Prospects for cool white dwarf science from Pan-STARRS

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Abstract. We discuss the prospects for new deep, wide–angle surveys of the Galactic cool white dwarf populations using data from Pan-STARRS: the Panoramic Survey Telescope & Rapid Response System.

1. Introduction

Cool white dwarfs (WDs) provide the means to measure the star formation history (see the article by Rowell elsewhere in these proceedings) and age of the population to which they belong, as well as laboratories for the study of matter under extremes of pressure. Large samples cannot be culled from photometry alone — cool WDs present colours that are indistinguishable from those of the profusion of field F/G/K dwarfs. However, using proper motion μ as a proxy for distance d (where generally μ ∝ 1/d), we can employ the technique of reduced proper motion (RPM) to distinguish the WDs from the much more luminous dwarfs provided we have a multi–epoch survey over a sufficiently large time baseline to yield accurate proper motions.

To date, the widest angle studies have had to employ legacy Schmidt photographic surveys to provide multi–epoch imaging. The photographic plates are limited in their seeing (typically 2 to 3 arcsec) and depth (typically R ∼ 19). Despite this, recent studies (e.g. [Harris et al., 2006]) have produced large samples (up to ∼ 10^4) of cool WDs thereby enabling determinations of the age of the disk population. However the depth of the resulting luminosity functions is as yet insufficient to determine the ages of the thick disk and spheroid of the Galaxy, and the total space density of the coolest, oldest thick disk and spheroid stars remains unknown (e.g. [Rowell & Hambly, 2011, hereafter RH11]).
2. Pan-STARRS

The Panoramic Survey Telescope and Rapid Response System[1] prototype ‘PS1’ — see Morganson et al. (2012) and references therein — is now well into its 3 year wide-angle observing campaign (the so-called ‘3π’ survey), aiming to survey 75% of the sky in the 5 grizyP1 passbands at least 4 times per year yielding a multi-epoch survey of stunning proportions. With a typical seeing of ∼ 1 arcsec, a depth surpassing the original SDSS, and near-infrared coverage that was impossible using photographic plates, Pan-STARRS will provide a rich hunting ground for cool WDs. At the time of writing, the 3π survey is essentially completely covered in all passbands with the expected number of individual epochs for this stage in the project; overall observational completeness stands at 59%. A fully world-public release of PS1 data is presently scheduled for the end of 2014; in the meantime, data access is restricted to scientists within those institutes that are part of the PS1 Science Consortium.

3. Depth and completeness

Figure[1] shows number–magnitude histograms for a 200 square degree equatorial strip (10° < α < 35° and −4.0° < δ < +4.0°) across the South Galactic Cap from the extant Pan-STARRS 3π survey. To be counted here, detections must be present in at least griP1 with at least 10 individual epochs. We compare also with the Rowell & Hambly survey sample by identifying the same objects in those catalogues employing the closest corresponding passbands (BRI). The increase in depth afforded by Pan-STARRS is clear, as is the general incompleteness in the photographic data (up to ∼ 50%) owing to the poorer seeing.

Figure 1. Number-magnitude histograms of sources in the extant 3π survey (solid lines labelled by passband) compared with similar from the SuperCOSMOS legacy Schmidt photographic survey (dotted lines labelled by passband).
4. Reduced Proper Motion diagrams

Proper motions from the full 3yr Pan-STARRS $3\pi$ survey are of course not yet available, but we can get a good idea of the potential gains by combining the new photometry with the legacy photographic plate proper motions. Figure 2 shows 3 RPM diagrams: on the left is that from the photographic plate survey data alone for the SGC subsample of the RH11 survey ($R < 19.75$); the middle panel shows the same objects but using the Pan-STARRS photometry; finally on the right we show the RPM diagram combining Pan-STARRS photometry with SuperCOSMOS proper motions without the $R=19.75$ cutoff. The tighter subdwarf sequence and cleaner separation of the WDs is clear when using Pan-STARRS, as is the enhanced depth (despite the necessity of employing still the photographic plate astrometry).

![RPM diagrams](image)

Figure 2. RPM diagrams for the [Rowell & Hambly](#) sample using the photographic photometry (left panel); the same sample but using PS1 photometry (middle panel); and a sample employing the photographic astrometry and PS1 photometry without the $R < 19.75$ cut employed by RH11 (right panel).

5. Discussion

[Tonry et al. (2012)](#) present new results from the Pan-STARRS Medium Deep Survey; however we suggest that it is the $3\pi$ survey that will sample the greatest volume for the coolest WDs, and will discover many objects amenable to spectroscopic follow-up on 4 to 8m–class facilities. The prospective numbers of cool WDs that will be detected in the $3\pi$ survey can be calculated using simple scaling arguments from the RH11 sample.
Volume sampled for a uniformly distributed population (e.g. the local spheroid population) will go as $d^3$ for distance $d$ limited by magnitude ($d_p_1/d_{RH11} = 10^{(r_{P1}−r_{RH11})/5}$) where $r_{P1}$ is the magnitude limit for a sample drawn from the PS1 $3\pi$ survey with proper motion characteristics similar to RH11. They found that RPM discriminates usefully with proper motions as low as $5\sigma_\mu$ and employed a magnitude-dependent lower proper motion limit typically between $60 < 5\sigma_\mu < 100$ mas/yr at the limit of the SuperCOSMOS survey data (their Figure 2). To estimate PS1 proper motion precision, we note the Irwin (1985) rule-of-thumb which states that in units of the scale size of well sampled faint point sources in uniform background noise (0.6 arcsec for PS1 corresponding to half–width at half–maximum), centroiding precision $\sigma_x$ is equal to relative flux precision $\sigma_f/f$. Hence $5\sigma_f$ detections will have centroids accurate to $\sigma_x \approx 0.12$ arcsec, and given $N = 60$ measurements over $\Delta t = 3.5$ yr, total proper motion precision will be typically $\sigma_\mu = \sqrt{2 \times (\sigma_x/\Delta t)(12/N)^{0.5}} \approx 22$ mas yr$^{-1}$ where the factor 12 comes from the variance of a uniform distribution. For a lower proper motion limit comparable to RH11, say $5\sigma_\mu = 80$ mas/yr, we require $\sigma_\mu = 16$ mas yr$^{-1}$ which corresponds to $\sigma_x \sim 87$ mas. This should be achieved a factor 1.4 (or 0.35 mag) brighter than the $5\sigma_f$ detection limit, the latter corresponding to 50% completeness at $r_{P1} \sim 21.6$ according to Figure 2, hence we choose $r_{P1} \sim 21.25$. Noting the 50% incompleteness in RH11 and that $r_{RH11} = 19.75$, the number of PS1 spheroid WDs will be $\sim 2 \times 2^3 \approx 16$ times higher. For the thin disk component, scale height effects reduce the distance exponent to 2, so the factor increase is $2 \times 2^2 \approx 8$; the thick disk increase will be somewhere between the two. Not only will the sample be significantly larger, but the availability of 5–colour photometry will greatly improve the RH11 analysis which was limited to 50% errors in photometric distances from 3–colour photographic photometry.

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