SWIFT-UVOT-CALDB-14-R02
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SWIFT UVOT CALDB RELEASE NOTE

SWIFT-UVOT-CALDB-14-R02: Coincidence Loss Corrections

0. Summary:

The coincidence loss CALDB file contains an empirical polynomial correction to the theoretical relation for coincidence loss in the photon-counting UVOT detector. It applies to photometry with an aperture radius of 5".

1. Component Files:

FILE NAME	VALID DATE	RELEASE DATE	VERSION
swucountcor20010101v102	2004-11-20	2007-06-28	102

2. Scope of Document:

This document describes the empirical determination of polynomial coefficients which modify the theoretical coincidence loss correction to provide optimal linearity for UVOT photometry.

3. Changes:

The empirical coincidence loss polynomial has been re-computed using a 5″ rather than 6″ photometry aperture. Small changes are also due to the use of corrected frametimes and deadtimes. The correction polynomial is now stored as a multiplicative function in the CALDB file. The new polynomial differs from the previous version by less than 1% for counts per frametime less than 0.8.

The previous version of this document included a test of the CALDB polynomial using different frame rates. However, the polynomial was applied incorrectly, and so the section has been removed until the test is redone.

4. Reason For Update:

The standard photometry aperture size has been changed from 6” to 5”.

5. Expected Updates:

The use of color terms when comparing UVOT and Stetson photometry is expected to improve the accuracy of the correction polynomial.

Because the size of the correction polynomial is so small, it may be that future updates will use a lower order polynomial.

6. Caveat Emptor:

No color terms were applied in the derivation of the coincidence loss polynomial.

No error is given on the polynomial coefficients.

The coincidence loss correction is nonlinear and diverges at the coincidence loss limit of 1 count per frametime (about 92 cts/s). At count rates near this limit, small errors in the accuracy of the coincidence loss correction can cause large errors in the corrected count rate.

The CALDB file contains information on the CCD clocking parameters (e.g. the number of horizontal clocks per row) which can be used to determine the frametime and the deadtime. Although this information is believed to be correct, it is not actually used by any of the UVOT software.

7. Data Used:

ObsID	***Target***	***Date***	***Filter***	***ExpTime***
00054210004	NGC 188	Oct 13, 2005	B	325
00130088002	GRB050525	May 26, 2005	B	764
00054211002	M67	Mar 2, 2006	B	441

ObsID	Target	Date	Filter	ExpTime

8. Description of Analysis:

From Poisson statistics, the theoretical correction for coincidence loss for a point source is given by

$$C_{theory} = -\ln(1 - C_{raw}\, ft(1-df)) / ft(1-df)$$

where C_{theory} is the theoretical coincidence loss corrected count rate, C_{raw} is the raw observed deadtime-corrected count rate, *ft* is the frame time, and *df* is the deadtime fraction. This equation applies to a single physical (4") CCD pixel and assumes that all coincidences are directly on top of each other with minimal blurring of a single event profile. The theoretical relation should be best approximated when using an aperture size comparable to the 9 physical CCD pixels used for centroiding the photon splash. Here we use a 5" radius aperture, and determine an empirical polynomial function of the counts per frametime, which is used to correct the theoretical coincidence loss correction. This correction is determined by observing a star field (NGC 188) with known precision photometry, applying the theoretical coincidence loss correction, and determining any adjustments needed to ensure linearity.

A pre-launch calibration of the coincidence loss polynomial was derived by comparing the response of the UVOT detectors to that of a photomultiplier tube. However, the accuracy of the ground-based calibration was suspect, because the illumination source was not point-like, and the pre-launch calibration performs badly with flight data.

The flight calibration of the coincidence loss polynomial was derived using a B band observation (00054210004) of the open cluster NGC 188 which has superb photometry to V=21 by Peter Stetson (2004, PASP, 116, 1012).

