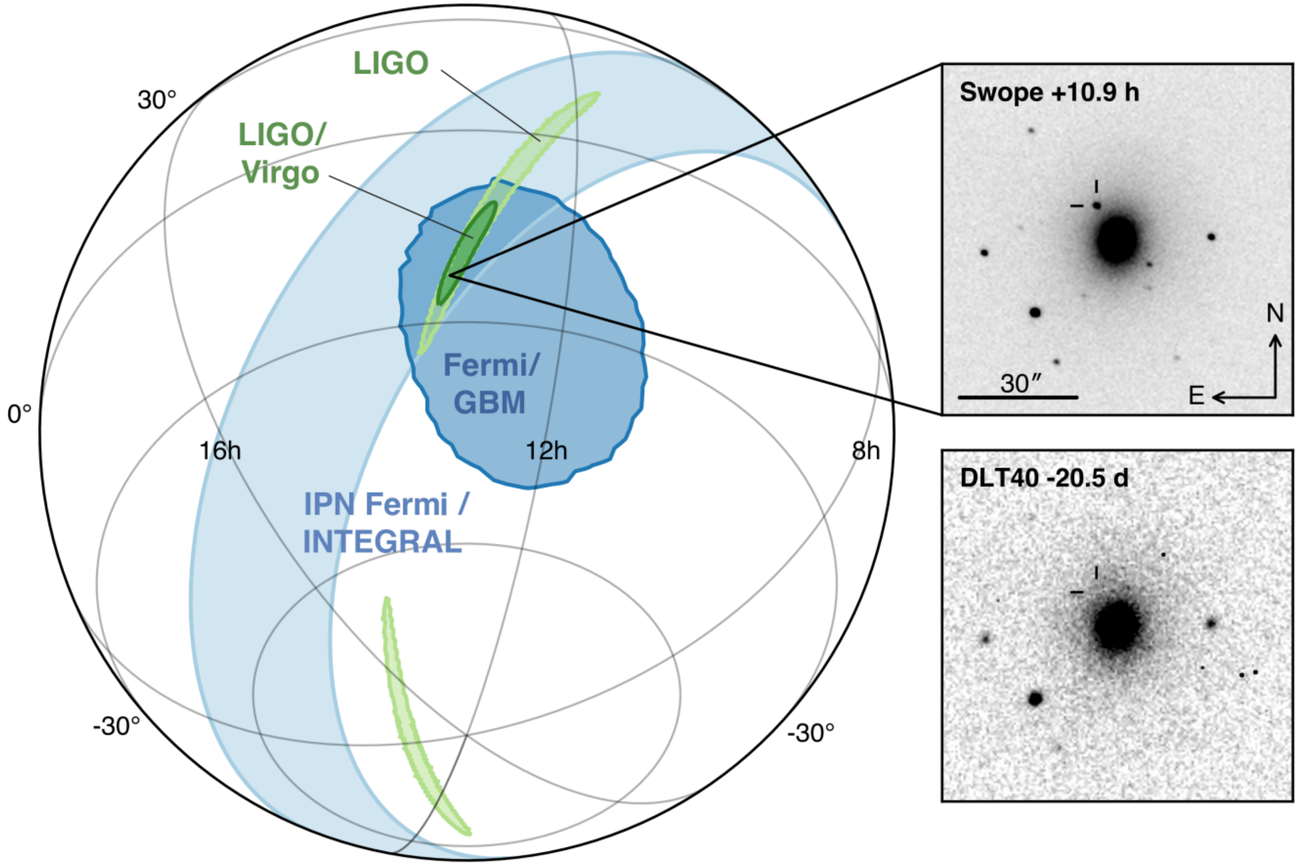
BNS merger & multi-messenger



BNS merger & multi-messenger

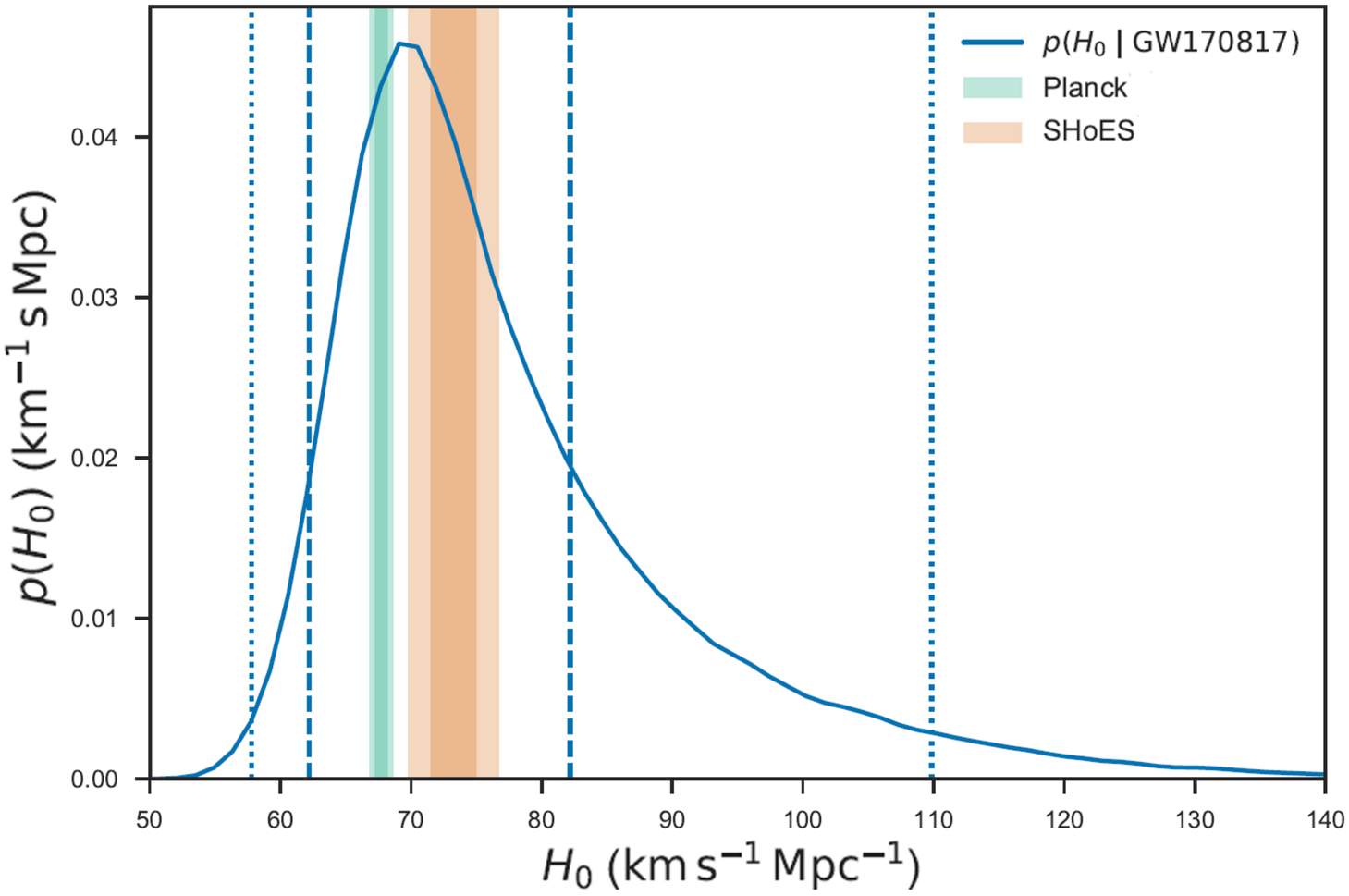


Abbott et al., Phys. Rev. Lett. 119, 161101 (2017)



Abbott et al., Astrophys. J. Lett. 848, L12 (2017)

