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CCDs at ESO: A Systematic Testing Program

T. M. C. Abbott

European Southern Observatory, Casilla 19001, Santiago 19, Chile

R. H. Warmels

European Southern Observatory, Karl-Schwarzschild-Straße 2, D 85748, Germany

Abstract. ESO currently offers a stable of 12 CCDs for use by visiting astronomers. It is incumbent upon ESO to ensure that these devices perform according to their advertised specifications (Abbott 1994). We describe a systematic, regular testing program for CCDs which is now being applied at La Silla. These tests are designed to expose failures which may not have catastrophic effects but which may compromise observations. The results of these tests are stored in an archive, accessible to visiting astronomers, and will be subject to trend analysis. The test are integrated in the CCD reduction package of the Munich Image Data Analysis System (ESO-MIDAS).

1. Introduction

At the time of writing we at ESO, La Silla offer 12 CCDs for use by visiting astronomers. These CCDs range in quality from a venerable RCA with read noise of 32 electrons per pixel to the most recent, a thinned Tektronix 2048^2 pixel device. Supporting all of these CCDs poses some unusual problems. ESO serves a very broad community, and the astronomers who use our CCDs range in ability from those who are quite new to the field to those with many years of experience in the use of modern, state-of-the-art detectors. We must be aware at all times of the current status of our CCDs so that even the most exacting visiting astronomers can be satisfied that their data is of uniformly high quality and that they are completely informed of any problems or limitations. Likewise, we must work to protect the less experienced astronomers by convincing ourselves that our CCDs are providing data of sufficient quality to ensure the success of a broad spectrum of observing programs. It is, therefore, not sufficient that we trust our CCDs to remain in the state determined when they are commissioned, nor that we depend on visiting astronomers to identify problems as they arise. Instead, we must make a concerted effort to regularly investigate the quality of the data delivered, whether or not any problems are known. To that end, we have instigated a systematic program of standard CCD tests at ESO, La Silla.

2. The Test Data

We currently test one CCD each week, and thus each CCD is tested every 3 months. These tests are not intended to be as thorough as might be performed in a specialized CCD lab; instead, they should expose as many problems as possible with minimal technical intervention and under the simple setups available with the CCD on the telescope. We can then investigate any problems that we identify with more sophisticated methods, or, if we judge the CCD to be functioning satisfactorily, the test results provide a baseline of its performance.

For each test, we collect the following data: (1) nine bias frames, (2) sixteen pairs of flat fields (both of each pair have the same integration time) using a stable light source and with exposure levels ranging from just above bias to digital saturation, (3) nine low-count-level (of order a few hundred electrons per pixel) flat-fields with stable light source, (4) one flat-field exposure obtained with 64 rapid shutter cycles, (5) three 30-minute dark images, and (6) the time taken to read out and display an image. All images include bias overscan regions in both dimensions, cover the entire light-sensitive, unbinned area of the CCD and are collected under the same circumstances as normal observing.

The light source used to obtain the flat fields may be either an LED or a beta light. Beta lights consist of a fluorescent screen stimulated by β decay from a small bulb of tritium. Since these present a possible radiation hazard and are prone to variation with temperature ($\sim -0.3\%$ per °C (Florentin, private communication)) we are in the process of replacing them with compact light sources consisting of a battery-powered LED regulated by feedback from a photo-diode. Like the beta lights, these are small enough to fit within a normal filter wheel in most La Silla instruments and exhibit a flux/temperature dependence of $\sim 0.2\%$ per °C (we expect to improve on this in future versions).

3. The Results

The information we expect to obtain from each test data set is as follows:

1. A 16-point transfer curve (Janesick et al. 1987, Figure 1a) generated for any window onto the images obtained.

2. Two 16-point linearity curves. We find that the linearity curves are most useful when expressed as count rate versus true exposure time (Figure 1b). We determine the mechanical shutter delay either by linear extrapolation of the normal linearity curve (observed counts versus exposure time), thus assuming the response of the CCD is linear, or by adjusting the exposure times such that the count rate curve is closest to a straight line, thus allowing for a first-order nonlinearity in the response of the CCD. We obtain the 16 pairs of frames in two groups of eight—the first with increasing exposure times and the second with decreasing exposure times, interleaved with those of the first group. In this way, we can reject trends observed in the CCD response that are probably caused by the effect of temperature variations on the light source. The linearity curves may be generated for any window onto the images obtained.

