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Bridging Art&Science: Exploring the Cosmos through Sonification at the University of Barcelona

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Abstract

We present a collaboration between the Institute of Cosmos Sciences (ICCUB) and the Laboratory of Sound Arts at the University of Barcelona, pairing PhD researchers to explore the intersection of art and science through the sonification of astrophysical phenomena. This project's first edition focuses on the sonification of gravitational waves, gravitational lensing, and the interaction between the Milky Way and the Magellanic Clouds.

By merging scientific precision with artistic creativity, we aim to inspire curiosity and deepen understanding of the cosmos. This paper showcases the innovative approaches and insights from this interdisciplinary collaboration, highlighting its ability to transcend traditional boundaries.

1 Introduction

The ICCUB explores the intersection of art and science through various initiatives, aiming to bridge the gap between scientific research and artistic expression. Notably, they collaborated with the Centre de Cultura Contemporània de Barcelona (CCCB) on exhibitions like

"Mars: The Last Frontier" and "Quantum: In Search of the Invisible," serving as scientific consultants and engaging in outreach activities.

They also collaborated with CERN and the Barcelona City Council on the "Collide" program, which offers research residencies at CERN and Hangar in Barcelona. This led to an artistic residency for Andy Gracie at ICCUB, where he developed "The End(s) of Everything(s)," exploring the concept of the end of the Universe.

ICCUB researchers participate in various art and science initiatives, including articles, interviews, talks, podcasts, and exhibitions, highlighting their commitment to fostering a relationship between the two fields.

1.1 The Institute of Cosmos Sciences

ICCUB is an interdisciplinary centre devoted to fundamental research in cosmology, astrophysics and particle, quantum and nuclear physics, and participates actively in international collaborations in these areas. It seeks to exploit connections and synergies among these research areas from a theoretical, observational and experimental perspective and also has a strong technology and knowledge transfer program connected to them.

1.2 The Fine Arts Faculty

The Faculty of Fine Arts at the University of Barcelona is dedicated to the creation, generation, and transmission of scientific and artistic knowledge in the fields of fine arts, design, and the conservation and restoration of cultural heritage.

The Sound Art Laboratory is devoted to teaching, researching and disseminating sonic arts. It provides a space for experimentation, educating the listening and appreciation of the many aspects of sound and the information it conveys. Since its foundation in 2008, it networks with many institutions nationally and internationally. Sound, as an interdisciplinary medium, is a growing relevant presence in the art and science fields since the last century; the purpose of this Laboratory is to stay updated, bringing it to the Faculty, and contributing to project the students' and researchers' works.

1.3 Joint sonification initiatives

The ICCUB and the Sound Art Laboratory of the UB Fine Arts Faculty have embarked on innovative joint sonification initiatives. These initiatives include the development of a **Hearing Pad** to translate scientific graphics into sound to improve the accessibility of blind researchers to science (with the collaboration of ONCE, Fundación ONCE and the Associació Catalana per a la Integració de les Persones Cegues) and the project **"Sound Ecologies - non audible sound landscapes and space meteorology"** in collaboration with Ivonne Villamil (UB Fine Arts Faculty), Plataforma Vértices, FGC, Ajuntament de Barcelona and the Barcelona Fabra Observatory, whichs focuses on "Non-audible sound landscapes" such

as electromagnetic radiation, space weather or meteorological phenomena.

Additionally, we have embarked in a Sonification Arts and Science Project which fosters interdisciplinary collaboration through PhD partnerships between ICCUB and the Fine Arts Faculty. This project pairs PhD students from both faculties to co-create a sonification piece inspired by their theses, merging artistic and scientific perspectives.

2 PhD collaborations in art and science

This project consists in the collaboration of pairs of PhDs, one from ICCUB and one from the UB Fine Arts Faculty, who embark upon a cocreation process to bring science and art closer together. The goals of this project are numerous:

1. **Explore the intersection of Art and Science**: Investigate and highlight the synergies between artistic expression and scientific research by creating a sonification piece inspired by a research thesis.
2. **Promote scientific understanding in the Arts**: Raise awareness within the Art sector about the scientific method.
3. **Open new perceptions in Science**: Show the scientific sector how using various sensory perspectives in research can provide new insights and enrich the interpretation of scientific data.
4. **Foster Interdisciplinary Collaboration**: Cultivate a culture of interdisciplinarity, recognizing the enrichment that comes from combining diverse fields of study and methodologies.

