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Working principle of the radio telescope and the study of the sun

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Abstract. Radio telescopes can help people observe celestial bodies far away from people, which is conducive for astronomers to observe and draw the trend of celestial transformations. The use of radio telescopes allows scholars to study and understand celestial bodies to a new height. At present, the more famous are the Webb Space Telescope in the United States, the Hubble Space Telescope and China's Tianyan. In the case of the eye of Heaven in Guizhou, China, the surface of the eye is covered by a metal layer one millimeter thick, so it can not withstand excessive pressure, and the maintenance personnel need to attach themselves to a giant helium balloon to reduce their weight, the whole process is so careful to ensure the safety of the precision instrument. So there are still some limitations in the development of radio telescopes. This paper will focus on the working principle of the radio telescope, the development of the radio telescope and techniques for observing the sun with radio telescopes, summarize the achievements of the radio telescope so far and the areas that need to be improved. To better understand radio telescopes.

Keywords: working principle, influence, development, observation technique.

1. Introduction

Radio telescopes need to be different from ordinary telescopes. Ordinary telescopes can take pictures of various celestial bodies in the universe, composed of optical lenses, etc., through the photos taken to let people understand the shape, colour, size and so on. The radio telescope is used to study radio waves from cosmic celestial bodies, and can also measure celestial radio intensity, frequency, etc., composed of antennas and receiving systems. Therefore, the obvious disadvantage of radio telescopes is that they cannot form images. In this paper, the working principle and development history of the radio telescope is introduced, and the advantages of the radio telescope and the need for improvement are pointed out. Studying this problem not only allows non-astrophysics students to understand the difference between radio telescopes and ordinary telescopes, to understand the working principle of radio telescopes but also helps astrophysics students to study its impact and improve it.

2. The way radio telescopes work

As shown in Figure 1, the basic workings of a radio telescope. Looking at this simplified image, the parabolic reflector is a parabolic surface that can be used to receive signals and observe celestial changes. Because the object is far enough away from the Earth, the signal in the object presents a parallel light directed at this paraboloid. When it encounters this paraboloid, it will be reflected to an intersection,

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where it will Feed Horn and signal out. Although a part of the light will be blocked by the Heed Horn, the light blocked is so limited that it can be ignored.

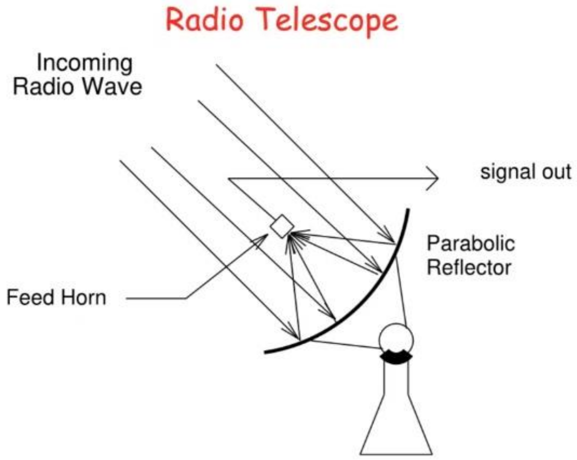

Figure 1. Simplified diagram of the working principle of radio telescopes [1].

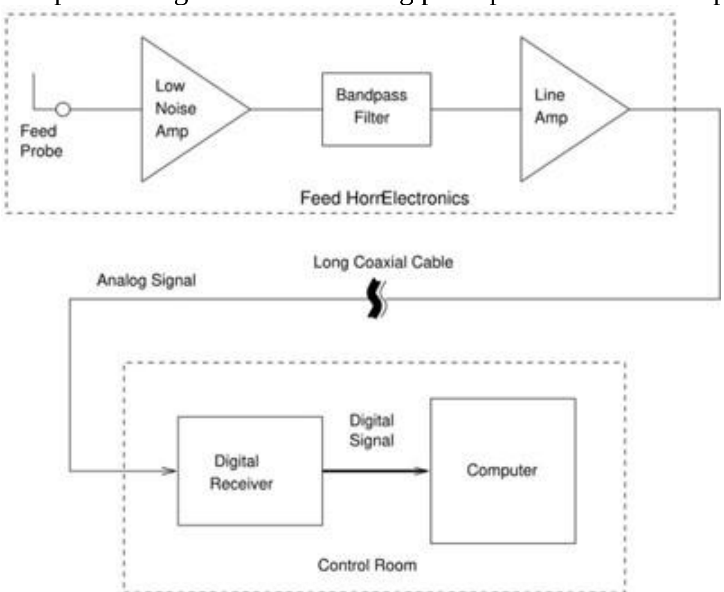

Figure 2. Steps for Reading information with radio telescopes [2].

The signal should be read after it is sent. As shown in Figure 2, after Low Noise Amp, the signal can be amplified, and then the amplified signal passes through the Bandpass Filter to filter out part of the signal and only the signal near the observation band is retained. After Line Amp, the signal and noise can be amplified synchronously, and then the analogue signal is converted into a digital signal and entered into the computer. The data can be observed.