Frametime and Deadtime:

Until about March 2006 there was some uncertainty about values of the frametime and deadtime to be used in the theoretical coincidence loss equation. Since V3.5 of the UVOT pipeline, the CCD frametime for an UVOT exposure has been stored in the FITS header, and has a value of 11.0322 ms for full frame exposures. The deadtime fraction is computed from the frametime by the formula *df = vtrans*nvpi / ft*

where *vtrans=6e-7s* is the vertical transfer time on the CCD, and *nvpi = 290* is the number of vertical pixel transfers per image. This formula yields a deadtime fraction for a full frame image of 0.01577. The deadtime correction = *1 – df* is now also recorded in the DEADC keyword in the FITS header.

Prior to March 2006, the task UVOTMAG (which computed the coincidence loss correction) had incorrect values of the frametime (=11.088ms) and deadtime = 0.0025974 hardcoded. (The frametime value was taken from the XMM/OM detector, and the deadtime value was a factor of six too small.) (The task UVOTMAG is now obsolete, and the coincidence correction is performed by the task UVOTCOINCIDENCE.) The UVOT software obtains the FRAMETIME from the FITS header when possible and computes the deadtime as above.

Early in the mission, there was also some uncertainty as to whether the value of the EXPOSURE keyword in the UVOT FITS header already had a deadtme correction applied. Prior to processing version V3.5, the correction was applied to image mode data but not to event mode data. Currently, the correction is applied to all data, and is recorded in the DEADC keyword.

NGC 188

To compare the UVOT photometry of NGC 188 with the B magnitudes in the Stetson catalog, we first selected stars in the Stetson catalog that had no neighbors within 12". A total of 198 of these isolated stars had matching sources on the UVOT image. The UVOT photometry was performed using a 10 pixel radius aperture with the sigma-clipped sky background taken between 55 and 70 pixels. The theoretical coincidence loss correction was applied to the raw UVOT counts prior to the background subtraction. These counts were then multiplied by a fourth-order polynomial correction factor

$$cts = cts * (1 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4)$$

where x is the observed number of counts per frametime, and the polynomial coefficients a_i are adjusted by a least squares program to provide the best match with the catalog photometry. No color correction term was applied. The zero point was also kept as a free parameter, to account for any possible exposure time problems for this particular exposure. (The best-fit zero point was found to be within 0.005 mag of the current CALDB value of 19.11.) The derived polynomial coefficients are given in Table 1. A plot of the empirical corrections as a function of *x,* the number of counts per frametime is shown in Figure 1. It can be seen that the empirical correction in the current CALDB is quite small, and never exceeds 3%. The new polynomial differs from the previous (6”) version by less than 1% for counts per frametime less than 0.8.

Early versions of the software contained an inconsistency because the polynomial was stated to be a multiplicative factor, but it was actually used as a division factor in the software. To maintain consistency with earlier versions of the software, the coincidence correction CALDB file now includes coefficients for both a multiplicative factor (MULTFUNC) and equivalent coefficients for a division (PLINFUNC) factor. It is recommended that future work always use the multiplicative factor.

Table 1: Polynomial Correction Coefficients

	X	***X^2***	***X^3***	***X^4***
5” Radius	***0.0658568***	***-0.0907142***	***0.0285951***	***0.0308063***

