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POSSIBLE IDENTIFICATION OF A METAL-RICH OLD MOVING GROUP: HIGH-RESOLUTION SPECTROSCOPY OF CANDIDATE MEMBERS^{1,2}

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ABSTRACT

Using new high-resolution spectroscopic observations from both the McDonald Observatory 2.7 m and Kitt Peak National Observatory 4 m telescopes, we observed four candidate members of the Ursa Major moving group previously suggested to instead belong to a significantly older kinematic assemblage. The Fe abundances we measure strongly suggest that these stars are not UMa members but form a more metal-rich group of stars ($+0.10 \leq [\text{Fe}/\text{H}] \leq +0.18$) with an age near 3 Gyr. Our $[\text{Ca}/\text{H}]$ determinations corroborate this result. The apparent similarities in metallicity and previously discovered *UVW* space motions lend credence to prior suggestions that these stars belong to a field kinematic structure of uniform age. Li abundances have also been derived from the 6707 Å feature for all four stars and show the differences expected from the stars' varying evolutionary states. The low Li abundance of one object, HD 88654, does not support its previously reported status as a post-T Tauri star candidate.

Key words: open clusters and associations: general — stars: abundances — stars: evolution — stars: late-type

1. INTRODUCTION

Moving groups are important to understanding the fundamental properties of open clusters and the evolution of the galaxy. The typical evaporation time of clusters is relatively short, only a few hundred million years (Wielen 1971), and following this time, the specific kinematic structure formerly defined by the cluster is, for the most part, retained as the stars form moving groups and gradually disperse into the Galactic field. However, clusters may not be the only source of moving groups. Instead, Wielen suggests that the dissipation of spiral arms may be the largest reservoir of moving groups. A recent analysis of the young Galactic *U-V* plane defined by the *Hipparcos* data reveals branch-like velocity distributions that may be attributed to spiral arm structure (Skuljan et al. 1999, hereafter S99).

Eggen (1994) defined a gravitationally unbound group of stars that share the same kinematics yet may be dispersed throughout the Galaxy as a “supercluster,” and a “moving group” as the part of a supercluster that enters the solar neighborhood and can be observed all over the sky. Today, several groups of stars have been labeled as moving groups; one of the most easily identifiable and well-known moving groups is in Ursa Major. The members of the UMa group have distinctive kinematics when compared to other disk field stars, and these stars' similarities in velocity were first recognized in terms of their common proper motion by Proctor (1869) and in terms of their radial velocities by Huggins (1871). The UMa group's metallicity is subsolar, with an average value of $[\text{Fe}/\text{H}] = -0.08$ (Boesgaard et al. 1988; Boesgaard & Friel 1990). This subsolar metallicity, in addition to the UMa group's relatively young age, distinct kinematics, and identifiable nucleus, make it one of the most established and well-defined moving groups to date (Soderblom & Mayor 1993). The UMa group

has provided valuable comparisons between stellar ensembles of different ages and metallicities, e.g., the younger Pleiades and older Hyades clusters (King & Schuler 2004; Soderblom & Clements 1987). Correctly identifying the members of this group and others will enable more studies of the evolution of groups and clusters in our Galaxy.

Over the last decade and a half, studies of radial velocities, photometry, *Hipparcos* parallaxes, activity measures, etc., have been carried out for the UMa group. King et al. (2003, hereafter K03) revisited the membership of UMa candidates and re-determined the group's age to be 500 ± 100 Myr. K03 noted that seven candidates appeared to form a well-defined, more evolved ($\tau \sim 2-3$ Gyr) evolutionary sequence in the color-magnitude diagram (CMD), and suggested that these stars may form a moving group that is significantly older than UMa (Fig. 1). In this paper we derive Fe, Ca, and Li abundances of four of these stars (HD 745, 18645, 81858A, and 88654) in order to investigate the possibility that these belong to a distinctive older kinematic group.

