FES PHOTOMETRIC CALIBRATION AT X = -208, Y = 1584

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Abstract

I present a revised photometric calibration of the reference point at (-208,1584) which has been in use for several months due to the reflected solar light present in the IUE optical system. The new calibration is simply an extension of the old calibration as no new corrections beyond a zero point shift, accounting for the reduced sensitivity of the position -208,1584, have been applied. As one might expect the lack of suitable photometric standards and the presence of very high sky backgrounds has degraded the overall accuracy of the calibration, but for reasonably bright objects and careful measurements of sky brightness the accuracy should be of the order of $0.^{mag}10$ (or better).

1. Intorduction.

The IUE Fine Error Sensor (FES) was originally intended as an acquisition camera and as a link in the attitude control algorithm (guide star). However since the beginning of the mission it was noted that the raw FES counts from a given source could be calibrated to generate the V (5550Å) magnitude of the UBV photometric system of Johnson and Morgan (1951,1953). Since the FES employs no filtering and uses a different photocathode (ITT S20 vs IP21 for the Johnson system) some additional corrections had to be used in order to achieve a reasonable transformation to the V filter of the Johnson system.

The two largest corrections in the transformation are the dead time correction and the color term. Both of these corrections were derived and discussed at great length by Pérez and Loomis 1991. They found that the very large dynamic range of 14 magnitudes (5 decades of flux level) caused the FES to exhibit very clearly the finding of Fernie (1976) that the dead time constant ρ is not a constant for a given photometer , but is a function of the count rate. It is important that dead time be taken into account when deducing the sky contribution to the total count rate. Prior to the presence of the *streak* it was not necessary to consider the sky contribution to the count rate. In the presence of the scattered light it is not only important to subtract the sky counts but it is also important to apply the dead time correction to both the sky and star counts before one forms the net (or true) star counts.

2. The zero point shift

In order to determine the zero point shift a sample of stars covering both fast track overlap and fast track underlap were chosen from the observing logs. A search of the simbad archive was employed to check for variable stars and to verify the V magnitude and color (B-V) were correct. A number of variables did turn up. As was noted by Pérez and Loomis (1991) this sample was weighted towards earlier type stars. One curious note should be mentioned. The data for underlap stars is much more uncertain due to the way in which the FES counts photons for these brighter stars. The larger track-scan pattern (Underlap) together with the lower counting rates, encountered with sampling further out in the wings of the point spread function for the star, causes the difference between the sky and star to be much smaller making it much harder to determine both the center of light and the net target counts. Operationally, it is much more difficult to observe stars of around 4^{th} magnitude than stars of say 6^{th} to 8^{th} magnitude.

The stars used in this sample are found in Tables 1 and 2, which lists the stars, the published V magnitude, the color index (B-V), and the raw uncorrected FES counts for both the target and the sky.

Table 1 lists only overlap stars while Table 2 repeats this information for the underlap stars. Only stars requiring the fast track dwell time were used. The brightness of the scattered light has almost eliminated the longer integrations of slow track. Only observations taken at x = -208, y = 1584 and containing sky measurements were considered. Some attempt was also made to include measurements with a wide range of sky contributions. Sky measurements range from much less then 10% of the net counts to nearly a factor of 10 x the net counts.

The Method of analysis is quite simple. All the stars listed in table 1 and 2 were used. The counts for the star and the background were corrected for the effect of dead time and the net counts formed. Color corrections were computed using the published (B-V) index. The FES magnitude (V_{fes}) was computed using the calibration of Pérez and Loomis which is valid for the reference point -144, -176. The mean difference between V_{fes} and the published V magnitude then represented the magnitude of the zero-point shift reflecting the reduced sensitivity of the point -208,1584. The results are presented graphically in Figure 1 which plots the residuals from the adjusted zero point as a function of brightness. As one can see most of the points lie within ± 0.1 magnitude.

