Galileo and Highlights of Telescope History

Galileo did not invent the telescope. Spectacles were known in the late Middle Ages. A Father Giordano of Pisa mentioned in a sermon in 1306, "It is not yet twenty years since the art of making spectacles, one of the most useful arts on earth, was discovered. I, myself, have seen and conversed with the man who made them first." Once lenses were available, it was only a matter of time until someone lined up two of them and noticed that objects seen through the combination appeared closer and larger. In 1608, **Hans Lippershey** in the Netherlands made this discovery; others may have done so independently at about the same time. Galileo did make his own telescope in 1609 after simply hearing about the invention.

What Galileo **was** first to do was turn his telescope to the sky. With it he made a number of remarkable astronomical discoveries. Among these:

- The Moon is not a featureless disk, but a landscape with dark and light areas (the dark areas we now call **maria**), mountains, valleys, plains, and craters.
- The Sun has dark spots.
- Venus has phases (crescent, half, full) like the Moon.
- Jupiter has four satellites or moons. (We now know it has many more; Galileo discovered the four largest.)
- Saturn seemed to have things sticking out to the side of it. Galileo referred to these as "ears". Later telescopes were able to resolve them into Saturn's rings.
- The Milky Way is not just a haze of light, but is made up of great numbers of faint stars.

The discoveries about Venus and Jupiter gave strong support for the Sun-centered model of the solar system.

Johannes Kepler is well known for his **Laws of Planetary Motion**. What may be less well known is that in 1611, he became the first to place a **convex eyepiece** in a telescope. Up to that time, eyepieces had all been concave lenses, as in today's opera glasses. A convex eyepiece inverts the image, as is now familiar to astronomers. It also provides two advantages: It provided a **wider field of view**, and it allowed the images to be projected onto a screen (as, for instance, we might want to do with an image of the Sun). Kepler also showed how the image could be turned right side up again with a third convex lens.

Isaac Newton invented the **reflecting telescope** in 1688. This was one way of getting around the problem of **chromatic aberration**, caused by the fact that lenses will not bring all colors (wavelengths) of light to the same focus. For a mirror, however, all wavelengths, hence all colors, will reflect in the same way.

Uranus became the **first planet discovered by telescope** in 1781, by William Herschel. We now know it had been observed on previous occasions, but it was mistaken for a star most of those times. The planets out to Saturn were known to the ancients, because they are readily visible to the unaided eye.

Ceres, the first **asteroid**, was discovered, by telescope, on January1, 1801.

In 1817, **Fraunhofer** began to identify absorption (dark) lines in the Sun's spectrum with specific chemical elements. This was the beginning of **astronomical spectroscopy.** Combining spectroscopy with telescopes allows us to learn about the composition of astronomical objects. It also allows us to learn about their motion; both the velocity component toward or away from us of their motion through space, and their rotational motion. An object's spectrum can also tell something about its temperature. It even allows us to detect the gravitational **redshift** of dense, massive objects such as white dwarf stars. The doppler shifted spectra of orbital motion is the technique that has been used to find the great majority of extrasolar planets that have been detected so far. As the planet orbits around the center of mass, so must the star, and it is the stellar motion that we observe.

The first astronomical photograph was a photo of the Moon taken in 1840 by **John William Draper**. This was the first time an astronomical observation could be recorded

by means other than notes and drawings. Charged Coupled Devices or CCD's are a more recent means of recording astronomical images.

Michelson first used **interferometry** to measure the angular diameters of Jupiter's satellites in 1891. An **interferometer** is a telescope combined with an auxiliary light collector set at some distance it, or two or more telescopes set some distance apart. By using the interference fringes produced by combining the light from the collectors, it becomes possible to measure distances and sizes with a resolution based on the distance between the collectors, rather than the size of a single collector.

The 100-inch telescope at Mount Wilson helped make some of the next major discoveries. By observing **Cepheid variables** in the Andromeda nebula in 1922-23, **Edwin Hubble** showed that Andromeda is far outside the Milky Way, and in fact a galaxy in its own right. Even before that, before 1918, Keeler, Slipher, and Campbell had begun measuring redshifts of galaxies at other observatories. Hubble combined the measurements of others with his own to establish that most galaxies are moving away from us (and each other), and that to a first approximation, the rate at which they are moving away is proportional to their distance. In other words, **the universe is expanding.**

Radio astronomy got its start in the 1930's. In 1933, **Karl Jansky** of Bell Labs figured out that static that was interfering transatlantic radio voice transmissions was coming from the Milky Way, and was strongest in the direction of Sagittarius, toward the center of the galaxy. In 1937, **Grote Reber** built the first parabolic dish radio telescope, 9 meters in diameter, and conducted the first sky survey at radio frequencies.

Infrared astronomy got started in the 1950's, when appropriate detecting materials were developed.

People began doing **astronomy from balloons and rockets** in the 1960's.

The first telescopes were put into orbit also in the 1960's. The first American ones were the **Orbital Astronomical Observatory** or OAO series, which operated at **ultraviolet** wavelengths. Putting a telescope above the atmosphere avoids the reduction in resolution that comes from atmospheric distortion. In addition, gamma rays, X-rays, and some ultraviolet and infrared wavelengths cannot penetrate Earth's atmosphere; they can only be seen from space.

The first gamma ray telescope was carried into orbit on the Explorer 11 satellite in 1961.

The first celestial X-rays observed were from a bright source discovered in **Scorpius** on a 1962 rocket flight. This source was named Scorpius X-1. A number of **X-ray astronomy satellites** were launched in the 1970's.

The first multiple-mirror telescope was built in Arizona in 1979.

Segmented mirrors were an advance pioneered by the **Keck Telescope** in 1985. Segmented mirrors allow building a telescope larger than any single mirror the technology of the time is able to produce. The Keck telescope also introduced the use of **adaptive optics**. The mirror segments are thin, and are backed by computer controlled actuators that adjust their shape to compensate for atmospheric distortion, and thus gain improved resolution. A **reference star** or a **laser beam** is used for reference.

Handout Author: Larry J. Friesen, Ph.D. ©2009
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