Astrometric Measurements of Double Stars in 2009

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Abstract: We report our results obtained during 2009 observations by GED. In this campaign, our group started measuring with a CCD camera in addition to measurements using digitized plates from DSS and 2MASS. Both spectral type and nature of every pair were determined from photometric and kinematical data.

Introduction
Following the work started in 2006 by GED [Lopez 2009], neglected double stars (observed and measured by Struve, Pourteau, Scheiner and Burnham) were selected for the 2009 campaign. A total of 13 double stars were chosen, 12 of which were measured and their parameters updated. Only one was not found in the coordinates given by WDS.

In our first study [Lopez 2009], we only determined the nature of the pairs. Now, since most of the secondary component information was incomplete, we decided to estimate the nature as well as spectral types (and luminosity class when there was enough data) of the members of these pairs.

In the section 2, we describe the methods of measurement and photometry used in this study. The section 3 describes the three methods used to know the nature of every pair. Section 4 explains how spectral types were estimated. And in section 5, we list astronomical catalogs used.

Measurements and Photometry
For all measurements, we used two methods: 1) measuring on digitized plates, downloaded from several surveys; and 2) using a CCD camera. The astrometric software, used in both cases, were: FV, Astrometrica (using UCAC2 or USNO-A2.0 Catalog) and REDUC.

Digitized Plates
As in Lopez [2009], we used the digitized plates downloaded from Digitized Sky Survey (hereafter DSS; http://stdatu.stsci.edu/cgi-bin/dss_plate_finder); and Two Micron All Sky Survey (hereafter 2MASS; http://irsa.ipac.caltech.edu/).

The reason for using REDUC in DSS plates was due to saturation problems in the plates caused by long times of exposure. In some cases, secondary components are hidden, partially or totally, by the brightness of the primary star. REDUC can split components in these situations that ASTROMETRICA can not.

However, REDUC needs some parameters to measure: orientation of plate respect to North, resolution of the image in arcsec/pixel, and the pixel size of CCD camera. As we were not able to find these values for the 2MASS plates, FV was chosen to perform measurements in 2MASS plates. FV doesn't need to these parameters to be set up and start to measure; it handles them internally.

CCD Measurements
The equipment used was composed of a Takahashi TOA-130 (F:1000 mm) refractor on a Takahashi TEMMA-200 equatorial mount. The CCD camera was a Lunatico Luna QHY-6 (752 x 582 pixels; 6.50 x 6.25 mm/pixel, Chip: ICX259AL Exview CCD
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Monocromo. For the measurements of STF 848, STF 968, STF 983 and STF 1088, a 0.75x focal reducer was used, obtaining a final focal length of 750 mm and a field of view of 22 x 16 arcminutes, and a resolution of 1.75 arcsec/pixel. However, without the focal reducer the field was of 17 x 13 arcminutes and a resolution of 1.30 arcsec/pixel (for BU 1423AC, STF 1302AC, STF 1329AC and STF 1338AB-C).

To find the values of angular distance (ρ) and position angle (θ), ASTROMETRICA was used in combination with an astrometric catalog (UCAC-2 or USNO A2.0) and the software named DOBLES. In one case, the USNO A2.0 catalog was used since UCAC2 wasn't able to find any reference star in the CCD image.

The software DOBLES was designed by Julio Castellanos for observation and measurements of comets. This program reads a text file created by ASTROMETRICA (a log file) where absolute positions of every star detected in the image are recorded. Then, DOBLES turns the positions into rho and theta for those selected stars that we want to measure.

Another option was to calculate rho and theta from absolute coordinates given by ASTROMETRICA, with known mathematical formulae in an Excel spreadsheet.

**CCD Photometry**

For the CCD photometry, ASTROMETRICA with USNO A2.0 and CMC-14 catalogs in combination with software FOCAS II were used to estimate magnitudes of components. In all cases, no photometric filter was adjusted on CCD camera.

