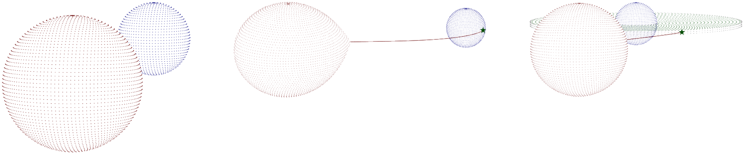
Detached Double White Dwarfs as AM CVn progenitors

Tom Marsh

Department of Physics, University of Warwick



$\longrightarrow$?

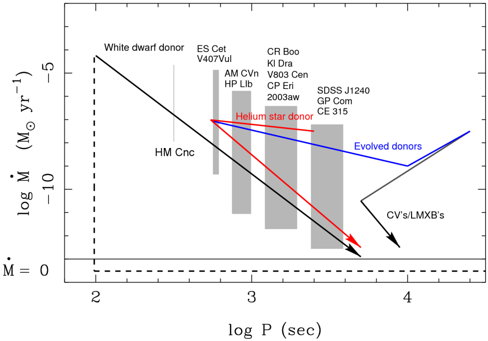
Talk Outline

1. Background: progenitor types and problems
2. Where are the extreme mass ratio systems?
3. Extremely low mass white dwarfs (Brown, Kilic et al)

Origins

Three possibilities:

1. Double white dwarfs (Paczyński 1967; Nelemans et al 2001)
2. White dwarf/helium star binaries (Iben & Tutukov 1991; Yungelson 2008)
3. CVs with evolved donors (Podsiadlowski et al 2003)



Nelemans 2005; also Nelemans et al (2001)

Other than the 5 minute binary HM Cnc, all models can explain the orbital periods, but the DWD model is favoured when it comes to abundances (Nelemans et al 2010)

Many are called, few are chosen . . .

We know of DWDs that will merge, but by no means all can become AM CVn stars:

For stable mass transfer one requires

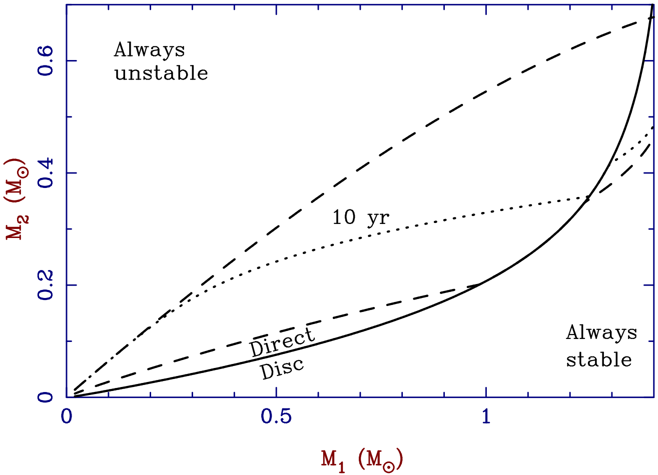
$$q = \frac{M_2}{M_1} < 1 + \frac{\zeta_2 - \zeta_L}{2} \approx \frac{2}{3}.$$

$[\zeta_2 = d\ln(R_2)/d\ln(M_2);\ \zeta_L = d\ln(R_L/a)/d\ln(M_2)]$

If no angular momentum is transferred from accretor to donor, a much more stringent condition applies:

$$q < 1 + \frac{\zeta_2 - \zeta_L}{2} - \sqrt{(1+q)\frac{\min(R_1, R_{\rm Circ})}{a}} \approx \frac{1}{5}.$$

(Marsh, Nelemans & Steeghs 2004)



Marsh, Nelemans & Steeghs (2004) parameterised the accretor spin/orbit coupling in terms of a timescale and showed that it had to be short ($<100\,\mathrm{yr}$) to have much effect.

