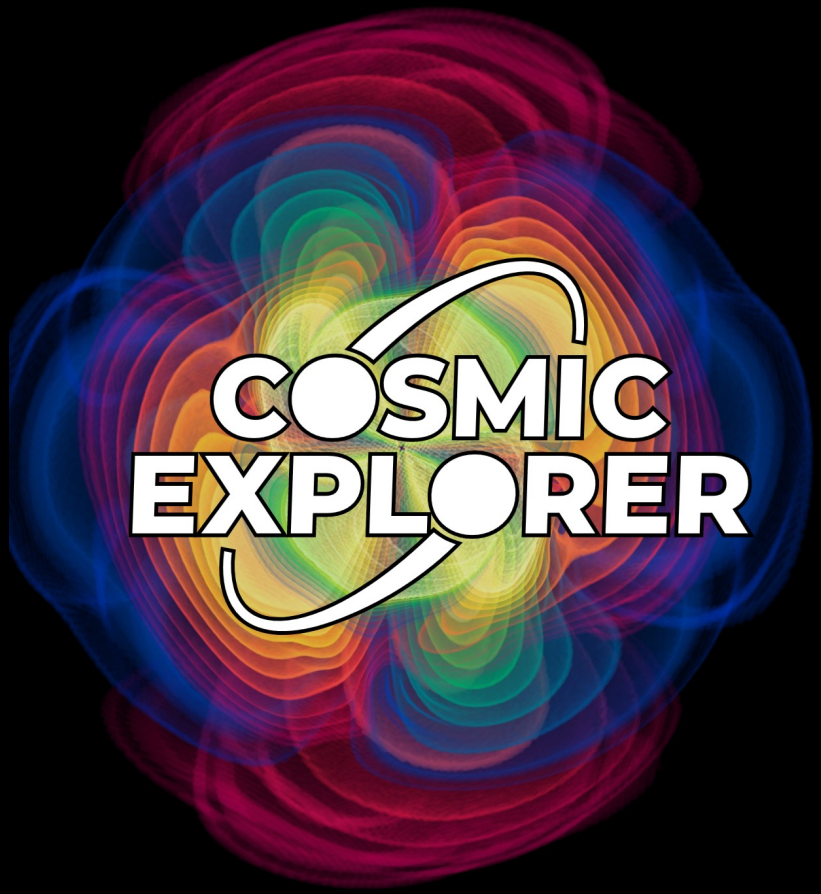


Pushing the GW frontier across astronomy, physics, and cosmology

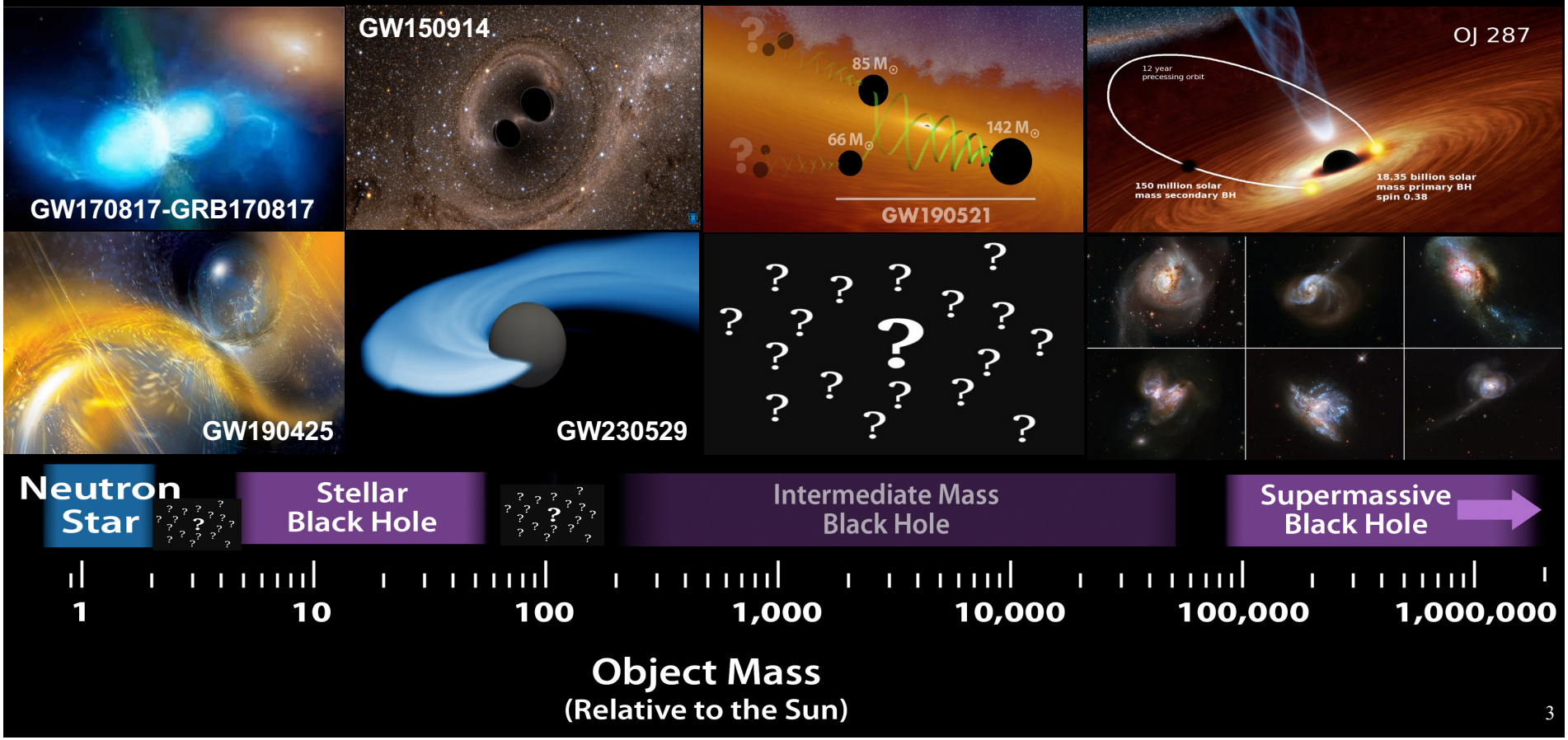
Alessandra Corsi(*)
Texas Tech University
(Johns Hopkins University)

