A&A 435, L5–L8 (2005)
DOI: 10.1051/0004-6361:200500101

Astronomy
&
Astrophysics

LP 349-25: A new tight M8V binary[⋆]

T. Forveille[1,2], J.-L. Beuzit[2], P. Delorme[1,2], D. Ségransan[3], X. Delfosse[2], G. Chauvin[4], T. Fusco[5], A.-M. Lagrange[2], M. Mayor[3], G. Montagnier[2], D. Mouillet[6], C. Perrier[2], S. Udry[3], J. Charton[2], P. Gigan[7], J.-M. Conan[5], P. Kern[2], and G. Michet[7]

[1] Canada-France-Hawaii Telescope Corporation, PO Box 1597, Kamuela, HI 96743, USA
e-mail: `Thierry.Forveille@cfht.hawaii.edu`
[2] Laboratoire d'Astrophysique de Grenoble, BP 53X, 38041 Grenoble Cedex, France
e-mail: `[Thierry.Forveille;Jean-Luc.Beuzit;Philippe.Delorme;Xavier.Delfosse;Anne-Marie.Lagrange;Guillaume.Montagnier;Christian.Perrier;Julien.Charton;Pierre.Kern]@obs.ujf-grenoble.fr`
[3] Observatoire de Genève, 51 Chemin des Maillettes, 1290, Switzerland
e-mail: `[Damien.Segransan;Michel.Mayor;Stephane.Udry]@obs.unige.ch`
[4] European Southern Observatory, Casilla 19001, Santiago 19, Chile
e-mail: `gchauvin@eso.org`
[5] ONERA-DOTA, 92322 Châtillon, France
e-mail: `[Thierry.Fusco;Jean-Marc.Conan]@onera.fr`
[6] Laboratoire d'Astrophysique, Observatoire Midi-Pyrénées, Tarbes, France
e-mail: `mouillet@bagn.obs-mip.fr`
[7] Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique, 5 place Jules Janssen, 92195 Meudon Cedex, France
e-mail: `[Pierre.Gigan;Genevieve.Michet]@obspm.fr`

Received 7 January 2005 / Accepted 19 March 2005

Abstract. We present the discovery of a tight M8V binary, with a separation of only 1.2 astronomical units, obtained with the PUEO and NACO adaptive optics systems, respectively at the CFHT and VLT telescopes. The estimated period of LP 349-25 is approximately 5 years, and this makes it an excellent candidate for a precise mass measurement.

Key words. stars: binaries: visual – stars: individual: LP 349-25 – stars: low-mass, brown dwarfs

1. Introduction

Thanks to persistent efforts with ground-based adaptive optics and spectroscopy (Forveille et al. 1999; Delfosse et al. 1999a,b; Ségransan et al. 2000), as well as with *HST* (Torres et al. 1999; Benedict et al. 2000, 2001; Hershey & Taff 1998), over 30 M dwarfs now have published masses with 10% precision or better. As a result, the empirical Mass–Luminosity relation is now fairly well constrained down to 0.1 solar mass (Delfosse et al. 2000). The near-IR relations for M dwarfs are tight and agree very well with theoretical predictions (Baraffe et al. 1998). By contrast, the *V* band relation diverges significantly from those models below ∼0.5 solar mass, and has considerable intrinsic dispersion. The motivation for additional measurements in that mass range is therefore now shifting towards characterizing – and understanding – that dispersion around the mean relation.

Below 0.1 solar mass on the other hand, empirical masses are much scarcer. Many binaries are now known in that mass range, and their separations are on average much tighter (typically <10 AU) than in more massive systems (e.g. Close et al. 2003; Bouy et al. 2003). Nonetheless, those that are currently known mostly have moderately long periods, ∼20 years and beyond, which reflect typical distances of ∼20–30 pc and the resolution limit of the observations. To our knowledge, the only objects with published dynamical masses well below 0.1 solar mass are the components of Gl 569BC (Lane et al. 2001; Zapatero Osorio et al. 2004) and 2MASSW J0746425+2000321 (Bouy et al. 2004). Both orbits are still preliminary, with grade 4 in the Washington Double Star catalog. The observations of 2MASS0746 only cover 35% of its period, albeit at a very favourable phase, while Gl 569BC has full orbital coverage but still somewhat sparse sampling. Perhaps more importantly, both systems are young enough that at least one of their components is actually

---

[⋆] Based in part on observations made at Canada-France-Hawaii Telescope, operated by the National Council of Canada, the Centre National de la Recherche Scientifique de France and the University of Hawaii, and in part on observations at the Paranal observatory, Chile, in ESO program 073.C-0155.

below the Brown Dwarf limit (0.070 solar mass, Chabrier et al. 2000), in spite of only moderately late spectral types. The age of 2MASS0746 is not independently determined, and the properties of Gl 569A can only constrain that of Gl 569BC to a broad interval (Zapatero Osorio et al. 2004), over which the model luminosity of the brown dwarf evolves by an order of magnitude. In any comparison with theory, age therefore enters as an unwelcome free parameter, and reduces the diagnostic value of those two binaries. A few additional systems are being followed, such as LHS 1070 (Leinert et al. 1994, 2001) and Gl 494 (Beuzit et al. 2004), but identifying additional late-M dwarfs binaries with periods under $\sim$10 years remains critically important.