2. DATA AND ANALYSIS

The spectroscopic observations of HD 745 and HD 18645 were made in 2004 October at the McDonald Observatory on the 2.7 m Harlan J. Smith Telescope with the 2dcoudé cross-dispersed echelle spectrometer and a thinned Tektronix 2048 × 2048 CCD with 24 μm pixels. A 2 pixel spectral resolution of $R \sim 60,000$ was produced by the use of the chosen slit and the folded Schmidt camera; signal-to-noise ratio values at 6707.8 Å of 143 for HD 18645 and 88 for HD 745 were achieved. HD 81858A and HD 88654 were observed with the KPNO 4 m telescope with the Cassegrain echelle spectrograph during 2004 December. Spectra were obtained for these stars using the 58-63 echelle grating, 226-1 cross-disperser, long-focus camera, and T2KB Tektronix 2048 × 2048 CCD; a 0.9" slit width produced a spectral resolution of $R \sim 40,000$ and signal-to-noise ratio values at 6707.8 Å of 145 for HD 81858A and 237 for HD 88654. Data reduction was carried out with standard routines in the IRAF package.

The equivalent widths of the Ca and Fe lines, listed in Table 1, were measured using the one-dimensional spectral analysis

¹ This paper includes data taken at the McDonald Observatory of the University of Texas at Austin.

² Based on observations obtained at Kitt Peak National Observatory, a division of the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

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FIG. 1.— Fig. 10 from K03 showing the seven candidate members for an old moving group plotted in the *Hipparcos*-based $[M_V, (B - V)]$ CMD (left) and $[M_V, (V - I)]$ CMD (right) with the Yale-Yonsei $[\text{Fe}/\text{H}] = -0.08$ isochrones of 600 and 400 Myr, respectively. Green et al. (1987) color transformation-based isochrones are plotted for $Z = 0.01$ (dotted line) and $Z = 0.02$ (long-dashed line), and Lejeune et al. (1998) color transformation-based isochrones are plotted for $Z = 0.01$ (solid line) and $Z = 0.02$ (short-dashed line). The two older fiducials are 2 and 3 Gyr Yale-Yonsei isochrones plotted for $Z = 0.02$ from Lejeune et al. (1998).

package SPECTRE and its profile-fitting routine. The lines in Table 1 are case a, allegedly clean lines from Thevenin (1990), from which we also took the oscillator strengths. In an effort to minimize errors in the abundances due to the oscillator strengths, we carried out a differential analysis relative to the Sun. During the 2004 October run at the McDonald 2.7 m telescope, we obtained a solar spectrum of the zenith daytime sky and measured the same lines as in our stellar data, analyzing them using the same process. Abundances were derived using the 2002 version of the LTE analysis package MOOG and Atlas 9 (Kurucz 1993) model atmospheres characterized by effective temperature (T_{eff}), surface gravity ($\log g$), microturbulent velocity (ξ), and metallicity, $[\text{m}/\text{H}]$. Initial T_{eff} values were calculated from the $B - V$ values listed in K03 from the $Z = 0.02$ Yale-Yonsei isochrone grids using the color transformations from Lejeune et al. (1998). Using these initial temperatures and an age of 3 Gyr, (Fig. 1), initial $\log g$ values were taken from the Yale-Yonsei isochrones (Yi et al. 2001). Initial ξ -values were determined by the following equation (Allende Prieto et al. 2004):

$$\xi = 1.645 + (3.854 \times 10^{-4})(T_{\text{eff}} - 6387) - 0.64(\log g - 4.373) - (3.427 \times 10^{-4})(T_{\text{eff}} - 6387)(\log g - 4.373).$$

