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Companions of old brown dwarfs, and very low mass stars*

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Abstract. Up to now, most planet search projects have concentrated on F to K stars. In order to considerably widen the view, we have started a survey for planets of old, nearby brown dwarfs and very low mass stars. Using UVES, we have observed 26 brown dwarfs and very low mass stars. These objects are quite inactive and are thus highly suitable for such a project. Two objects were found to be spectroscopic binaries. Another object shows significant radial velocity variations. From our measurements, we conclude that this object either has a planetary-mass companion, or the variations are caused by surface features. Within the errors of the measurements, the remaining objects are constant in radial velocity. While it is impossible to strictly exclude an orbiting planet from sparsely sampled *RV* data, we conclude that it is unlikely that these objects are orbited by massive planets with periods of 40 days or less.

Key words. stars: binaries: spectroscopic – stars: low-mass, brown dwarfs – stars: planetary systems: formation

1. Introduction

Precise measurements of the radial velocity (*RV*) of stars have lead to the discovery of more than 100 extrasolar planets. From these surveys it is concluded that at least 3% of G to K stars harbor giant planets (Queloz et al. 2002). The true fraction is certainly higher than that, since the mass-function for planets rises steeply towards smaller masses, and planets in long-period orbits are difficult to detect in *RV*-surveys. Most of the efforts for detecting extrasolar planets have hitherto been concentrated on old, solar-like F-K stars. The next logical step is to widen the view in order to find out which properties of the central star influences the presence or absence of planets. An important parameter is of course the mass of the central star. Since detecting planets in orbit around massive stars is rather difficult, the surveys should be widened to include objects of much smaller mass. A few surveys for planets of M-stars are now underway. Marcy et al. (1998) have studied 24 M-dwarfs for 4 years, and found a planet with $M \sin i = 2.1\ M_{\rm J}$ in orbit around the M4 dwarf Gl 876 (0.32 $M_{\odot}$). Delfosse et al. (1998, 1999) have surveyed all known M-dwarfs within 9 pc, north of −17 declination, and brighter than 15th mag in *V*. In total, the sample contained 136 stars. The *RV*-measurements had an accuracy between 10 and 70 m/s, sufficient for detecting giant planets. Apart from the planet of Gl 876 which was found independently, no other planet was found. Nearby low-mass objects are also suitable for searching long-period planets astrometrically. However, theses surveys yieled upper limits. For example, using the HST Fine Guidance Sensors, Benedict et al. (1998) could exclude planets more massive than 0.3 $M_{\rm J}$ and with periods of ∼600 days in orbit around Proxima Centauri and Barnard's Star (0.10 and 0.12 $M_{\odot}$). An upper limit of the frequency of planets was also derived from microlensing data. Gaudi et al. (2002) conclude from an analysis of microlensing data that less than 33% of the M-dwarfs in the Galactic bulge have companions of 1.0 $M_{\rm J}$ between 1.5 and 4 AU. Up to now, all surveys of M-dwarfs have focused on stars with masses of 0.3 $M_{\odot}$, or so. This is only a factor three lower than the G-dwarf surveys. In order to really find out what the influence of the mass of central star is, it is thus necessary to go to objects of much lower mass. In here we report on a survey of very-low-mass stars (VLMSs) and brown dwarfs (BDs). All of them have masses of 0.1 $M_{\odot}$ or less. Surveys of visual companions of BDs already have identified a number of BD-BD companions (Martín et al. 2000; Lane et al. 2001; Kenworthy et al. 2001; Reid et al. 2001; Close et al. 2002a; Potter et al. 2002; Goto et al. 2002). Additionally, a spectroscopic BD-BD companion has also been found (Basri & Martín 1999). This binary consists of two BDs with masses of 0.06 to 0.07 $M_{\odot}$. The orbital period is 5.8 days, the eccentricity 0.4 ± 0.05. While the aim of this project is to find out whether BDs and VLMs have planets, we will briefly review the arguments for and against the presence of giant planets in orbit around such low-mass objects first.

