Measurements of Faint and Wide Doubles in Boötes and Corona Borealis

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Abstract: Images of several double stars in Boötes and Corona Borealis published on the "Double Star Imaging Project" Yahoo Group page suggest magnitude issues compared with the corresponding WDS catalog data per Jan 2016. Taking additional images with V-filter enabled photometry and astrometry for these pairs as a counter-check.

1. Introduction

This paper identifies double star systems in both Boötes and Corona Borealis that appear to have visual magnitudes that are in conflict with the data as published in the Washington Double Star Catalog. During the course of a long term project to image double stars accessible to the backyard telescope, while employing a consistent imaging regime from one location, the sheer volume of images has allowed the authors to identify with a good degree of certainty double star systems having component magnitudes that are clearly in conflict with the published data. After visually identifying these suspect systems from the new images, the authors then consulted the University of Strasburg's website, VizieR, to access the online digital sky survey catalogs to confirm the visual observations.

The preliminary findings for the suspect Boötes systems are summarized below:

- SHJ 169 – WDS 13547+1824. Listed magnitudes are 2.72 & 9.99. The dim, very orange colored companion appears to be significantly dimmer, in the 10.5 to 11.0 range.
- STF 1791 – WDS 13568+1426. Listed magnitudes are 9.39 & 10.73. The image suggests that both components are dimmer than the records. An initial estimate suggests magnitudes of 10.0 and 11.3. The UCAC4 values do confirm slightly dimmer magnitudes than the WDS record but still a surprise given the new image. Vmag values are 9.616 and 10.516.
- ROE 74 – WDS 14156+2255. Listed magnitudes are 10.5 and 11.0. The image clearly shows that both components are dimmer than the data; an initial estimate being both, about a full magnitude dimmer. The UCAC4 provides a Vmag for A of 11.42 and an f-mag for B of 12.098.
- BU 1442 – WDS 14257+2338. This 5 component system has listed magnitudes in alphabetic order of 9.87, 10.21, 9.66, 13.06, and 9.90. The image (Figure 1) is very persuasive in that all components except D are within 0.3 mags of each other. This would suggest that the 10.21 listing for the magnitude of "B is incorrect. We estimate B to be mag. 9.8. The UCAC4 Vmag values for A through D are, 9.701, 9.921, 9.664, and 13.065. Figure 2 shows POSS I and POSS 2 images of this system.
- ALI 131 – WDS 14516+3453. Listed magnitudes are 9.69 and 12.3. With an exposure of 30 seconds and ISO of 800, my imaging setup has great difficulty resolving stars above magnitude 12.0. Bootes was high in the sky at the time ALI 131 was imaged, so the reduced atmosphere has provided some surprises. We estimate the secondary to be in the mag. 11.8 range. The UCAC4 data provides a Vmag for the primary of 9.657 with a formula gen-

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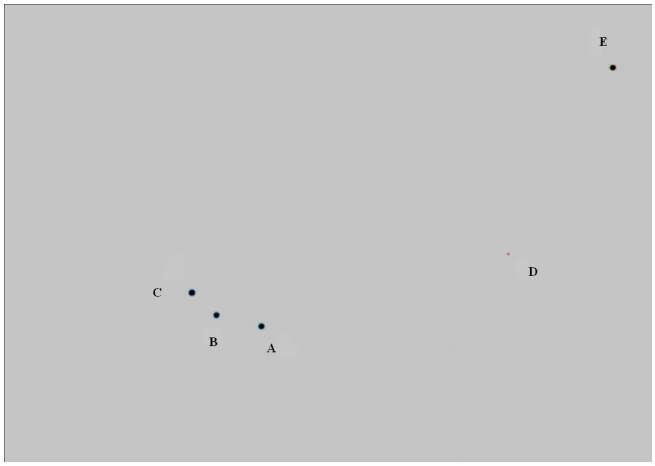

Figure 1. BU 1442 (2016)

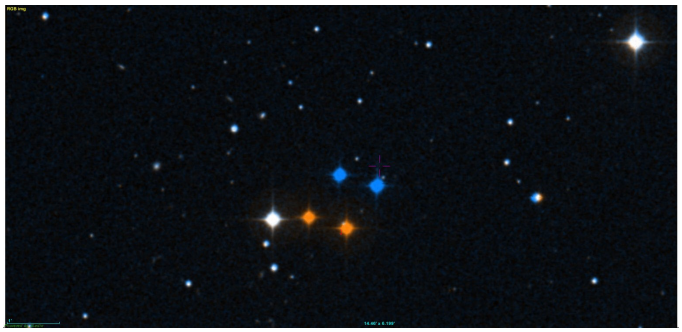

Figure 2. BU 1442 – POSS I (1950 in blue) to POSS II (1993 in orange). Only the components A and B move with common proper motion, while the other components show little to no motion.

erated Vmag for the secondary of 11.950.

