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Model Based Corrections to Data from Radiation Damaged Detectors.

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Abstract. Space based CCDs suffer continual bombardment from the hostile radiation environment which gradually degrades their performance and potentially limits their operational lifetime. As part of our effort to enhance the calibration of STIS (a spectrograph on-board the Hubble Space Telescope), we have developed a model of the readout process for CCD detectors suffering from degraded charge transfer efficiency. The model enables us to make predictive corrections to data obtained with such detectors. We present examples of the corrections possible using this technique and compare them to what can be achieved using a more conventional empirical approach. In addition we discuss some of the difficulties of providing users with automated implementations of this this kind of data analysis software.

1. Introduction

Charge Coupled Devices (CCDs) operating in hostile radiation environments suffer a gradual decline in their Charge Transfer Efficiency (CTE, or equivalently, an increase in charge transfer inefficiency, CTI). STIS and WFPC2 have both had their CTE monitored during their operation in orbit and both indeed show a measurable decline in CTE which has reached a level which can significantly effect scientific results (eg. Cawley et al 2001, Heyer 2001, Kimble, Goudfrooij and Gililand 2000).

As part of the Instrument Physical Modelling Group's effort to enhance the calibration of STIS we have developed a model of the readout process for CCD detectors suffering from degraded charge transfer efficiency. The model enables us to make predictive corrections to data obtained with such detectors.

2. The Model

Detailed discussion of the model development and the physics involved can be found in Bristow & Alexov et al. 2002 and Bristow 2003a. Our approach is to simulate the readout process at the level of individual charge transfers. That is we take an image (a charge distribution on a two dimensional pixel array) and transfer the charges out as they would be on a real chip. Throughout we keep track of the status of bulk traps in the silicon pixels as they interact with the charge distribution. The timescales and densities for these known traps

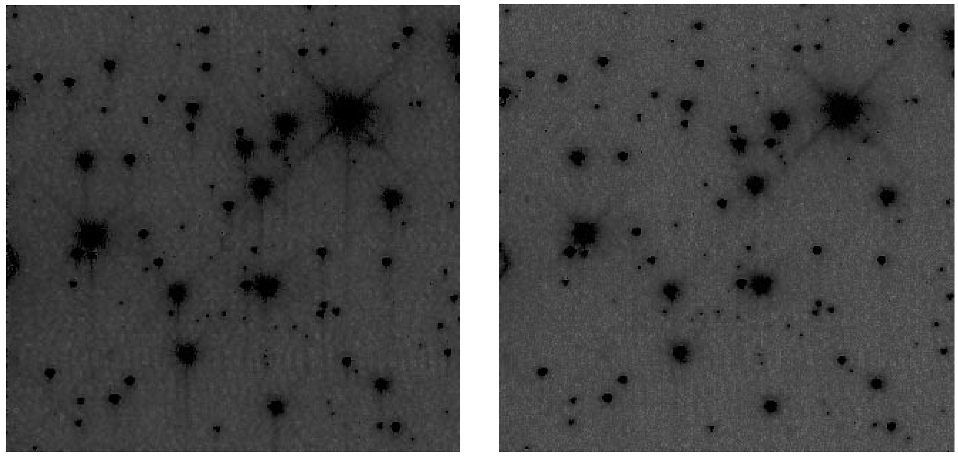

Figure 1. Left: A section of STIS image data suffering from significant CTI. Right: The same section after correction with the physical model. Note that trails under bright sources have been removed

are appropriate to the operating temperature and on-orbit radiation exposure respectively. The model has been optimised for the correction of STIS data, but could in principle be ported to other detectors.

3. Cleaning CTE Trails

The clearest aesthetic diagnostic of data suffering from poor CTE is the presence of trails under bright objects. This can be seen clearly in the section of STIS data shown in figure 1 (left), the read out direction is upwards. Figure 1 (right) shows the success of the simulation derived correction in cleaning these trails.

4. Photometric Corrections

Probably the most important effect of CTI is the loss of flux from the central isophotes of sources. It is possible to calibrate an empirical flux correction as a function of signal strength, background, epoch and position on the chip. Such a correction must be formulated and calibrated differently for photometric and spectroscopic data because of the differing nature of the spatial distributions of illumination and resulting charge. Moreover, empirical corrections *only apply to point sources.* On the other hand, modelling the readout process we are able to correct for any charge distribution and can therefore apply this method to all data whether photometric or spectroscopic and obtain a correction for every pixel, not just extracted sources or spectra.

Nevertheless the empirical corrections for STIS provide an ideal means of testing and calibrating the physical model, as the empirical corrections are essentially a distillation of what is to be learnt from the calibration data with respect to CTI. If the physical model reproduces empirical results on average for point sources then it is reasonable to conclude that it is correctly modifying

