Historical Milestones in Astronomy

The Rise of Aerial Telescopes in 17th and 18th Century Astronomy

By David Berns **July 2,2025**

Introduction

In the annals of astronomical history, the 17th and 18th centuries marked a critical period characterized by extraordinary ingenuity and technological advancement, prominently exemplified by the development of **aerial telescopes**. Confronted by significant optical limitations such as chromatic and spherical aberrations, astronomers pursued increasingly ambitious solutions, creating telescopes of unprecedented length and innovative design. The **aerial telescope**, which discarded the cumbersome tubes typical of early refractors, allowed objective lenses to be mounted high in the open air, dramatically extending focal lengths and reducing optical distortions.[3] This groundbreaking approach, championed by luminaries such as Christiaan Huygens, Johannes Hevelius, Adrien Auzout, and Giovanni Domenico Cassini, not only revolutionized observational capabilities but also laid foundational principles that profoundly influenced the evolution of modern astronomy.

Key Inventors and Contributors

Christiaan Huygens (1629–1695)

Dutch astronomer Christiaan Huygens (Fig. 1) played a crucial role in the advancement of telescope technology through his development of the **aerial telescope** concept. Alongside his brother, Constantijn Huygens Jr., Christiaan aimed to address the limitations of conventional refracting telescopes by *eliminating the long, cumbersome tube*. By the 1680s, they had successfully designed extremely long-focus telescopes known as *Tubi Optici Molimine Liberata* (Latin for "telescopes freed from the burden of the tube"), which featured objective lenses mounted high in the open air without the use of a tube.

Figure 1 Christiaan Huygens

In 1684, Christiaan published his design in *Astroscopia Compendiaria*, detailing how an objective lens could be adjusted atop a pole and aligned with a distant eyepiece using a taut string.7 The Huygens brothers were skilled lens makers, producing remarkably large lenses; in 1686, they created object-glasses with diameters of 8 to 8.5 inches and focal lengths of 170 and 210 feet. A notable 7.5-inch lens with a 123-foot focal length was presented to the Royal Society in 1690.[8]

Additionally, Christiaan invented the **Huygenian eyepiece** in 1662, a two-lens ocular design that expanded the field of view and minimized optical aberrations. Using his telescopes, Huygens discovered **Titan**, Saturn's largest moon, in 1655 and correctly identified the ring surrounding Saturn.[10] In 1686, he completed an aerial telescope measuring 210 feet in length—at that time the largest in the world—and subsequently donated it to the Royal Society.[11] Huygens' innovations significantly impacted telescope technology, establishing new standards for focal length and magnifying power.

Johannes Hevelius (1611–1687)

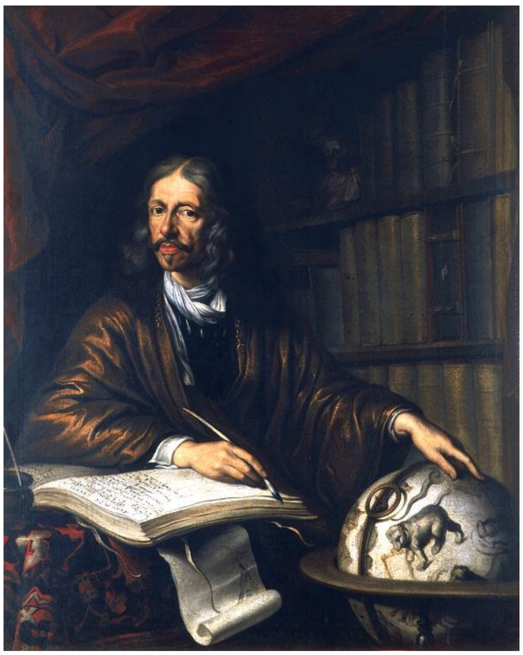

Figure 2 Johannes Hevelius

A wealthy brewer and astronomer in Danzig (now Gdańsk), **Johannes Hevelius** (Fig. 2) constructed some of the longest refracting telescopes of the 17th century. By 1647, he had published a groundbreaking lunar atlas titled *Selenographia*, and he consistently sought to increase telescope size to enhance observational accuracy. In 1673, he described in *Machinae Coelestis* his massive telescope featuring a focal length of 150 feet and an 8-inch objective lens.[14] Likely the longest tubed refractor ever built, this instrument utilized a wooden tube reinforced with tensioned wires to support the lens over such an extensive length.

Hevelius's telescopes, which ranged from 6 to 150 feet, gradually increased in size as he aimed to reduce optical aberrations. However, the 150-foot telescope was notoriously challenging to operate; even minor breezes caused the long tube and frame to flex or vibrate, resulting in compromised image quality.

Despite these difficulties, Hevelius conducted extensive observations from his elaborate rooftop observatory in Danzig. He is often regarded as the last great astronomer to make measurements without telescopic sighting; nonetheless, he utilized telescopes for discovery—identifying four new comets and cataloging over 1,500 stars.18192021 His relentless experimentation with increasingly longer telescopes showcased both the potential and the practical limits of refractor technology before the advent of aerial (tubeless) designs. Hevelius's work influenced many, leading the Royal Society to send Edmond Halley to learn from him in 1679,22 and laid the foundation for future advancements in telescope mounting and optics.

