# The Origin of High Field Magnetic White Dwarfs


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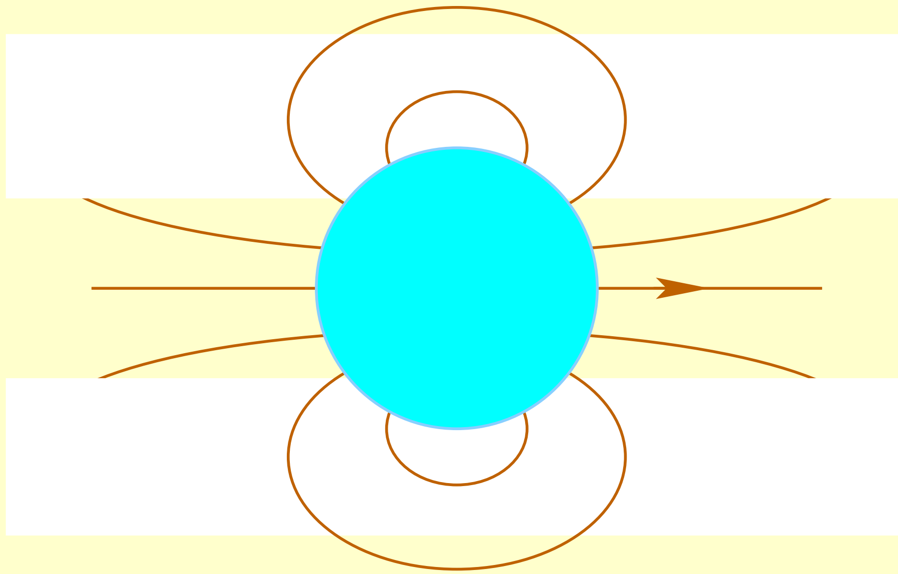



**with Dayal Wickramasinghe, James Liebert, Lilia Ferrario and James Pringle**

## Magnetic Fields in White Dwarfs

Surface Fields cover a wide range from $0 - 10^9\,\mathrm{G}$

Distinguish low fields $B < 10^6\,\mathrm{G}$ and high fields $B > 10^6\,\mathrm{G}$

Low fields are typically less than $10^5\,\mathrm{G}$

## Magnetic Cataclysmic Variables

Cataclysmic Variables are Semi-Detached binary system including a white dwarf.

Polars - AM Her systems

have typically $B = 10^7\,\mathrm{G} < B < 10^8\,\mathrm{G}$

Intermediate Polars - DQ Her systems

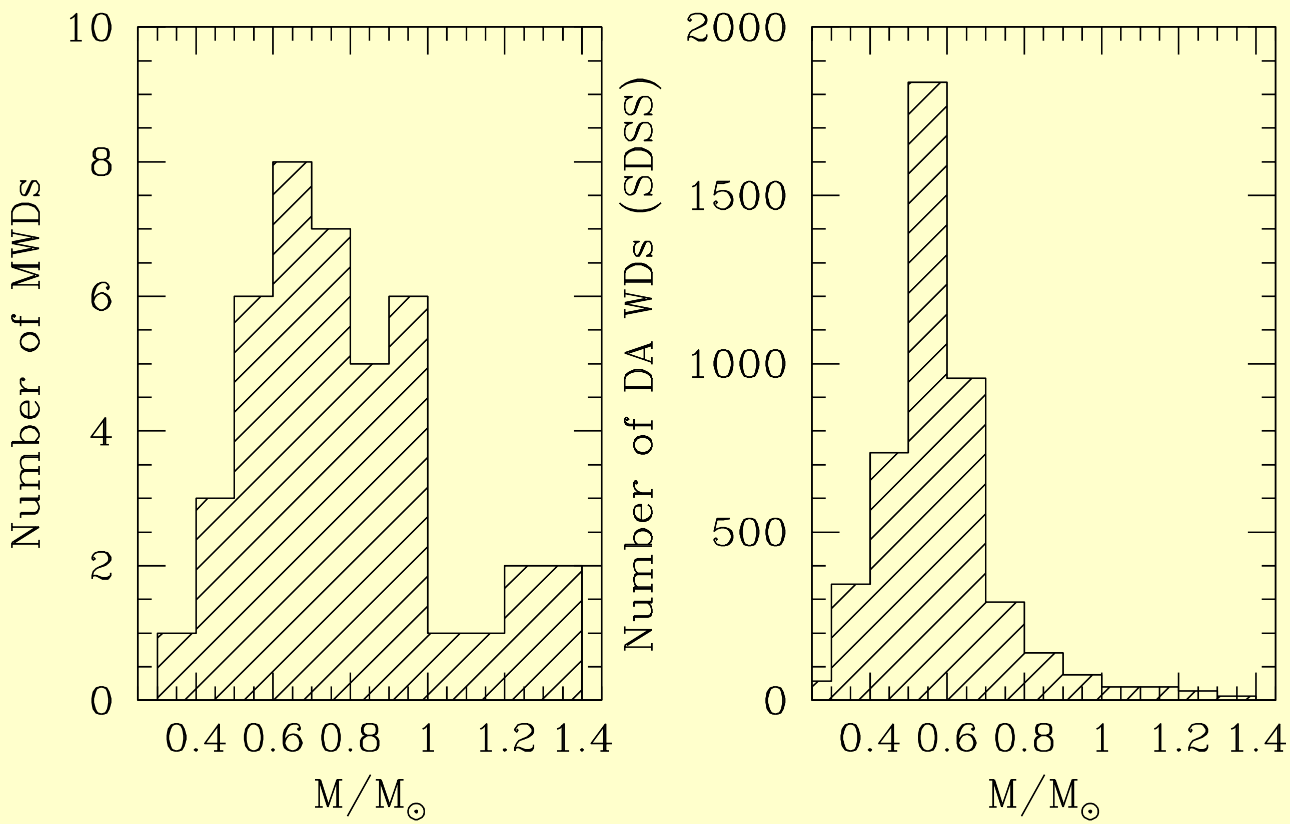
deduced to have $B = 5 \times 10^6\,\mathrm{G} < B < 10^7\,\mathrm{G}$

