# Neglected Northern Hemisphere Binary Star Systems with Updated Separations and Position Angles

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**Abstract**: We observed 58 widely-separated ($\rho$ > 3") northern hemisphere neglected binary star systems listed in theWashington Double Star catalog. Our goal was to obtain current separations and position angles of binaries that had not been observed in years or decades, and compare them with historical data. For each system, we fit Gaussian models to each component to determine the celestial coordinates and the corresponding position angles and angular separations of the binary. We combined these data with proper motions for each component from the recently-published UCAC5 catalog to determine the likelihood that each system was a true binary. We found that 29 candidate binaries were likely bona fide binaries, while 17 systems had large proper motion differences between components and were therefore deemed unlikely to be binaries. The remaining 12 systems had no proper motion listed.

## 1. INTRODUCTION

A comprehensive list of binary systems is the Washington Double Star [hereafter WDS] catalog, which is maintained by the U.S. Naval Observatory (1). The catalog include a list of "neglected" binary systems, consisting of unconfirmed binaries as well as systems which have not been observed for many years.

These systems provide a fertile research area for observers with small dedicated telescopes, as their properties can only be deduced by combining careful synoptic measurements with historical observations. This, in turn, can be used to create an aggregate database spanning many years. As an example, consider two solar-mass stars in a visual binary system with an angular separation 3" at a distance 100 pc. This system has an orbital period more than 1,000 yr, i.e. an annual position angle change less than 0.3 yr. Therefore, well-spaced observations are required over several decades to adequately sample the slow changes in position angle and angular separation.

In this paper, we report on observations of 59 visual doubles with angular separations exceeding 3" from the Northern Neglected WDS list. For all targets, we also retrieved proper motions from the recently-published UCAC5 proper motion catalog (2) based on GAIA data release 1. By combining our observation with proper motions for each component, we categorized the likelihood that each system is truly binary.

## 2. OBSERVATIONS

The observations were made using the Iowa Robotic Observatory (3) in southern Arizona. The IRO is a fully robotic telescope consisting of a 0.51 m f/6.8 Cassegrain reflector, a 2Kx2K back-thinned CCD imaging camera, and a 12-position filter wheel. We used a Sloan r' filter with exposure times between 1–3 sec depending on the apparent magnitude of the target stars. The observations were made at epoch 2017 March 30. Both nights had good observing conditions with clear skies and FWHM seeing between 1.8" – 2.0". Prior to analysis, each image had both CCD calibration (bias subtraction, dark-subtraction, flat-fielding) and a WCS astrometric solution (4) applied automatically.

## 3. DATA ANALYSIS

We fit circular Gaussian model profiles to each component using a downhill-simplex algorithm (Python library Scipy.optimize). For example, Figure 1 shows the double 05210+3728AB with overlaid contours from the Gaussian fits to each component. Using the derived centroid coordinates, we calculated the resulting binary

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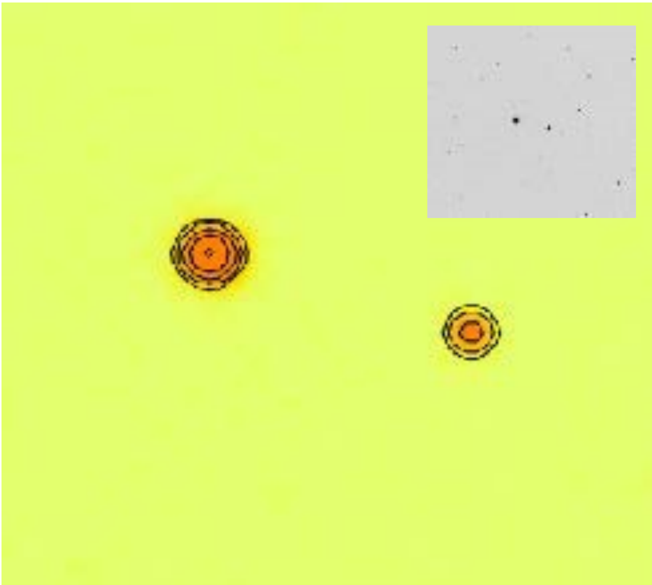

*Figure 1. Image of binary system 05210+3728AB on March 2017 showing overlaid contours from Gaussian fits to primary (A) and secondary (B) components. Inset shows the location of 05210+3728 in 3' x 3' field.*

angular separation (ρ) and position angle (φ). We also calculated the magnitude difference between primary and secondary components using the model-fit Gaussian peak amplitudes ($a_p$, $a_s$) and the expression,

$$\Delta m = 2.51 \log\left(\frac{a_s}{a_p}\right) \quad (1)$$

Stars in systems with a separation less than ~6" were deemed too close to reliably fit Gaussian model components due to component brightness overlap. For these systems we determined component centroid coordinates visually using the image display program DS9. This method did not yield peak amplitude, so magnitude difference was not calculated.

