Cool WDs in the WTS survey

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OUTLINE

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- Cool WDs identification
- Summary
White dwarfs

- evolutionary end-product of most stars when finishing their main sequence lifetime ($M < 8-12 \, M_\odot$)

- WD evolution is driven by a simple cooling process, duration ~ age of the Galaxy, so they are useful objects to probe the structure and evolution of the Galaxy

Cool white dwarfs ($T_{\text{eff}} < 5000 \, \text{K}$) provide information:

- Halo white dwarf population: only few members known so far...
- Initial mass function (distribution of stellar masses at birth)
- Age of the Galaxy from the cut-off in the luminosity function
- DA/non-DA WD ratio in the cool domain not well established yet
- Information about Hydrogen opacities (still need to be improved at low $T_{\text{eff}}$)
Cool WDs

Few have been detected so far in SDSS (Kilic et al. 2010a,b, but it is too shallow g,r ~22)

But, some of these ultra-cool WDs (T\(_{\text{eff}}\) < 4000K) are low-mass products of binary evolution, thus not representative for the oldest WDs (log g<7.5)

And in UKIDSS: Lodieu et al. (2009), Leggett et al. (2011)

Only 4 H pure ultracool WDs found so far: Kilic et al. 2012 & Catalán et al. (2012)

LSRJ0745+2627: brightest H-pure ultracool WD found using Leigh Smith μ catalogue

Catalán et al. (2012)
**WTS (WFCAM Transit Survey)**

- WFCAM at UKIRT telescope (Mauna Kea) + zyJHK filters

**Main aim:**
- detection of planetary companions to low-mass stars (transit method)
- PI: D. Pinfield, Co-PI: S. Hodgkin
- Take over the time span of five years many repeat observations in NIR bands (from 2007 until 2012)
- 6 sq degrees of total sky coverage: 4 fields
- 50% of the WTS observations are completed and reduced so far

**Deep images in J band:**
- 25 h in J band, increase the depth by stacking images (Simon Hodgkin at IoA), for 19h field so far
J band stacked images:
40 images, seeing < 1.2 arcsec, airmass < 1.5 and zeropoint > 22.8. The depth reached in this way is J = 23 mag (5σ).

We pick the first image (first epoch) as a reference, and then follow each detected star through all the other images. (Chi sq. minimization, ΔJ=0.5 mag)

2007-2009 images included

µ accuracy may still improve by including last stacked images (2010-2012)
**WTS fields optical broadband photometry**

- Optical broadband photometry:
  - SDSS $g', r', i'$
  - Obtaining depth of 25 mag (S/N=5)
- 3.5m telescope + LAICA at CAHA (20 nights awarded)
- INT + WFC at la Palma (6 nights awarded, bad weather)
- 100% of 19h, 17h fields covered
- 50% 3h, 7h fields covered (last december)
**WTS fields optical broadband photometry**

- Reduction:
  - Adapted Alhambra survey pipeline
    (astrometry calibration, image combination with Swarp, zeropoint)
  - Photometric calibration using IRAF tasks (using standard fields)
  - Aperture correction
  - Finally, cross-matching with J band catalogue using stilts (5 arcsec)
WD population in the WTS fields

- Napiwotzki (2008)
- based on the model of Galactic structure by Robin et al. (2003)
- population identification based on the results of the kinematic study of Pauli et al. (2006)
- calibrated with the local sample (Holberg et al. 2008)
- checked against the proper motion selected sample of cool WDs by Oppenheimer et al. (2001)

- more than 1500 WDs with $\mu>10$ mas/yr will be detected in the WTS fields (standard IMF)
- 100 cool WDs with $M_V>15$ mag ($T_{\text{eff}} < 5000$ K) most of them thick disc and halo members
Cool WDs

Cool WDs have SEDs very different from other types of cool objects

- **H-rich WDs**: show flux depression in the IR due to H molecule absorption
- **He-rich WDs**: become very red with $T_{\text{eff}}$

Synthetic magnitudes from:

Holberg & Bergeron (2006)
Kowalski & Saumon (2006)
Tremblay et al. (2011)
Bergeron et al. (2011)
Cool WDs have SEDs very different from other types of cool objects

- **H-rich WDs**: show flux depression in the IR due to H molecule absorption
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Selection criteria:

- $0.2 < g-r < 1.8$
- $-0.6 < r-i < 0.6$
- $g-i < 1.8$
- $0.2 < i-J < 1.4$
- $J > 14\;\mu > 100\;\text{mas/yr}$

Updated Holberg & Bergeron (2006)
To identify the membership of the WDs to a given population we use the rpm diagram:

\[ H_g = g + 5 \log \mu + 5 \]

Selection criteria:

- \( \mu > 100 \) mas/yr
- \( H_g > 22.5 \)

We identified:

- 6 WD candidates with \( \mu > 150 \) mas/yr
- 27 WD candidates with \( \mu > 100 \) mas/yr

In preparation: Catalán et al. (2012b)
**Effective temperature and composition**

Fit of griJ to synthetic magnitudes based on Levenberg-Marquardt method to minimize $\chi^2$ assuming two possible compositions H-pure (DA) and He-pure (DB)

**DA: 1500-140000K, log g=7.0-9.5**

**DB: 3500-40000K, log g=7.0-9.0**
Spectroscopic follow-up

4 of the cool WD candidates confirmed at GTC + OSIRIS R500R in July 2011

Gran Telescopio Canarias
GTC (La Palma Observatory)

Featureless spectra
Cool WD confirmation

More observing time needed to confirm the other candidates
Effective temperature and composition


![Graph showing spectral energy distribution of WD5b with $T_{\text{eff}} = 3380 K$.](image)

- **WD5b**
- $T_{\text{eff}} = 3380 K$
- $i$
- $r$
- $g$
- $J$
- $H/\text{He}$ mixed
- $\log g = 8.00$
- $\log N(\text{He})/N(\text{H}) = 5.72$

Fits by P.-E. Tremblay
Effective temperature and composition


We obtained time at Gemini North to get H band magnitudes to distinguish between H/He rich compositions
WTS data can be used to detect new cool WDs, 4 cool WDs spectroscopically confirmed so far, next steps:

- complete the optical imaging and analysis of the four WTS fields we will be in a position of ruling out or confirming IMFs
- Continue with spectroscopic follow-up of the coolest WD candidates

Other surveys: Alhambra Survey (8 sq deg, 20 medium-bands optical + JHK, lim. mag = 25)

Other research lines:
- Hydrogen opacities are rather uncertain at low $T_{\text{eff}}$:
  - test WD model atmospheres, brown dwarfs atmospheres
- Improve the initial-final mass relationship of pop. II WDs using the cool WDs detected