The standard sirens of the Hubble constant

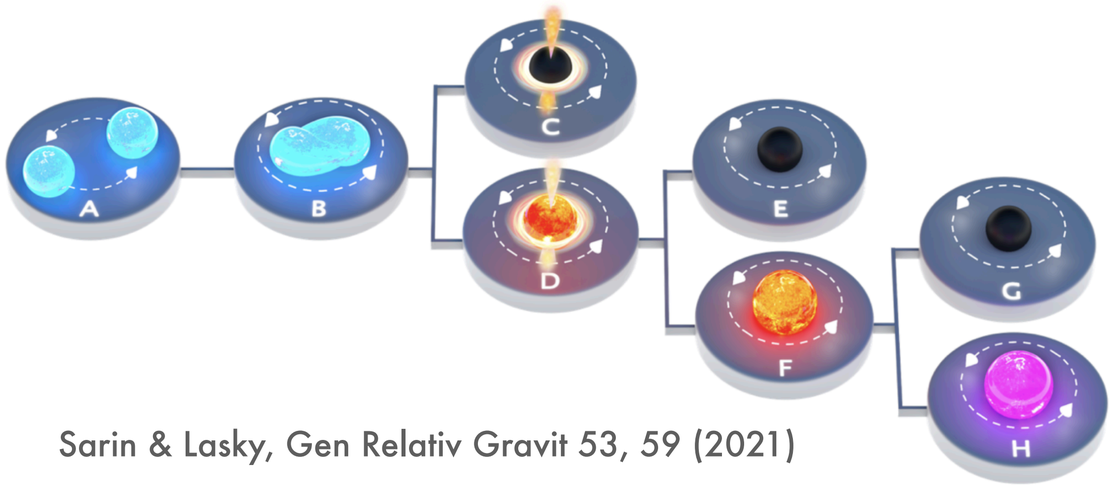


O(100) BNS standard sirens would provide a 1% determination of H_0.

Chen et al., Nature 562, 545–547 (2018)

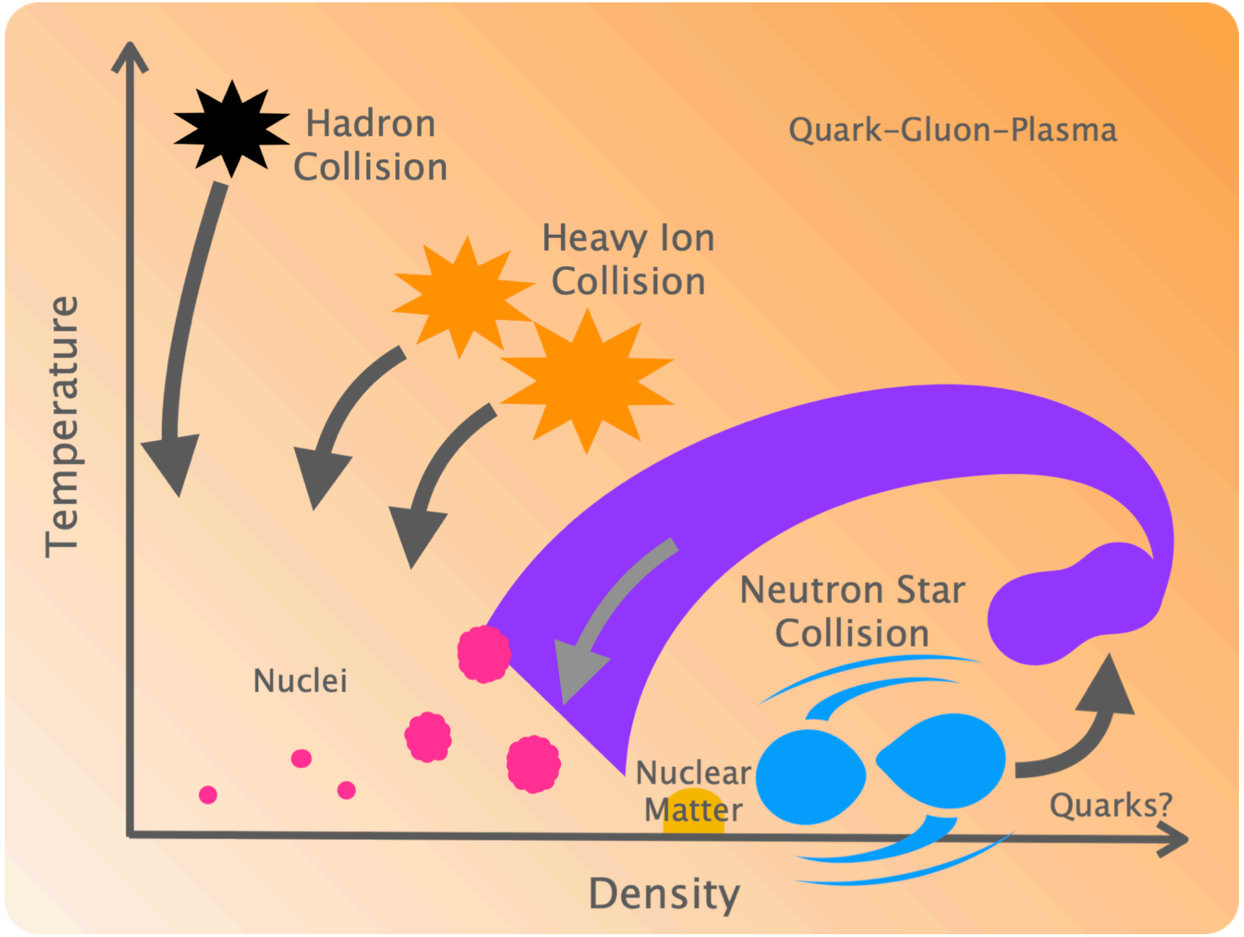
- *Luminosity distance measured from GW data*
- *Radial velocity of the galaxy measured from EM data*

BNS post-merger physics



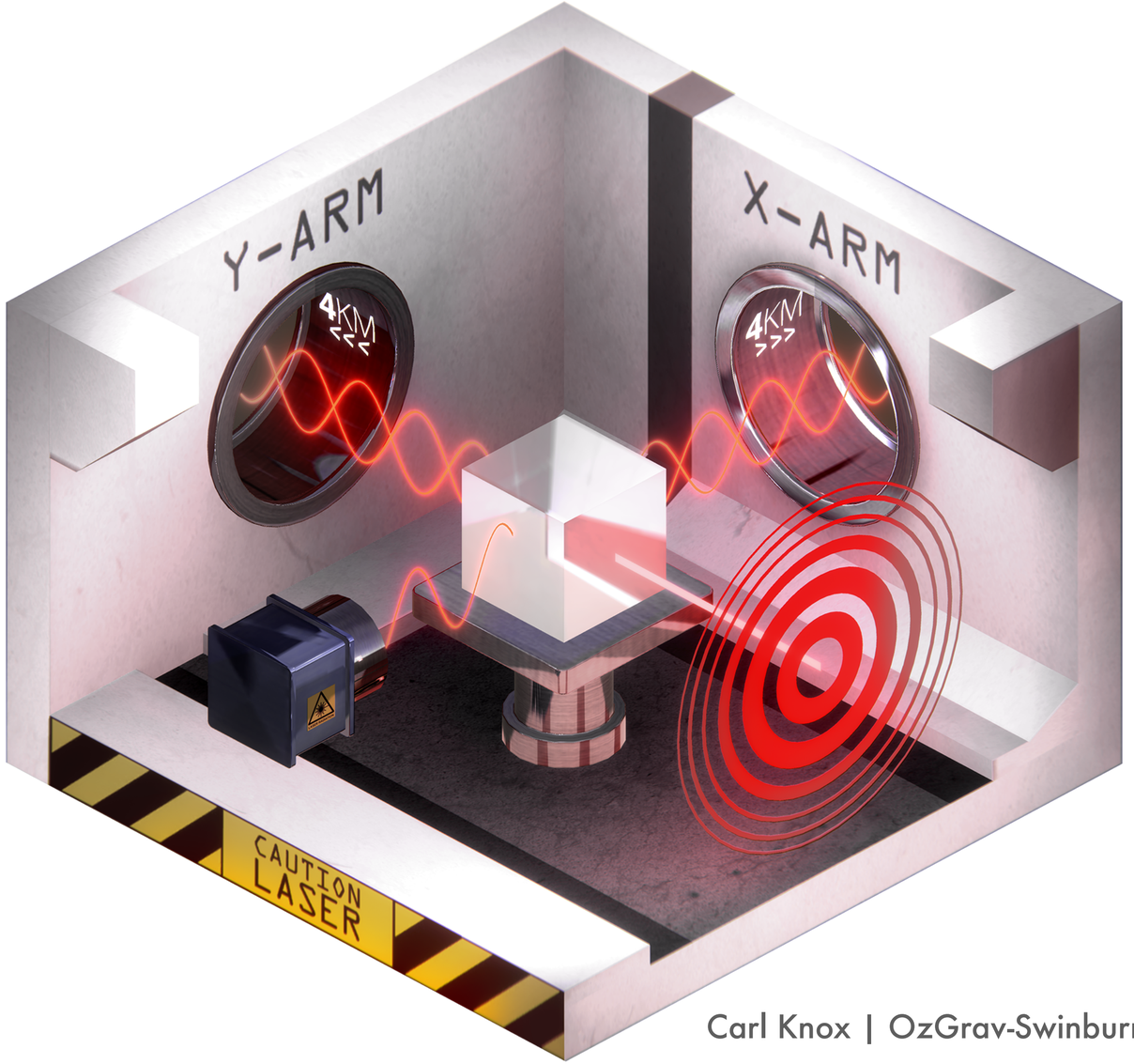
Sarin & Lasky, Gen Relativ Gravit 53, 59 (2021)

