SWIFT-XRT-CALDB-06
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SWIFT-XRT-CALDB-06: Boresight Analysis and Correction for the XRT

This document describes the calibration of the flight and ground software position accuracy for both Photon-Counting and Imaging Modes. A new boresight has been determined and has been verified for all cases.

Overview

In January 2005, it was discovered that the Spacecraft velocity aiding was effecting the XRT positions. This manifested itself as stellar aberration effects on the positions. Following the de-activation of the velocity aiding at 21:57 31st January 2005[1], additional calibrations of the XRT Image Mode were performed on DOY 32, 33 and 34. Furthermore, analysis of these data led to updates of the flight centroiding parameters, which were verified against more calibration data obtained on DOY 60.

After the Flight Software (FSW) update to Build 8.9 on May 28th 2005, there was an event (possibly a micrometeroid impact), which damaged the CCD. Several columns had to be identified as hot pixels in the FSW. To quantify the effect on the centroiding algorithm onboard, and also to determine if the accuracy was affected, several observations of Cygnus X-3 and Cygnus X-1 were taken in Image Mode on June 10th 2005.

During the first 6 months that *Swift* was on-orbit, there have been several reports of position degradation with time, although these have never actually been quantified. Nevertheless, to ensure that the boresight calibration is valid for the entire duration on-orbit to date, additional observations of Cygnus X-2 were obtained on 21st October 2005.

From comparing the XRT positions obtained from observations of calibration sources and GRBs with optical counterparts, it was determined that both the ground and the onboard default boresight needed to be calibrated and updated.

An idl script was written to recalculate the source position for different boresights reproducing the FSW behaviour. The script reads in the data from the header of the telemetered postage stamp message obtained in Image Mode. It then regenerates the centroid position in RA and DEC with or without the Telescope Alignment Monitor (TAM) correction (Hill et al.). The script positions were verified against the onboard RA and DEC positions for the default boresight position (300 x 300) and found to be identical. The script

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[1] Data obtained prior to 21:57 31 January 2005 are corrected for stellar aberration effects in the SDC data processing.

was run with different boresights on each observation of many sources. A position off-set in RA and DEC was obtained for each observation by comparing the script position with the known optical position. From looking at the average off-set versus boresight position, one can determine the best-fit boresight. For data from the June 10th observations, the 21st October observations and the GRBs, the best-fit boresight was almost constant in the XRT x-axis. The majority of the variation from test case to test case was in the XRT y-axis. This analysis was performed for both TAM corrected and non-TAM corrected data.

The best-fit boresight position for the Image Mode was verified against Photon Counting (PC) Mode data where the counting statistics are, in general, much improved. 11 sources and 36 observations were selected with a distribution of roll angles. To limit the number of variables this was performed for data which were not corrected by the TAM.

Nine boresight positions were tested in a matrix around the best-fit Image Mode boresight. The data are shown in the Figure 2 and Figure 4. From fitting a curve to the data, the boresight was further refined to 298.2 x 299.3. This was confirmed as the best-fit position against these observations. The mean off-set decreased from 4.54'' to 2.26''. Additional verification was performed by plotting the off-set in RA and Dec against the roll angle of the observation (see Figure 3), and verifying that there was no accuracy dependence on roll angle.

Following the boresight optimisation, an additional 12 sources were analysed over 36 observations with the new boresight. The average off-set from the optical positions was found to be 2.21'' as seen in the previous sample, with 97% of the positions less than 5'' from the optical position. These data are shown in Figure 6.

A catalogue of 45 GRBs with optical counterparts observed between December 2004 and October 2005 were analysed with the default boresight (Figure 7) and the best-fit boresight position of 298.2 x 299.3 (Figure 8). The average distance from the optical counterpart of 2.28'' was confirmed to be equivalent to that obtained for the calibration sources.

A parallel analysis of the GRB positions was performed by plotting the RA and DEC off-sets relative to the optical counterpart against boresight and fitting a sinewave, the details are in Morreti et al. We find that the implied boresight derived from the sinewave analysis is consistent with the value obtained in this analysis. A plot of the positions of the GRB obtained by the two methods is shown in Figure 8.

