SXT Calibration Note 43

**SXT Dark Current Orbital Correction Report**

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**Abstract**

The every-orbit UV flood of the SXT CCD charged up traps in the device that emptied over a period of time causing a change in dark current (dc) signal as a function of time after the end of the UV flood. SXT analysis software was modified in 1998 to adjust the dc signal to take account of the difference in time since UV flood of the SDC (dark image) and the X-ray image. Unfortunately, errors in this software caused SXT X-ray images to be over or under corrected. These errors were discovered in late 2015. This report details the dc-orbital effect and discusses the differences in SXT level-1 and level-2 images created with the old and new dc-orbit-correction IDL software.

# Contents



# 1 History

Not too long after entrance filter failures began in November 1992 it was discovered that CCD dark current (dc) varied over each daylight pass with a sharp decrease beginning at the end of UV flood. The cause of this variation is believed to be charge bleeding out of traps in CCD pixels (probably in the X-ray insensitive half of each pixel) that were filled during the UV flood. This is a dc effect only. For any given time the pedestal+spurious charge part of the CCD dark signal shows no variation with orbital phase nor exposure duration, although there are long term variations throughout the mission as detailed by Acton (2016). Subsequent analysis (Acton, 1994a) indicated that the orbital dc effect was present as early as November 1991.

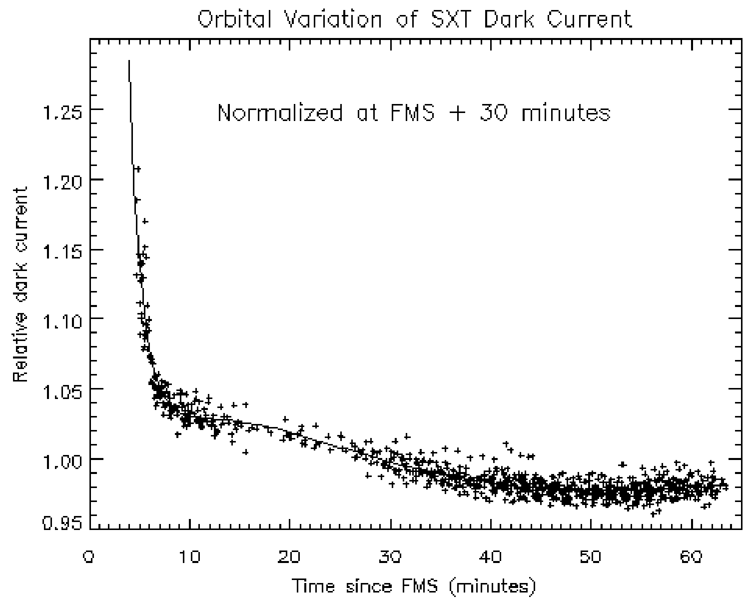



Figure 1: SDC dark current versus time since orbital sunrise with 5th-order polynomial fit to the data.

In December 1994 SXT experiments were run (Acton, 1994b) to better define the orbital variation of dark current and a 5th-order polynomial fit was derived (see the Appendix) to describe it, as illustrated in figure 1. In 1998 the program DC_ORBIT_CORRECT.PRO was written to adjust the CCD dark signal for the orbital phase difference between the dark frame and the data frame. As the polynomial fit used tim2fms (time since sunrise) from TIM2ORBIT.PRO as the independent variable, and this does not properly take account of differences in the the morning interval (UV flood duration) from time to time through the mission, the program SXT_UVF_INFO.PRO was written to generate the variable tfms for use in properly computing the factor for dc adjustment for any time in the mission. As discussed in section 3, tfms is the sum of the 128 sec *Yohkoh* morning set-up time plus the morning interval plus the time since the end of UV flood, in minutes. The programs GET_DC_IMAGE.PRO and DARK_SUB.PRO were also modified in January 1998 to incorporate dc orbital adjustment.

Unfortunately, for some situations, errors in SXT_UVF_INFO.PRO returned incorrect values of tfms. Also, DC_ORBIT_CORRECT.PRO applied the dark frame adjustment to the entire CCD dark signal rather than just to the dc part. All ensuing SXT data products, including those in the YLA as of the end of 2015, incorporated these errors – which impact the intensity levels in SXT images.

In early 2016 I corrected these IDL programs and the YLA level-1 and level-2 data products were regenerated. The SXT Science Composite level-2 products, SSCs and SSTs, are in the subdirectory SSC30 with version number 7. It is the purpose of this report to critically evaluate the dc-orbit-corrections, to present for the first time a thorough discussion of the problem, and to evaluate the magnitude of the errors in the YLA heritage SSCs (SSC27).

## 2 SDC example, 1999

For a period of 3.5 months in 1999, due to an error in the SXT observing tables, HR DPE=2 dark frames were taken much more frequently than usual. These 443 SDCs (all with cooled CCD and no SAA) provide the opportunity to study SXT dark signal properties and verify the accuracy of the 1994 fit illustrated in figure 1 and described in the Appendix.

## 2.1 CCD dark signal properties

Figure 2 presents, in units of DN per HR pixel, the total dark signal in these 443 SDCs, the dc part of the signal, and the pedestal+spurious noise portion of the signal. The solid line in panel B is a linear fit to the secular increase in dc. This smooth change with time has been removed from the dc in results presented from here on. The dc (panel B) is the average value of CCD rows 21:511 after SDC row 20 has been subtracted from each higher row. Starting at row 21 avoids error introduced by charge bleed-back from the serial register which always appears in the first few rows of an image. The pedestal+spurious (panel C) is the average of SDC row 20. Row 20 is assumed to have negligible dc because the accumulation time for this row is only about 8 ms. Higher rows have longer accumulation times because of the time it takes to read out the higher rows at a rate of $7.81\times10^{-3}$ sec row$^{-1}$.

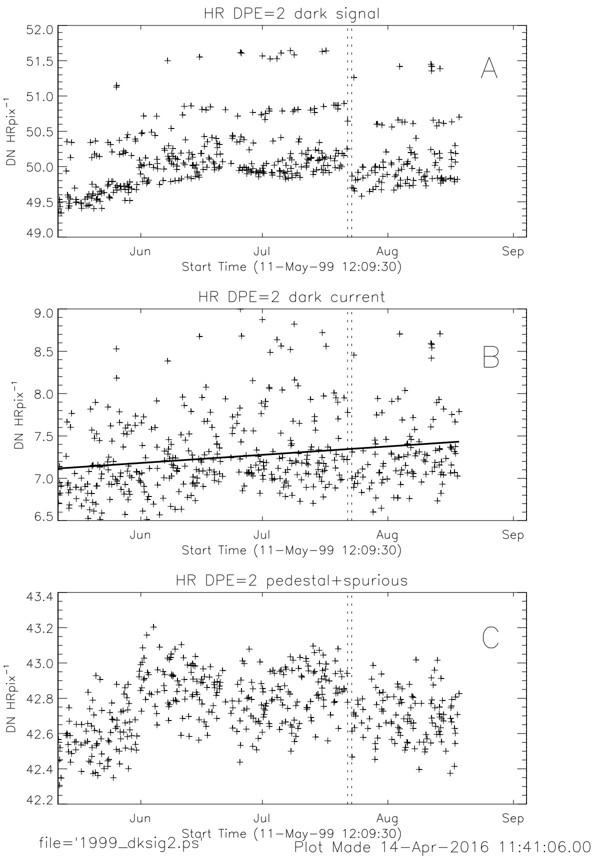



Figure 2: (A) Total dark signal. (B) Dark current with secular increase in dc indicated by the solid line. (C) Pedestal+spurious charge.

