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Two nearby M dwarf binaries from 2MASS

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ABSTRACT

We report the discovery of two binary M dwarf systems in the immediate solar neighborhood using 2MASS. The first is an M6.5 companion to the nearby G star HD 86728 (Gl 376). The known properties of HD 86728 indicate that the M dwarf (Gl 376B) is old, metal-rich and only 14.9 parsecs away. The M dwarf is highly active with both Hα and X-ray emission. Thus, Gl 376B offers the opportunity to study an old, bright, active M dwarf with known metallicity, age, and luminosity. We show that it is probable that Gl 376B is itself an unresolved pair. The other system consists of an M6.5 and an M8 dwarf with 14.5 arcseconds separation. We estimate a distance of ~ 16 parsecs for this very low mass pair. Stronger activity is observed in the M6.5 dwarf, supporting evidence that chromospheric activity is weakening near the hydrogen burning limit.

Key words: solar neighborhood – stars: low-mass, brown dwarfs – binaries: general

1 INTRODUCTION

Nearby binary stars have considerable importance for astronomical studies. The nearby star sample is the basis for determining the properties of the field disk population, such as the luminosity and mass functions, kinematics, binary fraction, and chromospheric and coronal activity. Furthemore, binary systems offer special opportunities to astronomers. Since the components of a system can be assumed to have the same age and composition, studies of one component can be used to constrain the properties of the other component. This is especially important for the coolest M dwarfs, whose complicated atmospheres are difficult to model. G dwarf primaries allow many otherwise unmeasurable properties of their M dwarf secondaries to be constrained, but surprisingly few wide systems suitable for ground-based follow-up are known.

We have recently begun a search using the Two Micron All Sky Survey (2MASS) aimed at identifying the nearest isolated M and L dwarfs in the solar neighborhood. Here we report the discovery of two nearby wide M dwarf secondaries of special interest in the course of that search.

2 DATA

Candidate nearby M dwarfs were identified using the pairing of 2MASS detections with USNO PMM scans (Monet, private comm.) of the Second Palomar Sky Survey (POSSII) plates (Reid et al. 1991). On the basis of the resulting BRIJHK magnitudes, nearby M dwarfs can be identified with high confidence. More details are given in Gizis et al. (1999, in prep.). The selection criteria are designed to produce a complete sample of M8 and cooler dwarfs, but necessarily include many M6.5 and M7 dwarfs. Objects with $K_s < 12$, $J - K_s > 1.0$ were selected for initial followup.

In the course of compiling the nearby star candidate list, we noted that two of the M dwarfs appeared to be companions to brighter stars and marked them for priority in follow-up spectroscopy. The 2MASS J2000 positions and magnitudes are given in Table 1. The first, 2MASSW J1000503+315545, is close (133 arcseconds east, 20 arcseconds north) to the nearby G star HD 86728, which appears in the nearby star catalog as Gl 376 (Gliese & Jahreiß 1991). Measurement of the POSSI and POSSII plates reveals the 2MASS source's proper motion is identical to Gl 376. Indeed, it is a little surprising that this source has not been noticed before. It is easily visible on the Palomar Sky Survey plates, and its proper motion is sufficient to be included in the LHS Catalogue (Luyten 1979), although it is within the halo of the bright star. We estimate $R \approx 14.5 \pm 0.5$ from the uncalibrated PMM scans. The common proper motion indicates it is associated, and we therefore denote this object Gl 376B. We henceforth refer to the primary (HD 86728) as Gl 376A.