(*) On behalf of the CE project

2024 April APS meeting
S10: Next Generation Gravitational Wave Detector Concept

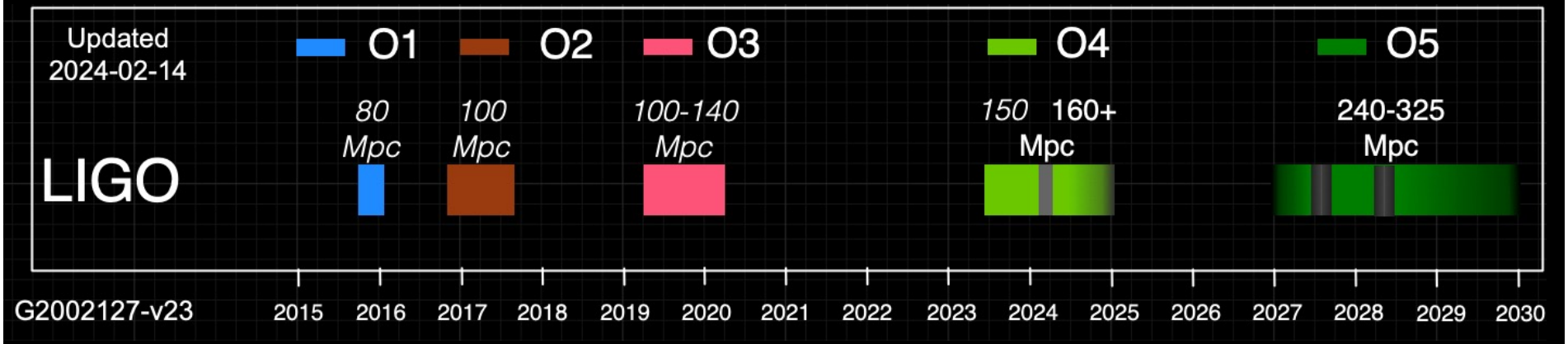
Current network of ground-based GW detectors

The mass spectrum of compact objects



LIGO: Observing scenario and post-O5 era

LVK 2018, LRR, 21, 3



Post-O5 Study → LIGO A# (LIGO-T2200287)

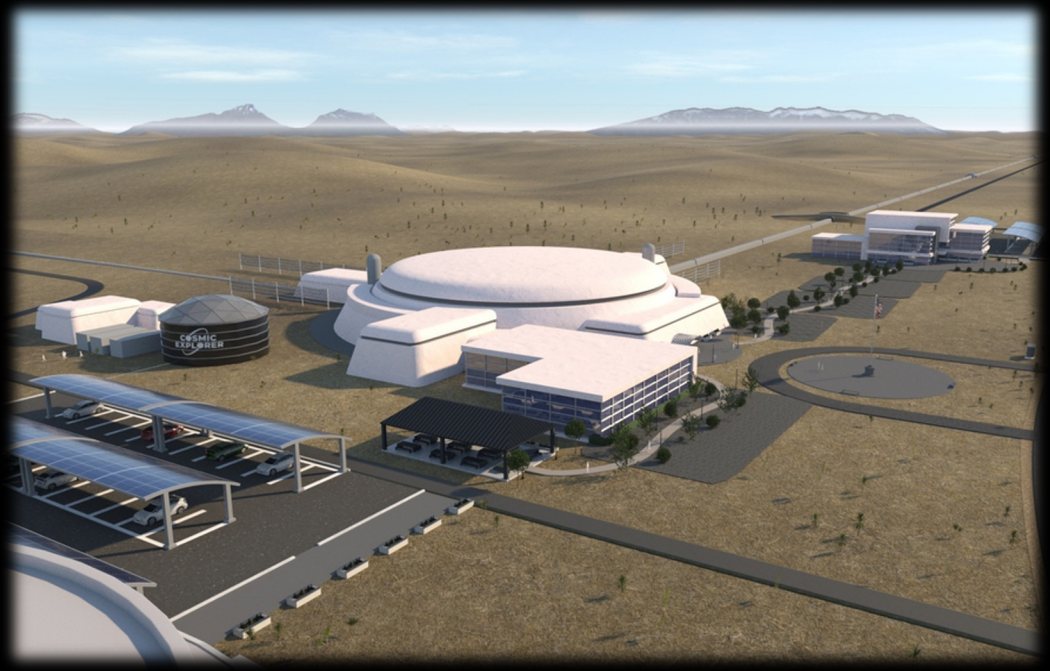
It envisions the following improvements on A+:

- 100 kg test masses;
- Higher stress (2x) test mass suspension fibers;
- Arm cavity power increased to 1.5 MW;
- Squeezing efficiency increased to 10 dB at high frequencies.
- Factor of ~2 reduction in coating thermal noise beyond A+

LIGO India (https://www.ligo-india.in/):

- Envisioned to start as an A+ detector (this is the current plan)
- Would be capable of A# hardware

Cosmic Explorer (CE): A next generation GW detector



- **Strongly endorsed** by the NSF MPSAC ngGW sub-comm (Kalogera's talk).
- Envisioned to be built with **LIGO technology**, scaled up to **40 km**. This minimizes technical risks and builds on the great success of LIGO!
- **CE reference design**: two L-shaped sites, 20+40 km.

https://cosmicexplorer.org/

Other CE/3G talks this week:
Biscoveanu's talk (C10)
Ballmer's talk (D10)
Kalogera's talk (this session)
Schutz's talk (M10)

