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The Initial–Final Mass Relationship of White Dwarfs in Common Proper Motion Pairs

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Abstract. A promising approach to decrease the uncertainties in the initial–final mass relationship, which is still poorly constrained, is to study white dwarfs for which external constraints are available, for instance, white dwarfs in common proper motion pairs (CPMPs). Important information of the white dwarf can be inferred from the study of the companion, since they were born at the same time and with the same initial chemical composition. In this contribution, we report new results obtained from spectroscopic observations of both members of several CPMPs composed of a F, G or K type star and a DA white dwarf.

1. Observations and Analysis

A preliminary list of targets was selected from the literature (Wegner & Reid 1991; Silvestri et al. 2001) and is composed of 11 common proper motion pairs (CPMPs), composed of a DA white dwarf and a FGK star. The observations were carried out using a suite of telescope/instrument configurations. The white dwarf members were observed with the LCS spectrograph on the HJS (2.7 m) telescope at McDonald Observatory (Texas) and also with the TWIN spectrograph on the 3.5 m telescope at Calar Alto Observatory (CAHA, Almeria, Spain), obtaining a FWHM resolving power of $\sim 4-5$ Å. The FGK companions were observed with the FOCES echelle spectrograph on the 2.2 m telescope at CAHA and with the SARG echelle spectrograph at the TNG telescope in La Palma (Canary Islands, Spain) with resolutions of $R \sim 47000$ and $R \sim 57000$, respectively. These spectroscopic observations have revealed that only 5 of the 11 white dwarf components were in fact of the DA type, whereas the rest of the candidates were misclassified.

In principle, the total age of each system can be obtained from the analysis of the FGK star member as follows: first, we derived the effective temperature, T_{eff}, using the available $VJHK$ photometry and following the method of

Table 1. Stellar parameters derived for the observed FGK stars

Name	$T_{\rm eff}$ (K)	Z	$\log(L/L_\odot)$	Age (Gyr)
G158−77[1]	4387 ± 27	–	–	–
BD+44°1847	5627 ± 49	0.011 ± 0.003	-0.188 ± 0.059	–[2]
BD+23°2539[1]	5666 ± 48	–	–	–
BD+34°2473	6268 ± 68	0.030 ± 0.008	0.369 ± 0.109	2.1 ± 1.5
BD−8°5980	5669 ± 52	0.012 ± 0.004	-0.151 ± 0.040	–[2]

[1] More observations are needed to complete the analysis of these stars.

[2] Isochrone fits do not provide reliable ages. Other indicators are being considered.

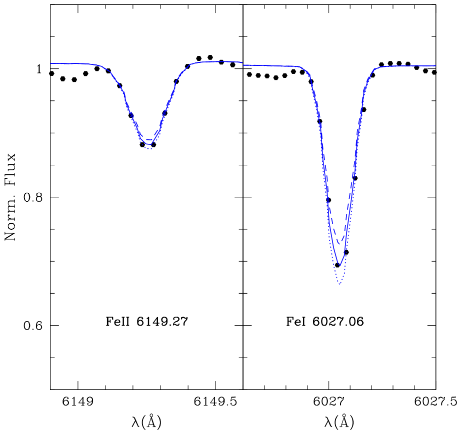

Figure 1. Fits of the observed spectra for the companion of WD 0913+442. The solid line is the fit corresponding to the derived Z and the dotted and dashed lines are spectra computed for $+3\sigma$ and -3σ from the average.

Masana, Jordi, & Ribas (2006) — see Table 1. Then, we fitted the observed spectra considering $T_{\rm eff}$ and assuming a value for $\log g$ using the SYNSPEC program and Kurucz atmospheres to derive the metallicity, Z (Fig. 1). We focused on those spectral windows where unblended lines of FeI, FeII and NiI are present: $5800-5900$ Å, $6000-6150$ Å and $6750-6850$ Å for Fe and $6100-6200$ Å and $7700-7800$ Å for Ni. When we know the distance and the apparent magnitude of the star the calculation of the luminosity, L, is straightforward. Finally, using the stellar models of Schaller et al. (1992) we performed an interpolation considering $T_{\rm eff}$, Z and L to obtain the ages of these stars, that is, the total ages of the white dwarfs in the CPMPs. The value of $\log g$ was adjusted iteratively for self–consistency. We have found that some of the observed stars are fairly unevolved and so, the use of isochrones to derive their ages with accuracy is not the best option. In these cases we are currently studying other age indicators such as chromospheric activity or X-ray luminosity.

