


## An Overview of Telescopes: History, Parts, and Types

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Article Info	ABSTRACT
<p><b>Article History</b>  Received 21-05-2025  Revision 09-07-2025  Accepted 01-09-2025</p> <p><b>Keywords:</b>  Telescope  Telescopes Evolution  Technology</p>	<p>The rapid advancement of astronomy necessitates continuous innovation in telescope technology; however, many studies focus solely on specific instruments without providing a comprehensive overview of their historical evolution and classification. This article addresses this gap by examining the evolution of telescopes from Galileo’s simple optical devices to the sophisticated modern instruments, such as the James Webb Space Telescope. The research employs a library-based method, analyzing books, scientific journals, and astronomical publications to classify different types of telescopes—both ground-based and space-based—according to their optical design, function, and scientific role. Findings reveal that telescopes have evolved from mere visual aids into advanced data-collecting systems, enabling deeper exploration of the universe’s origins and structure. Key technological innovations, including large-diameter mirrors and infrared detection, are highlighted as pivotal breakthroughs that enhance the capacity of modern astronomical research. This article emphasizes the significance of design innovations, including the utilization of large-diameter mirrors and infrared technology, in advancing modern astronomical research.</p> <p>This is an open-access article under the <a href="https://creativecommons.org/licenses/by-sa/4.0/">CC-BY-SA</a> license.</p> 

### I. Introduction

Telescopes are essential instruments that enable humans to observe celestial bodies with greater clarity and detail, serving as a bridge between the human eye and the vastness of the universe [1]. The invention and development of telescopes marked a turning point in

the history of science, as they opened new windows for astronomical discoveries and transformed humanity's understanding of the cosmos.

The history of telescopes can be traced back to the early 17th century, when Galileo Galilei refined a simple refractor telescope and used it to observe the surface of the Moon, the phases of Venus, and the moons of Jupiter. These observations not only challenged the geocentric worldview but also laid the foundation for modern astronomy. Nevertheless, the concept of magnifying distant objects through lenses had already been known among European optical craftsmen prior to this. In 1608, Hans Lippershey [2], a Dutch spectacle maker, applied for a patent on a device that could magnify distant objects, which is widely regarded as the birth of the telescope. Around the same time, Jacob Metius and Zacharias Janssen were also credited with producing similar instruments, reflecting a period of intense experimentation and innovation in the field of optical science.

Since then, telescopes have undergone continuous development, moving beyond simple refracting designs to incorporate reflecting systems introduced by Isaac Newton in the late 17th century. This innovation addressed key limitations of refractors, such as chromatic aberration, and expanded the potential of astronomical observation. Over the centuries, advancements in lens grinding, mirror technology, and later electronic detectors have significantly increased the capabilities of telescopes. In the modern era, telescopes are no longer confined to ground-based observatories. However, they are also deployed in space, exemplified by the Hubble Space Telescope and the James Webb Space Telescope, which utilize advanced technologies such as large-diameter mirrors and infrared sensors.

The evolution of telescopes demonstrates the close relationship between technological innovation and scientific progress. Each improvement in design and instrumentation has not only refined observational accuracy but also enabled astronomers to probe deeper into the universe's origins, structure, and dynamics. Understanding the historical development and classification of telescopes is therefore essential for appreciating their role in advancing both science and human knowledge.

Telescope development [3] Advances continued to be made rapidly in different parts of the world following Galileo's pioneering work. In the mid-17th century, Isaac Newton introduced the first reflecting telescope, which utilized a curved mirror instead of a lens to overcome chromatic aberration, a significant limitation of refracting telescopes at the time. Newton's design was revolutionary, laying the foundation for a new era of telescope construction. This concept was later refined in the early 18th century by John Hadley, who successfully built larger and more practical reflector telescopes, thereby enabling astronomers to make more precise and more accurate observations.

The 19th century marked another milestone in telescope innovation, particularly with the development of instruments equipped with large-diameter mirrors. A notable example was the Leviathan of Parsons town. [4] Built in Ireland by William Parsons, the Third Earl of Rosse. With a mirror diameter of 72 inches (1.83 meters), it held the title of the world's largest telescope for more than 70 years. The Leviathan played a crucial role in expanding astronomical knowledge, most famously by revealing the spiral structures of galaxies, which challenged and reshaped contemporary views of the universe. This discovery not only demonstrated the power of technological advancement in telescopes but also underscored their central role in driving paradigm shifts in astronomy.

