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SDSS catalog of stars in the Draco dwarf spheroidal galaxy

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ABSTRACT

The Sloan Digital Sky Survey (SDSS) has scanned the entire region containing the Draco dwarf spheroidal galaxy to 23^{rd} magnitude in g^*. We present a catalog of stars found in a 453 square arcminute, elliptical region centered on the Draco dwarf spheroidal galaxy. Objects in the catalog are matched with five previously published catalogs. The catalog contains SDSS photometry for 5634 individual objects, and also the photometry from matches to any of the other catalogs. A comparison of the photometry between catalogs allows us to identify 142 candidate variable objects. One hundred and twelve of the suspected variables have colors consistent with RR Lyrae variables.

Subject headings: catalogs — galaxies: dwarf — galaxies: individual (Draco dwarf spheroidal) — stars: variable – stars: RR Lyrae

1. INTRODUCTION

The Draco dwarf spheroidal companion to the Milky Way, at a distance of about 82 kpc (Mateo 1998), was discovered fifty years ago from examination of Palomar Observatory Sky Survey Schmidt plates (Wilson 1955). The horizontal branch for this dwarf galaxy is located at $g^* \sim 20$ and it covers more than 1/3 of a square degree on the sky. Draco is one

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of the nearest of the Galaxy's known dwarf spheroidal companions and is among the faintest known galaxies, with a luminosity of $2 \times 10^5 L_\odot$ (Grillmair et al. 1998).

Dwarf spheroidal galaxies typically contain many variable stars, predominately the RR Lyrae variables typical of older, metal-poor stellar populations (Stetson 1979). Draco is no exception. The first extensive study of Draco by Baade & Swope (1961) found 138 variable stars in the central part of Draco. They determined that all but five of these variables were RR Lyraes. The five remaining variables were deemed to be "anomalous" Cepheids. These Cepheids have a shorter period and so do not obey the period-luminosity relation for type II Cepheids (Carney & Seitzer 1986). These "anomalous" Cepheids have been found in other dwarf spheroidals since their discovery in Draco (Zinn 1978). Five carbon stars have also been found in Draco by Aaronson, Liebert, & Stocke (1982) and Margon et al. (2002). More recent compilations of variables in Draco are underway Kinemuchi et al. (2001).

The first detailed photometric survey of the Draco dwarf spheroidal galaxy was created by Baade & Swope (1961). Since then Draco has become one of the best studied dwarf galaxies with several more recent photometric surveys. We have created our own catalog of stars in Draco using data from the Sloan Digital Sky Survey (SDSS). We present wide area, $u^*g^*r^*i^*z^*$ CCD observations of Draco down to about $g^* \cong 23$, and construct a color magnitude diagram. We combine our catalog of SDSS stars in Draco with previously published photometric data in Draco, from: Baade & Swope (1961), Carney & Seitzer (1986), Stetson (1997), Grillmair et al. (1998), and Piatek et al. (2001) to create a heterogeneous catalog of Draco stars, with multiple epochs of observation which allow us to identify variable candidates.

2. OBSERVATIONS

The CCD imaging observations of Draco are taken from SDSS runs 1336 and 1339, which were obtained 2000 April 4 with the SDSS mosaic imaging camera (Gunn et al. 1998). The majority of the stars in the dwarf spheroidal fall on two frames of data in the same camera column (one continuous stream of drift-scan data). Since the precise calibration for the SDSS filter system is still in progress, magnitudes in this paper are quoted in the $u^*g^*r^*i^*z^*$ system, which approximates the final SDSS system (Smith et al. 2002). These systems differ absolutely (with negligible color terms) by only a few percent in $g^*r^*i^*z^*$, and no more than 10% in u^*. See Fukugita et al. (1996) and York et al. (2000) for further information on the filter system and the overall survey, respectively. The data were reduced with PHOTO (Lupton et al. in preparation) version 5.1.7. Pier et al. (2002) describes the astrometry and astrometric accuracy of the software. Hogg et al. (2002) describes our monitoring program for photometricity. These data are included in the public Early Data Release (EDR) (Stoughton et al. 2002).

In the course of commissioning a survey, the images are reduced several times as the software evolves. The data presented here have been reduced three times. The first reduction is called "rerun 0," and second is "rerun 1." Most of the data included in this paper are from "rerun 1," with some exceptions which are noted in the text below. "Rerun 2" was the version released in the EDR, and differs from "rerun 1" only in a small overall calibration offset. Since we recalibrate all of the photometry ourselves, the difference is not important. So, an object which is listed in the catalog by the SDSS id 1336-1-5-60-950 (Run-Rerun-CameraColumn-Field-ObjectID) is the same object as 1336-2-5-60-950 in the EDR.

The seeing for the Draco scans was typically 1.8" FWHM. Intercomparison of objects detected twice in overlapping scans is a good indication of relative photometric error, and for objects with $g^* < 19$, rms error for stellar sources is typically $< 4\%$. For objects between $20 < g^* < 21$, typical errors are 8%, growing to 20% at $g^* = 23$, near the detection limit. For reference, blue stars with $0 < B - V < 0.2$ have a SDSS g^* magnitude approximately equal to their Johnson V magnitude, while stars with $g^* - r^* = 1$ have $g \sim V + 0.45$. In general, $g^* = V + 0.54(B - V) - 0.07$ (Smith et al. 2002).

In order to obtain the best measurements at faint magnitudes, we used photometry derived from fits of the pointspread function (PSF) to stellar profiles. The SDSS code determines the PSF as a function of position in each CCD frame (1361 x 2048 pixels, or $9'$ x $13.7'$). While we were studying the stellar populations within Draco, we noticed a systematic shift in the color of the giant branch as a function of position within the Draco field. Further analysis showed that this result could be explained by systematic inaccuracies in the (PSF) photometry as modeled in the EDR reductions of the data (these systematics are corrected in later data releases). Since the code used to create the EDR did not accurately track rapidly varying point-spread functions, the PSF magnitudes in some regions of the sky were systematically shifted brighter or fainter by up to a tenth of a magnitude.

For this study, we were able to correct the EDR PSF magnitudes using the aperture magnitudes for bright objects. Although aperture magnitudes are quite noisy for faint stars, they are accurate for bright stars and not affected by the error in the calculated PSF. We used the brighter stars to calculate a correction to the PSF magnitudes, as a function of row and column in each frame. We fit a second degree polynomial to the deviations between the aperture and PSF magnitudes ($\mathrm{mag}(_{AP})-\mathrm{mag}(_{PSF})$) vs. CCD row and column for stars brighter than magnitude 19.5. We then used this polynomial to correct the photometry of *all* stars in the frame to the mean of the aperture photometry for that frame. The assumption here is that the aperture magnitudes are correct, and their calibration does not vary as the

PSF varies across rows or columns. This is a good assumption if we capture practically all of the light in each object, even in the sections of data with poorer seeing.

The results of this correction procedure are shown in Figure 1. The left panel shows the color-magnitude diagram for Draco, using PSF magnitudes, and the right panel shows the same diagram after correcting the PSF magnitudes. Though we did not use any information about the giant branch of Draco, notice that the giant branch of the dwarf galaxy is significantly narrower after correction. This is evidence that the correction technique significantly improved the accuracy of the photometry.

3. CREATING THE CATALOG

In order to generate a useful catalog of stars in the Draco dwarf galaxy, we first selected from the SDSS database those objects with $259° < \alpha < 261°$ and $57.4° < \delta < 58.4°$, which were marked as unsaturated, and which were far enough from the edge of the frame that they were completely contained on a single CCD detector. This latter criterion effectively eliminates only quite extended galaxies near the edges, since there is enough overlap between frames that point sources are completely contained on at least one frame. We also removed duplicate measurements of the same astronomical object, either by multiple observation or multiple software measurements of the same observation, by choosing only observations marked in the SDSS as 'primary.' For each direction in the sky, only one observation and instance of processing is considered 'primary,' so this flag effectively removes duplicates.

To determine a centroid of our elliptical region, stars in our original data set were binned into boxes of area 0.05 degrees on a side. Then, we fit an elliptical Gaussian (right ascension and declination of the center, major and minor axes, a position angle, and sky), to the binned data. The adopted center of the distribution is: $\alpha = 17:20:13.2$, $\delta = 57:54:45$ (J2000). The exact center of the fit shifted by ten arcseconds depending on how we weighted the fit, which yields an error bar on our chosen center. Other sources such as Baade & Swope (1961), Irwin & Hatzidimitriou (1995), and Cotton, Condon, & Arbizzani (1999) report the center of Draco as: $\alpha =$ 17:20:13 $\delta =$ 57:55:11 (J2000, converted from B1950), $\alpha =$ 17:20.3 $\delta =$ 57:55.1 (J2000, converted from B1950), and $\alpha =$ 17:20:12.39 $\delta =$ 57:54:55.3 (J2000) respectively. These positions for Draco's center are in good agreement with the value we found in right ascension, and off by about ten arcseconds in declination. The major axis of the ellipse fit is nearly constant in declination (PA $\sim 90°$) with Gaussian sigma 0.122 degrees (corrected for $\cos(\delta)$). The minor axis is 0.082 degrees in the declination direction implying an ellipticity of 1-0.082/0.122=0.33 in agreement with Hodge (1964) who found an ellipticity of 0.29 ± 0.04, and also in excellent agreement with Piatek et al. (2001) who find an ellipticity of 0.331 for Draco.

To increase the fraction of cataloged stars which are associated with the dwarf galaxy, we included only those stars in an elliptical region centered on the Draco dwarf galaxy (see Figure 2), which extends to about one third of the tidal radius measured by Odenkirchen et al. (2001). Of the 7417 objects within the area of this 2-sigma ellipse for our Draco catalog, 5492 were brighter than our adopted magnitude limit of 23.005 (this odd effective limit is due to rounding before the limit was applied). The actual number of SDSS objects in the final catalog, 5634, is slightly different, as 15 objects with suspicious SDSS photometry (mostly on bright star bleed trails) were removed, and 157 objects were added from previous data reductions of the same astronomical images. Positions on the sky of cataloged SDSS stars are displayed in Figure 2. Faint SDSS detections ($g^* > 22$) are shown as small black dots, while brighter stars are larger black dots. Galaxies (objects which the SDSS software determined to be extended) are not included in the plot.

