ASTRONIFY: AN OPEN-SOURCE PYTHON PACKAGE TO SONIFY ONE-DIMENSIONAL ASTRONOMICAL DATA

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ABSTRACT
Astronify is an open-source Python package for creating one-dimensional sonifications of astronomical data primarily for research and analysis purposes. In this brief Proceedings Abstract, we briefly describe the goals of the project, our design principles, choice sonification capabilities, and the testing processes we employed while we developed the first release version of the software. Astronify welcomes contributions from anyone interested in helping develop the software further, and to participate in the overall project’s goals to 1.) provide a sonification alternative to visual inspection when analyzing astronomical light curves and spectra, and 2.) to make professional astronomy more accessible and inclusive for everyone.

OVERVIEW
The Mikulski Archive for Space Telescopes (MAST) is an astronomical archive that hosts data from over 20 telescope missions, including flagship NASA missions James Webb and Hubble. MAST data is freely available to the public. Scientists across the world download hundreds of terabytes of MAST data per month to conduct their research. Providing sonifications of MAST datasets is an integral part of accomplishing core aspects of MAST’s mission: making this data accessible to all and maximizing its scientific return. Using sound instead of, or in concert with visualizations enhances the analysis of data. In some cases, sonifications have enabled discoveries where visual-based processes were inadequate [1,2]. Additionally, growing the use of sonification within professional astronomy makes the career more inclusive to those who are blind or visually impaired (BVI). These goals are shared by many sonification projects within astronomy (e.g., [3,4,5], and also the review from [6] on sonification within astronomy.)

Astronify [7] is an open-source Python package designed to produce sonifications of one-dimensional astronomical data for research and analysis purposes, thus providing an additional paradigm for scientists to analyze complex datasets. The initial focus of Astronify was to create sonified versions of light curves (measurements of an object’s brightness as a function of time), but in principle, any one-dimensional dataset can be sonified with the software. For instance, our team has begun to use Astronify on spectroscopic data (measurements of an object’s brightness as a function of wavelength).

A critical aspect of the Astronify project was partnering with Geneva Lake Astrophysics and STEAM (GLAS Education)1 to network with BVI science students and professionals. Through multiple rounds of usability tests, we incorporated their feedback and ideas throughout development. Published, peer-reviewed studies of sonification efficacies, when used in professional astronomy analysis tasks [8,9], will be an essential step in further developing Astronify (and research-motivated sonifications in general).

Astronify’s ultimate goal is to provide sonifications within the same primary MAST search interfaces used to preview and retrieve data. We aim to enable consistent, professional use of sonification in the field of professional astronomy, thus sonifications must not be isolated or separated from primary user workflows but incorporated directly into them. Currently, the first version of Astronify is publicly available as a Python package. Future work will include adding Astronify-created sonifications to MAST’s search interfaces alongside visualizations.

1. SOFTWARE
Astronify is under active development, the source code is hosted on GitHub3, documentation is on Read the Docs4, and it is installable via the Python Package Index. Astronify was designed to sonify time series data and its default parameters support MAST light curve data from the Kepler, K2, and TESS missions. Version v0.1 is complete and documented with its basic functionality. This includes configuration options for different use cases, and a modular design to allow for straightforward expansion in functionality (see fig. 1).

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1 https://glaseducation.org/ (visited on 2023-06-16)
2 https://github.com/spacetelescope/­­astronify (visited on 2023-06-16)
4 https://pypi.org/project/astronify/ (visited on 2023-06-16)

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Figure 1. Diagram showing the design of Astronify. The SoniSeries class (red circle) takes as inputs (purple rectangles) a data table, a “data-to-pitch” function that defines how the data will be transformed into pitch (a default function is provided), and various parameters to tune the sonification. The input sonification parameters include arguments to the data-to-pitch function (e.g. to define the output pitch range) as well as general sonification parameters such as playback speed and volume. The sonify function uses the inputs to produce the sonification and updates the input data table with pitch and onset (when each note is played) information. The sonification can then be played or written out to a .wav file.

All Astronify documentation is produced as standard HTML web pages by the Sphinx Python documentation package. We verified with our BVI network that the web pages are accessible to screen readers. Jupyter Notebook tutorials are also available, but because they are not accessible, tutorials are always available in HTML.

The fundamental functionality of Astronify is to sonify time series data, a two-column dataset. One column is time and the other column is data value—assumed to be called flux by default. The algorithm that Astronify uses to transform data values into pitches is as follows:

Given a center pitch, zero point, and pitch range, the data values will be scaled with a chosen stretch (linear, hyperbolic sine, hyperbolic arcsine, logarithmic or square root) such that the zero point maps to the center pitch and all pitches fall within the pitch-range. The given pitch range defines the maximum pitch boundaries, but depending on the parameters of sonification output pitches may not reach the edges.

In addition to the pitch-mapping algorithm, the user can also specify note length and mean time between notes. Time between notes determines the scaling in the time dimension, preserving the relative distance between data points. These are critical settings because Astronify sonifies every single data point—the time between notes determines how long the sonification lasts. The default values are .01 sec note spacing and 0.5 sec note duration. This means that there is significant overlap in the pitches temporally. This default works well for Kepler and TESS light curves because often the goal of analysis is to pick out changes from the background flux that might reveal transits or other phenomena. Additionally, while it is desirable for the distance between notes to be small due to the large number of data points, there is a note length limit. Below that limit, there are not enough complete wave periods over the duration of the note for it to sound properly.

