# Audio Astronomy: Making Night Skies Accessible to the Visually Impaired

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**Abstract**

Motivation: Astronomy is a fascinating hobby that brings the joy of observing night skies to millions of people around the globe, but is inaccessible to a large section of our population who are visually impaired. Conducting visual observations of the sky, using instruments like telescopes, is fundamental to astronomy. The entry barrier into astronomy caused by limitations due to visual disability needs to be overcome.

Goal: My goal is to develop *Audio Astronomy*, a sonification application that pairs with telescopes which enables visually impaired individuals to "listen" to the night sky and have a perceptual experience that corresponds to seeing the night sky.

Approach: Audio Astronomy takes a signal from an astro imaging sensor attached to a telescope, which is pointed at a target object in the night sky. It gathers additional information about this object from a digital sky map database, and then combines both types of information to generate a unique real-time auditory signature of the target object using sonification techniques.

Impact: With the availability of "go-to" telescopes on the market which can automatically point to thousands of known objects in the sky, coupled with my Audio Astronomy platform, visually impaired individuals would be empowered to independently engage in auditory stargazing.

**Problem**

The sky on a dark night is a fascinating sight and has driven people throughout history to look up in awe. Stargazing in particular has the ability to dazzle across all cultures. As an amateur astronomer I believe that astronomy should be accessible to everyone. However, astronomy is fundamentally visual and therefore inaccessible to a section of our population who are visually impaired. This is because conducting visual observations of the sky using instruments like telescopes is fundamental astronomy and constitutes the core of its practice.

In our society there is a growing push for inclusivity and making all walks of daily life, including education, work, and technology more accessible to diversely abled individuals. While Americans with Disabilities Act (ADA) has made great strides in breaking down barriers for people with disabilities in providing physical access to buildings, the spirit of the law has eluded entire fields of rewarding human endeavors such as astronomy. Therefore there is a great need to overcome the entry barrier to astronomy due to limitations imposed by visual disability.

Braille makes books accessible, tactile graphics make diagrams, maps, and charts accessible, and screen readers make computers and smartphones accessible to the non-sighted. However, there are no aids currently available to make telescopes and their views of the night sky accessible to the visually impaired.

**Current Work**

There are primarily two related areas of work that intersect visual impairment and astronomy: *tactile* methods, and *sonification* methods.

***Tactile Methods***

Astronomical Observatory of Padova started an initiative in 2000 to communicate astronomy to visually impaired people by publishing a website with special emphasis on accessibility for the non-sighted which included clean text layouts suitable for screen readers and tactile drawings that could be printed with thermoform or braille printers.

Dr. Amelia Ortiz-Gil from the University of Valencia in Spain developed a project called "The Sky in your Hands" (Ortiz-Gil et al., 2011; Heenatigala et al., 2013). This was a planetarium show for the visually impaired. The acoustic and narrative experience in this show was accompanied by tactile experience where the visitors would feel a hemisphere made of fiberglass with engravings representing the stars and constellations.

There are many other tactile resources that are available for visually impaired people to learn concepts in astronomy, including NASA 3D models[1], IAU Astronomy for Equity and Inclusion[2], NASA Chandra X-ray Observatory Braille/Tactile Posters[3] for 3D Printing, Touch of the Universe tactile kits[4], etc.

Tactile methods are useful for imparting conceptual knowledge about astronomy by tailoring existing educational materials to the needs of visually impaired people, but are not useful for actual hands-on astronomy.

### *Sonification Methods*

Sonification refers to information presentation by means of non-speech audio. Using sound for data analysis has enabled visually impaired professionals make significant contributions in their

[1] https://nasa3d.arc.nasa.gov/
[2] http://sion.frm.utn.edu.ar/iau-inclusion/
[3] http://chandra.si.edu/edu/fettutactile.html/
[4] http://astrokit.uv.es/index.html/

fields, including astronomy. Wanda Díaz-Merced, an astrophysicist, developed sonification methods for "listening" to astronomical data (Diaz, 2012).

Researchers at MIT (Cherston et al., 2016) applied sonification methods on real-time particle collision data from the ATLAS experiment at CERN. In addition to aiding scientific progress and promoting public outreach through this platform, they harnessed real-time sensor data from ATLAS as a canvass for music composition and artistic expression. The musical pieces generated from this work were played in the halls of the Montreux Jazz Festival.

