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A Model of the Local WD Population

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Abstract. We present a model of the solar neighbourhood (d<100 pc) white dwarf (WD) population and show its distribution in effective temperature and mass. The WDs are created by the death-rate of a population model matching the local stars observed by HIPPARCOS, considering depletion as caused by the "thin disk" dynamics.

For verification of our synthetic sample, we study the temperature distribution of a small volume-limited sample of observed WDs (Holberg et al. 2002). We use a single indicator R_{6300}: the number ratio of WDs with $T_{\rm eff} < 6300$ K over those with $T_{\rm eff} > 6300$ K. After correcting for a residual incompleteness with cool WDs, we find R_{6300} of 0.68(±0.24), in good agreement with our WD population model which suggests $R_{6300} = 0.77$.

With a magnitude limit of $B = 16.0$, the synthetic sample reduces from ≈ 13700 to only ≈ 1350 WDs. We use this to test the completeness of the prospective SPY WD sample. In the fields covered, it will deliver about 80% of the WDs with $d < 100$ pc and $B < 16.0$. A more detailed account of our results is given by Schröder et al. 2004.

There has been impressive progress in the recent decade on the observational side of white dwarf research. The on-going SPY observing campaign (SN Ia Progenitor surveY, see Napiwotzki et al. 2001, 2003; Koester et al. 2001), in particular, employs the ESO VLT for high resolution spectroscopy. SPY studies a very large but magnitude-limited WD sample, which contains a revised number of 1078 prospective objects. It covers nearly half the sky area and has a reach of, mostly, about 200 pc (the SPY candidate list contains a small fraction of more distant WDs within ≈ 600 pc) and $B < 16.5$.

Still, the larger part of the WD population within 100 pc distance is currently missed by observation because most (but the very nearest) WDs cooler than about 6000 K fall below the magnitude limit. This motivates computation of a synthetic WD sample, which will allow a proper understanding of the complete local WD population, and could be used to determine the age of the Galactic disk (Fontaine et al. 2001 and references therein).

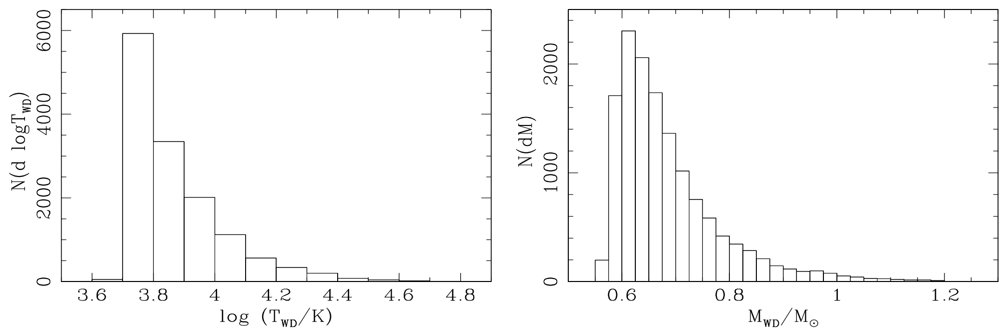

Figure 1. Temperature (left) and mass (right) distribution of a synthetic, complete sample of 13724 WDs for a volume of 100 pc radius around the Sun.

A Synthetic, Volume-Limited WD Population

The solar neighbourhood WD population has a continuous distribution of ages, as it is fed by the "death" rate of the local stellar population. For the solar neighbourhood single stars, within $d < 100$ pc, we already have population models which are a quantitative match of the Hipparcos (apparently) single star HR diagram, and the giant counts in particular (see Schröder 1998, Schröder & Sedlmayr 2001, Schröder & Pagel 2003). We here use the same grid of evolution tracks and initial mass function (IMF) as described in our latest paper for a sperical volume of 100 pc radius around the Sun: $dN/d\log M_* \propto M^\Gamma$ with $\Gamma_1 = -1.75$ for $M_* < 1.6 M_\odot$ and $\Gamma_2 = -2.35$ for $M_* > 1.6 M_\odot$. For the star formation rates (SFR, for $M_* > 0.9 M_\odot$) required and assumed disk ages, see Table 1.

In addition, the decrease in the local density of WDs due to dynamical processes in the Galactic disk must be taken into account. A steady kinetic energy interchange causes older stars to be diluted further into the column perpendicular to the Galactic plane (see Schröder & Pagel 2003). For comparison, we also tried a much simplified diffusion prescription, (models type 2 in Table 1).

In total, we obtain a number of 13700 synthetic WDs within $d < 100$ pc, for which we show the distribution in $T_{\rm eff}$ and mass (Fig. 1). The WD luminosities are based mostly on the detailed WD models of Chabrier et al. (2000). For WDs younger than about 1 Gyr, however, our cooling prescription follows the respective models of Wood (1995).

