Technical Instrument Report WFPC2 98-01

Time Dependence of the Charge Transfer Efficiency on the WFPC2

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ABSTRACT

New evidence is presented that the Charge Transfer Efficiency (CTE) problem has increased with time for the WFPC2. Using observations of the globular cluster Omega Cen in the F814W filter over a baseline of just over 3 years shows an increase in CTE loss for faint stars (20 - 50 DN at a gain of 15 within an aperture with a 2 pixel radius) at the top of the chip from 3 +/- 3% to 22 +/- 3%. The change with time is smaller for brighter stars, and for stars brighter than about 200 DN (equivalent to 400 DN for gain = 7) there is no significant change with time. These results are based on very short (14 second) exposures. In general, typical WFPC2 exposures are much longer than these short calibration images, resulting in higher background which significantly reduces the CTE loss and minimizes the CTE problem for most science observations.

1. Introduction

A recent Instrument Science Report (ISR 97-08, ‘‘New Results on Charge Transfer Efficiency and Constraints on Flat-Field Accuracy’’ by Whitmore and Heyer; see

http://www.stsci.edu/ftp/instrument_news/WFPC2/wfpc2_bib.html)

analyzed a set of WFPC2 observations of the globular cluster Omega Cen (=NGC 5139) taken in June, 1996, and developed formulae to remove the effects of Charge Transfer Efficiency (CTE) from aperture photometry to about the 2 - 3% level. Four parameters were required; the X and Y positions on the chip, the brightness of the star, and the background level. The following document continues our investigation of CTE on the WFPC2 by examining the time dependence.

NOTE: The current document is quite sketchy since it is primarily designed to explain the figures that are included below. A more complete article to be submitted to PASP is in the works.

2. Analysis

WFPC2 observations in the outskirts of the globular cluster Omega Cen were used to make the measurements. The F814W filter was employed since it provides the highest S/N determination of CTE (since the stars tend to be red and the background is lower than at F555W, resulting in larger values of CTE loss). The dataset used in ISR 97-08 was more efficient for measuring CTE than most of our earlier observations of Omega Cen due to the fact that the same field is placed on each of the different chips. Since the readout of each of the chips rotates by 90 degrees, the effect is that the same star is moved from top to bottom and from side to side, making a direct differential measurement of the same star at different positions very easy. For the other observations only one field was imaged, hence the need for an absolute rather than differential measurement. The existing ground-based data sets are not optimal for this comparison since they are of bright stars (Harris et al., 1993, AJ, 105, 1196) or of a small field (Walker 1994, PASP, 106, 828). Hence the first step of the analysis was to build a dataset from the fields used in ISR 97-08 to provide an absolute comparison. This "standard-wide" database has been corrected for CTE using the equations defined in ISR 97-08.

