

UCAC3 PROPER MOTION SURVEY. II. DISCOVERY OF NEW PROPER MOTION STARS IN UCAC3 WITH $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$ BETWEEN DECLINATIONS -47° AND 00°

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ABSTRACT

We present 474 new proper motion stellar systems in the southern sky having no previously known components, with $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$ between declinations -47° and 0° . In this second paper utilizing the U.S. Naval Observatory third CCD Astrograph Catalog (UCAC3) we complete our sweep of the southern sky for objects in the proper motion range targeted by this survey with R magnitudes ranging from 9.80 to 19.61. The new systems contribute a $\sim 16\%$ increase in the number of new stellar systems for the same region of sky reported in previous SuperCOSMOS Research Consortium On Nearby Stars (RECONS) surveys. Among the newly discovered stellar systems are 16 multiples, plus an additional ten components that are new common proper motion companions to previously known objects. A comparison of UCAC3 proper motions to those from *Hipparcos*, *Tycho-2*, Southern Proper Motion, and SuperCOSMOS indicates that all proper motions are consistent to $\sim 10 \text{ mas yr}^{-1}$, with the exception of SuperCOSMOS. Distance estimates are derived for all stellar systems having SuperCOSMOS Sky Survey B_J , R_{59F} , and I_{VN} plate magnitudes and Two Micron All Sky Survey (2MASS) infrared photometry. We find five new red dwarf systems estimated to be within 25 pc. These discoveries support results from previous proper motion surveys suggesting that more nearby stellar systems are to be found, particularly in the fainter, slower moving samples. In this second paper utilizing the UCAC3 we complete our sweep of the southern sky for objects in the proper motion range targeted by this survey with R magnitudes ranging from 9.80 to 19.61.

Key words: astrometry – solar neighborhood – stars: distances – stars: statistics – surveys

Online-only material: machine-readable table

1. INTRODUCTION

The third U.S. Naval Observatory (USNO) CCD Astrograph Catalog (UCAC3) (Zacharias et al. 2010) proper motion survey addresses the possibility that proper motion surveys using digitized scans of photographic plates might overlook some proper motion systems. The UCAC3 obtained accurate proper motions by combining CCD observations with early epoch photographic data. This survey utilizes the UCAC3 proper motions to discover new systems that have been missed in previous efforts. The first paper in this series (Finch et al. 2010a, hereafter U3PM1) confirmed this suspicion by revealing an additional 25.3% stellar systems having a proper motion of $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$ between declinations -90° and -47° over those found by the Research Consortium On Nearby Stars (RECONS)⁴ group using SuperCOSMOS Sky Survey (SSS) data. These new discoveries provided the impetus for this second paper of the series, which completes the sweep of the southern sky for systems with $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$ found in the UCAC3.

The data obtained from proper motion surveys aid astronomers in determining accurate stellar luminosity and mass functions, thereby revealing how the Galaxy’s stellar mass is divided among different types of stars. Our main goal—identifying the Sun’s nearest neighbors—provides a vast sample of red dwarf, subdwarf, and white dwarf stellar systems for studies of multiplicity, activity, ages, and exoplanet searches. Because of their proximity, the nearby stars offer the most accessible measurements of each of these characteristics.

Our UCAC3 proper motion survey is currently focused on the southern hemisphere, which has not been surveyed as systematically as the northern sky, where the pioneering surveys of Giclas (Giclas et al. 1971, 1978) and Luyten (Luyten 1979, 1980) were primarily carried out. Historically, proper motion studies have been focused on blinking photographic plates taken at different epochs to determine source motions. Recent surveys that complement the classic efforts utilize various techniques, plate sets, modern computers, and carefully tailored algorithms to effectively blink digitized images of photographic plates. In the southern sky, such surveys include Wroblewski & Torres (1994), Wroblewski & Costa (1999), Scholz et al. (2000, 2002), Oppenheimer et al. (2001), Pokorny et al. (2003), Lépine (2005, 2008), Deacon et al. (2005, 2009), and Deacon & Hambly (2007).

In an effort to understand the stellar population of the solar neighborhood, the RECONS group has been targeting the neglected southern sky to reveal new stellar proper motion systems. To date, these discoveries have been reported in six papers in The Solar Neighborhood (TSN) series (Hambly et al. 2004; Henry et al. 2004; Subasavage et al. 2005a, 2005b; Finch et al. 2007; Boyd et al. 2011). These new systems are discovered using the SSS data (Hambly et al. 2001b) and have been given the name SCR (SuperCOSMOS RECONS). Follow-up observations of intriguing systems are performed at the Cerro Tololo Inter-American Observatory (CTIO) 0.9 m telescope, where RECONS operates a trigonometric parallax program focusing on stars within 25 pc.

Our UCAC3 survey uses an approach fundamentally different from plate blinking to reveal proper motion systems. We take advantage of observations reported in many catalogs ranging in

⁴ <http://www.recons.org>

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Table 1
New Proper Motion Systems from the UCAC3 and SCR
Proper Motion Surveys

Paper	New Systems Total	New Systems ≤ 25 pc	References
U3PM1	442	15	Finch et al. (2010a)
U3PM2	474	4	This paper
TSN08	5	2	Hambly et al. 2004
TSN10	4	4	Henry et al. (2004)
TSN12	141	12	Subasavage et al. (2005a)
TSN15	152	25	Subasavage et al. (2005b)
TSN18	1605	30	Finch et al. (2007)
TSN25	2817	79	Boyd et al. (2011)
Total	5640	171	

epochs from the early 19th to the early twenty-first centuries, rather than directly using specific sets of digitized images from photographic plates. In this investigation we focus on stellar systems in the UCAC3 found between declinations -47° and 00° that have $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$, completing a sweep of the southern sky. The search region and proper motion range matches that in Boyd et al. (2011), hereafter TSN25, in which the lower proper motion cutoff was chosen to match that of the NLTT catalog. TSN25 reports 2817 new SCR systems, substantially adding to the number of new SCR systems found previously. In Table 1, we summarize the number of new stellar systems discovered, highlighting those estimated to be within 25 pc, for both the RECONS and UCAC3 surveys. In this paper, we will focus in particular on the two SCR searches (TSN18 and TSN25) that correspond to the same proper motion and declination ranges as this UCAC3 survey (U3PM1 and this paper). New stellar objects from this search are given USNO Proper Motion (UPM) names.

