The M-dwarfs in Multiples (MinMs) Survey - Stellar Multiplicity within 15 pc

K. Ward-Duong[1], J. Patience[1], R. J. De Rosa[1], J. Bulger[1], A. Rajan[1], D. McCarthy[2], C. Kulesa[2], S. Goodwin[3], R. Parker[4]

[1]*School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA 85287*

[2]*Steward Observatory, University of Arizona, Tucson, AZ, USA 85721*

[3]*Department of Physics and Astronomy, University of Sheffield, Sheffield S3 7RH, UK*

[4]*Institute for Astronomy, ETH Zurich, Wolfgang-Pauli-Strasse 27, CH-8093 Zurich, Switzerland*

Abstract. We present results from a large-scale, comprehensive M-dwarf companion study based on a volume-limited survey of 245 M-dwarfs within 15 pc. Diffraction-limited infrared archival data were analyzed to detect nearby companions to M-dwarfs from ∼1 to 100 AU. To supplement the high-resolution data, digitized wide-field archival plates were searched for companions with separations of 100 to 10,000 AU. The survey is fully sensitive to companions at the bottom of the main sequence over an unprecedented survey separation range of ∼3 to 10,000 AU, and the deepest images also reveal a number of substellar candidates. With multiple AO and wide-field epochs, follow-up observations have allowed us to confirm or reject companion candidates detected during our analysis. This provides confirmation of common proper motions, minimizes background contamination, and enables comprehensive statistics, including separation and mass ratio distributions, for M-dwarf binaries. Characterizations of the binary and multiple star frequency for M-dwarfs provide crucial insights into the low-mass star formation environment, and hold additional implications for the frequency and evolutionary histories of their associated disks and planets.

1. Introduction

M-dwarfs constitute the major fraction of stars within both the solar neighborhood and nearby star-forming regions, and their binary properties present observational tests of the star formation process. Key M-dwarf companion characteristics – including multiplicity fraction, mass ratios, and separation distributions – hold important implications for the universality of star formation, dynamical interactions, and the origin of the Galactic field stars. The high proper motions and low luminosities of nearby M-dwarfs enable identification of co-moving binary and multiple systems over a wide range of orbital separations; such statistics have focused on investigating solar-type stars (Duquennoy & Mayor 1991; Raghavan et al. 2010) and recently A-type stars (De Rosa et al. 2014), with the first seminal study of M-dwarfs taking place over 20 years ago (Fischer & Marcy 1992). As these studies explore stellar multiplicity over a diverse range of primary star masses, refined statistics for the lowest-mass, most abundant stars represent an integral part of understanding the overall stellar, brown dwarf, and planetary companion environment.

2. Sample and Techniques

We have conducted a large-scale M-dwarf companion study covering separations from ∼1 - 10,000 AU, based on a volume-limited survey of 245 M-dwarfs within 15 pc. Targets with accurate *Hipparcos* parallaxes were selected on spectral type and color within the M-dwarf range (Figure 1). High-resolution adaptive optics (AO) imaging data for these targets were analyzed from the Canada-France-Hawaii Telescope, MMT Observatory, Subaru Telescope, and Very Large Telescope to detect companions from ∼1 - 100 AU, while digitized wide-field archival plates were searched for companions to the full sample from ∼100 - 10,000 AU.

The combination of AO and widefield imaging provides full sensitivity to companions down to the bottom of the main sequence over a separation range of 3 - 10,000 AU. Multi-epoch observations have allowed us to confirm or reject all stellar companion candidates detected in our analysis based on common proper motion.

