UCAC4 Nearby Star Survey: A Search for Our Stellar Neighbors

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Abstract.

We present 16 photometric color-M_K relations using the U. S. Naval Observatory Fourth CCD Astrograph Catalog (UCAC4. These relations estimate distances to nearby red dwarfs at the ∼15% accuracy level using photometry from the Two-Micron All-Sky Survey (2MASS) and the AAVSO Photometric All-Sky Survey (APASS). A sample of nearby stars from the Research Consortium On Nearby Stars (RECONS group along with a supplemental list of very red stars all having accurate trigonometric parallaxes are used to generate the relations. Color, proper motion, and existing literature sources are used in an attempt to attain a clean sample of red dwarfs while limiting the amount of contamination from background giants. From this sample, we find 1761 candidate nearby M dwarfs estimated to be within 25 pc. Of this sample, 339 have no previously known published parallax or distance estimate and five of these are estimated to be within 10 pc. The nearest distance estimate of 5.9 pc was found for a star with V magnitude of 10.5. That several hundred new stars have been revealed so close to the Sun illustrates once again that there is considerable work yet to be done to map the solar neighborhood.

1. Introduction

Nearby stars represent the best candidates for detailed studies of stellar luminosity and mass functions, as well as stellar activity, ages, multiplicity, and exoplanets because they are the brightest members of their classes of stars. Candidate nearby stars are often selected by proper motion for follow-up studies to confirm proximity. One primary goal of the Research Consortium On Nearby Stars (RECONS) effort is to identify and characterize all stars within 25 pc of the Sun. This work represents an initial phase of candidate identification that permits trigonometric parallax investigations by, e.g., the Cerro Tololo Inter-American Observatory Parallax Investigation (CTIOPI; Riedel et al. 2014, and references therein).

The U. S. Naval Observatory Fourth CCD Astrograph Catalog (UCAC4; Zacharias et al. 2013) contains more than 100 million sources and has incorporated photometric data from both the American Association of Variable Star Observers (AAVSO) Photometric All Sky Survey (APASS) and the Two Micron All-Sky Survey (2MASS). The astrometric data in the catalog is a compilation of original observations coupled with results from large proper motion surveys (e.g., Lépine & Shara 2005). In this work, we search the UCAC4 to identify candidate nearby stars where a full discussion can be found in (Finch et al. 2014).

2. Photometric Distances

To obtain photometric distances for UCAC4 sources, we generated a new set of 16 photometric color-M_{K_s} relations using (a) $BVgri$ optical photometry from APASS, (b) JHK_S near-infrared photometry from 2MASS, (c) nearby red dwarfs with high-quality trigonometric parallaxes from the RECONS effort, and (d) a set of M dwarfs with spectral types M6.0 V to M9.5 V within 25 pc that is referred to as the supplemental sample in Henry et al. (2006). M_{K_s} magnitudes were calculated for all calibration stars and compared to the suite of photometric colors available ($BVgriJHK_S$). A minimum color range of one magnitude was required for a given color to be reliable thus reducing the 28 possible relations to 16. A second-order fit was used for all relations and the coefficients of these fits, as well as the applicable color range, are listed in Table .1. Not all calibration stars had useful data in all wavebands so the number of stars used is different for each color relation and ranges from 102 to 141.

3. UCAC4 Trawl for Nearby Stars

A series of cuts were applied to the UCAC4 catalog to identify 25 pc candidate members.

- Target must have photometry in at least two filters in the APASS catalog, with photometry errors (apase) $\leq$ 0.10 mag.
- Target must have photometry in all three JHK_S filters in the 2MASS catalog, with photometry errors (e2mpho) $\leq$ 0.10 mag.
- Target must not have a UCAC object flag (objt) = 1 or 2, indicating it is near an over-exposed star or a streaked object.
- Target must have a valid, non-zero proper motion.

