UTILIZATION OF RADIO TELESCOPES IN DETERMINING THE BEGINNING OF THE ISLAMIC CALENDAR

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Abstract

This study analyzes the use of radio telescopes in *rukyat al-hilāl* observations from the perspective of science and *fiqh*. In modern astronomy, radio telescopes have become essential for observing celestial objects emitting radio signals, including planets, stars, and other cosmic phenomena. However, its use in observing the *Hilāl* as a marker of the beginning of the Islamic month is still debated, especially from the perspective of Islamic law (*fiqh*). This study uses a literature study method with a qualitative descriptive approach. The study's results indicate that this technology is not scientifically suitable for detecting the *Hilāl* and determining the beginning of the Hijri month. Meanwhile, from a *fiqh* perspective, radio telescopes cannot be considered valid for observing the *hilāl* in determining the beginning of the Hijri month. Observing the *hilāl* in determining the beginning of the Hijri month requires a visual vision of the crescent moon object visible after sunset as a sign of the start of the new month in the Hijri calendar.

Keywords: *rukyat al-hilāl; radio telescope; science; Islamic law*

Abstrak

Penelitian ini menganalisis penggunaan teleskop radio dalam pengamatan *rukyat al-hilāl* dari perspektif sains dan fikih. Dalam astronomi modern, teleskop radio telah menjadi alat penting dalam pengamatan benda-benda langit yang memancarkan sinyal radio, termasuk planet, bintang, dan fenomena kosmik lainnya. Namun, penggunaannya dalam pengamatan *hilāl* sebagai penanda awal bulan qomariyah masih menjadi perdebatan, khususnya dalam perspektif hukum Islam (fikih). Penelitian ini menggunakan metode studi kepustakaan dengan pendekatan kualitatif deskriptif. Hasil penelitian menunjukkan bahwa secara sains, teknologi ini tidak cocok untuk tujuan mendeteksi *hilāl* dan menentukan awal bulan Hijri. Sedangkan dalam perspektif fikih, teleskop radio tidak dapat dianggap sah untuk digunakan pengamatan *hilāl* dalam penentuan awal bulan kamariah. Pengamatan *hilāl* dalam penentuan awal bulan kamariah mensyaratkan adanya penglihatan secara visual dari objek bulan sabit yang terlihat setelah matahari terbenam sebagai tanda dimulainya bulan baru dalam kalender Hijriyah.

Kata kunci*: rukyat al-hilāl; teleskop radio; sains; fikih*

A. Introduction

Determining the beginning of the month in the Hijri calendar plays a vital role in various Islamic religious observances, such as the Ramadan fast, Eid al-Fitr, and Eid al-Adha.[1] *Ḥisāb* (calculation method) and *rukyat* (observational) are two popular methods among Islamic astronomy academics in Indonesia. As one method, *Ḥisāb* offers certainty in determining the beginning of the month without waiting for observation results. Meanwhile, most Indonesian Muslims still use the *rukyat* method to determine the beginning of the Hijri month.[2] This method is better known as the traditional method because it still considers the results of observations when determining the beginning of the Hijri month. However, with the development of modern technology, questions have arisen about whether this traditional method can be supported or replaced by advanced technology, including optical telescopes, astronomical calculations (*ḥisāb*), and radio telescopes.[3]

Radio telescopes are one of the main tools in radio astronomy used to detect radio waves from celestial objects. In science, these telescopes have provided deep insights into cosmic phenomena that cannot be seen with the naked eye or optical telescopes. However, an interesting discussion has arisen regarding the relevance of using radio telescopes in the context of crescent moon observation. While optical telescopes have been widely used to clarify visual observations of the crescent Moon, radio telescopes work by capturing waves that are invisible to the human eye, so the question arises: can radio telescopes be used to detect the crescent Moon according to the visual requirements of Islamic law?[4]

This study aims to analyze the possibility of using radio telescopes in crescent moon observation from the perspective of science and Islamic jurisprudence. From the scientific side, we will explore how radio telescopes work, whether this

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[1] Fajrullah, Zikrullah Hadi, and Andi Evan Nisastra, "Rukyatul Hilal Instrument Design Based on Arduino," *Al-Hilal: Journal of Islamic Astronomy* 4, no. 1 (2022): 17–40.

[2] Ahmad Adib Rofiuddin and Ahmad Luqman Hakim, "NGOs Contestation on Islamic Hijri Calendar in Urban Muslim Society in Indonesia: From Authority to Identity," *Akademika : Jurnal Pemikiran Islam* 27, no. 2 (November 25, 2022): 171, doi:10.32332/akademika.v27i2.5357; Susiknan Azhari, *Kalender Islam: Ke Arah Integrasi Muhammadiyah-NU* (Yogyakarta: Museum Astronomi Islam, 2012).

[3] M. Aufa Anis Ar-Rofif, "Optimalisasi Instrumen Optik dan Pengaruhnya di Indonesia pada Kalibrasi Proses Setting Circle Teleskop Skywatcher 90/910 EQ2 untuk Keperluan Rukyat Hilal." (Undergraduate Thesis, Universitas Islam Negeri Walisongo, 2022).

[4] Roslan Umar et al., "Observations of the New Moon Using Optical Telescopes and Radio Telescope from the Perspective of Islam," *International Journal of Academic Research in Business and Social Sciences* 7, no. 8 (September 29, 2017): 561–75, doi:10.6007/ijarbss/v7-i8/3262.

technology can detect the crescent Moon, and what limitations radio telescopes have in crescent moon observation. From the perspective of jurisprudence, we will see whether crescent moon observation with non-visual tools such as radio telescopes is by the principles of Islamic law, which generally emphasize direct visual observation or optical aids that clarify the vision of the eye.

