A Voyage In Sound and Time - An Introduction To Sonification
Teacher Notes

Background summary

In this project, students investigate the questions 'Why Use Sound In Astronomy? To do Art, or Science, or both?'. They will do activities exploring sonification - representing various data as audio - and links between sound and human study of space, inspired by the work of today's contemporary scientists such as Wanda Diaz-Merced and Nicolas Bonne, among others. It will open up possibilities to students for making science accessible to more people, especially those who, like Wanda, are blind or visually impaired, as well as demonstrating that sonification has a wider impact too.

Key terms

data; planet; moon; sun; solar system; orbital motion; energy; sonification; sensor; plasma waves; heliosphere; frequency; audio; pitch; rhythm; sonority (ie tone colour/ instrumentation)

Context: this project will contextualise and deepen students' knowledge of science history and astronomy; familiarise students with data from astronomical instruments as well as techniques for representing that data in inventive ways; give students insight into making science more accessible, and give them opportunities to explore an interdisciplinary, creative approach to astronomy.

Outcomes: pupils will produce their own experimental sonifications using the online applications 'AfterGlowAccess' as well as 'Two Tone', and use the sonification game 'Black Hole Hunter'.

Exploring and taking inspiration from the album 'X-Ray Hydra' (a collaboration between Diaz-Merced, her colleague Gerhard Sonnert and composer Volkmar Studtrucker), pupils then create a short piece of sonic art (ie. music) based on recordings of the orbital motion of Galilean moons, to accompany a key scene from Brecht's play, 'Life of Galileo'.

Age range: 11-14 (but level of difficulty can easily be modified to suit individuals and different age groups)

Prerequisites: basic knowledge of astronomical objects, in deep space as well as in the Solar System; basic understanding of pitch and rhythm; familiarity with

Level of difficulty: pitched at +/- pre-iGCSE level

Aggregation level: not sure what to put here! But plenty of aggregation of data involved in this demonstrator.

Duration: 1-2hrs

Educational Objectives

Cognitive Objectives

- Gaining an understanding of astronomical data and what it can tell us about the cosmos
- Using the imagination to create innovative ways of interpreting data

Affective

- Recognising and characterising the sensory element(s) of interpreting data.
- Valuing the need for accessibility of study.
- Responding to scientific data analytically as well as artistically.

Psychomotor

- Manipulating digital materials.
- Plotting data.
- Using basic Python programming skills.
- Developing musical skills and relating those to scientific enquiry.

Curriculum links

Astronomy; Music technology; ICT; Music; Physics; Computer science; History; Visual Art & Graphics

Worksheet (please refer to the slideshow for class presentations)

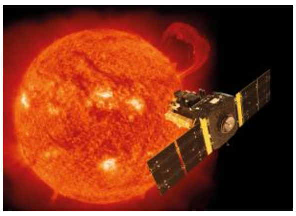
The Big Question: Why use sound in Astronomy? For Art, Science, or both?

Discovery activities:

Listen to this recording. What does it sound like to you?

This is the 'sound' of two black holes colliding. A bit later, we're going to find out how this recording was made and where the sounds came from.

Now listen to this recording. What do you think? Does it sound like anything you recognise? Or perhaps you've never heard anything like it before. It is actually a SONIFICATION of data gathered by a scientific instrument on board the SOHO (SOlar and Heliospheric Observatory) spacecraft, as shown in the artist's impression below (image source: https://solarsystem.nasa.gov/missions/soho/in-depth/).



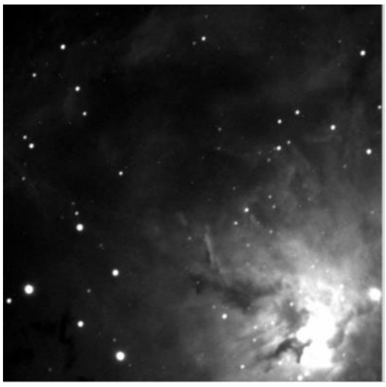
This data is what has allowed scientists to gain new understanding of what is happening inside our home star. The sounds you just heard are a representation of the movement of matter from deep inside the sun, and they give researchers a lot of clues about the way the sun's magnetic field works.
Now play the video via the link below to understand how the recording of the two black holes was made.