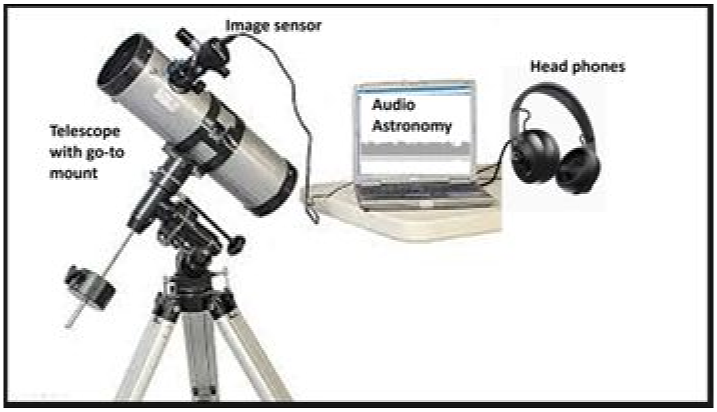
Zhigang Peng (2012) at Georgia Tech sonified seismographic data to bring it into the human auditory range. By "listening" to data from the Great East Japan Earthquake of 2011, he revealed that there were more aftershocks than what was initially reported.

Sonification methods have not only been applied to listen to data but also to aid in non-sighted experience of physical phenomena. For instance, Walker et al. (2006) tackle the problem of providing a sonically-accessible experience of live exhibits for visually impaired visitors in informal learning environments such as museums and zoos. In their *Accessible Aquarium* project, they develop a sonification system for experiencing aquaria via an audio interface.

In summation, there are examples of application of sonification in the domain of astronomy. But they are focused on acoustically analyzing astronomical data, a task that is not directly relevant to this project. On the other hand, there are examples of application of sonification in other domains, like sonifying sensor data from CERN or exhibits in aquaria, which are very relevant and can inform the development of this project.

**Solution**

My solution is to develop *Audio Astronomy*, a sonification application for interfacing with telescopes (of the kind that amateur astronomers use). This software application will be installed on a laptop or a mobile device which is connected to an astro imaging sensor (e.g., CCD or CMOS sensor) which in turn is connected to a “go-to” telescope as shown in the figure below.




Telescopes with computerized “go-to” mounts can automatically point at astronomical objects that a user selects. They are controlled using a hand control that usually has an audio interface which non-sighted individuals can use. Once the target object comes into the view of the telescope, the application will receive the signal of the target via the image sensor. This signal is sonified to produce a unique audio experience taking into account not only the features of the target object but also the viewing conditions which can then be heard via a pair of headphones.

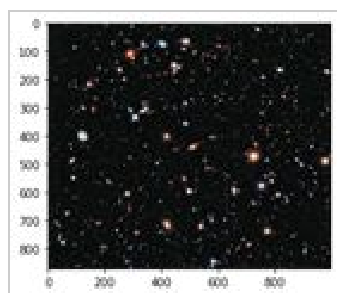
**Project Plan**

***Approach***

- Audio Astronomy application takes a signal from an astro imaging sensor attached to a telescope pointed at a target celestial object in the night sky.

- It gathers additional information about the target object from an open-source digital skymap database which comprises of the object's prominent astronomical features.
- It extracts patterns from the live image signal and combines it with features of the target object through the process of sonification. For instance, distance could be one of the scaling factors - the nearer the object is, the louder the audio signal would be and vice versa. Similarly other factors such as shape, size, color, reflectiveness of the target object can be mapped to a combination of pitch, timbre, tempo, rhythm stability, etc.
- This will generate a unique real-time auditory signature of the target object, taking into account not only the astronomical features of the object, but also the live viewing conditions in the sky.
- If the sonification scheme is designed appropriately, its audio output can enable visually impaired individuals to listen to the night sky and have a perceptual experience that approximately corresponds to sighted individuals seeing the night sky.

To demonstrate the feasibility of this concept, I present a minimum viable Python code that takes an astro image shown below and produces a unique audio representation of the same.




```
# First, some basic imports
import numpy as np
import scipy.signal
import sonify
from skimage import io, viewer, data, color
import astropy.io.fits
from astropy.stats import LombScargle

# load and reshape the image
my_image = data.hubble_deep_field().reshape(218,1000,4,3)

# do a bit of signal processing to find patterns in the image
# For additional background, see Jake VanderPlas' blog at https://jakevdp.github.io/blog/2015/06/13/lomb-scargle-in-python/
my_curve = np.sum(my_image, axis=(1,2,3))
my_time = range(0,my_curve.shape[0])
my_trend = scipy.signal.savgol_filter(my_curve, 25, polyorder=3)
```

```
my_percent_change = 100 * ((my_curve / my_trend) - 1)
my_frequency, my_power = LombScargle(my_time, my_percent_change, nterms=2).autopower(minimum_frequency=1/1.5, maximum_frequency=1/0.6, samples_per_peak=10)
my_period = 1 / my_frequency[np.argmax(my_power)]

# sonify the patterns in the image and play the sound
my_normalized_power = sonify.scale_list_to_range(my_power, new_min=30, new_max=127)
my_processed_signal_data = list(zip(my_frequency, my_normalized_power))
sonify.play_midi_from_data(my_processed_signal_data)
```

