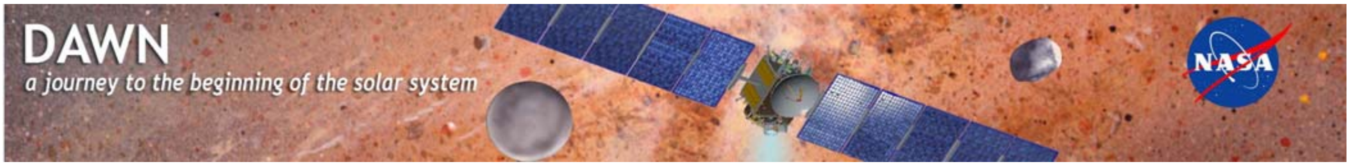


Silver to the Rescue

People see objects when light is reflected from or emitted by that object. The lens of the eye gathers and focuses the light so that it falls on the **retina** *(a thin layer of specialized cells at the back of the inside of the eyeball)*, resulting in a marvelous cascade of events that ultimately causes the brain to form an image of the object. Then we say that we “see” the object. The telescopes (see “What CAN You See With a Telescope?”) used by astronomers serve as an extension of the optical system of the eye, in the sense that they enhance the light gathering power of the observer. However, although you may not have thought of it in this way, the telescope/eye combination does not offer a way to store the images received, except in the memory of the observer. And herein lies a problem. Memories fade, are difficult to examine quantitatively, and are impossible to transfer or share directly and with complete accuracy from one individual to another, except in science fiction stories and movies. So, early astronomers often resorted to drawings to make permanent records of the things they observed. Clearly a better system was needed.

The Origins of Photographic Technology

Enter a man named **Louis Jacques Mandé Daguerre**. In the early part of the nineteenth century, he recorded the first photographic image. His technique was enormously cumbersome and difficult to work with by today’s standards. It involved exposing thin layers of silver to iodine vapors, thus forming a film of **silver iodide** (*containing* Ag^+ *ions*) on the surface of the layer of silver. Although Daugerre did not know it, when tiny silver iodide crystals are exposed to light, they become chemically activated. The silver iodide can then be easily converted or reduced to tiny metallic silver crystals, which appear black (unlike the bulk metal, which is shiny). So, when his metal plates were exposed to light reflected from an object, the silver iodide crystals receiving the light became activated. They were then converted to black, elemental silver particles when the plate was exposed to magnesium vapors, which served as the chemical reducing agent. In this way a permanent image was created, with the darkest areas corresponding to the most reflected light and so on. If you’ve ever looked at a film negative, you may have noticed that light and dark become reversed.

Photographic Opportunities in Astronomy

The importance of Daugerre’s process was immediately recognized by astronomers, who saw it as a way to make lasting images of celestial objects and record their positions in the sky, their brightness, and other features of interest. The photographic plates made by Daugerre were not very sensitive to faint objects, but they permitted the first photograph (called a Daugerrotype) of the moon to be recorded in 1840 after a 20-minute **exposure**. This was followed by the first photograph of a star (Vega) in 1850. And the first asteroid photograph was recorded by Max West on December 22, 1891. Interestingly, this photo was not of one of the larger asteroids, but rather was of one called 323 Brucia.

An 1852 daguerreotype of the moon taken by J.A. Whipple using a 15-inch refractor at the Harvard College Observatory.

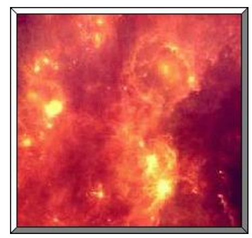
http://cfa-www.harvard.edu/newtop/previous/071700.html

Scientific Needs Fuel Technological Advances

Astronomers were happy to have available photographic techniques, but they really needed faster processes. Hours and hours of exposure often were required to obtain a single image of a star. A faster, but very complex, method was invented in 1851. This process, the **wet collodion process**, produced plates that had a much higher sensitivity than was previously available, but the plates had to be used immediately after they were prepared with the guncotton, alcohol, and ether solution. This was an inconvenience to say the least. Several really important advances were made in the 1870s that helped overcome some of these problems. The principal advancements centered on the development of highly sensitive, but dry, photochemical layers on glass or other plates called **emulsions**. These plates could be stored and used at the astronomer's convenience.

By the late 1870s new, dry emulsion plates utilizing **silver bromide** were being mass produced quickly and marketed at a low price. A major contributor to this development was George Eastman, the father of the Eastman Kodak Company. By the 1880s these emulsions had led to good photos of Saturn and Jupiter. Comets also were photographed and very long exposures provided images of individual stars in the Orion nebula. Sky surveying had begun, and the heavens were starting to be catalogued. Clearly, photography had begun to have a major impact on the science of astronomy.