- *Final product of BNS merger*
- *Phase transition*
- *Nuclear equation of state*



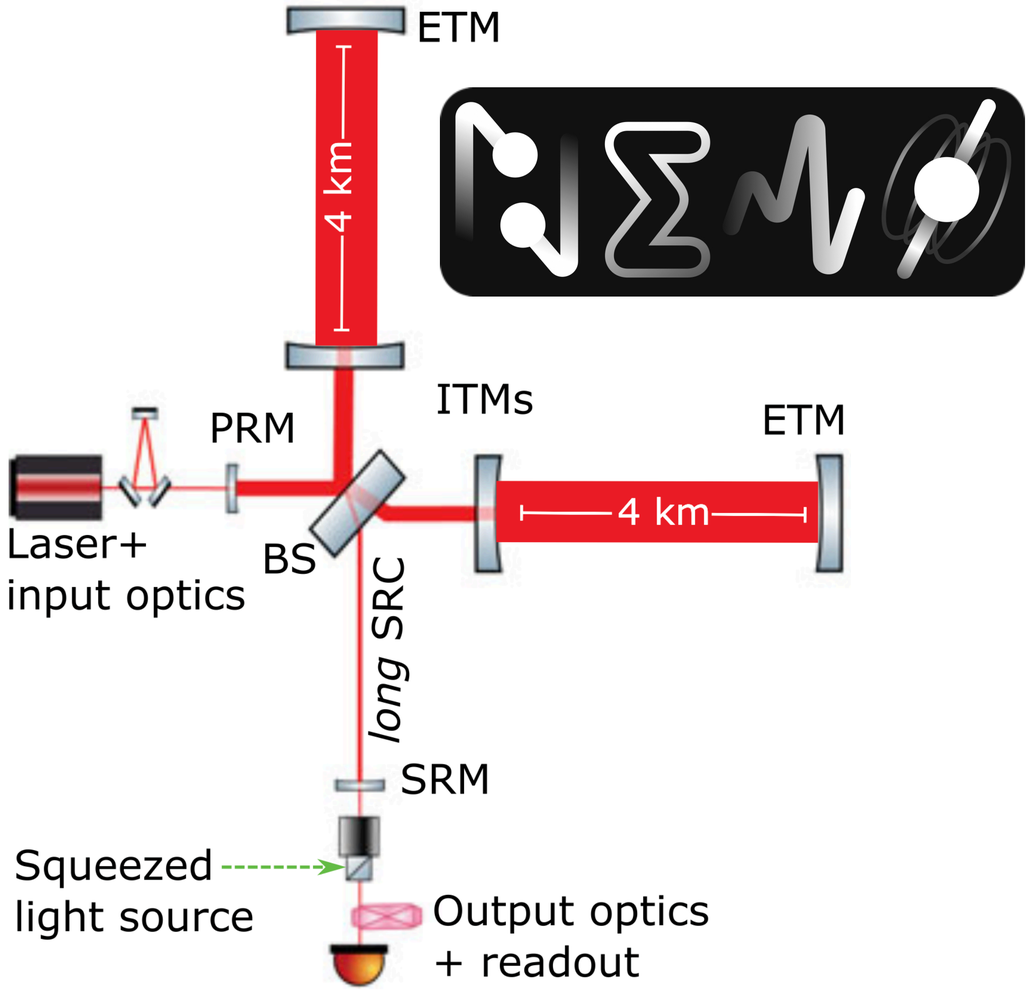
Evans et al., arXiv:2109.09882 (2021)

Future ground-based detectors and global network

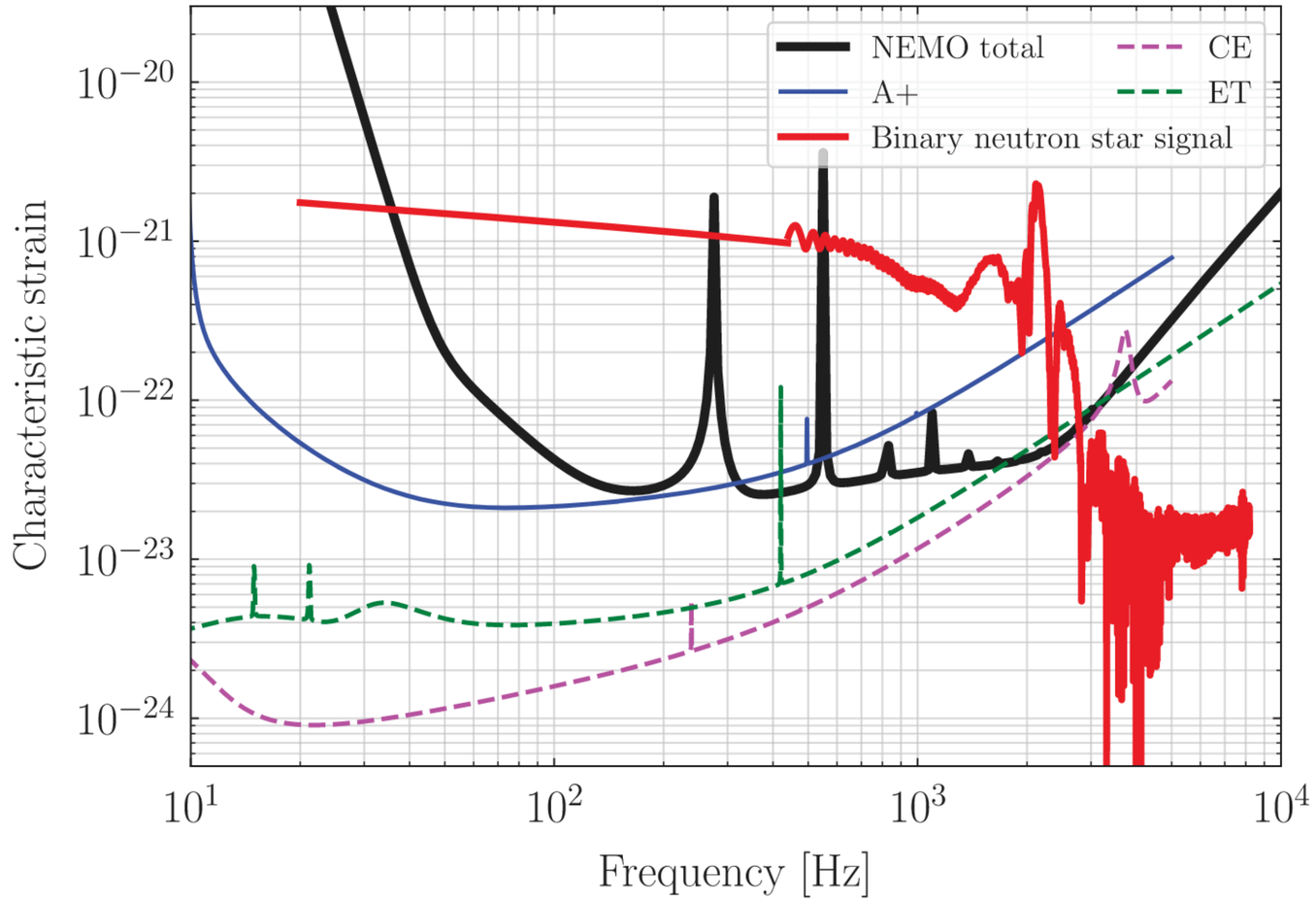


Carl Knox | OzGrav-Swinburne

Neutron Star Extreme Matter Observatory (NEMO)

