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McAlister/Hartkopff

Report from Prague

Last summer's IAU meeting in Prague got a lot of attention in the popular media because of the decision to demote Pluto. Of course, there was a lot more astronomy than just arguing about Pluto's status.

In this issue, Bob Argyle gives us a a review of the many double star activities reported on at the meeting. He tells us that the level of participation was very high, indicating an increased importance put on double star research. Read his complete report beginning on page 2.

Inside this issue:

Double Stars in Prague

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The recent IAU General Assembly in Prague (2006 Aug 13-25) has gone down in history as the meeting at which it was decided to eject Pluto from the elite family of Solar System planets. However, for the double star observer, there were much more interesting gatherings to attract the attention. During the latter half of the second week, the main event was the first joint Symposium for both the wide and close binary fraternity - Symposium 240 was held in Meeting Hall I and attracted about 200 regular attendees to the three and a half days of varied and stimulating talks.

Before this however, on the previous Thursday, Commission 26 (Double and Multiple Stars) had held its Business Meeting in which members reported on work carried out over the last 3 years. As always this started with a list of deaths over the preceding triennium. This year was particularly noteworthy, including as it did, Geoff Douglass and Dick Walker from USNO and Wulff Heintz from Swarthmore. On the positive side though 27 new members had joined, making a total increase of 50% over the past 6 years. This was followed by progress reports from various institutions and groups. A photograph of Commision 26 members is shown in Figure 1.

Figure 1: Commision 26 members at Prague. Photo by McAlister/Hartkopff.

At the suggestion of Brian Mason, and with the help of Kent Clark, I gave a short talk on the activities of amateur double star groups around the world, concentrating on the work of the Webb Society and the JDSO. In addition, the poster board contained a summary of the activities of the Liga Iberoamericana de Astronomia by Francisco Rica Romero, well-known to readers of this bulletin (and which can be found at the following website: http://www.lanzadera.com/estrellas_dobles_LIADA.htm). Francisco, unfortunately, was not able to attend the Prague meetings. Another poster of interest concerned the work of the Double Star Section of the Societe Astronomique de France. It was authored by Edgar Souliè who did come to the Symposium. Figure 2 summarizes amateur contributions from various sources.

The Webb Society Double Star Section, although founded in 1968, did not start producing instrumental measurements until the early 1980s using objective grating micrometers and again towards the end of that decade when commercially available filar micrometers began to appear, firstly from Ron Darbinian in California, then the RETEL in the UK. At pre-

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sent the RETEL is still available and until recently, it was also possible to buy one from van Slyke (the current instrument uses a reticle - see http://www.observatory.org/bfm.html). The Meca-Precis double-image micrometer is also still available in France (e-mail: mecaprecis36@wanadoo.fr). Whilst some filar measurement is still being done by Webb Society members, most of the work is concentrated on CCD imaging and astrometry from archival Schmidt plate surveys using such tools as Simbad and Aladin. In the period 2003-2006 members made 7716 measurements using the methods outlined above (the breakdown here is 24% micrometry, 13% CCD astrometry and 63% from archives). Until now, observations have been printed annually in the Section Circulars but from Circular 15 this will be in electronic format and plans are being made to put the previous Circulars on the Society website.

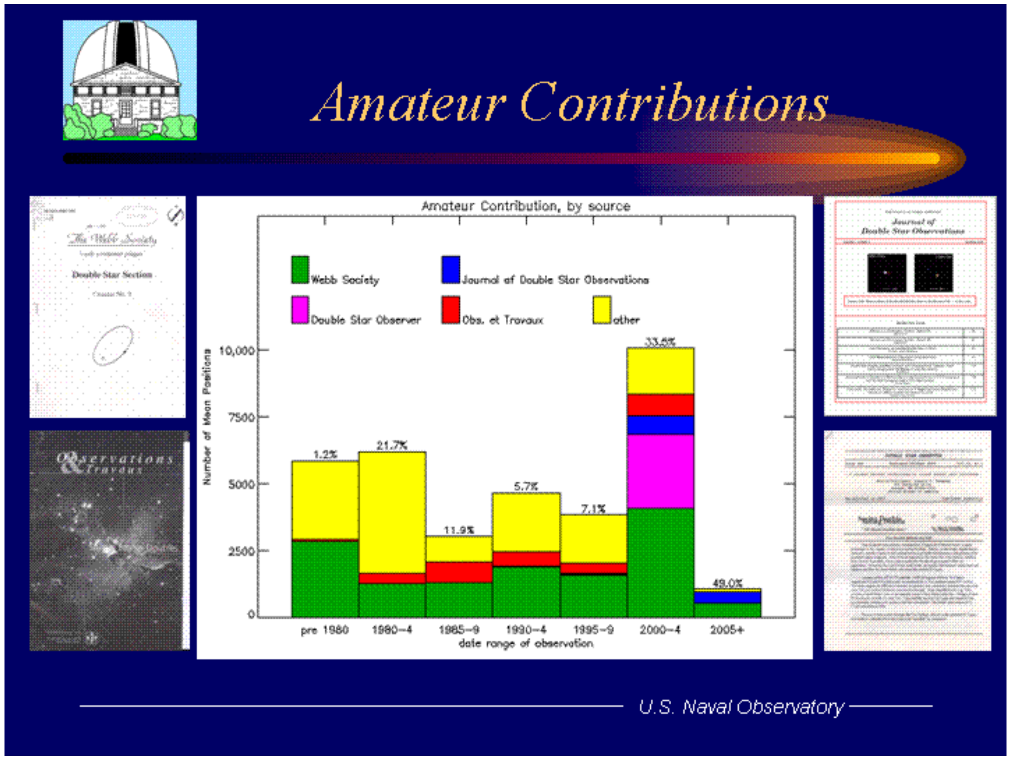

Figure 2: Slide from BDM talk at IAU 240 - Amateur Contributions

The JDSO which started in 2005, is the successor to the Double Star Observer, founded by Ron Tanguay and which ran between 1993 and 2005. It contains contributions of both research and general interest and is partly peer-reviewed. Dr. Brian Mason from the USNO became an Advisory Editor in summer 2005. JDSO is an freely accessible electronic publication, and a typical issue is between 1 and 3 MBytes - which averages out at about 40 pages. The main observers are David Arnold (578 measures using a 290-mm SCT and reticle eyepiece) and James Daley (measures of 207 pairs using a 9-inch OG and SBIG ST7 CCD). The main thrust of the observations is to re-examine pairs on the WDS neglected pairs list and add some modern measurements to the catalogue. Brian Mason, in his talk at the Symposium pointed out that relative positions, and from these proper motions, of wide pairs can be more reliable than "instantaneous" determinations of proper motion such as those determined by Hipparcos simply because of the leverage afforded by the long time scale. The situation regarding neglected doubles was summarized by Brian in Figure 3.

Counter-balancing the observational side, Francisco Rica Romero contributes some astrophysical investigations. The observations by Rainer Anton in the Summer 2006 issue highlight the lack of measurement in the southern hemisphere where even bright binaries, such as beta Phoenicis and delta Velorum, are passing through a critical orbital phase largely unobserved. Another productive center is the Garraf Observatory in Spain. The work of Tófol Tobal on neglected pairs has resulted in more than 4000 measures being made - these can be found on the WDS website.

During the second week, an evening Pro-Am meeting had been arranged at the nearby Faculty of Maths and Physics. I repeated the talk given earlier at C26 and the other speakers included Edgar Souliè, President of the Double Star Section of the Sociètè Astronomique de France who described the work being done in that country. The other speakers talked about variable stars, and included Arne Henden from the AAVSO and Katarina Olah from Konkoly Observatory, Hungary. It is clear that there are many active Czech amateur astronomers (for instance, Kamil Hornoch was awarded a prize at the General Assembly for his work in finding previously unknown novae in M31

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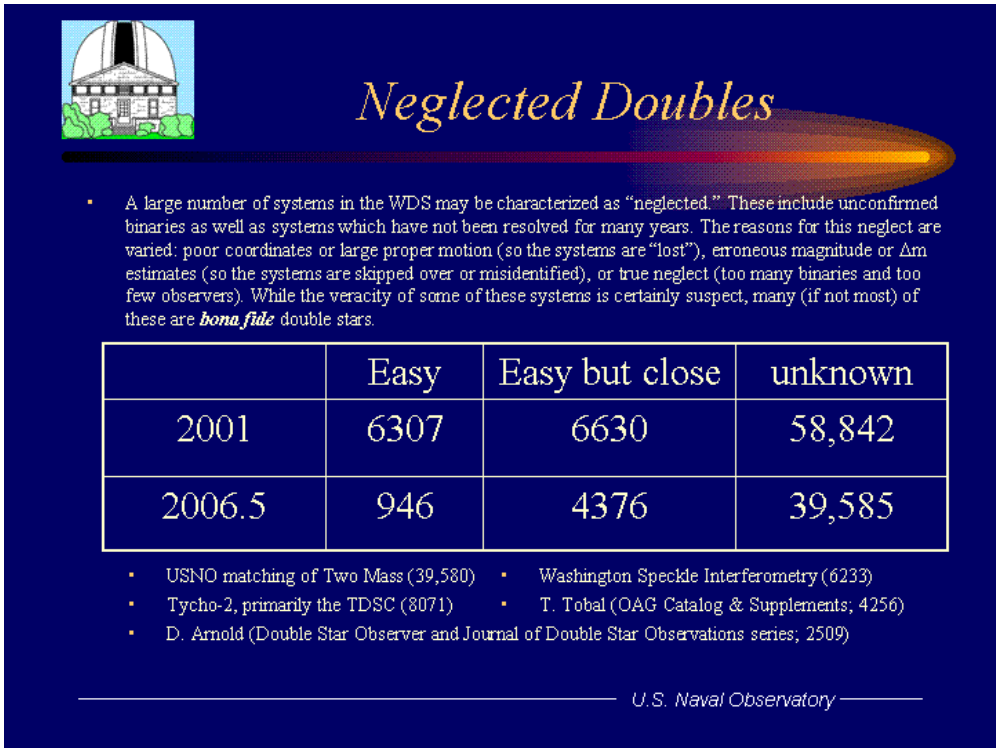

Figure 3: Slide from BDM talk at IAU 240 - Neglected Doubles.

from archive images) but none yet appeared to be involved in double star astronomy.

The last meeting of the General Assembly was Symposium 240 entitled `Binary Stars as Critical Tools and Tests in Contemporary Astrophysics'. The first morning was given over to invited reviews including summaries of the current state of long baseline optical interferometry in the northern and southern hemisphere given respectively by Harold McAlister and John Davis. Professor McAlister briefly described the history of stellar interferometry noting that Michelson's pioneering instrument fitted to the 100-inch Hooker reflector early last century would be on display at the American Musuem of Natural History in New York City from next year. He then went on to describe the contributions of instruments such as the Palomar Testbed Interferometer, the Navy Prototype Optical Interferometer (NPOI) on Anderson Mesa in Arizona, the no-longer operational Mark III instrument, and COAST at Cambridge in the UK. In the northern hemisphere, the next stage will be the full operation of the Keck Interferometer, using both 10-meter telescopes and the continuing development of the CHARA array on Mount Wilson with which the speaker was intimately familiar having played a major role in its proposal, design and construction. CHARA has six 1-meter telescopes and all are now in operation. The array is already producing some fascinating science and the possibilities are very exciting. With baselines of a few hundred meters, binaries as distant as 20 pc with periods of a few hours will be resolvable. The current program includes the direct measurement of stellar diameters of stars such as Vega, Regulus, delta Cephei, and nearby red dwarfs, and the resolution of double-line spectroscopic binaries in collaboration with spectroscopists Frank Fekel (Tennessee State) and Jocelyn Tomkin (Texas)

In the south, Professor John Davis (Sydney) recounted the early attempts at stellar interferometry from Narrabri where interferometric and spectroscopic data were first combined in an analysis of the 4 day pair alpha Virginis (Spica). Now the Sydney University Stellar Interferometer (SUSI) has taken over where the Narrabri instrument left off and is pursuing bright double-line binaries such as beta Cen and lambda Sco. In Chile the VLTI will use four of the VLT telescopes with a baseline of 130 meters and in combination with four 1.8-metre outrigger telescopes the baseline can be increased to 202 meters. A number of instruments have been designed to handle this data. VINCI is a test instrument designed for the K band, whilst MIDI operates in the N band (7 - 13 micron) and is thus extremely powerful for looking at circumstellar material as well as pre-main sequence binary stars. AMBER is being used to look at massive hot binaries such as gamma2 Velorum where a late O giant or supergiant is combined with a WC8 star. Both AMBER and SUSI data put the system at a significantly greater distance than that derived by Hipparcos.

Brian Mason, in his talk on "Classical observations of visual binaries and multiple stars", described the growth of the WDS and pointed out areas in which the amateur has done and can do something to help. These include identification of missing pairs, and de-

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termination of parameters which are unknown - there are many components, for instance, with no magnitudes and only 38% of the catalogue currently has proper motions. During the last few years the amateur contribution to the WDS has been a significant part of the work. Figure 2 shows how amateur contributions to the WDS have been made. Pre-1980, the small percentage was mainly due to the great observers such as Dembowski and Baize but from 1980 as interest grew so the amateur contribution became more significant. The rather small fraction between 1990 and 2000 was mostly as a result of a very large influx of data from large surveys such as Hipparcos, Tycho, 2MASS and the UCAC catalogues from USNO - numbering about 150,000 additional observations in all. From 2000 onwards the amateur work is a very significant proportion of the annual contributions.

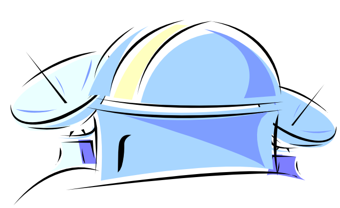
An example of the innovative approach of the amateur was the observation of the faint comites C and D close to Polaris, described by James Daley in JDSO Vol. 2 No. 2, page 51. As it happens, Nancy Evans later argued that these are not physical companions, because their age precludes that interpretation. She did present evidence for a close companion to Polaris of V=9 at a distance of 0.14 arc seconds from HST ACS observations. This is thought to be the 30-year spectroscopic component.

It would take too much space to include notes about all of the interesting talks heard at Symposium 240 but here is one which gave me food for thought. Attempts are now being made to detect exoplanets by measuring the wobble which they inflict on the parent star. This is done by measuring the separation of two stars with time. Using the NACO near-infrared adaptive optics facility on the VLT for example, it is possible to do this with phenomenal precision. The example given was the double star HJ 663 whose mag 5.0 primary (HD 19994 = 94 Cet) has a planetary companion with a period of 454 days. The mag 11.0 stellar companion appears to be in orbital motion and the distance has been closing since discovery in 1836 when it was 5.0 arc sec. The quoted separation for the epoch of observation was 2347.652 mas ± 91 microarcsecond!

A meeting about double stars, of this size and length, at an IAU General Assembly is unprecedented and represents a major increase in the perception of the importance of this subject. The proceedings of the meeting are being edited by Bill Hartkopf from USNO, Ed Guinan (Villanova University) and Petr Harmanec (Ondrejov Observatory, Czech Republic) and will be published by Cambridge University Press in the next 12 months or so. There were about 180 posters in addition to the invited talks.

I am grateful to Brian Mason for permission to use two of the graphs from his talk.

Bob Argyle has been observing visual double stars for almost 40 years, and has been Director of the Webb Society Double Star Section since 1970. He has been making micrometric measurements using an 8-inch refractor since 1990 and edited "Observing and Measuring Visual Double Stars" which was published by Springer in 2004.



An Interesting Stein Double-Double Pairing

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Abstract: Report on the observation of the double double pairing of two Stein discoveries in Cygnus. Each of the component pairs (STI9001 and STI2471) were discovered by Johan Stein in 1903 and 1909 respectively.

Introduction

While collecting data on neglected double star systems in Cygnus, I encountered what initially appeared to be a duplicate reading for STI2471 on my Cartes du Ciel sky chart. The chart indicated that STI2471 and STI9001 occupied the same location and extremely close theta and rho values. Upon imaging the area I was delighted to discover that both pairs did exist and formed a very nice parallelogram (See Figure 1). My first thought was that I was seeing some type of imaging ghosting as the relative alignments and separations were so close to each other. Repeated images provided the same view so I left the comfort of my computer and headed outside to examine the telescope and camera.

On arriving at the telescope, I noted it was close to zenith and the sky was clear and steady. The optics were free of any condensation or frost so it was time to confirm my image visually. I removed the camera and replaced it with a 15mm WA

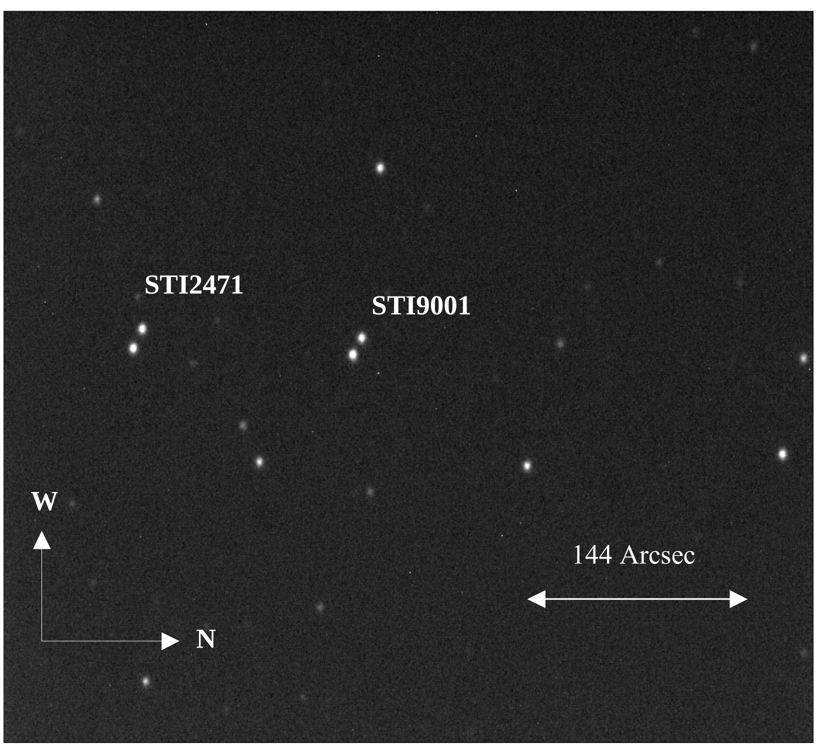

Figure 1: Image of the double-double, STI2471 and STI9001.

providing 163X magnification. It is important to note that my skies are dominated by light pollution (the reason why I selected double stars as my main subject of observations). Given that and my recent emergence from a well-lit house, my visual limiting magnitude was rather limited (at zenith I could just make out 4.5 magnitude stars). As a result my first view through the eyepiece provided a starless field. It always amazes me how much more the camera can grasp with only an 2 second exposure. After taking this into account I used averted vision and spied an intermittent glimpse of the two pairs. Bumping the magnification up to 246X with a 9.9mm orthoscopic eyepiece along with my steadily improving night vision afforded me a solid view of the two binary systems. My camera had not lied as they appeared clearly as four blue points of light of close to the same magnitude aligned in a beautiful parallelogram shape.

