Mon. Not. R. Astron. Soc. **347,** 685–690 (2004)

An active M8.5 dwarf wide companion to the M4/DA binary LHS 4039/LHS 4040

R.-D. Scholz,[1]★ N. Lodieu,[1] R. Ibata,[2] O. Bienaymé,[2] M. Irwin,[3]
M. J. McCaughrean[1] and A. Schwope[1]

[1]*Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D–14482 Potsdam, Germany*
[2]*Observatoire de Strasbourg, 11, rue de l'Université, F–67000 Strasbourg, France*
[3]*Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA*

Accepted 2003 September 29. Received 2003 September 23; in original form 2003 August 14

ABSTRACT

Low-mass and brown dwarfs have recently been found as wide companions to many nearby stars, formerly believed to be single. Wide binaries are usually found as common proper motion pairs. Sometimes, more than two objects share the same large proper motion, identifying them as nearby systems. We have found a third, low-mass component to a known wide binary at a distance of ∼21 pc, consisting of a red and a white dwarf (LHS 4039 and LHS 4040; ∼150 au separation) The new companion, APMPM J2354-3316C separated by ∼2200 au, was classified as M8.5 dwarf. In recent spectroscopic observations, it shows a very strong Hα emission line and blue continuum. Comparing this event to flares in late-type M dwarfs, we find some similarity with LHS 2397a, a nearby M8 dwarf which is so far the only known example of a low-mass star with a tight brown dwarf companion (separation <4 au). The level of the activity as measured by $L_{\mathrm{H}\alpha}/L_{\mathrm{bol}}$ is comparable to that of the M9.5 dwarf 2MASSW J0149+29 both during the flare and in quiescence.

Key words: binaries: visual – stars: flare – stars: kinematics – stars: low-mass, brown dwarfs – white dwarfs – solar neighbourhood.

1 INTRODUCTION

Many wide common proper motion (CPM) pairs or systems containing three and more components have been identified in high proper motion (HPM) surveys [e.g. the Luyten Half-Second (LHS) catalogue of Luyten (1979)]. With proper motions as large as in the LHS catalogue, i.e. with more than 0.5 arcsec yr^{-1}, there is a high probability that such systems are nearby (d < 50 pc), so that their angular separations of a few arcsec to many arcmin translate to physical separations of about 10^2–10^5 au. These large separations result in orbital periods from a few thousand to millions of years.

The gravitationally bound wide binaries and systems are interesting because they can be considered as coeval. Their large separation guarantees an independent evolution and allows an undisturbed investigation of the components. CPM systems containing a white dwarf provide the advantage that the age of the system can be estimated from white dwarf cooling theories. In addition, the question of whether cool white dwarfs represent a significant fraction of the Galactic halo dark matter component can be studied with CPM systems that involve a white dwarf and a metal-poor M subdwarf (Silvestri, Oswalt & Hawley 2002).

Close, Richer & Crabtree (1990) estimated that at least 3 per cent of local stars should be members of wide CPM systems. However, they considered only relatively bright (M_V < 9.0) stars. Recently, many low-mass stars (Kirkpatrick et al. 2001a; Lépine, Shara & Rich 2002; Lowrance, Kirkpatrick & Beichman 2002) and brown dwarfs (Burgasser et al. 2000; Gizis, Kirkpatrick & Wilson 2001; Kirkpatrick et al. 2001b; Wilson et al. 2001; Scholz et al. 2003) have been discovered as wide companions to nearby stars of spectral types F to K, whereas no new stellar or substellar companions have been found at wide separations around M dwarfs within 8 pc (Hinz et al. 2002).

The search for new HPM objects in the southern sky started as a survey of a few thousand square degrees using automatic plate measuring (APM) data of United Kingdom Schmidt Telescope (UKST) plates (Scholz et al. 2000, 2002a; Reylé et al. 2002) and aimed to complete the HPM catalogues (e.g. Luyten 1979) at fainter magnitudes, and thus to find still missing nearby low-luminosity objects. This survey, which was later extended to the whole southern sky using SuperCOSMOS Sky Survey (SSS) data (Hambly et al. 2001a; Hambly, Irwin & MacGillivray 2001b; Hambly et al. 2001c), concentrated on the search for nearby free-floating brown dwarf candidates (Lodieu, Scholz & McCaughrean 2002; Scholz & Meusinger 2002). It also led to the discovery of new CPM objects, such as one of the nearest (estimated distance 10–15 pc) cool white dwarf

---

★E-mail: rdscholz@aip.de

pairs (Scholz et al. 2002b) and the nearest brown dwarf, ε Indi B (Scholz et al. 2003), with the distance of 3.626 pc known from the *Hipparcos* parallax measurement of its primary, ε Indi A (ESA 1997).