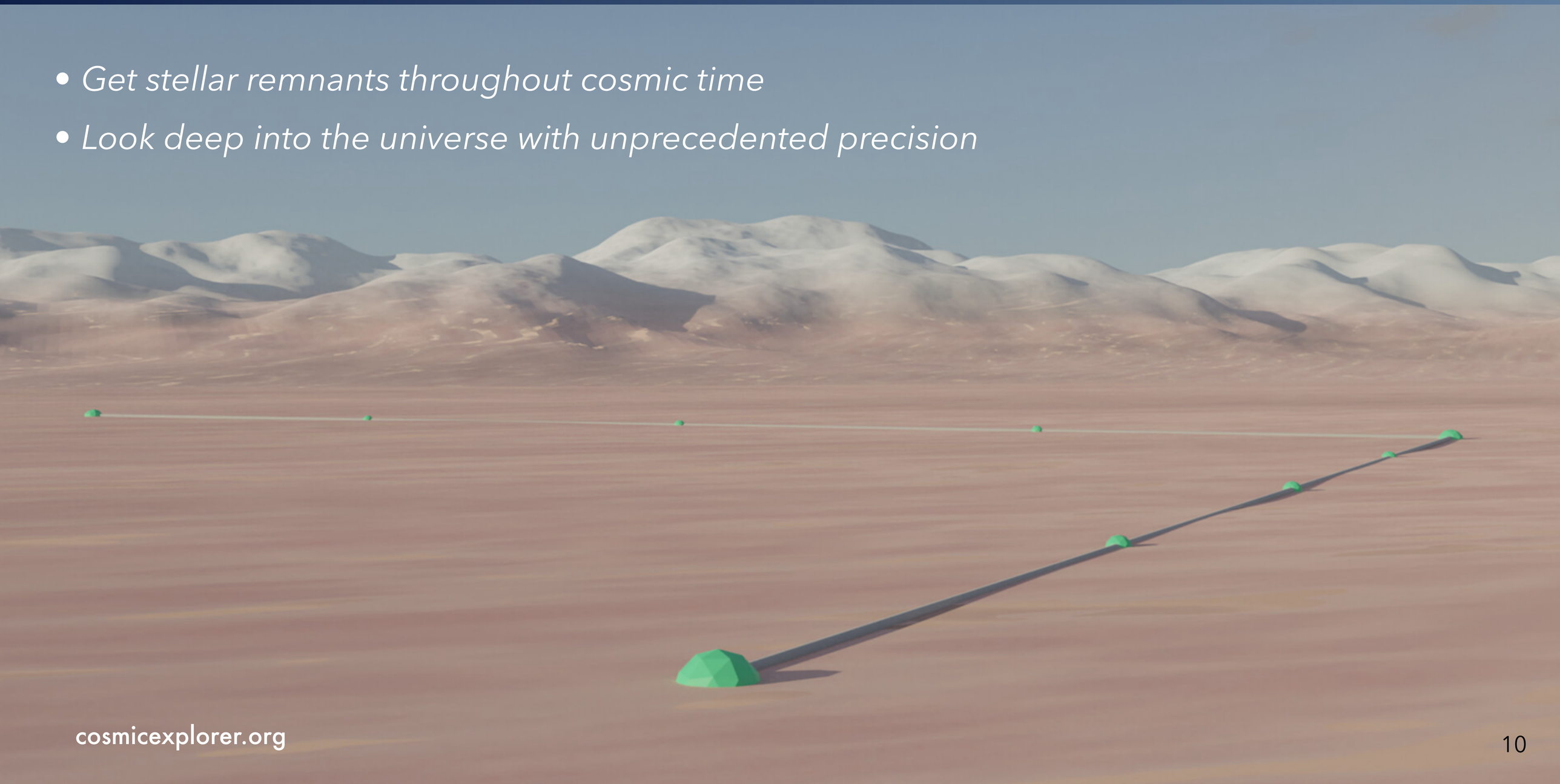


Ackley et al., doi:10.1017/pasa.2020.39 (2020)



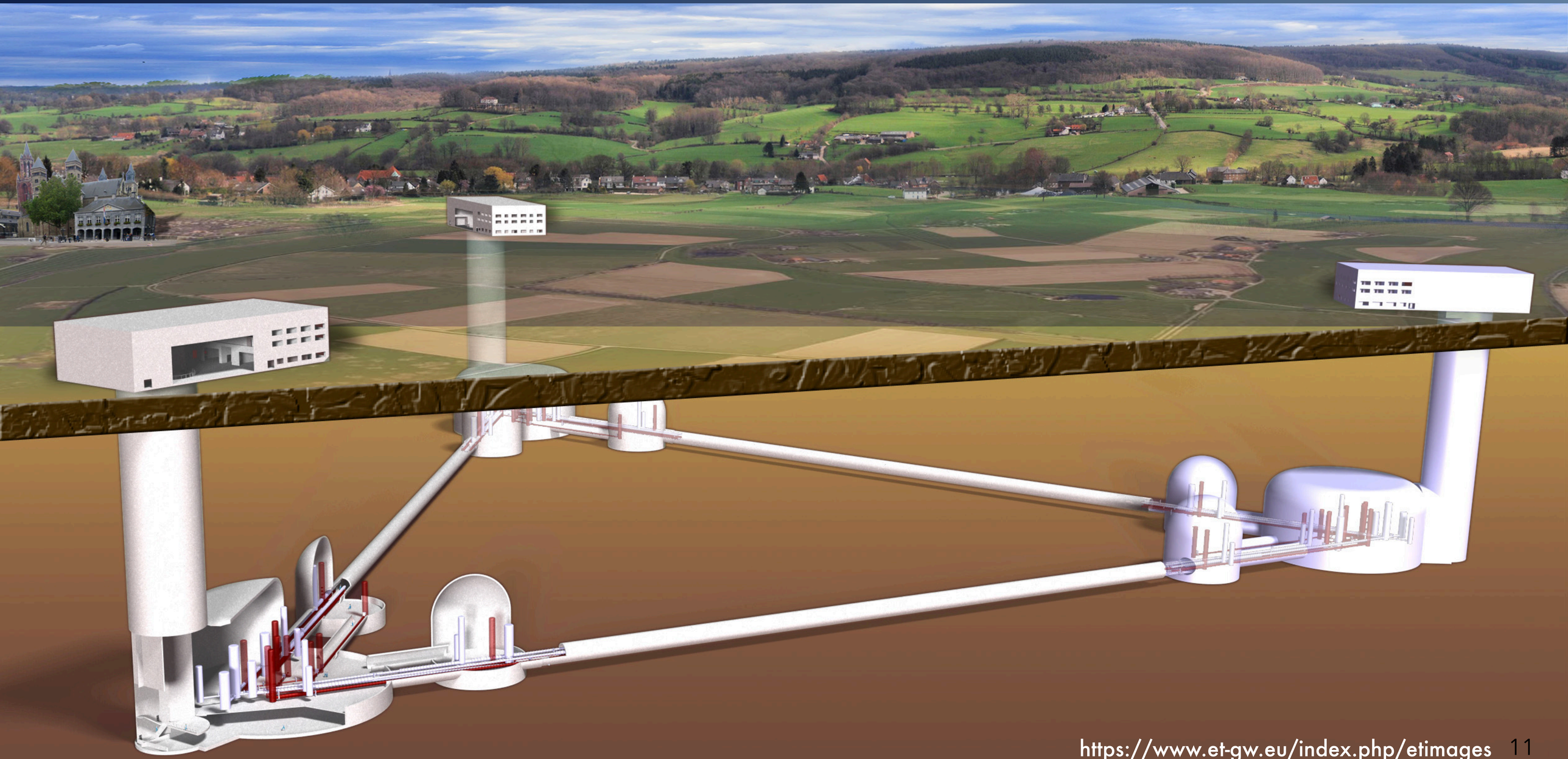
Cosmic Explorer (CE)