- HLD 120 – WDS 14527+0746. Listed magnitudes are 8.05 & 10.84. The image readily supports the magnitude of the primary but the data for the secondary is suspect. Initial estimates place the magnitude for "B" in the 11.7 range. The UCAC4 confirms the estimate with a Vmag of 8.046 for "A" and a formula generated Vmag for "B" of 11.61.
- COU 101 – WDS 14537+2321. Listed magnitudes are 8.65 and 12. The data for the primary appears to be correct but the lack of any trace of the companion in the image suggests that the magnitude of "B" is in the order of mag. 13.0 or more. UCAC4 provides Vmags of 8.765 and 13.228.
- HJ 243 – WDS 14571+3529. Listed magnitudes are 7.41 & 13.0. Again, the primary reflects the magnitude listed in the WDS. Unlike COU 101 above, the image clearly resolves the companion, suggesting a magnitude in the 12.1 range. As noted earlier, the increased declination angle, in good sky conditions, improves the resolution of the imaging setup. The UCAC4 data provides a Vmag value for the primary of 8.831 which we find surprising. A formula generated Vmag for the secondary is 12.335.
- HJ 2766 – WDS 15086+2507. Listed magnitudes are 5.81 & 10.0. With no other bright stars in the field, the primary appears correct at mag. 5.81. With a magnitude listing of 10.0 and a comfortable separation of 56.4 arc-seconds, I was expecting a very obvious high contrast pair. One is hard pressed to pick up any sign of the companion in the image at a first glance, but careful study of the photograph does reveal the companion. First estimates for the companion would be mag. 12.2. Oddly, once again as with HJ 243, the UCAC4 Vmag value at 8.443 is significantly dimmer than the WDS data. Not surprisingly, the Vmag for the companion is 12.19.
- HJ 567 – WDS 15101+3741. Listed magnitudes are 8.87 & 13.28. The bench mark image settings of a 30 seconds exposure with ISO 800 is resolving clearly, albeit dimly, the companion. Therefore an initial estimate of mag. 12.3 appeared appropriate. The UCAC4, surprisingly, supports the WDS data with Vmags of 9.141 and 13.227.

The preliminary findings for the suspect Corona Borealis systems are summarized below:

- UC 3111 – WDS 16037+3709. Listed magnitudes are 10.2 & 12.8. Once again, the benchmark exposure reveals a tantalizing hint of the dim companion to suggest a magnitude in the 13.0 range. The UCAC4 Vmag for "A" is very close at 10.366 while the formula generated Vmag of 13.179 supports the estimate of a slightly dimmer "B" component.
- SHJ 223 – WDS 16315+0818. Listed magnitudes for this 5 star system listed alphabetically are, 5.87, 11.70, 10.44, 10.35, and 11.90. It is clear from the image (Figure 3) that the magnitude of component "B" has no resemblance to the mag. 11.70 listed in the WDS. A 30 seconds exposure at ISO 1600 generates only the slightest hint of the "B" companion. Initial estimates are therefore in the 13.0+ range. For all other system stars, the WDS data is generally supported by the image. UCAC4 Vmag values in order are 5.791, 13.903, 10.809, 10.249, and 12.167. Both B & E values were generated from the formula.
- KU 53 – WDS 16229+3815. Listed magnitudes are 10.1 & 10.5 suggesting a very equal pair visually. The image tells quite a different story with a very noticeable ΔM, likely in the 1.0 range. Estimates based on the image are 10.4 and 11.4. The UCAC4 paints a slightly brighter picture but supports the