The measured equivalent widths and solar-metallicity model atmospheres characterized by these parameters were inputted into MOOG to derive abundances that were then normalized to solar values (determined from our daytime sky spectrum) in a line-by-line fashion. Final parameters of the model atmospheres were determined as follows. For each star we adjusted the T_{eff} of the model atmosphere until the Pearson's correlation coefficient characterizing the line-by-line normalized $[\text{Fe}/\text{H}]$ values versus the excitation potentials became zero. Similarly, the microturbulence of the model atmosphere was adjusted until the Pearson's correlation coefficient characterizing the line-by-line logarithmic reduced equivalent widths and $[\text{Fe}/\text{H}]$ values also became zero. Finally, we adjusted the $\log g$ parameter to obtain the same mean $[\text{Fe}/\text{H}]$ from Fe I and Fe II lines.

The final stellar parameters and abundances are given in Table 2, along with the uncertainties. The $[\text{Fe}/\text{H}]$ estimates are based on the Fe I values; T_{eff} values that produced linear correlation coefficients between the $[\text{Fe}/\text{H}]$ and excitation potential significant at the 1σ value were found, and the difference between those values and the final adopted temperatures were taken as our 1σ level of T_{eff} uncertainty. Table 3 contains our abundance sensitivities, a standard set of changes in abundances resulting from an arbitrary change in temperature, $\log g$, and microturbulence. Combining the 1σ T_{eff} excursion with the abundance sensitivity yields a 1σ abundance uncertainty due to uncertainty in T_{eff} . A similar process was used for microturbulence. The uncertainty in measurement was found from the line-to-line variance. The abundance uncertainties due to temperature, microturbulence, and measurement were added in quadrature to give the total Fe I and Ca I uncertainties in Table 2. The error in the Fe I-based $[\text{Fe}/\text{H}]$ and $[\text{Ca}/\text{H}]$ values due to uncertainties in $\log g$ are negligible (Table 3).

Li abundances were derived by spectrum synthesis using MOOG and the 6707 Å Li I region line list from King et al. (1997). We found that a downward adjustment of 0.2 dex to the scaled solar input C and N abundances was needed to produce an optimal synthesis for all four stars. We smoothed our synthetic spectra by convolving them with a Gaussian having a FWHM measured from 10 clean, weak stellar atomic lines in the observed spectrum. Total uncertainties for Li were found by adding temperature-based and synthesis errors in quadrature. The errors due to $\log g$ and microturbulence are negligible. In the case of HD 18645, we can only say with confidence that the value of $\log N_{\text{Li}} < 1.30$ is a conservative upper limit. Sample spectra and synthetic fits from both observing runs are shown in Figure 2, and the final Li abundances are given in Table 2.

3. DISCUSSION

3.1. Iron and Calcium Abundances

Three (HD 62668A, 81858B, and 136901) of the seven stars mentioned as possible candidate members for an older moving group by K03 were not included in this program, yet the abundance differences between the four presented in this paper