The object described here, APMPM J2354-3316C, was discovered as a nearby field brown dwarf candidate (based on its large proper motion and photographic photometry), and was subsequently identified as a CPM object to an already known wide binary, consisting of a mid-M dwarf and a white dwarf. To our knowledge, this is the first dM/WD pair complemented by a third, late-M dwarf component with all three components being widely separated and well suited for detailed follow-up observations.

2 BROWN DWARF COMPANION TO RED DWARF/WHITE DWARF BINARY?

2.1 Common proper motion

APMPM J2354-3316C was first detected in the HPM survey using APM measurements at only two epochs in different passbands (UKST B_J and R plates; for details of this survey, we refer the reader to the paper by Scholz et al. 2000) and later rediscovered in the SSS-based survey for nearby brown dwarf candidates (with additional R and I band data at different epochs; see Lodieu et al. 2002 and Scholz & Meusinger 2002 for a brief description of the search technique). It can also be found in the recently published HPM catalogue of Pokorny, Jones & Hambly (2003), produced by using SSS data covering the South Galactic Cap.

The CPM pair LHS 4039/LHS 4040 was easily identified by inspecting the finding charts at different epochs. These stars are separated by only about 103 arcsec and show the same large proper motion as APMPM J2354-3316C (about 0.5 arcsec yr^{-1} with a position angle of about 220°). Two more recent finding charts, one in the optical B band taken with the European Southern Observatory (ESO) 3.6-m telescope and one in the near-infrared K_s band taken from Two Micron All Sky Survey (2MASS) quick-look images, are shown in Figs 1 and 2, respectively. The extremely red optical-to-infrared colour of the brown dwarf candidate APMPM J2354-3316C is remarkable, especially if compared with the blue white dwarf LHS 4040.

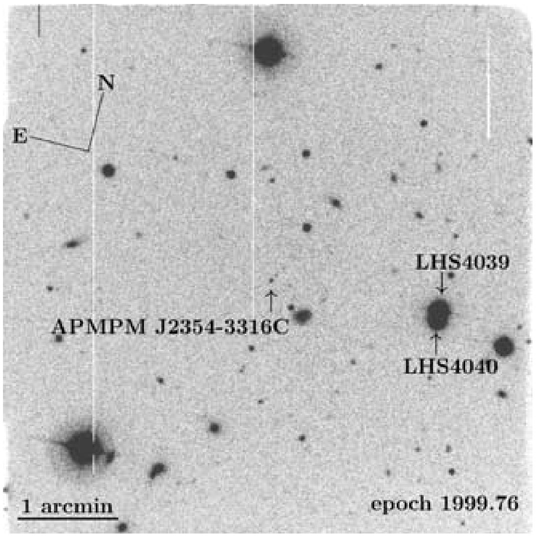

Figure 1. Optical finding chart for APMPM J2354-3316C (acquisition image from 1999 taken with the ESO 3.6-m telescope with a g filter). Also marked are the M4 dwarf LHS 4039 and the DA5 white dwarf LHS 4040.

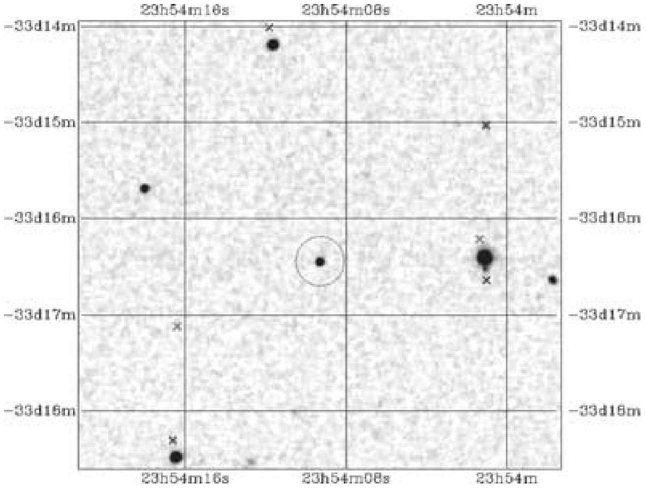

Figure 2. 2MASS K_s band quick-look image of APMPM J2354-3316C. In this near-infrared image (epoch 1999.57), the brown dwarf candidate (circled) appears much brighter than its white dwarf primary, LHS 4040 (compare with Fig. 1).