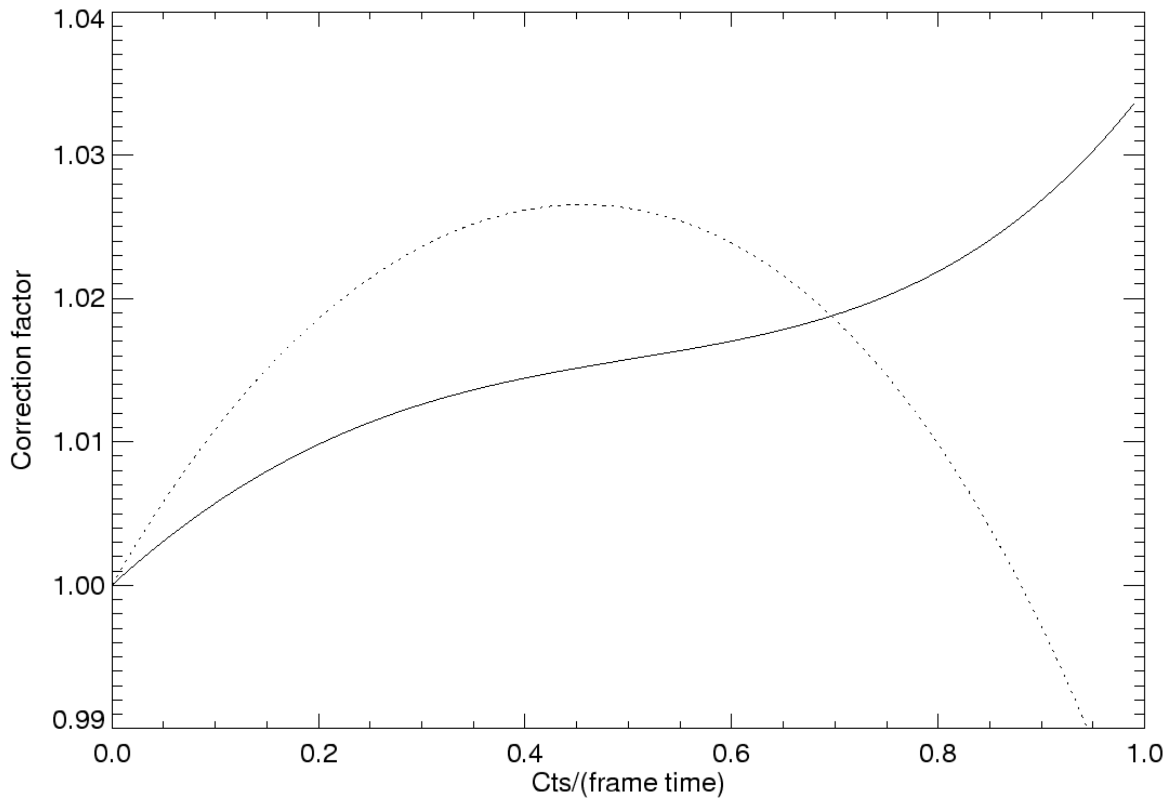

Figure 1: Polynomial Correction to the theoretical Co-I Loss (solid line). The previous correction for a 6” radius aperture is shown as the dotted line.

Figure 2 shows the results for NGC 188 for the cases of (1) no coincidence loss correction, (2) the theoretical coincidence loss correction, and (3) the current CALDB correction. This figure uses all 558 stars matched with the Stetson catalog and not just the 198 stars used to derive the polynomial coefficients. It can be seen that large deviations begin to occur at B $\simeq$ 17 when no coincidence loss correction is applied. The theoretical coincidence loss correction does quite well over the entire range, but the use of the current CALDB coefficients can smooth out some small undulations.