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The first argument for the possible presence of planets in orbit around VLMSs and BDs is that these objects have accretion disks when they are young. This is the result of the work by Comerón et al. (2000), who find an excess of the emission at 6.7 μm for 4 out of 13 VLMSs and BDs in the Chamaeleon I star forming region. Muench et al. (2001) concludes from the *JHK* colour-colour diagram of the Trapezium Cluster in Orion that the disk-frequency of low-mass members of the cluster is 50%, or higher. An excess of infrared emission of low-mass objects was also observed with ISOCAM in the Chameleon I dark cloud (Persi et al. 2000). Young, low mass objects apparently not only have a passive disks but also show signs of accretion, and outflow activity like in T Tauri stars (Muzerolle et al. 2000; Martín et al. 2001; Fernández & Comerón 2001). Accretion from a disk seems to be present even for objects with a mass of only 8–12 M_J (Testi et al. 2002). We thus can conclude that many young brown dwarfs have disks but are theses disks massive enough to form *giant* planets?

Disks of T Tauri stars have typically about 3% of the mass of the central object. If this is also true for BDs, the total mass of a a typical BD disk would be only a few M_J. However, observation Cha Hα 2 at 9.8 and 11.9 μm show that the disks of BDs are not just scaled down versions of T Tauri star accretion disks (Apai et al. 2002). We thus have to wait until mm-wavelength observations become available, to find out what the true masses of the disks of young BDs are. On the other hand, a small mass of the central object may help the formation of giant planets, because the small mass of the central object will result in relatively larger Roche-Lobes and larger feeding zones at typical planetary masses.

Giant planets may form either by a gravitational instability of the disk, or by accreting disk-gas onto a solid core of a few earth-masses (see review in Lin et al. 2000; Ward & Hahn 2000; Wuchterl et al. 2000). Before the discovery of the first extrasolar planets, it was generally believed that most giant planets would be found close to the so called snow-radius. The idea was that since the growth-rates of planetesimals increases at the snow radius because the amount of condensed elements increases, giant planets would also be found there (Lunine & Stevenson 1988). At distances much larger than the snow-radius the formation of giant planet would then be very slow. After the discovery of massive planets close to the stars, a number of scenarios for their formation were proposed. Wuchterl (1993) argued that the accretion of massive envelopes of giant planets points to a favorable zone inside of 0.1 AU. Another idea was that massive planets form indeed close to the snow-radius but then migrate inwards (Trilling et al. 1998). According to Armitage & Bonnell (2002), orbital migration also causes the so called BD-desert. These authors argue that orbital migration depends on the ratio between the disk-mass and the mass of the planet, and since the mass of the accretion disk of a 1.0 $M_\odot$ star corresponds to the mass of a BD, the orbital migration would become so strong that such an object would fall into the star. If this is true, it would imply that giant planets of BDs could not exist, because the disk of a BD seems to be about 1.0 M_J.

The tidal interaction between the disk and the planet would always pull the planet *inward*, and we thus expect to find planets at the snow-radius, or at *smaller* distances from the star. The position of the snow-line has recently been calculated by Sasselov and Lecar (Sasselov & Lecar 2000). The snow-radius is at 0.6 AU for solar-mass star and a passive disk. Using the formula published by Sasselov & Lecar (2000), we find that the snow-line corresponds to orbital periods between 20, and 40 days in the case of VLMSs and BDs. It is interesting to note that the surface density at the snow-radius is roughly the same for the disk of a solar-like star, and the disk of a BD. Giant planets thus are expected to have periods of 40 days or less if they exist. A one M_J-planet in a circular orbit would induce *RV*-variations with a amplitude of 750 m/s. As discussed in Desidera (1999), a planet orbiting a BD at very small distances will be tidally disrupted. This gives us a lower limit for the orbital period. For a one M_J planet orbiting an old 0.070 $M_\odot$ BD, this limit corresponds to an orbital period of 15 hours. The *RV*-variations induced by such a planet would be 2800 m/s. In summary, if BDs have giant planets, we expect them to have orbital periods between about half a day and 40 days. The aim of this work is to search for such objects.