The CPM pair L577-71/L577-72 was discovered by Luyten (1941) during his Bruce proper motion survey and listed as LHS 4039/LHS 4040 in the LHS catalogue (Luyten 1979). Luyten (1949) already described the pair as one containing a white dwarf. A first classification of the blue component as a DA white dwarf is given by Luyten (1952). More recent spectral classification was provided by Oswalt, Hintzen & Luyten (1988), where LHS 4039 and LHS 4040 are listed as dM4 and DA5+, respectively.

With additional epoch observations now available from the 2MASS point source catalogue (Cutri et al. 2003) and the second release of Deep Near-Infrared Survey (DENIS) data,[1] we were able to improve the proper motion measurements of APMPM J2354-3316C further. Using the multi-epoch positions given in Table 1, we obtained a proper motion of

$$\mu_\alpha \cos\delta = -327 \pm 07, \quad \mu_\delta = -382 \pm 11 \text{ (mas yr}^{-1}\text{)}.$$

We also obtained a new proper motion measurement for the two primaries, LHS 4039 and LHS 4040, which was complicated by the fact that their images were unresolved on all Schmidt plates. Whereas the values given in Reylé et al. (2002) for the unresolved pair did not deviate much from Luyten's data (Luyten 1979), there is a big difference between the original LHS proper motion and that of the revised LHS data (Bakos, Sahu & Nemeth 2002). Pokorny et al. (2003) have not included the pair in their catalogue. Our new positions of LHS 4039 and LHS 4040, as measured visually in the corresponding SSS FITS images with the ESO SKYCAT tool, are given in Table 1. Using these positions plus one from 2MASS, we obtained the following proper motions (confirming the original LHS values):

$$\mu_\alpha \cos\delta = -307 \pm 08, \quad \mu_\delta = -410 \pm 08 \text{ (mas yr}^{-1}\text{)},$$

$$\mu_\alpha \cos\delta = -326 \pm 21, \quad \mu_\delta = -390 \pm 13 \text{ (mas yr}^{-1}\text{)},$$

for LHS 4039 and LHS 4040, respectively.

---

[1] Now available at http://vizier.u-strasbg.fr/viz-bin/Cat?B/denis

Table 1. Positions and photometry of APMPM J2354-3316C, LHS 4039 and LHS 4040 at different epochs.

Epoch (yr)	APMPM (J2000)	LHS 4039 (J2000)	LHS 4040 (J2000)	APMPM (mag)	LHS 4039 (mag)	LHS 4040 (mag)	(s)
1980.546	$23^{h}54^{m}09^{s}.77\ -33^{\circ}16'19''.3$	$23^{h}54^{m}01^{s}.56\ -33^{\circ}16'16''.5$	$23^{h}54^{m}01^{s}.58\ -33^{\circ}16'23''.2$	$B_J = 22.20$	–	–	1
1988.787	$23^{h}54^{m}09^{s}.57\ -33^{\circ}16'22''.2$	$23^{h}54^{m}01^{s}.36\ -33^{\circ}16'19''.6$	$23^{h}54^{m}01^{s}.37\ -33^{\circ}16'26''.7$	$R = 19.24$	–	–	1
1994.855	$23^{h}54^{m}09^{s}.39\ -33^{\circ}16'25''.0$	$23^{h}54^{m}01^{s}.20\ -33^{\circ}16'22''.3$	$23^{h}54^{m}01^{s}.19\ -33^{\circ}16'28''.6$	$I = 16.57$	–	–	1
1996.608	$23^{h}54^{m}09^{s}.35\ -33^{\circ}16'25''.3$	$23^{h}54^{m}01^{s}.18\ -33^{\circ}16'23''.1$	$23^{h}54^{m}01^{s}.20\ -33^{\circ}16'29''.5$	$R = 19.30$	–	–	1
1999.574	$23^{h}54^{m}09^{s}.29\ -33^{\circ}16'26''.6$	$23^{h}54^{m}01^{s}.09\ -33^{\circ}16'24''.2$	$23^{h}54^{m}01^{s}.07\ -33^{\circ}16'30''.8$	$J = 13.05$	$J = 9.45$	$J = 13.96$	2
				$H = 12.37$	$H = 8.91$	$H = 13.86$	2
				$K_s = 11.88$	$K_s = 8.61$	$K_s = 13.73$	2
2000.682	$23^{h}54^{m}09^{s}.24\ -33^{\circ}16'27''.0$	–	–	$I = 16.00$	–	–	3
				$J = 13.13$	–	–	3
				$K = 11.83$	–	–	3
2000.745	$23^{h}54^{m}09^{s}.24\ -33^{\circ}16'26''.7$	–	–	$I = 16.05$	–	–	3
				$J = 13.03$	–	–	3
				$K = 11.96$	–	–	3