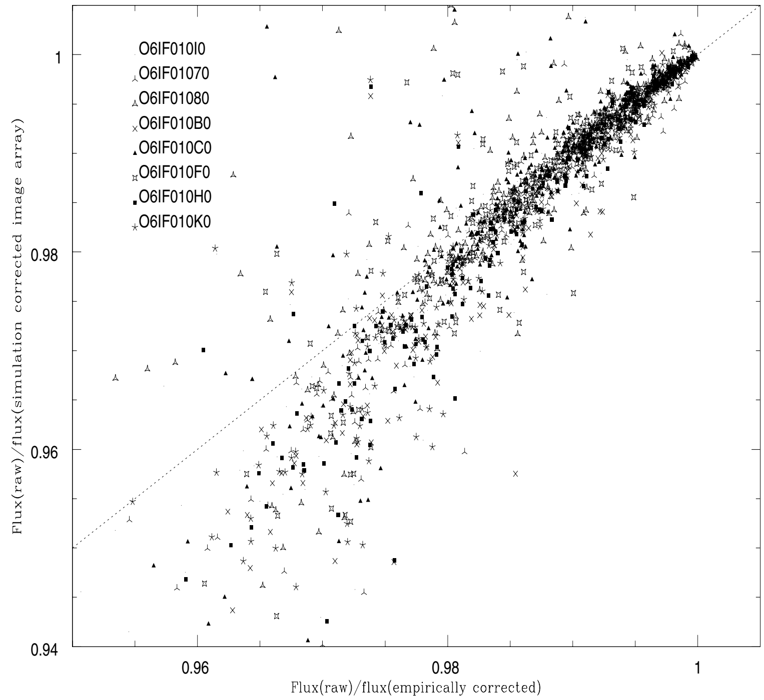

Figure 2. Comparison between empirical and model based corrections

the charge distribution and will also therefore correctly predict the CTI in extended sources and indeed the whole image array. A comparison between model based and empirical corrections, for sources to which the empirical corrections apply, is shown if figure 2. Beyond the general good agreement, there are many sources for which the model based and empirical corrections differ significantly.

The scatter is due to the fact that the non uniformity of the charge distribution causes the CTI experienced by each source to vary in a way which cannot be accounted for in the empirical corrections. Indeed, if we examine sources corresponding to outlying points in figure 2 in the raw image array, we find that the anomalous correction factor assigned by the physical model is easily understood by considering charge distribution in the surrounding pixels. For example, nearby sources, falling between the source in question and the read out register, will trail charge into the aperture, leading to a smaller CTI effect than the empirical calibration would suggest. (See Bristow 2003a&b).

5. Pipeline Integration

A complex and comprehensive data pipeline already exists for STIS. It relies upon a database of empirically derived and continually updated reference files selected by header keywords in each dataset. Introducing a model based component of the calibration leads to some conflicts. Some aspects of the calibration which fit neatly into one reference file have more than one physical source and vice versa. Specifically:

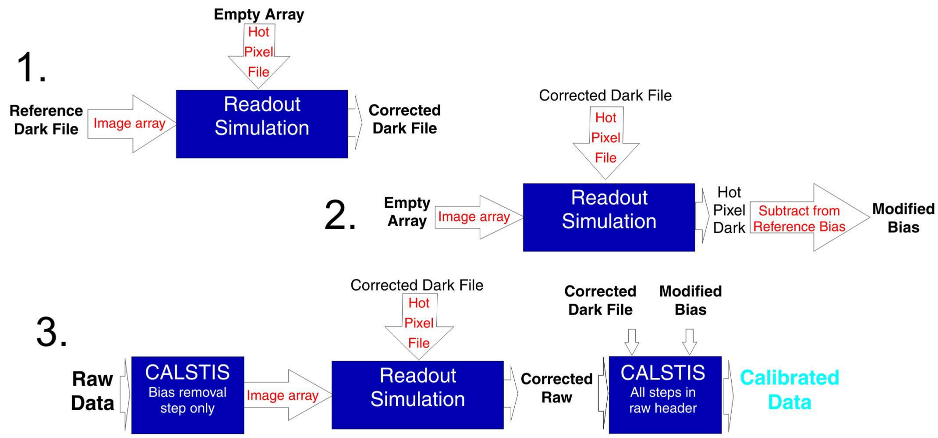

Figure 3. Schematic showing the preparation of CTI corrected data for the CALSTIS pipeline

- Reference files (bias and dark) must themselves be corrected for CTI effects
- The readout simulation generates hot columns from the hot pixels and thereby includes a correction for these features as well as CTI. However, the bias files provided for use in the pipeline, include these hot columns and other features not dealt with by the readout simulation.

However, a complete model based calibration of STIS is not yet possible. In addition, the simulation is CPU intensive and adds considerably to the total processing time, therefore the possibility to execute this as a stand alone process is also desirable. Figure 3 illustrates the incorporation of the model in a way which takes the above into account.

References

Bohlin, R. & Goudfrooij, P. 2003, STIS Instrument Science Report 2003-03

Bristow, P. & Alexov, A. 2002, CE-STIS-Instrument Science Report 2002-001

Bristow, P. 2003a CE-STIS-Instrument Science Report 2003-003, in preparation

Bristow, P. 2003b CE-STIS-Instrument Science Report 2003-001

Bristow, P. 2003c CE-STIS-Instrument Science Report 2003-002

Cawley, L., Goudfrooij, P. & Whitmore, B. 2001, Instrument Science Report WFC3 2001-05

Goudfrooij, P. & Kimble, R. A. 2002 in Proceedings of the 2002 HST Calibration Workshop, Eds Arribas, S., Koekemoer, A and Whitmore, B. (Space Telescope Science Institute)

Heyer, I., 2001, WFPC2 Instrument Science Report 2001-009

Kimble, R. A., Goudfrooij, P. & Gililand, R.L. 2000, Proc. SPIE Vol. 4013, p. 532-544, in UV, Optical, and IR Space Telescopes and Instruments, Ed. J. B. Breckinridge; P. Jakobsen