# First Speckle Interferometry Observation of Binary BU 1292

Meryl Adam[1], Stephanie Roberts[2], Miriam Schenk[3], Carmen VanRonk[3], Tara Loayza[3], Russell Genet[2,4,5], Bobby Johnson[3], Thomas C. Smith[6], and Paul Wren[5]

1. Saint Joseph High School, Santa Maria, California
2. Cuesta College, San Luis Obispo, California
3. Arroyo Grande High School, Arroyo Grande, California
4. California Polytechnic State University, San Luis Obispo
5. University of North Dakota, Grand Rapids
6. Dark Ridge Observatory, Weed, New Mexico

**Abstract** The star BU1292 was observed on October 21, 2013 on the 2.1-meter telescope at Kitt Peak National Observatory. A new position angle of 227.90° and separation of 0.225" was determined. This new data point was found to be slightly divergent from the previously calculated orbit. A new orbital period is calculated that is 3.221 years shorter than the previously calculated orbit.

## Introduction

On the night of October 21, 2013 BU 1292 (WDS 01078+0425) was observed on the 2.1 meter telescope with a speckle interferometry camera at Kitt Peak National Observatory as part of an eight day run. Subsequent to the observations, a group of students from Arroyo Grande High School, Saint Joseph High School, and Cuesta College worked together in a research seminar class to calculate the position angle and separation of the binary. The group chose binary BU 1292 because this star had no previous speckle interferometry observations. BU 1292 has a published orbital period of 285.3 years and a semi-major axis of 139.2 AU.

**Figure 1.** Team of high school authors.

Using data collected on BU 1292 during the observing run at Kitt Peak National Observatory in Arizona, the research seminar class determined the separation and position angle of this gravitationally bound double star and compared these results to past observations. This was the first observation of this binary using speckle interferometry. The discovery and first visual observation of the binary was in 1901 by S. W. Burnham, followed by thirteen more visual observations and one Hipparchus observation, not in that order.

## Calibration

Although full reduction of the Kitt Peak data had not been made yet, REDUC, a speckle autocorrelation program written by Florent Losse (2012), was used to estimate the camera angle, Δ, and pixel scale, E, for the run at Kitt Peak National Observatory. Five fairly wide binaries were observed during the run. For this paper, REDUC, in its "calibration" mode, was used to reduce a single observation of each of the five binaries on the night we observed BU 1292.

Inputs to REDUC were: (1) the interpolated values of position angle, θ, and separation, ρ, based on the January 2013 and 2014 predictions in the Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf and Mason 2013), and (2) the five FITS data cubes, one from each of the five wide binaries. The values used in the calibration, as well as the calibration results and supplemental information on visual magnitudes reported in the Washington Double Star Catalog (Mason et al. 2012), are given in Table 1.

| WDS | V1 | V2 | θ2013 | θ2014 | θ Obs | ρ2013 | ρ2014 | ρ Obs | Seq # | Δ | E |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01532+1526 | 8.75 | | 260.5 | 260.6 | 260.580 | 1.093 | 1.092 | 1.0922 | 942 | -11.66 | 0.01136 |
| 03122+3713 | 8.02 | 8.29 | 125.9 | 125.8 | 125.820 | 2.845 | 2.852 | 2.8506 | 964 | -11.53 | 0.01177 |
| 03362+4220 | 8.84 | 9.54 | 342.7 | 343.5 | 343.342 | 0.724 | 0.722 | 0.7224 | 983 | -11.02 | 0.01216 |
| 04041+3931 | 7.38 | 9.35 | 54.6 | 54.2 | 54.279 | 1.502 | 1.52 | 1.5165 | 1002 | -11.36 | 0.01119 |
| 23595+3234 | 6.47 | 6.72 | 338.2 | 338.9 | 338.762 | 2.324 | 2.347 | 2.3425 | 923 | -11.15 | 0.01176 |

**Table 1.** Calibration data.

The camera angles, Δ, and pixel scales, E, were averaged, and their standard errors of the mean calculated on a spreadsheet. The results were: Δ = -11.3° ±0.1 and E = 0.0116"/pixel ± 0.0002.

**Figure 2.** Paul Wren and Russ Genet stand in front of the top portion of the telescope.

## Observations

BU1292 was observed on October 21, 2013, on the 2.1-meter telescope at Kitt Peak National Observatory. The observations were made by Genet, Smith, and Wren. The telescope (Figure 2) is f/7.6 with an effective focal length of about 16 meters. The times-eight magnification increased the effective focal length to about 128 meters (420 feet). Frames were taken with an Andor Luca-R electron-multiplying CCD camera.