Methodology

Using data from the WDS, the Two Micron All Sky Survey, and my observations utilizing an RCX400 12" telescope in concert with a DSI Pro II (providing

WDS ID	Disc ID	Yr Disc	Yr Ob	# Ob	Theta	Rho	Mag 1	Mag 2	Notes
19531+5432	STI9001	1903	1903.6300	1	136.20	14.289	11.8	12.4	Note 1 PA 180 deg off (316.20)
19531+5432	STI9001	1903	1909.7500	2	131.70	13.800	11.8	12.4	PA 180 deg off (311.70)
19531+5432	STI9001	1903	1909.7600	3	131.60	13.725	11.8	12.4	PA 180 deg off (311.60)
19531+5432	STI9001	1903	1999.9000	4	117.00	11.870	11.8	12.4	Note 2 PA 180 deg off (297.00)
19531+5432	STI9001	1903	1999.9030	5	298.40	10.377	11.8	12.4	2MASS
19531+5432	STI9001	1903	2006.6816	6	299.04	10.881	11.8	12.4	
19531+5430	STI2471	1909	1909.7500	1	331.00	10.900	11.4	11.8	
19531+5430	STI2471	1909	1999.9030	2	296.20	11.929	11.4	11.8	2MASS
19531+5430	STI2471	1909	2006.6816	3	295.53	12.053	11.4	11.8	
19531+5431	STI9001/ STI2471	2006	1999.9030	1	357.40	155.000	11.4	11.8	2MASS
19531+5431	STI9001/ STI2471	2006	2006.6816	2	357.95	142.148	11.4	11.8	Waverly Observatory

Table 1: Historic data and new measurements of STI9001 and STI2471.

Notes

1. STI9001 is a renaming of STI2471a. This information taken with the readings of its corresponding pair STI2471 on 1909.7500 by Stein would lead me to conclude that he was aware of the double double nature of these stars. Such a view is in keeping with Stein's use of photographic plates to collect images of double stars for reduction. Despite this apparent awareness he did not take any theta or rho readings between the two pairs.
2. This reading looks like it may have been mistakenly taken of STI2471. The values appear to be closer to those obtained from the Two Micron All Sky Survey data taken in the same year for STI2471. Theta is 1.40 degrees and rho 1.493 arcsec less than the 2MASS readings for STI9001. By comparison, theta is 0.80 degrees and rho 0.059 arcsec from the 2MASS readings for STI2471.

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0.71 arcsec per pixel) I have prepared a table (Table 1) of all the known readings for STI2471, STI9001, and the discovery SOO 12. The Two Micron All Sky Survey data was reduced using the online Aladin software, while my images were reduced using Reduc software.

References

I. The Washington Double Star Catalog

II. "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."

III. James A. Daley, “Notes on the Double Stars of Father John W. Stein, S.J.” Journal of Double Star Observations Vol.2, No.4, Fall 2006.

Acknowledgements

The author would like to thank Dr. Brian Mason of the USNO for supplying the historical data on these systems.

Observations of Select Neglected Double Stars

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Abstract: Measurements of four neglected doubles in the USNO Northern list, set I1 were measured using a 105mm refractor and the Celestron/Baader 12.5mm Microguide eyepiece. All Observations were made at the Brookside Astronomical Observatory (BAO), Edmonton, AB Canada: 53.492°N, 113.569°W, elev. 660m.

The equipment used for these observations is a Stellarvue 105mm f/6.2 Apochromatic refractor, with a 2.5x Powermate and 12.5mm Celestron/Baader Microguide eyepiece.

The stars chosen in this report are taken from a subset of the master northern list of neglected multiple stellar systems for in the Washington Double Star (WDS) list of neglected stars published by the USNO[2]. The stars observed were: HJ 1022, BOT 3-AC, H 624-AB, and H 624-AC.

Method

The equipment system used was calibrated using the sidereal stellar drift method on the target star alpha Aquilae (Altair). Seven (7) drift timings were performed in succession, and the mean was found to be 12.85" ± 0.25% per scale division (SD). Position angle (PA) and separation measurements were made using the similar methods to that developed by Tanguay[3] and Teague[4].

First, the reticle was aligned by verifying that the stars which were to be measured were parallel to the inner calibrated measuring scale. Readings for the separation were read to the nearest 1/10th of a scale division, whenever possible, and confirmed three times before continuing. A mean of the three measurements was taken, before measuring the position angle. The primary was then re-centered, as necessary, such that it was in the center of the reticle's scale and field of view. Tracking of the equatorial mount was then turned off, allowing the natural sidereal drift of the target primary star until it reached the protractor scale on the reticle eyepiece. Position angles were determined by subtracting 90° from the readings on the inner scale, which was has markings every 5°, and is precise enough to get angles within about ½°. Duplicate PA drift measurements were taken and a third measurement and mean of all readings were determined in cases of ambiguity.

Several calibration stars were used to confirm the accuracy of the measurement system. All test measurements were with 1% of published values for separation distance and 0.5° of published position angles, before attempting the measurements made that are reported in this report.

Results of the measurements are given in Table 1.

Acknowledgments

The author wishes to gratefully acknowledge the use of the data for this report kindly provided by Brian Mason and his team of the US naval Observatory. The author also wishes to thank Mr. Thomas Teague, whose kind and timely input on format and guidance in the preparation of this first report by the author was very helpful.

References

Mason, Brian D. et al, US Naval Observatory. List of neglected northern double stars, Northern List, Set I.

Mason, Brian D. et al, US Naval Observatory. List of neglected northern double stars, Northern List, Set III.

Tanguay, Ronald C. "Observing Double Stars for Fun and Science", Sky & Telescope, http://skytonite.com/observing/doublestars/3304341.html

Teague, Thomas: "Double Star Measurement Made Easy", Sky and Telescope, July 2000, page 112-117.

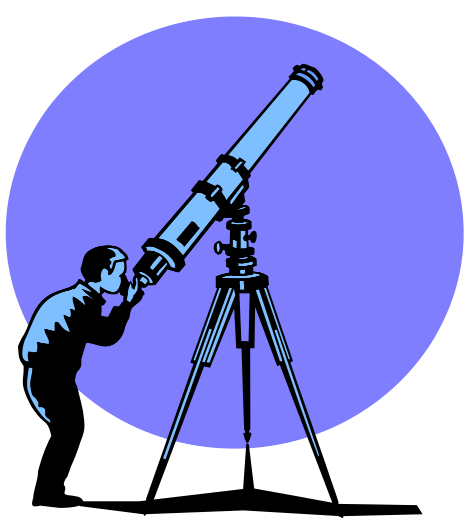
Observations of Neglected Double Stars

Name	J2000 RA+Dec	WDS Mags	PA (deg)	Sep (as)	Date	N	Notes
HJ 1022	00231+5146	5.8, 6.1	35.5	6.4	2006.620	2	1
BOT 3 AC	19455+3500	6.1, 8.5	24.5	38.6	2006.620	2	2
H 624 AB	23245+6217	5.2, 9.9	226.0	96.5	2006.623	1	3
H 624 AC	23245+6217	5.0, 8.7	258.0	215.2	2006.623	1	4

Table 1: Results of the double star measurements.

1. Notes:
2. 1. Neglected double, last obs. 1983; duplicate observations, spaced 1h apart.
3. 2. Neglected double, last obs. 1958; duplicate observations, spaced 1h apart.
4. 3. Not neglected, last obs. 2001; updated observation for 2006.
5. 4. Neglected(?), last obs. 1917; updated observation for 2006. H 624-CD not attempted.
6. All observations made with a SV105 f/6.2 APO Refractor, 12.5mm Celestron Microguide, 2.5x Powermate; 12.85" per scale division, on a Celestron ASGT mount. Seeing 4/5, Trans. 4/5.

The author has a Masters degree in physical chemistry and is currently working in quality control for a local GMP natural products pharmacology company, BioPak. He has been an amateur astronomy enthusiast with over 33 years of observing experience. He has designed several optical filter systems for use with amateur telescope equipment, and done some optical research and development in the recent past. He has logged over 15,000 total hours in the span of his lifetime, observing various deep sky objects, clusters, planets, and double stars.



Observation Report 2003-2004: Humacao University Observatory

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Abstract: We report on measurements of position angle and separation of binary stars obtained using a CCD camera coupled to a 31 inch telescope. The images where obtained in the fall of 2003 and the spring and fall of 2004.They where analyzed at the Humacao University Observatory afterwards as part of the ongoing research project on binary stars.

Introduction

This report includes measurements of separation and position angle of binary stars gathered from CCD images obtained using the National Undergraduate Research Observatory (NURO) 31 inch telescope in the fall of 2003 and the spring and fall of 2004. The Humacao Campus of the University of Puerto Rico is a member of NURO, a consortium of primarily undergraduate institutions (www.nuro.nau.edu) that share the 31 inch telescope, property of Lowell Observatory, for 120 nights per year. It is located roughly 20 miles east of Flagstaff, Arizona at Anderson Mesa, at an altitude of 7200 feet. We travel to the NURO telescope twice a year, usually during the spring and fall. The data presented in this report was acquired on 3 trips, one in the fall of 2003 and the others in spring and fall of 2004. At the time of these trips a TEK 512x512 CCD Camera was coupled to the NURO telescope. The camera had 27 micron pixels and was cooled to -110 ^{o}C to eliminate as much thermal electron noise as possible. A new CCD camera was installed recently; we will report data with this new camera in the future.

The data include 39 measurements obtained in October of 2003 and 87 measures for the year 2004. Some of the binaries where imaged both in the spring and the fall of 2004, so they show more than one measurement in the data tables.

The CCD images where analyzed by students pursuing undergraduate research projects at our observatory; they used two different methods to obtain the results on the table. First the students used the pixelization of the CCD images to obtain the separation and position angle (see Muller, Rafael et. all. , The Double Star Observer, **9**, 4-16, March/April 2003,for details). Then the CCD images where also analyzed using the software that is included in *The Handbook of Astronomical Image Processing for Windows*, by Richard Berry and James Burnell, Willman-Bell, Inc, Virginia (www.willbell.com) 2000. The Handbook includes the CD *AIP for Windows*, which has a feature that, with some care, allows for measurement of separation directly from the CCD image. Since the software does not provide for introducing your telescope's plate scale in the computations you have to make your final number crunching with a hand calculator. The software in the program is also mirror reversed as far as position angle is concerned, so you must be very careful when you figure the correct angle from the one given by the software.

There is a systematic error in position angle that occurs when the CCD camera is coupled to the telescope. This error can be corrected by using well known binary systems and binary systems that "don't move". The binary systems that "don't move" can be found in the neglected section of the Washington Double Star Catalog as binary stars that have been measured for the last 100 years and show no change in position angle. There are many of them in the Catalog. One can get detailed information on such systems by requesting the information from the database of the Washington Double Star (WDS) catalog. The procedure for doing so is simple and is outlined by Dr Brian Mason at the JDSO: Mason, Brian: Spring 2006, Requested Double Star Data from the US Naval Observatory JDSO **2**, 21-35. By imaging a mix of well known binaries and binaries that "don't move" (we use around 20 of them total) and comparing the value of position angle given in the WDS with the one obtained from our images one can correct for the systematic error in the position angle. We call such error the offset error and is incorporated in the position angle values given in Table 1 and Table 2.

Both Table 1 and Table 2 display first the WDS Name of the binary system, then the coordinates from the WDS are shown in the second column (both RA and Dec). The tables further present the visual magnitudes for the primary and the secondary. These values where also obtained from the WDS. Next we display our measurement of Position Angle (PA) and we further display the measured separation. Finally, in the NOTE column we post the number of images obtained in that particular night for a particular binary. We must stress that although sometimes more than one image of a binary was obtained on a particular night, in the analysis and calculations of PA and separation only one image was used in all cases.

Acknowledgements

We would like to acknowledge support for this project from the Puerto Rico Space Grant Consortium and the L.S. Alliance for Minority Participation of the University of Puerto Rico. We also receive support from the MARC Program at the Humacao Campus of the University of Puerto Rico. We also thank Ed Anderson of NURO for his efforts on behalf of our students.

NAME	RA + DEC	MAG A, B	PA (deg)	SEP (as)	DATE	NOTE
HJ 3235	000346.5 +125121	11.2, 11.2	25	16.6	2003.802	1
STI3089	000352.3 +551757	12.6, 13.2	124	16.6	2003.802	1
LDS3117	000421.6 +282924	14.3, 14.4	9	62	2003.802	1
BU 9001AC	000509.7 +451344	6.69, 10.58	237	21.6	2003.802	1
STF3064	000737.9 +400852	7.0, 10.0	8	25.9	2003.802	2
ARN 28AD	000944.2 +520141	7.62, 9.44	59	83.9	2003.802	1
HJ 1947AB	001621.5 +433542	6.16, 9.83	76	9.5	2003.802	1
STF 23AB	001728.7 +001915	7.8, 10.28	220	9.2	2003.802	1
GRB 34AB	001822.8 +44012	8.07, 11.04	64	35.4	2003.802	1
STF 36Aa-B	003223.7 +065719	5.68, 9.52	84	27.2	2003.802	1
STF 46 (55Piscium)	003955.5 +212618	5.56, 8.49	196	6.6	2003.802	2
STF 88AB (ψ_1 Piscium)	010540.9 +212823	5.27, 5.45	159	29.8	2003.802	2
WAL 14AC	015240.7 +571717	8.15, 9.70	104	64	2003.802	1
HJ 1115	021857.0 +283834	5.0, 11.3	207	60.7	2003.802	1
STFA 43Aa-B (Albireo)	193043.2 +275734	3.37, 4.68	56	35	2003.802	2
HJ 1486	201112 +1111	11.0, 11.0	98	10.9	2003.802	1
ES 204	201413 +3521	7.6, 10.5	276	15.3	2003.802	2

Table 1: Double star measurements made in 2003 (*continued on next page*)

Observation Report 2003-2004: Humacao University Observatory

NAME	RA + DEC	MAG A, B	PA (deg)	SEP (as)	DATE	NOTE
BAL2021	201457.7 +031446	10.6, 10.6	348	4.7	2003.802	1
SEI1422	210952.7 +365910	8.9, 11.0	335	21.4	2003.802	2
HJ 1619AB	211226. +143156	10.0, 11.0	171	6.8	2003.802	1
BU 270AB-C	211327.2 +071304	7.25, 14.01	28	30.7	2003.802	1
MLB 424	211530.2 +371919	9.3, 10.7	65	4.9	2003.802	2
STT 434AB	211900.0 +394457	6.67, 9.93	122	24.9	2003.802	S
BU 696AC	220430.1 +155128	7.95, 8.96	322	62	2003.802	1
HJ 1726	220651.5 +150501	11.0, 11.5	25	18.9	2003.802	1
LDS4955	221930. +151312	16.3, 17.0	7	68.1	2003.802	1
STI2720	222130.0 +583648	12.1, 12.1	162	14.3	2003.802	1
STI2722	222159.1 +561952	10.6, 13.0	72	14.4	2003.802	1
STI2728	222223.0 +551642	12.5, 13.1	38	14.3	2003.802	1
BU 172AB-C	222406.8 -045013	5.78, 10.1	342	54.4	2003.802	1
ARN 24AC	222548.0 -201413	6.7, 8.0	90.5	127.	2003.802	1
STF2922Aa-B (8 Lacerta)	223552.2 +393803	5.66, 6.29	186	22.7	2003.802	2
AG 423	223615.6 +294443	8.3, 9.7	156	23.5	2003.802	2
STT 475AB	223904.5 +372231	6.84, 10.8	72	15.6	2003.802	1
BU 1517	224911.1 +110652	11.0, 12.4	200	17.5	2003.802	1
HJ 1839	230023.9 +410729	8.8, 10.5	293	15.2	2003.802	2
STF2982	230931.5 +084038	5.12, 9.7	199	33.1	2003.802	1
STI2957	231339.4 +564748	11.9, 12.5	155	13.1	2003.802	1
HJ 307	231920.7 +132648	10.2, 11.7	314	25.8	2003.802	1

Table 1 (*cont. from previous page*): Double star measurements made in 2003.

