National Astronomy Meeting | White Dwarf Parallel Session | 11/7/2025

A different perspective: How the choice of disc model affects the interpretation of polluted white dwarfs

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Characterizing planetary material accreted by cool helium-atmosphere white dwarfs using an exponentially decaying disc model

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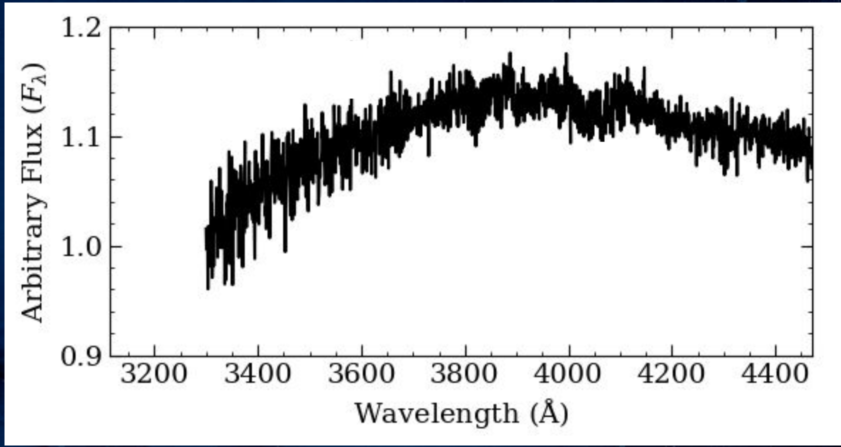
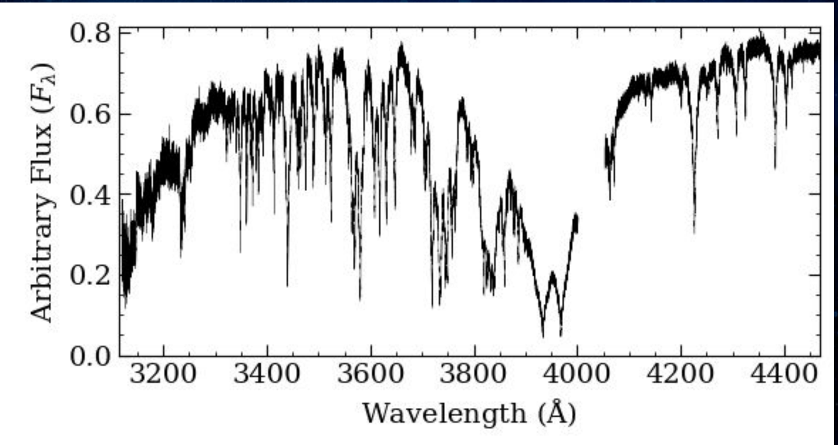
Polluted white dwarfs

Spectrum of 7000 K He-atmosphere WD



Spectrum of 7000 K He-atmosphere WD (polluted)



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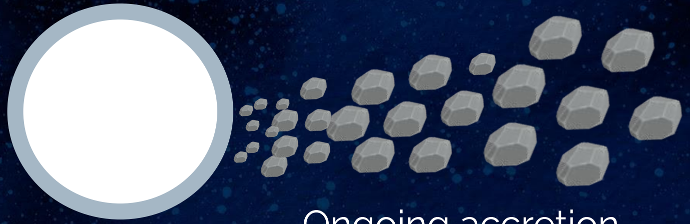


