Photometry of Faint Wide Doubles in Hydra

Wilfried R.A. Knapp

Vienna, Austria
wilfried.knapp@gmail.com

Chris Thuemen

Double Star Imaging Project
Pembroke, Ontario, Canada
thuemen_cm@yahoo.ca

Ross Gould

Double Star Notes, Australian Sky & Telescope
Canberra, ACT, Australia
rgould1792@optusnet.com.au

Abstract: Images of several double stars in Hydra published on the "Double Star Imaging Project" Yahoo Group page suggest magnitude issues compared with the corresponding WDS catalog data per end of 2014. Taking additional images with V and B filters enabled photometry for these pairs, suggesting significant corrections to the old data in WDS.

Introduction

During the evaluation of "Double Star Imaging Project" images made in Hydra, we found several double star systems displaying stellar magnitudes that were noticeably different from what one would expect based on the data listed in the WDS catalog.

The "Double Star Imaging Project" has been underway for approximately 4 years. Having imaged to date approximately 2200 systems with the same equipment setup, it did not take long to establish the limits of stellar magnitude that could be recorded using an exposure range of 20 to 30 seconds. Based primarily on the magnitudes for stars listed in the Washington Double Star Catalog, as well as other recognized sources such as the UCAC4, Tycho and Hipparcos surveys, the imaging system employed for this project is capable of recording, with a very high percentage, stars with magnitudes in the 11.5 to 11.8 range. This is very much dependent on having adequate component separations so that significantly brighter stars do not overwhelm the dimmer components, typically in the 5.0+ arc-second range. Once magnitude 12 was reached, stars were not recorded unless exceptional seeing and transparency conditions were encountered, or an exposure was pushed to durations of 45 to 60 seconds. Ultimately, what appeared to be a limiting factor resulted in a very useful tool for estimating star magnitudes. If a star is present in an image, it has to be brighter than +12 mag and if a star is not present it is most probably fainter than 12 mag. Having discovered what appeared to be discrepancies in the magnitude data contained in the WDS, the UCAC4 catalogue was accessed via Aladin to confirm our initial findings.

Therefore, based on these conditions, the first impressions from the initial observation and review of the raw images follow.

STF 1213 – The magnitude of the secondary as listed in the WDS is 12.5. The raw image clearly shows the companion to the northwest. Initial estimate based on the image is 11.5. Tycho shows +10.009mag for A and UCAC4 +9.82Vmag for A and +11.675mag model fit for B, no Vmag.

WZ 12 – The WDS lists the secondary's magnitude at 12. The unprocessed image of 30 seconds duration

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has a well defined secondary to the south south-east clearly brighter than 12th magnitude. Initial estimate based on the image is 11.3. Tycho shows +9.617mag for A and UCAC4 +11.321Mag model fit for B.

ROE 87 – The WDS indicates that we should be seeing a pair of near equal brightness stars, magnitudes of 9.8 and 9.9. The image suggests some Δm and A & B component magnitudes of 11.3 and 11.9 (see Figure 1). UCAC4 shows +11.163 Vmag for A and +12.261 mag model fit for B, no Vmag.

BAL 505 – Component magnitudes are listed as 10 and 11.3. The new image clearly records much dimmer stars. Initial estimates are 11.5 and 12.2. UCAC4 shows +11.49Vmag for A and +12.888mag model fit for B, no Vmag.

BAL 506 – This Baillaud pair was recorded on the same image as BAL 505. Both components are significantly brighter than BAL 505. The WDS data provides A & B magnitudes of 8.8 and 10.1. Estimates based on the new image are 10.0 and 11.4. UCAC4 shows +9.776 Vmag for A and +11.252 mag model fit for B, no Vmag.

J 1520 – As I input the RA and DEC co-ordinates into my mount to slew my imaging system to this double, I realized that the secondary was likely to be missed as a result of its listed magnitude of 12.7 and the Δm of 4.74. This would be further hampered by the 6.6 arc-seconds of separation. I was amazed that a 25 second exposure very clearly revealed the secondary with just a slight overlap of the primary and secondary (see Figure 2). Initial magnitude estimate for the secondary is 10.5.

STF 1229 – The WDS data lists component magnitudes of 9.52 and 12.5. Again, I was anticipating that the secondary was beyond the range of my imaging set up. The shortest duration exposure, 20 seconds, very easily revealed the companion. Based on this, a reasonable magnitude estimate for the companion would be 11.3 to 11.5. Summary of WDS data per end 2014 is shown in Table 1.