We are currently expanding Astronify to create a sonification snapshot of spectra produced by the James Webb Space Telescope. The goal of this functionality is to give the gist of a spectrum rather than detailed information. Like image previews, sonified previews convey the overall shape and high-level characteristics which allows a researcher to quickly decide if a spectrum has characteristics relevant to their research. These sonified previews will be available on MAST’s existing web interface alongside plot previews.

2. COMMUNITY FEEDBACK AND TESTING

To inform the design of Astronify, we ran two rounds of scripted usability tests with 7 BVI participants, organized a feedback workshop with the TESS TOI Vetting team, and shared two surveys with the wider community. We incorporated this feedback into our sonification defaults and captured ideas for software features in GitHub issues.

Figure 2 shows examples of the science cases we used in usability testing. We used two astronomical phenomena: stellar flares and exoplanet transits. Flares occur when a star releases a lot of energy in a surface explosion, that create a sudden increase in brightness (Fig. 2 top). Exoplanet transits are the dips in brightness we observe from a star when a planet passes in front of it and blocks some of the light (Fig. 2 bottom).
The sonification speed influenced the perception of its shape. A U-shape at medium speed begins to sound like a V-shape at fast speed, and the opposite—V-shapes sound flatter when sonified slowly. Slower sonifications allowed participants to better identify the subtle curves in the shape in focused sections, but it was more difficult for them to tell if the subtleties were relevant to the overall shape. Participants identified that an axis would be necessary to combat the speed distorting their perception, and critical to accurately compare different shapes. It was suggested that the axis could be presented as a metronome with a regular beat. Unanimously, participants preferred the medium speed.

Pitch mapping also had an influence on shape identification. Participants heard the shape differently when the pitch was inverted. Some participants preferred one mapping, while others found it useful to try different options depending on circumstance. Like the TESS Vetting Team, some participants found it easier to hear details in the high-pitch range of the inverted mapping. Concerns were raised about different people having different ranges of hearing.

When asked what additional sonification options would be useful for studying transits, users requested the ability to control the pitch range, pause the sonification, and easily skim backward to relisten to a particular moment. Participants felt that controlling these setting options would improve their accuracy in determining the shape.

2.3. Surveys

We solicited feedback from a wider pool of people through two surveys, presented as games—a more exciting way to engage a non-scientific audience. The player is presented with a sonification and then questions about what they have heard. There have been ~100 responses between both surveys, and more continue to trickle in.

Our first survey2 focused on recognizing flares and counting transits. ~80 people responded, of which 5 self-identified as BVI, and 26% of respondents had no science or data analysis background. The survey begins with a written description describing a flare and what it sounds like when sonified. Then there are 5 embedded sonifications each followed by the question, “Does this contain a flare?” Four out of five sonifications had a majority of participants correctly identify the presence of a flare (54%, 73%, 91%, and 98% responses were correct for these four), but one sonification had only 34% correct responses. Next, a written description defining a transit and describing what it sounds like when sonified. Then we shared 4 sonifications and after each asked how many transits were heard. Three of the four sonifications had a high correlation of correct transits counted (approximately 86%, 82%, and 85%), but one sonification only had 48% of people count correctly. The results of this survey showed us that people could identify patterns in sonifications, though we were concerned that lower signal-to-noise would negatively impact people’s ability to hear the patterns. In the comments, multiple people requested sonification examples to learn from before they started the test. This was helpful feedback—in future surveys, tests, and even public lectures, we made sure to

1 https://doi.org/10.5281/zenodo.7996756 (visited on 2023-06-16)

2 https://www.surveymonkey.com/r/Z6DGLRB (visited on 2023-06-16)
include examples to listen to first before asking people to analyze a sonification.

Our second survey 1 focused on identifying exoplanet characteristics. We had ~20 respondents who all self-reported as being sighted and had varying levels of familiarity with astronomy and data analysis. The survey has six questions. The first five explain different qualities in a transit (length of transit, length of period, number of transits) and then ask the participant to identify that quality in a sonification—like “Which transit was shortest” All of the questions had a majority of participants answer correctly (approximately 68%, 74%, 84%, 89% 100%, with many incorrect answers being almost correct). The sixth question was a write-in where people listened to a transit sonification and described what they heard. All respondents noted that there was a large gap between the two transits. Many people further explained that that meant the planet had a long year (orbital period).

3. CONCLUSION

This paper describes our initial work on Astronify, an open-source Python package to sonify one-dimensional astronomical data. We describe our use case, software, method of sonification, and usability research that went into the project. The sonifications produced by the software are intended for research and analysis purposes, and we have included blind and visually-impaired STEM students and professionals in our design and testing from the beginning of the project. While still early, our ultimate goal is to use Astronify to provide sonified data and previews alongside visual-based tools within the Mikulski Archive for Space Telescopes. This will provide a new way to analyze data for all users and increase accessibility for those who want to pursue astrophysics as a career. We encourage everyone to use Astronify, or contribute to it, as we build its features and capabilities.

4. ACKNOWLEDGMENTS

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5. REFERENCES


1 https://www.surveymonkey.com/r/HQR3N3M (visited on 2023-06-16)