Ongoing accretion

Accretion scenarios

1. Constant accretion rate

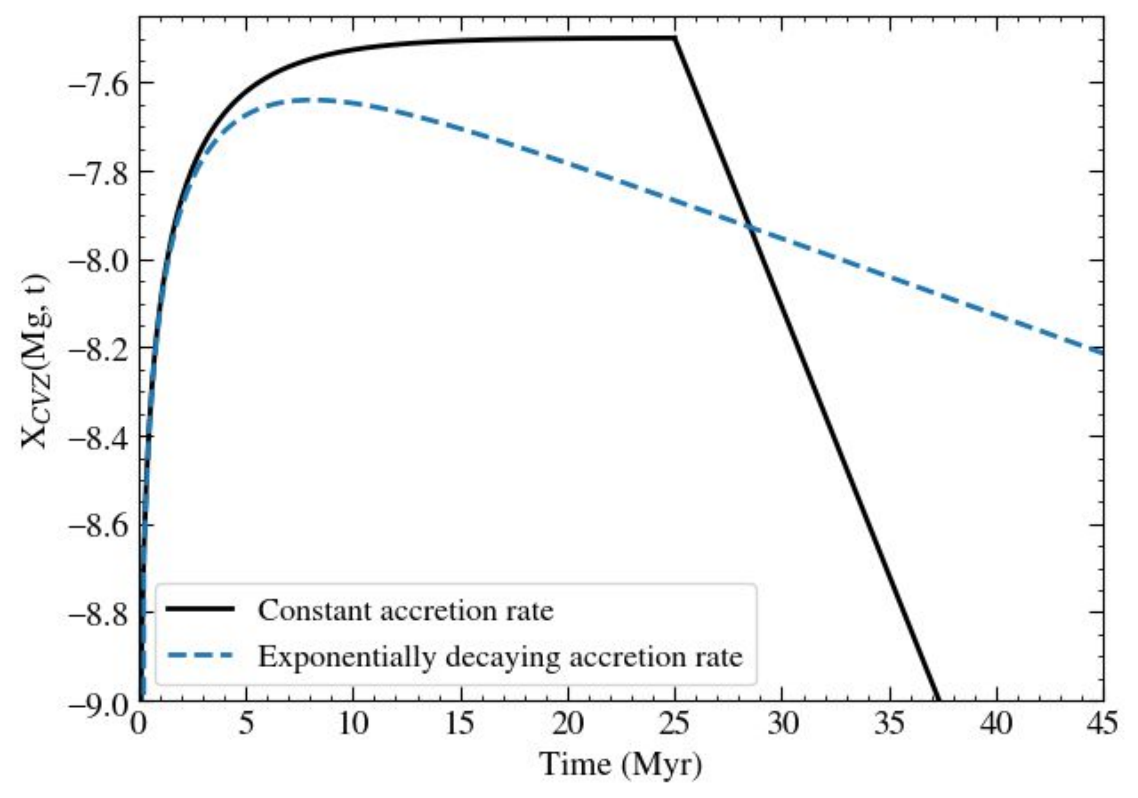
- Accretion disc is constantly **replenished**
- Accretion process can reach a **steady state** - material sinks as fast as it enters atmosphere

2. Exponentially decaying accretion rate

- Accretion disc is **not replenished**
- **Complex relationship** between accretion rate and sinking rate

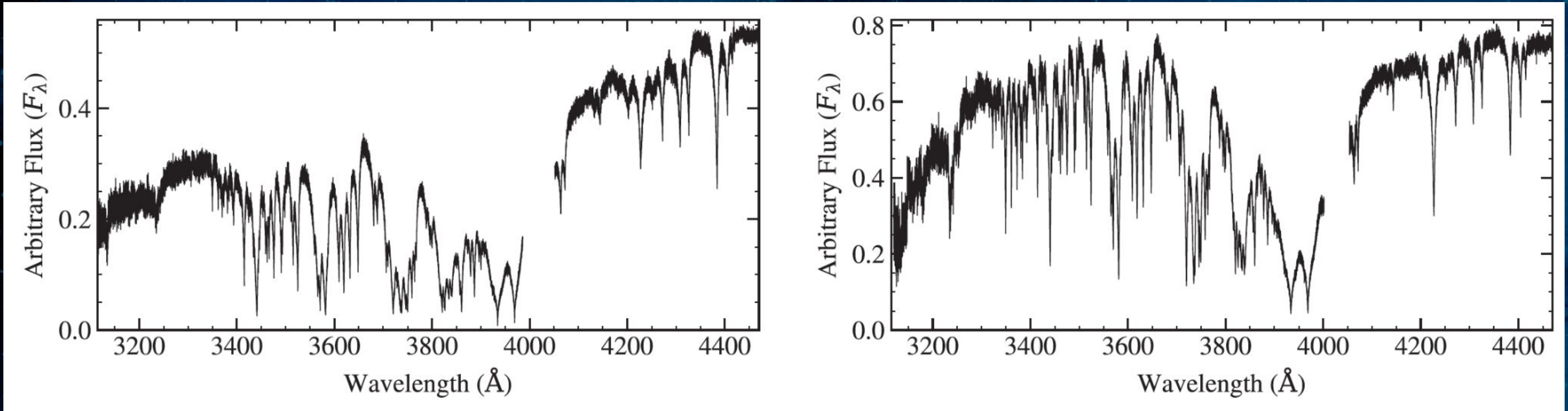
Jura et al. (2009)

