Overlooked wide companions of nearby F stars[★] (Research Note)

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ABSTRACT

Aims. We checked a sample of 545 F stars within 50 pc for wide companions using existing near-infrared and optical sky surveys.

Methods. Applying the common proper motion (CPM) criterion, we detected wide companion candidates with 6–120 arcsec angular separations by visual inspection of multi-epoch finder charts and by searching in proper motion catalogues. Final proper motions were measured by involving positional measurements from up to eleven surveys. Spectral types of red CPM companions were estimated from their absolute *J*-band magnitudes based on the HIPPARCOS distances of the primaries.

Results. In addition to about 100 known CPM objects, we found 19 new CPM companions and confirmed 31 previously known candidates. A few CPM objects are still considered as candidates according to their level of proper motion agreement. Among the new objects there are nine M0–M4, eight M5–M6, one $\approx$ L3.5 dwarf (HD 3861B), and one white dwarf (WD) (HD 2726B), whereas we confirmed two K, 19 M0–M4, six M5–M6, two early-L dwarfs, and two DA WDs as CPM companions. In a few cases, previous spectral types were available that all agree well with our estimates. Two companions (HD 22879B and HD 49933B) are associated with moderately metal-poor Gaia benchmark stars. One doubtful CPM companion, spectroscopically classified as WD but found to be very bright ($J = 11.1$) by others, should either be a very nearby foreground WD or a different kind of object associated with HD 165670.

Key words. proper motions – stars: abundances – binaries: general – stars: low-mass – white dwarfs – solar neighborhood

1. Introduction

Stellar binaries and multiple systems appear to be the main product of star formation if the primaries of these systems are at least as massive as the Sun. The solar neighbourhood, representing the average Galactic disk population of stellar systems that typically have existed for several Gyrs, is naturally one of the best-investigated regions with respect to multiplicity. The Research Consortium on Nearby Stars (RECONS)¹ states a multiplicity rate, i.e. the probability that a given system has more than one component, of 29% for their 10 pc sample. However, this overall “low rate is because M-type dwarfs dominate the solar neighbourhood (a full 73% of the stellar sample ... are M-type dwarfs), and do not have companions as often as their more massive stellar cousins”. Among the 100 nearest RECONS systems (with a horizon of about 6.5 pc), there are 70 where M dwarfs are the most-massive component, of which only 18 (26%) are known to have companions. On the other hand, there are 22 AFGK primaries, of which 12 (55%) are in known multiple systems. The RECONS 10 pc census shows a strong increase from 2000 to 2012 both in the number of M dwarfs (+25%) and in the number of stellar and LT-type companions (+26%).

The multiplicity of F- and G-type stars in a wider solar neighbourhood was the focus of investigations by Fuhrmann & Chini (2012, 2015), Chini et al. (2014), Tokovinin (2011, 2014), and Tokovinin & Lépine (2012). To distinguish between

visual and physical wide double stars, the common proper motion (CPM) of the components is often used as a criterion. In the era of photographic sky surveys, Luyten (1997) compiled a catalogue of CPM pairs. Frankowski et al. (2007) investigated CPM binaries in the HIPPARCOS catalogue, where both components are HIPPARCOS stars, compared their short-term (HIPPARCOS) and long-term (Tycho-2) proper motions, and used radial velocities as control data. The systematic search for faint CPM companions to HIPPARCOS stars (Gould & Chanamé 2004; Lépine & Bongiorno 2007) not only improved the statistics of the multiplicity of AFGK stars, but also allowed for a better characterisation of the lower-mass companions by making use of the knowledge about the primaries. One of the physical parameters of interest in that respect is the metallicity of M dwarfs and subdwarfs (e.g. Li et al. 2014). The CPM method continues to be useful, in particular for new deep surveys (e.g. Ivanov et al. 2013; Deacon et al. 2014). Focusing on a sample of nearby F stars, we demonstrate how much we can still improve the CPM statistics and find previously overlooked wide companions, even of well-known bright stars, in existing public surveys. The main results of this research note, which includes data on new, confirmed, and rejected CPM companions, are listed in Tables A.1, B.1, and C.1, respectively.

2. Sample definition and search method

2.1. SIMBAD F stars sample

From 1188 stars, for which SIMBAD lists spectral types F0 to F9 and parallaxes larger than 20 mas, we selected 545 with proper motions larger than 150 mas/yr to search for CPM companions.

[★] Tables A.1, B.1, and C.1 are also available at the CDS via anonymous ftp to [cdsarc.u-strasbg.fr](ftp://cdsarc.u-strasbg.fr) (130.79.128.5) or via <http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/587/A51>

¹ <http://www.chara.gsu.edu/RECONS/>

Our high proper motion 50 pc sample overlaps in part with the sample of Tokovinin (2014), which is about nine times larger. His sample reaches out to 67 pc, excludes stars with large parallax errors (>7 mas), and contains both F and G stars, but with a colour selection only corresponding to late-F and early-G stars (approximately F5V to G6V). Finally, he included only dwarfs and subgiants. We are aware of possible uncertainties (e.g. missing updates) in the SIMBAD data, in particular the spectral types (see also Scholz et al. 2015 concerning F-type subdwarfs).

2.2. Visual inspection and catalogue search

In our visual inspection of the sky areas around 545 F stars, we used IRSA finder charts tools² in several runs with image sizes from 0.5 arcmin to 3 arcmin. In addition, we extracted 1 arcmin and 2 arcmin finder charts from the UKIRT deep infrared sky survey (UKIDSS) and the visible and infrared survey telescope for astronomy (VISTA) archives³. We considered the Two Micron All-Sky Survey (2MASS; Skrutskie et al. 2006) images with their high resolution and dynamic range as reference and searched for CPM candidates in other images with epoch differences large enough to show a change in position similar to that of the primaries. Special attention was paid to objects overlapping with diffraction spikes and other known artifacts, as well as to those with very red or blue colours expected for very low-mass and white dwarf (WD) companions, respectively. A few cases are illustrated by selected finder charts in Figs. D.1–D.3.

