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

Edgardo Rubén Masa Martín

Double Star Section Coordinator
Syrma Astronomical Society
(Syrma-MED)
Valladolid, Spain
ermasa@teleline.es
http://www.med.syrma.net/

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: $\mu(\alpha) = -4 \pm 2$ mas·yr^{-1} and $\mu(\delta) = -10 \pm 3$ 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: $\mu(\alpha) = 39.1 \pm 8.5$ mas·yr^{-1} and $\mu(\delta) = -63.9 \pm 9.2$ 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.

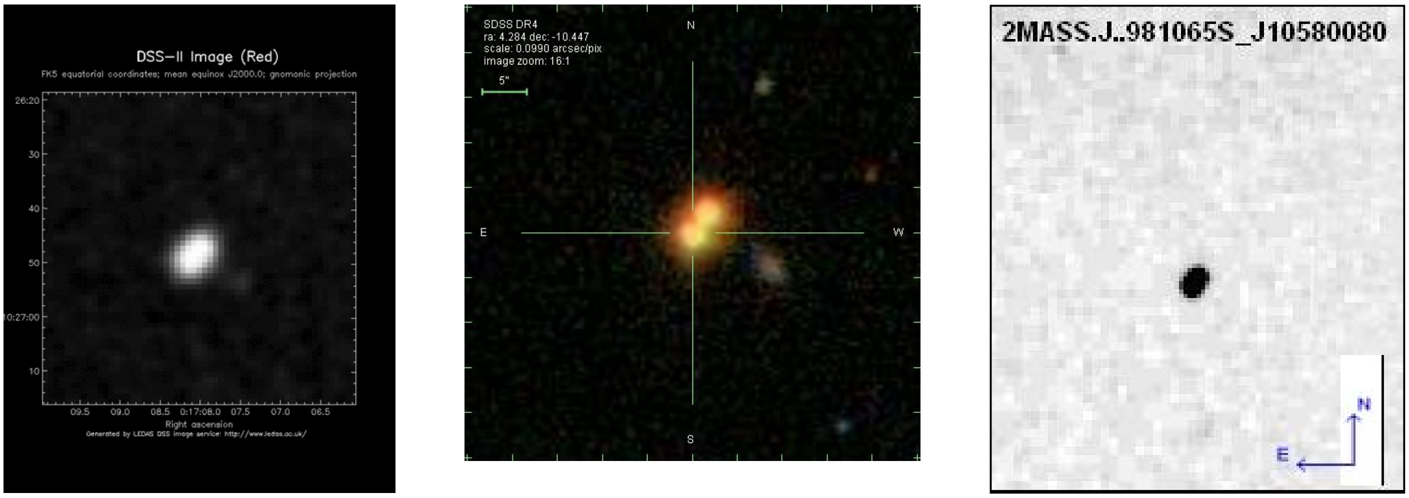


Figure 1: The system in plates of several surveys from different epochs.

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.

. . . Serendipitous Discovery of a New Binary System Candidate

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-

. . . Serendipitous Discovery of a New Binary System Candidate

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

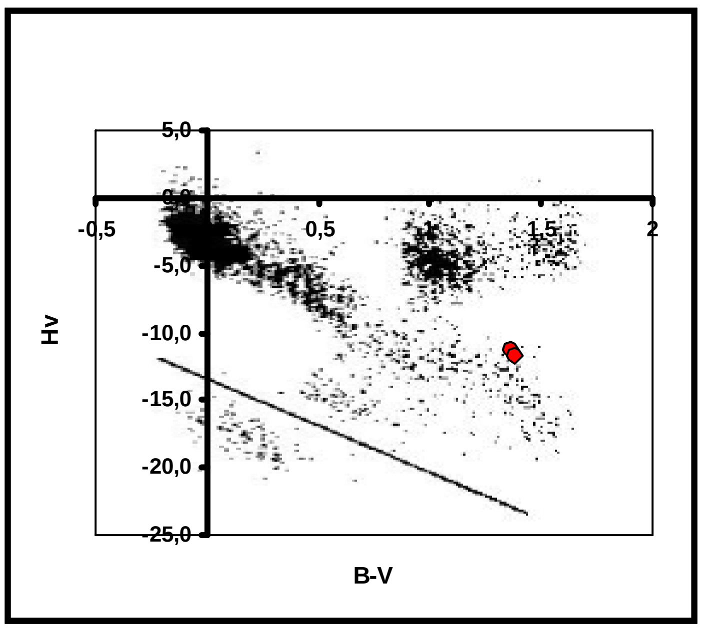


Figure 1. "Reduced-Proper-Motion Diagrams. II. Luyten's White-Dwarf Catalog" from Eric M. Jones (AJ, 177, 245-250 -1972)