Accretion scenarios



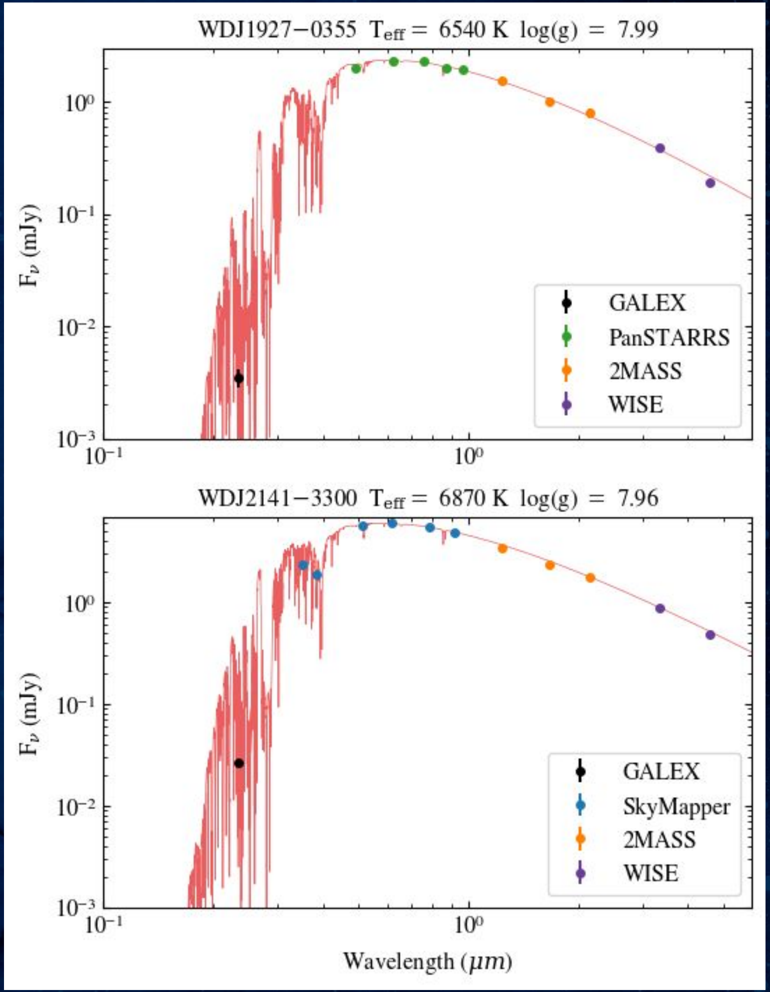
Scenarios **diverge** most notably for cool, He-atmosphere white dwarfs

The white dwarfs



WDJ 1927-0355

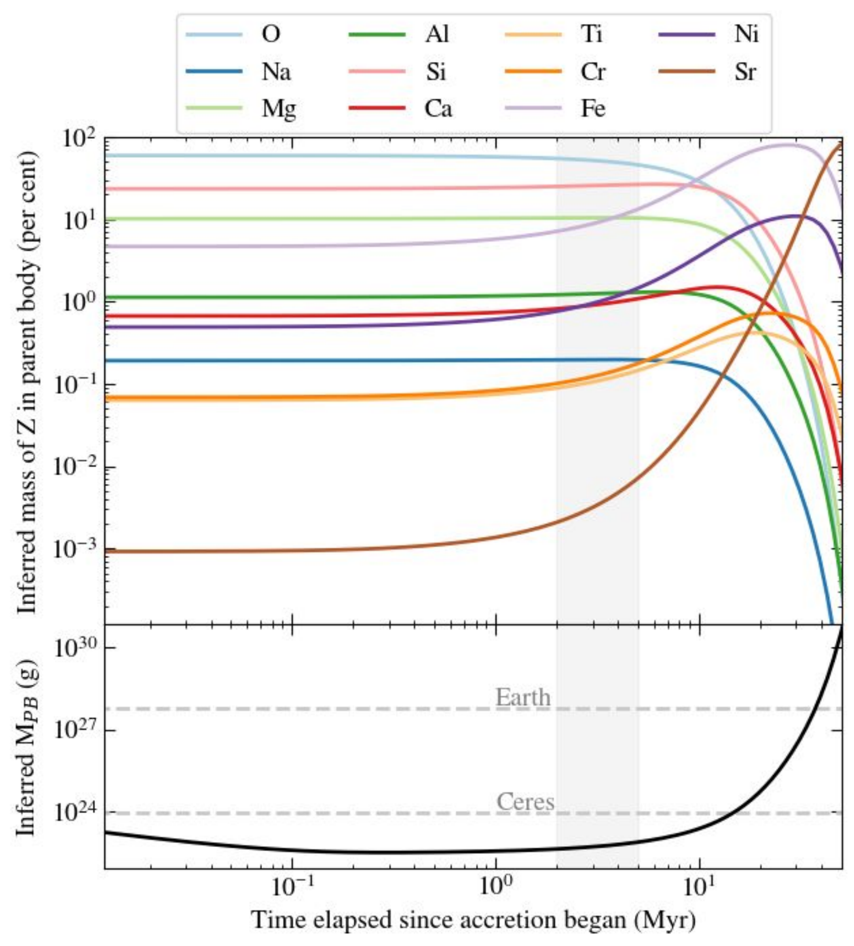
WDJ 2141-3300



Method

- Fitted **model atmospheres** to high-resolution (HIRES) spectra of **two** cool, He-atmosphere polluted white dwarfs

