SWIFT-UVOT-CALDB-##
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Revised by:
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Comments:

SWIFT UVOT CALDB RELEASE NOTE

SWIFT-UVOT-CALDB-##: Count Rate to Flux Ratio

0. Summary:

This product provides the in-orbit count rate to flux ratio for 6 filters of the UVOT.

1. Component Files:

FILE NAME	VALID DATE	RELEASE DATE	VERSION

2. Scope of Document:

This document contains a description of the count rate to flux ratio calibration analysis performed to produce the count rate to flux ratio calibration product for the UVOT calibration database.

3. Changes:

This is the first release of the IN-ORBIT count rate to flux conversion ratios, replacing ground based calibration data.

4. Reason For Update:

An update was undertaken to improve the count rate to flux ratio calibration with in-orbit observations of known standard stars.

5. Expected Updates:

Further updates are expected following further analysis of PSF and coincidence loss correction.

6. Caveat Emptor:

Due to the lack of faint spectroscopic standard stars, especially in the ultraviolet, the count rate to flux ratio for each filter has been calibrated with very few stars.

7. Data Used:

Observations of 4 white dwarfs and 2 Oke standard stars were taken in the UVOT filters. Where multiple observations were taken, images were aspect corrected and then co-added. Observation details, sorted by observation date, can be seen in Table 1.

Object Name	Filter	Date	ID	Mode	Exposure Time (sec)
WD1657+343	uvm2	25/02/2005	55900001	E	707.01
WD1657+344	uvw1	25/02/2005	55900002	E	572.35
WD1657+343	uvw2	25/02/2005	55900001	E	740.79
WD1657+343	v	25/02/2005	55900002	E	605.79
WD1121+145	uvm2	04/03/2005	55250010	E	671.82
WD1121+145	uvw1	04/03/2005	55250011	E	139.61
WD1121+145	uvw2	04/03/2005	55250010	E	715.78
WD1121+145	v	04/03/2005	55250011	E	412.77
WD1121+145	uvm2	05/03/2005	55250015	E	753.42
WD1121+145	uvm2	05/03/2005	55250015	I	760.102
WD1121+145	uvw1	05/03/2005	55250017	E	693.81
WD1121+145	uvw1	05/03/2005	55250017	I	699.719
WD1121+145	uvw2	05/03/2005	55250013	E	753.08
WD1121+145	uvw2	05/03/2005	55250013	I	759.694
WD1657+343	uvm2	06/03/2005	55900018	E	693.04

WD1657+343	uvm2	06/03/2005	55900018	I	698.704
WD1657+344	uvw1	06/03/2005	55900020	E	573.43
WD1657+344	uvw1	06/03/2005	55900020	I	580.012
WD1657+343	uvw2	06/03/2005	55900016	E	693.44
WD1657+343	uvw2	06/03/2005	55900016	I	700.201
WD1121+145	b	05/04/2005	55250019	I	1045.97
WD1657+343	u	12/04/2005	55900024	I	643.959
WD1657+343	v	12/04/2005	55900025	I	640.45
WD1121+145	v	13/04/2005	55250020	I	1577.75
WD1121+145	white	10/05/2005	55250021	I	54.1386
WD1657+343	uvw2	19/06/2005	55900029	I	685.464
WD1657+343	b	20/06/2005	55900030	I	951.898
WD1121+145	u	20/06/2005	55250023	I	487.445
WD1657+343	white	25/06/2005	55900032	I	157.362
WD1026+453	b	07/07/2005	55761006	I	455.297
sa95-42	b	07/07/2005	55763001	I	568.482
sa95-42	b	07/07/2005	55763003	I	569.409
WD0947+857	b	07/07/2005	55760005	I	395.554
G24-9	b	07/07/2005	55762002	I	655.488
WD1026+453	u	07/07/2005	55761005	I	290.699
WD0947+857	u	07/07/2005	55760004	I	236.541
WD1026+453	uvm2	07/07/2005	55761004	E	400.709
WD0947+857	uvm2	07/07/2005	55760002	E	400.709
WD0947+857	uvw1	07/07/2005	55760003	E	236.541
sa95-42	v	07/07/2005	55763002	I	509.655
sa95-42	v	07/07/2005	55763004	I	509.004
G24-9	v	07/07/2005	55762001	I	1032.82

