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SPECTROSCOPIC OBSERVATIONS OF HIGH PROPER MOTION DA WHITE DWARFS

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Abstract. We used the revised New Luyten Two-Tenths (rNLTT) catalog to select high proper motion white dwarf candidates. We studied the spectra of 70 hydrogen-rich (DA) white dwarfs, which were obtained at the Cerro Tololo Inter-American Observatory (CTIO) and extracted from the Sloan Digital Sky Survey (SDSS). We determined their effective temperature and surface gravity by fitting their Balmer line profiles to model white dwarf spectra. Using evolutionary mass-radius relations we determined their mass and cooling age. We also conducted a kinematical study of the white dwarf sample and found that most belong to the thin disk population. We have identified three magnetic white dwarfs and estimated their surface magnetic field. Finally, we have identified 6 white dwarfs that lie within 20 pc from the Sun.

1. INTRODUCTION

White dwarf stars are the final stage of evolution for the majority of stars, and can thus provide information about our Galaxy and its evolution. A number of recent studies have aimed at extending our knowledge of the local population of white dwarfs (e.g. Kawka and Vennes 2006, Subasavage et al. 2007). The current estimate of the completeness of the local sample of white dwarfs ($d < 20$ pc) is 80% (Holberg et al. 2008).

Since nearby white dwarfs are likely to have a large proper motion, we have used the revised New Luyten Two-Tenths (rNLTT) catalog (Salim and Gould 2003) to select our white dwarf candidates. We selected our candidates using the reduced proper motion diagram ($V - J$ versus $V + 5 \log \mu$, Salim and Gould 2002). To help distinguish between white dwarfs and cool subdwarfs, we used the optical-infrared colour diagram (Kawka et al. 2004).

2. OBSERVATIONS

We obtained spectroscopic observations using the R-C spectrograph attached to the 4m Blanco telescope at Cerro Tololo Inter-American Observatory (CTIO) on UT

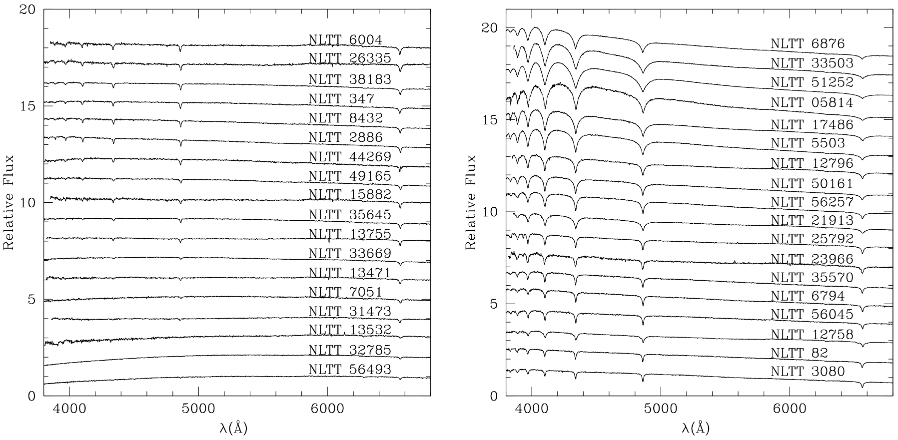

Figure 1: Spectra of rNLTT hydrogen-rich (DA) white dwarfs obtained at CTIO. Effective temperature decreases from top to bottom.

2007 July 7 to 16 and 2008 February 22 to 24. We used the KPGL2 grating (316 lines mm^{-1}) with an order sorting WG360 filter. The range of the spectra was 3700 Å to 7480 Å with a dispersion of 1.99 Å. The slit width was set to 1.5" which resulted in a spectral resolution of $\sim$ 8 Å. Each night we obtained a spectrum of a flux standard, Feige 110, EG 21 or GD 108. Fig. 1 shows the CTIO white dwarf spectra.

The current release (Data Release 6) of the Sloan Digital Sky Survey (SDSS) spectroscopic catalog contains over 1.1 million spectra. These spectra have a spectral coverage of 3800 Å to 9200 Å with a spectral resolution of $R \sim 2000$. We cross-correlated our list of white dwarf candidates with the SDSS and obtained 34 spectra of DA white dwarfs.

3. ANALYSIS

We analyzed the white dwarf stars by fitting their spectra with a grid of hydrogen-rich LTE models (Kawka et al. 2007 and references therein). This grid covers effective temperatures between 4500 K and 100 000 K and surface gravities from $\log g = 7.0$ to 9.5. The mass and cooling age of a white dwarf were determined using the evolutionary mass-radius relations of Benvenuto and Althaus (1999). For masses less than 0.45 M$_\odot$, helium core models (Benvenuto and Althaus 1998) were used, for masses with 0.45 M$_\odot$ $\leq$ M $\leq$ 1.2 M$_\odot$ carbon/oxygen core models were used (Althaus and Benvenuto 1997, 1998), and for masses larger than 1.2 M$_\odot$ the mass-radius relations of Hamada and Salpeter (1961) for a carbon core were used. Fig. 2 shows the effective temperature versus the surface gravity of the white dwarfs compared to the mass-radius relations of Benvenuto and Althaus (1999) and their masses and ages.