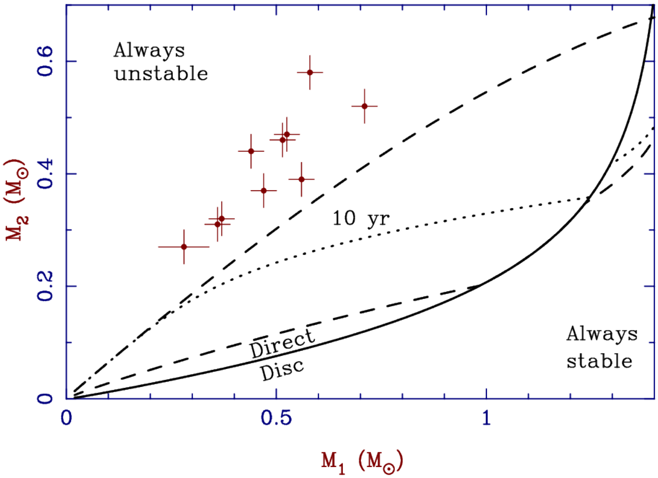
Investigations have led to a variety of answers as to the strength of the coupling:

Racine et al (2007) suggest that resonant tidal locking with normal modes on the accretor could be effective and stabilising.

Motl et al (2007) found strong, stabilising coupling in hydrodynamic computations.

Dan et al (2012) seem to find stability/instability in rough accord with weak coupling

(but remember comments by GN on hydro simulation timescales, and that stability is aided by high donor entropy).

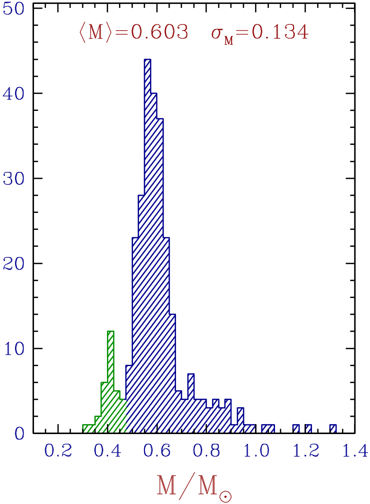


Up to 2010, all systems with good constraints on both masses had too equal mass ratios to survive mass transfer.

Searches

If we insist upon systems that require no spin/orbit coupling to survive, we must find white dwarfs with $M < 0.2\,\mathrm{M}_\odot$.

There are very few such low mass white dwarfs; existing surveys are probably biased against them.



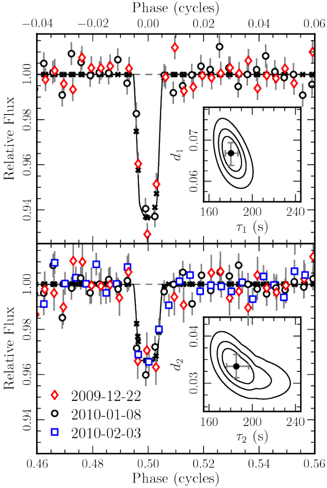
White dwarf masses from the PG survey (Liebert et al 2005)

Low mass white dwarfs found by chance – I

NLTT 11748 was the first DWD found to be eclipsing (Steinfadt et al 2010)

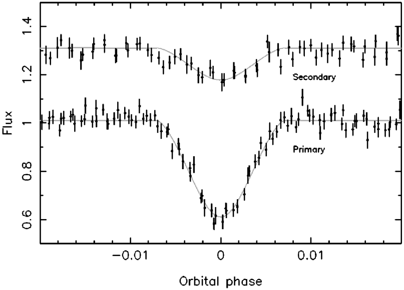
$P = 5.64\,\text{h}$, $i = 89.9^\circ$,
$M_1 \approx 0.15\,\mathrm{M}_\odot$, $M_2 \approx 0.7\,\mathrm{M}_\odot$

NB. $R_1 = 0.04\,\mathrm{R}_\odot$ enhances probability of eclipses.



6 and 3% deep primary and secondary eclipses.

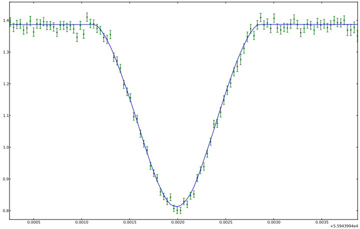
Low mass white dwarfs found by chance – II



CSS 41170, second eclipser, (Parsons et al 2011)

$P = 2.8\,\mathrm{h}$, $i = 89.2^\circ$, $M_1 = M_2 = 0.27\,\mathrm{M}_\odot$

[this one will merge.]