Table 1 – Table containing the observations used to calculate the in-orbit zero points. All of the sequence numbers in column 4 are missing their first three digits of 000. In column 5, I represents Image mode, and E represents Event mode

8. Description of Analysis:

The count rate to flux ratio for each filter can be calculated using several methods. One method uses known flux values of a source and predicted count rates, another method uses known flux values of a source and observed count rates. Vega, 2 Oke standard stars (SA95-42 and G24-9), and four white dwarfs (WD1657+343, WD0947+857, WD1026+453 and WD1121+145), were considered for this calibration.

8.1. Flux Values

There are three ways in which to obtain the flux value for a given source in a given filter.

The first and simplest way to obtain a flux is to use the spectrum of the source to provide a flux value at a given wavelength. The problem with this method is that it does not take into account any absorption/emission features that may lie in the spectrum. The effective filter wavelengths used for this method were, v = 5460Å, b = 4350Å, u = 3450Å, uvw1 = 2600Å, uvm2 = 2200Å, and uvw2 = 1930Å.

The second way to obtain a flux is to fit a continuum to the spectrum, and then interpolate a flux value at a given wavelength. This method has the advantage that it takes into account noise and spectral features. The effective filter wavelengths used for this method were v = 5460Å b = 4350Å, u = 3450Å, uvw1 = 2600Å, uvm2 = 2200Å, and uvw2 = 1930Å.

The third and final way to obtain a flux is to average the spectrum over a filter wavelength range. This method has the advantage that it takes into account noise, but spectral features will also affect the results. The wavelength ranges used for each filter for this method were v = 5000-6000Å, b = 3700-5000Å, u = 3000-4000Å, uvw1 = 2100-3200Å, uvm2 = 1700-3000Å, and uvw2 = 1700-2400Å.

Table 2 shows the results for the 2 Oke standard stars using these three methods. The best results were obtained using the interpolated flux method; these fluxes are plotted as magenta points in Figure 1. The b filter effective wavelength lies over an absorption feature in these spectra; only the interpolated flux method overcomes this problem.

Source	Filter	Single Flux (erg $s^{-1}cm^{-2}Å^{-1}$)	Interpolated Flux (erg $s^{-1}cm^{-2}Å^{-1}$)	Average Flux (erg $s^{-1}cm^{-2}Å^{-1}$)
SA95-42	V	2.2101721E-15	2.0694983E-15	2.0513979E-15
SA95-42	B	4.9748251E-15	4.5572350E-15	4.4581244E-15
G24-9	V	1.7898890E-15	1.7563877E-15	1.7388335E-15
G24-9	B	2.1937030E-15	2.1814456E-15	2.1256139E-15

Table 2 - Flux results for the two Oke standards SA95-42 and G24-9.

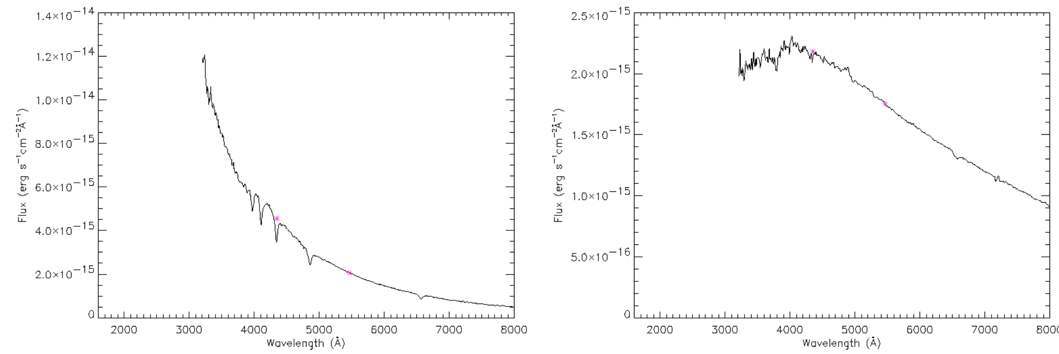

Figure 1 – SA95-42 (left) and G24-9 (right) spectra with final flux values for each filter highlighted in magenta (spectra obtained from http://kahuna.stsci.edu/instruments/observatory/cdbs/calspec.html).