In this analysis the TAM correction has not been applied. Preliminary results presented at the XRT Team Meeting in October (and in Hill et al.) using the default boresight (300 x 300), showed that the position accuracy was improved when the data were TAM corrected however, the positions show a residual off-set compared to those obtained with the new boresight. We find from preliminary analysis of the TAM correction with the new boresight, that the position accuracy is degraded. This is an indication that the TAM correction and the boresight position are not independent variables.

Calibration observations have been made in Image Mode with the updated boresight position and confirm this to generate improved FSW position accuracy. The boresight in the Teldef file, version 5, has been updated to reflect the new boresight and is available to download.

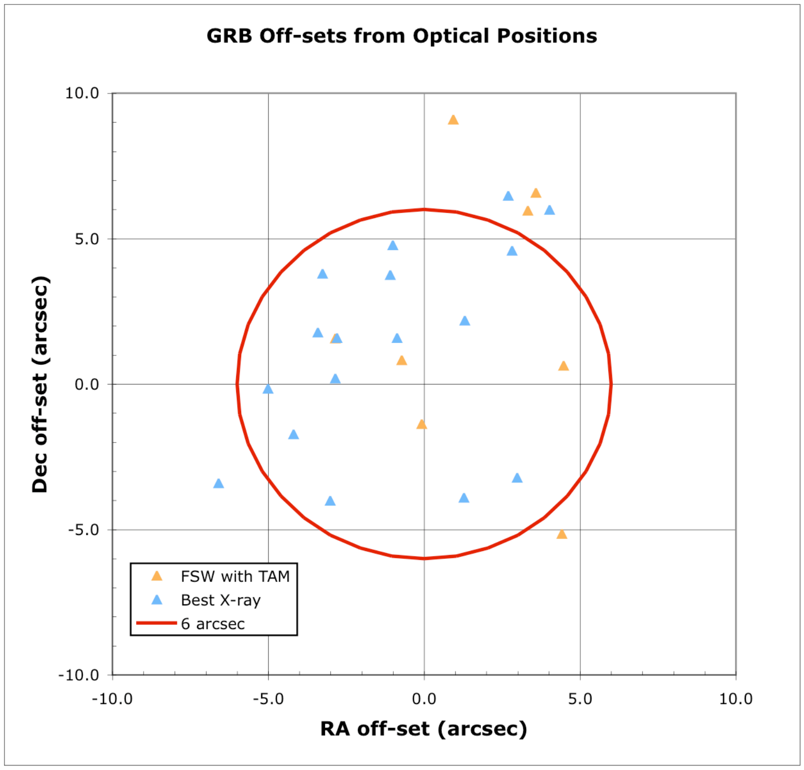


Figure 1 GRB off-sets from Optical positions with a default boresight position of 300x300.