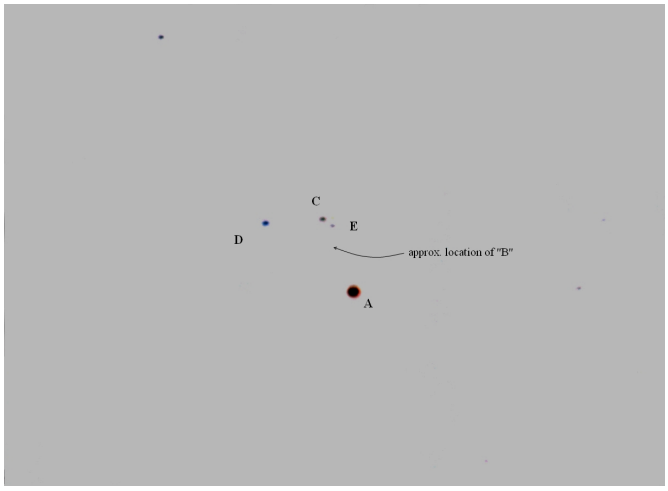

Figure 3. SHJ 223

estimated contrast in magnitudes. Values are 9.987 and 11.179 with the companion being formula generated.

Further Research

Images taken with iTelescope remote telescopes were in a first step plate solved and stacked with AAVSO VPhot. The stacked images were then plate solved with Astrometrica with URAT1 reference stars with Vmags in the range 10.5 to 14.5 mag. The RA/Dec coordinates resulting from plate solving with URAT1 reference stars in the 10.5 to 14.5 mag range were used to calculate Sep and PA using the formula provided by R. Buchheim (2008). *Err_Sep* is calculated as

$$Err\_Sep = \sqrt{dRA^2 + dDec^2}$$

with *dRA* and *dDec* as average RA and Dec plate solving errors. *Err_PA* is the error estimation for PA calculated as

$$Err\_PA = \arctan\left(\frac{Err\_Sep}{Sep}\right)$$

in degrees assuming the worst case that *Err_Sep* points at a right angle to the direction of the separation means perpendicular to the separation vector. Mag is the photometry result based on UCAC4 reference stars with Vmags between 10.5 and 14.5mag. *Err_Mag* is calculated as

$$Err\_\mathrm{Mag} = \sqrt{dVmag^2 + \left[2.5\log_{10}\left(1+1/SNR\right)\right]^2}$$

with *dVmag* as the average *Vmag* error over all used reference stars and *SNR* is the signal to noise ratio for the given star. The results are shown in Tables 1 and 2.

3. Summary

In most cases the suspected magnitude issues were confirmed by the photometry results.

Tables 3 and 4 present all the WDS, UCAC4, and the occasional piece of Nomad data for the magnitudes of the listed objects compared with our photometry results.

Acknowledgements

The following tools and resources have been used for this research:

- Washington Double Star Catalog
- iTelescope
- iT18: 318mm CDK with 2541mm focal length. CCD: SBIG-STXL-6303E. Resolution 0.73 arcsec/pixel. V-filter. Located in Nerpio, Spain. Elevation 1650m
- iT24: 610mm CDK with 3962mm focal length. CCD: FLI-PL09000. Resolution 0.62 arcsec/pixel. V-filter. Located in Auberry, California. Elevation 1405m
- AAVSO VPhot
- AAVSO APASS
- UCAC4 catalog via the University of Heidelberg website
- Aladin Sky Atlas CDS, SIMBAD, VizieR, UCAC4, Nomad, URAT1, GAIA
- 2MASS All Sky Catalog
- AstroPlanner
- Astrometrica

References

Buchheim, Robert, 2008, "CCD Double-Star Measurements at Altimira Observatory in 2007", *Journal of Double Star Observations*, **4**, 27-31.

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Table 1: Photometry and astrometry results for the selected Boo objects. Date is the Bessel epoch 2016 and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of the used telescopes: See Acknowledgements).