The uncertainties in $\rho$ and $\varphi$ were calculated in the following manner. We estimated that model-fit centroid positions had a 1σ uncertainty ±0.15 arcsec based on comparison of the fitted centroids with cataloged positions of field stars (e.g., Sloan Digital Sky Survey). Using standard error propagation analysis, the resulting uncertainties in the separation and position angle are,

$$\sigma_\rho = 2\sigma = 0.3'' \quad (2)$$

$$\sigma_\varphi = \frac{\sigma_\rho}{\rho} \quad \text{radians.} \quad (3)$$

Most target binaries had angular separations between 3" – 30", so the resulting position angle uncertainty was in the range 0.6° – 6°.

## 4. RESULTS

We determined the angular separations, position angles, and Sloan r' magnitude differences for 59 neglected binary systems at the heliocentric Julian date of 2457842. These are listed in Tables 1–2 along with measured J2000 coordinates of each primary component and proper motions from the UCAC5 proper motion catalog (2). The latter were used to categorize each system as a bona fide binary with high or low confidence, as described below.

For any binary, there will be two velocity components contributing to each component's total proper motion on the sky: the center of mass proper motion and the contribution from the component's orbital velocity in the binary system. For the long-period binaries considered in this survey, orbital speeds are a few km/s or less, corresponding to a differential angular speed between components $\Delta\mu_{orb} \lesssim 10$ mas/yr for systems at a distance 100 pc, and correspondingly less at greater distance. Hence, if the proper motion difference in either right ascension or declination significantly exceeds this value, it is increasingly unlikely that the system is a true binary.

For Tables 1 and 2, columns are organized as: WDS listed binary system name, right ascension and declination of primary components at epoch J2000, difference in magnitude (secondary magnitude minus primary magnitude), observed position angle, change in position angle from 2017 to last cataloged position angle, observed angular separation, change in angular separation from 2017 to last cataloged separation, magnitude of the proper motion vector difference between primary and secondary stars, proper motion uncertainties of primary and secondary stars, heliocentric Julian date, and number of nights observed. Table 3 is organized the same as tables 1 and 2, but omits the columns for the magnitude of the proper motion vector difference between primary and secondary stars and the proper motion uncertainties of primary and secondary stars.

We assigned each binary a high confidence or low confidence label based on the proper motion difference between the primary and secondary stars. These are listed in Tables 1 and 2 respectively. To be considered a high confidence binary system, the proper motion difference between components in each coordinate must be less than three times the larger of the proper motion uncertainty in that coordinate or 10 mas (to account for

*(Text continues on page 366)*

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*Table 1. High Confidence Binaries*

