

Journal of Double Star Observations

VOLUME 1 NUMBER 2

SUMMER 2005

Brian Mason Joins the *Journal of Double Star Observations*

In this second issue of the JDSO, we are excited to announce that Dr. Brian Mason, Director of the Double Star Program at the United States Naval Observatory, has joined us in the capacity of Advisory Editor.

Most of you will already be familiar with Dr. Mason, or at least know of him. If not, you will be if you continue observing double stars for long. In his position at the USNO, he is the main caretaker of the Washington Double Star Catalog, the primary database of double star data. Brian has been very helpful in encouraging and aiding amateur astronomer's observations of double stars. Of course he has an ulterior motive, because double star measurements made by



Brian Mason with the USNO speckle camera on the 26" telescope in Washington, D.C.

amateurs and published in some journal (including this one) will be incorporated into the WDS.

Brian is a frequent contributor to the binary stars newsgroup (<http://groups.yahoo.com/group/binary-stars-uncensored>), answering questions, offering tips, and issuing challenges ("can you measure ρ and ϕ of the *other* companions of Polaris?"). You can request past measurements of double stars you are studying through the USNO web site at

<http://ad.usno.navy.mil/proj/WDS>. Also, check out his article in this issue. He regularly observes double stars himself, employing speckle interferometry and the 26" Clark refractor at the USNO in Washington, D.C.

We look forward to working with Dr. Brian Mason.

Inside this issue:

Double Stars Studied by LIADA in 2002 Francisco M. Rico Romero	24
New Common Proper Motion Pairs Ross Stuart	33
New Common Proper Motion Pairs Containing White Dwarfs from SDSS Data John Greaves	41
Investigation into the Motions of "Neglected" Double Star WDS 01477+6351 R. Kent Clark, Jarrod Cunningham, Jessica Guidry, Jonathan Pearce, J.M. Sanders, Tiffany Scarborough	44
LDS 968 AB-C: The Distant Companion of HU575 Edgardo Ruben Masa Martin	49
On Line Double Star Resources at the U.S. Naval Observatory Brian D. Mason	57

Double Stars Studied by LIADA in 2002

Francisco M. Rica Romero

Coordinator of LIADA Double Star Group
Astronomical Society of Mérida, Spain
frica0@terra.es

Abstract: In this article we report the observational results of LIADA's Double Star Section in 2002. BVIJHK photometric, astrometric and kinematic data were studied for 67 visual double stars to obtain astrophysical data (spectral types, photometric distances, etc) and their nature, classifying them as optical, physical or common origin pairs.

Introduction

LIADA's Double Star Section reports 367 individual relative measurements averaged into 135 mean positions for 67 visual double stars. The angular separation ranges from 4.6" to 114.5". The mean internal errors were 0.2" and 0.09". CCD cameras, micrometric eyepieces, DSS (Digitalized Sky Survey) and 2MASS (Two Micron All Sky Survey) images were used. These measurements, in addition to BVIJHK optical-to-infrared photometric data (from Tycho-2 and 2MASS), and historical relative astrometry (from WDS), allowed us to obtain spectral types, photometric parallaxes, relative motion and other astrophysical data to classify visual double stars as physical (11%), common origin (6%), or optical (74%). We used several professional criteria to make the classification.

Spectral types were estimated using professional spectral-type relations and several professional reduced proper motion diagrams. Preliminary study results in a mean difference of only 0.5 subclasses of spectral type with respect to professional results.

In Romero (2005) we reported a new binary discovered by LIADA (GSC 1753-1506: [294.4° and 4.62" (1997.831); magnitude 12.0 (G9V) and 13.5 (K5V)]) with a crude period of 35,000 years.

Of the 67 double stars measured, 47 of them have been confirmed. A double star is confirmed when an observer made the second historical measure. Some have remained unconfirmed for quite a while, including many discoveries of John Herschel from 1820 and 1830. Five unconfirmed double stars could not be identified. Table I lists those double stars not identified using photographic surveys and astronomical

catalogs using Guice 8.0 and Aladin from CDS.

Relative Astrometry

The relative astrometry measurements were made using CCD cameras, micrometric eyepieces, Digitized Sky Survey plates (DSS) and Two Micron All Sky Survey CCD images (2MASS). Guide 6.0/7.0, Astrometrica for Windows and FitsView software were used for documentation and astrometry.

Observational data are shown in Table 2. In the first and second columns, the WDS identifier and discoverer code with their sequential numbers are listed; in the following columns, from left to right, the V magnitude of primary and secondary is listed (if the magnitude listed has two decimal numbers these came from Tycho-2 or else they came from calibrated GSC-I photometry); the spectral type and luminosity class in column (5) and (6); the epoch of the last relative astrometry made by LIADA in column (7); the position angle and the angular separation for the epoch of the measure in columns (8) and (9); the number of measurements in column (10); the observer code as follow: FMR = Francisco Rica -- Astronomical Society of Mérida --, ARU, --, Alejandro Russo, amateur from Argentina--, JRY, John Ryan -- "Spirit of 33"; amateur from Spain-- and BVD -- Rafael Benavides -- Astronomical Society of Córdoba (Spain) in column (11); the observation methods are listed in the next column (CCD: CCD camera; MCG: MicroGuide eyepiece; 2MASS: 2MASS project images; DSS: Digitized Sky Survey; AC2000: Astrographics Catalogue 2000).

In column (12) the nature of the double star code is as follow: PHY = Physical; OPT = Optical; CO = Common Origin; "¿?" = unknown; "--" = nature not studied. A "?" character means that the nature listed is not con-

Double Stars Studied by LIADA in 2002

(1) WDS No.	(2) Designation	(3) Mag. A	(4) Mag. B	(5) Epoch	(6) ρ	(7) θ
03064+3153	HJ 5456	9.0	11.0	1823	14.0	300
05301+5327	HJ 2263	11.0	11.0	1830	4.0	311
05514+3535	HJ 710	10.0	10.0	1820	10.0	335
03503-0011	HJ 667 AC	10.5	18.0	1820	15.0	300
04429-0629	HJ 26	9.0	11.0	1820	10.0	305

Table 1: Non-Identified, Unconfirmed Double Stars

firmed. In the last column the confirmed double stars show a "C" letter; a number indicates the years since the last measure. "#" character followed by a number refers to a note number.

Spectral Types and luminosity classes estimates.

In column (5) and (6) of Table II are listed, for both components, the spectral types and luminosity classes estimated by the LIADA group. When the luminosity class is unknown, then the spectral type matches with the main sequence dwarf is listed.

To estimate the spectral type and luminosity class for a star the following data is used:

- Photometric data: B, V and I optical photometry from Hipparcos and Tycho-2 catalogs and J, H and K infrared photometry from Two Micron All Sky Survey (2MASS).
- Kinematical data: Proper motions of the components with their errors are taken from Tycho-2, UCAC2 or USNO-B1.0 catalogs.

Photometric data were transformed to the spectral type and, when the stars are very red, to the luminosity class using J-H vs H-K two-color diagrams and several tables that relate photometric data with spectral data used by professionals (*M.S.Bessell & J. M. Brett (1988)* and *Gerald E. Kron (1988)* Several useful tables are from *Handbook of Space Astronomy and Astrophysics of the Harvard University*). The process transforms the magnitudes of the problem-star in energy in Jy ($1 \text{ Jy} = 10^{-23} \text{ erg} \cdot \text{sec}^{-1} \cdot \text{cm}^2 \cdot \text{Hz}^{-1}$) and compares the spectral distribution of a component with those of the empirical tables.

When the star is not red enough to obtain the luminosity class using only photometry data, then we must use Reduced Proper Motion Diagrams (Eric M. Jones, 1972; C. A. Nelson, 2003; Salim Salir, 2002). These diagrams relate the observational photometric data and proper motions with a parameter that is

characteristic of a population star (dwarfs, giants, subdwarfs, white dwarfs...).

Of the double stars studied by the LIADA group there are 19 components (13 dwarfs and 6 normal giants) with spectral types and luminosity classes obtained by professionals and published in the astronomical literature. These components are listed in Hipparcos/Tycho-2 and 2MASS catalogs so the BVJHK photometry and proper motions are also known. We have compared our spectral data with those obtained by professionals using spectroscopy. The mean difference was 0.5 spectral subclasses, and the luminosity class was estimated correctly in the 19 components.

Figure 1 shows the results of the comparison between the spectral types published in the professional astronomical literature with those estimated photometrically and kinematically by the LIADA group.

(Continued on page 29)

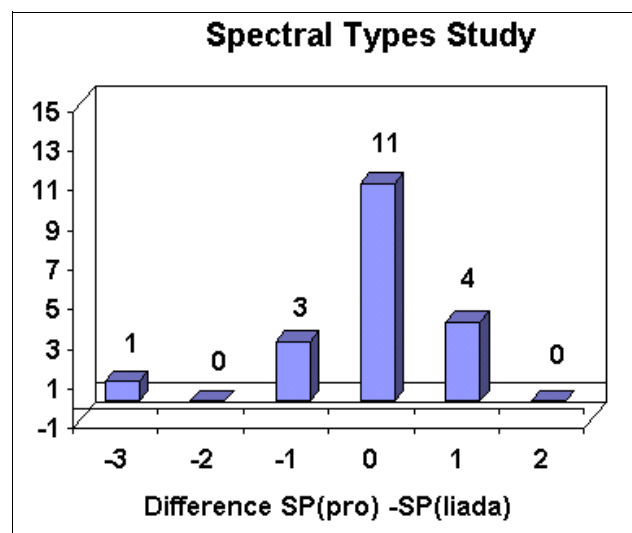


Figure 1: Comparison between the spectral types published in the professional astronomical literature [SP(pro)] with those estimated photometrically and kinematically by LIADA group [SP(liada)].

Double Stars Studied by LIADA in 2002

(1) WDS Id.	(2) Discoverer	(3) V_a	(4) V_b	(5) Sp(A)	(6) Sp(B)	(7) Epoch	(8) θ (°)	(9) ρ (")	(10) N	(11) Observer	(11) Method	(12) Type	(13) Notes
00003+1642	HJ 318	9.44	12.8			1999.830	61.6	26.62	3	FMR	2MASS	OPT	
00046-7745	LDS 832	12.2	12.2	K6V	K6V	1998.601	184.1	9.31	3	FMR	2MASS	OC/FIS	C, 240?
00037+1252	HJ 3235	10.3	11.30	K2III	K0V	2002.852	87.5	22.33	5	BVD	MCG	OPT	C, 173
00194+3108	HJ 620	10.36	12.5	F4V	G5V	1997.910	190.2	14.05	3	FMR	2MASS	?	C, 183, #20
00196-2057	HJ 1954	9.82	12.5	M0III	K4V	1996.682	115.0	31.23	1	BVD	DSS	OPT	C, 172
00224-1432	HJ 1958	11.8	12.8	F6V	G6III	1998.604	67.6	14.18	3	FMR	2MASS	OPT	C, 172
00254+4419	HJ 1963	8.70	12.7	A1V:	K0III:	1998.842	51.2	27.02	3	FMR	2MASS	OPT?	C, 173, #21
00290-1817	HJ 1974	11.5	13.5	G5V	G5V:	2000.740	159.0	23.74	3	FMR	2MASS	?	C, 173
00357-0604	HJ 1039	9.64	14.1	F7V	F9V	1998.822	268.3	53.69	3	FMR	2MASS	OPT	C, 175, #22
01072-6834	HDS 147	9.27	10.40	K3III	G/KIII	1998.803	323.7	26.50	3	FMR	2MASS	OPT	C, 11, #1
01116+2823	FMR 5	12.0	13.5	G9V	K5V	1997.831	294.4	4.62	2	FMR	2MASS	FIS/OC	New, #3
01126+2825	HJ 635	10.85	11.29	G5V	G7V	1997.831	127.3	15.00	3	FMR	2MASS	FIS?	C, 182, #2
01518-0750	HJ 2092	11.3	11.7	F6V	F5V:	1998.809	77.1	13.35	3	FMR	2MASS	OPT?	C, 172
01241+4522	HJ 2041	12.7	12.7	G5	G7	1998.899	335.7	4.99	3	FMR	2MASS	?	C, 172, #23
01572+2618	HJ 3243	10.43	10.77	M3III	G5V	1997.842	68.1	29.27	2	FMR	2MASS	OPT	C, 172
03404+3022	HJ 335	11.9	12.1	K2III	G7V	2002.184	251.6	15.34	3	JRY	CCD	OPT	C, 172
03465-1631	HD0 63	11.4	12.0	F6V	G1V	1998.672	294.1	22.65	3	FMR	2MASS	OPT	#4
03475+2406	STFA 8 CD	8.20	8.68	A7V	F6V	2002.184	224.5	54.50	4	JRY	CCD	FIS	#5
04009-1027	STF 487 AB	9.44	9.91	F1V	G7IV:	1998.855	9.8	12.11	3	FMR	2MASS	FIS?	
04009-1027	STF 487 AC	9.44	10.47	F1V	F5V	1998.855	229.8	20.20	3	FMR	2MASS	OPT	
04009-1027	STF 487 BC	9.91	10.47	G4V:	F5V	1998.855	215.1	30.39	3	FMR	2MASS	OPT	C, 159
04166-7030	STF 496 AB	11.13	10.83	M5III	F5V	1994.025	56.6	30.86	1	BVD	DSS	OPT	
04166-7030	STF 496 AC	11.13	11.92	M5III	K0	2002.117	23.0	38.72	3	BVD	MCG	OPT?	C, 172
04166-7030	STF 496 BC	10.83	11.91	F5V	K0	1994.025	329.2	21.40	1	BVD	DSS	OPT?	
04312-0726	HJ 24	10.50	14.0	M1III	F5V	1998.790	57.2	26.78	3	FMR	2MASS	OC?	C, 182, #6

Table 2: Relative astrometry, photometry, spectral data, and nature of measured double stars.

(Continued on page 27)

Double Stars Studied by LIADA in 2002

(1) WDS Id.	(2) Discoverer	(3) V_a	(4) V_b	(5) Sp(A)	(6) Sp(B)	(7) Epoch	(8) θ (")	(9) ρ (")	(10) N	(11) Observer	(11) Method	(12) Type	(13) Notes
05032+2921	HJ 354	11.1	12.1	M IIII	F9V	1996.050	296.6	11.45	2	BVD	DSS	OPT?	C, 182
05175+3312	CTT 4 AB	7.73	12.1	A2V		2002.184	105.0	108.84	4	JRY	CCD	OPT	C, 5
05175+3312	CTT 4 AC	7.73	11.0	A2V	MIIII	1998.088	282.7	111.99	2	FMR	2MASS	OPT	#9
05175+3312	CTT 4 AD	7.73	11.2	A2V	K2IIII	2002.184	270.7	94.34	4	JRY	CCD	OPT	C, 5, #9
05175+3312	CTT 4 AE	7.73	12.2	A2V	K4V:	2002.184	269.1	114.30	4	JRY	CCD	OPT	C, 5
05413+5329	ENG 22 AB	6.20	9.69	K0V	M1V	2002.184	71.3	98.15	4	JRY	CCD	FIS	
05445-2227	H 5 50 BC	6.16	11.33	K2V	F6V	1999.011	8.1	112.53	3	FMR	2MASS	OPT	170, #7
11045-6332	HDS1581 AB	9.95	11.67	G4IIII	F4V	1994.268	3.0	8.72	1	BVD&ARU	DSS	?	#10
11045-6332	FAB 10 AC	9.95	11.51	G4IIII		1994.268	350.4	19.57	2	BVD&ARU	DSS	OPT	#10
11075+2203	HDS1586	8.22	11.27	G1V	K1V	2002.373	211.8	14.35	4	JRY	CCD	OPT	C, 11, #11
11091+1105	HJ 176	10.85	12.9	G5V	G9V	2002.336	33.6	18.71	5	BVD	MCG	OPT?	#12
11258+2704	HJ 497	9.49	12.7	K0IIII:	G5V	2002.373	53.8	34.77	3	JRY	CCD	OPT	C, 182, #13
11330-7055	HDS1638	9.32	12.34	F5.5V	K0V	2001.118	189.9	8.57	3	FMR	2MASS	FIS?	C, 11
11368+2923	HJ 2579 AB	11.59	12.3			2002.373	351.4	14.33	4	JRY	CCD	OC	99, #14
11404+3003	HJ 507	9.44	14.0	G1V	M1.5V	2002.381	29.2	34.18	4	JRY	CCD	FIS/OC	C, 182
12003+1136	HJ 197	12.9	13.0	F9V	G6V	1996.304	273.7	15.14	1	BVD	DSS	OPT?	C, 182, #15
12089-0317	HJ 1211	10.61	13.4	F5:	K3	1999.077	150.4	11.46	3	FMR	2MASS	OPT	C, 174
12190-0138	HJ 206	13.2	11.8	K2	G0	2002.373	298.2	18.35	2	FMR	CCD	OPT	C, 182, #8
12266-1336	HJ 2611	12.4	12.4	G0	F6	1984.179	219.4	13.27	1	ARU	DSS	OPT?	C, 173
13254+5649	HJ 2652	11.5	12.5	G5V	K0V	2002.523	251.8	20.55	5	BVD	MCG	OPT	C, 172, #16
13313+2857	HJ 531	9.19	13.5	K2IIII	K0V	2002.507	41.5	35.98	2	BVD	MCG	OPT	C, 182, #17
13345+2503	HJ 2660	10.61	13.4	K0IIII	G5V	2002.373	143.1	28.26	4	JRY	CCD	OPT	C, 172
13419-1418	HJ 2669	11.2	12.5	K2IIII	F9V	1998.217	79.8	27.43	3	FMR	2MASS	OPT	C, 173
13469+3307	HJ 2681	12.8	13.1	F8V	F6	1998.185	262.6	13.80	3	FMR	2MASS	OPT?	C, 173
13492+0630	HJ 2686	9.29	13.7	F6V	F6V	2002.373	114.7	22.82	4	JRY	CCD	OPT	C, 172, #18
14123+3646	HJ 542	12.8	13.8	G1V	G0	2002.594	246.5	12.52	4	JRY	CCD	OC?	C, 183

Table 2 (cont.): Relative astrometry, photometry, spectral data and nature of measured double stars.

