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A search for companions to nearby southern M dwarfs with near-infrared speckle interferometry*

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Abstract. We searched the 9 M-dwarf primaries nearer than 5 pc and south of declination $\delta = -30°$ for companions with separations 1-10 AU and found none. Taken together with the 25 northern primaries studied by Henry and McCarthy (1990) the fraction of binaries and triples within the now complete sample of all M dwarfs within 5 pc is 9/34 = 26 $\pm$ 9%, and the average number of companions per system is 0.32 ± 0.10. This is lower by 2σ than the observed multiplicity fraction of 43 $\pm$ 5%, and companions per system of 0.49 ± 0.05 in the sample of nearby solar-type main sequence stars. It is also much lower than the extrapolated binary fraction among young stars in Taurus. We discuss the implications of this finding.

Key words: binaries: general – stars: low-mass – stars: luminosity function, mass function

1. Introduction

The multiplicity of M dwarfs matters in several respects: the number density and mass density of stars in the solar neighbourhood as well as the luminosity function, mass-luminosity relation and initial mass function at the end of the main sequence depend on it. In addition, M dwarfs with their intrinsically low mass and luminosity are natural targets to search for still less massive and fainter brown dwarf companions. The latter aspect led us to start a survey of nearby M dwarfs for multiplicity in 1985, and we now find that the question of stellar multiplicity itself is a topic of renewed interest. The high percentage of binaries among young stars (Reipurth and Zinnecker 1993, Ghez et al. 1993, Leinert et al. 1993) leaves little doubt that stellar multiplicity is closely related to the process of star formation. In this context, it is important to determine the dependence of stellar multiplicity on both mass and age. Examining the sample of nearby M dwarfs is useful in both regards because we can compare their multiplicity fraction to the well studied sample of higher mass G dwarfs in the solar neighbourhood (Duquennoy and Mayor 1991), and can compare them to young stars of similar masses but different ages found in star formation regions, thereby quantifying the change in multiplicity during the evolution of these stars to the main sequence.

A comprehensive search for M-dwarf companions has been done by Henry and McCarthy (1990) who surveyed all known M dwarfs north of declination $\delta = -30°$ within 5 pc by near-infrared speckle interferometry. The extension of this northern sample to 8 pc has been completed, and so far has primarily been used to discuss the initial mass function (Henry and McCarthy 1992) and mass-luminosity relation (Henry and McCarthy 1993). While near-infrared speckle interferometry is not as sensitive to very low-mass companions as are some other techniques, it has its advantages. It is more direct than astrometric searches because the detected separation is independent of the brightness ratio of the components, and because a secondary is actually imaged. With respect to the otherwise superb radial velocity techniques (see summary by Marcy and Butler 1995) infrared speckle programs have the advantages that they allow characterization of companions because brightness ratios and separations are measured, and that they reach faint objects like VB 10 (V = 17.5 mag) while yielding similar detection limits for all M dwarfs in a sample, and do not suffer the uncertainty of unknown orbital inclination. In addition, the region $0.1''$ to $5''$ ($\approx$ 0.5 AU to 25 AU for stars at 5 pc), where speckle interferometry is sensitive, is where companions to M dwarfs are most often found (Henry and McCarthy 1992). Therefore, it is no surprise that six out of the ten lowest mass stars (with well-

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Tables are also available in electronic form at CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-starsbg.fr/Abstract.html.

determined masses) were studied with this technique (Henry and McCarthy 1993). For these reasons, the speckle programs should be applied to as complete and comprehensive a sample of M dwarfs as feasible in order to improve the mass-luminosity relation for low-mass stars, and to determine accurately their multiplicity fraction.

2. Object list

In this paper we present near-infrared speckle observations for the ten M dwarfs nearer than 5 pc and south of $\delta = -30°$ that were not included in the study of Henry and McCarthy (1990). For ease of distinction we will refer in the following to Henry and McCarthy's sample as "northern" and to our sample as "southern" stars. Nine of the ten southern stars are primaries, while GL 551 (Proxima) is an M-dwarf companion to the α Cen system. The ten stars are listed in the first part of Table 1. The second part summarizes the northern M dwarfs within 5 pc (25 primaries), updated from Henry and McCarthy (1990) on the basis of new parallaxes. For the combined complete sample we then discuss the observed multiplicity and its implications.