The catalog presented in this paper overlaps several previously published photometric surveys of the Draco dwarf galaxy. The footprints of the five surveys which are cross-referenced to sources in our catalog are shown in Figure 2. Our catalog also includes the fainter ten of the twelve Draco stars with accurate photometry from Henden and Munari (2000). Their SDSS IDs, from brightest to faintest, are: 1339-1-5-62-26, 1336-1-5-61-148, 1336-1-5-61-119, 1339-1-5-61-384, 1336-1-5-61-478, 1339-1-5-61-366, 1336-1-5-61-370, 1336-1-5-61-294, 1336-1-5-61-685, and 1336-1-5-61-1227. Since there are so few, we do not include a separate column in the catalog table. In the remainder of this section, we describe the construction of a catalog of Draco stars with cross-references to the other catalogs. Ultimately, the overlapping catalogs are used to generate a list of possible variable stars.

We list in Table 1 a summary of stars detected in each previous survey, along with numbers of matches to SDSS detections. The main data product of this paper, with format specified in Table 2, is contained in the (electronic) Table 3. Table 3 contains identifications, magnitudes, colors and cross-references to other surveys for stars in Draco. The SDSS J2000 right ascension (in degrees), declination (in degrees), SDSS id (Run-Rerun-CameraColumn-Field-ObjectID), g^* magnitude, and $u^* - g^*$, $g^* - r^*$, $r^* - i^*$, $i^* - z^*$ colors of each object are listed as columns 1 through 8 of Table 3, respectively. These magnitudes have been derreddened using the E(B-V) tabulated in column 9, as derived from Schlegel, Finkbeiner, & Davis (1998). Following Cardelli, Clayton, & Mathis (1989), $A_{u^*} = 5.155E(B-V)$, $A_{g^*} = 3.793E(B-V)$, $A_{r^*} = 2.751E(B-V)$, $A_{i^*} = 2.086E(B-V)$, and $A_{z^*} = 1.479E(B-V)$. Measurements of the same objects in other catalogs are listed in columns 10 through 33, as described below. Note that the SDSS photometry is dereddened, while that of all the other catalogs is not. A flag indicating classification of the object as stellar ("s"), a resolved galaxy ("g") or of an indeterminant extent ("f" for faint) is indicated in column 34 of Table 3. All stars with $g^* > 22$ are classified as "faint." The 5766 lines in this table include the 5634 individual objects detected in the SDSS database, 19 objects from the Baade-Swope dataset which were not matched to SDSS objects, and 113 duplicate entries in cases where there exist Piatek objects in both the E1 and CO fields. The additional Baade-Swope entries were apparent in the SDSS images, so we were able to provide approximate astrometric positions even though no automated photometry was generated. We included multiple lines for Piatek duplicates to avoid adding yet four more columns to an already large table.

3.1. Photometry from Baade & Swope (1961)

The survey of area of Baade & Swope (1961) (hereafter BS61), approximately covering a circular region of radius $5'26''$ centered at R.A. $17^h19^m24^s$, Dec. $+57°58'06''$ (B1950), is completely contained within our catalog. Since the individual right ascensions and declinations were not included for each star in the BS61 catalog, the stars were matched by comparing the finding charts with SDSS images. Of the 624 stars in Table C of BS61, 563 were cross-identified with an object in the SDSS catalog, available in the SDSS Early Data Release (EDR). An additional 24 objects were measured in a previous software reduction (rerun 0) of the same data, and were included in our catalog. The majority of the data in Table 3 are from a software reduction called "rerun 1." The second number in the third field of Table 3 is the SDSS id rerun number, thus, a 0 there would indicate that rerun 0 was used. The photometry for these latter objects could differ systemmatically by a small amount from the majority of the objects in the catalog, and were not corrected to match large aperture photometry of bright stars. Several other BS61 stars were apparent in the SDSS images, but were not reliably measured in any automated SDSS data reduction. In most cases, the star was close enough to a very bright star that the automated detection software had difficulty deblending it. The approximate positions for nineteen such objects are included in Table 3, though no SDSS photometry is provided. One star could not be identified because it was not labeled in the BS61 finding chart. The remaining BS61 stars either could not be reliably identified on the SDSS images or lay close enough to an image defect that the data could not be used reliably.

The process of cross-referencing catalogs through visual identification of stars in finding charts and images is inherently prone to errors. To reduce and evaluate the error rate, several checks were performed. We plotted $g^* - V$ vs. $B - V$ for a set of magnitude ranges (Figures 3a and 3b). Here, g^* is the SDSS magnitude which is most similar to V. Except in unusual cases, stellar photometry should produce an approximately linear relationship between $g^* - V$ and $B - V$. The scatter should increase with the photometric errors at fainter magnitudes. The derived color relations (SDSS dereddened values compared to BS61 undereddened values) are:

$$g^* = V + 0.618(B - V) - 0.23, \tag{1}$$

$$g^* - r^* = 1.05(B - V) - 0.28. \tag{2}$$

This transformation is only slightly different from that found in Fukugita et al. (1996) (hereafter F96), based on preliminary SDSS filter transmission design. Outliers on the $g^* - V$ vs. $B - V$ plots were checked for mis-identification matches between SDSS and BS61, and several were found and corrected. Using the derived color transformations, the magnitudes of the detections of the same objects were directly compared in magnitude and color. Stars with significant differences in computed magnitudes or colors between different catalog observations are either variable, have unusual spectra which do not lead to linear color transformations, or are errors in either the SDSS or BS61 measurements. The outliers in magnitude are marked with diamonds in Figure 4a, and those outliers in color by diamonds in Figure 5a. Note that the photometry of BS61 is systematically shifted by several tenths of a magnitude at the faint end.

We compared the photometry between catalogs only for objects which are classified in the SDSS as stellar (column 34 of Table 3). Since the fraction of the light measured for galaxies differed between datasets, the inclusion of extended sources in the outlier detection process led to a large number of objects which appeared to vary in brightness from one observation to the next. This data cut did not have a large effect on the results from the BS61 data, since BS61 pre-selected only stellar objects, but is of greater import in comparing objects in other catalogs discussed below. Of the 586 BS61 objects matched to SDSS objects, only 25 were classified as galaxies by the SDSS, and 6 were fainter than 22^{nd} magnitude in g^* (and thus are classified only as "faint" in Table 3).

Stellar objects with a significant calculated photometric difference between SDSS and BS61 are flagged in column 13 of Table 3. Stars without significant photometric differences (as seen in Figures 4a and 5a) are flagged 0, stars with significant differences, but which have magnitudes and colors consistent with RR Lyrae variables (selection criteria are discussed below) are flagged as 1 and other variable candidate stars are flagged as 2 in this column. A flag value of 3 denotes an object which was not measured in the SDSS, BS61, or both. The BS61 id, V magnitude, and $B - V$ values are found in columns 10, 11, and 12 of Table 3, respectively.

3.2. Photometry from Stetson (1979)

The Stetson (1979) (hereafter S79) photometric survey consisted of new photometry for a subset (512 stars) of the BS61 catalog. The star identifications of the stars in Table V of S79 are the same star identifers as in Table C of BS61. Since the S79 stars are identical to the BS61 stars, the S79 photometric data were simply matched to the appropriate BS61 stars. The S79 id, V magnitude, and $B-V$ values are found in columns 14, 15, and 16 respectively in Table 3. The photometric difference flag in column 17 of Table 3 indicates whether or not there is a significant difference between the S79 (recalibrated BS61) photometry and SDSS data, as graphically shown in Figures 3c and 3d. The same $(B, B-V) \rightarrow (g, g-r)$ transform was performed as was used for BS61, and the outliers are shown in Figures 4b and 5b. The values of the flags have the same meanings as they do for BS61 (0:no difference, 1:RR Lyrae candidate, 2:unknown variable candidate, 3:no SDSS detection).

3.3. Photometry from Carney & Seitzer (1986)

The survey area of Carney & Seitzer (1986) (hereafter CS86) is broken up into two overlapping fields: Field 1 and Field 2. The total area (27 square arcminutes) of these two fields is completely contained within our catalog. Each of the two fields covers $4'.5$ in declination and $2'.9$ in right ascension and an outline of the field boundaries is drawn in Figure 2. Each field is approximately centered on a BS61 star; Field 1 is centered on BS69 star 92 and Field 2 on star 289. The two fields overlap by 3.4 square arcminutes (26%). An x and y value (in pixels) is given for each star in the two fields. To convert these x and y values to right ascension and declination, we created a transformation for each field. These transformations are accurate within about 1 arcsecond (rms). The transformation for Field 1 is:

$$\alpha = 260.08088 - 0.000307403 * x - 0.00000397545 * y \quad (3)$$

$$\delta = 57.87482 - 0.00000211255 * x + 0.000163354 * y, \quad (4)$$

and for Field 2 the transformation is:

$$\alpha = 260.0153958 - 0.00030713911 * x - 0.00000316997 * y \quad (5)$$

$$\delta = 57.88494 - 0.0000016845 * x + 0.0001632135 * y. \quad (6)$$

About half of the stars in each of the two fields were faint (V $\geq$ 23), and were not matched to the SDSS data. 370 of the 547 Field 1 stars were matched to SDSS detections, and 292 of the 423 Field 2 stars were matched. Most of the stars that were not identified had $V > 22.5$). Since the unmatched stars were not clumped in position on the sky, we believe that the coordinate transformation is not responsible for the fact that many of stars are not found in common between the catalogs. Almost all of the unmatched CS86 stars were either fainter than 23rd magnitude in V or close enough to brighter stars that the SDSS deblender did not identify them as isolated sources.

We used the same method to reduce and evaluate the error rate in CS86 data as we did in BS61 data. The transformation from B,V photometry to g^*, r^* photometry was different, however. The transformation from F96 was a good match to the data, so it was adopted:

$$g^* = V + 0.56(B - V) - 0.12, \tag{7}$$

$$g^* - r^* = 1.05(B - V) - 0.23. \tag{8}$$

The computed g^* values would differ by a few percent if we used the transformations derived in Smith et al. (2002) from comparisons of SDSS standard stars to Landolt standards. A comparison of our photometry with the corresponding photometry from ten stars in Henden and Munari (2000) support the claim that the Smith et al. (2002) transformations are a better match to modern CCD photometry than the theoretical transformations of F96. Since we are using the transformations only to look for outliers, it doesn't matter if the overall transformation is off by a few percent (either due to the transformation or the fact that our magnitudes are dereddened and CS86 data is not).

Figures 3e, 3f, 4c and 5c show the photometric comparisons between SDSS and CS86 data, and the outliers chosen as candidate variables. Twenty candidate variable objects were identified (of which 16 are consistent with Draco RR Lyrae variables in color and magnitude). These objects are either variable, have unusual spectra, or highlight photometric errors in at least one catalog. The CS86 Field 1 id, V magnitude, $B - V$ color, and variability flag are found in columns 18, 19, 20, and 21, respectively, and the CS86 Field 2 id, V magnitude, $B - V$ color, and variability flag are found in columns 22, 23, 24, and 25, respectively.