(Continued on page 28)

Double Stars Studied by LIADA in 2002

(1) WDS Id.	(2) Discoverer	(3) V_A	(4) V_B	(5) Sp(A)	(6) Sp(B)	(7) Epoch	(8) θ (°)	(9) ρ (")	(10) N	(11) Observer	(11) Method	(12) Type	(13) Notes
14189+3220	HJ 2709	11, 42	14, 6	F8V	G8V	1998, 340	84, 6	27, 46	3	FMR	2MASS	OPT	C, 173
14226+1159	HJ 236	12, 6	12, 8	F9V	G5V	2002, 597	285, 4	23, 01	4	JRY	CCD	OPT?	
14226+1159	FMR 2 BC	12, 8	18, 2	G5V	M1V:	2000, 256	105, 9	8, 32	2	FMR	2MASS	OPT?	
14296+1040	HJ 237	11, 6	13, 8	K1III	F9V:	2002, 597	47, 4	20, 76	3	JRY	CCD	OPT?	C, 183
16540-4148	JC 23 AF	5, 42	6, 54	B0.5Ia	O6III	1995, 422	20, 1	56, 72	1	ARU	DSS	OPT	#19
18004+4611	J 756	11, 8	12, 3	G4V		2002, 589	181, 7	3, 37	3	BVD	MCG	?	
18020+3153	SEI 555	11, 5	12, 5	F8V:	G3	2002, 597	109, 5	19, 37	4	JRY	CCD	OPT	C, 104
18093+5945	STF2300 AB	9, 22	11, 08	A8	F2	2002, 597	43, 4	13, 80	4	JRY	CCD	--	
18093+5945	STF2300 AD	9, 22	12, 64	A8	K0	2002, 597	88, 9	24, 70	4	JRY	CCD	OPT	
18093+5945	STF2300 BC	11, 08	12, 2	F2		2000, 275	186, 4	3, 49	2	FMR	2MASS	OPT?	
18213+3920	HJ 1321	10, 10	12, 0	K0III	K1III	2000, 259	77, 2	9, 66	3	FMR	2MASS	OPT	
22388+3000	MLB 725	11, 7	12, 8	G7V	G7	2002, 695	13, 2	8, 25	4	JRY	CCD	OPT?	C, 72
23033+0653	HJ 3161	10, 67	13, 1	G9III:	G6V:	2000, 685	251, 7	12, 08	3	FMR	2MASS	?	C, 173, #24
23224-1259	HJ 310	9, 79	10, 62	K0III	G3	1999, 513	337, 3	10, 41	3	FMR	2MASS	OPT	#25
23246+0617	HJ 3190	11, 6	13, 0	K3V	G2	2000, 494	3, 8	21, 75	3	FMR	2MASS	OPT	
23324+1229	HJ 312	12, 7	13, 5			1997, 743	90, 0	18, 37	3	FMR	2MASS	--	C, 183

Table 2 (cont.): Relative astrometry, photometry, spectral data, and nature of measured double stars.

Double Stars Studied by LIADA in 2002

Notes to Table 2:

- (# 1) **HDS 147**: In CCDM it is catalogued as RSU measured in 1973 (324° and 26°9)
- (# 2) **HJ 635**: Suspected to be physical according to our analysis of astrometry and BVJHK photometry; it is located 13' West of the WDS coordinate.
- (# 3) **FMR 5**: This object is composed of two stars separated by 4.62" and they are suspected to be physical according to photometric parallaxes using BVJHK bands.
- (# 4) **HDO 63**: PGC 13821 galaxy, of 14 magnitude, is 3' at SE. "HDO" double stars were discovered by Harvard Observatory. According to a lineal fit using Hipparcos, USNO-A2.0 and LIADA data the discover's measure of 1863 is in great error of about 3".
- (# 5) **STFA 8 CD**: In the Pleiades open cluster. C is the d scuti V647 Tau (8,25-8,30 mg., P=0,05 days)
- (# 6) Spectral types corrected by interstellar absorption.
- (# 7) **H5 50 B** is at 9.0 pc (Hipparcos) with a radial velocity of - 8 km/s ("3er. Bibliog. Cat. Of Stellar Radial Vel.", Barbier-Brossat, 1994). It has a spectral type of K2V according to Michigan Catalogue of HD stars (Houk, 1989) and "Spectra of Sourthen late-type dwarfs" (Cincunegui, 2004) which is in excellent agreement with LIADA result. LIADA searched for unknown companion but no candidate was found.
- (# 8) **HJ 206**: The star that John Herschel observed as the main component really is 1.2 magnitudes weaker than the secondary.
- (# 9) **CTT 4**: Components C and D seem to be a suspected common origin pair.
- (#10) Spectral type is corrected by interstellar extinction.
- (#11) **HDS 1586**: A search for unknown companions was carried out. No candidate was found; we studied the professional astronomical literature: Jaschel (1978), Duflot (2004). Tycho-2 proper motion for secondary are in great error.
- (#12) **HJ 176**: A weak star of 16^m magnitude was observed by Rafael Benavides at 10"3 of separation in direction 52°. According to JHK photometry it is a G/K star that surely is not bounded to the A or B components.
- (#13) **HJ 497 A** is a K0 star (PPM catalog).
- (#14) **HJ 2579**: Primary is a G5p star according to Skiff (2003) in "Catalogue of Stellar Spectral Classifications"; located at 2' West to WDS position.
- (#15) **HJ 197**: This pair is located 9' East of WDS position.
- (#16) **HJ 2652**: Both components have the same distance moduli but different proper motions.
- (#17) **HJ 531 A**: spectral type K3III (Jaschek, 1978 and Kennedy, 1983); Mv = + 0,1 (Corbally and Garrinson, 1984); Av=0.29, distance = 571 pc; (B-V)o=+1,16 (J. Guarinos, 1992).
- (#18) **HJ 2686 A**: It is HD 120406 a F0 star according to Henry Draper Catalog; Hipparcos parallax p = 0"005±0"001 and Mv = +2,8±0,6. BVJHK correspond with a F6V star.
- (#19) **JC 23 AF**: In NGC 6231: A = NSV20804; B = NSV8021.
- (#20) **HJ 620**: Components have very similar photometric parallaxes and different proper motions.
- (#21) **HJ 1963**: Primary is HD 2091 an A2 star (Henry Draper Catalog) located at 385 pc (Hipparcos). Photometric distance calculated by LIADA is 350 pc.
- (#22) **HJ 1039**: Primary is a F7V star (Michigan Catalogue).
- (#23) **HJ 2041**: If both components are dwarfs then the photometric parallaxes are very similar. Is this pair a binary star?
- (#24) **HJ 3161**: Primary is a K0 star (PPM and Simbad)
- (#25) **HJ 310**: Discovered in 1820 and confirmed in 1831 by John Herschel. Primary is HD220259 with spectral type of G8/K2 III ("Michigan Catalogue"); a spectral type of K0(III) is listed in "13th General Catalogue of MK Spectral Classification" (Buscombe, 1988). UBv for both components was obtained by D. Sinachopoulos and E. L. Van Dessel (1996) concluding that they are not physically bound.

(Continued from page 25)

The difference is expressed in spectral subclass. In 95% of the stars studied (18 of 19 stars) the difference is less or equal to 1 spectral subclass. In Table II there are many spectral types that were estimated using only JHK photometry due to the star component not being listed in Tycho-2, so their results are of lower accuracy than those obtained using BVJHK photometry. Table III shows the stars used to test the accuracy of the spectral type estimate procedure.

Studying the Nature of Visual Double Stars

To study the nature of visual double stars and classify them as optical, physical, common proper motion or common origin pairs, BVJHK photometric

and astrometric (proper motions and relative astrometry) data were used. The historical relative astrometry (θ corrected by precession and proper motions) in addition to our own measures are plotted in a X ($=\rho \cdot \sin(\theta)$) against Epoch and Y ($=\rho \cdot \cos(\theta)$) against Epoch diagrams. A linear fit shows the relative proper motion of B with respect to A. This data is very important because nearly all methods that allow us to know their nature use it. If a double star is physical then this data will give us the projected relative orbital motion and velocity.

The photometric and astrometric data are analyzed using several professional methods that allow us to classify visual double stars according to their nature. We use methods that study if an orbital motion could be possible with the observational astrometric

Double Stars Studied by LIADA in 2002

Name#1	Name#2	Mg _v	Sp_Lit	Ref.	Sp_LIADA	Differ.
	ARA1597 A	10.27	F8/G0V	1	G0V	-1
	WHC 29 A	7.22	G8/K0III	1	G8III	1
	HDS1595 A	8.87	K2III	1	K2III	0
	HJ 88 A	7.84	K0III	1	K0III	0
	HJ 3037 A	8.75	K1III	1	K1III	0
	HJ 3100 A	9.22	F5/6V	1	F8V	-2.5
	HJ 5025 A	9.34	F5/6V	1, 2	F6V:	-0.5
	HLD 32 A	8.37	F7V	1	F8V	-1
	LDS 201 A	8.73	G3V	1-3	G4V	-1
HD 11352		8.62	G5V	1	G4V	1
	STF 222 A	6.06	B9V	4	B9V:	0
	STF 222 B	6.70	A1Vn	4	A1V:	0
HD 9656	STF 136 A	7.31	A6V	6	A6V	0
HD 37394	ENG 22 A	6.20	K1V	2, 4	K0V	1
HD233153	ENG 22 B	9.69	M1V	4	M1V	0
HD 38392	H5 50 B	6.16	K2V	1, 5	K2V	0
	HJ 531 A	9.19	K3III	4	K2III	1
	HJ 1039 A	9.64	F7V	1	F7V	0
HD220259	HJ 310 A	9.79	K0III	3	K0III	0

Table 3: Comparison between LIADA's and Professional Spectral Types. Ref: 1: Michigan Catalog, 2: Henry Draper Catalog, 3: 13th General Catalog of ML Spectral Type, 4: Selected MK Spectral Types (Jaschek, 1978), 5: Spectra of southern late-type dwarfs (Cincunegui, 2004), 6: Washington Double Star Catalog (WDS).

and photometric data; methods that are based in an empirical study and methods based in a probability theory. Table II shows in column (12) the conclusion of this study. Of the 67 visual double stars measured in 2002, LIADA studied the nature of 65 of them. 74 % (48 visual double stars) were optical or optical suspected while only 11% (7 doubles) were physical or physical suspected. See Figure 2. Of the double stars studied there were pairs with photometric and astrometric data consistent with pairs located at the same distance with the same kinematic but not gravitationally bounded: they are called '*common origin*' and were 6% of all double stars studied.

About 9% of visual double stars have an undetermined nature due to insufficient or no accurate data; thus more astrometric and photometric data are needed. The very low percentage of physical pairs is not surprising. There has been little astrophysical interest in the neglected and unconfirmed visual double stars because a majority of them are optical pairs.

Physical Pairs Orbital Data

Table IV shows some orbital data for the physical pairs studied in this circular. Projected Separation (in A.U.), the expected semi-major axis (in arc second

and A.U.), the orbital period and the relative motion is showed in Table IV.

The projected separation in U.A. is calculated using the followed simple formula:

$$\text{Projected_separation} = \rho / \pi$$

where ρ is the angular separation and π is the mean parallax of the binary. LIADA considered the mean angular separation and the mean photometric parallaxes of the components. The photometric parallaxes were calculated using spectral types and luminosity class estimates and the absolute magnitude obtained from several professional references.

The expected semi-major axis, $E(a)$, in arcsecond, was calculated using the work of Paul Couteau (1960) by the followed formulae:

$$\text{Log } E(a) - \text{Log } (\rho) = 0.146$$

Where a and ρ are the semi-major axis and the angular separation, respectively. The orbital period was calculated using the following formula derived from the Kepler Laws:

Double Stars Studied by LIADA in 2002

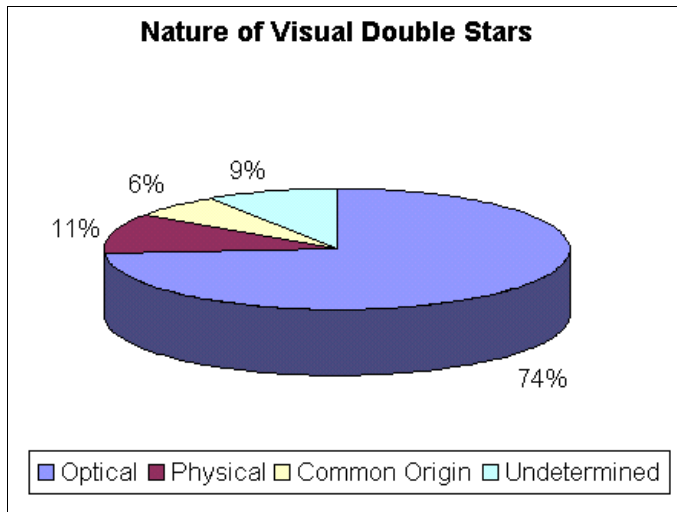


Figure 2: Study of the visual double star's nature. Most of the neglected and unconfirmed visual double stars are optical pairs with no astrophysical interest.

$$P = \sqrt{\frac{E(a)^3}{\sum M_{\square}}}$$

Proper motions

The proper motion data of the components is important because they inform us about the kinematics of the system's components and if they travel together in space. A physical pair or a common origin pair travels together in space, and so their proper motions are very similar, nearly the same. In physical pairs the difference in proper motions, that is, the relative proper motion, give the projected relative orbital motion of the binary. This is an important data for the study of the nature of double stars.

LIADA's Double Star Section has compiled

proper motions from the astronomical literature. Tycho-2, UCAC2 and USNO-B1.0 catalog are the main reference. The proper motion data for the components of several double stars are not listed in the WDS, so our group has reported them to Brian Mason, who has included them in WDS catalog.

Acknowledgements

This publication has made use of the Washington Double Star Catalog, UCAC2 and USNO-B1.0 maintained at the U.S. Naval Observatory.

This publication makes use of data products from the Two Micron All Sky Survey (2MASS), which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

The Digitized Sky Survey was produced at the Space Telescope Science Institute under a U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.

The Guide Star Catalog-I was produced at the Space Telescope Science Institute under U.S. Government grant. These data are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope.

The Guide Star Catalogue-II is a joint project of the Space Telescope Science Institute and the Osservatorio Astronomico di Torino. Space Telescope Science Institute is operated by the Association of Universities

Double Designation	r (A.U.)	E (a) (")	E (a) (A.U.)	Period (years)	Dm _x (mas*yr ⁻¹)	Dm _y (mas*yr ⁻¹)
LDS 832	760	13.03	1,064	33,000	+5.8	-5.1
FMR 5	853	6.47	1,194	35,000	---	---
ENG 22 AB	1,027	136.8	1,437	50,000	+4.4	+10.8
HDS1638	1,403	12.51	1,963	59,000	---	---
HJ 507	2,730	48.10	---	190,000	-0.7	-5.5
STF 487 AB	2,615	16.92	3,660	123,000	+0.7	+0.5
HJ 635	2,187	20.97	3,061	125,000	+0.5	+1.8
STFA 8 CD	7,117	75.96	9,960	542,000	+0.6	+0.4

Table 4: Physical Pairs Orbital Data

Double Stars Studied by LIADA in 2002

for Research in Astronomy, for the National Aeronautics and Space Administration under contract NAS5-26555. The participation of the Osservatorio Astronomico di Torino is supported by the Italian Council for Research in Astronomy. Additional support is provided by European Southern Observatory, Space Telescope European Coordinating Facility, the International GEMINI project and the European Space Agency Astrophysics Division.

This research has made use of the SIMBAD database, CDS, Strasbourg, France

References

- Barbier-Brossat, M.; Petit, M.; Figon, P., 1994, "Stellar radial velocities bibliography"; A & AS, **108**, **603B**.
- Bessell, M. S. and Brett, J.M., 1988, "JHKLM Photometry: Standard Systems, Passbands and Intrinsic Colors", PASP, **100**, 1134-1151
- Buscombe, W., 1998, "13th General Catalogue of MK Spectral Classification", Northwestern Univ., Evanston, Illinois, ISBN 0-939160-11-3.
- Cannon, A.J. and Walton Mayall, M., 1989, "The Henry Draper Extension", Harv. Ann. **112** (1949).
- Cincunegui, C.; Mauas, P. J. D., 2004, "Spectra of Sourthen late-type dwarfs", A & A, **414**, **699C**
- Corbally, C. J.; Garrison, R. F., 1984, "The MK Classification of Close Visual Binaries", Proceedings of the Workshop in honour of W.W. Morgan and P.C. Keenan, held at the University of Toronto.
- Cutri, R.N., *et al.*, Explanatory to the 2MASS Second Incremental Data Release. 2000, <http://www.ipac.caltech.edu/2mass/releases/second/index.html>
- Dommanget, J.; Nys, O., 2002, CCDM (Catalog of Components of Double & Multiple stars (Dommanget+ 2002), Observations et Travaux **54**, **5** (2002).
- Guarinos, J., 1992, "Visual Interstellar Extinction in the Galactic Disk", Evolution of Interstellar Matter and Dynamics of Galaxies. Proceedings of the International Conference, held in Prague, Czechoslovakia, May 21-25, 1991. Center for Theoretical Study, Workshop #1. Jan Palous, W. Butler Burton, Per Olof Lindblad, Eds., Cambridge University Press.
- Houk, N.; Smith-Moore, M., "Michigan Catalogue of HD stars, Vol.4", 1988, Ann Arbor, Dept. of Astronomy, Univ. of Michigan.
- Jaschek, M., 1978, "Catalogue of selected spectral types in the MK system", Bull. Inf. Centre Donnees Stellaires, **15**, 121
- Jones, Eric M., 1972, "Reduced Proper Motion Diagrams", AJ, **173**, 671-676
- Kron, Gerald E. and F.E. Roach, 1988, "The Distribution of (B-V) in Two Star Catalogs", PASP, **100**, 90-96.
- Hog, E. et al., 2000, "The Tycho-2 Catalogue of the 2.5 Million Brightest Stars", AJ, **335**, 27.
- Kennedy, P., 1981, "MK extension catalog.", Bull. Inf. Centre Donnees Stellaires, **21**, 91
- Lasker, B.M., *et al.*, 1992, Guide Star Catalogue Version 1.1
- Nelson, C.A. et al., 2002, "A Proper Motion Survey for White Dwarfs with the Wide Field Planetary Camera 2", ApJ, **573**, 644
- Röser, S.; Bastian, U., 1993, "The Final PPM Star Catalogue for Both Hemispheres", Bull. Inf. Cent. Donnees Astron. Strasbourg **42**, 11-16
- Salim, S., Gould, A., 2002, "Classifying Luyten Stars Using an Optical-Infrared Reduced Proper-Motion Diagram", ApJ, **575**, 83.
- Sinachopoulos, D.; van Dessel, E. L., 1996, "UBV photometry of wide visual double stars. V. Double stars with mainly K- and M- type primaries.", A & AS, **119**, **483S**.
- Skiff, A. B., 2003, "Catalogue of Stellar Spectral Classifications", Lowell Observatory
- Wenger, M., F. Ochsenbein, D. Egret, *et al.*, 2003, SIMBAD astronomical database, <http://simbad.u-strasbg.fr/>
- Zombeck, Martin V, 1990, Handbook of Space Astronomy and Astrophysics, Ed. Cambridge University Press, <http://ads.harvard.edu/books/hsaa/>

Mr. Romero has been a member of the Astronomical Society of Mérida in Spain for 12 years. He contributed two articles to the inaugural issue of this journal.

