Gaseous debris discs around white dwarfs

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Artists impression of SDSS J1228+1040 by Mark Garlick. Image of Saturn from NASA’s Cassini mission, NASA image saturn_malmerCassini_5m.jpg
Talk Outline

• **One** - The gaseous debris disc around SDSS J1228+1040

• **Few** - Common variability of gaseous debris discs

• **Many** - Frequency of gaseous debris discs around white dwarfs
Remnant Planetary Systems

SDSS J1228+1040

White dwarf

Photospheric absorption

Gänsicke et al. 2012, MNRAS, 424, 333

Jura & Young, 2014, Annu. Rev. Earth Planet. Sci., 42, 45

Gänsicke et al. 2012, MNRAS, 424, 333
Remnant Planetary Systems

SDSS J1228+1040

Dust

Roche limit
Dust sublimation

Photospheric absorption

Planetary debris

Observable

H atom
Heavy atom

White dwarf

Jura & Young, 2014, Annu. Rev. Earth Planet. Sci., 42, 45

Brinkworth et. al. 2009, ApJ, 696, 1402

Gänsicke et. al. 2012, MNRAS, 424, 333
Remnant Planetary Systems

SDSS J1228+1040

Jura & Young, 2014, Annu. Rev. Earth Planet. Sci., 42, 45

Brinkworth et. al. 2009, ApJ, 696, 1402

Gänsicke et. al. 2012, MNRAS, 424, 333
The gaseous component of the debris disc

Gänsicke et. al. 2006, Science, 314, 1908
Accretion disc in a binary

K. Horne and T. Marsh

![Diagram of accretion disc in a binary system]
Accretion disc in a binary
The gaseous component of the debris disc

Gänsicke et. al. 2006, Science, 314, 1908

SDSS J1228+1040
10 out of 18
Doppler Tomography

Fig. 3. A model image and the equivalent profiles formed by projection along an angle appropriate to orbital phases 0.25 (right-most profile) and 0.5 (lower profile).

As a series of line profiles at different orbital phases is therefore nothing more than a set of projections of the image at different angles. The inversion of projections to reconstruct the image is known as “tomography”, the case of medical X-ray imaging being perhaps the most famous, although it occurs in many other fields too. I now look at the two methods that have been applied in the case of Doppler tomography.

3.2 Inversion Methods

The mathematics of the inversion of projections dates back to the work of Radon in 1917 [60]. If one knows the function (in my notation) $f(V, \phi)$ for all $V$ and $\phi$, an art transformation—the Radon transform—can produce the desired end product, $I(V_x, V_y)$. In reality, things are not so easy, and we never have the luxury of knowing the line profiles at all orbital phases, although one can get close in some cases. With the advent of fast computers and the development of medical imaging, interest in the implementation of Radon’s transform...
Doppler Tomography

Manser et. al. 2016, MNRAS, 455, 4467
Doppler Tomography

Manser et. al. 2016, MNRAS, 455, 4467
Doppler Tomography

2011-01

Time evolution of peaks

Doppler Tomography

Manser et. al. 2016, MNRAS, 455, 4467
Doppler Tomography

Manser et. al. 2016, MNRAS, 455, 4467
New observations in March and May

- 2003-03
- 2007-07
- 2011-01
- 2014-03
- 2015-05

Wavelength [Å]

Normalized Flux

2016 March

2016 May
A Whole New Map

Manser et. al. in prep.
Some more comparing

Manser et. al. in prep.

New (20 epochs)
Old (18 epochs)
Spiral?
Even newer data!
Reached half way?

-1200 -800 -400 0 400 800 1200

Velocity [km/s]

-1.2 0.5 1.0 1.5 2.0 2.5 3.0 3.5

Normalised Flux

2006 Flipped

2017
Coadded X-Shooter spectrum

Wavelength [Å]