3. Observations and data analysis

The speckle observations for the southern stars were performed at various telescopes on various occasions, but mostly at ESO, La Silla. Usually, one-dimensional slit-scanning speckle-interferometry with a scan length of $\approx 10''$ was applied, but a few speckle measurements with 2D infrared cameras and a field-of-view of 3.6″ - 12.8″ were added. The limiting magnitude for target stars is K $\approx$ 9 mag for the 1D measurements and K $\approx$ 10 mag for the 2D camera measurements. Bad weather conditions during the observations in June 1990 made repeated measurements necessary for most of the objects. This additional effort in turn rendered the non-detections more reliable than a single observation would have done. Table 2 contains a detailed overview of techniques, dates, and telescopes used for the measurements.

As a rule, the observations were performed in the near-infrared K band (2.2 μm). In the case of 1D measurements observations were performed both in north-south and in east-west directions. Typically, an observation consisted of $\approx$ 1000 short exposures (resp. scans) of about 100 ms on the object as well as on a nearby pointlike reference star, and of a similar number of background exposures next to them. As usual the application of speckle reduction techniques resulted in the complex visibility of the object (=Fourier transform of the object brightness distribution), where the modulus was determined from power spectrum analysis and the phase both with the Knox-Thompson (Knox and Thompson 1974) and bispectrum (Lohmann et al. 1984) formalisms. For more detailed information on the 1D measurements see Perrier (1986) and Leinert and Haas (1989). For the 2D infrared cameras used see McCarthy et al. (1990) and Hofmann et al. (1993).

The obtained visibilities were checked for the characteristics of a companion – quasi-sinusoidal variations in visibility and a staircase step function in phase (in 2D visibilities, both of these characteristics show as stripes perpendicular to the separation vector of the components). This check turned out negative for all of the ten southern M dwarfs. We then determined an upper limit for the brightness of a possible undetected companion with a procedure used in Henry's (1991) thesis and slightly modified here.

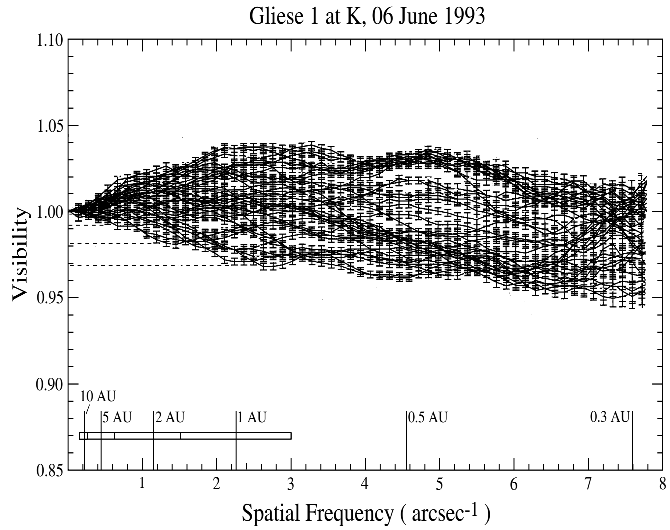

Fig. 1. Visibility plot used to determine the upper brightness limit for a possible companion. The plot consists of 36 projections including error bars of the measured 2D visibility for Gliese 1, which were obtained in steps of 5° of position angle. The small scatter between the individual projections shows that this has been an excellent measurement under good conditions. For projected separations of 1 AU, 2 AU, 5 AU and 10 AU it is indicated how limiting visibility values were read off the lower envelope of the projection curves. The bars indicate the range of separations searched for determining the companion magnitude limits given in Table 2. Since this is a nearby, comparatively bright star, it would also be possible to derive limits for separations of 0.5 AU and 0.3 AU, as indicated in the figure. See text for further details.

The principle is to determine how far the data deviate from the nominal result for a point source (visibility = 1.0, phase = 0.0) and then to determine the upper limit of the brightness for a companion at that value which would just result in this amount of change in visibility or phase. The procedure is best described for 2D data. Fig. 1 shows as an example the visibility data for Gliese 1. Thirty-six 1D visibility curves (and their errors) are plotted in the figure. An individual curve is obtained by projection after rotating for position angles varying from 0° to 180° in steps of 5°. We then consider the lower envelope of this family of curves, determined both by the size of the error bars and the systematic deviation of the projected 1D visibility curves from the nominal value 1.0 (This systematic deviation usually is due to imperfect compensation for seeing variations). We then use this lower envelope to derive an upper limit on the brightness of a possible companion for all possible separations. For example, Gliese 1 has a parallax of π_{trig} = 0.2194″. A companion at a projected separation of 1 AU then would produce the first minimum in

Table 1. Basic data for all M dwarfs within five parsecs.