Table .1: Details of the 16 Photometric Distance Relations

Color	Color Range [mag]	Stars Used [number]	Coeff. 1 [× color^2]	Coeff. 2 [× color]	Coeff. 3 [constant]	rms [mag]
V–J	3.1 – 7.0	118	−0.14260	+2.551	−1.0870	0.40
V–H	3.5 – 7.7	118	−0.13910	+2.657	−2.3950	0.41
V–K	4.0 – 8.0	118	−0.12390	+2.523	−2.4720	0.42
V–i	1.4 – 3.9	113	−0.33800	+3.663	+0.9571	0.38
B–J	4.2 – 9.0	140	−0.08928	+2.188	−2.6330	0.37
B–H	4.9 – 10.0	141	−0.09372	+2.347	−4.0930	0.39
B–K	5.0 – 10.0	141	−0.08031	+2.174	−3.8580	0.39
B–i	2.8 – 6.0	102	−0.13570	+3.091	−1.6910	0.38
g–J	3.9 – 7.8	113	−0.13290	+2.693	−2.8800	0.39
g–H	4.2 – 8.4	113	−0.11760	+2.796	−4.2560	0.41
g–K	4.5 – 8.8	108	−0.13480	+2.637	−4.2120	0.41
g–i	2.2 – 4.5	105	−0.13340	+3.619	−1.0110	0.39
r–J	2.9 – 6.2	107	−0.11530	+2.383	+0.2988	0.41
r–H	3.4 – 6.8	107	−0.28630	+2.502	−0.9758	0.42
r–K	3.5 – 7.1	102	−0.19210	+2.353	−1.0590	0.42
r–i	1.0 – 3.0	105	−0.26210	+3.237	+2.9860	0.41

– Target must have a Lyon-Meudon Extragalactic DAtabase (LEDA) galaxy flag (leda) = 0 and a 2MASS extended source flag (2mx) = 0 – both indicate a point source.

The remaining number of candidates after the cuts was 25,865,591. The photometric distance relations were then applied to these candidates requiring that (a) at least seven of the 16 relations were used, and (b) distances were estimated to be within 25 pc to produce a list of candidates numbering 381,054. This candidate list was then cross-checked with literature sources to find spectral types and previous distance estimates (either via trigonometric parallax or photometric). Dozens of known giants were extracted via this literature search and were used as empirical checks for the next two constraints imposed on the sample to minimize giant contamination.

We implemented the $J - K_S$ vs. $V - K_S$ color-color diagram coupled with the boundary constraints defined in Riedel (2012) that isolate regions of suspected dwarfs vs. those of giants. Figure .1 illustrates these boundaries with known dwarfs and giants overplotted in the left panel and the entire unknown sample of 381,054 (as a surface density plot) in the

right panel. Box 1 contains candidates that are most likely M dwarfs while Box 2 contains M dwarfs with significant giant contamination. The number of candidates within both boxes was reduced to 4424.

As a second constraint to minimize giant contamination, we implemented a reduced proper motion cut using the proper motions from UCAC4. Reduced proper motion is a useful tool for separating dwarfs from giants and takes the following form.

$$H_V = V + 5log\mu, \tag{1}$$

where μ is given in arcseconds per year. The reduced proper motion diagram with our known giants and dwarfs is plotted in the left panel of Figure .2 as well as the empirical boundary between the two samples. The unknown sample is plotted in the right panel of Figure .2. Once this criterion was implemented, another 2408 candidates from the sample of 4424 were removed yielding a sample of 2016 candidate nearby stars. After removing duplicate entries from this sample, a total of 1761 candidates remained.

From this sample of 1761 candidates, 669 have published trigonometric parallaxes, 749 have published photometric/spectroscopic distance estimates, and 4 are known giants. The remaining 339 candidates are new potential 25 pc members. A by-eye examination of these 339 candidates was performed using Aladin and revealed that 101 did not show any detectable proper motion. Further investigation of the epoch spreads of the plates indicated that all but six of the 101 targets had less than one arcsecond of total proper motion between the two epochs.

Finally, as is evident in Figures .1 and .2 a handful of bona fide M dwarfs have been eliminated by our selection criteria. Of the 181 known M dwarfs, a total of eight were omitted thus resulting in a ∼4% loss. This loss is acceptable given that we aim to obtain a clean sample of M dwarfs with minimal giant contamination.

