CCD Double Star Observations at Altimira Observatory: Spring 2008

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Abstract: A CCD imager and 11-inch Schmidt-Cassegrain telescope at Altimira Observatory is used for measurement of visual double stars. Separation and Position angle measurements of 42 double star pairs are reported; and corrected locations are provided for four pairs

Introduction

This report presents the current results of an ongoing project of double star measurement at Altimira Observatory. The equipment used is: a CCD imager (ST-8XE), photometric filters (Custom Scientific B, V, R-band, and "clear"), and 11-inch Schmidt-Cassegrain telescope (Celestron NexStar-11). Observations reported here have been made with the telescope at either F/6.3 (with a focal reducer) or F/10 (native focal length). In the F/6.3 configuration, the pixel scale is 1.1 arc-sec/pixel. With the focal reducer removed, the F/10 configuration pixel scale is 0.65 arc-sec/pixel. Typical star images have FWHM of about 3 arc-sec (primarily due to atmospheric seeing).

Typically, at least 6 images are taken of each pair. Images are reduced by bias, dark, and flat-fielding using CCDSoft. Images are then matched to an astrometric catalog (UCAC2 or USNO-B1.0) to determine the plate constants. Astrometry is conducted in one of three ways, depending on the separation and delta-mag of the pair. For wide pairs (separation > 2 X FWHM), the convenient double-star utility in MPO Canopus is used. With just a couple of mouse-clicks, this program reports the separation and position angle, and corrects the position angle to the equator and equinox of the date of observation. For closer pairs, or pairs with large delta-mag, I may use Astrometrica because its PSF display provides confidence that the stars are, indeed, well-enough separated on the image that the program can report accurate RA, Dec coordinates for each member of the pair. Since Astrometrica reports the coordinates of the individual stars (referenced to J2000), I have written Excel spreadsheets that use these data to calculate the pair's separation and position angle, and precess the position angle to the equator and equinox of the date of observation.

Finally, for pairs that are so close that the images of the two stars overlap significantly, I use a PSF-modeling procedure, illustrated in Figure 1. The intensity function I(x,y) of the image is modeled as the sum of two Moffat functions:

$$I(x,y) = I_P(x-x_P, y-y_P) + I_S(x-x_S, y-y_S) + C$$

where the functions I_P and I_S that represent the primary and secondary star PSFs (respectively) are Moffat functions, of the form

$$I(x,y) = \frac{I_0}{\left[1+\left(\frac{x}{\alpha_x}\right)^2+\left(\frac{y}{\alpha_y}\right)^2\right]^\beta}$$

The parameters of these Moffat PSFs are determined by a multi-parameter least-squares fit (using Excel's "Solver" utility), which yields the positions and peak intensities of the individual stars. The positions

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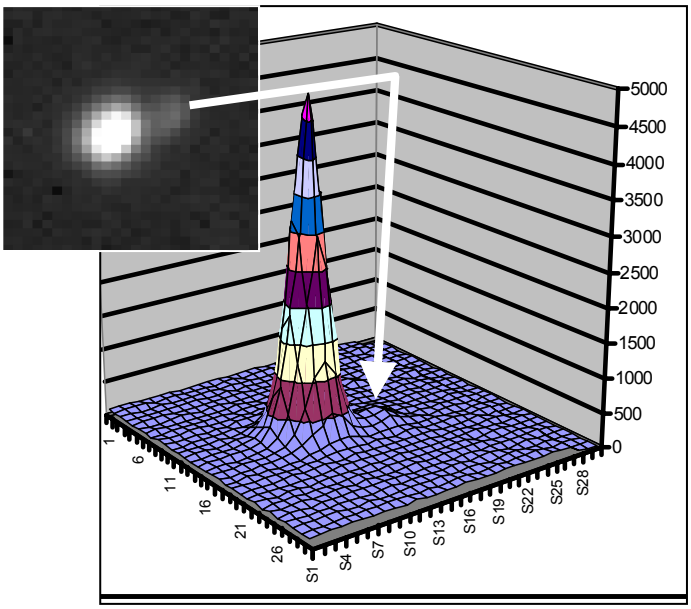

Figure 1: For close pairs, a PSF-modeling spreadsheet is used, that fits the image intensity profile to a pair of Moffat functions.

are then transformed to separation and position angle with another Excel spreadsheet. This method is described in Buchheim (2008). Tests with well-characterized pairs have demonstrated that this method can reliably measure separations as small as $\rho \approx 0.7$ X FWHM, even with delta-mag as large as a few magnitudes.

