Three New Common Proper Motion Binaries in Cetus, Pisces and Leo Minor Constellations

F. M. Rica

Astronomical Society of Mérida,
C/Toledo, no1 Bajo,
Mérida E-06800, Spain

Double Star Section of LIADA,
Avda. Almirante Brown 5100 (Costanera),
S3000ZAA Santa Fe, Argentina

frica0@gmail.com

Abstract: I present three new common proper motion binaries discovered during a project of measuring and study of neglected double stars. In addition to this, I present the study of two binaries also found by me but listed recently in the WDS catalog. Forty-four measures of position angles and angular distances were performed using public photographic and digital online surveys and catalogs with epoch between 1953 and 2011. The astronomical literature was consulted and my astrophysical characterization was determined by parameters such as spectral types, absolute magnitudes, distances, stellar masses, tangential velocities, reddening, etc. A dynamical study allowed me to classify these pairs of stars according to their nature. Four of them were classified as candidate common origin binaries and one as a candidate to be a binary with stellar components gravitationally bound

1. Introduction

A year ago, LIADA Double Star Section started a project called MIEDA, *Medición y Estudio de Estrellas Dobles Abandonadas* (Measuring and Study of Neglected Double Stars). In a first phase of this project we used the ALADIN tool (Bonnarel *et al.* 2000) using a designed script, to identify neglected double stars. In this phase I found 5 uncataloged common proper motion pairs, although two of them were recently listed in WDS during the edition of this work.

In this work I performed relative (θ and ρ) astrometric measures using photographic and digital online surveys in addition to astrometric catalogs (2MASS). A search for photometric and kinematical information was done in the astronomical literature. Finally astrophysical characterizations of the stellar components and a dynamic study of the double stars were performed.

The organization of this paper is as follows. In Section 2, I present the astrometric measures. In Section 3, I detail the astrophysical study. In Section 4, I discuss the study of the nature of these pairs. Section 5, includes detailed comments about the studied binaries. Finally in Section 6, I present my conclusions.

2. Measures of Position Angles and Angular Distances

In this work I use photographic plates from Digitized Sky Survey (hereafter DSS), and digital surveys such as DENIS (*Deep Near Infrared Survey of* *the Southern Sky*) in I, J, and K bands and SDSS (*Sloan Digital Sky Survey*) in *ugriz* bands. In addition to this, the astrometry of 2MASS catalog was used to obtain θ and ρ measures.

Antonio Agudo Azcona (AAA) performed an astrometric measure of FMR 27 in 2011 using a Schmidt-Cassegrain of 20 cm of diameter. The image was taken using a CCD Atik 16IC-S monochrome and a reduced focal Hirsch SCT f/6.3. This configuration gave a focal length of 1384 mm, a scale of 1.24 arcsec and a field of view of 16.1' x 12.0'.

Ramón Palomeque Messía (RPM) also performed an astrometric measure of FMR 27 using a Schmidt-Cassegrain of 20 cm of diameter. The image was taken using a Orion SSDS-II Color camera. He took 500 images of 1 second exposure time and later stacked 100 images using Maxim. Reduc was used for the astrometric measure.

Table 1 lists Forty-four position angles (θ) and angular distances (ρ) measures with observational epochs between 1953 and 2011. This table gives the WDS name (or the proposed name for those binaries not listed in WDS) in column (1), the Besselian observational epoch, the position angle and angular distances in columns (2)-(4); the aperture of the telescope (in inches) in column (5) and finally, in the last column the method used to obtain the relative astrometry:

- DSS: photographic plates from Digitized Sky Survey
- DENIS-*band*: digital images from DENIS. "*band*" is the photometric band used in the image (I, J, and K).
- SDSS-*band*: digital images from SDSS. "*band*" is the photometric band used in the image .
- 2MASS: astrometry from 2MASS catalog

3. The Astrophysical Study

A detailed astrophysical study of the new stellar systems and for the stellar components was performed (see Table 2). The guidelines of the astrophysical study were published in Benavides *et al.* (2010) in sections 3 to 10. The astrophysical data were corrected for interstellar reddening. The reddening was nearly negligible except for LEP 121 which E(B-V) = 0.09. In the followed subsections I add new points to the astrophysical guidelines.

