Investigation into the Motions of "Neglected" Double Star WDS 01477+6351

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Abstract: We report on the calibration of a bifilar micrometer and on measurements made of the double star WDS01477+6351. The last reported measurement of this star was in 1915 and we found its separation had changed from 88.8" to 45.9" and position angle changed from 139° to 175.5°. We investigated the apparent motion of this star and determined that the B component is moving too fast to be gravitationally bound to the A component. We also determined the proper motion of the B component to be 305 ± 2 mas/yr in right ascension and –4.5 ± 3.6 mas/yr in declination.

Introduction

We have recently procured a bifilar micrometer from Van Slyke Engineering to measure separation and position angles of "neglected" doubles as listed by the Astrometry Department of the United States Naval Observatory. The micrometer was attached to a Celestron Ultima 2000 telescope, which is a "goto" version of the popular 8 inch Schmidt-Cassegrain telescope.

We selected a subset of the neglected double stars for study using a program we wrote to search the WDS catalog (Mason 2001). Our requirements were that the stars be no dimmer than magnitude 9, be at least 10" separation at their last measurement, have been measured more recently than 1983, and have a magnitude difference between the two stars greater than 2.5. The magnitude and separation limits were chosen to make observation easy for relatively inexperienced observers using an 8 inch objective in light polluted skies. Observers using speckle interferometry with image intensifiers to measure double stars have difficulty making measurements when the brightness difference is large (Mason, 1994), so our criterion requiring a large magnitude difference selected stars that could not be conveniently measured by speckle interferometric techniques.

In the resulting list of candidate double stars, we were attracted to the WDS 01477+6351, to which we will refer by its discoverer code, ENG 7. The last reported measurement of this star was in 1915, and at that time, it had shown a considerable change in separation and position angle since its first measurement in 1892. This double star is in the constellation Cassiopeia, near ε Cas. The A component is a 5 mag, spectral class K0, main sequence star and is 33 ly from Earth (from Tycho 2, Hog 2000). The WDS reports a sizable proper motion for the A component of

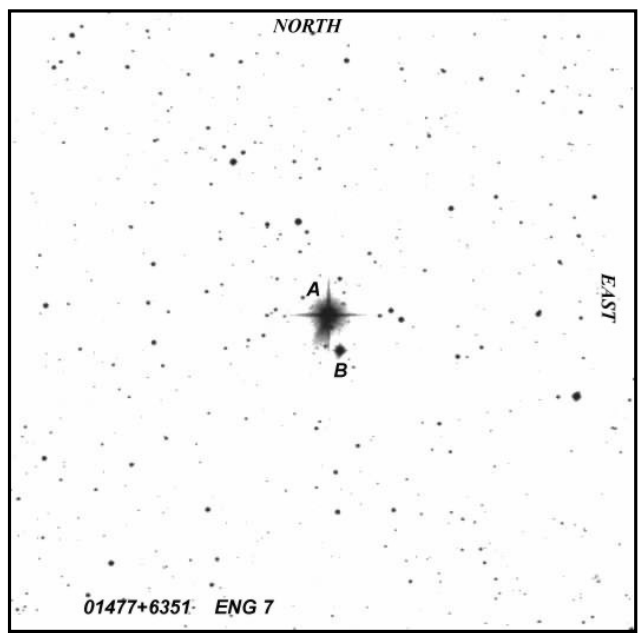

Figure 1: DSS image of WDS 01477+6351. The field is 15" across.

about 0.5" per year. The B component is 9 mag. A DSS image of the pair is shown in Figure 1.

In the sections to follow, we will describe our calibration of the bifilar micrometer and our measurements of ENG 7. We will then discuss the motion of ENG 7 to ascertain its possible binary nature and to determine the proper motion of the B component.

Calibration of the Bifilar Micrometer

The bifilar micrometer that we used is calibrated in inches and measures to 0.001 in. The cross hairs are illuminated by a red LED which can be pulsed. The eyepiece supplied with the micrometer has a focal length of 25 mm giving us a magnification of about 80 and a field of view of about 0.5°..