Results

The measurements of separation and position angle for each pair are provided in Table 1. Notes on selected pairs are provided where the results are interesting in some way.

"Calibration pairs": Three of the pairs reported here are on the list of WDS Candidate Calibration Systems. I try to include a few well-characterized pairs during each season, as a check on the consistency of my measurements, and the accuracy of data reduction. The results for these pairs, compared with the accepted ephemerides, are given in Table 2.

The reported measurement precision is the full range of measured values, for all of the images evaluated for each pair. This represents roughly the 1.7-sigma dispersion of results. In all cases, the measured values (this report) are consistent with the ephemeris values, within the dispersion of the measurements.

Significant Change: The separation or position angle of several of the systems in this report appear to have changed significantly since their most recent prior WDS-reported measurements. These are identified in Table 3.

Problematic Pairs: Five pairs whose measurements are reported in this paper gave me some special trouble. Since St. Paul advised that we should rejoice in our tribulations, the following paragraphs describe these particular sources of joy.

- STF 123 AB: As noted in the notes to the WDS, this pair (WDS 01283+5329) is probably the one identified as HU 1651 on the "neglected pairs" list. Their reported J2000 coordinates are essentially identical (HU 1651 A is reported to be just 15 arc-sec south of STF 123 A), and their reported magnitudes are identical. The one reported separation measurement of HU 1651 (in 1905) is discordant with the record of observations of STF 123, and it appears to have the components A/B reversed (B/A), causing a 180 degree flip in the position angle. Figure 2 illustrates the field of STF 123. My measurement of this pair (see Table 1) is consistent with other recent measurements of STF 123AB.

- HJ 3268: There is probably an error in the WDS J2000 coordinates for this pair (WDS 05107+1630). As illustrated in Figure 3, the correct location of the primary star is RA = 05:10:41.78, Dec = +16:30:43.6. The (apparently erroneous) WDS-reported position points to the location of a single star, more than an arc-minute NW of the pair HJ 3268.

- ROE 94: This pair is located in a cluttered field – there are three other pairs within a quarter of a degree, as illustrated in Figure 4. The WDS lists two pairs at essentially identical locations:

ROE 94 (WDS 23049+5120) is listed at J2000 position RA = 23:04:51.6, Dec = +51:19:24,

DBR 3 (WDS 23049+5119) is listed at J2000 position RA = 23:04:51.6, Dec = +51:19:23.

That is, their reported positions are different by only one arc-sec. Either one of them is misplaced, or they are actually a single pair with two different names.

The discovery report for ROE 94 gives its position as "1m11s preceding and 10.8' north of [catalog star]

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Name	WDS RA+Dec	WDS mags prim	sec	Position Angle theta	±	Separation (as) rho	±	Epoch	N nights	N images	Notes
STT 547 AB	00057+4549	8.98	9.15	187.5	2.2	6.0	0.3	2007.979	1	6	see Table 2
MLB 808	00289+3958	10	10.1	290.6	0.5	8.7	0.1	2007.998	1	6	
A 912	00336+4509	8.38	9.67	205.0	0.7	15.6	0.1	2007.979	1	9	
STF 123 AB	01283+5329	9.28	9.55	162.1	0.9	16.3	0.1	2007.979	1	6	=HU 1651 (?)
STF 123 AC	01283+5329	9.28	11.04	178.8	0.7	53.6	0.2	2007.979	1	6	
STF 123 BC	01283+5329	9.55	11.04	185.8	0.2	38.3	0.3	2007.979	1	6	
STF 123 CD	01283+5329	11.9	13.1	74.3	0.3	8.6	0.1	2007.979	1	5	
CHE 49	02070+2923	10.07	10.47	110.3	0.5	31.6	0.2	2007.979	1	6	
CHE 52	02074+2034	9.33	10.77	119.4	0.4	18.3	0.1	2008.105	1	7	
CHE 57	02084+2038	10.36	10.85	91.6	1.5	5.5	0.4	2008.110	1	5	
CHE 61	02089+2031	9.74	10.25	204.1	0.7	10.0	0.3	2008.110	1	6	
STF 296 AB	02442+4914	4.12	10	304.6	0.7	20.6	0.1	2007.998	1	6	
STF 296 BC	02442+4914	10	10.96	231.8	0.1	88.2	0.1	2007.998	1	2	
STF 422	03368+0035	6	8.9	271.5	1.4	6.8	0.2	2007.998	1	6	see Table 2
HJ 3268	05107+1630	9.4	10.1	271.8	0.6	10.1	0.1	2008.108	2	12	see text
SEI 114	05145+3634	11.2	11.9	117.5	1.3	8.1	0.1	2008.105	1	5	
SEI 116	05150+3630	11.33	11.33	290.1	0.1	23.1	0.1	2008.105	1	5	
SEI 118	05151+3623	10.5	10.8	343.9	0.3	18.5	0.1	2008.105	1	5	
SEI 117	05151+3630	10.26	12.04	250.2	0.4	14.4	0.1	2008.105	1	5	
SEI 131	05160+3624	11	11	13.8	0.3	19.1	0.2	2008.105	1	5	
SEI 137	05165+3635	10.13	12.33	122.5	0.2	21.3	0.1	2008.105	1	5	
HJ 3271	05172+3747	9.36	9.96	350.4	0.3	11.7	0.1	2008.105	1	5	
SEI 150	05172+3755	10.8	13	287.2	0.2	25.3	0.1	2008.105	1	5	
SEI 151	05174+3753	10	11	291.0	0.3	13.0	0.2	2008.105	1	5	