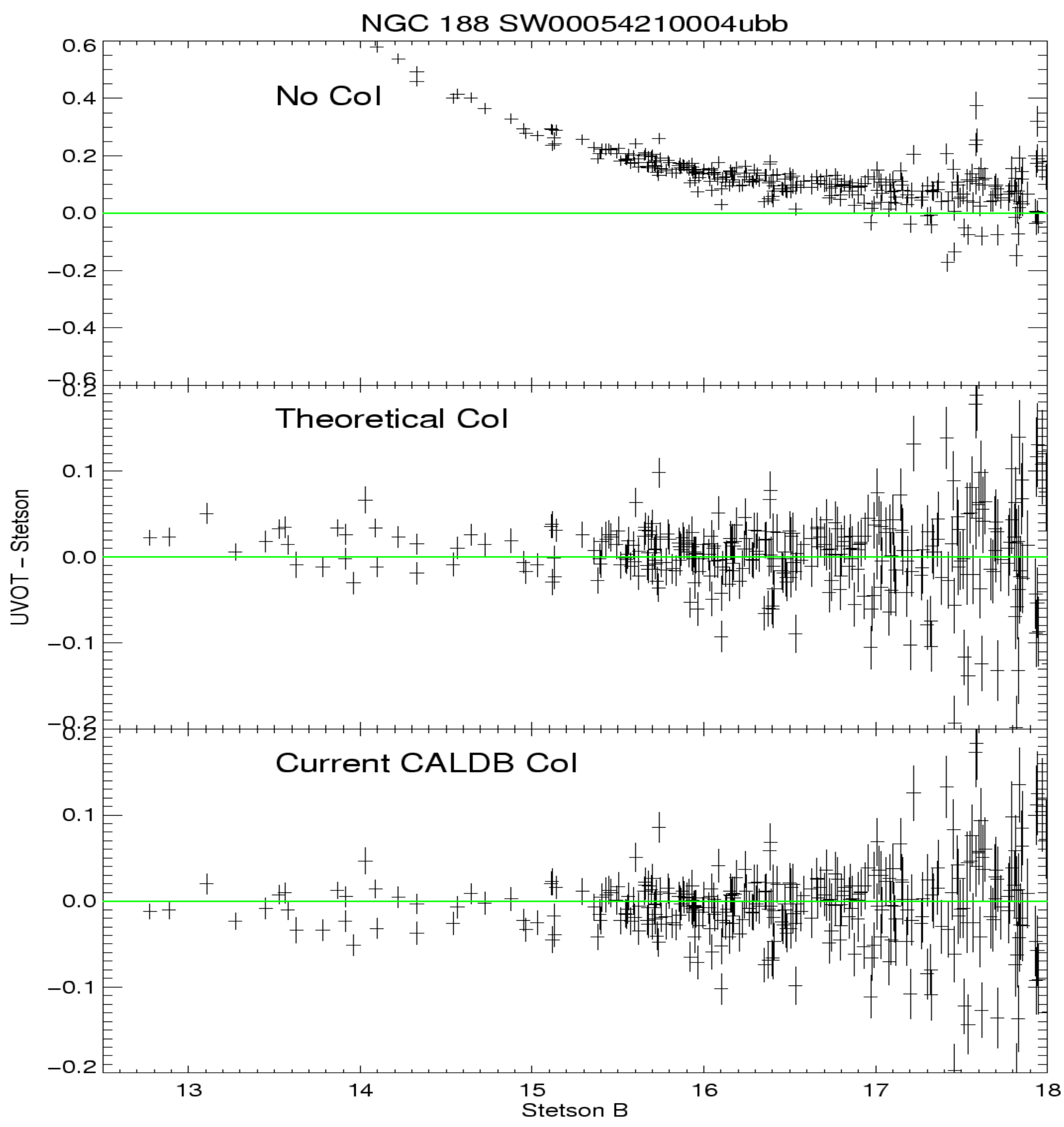

Figure 2: Different CoI corrections applied to the NGC 188 data

Figure 3 shows the residuals after determining the polynomial coefficients, as a function of both B magnitude and counts/frametime. There is no obvious trend in magnitude, but more data would be useful at higher countrates.