Journey of a Gravitational Wave

So what is sonification? This term simply means turning something into sound. If you have any kind of computer data (for example digital pictures, radio waves, any electromagnetic waves picked up by instruments on Earth or in space), it can be turned into something we can listen to. What reasons can you think of to make sounds in this way? Here's a clue: a great deal of astronomy study takes place with

images, graphs and other visual representations. But not everyone has the use of sight! Including curious, creative and clever people with a passion for astronomy…

Team up with a partner. Look at the image below. At least one of you needs to have full sight. If you both do, have one partner wear a blindfold - if you have full sight, describe it as precisely as you can to your partner, who doesn't. Can you imagine what might be the result if it was somehow turned into sounds? How would this be more useful to someone who is blind or visually impaired (BVI) than someone simply describing it?



It's a black and white image of the Lagoon Nebula, or Messier 8 (one of its catalogue numbers). Can you imagine a range of sounds that could be made by the differences between black and white?

AfterGlow Activity

<u>Make your own sonifications</u>

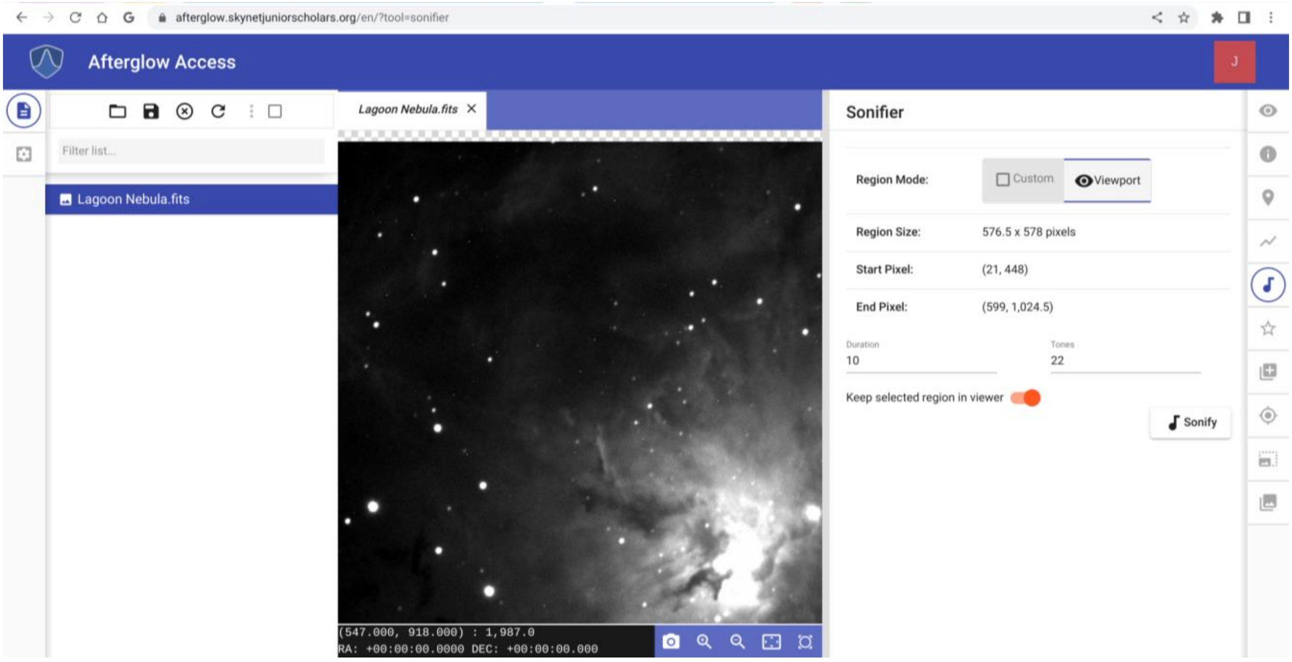
Navigate to this webpage: https://afterglow.skynetjuniorscholars.org/en/

You will need to create an account for this application by signing up with either a Skynet or a Google account.