. . . Serendipitous Discovery of a New Binary System Candidate

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

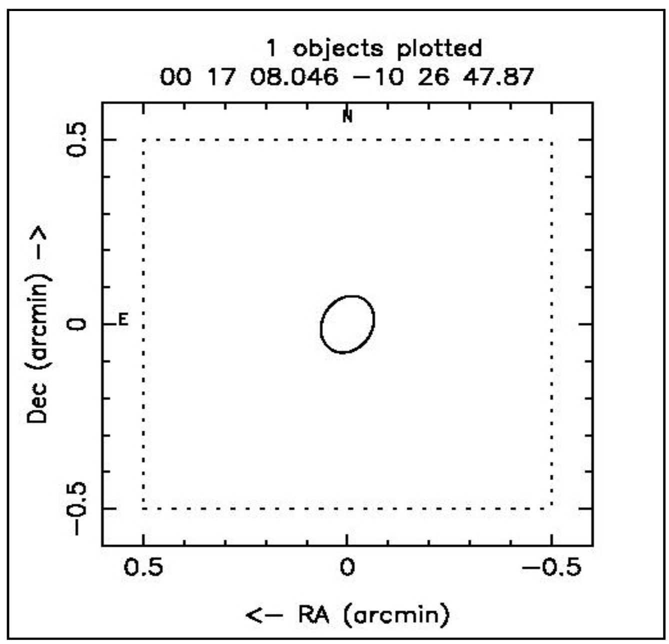


Figure 2: SSS plot of the system based in DSS plate for the epoch 1954.672. The oval shape is the unresolved pair. The intermediate position (J2000) of both sources is showed at the top of the graph. The FOV is 1' x 1'.

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

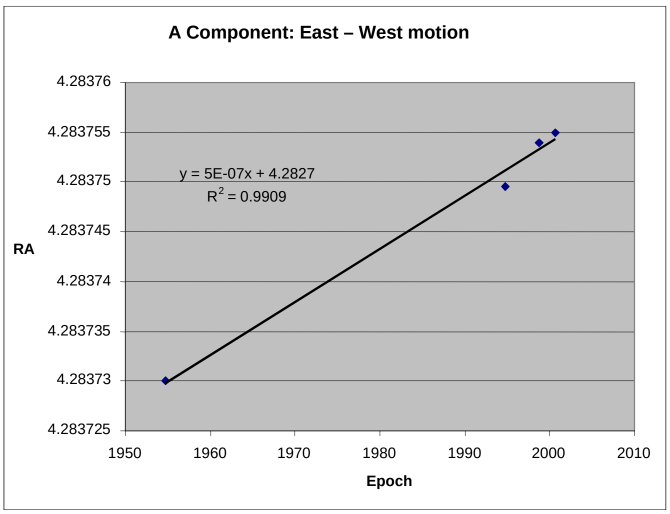


Figure 3: A component: Linear fit of the RA motion.

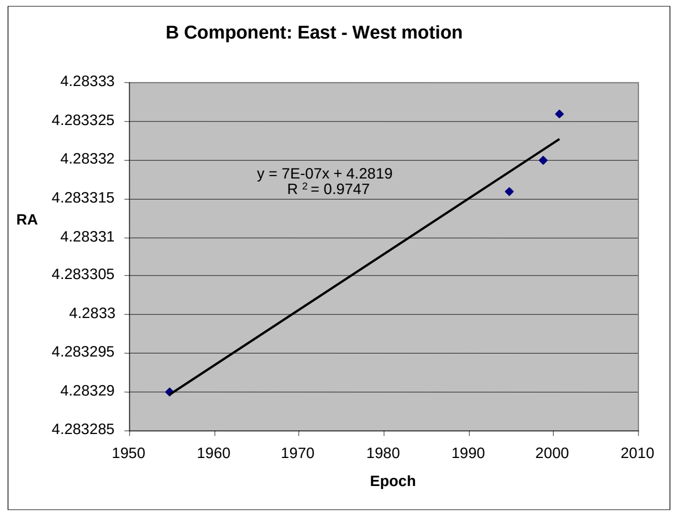


Figure 5. B component: linear fit of the RA motion.