Name	RA (2000.0)	DEC (2000.0)	V	J	H	K	π^c	M_K
southern stars ($\delta \leq$ -30°)								
Gliese 1	00 05 24.4	−37 21 26	8.55	5.25	4.74	4.52	0.2194	6.23
GJ 1061[a]	03 35 60.0	−44 30 46	13.01	7.50	6.97	6.63	0.2704	8.79
Gliese 191	05 11 40.6	−45 01 08	8.84	5.75	5.26	5.05	0.2567	7.10
LHS 288[a]	10 44 31.8	−61 11 38	13.87	8.45	7.99	7.68	0.2225	8.42
Gliese 551[b]	14 29 42.9	−62 40 47	11.09	5.28	4.70	4.36	0.7698	8.79
Gliese 674	17 28 40.0	−46 53 43	9.38	5.70	5.14	4.90	0.2168	6.58
Gliese 682	17 37 03.7	−44 19 09	10.95	6.57	5.96	5.68	0.2107	7.30
Gliese 825	21 17 15.3	−38 52 03	6.67	3.88	3.25	3.08	0.2588	5.14
Gliese 832	21 33 33.9	−49 00 32	8.66	5.25	4.70	4.48	0.2139	6.13
Gliese 887	23 05 52.0	−35 51 12	7.34	4.16	3.60	3.38	0.2786	5.60
northern stars ($\delta >$ -30°)								
GJ 1002	00 06 43.8	−07 32 22	13.76	8.31	7.76	7.43	0.2130	9.07
Gliese 15 A	00 18 23.3	+44 01 24	8.08	4.82	4.25	4.03	0.2820	6.28
Gliese 15 B[b]	00 18 23.3	+44 01 24	11.07	6.77	6.23	5.97	0.2820	8.22
Gliese 54.1	01 12 30.6	−16 59 57	12.05	7.26	6.71	6.42	0.2688	8.57
Gliese 65 AB	01 39 01.3	−17 57 01	12.00	6.24	5.67	5.33	0.3737	8.19
Gliese 83.1	02 00 13.2	+13 03 08	12.29	7.51	6.96	6.67	0.2248	8.43
Gliese 166C[b]	04 15 22.3	−07 39 32	11.19	6.73	6.20	5.96	0.2029	7.50
Gliese 234 AB	06 29 23.4	−02 48 51	11.08	6.38	5.78	5.49	0.2442	7.43
Gliese 273	07 27 24.5	+05 13 33	9.86	5.67	5.13	4.88	0.2654	7.00
GJ 1111	08 29 49.5	+26 46 37	14.79	8.20	7.62	7.26	0.2758	9.46
Gliese 388	10 19 36.4	+19 52 10	9.32	5.46	4.82	4.61	0.2046	6.18
LHS 292	10 48 12.6	−11 20 14	15.60	8.90	8.32	7.96	0.2203	9.68
Gliese 406	10 56 29.2	+07 00 53	13.45	7.06	6.44	6.08	0.4191	9.19
Gliese 411	11 03 20.2	+35 58 11	7.47	4.10	3.56	3.36	0.3949	6.34
Gliese 412 A	11 05 28.5	+43 31 37	8.76	5.55	4.97	4.76	0.2016	6.28
Gliese 412 B[b]	11 05 30.4	+43 31 18	14.40	8.66	8.14	7.85	0.2016	9.37
Gliese 447	11 47 44.4	+00 48 17	11.12	6.49	5.91	5.63	0.2982	8.00
Gliese 473 AB	12 33 17.2	+09 01 15	12.46	6.96	6.39	6.06	0.2279	7.85
Gliese 628	16 30 18.1	−12 39 45	10.08	5.91	5.37	5.10	0.2440	7.04
Gliese 687	17 36 26.0	+68 20 22	9.22	5.31	4.74	4.52	0.2191	6.22
Gliese 699	17 57 48.5	+04 41 36	9.55	5.27	4.77	4.51	0.5456	8.19
Gliese 725 A	18 42 46.4	+59 37 52	8.90	5.20	4.67	4.44	0.2852	6.72
Gliese 725 B[b]	18 42 47.2	+59 37 37	9.68	5.72	5.20	4.97	0.2852	7.25
Gliese 729	18 49 49.4	−23 50 11	10.47	6.21	5.67	5.39	0.3452	8.08
GJ 1245 AC	19 53 54.2	+44 24 55	13.41	7.78	7.26	6.89	0.2202	8.60
GJ 1245 B[b]	19 53 55.2	+44 24 56	14.00	8.33	7.83	7.44	0.2202	9.15
Gliese 860 AB	22 27 59.6	+57 41 48	9.59	5.56	4.97	4.71	0.2515	6.71
Gliese 866 ABC	22 38 33.4	−15 18 07	12.33	6.50	5.91	5.57	0.2895	7.88
Gliese 876	22 53 16.7	−14 15 49	10.18	5.92	5.32	5.06	0.2119	6.69
Gliese 905	23 41 54.7	+44 10 30	12.29	6.90	6.27	5.95	0.3160	8.49