Entering the 20th century, telescopes began to benefit from new technologies that revolutionized astronomical observation. The adoption of photography and spectroscopy [5], allowed astronomers to record permanent images of celestial objects and analyze their chemical compositions, motions, and physical properties with far greater accuracy. Another transformative milestone occurred in the 1930s, when Karl Jansky pioneered the development of radio telescopes, opening a new observational window beyond visible light and laying the groundwork for the field of radio astronomy. This breakthrough enabled the detection of cosmic radio emissions, including signals from galaxies, nebulae, and supernova remnants, thereby expanding the scope of astronomical research.

By the late 20th century, the placement of telescopes beyond Earth's atmosphere marked yet another leap forward. The launch of the Hubble Space Telescope (HST) in 1990 overcame atmospheric distortion, delivering unprecedented high-resolution images of

distant galaxies, nebulae, and other cosmic structures. Such observations not only enriched scientific understanding but also captivated the public imagination. In the 21st century, this progress has culminated in the James Webb Space Telescope (JWST), equipped with advanced infrared technology that enables astronomers to probe galaxies formed in the universe's earliest epochs.

With the advancement of technology, telescopes have evolved far beyond visual observation. Modern instruments now serve as sophisticated scientific tools capable of collecting and analyzing data across a wide range of wavelengths, from radio waves to gamma rays. Equipped with sensitive digital detectors and complex imaging systems, these telescopes enable researchers to investigate astrophysical phenomena such as black holes, exoplanets, and the large-scale structure of the universe, thereby deepening our understanding of its origin, evolution, and fate.

## **II. Method**

The method used in this study is a literature review, which involves a systematic examination of relevant and credible written sources. This approach enables the identification, analysis, and synthesis of knowledge related to the evolution, classification, and technological advancements of telescopes. The literature review process involved collecting data from a wide range of sources, including textbooks, peer-reviewed scientific journals, conference proceedings, and astronomical publications.

The collected literature was then analyzed to trace the historical development of telescopes, examine their structural components, and classify different types based on their optical design and function. In addition, synthesizing findings from various references provides a comprehensive understanding of how innovations in telescope design, such as the introduction of reflecting mirrors, catadioptric systems, and space-based observatories, have contributed to advancements in modern astronomy.

### III. Results and Discussion

#### Telescope Types

The classification of telescopes is generally based on their placement and the wavelength of electromagnetic radiation they observe. Broadly, telescopes are categorized into two types: Earth-based telescopes, which are positioned on the planet's surface, and space-based telescopes, which are placed beyond Earth's atmosphere. Each type has its own strengths and limitations, primarily determined by atmospheric interference, technological design, and scientific objectives.

#### 1. Earth-Based Telescopes

Earth-based telescopes are observational instruments positioned on the Earth's surface, typically in strategic locations such as mountaintops, deserts, or remote high-altitude regions. These sites are chosen to minimize the adverse effects of Earth's atmosphere, including turbulence, light pollution, and humidity, which can distort or obscure incoming light from celestial objects. By being situated in elevated and isolated areas, these telescopes can achieve sharper, more accurate observations.

Based on their design and the type of electromagnetic radiation they detect, Earth-based telescopes are generally classified into two main categories: optical telescopes, which rely on visible light to produce images, and non-optical telescopes, which are designed to capture other forms of radiation such as radio waves, infrared, or X-rays. Together, these instruments provide complementary perspectives of the universe, allowing astronomers to investigate a wide range of cosmic phenomena that cannot be studied with visible light alone.

##### a. Optical Telescopes

Optical telescopes [7] Utilize visible light to form images of celestial bodies. They remain the most familiar and widely used type, both in professional astronomy and amateur observations. Optical telescopes are classified into three designs:

- **Refractory Telescope:** A refractor telescope is the earliest type of telescope, pioneered in the 17th century by Galileo Galilei and later improved by Johannes Kepler, as

shown in Figure 1. It employs a convex objective lens as its primary optical element [8] which functions to collect light from distant celestial objects and bend it to a focal point, forming an image. The size of this objective lens is critical, as it determines the telescope's light-gathering ability and resolution. The optical system is housed within a long cylindrical tube that keeps the lenses aligned and prevents stray light from entering. At the same time, a focuser at the rear end allows the eyepiece to be adjusted for sharpness. The eyepiece itself magnifies the focused image, with interchangeable designs that permit variable levels of magnification. Supporting these components is a stable mounting system, typically either an altazimuth mount for basic movement or an equatorial mount for precise tracking of celestial objects as the Earth rotates.