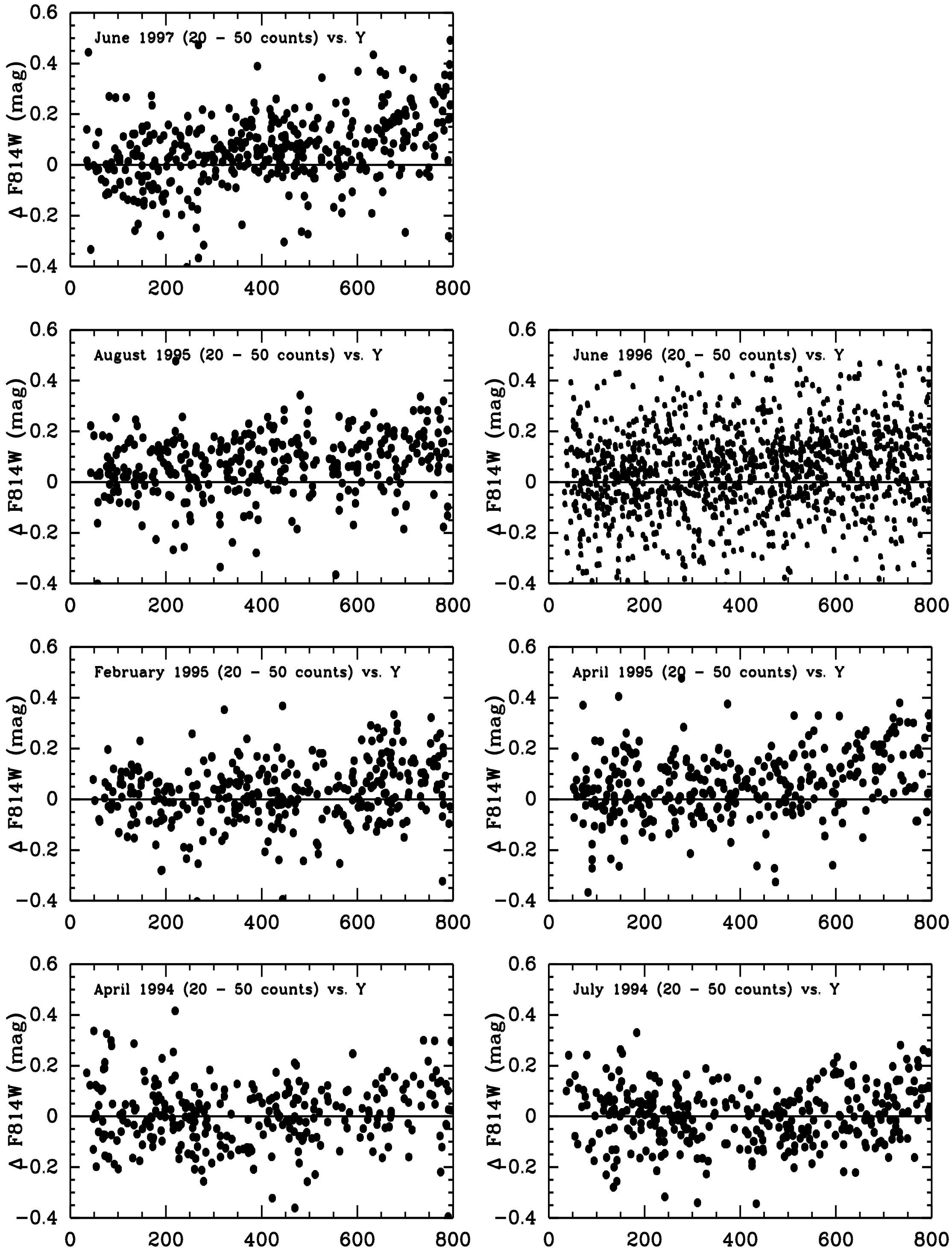
The datasets chosen for the comparison are listed in Table 1. They span the range from shortly after the cooldown (April 23, 1994) until the most recent observations of Omega Cen in June 1997.

Table 1. Datasets used in the Comparison

Date	MJD	Gain	Exp. Time	Dataset
April 28,1994	49470.8	15	14 seconds	u2d10206t
July 17,1994	49550.3	15	14 seconds	u2g4040at
February 15,1995	49763.4	15	14 seconds	u2g40o09t
April 6, 1995	49813.7	15	14 seconds	u2g40u09t
August 28, 1995	49957.2	15	14 seconds	u2uq010ot
June 29, 1996	50263.2	7	100 seconds	u34d010kt
June 26, 1997	50625.6	15	23 seconds	u3ak010am

Figure 1 shows the differences in magnitudes for the various datasets. The CTE loss can be seen as the tendency for the stars at higher values of Y to have positive residuals (i.e. fainter magnitudes). This particular cut was for stars with 20 to 50 DN within a 2-pixel radius aperture. It is clear that the earlier observations at the bottom of the diagram have much smaller values of CTE loss than the more recent observations at the top of the diagram.

Figure 1: Comparison of stellar magnitudes using a 2-pixel radius aperture with the F814W filter vs. our standard-wide comparison field as a function of row number (=Y) on the CCD.