2. Observations

Suitable targets for our project are BDs and very late-type stars close to the sun. The spectroscopic observations were carried out with the Uv-Visual Echelle Spectrograph (UVES) on the VLT Unit telescope 2 (KUEYEN) in service mode. Because the objects are extremely red, we use the setting which covers simultaneously the wavelength regions from 6670 to 8545 Å, and 8640 to 10 400 Å. This wavelength regions also contains the telluric bands between 6860 to 6930 Å, and 7600 to 7700 Å which we used as a secondary wavelength reference. Before the introduction of the iodine-cell, the telluric lines were often used for similar purposes in the past. The accuracy and the limitations of the method thus have been investigated thoroughly: using the Kitt Peak 1-m Vacuum Fourier Transform Spectrometer, Balthasar et al. (1982) have studied the line-shift of eleven telluric O_2-line in detail. The shifts were found to be 15 m/s, or less. These results agree well with results of Smith (1982) who find that *RV*-measurements of stars have typical errors of 8 m/s if the telluric lines are used as wavelength reference. Caccin et al. (1985) confirm these results and find that the shifts are caused by the wind in the earth atmosphere.

Standard IRAF routines of the Echelle package were used to flat-field and wavelength calibrate the spectra using frames taken with the standard flat-field and Thorium Argon lamps. Since the objects are relatively faint, the extraction was done in a different manner than usual. In the first step we extracted each order as a two dimensional spectrum, then subtracted the sky-background in the two-dimensional images, and finally extracted the spectrum of the object. No rebinning was done in order to achieve the highest possible accuracy for the *RV*-measurements. Except for the sky-subtraction, the data was thus reduced in the same way as in our previous UVES observations (Joergens & Guenther 2001). In that run we took always two spectra of the same object directly after each other in order to remove cosmic rays. Because we always took two spectra per night, we could calculate the error from the scatter of the

Table 1. Observing log.

object	No. of spectra	spectral type	average S/N[d]
2MASSW J0832045 − 012835	2	L1.5	17, 25
2MASSW J0952219 − 192431[a]	1	M7	71
2MASSW J1237270 − 211748	3	M6	34, 33, 26
2MASSW J2013510 − 313651	3	M6	33, 37, 39
2MASSW J2049197 − 194432	3	M7.5	22, 25, 24
2MASSW J2052086 − 231809	3	M6.5	40, 43, 38
2MASSW J2113029 − 100941[c]	3	M6	30, 33, 30
2MASSW J2135146 − 315345	3	M6	32, 26, 40
2MASSW J2147446 − 264406	3	M7.5	20, 22, 22
2MASSW J2202112 − 110946	3	M6.5	31, 34, 34
2MASSW J2206228 − 204705[b]	3	M8	27, 39, 37
2MASSW J2306292 − 050227	2	M7.5	13, 54
BRI B0021 − 0214	3	M9.5	31, 25, 29
BRI B0246 − 1703	2	M8	26, 27
BRI B1104 − 1227	3	M6.5	59, 65, 60
BRI B1507 − 0229	3	M6	27, 16, 28
Denis − P J0021.0 − 4244	2	M9.5	26, 26
LHS 2065	3	M9	42, 62, 60
LHS 2397	4	M8	36, 38, 38, 37
LHS 292[c]	3	M6.5	187, 174, 185
LHS 3566	2	M8.5	64, 61
UScoCTIO − 055	2	M5.5	27, 44
UScoCTIO − 075	3	M6	24, 35, 28
UScoCTIO − 085	3	M6	27, 19, 28
UScoCTIO − 100	3	M7	33, 31, 26
LP 944 − 20	6	M9	51, 68, 67,
LP 944 − 20			65, 62, 67

[a] It was recently discovered that this object is a spectroscopic binary (Reid et al. 2002).
[b] This object recently turned out to be a visual binary with a separation of 4.1 ± 1.1 AU (Close et al. 2002b).
[c] In this work we show that this object is a spectroscopic binary.
[d] The S/N-ratios of the spectra are derived from the number of photons detected in the wavelength-region between 6700 and 8500 Å, and taking the read-out-noise into account.

measurements. The result was that the errors are 90 m/s for the brighter sources. However, the objects discussed in this paper are fainter, and the S/N-ratio is significantly lower than in our previous paper. Most of the *RV*-measurements are thus limited by the S/N-ratio to 200–300 m/s. Table 1 gives an overview of the observations.