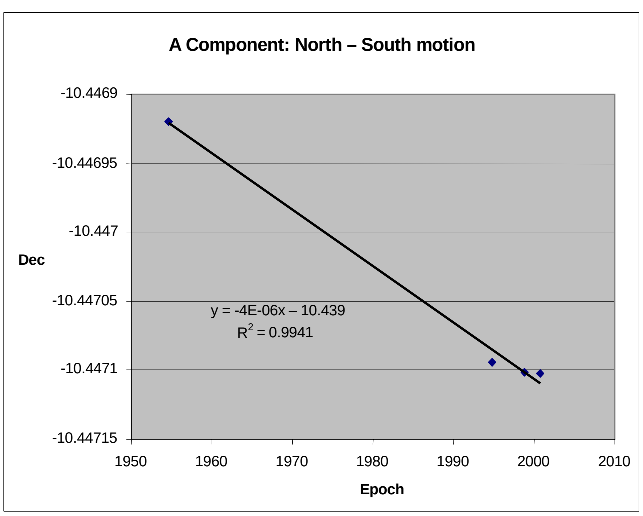


Figure 4: A component: linear fit of the declination motion.

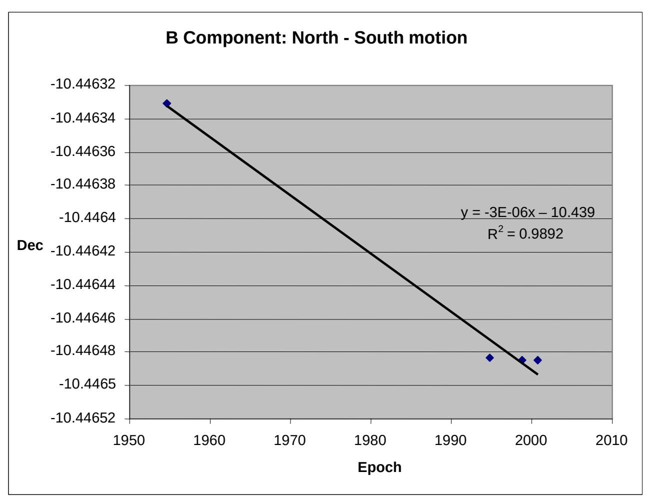


Figure 6: B component: linear fit of the declination motion.

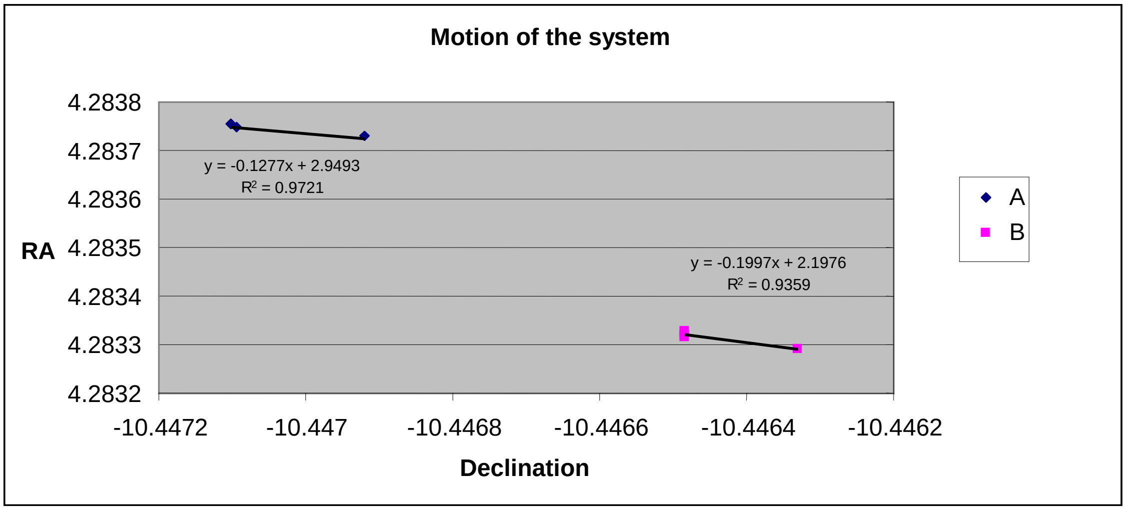


Figure 7: Comparison of the motion of two components throughout the time.

