Journal of Double Star Observations

VOLUME 11 NUMBER 1 January 1, 2015

Inside this issue:

Dynamic Studies of Struve Double Stars: STF4 and STF 236AB Appear Gravitationally Bound E. O. Wiley and F. M. Rica	2
Discovery of 4 New Double Stars in Constellation Serpens Joerg S. Schlimmer	9
How Nu Coronae Borealis Lost its Five Star Rating or One Less Star in the Northern Crown John Nanson, Steven C. Smith, and Chris Thuemen	12
Measuring Double Stars in Ursa Minor with a Micrometer and an Eyepiece Reticle Papadimitriou Athanassios	18
Double Star Measures Using the Video Drift Method - V Richard L. Nugent and Ernest W. Iverson	21
Measurements of Neglected Double Stars Report of September 2014 Joseph M. Carro	29
A Companion to the Eclipsing Variable AF Arietis Abdul Ahad	33
Observations of Epsilon Lyrae by the Video Drift Method Rick Wasson, Nancy Nelson, Eric Nelson, William Buehlman, Earl Wilson, Deanna Zapata	36
Identification and Spectral Classification of Close Red Dwarf Binary Stars James Chivers	42
Announcement: Maui High Resolution Binary Star Workshop	59

Dynamic Studies of Struve Double Stars: STF4 and STF 236AB Appear Gravitationally Bound

E. O. Wiley

Yankee Tank Creek Observatory, Lawrence, KS USA
ewiley@suddenlink.net

F. M. Rica

Astronomical Society of Mérida
frica0@gmail.com

Abstract: Dynamics of two Struve double stars, WDS 00099+0827 (STF 4) and WDS 02556+2652 (STF 326 AB) are analyzed using astrometric criteria to determine their natures as gravitationally bound or unbound systems. If gravitationally bound, then observed relative velocity will be within limits according to the orbital energy conservation equation. Full implementation of this criterion was possible because the relative radial velocities as well as proper motions have been estimated. Other physical parameters were taken from literature or estimated using published protocols. Monte Carlo analysis indicates that both pairs have a high probability of being gravitationally bound and thus are long-period binaries.

Introduction

The Washington Double Star Catalog (Mason et al., 2001), hereafter WDS, contains many systems with common proper motions but no detailed analysis of their nature. While many are unbound common origin systems, others may be gravitationally bound systems with long periods and only a small part of the orbit measured. Herein we analyze two systems, WDS 00099+0827 (STF 4) which comprises two components first measured by Struve in 1829 and WDS 02556+2652 AB (STF 326 AB), a triple system first measured by Struve in 1831 with a fainter companion with similar proper motions (LDS 883 AC) discovered by Luyten in 1936 (Struve 1837; Luyten 1969).

Several astronomers have proposed criteria for separating unbound from gravitationally bound systems based on separation and relative motion. Van de Kamp (1961) proposed a solution by calculating the conditions for a parabolic trajectory based on the *vis viva* equation; above a critical value, the trajectory must be hyperbolic, while below the critical value, it *may* be elliptical. Sinachopoulos & Mouzourakis (1992) sampled a number of wide doubles where both components were at similar distances and calculated the relative tangential and projected velocity of the secondary with respect to the primary, and from these results they calculated an orbital velocity for a circular orbit. They considered optical pairs to be those whose tangential velocity coupled with the error associated with this velocity exceeded the maximum orbital velocity, while those that did not may be bound. The limitation of both studies lay in the fact that the separation between pairs was a projected separation and did not take into account the radial velocity needed to calculate the 3-D relative velocity. Thus while a selected pair may be gravitationally bound, the answer is not definitive. Close et al. (1990) discriminated between optical and bound pairs by comparing the relative orbital velocity with the escape velocity, the minimum speed of an object needed to escape from the gravity of the companion star. Since most know wide systems have an escape velocity less than 5 km s^{-1}, they considered all systems with a tangential velocity of > 5 km $s^{-1} \pm 5\sigma$ as not gravitationally bound. Close et al. (1990) proposed that if the total velocity of the secondary was less than the escape velocity, then the candidate pair may be gravitationally bound within a calculated probability threshold:

$$\Delta V_{tot} < V_{esc} \quad (1)$$

Rica (2011) explored the relationship between these various criteria and demonstrated how they were related based on the total mechanical energy of a system. He derived the *vis viva* equation by considering the total orbital energy using relative quantities. This allows calculation of the maximum (contra minimum) orbital velocity of the binary:

$$v^2 = G(M_1 + M_2)\left(\frac{2}{r} - \frac{1}{a}\right) \quad (2)$$

where G is the gravitational constant (G = 0.0043 [(pc / Mo) * $(km/s)^2$]), M_1 and M_2 are the masses of primary and secondary relative to solar mass, r is the distance between the primary and secondary in parsecs, and a is the expected semi-major axis as calculated by Fischer and Marcy (1992). Masses for main sequence dwarfs can be estimated using the mass-luminosity relation of Henry and McCarthy (1993), given known magnitudes and distances.

The escape velocity can be derived directly from the conservation of energy equation (Rica 2011) and yields:

$$v_{esc} = \frac{\sqrt{2GM_{tot}}}{r} \quad (3)$$

where G is the gravitational constant, M_{tot} is the total mass of the system in solar units, and r is the distance between the primary and secondary in parsecs.

Using equations (2) and (3) with errors from catalogs (M_1, M_2, r) or empirically determined, Rica (2011, 2013) was able to characterize the probable relationship of a number of doubles.

Knowledge of radial velocities, distance, and relative motions permits the investigator to calculate two additional parameters, the tangential velocity (v_{tan}) and the total 3-D velocity:

$$v_{tan} = 4.74\Delta\mu \quad (4)$$

$$v_{tot} = \sqrt{\Delta v_r^2 + \Delta v_{tan}^2} \quad (5)$$

where V_{tan} is the tangential relative velocity (relative projected velocity) of the secondary to the primary in km/s, d is the distance in parsecs, $\Delta\mu$ is the relative proper motion of the secondary to the primary in arcsec/yr, Δv_{tot} is the total relative velocity of the system in km/s, and Δv_r is the relative radial velocity. Determination of ΔV_{tot} permits full implementation of the Close et al. (1990) criterion shown in formula (1) above.

Herein, we report a dynamical study of two double stars (WDS 00099+0827 = STF 4 and WDS 02556+2652 AB = STF326 AB), first cataloged by F. Struve, with common proper motions and known radial velocities. Studies of other Struve doubles are ongoing.

Methods

WDS historical measures for each pair were *kindly* supplied by Dr. Brian Mason of the U. S. Naval Observatory (Mason 2005). We import the theta and rho values into an Excel spreadsheet prepared by Francisco Rica that performs a weighted analysis resulting in estimation of the following parameters:

- Separation of component stars in x and y: x(AU) [E-W], y(AU) [N-S]
- Variation of theta and rho: $d\theta/dt$ (mas/yr) and $d\rho/dt$ (deg/yr)
- Variation of x and y coordinates in time: dx/dt (mas/yr) and dy/dt (mas/yr)
- Relative velocities along x, y, and z (km/s): Vx [E-W], Vy [N-S], Vz
- Projected total relative velocity: Vxy (km/s)
- Total apparent motion of B relative to A: $\Delta\mu$ (mas/yr)
- Total relative velocity: $Vtot$ (km/s)
- Maximum orbital velocity: $Vorb\_max$ (km/s)

Errors associated with certain values (e.g. $Vtot$) not directly calculated in the spreadsheet were obtained through Monte Carlo simulation with 10,000 iterations. Mass is calculated from equations given in Henry & McCarthy (1993) from magnitude and distance estimates gleamed from catalogues (for sources see Table 1). Dynamics are calculated from Rica (2011), and a Monte Carlo simulation is performed with 25,000 iterations to calculate the probability that the pair is gravitationally bound.

Catalog Sources and Astrophysical Data

Basic astrophysical data are shown in Table 1 and include WDS number and discoverer code, position, spectral types, mass, parallax and distance, proper motions in right ascension and declination, radial velocity, first and last observations (Epoch Range), and change in theta and rho over the history of observations ($\Delta\Theta$, $\Delta\rho$).

Dynamic Studies of Struve Double Stars: STF4 and STF 236AB Appear Gravitationally Bound

Table 1: Astrophysical Data and Catalog Sources

	WDS 00099+0827 = STF 4 (HD 531, HIP 795)			WDS 02556+2652 = STF326 AB (HD 18143 = HIP 13642)		
	Primary	**Secondary**	**Reference**	**Primary**	**Secondary**	**Reference**
AR2000 DEC2000	00:09:51.65 +08:27:11.4		ESA, 1997	02:55:38.89 +26:52:25.3		ESA, 1997
Spectral Types	G6V	G7V	Torres et al, 2006	K2IV	M0V	Gray et al. (2003); Pasinetti-Fracassini et al (2001).
Stellar Mass ($M_{\odot}$)	1.01 ±0.12	1.00 ±0.12	This study	0.90 ± 0.10	0.70 ± 0.08	This study
Parallax (mas)	13.11±1.29		ESA, 1997 Leeuwen, 2007	43.57±0.84		ESA, 1997 Leeuwen, 2007
Distance (pc)	75.4±7.4			23.5±0.5		
μ(a) (mas/yr) μ(d) (mas/yr)	+55.2±2.4 -11.4±2.1	+53.9±2.3 -9.6±2.0	Fabricius et al. (2002)	+274.0±1.7 -185.4±10.9	+270.1±10.9 -167.7±7.5	Fabricius et al. (2002)
Vrad (km/s)	13.8±2.0	14.6±2.0	Cutispoto et al. (2002)	31.8±1.8	27.0±1.8	Barbier-Brossat & Figon (2000)
Epoch Range	1829-2009		Mason et al. (2001 et seq.).	1831-2012		Mason et al. (2001 et seq.).
ΔΘ	4°		Mason et al. (2001 et seq.).	4°		Mason et al. (2001 et seq.).
Δρ	0.3"		Mason et al. (2001 et seq.).	4.3"		Mason et al. (2001 et seq.).

Results

Table 2 presents the relative motions and velocities obtained. Table 3 presents parameters calculated in the Monte Carlo simulations and the probabilities that the pairs meet three criteria: (1)van de Kamp's parabolic condition, (2) the probability that the total velocity (*Vtot*) is less than the maximum orbital velocity (*Vorb_max*), and (3) the probability that the total velocity is less than the escape velocity (*Vesc*). Figures 1-4 illustrate the relative motions of the two pairs.

Discussion and Conclusions

Calculated mass for STF 4 A was close to estimates in Allende Prieto and Lambert (1999), 0.99 ± 0.12 $M_{\odot}$ and Casagrande et al. (2011, Padova maximum likelihood mass of 0.97 $M_{\odot}$). Mass estimates for STF326 A in the literature range from 1.0 $M_{\odot}$ to 0.74 $M_{\odot}$ (Valenti & Fischer 2005; Howard et al., 2010; Shaya and Olling 2011; Tokovinin 2008 in decreasing order) while our estimates for STF326 B was higher than that estimated by Tokovinin (2008; 0.58 $M_{\odot}$).

Both pairs have a high probability that their total velocities are less than the escape velocities and both meet the parabolic condition. Of the two, WDS 00099+0827 (STF 4) has the highest probability of being bound as its total velocity is less than half of either the estimated maximum orbital velocity or the estimated escape velocity. The case for WDS 02556+2652 AB (STF 326 AB) is less clear cut: its estimated total velocity and estimated maximum orbital velocities are within errors. Thus it is estimated to be at the limit of its allowed maximum orbital velocity. However, based on the observation that the total velocity is lower than the estimated escape velocity, we conclude that it is also gravitationally bound. STF326 AB has both linear (Hartkopf and Mason 2011) and orbital (Hopmann 1967) solutions in the WDS, a situation that might not be uncommon for “short arc” binaries. An orbital solution calculation is being carried out by Francisco Rica using instant position and velocity (in addition to parallax and stellar mass). This work will be published in a future publication.

Although we did not analyze WDS 02556+2652 AC (LDS 883 AC), we have no reason to think that it does not form part of a common origin triple system. LDS883 C is similar in proper motion to STF326 AB (Zacharias et al. 2013; C is Gliese 118.2C). Orlov et al. (1995) report all three stars as having similar parallax values and as components of one of five moving clusters in the solar neighborhood.

The two systems analyzed were taken from a number of pairs discussed by Wiley (2012) that were charac-

(Continued on page 8)

Table 2. Relative Motions and Velocities

WDS	00099+0827	02556+2652
Disc	STF 4	STF 326AB
Epoch	1931.566	1971.561
Θ (deg)	274.23	219.68
ρ (arcsec)	5.24	6.08
x (AU), [E-W]	-396±39	-90.7±2.7
y (AU). [N-S]	29.0±2.9	-110.0±3.3
dr/dt (mas/yr)	-0.3±0.6	-29.5±0.5
dq/dt (deg/yr)	0.014±0.002	0.034±0.0024
dx/dt (mas/yr) [E-W]	0.3±0.6	16.7±0.4
dy/dt (mas/yr).[N-S]	1.3±0.2	24.3±0.4
Vx (km/s), [E-W]	0.1±0.2	1.9±0.1
Vy (km/s). [N-S]	0.5±0.1	2.7±0.1
Vz (km/s)	0.8±0.8	0.2±0.2
Vxy (km/s)	0.5±0.2	3.3±0.1
Vtot(km/s)	0.9±0.6	3.3±0.1
Vesc_max (km/s)	3.0±0.2	4.5±0.2

Table 3: Dynamical Results from Monte Carlo Analysis

WDS	00099+0827	02556+2652
Disc	STF 4	STF326AB
Δμ [mas/yr]	1.3±0.4	29.5±0.5
Vtotal [km/s]	1.1±0.6	3.3±0.1
Vorb_max [km/s]	2.1±0.4	3.1±0.6
Vesc [km/s]	3.0±0.2	4.5±0.2
p(Vorb_max > Vtotal)	90.9	0.383
p(Vesc >Vtotal)	99.5	1

Dynamic Studies of Struve Double Stars: STF4 and STF 236AB Appear Gravitationally Bound

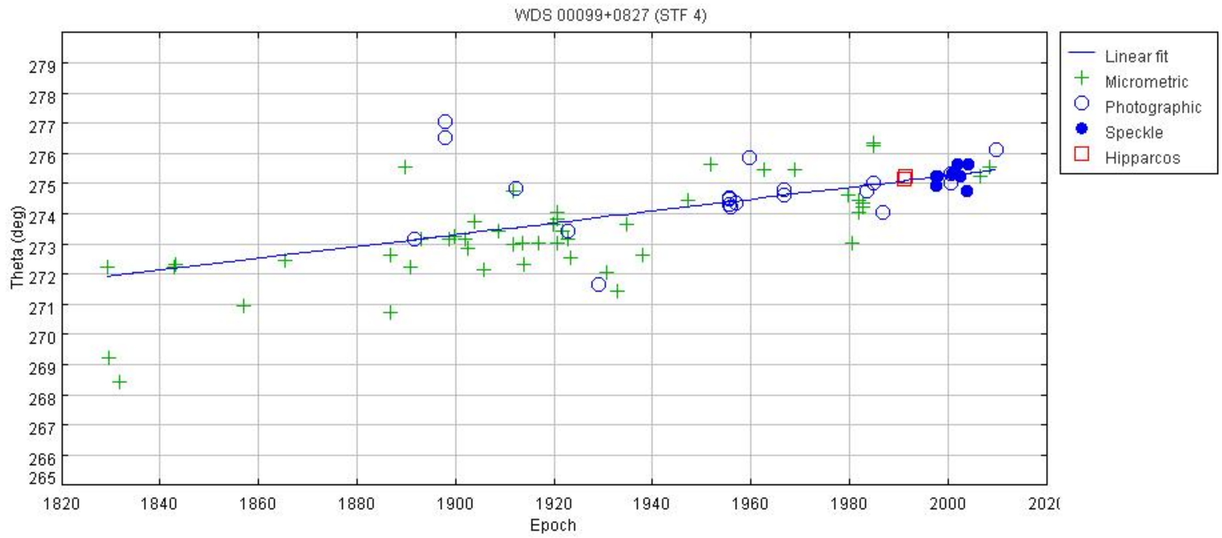


Figure 1. WDS 00099+0827 (STF 4). Theta versus Epoch over history of observations

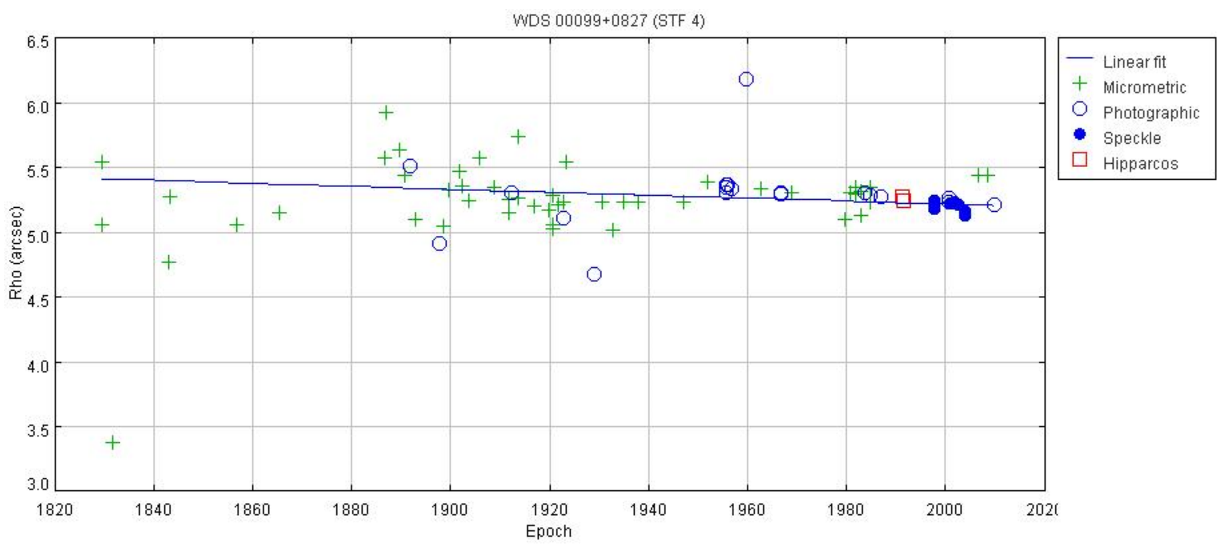


Figure 2. WDS 00099+0827 (STF 4). Rho versus Epoch over history of observations

Dynamic Studies of Struve Double Stars: STF4 and STF 236AB Appear Gravitationally Bound

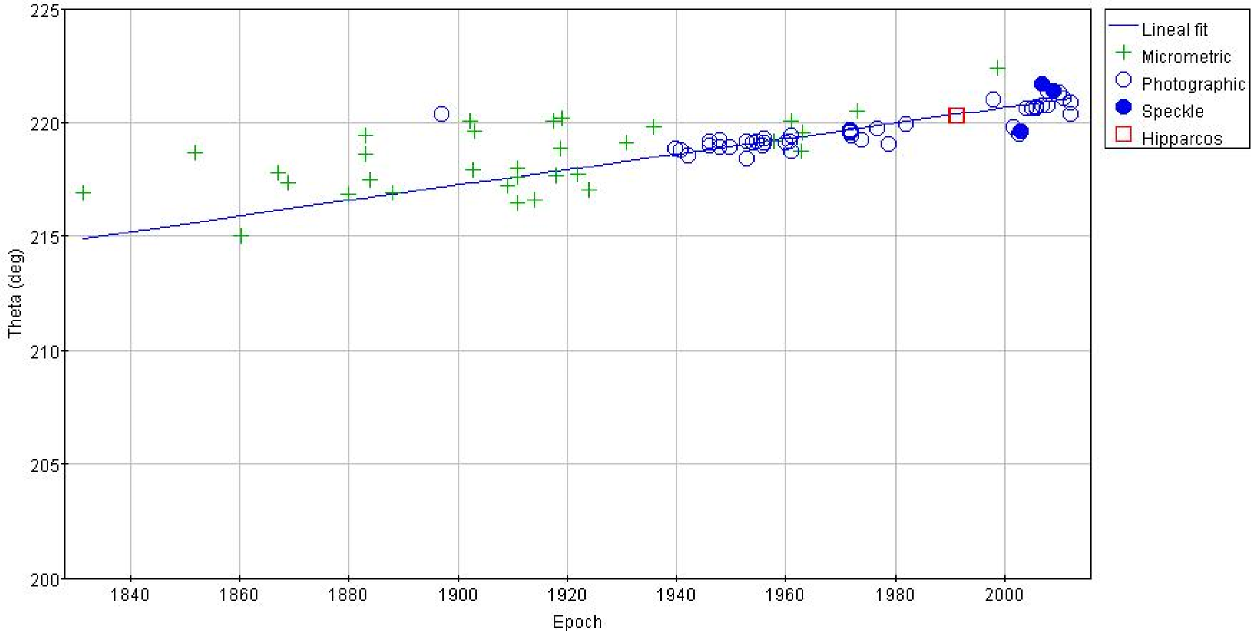


Figure 3. WDS 02556+2652 AB (STF 326 AB). Theta versus Epoch over history of observations.

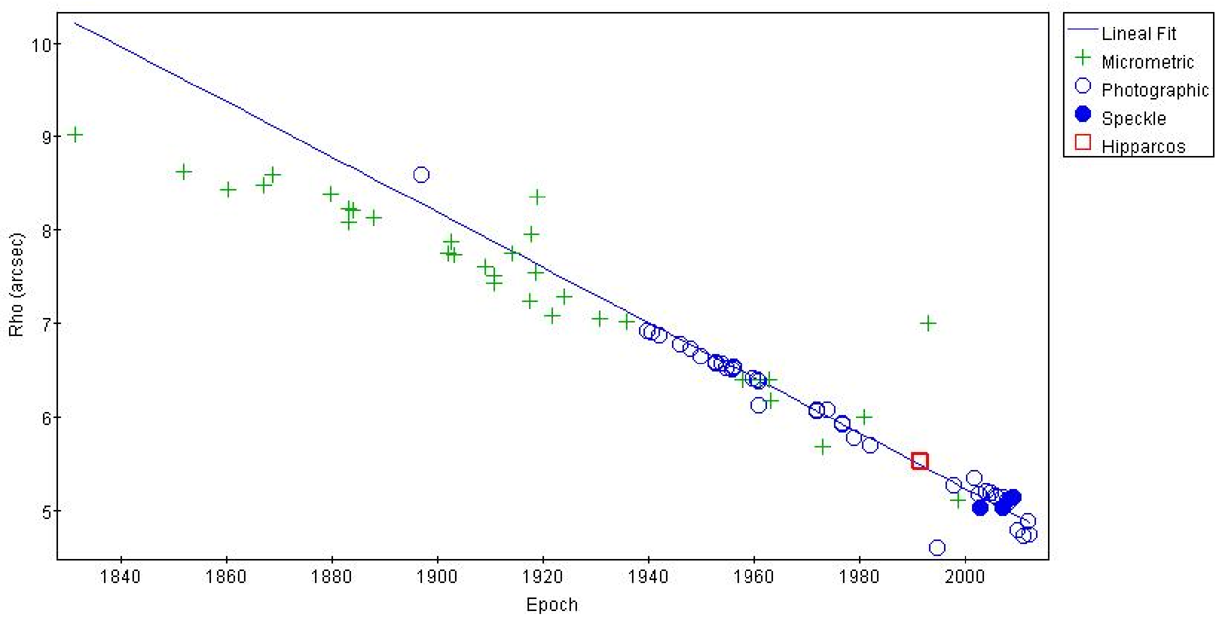


Figure 4. WDS 02556+2652 AB (STF 326 AB). Rho versus Epoch over history of observations.

Dynamic Studies of Struve Double Stars: STF4 and STF 236AB Appear Gravitationally Bound

(Continued from page 4)

terized as possible long-period binaries. They were selected from that list because we could access radial velocities for both components. We note that lack of radial velocities is a major impediment to analysis of many common proper motion pairs in the WDS that show some indications of interesting relative motion over their histories of observation. We also note that some pairs originally thought to have radial velocities for both components, in fact, do not; a cautionary tale that requires such data to be carefully evaluated.

Acknowledgements

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory and we gratefully thank Brian D. Mason and William I. Hartkopf for honoring our many data requests. This research also made use of the many catalogs (VizieR) and tools (Simbad, Aladin) maintained by the Centre de Données astronomiques de Strasbourg and we gratefully acknowledge the hard work of the many authors contributing to this resource.

References

Allende Prieto C., Lambert D. L., 1999, A&A, 352, 555. (J/A+A/352/555)

Anderson E., Francis C., 2012, AstL, 38, 331. (V/137)

Barbier-Brossat, M.; Figon P, 2000, A&AS, 142, 217. (III/213)

Close, L. M., H. B. Richer, Crabtree,D. R., 1990, AJ, 100, 1968.

Casagrande, L., Schoenrich, R., Asplund, M., Cassisi, S., Ramirez, I., Melendez, J., Bensby, T., Feltzing, S., 2011, A&A, 530A, 138.

Cutispoto, G., Pastori, L., Pasquini, L., de Medeiros, J. R., Tagliaferri, G., Andersen, J., 2002, A&A, 384, 491.

ESA - European Space Agency. 1997. SP-1200, vol. 1-17. (I/239)

Fabricius C., Hog, E., Makarov, V. V., Mason, B. D., Wycoff ,G. L., Urban, S. E, 2002, A&A, 384, 180. (I/276)

Fischer, D. A., Marcy, G. W., 1992, ApJ, 396, 178.

Gray, R. O., Corbally, C. J., Garrison, R .F., McFadden, M. T., Robinson, P. E., 2003, AJ 126, 2048. (J/AJ/126/2048)

Hartkopf, W. I., Mason, B. D., 2011, Catalog of Rectilinear Elements (v 2011.07.20) (http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/lin1)

Henry, T. J. & McCarthy, D. W., 1993, AJ, 106, 773.

Hopmann, J. 1967. Mitt. Univ. Sternw. Wien, 13, 49.

Howard, A. W., Marcy, G.W., Johnson, J .A., Fischer D. A., Wright J. T., Isaacson H., Valenti J. A., Anderson J., Lin D. N .C., Ida S., 2010, Science, 330, 653. (J/other/Sci/330.653)

Koen C., Eyer, L., 2002, MNRAS, 331, 45.

Luyten, W. J. 1969. Univ. Minnesota Proper Motion Survey #21.

Mason, B. D. 2005. JDSO, 1, 57.

Mason, B. D., Wycoff, G. L. Hartkopf, W. I., Douglass, G. G., Worley C. E., 2001-2013, AJ., 122, 3466. (B/wds/wds)

Orlov, V. V., Yatsevich, A. V., Panchenko, I. E., Rastorguev, A. S., 1995, AZh, 72, 495.

Pasinetti Fracassini, L. E., Pastori, L., Covino, S., Pozzi, A., 2001, A&A, 367, 521. (II/224)

Rica F. M., 2011, JDSO, 7, 254.

Rica, F. M., 2013, JDSO, 9, 221.

Shaya E. J., Olling R. P., 2011, ApJS 192, 2. (doi:10.1088/0067-0049/192/1/2). (J/ApJS/192/2)

Sinachopoulos D. & Mouzourakis P., 1992, AU Colloquium 135, ASP Conferences Series, 32, 353.

Struve, F.G.W., 1837, Mensurae Micrometricae, Petropoli.

Takeda G., Ford E. B., Sills A., Rasio F. A.; Fischer D. A., Valenti, J .A., 2007, ApJS, 168, 297. (J/ApJS/168/297/table2)

Tokovinin, A., 2008, MNRAS, 389, 925. (J/MNRAS/389/925/table2)

Torres, C.A.O., Quast, G.R., da Silva, L., de la Reza, R., Melo, C.H.F., Sterzik, M., 2006, A&A,460, 695

Valenti J. A. & Fischer D. A., 2005, ApJS, 159, 141. (J/ApJS/159/141/stars)

van de Kamp P., 1961, PASP, 73, 389.

van Leeuwen, F.,2007, A&A, 474, 653. (I/311/hip2)

Wiley E. O., 2012, JDSO, 8, 81.

Zacharias, N., Finch, C. T., Girard, T. M., Henden, A., Bartlett, J. L., Monet, D. G., Zacharias, M. I., 2013, AJ, 145, 44. (I/322A)

Discovery of 4 New Double Stars in Constellation Serpens

Joerg S. Schlimmer

Seeheim-Jugenheim, Germany
js@epsilon-lyrae.de

Abstract: During observations in the constellation Serpens, four new double stars could be found: USNO B1.0 1007-0241735, USNO B1.0 1004-0244945, USNO B1.0 0950-0252685 and USNO B1.0 0949-0248260. All these double stars are listed as single stars in USNO catalog but can be separated into two components. Separations are between 4 and 10 arc seconds. In 3 cases proper motions are known and comply with Halbwachs' criteria for possible common proper motion pairs.

Report

The observations were made with a 12-inch Newtonian telescope in combination with a Canon EOS 1100D camera. The focal length was 1500 mm; the field of view was about 0.9 x 0.6 square degrees. The reproduction scale was about 0.70 as/pixel [Schlimmer, 2013]. The planetary software Redshift 7 was used for telescope control. The data analyses were done with the software program REDUC [Losse].

For each observation, four field images with exposure times of 60 seconds were chosen. To correct the stacked image, flat and dark images were made. Deep Sky Stacker 3.3.4 [Coiffier] was used to stack the images.

In the analysis of the stacked images, four new double stars were found. All of the new double stars are listed in the SIMBAD astronomical database as single stars.

1. USNO B1.0 1007-0241735

This star is located in the neighborhood of δ Serpens. Coordinates for USNO B1.0 1007-0241735 are 15 35 50.7 in R.A and 10 43 35.6 in declination. Brightness is 10.29 magnitudes. The star can be separated into two components of similar brightness. Separation is 9.60 arc seconds, position angle is 1.6 degrees. There is no known proper motion. If the given brightness of USNO B1.0 1007-0241735 is interpreted as the combined magnitudes, the individual brightnesses of the components can be found. If brightness of both components is known, the Aiken criteria can be calculated. Because the separation is greater than maximum separation of Aitken's criteria [Romero, 2006], it can be expected that USNO B1.0 1007-0241735 is not a binary star.

Figure 1. USNO B1.0 1007-0241735, north is down, east is left

2. USNO B1.0 1004-0244945

The coordinates for USNO B1.0 1004-0244945 are 15 36 20.9 in R.A. and 10 26 51.3 in declination. It can be found only 39 arcsec from the high proper motion star TYC 933-563-1. USNO B1.0 1004-0244945 can also be separated into two components of similar brightness. The separation is about 4.39 arcsec and the position angle is 238.9°. There is a small proper motion of -4 mas/yr in R.A. and 4 mas/yr in declination. Separation doesn't satisfy Aitken's criteria for physical double stars, but with T = separation/proper motion = 776 years < 1000 years it achieves Halbwachs' criterion for possible common proper motion pairs [Halbwachs, 1986].

Figure 2. USNO B1.0 1004-0244945, north is down, east is left

3. USNO B1.0 0950-0252685

The observation field was centered on TYC 0361-00161-1 between ε Serpens and 43 Serpens. USNO B1.0 0950-0252685 can be found 1.9 arc minutes from TYC 361-1137-1. The coordinates for USNO B1.0 0950-0252685 are 15 54 31.4 in R.A. and 05 05 16.2 in declination. The brightness is 12.88 magnitudes. The star can be separated into two components. Separation is 5.46 arcsec, position angle is 320.3°. Proper motion is -6 mas/yr in R.A. and 4 mas/yr in declination. With T = 757 years for moving the distance of its own separation, it satisfies Halbwachs' criterion for possible common proper motion pairs [Halbwachs, 1986].

Figure 3: USNO B1.0 0950-0252685 north is down, east is left

4. USNO B1.0 0949-0248260

This star is located in the same observation field as the previous star and can be found 3.8 arc minutes from HD142576. USNO B1.0 0949-0248260 is the brightest star of these new double stars. Its brightness is 9.84 magnitudes, separation is 9.97 arcsec, and position angle is 296.4°. Proper motion is 4 mas/yr in R.A. and -24 mas/yr in declination. With T = 410 years for moving the distance of its own separation, it satisfies Halbwachs' criterion for possible common proper motion pairs [Halbwachs, 1986].

Figure 4: USNO B1.0 0949-0248260 north is down, east is left

The four double stars are listed in Table 1. First column lists the catalog name of the star, second and third columns are the R.A. and dec. coordinates, fourth col-

Discovery of 4 New Double Stars in Constellation Serpens

Table 1: New double stars in constellation Serpens

Name	RA	Dec	Mag	PM R.A.	PM Dec.	d Mag	Mag A	Mag B	date	Theta	p	Aitken limit	T=p/PM	Field centered
USNO-B1.0 1007-0241735	15 35 50.7	10 43 35.6	10.29	0	0	0	11.05	11.05	2014.504	1.6	9.6	5.50		del Serpens
USNO-B1.0 1004-0244945	15 36 20.9	10 26 51.3	12.09	-4	4	0	12.85	12.85	2014.504	238.9	4.39	2.40	776.05	del Serpens
USNO-B1.0 0950-0252685	15 54 31.4	05 05 16.2	12.88	-6	4	1	13.2	14.2	2014.463	320.3	5.46	1.71	757.17	TYC 0361-00161-1
USNO-B1.0 0949-0248260	15 55 18.4	04 59 21.2	9.84	4	-24	1	10.2	11.2	2014.463	296.4	9.97	6.8	409.76	TYC 0361-00161-1

umn gives the brightness, fifth and sixth columns give the proper motion in mas/yr if known, seventh column is the estimated difference in brightness, eighth and ninth columns give the calculated individual magnitude, column ten gives the date of observation, column eleven and twelve give the measured angle in degree and measured separation between the components in arc seconds, the thirteenth column shows the calculated Aitken limit p max in arc seconds, column fourteen gives the time in years how long the pair needs to move the distance of its own separation if proper motion is known, and column fifteen gives a short note to the image field in the neighborhood.

Acknowledgment

This research made use of the SIMBAD database, operated at CDS, Strasbourg, France, the USNO Image and Catalog Archive operated by the United States Naval Observatory, Flagstaff Station (http://www.nofs.navy.mil/data/fchpix), and the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

References

SIMBAD, CDS, Centre de Données astronomiques de Strasbourg, SIMBAD Astronomical Database, http://simbad.u-strasbg.fr/simbad/

Coiffier, Luc, http://deepskystacker.free.fr/english/

Halbwachs, J.L., 1986, Common Proper Motion stars in the AGK 3, Astronomy & Astrophysics Supplement Series 66, pages 131-148

Losse, Florent, http://www.astrosurf.com/hfosaf/uk/tdownload.htm#reduc.