Adrien Auzout (1622–1691)

Figure 3 Adrien Auzout

Adrien Auzout (Fig. 3), a French astronomer, was an early advocate for the development of exceptionally long focal-length telescopes. He crafted massive lenses with focal lengths of 300 to 600 feet, stretching the boundaries of refractor design beyond practical limits. Auzout even proposed the extraordinary concept of a 1,000-foot focal-length aerial telescope, which he claimed could potentially be used to observe "animals on the Moon."[24] Although this colossal instrument was never constructed, his daring ideas ignited interest in tubeless telescopes.

He conducted experiments with various aiming techniques and collaborated with the Académie Royale des Sciences in Paris to enhance telescope design. Auzout was one of the pioneers to utilize "aerial" configurations similar to those developed by Huygens, and some sources even attribute the conception of this idea to him or to the English scientist Christopher Wren, with Huygens ultimately popularizing it. Auzout's ambitious plans exemplify the 17th-century ambition to overcome chromatic aberration through the sheer extension of focal length.

Giovanni Domenico Cassini (1625–1712)

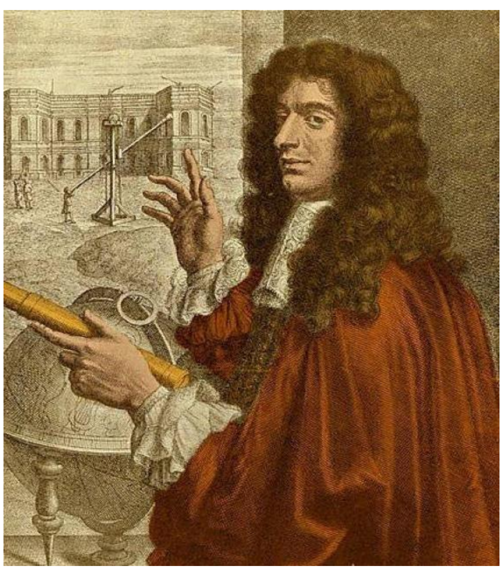

Figure 4 Giovanni Domenico Cassini

Invited to France, the Italian astronomer **Giovanni Domenico Cassini** (Fig. 4) made remarkable strides in astronomy by utilizing some of the finest long telescopes of his time.

At the Paris Observatory, he employed a range of enormous refractors and aerial telescopes, many crafted by the Italian optician **Giuseppe Campani** (Fig. 5), to conduct studies of the planets. To create a stable platform for these instruments, Cassini had a tall wooden structure known as the **Marly Tower** moved to the observatory grounds.

Figure 5 Giuseppe Campani

With telescopes boasting focal lengths of 35 to 100 feet, and aerial objectives reaching approximately 136 feet (≈41 m) crafted by Campani, Cassini discovered four moons of Saturn: **Iapetus** in 1671, **Rhea** in 1672, and **Tethys** and **Dione** in 1684, in addition to Huygens's earlier discovery of **Titan**. In 1675, he observed the faint dark division in Saturn's rings – now known as the **Cassini Division** – a challenging achievement that required exceptional resolving power. Remarkably, contemporary evaluations of Cassini's surviving lenses indicate they possess outstanding quality, with Strehl ratios around 0.94 (on a 0–1 scale), nearly achieving diffraction-limited performance.[32]

Optical quality of the five large Campani objective lenses preserved at the Paris Observatory
(all measurements at λ ≈ 633 nm with a Zygo interferometer; values refer only to the objective, without eyepiece or atmospheric effects)

Lens ID (Paris Obs. inventory)	Historical description	Clear aperture D (mm)	Focal length f @ 532 nm (m)	f/-number	RMS wave-front error (λ)	Strehl ratio	Notes
#40	"34-foot" lens (11 m) used for Cassini Division discovery, dated 1672	108	10.9	~f/80	0.049	**0.83**	Diffraction-limited; diagonal «striae» from glass inhomogeneities, but still very good for the 17th century
#41	120-foot (~39 m) aerial lens	239	40.2	~f/222	0.027	**0.94**	Optically superb—comparable to modern precision lenses
#42	145-foot (~47 m) aerial lens	238	47.3	~f/198	—	—	Wavefront could not be measured (lens exceeded interferometer pupil); quality therefore unquantified
#43	155-foot (~50 m) aerial lens	190	48.5	~f/265	0.027	**0.94**	Equally outstanding; identical WFE to #41
#44	~20-foot (~6 m) lens, probably the "small" tube Cassini mentions	137 † (masked)	6.3	~f/75	0.070	**0.67**	Noticeably worse; edges masked by cardboard to suppress larger aberrations

How to read these numbers

- **Strehl ≥ 0.80** is commonly taken as *diffraction-limited* for visual work. Lenses #40, #41 and #43 comfortably exceed this threshold; 44 falls below it, while #42 remains untested.
- A **Strehl of 0.94** (lenses #41, #43) means only a 6 % reduction in peak intensity relative to an ideal lens—remarkable for single-element crown glass cast and hand-polished in the 1670s.
- Cassini's historic **34-foot lens (40)**, at 0.83, was demonstrably good enough—chromatic blur aside—to deliver the ~1″ resolution required to glimpse the Cassini Division when the rings were maximally open in 1675.

Thanks to these exquisite optics, Cassini could detect Saturn's ring gap at the very edge of what the unaided human eye of the 17th century could perceive. His success stemmed not only from advantageous atmospheric conditions but also from the craftsmanship of experts like Campani, whose lenses were notably well-polished and precisely figured, exhibiting significantly reduced optical defects for their era.[34]

Cassini's groundbreaking achievements, enabled by aerial telescopes, represented the pinnacle of pre-achromatic refractor astronomy.