Table 1: Measured Position and Separation Angle of visual double stars in this study

Table 1 continued on next page.

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Name	WDS RA+Dec	WDS mags prim	sec	Position Angle theta	±	Separation (as) rho	±	Epoch	N nights	N images	Notes
SEI 156	05177+3757	10.7	10.8	244.7	0.3	24.3	0.3	2008.105	1	5	
SEI 161	05179+3758	9.7	11	309.7	0.4	13.2	0.2	2008.105	1	5	
SEI 196	05205+3722	10.7	11	209.6	0.6	10.1	0.1	2008.105	1	5	see Table 3
SEI 203 AB	05210+3728	9.8	10.8	251.9	0.2	21.4	0.1	2008.105	1	5	
TOB 28 BC	05210+3728	8.9	11.3	75.3	0.1	53.3	0.1	2008.105	1	5	
SEI 478	07208+3151	10	10.5	27.0	0.6	4.6	0.1	2008.110	1	4	
STF1196 AB-C	08122+1739	5.05	6.2	69.2	1.8	6.2	0.3	2008.283	1	7	see Table 2
STF1196 AB-D	08122+1739	5.31	8.89	106.5	0.1	278.1	0.3	2008.283	1	7	
POU3037	09154+2409	9.8	10.3	286.4	0.9	7.1	0.2	2008.283	1	7	see Table 3
FIL 21	09216-0243	8.8	10.5	2.2	0.9	11.2	0.2	2008.283	1	6	
SEI 520	10302+3050	10	10	2.3	0.7	7.7	0.3	2008.283	1	5	see Table 3
MLB 933	10432+3849	10	10.5	242.1	1.4	3.5	0.1	2008.283	1	5	
HJ 186	11404-0322	11.5	12.2	297.5	0.6	10.9	0.2	2008.283	1	7	see text
DBR 2	23046+5122	10	12.5	94.3	0.2	12.3	0.05	2007.951	1	4	
DBR 3	23049+5119	10.8	12.7	30.7	0.1	23.3	0.1	2007.951	2	13	see text
ROE 94	23049+5120	10.7	12.5	24.7	0.1	23.2	0.1	2007.951	2	13	see text
HJ 1846	23051+5118	11.1	11.3	144.1	0.2	9.3	0.05	2007.951	1	6	see text
MLB 102	23056+5758	11.63	12.83	115.1	0.1	8.7	0.05	2007.957	1	4	see Table 3