3.1 Photometry

Photometric information was obtained from the following catalogs:

- the infrared J, H, and K photometry from 2MASS (Hog et al. 2000) catalog,
- the V magnitude was determined using the red magnitudes from CMC14 (CMC 2006) and UCAC3 (Zacharias et al. 2009). For more detail, see the work published by Rica (2011a).
- I consulted the SDSS (Adelman-McCarthy J.K. *et al*. 2009) catalog. The *ugriz* photometry was converted to V, U-B, B-V, V-I Johnson photometry. For more detail about this transformation see the work published by Rica (2011a). Where SDSS photometry is available , we use the V magnitude determined if the star is weaker that 15 magnitude in *g* band.

4. Are These Double Stars Gravitationally Bound?

In Benavides *et al.* (2010), in section 9, and in Rica (2011b) I described in detail the criteria used to determine the nature of the pairs. The relative motions of the systems were calculated plotting rectangular coordinates x = ρ * sin θ and y = ρ * cos θ (prior to correction of θ for precession and proper motion) against time (read the Appendix in Rica (2011b)). The scope of the weighted linear fit (calculated using Mathematica 5.0) gave the value of the relative proper motion in arcsec*yr^{-1}. The initial weights for measures were assigned using a data weighting scheme published in Rica (2010).

If the distance is known then I can convert the relative motion in relative velocity (in km s^{-1} or in AU yr^{-1}), a key datum to determine if Keplerian motion is possible in these stellar systems. Often the uncertainties in the observational data don't allow the determination with certainty the nature of the pair. In that case, I determined the probability that a double star is gravitationally bound.

For this, I use celestial mechanics to determine if the relative projected velocity of B with respect to A is smaller than the maximum orbital velocity or the escape velocity. I analyzed the probability that a binary is a gravitationally bound system using a Monte Carlo simulation with 25,000 iterations. Monte Carlo methods are a class of computational procedures that rely on repeated random sampling to compute their results. For more detail, see section 5.2 of the work of Rica (2011b).

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Table 1: Astrometric measures.

Double	Epoch	θ (deg)	ρ (as)	Aperture	Observer	Method
FMR 26	1954.675	205.77	20.19	48	FMR	DSS
	1954.675	205.48	20.79	48	FMR	DSS
	1977.637	204.69	20.29	48	FMR	DSS
	1981.767	205.61	20.05	48	FMR	DSS
	1982.633	205.40	20.37	48	FMR	DSS
	1995.826	204.83	20.08	48	FMR	DSS
	1996.866	205.07	20.39	48	FMR	DSS
	1997.808	205.31	20.18	48	FMR	DSS
	1998.626	205.50	20.23	51	FMR	2MASS
	1999.595	205.65	20.34	39	FMR	DENIS-I
	1999.595	205.81	20.13	39	FMR	DENIS-J
FMR 27	1953.779	171.65	363.056	48	FMR	DSS
	1953.779	171.58	362.785	48	FMR	DSS
	1983.682	171.56	362.525	48	FMR	DSS
	1990.810	171.54	363.164	48	FMR	DSS
	1993.622	171.52	363.224	48	FMR	DSS
	1995.801	171.57	363.220	48	FMR	DSS
	1997.828	171.54	362.94	51	FMR	2MASS
	2011.907	171.50	362.85	8	AAA	CCD
	2011.983	171.49	362.69	8	RPM	CCD
LEP 122	1958.524	200.6	7.3	48	FMR	DSS
	1974.61	200.5	7.35	48	FMR	DSS
	1979.629	194.0	6.98	48	FMR	DSS
	1980.559	190.3	7.23	48	FMR	DSS
	1987.378	199.5	7.15	48	FMR	DSS
	1992.41	202.9	6.48	48	FMR	DSS
	1996.699	199.9	6.64	48	FMR	DSS
	1998.53	199.8	7.22	39	FMR	DENIS-K
	1998.53	200.5	7.17	39	FMR	DENIS-I
	1998.53	199.4	7.09	39	FMR	DENIS-J
	1999.507	200.6	7.21	51	FMR	2MASS
LEP 121	1976.483	134.2	3.53	48	FMR	DSS
	1996.545	134.0	4.70	48	FMR	DSS
	1998.414	130.7	4.09	51	FMR	2MASS
FMR 28	1955.29	138.49	18.56	48	FMR	DSS
	1983.849	139.14	18.43	48	FMR	DSS
	1989.928	139.01	18.81	48	FMR	DSS
	1993.197	138.82	18.68	48	FMR	DSS
	1998.217	139.00	18.70	51	FMR	2MASS
	1999.96	138.79	18.73	48	FMR	DSS
	2004.083	138.90	18.70	98	FMR	SDSS-g
	2004.083	138.91	18.58	98	FMR	SDSS-g
	2004.083	139.05	18.63	98	FMR	SDSS-g
	2004.083	138.75	18.64	98	FMR	SDSS-g