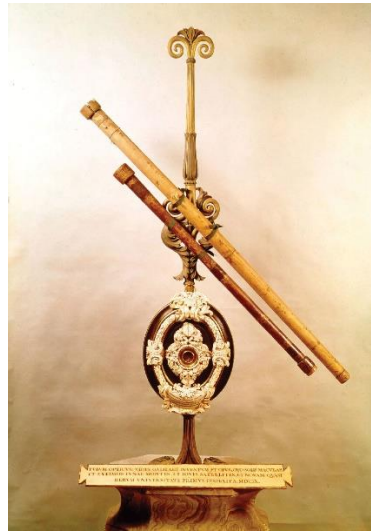


Figure 1. Galileo Telescope

Refractor telescopes have made foundational contributions to astronomy. Galileo's instrument enabled the discovery of Jupiter's four largest moons, Saturn's rings, and the phases of Venus. In contrast, larger refractors such as the Yerkes Observatory Telescope in the United States, with its 40-inch (1-meter) diameter lens, advanced the study of binary stars, stellar spectra, and planetary atmospheres. One of the main advantages of refractor telescopes is their ability to produce sharp, high-contrast images with minimal maintenance, since the sealed optical tube protects the lenses from dust and misalignment. They are also highly durable and excellent for

planetary and lunar observation, making them popular among amateur astronomers. However, they also come with disadvantages: large objective lenses are expensive and difficult to manufacture, and as their size increases, they become heavier and less practical for large-scale research. Refractors also suffer from chromatic aberration, a distortion caused by different wavelengths of light refracting at slightly different angles. However, modern designs use achromatic or apochromatic lenses to reduce this effect.

- **Reflector Telescope:** The reflector telescope, first introduced by Isaac Newton in the 17th century, employs a concave primary mirror as its main optical element, as shown in Figure 2. The mirror collects incoming light from celestial objects and reflects it to a focal point, where the image is formed. This system eliminates chromatic aberration, a common issue in refractor telescopes, since reflection does not disperse light by wavelength. The primary mirror is housed within a sturdy optical tube, often made from lightweight metals or composite materials to ensure stability. To direct the focused light toward the eyepiece or camera, a secondary mirror is placed strategically within the tube. Depending on the design—Newtonian, Cassegrain, or Ritchey-Chrétien—the arrangement of mirrors varies, influencing both compactness and image quality. Additional components include a focuser for adjusting clarity, an eyepiece or detector for magnification, and a mount system for precise tracking of celestial motion.



Figure 2. Isaac Newton reflector telescope

One of the most prominent modern examples of a reflector telescope is the Gran Telescopio Canarias (GTC) in Spain, which features a 10.4-meter segmented primary mirror, making it one of the largest optical telescopes in the world. [8]. Instruments like the GTC have enabled astronomers to study distant galaxies, stellar populations, and exoplanetary systems with exceptional clarity and depth.

Reflector telescopes offer several advantages, including the ability to construct large apertures at a lower cost compared to refractors, enabling them to collect more light and observe faint, distant objects. They are versatile for both professional research and amateur astronomy, with designs adaptable for astrophotography and spectroscopy. However, they also present disadvantages: the open tube design makes mirrors prone to dust and misalignment (collimation), requiring regular maintenance. Additionally, reflective surfaces gradually degrade over time and must be recoated to maintain efficiency. Large reflector telescopes also face challenges in mirror support and structural complexity, particularly as their diameter increases.

- **Catadioptric Telescope:** A catadioptric telescope combines both lenses and mirrors in a compact optical system (Figure 3), designed to reduce optical distortions and produce high-quality images across a wide field of view. This hybrid design merges the strengths of refractor and reflector telescopes while minimizing their weaknesses.