2. METHOD

2.1. UCAC3

The USNO CCD Astrograph Catalog (UCAC) project finished observations in late 2004 and has been producing astrometric catalogs since 2000 October. This astrometric survey was conceived to densify the optical reference frame to high accuracy beyond the *Hipparcos* and *Tycho* magnitudes. UCAC is the first all-sky survey performed with a CCD detector utilizing the high level of precision achievable with this technology. The first release, UCAC1 (Zacharias et al. 2000), was a partial catalog covering 80% of the southern sky. The second catalog, UCAC2 (Zacharias et al. 2004), contains roughly 80% of the entire sky and includes improved proper motions from the use of early epoch plates paired with the Astrograph CCD data. UCAC3 (Zacharias et al. 2010), released in 2009 August, is the first in the series to contain coverage of the entire sky. UCAC3 also includes double star fitting and has a slightly deeper limiting magnitude than UCAC2 due to a complete re-reduction of the pixel data (Zacharias 2010). In addition, data from the Two Micron All Sky Survey (2MASS) were used in UCAC3 to probe for and reduce systematic errors in UCAC observations, providing a greater number of reference stars to stack up residuals as a function of many parameters, such as observing site and exposure time. A detailed description of the astrometric reductions of UCAC3 can be found in Finch et al. (2010b). A detailed introduction to the UCAC3 can be found in the release paper (Zacharias et al. 2010) and the README file of the data distribution. A new edition, UCAC4 (N. Zacharias et al. 2012, in

preparation, UCAC4 release paper), is scheduled to be released later this year.

2.2. Proper Motions

The UCAC3 contains roughly 95 million calculated absolute proper motions. The majority of these are derived proper motions from the use of early epoch catalogs paired with the Astrograph CCD data. Earlier epoch data are all reduced to the International Celestial Reference Frame (ICRF). UCAC3 mean positions and proper motions are calculated using a weighted, least-squares adjustment procedure.

Bright stars with $R \sim 8\text{--}12$ in UCAC3 are combined with ground-based photographic and transit circle catalogs. These include all catalogs used for the production of the *Tycho-2* project (Høg et al. 2000), unpublished measures of over 5000 astrograph plates digitized on the StarScan machine (Zacharias et al. 2008), new reductions of Southern Proper Motion (SPM; Girard et al. 2011) data, and data from the SuperCOSMOS project (Hambly et al. 2001b). About 1.2 million star positions to about $B = 12$ entered UCAC from digitizing the AGK2 plates (epoch about 1930). The Hamburg Zone Astrograph and USNO Black Birch Astrographs contributed another 7.3 million star positions, mainly in the $V = 12\text{--}14$ mag range, in fields covering about 30% of the sky, and the Lick Astrograph plates taken around 1990 yielded over 1 million star positions to $V = 16$ in selected fields.

For all catalogs used to derive UCAC3 proper motions a systematic error estimate was added to the root mean square (rms) of the individual stars' random errors. The largest error floor added was 100 mas for the SuperCOSMOS data due to zonal systematic errors ranging from 50 to 200 mas when compared to 2MASS data.

To identify previously known high proper motion (HPM) stars in the UCAC3, a source list was compiled using the Vizier online data tool, along with targeted supplements from published literature. In the north we used the LSPM-North catalog (Lépine 2005) containing 61,977 new and previously found stars having proper motions greater than $0''.15 \text{ yr}^{-1}$. For the south we utilized many surveys, notably including the Revised NLTT Catalog (Salim & Gould 2003), which produced 17,730 stars with proper motions greater than $0''.15 \text{ yr}^{-1}$ and the RECONS efforts (SCR stars). For a full list of catalogs used, see the UCAC3 README file. While this list is not comprehensive, this effort tagged roughly 51,000 known HPM stars in UCAC3 over the entire sky. These previously identified HPM stars were given a mean position (MPOS) number greater than 140 million and do not have derived UCAC3 proper motions. We instead used the proper motion data from the catalogs themselves (see Section 4.5).

Proper motion errors in the UCAC3 catalog for stars brighter than $R \sim 12$ are only $\sim 1\text{--}3 \text{ mas yr}^{-1}$ in part because of the large epoch spread of roughly 100 years in some cases. The errors of the fainter stars range from ~ 2 to 3 mas yr^{-1} if found in SPM4 and ~ 6 to 8 mas yr^{-1} if SuperCOSMOS data are used in lieu of SPM4 data.

2.3. Search Criteria

In this second paper we survey the southern sky between declinations -47° and 0° using the same proper motion range as in U3PM1, $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$. In this area of the sky we identify an initial sample of 212,356 proper motion candidates. We utilize the same search criteria as in U3PM1,

using UCAC3 flags with values indicative of real proper motion objects. A visual check from a sample of stars confirmed that these flags still hold true in the region of the sky being surveyed. All stars must (1) be in the 2MASS catalog with an $e2mpho$ (2MASS photometry error) less than or equal to 0.05 mag in all three bands, (2) have a UCAC fit model magnitude between 7 and 17 mag, (3) have a double star flag (dsf) equal to 0, 1, 5 or 6, meaning a single star or fitted double, (4) have an object flag ($objt$) between -2 and 2 to exclude positions that used only overexposed images in the fit, (5) have an MPOS number less than 140 million, to exclude already known HPM stars, and (6) have a LEDA galaxy flag of zero, meaning that the source is not in the LEDA galaxy catalog. After all these cuts, there remain 17,516 “good” candidates, fewer than expected for this region of the sky, when compared to 9248 in U3PM1. A total of 7641 candidates were excluded from the “good” candidates due to being marked as previously known in the UCAC3 catalog (MPOS number greater than 140 million).

These candidates were then cross-checked via VizieR and SIMBAD to determine if they were previously known. All cross-checks are performed using a $90''$ search radius, with one exception (the NLTT catalog). A larger search radius of $180''$ was used when comparing UPM candidates to the NLTT and Luyten half-second (LHS) catalogs, which have been found to have inaccurate positions as reported in Bakos et al. (2002). Thus, UCAC3 proper motion candidates with positions differing from Luyten’s or any other known object by less than $90''$ are considered known. Those differing from Luyten’s by $90''$ – $180''$ are considered new discoveries but are noted as possible NLTT stars in the tables. Those differing by more than $180''$ from Luyten are considered new discoveries. All candidates matched to known stars had a final check to determine if the proper motion and magnitudes matched—those that match are considered known and not reported in this sample. As in U3PM1, it is not a goal of this paper to revise the NLTT catalog and assign proper identifications and accurate positions to NLTT entries; rather, the goal is to identify new HPM stars.

After this, in effect, second cross-check for previously known stars, the list was reduced to a manageable 3736 candidate proper motion objects. The 13,780 known objects found during this cross-check shows how incomplete the UCAC3 catalog can be in identifying previously known HPM objects with the given search criteria. Each of these candidates was then visually inspected to confirm proper motion by blinking the B_J and R_{59F} SuperCOSMOS digitized plate images. During blinking, we noticed that for declinations between roughly -33° and 0° the epoch spread was insufficient (~ 3 – 5 years) to visually verify proper motion for all candidates. For those candidates, a second sweep was done by blinking the POSS-I R and R_{59F} SuperCOSMOS digitized plate images. Nearly 87% of the candidates were found to have no verifiable proper motions and were discarded. The final counts of new discoveries are 500 proper motion objects in 474 systems. Among these are 25 multiple systems (24 doubles and one triple), of which ten were found to have common proper motion (CPM) to previously known primaries.

