SWIFT-UVOT-CALDB-15-03
Date Original Submitted: 2010-11-04
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Revision #3
Revised by: A. A. Breeveld
Sections Changed: 3,4,7,8
Comments: Third update – changing UV corrections to a quadratic curve, and optical corrections to best fit values.

SWIFT UVOT CALDB RELEASE NOTE

SWIFT-UVOT-CALDB-15: Sensitivity loss

0. Summary:

This CALDB product gives a correction for the gradual decline in sensitivity for each filter.

1. Component Files:

FILE NAME	VALID DATE	RELEASE DATE	VERSION

2. Scope of Document:

This document includes a description of the product, expected future updates, warnings for the user, a list of data the product is based on and finally the analysis methods used to create the product.

3. Changes:

This is the second update of the on-orbit calibration for this product. The sensitivity loss for the optical and white filters is still consistent with the last version of the calibration, but for **UV** filters the correction needs to be changed from linear to quadratic. In addition the values for the **Optical** and **White** filters are no longer being set to a nominal 1%, but are to be changed to their best-fit linear values.

3.1.CALDB file versions:

Version 1 (swusenscorr20041120v001.fits), released on June 30th 2010 contains correction factors for all filters of 1% per year, as described in **SWIFT-UVOT-CALDB-15-01**. It uses a start time for the decline in sensitivity of day 1826 (Jan 1, 2006) for the visual filters and day 1520 (March 1, 2005) for the UV filters.
Version 2 (swusenscorr20041120v002.fits), released on June 6th, 2012, erroneously

set the correction factors for all filters to 1.0 (i.e. no correction for decline in sensitivity).
Version 3 (swusenscorr20041120v003.fits), released on January 18th, 2013, corrects those errors so that the correction factors are as described in this document (Section 9), and the start date for the decline for all filters is January 1st, 2005.

3.2. CALDB content:

In the previous versions the decline in count rate was set to 1% in most filters, but in the CALDB this was implemented in a compound manner rather than linear. i.e. the correction factor was calculated as (SLOPE**DT rather than 1/(1.0-SLOPE*DT). Up until now the difference in the calculated correction has been negligibly small (e.g. after 10 years the correction was calculated as 1.105 rather than 1.111).

In this version, the CALDB file for each filter provides information to implement the best fit linear models in Table 2 for the V, B, U and White filters, and the quadratic fits in Table 3 for UVW1, UVM2 and UVW2. The linear or quadratic model is approximated using a series of time intervals, each with a power-law functional form:

C_corr = C_meas * (1.0 + OFFSET)*(1.0 + SLOPE)**DT

where DT is the time in years since the beginning of the interval. The parameters OFFSET and SLOPE are chosen to match the values of the linear or quadratic model at the beginning and end of each interval. Currently each interval has a duration of one year.

4. Reason For Update:

The **UV** filter sensitivity declines are no longer consistent with the 1% per year given in the previous versions.

5. Expected Updates:

The throughput is tested annually and may be updated if changes are seen.

6. Caveat Emptor:

7. Data Used:

Several photometric standard sources (see Table 1) have been observed from time to time throughput the mission to check for any changes in throughput. For this report all data up to and including March 2015 have been used. P041C was added to the monitoring stars for the first time.

source	RA	Dec	v	b	u	uvw1	uvm2	uvw2	white
WD1026+453	10 29 45.3	+45 07 03.0	✓	✓	✓	✓	✓	✓	
WD1121+145	11 24 15.9	+14 13 49.0	✓	✓	✓	✓	✓	✓	✓
WD1657+343	16 58 51.3	+34 18 51.0	✓	✓	✓	✓	✓	✓	✓
SA95–42	03 53 43.66	–00 04 33.9	✓	✓	✓				
SA95–102	03 53 07.58	+00 01 10.3	✓	✓	✓				

