Serendipitous Discovery and Parallax of a Nearby L-Dwarf

John R. Thorstensen

Department of Physics and Astronomy
6127 Wilder Laboratory, Dartmouth College
Hanover, NH 03755-3528
j.thorstensen@dartmouth.edu

J. Davy Kirkpatrick

Infrared Processing and Analysis Center, M/S 100-22
California Institute of Technology
Pasadena, CA, 91125
davy@ipac.caltech.edu

ABSTRACT

A field star serendipitously observed in a parallax program proved to have a proper motion of 562 mas yr\(^{-1}\) and a parallax of 82 ± 2 mas. The star is identified with 2MASS J07003664+3157266. A Keck LRIS spectrum shows its spectral type to be L3.5, as expected from its infrared and optical colors and absolute magnitude. This object had not been previously recognized as an L dwarf, perhaps because of crowding at its relatively low Galactic latitude (\(b = +15.8\) degrees).

Subject headings: stars – individual; stars – binary; stars – variable.

1. Introduction

The infrared sky surveys 2MASS, SDSS, and DENIS (Skrutskie et al. 1997; York et al. 2000; Epchtein et al. 1994) yielded a bountiful harvest of very cool low-luminosity dwarf stars, which prompted the extension of the conventional spectral classification sequence to \(L\) and \(T\) (Kirkpatrick et al. 1999).

An effort is underway to determine parallaxes for as many \(L\)- and \(T\)-dwarfs as possible. This is difficult, since these objects can be faint in the optical band where most parallax programs operate. A modest number of precise parallaxes have been secured in the optical (Dahn et al. 2002) and with infrared array detectors (Tinney, Burgasser, & Kirkpatrick 2003; Vrba et al. 2002), but more

---

\(1\) Based in part on observations obtained at the Michigan-Dartmouth-MIT Observatory.
parallaxes are needed. We describe here the chance discovery of a nearby L dwarf, as a field star in a parallax sequence aimed at a different object. Because of its unusual mode of discovery, the object was ‘born’ with a parallax.

2. Observations

2.1. MDM Astrometry and Photometry

One of us (JRT) is measuring parallaxes for a sample of cataclysmic binaries using the 2.4m Hiltner telescope at MDM Observatory on Kitt Peak, Arizona. Technical details of this program will be given elsewhere; a brief summary follows. A SITe CCD is used with a Kron-Cousins $I$-band filter to image an 8-arcminute square field at a scale of 275 mas per pixel. At each epoch a dozen or so short exposures (25 s for the field considered here) are taken to avoid saturating program or comparison stars and to average out the random centering errors. Image centers are measured using the IRAF implementation of DAOPHOT (Stetson 1987). A large number of stars are measured, not only to constrain the plate solution adequately but also to empirically estimate the scatter in the resulting parallaxes. The scale and orientation of each field is derived from fits to the USNO A2.0 catalog (Monet et al. 1996). An iterative procedure maps the star centers from each picture onto a standard set of tangent-plane coordinates, and offsets as a function of time are derived, which are then fit for parallax and proper motion. When conditions are appropriate, standardized photometry in $V$ and $I$ is obtained using Landolt (1992) standards for calibration.

In order to verify the procedures used in the MDM parallax program and to estimate the external accuracy, the fields of five ‘parallax standards’ were included. These were selected from among the LHS stars measured by Monet et al. (1992). The agreement is satisfactory, showing that the procedures are essentially correct. During the reductions it was noticed that a star near the edge of the field of LHS 1889 showed a large proper motion and parallax and a very red $V - I$ color. This proved to be 2MASS J07003664+3157266 (hereafter 2MASS 0700+3157); Table 1 lists its parameters. Fig. 1 gives a finding chart, and Fig. 2 shows its path across the sky and its parallactic ellipse. The colors and absolute magnitude in Table 1 yielded a preliminary classification of L3.

Because 2MASS 0700+3157 is much redder than the reference-frame stars, we must be careful with differential color refraction (DCR); Monet et al. (1992) discuss the problem. The $I$-band filter used here is narrower and redder than that used by Monet et al. (1992), which ameliorates the problem by a factor of about four. Even so, we did apply a correction, and confined most of the exposures to within ±1 hour of meridian passage. One set of exposures – unfortunately the only set with a large negative $X$ parallax factor – was taken at hour angles $+1^h \leq H \leq +2^h$. Excluding these exposures changed $\pi_{rel}$ from 81 to 79 mas. For the exposure farthest from the meridian, the full amplitude of the DCR correction relative to the comparison stars (typically $V - I = +1$) was 13 mas; allowing a generous 30 percent uncertainty in the DCR coefficient would shift the centroid in that image by 4 mas. This is as bad as it gets, so DCR evidently does not affect the parallax
too seriously.