Cosmic Explorer: 10x better than LIGO A+

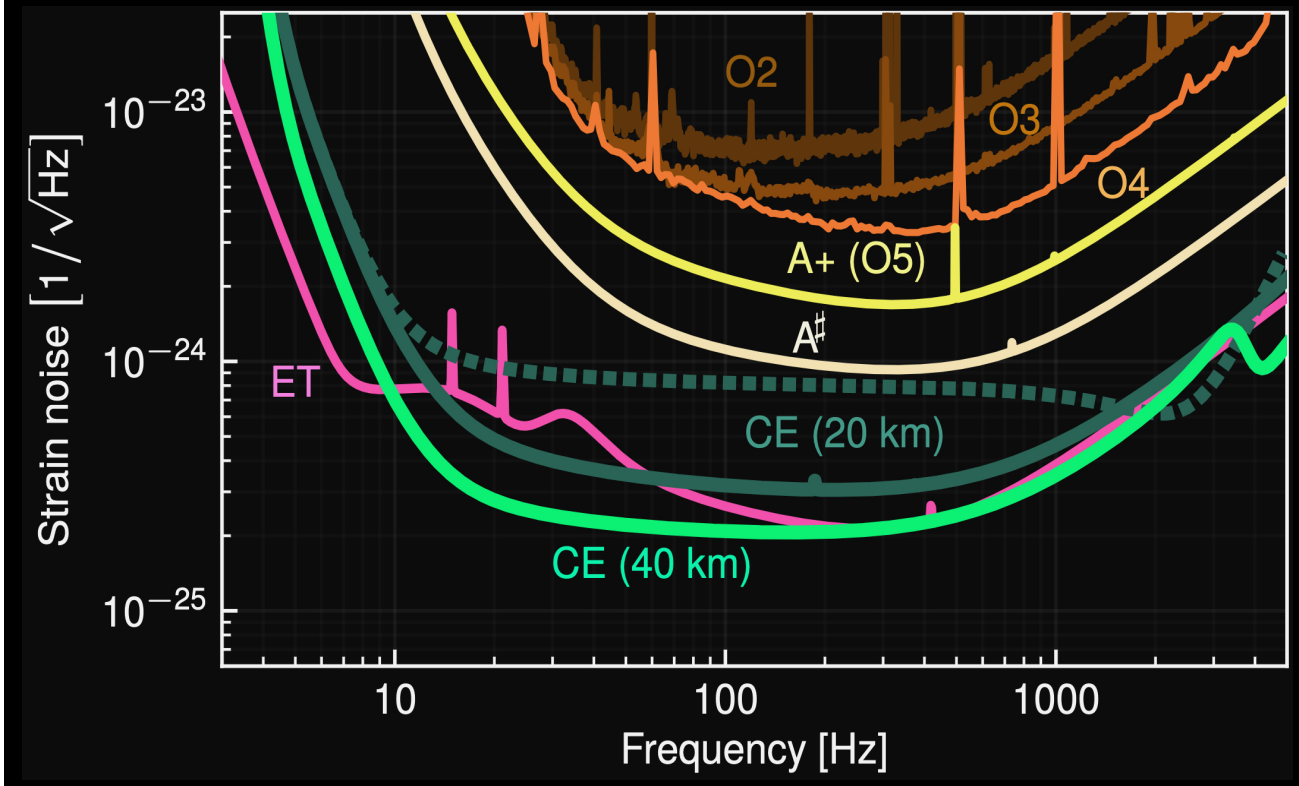


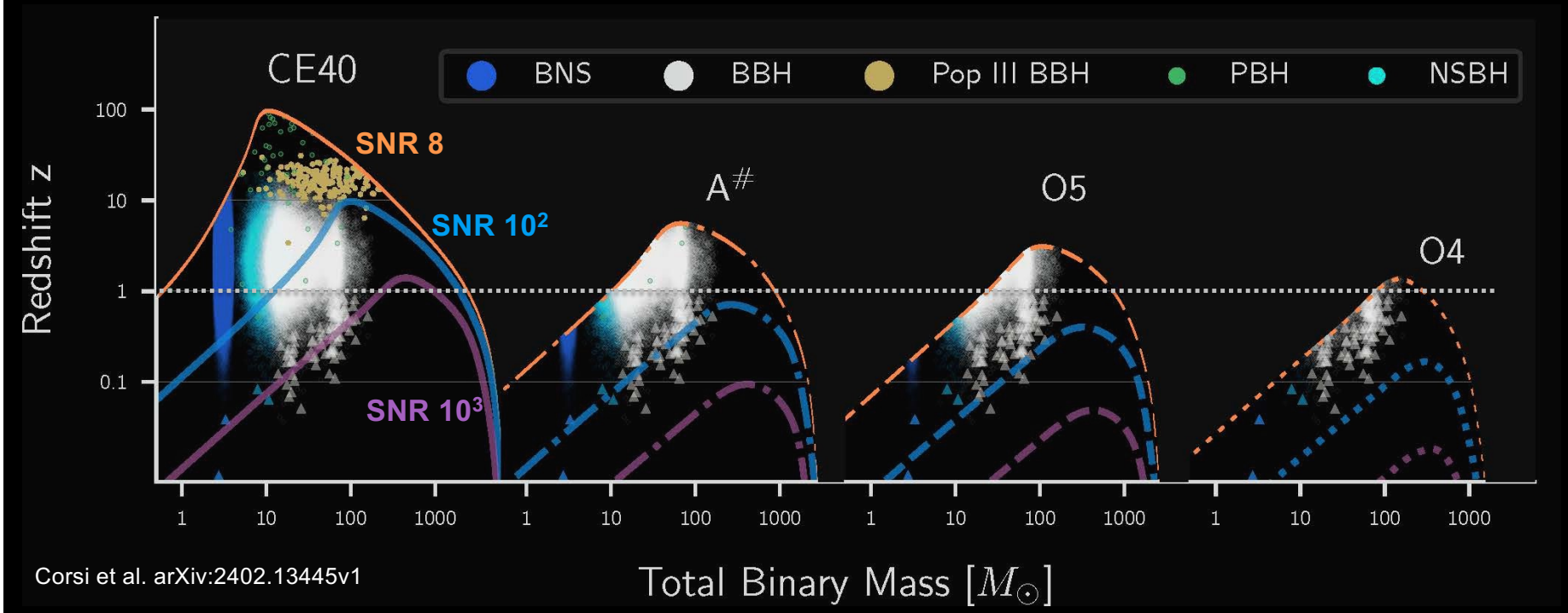
Figure credit: K. Kuns; Corsi et al. arXiv:2402.13445v1