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.

. . . Serendipitous Discovery of a New Binary System Candidate

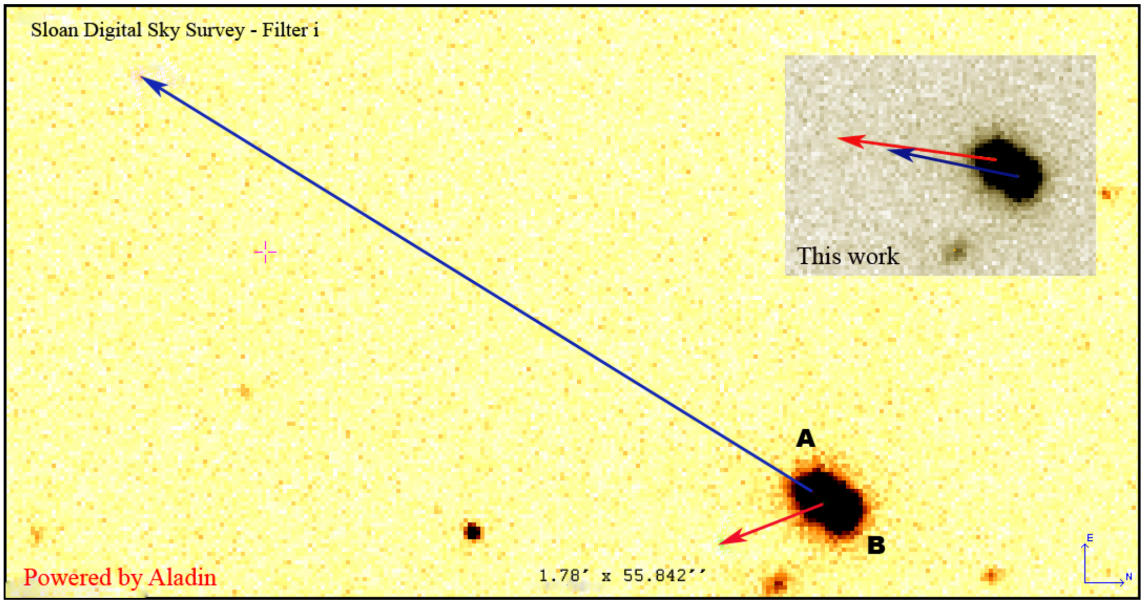


Figure 8: In this figure, the total proper motion vectors (for 1,000 years) derived from the literature are shown. UCAC-2 proper motion (large blue arrow) and USNO-B1.0 (red arrow) are represented. Note that these proper motions are for the whole system and that they are very different in magnitude and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

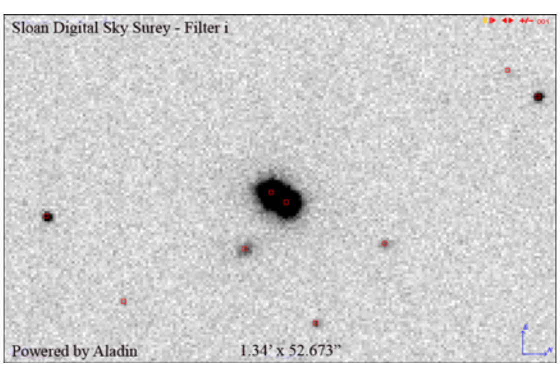
system is: $\mu\alpha$ = + 1.2 mas·yr^{-1} and $\mu\delta$ = -12.7 mas·yr^{-1}, in excellent agreement with the individual proper motions that we have reported. Finally, another checking was done to corroborate the goodness of our calculations using of Aladin. We did a blink using two plates (DSS and 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 (=ρ*sinθ) *vs* Epoch and Y (=ρ*cosθ) *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-

(Continued on page 43)



