

SWIFT-UVOT-CALDB-03-R02

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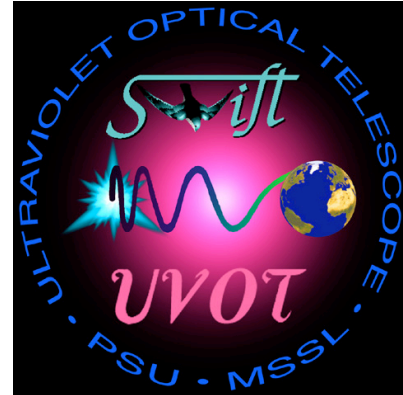
Date Revised: 13th March 2007

Revision #02

Revised by: Tracey Poole; Alice Breeveld

Pages Changed: All

Comments: Colour correction method adjusted to use in-orbit instrument response curves



SWIFT UVOT CALDB RELEASE NOTE

SWIFT-UVOT-CALDB-03-R02: COLOUR CORRECTIONS

0. Summary:

The colour corrections describe the relation of UVOT UBV magnitudes to standard Johnson UBV magnitudes.

1. Component Files:

None.

2. Scope of Document:

This document describes the UVOT-Johnson UBV Colour corrections and how they have been derived.

3. Changes:

This is the second release of the UBV Colour corrections, replacing first estimates.

In this version the colour correction is derived by simulation using the new in-orbit effective areas (uvot_caldb_effectiveareas_02b.doc) and checked by comparison with observations. This allows a much wider colour range to be used in the analysis.

4. Reason For Update:

An up-date was undertaken to base the colour correction on full spectral simulations using the in-orbit instrument effective area curves.

5. Expected Updates:

Further updates are expected with updates of the in-orbit effective area curves.

6. Caveat Emptor:

Due to the lack of faint spectroscopic standard stars, especially in the ultraviolet, the effective area curves have been calibrated with very few stars.

7. Data Used:

Observations of 9 Landolt stars, 1 white dwarf, with known UBV magnitudes were used for the optical filter analysis. Where multiple observations were taken, count rates were calculated for individual exposures and then averaged. Observation details, sorted by observation date, can be seen in Table 1.

Object Name	Filter	Date	Sequence Number	Mode	Exposure Time (sec)
sa104sw-338 & sa104sw-244	u	22/02/2005	55350004	I	1380.5
sa104sw-338 & sa104sw-244	v	22/02/2005	55350004	I	1626.1
WD1657+343	v	25/02/2005	55900002	E	605.79
sa101-278 & sa101-13	b	05/03/2005	54950011	I	1523.7
sa104sw-338 & sa104sw-244	b	06/03/2005	55350009	I	1155.1
PG1525-071B	b	07/03/2005	55750005	I	619.0
PG1525-071B	u	07/03/2005	55750003	I	1327.2
PG1525-071B	v	07/03/2005	55750001	I	1268.8
sa101-278 & sa101-13	b	09/03/2005	54950005	I	1210.0
sa104n-443 & sa104n-457	b	11/03/2005	55400005	I	508.2
sa104ne-367	b	11/03/2005	55450003	I	604.5
sa95sw-102	u	11/03/2005	54350005	I	569.9
sa95sw-102	v	11/03/2005	54350004	I	3706.5

WD1657+343	b	15/03/2005	55900003	I	351.0
sa104n-443 & sa104n-457	u	21/03/2005	55400012	I	2025.3
sa101-278 & sa101-L3	v	26/03/2005	54950003	I	2661.4
sa95sw-102	b	27/03/2005	54350011	I	1649.3
sa104ne-367	u	28/03/2005	55450005	I	868.6
sa104ne-367	v	05/04/2005	55450008	I	725.9
WD1657+343	u	12/04/2005	55900024	I	633.6
sa104n-443 & sa104n-457	v	19/04/2005	55400016	I	1128.0
WD1657+343	u	14/01/2006	55900035	I	82.6

Table 1 - Table containing the observations used to check the colour terms. 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 colour transforms from the UVOT UB_V system to the Johnson UB_V system were calculated using Pickles model spectra (Pickles, 1998, PASP, 110, 863), and GRB power law spectral models with power law ranging from spectral energy index $-2.0 < \alpha < 0.0$, SMC extinction ranging from $0.0 < A_v < 1.0$ and red shift ranging from $0.3 < z < 2.0$, see Figure 1 for an example.

