Discovery of a New Nearby Star

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ABSTRACT

We report the discovery of a nearby star with a very large proper motion of 5.05 ± 0.03 arcsec/yr. The star is called SO025300.5+165258 and referred to herein as HPMS (high proper motion star). The discovery came as a result of a search of the SkyMorph database, a sensitive and persistent survey that is well suited for finding stars with high proper motions. There are currently only 7 known stars with proper motions > 5 arcsec/yr. The spectrum and measured tangential velocity indicate that HPMS is a main-sequence star with spectral type M6.5. Trigonometric and photometric parallaxes have been determined yielding distance estimates of 2.3 (+1.0,-0.5) pc and 3.6 ± 0.4 pc respectively. If the former is correct the HPMS ranks 3rd in the list of nearest stellar systems. If the latter is correct it is 17th. A more precise trigonometric parallax measurement is expected to be completed near the end of the year.

Subject headings: stars:distances

1. Introduction

Proper motion surveys have historically revealed a large fraction of our nearest stellar neighbors. The usual method is to search plate pairs typically taken a decade or more apart for relative displacements. However, stars with large proper motions can get lost in the background. The SkyMorph database of the NEAT project [Near Earth Asteroid Tracking] (Pravdo et al. 1999) data is ideally suited to search for such objects. NEAT is a NASA-funded project intended to perform a comprehensive survey of near-earth asteroids. Beginning in 1995, several dedicated telescopes have been employed to repeatedly take CCD exposures of the sky mostly in the region within $\pm 25°$ of the celestial equator (excluding galactic latitudes $<\sim 20°$). The instantaneous fields-of-view have varied over the years with telescope and CCD camera, but generally covered areas of 2-3 deg^2. Our survey, thus far, has included data from May 1996 - Dec 2001 from two 1-m telescopes located on Maui. The total sky coverage is $\sim$ 10000 deg^2, and within the region of coverage there are typically 20 exposures at any given point. The revisit time ranges from hours to years. With such a large number of exposures over a $\sim$ 6 yr period, the Skymorph database is an ideal place to search for objects with very large proper motion.

2. Observations

We have searched the Skymorph database for objects with unfiltered CCD magnitudes in the range 11.0-18.0 having proper motions $>$ 0.25 arcsec/yr. Candidate objects were visually confirmed by comparison with Digital Sky Survey images using the overlay feature of the SkyView Program (McGlynn, Scollick and White 1996). A total of 3154 objects were found of which 63 had proper motions $>$ 1.0 arcsec/yr. $\sim$ 400 of these objects are previously uncatalogued, and a paper on these is in preparation (Pravdo 2003). The HPMS had the largest proper motion of all the detected objects: 5.05 ± 0.03 arcsec/yr. To further refine the HPMS proper motion determination we have included additional observations from the USNO A2.0 Catalogue (Monet 1998) and the 2nd Guide Star Catalogue (Morrison and McLean 2001). The measured parameters of our fast-moving star are given in Table 1. We derive from our observations a tangential velocity of 52.9 ± 11.7 km/s. This is consistent with the velocity dispersion of main sequence red dwarfs of $\sim$ 50 km/s (Binney and Merrifield 1991).

Figure 1 shows the motion of HPMS across the sky with images from the Palomar Sky Surveys and SkyMorph. The parallax was estimated by fitting the position of HPMS on 43 SkyMorph images (many averaged in sets of three) taken from Julian Dates 2450779-2452498 (November 26, 1997- August 11, 2002) to a reference frame defined by 12 nearby stars in the field. Since the HPMS is quite red, a significant correction for differential chromatic refraction (DCR) was required. The DCR correction was both estimated from first principles and fit to the data taken over one night with varying hour angles. We chose a value for the DCR correction that minimized the scatter in the position on single nights.

The NOVAS (Naval Observatory Vector Astrometry Subroutines) software package was used to derive the HPMS parallax and proper motion. NOVAS (http://aa.usno.navy.mil/software/novas/novas_info.html) is a well-known package of subroutines that allows one to determine the position of a star in the sky given a number of parameters. We fit the data using a Marquardt routine (Press et al. 1986) with NOVAS providing the input model. The parameters in the fit were parallax, the proper motions in RA and Dec., the mean RA and Dec., and the radial velocity. Since our fits were insensitive to the last three parameters they were fixed at a nominal RA and Dec. and at zero radial velocity. The best-fit proper motions are 3.39 ± 0.02 and 3.75 ± 0.02 arcsec/yr in RA and Dec., respectively. The parameter we are most interested in is the parallax. We allowed the proper motions to vary and calculated chi-squared at different values of the parallax. We interpret the resulting chi-squared changes in the standard way for one interesting parameter: a delta-chi-squared of one corresponds to one-sigma error (Lampton, Margon and Bowyer 1976).