Star	WDS sep. (as)	USA sep. (as)	time	Δ%
8 Lac	81.6	82.2 ± 1.1	29-SEP	0.7
λ Ari	37.8	38.5 ± 0.7	25-NOV	1.1

Table 1. Check of screw calibration of micrometer.

We calibrated the bifilar micrometer screw by measuring three double stars with well known separations. These were β Cygnii (Alberieo, ρ = 34.3"), 31 Cygnii (ρ = 105.8"), and 30/31 Cygnii (ρ = 330.7"). The measurement were made over a period of several nights in the late summer and fall of 2003. A total of 48 calibration measurements were made: ten of Alberieo, nine of 31 Cygnii, and 29 of 30/31 Cygnii, yielding a calibration constant of () a.s./inch (the uncertainty is the standard deviation of the mean).

We checked our calibration of the screw by measuring the separation of 8 Lacertae and λ Arietis and compared our measurements with the separation reported in the WDS catalog. These are shown in Table 1. Again our uncertainties are the standard deviation of the mean of the measurements. The uncertainty in the calibration constant was insignificant compared to the uncertainties in the individual measurements. For both 8 Lac and λ Ari, our measurements of the separation were within 1" of the accepted value.

Our measurements of the position angles of these double stars differed from accepted values by about 2°. Much of this discrepancy was apparently due to our inexperience measuring position angles as the position angles reported for other stars in this paper were self-consistent to within 1°. However, because our telescope has an altazimuth mount, field rotation was no doubt a contributing factor to the uncertainty.

Date	PA	Sep	aperture
1892	135	102.7	
1902.97	137.1	96.832	13
1907.75	137.5	93.48	40
1911.17	138.4	91.08	10
1913.04	139.1	90.389	13
1915.82	139.0	88.80	16
2003.87	175.5	45.9	8

Table 2: Measurements of ENG7 including ours at time 2003.87 .

Measurements of "Neglected" Double Star WDS01477+6351

We made 19 measurements of the separation of ENG7 and six measurements of the position angle over a period of about six weeks. The time average of these measurements is 2003.87, the mean separation was 45.9" ± 0.6" and the mean position angle was 175.5° ± 0.4°. We then requested the other measurements for this star from the USNO. Table 2 shows the previous six means for this star along with ours. Note that the separation closed by 42.9" and the position angle increased by 36.5°. between 1915 and 2003.

Motion of ENG7

The question arises, then, whether the changing separation and position angles of this star are due to the orbital motion of a gravitationally bound system or due to the space motions of two independent stars.

The relatively wide separation angle suggests that ENG 7 is an optical double. But to test this hypothesis, we investigated the apparent velocity of the B component of ENG 7 and compared that to the expected velocity of a similar bound system.

From the initial measurements in 1892 to ours in 2003, the separation angle changed by 103". If the system is bound then a distance of 33 light years can be assumed for the B component and it is easy to find that apparent distance narrowed from 1040 au to 464 au, yielding an apparent speed of about 24.6 km/s over this time period. Because we are looking at a projection of the motion on the sky, the actual speed of the B component must be no less than 24.6 km/s and would probably be greater.

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We then calculated the orbital speed of a star in such a bound system using the Law of Gravity and assuming a circular orbit with a radius of 500 au (7.48×10^{13} m), which would be the current separation.. The A component, being a class K main sequence star would have a mass about 0.5 solar mass (1×10^{30} kg). Then the orbital speed of the B component, relative to the A component, would be

$$v = \sqrt{Gm / r} = 944 \text{ m/s}.$$

Thus, the maximum speed of the B component, if it were in orbit with the A component, is much less than the observed minimum speed of B.

To remove the restriction on circular orbits, we also used the *vis viva* equation,

$$v = \sqrt{G(m_1 + m_2)(2/r + 1/a)},$$

to calculate the relative speed of the B component. We assumed a distance between the components of r = 400 au (6×10^{13} m), which is the current separation and an apparent semimajor axis of a = 1000 au (1.4×10^{14} m), which was the separation in 1892. Given that the B component is three magnitudes dimmer than the A component, we assumed that the B component would be a main sequence class M star and therefore have a mass of about 0.1 solar masses. The *vis viva* equation then yielded a relative speed of 1.5 km/s for the B component. So, again, the observed speed of the B component is much greater than the maximum speed it could have in a gravitationally bound system. Thus, we conclude that the B component is not gravitationally bound to the A component.