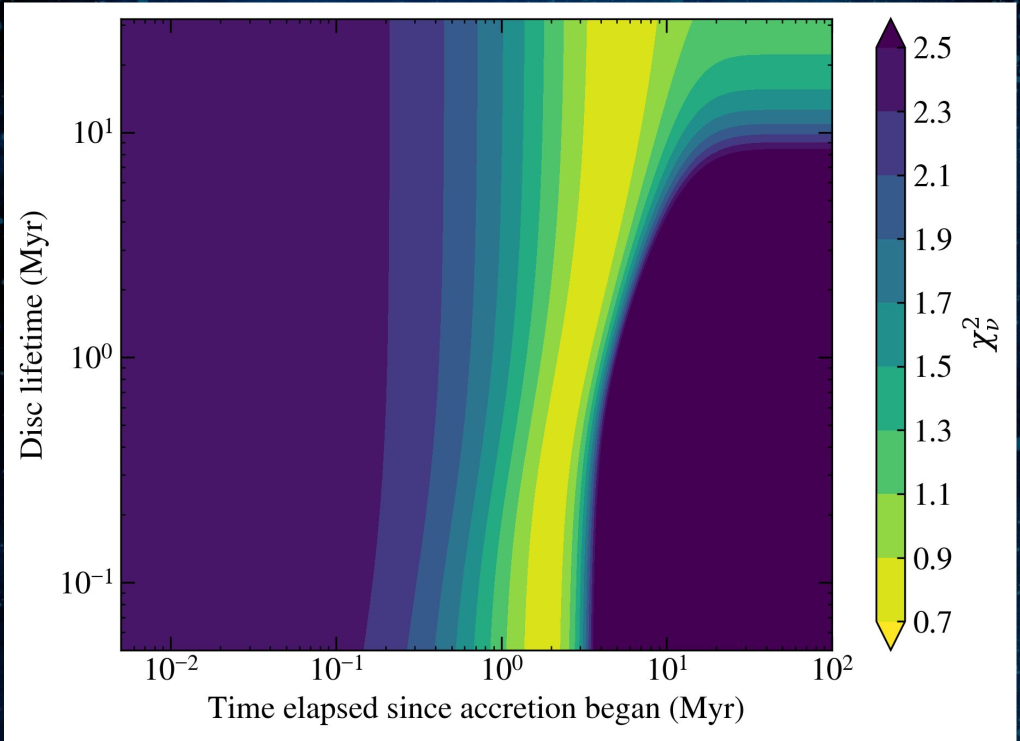
- Determined **masses** of metals in the convection zone of the white dwarf at the time of observation



Method

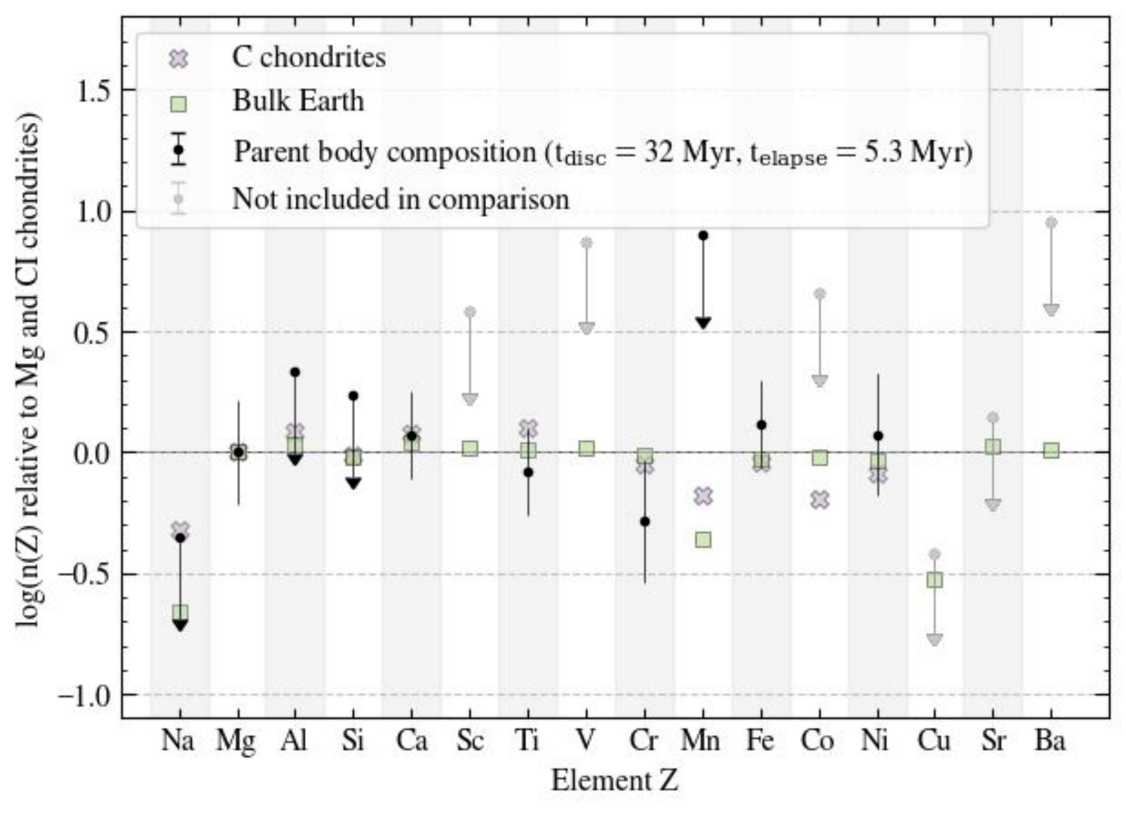
- Propagated masses of metals through **exponentially decaying disc model**
- Compared inferred masses of metals in parent body to common **solar system** objects