Romero, Francisco Rica, 2006, R.G. Aitken's Criterion to Detect Physical Pairs, Journal of Double Star Observations, Vol. 2 No. 1, 2006, Pages 36-41

Schlimmer Joerg, S., 2013, Double Star Measurement Using a Webcam - Annual Report of 2012, Journal of Double Star Observations, Vol. 9 No. 4 Pages 230-246

How Nu Coronae Borealis Lost its Five Star Rating or One Less Star in the Northern Crown

John Nanson
Star Splitters Double Star Blog, Manzanita, Oregon

Steven C. Smith
Castle Rock, Colorado
ssmith9831@aol.com

Chris Thuemen
Double Star Imaging Project, Pembroke, Ontario, Canada

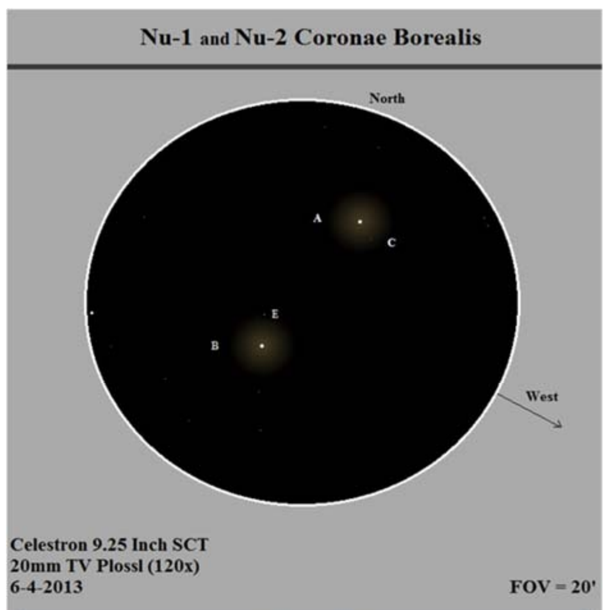
Abstract: This paper discusses our efforts to determine if the “D” and “E” components listed in the WDS for Nu-1 and Nu-2 Coronae Borealis were the same star.

In June of 2013, I had occasion to observe Nu-1 and Nu-2 Coronae Borealis, a beautiful pair of 5.4 and 5.6 magnitude orange-gold stars with a separation of 355 arc-seconds, located four degrees east of the Hercules Keystone. The WDS data at that time showed Nu-1 had 11.3 & 12.9 magnitude companions, while Nu-2 had a single 10.2 magnitude companion making Nu Coronae Borealis both literally and figuratively a “Five Star System”.

As I looked closely at the image in the eyepiece, four of the components (A-B-C & E) were easily spotted, but the fifth and faintest of the group, 12.90 magnitude “D”, was nowhere to be seen.

A careful examination of the position angles and separations of AD and BE (included at the bottom of the sketch in Figure 1) pointed to “D” and “E” being at either the same location or very close to it. Using the Aladin Sky Atlas I was able to not only pull up an image of the area, but also plot the WDS data for AD and BE over the top of the image (Figure 2). The resulting measures, which varied slightly from the WDS data shown at the bottom of Figure 1 confirmed my suspicion that “D” and “E” were at virtually the same location.

Since it was possible the missing 12.90 magnitude



16224+3348 SYSTEM COMPONENTS (Data as of June 4th, 2013)

NAME	CST	SAO	COORD_2000	DISCOV#	COMP	FIRST	LAST	OBS	PA	SEP	MAG1	MAG2
Nu 1 CrB	CrB	65257	16224+3348	STFA 29	AB	1835	2011	38	164	356.49	5.39	5.58
	CrB		16224+3348	H N 81	AC	1879	2002	7	241	68.10	5.39	11.30
	CrB		16224+3348	STFA 29	AD	1913	2002	5	153	277.10	5.39	12.90
nu 2 CrB	CrB	65259	16224+3348	H 6 18	BE	1879	2002	9	16	100	5.58	10.20

Quintuple system
5 visible stars in this system

Figure 1. J Nanson's sketch of Nu CrB.

How Nu Coronae Borealis Lost its Five Star Rating or One Less Star in the Northern Crown

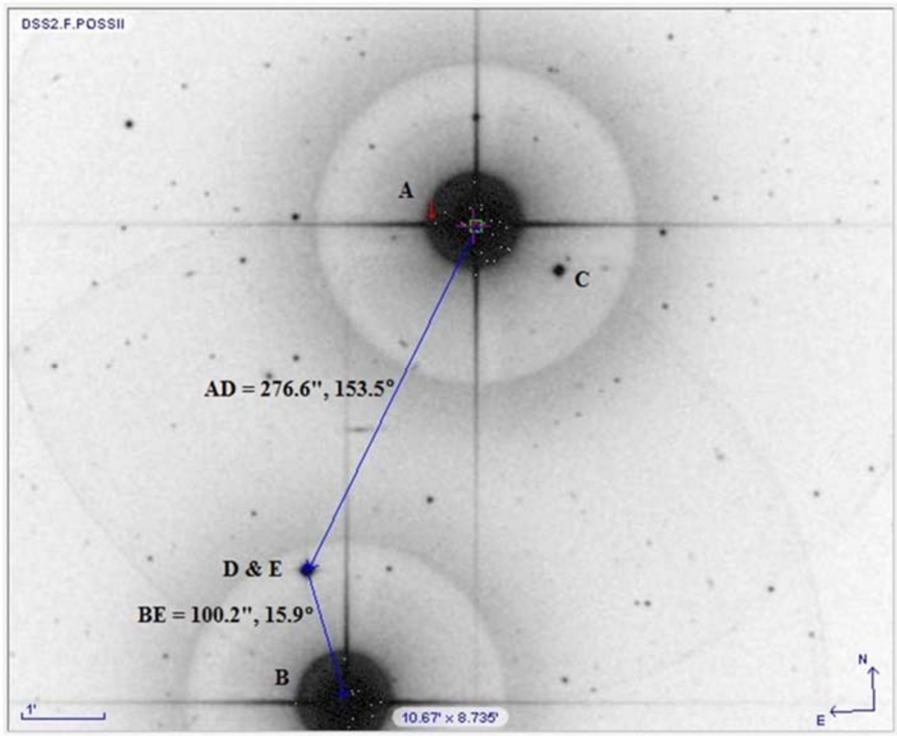


Figure 2. Vizier Plot

"D" component was hiding in the tenth magnitude glare of "E", I enlarged that image (see Figure 3) and found what appeared to be a candidate for "D", although it was so faint as to be unlikely and so indistinct it was far from conclusive

I posted my findings on my blog and there things stood until I received an email in August (2013) from Steve Smith, who had read my findings and wanted to assist in trying to locate "D". He included a photo he had recently taken of the area with a four inch refractor which also showed a possible candidate for "D" (see Figure 4), but this one was located on the opposite side of "E". While this candidate was widely separated from "E" and was relatively bright on the frame, we were unable to find any matching star on any of the sky survey photos and Steve has been unable to re-capture it in any of his subsequent photos (see Figure 5). We have since written this candidate off as most likely due to sensor noise or "hot pixels."

With repeated observations over the ensuing weeks, all of our efforts to locate "D" either visually or photographically were going nowhere, leaving us at an impasse. While we couldn't definitively eliminate the possibility of there actually being a "D" component, it nevertheless was possible our equipment was insufficient for detecting and/or resolving the potentially dim

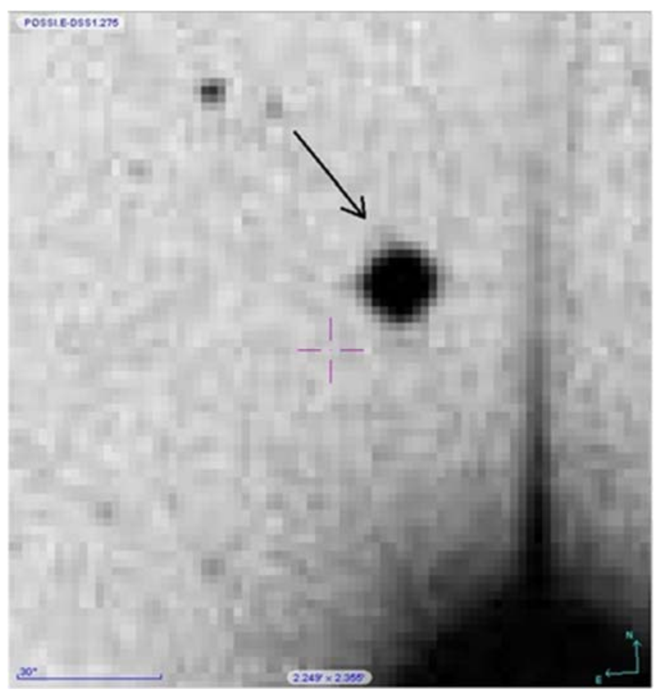


Figure 3. Vizier Image

How Nu Coronae Borealis Lost its Five Star Rating or One Less Star in the Northern Crown

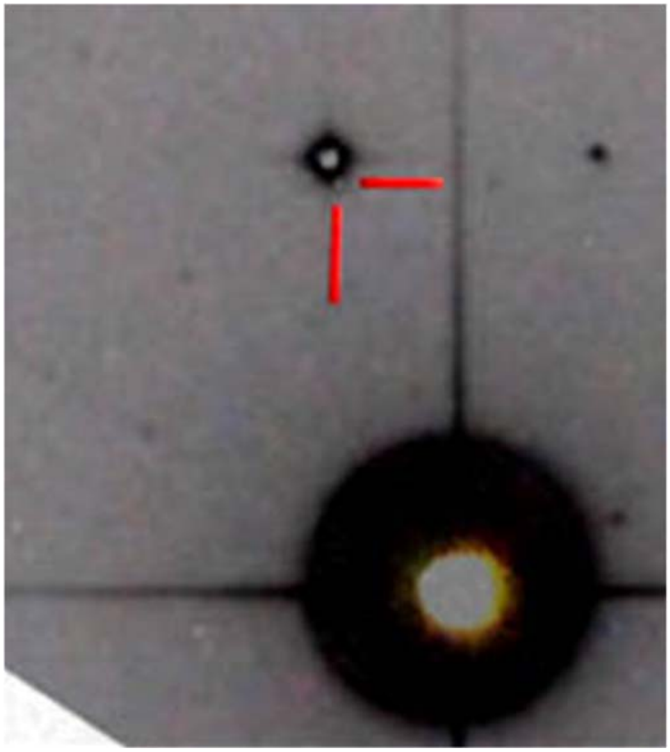


Figure 4. S. Smith August 2013 Photo of Nu 2 over-laid on top of DSS Survey photo in attempt to identify Possible "D" Component Candidates

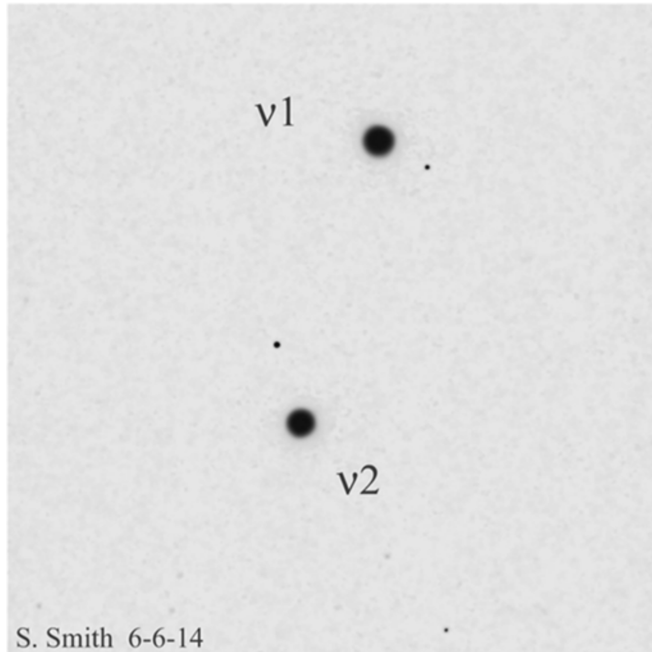


Figure 5. Recent photo of the Nu CrB area.

and tightly spaced component.

In June of 2013 I had sent a request to Brian Mason at the USNO for the detailed text file which lists all of the Nu CrB measures, from its discovery to the present day. Since the WDS data (both online and in the text file) didn't provide any separation and PA values specifically for the DE pair, Steve decided to put together an AutoCAD plot using the 2013 data to establish their separation and PA in order to determine whether or not they were beyond the visual and imaging capabilities of our equipment.

That plot (see Figure 6) showed the separation to be an exceedingly tight 0.32 arc-second, which would definitely place it well beyond the reach of our current equipment. A second plot (not shown) which used data from 1913 showed a separation of 1.13 arc-seconds between "D" and "E". But the plots also began to set in our minds the possibility that the data as presented was in error, as well as the distinct possibility that D & E were in fact the same star.

The WDS text file not only provided the historical record of measurements for the system, but also gave us the name of William Doberck, who was credited with the first measurements of the AD pair in 1913. I located his 1913 observation in a 1913 issue of *Astronomische Nachrichten* (see Figure 7), but initially didn't find it to offer anything more than the WDS file that Brian Mason had provided.

As emails and conjecture continued to pass between Steve, Chris and I over the intervening days, I found myself staring at Doberck's observations again one night, trying to match them with the data in the WDS file. Once again, I wasn't having much luck until it suddenly dawned on me that Doberck had reversed the letter designations for Nu-1 and Nu-2 CrB. In other words, he had identified Nu-1 Coronae Borealis as "B" in his log, and Nu2 as "A". Enlightened now with that critical nugget of knowledge, I was able to match Doberck's measurements in Astronomische Nachrichten with those in the WDS text file for Nu CrB.

The first entry in the 2013 WDS text file for AD shows this data from 1913:

```
STFA 29AD    1913 2002    5 154 153 281.7 277.1
5.39 12.9  M2IIIab
             1913.21        154.3   281.73
Dob1927  Ma   3
```

As I looked at Doberck's entries in the red box (see Figure 7), I saw those same numbers listed for the position angle (θ) and separation (ρ) of the pair Doberck

How Nu Coronae Borealis Lost its Five Star Rating or One Less Star in the Northern Crown

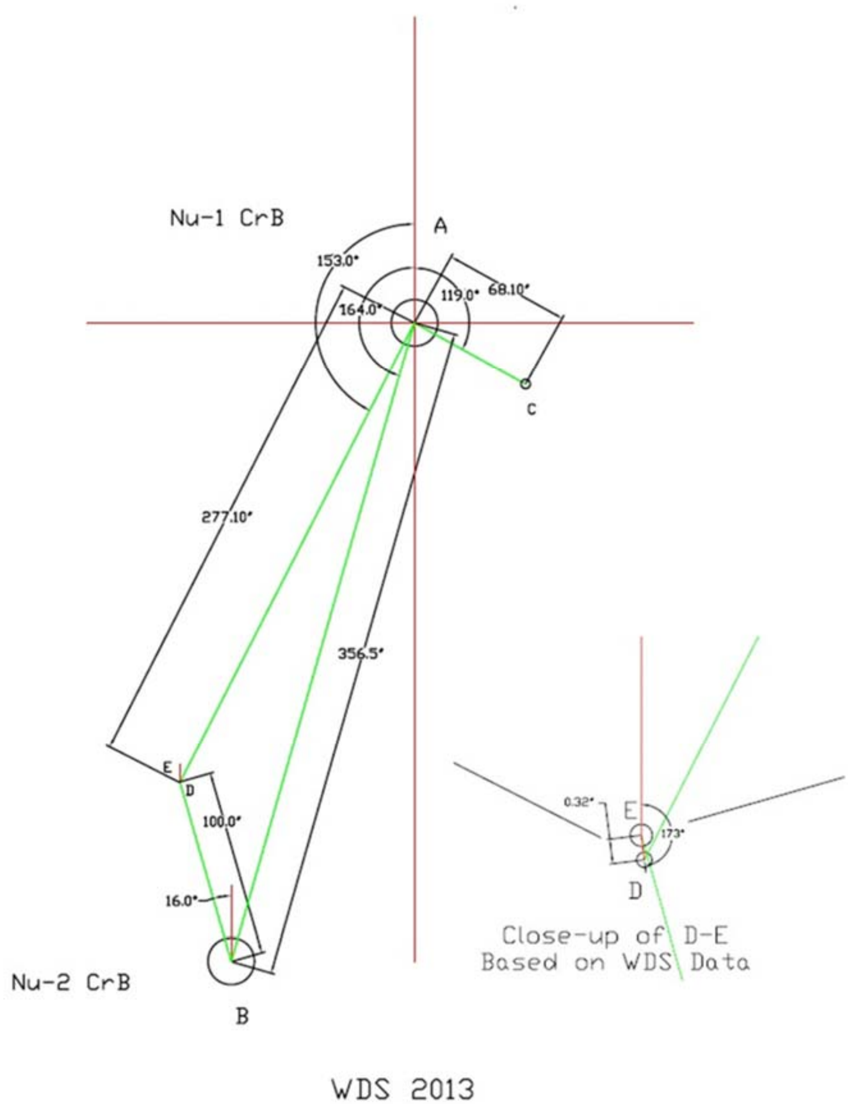


Figure 6: Nu CrB AutoCAD Plot of June, 2013, Data

had labeled as "BC". That pair is labeled "AD" in the WDS, which meant Doberck had measured to the companion from present-day Nu-1 CrB. Because the star he measured to is identified as "D" in the WDS, that meant Doberck's BC is the WDS's AD.

I went back to the WDS text file entry for BE and saw Doberck's name was also listed for the 1913.21 measurement of that pair:

```
H 6  18BE        1879 2002     9   16    16   104.6
100.0   5.58 10.2    K5III
                 1913.21          16.3        103.43
Dob1927   Ma   3
```

I compared the 16.3° and 103.43" listed there with his observing log, and immediately above the red box (see Figure 7) saw those same numbers in the section of his log he had labeled as AC. Aware now that Doberck's "A" is the WDS's "B", and his "C" is the WDS's "D", I could see the pair he labeled as "AC" was actually the stars labeled "B" and "D" in the WDS . . . . . . but the WDS identified that pair as BE.

The cloud of confusion surrounding Nu CrB for the past months suddenly evaporated with a burst of stellar clarity: where Doberck had measured to the same star from Nu-1 and Nu-2 (his BC and AC), the WDS listing showed two separate designations for the second star of those two pairs, AD and BE. In other words, "D" and "E" were the same star.

How Nu Coronae Borealis Lost its Five Star Rating or One Less Star in the Northern Crown

265 4695 266

BGC	Name	RA. 1915.0	Decl. 1915.0	1900 +	θ	n	ρ	n	t	Q	Power	Means 1900+	Means θ	Means ρ
7487	ξ Scorpii MC (cont.)	16h 0m	−11° 9′	13.48	62°.2	4	7″.17	4	−0h.1	m	450	13.46	62°.4	7″.40
7585	σ Coronae bor.	16 12	+34 5	13.38	217.4	4	4.91	4	−2.2	rg	450			
	H I 3			.43	217.8	4	—	–	−1.1	g	450			
				.46	217.4	4	4.84	4	−0.2	vg	450	13.42	217.5	4.87
7613	ρ Ophiuchi	16 20	−23 15	13.43	352.6	4	3.15	4	−0.3	g	250			
	H II 19			.45	352.0	4	3.39	4	−0.1	rg	450			
				.46	351.8	4	3.46	4	−0.2	m	450	13.45	352.1	3.33
7608	ν Cor. bor. AC	16 19	+34 0	12.45	16.30	5	—	–	−1.0	rb	150			
				13.39	16.90	4	102.35	5	−2.4	b	150			
				.46	16.43	3	103.84	6	+0.7	rg	150			
				.53	15.65	4	104.10	5	+0.8	m	150	13.21	16.32	103.43
»	» BC	»	»	12.45	154.73	4	—	–	−1.1	b	150			
				13.39	154.52	4	281.53	7	−2.3	b	150			
				.46	154.30	4	282.79	7	+0.5	rg	150			
				.53	153.82	4	280.88	7	+0.9	rb	150	13.21	154.34	281.73
7649	λ Ophiuchi	16 27	+ 2 10	13.45	73.0	5	1.18	4	−0.3	rg	450			
	H I 83			.46	73.2	4	1.33	4	0.0	rg	450			
				.48	73.7	5	1.19	4	+0.2	rb	450	13.46	73.5	1.23

from

***Astronomische Nachrichten*, Vol 196, pp. 265-66**

Figure 7: Doberck log

We set the issue aside for a time but that pause was interrupted in June, 2014, when Steve, who had resumed his imaging activities of Nu CrB as it became visible again in the evening sky, sent me his latest picture (Figure 5) along with a note that the WDS had revised the magnitudes for D & E; they were now at an identical magnitude of 11.53. The previous data from 2013 had listed those two stars with very different magnitudes, 12.90 for "D" and 10.20 for "E, which had reinforced the impression there were five stars in the Nu CrB system. (see Table 1).

Although the new magnitudes for "D" and "E" indicated someone else may have concluded the two stars might be one and the same, both AD and BE were still listed as though they were separate pairs. Well aware those magnitude changes could indicate the existence of additional information Steve and I didn't have, I pulled all of our information together and sent it to Bill Hartkopf and Brian Mason at the USNO.

In less the twenty-four hours I had a reply from Bill in which he described covering ground similar to what Steve and I had covered. At the end of his message were these welcome words:

> *"Bottom line - D and E are the same star. I'll change the component designation in the WDS and add a note.*
>
> *Cheers,*
> *Bill"*

And shortly later the WDS listing changed BE to BD and this note was added to the WDS notes file:

```
16224+3348 STFA 29      A: nu 1 CrB = 20 CrB
                        B: nu 2 CrB = 21 CrB
           H 6  18      BD: H VI 18. Confusion
in early component identification led to the BD
pair being misidentified as BE.
```

Both Steve and I were still wondering what had prompted the change in the magnitudes of both "D" and "E" to 11.53, so I sent another message to Bill asking whether someone else had realized the two letter designations actually referred to the same star. We learned from Bill's quick reply that he had been doing some matching of the UCAC4 Catalog against the WDS and "Since much of the matching was automated,

How Nu Coronae Borealis Lost its Five Star Rating or One Less Star in the Northern Crown

the

16224+3348 SYSTEM COMPONENTS (Data as of June 4th, 2013)

NAME	CST	SAO	COORD_2000	DISCOV#	COMP	FIRST	LAST	OBS	PA	SEP	MAG1	MAG2
Nu 1 CrB	CrB	65257	16224+3348	STFA 29	AB	1835	2011	38	164	356.49	5.39	5.58
	CrB		16224+3348	H N 81	AC	1879	2002	7	241	68.10	5.39	11.30
	CrB		16224+3348	STFA 29	AD	1913	2002	5	153	277.10	5.39	12.90
nu 2 CrB	CrB	65259	16224+3348	H 6 18	BE	1879	2002	9	16	100	5.58	10.20

16224+3348 SYSTEM COMPONENTS (Data as of June 12th, 2014)

NAME	CST	SAO	COORD_2000	DISCOV#	COMP	FIRST	LAST	OBS	PA	SEP	MAG1	MAG2
Nu 1 CrB	CrB	65257	16224+3348	STFA 29	AB	1835	2011	38	164	354.70	5.39	5.58
	CrB		16224+3348	H N 81	AC	1879	2002	7	241	68.10	5.39	12.62
	CrB		16224+3348	STFA 29	AD	1913	2002	5	153	277.10	5.39	11.53
nu 2 CrB	CrB	65259	16224+3348	H 6 18	BE	1879	2002	9	16	100	5.58	11.53

Table 1. Comparison of Nu CrB Data, June 2013 and June 2014

program found the same astrometry and photometry for AD and AE."

That cleared up the final bit of confusion in the database for Nu Coronae Borealis, conclusively removing one of the 5 stars that had been attributed to this system for nearly 100 years.

Acknowledgements

Many thanks to Brian Mason and especially to Bill Hartkopf, who was so quick to reply, to the many questions we directed to them. This paper couldn't have been written without the information they both so readily provided.

References

Doberck, William., 1913, "Sutton Double Star Observations", *Astronomische Nachrichten* 196 (1913), 253-268, at http://articles.adsabs.harvard.edu//full/1913AN....196..253D/0000147.000.html

Hartkopf, William., Mason, Brian., 2013 and 2013, *Washington Double Star Catalog*, http://ad.usno.navy.mil/wds/

MacKeown, P. Kevin., 2007, "William Doberck — Double Star Astronomer", *Journal of Astronomical History and Heritage* 10-1 (2007), 49-64, at http://www.narit.or.th/en/index.php/jahh

Nanson, John., 2013, "A Pair of Nu Ones: Nu-1 and Nu-2 in Boötes and Corona Borealis", Bestdoubles.wordpress.com: http://wp.me/pVYaT-1ss

Web Sites

Aladin Interactive Sky Atlas: http://aladin.u-strasbg.fr/aladin.gml

AutoCad: http://www.autodesk.com/

Double Star Imaging Project: https://groups.yahoo.com/neo/groups/double_star_imaging/info

SAO/NASA Astrophysics Data System: http://articles.adsabs.harvard.edu/

Star Splitters Double Star Blog: http://bestdoubles.wordpress.com/

Stelladoppie WDS Interface: http://stelledoppie.goaction.it/index2.php?section=1

Vizier: http://vizier.u-strasbg.fr/viz-bin/VizieR

Measuring Double Stars in Ursa Minor with a Micrometer and an Eyepiece Reticle

Papadimitriou Athanassios
Astronomical Society of Corfu, Greece

Abstract: Twenty-two binary stars were measured in Ursa Minor by using a micrometer for measuring the angular distance. An eyepiece reticle was also used for the more accurate measuring of position angle.

Introduction

First of all I used the excellent search engine for double stars "Stelle Doppie" and I selected double stars appropriate for my equipment, double stars with separation greater than 6 arcsec, Δmag greater than 1 mag, and stars not fainter than 12 mag. Also stars which were measured very recently were excluded.

Equipment

My equipment included Celestron's equatorial mount CG5 , a Newtonian telescope Konus 200 /1000, a Meade 12mm wireless astrometric eyepiece, a barlow TeleVue 2x, and Meade 9 mm wireless illuminated reticle eyepiece with micrometric x-y positioning controls. For measuring separation, the astrometric eyepiece with a Barlow, in which the linear scale was calibrated by a known method was used and it was found that the micrometer scale has divisions that are equal to 11.09 arcsec. An outer protractor 360° was constructed that was attached to the barlow, and a pointer was attached to the eyepiece (Ronald Tanguay 1998). A lever was also placed on the barlow so as to have a vibrationless tightening of the eyepiece. For measuring the position angle, an eyepiece with adjustable reticle was used which was aligned with an outer protractor**,** Figure 1.

This eyepiece was selected because:

1) When we measure the position angle, we should calibrate the protractor with the motion of the star in R.A., therefore when the drive motor is turned off the primary star has to run parallel to the linear scale. If we use the micrometer for this reason, the numbers on the linear scale will prevent a proper evaluation.

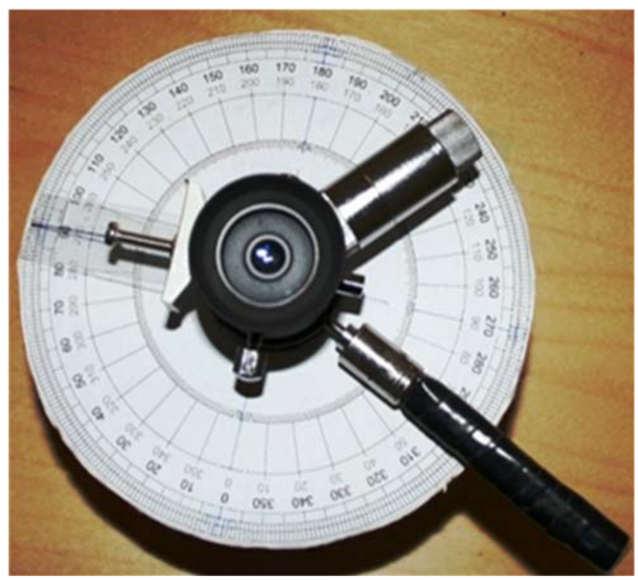


Figure 1. The reticle eyepiece with the outer protractor.

2) After this alignment with the method described above, we rotate the eyepiece in order to have the primary and secondary star in the same direction. Without doubt the measurement is better when both stars are situated between the lanes of the reticle, Figure 2.
3) When using the crosshairs of regulators we do not have to use the controller to bring the stars near the crosshair. Certainly the movement of the reticle

Measuring Double Stars in Ursa Minor with a Micrometer and an Eyepiece Reticle

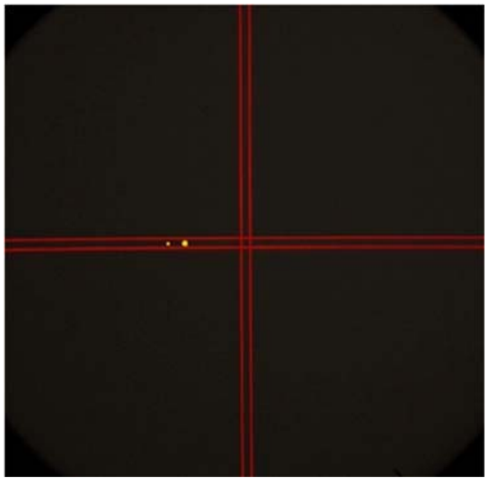


Figure 2. The stars are situated between the lanes of the reticle

does not affect the correct alignment with the outer protractor.

Comments

All observations were made in the summer of 2014 on Corfu Island. Primarily a few test measurements were performed in recently measured stars in order to ascertain if the equipment has significant deviations from the recent measurements. For example, the test that was done in STF 1972 AB in U.Mi has very few deviations from the last measurement in 2011 (Table 1). The equipment has proven to be well aligned and calibrated. Three observations were performed on each star and the final value was defined as the average of measurements. For both measurements 2x Barlow was used. The technique of measuring the position angle with the reticle eyepiece was considered particularly accurate. Table 2 gives the 22 measurements obtained in the summer of 2014.

Acknowledgments

I would like to thank the members of the Astronomical Society of Corfu for the use of their telescope .

I would also like to thank Gianluca Sordiglioni for providing a useful tool with lots of information about binaries on his website: http://stelledoppie.goaction.it

References

Tanguay, Ronald, *The Double Star Observer's Handbook,* Saugus, MA: Double Star Observer, 1998.

Table 1. Test with STF 1972AB

NAME	R.A	DEC	MAG1	MAG2	LAST SEP	OBS SEP	LAST P.A	OBS P.A
STF 1972 AB	15 29 11	(+) 80 26 55	6.60	7.30	31.40	31.50	79.00	79.00

Measuring Double Stars in Ursa Minor with a Micrometer and an Eyepiece Reticle

Table 2. Measures of 22 Double Stars in Ursa Minor

NAME	R.A	DEC	MAG 1	MAG 2	SEP (ρ)	P.A (θ)	N	DATE	NOTES
STF1761	13 32 01	71 43 01	9.30	10.10	20.4	69.8	3	2014.431	1
STF1798	13 55 02	78 23 59	7.60	9.60	8.3	11.0	3	2014.431	2
STF1822	14 09 37	72 50 04	9.00	10.80	14.3	50.0	3	2014.491	3
STF1840AB	14 19 54	67 46 56	7.00	10.00	30.3	222.0	3	2014.431	4
STF1841AB	14 21 07	67 48 10	7.30	11.00	35.2	264.3	3	2014.431	5
STF1859	14 28 31	73 03 18	8.60	10.10	20.5	234.5	3	2014.431	6
STTA130	14 32 17	80 20 27	9.00	9.40	52.3	298.0	3	2014.494	7
STF1897	14 53 35	69 45 46	7.60	11.00	34.2	319.5	3	2014.491	8
S 666	14 56 48	74 54 03	7.00	9.00	167.8	32.5	3	2014.494	9
HJL1089	14 59 24	83 19 39	9.60	10.70	58.9	333.0	3	2014.491	10
H 5 86AB	15 17 16	71 12 40	7.30	11.00	51.7	130.5	3	2014.491	11
H 5 86AC	15 17 16	71 12 40	7.30	11.40	94.6	115.0	3	2014.491	12
HAU 23	15 28 50	80 36 50	9.50	11.50	35.8	63.0	3	2014.491	13
STF1972AC	15 29 37	80 25 37	6.60	11.40	187.0	101.0	3	2014.431	14
STF1971	15 35 12	75 20 16	9.60	12.00	14.3	315.0	3	2014.494	15
A 856AC	15 43 22	81 19 09	8.30	11.10	62.7	343.0	3	2014.494	16
UC 3072	15 51 48	73 19 02	8.70	11.30	43.5	37.8	3	2014.491	17
STF2125	16 40 57	82 21 53	9.00	10.50	11.6	180.3	3	2014.491	18
KU 1	16 43 06	77 30 48	6.00	11.50	104.5	13.0	3	2014.494	19
HDO 143	16 45 58	82 02 14	4.20	11.20	77.0	2.0	3	2014.494	20
WAL 75AC	16 57 18	86 50 40	8.40	10.70	78.1	92.0	3	2014.494	21
WFC 190	17 20 04	75 22 33	9.80	10.50	8.3	39.0	3	2014.491	22

Table Notes:

1. Rho increased 0.1", theta decreased 1.2°
2. Rho increased 0.8", theta consistent with trend reported
3. Rho decreased 0.6", theta decreased 2°
4. Rho increased 3", theta consistent with trend reported
5. Rho increased 0.3", theta decreased 0.7°
6. Rho increased 0.6", theta increased 0.5°
7. Rho increased 1.2", theta decreased 1°
8. Rho decreased 0.4", theta increased 0.5°
9. Rho increased 3.2", theta increased 0.5°
10. Rho decreased 1.2", theta consistent with trend reported
11. Rho increased 0.7", theta increased 0.5°
12. Rho increased 0.1", theta increased 1°
13. Rho increased 0.8", theta decreased 1°
14. Rho increased 34.7", theta decreased 4° (measures reported from 1994)
15. Rho decreased 0.9", theta decreased 3°
16. Rho decreased 3.2", theta increased 3° (measures reported from 1999)
17. Rho increased 2.6", theta decreased 1.2°
18. Rho decreased 0.3", theta decreased 0.7°
19. Rho decreased 1.8", theta consistent with trend reported
20. Rho decreased 0.4", theta increased 1°
21. Rho decreased 1.2", theta increased 3°
22. Rho increased 0.3", theta decreased 1°

Double Star Measures Using the Video Drift Method - V

Richard L. Nugent
International Occultation Timing Association, Houston, Texas
RNugent@wt.net

Ernest W. Iverson
International Occultation Timing Association, Lufkin, Texas
ewiverson@consolidated.net

Abstract: Position angles and separations for 189 multiple star systems are presented using the video drift method. The drift method generates a Cartesian (x,y) coordinate pair for the primary and companion star for each video frame during the drift. Position angle and separation are calculated from these coordinates. Most doubles had 1,000's of (x,y) pairs analyzed per system. Several systems lacked measurements since the late 1800's and early 1900's. The video drift method provides high systematic accuracy.