Once you have the AfterGlow interface open, you can explore the features. First of all, click on the folder icon at the top left of the webpage. Follow the directory path below:

Files > Sample > Deep sky objects

Double click on the second file in the list, ‘Lagoon Nebula.fits’. You should then have the following in front of you:



To begin with, simply click the Sonify button. It may take a while to start, so be patient! What do you hear?

Now try changing both the ‘Duration’ and ‘Tones’ values to various settings - what happens?

If you have made astronomy images using the Faulkes Telescope, you can import these to AfterGlow as well. AfterGlow is able to import .fits (Flexible Image Transport System) files, which are used by astronomers worldwide to work with astronomy data. Using FITS, we can save and transfer the image itself, as well as a great deal of useful data such as filters used, coordinates of the target, exposure settings and so on, all in one file for convenience.

You may want to use a program such as GIMP (GNU Image Manipulation Program), or SAOImageDS9 (FITS reader and analyser) to begin with, stretching/ scaling your image first so that the full amount of data is visible, but make sure you save it as a FITS file so you can open it in AfterGlow!

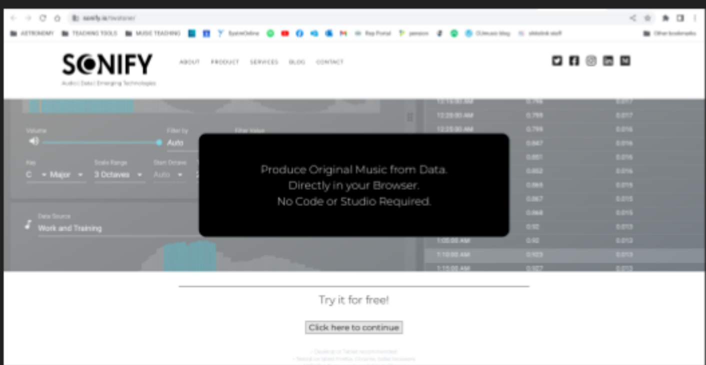
Here's a bit more information about AfterGlow Access from its creator, Timothy Spuck:

> 'Spuck begins by explaining that telescopes do not simply "see" pretty pictures of outer space when they are pointed into the night sky. Rather, they collect numerical data from the light they capture, and a computer takes this data and transforms it into pictures of outer space. At this part of the process, AfterGlow Access steps in. Instead of simply turning the data into an image by means of data visualisation, the program turns the raw numbers collected by the telescope into sound via sonification. Spuck says, "[Y]ou often hear a picture is worth 1000 words, well, how many words is a song worth?" The software sweeps across the data that are transformed into image pixels row by row, emitting a stream of sound that encodes information about each pixel as it moves from left to right, from the bottom row of pixels to the top. Pitch, volume, and timing are employed to convey the state of a pixel (i.e., its position and brightness), and with training, a listener can make out a mental representation of the image.' [*by Janet Weinstein, August 5, 2021, https://partnersforsight.org/*]

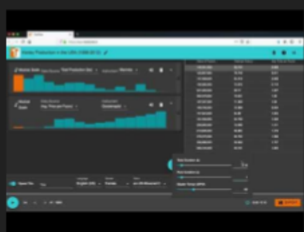
Here, Tim makes an important point about something that songwriters and music lovers have known for a long time - a song can communicate far more than just words alone. It turns out that astronomers, led by pioneers like Dr Wanda Diaz-Merced, are actually able to make more sense of their data by listening to it! In fact, the more we learn about this, it seems that literally anyone using data for research and analysis can make powerful use of sonification technologies. Now try this…

Two tone activity

Open the application 'TwoTone' by clicking on this link. Once open, click on the 'Launch App' button. You should see the following:

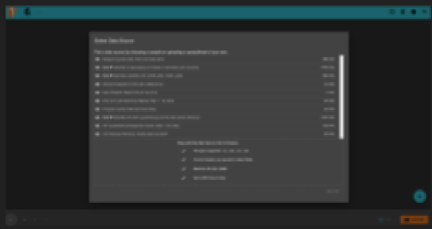


Tip: it is highly recommended to watch this video for a handy tutorial about the app:

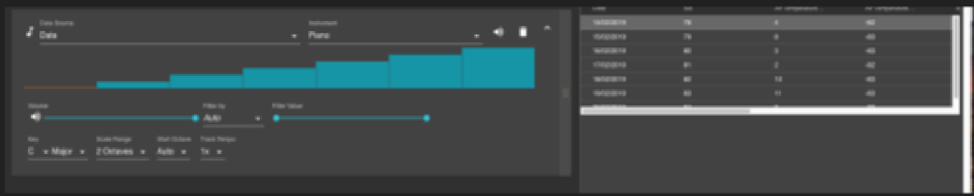


You'll then be asked to fill in some details in order to start the app - don't worry too much about leaving a comment.

Two Tone works with various file formats - the easiest is probably .xls, used for spreadsheets. Once in the app, you can experiment with some preset datasets, which should be interesting to investigate. These include some weather data for Mars, but all kinds of things alongside. Have a look through the library and check for yourself…



Once your dataset is loaded, you can again set different parameters for the sounds it will produce. The arrow in the top right of the data view will give you access to these, as pictured:



You can change the scale, the pitch range, the tempo and tone - try this with the different data available for each dataset (this one shows Mars weather conditions, by date).

Along with this resource there is a spreadsheet (.xls) file of data related to the orbits of the Galilean moons. Load this file into TwoTone.

The next challenge is to make a sonification of this data using TwoTone. Remember that this app has a feature where you can layer different data sets (hint: hover over the blue plus button and select the musical scale option), rather as a musician would using multitrack DAW (digital audio workstation) software. The process is similar, but are you making something creative, or doing science??? That is one of the big questions here of course.

Try loading the different moons as separate ‘tracks’, each with their own unique sound and character. What settings help you to differentiate (separate out) those different tracks the best? Why would that be useful for scientific analysis of the data?

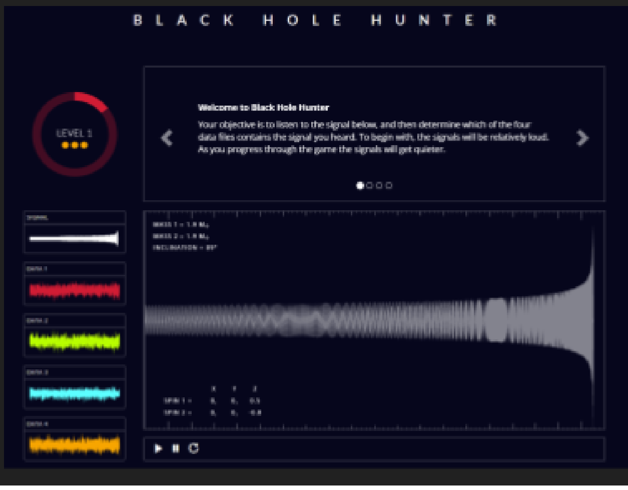
Remember this data set… It may come in useful later.

Also, here’s a nice factsheet from NASA

Black Hole Hunter Activity

This is a wonderful sonification game developed by scientists with [Cardiff University Gravitational Physics Group](), using data from the amazing [LIGO]() gravitational wave detector.

Click on the image below to go to the game's website where you will find more details and full instructions. Test your hearing prowess!