SA98–646	06 52 02.23	–00 21 16.6	✓	✓	✓				
SA101–278	09 56 54.50	–00 29 39.0	✓	✓	✓				✓
SA101–L3	09 56 54.99	–00 30 24.8	✓	✓	✓				✓
SA104–244	12 42 34.3	–00 45 47.0	✓	✓	✓				✓
SA104–338	12 42 30.3	–00 38 33.0	✓	✓	✓				✓
SA104–367	12 43 59.0	–00 33 30.0	✓	✓	✓				✓
SA104–443	12 42 20.0	–00 25 22.0	✓	✓	✓				✓
SA104–457	12 42 54.2	–00 28 49.0	✓	✓	✓				✓
PG1525–071	15 28 11.60	–07 16 27.0	✓	✓	✓				
PG1633+099	16 35 24.0	+09 47 47.0	✓	✓	✓				
G24–9	20 13 55.68	+06 42 44.9	✓	✓					
P041C	14 51 58.19	+71 43 17.3			✓	✓	✓	✓	

Table 1 Standard sources for monitoring throughput.

All the relevant data on these sources were downloaded from the Swift archive at HEASARC. Important keywords in each sky file and also the *uct.hk files were checked for any problems like ‘shift and toss’ loss, which could affect exposure times. However, not all the data had been processed with the same version of uvot2fits and the keywords were not all available for the earlier versions. The oldest reprocessing of data used here was uvot2fits 3.8 and the most up-to-date was uvot2fits 3.30.

8. Description of Analysis:

For each star, we made region and background files using the 5" aperture for the stars and 27.5 – 35" annulus for the background. We checked each exposure visually for any problems e.g. aspect correction not being applied correctly, or the images being smudged by drift. Where necessary the aspect correction was redone, or where unsuccessful, a special set of region files devised for that particular exposure.

The raw coordinates of each source measurement were checked to see whether they fell on the position of any of the small-scale areas of low sensitivity. All these measurements have been excluded.

Using UVOTMAGHIST (with LSSfile=CALDB), the fully corrected count rates (and errors) of the sources were extracted for each exposure and written into an excel spreadsheet. Both the co-incidence corrected count rates and those with LSS correction were recorded. Weighted means were calculated for those cases where there was more than one extension, i.e. when several exposures were taken on the same day. The LSS corrected count rates were used in the fits and plots.

The count rates were normalised using the mean count rate for each star in each filter in exposures taken within the first 500 days (the start date being defined as Jan 1st 2005, approximately when observations began). For stars not observed within the first 500 days, a factor taken from the fit was used to correct the starting value. This allows all stars to be plotted and fitted together, with the expected value for the beginning of the mission for each star being 1.0. Where the fitted line does not go exactly through 1.0, the points were re-normalised to ensure this parameter is 1.0. Standard stars only observed at the beginning on the mission, and not re-visited, have not been included.

The plots for each filter are shown at the end of this report. Figure 1 to Figure 3 show the **optical** data and Figure 4 to Figure 6 the **uv** data. The **white** is shown in Figure 7 to 9.

In each case the data were fitted with a weighted straight-line fit, shown in the plots. The linear fit parameters for the **optical** and **white** filters have not changed much. However, for the UV filters a straight line is no longer a good fit and a quadratic is required (see Section 9 for the formulation). The linear fit numbers are shown in Table 2 and the quadratic fit numbers in Table 3.

Filter	**% loss per year**
V	1.53 ± 0.07
B	0.92 ± 0.07
U	0.99 ± 0.10
UVW1	1.69 ± 0.12
UVM2	1.72 ± 0.13
UVW2	2.03 ± 0.13
White (bkgnd corrected, see section 8.1)	1.23 ± 0.09

Table 2 The observed change in throughput per year for each filter using a linear fit.

Parameters:	**Param[0]**	**Param[1]**	**Param[2]**
UVW1	1.0	2.0407×10^{-3}	-1.7483×10^{-3}
UVM2	1.0	-2.3304×10^{-3}	-1.3609×10^{-3}
UVW2	1.0	1.1076×10^{-3}	-1.9598×10^{-3}

Table 3 Fitting a quadratic curve to the UV filter data gives these parameters where the (normalised) count rate (c) at time t (yrs) is given by c=param[2]t^2+param[1]t+param[0], where t is zero on 1st Jan 2005.

8.1. White filter:

There is a large scatter in the white plot (Figure 7), some of which can be attributed to high background count rates, i.e. the failure of the coincidence correction to cope with high backgrounds. This is illustrated in Figure 8 where the measured count rate of WD1121+145 is plotted against background count rate. Only the white filter suffers from backgrounds high enough to cause a problem.