Notes: The last column gives the source of the data: 1 = SSS (photographic magnitudes), 2 = 2MASS, 3 = DENIS. Additional photometry of APMPM J2354-3316C ($R_C = 18.36$, $I_C = 16.15$, $J_s = 13.21$, $H = 12.61$, $K_s = 12.10$) was obtained from service observations with VLT-FORS1 and VLT-ISAAC in 2000 May. Entries with no value (–) show a lack of data (merged images).

The proper motions of APMPM J2354-3316C and LHS 4040 agree well within the errors, whereas that of LHS 4039 deviates from the common proper motion of those two by ∼20–30 mas yr^{-1}. This is not unexpected, because the orbital motion of LHS 4039 around LHS 4040 leads to a differential proper motion of 20–24 mas yr^{-1}, whereas that of APMPM J2354-3316C around LHS 4039/LHS 4040 yields only about 6–7 mas yr^{-1}. This assumes circular orbits in the plane of the sky, a distance of 21 pc, a mass of 0.5–0.8 $M_{\odot}$ for LHS 4040 (Wegner & Reid 1991; Bergeron, Liebert & Fulbright 1995) and masses of 0.2 and 0.1 $M_{\odot}$, respectively, for LHS 4039 and APMPM J2354-3316C.

2.2 Photometry

The photographic photometry served for the preliminary classification of APMPM J2354-3316C as a brown dwarf candidate and more accurate optical and near-infrared photometry from Very Large Telescope (VLT), 2MASS and DENIS observations are listed in Table 1. Also given is the 2MASS photometry for LHS 4039/LHS 4040. Unfortunately, this pair was unresolved in DENIS observations.

Although a trigonometric parallax measurement of the previously well-known pair LHS 4039/LHS 4040 is not available, one can independently estimate the distance of the individual components of the CPM system from photometric and spectroscopic observations. We obtain a spectroscopic distance of about 15 pc for LHS 4039, adopting the spectral type M4 (Oswalt et al. 1988) and using the absolute near-infrared magnitudes of M4 dwarfs given in Kirkpatrick & McCarthy (1994). A more conservative photometric distance estimate of about 21 pc is given in the ARICNS data base of nearby stars (http://www.ari.uni-heidelberg.de/aricns/), where a spectral type of M3.5 is assigned to this object. On the other hand, Silvestri et al. (2001) obviously apply a distance of 14 pc for LHS 4039/LHS 4040, referring to Smith (1997), but list LHS 4039 with an even later spectral type of dM5, which should place it even closer.

From our spectroscopic classification of APMPM J2354-3316C as an M8.5 dwarf (see next section), we obtain a spectroscopic distance of about 19.5 pc if we compare the 2MASS JHK_s magnitudes with the mean absolute magnitudes of two single M8.5 dwarfs given in Dahn et al. (2002). Our more uncertain near-infrared classification as an M8 dwarf would place the object at about 25 pc distance (from comparison with four M8 dwarfs in Dahn et al. 2002). These results for APMPM J2354-3316C are in good agreement with the ARICNS distance estimate of LHS 4039. Therefore, we adopt the distance of 21 pc for the wide triple system.

3 SPECTROSCOPIC CLASSIFICATION

The first optical spectra of APMPM J2354-3316C were taken with the ESO 3.6-m/EFOSC2 camera on 1999 October 3. The data reduction involved subtracting an averaged dark frame and dividing by an internal flat-field to remove fringes above 8000 Å. Wavelength calibration was made using He and Ar lines throughout the whole wavelength range. Flux calibration was achieved using an averaged sensitivity function created from a spectrophotometric standard star observed on the same night.

Two optical spectra – one of lower resolution taken with grism#1 (4000–10000 Å), not shown here, and one with grism#12 (6000–10000 Å), shown in Fig. 3 – were similar and typical of a very late-type M dwarf with a weak indication of Hα emission in the grism#12 spectrum. In the latter spectrum (exposure time 900 s), the object was classified as M8.7 using the PC3 index of Martín et al. (1999) and as M8.3 using spectral indices of Kirkpatrick et al. (1999). Visual comparison with template spectra (M7.5 to M9.5) from Kirkpatrick et al. (1999), Gizis et al. (2000) and Reid et al. (1999),[2] as well as with a large number of late-type M dwarfs observed during different runs with the same instrument set-up at the ESO 3.6-m telescope (Lodieu et al., in preparation), also lead to a classification between M8 and M9. Therefore, we adopted a spectral type of M8.5 from the optical spectroscopy.

