Transformation From SDSS Photometric System to Johnson-Morgan-Cousins System in HK Survey

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ABSTRACT

We calculate the transformation from the Sloan Digital Sky Survey (SDSS) photometric system to the Johnson-Morgan-Cousins System in the HK Survey. This research was done in late 2001, so the SDSS photometry was taken from the databases prior to the release of DR1. This paper is being posted because it is referenced in other papers in the literature, but will not be submitted to a refereed journal because it uses unpublished versions of the catalogs.

1. Introduction

The Sloan Digital Sky Survey (SDSS) photometric catalogs are an important source of stellar photometry, and must be understood in the context of decades of stellar research using different filter standards. In this paper a transformation is computed between the available SDSS photometry in October 2001 and stars of the HK objective prism survey as provided by T. Beers, private communication. A description of the HK survey and an earlier version of the catalog can be found at Preston, Schectman & Beers (1991). The overlaps between the catalogs are relatively few because the faint limit of the HK survey is at approximately the same magnitude as the saturation limit of the SDSS. Neither of the catalogs compared here are standard versions, but were the only comparables available at the time. Technical SDSS details can be found in Gunn et al., 1998; Hogg et al., 2001; Pier et al., 2003; Smith et al., 2002; and York et al., 2000. More recent transformation equations can be obtained from Jester et al., 2005; Karaali, Bilir & Tuncel, 2005; Bilir, Karaali & Tuncel, 2005; and West, Walkowicz & Hawley, 2005; and two other unpublished determinations that can be found in the documentation for the SDSS DR4 at:

http://www.sdss.org/dr4/algorithms/sdssUBVRITransform.html.
2. Query Consideration and Data Reduction

Table 1 lists the stars that were common to the HK survey and the SDSS survey in October 2001. Generation of both catalogs was a work in progress at that time. We selected from the HK catalog all stars whose J2000 coordinates matched SDSS catalog entries within:

\[ \Delta(RA) < 7.2''(0.002^\circ) \quad \Delta(Dec) < 7.2'' \]

We rejected any matches in which the SDSS star was saturated by checking the catalog flags:

\[(objFlags \& OBJECT\_SATUR) == 0\]

We use the magnitude calculated from a fit of modeled stellar profile (point-spread-function, or PSF magnitude) to each object. Because these stars are too bright for sky noise affect the quality of the photometry, the use of aperture magnitudes would have made little difference.

All photometry in Table 1 has been corrected for interstellar reddening using the \( E_{B-V} \) determined from the HK survey. Corrections for the SDSS photometry are determined from the standard extinction curve of Cardelli, Claydon, & Mathis (1989), which for SDSS filters yields:

\[
\begin{align*}
A_u^* &= 5.2E_{B-V}; \quad A_g^* = 3.2E_{B-V}; \quad A_r^* = 2.8E_{B-V}; \\
A_i^* &= 2.1E_{B-V}; \quad A_z^* = 1.5E_{B-V}
\end{align*}
\]

We noticed that the value of \((U - B)\) is -9.990 for some stars in the original HK list. They were replaced by “···” in the Table 1. When we calculate the transformation which requires \(U\) band, these stars were not included. Three stars were removed from the original matched list because their SDSS photometry was suspicious: \((RA, dec) = (199.9265, 3.9129), (224.7835, -0.2537), (200.7934, 4.6075)\). Two of the stars were close to other bright starts which may have confused the SDSS object delender.

3. Comparison of derived transformation to Fukugita et al. 1996

Figure 1 shows the color-color plots for the SDSS PSF magnitude against the HK survey U-B-V magnitudes of these stars. The coefficients in the equations, plotted as the lines, are derived using the Method of Least Squares. We notice that one star, \((221.5996, -0.1158)\) is half a magnitude brighter in SDSS filters than we expect (though the colors are the same). It is labeled using a bold font in Table 1. There is no reason to remove it from the catalog but we ignore it in all fits for filter transformations.