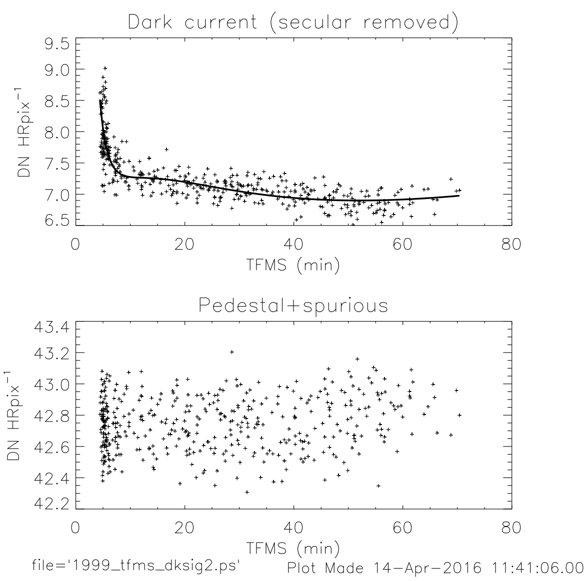



Figure 3: Dark current (upper) and pedestal+spurious (lower) versus tfms. In this case tfms minus 4 is the minutes since the end of UV flood.

The obvious step increase in dark signal on 1-Jun-99 in figure 2 is due to the increase in pedestal+spurious somehow caused by a situation in which the KSC tohbans, attempting to correct for a hard filter wheel error, left the instrument in SXT-CTL-MAN. This resulted in a 6 hour data gap in addition to the earlier 3 hour data gap caused by the filter wheel problem. I have no idea why these events impacted the level of spurious charge. It seems unlikely that the pedestal would be affected as this is electronically set within the CCD camera.

The double dotted lines in each panel of figure 2 denote the period of a CCD bakeout which reduced the spurious charge but did not appear to affect the dc.

Figure 3 shows dc and pedestal+spurious signal versus time since the end of the UV flood. The solid curve in the dc (upper) panel is the 5th order polynomial fit described in section 1 and the Appendix. It appears to be a satisfactory fit to these independent measurements. Note that pedestal+spurious is independent of time since UV flood.

## 2.2 Non-uniformity of dark current enhancement

In 1996 it was discovered (Acton, 1996) that the UV-flood enhanced dc was not uniform over the CCD but rather was stronger in the areas of the CCD which were moderately damaged by X-ray exposure. This is illustrated in figure 4. It is interesting that the dc does not appear to be as enhanced in the most severely X-ray damaged areas of the CCD just inside the east and west limbs as it is above the limbs and at disk center.

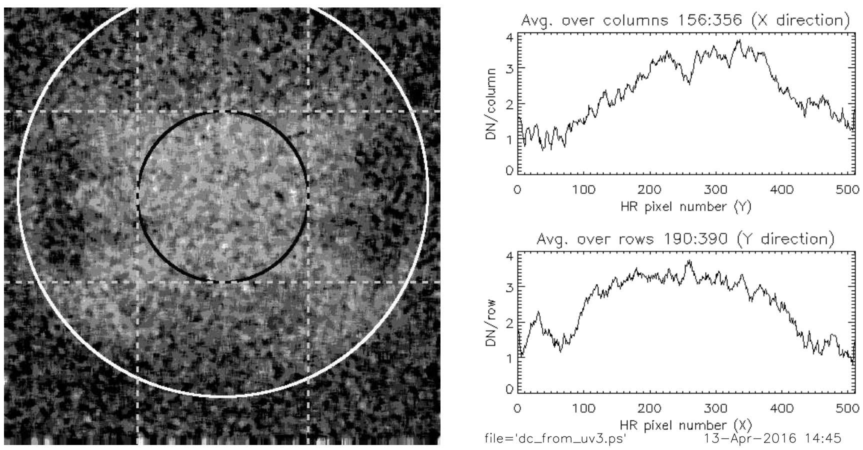



Figure 4: Left: Seven-pixel median-smoothed difference image from a 30 sec HR dark image starting 1.13 min after UV flood (2-Jun-96 19:23:06) minus one starting 29.2 min after UV flood (2-Jun-96 16:36:46). Circles denote areas for summation as discussed in the text. Broken lines mark the boundaries of the averages shown in the plots to the right. Right: Plots of averages over 201 columns (upper plot) and 201 rows (lower plot) of the smoothed difference image.

The variation of dc for different portions of the CCD can be studied using the 443 DPE=2 HR SDCs obtained due to the observing table error between 11-May-1999 and 18-Aug-1999. The areas sampled are shown in figure 4 where the center area is inside the black circle and the off-disk area is outside the white circle.

Figure 5 demonstrates the dc variation with tfms for these two portions of the CCD. Namely, the dc at the center of the X-ray damaged area is about 55% greater than it is for the off-disk portions of the detector. Note that the ratio of disk-center dc to off-disk dc is fairly stable after a tfms of about 6 minutes.

A difference image like that in figure 4 can be used to quantitatively evaluate the fraction of image pixels which are enhanced by dc increase from the UV flood and how much the enhancement is. The HR DPE=30 SDCs chosen for this analysis demonstrate the maximum effect. The early SDC (tfms=4.7 min, 9-Jul-96 10:14:37) is well into the early, strong, enhancement of dc shortly (starting 44 sec) after the end of the UV flood while the late SDC (tfms=50.8 min, 30-Jul-96 00:39:36) is at the dc minimum. The tfms position of these 2 SDCs are illustrated in figure 6.

The smoothed difference image of these two SDCs is visually indistinguishable from that shown in figure 4. The mean dark signals are 121.75 and 114.57 DN for the early and late SDCs respectively. For this case the boost in total dark signal averages about 7% and affects roughly 60% to 70% of the CCD pixels. Because of the noise in the difference image these results are, at best, only approximate.