Opticians and Other Contributors

Figure 6 Eustachio Divini

The advancements mentioned above were made possible by skilled lens makers.

The advancements mentioned above were made possible by skilled lens makers. Alongside Campani, his competitor **Eustachio Divini** (Fig. 6) in Rome and others refined lens-grinding techniques during the mid-17th century, supplying astronomers throughout Europe with improved optics. Their innovations resulted in larger, clearer lenses capable of being used at focal lengths of several tens of meters.

Figure 7 Robert Hooke

In England, scientists like **Robert Hooke** (Fig. 7) experimented with long telescopes, building a 36-foot instrument and even illustrating a design for an aerial telescope in 1684.[37, 38] Although Hooke was critical of Hevelius's traditional methods, he also contributed valuable ideas regarding the mounting and aiming of these cumbersome instruments. For instance, Hooke and his colleagues at the Royal Society considered using tall structures (such as the 200-foot Monument column in London) as fixed mounts for long object glasses – a concept that ultimately proved impractical due to vibrations and alignment issues.

The theoretical studies of optics encouraged by Constantijn Huygens Sr., the father of the Huygens brothers, as well as mathematician René Descartes, played a significant role in shaping these designs. By the early 18th century, astronomers such as James Bradley and James Pound in England continued to explore the use of Huygens' exceptionally long lenses for precise measurements. They even borrowed the 122-foot object glass from Huygens to mount on a tall mast, with one instance involving the creative repurposing of a 50-foot maypole to achieve this. These individuals, through their efforts in crafting superior glass and daringly utilizing these massive instruments, all contributed to the era of aerial telescopes.

Technical Evolution of Aerial Telescopes

Lens Design and Aberration Mitigation

Figure 8 A 17th Century Telescope

Seventeenth-century refracting telescopes were plagued by optical aberrations, with chromatic aberration being the most significant issue (Fig. 8). This phenomenon, which caused images to appear blurred with false-color halos, arose from the prism-like effects of simple lenses. Short-focus lenses exacerbated the problem, prompting telescope makers to discover that extending the focal length could significantly reduce the dispersion of colors. To halve the chromatic halo for a given aperture, one needed to square the focal length, meaning that doubling the lens diameter required the focal length to be quadrupled to maintain a constant color error.

This principle led to the dramatic elongation of telescopes, evolving from the 2–4 foot Galilean designs to the 15–20 foot Keplerian (astronomical) telescopes by the mid-17th century, and eventually to colossal instruments with focal lengths of 60–150 feet.

The increase in focal length not only mitigated chromatic blur but also minimized spherical aberration for a given lens shape (Fig. 9). However, constructing long-focus lenses required top-quality glass and precision grinding.

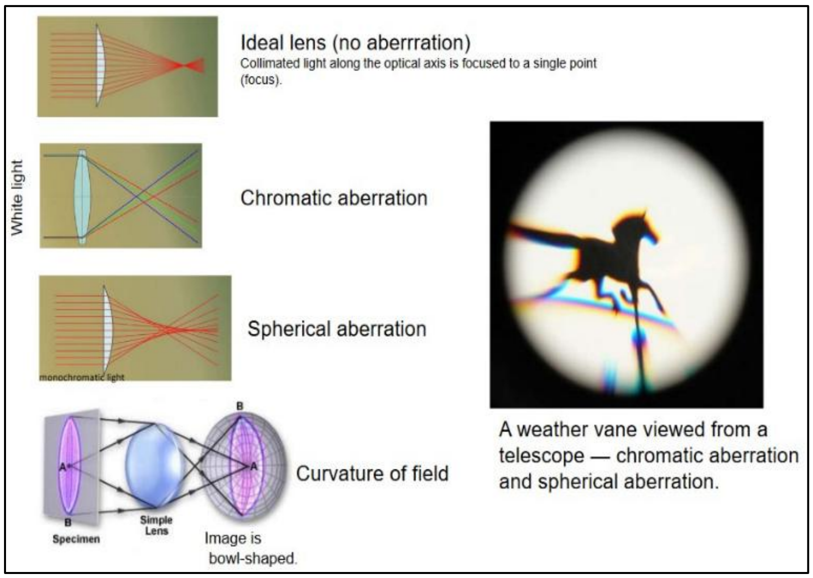

Figure 9   Optical Aberrations

Throughout the 17th century, glassmakers gradually succeeded in producing clearer, larger discs, although issues like bubbles and a greenish tint from iron impurities persisted. Artisans such as Campani and Divini honed their polishing techniques to achieve nearly spherical surfaces. Constantijn Huygens, in his unpublished work Dioptrica, analyzed these aberrations and proposed practical solutions, including employing very long focal lengths, utilizing diaphragms (or stops) to limit the impact of lens edges, and developing new eyepiece designs to enhance image clarity. Huygens's two-element eyepiece notably helped reduce residual color effects and improved field flatness, complementing the objective lens's performance. Despite these incremental advancements, true optical correction through the pairing of achromatic lenses was not realized until the mid-18th century. As a result, 17th-century scientists found themselves compelled to construct increasingly longer "object glasses" in their pursuit of better imaging quality.