Fukugita et al. (1996) described SDSS photometric system and gave the approximate color transformation equations from the Johnson-Morgan-Cousins system to the SDSS system. A comparison of our transformations to theirs is given below:
Fig. 1.— Color-Color plots of UBV system against SDSS PSF magnitude. The solid line is the least squares fit to the data. The dashed line indicates the transformation equation of Fukugita et al. (1996).
\[ F u k u g i t a ' s \ p a p e r \quad O u r \ R e s u l t \]
\[
g^* = V + 0.56(B - V) - 0.12 \quad g^* = V + 0.592(B - V) - 0.102
\]
\[
r^* = V - 0.49(B - V) + 0.11 \quad r^* = V - 0.451(B - V) + 0.082
\]
\[
u^* - g^* = 1.38(U - B) + 1.14 \quad u^* - g^* = 1.210(U - B) + 1.103
\]
\[
g^* - r^* = 1.05(B - V) + 1.14 \quad g^* - r^* = 1.043(B - V) - 0.185
\]

For the blue stars from which our transformation was derived, our transformations are similar to Fukugita’s. The \((u^* - g^*)\) transformation is the only one that is significantly discrepant. This is because the actual \(u^*\) filter response is different from the theoretical curve used by Fukugita et al.(1996).

4. Inverse Transformation Equations

We will discuss the inverse transformation from SDSS PSF magnitude to UBV system in this section. Magnitudes in the \(g^*\) filter and \(g^* - r^*\) color are used as the primary parameters in the equations since the noise in \(u^*\) is typically higher. We also considered other combinations of filters. Figures 2 and 3 show the results; the transformation is summarized below:

\[
U = g^* + 0.883(u^* - g^*) - 0.717 \quad U = u^* - 0.117(u^* - g^*) - 0.717
\]
\[
B = g^* + 0.348(g^* - r^*) + 0.175 \quad B = g^* + 0.162(u^* - g^*) + 0.094
\]
\[
V = g^* - 0.561(g^* - r^*) - 0.004 \quad V = r^* + 0.439(g^* - r^*) - 0.004
\]
\[
(U - B) = 0.754(u^* - g^*) + 0.835
\]
\[
(B - V) = 0.916(g^* - r^*) + 0.187
\]

5. Conclusion

We have derived transformation equations between HK catalog photometry and SDSS photometry.

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Fig. 2.— Transformation plot from SDSS photometric system to UBV system.
Fig. 3.— Transformation plot from SDSS photometric system to UBV system.
The SDSS is managed by the Astrophysical Research Consortium for the Participating Institutions. The Participating Institutions are the American Museum of Natural History, Astrophysical Institute Potsdam, University of Basel, Cambridge University, Case Western Reserve University, University of Chicago, Drexel University, Fermilab, the Institute for Advanced Study, the Japan Participation Group, Johns Hopkins University, the Joint Institute for Nuclear Astrophysics, the Kavli Institute for Particle Astrophysics and Cosmology, the Korean Scientist Group, the Chinese Academy of Sciences (LAMOST), Los Alamos National Laboratory, the Max-Planck-Institute for Astronomy (MPIA), the Max-Planck-Institute for Astrophysics (MPA), New Mexico State University, Ohio State University, University of Pittsburgh, University of Portsmouth, Princeton University, the United States Naval Observatory, and the University of Washington.

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Table 1. Catalog of HK Survey Cross-correlated with SDSS non-EDR Database

