SWIFT-UVOT-CALDB-##
Date Original Submitted: 7th November 2005
Prepared by: Tracey Poole
Date Revised:
Revision #01
Revised by:
Pages Changed:
Comments:

SWIFT UVOT CALDB RELEASE NOTE

SWIFT-UVOT-CALDB-##: Zero Points

0. Summary:

This product defines the in-orbit zero point and zero point error for the 7 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 zero point calibration analysis performed to produce the zero point calibration products for the UVOT calibration database.

3. Changes:

This is the first release of the in-orbit zero points, replacing ground based calibration data.

4. Reason For Update:

An update was undertaken to improve the zero point calibration with in-orbit observations of known standard stars.

5. Expected Updates:

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

6. Caveat Emptor:

The ground-based zero points were calculating using incorrect ground-based effective area curves. Therefore a comparison between the in-orbit zero points and the ground-based zero points in earlier versions of the CALDB is meaningless.

Due to the lack of faint spectroscopic standard stars in the UV, the UV and white zero points have been calibrated with very few stars.

7. Data Used:

Observations of 15 Landolt stars, 4 white dwarfs, and 2 Oke standard stars with known UBV magnitudes were used for the optical filter analysis. Observations of 4 faint white dwarf stars with known ultraviolet spectra were used for UV filter analysis. Where multiple observations were taken, images were spatially corrected and then co-added. Observation details, sorted by observation date, can be seen in Table 1.

Object Name	Filter	Date	Sequence Number	Mode	Exposure Time (sec)
sa101-278 & sa101-L3	v	19/02/2005	54950004	I	106.5449
WD1121+145	v	21/02/2005	55250008	E	687.55
SA104SW-338 & SA104SW -244	u	22/02/2005	55350004	I	1203.074
SA104SW-338 & SA104SW -244	v	22/02/2005	55350004	I	1428.4
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
WD1010+064	v	26/02/2005	55100009	E	620.26
WD1351+489	v	01/03/2005	55650006	E	502.77
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
sa101-278 & sa101-L3	b	05/03/2005	54950011	I	1204.011
sa101-278 & sa101-L3	u	05/03/2005	54950008	I	1548.106
sa101-278 & sa101-L3	u	05/03/2005	54950009	I	1548.294
WD1121+145	uvm2	05/03/2005	55250015	E	753.42
WD1121+145	uvm2	05/03/2005	55250015	I	760.1019
WD1121+145	uvw1	05/03/2005	55250017	E	693.81
WD1121+145	uvw1	05/03/2005	55250017	I	699.7188
WD1121+145	uvw2	05/03/2005	55250013	E	753.08
WD1121+145	uvw2	05/03/2005	55250013	I	759.6937
sa101-278 & sa101-L3	v	05/03/2005	54950006	I	1179.187
sa101-278 & sa101-L3	v	05/03/2005	54950007	I	1468.305
SA104SW-338 & SA104SW -244	v	05/03/2005	55350005	I	552.7382
SA104SW-338 & SA104SW -244	b	06/03/2005	55350009	I	1175.844
SA104SW-338 & SA104SW -244	b	06/03/2005	55350010	I	1477.882
SA104SW-338 & SA104SW -244	u	06/03/2005	55350007	I	569.0339
SA104SW-338 & SA104SW -244	u	06/03/2005	55350008	I	1476.271
WD1657+343	uvm2	06/03/2005	55900018	E	693.04
WD1657+343	uvm2	06/03/2005	55900018	I	698.7037
WD1657+344	uvw1	06/03/2005	55900020	E	573.43
WD1657+344	uvw1	06/03/2005	55900020	I	580.0117
WD1657+343	uvw2	06/03/2005	55900016	E	693.44
WD1657+343	uvw2	06/03/2005	55900016	I	700.2015
SA104SW-338 & SA104SW -244	v	06/03/2005	55350006	I	563.8593
WD1525-071B	b	07/03/2005	55750005	I	628.9206
WD1525-071B	b	07/03/2005	55750006	I	628.7882
WD1525-071B	u	07/03/2005	55750003	I	1348.488
WD1525-071B	u	07/03/2005	55750004	I	1348.984
WD1525-071B	v	07/03/2005	55750001	I	1289.175
WD1525-071B	v	07/03/2005	55750002	I	1288.866
sa101-278 & sa101-L3	b	09/03/2005	54950005	I	1229.343
sa98offset2-614 & sa98offset2-646	b	11/03/2005	54700003	I	1168.133
sa104n-443 & sa104ne-457	b	11/03/2005	55400005	I	518.5363
sa104n-443 & sa104ne-457	b	11/03/2005	55400007	I	504.028
sa104ne-479 & sa104ne-367	b	11/03/2005	55450003	I	614.192
sa95SW-102 & sa95SW-107	u	11/03/2005	54350005	I	579.03
sa98offset2-614 & sa98offset2-646 & sa98offset2-L5	u	11/03/2005	54700002	I	1273.277