Tube versus Tubeless Configurations

Early long telescopes were designed with tubes made of materials like wood or pasteboard, which were typically segmented. However, as the lengths of these telescopes increased, the tubes became cumbersome and difficult to manage. For instance, Hevelius’s remarkable 150-foot telescope (Fig. 10) featured a wooden structure reinforced with guy wires, resembling an open girder frame. Despite these efforts, the design remained unstable: the frame would flex and vibrate even with the slightest breeze, making it nearly unusable on many nights. Astronomers encountered diminishing returns when using tubes longer than approximately 100 feet, primarily due to structural sagging that led to misalignment of optics.

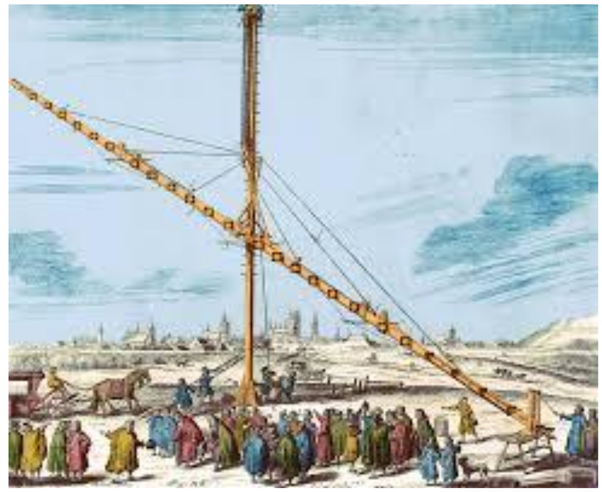

Figure 10 Hevelius’s 150-foot telescope

The significant breakthrough came with the introduction of the aerial telescope, which eliminated the need for a tube altogether.

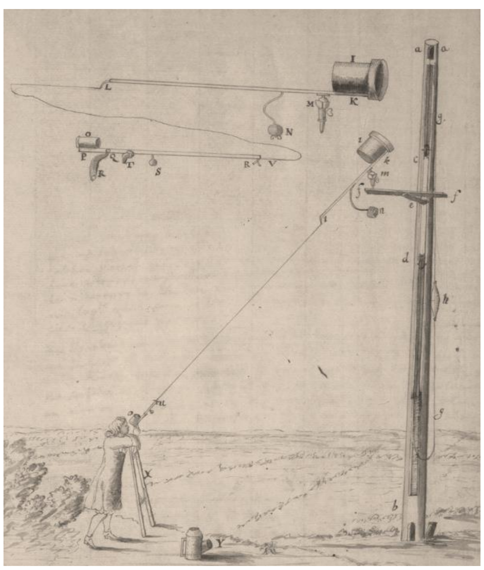

Figure 11 Huygens Aerial Telescope Design

Pioneered by the Huygens brothers around 1675, this innovative design involved mounting the objective lens at the top of a tall stand or pole, often articulated on a ball-and-socket joint for easier aiming (Fig. 11 and Fig 12). The astronomer would then hold a small handheld tube containing the eyepiece several feet or yards away, with a fine cord or string maintaining alignment between the two optics under tension.

This setup essentially created a "telescope" composed of two suspended optical components separated by the necessary distance. In discarding the bulky and heavy tube—what Huygens referred to as “the heaviness and disproportion of the tube”—the aerial design significantly lightened the overall structure, enabling astronomers to increase focal lengths practically without limit, constrained only by the feasibility of manipulating the lens and the available space.

Huygens even devised adjustable-height aerial masts and suggested utilizing church towers or cranes for accommodating very large lenses. In practice, various astronomers experimented with aerial telescopes boasting focal lengths ranging from 100 to 300 feet. However, aiming these telescopes at celestial objects presented a challenge, since observers could no longer sight along a tube.

Figure 12 A modern recreation of Huygens Aerial Telescope Design

To address this, Huygens devised targeting methods that involved adjusting the lens until the focused image of a bright celestial body—such as planets or stars—was projected onto a small screen, made of pasteboard or oiled paper, placed near the eyepiece. For faint objects, astronomers could shine a lantern at the objective lens and adjust until the reflection aligned with the eyepiece, ensuring accurate positioning. Though these techniques were somewhat cumbersome, they proved workable with skill. Crucially, the removal of the tube reduced drag and vibration, making it theoretically possible to utilize optics exceeding 200 feet in length.

Mounting and Stability Innovations

The aerial telescope required innovative mounting solutions to function effectively. Huygens' design featured a swiveling ball-joint mount positioned at the top of a tall, rigid pole, allowing the objective lens to be aimed freely at any part of the sky. These poles were often constructed like ship masts, reinforced with stays for stability. To facilitate coarse adjustments of the objective, a system of pulleys or winches was commonly employed. For finer adjustments, the observer would gently manipulate the eyepiece and tension a string connecting the two optics (Fig. 13). Some designs included auxiliary "sighting threads" extending from the objective, acting as a reference grid to improve aiming accuracy.

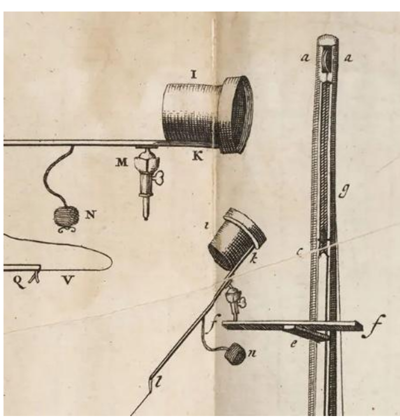

Figure 13   Huygen' s swiveling ball-joint mount

Notable figures, such as Robert Hooke, developed alternative mounting methods. Hooke's 70-foot aerial telescope, illustrated in “Astroscopia Compendiaria”, featured a 50-foot pole equipped with a counterweight and pivot mechanisms for both altitude and azimuth control. Despite these advancements, managing the trajectory of a yards-long beam of light proved challenging. Wind posed a significant obstacle, leading astronomers to favor the calmest nights for observations and even implement screens or enclosures around the lens mount to mitigate its effects. At the Paris Observatory, Cassini's team repurposed the wooden tower of the Marly water-machine, standing about 80 feet tall, specifically to mount long telescopes above the ground. This height allowed large objectives to be utilized at their full focal length in a horizontal orientation.

