Optical Observations of White Dwarf Pulsar Companions

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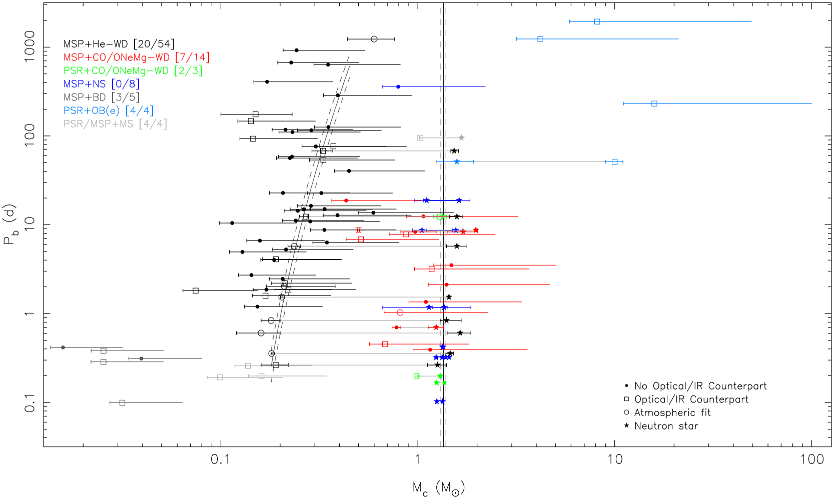
Pulsar binary companion zoo



Optical observations; what can we learn?

Photometry

Given a WD mass estimate (P_b-M_2, timing) and a WD cooling model

- T_{eff}
- d, τ_{wd}

Test suitability for spectroscopy ($V < 23$, $T_{\mathrm{eff}} > 5000\,\mathrm{K}$, $P_b < 20\,\mathrm{d}$)

Spectroscopy

Fit WD atmosphere model

- T_{eff}, $\log g$

Apply WD *M*-*R* relation

- R_{WD}, M_{WD}

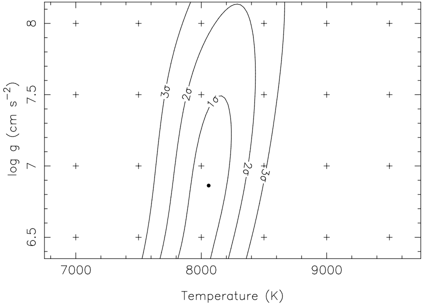
Compare with WD cooling model

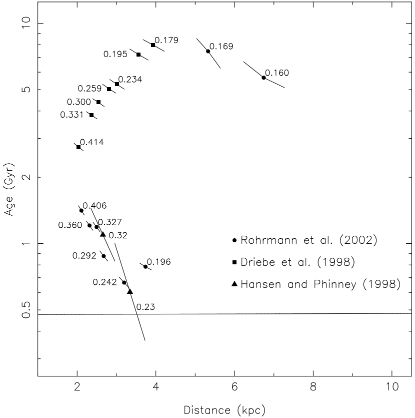
- d, τ_{wd}

Measure WD radial velocity curve

- K_{WD}, q+$M_{\mathrm{WD}} \rightarrow M_{\mathrm{psr}}$

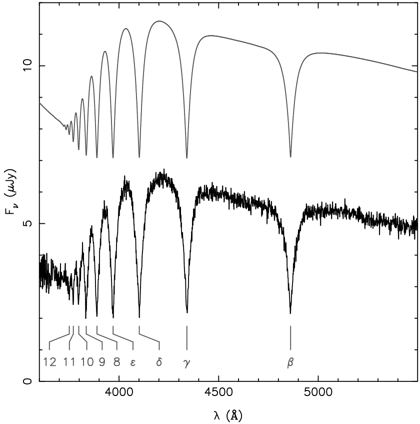
J0218+4232; $P_s = 2.3$ ms, $P_b = 2$ days