Table 2: Astrophysical data for the stellar component of the binaries.

	FMR 26		*FMR 27*		*LEP 122*		*LEP 121*		*FMR 28*	
	A	***B***	***A***	***B***	***A***	***B***	***A***	***B***	***A***	***B***
RA2000	01h 06m 20.62s		$01^h\ 07^m\ 27.07^s$		*18h 29m 16.90s*		$17^h\ 08^m\ 25.59^s$		$10^h\ 00^m\ 19.13^s$	
DEC_{2000}	*-22° 24′ 45.0″*		*+24° 53′ 41.8″*		*-30° 59′ 48.9″*		*-22° 09′ 24.0″*		*+31° 19′ 42.2″*	
V	*16.53* [a]	*19.2* [b]	*12.72* [a]	*15.42* [a]	*13.87* [a]	*14.65* [a]	*16.5* [g]	*17.5* [g]	*15.63* [f]	*18.93* [f]
B – V	---	---	---	---	---	---	---	---	---	---
V – I	---	---	---	---	---	---	---	---	---	---
K [c]	*12.38*	*13.45*	*10.65*	*12.11*	*9.49*	*9.94*	*12.21*	*12.79*	*13.21*	*15.18*
J – H [c]	*+0.60*	*+0.55*	*+0.42*	*+0.61*	*+0.48*	*+0.51 0.51*	*+0.47*	*+0.48*	*+0.57*	*+0.51*
H – K [c]	*+0.22*	*+0.28*	*+0.07*	*+0.16*	*+0.28*	*+0.22*	*+0.24*	*+0.25*	*+0.15*	*+0.23*
J – K [c]	*+0.82*	*+0.83*	*+0.50*	*+0.77*	*+0.76*	*+0.73*	*+0.71*	*+0.73*	*+0.72*	*+0.74*
V-K	*+4.15*	*+5.80*	*+2.07*	*+3.31*	*+4.38*	*+4.71*	*+4.3*	*+4.7*	*+3.14*	*+4.49*
μ(α) [mas/yr]	*-36.4 ± 4* [d]	*-30.7 ± 4* [d]	*+130 ± 2* [d]	*+138 ± 4* [d]	*+457* [d]	*+460*	*+368*	*+361*	*-29.5 ± 4.2* [d]	*-28.5 ± 4.3* [d]
μ(δ) [mas/yr]	*-99.0 ± 4* [d]	*-98.5 ± 4* [d]	*-4 ± 2* [d]	*-5 ± 4* [d]	*-158* [d]	*-155*	*+366*	*+367*	*-56.3 ±4. 2* [d]	*-62.4 ± 4.3* [d]
Spectral Type e)	*M2V*	*M4.5V*	*G9V*	*K7V*	*M2.5V*	*M3V*	*M3VI*	*M5VI*	*K6V*	*M2.5V*
Distance [pc] [e]	*192*	*118*	*212*	*228*	*43*	*41*	*108*	*113*	*385*	*383*
Mv [e]	*10.06*	*13.80*	*5.95*	*8.46*	*10.64*	*11.53*	*11.04*	*11.96*	*7.64*	*10.95*
BC [e]	*-1.76*	*-2.46*	*-0.22*	*-0.65*	*-1.90*	*-2.03*	*-2.1*	*-2.5*	*-0.57*	*-1.90*
Mass [e]	*0.37*	*0.18*	*0.84*	*0.66*	*0.37*	*0.26*	---	---	*0.70*	*0.37*
Vtan [km s^{-1}] [e]	*96*	*58*	*130*	*149*	*99*	*94*	*250*	*275*	*116*	*125*
E(B-V)	*0.01*	*0.01*	*0.04*	*0.05*	*0.02*	*0.02*	*0.09*	*0.09*	*0.02*	*0.02*

