Radio Waves: Another Eye to View the Universe

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In April of last year, a black hole at the center of the supergiant elliptical galaxy M87 in the constellation Virgo was revealed to the world for the first time ever by the Event Horizon Telescope (EHT). Albert Einstein's general relativity theory had been confirmed for the first time in 1919, when British astronomer Sir Arthur Eddington observed the gravitational lensing effect of starlight being bent by the Sun's gravitational field. The EHT team's success 100 years later in observing the M87 black hole—with a mass 6.5 billion times greater than the sun—showed that Einstein's theory also holds in cases of strong gravitational fields.

The "Earth-size" EHT radio telescope was used to observe this black hole 55 million light-years from the Earth, by utilizing a technology known as very long baseline interferometry (VLBI) to link together radio telescopes across the globe. The resolution achieved by EHT is approximately 20 microarcseconds (where one arcsecond equals 1/3600 degrees)—a level at which it would be possible to read a newspaper in New York from a sidewalk café in Paris. As EHT project director Sheperd Doeleman said, EHT has achieved something presumed to be impossible just a generation ago. Now we are in a new era where we can observe black holes directly using radio telescopes.

Radio waves are widely used in our daily lives—in things like Wi-Fi wireless internet technology, Bluetooth, DMB, and radios. But areas such as radio telescopes and radio astronomy can come across as unfamiliar to the public. Indeed, Wi-Fi, which is the standard for wireless internet technology, was developed by John O'Sullivan, an Australian physicist and engineer at the Commonwealth Scientific and Industrial Research Organization (CSIRO), and emerged out of the development of devices for radio astronomy to detect signals coming from mini black holes, which had been proposed in the 1970s by British physicist Stephen Hawking. The aperture synthesis technique used to image the M87 black hole observed by EHT was first developed by the British radio astronomer Martin Ryle and is commonly used today in medical imaging systems such as magnetic resonance imaging (MRI), computerized tomography (CT), and positron emission tomography (PET). Things like radio telescopes and radio astronomy may seem strange to us, but the science and technology that have emerged from them have become closely integrated parts of our daily life.

The birth of radio astronomy dates back less than 100 years. This is much briefer than the history of optical astronomy, which developed rapidly after the invention of the optical telescope in the 17th century—before which mankind had only been able to observe the night sky with the naked eye. The existence of electromagnetic waves was discovered in 1887 when the theories of the Scottish physicist James Clerk Maxwell, who had predicted them earlier in the 19th century, were experimentally proven by the German physicist Heinrich Hertz. Hertz discovered that electromagnetic waves also exhibited the same characteristics as light, such as refraction, reflection, and diffraction. Eight years later, the Italian electrical engineer Guglielmo Marconi invented a radio communication device, his successful experimentation laying the groundwork for the long-distance wireless communication of today. Around the same time, the American inventor Thomas Edison hypothesized that electromagnetic waves must also emerge beyond the Earth from the Sun, proposing experiments to detect them. These rapid advancements in electromagnetics and radio communication in the late 19th century paved the way for the radio astronomy that provides us with another eye to view the universe.

In 1932, American physicist and radio engineer Karl Jansky discovered radio waves that were being regularly detected from one particular direction—not produced naturally from the Earth, but coming from the center of the Milky Way galaxy—when he was investigating sources of static in radio transmissions for Bell Telephone Laboratories. It was the first discovery of cosmic radio waves and laid the foundation for the emergence of radio astronomy. Today, Jansky is called the "father of radio astronomy," and the basic unit for measuring the flux density in radio astronomy is called the "Jansky" (Jy; $1\mathrm{Jy} = 10^{-26}\ \mathrm{W/m^{-2}Hz^{-1}}$) in his honor.

Grote Reber, an American with a strong interest in amateur radio and astronomy, played a pivotal role in pioneering radio astronomy by merging those two fields. In 1937, he built the first parabolic radio telescope in his own backyard; it measured 9 meters in diameter, and he was able to use it to observe Jansky's discovery. Using his radio telescope, Reber went on not just to observe the Milky Way and the Sun, but also to discover the existence of radio galaxies like Cygnus A and Cassiopeia A, as well as supernova remnants. He was the first radio astronomer—and for the next decade or so, the world's only radio astronomer. Rapid developments in antennae, radar, and other wireless technology after World War II led to advancements in radio telescopes, paving the way for such important astronomical discoveries as the hydrogen line, quasars, pulsars, and cosmic background radiation.

Cosmic radio waves are very weak, and thus detecting them requires a telescope with a very large diameter. As mentioned before, the Jansky—a basic unit used in radio astronomy to represent the flux density of a radio source—is equivalent to 10^{-26} watts, which gives an indication of just how faint cosmic radio waves are. You need a telescope with a large diameter to detect just a weak cosmic radio signal, which explains why radio telescopes typically have diameters measuring in the dozens to even hundreds of meters.

There are several radio telescopes in South Korea. The first Korean radio telescope with a diameter of 14 meters is situated at the Taeduk Radio Astronomy Observatory at the Korea Astronomy and Space Science Institute in Daejeon. Completed in 1985, it has been put to active use studying regions where stars are formed, evolved stars, and interstellar clouds by observing radio molecular lines and continuum emissions. The Seoul National University Radio Astronomy Observatory has a radio telescope with a diameter of six meters, which has been used to observe radio sources at 230 GHz —the highest observation frequency in South Korea. Three 21-meter radio telescopes in Seoul, Ulsan, and Jeju have been linked up to form the Korean VLBI Network (KVN), which is the first VLBI facility in South Korea with the highest angular resolution of one milliarcsecond—capable of distinguishing the hair of someone standing on N Seoul Tower all the way from the peak of Hallasan Mountain on Jeju Island.

The KVN is capable of observing four radio frequencies (22, 43, 86, and 129 GHz) simultaneously, which is an ideal system for millimeter wavelength (over 30 GHz in radio frequency) VLBI observations.

KVN also boasts an innovative cosmic radio receiver, the world's first to be capable of simultaneously observing four frequencies in the 22, 43, 86, and 129-GHz bands. With the KVN, we can now observe the universe with four "eyes," and its receiver system is recognized as the global standard in VLBI, with exports to three radio telescopes in Italy, home of Galileo Galilei and Guglielmo Marconi. Also under way are efforts to implement the KVN's multi-frequency system in the Millimetron, a 10-meter space VLBI observatory to be launched by Russia in 2029. Radio astronomy in South Korea has a short history dating back just around 40 years—but like radio astronomy itself, it has made rapid strides based on outstanding scientific and technological capabilities. I look forward to seeing what new scientific discoveries emerge in the future with advances in scientific technology.

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