Our search was sensitive to angular separations from a few arcseconds to a few arcminutes. It was complementary to the work of Tokovinin & Lépine (2012) that aimed at angular separations of the companion larger than 30 arcsec. Using existing sky surveys, we tried to find CPM companions that have small separations. However, to detect very close companions with angular separations of the order of 1 arcsec or less, dedicated high-resolution imaging observations (e.g. Ehrenreich et al. 2010; Meshkat et al. 2015) are required.

Using the CDS cross-match service⁴ we also checked the fourth US Naval Observatory CCD Astrograph Catalogue (UCAC4; Zacharias et al. 2013) and the first US Naval Observatory Robotic Astrometric Telescope catalogue (URAT1; Zacharias et al. 2015) for possible new CPM companions within 2 arcmin of the primaries. We note that these catalogues were already the subject of CPM searches by Hartkopf et al. (2013) and Nicholson (2015). In our catalogue search, we did not require a correct proper motion measurement of the bright and sometimes problematic primaries in the given catalogue.

2.3. Proper motion measurements and CPM status

In our proper motion determinations we combined multi-epoch positional measurements from the following surveys (roughly sorted by epochs) if available:

- 1) photographic Schmidt plates scanned with the Automated Photographic Measuring (APM; McMahon et al. 2000) and SuperCOSMOS Sky Surveys (SSS; Hambly et al. 2001);
- 2) 2MASS (Skrutskie et al. 2006);

² Old: <http://irsa.ipac.caltech.edu/applications/FinderChart/> (for DSS, SDSS, and 2MASS 1–6 arcmin image sizes), new: <http://irsa.ipac.caltech.edu/applications/finderchart/> (with additional WISE images, and allowing for smaller image sizes).

³ <http://wsa.roe.ac.uk/> and <http://horus.roe.ac.uk/vsa/>

⁴ <http://cdsxmatch.u-strasbg.fr/xmatch>

- 3) DEep Near-Infrared southern sky Survey (DENIS; Epchtein et al. 1997);
- 4) UCAC4 (Zacharias et al. 2013);
- 5) Carlsberg Meridian Catalogue (CMC; Muiños & Evans 2014);
- 6) Sloan Digital Sky Survey (SDSS; Abazajian et al. 2009);
- 7) INT PHotometric H α Survey (IPHAS; Barentsen et al. 2014);
- 8) UKIDSS Large Area (UKIDSS LAS; Lawrence et al. 2007) and Galactic Plane Surveys (UKIDSS GPS; Lucas et al. 2008);
- 9) Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010);
- 10) URAT1 (Zacharias et al. 2015);
- 11) VISTA Hemisphere (VHS; McMahon et al. 2013) and Variables in the Via Lactea Surveys (VVV; Minniti et al. 2010).

Those CPM candidates with small separations that were not well-measured or were absent in the SSS/2MASS/DENIS/SDSS catalogues were detected visually in the corresponding FITS images; we performed this using the ESO skycat tool. Depending on the number of epochs available, the accuracy of the simple linear proper motion fit that used all input positions with equal weights varied considerably. No attempt was made to transform the target positions in different surveys to a common system before the proper motion fit as we expected individual centroiding errors affected by the close bright primaries to be larger ($\gtrsim 100$ mas) than systematic errors.

The proper motion errors of the CPM companions were typically much larger than those of the known primaries, although in some cases we achieved a high precision for the CPM companion and excellent agreement with the known proper motion of its primary. For the majority of the 19 new and 31 confirmed CPM companions shown in Tables A.1 and B.1, respectively, their proper motion components agreed to within 2σ of the formal errors with those of the primaries. For the primaries, we preferred the longer-time baseline proper motions of the UrHip (Frouard et al. 2015) or Tycho-2 (Høg et al. 2000) catalogues instead of the HIPPARCOS (van Leeuwen 2007) values. A few CPM companions, for which at least one of the proper motion components agreed only to within 3σ with that of the primary, are considered CPM candidates and are flagged with (?), whereas two objects with even larger discrepancies are considered doubtful CPM objects and are flagged with (??). Our overall level of agreement of the proper motion components is similar to that of Deacon et al. (2014), who described 57 new faint CPM objects of HIPPARCOS stars with total proper motion differences of less than 5σ (their Eq. (1)).

2.4. Spectral type estimates

The spectral types of red CPM companions (according to their near-infrared 2MASS, UKIDSS, or VISTA colours, and DENIS $I-J$ colours if available) were estimated based on the known distances of the primaries and the relation between absolute J magnitude and (early-K to late-L) spectral type from Scholz, Meusinger & Jahreiß (2005). Our spectral type estimates are in good agreement (within 0.5 subtypes) with previous classifications available for six M and two early-L dwarfs (Tables A.1 and B.1). Blue objects, simply assumed to be WD candidates, as well as possible subdwarf candidates are discussed in Sect. 4.

3. Results

The results of our survey are presented in Tables A.1, B.1, and C.1, listing new, confirmed, and rejected CPM companions together with their F star primaries, respectively. All 19 new CPM objects belong to primaries with distances between 25 and 50 pc according to their HIPPARCOS parallaxes. Among the 31 confirmed CPM companions, there are four within 25 pc (with parallaxes of 40–75 mas). One new object (HD 76493B) is a doubtful CPM companion not only because of the poor agreement of $\mu_\alpha \cos \delta$, but also because of the discrepancy between the short- and long-term proper motions of its primary HD 76493A. Such discrepancies hinting at the influence of unresolved companions are also seen for the known close binary HD 2057AB and for several other primaries in both Tables A.1 and B.1. If confirmed as CPM, HD 76493B would have the largest projected physical separation of all our targets (≈ 2600 AU).

