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The mass function of hydrogen-rich white dwarfs: robust observational evidence for a distinctive high-mass excess near 1 $M_{\odot}$

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ABSTRACT

The mass function of hydrogen-rich atmosphere white dwarfs has been frequently found to reveal a distinctive high-mass excess near 1 $M_{\odot}$. However, a significant excess of massive white dwarfs has not been detected in the mass function of the largest white dwarf catalogue to date from the Sloan Digital Sky Survey (SDSS). Hence, whether a high-mass excess exists or not has remained an open question. In this work, we build the mass function of the latest catalogue of data release ten SDSS hydrogen-rich white dwarfs, including the cool and faint population (i.e. effective temperatures $6000 \lesssim T_{\rm eff} \lesssim 12\,000$ K, equivalent to $12\ {\rm mag} \lesssim M_{\rm bol} \lesssim 13$ mag). We show that the high-mass excess is clearly present in our mass function, and that it disappears only if the hottest (brightest) white dwarfs (those with $T_{\rm eff} \gtrsim 12\,000$ K, $M_{\rm bol} \lesssim 12$ mag) are considered. This naturally explains why previous SDSS mass functions failed at detecting a significant excess of high-mass white dwarfs. Thus, our results provide additional and robust observational evidence for the existence of a distinctive high-mass excess near 1 $M_{\odot}$. We investigate possible origins of this feature and argue that the most plausible scenario that may lead to an observed excess of massive white dwarfs is the merger of the degenerate core of a giant star with a main-sequence or a white dwarf companion during or shortly after a common envelope event.

Key words: stars: luminosity function, mass function – white dwarfs.

1 INTRODUCTION

White dwarfs (WDs) are the typical end products of most main-sequence stars (see Althaus et al. 2010 and references therein). WDs are therefore the most numerous stellar remnants in the Galaxy. The mass distribution and mass function (MF) of hydrogen-rich (DA) WDs have been intensively studied during the last decades. These studies reveal a clear and predominant concentration of objects at ∼0.6 $M_{\odot}$ (e.g. Koester, Schulz & Weidemann 1979; Holberg et al. 2008; Kepler 2013; Kepler et al. 2015). A low-mass peak at ∼0.4 $M_{\odot}$ has been also frequently found (Liebert, Bergeron & Holberg 2005; Kepler et al. 2007; Kleinman et al. 2013). This feature is believed to arise as a simple consequence of binary star evolution. In this scenario, mass-transfer episodes truncate the evolution of the red giant exposing its low-mass core, which later becomes a (typically He-core) WD. Strong observational evidence in favour of this hypothesis has been provided during the last few years (Marsh, Dhillon & Duck 1995; Rebassa-Mansergas et al. 2011; Kilic et al. 2012), although some few low-mass WDs have been observed that exhibit neither radial velocity variations, nor infrared flux excess, the typical hallmarks of WDs with close companions (Maxted, Marsh & Moran 2000; Napiwotzki et al. 2007; Kilic, Brown & McLeod 2010).

Recent observational studies suggest also the existence of an excess of massive WDs near 1 $M_{\odot}$ (Liebert et al. 2005; Giammichele, Bergeron & Dufour 2012; Rebassa-Mansergas et al. 2015). This feature is generally interpreted as the result of WD+WD binary mergers. This, in turn, may indicate that the merger rate in the Galaxy is considerably larger than expected. Such a high merger rate may have strong implications in the production of Type Ia supernovae via the double-degenerate channel (Webbink 1984; Di Stefano 2010; Ji et al. 2013). It is also important to keep in mind, however, that the WD MF that results from analysing the so far largest spectroscopic

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sample of WDs from the Sloan Digital Sky Survey (SDSS; SDSS-III Collaboration et al. 2012) displays no evidence for a distinctive concentration of systems at those specific high-mass bins (Hu, Wu & Wu 2007; Kepler et al. 2007; De Gennaro et al. 2008). Whether or not, an excess of massive WDs exists is then a controversial issue.

In this work, we derive the MF of WDs from the latest spectroscopic catalogue of SDSS data release (DR) 10 (Kepler et al. 2015) and show that a clear excess near $\sim$1 $\mathrm{M}_{\odot}$ can only be seen if WDs of bolometric magnitude fainter than $\sim$12 mag are considered. We interpret this result as a robust observational evidence for the existence of an excess of massive WDs in the Galaxy. We also discuss possible origins leading to this feature.