The synthetic WD mass distribution depends on the prescription of the RGB/AGB mass-loss. We find, much like Wood (1995), a peak near $0.61\,M_\odot$. It shifts to lower $0.59\,M_\odot$ by selection effects with a magnitude-limited sample for $B < 16.0$. This is a bit higher than the observed peak, which is between $0.55\ M_\odot$ (Koester et al. 2001) and $0.59 M_\odot$ (Napiwotzki et al. 1999). Work is in progress to improve on the underestimated RGB and AGB mass-loss, i.e. by replacing the old Reimers relation by a better formula (Schröder 2004).

A Test of WD Cooling: Model versus Observation

For a quick characterization of different WD population models, as well as for comparison with a very small but (nearly) volume-limited sample of observed

Table 1. Prefered (boldface) and alternative (see text) WD population models: total number $N_{\rm WD}$ of objects with $d < 100\,{\rm pc}$ and their ratio R_{6300} of cool over hot WDs. Thin disk ages ($t_{\rm disk}$) are given in Gyrs. The SFRs are given in stars with $M > 0.9 M_\odot$ per Gyr. (1) indicates models with dilution according to disc kinematics, (2) stands for use of a simple diffusion approximation.

model	$\rm SFR_0$ [$\rm Gyrs^{-1}$]	$t_{\rm disk}$ [Gyrs]	$N_{\rm WD}$	R_{6300}
(1)	8.0	9.5	14350	0.89
(2)	7.6	9.5	12830	0.72
(1)	**8.2**	**9.0**	**13700**	**0.77**
(2)	7.8	9.0	12530	0.66
(1)	8.4	8.5	13100	0.70
(1)	8.6	8.0	12500	0.61

WDs (see below), we define a simple indicator, $R_{6300} = N_{\rm cool} \,/\, N_{\rm warm}$, the number ratio of the $N_{\rm cool}$ WDs cooler than 6300 K over the $N_{\rm warm}$ WDs which are hotter. This indicator has the additional advantage of being insensitive to complex model details below 6000 K. The temperature distribution shown in Fig. 1 (left panel) yields a ratio of cool over warm WDs of $R_{6300} = 0.77$. We estimate an uncertainty of R_{6300} in a synthetic WD population of about 10% due to the WD model properties. Furthermore, R_{6300} depends on the galactic disk age and dynamics (see Table 1).

Dramatic selection effects against cool (faint!) WDs call for a truly volume-limited, complete WD sample, as needed for a verificaton of our WD population model – even if that means a severely restricted sample reach. Holberg et al. (2002) present a list of observed WDs within 20 pc of the Sun and claim that completeness could be assumed for a subsample within $d < 13$ pc.

We re-assessed the effective temperatures of these WDs, using recent measurements from the literature, preferable from spectroscopic or multi-colour analysis (Bergeron et al. 2001 and others), or (for 13 WDs) the Bergeron et al. (1995) photometric calibrations. In order to improve completeness, we then excluded the 8 WDS with proper motions under $0\overset{''}{.}5$, none of which is a cool WD! The rest of the Holberg sample (13 cool and 19 hot WDs) is based on the fairly complete Luyten's half-second catalogue (LHS; Luyten 1976), which covers the whole sky with a limiting magnitude of 18.0 (Dawson, 1986). It gives $R_{6300} = 0.68(\pm 0.24)$. Within the large statistical error, in good agreement with our population model ($R_{6300} = 0.77$).

A Magnitude-Limited Sample to Estimate the Completeness of SPY

A magnitude-limited (i.e., $B = 16.0$) observed WD sample with larger reach will fail to recognise many of the old WDs which have cooled down below about 6000K and fallen below the brightness threshold. Hence, its temperature dis-

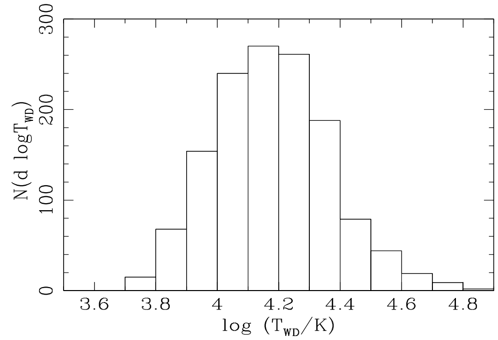

Figure 2. Temperature distribution of the magnitude-limited (B = 16.0) subsample of the WD population shown in Fig 1, leaving just about 1350 objects. Most of the cool WDs are lost from the left side of the temperature distribution.

tribution must differ considerably from a complete WD sample, as a synthetic sample (Fig. 2) demonstrates.

Such a magnitude-limited synthetic (sub)sample is a good bench mark test to the degree of completeness of, e.g., the SPY project. Considering only single objects and the sky coverage of SPY (48.5%), the benchmark should be 700 WDs (±10–12%) with $B < 16.0$ and $d > 100$ pc. For the SPY sample, after subtracting ≈ 10% of thick disk and halo WDs (Pauli et al. 2003), we arrive at an anticipated number of 550 WDs (±4%) within $d < 100$ pc and $B < 16.0$. Hence, SPY will deliver a fairly complete sample, 79%±15% of all local WDs.

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