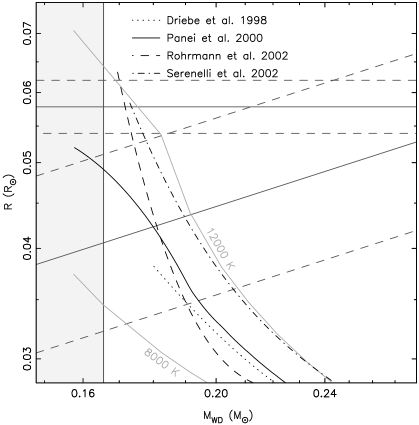




Results: $T_{\rm eff} = 8060$ K, $M_{\rm WD} = 0.21^{+0.11}_{-0.04}$ $M_\odot$, $d = 2.5$ to 4 kpc, $\tau_{\rm WD} < 1$ Gyr

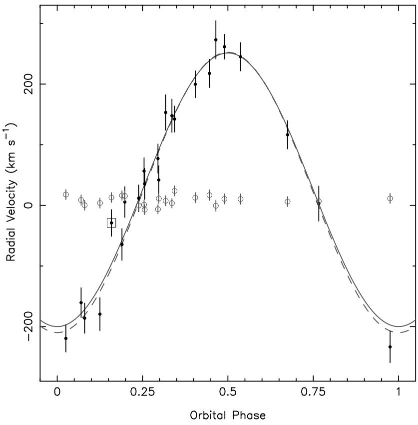
J1911−5958A; $P_s = 3.3$ ms, $P_b = 20$ h

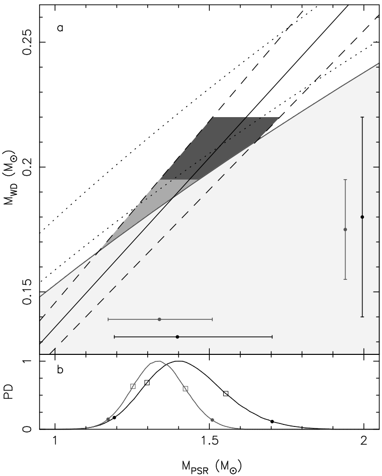




Results: $T_{\text{eff}} = 10090$ K, $\log g = 6.44$ cgs, $M_{\text{WD}} = 0.18 \pm 0.02\,M_\odot$, $d = 3.1$ kpc
Assuming $d = d_{\text{gc}}$; $M_{\text{WD}} = 0.175 \pm 0.010\,M_\odot$
WD radius marginally consistent with association with GC.

J1911–5958A; $P_s = 3.3$ ms, $P_b = 20$ h



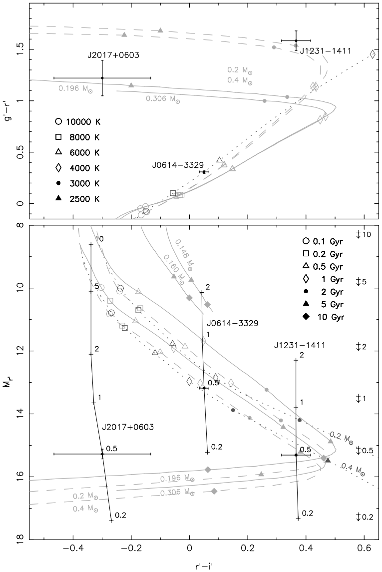


Radial velocity curve: $q = 7.36 \pm 0.25$, $M_{psr} = 1.40^{+0.16}_{-0.10}\,M_\odot$ or $1.34 \pm 0.08\,M_\odot$

PSR	P_b (d)	M_WD ($\mathrm{M}_\odot$)	τ_ch (Gyr)
J0613−0200	1.20	0.13–0.15	5.1
J1231−1411	1.86	0.19–0.22	2.6
J2017+0603	2.20	0.18–0.21	5.6
J0614−3329	53.6	0.28–0.33	2.8

Results:

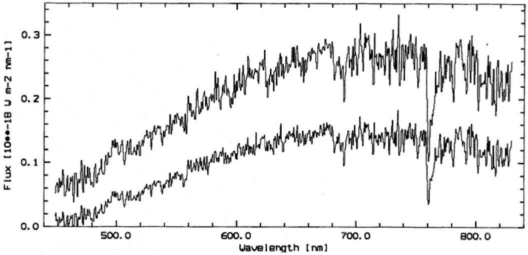
- J0614 much closer than DM distance.
- J1231 and J2017 much fainter, cooler and older. Must be nearby.
- J0613 not detected; given parallax distance, must be cold.