2 SDSS DR 10 WDS

In this section, we introduce the DA WD sample studied in this work and provide details on the space density and mass determinations that lead us to derive the MF.

2.1 Masses

Our sample of study is the latest version of the SDSS WD spectroscopic catalogue (Kepler et al. 2015), which currently contains about 30 000 objects. Given that we are interested in analysing the MF of DA WDs, we select only those of this subtype. For these, effective temperatures and surface gravities have been provided by the subsequent SDSS WD catalogues during the last ten years (Kleinman et al. 2004, 2013; Eisenstein et al. 2006; Girven et al. 2011; Kepler et al. 2015). These have been obtained fitting the Balmer lines sampled by the SDSS spectra with model atmosphere spectra (e.g. Koester 2010). Given that each SDSS DR yields recalibrated spectra respect to previous releases, each of the aforementioned SDSS WD catalogues provides updated values of effective temperatures and surface gravities obtained by re-analysing the SDSS recalibrated spectra. In this work we adopt the most updated (and therefore, more accurate) available values.

It is important to emphasize that fitting the Balmer lines with model atmosphere models results in overestimated surface gravity values for DA WDs cooler than $\sim$13 000 K (Koester et al. 2009), a problem related to the 1D treatment of convective energy transport within the framework of the mixing-length theory (Tremblay et al. 2011). However, 3D model corrections are now available, which can be applied to correct for this problem (Tremblay et al. 2013). We hence applied these corrections to all cool WDs and thus, rederived reliable effective temperatures and surface gravities.

Finally, using the cooling tracks of Renedo et al. (2010), we obtained the masses, the bolometric magnitudes and the SDSS u, g, r, i, z absolute magnitudes of all our DA WDs from the temperatures and surface gravities measured observationally. Distances were calculated from the distance moduli, taking into account the apparent SDSS u, g, r, i, z magnitudes. For the sake of comparison, we repeated this exercise using the updated cooling models of Bergeron, Wesemael & Beauchamp (1995).[1] We found no substantial difference between the masses, bolometric magnitudes and distances derived from the two cooling sequences considered. Extinction corrections were also found to be negligible.

2.2 Space densities

The $1/V_{\mathrm{max}}$ method (Schmidt 1968; Green 1980) is a widely used technique to derive the space densities of WDs (see e.g. Liebert et al. 2005; Harris et al. 2006; Hu et al. 2007; De Gennaro et al. 2008; Rebassa-Mansergas et al. 2015). Geijo et al. (2006) demonstrated that the $1/V_{\mathrm{max}}$ method not only is a good estimator of the WD space densities but also that it provides a reliable characterization of the WD luminosity function (LF). In this paper, we also adopt the $1/V_{\mathrm{max}}$ method to derive the space density of DA WDs in the SDSS. That is, we calculated the maximum volume V_{WD} in which each of our WDs would have been detected given the magnitude limits of the SDSS survey (Rebassa-Mansergas et al. 2015):

$$\begin{aligned} V_{\mathrm{WD}} = V_{\mathrm{max}} - V_{\mathrm{min}} &= \sum_{i=1}^{n_{\mathrm{plate}}} \frac{\omega_i}{4\pi} \int_{\mathrm{d_{min}}}^{\mathrm{d_{max}}} \mathrm{e}^{-z/z_0}\, 4\pi r^2 \mathrm{d}r \\ &= -\sum_{i=1}^{n_{\mathrm{plate}}} \frac{z_0 \times \omega_i}{|\sin b|} \left[\left(r^2 + \frac{2z_0}{|\sin b|} r + \frac{2z_0^2}{|\sin b|^2} \right) \mathrm{e}^{-\frac{r|\sin b|}{z_0}} \right]_{\mathrm{d_{min}}}^{\mathrm{d_{max}}} \end{aligned} \tag{1}$$

where b is the Galactic latitude of the considered WD, and ω_i is the solid angle in steradians covered by each SDSS plate.[2] The factor e^{-z/z_0} takes into account the non-uniform distribution of stars in the direction perpendicular to the Galactic disc, where $z = r \times \sin(b)$ is the distance of the WD from the Galactic plane and z_0 is the scaleheight, which is assumed to be 250 pc (Liebert et al. 2005; Hu et al. 2007). We considered the lower and upper g magnitude limits of each SDSS plate, which define the minimum and maximum volumes, V_{min} and V_{max} (where $V_{\mathrm{WD}} = V_{\mathrm{max}} - V_{\mathrm{min}}$). These magnitude limits corresponded to the minimum and maximum g magnitudes among all spectroscopic sources observed by each plate (Rebassa-Mansergas et al. 2015). However, as we show below, our sample is restricted to WDs of $g \leq 19$ mag. Hence, all the upper magnitude limits above this value were set to $g = 19$ mag. Moreover, in the cases where two or more plates observed the same region of sky, we considered the overlapping region with the largest volume.