Introduction

In our first paper (Nugent and Iverson, 2011) we described a new video method that computes both the position angle (PA) and separation (Sep) for a double star. A significant advantage of this method is that data collection and subsequent data analysis is almost completely automated with little human interaction. A short video clip of the multiple star system drifting across the field of view is evaluated by the freeware program *Limovie* (Miyashita, 2006) to capture 100's to 1,000's of (x,y) positions for each component. Although *Limovie* was originally written to measure the change in light levels during an occultation, it also produces a table of Cartesian (x,y) coordinates for both components along with the brightness levels for each video frame. *VidPro*, an Excel program written by co-author Nugent, reads the (x,y) coordinate data and computes the position angle, separation for each video frame. The position angles and separations are then averaged to give a final result.

Unlike other video/CCD methods, calibration doubles are not needed to determine plate scale or orientation. An east-west line does not need to be drawn, a star catalog is not needed since there is no "plate adjustment" performed for each double star system, and no video frames are discarded. Each double star drift is self calibrating (see Nugent and Iverson 2014 for a discussion of a onetime equipment calibration). The *VidPro* program computes a unique scale factor, an offset from the east-west direction compared to the camera's pixel array, and standard deviations for both position angle and separation for each drift. The offset of the pixel array alignment of the video camera's chip from the true east-west direction (drift angle) is calculated using the method of least squares to an accuracy of better than 0.02°.

Methodology

Preference was given to multiple star systems where the WDS lacked measurements for at least the past 10 years and had less than 10 measurements. This criterion applies to nearly all of the multiple star systems measured at the epoch of their measurement. In some cases, where one component of a complex system meets this requirement, all of the other components within the reach of our telescopes were also measured for completeness, even though they have been well measured in the past. Twelve doubles had more than 35 measurements. We routinely look at a few well measured doubles to support ongoing efforts to compare the Video Drift method with other measurement methods

Double Star Measures Using the Video Drift Method - V

(see discussion below). Fifteen systems lacked measurement since 1894-1945. The faintest system measured had primary/secondary magnitudes of +12.4, +15.4. These magnitudes were reached by author Nugent using a Collins I^3 Image Intensifier.

With some doubles not measured since the late 1800's or early 1900's, significant deviations in PA and Sep were sometimes observed. This is not surprising. These doubles were checked with the interactive Aladin Sky Atlas software (from the Centre de Données astronomiques de Strasbourg) to verify that the stars originally observed were identified and re-measured by us. Updated proper motions were taken into account from catalogs from the VizieR database to confirm the observed directional changes in PA and Sep.

Other doubles showed a significant deviation from the WDS summary catalogue value. The observational history was obtained from the U.S. Naval Observatory and both the position angle and separation were plotted against the year of observation. In most cases the data conformed to a general trend line. In a few cases the fit was very good and the least squares correlation coefficient was greater than 0.90. Graphing the data also showed which data points were obviously in error. Just comparing a new measurement to the WDS summary catalogue value and noting a large difference might cause an observer to incorrectly reject the new measurement when in fact it might to be a very good measurement.

Figure 1 is an example where the measurement reported in the WDS summary catalogue is very suspicious because it significantly deviates from the trend line. This illustrates the problem of putting too much trust in any single measurement. In many cases, comparison to the measurement history trend line gives a reasonable estimation of the relative position of the companion star. Although we have found this method useful for checking our results, it should be pointed out that the method does not always work. For reasons beyond the scope of this paper, a high correlation is not always found. In these cases it is best to reserve judgment and use other means to decide whether or not to publish the measurement.

It is easy to identify doubles which need checking by noting the offset from the WDS summary catalogue value, but it is much harder to identify suspect doubles where the WDS and measured value are close but widely separated from the trend line. Unfortunately the observational history is not available online and

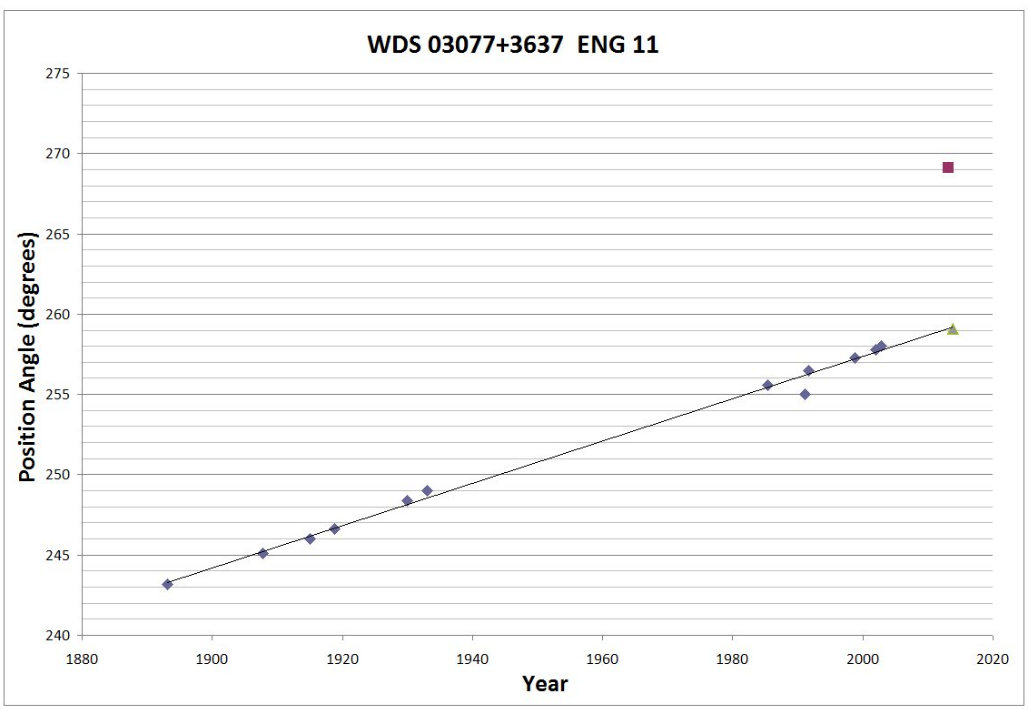


Figure 1. The diamonds represent historical position angle measurements for the double star 03077+3637 ENG 11 found in the WDS Observational Catalogue. The square represents the last measurement and current WDS Summary catalogue entry. Clearly this measurement is in error and illustrates a need for caution. The triangle represents our position angle measurement given in Table 2. After removing the wild data point (i.e., square) the Least Squares correlation coefficient is 0.9945.

Double Star Measures Using the Video Drift Method - V

Table 1. Telescopes used in this research. Scale factors will vary slightly due to the declination of the doubles.

Telescope	Aperture	Focal Length	Scale Factor
Meade LX-200	14″ (35 cm)	3556mm f/10	0.6″/pixel
Celestron refractor	6" (15.2 cm)	2400mm f/12	1.4"/pixel (barlow)

must be requested from the U.S. Naval Observatory. The staff at the US Naval Observatory kindly responds to reasonable numbers of requests for double star observations from the WDS historical database."

Calibration

In our paper (Nugent and Iverson, 2014), we discuss how to make a one time calibration to set the correct aspect ratio for the hardware configuration used for the recording of the videos. This calibration makes a slight adjustment to the video aspect ratio (width vs. height) to overcome the unavoidable skewing of the image aspect ratio caused by modern digital video recorders. With the one time video size adjustment (done automatically using an AviSynth script when *Limovie* opens the video file), our video aspect ratios closely matched the sky in the east-west and north-south directions. To confirm this, we measured long term stable doubles with no change in PA, Sep and also used RA, DEC coordinates from the VisieR star catalogs to compute the angular displacement and separation of known stars.

The telescope equipment used and scale factors are summarized in Table 1. The 189 double star measures are given in Table 2 beginning on the next page.

Acknowledgements

This research makes use of the Washington Double Star Catalog maintained at the US Naval Observatory, the Aladin Sky Atlas Interactive software program and the VisieR catalog database from the Center de Données Astronomiques in Strasbourg, France.

References

Aladin Interactive Sky Atlas, Centre de Données Astronomiques de Strasbourg, http://aladin.u-strasbg.fr/java/nph-aladin.pl

Miyashita, K. 2006, *LiMovie, Light Measurement Tool for Occultation Observation Using Video Recorder,* http://www005.upp.so-net.ne.jp/k_miyash/occ02/limovie_en.html

Nugent, R. and Iverson, E. 2011, *Journal of Double Star Observations*, 7, No. 3, 185-194

Nugent, R. and Iverson, E. 2014, *Journal of Double Star Observations*, 10, No. 3 214-222

VisieR catalog database: Centre de Données Astronomiques de Strasbourg, http://vizier.u-strasbg.fr/viz-bin/VizieR

Double Star Measures Using the Video Drift Method - V

Table 2. Results of 189 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	No.of x-y Pairs	Mag Pri	Mag Sec	Drifts	Nights
00022+2705	BU 733AC	323.9	0.1	177.5	0.25	2013.830	1682	5.83	9.88	3	1
00066+2901	ENG 1A,CD	199.7	0.1	141.9	0.28	2013.830	1939	6.14	10.70	3	1
00066+2901	STT 549AB	259.6	0.1	192.9	0.17	2013.830	1185	6.15	10.34	3	1
00080+3123	STTA256AB	112.9	0.1	110.7	0.16	2013.830	1742	7.13	7.28	3	1
00239+2930	STF 28AB	224.2	0.3	32.8	0.16	2013.830	2267	8.32	8.55	3	1
00307+3208	STT 11	317.3	0.1	196.6	0.19	2013.808	1496	7.57	7.70	3	1
00499+3027	STTA 9AB	244.2	0.1	117.1	0.16	2013.830	1713	7.75	8.81	3	1
00552+3814	KU 71	248.9	0.5	22.5	0.16	2013.808	2474	9.95	10.61	3	1
01002+3818	GRV 58	188.2	0.3	32.9	0.15	2013.808	2580	8.92	9.23	3	1
01060+4447	HJ 2013	239.5	0.6	23.7	0.18	2013.808	2718	8.26	11.30	3	1
01477+2829	STF 161	211.6	0.7	24.1	0.24	2013.860	2252	8.57	10.24	3	1
02015+3319	BU 872AC	319.9	0.1	100.7	0.17	2013.808	1986	8.74	11.17	3	1
02217+3441	PTT 4A,BC	294.6	0.6	15.4	0.13	2013.808	2378	10.53	11.52	3	1
02267+3207	HJL1018AB	78.4	0.1	73.2	0.16	2013.808	1904	9.62	9.56	3	1
02536+3618	ALI 41	331.0	0.8	14.2	0.16	2013.808	2482	11.26	11.54	3	1
03036+3627	BUP 37AB	268.4	0.1	99.2	0.20	2013.860	1809	7.75	9.95	3	1
03077+3637	ENG 11	259.1	0.1	135.8	0.23	2013.860	1540	7.44	9.15	3	1
03136+3909	STF 364	310.8	1.0	11.7	0.18	2013.860	2559	8.73	8.92	3	1
03232+2412	KU 80	181.5	0.4	27.2	0.21	2013.860	2238	10.30	10.56	3	1
03266+2843	TOK 13AB	129.4	0.1	96.4	0.19	2013.808	1809	6.59	10.00	3	1
03322+1133	AG 68	247.9	0.6	16.8	0.19	2014.011	1985	6.79	9.87	3	1
03334+2322	STT 57AC	3.93	0.1	69.0	0.16	2013.852	2024	7.17	7.67	3	1
03347+3848	HJL1022	214.6	0.1	136.0	0.20	2013.860	1989	7.96	9.80	3	1
03446+2754	STTA 38AB	52.1	0.1	135.1	0.17	2013.852	1648	6.78	6.91	3	1
03510+2939	STF 459AB	340.6	0.5	24.7	0.19	2013.860	2248	8.01	10.87	3	1
04384+3927	STF 568	199.7	0.7	21.3	0.18	2013.860	2563	8.49	11.78	3	1
04590+1433	SHJ 49AB	305.1	0.3	38.7	0.18	2014.011	1927	6.06	7.43	3	1
04590+1433	SHJ 49AC	89.6	0.2	54.9	0.20	2014.011	1825	6.06	9.60	3	1
05102+1400	S 468	166.1	0.3	26.2	0.16	2014.011	2127	8.62	8.86	3	1
05261+2250	HDS 713	129.3	0.4	24.0	0.15	2013.860	2096	10.00	10.19	3	1
05282-0156	HJ 702	148.6	0.5	24.0	0.22	2013.827	2037	8.46	9.35	3	1
05297-0106	STF 725	87.6	0.8	13.0	0.23	2013.827	1958	4.69	9.70	3	1
05320-0018	STFA 14AC	0.7	0.2	51.5	0.28	2013.827	2013	2.41	6.83	3	1
05331-0143	STF 734AC	243.2	0.4	29.6	0.24	2013.827	1904	6.67	8.35	3	1
05358-0059	STF 751	123.1	0.7	15.5	0.20	2014.074	2240	8.02	8.96	3	1
05382+1251	AG 315	159.4	0.3	29.7	0.18	2014.011	2058	9.76	10.62	3	1
05403+1521	STF 766AB	274.1	0.9	10.0	0.17	2014.011	2074	7.00	8.36	3	1
05429+0001	STF 782AB	305.1	0.3	47.0	0.26	2013.827	1828	8.60	8.83	3	1
05467+1103	AG 317	237.2	0.5	21.9	0.19	2014.011	1996	7.73	10.18	3	1
05571+1014	ARG 63AB	67.6	0.3	32.5	0.14	2014.011	1895	8.69	9.09	3	1
06065+1045	STF 840A,BC	247.7	0.5	21.4	0.17	2014.011	1969	7.17	8.95	3	1
06092+1139	STF 853	7.6	0.2	37.3	0.14	2014.011	2043	8.49	8.98	3	1
06599-0003	HJ 3287	79.1	0.5	22.3	0.20	2014.074	1972	8.94	9.10	3	1
07005-0031	BAL 749	134.3	0.6	17.5	0.19	2014.074	2059	8.91	9.44	3	1

Table continues on next page.

Table 2 (continued). Results of 189 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	No.of x-y Pairs	Mag Pri	Mag Sec	Drifts	Nights
07043+0129	STTA 82	318.9	0.1	89.9	0.26	2014.074	1735	6.54	7.62	3	1
07161+0202	BAL1783	30.0	0.5	20.3	0.18	2014.074	2037	10.53	10.48	3	1
07188+0252	STF1067	266.4	0.4	25.8	0.20	2014.074	1917	8.51	10.15	3	1
07201+0146	AG 138	320.9	0.4	24.5	0.19	2014.074	1992	9.64	10.65	3	1
07470+0001	ARN 45AD	46.5	0.2	63.4	0.23	2014.074	1862	8.41	9.64	3	1
07470+0001	ARN 45AE	276.8	0.2	61.7	0.25	2014.074	1787	8.41	9.97	3	1
07470+0001	STF1141AB	10.2	0.6	17.2	0.18	2014.074	2058	8.41	9.37	3	1
09127-2115	LDS3865	236.8	2.7	7.5	0.36	2014.329	1530	13.1	13.3	2	1
09133-0219	HJ 123AB	71.1	1.0	38.3	0.71	2014.329	1337	11.6	14.8	2	1
09133-0219	HJ 123AC	38.4	0.7	30.4	0.47	2014.329	1421	11.6	11.7	2	1
09140-2052	ARA1065	221.8	2.5	13.1	0.65	2014.329	1551	11.85	13.1	2	1
09536+2141	HJ 2511	122.1	1.4	13.3	0.33	2014.326	1490	11.7	12.7	2	1
09545-1255	HJ 4262AC	135.1	0.1	152.1	0.16	2014.219	2959	8.69	6.92	6	2
09593-2631	LDS3945	251.1	0.4	69.3	0.45	2014.326	1374	11.72	12.3	2	1
10205+0626	STF1426AB,C	10.1	1.4	7.3	0.20	2014.318	1097	7.30	9.43	2	1
10299-0457	J 1565	10.5	2.2	19.7	0.76	2014.326	1459	13.0	13.0	2	1
10459-2025	ARA 672	269.9	1.7	7.4	0.38	2014.326	1500	11.83	12.2	2	1
10507-1353	J 2657	162.0	2.2	8.0	0.36	2014.326	1527	12.60	12.9	2	1
10522-2248	ARA1785	142.9	2.0	7.7	0.30	2014.326	1609	12.48	12.5	2	1
10536-0742	J 90BC	193.9	1.6	11.6	0.36	2014.326	1451	10.94	12.4	2	1
10567-0542	GWP1501	84.8	3.9	9.5	0.94	2014.326	696	11.6	12.4	2	1
10576-1945	ARA 677	32.1	1.9	15.0	0.51	2014.329	1543	12.6	13.1	2	1
10577+1031	BPM 578	172.4	0.3	114.8	0.65	2014.329	1348	13.08	13.73	2	1
10585-1816	GWP1512	338.3	0.7	45.5	0.49	2014.329	1468	10.6	13.7	2	1
10589-0823	UC 2044	62.8	0.9	53.3	0.93	2014.329	1302	10.7	12.9	2	1
10590-1717	LDS 323	64.1	2.1	21.7	0.76	2014.329	1479	13.0	15.0	2	1
10594+1154	HDS1567	9.2	0.9	7.2	0.16	2014.329	1497	8.96	11.54	2	1
10598-0200	BAL 530	253.7	0.8	11.0	0.26	2014.329	1415	9.14	11.78	2	1
11011+0003	HJ 1182	106.8	0.8	32.7	0.54	2014.329	1313	7.29	12.3	2	1
11038-2100	UC 2066	326.4	0.7	44.9	0.57	2014.329	1475	10.7	12.5	2	1
11045-1940	HDS1580	284.9	1.2	17.3	0.38	2014.329	1522	9.76	11.07	2	1
11062-2028	UC 2079	32.0	1.0	42.6	0.74	2014.329	1493	13.4	14.8	2	1
11062-2723	LDS 334	122.1	0.3	132.3	0.64	2014.329	1182	11.7	13.8	2	1
11123-2117	ARA1091	263.4	2.1	6.7	0.26	2014.326	1313	11.04	12.1	2	1
11444-1641	J 1601	252.0	2.6	10.4	0.52	2014.326	1501	11.0	11.7	2	1
11533+0214	BAL1881	187.7	2.5	6.2	0.35	2014.326	1470	10.5	11.9	2	1
11582+0543	CBL 364AB	82.3	0.6	70.2	0.69	2014.329	1139	12.4	15.4	2	1
11582+0543	GWP1717AC	298.7	0.2	149.8	0.66	2014.329	988	12.4	13.3	2	1
11589-0147	GWP1722	340.0	0.4	79.0	0.76	2014.329	1378	12.3	14.5	2	1
12066-1701	HJ 1209	250.2	1.3	18.6	0.44	2014.329	1505	11.52	12.7	2	1
12106-1748	ARA 226	280.4	2.2	12.2	0.48	2014.329	1525	11.80	12.4	2	1
12133-0714	LDS 393	81.0	0.4	96.6	0.70	2014.329	1124	14.14	14.29	2	1
12151-0715	STF1619AB	266.0	1.7	6.9	0.21	2014.403	1323	8.06	8.30	2	1

Table continues on next page.

Double Star Measures Using the Video Drift Method - V

Table 2 (continued). Results of 189 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	No.of x-y Pairs	Mag Pri	Mag Sec	Drifts	Nights
12151-0715	STF1619AC	162.8	0.2	98.3	0.38	2014.403	1228	8.06	10.46	2	1
12163-2706	HJ 4509AC	111.5	0.4	27.7	0.18	2014.329	1505	8.20	12.6	2	1
12191-2726	HJ 4514	138.0	1.3	15.3	0.35	2014.326	1623	12.35	12.4	2	1
12222-1815	UC 2325	272.2	0.7	43.0	0.62	2014.329	1405	11.7	13.1	2	1
12226-1639	UC 2326	158.1	1.9	10.1	0.38	2014.329	1549	11.4	14.1	2	1
12314-3205	PRO 101	304.1	2.5	6.1	0.24	2014.326	1703	12.08	12.4	2	1
12357-1650	HJ 1218AB	259.3	0.5	11.1	0.19	2014.326	1457	6.6	11.0	2	1
12384-2236	ARA1795	63.7	1.9	10.8	0.34	2014.326	1552	11.8	12.6	2	1
12426-2437	HJ 4542	62.6	0.6	37.9	0.44	2014.326	1472	8.95	12.4	2	1
12459-2425	HJ 4549	86.5	1.6	11.9	0.36	2014.326	1576	11.01	11.03	2	1
12468-3319	HDO 219	219.8	0.4	77.1	0.43	2014.403	1337	5.86	12.0	2	1
12494-2639	LDS4277	79.7	0.4	84.5	0.56	2014.329	1309	10.77	12.91	2	1
12529-1732	UC 2421	257.0	1.6	19.8	0.64	2014.329	1505	12.2	13.7	2	1
13015-2134	ARA1482	60.9	1.5	12.5	0.33	2014.329	1396	11.46	13.2	2	1
13378+2819	HJ 3341AC	75.7	0.1	120.0	0.30	2014.403	1170	10.84	13.0	2	1
13451+1747	BUP 153AB	333.9	0.2	108.6	0.39	2014.411	1354	10.01	12.28	2	1
13569-2740	SEE 193	164.2	0.8	6.7	0.13	2014.411	1670	7.81	11.92	2	1
13577-2525	J 1610	283.5	1.7	11.1	0.34	2014.411	1598	12.77	12.71	2	1
14089-4328	SIN 88BC	270.7	0.3	50.2	0.37	2014.318	852	10.2	13.3	1	1
14216-1615	FOX 182	171.1	0.9	20.6	0.36	2014.411	1542	9.77	13.58	2	1
14475-3658	SEE 211	181.5	1.1	13.8	0.37	2014.411	1839	8.41	13.7	2	1
14489+2404	HJ 2747	47.8	1.7	12.8	0.32	2014.411	1597	11.60	12.6	2	1
14525+1844	BU 31AC	167.4	0.3	8.2	0.17	2014.411	1523	8.53	12.5	2	1
15019+1547	STF1902	191.5	0.4	25.9	0.18	2014.422	2120	8.99	9.61	3	1
15086+2507	HJ 2766	330.2	0.3	56.4	0.23	2014.441	2101	5.81	10.0	3	1
15125-3555	RSS 367AB	106.1	1.1	6.4	0.19	2014.493	1803	8.3	13.0	2	1
15131+1808	TOK 299	353.6	0.8	33.9	0.42	2014.411	1512	10.27	14.63	2	1
15169-0817	STF1925AB	17.8	2.2	5.5	0.22	2014.479	1411	8.14	9.85	2	1
15169-0817	STF1925AC	292.0	0.3	62.5	0.32	2014.479	1216	8.14	13.5	2	1
15169-0817	STF1925AD	287.3	0.2	118.8	0.50	2014.479	984	8.14	13.1	2	1
15169-0817	STF1925AE	276.4	0.1	208.6	0.49	2014.479	660	8.14	12.3	2	1
15282-3722	RST3920	284.8	0.2	11.8	0.13	2014.411	901	7.0	12.9	1	1
15288+3101	A 1369AC	258.4	0.2	73.1	0.16	2014.441	1902	10.66	10.48	3	1
15319+0940	STF1952AB,C	221.2	0.6	16.4	0.19	2014.422	2044	8.70	10.12	3	1
15325+0835	STTA140AB	179.5	0.1	113.7	0.20	2014.422	1875	8.30	8.74	3	1
15370-3137	RST1850AB	280.6	2.7	4.8	0.19	2014.411	1711	9.4	12.8	2	1
15434-1037	J 2663	51.9	2.4	7.1	0.30	2014.411	1436	11.95	12.1	2	1
16048+2514	HDS2270	7.7	0.3	27.3	0.17	2014.441	2268	9.47	9.61	3	1
16134-2758	AOT 64	145.3	1.7	13.5	0.39	2014.493	1641	11.23	12.6	2	1
16401+3038	LAU 3	262.7	0.1	80.1	0.17	2014.441	1865	9.86	10.52	3	1
16448-3144	BRT3031AC	197.7	2.1	7.7	0.25	2014.493	1710	11.55	12.72	2	1
16457+3000	STF2098AB	144.8	0.7	14.2	0.15	2014.441	2106	8.77	9.61	3	1
16457+3000	STF2098AC	128.2	0.1	65.7	0.14	2014.441	2157	8.77	8.81	3	1

Table continues on next page.

Double Star Measures Using the Video Drift Method - V

Table 2 (continued). Results of 189 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	No.of x-y Pairs	Mag Pri	Mag Sec	Drifts	Nights
16457+3000	STF2098AD	17.8	0.3	66.8	0.22	2014.441	2259	8.77	11.00	3	1
16458+0835	SHJ 239AB	228.2	0.1	84.7	0.20	2014.422	1646	5.33	9.29	3	1
16479-4058	SIN 98BC	71.1	0.5	89.9	0.68	2014.493	1526	11.0	13.9	2	1
16479-4058	SIN 98BD	288.4	0.4	103.2	0.59	2014.493	1475	11.0	12.7	2	1
16563-3123	SEE 312	51.5	0.4	21.1	0.13	2014.485	1649	9.0	13.6	2	1
16595+0942	STTA150AB,C	164.3	0.1	75.7	0.17	2014.422	1991	8.25	8.74	3	1
16599-2412	HJ 4907AB	35.2	2.3	6.3	0.27	2014.411	1599	9.67	10.16	2	1
17039+1941	BU 822AC	196.5	0.1	114.0	0.20	2014.441	1946	6.58	10.99	3	1
17153-3939	I 229	232.5	1.6	5.0	0.14	2014.485	1874	9.13	11.5	2	1
17311+3533	POP 20	25.3	1.9	8.5	0.25	2014.479	1788	13.4	14.5	2	1
17418-2032	ARA1129	272.7	1.8	6.6	0.31	2014.479	1462	11.57	12.1	2	1
17535-2231	ARA1828	101.0	3.0	7.2	0.37	2014.485	778	11.31	12.3	1	1
18073-3517	BRT1756AB	95.7	1.9	6.3	0.22	2014.485	1668	10.62	12.4	2	1
18134-2302	ARA2217AB	36.9	1.4	12.4	0.28	2014.485	1598	10.71	11.09	2	1
18134-2302	ABH 97AD	276.6	0.5	49.8	0.46	2014.485	1363	10.71	11.7	2	1
18134-2302	ARA2217BC	123.7	1.5	12.3	0.32	2014.485	1555	11.09	12.2	2	1
18134-2302	ABH 97BE	67.7	1.0	31.8	0.50	2014.485	1443	11.09	13.2	2	1
18143-1902	ARA 740	51.8	2.4	9.1	0.37	2014.485	1484	12.02	12.0	2	1
18174+2456	POU3380	73.9	2.1	12.9	0.44	2014.485	1583	12.20	13.03	2	1
19151-0428	LDS5873	99.6	0.2	85.2	0.24	2013.603	1601	10.03	10.44	3	1
19201+5334	A 1394AC	358.3	0.2	56.2	0.13	2013.732	3444	9.51	10.17	3	1
19264+0149	H 6 48	172.9	0.1	151.1	0.24	2013.592	2007	8.33	10.67	3	1
19411+1041	STF2558	307.8	0.5	27.5	0.23	2013.721	1979	8.11	11.89	3	1
19428+3741	STTA188AB	120.9	0.2	60.5	0.17	2013.603	2199	7.71	7.98	3	1
19428+3741	STU 11AC	228.0	0.1	146.0	0.19	2013.603	1790	7.71	8.14	3	1
19428+3741	STU 11AE	195.7	0.2	101.7	0.23	2013.603	1818	7.71	11.39	3	1
19581+5355	ARG 35	226.5	1.4	7.3	0.12	2013.732	3233	9.00	9.92	3	1
20058+3556	ABH 129AF	92.6	0.1	89.3	0.17	2013.603	1791	10.75	10.13	3	1
20058+3556	ABH 129AG	166.5	0.2	67.1	0.22	2013.603	2393	10.75	11.24	3	1
20105+3323	TOB 50	268.6	0.3	31.9	0.15	2013.721	2253	8.98	10.14	3	1
20264+5402	FRK 9	238.0	0.2	59.8	0.12	2013.732	2980	8.44	9.04	3	1
20312+1116	STF2690A,BC	255.2	0.8	17.6	0.22	2013.827	2032	7.12	7.39	3	1
20322-2209	HJ 2973AB	127.0	0.8	38.5	0.47	2013.803	6109	7.77	8.10	3	1
20482-0601	TOK 341	262.8	0.1	392.0	0.79	2013.803	3533	8.53	9.74	3	1
20515+5403	ARG 41AB	193.3	0.9	11.1	0.11	2013.732	3466	9.60	9.53	3	1
20527-0859	TOK 342AB	113.9	0.1	503.2	1.09	2013.803	2653	4.76	9.86	3	1
21036+5358	ES 2704AB	96.7	0.2	54.4	0.11	2013.732	2941	8.56	8.91	3	1
21143+3418	STTA216	47.1	0.1	101.9	0.16	2013.592	1977	7.35	8.09	3	1
21194+5219	ES 98BC	106.6	0.2	51.9	0.12	2013.732	2937	10.16	10.19	3	1
21224+5218	ES 2708	40.2	0.3	29.7	0.12	2013.732	3169	8.68	8.97	3	1
21268+3731	HEI9004AD	334.7	0.1	109.0	0.17	2013.603	2186	7.91	9.73	3	1
21308+4827	A 770AB,D	14.4	0.1	97.5	0.14	2013.732	2859	8.74	10.59	3	1
21424+0027	STF2817AB	154.9	0.5	25.8	0.25	2013.721	1989	8.88	9.20	3	1

Table concludes on next page.

Double Star Measures Using the Video Drift Method - V

Table 2 (conclusion). Results of 189 double stars using the video drift method.

WDS	Designation	PA°	σ-PA	Sep"	σ-Sep	Date	No.of x-y Pairs	Mag Pri	Mag Sec	Drifts	Nights
21432+3801	BLL 55AB	117.2	0.1	143.2	0.22	2013.603	1609	8.43	10.92	3	1
21443+2500	POU5472	202.2	1.2	23.4	0.30	2013.811	1162	11.47	13.05	3	1
21470+2930	GRV 503	330.7	0.5	20.2	0.16	2013.811	2345	11.29	11.30	3	1
21506+4017	SEI1539	259.8	0.4	26.9	0.16	2013.803	2480	11.46	11.85	3	1
22020+2651	HO 610AC	330.8	0.5	32.9	0.20	2013.811	2190	10.07	12.60	3	1
22020+2651	HO 610AE	239.0	0.2	57.2	0.22	2013.811	2094	10.07	12.13	3	1
22041+4437	LYS 18AB	85.0	0.5	28.4	0.18	2013.803	2520	10.45	12.23	3	1
22044+7013	STF2865	199.5	0.5	29.2	0.09	2013.721	5927	8.69	9.48	3	1
22083+6959	ARY 45	206.7	0.2	66.3	0.10	2013.721	5463	7.86	8.11	3	1
22363+2945	AG 423	154.4	0.6	23.6	0.22	2013.811	2354	8.48	11.27	3	1
22415+3003	STF2932AB	282.3	0.6	22.0	0.17	2013.827	2203	9.32	9.44	3	1
23066+4153	LYS 30	279.6	0.4	30.8	0.19	2013.803	2295	9.30	12.82	3	1
23267+4317	CHE 465	313.4	0.6	30.7	0.21	2013.803	1543	10.50	10.70	3	1
23268+4157	CHE 466	124.4	0.7	18.8	0.18	2013.803	2561	9.73	10.30	3	1
23549+2929	STTA252	144.4	0.1	110.7	0.12	2013.830	4056	6.77	8.37	6	2
23592+4112	HJL1113AC	192.5	0.1	114.3	0.15	2013.803	2487	7.78	8.22	3	1

Measurements of Neglected Double Stars Report of September 2014

Joseph M. Carro

Cuesta College, San Luis Obispo, California

Abstract: This article presents measurements of 25 neglected double stars. The stars were selected from the Northern List I of Neglected Double Stars published by the United States Naval Observatory. While, the photographs were obtained with a remote telescope, the astrometric reductions were done by the author. This report is part of a project to measure all of the neglected northern stars.

Methodology

The photographs were taken using a telescope located in the Canary Islands near the west coast of Africa. The telescope is located at an elevation of 2300 meters. The instrument has an effective focal length of 3,910 mm, an aperture of 356 mm, and is a Celestron of Schmidt-Cassegrain design. The observatory, which is called SLOOH, is a part of the Institute of Astrophysics. The methods used to calibrate the instruments of the SLOOH Observatory are unknown to this author.

The camera used most frequently was a CCD SBIG 10XME, but some photographs were taken using a CCD SBIG 2000XM.

The photographs were analyzed by the author using the programs CCD Soft v5 and SKY 6 The two programs are products of Software Bisque.

In most cases, a photograph was taken every two days until there were four photographs for each star. After accumulating four photographs, averages were calculated for the position angles and separations. All of the star patterns were compared with the data from ALADIN (part of the SIMBAD site) to insure correctness.

After measuring each star and calculating the results, comparisons were made with the published data. The results are listed in the table. At times, there were no comparative data. The numbers in the table represent averages of measurements.

Report

The following information was reported for each star: the WDS code with components, the discoverer code, the constellation, the position angle, the separation, the date of the first observation, and, following measures by the author, the results of other authors. The number of measurements for WDS values was the number taken from the WDS on the first observation date.

The column headings are: number of the Washington Double Star and components, DC = Discovery Code, PA = position angle, Sep = Separation, Mts = number of measurements, Con = Constellation, and the first observation date.

Acknowledgements

Grateful appreciation is extended to Russell Genet for his guidance and to Thomas Smith for his support.

This research made use of the SIMBAD database operated at CDS, Strasbourg, France, and the Washington Double Star Catalog maintained by the United States Naval Observatory.

