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Parallax measurements of six brown dwarfs*

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Abstract. Accurate parallax measurements allow us to determine physical properties of brown dwarfs, and help us to constrain evolutionary and atmospheric models and reveal unresolved binaries. We measured absolute trigonometric parallaxes and proper motions of six cool brown dwarfs using background galaxies to establish an absolute reference frame. The brown dwarfs in our sample have spectral types between T2.5 and T7.5. The observations were taken in the J-band with the Omega2000 camera at the 3.5 m telescope at CAHA during a time period of 27 months. We obtained absolute parallaxes for our 6 brown dwarfs with a precision between 3 and 6 mas. We compared our results with the study by Dupuy et al. (2012) and with the evolutionary models of Allard et al. (2012). For four of the six targets we found a good agreement in luminosity among objects of similar spectral types. The object 2MASS J11061197+2754225 is more than 1 mag overluminous in all bands pointing to binarity or higher order multiplicity.

Key words. stars: brown dwarfs – late type – infrared: astrometry – parallaxes – proper motions – stars: distances

1. Introduction

Since the discovery of the first brown dwarfs (BDs), Teide 1 by Rebolo et al. (1995) and Gliese229B by Nakajima et al. (1995), more than 1000 L and T type brown dwarfs have been discovered[1].

BDs cool and dim during their evolution. During their life, they change their spectral type because the effective temperature ($T_{\rm eff}$) decreases, with the exception of BDs in the L/T transition in which the $T_{\rm eff}$ is roughly constant. For a given BD with a given temperature, the interval of masses and ages that the BD could have is very wide, so that the age and the mass are degenerate. The $T_{\rm eff}$ is the physical parameter that drives the major changes in the observable photometric and spectroscopic features of brown dwarfs. However, among the known brown dwarfs emerge outliers which show that secondary parameters are also responsible for brown dwarf properties, such as gravity, metallicity, and cloud variability (Burrows et al. 2006; Burgasser et al. 2006; Liu et al. 2007).

Since the first parallax programs for brown dwarfs began with Dahn et al. (2002), Vrba et al. (2004), and Tinney et al. (2003), the relationship between the color and magnitude of BDs has been studied (Burgasser et al.

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* Based on observations taken with Omega-2000 at the 3.5 m telescope at the Centro Astronómico Hispano Alemán (CAHA) at Calar Alto, operated by the Max Planck Institut für Astronomie and the Instituto de Astrofísica de Andalucía (CSIC).

[1] www.dwarfarchives.org

Table 1. Summary of the results.

Object	μ_α (mas yr^{-1})	μ_δ (mas yr^{-1})	$\pi_{\rm rel}$ (mas)	$\pi_{\rm abs}$ (mas)	d (pc) (pc)	$d_{\rm phot}$ (pc)	$\chi^2/N_{\rm dof}$
2M J1106+2754	−311 ± 4	−438 ± 5	46 ± 3	48 ± 3	$20.6^{+1.0}_{-1.2}$	12.5 ± 1.4	21.8/17
ULAS J1302+1308	−445 ± 6	5 ± 7	67 ± 5	65 ± 5	$15.4^{+1.1}_{-1.4}$	16.1 ± 2.3	25.4/19
ULAS J1417+1330	−121 ± 4	50 ± 3	32 ± 3	33 ± 3	$30.3^{+2.5}_{-3.8}$	23.8 ± 5.1	23.0/17
2M J2254+3123	67 ± 3	187 ± 7	71 ± 2	72 ± 3	$13.9^{+0.5}_{-0.6}$	14.7 ± 1.9	23.4/17
ULAS J2320+1448	410 ± 4	121 ± 3	47 ± 3	47 ± 4	$21.1^{+1.6}_{-2.2}$	20.7 ± 3.6	22.6/19
ULAS J2321+1354	76 ± 4	−576 ± 6	83 ± 3	84 ± 4	$11.8^{+0.5}_{-0.6}$	10.8 ± 0.7	22.2/19

