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Search for nearby stars among proper motion stars selected by optical-to-infrared photometry

III. Spectroscopic distances of 322 NLTT stars⋆,⋆⋆

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ABSTRACT

Distance estimates based on low-resolution spectroscopy and Two Micron All Sky Survey (2MASS) J magnitudes are presented for a large sample of 322 nearby candidates from Luyten's NLTT catalogue. Mainly relatively bright (typically $7 < K_s < 11$) and red high proper motion stars have been selected according to their 2MASS magnitudes and optical-to-infrared colours ($+1 < R - K_s < +7$). Some LHS stars previously lacking spectroscopy have also been included. We have classified the majority of the objects as early-M dwarfs (M 2−M 5). More than 70% of our targets turned out to lie within the 25 pc horizon of the catalogue of nearby stars, with 50 objects placed within 15 pc and 8 objects being closer than 10 pc. Three objects in the 10 pc sample have no previously published spectral type: LP 876-10 (M 4), LP 870-65 (M 4.5), and LP 869-26 (M 5). A large fraction of the objects in our sample (57%) have independent distance estimates, mainly by the recent efforts of Reid and collaborators. Our distance determinations are generally in good agreement with theirs. 11 rather distant ($d > 100$ pc) objects have also been identified, including a probable halo, but relatively hot ($T_{\rm eff} \sim 13\,000$ K) white dwarf (LHS 1200) and 10 red dwarfs with extremely large tangential velocities ($250 < v_t < 1150$ km s^{-1}). Altogether, there are 11 red dwarfs (including one within 70 pc) with tangential velocities larger than about 250 km s^{-1}. All these objects are suspected to be in fact subdwarfs, if so, their distances would be only about half of our original estimates. The three most extreme objects in that respect are the K and early M dwarfs LP 323-168, LHS 5343 and LP 552-21 with corrected distances between 180 pc and 400 pc and resulting tangential velocities still larger than about 400 km s^{-1}.

Key words. techniques: spectroscopic – surveys – astrometry – stars: distances – stars: late-type – Galaxy: solar neighbourhood

1. Introduction

Whereas all Solar-type stars in the immediate neigbourhood of the Sun ($d < 25$ pc) are well known and accurately mapped after the successful Hipparcos mission (ESA 1997), our knowledge on the nearest lower-mass dwarf stars (and probably on white dwarf stars, too) is by far not complete. Henry et al. (2002) estimated the number of missing stellar systems within 25 pc as high as 63%. Within 10 pc the number of missing systems is still likely about 25% (Reid et al. 2003a) or even more than 30% (Henry et al. 2002).

Getting the nearby stellar sample completed is motivated by various astronomical research areas. It has been realised for a long time that the immediate Solar neighbourhood is the only region of a galaxy where there is a real chance for a complete registration of its stellar content. A complete volume-limited stellar sample provides the groundwork for the knowledge of the local stellar luminosity function, the mass function of field stars, and the Galactic star formation history (Reid et al. 2002b; Gizis et al. 2002; Cruz et al. 2003). Moreover, the nearest representatives of a given class of stars can be considered as benchmark sources allowing detailed follow-up studies. In addition,

⋆ The full version of Table 1 including all 322 objects and a corresponding file with individual notes on the table entries are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/442/211
⋆⋆ Figures 13 and 14 are only available in electronic form at http://www.edpsciences.org
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a new interest in the local stellar population arises from the field of extra-solar planet research. Planet search programs based on Doppler spectroscopy first concentrated on the brighter F, G and K dwarfs. Late-type dwarfs constitute only a small fraction in previous target samples (e.g. Cochran et al. 2002; Endl et al. 2003), but there is an increasing interest in M dwarfs (e.g. Butler et al. 2004). Recently, it has been demonstrated that Neptune-mass planets can be found around M dwarfs (Marcy et al. 2001; Butler et al. 2004). M dwarfs are by far the most numerous Solar neighbours, and the overwhelming majority of the missing nearby stars is also expected to be of spectral types M. Planets around nearby low-mass dwarfs are good targets for accurate astrometric mass determinations (Benedict et al. 2002), and photometric transit searches for planets in habitable zones are exceptionally sensitive for M dwarfs (Gould et al. 2003b). Finally, nearby, intrinsically faint stars will be prime targets for the imaging of extrasolar planets by future space-based missions. Direct imaging is a relatively "target starved" field. Finding more nearby neighbours is actually very important in this context.

Most of the stars within the 25 pc horizon of the Catalogue of Nearby Stars, 3rd edition (CNS3, Gliese & Jahreiß 1991), were originally detected as nearby candidates by their large proper motions. The Luyten Half Second (LHS) catalogue includes about 4500 stars with proper motions exceeding 0.5 arcsec/yr (Luyten 1979). The New Luyten Two Tenths (NLTT) catalogue of Luyten (1979–80) contains about 60 000 stars with proper motions larger than 0.18 arcsec/yr. Due to the large numbers of NLTT stars, only small sub-samples of the most remarkable objects with respect to different selection criteria (magnitudes, proper motions, colours) have been further investigated. Although the LHS stars have gotten more attention, there are still some LHS stars lacking spectroscopic classification. Unfortunately, the original NLTT colours are very crude estimates, and the positions were only given with very low accuracy, which hampered the cross-identification with other catalogues providing better photometry.

Special efforts were therefore needed in order to re-identify NLTT stars and to select nearby candidates based on better colour measurements. In two preceeding papers of this series, presenting the discovery of three very nearby ($d < 10$ pc) objects (Scholz et al. 2001, hereafter Paper I; and McCaughrean et al. 2002, hereafter Paper II), the combination of the NLTT with other optical sky surveys and especially with the new infrared data from the Two Micron All Sky Survey (2MASS, Cutri et al. 2003) was demonstrated to be an effective tool for finding previously unknown nearby red dwarfs.

In the present paper we describe the results of spectroscopic follow-up observations of a larger sample of NLTT stars (Fig. 1), preselected as nearby candidates on the basis of their optical-to-infrared colours. Some 30 of the southern nearby star candidates were detected in a new high proper motion survey based on APM measurements (Scholz et al. 2000) and on the systematic search (described by Lodieu et al. 2005) in the SuperCOSMOS Sky Surveys (SSS, Hambly et al. 2001) and in the 2MASS but later identified with known NLTT stars. Spectroscopic distances of non-NLTT stars, including high proper motion stars from other catalogues and from the new high proper motion survey in the southern sky, will be subject of the forthcoming paper in the series (Paper IV, Scholz et al. in preparation).

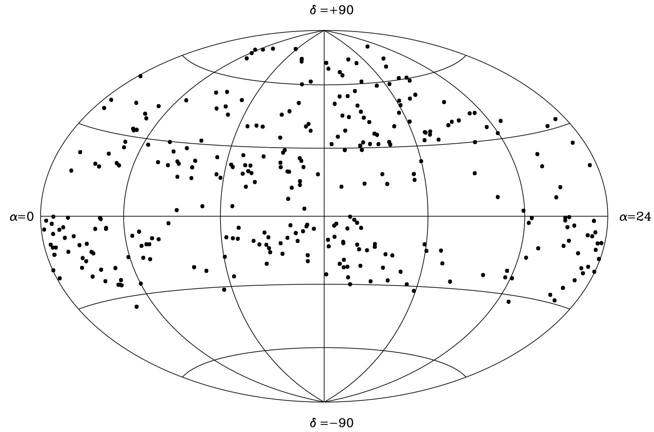

Fig. 1. Distribution in equatorial coordinates of the 322 NLTT stars with spectroscopic distance estimates obtained in this study.

This paper is organised as follows: Sect. 2 describes the selection of nearby NLTT candidates, their cross-identification with 2MASS and preliminary distance estimates based on their optical-to-infrared colours. Section 3 presents optical classification spectroscopy mainly obtained with the 2.2 m telescope at Calar Alto, including a comparison with previously available spectroscopy of objects in our sample. Section 4 shows the main results of the study, the spectroscopic distance estimates and their statistics. In Sect. 5 we consider interesting individual objects, and in Sect. 6 we draw some conclusions.

2. Selection of nearby NLTT candidates

2.1. Cross-identification of NLTT and 2MASS

When we started to combine the NLTT catalogue with the 2MASS data base in early 2001, the revised NLTT catalogue with improved coordinates (Gould & Salim 2003a; Salim & Gould 2003) was not yet available. The 2MASS was also not yet finished at that time, and it was the 2MASS Second Incremental Data Release, which we used for defining our sample. On the one hand, the NLTT catalogue was available with highly uncertain positions of high proper motion stars, but with poor optical photometry. On the other hand, 2MASS has produced a catalogue with both high-accuracy near-infrared (NIR) photometry and accurate positions at epoch around 1997−2000, but lacking proper motions.

The 2MASS data base provides a cross-identification with optical data, i.e. the closest match within 5 arcsec with an object from the Tycho-2 catalogue (Høg et al. 2000) or from the United States Naval Observatory (USNO) A2.0 catalogue (Monet et al. 1998). The large epoch difference between the 2MASS observations and the USNO A2.0 catalogue leads to missing optical counterparts of practically all high proper motion stars in the 2MASS data base.

The most important criteria for the selection of ~90% of the stars in our sample are described in the following three paragraphs (i) to (iii). The remaining ~10% are briefly described in Sect. 2.4. Many candidates were actually selected according to several of the selection criteria independently. Therefore, the 322 objects of our sample (Sect. 2.5) correspond to about 500 candidates from the various initial candidate lists.

(i) Since M dwarfs are expected to be much brighter in the NIR than in the optical, we first cross-identified the faint part of the NLTT ($m_r > 14.5$) with a sub-sample of bright ($K_s < 11$) 2MASS sources without optical counterparts (opt_flg = 0), extracted from the 2MASS data base (see also Paper I). A search radius of 60 arcsec was used taking into account the large positional errors in the NLTT. From about 500 northern stars, initially selected in this way, about 70 candidates remained in our final sample according to their preliminary distance estimates ($d < 30$ pc) based on their $R-K_s$ colours (see Sect. 2.3). A similar number (~60) of southern candidates were selected according to the above criteria after a cross-identification of the whole southern NLTT with the same sub-sample of bright 2MASS sources without optical counterparts (see also Paper II).

(ii) As an alternative way to identify NLTT stars in the 2MASS, we used the Carlsberg Meridian Catalogs (CMC 1999), including a subsample of 12405 NLTT stars (CDS I/256/nltt), with accurate positions at epochs between 1984 and 1998. The positions at epoch 2000, computed by VizieR[1] taking into account the proper motions, were then used for a direct identification with the 2MASS data base using a smaller search radius of 10 arcsec. The information on the optical counterparts of the 2MASS sources was not used here. The majority of the candidates in our final sample (>180) was selected from these stars on the basis of their preliminary distances below 25 pc obtained from their $(V - K)$ colours (see Sect. 2.3).

(iii) In addition to the NLTT sample in the CMC we also included stars with proper motions exceeding 100 mas/yr from the complete CMC (CDS I/256/stars) and from Tycho-2 (Høg et al. 2000). The stars which turned out to be NLTT stars are analysed in this study. These are 120 CMC and 10 Tycho-2 stars, which were preliminarily estimated to be within 25 pc based on their $(V-K)$ colours. Other high proper motion stars, which were not found in the NLTT, are subject of Paper IV (in preparation). A small number of Tycho-2 and CMC high proper motions could not be confirmed during the cross-identification process (TYC 1597-481-1, TYC 3635-2220-1, TYC 2137-1529-1, CMC 1101791).

Using the CMC and Tycho-2 for the cross-identification with 2MASS did not only give us the advantage of more accurate positions of the NLTT stars but also provided better photometry (see Sect. 2.2). Since the bright stars were expected to be measured by Hipparcos (ESA 1997), we identified only NLTT stars with $V > 9$ (CMC) or $V_T > 9$ (Tycho-2) with 2MASS.