Using data for WD1121+145 the counts with higher backgrounds can be corrected using the formula:
$corrcts = cts - m \times bkgnd$, where $m = -120$ and $cts = 181$
For WD1657+343 the gradient m is –151 and the measured decline as a proportion of the true count rate is the same for both WD1657+343 and WD1121+145. Therefore we assume a correction can be applied to all the **white** measurements. The equation is:

$$Truects = \frac{Meascts}{1 - 0.67 \times bkgnd}$$

Since the background is not necessarily the same for all the exposures taken on one day, these points have not been averaged in every case. The corrected plot is shown in Figure 9, and the rate of sensitivity loss is –1.23 ± 0.09% per year. The scatter is reduced and the gradient is now consistent with the optical filters. This is the value that should be used in the CALDB.

9. Correcting the measured count rates:

For the **v, b, u** and **white** filters the rate of decline should be set to the values given in Table 2.

To correct the measured count rate C_{meas} to the corrected C_{corr} the following equation should be used:

$$C_{corr} = \frac{C_{meas}}{(1 - R \times t)}$$

where t is the time in years since 1st January 2005 (i.e. approximately since launch) and R is the rate of decline (e.g. 0.01).

For the case of the **UV** filters the new correction using a quadratic curve should be used thus:

$$C_{corr} = \frac{C_{meas}}{(1 + param[1] \times t + param[2] \times t^2)}$$

where t is the time in years and *param*[1] and *param*[2] are given in Table 3.

In all cases the rate of decline is determined starting from 1st Jan 2005, so this should be the starting date for the CALDB.

10. Figures:

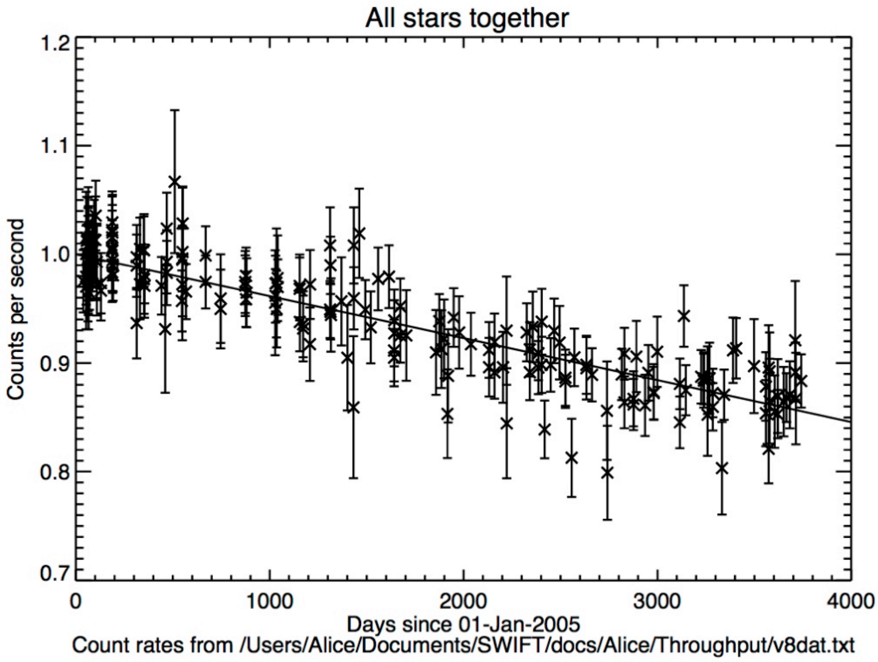

Figure 1 Count rates of standard stars in ***v*** *filter, normalised to the count rates within the first 500 days since 1st Jan 2005, against days since 1st Jan 2005.*