2.2. Keck Spectroscopy

The L dwarf candidate was confirmed spectroscopically on 2003 Jan 02 UT using the Low Resolution Imaging Spectrograph (LRIS; Oke et al. 1995) at the 10m W. M. Keck-I Observatory on Mauna Kea, Hawaii. Two consecutive 300 s exposures were obtained. A 400 lines/mm grating blazed at 8500 Å was used with a 1″ slit and 2048×2048 CCD to produce 7-Å-resolution spectra covering the range 6300 – 10100 Å. An OG570 filter eliminated second-order light. The data were reduced and calibrated using standard IRAF routines. Quartz-lamp flat-field exposures of the dome were used to normalize the response of the detector, and stellar spectra were extracted using apextract. The wavelength calibration is from a NeAr arc lamp exposures taken immediately after the 2MASS 0700+3157 observations, and the flux calibration is from an observation of Hiltner 600 (Hamuy et al. 1994) taken immediately before the observations of the target. Fig. 3 shows the reduced spectrum. The data are not corrected for telluric absorption, so atmospheric O$_2$ bands at 6867-7000, 7594-7685 Å and H$_2$O bands at 7186-7273, 8161-8282, ∼8950-9300, ∼9300-9650 Å are evident.

The spectral type was assigned following the guidelines established in Kirkpatrick et al. (1999). The resulting values of the classification ratios defined in that paper are CrH-a = 1.58(2), Rb-b/TiO-b = 1.21(3-4), and Cs-a/VO-b = 1.18(3-4), and the fit to the K I doublet indicates a subtype of (3). This gives a final spectral type of L3.5. Using the human eye alone to judge the type results in the same spectral type of L3.5 because the spectrum of 2MASS 0700+3157 is morphologically intermediate between the spectral standards 2MASS W J1146345+223053 (L3) and 2MASS W J1155009+230706 (L4) taken with the same instrumental setup. The spectral type is almost exactly as predicted on the basis of the colors and absolute magnitude. The spectrum shows neither Li I λ6708 absorption, nor Hα emission, to equivalent width limits of 0.3 and 0.2 Å respectively.

3. Discussion

Our spectrum does not provide an accurate radial velocity, but the transverse velocity is well-determined from the proper motion and parallax (see Table 1). The kinematics appear typical of a disk population object.

There does not appear to be any physical association between the L dwarf and the original target, LHS 1889. The two stars’ proper motions are similar but significantly different, and the parallax of the L dwarf puts it significantly closer than LHS 1889, for which Monet et al. (1992) obtain $\pi_{rel} = 52.8 \pm 0.9$ mas, and we find $\pi_{rel} = 48.2 \pm 1.4$ mas.
As noted earlier, the number of L-dwarfs with known parallax is still modest. The unusual channel through which this object was discovered immediately yielded a parallax and placed it well within the 25 pc limit of the Gliese & Jahreiss (1991) catalog of nearby stars.

This is among the closer and apparently brighter L dwarfs, yet it escaped detection until now, probably because of the relatively crowded field \( (b = 15.8 \text{ degrees}) \). L dwarfs have mostly been selected as 2MASS or DENIS detections without optical counterparts, a criterion which is difficult to apply to fast-moving objects in crowded fields. SDSS, another prolific source of L-dwarf discoveries, is not covering low latitudes. Interestingly, Salim et al. (2003) recently discovered an apparently even closer L dwarf at low latitude in their proper motion survey. It is very likely that other undiscovered L dwarfs lurk nearby at low latitude.

Acknowledgments. JRT thanks the NSF for support through AST 9987334, and especially thanks Cindy Taylor and Bill Fenton for taking some of the parallax pictures. The MDM staff cheerfully performed many extra instrument changes over the years to facilitate this project.

