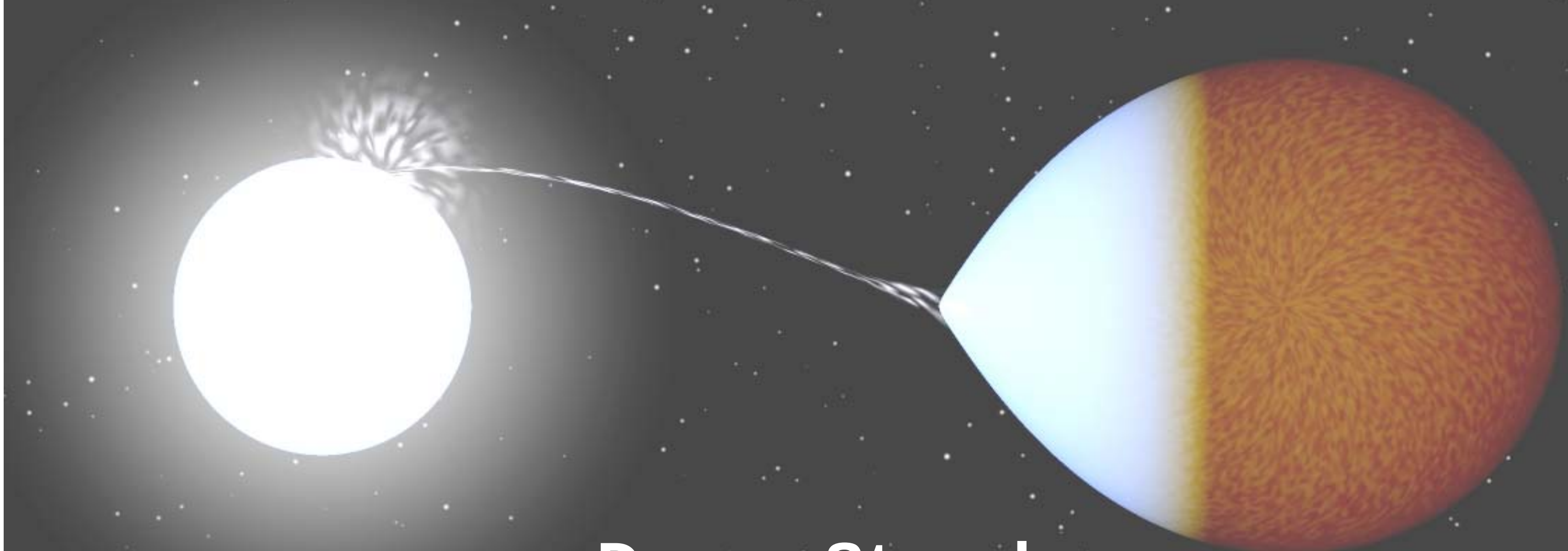
Binsim courtesy R.Hynes

Direct Impact Accretion in double white dwarfs



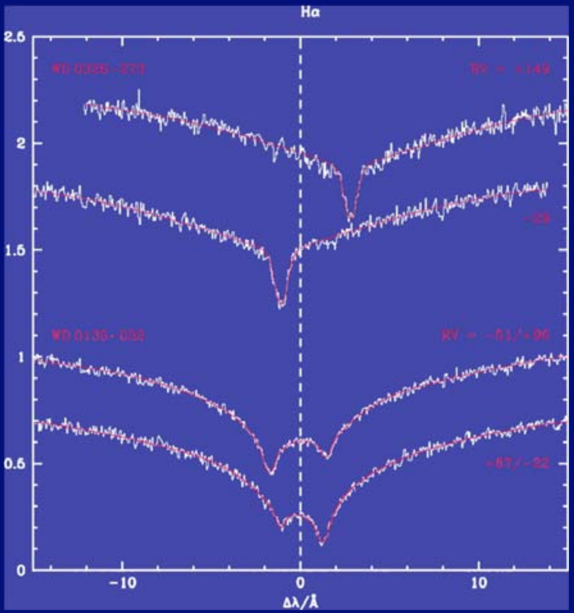
Danny Steeghs

Harvard-Smithsonian Center for Astrophysics & University of Warwick

G.Nelemans, T.Marsh, P.Groot, G.Roelofs et al.