CE White paper submitted to the NSF MPSAC ngGW panel: Evans, Corsi et al. eprint arXiv:2306.13745

Networks recommended by the NSF MPSAC ngGW panel (unranked):

- CE40, ET, LIGO-India
- CE40, ET
- CE40, CE20, LIGO-India
- CE40, CE20

GW discoveries that CE40 would enable



Corsi et al. arXiv:2402.13445v1

- Push the cosmic horizon to the boundary of BNS, BBH, NSBH populations
- Enable observations of new populations (Population III BHs; primordial BHs)
- SNR>100 signals enable precision measurements of NS radii and tests of GR

The impact of a ngGW detector network

ngGW Key Science Goals

Black Holes and Neutron Stars Throughout Cosmic Time

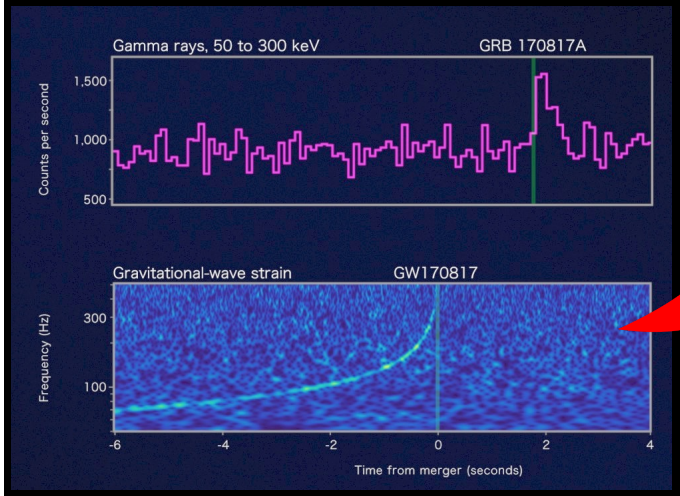
CE20+40 design essential because…

With only one ngGW detector, a BBH at z=10 would have a redshift uncertainty of +/-4 and due to the mass–redshift degeneracy a 40% uncertainty in the mass measurement → Detailed study of the high-z BBH population needs two ngGW detectors

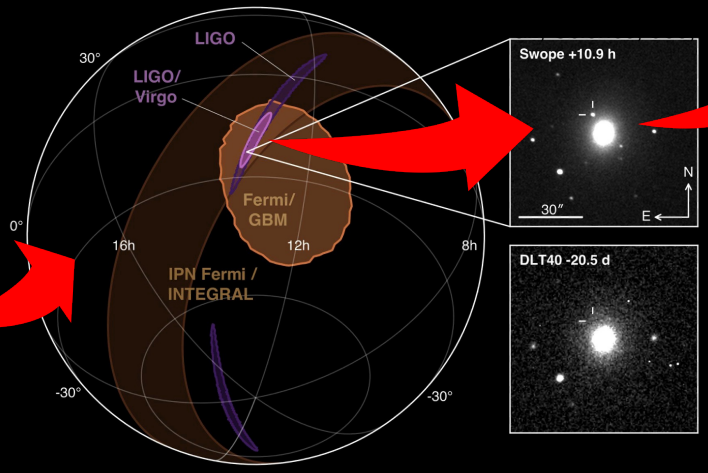
The impact of a ngGW detector network

ngGW Key Science Goals	CE20+40 design essential because…
Black Holes and Neutron Stars Throughout Cosmic Time	With only one ngGW detector, a BBH at z=10 would have a redshift uncertainty of +/-4 and due to the mass–redshift degeneracy a 40% uncertainty in the mass measurement → Detailed study of the high-z BBH population needs two ngGW detectors
Multi-Messenger Astrophysics and Dynamics of Dense Matter	Two ngGW detectors needed for <= 1 deg^2 up to z~0.2-0.3 and <= 10 deg^2 up to z~1 → Enabling MMA probes of BNS progenitor-ejecta-remnant diversity and of GRBs

Beyond GW discovery: Enabling MMA

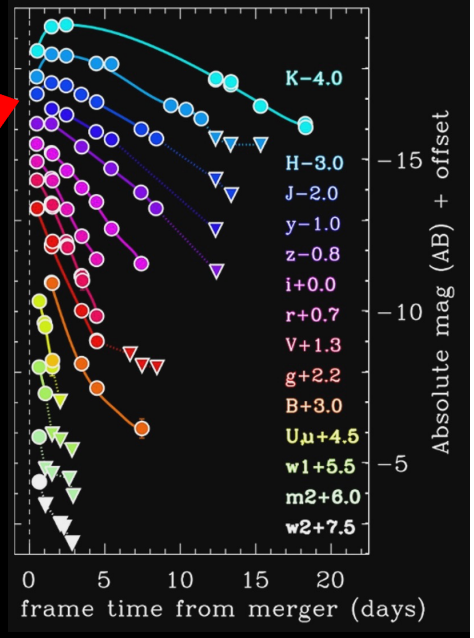


LIGO/Virgo; Fermi; NASA/DOE; NSF; EGO.