Objects with well established distance estimates from Hipparcos (ESA 1997) or ground-based trigonometric parallax measurements were excluded, except in some doubtful cases or if they were lacking spectroscopy. Objects with known spectral types (at the time when our sample was defined – in 2001) were also excluded from our target list for follow-up spectroscopy.

[1] http://vizier.u-strasbg.fr/

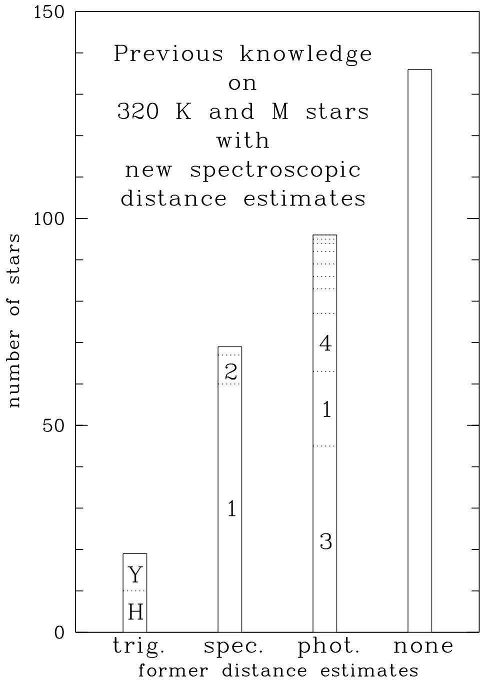

Fig. 2. Numbers of objects in our sample with previous distance estimates. Trigonometric distances are from the Hipparcos (H) and Yale (Y) catalogues, ESA (1997) and van Altena, Lee & Hoffleit (1995), respectively. Most of the former spectroscopic and photometric distances were derived by Reid and coworkers (1 = Reid et al. 2003b; 2 = Cruz & Reid 2002; 3 = Reid et al. 2002a; 4 = Reid & Cruz 2002).

As seen below (Fig. 2), about 20 objects with trigonometric distances remained in our sample, whereas about one quarter of our objects got independent spectroscopic distance estimates in the course of our study.

2.2. Improved optical photometry

Although the crude m_r magnitudes from the NLTT were used for part of our objects in the early sample definition phase, our preliminary photometric distance estimates of nearby candidates were based on improved photometry. First, we used R magnitudes from the USNO A2.0 catalogue (Monet et al. 1998) in the northern sky, as described in Paper I. For southern sky objects (see also Paper II) we preferred to use SSS R magnitudes (Hambly et al. 2001). The R magnitudes were assigned to the NLTT stars after a visual check of the NLTT/2MASS identifications with the help of Digitized Sky Survey (DSS) images combined with a catalogue query from the USNO A2.0 or with SSS images and catalogue data. The SSS web site[2], providing both multi-epoch and multi-colour photographic data in the form of images and object catalogues, and the DSS batch interface available at the National Astronomical Observatory of Japan[3] were extremely helpful during this process.

More accurate V magnitudes were obtained by the help of the already mentioned VizierR interface from the CMC (1999),

[2] http://www-wfau.roe.ac.uk/sss/

[3] http://dss.mtk.nao.ac.jp/

the TASS Mark III photometric survey of the celestial equator (Richmond et al. 2000), and from observations in the Geneva photometric system (Rufener 1988), if available. For the bright Tycho-2 stars in our sample we also extracted the Tycho V_T (ESA 1997) magnitudes. There are some uncertain V magnitudes in the CMC, as one can find out from the CMC notes: for some objects without magnitude determination, the magnitude was either taken (to one decimal place) from an input catalogue, or it was assigned a nominal magnitude of 12.

We did not apply the colour-dependent corrections to the CMC V and Tycho-2 V_T magnitudes proposed in the original catalogues descriptions, but just used them for a rough photometric distance estimate, in order to select the most promising candidates for spectroscopy. When using the photographic R magnitudes for our preliminary photometric distance estimates, we neglected possible systematic differences between the USNO A2.0 and SSS photometric systems. Generally, we expected the photographic R magnitudes from the USNO A2.0 and from the SSS to have an accuracy of a few tenths magnitudes, whereas the V magnitudes from various sources were probably a bit more accurate (typically $< \pm 0.1$ mag).

2.3. Selection based on optical-to-NIR colours

In order to get first estimates on the distances of the NLTT stars re-identified in archival optical data and cross-identified with the infrared data from the second incremental release of the 2MASS, we selected stars with known trigonometric parallaxes and computed their absolute NIR magnitudes as well as their optical-to-infrared colours. For all our candidates photographic R magnitudes were available either from the USNO A2.0 or from the SSS. A long colour base line was expected to provide a strong correlation with absolute magnitudes. Therefore, the $R - K_s$ colours were chosen to be implemented in our preliminary distance estimates.

Figure 3 shows the linear relationship

$$M_{K_s} = 2.60 + 1.077(R - K_s), \quad (1)$$

which we derived from using known nearby stars among the candidates found in our SSS/2MASS cross-identification (see also Paper II). Only stars with trigonometric parallax errors below 4 mas (filled symbols) were used for the fit. Other stars with larger errors are also plotted (open symbols). The spectral types, available for most of the stars shown in the figure, fall in the range between F7 and M 7. The large scatter is mainly due to the uncertainties of the photographic R magnitudes. We found this calibration satisfactory for our purpose. For simplicity, we applied the same relationship for objects with R magnitudes from the USNO A2.0 catalogue.

For objects with available V magnitudes from the CMC (1999), the TASS Mark III photometric survey (Richmond et al. 2000), or from Rufener (1988) we used the sixth-order polynomial relation between the absolute magnitude M_V and the $(V - K)$ colour derived by Reid & Cruz 2002 (see their Fig. 9 and the corresponding formula), where the difference between K and K_s magnitudes was neglected. If only Tycho V_T magnitudes were available, we adopted $V = V_T$.

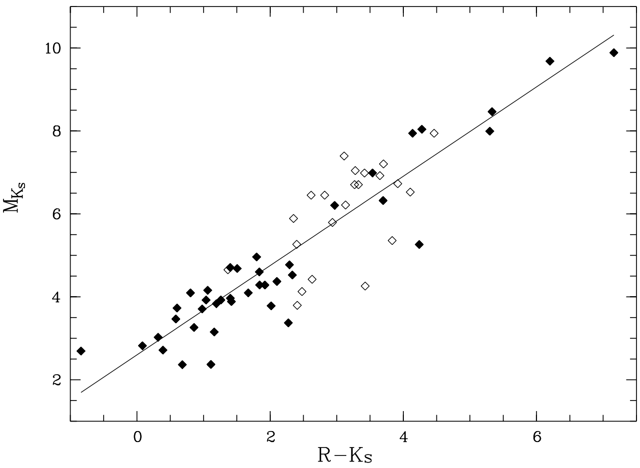

Fig. 3. Absolute magnitude M_{K_s} as a function of $R - K_s$ colour (R magnitudes from SSS, K_s magnitudes from 2MASS). Objects with trigonometric parallax errors <4 mas are shown as filled symbols, those with larger errors – as open symbols. The linear fit (solid line), based on the higher accurate sub-sample, was used for estimating preliminary photometric distances in order to select candidates within 30 pc for follow-up spectroscopy.

Objects were selected for follow-up spectroscopy if their rough photometric distance estimates were below 25 pc or 30 pc based on the V or R magnitudes, respectively. A larger photometric distance limit was chosen when the estimate was based on R magnitudes, in order to take into account their larger uncertainties. Many objects were included in the target list according to both selection criteria, and many objects appeared several times in the final list as coming from different initial candidate lists (NLTT/2MASS plus USNO A2.0 or SSS, CMC, Tycho-2, own high proper motion search using SSS).

2.4. Additional NLTT stars in our sample

About 30 stars were detected during various stages of a new high proper motion survey using first APM (Scholz et al. 2000) and later SSS measurements (see Lodieu et al. 2005). These stars were then identified as already known NLTT stars. Most of them were also found as candidates in our main selection procedures described in the previous subsections.

Another ten known proper motion stars, mainly from the LHS catalogue, were selected on the basis of their optical photometry (from APM measurements) and/or due to their uncertain spectral types (Luyten's rough "m" or "k" classification) during the early stages of our survey, when 2MASS data were not yet available Further ten poorly investigated LHS stars, without references in the Simbad data base bibliography[4] were also included. For the majority of these preselected ~20 LHS stars no good preliminary distances were available. Many of these stars turned out to be rather distant, according to our later spectral classification.

Most of the red dwarf stars in the CNS3 have spectral types from Reid et al. (1995) and Hawley et al. (1996). A handful of additional nearby candidates among the high proper

[4] http://simbad.u-strasbg.fr/Simbad

Table 1. Data on the first 20 stars out of the sample of 322. The full table is available via the CDS. Distances are accurate to about 20%.

Name (NLTT, LHS or Giclas)	α, δ (J2000)	Epoch (2MASS)	J	H	K_s	Prev. SpT	Ref.	Prev. dist. [pc]	Ref.	SpT	d_{spec} (this study) [pc]	v_t [km s^{-1}]
−17:6862	00 01 25.81 −16 56 54.2	1998.901	8.017	7.408	7.217	M 0.0	11	31.9	18	K7.0	30.2	50
191-43	00 08 55.13 +49 18 56.1	1998.849	10.864	10.320	9.980	M 5.5	26	15.8	26	M 5.5	16.8	32
644-94	00 09 13.55 −04 08 02.0	1998.712	8.584	7.977	7.725					M 2.5	20.3	20
LHS 105	00 09 17.22 −19 42 32.4	1998.619	10.883	10.327	10.074					M 4.0	31.8	174
584-94	00 17 40.65 −01 22 40.6	1998.707	9.237	8.567	8.356			28.6	26	M 3.0	23.6	39
705-15	00 21 39.43 −09 00 24.2	1998.792	9.714	9.149	8.867	M 5.5	12	22.5	26	M 3.5	24.0	34
G158-073*	00 24 25.20 −12 17 24.5	1998.605	8.825	8.213	7.979			26.3	26	M 2.5	22.6	30
G158-074*	00 24 26.20 −12 17 19.8	1998.605	10.748	10.167	9.906					M 4.0	29.9	39
705-28	00 25 50.97 −09 57 39.8	1998.819	9.883	9.250	8.952					M 3.0	31.8	30
193-488	00 26 02.59 +39 47 23.6	2000.441	10.990	10.398	10.102	M 4.5	26	30.8	26	M 4.5	26.8	30
G132-004	00 33 20.48 +36 50 26.2	1998.926	8.768	8.085	7.849					M 3.0	19.0	43
645-48	00 34 38.96 −02 25 00.4	1998.710	8.574	7.951	7.692			24.1	26	M 2.0	21.7	22
705-65	00 35 38.09 −10 04 18.6	1998.825	8.327	7.736	7.483			20.3	26	M 2.5	18.0	17
645-53	00 35 44.13 −05 41 10.2	1998.710	10.667	10.074	9.711	M 5.0	13	18.8	13	M 5.0	18.8	21
585-73	00 40 26.43 −00 08 40.9	1998.710	8.926	8.333	8.019					M 2.5	23.7	25
G270-100	00 56 30.21 −04 25 15.3	1998.704	10.444	9.832	9.563			30.0	15	M 4.0	26.0	51
LHS 1200	01 08 48.02 +15 15 22.7	1993.771								WD	110.0	290
G070-041	01 08 50.42 −03 40 33.7	1998.715	9.517	8.894	8.618					M 3.0	26.9	37
LHS 1204	01 09 31.25 +21 37 43.9	1997.778	10.087	9.534	9.272	M 1.0	16	27.8	42	M 4.0	22.1	58
G270-158	01 09 38.75 −07 10 49.7	2000.732	7.956	7.376	7.114	M 0.0	17	37.6	18	M 2.0	16.3	32

Notes: Names flagged by * indicate that additional notes on these stars are available in a separate notes file supplementing the electronic table available at the CDS. Some of the stars, for which their classification as normal K and M dwarfs leads to extremely large tangential velocities, may in fact be subdwarfs with roughly half as large distances and tangential velocities (see Sect. 4.2). References for previous spectral types and/or distance estimates are: 11 – Hawley et al. (1996), 12 – Gigoyan et al. (1998), 13 – Cruz & Reid (2002), 14 – Reid & Cruz (2002), 15 – van Altena et al. (1995), 16 – Buscombe (1998), 17 – Turon et al. (1993), 18 – ESA (1997), 22 – Reid et al. (2002a), 24 – Röser & Bastian (1988), 26 – Reid et al. (2003b), 27 – Weis (1986), 28 – Torres et al. (2000), 29 – Kirkpatrick et al. (1995), 30 – Tokovinin (1994), 32 – Weis (1988), 33 – Weis (1987), 36 – Gliese & Jahreiß (1991), 37 – Gizis (2000), 39 – Lee (1984), 42 – Weis (1984), 43 – Li & Hu (1998), 44 – Weistrop (1981), 45 – Fleming (1998), 46 – Paper I.

motion stars omitted in 1991 from CNS3 due to poor or missing optical photometry, and three more recently announced new nearby NLTT stars from Fleming (1998) were put on our observing program. Fleming's paper is a first attempt to fill the low velocity tail of the nearby star sample in selecting stars on the basis of their X-ray flux and providing distances on subsequently obtained VI-photometry. Nevertheless, a large portion of Fleming's stars turned out to show significant proper motions. The low proper motion stars from Fleming's paper will be presented in Paper IV. Last, but not least, also a few Hipparcos stars were included lacking spectral types. All ten Hipparcos stars contained in our sample were also selected from the CMC/2MASS cross-identification. Six of them had no previously known spectral types.