[a] V photometry from Jahreiß (1997), JHK from this paper, all other photometry from Leggett (1992); errors: $\leq$ 0.03 magnitudes in VJHK
[b] not a primary
[c] parallaxes are from the Third Catalogue of Nearby Stars, Jahreiß (1997)

the visibility curve at a spatial frequency of $1/(2\pi_{trig})$ = 2.28 arcsec^{-1}. The reading at this point is used to set an upper limit for the brightness of a possible companion for a separation of 1 AU. Similar readings are done for all other separations between 0.75 AU and 15 AU, of which those for 2 AU, 5AU and 10AU also are indicated in the figure.

For the phases, the procedure is similar. However, the phase of a binary may go either positive or negative, depending on the relative orientation of the two components. To set a detection limit using the phases, we plot the phase curves (including error bars) and their mirror curves reflected around the zero line. We then determine the lower envelope of the combined set of curves. The spatial frequency points, for which the value of the lower envelope has to be read, are different than those used for the visibility limits. The phase of a binary with separation d$''$ is a staircase step function, with the middle of the steps located at

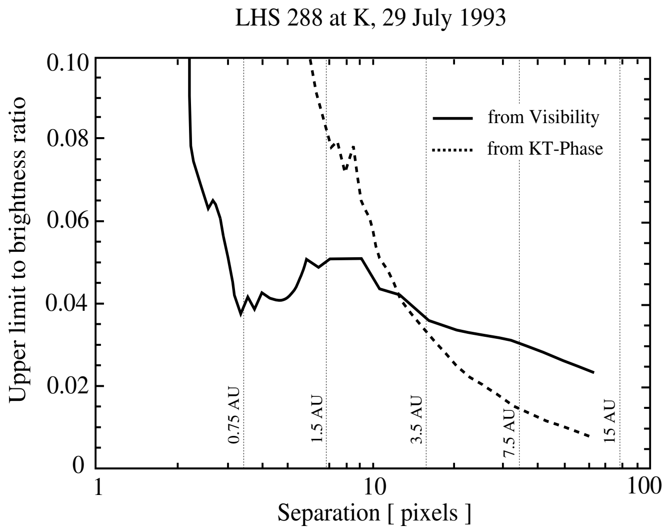

Fig. 2. Upper brightness limit of a possible companion as function of projected separation as derived from the 2D speckle measurements of LHS 288 from July 29, 1993. The solid line refers to the limits derived from the visibility measurement, the dotted line refers to the results obtained from the phase. The boundaries for the ranges attributed to the separations of 1 AU, 2AU, 5AU and 10 AU are indicated. The comparatively steep increase of the curves for small separations reflects the fact that this data set was obtained under only mediocre conditions. For details see text.

1/d, 2/d, 3/d ... (arcsec^{-1}). The limits are set at these spatial frequency points. For a companion 5 AU from Gliese 1 (d = 1.10″), for example, the five first middle points would occur at 0.91, 1.82, 2.74, 3.65 and 4.56 arcsec^{-1}.

Quantitatively, the limits at separations of 1, 2, 5 and 10 AU for the brightest companion that would not have been detected are determined from the lower envelopes as follows. The minimum for the visibility curve for a binary with brightness ratio X = I_B/I_A occurs at a visibility value of V_{min} = (1.0 - X)/(1.0 + X). If the lower envelope at the spatial frequency point to be read has the value $V_{env} < 1.0$, then the limit for the brightness ratio X of a possible companion is determined by the condition V_{min} = V_{env}, or X = I_B/I_A = (1-V_{env})/(1+V_{env}). Similarly, the step size in phase for a binary with brightness ratio X is $\Delta = 2\pi$ (X/(1+X)). The absolute value of the phase at the spatial frequency corresponding to the nth step then is $\Delta_n = 2\pi$n (X/1+X) rad. If the lower envelope of the phase curve at the nth step has the value $-\Delta_{env,n}$, the upper limit on the companion brightness is determined from the condition $\Delta_n = \Delta_{env,n}$, which yields $X_n = I_B/I_A = \Delta_{env,n}/(2\pi n - \Delta_{env,n})$. For wider binary separations, several phase steps can be used ($n > 1$). In that case we adopt as the limit for the brightness ratio of a possible companion: X = $\mathrm{Min}_{(i=1,n)}\, X_n$.

