Analysis of Chandra-LETG spectra of two DA white dwarfs and a PG1159 star

J. Adamczak [1], K. Werner [1], T. Rauch [1], S. Schuh [2], J. J. Drake [3], J. W. Kruk [4], A. Gautschy[5]

[1]Institute for Astronomy und Astrophysics, Kepler Center for Astro and Particle Physics, Eberhard Karls University Tübingen, Germany
[2]Georg August University Göttingen, Germany
[3]Harvard-Smithsonian Center for Astrophysics, Cambridge, USA
[4]NASA, Goddard Space Flight Center, USA
[5]ETH Zürich, Switzerland

16th of August 2010

Chandra LETG spectra of three objects:

- LB 1919: metal poor DA white dwarf
- GD 246: DA white dwarf
- PG 1520+525: non-pulsating PG 1159 star

Why X-rays?

- X-ray emission in hot white dwarfs ($> 30\,000\,\mathrm{K}$)
- Radiative levitation → blocking flux → metal poor white dwarfs
- Important line features of Fe and Ni detectable in X-rays

- X-ray emission in PG 1159 stars
- Born-again scenario → burning of residual H
- Pulsating stars define GW Vir instability strip
- Temperature sensitive X-ray range

NLTE model atmospheres – Tübingen Model Atmosphere Package (TMAP) – plane parallel – hydrostatic, radiative equilibrium

- Homogeneously mixed elements (PRO2 code, Werner et al. 2003)
- Chemically stratified (NGRT code, Dreizler 1999)

- Iron Opacity Interface IRONIC (Rauch & Deetjen 2003)

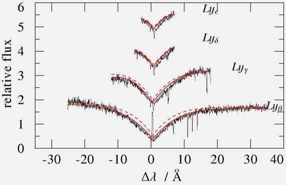
LB 1919

- Hottest of 90 DAs in EUVE all sky survey and 20 DAs analyzed by Wolff et al. (1998)
- One of the hottest DAs known ($T_{\rm eff} = 69\,000$K, $\log g = 8.08$, Vennes et al. 1997)
- Metal composition unknown – no suitable models
  Homogeneous scaled to G 191–B2B
  Stratified

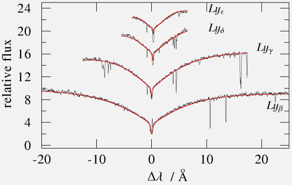
GD 246

- Different investigations: $T_{\rm eff} = 51\,300 - 60\,100\,$K, $\log g = 7.72 - 8.20$
- Metals: C, N, O, Si, P, S, Fe, Ni, Ge – Vennes et al. (2005)