3. Limits of the masses of companions

All except one of the 25 objects were observed at least twice. The results are listed in Table 2. The first column gives the name of the star, the second the heliocentric *RV* of the first spectrum. Listed in the third column is the time-difference between the first and the second spectrum. The fourth column gives the difference in *RV* between the two spectra as measured with the cross-correlation method. The last two columns are the same for the first and third spectrum. For determining the heliocentric *RV*, we had to measure the position of individual spectral lines, which is of course far less accurate than using the cross-correlation. The error of these values are 1.3 km s^{-1}. In the case of LHS 2397 four spectra where taken, and in the case of LP 944-20 six. Listed in Table 2 are always the time and *RV* differences to the first spectrum. The errors of the difference of *RV*s given in Table 2 are derived from the errors of the determination of the position of the telluric lines, and the photospheric lines of the two spectra. The errors of the difference of two *RV*s are thus larger than the determination of the *RV* for each of the objects. Nevertheless, since we used the cross-correlation, the errors are still much smaller than the error of the heliocentric *RV*. 2MASSW J2113029-100941, LHS 292 and 2MASSW J0952219-192431 will be discussed in the next section, and LP 944-20 will be discussed together with LHS 2065 in Sect. 5. In all other case the ΔRV is less than 3 Σ.

Deriving a unique upper limit for the masses of possible companions from the ΔRV-values is not possible, because the ΔRV-values depend on:

- the eccentricity of the orbit and if it is eccentric also on the node angle;
- the inclination of the orbit;
- the orbital period of the planet, and
- the orbital phase when the first observation was taken.

In order to avoid giving large tables for all possible combination of parameters, we prefer to discuss just a typical case. That is, we calculate the ΔRV-values for all phases, given the time-difference of the measurement, and mass of the central object. In order to limit the number of free parameters, we assume a round orbit. Given in the last column in Table 2 is then the mass of planet (m sin i) that would have been detected with a probability of ≥50%. As we outlined in the introduction, we expect that giant planets have periods of 40 days or less. We thus compute the upper limit for an orbital period of 40 days. However, that introduces the problem that the upper limit could not be derived for UScoCTIO-055, and UScoCTIO-075. In these two cases we thus use a period of 30 days. Except for BRI B1507-0229, the upper limits are a few M_J. However, because of all these restrictions, the upper limits given in Table 2 should not be taken as strict upper limits but as guidelines for the typical mass of companions that can be excluded. With just two or three *RV*-measurements there is always an orbit where $\Delta_{1,2,3} RV = 0$. but $m_{\rm companion}$ sin i is large. It is just that it is not likely that all planets of all BDs are in such orbits. We thus safely conclude that massive planets are not common for VLMSs and BDs. Possibly none of these objects is orbited by a massive planet with a period of 40 days.

Another interesting question is whether we can exclude a planet like the one of 51 Peg. The planet of 51 Peg has an m sin i of 0.47 M_J, and orbits the star with a period of 4.2 days. Although such a planet orbiting a 0.08 $M_\odot$ object would induce *RV*-variations with an amplitude of about 700 m/s, the sampling of the data allows to exclude such an object only in 10 of 23 objects (2MASSW J1237270-211748, 2MASSW J2049197-194432, 2MASSW J2113029-100941, 2MASSW J2135146-315345, BRI B0021-0214, Denis-P J0021.0-4244, 2MASSW J2013510-313651, LHS 2065, LHS 3566, UScoCTIO-085).