NAME	RA + DEC	MAG A, B	PA (deg)	SEP (as)	DATE	NOTE
STI 738	120317.7 +592405	10.1, 11.0	38	7	2004.390	3
STF1622 (2 Canes Venatici)	121607.5 +403936	5.86, 8.71	258	11.8	2004.390	3
STF1636 (17 Virgo)	122232.1 +051820	6.5, 10.48	337	20.8	2004.390	3
KZA 36 AC	122857.5 +373541	8.9, 10.5	327	86.4	2004.390	1
SHJ 145 (Delta Corvi)	122952.0 -163054	2.95, 8.47	216	24.3	2004.393	3

Table 2: Double star measurements made in 2004. (*continued on next page*)

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NAME	RA + DEC	MAG A, B	PA (deg)	SEP (as)	DATE	NOTE
STF1673AB	124256.1 -021504	9.1, 10.6	92	51	2004.393	1
COU 59AB	140042.1 +175355	9.9, 12.2	172	8.4	2004.390	1
ARA 74	140126.4 -163600	13.3, 13.3	15	13.4	2004.393	1
LDS1402	140227.1 +152033	15.1, 15.5	314	7	2004.390	1
HJ 2699BC	140304.6 +115418	8.3, 13.3	237	14.7	2004.390	1
ARA 695	140329.2 -193220	12.6, 12.9	60	8	2004.393	1
LDS2702	140808.3 +615558	12.2, 19.5	199	15.1	2004.393	1
BAL1169	140819.3 -001119	10.9, 11.3	297	14.5	2004.390	1
ARA 231	141028.7 -181011	12.9, 13.6	243	6.5	2004.393	1
HJ 542	141221.2 +364612	12.0, 12.0	68	12.5	2004.390	1
POU3162	141323.9 +242412	6.11, 12.8	347	6.9	2004.390	1
LDS 953	141329.8 +213739	13.7, 15.2	173	10.8	2004.390	1
STF1821 (Kappa Bootis)	141327.7 +514716	4.53, 6.62	237	13.5	2004.390	3
STFA 26AB (Iota Bootis)	141610.0 +512201	4.76, 7.39	34	39.7	2004.390	1
ES 1085	141630.2 +463309	8.8, 11.8	177	6	2004.390	3
BU 1442AC	142543 +233701	9.72, 9.50	75	80.4	2004.390	2
HJ 1258AB	145037.1 +432618	9.9, 13.8	216	25.7	2004.390	1
STF1888AB (Xi Bootis)	145123.2+90602.3	4.76, 6.95	314	6.9	2004.390	1
POU3176	145243.4 +235347	14.4, 13.0	1	7.4	2004.390	1
HJ 560	145536.9 +345723	9.2, 10.6	298	40.2	2004.390	3
STFA 27 (Delta Bootis)	151530.1 +331854	3.56, 7.89	79	102.4	2004.390	1
KZA 80	152042.0 +313315	9.5, 10.0	55	26.6	2004.390	3
HJ 2777	152225.3 +253727	7.5, 10.4	343	42.5	2004.390	1
KZA 87	152448.6 +293428	12.0, 12.5	1	11.8	2004.390	1
KZA 90	152725.4 +310141	12.5, 13.0	298	20	2004.390	1
GIC 131	153230.27+083208	13.6, 14.7	313	16	2004.390	1
POU3193	153522 +240818	13.2, 13.7	293	7.6	2004.390	1
STF1999AB (Struve 1999)	160425.9 -112657	7.52, 8.05	101	12.1	2004.390	1
H 3 7AC (Beta Scorpii)	160526.2 -194819	2.59, 4.52	17	13.8	2004.393	2

Table 2 (*cont. from previous page*): Double star measurements made in 2004. (*continued on next page*)

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NAME	RA + DEC	MAG A, B	PA (deg)	SEP (as)	DATE	NOTE
ARA 433	160635.8 -181911	11.6, 14.1	53	10	2004.393	1
ALI 370	160726.8 +354829	13.7, 14.1	147	14.3	2004.390	1
ALI 370	160726.8 +354829	13.7, 14.1	146.4	13.3	2004.762	1
POU3214	160748.8 +230529	11.1, 13.3	82	12.5	2004.390	1
POU3214	160748.8 +230529	11.1, 13.3	82	12.1	2004.762	1
STF2010AB (Kappa Herculis)	160804.5 +170249	5.10, 6.21	14	27.5	2004.390	3
STF2010AB (Kappa Herculis)	160804.5 +170249	5.10, 6.21	13.5	27	2004.762	1
HJ 1288	161240.8 -164518	11.0, 12.3	123	19	2004.393	1
STF2032AB (Sig. Cor. Bor.)	161440.8 +335131	5.62, 6.49	237	7.4	2004.390	3
STF2032AB (Sig.Cor. Bor.)	161440.8 +335131	5.62, 6.49	236	7.5	2004.762	1
ES 627	161835.7 +511951	9.6, 10.8	287	12	2004.390	1
ES 627	161835.7 +511951	9.6, 10.8	285.5	12	2004.762	2
STFA 35 (Nu Draconis)	173215.8 +551022	4.87, 4.90	310.8	63.6	2004.759	2
BU 1202AB-C	180132.3 +033127	8.43, 7.95	28	105.7	2004.390	1
BU 1202AB-E	180132.3 +033127	8.67, 10.20	139	86.7	2004.390	1
STF2293	180953.8 +482405	8.08, 10.34	83.2	12.9	2004.759	1
STF2330	183112.9 +131055	8.27, 9.69	167	17	2004.393	1
STF2330	183112.9 +131055	8.27, 9.69	166.2	16.7	2004.762	1
STF2337AB	183455.1 -144210	8.14, 9.05	297	16.6	2004.762	1
STF2337AB	183455.1 -144210	8.14, 9.05	296.5	16.8	2004.393	1
STF2346	183715.2 +073143	7.93, 10.0	299	29.8	2004.393	1
STF2346	183715.2 +073143	7.93, 10.0	297.2	29.9	2004.762	2
HJ 1349	184848.8 +331912	8.3, 10.7	91.1	29.5	2004.759	2
STFA 39AB (Beta Lyrae)	185004.7 +332145	3.63, 6.69	148.8	46.4	2004.759	1
STF2417AB (Theta Serpentis)	185613.18+041212	4.59, 4.93	104.5	23.1	2004.759	1
AG 375	191413.4 +262628	9.6, 10.5	295.5	18.8	2004.759	1
STFA 43Aa-B (Albireo)	193043.2 +275734	3.37, 4.68	55.5	34.5	2004.759	1

Table 2 (*cont. from previous page*): Double star measurements made in 2004. (*continued on next page*)

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NAME	RA + DEC	MAG A, B	PA (deg)	SEP (as)	DATE	NOTE
GYL 17	193144.6 +334801	7.5, 10.0	230.5	22.9	2004.759	1
STFA 44	193310.0 +600931	6.47, 8.19	286.5	75.6	2004.759	1
ARN 48	194057.6 +232918	8.20, 9.69	5.2	25.9	2004.759	1
HJ 603AB	195033.9 +384320	5.38, 10.54	113.8	56.5	2004.759	1
STFA 48AB	195322.6 +202013	7.14, 7.34	147.3	42.2	2004.759	1
HJ 1479	200550.3 +253603	8.4, 10.7	1.7	34	2004.759	1
HJ 1479	200550.3 +253603	8.4, 10.7	4.4	34	2004.762	1
ES 204	201413.9 +352142	7.6, 10.5	277.2	14.7	2004.759	1
BAL2021	201457.7 +031446	10.6, 10.6	343	4.5	2004.759	1
ENG 73AB	201654.5 +501643	8.24, 10.30	75.5	78.2	2004.759	1
STF2666Aa,C	201806.9 +404355	5.80, 11.11	208.1	34.1	2004.759	1
SEI1422	210952.7 +365910	8.9, 11.0	332.7	20.4	2004.759	1
HJ 1619AB	211226.5 +143156	10.0, 11.0	172.5	6.9	2004.759	1
BU 270AB-C	211327.2 +071304	7.25, 14.01	27.5	29.4	2004.759	1
MLB 424	211530.2 +371919	9.3, 10.7	62.2	4.9	2004.759	1
BU 696AC	220430.1 +155128	7.95, 8.96	322.3	63	2004.759	1
STI2720	222130.0 +583648	12.1, 12.1	159	14.2	2004.759	1
STI2722	222159.1 +561952	10.6, 13.0	73.1	14.8	2004.759	1
STI2728	222223.0 +551642	12.5, 13.1	38	14.3	2004.759	1
STF2922Aa-B (8 Lacerta)	223552.2 +393803	5.66, 6.29	186.1	21.9	2004.759	1
AG 423	223615.6 +294443	8.3, 9.7	154.8	24.4	2004.759	1
STT 475AB	223904.5 +372231	6.84, 10.8	72	15.8	2004.759	1
HJ 1839	230023.9 +410729	8.8, 10.5	294.5	14.7	2004.759	1
STF2982	230931.5 +084038	5.12, 9.7	197.5	32.6	2004.759	1
STI3007	233642.8 +581949	13.2, 13.2	119.5	8.9	2004.759	1
STI3012	233824.5 +580027	12.6, 12.6	98.2	7.8	2004.759	1
BAL1249	234102.7 +004307	9.2, 11.2	334.9	14.5	2004.759	1

Table 2 (*cont. from previous page*): Double star measurements made in 2004.

A Novel Method of Double Star Astrometry Using a Webcam and Self-Calibrating Measurement Software

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Abstract: A new double star software application, BinStar, is described. This application takes AVI sequences of doubles drifting across the FOV as input, and uses the drift rate, frame rate and declination to self-calibrate both image scale and orientation, so that separate calibration images are not required.

I became interested in double star observing for a variety of reasons, not least of which is that it presented an opportunity to contribute to "professional" science. After reading the book Observing and Measuring Visual Double Stars (Argyle, 2004), I was also convinced that double star measures could be done both accurately and with inexpensive equipment – all that was required was a little ingenuity.

I experimented with a variety of methods, but found I was unable to accurately and reliably measure the separation and position angle of calibration stars from the WDS catalogue. I then came across the website of Florent Losse, a French double star observer who discussed the use of a webcam for making double star measurements, and who had developed a piece of software called REDUC for performing the analysis based on webcam images. I was quite taken by this piece of software, save for two small issues. Firstly, it required capturing a calibration pair at the beginning and end of a session, which meant that the camera could not be touched during the session. This precludes removing the camera to insert a Barlow lens, and means recalibration must be done if the camera is jostled at all. Secondly, to my mind, calibrating on a double star – even a wide pair with very little motion - seems somewhat circular. It occurred to me, however, that an analysis program like REDUC combined with drift measurements could provide accurate results that are self-calibrated. With great optimism, a smattering of programming experience in Delphi, and a blissful ignorance of the amount of work required, I set about creating such a program, and thus was BinStar born.

The principle is, in theory, straightforward. To begin, an AVI video sequence is shot of a double star drifting across the field of view with the drive turned off. In other words, it is drifting at the sidereal rate. Given the declination of the pair and the frame rate of the sequence, it is straightforward to calculate the distance the star drifts between each frame, and from this the resolution scale (in pixels per arcsecond) can be established. It is then a matter of determining the separation of the stars in pixels, and converting that to arcseconds. In addition, the direction of drift is due west, and this can be used as a reference for determining the position angle. The inherent multiple sampling of a video sequence provides built-in averaging of many sample measures, which helps to compensate for atmospheric effects and camera noise.

In practice, this is not an easy set of tasks to automate for someone who is not an expert in image processing. The main difficulty in coding this application was getting the computer to find and track the stars reliably from frame to frame. Although it may have been simpler to have the user select the stars in each frame, this can be onerous with dozens or hundreds of frames. As a result, I developed two distinct methods of locating the stars from frame to frame.

The first method is a simple weighted average. The user begins by selecting the primary and secondary star in the first frame (or the first usable frame – one does not need to begin at frame zero), and three boxes are defined. One box is created around the primary, which then takes the monochrome value of each pixel within the box and finds the weighted mean point within the box. This is iterated a small number of times to zoom in on the true weighted mean point, which is then recorded to a precision of 0.01 pixels. The same procedure is completed for the secondary, and then for a "system box" as a whole, which finds the weighted mean "center of mass" of the two stars together. An offset vector for the primary box is calculated relative to the system box, and an offset vector of the secondary box is calculated from the primary. With each new video frame, the system box zooms in on the cm of the system, the primary box is placed at the offset position and iterated to center itself on the primary, and lastly the secondary box is placed at its offset and iterated to lock onto the secondary.

This method works effectively if the two stars are sufficiently separated. If the stars are too close, or if there is image glare between them, the centroiding boxes may drift off center, and in extreme cases one box may drift onto the other star.

The second method involves automatic peak identification. In this process, a smoothed copy of the system is sampled (the degree of smoothing is determined by the box size), and the pixel values are sorted in descending order by brightness (again using monochrome values). The brightest point is deemed to be the peak pixel of the primary. By going through the list, each point (which will be either the same brightness or slightly dimmer than the last) is tested for proximity to the primary peak. Any point that is adjacent to the primary peak (or another point labelled as part of the primary) is identified as part of the primary. The first point in the list that is *not* adjacent to a primary pixel is identified as the secondary peak. Further points in the list are then labelled as belonging to the primary, the secondary, or neither (to exclude noise). The pixel positions of the primary and secondary peaks are then used with the original (unsmoothed) image data to locate the centroid by identifying the mean from within one standard deviation of the peak. It is fairly crude by some standards, but I have been pleased with its effectiveness. This method can often detect the centers of even close pairs, where there may be some overlap between the primary and secondary bounding boxes. The downside of this method is that it does not work well for pairs that are very close in magnitude, as atmospheric effects can alter which point is brighter from frame to frame. For these pairs, the weighted average method is preferred.

Once each frame is analyzed and the centroid positions are recorded, the complete data set is analyzed. First, frame data are tested to see if they are, within acceptable limits, close to the first frame data. If not, the data is deemed inactive. Dropped or repeated frames are also inactivated in order to not skew the data. All active data is then used to calculate the average separation in pixels, and then converted to arcseconds as described above using the declination of the pair and the frame rate of the video. Also, the position data for both the primary and secondary are analysed using least squares linear regression, and the average of the two values is taken as due west. The position angle is then calculated relative to this line.

As a final step, the user can step through the complete sequence frame by frame, activating or inactivating individual frames as desired to eliminate obvious miscalculations. Notes can be made (including qualitative comments on the data, and perhaps the image scale etc), and then the data can be exported to a tab delimited text file, which can be imported into any spreadsheet for later analysis or publication.

Let me outline a typical observing session. For observing doubles I use a Celestar 8" SCT, with RA and DEC motors, but no go-to capability. I find that with a telrad and RACI finder, I can locate objects quite quickly, so a computer is not required. My camera is a Celestron Neximage, mounted in a Meade 644 flip mirror diagonal. I typically use a 26 mm super Plossl to locate and center the target pair, and then flip up the mirror, decide whether a Barlow is required, focus the image on the camera chip and adjust the frame rate and gain to achieve the best image. I then move the scope west in RA, turn off the drive, and begin capturing the video sequence when the pair drifts into the FOV. I have recently been using K3CCD Tools, which allows me to set a capture time, so I do not have to stop the video manually as I would do with AMCap. I typically use the star designation as the filename (eg STF2140.AVI) to avoid later confusion. I may take several sequences of one pair, or if I feel confident that the capture was good (lots of frames with clearly separated star images) I move on. In this way I will capture a dozen or so double stars in a casual evening's session.

Later, on a cloudy evening, I will run the AVI's through BinStar and analyse the results. I type in the designation, RA and DEC values, and the software

A Novel Method of Double Star Astrometry Using a Webcam and Self-Calibrating ...

calculates the epoch (in Julian and Besselian dates) from the file data. I run through the video sequence to determine appropriate start and end frames (in case the star drifts out of the FOV), and choose an appropriate box size and select the star images. I always use a flip mirror, so it is a straight-through system, but there is a radio button to select if a diagonal is used. Then it is a matter of selecting the GO button, and watching what happens. A zoom window can be used to see an enlarged version of what is happening in the main video window. When the sequence is complete, the results are displayed at the bottom of the window. At this point, it is wise to step through the sequence to see if there are any glaring errors – frequently atmospheric effects can split a star image into two, fooling the peak search algorithm. These frames can be deselected, and the results can be recalculated. I find the pixels/arcsec value to be a useful reference check – I know my system is ~1.7 without a Barlow and ~4.2 with a Barlow. If the value is something other than these numbers, there is a problem – most probably the DEC value was entered incorrectly, but on one occasion the frame rate of the AVI was not recorded correctly. I typically use the notes section for comments on the image quality, and if there was much motion due to poor seeing or wind on the scope. I save the values to the results file, and repeat with the next sequence.

So far I have been very pleased with BinStar, and to be honest, pleased with myself for creating it. There are still several limitations to this software. It is limited to a maximum video resolution of 640x480 (typical for a webcam), and as it samples the screen pixels directly, it must be run in the foreground. Stars that are close to the poles may not yield great results due to the limited drift – but this concern may turn out to be unfounded due to the added benefit of a greater number of frames. Pairs with large magnitude differences may not work with many webcams, and very close pairs with similar brightness may fool both search algorithms. The system assumes square pixels in the webcam, which is not always a given, and slow frame rates, required for fainter stars, lead to elliptical star images. And lastly, the algorithms themselves are not infallible, so occasionally a large number of frames must be manually discarded.

Some results of my current observing program, which consists primarily of stars on the WDS Neglected Doubles list, are presented in Table 1.

The BinStar application is written in Delphi, and I am more than willing to accept the charity of more knowledgeable programmers who wish to help in developing this project. BinStar is free for individual use, and may be downloaded from my website at http://budgetastronomer.ca/binary-stars.

Name	RA+DEC	PA	Sep	Date	N	Notes
STF 222	02109+3902	36.1	16.76	2005.846	1	1
STF 305	02475+1922	306.5	3.57	2006.059	1	2
STF 664	05152+0826	176.2	4.85	2006.059	1	3
STF1110	07346+3153	59.6	4.37	2006.059	1	4
STF1196	08122+1738	71.3	5.9	2006.291	1	5
STF1424	10200+1950	124.5	4.52	2006.292	1	6
STF1888	14514+1906	310.9	6.39	2006.481	1	7
STF1954	15348+1032	173.1	4.05	2006.481	1	8
STF1985	15559-0209	349.9	5.91	2006.481	1	8
STF2032	16147+3351	236.7	7.04	2006.481	1	

Table 1: Measurements of neglected doubles made with BinStar (*continued on next page*).

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Name	RA+DEC	PA	Sep	Date	N	Notes
STF2140	17146+1423	103.5	4.68	2006.514	1	11
STF2272	18055+0230	136.1	5.34	2006.481	1	12
STF2382	18443+3940	349.8	2.33	2006.481	1	13
STF2383	18444+3936	80.2	2.32	2006.481	1	14
STF2486	19121+4951	205.7	7.38	2006.481	1	15
STF2727	20467+1607	266.4	9.1	2005.846	1	16

Table 1 (*cont. from previous page*): Measurements of neglected doubles made with BinStar.

Notes:
1. 194 frames, f/10
2. 71 frames, f/10, noisy signal due to high gain, looks like overestimation on rho
3. 92 frames, taken at F/10, seeing less than ideal. STF 664 is the same as CHE 79
4. 142 frames, taken at F/10. STF 1110 is Castor.
5. 275 frames, f/10
6. 210 frames, f/10, very windy night, so the images jumped up and down a bit, but the star images were very good.
7. 58 frames, Fairly steady
8. 86 frames, used weighted average method
9. 57 frames, f/10.
10. 189 frames, appears to be clean data
11. 84 frames, Delta Mag on CCD is higher than visual, weighted average used
12. 64 frames
13. 83 frames, one pair of epsilon-lyra, the "double-double". Not bad given the conditions and tight pairing, but likely an underestimate.
14. 80 frames, the other pair from the "double-double". Again, likely an underestimate due to the proximity of the stars.
15. 293 frames, Super data, tight stars - used weighted avg due to similarity in mag
16. Gamma Delphinus, mediocre seeing, averaged between 71 frames at f/10 and28 frames at f/20

Ed trained as an evolutionary biologist and paleontologist He has been working in science education for the last two decades, teaching in Canada and Switzerland. He has been a space enthusiast since the moon landings, and has been actively observing with his growing collection of telescopes for four years. Ed's musings on amateur astronomy can be found at www.budgetastronomer.ca. He currently lives outside of Toronto.