sa95SW-102 & sa95SW-107	v	11/03/2005	54350004	I	3484.396
sa98offset2-614 & sa98offset2-646	v	11/03/2005	54700001	I	1311.605
sa101-278 & sa101-L3	v	12/03/2005	54900005	I	1198.263
sa101-278 & sa101-L3	u	14/03/2005	54900006	I	97.47584
sa101-278 & sa101-L3	v	17/03/2005	54900009	I	1022.553
WD1351+489	b	19/03/2005	55650020	I	213.807
WD1525-071B	b	19/03/2005	55750010	E	453.7
sa104n-443 & sa104ne-457	u	21/03/2005	55400012	I	1037.414
WD1311+129	u	22/03/2005	55550018	I	189.4904
WD1312+098	v	22/03/2005	55700014	I	2420.954
WD1311+129	v	22/03/2005	55550016	I	1698.044
sa101-278 & sa101-L3	v	26/03/2005	54950003	I	2704.816
sa95SW-102 & sa95SW-107	b	27/03/2005	54350011	I	1675.703
sa98offset2-614 & sa98offset2-646 & sa98offset2-L5	u	27/03/2005	54700005	I	2079.574
sa95SW-102 & sa95SW-107	v	27/03/2005	54350009	I	1638.081
sa104ne-479 & sa104ne-367	b	28/03/2005	55450006	I	609.7458
sa101-278 & sa101-L3	u	28/03/2005	54950016	I	2152.535
sa104ne-479 & sa104ne-367	u	28/03/2005	55450005	I	882.5349
WD1121+145	b	05/04/2005	55250019	I	1045.965
WD1311+129	b	05/04/2005	55550020	I	595.6235
sa104ne-479 & sa104ne-367	v	05/04/2005	55450008	I	737.518
WD1657+343	u	12/04/2005	55900024	I	643.9587
WD1657+343	v	12/04/2005	55900025	I	640.4502
WD1121+145	v	13/04/2005	55250020	I	1577.752
sa104n-443 & sa104ne-457	v	19/04/2005	55400016	I	1146.122
sa104ne-479 & sa104ne-367	v	19/04/2005	55450010	I	2315.435
WD1525-071B	b	20/04/2005	55750013	E	1350.1
WD1312+098	b	08/05/2005	55700022	I	271.112
WD1312+098	u	09/05/2005	55700023	I	208.456
SA104SW-338 & SA104SW -244	v	10/05/2005	55350013	I	1432.978
WD1121+145	white	10/05/2005	55250021	I	54.13856
WD1010+064	b	11/05/2005	55100017	I	816.9547
WD1010+064	u	11/05/2005	55100018	I	409.553
WD1351+489	u	15/06/2005	55650024	I	706.8891
WD1657+343	uvw2	19/06/2005	55900029	I	685.4642
WD1657+343	b	20/06/2005	55900030	I	951.8976
WD1121+145	u	20/06/2005	55250023	I	487.4452
WD1657+343	white	25/06/2005	55900032	I	157.3625
WD1026+453	b	07/07/2005	55761006	I	455.2969
sa95-42	b	07/07/2005	55763001	I	568.4822
sa95-42	b	07/07/2005	55763003	I	569.409
WD0947+857	b	07/07/2005	55760005	I	395.5543
G24-9	b	07/07/2005	55762002	I	655.4878

