SDSS1257+5428: an extreme mass ratio double white dwarf

an AM CVn progenitor and a new path to double white dwarfs

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Double white dwarfs (DWDs)

1. Potential progenitors of Type Ia supernovae (Webbink 1984, Iben & Tutukov 1984) . . .

2. . . . R CrB stars, single sdBs, sdOs, isolated millisecond pulsars, high mass white dwarfs, single low mass white dwarfs semi-detached double white dwarfs (AM CVns), *high-field magnetic white dwarfs*, *O (He) stars*, *hot DQs?*

3. Tests of binary evolution

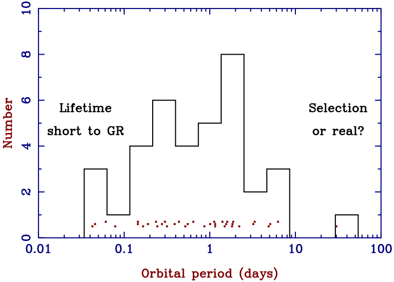
4. Dominant sources for the gravitational wave observatory *LISA* (Hils, Bender & Webbink 1990)

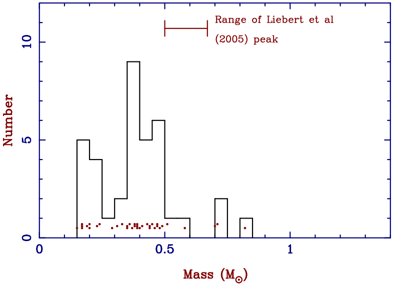
Current observational status of DWDs

Observations over the past two decades have led to 37 published orbits of DWDs (out of an estimated 100 million in the Galaxy)

Orbital periods range from 0.04 to 30 days.

Masses are low compared to single white dwarfs.





Saffer et al (1987); Marsh et al (1995); Marsh (1995); Holberg et al (1995); Maxted et al (2000); Maxted et al (2001); Napiwotzki et al (2001); Karl et al (2003); Napiwotzki et al 2004; Nelemans et al (2005); Morales-Rueda et al (2005); Kilic et al (2007, 2009, 2010); Mullaly et al (2009); Badenes et al (2009); Kawka et al (2010); Steinfadt et al (2010)

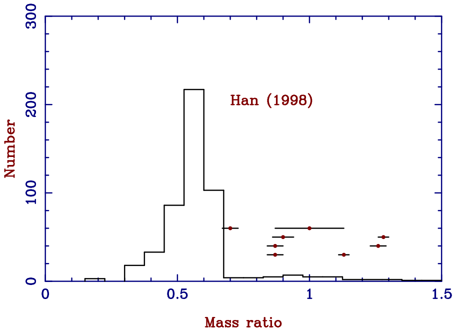
Mass ratios

Mass ratios of DWDs are crucial for their future evolution.

Measured values based upon double-lined systems are problematic, being much closer to equality than expected ⟹

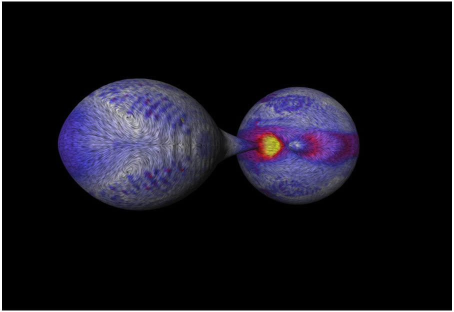
Possible problem with common envelope evolution?

Nelemans et al. (2001); Nelemans & Tout (2005); van der Sluys et al. (2006); Webbink (2008)



Future of DWDs

DWDs spiral in under gravitational wave losses and are fated to initiate mass transfer, which can be violently unstable, disrupting the lighter white dwarf in about 30 minutes



Simulations of white dwarf merger, Motl et al, 2007, 2010 . . . see also Marius Dan this conference

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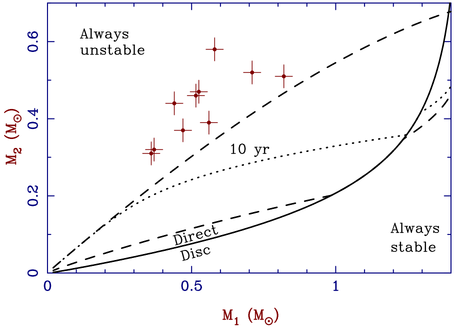
Angular momentum transfer from orbit to accretor is destablising ⟶ merger; extreme mass ratios are stablising ⟶ AM CVn stars



Marsh, Nelemans & Steeghs (2004) plus data

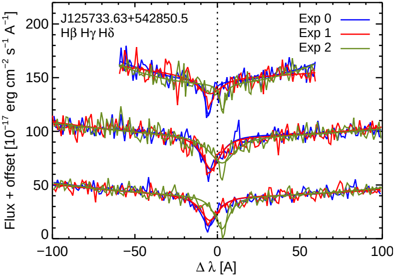
Until recently, all double white dwarfs of known mass ratio were doomed to merge.