The State of the Art of this article focuses on technological developments in crescent moon observation and the determination of the Islamic calendar. Many scholars have accepted the use of optical telescopes as a legitimate tool for observing the crescent Moon as long as it meets the principles of visual vision. On the other hand, radio astronomy has provided extensive knowledge about the universe, including observations of cosmic phenomena that cannot be seen with the naked eye. However, no in-depth research has combined analysis from the perspective of science and *fiqh* regarding the use of radio telescopes in crescent moon observation.

This paper is important because it fills a gap in the literature regarding the relevance of modern technology in supporting religious practices. With the increasing reliance on technology in everyday life, critically analyzing the limitations of technology use in religious contexts is necessary. Furthermore, this paper is interesting because it opens up a cross-disciplinary discussion between science and Islamic law. It provides a holistic perspective on how modern technology can (or cannot) carry out centuries-old religious traditions. Thus, this study will provide deeper insights into the limitations and potentials of using modern technology, such as radio telescopes, in the context of crescent sightings. This study will also clarify whether there is a consensus between contemporary science's perspective and Islamic jurisprudence's principles regarding using technology for crescent sighting and determining the beginning of the lunar month.

B. Method

This study uses a literature study method with a descriptive qualitative approach. A descriptive qualitative approach is used to describe and analyze data obtained from the literature. The focus is to deeply understand and explain the existing scientific and *fiqh* concepts, principles, and arguments.[5] In this approach,

[5] Muhammad Nazir, *Metode Penelitian* (Jakarta: Ghalia Indonesia, 1988); Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif dan R&D*, VIII (Bandung: Alfabeta, 2009).

the author describes and analyzes information from existing literature. The study's results will be presented as a descriptive narrative that tells the main findings related to using radio telescopes in *rukyat al-hilāl* observations and analysis from the perspective of science and *fiqh*.

C. Result and Discussion

1. Legal Foundation of *Rukyat al-hilāl*

Rukyat linguistically comes from the words *ra'ā-yarā-rukyatan*, which means, as explained in the *al-Munawwir* dictionary, namely, to see, to think, to suspect, to guess.[6] According to the Arab linguist al-Khalīl Ibn Aḥmad, the term *hilāl* refers to the first light of the Moon visible at the beginning of the new month, where the crescent Moon is visible to the human eye. In the context of language, the word *hilāl* is rooted in the verb *halla*, which means to appear, or from the passive form *uhilla*, which means to be seen. Both forms emphasize the importance of visual observation in determining the *hilāl*. Thus, the essence of the *hilāl* is not only the physical presence of the Moon in the sky but also the process of humans' direct witnessing.[7] *Hilāl* can also be interpreted as a crescent moon that rises on the first day of the lunar month.[8]

Based on this understanding, it can be concluded that the *hilāl* or crescent Moon is the part of the Moon that looks bright from Earth due to the reflection of sunlight after the conjunction, which is when the Moon is between the Sun and Earth. When the *hilāl* is visible after sunset, it indicates the beginning of a new month in the Hijri calendar. Therefore, observing the *hilāl* is essential in determining the time of worship in Islam, such as the beginning of Ramadan, Shawwal, and Dhulhijjah.[9]

If the terms *rukyat* and *hilāl* are combined, then *rukyat* al-*hilāl* means an effort to observe the *hilāl* with the human eye after sunset. *Rukyat* al-*hilāl* is often carried out on the 29th day at the end of the Hijri month to determine whether a new month

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[6] A W Munawwir, *Kamus Al-Munawwir Arab-Indonesia Terlengkap*, 1st ed. (Surabaya: Pustaka Progressif, 1984).

[7] Muhammad Nurkhanif, "Nalar Kritis Hadis Rukyat Al-Hilal : Kajian Hermeneutika dan Dekonstruksi Hadis," *Riwayah: Jurnal Studi Hadis* 4, no. 2 (2018): 265–80.

[8] Susiknan Azhari, *Ensiklopedi Hisab Rukyat* (Yogyakarta: Pustaka Pelajar, 2008); Muhyiddin Khazin, *Kamus Ilmu Falak* (Yogyakarta: Buana Pustaka, 2005).

[9] Ahmad Izzuddin, *Fiqih Hisab Rukyat* (Jakarta: Erlangga, 2007).

will begin or must wait one more day (perfecting the month to 30 days). *Rukyat al-hilāl* is carried out by observing the *hilāl* that appears on the western horizon shortly after sunset. The basic principle of *rukyat al-hilāl* is visual testimony, where the observation results must be carried out by someone who can be trusted. The testimony of the person who saw the *hilāl* with his own eyes is then used as a guideline by the competent authorities to determine the entry of the new month in the Hijri calendar.[10]

Technically, the crescent Moon is an astronomical phenomenon that occurs when only a tiny part of the Moon is illuminated by sunlight. The reflected light is sunlight hitting the surface of the Moon so that it appears as a crescent moon from the perspective of an observer on Earth. The appearance of this very weak crescent Moon is the basis for observations in determining the beginning of the new month. *Rukyat al-hilāl* is not just a technical process of astronomical observation but also part of the tradition and worship in Islam.