Figure 3. Catadioptric Telescope

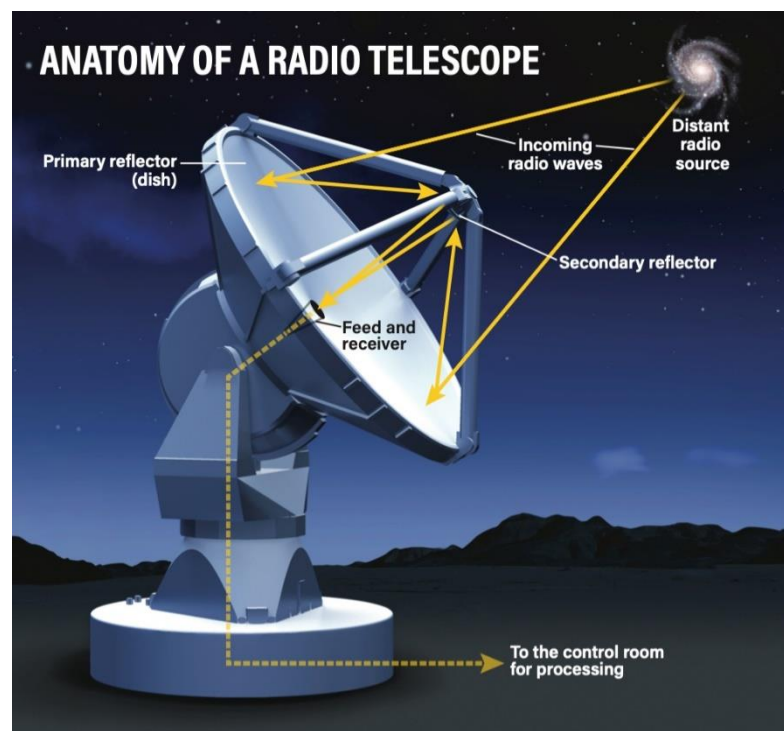
The system typically uses a spherical primary mirror to collect light, a secondary mirror to redirect the light path, and a corrector lens or corrector plate at the front of the tube to eliminate spherical aberration and improve image sharpness. The optical tube is usually short and portable, making it convenient for both transport and setup. A focuser and interchangeable eyepieces allow the observer to adjust magnification, while a mounting system provides stable tracking of celestial objects. One of the most widely used catadioptric designs is the Schmidt-Cassegrain Telescope (SCT), which employs a thin aspheric corrector plate with a folded light path, resulting in a compact yet powerful instrument. Another notable design is the Maksutov-Cassegrain Telescope (MCT), which uses a thick meniscus corrector lens for sharper images at high magnifications, often preferred for lunar and planetary observations.

Catadioptric telescopes offer several advantages, including excellent image quality with minimal aberrations, a compact and lightweight structure compared to large refractors or reflectors, and high versatility for both visual observation and astrophotography. Their portability makes them especially popular among amateur astronomers and educational institutions. However, they also come with disadvantages: the presence of multiple optical elements reduces light transmission, making them less effective for observing extremely faint objects compared to large reflectors. They can also be more expensive due to their complex design, and the enclosed tube structure may take longer to reach thermal equilibrium during observing sessions.

#### **b. Non-optical telescopes**

Non-optical telescopes detect forms of electromagnetic radiation beyond the visible spectrum, enabling astronomers to investigate cosmic phenomena that cannot be observed with traditional optical instruments. These telescopes have opened entirely new windows of discovery, allowing the study of the universe across radio, infrared, X-ray, and gamma-ray wavelengths. Each type plays a unique role in revealing hidden aspects of astrophysical processes.

- A **radio telescope** is a specialized instrument designed to detect and study radio waves emitted by astronomical objects such as pulsars, quasars, black holes, and distant galaxies [9]. Unlike optical telescopes that rely on visible light, radio telescopes extend the observational window of astronomy into longer wavelengths, enabling scientists to uncover cosmic phenomena that would otherwise remain hidden as shown in figure 4. The primary component of a radio telescope is a large parabolic dish antenna, which functions as a collector by gathering incoming radio waves and focusing them onto a receiver. At the focal point, a feed antenna and receiver system convert the weak radio signals into electrical signals, which are then amplified and processed. The signals are further analyzed by correlators and computers, allowing astronomers to construct images, measure spectra, and map large-scale cosmic structures. Modern arrays, such as the Very Large Array (VLA) in New Mexico, combine multiple dishes in an interferometric network, dramatically increasing resolution and sensitivity.



**Figure 4.** Radio Telescope Anatomy

One of the most remarkable achievements in this field is the Five-hundred-meter Aperture Spherical Telescope (FAST) in China, the largest single-dish radio

telescope in the world, capable of detecting faint signals from billions of light-years away. Radio telescopes have been central to groundbreaking discoveries, including the detection of the cosmic microwave background radiation (CMBR), the identification of pulsars, and the mapping of neutral hydrogen distribution across galaxies.