4. Brief discussion and notes on individual objects

In addition to the objects listed in Tables A.1 and B.1 there are 98 other known CPM objects among the 545 F stars (18%), mainly at small (< 5 arcsec) or large (> 120 arcsec) angular separations and of earlier spectral types (FGK). With our 19+31 new and confirmed CPM companions we add a further 9% (50% more CPM objects), which are mainly M dwarfs at intermediate angular separations. On average, both new and confirmed objects have projected physical separations of about 900 AU (ranging from about 200 AU to 2500 AU). Certainly, the high-resolution astrometric measurements of Gaia will bring the multiplicity rate of the F stars in our high proper motion 50 pc sample to the 50% level, as currently known for the small RECONS 6.5 pc sample, or even higher. Gaia will also provide accurate distances for individual system components and the CPM status for all nearby objects including those with relatively small proper motions.

We checked our primaries for clearly (repeatedly measured) non-solar metallicities using VizieR and found only two metal-poor stars, HD 22879A and HD 49933A, among our new and confirmed CPM systems, respectively. Both are Gaia benchmark stars with respect to metallicity (Jofré et al. 2014) with mean literature $[\text{Fe}/\text{H}]$ values of -0.85 and -0.39 , respectively. Their CPM companions, HD 22879B and HD 49933B, are therefore M subdwarf candidates that can be used for the calibration of M dwarf metallicities (e.g. Neves et al. 2012; Newton et al. 2014).

Our new and confirmed wide CPM companions of nearby F stars distributed all over the sky are good targets for spectroscopic follow-up observations, to verify their spectral types and to confirm their physical association with the primaries by radial velocity measurements. Our lowest-mass new CPM companion, the suspected $\approx L3.5$ dwarf HD 3861B, is of particular interest, as L-type companions of nearby F-type stars are rare (Wilson et al. 2001; Luhman et al. 2012; Gauza et al. 2012; Deacon et al. 2014). Our spectral type estimate for HD 3861B is also supported by its $J-K = +1.7$ measured in the UKIDSS LAS, which is a typical colour of a mid-L dwarf (Leggett et al. 2010).

The CPM criterion is also used for membership probability in moving star clusters (e.g. Gagné et al. 2015). One of our new CPM companions, HD 175317B (Table A.1), was previously considered a member of the AB Dor moving group by Malo et al. (2013), who did not mention the small separation (≈ 18 arcsec) and CPM with respect to HD 175317A. We consider this relatively close CPM pair most likely physically bound, although the $\mu_\alpha \cos \delta$ agreement is only within 3σ . This

does not exclude a moving group membership. The confirmed CPM companion HD 126679B (Table B.1) was investigated by Gagné et al. (2015), but was not found to be a member of any moving group.

A strong decline in the frequency of Sirius-like systems (AFGK stars with WD companions) beyond a distance of 20 pc was mentioned by Holberg et al. (2013), who predicted new discoveries of such systems with different observing techniques. In our search, we confirmed two WD CPM companions (Table B.1) and found one previously overlooked at a separation of about 20 arcsec to the early-F star HD 2726A (Table A.1). The new object, HD 2726B, was barely seen in 2MASS, but was clearly detected in DENIS ($J = 14.96$, $I-J = -0.33$) and VISTA VHS (mean $J = 14.83$, $J-K = -0.19$). Both of its proper motion components agree to within 1σ with those of HD 2726A.

Our most doubtful CPM confirmation, HD 165670H, is not red enough for an early-M dwarf classification (2MASS $J = 10.27$, $J-K_s = +0.39$) and was therefore also considered a WD candidate. Deacon et al. (2014) classified it as DA WD based on a near-infrared spectrum and found a fainter magnitude and bluer colour (UKIRT $J = 11.10$, $J-K = +0.15$). Their measured separation of 9.6 arcsec is 1.8 arcsec larger than ours, indicating centroiding problems or a change over time (no CPM?), but their proper motion ($+36 \pm 5$, -133 ± 5) is in better agreement with that of the primary. However, the primary shows a discrepancy between its HIPPARCOS and UrHip proper motions. More importantly, the J magnitude of HD 165670H is comparable to that of the nearest known WDs (Fig. 1 in Scholz et al. 2015). Therefore, this is either a very nearby WD in the foreground or a different kind of object (hot subdwarf?) associated with HD 165670A.

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Appendix A: Newly found CPM companions

Table A.1 presents our new CPM discoveries. Here we include some CPM companions with previous proper motion

measurements (three in UCAC4, four in URAT1) and/or spectral classifications (one early-M dwarf) whose association with the primary was not mentioned before.

Table A.1. Data on nearby F stars and their new CPM companions.

