

Introduction to Telescopes in Astronomy

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The [development and application of the telescope](#) is a four-century journey that overlaps with the 400-year [history of astronomy in Aberdeen](#). Telescopes were initially developed for military and maritime use and were quickly adapted for celestial observation triggering the birth of modern observational astronomy that fundamentally transformed our understanding of the Universe.

1. Origin of telescope

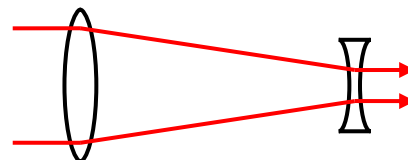
Origin of telescope emerged during the infancy of optics in ancient civilisations of Egypt, Mesopotamia, Greece and China. History of telescopes can be stretched back to 700 BC, where ancient empires of Assyrian, Egypt, Babylon and Greece all experimented with the lenses made from polished crystals.

The advent of science in Islamic world brought about advancement of optics with important discoveries were made by Al-Kindi (801–873) who postulated rays of light being emitted by all objects, Ibn Sahl (940-1000) who worked with lenses and wrote mathematical laws for calculating their shapes, and Ibn al-Haytham (965–1040) who created comprehensive review of all optic theories in his *Book of Optics* that laid the foundation of subsequent European expansion of optic science.

2. Early refracting telescopes (refractors)

What is today known as telescope goes back to an unsuccessful patent application for a device “for seeing things far away as if they were nearby” by German-Dutch spectacle-maker [Hans Lippershey](#) (c.1570–1619) in 1608. This design consisted of a convex objective lens and a concave eyepiece, and was seen as a military or commercial tool.

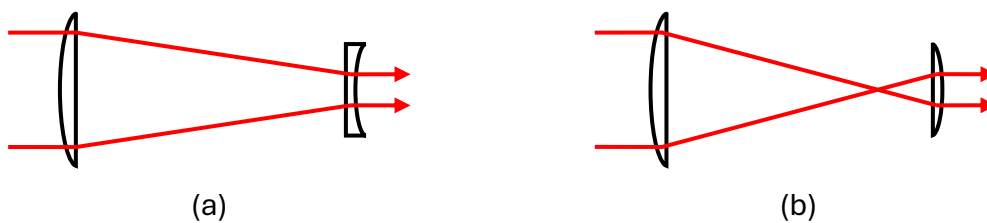
Based on Lippershey’s invention, [Galileo Galilei](#) (1564–1642) built his own improved telescopes from 1609 with a plano-convex objective and a plano-



Optical layout of Lippershey’s telescope

concave eyepiece and increased magnification from 3x (Lippershey's) to 30x (Galilean). He was the first to systematically use telescopes for astronomy, discovering Jupiter's four largest moons (later named as the Galilean moons), the phases of Venus, and craters on the Moon.

In 1611, [Johannes Kepler](#) (1571–1630), renowned for his three laws of planetary motion, proposed a design using two convex lenses. While both Lippershey's and Galilean telescopes produce erect (upright) images suitable for terrestrial watching, the Keplerian telescope inverted the image. However, since it offered a much wider field of view and generally much higher magnification than Galileo's model, the Keplerian telescope became the standard refractor for astronomical use.



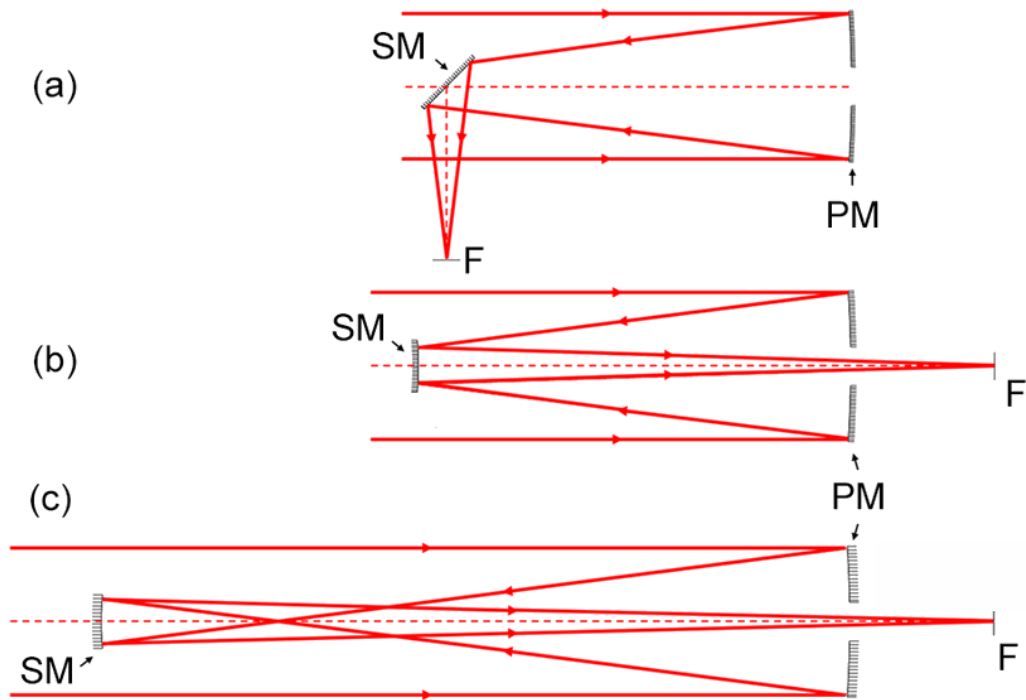
Optical layout of (a) Galilean telescope and (b) Keplerian telescope