New Common Proper Motion Pairs

Ross Stuart

9606 Greenbank Drive
Riverview, FL 33569 USA

Abstract: Seven uncatalogued pairs are discussed, four of them new. Five of the pairs are clearly physical, as determined by the Halbwachs criteria for common proper motion (cpm) pairs. In some cases it is surprising that the pairs were previously unreported. The projected separations range from 1700 to 5000 AU. The analysis methods are effective and can be employed well by amateur astronomers.

Introduction

Romero (2005) notes that some amateurs have not ensured the physical nature of new pairs that they have reported. The pairs introduced here are from a short list that includes both new and previously documented pairs. None is listed by Mason *et al.* (2001) [WDS]. They serve as examples for the analysis needed.

Table I presents the basic data for the pairs. Table II presents the analysis of the astrometric data and lists the nature of the pairs. Table III presents photometric data, plus distance and linear separation estimates.

Analysis Method

The earliest criteria used to distinguish cpm and optical pairs were based on the statistics of stellar distribution. These have generally been presented in the form of magnitude-based separation limits.

Aitken used the limit $\log s = 2.8 - 0.2m$ for including pairs in catalogues at a time when accurate proper motion data were rare. This criterion is very restrictive and is no longer appropriate. The zero-point is 10 arcsec for magnitude 9. Applying this over the whole sky includes approximately 10 spurious pairs, but excludes many more physical pairs. None of the pairs in this article satisfies this limit. As a point of note, Aitken (1911) simply provides distance limits for magnitude ranges. Aitken (1935) [footnote on p. 258] credits E. C. Pickering with suggesting the form $\log s = c - 0.2m$.

Poveda *et al.* (1982) use more rigorous statistics to evaluate a filtered subset of known pairs.

Sinachopoulos and Mouzourakis (1991) provide

an even more stringent limit, intended to eliminate all optical pairs from a catalogue. For equal components, their limit can be approximated (with a much steeper slope) as $\log s = 4.1 - 0.43m$, equivalent to 1.7 arcsec at magnitude 9.

More recent work has used the improving database of proper motion data to better determine the nature of individual pairs.

Halbwachs (1986) states three selection criteria for use in constructing lists of cpm pairs:

$$(\mu_1 - \mu_2)^2 < -2(\sigma_1^2 + \sigma_2^2) \ln 0.5 \quad (1a)$$

$$\mu > 50 \text{ mas/yr} \quad (1b)$$

$$T \equiv s/\mu < 1000 \text{ yr} \quad (1c)$$

where the μ_i are the proper motion vectors and the σ_i are the mean errors of their projections on the coordinate axes, μ is the smaller total proper motion and s is the separation of the pair.

Greaves (2004) selects pairs based on the ratio of their proper motion components being less than 1.5 in each coordinate and requires that the proper motions exceed four times their errors, which he reduces to two for the fainter secondaries. He applies the criteria using individual errors, since σ_μ varies with magnitude. Greaves also imposes an initial selection requirement that each proper motion component exceed 10 mas/yr.

Halbwachs has more formally derived his limits, so his criteria are adopted here, with modifications to accommodate improvements in the data.

If the proper motion errors in right ascension and declination are not very different (the usual case), then to good accuracy

$$\sigma_v^2 = (\sigma_A^2 + \sigma_B^2) \quad (2)$$

New Common Proper Motion Pairs

Table 1: Catalogue Measures.

(1) Pair	(2) Position (J2000.0)	(3) P (°)	(4) s (")	(5) V _A	(6) V _B	(7) Epoch	(8) Catalogue Nos.
1	18h 50m 04.4s -13° 16' 30"	250.9 251.2	29.05 28.95	8.95	9.44	1907.153 1991.638	AC2000.2 2544082/2544068 TYC 5705 507 1/5705 286 1
2	4h 11m 36.2s -20° 21' 22"	334.2 334.4	62.20 61.77	5.80	7.64	1918.837 1991.488	AC2000.2 2624974/2624968 TYC 5889 1441 1/5889 1440 1
3	15h 03m 26.1s -38° 44' 13"	8.9 8.9	53.25 53.25	9.10	9.68	1912.564 1991.620	AC2000.2 3421549/3421550 TYC 7821 1643 1/7821 1387 1
4	07h 50 55.8s -14° 10m 19s	277.8 278.8	12.02 11.89	10.27	10.31	1902.898 1991.570	AC2000.2 2419837/2419825 TYC 5423 3229 1/5423 2166 1
5	00h 44m 17.2s +31° 22' 58"	357.6 357.4	55.12 55.10	8.78	9.44	1900.040 1991.853	AC2000.2 859947/ 859946 TYC 2275 1223 1/2275 33 1
6	20h 07m 45.7s +19° 50' 14"	76.8 76.8	41.33 40.99	8.32	8.32	1895.676 1991.703	AC2000.2 796274/ 796308 TYC 1625 995 1/1625 1596 1
7	07h 26m 06.5s +21° 53' 28"	320.7 320.9	100.52 100.32	9.35	9.67	1893.718 1991.733	TYC 1359 1079 1/1359 1175 1 AC2000.2 696722/ 696702

Column Descriptions:

Col.1 - Pair identification. These are simply running numbers. Pairs 5 and 6 were noted, although not identified by Webb (1917), while Pair 7 was noted by Bidelman (see Alksnis(2001)). Extending the existing WDS numbering would make these WEB 11, WEB 12, and BID 2.

Col. 2 - Positions are for the equinox and epoch J2000.0, taken from Tycho-2. The positions are for the primary star.

Cols. 3 and 4 - Position angle (p) and separation (s) of the pair. The position angle is referred to the pole of J2000.0. The first relative position for each pair has been computed from the AC2000.2. The second relative position has been computed from the Tycho-2 epoch positions.

Cols. 5 and 6 - Johnson V magnitude for the components. These have been computed from the Tycho-2 B_r and V_T data using the transformations of Bessell (2000).

Col. 7 - The epoch of measurement. This is a mean of the individual catalogue epochs. The maximum difference for any pair is 0.32 yr.

Col. 8 - The catalog identifiers for the component positions, given as ID(A)/ID(B). The AC2000.2 (Hog, 2000) observed positions (not the combined multi-catalog solution) have been used for the later epoch. The median catalog single coordinate error for the AC positions is 134 mas, for the Tycho positions 15 mas.

where $\mathbf{v} = \boldsymbol{\mu}_B - \boldsymbol{\mu}_A$ is the proper motion difference. This allows writing (1a) as

$$v^2 < -2\sigma_v^2 \ln 0.05. \quad (3)$$

Substituting numerical values gives

$$H_v \equiv v/\sigma_v < 2.448 \quad (4)$$

where the parameter H_v is the significance of the proper motion difference in terms of its standard error. The value shown is for the 5% level that Halbwachs used. Significance levels of 2% and 10% yield $H_v = 2.80$ and $H_v = 2.15$, respectively. If $H_v < 2$, the proper motions are sensibly equal. If $H_v > 3$, they are different. There is a transitional region between 2 and 3.

New Common Proper Motion Pairs

Table 2: Analysis Results.

(1) Pair	(2)	(3) TYC	(4) μ_{α^*} (mas/yr)	(5) μ_{δ} (mas/yr)	(6) v (mas/yr)	(7) H_v	(8) μ (mas/yr)	(9) H_{μ}	(10) T (kyr)	(11) Assoc
1	A B	5705 507 1 5705 286 1	41.2 ± 1.2 40.6 ± 1.3	-155.1 ± 1.3 -152.6 ± 1.4	2.6 ± 1.9	1.4	157.9 ± 1.4	113	0.183 ± 0.002	cpm
2	A B	5889 1441 1 5889 1440 1	44.9 ± 1.0 45.3 ± 1.5	51.1 ± 1.0 48.3 ± 1.5	2.8 ± 1.8	1.6	66.2 ± 1.5	44	0.932 ± 0.021	cpm
3	A B	7821 1643 1 7821 1387 1	-123.1 ± 1.9 -123.5 ± 2.2	-31.2 ± 1.3 -31.9 ± 1.5	0.8 ± 2.2	0.4	127.0 ± 1.9	68	0.419 ± 0.006	cpm
4	A B	5423 3229 1 5423 2166 1	-7.4 ± 1.5 -5.5 ± 1.5	-1.4 ± 1.4 -0.1 ± 1.4	2.3 ± 2.1	1.1	5.5 ± 1.5	3.7	2.2 ± 0.6	opt
5	A B	2275 1223 1 2275 33 1	22.5 ± 1.5 26.8 ± 1.3	-34.8 ± 1.5 -35.4 ± 1.4	4.3 ± 2.0	2.2	41.4 ± 1.5	28	1.33 ± 0.05	bin?
6	A B	1625 995 1 1625 1596 1	35.8 ± 1.1 33.6 ± 1.1	0.9 ± 1.1 -0.8 ± 1.0	2.8 ± 1.5	1.8	33.6 ± 1.1	31	1.22 ± 0.04	cpm
7	A B	1359 1079 1 1359 1175 1	-5.7 ± 0.9 -2.6 ± 1.2	-8.7 ± 0.9 -8.9 ± 1.2	3.1 ± 1.5	2.1	9.3 ± 1.2	7.7	10.8 ± 1.4	opt

Column Descriptions:

Col. 1 – Pair identification. These are the same as in Table 1.

Col. 2 – Component identification.

Col. 3 – Tycho-2 catalogue number for each component.

Cols. 4 and 5 – The component proper motions in right ascension and declination along with their standard errors, taken from Tycho-2. The proper motion in right ascension already incorporates the $\cos \delta$ factor and is directly comparable with the declination value.

Col. 6 – Magnitude of the vector difference in the component proper motions and its standard error.

Col. 7 – Parameter corresponding to the first Halbwachs criterion, computed here as the ratio of v to its standard error. Values less than 2 imply cpm.

Col. 8 – Smaller of the total proper motions of the two components and its standard error.

Col. 9 – Parameter corresponding to the second Halbwachs criterion, computed here as the ratio of μ to its standard error. Values less than 6 indicate the proper motion may be too small to be reliable.

Col. 10 – Halbwachs time $T = s/\mu$ and its standard error. Values less than 1 kyr imply a cpm pair; greater than 3.5 kyr an optical pair.

Col. 11 – Association of the pair based on the content of columns 7, 9 and 10. Pairs are characterized as optical (opt), common proper motion (cpm) or binary (bin).

Halbwachs criterion (1b) was imposed to reduce the number of spurious pairs resulting when the proper motion was too small. Halbwachs apparently tried 28 mas/yr and found that too small. Equation (1b) is based on the AGK3 mean proper motion error of 8.3 mas/yr. This can be generalized to

$$H_{\mu} \equiv \mu/\sigma_{\mu} > 6 \quad (5)$$

where H_{μ} is the significance of the smaller of the total proper motions in terms of its standard error. Since the mean component error in the proper motions in Table 2 is 1.3 mas/yr, this corresponds to about 8 mas/yr.

Halbwachs' criterion (1c) is a statistical mechanism for eliminating pairs whose linear separation is

(Continued on page 37)

Table 3: Distance Estimates

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	
Pair		(M/C) _T	Spectral Class		B-V	K	J-H	J-K	Absolute Mag. M _K Sp B-V J-H J-K			Distance Modulus (K-M _K) Sp B-V J-H J-K HIP TYC			m-M (pc)	D (AU)						
1	A	5	G5 V	2	0.579	7.347	0.406	0.411	3.5	2.98	3.69	3.53	3.83	4.36	3.66	3.81	>3.32	3.86	59	1700		
	B			4	0.678	7.671	0.408	0.446	3.0	3.51	3.69	3.62	4.68	4.16	3.98	4.05						
2	A	12	A1 V+(F/G) F0 V	2	0.170	5.497	0.087	0.104	2.0	2.11	2.42	2.25	5.02	4.90	4.59	4.77	4.42	4.24	4.42	77	4700	
	B			2	0.332	7.017	0.247	0.208									3.61	3.61				3.62
3	A	7	G2/3 V	2	0.621	7.517	0.357	0.394	3.3	3.20	3.55	3.49	4.20	4.32	3.97	4.03	4.47	4.47	4.47	4.29	72	3800
	B				0.704	8.084	0.373	0.437	3.61	3.61	3.62											
4	A	0.9			0.229	9.876	0.112	0.142		1.80	1.89	1.92	8.07	7.99	7.96	8.02	8.70					
	B				0.049	10.129	0.093	0.084														1.16
5	A	4.2	G5	3	0.875	6.676	0.459	0.522	3.5	4.10	3.98	3.90	3.16	2.58	2.70	2.78	3.95	2.64	34	1900		
	B			3	1.039	6.978	0.535	0.635	3.5	4.44	4.27	4.28	3.46	2.54	2.71	2.70	2.21					
6	A	N/A	F0	3	0.338	7.508	0.205	0.172	2.0	2.14	2.33	2.07	5.51	5.37	5.18	5.44	>4.00	5.42	121	5000		
	B			3	0.369	7.664	0.172	0.166	2.0	2.25	2.21	2.03	5.56	5.31	5.35	5.53						
7	A	N/A	R3	1	1.424	5.794	0.695	0.961	-2.7	2.0	2.25	2.21	2.03	5.56	5.31	5.35	5.53	9.83	9.18	690	70000	
	B			1	1.335	6.957	0.572	0.729														8.53

Column Descriptions:

Cols. 1 and 2 – Pair and component identification. These are the same as in Table 2.

Col. 3 – Magnitude–color slope computed from Tycho-2 BT and VT data. Values near 6 suggest a physical main sequence pair.

Cols. 4 and 5 – Spectral classifications for the components; sources are: 1 = CGCS, 2 = MSC, 3 = HD, 4 = SIMBAD.

Col. 6 – (B – V) color computed from the Tycho-2 photometric data using the transformations provided by Bessell (2000).

Cols. 7 to 9 – Infrared magnitude (K) and colors (J – H) and (J – K) computed from the 2MASS photometric data using the transformations provided by Carpenter (2001, 2003). Median standard errors are 0.021, 0.036 and 0.030, respectively.

Cols. 10 to 13 – Absolute K magnitudes estimated from the spectral classification and colors.

Cols. 14 to 17 – Distance moduli corresponding to the absolute magnitudes in columns 10 to 13.

Cols. 18 and 19 – Distance moduli from Hipparcos and Tycho-1 parallaxes where available and accurate enough to be meaningful. If an inequality is provided, the stated modulus is a 2σ lower limit.

Col. 20 – Adopted distance modulus. This is based on an examination of the range and agreement of the values in columns 14 through 19.

Col. 21 – Distance computed from the adopted distance modulus.

Col. 22 – Projected linear separation of the components, assuming the pair is physical.

New Common Proper Motion Pairs

(Continued from page 35)

so large that the pair is more likely optical than physical. This is relatively independent of the astrometric accuracy, so it is retained without modification. Halbwachs relaxed this in his Table II (less certain pairs) to a limit on T of 3500 yr. T can be treated the same way as H_v . $T < 1000$ yr implies a physical pair, $T > 3500$ yr implies an optical pair; between these limits is a transitional region. As computed from the data, T turns out to be very well defined when compared with the broad extent of the regions of interest.

An additional quantity that can help characterize the pair is the magnitude-color slope. If both stars of a physical pair are on the main sequence, the ratio of their magnitude difference and color difference should be approximately the slope of the main sequence. This value varies somewhat along the main sequence and depends on the photometric system used. For the main sequence between A0 and K0, $\Delta V_T / \Delta(B - V)_T$ is about 6. For 2MASS photometry, $\Delta K / \Delta(J - K)$ is also about 6, but is much less uniform along the main sequence. Substantial disagreement with this value suggests that the pair is not a main sequence physical pair. The two stars might be main sequence stars at different distances. They might be related, but not both on the main sequence. Despite its limits, this test is useful.

Data were gathered for each pair from Høg *et al.* (2000) [Tycho-2], Urban *et al.* (1998) [AC2000.2] and Cutri *et al.* (2003) [2MASS]. These provided positions, proper motions and photometry. Additional sources were consulted as needed to improve results or fill gaps.

Table I provides a straightforward listing of the basic data for each pair in the standard format for a double star observation. The relative coordinates were computed from the epoch catalogue coordinates for the individual stars. Johnson V magnitudes were computed from the Tycho-2 photometry using the transformations provided by Bessell (2000).

Table II presents the astrometric data and the computed quantities needed to apply Halbwachs criteria for physical pairs. To compute H_v , H_μ and to assess the usefulness of T and other derived quantities, the errors of the input data were propagated to the values listed in the table. This was done numerically using small perturbations to the input values.