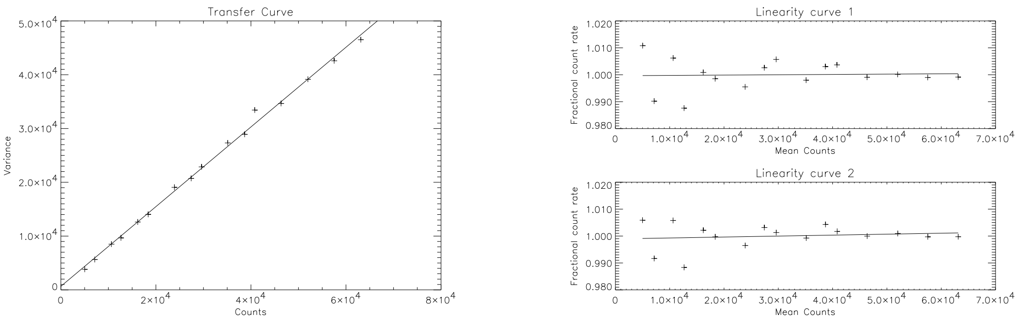

Figure 1. **a** (left): Sample transfer curve (TK#36). The abscissa is the mean counts per pixel in a 200^2 pixel region centered on the CCD. The ordinate is the variance of the same region in the image that results from the difference of two images of the same mean counts. **b** (right): Sample linearity curves expressed as count rate versus mean counts in an image using the same light source throughout (TK#36). The straight lines are linear fit to the data. The exposure times have been corrected for a shutter delay of 1.4 seconds.

3. A map of hot pixels in bias frames (obtained from a median stack of the nine raw bias frames).
4. A map of traps and other defects (obtained from a median stack of the nine low count level frames).
5. An estimate of bulk CTE in the horizontal and vertical directions (by the EPER method (Janesick et al. 1987)).
6. The amplitudes and frequencies of interference signals (from a Fourier analysis of raw bias frames).

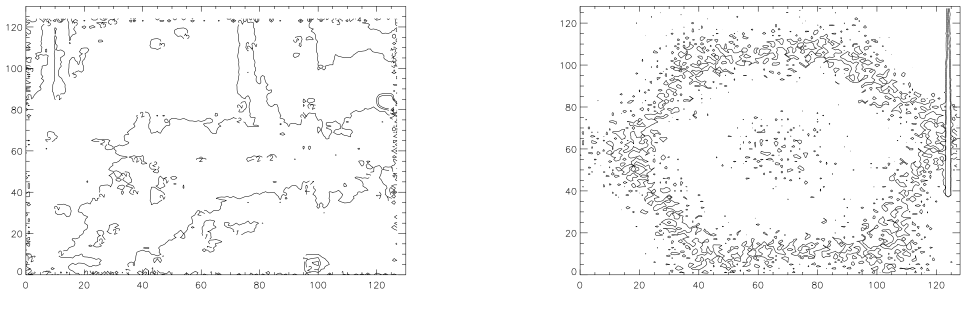

Figure 2. **a** (left): Sample dark current map (TK#36). Contours are labeled in electrons/pixel/hour. **b** (right): Sample shutter delay map (TK#25). The contours are at 0.016 seconds and 0.024 seconds. Note the hexagonal shape caused by the iris shutter.

7. The current values of all bias and clock voltages (normally measured by the CCD controller and recorded in image headers).
8. A map of dark current across the CCD (Figure 2a).
9. A map of the shutter pattern on the CCD (e.g., a star-shaped pattern in the case of an iris shutter (Figure 2b), obtained by analysis of the image made with 64 shutter cycles).

4. Implementation and Documentation

The test program has been integrated in the CCD reduction package of the Munich Data Analysis System (ESO-MIDAS) (ESO 1993), and will be available in the 94NOV release. Therefore, in addition to the already available pipe-line and interactive processing tools for CCD direct imaging data, the CCD package will also offer standard tools for testing the detector quality at ESO and at other institutes.

We issue a full report on the condition of a CCD each time a new CCD test data set is collected and reduced. We are in the process of developing an on-line test data archive to store the raw and reduced test data (ESO 1994) and a World Wide Web interface for browsing these data. These software systems are accessible via the Internet at the ESO Home Page[1]. We use the data obtained for normally functioning CCDs to define baselines for their performances. Trends in these data expose possible slowly developing problems and thus allow realistic preventive maintenance, reducing the probability of catastrophic failures. The most recent test data set combined with the history of a CCD's behavior provides the astronomer with an indication of the current performance and reliability of the device.

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[1]http://www.hq.eso.org/eso-homepage.html