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date 2016	N	Notes
SHJ 169	A	13 54 41.000	18 23 45.76	0.10	0.09	114.033	0.135	85.070	0.068	5.677	0.075	38.15	0.07	.360	5	1) 2) 3)
	B	13 54 48.982	18 23 55.56							10.348	0.071	119.79				
STF1791	A	13 56 49.185	14 25 58.66	0.10	0.07	21.002	0.122	158.793	0.333	9.400	0.081	90.09	0.08	.356	5	4)
	B	13 56 49.708	14 25 39.08							10.609	0.083	51.50				
ROE 74	A	14 15 39.011	22 54 45.20	0.05	0.07	6.991	0.086	288.083	0.705	11.749	0.032	96.34	0.03	.360	5	5)
	B	14 15 38.530	22 54 47.37							12.223	0.034	70.64				
BU 1442	A	14 25 44.427	23 36 43.37	0.17	0.14	45.319	0.220	74.409	0.278	9.699	0.072	73.70	0.07	.356	4	6) 7)
	B	14 25 47.603	23 36 55.55							9.964	0.072	65.69				
BU 1442	A	14 25 44.427	23 36 43.37	0.17	0.14	75.370	0.220	62.450	0.167	9.699	0.072	73.70	0.07	.356	4	6) 8)
	C	14 25 49.289	23 37 18.23							9.440	0.071	84.19				
BU 1442	A	14 25 44.427	23 36 43.37	0.17	0.14	249.852	0.220	284.484	0.051	9.699	0.072	73.70	0.07	.356	4	6) 8) 9)
	D	14 25 26.826	23 37 45.86							12.960	0.109	12.59				
ALI 131	A	14 51 38.779	34 52 34.23	0.04	0.05	8.850	0.064	112.382	0.415	9.608	0.081	85.34	0.08	.356	4	6)
	B	14 51 39.444	34 52 30.86							11.867	0.088	28.65				
HLD 120	A	14 52 39.171	07 46 24.64	0.05	0.05	15.576	0.071	225.072	0.260	7.999	0.070	287.83	0.07	.360	5	5) 2) 8)
	B	14 52 38.429	07 46 13.64							11.606	0.071	116.74				
COU 101	A	14 53 40.590	23 20 42.93	0.17	0.08	63.317	0.188	71.939	0.170	8.647	0.080	132.40	0.08	.356	5	4) 2) 8) 9)
	B	14 53 44.961	23 21 02.56							13.194	0.108	14.52				
HJ 243	A	14 57 06.839	35 29 24.16	0.08	0.05	17.951	0.094	23.199	0.301	7.258	0.090	201.10	0.09	.356	5	4) 2)
	B	14 57 07.418	35 29 40.66							12.363	0.105	19.49				
HJ 2766	A	15 08 35.562	25 06 31.30	0.07	0.09	57.644	0.114	330.559	0.113	5.852	0.060	291.71	0.06	.360	5	5) 2)
	B	15 08 33.476	25 07 21.50							12.226	0.064	51.38				
HJ 567	A	15 10 07.627	37 41 26.20	0.14	0.12	33.818	0.184	14.971	0.312	8.794	0.090	119.43	0.09	.356	3	4) 2) 9)
	B	15 10 08.363	37 41 58.87							13.262	0.126	11.90				

Table 1 Notes:

1. iT24 stack 5x1s
2. A too bright for reliable photometry
3. Astrometry results influenced by significant proper motion of A and B in similar direction but with very different speed
4. iT18 stack 5x3s
5. iT24 stack 5x3s
6. iT18 stack 4x3s
7. Very solid CPM pair with ident pm vector direction and very similar pm vector length. PM/yr ~1,365 arcseconds
8. Astrometry results influenced by high proper motion speed of A
9. SNR B<20

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Table 2. Photometry and astrometry results for the selected CrB objects. Date is the Bessel epoch 2016 and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of the used telescopes: See Acknowledgements).