Spectroscopic and photometric distances were computed for each star based on the available information. These, along with trigonometric parallax re-

sults, are presented in Table III and are used to compute projected linear separations. Consistency in the distance determinations helps confirm the physical nature of five pairs.

The main sequence data used were obtained from Cox (2000) [Table 15.7] and from Bessell and Brett (1988). K-band magnitudes were used for the distance modulus estimates because they are much less affected by interstellar absorption ($A_K \sim 0.1$ mag/kpc *vs.* $A_V \sim 0.8$ mag/kpc). The $B - V$ colors used for some of the estimates may be slightly reddened, but with distances generally less than 100 pc, $E_{B-V} < 0.03$, about the same size as the photometric errors.

The median accuracy of the colors is about 0.03 mag. When these are used to determine an absolute magnitude on the main sequence, the error is magnified by a factor of 6 (the MS slope). To this must be added the MS spread, which is about $\sigma = 0.4$ mag (See Houk *et al.* (1997)). The individual distances can be expected to be no more accurate than this, equivalent to about 20%. The actual scatter in the estimates for each pair is closer to 0.2 mag. The spread in the main sequence due to evolutionary effects will be reduced between two stars of common origin.

Notes on Individual Pairs

Pair 1

This is a bright pair that was missed by Struve, South, the Herschels, Luyten and van den Bergh (1958).

The spectral types from SIMBAD (G5 V and G0) may be affected by some confusion of the components since HD 174226 is the only HD entry for the pair. SIMBAD lists the primary as having the later type, despite being bluer. The 2MASS $J - K$ colors are compatible with main sequence spectral types G5 and G7. An additional complication is that the colors from Tycho-2 ($B - V = 0.579$ and 0.678) are noticeably bluer than the colors from Tycho-1, which gives 0.673 and 0.768 . This is largely due to a 3σ change in V_T for both components.

The distance determination uses only the 2MASS colors and the MK spectral classification. In any event, the pair is clearly physical.

Pair 2

The primary is HR 1300, a naked-eye star. This is too far south for Struve and probably too wide for South, but it's surprising that Dunlop didn't list it. Star A = HIP 19571, but its spectrum is composite, so the Tycho-2 proper motion, with its long time base, is used instead of the short-term Hipparcos result, which

New Common Proper Motion Pairs

might be affected by unmodeled orbital motion. The composite nature may partially account for the anomalously large value of the magnitude–color slope between the stars.

The spectroscopic and photometric distances for B are noticeably larger than the trigonometric values for A, but the astrometric data clearly show this to be a physical pair. The Hipparcos distance, accurate to 6%, is adopted.

Pair 3

From the spectral classification and the magnitude–color slope, the stars are on the main sequence. They pass all the tests for a physical pair. The distance estimate is based on all the individual results.

Pair 4

This pair is probably optical. No spectral classification has been published, but from the B – V colors, the stars are about A8 and A2, assuming MS membership. The 2MASS colors suggest A9 and A6. The magnitude–color slope indicates this is not a physical main sequence pair. Since A-type giants are uncommon, the stars are likely to be unrelated main sequence stars. H_μ is low and T is transitional, so despite the low value for H_v , this pair is unlikely to be physical.

Pair 5 (WEB 11)

Webb (1917) [Vol. II, page 18, remark under Σ I 1.] attributes this to Grover. This pair is also listed by Halbwachs (1986) [Table II, No. 7] and Greaves (2004) [GRV 40].

Despite the transitional values for H_v and T , this pair is almost certainly physical. The difficulty with H_v may be that orbital motion is being detected in the proper motion difference. The UCAC2 contains better proper motions for this pair ($\sigma_\mu = 0.7$ mas/yr *vs.* 1.4 for Tycho-2) and yields the following parameter values: $v = 2.5 \pm 0.9$ mas/yr, giving $H_v = 2.7$ (thus failing Halbwachs first criterion), $\mu = 42.4$ mas/yr, giving $H_\mu = 61$, and $T = 1.299 \pm 0.021$ kyr. A circular orbit in the plane of the sky with $a = s = 55.1''$ and total mass $M = 1.5M_\odot$ yields $v = 5.3$ mas/yr. Geometry and orbital dynamics could easily reduce this to the observed value.

The magnitude–color slope suggests these are physically related main sequence stars and the photometric distances are in good agreement. The spectral classifications (both G5) are not in good agreement with the colors, which suggest K0 and K3, but a remark in the HD indicates the spectra overlapped. The weighted mean of the Tycho-1 parallaxes

gives a distance of 38 ± 14 pc, in agreement with the mean photometric result, which is adopted.

Pair 6 (WEB 12)

Webb (1917) [Vol. II, page 214, as a remark under η Sge.] notes that there are several pairs in the field. This is the only one that appears to be physical. The astrometric data strongly imply cpm. The two stars are twins, so the magnitude–color slope was not computed. Giants of type F0 are uncommon, so Table III assumes the stars are on the main sequence, but greater luminosity cannot be completely excluded.

Pair 7 (BID 2)

Alksnis (2001) cites Bidelman as stating the pair is cpm. The magnitude–color slope was not computed since the two stars are not on the main sequence. Star A = HIP 36086, but the Tycho-2 proper motion is more accurate, so it is used.

The assertion that the pair is physical cannot be substantiated. H_v is in the transitional region, H_μ just qualifies and T is very clearly in the optical region.

Both of these stars are in the UCAC2 catalog of Zacharias *et al.* (2004). Using the proper motions there gives results that are little different: $H_v = 2.2$, $H_\mu = 12$, and $T = 12.0 \pm 1.0$ kyr.

The Hipparcos parallax for the primary was re-determined by Knapp *et al.* (2001) as 1.08 mas, with an asymmetric confidence interval of [.13, 4.48] which yields $M_K = -4.0$. Although they establish the absolute magnitude of early R stars as about $M_K = -2.0$, HIP 36086 is not as early as the bulk of the group treated. Its H – K color of +0.34 allows it to be identified in their Figure 1, from which $(V-K)_0 \sim 3.16$ can be estimated. Using this value, the trend of Figure 3 indicates $M_K \sim -2.7$. This is brighter than the clump giants noted in the figure, but fainter than the HIP parallax alone indicates. The distance is uncertain, but if the pair is physical, its projected linear separation exceeds 50000 AU.

Obiter dictum, Pluto transited between these stars on 1930 July 2.95 UT, shortly after its discovery.

Conclusion

Five of the seven pairs presented here, including three of the four new ones, are clearly physical pairs of long period.

The number of pairs in this article is small, so no definitive statements can be made, but it appears fairly straightforward for an amateur astronomer to apply tests for common proper motion before publishing pairs. Some care needs to be given to selecting and applying the criteria used.

New Common Proper Motion Pairs

The astrometric discrimination between physical and optical pairs can be quite strong given the improving accuracy in proper motions. The Tycho-2 data work very well for this purpose. When complete with respect to sky coverage, brighter stars and closer pairs, the UCAC will offer even better opportunity. Use of photometric data from the Tycho-2 and 2MASS catalogues is useful in confirming the astrometric assessment. Tycho-2 photometric data are generally good for main sequence membership testing, while 2MASS data allow distance determinations less affected by absorption. As proper motions improve, photometric discrimination of giants will become more important. The data used here don't support that.

Only one (Pair 3) of the seven pairs presents a completely clean assessment with no questions or conflicting data. The astrometric assessment proves correct for the others, but there are residual questions addressed in the individual discussions. The implication is that automating this process may be limited to computing the decision parameters, performing the cpm *vs.* optical assessment and then flagging conflicts requiring further examination. Consideration of the conflicts does not seem to affect the results in the limited sample here, but it is desirable to develop criteria that are relatively immune to minor data conflicts.

Halbwachs (1986) first criterion is becoming obsolete. Astronomers are now in the happy circumstance of having proper motions much more accurate than those available to Halbwachs. As accuracy improves, H_v for any given pair increases, eventually reaching the point where the stars can no longer be considered as having a truly common proper motion, their orbital motion having been detected. The astrometric criteria used will eventually have to support this.

Acknowledgements

The author has made extensive use of Project Pluto's *Guide* software package and thanks its developer, Bill J. Gray, for providing many features useful in this research.

This research has made use of the following catalogues maintained at or freely distributed by the U.S. Naval Observatory: Washington Double Star Catalog, Astrographic Catalog 2000, USNO CCD Astrometric Catalog and the Tycho-2 Catalogue.

This research has made use of the SIMBAD database, operated at the Centre de Données astronomi-

ques de Strasbourg (CDS). [Much use was made of the Vizier service. The catalogue access numbers are noted in the reference list for the many catalogues that are available from CDS.]

This research has made use of NASA's Astrophysics Data System.

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

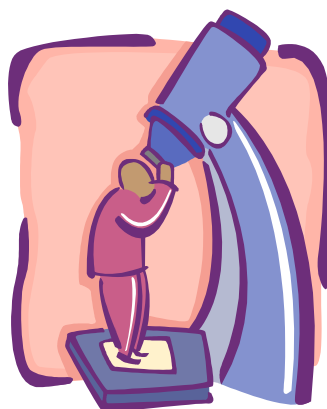
References

- Aitken, R. G. (1911) "The Definition of the Term Double Star", *PASP* **23**, 172.
- Aitken, R. G. (1935) *The Binary Stars*, McGraw-Hill. [as reprinted – Kent, J. T., ed. (1964) Dover Pub.]
- Alksnis, A. *et al.* (2001) "A General Catalogue of Galactic Carbon Stars", 3rd ed., *Balt. Astr.* **10**, 1. [CGCS. CDS No. III/227.]
- Bessell, M. S. (2000) "The Hipparcos and Tycho Photometric System Passbands", *PASP* **112**, 961.
- Bessell, M. S. and Brett, J. M. (1988) "*JHKLM* Photometry: Standard Systems, Passbands and Intrinsic Colors", *PASP* **100**, 1134.
- Cannon, A. J. and Pickering, E. C. (1918 – 24) "The Henry Draper Catalogue", *Harv. Ann.* **91 – 100**. [HD. CDS No. III/135.]
- Carpenter, J. M. (2001) "Color Transformations for the 2MASS Second Incremental Data Release", *AJ* **121**, 2851.
- Carpenter, J. M. (2003) "Color Transformations", in *2MASS All-Sky Data Release Explanatory Supplement Analysis of Release Catalogs*, section VI.4.b. URL = http://www.ipac.caltech.edu/2mass/releases/allsky/doc/sec6_4b.html. [This contains updated constants for the transformations developed in Carpenter (2001).]
- Cox, A. N., ed. (2000) *Allen's Astrophysical Quantities*, 4th ed., Springer.
- Cutri R. M. *et al.* (2003) *The 2MASS All-Sky Catalog of Point Sources*, University of Massachusetts and Infrared Processing and Analysis Center (IPAC/California Institute of Technology). [2MASS. CDS No. II/246]

New Common Proper Motion Pairs

- European Space Agency (1997) *The Hipparcos and Tycho Catalogues*, SP-1200. [HIP and Tycho-1. CDS No. I/239.]
- Greaves, J. (2004) "New Northern Hemisphere Common Proper Motion Pairs", *MNRAS* **355**, 585.
- Halbwachs, J. L. (1986) "Common Proper Motion stars in the AGK 3", *A&Ap Supp* **66**, 131.
- Høg, E. *et al.* (2000) "The Tycho-2 Catalogue of the 2.5 Million Brightest Stars", *A&Ap* **355**, L27. [Tycho-2. CDS No. I/259.]
- Houk, N. (1982) *Catalogue of Two-Dimensional Spectral Types for the HD Stars*, Vol. 3, Dept. of Astronomy, University of Michigan. [MSC. CDS No. III/80.]
- Houk, N. and Smith-Moore, M. (1988) *Catalogue of Two-Dimensional Spectral Types for the HD Stars*, Vol. 4, Dept. of Astronomy, University of Michigan. [MSC. CDS No. III/133.]
- Houk, N. *et al.* (1997) "The Properties of Main-Sequence Stars from Hipparcos Data", *Proceedings of the ESA Symposium 'Hipparcos – Venice '97, 13-16 May'*, ESA SP-402, 279.
- Knapp, G., Pourbaix, D. and Jorissen, A. (2001) "Reprocessing the Hipparcos data for evolved giant stars. II. Absolute magnitudes for the R-type carbon stars", *A&Ap* **371**, 222.
- Mason, B. D. *et al.* (2001) "The 2001 U. S. Naval Observatory Double Star CD-ROM. I. The Washington Double Star Catalog", *AJ* **122**, 3466. [WDS. The catalogue is updated nightly. The version used for this article was downloaded on 27 April 2005. URL: <http://ad.usno.navy.mil/wds/wds.html>]
- Poveda, A., Allen, C., Parrao, L. (1982) "Statistical studies of visual double and multiple stars. I - Incompleteness of the IDS, intrinsic fraction of visual doubles and multiples, and number of optical systems", *ApJ* **158**, 589.
- Romero, F. M. R. (2005) "GSC1753-1506: Discovery of a New Binary", *JDSO* **1**, 8.
- Sinachopoulos, D. and Mouzourakis, P. (1991) "A statistical approach for the recognition of physical visual double stars", *A&Ap* **245**, 513.
- Urban, S. E. *et al.* (1998) "The AC2000: The Astrophysical Catalogue on the System Defined by the HIPPARCOS Catalogue", *AJ* **115**, 1212. [AC2000.2 is the updated version of this. CDS No. I/275.]
- van den Bergh, S. (1958) "A List of Stars with Common Proper Motions", *AJ* **63**, 246.
- Webb, T. W., (1917) *Celestial Objects for Common Telescopes*, 6th ed., ed. Espin, T. E. [as reprinted – Mayall, M. W., ed. (1962) Dover Publ.]
- Zacharias, N. *et al.* (2004) "The Second U. S. Naval Observatory CCD Astrograph Catalog (UCAC2)", *AJ* **127**, 3043. [UCAC2. CDS No. I/289.]

Ross Shuart originally planned to become a professional astronomer, but diverted to a career in aerospace software where he still is 33 years later. His astronomical interests include double stars, astrometry, celestial mechanics and the astronomical data mining opportunities open to an amateur with a personal computer. He currently resides near Tampa, Florida, USA.



New Common Proper Motion Pairs Containing White Dwarfs from SDSS Data

John Greaves

Northampton, UK

Abstract: Spectroscopically identified white dwarfs from the SDSS data release 1 (Kleinman et al 2004) are matched against SDSS data release 1 proper motion survey (Gould & Kollmeier 2004) in the search for common proper motion companions

Introduction

Kleinman et al 2004 present a catalogue of spectroscopically identified white dwarfs from Sloan Digital Sky Survey (SDSS) data release 1 in which they also include proper motions derived via comparison to USNO B1.0 (Monet et al 2003) multiepoch positions. This dataset was compared to a global proper motion catalogue (Gould & Kollmeier 2004), an independently generated catalogue also combining SDSS and USNO B1.0 epoch data to derive proper motions within the area of data release 1. Although one survey derives the data secondary to a specific object search whilst the other is a global data processing exercise, they are not truly independent catalogues (in the technical sense) as they both utilise USNO B1.0 and SDSS data and also come from connected SDSS collaboration groups. However, both assume themselves accurate from the 20 milliarcsecond (mas) level upwards, and the current work further utilised only objects with total proper motion greater than 50 mas.

Recent serious updates and revisions of the positional data in the Washington Double Star Catalog (see <http://ad.usno.navy.mil/wds/wdstext.html> for details), and especially the efforts of Richard Jaworski in recovering many positions of Luyten's Double Stars (eg Jaworski, R, 2005), have meant that serious searches for new faint, relatively high proper motion, common motion pairs can be conducted, without concerns with respect to known, but lost, pairs. Accordingly, specialized catalogues can at times be searched against global surveys for common proper motion candidates and the results checked to see if the candidate findings are known, with literature available, or new and possibly in need of follow up, if sufficiently of interest. The present work gives an example of such a search in terms of white dwarfs in common proper motion pairs.

The 2654 objects in the above white dwarf catalogue having proper motions were matched against the 390,000+ stars in the above SDSS data release 1 proper motion catalogue as per the methods outlined in a common proper motion pair search of Gould & Kollmeier 2004 as outlined in Greaves 2005. In this instance proper motions had to match within ± 5 mas of each other, comfortably below the usual error in proper motion and obviously always no more than 10% of the total proper motion at the 50 mas lower threshold used in the search. A search radius of 6 arcminutes was used: the demarcations between visual binary, common proper motion pair, comoving pair, member of a moving group, star streams and neighbouring members of Galactic Populations such as Halo or Thick Disk stars are not clear, and often depend on the type of stars being looked at. It was felt that 6 arcmins would give a wide catchment area whilst still selecting stars having the chance to be gravitationally connected to each other independent of various selection effects, rather than being merely in comoving Galactic orbits. In the end, all of the seven pairs found were (very nearly) within 0.5 arcminutes of each other, with no pairs found between that and the upper 6 arcminutes' limit!

The white dwarf catalogue was also tested against itself using a search radius of one degree in a search for comoving pairs, on the assumption that white dwarfs of high common proper motion are still at least from a common population, even if too far apart to be likely physically connected. Two such pairs were found, interestingly one was common to the previous search.

Finally, the candidate objects were double checked against VizieR, WDS, and the Villanova White Dwarf Catalog (see acknowledgements) to ensure that they were not previously known as members of common proper motion pairs or binaries. All appear to be previously unknown.

New Common Proper Motion Pairs Containing White Dwarfs from SDSS Data

Results

Table 1 lists Right Ascension and Declination (J2000) for the primary of each pair, the primary being defined as the star brightest in SDSS r' magnitude.

Next follows the position angle (θ) in degrees and the separation (ρ) in arcseconds of the pair. The respective magnitudes of the primary and secondary are then given, followed by the spectral type of the SDSS spectroscopically identified white dwarf, which is the secondary in the case of the first six objects, and the primary in the case of the last entry in the table.