Table 3 shows the flux results for the 4 white dwarf stars using these three methods. The best results were obtained using the interpolated flux method. The flux values for these white dwarf stars are plotted as magenta points in Figure 2.

Source	Filter	Single Flux (erg $s^{-1}cm^{-2}Å^{-1}$)	Interpolated Flux (erg $s^{-1}cm^{-2}Å^{-1}$)	Average Flux (erg $s^{-1}cm^{-2}Å^{-1}$)
WD1657+343	V	9.0665969e-16	8.9190287e-16	9.0727473e-16
WD1657+343	B	1.8977703e-15	1.8710244e-15	2.2061488e-15
WD1657+343	U	4.1767787e-15	4.6035834e-15	4.7636517e-15
WD1657+343	UVW1	1.3883618e-14	1.3686581e-14	1.4291811e-14
WD1657+343	UVM2	2.5448091e-14	2.4996292e-14	2.4038354e-14
WD1657+343	UVW2	3.7178403e-14	3.8941977e-14	3.4064769e-14
WD0947+857	B	4.5005498E-15	3.5957453E-15	4.2306701E-15
WD0947+857	U	1.0011725E-14	9.0652194E-15	9.0075885E-15
WD0947+857	UVW1	2.8372662E-14	2.4432208E-14	2.5882860E-14
WD0947+857	UVM2	5.1316226E-14	4.4029298E-14	4.2857063E-14
WD1026+453	B	3.2585593E-15	2.4620660E-15	3.0715156E-15
WD1026+453	U	6.9344290E-15	6.2191259E-15	6.2812372E-15
WD1026+453	UVM2	3.3929346E-14	2.9345581e-14	2.8113912E-15
WD1121+145	V	6.1893519e-16	6.1885645e-16	6.1908051e-16
WD1121+145	B	1.2959170e-15	1.3086563e-15	1.5311729e-15
WD1121+145	U	3.5802849e-15	3.5891948e-15	3.7433185e-15
WD1121+145	UVW1	1.0588050e-14	1.1453028e-14	1.1815134e-14
WD1121+145	UVM2	2.1545150e-14	2.1705710e-14	1.8951233e-14
WD1121+145	UVW2	2.9320829e-14	2.9189367e-14	2.6714412e-14

Table 3 - Flux values for white dwarf WD1657+343, WD0947+857, WD1026+453, and WD1121+145.