TABLE 1
LINE DATA

Species	λ (Å)	χ (eV)	$\log gf$	EW(Sun) (mÅ)	$\log N$	EW(HD 745) (mÅ)	$\log N$	EW(HD 18645) (mÅ)	$\log N$	EW(HD 81858A) (mÅ)	$\log N$	EW(HD 88654) (mÅ)	$\log N$
Fe I	6120.25	0.91	-5.95	6.4	7.61	28.8	7.68	6.8	7.50	7.7	7.86	30.9	7.76
	6157.73	4.07	-1.26	63.7	7.52	90.2	7.71	81.9	7.61	65.6	7.68	87.6	7.56
	6173.34	2.22	-2.88	70.9	7.50	103.6	7.56	94.0	7.54	74.3	7.70	105.5	7.48
	6187.99	3.94	-1.72	52.0	7.64	71.1	7.65	57.3	7.54	49.9	7.70	75.0	7.65
	6301.50	3.65	-0.72	125.8	7.55	144.6	7.56	136.6	7.49	118.8	7.69	161.6	7.66
	6302.49	3.69	-1.15	90.8	7.53	116.9	7.66	...	...	104.9	7.95	...	...
	6355.04	2.84	-2.29	71.2	7.51	...	...	98.0	7.64	82.5	7.87	128.1	7.95
	6380.75	4.19	-1.40	53.1	7.56	79.5	7.75	67.7	7.62	60.6	7.81	86.2	7.78
	6393.60	2.43	-1.62	130.7	7.42	177.6	7.57	159.6	7.50	129.7	7.65	195.0	7.65
	6411.65	3.65	-0.82	38.9	7.77	159.5	7.81	146.7	7.71	128.9	7.91	167.4	7.80
	6421.35	2.28	-1.94	116.6	7.40	174.0	7.70	150.4	7.54	121.5	7.70	177.3	7.63
	6481.88	2.28	-3.01	71.0	7.66	104.3	7.73	90.6	7.65	66.8	7.70	...	...
	6496.47	4.79	-0.65	72.0	7.68	87.0	7.74	...	...	70.0	7.78	...	...
	6498.94	0.96	-4.69	53.7	7.65	96.6	7.72	75.6	7.71	46.3	7.67	96.2	7.63
	6518.37	2.83	-2.67	60.6	7.65	91.2	7.75	89.0	7.85	63.7	7.84	98.3	7.77
	6591.33	4.59	-2.07	15.1	7.74	21.3	7.64	15.8	7.69	11.5	7.68	29.7	7.84
	6593.88	2.43	-2.34	88.9	7.47	127.3	7.63	116.1	7.54	91.5	7.68	132.7	7.58
	6608.04	2.28	-4.02	20.8	7.61	53.4	7.72	32.8	7.74	18.7	7.68	49.7	7.65
	6609.12	2.56	-2.69	72.1	7.62	106.9	7.75	92.0	7.62	71.7	7.74	109.6	7.68
	6625.04	1.01	-5.38	19.2	7.65	60.5	7.77	44.2	7.98	17.7	7.77	60.8	7.76
	6627.56	4.55	-1.59	31.1	7.65	51.1	7.75	39.5	7.70	29.1	7.69	54.0	7.77
	6646.97	2.61	-4.01	13.4	7.69	40.6	7.82	...	...	13.6	7.82	40.6	7.83
	6653.91	4.15	-2.53	14.1	7.74	29.4	7.82	22.7	7.90	17.2	7.93	25.0	7.72
	6699.14	4.59	-2.22	9.0	7.63	22.5	7.82	9.8	7.60	11.7	7.83	21.0	7.78
	6703.58	2.76	-3.13	38.9	7.61	69.7	7.68	61.5	7.79	41.2	7.77	68.9	7.61
	6704.50	4.22	-2.67	7.8	7.65	19.8	7.80	...	...	11.6	7.93	19.7	7.80
	6710.32	1.48	-4.90	17.1	7.58	60.8	7.82	37.5	7.87	17.0	7.73	50.9	7.65
	6713.74	4.79	-1.52	23.5	7.62	38.9	7.69	39.2	7.85	28.0	7.81	37.1	7.64
	6716.25	4.58	-1.90	16.9	7.62	47.3	8.02	31.0	7.87	26.4	7.96	43.4	7.92
	6725.36	4.10	-2.30	19.1	7.62	42.3	7.80	33.6	7.85	22.5	7.80	39.7	7.74
	6726.67	4.61	-1.12	52.5	7.64	70.7	7.71	63.4	7.67	54.3	7.78	69.0	7.62
	6733.15	4.64	-1.52	28.3	7.60	48.6	7.73	46.5	7.83	32.6	7.77	46.6	7.66
	6739.52	1.56	-4.95	12.4	7.54	43.9	7.66	21.0	7.67	13.9	7.75	41.5	7.63
	6745.98	4.07	-2.74	8.5	7.62	25.5	7.85	17.7	7.90	13.0	7.92	...	...
	6746.98	2.61	-4.35	5.5	7.59	20.4	7.74	9.0	7.72	9.5	7.98	21.0	7.78
	6750.16	2.42	-2.48	78.1	7.38	115.2	7.52	...	...	80.9	7.57	112.4	7.35
	6752.72	4.64	-1.30	38.9	7.60	66.9	7.85	58.1	7.79	42.4	7.75	61.7	7.70
Fe II	6149.25	3.89	-2.72	39.3	7.54	44.6	7.67	60.0	7.64	57.5	7.78	52.6	7.75
	6247.56	3.89	-2.31	55.0	7.49	56.8	7.55	77.9	7.55	71.2	7.67	69.7	7.70
	6369.46	2.89	-4.25	20.5	7.63	32.7	7.86	47.7	7.95	33.0	7.80	32.4	7.79
	6416.93	3.89	-2.79	46.2	7.76	52.5	7.92	68.2	7.84	56.6	7.81	55.1	7.87
	6456.39	3.90	-2.08	64.1	7.46	69.3	7.60	89.2	7.52	88.3	7.81	70.1	7.48
Ca I	6516.08	2.89	-3.45	64.8	7.86	70.2	7.90	90.3	7.88	77.0	7.96	71.2	7.80
	6455.60	2.52	-1.50	59.4	6.50	89.1	6.63	74.4	6.58	57.6	6.59	83.9	6.49
	6464.68	2.52	-2.53	16.6	6.65	40.2	6.79	38.0	7.05	13.8	6.65	39.8	6.80
	6499.65	2.52	-1.00	93.2	6.54	120.6	6.65	110.5	6.61	85.9	6.59	128.2	6.68

