

## Measurements of BU109 in Cetus

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**Abstract:** Images of BU109 in Cetus raised questions about magnitudes and positions of components as listed in the WDS catalog, the most valuable resource for double star observers. Further research suggested changes for magnitudes and positions and questioned whether the most recent listed precise measurements are always the most precise measurements.

### Introduction

An image of BU 109 taken by Chris Thuemen in August 2012 and only recently presented on the *Double Star Imaging Project* Yahoo Group Site suggested magnitudes and positions of components B and C to be very different from the then current WDS data.

For illustration purposes, we show the relevant part of this image in negative grey scale and enhanced contrast demonstrating the components being very closely aligned in a straight line (Figure 1). A summary of WDS 2014.96 data is given in Table 1.

For comparison, the data of the corresponding UCAC4 objects:

BU109 B: UCAC4-368-000777 +11.092mag model fit and 11.068 aperture photometry, no Vmag. These values indicate that the WDS data might need a correction for the magnitude of component B

BU109 C: UCAC4-368-000778 +11.246mag model fit, +11.223mag aperture photometry and 10.696Vmag. While the latter value seems somewhat questionable,

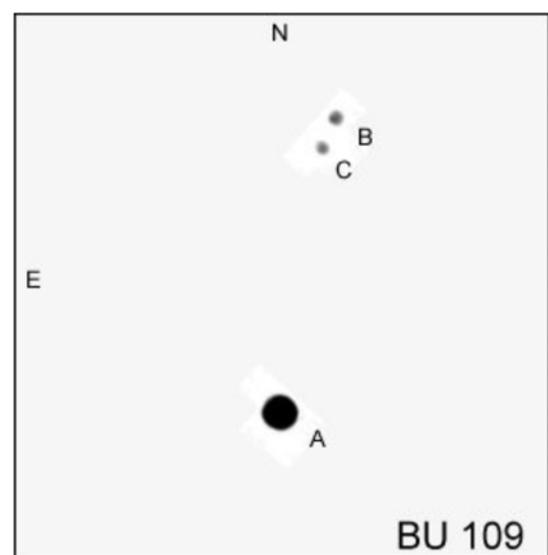


Figure 1. BU 109 (grey scale negative with gamma correction)

## Measurements of BU109 in Cetus

Table 1: WDS 2014.96 values for BU109

Name	WDS ID	RA	Dec	Sep	PA	M1	M2
BU 109AB	00405-1631	00:40:28.560	-16:30:59.800	97.5	356	6.6	9.1
BU 109AC	00405-1631	00:40:28.560	-16:30:59.800	94.9	355	6.6	9.4
BU 109BC	00405-1631	00:40:27.740	-16:29:14.503	11.7	160	9.1	9.4

these values indicate that the WDS data might need a correction for the magnitude of component C.

The image taken by Chris Thuemen, as well as the DSS and 2MASS images, show clearly that the components A, B, and C are more or less in a straight line. If the separation of 11.7" for BC is correct, then at least one of the separations AB or AC is in error.

Regarding separation AB or AC: as the WDS catalog includes position for A (in object AB) as well as for B (in object BC) it is easy to calculate separation and PA based on the formula provided by R. Buchheim (2008). Separation AB, based on this formula, is therefore 106.46" and PA is 351.53° - so the evidence for the separation error AB was contained in the WDS data.

## 2. Further Research

### 2.1 Additional images

To investigate further our initial findings, we concluded that the best approach would be to obtain a new image suitable for photometry and astrometry.

A single frame image of a 10 s exposure was taken with an online 320mm f/9.3 RC telescope having a resolution of 0.8 seconds per pixel and equipped with a V-filter, located in Siding Spring, Australia. Photometry was based on several UCAC4 Vmag (APASS) listed stars within the field of the double star system for the purpose of comparing and checking the new magnitude values against those listed in the UCAC4 catalog. The resulting values are included in Table 2.

In Table 3 we list the UCAC4 RA/Dec coordinates for

the BU109 components.

Using the formula provided by R. Buchheim (2008), new separation and position angles were calculated (Table 4) based on the UCAC4 values which are assumed to be the currently most precise available coordinates.

The UCAC4 based results in Table 4 are within a reasonable margin of error and in line with the estimated astrometry results based on the iTelescope image in Table 2, while the WDS catalog data, and in particular that for AB, is quite different and obviously in error.

In the next step we presented these findings to the USNO and suggested magnitude changes for BU109 B and C as well as a correction of separation AB.

This resulted in the following WDS updates in changes of estimated magnitudes for B to +10.4mag and C to +10.7mag and of separation AB to 105.6".

### 2.2 Research in the history of BU109

First, with regard to the apparent error regarding the separation of either AB or AC as shown in Table 1, let's look at the AB separations listed in the WDS text file for BU 109. The 2003.809 separation of 97.48" for AB (shown in Table 1) stands out as being significantly closer than any of the prior measurements. When we discard the three most anomalous measures in the text file (the 1980.000 separation of 120", the 1990.761 separation of 125.50", and the 2003.809 separation of 97.48"), we get an average separation for AB of 104.05" from the other nine measurements.