In England, there were ambitious plans to use the 200-foot Monument column in London (Fig. 14) as a telescope mount, which would involve directing a lens down its shaft; however, this concept ultimately proved impractical.

Figure 14 200-foot Monument column in London

Nevertheless, in a notable event in 1722, astronomers James Pound and James Bradley managed to mount a 212-foot focal-length aerial lens atop a tall pole—either a salvaged ship's mast or a maypole—to measure the diameter of Venus. The mounting was so makeshift that Pound had to borrow the maypole from a public square to support the telescope. Such anecdotes illustrate the blend of creativity and urgency that characterized the handling of these instruments.

By the early 18th century, many aerial telescopes were paired with specially designed tripods or masts, some even featuring gimbal mounts for the objective. Fine screw adjustments for the eyepiece stand were also introduced to aid in focusing. Despite these enhancements, the ease of use of aerial telescopes remained problematic; setting one up and aligning it with celestial objects continued to be a labor-intensive task that often required teamwork.

Focal Length Records and Optical Achievements

The advancement of focal lengths in the late 17th century was remarkable. Beginning with Huygens's relatively modest 23-foot telescope in 1655, which he used to discover Titan, astronomers quickly progressed to instruments with focal lengths of 60 feet and even 100 feet within just two decades. A notable milestone was Hevelius's 150-foot (approximately 45 meters) tubed refractor, built around 1672, although it had limited practical success. Huygens then surpassed this by successfully utilizing aerial telescopes with 170-foot and later 210-foot (64 meters) focal lengths by 1686. He noted that an 8.5-inch aperture lens with a 210-foot focus performed exceptionally well. His brother, Constantijn Huygens, also crafted a high-quality 170-foot focal length telescope with an 8-inch lens.

The ambitious claims made by Adrien Auzout suggested the existence of lenses with focal lengths ranging from 300 to 600 feet, indicating that a few such lenses were indeed ground. However, they likely remained underutilized for observations. Auzout's theoretical proposal of a 1,000-foot telescope remained unrealized. By the late 1680s and 1690s, the best object glasses in Europe typically had focal lengths ranging from 60 to 140 feet, with a few exceptional cases exceeding 200 feet. However, each increase in focal length offered diminishing returns in image clarity while significantly complicating handling. In summary, the evolution of the aerial telescope was marked by a relentless pursuit of longer focal lengths to reduce optical aberrations, a bold move towards tubeless designs to facilitate this extension, and the innovative yet cumbersome mechanical adjustments required to aim and stabilize these extraordinary instruments.

Observational Performance and Astronomical Discoveries

Astronomical Capabilities

Aerial telescopes, despite their cumbersome design, represented the pinnacle of optical astronomy in the 17th century. With their long focal lengths, these instruments typically had very large f-numbers (often ranging from f/50 to f/200), which considerably minimized chromatic dispersion at the eyepiece. As a result, they produced sharper, less color-distorted images compared to the shorter telescopes of earlier decades, allowing astronomers to discern finer details on bright celestial objects. For instance, Christiaan Huygens, using a 23-foot (7-meter) telescope in 1656, was able to resolve stars in the Orion Nebula, famously noting that the "middle" star of Orion's sword was actually a cluster of about a dozen stars immersed in a nebulous haze—an observation impossible to achieve with Galileo's smaller optics.

As telescopes grew in size, astronomers made significant advancements in planetary astronomy. In the 1650s, Huygens was able to clearly distinguish Saturn's rings as separate from the planet, resolving the mysterious appendages Galileo had observed.

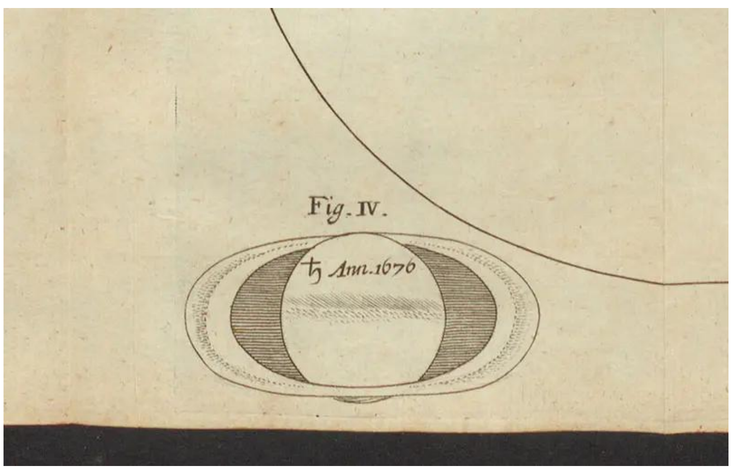

Figure 15 The division in Saturn's ring, discovered by Giovanni Domenico Cassini in 1675, now called the Cassini division, detail of a larger engraving, Philosophical Transactions of the Royal Society of London, vols. 9-12, no. 128, 1676 (Linda Hall Library)

By the 1670s, Giovanni Cassini, using Campani's high-precision refractors with focal lengths between 35 and 100 feet, not only observed Saturn's ring system but also detected a dark gap between the rings, now known as the Cassini Division, which has an angular width of only about 0.6 arcseconds from Earth (Fig 15). The ability of Cassini to identify this division in 1675 highlights the exceptional resolving power of his telescopes. Modern simulations indicate that under optimal conditions, a 5-inch aperture lens with a focal length over 100 feet could just reveal the division—precisely the tools Cassini employed.