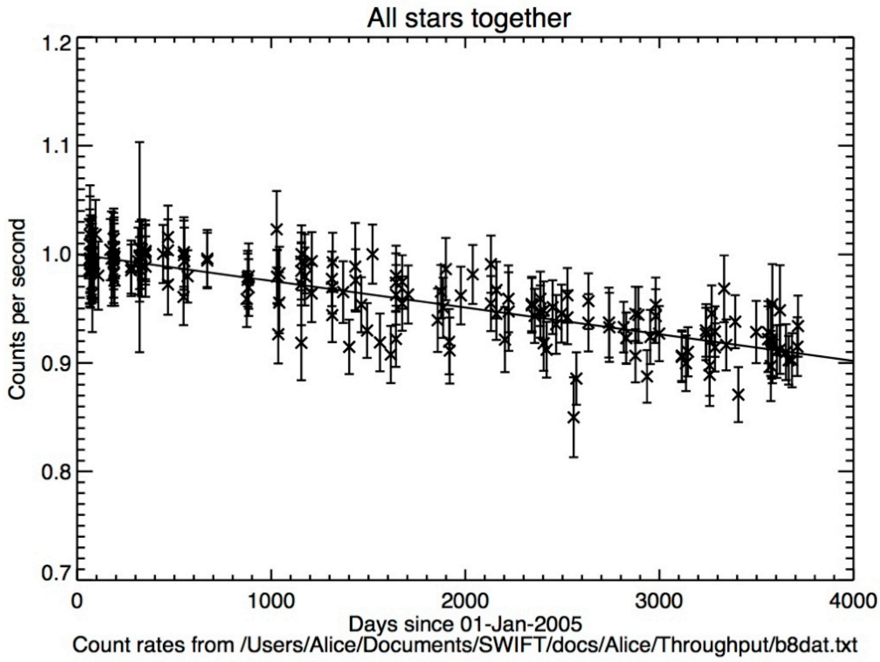

Figure 2 Count rates of standard stars in ***b*** *filter, normalised to the count rates within the first 500 days since 1st Jan 2005, against days since 1st Jan 2005.*

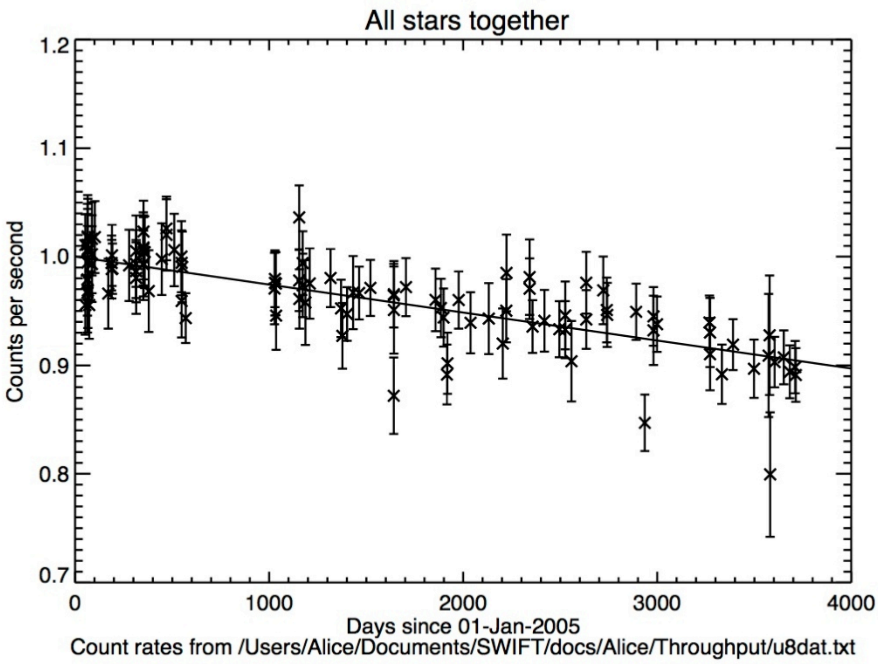

*Figure 3 Count rates of standard stars in **u** filter, normalised to the count rates within the first 500 days since 1st Jan 2005, against days since 1st Jan 2005.*

