

# Astrometric and Photometric Measurements of WDS 20210+1028

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**Abstract:** We report CCD astrometric and photometric measurements of the components of the double star system WDS20210+1028 (J 838) using the iTelescope network. Combined with historical observations, our measurements suggest that the existing fitted orbital solution may need to be modified.

## Introduction

This research project was part of an Astronomy Research Seminar offered by Cuesta College, supported by the Institute for Student Astronomical Research (InStAR), and conducted by Boyce Research Initiatives and Education Foundation (BRIEF).

As a proof of concept of our data analysis process, we decided to observe a double star system listed in the Washington Double Star Catalog (WDS) as having a “known” orbital solution. The double star system we selected had to be observable from the Northern hemisphere in June, with an angular separation greater than six arc seconds, and with a listed maximum magnitude difference of 2.5 between the stars. WDS 20210+1028 J838 (hereafter referred to as J 838) satisfied these criteria. Motivations for these criteria are discussed in the telescope selection section below.

Observations of J 838 were first reported by Jonckheere (1912), who found a separation of only 2.9". Robert Jonckheere (1888-1974) discovered and published measurements of over 3000 doubles in a career spanning circa 1908 to 1962, as described in detail by Knapp (2016a). Among others studying J 838 in the twentieth century, Jonckheere published four more observations between 1948 and 1958, which showed the pair's angular separation increasing to 3.5". Jonckheere (1952) noted (translated from French):

“Rapid movement on the arc clearly confirmed. This couple is probably formed by stars of very small mass located about 8 parsecs.”

Another veteran observer, George van Biesbroeck, made micrometer measurements of J 838 in 1966, and published them with measurements of other doubles in van Biesbroeck (1974). From that paper's Introduction:

“The present measures are a continuation of previous ones (Van Biesbroeck 1966). They will be the last ones that I made. My present physical condition precludes further work at the telescope. There has been no change in the method of observing or the telescopes used, except that on my 90th birthday in 1970 I was granted the use of the 90-inch (2.3-m) Steward Observatory telescope on Kitt Peak.”

*Note:* Dr. Van Biesbroeck observed last on the nights of 1974 January 1 and 2 with the 84-inch (2.1m) telescope. He wrote the above paragraph and compiled his last manuscript in the same month just before his 94<sup>th</sup> birthday. Immediately thereafter his health failed rapidly and he died on 1974 February 23.

This final paper, published posthumously, marked the end of a remarkable career in astronomy that began in 1904 (Tenn 2012).

The first calculated orbital elements for J 838 were published by Olević (2002) and give a period of 239.84 years, with periastron occurring at 1967.510. Eccentricity, semi major axis and inclination were given as 0.784, 7.451" and 77.6°, respectively. The Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf et al. 2011) classifies this orbit as category 5, “poorly determined”. The fitted orbit suggests that the pair is

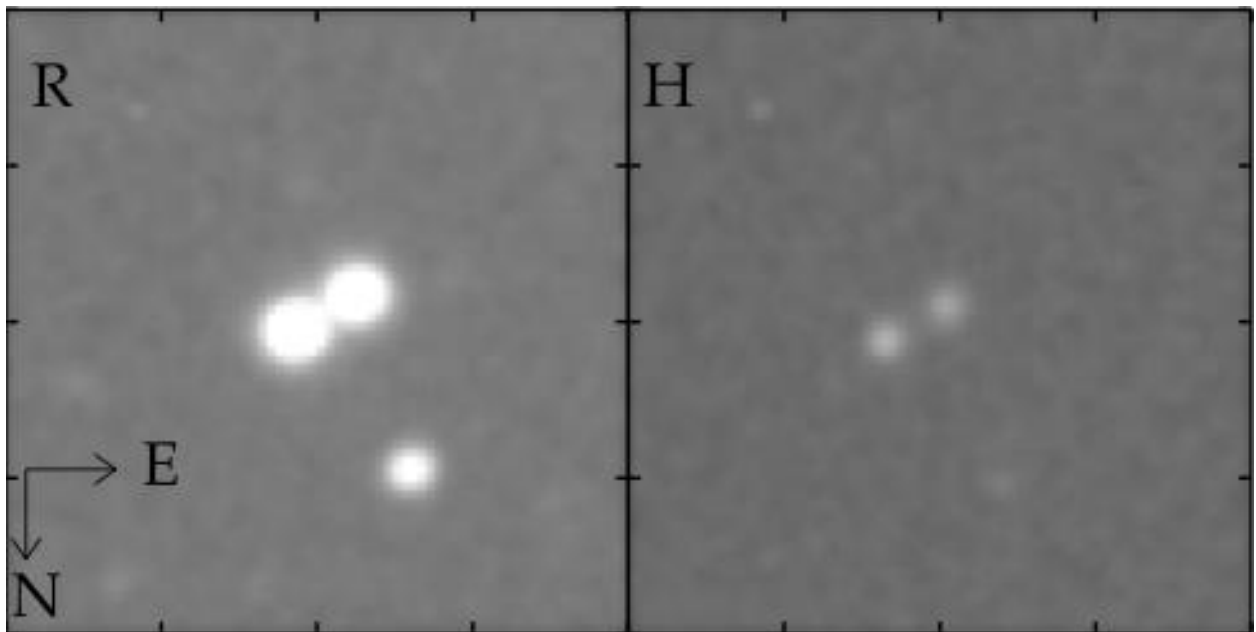
currently (2016) nearing maximum angular separation, which warrants further observations to more accurately constrain its shape and size.