A portable speckle interferometry camera (Genet 2013) was attached to the acquisition-guider unit at the Cassegrain focus of the 2.1-meter telescope (Figure 3). A magnification of times-eight was used to bring out the speckles. Observations were made using a Sloan i' filter so as to minimize atmospheric dispersion. The observation yielded a FITS data cube 512x512 pixels x1000 frames. Each of the 1000 exposures was 10 milli-seconds.

**Figure 3.** The Cassegrain focus of the 2.1-meter telescope. To the right of Genet is the gold-colored acquisition-guider unit. Below the acquisition-guider is the black-colored Barlow lens, filter wheel, and silver-colored Andor EMCCD camera of our portable speckle interferometry system.

The telescope was controlled from a nearby warm room (Figure 4). The USB Andor EMCCD camera was connected to the warm room via an Icron Ranger USB-to-Ethernet link and a 50-foot Category 5 cable.

**Figure 4.** In the warm room, Paul Wren selected the next double to observe while Tom Smith operated the telescope. Russ Genet operated the speckle camera station between them but got up to take this picture.

The FITS data cube for BU 1292 was loaded into REDUC. The first of 1000 frames is shown on the left of Figure 5. After the data cube was loaded, REDUC's "Autocorrelation" option was chosen. The autocorrelogram, shown on the right of Figure 5, was the result when "S4" was chosen as the kernel mask and the gain and bias adjustments were made to enhance the visual image. The calibration values determined for Δ and E were entered after placing REDUC in its "measure" mode. The resulting binary position angle, Θ, was 227.90°, while the separation, ρ, was 0.255".

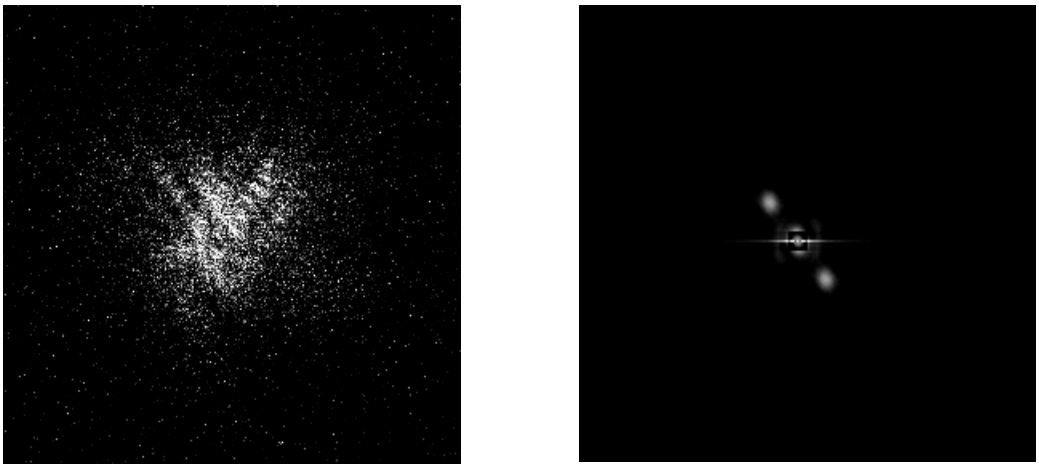

**Figure 5.** One image taken with the portable speckle interferometry camera system (left). Autocorellelogram (right).

## Comparison with Past Observation

Past observations were provided by Brian Mason at the U.S. Naval Observatory. These past observations can be seen in Table 2 along with the observation from October 21, 2013. The position angles were not precessed to a current epoch. When compared with past observations, the new data seems to agree with the motion predicted by past observations.

In Table 2, the first column is the Julian date of observation. Column two is the reported position angle, θ, in degrees from north while column three is the separation, ρ, in arc seconds. Column four is the telescope aperture in meters. Finally, column five is the published reference to the observation cited in the Washington Double Star Catalogue.

| Year | ρ | θ | Ap. | References |
|---|---|---|---|---|
| 1901.39 | 0.30 | 384.2 | 1.0 | Bu_1903 |
| 1936.57 | 0.30 | 346.3 | 0.6 | Vou1947b |
| 1945.576 | 0.25 | 346.2 | 0.6 | Vou9999 |
| 1948.19 | 0.21 | 337.3 | 2.1 | VBs1954 |
| 1958.3 | 0.20 | 310.5 | 2.1 | VBs1960 |
| 1961.7 | 0.21 | 317.6 | 0.9 | B_1962d |
| 1965.637 | 0.26 | 317.7 | 0.7 | Worl1971 |
| 1965.97 | 0.20 | 314 | 0.4 | Cou1967b |
| 1981.86 | 0.16 | 259.2 | 0.6 | Heil1983a |
| 1989.001 | 0.24 | 280.4 | 0.7 | Cou1989b |
| 1989.05 | 0.18 | 293.0 | 0.5 | LBu1989 |
| 1989.91 | 0.22 | 287.2 | 0.5 | LBu1990 |
| 1991.25 | 0.248 | 266 | 0.3 | HIP1997a |
| 1992.04 | 0.23 | 266.0 | 0.5 | LBul1992 |
| 2013 | 0.255 | 227.90 | 2.1 | Adam et al. |

**Table 2.** All published astrometric observations of BU 1292 (Mason et al. 2012).

In Figure 6 the position angle was plotted against the date of observation. The initial discovery observation (Bu_1903) was reported as 24.2 degrees but was plotted on the graph as 384.2 degrees to preserve the trend. Similarly, the separation was plotted against date of observation in Figure 7.