The result for the parallax is 0.43 ± 0.13 arcsec. The 1-sigma error is larger than we would like because the camera pixel sizes in the measurements, 1 and 1.4 arcsec, are not ideal for this purpose. It should also be noted that the telescopes that produced this data have not been previously used for parallax measurements. More precise observations with cameras designed for this purpose are underway.

A spectrum of the HPMS taken on 11 July, 2002 using the Apache Point 3.5 m ARC telescope is shown Figure 2. For comparison the spectra of the M6.5 V star GJ1111 and the M8 V star VB10 are also shown. The match to GJ1111 is good. We identify the HPMS as a main-sequence dwarf with spectral type M6.5 V based upon detailed examination of the CaH2 (λ7042-7046, λ6814-6846), CaH3 (λ7042-7046, λ6960-6990), and TiO5 (λ7042-7046, λ7126-7135) spectral features (Reid, Hawley and Gizis 1995). The relative strengths of the CaH and TiO bands show no evidence that the star is significantly metal-poor.

The HPMS was observed photometrically on the night of 7 August, 2002 at the JPL Table Mountain Observatory 0.6-meter telescope using broad band UBVRI Bessel filters and the facility CCD imaging system. Multiple UBVRI exposures of 15 Landolt (1992) stars ranging in color and air mass were also measured. With this data both linear and color-corrected extinction curves for each filter were computed. The nominal extinction coefficients and small ($\sim$ 1 mMag) color coefficients indicated a good photometric night.

The color-corrected extinction curves were used to compute the measured magnitudes listed in Table 1.

The HPMS is also in the soon-to-be-released 2MASS all-sky point source catalog [2MASS J02530084+1652532] (Kirkpatrick 2002), with magnitudes of J = 8.39$\pm$0.03, H = 7.88$\pm$0.04 and $K_s = 7.59 \pm 0.05$. The photometric measurements are summarized in Table 1. Combining these data with the trigonometric parallax given above allows estimation of the absolute magnitude. Despite the strong spectroscopic similarity to GJ 1111, the derived values are significantly fainter. For example, we derive $M_J = 11.58 \pm 0.35$ for the HPMS, as compared with $M_J = 10.40 \pm 0.03$ for GJ 1111. If our trigonometric parallax is accurate, then the HPMS is underluminous relative to a normal M6.5 disk dwarf by 1.2 ± 0.7 magnitudes. This result might be expected for an extreme metal-poor subdwarf, such as LHS 1826 (Gizis and Reid 1997), but, as noted above, there is no indication that HPMS is metal-poor. If the star has the same effective temperature as GJ 1111, then the low luminosity implies that the HPMS has a radius only 60% that of GJ 1111, or $\sim$ 0.68 $R_{Jupiter}$, violating electron degeneracy.

Given these results, we have estimated a spectrophotometric parallax for the HPMS. Dahn, et al. (2002) have shown that spectral type is well correlated with M_J for ultra-cool dwarfs. Using their linear relation, we derive $M_J = 10.59 \pm 0.25$, corresponding to a distance of 3.6 ± 0.4 parsecs. At this distance, which is almost identical to that of GJ 1111, HPMS is the 17th nearest system (and 27th nearest star) to the Sun.

3. Conclusions

We have found evidence for a previsouly unknown high proper motion star in our immediate solar neighborhood. The spectral data and velocity are consistent with a main sequence dwarf of spectral type M6.5 V. If the distance estimate from the trigonometric parallax is correct the star is the 3rd closest system to us. If the photometric value is correct it is the 17th. Since the NEAT survey has only covered the region $\pm 25^\circ$ in declination it is entirely possible that other faint nearby objects remain to be discovered.