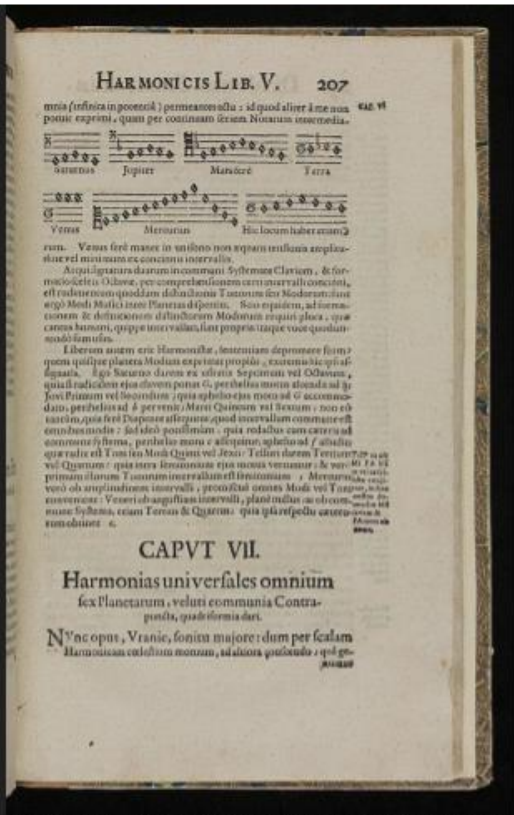


Pioneering Science

Some of the earliest known thinkers were already wondering about the connections between sound and the cosmos, even as far back as the 5th century BC (Pythagorus). He noticed that the pitch of a musical note is in inverse proportion to the length of string (or tube) that produces it. This and the numerical ratios between different pitches (frequencies) making harmonious sounds then led to the idea of *musica universalis,* or music of the spheres.

"Plato's *Republic* VII.XII reads: "As the eyes, said I, seem formed for studying astronomy, so do the ears seem formed for harmonious motions: and these seem to be twin sciences to one another, as also the Pythagoreans say."" [Davis, Henry (2010) [1901]. *The Republic: The Statesman of Plato*. Nabu Press].

Much later, in the 16th century, astronomer Johannes Kepler developed this idea, believing that sounds were made by celestial bodies which could only be heard by the human soul, not by normal hearing. In 1619 he published *Harmonices Mundi* (harmony of the worlds), theorising about planetary data, ratios and relationships between these data and the similarities with the science behind music, harmony and frequency.



Page from Kepler's *Harmonices Mundi*. The scales of each of the six known planets, and the moon, placed on five-line staffs.

More pioneering science: Dr Wanda Diaz-Merced

Once of the leading pioneers of sonification of data, and a globally recognised blind professional astronomer, Diaz-Merced is an incredible figure who has helped to transform the way data is interpreted and, in particular make science accessible to those who have been shut out due to having different physical abilities. The best introduction to Wanda and her work is probably to watch this well known TED talk that she gave in 2016:

The Future…

There is some important work being done currently in the field of sonification - it is an area of science that is quickly gaining in interest worldwide. You can be a part of this! According to a recent study published in Nature, only about 21% of projects using sonification are designed for research purposes, where the vast majority are for education (like this project) or engaging the public (for example the many sonification releases, available online by NASA and other organisations, as well as planetarium displays). This could well change over the coming years, particularly as sonification becomes more advanced (and standardised).

Galileo activity

Now go ahead… Use what you've learned to create a piece of music based on an important episode in science history, the moment when Galileo Galilei explains to an eleven year old boy that the Earth rotates around the sun… An assertion that would one day make him revoke all of his findings in order to save his life. But, in the imagination of playwright Bertold Brecht, Galileo inspired that young soul. You'll find the script (in French and English) included with files for this project.

Using the Galilean moons data you used with TwoTone as a source, and/ or the musical scales from Kepler's *Harmonices Mundi*, create a 1-2 minute musical work as a response to the dialogue from Brecht's play. You could interpret the raw data straight from the spreadsheet as a starting point - 'X-Ray Hydra' is a good example to use for ideas with this option. You could also use the exported audio files from TwoTone as samples or musical starting points for an electronic music exploration… try importing them as .wav or .mp3 files into Audacity which is free, or another DAW (digital audio workstation) of your choice. Logic Pro, Cubase, Protools, Reason, FL Studio, Ableton and a host of other programs will also work well. This is a free, creative activity where you'll need to use your imagination! The only instructions are on this slide…

Image credit: NASA/ James Webb Space Telescope - galaxy cluster SMACS 0723

Evaluation and Conclusion

What have you learned?