Notes:

a) Determined using UCAC3 (Zacharias el at. 2010) and 2MASS (Cutri 2000) photometry

b) Determined using USNO-B1.0 (Monet et al. 2003) photometry

c) 2MASS catalog

d) catalog PPMXL (Roeeser, Demleitner, & Schilbach 2010)

e) this work

f) SDSS catalog

g) WDS catalog;

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5. Notes on Stellar System

FMR 26

This is a very faint (16.53 and 19.2 magnitudes) binary located in the constellation Cetus (Figure 1). It is composed of M2V and M4.5V stars separated by about 20.2" with a common proper motion of -31 mas yr^{-1} in AR and -99 mas yr^{-1} in DEC. The secondary has a V magnitude of 19.2, determined using the USNO-B1.0 photometry. But, if we use the GSC2.3 photometry, a V magnitude of 18.2 and a M3V spectral type is obtained for the secondary component. The V magnitudes determined using a photographic catalog such as USNO-B1.0 and GSC2.3, have an uncertainty of about 0.3-0.4 magnitudes. To this value we have to add the systematic errors usually found in the photographic plates. I decided to use the V magnitude from USNO-B1.0 because the VJHK photometries are a better fit to the spectral types – photometry relations. These sources of error make our astrophysical data have larger errors than in other studies.

The Monte Carlo simulation indicates a common distance probability of about 60 % (146.5 ± 18.1 pc) and a probability of binarity (stellar components gravitationally bound) of less than 1%. The significant probability of common distance and the common proper motion of about 105 mas yr^{-1} (relative motion $\Delta\mu = 5.07 \pm 4.89$ mas yr^{-1}) for the components, suggest a binary nature of common origin (no orbiting stars).

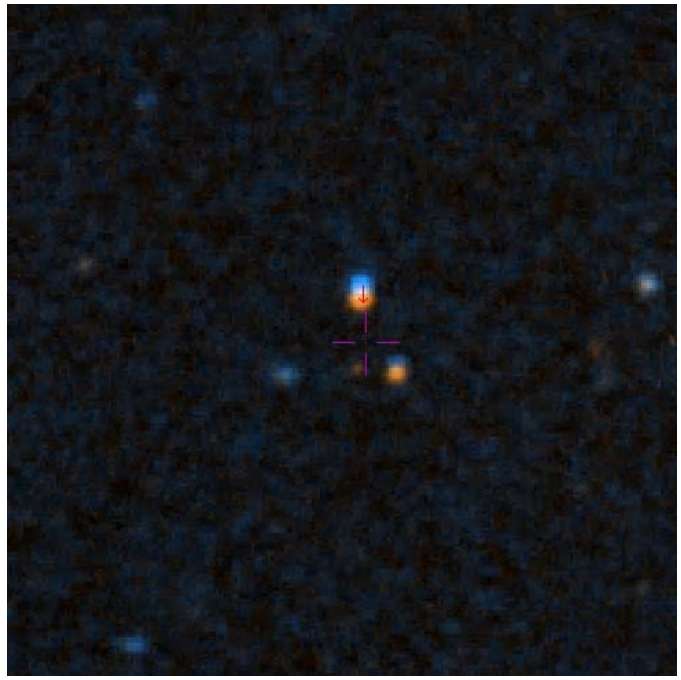

Figure 1: RGB image of the binary star FMR 26 where the apparent motion is clearly visible.