Determination of the Nature of Visual Double Stars Using Probability Theory

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Abstract: Nowadays the nature of many visual double and multiple stellar systems remain unknown and probably several tens of thousands of stellar systems could be optical. This situation prevents a better understanding of the formation of stars and stellar systems. So, it is very important to determine the true nature of the pairs we study. There are many tests used by professionals during the last decades. These tests can be used by amateurs because no important physical or mathematical knowledge is needed. In this work I comment in detail on tests based on probability theory that allow us determine the nature of visual pairs.

Introduction

Nowadays the nature of many double and multiple stellar systems remain unknown and probably several tens of thousands of stellar systems could be optical. This situation prevents a better understanding of the formation of stars and stellar systems.

Professional astronomers study relatively close visual double stars because they are physical in nature with orbital parameters or with important Keplerian motions. Astronomers do not have enough time to investigate the nature of wide double stars (mainly with rho > 10") and the human and technical resources would be poorly used because of those wide double stars only a few percent (about 10%) would be physical pairs. Amateurs have an important role, because we can spend time in determination of the nature of wide visual double stars.

Of the different criteria that help to determine the nature of visual double stars, there is a type of criterion that is based on probability theory analyzing the stellar distribution. This type of criterion is classified into two subtypes: (1) criteria that use the area distribution of stars with a determined bright (mainly brighter than secondary) and (2) criteria that uses the area density of stars with a determined proper motion (mainly with values between primary and secondary).

Historical background

After Bernadetto Castelli discovered Mizar to be a double star in 1617, astronomers thought that such pairs of stars were chance coincidence. During that time, astronomers thought that all stars have the same brightness, so dimmer stars were located at larger distances than brighter ones.

A work of John Mitchell (1768) disagreed rather strongly with Herschel over the question of how apparent magnitude is related to distance, but even more importantly, it contained a very simple statistical calculation on the question of the probability of finding two stars very close together on the sky, presuming them to be randomly distributed and given the total numbers of stars of any particular apparent magnitude. Mitchell's calculation showed that this probability is exceedingly low, so the fact that many such pairs are observed must imply that they are not chance coincidences in direction, but real physical pairs. It was not a difficult calculation and Herschel could easily verify it for himself, yet he seems to have purposely chosen to ignore it and proceeded with his observations to determine the first stellar parallaxes.

John Mitchell argued that the probability of observing two stars by chance closer than a certain apparent separation, was related to the arc of a disk with radius equal to that limit. The probability $p(\rho_{max})$

that two given stars are closer than the separation ρ_{max} is given by

$$P(\rho_{\max}) = \pi(\rho_{\max})^2 / (4\pi)$$

where ρ_{max} is assumed to be small and expressed in radians. The probability of these stars having a separation wider than ρ_{max} is then $1 - P(\rho_{max})$. If we now consider N stars randomly distributed in the sky, the probability that no pair is closer than ρ_{max} is

$$[(1 - P(\rho_{\max}))^N]^N$$

Mitchell applied this relation in order to calculate the probability that no pair like β Capricorni could exist in the sky. He estimated that 230 stars were at least as bright as these stars. He calculated that the probability of finding no star with a companion at least as close and at least as bright as the secondary component of β Capricorni was 1-1/80. Then, the probability that a system like β Capricorni could appear by chance was 1/80, and Mitchell concluded that β Capricorni was a system of stars bound by gravitation, a hypothesis that has yet to be refuted.

Struve (1827 - 1852) calculated $n(\rho_{max})$, the number of optical pairs with an apparent separation less than a certain limit ρ_{max} that should occur among N stars counted in a given area, A:

$$n(\rho_{\max}) = \frac{N(N-1)\pi{\rho_{\max}}^2}{2A}$$

Kubikowski, et al. (1959) considered the probability of finding a field star with magnitude m in the neighborhood of a given star given by

$$P(\rho_{\max}) = \frac{N(m)\pi{\rho_{\max}}^2}{A}$$

where N(m) is the number of stars with magnitude m. He assigned a given level (1%) to P, and he derived ρ_{max} as a function of the magnitude of secondary components. For example, he found that 1% of stars with magnitude 10 should have an optical bright companion. This 1% level is certainly not the proportion of optical systems among double stars, but only a means of deriving the contribution of optical pairs in the total number of binaries.

Van Albada(1968) and Bahcall & Soniera (1981) used another method, one based upon the distribution of the nearest neighbors. The probability that the nearest optical companion of a star is at a separation s is stated by a Poisson's law:

$$P(\rho \pm d\rho / 2) = \frac{2\pi\rho N}{A^{-\pi\rho^{2N/A}}} d\rho$$

They compared the histogram of the separation of the observed stars to this theoretical distribution and found that both were similar with regard to the larger separation in their samples. For close separations, they obtained an excess of systems due to physical binaries.

Bahcall et al. (1986) preferred the "near neighbors" method. They considered the separations between stars and all their neighbors closer than a given limit. The number of optical systems with separations $\rho \pm d\rho/2$ is then a linear function of ρ. Another formulation of this method is the so-called "two point correlation function" (Bahcall and Soniera, 1981). It consists of calculating $w(\rho)$, which is the relation between physical and optical pairs with the separation ρ.

Modern references in literature.

I carried out a search in astronomical professional literature for modern papers that have used these criteria. In papers where new wide companions or new wide stellar systems are discovered, it is the usual practice that authors use probability theory to obtain the probability that two stars were not chance coincidence.

The Mexican astronomers Poveda, Allen & Parrao (1982) in their work titled "*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*" filtered the Index Catalogue of Visual Double Stars (IDS) to eliminate optical systems in a statistical study.

To reduce the number of optical companions they applied a "1% filter" to each of the systems; the 1% filter consisted in testing if the faint companions (or secondaries) satisfy the following equation:

$$\pi s^2 N(m_2)_{l,b} < 0.01$$

Here, s is the angular separation of a secondary of magnitude m_2 from the primary, and $N(m_2)_{l,b}$ is the expected number of field stars per unit area brighter than apparent magnitude m_2 in the direction of the primary, which has galactic coordinates *l,b*.

Ciardullo et al. (1999) published a paper titled "*A Hubble Space Telescope Survey for Resolved Companions of Planetary-Nebula Nuclei*". In this work they used the following equation:

$$P = 1 - \left(1 - \frac{\pi\rho^2}{A}\right)^N$$

where ρ is the angular separation for both components in arcseconds, A is the area of the sky where we have searched for stars brighter that secondary (expressed in the same unit as ρ), and N is the number of stars brighter that secondary found in A. The expression $\pi\rho^2$ gives the circular area of the sky with radius equal to ρ. This professional team considered as physical pairs those that have a probability to be optical less than 5%.

G. Duchêne et al. (2001) published a paper titled "Visual binaries among high-mass stars". In this work they discovered new, very close visual double stars. They used probability theory and took into account the resolution power of their instruments depending on the magnitude of the star. They rejected in the calculation the area of the sky not resolved for their instruments and calculated the probability that a random star brighter than the secondary and weaker than the primary ($mag_{primary} \leq mag \leq mag_{secondary}$) is detected within separation ρ from the primary:

$$P = \sum_{K-K_p}^{K_S} n_k W_k$$

where n_k is the surface density in the considered field and W_k is the detectability area of stars at a given magnitude K (we must take into account that they used K band photometry). The value of W_k has the value $\pi(\rho^2 - \rho_{lim}(K))$ instead of the value $\pi\rho^2$. The term $\rho_{lim}(K)$ is the resolution power as a function of the K magnitude. So we can express

$$P = \sum_{K-K_\rho}^{K_S} \frac{N_k}{A} \pi(\rho^2 - \rho_{\lim}(K))$$

where A is the area where we have counted the stars with $mag_{primary} \leq mag \leq mag_{secondary}$. G. Duchêne et al. summed the probability for each magnitude because the resolving power changes with the secondary magnitude.

Using the Proper Motions of the Components

Grocheva & Kiselev (1998) proposed using the real distribution of proper motions for estimation of P instead of using the distribution of stars brighter than a given magnitude. The probability that two stars with proper motions between $\mu(A)$ and $\mu(B)$ with angular distance of ρ is:

$$P = \frac{\pi\rho^2 S}{A}$$

where $\pi\rho^2$ is the area of the sky with radius ρ, A is the studied area of the sky, and S is the number of stars with proper motions between $\mu(A)$ and $\mu(B)$ found in an area A.

Grocheva & Kiselev chose assumed binaries from the same catalog. The sample must be restricted to pairs whose ρ are limited by same quantity. For example it is possible use Aitken's criterion (Rica 2006). They studied a sample with few known optical and physical pairs to obtain a definite criterion for the identification. The distribution of proper motions was derived from the PPM catalog for stars North-polar area. Analyzing the resulting probabilities they conclude that only the probability of random proximity of proper motion $P_\mu = S/N$ (where N is the total stars in the area A) can be used to identify true physical binaries. Grocheva & Kiselev observed that for physical pairs $P < 0.01$ whilst for optical ones are larger.

Results of the Method Based on Probability Theory

I initially calculated the probability P for two or three clear optical visual double stars studied by LIADA. The result made me suspect that the limit of probability P used by same professionals was not the best. The value of P that I obtained for clear optical pairs is significantly smaller than what some astronomers think. Poveda, Allen & Parrao (1982) used a limit of P = 1%; Ciardullo et al. (1999) used a limit of P = 5%.

So a further study was needed to determine the distribution of P values for optical and physical pairs. I selected a sample of 48 optical pairs and 25 physical pairs studied by LIADA Double Star Section.

Determination of the Nature of Visual Double Stars Using Probability Theory

For each visual pair, I counted stars as bright or brighter than secondary component in an area of 5 x 5 degrees around primary star. I used the VizieR tool from the website of Centre de Données Astronomiques de Strasbourg. We must take special care in the selection of the catalogue. In my sample some secondary components were dimmer than 13th magnitude. So we must select a catalogue that lists dimmer stars. Some catalogs don't cover the whole sky (for example UCAC-2). We must too take into account the sensitivity of the photometric data listed in the catalogs. UCAC-2 magnitudes are sensitive to red band. GSC-I, in the southern hemisphere magnitudes are sensitive to blue band, etc.

Finally I used the followed catalogues :

For sky region in $\delta < 50$ degrees I used the UCAC-2 (Zacharias et al. 2004) catalog. This catalog covers the sky with $\delta < 50$ degrees. UCAC-2 is compiled by astrometric and photometric reductions of CCD images. The photometric response is between V and R bands. I added 0.3 magnitude to the photometry of the catalogue to obtain a value closer to that of V band. The 0.3 value was chosen without any criterion. We have taken into account that if we use CDS web page, this catalog has a supplement for bright stars.

For region with $\delta > 40$ degrees, I was used the GSC-I catalogue. GSC used several combinations of photometric filters and photographic emulsions. The photometry for the north hemisphere is slightly brighter than the V band. So, to compensate for the red response of GSC-I for northern hemisphere, the photometric limit in the count of stars was the secondary component plus 0.3 magnitudes.

Taking into account the dependence of stellar density with respect the galactic latitude, in this study we listed the galactic latitudes for the stars analyzed.

Results

The values of P for the 48 optical pairs range from 0.09 % to 9.07 %. Figure 1 shows the distribution of P values for the optical pairs.

A sample of 25 physical pairs was used to determine the distribution of P values (Figure 2). Although there was an overlapping range in distribution of P for optical and physical pairs, the values of P were much smaller for physical pairs. The values of P for the physical sample range from 0.003 % to 1.54 %. Of the physical pairs only one binary had orbital parameters calculated. A sample of orbital pairs must show very much smaller values of P (very near of zero) than wide physical pairs. The overlapping region ranges from 0.09 % to 1.54 % and so, initially, the determination of the nature of visual pairs will not be very clear in many cases.

Filtering Double Star Catalogs

Maybe the best way to use this method is filtering a double star catalogue, such WDS (Mason et al. 2003) to obtain a sample with high probability of being

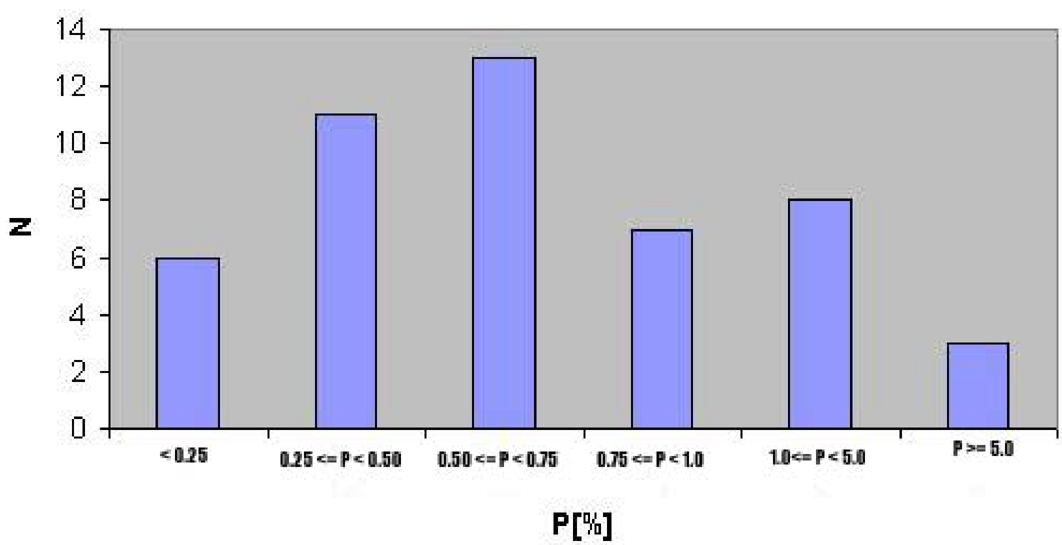

Figure 1: Distribution of P values for 48 optical pairs studied by LIADA Double Star Section.

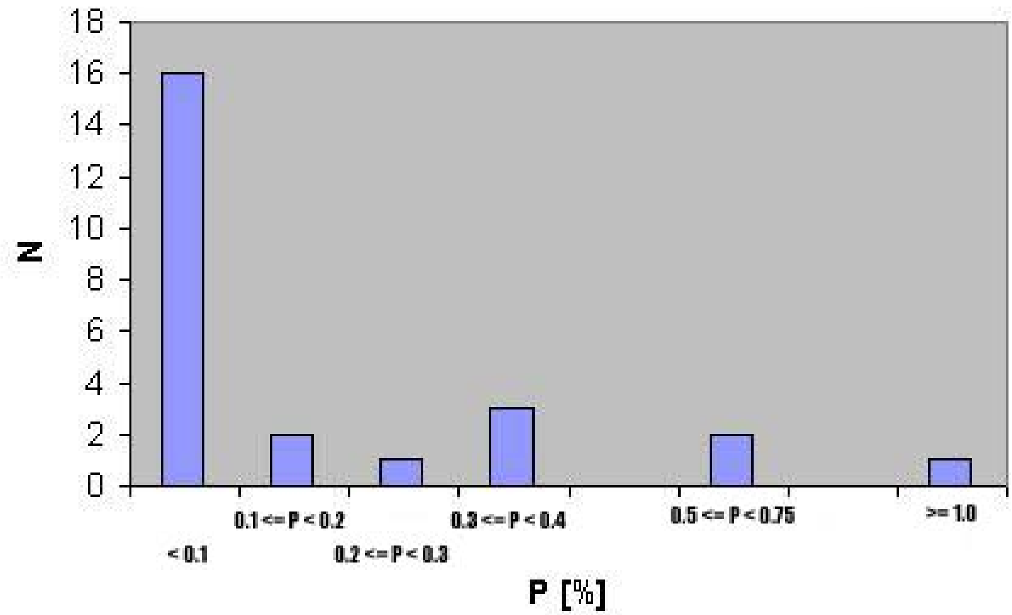

Figure 2: Distribution of P values for 25 physical pairs studied by LIADA Double Star Section.

physical or at least of common origin.

Ciardullo et al. (1999) used a value of $P = 5$ % to separate physical and optical candidates. They defined an optical pair to have P > 5 %. I used this 5 % filter to obtain candidates to be physical in my two samples of optical and physical pairs. The 5 % filter selected all physical pairs in the physical sample, but only rejected the 6 % of optical pairs in the optical sample. So this filter considered about 94 % of the optical pairs as candidate physical pairs.

Poveda, Allen & Parrao (1982) used a 1% filter to obtain an IDS-filtered with physical pairs from IDS catalog. They calculated that in this filtered sample must exist about 1% of optical pairs. The 1% filter considered as physical pairs about 98% of the systems in the LIADA physical sample and reject about 27% of optical pairs in the LIADA optical sample. For example, using the 1% filter, an artificial catalog with the same number of optical and physical double stars would have about 43 % of optical pairs after the filter process. Abt studied the list of 285 trapezium stellar systems published by Poveda in 2000. Abt, who knew the 1% filter of Poveda, was surprised, because he only found 14 physical trapezium stellar systems confirming our suspicion about the incorrect filters used in the literature.

As we can see, the best value for *P* is not so easy to choose and the value chosen depends on if we want to obtain a sample with only physical pairs or if we want not to reject many physical pairs. Table I shows the percent of physical and optical pairs in an initial artificial catalog. The first column gives the value of the filter *P* to consider a pair as physical. The second column lists the composition of the artificial catalog. The physical pairs (percent) considered to be physical by the filter are given in the next column. Column 4 gives the percent of optical pairs rejected by the filter. And finally the last column gives the composition of the filtered catalog

Example Calculation of the Probability of a Physical Pair

The visual double star FMR 5 was discovered by the author (Rica 2005) of this article. It is composed of 12.0 and 13.5 magnitude stars with an angular separation of 4.62 arcsec. There is very little astrophysical information in literature for this pair and I could not determine its nature using astrophysical tests. So in these cases we use probability theory to calculate the probability of chance projection of a star within 4.62 arcsec for the primary.

The value of the probability of a chance projection resulted be of 0.08 %. We must not interpret this value alone and must taken account the typical P val-

Filter	Initial artificial catalogue	Physical pairs	Rejected opticals	Filtered catalogue
P ≤ 5%	50,000 optical (50%) 50,000 physical (50%)	100%	6%	48,000 optical (49%) 50,000 physical (51%)
P ≤ 1%	50,000 optical (50%) 50,000 physical (50%)	98%	27%	36,500 optical (43%) 49,000 physical (57%)
P ≤ 0.5%	50,000 optical (50%) 50,000 physical (50%)	94%	65%	17,500 optical (27%) 47,000 physical (73%)
P ≤ 0.35%	50,000 optical (50%) 50,000 physical (50%)	92%	79%	10,500 optical (19%) 46,000 physical (81%)

Table 1: Results for different values of *P*.

ues for optical and physical pairs. About 80 percent of physical sample have $P \leq 0.08$ %. There was no optical pair in the optical sample with P <= 0.08 %. So in LIADA optical and physical samples all of pairs with $P \leq$ 0.08 % were physical one and we can conclude that FMR 5 is surely a physical double star.