On 2001 November 25, we took a near-infrared spectrum (0.94–2.5 μm, total exposure time 300 s) of APMPM J2354-3316C with the SOFI camera at the ESO New Technology Telescope (NTT). For details on the near-infrared data reduction, we refer to Scholz et al. (2003). Comparison with near-infrared standard spectra provided by Sandy Leggett[3] led to a classification of M8 with an error of half a subclass, which is consistent with the optical classification. We prefer the optical classification because the optical

---

[2] Available at http://dept.physics.upenn.edu/∼inr/ultracool.html

[3] ftp://ftp.jach.hawaii.edu/pub/ukirt/skl/

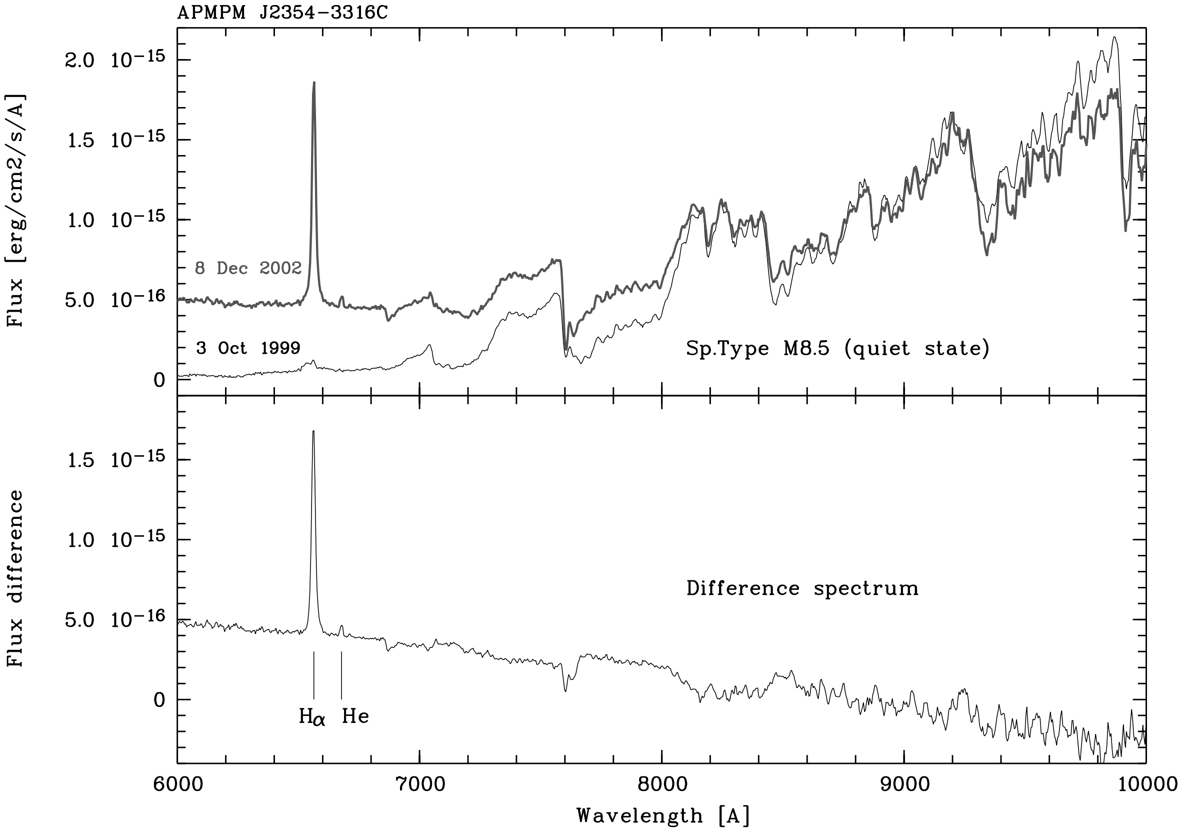

Figure 3. Upper panel: flux-calibrated spectra of APMPM J2354-3316C in quiet state from 1999 (thin line) and with strong Hα emission in 2002 (thick line). Lower panel: the difference spectrum is a perfect blue veiling continuum, plus Hα at 6563.8 Å and He I at 6678.1 Å in emission, with equivalent widths of 61.4 ± 5.0 and 2.3 ± 0.5 Å, respectively.

classification scheme is generally accepted as the more accurate one.