FMR 27

This high common proper motion pair, located in the Pisces, is composed by stars of 12.72 and 15.42 magnitudes with spectral types G9V and K7V (Figure 2). It is a very wide pair of stars separated by about 363". The relative astrometric measures and the high relative motion calculated (12.6 ± 8.6 mas yr^{-1}) suggest that this pair of stars could be not gravitationally bound (although the level of uncertainty don't allow us conclude this with security). If the UCAC3 proper motion is used, then the relative motion is reduced to 2.8 mas yr^{-1}. Even using this small relative motion, the criteria used conclude that the stellar components of FMR 27 are not gravitationally bound. So this pair of stars is likely a binary of common origin.

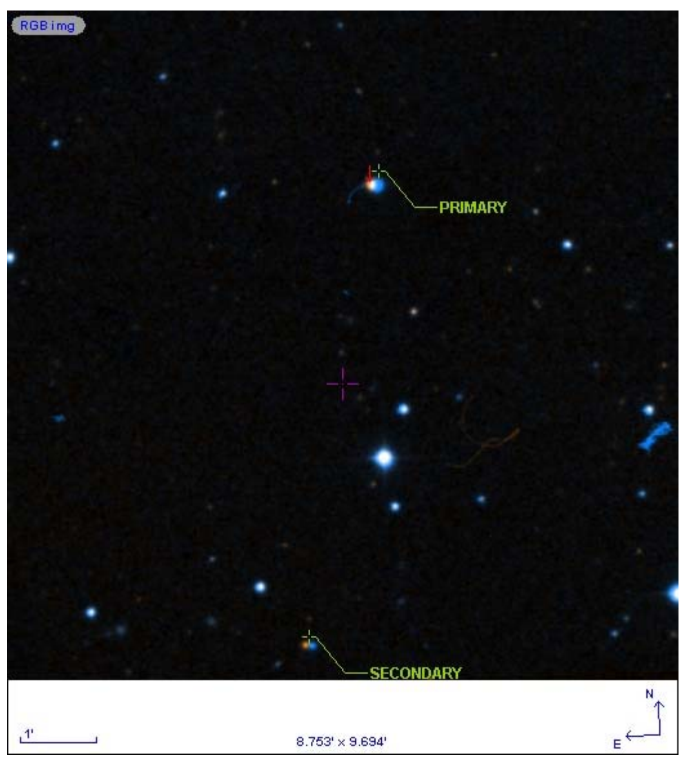

Figure 2: RGB image of the extremely wide binary star FMR 27 where the apparent motion is clearly visible

LEP 122 (WDS 18293-3100)

This is a very high common proper motion binary ($\mu = 0.483$ arcsec yr^{-1}) discovered by Lepine (2008) in

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the constellation Sagittarius. WDS catalog lists spectral types K+K (Figure 3). In this work I determined that this system is located 41 - 43 pc from us and is composed of 13.87 and 14.65 magnitude stars of spectral types of M2.5V and M3V. It is a close pair (about 7") with a poorly determined relative motion of 4.7 ± 6.2 mas yr^{-1}. The 25,000 Monte Carlo simulations that I ran showed that in 77 % of the simulations, the observed projected velocity was smaller than the maximum escape velocity. So this pair of stars is likely a binary with gravitationally bound stellar components. The projected distance calculated is 303 AU and using Kepler's Third Law (assuming circular and face-on orbit) a period of 9,400 years is obtained. A common origin nature cannot be ruled out.

Our measures, using 2MASS catalog and DENIS images, seem to be the same as those of Skiff (2011) listed in WDS catalog.

LEP 121 (WDS 17084-2209)

This is a very high common proper motion binary (0.488 arcsec yr^{-1}) discovered by Lepine (2008) in the constellation Leo (Figure 4). The WDS catalog lists spectral types K+K. In this work, I determined that this system is located at 108 - 113 pc and is composed of two subdwarf candidate stars of M3VI and M5VI spectral types with magnitudes 16.5 and 17.5 (WDS). I determined the subdwarf nature using reduced proper motion diagrams. LEP 121 is a close pair separated by 4.1" with a poorly determined relative motion of 16 mas yr^{-1}. This relative motion was calculated from the proper motion of the stellar components. Astronomical literature does not list proper motion data, so the proper motions listed in this work have been calculated from two photographic plates taken on 1976.483 and 1996.545. The projected distance is 453 AU. I calculated a very similar photometric distance for the primary (108 pc) and the secondary (113 pc) components. This common distance, in addition to the common proper motion, indicates that LEP 121 is a binary star. But the large relative motion suggests that it is a common origin binary with stellar component not gravitationally bound.