How might you use this in future?

Are you more inspired by the artistic side of this project or the scientific side? Or perhaps both equally?

LINKS

https://afterglow.skynetjuniorscholars.org/en/
https://twotone.io/tutorials/introduction-to-twotone/
https://www.system-sounds.com/jupiters-moons/
https://www.rha-audio.com/blog/sound-in-space-interstellar-audio
https://sci.esa.int/web/soho/
https://solarsystem.nasa.gov/missions/cassini/galleries/audio/?page=0&per_page=25&order=created_at+desc&search=&tags=cassini&condition_1=1%3Ais_in_resource_list&category=257
https://www.youtube.com/watch?v=-I-zdmg_Dno
https://www.indiatoday.in/science/story/in-a-first-researchers-may-have-just-detected-background-hum-of-the-universe-1760662-2021-01-19
https://www.sensorystudies.org/picture-gallery/spheres_image/
https://www.volkmar-studtrucker.de/en/newsreader-aktuelles-eng/items/x-ray-hydra-eng.html
https://www.astro4dev.org/7-ancient-cultures-and-how-they-shaped-astronomy-guest-blog/
https://www.rha-audio.com/blog/sound-in-space-interstellar-audio
https://soundcloud.com/esa/a-singing-comet
https://www.parkes.atnf.csiro.au/people/sar049/eternal_life/supernova/pulsars.html
http://hosting.astro.cornell.edu/~deneva/psr_sounds/pulsars_sounds.htm#:%7E:text=A%20weaker%20pulsar%2C%20you%20can,%22thumping%22%20amid%20the%20noise.&text=One%20of%20the%20brightest%20known%20pulsars%2D%2Devery%20pulse%20is%20audible.&text=Because%20of%20its%20extremely%20short,tone%20in%20both%20sound%20files%3F
https://www.nasa.gov/audience/forstudents/5-8/features/F_Tuning_in_Sounds_of_Space_5-8.html
https://radiojove.gsfc.nasa.gov/radio_telescope/data_analysis.php
https://radiojove.gsfc.nasa.gov/radio_telescope/rj2.0_overview.php
https://radiojove.net/kit/order_form.html
https://www.lorentzcenter.nl/the-audible-universe.html
https://www.nasa.gov/vision/universe/features/halloween_sounds.html
https://www.space.com/black-hole-and-galaxy-sonification
https://futurism.com/nasa-records-the-sounds-of-space
https://www.nbcnews.com/sciencemain/how-voyager-1-recorded-noises-when-theres-no-sound-interstellar-2d11701506
https://www.youtube.com/watch?v=DUdLRy8i9qI
https://www.youtube.com/watch?v=LIAZWb9_si4
https://app.gumroad.com/d/0a59e3e994132d1bf2172afb8a9bd0d5

https://app.gumroad.com/d/c27d787b2291df8f2f712e04b90ce9d7?_ga=2.89319000.234524729.1657113121-2055623482.1657113121
https://astromattrusso.gumroad.com/l/data2music-part2
https://www.astromattrusso.com/sonification
https://www.kimarcand.com/
https://news.harvard.edu/gazette/story/2021/01/harvard-scientist-turns-space-images-into-music/
https://earthsky.org/space/sounds-of-space-sonification-chandra/
https://arxiv.org/pdf/2206.13536.pdf
https://chandra.harvard.edu/blog/node/797
https://www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/whose-revolution-copernicus-brahe-and-kepler
https://lweb.cfa.harvard.edu/resources/software.html
https://aui.edu/
https://idataproject.org/
https://en.wikipedia.org/wiki/Wanda_D%C3%ADaz-Merced
https://royalsociety.org/topics-policy/diversity-in-science/scientists-with-disabilities/wanda-diaz-merced/
https://poc2.co.uk/2018/08/29/dr-wanda-diaz-merced-astronomer/