For this search we find a successful hit rate—defined as the number of new and known proper motion stars (21921) divided by the total “good” candidates extracted (25,157, including stars with an MPOS number >140 million)—of 87.1%, which is higher than the 81.4% hit rate found in TSN25. After looking into the calculation used in U3PM1 to determine the successful

hit rate a counting error was found. The number of real objects excluded the known proper motion objects tagged in the UCAC3 catalog (stars with an MPOS number >140 million). If we add these stars in the total for the U3PM1 count, we get a total of 7975 real objects giving a new successful hit rate of 86.2%, which is comparable to this paper. At least three factors mentioned in U3PM1 have been identified that can lead to false detections in the UCAC3 proper motion survey. First, some real objects are discarded during the sifting mentioned above, particularly because of the 2MASS criterion which states that JHK_s photometry errors must be less than 0.05 mag. Second, the UCAC3 contains many phantom proper motion objects due to incorrect matches during proper motion calculations. Third, other misidentifications arise from blended images, where a single source in an earlier epoch catalog can be matched with two stars in the UCAC3 data.

3. RESULTS

In Table 2, we list the 474 new proper motion stellar systems (500 objects) discovered during this search. The table of discoveries is presented in full in the online journal. We highlight the five red dwarf systems estimated to be within 25 pc in Table 3. In both tables we list names, coordinates, proper motions, 1σ errors in the proper motions, plate magnitudes from SuperCOSMOS, near-IR photometry from 2MASS, the computed $R_{59F} - J$ color, a distance estimate, and notes.

3.1. Positions and Proper Motions

All positions on the ICRF system, proper motions, and errors are taken directly from UCAC3, unless otherwise noted. For a few stars that were found during visual inspection without any UCAC3 data, information has been obtained from alternate sources (see Section 3.4). For this sample, the average positional errors reported in the UCAC3 catalog are 51 mas in R.A. and 50 mas in decl. For proper motions, the average errors reported in the UCAC3 for this sample are 8.0 mas yr^{-1} in $\mu_\alpha \cos \delta$ and 7.7 mas yr^{-1} in μ_δ .

3.2. Photometry

In Tables 2 and 3, we give photographic magnitudes from the SuperCOSMOS and 2MASS surveys. From SuperCOSMOS, magnitudes are given from three plate emulsions, B_J , R_{59F} , and I_{VN} . Magnitude errors are typically less than 0.3 mag for stars fainter than ~ 15 , with errors increasing for brighter sources. From 2MASS, JHK_s infrared photometry is given, with errors typically 0.05 mag or less due to the search criteria. Additional objects found during visual inspection are typically fainter with larger photometric errors. The $R_{59F} - J$ color has been computed to indicate the star’s color.

While SuperCOSMOS magnitudes are reported in the UCAC3, this sample was checked against the SuperCOSMOS catalog to rectify some mismatches found in the UCAC3 catalog. In some cases, SuperCOSMOS magnitudes are not given in the tables, due to blending, no source detection, high chi-square, or other problems where no reliable magnitude is available. 2MASS magnitudes are given for all but one object which was found visually that is not present in the 2MASS catalog, as indicated in the notes.

3.3. Distances

Plate photometric distance estimates are computed using the same method as in U3PM1 and previous SCR searches. Using

Table 2
New UCAC3 High Proper Motion Systems between Declinations -47° and 0° with $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$

Name	R.A. J2000.0 (deg)	Decl. J2000.0 (deg)	$\mu_\alpha \cos \delta$ (mas yr $^{-1}$)	μ_δ (mas yr $^{-1}$)	sig μ_α (mas yr $^{-1}$)	sig μ_δ (mas yr $^{-1}$)	B_J	R_{59F}	I_{IVN}	J	H	K_s	$R_{59F} - J$	Est. Dist. (pc)	Notes
UPM 0004-0833	1.1472383	-8.5664958	182.2	-26.3	8.6	8.6	14.680	12.649	11.643	10.874	10.255	10.072	1.775	63.8	
UPM 0004-1258	1.2061531	-12.9791222	102.0	-156.8	10.2	6.6	14.504	12.478	11.385	10.774	10.160	9.973	1.704	62.3	
UPM 0009-1539	2.4914975	-15.6590597	184.0	-15.7	8.7	8.7	17.100	15.050	13.144	12.387	11.793	11.562	2.663	93.0	
UPM 0011-1448	2.9555050	-14.8079581	179.8	-34.9	9.0	9.0	14.785	13.131	12.454	12.005	11.353	11.246	1.126	115.6	
UPM 0014-0029	3.6589169	-0.4939803	161.0	-104.7	13.7	14.0	17.819	15.829	13.947	12.292	11.708	11.457	3.537	58.7	
UPM 0014-1219	3.7410256	-12.3317842	183.9	-21.6	7.0	3.9	17.189	15.068	13.388	12.808	12.230	11.974	2.260	130.3	
UPM 0025-2547	6.3606617	-25.7849942	170.4	65.2	9.4	9.3	20.968	18.826	16.962	15.167	14.514	14.163	3.659	179.8	^a
UPM 0044-1647	11.1954375	-16.7984897	187.8	29.7	14.6	14.1	...	...	13.280	12.405	11.777	11.549	...	91.5	^b
UPM 0045-3602	11.2618550	-36.0381975	118.0	-136.9	3.2	2.4	15.862	13.863	11.982	11.398	10.888	10.610	2.465	67.0	
UPM 0048-0217	12.1068206	-2.2840133	163.9	-75.0	8.9	8.3	16.715	14.628	12.563	11.042	10.488	10.194	3.586	31.8	

Notes.

^a Proper motions suspect.

^b Number of relations used for distance estimate < 6 ; plate distance less reliable.

^c SuperCOSMOS plate magnitudes suspect.

^d Common proper motion companion; see Table 4.

^e Not detected during automated search but noticed by eye during the blinking process.

^f Subdwarf candidate selected from RPM diagram; plate distance (in brackets) is incorrect.

^g Possible NLTT star with a position difference $> 90''$ when compared to UCAC3 position.

(This table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)

Table 3
New UCAC3 High Proper Motion Systems Estimated to be within 25 pc between Declinations -47° and 0° with $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$

Name	R.A. J2000.0 (deg)	Decl. J2000.0 (deg)	$\mu_\alpha \cos \delta$ (mas yr $^{-1}$)	μ_δ (mas yr $^{-1}$)	sig μ_α (mas yr $^{-1}$)	sig μ_δ (mas yr $^{-1}$)	B_J	R_{59F}	I_{IVN}	J	H	K_s	$R_{59F} - J$	Est. Dist. (pc)	Notes
UPM 1349-4228	207.2552625	-42.4784189	-161.9	-84.6	1.3	3.0	14.468	11.703	...	9.449	8.863	8.622	2.254	24.4	
UPM 1648-3459	252.1200667	-34.9967942	178.6	142.5	4.4	4.4	...	14.631	...	10.687	10.161	9.907	3.944	22.1	
UPM 1654-3105	253.6846164	-31.0961000	-32.4	-215.9	7.4	7.2	15.122	13.553	11.977	10.072	9.482	9.237	3.481	23.8	^a
UPM 1718-2245A	259.6129147	-22.7616683	-160.7	-160.8	7.2	6.8	15.469	13.836	13.155	10.385	9.806	9.572	3.451	25.4	^b
UPM 1718-2245B	259.6213031	-22.7746183	-161.1	-154.8	10.9	9.6	...	14.787	13.289	10.207	9.608	9.375	4.580	13.2	^{b c}
UPM 1840-1934	280.1299600	-19.5831464	201.2	-89.8	8.8	8.1	...	13.733	12.400	10.264	9.706	9.450	3.469	20.7	

Notes.