Table 2: Results based on iTelescope image used with AAVSO VPhot

Name	RA	Dec	M2	M2 Err	Sep	PA	Date	N	Notes
BU 109AB	00:40:28.664	-16:30:59.529	11.130	0.041	106.17	353.22	2015.008	1	1)
BU 109AC	00:40:28.664	-16:30:59.529	11.276	0.041	95.21	354.81	2015.008	1	1)
BU 109BC	00:40:27.806	-16:29:13.838	11.276	0.041	11.31	159.78	2015.008	1	1)

#### Notes:

- Image for photometry taken with a single 10s exposure with telescope iT9 RC 320mm f/9.3 having a 0.8 arcsec resolution per pixel c/w V-filter. Uploaded to AAVSO VPhot and plate solved. RA/Dec coordinates, Separation and PA are estimates calculated with the tools provided by AAVSO VPhot. No photometry done for M1 as the WDS catalog value for BU109A did not appear questionable.

## Measurements of BU109 in Cetus

Table 3: RA/Dec positions based on UCAC4 coordinates

Name	UCAC4 ID	RA	Dec
BU 109A	368-000780	00:40:28.582	-16:31:00.047
BU 109B	368-000777	00:40:27.739	-16:29:14.462
BU 109C	368-000778	00:40:28.009	-16:29:25.153

Next, because all three stars are very close to being in alignment with one another, it should be possible to determine the separation of AC by subtracting the BC separation from the AB separation. When that operation is performed on the data in Table 1, it results in a separation for AC of 85.8", which is in notable disagreement with the 94.9" separation for AC shown in Table 1, as well as with the history of AC.

We can perform the same operation using the WDS data that immediately precedes the Table 1 data which was current at the time Chris Thuemen's image was taken. From the WDS text file, that would be the 1999.637 data for AB and AC, and the 1999.641 data for BC, all of which come from the same source (AJ 146, 76, 2013).

The 1999.637 separation for AB is 105.634" and the 1999.641 measure for BC is 11.393". Subtracting BC from AB, we get a separation of 94.241" for AC.. Looking at the actual 1999.637 measure for AC, we find a separation of 94.91".

In other words, the assumption that the separation of AC can be determined by subtracting BC from AB because all three components are more or less in line, works with the 1999 measures because they're all consistent with each other. It also works with Burnham's 1898.79 measures: 103.05" (AB) minus 11.24" (BC) equals 91.81", which matches well with Burnham's 1898.69 AC separation of 91.90".

The reason that method fails to work with the 2003.809 separation for AB is because the 2003 measure of AB is in error.

Looking further into the history of the AC and BC measures in the WDS text file, we find the measures of both are rather consistent, apart from the first estimates by S.W. Burnham in 1873, which he later improved on with precise readings in 1900.

The first magnitude we have for B is Burnham's estimate of 10 in 1873. It stays in that range until a 1916.84 reading of 12.2 and then drops to a 10.7 reading very quickly as of 1916.85. The magnitude of B then increases to 10.3 in 1917, increases again to 9.4 in 1980, then in 1998 is assigned values of 10.055, 9.770, and 9.726, all coming from 2MASS data. As of

Table 4: Separation and position angle based on UCAC4 coordinates

Name	Sep	PA
BU 109AB	106.28	353.45
BU 109AC	95.25	355.04
BU 109BC	11.37	160.04

1999.641, B was reduced to a magnitude of 11.09, which is the UCAC fit model value (from this source, previously cited: AJ 146, 76, 2013). The 11.09 value is the last magnitude listed in the WDS text file.

However, and this is where confusion enters the picture, the magnitude value we found listed for B in the WDS as of 2014.96 (Table 1) was 9.1. That value is also listed in an earlier version of the WDS downloaded into an Excel spreadsheet on 2014.44. At any rate, as a result of correspondence with the WDS on our initial findings, the magnitude of B was changed to its present value of 10.4.

For C, the pattern is very similar, again starting with an estimate of 10 in 1873 by Burnham, a low point of 12.0 coming on 1916.84, a gradual increase to 9.6 in 1980, followed by 2MASS values in 1998 of 10.155, 9.857, and 9.837. The final reading in the text file is the 1999 UCAC4 value of 11.25, which again is the UCAC fit model value. But, as we found with B, the magnitude value listed for C in the 2014.96 (Table 1) and 2014.44 versions of the WDS was a different number, specifically 9.4. Following our correspondence with the WDS, that value has now been changed to 10.7.

### 3. Conclusions

First impressions were completely confirmed by photometry and astrometry done on a recently taken image. It should be pointed out that the most recent measures listed in the WDS may be in disagreement with prior WDS measures, which is another way of saying the most recent measure may not be the best available measure. Therefore, if questions regarding the precision of current WDS parameters arise, it seems necessary to check first the historical record contained in the WDS text file of such a double in order to determine if there is a quality problem with the last recorded measurement.

### 4. Further Plans

Given that the current WDS data for BU 109 appears to have room for improvement, especially for magnitudes B and C as well as to some degree in RA/Dec coordinates respective Theta and Rho, we intend to

### Measurements of BU109 in Cetus

do further imaging on BU 109 as soon as there is again, sufficient altitude for imaging so that new photometry and astrometry data can be collected to obtain as precise measurements as possible to further improve the WDS data on this object.

#### Acknowledgements

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- Washington Double Star Catalog
- iTelescope
- AAVSO VPhot
- AAVSO APASS
- UCAC4 catalog via the University of Heidelberg website
- Aladin Sky Atlas CDS, SIMBAD, VizieR
- 2MASS All Sky Catalog
- AstroPlanner
- SAOImage DS9

#### References

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