| Name | RA+Dec | Δm | ϕ | Δϕ | ρ | Δρ | Δμ | σ_μ | Date | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 03467+4241 FOX 134 | 034645.013 +423927.45 | 1.2 | 107.7 ± 2.8 | 3.7 | 5.9 ± 0.2 | -0.2 | 3.16 | 18.41, 9.68 | 2457842.612 | 1 |
| 04260+4515 ES 567BC | 042602.179 +451359.98 | 0.2 | 128.1 ± 3.0 | -1.9 | 8.1 ± 0.2 | 0.0 | 3.08 | 11.51, 21.19 | 2457842.616 | 1 |
| 04477+3446 HJ 349 | 044740.621 +344622.89 | -0.4 | 266.7 ± 1.6 | -0.3 | 10.4 ± 0.3 | 0.0 | 1.42 | 24.2, 30.85 | 2457842.621 | 1 |
| 04484+4611 HJ 2239 | 044810.874 +461119.81 | 1.1 | 163.7 ± 2.8 | 0.7 | 13.6 ± 0.2 | 0.5 | 0.85 | 34.46, 46.02 | 2457842.622 | 1 |
| 05177+3757 SEI 156 | 051742.932 +375613.07 | 0.1 | 244.0 ± 2.1 | 2.0 | 24.8 ± 0.3 | -0.1 | 2.55 | 15.87, 13.57 | 2457842.627 | 1 |
| 05210+3728 SEI 203AB | 052058.510 +372830.81 | 2.1 | 251.2 ± 1.3 | 0.2 | 21.5 ± 0.2 | 0.0 | 9.43 | 27.42, <0.01 | 2457842.630 | 1 |
| 05231+3802S EI 225 | 052308.984 +380138.25 | -0.8 | 88.0 ± 0.4 | 0.0 | 26.2 ± 0.3 | 0.0 | 3.05 | 18.41, 6.69 | 2457842.631 | 1 |
| 05275+3425 TOB 35 | 052729.322 +342502.64 | 0.7 | 328.4 ± 2.9 | -0.4 | 21.2 ± 0.2 | 0.4 | 0.30 | 46.02, 50.00 | 2457842.632 | 1 |
| 05279+4441 ES 1377 | 052754.793 +444108.24 | N/A | 185.0 ± 5.7 | -0.8 | 4.0 ± 0.2 | -0.4 | 3.92 | 34.46, 13.57 | 2457842.633 | 1 |
| 05385+3201 J 901 | 053832.826 +320124.28 | N/A | 143.2 ± 8.2 | -5.6 | 2.8 ± 0.3 | -0.1 | 2.10 | 8.08, 46.02 | 2457842.635 | 1 |
| 05399+5145 ES 893 | 053956.724 +514518.05 | 0.5 | 225.0 ± 3.3 | 0.0 | 7.2 ± 0.2 | 0.0 | 3.27 | 15.87, 42.08 | 2457842.637 | 1 |
| 05497+3146 SEI 391AC | 054939.523 +314629.74 | 0.7 | 140.3 ± 2.6 | 0.3 | 27.5 ± 0.3 | -1.4 | 6.58 | 0.02, 0.03 | 2457842.639 | 1 |
| 05498+3127 SEI 392 | 054948.887 +312637.03 | 0.8 | 309.1 ± 4.0 | 2.1 | 8.7 ± 0.3 | 0.1 | 0.78 | 34.46, 38.21 | 2457842.641 | 1 |
| 05499+2259 POU 789 | 054953.621 +225847.66 | 1.6 | 251.3 ± 2.6 | -0.7 | 12.7 ± 0.3 | 0.0 | 6.53 | 24.20, 21.19 | 2457842.641 | 1 |
| 05523+3442 GYL 87 | 055214.353 +344120.96 | 0.5 | 327.2 ± 4.4 | 0.4 | 10.3 ± 0.3 | -0.6 | 1.53 | 46.02, 18.41 | 2457842.643 | 1 |
| 05525+3235 SEI 424 | 055230.662 +323440.52 | 0.7 | 265.7 ± 1.0 | 0.7 | 13.1 ± 0.2 | -0.2 | 1.42 | 27.42, 24.20 | 2457842.654 | 1 |
| 05553+2023 J 1914 | 055515.816 +202322.20 | 0.7 | 256.2 ± 2.1 | 6.2 | 7.8 ± 0.2 | 3.8 | 0.80 | 27.43, 50.00 | 2457842.656 | 1 |
| 05557+3127 SEI 440 | 055542.074 +312701.17 | 0.8 | 333.0 ± 2.6 | -1.0 | 13.9 ± 0.2 | 0.2 | 2.10 | 46.02, 18.41 | 2457842.657 | 1 |
| 05559+3104 SEI 442 | 055548.964 +310422.81 | 1.2 | 186.5 ± 2.1 | 1.5 | 25.1 ± 0.2 | -0.2 | 7.11 | 42.07, <0.01 | 2457842.660 | 1 |
| 05585+2727 J 252 | 055825.581 +272201.36 | 1.2 | 318.5 ± 3.8 | -0.5 | 5.2 ± 0.2 | -0.3 | 2.05 | 15.87, 18.41 | 2457842.660 | 1 |
| 05589+3143 SEI 450 | 055852.536 +314229.21 | -0.2 | 178.0 ± 1.9 | -1.8 | 28.8 ± 0.2 | -0.6 | 5.08 | 1.79, 4.46 | 2457842.660 | 1 |
| 06138+3509 GCB 16 | 061407.230& 350532.36 | 0.1 | 184.4 ± 4.1 | -0.6 | 6.4 ± 0.2 | -2.0 | 1.03 | 38.21, 30.86 | 2457842.664 | 1 |
| 06162+2051 J 1054 | 061610.209 +205127.90 | N/A | 138.8 ± 7.5 | -0.2 | 3.3 ± 0.3 | 0.3 | 2.20 | 46.02, 8.08 | 2457842.665 | 1 |
| 06279+3715 MLB 1028 | 062758.609 +371444.64 | 3.2 | 297.5 ± 2.3 | 7.8 | 7.9 ± 0.2 | 1.6 | 5.30 | 42.09, 13.57 | 2457842.669 | 1 |
| 06301+2756 J 2428 | 063003.892 +275749.44 | N/A | 178.9 ± 5.7 | 28.9 | 4.0 ± 0.2 | 0.0 | 1.77 | 21.19, 24.20 | 2457842.670 | 1 |
| 06368+2335 GCB 20 | 063621.872 +233818.56 | 0.5 | 229.2 ± 3.0 | 2.2 | 8.2 ± 0.2 | 0.2 | 0.22 | 46.02, 46.02 | 2457842.672 | 1 |
| 06442+3822 J 665 | 064405.904 +382233.01 | 2.8 | 66.5 ± 3.0 | -1.4 | 7.6 ± 0.3 | -0.8 | 2.55 | 8.08, 24.20 | 2457842.647 | 1 |
| 08036+4739 PKO 8 | 080346.120 +473905.06 | 0.1 | 249.8 ± 2.8 | -0.2 | 11.7 ± 0.3 | 3.9 | 0.54 | 46.02, 42.07 | 2457842.653 | 1 |
| 08334+3348 MLB 838 | 083325.805 +335017.90 | 0.0 | 18.2 ± 6.8 | -0.8 | 4.8 ± 0.3 | 0.6 | 3.22 | 6.69, 42.07 | 2457842.657 | 1 |

