A&A 526, A55 (2011)
DOI: 10.1051/0004-6361/201015289


Astronomy & Astrophysics

# Adaptive optics observations of the T10 ultracool dwarf UGPS J072227.51-054031.2★ (Research Note)

H. Bouy[1], J. H. V. Girard[2], E. L. Martín[1], N. Huélamo[1], and P. W. Lucas[3]

[1] Centro de Astrobiología, INTA-CSIC, PO Box 78, 28691 Villanueva de la Cañada, Madrid, Spain
e-mail: hbouy@cab.inta-csic.es
[2] European Southern Observatory, Alonso de Cordova 3107, Vitacura, Casilla 19001, Santiago 19, Chile
[3] Centre for Astrophysics, STRI, University of Hertfordshire, College Lane, Hatfield AL10 9AB, UK

Received 28 June 2010 / Accepted 17 August 2010

**ABSTRACT**

*Context.* With a spectral type of T10, UGPS J072227.51-054031.2 is one of the coolest objects known to date in the solar neighborhood.

*Aims.* Multiple systems are relatively common among early and mid-T dwarfs. We search for faint and close companions around UGPS J072227.51-054031.2.

*Methods.* We have obtained high spatial resolution images in the $H$ and $K_s$ bands using adaptive optics at the Very Large Telescope.

*Results.* With a Strehl ratio in the range 10−15%, the final images allow us to rule out the presence of a companion brighter than $H \lesssim 19.4$ mag at separation larger than 50 mas, and $H \lesssim 21.4$ mag at separation larger than 0.″1.

**Key words.** binaries: general – brown dwarfs – techniques: high angular resolution

## 1. Introduction

Tremendous efforts have been made over the past decade to study the ultracool end of the local field mass function. To date, several hundred methane dwarfs have been discovered as a result of sensitive surveys such as the 2MASS (Skrutskie et al. 2006), DENIS (Epchtein et al. 1997), UKIDSS (Lawrence et al. 2007) and CFHTBDS (Delorme et al. 2008) near-infrared surveys, and the SDSS survey (York 2000). Because methane dwarfs cannot sustain fusion in their core, their temperature drops continuously with time. A number of studies have therefore searched for ever cooler objects, representative of the proposed Y spectral class (Delorme et al. 2008; Burningham et al. 2008; Warren et al. 2007), and encountered a few objects with effective temperatures of only ≈600 K. Most recently, Lucas et al. (2010) reported the discovery of an ultracool dwarf (UGPS J072227.51-054031.2) with an effective temperature of only $T_{\rm eff} \approx 500$ K, making it the coolest brown dwarf known to date. They classify it as a T10, at the boundary between T and Y dwarfs. Because methane dwarfs are frequently found in multiple systems (Burgasser et al. 2003; Goldman et al. 2008), we decided to perform high angular resolution observations of the target to look for close companions. Resolving the source into a multiple system would further extend the domain of absolute magnitude for known ultracool dwarfs, and might significantly revise the estimated luminosity and mass of the primary component.

## 2. Observations and data reduction

The source UGPS J072227.51-054031.2 was observed with NACO, the Very Large Telescope (VLT) adaptive optics system (Lenzen et al. 2003; Rousset et al. 2003) and its laser guide star on the 2010 April 12 as part of program 285.C-5004. A set of deep images were obtained in $H$ and $K_s$ where the compromise between the target's luminosity and the AO performances is the best.

At the time the observations were prepared, Lucas et al. (2010) had ruled out the presence of companion at distances larger than 3″ using deep seeing limited images. We therefore decided to limit our study to the immediate vicinity of the target, and used a 512 × 512 pixels window with the S27 camera, providing a final field of view of ≈14 × 14″. This setting allows us a faster read-out and an optimized use of the cube mode. In cube mode, a data-cube with each individual *DIT* frame is saved, allowing for a careful frame selection and optimized weighting in the post-processing and co-addition. A set of 208 and 240 4 s individual images were acquired in $H$ and $K_s$, respectively. The target was too faint to be used as reference star for NACO's visible or near-infrared wavefront sensors. We therefore used the laser guide star for the high-order corrections, and the $R \sim 15.8$ mag star 2MASS J07222849-0540377 located at ∼19″ from the science target for tip-tilt correction (see Fig. 1). The ESO seeing monitor reports a DIMM seeing between $0.''5 \lesssim \sigma \lesssim 1.''0$, a coherence time of the atmospheric turbulence between $5 \lesssim \tau_0 \lesssim 10$ ms, while the sky transparency was classified as photometric.

The individual images were successively dark-subtracted and flatfielded using calibration frames obtained as part of the standard calibration sequence. The Strehl ratio was then measured on the target for each individual image of the cube by fitting a Moffat function to the target's point spread function (PSF), and dividing the corresponding normalized peak to the normalized peak of a theoretical VLT diffraction limited PSF. The individual images were then co-added weighted by their respective Strehl ratio. The final Strehl ratio is ≈12% in both the $H$ and $K_s$ image. Figure 2 shows the final images.