2.5. The final sample

Table 1, available in its full length only via the Centre de Données astronomiques de Strasbourg (CDS), lists all relevant information on the 322 spectroscopically classified objects of our sample. Column 1 gives the object names, Cols. 2−7 list the J2000 coordinates taken from 2MASS, Col. 8 gives the epoch of the 2MASS observations, Cols. 9−11 list the 2MASS JHK_s magnitudes, Col. 12 lists previously known spectral types, corresponding references are in Col. 13, Col. 14 lists previously determined distances with their references in Col. 15, Col. 16 lists the spectral types determined in the present paper, with the corresponding spectroscopic distances in Col. 16, and the resulting tangential velocities (using the original NLTT proper motions) in Col. 17.

Designations are from the NLTT (usually LP numbers, but also some Durchmusterung numbers), except for those starting with capital G, which were originally published in the Lowell proper motion survey (Giclas et al. 1971). Proper motions are not listed, but are generally between 0.18 and 0.5 arcsec/yr. For 43 stars with proper motions larger than about 0.5 arcsec/yr we give the LHS number instead of the NLTT name. For LHS 2288 and LHS 1200, which were below the detection limit of 2MASS, the coordinates are taken from the latest available SSS epoch measurements. All references for previously known spectroscopy and/or distance determinations are given in the notes to Table 1.

3. Follow-up classification spectroscopy

3.1. Spectroscopic observations and data reduction

Optical spectroscopic data were collected over a period of five years. With only a few exceptions, all objects from our sample were observed with the 2.2 m telescope of the German-Spanish Astronomical Centre on Calar Alto, Spain, i.e. using the same instrument setup as in Paper I. The focal reducer and faint object spectrograph CAFOS was used with the grism B 400 giving a wide wavelength coverage from about 3600 Å to 8500 Å and a dispersion of 10 Å per pixel on the SITe1d CCD. With a width of the entrance slit of typically between 1 and 2 arcsec (dependent on the seeing conditions), the effective resolution is about 20 to 30 Å *FWHM*. The vast majority of our objects were observed during two dedicated observing runs with (a) 10 nights in March 2002 (visitor mode) and (b) 6 nights in August/September 2002 (service mode). For the other targets spectra were taken in the frame of backup programs for 10 different observing runs with CAFOS during the period from 1999 to 2004.

One star with missing CAFOS spectrum (G008-017) as well as LHS 1200, for which we needed a higher-resolution spectrum for a radial velocity measurement (Sect. 4.3.1), were observed with the Nasmyth Focal Reducer Spectrograph at the 2 m telescope of the Thüringer Landessternwarte (TLS) Tautenburg in February 2004 and January 2005, respectively. The V 200 grism was used which yields a dispersion of 3.4 Å per pixel, or 12 Å *FWHM* for a slit width of 1 arcsec. Finally, for the star LP 869-26, which had a corrupted CAFOS spectrum, an additional spectrum was taken with the low-resolution spectrograph DOLORES at the 3.6 m Telescopio Nazionale Galileo (TNG) on the island of La Palma, Spain in August 2004. The grism LR-R (2.9 Å per pixel) was used; the resolution of the spectrum is 20 Å *FWHM* (see Fig. 10).

A large number of comparison stars of known spectral types, mainly taken from the NStars data base[5] and from the ARICNS data base for nearby stars[6] were observed during the nights of our target observations. In the range of spectral types between M 0.0 and M 6.5 such comparison stars were selected for nearly all spectral sub-types, whereas the coverage for K and late-M dwarfs was less complete. Observations of comparison stars were repeated regularly, with some spectral types being represented by several template stars. During the observing nights at the TLS 2 m telescope and at the TNG, only one or two comparison stars, with spectral types close to those of the targets, were included.

All spectra were reduced with standard routines from the ESO MIDAS data reduction package. Wavelength calibration was done with spectra of calibration lamps, except for the TLS spectra for which the night-sky lines were used following Osterbrock & Martel (1992). Flux-calibration was done by means of standard stars from Oke (1990). The one-dimensional spectra were extracted from the two-dimensional spectra using both the optimal extraction algorithm by Horne (1986) and a simple extraction method. In most cases, the results from both methods agree very well. For the faintest stars, the Horne algorithm provides a better signal-to-noise ratio. On the other hand, this method is more sensitive to variations of the background flux (e.g., due to stray light) and breaks down in the presence of strong background gradients. In these few cases, the results from the simple extraction were used.

3.2. Classification of M- and K-type spectra

The large number of comparison stars with known spectral types, spectroscopically observed together with our target stars, served as the basis for our spectral classification. These template spectra, shown in Figs. 13 and 14, represent in many cases

[5] http://nstars.arc.nasa.gov/

[6] http://www.ari.uni-heidelberg.de/aricns/

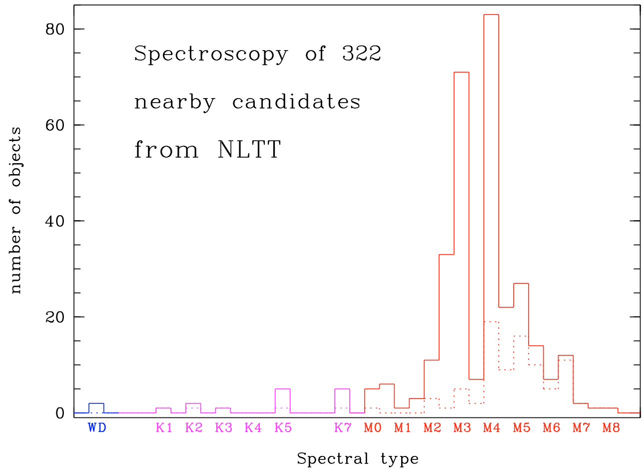

Fig. 4. Distribution of 322 objects with their spectral types determined in this study (solid line). The dotted line shows the subsample of 90 objects, for which we found previously published spectroscopy (see also Fig. 5).

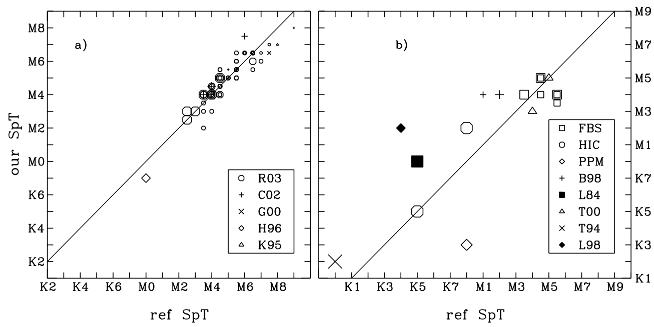

Fig. 5. The new spectral types derived in this study compared to previous spectroscopy – **a)** for 72 objects from R03: Reid et al. (2003b), C02: Cruz & Reid (2002), G00: Gizis (2000), H96: Hawley et al. (1996), K95: Kirkpatrick et al. (1995), and **b)** for 18 objects from FBS: Gigoyan et al. (1998), HIC: Hipparcos Input Catalogue (Turon et al. 1993), PPM: Positions and Proper Motions – North catalogue (Röser & Bastian 1988), B98: Buscombe (1998), L84: Lee (1984), T00: Torres et al. (2000), T94: Tokovinin (1994), L98: Li & Hu (1998). One object with G5 spectral type from HIC, classified by us as a K1 star, lies outside of the plotted range. The symbol sizes correspond to the magnitudes of the objects, with larger symbols used for brighter objects. Solid lines represent the coincidence of new and previous spectral types.

the mean of several standard spectra of a given spectral type. As one can see, the template spectra form a sequence, which is as expected, sorted by spectral type (Figs. 13 and 14). The only exception is the star Gl 273, which was planned to be used as the M 3.5 standard. Since this star turned out to have quite a peculiar spectrum, resembling an M 2.5 star in the blue part (Fig. 13) but exhibiting a much too red continuum in the red (Fig. 14), there were essentially no target stars with comparable spectra. A few target spectra, which were just in between M 3 and M 4, were however classified as M 3.5 type. Therefore, the histogram of the spectral types of our targets (Fig. 4) shows an apparent deep minimum for M 3.5 stars. We assume that ∼30% of our M 3 and M 4 dwarfs could be in fact M 3.5 dwarfs.

The classification based on the comparison with template spectra worked as follows: first, both the template and the target spectra were normalised at 7500 Å. Then we computed the absolute values of the differences between the flux densities of the target and the template, $\delta(\lambda) = |f_{\rm targ}(\lambda) - f_{\rm temp}(\lambda)|$. For every comparison with a template i, the mean value $\bar{\delta}_{\rm i}$ and the median $\tilde{\delta}_{\rm i}$ were computed. The spectral type of the target was subsequently identified with the spectral type of those templates where $\bar{\delta}_{\rm i}$ and $\tilde{\delta}_{\rm i}$ reach their minima. Usually, $\bar{\delta}_{\rm i}$ and $\tilde{\delta}_{\rm i}$ were at minimum with the same template. In cases, where $\bar{\delta}_{\rm i}$ and $\tilde{\delta}_{\rm i}$ led to different classifications, we simply adopted the spectral type corresponding to the smaller value of the two minima. In about 10 cases, where the minimum mean value was similar to the minimum median value, but their corresponding template spectral types differed by more than half a spectral sub-type, we took the average spectral type of these templates.

The classification of target spectra later than M 6.5 or earlier than M 0 required some interpolation and additional visual comparison of the spectra, since fewer template spectral subtypes were available for K-type and late-M spectra. For all stars classified by the comparison with template spectra as K-type, in particular for early-K stars, we used the atlas of spectra by Torres-Dodgen & Weaver (1993) for an additional check. Stars with Hα absorption lines stronger than their NaI lines (see Fig. 6 in Torres-Dodgen & Weaver 1993) were classified as G-type and excluded from our sample of nearby candidates. This concerned HD 206058 and LHS 3856. However, in case of LHS 3856 we are not sure that the correct target was observed spectroscopically.

The few spectra not observed at Calar Alto but with the TLS 2 m telescope and with the TNG, were classified by visual comparison with the few templates observed for comparison at the same telescope. Fortunately, these comparison stars were selected to have spectral types similar to our targets. However, some extrapolation was needed in these few cases. Of course, the Calar Alto templates could be used for an additional check of the results, which were consistent.

