THE COSMIC EXPLORER GRAVITATIONAL WAVE OBSERVATORY

Technical Note	**CE-T2300003-02**	2023/04/10

Network configurations for MPSAC

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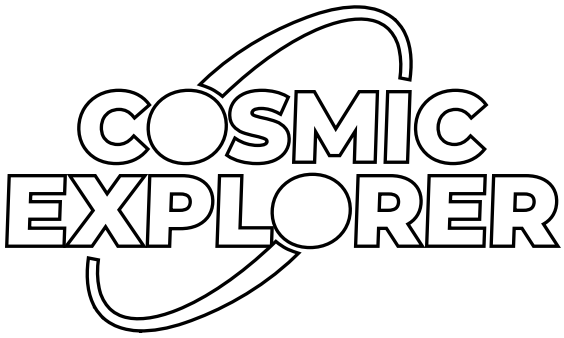
This is an internal working
note of the COSMIC EXPLORER project.



http://www.cosmicexplorer.org/

1 Context

The National Science Foundation (NSF) has formed an MPSAC sub-committee, tasked with recommending NSF on the future of ground-based gravitational-wave (GW) detectors in the US. The committee has solicited the preparation of white papers that compare the relative merits of possible detectors and networks.

This document provides the network configurations that the Cosmic Explorer (CE) project recommends be used by the community when preparing their white papers.

The following labels and locations are used in the tables and plots reported in the reminder of this document

- CE A: one L-shaped CE detector in the northwest of the US;
- CE B: one L-shaped CE detector in the southeast of the US;
- ET: one 10 Km triangular Einstein Telescope detector in Europe;
- LHO: one 4 Km L-shaped detector at the current LIGO Hanford site;
- LLO: one 4 Km L-shaped detector at the current LIGO Livingston site;
- LIO: one 4 Km L-shaped detector at the proposed LIGO India site.

Their sensitivities and exact locations are given below.

2 Networks

The science capability of a network of next-generation (XG) detectors will clearly depend on how many sites are included, and at which sensitivity. It will also depend on whether any current-generation observatories will still be online.

Here below we suggest a list of network configurations and network names to use for various investigations. This list covers most relevant configurations, without being unduly long. Current-generation observatories (LHO, LLO, LIO) are always assumed to be at the A# sensitivity; CE sites can have either 40 Km or 20 Km arm length (See Sec. 3).

- 0 XG detectors
  - "HLI": LHO + LLO + LIO
- 1 XG detector
  - "CE40LI": CE A 40 Km + LLO + LIO
  - "CE20LI": CE A 20 Km + LLO + LIO
  - "HLET": LHO + LLO + ET
- 2 XG detectors
  - "CE4020I": CE A 40 Km + CE B 20 Km + LIO
  - "CE40LET": CE A 40 Km + LLO + ET

  - "CE20LET": CE A 20 Km + LLO + ET

- 3 XG detectors
  - "CE4020ET": CE A 40 Km + CE B 20 Km + ET

3 Amplitude spectral densities

For Cosmic Explorer, we recommend using the sensitivity curves reported in version 6 of Ref. [1]. Specifically:

- For CE20, the file `cosmic_explorer_20km_strain.txt`
- For CE40, the file `cosmic_explorer_strain.txt`

For the Advanced LIGO A# detectors, we recommend the sensitivity curve reported in version 1 of the Ref [2].

Finally, for ET, we recommend the 10Km length xylophone sensitivity curve linked from the EGO document database [1].

These curves are show in Fig. 1 and the corresponding ASCII files are made available in a centralized GitHub repository for convenience.

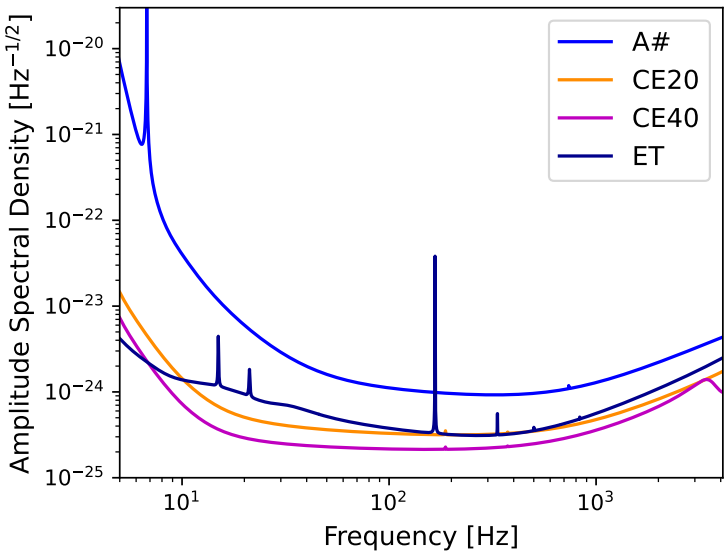


Figure 1: The amplitude spectral densities for A#, CE 20 Km, CE 40 Km and ET with 10 Km arm length.