It has to be noted however that the overall spectroscopic completeness of SDSS WDs is $\sim$40 per cent, and that it is found to vary significantly in colour space (Gentile Fusillo, Gänsicke & Greiss 2015). Therefore, a spectroscopic completeness correction needs to be taken into account in our space-density determinations (e.g. De Gennaro et al. 2008). We did this as follows. Gentile Fusillo et al. (2015) provide a list of 23 696 photometric sources with available proper motions and $g \leq 19$ mag from the full DR 10 footprint with a high-confidence probability for being a WD, of which 5857 have available SDSS spectra. For each of the 5857 WDs in the spectroscopic list, we obtained their $u-g$, $g-r$, $r-i$ and $i-z$ colours, and defined a 4D (one dimension per colour) sphere of 0.05 colour radius around each of them (see Camacho et al. 2014 for further details). Within each sphere, we obtained the number of photometric (N_{photWD}) and spectroscopic (N_{specWD}) WDs among the 23 696 and 5857 lists, respectively, and calculated the spectroscopic completeness as $C = N_{\mathrm{specWD}}/N_{\mathrm{photWD}}$. The space density of each WD, $1/V_{\mathrm{WD}}$, was then corrected by the spectroscopic completeness via $1/V_{\mathrm{WD}} \times 1/C$.

Of course, the above exercise limited our sample of study to 5857 DA WDs, namely those with available probabilities for being a WD

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[1] http://www.astro.umontreal.ca/~bergeron/CoolingModels/

[2] Each SDSS plate covers an area of the sky of $\sim$7 deg^2. Since the number of SDSS DR 10 plates is 4171, the total area is approximately $\sim$29 000 deg^2, without taking into account the overlapping areas.

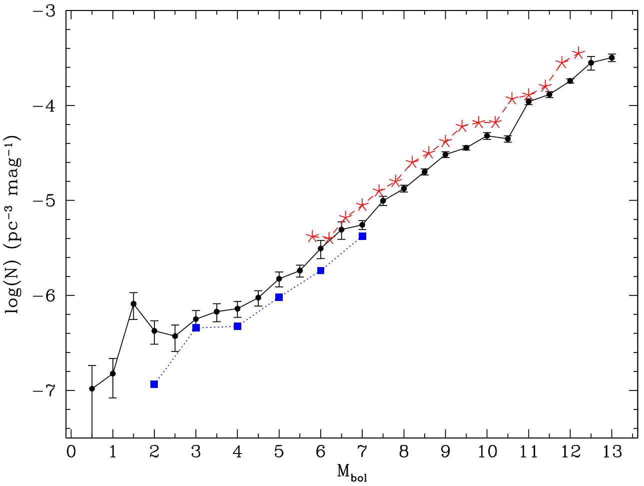

Figure 1. DA WD LF derived in this work (black solid dots). For comparison, we also show the SDSS LFs of De Gennaro et al. (2008, red stars) and Torres et al. (2014, blue squares).

Table 1. The values of the LF shown in Fig. 1 per $M_{\rm bol}$ bin. The units are pc^{-3} mag^{-1}.

$M_{\rm bol}$	log (N)	$M_{\rm bol}$	log (N)	$M_{\rm bol}$	log (N)	$M_{\rm bol}$	log (N)
0.5	−6.98	4.0	−6.14	7.5	−5.00	10.5	−4.35
1.0	−6.82	4.5	−6.02	8.0	−4.87	11.0	−3.96
1.5	−6.09	5.0	−5.82	8.5	−4.70	11.5	−3.88
2.0	−6.37	5.5	−5.74	9.0	−4.52	12.0	−3.74
2.5	−6.43	6.0	−5.51	9.5	−4.45	12.5	−3.55
3.0	−6.25	6.5	−5.31	10.0	−4.32	13.0	−3.50
3.5	−6.17	7.0	−5.26	–	–	–	–