The first CCD measurements (in 2001) were reported by Hartkopf et al. (2013), and the first published results for the system using speckle interferometry were by Mason et al. 2004. Cvetković, and collaborators in Eastern Europe, made seven measurements of J 838 with CCD astrometry between 2009 and 2013 (see Cvetković et al. 2016, and references therein). They also provide relative photometry (B and V band) for the pair:  $\Delta B = 0.35 \pm 0.02$  mag, and  $\Delta V = 0.06 \pm 0.01$  mag.

Three earlier papers in JDSO include measurements of this system. Muller et al. (2006, 2007) report CCD astrometry from 2005, while Knapp (2016b) reported V-band photometry for A and B members of the pair ( $12.54 \pm 0.01$  mag and  $12.58 \pm 0.01$  mag, respectively) based on 3-second exposures using iTelescope in 2015.

### Equipment, Observations and Data Reduction Procedures

CCD images were taken using the T11 and T18 telescopes, part of the iTelescope network. T11 is a CDK Planewave 0.50-m f/6.8 reflector with f/4.8 focal reducer, located in Mayhill, New Mexico. The CCD camera is 4008 by 2672 array with a pixel scale of  $0.81''$ . Additional images were taken using the T18 telescope located in Nerpio, Spain, using a Planewave 0.32-m f/8.0 reflector equipped with a 3072 by 2048 array imaging at a pixel scale of  $1.69''$ . Both cameras can easily resolve separations above five arc-seconds, as shown in Figure 1.



**Figure 1.** Example images of J 838 from the T11 telescope of the iTelescope network. Left: R filter. Right: H-alpha filter. The distance between divisions marked on the edge is  $15''$ .

A total of 22 images were acquired between epoch 2016.499 and 2016.574. Six images were taken with the T11 Telescope: two in R with exposure times of 120 seconds, two in B with exposures of 180 s, and two in hydrogen-alpha with exposure times of 180 s for a total of 6 images. Sixteen images were taken with the T18 Telescope, all with 90 s exposure times: four images each with the red, blue, hydrogen alpha, and no filter (“luminance”). We subsequently excluded the six images taken with the hydrogen alpha filter due to their inferior signal-to-noise ratio. The exposure times provided good signal-to-noise without saturation in the B and R bands which allows for both astrometric and photometric analysis.

The remaining sixteen images were preprocessed (dark and flat subtraction) by the iTelescope data reduction pipeline. MaximDL v6 was used to insert World Coordinate System (WCS) positions into the FITS headers through comparison of the image star field against the Fourth U.S. Naval Observatory CCD Astrograph Catalogue (UCAC4). During this process MaximDL typically used approximately 400 stars out of a database of 3000 stars for this particular star field. Mirametrics Mira Pro x64 was used to compute accurate position angles and separations of the component stars. The A and B stars were identified, marked, and then measured using the algorithms of Mira Pro to find the centroids of each component.