The software FOCAS II was designed by Julio Castellanos for photometry of comets and variable stars. It is used with ASTROMETRICA and two photometric catalogs (CMC-14 and USNO A2.0). ASTROMETRICA creates a file that is red by FOCAS II and calculates magnitudes for selected stars. In 2009, Rafael Benavides published an article [Benavides 2009] in which he studied the reliability of photometry using the software FOCAS II. According to this study, the accuracy of this method is ±0.2 magnitudes, using CMC-14 for obtaining photometry and as reference the Tycho-2 catalog.

**The Nature of the Pairs**

Three simple criteria were used to determine if these pairs were optical, common origin binaries, or physical binaries. In the next results we will include some professional criteria. These criteria were:

a) Criterion of Aitken (and Curtiss) [Rica 2006]

b) Criterion of Halbwachs[1986](modified by Francisco Rica)

c) Test of Relative proper motion.

**Criterion of Aitken (and Curtiss)**

Both criteria relate the total magnitude of a system with the maximum angular separation to be considered a physical pair.

For criterion of Aitken: log D(")= 2.8-0.2*log(Mg) and for Curtiss: log D(")=2.5-0.2*log(Mg), where Mg is the global magnitude of the pair.

**Criterion of Halbwachs[1986](modified by Francisco Rica)**

This variation of Halbwachs' criterion calculates the probability of a pair of being a CPM and, then, the time to cross the angular distance between two components (T) using proper motions. It gives the probability of being a physical or the other type.

**Test of relative proper motion**

Relative proper motion is the projected angular velocity of the secondary with respect to the primary star. This must be equal to the difference between individual proper motions of the components. It was calculated plotting rectangular coordinates x = ρ * sin θ and y = ρ * cos θ (prior to correction of θ by precession and proper motion) against time.

**Spectral Types and Luminosity Class**

Taking into account photometric and kinematical data available from CDS, in most of cases, spectral types and luminosity classes were estimated from photometric and kinematical data in combination with the Reduced Motion Proper (RPM) diagram. For this target, we used an Excel spreadsheet designed by Francisco Rica [Rica 2011] for studies of binaries stars in LIADA [Benavides 2010]. However, it must be said that if the stars belong to F or G-class, it is hard to distinguish a giant or a dwarf, even using an RPM diagram (which we used in all pairs, due to their zones are mixed).

**The Astronomical Literature**

The astronomical literature was consulted in order to obtain photometric, astrometric and kinematical data. VizieR and Simbad [Wenger et al. 2003] were used from the website of Centre de Donées Astronomiques de Strasbourg (CDS), maintained by the Strasbourg Observatory.

The photometric data come from several photometric catalogs: AC2000 catalog [Urban et al. 2001, hereafter AC2000]; The Hipparcos and Tycho Catalogs (ESA 1997, hereafter HIPPARCOS); 2MASS All-
The kinematical data were obtained from several astrometric catalogs: Tycho-2 Catalog [Hog et al. 2000, hereafter TYCHO-2]; The Hipparcos and Tycho Catalogs (ESA 1997 hereafter HIPPARCOS); UCAC2 Catalog [Zacharias et al. 2003, hereafter UCAC-2]; PPMX Catalog of positions and proper motions [Roeser et al. 2008, hereafter PPMX]; NOMAD Catalog [Zacharias et al. 2005: hereafter NOMAD); USNO B10 [Monet et al 2003, hereafter USNO B10); The Tycho Reference Catalog [Hog et al. 1998. from now on TYCHO]

RESULTS
In the Table 1, we display all the obtained measurements.

The first column, "Discoverer", is the name of discoverer and the number in his catalog. The column "RA+DEC" is the identifier of the pair inside the WDS catalog. The columns "Mag 1" and "Mag 2" are, respectively, the magnitudes of the primary and secondary components. The columns "PA (deg)" and "Sep (as)" are, respectively, the position angle (in degrees) and the angular distance (in arcseconds). The column "Epoch" is the epoch of the measurement (digitized plate or CCD image). Finally, the column "Notes" indicates how the measurement was obtained (digitized plate or CCD image).