An example for the resulting curves of brightness limit as a function of separation is shown in Fig. 2. The maximum values of these curves in the intervals 0.75 AU - 1.5 AU, 1.5 AU - 3.5 AU, 3.5 AU - 7.5 AU and 7.5 AU - 15 AU are given in Table 2 as values for 1, 2, 5 and 10 AU. If both visibility and phase contribute values for a full interval, the fainter of the two limits is adopted. Sometimes the measurements do not fully cover the lowest interval from 0.75 AU to 1.5 AU but only reach to projected separations of 1 AU. In this case the value for the upper brightness limit at 1 AU given in Table 2 is preceded by a colon.

A special case occurs when errors in seeing compensation lead to measured visibilities increasing into the forbidden region beyond 1.0. Here we take the size of the error bars as measure of the deviation from the nominal value and assure by visual inspection of the visibility curves that this treatment does not lead to unduly faint limits. The phases do not have this problem of seeing compensation.

One-dimensional data are treated in the same way, except that only measurements at a few, usually orthogonal position angles are available to determine the brightness limits.

4. The complete five parsec sample

The sample we want to discuss is the sample of all M dwarfs within 5 pc of the Sun. The present measurements were made to complement the northern survey of Henry and McCarthy (1990). This sample is volume-limited and complete in the sense that almost all M-dwarf systems within this volume already have been found. While discoveries adding new members to the sample cannot be excluded, the existence of such new systems cannot be conclusively inferred either. The sample is small, comprising only 34 systems with M-dwarf primaries, but otherwise is as complete as one can expect to obtain, and well suited for statistical purposes.

We are aware of the complication that a few of the stars just inside or outside the limit of 5 pc may be incorrectly included in the sample, or excluded from the sample, due to parallax errors. We decided to use the parallaxes as given in the Third Catalogue of Nearby Stars (Jahreiß 1997) and to set the limit at 5 pc based on those parallaxes.

Here we combine the data for southern stars with that of Henry and McCarthy (1990) and Henry (1991). Table 1 lists both the ten southern stars and the updated northern 5 pc sample, including the new parallaxes from Jahreiß (1997), and fully defines the membership of the sample. Only stars with trigonometric parallaxes $\geq 0.2000''$ are now included, so the stars Gliese 445, 526 and 873, and GJ 1116 AB included in Henry and McCarthy (1990) are not in the present sample. The new parallax of the double Gliese 412 AB now places it within 5 pc.

5. Results and discussion

5.1. Results for the combined sample

As already mentioned, no additional M-dwarf companions were found during the present extension of the survey of nearby M-dwarf primaries. In addition, no new companions have been found to the six secondaries also searched, Gliese 15B, 166C, 412B, 551, 725B and GJ 1245B. Table 2 gives the limits in M_K for possible companions of the southern stars studied here in the

Table 2. Companion magnitude limits for southern M dwarfs within Five Parsecs.

