Evolutions and Principles of Space and Radio Telescope

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Abstract. Contemporarily, various types of telescopes have been proposed as tools for cosmology observation. This study discusses main types of telescopes, i.e., space and radio telescopes people used to observe universe and gives deep description and comparison between them. Radio telescope is the telescope which can receive radio waves from the outer space and can detect waves in different wavelengths besides visible light. It has a long history, as radio telescope is built on Earth and relatively easier for people to make it, but the drawback is that radio telescope may be disturbed by nature conditions easily, even a small change in the strength of wind or the thickness of atmosphere can make a huge difference to the result. While space telescope is different. The first space telescope is Hubble Space Telescope, which is launched in 1990, thus the history of space telescope is relatively short. Compared with radio telescope, space telescope has its own advantage: since it works in space, changing nature conditions in Earth will not affect its precision, and some cancan work without the impact of infrared radiation of the Earth. However, the repair and maintenance cost are problems as it is difficult for people to go to space and fix the broken parts regularly. This paper can help people have a better understanding of these types of telescopes which are used frequently in observation for the universe.

Keywords: Telescope, FAST, JWST.

1. Introduction

After people finished exploring the landscapes and resources of the Earth, they set their eyesight on the vast and boundless universe. The universe contains so many things which can satisfy people's need and want, like another planet which is suitable for human habitation, a large sum of eco-friendly fuel which can replace the fossil fuel they use now. One can learn more about the universe and the galaxies contained through building telescopes. The science of understanding the universe includes astronomy and astrophysics. Similar to all natural sciences, astronomy is an experimental field of study. The experiments are observations, and telescopes are its observational tools. The emergence of telescopes has provided great convenience for human astronomical observation [1]. With the development of science and technology, more and more advanced telescopes have been built. Some telescopes are very famous, e.g., James Webb Space Telescope (JWST), Hubble Space Telescope (HST), Five-hundred-meter Aperture Spherical radio Telescope (FAST)and so on. Those telescopes listed made great contributions to human being as they can took photos of some galaxies far away from the Earth. For example, HST observed the first occupy planets people found called HD209458.

The Fig. 1 is an image caught by JWST. The landscape of "mountains" and "valleys" speckled with glittering stars is actually the edge of a star-forming region nearby, which is young and called NGC 3324 in the Carina Nebula. Captured in infrared light by NASA's new James Webb Space Telescope, this image reveals for the areas of star birth which was invisible previously. Telescopes help people see places far away which they cannot see before [2].

The "landscape" is called the Cosmic Cliffs, Webb's seemingly three-dimensional picture looks like craggy mountains on a moonlit evening. Actually, it is the edge of the giant, gaseous cavity within NGC 3324, and the tallest "peaks" in this image are about 7 light-years high. The cavernous area has been carved from the nebula by the intense ultraviolet radiation and stellar winds from extremely massive, burning, young stars located in the centre of the bubble. In the field of astronomy, the launch of these telescope marks a giant leap for mankind, the more advanced telescope makes images more clear and help scientists find more useful information about extragalactic system. This research will focus on concluding the characteristics of 2 telescopes, radio telescope and space telescope and show

their history and working principle, and show how they would contribute to the development of astronomy.



Fig. 1 A diagram collected by JWST.

2. Radio Telescope

In 1609, Italian physicist Galileo created the first astronomical telescope, which was the ancestor of modern telescope. The telescope made the astronomy turned from traditional observation and calculation to the modern scientific method which based on experiment and observation. Afterwards, astronomers have constantly developed and improved optical telescope. The design and manufacture of telescopes experienced refraction telescope, reflecting telescope and catadioptric telescopes, those telescopes are competing for development. In 1865, British physicist Maxwell established electromagnetic theory and concluded that the frequency of visible light is only a small part of the whole electromagnetic spectrum. In 1888, German physicist Hertz experiment discovered the existence of electromagnetic waves, confirming Maxwell's Theory. By 1990, the America had launched the Hubble Space Telescope going into space. 1931-1932, an American laboratory engineer Bellfield Jansky received data from the Milky Way galaxy using an antenna array. This opened the prelude of using radio waves to study celestial bodies. The prologue of Jansky's discovery sparked the attention of American radio engineer Ray Bo's Interest. In 1937, Ray Bo built a telescope in his own yard. The parabolic antenna has a diameter of 9.45 meters and a working wavelength of 1.87 meters, capable of receiving cosmic radio, which marked the invention of radio telescope [2].