Fine details on Jupiter (Fig. 16) were also documented during this period. Both Robert Hooke and Cassini reportedly observed spots on the planet around 1664-1665, with one likely being the Great Red Spot, and tracked these features to determine Jupiter's rotation period to be approximately 10 hours. Such observations required the substantial magnification and clarity that only the best long telescopes of the era could provide.

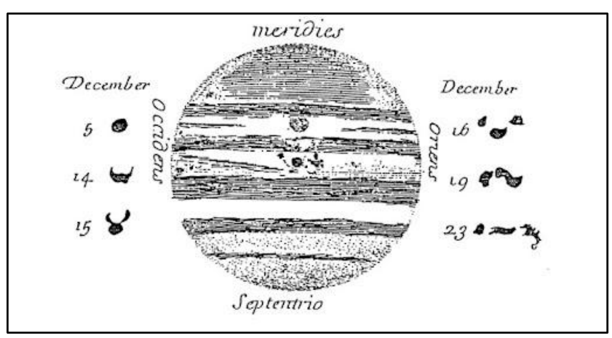

Figure 16 December 1690 sketch of new dark spot on Jupiter by G. D. Cassini and changes to the spot over 18 days

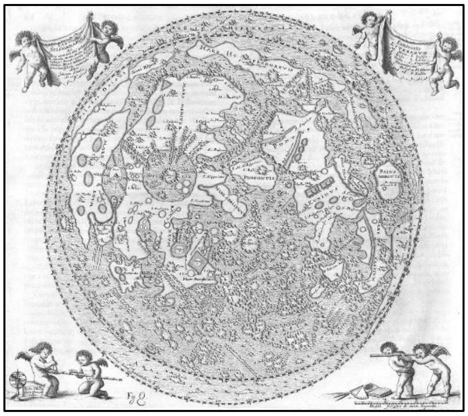

Figure 17 Hevelius Map of the Moon 1647

Additionally, features of the Moon were mapped with unprecedented precision by Hevelius and others; Hevelius's lunar maps from 1647 (Fig. 17) and subsequent works by selenographers benefited from the advancements in telescopic power that emerged by the late 1600s.

One of the most fruitful applications of aerial telescopes was the discovery of new satellites and other faint companions. Huygens's modest 12-foot and 23-foot telescopes led to the discovery of Titan (magnitude ≈ 8.5) orbiting Saturn. Building on this foundation, Cassini's larger telescopes in the 100-foot range enabled him to discover four previously unseen dim moons of Saturn, all with magnitudes between 10 and 12. Notably, he identified Dione and Tethys in 1684 "using a large aerial telescope... at the Paris Observatory." These discoveries expanded the known Solar System and would have been impossible with the much smaller Galilean telescopes that were common 50 years earlier.

Figure 18 Perseus from Hevelius' star atlas, published posthumously in 1690

During this period, double stars also began to capture attention. Although the systematic study of binary stars occurred later, the first close optical doubles, such as Mizar in Ursa Major and Gamma Arietis, were likely noted with long telescopes around this time. Hevelius, despite lacking crosshairs, compiled one of the most comprehensive star catalogs of his time, published posthumously in 1690, which featured many faint stars only detectable with his telescopes (Fig. 18). He also discovered several comets (at least four between 1652 and 1677) and was the first to correctly propose that comets follow parabolic orbits around the Sun.

Advantages over Earlier and Contemporary Telescopes

The aerial telescopes developed in the late 17th century marked a significant advancement in astronomical performance compared to the earlier refractors used by Galileo. Galileo's most effective telescopes, designed around 1609-1610, measured only 2 to 4 feet in length and offered magnifications of approximately 20 to 30 times. These instruments suffered from very narrow fields of view (15 to 20 arcminutes) and pronounced chromatic and spherical aberrations. Consequently, celestial bodies appeared as blurry spots surrounded by colored halos, and only the brightest planets and moons could be observed in detail.

In stark contrast, the refractors built by Huygens and Cassini, measuring between 60 and 100 feet long, could achieve magnifications of 100 times or more while delivering clearer images across wider fields of view. This advancement is particularly evident when comparing their observations of Saturn. While Galileo could barely perceive the planet's rings, mistaking them for "ears," Huygens was able to discern a well-defined ring structure by 1659. By 1675, Cassini further refined this observation, noting the separation of the rings, which he identified as a distinct gap. The enhancement in resolution—from a few arcseconds with Galileo's telescopes to better than 1 arcsecond with the best aerial telescopes—was critical to facilitating these breakthroughs. Additionally, the larger apertures (5 to 8 inches) of aerial telescopes enabled them to capture significantly more light compared to Galileo's 1-inch objectives, allowing astronomers to detect objects as faint as 11th-magnitude stars and comets.