Here we present the discovery of one such system, LP 349-25, using the adaptive optics systems of the CFHT and VLT telescopes. Section 2 presents the observations and the data analysis, while Sect. 3 briefly discusses the properties of the system.

2. Observations and data reduction

2.1. CFHT observations

The discovery observations were carried out on July 3rd 2004 at the 3.6-m Canada-France-Hawaii Telescope (CFHT), using the CFHT Adaptive Optics Bonnette (AOB) and the KIR infrared camera. The AOB, also called PUEO after the sharp-visioned Hawaiian owl, is a general-purpose adaptive optics (AO) system based on F. Roddier's curvature concept (Roddier et al. 1991). It is mounted at the telescope F/8 Cassegrain focus, and cameras or other instruments are then attached to it (Arsenault et al. 1994; Rigaut et al. 1998). The atmospheric turbulence is analysed by a 19-element wavefront curvature sensor and the correction applied by a 19-electrode bimorph mirror. Modal control and continuous mode gain optimization (Gendron & Léna 1994; Rigaut et al. 1994) maximize the quality of the AO correction for the current atmospheric turbulence and guide star magnitude. For our observations a dichroic mirror diverted the visible light to the wavefront sensor while the KIR science camera (Doyon et al. 1998, named after a cocktail drink) recorded near-infrared light. The KIR plate scale is 34.85 ± 0.10 per pixel, for a total field size of 36″ × 36″ (KIR on-line users manual). Excellent atmospheric conditions prevailed during the observation ($\sim$0.55″ seeing in the V band). The observation sequence consisted of 5 individual 15 s exposures at each position of an 8″ square+center offset pattern. The resulting images are excellent in spite of LP 349-25's faintness ($V = 17.5$, and 40 ADUs/cycle on the wavefront sensor), and its duplicity was obvious in real time at the telescope.

2.2. VLT observations

Confirmation observations of LP 349-25 were performed on September 26th 2004 with the NACO instrument at VLT UT4 (ESO Very Large Telescope, Paranal Chile). NACO consists of the NAOS adaptive optics system (Rousset et al. 2003; Lagrange et al. 2003), providing diffraction-limited images in the near infrared, and of the CONICA science camera (Lenzen et al. 1998), equipped with a 1024 × 1024 ALLADIN detector covering the 1–5 μm spectral domain. The main technical features of NAOS are a piezo-stack deformable mirror with 185 actuators and a separate tip-tilt mirror, two selectable Shack-Hartmann wavefront sensors operating either in the optical (450–950 nm) or in the near-IR (800–2500 nm) range, both featuring up to 14 × 14 subapertures. The LP 349-25 observations used the NAOS IR wavefront sensor, under clear sky and average turbulence conditions (0.6″ seeing and 7 ms coherence time). They were performed through the standard H broadband filter and used the S13 CONICA camera, which provides a 13.27 mas/pixel sampling (NACO on-line users manual). The observation sequence consisted of pairs of 7s exposures acquired on a 7 positions random offset pattern within a 5″ jitter box.

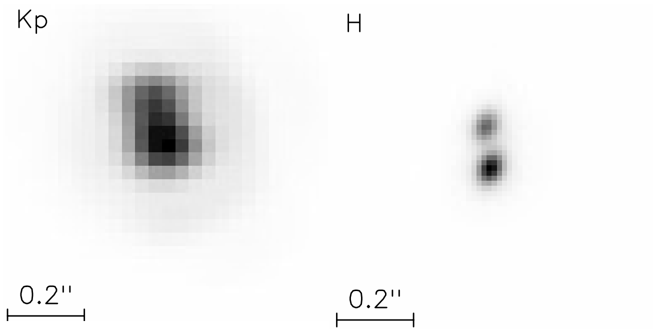

Fig. 1. Adaptive optics images of LP 349-25 with CFHT through a K' filter (*left*) and with the VLT through an H filter (*right*). The scale is indicated by a 0.2″ bar, and North is up and East left.

2.3. Data reduction

The reduction was performed within the ECLIPSE package (Devillard 1997). The individual raw data were flat-fielded using a normalised gain map, derived from images of the illuminated dome at CFHT, and from sky images taken at sunset for the VLT. The sky signal was estimated from a median across the jittered images. The individual flat-fielded images were then corrected from the sky image and stacked using a cross correlation algorithm.

