Exploring the History and Science Of the Telescope

by Charles Hughes

The Telescope
by Geoff Anderson
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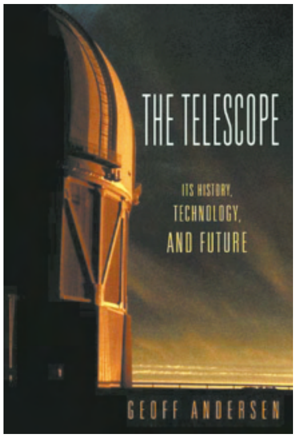
This book not only covers the history of the telescope but, more important, it describes the most recent breakthroughs in optical technology and engineering. It also describes the nature of light in detail, without having the disadvantages of a textbook on physics.

On the question of who exactly invented the telescope: Most books on telescopes say that Hans Lippershey, a Dutchman, was granted a patent by the Dutch government in 1608 for an instrument consisting of two lenses of glass which magnified distant objects. But author Geoff Anderson cites a reference by an Englishman, Thomas Diggs, who claimed that his father, Leonard, in 1571 had used a device to bring distant objects closer, saying that he could see what was taking place in private places. (Perhaps this was history's first spy glass?)

It is a popular misconception that the telescope was invented by Galileo Galilei of Pisa, Italy, born in 1564. According to Andersen, the story of how Galileo came to make his first telescope is as follows: Galileo was shown a telescope by a friend who happened to be a government official, who had custody of a telescope given to him by an inventor who wanted to be granted a patent for the device. Galileo borrowed the device and copied it, making some improvements in the instrument.

Galileo is well known for many original observations, such as the discovery of the four major satellites of Jupiter. But although he observed sunspots, he was not the first to report them; the ancient Chinese had beaten him to it.

At least one of Galileo's findings, Anderson reports, is suspect. His illustration published in a woodcut shows the Moon at the half phase, with the shadow splitting the lunar surface in half, and there is a large crater right in the middle, where no such large crater can be seen now. This crater is possibly Albattegius, but may also be a mistake, a fabrication, or perhaps the fault of the printer.



The Telescope and Light

Anderson does a thorough job of explaining the wave nature of light, and how it causes problems in precise telescope observations of the stars and celestial sights, in the two main categories of telescope, the reflector and refractor.

One major problem is that the wave nature of light causes light to be disrupted whenever it encounters an edge or obstruction in the light path. The edge of the telescope tube is such an obstruction, as is the diagonal mirror in a reflecting telescope, which directs the image to the side of the tube to bypass the observer's head.

The reflecting telescope has a mirror at the base of the tube to gather light and direct it up the tube to the ocular, which magnifies the image.

The early telescopes were refractors, in which the main light-gathering mechanism is a glass concave lens at the front of the telescope, which forms a real image. The light goes down to a small lens in front of the observer's eye, where the image is enlarged, and then to the eye.

Another problem is the non-homogeneous character of the atmosphere, which distorts light passing down from the star to the telescope.

Since the very beginning of the telescope, astronomers have attempted to enlarge the objective, either the front lens or the rear mirror to obtain a larger, unobstructed area of the main optic and thereby increase the resolution of the telescope; that is, the ability to see large, sharper details of a celestial object. That is the reason for the race in modern astronomy for ever more gigantic mirrors to gather more light from the celestial objects being observed.

As for the unsteadiness of the air, the only remedy (until the discovery of the technique of adaptive optics, which I will describe below) was to observe on those, often few, nights of the year when the atmosphere, or the seeing, was good.

Another recourse was to locate the observatory on a high mountaintop where the telescope was above most of the atmosphere, the most favorable sites also being near the ocean. (Two such prime sites are Chile and Hawaii.) With bad, turbulent air, however, the chances of someone at such an observatory seeing an object at sharp resolution, and with the limitations imposed by the diffraction effects of the light waves hitting the edges of the telescope tube, are little improved over those of an amateur instrument.

To see the wonders of the heavens, accepting the limitations of air turbulence and diffraction, Anderson states that a telescope of about 6-inches diameter is all that is needed. A refractor type is slightly superior, although more costly, with a long focal length that is, say, 15 times the diameter of the objective lens or mirror.

Of course, a third method of eliminating bad air is to put the telescope where there is none—in space. The Hubble has given us fantastic clear images of the universe, to the very limit that the 90-inch mirror is allowed by the laws of physics. The problem here is the size of the load in the Space Shuttle and the extreme cost of putting a telescope in space.

New Techniques

Chapter 10 and those following are the most interesting part of the book, as they explain the new techniques that have caused a revolution in telescope imaging.