Table 1 continued

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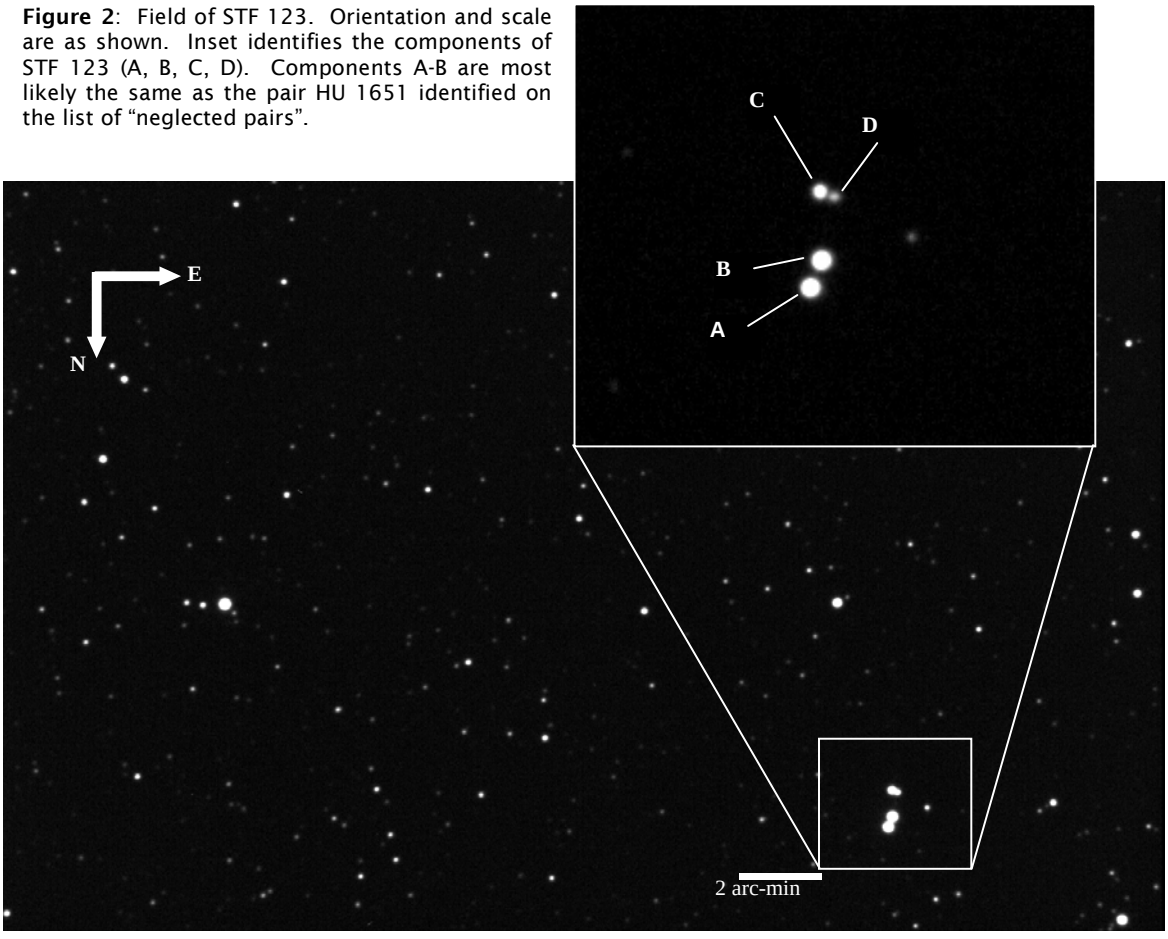
Name	Measured (this report) sep (a.s.)	PA (deg)	predicted ephemeris (2000.0) sep (a.s.)	PA (deg)	Eph. Grade
STT 547 AB	6.0 ± 0.3	187.5 ± 2.2	6.053	185.2	4
STF 422 AB	6.8 ± 0.2	271.5 ± 1.4	6.688	271.3	5
STF 1196 AB-C	6.2 ± 0.3	69.2 ± 1.8	5.914	69.3	4

Table 2: Confirmatory measurements of well-characterized pairs

Name	Prior WDS measurement year	change from prior measurement (current minus previous) Δρ (a.s.)	Δθ (deg)
SEI 196	1895	4.1	-111.4
SEI 478	1933	-1.4	0.0
MLB 102	1918	2.7	-46.9
SEI 520	1936	0.3	-12.7
ROE 94	1915	7.6	13.8

Table 3: Pairs whose parameters have changed significantly since prior report

Figure 2: Field of STF 123. Orientation and scale are as shown. Inset identifies the components of STF 123 (A, B, C, D). Components A-B are most likely the same as the pair HU 1651 identified on the list of "neglected pairs".