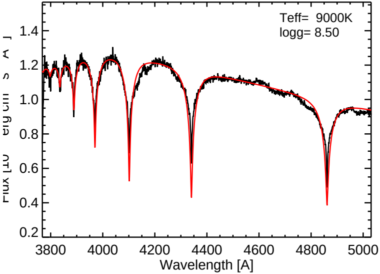
SDSS1257+5428

Found by Badenes et al. (2009) from a search of SDSS spectra for radial velocity variables (each SDSS spectrum is composed of 3x15 min exposures)

Period $P = 4.56\,\mathrm{h}$, high-amplitude $K = 323\,\mathrm{km/s}$, mass of visible white dwarf estimated to be $M_1 = 0.92\,\mathrm{M}_\odot$

$\Rightarrow$ invisible companion has $M_2 = 1.6\,\mathrm{M}_\odot \Rightarrow$ NS or BH!





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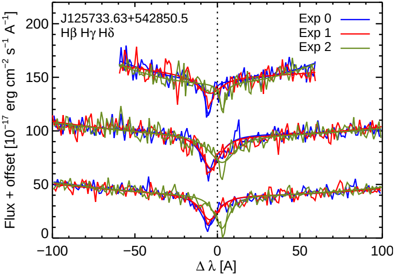

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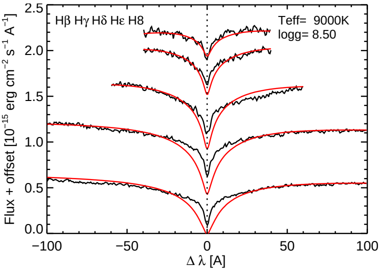
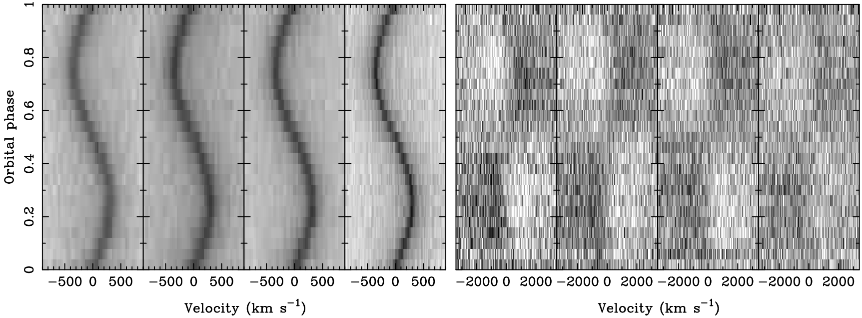




Left: 140 spectra on 4.2m WHT 2008 & 2009, phase-folded, ascending with time.

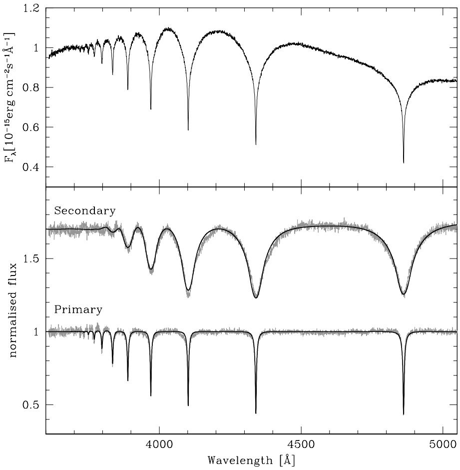
Right: after attempted removal of mean white dwarf spectrum

Mean spectrum in rest-frame of primary white dwarf.