The population of double white dwarfs

- Spectroscopic ***radial velocity surveys*** of WDs have revealed a large population of double degenerate binaries



SPY project

Napiwotski et al. 2006

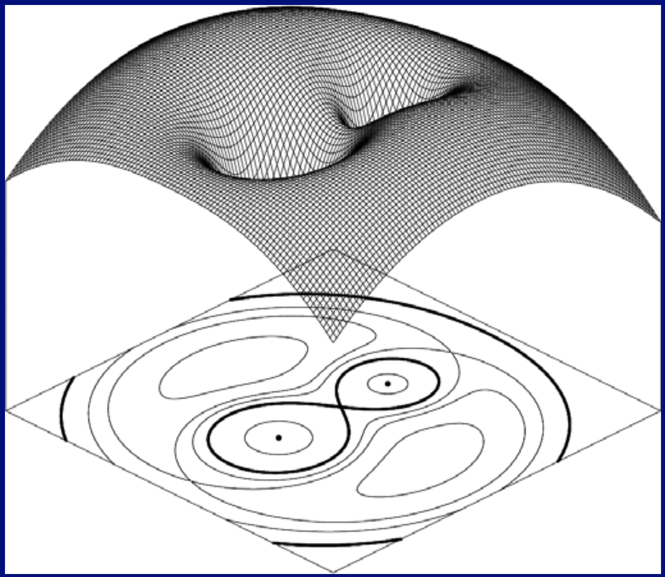
- ~15% of surveyed WDs are in a short period double; few $\boldsymbol{10^8}$ such systems in the Galaxy !

- Binary evolution towards shorter orbital periods driven by angular momentum loss via ***gravitational wave emission***

- A significant fraction (P_i < 10h) will enter a ***mass transfer phase*** within a Hubble time (Type Ia progenitors?)

Mass transfer and stability : merger vs accretion

- Initial stability of mass transfer determined by the response of the mass donor to mass loss:



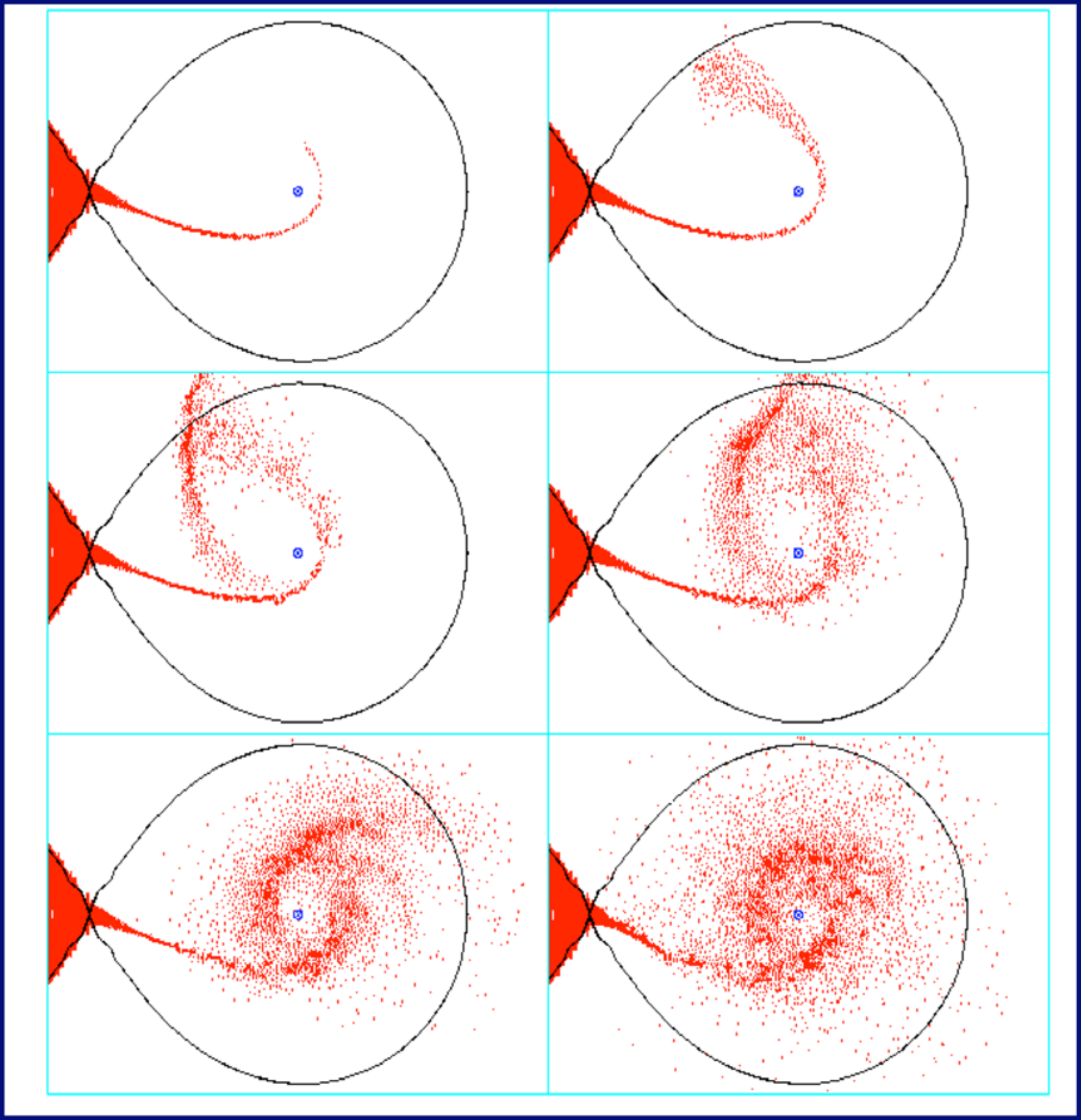
$$\zeta_2 = \partial \log R_2 \,/\, \partial \log M_2 < 0$$

- if donor radius relative to Roche-lobe radius grows, mass transfer runs away leading to rapid merger

- if donor remains within its Roche-lobe, mass transfer *can be* stable and its rate is determined by the orbital angular momentum loss