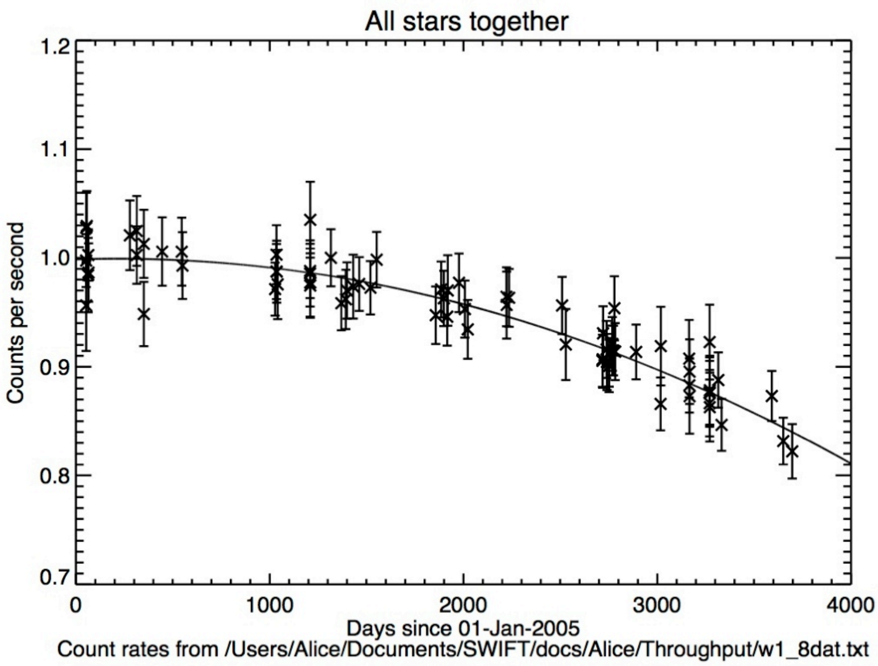

*Figure 4 Count rates of standard stars in **uvw1** filter, normalised to the count rates within the first 500 days since 1st Jan 2005, against days since 1st Jan 2005.*

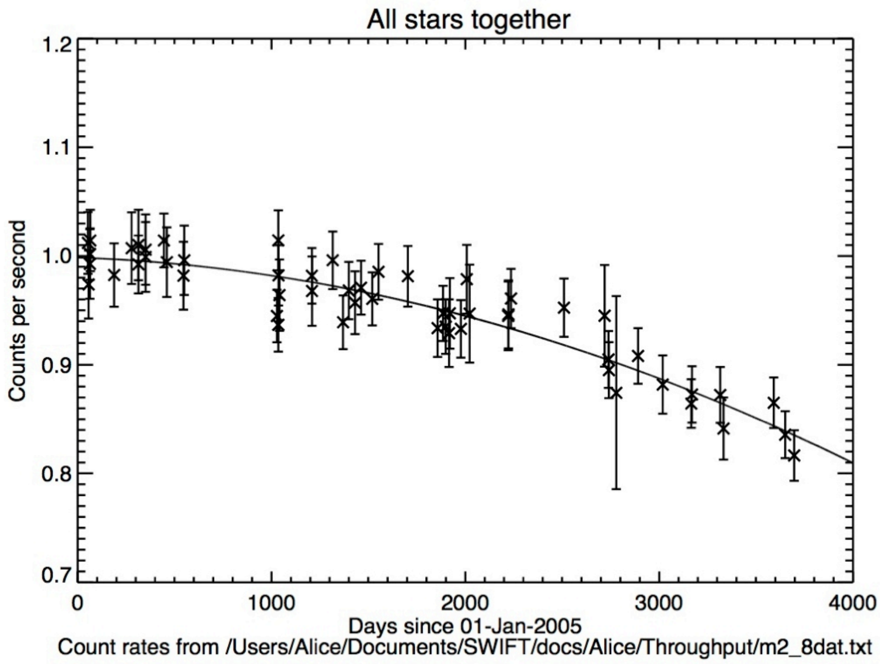

Figure 5 Count rates of standard stars in ***uvm2*** *filter, normalised to the count rates within the first 500 days since 1st Jan 2005, against days since 1st Jan 2005.*