When observing and studying radio waves from celestial bodies, radio telescope is the basic equipment used, the telescope is basically made up of directional antennas, which can collect radio waves, high sensitivity receiver which is used to amplify radio signals, the information recording instruments, processing and display system and so on (seen from Fig. 2). The complex structure makes the telescope run normally when observing the universe [3]. Principle of classical radio telescope is similar to that of optical reflecting telescope. As Ray Bo's Radio telescope was the ancestor of the classic radio telescope, the working principle of classic radio telescope can be explained using Ray Bo’s telescope. Its antenna is a rotating paraboloid, and radio waves from celestial bodies are focused on the focal point after paraboloid’s reflection, wave collection device "illuminator", which is connected to the receiver through a feeder wire, will collect the radio. Then, the receiver amplifies and detects the signal will be detected and analysed by the receiver, and being recorded down with an instrument at the output end, then the entire process has been completed [2]. Besides, the performance of radio telescope mainly depends on sensitivity and resolution ratio. The main purpose of using a telescope is to observe and understand the origin and evolution of the vast universe law in current years. Therefore, high light gathering ability and spatial resolution of telescopes are always preferred by astronomers. Collecting light energy strength is reflected in the ability to detect distant and weaker targets, spatial resolution is reflected in seeing details clearly, both of them have a significant impact on the observation results of the telescope [4]. The larger the

antenna aperture, the higher the sensitivity and resolution radio of the telescope. The sensitivity of the telescope reflects its ability to detect weak radio sources, and the resolution rate reflects the ability that the radio telescope distinguishes between two of radio point sources close to each other. The Radio telescope must have sufficient sensitivity and resolution rate, in order to detect the signal of the studied radio source during observation. It distinguishes radio source from adjacent background sources and observes its detailed structure. The developing history of radio telescope is the history to continuously improve the sensitivity and resolution rate.

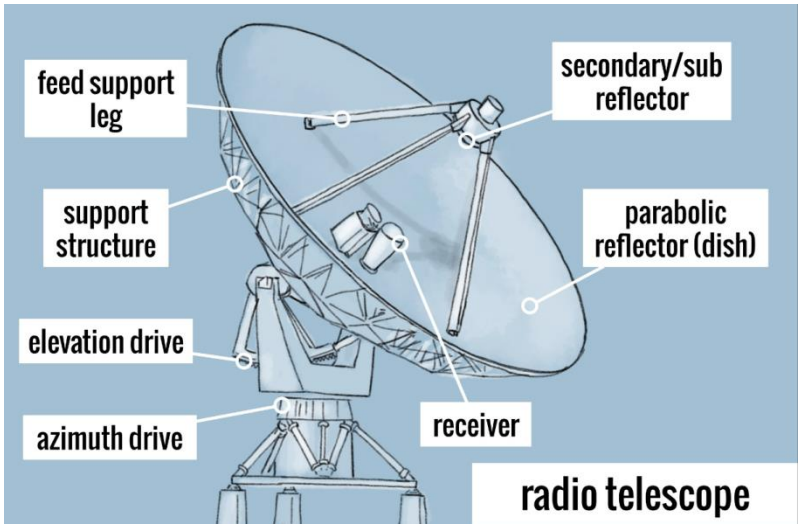


Fig. 2 A sketch of the principle for radio telescope.

3. Space Telescope

In 1608, a Dutch optician invented the first small telescope. The next explosive news is that British scientist Newton revolutionized astronomy. He invented a reflective telescope with a short lens barrel and no chromatic aberration, which later became the weather vane. One hundred years later, William Herschel discovered Uranus with a self-made telescope. He also built the largest reflecting telescope in the world at that time, and confirmed for the first time through observation that the stars in the Milky Way are distributed in a flat shape. Later in Ireland, a larger telescope was built by the 3rd Earl of Ross, and it was this telescope that discovered the first nebula that was not a blur but had structure. After the middle of the 19th century, with the development of science and technology and the improvement of craftsmanship, it became possible for people to build large and precise telescopes. The level of astronomical observation has been greatly improved accordingly, and astronomers have discovered that there are parts in the perihelion motion of Mercury that cannot be explained by Newtonian mechanics. Hubble laid the observation foundation for modern cosmology, the launch of the space telescope inspired thousands of people to explore the universe. In February 1942, they discovered that radar signals could be interfered with by sunspots and flares. In this way, the post-war radar was transformed into a radio telescope, which brought a second leap forward in the development of astronomical telescopes. However, due to the influence of the earth's atmosphere, most of the short-wavelength ultraviolet rays and X-rays cannot reach the ground. The only way to observe them is to go into the space, the place without atmosphere. Aerospace technology brought the third and most radical leap forward for the telescope. In December 1970, the American astronomer Giacconi led the launch of an X-ray satellite named "Liberty". The next milestone space telescope was launched on April 25, 1990. The huge space observatory built under the auspices of NASA - the Hubble Space Telescope with a diameter of 2.4 meters and working wavelengths from ultraviolet to near-infrared, carried by the space shuttle lift off. At a cost of $3 billion, it was the largest, most expensive, and most publicized of all astronomical observation projects. Now people have telescopes that are still operating in space orbit, such as Spitzer, Chandra, and so on, which will continue to obtain amazing data. When the future space telescope is supported by "adaptive optics technology

(AO)", it will usher in the era of giants. Over the past 400 years, the great progress of the telescope has continuously expanded our field of vision, guided the revolution of the human concept of the universe, and promoted the development of science, technology and society [5].