We did also try to use spectral indices as described in the classification scheme for M dwarfs developed by Reid et al. (1995), in particular the bandstrengths of TiO and CaH. However, the resolution of our spectra was much too low, in order to achieve reliable results. Therefore, we preferred our direct comparison with template spectra taken at the same spectral resolution and with the same instrument.

The distribution of spectral types derived for the 322 NLTT stars of the present study shows a pronounced maximum between M 2 and M 4.5; the majority of the stars have spectral types earlier than M 5 (Fig. 4). There is an apparent minimum at spectral type M 3.5 which is an artifact, caused by the fact that our M 3.5 reference star, Gl 273, turned out to be not useful as a template (see above).

3.3. Comparison with other spectroscopy

Meanwhile, published spectral types are available for about one quarter of the objects in our sample, mainly from the recently completed survey by Reid et al. (2003b) and Cruz & Reid (2002). For this subsample, the fraction of late-type (>M 5) M dwarfs is higher than for our whole NLTT sample. Consequently, the spectral types newly added by the present study are strongly concentrated at early-M dwarfs.

The majority (60) of the objects with previous spectroscopy come from the work by Reid et al. (2003b). The mean difference between our and their spectral types is exactly zero with a dispersion of 0.50 subtypes. If we add 12 objects from other spectroscopic studies, which we assume to be in the same system (Fig. 5a), we get a mean difference of −0.01 with a dispersion of 0.56 subtypes. Other previously published spectral types for objects in our sample are shown in Fig. 5b. Among the latter we see larger discrepancies, in particular for stars with earlier spectral types. The extreme outlier seen in Fig. 5b is LP 247-13, for which we assigned a spectral type of M 2.0, whereas Li & Hu (1998) classified it as K4. However, we note for this particular object a very blue continuum compared to the typical early M dwarf spectrum. A similar spectrum was observed by us for LHS 6388. These two objects may have blue companions, unresolved in our observations.

The relatively low resolution of our spectroscopy combined with the direct comparison of the full spectra with templates provides a classification nearly as accurate as achieved by others using slightly higher resolution classification spectroscopy in the same system (see Fig. 5a). Compared to other previous classifications (Fig. 5b), often not corresponding to the presently adopted system, our spectral types should be prefered.

3.4. Two White dwarf spectra

Two objects in our sample turned out to be white dwarfs. These are LHS 1200, which was originally selected due to its uncertain spectral type, and LHS 2288, which we selected as a faint red object ($E = 18.7, O - E \sim +3.2$) according to the APM catalogues (McMahon et al. 2000). The SSS magnitudes of LHS 1200 and LHS 2288 are $B_{\rm J} = 16.92, R = 16.79$ and $B_{\rm J} = 20.21, R = 18.50$, respectively. Both stars have almost completely been neglected in the literature, although LHS 1200 was included in the study of Eggen (1968) and is part of Luyten's white dwarf catalogue (Luyten 1970). The two objects are below the detection limit in the 2MASS. This is, with respect to their optical magnitudes and colours, already indicative of their possible white dwarf nature.

Our low-resolution spectra of LHS 1200 and LHS 2288 are shown in Fig. 6. LHS 1200 can be classified as an early-type DA white dwarf with broad Balmer lines, similar to the spectrophotometric standards Wolf 1346 and GD 140 (Massey et al. 1988). A more accurate classification of LHS 1200 will be given in Sect. 4.3.1 based on photometry. LHS 2288 appears with the given signal-to-noise to be a featureless cool DC white dwarf, similar to the spectra shown in Fig. 2a of Oppenheimer et al. (2001). Again, accurate photometry allows an estimate of the effective temperature of this object (see Sect. 4.3.2).

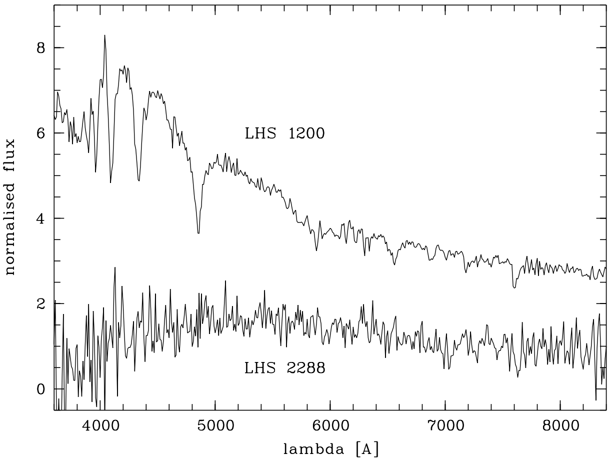

Fig. 6. CAFOS low-resolution spectra of two white dwarfs. The spectra are normalised at 7500 Å, that of LHS 1200 is offset by two flux units.

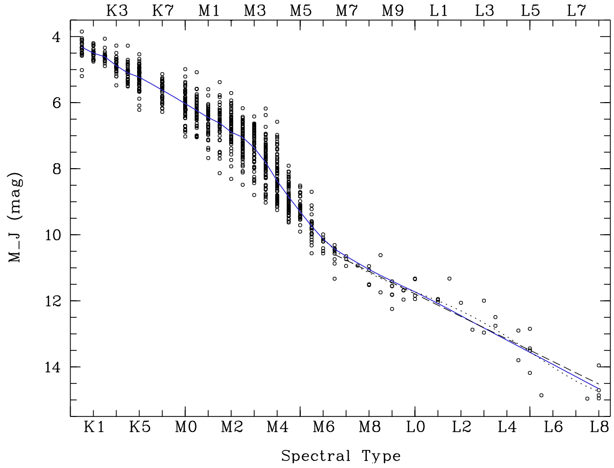

Fig. 7. Absolute magnitudes/spectral types calibration. The solid line represents our new calibration. For comparison we show the linear fit of Dahn et al. (2002, dashed line) and the fourth-order polynomial fit by Cruz et al. (2003, dotted line), which are both valid for later spectral types only (>M 6). Adopted mean M_J magnitudes are listed in Table 2.

Table 2. Absolute magnitudes M_J as a function of spectral types between K0 and L8 adopted for the distance estimates of the objects in our sample.

Sp. type	M_J	Sp. type	M_J	Sp. type	M_J
K0	4.32	M 0.0	6.03	L0.0	11.73
		M 0.5	6.24	L0.5	11.90
K1	4.50	M 1.0	6.45	L1.0	12.08
		M 1.5	6.62	L1.5	12.26
K2	4.61	M 2.0	6.89	L2.0	12.45
		M 2.5	7.05	L2.5	12.64
K3	4.88	M 3.0	7.37	L3.0	12.82
		M 3.5	7.81	L3.5	13.01
K4	5.10	M 4.0	8.37	L4.0	13.19
		M 4.5	8.85	L4.5	13.37
K5	5.23	M 5.0	9.30	L5.0	13.56
		M 5.5	9.74	L5.5	13.74
		M 6.0	10.13	L6.0	13.92
		M 6.5	10.43	L6.5	14.11
K7	5.62	M 7.0	10.65	L7.0	14.29
		M 7.5	10.85	L7.5	14.48
		M 8.0	11.05	L8.0	14.66
		M 8.5	11.23		
		M 9.0	11.40		
		M 9.5	11.57		

4. Spectroscopic distance estimates

4.1. K and M dwarfs

Figure 2 shows that about 20 objects in our sample of 322 objects have measured trigonometric parallaxes. All but 4 of these objects were previously lacking spectral types. About 70 objects have recently determined spectroscopic distances. Note that the total number of objects with previous spectral types is 90 (cf. Figs. 4 and 5).

We wanted to be comparable with the spectroscopic distance estimates of Cruz et al. (2003) using their M_J-spectral type relationship. However, this calibration is only valid for spectral types between M 6 and L8, i.e. with only little overlap to the range of spectral types in our sample. In order to expand this calibration to earlier spectral types, we carried out a new calibration on the basis of all K, M and L dwarfs in the forthcoming CNS4 (Jahreiß 2005) with trigonometric parallaxes better than 20 per cent. The calibration was performed in applying a robust locally weighted regression LOWESS as described in Cleveland (1979), with a smoothing factor of $f = 0.3$.

Figure 7 shows our new calibration, which at later spectral types (>M 8 – not relevant for the objects in our sample) is very similar to a linear fit, and which over the whole overlapping spectral range (M 6−L8) lies in between the linear fit by Dahn et al. (2002) and the higher-order fit by Cruz et al. (2003). The overall shape of the fit could also roughly be described by three linear relations in the intervals of K0−M 3, M 3−M 6.5 and M 6.5−L8, respectively. However, we prefer not to approximate the calibration by formulae, and list the relationship in Table 2. The dispersion is generally of the order of 0.4−0.5 mag. This transforms to a distance error of ∼20%.

Figure 8 shows that our distance estimates generally agree well with former estimates if available from trigonometric or recent spectroscopic and photometric measurements (see also Fig. 2). The object with the largest previously determined photometric distance in our sample is LHS 2048 ($d_{\rm phot}$ = 105 pc, Weistrop 1981), which we confirm by our classification of this star as an M 2.5 dwarf. However, there are some objects with large discrepancies (labeled in Fig. 8), which need to be explained. This seems even more important since in all the problematic cases the stars have previous trigonometric parallax measurements. Interestingly, all outliers above the line have ground-based parallaxes, while the only one object far below the line of equal distances has a Hipparcos parallax.

The Hipparcos star BD+32°588 (Hip 15102; ESA 1997) is the only star in our sample of K and M proper motion stars, which has a previous spectroscopic classification as a G-type star (G5, Turon et al. 1993). According to our spectrum taken at Calar Alto (spectrum at the bottom of Fig. 9), we classified it as a K1 star, based on the comparison with template spectra and

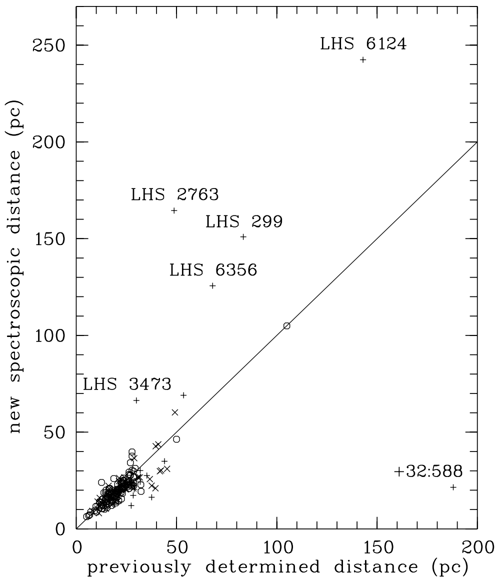

Fig. 8. The newly determined spectroscopic distances of 166 objects in our sample compared to their previous trigonometric (+), spectroscopic (×) and photometric (open circles) estimates. The line represents equal distances. The objects with the largest discrepancies are labeled (see text).

on the fact that the NaI absorption line is slightly stronger than the Hα line (cf. Fig. 6 in Torres-Dodgen & Weaver 1993). Its $J-K = 0.63$ is also more consistent with an early K-type rather than with G5. The star was suspected by Halliwell (1979) as a possible nearby star ($d < 25$ pc) but not further mentioned in the literature. The Hipparcos parallax of 5.32 ± 1.19 mas is in strong contrast to our nearly ten times smaller spectroscopic distance estimate of about 21 pc. The Hipparcos distance and the bright 2MASS magnitude $J = 6.16$ are not consistent with a main sequence star. This confirms that this object is an early K giant with $M_V = 1.6$ and $B - V = 0.96$, clearly brighter than a subgiant (with typical $M_V \sim 3.2$).

There are five objects where available trigonometric parallaxes show our spectroscopic distances to be too large: LHS 6356 (K5), LHS 6124 (K7), LHS 2763 (M 0), LHS 299 (M 0), and LHS 3473 (M 3). These objects labeled in Fig. 8, may in fact be subdwarfs (see Sect. 4.2). LHS 3473 and LHS 6356 have common proper motion companions (see Sect. 5.2).