4 A SPECTACULAR FLARE EVENT

A new optical spectrum of APMPM J2354-3316C was taken again with grism#12 using the ESO 3.6-m/EFOSC2 camera on 2002 December 8 (eposure time 540 s). Both flux-calibrated spectra are overplotted in the upper part of Fig. 3, whereas the lower part of Fig. 3 shows the result after subtracting the old spectrum from the new one.

The difference between the two spectra of the same object taken with the same instrument setup is striking. Not only does the recent spectrum exhibit a very strong Hα emission line with an equivalent width of 61.4 ± 5.0 Å, there is also a very strong blue continuum. Many other late-type M dwarf spectra were taken during that night, and none of them exhibited a blue continuum; hence an instrumental effect causing the blue continuum can be excluded. Although the instrumental response curve is somewhat uncertain above 8500 Å, we think the decline of the difference spectrum below zero longward of 9000 Å is also real. A similar difference spectrum was observed for 2MASSW J0149+29 and the depressed red flux was attributed to an apparent increase of the opacity during the flare (Liebert et al. 1999). For 2MASSW J0149+29, Liebert et al. (1999) could also demonstrate the weakening of the blue slope of the excess flare continuum with time.

Unfortunately, no other spectrum was taken in the night of 2002 December 8, so we do not know how long the event lasted. We assume it to be a spectacular flare similar to those in other late-type field M dwarfs. We do not consider here very young late-type dwarfs as observed in clusters (e.g. Barrado y Navascues et al. 2002). An overview of the flare activity at the cool end of the field M dwarfs is given by Martín & Ardila (2001). Among 10 known late-M (M7-M9.5) flare stars, there seem to be only two with a strong blue continuum veiling the molecular features during the flare. One of them is the M8 dwarf LHS 2397a (Bessel 1991); the other is 2MASSW J0149+29 (Liebert et al. 1999). In contrast to LHS 2397a and APMPM J2354-3316C, 2MASSW J0149+29 was observed to have a rich emission spectrum and relatively weak blue veiling. Compared to LHS 2397a, APMPM J2354-3316C shows an even stronger blue veiling and also a very strong Hα line. In addition to Hα emission, we also identify a He I emission line at 6678 Å with an equivalent width of 2.3 ± 0.5 Å during the flare.

We have measured the flux of the Hα line in the flare spectrum (2.8×10^{-14} erg cm^{-2} s^{-1}) and in the quiescence spectrum (5.0×10^{-16} erg cm^{-2} s^{-1}). Assuming a distance of 21 pc, we get a $L_{\mathrm{H}\alpha}$ of about 1.5×10^{27} erg s^{-1} during the flare and about a factor of 60 less in quiescence. Using absolute bolometric magnitudes of two M8.5 dwarfs given in Dahn et al. (2002), we get a mean bolometric luminosity of $L_{\mathrm{bol}} = 1.1 \times 10^{30}$ erg s^{-1}. The resulting values of $L_{\mathrm{H}\alpha}/L_{\mathrm{bol}}$ of about 0.0014 in the flare and of about 0.000024 in quiescence are similar to the values given by Liebert et al. (1999) for the M9.5 dwarf 2MASSW J0149+29 (0.0025 and 0.000025, respectively).

The slope of the difference spectrum shown in Fig. 3 is even steeper than in the highest flare state of 2MASSW J0149+29 (see top in fig. 3 of Liebert et al. 1999) by about a factor of 2. This indicates an even stronger heating of the photosphere during the flare in APMPM J2354-3316C. The slope of the strong blue continuum in LHS 2397a (fig. 10 in Bessel 1991) seems also to be steep but cannot be measured accurately because of the low signal-to-noise and the smaller wavelength interval shown. For details on the possible origin of the blue continuum, we refer the reader to the discussion by Liebert et al. (1999).

5 DISCUSSION

We have found a low-mass companion to a red dwarf/white dwarf wide pair at a separation of about 2200 au. The optical spectroscopy classifying the new CPM component as an M8.5 dwarf leads to an independent distance estimate of 19.5 pc, which is in good agreement with the photometric distance estimate of the two previously known CPM components of 21 pc given in the ARICNS data base. Much closer distance estimates of about 15 pc (e.g. Smith 1997; Silvestri et al. 2001) may be the result of a wrong classification (later than M3.5) of the red dwarf CPM component LHS 4039.

