Fall 10-30-2004

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Scholarly Commons Citation

von Hippel, T., Kilie, M., Munn, J., Williams, K., Libert, J., Winget, D. E., Metcalfe, T. S., & Et al. (2004). The White Dwarf Luminosity Function: The Shape of Things to Come. *ASP Conference Series, Vol. 999, 2005,* (). Retrieved from https://commons.erau.edu/publication/1172

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14^{th} European Workshop on White Dwarfs
ASP Conference Series, Vol. 999, 2005
D. Koester, S. Moehler

The White Dwarf Luminosity Function: The Shape of Things to Come

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Abstract. We describe a new survey for cool white dwarfs that supplements Sloan Digital Sky Survey photometry with USNO proper motions and follow-up spectroscopy. To date we have discovered and spectroscopically confirmed 80 new moderate temperature and cool white dwarfs. We have also found a handful of high-velocity white dwarfs and we expect a sizable fraction of these to be thick disk or possibly halo objects. Our survey is designed to find $\sim 10^4$ new white dwarfs, although only ~ 60 will be among the faintest white dwarfs ($M_{\rm V} \geq 16$), where most of the age-sensitivity resides. We discuss an extension of our survey to $V \approx 22$.

1. Introduction

We describe a new survey for cool white dwarfs (WDs). The goals of our survey are to (1) place the Galactic disk, thick disk, and halo on the same age scale to within 1 Gyr; (2) determine the age of the Galactic disk via WD cooling ages to within 1 Gyr, well beyond the current level of precision (e.g. Winget et al. 1987; Liebert et al. 1988; Wood 1992; Oswalt et al. 1996; Leggett et al. 1998; Knox et al. 1999); and (3) to improve our understanding of WD evolution. The second goal is the most demanding, and we anticipate working toward this for some time. The third goal may appear to be primarily in the domain of theory, but improved observations are critical to progress. For instance, the shape of the peak of the WDLF can constrain the timing and effect on cooling of crystallization and convective coupling of the atmosphere to the core. Also, the shape of the hot end of the WDLF constrains the degree of neutrino cooling in the core of high temperature WDs (see Kim et al., these proceedings). Of course, theoretical and observational advances are tightly coupled, as are what we learn from studies of cool white dwarfs and what the community learns through WD asteroseismology (see Corsico et al. 2004; Metcalfe et al. 2004; and Fontaine & Brassard, these proceedings).

Using the substantial photometry, astrometry, and spectroscopy from the Sloan Digital Sky Survey (see Kleinman, these proceedings), most of the laborious survey work has been done for us, and it is now possible to efficiently find the cool white dwarfs that are the key to Galactic stellar population ages. We are supplementing SDSS photometry and spectroscopy in such a manner as to find the cool WDs, most of which will not otherwise be found among the SDSS data.

2. Observational Approach

Our first approach was to supplement the SDSS photometry with narrow-band, DDO51 photometry, which we thought would isolate cool WDs from low metallicity main sequence stars. This approach turned out not to be viable (see Kilic et al. 2004; Kilic et al., these proceedings). Following this setback, we sought to find candidate WDs using reduced proper motions (see Munn et al. 2005). Proper motions were measured from a combination of SDSS astrometry and USNO plate astrometry. The reduced proper motions, which combine the proper motions with SDSS photometry, yielded hundreds of excellent candidate WDs. We then obtained classification-level spectroscopy for WD candidates with $g - i \geq 0$ ($T_{\rm eff} \leq 8000$) at the McDonald Observatory 2.7m telescope, the Hobby Eberly Telescope, and the MMT (see the Kilic et al. spectroscopy study, these proceedings). As of the date of this conference, we had observed 115 candidate WDs, 80 of which are WDs.

After we identify *bona fide* WDs from among the candidates, we will obtain J-, H-, and K-band photometry, which, along with the SDSS photometry, will yield the bolometric luminosities for these objects. Many of the new, cool WDs we are finding have no discernible spectroscopic features, but a subset of the most interesting WDs do have spectral features, and we will follow these up with higher signal-to-noise spectroscopy. We also intend to obtain trigonometric parallaxes for as many of the coolest WDs as possible.

2.1. What Have We Learned So Far?

The primary progress in our work so far has been observational, with a technique that now produces WDs from more than two-thirds of the candidates. Importantly, we are now starting to understand the recovery efficiency of WDs as a function of their location in the reduced proper motion diagram, which leads to a new WDLF (Munn et al. 2005) based on many more (≥ 6000) WDs than previously studied. We are also finding high velocity WDs. These objects could be thick disk or halo objects, or they could have been accelerated by asymmetric planetary nebulae winds (e.g., Fellhauer et al. 2003) or binary ejection (e.g., Davies et al. 2002). We are beginning to investigate these objects in order to determine their parent population(s). If these white dwarfs are thick disk or halo objects, then we are already on our way toward good relative ages between the major Galactic stellar populations.

