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Making Your Own Astronomical Camera

by Susan Kern and Don McCarthy

People are fascinated by the night sky. By patiently watching, one can observe many astronomical and atmospheric phenomena, yet the permanent recording of such phenomena usually belongs to serious amateur astronomers using moderately expensive, 35-mm cameras and to scientists using modern telescopic equipment. At the University of Arizona's Astronomy Camps, we dissect, modify, and reload disposed "One-Time Use" cameras to allow students to study engineering principles and to photograph the night sky.

Elementary school students from Silverwood School in Washington state work with their modified One-Time Use cameras during Astronomy Camp. Photo courtesy of the authors.

Today's disposable cameras are a marvel of technology, wonderfully suited to a variety of educational activities. Discarded plastic cameras are free from camera stores. Students from junior high through graduate school can benefit from analyzing the cameras' optics, mechanisms, electronics, light sources, manufacturing techniques, and economics. Some of these educational features were recently described by Gene Byrd and Mark Graham in their article in the *Physics Teacher*, "Camera and Telescope Free-for-All!" (1999, vol. 37, p. 547). Here we elaborate on the cameras' optical properties and show how to modify and reload one for astrophotography.

An Education in Optics

The KODAK One-Time Use cameras with (right) and without (left) the flash unit. The assembly at center is a non-flash unit with its front and back covers removed. Photo courtesy of the authors.

The "One-Time Use" cameras contain at least six interesting optical components. Three of these items are found on a single piece of molded plastic, which is associated with the viewfinder and can be removed as a single unit for further study and experimentation. This "viewfinder assembly" is a Galilean optical system using two lenses. As pointed out by Byrd and Graham, you can use it in reverse to act as a simple telescope. Other components include a simple magnifier for the exposure counter, a "light pipe" with a diffusing surface for the flash indicator, a parabolic reflector for the flash tube, and a cylindrical lens over the flash unit.

The camera's main aperture follows the design of a "front landscape" lens. It features a steeply curved, aspheric meniscus lens followed by a physical aperture "stop" to limit blurring by spherical aberration. Figure 1 shows a ray-trace of the approximate system, revealing its simplicity, wide field-of-view (~ 60 degrees), moderate distortion (~ 5 percent), curved focal plane (~ f/10), and a spot-size consistent with the resolution of the human eye (< 1 arcminute). The main lens has a focal length of about 26 mm. The underlying stop limits its collecting diameter to 2.5 mm, roughly similar to the pupil of the human eye in daylight but smaller than the eye's approximately 8-mm opening at night. Although far from perfect in its optical performance, this simple lens yields images consistent with viewing by the human eye. The design principles of the viewfinder and main aperture are provided in R. Kingslake's classic optics text, *Lens Design Fundamentals* (Academic Press: San Diego).

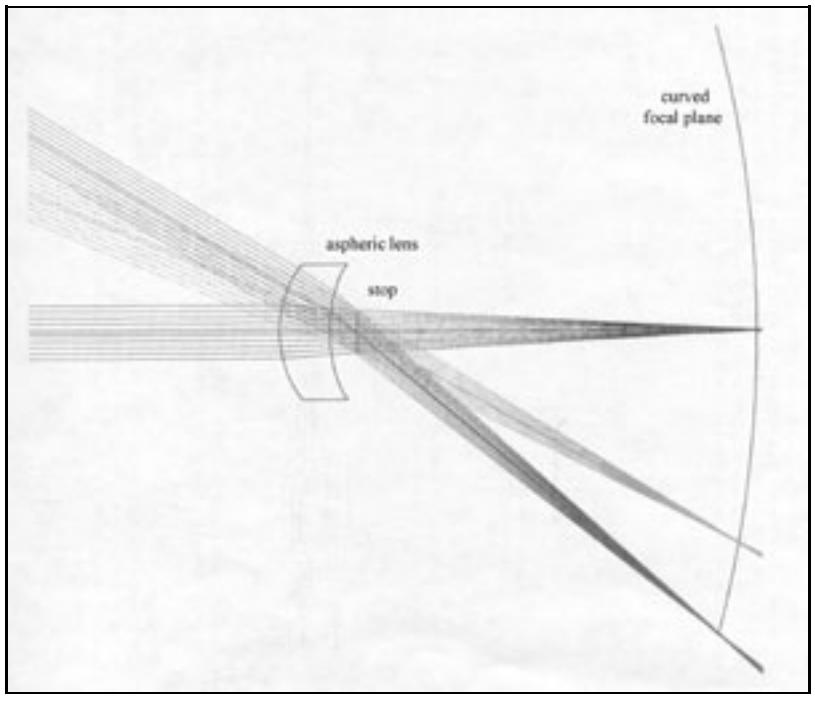

Figure 1. Computer ray trace of the simulated optics in a One-Time Use camera. This diagram shows the main aspheric lens followed by a "stop" which reduces the effects of

spherical aberration in the final image. The side field-of-view and curved focal plane are also apparent. Drawing courtesy of Roland Sarlot, Steward Observatory.