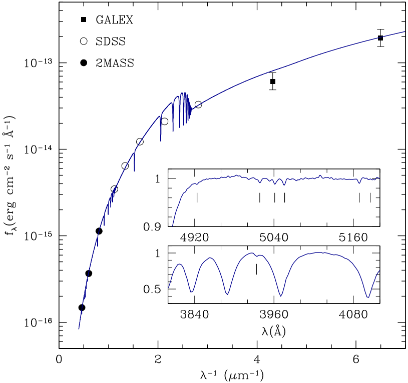


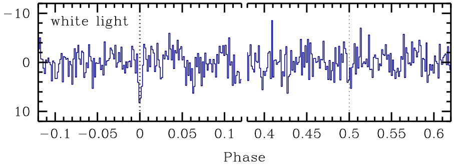
Low mass white dwarfs found by chance – III

GALEX J1717+6757, $V = 13.7$! Found through RVs, third eclipser!

$P = 5.9\,\mathrm{h}$, $i = 86.8°$, $M_1 = 0.18\,\mathrm{M}_\odot$, $M_2 > 0.86\,\mathrm{M}_\odot$

Near-solar Ca, Si & Fe! He $< 0.05\times$ solar. (Vennes et al 2011)



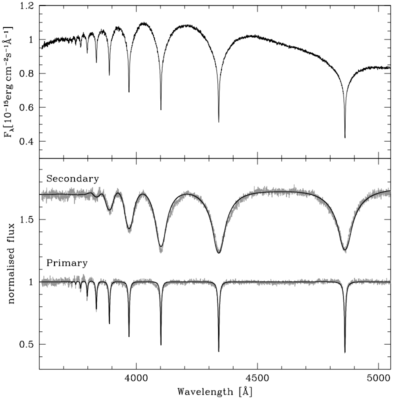


Low mass white dwarfs found by chance – IV

SDSS J1257+5428. Found through RVs, spectrum is a combination of a cool, low mass WD plus a hotter high mass one.

$P = 4.55\,\mathrm{h}$, $M_1 = 0.2\,\mathrm{M}_\odot$, $M_2 = 1.0\,\mathrm{M}_\odot$

(Badenes et al 2009; Kulkarni & van Kerkwijk 2010; Marsh et al 2011)



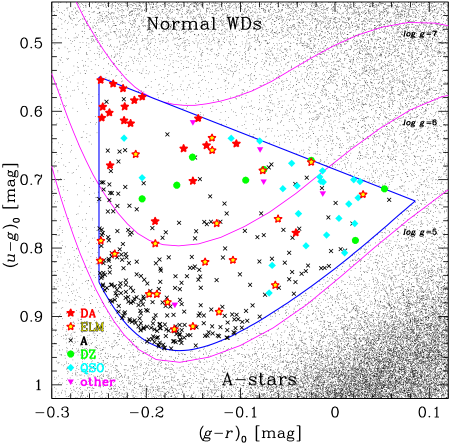
Marsh et al (2011)

ELM project – Brown, Kilic, et al

While looking for high-velocity early-type stars, Brown, Kilic et al hit a rich seam of very low mass white dwarfs, almost all in short-period binaries.

Many are potential AM CVn progenitors.