| HK Coord | GSC Coords | SDSS Coords | UBV system | SDSS PSF magnitude |
|----------|------------|-------------|-------------|--------------------|
|          | RA Dec     | RA Dec      | U B V       | u* g* r* i* z*     |
| 1        | 303110077 | 198.6167 3.4511 | 198.6159 3.4523 | 15.591 15.358 14.688 16.384 14.974 14.456 14.305 14.252 |
| 2        | 303110073 | 198.6225 5.5703 | 198.6217 5.5714 | 14.930 14.950 14.640 15.847 14.716 14.573 14.572 14.604 |
| 3        | 303110061 | 198.7546 3.4669 | 198.7540 3.4681 | 15.451 15.338 14.708 16.271 15.015 14.551 14.404 14.289 |
| 4        | 303110056 | 199.4292 2.9122 | 199.4284 2.9136 | 15.090 15.180 15.080 16.271 15.015 14.551 14.404 14.289 |
| 5        | 303110040 | 199.7233 3.5876 | 199.7230 3.5878 | 15.320 15.340 15.770 16.205 15.046 14.633 14.534 14.485 |
| 6        | 303110048 | 199.9633 5.8553 | 199.9626 5.8556 | 15.160 15.350 15.080 16.205 15.046 14.633 14.534 14.485 |
| 7        | 303110046 | 199.9279 3.9136 | 199.9281 3.9145 | 15.401 15.348 15.080 16.205 15.046 14.633 14.534 14.485 |
| 8        | 303110031 | 200.2954 5.5717 | 200.2956 5.5726 | 14.880 15.050 14.580 16.020 14.716 14.573 14.572 14.604 |
| 9        | 303110022 | 200.6808 3.6442 | 200.6812 3.6434 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 10       | 303110026 | 200.7858 3.5906 | 200.7862 3.5917 | 14.840 15.020 14.580 16.020 14.716 14.573 14.572 14.604 |
| 11       | 303110019 | 200.9633 2.1536 | 200.9627 2.1530 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 12       | 303110020 | 201.0854 3.4172 | 201.0859 3.4179 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 13       | 303110015 | 201.5829 3.9639 | 201.5831 3.9651 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 14       | 303110004 | 202.0821 3.3917 | 202.0821 3.3920 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 15       | 164770013 | 219.0267 3.6642 | 219.0262 3.6641 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 16       | 164770026 | 219.9288 2.9500 | 219.9286 2.9489 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 17       | 164770031 | 219.7417 4.0964 | 219.7411 4.0969 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 18       | 164770028 | 219.9288 2.9500 | 219.9286 2.9489 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 19       | 303170034 | 220.3283 4.6239 | 220.3291 4.6244 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 20       | 164770057 | 220.8487 4.8675 | 220.8486 4.8677 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 21       | 164770054 | 221.0037 3.9639 | 221.0035 3.9651 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 22       | 169810101 | 221.1496 -0.9181 | 221.1499 -0.9187 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 23       | 169810110 | 221.5996 -0.1158 | 221.5997 -0.1159 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
| 24       | 164770069 | 221.6121 3.9639 | 221.6126 3.9646 | 15.210 15.350 15.080 16.020 14.716 14.573 14.572 14.604 |
Table 1—Continued