Conclusions

In this work I have described and analyzed the tests based in probability theory to obtain the probability of chance projection of a pair of stars. The analysis showed that the distribution range of values for P in optical and physical samples have an overlapped region that makes difficult the clear classification of visual double stars in optical or physical pairs. The values of P used in professional literature to discriminate optical and physical pairs were far to be correct. This method could be useful to filter visual double star catalogs obtaining a filtered-catalog with a high percent of physical pairs. Other use of this test is to obtain the probability that a pair of stars be a chance projection.

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Abstract: This report contains theta/rho measurements from 87 different double star systems. The time period spans from 2005.800 to 2006.290. Measurements were obtained using a 20-cm Schmidt-Cassegrain telescope and an illuminated reticle micrometer. This report represents a portion of the work that is currently being conducted in double star astronomy at Divinus Lux Observatory in Flagstaff, Arizona.

In a previous article, the rationale was given for focussing upon measuring double stars that challenge the limits of one's equipment, and perhaps, the limits of the researcher as well. One additional element, which was not mentioned, is the fact that many of the double stars that appear in the WDS CATALOG are brighter than the listing would indicate. For example, since I have been giving more attention to 10th magnitude pairs, I have found that a number of doubles, which are listed as 11th magnitude pairs, are actually in the 10th magnitude range, and sometimes, even in the 9th magnitude range.

It must be pointed out that finding such pairs is not a task that can be quickly done. One must be willing to check every potential target that is listed in the CATALOG against an accurate star chart. Since I use a CD-ROM star chart, I am able to switch back and forth between the CATALOG and the star chart so that each pair of interest can have immediate magnitude verification. Of course, it is true that many of the doubles that are listed as 11th magnitude pairs in the CATALOG really have such a value, but I have found enough brighter ones to make the effort worthwhile.

As a result of making such a search, many more neglected double stars can be measured that actually fall within the range of the instrumentation that one is using. In addition, it can be intrinsically rewarding when one realizes that, occasionally, measurements are being made for certain double stars that have had no published measurements for over a century. Recovering this type of double star can almost be as exciting as finding a new pair. Frequently, significant theta/rho shifts will also be found as a consequence of the many decades that have passed since the last measurements were made. Hence, the researcher may wish to consider giving priority to this type of work as a way to enhance a double star measuring program.

As has been done in previous articles, the selected double star systems, which appear in this report, have been taken from the 2001.0 version of the Washinton Double Star Catalog, with published measurements that are no more recent than ten years ago. There are also some noteworthy items that are discussed pertaining to the following table.

To begin with, several double star systems have displayed significant theta/rho shifts since the last measurements were published. Consistent with the discussion above, it has been noted that STF 892 has been listed in the USNO Double Star CD 2001.0 as not having been measured since 1831, so measurements for this pair appear in the table. Because 174 years have passed since the earlier measurements were obtained, it is being reported that this double star has displayed a 7 degrees decrease in the theta value and a 9.5" increase in the rho value during this span of time. Proper motion by the reference point star appears to be responsible for these shifts.

Proper motion by one or both of the components has caused significant theta/rho shifts in three additional double stars. For ARG 66, proper motion by the

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companion star has caused an 11.5 degrees decrease in the theta value since 1968. Proper motion by both components of ARG 67 is responsible for a 7.8% increase in the rho value since 1961.In a like manner, proper motion by both components of J 2840 has brought about a 7 degrees decrease in the theta value since 1991.

Theta/rho shifts from proper motion are also being reported for STF 1327 AC, HJ 807 AB, and STF 1359 AB & AC. For STF 1327 AC, a large proper motion by the "A" star is responsible for a 3% increase in the rho value since 1996. Regarding HJ 807 AB, proper motion by both component stars has caused a 2.5 degrees increase in the theta value and a 5% increase in the rho value since 1969. For STF 1359 AB & AC, proper motion by the "A" component has brought about a decrease of 2 degrees in the theta value for "AB" since 1991 and, for "AC," proper motion by both components has caused a 2.5" increase in the rho value since 1923.

A large proper motion by the "B" component, for HJ 808 AB, is responsible for a 2.7 degrees decrease in the theta value and a 2.5% increase in the rho value since 1991. Likewise, "B" component proper motion has caused parameter shifts for KU 47 AB. Since 1960, increases of 5 degrees in the theta value and 8.5" in the rho value have occurred. Because almost a century has passed since the 1910 measurements were published for BUP 155 AC, a 2.5 degrees decrease for the theta value and a 50" increase in the rho value are being reported. Also noteworthy is the fact that a large proper motion has caused an increase of almost 5% in the rho value, for STF 1561 AC, since 1991.

Proper motions by both components, in five additional double stars, have caused theta/rho shifts that might be mentioned. The first such system, A 2379 A-BC, has undergone a 2 degrees decrease in the theta value and a 3.7% decrease in the rho value since 1962. Secondly, since 1984, KU 104 has shown an increase of 2.3% in the rho value. Thirdly, a decrease of almost 3 degrees in the theta value, since 1988, has been measured for HJ 217 AB. Next, STF 1961 AB has displayed a 2 degrees decrease in the theta value and a 3.5% increase in the rho value, since 1991. Lastly, proper motions in opposite directions, by the components of STF 1901, have caused a 2 degrees decrease in the theta value, since 1996.

The discussion regarding proper motion shifts concludes by examining two multiple star systems. For the STF 1945 AB/AC system, common proper motions by the "BC" components, relative to the "A" component, have caused theta value increases of 8 degrees and 7 degrees, respectively, for "AB" and "AC" since 1961. The rho values have increased by 3.7" and 2.8" during this same time period. The second multiple star system, which has displayed significant proper motion shifts, is STF 1996 AB/AC. In this case, common proper motions by the "AB" components, relative to the "C" component, have caused the theta value to increase by about 3 degrees, and rho value to increase by 11" for the "AC" measurements, since 1910.

Orbital motion appears to be the cause for a 2 degrees increase in the theta value and a slight increase in the rho value, for STF 1985, since 1996. This visual binary is one of a dozen, or so, that can be regularly monitored even with a small telescope.

In regards to STT 72 AC, a possible increase of 4 degrees in the theta value has been measured, but the obtained value of 326.8 degrees is not consistent with the historical record in the WDS CATALOG or with the data in the Hipparcos/Tycho Catalogs. These other sources suggest a value of around 323 degrees. The reason for this discrepancy is unclear, since STT 72 AC was remeasured with the same results being obtained. The measurements for STT 72 AB were consistent with catalog values, so calibration of the micrometer didn't seem to be a factor in obtaining this discordant theta value. Adding to the mystery is the fact that STT 72 AC is supposedly a relatively fixed, common proper motion system. Additional measurements by others should help to determine which theta value is more accurate.

Also being reported is the listing of a potentially new double star bearing the "ARN" prefix. ARN 86 (07354+0016) appears in the table as a possible common proper motion pair that doesn't seem to have been previously cataloged. This new submission is located near BAL 1108.

Next, it appears as though a quadrant flip may have occurred for HJ 460 AC as it is currently listed in the WDS CATALOG. This conclusion has been reached because the respective positions of the "AB" components should place the "C" component with a theta value of 21 degrees, rather than at 201 degrees. Hence the table gives measurements for HJ 460 (CA), in order to reflect values which more closely relate to those currently in the CATALOG. It might also be mentioned that the rho value for "AC" has decreased by 4.5" since 1991, because of proper motion by the "C" component. Additionally, the "C" component is also part of the double star LDS 6219.

In a like manner, because a quadrant flip occurred between 1828 and 1988 for the theta measurements pertaining to STF 1773 AB, the measurements for "AC" and "BC" are also reversed. The WDS CATALOG lists these additional measurements according to the 1828 configuration, while these component measurements, in this report, are consistent with the 1988 listing for "AB."

Lastly, in regards to LDS 968 AB-C, the 1996 rho value that is listed in the WDS CATALOG appears to be incorrect. The rho measurement listed in this report more closely matches the 1936 value of 135" rather than the 1996 value of 121".7. This conclusion has been reached, for the 1996 listing, because this is a relatively fixed, common proper motion pair.

Name	RA DEC	Mags	PA	Sep	Date	N	Notes
STF 871	06116-0046	8.9, 9.4	306.3	7.90	2005.800	1n	1
STF 892	06195+1220	10.4, 10.7	41.2	39.50	2005.800	1n	2
STT 74AB	06206+2511	7.1, 8.9	264.8	56.78	2005.800	1n	3
STT 72AB	06247+5940	7.5, 10.3	304.5	46.41	2005.926	1n	4
STT 72AC	06247+5940	7.5, 7.6	326.8	133.31	2005.926	1n	4
WFC 66	06498+0656	9.9, 10.5	322.0	7.41	2005.800	1n	5
AG 136	07066+3802	10.0, 10.3	216.3	6.91	2005.800	1n	6
ARG 66	07162-0216	9.6, 10.3	301.6	14.32	2005.926	1n	7
ARD 67	07327+0540	9.8, 10.2	140.0	24.69	2005.926	1n	8
ARN 86*	07354+0016	9.8, 9.9	181.1	32.59	2005.926	1n	9
J 2840	07377+1330	10.4, 10.6	281.9	7.90	2005.926	1n	10
SEI 488	08112+3255	10.3, 10.6	314.2	22.71	2005.984	1n	11
STT 91AB	08195+3503	7.2, 8.3	210.2	94.80	2005.984	1n	12
STF1224A-BC	08267+2432	6.9, 7.5	50.6	5.43	2005.984	1n	13
STF1250AB	08402+5147	10.1, 10.4	168.9	21.73	2005.984	1n	14
STF1266	08445+2827	8.7, 9.9	64.1	23.70	2005.984	1n	15
HJ 460AC	08525+2816	5.9, 6.3	200.8	273.54	2005.984	1n	16
STT 97	09084+2732	8.2, 8.2	237.4	51.35	2005.984	1n	17
HJ 807AB	09124-0709	9.6, 10.0	289.6	14.81	2005.984	1n	18
WFC 125	09133+0540	10.2, 10.4	76.3	8.39	2005.984	1n	19
STF1327AC	09155+2755	8.7, 10.4	16.8	28.64	2005.984	1n	20
HJ 808AB	09168+0814	10.3, 10.5	206.3	24.19	2006.060	1n	21
SHJ 107	09320+0943	5.1, 9.2	74.5	37.53	2006.060	1n	22
STF1359AB	09330+5615	9.7, 10.6	54.9	7.41	2005.984	1n	23
STF1359AC	09330+5615	9.7, 10.4	240.0	117.51	2005.984	1n	23
OSV 4AB	10151+3931	10.2, 10.5	40.7	97.76	2006.055	1n	24

\# Companion star is the brighter component.
* Not listed in WDS CATALOG.

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Name	RA DEC	Mags	PA	Sep	Date	N	Notes
STF1427	10220+4354	8.1, 8.5	214.7	9.38	2006.055	1n	25
STF1435	10280+1950	10.3, 10.7	202.0	8.39	2006.060	1n	26
HJ 2532AB	10296+3757	10.3, 10.6	70.1	12.84	2006.060	1n	27
FOX 166AC	10296+3757	10.3, 10.1#	250.8	201.45	2006.060	1n	27
SCA 71	10346-1258	9.4, 10.6	326.6	145.16	2006.156	1n	28
FIL 26	10457-0130	10.0, 10.1	260.6	20.74	2006.055	1n	29
KU 100	10503+2234	10.0, 10.1	103.3	47.89	2006.055	1n	30
STF1497	10586+0908	10.2, 10.7	70.6	16.79	2006.055	1n	31
HJ 172	11022+0945	10.1, 10.2	94.3	13.33	2006.058	1n	32
HJ 494	11131+4011	10.6, 10.7	141.0	31.11	2006.099	1n	33
KU 36	11133+3811	10.7, 10.7	136.7	8.89	2006.058	1n	34
A 2379A-BC	11182+1638	10.1, 10.3	48.0	27.65	2006.156	1n	35
STF1526	11187+0250	10.2, 10.3	180.6	30.12	2006.058	1n	36
STT 111	11301+2958	6.9,, 9.4	33.3	67.15	2006.058	1n	37
STF 1556	11363+1208	10.6, 10.7	51.8	8.89	2006.058	1n	38
STF1553	11366+5608	7.7, 8.1	165.2	5.93	2006.099	1n	39
STF1561AB	11387+4507	6.5, 8.1	248.3	9.38	2006.099	1n	40
STF1561AC	11387+4507	6.5, 9.4	90.2	164.91	2006.099	1n	40
HJ 209	12239-0303	10.6, 10.7	146.5	23.70	2006.079	1n	41
ES 2642	12280+4753	10.1, 10.3	257.2	28.14	2006.079	1n	42
HJ 519	12304+3608	10.2, 10.3	189.2	18.27	2006.079	1n	43
STF1653	12334+3202	9.6, 9.6	347.7	7.90	2006.079	1n	44
HJ 212	12335+1012	10.1, 10.2	264.4	21.73	2006.079	1n	45
STF1657	12351+1823	5.0, 6.3	270.5	20.24	2006.099	1n	46
BAL1162	12432+0000	10.0, 10.7	303.2	14.81	2006.079	1n	47
STF1678	12454+1422	7.2, 7.6	171.5	36.54	2006.099	1n	48
HJ 217AB	12459+1009	10.1, 10.4	25.2	33.08	2006.156	1n	49
HJ 523	12519+3447	10.3, 10.7	183.0	14.32	2006.079	1n	50
STF1689	12555+1130	6.9, 9.1	221.7	29.63	2006.099	1n	51
STF1721	13085+0107	10.1, 10.2	357.7	6.42	2006.101	1n	52
HJ 2649	13184+5420	10.2, 10.5	345.4	21.23	2006.101	1n	53
FOX 177	13217+1542	10.2, 10.4	86.9	17.28	2006.101	1n	54
HJ 1232	13276+0655	10.0, 10.5	306.5	12.84	2006.101	1n	55
ODE 11	13337+4801	9.5, 9.8	134.9	124.43	2006.101	1n	56
STF1765	13379+0221	10.4, 10.6	161.5	38.02	2006.101	1n	57

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Name	RA DEC	Mags	PA	Sep	Date	N	Notes
KU 104	13384+4306	10.1, 10.5	54.1	59.25	2006.156	1n	58
STF1773AB	13416+0736	9.9, 9.9	210.5	30.12	2006.230	1n	59
STF1773AC	13416+0736	9.9, 10.6	102.0	56.29	2006.230	1n	59
STF1773BC	13416+0736	9.9, 10.6	77.9	72.09	2006.230	1n	59
BU 613AB-C	13514+3441	10.3, 10.6	74.8	45.92	2006.156	1n	60
HJ 2678	13520-1955	10.1, 10.4	140.2	15.80	2006.101	1n	61
KU 47AB	13540+3209	10.2, 10.7	149.2	20.74	2006.230	1n	62
HJ 233	13572+1151	10.6, 10.7	133.8	19.75	2006.101	1n	63
BUP 155AC	13594+2515	10.6, 9.7#	91.4	308.10	2006.230	1n	64
STF1835A-BC	14234+0827	5.0, 6.7	193.7	5.93	2006.230	1n	65
STF1850	14286+2817	7.1, 7.6	262.1	25.68	2006.230	1n	66
HJ 554AB	14325+3442	10.3, 10.7	291.8	11.85	2006.137	1n	67
GLP 3	14327-1246	10.5, 10.7	322.3	79.00	2006.137	1n	68
ES 609AC	14375+4743	10.1, 10.2	117.5	79.00	2006.137	1n	69
LDS 968AB-C	14426+1929	9.1, 10.1	309.8	135.29	2006.230	1n	70
KU 48AB	14430+1310	10.4, 10.6	137.4	6.42	2006.137	1n	71
HJ 241	14485+1203	10.2, 10.7	140.8	17.28	2006.137	1n	72
HJ 1261	14539+5734	10.4, 10.5	17.0	8.89	2006.137	1n	73
ABT 9	14540-0945	10.7, 10.5#	336.3	23.21	2006.137	1n	74
AG 196	14547+5038	10.0, 10.7	139.1	27.16	2006.137	1n	75
HJ 4720	14573-0551	10.4, 10.5	212.5	12.84	2006.137	1n	76
STF1901	15010+3123	8.5, 10.5	184.9	19.26	2006.230	1n	77
STF1931AB	15187+1026	7.2, 8.0	166.7	13.33	2006.230	1n	78
STF1945AB	15280+1442	10.0, 10.5	311.2	40.49	2006.290	1n	79
STF1945AC	15280+1442	10.0, 10.5	306.1	48.39	2006.290	1n	79
STF1945BC	15280+1442	10.5, 10.5	280.9	9.38	2006.290	1n	79
HJ 254AB	15303+1543	9.9, 10.4	277.6	17.28	2006.173	1n	80
STF1949	15306+1303	10.1, 10.2	213.4	16.29	2060.173	1n	81
AOT 60	15306-1217	10.1, 10.6	356.6	39.50	2006.173	1n	82
STF1961AB	15346+4331	9.9, 10.1	21.0	28.14	2006.230	1n	83
HJ 4804	15459-0921	10.6, 10.7	283.3	19.26	2006.173	1n	84
STF1985	15559-0210	7.0, 8.6	353.0	6.42	2006.290	1n	85
STF1996AB	15565+5717	10.2, 10.6	108.0	19.26	2006.290	1n	86
STF1996AC	15565+5717	10.2, 10.6	143.9	160.96	2006.290	1n	86
STF2104	16487+3556	7.4, 8.7	21.0	5.93	2006.290	1n	87

