Jingle, Pluck, and Hum: Sonifications of Space Imagery Data

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ABSTRACT

Space imagery can often capture the imagination of the general public, inviting them to explore and learn more about our beautiful universe. To enhance this experience, we have converted 3 multi-wavelength images into musical form using a variety of sonification techniques. We tailored our approach to help elucidate key features in each image and to highlight the different views that observing in different wavelengths affords.

1. INTRODUCTION

Beginning in 2020, the Chandra X-ray Observatory has produced a series of multi-wavelength image sonifications to help share the beauty captured by astronomical telescopes in a new form. We present a new medley of three sonifications which were created for the 3rd series, *Jingle, Pluck, and Hum* [1]:

https://drive.google.com/file/d/1cGvYfkJfJ9kIR6-P_4s29KjBNxz0zDZX/view?usp=sharing

2. GOALS AND AESTHETICS

We set out to create musical versions of iconic space imagery. The sound is intended to communicate elements of the texture, spatial structure, and/or color in audio form, while highlighting the similarities and differences between scenes when viewed with different wavelengths. As with the imagery, the sonifications can be experienced ether as separate layers or as a composite. Our medley includes the composite, interspersed with segments of the isolated layers for demonstration purposes. The goal is to stimulate curiosity about the scientific background of the object appearing in the image and about the sonification process itself. There is a long history of innovating approaches to image sonification, we hope that our approach can continue this tradition and introduce sonification to a wide audience [2], [3].

3. DATA, DESIGN, AND COMPOSITIONAL CHOICES

We began with multi-wavelength image data of three systems: Westerlund 2, the Tycho supernova remnant, and the M87 galaxy. Simple mappings were chosen for each so that they could be quickly understood to the general public. Each sonification uses a different scanning direction, chosen to make the essential information present in the image detectable through sound. In all cases, the detected brightness controls the volume of the sound. Pitch and timbre mappings are chosen to optimally communicate features in the images.

3.1. Westerlund 2

Westerlund 2 is an active star formation region with a diffuse nebula and a dense cluster of bright stars. The data includes an x-ray image captured by the Chandra X-ray Telescope and an optical image captured by the Hubble Space Telescope. The key features we aimed to communicate through sound is the structure of the nebula on the left side of the optical image and the star cluster appearing in both optical and x-ray images. As this is a landscape-cropped image in which these features don't overlap much, we chose a left to right scanning path. The vertical position controls the musical pitch from a chosen set of notes. We used different timbres for the optical and x-ray layers: plucked/sustained strings for compact/diffuse optical light and bells for compact x-ray sources. More extended x-ray sources are captured by modulating the amplitude of sine waves corresponding to the same pitches as the discrete sources.

This is a musical version of the inverse spectrogram that is commonly used to sonify images [4], [5]. In its standard form, sounds can be generated by additive or subtractive synthesis with a regularly or exponentially spaced frequency grid. We quantized frequencies to a specific chord voicing and modulated the volume of musical sounds. We also included discrete musical sounds.

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3.2. M87

M87 is a massive galaxy and relatively nearby galaxy. It hosts a supermassive black hole which drives jets that interact with gas surrounding the galaxy. We began with an x-ray image of the outflow captured by Chandra and a radio image captured by the VLA. The key feature we aimed to communicate was the structure of the asymmetric outflows, which are similar in both images but more confined when viewed in x-ray light. Since there is a clear center and azimuthal asymmetry, we chose a radar-like azimuthal scan. The radial distance is mapped to musical pitch and each layer is constrained to a different pitch range (x-ray light is mapped to a higher frequency range than optical light). The different layers are also assigned to different but complementary scales. The azimuthal brightness profile is also used to control the brightness of the sound by modulating the cutoff frequency of a low-pass filter. Continuous synthetic sounds are used for each layer and a synthetic harp is added for point-like sources in the x-ray image.

This mapping is similar to previous azimuthal sonifications such as those using images of the human iris [6]. After transforming the raw image into a polar coordinate grid, this technique is essentially the same as a standard left-right inverse spectrogram. As with Westerlund 2, we differ from the standard approach by allowing more musical freedom and discrete notes.

3.3. Tycho

The Tycho remnant is the debris left over from a supernova that occurred within the Milky Way, and was observed from Earth in 1572. Different wavelengths of x-ray light captured by Chandra have been assigned to different colors to create a dramatic visual image. When viewed by Hubble, only background stars are visible. The key feature in this image is the color fluctuations appearing over the nearly circular remnant and the sharp out edge. Since the dominant colors vary radially, we chose an inside-out radial scan and mapped the hue of pixels to musical pitches. A harp is added to accentuate the point-like sources visible in the optical image. Additionally, the full x-ray spectrum measured by Chandra was scaled down to 50 octaves below the frequencies of light detected. The spectrum contains three peaks due to iron, silicon, and sulfur and you can hear how their relative proportions change radially within the remnant.

Color is often mapped to pitch in image sonifications but is typically used with probing, rather than scanning approaches, with good reason [7]. With our scanning approach, much spatial information is lost when pitch is used to indicate color rather than position. We believe the trade-off was reasonable for this image in which azimuthal variations were sub-dominant to radial variations.

4. VISUAL DISPLAY

Visuals were created to help communicate the sonification mapping and help users identify which visual elements correspond to which auditory elements. We used combinations of scanning lines, flashing points, and expanding bubbles for this purpose and overlaid them on top of the original images.

5. USER RESPONSE

Before release we solicited feedback from Christine Malec, a musician and astronomy enthusiast who is blind. She felt that they provided challenging but rewarding experience, saying "These are stimulating in a way that's hard to put into words." She confirmed that listening to individual layers first helped to parse the information but would also appreciate a version that is slowed down, allowing more time to digest. We have since created slower versions of previous work. As with the previous 2 Chandra sonification sets, the public response has been enthusiastic and positive. All 3 sets are among the highest rated 'images' in Chandra's photo album. On user-request, we have included audio-only downloads, which indicates interest and enjoyment in the sounds when divorced from visuals. The sonifications were listened to hundreds of thousands of times through social media and have led to new sonification projects with other agencies within NASA. They have also inspired several students to create their own image sonifications and to initiate mentorships with the authors. The works were featured in dozens of online outlets [8], [9], [10].

6. ACKNOWLEDGMENT

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