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

Data presented herein were obtained at the W. M. Keck Observatory from telescope time allocated to the National Aeronautics and Space Administration through the agency’s scientific partnership with the California Institute of Technology and the University of California. The Observatory was made possible by the generous financial support of the W. M. Keck Foundation. The authors wish to recognize and acknowledge the very significant cultural role and reverence that the summit of Mauna Kea has always had within the indigenous Hawaiian community. We are most fortunate to have had the opportunity to conduct observations from this mountain. J.D.K. acknowledges support of the Jet Propulsion Laboratory, California Institute of Technology, which is operated under contract by the National Aeronautics and Space Administration. J.D.K. would also like to express thanks for the assistance at Keck provided by Patrick Lowrance, Joel Aycock, Paola Amico, and Barbara Schaefer.
REFERENCES


Vrba, F. J., Henden, A. A., Luginbuhl, C. B., & Guetter, H. H. 2002, BAAS, 34, 33.05

Table 1. Parameters of 2MASS 0700+3157

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit or comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>7$^h$ 00$^m$ 36.66</td>
<td>ICRS; epoch 2000.</td>
</tr>
<tr>
<td>$\delta$</td>
<td>+31° 57' 25.8&quot;</td>
<td>ICRS; epoch 2000.</td>
</tr>
<tr>
<td>$\mu$</td>
<td>561.6 ± 0.8</td>
<td>mas yr$^{-1}$.</td>
</tr>
<tr>
<td>P.A.</td>
<td>166.64 ± 0.08</td>
<td>degrees</td>
</tr>
<tr>
<td>$V$</td>
<td>21.68 ± 0.03</td>
<td>(a)</td>
</tr>
<tr>
<td>$V - I$</td>
<td>5.26 ± 0.03</td>
<td>(a)</td>
</tr>
<tr>
<td>$J$</td>
<td>12.923 ± 0.023</td>
<td>2MASS</td>
</tr>
<tr>
<td>$H$</td>
<td>11.947 ± 0.016</td>
<td>2MASS</td>
</tr>
<tr>
<td>$K_s$</td>
<td>11.317 ± 0.023</td>
<td>2MASS</td>
</tr>
<tr>
<td>$V - K_s$</td>
<td>10.36 ± 0.04</td>
<td></td>
</tr>
<tr>
<td>$\pi_{\text{rel}}$</td>
<td>81 ± 2</td>
<td>mas</td>
</tr>
<tr>
<td>$\pi_{\text{abs}}$</td>
<td>82 ± 2</td>
<td>mas (b)</td>
</tr>
<tr>
<td>$1/\pi_{\text{abs}}$</td>
<td>12.2 ± 0.3</td>
<td>pc</td>
</tr>
<tr>
<td>$m - M$</td>
<td>+0.48 ± 0.06</td>
<td>mag</td>
</tr>
<tr>
<td>$M_V$</td>
<td>21.20 ± 0.07</td>
<td>mag</td>
</tr>
<tr>
<td>Sp.</td>
<td>L3.5</td>
<td></td>
</tr>
<tr>
<td>$v_T$</td>
<td>32.4 ± 0.8</td>
<td>km s$^{-1}$.</td>
</tr>
<tr>
<td>$v_T$ (LSR)</td>
<td>21</td>
<td>km s$^{-1}$; (c)</td>
</tr>
</tbody>
</table>

*From three $VI_{KC}$ image pairs obtained 2003 Jan 29 UT. The color terms in the standardization were small, but the object is much redder than any of the standard stars, so systematic uncertainties are larger than the formal errors shown.

*bThe correction to absolute parallax is from color-based distance estimates for the stars used to define the astrometric grid.

*cMagnitude of the transverse velocity only, referred to the transverse components of the local standard of rest.
Fig. 1.— [Included as a jpg file for the astro-ph version.] Chart showing 2MASS 0700+3751 and LHS1889, the original parallax target, from an MDM 2.4m I-band image. The lines indicate the proper motion for the next 50 years. The proper motions are similar, but significantly different.

Fig. 2.— Left panel: Positions of 2MASS 0700+3157, referred to its nominal position. The dashed curve is the trajectory computed for its fitted parallax and proper motion. Right panel: The same data, but in the reference frame moving with the computed proper motion. The tip of each arrow is the observation from a single image, and the tail is the position computed for the epoch of that image from the fitted parallax and proper motion.
Fig. 3.— Keck LRIS spectrum of 2MASS 0700+3751, displayed in linear and logarithmic flux units.