3. The rise of reflecting telescopes (reflectors)

[James Gregory](#) (1638–1675), a mathematician and astronomer graduated from Aberdeen's Marischal College was the first to publish in 1663 a design of what we today know as reflecting telescope. The Gregorian design has a concave primary and a concave secondary mirror to produce an erect image. Later this foundational two-mirror configuration was adapted by [Laurent Cassegrain](#) (c.1629–1693) with a concave primary and a convex secondary mirror to produce an inverted image and was [published in 1672](#).

Whilst both Gregorian and Cassegrain designs offer folded light path with multiple reflections, it is the latter that offers the much shorter physical tube length than the focal length leading to a much greater magnification for the same aperture. Therefore, Cassegrain's design became the standard for most modern professional telescopes.

The first functional reflecting telescope was designed and built by [Sir Isaac Newton](#) (1643–1727) in 1668. It used a concave primary mirror as in Gregorian and Cassegrain designs and a flat diagonal mirror. Since only a single curved mirror rather than multiple curved mirrors or glass lenses is required, the Newton telescope is easier to make and maintain and remained popular nowadays among amateur astronomers using relatively large apertures than those of refractors.



Optical layout of (a) Newtonian, (b) Cassegrain, and (c) Gregorian telescope.

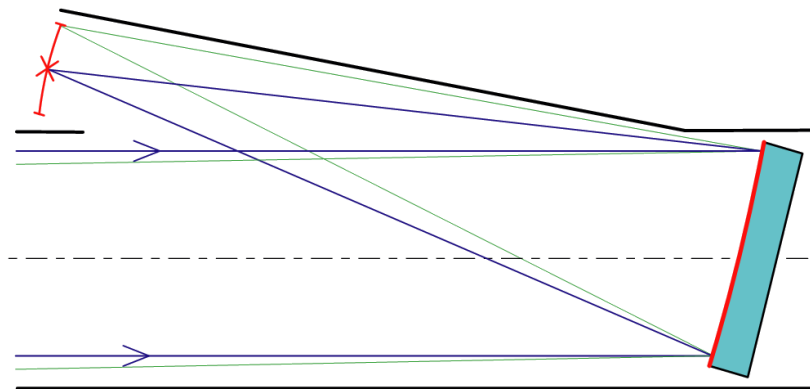
(PM: primary mirror, SM: secondary mirror, F: focal point). [[Image](#)]

4. Dawn of imaging the Universe with large reflecting telescopes

The Newtonian reflecting telescope was the foundational instrument for [Sir William Herschel](#) (1738–1822), one of the first professional astronomer in the world, in partnership with his sister, [Caroline Herschel](#) (1750–1848), a well-known early woman astronomer. For example, in 1781 Herschel discovered Uranus while using a 6.2” (inch) aperture, 7-foot focal length Newtonian telescope of his own manufacture. By refining Newton’s design and mastering the creation of large, high-quality metal mirrors, Herschel was able to map the skies with unprecedented detail.

As Herschel aimed to build larger instruments, he faced the limitation of low reflectivity in the secondary mirror used in the standard Newtonian design. To overcome this, he modified his largest telescopes with a ‘front-view’ design by eliminating the diagonal secondary mirror entirely and tilting the primary mirror slightly so he could view the formed image directly from at the front of the telescope tube. With this Herschelian configuration, he completed his famous [48” aperture, 40-foot \(focal length\) telescope](#) in 1789 in Slough, England, which remained the world’s largest telescope for 50 years.

With this 40-foot telescope, Herschel made several truly groundbreaking astronomical discoveries and studies, including Saturnian moons, numerous new nebulae that contributed to the catalogue eventually published as the General Catalogue of Nebulae and Clusters of Stars, Stellar Astronomy with double stars and confirmation of their gravitational binding, and Galactic Motion with the determination that the solar system is moving through space.



Optical layout of Herschelian telescope [Image]