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date 2016	N	Notes
KU 53	A	16 22 54.091	38 15 27.25	0.03	0.04	5.233	0.050	48.750	0.547	10.388	0.050	161.12	0.05	.412	5	1)
	B	16 22 54.425	38 15 30.70							11.106	0.051	114.45				
SHJ 223	A	16 16 44.819	29 09 00.50	0.02	0.02	53.797	0.028	23.082	0.030	6.668	0.030	272.99	0.03	.412	5	1) 2)
	B	16 16 46.429	29 09 49.99							13.911	0.039	42.17				
SHJ 223	C	16 16 47.225	29 10 22.11	0.02	0.02	63.020	0.028	92.246	0.026	10.776	0.031	176.27	0.03	.412	5	1)
	D	16 16 52.033	29 10 19.64							10.208	0.030	210.52				
SHJ 223	A	16 16 44.819	29 09 00.50	0.02	0.02	76.647	0.028	15.443	0.021	6.668	0.030	272.99	0.03	.412	5	1) 2)
	E	16 16 46.377	29 10 14.38							12.076	0.032	99.70				
SHJ 223	A	16 16 44.819	29 09 00.50	0.02	0.02	123.265	0.028	50.057	0.013	6.668	0.030	272.99	0.03	.412	5	1) 2)
	D	16 16 52.033	29 10 19.64							10.208	0.030	210.52				
SHJ 223	A	16 16 44.819	29 09 00.50	0.02	0.02	87.485	0.028	21.117	0.019	6.668	0.030	272.99	0.03	.412	5	1) 2)
	C	16 16 47.225	29 10 22.11							10.776	0.031	176.27				
SHJ 223	C	16 16 47.225	29 10 22.11	0.02	0.02	13.532	0.028	235.163	0.120	10.776	0.031	176.27	0.03	.412	5	1)
	E	16 16 46.377	29 10 14.38							12.076	0.032	99.70				
UC 311	A	16 03 42.627	37 08 57.56	0.02	0.02	9.582	0.028	15.117	0.169	10.380	0.021	210.53	0.02	.412		1)
	B	16 03 42.836	37 09 06.81							13.791	0.031	45.84				

Table 2 Notes:

1. iT24 stack 5x3s
2. A too bright for reliable photometry

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Table 3. Comparison catalog Boötes Data with Photometry Results (in red for large delta)

Bootes - Suspect Systems							
WDS ID	Co-ordinates	Mag. A	Mag. B/C/D	Mag. A	Mag. B/C/D	Mag. A	Mag. B/C/D
		Currently Listed WDS Magnitudes		Vmag. Values from UCAC4 (f)=Vmag from formula , (N)=Nomad (N,f)=Vmag. from Nomad Values using formula		Photometry results (# = too bright for reliable result)	
SHJ 169	13547+1824	2.72	9.99	8.308	10.309	#	**10.348**
STF1791	13568+1426	9.39	10.73	9.616	10.516	9.400	10.609
ROE 74	14156+2255	10.5	11.0	11.42	12.098 (f)	**11.749**	**12.223**
BU 1442AB	14257+2338	9.87	10.21	9.701	9.921	9.699	**9.964**
BU 1442AC	14257+2338	9.87	9.66	9.701	9.664	9.699	9.440
BU 1442AD	14257+2338	9.87	13.06	9.701	13.056	9.699	12.960
ALI 131	14516+3453	9.69	12.3	9.657	11.950 (f)	9.608	**11.867**
HLD 120	14527+0746	8.05	10.84	8.046	11.61 (f)	7.999	**11.606**
COU 101	14537+2321	8.65	12	8.765	13.228	8.647	**13.194**
HJ 243	14571+3529	7.41	13.0	8.831	12.335 (f)	7.258	**12.363**
HJ 2766	15086+2507	5.81	10.0	8.443	12.19	5.852	**12.226**
HJ 567	15101+3741	8.87	13.28	9.141	13.227	8.794	13.262

Table 4. Comparison catalog Corona Borealis Data with Photometry Results (in red for large delta)

Corona Borealis - Suspect Systems							
WDS ID	Co-ordinates	Mag. A	Mag. B/C/D	Mag. A	Mag. B/C/D	Mag. A	Mag. B/C/D
		Currently Listed WDS Magnitudes		Vmag. Values from UCAC4 (f)=Vmag from formula , (N)=Nomad (N,f)=Vmag. from Nomad Values using formula		Photometry results (# = too bright for reliable result)	
UC 3111	16037+3709	10.2	10.366	13.179 (f)	12.8	10.380	**13.791**
SHJ 223AB	16315+0818	5.78	11.70	5.791	13.903(f)	#	**13.911**
SHJ 223AC		5.78	10.44	5.791	10.809	#	10.776
SHJ 223AD		5.78	10.35	5.791	10.249	#	10.208
SHJ 223AE		5.78	11.90	5.791	12.167(f)	#	**12.076**
KU 53	16229+3815	10.1	10.5	9.987 10.405(N)	11.179(f) 11.182(N,f)	10.388	**11.106**