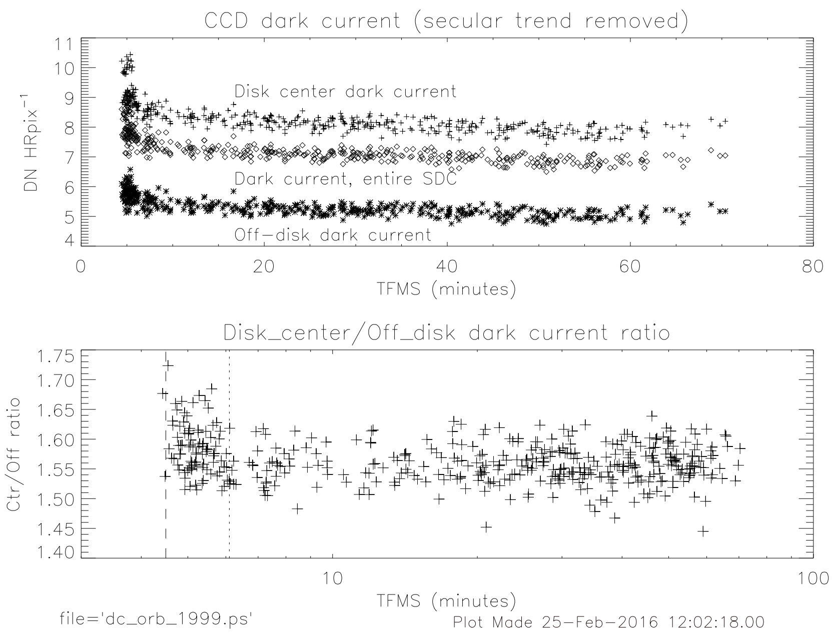
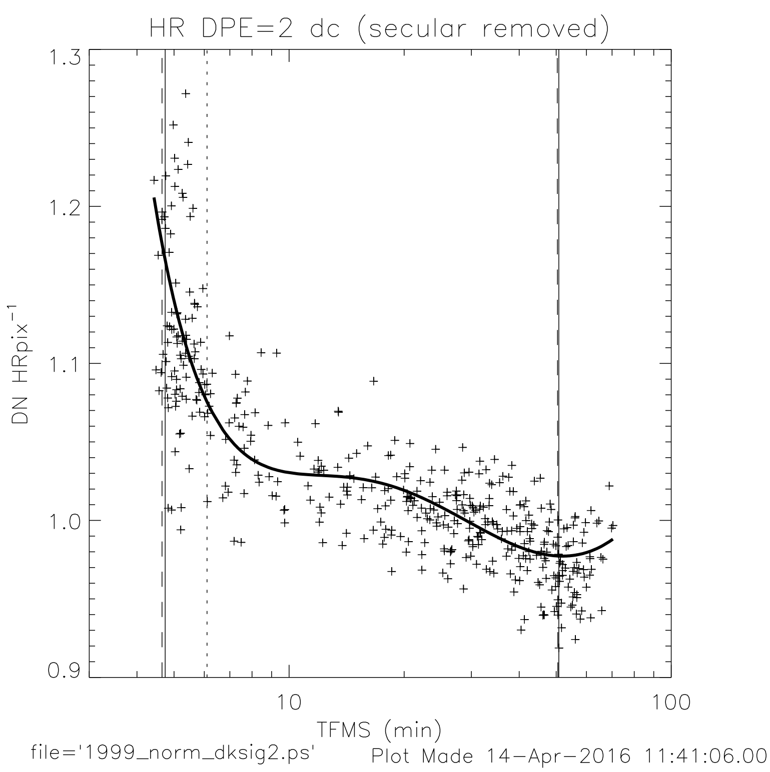



Figure 5: Upper panel: Orbital dependence of dc for different areas of the CCD. Lower panel: Disk-center dc is brighter than off-disk dc.

Figure 6: Dark current vs. tfms for 443 SDCs obtained between 11-May-99 12:09 and 18-Aug-99 13:50. Solid vertical lines mark the tfms of long-exposure SDCs discussed in the text. Broken vertical lines mark the tfms of equivalent (in resolution and DPE) X-ray images. The dotted vertical line at tfms=6.1 min marks the DC_ORBIT_CORRECT.PRO min_tfms cutoff time discussed in section 4.



# 3 Time since end of UV flood (tfms)

The so-called "morning interval" was a settable SXT command to determine the duration of the every-orbit (except when sunrise occurred during a Kagashima station pass) UV flood. X-ray exposures began immediately (i.e., after several CCD readout flushes to remove the charge from the heavy overexposure) after the cessation of the UV flood. Panel A of figure 7 plots the morning interval duration for the entire mission. Panel B of figure 7 plots the time of early (FMS<8 min) FFIs of the mission in units of seconds since orbital sunrise (FMS is short for First Minute of Sun). For most of the mission the morning interval was set at 128 sec.

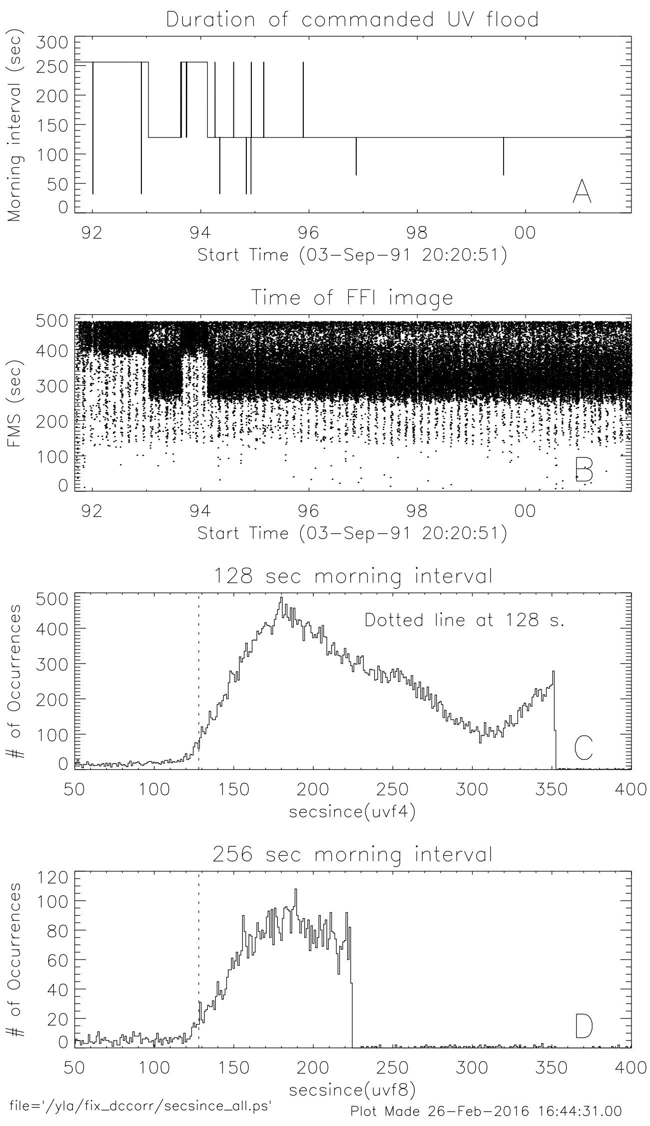



Figure 7: A: Duration of the SXT morning interval for the *Yohkoh* mission. B: Time of each of the 66,780 FFIs taken before FMS=8 min. Acquisition of X-ray images did not begin until the completion of the morning interval. The periodic indications when X-ray image acquisition began at about FMS=128 sec correspond to the occasions when orbit sunrise took place during a pass over the KSC tracking station. In these cases the morning interval was not implemented. C: Histogram of FFI start times versus SXT_UVF_INFO.PRO(index,/secsince) for times when morning interval was 128 seconds. D: Histogram of FFI start times for times when the morning interval was 256 seconds.

The independent parameter of the dc-orbit-correct function is tfms which is equal to minutes since the end of UV flood plus the morning interval (in minutes) plus the every-orbit set up time (in minutes) taken to acquire the sun and initiate *Yohkoh* fine pointing. The duration of this set up time was, surprisingly, not found in available YLA documentation. To determine it was the reason for the work reported in this section. The histograms of figure 7 unambiguously demonstrate that that the morning set up time was always 128 sec. The x-axis of plots C and D is seconds since the end of UV flood as returned by SXT_UVF_INFO.PRO(index,/secsince). So tfms=(128+morning_interval(sec)+secsince)/60 in minutes.

I have demonstrated that the *Yohkoh* morning set up time was 128 seconds. The SXT Interface Control Document (EICA, 1990) pages 5-30 to 5-31 specifies that the SXT is configured for UV flood at orbit day-night transition. Therefore, the every-orbit UV flood was actually equal to the morning interval plus 128 seconds or, normally, either 4.3 or 6.4 minutes.

# 4 Best compromise correction for orbital dc effect

As demonstrated in the references and in sections 1, 2, and 3 the intensity of CCD dc changes with time through an orbit. Therefore, if the orbital phase (tfms) of the X-ray image and the SDC are not the same the unadjusted dark signal correction will be in error. Namely, if the SDC is taken earlier in an orbit than the X-ray image the dark correction will be too large and *vice versa* if the SDC is obtained later than the X-ray image. For most cases this error is not large but should be corrected as well as we can.