Since photography offered such tremendous advantages to astronomers, they followed closely the efforts devoted in the late 1800s and early 1900s to improving the technique. For example, the original plates were sensitive largely to blue light, which severely limited the observational opportunities. However, such limitations were overcome by an accidental discovery by Vogel, who observed that green dyes in the emulsion caused enhanced sensitivity to red light, thereby absorbing more red light. This observation was immediately exploited and emulsions were soon formulated that were sensitive to all colors of the visible spectrum. Following that, emulsions sensitive to light lying outside the visible spectrum, e.g. electromagnetic radiation and **infrared** light, became available. Infrared technology makes it possible for astronomers to see and study invisible celestial objects hidden behind dust and gas



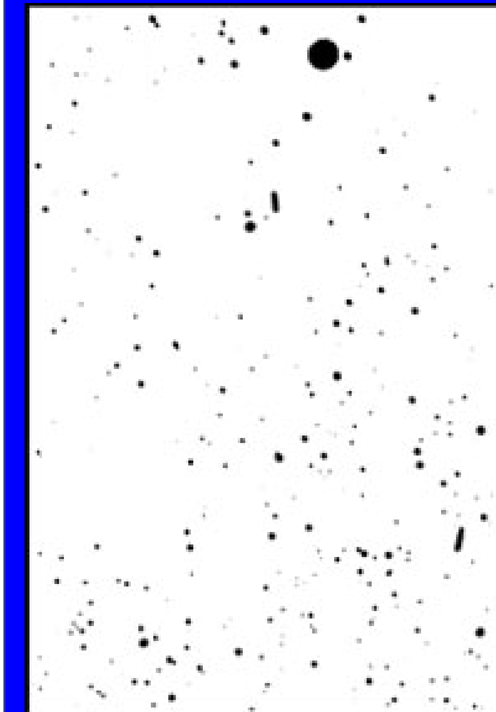
An infrared image of the constellation Orion taken by the Infrared Astronomical Satellite

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/ir_tutorial/orion.html

To understand the importance of these emulsion discoveries, it may help to understand how color can become visible. For instance, imagine you are wearing a green sweater. You are able to see the sweater as green because that is the color reflected. In other words, all other colors of the visible spectrum are absorbed except green, which is reflected and made visible. Remember that photographic technology during the late 1800s and early 1900s was limited to black and white photographs; therefore, the emulsion sensitivities to color are referring to light within the spectrum that was made visible in black and white images. To complicate matters, these plates are like photographic negatives used today. If you've ever looked at a negative, you know that light and dark are reversed (i.e. the whites of your eye look dark, while the pupils look white). This is because the negative, like the early emulsion plates, reveal light that has been absorbed not reflected.

Another major issue faced during the early photographic era was how to **increase the detail** available in a photograph. This involved developing techniques for reducing the grain size of the photo-chemically active agent in the emulsions. Procedures were developed that led to grain sizes ten times smaller than those of the original ones, greatly enhancing the detail that could be realized.

Finally, there was the issue of **increasing the sensitivity** of the emulsions. This issue relates to how fast the light comes in to strike the emulsion. A burst of light can be detected readily by a slow emulsion. However, if light just slowly dribbles into an emulsion, as is often the case when one focuses on remote and dim celestial objects, an emulsion may not detect the light successfully. This is because film emulsions suffer a rapid fall off in their ability to gather data after the initial surge of light. It is almost as if the emulsion gets tired after a while, and this is called "**reciprocity failure**." Efforts to overcome reciprocity failure are called "**hyposensitization**" of the emulsion. Much research has focused on hyposensitization techniques. These techniques are varied and involve such things as cooling the plate before exposure. Scientists at the Eastman Kodak Company and elsewhere have devoted much effort to understanding the science of hyposensitization.



Early starfield image: Can you find the two asteroids?

Roth, G.D., (1962). *The system of minor planet*. Princeton, NJ: Company Inc.

Photography has played an enormous role in the development of astronomy. Thin film emulsions remain historically important tools for astronomers, both professional and amateur. However, one should remember that small objects like asteroids appear in Earth-bound telescopes only as points of light. Fortunately, powerful digital photographic techniques that are revolutionizing astrophotography have emerged over the past few years (see "More Discoveries…Better Descriptions"). The Dawn mission will utilize these new photographic techniques in gathering new and important information about Ceres and Vesta.

Additional Resources

Web Sites

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/ir_tutorial/
This Infrared Astronomy Tutorial offers information about infrared technology, images, videos and links to educational activities.

http://www.daguerre.org/home.php
The Daguerreian Society Web site contains resources as well as an online gallery of daguerreotypes.

http://www.astro.virginia.edu/~afs5z/photography.html
Informative text about the history of photography for astronomical purposes.

http://www.getty.edu/art/collections/presentation/p41_126811-1.html
The Getty Museum offers a short video clip demonstrating the process of making a wet collodion negative. You can also check out photographs that were developed using this process.

Print Resources

Learner, R. (1981). *Astronomy through the telescope*. Van Nostrand Reinhold.

McSween, H.Y. (1999). *Meteorites and their parent planets***.** Cambridge; New York: Cambridge University Press.

Peebles, C. (2000). *Asteroids: A history*. Washington, DC: Smithsonian Institution Press.

Roth, G. D., (1962). *The system of minor planets*. Princeton, NJ: Company Inc.