Coadded X-Shooter spectrum

Normalised Flux

8400 8500 8600 8700 3.0 2.0 1.0

Ca II 8498; 8542; 8662 Å
O I 8446 Å

1.2

Ca K 3934 Å
Ca H 3969 Å

1.05

Mg II 4481 Å

0.975 1.000 1.025

8400 8500 8600 8700 1.0

Ca II 8498; 8542; 8662 Å
O I 8446 Å

4900 5000 5100 5200 5300 5400

1.00 1.05 1.10

Fe II 4924 Å
Fe II 5018 Å

1.05

Fe II 5169; 5198 Å
Fe II 5235; 5276; 5317 Å

1.075 1.000 1.025 1.050

Mg II 4481 Å

4900 5000 5100 5200 5300 5400

1.00 1.05 1.10

Si II 5041; 5056 Å

Fe II 4924 Å
Fe II 5018 Å

0.975 1.000 1.025

Ca K 3934 Å
Ca H 3969 Å

4900 5000 5100 5200

1.00 1.05 1.10

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4900 5000 5100 5200 5300 5400

1.00 1.05 1.10

Si II 5041; 5056 Å

8400 8500 8600 8700 1.0

Ca II 8498; 8542; 8662 Å
O I 8446 Å

0.9 1.0 1.2

Mg II 7877; 7896 Å
O I blend

1.1 1.2

O I 7772; 7774; 7775 Å
O I 8446 Å

1.3

Mg I 8806; O I 8820 Å
O I & Mg II blend

0.9 1.0 1.1 1.2

Ca II 8912; 8927 Å

0.975 1.000 1.025 1.050

Mg II 4481 Å

8400 8500 8600 8700

1.0 2.0 3.0

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Ca II 8912; 8927 Å

0.975 1.000 1.025 1.050

Mg II 4481 Å
April 2010 Hubble Spectrum

Gänsicke et. al. 2012, MNRAS, 424, 333
Comparing the two...

Manser et. al. in prep. — 2010 — 2016
Circumstellar gas

Si IV

Manser et al. in prep.
Circumstellar gas

Manser et al. in prep.

Si IV

Wavelength [Å]
Other variable gas discs

SDSS J1228+1040

Manser et. al. 2016, MNRAS, 455, 4467
Morphologically variable

SDSS J0845+2257   SDSS J1228+1040

Wilson et. al. 2014, MNRAS, 451, 3237
Manser et. al. 2016, MNRAS, 455, 4467
Morphologically variable

SDSS J0845+2257  SDSS J1228+1040  SDSS J1043+0855

Wilson et. al. 2015, MNRAS, 451, 3237  Manser et. al. 2016, MNRAS, 455, 4467  Manser et. al. 2016, MNRAS, 462 1461
Variable strength

SDSS J1617+1620

Wilson et. al. 2014, MNRAS, 445, 1878
**Variable strength**

**SDSS J1617+1620**

![Graph showing spectral data for SDSS J1617+1620 with wavelength on the x-axis and normalized flux on the y-axis, with dates and instrument names like WHT, Gemini, and X-shooter, and normalised flux values across different dates such as 2006 July 01, 2008 March 03, 2009 February 17, 2010 June 10, and normalized flux values such as 20.0 (with error margins), 15.0, 10.0, 5.0, and 0.0.](image)

Wilson et al. 2014, MNRAS, 445, 1878

**SDSS J1228+1040**

![Graph showing spectral data for SDSS J1228+1040 with wavelength on the x-axis and normalized flux on the y-axis, with dates and instrument names like WHT, Gemini, and X-shooter, and normalised flux values across different dates such as 2003-03, 2007-07, 2011-01, 2014-03, 2015-05, and normalized flux values such as 22.0 (with error margins), 18.0, 14.0, 10.0, 6.0, 2.0, and 0.0.](image)

Manser et al. 2016, MNRAS, 455, 4467
Variability

| Name               | Type | Features |
|--------------------|------|----------|
| SDSS J0738+1835    | DB   | e        |
| SDSS J0845+2257    | DB   | e, v     |
| SDSS J0959–0200    | DA   | e, v     |
| SDSS J1043+0855    | DA   | e, v     |
| WD 1144+0529       | DA   | e        |
| SDSS J1228+1040    | DA   | e, a, v  |
| HE 1349–2305       | DBA  | e        |
| SDSS J1617+1620    | DA   | e, v     |