WD1026+453	u	07/07/2005	55761005	I	290.6994
WD0947+857	u	07/07/2005	55760004	I	236.5406
WD1026+453	uvm2	07/07/2005	55761004	E	400.7085
WD0947+857	uvm2	07/07/2005	55760002	E	400.7085
WD0947+857	uvw1	07/07/2005	55760003	E	236.5406
sa95-42	v	07/07/2005	55763002	I	509.6547
sa95-42	v	07/07/2005	55763004	I	509.0038
G24-9	v	07/07/2005	55762001	I	1032.825

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:

Slightly different methods for calculating the zero points for optical and ultraviolet filters have been used. This is because there is a standard magnitude system in the optical, but not in the ultraviolet. In both cases the raw observed count rate has been corrected with the theoretical coincidence loss equation of,

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

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 for full frame), and df is the deadtime fraction (0.0155844 for full frame). 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 $x = C_{raw} ft$.

8.1. Optical Zero Points

Observations of 15 Landolt stars, 4 white dwarfs, and 2 Oke standard stars with known UBV magnitudes were considered (see Table 1 for observation details). All observations were reprocessed using the latest CALDB teldef file (swugen20041120v102.teldef). Raw count rates for each star were extracted using an aperture radius of 12 pixels (6 arcsec), and then corrected for coincidence loss. Optical zero points were then calculated using,

$$Z_{pt} = M_{std} + 2.5\log(C_{obs}).$$

Where Z_{pt} is the optical zero point (intercept of y axis in plot), M_{std} is the standard v, b or u magnitude of the star, and C_{obs} is the corrected observed count rate of the star in the v, b or u filters. Figures 1, 2 and 3 show the data used to produce the zero points for filters v, b and u respectively. The error bars produced in the plots are a direct consequence of the errors in extracting the raw observed count rate. Taking colour terms into account for these observations showed that there was little colour term dependence, therefore the optical zero points reported here do not consider colour.

Table 2 shows the latest in-orbit non-colour optical zero points (as from 21st July 2005).

Filter	Zero Point	RMS Error	Standard Error
V	17.88	0.09	0.02
B	19.16	0.12	0.02
U	18.38	0.23	0.06

Table 2 - In-orbit non-colour optical zero points.

