The past lives of metal polluted white dwarfs

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Planetary Systems Beyond Main Sequence II
Outline

- White Dwarf Pollution
- Mechanisms of pollution
- Our approach
- Preliminary results
White Dwarfs: DA and DB

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**Table 4.**

<table>
<thead>
<tr>
<th>Name</th>
<th>$V$</th>
<th>$B-V$</th>
<th>$%\Delta F_\nu$</th>
</tr>
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<tr>
<td>G1 9 1B 2 B</td>
<td>61980</td>
<td>0.042</td>
<td>0.000</td>
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<tr>
<td>GD 191-B2B</td>
<td>33482</td>
<td>0.010</td>
<td>0.001</td>
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<tr>
<td>Feige 66</td>
<td>574150</td>
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<td>SDSS J212412.14</td>
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<td>0.016</td>
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<td>SDSS J132434.39</td>
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</tbody>
</table>

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The use of pure-H models for G 191-B2B is inappropriate as a number of heavy metals have been detected in the UV spectrum of this star.

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In this paper, we consider the possibility of building an extended network of spectrophotometric standard stars by identifying well-studied, well-known DA stars as primary standards. The fluxes are in units of $\text{erg} \, \text{cm}^{-2} \, \text{s}^{-1} \, \text{Å}^{-1}$. The effective temperature in the hotter stars is significantly warmer than the ZZ Ceti window ($\sim 11,000 \degree \text{K}$), though we have not verified that their fluxes are stable all the time.

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**Fig. 1.—Spectra from the MMT overlaid with the best-fit model.** The model has been fluxed with six polynomials to match the observed spectrum. The spikes are due to cosmic-rays.

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In addition to our five targets, we observed the well-studied, high-$B-V$ stars SDSS 2122+0154 and SDSS 1914+0434. By comparing the effective temperatures derived from spectra that preserve the over-all spectral shape, we see the effects of reddening, in particular in the hotter (and therefore more distant) stars. By including reddening in the analysis, the two sets of temperatures are brought into agreement.

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Our exercise identifies a set of nine new standard candidates (Eisenstein et al. 2006).
White Dwarf Pollution

First White Dwarf with atmospheric pollution (Van Maanen 1917).

WD SDSS spectra (Dufour et al. 2010)
Polluted cool white dwarfs should accrete material from the exterior.
Mechanism of external pollution

Kilic & Redfield, 2007
Planetesimals Accretion

- Planetesimal transits around WD1145+017 (Vanderburg et al. 2015).
Proposed Mechanisms for planetesimals accretion


Two/Three widely separated planets (Veras & Mustill, 2013, Mustill, Veras & Villaver 2014)

Wide Binary Companion (Bonsor & Veras, 2015)

Asteroid belt and interaction with Planet (Bonsor, Mustill & Wyatt, 2011; Debes, Walsh & Stark, 2012; Frewen & Hansen, 2014)

Remnant Exo-Oort Cloud Comets (Veras, Shannon & Gänsicke, 2014; Caiazzo & Heyl, 2017)
Our method:

To compare the properties (mass, kinematics, …) of the polluted white dwarf sample with respect to non-polluted sample to find the mechanism(s) causing pollution.
Sample Selection

Polluted sample

Revisited literature for white dwarfs with calculated accretion rates and stellar parameters as distance, mass, cooling time, etc.

104 polluted white dwarfs with accretion

Non-Polluted sample

Spectroscopic identification from different surveys and catalogs: SDSS, PG Survey, SUPERBLINK survey, Villanova WD Catalog, etc.


The comparison sample was randomly selected from the non-polluted sample of 4540 objects.
Spatial distribution

Selected sample in Galactic Coordinates

Red: accretion sample  Blue: comparison sample  *: Polluted WD IR excesses
Mass distribution up to 25 pc from the Sun

Polluted sample
Mean Mass: \(0.64 \, M_\odot\)
Median Mass: \(0.62 \, M_\odot\)

Non-polluted sample
Mean Mass: \(0.65 \, M_\odot\)
Median Mass: \(0.61 \, M_\odot\)
Mass distribution up to 200 pc from the Sun

Polluted sample
Mean Mass: $0.66M_\odot$
Median Mass: $0.65M_\odot$

Non-polluted sample
Mean Mass: $0.64M_\odot$
Median Mass: $0.59M_\odot$
Initial-final mass relation
(Kalirai et al. 2008)

\[ M_{\text{final}} = (0.109 \pm 0.007) M_{\text{initial}} + 0.394 \pm 0.025 M_\odot \]
Progenitor mass of the WD samples

**Polluted sample**
Mean Mass: $0.66 \, M_\odot$
Median Mass: $0.65 \, M_\odot$

**Non-polluted sample**
Mean Mass: $0.65 \, M_\odot$
Median Mass: $0.59 \, M_\odot$

Mean initial mass: $2.43 \, M_\odot$
Median initial mass: $2.39 \, M_\odot$

Mean initial mass: $2.30 \, M_\odot$
Median initial mass: $1.84 \, M_\odot$

Koester et al. 2014 found a mean mass for progenitors of DA stars of $\sim 2 \, M_\odot$ which corresponds to A type stars in main sequence.
Connection to debris disks in the main sequence phase

Is circumstellar material of white dwarfs a remnant of the main sequence phase?

Detection rates of debris disk for A stars:
- 33% at 70 µm (Su et al. 2006)
- 25% at 100 µm (Thureau et al. 2013)

Exo-cometary activity in A stars (Rebollido et al. in prep.)
We are still analyzing: $<z>$, accretion rates, kinematics, ISM conditions...to guide our theoretical efforts.

Work in progress...

Thank you