Figures 9 and 10 show representative samples of our spectra of K and early M dwarfs and of mid- to late-type M dwarfs, respectively.

4.2. Subdwarf candidates

As mentioned already in Sect. 3.2, our spectral resolution is not high enough for computing reliable TiO and CaH indices (Reid et al. 1995) of our targets. Therefore, we can not distinguish between normal K and M dwarfs and subdwarfs using these indices according to the classification scheme for subdwarfs developed by Gizis (1997), which can in principle only be applied to M subdwarfs. The spectral resolution is in fact about 7 times lower than in Gizis (1997). Therefore,

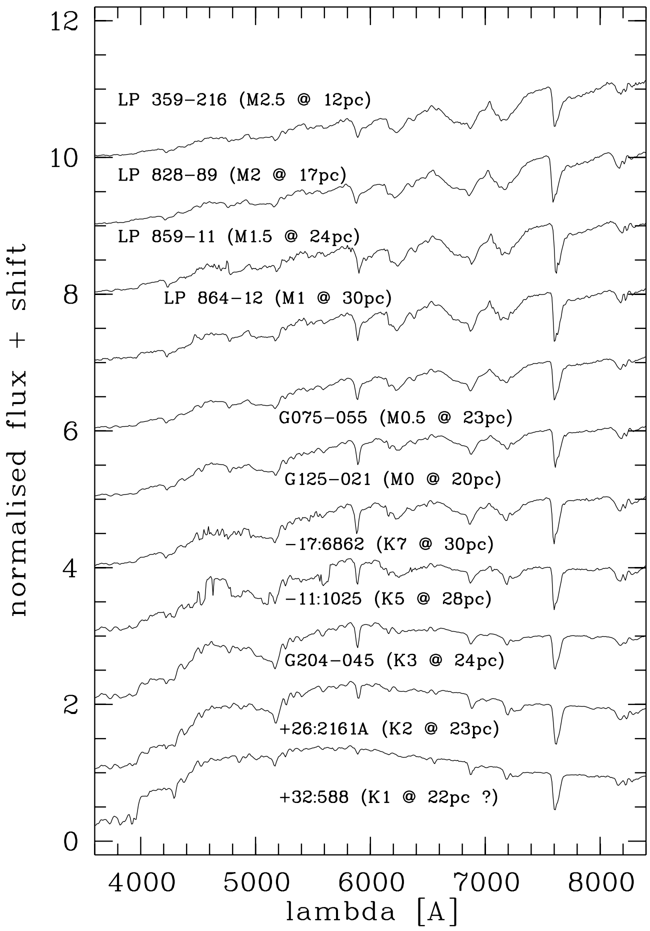

Fig. 9. CAFOS spectra of nearby early-type (<M 3) objects. One of the nearest objects of each spectral type (according to our distance estimates) is shown. The K1 star, BD+32°588, has a Hipparcos parallax, which places this star nearly ten times farther away (see text).

the relatively sharp TiO features are considerably smoothed, leading to systematically too large TiO5 indices. The CaH2 and CaH3 indices are also affected by smoothing in the region of the maximum at 7042−7046 Å whereas the CaH1 index does obviously make no sense with a resolution comparable to the distances between the wavelength intervals used for its definition.

We do, however, expect some subdwarfs in our proper motion selected sample. We have used the mean absolute magnitudes of normal K and M dwarfs with trigonometric parallax measurements for the spectroscopic distances of all objects in our sample. By doing so, we overestimate the distances of those objects, which are in fact subdwarfs. The comparison of the spectroscopic distances of some of our objects with previous determinations from ground-based trigonometric parallax measurements has already revealed some discrepancies (Fig. 8).

Figure 11 shows the spectroscopic distance estimates and the resulting tangential velocities of all 322 objects in our sample. The four most extreme objects as well as the five objects with already mentioned overestimated distances (Fig. 8) are labeled. Among the stars with trigonometric parallaxes in our sample, LHS 299 has the largest tangential velocity of about 440 km s^{-1}. Despite this previously known large velocity, there are no hints in the literature on the subdwarf nature of this

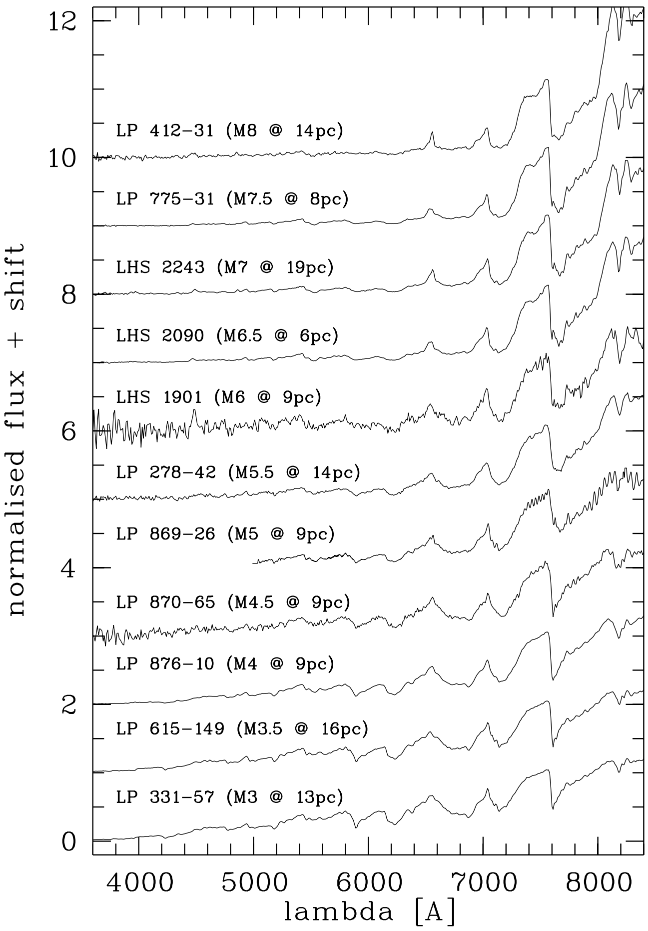

Fig. 10. Spectra of nearby mid- and late-type (M 3–M 8) objects. One of the nearest objects of each spectral type (according to our distance estimates) is shown. All spectra were taken with CAFOS, except for LP 869-26, which was obtained with the TNG.

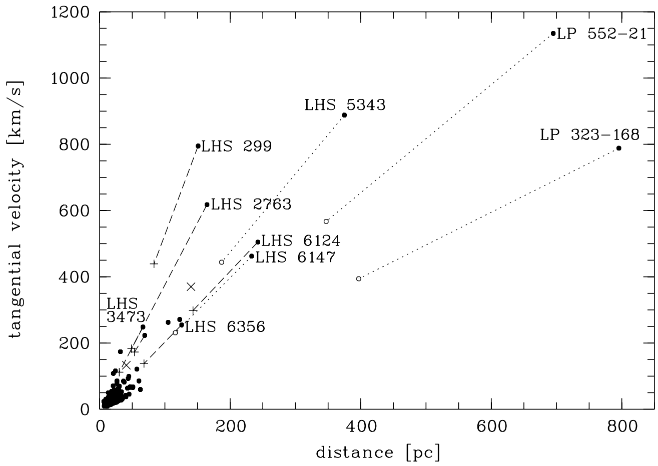

Fig. 11. Tangential velocities versus distances. The spectroscopic distances and resulting tangential velocities of 320 K and M dwarfs are shown by filled circles. The two white dwarfs are marked as crosses. Objects with trigonometric parallax data in addition to our spectroscopic distances are shown by dashed lines and plus signs (+). Candidate subdwarfs are illustrated by dotted lines and open circles. If these are in fact subdwarfs, the values derived from the spectroscopic distances are reduced by as much as 50%

object. Our distance estimate based on the assumed classification of LHS 299 as a normal M 0 dwarf is nearly twice as large as its trigonometric distance. This discrepancy can only be explained, if this object is in fact a subdwarf.

We expect that the distances to at least four other suspected subdwarfs may be only about half of our original estimates (indicated by the dotted lines and open circles in Fig. 11). Our original spectral classification of these four objects (LP 552-21, LP 323-168, LHS 5343, LHS 6147) ranges between K2 and M 0.5, and for a first guess we can assume similar sub-dwarf subtypes. There are four sdK7, three sdM0.0 and three sdM0.5 stars with ground-based trigonometric parallaxes listed in Gizis (1997). Using for some of these objects the Hipparcos (ESA 1997) parallaxes instead of the ground-based ones, we compute mean absolute magnitudes M_J of 6.9, 7.5 and 7.8 for sdK7, sdM0.0 and sdM0.5, respectively. Compared to the absolute magnitudes of normal K7, M 0.0 and M 0.5 dwarfs, these values are 1.3 to 1.6 mag fainter, corresponding to a factor of 0.55 to 0.48 in the computed distances, and thus reduce their tangential velocities by half.

Figure 12 shows the spectra of all K and M stars in our sample which have the largest tangential velocities, from ~250 km s^{-1} to ~1150 km s^{-1} (see also Fig. 11), based on

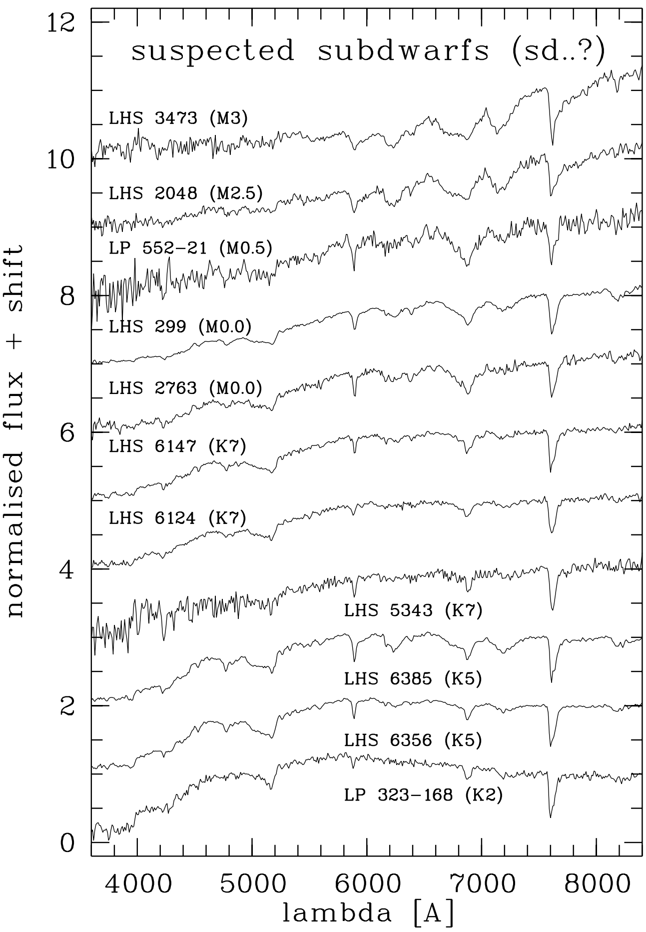

Fig. 12. CAFOS spectra of all high-velocity K and M stars (with approximately v_t > 250 km s^{-1}) according to our spectroscopic distance estimates, assuming that these objects are normal dwarf stars. All these objects may in fact be subdwarfs.

Table 3. Suspected subdwarfs with corrected distances and tangential velocities

Name	SpT^{corr}	d^{corr} [pc]	v_t^{corr} [km s^{-1}]
LP 552-21	sd: M 0.5	348	567
LHS 5343	sd: K7.0	187	444
LHS 299	sd: M 0.0	75	397
LP 323-168	sd: K2.0	398	394
LHS 2763	sd: M 0.0	82	309
LHS 6124	sd: K7.0	121	252
LHS 6147	sd: K7.0	116	231
LHS 6385	sd: K5.0	61	136
LHS 2048	sd: M 2.5	52	131
LHS 6356	sd: K5.0	63	127
LHS 3473	sd: M 3.0	33	124

their classification as normal dwarfs and the resulting large distances. With the given low resolution, these spectra do not provide any evidence on a subdwarf nature of the objects. The spectrum of the highest-velocity object, LP 552-21, looks a bit peculiar but does not allow an alternative spectral classification due to the low signal-to-noise. Comparison with the spectra of local K and early-M dwarfs (cf. Fig. 9) does not reveal any systematic differences.