3. Preliminary Results

As a comparison with the multiplicity of more massive stars, the companion star fraction for our sample is measured within a restricted 30-10,000 AU separation range, shown in Figure 2 (left panel). Shown from left to right are the companion star fractions for field A-type stars (blue point, De Rosa et al. (2014)), solar-type stars (yellow point, Raghavan et al. (2010)), and M-dwarfs (red point, this study). An upper limit to the companion star fraction for brown dwarf primaries is also shown (pink downward triangle, Allen et al. (2007)). The trend of increasing multiplicity as a function of primary mass is clearly seen. The distribution of projected companion separations (Figure 2, right panel) was corrected for incompleteness and fit with both free and restricted log-normal fits, representing the two limiting cases of the true distribution, given the observed distribution within the restricted separation range. The companion separation distribution is observed to rise to a higher frequency at smaller separations, appearing to peak at a closer separation than those measured for more massive primaries.

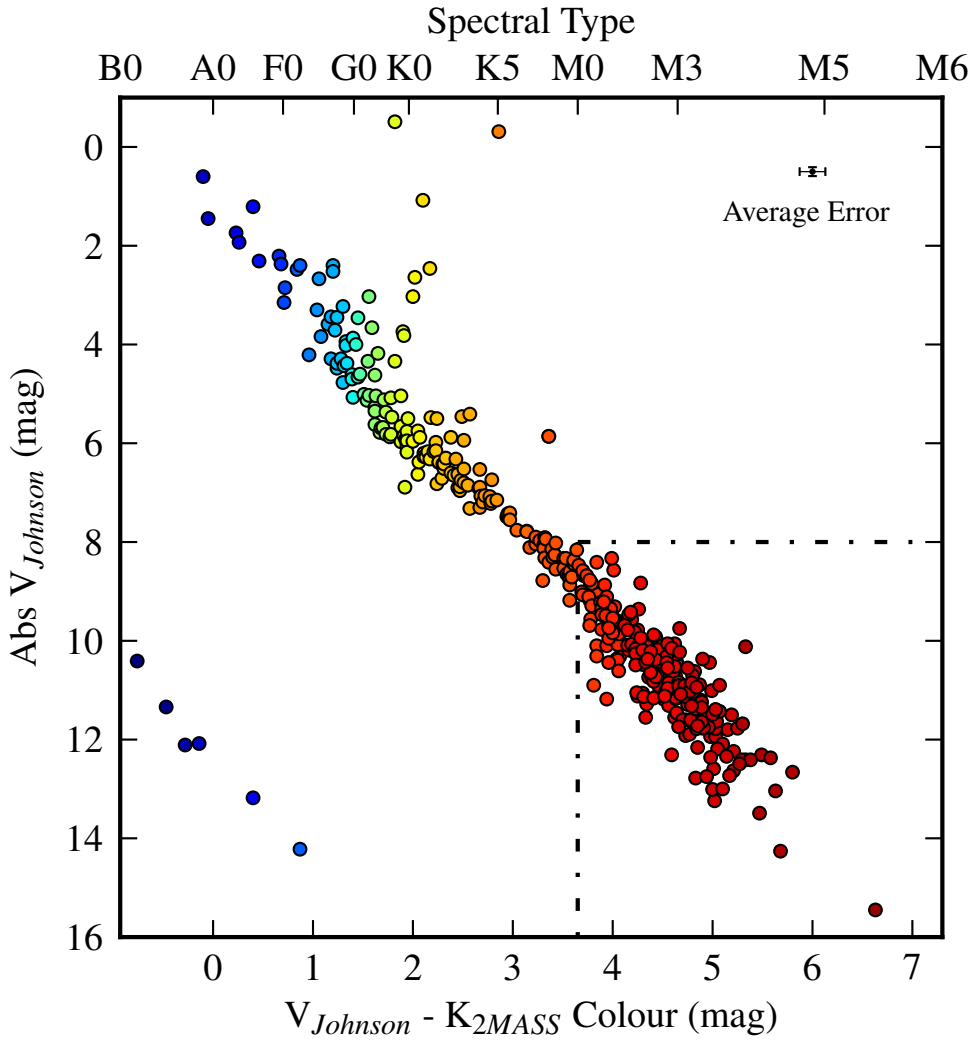

Figure .1: Color-magnitude diagram of the 449 stars within 15 pc meeting our *Hipparcos* parallax error and photometry criteria. The color and magnitude criteria used to select our sample of 245 M-dwarfs are shown with dashed-dotted lines enclosing our sample space on the CMD. An example of the typical errorbar size is shown in the upper right corner of the figure.