TABLE 2
STELLAR PARAMETERS AND ABUNDANCES

Object	$B - V$	M_V	T_{eff} (K)	$\log g$ (cgs)	ξ (km s ⁻¹)	[Fe/H]	[Ca/H]	$\log N_{\text{Li}}$
HD 745	0.887	1.92	5190 ± 55	3.58	1.23 ± 0.05	0.13 ± 0.04	0.13 ± 0.06	0.77 ± 0.09
HD 18645	0.780	2.58	5680 ± 90	3.85	1.83 ± 0.13	0.10 ± 0.07	0.10 ± 0.09	<1.30
HD 81858A	0.680	3.20	5930 ± 85	4.09	1.17 ± 0.12	0.18 ± 0.07	0.05 ± 0.07	1.98 ± 0.10
HD 88654	0.861	2.85	5240 ± 85	3.63	1.49 ± 0.12	0.10 ± 0.07	0.09 ± 0.09	0.60 ± 0.21

TABLE 3
ABUNDANCE SENSITIVITIES

Species	$\Delta T_{\text{eff}} \pm 150 \text{ K}$	$\Delta \log g \pm 0.25 \text{ cgs}$	$\Delta \xi \pm 0.25 \text{ km s}^{-1}$
Fe I	± 0.12	∓ 0.01	∓ 0.06
Fe II	∓ 0.08	± 0.11	∓ 0.08
Ca I	± 0.10	∓ 0.02	∓ 0.06

and those of the UMa moving group are unmistakable. Our analysis of the Fe abundances shows all four stars to be similarly supersolar, $+0.10 \leq [\text{Fe}/\text{H}] \leq +0.18$. The Ca abundances are $+0.05 \leq [\text{Ca}/\text{H}] \leq +0.13$, consistent within the errors with the Fe values. The resulting $[\text{Ca}/\text{Fe}]$ ratios (ranging from -0.13 to $+0.00$) are consistent with the metal-rich field disk star values from Edvardsson et al. (1993), which evince a mean of $+0.0$ with a ± 0.10 dex envelope for $[\text{Fe}/\text{H}] \geq 0.0$. Stars HD 745, 18645, and 88654 have the same $[\text{Fe}/\text{H}]$ and $[\text{Ca}/\text{H}]$ values within the errors; the solar-normalized Ca and Fe abundances of HD 81858A differ by 0.13 dex but are not significantly different given the uncertainties. Our stars' apparently high metallicities, along with the stars' alignment in the CMD, which fits exceedingly well with the 3 Gyr isochrones, suggests that they may form a coeval, metal-rich population.