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Notes:
1. In Orion. Relatively fixed. Spect. A0, A0.
2. In Orion. Sep. increasing; p.a. decreasing.
3. In Gemini. Separation slightly decreasing. Spect. B9, A0.
4. In Lynx. AB = sep. & p.a. inc. AC = cpm, (relfix?) Spect. AC = K0, A3.
5. In Monoceros. Position angle increasing. Spect. A3, F8.
6. In Auriga. Relatively fixed.
7. In Monoceros. Sep. & p.a. decreasing. Spect. G, G.
8. In Canis Minor. Separation increasing. Spect. K, F0.
9. In Canis Minor. Near BAL 1108. Possible common proper motion. Spect. F0.
10. In Gemini. Position angle decreasing.
11. In Cancer. Sep. decreasing; p.a. increasing. Spect. F8, G.
12. In Lynx. Sep. increasing; p.a. decreasing. Spect. A5, G0.
13. 24 Cancri. Common proper motion; p.a. increasing. Spect. F0V, F7V.
14. In Ursa Major. Relatively fixed. Common proper motion. Spect. G, G.
15. In Cancer. Relatively fixed. Common proper motion. Spect. F8, F8.
16. 53 Cancri. Sep. & p.a. decreasing. Spect. K0, M3.
17. In Cancer. Relatively fixed. Common proper motion. Spect. G0V, G0.
18. In Hydra. Sep. & p.a. increasing. Spect. G, G.
19. In Hydra. Common proper motion; p.a. increasing. Spect. G5.
20. In Cancer. Sep. increasing; p.a. decreasing. Spect. F8, F8.
21. In Cancer. Sep. increasing; p.a. decreasing. Spect. F5, K.
22. 6 Leonis. Slight decrease in p.a. Spect. K3III, F5.
23. In Ursa Major. AB = p.a. dec. AC = sep. inc. Spect. G5.
24. In Leo Minor. Relatively fixed. Common proper motion. Spect. M0.
25. In Ursa Major. Slight increase in p.a. Spect. F5V, F5.
26. In Leo. Relatively fixed. Common proper motion. Spect. G0, G.
27. In Leo Minor. AB = relfix; cpm. AC = sep. & p.a. inc. Spect. F8, G0, F5.
28. In Hydra. Sep. & p.a. slightly increasing. Spect. K5.
29. In Sextans. Decrease in p.a. Spect. G, G.
30. In Leo. Relatively fixed. Common proper motion. Spect. F8.
31. In Leo. Relatively fixed. Spect. F2, F5.
32. In Leo. Relatively fixed. Common proper motion. Spect. K5, M.
33. In Ursa Major. Sep. increasing; p.a. decreasing. Spect. F8, G0.
34. In Ursa Major. Relatively fixed. Spect. G0, G0.
35. In Leo. Sep. & p.a. decreasing.
36. In Leo. Relatively fixed. Common proper motion. Spect. G0, G0.
37. In Ursa Major. Relatively fixed. Common proper motion. Spect. A9, G5.
38. In Leo. Relatively fixed. Common proper motion. Spect. G5, G5.
39. In Ursa Major. Common proper motion; p.a. decreasing. Spect. G5, G5.
40. In Ursa Major. AB = cpm; p.a. dec. AC = sep. inc. Spect. G0V, G0, K0.
41. In Virgo. Common proper motion; sep. slightly decreasing. Spect. K, K.
42. In Canes Venatici. Common proper motion; sep. slightly decreasing.
43. In Canes Venatici. Sep. decreasing; p.a. increasing. Spect. F2.
44. In Canes Venatici. Relfixed. Common proper motion. Spect. F3V, F3V.
45. In Virgo. Relatively fixed. Common proper motion. Spect. G5, K.
46. 24 Comae Berenicis. Common proper motion; p.a. dec. Spect. K2III, A3.
47. In Virgo. Relatively fixed. Common proper motion. Spect. F8, G.
48. In Coma Berenices. Position angle decreasing. Spect. B8V, G5.
49. In Virgo. Position angle decreasing. Spect. G2V, K.
50. In Canes Venatici. Relatively fixed. Common proper motion. Spect. G, G.
51. In Virgo. Position angle increasing. Spect. M4III, F5.
52. In Virgo. Relatively fixed. Spect. F8, F8.

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53. In Ursa Major. Separation decreasing. Spect. K0, K0.
54. In Coma Berenices. Relatively fixed. Common proper motion. Spect. K5, K5.
55. In Virgo. Relatively fixed. Common proper motion. Spect. F8, G.
56. In Canes Venatici. Relatively fixed. Common proper motion. Spect. G0, G0.
57. In Virgo. Sep. & p.a. decreasing.
58. In Canes Venatici. Sep. & p.a. increasing. Spect. F8.
59. In Bootes. AB = sep. inc. AC = p.a. dec. BC = sep. dec. Spect. K2, F8, G5.
60. In Canes Venatici. Sep. & p.a. decreasing. Spect. F8, K0.
61. In Virgo. Position angle increasing. Spect. F5, F0.
62. In Canes Venatici. Sep. & p.a. increasing. Spect. K0, K0.
63. In Bootes. Position angle decreasing. Spect. G0, G0.
64. In Bootes. Sep. increasing; p.a. decreasing. Spect. K4, K0.
65. In Bootes. Common proper motion; p.a. increasing. Spect. A0V, F2V.
66. In Bootes. Relatively fixed. Spect. A1V, A1V.
67. In Bootes. Relatively fixed. Common proper motion. Spect. K0, K0.
68. In Libra. Sep. & p.a. increasing. Spect. G6V.
69. In Bootes. Relatively fixed. Spect. K0, G5.
70. In Bootes. Relatively fixed. Common proper motion. Spect. M0, M0.
71. In Bootes. Common proper motion; p.a. decreasing. Spect. K0, K.
72. In Bootes. Separation decreasing. Spect. K0.
73. In Draco. Common proper motion.
74. In Libra. Common proper motion.
75. In Bootes. Separation increasing. Spect. G5, F8.
76. In Libra. Relatively fixed. Common proper motion.
77. In Bootes. Sep. & p.a. decreasing. Spect. M2, G5.
78. In Serpens. Common proper motion; p.a. decreasing. Spect. F2V, G3V.
79. In Serpens. AB & AC = sep. & p.a. inc. BC = relfix; cpm. Spect. K2, K, K.
80. In Serpens. Common proper motion; p.a. slightly decreasing. Spect. G5.
81. In Serpens. Relatively fixed. Common proper motion. Spect. G0, G0.
82. In Libra. Separation increasing. Spect. G5.
83. In Bootes. Sep. increasing; p.a. decreasing. Spect. K2, F8.
84. In Libra. Relatively fixed. Common proper motion.
85. In Libra. Common proper motion; p.a. increasing. Spect. F8V, G0.
86. In Draco. AB = relfix; cpm. AC = sep. & p.a. inc. Spect. F8.
87. In Hercules. Relatively fixed. Spect. F2, F2.

SDSS J001708.1-102649.5 & SDSS J001707.99-102647.3: Serendipitous Discovery of a New Binary System Candidate

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Abstract: A discovery of a new binary system candidate, consisting of two twin M-dwarfs, is presented in this work. Data taken from astronomical literature and visual magnitudes estimates, proper motions, spectral types and luminosity classes, added to other important stellar parameters are shown hereby. All this information will be used later to clarify the probability of physical nature for the new system by using a diversity of professional characterization criteria.

Discovery

The pair discussed in this paper was located visually in a 2MASS plate (J band) while doing research about the closed system HU 3 (=WDS 00170-1020) in CETUS. The pair is 7' distant from HU 3, towards 162º and the main component has coordinates J2000 RA = 4.283755º and Dec = -10.447102º.

The new pair, which is not catalogued in WDS, is composed of two weak stars, almost identical and quite tight (something less than 3 arc-seconds angular separation). In the examined 2MASS plate, it can be seen immediately the double character of the source, since it shows an oval elongated shape, as if it was an "eight". Figure 1 shows the pair registered in plates DSS-II, 2MASS and SDSS.

Data From Astronomical Literature

The Aladin tool was used to search for information. The results of the main enquired catalogs:

- 2MASS (*Identification = 00170808-1026491)* makes only reference to a single source (the main star) and gives magnitudes J = 12.999, H = 12.399 y K = 12.240.
- USNO-A2.0 (*Identification = 0750-00065758 / Epoch: 1954.671*) gives magnitudes B = 16.1 and R = 14.2.
- USNO-B1.0 (*Identification = 0795-0003105 / Epoch: 1978.3*) gives values of the proper motion for a single source: μ (α) = -4 ± 2 mas·yr^{-1} and μ (δ) = -10 ± 3 mas·yr^{-1}. The reported magnitudes are B1 = 16.12, B2 = 15.99, R1 = 14.25, R2 = 14.49, and I(N) = 13.04.
- UCAC-2 (*Identification = 28125501 / Epoch: RA 1997.117 and Dec 1994.860)* reports a magnitude of 15.56 in UC photometric system. Again, it provides proper motions for a single source absolutely different in value and direction of the ones mentioned for USNO-B1. This values are: $\mu(\alpha)$ = 39.1 ± 8.5 mas·yr^{-1} and $\mu(\delta)$ = -63.9 ± 9.2 mas·yr^{-1}.
- GSC 2.2 (*Identification = S00032125296 / Epoch: 1996.836)* assigns a stellar nature to the source with magnitudes R = 14.19 and Bj = 15.95.

The SDSS catalogue separates perfectly both sources as different stars by measuring their brightness in the *ugriz* multiband system. Towards the southwest of the main star there is a weak source corresponding to a galaxy. Unfortunately, it doesn't give the spectra of the components, despite being one of the most valuable qualities of this survey. The data are shown in Table 1.

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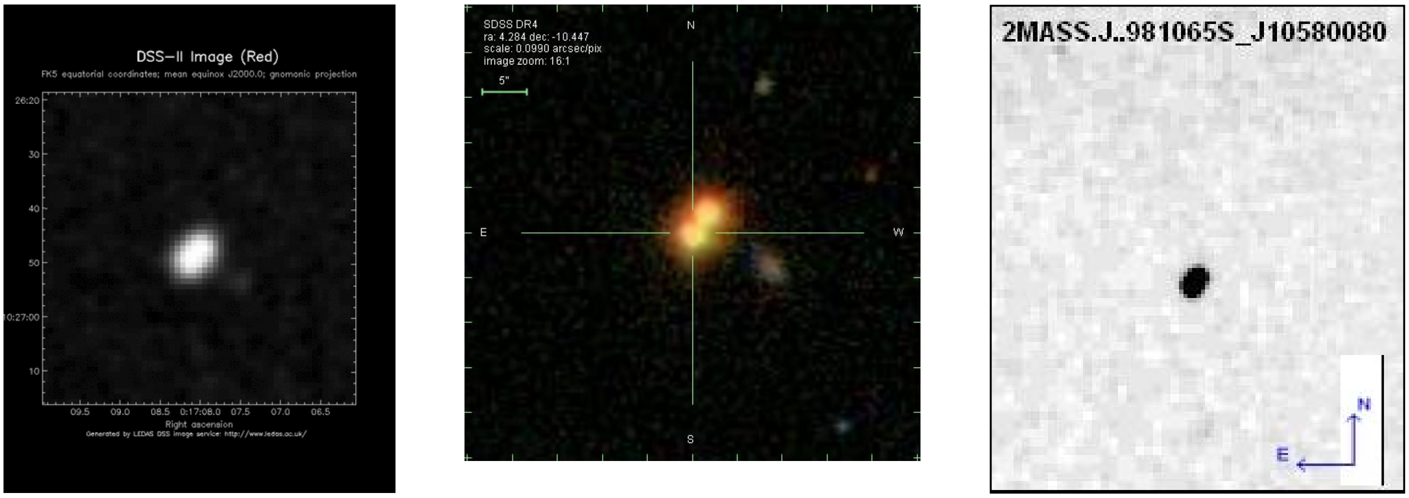

Figure 1: The system in plates of several surveys from different epochs.

VBI photometry estimate

None of the catalogs give the visual magnitude of the component. It was decided to make an estimate by means of transformations of the magnitudes offered by several important catalogues.

With R and Bj magnitudes given by GSC2.2 catalog and by applying the expression $V = R + [0.375 \times (B - R)] + 0.04$ (Rica, 2004), a value of $V = 14.89$ for the primary star was obtained.

If we use R and B magnitudes of the USNO-A2.0 catalog within the conversion $V = R_u + 0.23 + [0.32 \times (B - R)_u]$ (Salim & Gould, 2000), we got a very similar value to the one before: V = 15.038.

It was decided to calculate V, B and I magnitudes starting with the photometric data of SDSS catalog by using Lupton´s (2005) transformations. Having *ugriz* magnitudes for the two system components we could calculate separately BVI for each of them, with the idea of obtaining *a posteriori* the B – V and V – I color indexes. In the calculation, two sets of equations were used for each band (BVI) which involves different *ugriz* colors and, finally, the obtained results were averaged. The expressions of transformation are:

$$B = u - 0.8116(u - g) + 0.1313; \quad \text{sigma} = 0.0095$$
$$B = g + 0.3130(g - r) + 0.2271; \quad \text{sigma} = 0.0107$$

$$V = g - 0.2906(u - g) + 0.0885; \quad \text{sigma} = 0.0129$$
$$V = g - 0.5784(g - r) - 0.0038; \quad \text{sigma} = 0.0054$$

$$I = r - 1.2444(r - i) - 0.3820; \quad \text{sigma} = 0.0078$$
$$I = i - 0.3780(i - z) - 0.3974; \quad \text{sigma} = 0.0063$$

Results are shown in Table 2.

The V magnitudes obtained are weaker than those inferred for the main component by using the transformations of the GSC2.2 and USNO-A2.0 (14.89 and 15.038). This can be explained if we have in mind that the photometry is surely for both sources combined, which means that the magnitude of these catalogs is brighter than if they are taken each one separately. In order to corroborate this assumption, the combined or integrated magnitude of the system was calculated by using both visual magnitudes which have just been deduced. The following expression was used:

$$m_{AB} = m_B - 2.5 \log\left(\left(2.512^{(mB - mA)}\right) + 1\right)$$

Identification	Type	RA	Dec	u	g	r	i	z	Comp.
587727225691963564	Star	4.283755	-10.447102	19.464	16.82	15.49	14.833	14.502	A
587727225691963565	Star	4.283326	-10.446485	19.92	17.268	15.89	15.145	14.722	B

Table 1. SDSS photometry in *ugriz* bands.

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Comp.	Magnitude B			Magnitude V			Magnitude I			B-V	V-I
	[1]	[2]	Average	[3]	[4]	Average	[5]	[6]	Average		
A	17.45	17.46	17.45	16.14	16.05	16.09	14.29	14.31	14.30	1.36	1.79
B	17.90	17.93	17.91	16.59	16.47	16.53	14.58	14.59	14.58	1.38	1.95

Table 2. BVI photometry calculation.

Entering the values $m_A = 16.09$ and $m_B = 16.53$ from Table 2 into the equation we got a combined visual magnitude of $m_{AB} = 15.535$. Our result, which is very similar to the calculated values using GSC2.2 and USNO-A2.0, proves the goodness of our calculations and the combined nature of both professional photometries.

Spectral and Photometric Distances

By means of the spectral distribution of energy in BVI bands (Table 2), JHK (2MASS), and kinematics (reduced proper motion), a spectral class of M0.5V was obtained for the main component. 2MASS doesn't offer infrared photometry for the secondary. An estimation of JHK magnitudes of the secondary was made from the BVI calculated magnitudes. Conversion tables show that the secondary could have magnitudes J-H-K = 13.28 - 12.61 - 12.40. If we use these values, the spectral distribution of energy in BVIJHK jointly with the kinematics study, the secondary may had a spectrum M1.5V. Although it doesn't seem to be the case, it might happen that 2MASS gives a joint photometry as well, so that the spectrum that we have calculated for the main one, would in fact be combined for two components, this way the estimation made for the secondary may be weak. It was attempted to solve this uncertainty by using another independent spectral and photometric method.

In the astronomical literature there are several modern references that use SDSS data to make a connection between *ugriz* colors and absolute magnitudes in some bands enabling the inference of stellar spectra in a synthetic way. By means of these tools we have arrived at the following conclusions.

According to Karaali *et al.* (2005) we can derive the absolute visual magnitude from the absolute magnitude in *g* (SDSS) band:

$$M_V = 0.9972\,(Mg) - 0.046 \qquad (1)$$

The same authors Bilir *et al.* (2005) suggest another equation which calculates Mg on the basis of the colors $(g - r)$ y $(r - i)$:

$$Mg = a(g - r) + b(r - i) + c \qquad (2)$$

The constants a, b, and c, have values = 5.791; 1.242; 1.412, respectively.

In Henry *et al's* work (1994) the spectral type of the M dwarfs is connected to the absolute visual magnitude by using the equation:

$$M_V = 0.101(ST)^2 + 0.596(ST) + 8.96 \qquad (3)$$

The ST coefficient depends on the spectral type and can have the values: -2.0 for class K5V; -1.0 for class K7V; 0.0 for class M0V; 1.0 for class M1V.

This expression is valid for range K5V to M7V and has an uncertainty of ± 0.5 spectral subclasses. This range is over the whole spectral type in this work. Our procedure consists of replacing Mg (eq. 2) value in equation (1) in order to derive the visual absolute magnitude. Later, this last value will be replaced in equation (3). By simplifying and resolving the second grade equation which is obtained, we will infer the ST spectral index. Table 3 shows the results obtained with this method.

According to this procedure, the estimated spectra agree excellently with the ones obtained by spectral distribution. Only a little difference of 0.5 spectral subclasses for the main star can be seen. This uncertainty is valid according to the accuracy of the spectral distribution method (Rica, 2005; Masa, 2005). Consequently, based upon these results, we assume that the offered photometry by 2MASS is only for the main component. Finally, we get the deduced spectra as defined by the SDSS photometry, that is to say M1V and M1.5V.

As a final issue, the dwarf nature of both sources is demonstrated by using reduced proper motion diagrams (Jones, 1972; Nelson, 2003; Salim, 2002) which put the system at the bottom of the main sequence (Figure 1). The similar photometry in *ugriz* bands of SDSS of the both components was looking ahead about the similar spectra that the stars should have, so that we could check our estimate later.

Knowing the absolute visual magnitude and V mag-

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Star	g	r	i	g − r	r − i	Mg	M_V	ST	Spectral Class
A	16.82	15.49	14.833	1.330	0.657	9.930	9.856	1.242	M1V
B	17.268	15.89	15.145	1.378	0.745	10.317	10.242	1.675	M1.5V

Table 3: Synthetic spectral classes for M dwarfs by using SDSS photometry.

nitude we are able to derive the distance in parsecs (d) from each component by the well-known expression relating to the distance module:

$$V - Mv = 5 \log d - 5$$

The obtained distances were 176 and 185 parsecs for the A and B components respectively.

By analysing the distance modules (V - Mv) of the principal one (6.23) and the secondary one (6.29) we can see that the probability for both stars of being at the same distance is almost 100%. Similar spectra and equal distances are a strongly indicative of the fact that there is a physical connection between the pair components.