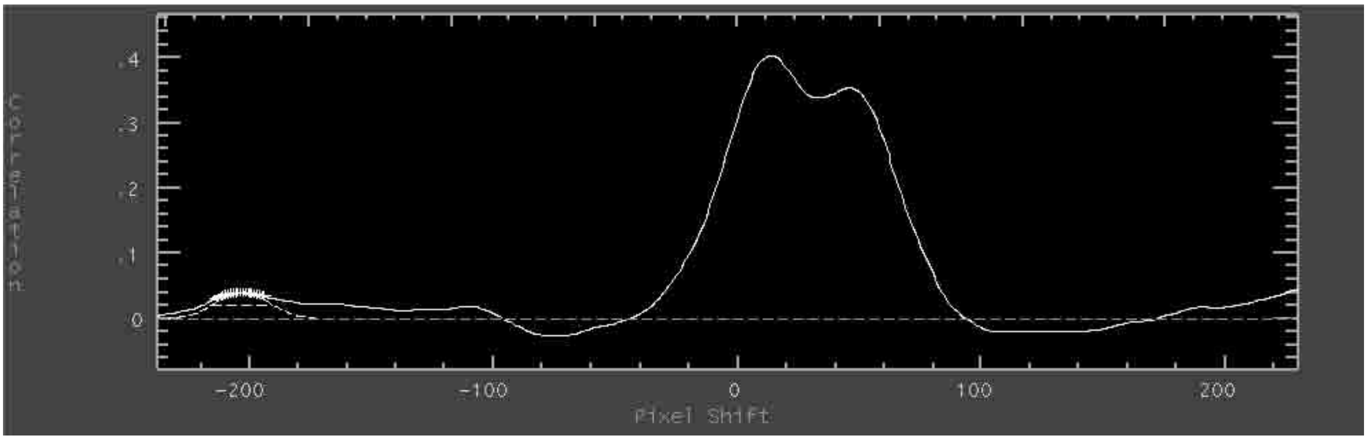

Fig. 1. Cross-correlation function of 2MASSW J2113029-100941, demonstrating that it is a double-line spectroscopic binary.

4. The spectroscopic binaries LHS 292, 2MASSW J2113-1009, and 2MAASSW J0952-1924

We took three spectra of the M6V-star 2MASSW J2113029-100941 at MJD 52106.317, 52115.107, and 52134.091. The first spectrum shows a nice Gaussian cross-correlation function. In the second spectrum the cross-correlation function is 4 km s^{-1} broader than in the first. The third spectrum then shows two peaks of about the same height and separated by 13 km s^{-1} (see Fig. 1). We thus conclude that 2MASSW J2113029-100941 is a double-line spectroscopic binary. Assuming an age of the order of 5 Gyrs and using the evolutionary tracks from Chabrier et al. (2000) the mass for both components are between 0.08 and 0.09 $M_{\odot}$. The distance is about 10 to 15 pc. From the separation of the peaks in the third spectrum we conclude that the orbital period has to be less than 3 years if the eccentricity is 0.4 or less.

As can be seen from Table 2, LHS 292 shows significant *RV*-variations. The first and the second spectrum of LHS 292 have about the same *RV*, and the cross-correlation peak has the same width. In contrast to this, the cross-correlation peak of the last spectrum is 10 km s^{-1} broader, asymmetric and the centre of mass is shifted by about 9 km s^{-1} in respect to the two other spectra. The lines are also shallower in the last spectrum than in the other two. The best explanation is that LHS 292 is also a double-line spectroscopic binary where one component is fainter than the other one. In this respect it is interesting to note that LHS 292 is known to show flare activity (Mullan & Mac Donald 2002) despite its old age.

Reid et al. (2002) recently discovered that 2MASSW J0952219-192431 is a double-line spectroscopic binary. We took just one spectrum of this star which shows only a single peak.

5. The two active objects LP 944-20 and LHS 2065

LP 944-20 (=BRI B0337-3535) is an isolated, non-accreting, BD identified through its Li abundance and low luminosity (Martín & Bouy 2002). The mass of LP 944-20 is estimated to be between 0.056 and 0.064 $M_{\odot}$, and its age is between 475 and 650 Myrs (Tinney & Reid 1998). Recent flux-measurements at 5, 9.8 and 11.9 μm do not show any excess emission (Apai et al. 2002), which implies that there is no disc. As pointed out by Tinney & Reid (1998), LP 944-20 is one of those very late type objects that are quite inactive despite their rapid rotation ($v \sin i$ of 28 km s^{-1}). The same conclusion can be drawn from our spectra. We also derive that the object is quite rapidly rotating($v \sin i = 32 \pm 4$ km s^{-1}) but no infrared CaII emission lines (λ 8498 Å, 8542 Å, 8662 Å) are seen. The X-ray emission in quiescence is so small that it has not been detected yet (Rutledge et al. 2000; Martín & Bouy 2002). On the other hand, the object is a non-thermal radio source (Berger et al. 2001), and a flare has been detected in the X-rays (Rutledge et al. 2000). Tinney & Tolley (1999) have detected small brightness variations of 0.04 mag. These are equivalent to $T_{\rm eff}$-variations of 20 K over the entire visible disc, or 400 K over 5% of the disc. Using the optical monitor of XMM, Martín & Bouy (2002) also find indication for a possible variability (standard deviation $\leq$0.08 mag).