Name HD	RA (J2000) [degrees]	Dec (J2000) [degrees]	Epoch [year]	π (Sep, PA) [mas] ([arcsec, °])	$\mu_{\alpha} \cos \delta$ [mas/yr]	μ_{δ} [mas/yr]	N_epochs	J (2MASS) [mag]	SpT	Ref
2057AB	6.286235	+48.047478	1998.849	22.82 ± 0.88	+281.3 ± 0.4 ^j	+1.0 ± 0.4 ^j	11000000010	6.38 ± 0.02	F8	2,3,4,S
2057D ^s	6.280679 ^a	+48.046743 ^a	1998.849	(13.6, 259)	+283 ± 26 ^{a,c}	-3 ± 10 ^{a,c}		≈12.5 ^e	≈M5	2,2,5,5
2726A	7.608672	-48.214951	1999.767	23.11 ± 0.43	+134.2 ± 0.8 ^j	-84.5 ± 0.8 ^j	21110000001	4.94 ± 0.04 ^f	F2V	2,3,8,S
2726B	7.600967 ^a	-48.212594 ^a	1999.767	(20.3, 295)	+135 ± 12 ^{a,c}	-94 ± 13 ^{a,c}		14.96 ± 0.14 ^g	WD	2,2,5,5
3861A	10.2991063	+9.3548251	2010.592	29.90 ± 0.45	-125.0 ± 0.6 ^j	-103.7 ± 0.6	01000102000	5.58 ± 0.03	F8V	7,3,4,S
3861B	10.2945415	+9.3556005	2010.592	(16.5, 280)	-121 ± 14 ^{a,d}	-79 ± 13 ^{a,d}		15.690 ± 0.006 ^g	≈L3.5	7,7,5,5
10226A	24.977409	-9.972228	1998.816	20.35 ± 0.81	+239.8 ± 1.7	+92.2 ± 1.3	01000200000	6.73 ± 0.02	F8	2,3,8,S
10226B	24.975580	-9.973311	1998.816	(7.6, 239)	+229 ± 21 ^d	+76 ± 16 ^d		≈12.6 ^e	≈M5	2,2,5,5
18404A	44.521691	+20.668737	1998.751	30.15 ± 0.30	+235.4 ± 0.6	-29.8 ± 0.6	01010100110	5.31 ± 0.20	F5IV	2,3,4,S
18404B	44.525723	+20.667135	1998.751	(14.8, 113)	+232 ± 7	-21 ± 4		10.47 ± 0.07	≈M3.5	2,2,5,5
22879A	55.091754	-3.216831	1998.732	39.12 ± 0.56	+688.6 ± 0.6	-213.0 ± 0.6	11100000010	5.59 ± 0.02	F9V	2,3,4,S
22879B	55.086450 ^a	-3.217122 ^a	1998.732	(19.1, 267)	+672 ± 15 ^{a,c}	-231 ± 14 ^{a,c}		12.09 ± 0.07 ^g	≈M6/sdM?	2,2,5,5
35681A	82.003845	+33.763836	1998.090	29.54 ± 0.51	+18.2 ± 0.4	-211.0 ± 0.4	01000111010	5.46 ± 0.02	F7V	2,3,4,S
35681E ^s (?)	82.004011	+33.761101	1998.090	(9.9, 177)	+33 ± 8	-231 ± 7		10.32 ± 0.08	≈M3.5	2,2,5,5
57334A	109.551348	-51.050465	2000.195	20.27 ± 0.52	+24.2 ± 1.0	-150.5 ± 1.0	61110000100	6.49 ± 0.02	F9V	2,3,8,S
57334B	109.543129	-51.059307	2000.195	(36.9, 210)	+20 ± 6 ^{b,i}	-158 ± 4 ^{b,i}		11.38 ± 0.02	≈M3.5	2,2,5,5
74868A	131.211449	-44.542557	2001.090	27.41 ± 0.36	-194.0 ± 1.2	+135.4 ± 1.0	01100000000	5.63 ± 0.02	F9	2,3,8,S
74868B (?)	131.215346 ^a	-44.542417 ^a	2001.090	(10.0, 87)	-231 ± 15 ^{a,b}	+158 ± 17 ^{a,b}		≈11.9 ^e	≈M5	2,2,5,5
76493A	134.444037	+38.258907	2000.022	21.52 ± 1.58	-119 ± 0.4 ^j	-87.6 ± 0.4 ^j	61011200100	6.13 ± 0.03	F5	2,3,4,S
76493B (??)	134.463382	+38.256172	2000.022	(55.6, 100)	-98 ± 5 ^h	-79 ± 5 ^h		13.09 ± 0.03	≈M5.5	2,2,5,5
129926A	221.500396	-25.443171	1998.479	33.02 ± 0.92	-151.5 ± 1.1	-107.3 ± 0.6	01100000200	4.12 ± 0.63 ^f	F0IV	2,3,3,S
129926D ^s	221.504310	-25.449644	1998.479	(26.6, 151)	-145 ± 16 ⁱ	-123 ± 18 ⁱ		10.90 ± 0.03	≈M4	2,2,5,5
141103A	236.820746	-0.269923	2006.568	20.55 ± 0.64	-243.0 ± 0.3	-21.3 ± 0.3	01000101000	5.94 ± 0.02	F5	7,3,4,S
141103B	236.816820	-0.269806	2006.568	(14.1, 272)	-243 ± 16 ^{a,d}	-12 ± 39 ^{a,d}		≈13.5 ^e	≈M6	7,7,5,5
143306A	240.618486	-56.854485	2000.170	29.56 ± 0.40	-148.3 ± 4.4	-117.1 ± 4.1	41210000100	5.60 ± 0.03	F8V	2,3,8,S
143306B	240.638832	-56.849342	2000.170	(44.1, 65)	-146 ± 3 ^{c,i}	-118 ± 4 ^{c,i}		10.46 ± 0.02	≈M3.5	2,2,5,5
155060A	256.9818847	+32.1053256	2013.918	27.36 ± 0.43	-161.7 ± 0.3	-41.4 ± 0.3	01000200010	6.12 ± 0.03	F8	1,3,4,S
155060B	256.9812906	+32.1036278	2013.776	(6.4, 197)	-170 ± 9 ^h	-49 ± 13 ^h		9.28 ± 0.17	≈M1	1,1,5,5
175317A	283.879186	-16.376575	1998.290	31.53 ± 0.33	-27.9 ± 0.7	-184.4 ± 0.7	11110000110	4.73 ± 0.04 ^f	F5V	2,3,8,S
175317B ^p (?)	283.882362	-16.380438	1998.290	(17.7, 142)	-37 ± 4 ^h	-180 ± 3 ^h		9.13 ± 0.03	≈M1 ^q	2,2,5,5
181096A	289.2140625	+47.0002178	2013.810	23.79 ± 0.32	-8.9 ± 0.4	+291.2 ± 0.4	41010000110	5.15 ± 0.27 ^f	F6IV:	1,3,4,S
181096B	289.2041292	+47.0092125	2013.661	(40.5, 323)	-9 ± 3 ^c	+289 ± 1 ^c		10.09 ± 0.02	≈M2.5	1,1,5,5
188769A	300.253517	-64.807938	2000.430	24.11 ± 0.64	+154.3 ± 1.3 ^j	-242.1 ± 1.3 ^j	11200000000	6.01 ± 0.02	F3IV	2,3,8,S
188769B	300.238788 ^a	-64.807814 ^a	2000.430	(22.6, 271) ^a	+155 ± 17 ^{a,c}	-194 ± 38 ^{a,c}		≈12.6 ^e	≈M5	2,2,5,5
215588A	341.2647036	+58.1465458	2013.438	28.22 ± 0.32	-61.0 ± 0.4	-135.9 ± 0.4	01010011110	5.95 ± 0.03	F5	1,3,4,S
215588B	341.2647767	+58.1425542	2013.468	(14.4, 179)	-56 ± 4 ^h	-138 ± 4 ^h		9.97 ± 0.05	≈M3	1,1,5,5
218235A	346.575431	+18.517733	1997.773	22.96 ± 0.49	+227.7 ± 1.1	+60.3 ± 1.0	01000100000	5.30 ± 0.02	F6Vs	2,3,8,S
218235B	346.570271 ^a	+18.518478 ^a	1997.773	(17.8, 279) ^a	+229 ± 22 ^{a,d}	+69 ± 7 ^{a,d}		≈12.8 ^e	≈M5.5	2,2,5,5