(Continued on page 32)

Measurements of Neglected Double Stars Report of September 2014

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
00148+6250 AB	STF 10	***176.1***	***18.1***	4	CAS	2014 07 31
JDSO (Nugent)		176	17.6			2011
JDSO (Wiley)		175.6	17.64			2012
WDS		180	20.0			1789
WDS		176	17.6	41		2012
00148+6250 AC	STF 10	***103.4***	***55.7***	4	CAS	2014 07 31
JDSO (Frey)		102.3	55.9			2008
WDS		101	55.7			2000
WDS		103	55.4	5		2012
00218+6628 AC	STT 7	***260.0***	***48.9***	4	CAS	2014 07 31
Tycho-2		258.8	48.95			1991
Webb		257.0	51.5			1880
Webb (Harshaw)		259.0	50.2			1992
WDS		256	52.4			1847
WDS		260	48.5	25		2011
00218+6628 AD	STT 7	***101.6***	***109.3***	4	CAS	2014 07 31
Tycho-2		102.2	109.02			1991
Webb (Harshaw)		103.0	108.6			1992
WDS		103	105.2			1880
WDS		102	109.1	14		2003
00218+6628 CD	STT 7	***95.0***	***155.4***	4	CAS	2014 07 31
WDS		94	154.1			1893
WDS		95	155.3	14		2003
00232+5146 AB	HJ 1022	***40.5***	***5.4***	4	CAS	2014 07 20
JDSO (Hennig)		35.5	6.4			2007
WDS		16	3.5			1828
WDS		40	5.9	16		2011
01283+5329 AB	HU 1651	***161.7***	***16.5***	5	CAS	2014 07 21
JDSO (Buchheim)		162.1	16.3			2008
OAG (Comellas)		161	16			1980
Tycho-2		162.1	16.5			1991
WDS		166	13.5			1831
WDS		162	16.3	19		2007
01283+5329 AC	HU 1651	***169.5***	***52.3***	5	CAS	2014 07 21
JDSO (Buchheim)		178.8	53.6			2008
WDS		179	54.1			1902
WDS		179	53.6	7		2007
01283+5329 BC	HU 1651	***173.1***	***36.0***	5	CAS	2014 07 21
JDSO (Buchheim)		185.8	38.3			2008
WDS		188	38.2			1902
WDS		186	38.3	7		2007
01283+5329 CD	HU 1651	***73.8***	***8.4***	5	CAS	2014 07 21
JDSO (Buchheim)		74.3	8.6			2008
WDS		78	9.3			1902
WDS		74	8.6	7		2007

Measurements of Neglected Double Stars Report of September 2014

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
02145+5912 AB	STI 1812	***58.6***	***10.7***	4	CAS	2014 08 06
WDS		41	8.0			1908
WDS		59	10.7	8		2011

15569+3613 AB	SPN 1	***86.8***	***25.6***	5	CRB	2014 07 20
WDS		87	25.4			1998
WDS		87	25.7	4		2007

This star is listed on the Northern Neglected Star list as HJ 258.

17299+3035 AB	SLE 29	***29.7***	***11.5***	6	HER	2014 06 17
WDS		74	37.6			1982
WDS		74	37.6	1		1982

18092+4314 AB	ES 1417	***207.7***	***13.7***	4	HER	2014 06 17
JDSO (Soon)		208.05	13.51			2006
WDS		245	6.7			1893
WDS		207	13.3	7		1915

19192+3715 AB	ES 2113	***337.4***	***4.7***	4	LYR	2014 09 03
Webb (Soon)		339.3	4.59			2006
WDS		352	4.5			1924
WDS		339	4.6	4		2006

19300+4010 AB	MLB 978	***144.8***	***4.8***	4	CYG	2014 08 17
WDS		140	4.4			1935
WDS		145	4.8	6		2006

19300+4010 AC	MLB 978	***307.1***	***42.8***	4	CYG	2014 08 17
OAG (Tob)		308.2	44.7			1982
WDS		310	39.0			1935
WDS		307	43.0	3		2006

19303+2911 AB	MLB 697	***9.7***	***7.6***	4	CYG	2014 08 17
WDS		3	3.1			1931
WDS		7	7.2	2		2006

For 19303+2911, It is noted that the average value of my position angle measurements is significantly different from the WDS data. Photographs were taken on 17, 23, 26, and 31 August 2014. The measurements were consistent, with a Standard Deviation of +/-0.51. The separation average is close to the published value.

19303+2911 AC	MLB 697	***96.6***	***4.8***	4	CYG	2014 08 17
Webb (Soon)		100.55	4.50			2006
WDS		99	4.2			1931
WDS		101	4.5	2		2006

21478+5743 AB	FOX 263	***300.2***	***16.7***	4	CEP	2014 08 29
OAG (Tob)		301.6	16.03			1983
WDS		313	19.5			1905
WDS		301	17.2	7		2007

Measurements of Neglected Double Stars Report of September 2014

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
21576+6708 AB	HJ 1711	***244.8***	***9.4***	4	CEP	2014 08 29
WDS		250	12.0			1825
WDS		254	9.1	7		2006

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
22320+6311 AB	LMP 20	***11.1***	***59.9***	4	CEP	2014 08 29
WDS		15	63.0			1898
WDS		11	60.3	10		2012

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
22320+6311 AD	LMP 20	***254.1***	***39.1***	4	CEP	2014 08 29
WDS		254	38.6			1933
WDS		254	39.1	3		2003

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
22320+6311 BC	LMP 20	***24.8***	***18.3***	4	CEP	2014 08 29
WDS		23	18.4			1898
WDS		25	18.3	9		2012

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
22500+6018 AB	HJ 1821	***103.7***	***11.5***	4	CEP	2014 08 30
WDS		110	8.0			1828
WDS		103	11.7	7		2006

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
23448+5627 AB	BAR 64	***318.5***	***350.4***	4	CAS	2014 08 09
OAG (Tob)		318.7	352.7			1983
WDS		319	350.3			1899
WDS		319	351.8	8		2003

WDS number	D.C.	P.A.	Sep	Mts	Con	Date
23591+5658 AB	ES 38	***237.2***	***24.3***	5	CAS	2014 08 16
WDS		238	18.2			1900
WDS		237	23.9	6		2006

References:

Buchheim, R., "CCD Double Star Observations at Altamira Observatory: Spring 2008", JDSO 2008

Frey, T., "Visual Double Star Measurements with an Alt-Az Telescope", JDSO 2008

Harshaw, R., "New Measures for Some Neglected Pairs of the WDS Catalog", Webb 1992

Hennig, D., "Observations of Select Neglected Double Stars", JDSO 2007

Mason, B., Washington Double Star Catalog - Northern Neglected Stars List 1

Nugent, R., "A New Video Method to Measure Double Stars", JDSO 2011

OAG Catalog as published by the United States Naval Observatory on their website

Soon, A., "CCD Observations of Double Stars at Waverly Observatory", Webb 2006

Soon, A., "Measurements of Double Stars with a CCD Camera", Webb 2006

Wiley, E., "Measures and Relative Motions of Some F. G. W. Struve Double Stars", JDSO 2012

A Companion to the Eclipsing Variable AF Arietis

Abdul Ahad

Luton, Bedfordshire, United Kingdom
aa_spaceagent@yahoo.co.uk

Abstract: In this paper the eclipsing variable star AF Arietis is shown to have a wide 12th magnitude companion, currently not included in the WDS catalog. The identified component appears to be following the same space motion as the 6th magnitude AB eclipsing pair and is situated at a broadly similar spectral distance from Earth, which suggest it might be a physical member of the system.

Introduction

AF Arietis is a little known variable star to be found 3.5^o east of Hamal, the leading star in Aries (Figure 1). Positioned at ICRS 02^h 22^m 06.62^s, +22^o 52' 24.93"(2000.0), AF Arietis has a mean apparent visual magnitude of 6.61 and it also bears the catalog designations of HIP 11035 and HD 14595. The SIMBAD database describes AF Arietis as an eclipsing binary of Algol type (detached).

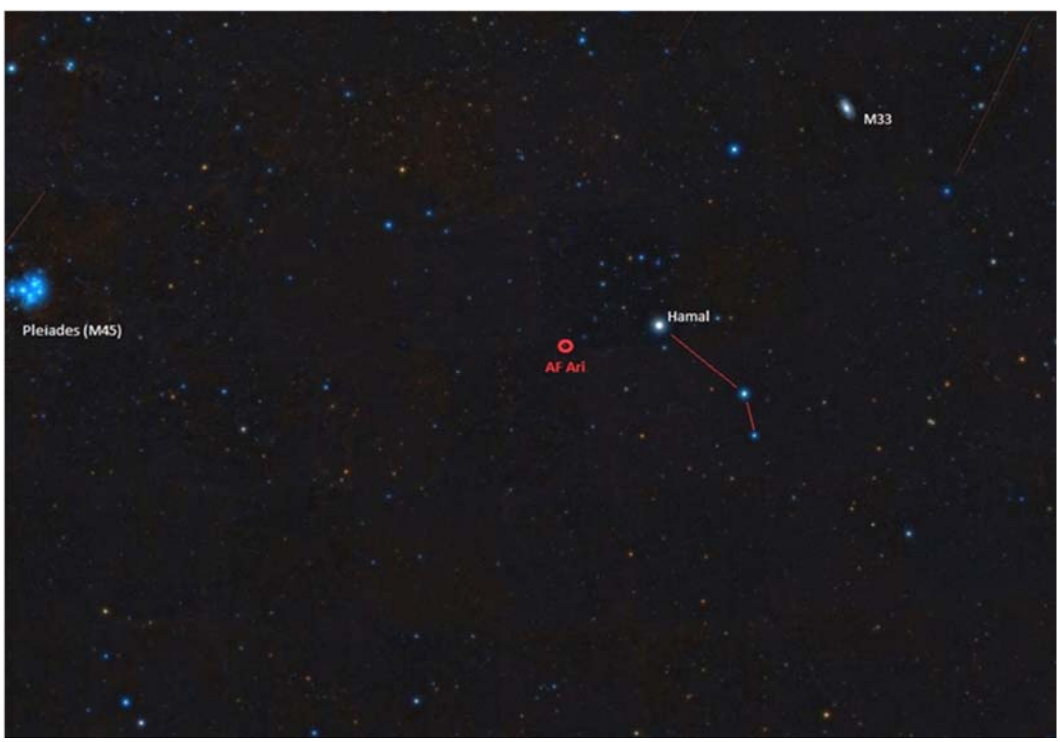


Figure 1. Location of AF Arietis [Source: SDSS]

A Companion to the Eclipsing Variable AF Arietis

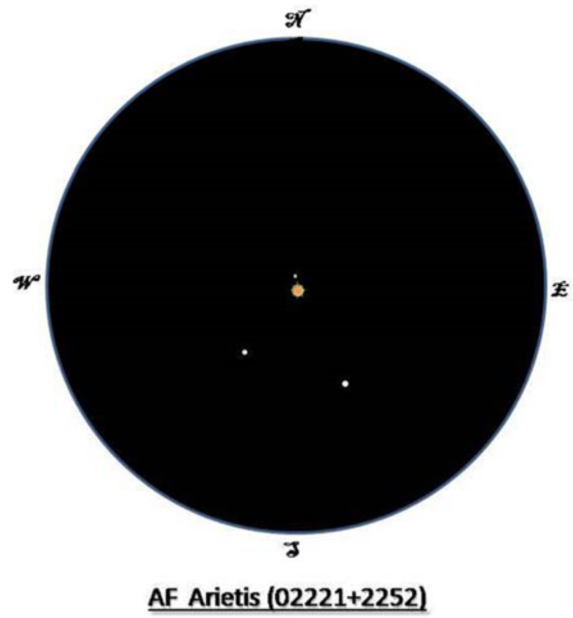
Observations and Analysis

Hauck [2011] states that the AF Arietis system is a well-detached binary whose components revolve around each other in an eccentric orbit over a period of 153 days. Various orbital parameters are then provided, and the components are identified as a spectral type G3III giant which is being orbited by an A5V main sequence dwarf. The latter causes the eclipses that result in the observed variation of light from the system. Mass estimates are also provided for the A and B components of 2.65 (± 0.15) and 1.85 (± 0.05) solar masses, respectively.

The AAVSO database [2] was queried for the period 2002 December 7th to 2007 October 16th, which confirmed the light curve of AF Arietis and showed it to be fluctuating between V mag 6.3 to 7.1. The variability type is listed as an Algol-type eclipsing binary in both the GCVS and SIMBAD databases. From the frequency and depth of the observed eclipses and the detached nature of the components in this system it is very similar to the Zeta Aurigae system. A measured parallax of 5.31 (± 0.53) milliarcseconds places the AF Arietis system at a distance of 615±60 light-years (190±20 parsecs) from Earth. Hauck (2011) stated the AB components to have an orbital semi-major axis of 0.97 AU. At a distance of 615 ly, this translates to an angular separation of just 0.005″. This means the eclipsing components of AF Arietis would only be resolvable into two separate stars with advanced imaging techniques and using instruments of large aperture. Consequently, for the purposes of "visual" double star observing, AF Arietis will appear as a single star in all amateur sized telescopes. In the remainder of this paper, the combined astrophysical characteristicsof the eclipsing pair, such as their total visual brightness, proper motion, color index, etc shall therefore be collectively referred to as the "A component". The new 12th magnitude outlying companion reported in this paper will henceforth be referred to as the "B component".

I imaged AF Arietis for the very first time as a double star using the SSON 61-centimeter Cassegrain telescope [3] on 2014 September 4th. I later visually observed and sketched it with a Skywatcher Evostar 120mm refractor on 2014 September 24th at 21:20 UT (Figure 2).

Even though there is a large Δm of over five magnitudes between components in this double, the new companion can still be glimpsed in small aperture telescopes. Providing that a moderate amount of magnification is used to isolate it from the glare of the bright primary, the faint companion presents itself as a ghostly speck of light on clear moonless nights.



Field sketch made with a 120mm (4.75 inch) refractor at x159 magnification

Figure 2. Field sketch made by the author showing the new B companion to the north of the 6th magnitude primary, which appeared a shade of pale bronze in color.

Astrometry performed on the SSON FITS image confirmed the latest measurements in 2014:

Position Angle (θ): 347.4° (epoch 2014.676)
Separation (ρ): 28.33″ (epoch 2014.676)

The UCAC4 catalog [4] highlighted the components to be sharing common proper motions, as shown in Table 1.

Note that the proper motion vectors are closely aligned in both magnitude and in direction, considering the small error margins in each.

From the 2MASS catalog [5], I provide J and K-band magnitudes for the component stars shown in Table 2.

Given the eclipsing nature of the A component, where both its brightness and color are variable over time, the 2MASS (J-K) color index in Table 2 is not an absolute indicator of spectral classification in this particular instance. However, I believe G3III classification stated by Hauck (2011) to be a more accurate fit than the G2IV spectral classification currently in SIMBAD. A G3III giant star typically has an absolute magnitude around +0.5, which, when inserted into the distance

Table 1: Proper Motion of the Components

	PM in RA	Error	PM in Dec	Error
A component	-13.6 mas/yr	±1.0	-1.3 mas/yr	±1.0
B component	-10.2 mas/yr	±1.3	-2.0 mas/yr	±0.9

Table 2: 2MASS Photometry

	J mag	K mag	Color Index (J-K)
A component	5.282	4.461	+0.82
B component	10.493	10.060	+0.43

modulus formulae along with the mean V mag of 6.61, further supports the parallax-measured distance of the primary in the region of 600 ly.

The B component identified in this paper is of approximate V mag ~12, which is consistent with it being a main sequence dwarf placed at the 600 ly estimated distance of the system. Its color index of +0.43 stated in Table 2 is probably slightly reddened by interstellar absorption, given that the distance of this system is twice that of similar systems studied in past papers which were typically between 200 to 400 ly away. Applying a small correction for interstellar reddening of -0.05 to the B component's color index, yields an improved fit to a late G / early K-type dwarf in the 2MASS (J-K) table [6]. Now late G-type dwarfs typically tend to be of absolute magnitudes of around +6. This value, when combined with the apparent V mag of 12 in the distance modulus formula, then gives a distance of the B component of just over 500 ly. This places the B component at a broadly similar distance from Earth as the A component's 600 ly shown above.

Assuming a similar distance of 600 ly, the angular separation of 28.33 arc seconds translates to a projected linear separation of about 5200 AU.

This distance - although vast - is still nevertheless within acceptable limits for the components to be loosely gravitationally bound, as was previously shown by using the α Librae system as an example [7].

Conclusions

Given the similar proper motion shared with the variable A component, and it being of a visual brightness and a 2MASS (J-K) color which are both consistent for it to be a main sequence dwarf placed at the same physical distance, on a balance of probabilities, the new B component is probably a physical member of the system rather than an optical one. It is recommended that AF Arietis be added to the WDS catalog as an exciting new visual double star.

Acknowledgments

This research has made use of the SIMBAD and VizieR databases maintained at the Centre de Données astronomiques, Strasbourg, France and the Washington Double Star catalog maintained at the US Naval Observatory. The AAVSO database was accessed to ascertain the variable nature of the primary. Appreciation is also expressed to Dr William Hartkopf at the USNO for reviewing the paper and for providing helpful comments.

References

1. Hauck, N. "AF Ari - Ein heller Bedeckungsveraenderlicher mit einem G-Riesen" http://adsabs.harvard.edu/abs/2011BAVSR..60..150H.

2. American Association of Variable Star Observers (AAVSO) http://www.aavso.org/data-download.

3. Sierra Stars Observatory Network (SSON) http://www.sierrastars.com.

4. The Fourth US Naval Observatory CCD Astrograph Catalog.

(UCAC4) Zacharias, N. et al, 2013 AJ 145, 44.

5. The Two Micron All-Sky Catalog of Point Sources, Cutri, et al, 2003 http://pegasus.phast.umass.edu/.

6. Ahad, A. 2012, "A New Common Proper Motion Double Star in Cetus", JDSO, **8**, 332-334.

7. Ahad, A. 2014, "Two New CPM pairs in Libra", JDSO, **10**, 254-255.

Observations of Epsilon Lyrae by the Video Drift Method

Rick Wasson[1], Nancy Nelson[2, 3], Eric Nelson[2, 3], William Buehlman[4], Earl Wilson[5], and Deanna Zapata[6]

1. Sunset Hills Observatory, Murrieta, California
2. Kanab Creek Observatory, Kanab, Utah
3. Coursera Online University
4. California State Polytechnic University, Pomona
5. Lone Pine, California
6. University of California, Los Angeles

Abstract: The major components of the famous "double-double" star Epsilon Lyrae, STF2382AB and STF2383CD, were measured by the Video Team at the Apple Valley Double Star Workshop in 2013, using the Video Drift Method. The results are in reasonable agreement with other recent measures and predictions of the latest orbital solutions.

Introduction

The Apple Valley Double Star Workshop (Brewer, et al, 2014) brought together students, teachers and amateur astronomers, to learn about and practice measuring double stars by several different methods. The workshop was held at the Lewis Center for Educational Research in Apple Valley, California in July, 2013.

The "Video Drift Team," consisting of authors Wasson, Wilson and Buehlman, who carried out the observations. Authors Nelson and Zapata joined the team after the workshop, reducing portions of the data and contributing to this written paper. The major components of the famous double star Epsilon Lyrae, STF2382AB and STF2383CD, were measured and compared with the projected orbits and other recent measures.

Equipment

The equipment used was described by Wasson (2014). The telescope was a portable Orion 12-inch f/4.9 "Go-To" Dobsonian (alt-az mount). The camera used in place of a 1¼" eyepiece was a PC-164c low-light surveillance CCD video camera, providing 30 frames/second NTSC digital video images. The chip contains 510(H) x 492(V) rectangular pixels (9.6μ x 7.5 μ) for an overall detector size of 4.9mm(H) x 3.7mm (V). H and V indicate horizontal and vertical video frame dimensions, respectively. The observations of Epsilon Lyrae were made with a 3X Barlow lens, for higher magnification to separate the close pairs.

A "Kiwi" GPS time inserter, originally intended for accurate timing of asteroid occultations, added a GPS time display to each video frame. A Canon ZR-200 mini DV camcorder was used to record the video stream on cassette tape.

The bright stars of Epsilon Lyrae (magnitudes 5-6) initially produced slightly over-exposed images and the stars were not easily split on the camcorder monitor. Therefore, a 13% neutral density ("moon") filter was installed to reduce the light intensity, avoid over-exposure and improve video image quality. A color filter would have been preferable, because limiting the wavelength tends to sharpen the star images, but unfortunately, none was available.

Observing Procedure

All observations were made using the video drift method (Nugent & Iverson, 2011), as adapted by Wasson (2014) for a Dobsonian telescope. In this technique, the video camera was first rotated until the frame was roughly aligned east-west horizontally, to match

Observations of Epsilon Lyrae by the Video Drift Method

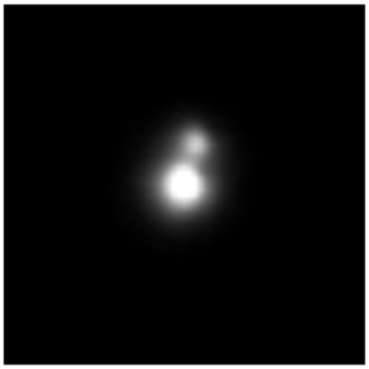


Figure 1. Epsilon Lyrae north-west pair, STF2382AB. REDUC Shift & Add image of best 117 (25%) of 473 frames from drift "a." North is up, east at left in Figures 1-3.

Figure 2. Epsilon Lyrae south-east pair, STF2383CD. REDUC Shift & Add image of best 42 (8%) of 495 frames from drift "a."

the sidereal motion. To make an observation, the target stars were moved slightly out of the field eastward, the telescope drive was turned off, and a video recording was made as the stars drifted across the field. The recording was stopped once the stars drifted completely out of the field, and the tracking motors were turned back on to avoid losing the stars. This process was repeated for a total of 14 "drifts" for each target double star. To insure that video runs were not confused later during data reduction, one of the team members kept a hand-written log sheet, labeling the drifts a, b, c, etc., and recording the drift letter and approximate time of each drift.

The motor-driven alt-az mount of the Dobsonian telescope was capable of tracking the stars, but continuous field rotation presents a challenge for calibration and measurement of Position Angle. However, in the video drift method, each video drift sequence is a stand-alone package of information which contains data for calibration of pixel scale and sky orientation, by using the known sidereal drift rate coupled with accurate GPS time for each frame. Of course, the video sequence also contains many image samples (frames) used for double star measurement. No other calibration observations were made.

For the telescope focal length of 1500mm, the field of view is small: about 11.2 x 8.5 arc minutes. With the 3x Barlow, the field is three times smaller, but typical drift times for Epsilon Lyrae were still over 15 seconds, providing about 500 video frames for each drift.

Stars Observed

On the first night of the workshop, 13 July 2013, the famous, bright "double-double" star Epsilon Lyrae was chosen as a convenient yet challenging target for the video drift method. The two main pairs, shown in Figures 1 and 2, were first noted as double by William Hershel in 1779, but not measured until 1831 by F.W. Struve. The Washington Double Star Catalog (WDS) designation is 18443+3940. Since the separation of each pair is only about 2", neither pair could be cleanly split on the video monitor, so a 3x Barlow lens was used to increase magnification.

The north-west pair is STF2382AB. The WDS provides the following data: precise coordinates RA 18h 44' 20.34" and Dec +39^{o} 40' 12.4"; magnitudes 5.15 and 6.10; spectral types A4V and F1V; PA 346^{o} and separation 2.2" as of 2010. A "premature" orbit, provided in the 6th Orbit Catalog of the WDS, has been estimated with a period of 1725 years.

The south-east pair is STF2383CD. The WDS provides the following data: precise coordinates RA 18h 44' 22.78" and Dec +39^{o} 36' 45.8"; magnitudes 5.25 and 5.38; spectral types A8Vn and F0Vn; PA 79^{o} and separation 2.3" as of 2010. The WDS 6th Orbit Catalog gives a preliminary orbit for this pair, with an estimated period of 724 years.

On the night of 14 July 2013, several wider but fainter doubles were observed, so no Barlow lens was required and no "moon" filter was used. The multiple star WDS 19448-2029 HJ2890 was observed and components AC, AD and AE were measured. The faint component B, only about 3" from A at magnitude 13.9, was not visible. Unfortunately, as can be seen in the misshapen star images of Figure 3, the telescope was not well collimated, which must tend to bias the measures of PA and Separation. In addition, the seeing was poor due to hot, windy conditions, and the target stars were quite low in the south. Therefore, the quality of those observations was poor, much worse than typically achieved with the video drift method; the measures are not considered reliable, and are not reported here.

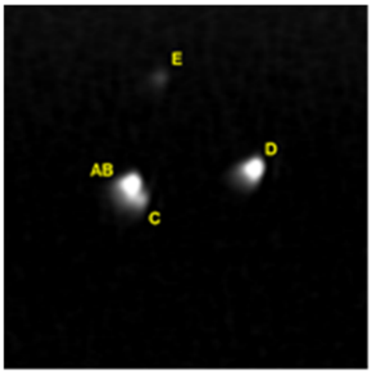


Figure 3. The field of WDS 19448-2029 components. Flared distortion of star images was caused by poor telescope collimation.

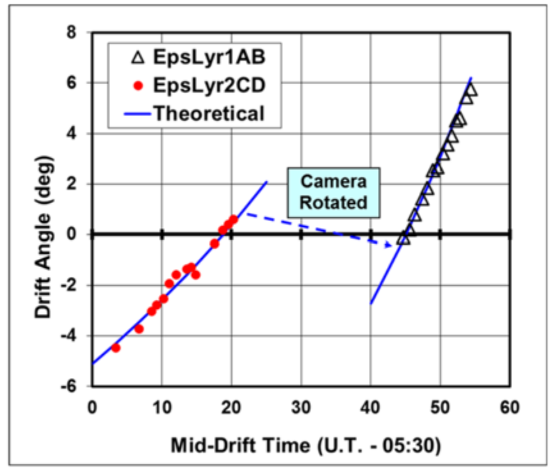


Figure 4. Change in Drift Angle during observations, caused by alt-az mount field rotation.

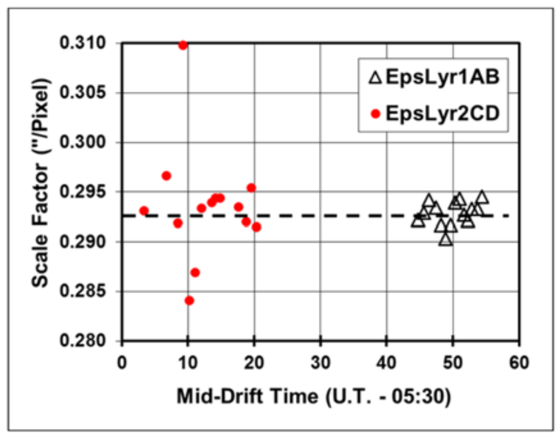


Figure 5. Scale Factor measured for each drift.

Data Reduction

Data processing of drift videos involves use of several software programs, available free on-line. These programs, as well as the uploaded digitized video files and a set of tutorial instructions, were provided to each team member by the team leader (Wasson). A common drift ("a") was assigned to be processed by all members, so that results could be compared.

Unfortunately, sufficient time and a suitable computer were not available during the Workshop for a hands-on demonstration and team practice with the software. Therefore, all the data reduction was done after the Workshop, with communication only by email or phone, leading to a rather long "learning curve" and final reduction.

VidPro Calibration

Calibration of Drift Angle (camera orientation to the sky) and image scale (arc-seconds per pixel) for each recorded video "drift" made use of the "VidPro" spreadsheets of Nugent & Iverson, 2011. The spreadsheets, adapted for close doubles as described by Wasson, 2014, were used for calibration. However, they could not be used for measurement because the stars were too close together; the "LiMovie" program (Miyashita, 2008), which provides input data to the VidPro spreadsheets, could not track the stars separately across an entire drift.

Figure 4 shows the Drift Angle calibration data calculated by the VidPro spreadsheets, where each point represents one drift. The non-linearity of the Alt-Az mount field rotation is very noticeable, becoming faster as the high-overhead stars approached the meridian; field rotation rate actually approaches infinity if a star passes through the zenith point.

The "theoretical" lines were calculated according to the method outlined by Wasson, 2014; the curvature of the lines is caused by the accelerating rotation rate, but the absolute level of Drift Angle depends on the orientation of the camera, so it was adjusted to match the level of the points of each series of drifts. Between the two drift series (for the two pairs observed), the video camera was re-oriented in the telescope to make the stars drift roughly horizontally across the frame once again.

Figure 5 shows the Scale Factor calibration points for each drift, calculated by the VidPro spreadsheets. Three drifts (d, e, and f) for the CD pair had unusually large variations: 2% to 6%. Extra effort was made in re-reducing and double checking these drifts, but no clear explanation was found; however, in drift "d" (the highest), the stars did show considerable "bouncing" due to wind gusts. Using the 3x Barlow, the average scale factor was 0.2933 arc-sec/pixel.

Observations of Epsilon Lyrae by the Video Drift Method

REDUC Analysis

The REDUC freeware program (Losse, 2011) was used to measure Position Angle (PA) and Separation for each video drift. REDUC capabilities, as applied to the Video Drift Method, were described by Wasson, 2014.

Analysis was typically done according to the following pattern. All the frames in a drift were sorted, using the "Best of - Max" option. A group of frames was then selected from the best frames in the drift (e.g., best 10%), and were analyzed in the "Auto" mode. Next, those same frames were Shifted & Added (registered and stacked) to produce a single frame of higher quality, and measured again. Finally, this frame was measured once more, using the "Surface" method within REDUC that is capable of modeling overlapping point spread functions.

After all the drifts had been analyzed, it was discovered that all the frames had been "stretched" 12.5% horizontally while editing each drift in the "VirtualDub" program (Lee, 2010). This spacial distortion invalidated the calibration data as well as the measurements. The source of the "stretch" problem was briefly described by Wasson, 2014.

Rather than re-reduce all the data, corrections were derived for the calibration quantities (Drift Angle and Scale Factor) as well as for the measurement quantities (PA and Separation). Although there may be some approximations in the correction equations, it is believed that they fix most of the distortion errors.

After correcting the data for all drifts, a simple way to avoid the "stretch" problem was discovered, utilizing the tools already in the VirtualDub program. As a spot check on the corrections, one drift for each pair was re-analyzed, starting with the original video clips. The results compared closely (within ~0.6^o PA, ~0.05" Sep) with the "corrected" data, validating the corrections.

PA and Separation Measures

Results of measurements of the two close pairs are summarized in Table 1. The data columns are: Discovery designation, WDS designation, WDS magnitudes, measured Position Angle (PA), standard deviation of PA, measured Separation, standard deviation of Separation, number of drifts recorded, and total number of measurements for all drifts combined.

As described above, the measures were made using three methods within REDUC: Auto, Shift&Add/Auto, and Shift&Add/Model. Each method was typically re-run using two or three different samples of the "best" frames (e.g., the best 25%, 10% and 5% of the total number of frames in a drift). In this way, four to eight measures were made for each drift, and the total number of measures far exceeded the number of drifts. The average and σ values of all measures (# Meas.) are given in Table 1. Each drift used its calibration data point shown in Figures 4 and 5. All measures include correction of the frame horizontal "stretch" problem discussed above.

For the CD pair, in which the stars have very similar magnitudes, only frames where REDUC found the correct (western) star as the primary (brightest) were used for measurement. This process discarded about a quarter of the frames, in which the secondary appeared brighter, thereby excluding frames having a 180 degree PA error.

Comparison with Other Observations

Comparisons with measures of STF2382AB made over the last ten years, including modern techniques (e.g. speckle interferometry and CCD astrometry), are shown in Figure 6. The "Orbit" lines are yearly predicted points in the WDS 6th Orbit Catalog for the orbits of Mason, et al., 2004 and Novakovic & Todorovic, 2006. PA predictions are virtually identical for both orbits.

Similar comparisons for STF2383CD are shown in Figure 7, where the orbit solution is that of Docobo and Costa, 1984.

Table 2 shows the Delta (difference) between the PA and Separation measured by the Video Drift Team and the PA and Separation of the Orbital Ephemerides (for date of observation) from WDS for STF2382AB and STF2383CD. The WDS data for STF2382AB is the predicted orbit of Novakovic & Todorovic, 2006. The WDS data for STF2383CD is from the orbit solution of Docobo and Costa, 1984. The overall Video Team results are reasonably good, generally comparable with the widely used CCD astrometry method.

(Continued on page 41)

Table 1. Video Drift measures of Epsilon Lyrae with a 12-inch telescope on Besselian date 2013.529.

Name	WDS	Magnitude	PA	σ PA	Sep.	σ Sep.	# Drifts	# Meas.
STF2382AB	18443+3940	5.15, 6.10	346.6	1.0	2.41	0.12	14	62
STF2383CD	18443+3940	5.25, 5.38	77.4	0.8	2.42	0.09	14	108

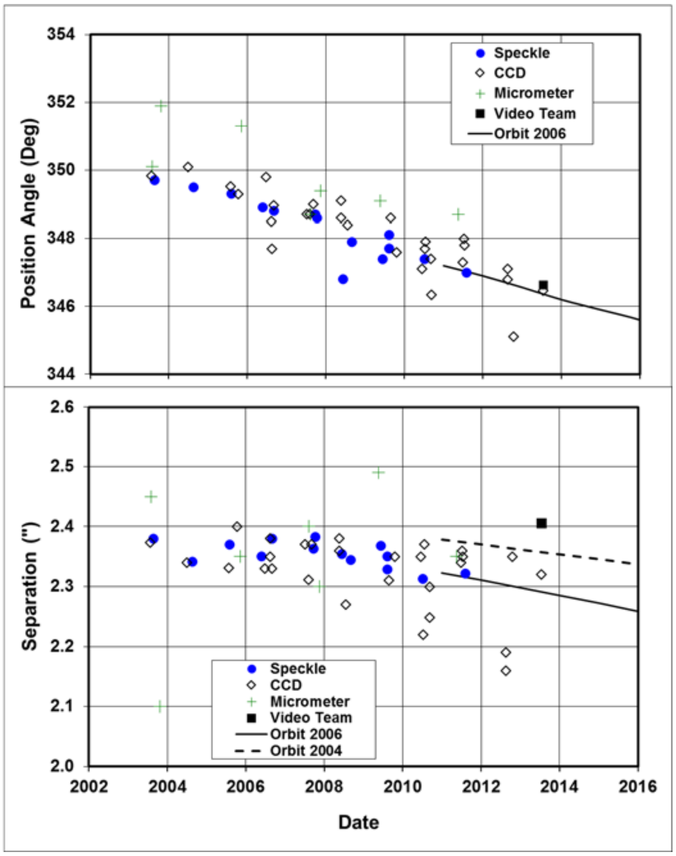


Figure 6. STF2382AB comparison of the Video Team measures with recent measures and predicted orbits.