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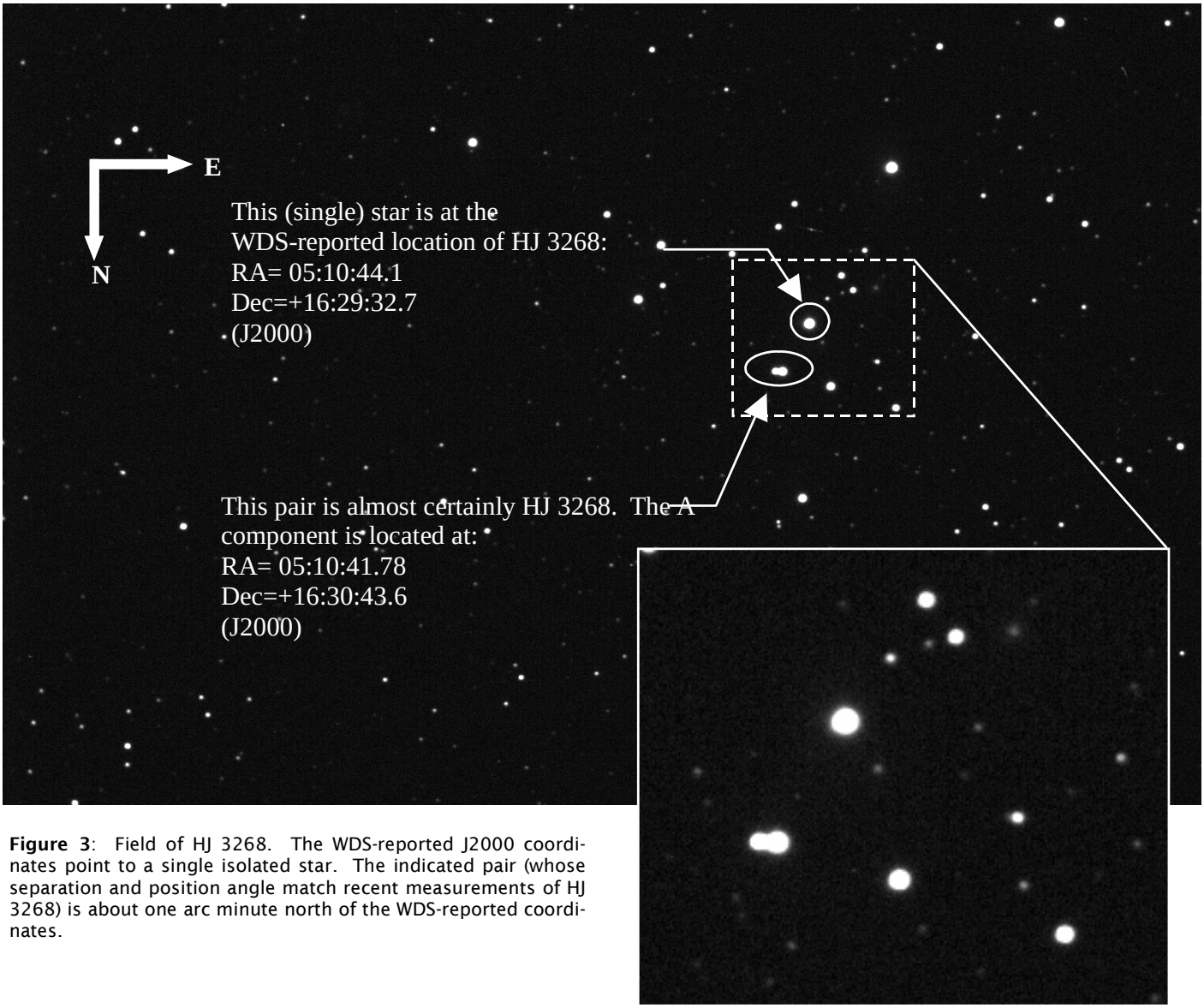

Figure 3: Field of HJ 3268. The WDS-reported J2000 coordinates point to a single isolated star. The indicated pair (whose separation and position angle match recent measurements of HJ 3268) is about one arc minute north of the WDS-reported coordinates.