Name	Technique	UT Date	Telescope	λ	1 AU	2 AU	5 AU	10 AU
Gliese 1	1D NS	13 Nov 85	ESO 2.2m	K	:9.6	9.9	10.2	10.7
	1D EW	01 Nov 85	ESO 3.6m	L′	:9.9	10.2	10.5	11.4
	1D NS	15 May 92	ESO 2.2m	K	9.2	10.1	10.7	11.9
	1D EW	15 May 92	ESO 2.2m	K	:10.0	10.5	11.0	12.5
	2D SPK	06 Jun 93	CTIO 4.0m	K	10.5	11.0	11.8	12.5
GJ 1061	2D SPK	30 Jul 93	NTT 3.5m	K	11.9	12.3	13.2	14.2
Gliese 191	1D NS	06 Nov 85	ESO 2.2m	K	10.3	10.3	10.9	11.6
	1D NS	15 May 92	ESO 3.6m	K	:10.0	10.1	11.3	13.0
	1D NS	16 May 92	ESO 3.6m	K	:10.2	10.9	12.2	13.4
	1D EW	15 May 92	ESO 3.6m	K	:10.1	10.1	10.8	12.4
LHS 288	1D NS	02 Jun 90	ESO 3.6m	K		12.1	13.4	14.1
	1D EW	02 Jun 90	ESO 3.6m	K		:11.7	12.2	13.7
	2D SPK	29 Jul 93	NTT 3.5m	K	11.6	11.6	12.1	13.1
Gliese 551	1D NS	15 May 92	ESO 3.6m	K	12.9	13.7	14.8	15.3
	1D EW	15 May 92	ESO 3.6m	K	12.9	13.8	14.9	15.1
Gliese 674	1D NS	03 Jun 90	ESO 3.6m	K		9.5	10.0	11.6
	1D EW	03 Jun 90	ESO 3.6m	K		:9.6	10.0	11.4
	1D NS	16 May 92	ESO 3.6m	K	9.6	9.9	11.1	13.0
	1D EW	16 May 92	ESO 3.6m	K	10.2	10.6	10.7	12.3
	2D SPK	29 Jul 93	NTT 3.5m	K	10.4	10.9	11.4	11.8
Gliese 682	1D NS	01 Jun 90	ESO 3.6m	K		10.2	11.0	11.7
	1D EW	01 Jun 90	ESO 3.6m	K	:10.4	10.8	11.7	13.2
	1D NS	16 May 92	ESO 3.6m	K	:10.4	11.0	11.6	12.2
	1D EW	16 May 92	ESO 3.6m	K	:10.5	11.7	12.2	13.0
Gliese 825	1D NS	04 Jun 90	ESO 3.6m	K	8.5	8.5	8.2	9.3
	1D EW	04 Jun 90	ESO 3.6m	K	7.7	7.4	8.4	9.3
	1D NS	15 May 92	ESO 3.6m	K	8.8	9.0	10.1	11.0
	1D EW	14 May 92	ESO 3.6m	K	8.5	8.1	9.0	10.7
	2D SPK	09 Jul 95	NTT 3.5m	K	9.0	9.3	10.1	10.5
Gliese 832	1D NS	18 Nov 85	ESO 2.2m	K	:9.2	9.6	10.3	11.4
	1D EW	18 Nov 85	ESO 2.2m	L′	:9.2	10.1	10.5	11.7
	1D NS	16 May 92	ESO 3.6m	K	:8.8	9.4	10.6	11.6
	1D EW	16 May 92	ESO 3.6m	K	9.3	9.4	10.1	11.4
	2D SPK	06 Jun 93	CTIO 4.0m	K	11.1	11.2	12.2	12.4
Gliese 887	1D NS	04 Jun 90	ESO 3.6m	K	8.8	9.3	10.0	11.1
	1D EW	04 Jun 90	ESO 3.6m	K	8.2	8.9	10.0	11.2
	1D NS	15 May 92	ESO 3.6m	K	9.2	9.6	10.7	12.2
	1D EW	15 May 92	ESO 3.6m	K	9.3	9.4	10.4	11.1
	2D SPK	06 Jul 93	NTT 3.5m	K	9.6	9.7	10.9	11.8

The brightness limits are given in absolute magnitudes

four projected separation ranges, 1, 2, 5 and 10 AU. The photometric information on these sources is summarized in Table 1. In most cases stars at the end of the main sequence, corresponding to $M_K \approx 10.0$, can be excluded between 1 and 10 AU. For the two brightest sources we have probed to the end of the main sequence only for larger separations. In addition, Table 3 updates the limits for the brightnesses of possible companions for the northern M dwarfs, using some new 2D speckle data and updated parallaxes. These data supersede those in Henry and McCarthy (1990).

The combined sample of the 34 M-dwarf primaries contains seven binaries and two triple systems, summarised in Table 4. We note that for the purposes of an M dwarf survey of multiplicity, only M-dwarf primaries are counted. So, Gliese 166C and 551 (Proxima) are not included in the 34 M-dwarf systems since they are members of the triple systems 40 Eri and α Cen, respectively, which contain higher mass primaries. In addition, while the M-dwarf secondaries Gliese 15B, 412B, 725B, and GJ 1245B were searched for companions, they are not included in the multiplicity calculation because they are not primaries.

Table 3. Updated summary of magnitude limits for northern M dwarfs within five parsecs[a,b].