zero point shift $= -0.46 \pm 0.06$ **for overlap stars**

zero point shift $= -0.78 \pm 0.11$ **for underlap stars**

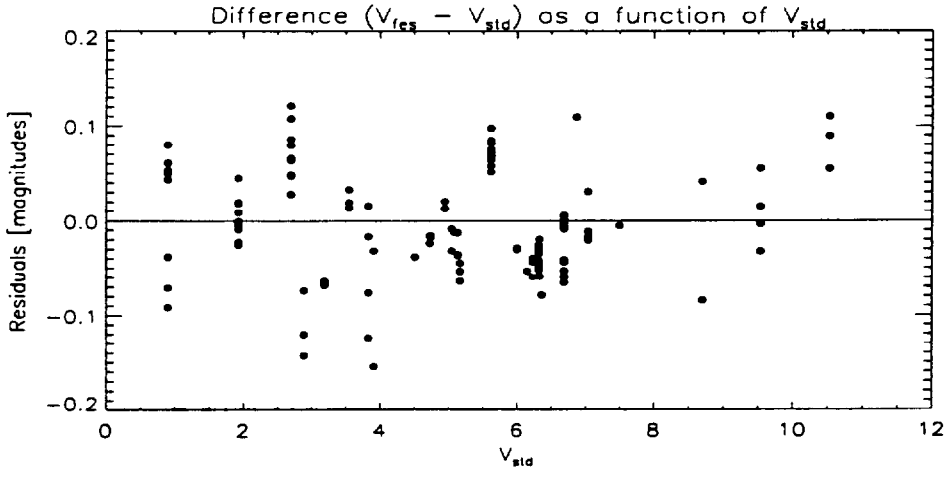

Figure 1: Plot of residuals as a function of brightness, after applying the above zero points to the calibration given in Pérez and Loomis 1991.

Below I list a simple recipe for transforming FES counts to the Johnson V. This calibration is valid only for the reference point X = -208, Y =1584. Anyone wishing to use the FES as a photometer should do so only with great care if any significance is to be placed on the results (e.g. light curves, exposure times...). Very faint sources should not be attempted as the sky background varies tremendously with time (as well as Beta angle) changing by several magnitudes depending on different sources of scattering (e.g. Earth or Moon light) and geometry.

- **Dead-time correction**

$$C_t = \frac{C_r}{(1 - 8.13X10^{-5} * C_r^{0.820})} \tag{1}$$

Where C_t and C_r represent the true and raw FES counts. **Note that this correction is applied to both the star and background counts.**

- **Net counts**

$$C_{net} = C_t - C_{bkg} \tag{2}$$

- **Color correction term**

$$color = -0.3368 * (B - V) + 9.089X10^{-2} * (B - V)^2 + 5.574X10^{-2} * (B - V)^3 \tag{3}$$

- **Transformation to Johnson V**

$$V_{fes} = -2.5 * log_{10}(C_{net}) + color + z \tag{4}$$

where z = 16.03 for overlap stars
and z = 10.36 for underlap stars
when measured at the reference point -208, 1584.

- **Errors**

The errors of this zero point come from several sources. First we must consider the errors associated with the calibration for the old reference point along with the scatter in determining the zero point shift for the point -208,1584. According to Pérez and Loomis 1991, the errors associated with their calibration were better then 0.05 mag. If we combine this with the rms scatter of this calibration of ±0.06 mag. for overlap and ±0.11 mag. for underlap then one can see that in the worst case the error associated with this calibration is slightly greater then ±0.12 mag. for underlap stars. Overlap stars will have an error which is somewhat less then ±0.10 mag. Other sources of errors are also present. for example photon statistics for both the star and the sky will contribute a percent or two. Also differences in the focus could introduce some error if counts with a large difference in focus are compared. But these sources of error should not be large and should not contribute significantly to the overall accuracy of this calibration.

I would also like to emphasis that the purpose of this calibration is not to provide a completely rigorous transformation but to provide a rough estimate of the optical brightness of targets observed

by the FES. The continued presence of the FES *streak* complicates any attempt at FES photometry. Great care must be exercised in interpreting any results obtained using the FES.

References

Fernie, J.D. 1976, PASP, **88**, 969.

Johnson, H.L., Morgan, W.W. 1951, Ap J, **114**, 522.

Johnson, H.L., Morgan, W.W. 1953, Ap J, **117**, 313.

Pérez, M., Loomis, C., 1991, IUE 3-Agency Meeting (November 1991).

TABLE 1. List of Stars (fast track/overlap)

Target	V_{std}	$(B-V)_{std}$	FES cts	Bkgnd
HD 82150	4.51	1.44	25047	65
HD 21790	4.73	-0.09	24389	1349
HD 21790	4.73	-0.09	24503	1327
HD 184171	4.74	-0.13	24158	720
HD 184171	4.74	-0.13	24128	720
HD 40967	4.95	-0.12	20698	1195
HD 40967	4.95	-0.12	20839	1256
HD 42690	5.05	-0.20	20032	1042
HD 42690	5.05	-0.20	20379	1090
HD 175687	5.08	0.13	18144	923
HD 48879	5.14	-0.17	18611	800
HD 48879	5.14	-0.17	18941	846
HD 48879	5.14	-0.17	18955	860
HD 38666	5.17	-0.28	19819	1473
HD 38666	5.17	-0.28	19758	1600
HD 38666	5.17	-0.28	19645	1600
HD 206267	5.62	0.21	11981	1652
HD 206267	5.62	0.21	12048	1631
HD 206267	5.62	0.21	11888	1579
HD 206267	5.62	0.21	11938	1618
HD 206267	5.62	0.21	11913	1644
HD 206267	5.62	0.21	11853	1664
HD 206267	5.62	0.21	11638	1519
HD 206267	5.62	0.21	11838	1615
HD 206267	5.62	0.21	11879	1560
HD 206267	5.62	0.21	11881	1540
HD 206267	5.62	0.21	11934	1544
HD 206267	5.62	0.21	12064	1581
HD 172883	6.00	-0.07	9965	970
HD 172883	6.00	-0.07	9961	950
HD 169236	6.15	1.00	8109	1389
HD 57708	6.23	0.68	7102	650
HD 57708	6.23	0.68	7121	650
HD 57708	6.23	0.68	7454	950
HD 197770	6.32	0.33	6718	406
HD 197770	6.32	0.33	6755	432
HD 197770	6.32	0.33	6773	450
HD 197770	6.32	0.33	6806	469
HD 197770	6.32	0.33	6818	468
HD 197770	6.32	0.33	6849	454