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*Table 2. Low Confidence Binaries*

| Name | RA+Dec | Δm | ϕ | Δϕ | ρ | Δρ | Δμ | σ_μ | Date | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 03493+2424 HL 30AB | 034916.805 +242346.35 | 3.9 | 13.4 ± 1.2 | 1.4 | 69.8 ± 0.2 | -2.4 | 57.03 | <0.01, <0.01 | 2457842.612 | 1 |
| 04020+6231 SLE 43AD | 040158.322 +623050.42 | 2.2 | 277.9 ± 1.5 | -1.1 | 19.9 ± 0.2 | 0.8 | 16.05 | <0.01, <0.01 | 2457842.614 | 1 |
| 04076+3804 ALC 1AE | 040734.354 +380428.37 | 0.0 | 99.6 ± 0.1 | N/A | 746.0 ± 0.2 | 26.0 | 68.04 | <0.01, <0.01 | 2457842.613 | 1 |
| 04125+3538 HJ 341 | 041231.205 +354359.23 | 0.2 | 333.4 ± 2.6 | 2.4 | 13.8 ± 0.2 | 1.0 | 12.25 | 24.20, <0.01 | 2457842.615 | 1 |
| 05179+3724 SEI 162 | 051754.782 +372336.09 | 1.6 | 223.5 ± 3.6 | -0.5 | 24.1 ± 0.4 | 2.9 | 28.62 | <0.01, 0.02 | 2457842.627 | 1 |
| 05161+3632 SEI 132 | 051606.174 +363141.65 | -0.1 | 113.6 ± 2.8 | -5.6 | 25.0 ± 0.2 | 0.4 | 9.51 | <0.01, <0.01 | 2457842.626 | 1 |
| 05380+3643 SEI 358 | 053758.715 +364234.70 | 0.6 | 196.8 ± 3.6 | 0.8 | 17.8 ± 0.3 | -0.4 | 9.97 | 6.68, <0.01 | 2457842.637 | 1 |
| 05463+3152 SEI 384 | 054616.199 +315220.59 | 1.5 | 175.4 ± 4.1 | -0.6 | 13.9 ± 0.3 | 0.2 | 11.15 | <0.01, <0.01 | 2457842.639 | 1 |
| 06050+2913 MLB 750 | 060458.089 +291122.01 | 0.9 | 236.5 ± 3.2 | -0.5 | 6.6 ± 0.2 | 0.3 | 10.67 | 0.07, <0.01 | 2457842.663 | 1 |
| 06125+2025 J 1926 | 061227.013 +202437.67 | N/A | 0.2 ± 5.8 | 5.2 | 6.1 ± 0.2 | 5.0 | 46.35 | <0.01, <0.01 | 2457842.663 | 1 |
| 06204+2331 J 1822 | 062037.252 +232819.31 | 0.5 | 2.9 ± 3.9 | -1.1 | 7.0 ± 0.2 | 2.0 | 23.90 | <0.01, <0.01 | 2457842.665 | 1 |
| 06335+6712 MLB 457 | 063335.777 +671138.78 | N/A | 307.2 ± 5.9 | 18.2 | 4.5 ± 0.3 | -1.7 | 22.61 | <0.01, <0.01 | 2457800.678 | 1 |
| 06383+2427 HO 625AC | 063818.901 +242701.71 | 4.4 | 352.2 ± 1.4 | -0.8 | 50.5 ± 0.2 | 0.4 | 42.47 | 1.07, 0.02 | 2457842.674 | 1 |
| 07208+3151 SEI 478 | 072051.463 +315102.00 | N/A | 16.6 ± 5.5 | -8.2 | 4.2 ± 0.2 | -1.8 | 23.36 | 2.27, <0.01 | 2457842.650 | 1 |
| 09251+2933 BU 1423AC | 092507.977 +293249.02 | 2.7 | 51.7 ± 0.6 | -0.3 | 155.2 ± 0.2 | 0.8 | 47.79 | <0.01, <0.01 | 2457842.682 | 1 |
| 09390+3017 ARY 51 | 093859.331 +301631.56 | 0.7 | 273.0 ± 0.2 | 0.0 | 118.7 ± 0.2 | -0.9 | 37.89 | <0.01, 5.48 | 2457842.692 | 1 |
| 11125+3549 STTA108BD | 111244.285 +354947.96 | 0.0 | 247.8 ± 0.7 | 19.9 | 159.9 ± 0.4 | 7.0 | 245.82 | <0.01, <0.01 | 2457842.759 | 1 |