Our measure with epoch 1998.414 was obtained using 2MASS catalog. WDS lists a measure from Skiff (2011) that seems to be also obtained using the 2MASS catalog or image.

FMR 28

This is a distant and faint common proper motion (0.064 arcsec yr^{-1}) binary located in the constellation Leo Minor at about 384 pc (Figure 5). It is composed of two dwarf stars of K6V and M2.5V spectral types

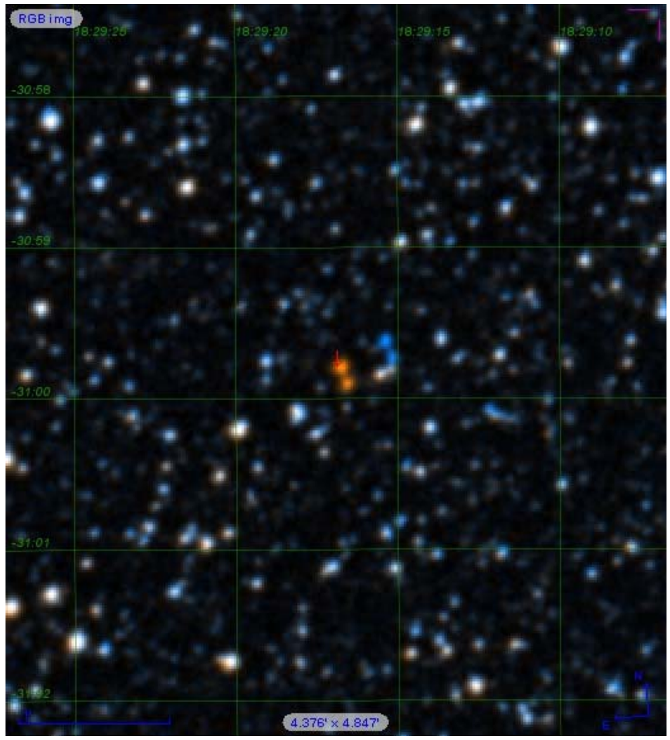

Figure 3: RGB image of the binary star LEP 122 where the apparent motion is clearly visible

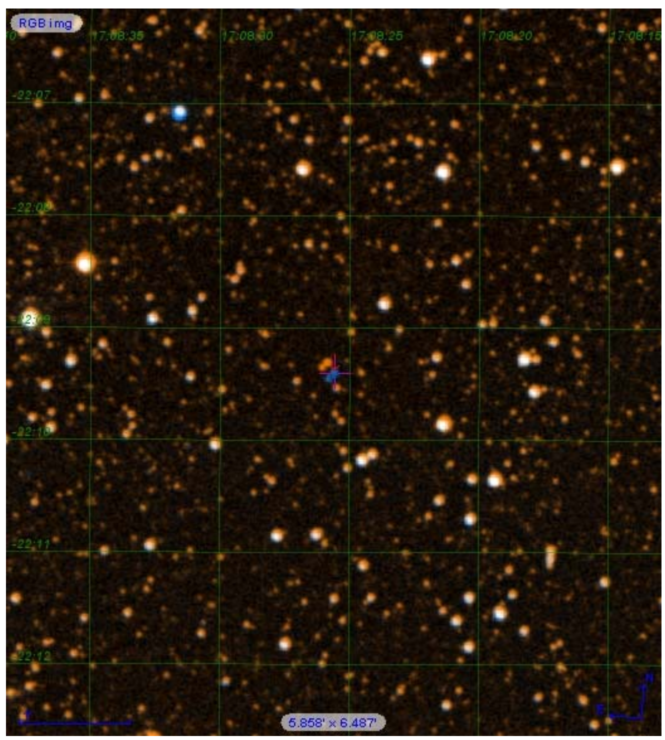

Figure 4: RGB image of the binary star LEP 121.