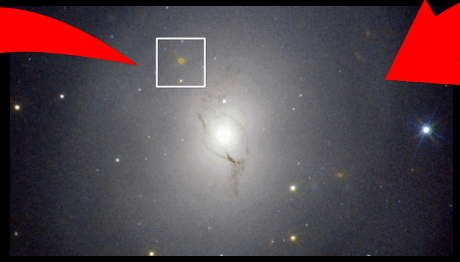


Abbott et al. 2017, ApJL, 848 L12

Valenti et al., ApJL, 848, L24,



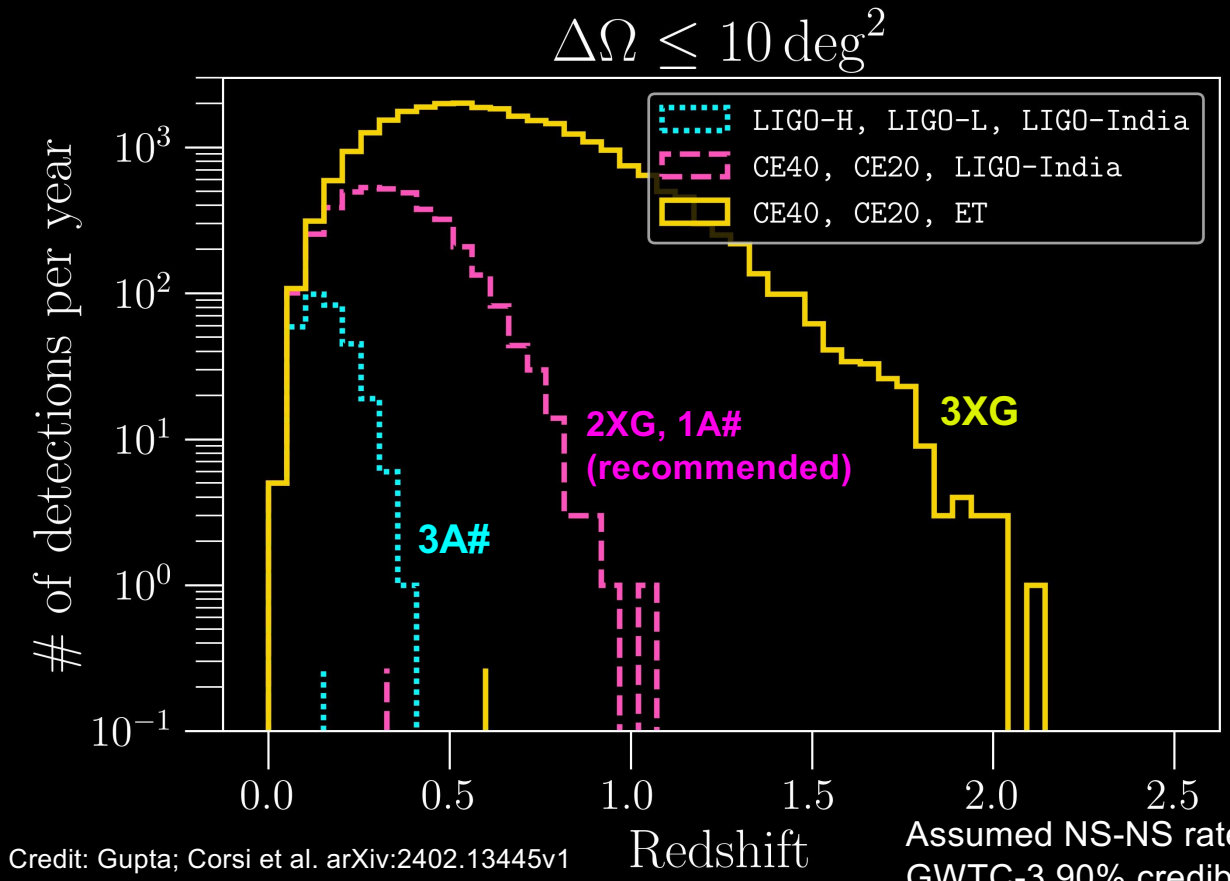
Drout et al. 2017, Science, 358, 1570



Troja et al. 2017, Nature, 551, 71;
See also Margutti et al. 2017, ApJL, 848, L2

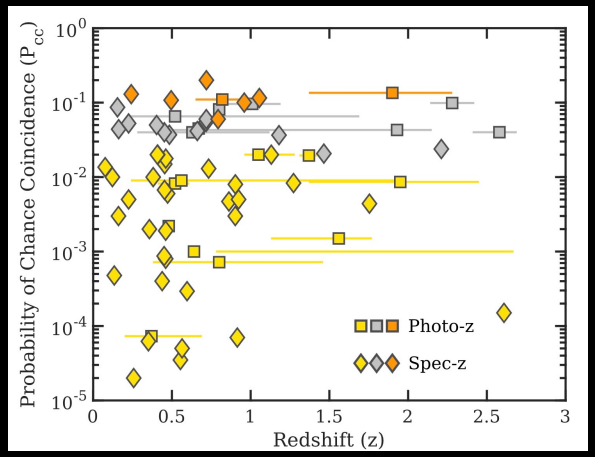
Hallinan, Corsi et al. 2017, Science, 358, 1579

The critical role of GW detector networks for MMA



Credit: Gupta; Corsi et al. arXiv:2402.13445v1

Short GRB redshifts:
gold, silver, bronze samples



Fong et al. 2022 ApJ 940 56

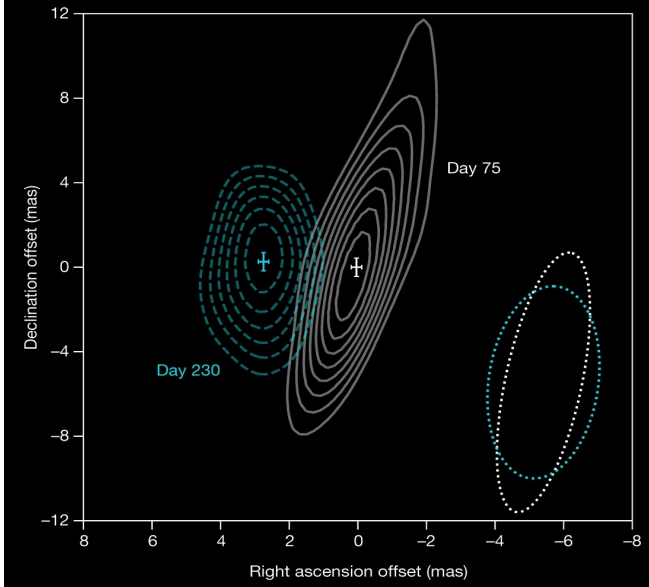
Assumed NS-NS rate is 320 $Gpc^{-3}\ yr^{-1}$
GWTC-3 90% credible interval is 10-1700 $Gpc^{-3}\ yr^{-1}$