Figure 19 The first reflecting Telescope built by Sir Isaac Newton in 1668

While aerial refractors were impressive for their time, they faced competition from the emerging technology of reflecting telescopes. Newton's first reflecting telescope (Fig. 19), constructed in 1668, featured a 6-inch focal length and a 1.3-inch metal mirror, serving as a remarkable technical achievement but lacking the power to surpass the large refractors.

For decades, reflecting telescopes remained largely experimental due to the challenges associated with creating large, polished mirrors. It wasn't until 1721 that John Hadley (Fig. 21) showcased a competitive reflector, introducing a 6-inch Newtonian telescope with a 62-inch (5¼-foot) focal length to the Royal Society (Fig. 20). When tested against one of the Huygens brothers' impressive aerial telescopes (7.5-inch diameter and 123-foot focal length), Hadley's shorter reflector demonstrated comparable magnification, producing images that were equally distinct, albeit slightly less bright. Thus, by 1720, it became clear that a well-constructed mirror telescope, only a few feet long, could compete effectively with much larger aerial refractors. This marked a pivotal moment in telescope design, revealing a shift toward more compact and manageable instruments.

Figure 21 John Hadley

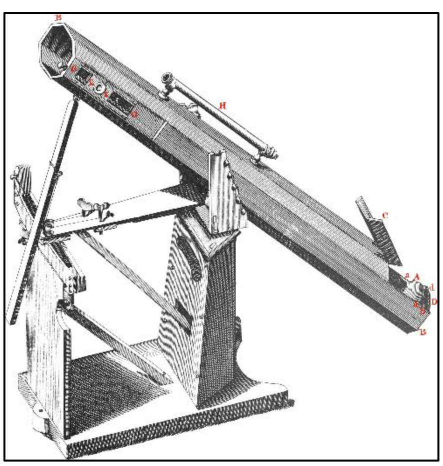

Figure 20 Hadley's 6-inch reflecting telescope, 1722

Another major innovation, the achromatic refractor, soon rendered aerial telescopes obsolete. In 1733, amateur astronomer Chester Moor Hall discovered that combining two different types of glass could effectively counteract chromatic dispersion. This idea was further perfected by optician John Dollond, who by 1758 was producing achromatic doublet lenses. These new objectives, made from both crown and flint glass, significantly reduced chromatic distortion. By using a 3 to 4-foot focal length achromatic telescope, astronomers could achieve the sharp, color-corrected views that previously required an immense 60 to 100-foot single lens.

In 1765, Dollond's son presented a small achromatic refractor to the Greenwich Observatory. It outperformed the observatory's best long-focus telescope, leading to the rapid obsolescence of the old aerial refractors. This sentiment resonated throughout Europe; by the 1760s and 1770s, serious observers transitioned to shorter achromatics or mid-sized reflectors instead of struggling with the cumbersome aerial instruments. Consequently, aerial telescopes quickly became relics of the past—curiosities that showcased the ingenuity of the previous century.

Evolution of Telescope Performance: Galilean, Aerial, and Reflecting Designs

To better appreciate the technological leap represented by aerial telescopes, it is helpful to compare them directly with their immediate predecessors and successors. Each major class of instrument—Galilean telescopes, aerial refractors, and early reflectors—embodied distinct design philosophies, trade-offs, and scientific capabilities. The Galilean refractor, though revolutionary in the early 17th century, was hampered by narrow fields of view and significant optical aberrations.

In contrast, aerial refractors pushed the boundaries of lens-making to mitigate chromatic and spherical aberration, achieving remarkable image clarity at the cost of usability. Meanwhile, reflecting telescopes, though still in their infancy during the aerial era, hinted at a more compact and chromatically superior path forward.

The table below provides a comparative summary of these three classes of telescopes, emphasizing their optical characteristics, operational practicality, and scientific utility. This overview underscores the transitional role aerial refractors played in bridging the gap between rudimentary optics and the precision instruments that would emerge by the 18th century.

Comparative Analysis Table: Galilean vs. Aerial Refractors vs. Early Reflectors

Feature	Galilean Telescopes (1609–1640s)	Aerial Refractors (1650s–1720s)	Early Reflectors (1668–1720s)
Optical Design	Convex objective + concave eyepiece	Single-element convex objective + Huygenian eyepiece	Metal mirror (speculum) + secondary mirror (Newtonian)
Focal Length	2–4 ft (≈0.6–1.2 m)	60–210 ft (18–64 m), some >300 ft theoretical	6 in–5 ft (0.15–1.5 m)
Aperture Size	~1 inch (~25 mm)	4–8.5 inches (100–215 mm)	1.3–6 inches (33–152 mm)
F-ratio (f/#)	f/15–f/30	f/80–f/200	f/5–f/10 (Hadley)