Figures 1, 3, and 6 demonstrate that the algorithm given in the Appendix adequately describes the change in average dc signal as a function of time since the end of the UV flood. Section 2.2 shows that the dc enhancement is not uniform over the CCD and figure 5 shows that the center to off-limb enhancements does not stabilize to a single ratio until several minutes after the end of the UV flood.

Due to statistical noise as well as the complexity of the dc orbit effect it is judged adequate to do the dark signal adjustment as a multiplicative correction to the dc portion of the dark image, even though extreme cases for which the SDC or X-ray image come from very near to the UV flood will still be subject to some remaining dark frame error.

## 4.1 Choice of min_tfms, extreme case

The equation given in the Appendix, which describes the dc change as a function of tfms (tfms is defined in section 3), is used in DC_ORBIT_CORRECT.PRO to calculate the dc correction factor. Experience has shown that significant error in dc correction factor happens when the algorithm is applied for small values of tfms, due to the very steep slope of the function there. For this reason DC_ORBIT_CORRECT.PRO includes a parameter, min_tfms to preclude using times less than this to calculate the correction factor. I.e., if either the SDC or the X-ray image have a tfms less than min_tfms then their tfms for purposes of the the calculation is set equal to min_tfms. For the YLA heritage data (SSC27) min_tfms=4.5. SSC29 employs the updated dc correction software but has been generated with no dc-orbit-correction for comparison purposes. Finally, SSC30 was produced with min_tfms=6.1 for reasons explained below.

Dark current orbit effects are greatest for cases when the solar X-ray emission is weak, requiring long exposures and thus more dc. I have attempted to optimize the parameter min_tfms by comparing long (30 sec) HR exposures obtained at solar minimum. I have chosen matching X-ray and SDC images having early and late tfms. In this comparison the early X-ray images are dark corrected with the late SDCs and *vice versa*. The mean positive signals in these dc-orbit-corrected images are then compared to X-ray images dark corrected with SDCs obtained at the same tfms as the X-ray exposures (thus requiring no dc-orbit-correction). Different values of min_tfms has been tried in order to determine the best match (in terms of mean positive DN/pixel) between the dc-orbit-corrected images and the same-tfms dark corrected images.

The 4 SXT exposures chosen for this analysis are

| | Image date | Filt | Res | Type | Exp.(s) | tfms(min) |
|---|---|---|---|---|---|---|
| 0 | 9-JUL-1996 03:15:19 | AlMg | HR | Dark | 30.2 | 4.74 |
| 1 | 30-JUL-1996 00:39:36 | AlMg | HR | Dark | 30.2 | 50.80 |
| 2 | 27-JUL-1996 12:40:41 | AlMg | HR | Norm | 30.2 | 50.82 |
| 3 | 13-AUG-1996 00:59:43 | AlMg | HR | Norm | 30.2 | 4.65 |

The IDL program DC_ORBIT_CORR_TEST.PRO enables the calculations and comparisons described above. The secular increase in dc, illustrated in figure 2B, for a month only amounts to about 1.3% of the dc and has been ignored. In this analysis the visible stray light has been removed and saturated pixels are not included in the averages. The X-ray signal averages only include the pixels with positive signals. The 2 X-ray images listed above, prepared with SXT_PREP and with saturated pixels set equal to 0, are shown in figure 8. The results of this analysis are given in table 1.

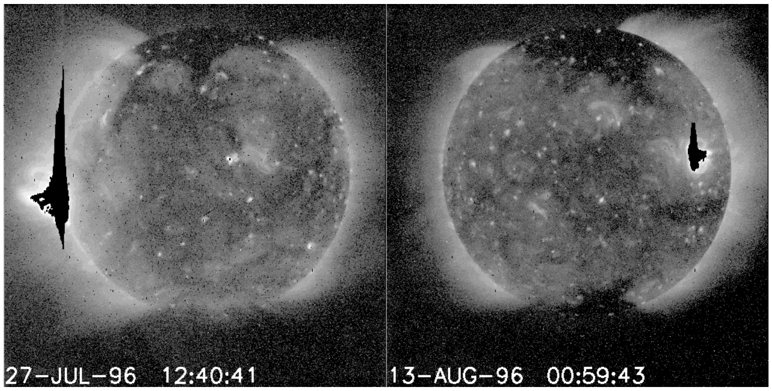



Figure 8: X-ray exposures (HR, DPE=30, 30.2 sec) chosen for min_tfms analysis. The images are scaled logarithmically and saturated pixels set to 0. The image on the left was obtained at tfms=50.82 min. That on the right was taken at tfms=4.65 min.

Table 1: Choosing min_tfms.

| | | A | B | C<br>Error | D | E | F<br>Error |
|---|---|---|---|---|---|---|---|
| 1 | tfms SDC (min) | 4.74 | 50.80 | | 50.80 | 4.74 | |
| 2 | tfms X-ray (min) | 4.65 | 4.65 | | 50.82 | 50.82 | |
| 3 | No orbit correction (DN/pix) | 275.7 | 317.8 | 15.1% | 565.7 | 517.9 | -8.4% |
| 4 | min_tfms=4.5 (DN/pix) | — | 246.2 | -10.7% | — | 609.9 | 7.8% |
| 5 | min_tfms=6.0 (DN/pix) | — | 275.7 | 0.0% | — | 568.9 | 0.6% |
| 6 | min_tfms=6.1 (DN/pix) | — | 277.0 | 0.5% | — | 567.1 | 0.2% |
| 7 | min_tfms=6.2 (DN/pix) | — | 278.3 | 0.9% | — | 565.3 | -0.1% |
| 8 | min_tfms=7.0 (DN/pix) | — | 285.6 | 4.0% | — | 555.2 | -1.9% |

In table 1 columns A, B, and C refer to the early-tfms X-ray image and cell A3 gives the X-ray signal when corrected with an SDC obtained at almost the same tfms. Likewise, columns D, E, and F are for the late-tfms X-ray image and cell D3 gives the X-ray signal when corrected with an SDC obtained at almost the same tfms. Cells B3 and E3 give the signals for the cases when the X-ray image is remote in time from the SDC with no dc-orbit-correction. Columns B4→B8 and E4→E8 give the dc-orbit-corrected X-ray signals for different values of min_tfms. Columns C and F give the percent by which the values in B3→B8 and E3→E8 deviate from the assumed correct values in A3 and D3. There is no perfect solution but I conclude that min_tfms=6.1 min is an adequate compromise. The effect of this optimized dc-orbit-correction on all of the SSCs of the mission will be evaluated in section 5.

# 5 Evauation of effect of dc-orbit-correction

The analysis in the following sections 5.3 and 5.2 compares the sums of positive pixels of SXT Science Composite (herein both dual-composite SSCs and triple-composite SSTs are referred to as SSC) images generated with and without dc-orbit-correction. All SSC preparation used dc_interpolation, i.e., interpolating between long and short exposure SDCs to create a dark frame corresponding to the exposure of the X-ray image. Section 5.1 compares the total signals in the SDCs themselves.

Recall that we are comparing 3 different versions of SSC.

**SSC27** The improperly dc-orbit-corrected SSCs produced between 1998 and 2016. This incorrect processing was applied to all SXT level-1, level-2, and level-3 data products. However the error is not important for the level-3 movies which are not intended for quantitative analysis.

**SSC29** This new version uses corrected analysis software but without any dc-orbit-correction. It has been prepared only for the purpose of studying the quantitative importance of the dc-orbit-correction.

**SSC30** These SSCs have been prepared with corrected software, use dc-orbit-correction, and have been archived in the YLA in place of SSC27.