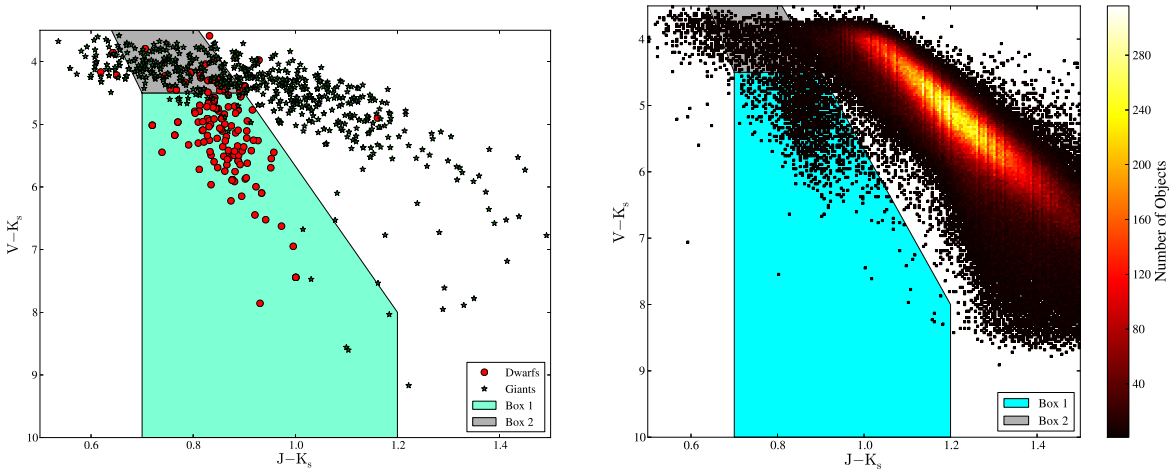

Figure .1: **Left:** Color-color plot showing the regions (shaded boxes) where dwarfs are expected vs. those of giants and overplotted are the known giants (*stars*) and the known dwarfs (*circles*). **Right:** Same plot as left except now overplotting the sample of 381,054 candidates (as a surface density plot).

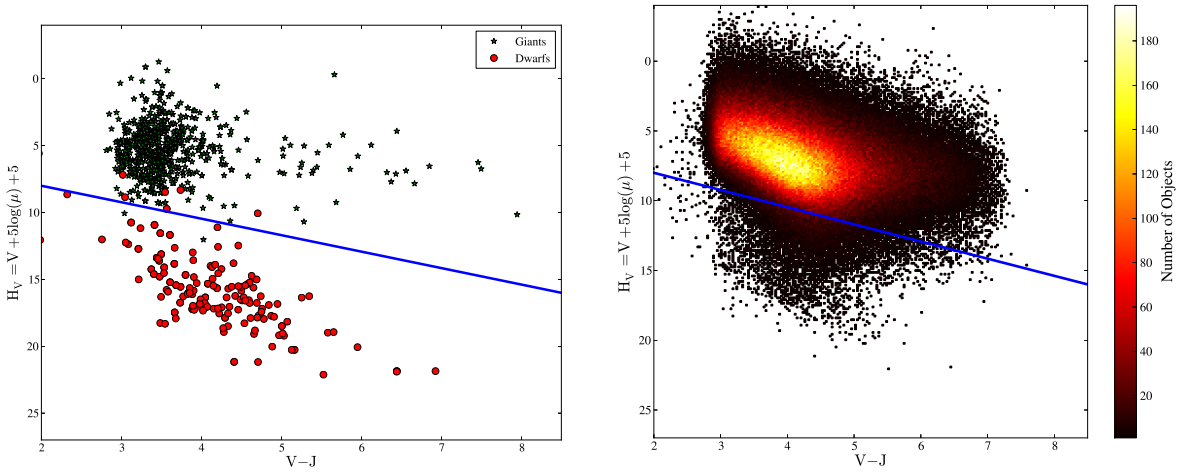

Figure .2: **Left:** Reduced proper motion diagram illustrating the dividing line between the sample of known giants (stars) vs. that of known dwarfs (circles). **Right:** Same plot as left except now overplotting the 381,054 candidates (as a surface density plot).

4. Results

A total of 339 candidate nearby stars within 25 pc have been identified by this effort, including five estimated to be within 10 pc. A sky distribution plot is shown in Figure .3 and illustrates that the majority of the new discoveries are in the southern hemisphere, likely the result of historical undersampling relative to the north. Follow-up trigonometric parallax efforts are needed to confirm proximity.