In Table 2, we list the atmospheric parameters derived from the fitting of the theoretical models of D. Koester to the Balmer lines using the package SPECFIT of IRAF, and following the procedure described in Bergeron, Wesemael, & Fontaine (1992) — see Fig. 2. This package is based on χ^2 minimization using the method of Levenberg–Marquardt (Press et al. 1992). Once we have $T_{\rm eff}$

Table 2. Stellar parameters derived for the observed white dwarfs

WD name	$T_{\rm eff}$ (K)	$\log g$ (dex)	$M_{\rm f}$ ($M_\odot$)	$t_{\rm cool}$ (Gyr)	$t_{\rm ms}$ (Gyr)	$M_{\rm i}$ ($M_\odot$)
0023+109	10377 ± 230	7.92 ± 0.08	0.56 ± 0.03	0.49 ± 0.08	–	–
0913+442	8918 ± 111	8.29 ± 0.02	0.78 ± 0.01	1.72 ± 0.06	–	–
1304+227	10798 ± 120	8.21 ± 0.05	0.73 ± 0.13	0.73 ± 0.06	–	–
1354+340	13650 ± 437	7.80 ± 0.15	0.49 ± 0.10	0.14 ± 0.02	2.03 ± 1.57	$1.62^{+1.00}_{-0.30}$
2253−081	7200 ± 170	8.40 ± 0.08	0.87 ± 0.03	3.75 ± 0.19	–	–

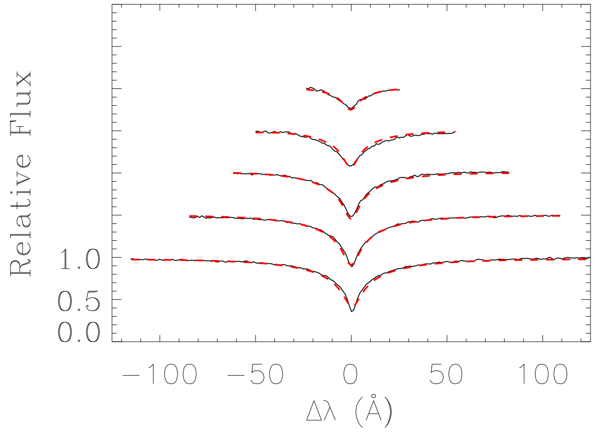

Figure 2. Fits of the observed Balmer lines for the case of WD 0913+442. Lines range from Hβ (bottom) to H8 (top).

and $\log g$ of each star, we derive its mass, $M_{\rm f}$, and cooling time, $t_{\rm cool}$, using the cooling sequences of Salaris et al. (2000). Since we already know the total age of the white dwarf (from the companion), we obtain the main–sequence lifetime of the white dwarf progenitor, $t_{\rm ms}$, by subtracting its cooling time from the total age, if this value is available. Finally, using the stellar models of Domínguez et al. (1999) we compute the mass of the progenitor in the main sequence, $M_{\rm i}$.

2. The Initial–Final Mass Relationship

In Fig. 3 we show the final mass versus the initial mass of the white dwarf in a CPMP for which the analysis has been completed. Also plotted are the results for the white dwarfs in the open clusters M 35 (Williams, Bolte, & Koester 2004) and M 37 (Kalirai et al. 2005). We used the atmospheric parameters reported by these authors and then, for the sake of internal consistency, we followed the same procedure as for the white dwarfs in our list. The main drawback of using CPMPs is the uncertainty in the determination of the age of the companion, which can be minimized by selecting evolved stars. However, the fact that these systems are potentially more abundant and closer to us makes them promising targets, since a better spectroscopic study of both members of the CPMPs can be done. White dwarfs in CPMPs also allow a wide age coverage. This is not the case for open clusters, which are younger and do not contribute to the low–mass range of the initial–final mass relationship. A first inspection of Fig. 3 reveals as

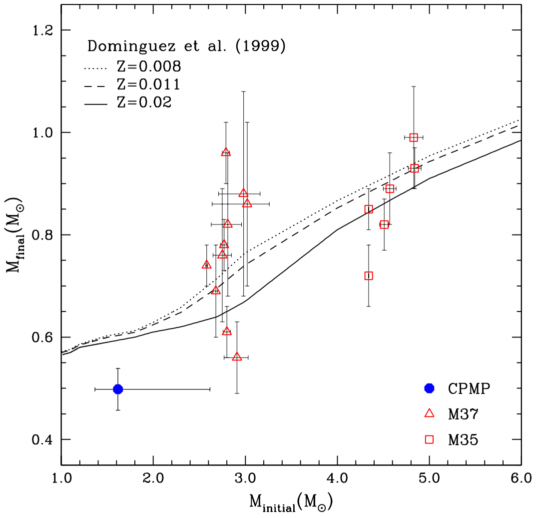

Figure 3. $M_{\rm f}$ versus $M_{\rm i}$ obtained for a white dwarf in a CPMP (circles) and for white dwarfs in the open clusters M 35 (squares) and M 37 (triangles)

well a large scatter in the distribution, which let us think that, maybe, the initial–final mass relationship is not a single–valued function. More observational data and improved theoretical stellar models (mainly in the AGB phase) will help to better establish this function. In this sense, to further extend the sample, a cross–correlation of the SIMBAD database and the Villanova White Dwarf Catalog has provided us with more pairs, which we expect to study shortly.

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