[1]Note: In practice, a triangular ET detector is often simulated by creating 3 L-shaped detectors with intra-arms angles of 60°, each rotated by 240° CCW relative to the previous. Each of these three detectors is thus assigned the sensitivity curve we link to. See for example how this is implemented in Bilby.

4 Locations

The locations of the detectors are reported in Table 1.

For CE, we recommend locations and orientations that are different from what was utilized in Ref. [3]. Since sites have not yet been selected for the CE detectors, here we merely choose two locations with a distance comparable to the size of the continental US (the corner stations are off the coasts of Washington State and Texas). The orientations are chosen such that the two CE can access both GW polarizations (see technical note T2300002 in the CE DCC).

We recommend using a triangular ET, at the Sardinian site published by Ref. [4]. We orient the triangle such that one of the arms is along the south-north direction, and the other two arms lay westward of it (See Fig. 2).

For LIGO India, we use the location and orientation given by v1 of Ref [5]. Finally, we use the location and orientation of the existing LIGO sites as reported in Tables 4 and 18 of Ref [6] and coded up in Bilby.

	Latitude	Longitude	Orientation
CE A	46°00′00″	−125°00′00″	260.0°
CE B	29°00′00″	−94°00′00″	200.0°
ET	40°31′00″	9°25′00″	90.0°
LLO	30°33′46.4196″	−90°46′27.2654″	197.7165°
LHO	46°27′18.5280″	−119°24′27.5657″	125.9994°
LIO	19°36′47.9017″	77°01′51.0997″	117.6157°

Table 1: Position and orientation of the detectors. Latitudes (Longitudes) are positive in the north hemisphere (East of the Greenwich meridian). The orientation column reports the angle north of east of the x-arm (Note: here we follow the same convention used in Bilby, which is different from what used in Refs [5, 6], where the orientations of the detectors are reported as clockwise rotations from the local north). For L-shaped detectors, the x-arm is defined as the one that completes a right-handed coordinate systems together with the other arm and the local outward vertical direction. For ET, the x-arm is defined such that the two other arms lay westward of it.