Name	Technique	λ	1 AU	2 AU	5 AU	10 AU
GJ 1002	1D SPK	K		11.5	11.5	11.5
Gliese 15 A	1D SPK	K	11.8	11.8	11.8	11.8
Gliese 15 B	1D SPK	K	11.7	12.5	12.9	13.2
Gliese 54.1	1D SPK	K	10.8	13.3	13.7	13.7
Gliese 65 AB			companion detected[c]			
Gliese 83.1	1D SPK	K	11.1	14.4	14.7	14.7
Gliese 166 C	1D SPK	K		12.3	12.8	12.8
Gliese 234 AB			companion detected[c]			
Gliese 273	2D SPK	K	12.3	13.3	13.3	13.3
GJ 1111	1D SPK	K	11.3	11.3	11.3	14.4
Gliese 388	1D SPK	K	11.0	11.0	12.4	12.4
LHS 292	1D SPK	K		11.1	12.3	12.6
Gliese 406	1D SPK	K	12.4	12.4	13.4	
Gliese 411	1D SPK	K	10.8	10.8	11.5	12.6
Gliese 412 A	2D SPK	K	11.4	12.3	12.6	12.6
Gliese 412 B	2D SPK	K		13.4	13.4	13.9
Gliese 447	1D SPK	K	11.3	12.0	12.6	13.3
Gliese 473 AB			companion detected[c]			
Gliese 628	1D SPK	K	10.0	10.0	10.0	10.7
Gliese 687	1D SPK	K	10.1	10.5	11.0	11.8
Gliese 699	1D SPK	K	12.4	12.6	13.6	
Gliese 725 A	1D SPK	K	10.7	11.1	12.0	12.2
Gliese 725 B	1D SPK	K	10.7	11.2	12.6	12.6
Gliese 729	1D SPK	K	11.7	11.7	12.3	13.4
GJ 1245 AC			companion detected[c]			
GJ 1245 B	1D SPK	K	12.4	12.9	13.2	13.2
Gliese 860 AB			companion detected[c]			
Gliese 866 ABC			companion detected[c]			
Gliese 876	1D SPK	K		10.8	11.2	11.3
Gliese 905	1D SPK	K	12.1	13.4	13.4	13.7

[a] Membership updates include new parallaxes from Jahreiß (1997).
[b] Detection limits include data from Henry (1991) and effects of new parallaxes. These limits supersede those given in Henry & McCarthy (1990).
[c] See Henry & McCarthy (1990) for details.

5.2. Fraction of binaries

The so-called degree of multiplicity = (number of systems having at least one companion)/(total number of systems) is 9/34 = 26 $\pm$ 9%. The average number of companions per system is 0.32 $\pm$ 0.10. With the small number of binary or multiple systems involved, we hesitate to consider a breakdown by brightness, brightness ratio or orbital parameters, except for noting that the average subclass for both the entire primary sample and the multiples is $\approx$ M4. This value will be compared to young stars observed in the star formation regions discussed below.

It should be noted that, except for possible incompleteness corrections, the fraction of binaries given here is thought of as being complete, although our own measurements only cover the range of $0.1''$ - $5''$. E.g., there is no companion in our sample with separation d $> 100''$, let alone $1000''$. However, it is assumed that such a companion, if it were present within our sample, would have been found and would be known to us (see Proxima Cen, which is at $> 2°$ from its primary). The largest separation occurring in our sample occurs in Gliese 15 with d = $44''$.

Table 4. Multiple systems in the M dwarf five parsec sample.

Name	Type	Refs
Gliese 15	binary	GJ,HM
Gliese 65	binary	GJ,HM
Gliese 234	binary	GJ,HM
Gliese 412[a]	binary	GJ
Gliese 473	binary	GJ,HM
Gliese 725	binary	GJ,HM
GJ 1245	triple	GJ,HM
Gliese 860	binary	GJ,HM
Gliese 866[b]	triple	HM,LH

[a] new parallax places system within 5 pc; not included in Henry and McCarthy (1990)
[b] third component spectroscopically detected, private communications by A.Duquennoy and D.Latham
references: GJ = Jahreiß (1997), HM = Henry and McCarthy (1990), LH = Leinert et al. (1990)

5.3. Comparison to solar-type stars

Here we compare these results on multiplicity with those for nearby solar-type main sequence stars in order to check for a mass dependence of multiplicity. Solar-type stars in the Duquennoy and Mayor (1991) sample give a measured degree of multiplicity of 43 $\pm$ 5%, which after correction for unobservable orbits increases to 53 $\pm$ 6%. This is higher than for the 5 pc sample of M dwarfs by 2σ, resp. 3σ. The average number of companions per system found for solar-type stars by Duquennoy and Mayor (1991) was 0.49 $\pm$ 0.05 (measured) resp. 0.60 $\pm$ 0.05 (corrected), again different by 2σ to 3σ. A decrease of multiplicity with mass on the lower part of the main sequence, indicated as a 1σ effect already in the earlier study by Fischer and Marcy (1992), thus gets additional support by our measurements.