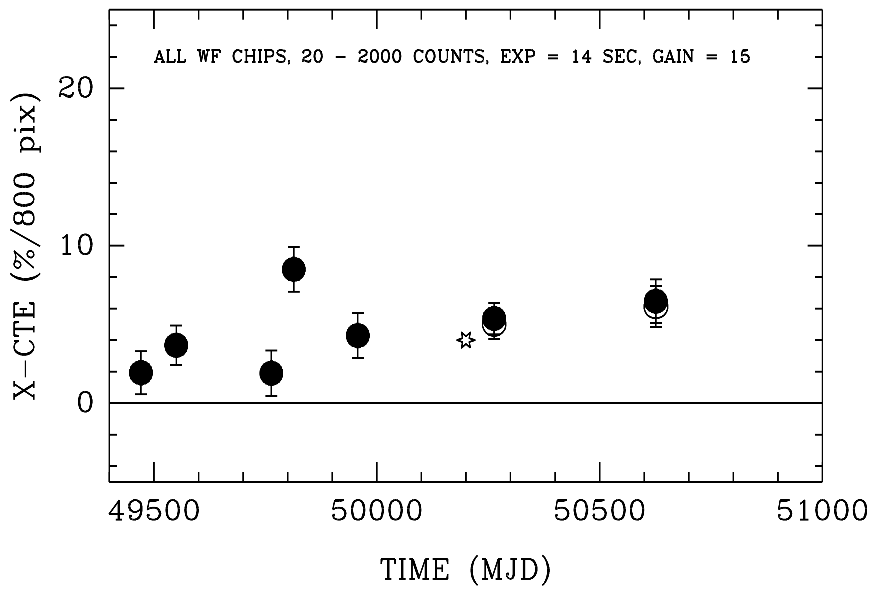
NOTE: The June 1996 observations use different chips than were used to establish the standard-wide comparison field measurement so that the comparison is not simply the same data with and without the CTE correction. See Figure 1 in ISR 97-08 to make this clearer (e.g., field 1 with the WF2 was compared to field 1 with WF3, so the Y direction is 90 degrees different).

Figure 2 shows the value of CTE loss as a function of time. The increase for Y-CTE is obvious (slope = 0.0104 +/- 0.0012), while the increase in X-CTE is much smaller, if there is any significant trend at all (slope = 0.0032 +/- 0.0022).

One complicating feature is that while the earlier 5 observations used an exposure time of 14 seconds, the 2 most recent measurements used exposure times of 100 seconds and 23 seconds. This affects the amount of CTE loss in two ways; 1) the proportion of bright stars (with lower CTE loss) is larger than for the 14-second exposures, hence lowering the average amount of CTE loss; 2) the background is higher which also results in less CTE loss. The raw values for these two observations are plotted as open cycles while the values scaled to the expectation for a 14 second exposure are plotted as solid circles. The correction for the 100-second exposure is fairly large while the correction for the 23-second exposure is quite small. The star shows the values predicted for MJD=50263 based on the equations in ISR 97-08 for the data on this date. The agreement is very good. Another detail is that the counts for gain=15 observations are multiplied by 2 before using them in the equations from ISR 97-08, which were derived for gain=7 data (which are more typical of science observations).

Figure 3 shows that there is essentially no trend in Y-CTE loss vs. time for stars brighter than 200 counts (equivalent to 400 counts at gain=7). The uncertainties are quite large for the brightest stars since there are very few stars of this brightness. For the fainter stars there are clear trends that the CTE loss is increasing with time. In the case of the 20 - 50 DN data, it appears that CTE loss has increased from 3 +/- 3% to 22 +/− 3% in just over 3 years. The predictions for the June 1996 data based on the equations in ISR 97-08 (represented by stars in Figure 3) are in fair but not great agreement with the observations.

Figure 2: The comparison for both Y-CTE (bottom figure) and X-CTE (top figure) based on observations of Omega Cen through the F814W filter and stars with 20 - 2000 counts (mean value of around 100 DN, equivalent to 200 DN at gain=7). The open symbols represent measurement with exposure times longer than 14 seconds. The values corrected to 14 seconds (using the equations in ISR 97-08) are shown above the open circles. The stars show the predictions based on the equations in ISR 97-08 for the June 1996 data (offset slightly in MJD to make them more visible).