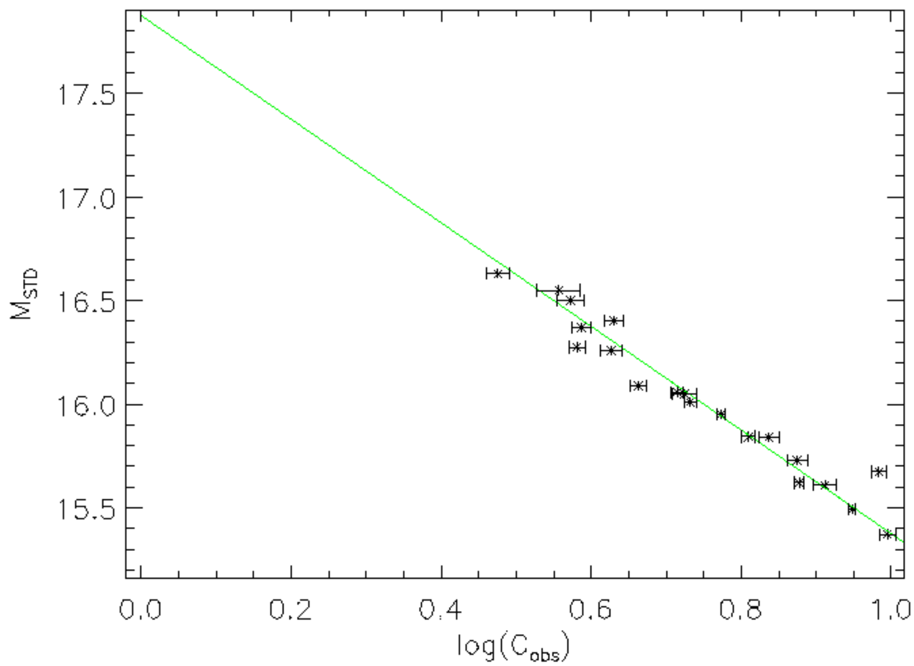

Figure 1 - V filter zero point data.

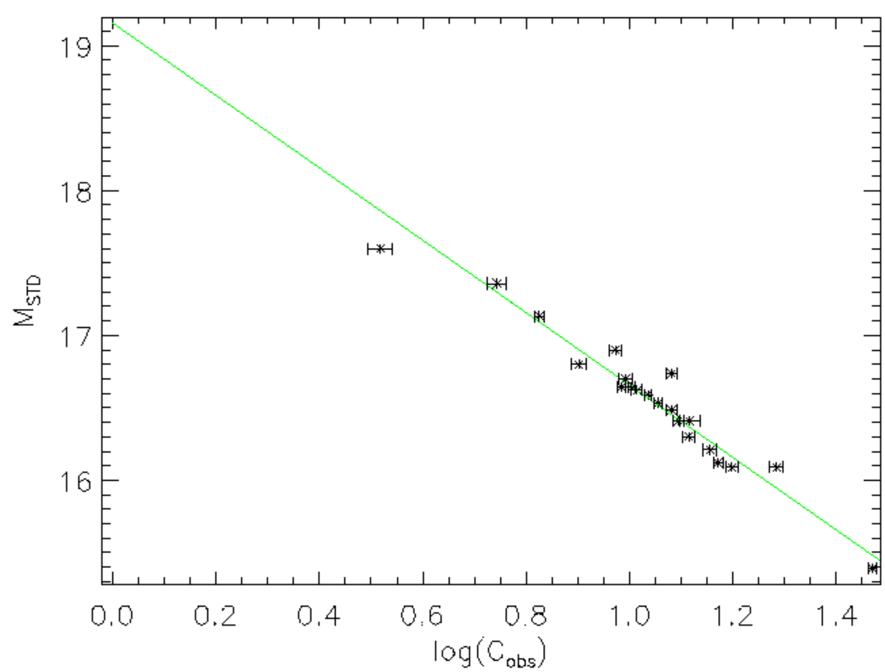

Figure 2 - B filter zero point data.