We obtained six spectra of this object. The average heliocentric velocity is 8.3 ± 1.3 km s^{-1} which agrees well with 10.0 ± 2.0 km s^{-1} given by Tinney (1998). The ΔRV-values derived are given in Table 2. At first glance the object seems to be variable but a more detailed analysis is needed. The crucial question is whether the *RV*-variations are still consistent with the errors, or larger than that. As a first step we carefully derive the error of the measurements by cross-correlating the spectra of LP 944-20 with a number of different templates. We then derive the total error for each data-point from the scatter of these values, taking also the error of the telluric correction into account. Shown in Fig. 2 on the *X*-axis the *RV*-variations (absolute-value of the difference between the measured *RV* and the average *RV*), and the error of each measurement on the *Y*-axis. The leftmost dashed line in Fig. 2 shows the dividing line for 50%. That is, if the object is not variable, 50% of the data-points would be left of this line, and 50% right of it. However, 5 out of 6 measurements are right of this line. This indicates that the scatter of *RV*-variations is *larger* than errors of the measurements. The probability that this is just a coincidence is 0.09. For the rightmost line, it is expected that 0.3% of the data-points are right of this line and 99.7% are left of it. Again we find that 2 out of 6 measurements are on the line

Table 2. *RV*-measurements. Because the cross-correlation method is used and the absolute velocity of the templates is unknown, we give here only the differences in velocity between the first, and the other spectra.

object	RV[d] $[\mathrm{km\,s^{-1}}]$	Δt $1-2$ [days]	ΔRV $1-2$ $[\mathrm{km\,s^{-1}}]$	Δt $1-3$ [days]	ΔRV $1-3$ $[\mathrm{km\,s^{-1}}]$	upper limits for $m \sin i$ $[M_J]$[a]
2MASSW J0832045 − 012835	20.0	55.9	1.30 ± 1.23			4.0
2MASSW J1237270 − 211748	−8.7	35.1	−0.37 ± 0.14	71.6	0.14 ± 0.31	0.9
2MASSW J2013510 − 313651	−21.3	61.8	0.19 ± 0.30	71.6	0.33 ± 0.30	0.6
2MASSW J2049197 − 194432	−41.5	8.8	0.08 ± 0.30	27.8	0.26 ± 0.29	0.4
2MASSW J2052086 − 231809	34.4	8.8	−0.51 ± 0.33	27.8	−0.57 ± 0.31	2.2
2MASSW J2113029 − 100941	−6.4	8.8	−0.19 ± 0.52	27.8	0.54 ± 0.51	0.8
2MASSW J2135146 − 315345	17.7	62.9	0.75 ± 0.33	72.7	0.09 ± 0.34	0.5
2MASSW J2147446 − 264406	31.2	63.9	1.07 ± 0.52	75.7	0.99 ± 0.41	2.9
2MASSW J2202112 − 110946	−9.4	8.9	−0.75 ± 0.68	27.8	−0.99 ± 0.74	3.2
2MASSW J2206228 − 204705[c]	11.2	8.9	−0.65 ± 0.44	27.8	−0.53 ± 0.54	1.7
2MASSW J2306292 − 050227	–	9.8	useless			–
BRI B0021 − 0214	16.0	28.0	−0.18 ± 0.20	41.8	useless	0.6
BRI B0246 − 1703	5.6	34.9	0.58 ± 0.13			4.2
BRI B1104 − 1227	9.6	31.8	0.46 ± 0.17	56.8	useless	2.2
BRI B1507 − 0229	−37.7	10.1	−2.14 ± 2.90	27.1	−2.50 ± 2.8	8.4
Denis − P J0021.0 − 4244	3.7	43.9	−0.30 ± 0.27			2.3
LHS 2065	7.1	8.9	−1.13 ± 0.85	31.8	−0.26 ± 0.25	1.1
LHS 2397	33.1	29.8	−2.19 ± 0.75	38.7	−0.25 ± 0.99	
LHS 2397		51.7	−0.95 ± 0.88			3.4
LHS 292	1.7	40.0	9.38 ± 0.55	53.7	−0.10 ± 0.45	[f]
LHS 3566	−21.5	71.7	0.20 ± 0.27			1.1
UScoCTIO − 055	−5.4	20.0	0.75 ± 0.27			2.5[b]
UScoCTIO − 075	−5.3	20.0	−0.74 ± 1.47			2.5[b]
UScoCTIO − 085	−21.3	17.0	−0.35 ± 0.50	27.0	0.26 ± 0.40	0.9
UScoCTIO − 100	−3.6	19.0	2.16 ± 1.50	25.9	0.35 ± 1.50	1.0
LP 944 − 20[e]	8.9	23.9	−0.45 ± 0.14	24.9	−1.24 ± 1.44	
LP 944 − 20		35.0	0.37 ± 0.09	47.0	−1.06 ± 0.22	
LP 944 − 20		48.1	−0.52 ± 0.76			