3.4. Photometry from Piatek et al. (2001)

Out of the nine tables in and around Draco in Piatek et al. (2001) (hereafter P01), only three (Tables a, b, and d) overlap data within our catalog. Field C0 from P01 contains the majority of stars found within our catalog. Of the 11381 C0 stars within our catalog region, 4796 stars matched to stars within our catalog. 132 of the unidentified stars were found in the rerun 0 version of the reduction software. As was true in comparing our catalog to those of BS61 and CS86, most of the unmatched stars brighter than $V = 22.5$ were not detected in the SDSS because they were not deblended from bright stars. Out of the 1294 stars in E1 (P01 Table b) and 191 stars in W1 (P01 Table d) within our catalog region, 444 and 60, respectively, stars were identified in our catalog. An additional five of the unidentified stars in Table b and two of the unidentified stars from Table d were found in the rerun 0 version of the reduction software. A total of 5326 matches to P01 objects were made out of a total of 5634 unique objects in the SDSS catalog. Again, about 90% of the stars brighter than $V = 22.5$ are matched with objects in the SDSS database.

For bluer colors, $V - R \leq 0.875$, the F96 color transformations work well:

$$g^* = V + 0.96(V - R) - 0.14, \tag{9}$$

$$g^* - r^* = 1.80(V - R) - 0.27. \tag{10}$$

For redder stars, we used the transformation:

$$g^* = V + 0.70, \tag{11}$$

$$g^* - r^* = 0.03. \tag{12}$$

Figures 3g, 3h, 4d, and 5d show a comparison of the photometry between P01 and SDSS catalogs; stars with inconsistent photometry are marked with a diamond-shaped symbol. 134 of the 2374 matched objects are flagged as possible variable stars. Due to saturation of P01 photometry on the bright end, we did not compare photometry for stellar objects brighter than $V = 17$. The P01 id, V magnitude, $V - R$ color, and match flag are found in columns 26–29 of Table 3, respectively.

Note that in cases where there is a match of the same SDSS star to a P01 C0 and either a P01 E1 or P01 W1 field, that there are two lines of entries in Table 3, one for each match, with the SDSS information duplicated.

3.5. Photometry from Grillmair et al. (1998)

The survey of area of the HST observations of Draco by Grillmair et al. (1998) (hereafter G98) is completely contained within our catalog and is roughly centered and almost completely contained within CS86 Field 1 (See Figure 2). It was necessary to create a transformation from G98 x and y to R.A. and Dec. for the three G98 fields (WF2, WF3, and WF4). For the WF2 field the transformation is:

$$\alpha = 260.038354 - 0.0000336621 * x - 0.00003946221 * y \tag{13}$$

$$\delta = 57.90812 - 0.0000209702 * x + 0.000017888 * y. \tag{14}$$

For WF3 the transformation is:

$$\alpha = 260.039295 - 0.000039238 * x + 0.000033847 * y \tag{15}$$

$$\delta = 57.90852 + 0.0000179864 * x + 0.000020851 * y. \tag{16}$$

And for WF4 the transformation is:

$$\alpha = 260.04099 + 0.0000342794 * x + 0.000038953 * y \tag{17}$$

$$\delta = 57.90783 + 0.0000206995 * x - 0.000018216 * y. \tag{18}$$

These fields are from one pointing of WFPC2.

The G98 data are taken with the Hubble Space Telescope and therefore includes very faint stars. There are 50 stars with V magnitude ≤ 23 in the WF2 data, 46 in the WF3 data, and 56 in the WF4 data. A total of 88 stars were matched by position to stars in our catalog, including 6 from the "rerun 0" version of the catalog. Since F96 provided no transformations from V,I to g^*, r^* filter systems, we generated our own transformation equations from the data:

$$g^* = V + 0.991(V - I) - 0.15, \tag{19}$$

$$g^* - r^* = 1.25(V - I) - 0.24. \tag{20}$$

The G98 id (id-WF chip number), V magnitude, $V - I$ color, and photometric matching flag are found in columns 30, 31, 32 and 33 of Table 3, respectively. No stars were selected as variables by comparison to the G98 catalog (see Figures 3i, 3j, 4e and 5e).

4. ANALYSIS

The catalog of Table 3 is intended to provide a reference to researchers interested in the stellar populations and structure of Draco. The extensive cross-references to the literature provide an opportunity to select variable candidates based on multi-epoch photometry over a long baseline. Though the filter systems are inhomogeneous, roughly linear behavior for most colors yields a good list of candidate variables across the Draco field.

Table 4 lists all 142 candidate variables selected from Table 3. The columns of Table 4 are: right ascension, declination, SDSS ID, SDSS g^*, $g^* - r^*$, $u^* - g^*$, suspected variable type (RR Lyrae , QSO, Cepheid or Unknown), matching catalog (BS61, S79, CS79, P01, or G98), and the δg^* and $\delta(g^* - r^*)$ between the SDSS observation and the transformed magnitude and color of the cross reference observation onto the SDSS $(g^*, g^* - r^*)$ system. A positive value of delta g^* or delta $g^* - r^*$ means the star was fainter or redder respectively in the SDSS than in the comparison catalog. The last column gives the identity of the object from other catalogs.

Since the observations with the full set of filters for SDSS observations for each object are obtained within minutes of each other, most stars can be expected to be at a single point in their light curve. By plotting the colors of known RR Lyrae stars from BS61, we determined that in Draco these variable stars lie in a narrow region of the H-R diagram (see Figure 6). Therefore, we tentatively identify all 112 stars in the range $19 < g^* < 20.8$, $g^* - r^* < 0.4$, $2.7(g^* - r^*) + 19.2 < g^* < 2.7(g^* - r^*) + 20.1$ as RR Lyrae candidates. These objects have a one in the variability flag fields of Table 3, and are labeled as "RR Lyrae" in Table 4. Objects which are suspected to vary but which do not lie in the region inhabited by RR Lyrae stars have a one in the variability flag fields of Table 3 and are labeled as "unknown" in Table 4. There are only 30 objects suspected of varying which have colors outside the region known to contain RR Lyrae variables. A few of these might be RR Lyrae variables as well, as their colors place them only slightly outside our RR Lyrae color box.

The location of all variable candidates is summarized in the color magnitude diagram presented in Figure 6. Variable candidates from each cross-referenced catalog are marked with a separate color while all SDSS stars are indicated as black dots. The variables from the BS61 survey are well confirmed (Nemec 1985) with full light curves. We were able to find the positions of 135 of the 137 BS61 variable objects within eight arcminutes of the center of Draco. Two of the 137 did not appear to be in the central part in the finding charts, so they were not included. Note that the numbering system for the BS61 variable stars is separate from the photometric table with which we matched our data; we did not match the photometry for the variable star list. We recover 82 (60%) of the 135 BS61 variables, which are identified in the last column of Table 4. We also recover 28 numbered BS61 variables outside the inner eight arcminutes, and three BS61 variables which were not given a number. Since most of the variables were detected from only two epochs of photometry, we would not expect to recover all of the variable objects in Draco from this technique.

Two of the variable candidates (1339-1-5-60-207 and 1339-1-6-61-504) are known quasars from Schneider et al. (2002). These objects are indicated by a large black circle in Figure 6, and labeled "QSO" in the last column of Table 4.

Five known carbon stars are included in Table 3. SDSS stars 1336-1-5-61-267, 1336-1-5-61-436, and 1336-1-5-61-484 correspond to Aaronson, Liebert, & Stocke (1982) stars $C2 = J$, C1, and C3, respectively. SDSS stars 1336-1-5-60-249, 1336-1-5-61-436, and 1336-1-5-60-294 correspond to Margon et al. (2002) stars J171942.4+575838, J171957.7+575005, and J172038.8+575934, respectively. Object 1336-1-5-61-267 is apparently variable and we detect it as such in multiple catalog comparisons. It appears as a multi-colored point at $(g^*, g^* - r^*) = (18.02, 1.13)$ in Figure 6, and is identified as type "Carbon" in the last column of Table 4.

5. CONCLUSIONS

A matched catalog of 5634 objects in the Draco dwarf field, extending over four times the area of the Baade & Swope (1961) catalog and reaching to approximately one third the new tidal radius of Odenkirchen et al. (2001), has been assembled. We selected five color data from the SDSS with $15 < g^* < 23$, within the elliptical region $[(\alpha - 260.051)/0.460]^2 + [(\delta - 57.913)/0.164]^2 < 1$, where α and δ are in J2000 degrees. This SDSS data was merged with several existing data sets to produce our final catalog. The data sets include: Baade & Swope (1961), Carney & Seitzer (1986), Stetson (1997), Grillmair et al. (1998), and Piatek et al. (2001).

Using only stellar sources with $g^* < 23$, we identify 142 candidate variable stars, of which 113 were identified as variables in BS61, one is a known carbon star, and two are known QSOs. Since the SDSS observations were taken nearly simultaneously in all filters, the catalog colors and distance to the Draco dwarf can be used to identify potential RR Lyrae stars. Nearly 80% of the candidate variable objects have colors consistent with those of RR Lyrae variables. Only 6 (23%) of the 26 objects which do not have previous identifications are classified as RR Lyrae candidates on the basis of their colors. We report all astrometric and photometric transformations used to compare our data with previous catalogs.

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Fig. 1.— Draco photometry without (left) and with (right) photometric correction. The PSF photometry in the EDR contains systematic errors which shift the photometry in any filter in some regions of the sky brighter or fainter by up to a tenth of a magnitude. By comparing the PSF photometry to large aperture photometry for bright stars, we were able to calculate the photometric corrections to the PSF photometry as a function of position on the sky. Note the much tighter giant branch after the correction.

Fig. 2.— Catalog Footprint. We show the positions of all of the brighter stellar objects ($g^* < 22$, larger black dots) and faint objects ($g^* > 22$, smaller black dots) in our catalog. For convenience, we include large black circles in the positions of bright stars from the Guide Star Catalog (Lasker et al 1988). We do not show extended objects brighter than $g^* = 22$, since these show clustering that is not correlated with the clustering of stars in the Draco dwarf spheroidal galaxy. The positions of candidate variable stars selected by comparisons with photometry in previous catalogs are shown. For reference, we also show the field of view of the five other catalogs of stars in Draco with which we compare our results. The field of view of the Stetson (1997) catalog is identical to that of Baade and Swope (1961). Field 1 of Carney and Seitzer (1986) is to the left (higher RA) of their field 2.

Fig. 3.— Filter transformations and Outlier Identification. Dashed lines are the transformations found in Fukugita et. al. (1996), while the solid lines are our computed transformations. The Fukugita transformation fits the Carney & Seitzer (1986) data, but we fitted our own transformations to the previous catalogs even though they use similar filters. The diamonds indicate those stars whose photometry was significantly different between the catalogs.

