Rubin Rhapsodies: Sonification of LSST Data for Enhanced Data Exploration and Accessibility

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Abstract

Sonification is the use of non-speech audio to convey information. While visualizations are the traditional means of making data accessible to scientists as well as to the public, sonifications are a less common but powerful alternative. In scientific visualizations, specific data properties are mapped to visual elements such as color, shape, or position in a plot. Similarly, data properties can be matched to sound properties, such as pitch, volume, timbre, etc. In order to successfully convey information, both visualizations and sonifications need to be systematic, reproducible, and avoid distorting the data. By incorporating sonifications alongside traditional modes of data analysis, we propose that sonification can foster inclusivity and enable complementary methods of exploring the rich, complex, and multidimensional Rubin LSST dataset. Furthermore, our interdisciplinary approach employs traditional notation and orchestrations to convey information in a more approachable and memorable format.

This collaboration is supported by a Heising-Simons Foundation grant awarded to three Rubin LSST Science Collaborations[1] aimed at funding equity and excellence in Rubin science and its part of a multi-step program to establish a partnership between University of Delaware and Lincoln University and a data-intensive interdisciplinary portfolio of pedagogy and research at Lincoln University, nation's first degree-granting Historically Black College and University.

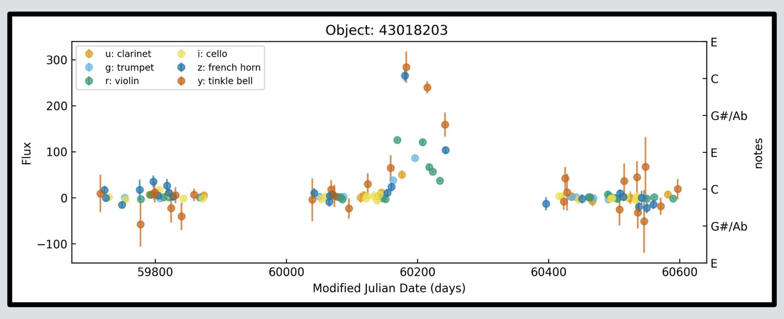
The Case for Sound with Rubin

- Sonification is the practice of generating an audible representation of data [2].
- Equity and research inclusion: Sonification makes data accessible to people that cannot or cannot easily access visual information [3].
- Aiding discovery: Sonification enables ways to explore LSST data that can enhance our intuition and understanding by providing an alternative way to access information or when used in conjunction with visualizations of data.
  Because LSST data are so complex (many data and metadata features), we can benefit tremendously from the extension of the representation space beyond visual elements.
- Sonifications are becoming more common in astronomy to represent 1D time series, typically evenly sampled (e.g. Kepler [4]), as well as images (e.g. Chandra [5]) but producing effective sonifications of 6-band, unevenly spaced lightcurves *and* the corresponding metadata is uncharted territory.

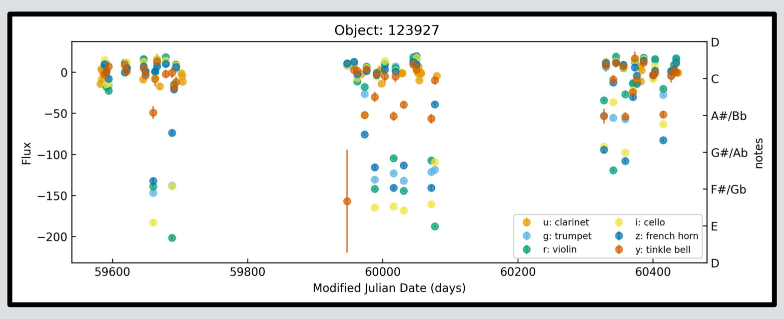
Sonifications

Below are lightcurves of four different astrophysical objects from the Photometric LSST Astronomical Time series Classification Challenge (PLAsTiCC) [6]. The data is colored according the its corresponding photometric band and assigned an instrument. In each band, flux is mapped to pitch, uncertainty to volume. The sonification was done using *sonify* [7], an open-source software library for turning data into MIDI audio. Modifications of the software to suite the needs of the Rubin data have been implemented in the code base which is available at https://github.com/fedhere/RubinRhapsodies.git