The proper motion details in milliarcseconds for Right Ascension and Declination of the primary ($\mu\alpha A$ and $\mu\delta A$) and secondary ($\mu\alpha B$ and $\mu\delta B$) follow, with Right Ascension being corrected for Declination via $\mu\alpha \times \cos(\text{Declination})$. These data are somewhat standard and similar to the WDS layout. Extra data comes in terms of the $u'-g'$ and $g'-r'$ colours from the SDSS photometry, which allow a comparison between the stars, and a simple assessment of the untyped companions' spectral classes.

Red Primaries

The first five entries in Table 1 have red primaries from their SDSS colours, and their similar distances, based upon their presumed association as a result of their large common proper motions, and given their magnitudes relative to the white dwarfs, are likely to be red dwarfs. Red dwarf and white dwarf common proper motion pairs are fairly common amongst high proper motion faint pairs. (The

fact that these stars are the given as the primaries in the system reflects the choice of SDSS passband used, *ie* r' . If g' had been used the presumed red dwarfs would be a mix of primaries and secondaries, as that passband overlaps traditional Johnson B and V, and the same would probably also be true of Johnson V).

Blue Companions

The last two entries have SDSS colours not dissimilar to, in fact very similar to, the colours of the spectroscopically confirmed white dwarfs. Indeed, the colours of both the primary and secondary for each pair are very close, making each pair something of a twin star.

The sixth entry actually has the primary as the unknown star, it being just brighter in both r' and g' , and the secondary as the spectroscopically confirmed white dwarf, despite the latter being quite similar in brightness to the former (there being roughly half a magnitude between them). Some selection effect in the original survey has led to one of the two stars being found, and not the other, it seems.

The seventh entry in Table 1 is also intriguing. Here the primary is the spectroscopically confirmed white dwarf, and again the two stars have very similar colours. However, unlike in the sixth entry, where the apparent brightness is also very similar as would be expected for a pair of similar objects at a common distance, in this instance the secondary is quite markedly fainter than the primary.

USNO B1.0 and POSS images show that the pair is a valid common proper motion pair, and also they have the relatively small separation of around 9 arcseconds,

RA J2000	Dec J2000	θ (°)	ρ (")	$r' A$	$r' B$		spec	$\mu\alpha A$	$\mu\delta A$	$\mu\alpha B$	$\mu\delta B$	$u'-g'A$	$g'-r' A$	$u'-g'B$	$g'-r' B$
09 51 03.7	+01 04 17	305	26.8	14.52	15.95		DB2	-071	-029	-069	-032	2.68	+1.34	-0.12	-0.36
11 10 29.4	-00 33 53	312	13.7	16.49	18.65		DA5	-071	+006	-077	+010	2.74	+1.51	+0.42	-0.04
17 32 32.0	+59 05 15	53	30.9	17.72	18.84		DA	-007	-055	-003	-052	2.71	+1.53	+0.27	+0.10
17 33 44.9	+55 44 36	225	24.0	18.72	18.73		DC	-016	+057	-014	+058	2.22	+1.48	+0.41	+0.05
21 10 57.5	-06 42 56	85	16.8	15.06	16.59		DA	-043	-084	-047	-087	2.63	+1.44	-0.05	-0.38
21 15 07.4	-07 41 34	181	17.1	16.91	17.40		DA5	-027	-115	-025	-116	0.35	-0.08	+0.41	+0.09
23 26 59.2	-00 23 48	329	9.2	17.61	19.24		DA	+053	-029	+051	-033	0.48	-0.09	+0.45	+0.13

Table 1. SDSS White dwarfs in unknown common proper motion pairs. Proper motions are corrected by $\cos(\text{dec})$ in RA and are in milliarcseconds (mas). The spectra are for the spectroscopically identified white dwarfs, which are the secondary in each but the last-most pair. Epochs are 2000 throughout. (NB The first and fifth pair were also noted as common proper motion pairs in Greaves 2005, although no white dwarf work was done in that common proper motion survey and their identity as such was not realised, and so are retained here although technically "pre-known". Whilst this article was in press they have become designated GRV 1037 and GRV 1141 respectively).

New Common Proper Motion Pairs Containing White Dwarfs from SDSS Data

RA J2000	Dec J2000	$\theta(^{\circ})$	$\rho(^{\circ})$	r' A	r' B	spec	$\mu\alpha$ A	$\mu\delta$ A	$\mu\alpha$ B	$\mu\delta$ B	u'-g'A	g'-r' A	u'-g'B	g'-r' B
02 25 31.0	-09 04 15	228	21.2	19.59	19.77	DA DA	+082	-003	+084	+001	+0.36	-0.10	+0.30	+0.02
09 51 02.2	+01 04 33	230	45.1	15.95	17.88	DB2 DA4	-069	-032	-075	-039	-0.12	-0.36	+0.27	-0.15

Table 2. Two SDSS White dwarf comoving pairs. Proper motions are corrected by $\cos(\text{dec})$ in RA and are in millarcseconds (mas) and separation in arcminutes. Note that the "primary" of the second pair is also the secondary of the first pair listed in Table 1.

so this potential white dwarf pair carries some interest. Around 50 years ago the separation may have been 0.3 arcseconds wider, given the USNO B1.0 derived separation, however this negligible amount is small compared to the differing positional errors of the SDSS and USNO B1.0 catalogues, and the position angle at the two epochs remains pretty much unchanged, so this change may be more artificial than real, and there may be no relative motion.

The Comoving Pairs

Table 2 lists the two comoving pairs, with the same entries as for Table 1, except here separation (ρ) is given in arcminutes and the spectral class for both stars is given. Of the 2654 spectroscopically confirmed white dwarfs having proper motion values in Kleinman, *et al.* 2004, only these two pairs had common proper motions greater than 50 mas whilst also lying within one degree of each other on the sky.

Of special note is that the brightest star of the second pair in the list is also the white dwarf secondary of the first pair listed in Table 1, making it not only a candidate member of a nearby moving group of Thick Disk or Halo evolved stars, but also a common proper motion red dwarf - white dwarf binary.

Conclusion

The revision of the positions for historical data in classical astrometric catalogues, and especially of classical compilation catalogues such as the WDS, allows them to be used in tandem with the many modern survey lists to check and ensure novel, and hopefully interesting, discoveries. Further, the astrometric precision given in some modern source catalogues, even ones primarily photometric in their remit, enables cross matching of disparate catalogues in order to do various searches, including at times searches for common proper motion pairs.

Common proper motion pairs are often at least from a common source population, with higher mo-

tion ones belonging to specific Galactic population groups of some interest, and at most of common origin, informative in terms of constraints on formation theories, and, also on Galactic structure, for such pairs have evidently remained undisturbed after many orbital crossings across the Galactic disk and long passages through the Galactic Halo.

These sorts of objects can be interesting within themselves, and in future when sufficient are known may provide enough numbers for statistical assessments of their populations.

The positional improvement on classical information helps avoid the continuous rediscovery of the same objects, whilst global common proper motion catalogues allow the search for new candidate objects of various subgroups, whether via self-testing the catalogue or via searching it using catalogues of specialized objects as a seed.

Acknowledgements

This research utilises data products of the Sloan Digital Sky Server (www.sdss.org), specifically data release 1, as well as the USNO WDS (Washington Double Star Catalog <http://ad.usno.navy.mil/wds/>). Cross identification and lack of previous identification double checking also made use of the VizieR service at the CDS Strasbourg and the Live Villanova White Dwarf Catalog (<http://www.astronomy.villanova.edu/WDCatalog/index.html>)

References

- Gould, A., & Kollmeier, J. A., 2004, *ApJS* **152**, 103
- Greaves, J., 2005, Webb Society Double Star Section Circular number 13 (DSSC 13)
- Jaworski, R., 2005, Webb Society Double Star Section Circular number 13 (DSSC 13)
- Kleinman, S. J. *et al.*, 2004, *ApJ*, **627**, 426
- Monet, D. G., *et al.*, 2003, *AJ*, **125**, 984

The author often searches for more astrophysically interesting variables in datasets, such as lists of new RR Lyrae's and δ Cep stars. Recently, he has been trying to show how binaries can be found (or confirmed) in proper motion surveys.

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

R. Kent Clark, Jarrod Cunningham, Jessica Guidry, Jonathan Pearce,
J.M. Sanders, Tiffany Scarborough

Department of Physics
University of South Alabama
Mobile, AL 36688

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

Introduction

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

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

In the resulting list of candidate double stars, we were attracted to the WDS 01477+6351, to which we will refer by its discoverer code, ENG 7. The last re-

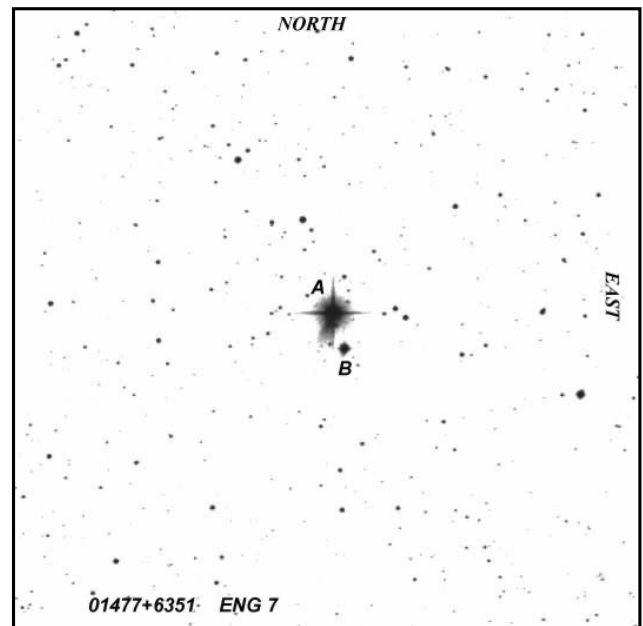


Figure 1: DSS image of WDS 01477+6351. The field is 15” across.

ported measurement of this star was in 1915, and at that time, it had shown a considerable change in separation and position angle since its first measurement in 1892. This double star is in the constellation Cassiopeia, near ϵ Cas. The A component is a 5 mag, spectral class K0, main sequence star and is 33 ly from Earth (from Tycho 2, Hog 2000). The WDS reports a sizable proper motion for the A component of

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

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

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

Calibration of the Bifilar Micrometer

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

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

Table 1. Check of screw calibration of micrometer.

about 80 and a field of view of about 0.5°.

We calibrated the bifilar micrometer screw by measuring three double stars with well known separations. These were β Cygnii (Alberio, $\rho = 34.3''$), 31 Cygnii ($\rho = 105.8''$), and 30/31 Cygnii ($\rho = 330.7''$). The measurement were made over a period of several nights in the late summer and fall of 2003. A total of 48 calibration measurements were made: ten of Alberio, nine of 31 Cygnii, and 29 of 30/31 Cygnii, yielding a calibration constant of 0 a.s./inch (the uncertainty is the standard deviation of the mean).

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

Our measurements of the position angles of these double stars differed from accepted values by about 2°. Much of this discrepancy was apparently due to our inexperience measuring position angles as the position angles reported for other stars in this paper were self-consistent to within 1°. However, because our telescope has an altazimuth mount, field rotation

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

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

was no doubt a contributing factor to the uncertainty.

Measurements of “Neglected” Double Star WDS01477+6351

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

Motion of ENG7

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

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

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

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

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

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

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

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

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

to calculate the relative speed of the B component. We assumed a distance between the components of $r = 400$ au (6×10^{13} m), which is the current separation and an apparent semimajor axis of $a = 1000$ au (1.4×10^{14} m), which was the separation in 1892. Given that the B component is three magnitudes dimmer than the A component, we assumed that the B com-

ponent would be a main sequence class M star and therefore have a mass of about 0.1 solar masses. The *vis viva* equation then yielded a relative speed of 1.5 km/s for the B component. So, again, the observed speed of the B component is much greater than the maximum speed it could have in a gravitationally bound system. Thus, we conclude that the B component is not gravitationally bound to the A component.

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

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

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

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

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

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

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

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

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

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

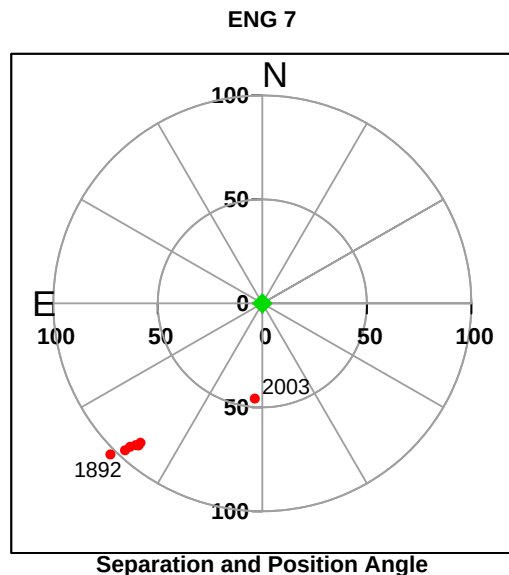


Figure 2: Position angle and separation of ENG 7 from 1892 to 2003.87 showing the apparent linear motion of the B component relative to the A component. ρ and θ used in the figure are printed in Table 2.

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

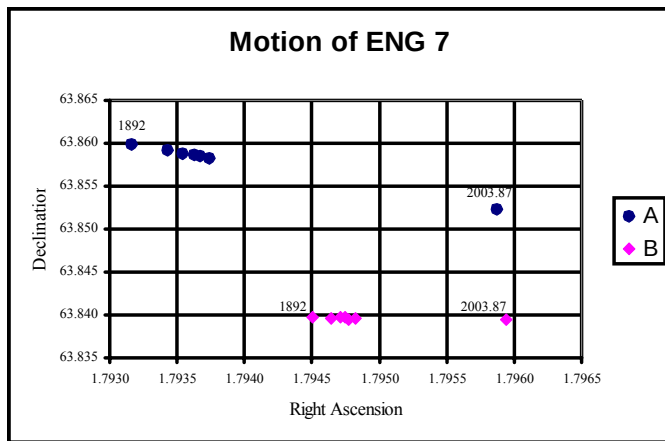


Figure 3: J2000.0 coordinates of ENG 7 A and B in the years of observation.

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

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

Conclusions

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

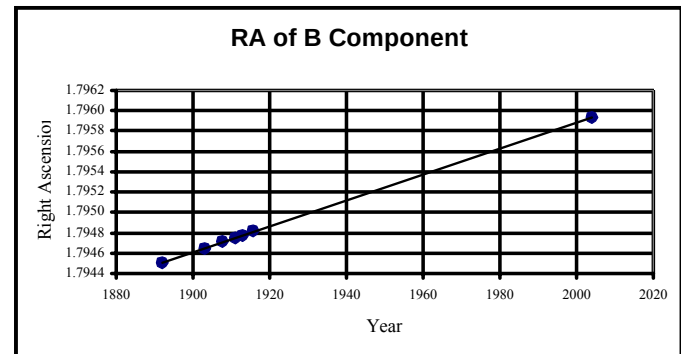


Figure 4: East/West motion of ENG 7B. The line is a least squares fit to the data and has a slope of $(1.279 \pm 0.006) \times 10^{-8}$ hr/yr corresponding to a proper motion of 305 ± 2 mas/yr.

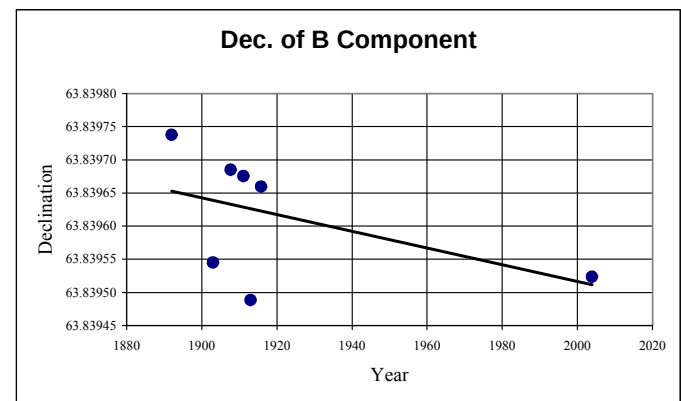


Figure 5: North/South motion of ENG 7B. The fitted line has a slope of $-(1.3 \pm 1.0) \times 10^{-6}$ deg/yr corresponding to a proper motion of -4.5 ± 3.6 mas/yr. Note that the entire vertical scale spans $1.25''$, the uncertainty of our measurement is $\pm 0.6''$.

mas/yr in declination.

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

Acknowledgements

We wish to acknowledge Sigma Pi Sigma (the physics honorary society) for an Undergraduate Research Award to fund the purchase of the bifilar micrometer. We also would like to acknowledge Dr. Brian Mason for advice and encouragement and for providing historical data on ENG 7.

This project made use of the Washington Double

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

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

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

Mason, B.D., G.L. Wycoff, et al., 2001, “The 2001 US Naval Observatory Double Star CD-ROM. I. The Washington Double Star Catalog”, *AJ*, **122**, 3466.

Mason, B.D., 1994, “Speckles and Shadow Bands”, Ph.D. dissertation, Georgia State University.

References

Hog, E. et al., 2000 “The Tycho-2 Catalogue of the 2.5 Million Brightest Stars”, *AJ*, **335**, 27.

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



LDS 968 AB-C: The Distant Companion of HU575

Edgardo Ruben Masa Martin

Double Star Section Coordinator
Syrma Astronomical Society
(Syrma-MED)
Valladolid, Spain

Abstract: The astronomer Peter van de Kamp (1901-1955) published (Astronomical Journal, 1939) a short note including a study on the separated component of the orbital system HU575 (=WDS14426+1929). This new companion (LDS 968 AB-C) had been discovered by Janet M. DeVilbiss some years before. HU575 AB has two close components with magnitudes 9.77 and 10.05. The distance between them is 0.7". The distant companion has magnitude 10 and is placed at 135" from the main component, according to DeVilbiss' measurement. The relevant van de Kamp's result lies in detecting the common proper motion of about 0.31" by year, from the closer pair to the furthest component, predicting a potential physical relationship: "*A physical connection between the two stars is strongly indicated.*" As we can see in the WDS data, the remote component was catalogued with Luyten's observer code (LDS 968) when it was actually discovered by Miss DeVilbiss.