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BD+50º3940" (Roe, 1916). In order to check the location of this pair, I took the J2000 coordinates of BD+50º3940, precessed them to 1915 (the epoch of Roe's observations), subtracted 1m11s of RA and added 10m48s of Dec, and then precessed the result back to J2000. The resulting location for ROE 94 is (J2000) RA = 23:04:55.4, Dec = +51:21:21.9. As illustrated in Figure 4, this points to a pair that is about 2 arc-min north of the WDS-reported position of DBR 3. These two pairs are almost identical twins in terms of magnitudes, separation, and position angle!

I was not able to track down the discovery report for DBR 3.

I think that what this all means is that: (a) they are, indeed, two different pairs, (b) the WDS-reported position of Roe 94 is in error, but can now be corrected; and (c) the separation and position angle of Roe 94 have changed significantly since its last measurement in 1915.

- HJ 1846: This pair is in the same field of view as Roe 94 (refer to Figure 4), and its position also appears to be mis-located in the WDS. The WDS gives its precise J2000 position as RA = 23:05:13.3, Dec = +51:17:37. This position points to a star with a

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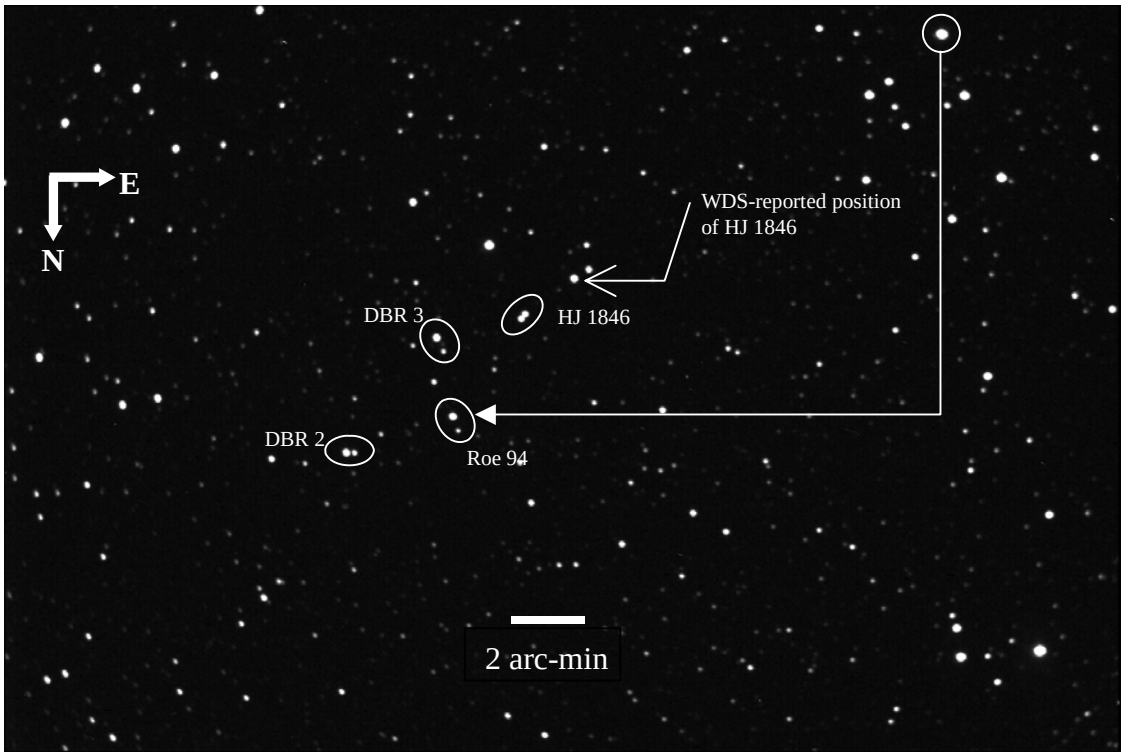

Figure 4: The busy field of view that contains Roe 94, DBR 3, HJ 1846, and DBR 2. Roe 94 and DBR 3 are nearly identical twins in terms of separation, position angle, and magnitudes.