Acknowledgements. KWD is supported by an NSF Graduate Research Fellowship (DGE-1311230). RJDR acknowledges support from a Science and Technology Facilities Council grant (ST/H002707/1). This research has made use of the following resources: the SIMBAD database, operated at CDS, Strasbourg, France; data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and IPAC/Caltech, funded by NASA and the NSF; the Washington Double Star Catalogue maintained at the US Naval Observatory; the facilities of the Canadian Astronomy Data Centre operated by the National Research Council of Canada with the support of the Canadian Space Agency; data obtained from the ESO Science Archive Facility; and data obtained from the SuperCOSMOS Science Archive, prepared and hosted by the

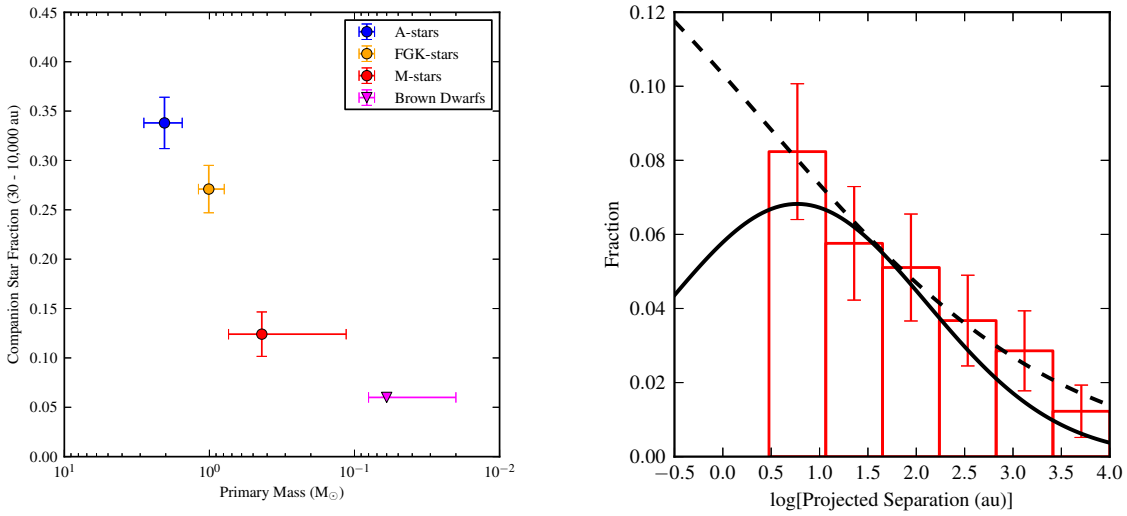

Figure .2: (**left**) The companion star fraction (CSF) over a restricted separation range of 30-10,000 AU, showing the decrease in companion frequency as a function of decreasing primary mass. (**right**) The companion separation distribution for the M-dwarfs in our survey over the full 3-10,000 AU range, shown with both free (dashed) and restricted (solid) log-normal fits.

Wide Field Astronomy Unit, Institute for Astronomy, University of Edinburgh, which is funded by the UK Science and Technology Facilities Council.

References

Allen, P. R., Koerner, D. W., McElwain, M. W., Cruz, K. L., & Reid, I. N. 2007, AJ, 133, 971

De Rosa, R. J., Patience, J., Wilson, P. A., et al. 2014, MNRAS, 437, 1216

Duquennoy, A., & Mayor, M. 1991, A&A, 248, 485

Fischer, D. A., & Marcy, G. W. 1992, ApJ, 396, 178

Raghavan, D., McAlister, H. A., Henry, T. J., et al. 2010, ApJS, 190, 1

Adam Kowalski and Suzanne Hawley at one of the many snack breaks.