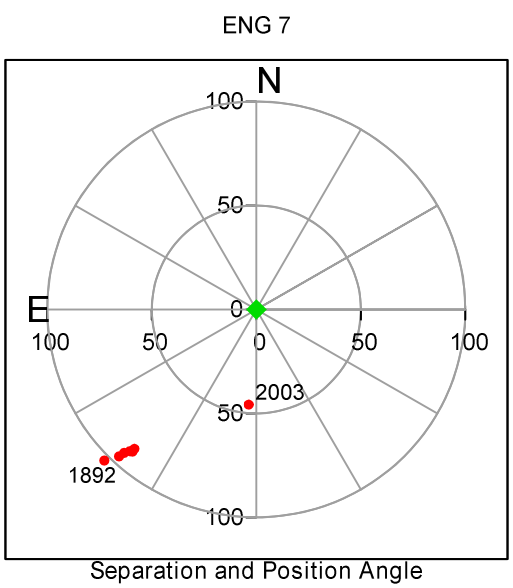

Figure 2: Position angle and separation of ENG 7 from 1892 to 2003.87 showing the apparent linear motion of the B component relative to the A component. ρ and θ used in the figure are printed in Table 2.

Having determined that the ENG 7 system is most likely an optical double, rather than a visual binary, we plotted the positions of the B component relative to A using the reported separations and position angles. This is shown in Figure 2 and the B component has what appears to be linear motion. Such linear motion would be expected for independent stars with different proper motions. Since the proper motion of the A component is known, we can use the separations and position angles to obtain the proper motion of the B component.

We calculated the absolute position of the B component in the sky over this time period. First, we used the precision coordinates and proper motion of the A component reported in the WDS catalog to calculate the RA and dec. of the A component at each of the reported measurements (epoch 2000 coordinates were used throughout). We then calculated the RA and dec. of the B component at the corresponding times using the reported separation and position angles.

The J2000 coordinates of the A component in the year of observation are calculated using

$$RA_{\text{date}} = RA_{2000} + \mu_\alpha (Y - 2000)$$

$$dec_{\text{date}} = dec_{2000} + \mu_\delta (Y - 2000)$$

where RA_{2000} and dec_{2000} are the J2000 coordinates of ENG 7 as reported in the WDS, Y is the year of observation, μ_δ is the proper motion in declination in arcseconds/1000 yr, and μ_α is the proper motion in right ascension in seconds/1000 yr.

Because the angular displacements of the B component from the A component are so small, we assumed a flat sky and calculated the coordinates of the B component in each of the years of observation in J2000 coordinates using

$$RA_B = RA_A + \rho\sin(\phi) / (3600 \cdot 15)$$

$$dec_B = dec_A + \rho\cos(\phi) / 3600$$

where $RA_{B(A)}$ is right ascension and $dec_{B(A)}$ is the declination of the B(A) component, ρ is the reported separation in arc seconds, and ϕ is the reported position an-

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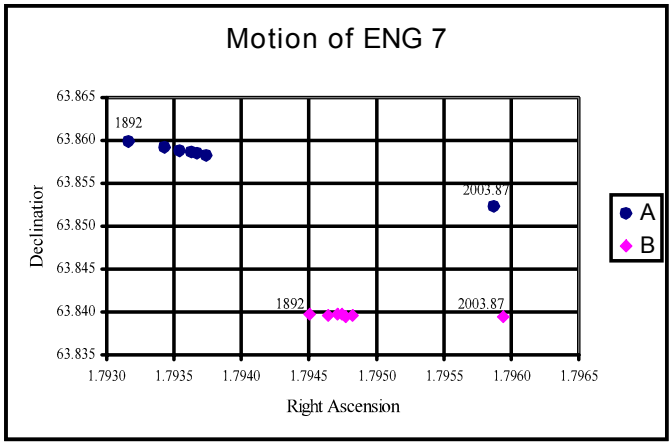

Figure 3: J2000.0 coordinates of ENG 7 A and B in the years of observation.