based on their photometric colours and proper motions, as well as with available values of effective temperatures and surface gravities obtained fitting their SDSS spectra. This excluded, for example, all confirmed spectroscopic WDs with $g > 19$ mag. Therefore, the possibility exists that our considered sample cannot be taken as complete (this completeness is not the spectroscopic completeness above discussed). A fairly standard way to check this is to compute the average value $\langle V - V_{\rm min}\rangle/\langle V_{\rm max} - V_{\rm min}\rangle$ (where V is the volume of the WD), which should be ∼0.5 if the sample is complete (Green 1980). In our case the sample of DA WDs with spectroscopic determinations resulted in an average value of 0.48. We can therefore consider this sample as reasonably complete.

Our selected DA WD sample has a mean mass of 0.59 ± 0.12 M$_{\odot}$, in agreement with those found in previous SDSS studies (e.g. Kepler et al. 2007; De Gennaro et al. 2008). The signal-to-noise ratio of the SDSS spectra is >10 in 95 per cent of the cases, which leads to average uncertainties in the effective temperature and mass determinations of ∼300 K and ∼0.03 M$_{\odot}$, respectively. The mass uncertainties are below 0.1 M$_{\odot}$ in 99.5 per cent of the cases.

The WD LF obtained from our selected sample is shown in Fig. 1 (see also Table 1), where the uncertainties are calculated following Boyle (1989). Inspection of this figure reveals that our LF covers a wide range of $M_{\rm bol}$ bins, reaching values as large as 0.5 mag. However, we note that the shape of the LF should be taken with some caution for $M_{\rm bol} \leq 2.5$ due to the increasing uncertainties. For comparative purposes, in Fig. 1, the SDSS WD LFs of De Gennaro et al. (2008) and Torres et al. (2014) are also displayed. It is clear that the three works yield LFs of very similar shapes, although the absolute levels are somewhat different. This is most likely a consequence of the slightly different completenesses of the three samples. In particular, samples that are more complete result in larger space densities. The similarity between the three LFs indicates that (1) our spectroscopic completeness and $1/V_{\rm max}$ corrections are properly done; and that (2) our sample is indeed reasonably complete (at least within the context of the magnitude limits of SDSS, i.e. it does not account for populations of WDs that are too faint ($M_{\rm bol}$ > 13 mag) to be included in the observed sample).

3 THE DA WD MASS FUNCTION

The MF of our sample of 5857 DA WDs is illustrated in Fig. 2. It displays a predominant peak at ∼0.6 M$_{\odot}$, a classical feature that has been previously identified in numerous studies (e.g. Koester et al. 1979; Kepler et al. 2007; De Gennaro et al. 2008; Holberg et al. 2008). Our MF reveals also the existence of low-mass WDs ($M_{\rm wd}$< 0.55 M$_{\odot}$) that are thought to arise as a consequence of mass transfer in binaries (Marsh et al. 1995; Rebassa-Mansergas et al. 2011). Low-mass WDs have been also frequently identified in previous MFs (e.g. Liebert et al. 2005; Kepler et al. 2007). Finally, a distinctive high-mass excess can be seen in the ∼0.8–1 M$_{\odot}$ mass interval of our MF. This feature has been found not only in MFs derived from magnitude-limited samples of DA WDs (Liebert et al. 2005; Rebassa-Mansergas et al. 2015), but also in the mass distribution of local (and therefore volume-limited sample of) DA WDs (Giammichele et al. 2012). However, it has to be emphasized that previous MFs obtained from earlier releases of the SDSS DA WD catalogue do not display a significant excess of massive WDs at those specific mass bins (Hu et al. 2007; Kepler et al. 2007; De Gennaro et al. 2008). We investigate this discrepancy in what follows.