Notes. Possible and doubtful CPM candidates are marked with (?) and (??), respectively. The 11-digit number N_epochs gives the number of epochs from SSS/APM, 2MASS, DENIS, UCAC4, CMC, SDSS, IPHAS, UKIDSS, WISE, URAT1, and VISTA, which were used in the proper motion determination. Visual position measurements in images of: ^(a) 2MASS; ^(b) DENIS; ^(c) SSS; ^(d) SDSS; ^(e) not measured by 2MASS, estimated from visual comparison with other 2MASS objects in the field; ^(f) poor photometry according to 2MASS quality flag; ^(g) J magnitude from DENIS or UKIDSS; ^(h) similar proper motion in URAT1 (Zacharias et al. 2015); ⁽ⁱ⁾ similar proper motion in UCAC4 (Zacharias et al. 2013); ^(j) HIPPARCOS proper motion of van Leeuwen (2007) and UrHip or Tycho-2 proper motion do not agree within their errors; Listed (without or with a different proper motion) in: ^(k) Tokovinin (2014) or Tokovinin (2011); ^(l) WDS (Mason et al. 2001); ^(m) also in Wycoff et al. (2006); ⁽ⁿ⁾ discovered by Mugrauer et al. (2004); ^(o) also in Hartkopf et al. (2013); ^(p) member of AB Dor moving group according to Malo et al. (2013); ^(q) Riaz et al. (2006) determined M0.5 spectroscopically; ^(r) mentioned as CPM by Nicholson (2015); ^(s) other (visual or physical) components are listed in the WDS; ^(t) discovered by Gauza et al. (2012), who classified it spectroscopically as L1. Components B and C form a close binary system composed of an M8 and L3 dwarf (Gizis et al. 2003) found to be co-moving with HD 221356A at a very wide separation of about 452 arcsec (Caballero 2007); ^(u) discovered by Wilson et al. (2001) with spectroscopic classification of L0; ^(v) similar proper motion in Naval Observatory merged astrometric dataset (NOMAD; Zacharias et al. 2004) with reference to an unpublished YB6 catalogue; ^(w) discovered by Luhman et al. (2012) and classified as M2; ^(x) Sep=85 arcsec (?) in Luyten (1997); ^(y) discovered and classified as M4.5 by Lowrance et al. (2002); ^(z) SIMBAD lists an identical proper motion as for the primary without reference and a spectral type of M1 according to Bidelman (1985); ^(aa) discovered and classified as DA WD CPM companion Hip 88728B by Deacon et al. (2014); ^(ab) Shares a common radial velocity with the primary according to RAVE (Kordopatis et al. 2013); ^(ac) according to Gagné et al. (2015) a nearby potential >M5 dwarf; ^(ad) discovered by Chini et al. (2014); ^(ae) Bidelman (1980) mentioned as wide CPM companion and estimated a spectral type of M2 or M3; ^(af) exoplanetary host star; ^(ag) SIMBAD lists a HIPPARCOS parallax of 47.8 ± 5.0 mas and proper motion similar to that of Hip 10531. Comparison of SSS, 2MASS and SDSS finder charts confirms the small URAT1 proper motion indicating that Hip 10529 is a background object unrelated to the nearby star Hip 10531; ^(ah) SIMBAD erroneously lists a large proper motion similar to that of HD 187691A and spectral type of M4, which should be assigned to HD 187691C separated by 22 arcsec.

References. Position/Epoch, parallax of primary (angular separation and position angle of CPM companion – for URAT1 data, we neglected small epoch differences of ≤ 0.3 years), proper motion, spectral type: (S) SIMBAD; (1) URAT1; (2) 2MASS; (3) HIPPARCOS (van Leeuwen 2007); (4) UrHip (Frouard et al. 2015); (5) this paper; (6) UKIDSS GPS; (7) UKIDSS LAS; (8) Tycho-2 (Høg et al. 2000); (9) corrected HIPPARCOS data (Fabricius & Makarov 2000); (10) SPM4 (Girard et al. 2011); (11) Limoges et al. (2013).

Appendix B: Previously known CPM companion candidates confirmed with new data

In Table B.1 we list F star companions known in the literature with missing or uncertain proper motion measurements. In particular, we include companions previously listed without proper

motion in Tokovinin (2014) or in the WDS catalogue (Mason et al. 2001). For some URAT1 CPM companions recently identified by Nicholson (2015), we provide improved proper motion and spectral type estimates. CPM companions of HIPPARCOS stars already reported by Gould & Chanamé (2004) and Lépine & Bongiorno (2007) are not considered here.

Table B.1. Data on confirmed CPM companions of nearby F stars.

