Astronomical Data Analysis Software and Systems IX
ASP Conference Series, Vol. 216, 2000
N. Manset, C. Veillet, and D. Crabtree, eds.

The Removal of Periodic Read-Out Patterns from Science Frames

J.-P. De Cuyper, H. Hensberge

Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussel, Belgium

Abstract. Bias frames taken with CCDs should be homogeneous in intensity. In practice, they fulfill this requirement often sufficiently well, although deviations from homogeneity may be detectable. However, sometimes a clear pattern is superposed on the frame, and this pattern may vary with time. Using a large number of bias frames obtained in one specific run, the time-dependent pattern was found to be built up of a fixed one-dimensional periodic function whose phase-shift varies from row to row. It was successfully removed from calibration and science frames through the use of pre- and upscan "bias" pixels available in each of these frames.

1. Structure Observed in Bias Frames

Often a simple test, like taking the average of each column, shows that the bias frame is not flat. In practice, there is often a slow variation of the read-out level along the row direction of the detector. Over 10 observing runs at ESO, with four different detectors, the difference between bias frames taken during a same run could be represented by a level offset varying in the same way linearly along all rows. This variation was only seen with the TEK CCDs, and is presumably due to the use of the system before the configuration was stable, as a stronger gradient occurs preferentially in the start of a run, and may reappear (less strong) in the start of the next nights. These variations and lack of flatness are easily corrected, and from now on, it will be assumed that such effects have been eliminated. More information on the bias frames of these observing runs can be found in De Cuyper & Hensberge (2000).

2. Periodic Patterns seen in Observing Run 92.04

All 24 bias frames of the 92.04 observing run show striped patterns at the level of the read-out noise. Two examples are shown in Figure 1a, giving an idea of the observed range of pattern from frame to frame. Decisive progress in understanding how such patterns build up followed from the recognition that we see a one-dimensional periodic function that is phase-shifted from row to row.

The function is multi-peaked (Figure 2) with a semi-amplitude of 10 e^{-} and repeats after 439 pixels. Hence the period is not much shorter than the time needed to read a row. The phase-shift from one row to the next is nearly

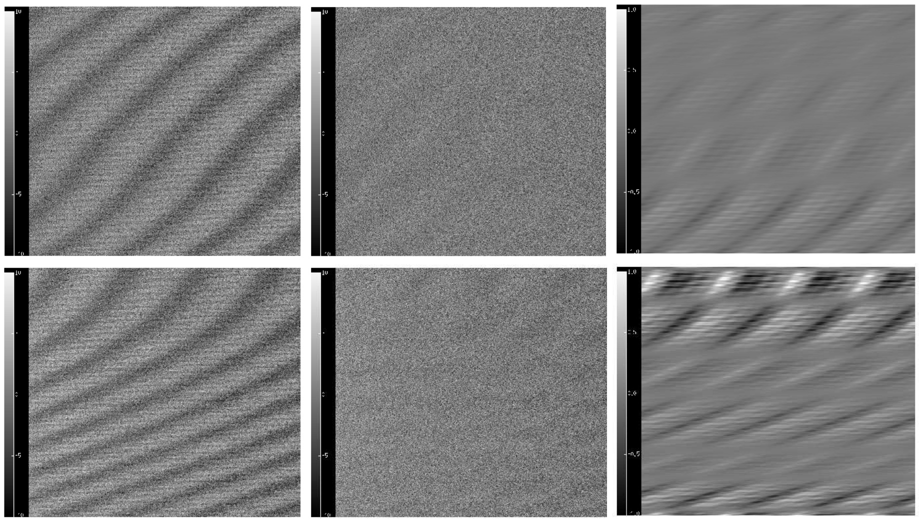

Figure 1. The left panels (a) show the time dependent stripe patterns on rectified bias frames in observing run 92.04 and the middle panels (b) the corrected frames using only the information in the selected overscan pixels (Cut values in intensity: -40 to +40 e^{-}). The right panels (c) show the difference with the correction obtained by fitting the whole bias frame (Cut values in intensity: -4 to +4 e^{-})

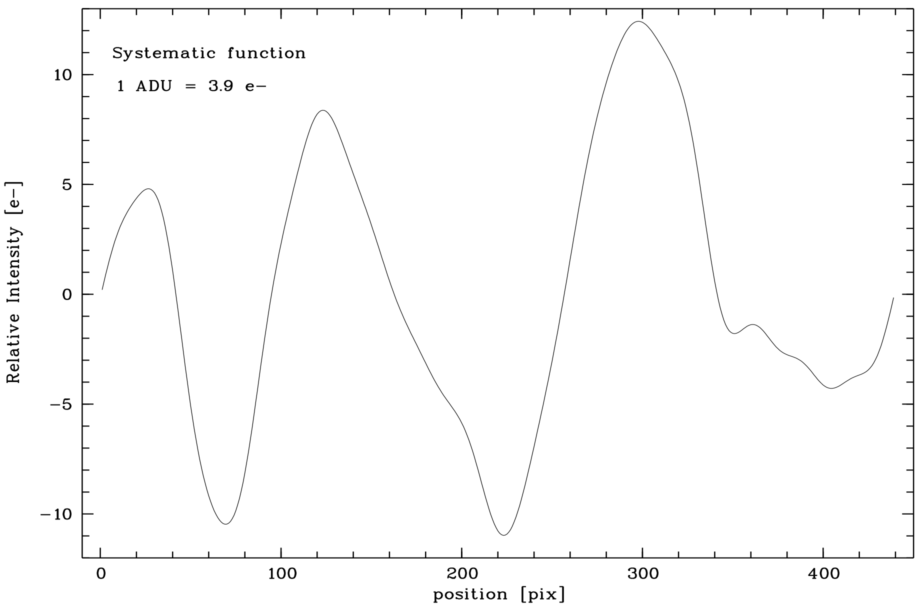

Figure 2. The periodic systematic function superposed on all rows of all frames in observing run 92.04 (Period 439 pix).