The main difference between the analysis presented here and those of Kepler et al. (2007), Hu et al. (2007) and De Gennaro et al. (2008) is that, unlike us, they only considered DA WDs with $T_{\rm eff}\gtrsim$12 000–13 000 K (i.e. WDs of $M_{\rm bol} \lesssim$12). The reason for this is simply because 3D model atmosphere corrections for such cool WDs (Tremblay et al. 2013) were not available at that time. It is therefore possible that massive DA WDs were systematically

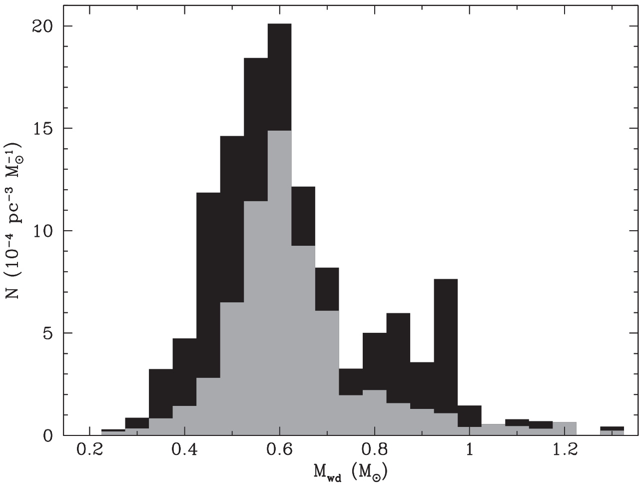

Figure 2. MF of DA WDs derived in this work (black for WDs of $M_{\rm bol} \leq 13$, grey for WDs of $M_{\rm bol} \leq 12$). The high-mass excess near 1 M$_{\odot}$ disappears when considering DA WDs with $M_{\rm bol} \leq 12$.

Table 2. Fraction of DA WDs fainter than $M_{\rm bol} = 12$ mag as a function of mass.

Mass ($M_\odot$)	0.55–0.65	0.65–0.75	0.75–0.85	0.85–0.95	0.95–1.05	>1.05
Fraction	0.06	0.07	0.18	0.16	0.21	0.15

excluded as a consequence of only considering WDs of $M_{\rm bol}$ brighter than ∼12 mag. Indeed, and as can be seen in Fig. 2, the excess of massive WDs disappears if we apply this cut to our sample.

It is well known that massive WDs ($\gtrsim$0.8 $M_\odot$) cool down considerably slower than typical WDs of ∼0.6 $M_\odot$ (Althaus et al. 2005, 2007). However, the main-sequence progenitor lifetimes (for solar metallicities) are much shorter for the precursors of massive WDs – see e.g. Pietrinferni et al. (2004). This implies that, roughly speaking, for decreasing luminosities, the fraction of massive WDs becomes increasingly larger, simply because these WDs have had more time to cool down than regular ones. However, we note that the validity of this assessment depends on the specific star formation history of the Galactic disc, as well as on possible metallicity effects on the initial-to-final mass relation and on the WD cooling (e.g. Althaus et al. 2015; Romero, Campos & Kepler 2015). Hence, we checked if the fraction of massive WDs in our sample increases considerably for increasing bolometric magnitudes, and we found that this is indeed the case (see Table 2). This naturally explains why the fraction of massive WDs excluded in previous analyses of the SDSS sample is larger when the $M_{\rm bol} \leq 12$ mag magnitude cut is applied to the observed sample.

In the following section, we argue the most plausible explanation for the existence of an overabundance of massive WDs may be the merger of the degenerate core of a giant star with its companion (either a main-sequence star or a WD) during or shortly after a common envelope event. Hence, we expect a large fraction of our observed massive WDs to be the result of such mergers. In such cases, the lifetime of the binary system before the merger takes place should be of the same order of the progenitor lifetimes of single massive WDs, otherwise WDs that result from such mergers would not have had enough time to cool down and would therefore not be excluded when applying the $M_{\rm bol} \leq 12$ mag cut. The timescale for a merger event during common envelope can be as short as ∼0.15 Gyr (Briggs et al. 2015), which is considerably faster than e.g. the 0.25 Gyr needed for the progenitor of a 0.8 $M_\odot$ WD to become a WD (Pietrinferni et al. 2004). Thus, concluding that a $M_{\rm bol} \leq 12$ cut equally excludes massive WDs that evolved as single stars and massive WDs that may arise as a result of mergers seems to be a reasonable assumption.

4 ON THE POSSIBLE ORIGIN OF THE HIGH-MASS EXCESS

In the previous section, we provided further and robust observational evidence for the existence of an excess of massive DA WDs near 1 $M_\odot$. In this section, we briefly discuss the possible origins of this feature.

(i) The first possible explanation is that a large number of massive DA WDs are formed by single-star evolution. For instance, Ferrario et al. (2005) proposed a specific shape for the initial-to-final mass relationship that accounts for ∼28 per cent of all single WDs having masses in excess of ∼0.8 $M_\odot$. However, detailed numerical simulations have recently shown that such an initial-to-final mass relationship cannot account for the existence of all massive WDs (Rebassa-Mansergas et al. 2015).