As for *rukyat al-hilāl*, it has been said that it is included in the worship part; this is solely because of following the command of the Prophet Muhammad, as explained in several hadiths. The hadiths of the Prophet Muhammad explain *rukyat* as narrated by Ibn Umar.[11] Determining the beginning of the lunar month using the *rukyat* method is by conducting direct observation on the 29th or end of the month; if the crescent Moon has been seen, then the next day is the beginning of the month, but when the crescent Moon is not seen then the month is completed to 30 days. Nowadays, using aids in *rukyat al-hilāl* has become an important topic often debated among scholars. Along with technology development, especially in astronomy, questions arise about how far these aids can be used without changing the essence of *rukyat*. *Rukyat* is a direct observation of the crescent Moon with the human eye. This is in line with the hadith, which states that observations are made to determine the beginning of the months of Ramadan and Shawwal. In this context, direct observation is the main requirement.[12] Therefore, *rukyat* is interpreted as an activity

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[10] Muh. Nashirudin, *Kalender Hijriah Universal: Kajian Atas Sistem dan Prospeknya di Indonesia* (Semarang: El-Wafa, 2013); Ahmad Adib Rofiuddin, "Dinamika Sosial Penentuan Awal Bulan Hijriah di Indonesia," *Istinbath* 18, no. 2 (2019), http://www.istinbath.or.id.

[11] Abu Husein Muslim bin Al-Hajaj Al-Qusyairi Al-Naisaburi, *Ṣaḥīḥ Muslim* (Riyad: Bait Al-Afkar Al-Dauliyah, 1998); Imam Muhammad Al-Bukhari, "Ṣaḥīḥ Bukhari"," n.d., https://sunnah.com/bukhari:1042,; Ibnu Hajar Al-Atsqalani, *Fath Al-Bāri Ala Sharh al-Bukhārī* (Beirut: Dar al-Fikr, 1995).

[12] Abdul Salam Nawawi, *Ilmu Falak* (Surabaya: Aqoba Press, 2010).

involving the ability to see and direct interaction with the observed phenomenon. Most scholars agree that observation must be done with the naked eye. However, when aids are used, several criteria must be met to remain valid.

With the development of technology, telescopes have become one of the tools often discussed in the context of *rukyat al-hilāl*. Optical telescopes, which clarify objects that are difficult to see with the naked eye, can help observe the *hilāl*. This telescope works in the visible light spectrum, the same spectrum as that seen by the human eye.[13] Scholars who support using optical telescopes argue that this tool does not change the nature of *rukyat* but only clarifies vision. In this case, the telescope does not replace the role of the human eye but rather enhances the ability to see.

On the other hand, some scholars reject using aids, including telescopes, in *rukyat al-hilāl*. They argue that using tools such as telescopes can distract from the essence of *rukyat*, which should be done directly. This opinion is based on the understanding that *rukyat* is a form of worship that requires direct involvement in viewing natural phenomena, and aids can reduce this practice's spiritual and traditional dimensions. They prefer a pure and straightforward approach, where *rukyat* is done directly using the naked eye without technological intervention.[14]

An example of a scholar who allows using aids in *rukyat al-hilāl* is Muḥammad Bakhīt al-Muṭī'ī. He is a scholar from the Ḥanafī school of thought. Al-Muṭī'ī explained the permissibility of a *rukyat* to use aids with several criteria that must be met so that the tool is valid for use in *rukyat*. First, the assistance must clarify existing objects, meaning it helps the eyesight see small and distant objects closer and more precisely, not replace visual observation. Second, the tool must not use a method with reflection because what is seen from the reflection is not the *hilāl* but a picture of the *hilāl*.[15]

In contrast to al-Muṭī'ī's opinion, some scholars have their views about the impermissibility of using aids to perform *rukyat al-hilāl*. His name is Ibn Ḥajr al-Haytamī. The reason al-Haytamī did not allow the use of such aids, as quoted by

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[13] Farid Ruskandana, *Rukyah Dengan Teknologi; Upaya Mencari Kesamaan Pandangan Tentang Penentuan Awal Ramadan dan Syawal* (Yogyakarta: Gema Insani Press, 1994).

[14] Khafid, "Hisab dan Rukyat Kontemporer, Peran Kemajuan Teknologi Sebagai Solusi Sekaligus Pemicu Permasalahan Baru," in *Seminar Hisab dan Rukyat Kontemporer di IAIN Walisongo* (Semarang, 2009).

[15] Muḥammad Bukhīt al-Muṭī'ī, *Irshād Ahli al-Millah 'ilā Ithbāti al-Ahillah,* (Egypt: Kurdistan al-'Ilmiyyah, 1914).

Kristiane, was to avoid his worries that if he used an aid, what he would see would not be the *hilāl* but a picture or shadow of the *hilāl* or it could even be that it was not the *hilāl*, but a planet that resembled the *hilāl*. The example he gave was like seeing the *hilāl* in a mirror reflection.[16]

Technology development has also given rise to more sophisticated observation methods, such as digital cameras or sensor-based devices that detect light. If we refer to the opinion of al-Muṭī'ī, then as long as the tool used is to clarify existing objects, not replacing visual observation, in its original reality (what is produced is the same as what is seen by the eye). This technology is permissible because utilizing the technology currently developing creates a tremendous potential for opportunities to see the crescent Moon when determining the beginning of the lunar month while still not ignoring the basic method of *rukyat* that the Prophet has exemplified.

There is concern that if technology continues to develop, the practice of *rukyat* may lose its meaning and spiritual value. In conclusion, scholars' perspective on using aids in *rukyat al-hilāl* shows the dynamics between tradition and innovation. However, al-Muṭī'ī agrees that using aids is permissible if the tool does not change the nature of the *rukyat* itself. One of the tools used at this time is the optical telescope and crescent image processing from the results of crescent photography, which helps clarify crescent observations. This is still acceptable because the results of using this technology provide the same object results as what is seen by the naked eye. In scientific terms, it is still in the visible light spectrum.

