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**Telescope**

[](http://en.wikipedia.org/wiki/File:100inchHooker.jpg)

The 100 inch (2.5 m) Hooker [reflecting telescope](http://en.wikipedia.org/wiki/Reflecting_telescope) at [Mount Wilson Observatory](http://en.wikipedia.org/wiki/Mount_Wilson_Observatory) near [Los Angeles](http://en.wikipedia.org/wiki/Los_Angeles), California.

A **telescope** is an instrument that aids in the observation of remote objects by collecting [electromagnetic radiation](http://en.wikipedia.org/wiki/Electromagnetic_radiation) (such as [visible light](http://en.wikipedia.org/wiki/Visible_light)). The first known practical telescopes were invented in the [Netherlands](http://en.wikipedia.org/wiki/Netherlands) at the beginning of the 17th century, using glass lenses. They found use in terrestrial applications and astronomy.

Within a few decades, the [reflecting telescope](http://en.wikipedia.org/wiki/Reflecting_telescope) was invented, which used mirrors. In the 20th century many new types of telescopes were invented, including [radio telescopes](http://en.wikipedia.org/wiki/Radio_telescopes) in the 1930s and [infrared telescopes](http://en.wikipedia.org/wiki/Infrared_telescopes) in the 1960s. The word *telescope* now refers to a wide range of instruments detecting different regions of the [electromagnetic spectrum](http://en.wikipedia.org/wiki/Electromagnetic_spectrum), and in some cases other types of detectors.

The word "*telescope*" (from the [Greek](http://en.wikipedia.org/wiki/Greek_language) [τῆλε](http://en.wiktionary.org/wiki/%CF%84%E1%BF%86%CE%BB%CE%B5), *tele* "far" and [σκοπεῖν](http://en.wiktionary.org/wiki/%CF%83%CE%BA%CE%BF%CF%80%CE%AD%CF%89), *skopein* "to look or see"; τηλεσκόπος, *teleskopos* "far-seeing") was coined in 1611 by the Greek mathematician [Giovanni Demisiani](http://en.wikipedia.org/wiki/Giovanni_Demisiani) for one of [Galileo Galilei](http://en.wikipedia.org/wiki/Galileo_Galilei)'s instruments presented at a banquet at the [Accademia dei Lincei](http://en.wikipedia.org/wiki/Accademia_dei_Lincei). In the [*Starry Messenger*](http://en.wikipedia.org/wiki/Starry_Messenger) Galileo had used the term "perspicillum".

[](http://en.wikipedia.org/wiki/File:Kepler_CCD_matrix.jpg)**History**

Modern telescopes typically use [CCD](http://en.wikipedia.org/wiki/Charge-coupled_device) instead of film for recording images. This is the sensor in the [Kepler](http://en.wikipedia.org/wiki/Kepler_%28spacecraft%29) spacecraft

The earliest recorded working telescopes were the [refracting telescopes](http://en.wikipedia.org/wiki/Refracting_telescope) that appeared in the [Netherlands](http://en.wikipedia.org/wiki/Netherlands) in 1608. Their development is credited to three individuals: [Hans Lippershey](http://en.wikipedia.org/wiki/Hans_Lippershey) and [Zacharias Janssen](http://en.wikipedia.org/wiki/Zacharias_Janssen), who were spectacle makers in Middelburg, and [Jacob Metius](http://en.wikipedia.org/wiki/Jacob_Metius) of [Alkmaar](http://en.wikipedia.org/wiki/Alkmaar). [Galileo](http://en.wikipedia.org/wiki/Galileo_Galilei) heard about the Dutch telescope in June 1609, built his own within a month, and greatly improved upon the design in the following year.

The idea that the [objective](http://en.wikipedia.org/wiki/Objective_%28optics%29), or light-gathering element, could be a mirror instead of a lens was being investigated soon after the invention of the refracting telescope. The potential advantages of using [parabolic mirrors](http://en.wikipedia.org/wiki/Parabolic_reflector)—reduction of [spherical aberration](http://en.wikipedia.org/wiki/Spherical_aberration) and no [chromatic aberration](http://en.wikipedia.org/wiki/Chromatic_aberration)—led to many proposed designs and several attempts to build [reflecting telescopes](http://en.wikipedia.org/wiki/Reflecting_telescope). In 1668, [Isaac Newton](http://en.wikipedia.org/wiki/Isaac_Newton) built the first practical reflecting telescope, of a design which now bears his name, the [Newtonian reflector](http://en.wikipedia.org/wiki/Newtonian_telescope).