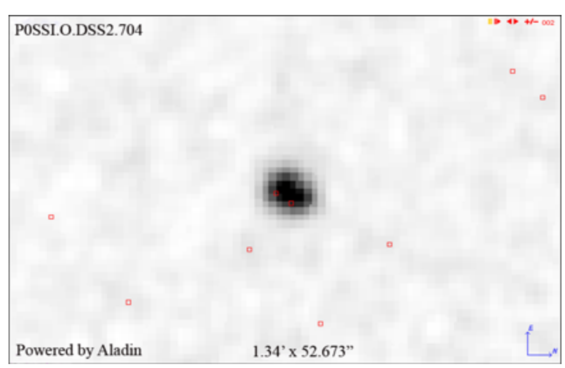


Figure 9: Two planes extracted from Aladin´s blink based on the images of 1954.672 (right) and 2000.7401. The red squares represent the sources registered by SDSS and are used as reference to see the displacement of the system. The elongation moves in block demonstrating the common proper motion of the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

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.

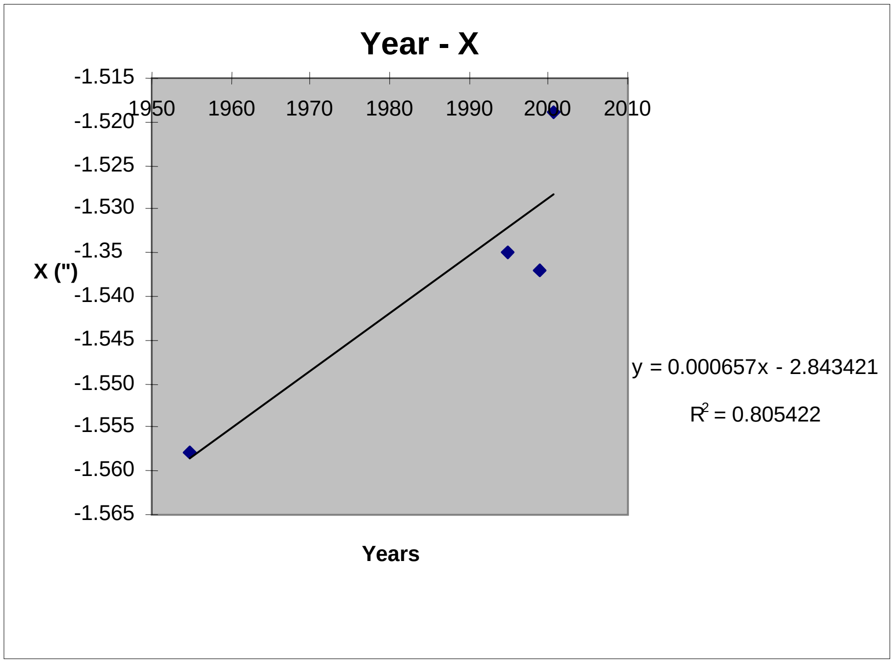


Figure 10: Linear fit to X parameter.

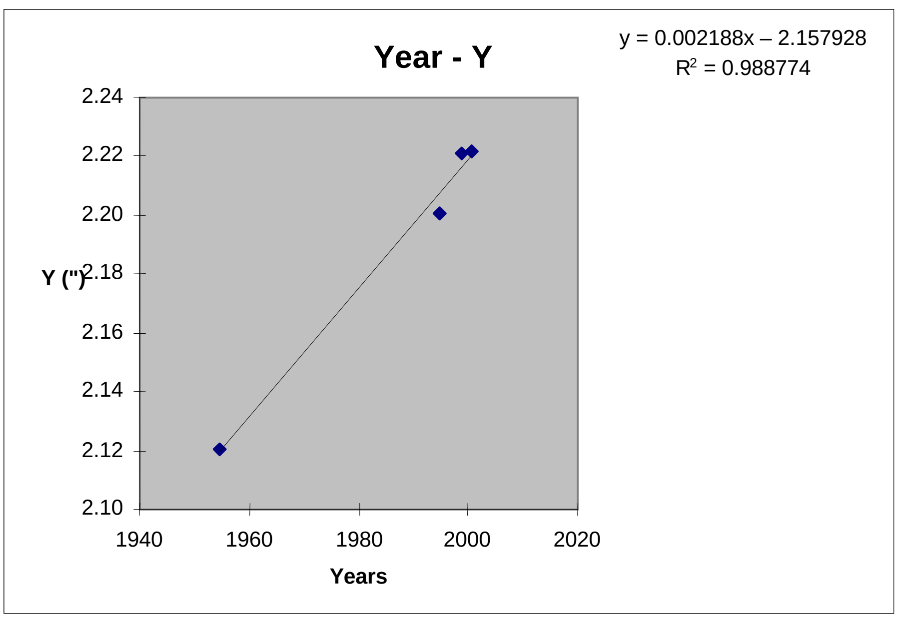


Figure 11: Linear fit to Y parameter.