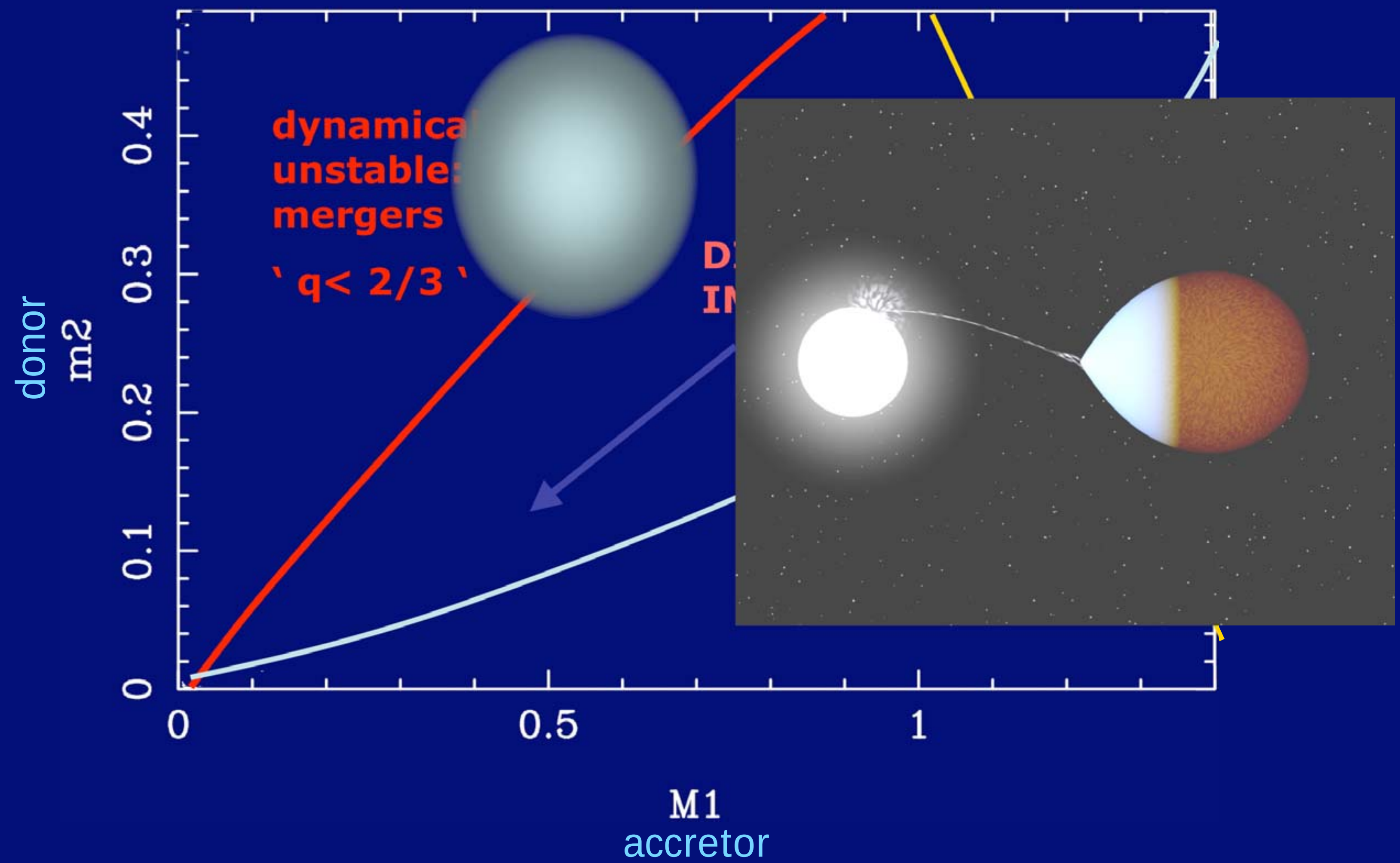
Courtesy NASA/GSFC

Disks if $R_1 << R_{L1}$



Mass transfer between two white dwarfs at contact

• Post common-envelope detached double white dwarfs driven into contact by gravitational waves (P<10hrs)



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Angular momentum transport

- Loss of orbital angular momentum via gravitational wave radiation:

  $dJ_{GR}/dt = -32/5\ G^3/c^5\ M_1 M_2 M/a^4\ J_{orb}$

- Transfer of momentum via mass loss:

  $dJ_2/dt = (GM_1R_h)^{1/2}\ dM_2/dt$

- An extended accretion disc effectively couples transferred angular momentum (J_2) back to the orbit via tides