2. History of Radio Telescope

A radio telescope is a directional radio antenna used in radio astronomy. It is also used to track and collect data from satellites and spacecraft. In astronomy, a radio telescope differs from an optical telescope in that it operates in the radio frequency range of the electromagnetic spectrum. As such, a radio telescope can detect and collect information from radio sources in space. A radio telescope is typically a sizeable parabolic antenna or "dish" used singly or as part of an array. Radio observatories are generally located far from urban areas to avoid electromagnetic interference (EMI) from radio, television, radar, and other

[16] Desy Kristiane, "Penggunaan Teleskop Untuk Rukyat al-Hilal: Analisis Pendapat Muḥammad Bakhit al-Muṭī'ī dengan Ibn Ḥajr Al-Ḥaitamī," *Bilancia* 13, no. 2 (2019): 331–54.

electronic devices.[17] This is similar to how optical telescopes are placed away from light pollution. However, radio observatories are often located in valleys to provide extra protection from EMI, as opposed to optical telescopes, generally placed on mountaintops to get a more precise atmosphere. Radio telescopes are designed to pick up radio signals emitted by objects in space. The main difference between radio and optical telescopes is the type of signals they pick up. While optical telescopes pick up visible light waves as part of the electromagnetic spectrum, radio telescopes pick up electromagnetic waves in the form of radio signals.[18]

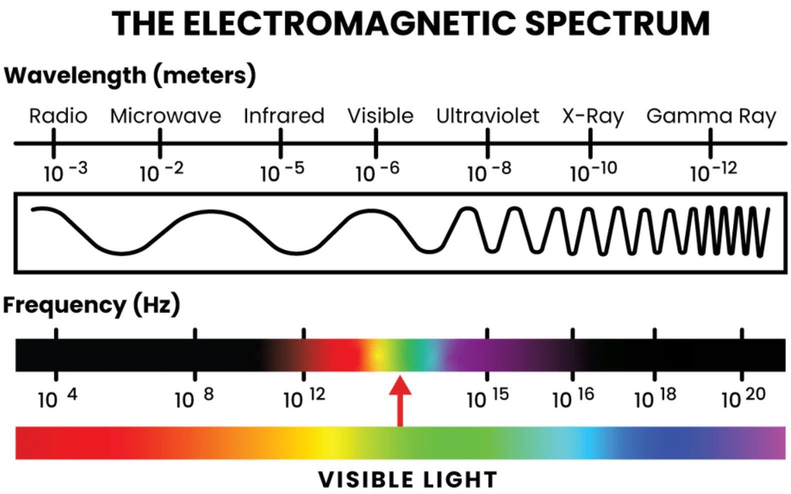

Figure 1. The Electromagnetic Spectrum

Due to the differences in the types of signals captured, the instruments used to collect these signals are also different. Optical telescopes use lenses or mirrors as the main component to collect light, which is then forwarded to an optical detector such as the human eye or a camera. A two-dimensional image of the observed object will be seen or recorded from this detector. In contrast, radio telescopes use a parabola to collect radio signals. The radio signal is then directed to a small antenna as a detector. There are also radio telescopes that do not use a parabola. However, only a long wire stretched as a signal receiver. The shape of the antenna used also varies according to needs.[19]

[17] Jonathan M Marr, Ronald L Snell, and Stanley E Kurtz, *Fundamentals of Radio Astronomy: Observational Method* (Florida: CRC Press, 2016).

[18] A. Richard Thompson, James M. Moran, and George W. Swenson Jr, *Interferometry and Synthesis in Radio Astronomy*, Third Edition (Cham Switzerland: Springer Nature, 2017).

[19] Bernard F. Burke, Francis Graham-Smith, and Peter N. Wilkinson, *An Introduction to Radio Astronomy* (Cambridge: Cambridge University Press, 2019).

The history of the radio telescope began in the early 20th century with an accidental discovery by an American engineer named Karl Guthe Jansky in the 1930s. Jansky, who worked at Bell Telephone Laboratories, was initially tasked with investigating the source of static interference in transatlantic radio signals. Through a series of experiments, he detected a mysterious radio signal coming from outer space. In 1931, Jansky realized that the signal was coming from the center of the Milky Way galaxy, specifically from the direction of the constellation Sagittarius. Jansky's discovery marked the birth of radio astronomy, a new branch of astronomy that does not rely solely on visible light to study the universe.[20]

After Jansky's discovery, interest in radio astronomy began to increase. However, the development of radio telescopes at that time was still minimal. It was not until 1937 that Grote Reber, a radio engineer and amateur astronomer from Illinois, built the first radio telescope in his backyard. Unlike the simple antenna used by Jansky, Reber's telescope used a 9-meter-wide metal dish that more closely resembled the shape of a modern radio telescope. With this tool, Reber succeeded in mapping the distribution of radio wave sources in the sky and discovered radio emissions from various other celestial objects. His work became the foundation for the further development of radio telescopes.[21]

Radio astronomy began to develop after World War II. The radio science and technology used during the war, especially radar, provided an excellent impetus for scientists to develop more sophisticated instruments. Many postwar radio astronomers came from the radar science community. One of the significant advances in radio astronomy came in 1946 when Martin Ryle first used the technique of interferometry at the University of Cambridge, England. Interferometry allowed several radio telescopes to be combined and function as one large telescope with much higher resolution. This discovery revolutionized radio astronomy, allowing for much more detailed observations of objects in space.