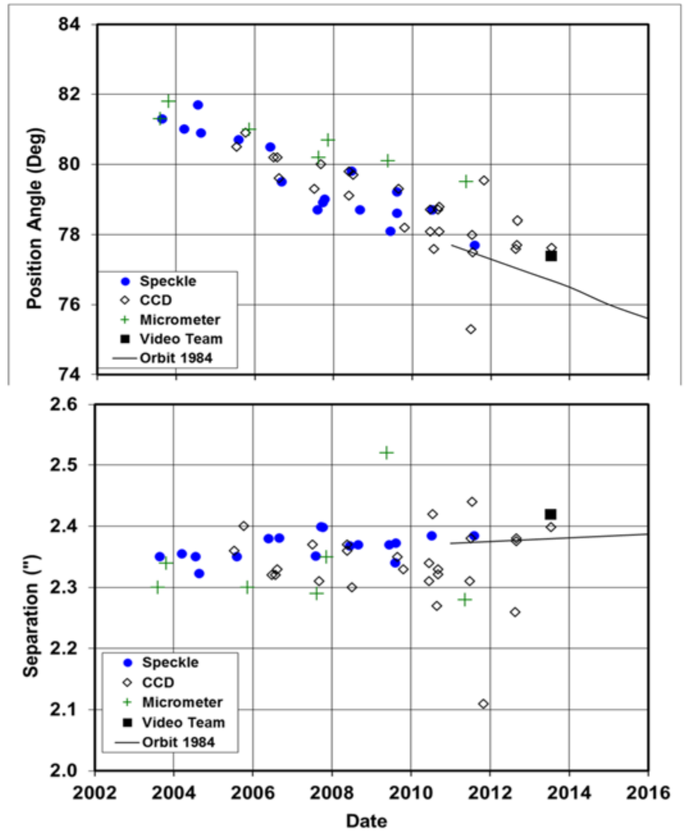


Figure 7. STF2383CD comparison of the Video Team measures with recent measures and predicted orbit.

Table 2. Video Team Comparison with WDS Orbit Predicted Values

Name	WDS	PA Obs (deg)	PA WDS (deg)	Delta (deg)	Sep Obs (arc sec)	Sep WDS (arc sec)	Delta (arc sec)
STF2382AB	18443+3940	346.6	346.4	0.2	2.41	2.292	0.12
STF2383CD	18443+3940	77.4	76.7	0.7	2.42	2.380	0.04

Acknowledgements

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory, and the authors wish to particularly thank Brian Mason for providing lists of all available observations for our target stars.

The authors are grateful to Mark Brewer and Russ Genet for organization and facilitation of the Apple Valley Workshop. We also want to thank the High Desert Astronomical Society and the Luz Observatory for their assistance in making this seminar possible; and we thank the Lewis Center for Educational Research for providing us with the excellent facilities that were used to conduct the seminar.

References

Brewer, Mark, et al., 2014. "Apple Valley Double Star Workshop," *Journal of Double Star Observations*, **10**, 160-164.

Docobo, J.A. & Costa, J.M., 1984. *Inf. Circ.*, **92**, 1.

Lee, Avery, 2010, "VirtualDub 1.9.11," http://www.virtualdub.org.

Losse, Florent, 2011. "REDUC 4.62." http://www.astrosurf.com/hfosaf.

Mason, B.D., Hartkopf, W.I., Wycoff, G.L., Rafferty, T.J., Urban, S.E., & Flagg, L., 2004. *AJ*, **128**, 3012.

Miyashita, Kazuhisa, 2008, "LiMovie 0.9.29b," http://www005.upp.so-net.ne.jp/k_miyash/occ02/limovie_en.html.

Novakovic, B. & Todorovic, N., 2006. *Serbian Astronomical Journal*, **172**, 21.

Nugent, R. L. and Iverson, E. W., 2011. "A New Video Method to Measure Double Stars." *Journal of Double Star Observations*, **7**, 185-194.

Wasson, Rick, 2014. "Measuring Double Stars with a Dobsonian Telescope by the Video Drift Method," *Journal of Double Star Observations*, **10**, 324-341.

Rick Wasson is a retired Aeronautical Engineer, and has been an amateur astronomer for about 60 years. His main interests are double stars, asteroid occultations, photometry and spectroscopy.

Nancy Nelson is a retired engineer and avid amateur astronomer. Nancy has been interested in astronomy as long as she can remember.

Eric Nelson is a retired engineer and enthusiastic amateur astronomer. His interests include double stars, spectroscopy, and anything having to do with physical cosmology.

William Buehlman is an active amateur astronomer and an undergraduate student at Cal Poly Pomona pursuing a B.S. in Aerospace Engineering. His interests include double stars and expanding his knowledge of astronomy.

Earl Wilson is a retired environmental researcher, a long-time amateur astronomer, President of the China Lake Astronomical Society, serves on the Board of Directors of Western Amateur Astronomers, and is a public advocate for night lighting issues. His interests include archeoastronomy, photometry, occultations, meteor events, variable stars, and other transients.

Deanna Zapata studies Physics at UCLA and enjoys amateur astronomy in her free time.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

James Chivers

Montgomery, Powys, Wales
chiversjames@ymail.com

Abstract:The position angle, angular and linear separation, distance, and spectral class of 713 red dwarf binary star systems are reported based on data-mining the Sloan Digital Sky Survey Data Release 10. 707 of these systems are new discoveries.

Introduction

The aim of this experiment was to combine results from two of the 100+ tables that form the Sloan Digital Sky Survey (SDSS) Data Release 10 (Ahn et al. 2012) with the earlier works on M dwarf stars authored by Bochanski, J. J. et al. (2010) and by West, A. A. et al. (2011). The 2010 paper described how the de-reddened SDSS (r-z) magnitude could be used to predict the absolute magnitude of a red dwarf star and hence its distance from the observer. The 2011 paper demonstrated how the de-reddened SDSS (r-i) and SDSS (i-z) magnitudes could be used as predictive tools to allocate stars to the sub-types between M0 and M9 inclusive.

Previous papers by Chivers have relied heavily on proper motion data. In the past, obtaining reliable proper motion data has required accurate astrometric information obtained over a period of years – the more years the better. With close double stars (3 to 5 arc seconds separation) many of the early surveys lacked the resolution to report the two components of such objects separately. A close double star would be reported as a single object situated somewhere on the straight line joining the two components - with the exact position depending on their relative brightness.

For this reason, this study has used a combination of the colours of the two stars plus their angular and linear separations as the primary diagnostic tools. As with previous papers (Chivers, 2014), the emphasis has been on identifying a relatively small number of very strong candidates, rather than a much larger number of possible red dwarf pairs.

Method

STEP 1 – A Structured Query Language (SQL) program was created using the CASJOBS facility that can be accessed at http://skyserver.sdss3.org/casjobs/login.

Two tables from Data Release 10 were used:

Neighbors – this identifies all SDSS objects that lie within 30 arc-seconds of each other.

PhotoObjAll – this contains astrometric and photometric information on every SDSS detection.

The first section of the program was designed to identify pairs of objects separated by between 3 and 5 arc seconds (Distance between 0.05 and 0.0833), where the two components were both stars (Type = 6) and primary objects (Mode = 1) and where both stars had clean photometry (Clean = 1).

The second section checked that the i-band magnitude was less than 18.0, that the galactic extinction in the r-band was less than 0.1 magnitudes, and that the difference between the i-band magnitudes for the two components was less than 0.5 magnitudes.

The third section calculated the SDSS (r-i) and SDSS (i-z) magnitudes and only those pairs of stars where both components had colours characteristic of red dwarf stars were processed further.

STEP 2 – The de-reddened magnitudes in the SDSS r, i, and z bands were determined by eliminating the galactic extinction from the downloaded PSF magnitudes. Then the de-reddened SDSS (r-i), (i-z), and (r-z) magnitudes were calculated.

STEP 3 – The designation of the primary star was

Identification and Spectral Classification of Close Red Dwarf Binary Stars

based on the SDSS r-band magnitude. Once the primary star was known, the separation and the position angle between the two components could be calculated.

STEP 4 – The allocation to a spectral sub class (M0 to M9) was based on the average value obtained from analysis of the de-reddened SDSS (r-i) and SDSS (i-z) colours.

STEP 5 – The absolute magnitude (Mr) for both components of each candidate pair was calculated using the de-reddened SDSS (r-z) colour and the distance to each star calculated using the standard formula –

$$\textit{Distance Modulus} = 5(\log d) - 5$$

where *Distance Modulus* = (Apparent magnitude – Absolute magnitude) and d = distance in parsecs

Only pairs where the percentage difference in the two calculated distances was less than 5% were subject to additional processing.

Results and Discussion

A total of 713 pairs of stars were identified where both components had the SDSS (r-i) and SDSS (i-z) colours associated with red dwarf stars and where the angular separation between the components was between 3 and 5 arc seconds and where the difference in the linear distance to the two stars was within five percent.

All 713 pairs were checked visually using the "Image List" facility available via the SDSS SkyServer page: http://skyserver.sdss3.org/public/en/home.aspx. This is an important precaution to take because it is not unknown for image artifacts to be included in astronomical catalogs. See Table 2 in the tabulated results section at the end of the paper.

Six pairs were already listed in the Washington Double Star Catalog and in five of the six cases the position angle and separation calculated using the SDSS data were very similar to the most recent results available from the Vizier site: http://vizier.ustrasbg.fr/viz-bin/VizieR.

The allocation of each star to a spectral sub-class (M0 to M9) was done using the results obtained by West and all values should be taken as being ±1. As would be expected, the primary star is either of an earlier sub-type than the secondary star or is of the same spectral type. Both components are at virtually the same distance from the observer and, because early M dwarfs are more luminous than later M dwarfs, they will appear brighter.

The binary star systems presented in this paper vary in linear distance from the observer from between 36 and 1443 parsecs and the separation between the components varies between 111 and 6671 AU.

The results for all 713 binary star systems are given in Table 2 and contains astrometric data, magnitudes, angular separation, position angle, the colors, spectral classifications, linear distance, and linear separation of the two components.

Conclusions

Combining data from a number of different SDSS Data Release 10 tables greatly accelerates the process of identifying candidate red dwarf binary star systems. The temptation to be too lenient when deciding what selection criteria to use should always be resisted because even a small relaxation in the rigour with which these constraints are selected and applied can result in large numbers of "false positive" discovery claims. The quality of any discovery claim is always more important than the quantity

(Continued on page 58)

Table 1 – Pairs already listed the Washington Double Star Catalog

Number	Discoverer Code	This study PA	This study Sep	WDS PA	WDS Sep	WDS Name
40	SKF 1001	113.02	3.02	34	3.8	01094+0057
277	LDS 3015	23.73	3.11	23	3.0	10353+5323
339	LDS 5204	272.43	4.03	272	4.0	11216+5111
634	LDS 1430	57.12	3.62	59	3.6	15575+4933
678	LDS 2732	244.14	3.23	244	3.2	17179+6718
694	LDS 5253	194.75	4.20	195	4.1	23099+0034

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
1	00 02 58.415	-11 06 10.94	16.80	16.90	235.72	4.52	2000.737	1.16	0.60	1.18	0.60	3	3	192	866
2	00 03 37.260	+26 32 23.09	16.73	17.18	32.00	3.89	2003.743	0.65	0.46	0.72	0.51	1	1	481	1868
3	00 07 28.414	+05 32 00.09	15.32	15.62	203.60	3.84	2008.770	0.73	0.32	0.82	0.36	0	1	265	1016
4	00 13 14.723	+06 08 29.65	18.01	18.46	137.80	3.38	2008.757	1.19	0.67	1.33	0.71	3	4	275	930
5	00 15 03.302	-03 38 29.64	16.80	17.14	348.18	3.49	2008.683	0.65	0.31	0.75	0.35	0	1	590	2057
6	00 15 27.226	+05 19 26.77	16.24	16.28	72.60	3.11	2008.757	0.99	0.56	0.99	0.57	2	2	199	618
7	00 17 24.553	-05 08 11.55	18.20	18.75	156.63	3.64	2008.888	1.54	0.83	1.63	0.92	5	5	149	543
8	00 18 10.532	-03 56 53.73	16.07	16.29	214.29	3.95	2008.888	1.08	0.56	1.13	0.59	3	3	159	629
9	00 18 13.050	-02 58 49.11	18.82	19.41	30.63	3.26	2008.830	1.26	0.70	1.40	0.77	4	4	353	1152
10	00 19 15.261	-02 04 23.67	16.43	16.51	286.45	3.12	2008.683	0.57	0.30	0.59	0.33	0	0	575	1794
11	00 21 39.501	-08 24 36.76	17.66	17.78	24.02	4.17	2009.791	0.77	0.44	0.79	0.44	1	1	639	2663
12	00 22 08.218	-20 13 47.13	18.94	19.16	86.96	4.58	2004.953	1.18	0.60	1.21	0.62	3	3	496	2272
13	00 25 09.410	-15 08 45.06	18.11	18.29	94.64	4.31	2006.711	1.03	0.58	1.06	0.59	3	3	435	1876
14	00 25 49.644	+00 34 41.13	18.97	19.09	103.72	3.85	2003.875	1.39	0.72	1.41	0.71	4	4	312	1200
15	00 25 52.656	+26 37 56.11	17.94	18.09	233.02	4.38	2008.817	1.06	0.57	1.10	0.57	3	3	388	1700
16	00 26 42.633	+01 21 47.10	18.36	18.83	192.26	3.85	2008.756	0.81	0.44	0.86	0.55	1	2	819	3150
17	00 27 04.947	+04 39 37.57	17.98	18.04	264.82	4.01	2008.770	1.05	0.50	1.06	0.52	2	2	439	1760
18	00 27 13.405	+03 20 18.80	18.59	18.67	231.85	4.57	2008.756	1.20	0.66	1.24	0.67	3	3	362	1654
19	00 27 20.800	-15 56 47.35	16.07	16.55	77.51	4.45	2006.744	0.87	0.49	0.98	0.54	2	2	240	1069
20	00 33 25.719	-18 55 40.12	16.90	17.37	293.72	4.89	2006.711	1.15	0.55	1.25	0.62	3	3	212	1035
21	00 34 00.963	+23 53 35.29	18.16	18.49	355.26	3.20	2008.751	1.18	0.60	1.24	0.63	3	3	347	1107
22	00 34 47.047	-10 03 00.51	17.79	18.05	39.94	4.26	2000.740	1.03	0.55	1.10	0.55	2	3	394	1675
23	00 41 31.072	-08 26 31.58	18.36	18.84	149.46	3.94	2009.742	1.14	0.64	1.26	0.67	3	3	378	1489
24	00 41 53.771	-00 16 05.46	17.39	17.54	159.10	3.09	2003.886	1.25	0.64	1.29	0.65	3	3	204	631
25	00 43 26.095	+20 59 12.07	18.20	18.55	20.17	3.21	2009.046	1.17	0.62	1.23	0.67	3	3	343	1103
26	00 44 38.431	+24 01 35.05	17.99	18.48	337.12	3.86	2009.737	0.59	0.32	0.70	0.35	0	1	1137	4390
27	00 44 43.374	+23 46 23.88	17.63	18.08	318.31	4.84	2004.723	0.92	0.50	1.05	0.53	2	2	453	2193
28	00 48 23.961	+21 35 17.31	18.92	19.44	183.29	4.50	2009.071	1.03	0.62	1.17	0.63	3	3	596	2683
29	00 48 35.495	+23 52 38.37	15.45	15.84	70.65	3.60	2009.737	0.64	0.32	0.71	0.40	0	1	323	1161
30	00 48 47.979	+03 32 19.15	18.81	19.06	10.63	3.80	2008.754	1.28	0.64	1.30	0.69	3	4	377	1432
31	00 51 53.676	+23 19 42.35	18.26	18.41	37.58	4.09	2009.071	0.78	0.42	0.82	0.43	1	1	842	3443
32	00 54 09.885	+05 04 19.20	16.81	16.88	55.16	4.64	2008.770	1.26	0.67	1.27	0.68	3	4	148	686
33	00 54 47.814	-09 57 22.38	18.79	19.34	333.74	4.96	2000.740	1.04	0.53	1.17	0.58	2	3	619	3071
34	00 55 12.070	+05 25 42.48	18.59	18.61	69.12	3.93	2008.770	0.75	0.41	0.71	0.44	1	1	1045	4107
35	00 55 19.934	+22 13 20.12	16.04	16.46	233.44	3.77	2009.049	0.59	0.34	0.67	0.38	0	1	448	1690
36	00 56 21.179	+20 40 54.43	17.79	17.87	212.23	4.75	2009.057	0.95	0.44	0.95	0.46	2	2	515	2446
37	00 59 56.693	+20 40 53.95	17.98	18.32	108.21	4.94	2009.057	0.69	0.31	0.76	0.35	0	1	984	4857
38	01 04 28.146	+20 39 26.94	15.98	16.48	329.97	3.38	2009.057	0.71	0.33	0.83	0.39	0	1	365	1236
39	01 09 25.244	+00 57 11.30	16.45	16.58	34.13	3.79	2003.886	1.46	0.78	1.49	0.81	4	5	78	297
40	01 09 26.787	+06 07 11.47	17.17	17.45	113.02	3.02	2005.742	0.99	0.51	1.05	0.56	2	2	323	975
41	01 13 10.436	+23 00 11.08	18.79	18.88	85.79	4.04	2004.707	1.32	0.66	1.35	0.68	4	4	337	1363
42	01 16 27.264	-10 21 44.14	17.08	17.13	162.91	4.39	2000.737	1.19	0.61	1.21	0.62	3	3	200	878
43	01 17 56.102	+00 01 09.29	17.47	18.01	350.19	4.93	2003.886	1.04	0.59	1.15	0.66	3	3	308	1515
44	01 18 05.854	+12 34 05.69	18.48	18.54	140.99	3.04	2008.839	0.74	0.40	0.74	0.44	1	1	1005	3055
45	01 18 18.429	-21 42 43.06	14.60	14.83	321.22	3.58	2006.892	0.63	0.36	0.69	0.35	0	1	214	768
46	01 18 22.694	-09 37 27.00	16.96	17.22	109.18	3.88	2000.737	1.05	0.55	1.11	0.60	2	3	254	986
47	01 18 58.311	+14 23 55.01	16.17	16.78	14.99	4.22	2000.915	0.65	0.32	0.78	0.40	0	1	443	1872
48	01 26 40.691	+06 44 22.96	17.91	18.24	180.84	4.90	2005.781	1.00	0.58	1.09	0.61	2	3	406	1989
49	01 27 06.699	+00 12 43.96	18.54	18.62	45.91	4.23	2001.863	1.00	0.48	0.98	0.50	2	2	647	2738
50	01 29 42.011	+15 03 46.09	17.05	17.46	19.20	3.00	2000.915	0.92	0.51	1.02	0.57	2	2	337	1012

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
51	01 37 39.892	-18 21 33.14	17.25	17.39	203.90	4.63	2004.956	0.66	0.37	0.69	0.39	1	1	666	3081
52	01 37 59.049	-02 00 03.41	18.42	18.65	345.60	4.03	2008.830	0.99	0.55	1.06	0.54	2	2	555	2237
53	01 39 04.698	-06 28 28.11	18.33	18.69	141.37	4.78	2009.044	0.85	0.41	0.91	0.44	1	2	812	3884
54	01 41 38.679	+02 47 01.48	18.47	18.78	26.97	4.70	2008.756	1.07	0.53	1.13	0.55	2	3	522	2457
55	01 42 38.813	-00 52 10.44	18.37	18.44	72.87	3.01	2001.863	1.13	0.59	1.17	0.60	3	3	404	1218
56	01 43 17.694	-01 51 28.48	15.47	15.54	21.87	4.85	2008.833	1.49	0.82	1.51	0.84	5	5	45	221
57	01 43 28.387	-05 30 10.36	17.39	17.50	9.44	3.58	2008.997	0.60	0.33	0.50	0.46	0	1	836	2993
58	01 45 33.942	+00 04 13.00	16.88	17.11	146.20	3.39	2003.886	0.93	0.44	0.98	0.48	2	2	339	1149
59	01 45 54.824	+02 09 43.54	17.79	17.96	284.67	4.90	2009.740	0.75	0.45	0.74	0.53	1	2	672	3292
60	01 49 16.579	-17 51 30.26	16.82	16.89	12.58	3.79	2006.892	1.40	0.75	1.40	0.75	4	4	109	414
61	01 51 45.363	-00 46 25.27	18.00	18.26	190.19	3.09	2003.886	1.20	0.59	1.25	0.63	3	3	313	968
62	01 53 04.996	-01 14 41.95	15.76	15.97	287.14	3.90	2003.886	0.81	0.45	0.86	0.48	1	2	242	945
63	01 53 13.169	-06 04 53.77	18.81	19.11	137.23	4.17	2009.003	1.32	0.73	1.38	0.73	4	4	317	1324
64	01 54 26.613	+01 36 26.79	18.36	18.74	338.26	3.15	2008.757	1.11	0.56	1.17	0.59	3	3	451	1419
65	01 54 45.084	+02 07 49.43	16.09	16.38	264.45	3.51	2009.740	0.66	0.33	0.75	0.36	0	1	410	1438
66	01 55 15.073	+00 31 37.01	18.14	18.58	148.16	4.22	2003.886	0.54	0.32	0.63	0.38	0	1	1291	5445
67	01 59 52.049	-03 48 57.91	17.42	17.90	111.29	3.45	2008.975	1.27	0.65	1.34	0.72	3	4	201	695
68	02 00 16.582	-00 46 14.77	17.75	18.10	347.50	4.19	2003.886	0.96	0.55	1.03	0.60	2	3	420	1761
69	02 02 11.637	-15 13 47.83	15.49	15.61	65.98	3.28	2008.000	0.86	0.45	0.89	0.47	2	2	198	649
70	02 07 19.342	-11 53 21.54	18.24	18.78	109.75	3.59	2008.000	1.28	0.66	1.38	0.71	3	4	283	1015
71	02 12 26.024	-05 51 47.53	18.27	18.60	61.90	3.61	2009.003	1.21	0.62	1.28	0.65	3	3	338	1218
72	02 16 41.391	-05 47 56.97	15.79	15.84	312.46	3.02	2009.003	0.64	0.29	0.65	0.29	0	0	395	1192
73	02 18 23.298	-00 14 54.94	19.20	19.32	299.62	3.19	2003.886	1.37	0.66	1.38	0.67	4	4	391	1244
74	02 18 55.730	-01 01 36.32	17.73	18.09	312.28	4.77	2004.776	0.57	0.36	0.68	0.38	0	1	955	4557
75	02 21 38.413	-05 09 42.61	17.97	18.32	182.81	3.27	2008.975	0.82	0.42	0.90	0.42	1	1	711	2324
76	02 22 52.616	+00 38 54.63	19.29	19.59	276.78	3.47	2001.964	1.49	0.79	1.54	0.82	4	5	283	980
77	02 23 31.007	+02 55 27.69	15.92	16.38	122.91	4.63	2008.683	1.02	0.54	1.13	0.60	2	3	165	763
78	02 23 44.525	-05 42 54.16	17.56	17.87	80.68	3.31	2009.003	1.22	0.62	1.26	0.64	3	3	244	809
79	02 29 49.404	-08 05 08.67	16.95	17.17	84.74	3.19	2000.888	0.60	0.33	0.65	0.37	0	1	666	2122
80	02 30 03.772	+00 59 10.61	15.72	16.22	337.38	4.42	2008.757	0.63	0.34	0.75	0.40	0	1	356	1571
81	02 30 06.210	-05 31 44.48	18.96	19.31	282.95	4.28	2009.003	1.08	0.59	1.18	0.60	3	3	582	2494
82	02 34 16.250	+01 55 47.63	17.36	17.71	203.54	4.97	2008.683	1.34	0.66	1.39	0.70	4	4	173	862
83	02 35 58.268	-06 35 20.93	16.15	16.32	110.68	4.35	2009.044	0.68	0.37	0.73	0.38	1	1	393	1708
84	02 37 25.274	-06 37 38.10	16.22	16.71	269.96	4.08	2006.881	0.96	0.45	1.06	0.50	2	2	242	987
85	02 38 49.709	-06 53 10.24	16.50	16.88	17.87	4.89	2009.044	0.67	0.36	0.76	0.40	1	1	472	2308
86	02 39 02.158	-08 25 10.85	17.87	17.87	352.88	3.45	2000.888	1.01	0.52	1.01	0.54	2	2	427	1470
87	02 40 46.082	-01 13 40.58	17.20	17.83	146.34	4.30	2002.777	1.11	0.60	1.25	0.66	3	3	244	1048
88	02 41 56.664	-07 10 58.74	18.16	18.22	265.19	3.29	2009.044	1.25	0.69	1.27	0.69	3	4	271	893
89	02 45 43.392	-06 29 58.64	18.04	18.39	300.56	3.89	2009.003	1.36	0.74	1.41	0.78	4	4	207	806
90	07 51 43.488	+13 33 19.03	18.50	18.83	76.20	4.56	2004.946	0.94	0.54	1.02	0.55	2	2	633	2886
91	07 53 54.420	+27 36 33.40	17.69	17.75	109.43	4.01	2001.969	1.18	0.62	1.16	0.64	3	3	274	1096
92	07 55 48.359	+48 33 56.19	17.36	17.45	10.21	4.72	2003.812	1.36	0.65	1.40	0.67	4	4	165	780
93	07 55 51.976	+05 31 25.43	17.45	17.45	25.28	4.01	2003.075	1.50	0.78	1.47	0.80	4	4	120	482
94	07 57 03.025	+11 28 46.17	18.90	19.23	181.00	4.04	2005.047	1.09	0.62	1.21	0.64	3	3	518	2092
95	07 57 52.254	+10 07 17.13	17.67	18.13	153.41	3.47	2005.096	1.05	0.57	1.16	0.62	2	3	344	1195
96	07 57 54.819	-01 34 42.41	17.53	18.15	39.79	3.12	2001.213	0.71	0.36	0.85	0.42	1	1	727	2268
97	07 58 16.038	-01 25 51.66	15.53	15.66	107.67	4.34	2001.216	0.23	0.97	0.24	0.98	2	2	244	1057
98	07 59 17.484	+15 52 55.86	18.89	19.06	185.46	3.67	2004.948	1.12	0.58	1.13	0.59	3	3	554	2034
99	07 59 54.993	+06 00 07.26	19.01	19.06	132.19	3.44	2003.075	1.25	0.69	1.28	0.70	4	4	398	1371
100	08 01 06.143	+05 03 51.19	16.13	16.63	295.41	4.22	2002.868	0.68	0.37	0.81	0.44	1	1	381	1607

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
101	08 02 42.078	-01 02 20.41	18.00	18.61	272.05	4.62	2000.258	0.73	0.39	0.86	0.46	1	2	837	3866
102	08 03 48.003	+03 04 51.20	16.41	16.74	220.53	3.15	2001.139	0.62	0.33	0.67	0.35	0	1	524	1650
103	08 03 57.328	+07 29 50.13	18.81	18.90	89.00	3.33	2006.016	0.93	0.53	0.94	0.55	2	2	738	2453
104	08 04 41.621	+03 32 38.18	19.46	19.66	209.26	3.20	2002.868	1.53	0.87	1.59	0.87	5	5	256	819
105	08 04 46.994	+11 28 00.67	18.84	19.28	38.48	4.83	2005.194	1.06	0.59	1.13	0.65	3	3	568	2744
106	08 04 57.122	+17 00 54.19	17.31	17.43	127.04	3.33	2004.288	1.16	0.63	1.21	0.65	3	3	226	752
107	08 05 36.156	+02 53 05.77	18.95	19.46	128.39	3.94	2001.140	1.25	0.70	1.36	0.75	4	4	383	1508
108	08 05 50.988	+04 20 39.09	18.40	18.77	234.59	3.13	2002.120	0.67	0.33	0.73	0.41	0	1	1176	3677
109	08 05 56.367	+04 47 16.14	19.05	19.39	271.86	3.92	2003.075	1.16	0.65	1.23	0.67	3	3	498	1952
110	08 10 50.996	+01 45 43.95	18.34	18.67	15.37	3.62	2001.140	0.57	0.33	0.63	0.36	0	0	1369	4951
111	08 10 55.847	+04 24 06.12	17.11	17.22	295.89	3.02	2002.120	0.96	0.51	0.97	0.53	2	2	334	1010
112	08 11 52.442	+05 56 48.48	17.29	17.53	325.31	3.01	2003.076	0.73	0.41	0.79	0.41	1	1	594	1788
113	08 11 53.463	+07 47 34.26	16.05	16.56	10.50	3.62	2006.084	0.65	0.33	0.74	0.40	0	1	417	1512
114	08 12 37.227	+03 31 42.19	18.02	18.21	227.65	3.30	2001.140	0.80	0.44	0.86	0.44	1	1	709	2342
115	08 13 13.583	+03 13 52.00	18.57	19.14	193.19	3.72	2002.120	0.99	0.50	1.10	0.56	2	3	637	2370
116	08 15 52.259	+02 49 58.23	16.49	17.08	46.78	4.21	2002.120	0.63	0.30	0.76	0.36	0	1	546	2296
117	08 16 11.538	+04 17 21.64	18.86	19.46	305.18	4.52	2002.120	1.42	0.73	1.55	0.80	4	5	274	1239
118	08 16 55.519	+11 35 58.94	15.98	16.54	124.12	4.70	2005.194	0.78	0.44	0.89	0.51	1	2	284	1333
119	08 18 32.267	+03 05 43.79	18.54	18.70	193.73	3.35	2002.174	0.75	0.48	0.76	0.51	1	2	928	3109
120	08 18 35.269	+03 02 26.33	17.52	17.57	303.46	4.57	2002.120	0.57	0.34	0.58	0.34	0	0	910	4159
121	08 19 59.471	+06 30 36.18	17.15	17.32	339.12	3.52	2003.076	1.28	0.65	1.32	0.68	3	4	170	599
122	08 22 14.435	+09 45 01.00	18.63	19.03	192.42	4.99	2006.016	0.97	0.51	1.09	0.53	2	2	655	3266
123	08 22 43.644	+15 34 35.31	16.41	16.51	121.52	4.02	2004.951	0.69	0.35	0.73	0.36	1	1	447	1798
124	08 24 11.444	+10 55 16.92	18.96	19.09	152.90	3.23	2005.194	1.21	0.62	1.22	0.63	3	3	469	1518
125	08 30 23.411	+45 12 08.69	18.76	19.19	33.26	3.02	2001.072	1.22	0.65	1.32	0.71	3	4	391	1181
126	08 31 23.929	-03 23 20.00	18.53	18.60	301.03	3.58	2006.881	1.25	0.64	1.25	0.65	3	3	350	1254
127	08 31 54.658	+18 54 04.46	18.13	18.35	258.92	3.44	2004.948	0.64	0.37	0.70	0.37	1	1	1037	3570
128	08 31 59.090	+35 03 32.89	17.71	17.88	10.88	4.66	2001.969	0.67	0.33	0.69	0.35	0	1	881	4100
129	08 35 28.782	+10 26 57.32	17.94	18.07	122.48	3.89	2006.016	0.61	0.28	0.63	0.33	0	0	1112	4324
130	08 36 13.929	+18 03 19.62	19.22	19.58	126.91	3.37	2004.951	1.32	0.72	1.41	0.74	4	4	383	1289
131	08 36 50.400	+46 19 19.27	18.29	18.42	7.46	3.07	2001.072	1.18	0.64	1.24	0.65	3	3	336	1028
132	08 38 26.458	+03 36 00.00	18.49	18.95	142.76	3.19	2002.120	1.38	0.74	1.46	0.78	4	4	247	789
133	08 39 28.223	+03 56 28.01	17.80	18.06	336.34	3.47	2002.120	0.64	0.38	0.73	0.37	1	1	884	3065
134	08 39 32.158	-01 08 43.79	18.11	18.38	250.77	3.58	2000.173	1.15	0.58	1.21	0.59	3	3	368	1316
135	08 41 00.928	+53 39 47.51	16.24	16.77	24.82	3.48	2000.337	1.10	0.58	1.20	0.64	3	3	165	573
136	08 41 02.620	+50 44 50.60	17.89	18.22	204.75	3.69	2000.258	1.32	0.71	1.39	0.72	4	4	213	787
137	08 41 07.356	-02 26 38.56	18.06	18.34	181.32	3.10	2006.881	0.76	0.42	0.83	0.44	1	1	789	2449
138	08 42 31.479	-03 17 17.76	17.70	17.73	166.52	3.99	2007.198	0.69	0.40	0.71	0.40	1	1	762	3039
139	08 45 44.792	+11 34 04.42	17.72	17.74	202.34	3.43	2006.016	0.59	0.33	0.61	0.34	0	0	964	3309
140	08 47 12.880	+02 51 03.35	17.07	17.21	306.83	4.15	2001.140	0.90	0.47	0.93	0.48	2	2	380	1580
141	08 47 15.822	+02 15 33.74	18.02	18.44	318.88	3.67	2000.916	0.90	0.47	1.00	0.52	2	2	583	2143
142	08 47 37.848	+10 28 45.83	16.76	17.07	57.79	4.43	2006.016	0.90	0.45	0.97	0.48	2	2	338	1496
143	08 47 41.176	+43 15 34.11	18.57	18.94	288.23	3.39	2002.024	0.63	0.39	0.75	0.39	1	1	1264	4283
144	08 48 10.439	+36 00 27.77	19.06	19.54	12.46	3.99	2002.106	1.18	0.61	1.29	0.66	3	3	514	2050
145	08 49 30.047	+53 34 51.56	18.12	18.55	350.60	3.42	2000.261	1.01	0.53	1.12	0.55	2	3	479	1639
146	08 49 36.956	+11 33 49.27	16.83	17.07	107.00	3.10	2006.084	1.58	0.65	1.62	0.67	4	4	97	301
147	08 49 45.784	+52 50 26.16	17.86	18.29	289.10	4.23	2000.261	0.72	0.35	0.83	0.40	1	1	837	3538
148	08 49 48.752	-02 39 02.30	16.46	16.54	276.26	4.18	2007.198	0.86	0.41	0.88	0.43	1	1	329	1376
149	08 49 59.378	-02 04 34.83	17.95	18.45	356.47	4.79	2006.881	0.59	0.30	0.70	0.35	0	1	1137	5442
150	08 50 18.167	+42 08 06.86	18.74	19.34	228.80	3.23	2001.967	0.91	0.54	1.04	0.61	2	3	722	2329

