Overview

We performed the largest high angular resolution (FWHM ≥ 0.15") binary survey of cool subdwarfs. We found:
- A cool subdwarf binary rate of 11.6% ± 1.8%, approximately a factor of 3 lower than similar spectral type dwarf stars
- A cool subdwarf triple rate of 1.7% ± 0.7%
- A ≈3σ disparity in the luminosity between companion stars compared to binary dwarf systems
- A lack of closely separated subdwarf companions compared to binary dwarf systems

Introduction

Cool subdwarfs are the oldest members of the low-mass stellar population. Mostly present in the galactic halo, subdwarfs are characterized by their low metallicity. Measuring their binary fraction and comparing it to solar-metallicity stars could give key insights into the star formation process early in the Milky Way’s history. However, because of their low luminosity and relative rarity in the solar neighborhood, binary surveys of cool subdwarfs have suffered from small sample sizes and incompleteness. Previous surveys (Lodieu et al. 2009, Ito et al. 2009, Zhang et al. 2013) have suggested that the binary fraction of red subdwarfs is much lower than for their main-sequence cousins.

Target stars

The 344 target stars were selected from the photometric work of Marshall (2007). All target stars fall in the subdwarf region of a reduced proper motion diagram, as seen in Figure 2, and all stars in a sample of 24 exhibit spectral characteristics of cool subdwarfs. The V-magnitude and (V − J) colors of the target stars are shown in Figure 1.

Data Reduction

To identify close companions, a custom locally optimized PSF subtraction algorithm was applied to centered cutouts of all images. An example of this is seen in Figure 3. Contrast ratios were performed using standard aperture photometry for wide systems, and for close companions using the PSF algorithm to remove the blended contributions of each star.

Seven low-detection significance companions were identified for follow-ups using Keck II. An example of a confirmed binary system is shown in Figure 4.

Robo-AO Observations

We obtained high-angular-resolution images of the 344 subdwarfs using the Robo-AO laser adaptive optics system (Baranec et al. 2014, http://robo-ao.org/) mounted on the Palomar 60 inch telescope. The first robotic laser guide star adaptive optics system, the automatic Robo-AO system can efficiently perform large, high-resolution surveys. Specifications of the survey are summarized in the table below.

<table>
<thead>
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<th>Filter</th>
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<tr>
<td>FWHM resolution</td>
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<td>Field size</td>
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<td>Subdwarf targets</td>
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<td>Targets observed/hour</td>
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<td>Observation dates</td>
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</table>

Discoveries

Of the 344 verified subdwarf targets observed, 40 appear to be in multiple star systems for an apparent binary fraction of 11.6% ± 1.8%. This count includes 6 multiple systems first recorded in the NLTT (Luyten 1979). 13 systems first recorded in the NLTT (Salim & Gould 2002), 1 wide binary found in the LSFM (López et al. 2012), 6 spectroscopic binaries, and 16 newly discovered multiple systems. We also observe a triple fraction of 1.7% ± 0.7%. Cutouts of the 22 closest multiple systems are shown in Figure 5.

Comparison to Dwarfs

The lack of low-contrast subdwarf companions is further illustrated in Figure 7. A two sample K-S test rejects the null hypothesis that the two populations are similar at a confidence of 2.8σ.

Conclusion

In the largest high-angular resolution binary survey of cool subdwarfs, we observed 343 stars with the Robo-AO robotic laser adaptive optics system, sensitive to companions at FWHM ≥ 0.15” and A m ≤ 6. Of those targets, we observed 16 new multiple systems and 4 new companions to already known binary systems. When including previously recorded multiple systems, this implies a multiplicity rate for cool subdwarfs of 11.6% ± 1.8% and a triple fraction of 1.7% ± 0.7%. When comparing our results to similar surveys of dwarf binarity, we note an apparent lack of close binaries, as has been previously observed in the literature. We also observe a 2.8σ difference in relative magnitude differences between companions.

References

Luyten, W. J. 1979b, New Luyten Catalogue of Stars with Proper Motions Larger than 20 arcsec/yr (Minneapolis: Univ. Minnesota Press)
López, C. E., Calandra, F., Chalela, M., et al. 2012, JDSO, 8, 78

Acknowledgements

The Robo-AO system is supported by collaborating partner institutions, the California Institute of Technology and the Joint University Centre for Astronomy and Astrophysics, and by the National Science Foundation under Grant No. AST-0846001, AST-0843313, and AST-1257902, by the Mount Cuba Astronomical Foundation, by a gift from Samuel Oschin.

Contact Information

- Web: http://carl.web.unc.edu/
- Email: carlweb@unc.edu