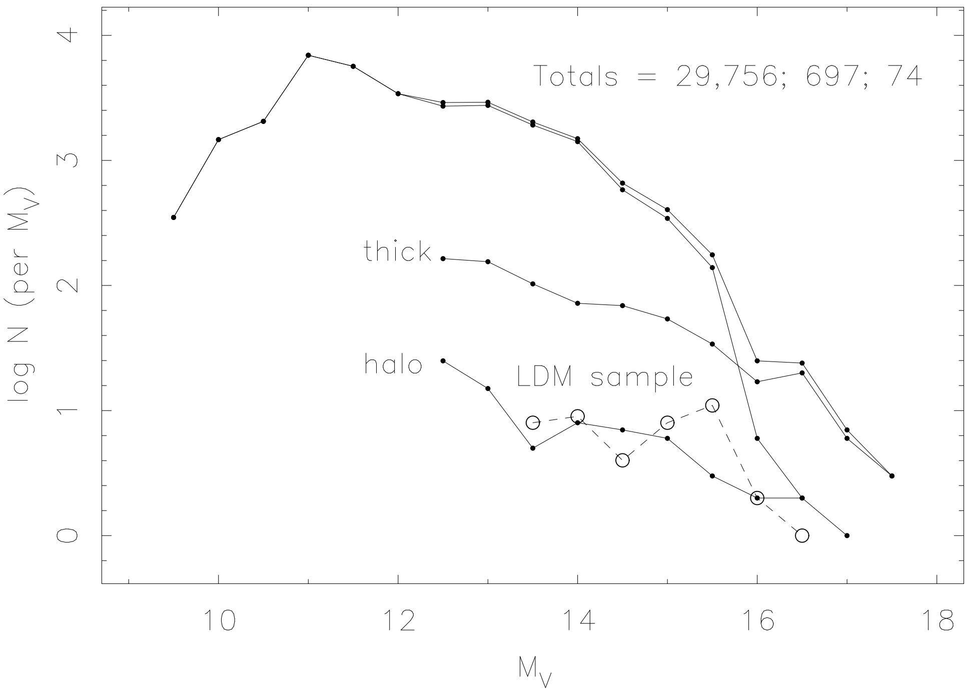

Figure 1. Expected number of WDs found in our survey as a function of absolute V magnitude. This estimate assumes the WDLF of Liebert et al. (1988) for the disk, and that the thick disk and halo are single-burst, 12 Gyr old populations, with 0.2% and 2% of the disk normalization, respectively. The thick disk normalization, in particular, is conservative and may be higher by even an order of magnitude. This calculation also assumes an 8000 square degree survey at a mean Galactic latitude of 40 degrees. This calculation incorporates only the magnitude limit, and not the proper motion limit, so the number of the hottest WDs will be overestimated, as many of them are too distant for a measurable proper motion. The total number of expected disk, thick disk, and halo WDs, respectively, are listed in the upper right corner of the figure.

2.2. Expected Survey Yield

We expect our survey to increase the number of WDs in the WDLF from the current value of ∼400 (Liebert et al. 1988) to $\sim 10^4$. Because it is always easier to find brighter representatives of any population, most of these WDs will populate the bright and middle portion of the WDLF (see Figure 1). Unfortunately, the critical faint end of the WDLF, though improved, will still be poorly populated.

Our survey should discover hundreds of new thick disk WDs and dozens of halo WDs. These discoveries will allow us to make a careful comparison of the properties of disk, thick disk, and halo WDs, and begin to work out the relative ages of these Galactic populations.