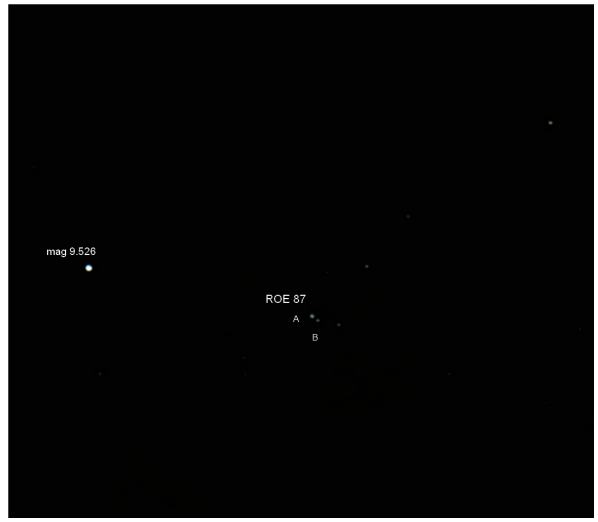

Figure 1. ROE87 with A and B just resolved – both stars seem much fainter than 9.8/9.9mag and B seems much fainter than A so there is obviously some Δm

Figure 2. J1520 with B easily resolved – has therefore to be far brighter than magnitude 12.7.

Table 1: WDS 2014 values as of year end 2014 for all objects

Name	WDS ID	RA	Dec	Sep	M1	M2	PA
STF1213	08179+0628	08:17:56.561	+06:28:07.701	6.1	10.01	12.5	306
WZ 12	08219-0139	08:21:51.901	-01:38:49.000	8.1	9.62	12	155
ROE 87	08262-0605	08:26:01.209	-05:51:55.100	7.8	9.8	9.9	246
BAL 505	08308-0219	08:30:43.410	-02:19:17.600	11.9	10	11.3	161
BAL 506	08312-0212	08:31:14.329	-02:11:57.700	6.3	8.8	10.1	123
J 1520	08259-0847	08:25:53.311	-08:47:05.100	6.6	7.96	12.7	304
STF1229	08268+0226	08:26:46.829	+02:25:46.700	21.7	9.53	12.5	116

Further Research

To investigate further our initial findings, we concluded that the best approach would be to obtain new images suitable for photometry. From the telescopes available via iTelescope we selected iT9 with location in Australia to have reasonable altitude for objects in Hydra. iT9 offers availability of V and B filter to make photometry in both wave bandwidths, making it possible to calculate the B-V color index. For this telescope transformation coefficients are also given making it possible to adapt the photometry results to the Landolt 1992 standard. Specifications of iT9 are 317mm RCOS with 2331mm focal length, and resolution of 0.8 arcsec/pixel. It is located in Siding Spring, Australia at an elevation 1165m.

The results are shown in Table 2.

Visual Observations

To check the measured values and especially the calculated B-V color index we invited Ross Gould with location in Australia (thus with reasonable altitude for observing objects near the head of the Hydra at this time of the year) to join us with a visual observation report for the objects in discussion:

Because of the relatively faint stars in the list of objects, I observed visually with a 235mm SCT (C9.25) telescope which is housed in a small dome. Although in a suburban location, stars to magnitude ~14 can be seen on moonless nights. My first observing run, however, was only two days before Full Moon. Despite this it was possible to observe even the faintest stars involved. Follow-up observations were made on two darker nights after Full Moon, one with the C9.25, and one with a Takahashi Mewlon 210".

The results night by night were fairly consistent. And they demonstrated the usual experience that estimates of delta-m tend to be better than outright estimates of magnitudes. There was no systematic difference between the 235mm and 210mm apertures except that the smaller aperture showed all doubles fainter. Because they have nearly equal focal lengths, the same eyepieces were used with almost the same magnifications.

At the time of observing I did not have the new photometry data, only the old data from the WDS, which I knew was problematic. This was to avoid bias in visual observing. The following summary notes are based mainly on my two nights of darker sky while making some use of the results from the night of bright moon.