[a] Upper limits of the mass of the companion assuming a planet in a circular orbit with a period of 40 days.
[b] With Δt of 20 days it makes no sense to compute an upper limit for a 40 day period, we thus use a 30 day period.
[c] This object recently turned out to be a visual binary with a separation of 4.1 ± 1.1 AU (Close et al. 2002b), which might have influenced the *RV* determination of this object. Reid et al. (2002) gives 8 ± 2.0 $\mathrm{km\,s^{-1}}$ as *RV* of Hα, and 16.3 ± 2.7 $\mathrm{km\,s^{-1}}$ for the photospheric lines. We find 10.8 ± 1.3 $\mathrm{km\,s^{-1}}$ which is in the middle of the two.
[d] Absolute *RV* of the first spectrum. Because this measurements where made by measuring individual lines, the accuracy is only 1.3 $\mathrm{km\,s^{-1}}$.
[e] Shown in the case of LP 944-20 are always the time, and velocity difference between the first, and the other five spectra. No upper limit is given, because the object shows *RV*-variations.
[f] This object is presumably a spectroscopic binary.

or even right of it. The probability that this is a chance coincidence is 0.0001. We thus conclude that the object shows *RV*-variations.

There are of course two possibilities: one is that this BD is in fact orbited by a planetary mass object. The other explanation is that the *RV*-variations are caused by spots. For stars in the Hyades, which have a similar age as LP 944-20, Paulson (2002) derived a relation between $v \sin i$ and the rms-scatter of the *RV*. For a $v \sin i$ of 30 $\mathrm{km\,s^{-1}}$, the rms-scatter of the *RV* of a star would be 80 m/s. The *RV*-variations of LP 944-20 are thus larger than those of stars of the same $v \sin i$. Saar et al. (1997) derived a relation between $v \sin i$, the filling factor, and the amplitude of the *RV*-variations. If we put in 1500 m/s for the amplitude of the variations, the filling-factor would be 9%. Such a large filling-factor is unusual for stars of the same age and $v \sin i$ as LP 944-20. A dark spot covering 9% of the surface of the star would not be consistent with the photometric measurements either. We can also use our spectra to measure the temperature fluctuations. As pointed out by Reid et al. (1995), the ratio of the fluxes in the 7042 to 7046 Å-band versus the flux in the 7126 to 7135 Å-band can be used for determining the temperatures of very late-type objects. In the original paper, this relation is derived only up to the spectral type M5. For spectral types later then M7, a similar relation can be derived. LP 944-20 has a temperature of about 2350 K which falls into the region where this relation between the flux-ratio and the temperature works well. We derived this ratio for all our spectra of LP 944-20, and find that the variations are $\leq 20 \pm 10$ K