The invention of the [achromatic lens](http://en.wikipedia.org/wiki/Achromatic_lens) in 1733 partially corrected color aberrations present in the simple lens and enabled the construction of shorter, more functional refracting telescopes. Reflecting telescopes, though not limited by the color problems seen in refractors, were hampered by the use of fast tarnishing [speculum metal](http://en.wikipedia.org/wiki/Speculum_metal) mirrors employed during the 18th and early 19th century—a problem alleviated by the introduction of silver coated glass mirrors in 1857, and aluminized mirrors in 1932. The maximum physical size limit for refracting telescopes is about 1 meter (40 inches), dictating that the vast majority of large optical researching telescopes built since the turn of the 20th century have been reflectors. The largest reflecting telescopes currently have objectives larger than 10 m (33 feet).

The 20th century also saw the development of telescopes that worked in a wide range of wavelengths from [radio](http://en.wikipedia.org/wiki/Radio_telescope) to [gamma-rays](http://en.wikipedia.org/wiki/Gamma-ray_telescope). The first purpose built radio telescope went into operation in 1937. Since then, a tremendous variety of complex astronomical instruments have been developed.

**Types of telescopes**

The name "telescope" covers a wide range of instruments. Most detect [electromagnetic radiation](http://en.wikipedia.org/wiki/Electromagnetic_radiation), but there are major differences in how astronomers must go about collecting light (electromagnetic radiation) in different frequency bands.

Telescopes may be classified by the wavelengths of light they detect:

* [X-ray telescopes](http://en.wikipedia.org/wiki/X-ray_telescope), using shorter wavelengths than ultraviolet light
* Ultraviolet telescopes, using shorter wavelengths than visible light
* [Optical telescopes](http://en.wikipedia.org/wiki/Optical_telescope), using [visible light](http://en.wikipedia.org/wiki/Visible_light)
* [Infrared telescopes](http://en.wikipedia.org/wiki/Infrared_telescope), using longer wavelengths than visible light
* [Submillimetre telescopes](http://en.wikipedia.org/wiki/Submillimetre_astronomy), using longer wavelengths than infrared light

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| --- | --- | --- | --- | --- | --- | --- | --- |
| [**Light Comparison**](http://en.wikipedia.org/wiki/Electromagnetic_spectrum) | | | | | | | |
| **Name** | **Wavelength** | [**Frequency (Hz)**](http://en.wikipedia.org/wiki/Hertz#SI_multiples) | [**Photon Energy (eV)**](http://en.wikipedia.org/wiki/Electronvolt#Properties) |  |  |  |  |
| [Gamma ray](http://en.wikipedia.org/wiki/Gamma_ray) | less than 0.01 nm | more than 10 EHZ | 100 keV - 300+ GeV | [X](http://en.wikipedia.org/wiki/Gamma-ray_astronomy) |  |  |  |
| [X-Ray](http://en.wikipedia.org/wiki/X-Ray) | 0.01 to 10 nm | 30 PHz - 30 EHZ | 120 eV to 120 keV | [X](http://en.wikipedia.org/wiki/X-ray_telescope) |  |  |  |
| [Ultraviolet](http://en.wikipedia.org/wiki/Ultraviolet) | 10 nm - 400 nm | 30 EHZ - 790 THz | 3 eV to 124 eV |  |  |  |  |
| [Visible](http://en.wikipedia.org/wiki/Visible_light) | 390 nm - 750 nm | 790 THz - 405 THz | 1.7 eV - 3.3 eV | [X](http://en.wikipedia.org/wiki/Visible_spectrum_telescopes) |  |  |  |
| [Infrared](http://en.wikipedia.org/wiki/Infrared) | 750 nm - 1 mm | 405 THz - 300 GHz | 1.24 [me](http://en.wikipedia.org/wiki/Milli)V - 1.7 eV | [X](http://en.wikipedia.org/wiki/Infrared_telescope) |  |  |  |
| [Microwave](http://en.wikipedia.org/wiki/Microwave) | 1 mm - 1 meter | 300 GHz - 300 MHz | 1.24 meV - 1.24 [µe](http://en.wikipedia.org/wiki/Micro-)V |  |  |  |  |
| [Radio](http://en.wikipedia.org/wiki/Radio) | 1 mm - km | [300 GHz](http://en.wikipedia.org/wiki/Extremely_high_frequency) - [3 Hz](http://en.wikipedia.org/wiki/Extremely_low_frequency) | 1.24 meV - 12.4 [fe](http://en.wikipedia.org/wiki/Femto-)V | [X](http://en.wikipedia.org/wiki/Radio_telescope) |  |  |  |

