One of the first discoveries made by Galileo in the winter of 1609–10 was that a telescope reveals stars to us that are fainter than the eye can see without the telescope. The band of the Milky Way is mostly made up of faint stars. He described this in one of the first scientific best sellers, his book *The Sidereal Messenger*. He wrote, “For the Galaxy is nothing else than a congeries of innumerable stars distributed in clusters.”

While it is the focal length of a telescope that provides the magnification, there are practical limits to magnification that can be achieved. For a fifteen-centimeter (six-inch) diameter of ninety-centimeter focal length, one can rarely use eyepieces that give more than 150 power. Having a longer focal length telescope of the same diameter does not really help you much.

The German-born English astronomer William Herschel (1738–1822) was one of the first people to grasp the importance of the collecting area of the telescope and how that is effectively the light-gathering power. He strove to build reflecting telescopes with the largest possible diameter. His most productive telescope was one of focal length twenty feet, with a diameter of 47.5 centimeters (18.7 inches). If we have two telescopes of similar design, and one is twice the diameter of the other, the larger telescope allows you to see stars that are four times fainter, because its objective has four times the area of the objective of the smaller telescope.

Until the beginning of the twentieth century, most astronomers worked with refracting telescopes (the kind with the lens up front). They were mostly interested in measuring the positions of the stars with ever greater precision. Herschel, on the other hand, was more interested in mapping the whole sky, discovering double stars, nebulae, and star clusters. He speculated on the
structure and evolution of the Galaxy. For this he needed to be able to detect the faintest stars possible. So he cast mirrors out of the kind of metal used to build church bells. Finally, in 1857 it was possible to make a glass telescope mirror whose front surface was coated in a layer of silver.⁴

Consider the drawing of the Orion Nebula shown in Figure 8.1. This was made by the Harvard astronomer George Phillips Bond (1825–1865) using the fifteen-inch diameter refractor of Harvard College Observatory and his eye.⁵

Photography was invented about 1838 by Louis Daguerre and Joseph Niepce.⁶ At first only the Sun or Moon could be imaged, but by 1882, photography had improved to the point that images of the Orion Nebula could be made.⁷ In Figure 8.2 we see a 137-minute exposure by Henry Draper. It revealed stars to magnitude 14.7, which is three thousand times fainter than the naked eye can detect.

One of the first successful professional reflecting telescopes was the thirty-six-inch diameter Crossley telescope.⁸ It was acquired from a rich English amateur and reengineered to work at the latitude of Lick Observatory. With it the second Lick director, James Keeler, photographed many faint nebulae and clusters. And in 1908 a sixty-inch diameter reflector came on line at

Figure 8.1  Drawing of the Orion Nebula by George Phillips Bond, 1859–1863.  
Source: George Phillips Bond, 1859–1863.
Mt. Wilson Observatory near Pasadena, California. By this point reflectors had supplanted refractors as the telescopes of choice for professional astronomers.\footnote{9}

Photography continued to improve up to 1970. But the \textit{quantum efficiency} (or QE) of photographic emulsions has never been very impressive. The QE is the efficiency with which light is converted into an image on film, or the efficiency of converting light into electrons, which can be amplified in a photomultiplier tube or accumulated in the silicon layer of a solid state
Improvements in Astronomical Imaging

Figure 8.4 Supernova 2012fr is seen just above the central bulge of NGC 1365 in this combination ultraviolet/optical image from the Swift satellite. *Courtesy Peter Brown, Texas A&M University.*

detector. Typically, photographic plates never exceeded a QE of 3 percent, though that could be increased to 10 percent with hypersensitization. Today, astronomers use charge coupled devices (CCDs), which can achieve QEs greater than 80 percent at some wavelengths. This allows a forty-inch diameter telescope to take images deeper than one could take in the 1960s with the Palomar two-hundred-inch telescope using photographic plates.

Endnotes

4. Ibid., p. 167.