Figure 9 illustrates the importance of dc-orbit-correction for an extreme case. This image was obtained during a CCD bakeout when the temperature of the CCD was 22.5 °C, making for a much higher dc. While the appearance of this very noisy image isn't lovely it is much improved by the correction. The positive signal in the corrected (right) image is only 39% of the image on the left.

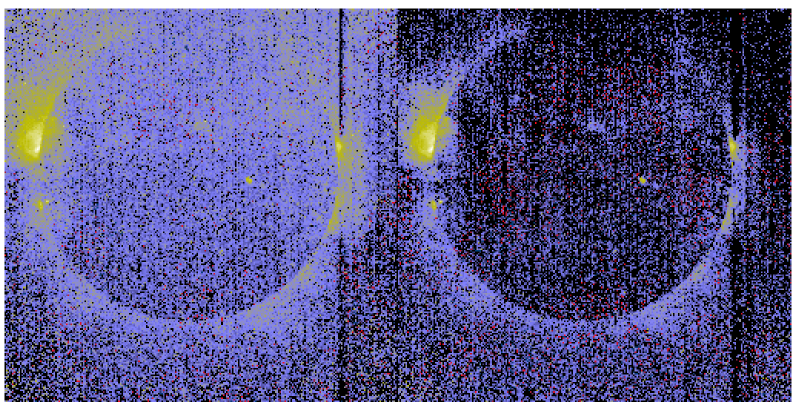


Figure 9: Quarter resolution AlMg image of 7-APR-1994 23:04 without (left) and with (right) dc-orbit-correction.

## 5.1 Effect on SDCs

The programs SXT_UVF_INFO.PRO, DC_ORBIT_CORRECT.PRO, and GET_DC_IMAGE.PRO have been revised and corrected. Based on the work described in section 4.1 a value of min_tfms=6.1 has been hard-coded in DC_ORBIT_CORRECT.PRO. To evaluate the significance of the dc orbital adjustment I have selected one HR AlMg SSC per week for the entire mission and created a data set of the 1072 SFRs used in creating these 527 SSCs. DPE for these 1072 FFIs ranged from 9 to 30 (exposures ranging from 17.2 ms to 30.2 s). Using GET_DC_IMAGE.PRO I produced a dark frame with and without dc-orbit-correction for each of these SFRs. The results of this analysis are displayed in figures 10 and 11.

Note that the effect of dc-orbit-correction is less important early in the mission when the CCD dark current was a smaller fraction of the SDC signal. The histogram of figure 10 demonstrates that there are about 20% more SDC increases than decreases from dc-orbit-correction. Figure 11 shows that, as expected, orbit corrections are larger for longer exposures for which CCD dark current comprises a larger fraction of the SDC signal. This analysis treats only cases with the CCD cooled to below -20 °C. As dark current increases substantially with increasing CCD temperature dc-orbit-correction is more important, as demonstrated in figure 9.

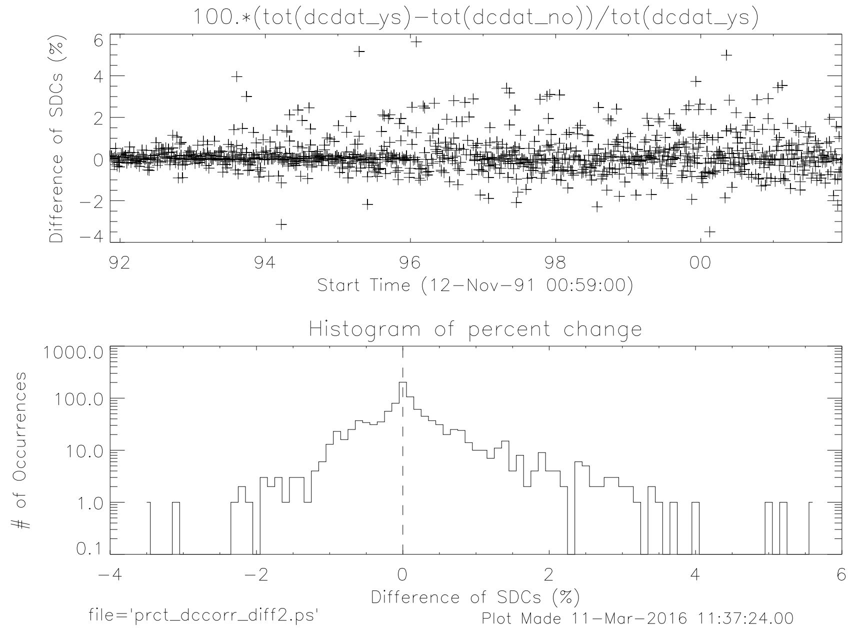



Figure 10: Percent difference in total SDC signal between dark images created with and without dc-orbit-correct.

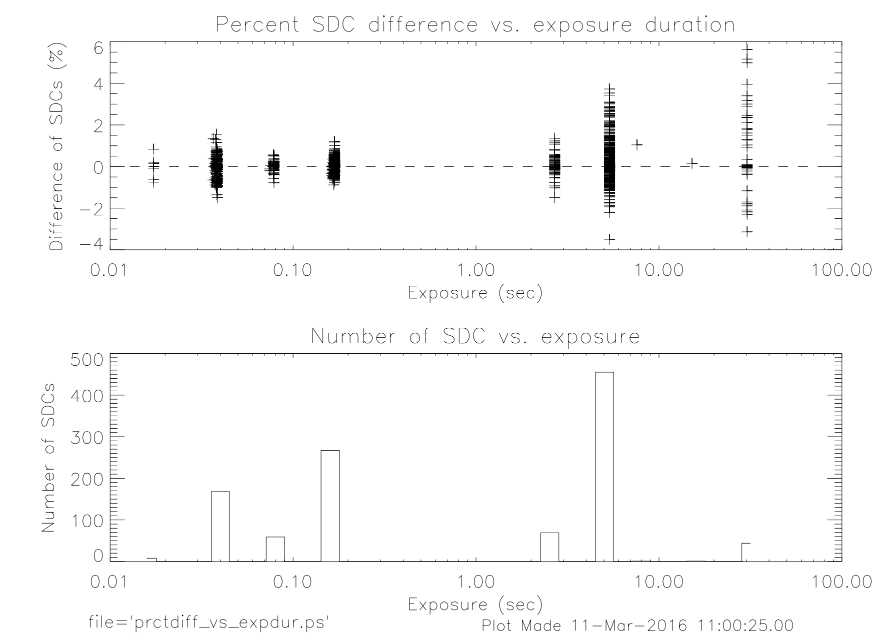



Figure 11: Illustration of the dependence of the effect of dc-orbit-correct versus exposure duration.

### 5.2 Difference of SSC30 from no dc-orbit-correction (SSC29)

Although figure 9 shows a case with a factor of 2.5 dc-orbit-correction this is not representative of the normal case with a cooled CCD. This is illustrated for 302,436 cold-CCD SSCs in figure 12.