During the 1950s and 1960s, large radio telescopes began to be built in various countries. In the United States, the National Radio Astronomy Observatory (NRAO) was established in Green Bank, West Virginia, in 1957. The 300-foot radio telescope

[20] Woodruff T. Sullivan, *Cosmic Noise: A History of Early Radio Astronomy*, Third (Washington: University of Washington, 2009).

[21] Thompson, Moran, and Swenson Jr, *Interferometry and Synthesis in Radio Astronomy*.

at Green Bank became one of the most potent instruments in the world at the time.[22] In Britain, the Lovell radio telescope at Jodrell Bank, which began operating in 1957, was the third largest radio telescope in the world at the time, with a dish measuring 76 meters (250 ft) in diameter. During this time, radio astronomy became one of the most essential tools for understanding cosmic phenomena that could not be observed in visible light, such as radio pulses from very distant pulsars and quasars.

A more recent development occurred in the 1970s when the large array (VLA) was constructed in New Mexico, United States. The VLA consists of 27 radio telescopes that can be moved along different paths and work together to create high-resolution images using interferometry techniques. The VLA has become an icon in radio astronomy and has been used in many important discoveries, including observing galaxies and neutron stars and studying black holes.[23]

Figure 2. Very Large Array (VLA) di New Mexico, Amerika Serikat

In the late 20th and early 21st centuries, radio astronomy peaked with the development of larger and more sensitive radio telescopes. One of the most significant projects is the Atacama Large Millimeter/submillimeter Array (ALMA) located in the Atacama Desert, Chile. ALMA, consisting of 66 radio antennas, became fully operational in 2013 and is being used to study the formation of stars, planets, and distant galaxies in unprecedented detail.[24]

[22] National Radio Astronomy Observatory, "Green Bank," *Https://Science.Nrao.Edu/about/Greenbank*, November 16, 2024.
[23] National Radio Astronomy Observatory, "Very Large Array," *Https://Public.Nrao.Edu/Telescopes/Vla/*, November 26, 2024.
[24] Burke, Graham-Smith, and Wilkinson, *An Introduction to Radio Astronomy*.

Figure 3. Atacama Large Millimeter/submillimeter Array (ALMA)

The history of radio telescopes reached a pinnacle in 2019 when the Event Horizon Telescope (EHT) captured the first image of a black hole. The EHT used a global network of radio telescopes working together as one large virtual telescope with a diameter the size of the Earth using Very Long Baseline Interferometry or VLBI. This achievement was one of the most outstanding achievements in modern astronomy. It demonstrated the incredible potential of radio telescopes in studying the universe.[25]

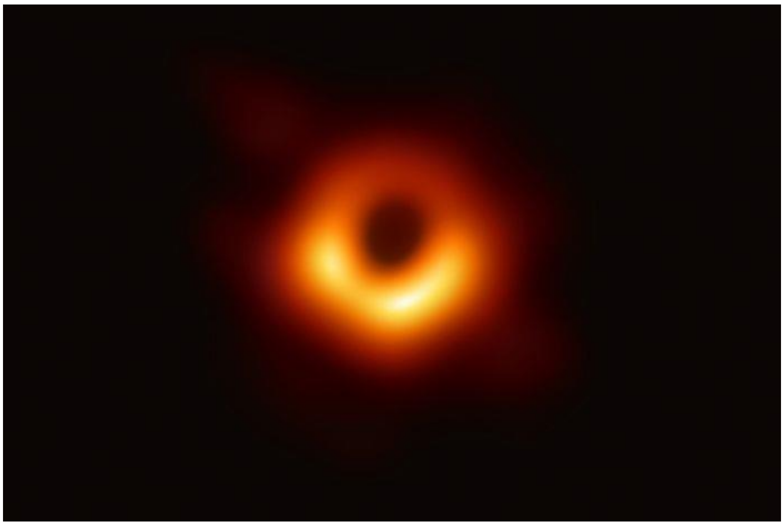

Figure 4. First Blackhole

A radio telescope consists of several essential components designed to detect, amplify, and interpret radio waves from astronomical sources: Antenna (Dish), Receiver, Amplifier, Digital Signal Processor, Computer System, Mount and

[25] Sullivan, *Cosmic Noise: A History of Early Radio Astronomy*.

Structure, and Feedhorn.[26] Some radio telescopes are also equipped with additional components, such as correlators in radio interferometry (an array of radio telescopes working together), which combine signals from multiple antennas to increase resolution. With all these parts working together, radio telescopes can detect and study astronomical phenomena that are invisible to the naked eye, such as pulsars, quasars, and microwave cosmic background radiation.[27]

Figure 4. Radio Telescope Components

The way radio telescopes work is based on their ability to detect radio waves emitted by astronomical objects in space. Unlike optical telescopes that use visible light, radio telescopes capture radio signals that are part of the electromagnetic spectrum with wavelengths longer than visible light, ranging from a few millimeters to several meters. This process allows radio telescopes to see phenomena and objects that cannot be observed with optical telescopes, such as pulsars, quasars, nebulae, and interstellar gas clouds.[28]

AA radio telescope works through several main components: a large parabolic antenna, a radio receiver, a signal amplifier, and a data processing system. The parabolic antenna, often called a "dish," is the primary collector of radio signals. This parabolic shape allows it to direct radio waves from space to a single focal point, similar to how mirrors in optical telescopes focus light on a specific point. This large

[26] Burke, Graham-Smith, and Wilkinson, *An Introduction to Radio Astronomy*.
[27] Thompson, Moran, and Swenson Jr, *Interferometry and Synthesis in Radio Astronomy*.
[28] Ibid.

antenna is essential because radio signals from space are generally very weak and require a large collecting area to increase sensitivity.

