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A search for high proper motion objects in the UKIDSS Galactic plane survey

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Abstract. The UKIDSS Galactic Plane Survey (GPS) began in 2005, as a 7 year effort to survey approximately 1800 deg^2 of the northern Galactic plane in the J, H, and K pass-bands. The survey also included a second epoch of K band data with a baseline typically >1.8 years for the purpose of investigating variability, this also allows for the measurement of stellar proper motions. We have calculated and visually verified proper motions for 617 high proper motion (> 200 $mas\ yr^{-1}$) sources from some 900 deg^2 of sky, 153 of which are new detections. Among these we have a new spectroscopically confirmed T5 dwarf and a further T6 dwarf awaiting confirmation, 14 new L dwarf candidates, and two new common proper motion systems containing ultracool dwarf candidates. The high source density in the Galactic plane leads to a high rate of mismatches. Spurious high proper motion detections are common and visual verification is essential as a result. The rate of false positives increases dramatically towards lower Galactic longitudes, though the reliability of detections improves at lower proper motions, and hence these data are potentially useful for identifying members of clusters within a few hundred pc. Gaia will vastly proper motion searches in the Galactic plane, though searches in current NIR surveys maintain their usefulness by probing deeper for brown dwarfs and identifying low mass benchmark companions to Gaia's objects.

Key words. Catalogues – Proper motions – Binaries:general – Brown dwarfs – Stars:low mass

1. Introduction

The two epochs of high resolution UKIDSS GPS data (Lawrence et al. 2007, Lucas et al. 2008) provide a new resource to search for previously missed high proper motion objects, especially brown dwarfs which would typically have been undetected in previous optical searches, and also to investigate stellar variability (see e.g. Contreras Peña et al. 2014).

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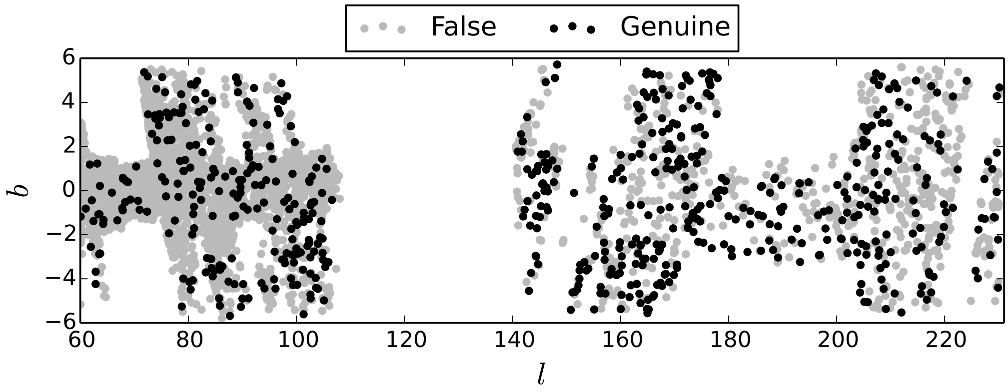

Fig. 1. The distribution of high proper motion candidates in Galactic coordinates. The fraction of false positives increases with source density at lower galactic latitudes. High proper motion sources are relatively nearby and we expect them to be at a fairly constant density across the sky, which appears to be the case here. This suggests the higher source density is not inhibiting our sensitivity to high proper motion sources to any great degree, at least at $l > 60°$.

In recent years there have been a multitude of very nearby object discoveries.

Examples of recent < 10 pc discoveries include: Artigau et al. (2010) identified DENIS J081730.0-615520, a T6 dwarf at 4.9pc and $b \sim$ -14° in the DEep Near-Infrared Survey of the Southern sky (DENIS, Epchtein et al. 1997). Gizis et al. (2011) and Castro & Gizis (2012) identified 2 L dwarfs within 10 pc of the sun at low Galactic latitudes by searching for detections in WISE with no corresponding detection in 2MASS. Luhman (2013) identified WISE J104915.57-531906.1, a binary brown dwarf system at 2 *pc* in the WISE dataset. Mace et al. (2013a) and Cushing et al. (2014) discovered numerous late T dwarfs in the WISE survey, including WISE J192841.35+235604.9 (T6) and WISE J200050.19+362950.1 (T8) both of which are in the Galactic plane and likely to be within 8 pc. Scholz (2014) used WISE data to identify a 5-7 pc (taking into account the possibility of multiplicity) ~M9 type UCD in the Galactic plane. Interestingly, some of the objects listed above could have been identified in previous surveys but for the effect of source confusion on both colour-based and proper motion-based searches. A search of the 2 epoch high resolution GPS dataset could be expected to reveal many previously unidentified objects in the solar neighbourhood.

2. Proper motion calculation

We paired UKIDSS GPS K band FITS file catalogues with epoch differences > 1.8 years and $l > 60°$ and matched their contents using a 24" radius and a K band difference tolerance of 0.3 magnitudes using a Sky+1d best match in STILTS (Taylor 2006). We selected high quality reference sources and used them to create a unique 2nd order polynomial coordinate transform for every source. Where reference source density and distribution allowed we fit the polynomial transformation using reference sources local to each target. These transformations map the second epoch array coordinates onto the first epoch array coordinate frames and produces a more accurate motion measurement than transformation of each frame as a whole (see Smith et al. 2014 Figure 2).