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY RA	PRIMARY DECL	MAGNITUDE A	MAGNITUDE B	PA	SEP	DATE	PRIMARY R-I	PRIMARY I-Z	SECONDARY R-I	SECONDARY I-Z	TYPE M+	TYPE M+	DIST. PARSEC	SEP. AU
151	08 50 34.235	+46 13 54.98	17.50	17.92	77.40	4.81	2001.287	0.64	0.31	0.73	0.38	0	1	835	4014
152	08 51 49.047	-01 27 21.50	18.56	18.76	158.89	4.21	2007.198	0.82	0.41	0.89	0.43	1	1	904	3804
153	08 53 09.221	+16 51 56.64	18.58	18.73	247.04	4.51	2005.047	0.95	0.46	0.96	0.53	2	2	693	3125
154	08 54 02.759	+38 34 34.92	17.13	17.58	101.01	3.64	2001.969	1.05	0.57	1.13	0.63	3	3	267	974
155	08 54 02.878	+39 21 35.59	17.15	17.61	33.83	4.67	2002.024	0.83	0.48	0.93	0.55	2	2	425	1986
156	08 55 43.968	+51 53 27.12	15.87	15.88	193.48	4.21	2000.907	1.28	0.65	1.29	0.65	3	3	95	401
157	08 56 29.961	-00 33 30.28	18.85	19.05	340.99	3.37	1999.220	1.44	0.81	1.50	0.81	4	5	239	807
158	08 57 07.425	+29 15 12.19	16.93	17.40	261.54	3.31	2003.179	0.86	0.49	0.97	0.55	2	2	362	1199
159	08 57 11.701	+31 58 47.94	18.09	18.27	243.02	3.69	2002.999	0.57	0.33	0.61	0.32	0	0	1220	4502
160	08 57 57.716	+28 45 17.19	17.15	17.52	204.68	3.70	2003.971	0.97	0.53	1.03	0.56	2	2	332	1229
161	09 00 46.475	+47 18 15.34	17.69	17.91	241.20	4.66	2001.287	1.23	0.70	1.27	0.70	3	4	228	1062
162	09 01 00.420	+19 22 21.15	16.79	16.84	93.74	3.87	2004.957	1.16	0.58	1.17	0.58	3	3	194	751
163	09 01 24.013	+00 31 28.86	18.90	19.32	142.66	4.79	2007.198	1.02	0.49	1.11	0.55	2	3	708	3392
164	09 01 27.204	+36 21 59.80	16.85	17.05	187.31	4.79	2002.851	0.58	0.34	0.64	0.37	0	0	647	3101
165	09 01 42.266	-02 37 41.03	16.37	16.56	198.49	3.41	2001.213	0.63	0.32	0.63	0.35	0	0	517	1762
166	09 01 57.971	+34 01 51.03	15.09	15.23	178.60	3.27	2002.999	0.83	0.43	0.87	0.45	1	1	178	583
167	09 02 48.596	+83 24 49.69	18.65	18.98	169.40	3.15	2006.303	0.94	0.54	1.03	0.58	2	3	655	2060
168	09 03 41.622	+55 09 20.56	15.77	16.13	250.08	3.29	2000.258	0.71	0.35	0.81	0.39	1	1	322	1061
169	09 03 44.817	+04 52 43.29	15.92	16.55	90.52	3.44	2002.174	0.87	0.44	1.02	0.52	1	2	238	819
170	09 03 49.168	+36 30 20.21	17.37	17.63	172.32	3.31	2002.950	0.56	0.35	0.60	0.37	0	0	859	2844
171	09 05 26.493	+53 52 39.50	18.31	18.62	133.19	4.74	2000.258	0.58	0.35	0.65	0.39	0	1	1265	5999
172	09 05 58.776	+55 29 59.95	18.50	18.70	69.95	3.21	2000.258	0.81	0.47	0.86	0.48	1	2	845	2714
173	09 07 53.093	+01 34 48.86	17.88	18.30	2.33	3.69	2007.198	1.18	0.63	1.27	0.66	3	3	292	1077
174	09 08 41.716	+57 02 01.98	18.38	18.66	219.94	4.10	2003.062	0.64	0.33	0.72	0.36	0	1	1227	5032
175	09 10 31.942	+25 56 44.42	14.99	15.30	145.27	4.46	2004.291	0.70	0.37	0.79	0.41	1	1	221	986
176	09 10 45.572	+35 52 01.23	16.88	16.92	313.85	3.38	2002.950	1.08	0.56	1.04	0.60	3	3	236	798
177	09 12 43.647	+00 49 13.04	18.53	18.89	166.70	3.97	2007.198	0.71	0.33	0.73	0.43	0	1	1193	4730
178	09 12 54.697	+01 41 03.63	18.64	18.65	294.95	3.23	2007.198	0.80	0.42	0.82	0.43	1	1	952	3073
179	09 13 09.262	+01 34 23.03	18.26	18.36	131.07	3.90	2006.881	1.43	0.71	1.45	0.74	4	4	211	823
180	09 13 32.317	+12 58 36.42	18.10	18.63	7.13	3.30	2006.085	1.47	0.82	1.57	0.86	5	5	162	536
181	09 14 56.229	+03 17 20.53	18.85	19.12	105.44	4.88	2001.140	1.48	0.80	1.52	0.82	4	5	233	1137
182	09 15 40.383	+26 05 00.03	16.30	16.73	17.79	3.76	2004.291	0.68	0.39	0.78	0.44	1	1	409	1534
183	09 16 02.803	+36 09 03.86	18.75	18.85	7.43	3.07	2003.067	0.87	0.46	0.90	0.50	2	2	850	2613
184	09 16 14.871	+02 01 42.96	18.42	19.03	345.38	4.33	2006.881	0.73	0.37	0.85	0.47	1	2	1026	4439
185	09 16 37.818	+28 53 25.59	19.07	19.48	90.21	3.29	2003.971	1.18	0.68	1.25	0.72	3	4	470	1548
186	09 17 04.576	+59 05 06.76	18.57	19.00	277.99	4.46	2000.321	0.67	0.35	0.76	0.42	1	1	1232	5495
187	09 18 31.930	+32 52 25.74	18.50	19.07	39.61	3.10	2003.179	0.71	0.38	0.84	0.41	1	1	1116	3459
188	09 19 20.803	-02 36 51.58	17.01	17.01	340.32	4.11	2001.213	0.85	0.45	0.84	0.46	1	1	413	1700
189	09 19 49.578	+17 04 33.26	18.67	18.85	99.85	3.62	2005.096	1.06	0.60	1.11	0.58	3	3	532	1929
190	09 20 29.965	+01 36 08.85	18.98	19.04	216.14	3.07	2006.881	1.25	0.65	1.29	0.67	3	4	406	1247
191	09 21 39.448	+55 45 42.14	15.94	16.41	188.88	4.75	2000.258	0.93	0.51	1.04	0.56	2	2	200	952
192	09 21 39.713	-01 30 04.94	15.51	15.97	143.43	3.49	2001.213	0.81	0.41	0.89	0.48	1	2	229	801
193	09 21 47.920	+29 28 42.30	17.43	17.87	217.48	3.25	2003.971	0.93	0.55	1.00	0.61	2	3	382	1242
194	09 22 17.819	+35 25 46.40	18.11	18.54	228.96	3.31	2003.067	1.09	0.67	1.16	0.70	3	3	358	1183
195	09 23 37.196	+29 31 22.98	16.92	17.40	101.01	4.66	2004.209	0.60	0.36	0.74	0.37	0	1	640	2983
196	09 23 41.333	+41 31 12.58	16.89	16.90	78.67	3.93	2002.106	1.03	0.54	1.05	0.54	2	2	255	1002
197	09 23 59.364	+15 09 46.88	15.25	15.58	208.45	4.89	2005.931	0.90	0.44	0.97	0.49	2	2	169	825
198	09 24 31.661	+27 19 12.19	17.99	18.39	46.26	4.15	2004.291	0.82	0.46	0.94	0.48	1	2	653	2707
199	09 25 41.492	+62 40 08.61	18.22	18.79	120.69	3.83	2003.812	0.71	0.43	0.82	0.48	1	2	910	3488
200	09 25 43.423	+61 30 36.10	18.18	18.77	330.70	3.58	2000.263	0.95	0.56	1.05	0.60	2	3	533	1906

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
201	09 28 02.880	-00 23 59.33	17.76	18.12	0.67	3.87	2000.173	0.61	0.30	0.69	0.34	0	0	1007	3896
202	09 29 06.403	+10 24 07.14	17.15	17.43	78.20	3.11	2003.076	0.69	0.38	0.77	0.42	1	1	595	1849
203	09 31 47.742	+16 39 00.90	18.50	19.06	312.50	4.05	2005.189	0.74	0.48	0.87	0.53	1	2	908	3677
204	09 32 14.546	+22 46 53.50	18.58	19.17	307.74	3.54	2004.957	1.08	0.63	1.24	0.67	3	3	455	1612
205	09 33 42.618	+10 20 51.20	18.86	18.98	72.10	4.30	2003.982	1.12	0.62	1.18	0.61	3	3	497	2133
206	09 34 30.123	+35 02 40.80	16.92	17.36	254.82	3.44	2003.179	1.05	0.54	1.14	0.58	2	3	257	885
207	09 34 39.361	+18 57 52.16	18.12	18.25	57.21	3.61	2005.096	1.14	0.51	1.11	0.58	2	3	408	1474
208	09 35 35.540	+30 14 52.68	17.11	17.68	92.94	3.24	2004.209	1.10	0.63	1.22	0.67	3	3	232	753
209	09 38 54.197	+59 08 31.17	17.90	18.29	273.69	4.78	2000.258	0.61	0.33	0.71	0.37	0	1	1027	4907
210	09 38 58.461	+39 05 23.53	17.80	17.98	45.89	4.22	2002.950	1.00	0.57	1.03	0.58	2	2	404	1702
211	09 38 58.515	+29 22 53.37	18.83	19.36	98.65	4.75	2004.212	1.34	0.69	1.40	0.76	4	4	333	1580
212	09 39 19.822	+57 48 00.86	18.66	18.93	224.30	3.58	2000.258	1.44	0.78	1.49	0.82	4	5	225	805
213	09 40 16.713	+11 59 46.62	18.76	18.84	350.44	4.36	2003.971	1.26	0.66	1.27	0.67	3	3	369	1609
214	09 44 46.424	+30 04 37.39	18.44	18.93	210.25	4.86	2004.209	0.52	0.38	0.69	0.40	0	1	1374	6671
215	09 45 00.241	+16 47 12.98	18.70	18.97	244.04	3.56	2005.194	0.96	0.53	1.03	0.58	2	2	660	2350
216	09 46 23.255	+45 12 14.19	18.60	19.07	264.75	4.26	2001.970	0.97	0.54	1.08	0.55	2	2	644	2740
217	09 46 56.103	+47 59 08.28	18.34	18.40	85.40	3.47	2001.890	1.35	0.67	1.35	0.68	4	4	264	918
218	09 47 12.200	+19 49 57.65	15.34	15.52	259.87	3.47	2005.096	0.94	0.46	1.00	0.46	2	2	164	568
219	09 48 31.159	+05 38 46.66	16.91	17.13	26.30	4.69	2002.120	0.65	0.33	0.71	0.35	0	1	615	2887
220	09 48 44.552	+41 23 50.48	19.48	19.96	289.06	4.79	2002.851	2.03	1.06	2.18	1.11	6	7	101	483
221	09 48 56.865	+25 09 18.84	18.46	19.13	220.55	4.51	2004.951	1.28	0.75	1.45	0.79	4	4	275	1239
222	09 49 08.915	+49 17 30.80	18.72	19.38	95.76	3.87	2001.964	1.18	0.63	1.34	0.67	3	4	426	1647
223	09 50 33.219	+19 13 45.15	16.06	16.49	142.36	3.59	2005.096	0.98	0.57	1.06	0.59	2	3	188	677
224	09 51 02.233	+24 31 32.24	18.69	19.17	276.50	4.00	2004.957	0.75	0.37	0.84	0.40	1	1	1183	4732
225	09 52 23.229	+11 37 53.27	15.73	16.25	331.50	3.22	2003.971	0.61	0.33	0.72	0.39	0	1	379	1220
226	09 52 31.963	+20 16 23.71	17.27	17.86	222.37	3.03	2005.096	0.93	0.52	1.07	0.58	2	3	367	1109
227	09 54 21.456	+06 40 06.36	18.70	19.38	35.34	4.91	2002.120	0.82	0.52	1.01	0.56	2	2	833	4089
228	09 54 36.277	+38 51 43.72	18.96	19.08	49.89	3.24	2002.999	1.07	0.61	1.10	0.61	3	3	575	1864
229	09 54 38.972	+46 46 26.85	17.66	17.99	347.96	4.46	2002.035	0.57	0.32	0.64	0.37	0	1	986	4400
230	09 54 48.884	+08 12 43.54	17.93	18.07	20.50	3.20	2002.194	0.67	0.40	0.71	0.43	1	1	858	2750
231	09 54 59.547	+53 25 12.75	18.01	18.46	181.47	3.39	2002.120	1.48	0.82	1.58	0.87	5	5	149	505
232	09 55 17.855	+33 05 09.78	18.83	19.21	248.01	4.25	2004.211	1.33	0.70	1.41	0.74	4	4	322	1369
233	09 55 33.123	+19 49 40.45	16.53	16.94	271.28	3.74	2005.096	0.62	0.32	0.68	0.36	0	1	565	2114
234	09 55 59.478	+07 32 43.56	18.88	19.26	253.02	4.73	2002.934	1.11	0.64	1.16	0.69	3	3	512	2422
235	09 57 14.557	+10 32 15.68	15.68	15.79	28.48	4.05	2003.075	0.77	0.38	0.79	0.40	1	1	274	1107
236	09 57 48.539	+11 57 54.94	17.44	17.88	174.09	3.66	2003.076	1.16	0.53	1.23	0.58	3	3	285	1045
237	09 59 51.039	+35 39 06.13	18.29	18.47	45.56	4.56	2003.179	1.16	0.65	1.18	0.67	3	3	353	1611
238	09 59 52.618	+40 48 27.67	17.31	17.63	92.81	3.38	2002.950	0.60	0.36	0.66	0.41	0	1	752	2540
239	10 00 12.436	+02 35 27.60	18.47	18.93	40.26	3.40	2000.343	0.60	0.30	0.69	0.36	0	1	1431	4863
240	10 00 49.282	+04 19 46.93	18.53	18.68	111.71	4.00	2001.140	0.72	0.39	0.75	0.42	1	1	1083	4331
241	10 06 08.745	+51 18 59.80	18.23	18.28	119.79	3.58	2001.970	0.79	0.39	0.79	0.40	1	1	853	3055
242	10 06 55.292	+80 02 24.41	17.61	17.67	216.16	4.05	2006.303	0.95	0.52	0.96	0.54	2	2	416	1685
243	10 07 53.215	+34 36 17.23	16.01	16.52	116.90	3.33	2004.130	1.02	0.50	1.13	0.55	2	3	188	625
244	10 09 03.653	+39 58 11.82	17.80	18.05	57.93	3.50	2003.226	1.17	0.61	1.21	0.66	3	3	289	1014
245	10 09 10.175	+22 59 04.05	18.35	18.95	160.15	3.09	2004.971	1.03	0.56	1.16	0.63	2	3	490	1511
246	10 09 56.886	+09 29 07.96	16.48	17.11	16.95	3.74	2002.194	0.55	0.31	0.70	0.39	0	1	591	2209
247	10 10 00.060	-02 36 08.83	19.03	19.36	54.77	3.74	2001.213	1.31	0.69	1.35	0.77	4	4	369	1377
248	10 11 32.014	+54 17 01.08	17.92	18.41	261.74	3.43	2002.024	0.91	0.44	1.01	0.49	2	2	579	1982
249	10 11 39.003	+21 32 16.16	16.39	16.58	115.17	3.55	2005.096	1.35	0.64	1.41	0.64	4	4	112	398
250	10 12 00.557	+26 02 45.55	18.55	18.81	137.10	4.36	2004.957	0.89	0.47	0.94	0.49	2	2	771	3363

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
251	10 13 33.544	+48 39 57.12	18.04	18.29	236.89	4.48	2001.970	0.73	0.39	0.80	0.41	1	1	843	3778
252	10 15 19.463	+24 00 04.05	16.91	16.95	236.44	3.10	2005.047	1.35	0.67	1.36	0.70	4	4	133	411
253	10 16 47.088	+19 55 05.20	19.04	19.43	75.33	3.43	2005.189	1.20	0.67	1.28	0.70	3	4	451	1547
254	10 17 04.229	+26 21 53.70	15.40	15.43	275.37	3.93	2004.957	1.08	0.58	1.08	0.59	3	3	115	451
255	10 18 07.678	+48 37 45.62	17.02	17.44	313.15	3.61	2002.035	1.32	0.70	1.39	0.73	4	4	147	531
256	10 18 54.702	+51 33 15.88	16.52	17.15	76.61	4.41	2002.248	0.66	0.41	0.81	0.48	1	2	452	1995
257	10 19 13.494	+20 08 16.72	18.40	18.65	274.66	3.35	2005.194	1.44	0.71	1.48	0.73	4	4	227	760
258	10 19 27.204	+07 34 05.66	17.74	18.00	208.74	3.20	2002.174	1.21	0.68	1.25	0.70	3	4	243	777
259	10 19 52.227	+18 55 44.41	18.82	19.09	74.71	3.07	2005.194	1.04	0.57	1.06	0.62	3	3	602	1849
260	10 20 32.363	+15 45 56.77	15.71	16.09	347.37	3.90	2006.016	0.91	0.48	0.99	0.53	2	2	196	765
261	10 20 40.050	+30 53 08.86	17.34	17.78	189.03	4.10	2004.291	0.92	0.49	0.99	0.53	2	2	412	1685
262	10 21 12.848	+07 41 00.66	18.20	18.76	59.00	3.45	2002.174	0.56	0.32	0.70	0.36	0	1	1291	4458
263	10 22 52.186	+38 23 05.95	15.42	15.51	216.32	4.73	2003.180	1.10	0.62	1.14	0.62	3	3	105	496
264	10 23 33.463	+22 54 17.08	16.33	16.35	298.60	3.04	2005.096	0.57	0.30	0.57	0.30	0	0	554	1682
265	10 24 01.634	+42 03 30.82	17.53	17.98	353.38	4.33	2003.226	0.68	0.35	0.76	0.40	1	1	774	3349
266	10 25 43.438	+11 58 20.20	18.60	18.71	88.02	3.98	2003.076	1.12	0.64	1.16	0.66	3	3	426	1694
267	10 26 25.220	+26 28 04.71	17.76	17.98	263.96	4.11	2004.957	0.71	0.33	0.76	0.36	0	1	829	3407
268	10 26 51.053	+21 06 04.63	18.48	19.02	106.13	3.55	2005.096	1.21	0.62	1.33	0.66	3	4	374	1328
269	10 27 56.052	+44 13 32.47	18.23	18.44	317.31	3.45	2002.950	1.19	0.62	1.22	0.64	3	3	343	1184
270	10 28 06.167	+43 26 13.48	15.92	16.87	206.50	4.00	2002.950	0.58	1.08	1.26	0.68	3	3	147	588
271	10 29 06.366	+28 42 20.52	19.27	19.44	348.23	4.28	2004.970	1.70	0.97	1.71	1.01	6	6	161	690
272	10 30 37.049	+43 58 43.40	18.06	18.66	49.20	3.68	2002.950	0.79	0.40	0.90	0.49	1	2	771	2839
273	10 30 56.841	+58 16 40.70	16.56	16.81	343.69	4.03	2001.071	0.71	0.32	0.78	0.35	0	1	483	1944
274	10 31 41.622	+17 25 57.53	18.45	18.58	177.63	4.19	2005.356	0.81	0.43	0.84	0.43	1	1	881	3688
275	10 33 31.657	+33 12 19.07	17.95	18.15	320.79	3.72	2004.083	1.25	0.68	1.29	0.69	3	4	251	936
276	10 34 31.143	+12 37 22.05	16.43	16.50	63.91	3.70	2003.982	0.91	0.51	0.93	0.51	2	2	266	982
277	10 35 10.816	+53 23 33.04	15.07	15.38	23.73	3.11	2001.888	0.98	0.53	1.04	0.54	2	2	126	391
278	10 38 54.234	+22 05 58.75	16.49	17.11	82.28	3.99	2005.096	1.31	0.73	1.44	0.79	4	4	110	437
279	10 39 34.036	+07 41 26.05	17.97	18.50	150.81	3.58	2002.120	0.66	0.34	0.78	0.41	0	1	962	3441
280	10 40 31.974	+51 03 57.59	18.99	19.23	201.90	3.01	2002.035	1.07	0.55	1.11	0.57	2	3	646	1946
281	10 40 39.242	+57 18 55.79	14.42	16.40	69.03	4.38	2002.120	-0.93	2.20	1.30	0.61	0	3	129	564
282	10 41 27.746	+06 24 49.20	18.39	18.72	321.65	3.96	2002.120	0.62	0.35	0.68	0.40	0	1	1237	4894
283	10 42 01.832	+10 22 49.33	18.19	18.73	300.41	4.10	2003.245	1.29	0.79	1.40	0.85	4	4	225	922
284	10 42 27.071	+39 43 18.96	17.48	17.52	139.08	4.23	2003.087	0.88	0.48	0.89	0.51	2	2	458	1939
285	10 42 54.261	+12 49 59.90	18.44	19.12	304.03	4.31	2003.982	0.75	0.40	0.94	0.45	1	2	960	4138
286	10 43 02.945	+15 51 34.65	18.70	18.71	236.89	3.61	2005.427	1.02	0.52	1.01	0.53	2	2	629	2269
287	10 43 04.435	+20 58 54.79	17.88	18.30	25.60	3.22	2005.189	0.56	0.33	0.65	0.38	0	1	1104	3550
288	10 43 05.083	+35 23 32.90	17.44	17.72	139.44	3.62	2004.206	0.77	0.39	0.84	0.44	1	1	598	2167
289	10 43 23.181	+43 10 19.29	18.82	19.38	211.46	3.87	2003.226	0.88	0.45	1.01	0.52	2	2	892	3451
290	10 45 50.138	+41 21 23.00	17.91	18.28	128.33	4.71	2003.231	1.01	0.55	1.09	0.60	2	3	421	1985
291	10 46 19.531	+36 13 13.91	17.49	18.02	243.27	3.59	2004.083	1.15	0.57	1.25	0.62	3	3	279	1001
292	10 47 39.449	+14 12 17.69	18.27	18.54	138.90	3.15	2003.982	1.07	0.61	1.13	0.65	3	3	411	1297
293	10 48 29.560	+14 33 39.35	17.82	17.85	307.49	3.86	2003.982	1.20	0.58	1.19	0.59	3	3	294	1135
294	10 49 58.741	+18 36 24.16	18.54	18.93	233.81	3.83	2005.356	1.22	0.68	1.30	0.73	3	4	340	1303
295	10 50 06.993	+52 32 54.71	18.70	18.85	188.66	4.02	2002.248	1.08	0.54	1.11	0.53	2	3	564	2268
296	10 50 59.589	+36 19 14.43	18.34	18.39	80.91	4.51	2004.083	0.86	0.49	0.89	0.51	2	2	683	3082
297	10 51 16.195	+37 47 45.11	18.01	18.42	74.49	3.84	2004.130	0.83	0.45	0.92	0.50	1	2	661	2539
298	10 53 27.660	+59 16 38.07	17.96	18.15	119.95	4.67	2002.120	0.58	0.33	0.59	0.35	0	0	1128	5266
299	10 53 40.017	+07 24 03.94	14.56	14.73	242.66	3.47	2002.120	0.76	0.42	0.81	0.45	1	1	155	539
300	10 53 43.814	+45 14 01.02	17.70	17.94	17.92	4.89	2002.950	1.09	0.56	1.14	0.59	3	3	337	1646

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
301	10 54 17.494	+13 58 13.07	18.34	18.66	265.85	4.49	2003.982	0.84	0.40	0.91	0.43	1	2	819	3682
302	10 55 03.003	+33 49 55.77	17.68	17.98	294.32	3.58	2004.283	1.00	0.52	1.05	0.55	2	2	407	1458
303	10 56 07.147	+59 49 38.68	16.24	16.28	262.10	3.99	2001.378	0.77	0.43	0.79	0.43	1	1	330	1316
304	10 56 27.518	+09 08 36.64	16.00	16.28	102.87	3.60	2002.194	0.71	0.34	0.79	0.37	1	1	364	1310
305	10 57 43.257	+23 04 05.38	19.03	19.45	236.37	4.46	2005.096	1.13	0.61	1.21	0.69	3	3	533	2380
306	10 58 28.585	+41 02 22.17	18.23	18.74	81.08	3.05	2003.313	1.09	0.56	1.20	0.62	3	3	428	1304
307	10 58 40.417	+06 47 50.04	18.50	18.77	35.44	4.21	2002.120	0.57	0.40	0.62	0.43	0	1	1318	5550
308	10 59 26.400	+06 56 57.57	17.36	17.59	228.89	3.58	2002.175	1.11	0.56	1.16	0.61	3	3	275	986
309	11 00 22.354	+20 40 03.33	17.90	18.08	284.36	4.50	2005.189	1.23	0.67	1.28	0.69	3	4	251	1132
310	11 00 23.732	+62 22 10.77	17.75	17.94	182.07	3.94	2001.072	1.00	0.51	1.05	0.53	2	2	420	1654
311	11 00 28.984	+29 57 44.61	18.61	19.07	68.34	4.47	2004.367	0.90	0.43	1.00	0.48	1	2	817	3649
312	11 00 50.227	+37 56 45.88	18.95	19.17	227.99	4.54	2003.316	1.02	0.61	1.08	0.61	3	3	618	2806
313	11 00 57.873	+12 47 42.76	18.69	19.05	119.56	4.27	2003.223	0.80	0.42	0.89	0.45	1	2	999	4269
314	11 01 26.452	+11 13 45.47	17.71	17.90	352.05	4.82	2003.245	1.24	0.70	1.26	0.72	4	4	224	1079
315	11 03 25.665	+49 35 02.92	16.93	17.11	289.17	3.05	2002.106	1.17	0.62	1.19	0.63	3	3	195	594
316	11 03 35.809	+19 48 17.74	17.99	18.20	157.44	4.55	2005.356	1.41	0.70	1.45	0.71	4	4	197	897
317	11 04 00.648	+39 11 17.35	16.66	17.00	49.59	3.25	2004.130	1.18	0.62	1.26	0.68	3	3	164	532
318	11 04 02.545	+09 23 19.09	18.28	18.61	153.74	3.46	2002.944	1.04	0.50	1.10	0.53	2	2	524	1811
319	11 04 25.479	+66 03 44.71	18.28	18.83	254.56	3.57	2000.264	0.89	0.48	1.00	0.54	2	2	665	2375
320	11 06 12.606	+11 32 45.81	18.11	18.29	148.52	3.58	2003.223	1.06	0.57	1.09	0.58	3	3	421	1507
321	11 07 00.147	+47 12 59.91	15.52	15.58	95.55	3.43	2002.950	1.29	0.69	1.30	0.69	4	4	76	262
322	11 08 13.873	+18 52 40.83	18.69	18.88	6.02	4.04	2005.356	0.79	0.45	0.80	0.48	1	1	979	3956
323	11 08 57.291	+25 03 03.27	17.62	17.96	159.71	4.08	2005.096	0.93	0.49	1.00	0.53	2	2	451	1840
324	11 09 51.573	+30 00 30.18	15.93	16.44	228.88	3.16	2004.957	0.82	0.43	0.94	0.49	1	2	264	833
325	11 09 53.861	+53 46 57.03	16.75	16.79	324.59	3.25	2002.248	1.07	0.62	1.11	0.62	3	3	201	655
326	11 12 09.273	+12 17 12.75	18.61	18.76	281.35	4.92	2003.245	0.83	0.43	0.87	0.43	1	1	904	4447
327	11 12 30.951	+21 59 41.79	17.09	17.25	211.46	4.70	2005.189	0.95	0.44	1.00	0.46	2	2	369	1734
328	11 12 34.427	+36 28 28.69	15.86	16.02	120.88	4.30	2004.083	0.69	0.39	0.72	0.41	1	1	332	1427
329	11 13 01.948	+18 16 45.48	17.42	17.85	293.20	3.05	2005.252	0.68	0.35	0.75	0.39	0	1	748	2280
330	11 13 29.653	+22 59 14.52	17.63	17.84	232.23	3.12	2005.252	0.67	0.37	0.72	0.39	1	1	785	2449
331	11 14 57.950	+28 29 23.06	16.33	16.56	146.78	3.96	2004.957	0.81	0.42	0.87	0.45	1	1	330	1305
332	11 15 09.940	+40 22 50.16	17.39	17.69	162.38	4.48	2003.313	0.77	0.41	0.82	0.45	1	1	585	2620
333	11 16 39.502	+28 41 19.85	16.94	17.19	337.75	3.76	2004.951	1.09	0.54	1.15	0.57	2	3	243	912
334	11 17 58.325	+54 18 48.11	16.97	17.22	137.72	4.63	2001.964	0.87	0.51	0.93	0.54	2	2	355	1641
335	11 18 22.042	+49 06 01.64	16.68	16.87	42.41	3.95	2002.219	0.59	0.30	0.63	0.35	0	0	621	2455
336	11 18 27.061	+33 35 07.42	17.66	18.12	337.47	3.45	2004.283	0.61	0.33	0.71	0.39	0	1	919	3174
337	11 18 44.116	+59 49 31.66	18.44	19.01	77.14	4.77	2002.120	1.18	0.60	1.32	0.66	3	4	385	1837
338	11 21 00.185	+14 13 09.43	17.46	17.51	13.86	3.96	2003.076	0.68	0.36	0.66	0.41	1	1	724	2868
339	11 21 33.597	+51 12 00.07	16.23	16.24	272.43	4.03	2001.970	1.29	0.71	1.29	0.72	4	4	102	409
340	11 21 54.127	+21 39 52.22	18.46	18.67	13.49	3.87	2005.189	1.13	0.64	1.18	0.66	3	3	397	1536
341	11 22 12.583	+67 35 51.87	15.93	16.05	92.55	3.57	2000.321	0.77	0.42	0.80	0.42	1	1	293	1045
342	11 22 39.612	+33 05 14.09	18.57	19.05	72.95	3.06	2004.291	1.04	0.51	1.13	0.59	2	3	576	1760
343	11 22 40.312	+33 13 26.21	19.03	19.40	180.16	3.86	2004.283	1.29	0.65	1.38	0.66	3	4	411	1590
344	11 23 48.749	+25 35 46.42	18.18	18.54	83.88	3.92	2005.096	0.64	0.36	0.72	0.37	0	1	1101	4316
345	11 24 29.915	+47 38 29.77	17.88	18.09	325.30	3.02	2003.177	0.73	0.38	0.77	0.41	1	1	802	2424
346	11 28 24.007	-06 39 53.15	17.67	17.92	174.95	3.66	2006.016	0.57	0.34	0.63	0.35	0	0	971	3558
347	11 29 55.865	+42 32 06.64	18.63	19.02	39.40	3.95	2003.313	1.35	0.77	1.44	0.77	4	4	267	1055
348	11 31 04.789	+53 21 33.80	16.71	16.85	163.79	4.99	2001.964	0.56	0.33	0.58	0.35	0	0	646	3223
349	11 32 53.467	+30 57 52.32	17.64	17.96	253.27	3.39	2004.367	1.09	0.61	1.16	0.64	3	3	304	1031
350	11 33 25.490	+61 21 45.99	15.88	16.15	159.46	4.54	2000.908	1.10	0.60	1.13	0.63	3	3	137	624