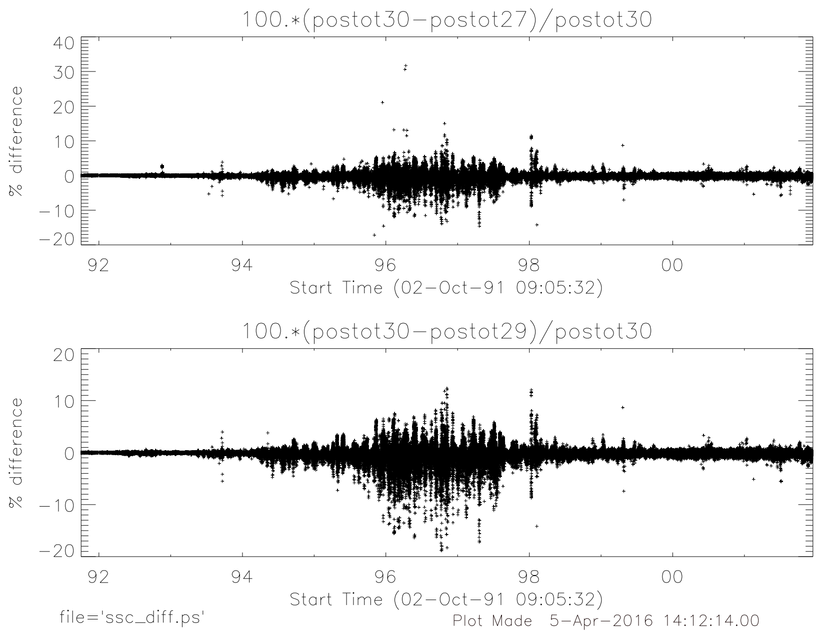



Figure 12: Percent difference between different versions of SSCs. Upper panel: SSC30 and (improperly corrected) SSC27. Lower panel: SSC30 and (not dc-orbit-corrected) SSC29. In the title of the plots postot means total (sum) of the positive pixels in an image.

The top panel of figure 12 shows the case of the new, fully corrected, SSC30s as compared to the heritage SSC27s, discussed more fully in the next section. The lower panel illustrates the case of dc-orbit-correction (SSC30) versus no such correction (SSC29). The two cases appear at first glance to be very similar with a correlation of 0.88. I.e., the mis-corrected composites of SSC27 have a similar pattern of error as if no dc-orbit-correction had been applied. In detail, on an image to image basis, the differences of SSC30 and SSC29 corrections are not identical as illustrated in figures 13 and 14.

### 5.3 Differences of SSC30 (this work) from SSC27 (YLA heritage)

The issue that motivated the work reported in this paper is the question of, "How incorrect are the mis-dc-orbit-corrected level-1 and level-2 data in the YLA?" I believe that the revisions to the software used to produce SSC30 are correct. The percent differences in SSC image totals (positive pixels only), for the entire *Yohkoh* mission, of SSC30 and SSC27 have been shown in upper plot of figure 12. Figures 15 and 16 present these results in greater detail. The average value of the positive differences is 0.29%. As shown in the histogram the negative differences are a bit greater with an average value of -0.36%.

### 5.4 Difference between new and old level-1 full frame images (FFI)

In section 5.1 we examined the differences in the SDCs used to dark-correct 1072 HR AlMg FFIs spread uniformly throughout the *Yohkoh* mission. In this section we will present the percent differences in the total positive signal (saturated areas set to 0) in these level-1 FFIs between the new and old (YLA2015) software.

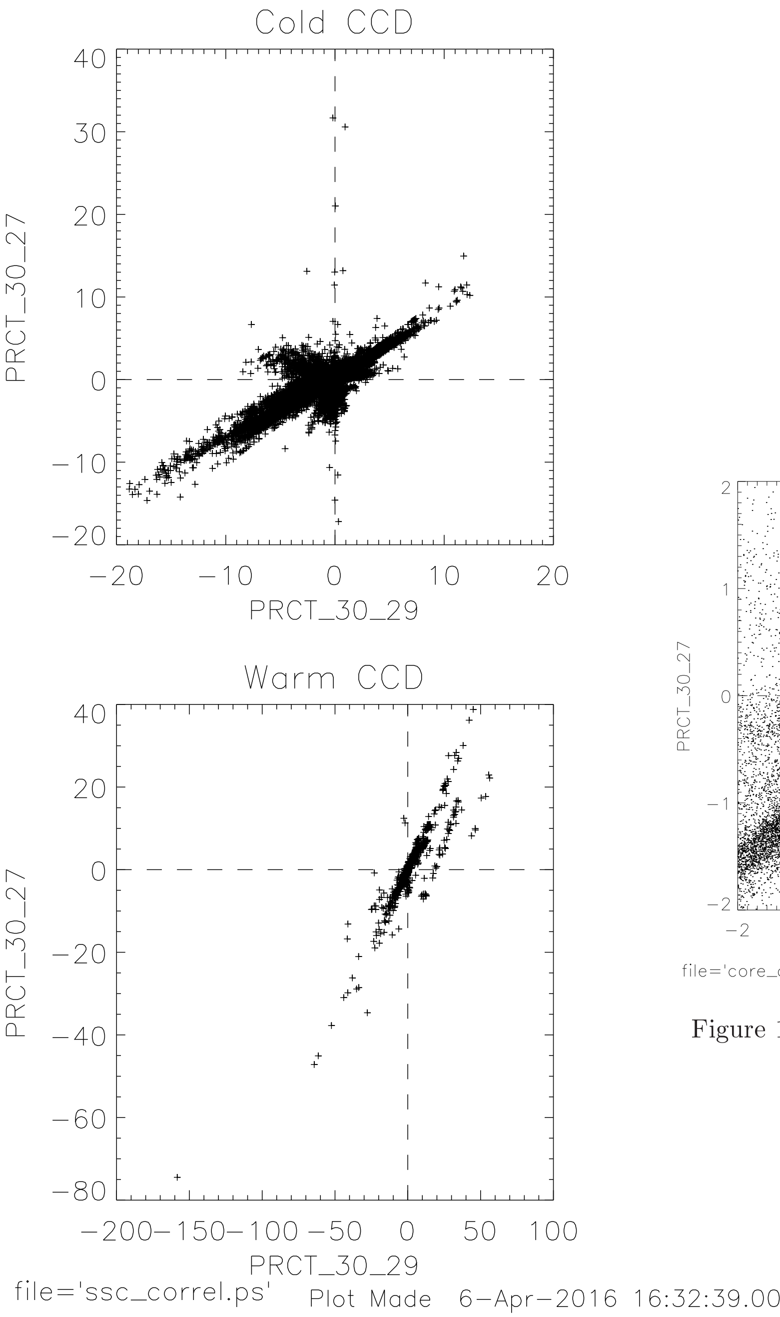



Figure 13: Top: Correlation plot of percent differences between SSC30 and SSC29(no correction) versus SSC30 and SSC27 (YLA heritage) for the composites with a cold CCD. Bottom: Same comparison for the 1559 SSCs with a warm CCD.

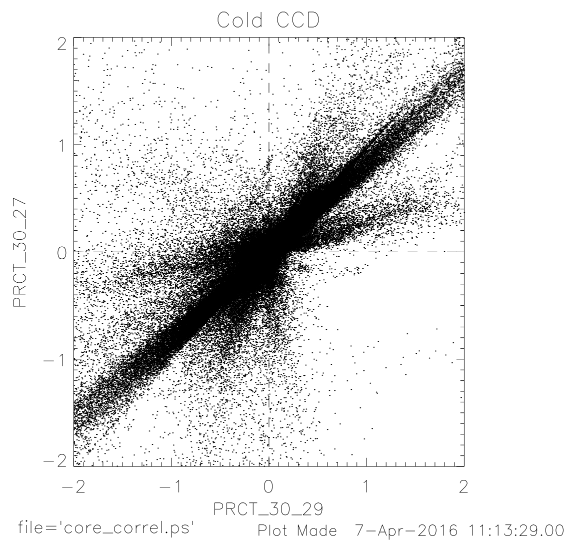



Figure 14: Core portion of figure 13, top.