3. High proper motion sources

From the 167 million source results table we selected 5,655 good quality high proper motion (> 200 $mas\ yr^{-1}$) candidates for visual verification. The high source density in the Galactic

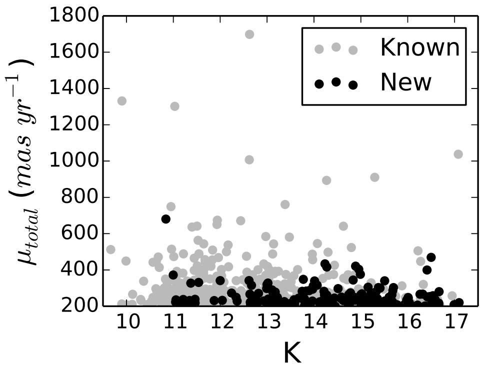

Fig. 2. The distribution in K band magnitude and total proper motion of the 617 total high proper motion sources identified. The 153 previously unidentified sources are shown in black. The previously identified sources are shown in grey.

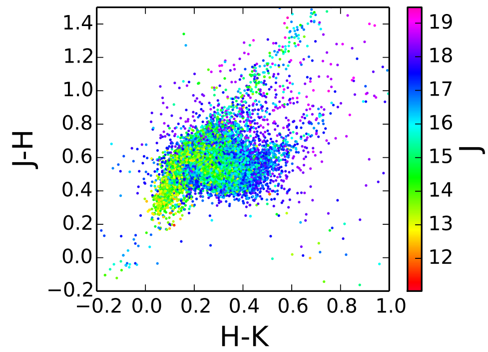

Fig. 3. A 25,729 source UKIDSS DR8 only sample which pass our quality control cuts in ellipticity, morphological classification and magnitude error; have low proper motion ($\mu < 200\ mas\ yr^{-1}$); have motion between the epochs > 200 *mas*; and DR8 coverage in J, H, and K.

plane produced many mismatches (see Fig. 1), which were the dominant cause of false detections and make visual verification essential for a trustworthy high proper motion source identification.

We identified 617 genuine high proper motion sources, 153 of which were previously unidentified (Fig. 2). Among these we find 14 new candidate L dwarfs, one of which is a proper motion companion (2.2” separation)to an early M dwarf and another which is likely to be within 25 pc; and two T dwarfs within 25 pc, a T6 dwarf and a T5 dwarf with possible low gravity/high metallicity spectral features.

4. Low proper motion sources

The fraction of false positive high proper motion detections decreases with decreasing apparent proper motion as might be expected. This suggests that the lower proper motion results, of which there are too many to feasibly inspect visually, might be useful without visual verification. Figure 3 shows a two colour magnitude (J, J-H, H-K) diagram of 25,729 high quality sources with UKIDSS DR8 JHK detections, proper motion less than 200 $mas\ yr^{-1}$, and motion between the epochs greater than 200 *mas*. This selection is a fairly clean sample of nearby sources with minimal contamination by more distant reddened stars which may be either false proper motion detections or in fact genuine genuine distant Galactic sources. We are likely to find many more previously unidentified brown dwarfs, subdwarfs and white dwarfs within this sample (Fig. 4 shows a reduced proper motion plot for the high proper motion sample). The low proper motion selection may also prove useful for identification of new members of nearby clusters, low mass companions to known proper motion stars, and new members of nearby young moving groups.

5. Summary

We have identified 153 new high proper motion ($\mu > 200\ mas\ yr^{-1}$) sources within approximately 900 deg^2 of the UKIDSS GPS. These include a pair of T dwarfs within 25 pc, 14 new L dwarf candidates and two new common proper motion systems containing an ultracool dwarf candidate. We are continuing to mine the lower proper motion ($\mu < 200\ mas\ yr^{-1}$) for interesting objects which may have gone undetected in existing proper motion and photometric searches of the Galactic plane. In the context of Gaia, proper motion catalogues such as these allow us to search for low mass companions to the brighter main sequence stars and

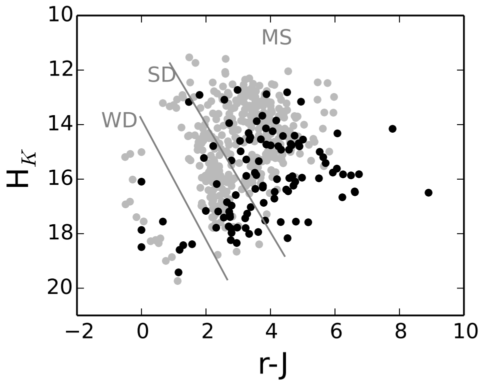

Fig. 4. An r-J vs. K band reduced proper motion plot of the 104 new (black) and 391 previously identified (grey) high proper motion sources for which we have r and J photometry. White dwarf, subdwarf, and main sequence populations are labelled (see e.g. Salim & Gould 2002, figure 2).

white dwarfs that Gaia will find. These can then be used as benchmarks to test theories of brown dwarf formation and evolution. Gaia also offers an opportunity to follow up candidate astrometric microlensing events which may be identified in proper motion searches such as these.

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