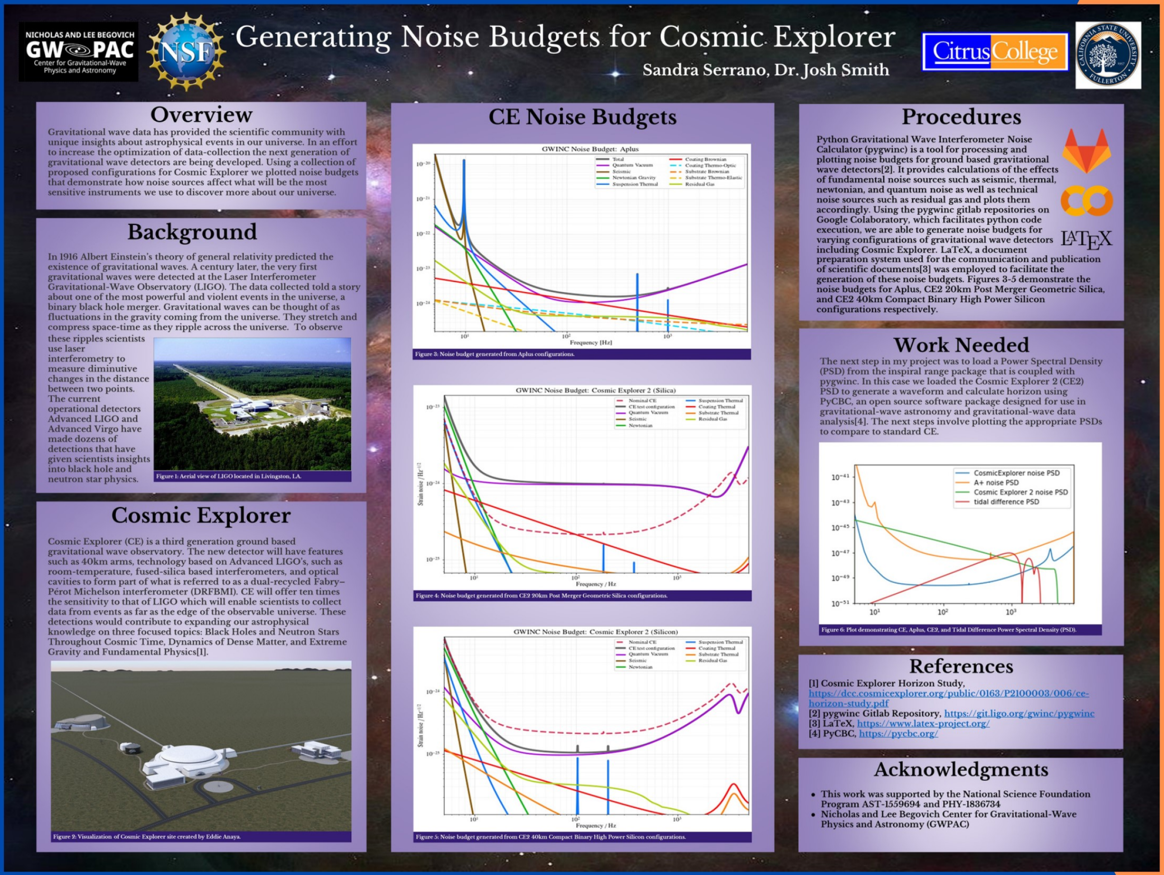
SANDRA SERRANO



Generating Noise Budgets for Cosmic Explorer

Sandra Serrano, Dr. Josh Smith

Overview

Gravitational wave data has provided the scientific community with unique insights about astrophysical events in our universe. In an effort to increase the optimization of data-collection the next generation of gravitational wave detectors are being developed. Using a collection of proposed configurations for Cosmic Explorer we plotted noise budgets that demonstrate how noise sources affect what will be the most sensitive instruments we use to discover more about our universe.