^a Possible NLTT star with a position difference $>90''$ when compared to UCAC3 position.

^b Common proper motion companion; see Table 4.

^c Not detected during automated search but noticed by eye during the blinking process.

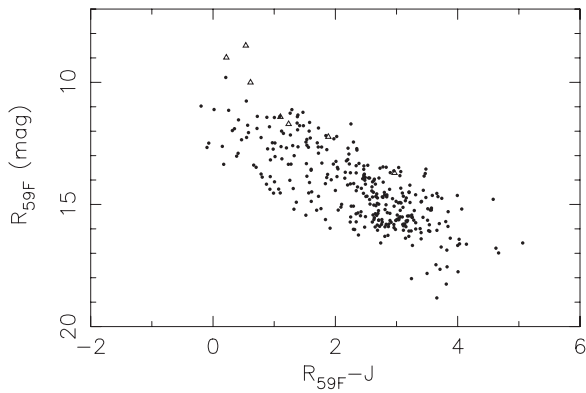


Figure 1. Color-apparent magnitude diagram for all proper motion systems in the sample having an $R_{59F} - J$ color. New proper motion objects are represented by solid circles while known objects (CPM companions to new objects) are represented with open triangles. Data below $R_{59F} = 17$ are CPM candidates noticed during visual inspection.

the relations in Hambly et al. (2004), 11 distance estimates are generated based on colors computed from the six-band photometry. This method assumes that all objects are main-sequence stars and provides distances accurate to 26%, determined from the mean differences between the true distances for stars with accurate (errors less than 10 mas) trigonometric parallaxes and distances estimated from the relations. Errors are higher for stars with missing photometry, resulting in fewer than 11 relations, and stars that are not single, main-sequence red dwarfs, e.g., cool subdwarfs and white dwarfs. It is possible to produce a distance with only one relation; however, six are needed to be considered “reliable” because that allows for 1 mag dropout. Stars having fewer than six relations are identified in the notes to Tables 2 and 3. If a star is identified as a possible subdwarf, the distance estimate is expected to be too large and is given in brackets.

3.4. Additional Objects

In Table 2 we include 17 additional proper motion objects found during visual inspection of the candidate fields. These objects are CPM companion candidates that either have fainter limiting magnitudes than implemented for this search, were eliminated from the candidate list by the search criteria, or have UCAC3 proper motions less than $0''.18 \text{ yr}^{-1}$. These new visual discoveries have all been cross-checked with VizieR and SIMBAD using the same methods described above for the main search. Proper motions have been obtained from UCAC3, SPM4, PPMXL (Roeser et al. 2010), or SuperCOSMOS, in that order. For stars that were not found in the UCAC3 data, positions were computed using the epoch, coordinates, and proper motion obtained from the corresponding catalog. Magnitudes are obtained using the 2MASS and SuperCOSMOS catalogs to compute distance estimates.

4. ANALYSIS

4.1. Color–Magnitude Diagram

In Figure 1, we show a color–magnitude diagram of the 334 new UPM proper motion objects (solid circles) and seven known objects (open triangles, companions to UPM objects) from this search having $R_{59F} - J$ colors. Symbols that fall below $R_{59F} \sim 17$ are CPM companion candidates noticed during visual inspection. The brightest new object, UPM 0747-2537A,

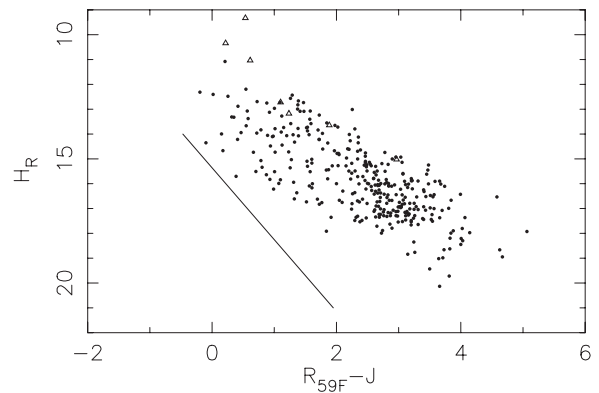


Figure 2. RPM diagram for all proper motion systems in this sample having an $R_{59F} - J$ color. New proper motion objects are represented by solid circles while known objects (CPM companions to new objects) are represented with open triangles. The empirical line separates the subdwarfs from where white dwarf candidates would be found. No white dwarf candidates were found in the current search.

has $R_{59F} = 9.80$ and is estimated to be at a distance of 40.6 pc. The reddest object found in this search is UPM 1848-0252 with $R_{59F} - J = 5.06$, $R_{59F} = 16.57$, at an estimated distance of 26.9 pc.

The subdwarf population is not as well defined as in TSN18 and TSN25 because there are far fewer new objects. Nonetheless, a separation can be seen below the concentration of main-sequence stars.

4.2. Reduced Proper Motion Diagram

In Figure 2, we show that the reduced proper motion (RPM) diagram for all objects also plotted in Figure 1, with similar symbols for new and known objects. The RPM diagram is a good method to help separate white dwarfs and subdwarfs from main-sequence stars, under the assumption that objects with larger distances tend to have smaller proper motions. Using the same method as in U3PM1 and TSN25 we obtain $H_{R_{59F}}$ via a modified distance modulus equation, in which μ is substituted for distance:

$$H_{R_{59F}} = R_{59F} + 5 + 5 \log \mu.$$

The solid line seen in Figure 2 is used to separate white dwarfs from subdwarfs. This is the same empirical line used in U3PM1 and previous TSN papers. No white dwarf candidates have been found during this latest search.

Subdwarf candidates have been selected using the same method as in U3PM1 and TSN25—stars with $R_{59F} - J > 1.0$ and within 4.0 mag in H_R of the empirical line separating the white dwarfs are considered subdwarfs. From this survey there are 17 subdwarf candidates, all with distance estimates greater than 122 pc, with the exception of one, UPM 1712-4432, with an estimated distance of 33.9 (see Section 4.4). Because the relations used to estimate distances assume that stars are on the main sequence, underluminous cool subdwarfs and white dwarfs have large distances, which can, in fact, be used to identify such objects. The distance estimates for these stars are presumably erroneous and are given in brackets in Tables 2–4. Follow-up spectroscopic observations will be needed to confirm all subdwarf candidates.