Fig. 4.— Magnitude differences between stars in each catalog. We show the difference between the g^* magnitude from the SDSS catalog and the g^* magnitude computed from each of the five previous Draco dwarf catalogs. Only stellar objects (brighter than $g^* = 22$) which are in common between the SDSS and each of the other catalogs are included. Diamonds indicate a candidate variable star.

Fig. 5.— Color differences between stars in each catalog. We show the difference between the $g^* - r^*$ color from the SDSS catalog and the $g^* - r^*$ color computed from each of the five previous Draco dwarf catalogs. Only stellar objects (brighter than $g^* = 22$) which are in common between the SDSS and each of the other catalogs are included. Diamonds indicate a candidate variable star.

Fig. 6.— Variable Candidate Color Magnitude Diagram. This H-R diagram shows the data from Table 4. The objects which are variable candidates are indicated with a different color for each comparison catalog. Some objects are selected as variable in more than one catalog comparison. The color-magnitude selection box for RR Lyrae variable candidates is

indicated within the red lines. The two known QSOs which were selected as variables are indicated by large black circles. The known carbon star which was selected as variable is the multi-colored point at $(g^*, g^* - r^*) = (18.02, 1.13)$.

Table 1. Summary of Object Matching to Previous Catalogs

	BS61	S79	CS86		P01			G98
			Field1	Field2	Table a	Table b	Table d	
No. of stars*	624	512	547	423	11,381	1,294	191	152
Total Matched	586	488	370	292	4,928	449	62	88
Re-Run 1 Stars	562	467	363	288	4,796	444	60	82
Re-Run 0 Stars	24	21	7	4	132	5	2	6
Possible Variables**	2	6	11	9	126	7	0	0

*Number of stars contained within our survey area with $V \leq 23$

**Includes RR Lyrae and Unknown variables

Table 2. Format of Catalog in Table 3

Column	Format	Description
1	9.5f	Right Ascension (J2000 degrees)
2	8.5f	Declination (J2000 degrees)
3	17s	SDSS ID (Run-Rerun-Camcol-Field-ID)
4	7.2f	g^* - dereddened, aperture corrected Luptitude from PSF-fitting
5	6.2f	$u^* - g^*$
6	6.2f	$g^* - r^*$
7	6.2f	$r^* - i^*$
8	6.2f	$i^* - z^*$
9	6.4f	E(B-V)
10	6s	Baade-Swope ID
11	6.2f	Baade-Swope V
12	6.2f	Baade-Swope B-V
13	1d	Baade-Swope flags *
14	6s	Stetson ID
15	6.2f	Stetson V
16	6.2f	Stetson B-V
17	1d	Stetson flags *
18	6s	Carney-Seitzer Field 1 ID
19	6.3f	Carney-Seitzer Field 1 V
20	6.3f	Carney-Seitzer Field 1 B-V
21	1d	Carney-Seitzer Field 1 flags *
22	6s	Carney-Seitzer Field 2 ID
23	6.3f	Carney-Seitzer Field 2 V
24	6.3f	Carney-Seitzer Field 2 B-V
25	1d	Carney-Seitzer Field 2 flags *
26	9s	Piatek ID
27	7.3f	Piatek V
28	5.2f	Piatek V-R
29	1d	Piatek flags *
30	6s	Grillmair ID-Field
31	6.3f	Grillmair V
32	6.3f	Grillmair V-I
33	1d	Grillmair flags *
34	1s	Type (s - star; g - galaxy; f - faint, $g^* > 22$)

*0 - Match; 1 - RR Lyrae; 2 - Unknown variable; 3 - Unmatched

Note. — Single spaces are inserted between columns.

Table 3. Cross-Referenced Draco Catalog

RA	DEC	SDSS id	g*	u*-g*	g*-r*	r*-i*	i*-z*	E(B-V)	BS id	BS V	BS B-V	BS flag
259.59433	57.90571	1339-1-5-60-1510	22.98	1.42	1.51	0.86	0.43	0.0262				3
259.59869	57.90565	1339-1-5-60-1511	22.94	-0.16	-0.06	-0.66	1.46	0.0262				3
259.59895	57.92744	1339-1-5-60-291	19.08	1.38	2.66	1.06	0.61	0.0257				3
259.59919	57.94193	1339-1-5-60-1252	22.51	0.89	0.51	0.61	0.29	0.0254				3
259.59940	57.91351	1339-1-5-60-383	21.31	1.32	1.57	1.19	0.62	0.0261				3

Note. — Table 3 is presented in its entirety in the electronic version of The Astrophysical Journal Supplements. A portion is shown here for guidance regarding its form and content. The full catalog contains 34 columns of information on 5766 stars.

Table 4. Candidate Variable Objects

R.A.	Dec.	SDSS ID	g	g-r	u-g	type	Other Catalog(s)†,c	delta g	delta g-r	Variable Refrence ‡
259.64816	57.87486	1339-1-5-61-655	20.27	-0.01	1.31	Unknown	P01	0.559	0.116	—
259.66009	57.87728	1339-1-5-61-652	19.91	0.15	1.09	RR Lyrae	P01	-0.680	-0.210	—
259.70073	57.92844	1339-1-5-60-102	20.69	0.43	2.33	Unknown	P01	-0.025	-1.000	—
259.73549	57.98246	1339-1-5-60-239	20.73	-0.88	0.91	Unknown	P01	0.849	0.326	—
259.74238	57.88235	1339-1-5-61-689	20.14	0.18	0.80	RR Lyrae	P01	1.153	1.242	BS-76
259.74469	57.88249	1339-1-5-61-688	19.91	0.08	0.95	RR Lyrae	P01	-1.237	-1.108	BS-109
259.75711	58.00798	1339-1-5-60-207	18.70	0.08	0.20	Unknown	P01	-0.524	0.062	QSO
259.77357	57.92739	1339-1-5-61-569	20.37	0.26	0.87	RR Lyrae	P01	0.684	0.404	BS-159
259.77654	57.83001	1339-1-5-61-369	19.21	0.14	0.95	Unknown	P01	1.486	1.220	BS-134
259.78363	57.97636	1339-1-5-60-261	18.24	-0.04	1.15	Unknown	P01	-0.414	-0.184	BS-157
259.79617	58.01210	1339-0-5-60-49	20.84	1.80	1.56	Unknown	P01	0.393	0.370	—
259.79988	57.91029	1339-1-5-61-626	20.41	0.19	1.17	RR Lyrae	P01	-0.497	-0.764	BS-22
259.82323	57.89237	1339-1-5-61-704	19.61	-0.03	1.15	RR Lyrae	P01	-0.784	-0.246	BS-73
259.82668	57.87930	1339-1-5-61-750	20.32	0.14	1.10	RR Lyrae	P01	0.702	0.716	BS-110
259.84590	57.83288	1339-1-5-61-106	19.69	0.02	1.19	RR Lyrae	P01	-1.281	-0.952	BS-137
259.84705	57.93216	1339-1-5-61-590	20.54	0.28	0.93	RR Lyrae	P01	0.933	0.874	BS-15
259.86091	57.89279	1339-1-5-61-732	20.45	0.31	1.05	RR Lyrae	P01	0.414	0.472	BS-107
259.87057	57.82140	1339-1-5-61-908	20.40	0.31	0.90	RR Lyrae	P01	0.410	0.364	BS-47
259.87712	57.94266	1339-1-5-61-183	19.38	-0.01	1.14	RR Lyrae	P01	0.517	0.980	BS-14
259.89192	57.92656	1339-1-5-61-235	20.43	0.17	1.18	RR Lyrae	P01	0.672	0.602	BS-18
259.89579	57.84657	1339-1-5-61-884	19.98	0.12	1.20	RR Lyrae	P01	1.027	1.254	BS-45
259.90025	57.90432	1339-1-5-61-280	18.12	0.19	1.26	Unknown	P01	0.328	0.388	BS-194
259.90181	57.82497	1339-1-5-61-911	20.38	0.09	1.02	Unknown	P01	0.405	0.252	BS-46
259.90992	57.79015	1339-1-5-62-406	20.28	0.16	1.11	RR Lyrae	P01	0.413	0.520	BS-50
259.91930	57.97742	1336-1-5-60-737	20.29	0.43	1.29	Unknown	P01	1.000	1.960	—
							S79*	-0.035	-0.043	
							BS61*	0.008	-0.169	
259.92261	57.89095	1339-1-5-61-763	20.38	0.22	1.37	RR Lyrae	P01	0.397	0.490	BS-129
							CS86[2]	0.455	0.811	
259.92724	58.05734	1336-1-5-60-578	19.53	-0.17	1.31	RR Lyrae	P01	-1.572	-1.600	BS-2
259.92756	57.89161	1339-1-5-61-762	19.89	0.09	0.94	RR Lyrae	P01	-0.541	-0.234	BS-188
							CS86[2]	-0.585	-0.178	
259.93739	57.90498	1336-1-5-60-525	20.28	0.28	1.04	RR Lyrae	P01	0.399	0.298	BS-127
							CS86[2]	0.363	0.508	
							S79	0.278	-0.393	
							BS61*	0.318	-0.487	
259.93800	57.97613	1336-1-5-60-769	20.24	0.27	1.22	RR Lyrae	P01	1.858	-1.160	—
							S79*	-0.006	-0.035	
							BS61*	0.038	-0.067	
259.94096	57.94053	1336-1-5-60-355	20.10	0.19	1.40	RR Lyrae	P01	0.381	0.730	BS-104
							CS86[2]	0.243	0.614	
259.94262	57.79564	1339-1-5-62-407	20.13	0.23	1.06	RR Lyrae	P01	0.413	0.482	BS-86
259.95101	57.91426	1336-1-5-60-1053	19.79	0.00	1.26	RR Lyrae	P01	-0.308	0.090	BS-20
							CS86[2]	-0.505	-1.158	
259.95303	57.94910	1336-1-5-60-867	20.42	0.23	1.24	RR Lyrae	P01	1.075	0.914	BS-147
							CS86[2]	0.373	-0.044	
259.95442	57.99014	1336-1-5-60-1504	21.79	0.61	0.61	Unknown	P01	0.615	0.934	—
259.95470	58.03670	1336-1-5-60-622	20.59	0.37	1.16	RR Lyrae	P01	0.514	0.586	BS-93