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with magnitudes 15.63 and 18.93. It is separated by 18.6 - 18.7" with a relative motion of 2.26 ± 3.40 mas yr^{-1}. The projected distance is 7,181 AU. I calculated a very similar photometric distance for the primary (385 pc) and the secondary (383 pc) component. This common distance, in addition to the common proper motion indicates that FMR 28 is surely a binary star. The 25,000 Monte Carlo simulations that I ran showed that only in the 5-6% of simulations the observed projected velocity was less than the maximum escape velocity. So FMR 28 is likely a common origin binary star.

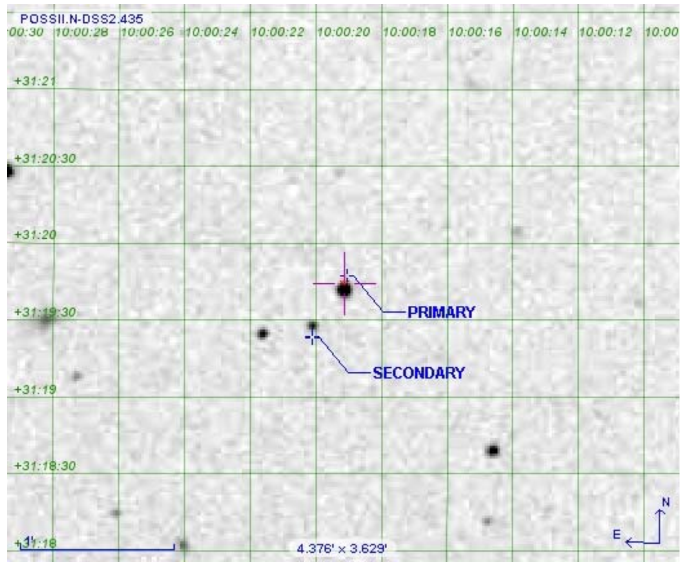

Figure 5: Photographic plate where FMR 28 appears at the center of the image.

Conclusions

During the course of the MIEDA project I found 5 uncataloged wide common proper motion pairs. During the completion of this study two of them were recently included to WDS catalog, so in this work I present three new common proper motion binaries (FMR 26, FMR 27 and FMR 28). Astrophysical characterizations and astrometric measurements were performed. In spite of the low quantity of the astrometric measures and the small time baseline (less than 50 years), I performed a dynamical study to determine the probability to be pairs with stellar components gravitationally bound. All five pairs have stellar components with a significant possibility to be the same distance from us and with common proper motion. But only one pair (LEP 122) has the likely probability to be gravitationally bound. LEP 122 is a pair of red dwarf stars (M2.5V and M3V) separated by 303 AU and located at a distance of about 42 pc. Its orbital period is estimated to be about 9,400 years. The other pairs are surely binary stars of common origin, that is, with stellar components that don't orbit each other.

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References

Adelman-McCarthy J. K. *et al.,* 2009, ApJS, 182, 543

Benavides R., Rica F., Reina E., Castellano J., Naves R., Lahuerta L., Lahuerta S., 2010, JDSO, 6, 30

Bonnarel F. et al., 2000, A&AS, 143, 33

CMC, 2006, Copenhagen University Obs., Institute of Astronomy, Cambridge, Real Instituto y Observatorio de la Armada en San Fernando

Cutri R. N. et al. Explanatory to the 2MASS Second Incremental Data Release, 2000, http://www.ipac.caltech.edu/2mass/releases/second/index.html

Høg E. et al., 2000, A&A, 355, 27

Lepine S., 2008, AJ, 135, 2177

Monet D. G. et al., 2003, AJ, 125, 984

Rica F. M., 2010, RMxAA, 46, 263

Rica F. M., 2011a, JDSO, 7, 114

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

Roeeser S., Demleitner M., Schilbach E., 2010, AJ, 139, 2440

Skiff B. A., 2011, private communication

Zacharias N. et al., 2009, VizieR Online Data Catalog, 1/315, http://vizier.ustrasbg. fr/viz-bin/VizieR?-source=I/315

Zacharias N. et al., 2010, AJ, 139, 2184