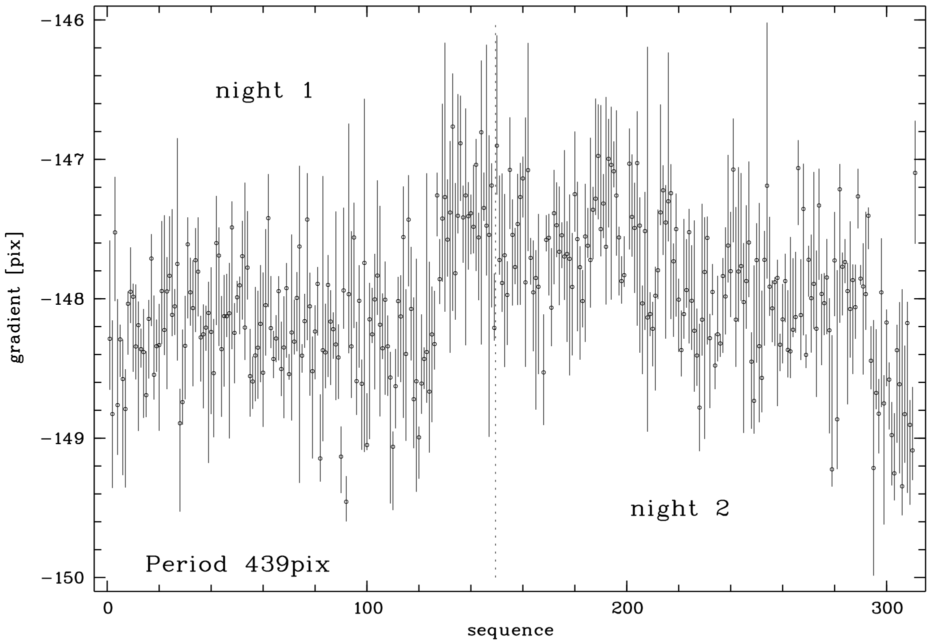

Figure 3. Variability of the phase shift during the read-out of a frame. Dots indicate the mean shift from row to row for each image; while the bars indicate the total range of the measured shifts from row to row. The horizontal axis shows the time sequence of the images of observing run 92.04.

one-third of the period and generates in combination with the 3 peaks the visual pattern present in Figure 1a. A slight, smooth variation in the phase shift from row to row produces stripes that are curved rather than straight.

The periodic function was actually reconstructed by estimating its periodicity from an initial FFT analysis, after which the phase-shifts were iteratively improved by cross-correlation with subsequent approximations of this periodic function. These approximations were iteratively obtained by averaging phase-shifted rows of all bias images.

3. Removal of the Periodic Pattern

The multi-peaked function shown in Figure 2 is represented by a Fourier series with 16 terms and its phase variation between rows is parameterized by a polynomial of degree 7 (suitable to describe the variation over the rows of all bias frames). On all but the bias frames, the phase parameters had to be determined from trustworthy overscan pixels (6 up-scan rows and 40 pre-scan columns were used). This was done by a least-squares algorithm with initial estimates for the phase shifts being obtained again from cross-correlation of individual rows with the systematic function. For each calibration or science frame, the range in phase shift from row to row and the mean value of this shift are shown in Figure 3.

4. Accuracy of the Correction

Figure 1b shows the bias frames of Figure 1a corrected for the periodic pattern using only the information in the selected overscan pixels. Figure 1c shows the difference between this model and the one derived using the information over the whole bias frame (Note that the scale differs by a factor of 10). A check over all bias frames indicates that the rms in images as shown in Figure 1c lies below 0.5 e^- and that local differences may reach 4 e^-. This shows that the procedure applied to the overscan pixels results in good estimates of the phase shifts. Moreover, the fact that the parameter space covered by all frames is already covered by the subsample of the bias frames adds confidence that no spurious results were produced.

5. Conclusions

- Time-dependent stripe patterns created during read-out were represented by a one-dimensional periodic function, whose phase shift between different rows varies smoothly in time intervals small with respect to the read-out time of a frame.
- The removal of this time-dependent pattern reduced the read-out noise from 11.3 e^- to 9.4 e^-. More importantly, its removal prevents that subsequent data reduction algorithms, which assume pure random noise, suffer from systematic noise.
- Pattern characteristics do not correlate with any obvious observing parameters (as time, type of frame, telescope position, etc.). Hence the periodic read-out pattern is presumably due to electronic noise caused by grounding problems in the CCD camera.

Acknowledgments. This research was carried out in the framework of the project "IUAP P4/05" financed by the Belgian Federal Scientific Services (DWTC/SSTC). We thank H. Van Diest for help with the data handling. This work is based on observations obtained at the European Southern Observatory (E.S.O.), La Silla, Chile.

References

De Cuyper, J.-P. & Hensberge, H. 2000, in Optical Detectors for Astronomy, Proceedings of the ESO CCD Workshop held in Garching Germany Sep. 13-16 1999, eds. P. Amico & J.W. Beletic, ASSL Series Kluwer Academic Publisher, in press