Table 4—Continued

R.A.	Dec.	SDSS ID	g	g-r	u-g	type	Other Catalog(s)[†,c]	delta g	delta g-r	Variable Refrence [‡]
259.95796	57.81791	1339-1-5-61-958	19.77	-0.02	1.17	RR Lyrae	P01	-0.926	-0.812	BS-48
259.96361	57.83811	1336-1-5-61-101	21.18	0.98	0.37	Unknown	P01	1.081	1.178	—
259.96370	57.81209	1339-1-5-61-967	20.09	0.11	1.02	RR Lyrae	P01	0.671	0.632	BS-85
259.96382	57.88907	1336-1-5-61-277	20.46	0.22	1.54	RR Lyrae	P01	0.482	0.508	BS-196
							CS86[2]	0.726	0.905	
259.96792	57.98671	1336-1-5-60-245	21.79	0.66	0.92	Unknown	P01	0.905	1.452	BS-144
259.96842	57.87396	1336-1-5-61-993	20.42	0.22	1.18	RR Lyrae	P01	-0.284	-0.446	BS-33
259.97258	57.81262	1339-1-5-61-969	20.37	0.23	0.82	RR Lyrae	P01	-0.752	-1.200	BS-84
259.97731	57.88219	1336-1-5-61-946	20.42	0.23	0.96	RR Lyrae	P01	0.886	0.752	BS-78
259.98065	57.86038	1336-1-5-61-1078	20.39	0.20	1.23	RR Lyrae	P01	-0.802	-1.230	BS-39
259.98082	57.81681	1336-1-5-61-479	19.55	0.04	1.16	RR Lyrae	P01	-0.311	0.130	BS-114
259.98440	57.87989	1336-1-5-61-328	20.08	0.17	1.21	RR Lyrae	P01	0.609	0.926	BS-32
259.98606	57.93344	1336-1-5-60-973	20.51	0.30	1.16	RR Lyrae	P01*	0.129	0.120	BS-16
							CS86[1,*]	0.062	-0.077	
							CS86[2]	0.573	0.763	
259.99224	57.91310	1336-1-5-61-6	20.36	0.41	1.45	Unknown	P01*	0.014	-0.148	—
							CS86[1]	0.331	0.045	
							CS86[2,*]	0.176	0.003	
259.99545	57.90403	1336-1-5-61-826	19.99	0.18	1.18	RR Lyrae	G98*	0.125	0.150	BS-24
							P01	0.216	0.486	
							CS86[1]	-0.507	-0.095	
							CS86[2,*]	-0.265	0.286	
259.99668	57.94619	1336-1-5-60-922	20.47	0.28	1.11	RR Lyrae	P01	1.008	0.874	BS-65
							CS86[1]	0.439	1.012	
							CS86[2,*]	-0.004	-0.118	
259.99791	58.05947	1336-1-5-60-597	20.38	0.24	0.97	RR Lyrae	P01	1.210	1.032	BS-55
259.99839	57.91189	1336-1-5-61-7	20.11	0.33	1.15	RR Lyrae	G98*	-0.124	-0.051	—
							P01	-0.338	-0.426	
							CS86[1,*]	-0.081	0.046	
							CS86[2,*]	-0.058	0.072	
							S79*	-0.046	-0.070	
							BS61*	0.009	-0.154	
260.00124	57.89062	1336-1-5-61-915	20.45	0.23	1.14	RR Lyrae	P01	1.623	1.472	BS-74
							CS86[1,*]	-0.061	-0.116	
							CS86[2]	0.299	0.524	
260.00285	57.89625	1336-1-5-61-267	18.02	1.13	3.07	Unknown	P01	0.319	0.212	Carbon
							CS86[1,*]	-0.049	-0.256	
							CS86[2,*]	-0.025	-0.248	
							S79	-0.128	-0.362	
							BS61*	-0.073	-0.352	
260.00939	58.02230	1336-1-5-60-476	19.58	-0.01	1.17	RR Lyrae	P01	-1.622	-1.440	BS-59
260.01286	57.83103	1336-1-5-61-1214	20.31	0.17	1.33	RR Lyrae	P01	-0.336	-0.442	BS-113
260.02392	57.93595	1336-1-5-60-373	20.94	0.96	0.35	Unknown	P01	0.588	0.636	—
							CS86[1]	0.615	0.695	
							S79	0.660	0.665	
							BS61	0.729	0.476	
260.02500	57.89691	1336-1-5-61-884	19.61	0.08	1.24	RR Lyrae	P01	0.054	0.512	BS-27
							CS86[1]	-0.652	-0.176	

Table 4—Continued

R.A.	Dec.	SDSS ID	g	g-r	u-g	type	Other Catalog(s)[†,c]	delta g	delta g-r	Variable Refrence [‡]
260.02551	58.03505	1336-1-5-60-641	19.96	0.11	1.11	RR Lyrae	P01	0.345	0.560	BS-58
260.02727	57.82912	1336-1-5-61-1242	20.61	0.30	1.15	RR Lyrae	P01	0.376	0.390	BS-186
260.02962	57.99697	1336-1-5-60-734	20.29	0.23	1.02	RR Lyrae	P01	0.449	0.482	BS-98
260.03149	57.97373	1336-1-5-60-290	18.47	0.70	1.58	Unknown	P01	0.374	0.844	—
							S79*	-0.051	-0.047	
							BS61*	0.003	0.111	
260.03395	58.04203	1336-1-5-60-637	20.30	0.37	1.19	RR Lyrae	P01	0.631	0.712	BS-57
260.03553	57.79121	1336-1-5-61-1389	20.29	0.27	1.09	RR Lyrae	P01	0.517	0.612	BS-49
260.03697	57.93967	1336-1-5-60-375	20.44	0.22	1.25	RR Lyrae	P01	1.380	1.192	BS-126
							CS86[1,*]	-0.036	0.104	
260.03703	57.92476	1336-1-5-60-1097	20.48	0.31	1.05	RR Lyrae	G98*	-0.097	-0.053	BS-160
							P01*	-0.099	0.004	
							CS86[1]	0.467	0.262	
260.03847	57.91065	1336-1-5-61-250	20.05	0.20	1.11	RR Lyrae	G98*	-0.121	0.025	BS-68
							P01	-0.839	-1.024	
							CS86[1,*]	0.003	0.034	
260.04789	57.96733	1336-1-5-60-860	20.42	0.18	1.02	RR Lyrae	P01	0.970	0.972	BS-123
260.05178	57.90319	1336-1-5-61-868	19.59	-0.06	1.26	RR Lyrae	P01	-0.773	-0.258	BS-72
							CS86[1,*]	-0.129	0.258	
260.05709	57.95686	1336-1-5-60-915	20.36	0.23	1.36	RR Lyrae	P01	-0.766	-0.814	BS-184
							CS86[1,*]	0.187	0.011	
260.06165	57.90899	1336-1-5-61-627	20.24	0.67	1.15	Unknown	G98*	0.218	0.130	—
							P01*	0.225	0.220	
							CS86[1]	0.210	0.219	
							S79*	0.166	0.123	
							BS61*	0.320	0.018	
260.06334	57.98805	1336-1-5-60-807	20.57	0.24	1.07	RR Lyrae	P01	-0.373	-0.570	BS-8
260.06422	57.89098	1336-1-5-61-334	20.69	0.24	1.61	RR Lyrae	P01*	0.124	-0.300	BS-171
							CS86[1]	0.503	-0.035	
260.06524	57.90470	1336-1-5-61-875	20.54	0.32	0.93	RR Lyrae	G98*	-0.010	0.075	BS-71
							P01	0.757	0.644	
							CS86[1]	0.396	0.736	
260.07075	57.87772	1336-1-5-61-1064	20.51	0.24	1.15	RR Lyrae	P01*	-0.227	-0.246	BS-34
							CS86[1]	0.645	0.030	
260.07115	57.77800	1336-1-5-61-1423	19.95	0.15	1.35	RR Lyrae	P01	-0.351	0.006	BS-140
260.07345	57.86679	1336-1-5-61-91	20.15	0.20	1.23	RR Lyrae	P01	-0.801	-0.952	BS-36
260.07361	57.95369	1336-1-5-60-950	21.87	0.51	0.93	Unknown	P01*	0.114	0.114	—
							CS86[1,*]	-0.020	0.173	
							S79*	0.117	-0.016	
							BS61	0.470	0.047	
260.07414	57.95210	1336-1-5-60-948	19.22	0.21	1.04	Unknown	P01	-0.376	-0.384	BS-141
							CS86[1]	-0.308	-0.078	
260.07524	57.87247	1336-1-5-61-92	21.25	0.10	1.37	Unknown	P01	0.324	0.640	—
260.08537	58.01548	1336-1-5-60-714	20.64	0.27	1.02	RR Lyrae	P01	-0.207	-0.432	BS-5
260.08782	57.87185	1336-1-5-61-1106	20.21	0.24	1.17	RR Lyrae	P01	0.386	0.258	BS-81
							S79	-0.356	-0.422	
							BS61*	-0.289	-0.653	
260.09410	57.78254	1336-1-5-61-1420	21.28	0.65	0.51	Unknown	P01	-0.322	-0.574	—