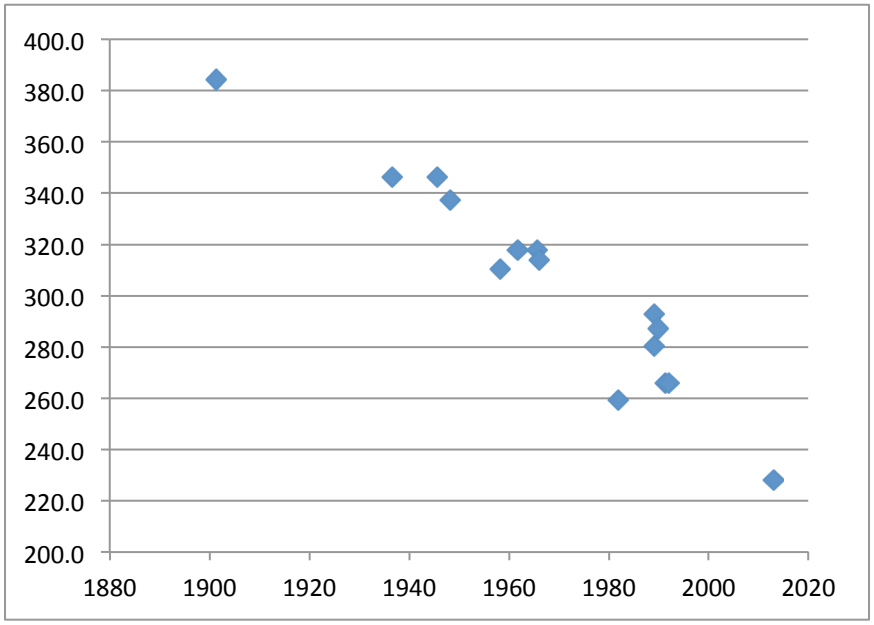


**Figure 6**. Plot of position angle v. time.

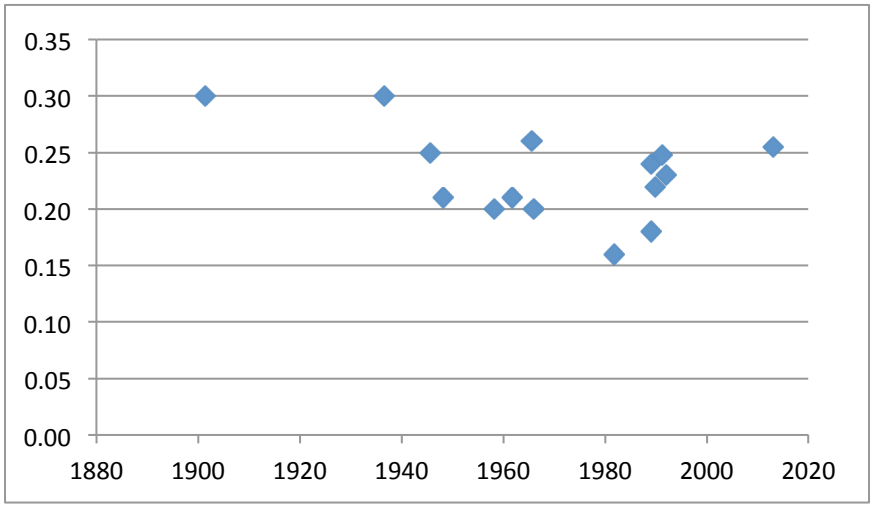


**Figure 7.** Plot of separation v. time.

Using the Microsoft Paint program and the data from the Kitt Peak observation, the new observational point and the predicted point were plotted on an image from the Naval Observatory (Hartkoph & Mason 2012) of the previously calculated orbit and past observations (Figure 8). Using the scale on the image of the previously calculated orbit, it was calculated that the ratio between pixels on Paint and separation in arc seconds was 700:1. The center coordinates of the binary in paint pixels was (272.5, 264.5). Using the position angle and known separation, simple trigonometry was used to find the distance in arc seconds in the x and y distances of the star from the center, (.189", .171"). These were then converted into pixels using the previously determined 700:1 ratio, (140.2, 144.8). Using these new coordinates, a new data point was added to the orbit plot from the Washington Double Star Catalog. A predicted point for the same date and time, predicted by ephemerides from the Sixth Orbit Catalog, was calculated in the same manner and also added to the graph of the orbit plot.