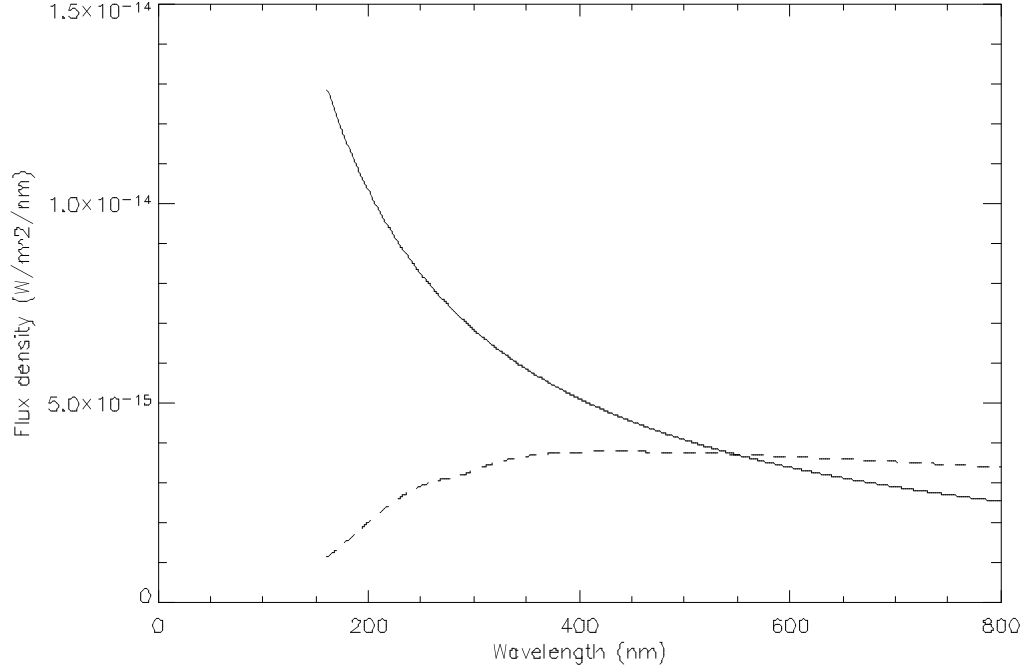


Figure 1 GRB model spectrum with solid line: $z = 0.3$ and $A_v = 0$; dashed line $z = 0.3$ and $A_v = 1.0$

To produce the Johnson colours and magnitudes, the Pickles and GRB models were folded through the Landolt-Johnson effective area curves (Landolt, 1992, AJ, 104, 340).

These spectra were then also folded through the latest UBV UVOT in-orbit effective area curves (uvot_caldb_effectiveareas_02b.doc) to produce the expected UVOT count rates. These count rates were then converted into magnitudes and colours using the equation,

$$M_{source} = Z_{pt} - 2.5 \log(C_{source})$$

where M_{source} is the calculated magnitude in the UVOT system, Z_{pt} is the zero point value for each UVOT filter (uvot_caldb_zeropoints_03b.doc), and C_{source} is the count rate of the source obtained by folding the spectrum through the UVOT in-orbit effective area curves.