STF 793 (WDS 05588+7134)
See Figure 1. According to historical data from the WDS, this system was measured four times between 1830 and 1926. The first measurement was made by John Herschel (Rho: 18”; Theta: 235.1º; Epoch: 1830.04)[Herschel 1833]. In 1927 a last measurement appears, made by E. Opik (Rho: 10.93”; Theta: 242.7º; Epoch: 1926.24)[Opik 1927].

The close separation of both components (less than 10 arcsec) prevented us using the DSS plates for measurements. So, we measured using a 2MASS plate.

The B and V magnitudes for component A are, respectively, 9.97 and 9.33 (HIPPARCOS). However, for the component B only the B magnitude (12.69) is available (AC 2000). The magnitudes in infrared bands (2MASS) are J: 8.23; H: 8.18 and K: 8.03 (component A); and J:9.16; H: 8.69 and K: 9.93 (component B).

Taking into account the photometric and kinematical data, and RPM diagrams, we estimated the spectral type and luminosity class of both components. For A, it is a F7 (in professional literature it is F8 [Wright et al. 2003]). The spectral type for B is B8.

The proper motion is only available for the primary component: \( \mu(\alpha) = -60.0 \pm 1.4 \) mas/yr and \( \mu(\delta) = -69.3 \pm 1.4 \) mas/yr (TYCHO-2). Because the proper motion for B is unknown, we determined the relative proper motion for this system using our measures and measurements from the historical data. It is \( \Delta \mu(\alpha) = 58.41 \pm 6.55 \) mas/yr and \( \Delta \mu(\delta) = 59.31 \pm 1.61 \) mas/yr. According to these high values we can state that this system is an optical pair.

STF 848DH (WDS 06085+1358)
See Figure 2. Reviewing the historical data from

![Figure 1: CCD Image, January 10, 2009 (Miguel Muro)](image1)

![Figure 2: CCD image, STF 848, January 17, 2009 (Miguel Muro)](image2)
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WDS, this system was measured four times between 1907 and 1999. The first time was in 1907 (Rho: 55.53”; Theta: 109.4º; Epoch: 1907.04) [Urban, S. et al. 1998]. The last measurement was made in 1999 (Rho: 54.43”; Theta: 109.9º; Epoch: 1999.89) (2MASS Point Src Cat., 2003 all-sky release 1999).

This pair is in the open cluster NGC 2169, located in Orion. Additionally, in the historical measurement, the next situation is indicated:

"There has been considerable confusion in component identification for this complicated multiple. Components K, J, M, O, and Q were actually H, G, F, I, and J, respectively; pairs labeled PR, PS, PT, and PU were actually JR, RS, ST, and SU, respectively. Three CE measures actually were of JI, while one other was of DH. It is believed (but not guaranteed!) that components are now identified consistently." [Mason, 2011]

The B and V magnitudes both component D and H coming from TYCHO-2. So, for component D, the B and V magnitudes are, respectively, 8.22 and 8.31. The B-V color index is -0.01. While, the H component has B magnitude of 11.39 and V magnitude if 10.01 and a B-V index of 1.17. Additionally, using an unfiltered CCD, we obtained the value of magnitude in R band, being for A and B, respectively, 8.14 and 9.44. In infrared bands, from 2MASS, the A component has magnitudes J:8.68; H: 8.76; and K:8.79. For component B, the magnitudes in J, H and K bands are 7.88, 7.29 and 7.19, respectively.

Making use of these photometric and kinematical data, the estimated that component D has spectral type and luminosity class B8V (in the professional literature it is a B8, [Wright et al. 2003]). Component H was estimated as a K2III [in the professional literature: K5, Skiff 2008].