For the spectral estimation, the possible reddening due to the interstellar absorption was not taken into account. The system galactic latitude (-71.47º) places the components in a position near to the Galactic South Pole so the reddening is almost certainly unnoticed.

Relative Astrometry

Four measures of Theta and Rho were made over some historical plates coming from several surveys: DSS, SSS, 2MASS, and SDSS.

For measurements the fv software, version 4.2 was used. With the Image Probe tool, five centroids were calculated for each component by working out the average of the results. The obtained positions (RA and Dec J2000 for the observation date) were transformed into polar coordinates: position angle and angular distance. The measurement over the plates was very difficult because of the overlapping of both the sources due to overexposure. To aid in the measurements, the Make Contour Map function was used in order to put a limit to the areas of both sources more exactly. It should be necessary to make new relative astrometry measures by means of more precise techniques. The results of this work are shown in Table 4.

The differences among the obtained positions are very small (especially in RA) and we had to treat rounding in the decimal figures with extreme care because the minimum difference might change theta and rho values significantly.

An attempt to reduce the DSS plates astrometrically was made using Astrometrica software and UCAC-2 catalog, but in all cases a single intermediate position between the components was obtained: the program was unable separate the sources.

The DSS plate (epoch 1954.672) has the worst quality of all those studied and we decided to weight the reliability of the positions that we measured. For it, information of SuperCOSMOS Sky Survey was extracted. This project calculates positions on the digitized plates besides others parameters and data products are available as a text format catalog. Again, it was observed that the position for our system was an intermediate position between both components (see Figure 2). Assuming that this average position is located in the center of the *oval shape* of the system, we decide to calculate the mean of our positions and to compare the result with SSS's position. The figures

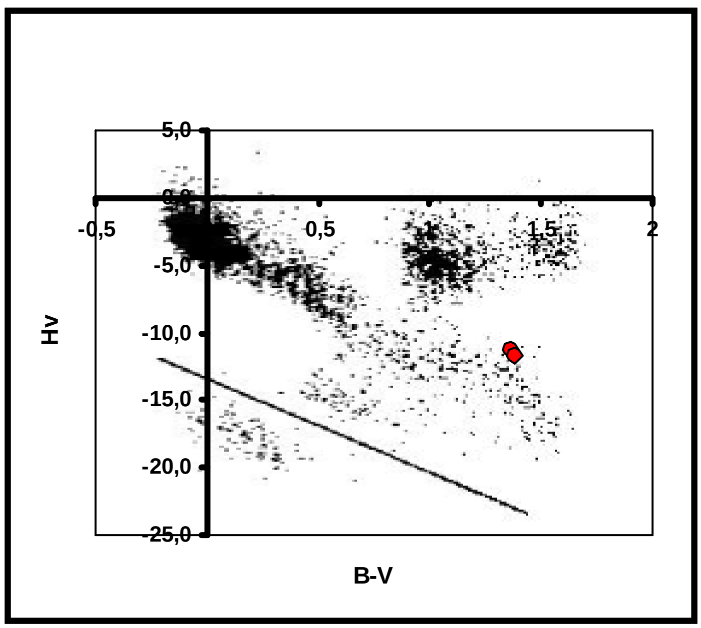

Figure 1. "Reduced-Proper-Motion Diagrams. II. Luyten's White-Dwarf Catalog" from Eric M. Jones (AJ, 177, 245-250 -1972)

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Survey	Epoch		RA HH MM SS.S	RA (°)	Dec ° ' "	Dec (°)	θ	ρ
DSS	1954.6720	A	00 17 08.0952	4.28373	-10 26 48.90998	-10.44691944	323.692	2.631
		B	00 17 07.9896	4.28329	-10 26 46.79002	-10.44633056		
SSS	1994.7820	A	00 17 08.09988	4.2837495	-10 26 49.54	-10.4470944	325.095	2.683
		B	00 17 07.99582	4.2833159	-10 26 47.340	-10.4464833		
2MASS	1998.7902	A	00 17 08.10096	4.283754	-10 26 49.566	-10.4471017	325.324	2.701
		B	00 17 07.9968	4.28332	-10 26 47.345	-10.4464847		
SDSS	2000.7401	A	00 17 08.1012	4.283755	-10 26 49.5672	-10.447102	325.637	2.691
		B	00 17 07.99824	4.283326	-10 26 47.346	-10.446485		

Table 4. Positions of the components in the observation dates and relative astrometry obtained for the system.

follow:

Mean position of SSS: RA = 00 17 08.0460 Dec = -10 26 47.87

Mean position of this work: RA = 00 17 08.0424 Dec = -10 26 47.85

We can see that there is an excellent agreement. According to the literature, the global astrometric accuracy of SSS-POSS is about ±0.25 arcsec. As the differences between the two positions above are inside this range, we can conclude that our positions are valid.

The values of Theta and Rho derived for the epoch 2000.7401 were taken directly from the astometry given in th SDSS. These positions are high quality so that the relative astrometry obtained is the most reliable of all which we present.

By observing the Rho values at different times, we noticed that the system has remained practically fixed in distance. About two degrees change in PA (increasing) was observed.

Proper motions

The astronomical literature references about proper motions (USNO-B1.0 and UCAC-2) are incomplete and divergent. No proper motions in SDSS and SSS data products were found. Therefore, it was decided to make an estimate of the proper motions for

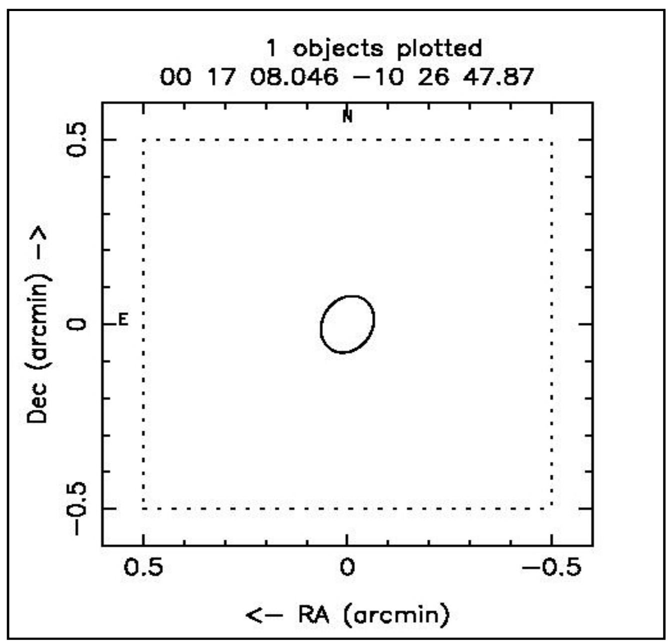

Figure 2: SSS plot of the system based in DSS plate for the epoch 1954.672. The oval shape is the unresolved pair. The intermediate position (J2000) of both sources is showed at the top of the graph. The FOV is 1' x 1'.

the two stars by taking their positions and observation dates shown in Table 4. Our results will be compared with those in the catalogs.

A graphical study was made in RA and Dec for each component by representing in dispersion graphs RA *vs* Epoch and Dec *vs* Epoch. Later a linear fit of the points in each graph was made. The slope of each line of the adjustment is the annual proper motion for each coordinate, and it is expressed in degrees. This value was transformed into miliarseconds per year (mas·yr^{-1}).

In Figures 3, 4, 5 and 6 the graphical study is shown. In Figure 7 the integral motion of the system in RA and Dec is represented.

By analysing the slopes of each adjustment lines (Figures 3 - 6) proper motions in RA and Dec were obtained of each component, as well as the total proper motion of the system and the position angle of its displacement related to celestial North Pole and Eastward. The reported errors come from the deviations of

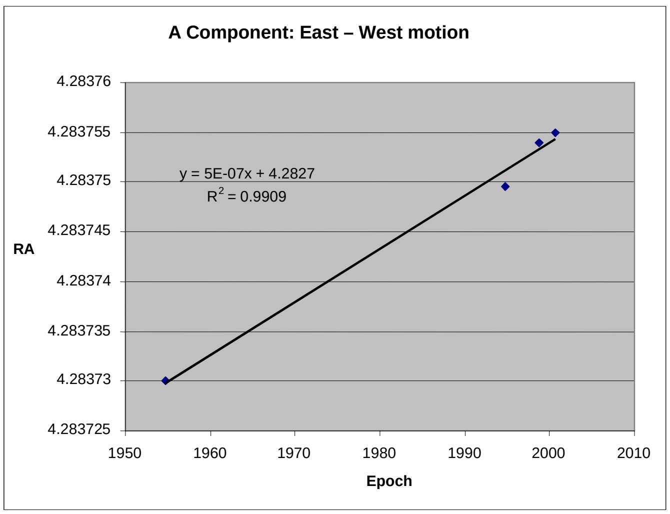

Figure 3: A component: Linear fit of the RA motion.

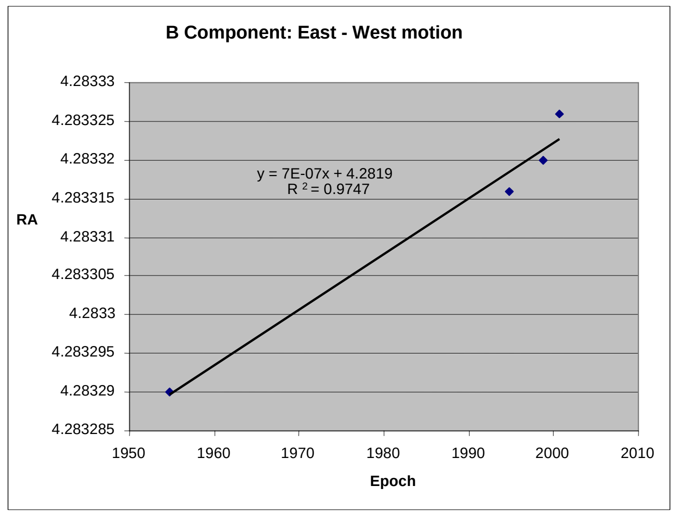

Figure 5. B component: linear fit of the RA motion.

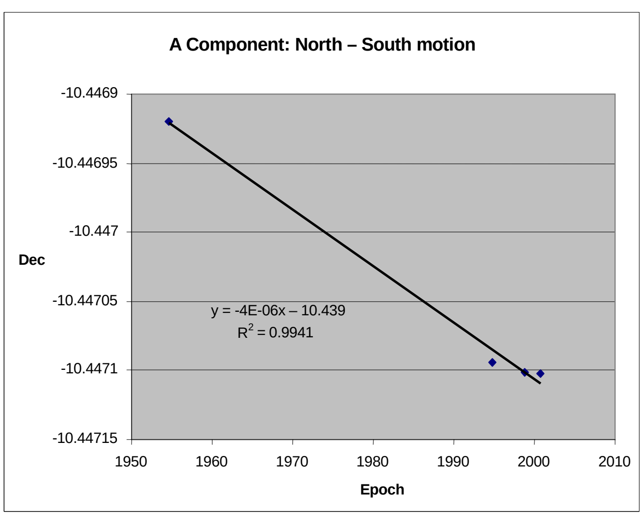

Figure 4: A component: linear fit of the declination motion.

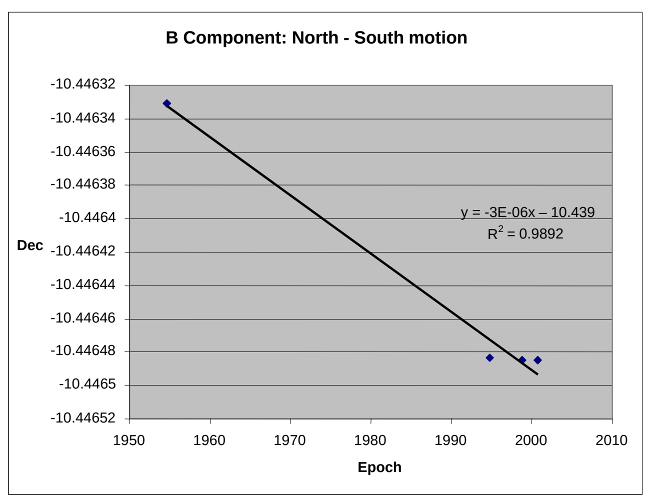

Figure 6: B component: linear fit of the declination motion.

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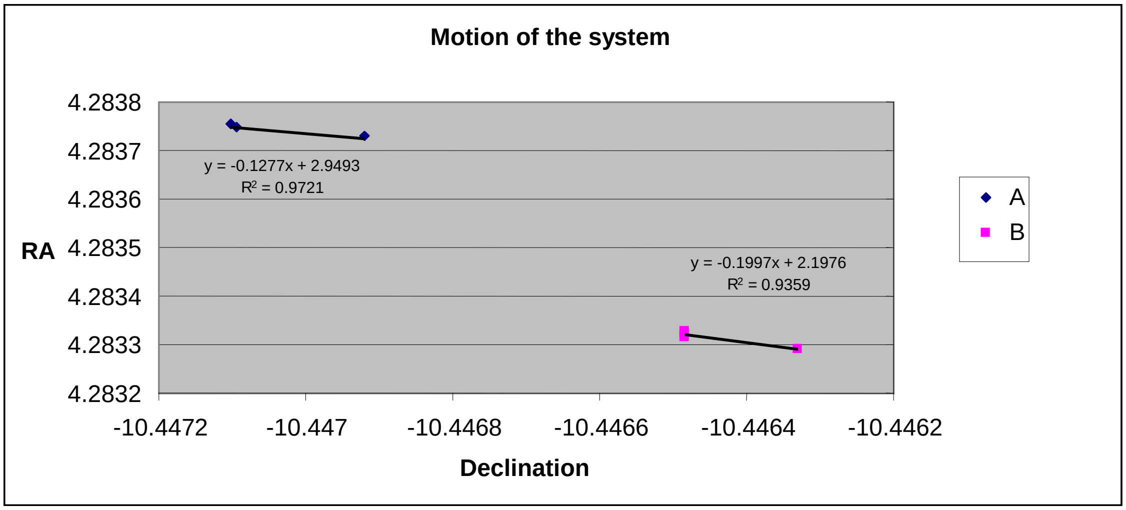

Figure 7: Comparison of the motion of two components throughout the time.

each slope calculated by Excel. The difference in motion is of the order of the errors. The results are gathered in Table 5.

The analysis of Figure 7 shows that both stars follow almost parallel trajectories in their displacements, since the fitted equations are very similar to each other and, more specifically, their slopes are also very similar one to another. This fact suggests that, in the beginning, we could think about a common proper motion of both components.

If we compare our results with the ones offered by literature we can see that the USNO-B1.0 and UCAC-2 proper motion values are absolutely divergent. The reason of this disagreement is, surely, that both catalogues have calculated the proper motions on the basis of a certain combination of the motions of two components; that is to say, they offer a *joint proper motion* (see Figure 8). Let's remember that the system is an unresolved pair on the old plates. Nevertheless, it is significant that the data of the catalogues is so different. We do not know the reason.

Assuming that the *joint proper motion* is calculated by means of average positions of the system in several epochs, we might do a simple estimation of this value. We have positions of good quality with which to work: that of SSS (epoch 1954.672; RA = 00 17 08.046 and Dec = -10 26 47.87) and that of SDSS (epoch 2000.7401; average of the positions of the Table 4: RA = 00 17 08.04972 and Dec = -10 26 48.4566). The proper motion is obtained by expressions:

$$\mu\alpha = d\alpha / dt$$
$$\mu\delta = d\delta / dt$$

The baseline or Δt is 46.0681 years.

We calculated that the joint proper motion for the

Component	μα mas•yr^{-1}	σ(μα) ±	μδ mas•yr^{-1}	σ(μδ) ±	μ_{Total} mas•yr^{-1}	Position Angle (°)
A	+1.9	0.1	-14.7	0.8	14.8	172.6
B	+2.6	0.3	-12.6	0.9	12.8	168.3

Table 5: Proper motions deduced from the old astrometry.

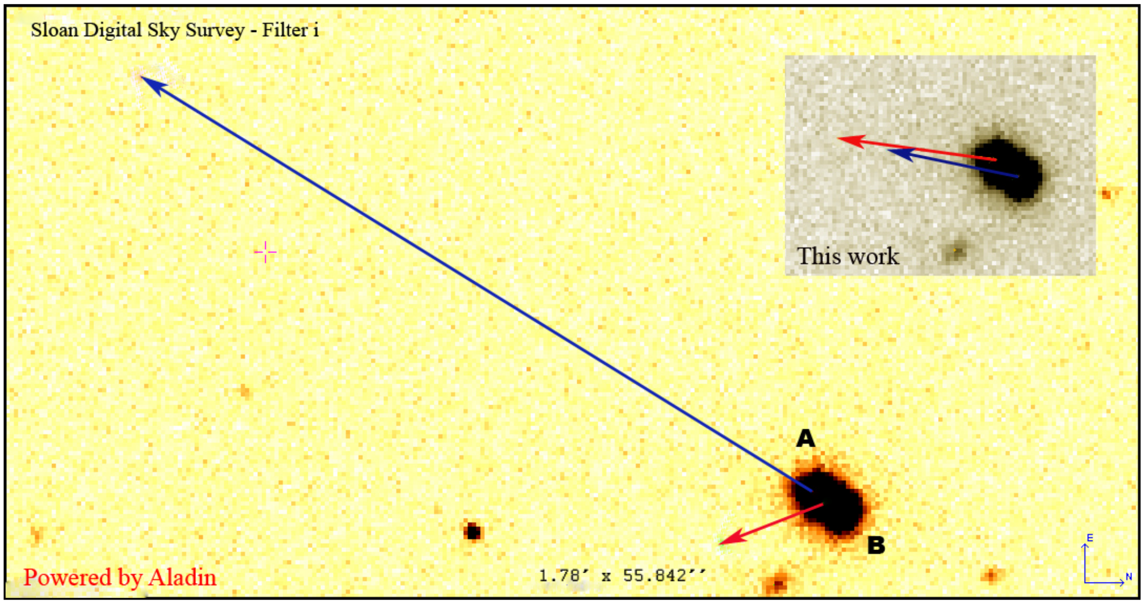

Figure 8: In this figure, the total proper motion vectors (for 1,000 years) derived from the literature are shown. UCAC-2 proper motion (large blue arrow) and USNO-B1.0 (red arrow) are represented. Note that these proper motions are for the whole system and that they are very different in magnitude and direction. The inset shows the total proper motion as calculated in this paper.

system is: $\mu\alpha = + 1.2$ mas·yr^{-1} and $\mu\delta = -12.7$ mas·yr^{-1}, in excellent agreement with the individual proper motions that we have reported. Finally, another checking was done to corroborate the goodness of our calculations using of Aladin. We did a blink using two plates (DSS and SDSS) (Figure 9). It was observed, clearly, that the oval shape of the system was moving lightly in the direction that we have calculated.