After the radio waves are collected and reflected to the focal point, the signal is captured by a radio receiver located at the parabola's focus. This sensitive receiver converts the captured radio signal into an electrical signal. However, because the radio signal from outer space is weak, the resulting electrical signal is also tiny. Therefore, this signal must be amplified using a signal amplifier before further processing. The amplifier is used to increase the strength of the signal so that the data processing instrument can better analyze it.[29]

In addition, the working principle of radio telescopes also often involves using a technique known as interferometry, which allows several radio telescopes to work together as one unit to increase the resolution of observations. In this technique, several radio telescopes are positioned at different locations but are pointed at the same object. The signals from each telescope are combined electronically to create a single image with a much higher resolution than a single telescope. This interferometry is essential for studying the details of very small or distant objects, such as black holes or quasars on the universe's outskirts.[30]

Because radio waves have a longer wavelength than visible light, radio telescopes are not affected by weather conditions like optical telescopes. This allows radio telescopes to operate day and night in cloudy or rainy weather. Radio telescopes can be placed in valleys or low-lying areas to protect them from electromagnetic interference (EMI) from human activities, such as television signals, radar, or other communications devices.[31]

3. Observational Results of Radio Telescope

The National Radio Observatory (NRAO) in Green Bank, West Virginia, has captured a unique radio image of the Moon using radio telescopes. Unlike visible-light images that show the phases of the Moon based on its orbit around Earth, radio images of the Moon always appear "full" at each phase. This is because radio

[29] Marr, Snell, and Kurtz, *Fundamentals of Radio Astronomy: Observational Method*.

[30] Umar et al., "Observations of the New Moon Using Optical Telescopes and Radio Telescope from the Perspective of Islam."

[31] Irvan Irvan and Leo Hermawan, "Mengenal Jenis-Jenis Teleskop dan Penggunaannya," *Al-Marshad: Jurnal Astronomi Islam Dan Ilmu-Ilmu Berkaitan* 5, no. 1 (June 20, 2019): 74–89, doi:10.30596/jam.v5i1.3125.

telescopes detect radio emissions from the entire surface of the Moon, which relies not on reflected sunlight but radiation emitted from the Moon's surface.[32]

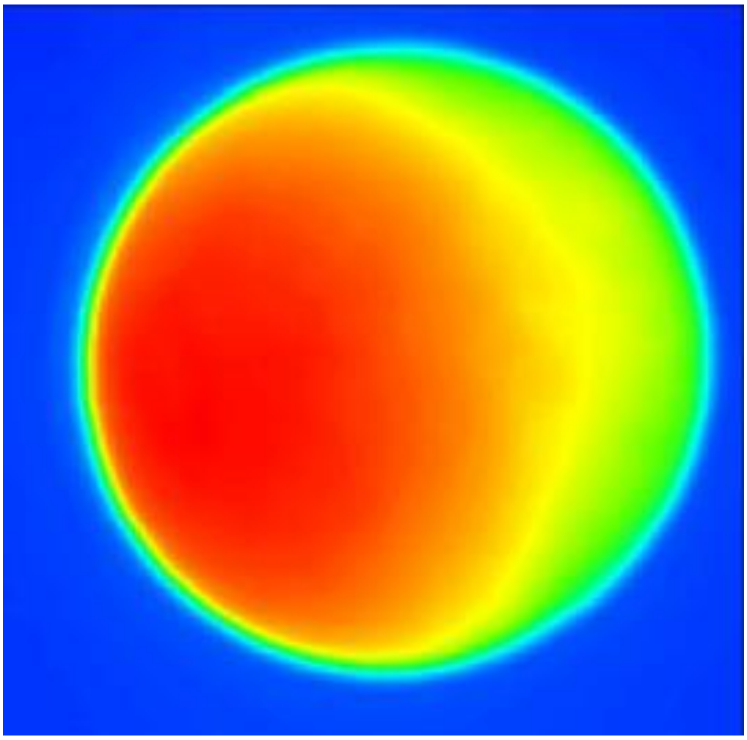

Figure 5. Moon's Radio Image

In this radio image, colors show temperature variations on the Moon's surface. Blue areas represent colder regions, while red areas show warmer regions. Radio waves can penetrate the surface layers and reveal details of temperature and composition, even invisible structures beneath the surface at optical wavelengths. Because the Moon has no atmosphere, its surface temperature fluctuates wildly: the side exposed to the sun is hotter, while the side exposed to the sun is very cold. The phases of the Moon, as captured by radio waves, are always entire disks, with the resulting image showing the surface temperature of the Moon, not the physical Moon.[33] The observation of the new Moon using a radio telescope was done by the Metsähovi Radio Observatory of Aalto University in Finland with a radio telescope

[32] Dhani Herdiwijaya, "Teleskop Radio Sebagai Media Penentuan Awal Bulan dalam Perspektif Astronomi," in *Webinar Dies Natalis Ke-6 Ilmu Falak UINSA Himpunan Mahasiswa Prodi Ilmu Falak* (Surabaya: Universitas Islam Negeri Sunan Ampel, 2021).

[33] Ibid.

called MRO-1.8. The operating frequency range of this radio telescope is between 10.7 and 11.7 GHz.[34]

The new Moon or *hilāl* appears as a disk with weak light intensity because its position has just come out of the Earth's shadow after conjunction or ijtimak. In this condition, only a tiny part of the Moon's surface reflects sunlight toward the Earth, making it appear as a thin crescent with very dim light intensity. The crescent appears on the western horizon after sunset. It has a short duration of appearance, depending on astronomical factors such as the elongation angle (the angular distance of the Moon from the sun) and the height of the Moon above the horizon.