Table 4—Continued

R.A.	Dec.	SDSS ID	g	g-r	u-g	type	Other Catalog(s)[†,c]	delta g	delta g-r	Variable Refrence [‡]
260.10083	57.86138	1336-1-5-61-1150	19.88	0.11	1.14	RR Lyrae	P01	-0.579	-0.124	BS-132
260.10812	57.94047	1336-0-5-60-421	20.07	0.43	0.96	Unknown	P01*	0.059	0.142	—
							S79	-0.332	-0.169	
							BS61*	-0.188	-0.348	
260.11124	57.90755	1336-1-5-61-290	20.51	0.20	1.20	RR Lyrae	P01	-0.550	-0.934	BS-106
260.11766	57.95019	1336-1-5-60-417	19.85	0.06	1.04	RR Lyrae	P01	0.287	0.672	BS-103
260.12558	57.84441	1336-1-5-61-139	19.73	0.01	1.08	RR Lyrae	P01	0.101	0.334	BS-135
260.12974	57.96027	1336-1-5-60-958	20.43	0.29	1.06	RR Lyrae	P01	0.435	0.308	BS-158
260.13549	57.91925	1336-1-5-61-32	20.63	0.36	0.98	RR Lyrae	P01	1.466	1.368	BS-21
							S79	-0.058	0.538	
							BS61*	-0.025	0.506	
260.13768	57.95849	1336-1-5-60-986	19.51	-0.12	1.29	RR Lyrae	P01	-0.884	-0.156	BS-124
260.14471	57.89721	1336-1-5-61-1016	21.94	1.54	1.38	Unknown	P01*	0.121	0.110	—
							BS61	0.498	0.342	
260.14936	57.82179	1336-1-5-61-1346	20.44	0.45	0.83	Unknown	P01	0.735	0.450	BS-138
260.15351	57.87019	1336-1-5-61-660	20.23	0.19	1.06	RR Lyrae	P01	0.529	0.478	BS-40
260.15828	57.92527	1336-1-5-61-848	20.32	0.32	1.46	RR Lyrae	P01	1.040	0.932	BS-162
260.15994	57.87658	1336-1-5-61-408	20.44	0.29	1.27	RR Lyrae	P01	-0.364	-0.430	BS-35
260.16906	57.91449	1336-1-5-61-936	20.50	0.26	0.93	RR Lyrae	P01	0.587	0.530	BS-161
260.17357	57.83108	1336-1-5-61-1332	20.01	0.09	1.14	RR Lyrae	P01	0.819	1.026	BS-82
260.17433	57.96383	1336-1-5-60-996	20.48	0.25	0.83	RR Lyrae	P01	-0.439	-0.524	BS-12
260.17624	57.98114	1336-1-5-60-895	20.38	0.21	0.93	RR Lyrae	P01	0.745	0.768	BS-169
260.17851	57.85796	1336-1-5-61-1235	19.64	0.02	1.11	RR Lyrae	P01	0.224	0.758	BS-41
260.18800	57.85765	1336-1-5-61-1239	19.58	0.02	1.04	RR Lyrae	P01	-0.434	-0.088	BS-164
260.19653	57.96645	1336-1-5-60-999	19.31	-0.17	1.16	RR Lyrae	P01	-0.100	0.550	BS-13
260.19697	57.92301	1336-1-5-61-902	19.92	0.04	1.29	RR Lyrae	P01	-0.533	-0.140	BS-185
260.20741	57.90137	1336-1-5-61-1058	20.42	0.21	1.06	RR Lyrae	P01	-0.547	-0.780	BS-25
260.21321	57.86324	1336-1-5-61-130	20.53	0.38	0.85	RR Lyrae	P01	1.061	0.848	BS-133
260.21460	57.97171	1336-1-5-60-509	19.26	0.63	1.46	Unknown	P01	0.821	1.548	—
260.21700	58.02371	1336-1-5-60-767	19.57	-0.01	1.22	RR Lyrae	P01	-1.409	-0.946	BS-94
260.21794	57.92034	1336-1-5-61-964	20.22	0.24	0.31	RR Lyrae	P01	-0.377	0.258	—
							BS61*	0.253	0.344	
260.21987	57.84490	1336-1-5-61-159	19.61	-0.01	1.42	RR Lyrae	P01	0.441	0.944	BS-177
260.22526	57.95146	1336-1-5-61-777	20.71	0.83	0.79	Unknown	P01	0.342	0.434	—
260.23602	57.89786	1336-1-5-61-1100	20.53	0.28	1.33	RR Lyrae	P01	1.297	1.144	BS-75
260.23839	57.83363	1336-1-5-61-1361	19.48	-0.05	1.10	RR Lyrae	P01	-1.615	-1.480	BS-178
260.24357	57.89214	1336-1-5-61-649	20.42	0.29	0.97	RR Lyrae	P01	1.051	1.082	BS-175
260.24627	58.00153	1336-1-5-60-858	19.78	-0.07	1.28	RR Lyrae	P01	-0.708	-0.574	BS-97
260.24700	58.02391	1336-1-5-60-270	19.47	-0.03	1.16	RR Lyrae	P01	-0.079	0.420	BS-118
260.25222	57.86466	1336-1-5-61-1267	21.37	-0.13	0.61	Unknown	P01	0.579	0.392	—
260.26119	57.88066	1336-1-5-61-673	19.76	0.07	1.10	RR Lyrae	P01	0.734	0.988	BS-80
260.26461	57.99732	1336-1-5-60-888	20.36	0.23	1.04	RR Lyrae	P01	0.796	0.896	BS-96
260.27663	57.86468	1336-1-5-61-1285	20.06	0.11	1.20	RR Lyrae	P01	1.021	1.154	BS-112
260.27901	57.99500	1336-1-5-60-913	20.46	0.28	1.07	RR Lyrae	P01	-0.325	-0.620	BS-95
260.27955	57.90240	1336-1-5-61-396	20.39	0.24	1.06	RR Lyrae	P01	-0.327	-0.696	BS-70
260.28048	57.96674	1336-1-5-60-1073	20.34	0.16	1.23	RR Lyrae	P01	1.171	1.042	BS-183
260.28602	57.79628	1336-1-5-62-310	20.14	0.18	1.24	RR Lyrae	P01	0.295	0.540	BS-87
260.30299	58.02519	1339-1-6-61-405	19.94	0.03	1.34	RR Lyrae	P01	0.416	0.750	BS-181

Table 4—Continued

R.A.	Dec.	SDSS ID	g	g-r	u-g	type	Other Catalog(s)[†,c]	delta g	delta g-r	Variable Refrence [‡]
260.30423	57.89739	1336-1-5-61-1147	19.65	0.02	1.04	RR Lyrae	P01	-0.437	0.146	BS-189
260.30846	57.90981	1336-1-5-61-1102	20.33	0.25	0.94	RR Lyrae	P01	-0.221	-0.470	BS-128
260.31889	57.89216	1336-1-5-61-1178	19.98	0.14	1.20	RR Lyrae	P01	-0.959	-0.904	BS-26
260.32756	57.79548	1336-1-5-62-319	19.84	0.10	1.21	RR Lyrae	P01	-0.497	-0.026	BS-199
260.32928	57.89011	1336-1-5-61-1193	20.35	0.20	0.91	RR Lyrae	P01	0.897	0.902	BS-130
260.33418	57.82171	1336-1-5-61-1426	20.35	0.13	1.07	RR Lyrae	P01	0.731	0.670	BS-166
260.34115	57.82410	1336-1-5-61-1422	20.16	0.05	1.17	RR Lyrae	P01	0.456	0.194	BS-139
260.35674	57.84176	1336-1-5-61-190	20.44	0.35	1.09	RR Lyrae	P01	0.764	0.818	BS-197
260.37540	57.97799	1339-1-6-61-469	20.24	0.22	1.06	RR Lyrae	P01	0.450	0.400	BS-61
260.39565	57.85005	1339-1-6-62-330	20.79	0.78	0.98	Unknown	P01	0.508	0.150	—
260.40182	57.93293	1339-1-6-61-551	20.19	0.14	1.18	RR Lyrae	P01	0.482	0.338	—
260.41938	57.91002	1339-1-6-61-307	19.90	0.11	1.18	RR Lyrae	P01	-0.582	-0.106	—
260.42271	57.87652	1339-1-6-62-301	21.52	0.36	0.26	Unknown	P01	0.555	0.000	—
260.42448	57.90823	1339-1-6-61-584	20.40	0.22	1.01	RR Lyrae	P01	0.537	0.346	—
260.44703	57.88509	1339-1-6-62-293	20.24	0.21	1.14	RR Lyrae	P01	0.302	0.084	—
260.45115	57.96817	1339-1-6-61-504	20.11	0.07	0.16	RR Lyrae	P01	-0.538	-0.326	QSO