The proper motion for component D is $\mu(\alpha)$: -4.67 ± 3.42 mas/yr and $\mu(\delta)$: -3.07 ± 1.90 mas/yr (HIPPARCOS). For H, the values are $\mu(\alpha)$: -23.6 ± 6.8 mas/yr and $\mu(\delta)$: 10.9 ± 6.9 mas/yr (UCAC-2). Comparing their proper motions, we can affirm the nature of this pair is optical. The Curtiss, Aitken and Rica’s criteria show the optical nature, as well. Additionally, we calculated the relative proper motion and the result is: $\Delta(\alpha)$: -7.01 ± 9.39 mas/yr and $\Delta(\delta)$: 1.11 ± 6.24 mas/yr.

**STF 968BC (WDS 06529+5241)**

See Figure 3. In the historical data of WDS, there are only two measurement for this pair. The first time was in 1907 (Rho: 8.39”; Theta: 60.5º; Epoch: 1907.89) by S. W. Burnham [Burnham, 1913]. The last measurement was made in 1926 by E. Opik (Rho: 8.22”; Theta: 57.0º; Epoch: 1926.23)[Opik 1927]

For the B component, its B and V magnitudes are, respectively, 9.57 and 9.19 (TYCHO-2), and the B-V color index is 0.33. For component C, only the B magnitude is available, and is 12.87 (USNO-B1.0). The infrared photometry gives magnitudes for component A, J: 8.73; H: 8.63; K: 8.54; and for component B, J: 11.58; H: 11.17; K: 11.02. Additionally, using an unfiltered CCD, we obtained in R band for B and C;
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9.44 and 12.78, respectively.

Taking into account the photometric and kinematical data of B, the estimated spectral type and luminosity class were A9V (in the professional literature: A2 [Wright et al. 2003]). However, the spectral type for C is not clear, because only the infrared magnitudes are available. It may be a K-class star.

The proper motions for both components come from two different catalogs. For the A component, PPMX gives the values: \(\mu(\alpha)\): -5.05 \pm 1.2 \text{ mas/yr} and \(\mu(\delta)\): -28.65 \pm 1.2 \text{ mas/yr}. In USNO ·B1.0, component B has the values: \(\mu(\alpha)\): 50 \pm 12 \text{ mas/yr} and \(\mu(\delta)\): 24 \pm 8 \text{ mas/yr}. Additionally, we determined the relative proper motion to be \(\Delta\mu(\alpha)\): 21.83 \pm 3.67 \text{ mas/yr} and \(\Delta\mu(\delta)\): 27.14 \pm 2.55 \text{ mas/yr}. According to these values, this pair is optical.

**STF 983AC (WDS 06562+3428)**

See Figure 4. According to the historical data from WDS, this system was measured 5 times. The first measurement is dated 1900 (Rho: 22.23"; Theta: 191.2°; Epoch: 1900.12) [Urban et al. 1998]. The last measurement was in 1948 (Rho: 22.23"; Theta: 191.2°; Epoch: 1948.20) [Urban et al. 1998].

From TYCHO-2, the V and B magnitudes, and B-V color index for the A component are, respectively, 8.69, 10.59 and 1.57. The B and V magnitudes for component C were found in GSC23 to be 13.33 and 12.48, respectively. The B-V color index is 0.85. From CMC-14, the R magnitude for A and C are, respectively, 11.47 and 10.67. Additionally, using an unfiltered CCD in combination with ASTROMETRICA plus CMC-14 and FOCAS II, we obtained a magnitude of 12.80 in V band. In the infrared bands, the JHK magnitudes for A are (4; 3.118 and 2.75). For B (11.06; 10.67 and 10.61) (2MASS).

Considering both kinematic and photometric data of the two components, we estimated their spectral types to be M5III (Component A) (in professional literature: M0 [Wright et al. 2003]) and K1III (component C).

The proper motions for both members are from two catalogs. The proper motion of primary component is \(\mu(\alpha)\): 2.54 \pm 1.3 \text{ mas/yr} and \(\mu(\delta)\): -6.32 \pm 1.4 \text{ mas/yr} (PPMX). For the secondary component, \(\mu(\alpha)\): -3.4 \pm 4.4 \text{ mas/yr} and \(\mu(\delta)\): -3.1 \pm 3.3 \text{ mas/yr} (NOMAD).