STF 1213: 235mm: The primary was of middling brightness, the companion quite a lot dimmer, I estimat-

Table 2: Photometry results based on iT9 images used with AAVSO VPhot. M1 = transformed measured magnitude of primary. M2 = transformed measured magnitude of secondary. B-V M1 = color index for primary. B-V M2 = color index for secondary. Date = Bessel period of observation. N = number of images used in a stack for photometry

Name	WDS ID	M1	M2	B-V M1	B-V M2	Date	N	Notes
STF1213	08179+0628	9.842	11.486	0.387	0.546	2015.320	5	1)
WZ 12	08219-0139	9.525	11.398	0.493	0.853	2015.320	4	2)
ROE 87	08262-0605	11.399	12.319	0.239	0.619	2015.323	14	3)
BAL 505	08308-0219	11.434	12.985	0.047	0.194	2015.322	6	4)
BAL 506	08312-0212	9.908	11.261	0.537	0.629	2015.323	8	5)
J 1520	08259-0847	7.816	10.383	0.689	0.547	2015.435	4	6)
STF1229	08268+0226	9.509	11.777	0.397	0.973	2015.437	5	7)

Notes:

1. Transformation influence negligible, B-V color index puts both components in the yellow-white color range
2. Transformation influence in the lower second digit range, primary yellow-white and secondary reddish yellow
3. Transformation influence negligible, primary rather white and secondary yellow
4. Transformation influence in the lower second digit range, both components in the white color range
5. Transformation influence negligible, both components in the yellow color range
6. Transformation influence negligible. Both components in the yellow color range
7. Transformation influence for B in the lower second digit range and for A negligible. Primary yellow-white and secondary reddish yellow

ed ~1.5 magnitudes. The primary had a slightly yellowish tone. These details were confirmed with 210mm. This pair, like the others, was better seen at 196x/200x than at ~100x or ~127x. The secondary star was clearly brighter than the WDS mag 12.5, and the delta-m less than 2.5.

WZ 12: This one was seen at ~100x with both telescopes as an easy though not bright pair, significantly uneven - my delta-m estimates were ~1.5 (210mm) and nearly 2 (235mm). At about 200x it was an easy and obvious pair, the primary a dull yellow color with 235mm, vaguely yellowish (210mm). I should mention my impression that the 210mm lost around 0.5 magnitude compared to 235mm, whereas based on aperture it should have been half that.

ROE 87: This was in some respects the most interesting of the doubles. First, because there was a significant discrepancy between the WDS positions for approximate and precision. As well, it was plainly dimmer and less equal through the telescope than the old magnitude data (recorded in WDS) suggested. My estimate of delta-m was a bit more than 0.5; photometry suggests close to 1.0. It was a rather dim little pair with 235mm, though well seen at 196x. With 210mm it was clear that the stars were dimmer than I'd thought with 235mm, and much dimmer than the WDS magnitudes.

History note on ROE 87: E.D. Roe (1859-1929) was an American observer who had a 6.5-inch refractor of his own, though some of his observing was at Yerkes Observatory. This double was discovered with the 6.5-inch in 1915 [Roe, 1915] and there's a note that "exact position not yet determined". It appears the WDS designation (approximate position) is from Roe's discovery position as precessed to J2000 for the declination, with a small change for RA. His original magnitude estimates likewise survived into the present in the WDS. Roe did well to measure such a faint pair with only 6.5-inch aperture even though the separation is easy. His magnitude estimates are a surprise, much too bright, and far too similar for a pair that visually has an obvious difference. His discovery note is in *Astronomische Nachrichten*, vol. 202, pp.99ff.

BAL 505: Very dim pair with 210mm, better seen with 235mm; in both, ~200x was better than ~100x. My best estimate of delta-m was about 1-1.5. The B star was very faint with 210mm, much easier with 235mm; with the latter the delta-m looked closer to 1.0. The stars were obviously much fainter than the WDS numbers.

BAL 506: Seen double at 100x; again better at ~200x. In both telescopes I estimated delta-m around 1, and thought the magnitudes fainter than WDS, though not outright faint. Visually, I thought the secondary star a bit brighter than the new photometry shows. There was a hint of color tone in the brighter star, 'not white', but no more than that.

J 1520: Knowing Jonckheere's reputation for estimating magnitudes brighter than is the case, I wondered just how faint the B star would be, listed at 12.7 in WDS. This one was observed only with 210mm, having been added to the list later. Seen double at 100x, it was a passably bright deep yellow primary with a little speck of a secondary star. More power improved the view (127x, 200x) but did not make the secondary look brighter, as happens with some doubles. The secondary was clearly much brighter than the WDS magnitude 12.7. I thought it possibly around 11.5, so the photometry giving ~10.4 was a surprise.

STF 1229: Not a difficult pair with 210mm. A moderate star with fairly wide lesser companion, and at 200x I estimated the magnitudes as ~9.5 and ~11.5, so delta-m around 2. I saw the secondary star brighter than the WDS mag 12.5, therefore delta-m less than the WDS numbers give. No particular colour impression of the brighter star; off-white perhaps. More aperture would have been useful here.