In this paper spectral types and luminosity classes for the whole system are deduced using optical and infrared photometry, and a new relative astrometry is obtained. A study on the nature of the system is also presented.

HU 575 AB: An orbital pair

This pair was discovered by Hussey, who measured it the first time in 1902.51. Since then until 2001, 144 official measurements have been accumulated in the WDS catalog, being a frequently observed pair. The reason lies in the fact that the orbital system has a period of 51.7 years, with the secondary moving in retrograde sense. Its orbit is collected in the *Sixth Catalog of Orbits of Visual Binary Stars* by William I. Hartkopf & Brian D. Mason. In Table 1 are shown the positions of the secondary for the next five years. The apparent relative orbit is shown in Figure 1.

The system is formed by two stars whose magnitudes are 9.773 and 10.05 as listed in the CCDM catalog. Practically all sources report spectral type M0 for the main component, but the NLTT catalog (Luyten, 1969) lists a K5 spectrum. According to the spectral distribution of energy in BVJHK bands and the kinematic data (reduced proper motion), a K8V spectrum was found (jointly for AB), our result being in the same range with the professional measurements. It is,

Year	Theta (°)	Rho (")
2005.0	174.3	0.690
2006.0	171.3	0.683
2007.0	168.2	0.669
2008.0	164.9	0.650
2009.0	161.5	0.625
2010.0	157.6	0.600

Table 1: Future positions of HU 575.

therefore, a red dwarf lying on the main sequence and it is 22.5 parsecs (73 light-years) distant deduced from Hipparcos catalog data. The NLTT catalog puts it near 18.98 parsecs changing slightly the value of the trigonometric parallax. The important annual proper motion of AB pair from Tycho-2 is: $\mu_\alpha = -0.261 \pm 0.0013$ as/yr and $\mu_\delta = -0.179 \pm 0.0014$ as/yr.

LDS 968 AB-C: The Distant Companion of HU 575

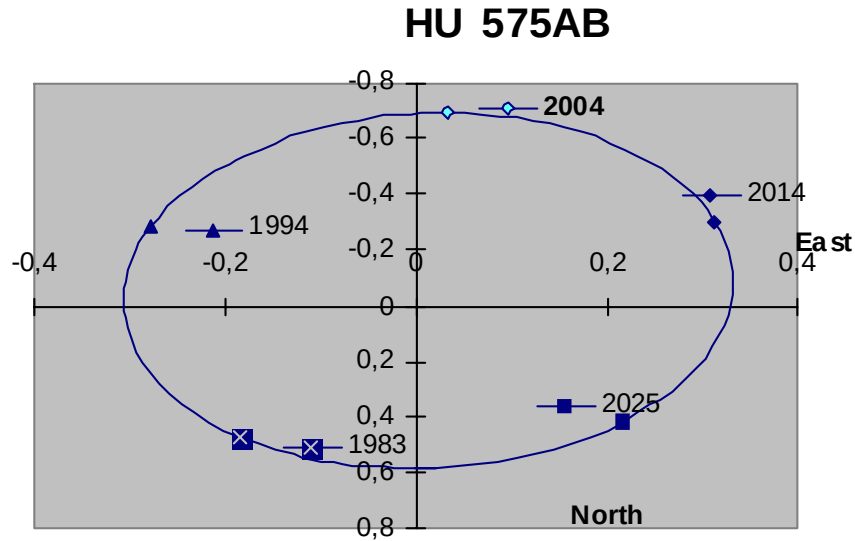


Figure 1: Apparent relative orbit of HU 575AB

C component (LDS 968 AB-C)

The distant component is a star with magnitude $m_V=10.08$ (Hipparcos) that has a proper motion almost identical to the AB pair, as we can see again in the Tycho-2 catalog: $\mu_\alpha = -0.2633 \pm 0.0013$ as/yr and $\mu_\delta = -0.1785 \pm 0.0013$ as/yr, which is a strong indication of a physical relationship with the main component.

According to the spectral distribution of energy in BVJHK bands and the kinematic data (reduced proper motion), an identical spectrum to the AB pair one was measured, that is to say, K8V. The professional astronomical literature assigns M0 and K5, just as it was in the HU 575 AB case and places the distance at 25.9 parsecs (84 light-years) or puts it into 18.98 parsecs again, as it appears in the consulted sources.

The methodology used to determine spectral types and luminosity classes by the LIADA Double Stars Group follows:

- Photometric data (JHK from 2MASS and BV from Hipparcos/Tycho-2) were transformed to the spectral type. If the stars are very red, it is also possible to deduce the luminosity class by using J-H vs H-K two-color diagrams [M. S. Bessell & J. M. Brett (1988) and Gerald E. Kron (1988)] and several tables that relate photometric data with spectral data. Several useful tables are from *Handbook of Space Astronomy and Astrophysics* of the Harvard University. The process transforms the magnitudes of the “problem-star” in energy in Jy

($1 \text{ Jy} = 10^{-23} \text{ erg} \cdot \text{cm}^2 \cdot \text{sec}^{-1} \cdot \text{Hz}^{-1}$) and compares the spectral distribution of a component with those of the empirical tables.

- When the star is not red enough to obtain the luminosity class by using only photometric data, then we must use Reduced Proper Motion Diagrams (Eric M. Jones, 1972; C. A. Nelson, 2003; Salim S., 2002). These diagrams relate the observational photometric data and proper motions with a parameter that is characteristic of a population star (dwarfs, giants, subdwarfs, white dwarfs...)
- Precision: comparing our spectral data on 19 components with well-determined proper motions and precise BVJHK photometry, with those obtained by professionals using spectroscopy, the mean difference is 0.5 spectral subclasses and the luminosity class was estimated correctly in all components (F. M. Rica, 2005).

Next, an image of the whole system showing the proper motion of the stars for one thousand-year period is shown in Figure 2. It can be observed that the trajectories are practically parallel.

On the discovery of C component

We will treat now the matter of the attribution of the discovery of C component. We saw before, in WDS, that the first historical measurement is attributed to Luyten. However, Peter van de Kamp published (van de Kamp, 1939) a brief description entitled “A Distant

LDS 968 AB-C: The Distant Companion of HU 575

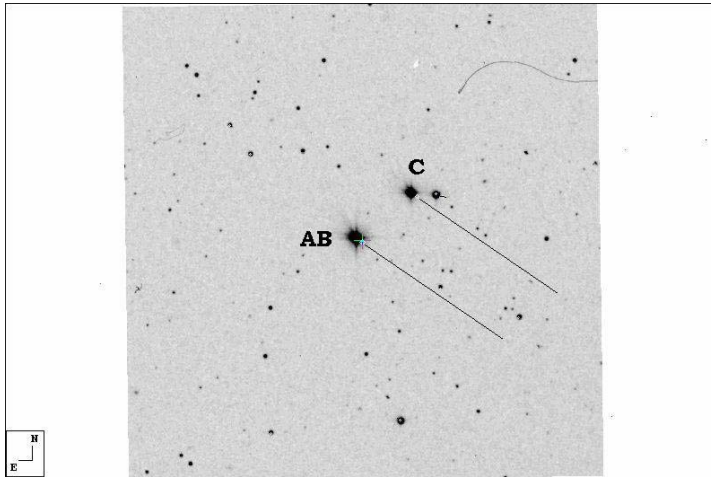


Figure 2: Simulation of the trajectories of the common proper motion for a thousand-year period. This composition is produced with Guide 8.0 software on the DSS palate.

Companion To HU 575 = ADS 9352" where it is made clear that Janet M. DeVilbiss (a woman astronomer who collaborated with him on repeated occasions) measured the AB-C pair on two plates taken on the nights 1933.240 and 1934.178, and on two more taken at 1939.225. She got the values of $309''$ and $135''$ for theta and rho respectively. Though it was not specified, we must suppose that the values of the relative astrometry were the result of working out the average of the measurements made with the four plates. If we accept this premise, then the final epoch for the observation (at worst) must be the average of the dates when the plates were made, that is to say, 1935.547.

This observation predates by a short period Luyten's observation (1936) and therefore it ought to be put in WDS catalog. The complete original note is shown in Figure 3.

In this paper, van de Kamp explains how the proper motions of AB and C components were deduced and, in light of their similar values, that there probably was a physical connection between them. Note that the proper motions obtained by van de Kamp are very similar to the current ones, confirming the observers' good work.

Just a year later, in 1940, van de Kamp and DeVilbiss published a new work jointly (van de Kamp, DeVilbiss, 1940) entitled "*Proper motions of some double stars.*" In this paper the authors present a list where the proper motions for eight orbital systems are deduced, including measurements of the pair we are studying. One fragment from the article is shown in Figure 4.

Relative Astrometry

LDS 968 AB-C has only four official measurements of position angle and of separation since 1936, Luyten's measure date. The historical measures are listed in Table 2.

Two parameters have remained fixed since the first official measurement except the last value of the distance in the entry of 1996.518 by Walt L. Sanders. The huge disagreement in *rho* indicates either an error by Sanders' or a transcription mistake in the WDS. This veteran observer works with the Lick 36-inch refractor and uses a Clark filar micrometer. At present he is working on a project started in 1966

A DISTANT COMPANION TO HU 575 = A.D.S. 9352

By PETER VAN DE KAMP.

HU 575 ($14^h 38^m.0$, $+19^\circ 55'$, 1900; BD+20° 3010) is a binary¹ with a period of 50.6 years, semi-axis major of $''66$ and with magnitudes 10.0 and 10.5 for the components. The dynamical parallax¹ based on these elements is $''047$; a spectroscopic parallax² of $''029$ for the brighter component (spectrum M0) has been published.

The positions of BD+20° 3010 and of the neighbouring star BD+20° 3009 have been measured by Miss DEVILBISS on two plates taken on the nights 1933.240, 1934.178 and on two plates taken 1939.225. BD+20° 3009 is in position angle 309° at a distance of $135''$ and is approximately one magnitude fainter than BD+20° 3010. The following relative proper motions are derived:

	μ_x	μ_y	μ	p
BD+20° 3010	$-''24$	$-''17$	$''29$	235°
BD+20° 3009	$-''26$	$-''19$	$''32$	234°

A physical connection between the two stars is strongly indicated. The difference in motion is of the order of the errors.

REFERENCES

1. *Union Obs. Cir. No. 98*, 350, 1937.
2. *Astroph. Jour.*, **81**, 252, *Mount Wilson Contr.* **22**, 122; 1934.

*Sproul Observatory
Swarthmore College
Swarthmore, Pennsylvania
1939, April 3.*

Figure 3: Van de Kamp's 1939 note on the discovery of HU 575C

LDS 968 AB-C: The Distant Companion of HU 575

32

THE ASTRONOMICAL JOURNAL

No. 1125

PROPER MOTIONS OF SOME DOUBLE STARS

FROM PHOTOGRAPHS TAKEN WITH THE TWENTY-FOUR INCH SPROUL REFRACTOR

BY PETER VAN DE KAMP AND JANET M. DEVILBISS

ADS	Name	1900 R. A.	1900 Decl.	Vis. Mag.	Sp.	$\mu_{\alpha} \cos \delta$	μ_{δ}	p. e.	Intervals
		h m	° ' "			"	"	"	
9352	Hu 575 AB " C	14 38.0 "	+19 55 "	9.5 10.5	M0 M0	-.243 -.262	-.170 -.186	±.006 "	6, 5

Figure 4: Fragment of article from Van de Kamp and DeVilbiss, 1940. **Note:** The electronic documents shown here have been extracted from ADS (Astrophysics Data System) and they are © from the American Astronomical Society.

(Sanders, 1966) where he studies primarily wide M dwarf stars. As he hasn't yet finished his survey, the measurements appear with the Sdr9999 code in the WDS and are waiting to be published in the definitive work. Sanders has an *Unpublished Results File* on the WDS Internet site. We have inspected this file and the value of the distance is 121.7"; therefore it seems that there is no mistake WDS transcription.

Updating parameters

A measurement was made in order to update the relative astrometry using fv 4.0.1 software, a FITS viewer and editor tools developed at the High Energy Astrophysics Science Archive Research Center (HEARSAC) at NASA/GSFC. We used a J band plate from 2MASS dated in 2000.187.

Also, by means of the catalog AC2000.2, we obtained positions in RA and DEC for the epoch 1898.451, which were transformed into Theta and Rho. This new measurement has great historical value due to its antiquity.

Using a DSS plate dated in 1955.359 we obtained a third measurement. We use, again, the software fv as tool of measurement. The results obtained are presented in Table 3.

Our measurements are in agreement with the three historical (Luyten, Hipparcos and Tycho) measurements, this way the Sanders' error is confirmed.

Nature

Several professional criteria of characterization were used to determine if there was or not a physical association between AB and C components. The empirical Aitken's criteria defines it optical. Nevertheless, it is a curiosity that Aitken actually includes it with the code ADS9352C in his own catalog, probably because of the special feature of having similar proper motions and to be a nearby pair, therefore a wide one, with strong possibility of a physical relationship.

The modified J. L. Halbwachs criterion (Rica, 2004) yields a probability of 99% of a physical relationship. The Jean Dommanget (1955), Dimitris Sina-chopoulos (1992) and Wilson (2001) criteria, which were also applied in this study, indicate that LDS968 AB-C is a physical pair.

The other two criteria used, which are of Van de Kamp (1968) and Abt (1988) do not support the previous result.

According to the obtained values we could say that

Date	P.A.	Sep.	Mag. A	Mag. B	N	RefCode	Aperture	Method
1936.	309.	135.	10.6	11.2	1	Luy1969	24	H
1991.25	309.4	135.093	9.77	10.12	1	HIP1997b	54	T
1991.46	309.4	134.972	9.25	10.28	1	TYC2000c	07	T
1996.518	309.2	121.7	.	.	2	Sdr9999	36	A

Table 2: Historical data for LDS 968 AB-C

LDS 968 AB-C: The Distant Companion of HU 575

Source	Epoch	Theta (")	Rho (")
AC2000.2	1898.451	309.414	134.787
DSS	1955.359	309.467	135.027
2MASS	2000, 187	309.595	135.087

Table 3: Measurements made by the author.

LDS968 AB-C could be surely a physical double star. Because not all of the criteria were in total agreement, there is the possibility that it is, only, a common origin pair. The first statement is corroborated by van de Kamp (1939) and later for Miss Lippincott (1960), who measured the parallax and the proper motions of this system. In her own words: *"The agreement of the μ and π values leaves no doubt about the physical connection between AB and C."* We have found, also, another professional work (Upgren and Kuzma, 1983) that makes reference to Lippincott and confirms their opinion. He remarks in his article that *"...their nearly identical proper motion confirms their physical association detected previously by Lippincott."*

Relative proper motion

The annual relative proper motion, that is, the difference between the proper motions of the components, give us the projected relative orbital motion and the velocity of the binary systems. This parameter provides other important criteria for the study of double stars (Hall, 1892).

The historical relative astrometry, in addition to our own measurements are plotted in a X ($=\rho \cdot \cos\theta$) vs Epoch and Y ($=\rho \cdot \sin\theta$) vs Epoch diagrams. A linear fit shows the relative proper motion of C in relation to AB, expressed in arcseconds per year. We can compare our values with those calculated using the individual proper motions of the astronomical literature. If similar results are found, it would indicate that the observed trajectory is in a good agreement with the individual proper motions and gives an idea of the precision of the historical measurements.

The total relative proper motion can also be computed by means of the expression:

$$(\mu_{\text{Total relative}})^2 = (\mu_X)^2 + (\mu_Y)^2$$

According this statement and using our measurements along with the historical data, which cover 102 years, the relative proper motion of the system was calculated: $\mu(\alpha) = -2.3$ mas/yr and $\mu(\delta) = +1.3$ mas/yr. These values are in excellent agreement with those

obtained from the individual proper motions of the catalogue Tycho-2 (-2,3 and +0.5 mas/yr), so LDS968 AB-C is a common proper motion pair. In the calculation we have rejected the 1936 measurement because we think that it has an important error. We believe that Luyten did not measure the pair but simply copied Devilbiss's measurement without doing any checking. The linear regression shows that, for the epoch 1936.0, the values of theta and rho would be approximately 309.43" and 134.91"; therefore, there is a notable difference with Devilbiss's values.

Orbital parameters

If the stars are gravitationally bound, a possible orbital period of about 320,000 years has been calculated by means of the equation (from Couteau, 1960):

$$P = 1656 \frac{(r\rho)^{3/2}}{\sqrt{\Sigma m}},$$

where r is the average distance to the system in parsecs, ρ is the angular separation and Σm is the sum of masses of the components. This last parameter is derived from the expression given by P. Baize (1947) which is based on the mass-luminosity relation (Figure 5)

$$\log m = -0.1117 (M_B - 4.77)$$

where M_B is the bolometric absolute magnitude.

Therefore, the average period is inferred as a function of the separation, the distance in parsecs and the bolometric magnitude of the components.

The completed orbital data gives an expected semi-axis major of 4,620 A.U. (189.07") and a projected separation of 3,301 A.U.