Results: WDJ 1927-0355



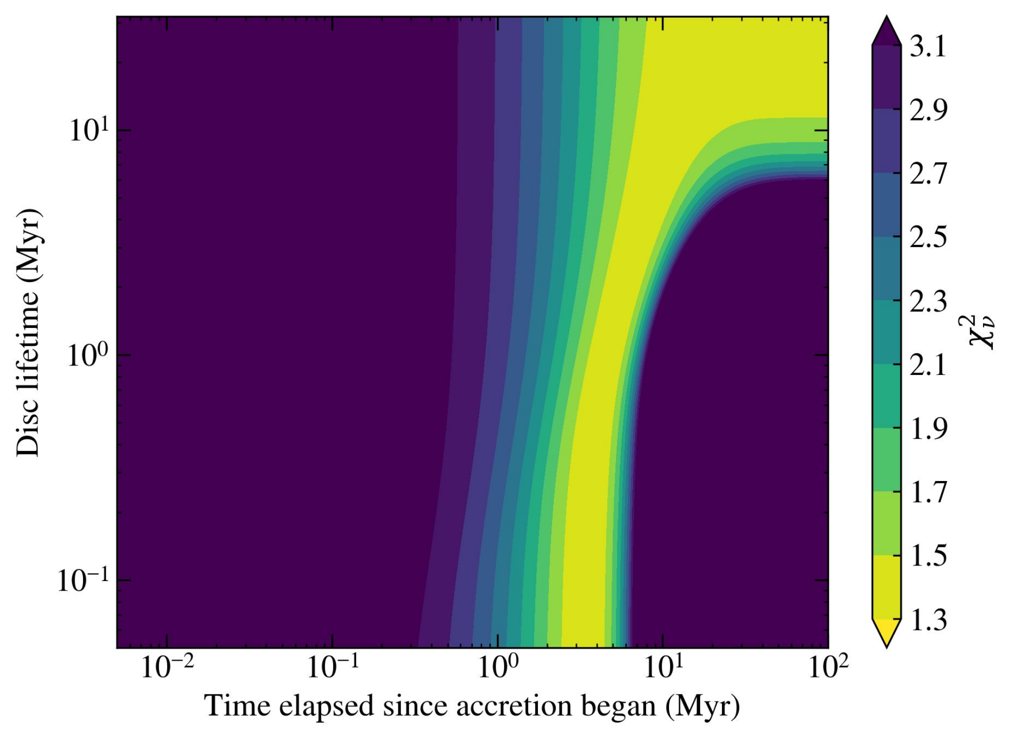
- Best-matching with **bulk Earth** and **chondrite** compositions
- Two free parameters **degenerate** over contour plot