The impact of a ngGW detector network

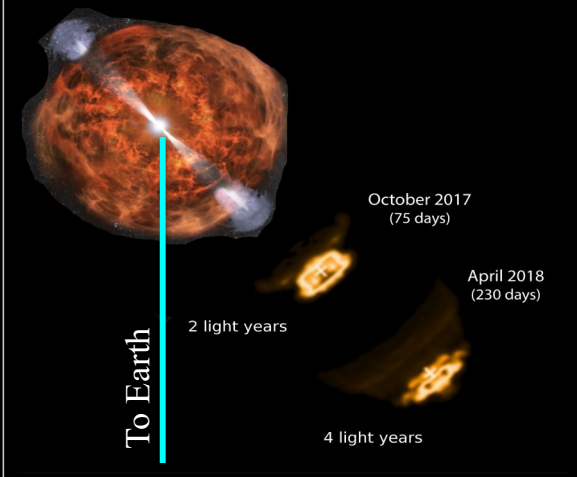
ngGW Key Science Goals	CE20+40 design essential because…
Black Holes and Neutron Stars Throughout Cosmic Time	With only one ngGW detector, a BBH at z=10 would have a redshift uncertainty of +/-4 and due to the mass–redshift degeneracy a 40% uncertainty in the mass measurement → Detailed study of the high-z BBH population needs two ngGW detectors
Multi-Messenger Astrophysics and Dynamics of Dense Matter	Two ngGW detectors needed for <= 1 deg^2 up to z~0.2-0.3 and <= 10 deg^2 up to z~1 → Enabling MMA probes of BNS progenitor-ejecta-remnant diversity and of GRBs
Fundamental Physics and Precision Cosmology	Localization of large numbers of events achievable with two ngGW detectors needed for substantial improvement in the GW measurement of H_0

H_0 Cosmology: The case of GW170817

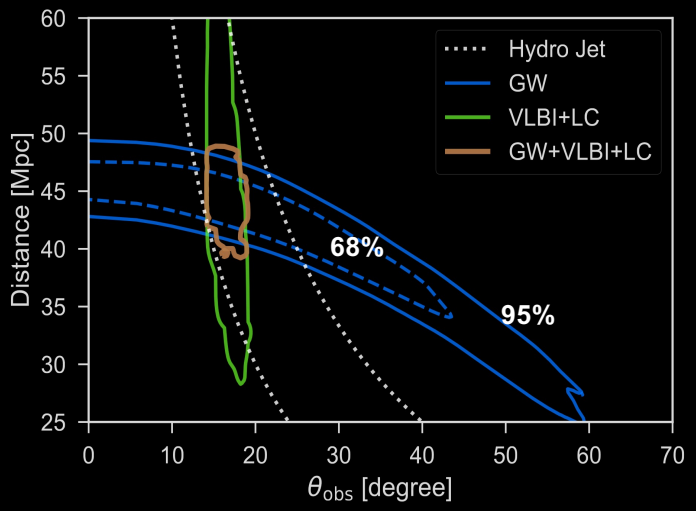
~15 more localized GW170817-like events could bring resolution to the current tension in H_0 measurement between Planck CMB and Cepheid-supernova measurements (as compared to 50–100 GW events alone).



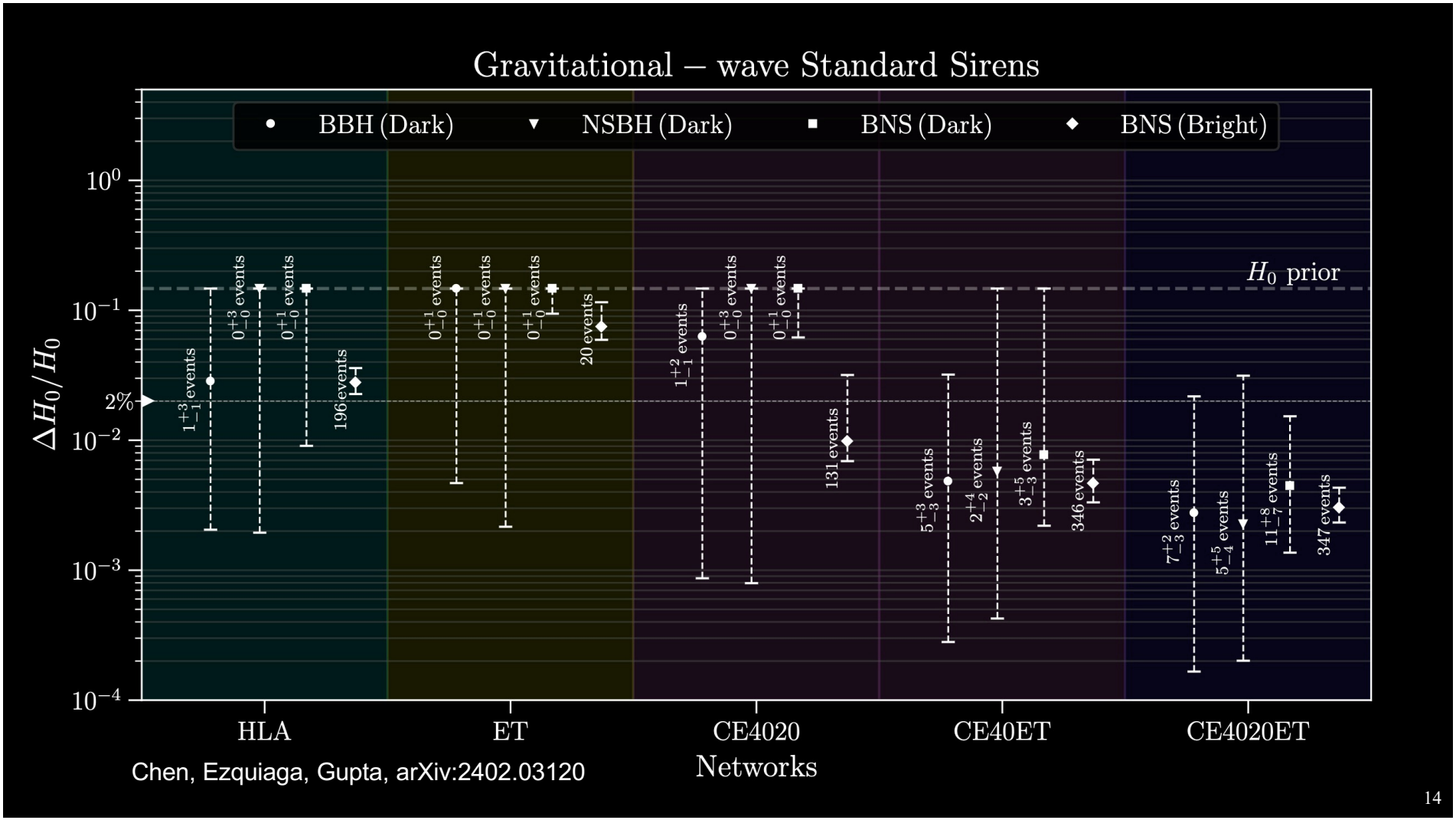
Mooley,.., Corsi et al. 2018, Nature, 561, 355
Also Ghirlanda et al. 2019, Science, 363, 968