***Resources required***

| **Resource** |
|---|
| Celestron NexStar 5 SE Telescope |
| ZWO ASI224MC CMOS Astronomy Camera |
| Laptop |
| A pair of good quality headphones |
| Anaconda Python programming environment |
| Sonification library with Python API |
| Astronomical database with Python API |

I have access to all the above resources required for this project.

***Milestones***

| **Milestone** |
|---|
| Learn to perform astro-imaging with the ZWO sensor. |
| Explore sonification methods that can be applied to ZWO sensor data. |
| Survey and select an open source astronomical database that can be queried via API. |

| |
|---|
| Develop *Audio Astronomy* prototype 1<br>● Explore signal capture from ZWO sensor of the target object.<br>● Identify methods for combining target object's data from an astronomy database with the live signal from ZWO sensor.<br>● Design a sonification scheme (audio design).<br>● Implement the sonification scheme using signal-processing techniques provided by the sonification platform. |
| User study: Test *Audio Astronomy* prototype 1 with mentors and users and get feedback |
| Incorporate feedback and develop *Audio Astronomy* prototype 2 |
| Reach out to institutions such as Perkins School for the Blind, Lowell Association for the Blind, Our Space Our Place, etc., and arrange to throw a Star party! Obtain feedback from larger audience. |
| Complete project report |

***Risks***

| **Risk** | **Mitigation** |
|---|---|
| The signal properties from the image sensor may not be suitable for sonification. | Seek online image/video samples from ZWO or similar sensors and try sonification first. |
| Data from the sensor (signal) is of a different kind than the data from the astronomical database (table). They may fail to be meaningfully combined with each other for sonification. | Establish feasibility by performing simple experiments with samples of signals and tabular data and different methods for combining them. |
| The audio experience may fail to provide the same perceptual experience for the non-sighted as looking at the sky. | Perhaps enhance audio experience with tactile experience of the target object. |
| Data from the sensor is flawed due to interference from, for example, cloud cover or man made object interference. | Overlay astro imaging with established maps of the sky to determine whether the degree of interference falls within a specified threshold |

**Personal Statement**

My love for the sky started with the movie *Apollo 13*. I was hooked on both the death-defying perils of space travel as well as the beauty in the night sky. I gobbled up any books about space I could find. I binge played *Kerbal Space Program*, both for the strange green creatures who act as pilots as well as hyper-realistic physics. Naturally, astronomy seemed like a logical stepping stone for my interests. I bought a telescope, thinking, *"How hard could it be?"* I learned very quickly that it was more difficult than any hobby I had attempted. However, it was fun just being outside with my telescope, listening to the frogs in spring and summer and a million insects singing in a perfect cacophony. I even became a card-carrying member of Amateur Telescope Makers of Boston (ATMoB) in freshman year. (ATMoB is located right next to the MIT Haystack Observatory!) But when I was skilled enough to look in the eyepiece and discern the colors of the planets, stars, and occasionally, deep sky objects, it simply took my breath away. Everyone should be able to experience the spectacular show the universe puts on every night.

My family has been volunteering with an organization called Vision-Aid since 2016. Vision-Aid is a Boston based non-profit organization that serves the visually impaired community. Through my parents' work in this organization, I was exposed to the various services that cater to the unique needs of visually impaired individuals, especially in underserved communities. One that interested me the most was a Python programming course taught for visually impaired students. Because I have a working knowledge of Python, I volunteered and became one of the teaching assistants for this course. Through this experience I became familiar with the immense challenges faced by these students to become successful at programming, which is also an inherently visual activity.

Everyone should be able to experience the night sky, and working with the Vision-Aid students and seeing them overcome their challenges with coding led me to questions about how it would be possible to aid such students in experiencing the sky, which became the basis of my project. This project has the potential to open up a whole new human experience that remains inaccessible to the visually impaired even in this age of greater inclusivity.

**References**

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