8.1 Johnson colour versus UVOT colour

Johnson colour was then plotted against UVOT colour and a fit to this data was performed using a two degree polynomial. Throughout this document the capital letters U, B, and V refer to Johnson magnitudes and lower case

letters u, b, and v refer to UVOT magnitudes. Figure 2 shows the results of this fit to the data for U-B versus u-b (top plot), B-V versus b-v (middle plot) and U-V versus u-v (bottom plot). The blue solid line in each plot shows the best polynomial fit to the Pickles data, the solid green line in each plot shows the best polynomial fit to the GRB models data, and the red solid line shows $x=y$. The residuals to the fits are shown in the lower panel of each plot, and show good agreement to within 0.05 magnitudes, apart from a few outliers. The black points represent the Pickles stars and the green points represent the GRB models.

These simulated fits were then checked using observations. Figure 3 plots the Johnson and UVOT colours of the observed Landolt stars used for zero point analysis (see `uvot_caldb_zeropoints_03b.doc` for details on the analysis of these stars). This figure shows that within the scatter of these observations, the fits produced with the Pickles stars agree with the observations.

The colour terms given from the polynomial fits with the Pickles stars are as follows:

$$U-B = 0.034[\pm 0.007] + 0.862[\pm 0.007](u-b) + 0.055[\pm 0.006](u-b)^2$$

$$-1.482 < u-b < 1.871$$

RMS error on the fit: 0.0573 mag

$$B-V = -0.004[\pm 0.004] + 1.039[\pm 0.011](b-v) - 0.037[\pm 0.007](b-v)^2$$

$$-0.364 < b-v < 1.935$$

RMS error on the fit: 0.0253 mag

$$U-V = 0.071[\pm 0.010] + 0.899[\pm 0.008](u-v) + 0.018[\pm 0.003](u-v)^2$$

$$-1.846 < u-v < 3.558$$

RMS error on the fit: 0.0752 mag

The colour terms given from the polynomial fits with the GRB models are as follows:

$$U-B = 0.086[\pm 0.003] + 0.886[\pm 0.007](u-b) + 0.050[\pm 0.006](u-b)^2$$

$$-1.380 < u-b < 0.543$$

RMS error on the fit: 0.0775 mag

$$B-V = -0.008[\pm 0.001] + 1.012[\pm 0.003](b-v) - 0.018[\pm 0.002](b-v)^2$$

$$-0.124 < b-v < 1.483$$

RMS error on the fit: 0.0342 mag

$$U-V = 0.162[\pm 0.002] + 0.904[\pm 0.002](u-v) + 0.010[\pm 0.002](u-v)^2$$

$$-1.505 < u-v < 2.026$$

RMS error on the fit: 0.1017 mag

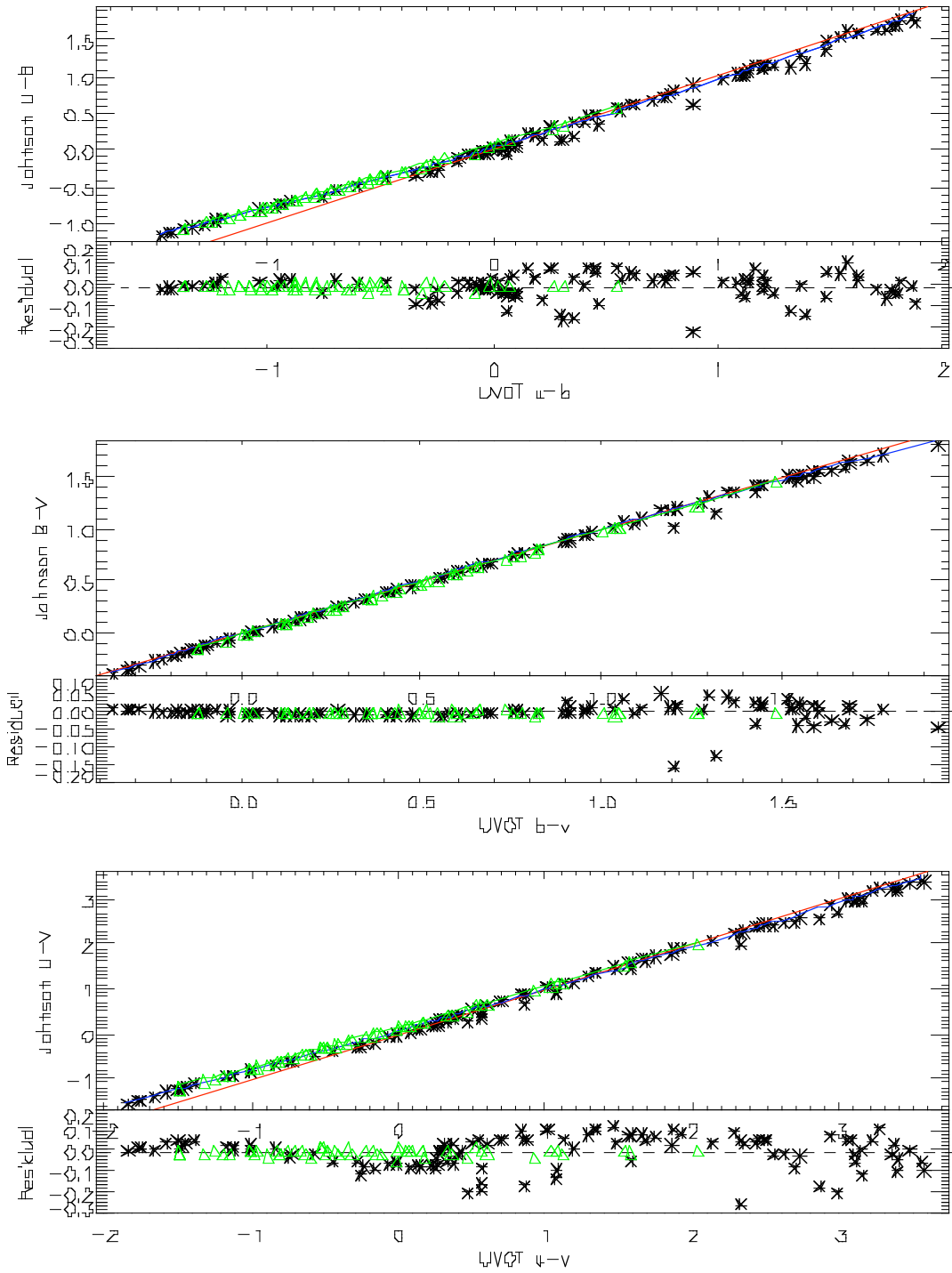


Figure 2 - Johnson colours versus UVOT colours. The blue solid line in each plot is the two degree polynomial fit, the red solid line in each plot is $x=y$. The black data points represent the Pickles stars, and the green data points represent the GRB models.