Credit: Berry, Gottlieb, Mooley, Hallinan, NRAO/AUI/NSF



Hotokezaka et al. 2019, Nature Astron., 3, 940



Chen, Ezquiaga, Gupta, arXiv:2402.03120

The impact of a ngGW detector network

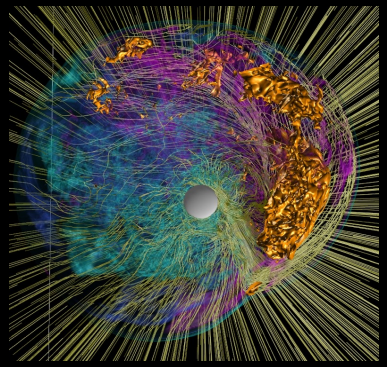
ngGW Key Science Goals	CE20+40 design essential because…
Black Holes and Neutron Stars Throughout Cosmic Time	With only one ngGW detector, a BBH at z=10 would have a redshift uncertainty of +/-4 and due to the mass–redshift degeneracy a 40% uncertainty in the mass measurement → Detailed study of the high-z BBH population needs two ngGW detectors
Multi-Messenger Astrophysics and Dynamics of Dense Matter	Two ngGW detectors needed for <= 1 deg^2 up to z~0.2-0.3 and <= 10 deg^2 up to z~1 → Enabling MMA probes of BNS progenitor-ejecta-remnant diversity and of GRBs
Fundamental Physics and Precision Cosmology	Localization of large numbers of events achievable with two ngGW detectors needed for substantial improvement in the GW measurement of H_0
Dark Energy, Matter and Novel Sources	Two ngGW detectors needed to ensure confidence in detection of poorly modeled and/or new sources, measure polarization for tests of GR...

Novel sources of GWs

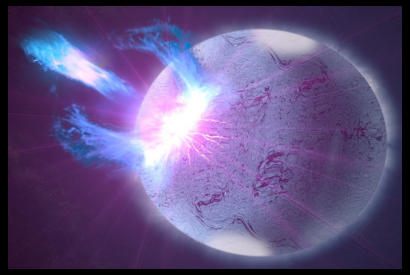
Credit: K. Hokusai

Continuous GWs and bursts (unmodelled signals) are the MMA of the future:

- A# should detect ~1, CE should detect ~30 millisecond pulsars at ellipticity ~10^{-9}
- Two ngGW observatories critical to ensure confidence in detection of poorly modeled sources



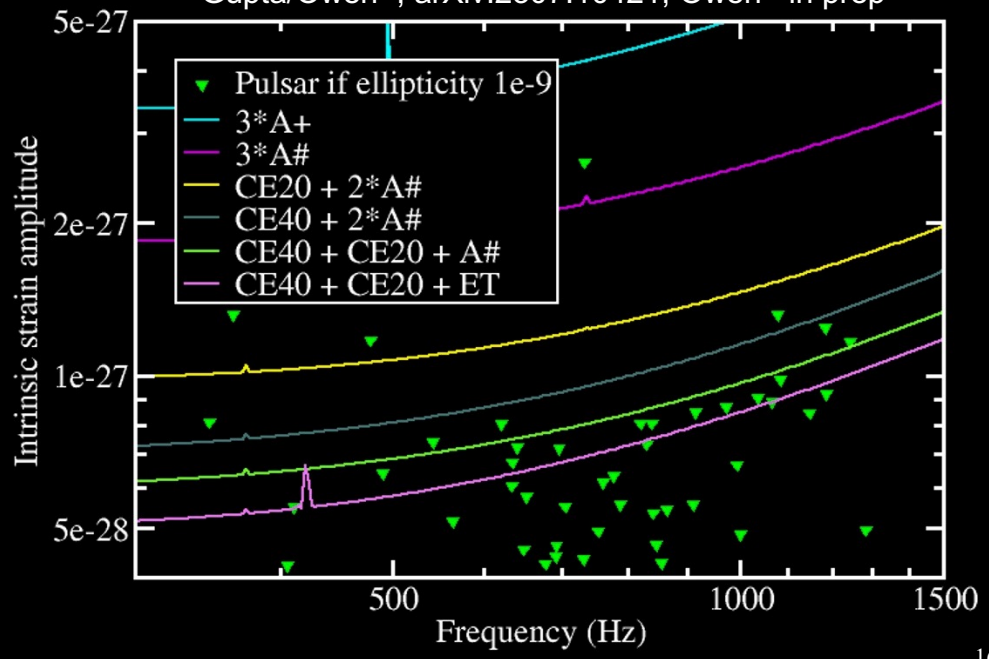
Blondin/Mezzacappa, Nature 445, 58 (2007)



Merfeld's GW searches for SGRs/FRBs.