- *Get stellar remnants throughout cosmic time*
- *Look deep into the universe with unprecedented precision*



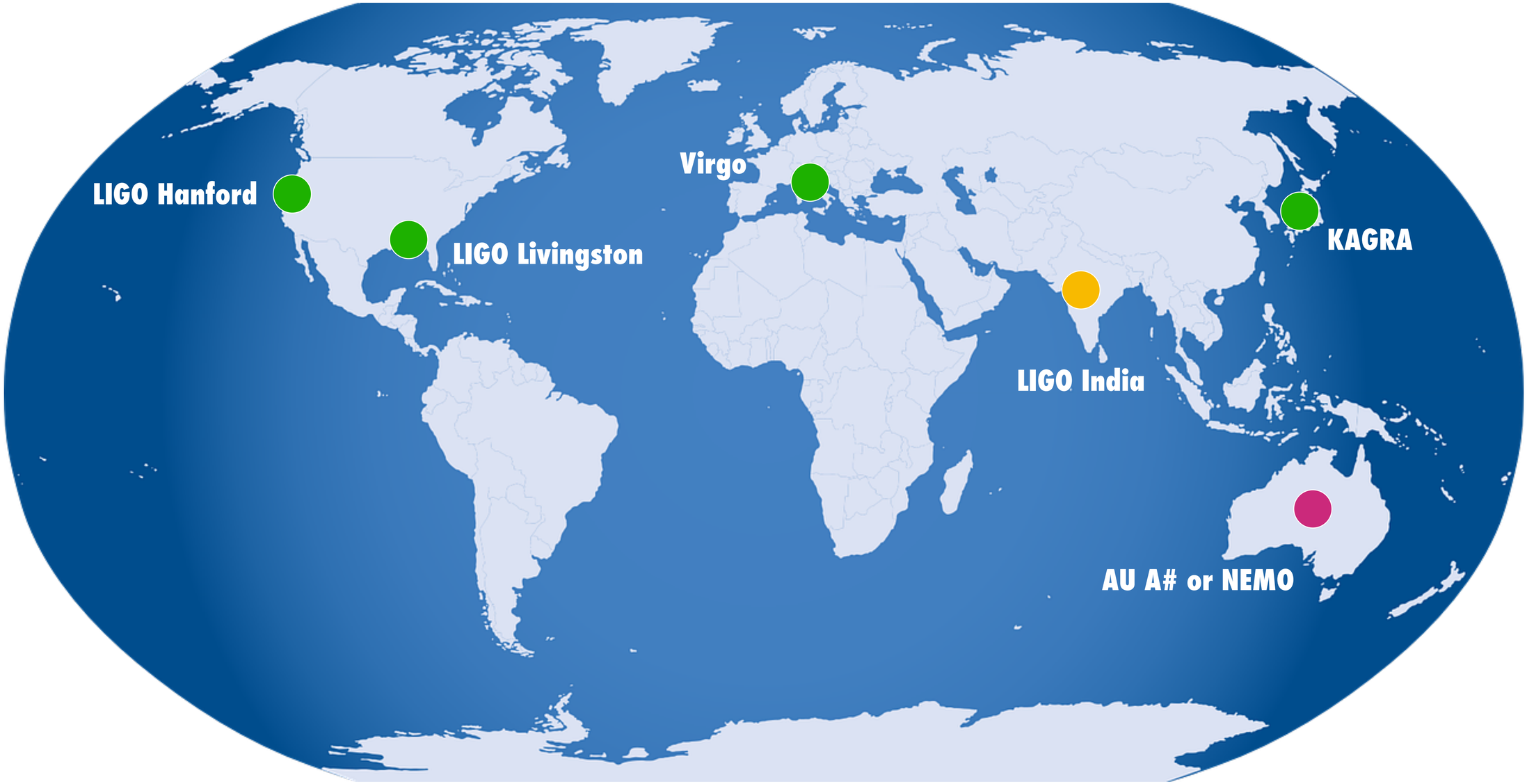
cosmicexplorer.org

Einstein Telescope (ET)