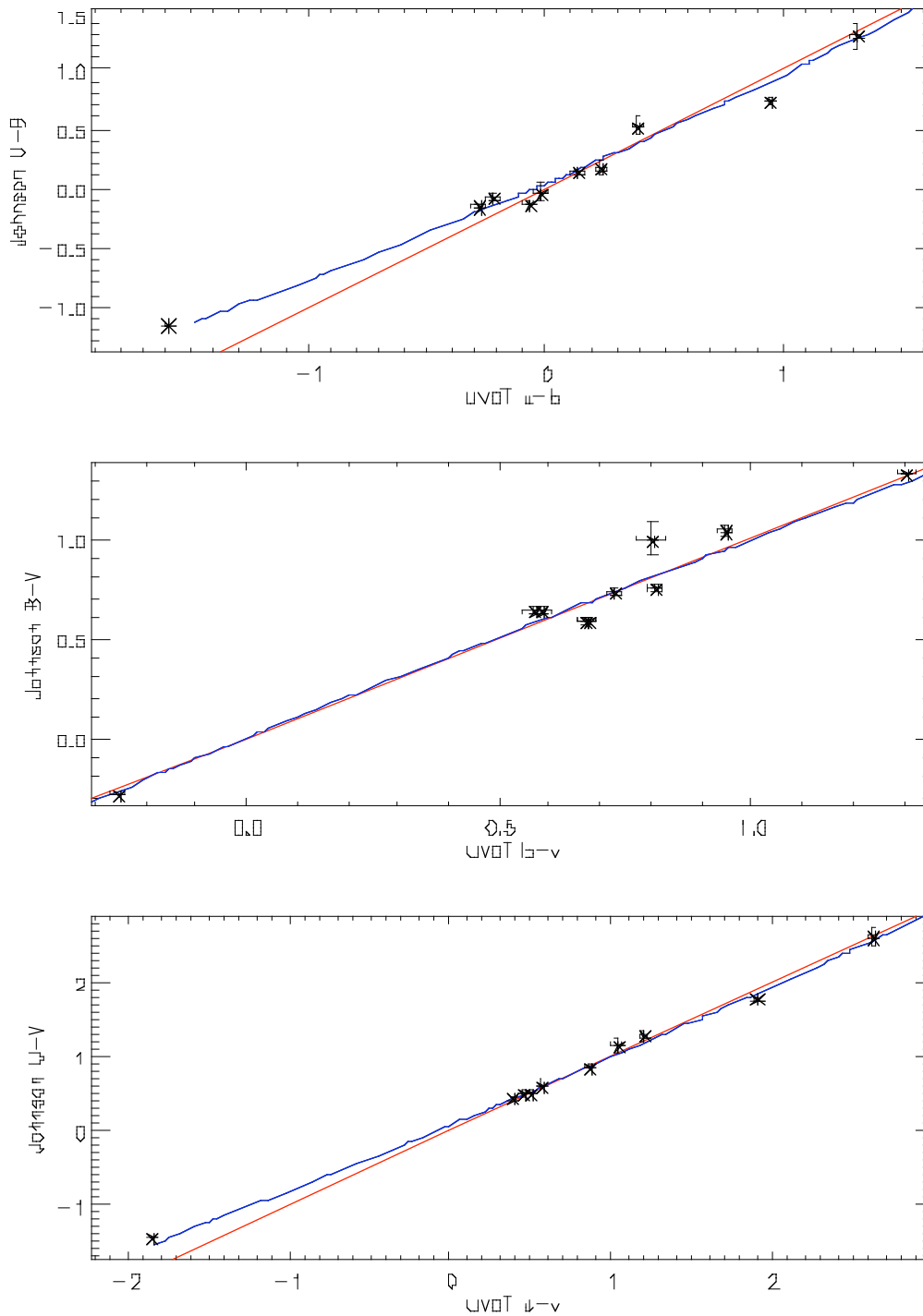


Figure 3 - Johnson colours versus UVOT colours for observed Landolt stars. The blue solid line is the two degree polynomial fit obtained from fitting Pickles stars, and the red line is $x=y$.

8.2 Johnson magnitude versus UVOT colour

Johnson magnitude was then plotted against UVOT colour and a fit to this data was performed using a three degree polynomial fit. Figure 4 shows

the results of this fit to the data for B-v versus b-v (top left plot), B-b versus u-b (top right panel), V-v versus b-v (middle left plot), V-v versus u-v (middle right plot), U-u versus u-b (bottom left plot), and U-u versus u-v (bottom right plot). The blue solid line in each plot shows the best polynomial fit to the data. The residuals to this fits are shown in the lower panel of each plot (black data points), and show good agreement to within 0.05 magnitudes. The black points represent the Pickles stars and the green points represent the GRB models. Figure 4 shows that the Pickles stars and the GRB models do not follow the same fit, therefore a two degree polynomial fit was performed on the GRB model data, which can be seen as the red solid line in Figure 4. Again, the residuals to the GRB fit (green data points) are shown in the lower panel of each plot, and show good agreement to within 0.05 magnitudes.