**The highest fields are found in single white dwarfs**

## Numbers of Magnetic White Dwarfs

| | Wide Binaries | Semi–detached | Single |
|---|---|---|---|
| High B | NONE | 25% | 10% |
| Low B | ALL | 75% | 90% |

# Masses of White Dwarfs




Measured masses of MWDs (Kawka et al. 2007)
compared with DA WDs in the SDSS (Kepler et al. 2007)

**Magnetic white dwarfs span the same range of mass as non-magnetic**

**They do however tend to be more massive**

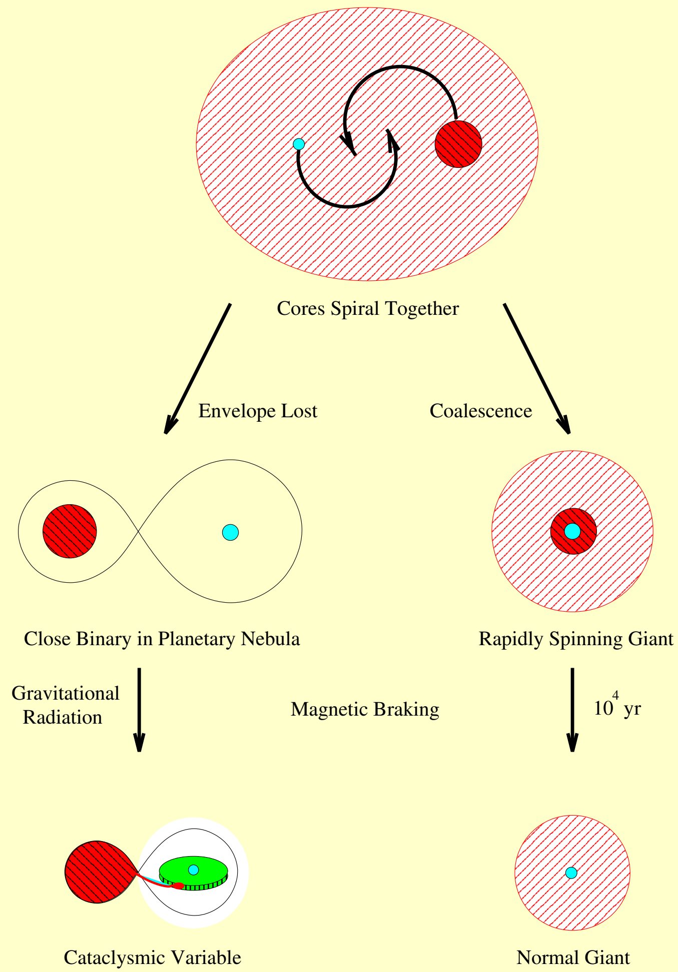
**Mean mass of HFMWDs is $0.78\,M_{\odot}$**