The orbital periods which we have deduced are unusual, but are possible. The astronomer van Biesbroeck (1957) made a study of wide binaries with well-determined parallaxes. The systems that he listed had projected linear separations ranging from 7,500 to 44,000 A.U. This last value represents orbital periods of some ten million years! The projected separation for our system is 3,301 A.U., a value that is not as unlikely as it might seem at first. A typical example such as just described could be the case of the triple system α Centauri: the AB pair has a period of 80.09 years and a semi-axis major of 23.2 A.U. The C component (Proxima Centauri) is distant from the main pair $2^\circ 11'$, that is, 14,000 astronomical units of projected separation, equivalent to an orbital period on the or-

LDS 968 AB-C: The Distant Companion of HU 575

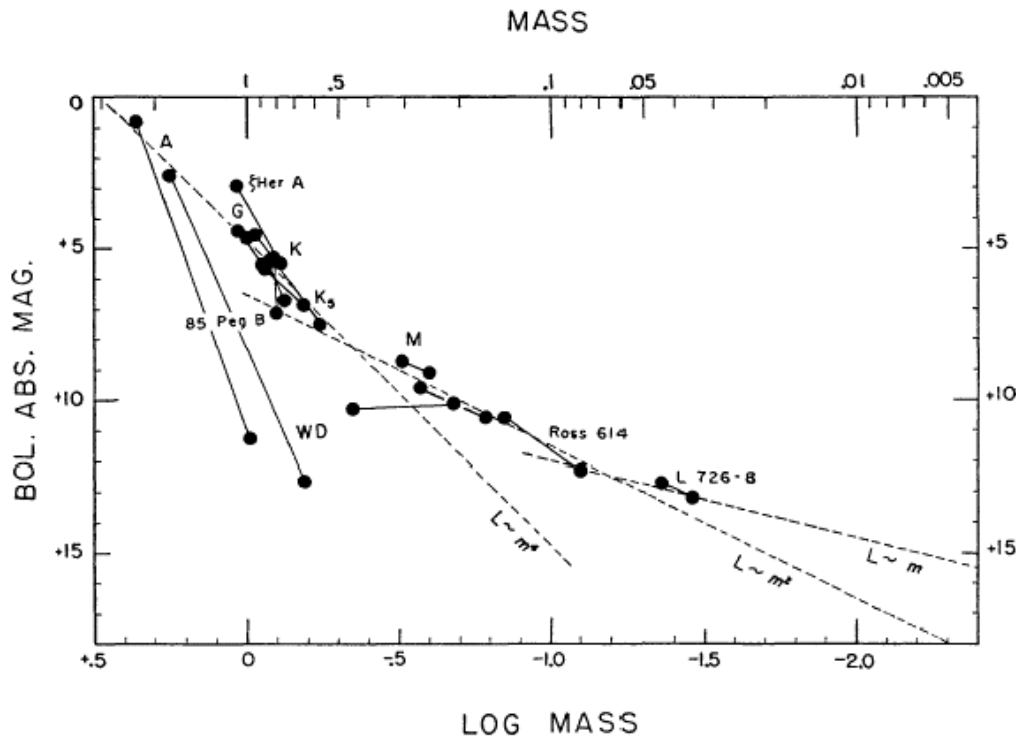


Figure 5: Mass-luminosity diagram for visual binaries (Van de Kamp, 1961).

der of a million years.

Conclusions

This study demonstrates by means of historical documents that the C component (LDS 968 AB-C) of Hu 575 was discovered by Miss DeVilbiss. The attribution of the discovery to Luyten is an error that should be corrected in WDS.

We have detected an error in the Sanders' historical measure (1996.518) for AB-C pair. The value of the separation is not congruent with the other three historical ones.

Using professional catalogs as described in the text, we have updated the relative astrometry for the AB-C pair with three new measurements. Values in 1898.451: 309.414" and 134.787". Values in 1955.359: 309.467" and 135.027". Values in 2000.187: 309.595" and 135.087".

Spectral types and luminosity classes are deduced by using optical and infrared photometry, jointly with the kinematic data (reduced proper motion). Identical K8V spectral types and luminosity classes for the components have been obtained. We think that luminosity classes that we have inferred are an important and new contribution because there are no references

about them in the astronomical literature.

A study of the system LDS 968 AB-C (applying several professional criteria) indicates that it is surely a physical binary star. Orbital parameters have been derived.

This system was included in the 4th Observational Program (October/December 2004) of LIADA'S Double Stars Section.

Acknowledgements

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

This research has made use of data products from the Two Micron All Sky Survey (2MASS), which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center, California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.

This research has made use of Aladin, an interactive software sky atlas allowing the user to visualize digitized images of any part of the sky, to superimpose

LDS 968 AB-C: The Distant Companion of HU 575

entries from astronomical catalogs or personal user data files, and to interactively access related data and information from the *SIMBAD*, *NED*, *VizieR*, or other archives for all known objects in the field. *Aladin* is particularly useful for multi-spectral cross-identifications of astronomical sources, observation preparation and quality control of new data sets (by comparison with standard catalogues covering the same region of sky).

This research has made use of Guide 8.0 astronomical software of Project Pluto.

This research has made use of fv 4.0.1 software, a tool for viewing and editing any FITS format image or table. It is provided by the High Energy Astrophysics Science Archive Research Center (HEARSAC) at NASA/GSFC. The package is available in

<http://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/>

This research has made use of DSS. The Digitized Sky Surveys were produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.

Thanks to Francisco Rica, his comments have been a great help.

Finally, the author is very grateful to Mrs. Teresa Herranz Yuste for her preliminary translation (Spanish-English) of this work.

References

- Abt, H. A., 1988, *Maximum Separations Among Cataloged Binaries*, *Astron. J.*, 331, 922-931.
- Bonnarel F., et al., *The ALADIN interactive sky atlas. A reference tool for identification of astronomical sources.*, *Astron. Astrophys., Suppl. Ser.*, 143, 33-40 (2000) - April(I) 2000.
- Baize, P., 1947, *B.A.*, 13, p.2.
- Bessel, M. S. And Brett, J. M., 1988, *JHKLM Photometry: Standard Systems, Passbands and Intrinsic Colors*, *PASP*, 100, 1134-1151.
- Couteau, P., 1960, *Contribution a l'étude du dénombrement des étoiles doubles visuelles*, *Journal des observateurs*, volume 43, n° 3, p. 52.
- Cutri, R. N. Et al., *Explanatory to the 2 MASS Second Incremental Data Release.*
<http://www.ipac.caltech.edu/2mass/releases/second/index.html>.
- Eric, M. J., 1972, *Reduced Proper Motion Diagrams*, *Astron. J.*, 173, 671-676.
- Gerald, E. K. And Roach, F. E., 1988, *The Distribution of (B-V) in Two Star Catalogs*, *PASP*, 100, 90-96.
- Hall, A., 1892, *Notes on double stars (I) and (II)*, *Astron. J.*, 12.
- Hog, E. Et al., 2000, *The Tycho-2 Catalogue of 2.5 Million Brightest Stars*, *Astron. J.*, 335, 27.
- Martin, V. Z., *Handbook of Space Astronomy and Astrophysics*, Ed. Cambridge University Press, <http://ads.harvard.edu/books/hsaa/>
- Nelson, C. A. et al., 2002, *A Proper Motion Survey for White Dwarfs with the Wide Field Planetary Camera 2*, *Ap. J.*, 573, 644.
- Lippincott, S. L., 1960, *Parallax and orbital motion of HU 575 = ADS 9352 from photographs taken with the 24-inch Sproul refractor*, *Astron. J.*, 65, 383.
- Rica, F. M., 2004, *LIADA's Double Stars Section Circular*, 6 (In Spanish), 23-26.
- Rica, F. M., 2005, *LIADA's Double Stars Section Circular*, 2 (In English), 11-12.
- Sanders, W. L., 1966, *Micrometer measures of wide M-type double stars*, *Astron. J.*, 71, 1008.
- Salim, S., Gould, A., 2002, *Classifying Luyten Stars using an Optical-Infrared Reduced Proper Motion Diagram*, *Ap. J.*, 575, 83.
- Ungren, A. R. and Kuzma, T. J., 1983, *Parallaxes and proper motions. XV*, *Astron. J.*, vol. 88, p. 132-134.
- Van de Kamp, P., 1939, *A distant companion to HU 575 = ADS 9352*, *Astronomical Journal*, vol. 48, iss. 1107, p. 80-80.
- Van de Kamp, P., 1961, *Double Stars*, Publications of the Astronomical Society of the Pacific, vol. 73, iss. 435, p. 395.
- Van de Kamp, P. and DeVilbiss J. M., 1940, *Proper motions of some double stars*, *Astronomical Journal*, vol. 49, iss. 1125, p. 32-32.
- Van Viesbroeck, G., 1957, *Very Close and Very Wide Double Stars*, *Journal of the Royal Astronomical*

LDS 968 AB-C: The Distant Companion of HU 575

Society of Canada, Vol. 51, p.38.

Wenger, M., Ochsenbein, F., Egret, D. Et al., *SIMBAD astronomical database*, <http://simbad.u-strasbg.fr/>

Other General References

The following works, though not specifically cited in this article, were useful to the author and may be useful to the reader.

Aitken, R.G. 1932, *New General Catalogue of Double Stars within 121 degrees of the North Pole*, Carnegie Institution of Washington.

Barton, S.G. 1926, *AJ* **36**, 155.

Burnham, S.W. 1906, *General Catalogue of Double Stars within 121 degrees of the North Pole*, Carnegie Institution of Washington.

ESA 1997, *The Hipparcos and Tycho Catalogues* (ESA SP-1200) (Noordwijk: ESA).

Fabricius, C. & Makarov, V.V. 2000, *A&AS*, **144**, 45.

Fabricius, C., Hoeg, E., Makarov, V.V., Mason, B.D., Wycoff, G.L., & Urban, S.E. 2002, *A&A*, **384**, 180.

Hartkopf, W.I., Mason, B.D., & Worley, C.E. 2001, *AJ*, **122**, 3472.

Hartkopf, W.I., McAlister, H.A., & Mason, B.D. 2001, *AJ*, **122**, 3480.

Hoffleit D., Warren, Jr., W.H. 1991, *The Bright Star Catalogue, 5th Revised Ed.*, (Preliminary Version).

Innes, R.T.A. 1927, *Southern Double Star Catalogue, -19 to -90 degrees*, Union Observatory, Johannesburg, South Africa.

Jeffers, H.M. & van den Bos, W.H. 1963, *Index Catalogue of Visual Double Stars, 1961.0*, Pub. of the Lick Observatory, 21.

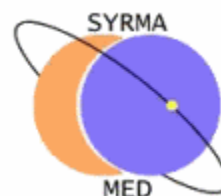
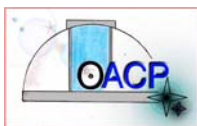
Mason, B.D., Wycoff, G.L., Hartkopf, W.I., Douglass, G.G., & Worley, C.E. 2001, *AJ*, **122**, 3466.

Morlet, G., Salaman, M., & Gili, R. 2000, *A&AS*, **145**, 67.

Worley, C.E., & Douglass, G.G. 1984, *Washington Visual Double Star Catalog, 1984.0*, U.S. Naval Observatory, Washington.

Worley, C.E., & Douglass, G.G. 1997, *A&AS*, **125**, 523

The author observes double stars from his private observatory called Camino de Palomares Astronomical Observatory (OACP). He is coordinator of the Double Star Section of the Syrma Astronomical Society (Syrma-MED), Valladolid, Spain. Mr. Masa contributed an article to the inaugural issue of this journal.



On Line Double Star Resources at the U.S. Naval Observatory

Brian D. Mason

United States Naval Observatory
Washington, D.C.

Abstract: Double Star Resources available through the world wide web from the U.S. Naval Observatory are described in this article.

For over one hundred years the astronomers at the U.S. Naval Observatory (USNO) have made observations, calculated orbits, and maintained catalogs related to double stars. These have led to an assortment of data products and other resources which we maintain and keep online. These resources will be enumerated below, although, exploring the website links on your own is probably the best way to learn what is available.

1. Washington Double Star (WDS)

Catalog

<http://ad.usno.navy.mil/wds/wds.html>

History

The root catalog at the USNO, the WDS was established by Charles Worley in the early 1960s when Lick Observatory double star astronomers were retiring. Worley transferred their Index Catalogue of Double Stars (IDS) and drawers of measures to Washington. The IDS was created from a merger of Aitken's Double Star (ADS) catalog and the Southern Double Star (SDS) Catalogue of Innes and van den Bos. The ADS was the successor to Burnham's Double Star (BDS) Catalogue which was published in 1906. Thus, next year marks the centennial of the publication of the great-grand-catalog of the WDS!

Website

The WDS web site contains both the WDS summary catalog and lists of references and notes associated with it. Measures and systems are constantly being added to the WDS database [figure 1], and programs are run every night to build a new summary catalog. Also on the web site are brief overviews of the data and some statistics associated with them.

Cross references to various other catalogs (ADS and BDS number) are provided as well as explanations when entries in those earlier catalogs have been omitted from the WDS. Various people and groups who, for one reason or another, did not publish their data have electronic listings of their data here. In 2001, lists of "neglected doubles" were prepared for the USNO Double Star CD. These have provided fodder both for our observing programs as well as others. Finder charts are provided for a sample of the arguably easiest resolvable of these as well. The Hipparcos and Tycho

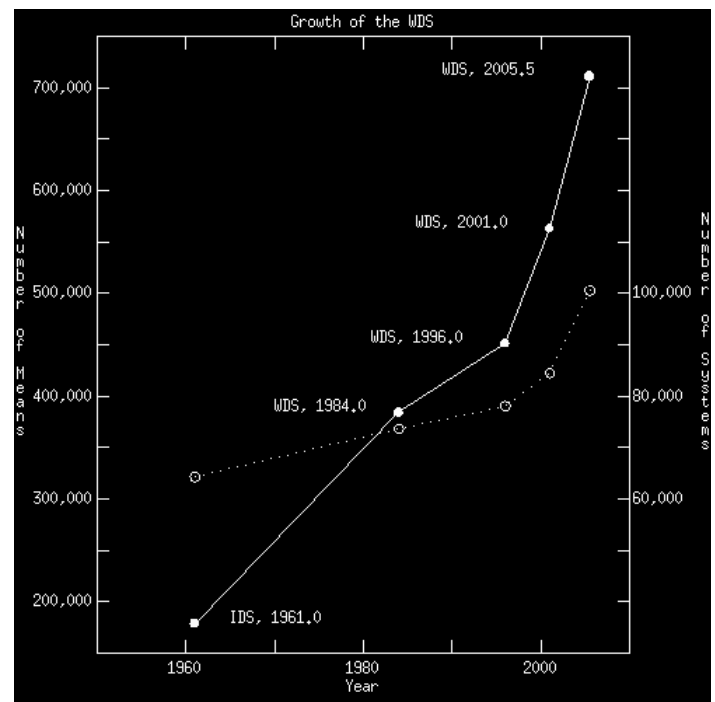


Figure 1: Growth of the Washington Double Star Catalog.

On Line Double Star Resources at the U.S. Naval Observatory

mission was a major source of data for the WDS; lists of doubles discovered by those missions and cross-references to the WDS are also provided. Lists of changes since the WDS, 2001.0 (CD version) are provided (for example, removal of may duplicate discovery designations added by the IDS), lists of well-examined, suspected single stars, and other ancillary files.

Catalog

The WDS catalog, modeled on the IDS style, provides summary information for each measured pair known. An example is given below, along with an explanation of each field. [figure 2]

11182+3132 10 digit approximate position (J2000) of the system primary star. 11 hours, 18.2 minutes RA, +31 degrees, 32 minutes declination. These serve as the shorthand coordinates for all pairs in the WDS.

STF1523AB Discovery and component designation. This is #1523 in the lists of F.G. W. Struve. Since this is designated AB, it indicates that these are (probably) the two brightest stars in a multiple star system. If the "AB" were not provided it would be a simple double star system. This one has additional components.

1780 Date (year) of first observation.

2004 Date (year) of most recent observation.

1530 The number of mean published positions for the pair. Fewer than a dozen systems in the WDS have this many.

144 position angle at "first" date.

245 position angle at "last" date.

3.5 separation in seconds of arc at "first" date.

1.7 separation in seconds of arc at "last" date.

4.33 V magnitude of the primary.

4.80 V magnitude of the secondary.

F9V G9V Spectral types of the primary and secondary. It is rare to have both. Since the WDS is not a catalog of spectral types, this is ancillary data. Many systems have no spectral type information at all.

-454-591 Proper motion in RA and Dec of the primary.

-454-591 Proper motion in RA and Dec of the secondary. Only about 20% of WDS systems have secondaries with a proper motion listed.

+32 2132 Cross-reference for the pair. In this case, BD+32 2132.

NOD Notes columns indicating (in this case) that the pair has a more extensive note in the WDS notes file, an Orbit in the 6th Orbit Catalog, and an entry in the Delta-M Catalog.

111811.2 +313150. Precise position. 11 hours, 18 minutes, 11.2 seconds RA, +31 degrees, 31 minutes, 50. seconds Dec. Unlike the WDS coordinate this lists the precise position of the primary of this subsystem. For example, a CD pair would have the same WDS coordinate but a different precise coordinate. Nearly 95% of WDS pairs have these very precise positions and more are being constantly added.

Future

The WDS will continue to grow, though there are no anticipated format changes in the future. The biggest task on the horizon will be the matching of the WDS with the UCAC3 when it is released and a new "neglected double" list will be prepared soon.

2. Sixth Catalog of Orbits of Visual Binary Stars (ORB6)

<http://ad.usno.navy.mil/wds/orb6.html>

History

The first two Catalogs were published by the great South African visual interferometrist William S. Finsen in 1934 and 1938. In 1963, Charles Worley published a visual orbit catalog and then in 1970 he collaborated with Finsen to produce the 3rd Catalog. In 1983 Charles teamed with Wulff Heintz (the "Swarthmore Orbit Machine") and produced the 4th Catalog. Charles continued working on orbits and had made additions and regrading of orbits, the bulk of which was incomplete at the time of his death in 1997. In 2001, Hartkopf and Mason took Worley's work and produced the Fifth Catalog which appeared on the Double Star CD. Before very long, the online version diverged from this and was dubbed the Sixth Catalog.