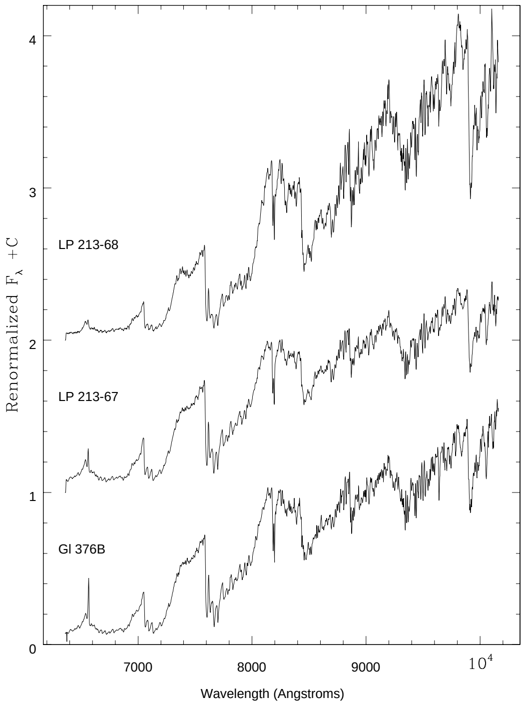

Figure 1. The Keck spectra of the three nearby M dwarfs.

A spectrum of Gl 376B was obtained on 04 March 1999 with LRIS spectrograph (Oke et al. 1995) on the Keck II telescope using the setup described in Kirkpatrick et al. (1999). A second spectrum was obtained at the Hale 200 in. telescope at Palomar Mountain on 24 May 1999. The Keck spectrum is shown in Figure 2. The spectral type of Gl 376B is M6.5 V with an Hα equivalent width of 16Å in the Keck spectrum and and 13 Å in the lower resolution Palomar spectrum. Spectral types are on the Kirkpatrick, Henry & McCarthy (1991) system, and were determined by visually comparing our spectrum to stars of known spectral type taken with the same setup.

Our second system consists of the M dwarfs 2MASSW J1047126+402643 and 2MASSW J1047138+402649. The two sources show common proper motion of $\mu_\alpha = -0.30$ and $\mu_\delta = -0.03$ arcseconds per year relative to other stars in the field, as measured from the POSSI and 2MASS images, and have a separation of 14.5 arcseconds. Both the position and the proper motion agree with the two Luyten (1979-1980) NLTT sources LP 213-67 and LP 213-68, and we adopt those names henceforth. The two M dwarfs were observed at Keck II on 05 March 1999. The primary, LP 213-67, has a spectral type of M6.5 V and an Hα equivalent with of 6.9Å. The secondary, LP 213-68, is an M8 V with an Hα equivalent width of 3.7 Å.

3 DISCUSSION

Gl 376A has been extensively studied, and as a result, its properties are well determined. The Hipparcos parallax places it at 14.9 parsecs (Perryman et al. 1997). Taylor's (1995) analysis of all metallicity determinations of the star indicates that $[Fe/H] = +0.170 \pm 0.052$. Using the Hipparcos distance and Edvardsson et al.'s (1993) photometry, Ng & Bertelli (1998) find $M = 1.02$ M$_\odot$ and $\log age = 9.854 \pm 0.083$. This age is in good agreement with Barry's (1988) estimate of $\log age = 9.93$ Gyr based on the CaII chromospheric emission lines. Duquennoy, Mayor & Halbwachs (1991) find a constant radial velocity of +55.83 km/s, and both the Hipparcos observations (Perryman et al. 1997) and ground based astrometry (Heintz 1988) indicate that there is no close companion. Although there is an IDS and CCDM entry for a bright, nearby companion to Gl 376A in SIMBAD, this entry has been deleted from the more recent Washington Visual Double Star Catalog (Worley et al. 1996) and there is clearly no such double on the Palomar plates. We note that Gl 376B should have been included in the Duquennoy & Mayor (1991) analysis of the frequency of binary companions, though it appears in a separation range in which they assumed 50% incompleteness and therefore, in a sense, was accounted for by their analysis.

The Hipparcos parallax and 2MASS photometry implies $M_K = 8.19$ for Gl 376B. However, the typical absolute magnitude of an M6.5 dwarf is $M_K = 9.60$ (Kirkpatrick & McCarthy 1994). Furthermore, our estimate of $R \approx 14.5$ implies $M_R \approx 13.4$, which is brighter than the typical M6.5 value of $M_R = 15.13$ (Kirkpatrick & McCarthy 1994), but consistent with the K_s discrepency. The apparent overluminosity of Gl 376B may be partially explained if it is actually a near-equal luminosity binary (or triple!). The high metallicity of the system may also partially account for the apparent overluminosity of the M dwarf with respect to the typical field main sequence.