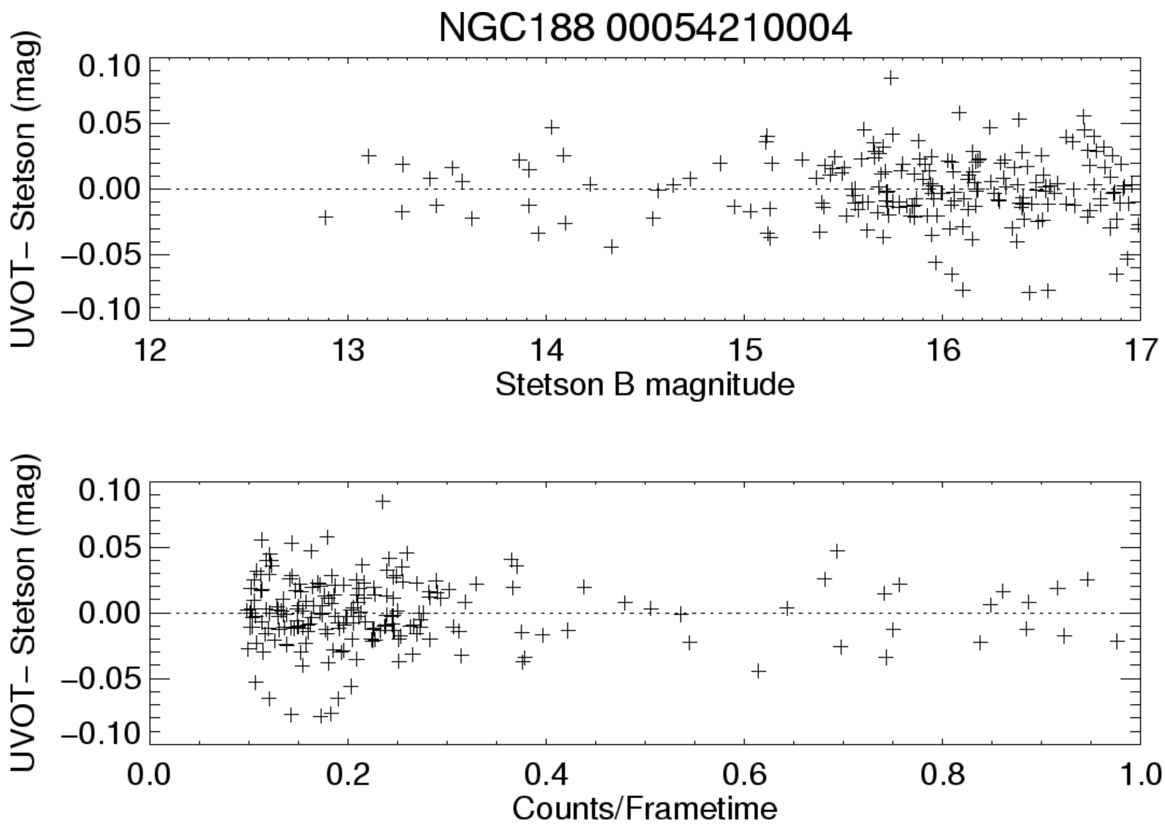

Figure 3: Linearity vs. Counts/Frametime

GRB050525

To test whether the coincidence loss correction derived from the NGC 188 data applies to other UVOT images, we performed a similar test with a B image (00130088002) of the field of GRB050525. This field has BV photometry available from Arne Henden (ftp://ftp.aavso.org/public/grb/)for comparison. Figure 4 compares the UVOT photometry with the Henden photometry using the the theoretical correction, and the theoretical plus current CALDB empirical correction. The use of the empirical correction provides better linearity (less trending of the residuals shown in Figure 4). However, for this dataset, an offset of 0.013 mag is required to match the UVOT and the Henden photometry.