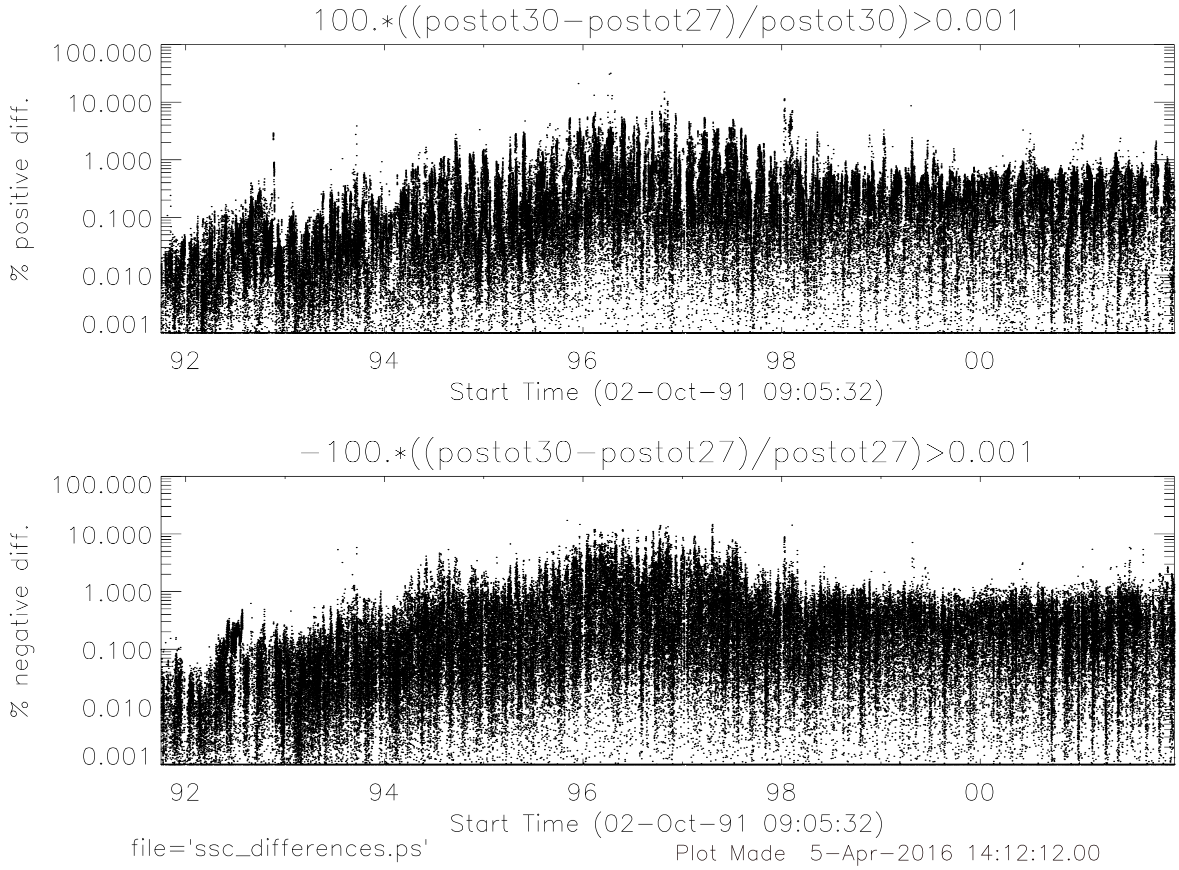



Figure 15: Log-scaled positive (upper) and negative (lower) percent differences between SSC30 and SSC27.

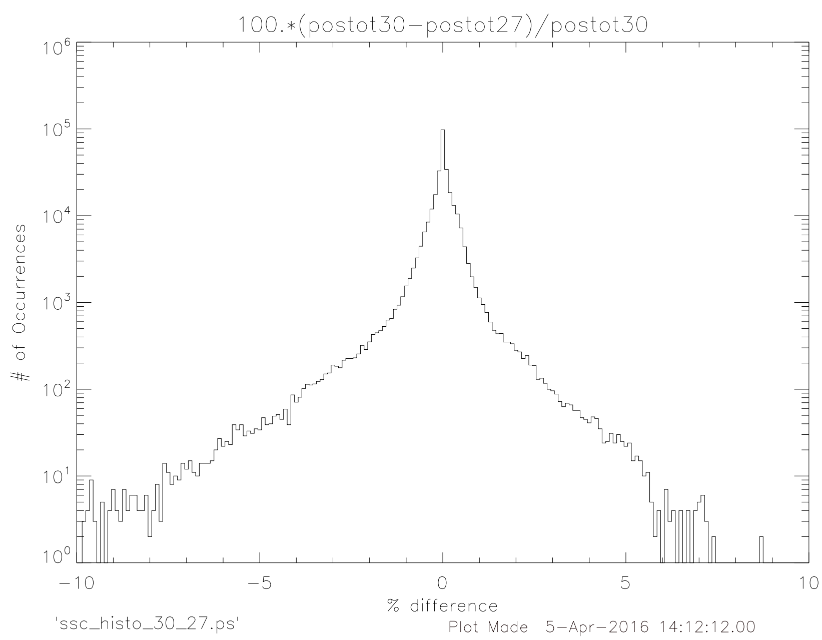



Figure 16: Histogram of percent differences between SSC30 and SSC27.

The results for the 1072 AlMg HR FFIs are displayed in figure 17. The average of the absolute differences of this mission-long sample of level-1 SXT data products is 1.5%.