[†]BS61,S79,CS86,P01,G98

[‡]Baade & Swope Variables found in BS61 Table B

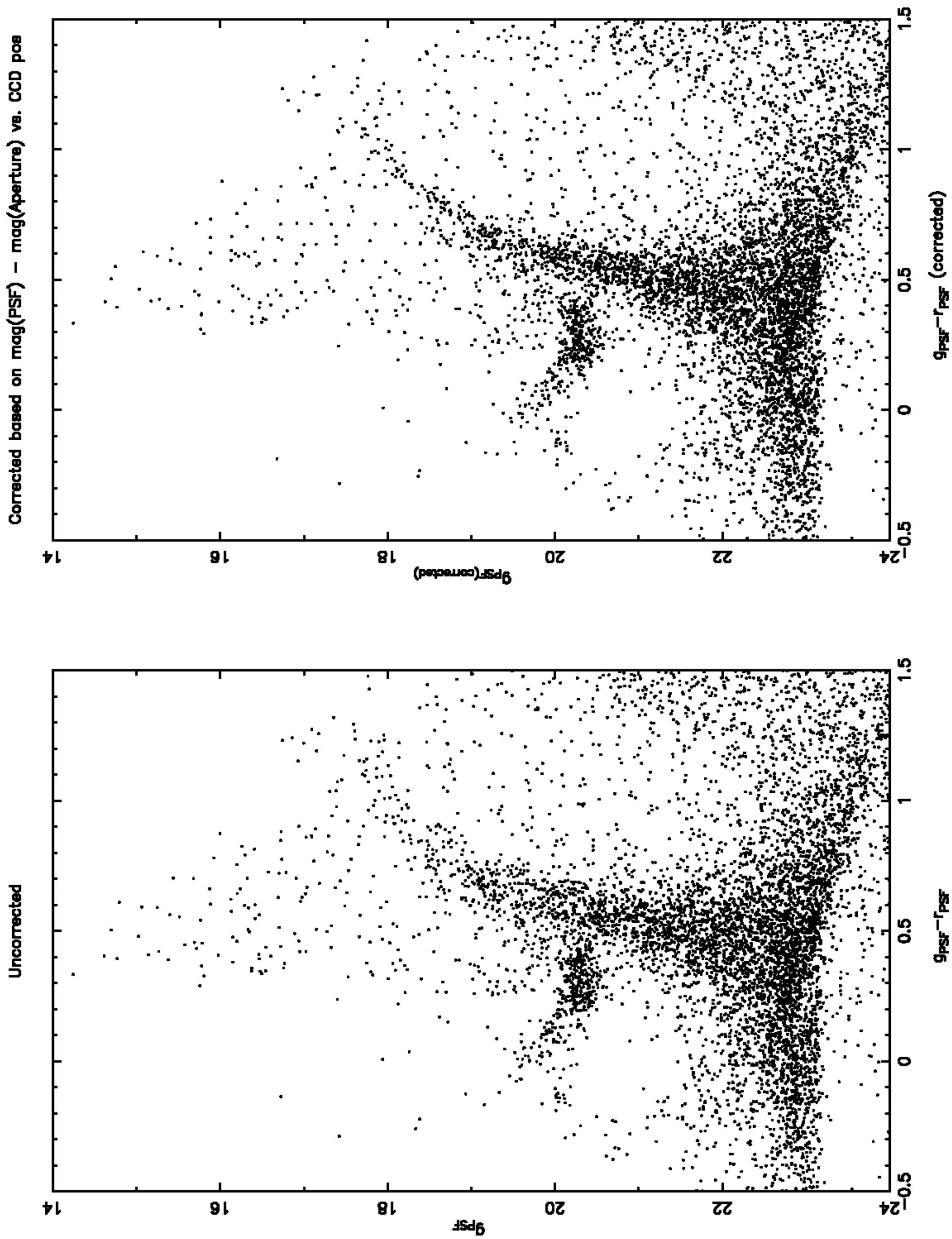
*Not variable in this catalog

[1]CS86 Field 1

[2]CS86 Field 2

[c]P01 data from Field C0 unless otherwise noted

[e]P01 Field E1


Corrected based on mag(PSF) − mag(Aperture) vs. CCD pos
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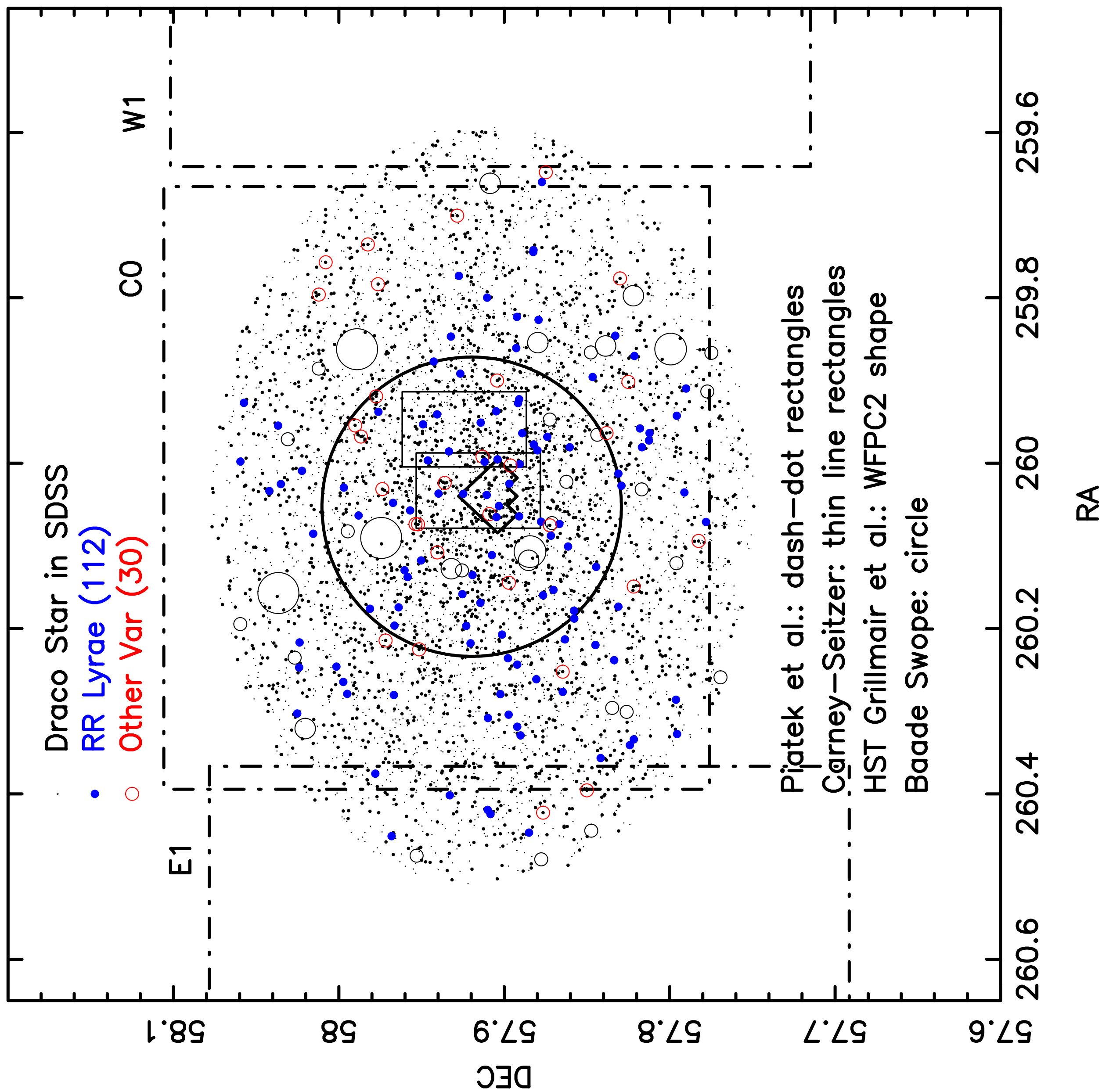
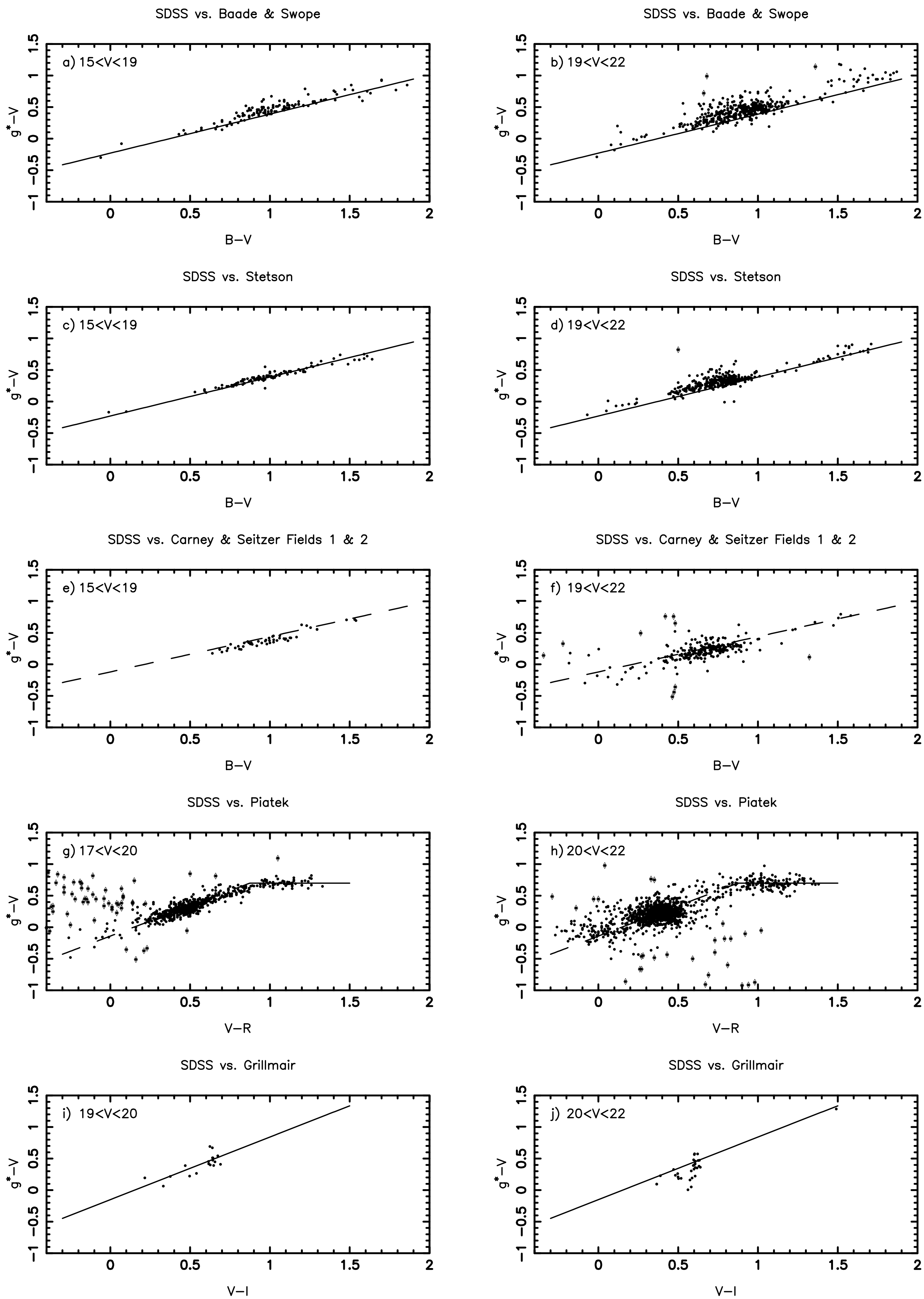
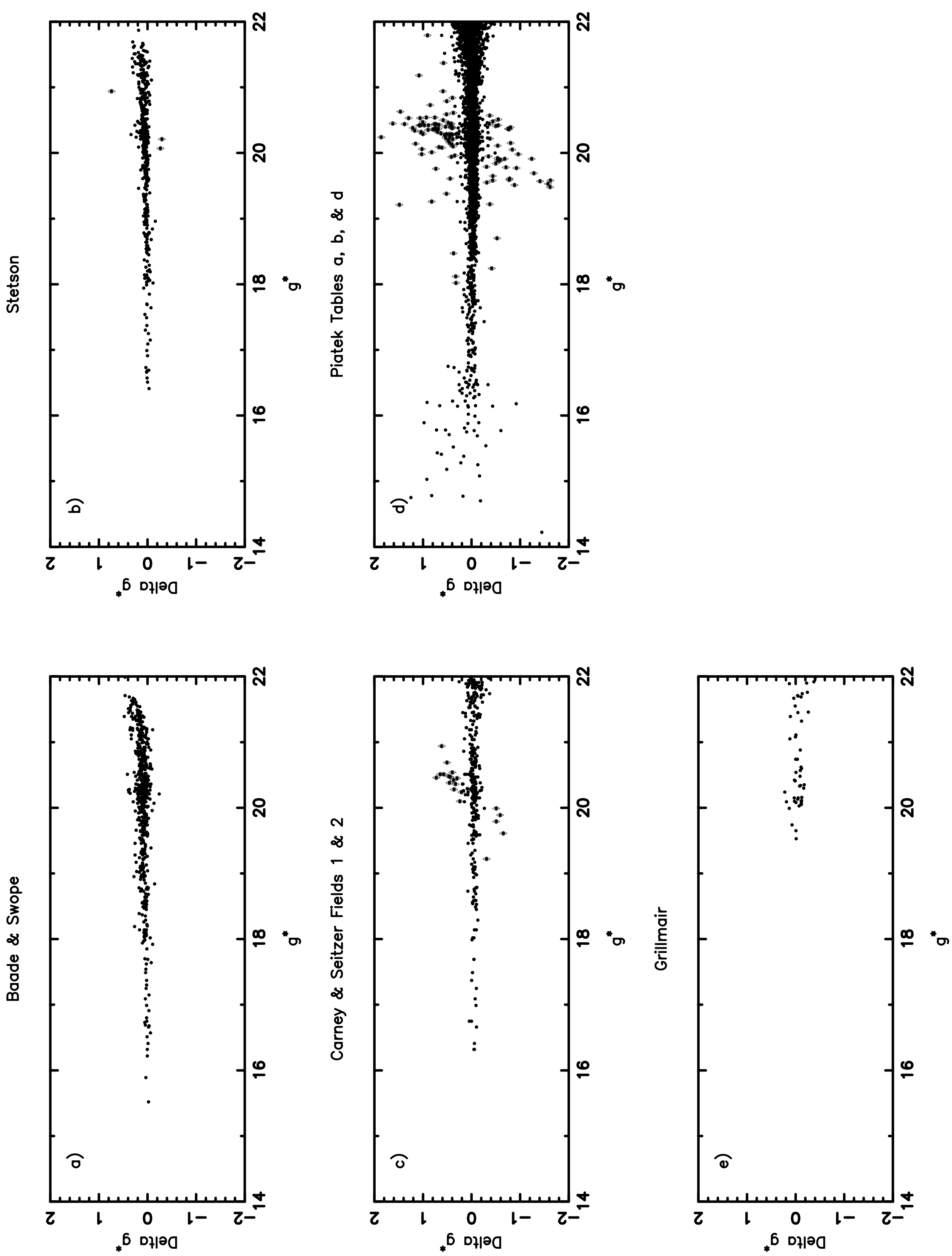
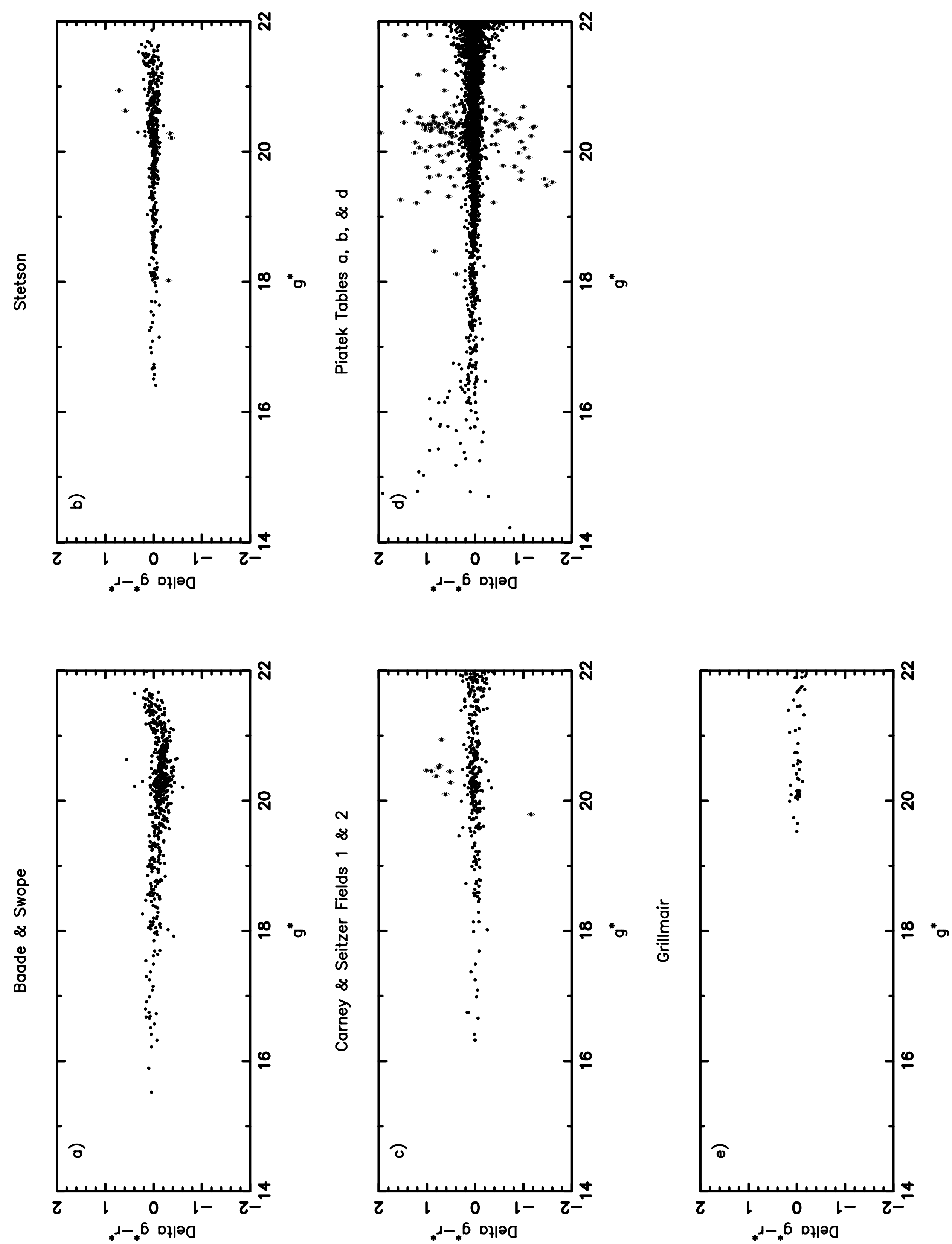
Uncorrected
g_PSF
g_PSF−r_PSF