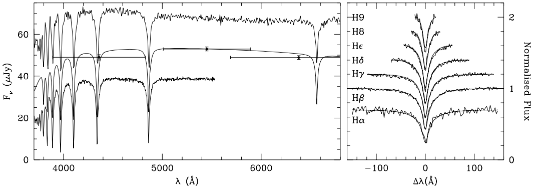
(Bassa et al. in prep)

Thank you for your attention!

Early observations; *dichotomy in cooling properties*



J0437−4715 (Danziger et al. 1993)



J1012+5307 (van Kerkwijk et al. 1996)

J0437−4715:

$P_\mathrm{b} = 5.74\,\mathrm{d}$,
$M_\mathrm{WD} = 0.25 \pm 0.01\,\mathrm{M}_\odot$,
$T_\mathrm{eff} = 3950 \pm 150\,\mathrm{K}$,
$\log g = 6.98 \pm 0.15$ cgs,
$\tau_\mathrm{ch} \sim 5\,\mathrm{Gyr}$

J1012+5307:

$P_\mathrm{b} = 0.60\,\mathrm{d}$,
$M_\mathrm{WD} = 0.16 \pm 0.02\,\mathrm{M}_\odot$,
$T_\mathrm{eff} = 8550 \pm 25\,\mathrm{K}$,
$\log g = 6.34 \pm 0.20$ cgs,
$\tau_\mathrm{ch} \sim 9\,\mathrm{Gyr}$

J1012 older but hotter?

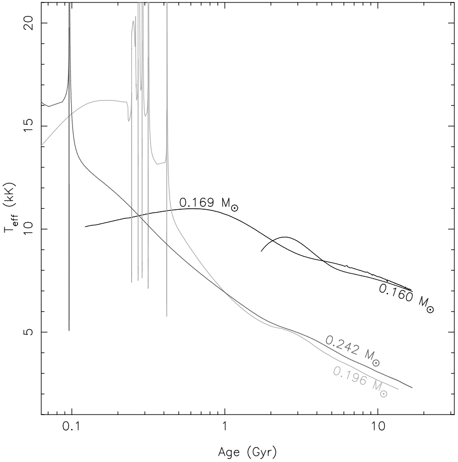
White dwarf cooling: in theory

Hydrogen envelopes

WDs born with thick hydrogen envelope (upto 3% M_{wd}), residual hydrogen burning in the envelope keeps the WD warm.

However, above a certain mass (about 0.2 $M_\odot$), hydrogen shell flashes reduce envelope mass and allow faster cooling.

Thick envelopes cool slow, thin envelopes cool fast



(Alberts et al. 1996, Driebe et al. 1998, Althaus et al. 2001)

White dwarf cooling; in practice

PSR	P_b (d)	M_{WD} ($M_\odot$)	T_{eff} (K)	τ_{ch} (Gyr)	T_{eff} measurement
J0751+1807	0.26	0.19 ± 0.03	4000	7.1	Bassa ea 06
J1738+0333	0.35	0.18 ± 0.01	9130	4.1	Antoniadis ea, in prep.
J1012+5307	0.60	0.16 ± 0.02	8550	8.6	van Kerkwijk ea 96, 05
J1911−5958A	0.83	0.18 ± 0.02	10900	17	Bassa ea 06
J1909−3744	1.53	0.204 ± 0.003	8700	3.3	van Kerkwijk ea, in prep.
J0218+4232	2.03	$0.21^{+0.11}_{-0.04}$	8060	0.5	Bassa ea 03
J0437−4715	5.74	0.25 ± 0.01	3950	6.7	Durant ea 12
B1855+09	12.3	0.27 ± 0.01	4800	4.8	van Kerkwijk ea 00
J1713+0747	67.8	0.33 ± 0.04	3700	8.5	Lundgren ea 96

van Kerkwijk et al. (2005) argued thick envelopes for J1012, J1738, J1909 ($P_b < 1.6$ d). But J0751 very faint and cool (Bassa et al. 2006). Lost envelope due to irradiation?

White dwarf cooling; in practice