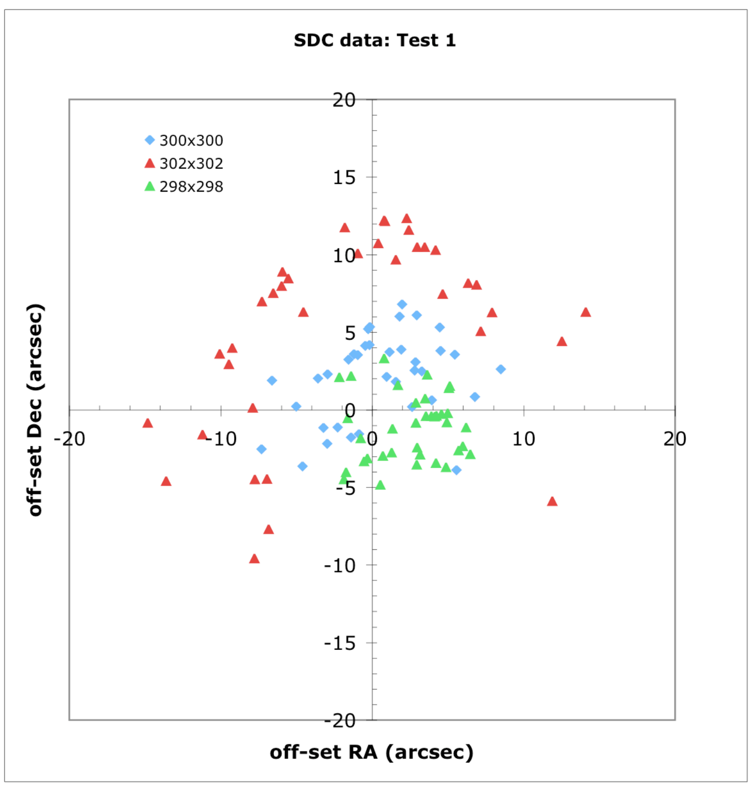


Figure 2 Variation of position off-sets for 36 observations of 11 sources with three boresight positions. Default at 300x300, best estimate from Image Mode 298x298 and 302x302 for comparison.

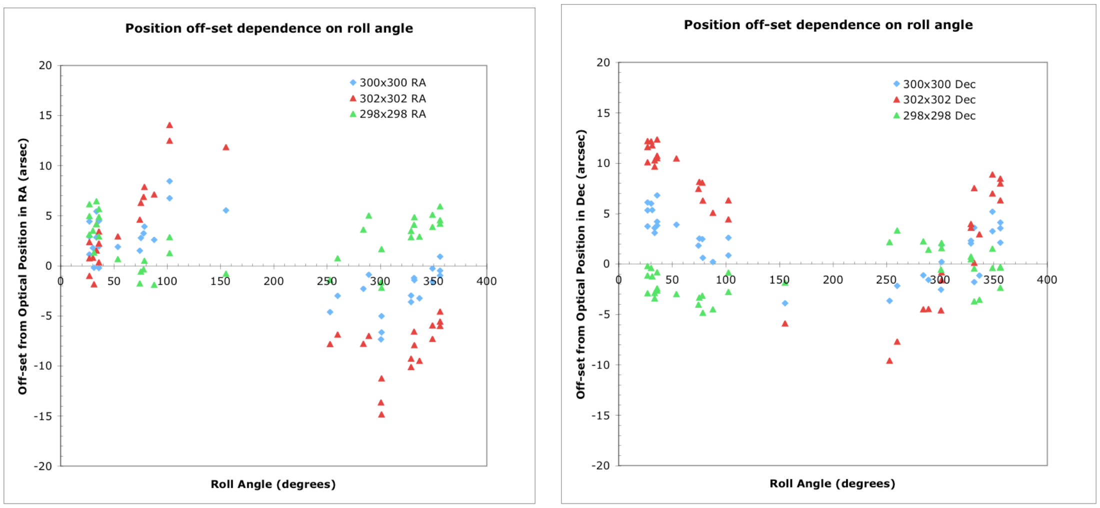
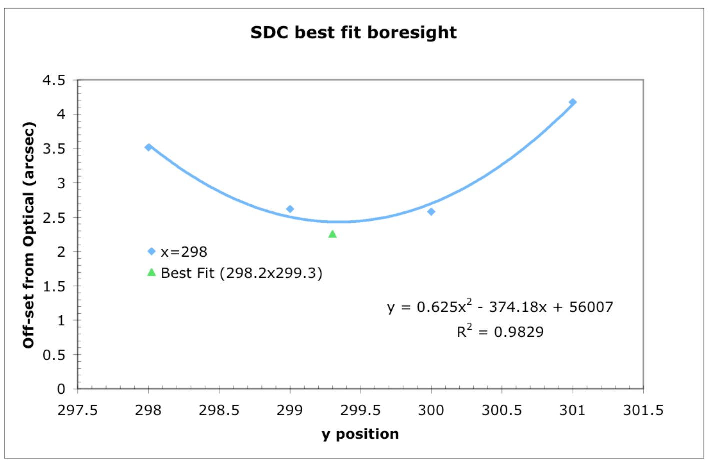


Figure 3 Variation of off-set in RA (left) and Dec (Right) with roll angle for different bore-sight positions; 300x300 (default), 298x298 (best-estimate Image Mode) and 302x302 for comparison.