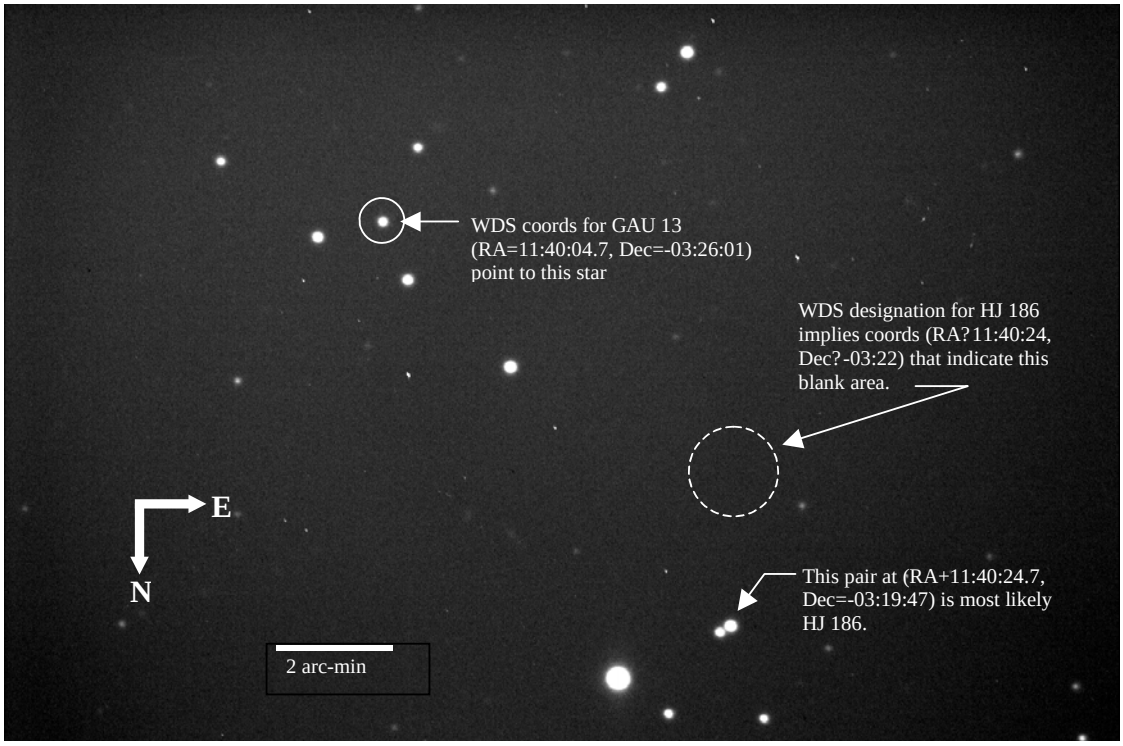

Figure 5: Field that should include GAU 13 and HJ 186. (Note that the scale is different from the previous images). The WDS coordinates given for GAU 13 point to a star without any apparent companion. The WDS identifier for HJ 186 may plausibly be for the prominent pair indicated.

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neighbor separated by ρ = 26.41 arc-sec in position angle θ = 126.6 deg; these parameters are discordant with the most recent WDS-reported measurement of HJ 1846 (separation = 9.3 arc-sec at position angle θ = 144 degrees in 2004).

There is an equal-brightness pair located at RA = 23:05:05.2, Dec = +51:18:44.7 (i.e. about 1.7 arc-min northwest of the WDS-reported location) whose parameters are consistent with the reported values for HJ 1846. Hence, this is how I identify HJ 1846 on Figure 4.

- HJ 186 (?): Once upon a movie scene, young Indiana Jones found himself alone in a desolate place, and he exclaimed, "Everyone's lost except me!" The same might be true of this star. A CCD image of the relevant field is shown in Figure 5. Two WDS pairs should be in this field: GAU 13 and HJ 186. For GAU 13, the WDS-reported J2000 position (RA = 11:40:04.7, Dec = -03:26:01) points to a single star, with no apparent partner. The WDS notes for GAU 13 state that "Gauchet calls this HJ 186, but it seems to be another pair." I find no plausible companion to this star in my image.

The WDS does not have precise coordinates for HJ 186, but its designator indicates that it should be at approximately RA ≈ 11:40:24, Dec ≈ -03:22. There is no star at this location, but roughly 2 arc-minutes northward, there is a beautiful pair of 12th magnitude stars. The J2000 coordinates of the brighter member of this pair are: RA = 11:40:24.37, Dec = -03:19:47. Assuming that this pair is, indeed HJ 186, then its parameters indicate slight motion since the one prior measurement in 1911. It is this pair that I report as "HJ 186" in Table 1. The identification of this pair with HJ 186 is plausible, but without a reference to the discovery report (which I do not have) it is certainly not definitive.

Acknowledgements

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