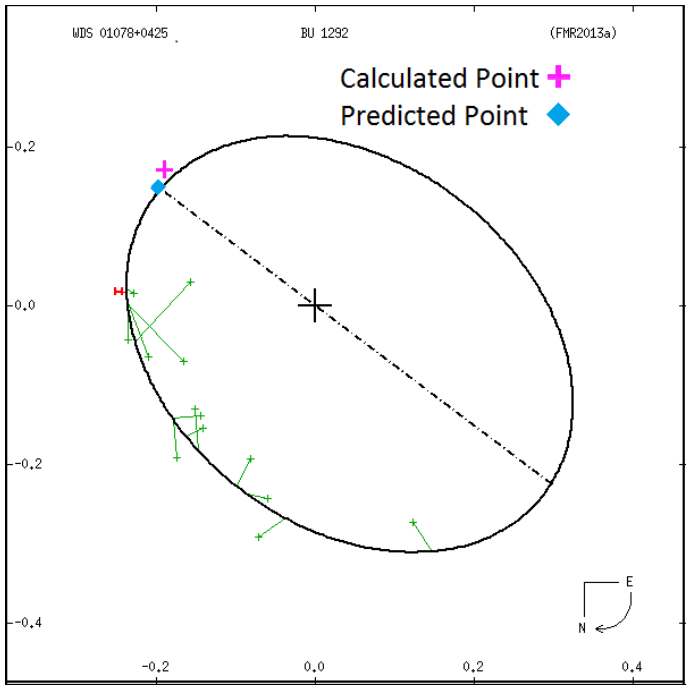


**Figure 8.** Plot of all Observations

The speckle interferometry and Hipparchus observations are more accurate than the visual observations. Taking this into account, the newly calculated point is not directly aligned with the predicted point. The difference in position angle between the predicted point and the calculated point for the speckle interferometry observations was 4.2°. Comparing this to previous points, it can be roughly estimated that the orbit is off by 3.2 years. Subtracting this from the previously calculated orbit of 285.3 years, it can be estimated that the orbit should be about 282.1 years. The semi-major axis of the orbital ellipse also needs to be adjusted. The difference between the new and the old axes is .011".

## Conclusion

The most recently calculated position angle of BU 1292 is 227.90° and separation is 0.255". It has been determined that the published orbital of this star was and is most likely about 3.221 years too long.

## Acknowledgments

For their contributions to the paper, we would like to express much gratitude to the NOAO National Optical Astronomy Observatory and Kitt Peak National Observatory for the time on their 2.1m telescope. A special thanks to Andor Technologies for loaning us the camera used for the observations. Finally, the team would like to express much gratitude to Brian Mason for providing data from the US Naval Observatory. To all who helped with the composition of this paper and to the external reviewers, thank you.

## References

van den Bos, W. H. 1962. Micrometer measures of double stars II. *The Astronomical Journal*, 67, 141.

Couteau, P. 1967. Measures d'etoiles doubles faites AU refracteur de 38cm de l'Observatoire de Nice. *Journal des Observateurs*, 50, 41.

ESA. 1997. The Hipparcos and Tycho catalogues. VizieR On-Lline Data Catalog: I/239. 1997yCat.1239....0E.

Genet, R. M. 2013. Portable speckle interferometry camera system. *Journal of Astronomical Instrumentation,* 2, 2, 1340008.

Hartkopf, W. I. & Mason, B. D. 2012. *Sixth Catalog of Orbits of Visual Binary Stars*. Washington: US Naval Observatory.

Heintz, W. D. 1983. Micrometer observations of double stars and new pairs. XI, *Astrophysical Journal Supplement Series,* 51, 249-268.

Le Beau, J. 1989. Measures d'etolies doubles visuelles. *Observations et Travaux*, 17, 24.

Le Beau, J. 1990. Binary measurements made at Nice with the 50-cm telescope. *Astronomy and Astrophysics Supplement Series*, 85, 889.

Le Beau, J. 1992. Measures d'etoiles doubles visuelles. *Observations et Travaux*, 30, 30-34.

Losse, F. 2012. REDUC V4.7. http://www.astrosurf.com/hfosaf/Reduc/Tutorial.htm.

Mason, B. D., Wycoff, G. L., & Hartkopf, W. I. 2012. *The Washington Double Star Catalog*, Washington: U.S. Naval Observatory.

Voûte, J. 1947. Measures of double stars, 5th series. *Annalen v.d. Bosscha-Sterrenwacht*, 6, 3.

Worley, C. E. 1971. Micrometer measures of 1,343 double stars. *Publications of the U.S. Naval Observatory,* 22, 136.