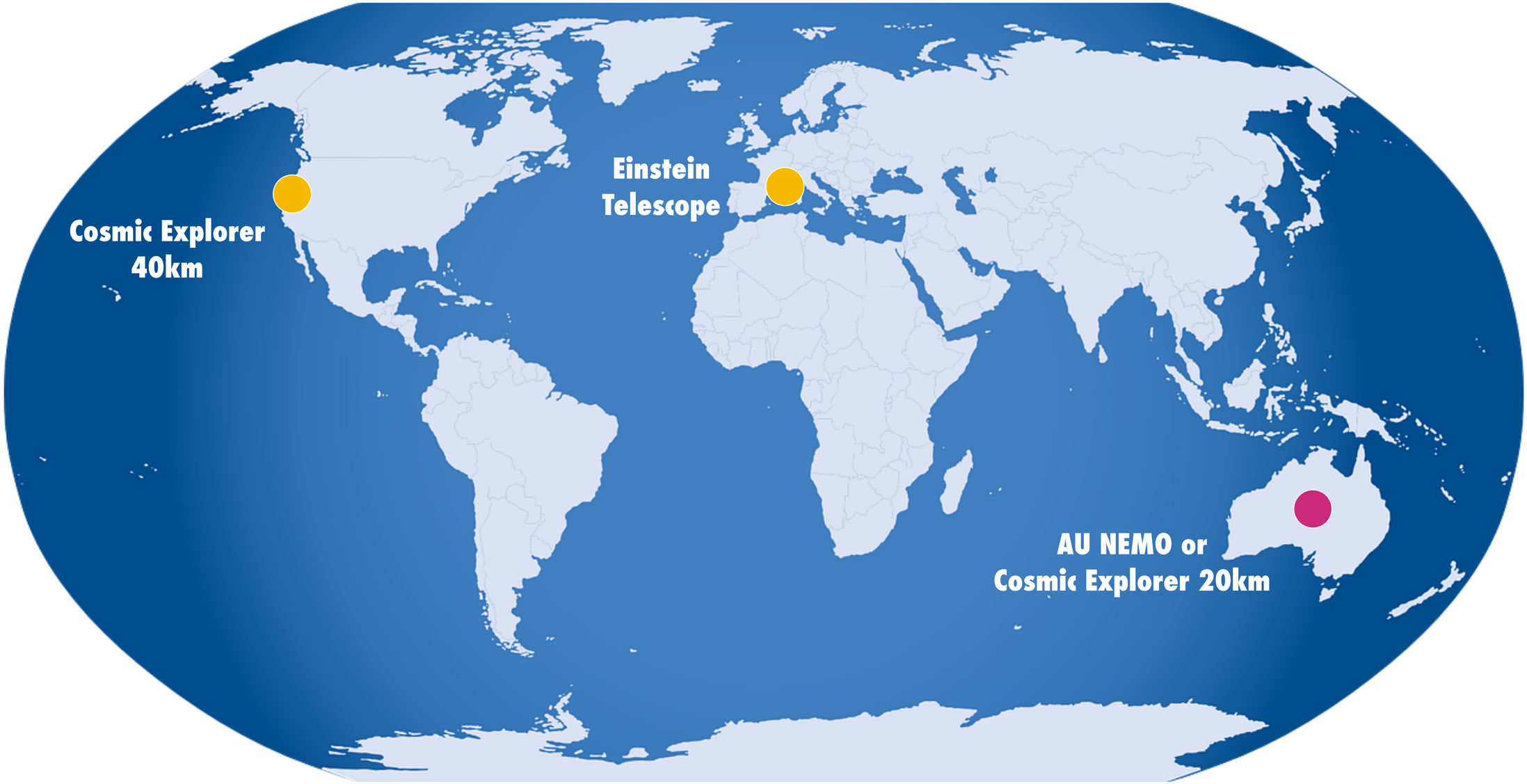


https://www.et-gw.eu/index.php/etimages

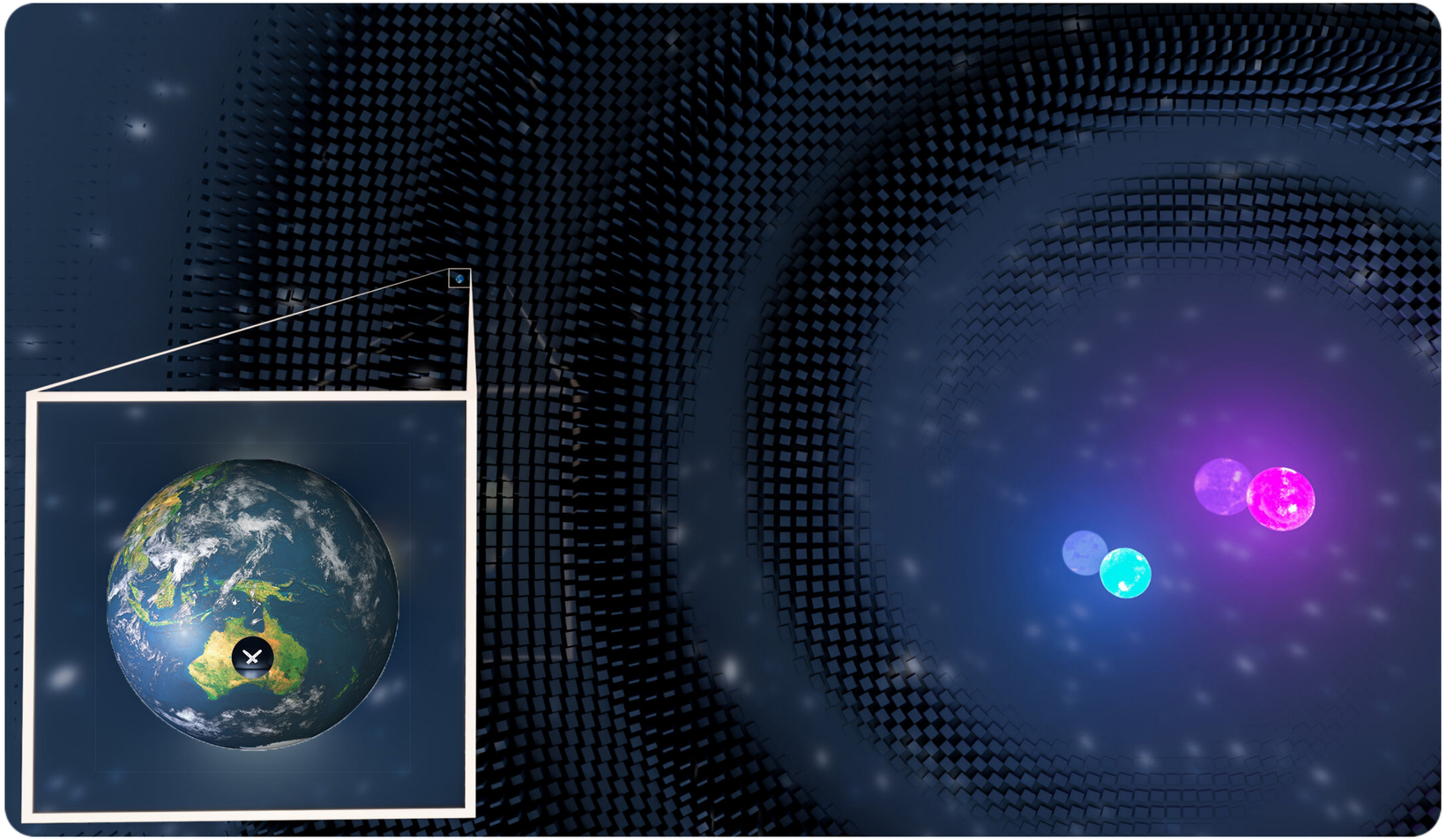
Current generation global network



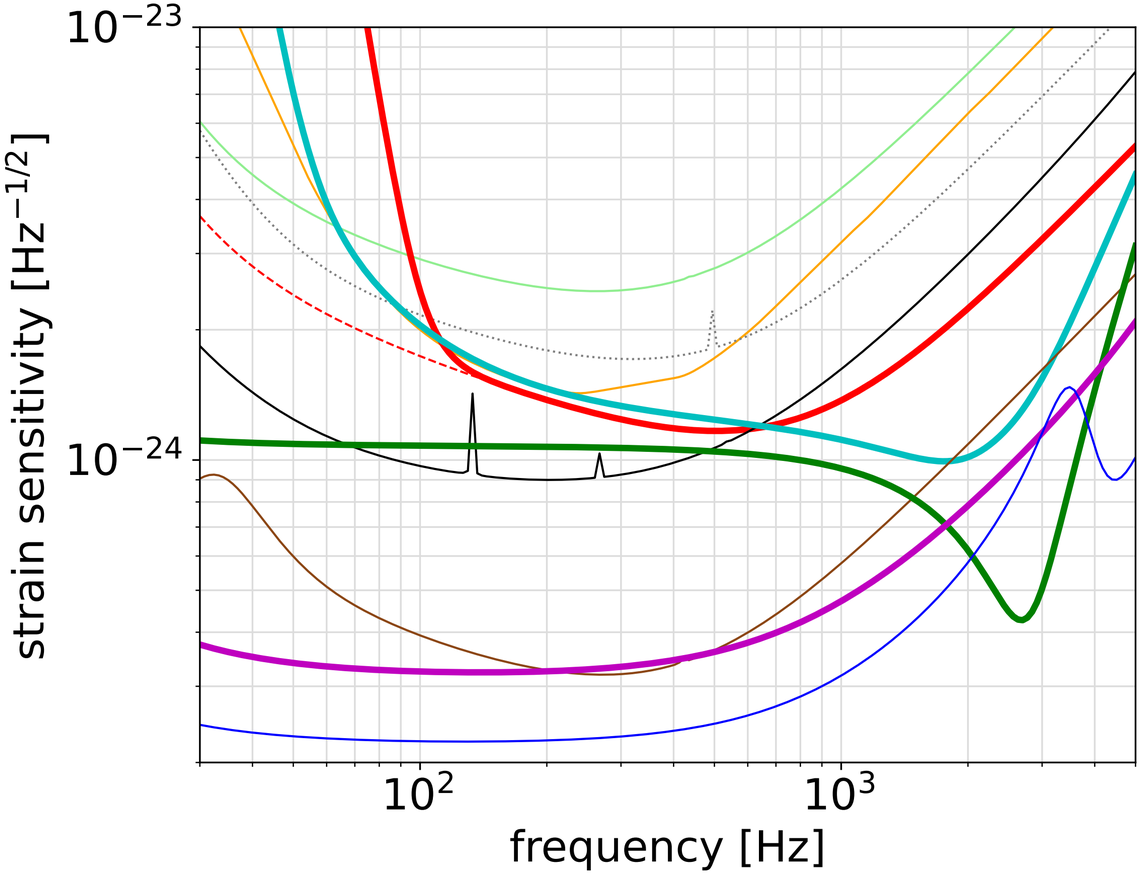
Next generation global network



What will an Australian detector bring us?



