# Chapter 14 Active Galactic Nuclei and Pulsars

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## ABSTRACT

With the discovery of radio emission of extraterrestrial origin, it had opened a new and broader window in the electromagnetic spectrum to observe the sky. Two of the common sources of radio emissions are active galactic nuclei (AGN) and pulsars. AGN are very luminous at radio wavelength and are powered by the accretion disk surrounding supermassive black holes at the center. AGN are useful as an alternative standard ruler to determine cosmological parameters. Pulsars, on the other hand, is a type of neutron star that is highly magnetized and rotates at enormous speed. This cosmic lighthouse produces a very precise pulsation period that can be used as cosmic clock.

## THE DISCOVERY OF THE RADIO SKY

It was 1931. Karl Guthe Jansky was wondering what was the source that was causing a mysterious steady hiss in his antenna. He had ruled out all possible terrestrial sources. So, what could it be?

Few years back in 1928, Jansky joined the Bell Telephone Laboratories in Holmdel, New Jersey. At that time, Bell Labs wanted to use short wavelength radio waves for telephone calls across the Atlantic. While the technology for short wavelength radio waves transmission was quite well established, engineers also required to know sources of noise that might interfere with this transatlantic radio telephone service. Thus, Jansky was tasked to find all the possible sources of static that might interfere with the radio voice transmissions. This young engineer then built an antenna for the job. His equipment consisted of an antenna array that was rotatable, a short-wave measuring set and an automatic intensity recorder, and was tuned to a wavelength of 14.6 meters (frequency of 20.5 MHz). The turntable antenna was rotated about a vertical axis and was highly directive in the horizontal plane. It therefore allowed him to determine the directions of any radio signals. The rotating antenna was jokingly known as "Jansky's merry-go-round".

After several months of observations, Jansky found static from thunderstorms, both local and distant, with strength fluctuating greatly with time. On top of that, his records also showed the presence of a

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faint persistent hiss of unknown origin and was unable to associate it with any sources of terrestrial origin. This unknown source of static rose and fell once a day, and for some weeks the signal seemed to be the strongest when the antenna was pointed toward the Sun, which logically led Jansky to think that it might be the radiation from the Sun. As Jansky continued to follow the signal for several months, he found that the peak intensity of the radio waves did not quite match up with the movements of the Sun. Instead of repeating every 24 hours as it would for a solar day, the source repeated every 23 hours and 56 minutes, which corresponded with a sidereal day, i.e. the Earth rotational period with respect to the stars. This observation eliminated the source from inside the solar system; it had to be from objects beyond our Sun that is stationary with respect to the stars. In the paper published in 1933, Jansky narrowed down the coordinates of the source to a right ascension of 18 hours and a declination of -10 degrees, in the direction of the constellation Sagittarius. He was confident that the value of the right ascension was accurate, but the measurements of declination had a huge error of  $\pm$  30 degrees. At that time, he was unsure of the source due to the huge error in declination, but offered two possible regions fixed in space to be considered – one was the center of our Milky Way galaxy, and the other was the point in space towards which our solar system was moving with respect to the other stars.

Two years later, Jansky published another paper in the Proceedings of Institute of Radio Engineers after further analysis of the data on the mysterious hiss-like static. This time he concluded that the source of this interstellar interference "is located in the stars themselves or in the interstellar matter distributed throughout the Milky Way". Jansky raised a question that if the stars were the source, similar radiation but with stronger intensity would naturally be expected from the Sun since the Sun is also a star and it is located so much closer to us. However, he had detected none of it. Unknown to him, the absence of solar radiation detection was due to the fact that the observations were done during the periods of low solar activity. Jansky eventually identified that the radio emission was coming from the center of our Milky Way galaxy, since the signal was the strongest when the antenna was pointed toward that direction. He wanted to continue the investigation of this discovery on the galactic radio waves, but unfortunately, he was reassigned to another project by Bell Labs, so no further advancement was made by him in this field.

Jansky's work on this new approach to astronomy had fascinated a young ham radio operator named Grote Reber. In 1937, Reber built the world's first radio telescope in his backyard and in the subsequent years, he did the first surveys of radio waves from the sky. He published his data in 1944 as contour maps showing the brightness of the sky at 160 MHz. His map revealed several minor maxima in the constellations Cygnus, Cassiopeia, Canis Major and Puppis. The radio source in Cygnus, known as Cygnus A (Cyg A), would prove to be important later in the studies of radio galaxies.

With the discovery of radio emission of extraterrestrial origin, it had opened a new and broader window in the electromagnetic spectrum to observe the sky. We can now not only see the visible light universe with our eyes, but also "listen" to the radio sky with our ears. Radio waves can penetrate through dust allowing us to peer into regions that are obscured by dust at optical light. Soon, radio astronomy would reveal a dynamic and violent universe not seen with optical astronomy. Radio astronomy has slowly emerged to become a new field in astronomy in the early 1950s, with several groups of radio engineers from World War II turning their attention to the study of radio astronomy after the end of the war.

Jansky's pioneering efforts in radio astronomy were not gone unnoticed. In his honor, the fundamental unit of flux density (the strength of radiation) used by radio astronomers, the jansky (Jy), is named after him. 20 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: www.igi-global.com/chapter/active-galactic-nuclei-and-pulsars/250954

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