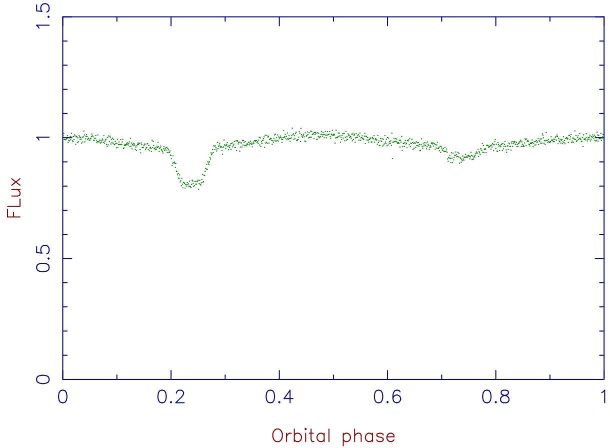
Brown et al (2012) ⟶



ELM highlights

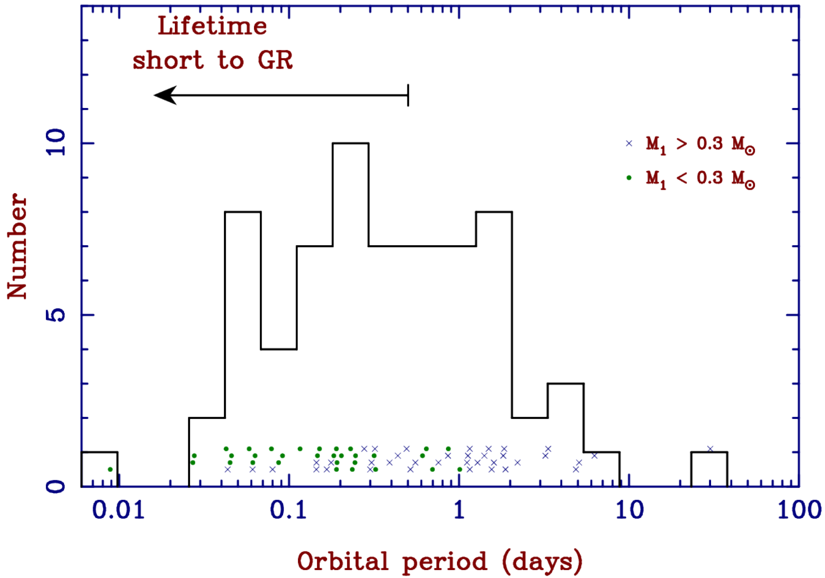
1. $P = 12.8\,\mathrm{min}$ (and falling . . .) DWD eclipser (#4!) SDSS J0651+2844 (Brown et al 2011)
2. SDSS J1065-1003, SDSS1630+4233, both with $P \approx 40\,\mathrm{mins}$ (Kilic et al 2011a, 2011b).
3. SDSS1053+5200, $P \approx 60\,\mathrm{mins}$ (Kilic et al 2010).
4. First low-mass WD pulsator, SDSS1840+6423 (Hermes et al 2012).
5. Total of 24 new DWDs that will merge in $< 10\,\mathrm{Gyr}$ (Kilic et al 2012).