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
351	11 34 02.355	+70 58 49.02	18.00	18.58	111.47	3.50	2006.303	0.97	0.52	1.09	0.57	2	3	490	1713
352	11 38 11.241	+17 47 51.03	18.36	18.47	39.73	3.81	2005.416	0.97	0.49	0.97	0.55	2	2	593	2263
353	11 38 19.761	+08 30 36.63	18.60	18.79	110.79	3.61	2002.175	1.11	0.56	1.18	0.59	3	3	478	1726
354	11 40 38.040	+72 32 27.76	15.23	15.64	246.38	3.79	2006.328	0.71	0.35	0.80	0.39	1	1	254	964
355	11 40 53.259	+28 02 13.05	16.48	16.55	78.04	3.11	2004.973	1.23	0.60	1.24	0.61	3	3	147	459
356	11 41 31.254	+72 55 09.10	16.96	16.97	49.90	3.19	2006.303	1.20	0.62	1.21	0.62	3	3	185	592
357	11 43 08.574	+71 05 35.04	18.47	18.90	298.45	4.67	2006.328	1.17	0.68	1.26	0.75	3	4	351	1639
358	11 43 14.696	+20 31 17.80	18.10	18.40	165.21	4.85	2005.252	1.30	0.71	1.35	0.76	4	4	236	1146
359	11 43 49.640	+03 08 43.53	17.86	17.97	71.22	4.72	2000.979	1.17	0.60	1.19	0.61	3	3	305	1440
360	11 46 36.301	+54 32 46.17	18.45	18.64	51.26	3.62	2001.964	1.28	0.69	1.32	0.71	4	4	299	1083
361	11 47 53.084	+35 44 11.49	17.82	17.98	146.07	3.32	2004.291	0.75	0.40	0.81	0.42	1	1	727	2413
362	11 48 07.214	-01 36 31.54	18.68	18.73	215.69	4.33	2000.171	1.08	0.56	1.09	0.59	3	3	530	2296
363	11 48 58.342	+07 37 27.90	18.12	18.72	276.85	3.69	2003.248	0.87	0.50	0.99	0.59	2	2	606	2238
364	11 49 42.820	+34 03 31.56	17.97	18.24	101.28	4.42	2004.291	0.92	0.54	0.95	0.56	2	2	514	2272
365	11 50 37.434	+39 03 17.93	18.88	19.41	117.18	4.89	2003.316	1.06	0.59	1.17	0.64	3	3	582	2847
366	11 50 41.114	+29 02 27.68	17.04	17.13	225.81	4.90	2004.951	0.76	0.41	0.76	0.45	1	1	493	2418
367	11 52 13.420	+55 29 57.92	19.04	19.28	25.63	4.27	2001.964	1.48	0.75	1.56	0.78	4	5	260	1110
368	11 53 38.848	+33 43 22.89	17.39	17.43	145.89	4.44	2004.291	1.12	0.61	1.13	0.62	3	3	257	1141
369	11 53 52.646	+41 59 19.29	18.18	18.23	82.20	3.92	2003.313	1.51	0.89	1.51	0.89	5	5	143	561
370	11 54 27.242	+08 23 54.26	16.68	17.11	300.27	3.91	2003.248	0.91	0.48	1.02	0.49	2	2	310	1212
371	11 55 14.344	+06 45 14.79	17.83	18.33	308.75	4.33	2006.019	0.83	0.47	0.92	0.53	2	2	600	2601
372	11 57 54.360	+54 52 59.74	18.41	18.72	258.26	3.49	2002.248	0.81	0.42	0.90	0.46	1	2	848	2960
373	11 59 36.105	-03 29 21.16	16.03	16.41	199.86	4.24	2000.116	0.68	0.35	0.77	0.40	0	1	382	1621
374	12 00 07.690	+07 27 06.55	18.79	18.94	78.22	3.25	2006.017	0.85	0.41	0.86	0.47	1	2	968	3147
375	12 00 55.529	+45 53 53.43	17.76	18.11	240.84	3.11	2003.231	0.83	0.47	0.90	0.51	2	2	576	1787
376	12 01 16.032	+61 32 57.84	18.00	18.05	68.80	4.11	2001.378	1.17	0.60	1.17	0.61	3	3	324	1330
377	12 01 20.849	-02 23 50.25	18.36	18.49	20.42	3.41	2000.171	0.97	0.50	0.97	0.52	2	2	606	2067
378	12 01 46.027	+01 18 19.81	17.13	17.73	69.39	3.06	2000.343	0.70	0.42	0.84	0.46	1	1	567	1733
379	12 02 21.629	+16 11 25.74	18.81	18.93	219.61	3.92	2004.075	1.38	0.75	1.40	0.77	4	4	275	1079
380	12 02 27.570	+69 25 14.78	18.69	18.87	314.92	4.45	2006.303	1.04	0.57	1.08	0.58	3	3	562	2498
381	12 02 40.130	+66 27 37.36	17.38	17.41	237.61	3.08	2000.321	1.13	0.59	1.14	0.59	3	3	262	807
382	12 02 40.500	+39 27 55.12	17.51	17.95	225.80	3.11	2004.130	0.90	0.49	1.03	0.54	2	2	437	1362
383	12 04 50.952	+54 01 29.25	17.44	17.87	356.31	3.07	2001.964	0.68	0.38	0.77	0.43	1	1	705	2162
384	12 05 21.077	+41 53 30.99	18.08	18.32	87.64	3.65	2003.248	0.63	0.33	0.68	0.38	0	1	1076	3927
385	12 06 58.248	+27 39 22.54	17.62	18.07	309.93	4.97	2004.973	0.84	0.46	0.93	0.51	1	2	540	2683
386	12 07 21.080	-02 32 21.76	17.98	18.20	204.43	3.29	2000.116	1.28	0.69	1.33	0.71	4	4	238	781
387	12 07 53.814	+57 19 09.66	16.80	17.10	266.99	3.87	2001.967	1.00	0.51	1.09	0.55	2	2	268	1038
388	12 08 28.297	+13 38 09.65	17.40	17.96	241.95	4.77	2003.245	0.58	0.28	0.68	0.34	0	0	931	4440
389	12 08 48.603	-00 40 06.48	17.01	17.06	344.72	3.59	2007.300	1.24	0.65	1.23	0.67	3	3	172	618
390	12 11 10.112	+36 21 13.53	17.79	18.12	9.72	3.02	2004.083	1.47	0.77	1.52	0.84	4	5	145	439
391	12 13 16.879	-01 16 40.18	18.16	18.39	8.18	3.62	2000.116	1.20	0.64	1.22	0.67	3	3	321	1162
392	12 14 48.581	-03 16 18.09	19.16	19.33	176.13	4.81	2000.171	1.43	0.80	1.46	0.82	4	4	282	1356
393	12 15 09.707	+01 24 27.55	19.14	19.48	124.79	3.69	2000.343	1.53	0.79	1.57	0.84	5	5	250	925
394	12 15 33.124	+50 10 43.15	18.85	18.90	285.81	4.26	2002.219	1.18	0.60	1.18	0.63	3	3	469	1996
395	12 15 50.132	+12 35 14.51	16.86	16.92	122.72	3.49	2003.223	0.68	0.35	0.68	0.37	0	1	565	1974
396	12 15 57.501	+05 55 01.64	18.93	19.02	285.18	4.38	2001.290	1.55	0.84	1.58	0.86	5	5	199	870
397	12 16 01.043	+32 32 35.75	17.53	17.70	132.99	3.13	2004.362	0.62	0.35	0.67	0.37	0	1	828	2589
398	12 16 14.926	-00 02 42.76	17.94	18.56	45.88	3.26	1999.221	0.90	0.50	1.04	0.57	2	2	538	1752
399	12 16 21.702	+03 03 05.73	16.50	16.91	58.04	4.28	2000.343	0.64	0.36	0.72	0.41	0	1	496	2123
400	12 16 27.929	+19 52 43.47	17.75	18.13	155.62	3.79	2005.252	1.45	0.74	1.51	0.80	4	5	157	595

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
401	12 17 17.004	+44 01 59.22	19.04	19.56	233.28	3.96	2003.226	1.18	0.65	1.27	0.69	3	4	490	1938
402	12 17 35.957	+24 24 35.71	18.84	19.19	4.55	3.96	2005.050	1.15	0.64	1.25	0.67	3	3	456	1807
403	12 20 32.739	-02 04 11.07	15.68	15.97	283.74	3.58	2000.171	1.52	0.82	1.56	0.84	5	5	50	179
404	12 23 11.206	+22 44 08.14	17.93	18.28	133.96	3.89	2005.189	1.38	0.70	1.44	0.74	4	4	201	781
405	12 23 26.640	+35 07 44.41	18.56	18.79	355.24	4.75	2004.291	0.70	0.39	0.74	0.40	1	1	1160	5513
406	12 23 41.667	+49 04 17.30	15.10	15.53	118.76	3.08	2002.106	0.83	1.54	1.68	0.83	5	5	36	111
407	12 23 45.107	+07 16 46.67	18.02	18.23	357.77	3.37	2003.248	0.59	0.32	0.65	0.36	0	0	1116	3764
408	12 24 21.045	+35 06 51.31	18.80	18.97	180.60	3.09	2004.291	0.94	0.50	0.98	0.50	2	2	765	2368
409	12 25 37.234	+05 34 49.07	18.35	18.71	55.96	4.62	2001.290	0.79	0.44	0.89	0.48	1	2	820	3791
410	12 26 21.675	+26 30 03.97	17.66	18.11	150.77	3.04	2005.050	1.38	0.75	1.46	0.79	4	4	167	506
411	12 26 23.509	+08 51 24.93	16.46	16.66	140.12	3.54	2002.194	1.09	0.54	1.12	0.57	2	3	197	695
412	12 26 40.393	+00 08 08.65	17.86	18.43	212.53	4.45	1999.218	0.83	0.47	0.93	0.51	1	2	625	2781
413	12 27 03.932	+26 02 52.46	17.77	17.88	336.38	4.97	2005.050	0.81	0.43	0.84	0.45	1	1	627	3119
414	12 27 52.986	+16 37 23.55	18.03	18.30	162.27	4.83	2005.430	1.39	0.73	1.46	0.73	4	4	199	961
415	12 28 08.930	+61 50 17.86	15.08	15.13	195.78	3.55	2001.391	1.09	0.63	1.10	0.64	3	3	91	322
416	12 28 11.539	+27 11 45.87	17.26	17.53	312.76	3.38	2004.973	0.63	0.28	0.68	0.32	0	0	802	2706
417	12 28 47.935	+03 00 01.86	17.39	17.85	217.57	3.64	2000.343	1.16	0.62	1.26	0.64	3	3	247	899
418	12 29 00.612	+30 06 12.96	18.61	18.63	130.41	3.66	2004.392	1.04	0.54	1.06	0.55	2	2	558	2038
419	12 29 16.987	+05 56 17.97	16.44	16.52	276.89	3.40	2001.290	1.40	0.76	1.43	0.76	4	4	89	304
420	12 29 47.868	-00 29 43.25	18.21	18.40	65.93	3.41	1999.221	1.18	0.62	1.23	0.64	3	3	338	1152
421	12 30 20.353	+09 49 04.48	18.78	18.89	355.41	4.13	2003.319	1.33	0.70	1.34	0.72	4	4	316	1304
422	12 31 19.290	+53 32 20.82	19.36	19.71	140.49	3.18	2002.036	1.51	0.81	1.58	0.85	5	5	272	865
423	12 32 10.907	+02 06 14.95	17.38	17.46	112.67	3.27	2000.343	1.56	0.79	1.58	0.81	5	5	103	338
424	12 32 59.960	+40 25 58.98	17.33	17.47	331.48	4.60	2003.316	0.89	0.48	0.92	0.50	2	2	425	1954
425	12 33 06.654	+26 00 27.72	15.83	16.01	350.86	3.48	2005.252	0.64	0.31	0.68	0.34	0	0	389	1354
426	12 34 53.605	+34 47 04.29	15.66	16.17	95.63	4.37	2004.283	1.03	0.52	1.14	0.59	2	3	150	657
427	12 35 07.240	+13 49 08.93	18.01	18.59	194.84	3.32	2003.076	1.59	0.93	1.71	1.04	5	6	108	358
428	12 35 08.841	+33 20 12.16	18.28	18.90	348.96	4.56	2004.362	0.79	0.42	0.93	0.47	1	2	842	3836
429	12 35 11.322	-02 53 50.04	17.90	17.99	87.11	4.04	2000.171	0.98	0.52	0.99	0.56	2	2	451	1821
430	12 35 15.318	+67 40 17.64	18.78	18.99	133.01	3.17	2000.321	0.92	0.48	0.96	0.49	2	2	813	2576
431	12 35 41.749	+13 26 00.73	17.90	18.18	145.74	4.63	2003.223	1.29	0.68	1.35	0.69	4	4	232	1075
432	12 35 48.341	+17 16 13.92	18.57	18.78	190.00	3.34	2005.430	0.77	0.44	0.84	0.47	1	2	938	3130
433	12 37 31.074	+24 52 43.51	18.91	19.17	340.60	3.28	2005.050	0.97	0.53	1.12	0.49	2	2	720	2365
434	12 38 05.211	+22 57 06.21	18.99	19.36	344.43	3.24	2005.195	1.04	0.44	1.11	0.48	2	2	781	2529
435	12 38 27.968	+37 19 14.98	18.45	18.61	129.46	4.10	2004.207	0.94	0.47	0.95	0.50	2	2	680	2787
436	12 39 18.253	+18 35 48.82	18.94	19.23	325.39	4.98	2005.430	1.32	0.66	1.38	0.66	4	4	376	1871
437	12 39 50.848	+36 05 07.62	18.06	18.57	96.38	4.57	2004.283	0.84	0.48	0.94	0.52	2	2	658	3004
438	12 40 06.546	+26 21 23.46	18.65	18.98	155.07	3.43	2004.973	1.23	0.59	1.28	0.62	3	3	414	1421
439	12 40 27.846	+10 43 52.73	16.91	17.40	309.27	4.52	2003.319	0.83	0.49	0.95	0.55	2	2	372	1682
440	12 43 09.012	+32 12 54.42	17.47	17.76	277.64	3.16	2004.316	0.78	0.43	0.84	0.47	1	2	576	1822
441	12 43 58.872	-02 30 15.17	16.71	16.82	106.36	3.36	2006.331	1.09	0.58	1.09	0.58	3	3	212	713
442	12 44 42.209	+00 25 37.82	18.43	18.49	64.17	3.82	2006.331	1.31	0.68	1.33	0.70	4	4	283	1083
443	12 44 51.021	-06 28 54.37	18.65	19.22	240.78	4.05	2006.085	0.84	0.43	0.97	0.50	1	2	901	3644
444	12 45 12.585	+07 35 12.08	17.96	17.99	210.24	4.93	2003.248	1.07	0.58	1.07	0.58	3	3	384	1893
445	12 46 06.459	+60 16 01.62	18.20	18.66	152.20	3.05	2001.287	0.70	0.25	0.72	0.37	0	1	1177	3588
446	12 46 10.955	+05 31 00.68	19.31	19.40	67.41	3.70	2006.331	1.44	0.74	1.49	0.74	4	4	321	1184
447	12 46 42.217	+05 00 47.56	15.45	16.92	21.95	3.39	2006.085	-0.25	1.37	1.04	0.53	2	2	262	889
448	12 47 47.666	+05 18 23.48	16.57	16.86	336.41	3.06	2006.331	0.78	0.39	0.81	0.41	1	1	415	1270
449	12 49 38.377	+25 51 11.58	18.31	18.87	208.16	3.79	2005.252	0.95	0.52	1.05	0.59	2	3	582	2206
450	12 50 37.877	+31 17 22.59	18.86	19.26	80.04	4.45	2004.316	1.33	0.69	1.41	0.71	4	4	337	1500

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
451	12 50 46.344	+23 26 46.66	17.42	17.76	47.34	4.80	2005.189	0.79	0.40	0.87	0.43	1	1	578	2776
452	12 51 02.814	-02 20 13.83	19.20	19.60	1.28	4.32	2000.171	1.35	0.69	1.41	0.72	4	4	389	1680
453	12 51 54.228	+53 54 03.68	18.16	18.61	294.64	3.96	2002.248	1.06	0.57	1.15	0.62	3	3	429	1699
454	12 53 40.872	+25 36 06.19	17.76	17.87	34.00	4.44	2005.050	0.77	0.46	0.80	0.48	1	1	628	2784
455	12 54 40.080	-01 59 42.52	18.43	18.51	8.51	3.48	2000.171	0.53	0.35	0.54	0.36	0	0	1443	5013
456	12 55 12.308	+30 19 30.12	18.57	18.66	122.93	3.14	2004.392	1.24	0.66	1.29	0.66	3	3	341	1069
457	12 56 37.821	+60 45 37.12	17.62	18.07	54.08	3.57	2002.120	0.83	0.42	0.93	0.46	1	2	586	2089
458	12 56 50.041	+39 56 06.69	18.60	18.99	213.15	3.16	2004.075	1.26	0.72	1.37	0.76	4	4	309	977
459	12 58 26.401	+09 39 28.83	16.25	16.81	278.75	4.89	2003.319	1.10	0.58	1.23	0.66	3	3	161	790
460	12 59 12.011	+31 23 40.08	17.93	18.51	46.41	3.43	2004.362	1.35	0.72	1.44	0.78	4	4	206	707
461	13 00 53.892	-02 11 17.59	18.52	18.73	177.61	3.68	2000.116	1.04	0.56	1.05	0.58	2	3	545	2004
462	13 03 19.194	+67 58 53.41	18.21	18.78	23.45	4.93	2000.321	0.69	0.36	0.83	0.44	1	1	982	4838
463	13 09 36.180	+29 34 10.63	18.54	19.16	13.22	4.38	2004.392	0.72	0.43	0.85	0.50	1	2	1033	4520
464	13 09 39.710	+46 40 37.12	17.98	18.19	97.45	4.66	2003.191	1.25	0.63	1.28	0.64	3	3	278	1294
465	13 10 00.829	+08 20 17.10	17.65	18.15	103.53	4.44	2003.248	1.21	0.60	1.31	0.65	3	3	262	1164
466	13 10 09.520	+18 30 33.41	15.28	15.37	321.87	3.01	2005.353	1.14	0.57	1.17	0.60	3	3	99	298
467	13 10 23.868	+17 10 06.73	16.93	17.25	107.55	4.00	2005.427	1.18	0.61	1.23	0.64	3	3	196	783
468	13 10 44.301	+14 34 32.89	19.16	19.74	284.16	4.82	2004.075	2.14	1.18	2.31	1.27	7	8	67	321
469	13 10 46.680	+07 39 54.58	18.91	19.12	131.49	3.76	2003.248	1.43	0.75	1.47	0.79	4	4	269	1014
470	13 11 48.303	+62 49 29.95	18.25	18.87	350.14	3.06	2001.391	0.64	0.39	0.82	0.43	1	1	1055	3230
471	13 12 14.131	+40 09 11.52	18.26	18.92	90.98	3.59	2003.316	1.07	0.53	1.23	0.60	2	3	459	1648
472	13 12 14.647	-00 49 27.25	15.73	16.23	64.30	3.90	1999.218	1.24	0.66	1.33	0.71	3	4	95	372
473	13 13 35.220	+19 03 05.97	18.81	18.87	352.73	4.22	2005.353	1.02	0.56	1.06	0.58	2	3	599	2524
474	13 13 42.574	+25 42 58.49	18.54	18.73	334.77	3.81	2004.973	0.99	0.41	0.97	0.49	2	2	712	2714
475	13 13 47.380	+55 50 14.20	18.99	19.10	309.03	3.84	2003.180	1.11	0.59	1.13	0.61	3	3	565	2171
476	13 14 40.107	+04 40 00.46	15.59	15.60	210.18	3.85	2001.214	0.85	0.44	0.86	0.44	1	1	217	834
477	13 16 54.684	+45 56 02.54	18.86	19.12	317.30	3.83	2003.177	0.93	0.44	0.98	0.46	2	2	870	3336
478	13 16 59.445	+47 39 51.83	17.62	18.17	298.73	3.44	2003.177	1.11	0.53	1.24	0.61	2	3	321	1102
479	13 17 14.454	+50 19 09.82	18.86	19.39	268.48	3.51	2002.107	0.94	0.49	1.05	0.54	2	2	795	2795
480	13 18 18.548	+46 15 40.54	18.81	19.09	214.73	4.06	2003.177	1.44	0.84	1.50	0.87	5	5	223	908
481	13 20 04.116	+24 26 01.63	17.78	18.27	178.54	3.09	2005.252	0.55	0.34	0.66	0.41	0	1	1032	3193
482	13 20 26.880	+57 10 22.43	16.50	16.75	19.87	3.69	2003.188	0.73	0.41	0.78	0.44	1	1	412	1521
483	13 21 43.232	+29 13 45.17	17.72	17.89	253.93	3.75	2004.392	0.78	0.41	0.81	0.41	1	1	678	2545
484	13 22 10.383	+06 04 07.54	18.36	18.70	60.51	3.76	2003.248	1.25	0.65	1.30	0.69	3	4	320	1203
485	13 22 41.789	+67 49 13.20	15.61	15.76	19.04	3.37	2000.321	1.01	0.54	1.04	0.57	2	2	149	501
486	13 22 42.722	+02 22 02.13	19.11	19.48	203.59	4.16	2000.340	1.60	0.85	1.66	0.89	5	5	205	852
487	13 22 47.452	+64 23 49.35	18.91	19.42	223.87	3.17	2000.261	1.30	0.73	1.44	0.76	4	4	335	1061
488	13 23 38.487	+38 19 32.04	17.70	18.31	39.68	4.68	2004.075	1.34	0.73	1.45	0.79	4	4	186	869
489	13 24 47.659	+03 55 27.32	19.18	19.27	112.81	3.25	2001.214	1.24	0.66	1.25	0.67	3	3	460	1497
490	13 24 56.412	+00 21 14.57	17.76	18.17	150.25	4.02	2000.316	0.82	0.48	0.91	0.50	2	2	582	2340
491	13 25 46.688	+59 59 10.43	16.28	16.89	12.14	4.14	2001.288	0.75	0.41	0.88	0.48	1	2	356	1473
492	13 27 15.331	+29 21 30.85	17.63	17.90	160.92	3.19	2004.392	1.04	0.53	1.09	0.56	2	3	367	1170
493	13 27 22.781	+50 36 05.38	18.23	18.52	263.56	3.41	2003.246	0.90	0.48	0.97	0.53	2	2	633	2154
494	13 27 36.001	+12 58 47.56	16.40	16.83	102.12	4.55	2003.223	1.26	0.70	1.34	0.73	4	4	119	543
495	13 29 30.012	+50 12 56.81	18.96	19.01	12.66	4.41	2003.324	1.32	0.72	1.32	0.72	4	4	341	1502
496	13 30 26.998	+06 20 11.12	17.80	18.40	299.64	3.11	2006.399	0.57	0.32	0.69	0.39	0	1	1060	3292
497	13 31 20.998	+03 28 12.34	18.64	19.19	110.99	3.17	2000.340	0.97	0.54	1.09	0.57	2	3	652	2068
498	13 32 39.071	+14 37 43.39	18.29	18.56	113.44	4.29	2004.075	1.09	0.59	1.15	0.59	3	3	429	1842
499	13 33 46.932	+00 59 59.47	15.86	16.20	115.61	4.04	1999.218	0.87	0.46	0.94	0.50	2	2	230	928
500	13 33 49.683	+67 11 19.76	17.32	17.95	277.28	3.70	2000.321	0.74	0.42	0.90	0.48	1	2	567	2097

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY RA	PRIMARY DECL	MAGNITUDE A	MAGNITUDE B	PA	SEP	DATE	PRIMARY R-I	PRIMARY I-Z	SECONDARY R-I	SECONDARY I-Z	TYPE M+	TYPE M+	DIST. PARSEC	SEP. AU
501	13 35 48.580	+58 21 49.95	17.22	17.71	236.77	3.07	2001.288	0.73	0.39	0.85	0.44	1	1	580	1782
502	13 35 55.552	+29 07 22.91	18.96	19.12	57.07	4.13	2004.392	1.49	0.72	1.51	0.77	4	4	263	1084
503	13 36 16.134	+32 40 14.61	17.66	17.98	43.27	4.59	2004.291	0.70	0.42	0.77	0.45	1	1	720	3303
504	13 36 18.843	+05 42 07.59	16.45	17.04	137.97	4.81	2006.396	0.64	0.35	0.80	0.42	0	1	484	2329
505	13 37 05.564	+41 49 02.09	17.57	18.00	163.46	3.20	2003.325	1.31	0.70	1.39	0.75	4	4	188	600
506	13 37 35.703	+42 42 32.08	16.45	16.48	355.98	3.92	2003.226	0.84	0.41	0.87	0.43	1	1	329	1290
507	13 38 18.114	+32 29 53.53	18.44	18.74	21.49	3.25	2004.283	0.72	0.40	0.79	0.44	1	1	1014	3293
508	13 38 33.672	+05 13 59.94	16.67	17.00	161.41	3.48	2006.396	0.84	0.47	0.92	0.52	2	2	341	1187
509	13 38 34.320	+61 09 01.38	18.12	18.36	353.50	3.28	2001.391	0.65	0.34	0.72	0.34	0	1	1073	3519
510	13 39 50.187	+13 44 47.04	18.58	19.14	165.13	4.25	2003.409	0.72	0.48	0.85	0.53	1	2	976	4144
511	13 40 10.425	+38 04 48.58	18.81	19.31	310.04	4.20	2004.075	1.32	0.64	1.34	0.74	3	4	364	1529
512	13 40 18.235	+23 55 56.25	18.00	18.06	299.87	4.46	2005.050	0.97	0.52	0.99	0.53	2	2	485	2162
513	13 42 59.055	+38 10 26.30	19.00	19.32	108.78	3.35	2003.316	1.10	0.59	1.15	0.62	3	3	585	1959
514	13 43 26.217	+05 50 27.37	18.01	18.41	61.70	3.02	2003.248	0.75	0.42	0.85	0.46	1	2	774	2336
515	13 44 02.364	+23 30 39.43	18.63	18.81	9.34	4.03	2005.050	1.19	0.59	1.23	0.61	3	3	424	1708
516	13 44 27.326	+43 54 00.78	16.73	16.93	128.55	3.42	2003.232	1.60	0.86	1.65	0.89	5	5	66	224
517	13 44 32.610	+06 25 43.10	18.80	18.94	241.33	3.20	2003.319	0.88	0.46	0.90	0.47	2	2	893	2860
518	13 45 04.024	+03 08 55.02	18.09	18.29	49.74	4.36	2000.340	1.14	0.60	1.17	0.63	3	3	353	1540
519	13 45 40.241	+30 17 07.03	18.99	19.34	251.84	3.79	2004.362	1.33	0.71	1.42	0.72	4	4	345	1306
520	13 45 57.288	+00 41 43.41	16.10	16.46	17.73	3.02	2006.399	0.64	0.39	0.74	0.43	1	1	391	1180
521	13 46 59.452	+46 18 16.56	18.81	18.96	10.18	3.20	2003.177	1.26	0.66	1.28	0.69	3	4	375	1199
522	13 47 09.971	+06 39 11.42	18.15	18.53	164.98	3.28	2003.248	1.10	0.56	1.19	0.57	3	3	412	1350
523	13 48 38.747	+55 59 01.01	17.96	17.99	39.54	4.55	2003.188	1.12	0.54	1.12	0.58	3	3	363	1651
524	13 49 05.795	+45 40 32.10	18.53	19.10	291.44	3.80	2003.191	1.26	0.71	1.36	0.77	4	4	313	1188
525	13 49 06.794	+05 12 43.12	17.61	17.64	81.40	3.46	2001.290	0.70	0.38	0.73	0.38	1	1	726	2514
526	13 49 53.174	+30 10 53.03	18.63	19.05	83.43	3.79	2004.362	0.97	0.54	1.06	0.55	2	2	649	2460
527	13 50 01.087	-05 40 56.82	17.09	17.26	196.59	3.55	2006.399	1.05	0.57	1.10	0.60	3	3	260	924
528	13 51 05.345	+26 22 32.51	18.57	19.10	358.56	4.96	2004.447	0.62	0.36	0.77	0.41	0	1	1310	6495
529	13 52 23.520	+31 15 03.44	17.56	18.09	242.83	4.34	2004.362	0.57	0.30	0.70	0.38	0	1	948	4117
530	13 56 18.948	+04 50 27.82	18.77	19.09	207.62	4.86	2001.214	0.87	0.46	0.97	0.47	2	2	874	4250
531	13 57 42.248	+44 47 06.22	18.26	18.53	329.15	3.20	2003.191	0.60	0.33	0.68	0.35	0	1	1233	3947
532	13 58 09.983	+17 44 24.08	17.30	17.68	311.41	3.31	2005.353	0.83	0.47	0.94	0.50	2	2	460	1523
533	13 58 31.662	+54 07 33.56	17.32	17.77	141.97	3.20	2003.188	1.06	0.55	1.15	0.62	2	3	296	946
534	13 59 09.145	+57 23 45.83	16.21	16.76	42.18	4.99	2002.437	0.91	0.41	1.04	0.47	1	2	271	1349
535	13 59 58.071	+30 19 53.52	17.28	17.43	16.58	4.62	2004.308	0.88	0.47	0.90	0.50	2	2	430	1984
536	14 01 48.921	+08 41 49.87	17.84	18.00	196.73	4.46	2003.322	1.16	0.57	1.20	0.61	3	3	314	1401
537	14 03 35.384	+03 40 42.68	17.65	18.21	327.75	4.50	2000.357	1.03	0.59	1.15	0.62	3	3	350	1575
538	14 04 38.805	+34 26 53.49	17.89	18.16	116.59	4.28	2004.209	1.30	0.62	1.34	0.65	3	4	251	1074
539	14 05 38.845	+16 36 22.00	18.36	18.60	40.19	3.59	2005.359	1.48	0.83	1.53	0.85	5	5	176	630
540	14 05 55.948	+48 58 05.44	17.66	17.92	79.13	3.05	2003.246	1.22	0.63	1.26	0.65	3	3	248	757
541	14 06 02.073	+36 36 15.68	18.69	18.83	63.04	3.00	2003.316	0.82	0.49	0.85	0.53	2	2	855	2565
542	14 06 38.258	+05 41 02.51	17.95	18.36	156.80	4.34	2003.319	0.81	0.44	0.92	0.48	1	2	671	2911
543	14 07 08.227	+12 03 09.60	16.86	17.49	155.91	4.21	2003.314	1.04	0.56	1.19	0.63	2	3	240	1009
544	14 08 47.605	+06 04 39.49	18.45	18.50	126.99	4.65	2003.322	0.74	0.44	0.75	0.46	1	1	931	4330
545	14 09 19.605	+42 06 06.00	18.04	18.46	85.45	3.67	2003.232	1.09	0.58	1.17	0.63	3	3	384	1409
546	14 09 54.828	+07 00 11.98	18.69	19.23	260.05	4.03	2003.322	0.85	0.47	0.93	0.52	2	2	883	3556
547	14 10 41.785	+14 36 33.83	18.21	18.34	50.38	3.05	2003.472	1.87	0.99	1.90	1.03	6	6	75	229
548	14 10 56.898	+15 25 02.71	18.99	19.01	22.21	3.52	2005.362	1.24	0.60	1.28	0.59	3	3	452	1589
549	14 12 23.255	+50 03 49.73	18.57	19.11	255.00	3.42	2003.246	0.63	0.35	0.74	0.43	0	1	1317	4505
550	14 16 11.275	+63 25 06.63	16.43	16.47	142.51	4.78	2007.199	0.99	0.53	1.00	0.54	2	2	225	1076

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
551	14 18 01.095	+48 57 15.47	18.81	18.83	302.71	3.26	2003.324	1.07	0.58	1.05	0.62	3	3	551	1794
552	14 19 24.809	+08 02 17.52	16.74	16.85	65.57	3.95	2003.322	0.70	0.39	0.72	0.41	1	1	486	1922
553	14 20 58.750	+37 07 42.02	15.59	16.03	249.47	3.72	2003.325	1.04	0.55	1.13	0.59	2	3	140	521
554	14 21 46.663	-00 07 54.20	18.78	19.03	120.31	3.30	1999.221	0.96	0.48	1.00	0.55	2	2	734	2420
555	14 22 14.683	+12 38 57.03	18.27	18.50	256.67	3.65	2003.409	1.02	0.50	1.06	0.54	2	2	530	1932
556	14 22 24.858	+05 24 54.82	15.92	16.00	224.57	3.36	2003.322	0.60	0.33	0.62	0.34	0	0	421	1414
557	14 22 50.634	+44 34 02.74	18.34	18.84	153.25	3.61	2002.107	1.02	0.53	1.09	0.60	2	3	531	1918
558	14 24 56.310	+46 59 54.32	17.49	17.65	343.87	4.18	2003.324	1.22	0.68	1.25	0.69	3	4	214	892
559	14 25 15.094	+27 03 11.51	18.31	18.83	146.75	3.33	2004.390	1.23	0.63	1.32	0.68	3	4	332	1104
560	14 25 43.264	+37 18 59.75	17.52	17.52	186.82	4.28	2003.325	0.82	0.45	0.82	0.47	1	1	532	2277
561	14 26 42.472	+52 24 18.05	18.60	18.95	46.36	3.76	2003.188	1.43	0.77	1.49	0.80	4	4	232	873
562	14 28 18.037	+55 59 51.21	18.85	19.30	343.20	3.07	2002.437	1.02	0.57	1.11	0.62	2	3	624	1918
563	14 28 48.932	+09 00 07.53	17.65	17.84	122.67	3.31	2003.322	1.11	0.57	1.14	0.60	3	3	314	1041
564	14 28 55.768	+45 11 36.36	18.57	19.18	54.88	4.37	2002.107	0.74	0.50	0.97	0.48	1	2	906	3959
565	14 29 13.492	+40 18 08.33	18.17	18.37	311.14	3.03	2003.232	0.93	0.50	0.99	0.53	2	2	565	1715
566	14 29 39.253	+45 02 22.26	18.00	18.16	115.91	4.15	2002.107	0.72	0.37	0.74	0.41	1	1	867	3596
567	14 30 53.529	+38 21 52.96	17.82	18.42	182.76	3.23	2003.314	1.05	0.57	1.19	0.63	3	3	368	1189
568	14 31 44.104	+34 30 22.05	17.21	17.33	191.10	3.48	2003.475	0.95	0.56	0.97	0.56	2	2	333	1159
569	14 32 20.600	+39 15 26.63	15.81	16.07	150.95	3.03	2003.232	0.75	0.42	0.80	0.42	1	1	292	885
570	14 32 24.235	+56 46 17.53	19.17	19.64	339.76	4.63	2002.437	1.25	0.63	1.30	0.72	3	4	474	2193
571	14 34 05.964	+35 04 50.29	17.72	17.78	17.80	3.17	2003.316	0.73	0.40	0.75	0.42	1	1	715	2265
572	14 34 48.929	+16 36 37.96	17.09	17.51	246.24	3.92	2005.356	1.30	0.62	1.37	0.65	3	4	176	689
573	14 37 16.457	+29 59 43.67	16.60	17.15	242.86	4.86	2004.288	0.93	0.50	1.03	0.56	2	2	282	1370
574	14 40 40.811	+40 02 49.47	18.92	19.31	203.69	3.78	2003.226	0.99	0.53	1.08	0.58	2	3	702	2656
575	14 43 06.324	+48 33 12.07	18.29	18.44	55.01	3.41	2002.350	1.14	0.60	1.17	0.61	3	3	389	1324
576	14 45 58.429	+29 33 34.65	18.47	18.53	270.88	4.04	2004.291	0.85	0.48	0.74	0.60	2	2	776	3134
577	14 46 12.078	+13 53 39.77	18.83	19.20	295.14	4.40	2005.364	1.30	0.65	1.42	0.67	3	4	359	1577
578	14 46 14.031	+17 28 24.45	17.97	18.39	292.07	4.45	2005.190	0.58	0.36	0.70	0.39	0	1	1056	4701
579	14 46 29.107	+58 01 02.27	17.71	17.89	279.30	3.47	2001.378	0.86	0.46	0.91	0.46	2	2	553	1917
580	14 47 54.065	+51 32 51.97	17.00	17.37	349.64	4.07	2003.188	1.32	0.69	1.39	0.73	4	4	144	588
581	14 49 46.117	+54 41 16.55	19.15	19.32	310.82	4.38	2002.352	1.19	0.65	1.20	0.69	3	3	499	2185
582	14 50 22.512	+34 53 45.70	16.67	16.81	253.03	4.93	2003.475	0.75	0.39	0.80	0.41	1	1	433	2133
583	14 51 25.781	+10 46 06.84	15.70	15.93	215.29	3.59	2003.245	1.03	0.55	1.10	0.58	2	3	145	522
584	14 52 04.466	+11 57 46.89	17.38	17.40	58.57	3.14	2003.409	1.45	0.79	1.43	0.81	4	4	123	385
585	14 52 11.992	+05 45 37.79	18.31	18.69	159.77	3.39	2003.322	0.92	0.50	0.99	0.55	2	2	622	2106
586	14 52 24.006	+11 01 56.49	17.73	17.93	279.83	4.96	2003.472	1.21	0.61	1.24	0.64	3	3	266	1319
587	14 52 51.536	+52 21 02.20	15.27	15.41	112.95	4.27	2003.180	0.66	0.34	0.67	0.35	0	0	289	1232
588	14 53 42.393	+18 19 18.57	16.43	16.49	268.08	3.55	2005.190	1.06	0.52	1.06	0.55	2	2	207	734
589	14 56 00.465	+11 05 18.27	18.42	18.78	354.30	3.76	2003.409	0.75	0.43	0.82	0.47	1	1	936	3522
590	14 56 12.408	+39 00 02.74	18.29	18.46	294.78	4.85	2003.232	0.57	0.35	0.61	0.39	0	1	1245	6031
591	14 59 46.200	+34 06 43.11	16.65	17.20	71.16	3.55	2003.475	1.16	0.57	1.27	0.63	3	3	185	657
592	14 59 48.355	+59 05 18.27	17.87	18.31	46.26	3.26	2000.261	1.07	0.58	1.16	0.64	3	3	360	1173
593	15 01 32.631	+33 16 46.82	17.85	18.31	196.13	4.40	2003.475	0.71	0.36	0.80	0.41	1	1	846	3722
594	15 05 21.404	+35 54 58.23	19.06	19.55	317.43	4.97	2003.314	1.13	0.57	1.24	0.65	3	3	572	2842
595	15 05 26.380	+33 43 00.28	18.81	19.05	140.36	4.07	2003.325	0.91	0.59	0.98	0.59	2	2	705	2866
596	15 07 30.765	+40 45 12.32	18.67	19.19	66.57	4.75	2003.114	1.03	0.56	1.14	0.59	2	3	582	2761
597	15 09 49.186	+14 51 03.82	15.96	16.21	165.96	3.59	2005.354	0.94	0.46	0.99	0.49	2	2	218	782
598	15 10 55.064	+41 04 22.40	15.71	16.08	331.45	3.00	2002.107	0.76	0.38	0.84	0.43	1	1	282	848
599	15 11 40.132	+17 35 21.66	18.68	18.89	341.88	3.43	2005.190	0.75	0.40	0.79	0.43	1	1	1096	3758
600	15 13 11.399	+52 27 55.47	18.53	18.86	279.75	4.82	2002.437	0.90	0.45	0.99	0.48	2	2	754	3633