As space telescope is a branch of optical telescope, the working principle can be simplified and explained by using the working principle of optical telescope. In order to observe distant objects. It can magnify the small angle of the distant object at a certain magnification, so that it has a large angle in the image space, making objects that could not be seen or distinguished with the naked eye become clear and recognizable. As for the modern telescopes, The light from the observed target in space enter the primary mirror firstly, then reflect onto the secondary mirror, and then shoot towards the central hole of the primary mirror from the secondary mirror. Passing through the central hole to reach the focal plane of the main mirror to form a high-quality image, and finally using scientific instruments for precision processing, the final processed data is transmitted through the relay satellite system and is sent back to the ground. But space telescopes need more to prepare when taking observation. Operators need to point the Webb telescope at a bright, isolated star in the constellation Ursa Major. When using Webb's near-infrared camera detector, expect to see 18 individual "stars." Operators will keep adjusting to make each "star" as small and sharp as possible until they are all gathered in the sensor's view. Only in this way can the 18 independent sub-mirrors achieve the resolution of "a beautiful single-chip main mirror". "It's an elaborate, detailed step," said Lee Feinberg, Webb Telescope Components Leader. So to speak, the successfully launch and operation of a space telescope is unable to forget the efforts of many people who work hard many years [6].

4. Comparison

Compared with space telescope, radio telescope has a longer history, as radio telescopes are built on Earth and it is easier for people to make, while space telescopes need some complex preparation process because they need rockets to send them to the space and people can only control them by using computer program or sending astronauts to do it manually. Moreover, mostly, it can detect galaxies of larger range, as optical telescopes can only detect electromagnetic wave with regular frequencies, for example, JWST can only detect visible light and infrared wave, while radio telescopes can receive electromagnetic waves of all frequencies in the electromagnetic spectrum. Thirdly, however, radio telescopes have more inevitable limitations compared with space telescopes, atmosphere is a good example, as atmosphere plane gets in the way, what with its clouds and smoke and haze that can block light from distant stars or nearby planets. Even just the air in a clear sky blocks a huge range of the wavelengths of light, pretty much only letting through visible light, and a smattering of infrared and radio waves. The atmosphere has also distraction. At day, visible light from the sun bounces off of air molecules and other small particles and completely overwhelms the light from any other star people might want to look at. At night, the light from the moon and from human sources bounces off the same particles and outshines the light from most distant and faint stars and galaxies, washing out their images. The atmosphere also messes things up, air is constantly moving, and similar to a heat mirage, this turbulence blurs and distorts starlight, which causes stars to winkle, and telescope images of stars to be blurry. While the space telescopes can avoid these problems. Besides, a space telescope can make observations 24 hours a day, and it can be put far enough away from the Earth’s infrared warmth and then cooled down really cold so that it can take clean infrared images, which is considered to take clearer photos.

5. Limitations & Prospects

Although the technology has developed rapidly, there are still some limitations on space telescope and radio telescope. As for the space telescope, the maintenance and repairs are problems for humans, reason being, people do not have enough technology to support them to perform tasks in outer space, especially those telescopes far away from the Earth. For example, the JWST, which works at the point

Lagrange 2, is too far away from the Earth, thus people are unable to fix it when something went wrong or recycle it when it broke down, that's why it carried fuel for using 10 years and every step of launching and changing angles of rockets propulsion had been calculated for many times in case that it can work properly when completing the designated action on the track. Besides, the running of radio telescope is facing limitations: Firstly, in natural environments, the impact of wind loads on the mirror of telescopes can affect the accuracy of mirror shape fitting, which may lead to defocusing and pointing errors, thereby reducing the sensitivity and resolution of telescopes and severely limiting their performance [7].Secondly, With the increase of the radio telescope aperture, the self-weight and temperature will have unprecedented adverse effects on the shape accuracy of the reflector, sometimes a small change in the data collected may affect the shape of final diagram processed and analysed by the computers [8].

With the development of science and technology, more and more innovations will be made incoming radio telescopes (seen from Fig. 3). Although the FAST does not have an advantage in discovering and locating fast radio bursts, but the in-depth detection of repeated bursts and special sources can show the full potential of FAST. [9]. Additionally, there is evidence showing that more radio telescopes will be built [10].