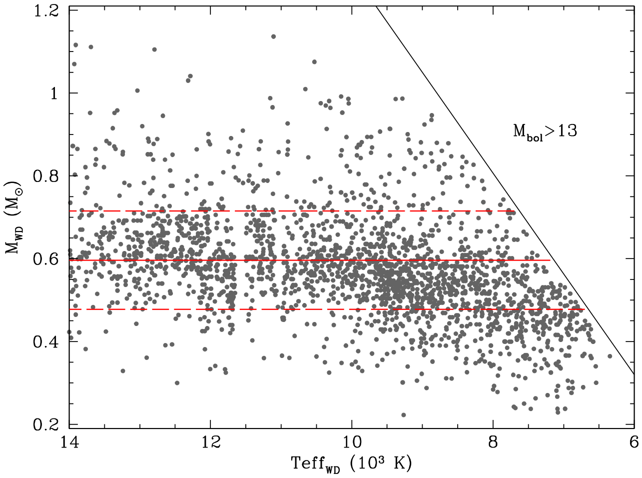

Figure 3. DA WD mass as a function of effective temperature. The red solid line indicates the average mass $\langle M_{\rm wd}\rangle$ of the sample, the red dashed lines indicate $\langle M_{\rm wd}\rangle \pm \sigma$. The area delimited by the solid black line is for $M_{\rm bol} > 13$ mag and it is empty due to our cut in the LF (see Fig. 1).

(ii) A recent burst in the star formation history of the Galactic disc may contribute to increase the fraction of observed massive WDs. Indeed, Rowell (2013) suggested that the star formation rate (SFR) has two broad peaks at around 2 and 7 Gyr ago. This could increase the number of massive WDs during the last 2 Gyr given their shorter main-sequence lifetimes. However, Rebassa-Mansergas et al. (2015) also demonstrated that such an SFR cannot explain the observed overabundance of massive WDs.

(iii) A third explanation for the existence of a large fraction of massive WDs could be that the $1/V_{\rm max}$ method somehow overestimates the space density of massive WDs. Since such WDs cannot be seen out to large distances, they are assigned a large weight by the $1/V_{\rm max}$ method, hence largely contributing to the space density and MF. However, the volume-limited sample of DA WDs, which does not require the $1/V_{\rm max}$ correction, displays also a clear excess of massive WDs near 1 $M_\odot$.

(iv) The stellar parameters derived from the spectra of cool WDs required 3D corrections (Tremblay et al. 2013). If these corrections are somehow inaccurate, then we would expect a clear dependence of the mass on the effective temperature. We find that this is not the case in our sample (see Fig. 3). We can safely conclude then that 3D corrections are not responsible for the observed overabundance of massive WDs.

(v) The typical SDSS exposure times are 30–90 min, depending on the considered plate. This implies that massive WDs observed by SDSS may be associated with intrinsically lower signal-to-noise ratio spectra, as these WDs are smaller and therefore less luminous. Hence, the mass uncertainties might be systematically higher for massive WDs. The mass uncertainties of our considered sample are below 0.1 $M_\odot$ in 99.5 per cent of the cases. We thus rederived the MF excluding all WDs with errors above 0.03 $M_\odot$ and found that the MF that results from this exercise does not differ significantly from the one obtained using the full sample. Therefore, the mass uncertainties are unlikely to be at the root of the observed excess of massive WDs.