The project uses a flexible, collaborative approach, allowing PhD pairs to design their own work methods. The ICCUB Communications Officer manages the project, organizing periodic meetings. The final product is an artistic work inspired by the scientific thesis. These will be presented at two Arts & Science Days: one on October 22, 2024, for ICCUB and Fine Arts Faculty members, and another in early 2025, open to all audiences.

2.1 Sonification of gravitational waves and the effect of gravitational lensing

Gravitational waves are oscillations of space-time, which are created when very massive astrophysical objects accelerate. Gravitational waves have been observed by detectors LIGO, Virgo and KAGRA, coming from compact binary systems. Compact binary systems consist of two compact objects (neutron stars or black holes) that orbit each other. They emit gravitational waves, which makes them lose energy and come closer together. The binary components end up merging into another, more massive, compact object, emitting gravitational waves that travel through space-time in all directions at the speed of light and will

also pass through the Earth, where they can be detected.

While gravitational waves travel through the cosmos, they can encounter a massive astrophysical object. In this case, the gravity of this object distorts the waves, creating an effect known as gravitational lensing. If these lensed waves arrived at the detectors, the signal would be different than a signal which has not been lensed. Gravitationally lensed gravitational waves have not been detected yet, but are expected to be observed. The effect of gravitational lensing can create multiple images. In some cases, it can cause interference between the images. We focus on the lensing interference for our sonification.

We have first sonified gravitational waves from binary black hole systems. Then, we sonified gravitational waves affected by gravitational lensing in the interference regime. Although previous sonifications of general gravitational waves exist, gravitationally lensed gravitational waves had not been sonified until our recent work [1].

The details about the physical process and parameters, as well as the sonification procedure, can be found in [1]. The results can be found in the following websites:

- https://zoom3.net/sonificacions/ona-gravitacional.html – Gravitational waves from the merger of two black holes.
- https://zoom3.net/sonificacions/ona-gravitacional-lent.html – Gravitational waves from the merger of two black holes, affected by a gravitational lens. This website allows you to see the shape of the gravitational wave while you change the parameters. The automatic sonification is still not available, it is a work in progress.
- https://zoom3.net/sonificacions/ona-gravitacional-lent-exemples.html – Gravitational waves from the merger of two black holes, affected by a gravitational lens. This website shows the recordings of the sonifications of some of the parameter configurations.

The key point of this work is that the interference effect of lensing can be reproduced by single waves through sound. Superimposing the sounds of two single gravitational waves is analogue to using the physical equations to describe the lensing effect. One has to be careful, however, when doing the sonification. If we would like to shift the frequency to the audible range, it cannot be done directly in the time domain without modifying the interference pattern. If we want to preserve the interference pattern, we need to use the Fourier Transform and do the shift in frequency domain, as described in Fig. 1.

2.2 Sonification of the galactic interaction between the Milky Way and the Magellanic Clouds

The more clearly visible galaxies to the naked eye in the night sky are the Magellanic Clouds, the biggest galaxies in the Milky Way neighbourhood. Because they are so close, the Magellanic Clouds provide astronomers with a unique window into the complexities of galactic systems, which make them the ideal case for studying galactic interactions, stellar evolution, and the fundamental principles underlying the formation and dynamics of galaxies.