These simulated fits were checked using observations. Figure 5 plots the Johnson and UVOT colours of the observed Landolt stars used for zero point analysis (see uvot_caldb_zeropoints_03b.doc for details on analysis of these stars). This figure shows that within the scatter of these observations, the fits produced with the Pickles stars agree with observations.

The colour terms given from the polynomial fits for the pickles stars are as follows:

$$B-b = 0.021[\pm 0.003] + 0.005[\pm 0.012](b-v) - 0.014[\pm 0.022](b-v)^2 - 0.011[\pm 0.010](b-v)^3$$

$$-0.364 < b-v < 1.935$$

RMS error on the fit: 0.0203 mag

$$B-b = 0.011[\pm 0.004] - 0.011[\pm 0.008](u-b) - 0.008[\pm 0.004](u-b)^2 - 0.002[\pm 0.004](u-b)^3$$

$$-1.482 < u-b < 1.871$$

RMS error on the fit: 0.0295 mag

$$V-v = 0.029[\pm 0.002] - 0.009[\pm 0.009](b-v) - 0.037[\pm 0.016](b-v)^2 + 0.017[\pm 0.007](b-v)^3$$

$$-0.364 < b-v < 1.935$$

RMS error on the fit: 0.0144 mag

$$V-v = 0.026[\pm 0.002] - 0.014[\pm 0.002](u-v) - 0.005[\pm 0.001](u-v)^2 + 0.002[\pm 0.0005](u-v)^3$$

$$-1.846 < u-v < 3.558$$

RMS error on the fit: 0.0146 mag

$$U-u = 0.042[\pm 0.010] - 0.130[\pm 0.020](u-b) + 0.053[\pm 0.010](u-b)^2 - 0.013[\pm 0.010](u-b)^3$$

$$-1.482 < u-b < 1.871$$

RMS error on the fit: 0.0732 mag

$$U-u = 0.069[\pm 0.012] - 0.093[\pm 0.009](u-v) + 0.037[\pm 0.007](u-v)^2 - 0.007[\pm 0.002](u-v)^3$$

$$-1.846 < u-v < 3.558$$

RMS error on the fit: 0.0712 mag

The colour terms given from the polynomial fits for the GRB models are as follows:

$$B-b = 0.016[\pm 0.0003] - 0.009[\pm 0.001](b-v) - 0.023[\pm 0.001](b-v)^2$$

$$-0.124 < b-v < 1.483$$

RMS error on the fit: 0.0012 mag

$$B-b = -0.018[\pm 0.0005] - 0.045[\pm 0.001](u-b) - 0.014[\pm 0.001](u-b)^2$$

$$-1.380 < u-b < 0.543$$

RMS error on the fit: 0.0019 mag

$$V-v = 0.023[\pm 0.001] - 0.021[\pm 0.003](b-v) - 0.005[\pm 0.003](b-v)^2$$

$$-0.124 < b-v < 1.483$$

RMS error on the fit: 0.0036 mag

$$V-v = 0.010[\pm 0.0007] - 0.012[\pm 0.0006](u-v) - 0.0009[\pm 0.0006](u-v)^2$$

$$-1.505 < u-v < 2.026$$

RMS error on the fit: 0.0039 mag

$$U-u = 0.068[\pm 0.003] - 0.159[\pm 0.007](u-b) + 0.036[\pm 0.006](u-b)^2$$

$$-1.380 < u-b < 0.543$$

RMS error on the fit: 0.0111 mag

$$U-u = 0.172[\pm 0.002] - 0.108[\pm 0.002](u-v) + 0.009[\pm 0.002](u-v)^2$$

$$-1.505 < u-v < 2.026$$

RMS error on the fit: 0.0124 mag

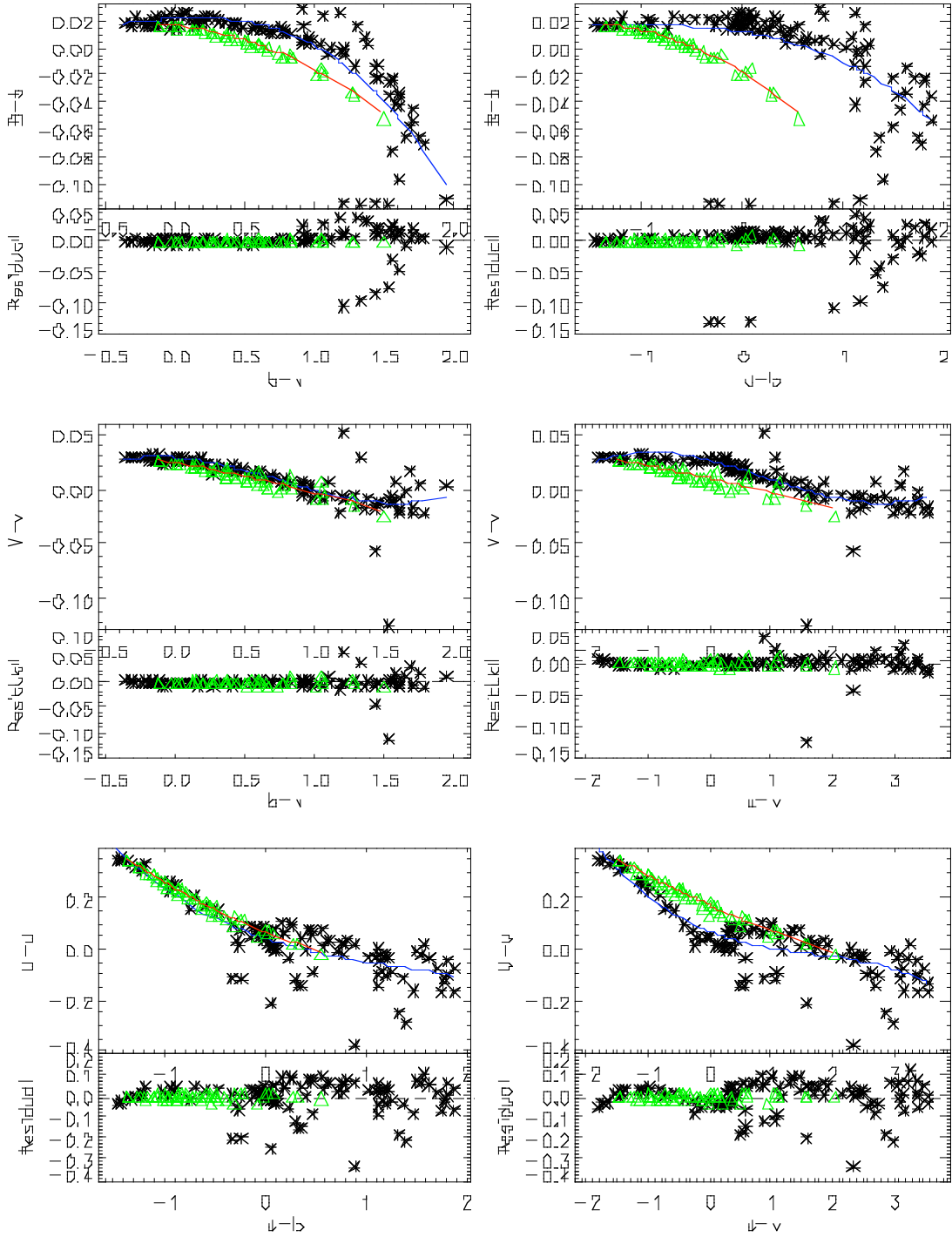


Figure 4 - Johnson versus UVOT colours. The blue solid line in each plot is the three degree polynomial fit to the pickles data, the red solid line in each plot is the two degree polynomial fit to the GRB models. The black data points represent the Pickles stars, and the green data points represent the GRB models.