★ Based on observations obtained with the ESO Telescopes at the Paranal Observatory under program 285.C-5004.

**Table 1.** Astrometry and photometry of the sources present in the NACO images.

| RA (J2000) | Dec (J2000) | *Z* | *Y* | *J* | *H* | $K_s$ |
|---|---|---|---|---|---|---|
| 07:22:27.60 | –05:40:38.3 | 17.24 ± 0.01 | 16.96 ± 0.01 | 16.46 ± 0.01 | 15.77 ± 0.02 | 15.71 ± 0.15 |
| 07:22:27.28 | –05:40:30.0 | 20.45 ± 0.06 | 17.37 ± 0.01 | 16.49 ± 0.01 | 16.87 ± 0.02 | 16.72 ± 0.15 |
| 07:22:27.02 | –05:40:39.2 | 17.83 ± 0.01 | 17.69 ± 0.01 | 17.32 ± 0.01 | 17.00 ± 0.02 | 17.25 ± 0.15 |
| 07:22:26.97 | –05:40:29.4 | 19.66 ± 0.03 | 19.04 ± 0.04 | 18.52 ± 0.03 | 18.13 ± 0.02 | 17.85 ± 0.15 |
| 07:22:27.79 | –05:40:34.7 | 20.86 ± 0.08 | 21.51 ± 0.35 | 19.70 ± 0.09 | 19.24 ± 0.02 | ... |
| 07:22:27.64 | –05:40:33.0 | 21.20 ± 0.11 | 20.34 ± 0.13 | 19.74 ± 0.10 | 19.36 ± 0.02 | 18.86 ± 0.15 |
| 07:22:27.56 | –05:40:34.4 | 20.80 ± 0.08 | 20.65 ± 0.17 | 19.82 ± 0.10 | 19.18 ± 0.02 | 18.99 ± 0.15 |
| 07:22:27.34 | –05:40:26.8 | 21.48 ± 0.14 | ... | ... | 19.90 ± 0.03 | 19.54 ± 0.15 |

**Notes.** *Z*, *Y* and *J* photometry from (Lucas et al. 2010); *H* and $K_s$ photometry from NACO (this study).

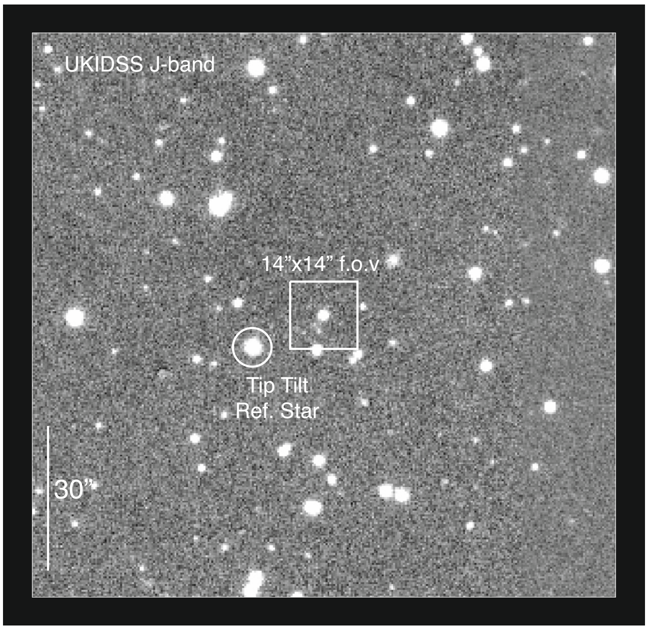


**Fig. 1.** UKIDSS *J*-band image showing the field of view of the NACO images, and the tip-tilt reference star. The scale is indicated. North is up and east is left.

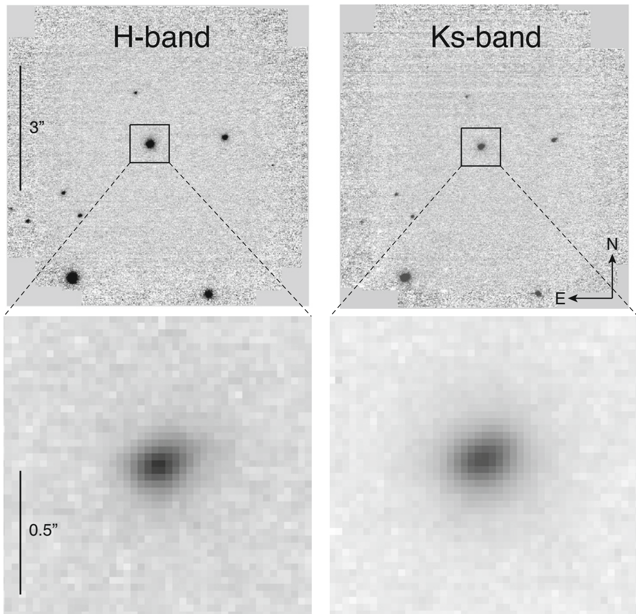


**Fig. 2.** NACO *H* (*left*) and $K_s$ (*right*) images of UGP J072227.51-054031.2. *The lower panels* show a zoom on the target. The scale and orientation are indicated.