Website

One of the features of earlier versions of the visual orbit catalogs was a single number grade (1-5) indicating, very generally, the quality of the orbit. Much of the effort in producing the Fifth Catalog was a labori-

On Line Double Star Resources at the U.S. Naval Observatory

★ WDS frame - Galeon

File Edit View Tab Settings Go Bookmarks Tools Help

◀ Back ▶ ▶ ⏮ ⏭ 🏠 ⓧ Stop 100 🔍

http://ad.usno.navy.mil/wds/wdsnewframe2.html

WDS Identifier	Discover Epoch	Comp	EPOCH Frst Last	#	THETA Fst Lst First Last	RHO	Magnitudes Pri Sec	Spectral Type	Prop Mot RA" DEC"	2nd PM RA" DEC"	DM Desig Note	Precise Coordinate
11179-5914HDS1612	1991	1991	1 124 124	0.2	0.2	7.77	8.01	B9IVp...	-022+006		-58 3433	111753.7 -591411.
11179-5935TDS7779	1991	1991	1 189 189	0.7	0.7	11.58	11.80		-013+003	-013+003		111752.1 -593509.
11180+3951LDS4081	1960	1960	1 74 74	330.0	330.0	14.7	18.8		-127-015			111758.5 +395109.
11181+3617KZA 16	1984	1999	2 330 330	8.1	8.2	11.0	11.5					111804.7 +361614.
11181-6826HDS1613	1991	1991	1 286 286	0.3	0.3	9.08	10.45	A1IV	-018+002		-67 1706	111803.5 -682607.
11182+3132STF1523AB	1780	2004	1530 144 245	3.5	1.7	4.33	4.80	F9V G9V	-454-591	-454-591	+32 2132 NOD	111811.2 +313150.
11182+3132CHR 178Bb	1988	1994	2 104 75	0.1	0.0	4.4			-454-591			111810.9 +313145.
11182+3132POP1219AC	1990	1998	2 314 318	54.3	55.4	4.4	15.0		-454-591			111810.9 +313145.
11182+1638A 2379A-BC	1895	2002	8 52 49	29.7	28.1	10.12	10.36		-011-031	-036-028	+17 2338	111800.4 +163656.
11182+1638A 2379BC	1911	1990	9 257 281	0.4	0.4	11.1	11.6		-036-028	-036-028		D 111802.0 +163716.
11182-2643B 211	1926	1991	6 43 48	1.1	1.1	9.92	11.04	G5	-012-025	-012-025	-26 8477	D 111810.0 -264316.
11182-7258HEI 501	1989	1989	1 243 243	2.2	2.2	11.7	12.0		-016+005			111815.5 -725755.
11183+6858TDS 630	1991	1991	1 240 240	2.0	2.0	11.11	11.36		+030+022	+030+022		111817.6 +685823.
11183+0746HEG 1	1980	1980	1 18 18	0.5	0.5	16.99						111816.9 +074558.
11183-1323HU 129	1900	1985	12 350 240	0.7	0.6	9.5	11.3	G3V	+041-069		-12 3393	D 111816.8 -132330.
11182-5014ETN 182	1922	2000	2 310 208	4.4	4.5	0.1	10.7	A1V	024+005		58 2441	111820.8 -501255.

Done.

Figure 2: Screen shot of WDS catalog from USNO web site.

ous effort to generate algorithms and rules to make the grading more objective. These are all explained in great detail. Also a link to systems deemed sufficient for gross calibration purposes is provided (<http://ad.usno.navy.mil/wds/orb6/orb6c.html>).

Catalog

For each of the 1832 orbits of 1735 systems, ORB6 provides epoch 2000 precise coordinates, WDS coordinate and discovery designation as well as a variety of cross references (ADS, HIP and HD number), and the magnitudes of both components. For the actual orbits we provide the seven classical Campbell elements in their usual units and errors to these values (when provided), the orbital grade (again, 1-5, with 1 = "definitive" and 5 = "indeterminate"), notes to the system, the reference for the orbit, an ephemeris providing predicted positions for the next five years, and a figure providing a visual representation of the orbit overplotted with all WDS data. Systems in the WDS which have entries in ORB6 have an "O" or "C" in the note area of the WDS. There are also pairs in ORB6 which are not in the WDS. These, for example, include orbits calculated from their submotions (astrometric wobble), or baseline-only solutions from long baseline optical interferometry. [See Figure 3 for a screen capture and Figure 4 for an orbit plot.]

Future

In addition to the usual growth, the next major release of the Orbit Catalog will try to resolve some of the pairs with multiple orbits, re-examine the list of Calibration Pairs, and the orbit plot will now show the region where systems are predicted to be over the ephemeris period. This will give a visual representation of whether an orbit pair needs to be observed or not. Future editions will probably also include additional elements for systems with combined astrometric/spectroscopic orbits.

3. Fourth Catalog of Interferometric Measurements of Binary Stars (INT4)

<http://ad.usno.navy.mil/wds/int4.html>

History

The 4th Catalog began as an internal database collecting speckle interferometric measures of double stars made by Hal McAlister and other observers into a cohesive collection. The 1984 Catalog, consisting primarily of photographic data, was replaced by the nearly twice as large Second Catalog in 1988 as CHARA was switching from photographic to ICCD data acquisition. This Catalog was maintained on the web for many years and gained a broader definition of interferometry when lunar occultation measures were added in the 1990s. The Catalog moved from Georgia State University to the US Naval Observatory in 1999

On Line Double Star Resources at the U.S. Naval Observatory

Sixth Orbit Catalog (frames version) - Mozilla Firefox

FileEditViewGoBookmarksToolsHelp

http://ad.usno.navy.mil/wds/orb6/orb6frames.html

Go

MembersWebMailConnectionsBiz JournalSmartUpdateMktplace

Sixth Catalog of Orbits of Visual Binary Stars: Orbital Elements

RA,Dec (J2000)....	WDS.....	DD.....	HD....	*V1...*	pppp.pppppp*	aaa.aaaaa*	iii.iii	000.0000*	TTTT.TTTTT*	e.eeeee	ooo.ooo	EQX	G	N	P	E	REF.....			
ADS	HIP...	*V2...*			+/-	+/-	+/-	+/-	+/-	+/-		LAST								
111551.90+131827.3	11159+1318	MCA 35	97907 55016	5.32 .	8.112 0.0078	y .	0.0462 0.0011	a .	49.1 4.1	283.3 4.4	1974.015 0.028	y .	0.415 0.008	156.5 1.6	2000 1993	4	N	P	E	Msn1997b
111551.90+131827.3	11159+1318	MCA 35	97907 55016	5.32 .	8.00 .	y .	0.042 .	a .	36.7 .	30.6 .	1998.35 .	y .	0.677 .	65.0 .	2000 1993	4	N	P	E	Mnt2002a
111614.98+131618.1	11162+3136	A 2157 ADS 8109	97936 55055	9.02 11.98	619.930 .	y .	1.3822 .	a .	162.85 .	135.96 .	2043.770 .	y .	0.2048 .	286.72 .	2000 1983	5	P	E		Pop1996b
111810.92+313145.1	11182+3132	STF1523AB ADS 8119	98231 55203	4.33 4.80	59.878 .	y .	2.536 .	a .	122.13 .	101.85 .	1935.195 .	y .	0.398 .	127.94 .	2000 1994	1	N	P	E	Msn1995

Ephemerides



WDS	Name	Grade	Reference	Theta 2005	Rho 2005	Theta 2006	Rho 2006	Theta 2007	Rho 2007	Theta 2008	Rho 2008	Theta 2009	Rho 2009
11159+1318	MCA 35	4	Msn1997b	314.9	0.039	36.9	0.021	127.0	0.028	197.6	0.031	238.7	0.046
11159+1318	MCA 35	4	Mnt2002a	320.3	0.038	17.3	0.020	206.6	0.030	236.5	0.049	252.5	0.058
11162+3136	A 2157	5	Pop1996b	244.2	1.087	243.3	1.085	242.4	1.083	241.5	1.081	240.6	1.079
11182+3132	STF1523AB	1	Msn1995	245.5	1.746	239.2	1.706	232.6	1.668	225.6	1.636	218.5	1.615
11182+3132	STF1523AB	0	Msn1995	25.2	0.022	265.0	0.078	225.5	0.006	263.6	0.072	225.5	0.029

Find: STF152

Find Next

Find Previous

Highlight

Match case

Done

Figure 3: Screen shot of Sixth Orbit Catalog (ORB6) from USNO web site.

and soon included data from the WDS under a broader characterization of "high resolution." This includes interferometry, lunar occultation, adaptive optics, satellite observations, and others. Since its origin, the Catalog has contained measures of double stars as well as stars examined for duplicity but were unresolved. It contains over 165,000 observations of more than 47,000 pairs and almost 20,000 never resolved stars. Unlike the WDS this is a comprehensive listing of the measures, not a summary catalog.

Website

The 4th Catalog Website contains various statistical parameters regarding the data, references, and links to all the individual data files, in 1-hour right ascension bands.

Catalog

Each system has an identification line which lists the WDS coordinate and Discovery Designation as well as other cross-identifications, such as HD or HIP number to help identify the system. The data lines are similar to the WDS, but contain additional fields for errors when those are provided as well as information about the filter used for collecting the data.

Future

There is a plethora of new interferometric data from long baseline optical interferometers which have measures of the baseline and visibility, but not

the classical position angle and separation. Finding a way to incorporate these data will be quite a challenge.

4. Second Photometric Magnitude

Difference Catalog (DM2)

<http://ad.usno.navy.mil/wds/dm2.html>

History

The Delta-M Catalog owes much of its genesis to the work of G.P. Kuiper. In the early to mid-part of the 20th Century Kuiper discovered many close companions to bright doubles and began a long process of analyzing the multiplicity characteristics of different spectral and luminosity classes. One of Kuiper's conclusions was that the expected separation-delta-m space for wider, larger delta-m systems was under-represented. In the middle of the century significant work was initiated to measure the magnitude differences, but not the separation with a variety of specialized instruments (e.g., comparison image micrometers, wedge photometers, double-image and polarizing photometers, area scanners and other methods. Charles Worley, in his perusal of archival publications in the USNO library, collected these in the unpublished, but privately circulated, Delta-M catalog. When the USNO Double Star CD was pressed in 2001 this catalog was included. Since 2001 additional measures of Delta-m have been added as well as the extraction of estimates

On Line Double Star Resources at the U.S. Naval Observatory

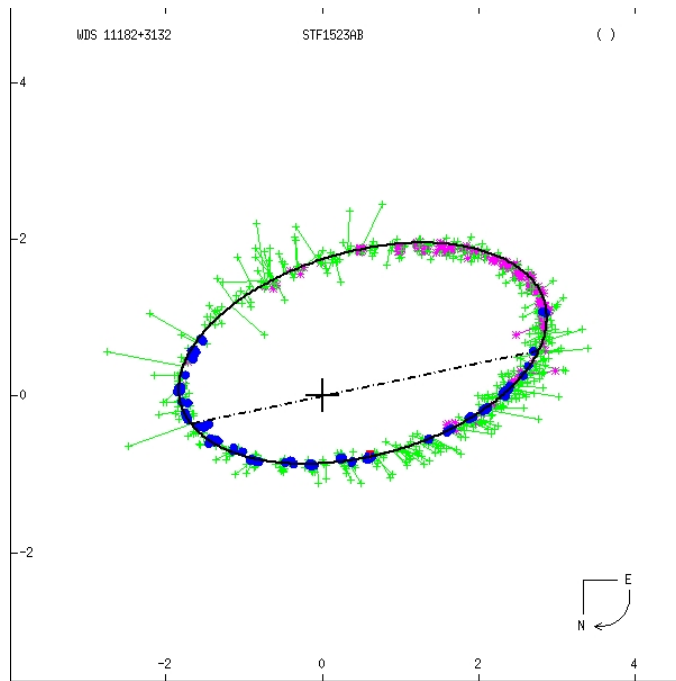


Figure 4: Representation of apparent relative orbit of STF1 523 AB plotted by ORB6.

of this quantity contained in the WDS.

Website

The website contains a link to the catalog, references, and a descriptive key of the types of methods as well as the number and mean delta-m of the measures made by the various methods.

Catalog

Unlike the WDS, the Delta-m Catalog is not a summary file but a line by line listing of all delta-m measures. It contains over 79,000 individual measures of over 31,000 different systems. Systems in the WDS which have measures in the Delta-m Catalog have a "D" in the note area of the WDS. There are also pairs in the Delta-m Catalog which are not in the WDS. These, for example, include pairs measured by lunar occultation which have no differential measure of position angle and separation --- lunar occultation pairs are detected, not resolved.

The delta-m Catalog contains the following information:

11182+3132 10 digit approximate position (J2000), as the WDS.

STF1523AB Discovery and component designation, as the WDS.

0.40 Mean magnitude difference.

1 Number of measures contained in the mean.

TtB2000 Reference (keyed to the reference file) from which the measure was extracted.

U Method (keyed to the method file) of the technique used for the measure. The previously unique Delta-m method file and WDS method file, are now the same.

free form data Following the listing of methods is a wide free form column which can contain a variety of information, for example, the central wavelength and FWHM of the filter used for the measure, the error of the measure, whether or not it was extracted from the WDS, notes that the measure is uncertain, one (or both) of the components is variable or not in the WDS, when the data was taken, etc.

Future

While the 2MASS Catalog has been matched with the WDS, we've yet to extract the JHK delta-m values from 2MASS.

5. Double Star Library

<http://ad.usno.navy.mil/wds/dsl.html>

This is the official web page of Commission 26 (Double and Multiple Stars) of the International Astronomical Union (IAU). Three times since the inception of Commission 26 (C26) USNO astronomers have served as president of the Double Star Commission [Kai Strand (1964-1967), Charles Worley (1994-1997), William Hartkopf (2003-2006)]. The Double Star Library has been maintained by the current president for over a decade. It includes membership lists of C26, copies of the more recent (since 1993) Circulars of the Commission, and other C26 and IAU related links. Also included are links to national and international meetings related to binary star research, bibliographies of double star papers over the past several years in professional journals, and links to USNO and other double star catalogs and organizations.

On Line Double Star Resources at the U.S. Naval Observatory

6. Double Star Astronomy at the U.S.

Naval Observatory

http://ad.usno.navy.mil/wds/ds_history.html

This was started simply as a site for the Obituary of Charles Worley in 1998. Gradually it collected other information, statistics, photographs and anecdotes about USNO double star astronomers over the years. Generally the website divides the USNO work by method arranging them by micrometry, photography, speckle interferometry, and WFC catalog extraction. Each of these fields has a narrative describing it, a list of USNO astronomers who collected data this way and their contributions to the WDS, photographs from the USNO archive of them as well as related notes. While discovery of new pairs has never been a priority, some of these, as well as the circumstances of their discovery, are enumerated as well. The site also contains USNO contributions to several historically important systems, and obituaries, minor planet announcements, and other supplementary documents related to various USNO astronomers.

7. Washington Multiplicity Catalog (WMC)

<http://ad.usno.navy.mil/wds/newwds.html>

Historically, double star data were taken visually, spectroscopically, or photometrically, and while some overlapped, the fields were generally separate. Over the past decades the synergy between techniques has increased and a Multi-Commission meeting was held at the IAU General Assembly in Manchester in 2000 "whose AIM [was] to develop a simple, unambiguous, flexible, and computer friendly

designation scheme for stellar companions (including planets)." Several schemes were put forward and it was decided at that time to try the WMC scheme. A half hour band of the sky was prepared and presented at various commission meetings and at a Special Session during the IAU General Assembly Meeting in Sydney (2003). At that time a Working Group was established to produce an all-sky WMC. It is planned to present this at the IAU General Assembly in Prague (2006). The website archives discussions related to these topics and has an online sample WMC for the 1/2 hour band. To see the sample WMC go to http://ad.usno.navy.mil/wds/wmc/wmc110_intro.html.

8. Linear Elements Catalog

(coming soon, no link yet)

There is no link to the Linear Elements Catalog, but this will be included in the next Double Star CD. The WDS, in the column for "O" (i.e., Orbit) has, for ~1500 systems, an "L" indicating a linear solution has been calculated. These pairs with different proper motions are optical pairs that only appear near each other in the sky. The least-squares solution of the linear fit will include the time, position angle, and separation at closest (apparent) approach as well as a differential proper motion in RA and Dec. Figures will be provided which illustrate the quality of the fit. The ephemeris of these systems can possibly provide calibration of a quality greater than that for the Calibration Quality Orbits, described above. In some cases, orbital motion can be seen in the linear fit due to motion of one which is not strictly linear. Some systems, as mentioned above, carry a "C" code in the appropriate motion column indicating it has both an orbit and



Journal of Double Star Observations

Summer 2005
Volume 1, Number 2

Editors

R. Kent Clark
Rod Mollise

Editorial Board

Justin Sanders
William J. Burling
Daniel LaBrier

Advisory Editor

Brian D. Mason

The *Journal of Double Star Observations* is an electronic journal published quarterly by the University of South Alabama. Copies can be freely downloaded from <http://www.southalabama.edu/physics/jdso>.

No part of this issue may be sold or used in commercial products without written permission of the University of South Alabama.

©2005 University of South Alabama

Questions, comments, or submissions may be directed to rkentclark@jaguar1.usouthal.edu or to rmollise@aol.com

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.

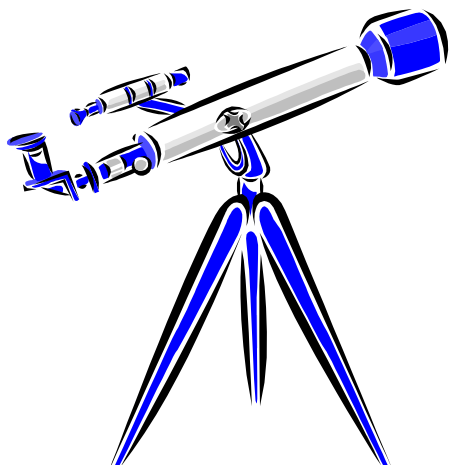
Not all articles will undergo a peer-review. Articles that are of more general interest but that have little new scientific content such as articles generally describing double stars, observing sessions, star parties, etc. will not be refereed.

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 www.southalabama.edu/physics/jdso.

Submissions should be made electronically via e-mail to rclark@jaguar1.usouthal.edu or to rmollise@aol.com. Articles should be attached to the email in Microsoft Word or text format. All images should be in jpg or fits format.

Correction

In the Spring 2005 issue, in the table of data on page three a number was inadvertently omitted. On line 3, column labeled "N", there should be a "1". The omission has been corrected in the online version currently posted on the JDSO web site. We apologize for this error; the fault is entirely ours, and not the author's.



We're on the web! <http://www.southalabama.edu/physics/jdso>