Relative proper motion.

Using relative astrometry (θ and ρ) obtained in this work (Table 4) which covers a 46-year period, the annual relative proper motion of B component was obtained with regard to the main star. This parameter gives us an idea of the relative orbital velocity of the system when there is physical union (projected relative orbital motion). The relative astrometry were represented in each of the diagrams X ($=\rho*\sin\theta$) *vs* Epoch and Y ($=\rho*\cos\theta$) *vs* Epoch (Table 6) with a later linear fit of the points (Figures 10 and 11). The slopes of each line fit are the annual relative proper motion in RA and Dec respectively and expressed in "/year.

The results are reported in Table 7. It is mathe-

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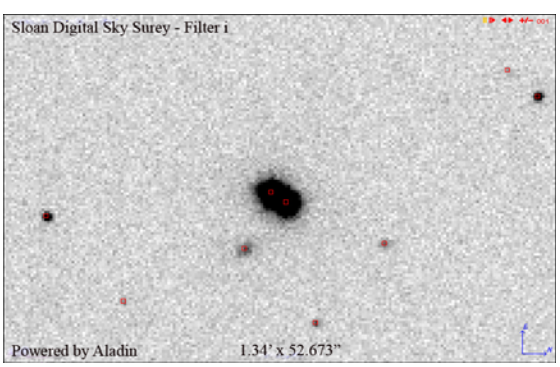

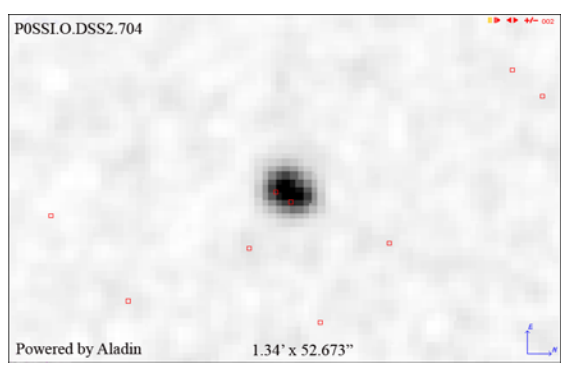

Figure 9: Two planes extracted from Aladin´s blink based on the images of 1954.672 (right) and 2000.7401. The red squares represent the sources registered by SDSS and are used as reference to see the displacement of the system. The elongation moves in block demonstrating the common proper motion of the components.

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Epoch	Theta	Rho	x	y
1954.672	323.692	2.631	-1.558	2.1202
1994.782	325.095	2.683	-1.535	2.2003
1998.7902	325.324	2.701	-1.537	2.2213
2000.7401	325.637	2.691	-1.519	2.2214

Table 6: Deduction of X-Y parameters.

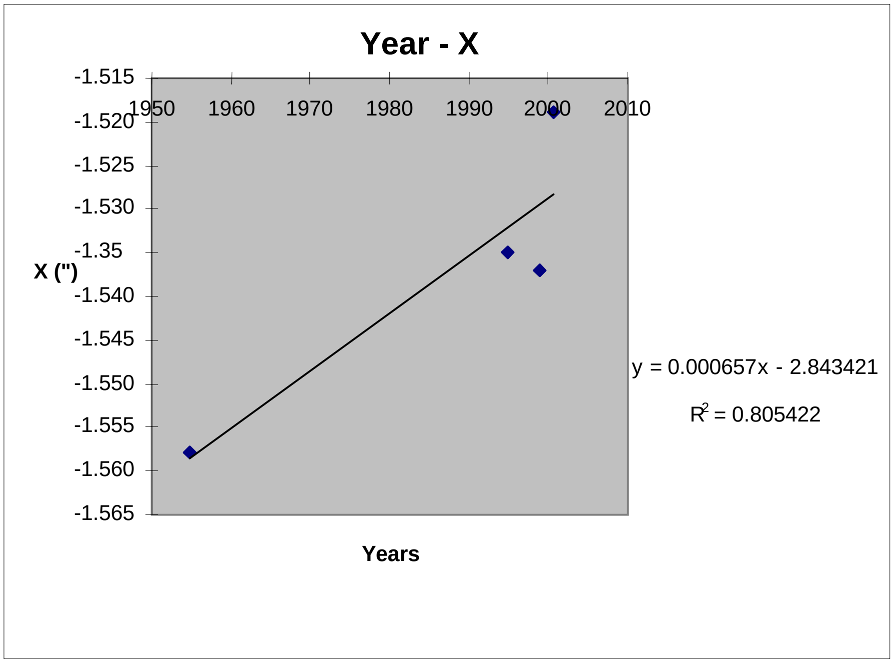

Figure 10: Linear fit to X parameter.

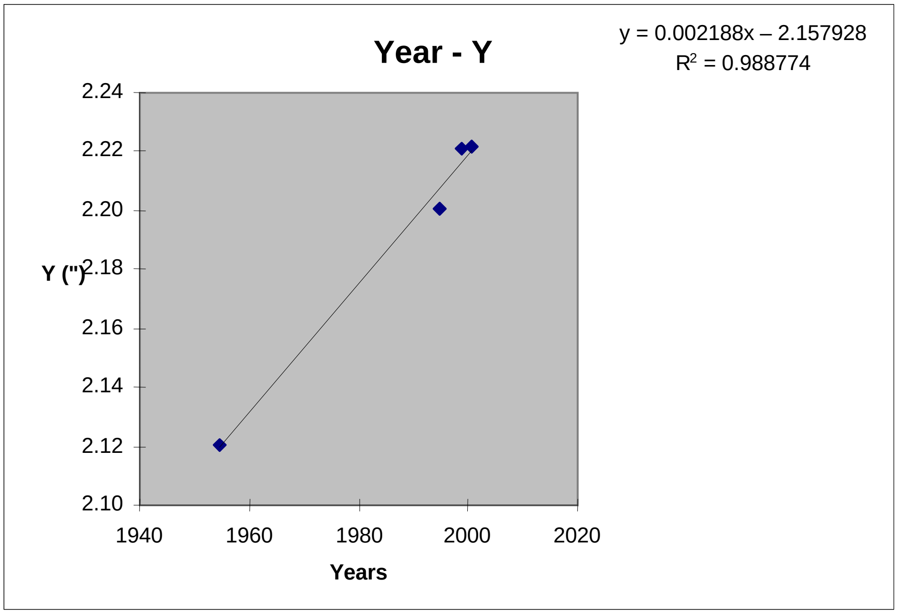

Figure 11: Linear fit to Y parameter.

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matically certain that the relative proper motion is the difference between the individual proper motions of each component. According to it, by operating with the data of Table 5 and making a comparison with the ones of Table 7, we can see that there is a strong agreement: again the difference in motion is within the errors reported by Excel. We see that the relative motion is small so both stars are moving together in the space. Common origin?

Effective temperature (T_{eff})

Despite being a large amount, the M dwarfs are also the most unknown ones. So much so, that even their effective temperature scale is not defined clearly; a parameter which is fundamental in stellar astrophysics. There are quite a lot of authors who have dealt with this study, but there had been no consensus on how to fix the parameter which defines the atmospheric models for this type of star. This is the reason why the effective temperature values for a determined MV spectra can be so different, as much upward as downward when checked in the abundant literature.

Veeder (1974) proposed a relation to derive T_{eff} on the basis of the colour index V – K, with the uncertainty of ± 150ºK and this relation provides a good adjustment for effective temperatures in range from ~ 2,500ºK to ~ 4,500ºK:

$$\log T_{eff} = 3.77 - 0.052(V\text{- }K) \pm 150$$

The calculated temperatures with this relation, as we have been able to check, are most conservative. Tsuji *et al.* (1996), apart from establishing their own scale, gathered the majority of the found tendencies, by comparing the most modern investigations of the epoch which are toward high temperature scales (Kirkpatrick, 1991), toward lower ones (Brett, 1995), and toward intermediate ones (Berriman *et al.*, 1992; Tinney *et al.*, 1993; Jones *et al.,* 1994).

More recent studies (Houdashelt, 2000) propose a large table of empiric relations color-temperature, involving different color indexes in the most representative photometric systems. We decided not to apply this relation in our study because our colors V – I, B –V and V – K, were out of the photometric ranges demanded by Houdashelt's equations, which meant that the derived temperatures were, in our opinion, too high (T_{eff} > 4,000 K for the main star).

According to Leggett (2001), the better present estimation is that M-dwarfs have an effective temperature range from 2,100 to 3,700 K. On this assumption and since the Veeder's estimation is in agreement with these limits, we decided to use his expression in this preliminary estimation. We think that it works out the average of T_{eff} values. Our results are shown in Table 8.

Bolometric Correction and Bolometric Absolute Magnitude

We used the Lang's (1992) proposed expression when we calculated the bolometric correction (BC):

$$BC = -8.499\ [\log T_{eff} - 4]^4 + 13.421\ [\log T_{eff} - 4]^3 -$$

$\Delta\mu(\alpha)$ mas*yr $^{-1}$	$\sigma[\Delta\mu(\alpha)]$ ±	$\Delta\mu(\delta)$ mas*yr $^{-1}$	$\sigma[\Delta\mu(\delta)]$ ±	$\mu_{Total\ Relative}$ mas*yr $^{-1}$
+0.66	0.23	+2.20	0.16	2.3

Table 7: Relative proper motion of the system.

Component	V- K	Log T_{eff}	T_{eff} ± 150 (K)	Notes
A	3.85	3.5698	3,714	(a)
B	3.99	3.5625	3,652	(b)

Table 8: Effective temperatures. (a).- V-K obtained by using 2MASS photometry. (b). - V-K synthetic, theoretical value for M1,5V.

$$8.131\,[\log T_{eff} - 4]^2 - 3.901\,[\log T_{eff} - 4] - 0.438$$

We got that $BC_{(A)} = -1.624$ and $BC_{(B)} = -1.722$ using the equation for each component of the effective temperatures in Table 8.

The bolometric absolute magnitude (M_{bol}) will be given immediately by the equation:

$$M_{bol} = M_V + BC$$

And therefore $M_{bol\,(A)} = 8.23$ and $M_{bol(B)} = 8.52$.

Luminosity

In order to deduce the luminosity of each component in terms of the solar luminosity, we used the known equation:

$$L = 10^{((4.75 - Mbol) / 2.5)}$$

Where Mbol is the bolometric magnitude of the problem-star. The derived luminosities yield values of LA = 0.04 and LB = 0.03.

Masses

We used the equation derivate by Delfosse et al. (2000) to estimate the masses in terms of solar mass. In the work, they investigated stars with very low masses and they also deduced several expressions in order to calculate the masses of the M-dwarfs with great accuracy. The expression that we used in our work involves the visual absolute magnitude. The adjustment is valid for MV in the interval [9,17].

$$\log\left(\frac{M}{M_\odot}\right) = 10^{-3}\left(0.3 + 1.87M_V + 7.614M_{V^2} - 1.698M_{V^3} + 0.060958M_{V^4}\right)$$

We got values of 0.51⊙ and 0.46⊙ for the main component and the secondary component respectively. The solar mass is equal to 1.

Radii

Using Popper(1980) we could deduce the radii for the components in terms of a solar radius. The expression which enables its calculation is:

$$\log R = -0.2\ Mv - 2Fv + 0.2\ C1 \qquad (4)$$

Where R is the star radius; Mv is the visual absolute magnitude; Fv represents a luminosity function by area unit and C1 is a solar constant with a value of about 42.3615. It is possible to redefine this expression if we express the luminosity function in the following terms:

$$Fv = \log T_{eff} + 0.1\ BC$$

If we replace it in (4) we get the final expression which we used in this work and is defined in terms of effective temperature and bolometric magnitude terms:

$$\log R = -0.2\ Mv - 2\log T_{eff} - 0.2\ BC + C$$

The value for the constant C is 1/5 of C1, that is to say C = 8.4723.

The final values obtained were RA⊙ = 0.49 and RB⊙ = 0.44 and the solar radius is equal to 1.

Superficial Gravity (log g).

For this calculation we made use of the work of Habets & Heintze (1981), where they give an equation on the basis of the masses and the radii being $\log g_\odot = 4.44$.

$$\log g = \log(M/M_\odot) - 2\log(R/R_\odot) + \log g_\odot$$

With the previously deduced masses and radii we got log g (A) = 4.78 and log g (B) = 4.82.

Global summary of astrophysical data

Below is a summary (Table 9) of all astrophysical parameters that we have deduced in this research.

Study of the nature of the system

In order to evaluate the possibility of a physical or optical nature of the system, several criteria of characterization were used: the Dommanget's criteria (1955), the van de Kamp's one (1968), the Sinachopoulos' one (1992), the Abt's one (1988) and the Wilson's one (2001). These criteria make use of photometric, astrometric, kinematic and spectroscopic data. With the contributed data, the Dommanget's criterion (based on the dynamical parallax), establishes a limit of 1.6 $mas \cdot yr^{-1}$ in the total relative proper motion in order that the pair is considered to be physically bounded. In our calculus we obtained a value of 2.3 $mas \cdot yr^{-1}$. We think that this small difference could be assumed by the errors of our measurements so, according to this criterion, the system is a physical one. The system did not pass the test with the hyperbolic criterion

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Parameter	**Components**		
	A	**B**	**References**
Photometry			
B	17.45	17.91	Lupton (2005)
V	16.09	16.53	Lupton (2005)
I	14.30	14.58	Lupton (2005)
M_V	9.856	10.242	Kaarali *et al.* (2005)
CB	-1.624	-1.772	Lang (1992)
M_{bol}	8.23	8.52	
Spectral	M1V	M1.5V	Henry et al. (1994)
Effective temperature			
Log T_{eff}	3.5698	3.5625	
T_{eff} ±150 K	3.714	3.652	Veeder (1974)
Masses			
log (M /M⊙)	-0.29	-0.335	Delfosse *et al.* (2000)
Mass (Sun = 1)	0.51	0.46	
Radii			
log R	-0.3137	-0.3567	Popper (1980)
R (Sun = 1)	0.49	0.44	
Luminosity			
L (Sun = 1)	0.04	0.03	
Gravity			
log g (Sun = 4.44)	4.7774	4.8185	Habets, Heintze (1981)
Distance (parsec)	176	181	
Proper motion (mas*yr $^{-1}$)			
μα	+1.9 ± 0.1	-14.7 ± 0.8	
μδ	+2.6 ± 0.3	-12.6 ± 0.9	
Relative motion (mas*yr $^{-1}$)			
Δμ(α)	----	+0.66 ± 0.23	
Δμ(δ)	----	+2.20 ± 0.16	

Table 9: Summary of Astrophysical data.

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of Van de Kamp. All the rest agree with the assignment of a physical nature for the pair. The Halbwachs' criterion, modified by Rica (2004), classify the pair as *surely physical* by calculating a probability of physical relation of 86%. In accordance with theses results it may be possible that we have a truly binary system with a probable orbital period of about 24,980 years (Couteau, 1960). The expected semi-axis major could be of 811 A.U. (3.72") with a projected separation of 580 A.U. Circular and face-on orbit is assumed.

Conclusions

We present the discovery of a new binary system candidate with strong evidence of a physical bound between the components, as several criteria of characterization shown. These criteria have been used in professional works and we have put it into practice in this study. The components, which are two dwarfs of M-early spectra (deduced by meaning of two different methods), seem to share proper motion as we can gather from our deductions. The photometric distances that we have inferred, place both stars nearly at the same distance. These two facts corroborate the physical nature of the pair. Relative astrometry is contributed for the system. It would be necessary to make other measurements of Theta and Rho by more accurate techniques, though.

The use of SDSS was fundamental to distinguish both sources as separated stars, as well as to offer whole and accurate *ugriz* photometry for each component.

The pair will be proposed to Brian Mason as a new double named MRI 1 for its inclusion in WDS.

Acknowledgements

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

This research has made use of GSC 2.2 catalog.

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 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.

This research has made use of SuperCOSMOS Sky Surveys (SSS). SSS is an advanced photographic plate digitising machine. Part of its programme is to systematically digitise sky survey plates taken with the UK Schmidt telescope (UKST), the ESO Schmidt, and the Palomar Schmidt, and to make the data publicly available.

This research has made use of Sloan Digital Sky Survey (SDSS). Funding for the SDSS and SDSS-II has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, the U.S. Department of Energy, the National Aeronautics and Space Administration, the Japanese Monbukagakusho, the Max Planck Society, and the Higher Education Funding Council for England. The SDSS Web Site is http://www.sdss.org/.

The SDSS is managed by the Astrophysical Research Consortium for the Participating Institutions. The Participating Institutions are the American Museum of Natural History, Astrophysical Institute Potsdam, University of Basel, Cambridge University, Case Western Reserve University, University of Chicago, Drexel University, Fermilab, the Institute for Advanced Study, the Japan Participation Group, Johns Hopkins University, the Joint Institute for Nuclear Astrophysics, the Kavli Institute for Particle Astrophysics and Cosmology, the Korean Scientist Group, the Chinese Academy of Sciences (LAMOST), Los Alamos National Laboratory, the Max-Planck-Institute for Astronomy (MPIA), the Max-Planck-Institute for Astrophysics (MPA), New Mexico State University, Ohio State University, University of Pittsburgh, University of Portsmouth, Princeton University, the United States Naval Observatory, and the University of Washington.

This research has made use of The Astrophysics Data System (ADS) in order to consult several professional Works. Web Site: http://adswww.harvard.edu/index.html

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 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 fv 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 Guide 8.0 astronomical software of Project Pluto.

This research has made use of Astrometrica, an interactive software tool for scientific grade astrometric data reduction of CCD images. The author: Herbert Raab. Internet site: http.//www.astrometrica.at/

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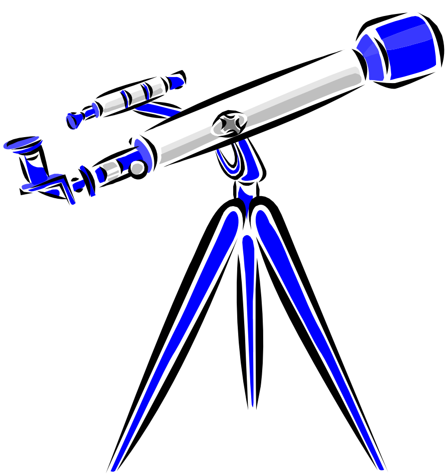

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