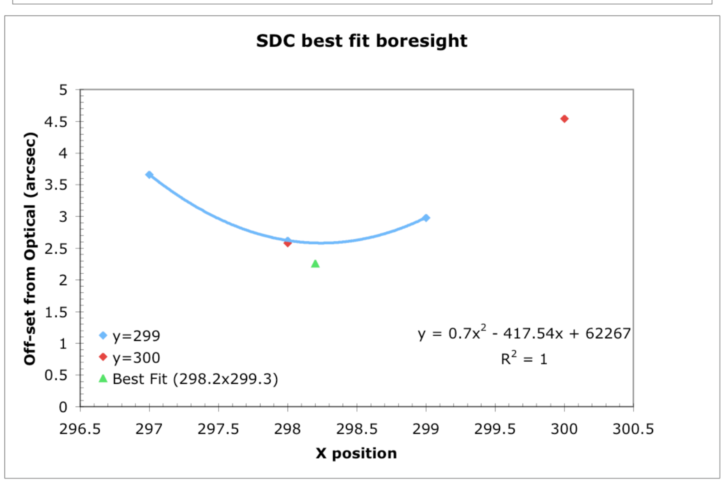


Figure 4 Polynomial fit to the average off-set from the optical position for 36 observations of 11 sources, for 10 boresight positions yeilding a best-fit boresight position of 298.2x299.3.

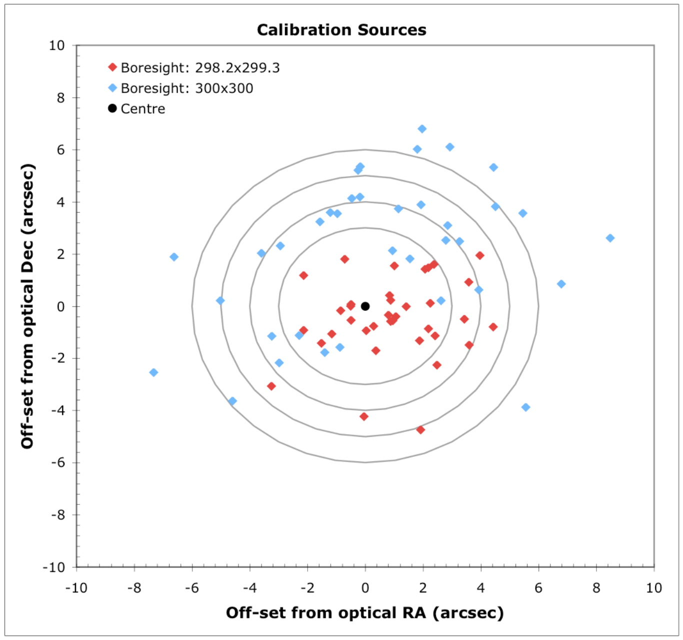


Figure 5 A comparison of calibration source position off-sets from optical positions for the default boresight and for a corrected boresight. The mean off-set for the boresight corrected positions is 2.26'' compared to 4.54'' for the default boresight.