4.3. New Common Proper Motion Systems

In this search, we find 25 CPM candidate systems consisting of 24 binaries and one triple. Included in these CPM systems are

Table 4
Common Proper Motion Candidate Systems

Primary	$\mu_{\alpha} \cos \delta$ (mas yr ⁻¹)	μ_{δ} (mas yr ⁻¹)	Distance (pc)	Secondary/Tertiary	$\mu_{\alpha} \cos \delta$ (mas yr ⁻¹)	μ_{δ} (mas yr ⁻¹)	Distance (pc)	Separation (")	θ (°)	Notes
UPM 0209-3339A	-86.1	-166.9	49.5	UPM 0209-3339B	-112.9	-170.2	...	11.6	78.1	a b
UPM 0443-4129A	186.1	4.3	39.3	2MASS J04430760-4128575B	-107.5	-53.1	...	6.8	339.2	a b c
UPM 0528-4313A	-75.6	164.7	70.4	UPM 0528-4313B	-86.3	163.2	109.1	42.1	209.0	a
UPM 0659-0052A	-58.3	-184.1	78.2	UPM 0659-0052B	...	...	...	13.8	151.6	a b c
UPM 0704-0602A	...	...	123.4	UPM 0704-0602B	99.5	-153.0	37.8	12.2	359.1	a b c d
UPM 0747-2537A	-148.5	101.9	40.6	UPM 0747-2537B	-151.3	102.3	47.3	12.0	237.4	b
UPM 0800-0617A	135.2	-233.8	[175.5]	UPM 0800-0617B	...	...	...	5.8	297.2	a b c e
BD-04 2807A	-142.1	-37.1	19.5	UPM 1009-0501B	-190.5	92.1	...	20.9	338.5	a b
UPM 1020-0633A	-179.8	-27.8	34.8	SCR 1020-0634B	-181.5	-24.2	37.5	87.3	157.2	
UPM 1031-0024A	-207.4	-105.6	55.1	UPM 1031-0024B	-142.5	-96.9	...	7.4	91.4	a b f
UPM 1056-0542A	-98.1	-173.8	76.5	UPM 1056-0542B	-63.9	-173.3	...	9.0	86.2	a b
UPM 1142-2055A	-186.7	44.2	41.2	UPM 1142-2055B	...	...	...	8.3	167.6	a b c
NLTT 28641A	-201.8	6.2	...	UPM 1149-0019B	-201.5	2.2	...	27.3	128.2	a b
UPM 1159-3623A	-182.1	-101.4	113.1	UPM 1159-3623B	-172.6	-92.4	132.4	13.6	303.7	a
UPM 1226-2020A	-137.6	-119.8	72.3	UPM 1226-2020B	-146.3	-117.3	...	7.0	333.3	a b
SCR 1226-3515A	-192.3	41.0	56.5	UPM 1226-3516B	-200.5	38.3	127.5	49.8	191.3	a g
				UPM 1226-3516C	-115.2	8.5	243.3	97.0	146.9	a c g
UPM 1315-2904A	-190.6	-27.5	89.6	UPM 1315-2904B	-209.7	-1.5	149.3	5.9	332.6	a
2MASS J13465039-2112266A	-186.8	-44.0	46.8	UPM 1346-2111B	-112.1	-60.0	86.8	82.2	350.8	a c
UPM 1718-2245A	-160.7	-160.8	25.4	UPM 1718-2245B	-161.1	-154.8	13.2	54.3	149.2	a
UPM 1724-0318A	143.7	-126.7	92.0	UPM 1724-0318B	...	...	169.5	5.5	325.4	a b c
TYC 7897 997 1A	-10.4	-160.2	40.3	UPM 1749-4404B	0.0	-204.9	...	19.8	254.0	a b c d
TYC 8344 154 1A	51.6	-179.5	...	UPM 1757-4632B	59.7	-185.1	...	30.7	296.9	a b
UPM 2049-0304A	83.1	-185.7	...	UPM 2049-0304B	...	...	...	5.3	1.5	a b c
2MASS J22294694-0432036A	160.9	-86.5	50.8	UPM 2229-0432B	...	...	...	8.7	134.7	a b c
UPM 2250-2908A	186.9	-9.2	115.3	UPM 2250-2908B	182.3	-17.0	155.7	5.4	241.4	a b c

Notes.

^a Not detected during automated search but noticed by eye during the blinking process.

^b Number of relations used for distance estimate <6; plate distance less reliable.

^c Proper motions suspect.

^d SuperCOSMOS plate magnitudes suspect.

^e Subdwarf candidate selected from RPM diagram; plate distance (in bracket) is incorrect.

^f Source not in 2MASS.

^g Possible NLTT star with a position difference >90'' when compared to UCAC3 position.

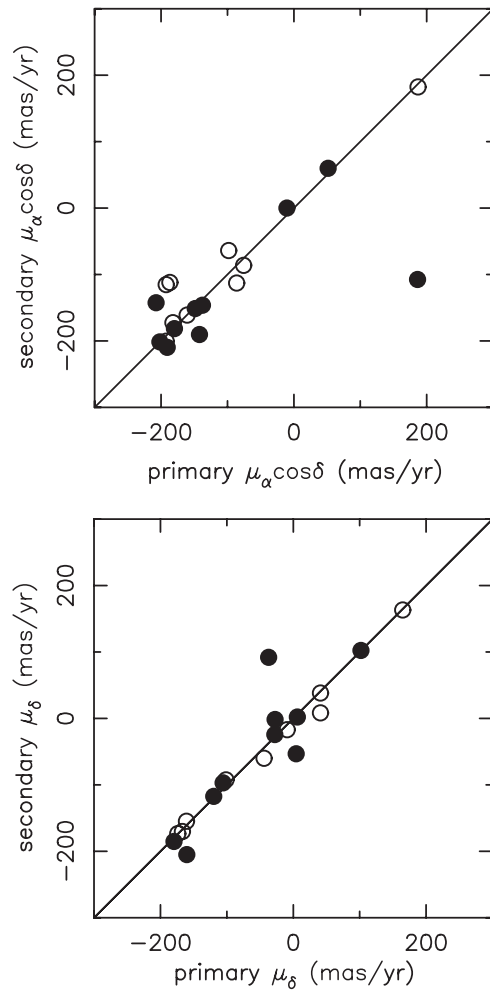


Figure 3. Comparisons of proper motions in each coordinate, $\mu_\alpha \cos \delta$ (top) and μ_δ (bottom), for components in CPM systems. Proper motions from the UCAC3 catalog are represented by solid circles while proper motions manually obtained through other means are denoted by open circles. The solid line indicates perfect agreement. Information on the outliers can be found in Section 4.4.

16 new systems and nine known systems with newly discovered components.