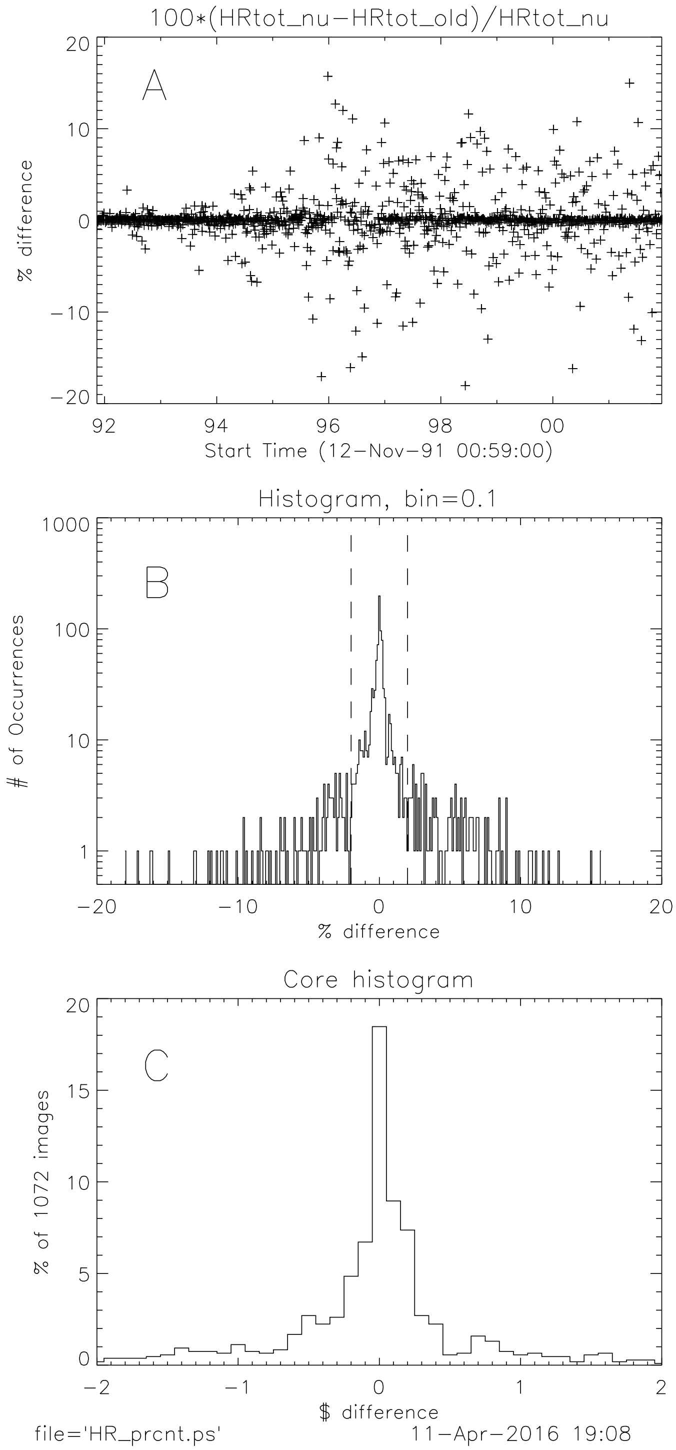



Figure 17: (A) Percent difference of the total positive signal in 1072 SXT level-1 FFIs prepared with corrected software (HRtot_nu) and with pre-2016 (HRtot_old) software. (B) Histogram of the differences in A. (C) Core portion of the histogram in B.

# 6 Conclusion

Dark signal subtraction, required to turn SXT raw X-ray images into level-1 and level-2 data products, is a tricky business. Dark frames (SDC) were acquired throughout the mission. On 8-Dec-1992 weekly SDC collection became routine with a standardized SDC command table. When it was learned that the CCD dark current evolved in a repeatable way through every daylight pass an algorithm was derived (see the Appendix) permitting approximate SDC adjustment for this orbital effect. Unfortunately, errors were made in the software used to implement this correction, errors which were not discovered until October 2015. The problem programs have been modified and corrected and YLA level-1 and level-2 data products have been regenerated. It is the purpose of this report to quantitatively evaluate the severity of the X-ray image intensity changes between the pre-2016 and new data products.

The changes can be substantial, reaching tens of percent of total X-ray signal. They are stronger around sunspot minimum, are more pervasive for level-1 images than for level-2, and can be considerably more important for warm-CCD operation when the dark current itself is much larger. Because of the way the correction works the adjustments can be either positive or negative.

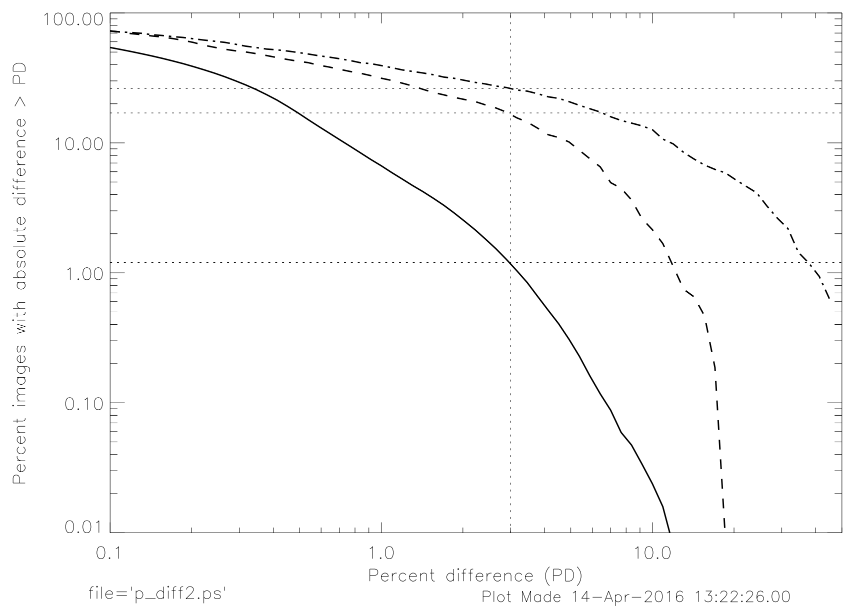



Figure 18: Nomogram showing the percent of SXT images impacted by old dc-orbit-correction software as a function of the percentage (new-old/new) absolute difference between the new and old intensities. The solid line is based on 302,436 SSCs with a cold CCD, the broken line from 1599 SSCs with a warm CCD, and the dot-dash line from 1072 level-1 FFIs with a cold CCD. The dotted lines are to guide the eye for reading off values as described in the text. All cases were spread evenly over the entire *Yohkoh* mission.

These analyses are detailed in preceding sections. Figure 18 summarizes the results for 3 different cases. E.g., if you wish to know what percentage of SXT images having a 3% or greater difference between the new and old cases you can read from the plot that 1.2% of SSCs with cold CCD and 17% of warm CCD SSCs are so affected and for level-1 AlMg HR FFis the fraction is 26%.

This work provides sufficient justification to mandate the regeneration of YLA level-1 and level-2 SXT data products. However, my work does not properly assess the possible error in any given scientific analysis which used the old intensities. On a pixel to pixel basis my results may be misleading. First off, for a given case the dc adjustment is a function of the plus or minus time (tfms) difference between the SDC and X-ray image so the old data will be OK for cases where the SDC and X-ray image have the same, or nearly the same, tfms. For faint portions of an image the error will be larger and for the bright portions smaller, perhaps much smaller, depending on feature intensity. This is illustrated in figure 18 between the solid and dotted curves. The former, from SSCs, includes the bright active region data. The latter, from FFIs with saturated portions redacted, display the case for the fainter general corona. For flares the old YLA data are OK because the signal for bright X-ray features is so much greater than the dark signal.

The old, erroneous, YLA data products such as, e.g., SSC27 have not been retained in the YLA. For cases for which it is important to know precisely the potential impact of dc-orbit-correction errors it may be best to redo the analysis with the new YLA data. Alternatively, for comparison, the old level-1 or level-2 data may be regenerated as follows. The erroneous version of the programs GET_DC_IMAGE.PRO, DC_ORBIT_CORRECT.PRO, and SXT_UVF_INFO.PRO have been retained with the new names OLD_GET_DC_IMAGE.PRO, OLD_DC_ORBIT_CORRECT.PRO, and OLD_SXT_UVF_INFO.PRO but otherwise internally unchanged. To regenerate the old, potentially erroneous, SXT data products it is only necessary to start an IDL session and compile (.run) these three OLD_xxx codes and then proceed to create SXT higher level data products in the usual way.

# 7 Appendix

The dc-orbit-correction algorithm and how it is applied is as follows.

```
fit=[ 1.9883628d0, $
     -7.1686219d0, $
      10.122472d0, $
     -6.9061794d0, $
      2.2587795d0, $
     -0.28179413d0]

min_tfms=6.1

;  Orbit time parameter for the dark current images
tfms_dc = alog10(sxt_uv_info(dcindex,/tfms)>min_tfms)

;  Orbit time parameter for the data image
tfms_im = alog10(sxt_uvf_info(imindex,/tfms)>min_tfms)

dc_signal = 0.0d0
im_signal = 0.0d0

; Calculate polynomial and correction factor
for i=n_elements(fit)-1,0,-1 do begin
   dc_signal = dc_signal*tfms_dc + fit(i)
   im_signal = im_signal*tfms_im + fit(i)
endfor
dc_signal = 10^dc_signal
im_signal = 10^im_signal
factor0=float(im_signal/dc_signal)
```

The adjusted dc portion of the dark frame is computed by multiplying the dc portion of the SDC by factor0 and then adding back the pedestal+spurious part to prepare the dark frame for subtraction from the decompressed level-0 X-ray image. The pedestal+spurious part of the SDC is defined as the signal in line 15 (QR) or line 20 (HR and FR) of the SDC.

## References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