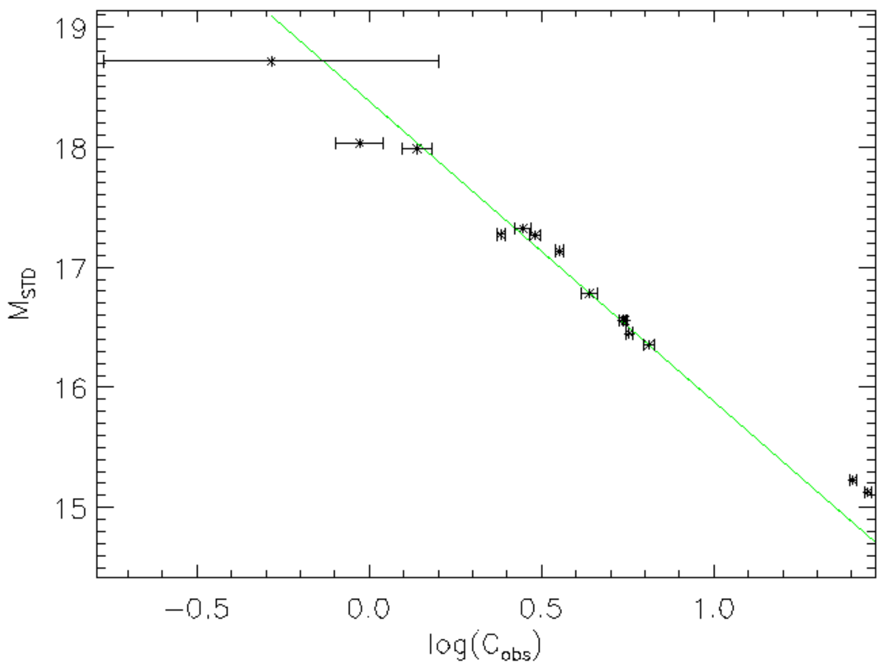

Figure 3 - U filter zero point data.

8.2. Ultraviolet Zero Points (and the White filter)

Observations of 4 faint white dwarf stars with known ultraviolet spectra were considered. Raw count rates for each star were extracted using an aperture radius of 24 pixels (12 arcsec), and then corrected for coincidence loss. For white filter observations an aperture radius of 12 pixels (6 arcsec) was used.

Magnitude systems are not widely used in the ultraviolet; so the zero points are calculated by standardising the count rates to a Vega spectrum. The ground-based throughput of the instrument in each filter is known, so by convolving the known spectra of the white dwarf stars with the filter throughputs, an expected count rate for each star can be calculated. In the same way the spectrum of Vega can be convolved with the known filter throughputs to produce a Vega count rate. The Vega count rate for each filter can then be corrected using the ratio of the observed to expected white dwarf count rates given as,

$$C_{veg\_corr} = C_{vega}\left(\frac{C_{obs}}{C_{\exp}}\right).$$

Where C_{veg_corr} is the corrected Vega count rate for each white dwarf star in each ultraviolet filter, C_{veg} is the count rate of Vega in each ultraviolet filter, C_{obs} is the observed count rate of each white dwarf star in each ultraviolet filter, and C_{exp} is the expected count rate of each white dwarf star in the each ultraviolet. Vega corrected count rates for the white filter were calculated in the same way.

Ultraviolet and white zero points were then calculated using,

$$Z_{pt} = M_{vega} + 2.5\log(C_{vega\_corr})$$

Where Z_{pt} is the ultraviolet (or white) zero point, M_{vega} is the standard Vega magnitude for each ultraviolet (or white) filter (0.025), and C_{veg_corr} is the corrected Vega count rate for each white dwarf star in each ultraviolet (or white) filters. The final zero point for each filter was calculated by averaging over all the observations in that filter.

Figures 4, 5, 6 and 7 show the data used to produce the zero points for filters uvw1, uvm2, uvw2 and white respectively. The error bars produced in the plots are a direct consequence of the errors in extracting the raw observed count rate.

Table 3 shows the latest in-orbit non-colour ultraviolet zero points (as from 21st July 2005). Please note that due to the small number of standard stars used, we expect the UV and white zero points to be dominated by systematic errors, which could be as high as 10% due to the errors on the input spectra and effective area curves (currently these errors are not included in the analysis).

Filter	Zero Point	RMS Error	Standard Error
UVW1	17.69	0.02	0.01
UVM2	17.29	0.23	0.10
UVW2	17.77	0.02	0.01
White	19.78	0.02	0.01

Table 3 - In-orbit non-colour ultraviolet zero points.