The majority of the white dwarfs in our sample are cool ($T_{\rm eff} < 10\,000$ K) and hence old white dwarfs, with an average temperature of $\sim$ 8300 K. The average mass of our sample of white dwarfs is $M = 0.70$ M$_\odot$ with a dispersion of $\sigma_M = 0.19$ M$_\odot$, which is slightly higher than the average mass of the local sample of white dwarfs ($M = 0.665$ M$_\odot$ Holberg et al., 2008). We have identified 3 new white dwarfs (NLTT 27781, 33669 and 56257) that are more massive than $1 M_\odot$. All three stars are cooler

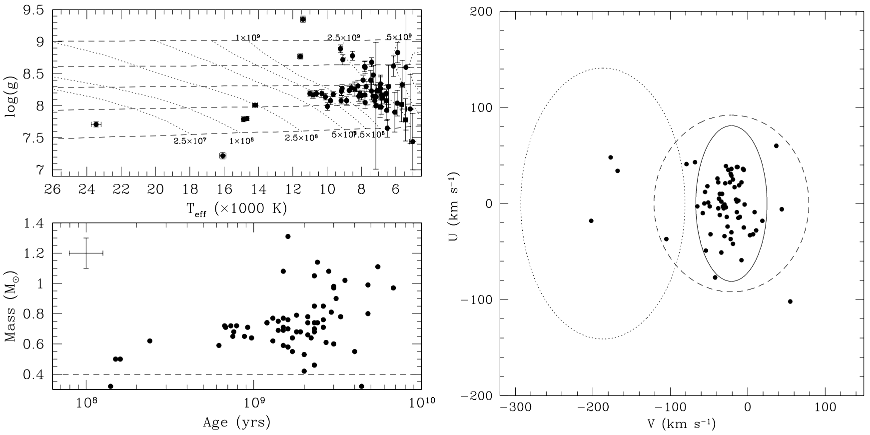

Figure 2: *Top left*: Effective temperature and surface gravity of the rNLTT DA white dwarfs compared to the mass-radius relations of Benvenuto and Althaus (1999) and their masses and cooling ages (*bottom left*). We exclude objects for which we did not determine a surface gravity. Typical error bars for masses and ages are shown at the top left corner of the figure. *Right:* U vs. V diagram showing rNLTT DA white dwarfs. The solid and dashed lines show the 2σ velocity ellipses of the thin and thick disk populations, respectively. The dotted line shows the 1σ ellipse of the halo population (Chiba and Beers 2000).

than 10 000 K and the possibility that helium is contributing toward the broadening of the Balmer lines, and hence mimicking a massive white dwarf, cannot be ruled out. Parallax measurements are needed to confirm their masses.

We have identified 3 magnetic white dwarfs in our sample, two of which are new (NLTT 12758 and NLTT 24770). NLTT 20629 (SDSS J085830.85+412635.1) was reported to be magnetic by Schmidt et al. (2003). We have estimated the surface magnetic field strength from the Zeeman split Balmer lines of NLTT 12758, NLTT 20629 and NLTT 24770 to be 1.7 MG, 1.2 MG and 1.3 MG, respectively. All three magnetic white dwarfs are cool, i.e., $T_{\rm eff} < 8000$ K.

NLTT 33108 (WD 1307+354) is a known representative of ZZ Ceti stars and it lies near the red edge of the ZZ Ceti instability strip. Our spectroscopically determined parameters ($T_{\rm eff} = 11\,000 \pm 70$ K, $\log g = 8.19 \pm 0.04$) are in agreement with previous atmospheric parameters measurements (e.g. $T_{\rm eff} = 11\,180 \pm 164$ K, $\log g = 8.15 \pm 0.05$, Liebert et al. 2005).

Three of our stars (NLTT 1374, 7051 and 19311) are in common proper motion binaries. These systems allow the gravitational redshift of the white dwarf to be measured and hence providing another method for determining the mass.

4. KINEMATICS

We calculated the velocity components U, V, and W using Johnson and Soderblom (1987) and assuming $v_{\rm rad} = 0$. We calculated the absolute magnitudes from our effective temperature and surface gravity measurements and then estimated the distance to the white dwarfs from the stars' absolute and apparent magnitudes.

Fig. 2 shows the U versus V measurements compared to the 2σ thin and thick disk velocity ellipses, and 1σ halo velocity ellipse (Chiba and Beers 2000). Fig. 2 shows that most white dwarfs in our sample belong to the thin disk population. Based on kinematics alone there are 4 halo candidates, but 3 of them (NLTT 1374, 6876 and 33503) are too hot (i.e., too young) to belong to the old Galactic halo. Only NLTT 31473 with $T_{\rm eff} = 5420 \pm 120$ K remains a halo candidate.

5. SUMMARY

We have conducted a spectroscopic study of 70 DA white dwarfs from the rNLTT catalog, out of which half are new spectroscopically confirmed white dwarfs. We have determined their effective temperatures and surface gravities by fitting their Balmer line profiles to synthetic spectra. Using available mass-radius relations we have determined their mass, age, distance and velocity components U, V and W. We have discussed their membership to the different populations in the Galaxy.

We have identified 6 stars that are within 20 pc of the Sun. One of these is a known white dwarf (NLTT 19653) with a trigonometric parallax (Van Altena et al. 1994) that place the star at 22 ± 2 pc, which is in reasonable agreement with our distance estimate of 18 ± 2 pc. The remaining 5 stars (NLTT 7051, 12758, 13532, 33669 and 56257) require trigonometric parallax measurements to confirm their distances.

Acknowledgments

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