

Direct Impact Accretion in  
AM CVn stars

and its effect upon their evolution

Tom Marsh

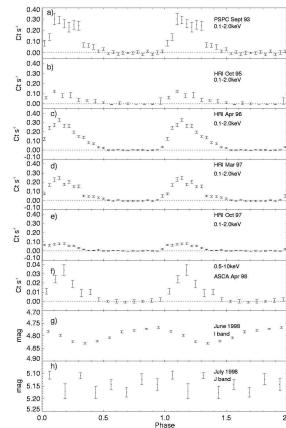
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V407 Vul (RX J1914.4+2456)

- On/off X-ray light curve, period **9.5** minutes.
- Same period at optical and IR wavelengths.
- No other periods seen.
- Weak line emission.
- No circular polarisation.
- “Super-soft” X-ray spectrum,  $kT \sim 50$  eV



Ramsay et al (2000)

### What is V407 Vul?

- Cropper et al. (1998): first magnetic, mass-transferring double white dwarf.  $P = 9.5 \text{ min.}$ 
  - *but no circular polarisation.*
- Wu et al. (2002): electric star, cf Jupiter-Io.  $P = 9.5 \text{ min.}$ 
  - *but short lived ( $\sim 1000 \text{ yr}$ ).*
- Norton et al (2002): face-on “intermediate polar”.  $P \sim \text{hours.}$ 
  - *but no line emission or other periods.*

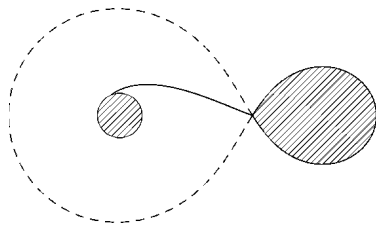
### Accretion by Direct Impact

At  $P = 9.5 \text{ min}$ , the stream can crash directly into the accreting white dwarf:

*Nelemans et al (2001)*  
*Marsh & Steeghs (2002)*

This explains:

- 50% X-ray duty cycle
- Lack of circular polarisation
- Lack of line emission
- Soft X-ray spectrum



*Whatever the true nature of V407 Vul, direct impact accretion is an inevitable consequence of the start of mass transfer between most double white dwarfs.*

e.g. Nelemans et al (2001).

### Mass Transfer

If donor overfills its Roche lobe by  $\Delta$  then:  $-\dot{M}_2 \propto e^{\Delta/H}$  ( $H \sim 100$  m)

CVs, LMXBs: 
$$\frac{1}{2R_2} \frac{d\Delta}{dt} = -\frac{\dot{J}_{\text{GR}}}{J_{\text{orb}}} + \left(\frac{5}{6} - q\right) \frac{\dot{M}_2}{M_2}$$

Ultra-compact: 
$$\frac{1}{2R_2} \frac{d\Delta}{dt} = -\frac{\dot{J}_{\text{GR}}}{J_{\text{orb}}} + \left(\frac{5}{6} - q - \sqrt{(1+q)r_h}\right) \frac{\dot{M}_2}{M_2} - \frac{kM_1R_1^2}{\tau_S J_{\text{orb}}} \omega$$

### A Tale of Two Systems

Solid line:

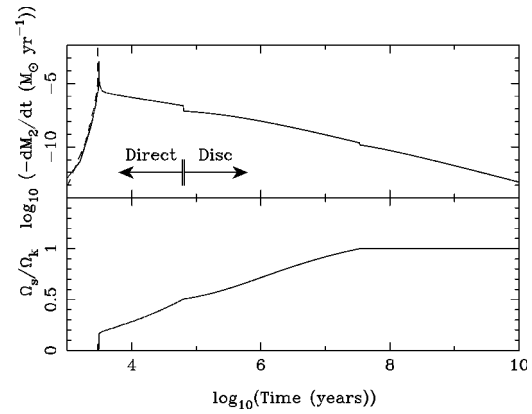
$$M_1 = 0.500 M_{\odot}$$

$$M_2 = 0.125 M_{\odot}$$

Dashed line:

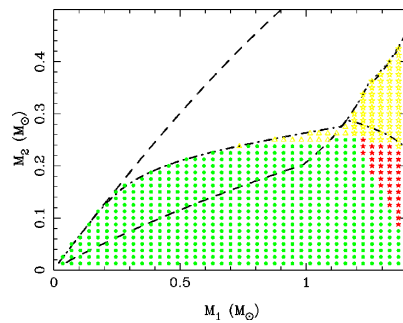
$$M_1 = 0.500 M_{\odot}$$

$$M_2 = 0.126 M_{\odot}$$

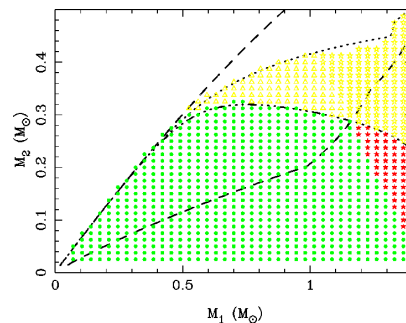


### Numerical Integrations

Survival depends upon synchronisation of accretor's spin



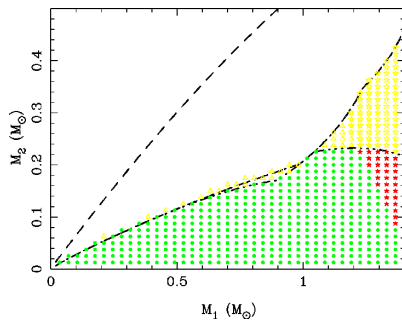
$$\tau(\text{sync}) = 10 \text{ yr}$$



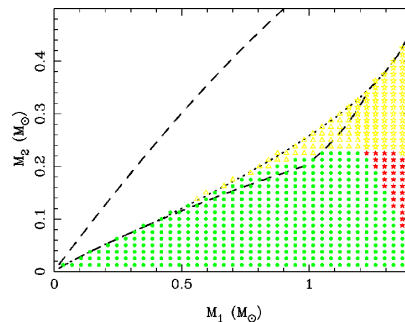
$$\tau(\text{sync}) = 0.1 \text{ yr}$$

What matters is the accretor's size

Direct impact:



Disc only:



(Both plots have zero synchronisation torque.)

Size of Accretor vs Direct Impact

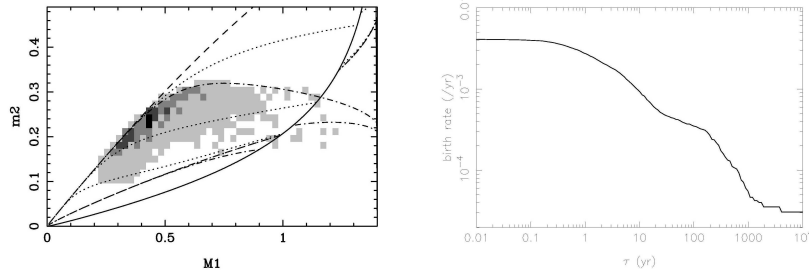
$\sqrt{(1+q)r_h}$  is the destabilising term.

Direct:  $r_h = R_{\text{circ}}/a$

Disc:  $r_h = R_1/a$

But  $R_1 \sim R_{\text{circ}}$  so similar effect in each case

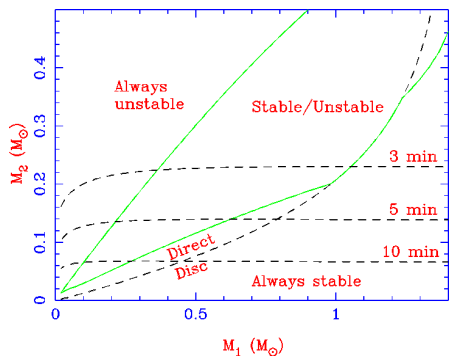
### Effect upon birth rate of AM CVn stars



Synchronisation torque must be  $< 1000$  yr to have much effect

DWD path to AM CVns uncertain by factor of 100

### The Need for More Systems



- KUV 01584-0939
  - $P = 10.3$  mins
  - Woudt & Warner (2002)
- V407 Vul
  - $P = 9.5$  mins
  - Cropper et al (1998)
- RX J0806.3+1527
  - $P = 5.4$  mins
  - Ramsay et al (2002)
  - Israel et al (2002)

### Conclusions

1. Direct impact accretion is inevitable during mass transfer between double white dwarfs.
2. The loss of angular momentum from the large relative size of the accreting white dwarf is destabilising.
3. Strong spin-orbit synchronisation is needed to counteract the destabilisation.
4. Well worth trying to find more very short period systems.