However, there is a caveat to this. Fischer and Marcy (1992) found a best estimate of M dwarf multiplicity which was higher by 10% in degree of multiplicity and higher by 0.19 in companions per system than found by Henry and McCarthy (1990) for their sample of nearby M dwarfs. The difference resulted in part from the addition of short-period spectroscopic binaries, which were not found in Henry and McCarthy's 5 pc sample with the same frequency, but mainly from the correction for detection probability applied by Fischer and Marcy, where the detection probability as given in their Table 2 averages to 0.83. One would have to add just one spectroscopic companion to Henry and McCarthy's (1990) sample to make the two studies observationally even for short period companions. Such a companion has indeed been found in the meantime, to Gliese 866 (see Table 4). Close binaries appear not to present a problem here. If we nevertheless assume that the same numerical corrections which lead from Henry and McCarthy's to Fischer and Marcy's result should also be applied to the complete 5 pc sample presented here, we would end up with a predicted degree of multiplicity of 35$\pm$10 % and a predicted number of 0.46$\pm$12 companions per system for the M dwarfs within 5 pc. The difference between M dwarfs and solar-type stars then would be reduced to 1.2 σ for these two measures. This makes the observational evidence for a mass dependence of multiplicity weaker. However, this upward correction of multiplicity is not necessarily correct, since it is not clear a priori whether the nearby sample or the Fisher and Marcy sample is the "unusual" one. We conclude that our data indicate a decrease of multiplicity with mass for the main sequence, but we caution that one should use a larger sample before accepting this statement as an established fact.

5.4. Comparison to young stars in Taurus

For M dwarf masses, 0.60 $M_\odot \geq M \geq 0.08\ M_\odot$, the pre-main sequence evolutionary tracks of D'Antona and Mazzitelli (1994) run almost prependicularly through the Hertzsprung-Russell diagram. Thus, stars that arrive on the main sequence as M dwarfs are observed as M stars in star-forming regions. Here we compare the nearby M dwarfs to young stars in the Taurus star formation region using the most complete surveys of young stars in Taurus (Leinert et al. 1993 for the mainly Hα selected T Tauri stars from the Herbig-Bell catalogue, Köhler et al. (1997) for the X-ray selected stars from the ROSAT survey). The subsample chosen includes only those stars classified as of spectral type M0 and later. The average spectral type of the stars in this subsample is M2, a little earlier than found for the nearby M dwarfs, probably because at the distance of the Taurus clouds we are missing the faintest young stars. The multiplicity in this subsample is indistinguishable from that found for the full sample of young stars in Taurus. We find an observed degree of multiplicity of 49 $\pm$ 8% and an average number of companions per system of 0.54 $\pm$ 0.08. This is higher by a factor of 1.9 $\pm$ 0.5 (1.8 σ) than the observed multiplicity for the nearby M dwarf sample.

The interpretation of these observed numbers depends on various, partly contradictory and not very definite arguments. As mentioned above, the local M dwarf sample may not be fully representative, and the true average M dwarf multiplicity after incompleteness corrections could be higher by about a factor of 1.3. On the other hand, the results of the Taurus samples certainly have to be corrected upwards: for the fraction of stars not yet observed with the highest resolution techniques (lunar occultation, radial velocity studies), for the ranges in separation not accessible to the presently used techniques at the distance of the Taurus clouds, and finally again for incomplete detection probability. The total correction is probably larger than the one proposed for the M dwarf multiplicity. In addition, the separation ranges sampled in the nearby and Taurus samples is rather different ($\approx$1-100 AU in the former, mostly 20 AU -1800 AU in the latter), and correcting the two multiplicity fractions in order to make a direct comparison is not straightforward. To complicate matters further, the sample of young stars in Taurus may not be representative for average star formation. Prosser et al. (1994) found the multiplicity of Trapezium stars to be the same as stars on the main sequence, and Brandner et al. (1996) found a similar result in a CCD imaging survey of southern T Tauri stars. But these surveys, conducted at visible and far red wavelengths, may have missed a number of companions, either because they are close or too faint compared to the primary or because they are readily detectable only at near-infrared wavelengths. It is not yet possible, given the relatively small sample sizes, to estimate with confidence the combined effects of the different observational techniques and the different regions searched in the various samples. However, we expect that at least in the case of the Taurus stars, the multiplicity fraction is larger than for the 5 pc M dwarfs by a factor of two or more.

6. Conclusion

The completion of the sample of M dwarfs within 5 pc, although a small sample of only 34 systems, has given additional support to two variously questioned conclusions:

1. The multiplicity of main sequence M dwarfs is lower than that of their solar-type counterparts.

2. The multiplicity of main sequence M dwarfs is lower than that of young M stars in Taurus.

An obvious way to increase the statistical weight of these conclusions is to increase the local M dwarf sample to a similar size as the samples with which it is to be compared by extending it to larger distances.

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