As wavelengths become longer, it becomes easier to use antenna technology to interact with electromagnetic radiation (although it is possible to make very tiny antenna). The near-infrared can be handled much like visible light, however in the far-infrared and submillimetre range, telescopes can operate more like a radio telescope. For example the [James Clerk Maxwell Telescope](http://en.wikipedia.org/wiki/James_Clerk_Maxwell_Telescope) observes from wavelengths from 3 μm (0.003 mm) to 2000 μm (2 mm), but uses a parabolic aluminum antenna. On the other hand, the [Spitzer Space Telescope](http://en.wikipedia.org/wiki/Spitzer_Space_Telescope), observing from about 3 μm (0.003 mm) to 180 μm (0.18 mm) uses a mirror (reflecting optics). Also using reflecting optics, the [Hubble Space Telescope](http://en.wikipedia.org/wiki/Hubble_Space_Telescope) with [Wide Field Camera 3](http://en.wikipedia.org/wiki/Wide_Field_Camera_3) can observe from about 0.2 μm (0.0002 mm) to 1.7 μm (0.0017 mm) (from ultra-violet to infrared light).

* [Fresnel Imager](http://en.wikipedia.org/wiki/Fresnel_Imager), an optical lens technology
* [X-ray optics](http://en.wikipedia.org/wiki/X-ray_optics), optics for certain x-ray wavelengths

Another threshold in telescope design, as photon energy increases (shorter wavelengths and higher frequency) is the use of fully reflecting optics rather than glancing-incident optics. Telescopes such as [TRACE](http://en.wikipedia.org/wiki/TRACE) and [SOHO](http://en.wikipedia.org/wiki/SOHO) use special mirrors to reflect [Extreme ultraviolet](http://en.wikipedia.org/wiki/Extreme_ultraviolet), producing higher resolution and brighter images then otherwise possible. A larger aperture does not just mean more light is collected; it is collected at a higher diffraction limit.

Telescopes may also be classified by location: ground telescope, [space telescope](http://en.wikipedia.org/wiki/Space_telescope), or [flying telescope](http://en.wikipedia.org/wiki/Flying_telescope). They may also be classified by whether they are operated by [professional astronomers](http://en.wikipedia.org/wiki/Astronomer) or [amateur astronomers](http://en.wikipedia.org/wiki/Amateur_astronomer). A vehicle or permanent campus containing one or more telescopes or other instruments is called an [observatory](http://en.wikipedia.org/wiki/Observatory).

[](http://en.wikipedia.org/wiki/File:Telescope.jpg)**Optical telescopes**

50 cm refracting telescope at [Nice Observatory](http://en.wikipedia.org/wiki/Nice_Observatory).

An optical telescope gathers and [focuses](http://en.wikipedia.org/wiki/Focus_%28optics%29) light mainly from the visible part of the [electromagnetic spectrum](http://en.wikipedia.org/wiki/Electromagnetic_spectrum) (although some work in the [infrared](http://en.wikipedia.org/wiki/Infrared) and [ultraviolet](http://en.wikipedia.org/wiki/Ultraviolet)). Optical telescopes increase the apparent [angular size](http://en.wikipedia.org/wiki/Angular_size) of distant objects as well as their apparent [brightness](http://en.wikipedia.org/wiki/Brightness). In order for the image to be observed, photographed, studied, and sent to a computer, telescopes work by employing one or more curved optical elements, usually made from [glass](http://en.wikipedia.org/wiki/Glass) [lenses](http://en.wikipedia.org/wiki/Lens_%28optics%29) and/or [mirrors](http://en.wikipedia.org/wiki/Mirror), to gather light and other electromagnetic radiation to bring that light or radiation to a focal point. Optical telescopes are used for [astronomy](http://en.wikipedia.org/wiki/Astronomy) and in many non-astronomical instruments, including: [*theodolites*](http://en.wikipedia.org/wiki/Theodolite) (including *transits*), [*spotting scopes*](http://en.wikipedia.org/wiki/Spotting_scope), [*monoculars*](http://en.wikipedia.org/wiki/Monocular), [*binoculars*](http://en.wikipedia.org/wiki/Binoculars)*,* [*camera lenses*](http://en.wikipedia.org/wiki/Camera_lens), and *spyglasses*. There are three main optical types:

* The [refracting telescope](http://en.wikipedia.org/wiki/Refracting_telescope) which uses lenses to form an image.
* The [reflecting telescope](http://en.wikipedia.org/wiki/Reflecting_telescope) which uses an arrangement of mirrors to form an image.
* The [catadioptric telescope](http://en.wikipedia.org/wiki/Catadioptric#Catadioptric_telescopes) which uses mirrors combined with lenses to form an image.