Radio telescopes offer several advantages, including the ability to observe celestial objects both day and night, penetrate interstellar dust that blocks visible light, and detect phenomena invisible to optical instruments. They also open opportunities for studying the early universe, galaxy formation, and the search for extraterrestrial intelligence (SETI). However, they also have notable disadvantages: radio waves are extremely weak, requiring very large dish sizes or arrays to achieve high sensitivity. Additionally, radio telescopes are highly susceptible to radio frequency interference (RFI) from human-made sources, such as mobile phones, satellites, and broadcasting stations, which can contaminate the data. Their enormous size and cost also make construction and maintenance challenging, often requiring remote locations and international collaboration.

- **The Infrared Telescope** is designed to detect heat radiation or infrared light emitted by celestial objects, allowing astronomers to observe phenomena that remain invisible in the optical spectrum [10]. These telescopes are particularly useful for studying protostars, star-forming regions, planetary systems in formation, and the dusty environments of galaxies, as well as for probing the early universe. The primary component of an infrared telescope is its primary mirror or lens, which collects infrared radiation and focuses it onto a detector. The detector, often made from specialized semiconductor materials such as mercury-cadmium-telluride (HgCdTe) or indium-antimonide (InSb), is highly sensitive to heat emissions. Because infrared radiation is strongly absorbed by water vapor in the atmosphere, infrared telescopes often require placement in high-altitude locations, airborne platforms, or outer space. Cooling systems, such as cryogenic coolers or liquid helium, are also crucial in reducing thermal noise from the telescope itself, thereby ensuring the accurate detection of faint signals.

One of the most notable examples is SOFIA (Stratospheric Observatory for Infrared Astronomy), a joint NASA and DLR project, which housed a 2.5-meter telescope aboard a modified Boeing 747 aircraft. By operating at altitudes of up to 13 km, SOFIA minimized atmospheric interference, enabling groundbreaking infrared observations. Other critical infrared observatories include the Spitzer Space Telescope and the James Webb Space Telescope (JWST), which have revolutionized our ability to study exoplanets and distant galaxies in the infrared spectrum.

Infrared telescopes offer several significant advantages, including the ability to penetrate interstellar dust clouds that block visible light, detect cooler astronomical objects that emit little to no visible light, and observe redshifted light from the most distant galaxies. This makes them essential for understanding the processes of stellar and planetary formation, as well as for probing the early stages of cosmic evolution. However, they also face several disadvantages: infrared radiation from Earth's atmosphere and the telescope itself can easily overwhelm faint cosmic signals, necessitating costly cooling systems and specialized detectors. Their operation is also constrained to remote, airborne, or space-based platforms, making construction, deployment, and maintenance significantly more complex and expensive compared to optical telescopes.

- **X-ray and Gamma-ray Telescopes**

X-ray and Gamma-ray Telescopes are specialized instruments designed to detect the most energetic forms of electromagnetic radiation emitted by extreme cosmic phenomena such as black holes, neutron stars, quasars, active galactic nuclei, and supernova remnants. Unlike optical or infrared light, X-rays and gamma rays cannot be focused by traditional lenses or mirrors because of their extremely short wavelengths and penetrating nature. Instead, these telescopes employ grazing incidence mirrors (for X-rays) that allow photons to be reflected at very shallow angles onto detectors. In contrast, gamma-ray telescopes often rely on scintillation detectors or solid-state detectors that record interactions when gamma-ray photons strike the material.

Because Earth's atmosphere absorbs almost all X-ray and gamma-ray radiation, these telescopes are typically deployed in space-based observatories. Notable examples include the Chandra X-ray Observatory, which has provided detailed imaging of high-energy processes around black holes and supernova remnants, and the Fermi Gamma-ray Space Telescope, which has mapped the gamma-ray sky to study phenomena such as gamma-ray bursts and pulsars. On Earth, high-altitude balloon missions and aircraft platforms have been used to test instruments and conduct complementary short-term observations.

The advantages of X-ray and gamma-ray telescopes are profound. They allow astronomers to explore the universe's most violent and energetic processes, providing insights into the behaviour of matter under extreme gravity and magnetic fields, as well as the role of high-energy radiation in galaxy and star evolution. These observations are crucial for understanding fundamental physics, including the nature of dark matter and the processes driving cosmic explosions. However, there are significant disadvantages: the need to operate above Earth's atmosphere means these telescopes require complex and costly space missions, often with limited lifespans due to fuel or cooling system constraints. Additionally, the instruments themselves are technically challenging to design, as detectors must be both highly sensitive and resistant to background noise from cosmic rays and solar radiation.