One binary system, UPM 0800-0617AB, is a possible subdwarf binary system. The lone triple is an SCR system with two newly discovered components. In Table 4, we list the CPM system primaries and companions, their proper motions, and the companions' separations and position angles relative to the primaries (defined to be the brightest star in each system using the UCAC bandpass or an alternate bandpass if a UCAC value is not available). We also provide distance estimates for each component, where possible. Components were determined to be potentially physically associated using distance estimates in conjunction with the proper motions and visual inspections. However, most of the companions were found during visual inspection, meaning that proper motions, 2MASS and/or SuperCOSMOS magnitudes may be missing or suspect, as identified in the notes. For systems with data missing in Table 4, the physical connection of the system components should be considered tentative.

In Figure 3, we show comparisons of the proper motions in each coordinate for the 19 CPM systems for which both components have a listed proper motion. CPM candidates having proper motions from the UCAC3 are represented by solid

circles while those with proper motions from other sources are represented by open circles. If a proper motion was not present in the UCAC3, data were obtained manually from the SPM4, PPMXL, or SuperCOSMOS databases, in that order.

4.4. Notes on Specific Stars

UPM 0443-4129AB is a possible CPM binary. However, UPM 0443-4129A has a suspect proper motion and the companion's distance estimate uses fewer than six relations. It is possible that this pair is a case of a chance alignment. See Table 4 for more details.

BD-04 2807AB is a possible CPM binary. However, the primary has a suspect proper motion, a distance estimate that uses fewer than six relations, and there is no distance estimate for the secondary. It is possible that this pair is a case of a chance alignment. See Table 4 for more details.

UPM 0747-2537A is the brightest new discovery from this search with $R_{59F} = 9.80$ and an estimated distance of 40.6 pc. However, only one relation was viable, making the distance estimate unreliable.

UPM 0800-0617AB is a possible candidate for a binary subdwarf system. The primary is a possible subdwarf at an estimated distance of 175.5 pc. The secondary is at a separation of $5''.8$ at position angle $297^\circ.2$ from the primary. Color information is insufficient for a reliable distance estimate.

UPM 1226-3516 B and C are in a candidate triple system with SCR 1226-3515A. The A and B components are separated by $49''.8$ at a position angle of $191^\circ.3$. The C component has a separation of $97''.0$ at a position angle of $146^\circ.9$ from the primary. The C component has a suspect proper motion and the distance estimates for all three components are inconsistent. In particular, the C component may not be a part of the system. See Table 4 for more details.

UPM 1712-4432 is a subdwarf candidate with $R_{59F} = 13.04$ and $R_{59F} - J = 1.01$ at a distance of 33.9 pc. However, only three relations were viable, making the distance estimate unreliable. SuperCOSMOS magnitudes are indicative of a blended image, meaning this is likely not what it seems.

UPM 1718-2245B has an estimated distance of only 13.2 pc based on seven relations, making it the nearest candidate in the sample. However, the primary has a distance estimate of 25.4 pc based on ten relations so we favor the larger distance for the system.

UPM 1848-0252 is the reddest new discovery from this search, with $R_{59F} - J = 5.06$ and an estimated distance of 26.9 pc.

4.5. Comparison to Previous Proper Motion Surveys

During production of the UCAC3 catalog, we made an effort to tag previously known HPM stars. For these stars, proper motions were taken from their respective catalogs rather than calculated using UCAC3 methodology, which made comparisons to other catalogs/surveys difficult. However, during the present search we have found 104 stars in both the *Hipparcos* and *Tycho-2* catalogs that are not tagged as HPM stars in the UCAC3 catalog—these stars are proper motion candidates that were found to be in *Tycho-2* during cross-checking. A $2''.5$ radius was used to match these stars to sources in the *Hipparcos* catalog so that we can compare the bright end of the UCAC3 proper motion stars ($R \sim 7.13\text{--}13.66$) to stars in both the *Tycho-2* and *Hipparcos* catalogs. In Figure 4, we compare proper motions in R.A. and decl. for these stars as given in UCAC3, *Hipparcos*,

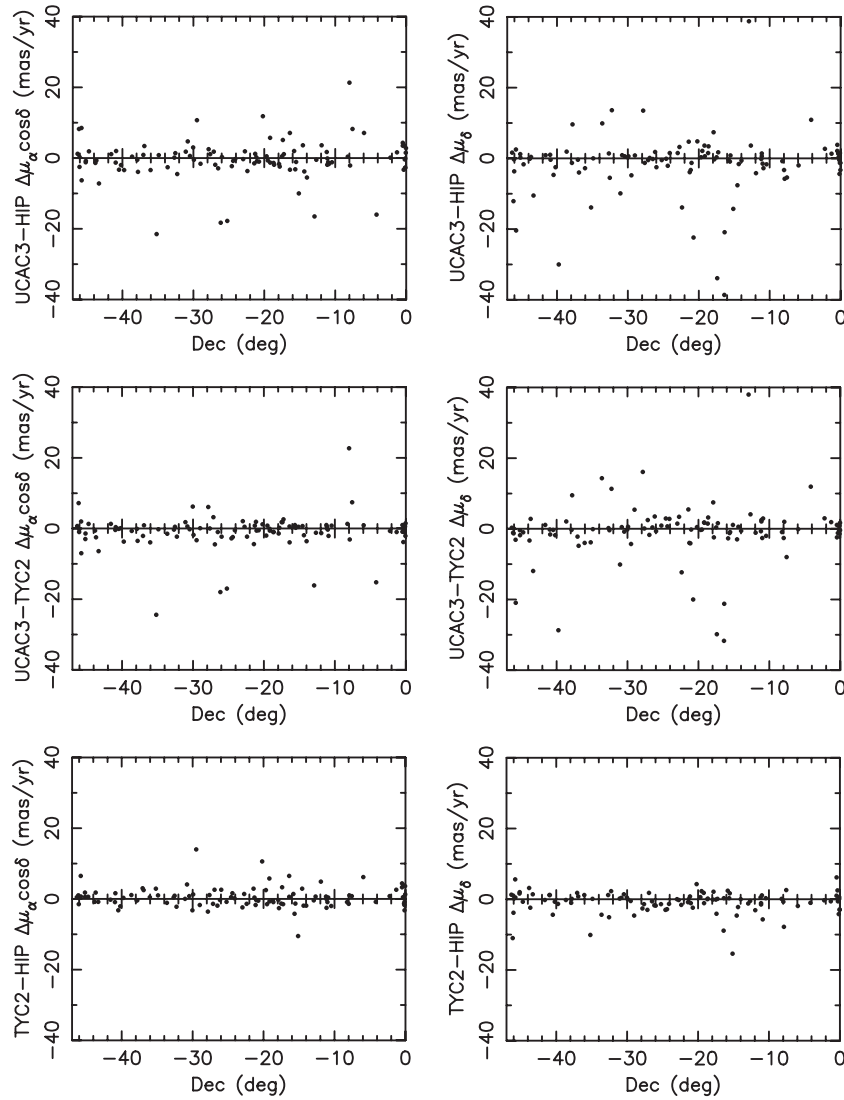


Figure 4. Comparisons of UCAC3, *Hipparcos* and *Tycho-2* proper motions per coordinate, $\Delta\mu_\alpha \cos \delta$ (left column) and $\Delta\mu_\delta$ (right column).