Target	V_{std}	$(B-V)_{std}$	FES cts	Bkgnd
HD 197770	6.32	0.33	6874	465
HD 197770	6.32	0.33	6879	447
HD 197770	6.32	0.33	6883	433
HD 197770	6.32	0.33	6870	483
HD 36285	6.33	-0.19	7377	174
HD 36285	6.33	-0.19	7755	350
HD 154962	6.36	0.69	6257	215
HD 60753	6.69	-0.09	5580	518
HD 60753	6.69	-0.09	5544	523
HD 60753	6.69	-0.09	5552	495
HD 60753	6.69	-0.09	5532	534
HD 60753	6.69	-0.09	5516	510
HD 60753	6.69	-0.09	5539	498
HD 60753	6.69	-0.09	5854	660
HD 60753	6.69	-0.09	5850	667
HD 60753	6.69	-0.09	5891	654
HD 60753	6.69	-0.09	5907	608
HD 60753	6.69	-0.09	5911	648
HD 60753	6.69	-0.09	5916	648
HD 165052	6.87	0.09	7657	4321
HD 93521	7.04	-0.28	5253	1346
HD 93521	7.04	-0.28	5255	1335
HD 93521	7.04	-0.28	5000	1240
HD 93521	7.04	-0.28	5089	1182
HD 93521	7.04	-0.28	5253	1346
HD 93521	7.04	-0.28	5255	1335
HD 93521	7.04	-0.28	5000	1240
HD 93521	7.04	-0.28	5089	1182
HD 169582	8.70	0.54	2278	1611
HD 169582	8.70	0.54	2348	1600
HD 186994	7.50	-0.13	3505	1021
BD +75 325	9.54	-0.37	1067	636
BD +75 325	9.54	-0.37	1052	628
BD +75 325	9.54	-0.37	3849	3476
BD +75 325	9.54	-0.37	3891	3487
BD +28 4211	10.53	-0.34	1539	1380
BD +28 4211	10.53	-0.34	1557	1406
BD +28 4211	10.53	-0.34	1539	1385
BD +28 4211	10.53	-0.34	1528	1393

TABLE 2. List of Stars (fast track/underlap)

Target	V_{std}	$(B-V)_{std}$	FES cts	Bkgnd
HD 29139	0.90	1.54	6675	1700
HD 29139	0.90	1.54	6817	1700
HD 29139	0.90	1.54	6908	1700
HD 29139	0.90	1.54	6357	1751
HD 29139	0.90	1.54	6339	1865
HD 29139	0.90	1.54	6392	1805
HD 29139	0.90	1.54	6517	1905
HD 29139	0.90	1.54	6483	1946
HD 47105	1.93	0.04	2234	55
HD 47105	1.93	0.04	2273	55
HD 47105	1.93	0.04	2318	56
HD 47105	1.93	0.04	2279	81
HD 47105	1.93	0.04	2288	53
HD 47105	1.93	0.04	2266	87
HD 47105	1.93	0.04	2353	139
HD 47105	1.93	0.04	2334	112
HD 47105	1.93	0.04	2707	471
HD 47105	1.93	0.04	2736	648
HD 31398	2.70	1.53	1830	858
HD 31398	2.70	1.53	1812	858
HD 31398	2.70	1.53	1847	893
HD 31398	2.70	1.53	1824	903
HD 31398	2.70	1.53	1801	874
HD 31398	2.70	1.53	1889	1000
HD 31398	2.70	1.53	1900	1000
HD 31398	2.70	1.53	1895	957
HD 31398	2.70	1.53	1889	953
HD 143018	2.89	-0.19	3096	2090
HD 143018	2.89	-0.19	3149	2100
HD 143018	2.89	-0.19	2784	1700
HD 30652	3.19	0.45	698	14
HD 30652	3.19	0.45	694	8
HD 30652	3.19	0.45	702	19
HD 38678	3.55	0.10	890	400
HD 38678	3.55	0.10	884	400
HD 38678	3.55	0.10	673	176
HD 23180	3.83	0.05	2078	1658
HD 23180	3.83	0.05	2179	1800
HD 23180	3.83	0.05	1298	919
HD 23180	3.83	0.05	1273	860
HD 138905	3.91	1.01	1531	1183
HD 138905	3.91	1.01	1490	1179