The kinematical data indicate the optical nature of this pair. Applying both Aitken, Curtiss and Rica criteria the result is also an optical pair.

Further, we calculated the relative proper motion which also indicates the optical nature. The values in RA and DEC are: \(\Delta\mu(\alpha)\): -13.97 \pm 6.58 \text{ mas/yr} and \(\Delta\mu(\delta)\): -13.11 \pm 3.79 \text{ mas/yr}.

**STF 1088CD(STF 1087CD)(WDS 07260+1406)**

See Figure 5. In the historical register of WDS, the total number of measurements is 11. The first measure was made in 1829 by F.G.W Struve (Rho: 19.88"; Theta: 41.9°; Epoch: 1829.55) [Struve 1837]. The last measurement was in 1997 (Rho: 23.00"; Theta: 38.2°; Epoch: 1997.83) (2MASS Point Src Cat., 2003 all-sky release (http://pegasus.phast.umass.edu/))

This system has had troublesome identification of some members. According to historical data from WDS, this pair is the same than STF 1087. That is, the pair STF 1087BC is the same as STF 1088BC.

Reviewing the historical data, another three pairs were measured in 1984 by G. Soulie [Soulie 1984]. Their identifier (and relative astrometry) are STF 1088 AE (\(\rho\): 137.40" and \(\theta\): 224.2°), STF 1088 AF (123.98" and 225.9°) and SLE 411 AR (131.31" and 218.7°). After examining the plates following the relative astrometry of these pairs, we found that STF 1088 AE, STF 1088AF and SLE 411 AR are the same pair (STF 1088 AE = STF 1088AF = SLE 411AR). Note that the magnitudes of their components are not indicated.

The CD pair is composed by two stars with V magnitudes of 8.71 (TYCHO) (component C) and 11.73 (GSC23) (component D). In the B band, their magnitudes are, respectively, 8.85 (TYCHO) and 11.98 (GSC23). The B-V color index for C is 0.12 (TYCHO), while for D is 0.25. In the infrared bands the magnitudes for C are J: 8.39; H: 8.36; K: 8.33. For D, this
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magnitudes are J: 10.62; H: 10.37; K: 10.26. Using these data in combination with the kinematical data, we have estimated the spectral type for both components: A4V (Component C) (in professional literature: A2 [Wright et al 2003]) and F6 (Component D) (Not available in professional literature).

With respect to the kinematical data, the proper motion for C is
\[ \mu(\alpha): -4.8 \pm 1.2 \text{ mas/yr} \] and
\[ \mu(\delta): -18.8 \pm 1.1 \text{ mas/yr} \] (TYCHO-2). Component D has proper motions in RA and DEC of
\[ -4.31 \pm 1.1 \text{ mas/yr} \] and
\[ 1.20 \pm 1.1 \text{ mas/yr} \] respectively (PPMX). Comparing these values, we believe this pair is optical. This same result occurs when we calculate the relative proper motion:
\[ \Delta \mu(\alpha): 7.16 \pm 1.17 \text{ mas/yr} \] and
\[ \Delta \mu(\delta): 17.19 \pm 1.18 \text{ mas/yr} \]

Applying the Curtiss, Aitken and F. Rica criteria, the results obtained were the same: optical pair.

**STF 1302 AC (WDS 09012 + 0245)**

See Figure 6. According to historical measurements from the WDS, this pair was measured twice. The first time was in 1879 by S.W.Burnham (Rho: 31.92; Theta: 269.5º; Epoch: 1879.23) [Burnham 1883]. The last measurement was made in 1904 by the same observer (Rho: 32.06; Theta: 267.6º; Epoch: 1904.25) [Burnham 1906].