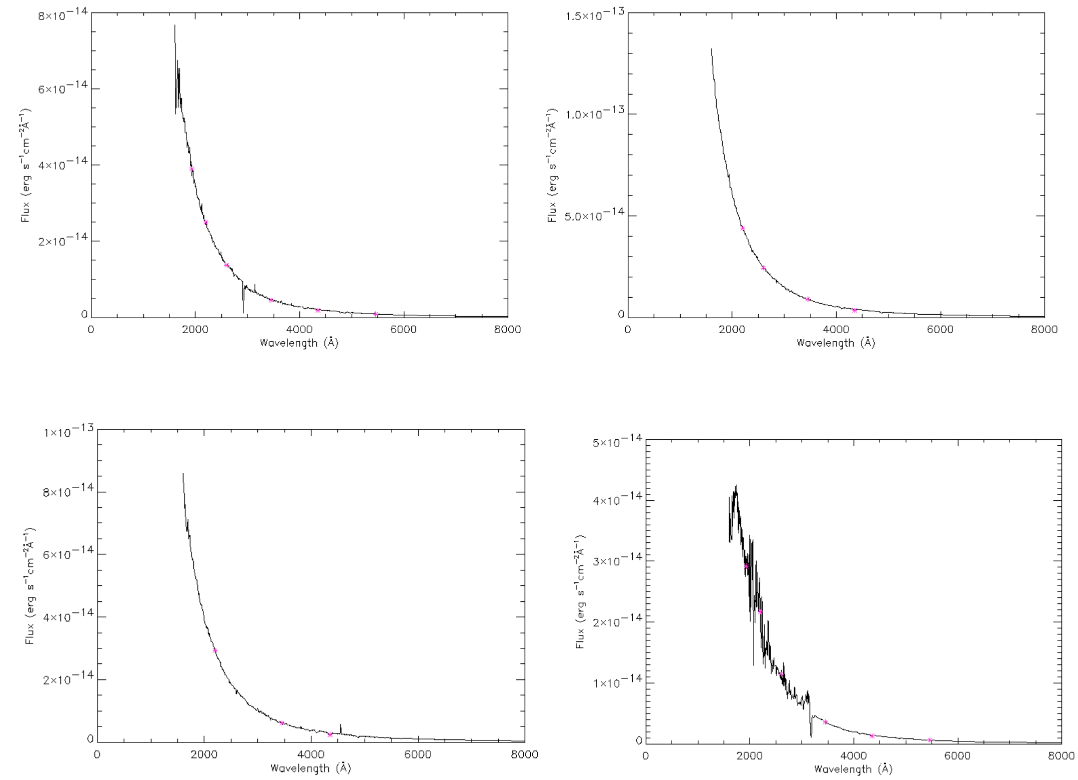

Figure 2 - WD1657+343 (top left), WD0947+857 (top right), WD1026+453 (bottom left), and WD1121+145 (bottom right) spectra with final flux values for each filter highlighted in magenta. WD1657+343 spectrum obtained form the HST MAST archive, WD0947+857 and WD1026+453 spectra obtained from the HST and IUE MAST archive, and WD1121+145 spectrum obtained form the IUE MAST archive.

Table 4 shows the results for Vega using these three methods. The best results were obtained using the interpolated flux method and these fluxes are plotted as magenta points in Figure 3. The b filter wavelength lies over an absorption feature in the Vega spectrum; only the interpolated flux method overcomes this problem. The increase in flux at 4000Å in the Vega spectrum is taken into account in the average flux method, but not the other two methods affecting the u filter flux values.

Filter	Single Flux (erg s^{-1}cm^{-2}Å^{-1})	Interpolated Flux (erg s^{-1}cm^{-2}Å^{-1})	Average Flux (erg s^{-1}cm^{-2}Å^{-1})
V	3.6304594e-9	3.6306912e-9	3.5876731e-9
B	5.6311387e-9	7.0223849e-9	6.0843888e-9
U	3.1627082e-9	3.1636016e-9	4.0079113e-9
UVW1	3.9287368e-9	3.8257152e-9	3.9455414e-9
UVM2	5.1245950e-9	4.9732187e-9	4.5739873e-9
UVW2	5.4993000e-9	5.5998533e-9	5.2577881e-9

Table 4 - Flux values for Vega.