Field of View	Narrow (~15–20 arcminutes)	Wider; limited by eyepiece and aberrations	Moderate; wider than Galilean, depending on mirror quality
Chromatic Aberration	Severe	Reduced by long focal length	None (mirrors are achromatic)
Spherical Aberration	Moderate	Mitigated by long f-ratio	High unless mirrors are perfectly shaped
Image Orientation	Upright, non-inverted	Inverted	Inverted
Usability / Handling	Simple and compact	Extremely difficult: aerial alignment, height issues	Easier than aerials; still experimental pre-1720
Mounting Requirements	Minimal (handheld or basic tripod)	Extremely tall poles, ball-joint mounts, tension lines	Alt-azimuth or equatorial mounts (still rudimentary)
Light-Gathering Power	Poor	Excellent (up to 60× Galileo's)	Moderate (high for size, but mirrors tarnish quickly)
Resolution Capability	~5–10 arcseconds	~1 arcsecond (best optics)	~2 arcseconds (Hadley's 6")
Notable Observations	Jupiter's moons, Venus phases, Moon's surface	Cassini Division, Titan, multiple Saturnian moons	Early planetary detail, Great Red Spot (tentative)
Key Limitations	Poor image quality, narrow FOV	Alignment, weight, fragility, difficult pointing	Mirror oxidation, small apertures, low durability
Scientific Impact	Pioneered telescopic astronomy	Enabled planetary satellite discovery, early double stars, refined lunar/planetary maps	Demonstrated future potential of compact optics
Obsolescence Cause	Superseded by Keplerian and aerial refractors	Replaced by achromatic refractors and reflectors	Eclipsed by improved achromatic lenses post-1750

Usability and Legacy

While aerial telescopes enabled significant discoveries, they were notoriously hard to operate. Even experienced observers often found them maddening, especially on anything other than calm, clear nights. Aligning the telescope's invisible optical axis to a small celestial target frequently involved considerable trial and error. Patience, keen eyesight, and often the help of one or two assistants to adjust the lens or holding cord were essential for effective use. Many aerial telescopes spent more time being set up or locked onto a target than actually conducting observations. Hevelius remarked that his enormous telescope was "seldom used to its full potential," hindered by wind and mechanical difficulties.

While the aerial design addressed the issue of tube flexure, it introduced new challenges related to alignment and stray light. Without a tube, ambient light could easily disrupt observations; as a workaround, observers often employed long shields or shrouds near the eyepiece to block unwanted illumination. Consequently, the contributions of aerial telescopes were relatively limited considering their immensity.

They were particularly effective at specific tasks, such as detecting close double stars or faint moons near bright planets, which required high resolution and contrast. A notable example is James Bradley's use of a 212-foot aerial telescope to measure Venus's tiny disc in 1722. However, for general sky surveying or routine observations, smaller telescopes proved far more convenient.

By the 18th century, astronomers began to liken the extensive aerial telescopes to white elephants—impressive but impractical. The French astronomer Maupertuis wittily suggested in 1730 that these lengthy lenses might serve better as fixed horizontal telescopes using mirrors rather than pursuing moving stars.

Nevertheless, aerial telescopes left an important legacy. They pushed the boundaries of lens grinding and polishing, demonstrating that near-perfect large optics could be crafted by hand. The experience gained from handling long-focus optics directly influenced the design of later precision instruments, such as the mural quadrants and transit telescopes of the 18th century, which, while much shorter, benefited from the knowledge of alignment and support developed with aerial scopes. The scientific drive to conquer chromatic aberration through extreme focal lengths also indirectly spurred the search for new solutions, ultimately leading to the creation of the achromatic lens. Architecturally, the era of aerial telescopes saw the establishment of the first purpose-built observatories, like the great tower of the Paris Observatory and Hevelius's multi-roof observatory with opening hatches, which laid the groundwork for modern observatories featuring domes and mounts.

By the late 1700s, the age of aerial telescopes had come to a definitive end. The largest telescopes in the world would soon become reflectors, such as William Herschel's 40-foot (12 m) reflector (Fig. 22) built in 1789, with a 48-inch metal mirror—an instrument far surpassing the light-gathering power of any refractor until the late 19th century. In retrospect, the 17th-century aerial refractors served as a crucial bridge, extending humanity's vision at a time when mirror technology and multi-element lenses were still developing. They enabled astronomers like Huygens, Cassini, and Hevelius to conduct the first detailed surveys of the heavens, far exceeding the limited observations made by Galileo. While rapidly becoming obsolete, aerial telescopes exemplified the extraordinary lengths—both literally and figuratively—that scientists would undertake in the pursuit of knowledge.

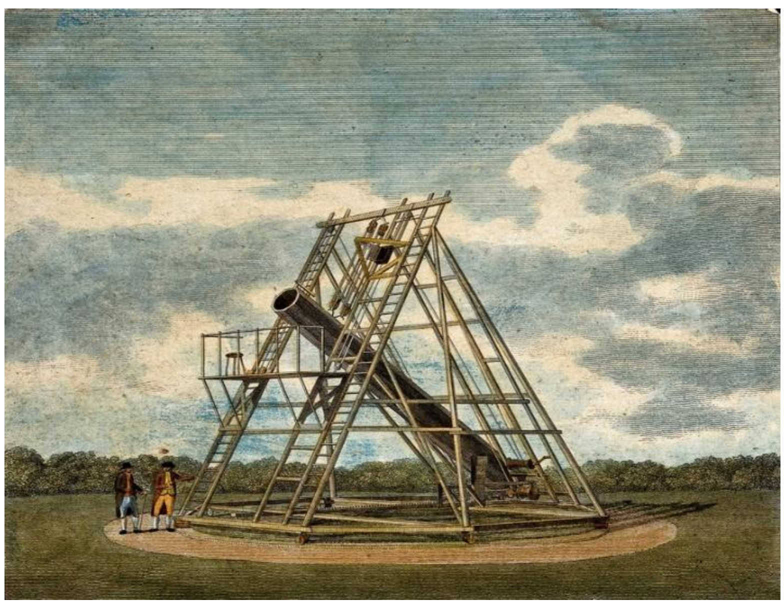

Figure 22 William Herschel's 40-foot (12 m) reflector