The V and B magnitudes for A are 9.31 and 10.03, respectively (TYCHO-2). For component C, only the V magnitude comes from NOMAD, but it is inaccurate. Additionally, the CCD photometry in V band for C gives us a magnitude of 13.86. The value of B-V color index for A is available and is 0.72 (TYCHO-2). From 2MASS, the JHK magnitudes are for A: J: 7.46; H: 7.15; K: 7.05. The magnitudes of component C are J: 12.62; H: 12.25; K: 12.19. Taking into account all photometric and kinematical data the spectral types estimated are K0V(A) and G-class star (C).

The values of proper motion for component A are:
\[ \mu(\alpha): -48.4 \pm 1.1 \text{ mas/yr} \] and
\[ \mu(\delta): 29.6 \pm 1.1 \text{ mas/yr} \] (TYCHO-2). And for component B
\[ \mu(\alpha): 30.0 \pm 9.0 \text{ mas/yr} \] and
\[ \mu(\delta): -14.0 \pm 9.0 \text{ mas/yr} \] (USNO B10). Additionally, we determined the relative proper motion for this pair, obtaining:
\[ \Delta \mu(\alpha): 75.84 \pm 5.07 \text{ mas/yr} \] and
\[ \Delta \mu(\delta): 46.63 \pm 6.3 \text{ mas/yr} \]. These values, both the individual proper motion and the relative proper motion, indicate the system is an optical pair. The same result is obtained if we apply the Curtiss, Aitken and F. Rica criteria.

**STF 1329AC. (WDS 09157-0114)**

See Figure 7. According to the WDS, this pair was measured only once in 1911 by S. W. Burnham (Rho: 57.29; Theta: 101.5º; Epoch: 1911.12) [Burnham 1913].

When we looked for the C component using the values of rho and theta given by the WDS, we could not find any star in the indicated position. However, there is star in a similar position angle, but it is about 100' away from the original position. This situation will be the subject of another article.

The B and V magnitudes for A are 9.77 and 9.04, respectively (HIPPARCOS), which were transformed into Johnson-Cousin standard system, to 9.59 and 8.97. However, we made photometric measurements for this pair using the software Astrometrica with CMC-14 and the results were similar to HIPPARCOS in V magnitude for A (8.95). The infrared JHK magnitudes for A are (7.81; 7.52; 7.43) and for C are (11.80;
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The spectral types and luminosity class estimated from these photometric data were K0V (component A) (in literature professional: G2/3V [Wright et al. 2003]) and K1V (Component C).

The kinematical data for A are: \( \mu(\alpha) = -116.5 \pm 1.1 \) mas/yr and \( \mu(\delta) = -73.0 \pm 1.0 \) mas/yr (TYCHO-2). For C, \( \mu(\alpha) = 4.0 \pm 2.0 \) mas/yr and \( \mu(\delta) = -30.0 \pm 3.0 \) mas/yr (USNO B10).

The calculated relative proper motion is \( \Delta \mu(\alpha) = 140.34 \pm 55.77 \) mas/yr and \( \Delta \mu(\delta) = 38.24 \pm 18.6 \) mas/yr. Comparing the values of proper motion the nature of this pair is clearly optical. Applying the Curtiss, Aitken and F. Rica criteria the result is also an optical pair.

\textbf{STF 1338AB-C (WDS 09210+3811)}

See Figure 8. The WDS catalog lists 7 measurements between 1879 and 1999. The first one is dated 1879 (Rho: 143.4°; Theta: 167°; Epoch: 1879) [Ball 1884] and the last one was in 1999 (Rho: 144.02°; Theta: 166.3°; Epoch: 1999.22) (2MASS 2003).

The B, V, and B-V magnitudes for A are, respectively, 6.65, 6.20, and 0.38 (TYCHO-2), which, when transformed into Johnson system are, respectively, 6.54, 6.16, and 0.38. The photometry of C is from GSC2.3, being B (12.68) and V (12.42). The B-V color index for this component is 0.24. The infrared J, H and K magnitudes from 2MASS are for A (5.28, 5.08, 5.06) and for C (11.62, 11.40, 11.37). Using these photometric data, the spectral types and the luminosity classes for A and C are, respectively, A2V and G2V. In the professional literature the spectral type of A is B9 [Fabricius, et al. 2002].