Khanam's talk on bar-mode post-merger GWs (D03)

Gupta/Owen+, arXiv:2307.10421; Owen+ in prep



Conclusion and outlook

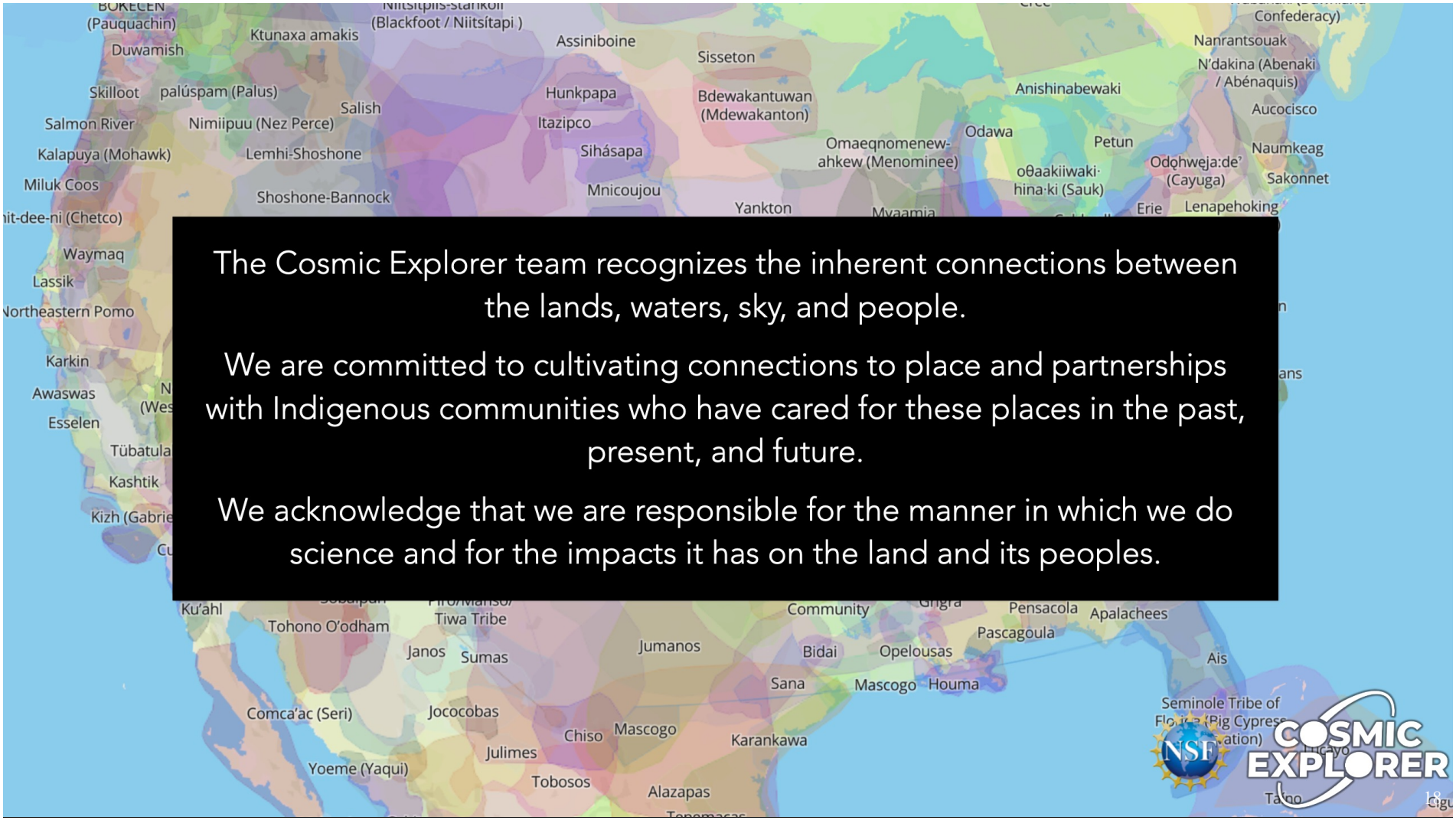
- CE40+20 km with a single 4 km LIGO at A# sensitivity can allow the United States to independently achieve the full range of ngGW science goals.
- CE's scientific output greatly enhanced by operating as part of an international network of GW observatories (coordination with ET on-going).
- With foundations laid by decades of National Science Foundation investment and the work of a large community of scientists, CE is poised to propel another revolution in our understanding of the universe!

Second Cosmic Explorer Symposium (online), Apr. 23-25, 2024:

- This event will bring together the community to discuss important aspects of the Cosmic Explorer observatory design, covering both observational and instrument science, with a focus on topics of high impact for the facility design.
- Participation is free, but please register here: https://indico.mit.edu/e/CES2024

NeXt-Generation Collaborative Design (XGCD) meetings:

- A forum for regular discussions between the teams that work on common design aspects of Einstein Telescope and Cosmic Explorer.
- Open to the ET collaboration and CE consortium members (join the CE Consortium).
- Meetings on optical design and straylight mitigation so far, material available at: https://indico.gssi.it/e/xgcd


The Cosmic Explorer team recognizes the inherent connections between the lands, waters, sky, and people.
We are committed to cultivating connections to place and partnerships with Indigenous communities who have cared for these places in the past, present, and future.
We acknowledge that we are responsible for the manner in which we do science and for the impacts it has on the land and its peoples.
(Pauquachin)
Duwamish
Ktunaxa amakis
(Blackfoot / Niitsítapi)
Assiniboine
Sisseton
Confederacy)
Nanrantsouak
N'dakina (Abenaki / Abénaquis)
Skilloot
palúspam (Palus)
Salish
Hunkpapa
Bdewakantuwan (Mdewakanton)
Anishinabewaki
Aucocisco
Salmon River
Nimiipuu (Nez Perce)
Itazipco
Odawa
Petun
Kalapuya (Mohawk)
Lemhi-Shoshone
Sihásapa
Omaeqnomenew-ahkew (Menominee)
Naumkeag
Miluk Coos
Shoshone-Bannock
Mnicoujou
oθaakiiwaki·hina·ki (Sauk)
Odǫhwęja:de' (Cayuga)
Sakonnet
Yankton
Erie
Lenapehoking
Waymaq
Lassik
Karkin
Awaswas
Esselen
Tübatula
Kashtik
Kizh (Gabrie
Ku'ahl
Tohono O'odham
Tiwa Tribe
Community
Pensacola
Apalachees
Pascagoula
Janos
Sumas
Jumanos
Bidai
Opelousas
Ais
Sana
Mascogo
Houma
Comca'ac (Seri)
Jococobas
Chiso
Mascogo
Karankawa
Julimes
Yoeme (Yaqui)
Tobosos
Alazapas
Seminole Tribe of
NSF
COSMIC EXPLORER