After this cosmetic processing, we used the point-source mode of the MISTRAL myopic deconvolution package (Mugnier et al. 2004) to extract the coordinates and intensities of the two stars, from which we derived the parameters of interest, separation, PA and relative photometry. The astrometric calibration was derived from the standard Orion field (McCaughrean & Stauffer 1994) and the HIP 482 wide binary. This verified the expected pixel scale of both instruments. NACO was, as expected, found oriented within 0.1 degree of North, and KIR was found rotated by -2.0 ± 0.2 degrees. Centroiding errors and imperfect knowledge of the point-spread function completely dominate our uncertainty budget at the small separation of LP 349-25.

Figure 1 displays the two reduced images and Table 1 summarizes the extracted parameters.

Table 1. Adaptive optics measurement of LP 349-25.

ρ $''$	θ deg	Δm	Date	Filt.
0.125 ± 0.010	12.7 ± 2.0	0.26 ± 0.05	03 Jul. 2004	K'
0.107 ± 0.010	7.1 ± 0.5	0.38 ± 0.05	26 Sep. 2004	H

3. Discussion

LP 349-25 is a recent addition to the solar neighborhood inventory, in spite of its figuring in the Luyten Two Tenth Catalog (Luyten 1980). It was first recognised as a nearby star by Gizis et al. 2000, during a spectroscopic survey of candidate cool nearby stars selected from red 2MASS/POSS colours. They derive an M8V spectral type, and estimate a photometric distance of 8.4 pc from the relatively insensitive $J - K_s$ colour index. Reid et al. (2003) use narrow band spectral indices and J band photometry to derive a more precise distance, 7.7 ± 0.8 pc. We approximately correct that determination for the new companion, and adopt a distance for the system of 10.1 ± 1.2 pc.

The companion is bright in the infrared, $K' = 10.46$, and on that ground alone it is highly improbable that it is a background star. At the position of LP 349-25 the density of the 2MASS catalog for $K < 11$ is 60 sources/square degree. The probability to find such a bright star within even an arcsecond of LP 349-25 is therefore only 1.5×10^{-6}. Additionally, the companion cannot be much bluer than the primary, or the system would have produced a stronger signal on the visible wavefront sensor. Galactic reddening behind LP 349-25 ($l_{\rm II} = 115.81$ deg, $b_{\rm II} = -40.22$ deg) is very small (approximately $E(B - V) = 0.06$, Burstein & Heiles 1982), and a background star would thus need to be intrisically as red as LP 349-25. This would make it either an unrelated red dwarf in the immediate solar neighbourhood, or a halo giant at ~20 kpc. Both possibilities are highly unlikely.

The proper motion and parallax are large (+399.8 ± 5.5 mas/yr and −177.2 ± 5.5 mas/yr Salim & Gould 2003); 130 ± 13 mas, assuming for the sake of this particular argument that the star is actually single), but largely cancel out between the dates of our two observations, with a total motion of only −19 ± 7 and −47 ± 4 mas. The separation of the two components actually changed by −14 ± 15 mas and −16 ± 15 mas. This is compatible with the expected orbital motion of ~30 mas (uncertain by a factor of a few), but only helps excluding a background object at the 2σ level.

LP 349-25 however has been previously examined for multiplicity, with the HOKUPAA adaptive optics system on GEMINI (Close et al. 2002), and it was then found unresolved. The two components were most likely less separated at that time (September 18th and 19th 2001), or perhaps for this particular target Close et al. 2002 did not obtain as good an adaptive optics correction as we have. Had the system however been significantly wider than found here, Close et al. (2002) would have been able to resolve it even with degraded correction. Their negative result demonstrates that LP 349-25 is not a long period system, which we would have serendipitously observed close to periastron. It also definitely ensures that the companion is not a background star, which on that date would have been separated by 1.3″, and very obviously resolved. A background star would in addition have been separated by 21.9″ at the 1954 epoch of the blue plate of the first Palomar Survey, and again it would be very easily seen.

For late-M and early-L dwarfs, one spectral subtype corresponds to approximately 0.35 mag at H band (e.g. Vrba et al. 2004). The observed contrast therefore indicates that the make-up of the pair is M7.5V+M8.5V or M8V+M9V. At the 10 pc distance of the system, its 0.12″ separation translates to 1.2 AU. If the stars have reached the main sequence (age >~ 1 Gyr), as implicitly assumed to evaluate the distance, both masses are approximately 0.08 $M_\odot$ (Baraffe et al. 1998), just above the Brown Dwarf limit. Adopting the main sequence masses, and correcting for the 1.35 statistical factor between instantaneous projected separation and semi-major axis (Duquennoy & Mayor 1991), the orbital period is approximately 5 years. This estimate obviously has significant uncertainties, but it makes LP 349-25 one of the best candidates for an accurate mass determination below 0.1 $M_\odot$. We plan to monitor its relative motion with adaptive optics and will attempt to obtain a spectroscopic orbit, but a precise trigonometric parallax and an astrometric orbit will be equally important for the mass determination.