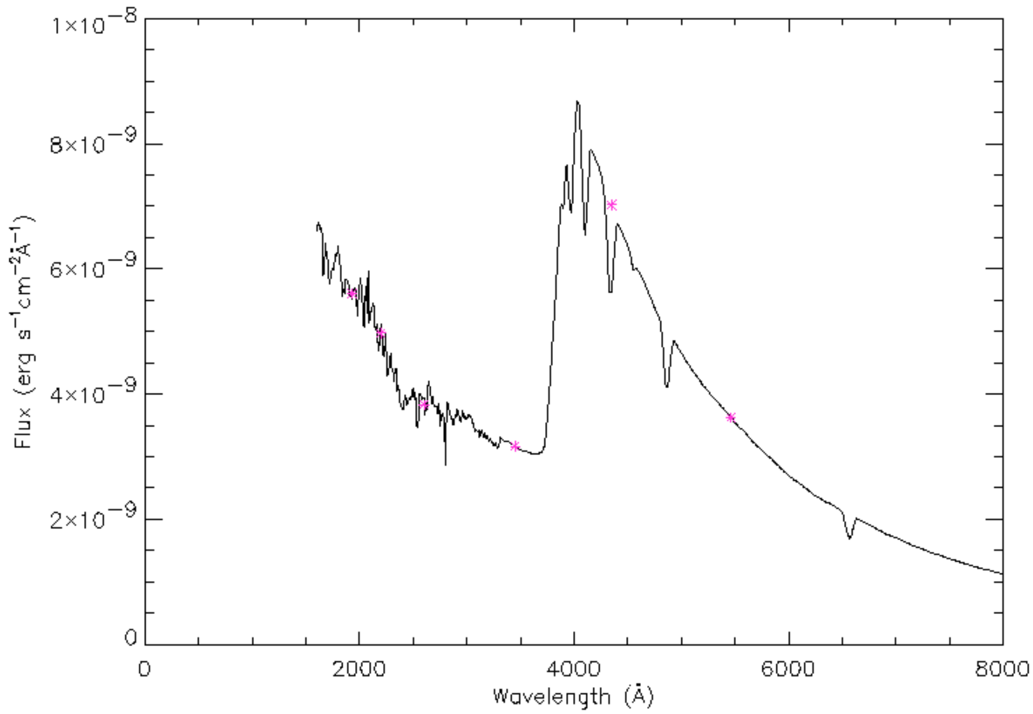

Figure 3 - Vega spectrum with flux points highlighted in magenta (spectrum obtained from http://www.eso.org/observing/standards/spectra/hr7001.html).

8.2. Count Rate Values

All observations were reprocessed using the latest CALDB teldef file (swugen20041120v102.teldef). Observed count rates for the 6 observed stars for each filter were obtained using a 12 pixel (6 arcsec) aperture radius for optical filters and a 24 pixels (12 arcsec) radius for ultraviolet filters. All observed count rates were then corrected using the theoretical coincidence loss equation,

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

where C_{theory} is the theoretically coincidence loss corrected count rate, C_{raw} is the raw observed count rate, ft is the frame time (0.011088s), and df is the deadtime fraction (0.0155844). This theoretical coincidence loss is then corrected by multiplying by the ground-based empirical formula,

$$f(x) = 1.0 + 0.2966x - 0.492x^2 - 0.4183x^3 + 0.2668x^4 ,$$

Where $x = C_{raw} ft$.

Predicted count rates for the 6 observed stars and Vega were obtained by convolving the known spectrum of each source with the instrument throughput (i.e. the in-orbit effective area curves) for each filter. In the case of the observed stars, if the in-orbit effective area curves are truly representative, the observed and predicted count rate values should be the same.

Table 5 show the results of the observed and predicted count rates. This table shows that the observed and predicted data are not the same therefore there must be a reasonably large error in the ratio that was used to calculate the in-orbit effective areas. Alternatively these results could show that the shape or extent of the effective areas is not perfectly known.

Source	V	B	U	UVW1	UVM2	UVW2
SA95-42 Observed	8.16 ±0.14	29.48 ±0.26	-	-	-	-
SA95-42 Predicted	8.92	31.17	-	-	-	-
G24-9 Observed	7.49 ±0.16	15.77 ±0.22	-	-	-	-
G24-9 Predicted	7.44	15.39	-	-	-	-
WD1657+343 Observed	3.74 ±0.07	14.85 ±0.16	32.57 ±0.30	38.80 ±0.21	31.86 ±0.16	61.47 ±0.36
WD1657+343 Predicted	3.91	15.14	31.38	38.96	39.28	61.12
WD0947+857 Observed	-	27.55 ±0.37	58.93 ±0.65	70.34 ±0.71	57.34 ±0.46	-
WD0947+857 Predicted	-	29.13	59.21	70.28	68.11	-
WD1026+453 Observed	-	19.26 ±0.29	39.23 ±0.45	-	57.07 ±0.46	-
WD1026+453 Predicted	-	21.32	41.22	-	44.90	-
WD1121+145 Observed	2.99 ±0.05	12.41 ±0.15	25.30 ±0.31	32.12 ±0.19	25.89 ±0.13	47.68 ±0.22

WD1211+145 Predicted	2.68	10.39	24.29	31.40	31.39	48.35
Vega Predicted	15534847.	46541885.	22184292.	11115935.	7668302.3	10506903.