Table 3 lists all suspected subdwarfs (according to our original estimates approximately $v_t > 250$ km s^{-1}) with their roughly corrected (reduced by 50%) distances and tangential velocities. The spectra of all these objects are shown in Fig. 12. Note that five of them have trigonometric distances which correspond to 30% to 60% of our original estimates (see Table 1 and Fig. 8). LHS 2281 is one more object in our sample with $v_t > 200$ km s^{-1} according to our original distance estimate of 69 pc. This is, however, in good agreement with its Hipparcos distance of 54 pc. The next smaller tangential velocity is measured for LHS 105 with about 170 km s^{-1} according to our original distance estimate of about 32 pc. Therefore, a threshold of $v_t > 250$ km s^{-1} seems to be justified for suspecting objects in our sample as subdwarfs.

4.3. White dwarfs

4.3.1. LHS 1200

A first rough distance estimate for the early-type DA white dwarf LHS 1200 is based on our assumption that it has a similar absolute magnitude as the two relatively hot white dwarfs Wolf 1346 and GD 140, both classified as DA3 (Greenstein 1984). These two objects have very similar Hipparcos (ESA 1997) parallax measurements of about 68 mas and 65 mas for Wolf 1346 and GD 140, respectively. We compared the SSS B_J and R magnitudes of Wolf 1346 and GD 140 ($B_J = 11.90, R = 12.03$ and $B_J = 12.02, R = 12.09$) with those of LHS 1200 (see Sect. 3.4). The resulting distance of LHS 1200 is $d_{B_J} = 133$ pc or $d_R = 148$ pc. Note the good agreement of these two estimates, which is also due to the fact that all three objects have nearly the same colour ($B_J - R \sim -0.1$). The mean distance of about 140 pc combined with the proper motion of about 0.55 arcsec/yr yields a very high tangential velocity of about 370 km s^{-1}. Such a velocity would classify LHS 1200 as a member of the Galactic halo. Compared to the well known halo DA7 white dwarf LHS 56 (Liebert et al. 1988) at a distance of about 18 pc, LHS 1200 is roughly 3 mag fainter in the optical (SSS) and exhibits an about 7 times smaller total proper motion, in good agreement with the expectations for a halo object being 8 times more distant.

A more accurate distance can be obtained from the Sloan Digital Sky Survey (SDSS) photometry of LHS 1200. In the 3rd data release, DR3[7], we find $u = 16.717, g = 16.541, r = 16.872, i = 17.119, z = 17.388$. The SDSS colours agree well with those of DA3 and DA3.5 white dwarfs in Harris et al. (2003) and Kleinman et al. (2004). Using the photometric transformation of Fukugita et al. (1996) we obtain $V = 16.715, V - R_c = -0.032$ and $V - I_c = -0.077$, consistent with a $T_{eff} = 13000$ K, i.e. DA3.5 white dwarf with an absolute magnitude of $M_V \sim 11.5$ (cf. Table 3 and Fig. 6 in Bergeron et al. 1995). Adopting the spectral type of DA3.5 and assuming an uncertainty of 0.35 mag for the above given absolute magnitude we compute a distance of 110 ± 20 pc. The corresponding tangential velocity is about 290 km s^{-1}. Note that the alternative spectral type of DA3 would allow a direct distance estimate using SDSS photometry of three DA3 white dwarfs with measured Hipparcos parallaxes: Feige 22, G 93-48, and Wolf 1346 (Smith et al. 2002; ESA 1997). As expected, the resulting distance would be larger, ~150 pc, and the tangential velocity still extremely large.

The Tautenburg spectrum of LHS1200, covering a smaller wavelength interval but having a better spectral resolution than the CAFOS spectrum shown in Fig. 6, was used for a rough estimate of the radial velocity by measuring the wavelengths of the line cores of the Balmer lines Hβ and Hγ relative to sky background lines in the same wavelength range. For both lines the same uncorrected shift of +2.5 (±1) Å is measured. If we apply the required gravitational redshift correction, which is of the order of −30 km s^{-1} (Silvestri et al. 2001), we derive a heliocentric radial velocity of about $+115 \pm 60$ km s^{-1}. Using the latter and the distance of 110 ± 20 pc, we compute a heliocentric space velocity following Johnson & Soderblom (1987) of $(U, V, W = -116 \pm 32, -184 \pm 63, -219 \pm 54)$ km s^{-1}. Despite the large errors, this very high space velocity supports a Galactic halo membership of LHS 1200. In particular, it does not share the Galactic rotation speed of the local spiral arm (V), and it also shows a large velocity perpendicular to the Galactic plane (W).

4.3.2. LHS 2288

For LHS 2288, which we classified as a cool white dwarf, we first apply the photographic absolute magnitude-colour relation

$$M_{B_J} = 12.73 + 2.58(B_J - R), \quad (2)$$

derived by Oppenheimer et al. (2001) and obtain a photometric distance of 41 pc. Again we are lucky enough to find this

[7] http://www.sdss.org/dr3/

object in the SDSS so that we can derive a more accurate photometric distance. The SDSS magnitudes, $u = 22.259, g = 20.065, r = 18.921, i = 18.541, z = 18.325$ can be transformed to $V = 19.454, V - R_c = +0.790, V - I_c = +1.412$ (Fukugita et al. 1996). Using the M_V vs. $V - I_c$ relationship for cool white dwarfs from Salim et al. (2004; their Eq. (7)), we obtain an absolute magnitude of $M_V = 16.23$. Assuming again an uncertainty of 0.35 mag in the absolute magnitude, we get a distance of 44 ± 7 pc, in very good agreement with the previous distance estimate.

Combined with the proper motion of about 0.68 arcsec/yr, this yields a more moderate tangential velocity of about 140 km s^{-1} for LHS 2288, probably placing this object in the Galactic thick disk population. Compared to the sample presented in Oppenheimer et al. (2001), this object seems to be a relatively nearby representative of the cool white dwarfs. From its SDSS colours it resembles SDSS J0854+35, an ultracool white dwarf with only mild collision-induced absorption (Gates et al. 2004), with LHS 2288 being located at slightly shorter distance.

5. Notes on individual objects

Included in Table 1 are flags, indicating that additional notes are available for these stars. These notes are collected in a separate file supplementing the corresponding data file of Table 1, available via the CDS. The notes are mainly dealing with spectral features mentioned during the inspection of the low-resolution spectra, e.g. (weak indication of) Hα emission lines (43 stars), but do also include brief information on common proper motion companions.

In the following subsections we consider some of the most remarkable and interesting (groups of) individual stars in our sample in more detail.

5.1. Sample stars within 10 pc

According to our spectroscopic distances there are in total eight stars within 10 pc, usually in good agreement with independent determinations. Only three of these objects had previously announced spectroscopic distances. However, all others were known as very nearby stars from recent photometric distance determinations.

The nearest one, the M 6.5 dwarf LHS 2090, was already published in Paper I with a first spectroscopic distance estimate of 6.0 ± 1.1 pc. Reid & Cruz (2002) determined a photometric distance of 5.2 pc. It's preliminary trigonometric parallax of 159.02 ± 4.46 mas on the RECONS homepage[8] confirms very nicely our new spectroscopic distance of 6.3 pc.

Available optical photometry yields a distance of 7.1 pc (Jahreiß 2005) for the second nearest of our sample, the M 5 dwarf G 161-71, very close to the 6.9 pc given in Table 1. Note that a spectral type of M 5Ve was already assigned to this star by Torres (2000).

LHS 6167 (M 5 at 7.3 pc) is most probably identical with the faint X-ray source 1RXS J091535.4-103538 (Voges et al. 2000). Reid et al. (2002a) found a similar photometric distance of 6.7 pc. A spectral type M 4-5 was previously assigned to this star by Gigoyan et al. (1998).

For LP 775-31 (M 7.5 at 8.2 pc) there are several independent distance determinations in the literature. Reid & Cruz (2002) obtained a photometric distance of 6.4 pc. whereas Cruz & Reid (2002) initially typed this star as M 6 at 11.3 pc but later revised it to M 7 at 8.6 pc in Cruz et al. (2003). In Paper II, a much later spectral type of M 8 and a correspondingly shorter distance of 6.4 pc were derived. Reid (2003) also lists this star with a spectral type of M 8.

For LP 870-65 (M 4.5 at 8.7 pc) available optical photometry yields a slightly larger distance of 10.7 pc (Jahreiß 2005), whereas Reid et al. (2003b) found a photometric distance of 10.1 pc.

For LP 876-10 (M 4 at 8.7 pc) available optical photometry yields 7.8 pc (Jahreiß 2005), and Reid et al. (2003b) found even 7.2 pc as photometric distance.

For LHS 1901 (M 6 at 9.3 pc) Reid et al. (2003b) found a photometric distance of 7.8 pc and a spectroscopic distance of 8.0 pc by classifying this star as M 6.5 dwarf.

LP 869-26 (M 5 at 9.4 pc) may be identical with the bright X-ray source 1RXS J194453.7-233743 (Voges et al. 1999). Optical photometry yields 10.7 pc in Jahreiß (2005), whereas Reid et al. (2003b) found a similar photometric distance of 9.2 pc.

One object, LP 869-19, with a previous photometric distance of 9.8 pc as determined by Reid et al. (2003b) is according to our spectral classification as an M 4 dwarf placed slightly further away, at 11.6 pc.

5.2. Binaries and common proper motion stars

About 6% of the stars in our sample are apparently components of (wide) binaries, which usually appear in Luyten's catalogue of double stars with common proper motion (LDS; Luyten 1940–87). All these stars are also marked by * in Table 1 and have a brief comment in the separate notes file supplementing the electronic table available at the CDS:

G158-073 (M 2.5 at 23 pc) and G158-074 (M 4 at 30 pc), LDS 3163 (sep. 15 arcsec). The independent spectroscopic distance estimates of the two components are in reasonable good agreement. G158-073 has a photometric distance of 26 pc in Reid et al. (2003b).

CD−25°1159 (M 2 at 17 pc) is a close binary of nearly equally bright components detected by Hipparcos (sep. 0.3 arcsec, ESA 1997). We did not resolve the binary in our spectroscopic observations. Therefore, a correcting factor of 1.4 has to be applied to our distance estimate, which is then in better agreement with the Hipparcos distance to the system (28 pc).

LP 831-14 (M 2.5 at 28 pc) and the bright F2V star Zeta For (not part of our survey, with a Hipparcos parallax of 30.92 ± 0.77 mas; ESA 1997) form the pair LDS 3446 (sep. 176 arcsec). Their proper motions are slightly different (Salim & Gould 2003). Our spectroscopic distance estimate agrees well with the Hipparcos measured distance.

[8] http://www.chara.gsu.edu/RECONS

G221-027 (M 4 at 17 pc; classified as M 4 at 15 pc by Cruz & Reid 2002) and LP 31-302 (not part of our survey, but classified by Cruz & Reid (2002) as M 5 at 13 pc), LDS 1589 (sep. 5 arcsec). The various distance estimates are in good agreement with each other.