## 2. Space Telescope

To overcome the blurring and absorption effects of Earth's atmosphere, telescopes have been placed in outer space, where they can observe the cosmos across a full range of wavelengths. These instruments have transformed astronomy by providing data unattainable from the ground. Several of the most influential space telescopes include:

**Hubble Telescope** Launched jointly by NASA and the European Space Agency (ESA) on April 24, 1990, aboard the Space Shuttle Discovery (STS-31 mission), the Hubble Space Telescope (HST) is one of the most iconic and influential astronomical instruments ever built [11]. Despite facing delays and cost overruns during

development, Hubble marked a revolutionary milestone in space-based astronomy. Shortly after its deployment in low Earth orbit, the telescope encountered a serious flaw: its primary mirror suffered from spherical aberration, which blurred images. This problem was corrected in 1993, when astronauts aboard the Endeavour shuttle conducted a servicing mission and installed corrective optics (COSTAR), effectively giving Hubble “glasses” to restore its intended performance.

The telescope features a 2.4-meter primary mirror and is equipped with various scientific instruments, including Wide Field Cameras, spectrographs, and fine guidance sensors, enabling it to capture images across ultraviolet, visible, and near-infrared wavelengths. Its design allows for servicing and upgrades in orbit, which extended its operational life far beyond initial expectations.

Over its decades of operation, Hubble has produced hundreds of thousands of high-resolution images that have transformed our understanding of the cosmos. It has played a crucial role in key discoveries, such as the precise measurement of the universe’s expansion rate (through Cepheid variable stars and Type Ia supernovae), the detailed study of star formation in nebulae, the detection of exoplanet atmospheres, and the deep-field surveys that revealed galaxies billions of light-years away, providing a glimpse into the early universe.

The advantages of Hubble include its ability to bypass atmospheric distortion, offering unprecedented clarity in its observations, as well as its longevity through multiple servicing missions. However, its limitations include its restricted wavelength coverage (it cannot detect far infrared or high-energy radiation such as X-rays), its relatively small mirror compared to newer observatories, and its eventual decline as servicing missions ceased after the retirement of the Space Shuttle program. Nevertheless, the Hubble Telescope remains a cornerstone of modern astronomy, not only as a scientific instrument but also as a cultural icon that has inspired public interest in space through its breathtaking imagery and groundbreaking discoveries.

**James Webb Space Telescope (JWST)** James Webb Space Telescope [12] launched on December 25, 2021, aboard an Ariane 5 rocket from French Guiana, represents the

most advanced space observatory to date. A collaborative effort between NASA, the European Space Agency (ESA), and the Canadian Space Agency (CSA), JWST is designed primarily for infrared astronomy, enabling it to peer deeper into the cosmos than its predecessors. Unlike Hubble, which orbits Earth, JWST is positioned at the second Lagrange point (L2), approximately 1.5 million kilometers from Earth, providing a stable thermal environment with minimal interference from Earth's atmosphere and reflected light.

At the heart of JWST is its 6.5-meter segmented primary mirror, constructed from 18 hexagonal beryllium-coated segments plated with gold to maximize reflectivity in the infrared spectrum. This mirror, nearly three times the diameter of Hubble's, gives JWST far greater light-gathering power. The telescope is also equipped with a multi-layered sunshield the size of a tennis court, which blocks heat and light from the Sun, Earth, and Moon, allowing its instruments to operate at cryogenic temperatures. JWST carries four main scientific instruments:

- NIRCam (Near Infrared Camera) – for deep imaging of distant galaxies and star-forming regions.
- NIRSpec (Near Infrared Spectrograph) – capable of analyzing the composition of thousands of galaxies simultaneously.
- MIRI (Mid-Infrared Instrument) – extending observations into longer infrared wavelengths, ideal for studying cold objects like protostars and planetary disks.
- FGS/NIRISS (Fine Guidance Sensor/Near Infrared Imager and Slitless Spectrograph) – ensuring precise pointing and enabling studies of exoplanet atmospheres.

The telescope's scientific goals include observing the first galaxies formed after the Big Bang, tracing the evolution of stars and planetary systems, and analyzing the atmospheres of exoplanets for potential signs of habitability. Within its first year of operation, JWST delivered groundbreaking images of galaxy clusters, stellar nurseries, and exoplanetary atmospheres, surpassing expectations and opening new frontiers in cosmology and planetary science.

The advantages of JWST lie in its unparalleled sensitivity, infrared optimization, and ability to see further back in time than any previous telescope. However, it also faces challenges: its distance from Earth makes servicing impossible, unlike Hubble, and its operations rely heavily on the durability of its delicate sunshield and instruments. Despite these limitations, JWST stands as a transformative tool in modern astronomy, poised to answer fundamental questions about the origin of the universe, the formation of galaxies, and the potential for life beyond Earth.