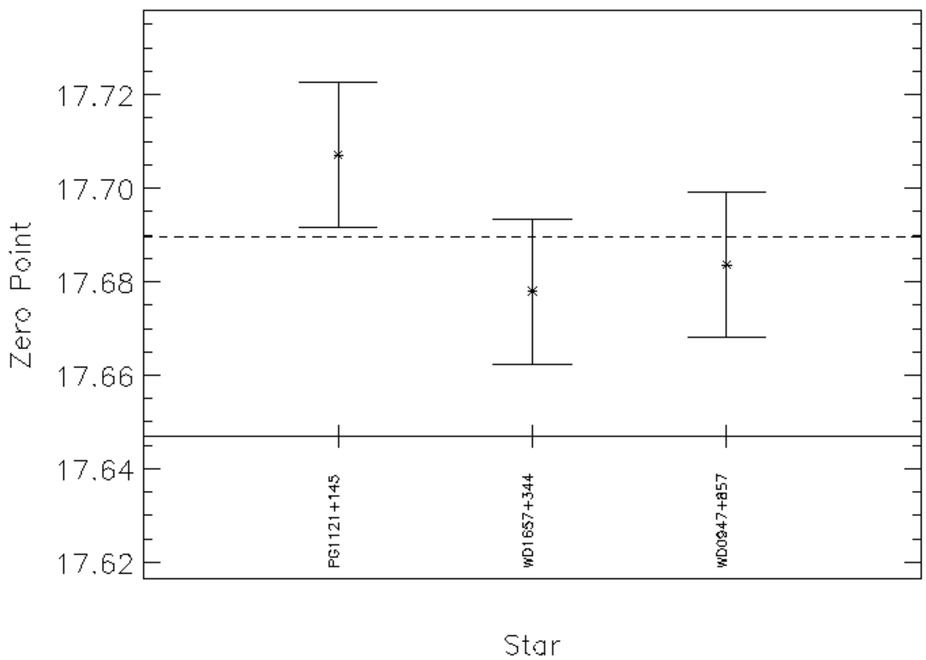

Figure 4 - UVW1 filter zero point data.

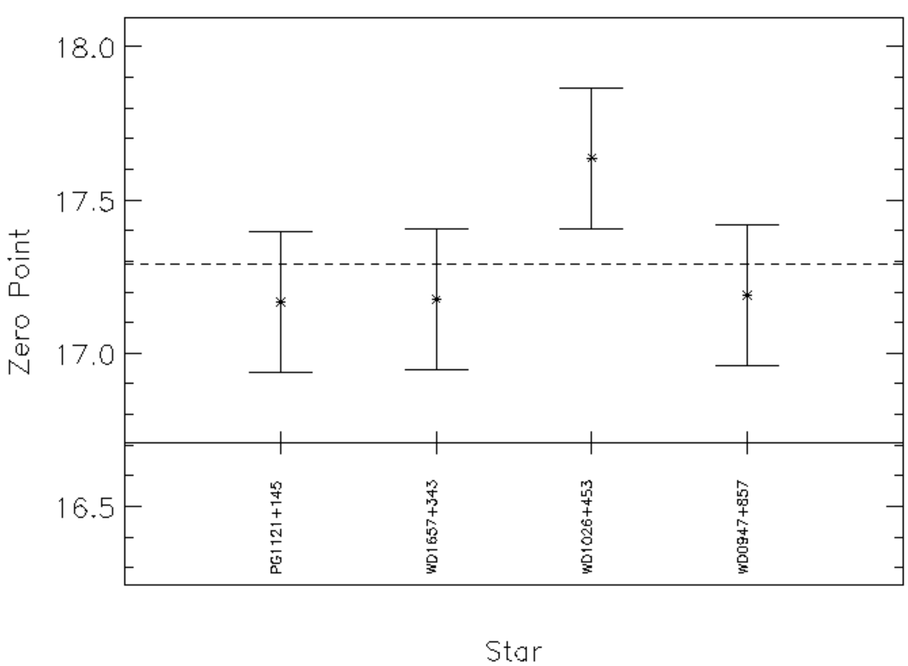

Figure 5 - UVM2 filter zero point data.