LP 359-216 (M 2.5 at 12 pc) and its fainter companion LP 359-186 (not part of our survey), LDS 6160 (sep. 167 arcsec). LP 359-216 was originally selected by us as a nearby candidate according to its Tycho-2 proper motion and photometry compared to its 2MASS magnitudes. It is the nearest M 2.5 dwarf in our sample. We identify LP 359-216 with the bright X-ray source 1RXS J050315.1+212351 (Voges et al. 1999) and HD 285190. Simbad, however, gives a spectral type of K0 for the latter and does not associate the two names with each other. Our spectrum of LP 359-216 (on top of Fig. 9) clearly rules out a K-type object. The trigonometric parallax of 36.5 ± 8.6 mas for LP 359-216 (van Altena et al. 1995) is in strong contrast with our much closer distance estimate, even if we take into account the relatively large error of the trigonometric parallax. If we assume LP 359-216 and LP 359-186 be associated and prefer our spectroscopic distance estimate to the trigonometric one, the projected physical separation of the system reduces from ∼4600 AU to ∼2000 AU. The 2MASS colours and magnitudes of LP 359-186 ($J - K_s = +0.86$, $J = 9.75$) are consistent with an M 5 dwarf secondary at 12 pc distance. In view of these facts the trigonometric parallax seems to be debatable.

LP 784-12 (M 1.5 at 21 pc) is a close binary measured by Hipparcos (sep. 0.37 arcsec; ESA 1997). We did not resolve the binary in our spectroscopic observations. Therefore, a correcting factor of up to 1.4 has to be applied to our distance estimate, which is then in better agreement with the Hipparcos distance to the system (29 pc).

LP 729-54 (M 4 at 13 pc) and the fainter companion LP 729-55 (not part of our survey), LDS 3977 (sep. 14.5 arcsec). Reid et al. (2003b) give a spectral type of M 3.5 with a distance of 50 pc for LP 729-55. We suppose that they have assigned the spectral type to the wrong object, yielding a much too large distance to the system.

LP 790-47 (K5 at 62 pc) and its fainter companion LP 790-46 (not part of our survey), LDS 3984 (sep. 24.5 arcsec). Both stars have accurate proper motion measurements in the UCAC2 (Zacharias et al. 2004), which agree within the errors. The pair appeared in the study of halo common proper motion stars by Ryan (1992), but was not further investigated, since red stars were excluded from the analysis. Our moderately large value of the tangential velocity determined for LP 790-47 ($\sim$60 km s^{-1}) hints at a thick disk membership of the pair.

BD+26°2161A (K2 at 23 pc) and its slightly fainter companion BD+26°2161B (also part of our survey but not observed spectroscopically) are mentioned in the NLTT notes (sep. 5 arcsec). The spectrum of BD+26°2161A is shown in Fig. 9. This pair could already have been suspected as nearby from Hipparcos observations, since both stars have positive Tycho parallaxes, which in case of the primary is highly significant: 63.1 ± 11.1 mas, whereas the value for the secondary is smaller: 33.1 ± 17.1 mas (ESA 1997). The primary is not included in the list of suspected nearby Tycho stars of Makarov (1997), although it seems to fulfil his selection criteria.

LP 852-5 (M 3 at 24 pc) and its 2.2 mag fainter companion LP 852-6 (not part of our survey), LDS 4178 (sep. 14 arcsec). The 2MASS colours and magnitudes of the secondary ($J - K_s \sim +0.86$, $J = 11.47$) are consistent with a mid-M spectral type (∼M 5.5) at ∼25 pc.

LP 65-440 (M 4 at 19 pc) is one component of the unresolved (also in 2MASS) binary LDS 2674 (sep. 1.5 arcsec). The distance may therefore be up to 1.4 times larger (in case of an equal spectral type of both components).

LP 797-105 (M 2.5 at 33 pc) has a bright companion, LP 797-104 (not part of our survey, sep. 138 arcsec) with a Hipparcos parallax of 27.4 ± 1.6 mas, in good agreement with our spectroscopic distance of LP 797-105. The UCAC2 proper motions of the two objects almost agree within their errors (Zacharias et al. 2004).

LP 439-442 (M 3 at 24 pc) and its 1.2 mag fainter companion LP 439-441 (not part of our survey), LDS 1415 (sep. 15 arcsec). The much shorter photometric distance estimate (13 pc) for LP 439-442 by Reid & Cruz (2002) probably results from an error in reading the correct V magnitude from Ryan (1992, i.e. $V = 13.1$, and not $V = 13.95$ as used by Reid & Cruz. The 2MASS colours and magnitudes of the secondary ($J - K_s \sim +0.87$, $J = 10.46$) are fully consistent with an ∼M 4 dwarf at ∼25 pc.

LP 806-5 (M 2.5 at 22 pc) has a slightly (0.1 mag) brighter wide companion LP 806-4 (not part of our survey, sep. 197 arcsec), which could have the same spectral type. Both components have accurate proper motion measurements in the UCAC2 (Zacharias et al. 2004), which agree within their errors.

LHS 3473 (M 3 at 66 pc) and its only slightly (0.3 mag) fainter companion LHS 3474 (sep. 4.5 arcsec) are unresolved on Schmidt plates. A spectrum was observed for LHS 3473 only. The spectrum, taken at a seeing of about 1 arcsec, is clearly unaffected by the close companion. The trigonometric parallax of LHS 3473 (33.3 ± 3.0 mas) listed by van Altena et al. (1995) places the system at only 30 pc distance. Therefore, we assume LHS 3473 to be a subdwarf. The two objects are well resolved in 2MASS and have similar NIR colours. Therefore, the system probably consists of two subdwarfs with a projected physical separation of 135 AU and a tangential velocity of $\sim$110 km s^{-1} with respect to the Sun.

LHS 6356 (K5 at 126 pc) has a trigonometric distance ($d = 68$ pc, van Altena et al. 1995) only half as large as our spectroscopic one, indicating that it is in fact a subdwarf. Its common proper motion companion, LHS 6357 (sep. 8 arcsec according to the NLTT notes), is still lacking a spectral type, but has a similar although uncertain trigonometric parallax of 20 ± 5 mas (Harrington & Dahn 1980). LHS 6357 is roughly 0.8 mag fainter in the NIR (2MASS). It may also be a subdwarf, but of a later spectral type.

5.3. Dubious common proper motion pairs

LP 932-83 (M 5 at 10 pc) and its brighter companion Hip 112648 (not part of our survey, Hipparcos parallax: 23 ± 2 mas), LDS 4999 (sep. 217 arcsec). The Hipparcos distance of the K7 primary is four times larger than our spectroscopic distance of the secondary. The physical association of the two objects may be not real, although their proper motions almost agree within the errors (Zacharias et al. 2004; Salim & Gould 2003). We note that Reid & Cruz (2002) determined a photometric distance of 14 pc for LP 932-83, in good agreement with our spectroscopic distance estimate. Even if we assume LP 932-83 to be a close binary a discrepancy with the distance of Hip 112648 remains.

The object with our largest estimated spectroscopic distance (~800 pc), the K2 star LP 323-168, which we suspect to be a subdwarf with a distance more like ~400 pc, has an apparent common proper motion companion, LP 323-169, at an angular separation of about 3 arcmin, as claimed in the NLTT remarks. In strong contrast to the assumed physical association of the two objects, we classify the latter as a nearby ($d \sim 14$ pc) M 4.5 dwarf. According to our own determination (using positions from the APM catalogue of McMahon et al. (2000), the SSS and the 2MASS) and according to the USNO CCD Astrograph Catalog (UCAC2, Zacharias et al. 2004) the two objects have clearly different large proper motions. It is just by chance that two different high proper motion stars, a distant high-velocity representative of the Galactic halo and a member of the Solar neighbourhood, appear in the same small sky field.

LP 731-76 (M 5 at 11 pc) and its bright apparent companion BD−10°3166 (not part of our survey), LDS 4041 (sep. 17 arcsec). Although the K0 primary has a long bibliography in the Simbad data base, where it is also mentioned as a planetary host star (Butler et al. 2000), the star (system) did not yet get attention for its proximity. The common proper motion is doubtful, because the UCAC2 proper motions (Zacharias et al. 2004) of the two stars are significantly different, in particular in declination (−93 vs. −6 mas/yr). Finally, a physical association of the two objects can be ruled out on the basis of a photometric distance estimate for BD−10°3166. Using $V = 10.08, B - V = +0.84, U - B = +0.58$ and the optical absolute magnitude-colour relation described in the forthcoming CNS4 (Jahreiß 2005), we derive a photometric distance of about 64 pc for this K0V star, six times larger than our spectroscopic distance to LP 731-76.

LP 709-85 (M 3 at 26 pc) and its fainter companion LP 709-68 (not part of our survey), LDS 3366 (sep. 150 arcsec), have significantly different proper motions (Zacharias et al. 2004), which may question their physical relationship at the given distance.

5.4. A possible new pair that was rejected

During the process of cross-identification of our sample stars with those of other recent distance determinations we realised that LP 931-53 (M 2.5 at 26 pc) seems to have a common proper motion companion, LP 931-54, which was found by Reid et al. (2003b) to lie at approximately the same distance (32 pc). The angular separation between the two NLTT stars is about 15 arcmin, their proper motions ($\mu_\alpha \cos\delta, \mu_\delta$) as given in the NLTT are $(-289, -333)$ and $(-133, -386)$ mas/yr for LP 931-53 and LP 931-54, respectively. Much more similar values, $(-286, -342)$ and $(-285, -387)$ mas/yr, can be found in the Yale/San Juan Southern Proper Motion catalogue (Platais et al. 1998). We have checked the proper motions of the two stars using all available SSS data (8 different epochs) combined with 2MASS and DENIS (Epchtein et al. 1997) positions, yielding $(-286, -350)$ and $(-150, -411)$ mas/yr with errors smaller than 10 mas/yr. Since these values confirm the different proper motions originally reported in the NLTT, we therefore reject our initial assumption that the two objects form a wide binary at the given distance and angular separation. However, they may be members of a stellar stream in the Solar neighbourhood.

5.5. Nearby candidates from Fleming (1998)

As already mentioned in Sect. 2.4, we have included a few stars previously found as nearby candidates by Fleming (1998) based on their X-ray fluxes. The above mentioned M 4.5 star, LP 323-169, as well as two other objects (G179-055; M 4 at 14 pc and G224-065; M 3.5 at 26 pc) were originally selected from the list of nearby candidates found by Fleming (1998). One more object contained in Fleming's list was selected independently by us as a nearby candidate and confirmed as such by our spectroscopy (LP 463-23; M 5.5 at 14 pc). In all four cases our spectroscopic distance estimates place these stars within or close to the 25 pc radius, in good agreement with the photometric distances predicted by Fleming. G179-055 was found to be a spectroscopic binary (Mochnacki et al. 2002). Further stars from Fleming (1998), with proper motions below the NLTT proper motion limit of 0.18 arcsec/yr, will be described in Paper IV.

5.6. Three nearby halo stars?

There are two stars, LHS 269 and LHS 436, which have spectroscopic distances within 25 pc and tangential velocities larger than 100 km s^{-1}. Both have been classified as mid-M dwarfs (M 5 and M 5.5). A very large tangential velocity ($\sim$ 175 km s^{-1}) was obtained for the M 4 dwarf LHS 105 at about 32 pc distance. Such high velocities may indicate a Galactic halo membership of these normal M dwarfs, although radial velocities are still lacking, and the space velocities could also be consistent with the thick disk population. Other normal (non-metal-poor) mid-M dwarfs with very large space motions were recently reported by Lépine et al. (2003).

5.7. Nearby K dwarfs or distant (sub)giants?

The earliest-type (K1) object in our sample of NLTT stars, BD+32°588 (Fig. 9), was initially identified as a nearby ($d \sim$ 22 pc) dwarf. The Hipparcos parallax, corresponding to a much larger distance ($d \sim 190$ pc), of this rather bright ($J \sim 6.2$) star only allows the alternative interpretation that it is in fact a high-velocity (v_t ∼ 170 km s^{-1}) early-K giant (see also Sect. 4.1). For other K stars, classified by us as nearby objects, our distances agree well with previous trigonometric parallax measurements. However, there are two other bright early-K stars, BD+26°2161A (J ∼ 6.4) and G204-045 (J ∼ 6.8), placed by our spectroscopic distances within 25 pc. Their spectra are also shown in Fig. 9. These two stars are still lacking accurate trigonometric parallaxes (the Tycho parallaxes of BD+26°2161A and its common proper motion companion have errors of ∼20% and ∼50%, respectively; see Sect. 5.2). We can not exclude their possible (sub)giant nature. All other objects in our sample are fainter and of later spectral type. Therefore, we do not expect to find more (sub)giants among these high proper motion stars.