In order to obtain the proper motion for both components, we consulted HIPPARCOS and NOMAD catalogs for individual proper motions of A and C, respectively. For A \( \mu(\alpha) = -43.49 \pm 1.48 \) mas/yr and \( \mu(\delta) = -20.01 \pm 0.86 \) mas/yr; and for C, \( \mu(\alpha) = -9.5 \pm 0.9 \) mas/yr and \( \mu(\delta) = -3.0 \pm 0.8 \) mas/yr. The annual relative proper motion is \( \Delta \mu(\alpha) = 30.47 \pm 13.97 \) mas/yr and \( \Delta \mu(\delta) = 14.6 \pm 13.11 \) mas/yr. These values (individual and relative proper motion) point to an optical nature of the pair.

\textbf{BU 1423AC (WDS 09251+2933)}

See Figure 9. According to the WDS, this pair was measured twice. The first measurement was in 1911 by S.W. Burnham (Rho: 189.6°; Theta: 49.4°; Epoch: 1911.19) [Burnham 1913]. The last measurement was in 1983 by Tofol Tobal (Rho: 154.38°; Theta: 51.7°; Epoch: 1983.038) [Tobal 2005].

From TYCHO-2, the B, V, and B-V magnitudes of A are, respectively, 8.87, 8.84, and 0.04. Photometry for the C component was obtained from NOMAD. So, B, V, and B-V magnitudes are 12.40, 12.01, and 0.39, respectively. The JHK magnitudes extracted from 2MASS are for A (8.65, 8.68, 8.66) and for C (10.64, 10.35, 10.28). Using these photometric data, the spectral types and the luminosity classes for A and C are, respectively, A2V and G2V. In the professional literature the spectral type of A is B9 [Fabricius, et al. 2002].

With the aim of determining the nature of this pair, we consulted HIPPARCOS and NOMAD catalogs for individual proper motions of A and C, respectively. For A \( \mu(\alpha) = -25.3 \pm 1.2 \) mas/yr and \( \mu(\delta) = 5.26 \pm 0.60 \) mas/yr; and for C, \( \mu(\alpha) = 13.8 \pm 0.7 \) mas/yr and \( \mu(\delta) = -11.6 \pm 0.7 \) mas/yr. According to these values, this system is an optical pair.
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Using the Curtiss, Aitken and F. Rica criterion, the result is the same: optical pair.

**SEI 518 (WDS 09594+3125)**

See Figure 10. The WDS catalog lists two measurement for the same year, 1898. One was made by J. Scheiner (Rho: 25.59"; Theta: 140.5°; Epoch: 1898.2) [Scheiner 1898]. The last measurement was by Urban, et al. [1998].

Using the WDS precise coordinates, we could not find any pair whose rho and theta agree with the values given by WDS. Moreover, the historical data contains the note, "Neither component seen on POSS plate; maybe flaws on AC Potsdam plate" [Mason, 2011].

We consider this pair a lost pair. In Figure 10, the approximate position given by the WDS of this pair is marked with a black cross.

**POU 5647 (WDS 22090+2518)**

See Figure 11. According to WDS historical data, this pair was measured only one time in 1898 by M. A. Pourteau (Rho: 17.3"; Theta: 146.7°; Epoch: 1898.73)[Pourteau 1933].

The B, V, and B-V magnitudes for A were obtained from TYCHO-2 and are 10.61, 9.92, and 0.69, respectively. For B, the B, V, and B-V magnitudes are, respectively, 14.02 (GSC 2.2), 13.60 (GSC 2.3) and 0.42. The infrared JHK magnitudes (2MASS) are for A (8.78, 8.55, 8.49) and for B (12.47, 12.15, 12.11). From these photometric values, the spectral types and luminosity classes were estimated to be G1 (A component) and F8 (B component). Spectral types for both stars were not found in the professional literature.