Name HD	RA (J2000) [degrees]	Dec (J2000) [degrees]	Epoch [year]	π (Sep, PA) [mas] ([arcsec, °])	$\mu_\alpha \cos \delta$ [mas/yr]	μ_δ [mas/yr]	N_epochs	J (2MASS) [mag]	SpT	Ref
1352A	4.458214	+16.331064	1998.737	22.31 ± 0.60	+223.0 ± 0.4	-29.3 ± 0.4		6.29 ± 0.02	F6V	2, 3, 4, S
1352B ^{k,l} (?)	4.453571	+16.327650	1998.737	(20.2, 233)	+225 ± 4 ^c	-41 ± 4 ^c	41011100110	11.66 ± 0.02	≈M4	2, 2, 5, 5
9826A*	24.199358	+41.405582	1998.838	74.12 ± 0.19	-173.6 ± 0.5	-381.8 ± 0.5		3.18 ± 0.21	F9V	2, 3, 4, S
9826D ^{k,l,m,s,g}	24.210084	+41.392387	1998.838	(55.6, 149)	-182 ± 4 ^c	-385 ± 4 ^c	41010000110	9.39 ± 0.02	≈M4.5 ^g	2, 2, 5, 5
18900A	45.898458	+36.442005	1998.792	23.71 ± 0.66	+166.0 ± 0.4	-46.7 ± 0.4		6.55 ± 0.03	F8	2, 3, 4, S
18900C ^{k,l,s}	45.901000 ^a	+36.441689 ^a	1998.792	(7.4, 99) ^a	+156 ± 20 ^{a,d}	-87 ± 20 ^{a,d}	01000100000	≤12.5 ^e	≤M5	2, 2, 5, 5
31975A	73.273518	-72.407852	1998.921	30.82 ± 0.28	-45.3 ± 1.3	+270.5 ± 1.5		5.33 ± 0.02	F9VFe-0.5	2, 3, 8, S
31975B ^{k,l} (?)	73.260386	-72.405548	1998.921	(16.5, 300)	-51 ± 18 ^c	+248 ± 8 ^c	31200000000	11.73 ± 0.06 ^g	≈M5	2, 2, 5, 5
33632A	78.322777	+37.337357	1998.822	38.29 ± 0.55	-146.0 ± 0.4	-137.5 ± 0.4		5.43 ± 0.02	F8V	2, 3, 4, S
33632B ^{k,l,s}	78.326897	+37.346207	1998.822	(34.0, 20)	-145 ± 1 ^{c,h}	-139 ± 1 ^{c,h}	11010011010	10.38 ± 0.03	≈M4	2, 2, 5, 5
49933A	102.7076176	-0.5413573	2010.123	33.69 ± 0.42	+22.0 ± 0.4	-187.0 ± 0.4		4.99 ± 0.02 ^f	F3V	6, 3, 4, S
49933B ^{l,m}	102.7083317	-0.5397087	2010.123	(6.5, 23)	+7 ± 15 ^b	-199 ± 18 ^b	01000012010	8.39 ± 0.04	≈M0/sdM?	6, 6, 5, 5
75289A*	131.918255	-41.736645	1999.159	34.31 ± 0.32	-19.5 ± 0.8	-227.7 ± 0.8		5.35 ± 0.02	F9VFe+0.3	2, 3, 8, S
75289B ^{k,l,m,o}	131.926087	-41.735394	1999.159	(21.5, 78)	-4 ± 13 ^c	-212 ± 15 ^c	31110000100	11.75 ± 0.04	≈M5	2, 2, 5, 5
84999A	147.747331	+59.038689	1999.885	28.06 ± 0.20	-294.7 ± 0.4	-150.7 ± 0.4		3.27 ± 0.23	F2IV	2, 3, 4, S
84999B ^{l,m}	147.741606	+59.040123	1999.885	(11.8, 296)	-293 ± 2	-149 ± 2	01000100010	8.78 ± 0.03	≈M0	2, 2, 5, 5
89125A	154.310830	+23.106316	1998.071	43.85 ± 0.36	-412.9 ± 0.4	-96.2 ± 0.4		5.00 ± 0.26 ^f	F6V	2, 3, 4, S
89125B ^{k,l,m,z}	154.308779	+23.107351	1998.071	(7.7, 299)	-398 ± 15 ^{d,z}	-118 ± 15 ^{d,z}	01000200000	8.36 ± 0.03	≈M1.5 ^c	2, 2, 5, 5
89744A*	155.544047	+41.229637	1998.260	25.36 ± 0.31	-118.8 ± 0.3 ^j	-139.1 ± 0.3 ^j		4.86 ± 0.02	F7V	2, 3, 4, S
89744B ^{k,l,m,s,u}	155.562043	+41.240746	1998.260	(63.0, 51)	-123 ± 5 ^{d,h}	-131 ± 6 ^{d,h}	01000100210	14.90 ± 0.04	≈L0.5 ^u	2, 2, 5, 5
102574A	177.0974417	-10.3135272	2014.258	23.23 ± 0.45	-105.2 ± 0.7	-107.6 ± 0.7		5.17 ± 0.02	F7V	1, 3, 4, S
102574D ^{k,l,m,o,s}	177.0988817	-10.3184158	2014.302	(18.3, 164)	-108 ± 7 ^{c,h}	-109 ± 7 ^{c,h}	11110000111	11.33 ± 0.07 ^g	≈M4	1, 1, 5, 5
102634A	177.2545422	-0.3186442	2013.846	28.50 ± 0.49	-207.1 ± 0.4 ^j	+5.4 ± 0.4 ^j		5.21 ± 0.02 ^c	F6V	1, 3, 4, S
102634B ^{k,l,o,r} (?)	177.2605606	-0.3233306	2013.731	(27.5, 128)	-201 ± 2 ^{c,h,i}	+2 ± 2 ^{c,h,i}	41111302210	9.96 ± 0.02	≈M3	1, 1, 5, 5
116457A	201.308092	-64.485161	2000.321	25.51 ± 0.24	-153.9 ± 0.9	-22.5 ± 0.8		4.94 ± 0.24 ^j	F3IV	2, 3, 8, S
116457B ^s	201.304426	-64.479156	2000.321	(22.4, 345)	-149.2 ± 5.1 ⁱ	-16.3 ± 5.5 ⁱ		10.26 ± 0.04	≈M3	2, 2, 10, 5
124553A	213.588833	-5.947687	1999.123	23.33 ± 0.53	-305.5 ± 0.4	+83.3 ± 0.4		5.32 ± 0.02	F9V	2, 3, 4, S
124553B ^{k,l}	213.585935	-5.952792	1999.123	(21.1, 210)	-304 ± 2 ^c	+84 ± 3 ^c	31010000111	10.53 ± 0.02	≈M3	2, 2, 5, 5
126679A	216.839157	-14.838769	1998.603	22.42 ± 0.93	-172.3 ± 0.8	-59.7 ± 0.8		6.40 ± 0.05	F7V	2, 3, 8, S
126679B ^{l,z}	216.848140	-14.844262	1998.603	(37.0, 122)	-173 ± 6 ^v	-66 ± 4 ^v	31101000101	12.76 ± 0.02	≈M5 ^z	2, 2, 5, 5
