5000 EXOPLANETS: LISTEN TO THE SOUNDS OF DISCOVERY

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ABSTRACT

We have created a sonification and visualization to celebrate the discovery of the 5000th exoplanet and to communicate the exciting history of discovery to the general public. Our work provides a visceral experience of how our knowledge of alien worlds has progressed. A relatively simple and straightforward sonification mapping is used to make the informational content as accessible to the general public as possible. Listeners can see and hear the timing, number, and relative orbital periods of the exoplanets that have been discovered to date. The sonification was experienced millions of times through NASA's social media channels and there are plans to update the sonification as future milestones are reached.

1. INTRODUCTION

Since the discovery of the first exoplanets in 1992, humanity's progress in discovering worlds outside of the solar system has progressed dramatically. Thanks to the development and refinement of several techniques and the launch of dedicated space-based telescopes, the pace of discovery has increased from roughly one per year to dozens or even hundreds per month. In 2019 we converted the history of discovery of the first 4000 exoplanets into a musical and educational experience. As the planet count approached 5000 according to NASA's Exoplanet Archive, NASA contacted us to request an updated version for upcoming milestone [1]. We produced a new version with improved visuals which was released as the 5000th planet was announced on March 21, 2022 [2], [3]. The video is available at
https://drive.google.com/file/d/1a8OM3BqONMIxpFHSLuWhhE2a10AVMmeW/view?usp=sharing.

2. GOALS AND AESTHETICS

The wealth of known exoplanets is commonly communicated graphically, either through scatter plots or more sophisticated visualizations [4], [5]. Some sonifications of the catalog have also been produced [6]. While engaging and informative, these typically flatten the time dimension to a static axis on a graph or do not address time at all. Our goal was to create a time-based musical sonification that gives the listener a visceral experience of how our knowledge of alien worlds has progressed. In addition to communicating the pace of discovery, some general trends in the types of planets discovered and some key events should also be audible. It is intended to have artistic and pedagogical value.

Since our goal is the reach and impact the general public (largely through social media), we chose a relatively pleasing and consonant aesthetic. It begins calm and contemplative when discoveries were rare but reaches energetic heights towards the end as detections became regular.

3. DESIGN AND COMPOSITIONAL CHOICES

The sonification is designed to be almost immediately understandable to a general audience on first listen, and hence, simplicity in design is key. The time data is compressed from 30 years to just over a minute. This pace keeps the large early gaps between discoveries short while keeping the small gaps that occur later on long enough to be clearly perceived. The discovery times are quantized to months because this is the native time resolution of the Exoplanet Archive and because the regular rhythm maintains interest by helping to build tension as the piece develops.

The pitch of each note is controlled by the orbital frequency of the exoplanet. Higher orbital frequencies (smaller orbital periods) are mapped to higher note frequencies. The scaling is logarithmic rather than linear so that the enormous range of orbital frequencies (spanning roughly 9 orders of magnitude) can be mapped to a comfortable human hearing range. We think of this as a compressed 'Music of the Spheres' mapping as it maintains a relation between orbital and audio frequency. The mapped frequencies were quantized to a dense voicing of an Emaj13 chord containing 23 different notes. A consonant harmony is chosen to avoid harsh dissonances which would be incongruous with the aesthetic goal. A chord voicing was used (rather than a regular scale) because there are times when nearly every mapped note is played and sufficient space is required between low tones to prevent the result from sounding muddy.

The number of planets within a certain note frequency bin discovered in a given month is used to control the note velocity. This is chosen to be consistent with the intuition that a larger number of planets should be louder, without requiring an individual note for every planet. In some months, up to 241 planets were discovered within the same frequency bin and playing a note for each would lead to an unmanageably large dynamic range.

The spatial positioning of the audio is based on the planets' position on the celestial sphere. The animation shows the entire celestial sphere in galactic coordinates with an equirectangular projection. To match the visuals, the galactic longitude [-180,180] was mapped to the stereo positioning from left to right.

We chose to use an electric guitar as it is familiar, has a relatively large range, and has a suitably short decay to make densely occurring transients audible. The range was extended by pitch-shifting the highest and lowest notes. We limited ourselves to a single instrumental timbre to maintain

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simplicity and cohesion. More information could be communicated by assigning different sounds to different planet detection methods (for example) but this would increase the cognitive load and the time needed to communicate the mapping. Low sustained notes were played on a guitar with an EBow to help ground the piece during breaks between early discoveries and to help build excitement towards the end.

4. DATA AND METHODOLOGY

The data was accessed from NASA's Exoplanet Archive and through personal communication with its administrators. This is an online archive that collates and cross-correlates astronomical information on exoplanets and their host stars based on published results. The sonification uses data of the discovery date (year and month), orbital period, and celestial coordinates of each planet while the visualization also uses the method that was used to detect the planet. Many discovery dates were ambiguous and needed to be resolved by inspection of published work. Several planets do not have published values for their orbital period (mainly because this can't be determined accurately for planets discovered with certain methods). In these cases, a period is estimated by using the planet's semi-major axis and host star mass according to Kepler's 3rd law.

The data processing and implementation of the sonification design were done in python. The logarithms of the planets' relative orbital frequencies were squared and then mapped to the chosen set of musical notes. The squaring was used to shift the peak of the distribution towards the middle of the mapped frequency range as otherwise the vast majority of planets would be heard as very high notes. We took the square root of the number of planets discovered in the same frequency bin each month and mapped it to midi note velocity from 45 to 127. Stereo positioning was achieved by allocating notes to separate midi tracks and then panning each in Logic Pro. A limited spatial resolution of 5 channels was deemed sufficient.

The guitar sound was created by acoustic recording of a Fender Jazzmaster running through a Boss Reverb pedal. A sample pack was created by recording each note on the guitar with 5 different velocities. The sounds were assigned to a sampler in Logic Pro to be triggered by midi note events. The sustained drone sound is the same guitar played by an Ebow being run through a distortion pedal. Additional guitar chords were recorded live to accentuate moments when several hundred exoplanets were announced at one time.

5. VISUAL DISPLAY

The animation was created to communicate the sonification mapping visually and to provide additional information. It shows the entire celestial sphere as viewed from Earth. A digital counter indicates the year and the running total and as each planet is discovered a circle appears at its location on the celestial sphere. The size of the circle indicates the relative size of the planet's orbit so is also correlated with the musical pitch heard at the same time (larger orbits have smaller frequencies and hence lower pitch). The color of the circle indicates the method used to detect the planet. The visuals show patterns that are not audible in the sonification such as the timing and relative numbers of planets discovered with each method.

The video was created in python using a catalog of visible stars and a stellar density image created with Gaia data to simulate the Milky Way. Frames were rendered in python and then stitched with ffmpeg. Layers were combined in Final Cut Pro.

6. USER RESPONSE

Both sonification videos were posted by NASA on March 21, 2022 along with a written feature. Within the first month of release, the equirectangular version has been watched 144 thousand times on NASA's Youtube channel, 473 thousand times through NASA's Twitter account, and over 2 million times through NASA's Instagram channel. Some of the top-rated comments on Instagram were *"This actually goes hard"*, *"Stunningly beautiful 😍🙌"*, *"that is so amazing… it sounds so calming"*, and *"Music of the spheres 2022 edition!"* [7]. These comments indicate that listeners experienced it as both calming and exciting, as awe-inspiring, and even picked up on the connection to ancient ideas of musica universalis. The video was also featured by several online media outlets [8], [9], [10], [11], [12].

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8. REFERENCES

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