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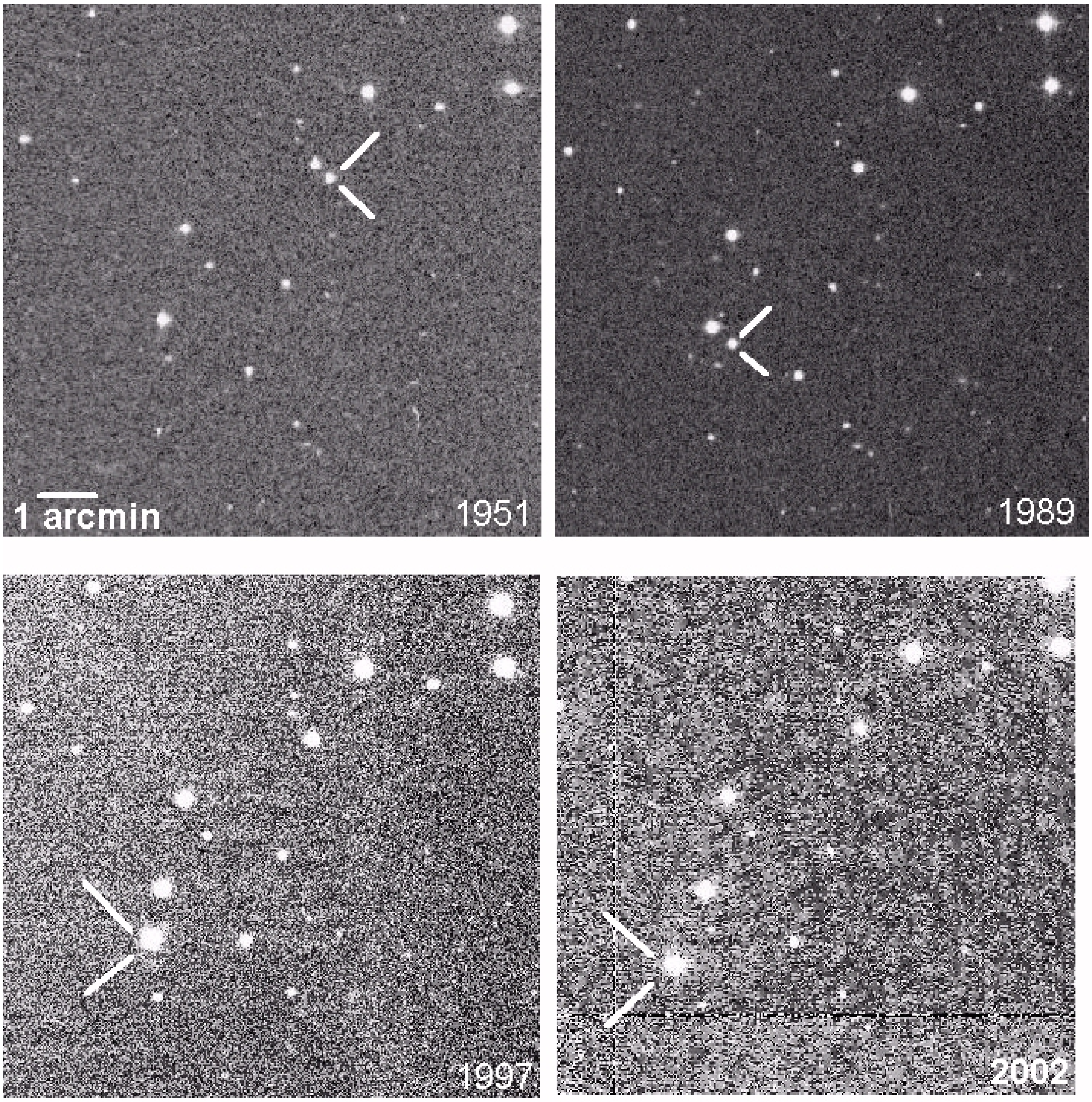

Fig. 1.— Images from the Palomar Sky Surveys and SkyMorph (lower panels) show the motion of HPMS south and east across the sky from 1951 until the current epoch.