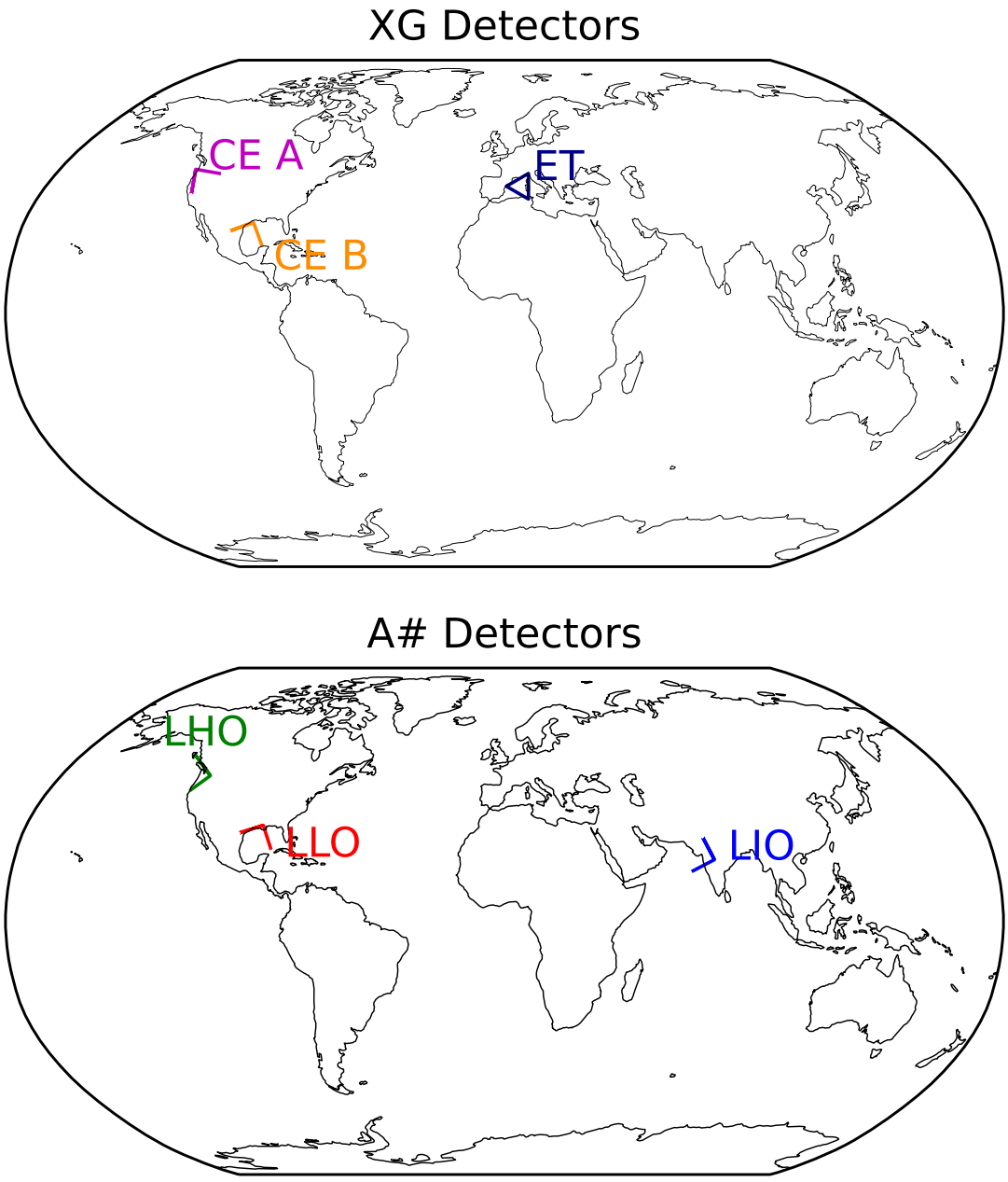


Figure 2: Location and orientation of the detectors.

5 Code and data availability

The notebook used to produce the plots in this document, as well as the noise spectral densities, are available in a dedicated GitHub repository.

References

[1] Kevin Kuns, Evan Hall, Varun Srivastava,Joshua Smith, Matthew Evans, Peter Fritschel, Lee McCuller, Christopher Wipf, Stefan Ballmer. Cosmic Explorer Strain Sensitivity. https://dcc.cosmicexplorer.org/CE-T2000017-v6/public, 2023.

[2] Kevin Kuns, Peter Fritschel. A# Strain Sensitivity. https://dcc.ligo.org/LIGO-T2300041-v1/public, 2023.

[3] Matthew Evans, Rana X Adhikari, Chaitanya Afle, Stefan W. Ballmer, Sylvia Biscoveanu, Ssohrab Borhanian, Duncan A. Brown, Yanbei Chen, Robert Eisenstein, Alexandra Gruson, Anuradha Gupta, Evan D. Hall, Rachael Huxford, Brittany Kamai, Rahul Kashyap, Jeff S. Kissel, Kevin Kuns, Philippe Landry, Amber Lenon, Geoffrey Lovelace, Lee McCuller, Ken K. Y. Ng, Alexander H. Nitz, Jocelyn Read, B. S. Sathyaprakash, David H. Shoemaker, Bram J. J. Slagmolen, Joshua R. Smith, Varun Srivastava, Ling Sun, Salvatore Vitale, and Rainer Weiss. A horizon study for Cosmic Explorer: Science, observatories, and community, 2021, 2109.09882.

[4] Marica Branchesi et al. Science with the Einstein Telescope: a comparison of different designs. *arXiv*, 3 2023, 2303.15923.

[5] Shivaraj Kandhasamy, Sukanta Bose. LIGO India Observatory (LIO) coordinate system for GW analyses. https://dcc.ligo.org/LIGO-T2000158-v1/public, 2020.

[6] LIGO Scientific Collaboration. Determination of Global and Local Coordinate Axes for the LIGO Sites. https://dcc.ligo.org/LIGO-T980044/public, May 2009.