We also performed a photometric analysis of J 838 using our custom IDL (Interactive Data Language) scripts to calibrate our data. A zeropoint magnitude was calculated by querying auxiliary data within each image's field of view and performing relative photometry for each star in the image. The calibration process used 38 stars for B-band photometry in the Tycho Catalog (Høg, 2000) and 66 stars for R-band photometry in the USNO-B1 Catalog (Monet et. al., 2003). The magnitude values were then plotted in a histogram, with each image's list of calculated magnitudes returning a normal distribution. We fitted a Gaussian curve for each histogram and calculated a reduced  $\chi^2$  of about unity. We measure an average magnitude zeropoint for the 20.9 and 19.4 with a standard deviation of 0.4, 0.3 for the B-band and R-band images, respectively.

In order to measure the integrated flux of each star, including J 838, we measured the average FWHM of the PSF ( $\sim 4''$ ) and used this as the aperture size. The uncertainties in this integrated flux was measured through the variation of the background counts. The variation in the background was calculated by measuring the standard deviation of the integrated flux of non-overlapping apertures of the same size, all  $20''$  away from the listed coordinates of each star. We also note that our photometric uncertainties also accounts for the error associated with measuring an average zeropoint magnitude. The result of our photometric analysis are all listed in Table 2.

## Results

Table 1 shows our calculated angular separation and position angle for J 838, and the uncertainty in each. We find a mean and position angle of  $119.27^\circ \pm 0.06^\circ$  and an angular separation of  $6.75'' \pm 0.01''$ , slightly but significantly larger than the 2013.5285 measurement of  $6.64''$  reported by Cvetković et al. (2016), and the largest angular separation for this system measured to date.

WDS 20210+1028 = J 838 Astrometry			
Telescope: (number of images used in each filter)	Epoch 2016.511	$\theta$ (degrees)	$\rho$ (arcseconds)
T11: (2 R), (2 B) T18: (4 R), (4 B), (4 luminance) 16 images total	Mean	119.27	6.75
	Standard deviation	0.21	0.03
	Std. error of mean	0.06	0.01
2013.5285 measurement (Last one previous to this investigation)		118	6.64

*Table 1.* Results of Mira Pro astrometric measurements of WDS 20210+1028.

Table 2 summarizes our new photometry for each star, from the T11 images. We also report differential magnitudes between the components, which we can determine more accurately. Note that our results are in disagreement with those of Cvetković et al. (2016), who report  $\Delta B = 0.35 \pm 0.02$  mag.

WDS 20210+1028 = J 838 Photometry			
Filter	Star A	Star B	$\Delta m$
B image #1	$13.68 \pm 0.07$	$13.42 \pm 0.07$	0.26