4.1 Local Statistics

By evaluating the sample of 669 candidates recovered in this work that have previous trigonometric parallaxes, we find that 532 have distances within 25 pc and 110 are beyond 25 pc – a success rate of 84%. We then infer that ∼285 of the 339 new candidates are likely within 25 pc. To estimate the impact this new nearby candidate sample has on the local statistics, we use the RECONS 25 pc Database. As on 01 January 2014, there are 2169 systems known within 25 pc based on accurate trigonometric parallaxes (i.e., parallax errors less than 10%). Therefore, 285 new members of the 25 pc sample represent an increase of 13%. We expect ongoing astrometric efforts (e.g., USNO, CTIOPI) as well as European Space Agency's Gaia astrometric mission will verify proximity for these targets as well as to better populate the sample of M dwarfs within 25 pc overall.

5. Conclusions

We use the UCAC4 catalog, which compiles previous astrometric efforts in addition to original astrometric results as well as the photometric catalog of the APASS, to identify new nearby M dwarfs within our 25 pc horizon of interest. To aid in this effort, we developed color-M_{K_S} relations using the UCAC4 catalog cross-matched with known M dwarfs that have

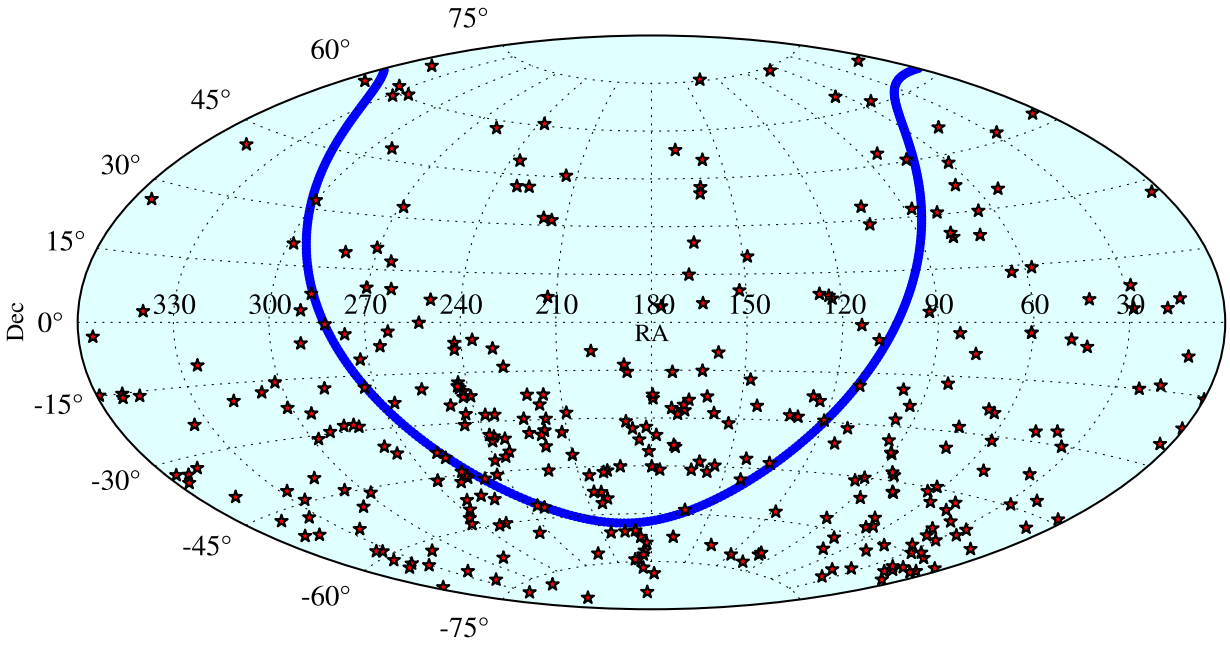

Figure .3: Aitoff sky projection illustrating the 339 new nearby candidates (stars). The Galactic Plane (blue curve) is also shown for reference.

accurate trigonometric parallaxes. We also utilize color-color and reduced proper motion diagrams to better permit giant discrimination. The final sift revealed 339 candidate new nearby stars within 25 pc, including five within 10 pc. All tabular data from this survey, as well as additional details related to the survey, can be found in Finch et al. (2014).

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