**Mean mass of WDs is $0.58\,M_{\odot}$**

**Not sufficient as a selection effect**

**We conclude that the origin of high magnetic fields in white dwarfs is intimately tied up with their duplicity**

# Common Envelope Evolution



## Magnetic Dynamo

**Spiralling cores create differential rotation**

**converts poloidal to toroidal field – $\Omega$ Dynamo**

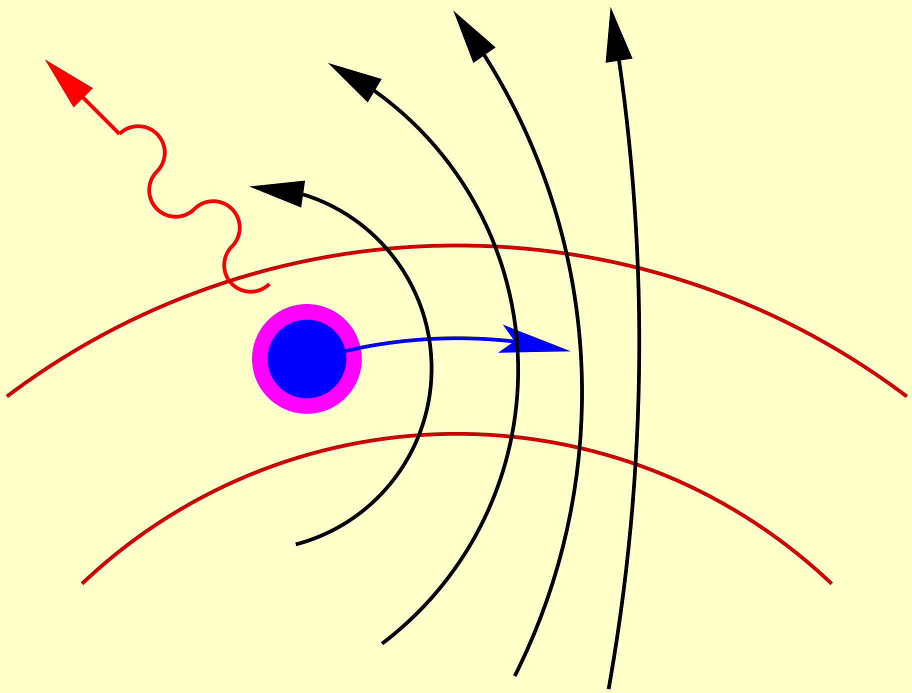
**Giant-like nuclear burning drives convection with helicity**

**converts toroidal to poloidal field – $\alpha$ Dynamo**

**Differential rotation is greatest when cores are closest**

**strongest fields when cores are about to merge**

# Magnetic Dynamo



Regős and Tout 1995

## Low Accretion Rate Polars

**Periods from 1.3 to** $4.39\,$**h and fields 42 to** $65\,$**MG**

**All have low temperatures** $7{,}500 < T_{\rm eff}/{\rm K} < 13{,}000$

**Detached systems sufficiently close for wind accretion**

**Magnetic analogies of pre-CVs like V471 Tau**

## Double Degenerate Systems

**To form a close system of two white dwarfs the first star must evolve either without common envelope evolution or must emerge as a wide detached system**

**it is therefore expected to have a low magnetic field**

**The second can then emerge with a high field and is often of low mass**

For example $G62-46$, $G141-2$, $EUVE\,1439+75$

**Other systems form from triple stars in which two cores merge**

For example $EUVE\,J0317-855$, LB11146

## Freezing of Magnetic Fields (Potter 2008/9)

Orbital energy of cores $E_{\rm orb} = \frac{GM_{\rm c}M_2}{a}$

Magnetic energy in a torus $E_B = B^2/2\mu_0\, 2\pi a\, \pi r_{\rm dyn}$

**Close to merging $E_B \approx E_{\rm orb}$ for $10^9 < B/{\rm G} < 10^{11}$**

**Emerging as a typical AM Her system $B \approx 3 \times 10^9\,{\rm G}$**

**For a typical hot subdwarf field penetration**

$$B_{\rm WD} = B\frac{t_{\rm CE}}{10^8\,{\rm yr}}$$

**So for a field of $10^8\,{\rm G}$ require $t_{\rm CE} \approx 3 \times 10^6\,{\rm yr}$**

## Space Density Estimates and CE Evolution

**Space densities and lifetimes are not well known**

**All CVs $1.1 \pm 2.3 \times 10^{-5}$ per cubic parsec**

**about one quarter are magnetic**

**All WDs $3 \times 10^{-3}$ per cubic parsec**

**about one tenth are HFMWDs**

**Assume observable lifetime of a CV is one tenth that of a WD**

**So three times as many systems entering a CE phase should merge as end up separated but close enough to become a CV**

## Conclusions

- No white dwarf with a surface magnetic field over 3 MG has been found in an entirely detached binary system.
- The progenitors of all highly magnetic white dwarfs must be close binary stars.
- A likely origin of the high magnetic fields is a magnetic dynamo operating during common envelope evolution.
- All single highly magnetic white dwarfs have resulted from core merging in a common envelope.