When the crescent Moon is observed with a radio telescope, the image obtained differs from optical observations. In radio observations, the intensity of the signal reflected by the Moon is detected based on the emission of radio waves reflected from its surface. Because the light intensity of the new Moon is very weak and the diameter of the radio telescope antenna is small, the radio telescope can only capture signals with low intensity. The crescent Moon appears as a faint disk at radio wavelengths, and the signals received are not as straightforward as observations during the complete moon phase. The new Moon *(hilāl*) temperature is only around 230.4 - 232.8 Kelvin (-43 - -40 C). The observation was carried out several times from 2018 to 2019 using the radio telescope above.

Based on Herdiwijaya's presentation on radio telescopes, it can be concluded that the smaller the diameter of the radio telescope dish, the smaller the resolution produced by the radio telescope. Observations of the crescent Moon using a radio telescope only create the appearance of the Moon's temperature according to the sunlight that is hitting the Moon. This means that observations made during the New Moon do not form a crescent moon but remain round like the physical Moon.[35]

4. Scientific and *Fiqh* Analysis of *Rukyat al-Hilāl* Observations Using Radio Telescopes

Observing the young crescent Moon using a radio telescope from a scientific perspective raises several interesting questions regarding how this technology can

[34] Juha Kallunki, "A Calibration of the Small Solar Radiotelescope Using a New Moon," *Physics & Astronomy International Journal* 3, no. 3 (May 10, 2019): 110–12, doi:10.15406/paij.2019.03. 00167.

[35] Akh Mukarram, Dhani Herdiwijaya, and Hendro Setyanto, "PeluangTeleskop Radio Sebagai Media Penentuan Awal Bulan Dalam Perspektif Astronomi & Fiqh" (Indonesia: Universitas Islam Negeri Sunan Ampel (https://www.youtube.com/watch?v=0fOZhwhnGDA&ab_channel= IlmuFalakUINSA), November 24, 2021).

(or cannot) be used to detect the crescent Moon and determine the beginning of the lunar month. *Rukyat al-hilāl* is a tradition in Islam that aims to see the first crescent Moon that marks the start of a new month in the Hijri calendar. Scientifically, this is an astronomical phenomenon in which a small part of the Moon illuminated by sunlight begins to be visible from Earth. Radio telescopes, as sophisticated scientific tools used in astronomy to capture radio waves from celestial objects, have a function different from that of optical telescopes or the human eye in observing the crescent Moon.

Radio telescopes capture radio waves emitted by astronomical objects in space, such as stars, galaxies, and other objects. Radio waves are a part of the electromagnetic spectrum that lies outside the range of visible light, so the human eye cannot see them. These waves are often emitted by objects with high energy activity or specific physical processes, such as exploding stars, magnetic activity, or significant events in space. Radio telescopes capture these radio waves with large parabolic antennas and translate them into data scientists can analyze.

However, in this discussion, the Moon is a relatively "cold" celestial body in the radio spectrum, and most of the reflections seen from its surface are sunlight, which is in the visible light spectrum. Therefore, radio telescopes cannot capture these light reflections and will not be effective in detecting the crescent Moon, which is a visual phenomenon that depends on the observation of visible light. In this case, radio telescopes are not designed to capture moonlight but to detect radio wave signals from celestial objects emitting such waves.

In the context of crescent moon observation, radio telescopes are not suitable for visual observation needs. The Moon, including the crescent Moon, only emits visible light from reflected sunlight, and the radio waves that the Moon may emit are very weak or irrelevant for this purpose. Radio telescopes cannot capture or analyze these visible light reflections. In contrast, radio telescopes are more suitable for detecting objects that cannot be seen with the naked eye, such as neutron stars, pulses, or supernova remnants, which emit strong radio signals.

In this case, radio telescopes do not significantly contribute to crescent observation because crescent requires a tool to capture visible light, such as an optical telescope. Crescent observation is done when the Moon is at the right angle in the sky, and the reflection of sunlight from the Moon begins to be seen very weakly. This requires a tool that magnifies visible light, not radio waves. In other words, radio telescopes are irrelevant for crescent observation because they cannot capture signals related to visible light needed to see the crescent.

From a scientific perspective, using radio telescopes is not considered relevant for crescent moon observation. Although radio telescopes are significant for astrophysics and cosmology research, such as detecting radio wave sources from distant galaxies or dead stars, in the context of crescent moon observation, this technology does not work because of its inability to capture visible light. To observe the crescent Moon, a visual optical phenomenon, telescopes that work in the visible light spectrum remain the best choice. Using radio telescopes in science will not provide the expected results in crescent moon observation. This is due to the fundamental differences in the function and purpose of radio telescopes compared to optical telescopes that can capture visible light from the Moon. Therefore, from a scientific perspective, radio telescopes are unsuitable for crescent moon observation and determining the beginning of the lunar month.

Analysis of the use of radio telescopes in crescent observation from a scientific perspective shows that this tool is unsuitable. Although radio telescopes are very useful in astronomical research to study objects that emit radio waves, they cannot capture the visible light needed to see the crescent. In the context of crescent observation, optical telescopes that work in the visible light spectrum are much more relevant. Although advanced tools in science, radio telescopes are not suitable for crescent observation, which depends on the visual detection of the first crescent.

Using radio telescopes to observe the crescent Moon from the perspective of Islamic jurisprudence requires an in-depth analysis of the basic principles of determining the beginning of the lunar month. In Islam, the traditional method recognized is *rukyat al-hilāl*, which directly observes the crescent Moon in the sky. *Rukyat al-hilāl* is vital in determining the beginning of the months of Ramadan, Shawwal, and Dzulhijjah, which are related to worship and include fasting and hajj. Based on the hadith of the Prophet Muhammad, which reads: If you see it (the crescent Moon), then fast, and if you see it (again), then break your fast (carry out Eid al-Fitr). And if (your perspective) is blocked by clouds, then complete the number of the month of Sha'ban with an even 30 days.