6. Conclusions

Compared to the expected large numbers of missing stellar systems within the 25 pc horizon – about 2000 systems are known, whereas 3500 are missing according to Henry et al. (2002) – our study has investigated and uncovered only a small fraction of the unknown close neighbours to the Sun. Clearly, further efforts are needed to complete the 25 pc sample.

Among the nearest objects found, there are eight stars with distances smaller than 10 pc (see Sect. 5.1). For five of them, spectroscopic distances are published here for the first time. There are eight objects without any previous distance estimates that we find to be within 15 pc: LP 780-32 (M 4 at 10.7 pc), LP 64-185 (M 4 at 12.3 pc), LP 331-57 (M 3 at 12.7 pc), LHS 5140 (M 4 at 13.0 pc), G100-050 (M 5 at 13.6 pc), LP 278-42 (M 5.5 at 13.8 pc), G123-045 (M 4 at 14.1 pc), and G036-026 (M 5 at 14.3 pc). We have to keep in mind that some of our M 3 and M 4 dwarfs may be in fact M 3.5 dwarfs (see Sect. 3.2) and therefore located slightly nearer or farther, respectively. Out of all 322 objects in our sample, 138 did not have any previous distance determination.

With few exceptions, mainly concerning suspected subdwarfs, our distance estimates agree well with previously determined values. The distances of components in common proper motion systems are generally consistent with each other. However, there are two cases, LDS 6160 and LDS 4999, which need an additional check of the results, since our spectroscopic distance disagrees with a trigonometric distance. The distant K2 star LP 323-168 and the nearby M 4.5 dwarf LP 323-169, mentioned in the NLTT remarks as a possible common proper motion pair, are definitely not physically associated. LP 731-76 and BD−10°3166 (LDS 4041) can almost certainly be ruled out as a physical pair.

The maximum tangential velocity left after a 50% reduction of the largest distances in our sample is about 570 km s^{-1}, i.e. almost within the usual range for subdwarfs. The tangential velocities of the K and M subdwarfs listed in Gizis (1997) are all smaller than 500 km s^{-1} (typically between 200 and 400 km s^{-1}). An extremely large tangential velocity (580 km s^{-1}) was determined for the recently discovered sdM1.5 object, SSSPM J1530−8146 (Scholz et al. 2004). There is, however, one object with an uncertain sdK7 spectral type, at the spectroscopic distance of about 375 pc and with a tangential velocity larger than 1300 km s^{-1} reported by Lépine et al. (2003). With such an extra-ordinary high velocity this latter object, LSR 0400+5417, belongs no longer to the Galaxy. Adopting here again an absolute magnitude of $M_J = 6.9$ for sdK7 stars, we compute a somewhat smaller distance of 274 pc for this object based on its 2MASS J magnitude, which was not considered by Lépine, Rich & Shara (2003). This reduces the tangential velocity of LSR 0400+5417 to about 950 km s^{-1}, which is still a record value.

The relatively hot (∼DA3.5) white dwarf LHS 1200 is so faint that it must be located farther than 100 pc. A conservative distance estimate of 110 ± 20 pc based on SDSS photometry, its large proper motion and our radial velocity measurement lead to a very high heliocentric space velocity typical of Galactic halo members. We can not exclude that it is even hotter (DA3), and consequently at an even larger distance of about 150 pc, and with an even more extreme space velocity. Further investigation of this interesting object is needed.

About 85% of our M and K stars are found to lie within 30 pc, and 72% are within 25 pc. This is a high success rate, if we consider our preliminary photometric distances used for the selection of the spectroscopic targets as rough estimates only. We must also take into account that about one third of the objects beyond 30 pc were selected for other reasons than for their optical-to-infrared colours and for their corresponding photometric distance estimates. The high success rate indicates that a purely photometric selection based on all available photographic optical magnitudes combined with the meanwhile completed 2MASS data base may be worth doing.

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Online Material

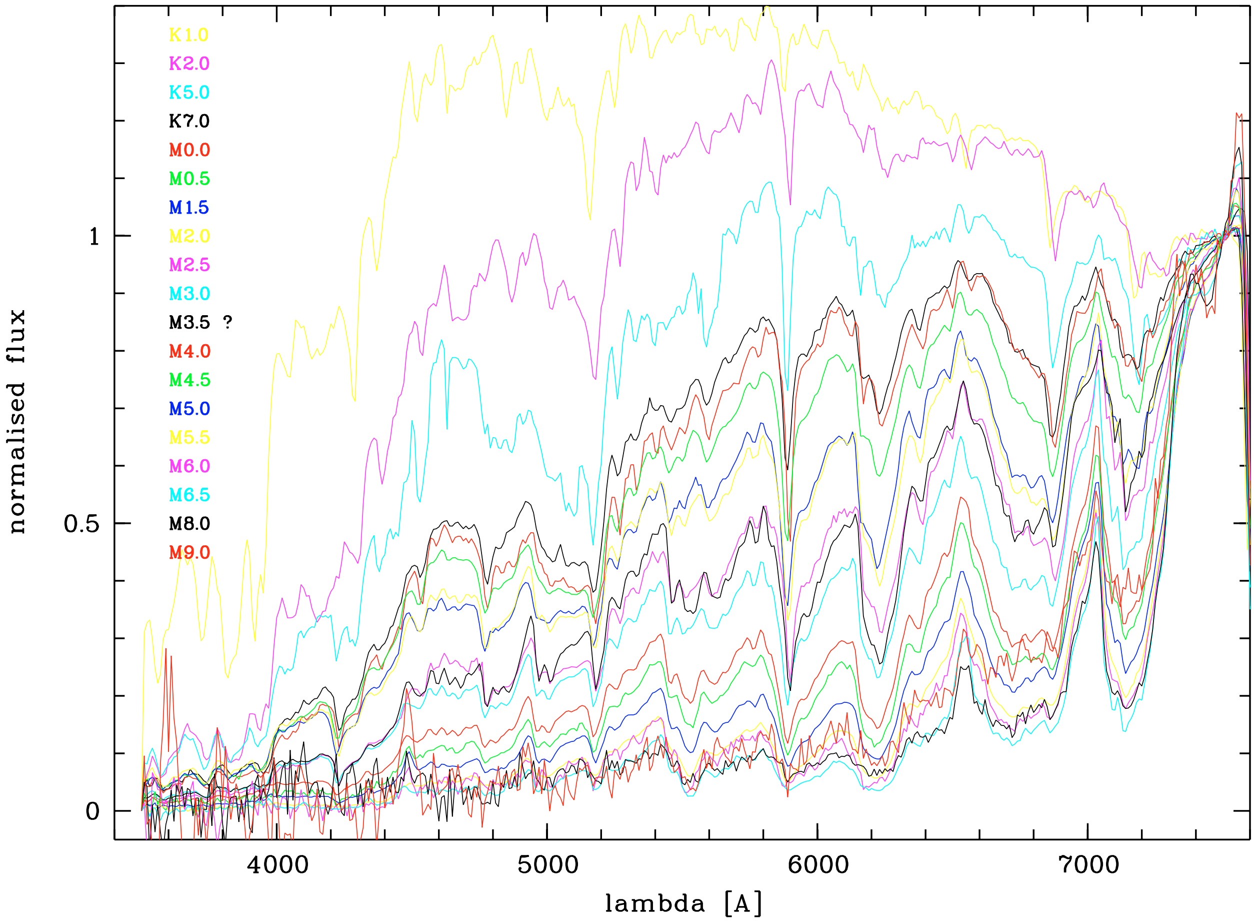

Fig. 13. Blue part of the standard spectra, normalised at 7500 Å, used for the classification of the targets. The spectra form a sequence with increasing spectral type. The only exception is the M 3.5 standard (Gl 273), which is more similar to M 2.5 in the spectral range shown.

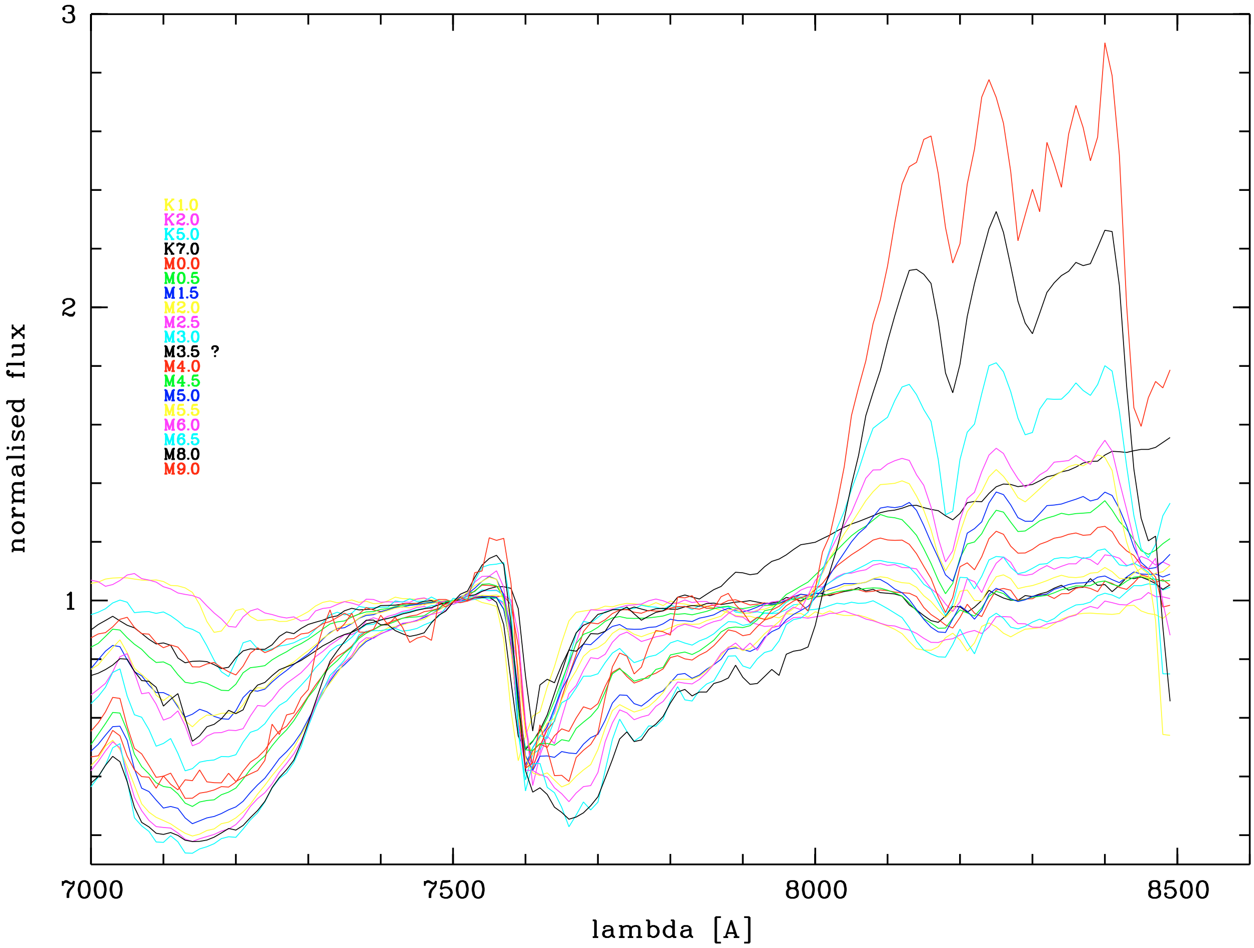

Fig. 14. Red part of the standard spectra, normalised at 7500 Å, used for the classification of the targets. Again, the spectra form a sequence with increasing spectral type, except for M 3.5 (Gl 273), which appears much too red in this spectral range.