Level	Seeing and Hearing the Invisible
High School	
Time Required	**Lesson Summary**
180 minutes (3 – 60-minute class periods)	Students will understand how data from radio telescopes are used to create images of celestial objects. They will further explore ways to enhance visual representations by including sound using Afterglow Access sonification software tool.

Standards

NGSS

PS4.A: Wave Properties Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2),(HS-PS4-5)

PS4.B: Electromagnetic Radiation Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4)

PS4.C Information Technologies and Instrumentation. Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Vocabulary	Objectives
Electromagnetic spectrum Radio Waves Radio telescope Array Sonification	• Students will be able to explain how images from radio telescopes are formed. • Students will be able to explain and apply the process of image sonification. • Students will be able to create visual, auditory, and tactile representations of an object from radio telescope data.

Materials

PC computers with internet connection
Headphones for each student
Gmail or Skynet accounts for students
AgA manual (download from IDATA to student computers) available at https://idataproject.org/resources/
Printed instructions

For demo:
UV light
Any of the following: $5, $10, $20 bills, credit card, driver license
Remote control
Cellphone or computer camera

For each student:
Color pencils or markers set
Clay for asteroid models
Paper suitable for creating the plaques

Pre-Requisites

Students need to be familiar with the properties and applications of electromagnetic waves and the electromagnetic spectrum.
Familiarity with piano keyboards and musical notes would be helpful. Virtual piano https://www.onlinepianist.com/virtual-piano and various free smartphone apps can be used as needed.

Safety Considerations

Students should be careful when completing activities involving sound and keep the volume reasonably low to avoid damaging their hearing.

Pacing Notes

This lesson is expected to take 180 minutes or three 60-minute class periods. The three class periods do not have to be on consecutive days. For example, the teacher may choose to give more time for homework research and practice with the software and implement the lesson on three Fridays.
Day 1 – Students explore radio astronomy and image formation from radio telescope data. Introduce Afterglow Access (AgA) website and demonstrate activities.

Day 2 – Students explore AgA and complete several activities involving manipulating astronomical images.
Day 3 - Students research significant radio astronomy discoveries. They prepare presentations summarizing their research, demonstrating sonified images, and a tactile model of an asteroid based on radar data.

Before the Lesson

Secure a class set of computers and headphones. Make sure that students have Gmail accounts and can access AgA from classroom computers. You may need to contact your IT department and ask that access to AgA and other websites used in the lesson is permitted. Familiarize yourself with the software using the AGA manual and practice the activities. Create a document listing relevant websites that you can share with the students on your school online platform.

Assessments	**Classroom Instructions**
Pre-Activity Assessments	**Introduction**
Use students' responses to assess their level of understanding of the electromagnetic spectrum and reteach concepts if necessary.	While you are working on administrative duties students should identify each category of energy on the electromagnetic spectrum. In addition, they should list at least one application of the waves from each region. They can do this electronically or on a small piece of paper.
Activity Embedded Assessments	**Activities**
Ask students to	1. Introduce the project with an engagement activity. a. Demonstrate that infrared waves can be made visible by pointing a remote control at the camera of a cell phone and pressing any button. b. Demonstrate that ultraviolet light can be made visible by illuminating a crisp $20 bill, a driver license, or a credit card with UV light. 2. Tell students that they will explore how radio telescopes collect data and how the data is used to form images. 3. Explain that when a radio telescope scans a given area of the sky it receives radio waves from each little spot in the area. A

brainstorm and provide pixel use analogies from every-day experience. Ask students to explain how they selected the colors for their drawings. Students identify the astronomical object from their pixel sheets. Check if all students have accessed AgA and provide help as needed. You may ask other students to provide peer help. Students translate an image into sound and a sound into image. Have students play the sound and display their drawings. Allow students to revise work based on peer feedback. Students download or take screenshots	radio telescope records signal strength. The information is stored in pixels and processed by a computer. The brightness of each pixel is recorded as a number. The data can be further processed to create a visual representation. 4. Distribute data sheets 1 and 2 as well as color pencils sets. Explain that the boxes represent the data collected by a radio telescope as recorded in pixels. The brightness of each pixel is recorded as a number. Ask students to choose their own colors and color the pixels by the number. (This activity was modified from https://www.gb.nrao.edu/epo/image.html) 5. Have students display the images they colored on the wall. Project the actual images on the screen and ask students to identify the objects represented on students' drawings. The images corresponding to data sheets 1 and 2 are available from https://www.gb.nrao.edu/epo/image.html 6. Display astronomical images in different wavelengths from https://contrib.pbslearningmedia.org/WGBH/buac20/buac20-int-astrowavelengths/index.html 7. Ask students to access and explore the website and write down the specific information provided only by the radio images. 8. Introduce Afterglow Access (AgA) website and explain that it is an astronomy image and data analysis software tool they will use to explore how astronomical data can be processed and manipulated. Have students log in AgA with their Gmail accounts and follow along as you demonstrate the main features and controls on the screen. Allow students sufficient time to explore the tools using the AgA manual. 9. Explain and demonstrate the sonification tool. Allow students to explore on their own using sample files as well as other FITS format files they can upload in the AgA work folder. 10. Extend the sonification activity by having students use the Virtual Piano to represent a simple image they draw through sound. As one student plays the sound on the piano for the class, the other students try to recreate the image on paper. This activity may be challenging and time consuming and it would be helpful if the teacher creates some samples in advance as examples. 11. Students complete several tasks in AgA individually or with a partner. They use the Asteroid 216 Kleopatra from the sample folder (in Solar System subfolder) to produce an image similar to a strobe photography image that represents the motion of the asteroid in time. 12. Students identify the asteroid among the other objects and determine the direction in which it is moving. You may also