129502A	220.765132	-5.658098	1999.132	54.73 ± 0.20	+108.9 ± 0.4 ^j	-316.0 ± 0.4 ^j		3.34 ± 0.28 ^f	F2V	2, 3, 4, S
129502B ^{l,*}	220.754618	-5.652752	1999.132	(42.3, 297)	+104 ± 4 ^{c,d}	-319 ± 4 ^{c,d}	21210100111	10.72 ± 0.04	≈M5	2, 2, 5, 5
132052A	224.295897	-4.346479	1999.115	37.17 ± 0.32	-98.5 ± 0.4	-153.6 ± 0.4		4.13 ± 0.28 ^f	F0V	2, 3, 4, S
132052B ^r	224.290225	-4.343605	1999.115	(22.8, 297)	-92 ± 14 ^{c,h}	-165 ± 8 ^{c,h}	11100000010	12.19 ± 0.11 ^g	≈M6	2, 2, 5, 5
132375A	224.720010	-4.989197	1999.115	29.61 ± 0.47	-360.4 ± 0.4	-105.0 ± 0.4		5.14 ± 0.02 ^f	F8V	2, 3, 4, S
132375B ^{k,l,m}	224.721083	-4.986747	1999.115	(9.6, 24)	-378 ± 21	-95 ± 12	01100000011	9.24 ± 0.05	≈M1	2, 2, 5, 5
142529A	239.261144	-48.162132	1998.447	20.64 ± 0.48	-101.1 ± 1.0 ^j	-101.0 ± 1.0 ^j		5.54 ± 0.03	F1IV	2, 3, 8, S
142529B ^{l,o}	239.255926	-48.155563	1998.447	(34.1, 314)	-100 ± 5 ^{c,i}	-95 ± 9 ^{c,i}	41010000100	9.03 ± 0.02	≈K7	2, 2, 5, 5
147449A	245.518117	+1.029096	2000.400	36.67 ± 0.33	-158.0 ± 0.4	+51.8 ± 0.4		4.29 ± 0.22 ^f	F0V	2, 3, 4, S
147449B ^{l,w} (?)	245.526848	+1.021001	2000.400	(42.9, 133)	-151 ± 3 ^{c,d,h}	+47 ± 3 ^{c,d,h}	41110100110	8.68 ± 0.03	≈M1.5 ^w	2, 2, 5, 5
165670A	271.711628	+8.875950	2000.208	24.74 ± 0.69	+50.5 ± 0.4 ^j	-147.2 ± 0.4 ^j		6.00 ± 0.02	F5V	2, 3, 4, S
165670H ^{l,s,g} (??)	271.711935	+8.873803	2000.208	(7.8, 172)	+86 ± 7 ^g	-119 ± 7 ^g	01000000010	10.27 ± 0.10	≈M3 ^g /WD ^g	2, 2, 1, 5
166285A	272.475023	+3.119825	2000.419	21.31 ± 0.31	+15.9 ± 0.4	-193.1 ± 0.4		4.67 ± 0.23	F6V	2, 3, 4, S
166285B ^{k,l,s}	272.474717	+3.117978	2000.419	(6.7, 189)	+6 ± 20	-221 ± 20	01000000010	8.26 ± 0.13	≈K3	2, 2, 5, 5
176441A	284.927192	+16.252560	2000.208	21.38 ± 0.83	-99.1 ± 0.4	-121.4 ± 0.4		6.12 ± 0.03	F5	2, 3, 4, S
176441B ^{l,r,s}	284.924690	+16.248047	2000.208	(18.4, 208)	-97 ± 2 ^{c,h}	-130 ± 7 ^{c,h}	41001000110	12.10 ± 0.04	≈M4	2, 2, 5, 5
185395AB	294.1105231	+50.2221189	2013.803	54.54 ± 0.15	-7.2 ± 0.4	+264.2 ± 0.4		3.88 ± 0.28 ^f	F3V	1, 3, 4, S
185395E ^{l,o,s,*}	294.0599208	+50.2204692	2013.622	(116.7, 267)	-3 ± 3 ^{c,i}	+261 ± 8 ^{c,i}	41010000110	8.98 ± 0.03	≈M3.5 [*]	1, 1, 5, 5
193307A	305.420994	-49.999325	1999.786	32.24 ± 0.47	-359.5 ± 0.8	-249.5 ± 0.8		5.24 ± 0.02	F9V	2, 3, 8, S
193307B ^{l,o}	305.412983	-49.996429	1999.786	(21.3, 299)	-348 ± 7 ^{b,c,i}	-262 ± 12 ^{b,c,i}	31100000101	9.54 ± 0.03	≈M2.5	2, 2, 5, 5
197373A	310.074542	+60.505283	1999.715	30.39 ± 0.27	+13.4 ± 0.4	+186.5 ± 0.4		5.12 ± 0.04 ^f	F6IV	2, 3, 4, S
197373B ^{k,l}	310.086529	+60.508324	1999.715	(23.9, 63)	+14 ± 2 ^{c,h,i}	+189 ± 2 ^{c,h,i}	31010000110	10.08 ± 0.03	≈M3	2, 2, 5, 5
204485A	322.034397	+32.225300	1998.455	22.36 ± 0.34	+133.7 ± 0.4	+79.5 ± 0.4		5.16 ± 0.05 ^f	F0V	2, 3, 4, S
204485B ^r (?)	322.035177	+32.228657	1998.455	(12.3, 11)	+117 ± 6	+69 ± 6	01000000010	10.81 ± 0.05	≈M3.5	2, 2, 1, 5
208502A	328.748885	+53.935604	2000.455	21.00 ± 0.41	+147.6 ± 0.5	+85.7 ± 0.5		5.99 ± 0.02	F5	2, 3, 4, S
208502B ^{l,r} (?)	328.744662	+53.937687	2000.455	(11.7, 310)	+163 ± 6 ^h	+88 ± 5 ^h	01000011010	9.99 ± 0.04	≈M3	2, 2, 5, 5
209268A	330.896861	-55.976936	1999.855	20.81 ± 0.58	-241.0 ± 1.5	-93.3 ± 1.3		5.85 ± 0.02	F7V	2, 3, 8, S
209268B ^{l,m,o,*} (?)	330.892629	-55.988174	1999.855	(41.3, 192) [*]	-255 ± 5 ^c	-84 ± 6 ^c	41110000101	10.16 ± 0.03	≈M2.5	2, 2, 5, 5
210855A	332.9548478	+56.8398414	2013.650	26.77 ± 0.18	+237.5 ± 0.4	+128.5 ± 0.4		4.68 ± 0.29 ^f	F8V	1, 3, 4, S
210855C ^{l,m,o,s}	332.9762514	+56.8301425	2013.357	(54.7, 130)	+238 ± 1	+130 ± 1	10010013010	14.505 ± 0.002 ^g	DA WD	1, 1, 5, 11
221356A	352.881212	-4.087308	1998.723	38.29 ± 0.54	+178.0 ± 0.9	-191.9 ± 0.9		5.49 ± 0.02	F8V	2, 3, 8, S
221356D ^{l,s,t} (?)	352.878967 ^a	-4.089861 ^a	1998.723	(12.2, 221) ^a	+158 ± 9 ^{a,d}	-202 ± 14 ^{a,d}	01000100001	≈13.9 ^e	≈L0.5 ⁱ	2, 2, 5, 5