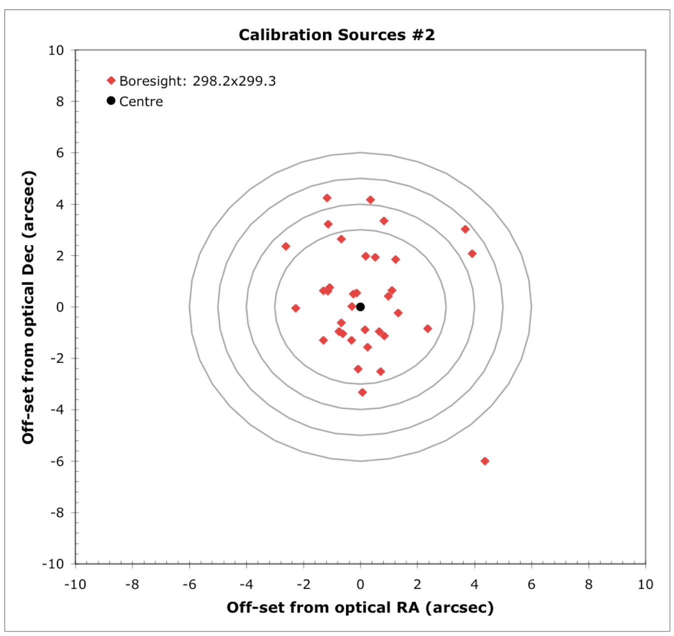


Figure 6 A comparison of additional calibration source position off-sets from optical positions for a corrected boresight. The mean off-set for the boresight corrected positions is 2.21''.

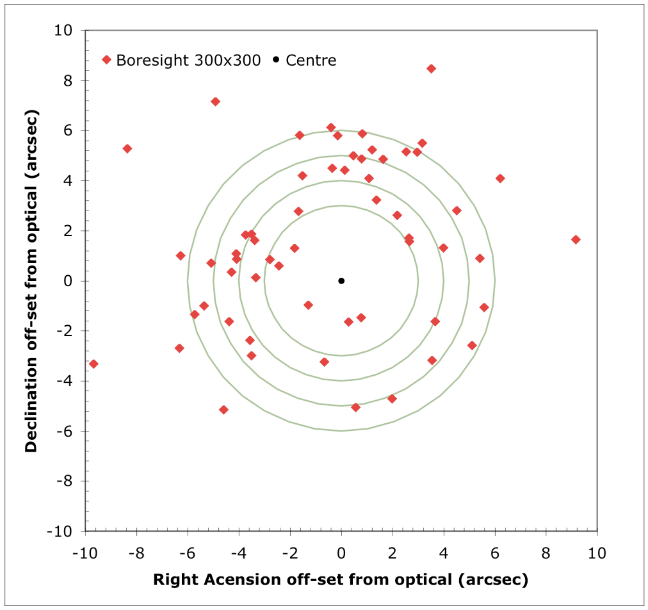


Figure 7 GRB position off-sets from optical positions for the default boresight.

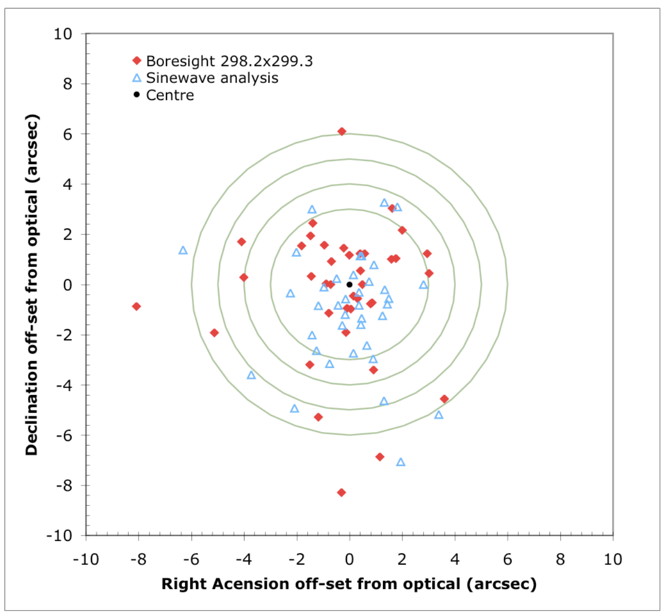


Figure 8 A Comparison of GRB position off-sets from optical positions for a sinewave corrected fit and using a corrected boresight.

References

Hill, J.E. et al., "The unique operating Modes of the Swift X-ray Telescope", 2005, Proc. SPIE, 5898, 589815-1

Moretti et al, Astronomy & Astrophysics, 2005, submitted