Network scenarios



- Virgo+
- KAGRA+
- LIGO O5 (A+) reference
- LIGO post-O5 (A#)
- A# with 100 Hz f^{-6} rolloff
- Voyager
- NEMO
- ET
- CE-20km-PMO
- CE-20km-CBO
- CE-40km-CBO

Three scenarios:

	Global env	AU detector
Late 2020s (2G)	LIGO post O5 (A#)	**A# with low-freq rolloff**
2030s (2.5G)	Voyager	**A# with low-freq rolloff** or **NEMO**
2040s (3G)	CE-40km & ET	**NEMO** or **CE-20km-PMO** or **CE-20km-CBO**

PMO — Post-Merger Optimized
CBO — Compact Binary Optimized

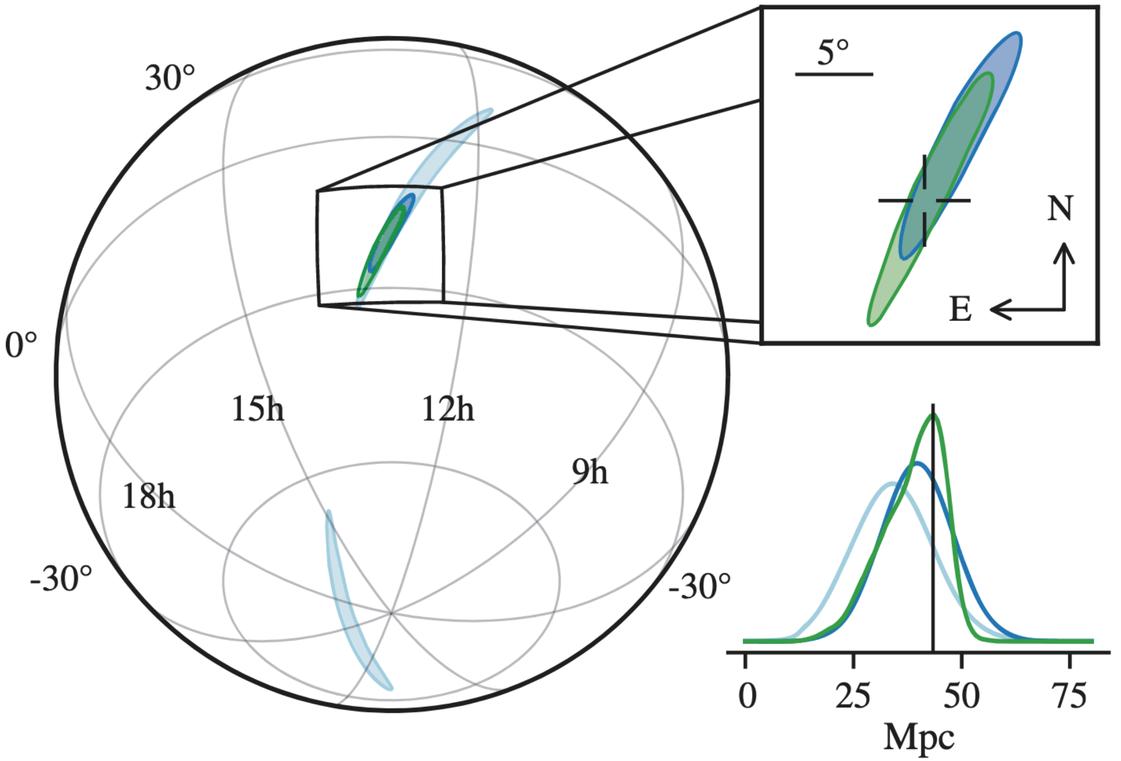
Metric

Number of BNS events per year with:

- *Signal-to-noise ratio* ***> 10***
- *Luminosity distance* ***< 500 Mpc***
- *90%-credible sky area* ***< 10 deg²***

Detectable, close enough (reachable by the telescopes), and well-localised

Abbott et al., Phys. Rev. Lett. 119, 161101 (2017)



GW170817

- ***Light blue:*** *low-latency HL, 190 deg²*
- ***Dark blue:*** *low-latency HLV, 31 deg²*
- ***Green:*** *high-latency HLV,* ***28*** *deg²*

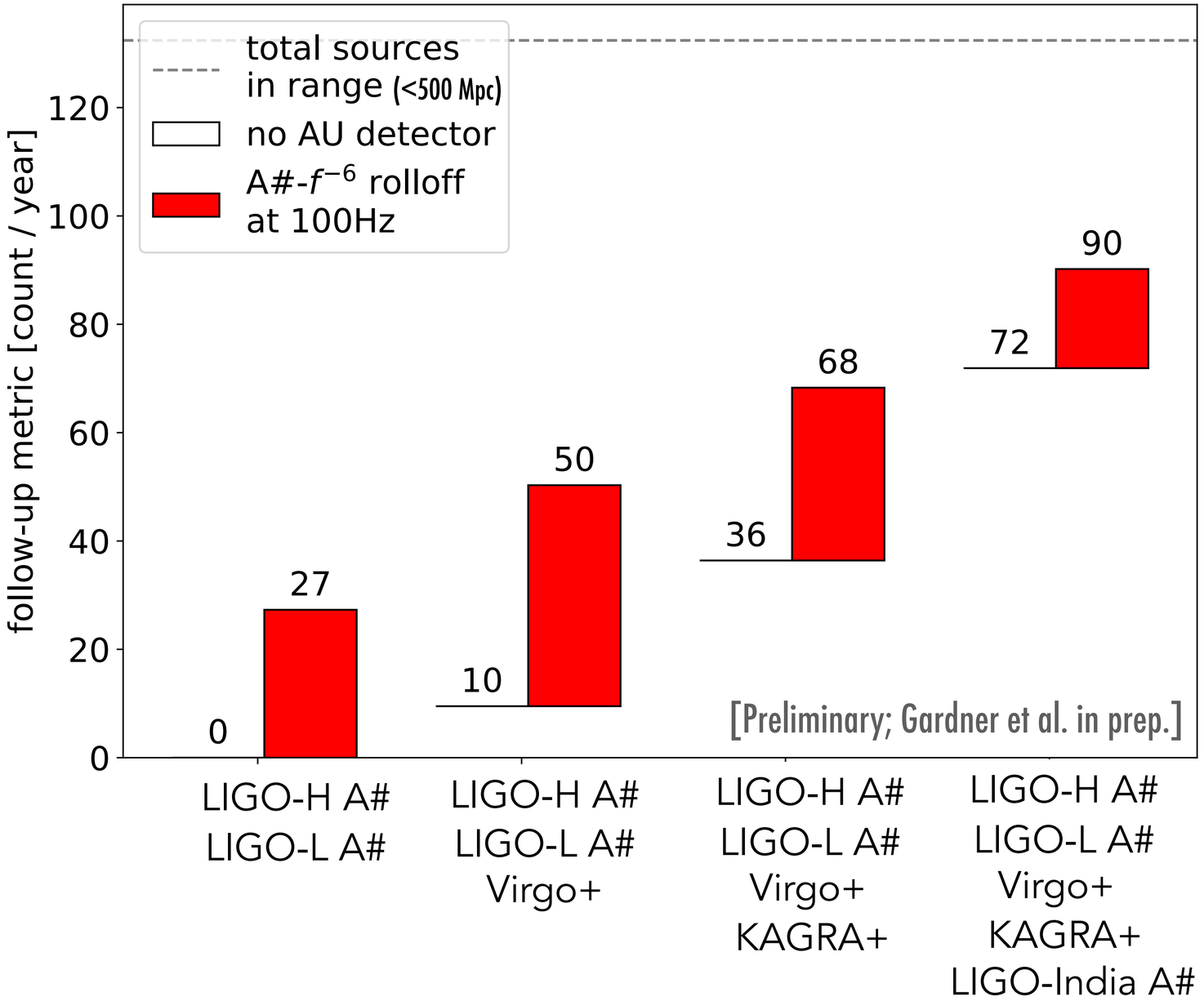
Scenario 1: Australian A# in 2G

- *Although an Australian 2G detector does not largely improve detection rate, it significantly contributes to sky localisation*

2G – late 2020s:

A# with low-freq rolloff

[Global env: LIGO post-O5 (A#)]