3. Radio telescopes history

At Bell Laboratories in New Jersey in 1931, radio engineer Karl Guthe Jansky is an American, who was in charge of looking for and identifying phone interference signals, found to have a maximum radio interference every 23 hours, 56 minutes and 04 seconds. After careful analysis, he concluded in a 1932 paper that it was radio radiation from the Milky Way. Thus, Karl Guthe Jansky began a new era in the study of celestial objects using radio waves. Using a rotating array of antennas 30.5 meters long and 3.66 meters high, he achieved a 30-degree wide "fan" directional beam at a wavelength of 14.6 meters. Since then, the history of radio telescopes has been one of increasing resolution and sensitivity [3].

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After Karl Guthe Jansky received radio signals from the Milky Way galaxy, the American G. Reber worked hard to build a radio telescope, and finally succeeded in 1937. Before World War II, there was no other parabolic radio telescope like it in existence. Its parabolic antenna has a diameter of 9.45 meters and a "pencil" beam of 12 degrees at a wavelength of 1.87 meters, measuring radio waves from the Sun and other celestial bodies. In 1939, G. Reber received radio waves from the centre of the Milky Way galaxy and drew the first chart based on the observations. Radio astronomy was born. The antenna used by Reber was the world's first dedicated radio telescope for astronomical observations, and Reber is also known as the first parabolic radio telescope [4].

The largest parabolic radio telescope in the world, with a diameter of 76 meters, was constructed in 1955 after construction on a fixed parabolic radio telescope with a diameter of 66.5 meters began in 1946 at the University of Manchester in the United Kingdom. At the same time, competition for the construction of early radio telescopes of various sizes and shapes erupted between Australia, the United States, the Soviet Union, France, the Netherlands, and other nations. Aside from a few pieces of equipment with a diameter of under 10 meters, primarily employed to study the sun, there were also a number of parabolic telescopes with a diameter of 20 to 30 meters, the development of early radio interferometers and synthetic aperture radio telescopes. Since the 1960s, there have been 42.7 meters of the National Radio Astronomy Observatory in the United States, 45.8 meters in Canada, 64 meters of fully rotating paraboloid in Australia, 305 meters of fixed spheres in the United States, radio telescopes operating in the centimetre and decimetre range (see Fixed Spherical Radio Telescope), and a number of millimetre wave radio telescopes with a diameter of about 10 meters. Because of the high cost of rotating parabolic antennas, the technology of antennas with fixed or semi-fixed aperture shapes (including paraboloids, spheres, parabolic cylinders, and parabolic transects) was developed, leading to the construction of more interferometers and cross arrays (see Mills Cross) [5].

In 1960, Martin Ryle (Ryle) of the Cavendish Laboratory of the University of Cambridge, UK, used the principle of interference to invent the synthetic aperture radio telescope, which greatly improved the resolution of radio telescopes. The basic principle is that two radio telescopes separated by two places receive the radio waves of the same celestial body, and the two waves interfere, and the equivalent resolution can be equivalent to a single-aperture radio telescope whose aperture is equivalent to the distance between two places. Ryle won the 1974 Nobel Prize in Physics for his invention [6].

The initial start and development of radio astronomy technology benefited from the "military conversion" of a large number of retired radars after World War II. Radio telescopes work differently from radar, which sends out radio waves and then picks up the echoes reflected by objects, whereas radio telescopes passively pick up radio waves emitted by celestial bodies. In the 1950s and 1960s, with the development and improvement of radio technology, people successfully studied the radio interferometer, very long baseline interferometer, synthetic aperture telescope and other new radio telescope radio interferometer technology enables people to extract useful signals from noise more effectively; Very long baseline interferometers are usually thousands of kilometres apart. Several radio telescopes made interferometric observations, which greatly improved the resolution. From the late 1960s to the early 1970s, not only a number of technologically mature, highly sensitive and high-resolution synthetic aperture radio telescopes were built, but also the so-called modern radio telescopes with extremely high resolution very long baseline interferometers were invented. On the other hand, the design of the classical radio telescope antenna was improved on the basis of computing technology, and a large precision trackable parabolic radio telescope with a diameter of 100 meters was built (near Bonn, Federal Republic of Germany) [7].

Since the 1980s, Europe's VLBI network, the United States' VLBA array, and Japan's space VLBI have been put into use, which is a representative of a new generation of radio telescopes, and their sensitivity, resolution and observation band have greatly exceeded the previous telescopes. The United States Very Long Baseline Array (VLBA) consists of 10 parabolic antennas spanning 8,000 kilometres from Hawaii to SAN Croix, with an accuracy 500 times that of the Hubble Space Telescope and 600,000 times that of the human eye. The resolution it achieves is comparable to a person standing in New York reading a Los Angeles newspaper [8].