Table 5 - Observed and predicted count rate values for the 6 observed standard stars and the predicted count rate for Vega.

8.3. Count Rate to Flux Conversion

The count rate to flux conversion was calculated using the different count rate values and the respective flux values. Figure 4 plots these results where the key on the plot indicates the observed star and method used. The average conversion ratio is indicated by the solid black line. Figure 4 shows that there is a spread of ratio values, depending upon which method is used.

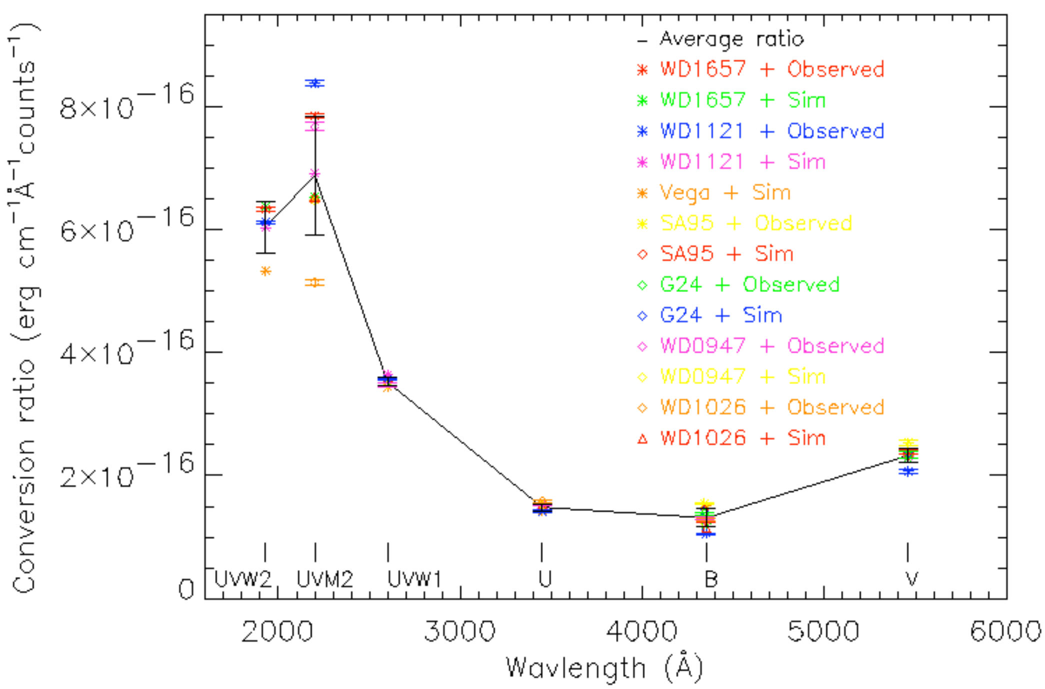

Figure 4 - Count Rate to flux ratio results. The black solid line represents the average ratio with errors.

Finally, Table 6 shows the average count rate to flux ratio (solid black line in Figure 4), and the standard deviation of the average for each filter (solid black error bars in Figure 4).

Filter	Wavelength (Å)	Ratio	Ratio Error
V	5460.0	2.236803E-16	1.211080E-17
B	4350.0	1.313720E-16	1.429925E-17
U	3450.0	1.485137E-16	6.016375E-18
UVW1	2600.0	3.520731E-16	6.909226E-18
UVM2	2200.0	6.886721E-16	9.632383E-17
UVW2	1930.0	6.039047E-16	4.207662E-17

Table 6 - Average count rate to flux ratio results.