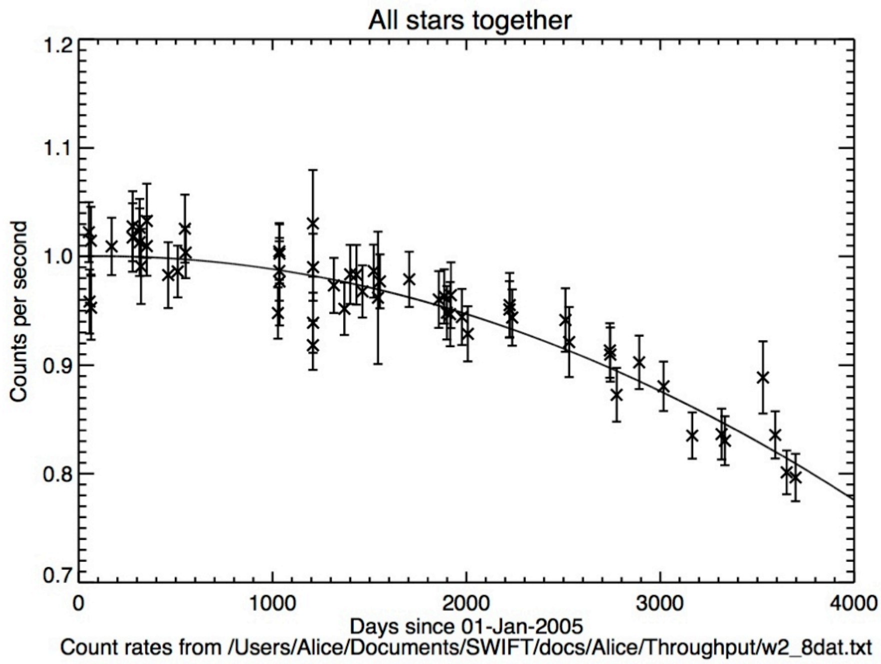

Figure 6 Count rates of standard stars in ***uvw2*** *filter, normalised to the count rates within the first 500 days since 1st Jan 2005, against days since 1st Jan 2005.*

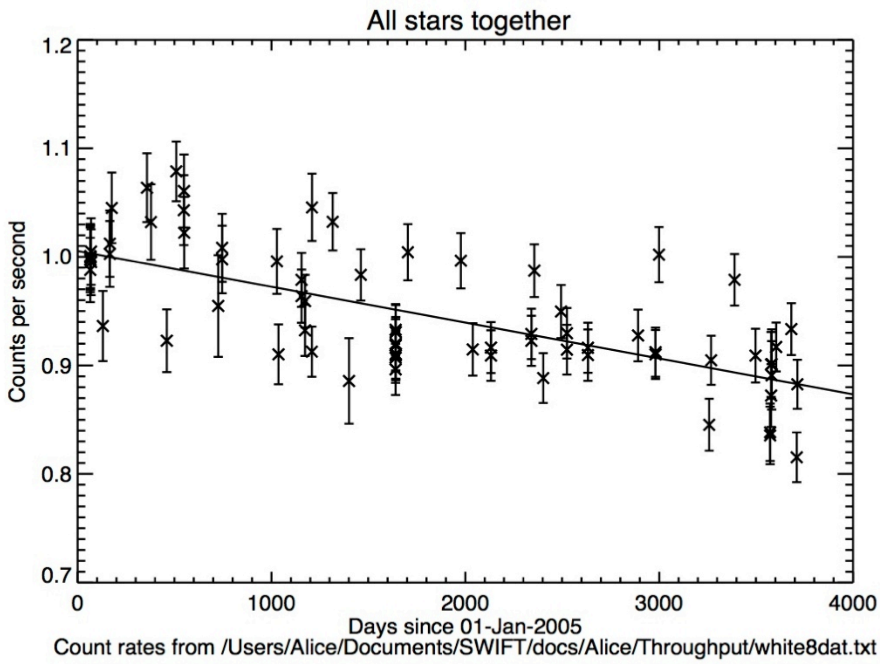

*Figure 7 Count rates of standard stars in **white** filter, normalised to the count rates within the first 500 days since 1st Jan 2005, against days since 1st Jan 2005.*