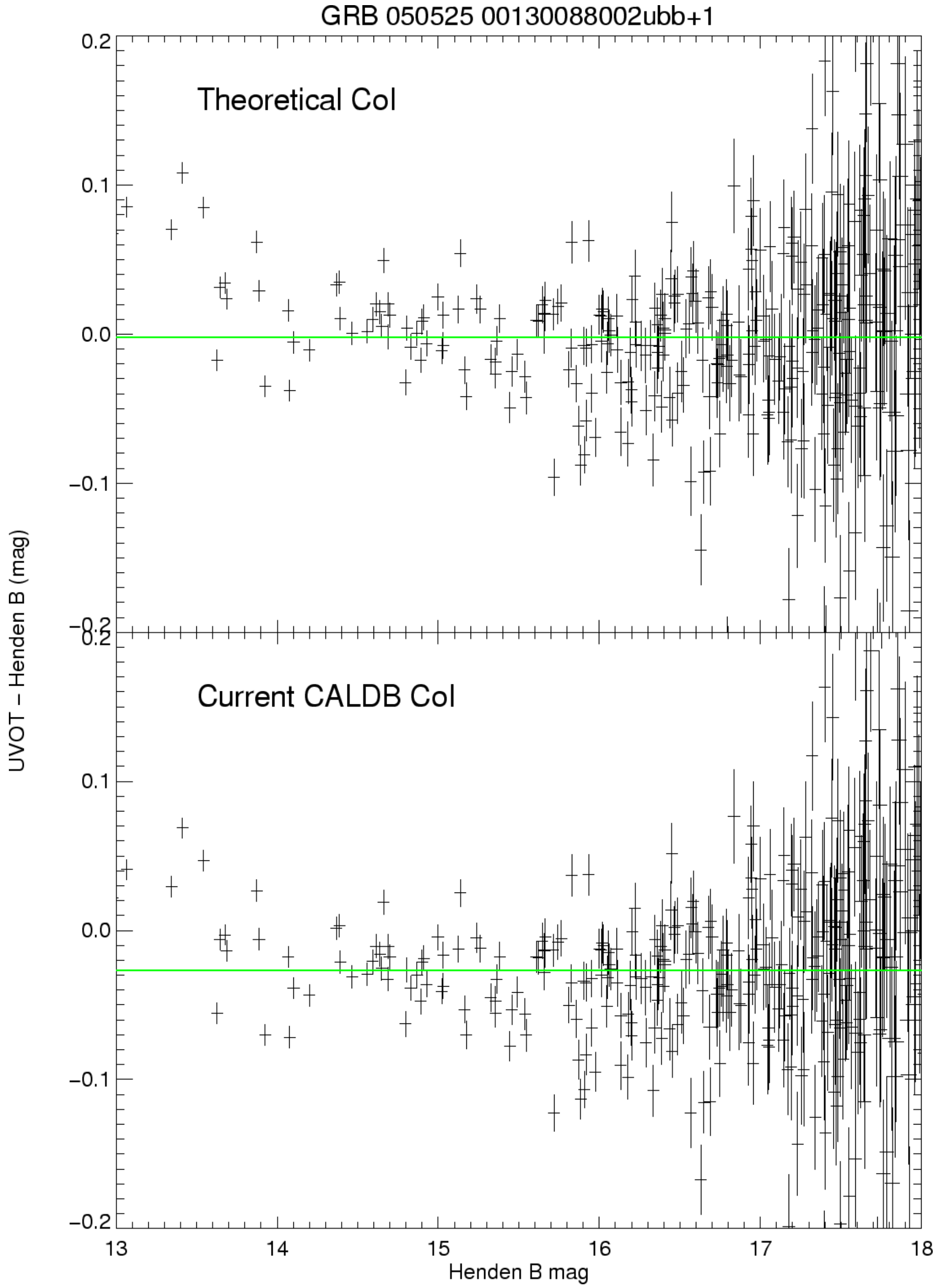

Figure 4: Coincidence loss correction for GRB050525

To test the accuracy of the coincidence loss correction at large count rate we compared UVOT B photometry of the open cluster M67 with the photometry of Stetson (2000, PASP, 112, 925). There are 17 stars in common with 12.5 < B < 14, corresponding to count rates larger than 0.7 counts/frametime, when the theoretical coincidence loss correction is larger than a factor of 1.7. Figure 5 shows that there is little trending of the residuals with magnitude, although the scatter of ~0.035 mag is larger than at fainter magnitudes.