As explained at the beginning, *rukyat al-hilāl* is an activity where someone observes the *hilāl*, namely the light of the crescent Moon that is visible after sunset on the western horizon on the 29th. Both observations use the naked eye or optical aids such as telescopes, digital cameras, and supporting applications to process the crescent image so that it can be seen. Several methods used in the *rukyat al-hilāl* observation process, if using the opinion according to al-Muti'i, are permissible as long as the aids/technology are to clarify existing objects, do not replace visual observation, in reality (what is produced is the same as what is seen by the eye), meaning here if what is seen is a crescent moon (*hilāl*) then the results obtained from the aids must also be a crescent. That is what is meant by according to the reality of what the eye sees.

With the development of technology, especially in the world of telescopes, several types have emerged, including the radio telescope. Radio telescopes are different from ordinary telescopes (optics), where optical telescopes capture visible light waves so that what is produced is what the eye sees. In contrast, radio telescopes capture electromagnetic waves through radio signals. Radio wavelengths are something that the human eye cannot observe because human vision is in visible light waves. So, *rukyat* using radio telescopes will produce what cannot be seen by the eye or what does not match what is seen by the eye. The difference can be seen from the comparison of the two images below.

Figure 6. Crescent in visible light wavelengths

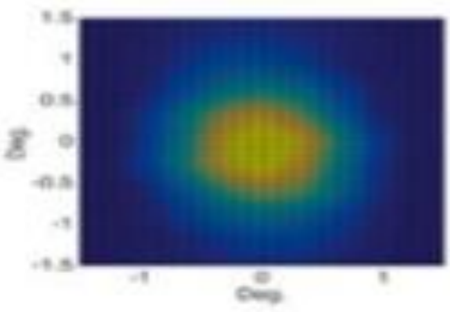

Figure 7. Crescent in radio wavelengths

The image on the left (image 6) is of the crescent Moon at the beginning of the month of Rabiul Awal 1446 H, which was captured at the Sunan Ampel Astronomical Observatory in Surabaya. The image clearly shows what the crescent Moon means: the light of the crescent Moon that is visible after the sun sets on the western horizon. Meanwhile, the image next to it (image 7) results from an image of the crescent Moon from observations using a radio telescope. The image produced by observations using the radio telescope does not look like what we usually see with the naked eye. The resulting image is a designation of the temperature variations on the surface of the Moon during the new Moon (in the form of a crescent moon). The temperature in red is warmer, and the blue color is colder. In observations using a radio telescope, the phases of the Moon captured through radio waves will always be in the form of an entire disk with the results of the image of the appearance of the temperature of the Moon's surface, not the physical Moon.[36]

From a *fiqh* perspective, technology may be used in observing the crescent Moon as long as it supports the conditions that have been determined by the sharia, namely that the aid must be able to clarify existing objects, meaning that it helps the eye to see small and distant objects closer and more precise, not to replace visual observation. Second, the tool may not use a reflection method because what is seen from the reflection is not the crescent Moon but an image of the crescent Moon. As for radio telescopes that capture radio waves, they produce an image that is not seen with the eye, as seen in Figure 7. Namely, an image of temperature differences in the physical Moon remains like an entire disk. The crescent Moon is not depicted like that of an optical telescope. So, the observations produced with a radio telescope do not meet the requirements of visual vision (as seen with the human eye). Because it does not meet the criteria, the practice used to observe the *rukyat al-hilāl* is considered invalid from a *fiqh* perspective.

It is different if the use of a radio telescope is done to observe the crescent Moon, but not to determine the beginning of the month, but -for example- to measure the temperature of the Moon in each of its phases, or if not only to verify the validity of the calculation results of the calculation of the beginning of the lunar month when the sky is cloudy. In conclusion, using a radio telescope to observe the crescent Moon is not by Islamic law principles. Radio telescopes cannot detect visible light from the crescent Moon, so they cannot be used to observe the crescent Moon. Observation of the crescent Moon must be done visually, either with the naked eye or with optical aids that clarify the light of the crescent Moon, by the

[36] Herdiwijaya, "Teleskop Radio Sebagai Media Penentuan Awal Bulan dalam Perspektif Astronomi."

provisions of Islamic law. Thus, radio telescopes cannot be considered valid for observing the crescent Moon from a *fiqh* perspective.

D. Conclusion

From a scientific perspective, observation of *rukyat al-hilāl* using radio telescopes shows that this technology is unsuitable for detecting the crescent and determining the beginning of the lunar month. Radio telescopes work by capturing radio waves from astronomical objects in space. However, these waves are irrelevant in observing the crescent, a visual phenomenon based on the reflection of visible light from the Moon. Since radio telescopes are not designed to capture the visible light required to see the crescent, they cannot provide the desired results in the context of crescent moon observation. The use of radio telescopes in crescent observation is not by Islamic law principles. Observation of the crescent in Islam requires direct vision of the crescent Moon that is visible after sunset as a sign of the beginning of a new month in the Hijri calendar. Radio telescopes capture radio waves and cannot detect the visible light required to see the crescent. Since the crescent is a visual phenomenon involving the reflection of sunlight, only tools that can clarify visible light, such as optical telescopes, can be used by Islamic law. Thus, radio telescopes cannot be considered valid from a *fiqh* perspective for crescent observation.

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