References

Arsenault, R., Salmon, D., Kerr, J., et al. 1994, in Adaptive Optics in Astronomy, ed. M. A. Ealey, & F. Merkle, SPIE Proc., 2201, 833

Baraffe, I., Chabrier, G., Allard, F., & Hauschildt, P. H. 1998, A&A, 337, 403

Benedict, G. F., McArthur, B. E., Franz, O. G., Wasserman, L. H., & Henry, T. J. 2000, AJ, 120, 1106

Benedict, G. F., McArthur, B. E., Franz, O. G., et al. 2001, AJ, 121, 1607

Beuzit, J.-L., Ségransan, D., Forveille, T., et al. 2004, A&A, 425, 997

Bouy, H., Brandner, W., Martín, E. L., et al. 2003, AJ, 126, 1526

Bouy, H., Duchêne, G., Köhler, R., et al. 2004, A&A, 423, 341

Burstein, D., & Heiles, C. 1982, AJ, 87, 1165

Chabrier, G., Baraffe, I., Allard, F., & Hauschildt, P. 2000, ApJ, 542, 464

Close, L. M., Siegler, N., Potter, D., Brandner, W., & Liebert, J. 2002, ApJ, 567, L53

Close, L. M., Siegler, N., Freed, M., & Biller, B. 2003, ApJ, 587, 407

Delfosse, X., Forveille, T., Mayor, M., Burnet, M., & Perrier, C. 1999a, A&A, 341, L63

Delfosse, X., Forveille, T., Udry, S., et al. 1999b, A&A, 350, L39

Delfosse, X., Forveille, T., Ségransan, D., et al. 2000, A&A, 364, 217

Devillard, N. 1997, The Messenger, 87, 5

Doyon, R., Nadeau, D., Vallée, P., et al. 1998, in Infrared Astronomical Instrumentation, ed. A. M. Fowler, SPIE Proc., 3354, 760

Duquennoy, A., & Mayor, M. 1991, A&A, 248, 485

Forveille, T., Beuzit, J.-L., Delfosse, X., et al. 1999, A&A, 351, 619

Gendron, E., & Léna, P. 1994, A&A, 291, 337

Gizis, J. E., Monet, D. G., Reid, I. N., et al. 2000, AJ, 120, 1085

Hershey, J. L., & Taff, L. G. 1998, AJ, 116, 1440

Lagrange, A.-M., Chauvin, G., Fusco, T., et al. 2003, Proc. SPIE, 4841, 860

Lane, B. F., Zapatero Osorio, M. R., Britton, M. C., Martín, E. L., & Kulkarni, S. R. 2001, ApJ, 560, 390

Leinert, C., Weitzel, N., Richichi, A., Eckart, A., & Tacconi-Garman, L. E. 1994, A&A, 291, L47

Leinert, C., Jahreiß, H., Woitas, J., et al. 2001, A&A, 367, 183

Lenzen, R., Hofmann, R., Bizenberger, P., & Tusche, A. 1998, Proc. SPIE, 3354, 606

Luyten, W. J. 1980, University of Minnesota Minneapolis, 55, 1

McCaughrean, M. J., & Stauffer, J. R. 1994, AJ, 108, 1382

Mugnier, L. M., Fusco, T., & Conan, J.-M. 2004, J. Opt. Soc. Am. A., 21(10), 1841

Reid, I. N., Cruz, K., Allen, P., et al. 2003, AJ, 126, 3007

Rigaut, F., Arsenault, R., Kerr, J., et al. 1994, in Adaptive Optics in Astronomy, ed. M. A. Ealey, & F. Merkle, SPIE Proc., 2201, 149

Rigaut, F., Salmon, D., Arsenault, R., et al. 1998, PASP, 110, 152

Roddier, F., Graves, J. E., Mc Kenna, D., & Northcott, M. J. 1991, in SPIE Proc., 1524, 248

Rousset, G., Lacombe, F., Puget, P., et al. 2003, Proc. SPIE, 4839, 140

Salim, S., & Gould, A. 2003, ApJ, 582, 1011

Ségransan, D., Delfosse, X., Forveille, T., et al. 2000, A&A, 364, 665

Torres, G., Henry, T. J., Franz, O. G., & Wasserman, L. H. 1999, AJ, 117, 562

Vrba, F. J., Henden, A. A., Luginbuhl, C. B., et al. 2004, AJ, 127, 2948

Zapatero Osorio, M. R., Lane, B. L., Pavlenko, Ya., et al. 2004 [arXiv:astro-ph/0407334]