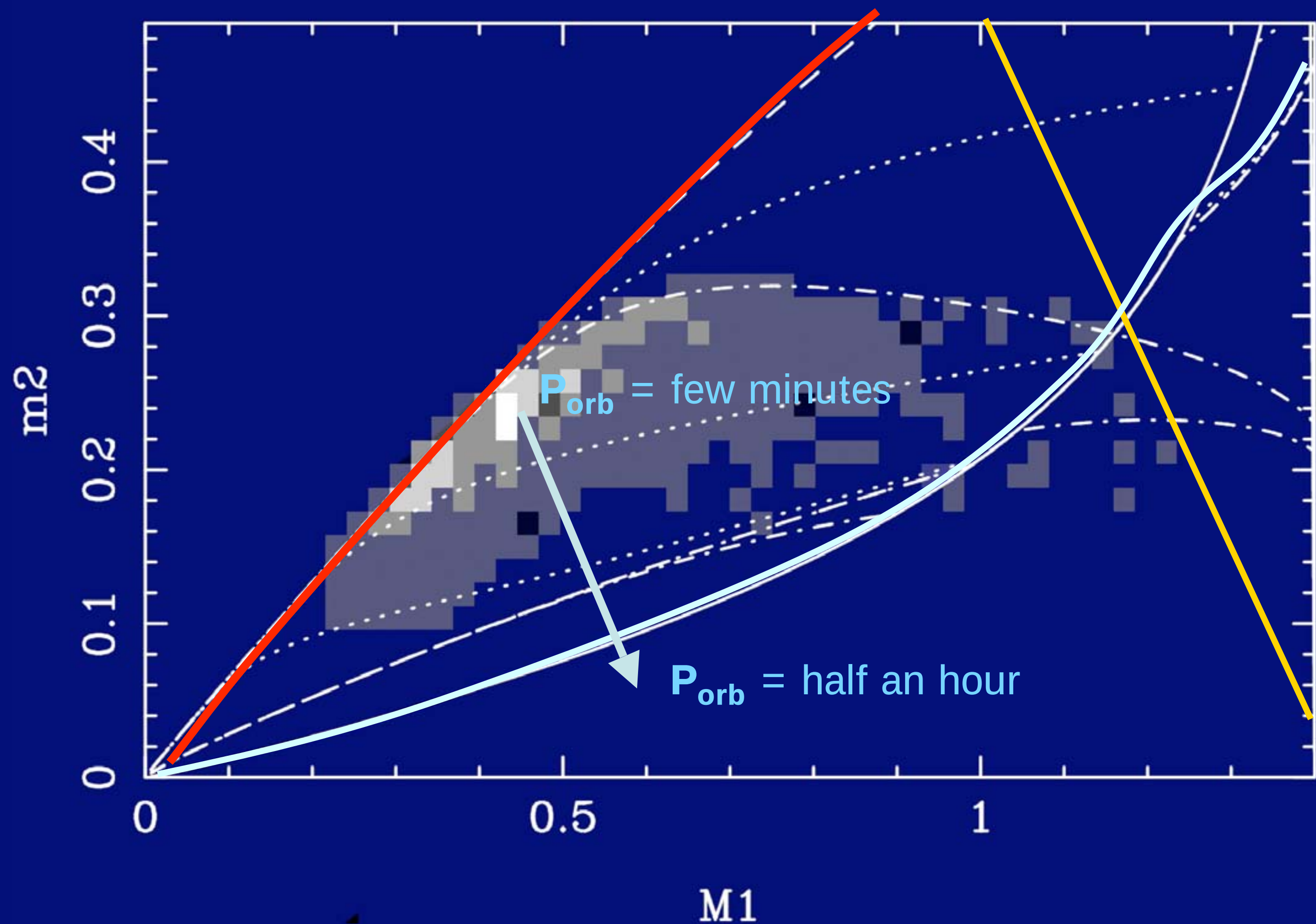
- What if there is no disk but angular momentum is dumped onto the primary?