As would be expected, there was no color impression of the fainter stars in the doubles. A much larger telescope might allow enough light for the eye to see color; the 235mm aperture did not.

Summary

First impressions regarding questionable magnitude data for the objects in Table 1 were completely confirmed by photometry – all pairs seem to have quite different mag values than current WDS (end of 2014) listed, at least for the B component but several times also for A.

While it was an interesting procedure to not only take images with V- but also with B-filter, thus being able to calculate the B-V color index, the transformation results (with only minor corrections of mag values well within the error range of the measurements without transformation) seem not worth the effort if not aiming for highest possible accuracy. On the other hand the knowledge of the B-V color index seems highly relevant for visual observing, as while color sensitivity might be quite individual, on average the blue-white stars are easier to resolve than

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stars with reddish hues – and this is certainly interesting when it comes to resolving double stars.

The visual observation reports show the measured B-V color index was in most cases confirmed by visual observation for the brighter primary but it seems impossible to get a visual color impression for stars fainter than mag 10. The question remains if an "invisible" color hue can still be an influencing factor for resolution. But at least in 2 cases the reddish B-V color index seems to have played no role for resolving the companion and estimating its magnitude. As the given set of objects did not offer extreme contrasts like blue-white primary and red secondary or the other way around, final conclusions are not possible, so there is room for further investigation.

With some exceptions the visual magnitude impression from images or from direct visual observation are fairly accurate, but it seems clear that both can only give a good reason for checking magnitudes with photometry as surprising differences are always possible. This has certainly to do with different color perception in unfiltererd CCD‘s as well as in visual observation versus images taken with a V-filter – the use of a V-filter might not be considered an exact equivalent with visual observation but it gives at least a standard to determine visual magnitudes far more accurately than the best estimates an unaided visual observer can achieve using a telescope.

A summary of the findings is given in Table 3.

Table 3: Summary of findings compared with Tycho 2 and UCAC4 catalog. UCAC4 value with V means visual magnitude (V filter) usually based on APASS and f means model fit magnitude calculated from J- and K-band mags. B-V: w=white, y=yellow, r=red

Object	WDS Mag	Visual Impression from Images	Tycho2 Mag	UCAC4 Mag	Photo-Metry Mag	B-V	Results of Visual Observations
STF1213A	10.01	Estimate for B 11.5mag	10.009	9.82V	9.842	yw	Slightly yellowish primary. B is brighter than 12.5, delta-m ~1.5, so about m10 and 11.5
STF1213B	12.5		-	11.675f	11.486	yw	
WZ 12A	9.62	Estimate for B 11.5mag	9.617	9.561V	9.525	yw	Dull yellow colour. Secondary certainly brighter than WDS mag, and delta-m less, around 1.5 or a little more
WZ 12B	12		-	11.321f	11.398	yr	
ROE 87A	9.8	Image suggests some Δm and magnitudes of 11.3 and 11.9	-	11.163V	11.399	w	Much fainter than WDS mag, and delta-m estimated 0.5+
ROE 87B	9.9		-	12.261f	12.319	y	
BAL 505A	10	Estimate A/B 11.5/12.2mag	-	11.490V	11.434	w	Both mags much fainter than WDS, perhaps 11+ and 12.5. Delta-m around 1-1.5
BAL 505B	11.3		-	12.888f	12.985	w	
BAL 506A	8.8	Estimate A/B 10.0/11.4mag	10.056	9.776V	9.908	y	Hint of colour tone, not white; fainter than WDS; perhaps 9.5+ and 10.5+; delta-m around 1.0
BAL 506B	10.1		-	11.252f	11.261	y	
J 1520A	7.96	Estimate for B 10.5mag	7.961	8.758V	7.816	y	Fairly bright and deep yellow primary. Secondary brighter than WDS mag; perhaps 11.5, though didn't look as bright as ~10.4
J 1520B	12.7		-	-	10.383	Y	
STF1229A	9.53	Estimate A/B 11.3/11.5mag	9.533	9.546V	9.509	yw	Off-white primary? Secondary brighter than WDS mag; delta-m around 2.0
STF1229B	12.5		-	11.546f	11.777	yr	

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- Washington Double Star Catalog
- iTelescope
- AAVSO VPhot
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- UCAC4 catalog via the University of Heidelberg website
- Aladin Sky Atlas CDS, SIMBAD, VizieR
- 2MASS All Sky Catalog
- AstroPlanner V2.2

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biography of Roe at www.pme-math.org/organization/historyharwood.html