The kinematical data of both components were obtained from two different catalogs. The A component proper motion is \( \mu(\alpha) = -85.8 \pm 1.2 \text{ mas/yr} \) and \( \mu(\delta) = -62.9 \pm 1.2 \text{ mas/yr} \) (TYCHO). Meanwhile, for B \( \mu(\alpha) = 6.95 \pm 10.3 \text{ mas/yr} \) and \( \mu(\delta) = -12.2 \pm 10.3 \text{ mas/yr} \) (PPMX). Because of the high value of errors in proper motion values of secondary component, we calculated the relative proper motion, obtaining \( \Delta \mu(\alpha) = 90.44 \pm 1.04 \text{ mas/yr} \) and \( \Delta \mu(\delta) = 64.03 \pm 2.1 \text{ mas/yr} \). Comparing the kinematical data, both individual and relative proper motion, the nature of this pair is optical. The Curtiss, Aitken and F. Rica criteria confirm the optical nature for this system.

**STF 2947AC (WDS 22490+6834)**

See Figure 12. The WDS catalog lists 5 measurements for the AC pair. The first measurement was made in 1894 (Rho: 109.018"; Theta: 206.4°; Epoch: 1894.89)[Urban et al. 1998] and the last one in 1925 by E. Opik (Rho: 111.19°; Theta: 206.4°; Epoch: 1925.05)[Opik 1927].

The B and V magnitudes for A and C were ob-
Astrometric Measurements of Double Stars in 2009

tained from two different catalogs. For the A component, B, V and B-V magnitudes are, respectively, 7.35; 6.89 and 0.43 (HIPPARCOS). Component C has magnitudes of 13.32 (B), 12.63 (V), and 0.69 (B-V) (NOMAD). The infrared JHK bands were obtained from 2MASS for both stars. A has magnitudes of 5.87 (J), 5.73(H) and 5.64(K); and C, magnitudes of 10.72 (J), 10.30(H) and 10.20 (K). Using this photometric data, the spectral types and luminosity classes for both components are F5V (A) (F5 [Fabricius et al. 2002]) and K2V(C) (its spectral type is not available in professional literature).

The kinematical data of A and C were obtained from HIPPARCOS (component A) and PPMX (component C). The proper motion of A is $\mu(\alpha) = 117.30 \pm 0.96$ mas/yr and $\mu(\delta) = 67.39 \pm 0.72$ mas/yr. The C component has $\mu(\alpha) = 10.5 \pm 1.8$ mas/yr and $\mu(\delta) = -20.3 \pm 1.8$ mas/yr. The relative proper motion for this pair is $\Delta \mu(\alpha) = -114 \pm 11$ mas/yr and $\Delta \mu(\delta) = -83.6 \pm 4.2$ mas/yr. These high values in both the individual and the relative proper motions indicate an optical

(Continued on page 97)

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**Notes:**
1. DSS
2. 2MASS
3. CCD
Astrometric Measurements of Double Stars in 2009

nature for the AC pair. The Curtiss, Aitken and F. Rica criteria obtain the same conclusion: optical pair.

Acknowledgements

This work has made use of SIMBAD and VIZIER-tools from CDS (http://cdsweb.u-strasbg.fr/)

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

Some of the data presented in this paper were obtained from the Multimission Archive at the Space Telescope Science Institute (MAST). STScI is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555. Support for MAST for non-HST data is provided by the NASA Office of Space Science via grant NAG5-7584 and by other grants and contracts.

This research has made use of the NASA/ IPAC Infrared Science Archive, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

We want to thank Francisco Rica for his help during the realization of this article and Alejandro Mendiolagoitia for his corrections in English.

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Software
FV: http://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/fv_download.html

ASTROMETRICA: http://www.astrometrica.at

REDCUT: http://astrosurf.com/hfosaf/

FOCAS: http://www.astrosurf.com/cometas-obs/_Articulos/Focas/Focas.htm

Digitized Plates
DSS: http://stdatu.stsci.edu/cgi-bin/dss_plate_finder)

2MASS: http://irsa.ipac.caltech.edu/