In only one of our optical spectroscopic observations, the newly detected object showed a remarkably strong Hα (plus weak He I) emission line together with a very blue continuum. A similar spectrum, although with lower signal-to-noise, has been observed in the nearby M8 dwarf, LHS 2397a, which is so far the only known example of a low-mass star with a tight brown dwarf companion (separation less than 4 au) (Freed, Close & Siegler 2003). Compared with another late-type (M9.5) dwarf with a spectacular flare (2MASSW J0149+29), the flare spectrum of APMPM J2354-3316C shows an even steeper blue continuum, but a less diverse emission line spectrum.

The spectrum obtained at the epoch of the flare event shows some similiarity with the spectrum of a cataclysmic variable (CV); it resembles, for instance, that of the low-accretion rate dwarf nova RBS1955 (Schwope et al. 2002). The complete absence of the blue component in APMPM J2354-3316C at times, however, rules out a possible nature as a CV-like object. Even for a very cool white dwarf primary, a hypothetical old CV would not have escaped detection with our low-resolution spectroscopy. The accurate (non-photographic) multi-epoch $IJHK_s$ photometry (see Table 1) does not hint at strong variability.

APMPM J2354-3316C was in the field of view of an X-ray observation with *XMM–Newton* (Revolution 369, ObsId 0103461101, Principal Investigator: Aschenbach, observation date 2001 December 13). The target of the X-ray observations was a comet (C2000 WM1), which was detected as a bright extended X-ray and optical source in the European Photon Imaging Camera (EPIC) and Optical Monitor (OM) images. APMPM J2354-3316C is located behind the bright extended structure in those images, which prevents a proper source search. However, inspection of the images reveals that no X-ray point source is detected at the position of APMPM J2354-3316C. A rough upper limit of the X-ray count rate in the 0.2–12 keV band is derived from the noise properties of the X-ray image at the target position, $<4 \times 10^{-4}$ s^{-1}. Assuming an unabsorbed Raymond–Smith plasma of 1 keV, the count rate converts to $F_X < 6 \times 10^{-16}$ erg cm^{-2} s^{-1} and $L_X < 3 \times 10^{25}$ erg s^{-1}. Hence, APMPM J2354-3316C was clearly in an inactive state at the time of the X-ray observation.

The CPM pair LHS 4039/LHS 4040 has an estimated age of about 1.8 Gyr (Silvestri et al. 2001), and we may assume APMPM J2354-3316C to have the same age. Gizis et al. (2000) have shown that, contrary to the well-known stellar age–activity relationship, older late-type field stellar dwarfs seem to be more active than younger field (brown) dwarfs. However, they have also found none of the late-M dwarfs (M7 or later) to be very active, as measured by the ratio of Hα to bolometric luminosity. In that respect, APMPM J2354-3316C is similar to other late-type dwarfs – as, for example, 2MASSW J0149+29.

ACKNOWLEDGMENTS

This paper is based on observations collected with the ESO VLT, NTT and 3.6-m telescope, Chile. We would like to thank Hartmut Jahreiß for information on LHS 4039/LHS 4040. This work is based on measurements of UKST plates with the APM machine at the Institute of Astronomy, University of Cambridge, UK, with the SuperCOSMOS machine at the Wide-Field Astronomy Unit of the Institute for Astronomy, University of Edinburgh, and on observations collected at the European Southern Observatory, Chile (ESO No. 64.H-0417, 65.L-0689, 68.C-0664, 70.C-0568). We acknowledge the use of the SIMBAD data base and the VizieR service operated at the CDS Strasbourg and of data products from the 2MASS, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Centre/California Institute of Technology, funded by the NASA and the NSF. Finally, we would like to thank the anonymous referee for his useful comments.