**Chandra X-ray Telescope** Launched on July 23, 1999, by NASA using the Space Shuttle Columbia on the STS-93 mission, Chandra [13] Named after Subrahmanyan Chandrasekhar, a Nobel Prize-winning astrophysicist renowned for his work on stellar evolution and black holes, the Chandra X-ray Observatory has revolutionized the study of extreme cosmic phenomena.

Chandra operates in a highly elliptical orbit, reaching up to one-third of the distance to the Moon, which allows it to spend long periods outside Earth's radiation belts. This positioning reduces background interference, enabling extended and uninterrupted observations of faint X-ray sources. Unlike visible-light telescopes, which use mirrors or lenses, Chandra employs grazing-incidence mirrors arranged in nested cylindrical shells. These mirrors are coated with high-reflectivity materials and designed to reflect X-rays at very shallow angles, focusing them onto their sensitive detectors. Chandra has been instrumental in significant discoveries, such as providing the first detailed X-ray images of supernova remnants like Cassiopeia A, detecting jets of material being ejected from supermassive black holes, and mapping the distribution of dark matter in galaxy clusters through gravitational lensing combined with X-ray data. It has also shed light on the violent processes surrounding neutron stars, pulsars, and binary star systems, deepening our understanding of the high-energy universe.

The advantages of Chandra include its unprecedented angular resolution in X-rays (better than 0.5 arcseconds) and its ability to capture faint and distant X-ray sources, making it the most powerful X-ray telescope to date. However, its operational lifespan is limited by consumables such as fuel for orientation adjustments, and unlike optical telescopes, it is restricted to observing only the high-energy spectrum.

Despite these challenges, Chandra continues to operate well beyond its original 5-year mission design and remains a cornerstone of high-energy astrophysics, complementing other observatories, such as Hubble, Spitzer, and JWST, in painting a multi-wavelength picture of the universe.

**Spitzer Space.** The Spitzer Telescope was launched on August 25, 2003, by NASA using a Delta II rocket from Cape Canaveral. Spitzer [14] Specifically designed to operate in the infrared spectrum, Spitzer played a vital role in observing star formation, distant galaxies, exoplanets, and dust-shrouded regions of space that are invisible in optical light. After nearly 17 years of operation, Spitzer was decommissioned on January 30, 2020. Throughout its mission, Spitzer made groundbreaking contributions. It revealed previously hidden regions of star formation inside dense molecular clouds, discovered some of the most distant known galaxies, and provided critical data for studying the structure of the Milky Way's spiral arms. One of its most notable achievements was detecting and characterizing the TRAPPIST-1 planetary system, identifying seven Earth-sized exoplanets orbiting a nearby ultra-cool dwarf star – an extraordinary milestone in exoplanet research.

The advantages of Spitzer included its ability to peer through cosmic dust, which blocks visible light, and to detect cooler celestial objects that are invisible to optical telescopes. Its sensitivity allowed astronomers to study the thermal signatures of exoplanet atmospheres, advancing the search for potentially habitable worlds. However, its coolant supply was depleted in 2009, limiting operations to shorter infrared wavelengths during its “warm mission.” Additionally, being relatively small compared to JWST, Spitzer's resolution and sensitivity were constrained.

Despite these limitations, Spitzer left a lasting scientific legacy. It served as a bridge between earlier infrared missions, such as IRAS, and future observatories like JWST, significantly enriching our understanding of the infrared universe. Spitzer was placed into a heliocentric Earth-trailing orbit, gradually drifting farther from Earth to minimize infrared interference from our planet. Its design featured an 85-centimeter

beryllium primary mirror, cooled by liquid helium to just a few degrees above absolute zero, ensuring maximum sensitivity to faint infrared emissions.

#### IV. Conclusion

The evolution of telescopes from simple optical instruments in the 17th century to the advanced space observatories of the 21st century reflects the remarkable progress of human efforts to understand the universe. Ground-based innovations, such as the Yerkes Observatory refractor and the Gran Telescopio Canarias reflector, have significantly advanced visual astronomy by providing detailed data on nearby celestial bodies and distant galaxies. These instruments laid the foundation for observational techniques and discoveries that continue to shape astronomical research today. In parallel, the deployment of space-based telescopes – including the Hubble Space Telescope, the James Webb Space Telescope, the Chandra X-ray Observatory, and the Spitzer Space Telescope – has overcome the limitations of Earth's atmosphere, enabling observations across multiple wavelengths from infrared to X-rays. Data from these instruments have revealed key insights into cosmic phenomena such as star and planet formation, galaxy evolution, and the nature of high-energy objects like black holes. Moreover, they have deepened scientific understanding of the universe's origins and its evolution since the Big Bang.