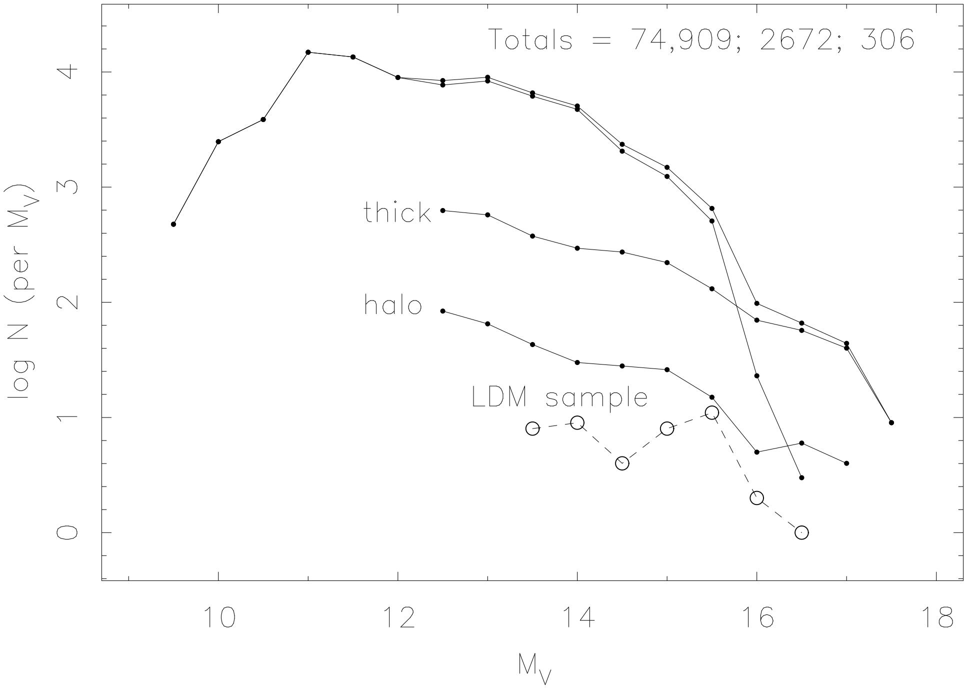

Figure 2. Same as Figure 1, but for a survey to $V = 21$. This plot overestimates the number counts of the hottest WDs to a greater degree than Figure 1.

3. The Next Step

How do we find more of the coolest WDs where most of the age sensitivity resides? Our current survey is limited by the depth of the proper motion first epoch plate material, as well as the HET and MMT spectroscopic limit, at g $\leq$ 20. While it is possible to obtain fainter spectroscopy at Gemini or Keck, or with very long exposures, we need a new astrometric epoch to push past our current survey magnitude limit, which is set by the depth of the POSS plate material used in the USNO astrometry. We suggest a simple imaging survey to r or $i = 22$ over 2000–8000 square degrees. This deep astrometric epoch would be well-matched to the initial SDSS epoch and its filters. In Figures 2 and 3 we show the number of WDs we expect would be found in an 8000 square degree survey to $V = 21$ and 22, respectively.

Acknowledgments. TvH, MK, and DEW appreciatively acknowledge support for this research from NASA through LTSA grant NAG5-13070 and from NSF through grant AST-0307315. TSM acknowledges support from the Smithsonian Institution through a CfA Postdoctoral Fellowship, and thanks the SAO TAC for allocating time for this project on the MMT. TDO acknowledges the NSF for support for this work through AST-0206115.

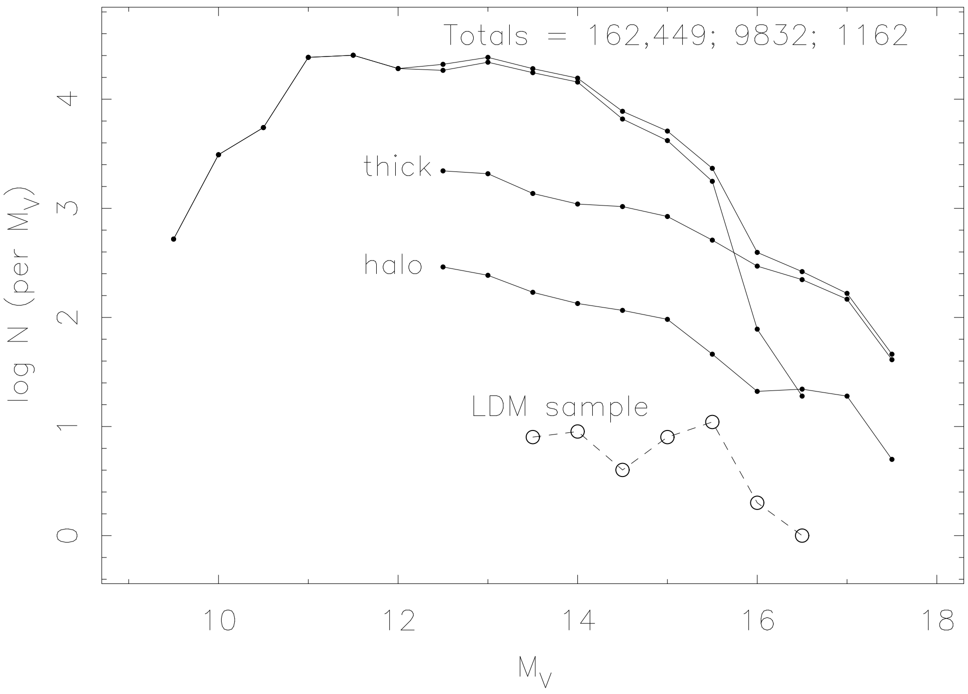

Figure 3. Same as Figure 1, but for a survey to $V = 22$. This plot overestimates the number counts of the hottest WDs to a greater degree than Figures 1 or 2.

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