| HK Coord | GSC Coords | SDSS Coords | UBV system | SDSS PSF magnitude |
|----------|------------|-------------|-------------|-------------------|
|          | RA Dec     | RA Dec      | U B V       | u^* g^* r^* i^* z^* |
| 25       | 303170014  | 221.7533 4.9250 | 221.7531 4.9256 | 14.392 14.566 14.116 15.253 14.371 14.122 14.066 14.050 |
| 26       | 169810119  | 222.4554 2.0433 | 222.4559 2.0423 | 15.232 15.104 14.524 15.888 14.674 14.239 14.152 14.053 |
| 27       | 303010160  | 222.8217 0.7903 | 222.8224 0.7917 | 15.082 15.114 14.774 15.809 14.860 14.772 14.769 14.801 |
| 28       | 164770095  | 223.0192 3.3558 | 223.0181 3.3569 | 13.952 13.994 13.634 14.733 13.708 13.514 13.489 13.562 |
| 29       | 303250103  | 223.2250 3.0119 | 223.2244 3.0126 | 15.082 15.114 14.774 15.809 14.860 14.772 14.769 14.801 |
| 30       | 303010147  | 223.4338 1.6775 | 223.4338 1.6780 | 15.033 15.072 14.372 15.811 14.639 14.199 14.092 14.002 |
| 31       | 303010122  | 224.1288 1.5625 | 224.1288 1.5633 | 14.482 14.362 15.393 14.210 14.277 14.522 14.522 |
| 32       | 164720014  | 224.1600 1.0669 | 224.1595 1.0662 | 14.894 14.364 15.593 14.477 14.148 14.032 14.013 |
| 33       | 303010119  | 224.1821 2.0694 | 224.1822 2.0694 | 15.573 15.652 15.112 16.347 15.345 14.988 14.846 14.804 |
| 34       | 303250074  | 224.3604 2.9856 | 224.3599 2.9851 | 14.603 14.792 14.422 15.447 14.543 14.297 14.202 14.214 |
| 35       | 303010098  | 224.7829 -0.2539 | 224.7820 -0.2537 | 15.573 15.652 15.112 16.347 15.345 14.988 14.846 14.804 |
| 36       | 303010099  | 225.2812 1.9531 | 225.2810 1.9540 | 15.422 15.564 15.064 16.214 15.255 14.907 14.792 14.761 |
| 37       | 164720041  | 225.4275 1.2161 | 225.4274 1.2165 | 14.172 13.802 14.928 13.828 13.637 13.597 13.646 |
| 38       | 303010084  | 225.5146 1.0722 | 225.5137 1.0718 | 14.523 14.422 13.792 15.354 14.074 13.591 13.429 13.431 |
| 39       | 303010099  | 227.4396 -0.9191 | 227.4394 -0.9195 | 14.893 14.932 14.322 15.604 14.534 14.040 13.860 13.756 |
| 40       | 228940007  | 353.0421 0.0939 | 353.0421 0.0937 | 13.840 13.699 13.534 14.669 13.511 13.584 13.688 13.902 |
| 41       | 228940006  | 353.0750 -0.0731 | 353.0752 -0.0736 | 15.663 15.506 15.444 16.574 15.368 15.507 15.644 15.707 |
| 42       | 228940004  | 353.1646 -0.9369 | 353.1648 -0.9368 | 14.260 14.456 14.074 15.028 14.232 13.980 13.903 13.837 |
| 43       | 228940009  | 353.3700 0.9594 | 353.3702 0.9591 | 14.407 14.538 14.044 15.276 14.270 13.920 13.730 13.703 |
| 44       | 228940005  | 353.4475 -0.5358 | 353.4482 -0.5360 | 14.698 14.859 14.414 15.528 14.617 14.290 14.154 14.132 |
| 45       | 228940003  | 353.4846 -1.2039 | 353.4847 -1.2041 | 14.806 14.646 14.544 15.755 14.610 14.664 14.744 14.811 |
| 46       | 228940014  | 353.9450 0.8819 | 353.9454 0.8817 | 14.645 14.526 14.434 15.621 14.362 14.484 14.578 14.661 |
| 47       | 228940017  | 354.0967 0.0700 | 354.0973 0.0702 | 14.321 14.487 14.034 15.116 14.283 13.928 13.752 13.841 |
| 48       | 228940020  | 354.5200 -0.4206 | 354.5199 -0.4203 | 15.000 15.069 14.764 15.911 14.852 14.712 14.683 14.731 |
| HK Coord | GSC Coords RA | GSC Coords Dec | SDSS Coords RA | SDSS Coords Dec | U | B | V | U* | g* | r* | i* | z* |
|----------|---------------|----------------|----------------|----------------|---|---|---|----|----|----|----|----|
| 49       | 228940019     | 354.8287       | 0.0617         | 354.8294       | 0.0616 | 14.014 | 14.271 | 13.856 | 14.794 | 14.044 | 13.769 | 13.616 | 13.675 |
| 50       | 228940030     | 354.9933       | -0.8097        | 354.9939       | -0.8094 | 15.034 | 14.974 | 14.586 | 15.908 | 14.767 | 14.530 | 14.428 | 14.432 |
| 51       | 228940031     | 355.0013       | -0.5106        | 355.0020       | -0.5109 | 14.290 | 14.162 | 14.116 | 15.255 | 14.073 | 14.229 | 14.352 | 14.506 |
| 52       | 228940033     | 355.0225       | -0.3222        | 355.0226       | -0.3219 | 15.183 | 15.032 | 14.926 | 16.069 | 14.890 | 15.046 | 15.161 | 15.198 |
| 53       | 228940034     | 355.4050       | 0.0236         | 355.4052       | 0.0231 | 14.988 | 14.865 | 14.696 | 15.889 | 14.634 | 14.679 | 14.748 | 14.886 |
| 54       | 228940036     | 355.5304       | 0.5481         | 355.5305       | 0.5480 | 15.011 | 14.955 | 14.696 | 15.840 | 14.767 | 14.662 | 14.638 | 14.606 |
| 55       | 228940029     | 355.5604       | -0.8592        | 355.5609       | -0.8591 | 14.453 | 14.533 | 14.274 | 15.407 | 14.348 | 14.227 | 14.275 | 14.311 |
| 56       | 228940028     | 355.8275       | -1.1953        | 355.8280       | -1.1952 | 14.862 | 15.064 | 14.634 | 15.669 | 14.713 | 14.505 | 14.332 | 14.364 |
| 57       | 228940046     | 356.1296       | -0.4364        | 356.1294       | -0.4363 | 15.252 | 15.214 | 14.766 | 16.197 | 14.945 | 14.607 | 14.521 | 14.477 |
| 58       | 228940054     | 357.1179       | 0.4003         | 357.1192       | 0.3994 | 14.361 | 14.486 | 14.116 | 15.246 | 14.182 | 13.980 | 13.981 | 13.906 |