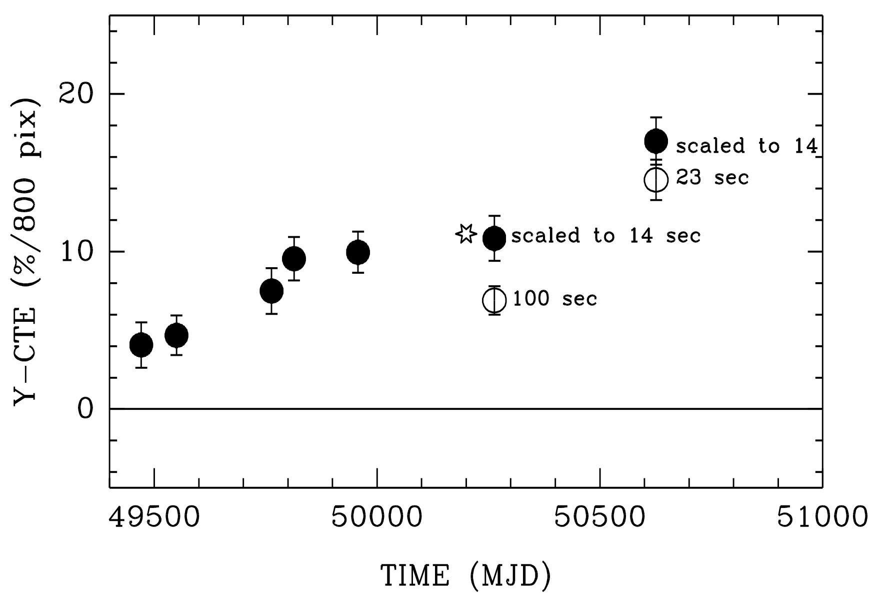
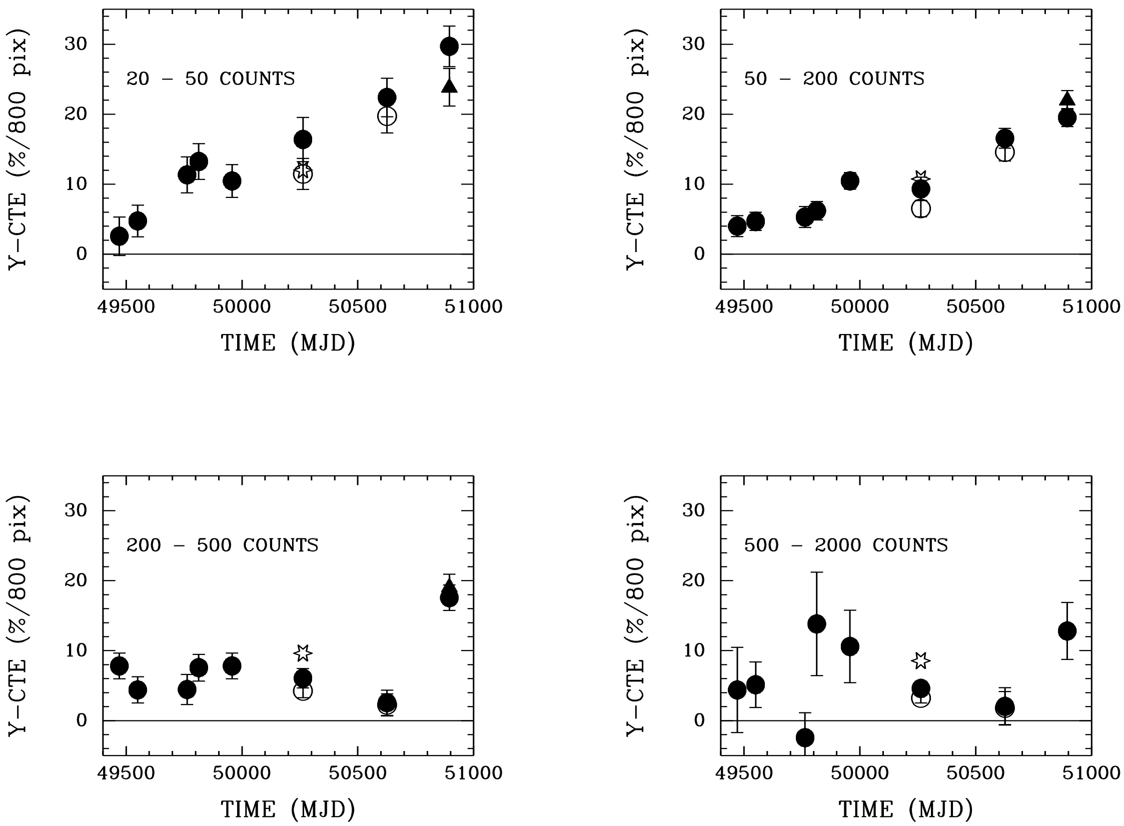