Results: WDJ 1927-0355



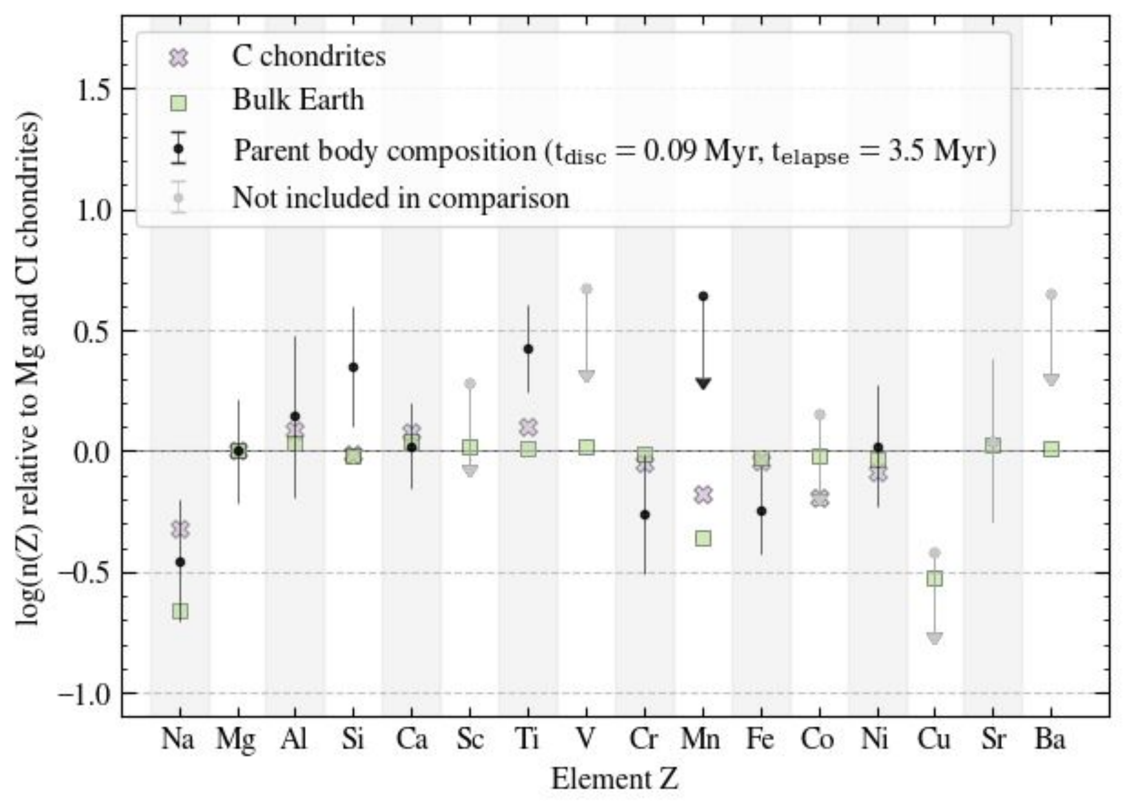
Composition		Minimum χ^2_ν WD J1927−0355
Bulk Earth		0.8
Earth crust		65.2
Chondrites	C	1.9
	E	2.8
	H	2.0
	L	2.8
	LL	3.2
Achondrites	Aubrites	51.9
	Brachinites	3.9
	Diogenites	32.1
	Eucrites	63.2
	Howardites	31.5
	Urelites	9.9
Stony-iron	Mesosiderites	9.4
	Pallasites	18.3

Results: WDJ 2141-3300



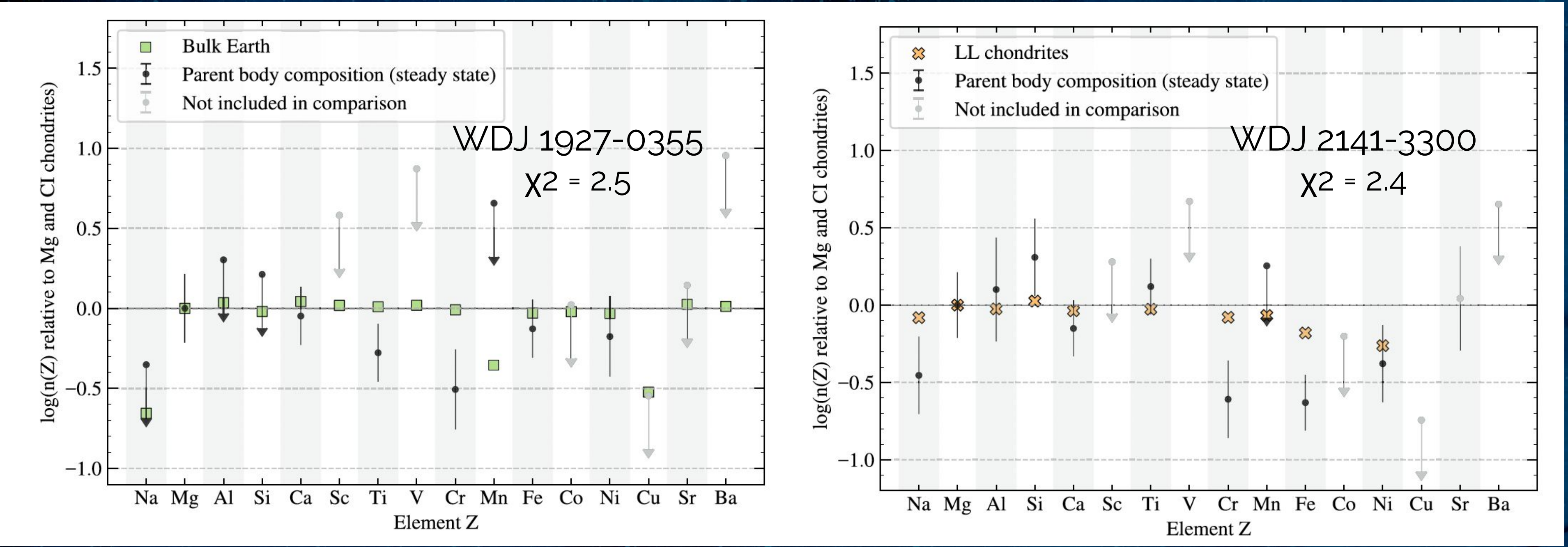
- Best-matching with **bulk Earth** and **chondrite** compositions
- Two free parameters **degenerate** over contour plot