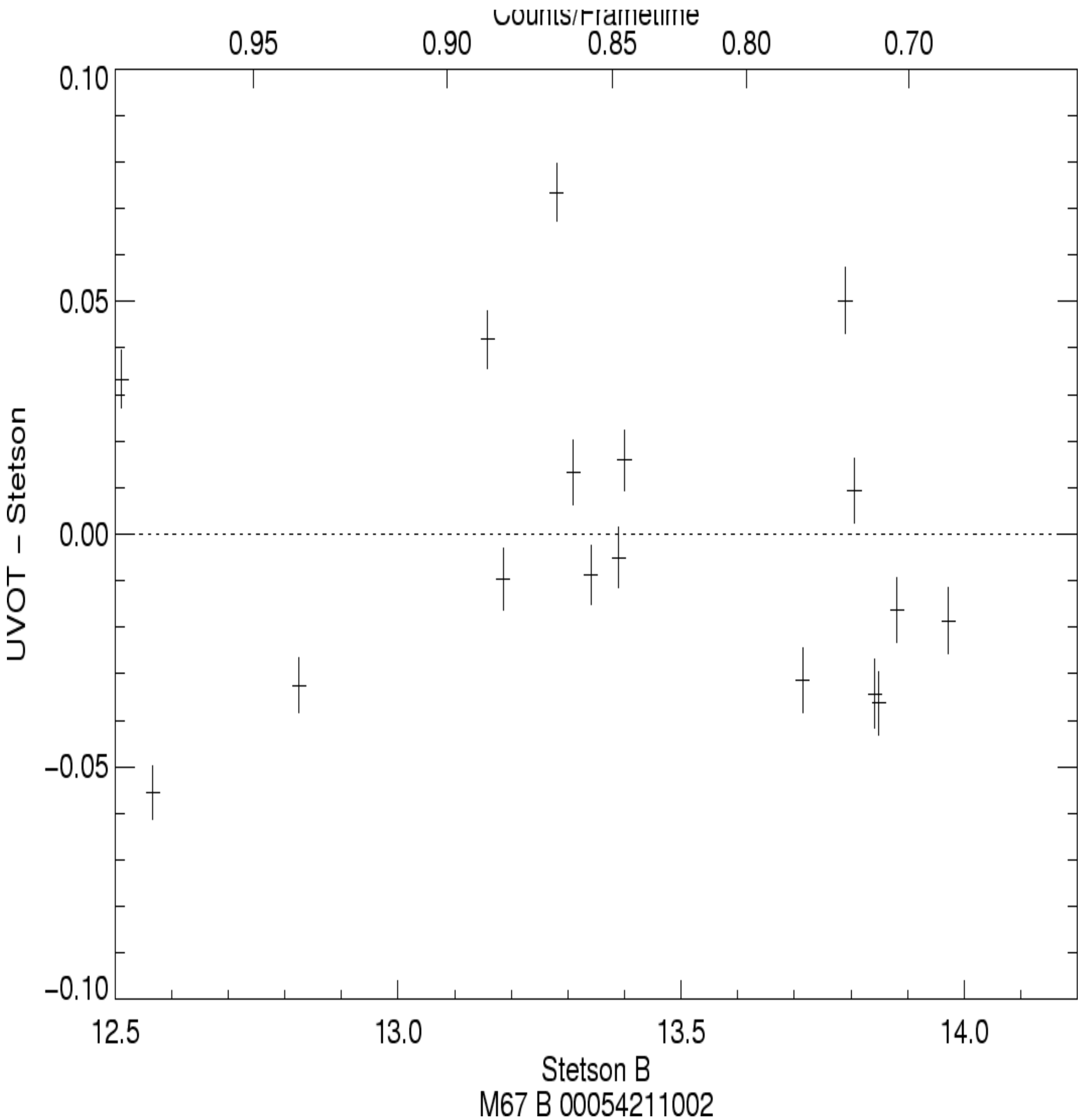

Figure 5: Comparison of UVOT B photometry of M67 with Stetson (2000)