Separate with "disentangling"

Primary is cool, low mass; secondary is hotter, high-mass and rapidly rotating ($v \sin i \sim 1000\,\mathrm{km/s}$)

Marsh et al (2010) (see also Kulkarni & van Kerkwijk 2010)



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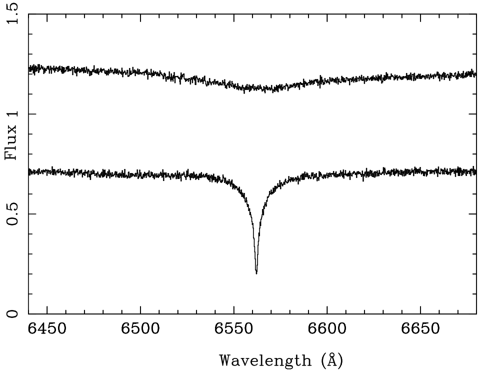
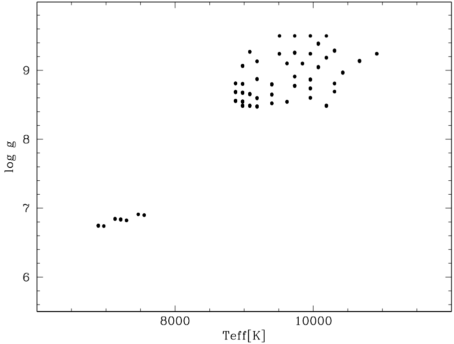
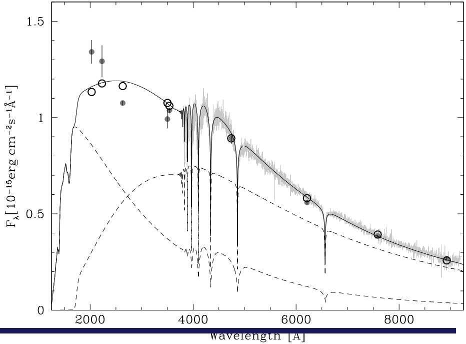


Model atmosphere fits (Koester et al 2005) to disentangled spectra constrain the cool component better than its hotter companion.



Swift/UVOT fluxes suggest a somewhat higher temperature ($\sim 12500\,$K) for the massive component which should dominate in the FUV.

Marsh et al (2010)



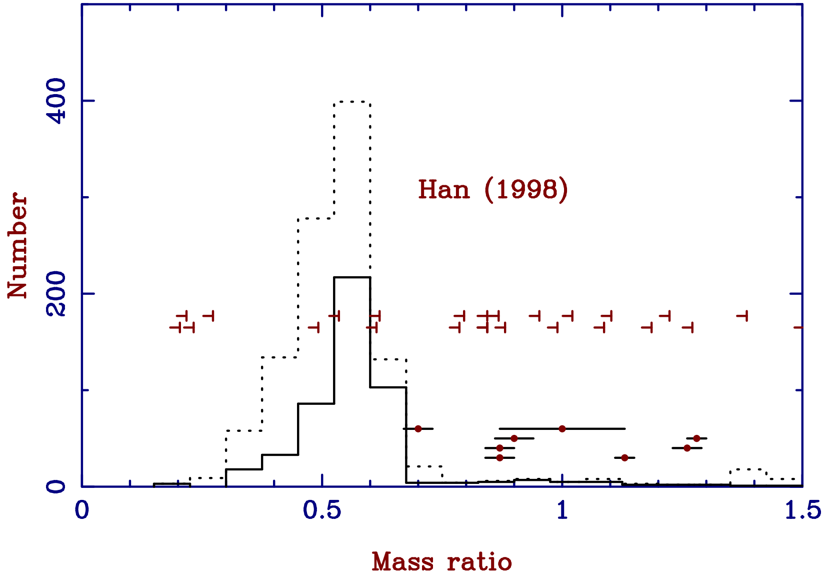
Summary & Conclusions

1. $M_1 \approx 0.2\,\mathrm{M}_\odot$, $T_1 = 7000 - 7500\,\mathrm{K}$;
   $M_2 \approx 1\,\mathrm{M}_\odot$, $T_2 = 9000 - 12500\,\mathrm{K}$

2. He/CO or possibly He/ONe DWD.

3. Mass ratio $q = M_1/M_2 \approx 0.2$, extreme enough to avoid merging: SDSS1257 will become an AM CVn star.

4. Rapid rotation implies accretion of $\sim 0.04\,\mathrm{M}_\odot$. Suggests last mass transfer was not via a common envelope (CE).
   All current DWD models have a CE as the final phase, so SDSS1257 requires a new evolutionary path to DWDs.



Han (1998)
Number
Mass ratio
0
200
400
0
0.5
1
1.5