Results: WDJ 2141-3300



Composition		Minimum χ^2_ν WD J2141−3300
Bulk Earth		1.8
Earth crust		31.0
Chondrites	C	1.3
	E	2.7
	H	2.3
	L	1.9
	LL	1.8
Achondrites	Aubrites	20.7
	Brachinites	2.3
	Diogenites	16.8
	Eucrites	24.6
	Howardites	10.8
	Urelites	8.3
Stony-iron	Mesosiderites	1.6
	Pallasites	42.8

Results: Constant accretion rate model



Best-matching compositions chondrites/bulk Earth, steady state, worse χ^2

The exponentially decaying disc model provides **better-matching solutions** for our two white dwarfs

It also enables us to provide a **mass range** of the parent body, which for our systems is between the mass of a **small moon** and **dwarf planet**

Conclusions

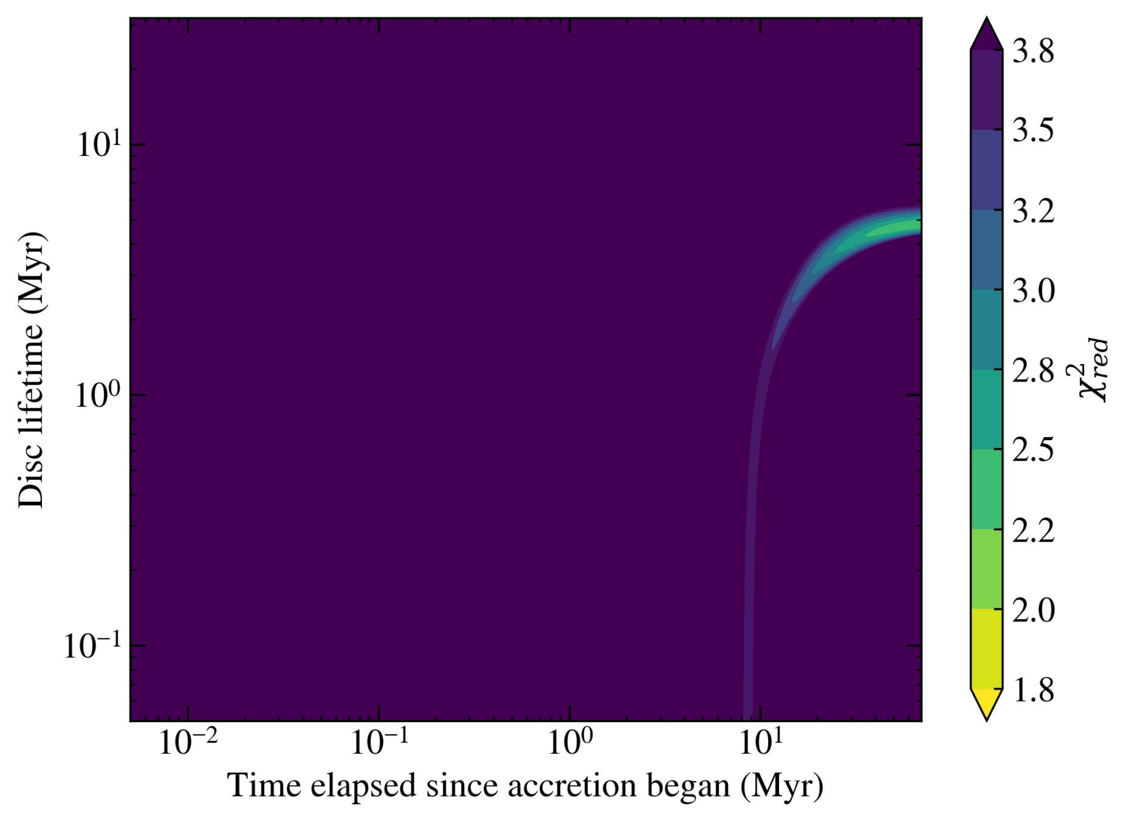
- I have studied two **cool**, **He-atmosphere** white dwarfs accreting planetary debris.