2008; Schilbach et al. 2009; Marocco et al. 2010; Faherty et al. 2012; Dupuy et al. 2012, among others). One of the most significant results of these studies is the large dispersion in luminosity for objects with similar spectral types (Faherty et al. 2012), which shows the importance of other factors such as gravity, metallicity, sedimentation and binarity (Tsuji et al. 1996; Burrows et al. 2006; Saumon & Marley 2008). Increasing the number of cool brown dwarfs with accurate distance measurements allow us to understand the variation in the color-magnitude and H-R diagrams, as we can determine the luminosity more accurately. Also the J-band bump in the color-magnitude diagram, a brightening observed in the J band for brown dwarfs with spectral types between T1 and T5, is not well understood (Burgasser et al. 2002; Tinney et al. 2003; Vrba et al. 2004). There are still few objects with parallaxes in the L/T transition, which prevent the progress of understanding brown dwarf evolution.

2. Data

We selected six T brown dwarfs with spectrophotometric distances smaller than 25 pc and brighter than 18 mag in J-band. Images were taken with Omega-2000, at the 3.5 m telescope at CAHA. The field of view is 15.4 × 15.4′, with a resolution of 0.″45 pixel^{-1}. The baseline of our observations is 21 months. In the case of ULAS J232035.28+144829.8, we used also one observation in the methane filter from 2009; therefore the baseline is 3.25 years.

3. Analysis

We performed astrometry using the software SExtractor (Bertin & Arnouts 1996) and SCAMP (Bertin et al. 2006). We estimated the differential chromatic refraction effect of the targets as explained in Monet et al. (2013) and Stone (1996). This effect was negligible in comparison with other sources of error (1 mas/epoch). We calculated the relative parallaxes of our targets (using field stars as references), fitting positions of the targets in each epoch, proper motions and parallaxes. In order to determine the absolute parallaxes, we calculated the average parallax of the extragalactic sources in our fields. Then, the absolute parallax is: $\pi_{\rm absolute} = \pi_{\rm relative} - \pi_{\rm extragal.}$.

4. Discussion of the results

Our estimation of the luminosity agrees with the luminosities of objects with similar spectral types for four of our six targets. The object ULAS J141756.22+133045.8 is slightly overluminous (around 0.5 mag) in the WISE color-magnitude plot. The object 2MASS J11061197+2754225 is more than 1 mag overluminous in all the bands, pointing to binarity or even higher multiplicity. In order to confirm this result, high resolution imaging and high resolution spectroscopy would be needed. To summarize, we provided parallaxes of some targets for the first time, with a precision up to 4 mas yr^{-1} in proper motions and 3 mas in parallaxes.

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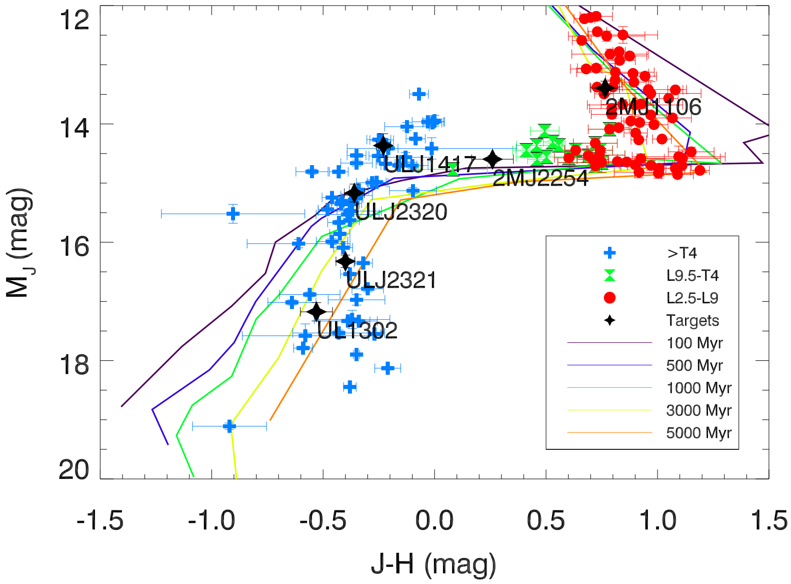

Fig. 1. Color-magnitude diagram in the MKO system showing the brown dwarf sample from Dupuy et al. (2012), our targets and the BT Settl models (Allard et al. 2012).

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