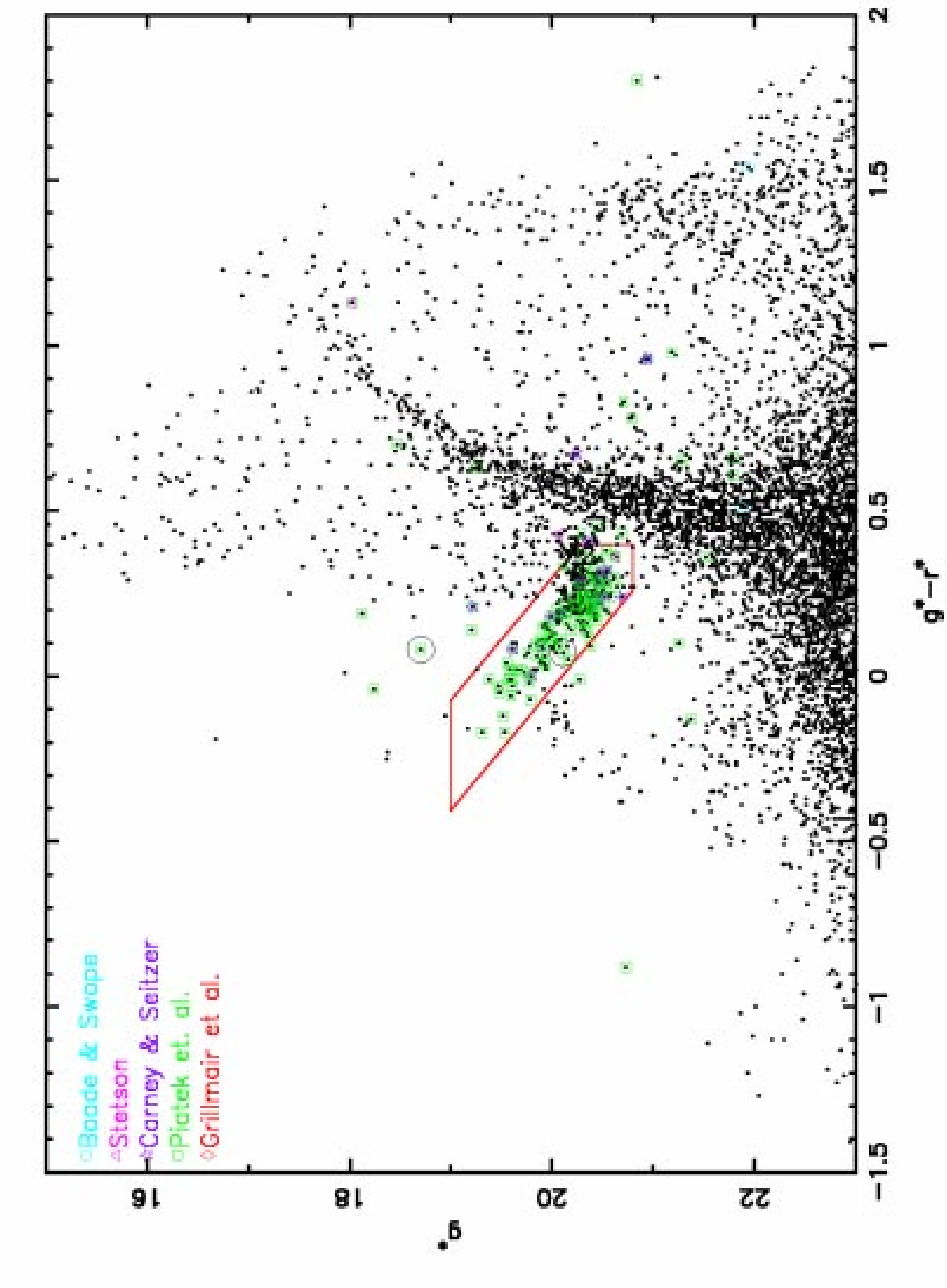

Draco Star in SDSS
RR Lyrae (112)
Other Var (30)
W1
C0
E1
Piatek et al.: dash-dot rectangles
Carney-Seitzer: thin line rectangles
HST Grillmair et al.: WFPC2 shape
Baade Swope: circle
259.6
259.8
260
260.2
260.4
260.6
RA
58.1
58
57.9
57.8
57.7
57.6
DEC


SDSS vs. Baade & Swope
a) 15<V<19
SDSS vs. Baade & Swope
b) 19<V<22
SDSS vs. Stetson
c) 15<V<19
SDSS vs. Stetson
d) 19<V<22
SDSS vs. Carney & Seitzer Fields 1 & 2
e) 15<V<19
SDSS vs. Carney & Seitzer Fields 1 & 2
f) 19<V<22
SDSS vs. Piatek
g) 17<V<20
SDSS vs. Piatek
h) 20<V<22
SDSS vs. Grillmair
i) 19<V<20
SDSS vs. Grillmair
j) 20<V<22
g*−V
B−V
V−R
V−I


Baade & Swope
Stetson
Carney & Seitzer Fields 1 & 2
Piatek Tables a, b, & d
Grillmair
a)
b)
c)
d)
e)
Delta g*
g*
2
1
0
−1
−2
14
16
18
20
22



Baade & Swope
Stetson
Carney & Seitzer Fields 1 & 2
Piatek Tables a, b, & d
Grillmair
a)
b)
c)
d)
e)
Delta g*−r*
g*



Baade & Swope
Stetson
Carney & Seitzer
Piatek et. al.
Grillmair et al.
g*
g*−r*
16
18
20
22
−1.5
−1
−0.5
0
0.5
1
1.5
2