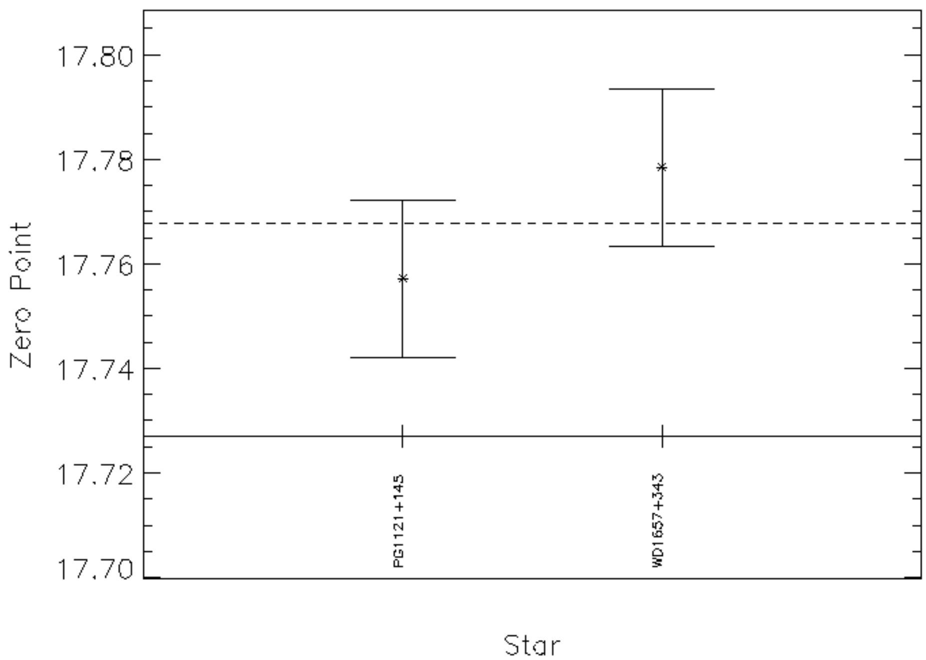

Figure 6 - UVW2 filter zero point data.

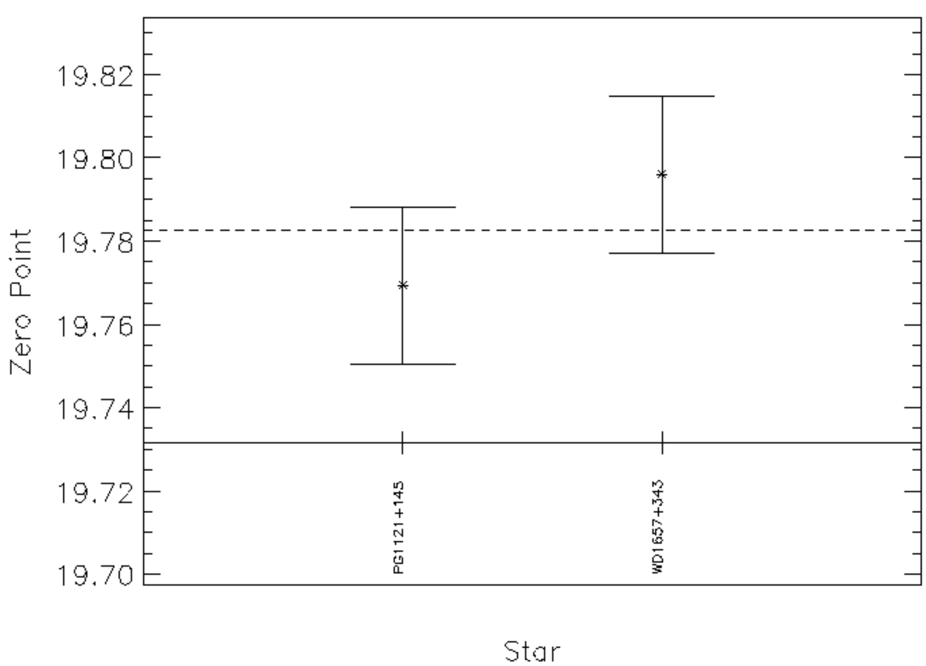

Figure 7 - White filter zero point data.