After the 21st century, the resolution of radio is thousands of times higher than that of other bands, which can reveal the core of radio objects more clearly. The successful development of synthetic aperture technology makes the radio telescope convenient for imaging ability. The synthetic aperture radio telescope is equivalent to the camera working in the radio band. In order to receive cosmic signals more clearly, scientists have proposed moving radio telescopes into space [9].

Scientists plan to send messages from Earth into space, hoping to actively contact other life in the solar system and pick up their signals. Astronomers will beam signals through radio telescopes to hundreds of distant galaxies in hopes of making groundbreaking discoveries [10].

The project is being led by scientists at the Search for Extraterrestrial Intelligence Institute in California. They see the plan as an important step in human space exploration. If the plan goes well, a region of space 20 light years from Earth will receive these messages [11].

4. Drawbacks of radio telescopes

Because radio telescopes are susceptible to interference from electromagnetic signals, radio telescopes can only be built in remote places, such as deserts and mountains. So as not to interfere with each other, thus affecting the accuracy of the result. Radio telescopes take up a lot of space and waste a lot of land. And for most countries, radio telescopes are expensive. All of these drawbacks inhibit the development of radio telescopes.

5. History of the development of solar radio telescopes

It was founded in 1890 by Thomas. Edison's method of using cables around iron ore to detect solar radio signals was not put into practice, and the earliest observations of the sun began in the 1930s. British physicist Sir Oliver J. Lodge built a solar radio detector in 1897-1900 that was more complex than Edison had envisioned, but still lacking in sensitivity. A subsequent facility built by German astronomers Johannes Wilsing and Julius Scheiner also failed to observe radio signals from the Sun, but they were the first astronomers to write down and publish targets for solar radio observations. In 1900, French graduate student Charles Norman built a wire antenna and mounted it on a glacier in the Alps, and he came very close to detecting low-frequency radio bursts from the Sun. Unfortunately, however, it was during a trough year of solar activity. After that, solar radio observations fell silent for many years. It was not until the 1920s when British physicist Olivier Heaviside confirmed the existence of the ionosphere, that radio astronomers realized that only high-frequency radio receivers (>20 MHz) could pick up the solar radio signals penetrating the Earth's ionosphere. In 1942, British air defence radar was subjected to intense radio interference, which was later analyzed to be related to solar flares. In the same year, Bell Laboratories in the United States detected the first 1 cm and 10 cm radio radiation of the quiet sun (published in 1945). Grote Reber, an American astronomer, used a self-made radio telescope to detect a strong solar radio signal of 160 MHZ in continuous observations, and in 1944 published a related research paper in the ApJ (Figure 1), becoming the first astronomer to publish the results of solar radio observations. After the end of World War II, solar radio astronomy ushered in an unprecedented vigorous development.

6. Solar observation techniques with radio telescopes

The sun can predict changes in the weather and thus act as a weather forecast. The study of solar element burst mechanism, micro flare physics, three-dimensional magnetic structure, etc., can understand the origin of solar bursts, coronal heating, catastrophic space weather forecast and other important research and application. It can be seen that the use of radio telescopes to observe the sun plays an important role in the development of astronomy. Of course, the existing solar radio telescopes still difficult to meet these needs. The spatial distribution of radio bursts is helpful for further study of violent eruptions on the solar surface. There are many kinds of radio imaging techniques, including scanning mode, multi-beam mode and synthetic aperture mode.

Scanning radio imaging can be achieved using a single radio telescope feed, which is a simple method, but the time resolution is low and the spatial resolution is limited by the aperture of a single telescope.

Even huge, sensitive Radio telescopes like China's FAST (Five hundred meters Aperture Spherical Radio Telescope) At the maximum operating frequency of 3GHz, the spatial resolution of the image of the sun by scanning this way is about 1.5 arc minutes, and the entire sun is only about 400 pixels. So using a single radio telescope has some limitations. In addition, radio observations of the Sun are also related to the Earth's atmospheric window, which exists because the atmosphere is transparent to only a few specific wavelengths, and only in three wavelengths: optical, near-infrared, and radio. The observation of these three bands can be carried out on the ground because the atmosphere does not absorb them significantly, so the centimetre to ten meters level can be observed on the ground, of course, the other bands need to go to higher observation positions or can only be observed outside the atmosphere. There is also a problem worth thinking about, the radio telescope can be seen as a huge convex lens, in the study also need to solve the problem of heat dissipation, otherwise, it will become a giant "solar stove". Of course, if the wavelength is very short, using the scanning method can also be mapped to obtain the solar radio image.

7. Conclusion

This paper introduces the development history, working principle, disadvantages of radio telescopes and using radio telescopes to study changes on the surface of the sun. This paper does not put forward the improvement measures for the disadvantages and does not put forward the need to use other knowledge and attention points when using the radio telescope. Future research can focus on developing ways to reduce the impact of the surrounding environment on the radio telescope, minimize experimental errors, and reduce the footprint of the radio telescope and its research costs so that more countries can begin to study astronomy. Future research on solar radio telescopes can focus on the aspects of spatial resolution, sensitivity and fast imaging.

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