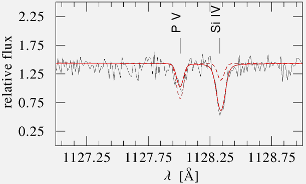
LB 1919 – FUSE – GD 246

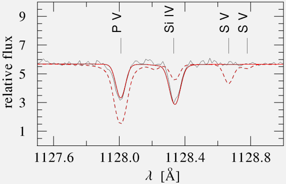


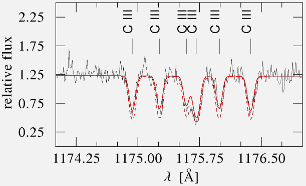
69 000 K
↓
54 000 K

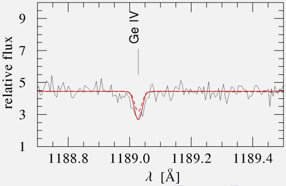


57 000 K



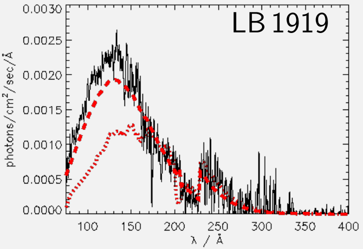






FUSE results

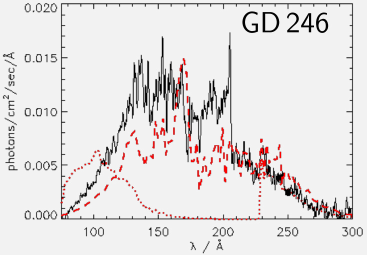
WD	Element	Abundance [X/H]	Uncertainty	Ions	Diff	Literature
LB 1919	C	$4.63 \cdot 10^{-7}$	$2.5 \cdot 10^{-7}$	C III	$=$	
	O	$4 \cdot 10^{-6}$		O VI	$>$?	
	Si	$1.2 \cdot 10^{-7}$	$2 \cdot 10^{-8}$	Si III+IV	$<$	
	P	$3 \cdot 10^{-9}$	$1 \cdot 10^{-9}$	P V	$>$	
	S	$1 \cdot 10^{-7}$	$5 \cdot 10^{-8}$	S IV+VI	$>$?	
GD 246	C	$< 3.2 \cdot 10^{-8}$		C III	$>$	
	O	$< 6 \cdot 10^{-8}$		O VI	$>$	$1.6 \cdot 10^{-7}$ Barstow et al. (2003)
	Si	$1.2 \cdot 10^{-7}$	$2 \cdot 10^{-8}$	Si IV	$<$	$5.0 \cdot 10^{-8}$ Wolff et al. (2001)
						$3.2 \cdot 10^{-8}$ Chayer et al. (2001)
						$1.2 \cdot 10^{-7}$ Barstow et al. (2003)
	P	$4 \cdot 10^{-9}$	$2 \cdot 10^{-9}$	P V	$>$	$6.3 \cdot 10^{-9}$ Chayer et al. (2001)
						$7.5 \cdot 10^{-9}$ Wolff et al. (2001)
	S	$5 \cdot 10^{-9}$	$2 \cdot 10^{-9}$	S VI	$>$	$< 3.0 \cdot 10^{-6}$ Wolff et al. (2001)
	Ge	$5 \cdot 10^{-9}$	$1 \cdot 10^{-9}$	Ge IV	$<$	$2.5 \cdot 10^{-9}$ Vennes et al. (2005)
	Fe	$< 1 \cdot 10^{-6}$			$>$	$< 2.0 \cdot 10^{-5}$ Wolff et al. (2001)
						$3.0 \cdot 10^{-7}$ Vennes & Dupuis (2002)
	Ni	$< 1 \cdot 10^{-6}$			$>$	



$T_{\text{eff}} = 56\,000\,\text{K}, \log g = 8.5$

H, C, O, Si, P, S

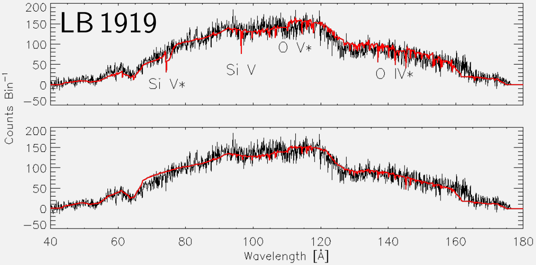
Homogeneous	Diffusion
$N(\text{H I}) = 1.6 \cdot 10^{19}\text{cm}^{-2}$	$N(\text{H I}) = 1.7 \cdot 10^{19}\text{cm}^{-2}$
$N(\text{He I}) = 0.02 \cdot N(\text{H I})$	$N(\text{He I}) = 0.02 \cdot N(\text{H I})$
$N(\text{He II}) = 0.04 \cdot N(\text{H I})$	$N(\text{He II}) = 0.04 \cdot N(\text{H I})$



$T_{\text{eff}} = 55\,000\,\text{K}, \log g = 7.3$

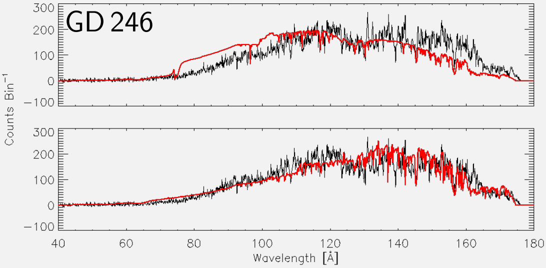
H, C, O, Si, P, S, Ge, Fe

Homogeneous	Diffusion
$N(\text{H I}) = 1.9 \cdot 10^{19}\text{cm}^{-2}$	$N(\text{H I}) = 2.0 \cdot 10^{19}\text{cm}^{-2}$
$N(\text{He I}) = 0.04 \cdot N(\text{H I})$	$N(\text{He I}) = 0.02 \cdot N(\text{H I})$
$N(\text{He II}) = 0.42 \cdot N(\text{H I})$	$N(\text{He II}) = 0.02 \cdot N(\text{H I})$



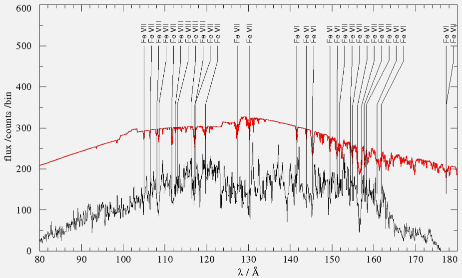
$T_{\text{eff}} = 56\,000\,\text{K}, \ \log g = 8.5$
homogeneous

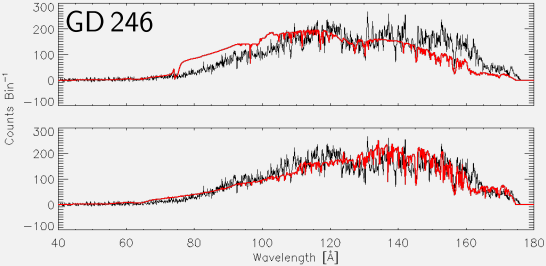
$T_{\text{eff}} = 52\,000\,\text{K}, \ \log g = 8.5$
diffusion