3.2. Space Motions

The four stars observed in this paper were noted by K03 to have similar kinematic properties that were not correlated with those of the UMa group. The heliocentric space motions U , V , and W for all seven candidate members of the possible new moving group are taken from K03 and listed in Table 4. The probable intermediate age of these stars makes the identification of similar kinematics somewhat difficult because their ages are on the order of the dissolution times (Wielen 1971) of clusters, which allows enough time for significant changes in the individual velocities of each star. However, some similarities are still evident. For instance, the U -component is positive for all seven stars, with a mean of $+15 \text{ km s}^{-1}$. This differs from nearby B-, A-, and F-type disk field stars, which have an average U -velocity of -12 km s^{-1} (Asiain et al. 1999). With the exception of HD 81858AB, possibly due to binarity, the V - and W -components are negative for the remaining six stars. As noted by K03, several stars have one or more components that are indistinguishable with another star within the errors. HD 745 and 88654 are indistinguishable in all motions, but this concordance is by no means true among all seven stars. Yet, if these stars are part of a moving group that came from dissolved spiral arms, similar U -, V -, and W -components are not necessarily expected (S99). When plotted over the U - V structures found in Figure 10 of S99, the stars presented here all lie along or near one of the U - V structures (Fig. 3).

TABLE 4
SPACE MOTION

Object	U (km s^{-1})	σ_U (km s^{-1})	V (km s^{-1})	σ_V (km s^{-1})	W (km s^{-1})	σ_W (km s^{-1})
HD 745	+20.904	3.161	-4.325	1.687	-5.532	1.533
HD 18645	+10.539	1.508	-8.476	1.575	-5.897	1.359
HD 81858AB	+11.203	0.576	+3.506	0.482	+0.624	0.549
HD 88654	+17.851	1.607	-2.986	0.962	-7.240	0.721
HD 62668A	+20.435	1.839	-10.747	3.572	-19.109	2.938
HD 136901	+7.795	4.894	-7.291	2.924	-24.653	2.757

FIG. 2.— Spectrum of UMa candidate HD 745 (symbols) obtained at the McDonald Observatory 2.7 m telescope and three synthesized spectra (lines) with $\log N_{\text{Li}}$ values of 1.20, 0.75, and -4.00 (top), and the spectrum of UMa candidate HD 81858A obtained at the Kitt Peak National Observatory 4 m telescope and three synthesized spectra with $\log N_{\text{Li}}$ values of 2.40, 1.98, and -1.70 (bottom).

3.3. Previous Studies

Earlier abundance analyses of our four stars is limited. One study has previously derived metallicities for stars HD 81858A and 18645: the Geneva-Copenhagen survey by Nordström et al. (2004). Our positive $[\text{Fe}/\text{H}]$ values of $+0.18$ and $+0.10$ for these stars are different from their photometric metallicities of -0.08 for HD 81858A and -0.48 for HD 18645. Their T_{eff} values of 5770 K for HD 81858A and 5120 K for HD 18645 differed from our estimates of 5930 and 5680 K, respectively. However, even if we adopt the Nordström et al. T_{eff} for HD 18645 and adjust the gravity and microturbulence with the same process as above, we find $[\text{Fe}/\text{H}] = -0.18$, a factor of 2 larger than the photometric value. The occasionally abnormally low photometric metallicities derived for cool stars by Nordström et al. (2004) have been previously noted by King & Schuler (2005). As a check, we used 2MASS photometry to determine temperatures from $V - K$ values, which we then converted to $V - K_{\text{ESO}}$ values (Table 5) with transformations provided by Carpenter (2001). The T_{eff} data were extracted from Lejeune et al. (1998) and are in close agreement with the spectroscopic determination with the exception of HD 18645; for this star, the $V - K$ T_{eff} is 270 K lower than our