We may compare Gl 376B's Hα emission strength to similar known M dwarfs observed by Hawley, Gizis & Reid (1996). Despite its great age, Gl 376B is one of the most active nearby field M dwarfs. Since strong emission was observed twice, it is unlikely that a flare is responsible. We note that the ROSAT All-Sky Survey (Voges et al. 1999) source 1RXSJ 100050.9+315555 is coincident with Gl 376B. Adopting the calibration given by Fleming et al. (1993), we find $f_X = 1.4 \times 10^{-12}$ erg s^{-1} cm^{-2} if the M dwarf is the X-ray source. With an implied luminosity of $\log L_X = 27.5$ (or 27.2 if it is an equal-luminosity binary), Gl 376B is very active compared to the limited sample of late M dwarfs observed by Fleming et al. While we cannot rule out the possibility that some of the flux is due to the G primary, the ROSAT position with its 30 arcsecond uncertainty does not match the G star and Barry (1988) find little chromospheric activity, which suggests that much or all of the observed X-ray. Hünsch et al. (1999) find nearby old G stars with $\log L_X < 27$, and they do not attribute the ROSAT source to Gl 376A.

The high activity level cannot be due to youth, since the G primary is known to be old from two independent techniques. This strongly suggests that Gl 376B is a short-period binary which maintains a rapid rotation rate via tidal interaction (Young et al. 1987). An unresolved companion would thus explain both the high activity level and the apparent overluminosity of Gl 376B. The postulated companion, Gl 376C, should be detectable via high resolution spectroscopy and radial velocity monitoring.

Both members of the LP 213-67/68 system show Hα emission. We note that the M6.5 primary has stronger emis-

Table 1. 2MASS Data

Name	R.A.	Dec.	J	H	K_s	Epoch
Gl 376B	10:00:50.30	+31:55:45.9	10.30	9.68	9.27	21 March 1998
LP 213-67	10:47:12.65	+40:26:43.7	11.42	10.78	10.40	05 April 1998
LP 213-68	10:47:13.82	+40:26:49.3	12.45	11.71	11.28	05 April 1998

sion than the M8 secondary. This is consistent with the general observation that in the Pleiades and the field, the chromospheric activity levels are becoming weaker as the hydrogen burning limit is approached (Tinney & Reid 1998), although the hotter component could be more active due to chance or the influence of an unseen companion.

We have derived the relationship $M_K = 7.59 + 2.25 \times (J - K)$ using trigonometric parallax data for M7 and later dwarfs (Gizis et al. 1999, in prep.). This implies a distance of 16 parsecs for the M8 secondary. Another estimate may be obtained using Kirkpatrick & McCarthy's (1993) value of $M_K = 9.6$ for M6.5 dwarfs. In this case, the estimated distance for the primary is 14.5 parsecs. The tangential velocity of ~ 23 km s^{-1} does not a give a strong clue to the age of this system, but an age of a few Gigayears is likely given the M6.5's activity level.

4 CONCLUSION

We have discovered an M dwarf member of the Gl 376 system. This offers the opportunity to study a old, metal-rich M dwarf with known properties. Most active, metal-rich objects are young (such as the Hyades) and therefore it is difficult to disentangle the effects of youth and metallicity. It is perhaps unfortunate that Gl 376B is likely an unresolved double, because we cannot presently use its position to measure the shift of the main sequence with metallicity. On the other hand, detection of Gl 376C would allow mass ratio for the M dwarf to be determined, giving an additional contraint for models, and would allow the luminosity ratio of the system to be measured. Of course, if a direct orbital mass determination proves to be possible, or if the system proves to be eclipsing, this system would provide a unique constraint on stellar structure, atmospheric, and coronal models near the hydrogen burning limit.

We have also identified a nearby pair of cool M dwarfs. LP 213-67 and LP 213-68 appear to be a normal pair of M dwarfs just above the hydrogen burning limit. We note that the two components are easily resolved and would have simultaneously measureable parallaxes. With a separation of ~ 230 AU, an orbital period is not likely in the near future, but the system should allow comparative study of M6.5 and M8 dwarfs.

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