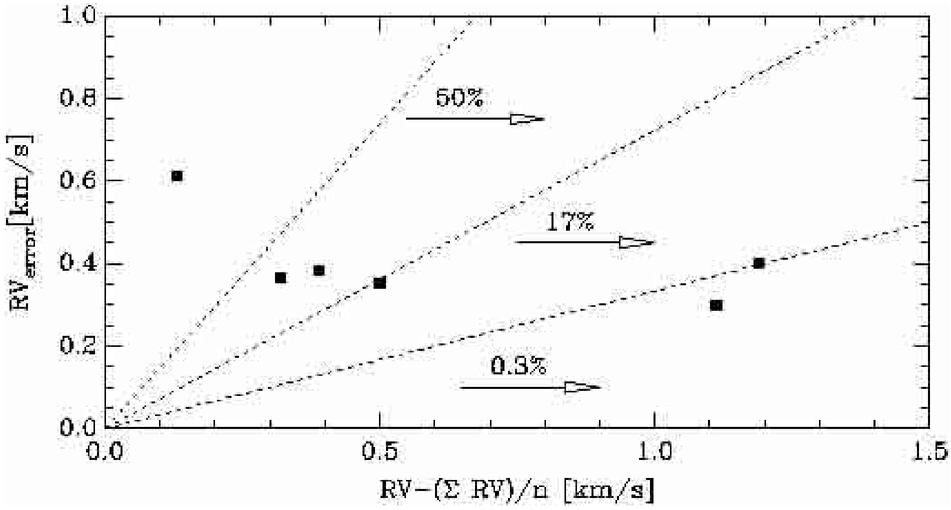

Fig. 2. Does LP 944-20 show significant *RV*-variations? Shown are the *RV*-measurements (mean value subtracted), versus the error of the *RV*. If LP 944-20 would be constant, only three of the points should be right of the 50%-line, and only one right of the 17%-line. However, we find that 5 out of 6 points are right of the first, and 3 are right of the 17%-line. Two are at, or even right the 0.3% line. The probability that this is a chance coincidence is 0.0001. We thus conclude that the *RV* of LP 944-20 is variable.

peak-to-peak. In agreement with previous photometric data, we thus conclude that there are no big spots on this object. On the other hand, one may envision that a BD looks more like a planet than a star. For example, Saturn has a jet-stream at the equator with a peak velocity of 500 m/s. If part of the jet-stream layers are covered by clouds, *RV*-variations would be induced without large variations of the brightness. We thus conclude that the *RV*-variations are either caused by surface features that do not resemble dark sunspots, or by an orbiting body. With our data it is of course entirely impossible to derive an orbit for the hypothetical object. If the companion would have a period of less than two years, its mass would be in the planetary regime ($\leq 13\ M_J$).

LHS 2065 is even more active than LP 944-20, as large flares have been observed in X-rays and in the optical on this object (Schmitt & Liefke 2002; Martín & Ardila 2001). The energy released in one of the X-ray flares exceeds even the largest solar flares by an order of magnitude. Like in LP 944-20 the temperature fluctuations of 26 ± 10 K peak-to-peak are small. With a distance of 8.5 pc (Monet 1992), this object also belongs to the nearest VLMSs. Despite the similarity to LP 944-20, we do not find significant *RV*-variations. The *RV* given by Tinney (1998) of 8.7 $\mathrm{km\,s^{-1}}$ agrees fairly well with the value that we derived of 6.6 ± 1.3 $\mathrm{km\,s^{-1}}$.

6. Discussion and conclusions

We have observed 25 BDs and VLMSs at least twice. Two objects turned out to be spectroscopic binaries, and another object which we took only one spectrum is also spectroscopic binary. The fraction of spectroscopic binaries in our sample of BDs and VLMSs thus is 12 ± 7%. For solar-type stars Abt & Levy 1976 finds that while 65% of the stars are binaries, only 9% have periods of 100 days or less. Although our sample is very small, we may conclude that the frequency of short-period binaries of VLMSs and BDs is roughly the same as that of solar-type stars. This result is also in good agreement with the results of Close et al. (2002b) who find the same fraction of visual binaries (separations of less than 3 AU) for low-mass objects (spectral types M8 and M9) and higher mass (spectral types M0 to M6) stars. The discovery of the spectroscopic BD-BD binary PPL15 (Basri & Martín 1999) and the numerous visual BD-BD binaries also points in the same direction.

Significant *RV*-variations where detected in LP 944-20. These variations could either be caused by an orbiting planet, or by surface features. Since LP 944-20 occasionally shows large flares, surface features induced by strong magnetic fields are a possibility. On the other hand, the small amplitude of the temperature variations implies that *RV*-variations are not caused by a normal star-spot. Additionally, LHS 2065 shows an even larger flare activity than LP 944-20, but does not show significant *RV*-variations.

For the other 19 objects, we do not find significant *RV*-variations. While it is impossible to strictly exclude an orbiting planet from sparsely sampled *RV*-data, we find that it is unlikely that these objects are orbited by planets with the mass of a few M_J, and periods of 40 days or less. This result is interesting because if VLMSs and BDs have giant planets, these are expected to have periods of 40 days or less. While it is certainly not possible to exclude the presence of massive planets in orbit around VLMSs and BDs, this work is another piece of evidence that a number of giant planets in orbit around low-mass objects is equal to or less than that of higher mass stars.

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