Fig. 3.— The six stars from Table 4 (squares) overplotted onto Fig. 10 from S99 (reprinted with permission from the Royal Astronomical Society [J. Skuljan et al., MNRAS, 308, 731 (1999)]). Three of the four stars we analyzed appear directly over the top branch, referred to as the Sirius branch in S99.

spectroscopic value but 290 K higher than the Nordström et al. (2004) estimate.

Heiter & Luck (2003) used HD 81858A as a comparison star when deriving the $[\text{Fe}/\text{H}]$ of planetary hosts. They found an $[\text{Fe}/\text{H}]$ value of $+0.02 \pm 0.05$ using a similar temperature, $T_{\text{eff}} = 5950$ K, and $\log g$, 4.15, but a significantly higher microturbulence value, 1.45, compared to our estimate, 1.17. If we increase our microturbulence to 1.45 while keeping the other parameters the same, our metallicity lowers to $+0.12$, in agreement with that of Heiter & Luck (2003) within the combined uncertainties.

3.4. Lithium and the Evolutionary Status of HD 88654

Torres et al. (2000) identified HD 88654 as a stellar counterpart of an X-ray source, suggesting this object may be a post-T Tauri star (PTTS). PTTSs are low-mass stars between the youthful ages of ~ 10 and ~ 70 Myr and have a significant amount of Li in their atmospheres (Jensen 2001). Given the now well-established decline in Li abundance with increasing age for solar-type stars on the pre- and early main sequence, we make the reasonable assumption that a PTTS should therefore have at least as much Li as an older zero-age main-sequence Pleiades dwarf of similar mass. Seven dwarfs in the Pleiades cluster with T_{eff} within 100 K of that of HD 88654 have Li abundances that range from 2.30 to 3.17 (King et al. 2000). Based on this, HD 88654 does not have the Li abundance ($\log N_{\text{Li}} = +0.60$) to support a classification as a PTTS. Instead, the Li abundances found in

TABLE 5
PHOTOMETRIC TEMPERATURES

Object	$V - K$	$V - I$	T_{spec} (K)	T_{phot} (K)
HD 745	2.129	0.9	5190 ± 55	5110.83
HD 18645	1.891	0.83	5680 ± 90	5414.83
HD 81858A	1.464	0.67	5930 ± 85	6001.04
HD 88654	1.992	0.88	5240 ± 85	5281.57

Table 2 exhibit low values expected from dilution by deepening convection zones arising from post-main-sequence evolution.

4. SUMMARY

Over the last few decades, high-resolution spectroscopy has made vast improvements in refining the membership of open clusters and moving groups. Accurately defining memberships allows for a greater understanding of both Galactic and stellar evolution. In this paper we confirm that HD 745, 18645, 81858A, and 88654 are not members of the UMa moving group. The stars' abundances are uniformly supersolar, ($+0.10 \leq [\text{Fe}/\text{H}] \leq +0.18$), differing from the mean metallicity ($[\text{Fe}/\text{H}] = -0.08$) of the UMa group. In addition, their positions on the CMD indicate an age of 2–3 Gyr as opposed to the 0.5 Gyr age of the UMa group.

The kinematic similarities of the seven older stars noted by K03 are manifest in the U - V plane. Our objects appear to reside along one of the young kinematic filaments identified by S99, suggesting they may be remnants of a spiral structure. The low and varying Li abundances of our sample appear as expected for stars of their advanced and varying evolutionary states. HD 88654, previously nominated as a PTTS, has a low Li abundance ($\log N_{\text{Li}} = 0.6$), which is inconsistent with this designation.

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