of images, record sonification, and use them in their presentations. Students display their models and plaques. Use gallery walk strategies for students to view the models and provide feedback on sticky notes. Students present projects and answer questions from the audience. Students provide peer evaluation using a rubric.	extend this activity and relate it to prior physics concepts by asking them to determine the speed of the asteroid at the time the images were taken. 13. Students use the sonification tool to add sound to the image. Have students screen record the sonification. (If they are unable to screen record on their computers, you can allow them to use their cell phones or open a Zoom session where students can share their screen with sound enabled and you can record the session.) 14. As an optional extension, students use radar images of 216 Kleopatra to create a clay model of the "dog bone" asteroid and create a plaque that explains how the data was collected and includes some facts about Kleo. 15. Assign for homework: Students research the different types of radio telescopes and the significant discoveries of radio astronomy. They gather information and images for a slide presentation or a poster they will complete in groups the next day. 16. On day 3, divide the class in groups and give them time to share and discuss the information from their homework research. Groups prepare presentations (posters, slide shows, etc.) summarizing their research and placing their project in historical context. Groups also present their work to the class.
Post Activity Assessments	**Closure**
As you facilitate the discussion, take note of students' answers and identify areas you need to address in future lessons. Accept all answers without judgment and ask follow-up questions.	Whole class discussion To ensure full participation, have an object that students can safely toss to each other. A student who answered a question or shared will pass the object to another student who has not yet participated. Ask the following questions: ● What did you learn about radio astronomy as you completed this activity? ● Share one thing about radio astronomy that you learned from other groups' presentations. ● What are some ways that can help people with visual disabilities imagine the universe? ● How can this activity be improved and extended? ● Anything else related to this activity you would like to share?
Culturally Inclusive/Responsive Components	
● Have students research the discovery of pulsars and the contributions of Jocelyn Bell Burnell to radio astronomy. Ask them to write a brief opinion essay responding to the	

questions: Why was Jocelyn Bell not awarded the Nobel Prize for the discovery of the pulsars? Did she deserve it? Do you think that she and other women astronomers would receive recognition today? Can you provide other examples of people not getting the recognition they deserve?

- Some students with special needs may struggle with academic tasks but excel in computer application activities and should be encouraged and praised. The teacher should ensure that they are teamed up with classmates who can explain the written instructions.
- Students may be asked to research the contributions of their culture in the field of radio astronomy and include these in their presentations.

Educator Resources

Creating a radio image:
https://www.gb.nrao.edu/epo/image.html

Astronomical images in different wavelengths:
https://contrib.pbslearningmedia.org/WGBH/buac20/buac20-int-astrowavelengths/index.html

IDATA website:
https://idataproject.org/resources/

AgA:
https://afterglow.skynetjuniorscholars.org/

Radar images of Kleopatra (article)
https://news.cornell.edu/stories/2000/05/radar-shows-giant-bone-shaped-asteroid

Astronomers Catch Images of Giant Metal Dog Bone Asteroid

https://nssdc.gsfc.nasa.gov/planetary/news/kleopatra_pr_20000504.html

Pulsar in sound video:
https://www.youtube.com/watch?v=35SbvnYEc9c

Journeys of Discovery: Jocelyn Bell Burnell and Pulsars Video (6 min):
https://www.youtube.com/watch?v=z_3zNw91MSY

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Below is a list of the lesson titles included in the series. All lessons can be accessed from this web page, https://superknova.org/educational-resources/.

Middle School

Introduction to Satellites
Weather Predicting
Introduction to Radio Wave Communication
The Importance of Radio Astronomy
Cubesat Model Building
Understanding FM Radio
Radio Frequency Technology
Diffraction of Radio Waves
Who Decides if You Get 5G?

High School

The Uses of Radio Waves and Frequency Allocation
Is Radio Technology Safe?
Diffraction of Radio Waves
Measuring Sea Surface Temperatures with Satellites
Marine Animal Tracking and Bathymetry
How to Design Your Own Crystal Radio
How Radio Waves Changed the World
Simple Wireless Communication
Seeing and Hearing the Invisible
Local Wireless Radio Frequency Communication
Investigating the Internet Connection
The Geometry of Radio Astronomy

Informal

Modeling Radio Astronomy