$T_{\text{eff}} = 55\,000\,\text{K}, \ \log g = 7.3$
homogeneous

$T_{\text{eff}} = 55\,000\,\text{K}, \ \log g = 7.9$
diffusion





$T_{\rm eff} = 55\,000\,{\rm K},\ \log g = 7.3$
homogeneous

$T_{\rm eff} = 55\,000\,{\rm K},\ \log g = 7.9$
diffusion

LB 1919

- $T_{\mathrm{eff}} = 54\,000 \pm 2\,000\,\mathrm{K}$, $\log g = 8.2 \pm 0.3$
- First time metal abundances for C, O, Si, P, and S, no Fe, Ni
- Stratified models → cause for metal poorness has to be found in earlier evolutionary state

GD 246

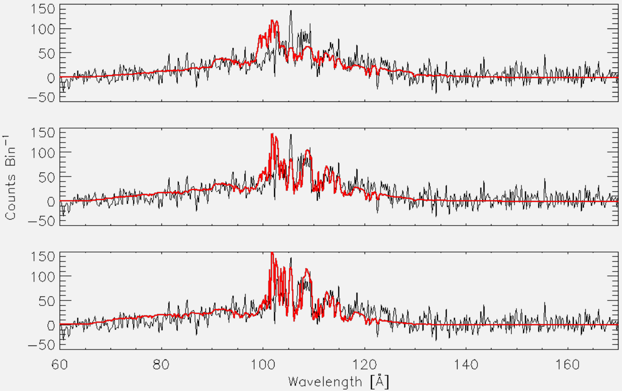
- $T_{\mathrm{eff}} = 57\,000 \pm 2\,000\,\mathrm{K}$, $\log g = 7.6 \pm 0.3$
- Metal abundances for C, O, Si, P, S, Fe, (Ni), and Ge

PG 1520+525

- $T_{\rm eff} \approx 100\,000\,$K, $\log g > 5.7$ (IUE) Wesemael et al. 1985
- $T_{\rm eff} = 140\,000\,$K, $\log g = 7.0$ (optical) Werner et al. 1991
- $T_{\rm eff} = 150\,000\,$K, $\log g = 7.5$ (HST) Dreizler & Heber 1998, $C/He = 0.3$, $O/He = 0.1$, $N/He < 10^{-4}$ (number ratio)

- Ne VII 973 Å (FUSE) Ne: 2% (mass fraction), Werner et al. 2004

PG 1520+525: He, C, O, Ne, Mg, $\log g = 7.5$



$T_{\mathrm{eff}} = 140\,000\,\mathrm{K}$

$T_{\mathrm{eff}} = 150\,000\,\mathrm{K}$

$T_{\mathrm{eff}} = 160\,000\,\mathrm{K}$

	PG 1159−035	PG 1520+525
$T_{\rm eff}$ [K]	$140\,000 \pm 5\,000$	$150\,000 \pm 5\,000$
$\log g$	7.0 ± 0.5	7.5 ± 0.5
He	0.33	0.43
C	0.48	0.38
O	0.17	0.17
Ne	0.02	0.02
Mg		$< 6 \cdot 10^{-3}$ (10 $\times$ solar)

Table: PG 1159–035: Jahn et al. (2007), PG 1520+525: Dreizler & Heber (1998)

PG 1520+525

- $T_{\rm eff}$ constrained to $150\,000 \pm 5\,000$ K, $\log g = 7.5$
- Element abundances confirmed, Mg estimated

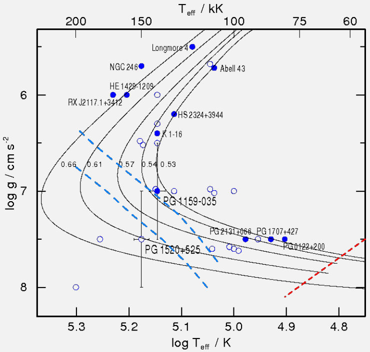


Figure: Post-AGB evolutionary tracks by Miller Bertolami & Althaus (2006). Red edge: Quirion et al. (2006), blue edge: Quirion (2009).

Summary

Chandra LETG spectra of three objects:

- LB 1919: metal poor DA white dwarf
  FUSE: abundances determined
  EUVE: stratified – homogeneous models
  Chandra: no Fe, Ni
- GD 246: DA white dwarf
  FUSE, Chandra: abundances, lines
  EUVE: stratified – homogeneous models
- PG 1520+525: non-pulsating PG 1159 star
  Chandra: temperature constrained