- **e** - Gaseous emission
- **a** - Gaseous absorption
- **v** - Spectroscopic or photometric Variability
Variability

| Name             | Type | Features |
|------------------|------|----------|
| SDSS J0738+1835  | DB   | e        |
| SDSS J0845+2257  | DB   | e, v     |
| SDSS J0959–0200  | DA   | e, v     |
| SDSS J1043+0855  | DA   | e, v     |
| WD 1144+0529     | DA   | e        |
| SDSS J1228+1040  | DA   | e, a, v  |
| HE 1349–2305     | DBA  | e        |
| SDSS J1617+1620  | DA   | e, v     |

Manser et al. 2003–04, Dufour et al. 2012

Variability of the gaseous disc at SDSS J1043+0855 appears to be remarkably similar to the observed gaseous component to the debris disc. To cross one another and inducing collisions which produces generation from an asteroid colliding with a pre-existing disc could be depleted; a recent planetesimal impact on the gaseous disc in SDSS J1043+0855, which do not show any long term decay.

We infer a total accretion rate based on the mass fluxes method used in continuum fitting, as well as the statistical detection rates are given with errors where known. Values derive from observation.

Metal polluted white dwarfs with circumstellar gas detected in SDSS J1617+1620. Only SDSS J0738+1835 has displayed variability, as the dust cloud settled into the disc.
Detected Remnant Planetary System statistics

Metal pollution: Koester et al. 2014

25 - 50%
Detected Remnant Planetary System statistics

**Metal pollution**  Koester et. al. 2014  25 - 50 %

**Dusty disc**  Farihi et al. 2009  Rocchetto et al. 2015  1 - 3 %
Detected Remnant Planetary System statistics

Metal pollution  Koester et. al. 2014  25 - 50 %
Dusty disc  Farihi et al. 2009  Rocchetto et al. 2015  1 - 3 %
Gaseous component  ??? %

Gaseous component
The sample

Figure 2. Colour–colour diagrams illustrating the location of the 27 639 DR7 spectroscopic objects that we used as training sample for our selection method. DA white dwarfs, non-DA white dwarfs, NLHS and quasars are shown as blue, yellow, red and green dots, respectively. The colour cuts that define our initial broad selection from Table 2 are overlaid as red lines. Objects outside this selection were not classified and are therefore plotted as grey dots.

Gentile Fusillo et. al. 2015, MNRAS, 448, 2260
The sample

![Graph showing the sample with different symbols and colors.](image)

- **DA**: SDSS J1228+1040
- **DB**: SDSS J1617+1620
- **DAB**: SDSS J0845+2257
- **Other**: SDSS J1043+0855, SDSS J0738+1835, SDSS J1144+0529, SDSS J0959–0200

**Legend:**
- **DA**: Star symbol
- **DB**: Circle symbol
- **DAB**: Inverted triangle symbol
- **Other**: Diamond symbol

**Note:** The graph is a u–g vs. g–r color-color diagram. Each symbol represents a different white dwarf, classified into DA, DB, DAB, or Other, with varying colors to differentiate them.
The frequency of gaseous discs

9079 single white dwarfs
The frequency of gaseous discs

9079 single white dwarfs

6 Gasesous components
The frequency of gaseous discs

9079 single white dwarfs

6 Gaseous components

Frequency of observable gaseous debris discs at white dwarfs

$0.07^{+0.03}_{-0.02} \%$
# Detected Remnant Planetary System statistics

| Component                  | Source                                      | Percentage |
|----------------------------|---------------------------------------------|------------|
| Metal pollution            | Koester et. al. 2014                        | 25 - 50 %  |
| Dusty disc                 | Farihi et al. 2009, Rocchetto et al. 2015  | 1 - 3 %    |
| Gaseous component          |                                             | 0.07 %     |
| Component                          | Statistics          | References                      |
|-----------------------------------|---------------------|---------------------------------|
| Metal pollution                   | 25 - 50 %           | Koester et. al. 2014            |
| Dusty disc                        | 1 - 3 %             | Farihi et al. 2009, Rocchetto et al. 2015 |
| Gaseous component                 | 0.07 %              |                                 |
| Debris discs with a gaseous component | 2 - 10 %         |                                 |
Summary

- SDSS J1228+1040 is well studied, but still many unanswered questions.
- An observable gaseous component appears to be linked with variability.
- Determined the frequency of a gaseous component to a debris disc at a white dwarf.
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Thanks for listening!

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