- The He atmospheres mean the debris takes **more time to sink**, and therefore the choice of disc model is significant.

- I found that the **exponentially decaying disc model** provides **better matches** to the accretion scenario and planet composition for the two white dwarfs.

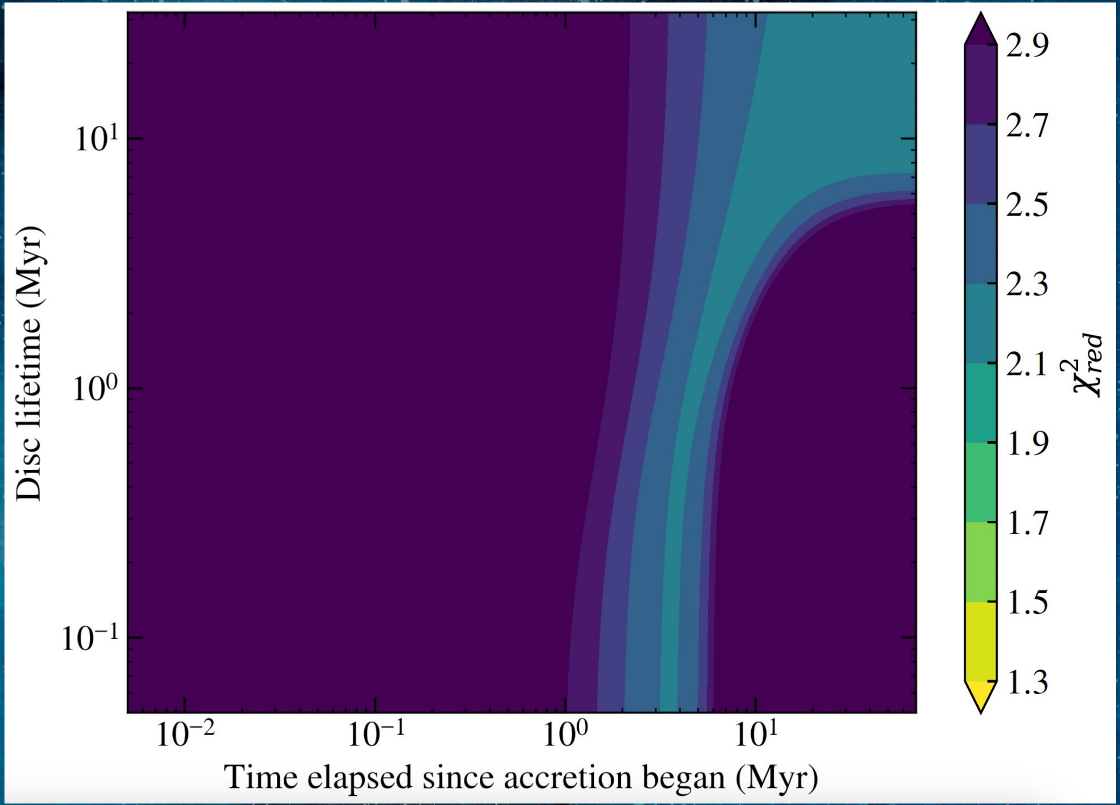
- The two systems considered in this work were found to be accreting bulk **Earth**-like parent bodies at least the mass of a **small moon.**

Extra slides



Mesosiderite solution for WDJ 2141-3300

Extra slides



Ratioed relative to Ca rather than Mg (WDJ 2141-3300)

Extra slides

$$M_{\mathrm{PB}}(Z, t_{\mathrm{elapse}}) = \frac{M_{\mathrm{CVZ}}(Z)(t_{\mathrm{disc}} - t_{\mathrm{set}}(Z))}{t_{\mathrm{set}}(Z)(\mathrm{e}^{-t_{\mathrm{elapse}}/t_{\mathrm{disc}}} - \mathrm{e}^{-t_{\mathrm{elapse}}/t_{\mathrm{set}}(Z)})}$$

$$\chi_\nu^2 = \frac{1}{\nu} \sum_{i=1}^{N} \left(\frac{\left(Y_{i,\mathrm{WD}} - Y_{i,\mathrm{SS}}\right)^2}{\sigma_{\mathrm{WD}}^2(Z_i) + \sigma_{\mathrm{WD}}^2(Z_{\mathrm{ref}})} + \frac{1 - S(Y_{i,\mathrm{WD}})}{\sigma_i} \right)$$

$$Y_i = \log\left(n(Z_i)/n(Z_{\mathrm{ref}})\right)$$