Beyond these basic optical types there are many sub-types of varying optical design classified by the task they perform such as [Astrographs](http://en.wikipedia.org/wiki/Astrograph), [Comet seekers](http://en.wikipedia.org/wiki/Comet_seeker), [Solar telescope](http://en.wikipedia.org/wiki/Solar_telescope), etc.

**Radio telescopes**

[](http://en.wikipedia.org/wiki/File:USA.NM.VeryLargeArray.02.jpg)The [Very Large Array](http://en.wikipedia.org/wiki/Very_Large_Array) at Socorro, New Mexico, United States.

Radio telescopes are [directional](http://en.wikipedia.org/wiki/Directional_antenna) [radio antennas](http://en.wikipedia.org/wiki/Radio_antennas) used for [radio astronomy](http://en.wikipedia.org/wiki/Radio_astronomy). The dishes are sometimes constructed of a conductive wire mesh whose openings are smaller than the [wavelength](http://en.wikipedia.org/wiki/Wavelength) being observed. Multi-element [Radio telescopes](http://en.wikipedia.org/wiki/Radio_telescope) are constructed from pairs or larger groups of these dishes to synthesize large 'virtual' apertures that are similar in size to the separation between the telescopes; this process is known as [aperture synthesis](http://en.wikipedia.org/wiki/Aperture_synthesis). As of 2005, the current record array size is many times the width of the [Earth](http://en.wikipedia.org/wiki/Earth)—utilizing space-based [Very Long Baseline Interferometry](http://en.wikipedia.org/wiki/Very_Long_Baseline_Interferometry) (VLBI) telescopes such as the [Japanese](http://en.wikipedia.org/wiki/Japan) [HALCA](http://en.wikipedia.org/wiki/HALCA) (Highly Advanced Laboratory for Communications and Astronomy) [VSOP (VLBI Space Observatory Program) satellite](http://www.vsop.isas.ac.jp/). Aperture synthesis is now also being applied to optical telescopes using [optical interferometers](http://en.wikipedia.org/wiki/Optical_interferometry#Astronomical_optical_interferometry) (arrays of optical telescopes) and [aperture masking interferometry](http://en.wikipedia.org/wiki/Aperture_masking_interferometry) at single reflecting telescopes. Radio telescopes are also used to collect [microwave radiation](http://en.wikipedia.org/wiki/Microwave_radiation), which is used to collect radiation when any visible light is obstructed or faint, such as from [quasars](http://en.wikipedia.org/wiki/Quasar). Some radio telescopes are used by programs such as [SETI](http://en.wikipedia.org/wiki/Search_for_Extraterrestrial_Intelligence) and the [Arecibo Observatory](http://en.wikipedia.org/wiki/Arecibo_Observatory) to search for extraterrestrial life.

**X-ray telescopes**

[](http://en.wikipedia.org/wiki/File:Heao_b.jpg)[Einstein Observatory](http://en.wikipedia.org/wiki/Einstein_Observatory) was a space-based focusing optical X-ray telescope from 1978.

[X-ray](http://en.wikipedia.org/wiki/X-ray) telescopes can use [X-ray optics](http://en.wikipedia.org/wiki/X-ray_optics), such as a [Wolter telescopes](http://en.wikipedia.org/wiki/Wolter_telescope) composed of ring-shaped 'glancing' [mirrors](http://en.wikipedia.org/wiki/Mirror) made of [heavy metals](http://en.wikipedia.org/wiki/Heavy_metals) that are able to reflect the rays just a few [degrees](http://en.wikipedia.org/wiki/Degree_%28angle%29). The mirrors are usually a section of a rotated [parabola](http://en.wikipedia.org/wiki/Parabola) and a [hyperbola](http://en.wikipedia.org/wiki/Hyperbola), or [ellipse](http://en.wikipedia.org/wiki/Ellipse). In 1952, [Hans Wolter](http://en.wikipedia.org/wiki/Hans_Wolter) outlined 3 ways a telescope could be built using only this kind of mirror. Examples of an observatory using this type of telescope are the [Einstein Observatory](http://en.wikipedia.org/wiki/Einstein_Observatory), [ROSAT](http://en.wikipedia.org/wiki/ROSAT), and the [Chandra X-Ray Observatory](http://en.wikipedia.org/wiki/Chandra_X-Ray_Observatory). By 2010, Wolter focusing X-ray telescopes are possible up to 79 keV.