****Assuming GWTC-2 BNS merger rate**

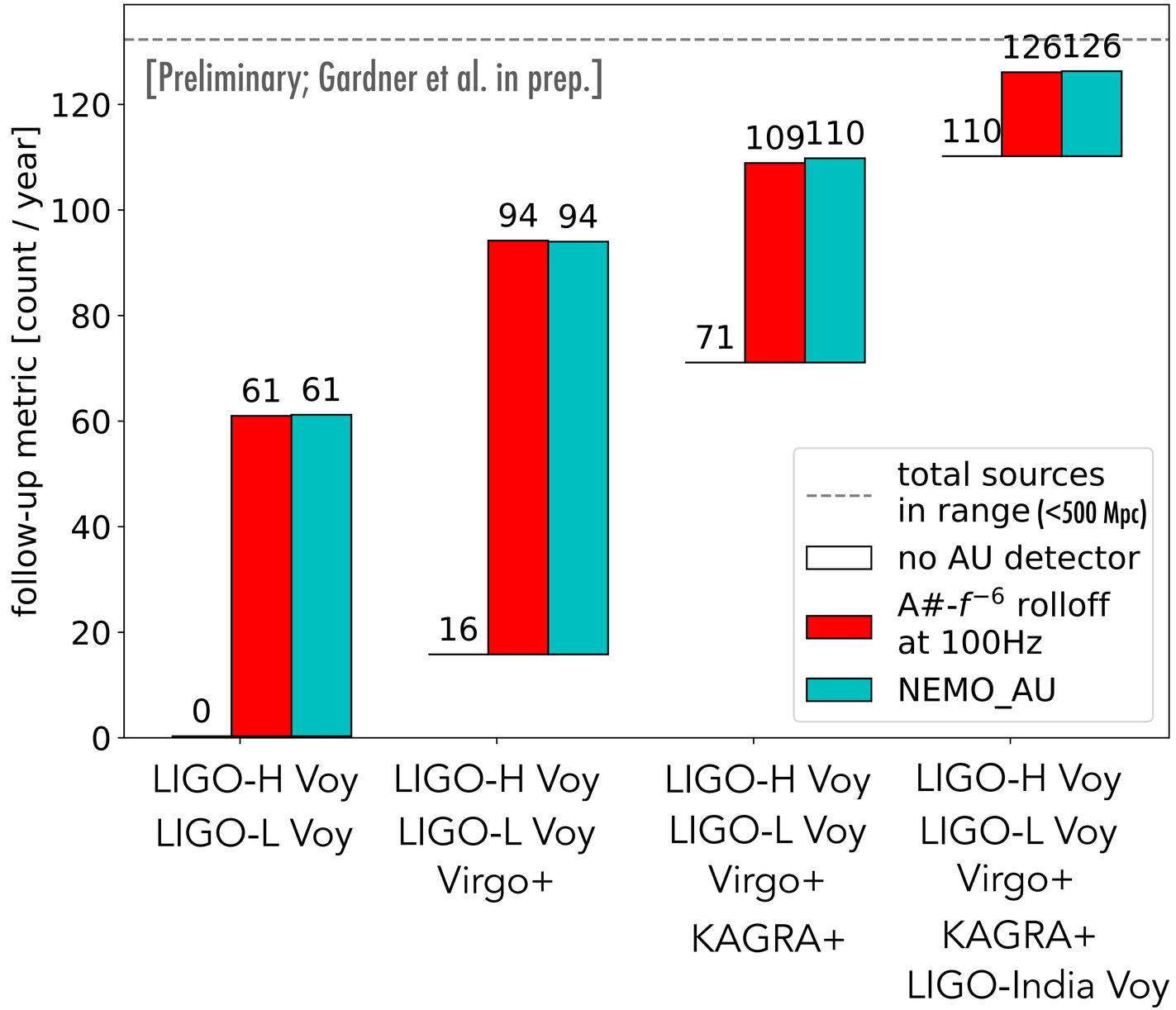
Scenario 2: Australian NEMO in 2.5G

- ***A#*** *and* ***NEMO*** *are similarly relevant in 2.5G*
- *Largely improves the metric*
- *Benefits are more significant if less 2.5G detectors are available in the network*
- *Capped by the total number of events*
- ***NEMO*** *also enables post-merger study before 3G era*

2.5G – 2030s:

A# with low-freq rolloff or NEMO

[Global env: Voyager]



****Assuming GWTC-2 BNS merger rate**

Scenario 3: Australian NEMO/CE-20km in 3G

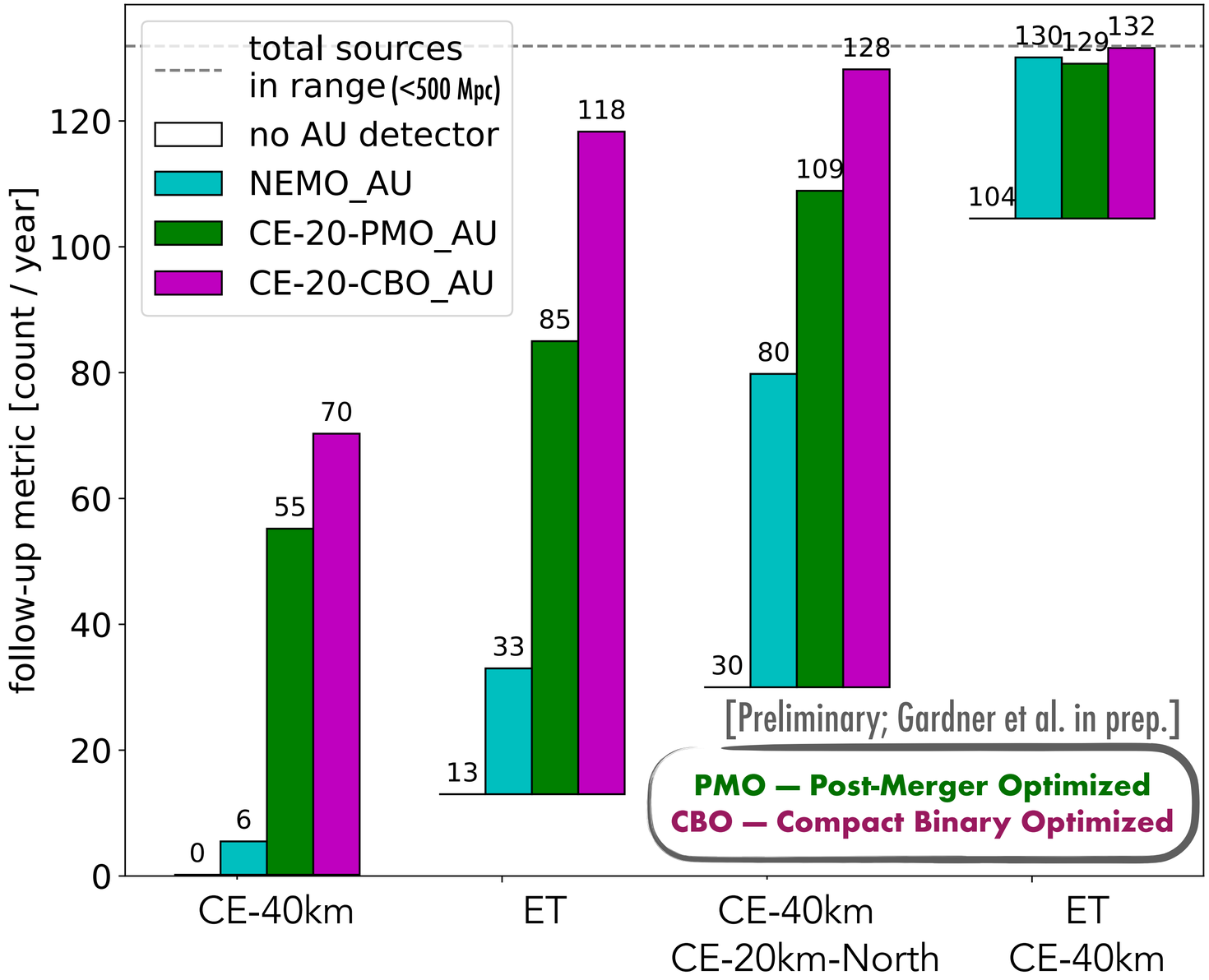
- *All three configurations (NEMO and 2 CE-20km options) make significant contributions*
- *Again, capped by the total number of events*

3G – 2040s:

NEMO* or *CE-20km-PMO

or CE-20km-CBO

[Global env: CE and ET]



**Assuming GWTC-2 BNS merger rate

Summary

- *An Australian detector would significantly contribute to the sky localisations*
- *Large number of multi-messenger events*
- *Cosmology –– leads to the determination of Hubble constant*
- *Dynamics of dense matter –– jets, kilonovae, nuclear matter equation of state, etc.*
- *We are developing the science case, the required technology, the instrument design, and an international partnership for a future-generation detector on Australian soil.*

Thanks!

Questions?