We extracted the photometry of all sources brighter than the 3-$\sigma$ local noise using standard aperture photometry procedures within IRAF[1]. The zeropoints were computed using the *H* and $K_s$ photometry of four sources with a counterpart in the UKIDSS survey. The final uncertainties are largely dominated by the zeropoint uncertainties, computed as the 1-$\sigma$ standard deviation between the four measurements.

## 3. Analysis and conclusions

No obvious close companion is detected around the target. A careful PSF subtraction using the two brightest sources present in the field produces clean residuals. Figure 3 shows the 3-$\sigma$ limit of detection of the *H* and $K_s$ images, computed using the standard deviation of the radial profile of the PSF. The source is slightly elongated towards the tip-tilt reference star, and Fig. 3 represents an average of the limit of sensitivity over all azimuthal

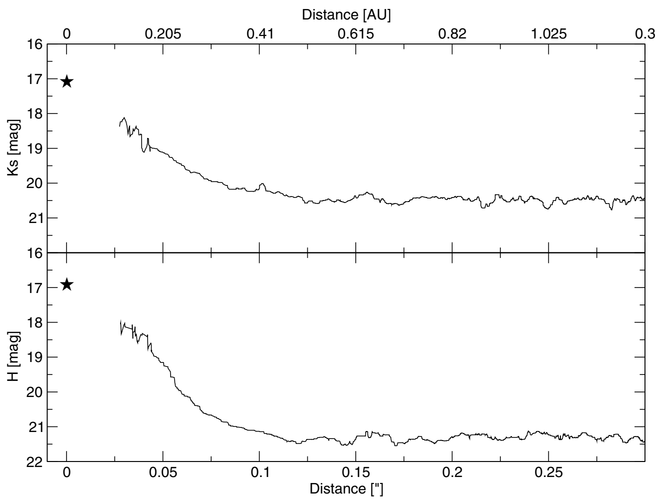


**Fig. 3.** Limit of sensitivity of our observations, computed as the 3-$\sigma$ standard deviation of the radial profile of the PSF. The projected distance scale assuming a distance of 4.1 pc is indicated. The luminosity of UGPS J072227.51-054031.2 is indicated with a star.

[1] IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

directions. The observations allow us to rule out the presence of a companion brighter than $H \lesssim 19.2$ mag and $K \lesssim 19.1$ mag at separation larger than 50 mas (0.205 AU at 4.1 pc), and $H \lesssim 21.2$ mag and $K_s \lesssim 20.2$ mag at separation larger than $0\farcs1$ (0.41 AU at 4.1 pc). A total of seven additional sources are present in the image. Table 1 gives an overview of their astrometry and photometry. All but one are detected in the $J$-band image dated 2006 November 28 of Lucas et al. (2010), and are located at the same absolute position (within $0\farcs1$) in our NACO images while the target has moved by more than $3''$ between these two epochs. We therefore rule out these six sources as possible companions based on their inconsistent proper motion. The last source is significantly redder than the target ($H-K_s = 0.36$ mag). As a cooler companion would be expected to be bluer, we reject this last source as a possible companion.

## References


Burgasser, A. J., Kirkpatrick, J. D., Reid, I. N., et al. 2003, ApJ, 586, 512

Burningham, B., Pinfield, D. J., Leggett, S. K., et al. 2008, MNRAS, 391, 320

Delorme, P., Willott, C. J., Forveille, T., et al. 2008, A&A, 484, 469

Epchtein, N., de Batz, B., Capoani, L., et al. 1997, The Messenger, 87, 27

Goldman, B., Bouy, H., Zapatero Osorio, M. R., et al. 2008, A&A, 490, 763

Lawrence, A., Warren, S. J., Almaini, O., et al. 2007, MNRAS, 379, 1599

Lenzen, R., Hartung, M., Brandner, W., et al. 2003, SPIE Conf. Ser. 4841, ed. M. Iye, & A. F. M. Moorwood, 944

Lucas, P. W., Tinney, C. G., Burningham, B., et al. 2010, MNRAS, 408, L56

Rousset, G., Lacombe, F., Puget, P., et al. 2003, in Adaptive Optical System Technologies II, ed. P. L. Wizinowich, & D. Bonaccini, Proc. SPIE, 4839, 140

Skrutskie, M. F., Cutri, R. M., Stiening, R., et al. 2006, AJ, 131, 1163

Warren, S. J., Mortlock, D. J., Leggett, S. K., et al. 2007, MNRAS, 381, 1400

York, D. G., Adelman, J., Anderson, J. E., Jr., et al. 2000, AJ, 120, 1579