**Gamma-ray telescopes**

Higher energy X-ray and [Gamma-ray](http://en.wikipedia.org/wiki/Gamma-ray) telescopes refrain from focusing completely and use coded aperture masks: the patterns of the shadow the mask creates can be reconstructed to form an image.

X-ray and Gamma-ray telescopes are usually on Earth-orbiting [satellites](http://en.wikipedia.org/wiki/Satellite) or high-flying balloons since the [Earth's atmosphere](http://en.wikipedia.org/wiki/Earth%27s_atmosphere) is opaque to this part of the electromagnetic spectrum. However, high energy x-rays and gamma-rays do not form an image in the same way as telescopes at visible wavelengths. An example of this type of telescope is the [Fermi Gamma-ray Space Telescope](http://en.wikipedia.org/wiki/Fermi_Gamma-ray_Space_Telescope).

The detection of very high energy gamma rays, with shorter wavelength and higher frequency than regular gamma rays, requires further specialization. An example of this type of observatory is [VERITAS](http://en.wikipedia.org/wiki/VERITAS). Very high energy gamma-rays are still photons, like visible light, whereas [cosmic-rays](http://en.wikipedia.org/wiki/Cosmic-rays) includes particles like electrons, protons, and heavier nuclei.

A discovery in 2012 may allow focusing gamma-ray telescopes. At photon energizes greater than 700 keV, the index of refraction starts to increase again.

**High-energy particle telescopes**

[High-energy astronomy](http://en.wikipedia.org/wiki/High-energy_astronomy) requires specialized telescopes to make observations since most of these particles go through most metals and glasses.

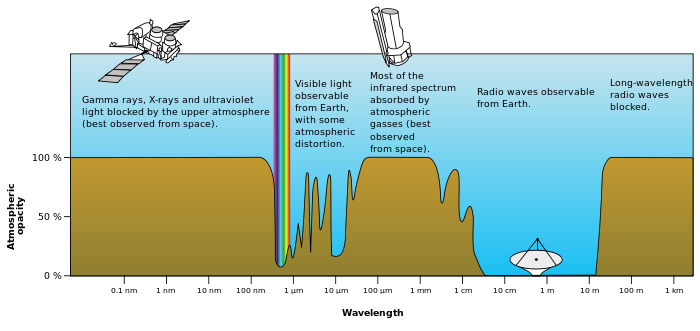
In other types of high energy particle telescopes there is no [image-forming optical system](http://en.wikipedia.org/wiki/Image-forming_optical_system). [Cosmic-ray telescopes](http://en.wikipedia.org/wiki/Cosmic-ray_observatory) usually consist of an array of different detector types spread out over a large area. A [Neutrino telescope](http://en.wikipedia.org/wiki/Neutrino_telescope) consists of a large mass of [water](http://en.wikipedia.org/wiki/Water) or [ice](http://en.wikipedia.org/wiki/Ice), surrounded by an array of sensitive light detectors known as [photomultiplier](http://en.wikipedia.org/wiki/Photomultiplier) tubes. [Energetic neutral atom](http://en.wikipedia.org/wiki/Energetic_neutral_atom) observatories like [Interstellar Boundary Explorer](http://en.wikipedia.org/wiki/Interstellar_Boundary_Explorer) detect particles traveling at certain energies.

**Types of telescope mount**

A telescope mount is a mechanical structure which supports a telescope. Telescope mounts are designed to support the mass of the telescope and allow for accurate pointing of the instrument. Many sorts of mounts have been developed over the years, with the majority of effort being put into systems that can track the motion of the stars as the Earth rotates. The two main types of tracking mount are:

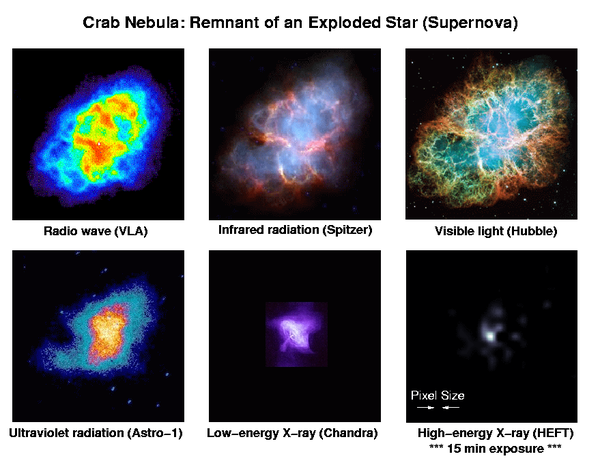
* [Altazimuth mount](http://en.wikipedia.org/wiki/Altazimuth_mount)
* [Equatorial mount](http://en.wikipedia.org/wiki/Equatorial_mount)

**Atmospheric electromagnetic opacity**

[](http://en.wikipedia.org/wiki/File:Atmospheric_electromagnetic_opacity.svg)Since the atmosphere is opaque for most of the electromagnetic spectrum, only a few bands can be observed from the Earth's surface. These bands are visible – near-infrared and a portion of the radio-wave part of the spectrum. For this reason there are no X-ray or far-infrared ground-based telescopes as these have to be flown in space to observe. Even if a wavelength is observable from the ground, it might still be advantageous to fly it on a satellite due to [astronomical seeing](http://en.wikipedia.org/wiki/Astronomical_seeing).

A diagram of the [electromagnetic spectrum](http://en.wikipedia.org/wiki/Electromagnetic_spectrum) with the Earth's atmospheric transmittance (or opacity) and the types of telescopes used to image parts of the spectrum.

**Telescopic image from different telescope types**

[](http://en.wikipedia.org/wiki/File:800crab.png)Different types of telescope, operating in different wavelength bands, provide different information about the same object. Together they provide a more comprehensive understanding.

A 6′ wide view of the [Crab nebula](http://en.wikipedia.org/wiki/Crab_nebula) supernova remnant, viewed at different wavelengths of light by various telescopes

**Telescopes by spectrum**

Telescopes that operate in the [electromagnetic spectrum](http://en.wikipedia.org/wiki/Electromagnetic_spectrum):

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| --- | --- | --- | --- |
| **Name** | **Telescope** | **Astronomy** | **Wavelength** |
| [Radio](http://en.wikipedia.org/wiki/Radio_spectrum) | [Radio telescope](http://en.wikipedia.org/wiki/Radio_telescope) | [Radio astronomy](http://en.wikipedia.org/wiki/Radio_astronomy) ([Radar astronomy](http://en.wikipedia.org/wiki/Radar_astronomy)) | more than 1 mm |
| [Submillimetre](http://en.wikipedia.org/wiki/Terahertz_radiation) | [Submillimetre telescopes](http://en.wikipedia.org/wiki/Category:Submillimetre_telescopes)\* | [Submillimetre astronomy](http://en.wikipedia.org/wiki/Submillimetre_astronomy) | 0.1 mm - 1 mm |
| Far Infrared | – | [Far-infrared astronomy](http://en.wikipedia.org/wiki/Far-infrared_astronomy) | 30 µm - 450 µm |
| [Infrared](http://en.wikipedia.org/wiki/Infrared) | [Infrared telescope](http://en.wikipedia.org/wiki/Infrared_telescope) | [Infrared astronomy](http://en.wikipedia.org/wiki/Infrared_astronomy) | 700 nm - 1 mm |
| [Visible](http://en.wikipedia.org/wiki/Visible_spectrum) | [Visible spectrum telescopes](http://en.wikipedia.org/wiki/Visible_spectrum_telescopes) | [Visible-light astronomy](http://en.wikipedia.org/wiki/Visible-light_astronomy) | 400 nm - 700 nm |
| [Ultraviolet](http://en.wikipedia.org/wiki/Ultraviolet) | [Ultraviolet telescopes](http://en.wikipedia.org/wiki/Category:Ultraviolet_telescopes)\* | [Ultraviolet astronomy](http://en.wikipedia.org/wiki/Ultraviolet_astronomy) | 10 nm - 400 nm |
| [X-ray](http://en.wikipedia.org/wiki/X-ray) | [X-ray telescope](http://en.wikipedia.org/wiki/X-ray_telescope) | [X-ray astronomy](http://en.wikipedia.org/wiki/X-ray_astronomy) | 0.01 nm - 10 nm |
| [Gamma-ray](http://en.wikipedia.org/wiki/Gamma-ray) | – | [Gamma-ray astronomy](http://en.wikipedia.org/wiki/Gamma-ray_astronomy) | less than 0.01 nm |