The detection of lithium in cool white dwarf atmospheres

Benjamin C. Kaiser (ben.kaiser[at]unc.edu) & Mark Hollands (M.Hollands.1[at]warwick.ac.uk)

J. Christopher Clemens, Simon Blouin, Patrick Dufour, Ryan J. Hegedus, Joshua S. Reding, and Antoine Bédard

Pier-Emmanuel Tremblay, Boris Gänsicke, Detlev Koester, and Nicola Gentile-Fusillo
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Part I

Benjamin C. Kaiser

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WD J1644–0449

Kaiser et al. Science 370, id. abd1714 (2020)
Kaiser et al. *Science* **370**, id. abd1714 (2020); style from Swan et al. 2019
Galactic Li/Fe Expectation from Nucleosynthetic Modeling

Galactic Li/Fe Enrichment Curve
CI Chondrites

(Prantzos 2012)
(Lodders+ 2009; Bouvier+ 2010)
Kaiser et al. Science 370, id. abd1714 (2020)
Hand-off to Mark
The detection of lithium in cool white dwarf atmospheres
Part III
Benjamin C. Kaiser

J. Christopher Clemens, Simon Blouin, Patrick Dufour, Ryan J. Hegedus, Joshua S. Reding, and Antoine Bédard
Ben Kaiser KITP 2021

Kaiser et al. 2021 in prep.
Kaiser et al. 2021 in prep.
Crust-like material

Mantle-like material

Primitive material

Kaiser et al. 2021 in prep.
Crust-like material

Mantle-like material

Primitive material

Kaiser et al. 2021 in prep.
Age of the Universe

- Galactic Li/Fe Enrichment Curve
- WDJ1644-0449 Photospheric
- WDJ1644-0449 Steady State
- SDSSJ1330+6435 Photospheric
- SDSSJ1330+6435 Steady State
- WDJ1824+1213 Photospheric
- WDJ1824+1213 Steady State
- WDJ2317+1830 Photospheric
- WDJ2317+1830 Steady State
- LHS2534 Photospheric
- LHS2534 Steady State
- CI Chondrites

Ben Kaiser KITP 2021

Kaiser et al. 2021 in prep.
Suggested Galactic Li/Fe Enrichment Curve

Age of the Universe

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Kaiser et al. 2021 in prep.
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The detection of lithium in cool white dwarf atmospheres – part 2

KITP meeting 2021-03-29

Mark Hollands, Pier-Emmanuel Tremblay, Boris Gänsicke, Detlev Koester, Nicola Gentile-Fusillo
Alkali metals in 4 DZ white dwarfs

- Building sample of WDs within 40pc of the Sun
  - Tremblay et al., MNRAS 497, 130 (2020)
  - McCleery et al., MNRAS 499, 1890 (2020)
- Found 4 DZs with Li, one with K
  - 1 object in common with Kaiser et al.
- $T_{\text{eff}}$ 3500–5000 K ($t_{\text{cool}}$ 6–10 Gyr)
LHS 2534

He dominated atm
B = 2.1MG
LHS 2534

He dominated atm
B = 2.1MG
WD J2317+1830

WD J2317+1830 (GTC)

H+He mixed atm

Flux [erg s⁻¹ cm⁻² Å⁻¹]

Wavelength [Å]
WD J1824+1213

H+He mixed atm
SDSS J1330+6435

He dominated atm
Challenges in modelling

- Used Koester model atmospheres
- Objects all very cool (3500–5000K)
  - Very high densities in models
- Molecular opacities (i.e. CIA) v. important:
  - $\text{H}_2-\text{H}_2$, $\text{H}_2-\text{He}$, $\text{H}_2-\text{H}$, $\text{H}-\text{He}$, $\text{He}-\text{He}-\text{He}$
- Coolest WD masses too small
- Li line widths are weird...
$M = 0.55 \, M_{\odot}$  
$T_{\text{eff}} = 4780 \, \text{K}$

$M = 1.00 \, M_{\odot}$  
$T_{\text{eff}} = 4210 \, \text{K}$

$M = 0.28 \, M_{\odot}$  
$T_{\text{eff}} = 3350 \, \text{K}$

$M = 0.38 \, M_{\odot}$  
$T_{\text{eff}} = 3660 \, \text{K}$
The oldest WD with a dusty disc
The oldest WD with a dusty disc

\[ \log \left( \frac{M_{\text{cvz}}}{M_{\text{wd}}} \right) = -7.9 \]

\[ \tau_{\text{Na}} = 4000 \text{ yr} \quad \tau_{\text{Ca}} = 2000 \text{ yr} \]

\[ \tau_{\text{Li}} = 10,000 \text{ yr} \]
The oldest WD with a dusty disc

- $\dot{m}_\text{Li} = 760 \text{ g/s}$
- $\dot{m}_\text{Na} = 92,000 \text{ g/s}$
- $\dot{m}_\text{Ca} = 37,000 \text{ g/s}$
- $\dot{m}_\text{crust} \approx 3,000,000 \text{ g/s}$ (3 tonne/s)
- $t_{\text{cool}} = 9.5 \pm 0.2 \text{ Gyr}$

$\log(M_{\text{cvz}}/M_{\text{wd}})$

$t_{\text{Li}} = 10,000 \text{ yr}$

$\tau_{\text{Ca}} = 2000 \text{ yr}$

$\tau_{\text{Li}} = 10,000 \text{ yr}$
Abundance analysis