SDSS J0651+2844

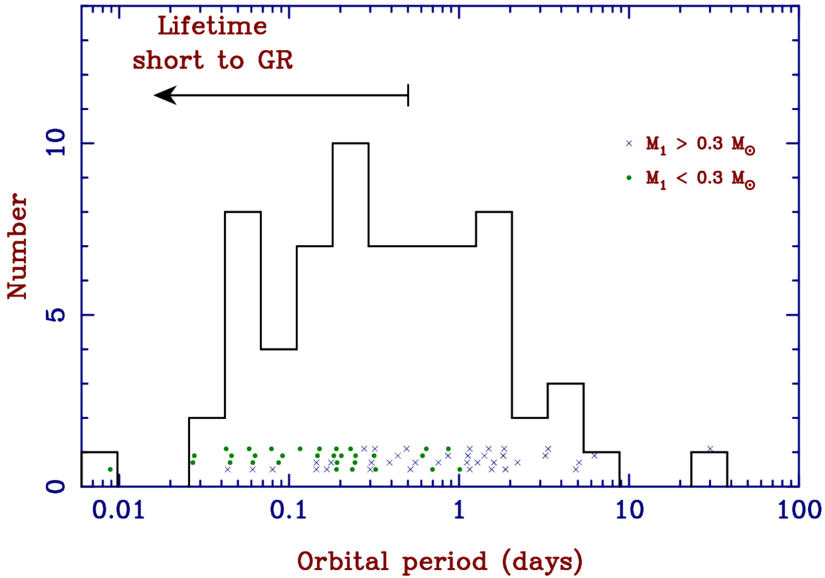


Groot et al, Jan 31 2012, ULTRACAM/WHT

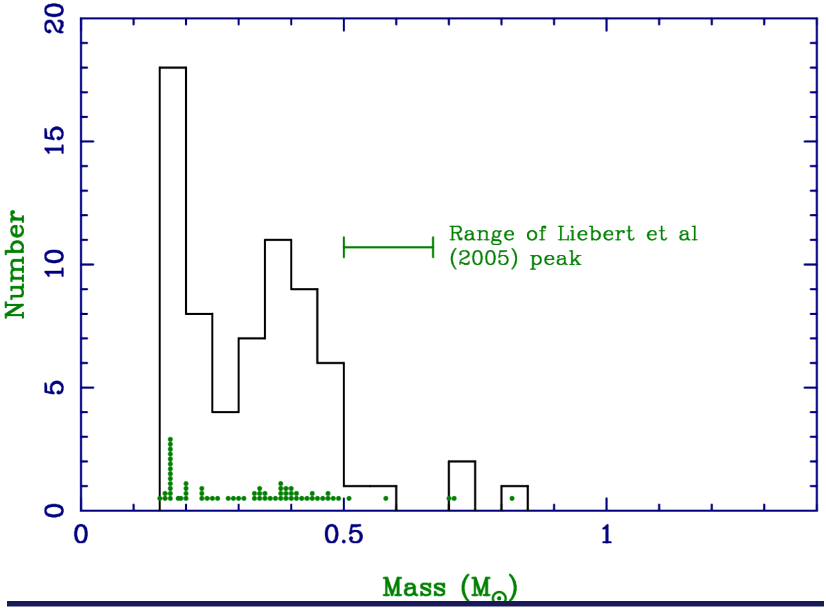
DWD AM CVn progenitors



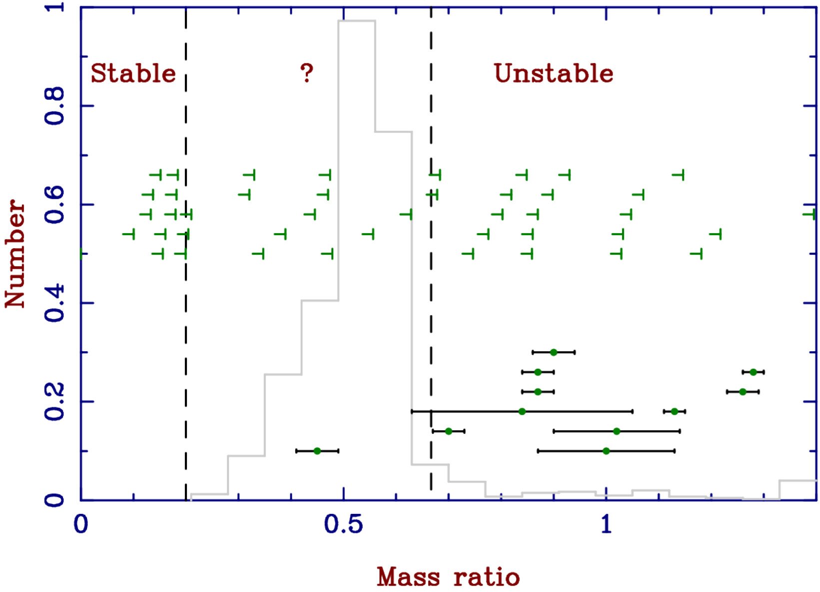
Period distribution



Mass distribution of brightest WDs



Mass ratio distribution, brightest/faintest



A few thoughts

30 % of ELMs have thick disk/halo kinematics – connected to metal abundance patterns seen in AM CVns?

About the same number of AM CVn DWD progenitors as AM CVns have now been found in SDSS.

But ELM white dwarfs are large, typically $\sim 4\times$ larger than the accretors which dominate AM CVns, and so for the same temperature they can be seen $4\times$ further away. Thus although ELM binaries live only ~ 1 Gyr, they may explain only $\sim 10\%$ of AM CVns (Brown et al 2011; Roelofs et al 2007) allowing for factor 2 ↓ (Carter this meeting)

There may still be a need for $q > 0.2$ AM CVn progenitors.

Conclusions

1. DWDs are strong contenders as AM CVn progenitors.
2. Within the past few years numerous systems have been discovered which have the potential to avoid merging.
3. These can produce a significant number of AM CVns, but accretor/orbit coupling may still be needed to explain all AM CVns.