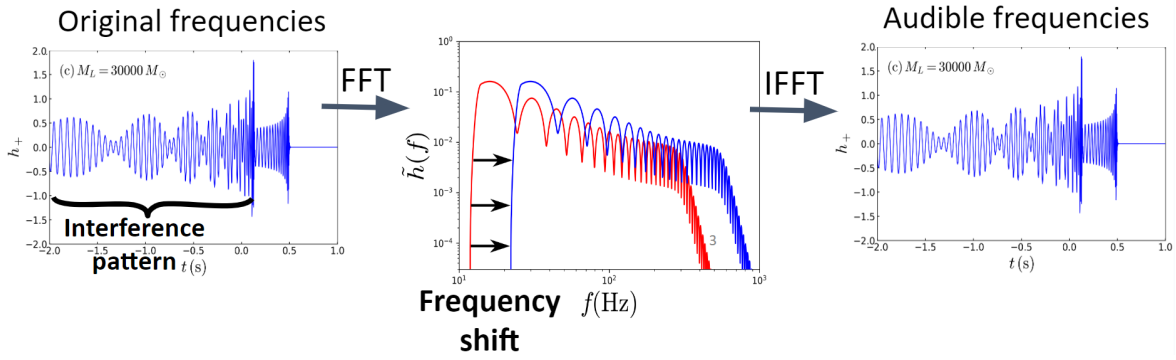

Figure 1: Process of shifting the frequencies of the sonification into an audible range. The original wave (left subfigure), represented as the distortion of spacetime h_+ as a function of time t, has a characteristic interference pattern. Shifting directly the frequency would modify the interference pattern, which depends on the phase, which in turn depends on the frequency. The way to shift the frequency while preserving the interference pattern is to do a Fourier Transform instead. The frequencies are modified in the frequency domain (center subfigure, representing $\tilde{h}_+$, the Fast Fourier Transform (FFT) of h_+, as a function of frequency f). Once the frequencies are shifted, we recover the wave in time domain by doing the Inverse Fast Fourier Transform (IFFT), shown in the right subfigure.

However, the study of the formation and evolution of the Magellanic Clouds cannot be done only by using observational data. Observations give us only a static picture of the whole process, and that is why researchers studying these kinds of systems also use numerical simulations, with the goal of reproducing the whole past interaction process. In this context, the KRATOS suite of simulations [2] was presented with the aim of studying the formation of substructures in the LMC-like disc after the interaction with a SMC-mass galaxy.

The aim of this project is to develop a sonification of the visualization of one of the KRATOS simulations (see Fig. 2). By converting the visual data from the simulation into sound, we aim to create an auditory representation that complements traditional visual analysis, potentially enhancing understanding and accessibility. This approach will allow users to perceive the simulation's dynamics in a novel way, providing an additional layer of interpretation that could be particularly useful for educational and outreach purposes.

To do this, we focus on three key channels. First, we will sonify the relative position between galaxies, where the intensity will correspond to the distance and the pan will reflect their position. Second, we will sonify the bar property of the Large Magellanic Cloud (LMC), where the pitch is provided by the bar pattern speed and pan by the direction of the bar. And third, the thickness of the LMC itself. These auditory representations provide new ways to interpret the simulation data, complementing visual analysis and enhancing accessibility.

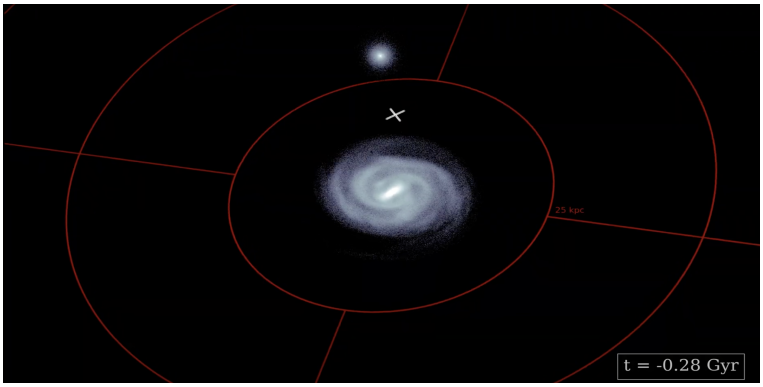

Figure 2: Snapshot of the representation of the Magellanic Clouds interaction for the KRATOS (K6) simulation. Visit https://www.oscarjimenezarranz.com/visualizations/the-kratos-suite to view the entire video.

3 Future

We are committed to continuing and expanding this project through several initiatives. First, we will host an Open Art and Science Day in early 2025 with Hangar Barcelona.

Second, we plan to extend the project to all research institutes at the University of Barcelona, aiming to consolidate it as an annual event.

Finally, we aim to integrate the project within the CHARM-EU framework, promoting interdisciplinary collaboration across institutions and countries through the conjoint doctoral program.

Acknowledgments

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