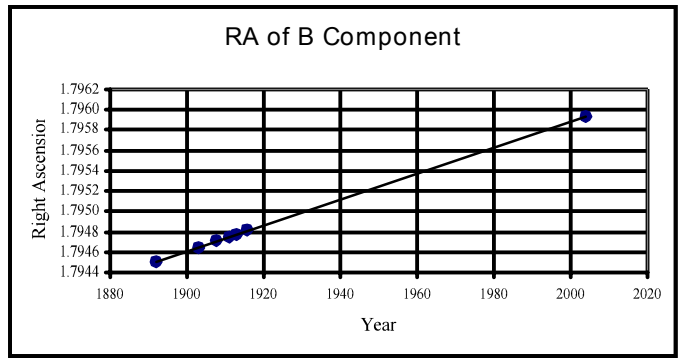

Figure 4: East/West motion of ENG 7B. The line is a least squares fit to the data and has a slope of (1.279 ± 0.006) x 10^{-8} hr/yr corresponding to a proper motion of 305 ± 2 mas/yr.

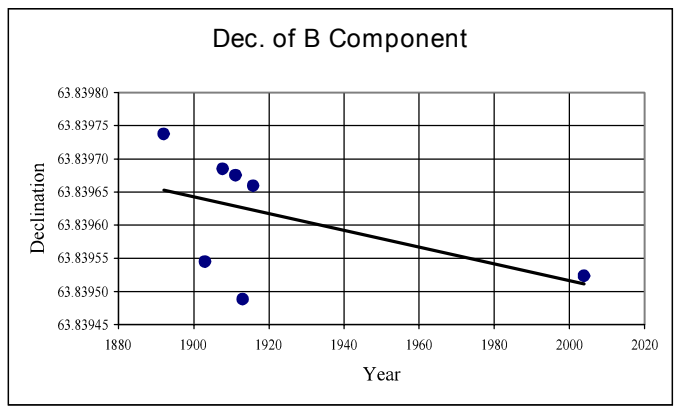

Figure 5: North/South motion of ENG 7B. The fitted line has a slope of -(1.3 ± 1.0) x 10^{-6} deg/yr corresponding to a proper motion of -4.5 ± 3.6 mas/yr. Note that the entire vertical scale spans 1.25", the uncertainty of our measurement is ±0.6".

gle. The factors of 3600 and 15 are for unit conversion. Figure 3 shows the results of the motion of both components of ENG 7. Again, it can be seen that the motion of the B component is apparently linear.

We then plotted the RA coordinates of the B component as a function of time and made a least squares linear fit to determine the E/W proper motion of the star. See Figure 4. The fit yielded a slope with a value that corresponds to a proper motion in right ascension of 305 ± 2 mas/yr and a correlation coefficient $r^2 = 0.9999$. Fitting the declination measurements, Figure 5, resulted in a fit with a slope that corresponds to a north-south proper motion of –4.5 ± 3.6 mas/yr. The r^2 of this fit was a poor 0.24 due to the large scatter in the points. The proper motion in this direction is very small and we believe the point scatter is just a result of the measurement uncertainty. For example, our measurements of the B component yield a declination uncertainty of ±0.6", which is half the total length of the *y* axis in Figure 5.

Conclusions

Using historical data and our own recent measurements, we observe that the speed of the B component of ENG 7 (assuming it is 33 ly distant) must be at least 25 km/s, but that dynamics and conservation of energy require that the orbital speed of the B component be no more than about 1 km/s for such a system to be gravitationally bound. We plotted the position of the B component, determined that it was moving linearly across the sky, and determined its proper motion to be 305 ± 2 mas/yr in RA and –4.5 ± 3.6 mas/yr in declination.

Because the apparent speed of the star is too large for a gravitationally bound system and because the motion of the B component is consistent with a straight line, we conclude that this pair must be an optical double.

Acknowledgements

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This project made use of of the Washington Double

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Star Catalog maintained at the U.S. Naval Observatory.

This research made use of the Digitized Sky Survey produced at the Space Telescope Science Institute.

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J. Cunningham, J. Guidry, J. Pearce, and T. Scarborough were all undergraduate physics majors at the University of South Alabama at the time this research was performed. Clark and Sanders are on the physics faculty and teach astronomy at the university.