Notes. For notes and references see Table A.1.

Appendix C: Rejected CPM companions

Table C.1 lists objects that appeared to be CPM companions according to SIMBAD. We have determined new proper motions that are in disagreement with those of the F star primaries.

Table C.1. Data on rejected CPM pairs including F stars.

Name	RA (J2000) [degrees]	Dec (J2000) [degrees]	Epoch [year]	π (Sep, PA) [mas] ([arcsec, °])	$\mu_\alpha \cos \delta$ [mas/yr]	μ_δ [mas/yr]	N_epochs	<i>J</i> (2MASS) [mag]	SpT	Ref
Hip 10529 ^{<i>lm,s,★</i>}	33.9222039	+67.6770014	2013.577	$4.6 \pm 18.3^\star$	$-7 \pm 6^\star$	$-6 \pm 6^\star$	01000000010	8.78 ± 0.03	F2	1,9,1,S
Hip 10531	33.9324656	+67.6711650	2013.591	(25.3, 146) ^{<i>★</i>}	$+518.1 \pm 0.3$	-304.8 ± 0.3		5.66 ± 0.03	K2V	1,1,4,S
HD 187691A	297.756919	+10.415750	2000.573	52.11 ± 0.29	$+242.3 \pm 0.3$	-136.5 ± 0.2		4.23 ± 0.32^f	F8V	2,3,3,S
HD 187691B ^{<i>l,o,s,★</i>}	297.752457	+10.413567	2000.573	(17.6, 244) ^{<i>★</i>}	$-6 \pm 22^{h,★}$	$-23 \pm 12^{h,★}$	01000100010	10.31 ± 0.04	? ^{<i>★</i>}	2,2,5,5

Notes. For notes and references see Table A.1.

Appendix D: Selected finder charts

Figure D.1 shows the IRSA finder charts of the new nearby ($d = 25.6$ pc) CPM pair HD 22879AB. The faint $\approx M6/sdM?$ companion HD 22879B overlaps with the diffraction spike of its primary, the Gaia benchmark metal-poor star HD 22879A, but it was visually measured in the 2MASS images and the photographic IR image taken from the SSS. The red and blue circles show the change in the positions of the components from 1998 (2MASS) to 2013 (URAT1).

Fig. D.1. Finder charts of 1×1 arcmin² (north is up, east to the left) from photographic plates of the Digitized Sky Surveys (DSS) and from 2MASS of the CPM pair HD 22879AB. Red circles: first-epoch (1998.732) positions (2MASS) of components A (*left*) and B (*right*), blue circles: last-epoch (2012.955) positions (URAT1), green crosses: 2MASS artifacts.

Fig. D.2. *Top*: finder chart of 1×1 arcmin² (north is up, east to the left) from UKIDSS LAS (*K*-band) centred on HD 3861B. *Bottom*: 30×30 arcsec² 2MASS finder charts of the CPM pair HD 3861AB. Red circles: first-epoch (2000.723) positions (2MASS) of components A (*left*) and B (*right*), blue circles: last-epoch (2010.592) positions (UKIDSS LAS), green crosses: 2MASS artifacts.

Fig. D.3. *Top*: finder chart of 1×1 arcmin² (north is up, east to the left) from VHS (*J*-band) centred on HD 2726B. *Bottom*: finder charts of 30×30 arcsec² from photographic plates of the Digitized Sky Surveys (DSS) and from 2MASS of the CPM pair HD 2726AB. Red circles: first-epoch (1992.841) positions (DSS2 IR) of components A (*left*) and B (*right*), blue circles: last-epoch (2011.625) positions (VHS), green crosses: 2MASS artifacts.

As a second example, HD 3861AB, which is our new CPM pair containing the latest-type ($\approx L3.5$) companion that was not detected on photographic plates, is shown in Fig. D.2. Again, the companion appeared close to the diffraction spike of its primary and was visually measured in 2MASS. The small 2MASS finder charts illustrate the proper motion of the components by the red and blue circles, whereas the UKIDSS LAS finder chart is centred on HD 3861B.

Finally, we show the IRSA and VHS finder charts of HD 2726AB in Fig. D.3; the new WD companion is clearly seen in two of the photographic images, although it appears very faint in 2MASS. Interestingly, the deeper near-infrared data from the VHS provided the last-epoch data for this rather blue object, thus helping us to confirm the CPM illustrated by the red and blue circles.