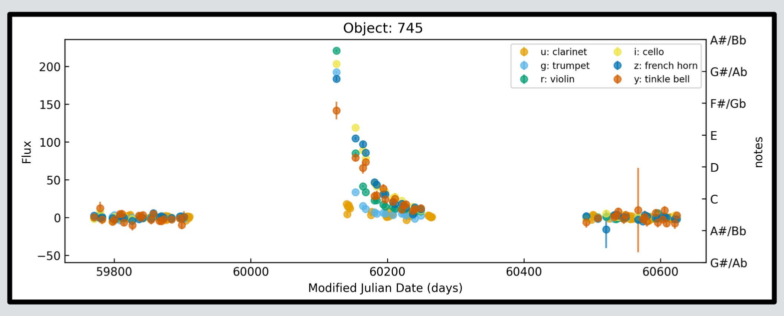
Type Ibc Supernova



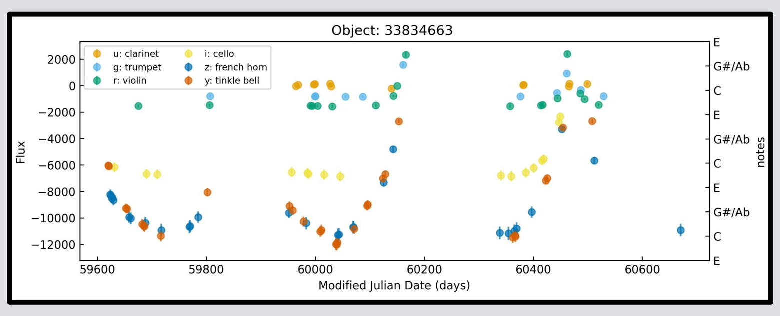
Eclipsing Binary



Type Ia Supernova



Mystery Object



Scan the code with your phone camera to hear the sonifications of the data above on our website!
Be careful! *Some notes can be very high pitched. Make sure the volume is appropriate.*