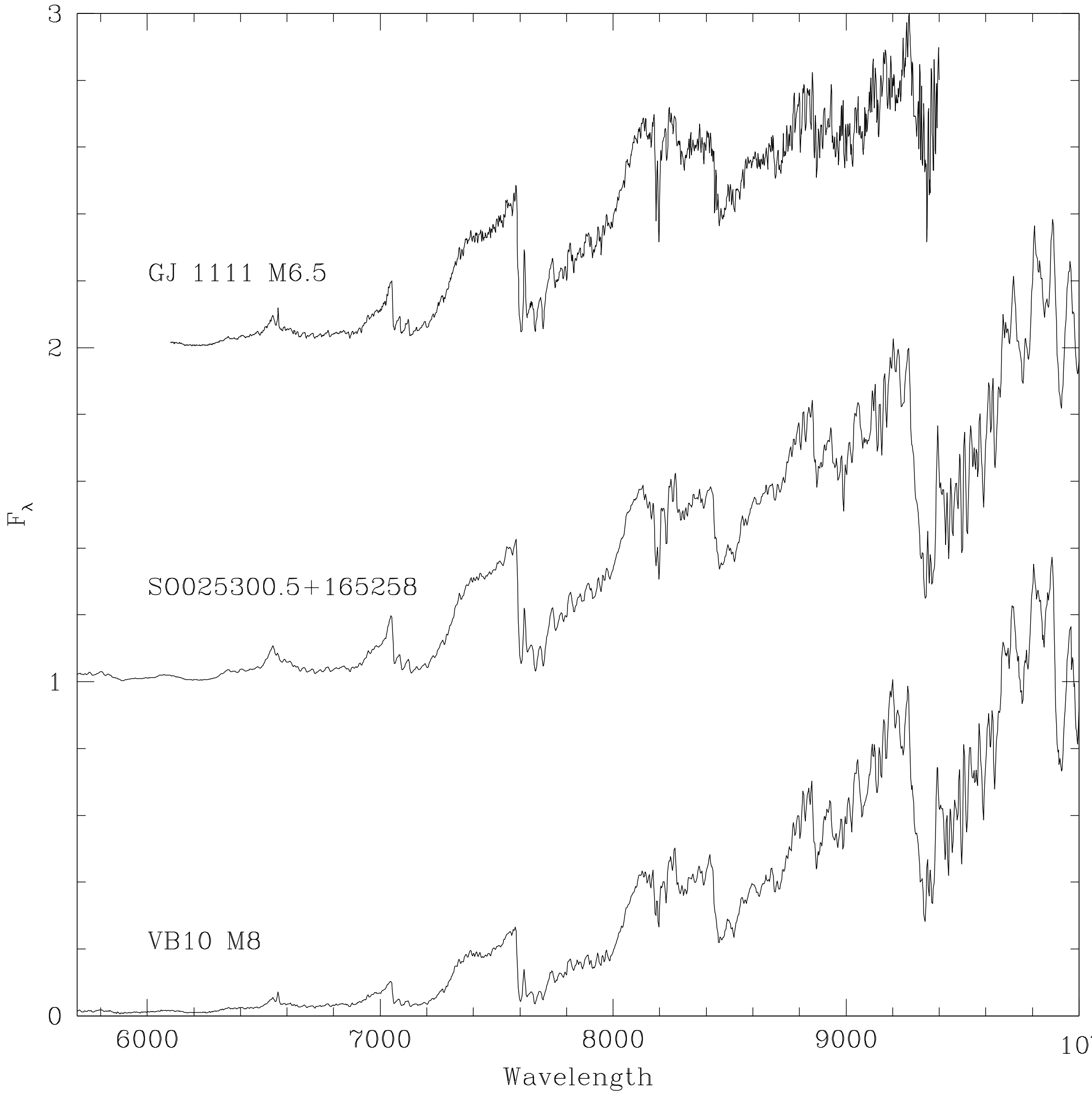

Fig. 2.— The spectrum of HPMS compared with two standard stars. Based upon this comparision and detailed analysis of spectral features HPMS is a main sequence dwarf with spectral type M6.5.

Table 1. HPMS Parameters

RA (J2000)[a]	43.24369°
DEC (J2000)[a]	16.89200°
Epoch[a]	1989.84
Magnitudes (B,V, R, I, J, H, K_s)[b]	17.21± 0.11, 15.40 ± 0.08, 13.26 ± .06, 10.66 ± 0.03, 8.39 ± 0.03, 7.88 ± 0.04, 7.59 ± 0.05
Spectral Type	M6.5 V
Proper Motion	5.05 ± 0.03 arcsec/yr
Position Angle	137.9 ± 0.3°
Parallax (π)	0.43 ± 0.13 arcsec
Distance ($1/\pi$)	2.3 (+1.0,-0.5) pc
Tangential Velocity	52.9 ± 11.7 km/s

[a]From 2nd Guide Star Catalogue

[b]B,V,R,I are from this work. J, H, K_s are from the 2MASS Catalogue.