and *Tycho-2*. These plots show that the differences in proper motions are small, in general less than 10 mas yr^{-1} , and no significant systematic errors as a function of declination are seen. The rms differences between UCAC3 proper motions in $\Delta\mu_\alpha \cos \delta$ and $\Delta\mu_\delta$ and those from *Hipparcos* are 5.7 and 9.1 mas yr^{-1} , respectively. Comparisons to *Tycho-2* yield rms differences of 5.2 and 8.3 mas yr^{-1} , respectively. Lower rms differences of 3.0 mas yr^{-1} in $\Delta\mu_\alpha \cos \delta$ and 3.2 mas yr^{-1} in $\Delta\mu_\delta$ are seen when comparing the *Hipparcos* to *Tycho-2* proper motions.

To investigate the fainter end of UCAC3, we compare results for 77 stars ($R \sim 10.88\text{--}16.69$) that are in both the SPM4 and SuperCOSMOS catalogs that were not tagged as HPM stars in the UCAC3 catalog—these stars are proper motion candidates that were found to be SCR stars during cross-checking. A $2''.5$ radius was used to match these stars to sources in the SPM4 catalog. The SPM4 catalog only covers decl. = -90 to -20 sky area, limiting the area included for this comparison. In Figure 5, we compare proper motions in R.A. and decl. for these stars as given in UCAC3, SuperCOSMOS, and SPM4. These plots show that differences in proper motions are similar to those found for brighter stars when comparing UCAC3 and SPM4, but the differences are much larger for the SuperCOSMOS results. The rms differences between UCAC3

proper motions in $\Delta\mu_\alpha \cos \delta$ and $\Delta\mu_\delta$ and those in SPM4 are 6.0 and 5.7 mas yr^{-1} respectively. Comparisons to SuperCOSMOS yield rms differences of 16.5 and 14.1 mas yr^{-1} , respectively. In Figure 5, we also see that proper motions in decl. appear to be systematically shifted in the SuperCOSMOS data. These high rms results and the systematic shift are also seen in the comparison of the SPM4 to the SuperCOSMOS proper motions, yielding rms differences of 15.6 and 15.2 mas yr^{-1} in $\Delta\mu_\alpha \cos \delta$ and $\Delta\mu_\delta$, respectively. The higher rms differences for the SuperCOSMOS proper motions are in agreement with the findings of TSN18 and U3PM1 where SCR proper motions were found to have higher rms differences when compared to other external catalogs. It is worth noting that the SuperCOSMOS proper motion rms reported here are not representative of the entire catalog. Objects having $R \sim 16\text{--}19$ with $\mu > 0''.10 \text{ yr}^{-1}$ in the SuperCOSMOS catalog should have an rms no greater than 10 mas yr^{-1} , and considerably better for fields with decades between the epochs (see Tables 1 and 3 from Hambly et al. (2001a)).

Random and systematic differences of order 10 mas yr^{-1} in proper motions between the various catalogs, particularly at the faint end, are expected because of different data quality, measurements, reductions, and epoch differences.

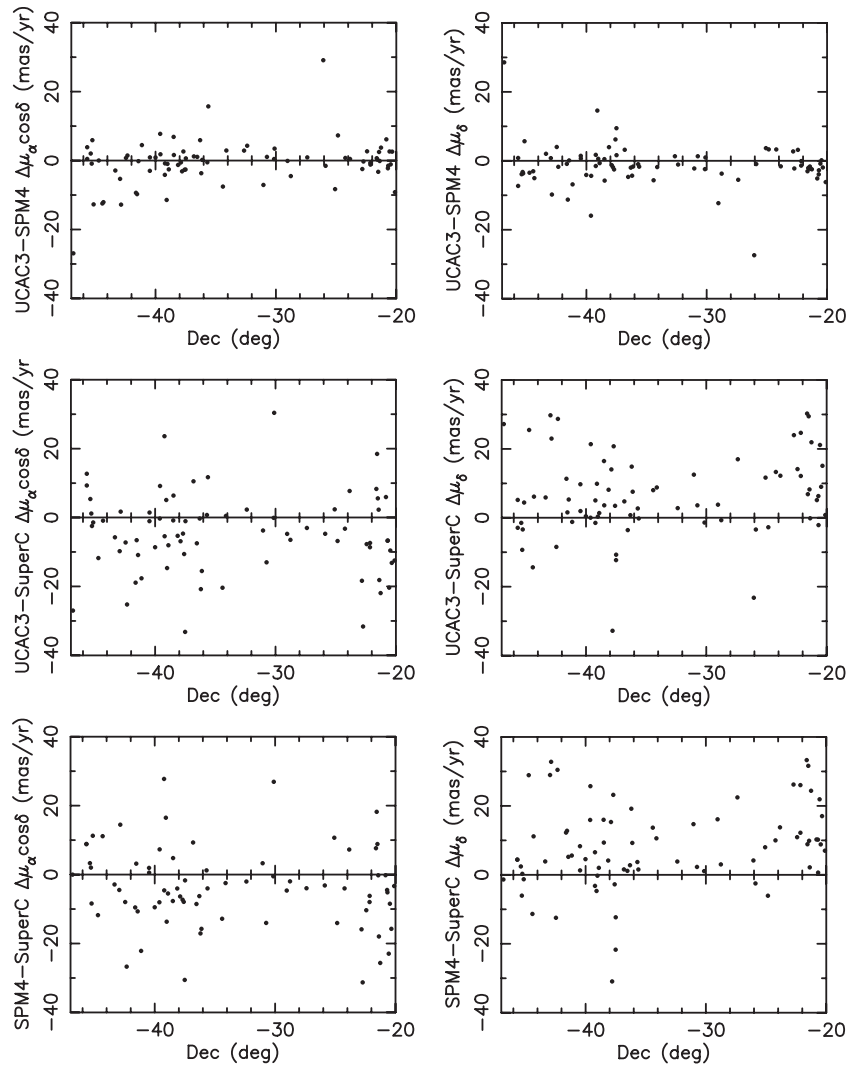


Figure 5. Comparisons of UCAC3, SuperCOSMOS, and SPM4 proper motions per coordinate, $\Delta\mu_\alpha \cos \delta$ (left column) and $\Delta\mu_\delta$ (right column).