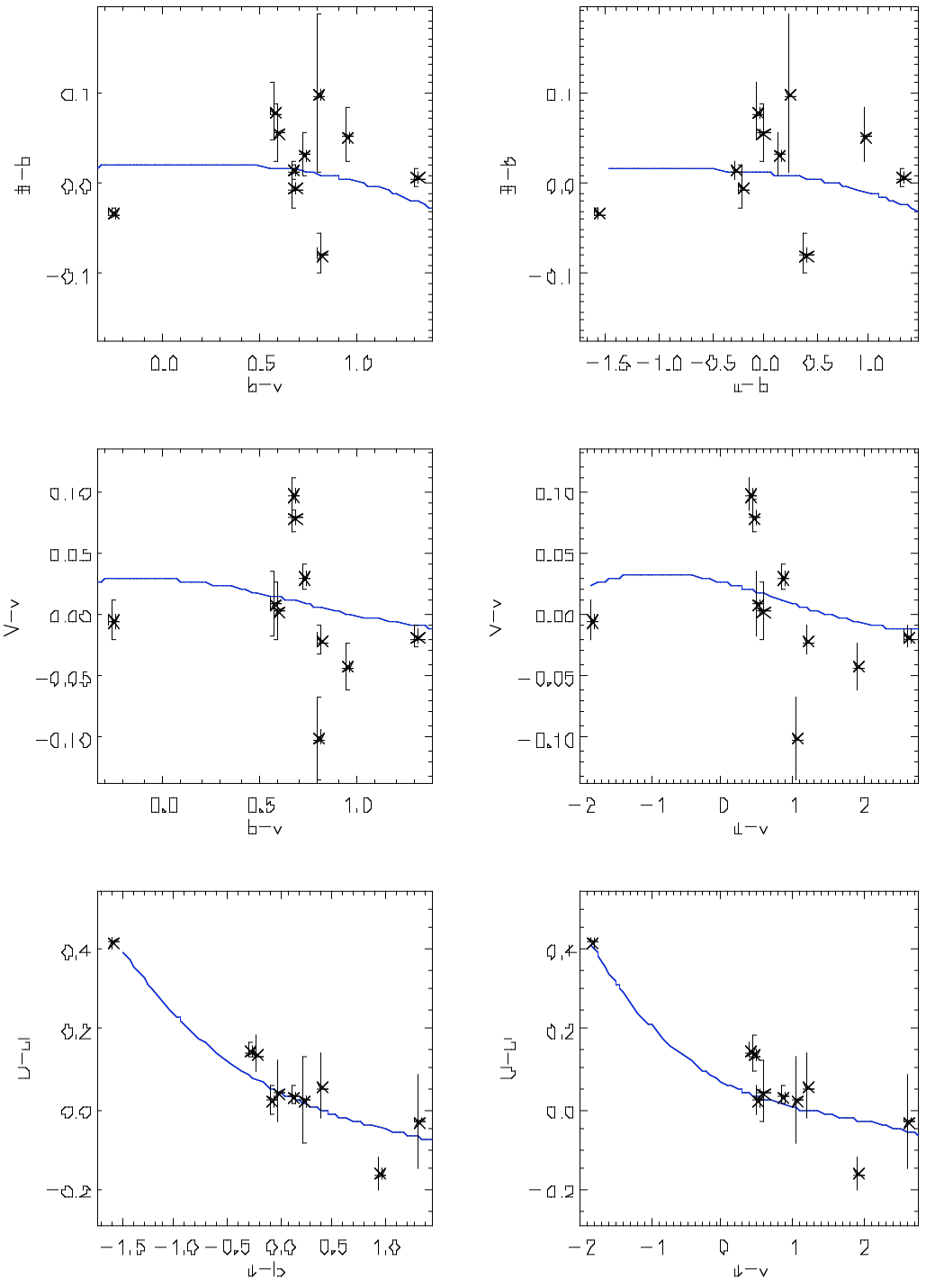


Figure 5 - Johnson versus UVOT colours for observed Landolt stars. The blue solid line is the three degree polynomial fit obtained from fitting Pickles stars.