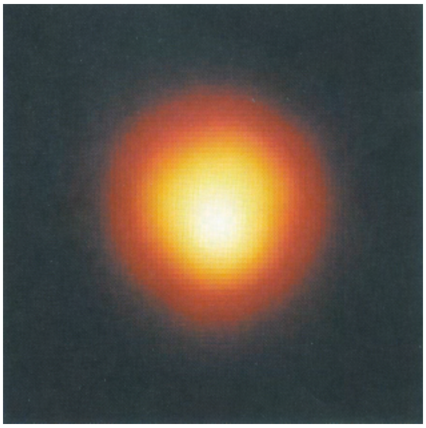
These new advances have come about through the use of advanced laser and light techniques linked to the ability of supercomputers, which were developed out of the "beam defense" technology of the last 10 years, and declassified at the end of the Cold War in the 1990s.

How these advances work require understanding how light forms images. Huygens and other scientists in the 17th Century proved that light was a wave, and not a particle, but this idea was contested by Newton. (Newton had many erroneous ideas about the nature of light, as noted below.)

One problem with early refractor telescopes was chromatic aberration, the tendency for different colors of light traversing the telescope objective to fail to focus at the same point. (Mirrors do not have this problem; all colors focus at the same point.) Newton taught that it was impossible to correct the objective of a refractor for this problem.

To correct this chromatic problem somewhat, telescope makers increased the focal length of the telescope while keeping the diameter of the lens small. But this method of correction caused telescopes to assume grotesque lengths. No doubt readers have seen illustrations of early instruments, such as the telescopes at the Paris Observatory in the 17th Century, that were 100 feet long, supported on high towers with ropes and pulleys.

In 1759, John Dolland proved Newton wrong by inventing the achromatic objective for the refractor, using two different types of glass sandwiched together to get most of the light to focus at a single point with only a moderate focal length. Unfortunately Newton's authority had kept the development of the refractor back 50 years or more.



Hubble Space telescope (STSci/AURA)

Betelgeuse, a red giant in the Orion constellation, in the first image resolving the disk of a distant star. The star is 20/1,000ths of an arc second in diameter.

Getting back to how the wave nature of light causes trouble for astronomers: If you observe a bright star through a telescope on a night that has good air transparency, or good seeing, you can not see the star's disc because it is too far away to be resolved unless you make use of the advanced laser techniques.

Instead, you will see a ring like a bull's-eye made up of light and dark concentric rings. The dark rings are caused by light waves interfering with each other, a wave crest cancelling out a trough. The bright rings occur when the waves coincide and reinforce each other. This is termed a diffraction spot or an Airy ring.

Without the boost in resolution provided by the new beam technology, even a large Earth-bound mirror cannot resolve the disc of a distant star. This type of telescope can resolve an angle of about 1 arc second.

To get an idea of what this means: A circle is divided into 360 parts, each part called a degree. The degree is divided into 60 parts, each one called a minute. The minute is split into 60 seconds. The Moon is about 1,800 seconds wide, and Mars is about 24 seconds, when it is closest to the Earth.

One of the largest stars closest to us is about 20/1,000ths of an arc second, which is why the disc cannot be resolved even in a giant telescope. The star in question is the famous red giant Betelgeuse in the constellation of Orion, 400 light years away. Astronomers did finally obtain an image of Betelgeuse, which is illustrated as a color plate in this book (see photo).

Optical Breakthroughs

One breakthrough was the discovery that if two or more telescope mirrors were separated, the lateral distance separating them acted as single mirror with amplified resolution. For example, two 100-foot mirrors separated by 1 mile and connected together electronically would be equivalent to a mirror with the resolving power of one mirror that was 1 mile plus 200 feet in diameter.

I say here "mirror," because large refractors were abandoned as an option in observatory telescopes a hundred years ago. The largest refractor ever built was the 40-inch refractor at Yerkes Observatory in Williams Bay, Wisconsin, in about 1890. Large, heavy glass lenses could not be mounted on the front of a tube beyond this size.

More recently, however, improvements in mirror fabrication to make telescope mirrors light, thin, and deformable have made it possible to make huge mirrors, which can be fitted together like tiles to build up a large mirror out of small, thin, very well figured segments. The overall optical properties of the whole can be controlled by computer-operated mechanical fingers behind each segment.

Several of these monsters can be interconnected electronically to make a super mirror, increasing the size of the diffraction spot for the observer. Thus it could give the observer the excessive resolution needed to image a star like Betelgeuse. However, the rough air is still a problem.

Anderson explains how the new technique known as adaptive optics solves the problems of turbulent air. It uses a laser aimed into the field of view of the telescope, which probes the air mass, feeding information into a very advanced computer. This produces a map or model of the air turbulence and feeds this model to actuators behind each mirror segment, so that the mirror shape is coincident with the air wave front, thus producing a well defined image of the star.

I recommend this book for anyone wishing to understand the latest advances in astronomical science, as well as telescope history.