. . . Serendipitous Discovery of a New Binary System Candidate

(Continued from page 41)
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 $^{-1}$	$\sigma[\Delta\mu(\delta)]$ ±	$\mu_{\text{Total Relative}}$ 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•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•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

(Continued on page 46)

. . . Serendipitous Discovery of a New Binary System Candidate

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.

. . . Serendipitous Discovery of a New Binary System Candidate

(Continued from page 44)

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/

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

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

References

Abt, H. A., 1988, *Maximum Separations Among Cataloged Binaries*, Astron.J., 331, 922-931.

Berriman, G. et al., 1992, *Effective temperatures of M dwarfs*, Astrophysical Journal, Part 2 – Letters (ISSN 0004-637X), vol. 392, no. 1, June 10, 1992, p. L31-L33.

Bonnarel F., Fernique P., Bienayme O., Egret D., Genova F., Louys M., Ochsenbein F., Wenger M., Bartlett J.G., *The ALADIN interactive sky atlas. A reference tool for identification of astronomical sources.*, Astron. Astrophys., Suppl. Ser., 143, 33-40 (2000) – April(I) 2000.

Brett, J. M.; Plez, B., 1993, *Model Atmospheres and the T/eff Scale for M Dwarfs*, Astron. Soc. of Australia. Proceedings V.10:3, P.250.

Brett, J. M., 1995, *Opacity sampling model photospheres for M dwarfs. I. Computations, sensitivities and comparisons*, Astronomy and Astrophysics, v.295, p.736.

Bessel, M. S. And Brett, J. M., 1988, *JHKLM Photometry: Standard Systems, Passbands and Intrinsic Colors*, PASP, 100, 1134-1151.

Bilir, S.; Karaali, S.; Tunçel, S., 2005, *Absolute magnitudes for late-type dwarf stars for Sloan photometry*, Astronomische Nachrichten, Vol.326, Issue 5, p.321-331.

Caussade, A., 2004, *Cálculo del diámetro de una estrella*, http://www.armandocaussade.com/astronomy/diameter.html, software Diameter, © Armando Caussade.

Couteau, P., 1960, *Contribution a l'étude du dénombrement des étoiles doubles visuelles*, Journal des observateurs, volume 43, nº 3, p. 52.

Cutri, R. N. *et al.*, *Explanatory to the 2 MASS Second Incremental Data Release.*

http:// www.ipac.caltech.edu/2mass/releases/second/index.html

Delfosse, X.; Forveille, T.; Ségransan, D.; Beuzit, J.-L.; Udry, S.; Perrier, C.; Mayor, M., 2000, *Accurate masses of very low mass stars. IV. Improved mass-luminosity relations,* Astronomy and Astrophysics, v.364, p.217-224.

Dommanget, J., 1955, *Critère de non-périodicité du mouvement relatif d'un couple stellaire visuel*, Bulletin Astronomique, Paris, tome 20, fascicule 7, p, I ; Communication de l'Oservatoire Royal de Belgique, nº 91.

Dommanget,J.,1958, *Les associations stellaires optiques parmi les étoiles doubles visuelles*, Ciel et Terre, Vol. 74, p. 443.

Eric, M. J., 1972, *Reduced Proper Motion Diagrams*, Astron. J.,173, 671-676.

Gerald, E. K. And Roach, F. E., 1988, *The Distribution of (B-V) in Two Star Catalogs*, PASP, 100, 90-96 .

Habets, G. M. H. J.; Heintze, J. R. W., 1981, *Empirical bolometric corrections for the main-sequence*, Astronomy and Astrophysics Supplement Series, vol. 46, Nov. 1981, p. 193-237.

Halbwachs, J. L., 1986, *Common proper motion stars in the AGK 3*, Astronomy and Astrophysics Supplement Series (ISSN 0365-0138), vol. 66, no. 2, Nov. 1986, p. 131-148.

Hall, A., 1892, *Notes on double stars (I) and (II)*, Astron. J., 12.