Background

In 1916 Albert Einstein's theory of general relativity predicted the existence of gravitational waves. A century later, the very first gravitational waves were detected at the Laser Interferometer Gravitational-Wave Observatory (LIGO). The data collected told a story about one of the most powerful and violent events in the universe, a binary black hole merger. Gravitational waves can be thought of as fluctuations in the gravity coming from the universe. They stretch and compress space-time as they ripple across the universe. To observe these ripples scientists use laser interferometry to measure diminutive changes in the distance between two points. The current operational detectors Advanced LIGO and Advanced Virgo have made dozens of detections that have given scientists insights into black hole and neutron star physics.

Figure 1: Aerial view of LIGO located in Livingston, LA.

Cosmic Explorer

Cosmic Explorer (CE) is a third generation ground based gravitational wave observatory. The new detector will have features such as 40km arms, technology based on Advanced LIGO's, such as room-temperature, fused-silica based interferometers, and optical cavities to form part of what is referred to as a dual-recycled Fabry–Pérot Michelson interferometer (DRFBMI). CE will offer ten times the sensitivity to that of LIGO which will enable scientists to collect data from events as far as the edge of the observable universe. These detections would contribute to expanding our astrophysical knowledge on three focused topics: Black Holes and Neutron Stars Throughout Cosmic Time, Dynamics of Dense Matter, and Extreme Gravity and Fundamental Physics[1].

Figure 2: Visualization of Cosmic Explorer site created by Eddie Anaya.

CE Noise Budgets

Figure 3: Noise budget generated from Aplus configurations.

Figure 4: Noise budget generated from CE2 20km Post Merger Geometric Silica configurations.

Figure 5: Noise budget generated from CE2 40km Compact Binary High Power Silicon configurations.

Procedures

Python Gravitational Wave Interferometer Noise Calculator (pygwinc) is a tool for processing and plotting noise budgets for ground based gravitational wave detectors[2]. It provides calculations of the effects of fundamental noise sources such as seismic, thermal, newtonian, and quantum noise as well as technical noise sources such as residual gas and plots them accordingly. Using the pygwinc gitlab repositories on Google Colaboratory, which facilitates python code execution, we are able to generate noise budgets for varying configurations of gravitational wave detectors including Cosmic Explorer. LaTeX, a document preparation system used for the communication and publication of scientific documents[3] was employed to facilitate the generation of these noise budgets. Figures 3-5 demonstrate the noise budgets for Aplus, CE2 20km Post Merger Geometric Silica, and CE2 40km Compact Binary High Power Silicon configurations respectively.

Work Needed

The next step in my project was to load a Power Spectral Density (PSD) from the inspiral range package that is coupled with pygwinc. In this case we loaded the Cosmic Explorer 2 (CE2) PSD to generate a waveform and calculate horizon using PyCBC, an open source software package designed for use in gravitational-wave astronomy and gravitational-wave data analysis[4]. The next steps involve plotting the appropriate PSDs to compare to standard CE.

Figure 6: Plot demonstrating CE, Aplus, CE2, and Tidal Difference Power Spectral Density (PSD).

References

[1] Cosmic Explorer Horizon Study, https://dcc.cosmicexplorer.org/public/0163/P2100003/006/ce-horizon-study.pdf
[2] pygwinc Gitlab Repository, https://git.ligo.org/gwinc/pygwinc
[3] LaTeX, https://www.latex-project.org/
[4] PyCBC, https://pycbc.org/

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This summer I used existing repositories from GitHub to generate and plot noise curves for proposed configurations of a third gravitational wave detector called Cosmic Explorer.

Alternate Text:

Sandra Serrano

Quote: "This summer I used existing repositories from GitHub to generate and plot noise curves for proposed configurations of a third gravitational wave detector called Cosmic Explorer."

Image of Sandra Serrano

Image of text and graphic laden project presentation entitled "Generating Noise Budgets for Cosmic Explorer. Sandra Serrano, Dr. Josh Smith"