Outcomes and Future Work

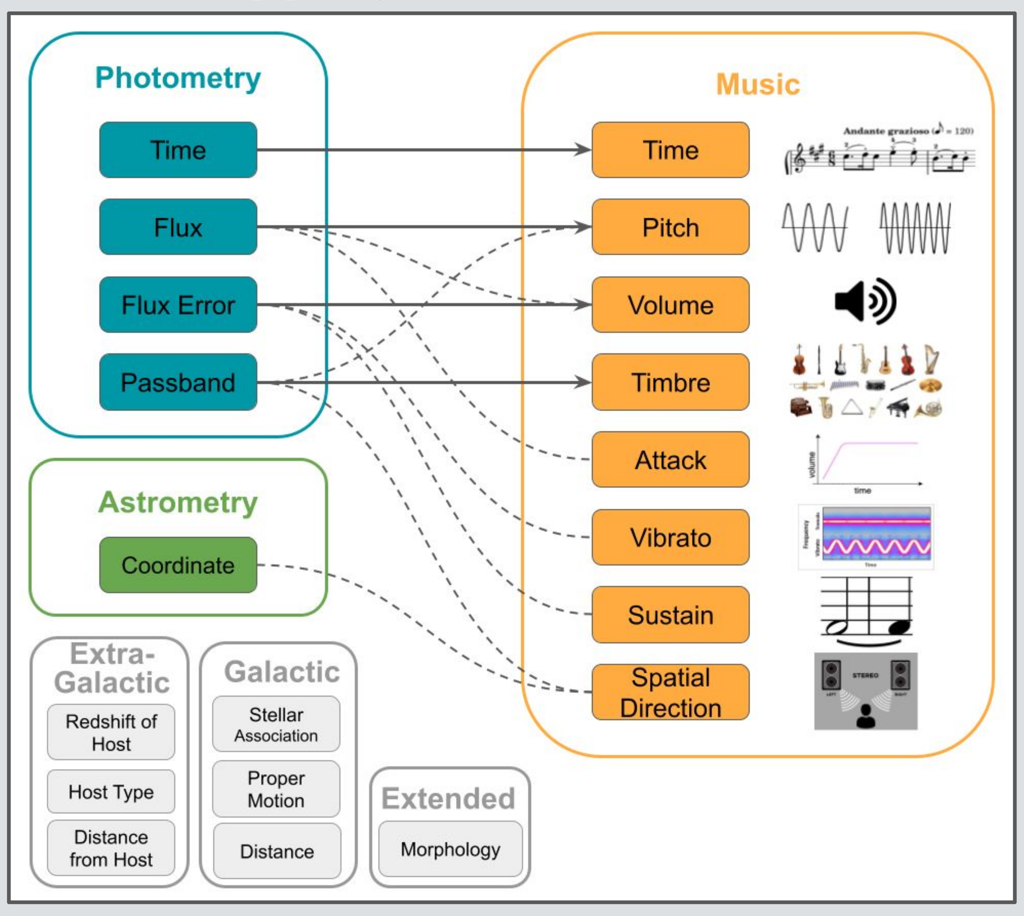
- We prototyped a mapping between LSST data features and sound
- We developed a framework for interdisciplinary collaborations of musicians, astrophysicists, and data scientists.
- We produced a glossary (available on the project's webpage) of music and astrophysics terms that aids communication between musicians and astrophysicists
- Many more mapping schemes should be evaluated
- Controlled experiments will have to be conducted to assess their effectiveness
- The Rubin team has to be engaged to enable implementation of sonification

Parameter Mapping Scheme

How do we select which elements of the data to map onto which elements of the sound?

- **Time → Time:** A boon of mapping time series data to music is that music is also a time series, making this match obvious!
- **Flux → Pitch:** This "intuitive" mapping associates higher brightness with higher notes.
- **Flux Error → Volume:** This mapping de-emphasizes less accurate measurements.
- **Passband → Timbre:** We opted to use different instruments to represent this categorical variable.

NOTE: sonification require a quantization or binning of both time and flux to generate sound representations that are perceptively effective, which adds small inaccuracies in the data representation



Rubin Rhapsodies parameter mapping schema. LSST time domain features data are shown on the left and sound properties on the right. Potential mappings we considered are shown by the dashed lines, whereas the mappings we chose are indicated by the solid arrows. Additional parameters associated with extragalactic, galactic, and extended sources that should be considered for sound mapping are shown.

Orchestrating the LSST Data

- Choosing a key
  - F Major Lydian is the key the sonification is in.
  - The fourth note in the key is raised by a half step which gives it a brighter sound.
- Mapping instruments to photometric bands
  - We chose "brighter" sounding instruments for higher frequency of light
  - Each band has a specific sound so one band would not be louder than the next
- Choosing instruments
  - The *flute* and *trumpet* are both "bright" sounding instruments and they both produce sharper sounds so we associated them to bluer bands (*u, g*)
  - The *violin* and *cello were* two of the initial instruments we had chosen for the sonification
  - The cello was switched with the *bassoon* because the violin and the cello had similar sounds in the sonification given the range of pitch that was imposed by the mapping to flux
  - A *tinkle bell* was chosen for the Y band. The bell allows for a large pitch range. Y is between the traditionally classified optical and infrared spectral regimes, justifying a different kind of instrument.
- It was noticed that only some instruments sounded realistic and others were stretched beyond the pitch range of the instrument
  - Based on the flux range we had to choose instruments that were capable of large pitch ranges
- Pauses between observations sounded disorienting to the audience
  - We added a 'drone' - a simple continuous pattern in the background
  - We mapped the drone to the moon cycle to maintain physical meaning

References

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