- Spin – orbit coupling : non-synchronous rotation leads to angular momentum transport via tidal/magnetic or viscous torques

  $dJ_{SO}/dt = kM_1R_1^2\ (\Omega_s - \Omega_o)\ /\ \tau_s$

Mass transfer between two white dwarfs

- Semi-detached 'direct-impact' birth at P~few mins

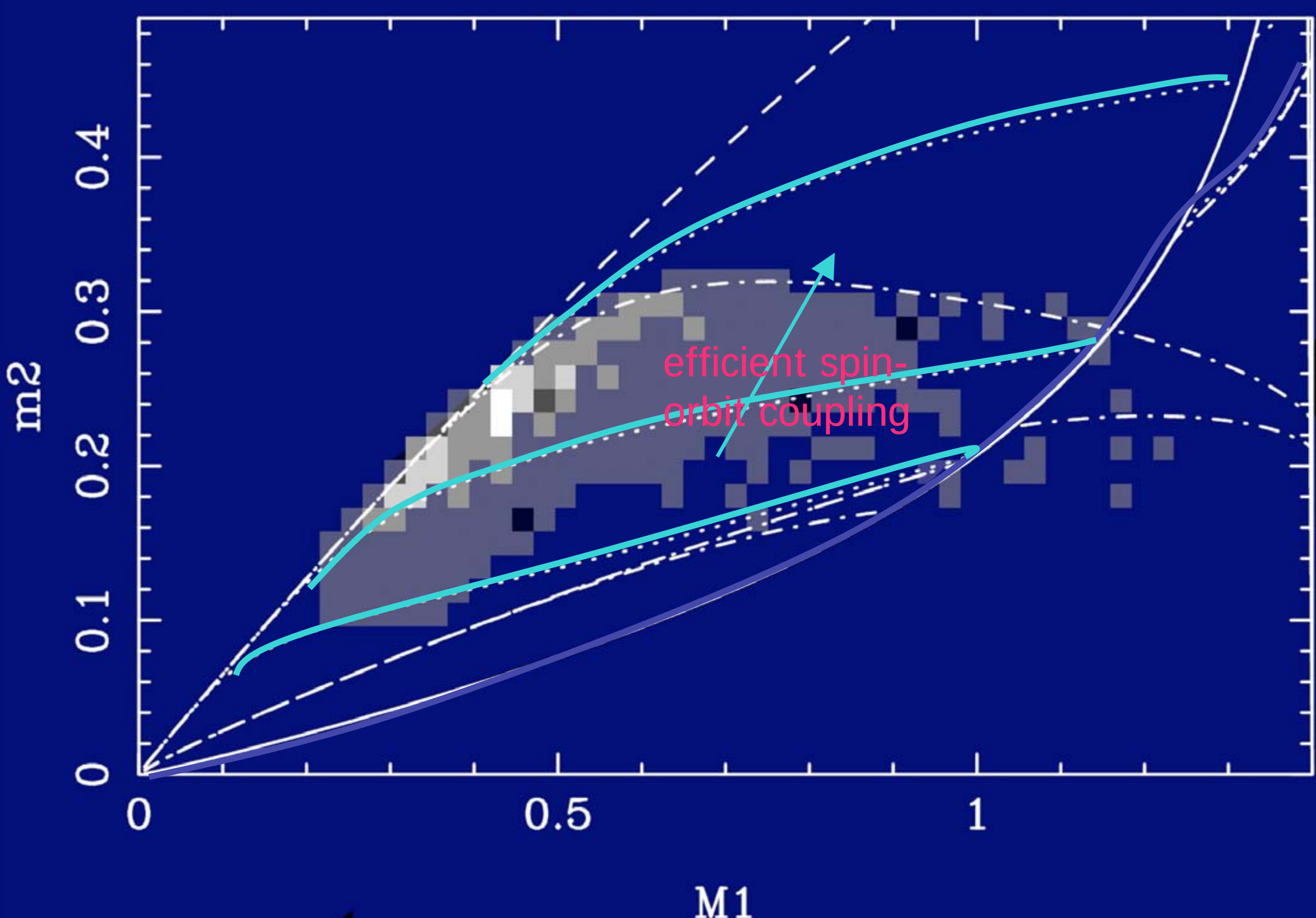


Nelemans et al. 2001, Marsh & Steeghs 2002, Marsh, Nelemans & Steeghs 2004

Webbink & Iben 1987