REFERENCES

Bakos G. A., Sahu K. C., Nemeth P., 2002, ApJS, 141, 187

Barrado y Navascues D., Zapatero Osorio M. R., Martìn E. L., Béjar V. J. S., Rebolo R., Mundt R., 2002, A&A, 393, L85

Bergeron P., Liebert J., Fulbright M. S., 1995, ApJ, 444, 810

Bessel M. S., 1991, AJ, 101, 662

Burgasser A. J. et al., 2000, ApJ, 531, L57

Close L. M., Richer H. B., Crabtree D. R., 1990, AJ, 100, 1968

Cutri R. M. et al., 2003, The 2MASS All-Sky Catalog of Point Sources. Univ. Massachusetts and Infrared Processing and Analysis Centre (IPAC/California Institute of Technology)

Dahn C. C. et al., 2002, AJ, 124, 1170

ESA, 1997, *Hipparcos* and Tycho catalogues. ESA-SP 1200

Freed M., Close L. M., Siegler N., 2003, ApJ, 584, 453

Gizis J. E., Monet D. G., Reid I. N., Kirkpatrick J. D., Liebert J., Williams R. J., 2000, AJ, 120, 1085

Gizis J. E., Kirkpatrick J. D., Wilson J. C., 2001, AJ, 121, 2185

Hambly N. C. et al., 2001a, MNRAS, 326, 1279

Hambly N. C., Irwin M. J., MacGillivray H. T., 2001b, MNRAS, 326, 1295

Hambly N. C., Davenhall A. C., Irwin M. J., MacGillivray H. T., 2001c, MNRAS, 326, 1315

Hinz J. L., Mc Carthy D. W., Jr, Simons D. A., Henry T. J., Kirkpatrick J. D., Mc Guire P. C., 2002, AJ, 123, 2027

Kirkpatrick J. D., McCarthy D. W., 1994, AJ, 107, 333

Kirkpatrick J. D. et al., 1999, ApJ, 519, 802

Kirkpatrick J. D., Liebert J., Cruz K. L., Gizis J. E., Reid I. N., 2001a, PASP, 113, 814

Kirkpatrick J. D., Dahn C. C., Monet D. G., Reid I. N., Gizis J. E., Liebert J., Burgasser A. J., 2001b, AJ, 121, 3235

Lépine S., Shara M. M., Rich R. M., 2002, AJ, 123, 3434

Liebert J., Kirkpatrick J. D., Reid I. N., Fisher M. D., 1999, ApJ, 519, 345

Lodieu N., Scholz R.-D., McCaughrean M. J., 2002, A&A, 389, L20

Lowrance P. J., Kirkpatrick J. D., Beichman C. A., 2002, ApJ, 572, L79

Luyten W. J., 1941, The Bruce Proper Motion Survey. Univ. Minnesota Press, Minneapolis

Luyten W. J., 1949, ApJ, 109, 528

Luyten W. J., 1952, ApJ, 116, 283

Luyten W. J., 1979, LHS Catalogue, 2nd edn. Univ. Minnesota Press, Minneapolis

Martín E. L., Ardila D. R., 2001, AJ, 121, 2758

Martín E. L., Delfosse X., Basri G., Goldman B., Forveille T., Zapatero Osorio M. R., 1999, AJ, 118, 2466

Oswalt T. D., Hintzen P. M., Luyten W. J., 1988, ApJS, 66, 391

Pokorny R. S., Jones H. R. A., Hambly N. C., 2003, A&A, 397, 575

Reid I. N., Kirkpatrick J. D., Gizis J. E., Liebert J., 1999, ApJ, 527, L105

Reylé C., Robin A. C., Scholz R.-D., Irwin M., 2002, A&A, 390, 491

Scholz R.-D., Meusinger H., 2002, MNRAS, 336, L49

Scholz R.-D., Irwin M., Ibata R., Jahreiß H., Malkov O. Yu., 2000, A&A, 353, 958

Scholz R.-D., Ibata R., Irwin M., Lehmann I., Salvato M., Schweitzer A., 2002a, MNRAS, 329, 109

Scholz R.-D., Szokoly G. P., Andersen M., Ibata R., Irwin M., 2002b, ApJ, 565, 539

Scholz R.-D., McCaughrean M. J., Lodieu N., Kuhlbrodt B., 2003, A&A, 398, L29

Schwope A. D., Brunner H., Buckley D., Greiner J., Heyden K.v.d., Neizvestny S., Potter S., Schwarz R., 2002, A&A, 396, 895

Silvestri N. M., Oswalt T. D., Wood M. A., Smith J. A., Reid I. N., Sion E. M., 2001, AJ, 121, 503

Silvestri N. M., Oswalt T. D., Hawley S. L., 2002, AJ, 124, 1118

Smith J. A., 1997, PhD thesis, Florida Inst. Technol.

Wegner G., Reid I. N., 1991, ApJ, 375, 674

Wilson J. C., Kirkpatrick J. D., Gizis J. E., Skrutskie M. F., Monet D. G., Houck J. R., 2001, AJ, 122, 1989

This paper has been typeset from a TEX/LATEX file prepared by the author.