Analysis of White Dwarf Spectra from the Sloan Digital Sky Survey

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Abstract

This work analyzed spectra of 25 white dwarfs from the Sloan Digital Sky Survey (SDSS). We found that all white dwarfs in this sample contain the same set of absorption lines, suggesting the same surface composition. Spectra of these white dwarfs are dominated by blackbody emission with peak wavelength approximately 4,000 Angstrom, in purple color, indicating high surface temperature. We estimated surface temperatures of white dwarf using Wien's Law to be at least 7,000 – 8,000 K, corresponding to flux of $1.53 \times 10^8 - 2.40 \times 10^8$ Wm^{-2}, estimated by Stefan-Boltzmann's Law. White dwarfs in our sample are of type dA, dO, and dQ and have color indices comparable to G and F main sequence stars. We note the difference in surface gravity of these white dwarfs by observing the width of hydrogen absorption lines due to pressure broadening.

Methodology

White dwarfs sample used in this analysis were selected from the Sloan Digital Sky Survey (SDSS), a 2.5-meter automated telescope in New Mexico (USA) dedicated to imaging and spectroscopic survey of about a quarter of the sky. Spectroscopic survey of SDSS mainly targets galaxies, resulting in more than one million spectra, but also targets other interesting objects, such as white dwarfs, brown dwarfs, quasars. These data are available to the public on the SkyServer Database (http://cas.sdss.org), which can be accessed using SQL interface. The SQL syntax used to select spectra is based loosely on white dwarf color selection criteria of Eisenstein et al. (2006). Briefly, we select point-like object (not extended objects like galaxies) with $-2.0 < u - g < 0.833 - 0.667(g - r)$ where *u, g,* and *r* are observed magnitude in SDSS *u, g,* and *r* filters, respectively. We apply this selection to objects with photometric data and spectra within RA between 170 – 180 degrees and Dec between 0 and 10 degrees. This SQL query yields 406 white dwarf candidates. We then inspect each spectrum to select candidates whose spectra have high signal-to-noise ratio, as indicated by smoothness of the spectrum; this yields the final sample of 25 white dwarfs. Finally, we used the *VisualSpec* software (*http://www.astrosurf.com/vdesnoux*) to read spectra from the Flexible Image Transportation System (FITS) format, study overall characteristic of spectra, and identify spectral lines in each spectrum.

Results

All white dwarf spectra share the same general shape: spectrum dominated by blackbody radiation peaking near 4,000 Angstrom, purple color, shown in Fig. 1. But since our spectral data ends at 3,800 Angstrom we can not judge whether the actual peak situates at shorter wavelength. Therefore we can estimate the *lower limit* of surface temperature of white dwarfs using Wien's Law. This estimate is a lower limit because the actual wavelength of blackbody peak could be at shorter wavelength, for example 2,000 Angstrom, where we can not observe with SDSS.

Using Wien's law, $T\ [K] = 0.0029\ m / \lambda_{max}$, where λ_{max} is the wavelength of blackbody peak, and given the observed peak at 4,000 A, we estimate the lower limit of surface temperature of white dwarfs to be 7,000 – 8,000 K, which corresponds to the flux given by the Stefan - Boltzmann's Law ($F = \sigma T^4$) of 1.5 x 10^8 – 2.4 x 10^8 Wm^{-2}. Color indices of white dwarfs are comparable to G and F main sequence stars on the H-R diagram because their temperatures approximate 7,000 – 8,000 K.

Since wavelengths of absorption and emission lines are characteristic to atomic elements, it is possible to identify surface composition of white dwarf by comparing the wavelength of observed lines and database of spectral lines from laboratory (available in the *VisualSpec* software. We identify the lines by, first, search for all possible lines in the wavelength range of interest, and then, second, identify the elements responsible for the spectral lines by considering its laboratory intensity and the relative cosmic abundance of the elements. Here we assume that solar system's relative abundance can be applied to white dwarfs.

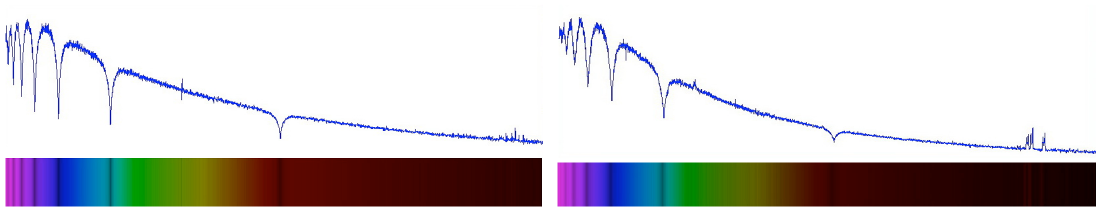

Fig. 1 Examples of white dwarf spectra from SDSS. The lower panels show synthesized spectra based on the data. The white dwarf shown on the right has significantly broader Balmer (hydrogen) absorption lines due to pressure broadening. This suggests that the sample shown on the right has stronger surface gravity.

The most prominent spectral lines found in all sample are Balmer absorption lines due to hydrogen in the first excited state (n = 2), namely H_α, H_β, H_γ, H_δ, H_ε, H_ζ, and H_η. But other subtle lines are also present, including Fe I, S II, He I, Ne I, Ti I, Ti II, N I, Mn I, O I Ni I, Cr I, and C II.

White dwarfs can be classified into six types, namely dA, dB, dC, dO, dZ, and dQ with characteristics listed in Table 1. In our white dwarf sample, we have found three types, including dA, dO, and dQ.

Table 1. Spectral classification of white dwarfs (http://www.thaispaceweather.com)

Type	Characteristics
dA	Only Balmer lines; no He I or metals present
dB	He I lines; no H or metals present
dC	Continuous spectrum, few or no lines visible
dO	He II strong; He I or H present
dZ	Metal lines only; no H or He lines
dQ	Carbon features, either atomic or molecular in any part of the spectrum

Summary

We analyze spectra of 25 white dwarfs from SDSS and found their spectra to be dominated by blackbody emission and hydrogen absorption lines (Balmer lines). Lower limit of surface temperatures are found via Wien's Law to be 7,000 – 8,000 K. We found white dwarf type dA dO and dQ, but not type dB dC and dQ. Absorption line broadening of Balmer lines due to surface gravity is observed differently in each white dwarf.

Reference

Eisenstein, D. J., et al., 2006, ApJS, 167, 40