In current period, JWST is the most advanced space telescope, the built of it has promoted the developing of frontier optical imaging observation technology. During the research and development period of JWST, the America simultaneously adopted various technological approaches to tackle large-aperture optical imaging technology. In addition to block deployable technology. It also includes large-aperture single mirror imaging technology, in orbit assembly imaging technology, thin film diffraction imaging technology, optical interference synthesis aperture imaging technology, micro lens array imaging technology, etc., involving the Advanced Research Projects Agency (DARPA) of the US Department of Defense, the National Reconnaissance Agency Military institutions and industrial enterprises such as Loma Corporation (LM). The new application scenarios and even form new combat concepts will be led due to the successful development of the JWST project, JWST, the most advanced space telescope, is expected to further drive the development of cutting- edge technologies for large- -aperture optical imaging [11].

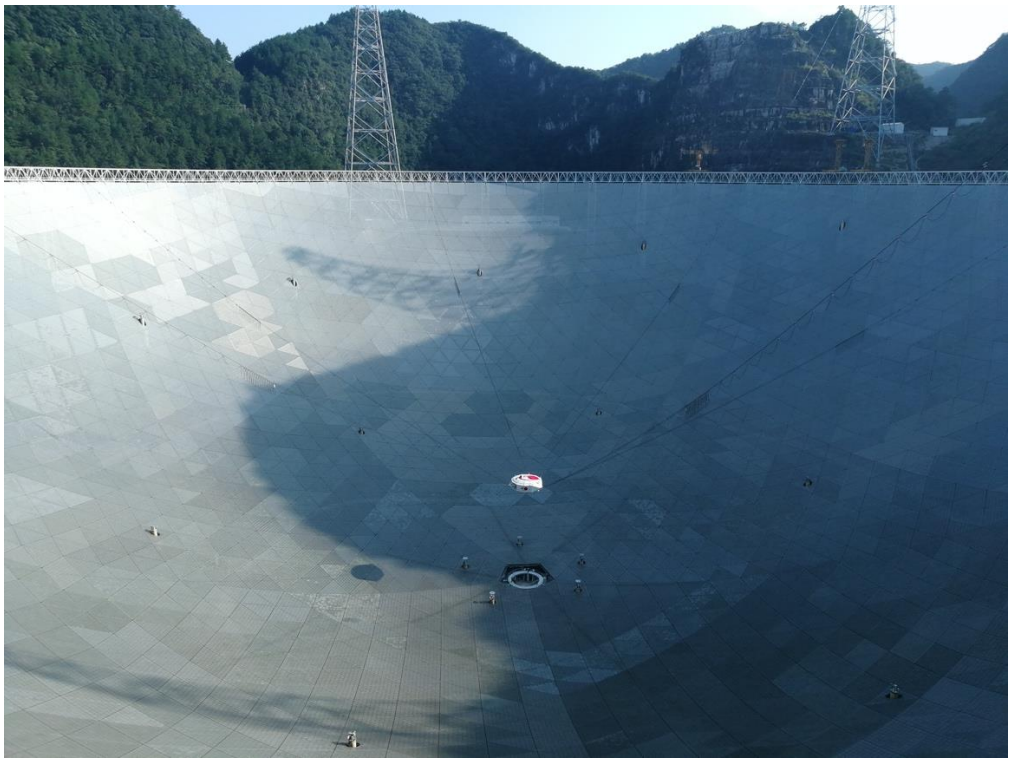


Fig. 3 The FAST feed compartment during the upgrade process

6. Conclusion

To sum up, this study investigates the comparison of the space telescope and the radio telescope based on their histories, working principles, and their limitations and further outlooks. The paper focused on narrating the characteristics of 2 types of telescopes, radio telescope and space telescope, gives description of histories and working principles of 2 types of telescopes and shows their limitations and outlooks. The radio telescopes are invented after the discovery of electromagnetic spectrum, they can receive radio waves from the outer space, and they may have a large floor area as the larger the area of the telescope, the larger light receiving area will be, which means that it has stronger ability to receive weak signals, and can increase the number of observable samples. The space telescope has not been launched until 1990s due to the space technology has not reached a certain level. The space telescope can avoid some disturbances which are unable to ignore in Earth like the atmosphere and the infrared emissions from the Earth itself. Compared with radio telescope, space telescope can take photos of galaxies more directly while the repair and maintained costs are non-negligible and sometimes the telescope cannot be recycled as it works too far away from the Earth. They both have limitations in their fields. The radio telescope may be affected by the natural conditions (e.g., the landscape and weather), space telescope may face problem when some parts of it go wrong and require maintenance. Nevertheless, the outlooks of these telescopes may reduce their limitations in this area: China planned to build 5 more FAST to Form a giant array, and promote the development of cutting-edge optical imaging observation technology. Overall, these results offer a guideline for description and comparison for radio telescope and space telescope.

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