Figure 3: Y-CTE loss as a function of time for four different ranges of the target brightness. The open symbols again represent measurements with exposure times longer than 14 seconds, with the corrected value above as a filled circle. The stars show the predictions based on the equations in ISR 97-08 for the June 1996 data.



3. Perspective

While an increase in CTE loss from 3% to 22% over roughly three years for faint stars is somewhat alarming, it is important to keep four things in mind:

- Most science observations are much longer than these 14-second calibration exposures. The result is that the background is much higher, which drastically reduces the amount of CTE loss in most science data (e.g., see Figure 9 of ISR 97-08).
- While a single faint star at the top of a chip may suffer 20% CTE loss, the average for a randomly distributed field will only be 10% with a rms scatter of about 7%.
- Modifications to the formulae presented in ISR 97-8 should allow observers to correct their data to a mean accuracy of about 4%.
- There is essentially no increase in CTE loss for stars brighter than about 200 DN (400 DN for gain=7).

4. Current Recommendations

Our current recommendations for correcting for CTE loss in aperture photometry are outlined below. It should be kept in mind that these recommendations will probably evolve as more data is obtained and analyzed.

Note: This section was updated July 17, 1998. An updated equation for correcting for the temporal dependence of CTE on the WFPC2 is included below. This both includes the recent data taken March 23, 1998, and corrects for the fact that the earlier equations had not been normalized properly.

1. Correct the value of Y-CTE predicted from the equations

in ISR 97-08 (p. 26) by multiplying by:

$$1 + 0.00094 \times (MJD - 50263) \quad \text{, equation \# 1 (for Y-CTE)}$$

where MJD is the Modified Julian Date of your observations, and 50263 is the MJD on the date when the dataset used to determine the equations in ISR 97-08 were taken (i.e., June 29, 1996).

Examples of the correction are:

MJD	Date	Correction factor for Y-CTE
49471	April 28, 1994	0.26
50263	June 29, 1996	1.00
50895	March 23, 1998	1.59

Note: Equation #1 was derived based on the mean of the fits to the 20-50 and 50-200 DN panels in Figure 3 (updated) in the addendum to this document, which give nearly the same values for the slope in the equation. The other panels were not used since the scatter is much larger, although they are consistent within the errors.

2. The situation is less clear for X-CTE, since there is only weak evidence for an increase (i.e., the slope in Figure 2a is 0.0032 +/- 0.0022). Hence it is probably reasonable to simply use the equations for X-CTE in ISR 97-08 (p. 26) with no correction. However, if you choose to make a correction, the equation would be:

$1 + 0.00052 \times (MJD - 50263)$, equation # 2 (for X-CTE)

Examples of the correction are:

MJD	Date	Correction factor for X-CTE
49471	April 28, 1994	0.59
50263	June 29, 1996	1.00
50895	March 23, 1998	1.33

3. Once you have made your corrections to Y-CTE and X-CTE, use equation # 1 from ISR 97-08 to determine the total CTE correction.

Note: The correction equations in ISR 97-08 were derived from gain 7 data. In order to correct gain 15 observations, counts should be multiplied by 2 before using them in the CTE equations in ISR 97-08.

5. Addendum:

Calibration proposal 7929 has been added to the Cycle 7 calibration plan in order to monitor the change in CTE every 6 months. After analysis of the F814W (14s) data from the first visit of proposal 7929 (March 23, 1998), we have found that the CTE loss is continuing to increase with time. Below is an updated Figure 3.

Figure 3 (updated): Y-CTE loss as a function of time for four different ranges of the target brightness. The open circles represent measurements with exposure times longer than most of the other exposures (i.e., 14 seconds), with the normalized value shown above as a filled circle. The stars show the predictions based on the formulae in ISR 97-08 for the June 1996 data.