USING THE LYNXX CCD CAMERA ON A SMALL TELESCOPE FOR VARIABLE STAR OBSERVATIONS

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Abstract

The new small CCD cameras combined with a short focal length lens (a three-inch lens at f/4.0) of high quality produce a combination that we have found ideal for observing variable stars to magnitude 15 with exposures as short as 5 minutes. The potential and future implications for AAVSO observations with this type of system is great. A discussion of this system and some representative observations are presented, and some of the implications for future AAVSO data acquisition are discussed.

At the E. E. Barnard Observatory, southwest of Boulder, Colorado, we have combined a SpectraSource PCLynxx CCD camera with a six-position filter wheel and a three-inch aperture f/4.0 7-element aerial camera lens to produce a very compact instrument for doing BVRI photometry. Using the 12-inch focal length lens with the Lynxx CCD chip gives a field of view of about 0.5 degree, which is very similar to the AAVSO "d" chart, assuring that several comparison stars will be obtained at the same time as the variable star. By observing the comparison stars simultaneously with the variable star, we obtain the same sky conditions for the comparison stars as well as the variable. This allows us to work in sky conditions that are of less than photometric quality. The CCD chip that is employed in the Lynxx system has an active area of 2.64 x 2.64 mm, and is 195 by 165 pixels in extent. Each active pixel is 16 x 13.75 micrometers, which with a 12-inch focal length lens, gives a pixel size of 11 x 9 arcsec. The resolution of the objective lens plus the degradation from seeing motions will still place the image of a star on a single pixel.

The CCD chip is most sensitive in the red and near infrared wavelengths (the detective quantum efficiency is about 60% there), and we estimate a red (R) limiting magnitude of around 15 for a five-minute exposure with the 3-inch objective lens. Visual-filter observations are estimated to have a limit about two magnitudes brighter. Exposures of up to one hour are possible and can increase the limiting magnitude by more than three magnitudes. However, a sequence of 12 five-minute exposures will give comparable results and will place much less stringent requirements on tracking. Multiple observations are also advantageous for distinguishing pixel errors caused by cosmic ray events. Blue observations are possible on bright stars, but the CCD chip loses sensitivity quickly in the blue, and ultraviolet observations are nearly impossible, probably even with a completely reflective telescope. Observations in red or near-infrared wavelengths are ideal because of the high chip sensitivity, low sky brightness in the red, and the increased brightness of many cool (and therefore red) variable stars of interest to AAVSO observers. At the E. E. Barnard Observatory, we will soon employ a six-inch-aperture f/4.0 reflecting telescope to enable us to obtain stars to magnitude 18 in the red with a 20 minute exposure.

The well capacity of the individual pixels in the Lynxx CCD is in excess of 150,000 counts, which gives a wide dynamic range with great accuracy in magnitude measurement. We estimate that highly accurate relative photometry can be obtained over a range of 3 to 4 magnitudes. To make observations over a greater range will require varying the exposure time (the Lynxx CCD system allows exposures as short as 0.01 second and as long as 4000 seconds). For an excellent review of the Lynxx system see DiCicco 1991.

CCD observations must be made carefully in order to obtain the high photometric quality described above. Each pixel must have its relative sensitivity measured by a process called flat-fielding. The usual method to do this is to make exposures at different times into sunset (twilight sky) or of a uniform light source, being careful not to overexpose the chip to light. These exposures must be made for each filter that will be used during the following night. During all exposures a certain number of counts will also accumulate due to thermal noise in each pixel, and an exposure of length equal to that of the program stars must be made with the shutter closed to allow subtraction of these accumulated "dark" counts. The computer software supplied with the systems will allow all these processes to be done to produce a clean observed picture. These pictures can be stored on floppy disks or on a hard disk in the computer for later analysis (on cloudy nights?). The computer software will also allow photometry of individual stars, or enhancements of the image for contrast, and even false-color images.

A common mistake made by amateur observers with CCD cameras is to use them with the largest aperture available. This will increase the limiting magnitude of the system, but a small aperture lens will reach to quite faint magnitudes, as was demonstrated above. The resulting small field of view of a large aperture (and long focal length) telescope used with a small chip like the Lynxx will make it nearly impossible with small CCD's to obtain simultaneous comparison star and variable star observations; these simultaneous observations are of the greatest benefit to the reduction of CCD observations. The small field of view also makes locating and identifying subject star fields very difficult.

We suggest that short focal-length telescopes equipped with the new CCD systems are ideal for monitoring variable stars in the AAVSO program. The AAVSO may need to change some of its recording procedures to accommodate these systems, however: the high sensitivity in the red and infrared wavelengths may necessitate the adoption of standard filters for use in this region. The high accuracy of magnitude measurement will necessitate development of comparison star sequences in which magnitudes are known to at least magnitude ± 0.02. CCD camera observations made with wide fields of view can certainly be used to accomplish this goal, but will require careful absolute photometric methods. We routinely monitor stellar extinction at least once during the night, and more frequent monitoring can provide enough data to make absolute photometry possible. With larger-aperture instruments, routine monitoring of very faint galaxies can be done to observe supernovae, and once discovered, one can obtain very accurate light curves for them.

We have also found that the combination of the CCD chip with a small-aperture lens is very useful for monitoring the sky environment of the observatory. For the last five months, we have routinely monitored twilight sky brightness at the zenith to detect the presence of thin, high-altitude clouds and/or volcanic ash. This routine monitoring can be very helpful in predicting the quality of the following night.

The advent of relatively inexpensive, cooled CCD cameras has advanced the potential for photoelectric photometry by a quantum leap! For the first time the amateur with a small observatory has available an instrument that, if used carefully, will permit highly accurate photometry to be made to magnitudes reaching even 18 or 19 with long exposures. The AAVSO must prepare for the avalanche of highly accurate data that will result from this technology.

References

DiCicco, D. 1991, *Sky & Telescope*, **81**, 257.