

An Equatorial View of the Heavens Above

Radio Astronomy in Puerto Rico

STEM careers video

Teacher & Learner Guide

This guide provides background information about the the setting and context of the short film, answers frequently asked questions, and suggests topics for student discussion or reflective writing.

Background Information

Arecibo Observatory, located on the island of Puerto Rico, is the largest radio telescope in the world, and one of the most sensitive. Its most striking feature is its reflecting dish for collecting radio waves. The circular reflector has a diameter of 305 meters and is 51 meters deep. You may have seen it featured in motion pictures or TV shows, including the James Bond film *GoldenEye*.

The Arecibo dish is held stationary because of its immense size, but its antennas can be directed to look at different parts of the sky. They are located on a platform suspended high above the reflector. Technicians who work on the telescope walk about on this platform, which hangs hundreds of feet above ground and is prone to swaying in the wind.

To obtain the curved shape needed for reflecting radio waves, Arecibo's dish was built inside a huge natural sinkhole, in a remote area of stunning natural beauty. The observatory is part of the National Astronomy and Ionosphere Center (NAIC), and, in addition to radio astronomy research, supports planetary radar and terrestrial aeronomy research. As mentioned on the video, the observatory is active 24 hours a day, seven days a week – even on Christmas Day. Scientists from around the world treasure the opportunity



to conduct observations at Arecibo, and the data collected at the observatory are used by many people throughout the scientific community.

The observatory first opened in 1963 and has been upgraded several times since then. Its equatorial location was specially chosen so that, as the Earth rotates once a day on its own axis, the telescope dish traces a wide circular path across the skies and through the twelve constellations of the zodiac. This allows a broad range of observations. If it had been placed at the North Pole instead, its view of the skies would barely change as the planet rotated, and it would be limited to observing a small patch of sky surrounding the North Star.

One hundred and forty people work at the observatory, in many different capacities. It is an important feature of the local economy and a source of great pride to the people of Puerto Rico. As you might gather from watching the video, it takes many people with varied skills to keep the observatory running. There are scientists doing research, technicians and engineers maintaining the telescope, and educators working with the public.



Frequently Asked Questions (FAQs)

How is a radio telescope different from an optical telescope?

When we hear the word *telescope* we usually think of an optical telescope, which greatly magnifies visible objects in the sky. A radio telescope, however, shows what is invisible, allowing us to “see” celestial objects emitting radiation at frequencies our eyes can’t detect. Imagine driving a car in dense fog. Even with your headlights on, you aren’t able to see very far in front of you. If your car could process and display radio waves, you’d be able to see through the fog! A radio telescope can similarly peer through dust and find shrouded objects in the sky. We are able to translate this information and use it to “see” distant planets, stars, galaxies, and other celestial bodies.

Are all radio telescopes set in the ground?

Because Arecibo Observatory is the largest radio telescope in the world, it has a different design from most. Arecibo’s large dish makes it very sensitive to

subtle changes in frequency, but it would be very difficult to support such a structure above the ground. Most radio telescopes have diameters of only 12 to 25 meters and can be tilted to look all over the sky. Arecibo’s dish can’t be moved or tilted, but its focusing antennas can be directed to look at different parts of the sky.

How long will Arecibo Observatory last?

Because we humans haven’t had large radio telescopes for very long, it’s hard to know exactly how long Arecibo will last. The observatory was built in 1963, and pieces of its physical structure and technology are continually being updated and replaced. The dish itself doesn’t have to be modern or high-tech: it is simply a metal mesh (like heavy chicken wire) forming a reflecting surface to focus radio waves onto an antenna. It is made up of many small panels that are repaired or replaced as needed. The specialized computer equipment that translates radio waves into images is very expensive, however, and it is replaced infrequently, perhaps every couple of decades. Other electronic equipment is less specialized, and it is repaired or replaced more often.

What are the different parts of the telescope?

A radio telescope is made up of a dish, or reflecting surface (the most visible part of the telescope), and antennas/receivers, which can be positioned to collect radio waves from different areas on the sky. The dish focuses radio waves onto antennas, which are sensitive to certain wavelengths. A smaller reflector called a Gregorian dome also helps focus the radiation for the antennas to gather. The antennas then send data to a correlator, one of the less obvious, but critical, components of the telescope. A correlator is a dedicated computer that transforms data into an image or spectrum that can be used in scientific research. Other parts of the telescope include specialized computer hardware that traps the signals from the antennas and monitors local conditions, mechanical gearboxes that control the movements of the antennas, cryogenics to keep sensitive electronics cool, and fiberoptics to transmit data.

Because Arecibo is so large, a 900-ton platform is suspended above the dish. Giant jacks allow movement of the platform, which holds the antennas and the Gregorian dome. Walkways let engineers access anything they need to work on to make sure that the antennas can be properly adjusted to point at different parts of the sky.

What purpose does the shape of the dish serve?

The curvature of the dish directs the radio waves onto the antennas. Because this curving surface is integral to the function of the telescope, Arecibo’s location was chosen expressly to take advantage of a natural limestone sink-hole, which cradles the dish from below.