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
601	15 13 35.255	+30 26 00.90	18.77	18.89	232.50	4.86	2003.475	1.35	0.69	1.32	0.74	4	4	314	1526
602	15 14 57.727	+51 24 53.92	18.71	19.12	279.83	4.66	2002.352	1.03	0.56	1.11	0.59	2	3	594	2769
603	15 15 28.467	+19 25 56.05	17.52	17.58	227.72	3.06	2004.452	1.23	0.65	1.25	0.66	3	3	217	666
604	15 17 20.053	+57 00 47.73	17.93	18.04	327.69	4.20	2006.331	0.66	0.37	0.68	0.40	1	1	913	3837
605	15 23 55.837	+08 40 57.78	18.31	18.34	297.87	4.64	2003.245	0.71	0.36	0.74	0.37	1	1	1018	4720
606	15 24 12.586	+29 19 37.88	18.34	18.41	52.98	3.51	2004.209	0.96	0.53	0.99	0.53	2	2	565	1981
607	15 25 03.438	+08 47 27.10	17.22	17.65	5.92	3.77	2003.314	0.58	0.31	0.66	0.34	0	0	829	3129
608	15 25 05.592	+60 33 49.08	18.00	18.34	303.79	4.63	2000.321	0.73	0.42	0.81	0.43	1	1	814	3771
609	15 26 17.800	+17 15 32.55	18.53	18.95	183.52	4.94	2004.452	1.10	0.58	1.18	0.64	3	3	467	2307
610	15 27 32.334	+30 12 14.47	17.14	17.72	189.89	3.85	2003.475	0.91	0.46	1.02	0.54	2	2	388	1493
611	15 28 01.142	+38 44 23.91	17.87	17.96	16.18	3.45	2003.404	0.85	0.42	0.88	0.43	1	1	633	2183
612	15 32 20.691	+43 55 32.62	18.71	18.92	23.60	4.95	2002.350	1.18	0.61	1.23	0.63	3	3	438	2169
613	15 33 41.609	+54 59 44.11	15.39	16.36	350.05	3.22	2005.428	-0.20	1.44	1.03	0.49	2	2	215	693
614	15 35 39.243	+42 12 56.20	16.99	17.10	171.09	4.90	2002.350	0.91	0.50	0.94	0.53	2	2	343	1680
615	15 37 24.900	+64 09 39.64	16.32	16.74	157.24	3.98	2005.416	0.65	0.32	0.74	0.36	0	1	481	1914
616	15 38 23.491	+57 17 03.49	17.83	17.87	5.05	3.19	2000.321	1.09	0.60	1.09	0.60	3	3	340	1083
617	15 38 28.185	+39 29 08.58	18.93	19.50	163.37	3.09	2003.324	1.07	0.57	1.15	0.65	3	3	612	1893
618	15 38 54.773	+54 19 56.10	18.63	19.13	80.48	4.98	2001.072	1.41	0.76	1.51	0.82	4	5	241	1200
619	15 39 09.832	+46 35 57.83	15.80	16.24	272.68	3.81	2002.353	1.14	0.59	1.23	0.63	3	3	126	478
620	15 39 16.602	+40 29 36.99	18.63	18.81	129.12	3.77	2003.324	0.77	0.39	0.81	0.42	1	1	1049	3958
621	15 39 57.075	+38 50 47.67	16.97	17.26	218.14	3.46	2003.324	0.89	0.46	0.95	0.49	2	2	374	1295
622	15 42 31.998	+15 05 30.32	18.66	18.87	252.38	3.88	2005.367	1.23	0.61	1.29	0.59	3	3	406	1578
623	15 43 22.078	+46 19 04.97	16.30	16.66	206.53	3.58	2002.437	1.06	0.56	1.13	0.59	2	3	187	672
624	15 44 56.192	+27 08 11.90	17.49	18.04	332.34	3.50	2003.475	1.20	0.64	1.34	0.70	3	4	226	791
625	15 49 43.607	+48 44 30.35	18.66	18.74	70.13	4.75	2001.375	1.23	0.61	1.24	0.61	3	3	400	1897
626	15 50 29.810	+36 44 16.85	18.04	18.58	326.36	4.27	2003.406	0.82	0.32	0.92	0.38	1	1	830	3539
627	15 50 36.733	+56 16 50.72	18.39	18.79	359.45	3.14	2000.321	0.79	0.45	0.88	0.47	1	2	849	2665
628	15 51 03.022	+55 14 22.06	18.39	18.72	188.27	4.99	2001.225	1.05	0.57	1.11	0.60	3	3	488	2432
629	15 51 16.339	+42 47 03.03	18.63	18.77	19.50	4.64	2003.180	1.09	0.63	1.13	0.60	3	3	479	2220
630	15 51 29.949	+56 40 22.38	18.42	18.61	336.72	3.45	2000.321	1.12	0.55	1.15	0.58	3	3	455	1570
631	15 52 32.014	+17 38 24.31	17.57	17.66	307.38	4.49	2004.447	1.25	0.68	1.26	0.69	3	4	212	951
632	15 55 06.921	+49 53 57.70	18.30	18.46	318.42	4.08	2001.392	0.87	0.46	0.91	0.48	2	2	709	2897
633	15 57 18.689	+16 15 22.14	17.30	17.66	313.59	3.19	2004.447	0.59	0.35	0.67	0.37	0	1	792	2528
634	15 57 25.654	+49 33 08.27	15.52	15.72	57.12	3.62	2001.392	0.92	0.49	0.95	0.52	2	2	175	635
635	15 57 38.614	+58 20 26.05	18.70	19.10	293.22	4.81	2004.453	1.20	0.67	1.30	0.69	3	4	390	1872
636	15 59 12.630	+52 50 32.38	17.56	18.06	350.82	3.90	2000.261	0.63	0.36	0.76	0.42	0	1	808	3150
637	15 59 50.353	+43 34 48.38	18.00	18.58	83.31	3.28	2002.437	0.89	0.49	0.98	0.56	2	2	588	1929
638	15 59 52.508	+55 57 17.95	18.62	19.04	231.29	3.02	2000.321	1.22	0.69	1.31	0.72	3	4	356	1073
639	16 08 49.816	+46 19 26.59	18.18	18.40	353.11	3.63	2001.392	1.07	0.56	1.13	0.56	3	3	436	1582
640	16 12 43.835	+48 37 45.71	19.17	19.23	39.39	3.63	2001.290	1.43	0.77	1.42	0.79	4	4	298	1079
641	16 12 49.090	+31 15 59.03	18.73	18.93	332.92	3.41	2003.194	1.25	0.67	1.29	0.69	3	4	363	1237
642	16 18 41.937	+54 11 42.16	18.42	18.44	351.33	4.04	2004.453	0.72	0.36	0.73	0.39	1	1	1056	4266
643	16 18 54.388	+45 06 26.43	17.61	17.75	4.39	4.63	2001.375	1.25	0.65	1.29	0.66	3	3	220	1020
644	16 23 20.015	+46 47 02.33	17.59	17.74	29.81	4.37	2000.261	1.32	0.66	1.34	0.68	4	4	198	865
645	16 24 09.420	+36 15 53.50	18.89	19.24	106.79	4.25	2002.353	1.22	0.61	1.27	0.68	3	4	442	1878
646	16 29 00.245	+35 43 20.35	16.84	17.13	65.65	3.65	2002.353	0.63	0.32	0.68	0.37	0	1	622	2266
647	16 29 51.710	+43 47 22.32	17.49	17.94	347.78	3.09	2000.261	1.25	0.71	1.33	0.75	4	4	196	605
648	16 32 03.518	+45 35 47.51	16.97	17.16	182.61	4.29	2000.261	1.38	0.74	1.42	0.77	4	4	120	514
649	16 39 01.195	+50 39 49.64	17.16	17.81	23.06	4.84	2003.481	1.07	0.50	1.22	0.58	2	3	291	1407
650	16 39 03.510	+33 52 45.70	18.51	18.73	234.84	3.53	2002.353	1.32	0.68	1.36	0.72	4	4	290	1025

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY		MAGNITUDE		PA	SEP	DATE	PRIMARY		SECONDARY		TYPE	TYPE	DIST.	SEP.
	RA	DECL	A	B				R-I	I-Z	R-I	I-Z	M+	M+	PARSEC	AU
651	16 43 38.737	+45 32 41.72	19.53	19.90	156.45	3.64	2001.225	1.62	0.86	1.68	0.91	5	5	237	860
652	16 45 49.526	+49 01 27.05	17.61	18.03	89.55	3.13	2004.453	1.30	0.64	1.37	0.70	3	4	212	662
653	16 46 20.640	+50 34 08.23	17.77	18.30	320.98	3.24	2005.416	0.65	0.40	0.79	0.45	1	1	823	2669
654	16 47 12.563	+33 00 16.73	16.43	16.46	122.35	3.91	2003.180	0.73	0.40	0.74	0.40	1	1	403	1575
655	16 49 27.641	+51 23 48.92	17.78	17.92	204.10	3.64	2005.416	0.71	0.39	0.74	0.42	1	1	775	2823
656	16 49 28.508	+40 05 10.18	17.86	17.89	308.88	3.47	2001.395	1.19	0.62	1.21	0.64	3	3	280	971
657	16 51 41.786	+43 43 58.90	17.27	17.41	124.58	3.13	2000.338	0.66	0.37	0.67	0.40	1	1	682	2133
658	16 52 43.732	+45 47 21.91	17.60	17.76	65.97	4.59	2003.481	0.98	0.54	1.03	0.57	2	2	381	1749
659	16 54 52.296	+41 38 22.09	18.30	18.37	198.07	4.51	2001.225	0.62	0.31	0.65	0.29	0	0	1275	5754
660	16 55 38.908	+61 10 20.81	15.63	15.83	180.33	3.55	2000.258	0.61	0.34	0.65	0.36	0	0	359	1275
661	16 56 52.832	+38 23 29.08	18.40	18.80	214.64	4.75	2001.225	1.05	0.55	1.11	0.58	2	3	515	2442
662	16 57 13.144	+46 05 28.74	17.36	17.60	90.18	4.26	2005.417	0.87	0.47	0.94	0.49	2	2	446	1901
663	16 57 55.274	+39 18 09.36	18.65	19.22	354.85	3.83	2001.395	0.75	0.36	0.90	0.41	1	1	1131	4325
664	16 58 00.816	+49 31 13.85	17.15	17.31	169.30	4.04	2005.417	0.66	0.32	0.70	0.35	0	1	688	2777
665	16 58 44.204	+44 28 33.50	18.58	19.02	36.04	4.40	2004.453	0.91	0.47	1.05	0.50	2	2	733	3221
666	16 59 16.887	+46 13 04.93	18.56	18.85	90.13	4.65	2005.417	0.97	0.51	1.04	0.53	2	2	645	3002
667	16 59 35.783	+41 06 22.70	15.73	16.11	271.45	3.55	2000.338	1.03	0.54	1.09	0.57	2	3	156	554
668	17 02 17.720	+45 23 10.56	17.31	17.70	201.67	3.01	2005.444	1.10	0.56	1.17	0.62	3	3	278	838
669	17 03 03.370	+63 33 59.78	15.98	16.07	85.11	3.10	2006.331	0.81	0.47	0.83	0.47	1	2	264	818
670	17 04 10.214	+31 59 14.55	17.91	17.98	237.96	3.52	2001.392	1.12	0.58	1.15	0.59	3	3	339	1195
671	17 05 22.740	+64 39 59.92	16.18	16.52	217.10	4.21	2006.394	0.95	0.48	1.01	0.52	2	2	233	980
672	17 08 26.633	+57 57 59.07	16.39	16.47	98.61	3.90	2000.259	0.71	0.41	0.73	0.40	1	1	405	1578
673	17 08 41.021	+34 30 03.63	16.97	17.38	68.76	4.68	2001.291	1.08	0.53	1.17	0.56	2	3	256	1200
674	17 09 07.104	+34 22 46.54	16.93	17.07	303.78	3.41	2001.291	0.72	0.37	0.75	0.39	1	1	534	1817
675	17 09 32.703	+43 24 18.35	17.68	17.81	89.60	3.76	2005.435	0.70	0.37	0.72	0.41	1	1	768	2886
676	17 10 16.584	+58 00 36.93	19.40	19.66	321.34	4.50	2000.259	1.51	0.80	1.53	0.84	5	5	289	1301
677	17 15 06.523	+36 04 20.80	18.03	18.35	222.45	3.27	2004.453	0.99	0.55	1.09	0.56	2	3	460	1506
678	17 17 56.272	+67 17 13.47	18.27	18.50	244.14	3.23	2000.264	1.27	0.67	1.34	0.70	3	4	281	905
679	17 19 21.236	+40 44 20.98	18.65	18.69	140.80	3.82	2005.365	1.51	0.74	1.53	0.76	4	4	212	809
680	17 22 54.086	+44 40 22.17	17.28	17.50	79.31	4.81	2005.444	1.21	0.64	1.27	0.66	3	3	205	984
681	17 26 51.332	+52 32 00.83	17.24	17.34	262.16	4.70	2000.259	1.09	0.64	1.09	0.66	3	3	244	1146
682	17 29 27.129	+35 32 04.52	18.35	18.64	244.18	4.97	2005.365	0.65	0.33	0.70	0.37	0	1	1203	5981
683	17 31 33.155	+36 43 43.48	17.51	17.89	346.93	3.56	2005.365	0.68	0.31	0.78	0.31	0	1	822	2929
684	17 33 21.812	+43 06 26.44	18.11	18.28	238.45	3.77	2005.444	1.27	0.63	1.30	0.66	3	4	279	1053
685	17 35 18.763	+50 57 16.71	17.30	17.44	180.95	3.50	2001.717	1.04	0.54	1.07	0.54	2	2	316	1105
686	17 38 20.012	+26 56 31.55	17.77	18.29	43.01	4.98	2004.710	0.96	0.46	1.07	0.50	2	2	492	2448
687	20 35 46.849	-20 18 49.81	19.21	19.23	300.26	4.21	2004.699	1.41	0.75	1.43	0.75	4	4	319	1340
688	21 35 43.302	-08 49 45.58	17.78	18.00	260.63	4.97	2001.717	1.02	0.55	1.07	0.58	2	3	388	1926
689	21 36 04.565	+08 05 55.09	17.96	18.06	250.66	4.20	2008.827	1.16	0.58	1.19	0.60	3	3	328	1379
690	21 45 29.916	-05 34 49.80	18.39	18.59	287.17	3.01	2004.707	0.91	0.49	0.96	0.49	2	2	671	2019
691	21 47 31.006	-05 40 25.78	17.83	18.17	32.70	3.19	2004.707	0.98	0.48	1.03	0.53	2	2	475	1516
692	22 53 31.306	-19 26 19.38	17.03	17.54	7.68	4.35	2004.953	0.87	0.50	0.98	0.56	2	2	369	1605
693	23 09 04.928	-10 18 29.11	18.02	18.12	359.40	3.33	2001.718	1.18	0.64	1.18	0.67	3	3	305	1014
694	23 09 46.721	-00 33 56.34	15.38	15.41	194.75	4.20	2004.775	1.22	0.67	1.23	0.67	3	3	81	339
695	23 15 42.553	-07 04 21.92	18.56	19.09	126.42	3.07	2009.788	1.20	0.61	1.26	0.70	3	4	398	1222
696	23 16 15.779	-20 31 16.31	17.82	18.35	124.82	4.03	2004.953	0.72	0.41	0.85	0.45	1	1	762	3068
697	23 18 04.543	-20 33 33.02	18.35	18.97	142.26	3.52	2004.953	0.54	0.33	0.69	0.41	0	1	1372	4825
698	23 20 52.280	-09 34 46.21	18.47	18.92	90.20	4.65	2000.737	1.17	0.64	1.23	0.69	3	3	391	1814
699	23 25 16.693	+16 20 29.71	15.96	16.57	267.23	4.06	2006.717	1.32	0.74	1.43	0.80	4	4	85	343
700	23 28 23.793	-20 17 22.41	16.85	16.93	131.23	3.19	2004.953	0.53	0.33	0.54	0.34	0	0	716	2284

Table continues on next page.

Identification and Spectral Classification of Close Red Dwarf Binary Stars

#	PRIMARY RA	PRIMARY DECL	MAGNITUDE A	MAGNITUDE B	PA	SEP	DATE	PRIMARY R-I	PRIMARY I-Z	SECONDARY R-I	SECONDARY I-Z	TYPE M+	TYPE M+	DIST. PARSEC	SEP. AU
701	23 32 41.903	-20 45 41.54	19.28	19.58	296.57	4.92	2004.953	1.52	0.75	1.62	0.79	4	5	273	1344
702	23 38 49.727	+00 33 50.02	16.78	17.01	68.11	3.10	2003.741	0.59	0.32	0.63	0.33	0	0	655	2033
703	23 39 14.251	-03 24 00.64	17.15	17.48	30.59	4.12	2008.830	0.83	0.42	0.87	0.47	1	2	470	1938
704	23 42 40.729	-06 22 24.08	16.50	16.59	209.07	3.77	2009.788	1.14	0.65	1.15	0.66	3	3	159	598
705	23 43 22.280	-01 14 08.72	18.10	18.68	315.08	3.80	2003.741	0.75	0.38	0.88	0.44	1	2	857	3255
706	23 44 04.566	+15 34 33.78	17.55	17.87	174.27	4.47	2000.740	1.21	0.64	1.28	0.67	3	4	233	1040
707	23 44 55.423	-10 46 15.55	16.84	16.98	27.23	3.28	2000.879	0.95	0.44	0.98	0.47	2	2	325	1065
708	23 45 16.291	-02 56 27.94	18.17	18.41	130.66	3.04	2008.830	1.19	0.69	1.27	0.72	3	4	292	890
709	23 45 27.744	+00 54 46.16	17.81	17.87	182.57	3.76	2003.741	0.90	0.45	0.91	0.48	2	2	541	2030
710	23 46 12.724	-19 40 26.55	17.17	17.35	296.15	3.46	2004.953	1.01	0.57	1.04	0.57	2	3	296	1026
711	23 49 37.863	+00 39 54.90	16.73	17.09	275.32	3.81	2001.881	0.60	0.28	0.67	0.33	0	0	653	2486
712	23 52 34.681	-06 53 40.90	18.72	19.01	191.98	3.47	2009.788	1.22	0.65	1.28	0.65	3	3	403	1397
713	23 54 52.710	+16 54 08.16	18.75	19.05	354.61	4.87	2008.754	0.97	0.52	1.05	0.55	2	2	686	3342

(Continued from page 43)

Acknowledgements

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory and the VizieR database of astronomical catalogs, maintained at the Centre de Données Astronomiques, Strasbourg, France.

Funding for SDSS-III has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, and the U.S. Department of Energy Office of Science.

The SDSS-III web site is http://www.sdss3.org/. SDSS-III is managed by the Astrophysical Research-Consortium.

References

Bochanski, J. J., *et al*., 2010, *AJ*, **139**, 6.

Chivers, J., 2014, JDSO, **10**, 1.

Chivers, J., 2014, JDSO, **10**, 4.

Christopher P. Ahn, et al., 2012, *ApJS,* **203,** 21.

West, A. A., et al., 2011, *AJ*, **141**, 97.

Maui High Resolution Binary Star Workshop

Large Low-Cost Automatic Telescopes and Instrumentation
for
Astrometric and Spectroscopic Observations of Close Binary Stars

Wednesday - Friday, January 21-23, 2015
University of Hawaii's Institute for Astronomy Maui

Organizer: Russ Genet, California Polytechnic State University, russmgenet@aol.com, (805) 438-3305
Host: J.D. Armstrong, University of Hawaii, IfA Maui, jd@ifa.hawaii.edu

Double star conference participants pose in front of the University of Hawaii's Institute for Astronomy, Maui (Makialani). This 2012 international conference was also organized by Russ Genet and hosted by J.D. Armstrong.

Topics for Discussion

Topics for discussion at the workshop include but are not limited to the science payoffs for observing close visual binary stars, sparse aperture 4-meter and larger telescopes, precision positioning and phasing of sub-aperture mirrors, extremely stiff space-frame structures, low-cost large telescope enclosures, automation of speckle interferometry and spectroscopy, advanced processing techniques for speckle interferometry including bispectrum analysis and multi-frame blind deconvolution, high-resolution spectrographs for high resolution radial velocities, using the same telescope for both speckle interferometry astrometry and spectroscopic radial velocities versus using separate telescopes, obtaining astrometric and spectroscopic observations of close visual binaries at the same observatories in a unified program, and planning a follow-up to the Maui workshop, the 2016 July 15-17 international conference at Concordia University Irvine.

Background

Assumption-free, model-independent, direct measures of non-interacting stellar mass can be obtained by combining the astrometric orbits and radial velocity curves of visual binaries. While over 2000 astrometric orbits of visual binaries have been established and over 2000 binary radial velocity curves have been obtained, the overlap between these two sets is not great because the astrometric orbits tend to be of longer-period, more widely separated binaries, while the radial velocity curves are primarily of shorter-period, more closely spaced binaries with larger differential radial velocities. Technological advances are increasing the possibilities for overlap between visual and spectroscopic binaries, thanks to higher spatial resolution astrometric observations of more closely spaced binaries and higher spectroscopic resolution observations of more slowly revolving binaries.

However, higher astrometric and spectroscopic resolutions both require larger-aperture, more expensive telescopes. Furthermore, significantly enlarging the number of binaries with both well-established astrometric orbits and radial velocity curves will require that a large number of observations be regularly made over a number of years. There simply is not enough observational time for these observations on sufficiently large-aperture currently available telescopes. While obtaining funding for four-meter or larger *filled*-aperture telescopes dedicated to astrometric or spectroscopic observations of binaries would be difficult, *sparse*-aperture telescopes might be affordable. It is helpful that the required field-of-view for both astrometric and spectroscopic observations is only a few arcseconds. It is also helpful that mission-dedicated telescopes can be automated and operated and maintained at a relatively low cost.

While the masses of stars in the middle of the main sequence are known with reasonable accuracy, this is not the case for evolved stars or for stars on either end of the main sequence. Few short-period binaries containing one of these stars as components are known because the brightness differences between the two components are often large, making them difficult to observe both astrometrically and spectroscopically. The differential magnitudes between parent stars and their exoplanets are much larger than for binary stars, so borrowing mask and coronagraph technology from the exoplanet community makes sense. Observing binaries with these components will require that many new binaries with appropriately short orbits be discovered, a process that should be enhanced through candidates suggested by Gaia, LSST, and other surveys.

Observing close, short-period binaries, as well as exoplanets, planetary objects, and objects in Earth orbit, all share a difficult, high resolution requirement although just over a narrow field-of-view. Another commonality shared by many, but not all of these observations, is a large differential magnitude between objects within the field -of-view. Ground-based observations share the common difficulty of observing through the Earth's atmosphere, mitigated to some extent by just observing within an isoplanatic patch.

It is not surprising that there are many commonalities between narrow field-of-view telescopes (sometimes specialized for high contrast), instrumentation (much of it high speed to circumvent atmospheric limitations), and the reduction and analysis software to recover as much information as possible from difficult targets. Three communities have been advancing the telescope, instrument, and software technologies used to make, reduce, and analyze these challenging observations. These are: (1) the close binary star astrometry community, (2) the exoplanet and solar system imaging community, and (3) the space situational awareness community.

Hawaii was chosen as the venue for this workshop due to the large number of astronomers, engineers, and others in Hawaii that are involved in advancing the technologies in these three communities. Maui, in particular, was chosen because it is home to much of the space situational awareness observational community and also the home of University of Hawaii's Institute for Astronomy, Maui, noted for its innovative and welcoming "aloha" spirit.

A good example of such across-community commonality is developments to discover and observe faint objects close to bright objects. While exoplanet observations is the most difficult case of such high differential magnitudes, extending binary star, asteroid, and Earth-orbit observations to greater differential magnitudes would be beneficial. It is not surprising that the exoplanet community has expended considerable resources to advance the design of masks and coronagraphs to facilitate such observations. The advances made by the exoplanet community are being transferred to and shared with the other communities. An example is a full-aperture mask development program for fully automated, ground-based telescopes devoted to speckle photometry of close binary stars. Ed Foley, a Master's student at California Polytechnic State University, is devoting his thesis to the development of radially-positioned masks for smaller telescopes. He is evaluating two masks: one he designed and the other designed by Neil Zimmerman at Princeton University specifically for Ed's on-telescope evaluation.

Another example is multi-frame blind deconvolution (MFBD). This family of reduction techniques iteratively extracts more information from observations than across-data-cube averaging techniques, but is computationally expensive. While only affordable initially by the space situational awareness community, rapid advances in computer technology now allow these advances to be shared with the other communities.

Telescopes also share commonalities. Some telescopes have been designed to provide very high contrast by avoiding obstructions. Another common theme has been sparse-aperture approaches to achieve high resolution at relatively low cost. An example is the exploratory consideration of a very low cost, fully automatic, ground-based, 4-meter sparse-aperture telescope that could be devoted to the speckle interferometry of close visual binary stars.

This possibility, which will be discussed at the workshop, is introduced below.

Sparse-Aperture Speckle Interferometry Telescope

Obtaining the position angles and separations of close visual binaries over time, when combined with distances from Hipparcos (and also soon from Gaia), can lead to orbital solutions and the determination of dynamical masses. Binaries with smaller apparent separations not too distant from Earth have relatively short periods. This allows obits to be determined with high precision after observing just one or two orbits.

However, such short period binaries often have separations much smaller than the seeing disk. Thus they require special observational techniques such as speckle interferometry which overcomes normal seeing limitations by taking many very short exposures at high magnification and analyzing the resulting speckles in Fourier space to obtain position angles and separations. Binaries with a separation of 0.2 arc seconds (200 mas) can be observed on a 1-meter telescope, while speckle observations of binaries with separations of 50-mas can be obtained on telescopes with apertures of 4-meters. Even larger apertures and smaller separations would be very valuable scientifically.

Various 4-meter class telescopes have been used to build up observational records of many short-period binaries over the past several decades. Observing time on 4-meter class telescopes is increasingly difficult to obtain, however, as they are now being utilized in various specialized programs with permanently mounted instruments. Thus we may no longer be able to continue building our observational record for known binaries, let alone follow up on the many new short-period binaries that will be discovered by Gaia and other surveys.

An economical, dedicated, 4-meter class telescope would benefit the astrometric observations of close binaries—especially if it could be automated. While the cost of a conventional “filled aperture” 4-meter telescope would be prohibitive, an automated “sparse aperture” 4-meter telescope that was dedicated to discovering new close binaries as well as continuing the observation of known close binaries might be economically feasible.

Several in-person discussions have been held to explore possibilities, including discussions at the Portland VIII Alt-Az Initiative Workshop, at CHARA on Mt. Wilson, at the Large Binocular Telescope Organization in Tucson, and at Lowell Observatory and the Navy Precision Optical Interferometer in Flagstaff. These initial discussions considered several 4-meter class telescope possibilities including a multiple short-baseline Michelson interferometer mounted on a single equatorial tracking platform, a Fizeau interferometer similar to the Large Binocular Telescope (but much smaller), and a sparse-aperture speckle interferometry telescope. The sparse-aperture speckle interferometer has been chosen for further consideration due to its likely low cost, ability to operate in a “snapshot” mode, and its familiarity and relative simplicity of operation.

An interesting example of a sparse aperture system is one of the 8-meter VLT telescopes at Paranal (Unit 4) which employs a non-redundant mask with seven holes that reduces the telescope’s light gathering area from 49 square meters down to less than 8 square meters, eliminating 85% of the light. The mask improves the achievable resolution of the telescope as well as its dynamic range, albeit with a reduced faintness limit. (See *Sparse Aperture Masking at Paranal,* Sylbestre Lacor et al, https://www.eso.org/sci/publications/messenger/archive/no.146-dec11/messenger-no146-18-23.pdf).

Sparse aperture systems are similar to conventional telescopes except that major portions of the primary mirror have been removed. While the cost of several small mirrors is much less than the cost of one large mirror (and the telescope structure is also much lower in cost), the individual mirrors need to be accurately positioned and need to have closely matched focal lengths.

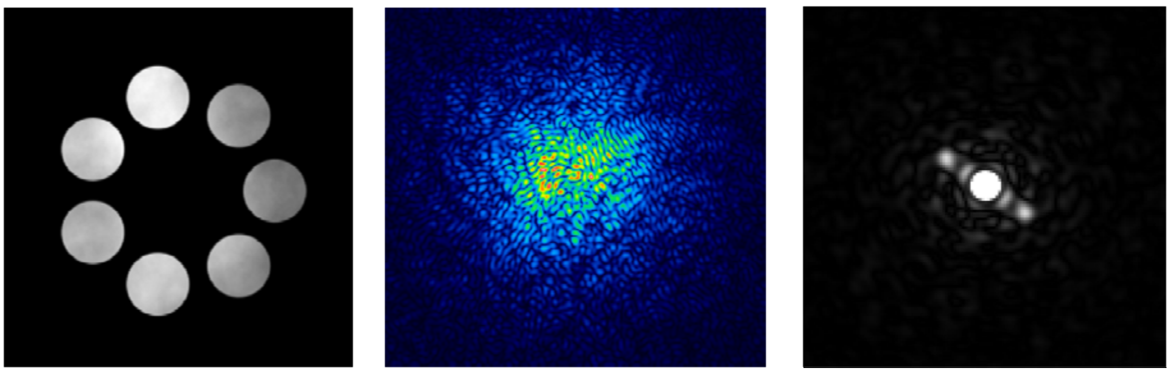
Economies might be achieved by taking advantage of the image simplicity of visual binaries (essentially just two well-spaced apart points of light). Full automation, if it could be achieved, could significantly reduce operational costs.

At this point in time, consideration is being given, in a broad-brush, preliminary manner, to the conceptual design and operation of a dedicated, automated 4-meter sparse aperture telescope for observing close binary stars and similar objects. The feasibility of scaling up such a telescope well beyond 4 meters may also be considered.

This telescope, as currently envisioned, would feature somewhere between 5 and 15 low-cost spherical mirrors, each between 12 and 24 inches in diameter. The mirrors might be arranged in a non-redundant pattern with a set of unique baseline lengths and angles. Another arrangement might purposely employ a symmetrical pattern to more easily filter out undesirable artifacts in Fourier space. Each mirror would be controlled in tip, tilt, and piston by three precision positioners, and would be mounted on a rigid space frame incorporated into an alt-az mount.

Maui High Resolution Binary Star Workshop

One of the simulations that has been made with Dave Rowe's Atmospheric Distortion Simulator (ASD) evaluated a sparse aperture mirror with outside diameter of 2 meters containing 7 sub-aperture mirrors each 50 cm in diameter symmetrically located in a ring at the perimeter. This might be similar to an initial small-scale prototype. This composite aperture is shown (left). A double star with 0.2" separation and 3.0 magnitudes brightness difference was simulated. A typical instantaneous image is shown (center). The third figure (right) shows the speckle reduction results for a FITS cube of 500 images. A reference (single) star was used for deconvolution. The Fried cell diameter was 10 cm and the simulations were noise-free and aberration-free. We ran a couple of simulations at 4-meter aperture and they also looked promising.



The difference between small off-axis parabolic and spherical mirrors for this application has been considered. This difference does not appear to be significant for the very small field of view under consideration. An optical manufacture, Hubble Optics, has evaluated manufacturing a set of spherical mirrors with sufficiently closely matched focal lengths. The cost appears to be modest. A spherical secondary might be employed and the primary mirrors placed in a sparse-aperture, Dall-Kirkham optical arrangement.

The cost of the positioners also appears to be modest. The cost of the telescope's stiff space frame has not been estimated yet, although it is not expected to be too high. A very rough cost estimate suggests that the telescope itself, not counting instrumentation and enclosure, might be built (with significant student contributions) for a few $100K.

Journal of Double Star Observations

January 1, 2015
Volume 11, Number 5

The Journal of Double Star Observations is an electronic journal published quarterly. Copies can be freely downloaded from http://www.jdso.org.

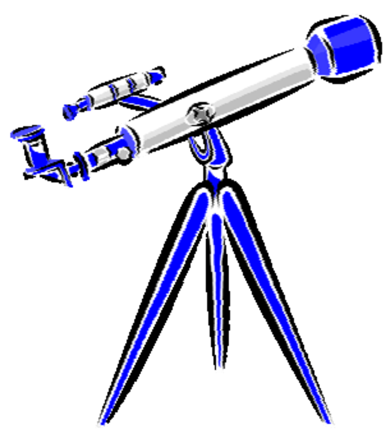
Questions, comments, or submissions may be directed to rclark@southalabama.edu or to rmollise@bellsouth.net

The *Journal of Double Star Observations* (*JDSO*) publishes articles on any and all aspects of astronomy involving double and binary stars. The *JDSO* is especially interested in observations made by amateur astronomers. Submitted articles announcing measurements, discoveries, or conclusions about double or binary stars may undergo a peer review. This means that a paper submitted by an amateur astronomer will be reviewed by other amateur astronomers doing similar work.

Not all articles will undergo a peer review. Articles that are of more general interest but that have little new scientific content such as articles generally describing double stars, observing sessions, star parties, etc. will not be refereed.

Submitted manuscripts must be original, unpublished material and written in English. They should contain an abstract and a short description or biography (2 or 3 sentences) of the author(s). For more information about format of submitted articles, please see our web site at http://www.jdso.org

Submissions should be made electronically via e-mail to rclark@southalabama.edu or to rmolise@bellsouth.net. Articles should be attached to the email in Microsoft Word, Word Perfect, Open Office, or text format. All images should be in jpg or fits format.



We're on the web!

http://www.jdso.org