Central to these advancements are design innovations, including the construction of large, high-precision mirrors, the application of adaptive optics in ground-based telescopes, and the integration of infrared and multi-wavelength technologies in space observatories. These technological breakthroughs not only enhance the resolution and sensitivity of telescopes but also expand the horizons of modern astronomy, enabling it to address fundamental questions about the universe's structure and humanity's place within it. The revolutionary discoveries made possible by telescopes continue to inspire both the scientific community and the broader public. As future generations of telescopes, both on Earth and in space, are developed with even more advanced capabilities, astronomy is poised to uncover even more profound truths about the cosmos, offering new perspectives on the mysteries of existence and the vast complexity of the universe.

## References

- [1] I. Irvan and L. Hermawan, "Mengenal Jenis-Jenis Teleskop dan Penggunaannya," *Al-Marshad J. Astron. Islam dan Ilmu-Ilmu Berkaitan*, vol. 5, no. 1, pp. 74–89, 2019, doi: 10.30596/jam.v5i1.3125.
- [2] Albert Van Helden, *The invention of the telescope*. Philadelphia: The American Philosophical Society, 1977.
- [3] H. C. King, *The History of Telescopes*. New York, 1997.
- [4] A. Van Weerden, "Astronomy in 1848 Astronomy in 1848 : the rings of Saturn , the Leviathan of Parsonstown , and the moon Hyperion," no. December, 2022.
- [5] I. G. Gandjar, "Spektroskopi Molekuler untuk Analisis Farmasi," *Gadjah Mada Univ. Press*, vol. 1, no. December, pp. 1–6, 2006.
- [6] H. Kihm, H.-S. Yang, I. K. Moon, J.-H. Yeon, S.-H. Lee, and Y.-W. Lee, "Adjustable bipod flexures for mounting mirrors in a space telescope," *Appl. Opt.*, vol. 51, no. 32, p. 7776, 2012, doi: 10.1364/ao.51.007776.
- [7] R. N. Wilson, *Reflecting Telescope Optics II*. Berlin: Springer Science & Business Media, 2013.
- [8] M. S. Ummah, "No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title," *Sustain.*, vol. 11, no. 1, pp. 1–14, 2019, [Online]. Available: [http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484\\_SISTEM\\_PEMBETUNGAN\\_TERPUSAT\\_STRATEGI\\_MELESTARI](http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI)
- [9] J. L. Jonas and T. M. T. in S. Africa, "The MeerKAT Radio Telescope PoS(MeerKAT2016)001," *Proc. Sci.*, pp. 1–23, 2016, [Online]. Available: <http://pos.sissa.it/>
- [10] W. Sutherland *et al.*, "The Visible and Infrared Survey Telescope for Astronomy (VISTA): Design, technical overview, and performance," *Astron. Astrophys.*, vol. 575,

2015, doi: 10.1051/0004-6361/201424973.

- [11] N. Scoville *et al.*, " COSMOS: Hubble Space Telescope Observations ," *Astrophys. J. Suppl. Ser.*, vol. 172, no. 1, pp. 38–45, 2007, doi: 10.1086/516580.
- [12] J. P. Gardner *et al.*, "The James Webb space telescope," *Space Sci. Rev.*, vol. 123, no. 4, pp. 485–606, 2006, doi: 10.1007/s11214-006-8315-7.
- [13] M. C. Weisskopf, B. Brinkman, C. Canizares, G. Garmire, S. Murray, and L. P. Van Speybroeck, " An Overview of the Performance and Scientific Results from the Chandra X-Ray Observatory ," *Publ. Astron. Soc. Pacific*, vol. 114, no. 791, pp. 1–24, 2002, doi: 10.1086/338108.
- [14] M. W. Werner, "The spitzer space telescope mission," *Adv. Sp. Res.*, vol. 36, no. 6, pp. 1048–1049, 2005, doi: 10.1016/j.asr.2005.04.012.
- [15] T. M. Brown *et al.*, "Las Cumbres Observatory Global Telescope Network," *Publ. Astron. Soc. Pacific*, vol. 125, no. 931, pp. 1031–1055, 2013, doi: 10.1086/673168.