Why is Arecibo so large?

Arecibo is 305 meters in diameter, almost the length of three football fields. Its large size enables it to gather information at very high frequency resolution. The larger the dish, the better the quality of the information it can focus onto the antennas. Just as a large bucket can hold a lot of water, a large telescope dish can collect a lot of photons!

Why is it important to observe outer space at many frequencies?

Knowing what is going on in outer space helps us to understand the history of our galaxy and the universe, how stars and planets formed, how the Earth formed, and whether other planets might have conditions capable of supporting life. Astronomers also study the mysteries of the cosmos out of pure curiosity, and discoveries made at Arecibo could give us clues to our planet’s future as well. If life exists on other planets, it may be detected with radio telescopes. In 1974, Arecibo sent out a message towards a globular cluster 25,000 light years away in hopes of contacting an alien intelligence.

For More Information:

The National Astronomy and Ionosphere Center:

<https://www.naic.edu/ao>

Radio Jove:

<https://radiojove.gsfc.nasa.gov/>



Questions for Class Discussion

1. Both Mayra Lebrón Santos and Carmen Pantoja have advanced degrees. Did they face obstacles in obtaining their educations? Why do you think Mayra feels it is important to give back to the community?

Notes for the discussion

Depending on your geographical location, the resources available for studying science vary. For instance, only 32 graduate degrees are offered by the University of Puerto Rico. This means that for certain fields, it may be necessary to go elsewhere for school. Mayra Lebrón Santos went to Mexico to receive her doctorate.

The video notes that Carmen Pantoja was the first Puerto Rican woman to become a professional radio astronomer. In many fields of science and technology, in both academic and professional settings, there is still a gender imbalance. Mayra and Carmen talk about providing examples for others considering entering the sciences. They consider it important to take part in outreach and education alongside their research.

2. How important do you think it is for astronomers and other scientists to speak other languages or to visit other countries?

Notes for the discussion

Scientists from many countries do research at Arecibo Observatory, and data gathered at Arecibo is used all over the world. Scientists often collaborate with people from other countries or go to other countries to study. Carmen Pantoja, for instance, spent time at the Smithsonian Astrophysics Observatory in Cambridge, Massachusetts, and Mayra Lebrón Santos did her graduate work in Mexico. Studying or working in other countries not only opens up new avenues of research and opportunity but also expands people's world views by exposing them to other cultures and values, something that can be extremely important in science – and in life.

3. Why is it important to have radio telescopes in addition to optical telescopes? What do radio telescopes allow us to see that we can't see with optical telescopes?



Notes for the discussion

Mayra Lebrón Santos tells us that radio astronomy is particularly important in studying the formation of stars because stars form inside clouds of gas and dust, through which their light and activity can't be seen. Radio telescopes can penetrate the clouds to "see" what's within them. If we didn't have radio telescopes, we would only be able to guess at how these stars were forming.

4. How often have you had the opportunity to visit scientific research facilities, or to talk with scientists about their work?

Notes for the discussion

One of the most interesting things about Arecibo Observatory is that visitors of any age can see the telescope and learn about the work that is done there. We often don't think about certain careers unless we know someone in the field. Mayra Lebrón Santos emphasizes the importance of giving back to the community by participating in outreach efforts. One way you can meet scientists is to visit laboratories or other places where research is done. At some research facilities, it is possible to volunteer or do internships.

5. What are some of the applications of the data gathered at Arecibo?

Notes for the discussion

Despite the amazing tools we have for looking at the sky, there is so much we don't yet know about the solar system and our galaxy. As we accumulate knowledge over time, we will have a better sense of the processes of star and planet formation and evolution. More sensitive instruments for gathering data will allow us to detect a broader range of radio waves coming from the farthest reaches of space. We could discover new planets or astronomical phenomena. If life exists elsewhere in the universe, radio telescopes are one important way we could discover it.



NASA, ESA, and the Hubble Heritage Team (STScI/AURA) –
ESA/Hubble Collaboration

Questions for Reflection

These can be used as writing assignments, as homework, or as in-class assignments.

1. Have you ever visited a place and wanted to work there? What would you like to do there? Do you think it would be possible to volunteer there? Or do you think you could work there in a job that does not require a particular degree? Mayra Lebrón Santos mentions that in college she began working at the observatory.

2. What do people in your family do for work? Did they have to complete a certain level of education to do their jobs?

3. Do you think you would be willing to travel to another country to study a subject that interests you? What do you think the challenges would be? In what ways do you think it is important to study in another country?

4. What skills or personality traits do you have that you think would make you good at a field you wish to enter? Both Mayra Lebrón Santos and Carmen Pantoja are more than scientists. They have great passion for their subject, and they are interested in getting other people excited about astronomy.

5. Mayra Lebrón Santos expresses an appreciation for the beauty of astronomy. She calls astronomers "the artists among scientists." Do you think these feelings are important to what she does?

For more information about our educational film series or to discuss its use in a educational setting, please contact the GEAS Project at New Mexico State University.

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<https://astronomy.nmsu.edu/geas>



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