SuperCOSMOS, for example, uses Schmidt plates for both early and recent epochs which typically show large errors. The proper motions of faint stars in UCAC3 are based on early epoch Schmidt plates for the sky area north of -20 deg decl. and CCD observations for recent epoch data. A combination of CCD data and early astrograph data (SPM plates) is used south of -20 deg, with significantly smaller errors. The SPM4 proper motions are derived entirely on SPM astrograph plates from two epochs. At the bright end proper motions are more reliable due to the higher quality of *Hipparcos* and *Tycho-2* data as well as availability of many other star catalogs, most of which have been used in common between *Tycho-2* and UCAC3. However, there can be large differences between *Hipparcos* and *Tycho-2* for some stars because the *Hipparcos* proper motions are based on only about 3.5 years of observing (although with high quality), while *Tycho-2* proper motions are based on typically 100 years epoch difference. Multiplicity and residual orbital motions sometimes render *Hipparcos* proper motions inferior in spite of their small formal astrometric errors.

In TSN25 a total of 3073 objects were reported, all of which fit within the proper motion and declination constraints of this paper. During this UCAC3 search, only 770 of the 3073 objects reported in TSN25 were recovered, or a low 25.1% recovery rate. This is primarily due to the UCAC3 catalog having no proper

motion or a reported proper motion not meeting the criteria of this paper ($0'.40 \text{ yr}^{-1} > \mu \geq 0'.18 \text{ yr}^{-1}$) for $\sim 70\%$ of the new discoveries listed in TSN25.

The *Hipparcos* catalog contains 118,218 total objects, of which 1690 meet the proper motion and declination constraints of this paper. *Tycho-2* contains 2539,913 total objects in the main catalog, of which 3187 meet similar limits. We recover 1316 *Hipparcos* stars and 2543 *Tycho-2* stars using the search criteria of this paper, yielding recovery rates of 77.9% and 79.8%, respectively. Objects missed in this UCAC3 survey are primarily due to UCAC3 lacking a source detection for $\sim 15\%$ of the *Tycho-2* objects. The relatively high recovery rates of UCAC3, when compared to the *Hipparcos* and *Tycho-2* catalogs, implies that the UCAC3 can be used as a reliable source to search for new proper motion stars with $\mu = 0.18\text{--}0'.40 \text{ yr}^{-1}$ for other portions of the sky.

5. DISCUSSION

We have completed a sweep of the southern sky for new proper motion systems using the UCAC3 catalog. So far, we have uncovered 916 new proper motion systems, of which 474 are described in this paper. These systems constitute an increase of 19.4% over the total number of SCR systems discovered in

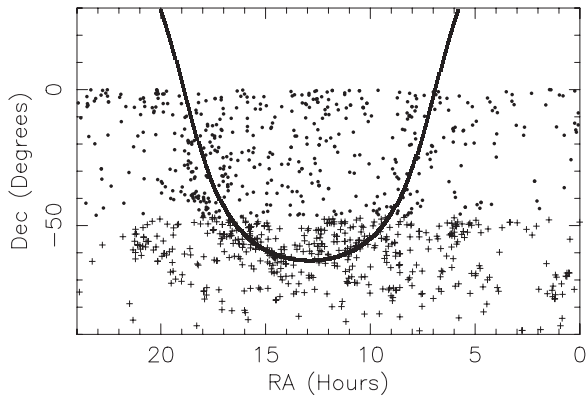


Figure 6. Sky distribution of all UCAC3 proper motion survey objects reported in U3PM1 (plus signs) and this paper (solid circles), i.e., those between declinations -90° and 0° having $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$. The curve represents the Galactic plane.

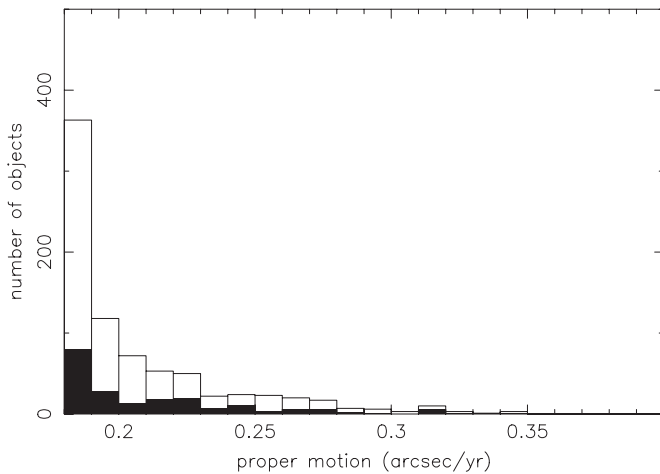


Figure 7. Histogram showing the number of proper motion objects in $0''.01 \text{ yr}^{-1}$ bins for the entire UCAC3 proper motion sample (empty bars) and the number of those objects having distance estimates within 50 pc (filled bars).

the southern sky and an increase of 20.7% over SCR systems in the southern sky with $0''.40 \text{ yr}^{-1} > \mu \geq 0''.18 \text{ yr}^{-1}$. This UCAC3 proper motion survey has added 3.8% to the list of entries in the NLTT catalog south of decl. $= 0^\circ$ with 974 new proper motion objects from U3PM1 and this paper.

In Figure 6, we show the sky distribution of systems found to date during the UCAC3 proper motion survey. Plus signs represent objects from U3PM1 and solid circles represent objects described in this paper. Overall, the distribution of new objects is similar to that seen in Figure 6 of TSN25, including the discovery of many new proper motion systems along the Galactic plane.

In Figure 7, we show a histogram of the number of proper motion systems discovered to date during the UCAC3 proper motion survey, in $0''.01 \text{ yr}^{-1}$ bins, and highlighting the number of those having distance estimates within 50 pc. Predictably, this plot shows that the slowest proper motion bins have the most new systems. This confirms the trend reported in TSN18, TSN25, and U3PM1 and suggests once again that more nearby stars are yet to be found at slower proper motions.

We have found a total of 57 CPM candidate systems during this UCAC3 proper motion survey, including 55 binaries and two triples. These systems have separations of $1''$ – $359''$ and will need further investigation to confirm which of the systems are, in fact, gravitationally linked. In addition, we have revealed a

total of 48 subdwarf candidates, each of which is worthy of follow-up observations, given the scarcity of nearby subdwarfs. Finally, we have found 20 red dwarf systems likely to be within 25 pc. We plan to obtain CCD photometry through *VRI* filters for stars having estimated distances within 25 pc in order to make more reliable distance estimates using the *VRIJHK* relations presented in Henry et al. (2004). Stars estimated to be within 10 pc will then be put on the CTIO parallax program, potentially to join the ranks of the few hundred systems known to be so close to the Sun (Henry et al. 2006).

We thank the entire UCAC team for making this proper motion survey possible, and the USNO summer students, who helped with tagging HPM stars in the UCAC3 catalog. Special thanks go to members of the RECONS team at Georgia State University for their support, and John Subasavage in particular for assistance with the SCR searches. This work has made use of the SIMBAD, Vizier, and Aladin databases operated at the CDS in Strasbourg, France. We have also made use of data from the Two Micron All Sky Survey, SuperCOSMOS Science Archive, and the Southern Proper Motion catalog.

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