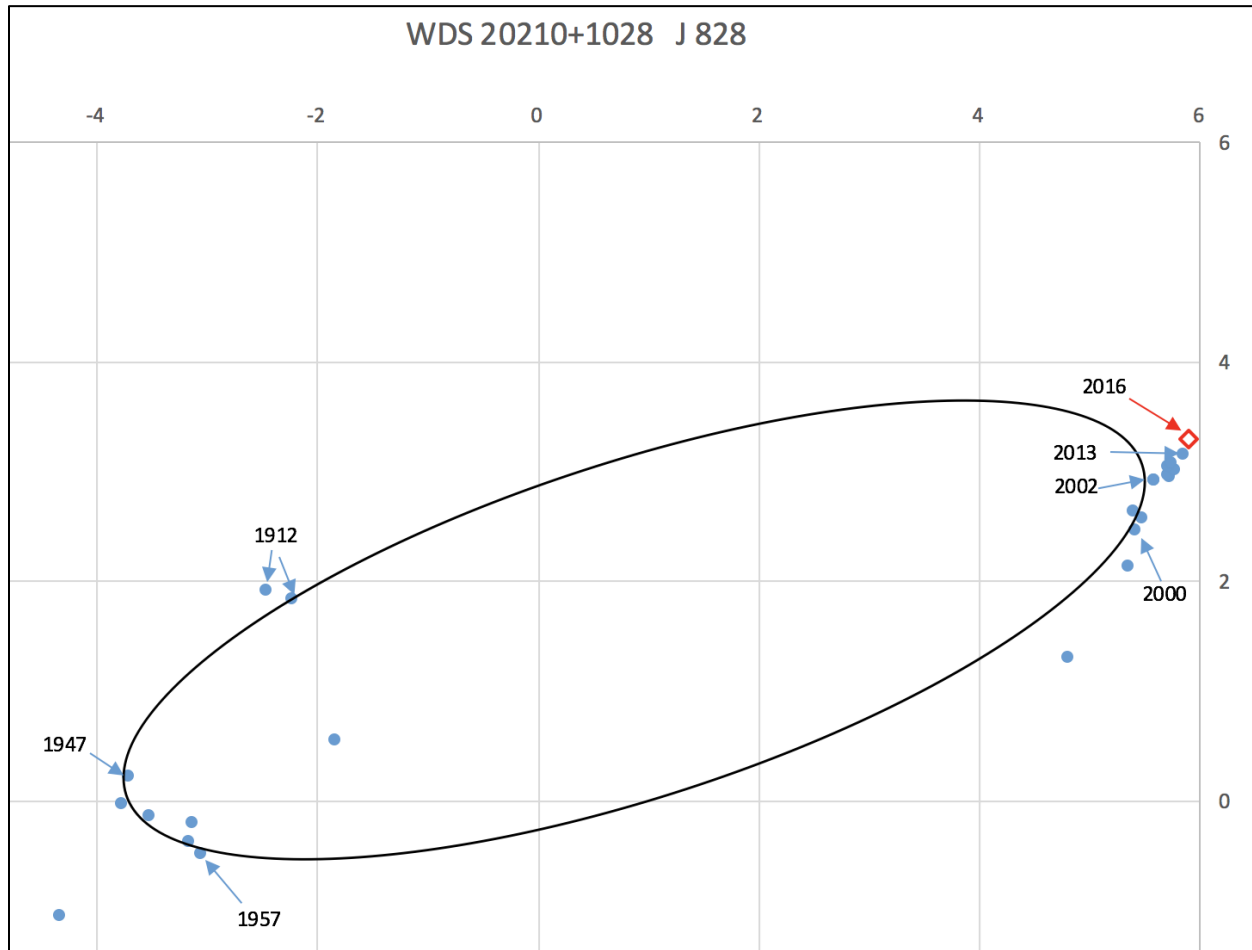
B image #2	$13.63 \pm 0.08$	$13.38 \pm 0.08$	0.25
R image #1	$11.68 \pm 0.03$	$11.91 \pm 0.03$	0.23
R image #2	$11.67 \pm 0.03$	$11.91 \pm 0.03$	0.24

**Table 2.** Photometry results for J 838.

## Discussion

Our astrometry, derived from our sixteen images, are plotted together with historical data from the WDS (Figure 3). Olević's (2002) fitted orbit does not include data points taken since 1995. Inclusion of the more recent measurements suggests that the apparent orbit is more elongated than the model, which predicts that the maximum angular separation occurs close to the current epoch. Further observations over the next decade can reveal whether J 838's angular separation will continue to increase or reach a maximum.

Our own photometry and that of Knapp (2016b) suggests that these stars are either of late spectral type (K or M), or significantly reddened by interstellar dust, or a combination of both. Even if we include the published near-infrared photometry of each component from the 2MASS (Skrutskie et al. 2006), we conclude that only spectroscopy of each component star will be able to separate these effects reliably.



**Figure 2.** XY plot of historical observations of J838 A&B's relative position (solid blue circles). Our result (Table 1) is shown as a red diamond. The included ellipse is a reproduction of the orbit determined by Olević 2002 which included data from 1912 until 2002.

## Conclusions

We obtained astrometry and B and R band photometry in 2016.5 of the double star system J 838 using the T11 and T18 telescopes of the iTelescope network. Our astrometry, combined with other recent observations, shows that this double star system has a maximum angular separation larger than that predicted by the orbital model of Olević (2002). We have demonstrated that this system is fairly easy to observe with small-to-moderate moderate-sized telescopes. Astrometric observations of such systems as their relative path on the sky approaches maximum separation and curvature can improve their fitted orbits. We encourage astronomers to obtain imaging and spectra of J 838's component stars to determine their orbits, spectral types, and metallicities, as a prerequisite to estimating their masses.

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