*Table 3. Systems without UCAC5 Proper Motion*

| Name | RA+Dec | Δm | ϕ | Δϕ | ρ | Δρ | Date | N |
|---|---|---|---|---|---|---|---|---|
| 03267+4110 J 889 | 032646.903 +410850.52 | N/A | 61.0 ± 9.2 | -36.0 | 2.1 ± 0.3 | -0.8 | 2457842.609 | 1 |
| 03495+5239 ES 12DE | 034924.675 +524019.45 | N/A | 223.9 ± 9.0 | -6.1 | 2.4 ± 0.3 | -0.3 | 2457842.611 | 1 |
| 04113+2630 LDS5514BC | 041113.457 +262952.35 | 0.0 | 305.2 ± 2.3 | 5.2 | 11.0 ± 0.2 | 0.0 | 2457842.614 | 1 |
| 05119+3631 SEI 93 | 051149.163 +363028.70 | N/A | 146.7 ± 5.5 | 21.7 | 3.9 ± 0.2 | -0.7 | 2457842.625 | 1 |
| 05225+6011 LEO 11 | 052232.232 +601123.64 | N/A | 215.6 ± 6.4 | 4.6 | 2.9 ± 0.2 | -0.5 | 2457842.631 | 1 |
| 06212+2108 S 513BE | 062110.309 +210745.216 | 1.7 | 327.8 ± 1.5 | 0.8 | 40.6 ± 0.2 | -0.5 | 2457842.666 | 1 |
| 06214+3402 MLB1044 | 062126.528 +340155.550 | 1.3 | 126.0 ± 3.1 | 1.0 | 7.4 ± 0.2 | 0.5 | 2457842.667 | 1 |
| 06377+6129 BUP 91AC | 063741.334 +612854.14 | -0.2 | 92.3 ± 0.2 | -1.7 | 397.5 ± 0.4 | 17.6 | 2457842.673 | 1 |
| 07018+6617 MLB 400 | 070140.898 +661654.20 | N/A | 214.0 ± 9.9 | 24.0 | 2.1 ± 0.3 | 0.0 | 2457842.647 | 1 |
| 07059+3603 STF1013 | 070551.903 +360255.17 | N/A | 56.6 ± 4.6 | 1.6 | 4.4 ± 0.2 | -0.3 | 2457842.649 | 1 |
| 08010+3454 MLB 932 | 080101.534 +345310.10 | 0.7 | 56.0 ± 4.8 | 4.0 | 4.6 ± 0.3 | 0.2 | 2457842.652 | 1 |
| 10432+3849 MLB 933 | 104316.264 +384840.83 | N/A | 246.1 ± 5.0 | -1.9 | 3.5 ± 0.2 | -0.1 | 2457842.738 | 1 |

*(Continued from page 363)*

possible orbital motion contribution).

Twelve candidate systems did not have proper motions listed for both the primary and secondary star. These systems are listed in Table 3, where their binary status is indeterminate due to the lack of knowledge on their proper motions.

## 4. ACKNOWLEDGEMENTS

Recognition for observation and data analysis collaboration goes to Brandon Schuemann and Darean Witt.

This research used the Washington Double Star Catalog, maintained at the U.S. Naval Observatory, and the VizieR and SIMBAD databases, both maintained at CDS, Strasbourg, France. This research was supported by the National Science Foundation under grant No. 1517412.

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