(vi) The merger of two WDs is currently the most widely accepted explanation for the existence of an excess of massive WDs (Marsh et al. 1997; Vennes 1999; Liebert et al. 2005; Giammichele et al. 2012; Rebassa-Mansergas et al. 2015). If that is the case, then a large fraction of all massive WDs is expected to be magnetic (García-Berro et al. 2012; Ji et al. 2013). Population synthesis studies however do not predict more than ∼10 per cent of the entire WD population being the result of WD+WD binary mergers (e.g. Han, Podsiadlowski & Eggleton 1994; Han 1998; García-Berro et al. 2012; Toonen, Nelemans & Portegies Zwart 2012). Although these simulations generally assume a constant SFR, the results are not expected to change considerably when assuming e.g. a bimodal SFR such as the one suggested by Rowell (2013). Therefore, if the high-mass excess arises as a consequence of WD+WD mergers, then the merger rate in the Galaxy should be much higher than currently expected. This has strong implications for the production of Type Ia supernovae within the double degenerate scenario (Di Stefano 2010). For that to be the case, the merger of the two WDs must exceed the Chandrasekhar mass limit of $\sim$1.4 $\mathrm{M}_{\odot}$, which seems to be unlikely based on our (and also previously published) MF, as it does not reveal a significant excess of WDs more massive than 1 $\mathrm{M}_{\odot}$. However, it is important to mention that WDs of mass $\gtrsim$ 1 $\mathrm{M}_{\odot}$ and effective temperatures below 10 000 K are associated with $M_{\mathrm{bol}} \gtrsim 13$ mag (Renedo et al. 2010), hence these massive WDs are underrepresented in our sample (see Fig. 1).

(vii) An additional explanation leading to the formation of high-mass ($\gtrsim$0.8 $\mathrm{M}_{\odot}$) WDs is the merger of the degenerate core of a giant or asymptotic giant branch star with a WD companion after a common envelope event (Kashi & Soker 2011). In this scenario a circumbinary disc is formed around the two stars from material that remains bound after the common envelope phase. The interaction of the circumbinary disc with the binary system reduces the orbital separation and results in the merger of the (still hot) core of the giant and the WD companion. Whilst this so-called core-degenerate scenario is proposed as a viable channel for Type Ia supernovae (Ilkov & Soker 2012, 2013; Soker et al. 2013; Soker, García-Berro & Althaus 2014; Soker 2015), the resulting mergers which do not exceed the Chandrasekhar mass will form massive WDs instead (Aznar-Siguán et al. 2015). In a similar way, massive WDs may form as a result of the merger of the degenerate core of a giant or asymptotic giant star with a main-sequence companion during a common envelope phase (Briggs et al. 2015). After the envelope is ejected the resulting merger will evolve through the asymptotic giant branch in the same was as a single star and form a massive WD.

Based on the previous discussion, we consider that the most plausible scenarios that may lead to the observed excess of massive WDs involve the merger of the degenerate cores of giant stars with their main-sequence/WD companions during/after the common envelope phase, and/or the merger of WD+WD binaries. However, Briggs et al. (2015) suggest that WD+WD mergers typically produce WDs more massive than 1 $\mathrm{M}_{\odot}$. If this is the case, then the WD+WD merger channel is not expected to significantly contribute to an excess of massive WDs, as our MF clearly reveals a scarcity of systems above 1 $\mathrm{M}_{\odot}$ (Fig. 2). Furthermore, the number of WD mergers that form through the core-degenerate channels is predicted to be much larger than the number of WDs that result from the merging of WD+WD binaries (see e.g. García-Berro et al. 2012; Briggs et al. 2015). Finally, it has to be emphasized that the predicted mass distribution of core-degenerate mergers peaks at $\sim$0.8–0.9 $\mathrm{M}_{\odot}$ (depending on the value of common envelope efficiency assumed in the simulations) and smoothly declines towards lower and larger values (Briggs et al. 2015). The expected population of core-degenerate mergers thus falls precisely within the mass range where the high-mass excess is observed in our MF (Fig. 2).

5 SUMMARY AND CONCLUSIONS

We have obtained the MF of the latest catalogue of SDSS (DR 10) DA WDs, including for the first time the cool and faint (i.e. 6000 $\lesssim T_{\mathrm{eff}} \lesssim 12\,000$ K, 12 mag $\lesssim M_{\mathrm{bol}} \lesssim 13$ mag) population. We demonstrate that a clear high-mass excess is present in our MF, which disappears if only hot and bright DA WDs are considered ($T_{\mathrm{eff}} \gtrsim 12\,000$ K, $M_{\mathrm{bol}} \lesssim 12$ mag). We interpret our result as an additional and robust observational evidence for the existence of a high-mass excess near 1 $\mathrm{M}_{\odot}$. Although the merger of WD+WD binaries appears as a reasonable explanation of this observed feature, sophisticated population synthesis studies have shown this channel does not contribute significantly to explain the observed excess of massive WDs. Thus, we argue that the most plausible scenario leading to this feature is the merger of the degenerate core of a giant or asymptotic giant branch star with a main-sequence or WD companion during, or shortly after, a common envelope episode.

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