White dwarfs with oxygen-rich atmospheres
White dwarf mass distribution

The initial-mass final-mass relation

mostly based on WDs in open clusters & stellar models

e.g. Dobbie et al. 2009, MNRAS 395, 2248

practically no constraints at $M<2M_{\odot}$
IMF constraints from common proper motion WD pairs

\[ \Delta \tau = (1.67 \pm 0.05) \times 10^9 \text{yr} \]

Girven et al. 2010, MNRAS 404, 159

WD pairs with unequal cooling ages strongly constraint their progenitor masses

The initial-mass final-mass relation

The above summary suggests that evolution of stars in the mass range of 8–10 $M_\odot$ as well as slightly above 10 $M_\odot$ will have a variety of interesting outcomes and thus deserves further study.


SN for $M>8.5^{(+1-1.5)}$ M$_\odot$  

- ONe core
- electron-capture SN
- core-collapse SN
The initial-mass final-mass relation

- nuclear reaction rates?
- convective mixing/overshooting?
- mass loss?

need massive white dwarfs that tell us about their core composition

SN for $M > 8.5^{(+1-1.5)}$ $M_{\odot}$


The above summary suggests that evolution of stars in the mass range of 8–10 $M_{\odot}$ as well as slightly above 10 $M_{\odot}$ will have a variety of interesting outcomes and thus deserves further study.


- ONe core
- electron-capture SN
- core-collapse SN

SN2008ha, M85-OT, NGC300-OT
Hydrogen-rich (DA)

DA (hydrogen)

T_{\text{eff}} = 6000 - 100000 \text{K}
Helium-rich (DO/DB/DC)

**DB (hydrogen)**

- Teff $\geq 40000K$
- Teff $= 10000 - 40000K$
- Teff $< 10000K$

**Diagram:**
- DO: Teff $\geq 40000K$
- DB: Teff $= 10000 - 40000K$
- DC: Teff $< 10000K$
DQ = cool, carbon-rich

Teff < 12000K
Are very carbon rich DQs as the progeny of massive progenitors?

(see Klaus’ talk on H1504+65 and Patrick’s talk on hot DQs)
So far… O/C < 1

⇒ simply search ~26000 SDSS spectra for oxygen absorption

...found them 😊

Model spectra
WDs with oxygen-rich atmospheres: SDSS0922+2928

(phot) $T_{\text{eff}} = 8270 \pm 320$ K @ $\log g = 8$

$\log(H/He) = -5.0$
$\log(C/He) = -2.6$
$\log(O/He) = -2.0$
$O/C \approx 4$

Gänsicke et al. 2010, Science 327, 188
WDs with oxygen-rich atmospheres: SDSS1102+2054

(phot) $T_{\text{eff}} = 8270 \pm 320 \text{K} @ \log g = 8$

(spect) $T_{\text{eff}} \approx 10500 \text{K} @ \log g = 8$

$\log(\text{H}/\text{He}) = -3.2 / -4.0$
$\log(\text{C}/\text{He}) = -3.2 / -3.6$
$\log(\text{O}/\text{He}) = -1.8 / -1.8$

$\text{O}/\text{C} \approx 25 / 63$

Gänsicke et al. 2010, Science 327, 188
What about the progenitor of such ONe core?

The problem: most ONe cores will have a CO layer that is sufficiently thick to hide the oxygen …

… unless descending from a star close to the core-collapse boundary?

Garcia-Berro & Iben 1997, 485, 765

The mass $\Delta M_{CO}$ of the CO layer above the ONe core and the mass $\Delta M_{\text{neon free}}$ of the neon-free layer in the outer part of the CO layer are decreasing functions of model mass. In the 9, 10, and 10.5 $M_\odot$ models, $\Delta M_{CO} = 0.05, 0.015,$ and $0.0065 M_\odot$, respectively, and $\Delta M_{\text{neon free}} \sim 0.014, 0.009,$ and $0.0036 M_\odot$, respectively.
WDs with oxygen-rich atmospheres

- rare: 2 out of 1000s in SDSS
- O/C > 1 $\Rightarrow$ definite ONe core (O heavier than C!)
- Must have descended from MS star near the core-collapse boundary $\Rightarrow$ should be massive!

- preliminary (1-year) parallax: $d=68^{(+14-10)}$ pc $\Rightarrow$ Mwd$\sim$1M$_{\odot}$ @ Teff =10500K
Need: better spectra

Approved X-shooter observations sensitive to log[Ne/He]~2
(we really could do with an ELT…)

![simulation!](image_0x0_to_724x543)
Need: better spectra

HST/COS Cycle 18 program: Teff & sensitive to log[Mg/He]~-9
Conclusions

• we have identified two cool WDs with photospheric O/C > 1

• must be ONe cores, and most likely descended from massive progenitors

• should be massive themselves...

• UV spectroscopy and better optical data will provide accurate Teff, Mwd as well as O, Ne, Mg abundances