Henry, Todd J.; Kirkpatrick, J. Davy; Simons, Douglas A., 1994, *The solar* , The Astronomical Journal, vol. 108, no. 4, p. 1437-1444.

. . . Serendipitous Discovery of a New Binary System Candidate

Houdashelt, M. L.; Bell, R. A.; Sweigart, A. V., 2000, *Improved Color-Temperature Relations and Bolometric Corrections for Cool Stars*, The Astronomical Journal, Volume 119, Issue 3, pp. 1448-1469.

Jones, H. A. et al., 1994, *An infrared spectral sequence for M dwarfs*, Monthly Notices of the Royal Astronomical Society, vol. 267, no. 2, p. 413-4.

Karaali, S.; Bilir, S.; Tunçel, S., 2005, *New Colour Transformations for the Sloan Photometry, and Revised Metallicity Calibration and Equations for Photometric Parallax Estimation,* Publications of the Astronomical Society of Australia, Volume 22, Issue 1, pp. 24-28.

Kirkpatrick, J. D., 1991, *A standard stellar spectral sequence in the red/near-infrared – Classes K5 to M9*, Astrophysical Journal Supplement Series (ISSN 0067-0049), vol. 77, Nov. 1991, p. 417-440.

Lang, K. R., 1992, .Astrophysical Data: Planets and Stars, Springer-Verlag, New York.

Leggett, S. K.; Allard, F.; Geballe, T. R.; Hauschildt, P. H.; Schweitzer, Andreas, 2001, *Infrared Spectra and Spectral Energy Distributions of Late M and L Dwarfs*, The Astrophysical Journal, Volume 548, Issue 2, pp. 908-918.

Lupton, R., 2005, *Transformations between SDSS magnitudes and UBVRcIc, http://www.sdss.org/dr4/algorithms/sdssUBVRITransform.html#Lupton2005*

Martin, V. Z., *Handbook of Space Astronomy and Astrophysics*, Ed. Cambridge University Press, http://ads.harvard.edu/books/hsaa/

Masa, E. R., 2005, *LDS 968 AB-C: The Distant Companion of HU 575*, Journal of Double Star Observations, Vol. 1 nº 2, 50.

Nelson, C. A. Et al., 2002, *A Proper Motion Survey for White Dwarfs with the Wide Field Planetary Camera 2*, Ap. J., 573, 644

Popper, D. M., 1980, *Stellar Masses*, Ann. Rev. Astron. Astrophys., 18:115-64.

Reid, I. Neill; Gizis, John E.; Kirkpatrick, J. Davy; Koerner, D. W., 2001, *A Search for L Dwarf Binary Systems*, The Astronomical Journal, Volume 121, Issue 1, pp. 489-502.

Rica, F. M., 2004, Circular Sección de Estrellas Dobles LIADA, 6 (En español), 23-26.

Rica, F. M., 2004, Circular Sección de Estrellas Dobles LIADA, 7, 32-34.

Rica, F. M., 2005, Circular Sección de Estrellas Dobles LIADA, 2 (En inglés), 11-12 .

Salim, S., Gould, A., 2000, ApJ, 539, 241.

Salim, S., Gould, A., 2002, *Classifying Luyten Stars using an Optical-Infrared Reduced Proper Motion Diagram*, Ap. J., 575, 83

Sinachopoulos, D.; Mouzourakis, P., 1992, *Searching for Optical Visual Double Stars*, Complementary Approaches to Double and Multiple Star Research, ASP Conference Series, Vol. 32, IAU Colloquium 135, 1992, H.A. McAlister and W.I. Hartkopf, Eds., p. 252.

Tinney, C. G.; Mould, J. R.; Reid, I. N., 1993, *The faintest stars – Infrared photometry, spectra, and bolometric magnitude*, Astronomical Journal (ISSN 0004-6256), vol. 105, no. 3, p. 1045-1059.

Tsuji et al., 1996, *Dust formation in stellar photospheres: a case of very low mass stars and a possible resolution on the effective temperature scale of M dwarfs*, Astronomy and Astrophysics, v.305, p. L1.

Veeder, G. J., 1974, *Luminosities and temperatures of M dwarf stars from infrared photometry*, Astronomical Journal, vol. 79, p. 1056-1072.

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

Camino de Palomares
Astronomical Observatory

SYRMA M.E.D.