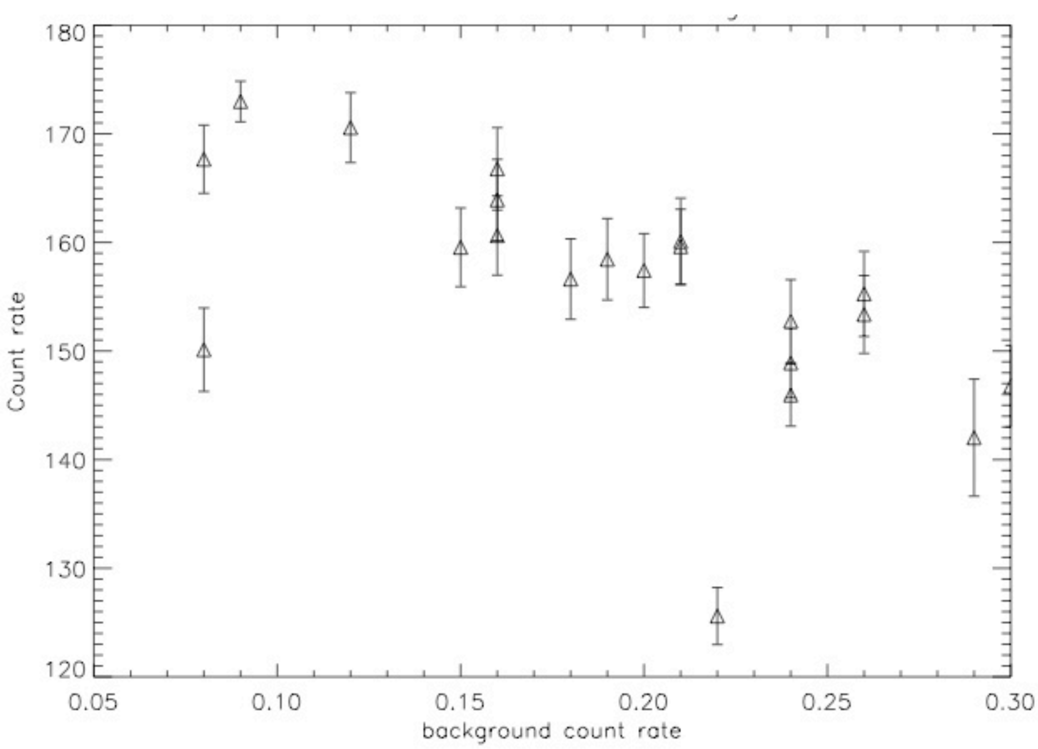

*Figure 8 showing how count rates in the **white** filter in WD1121+145 are significantly affected by the background level.*

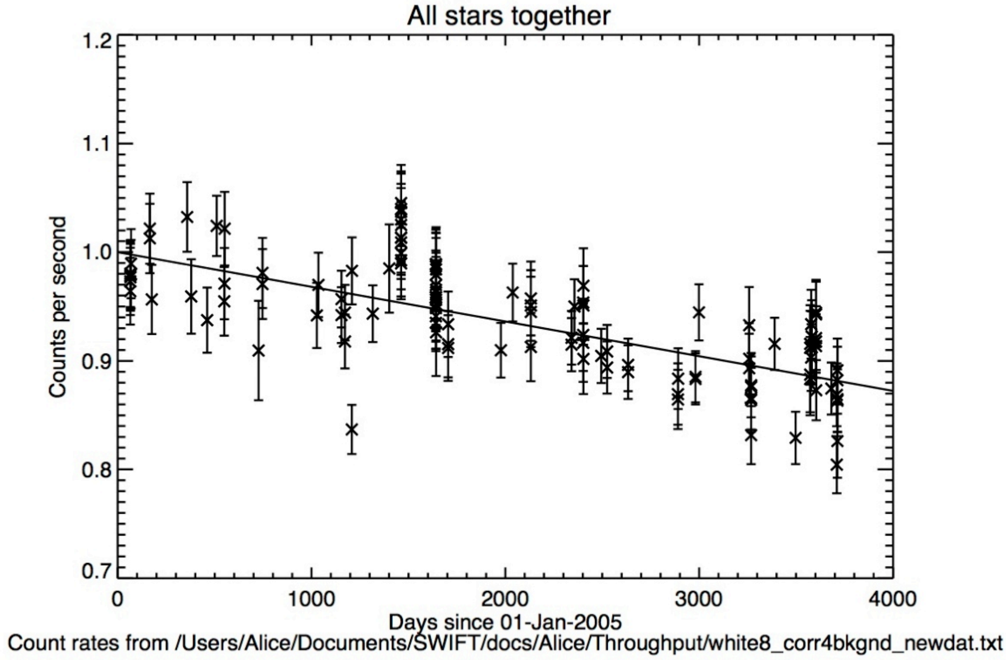

Figure 9 ***White*** *data corrected for background count rate.*