Surviving the direct-impact phase

- Survival of the initial direct impact phase uncertain

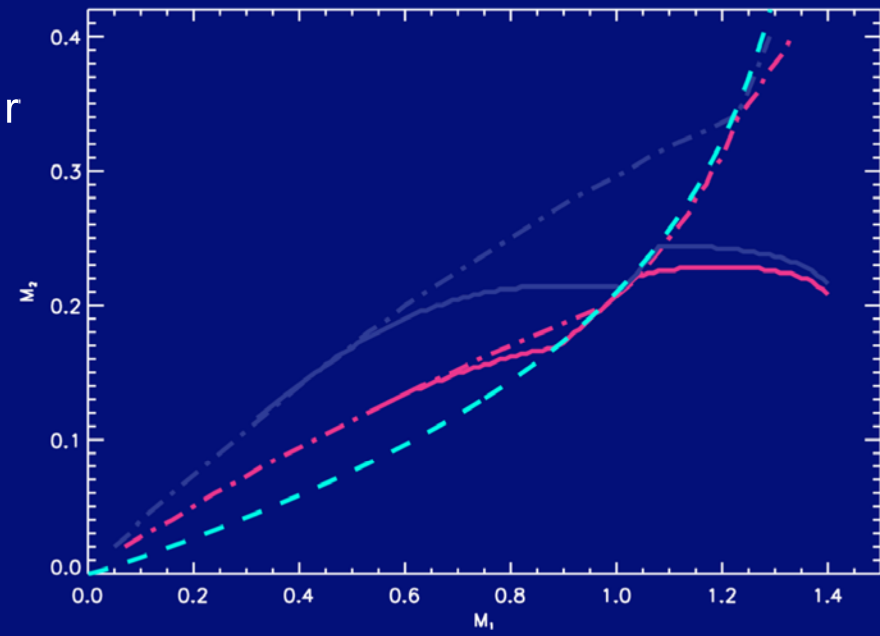


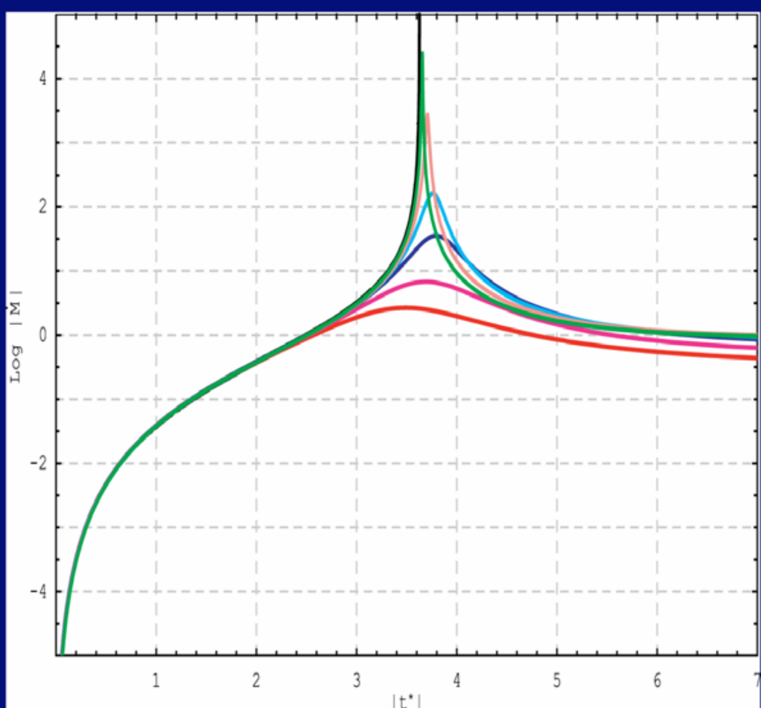
- Crucial for using AM CVns to probe DWD progenitor population

Recent theoretical developments

- Gokhale, Peng & Frank 2007

  v. similar conclusions including donor star tidal and advective term and donor star asynchronism





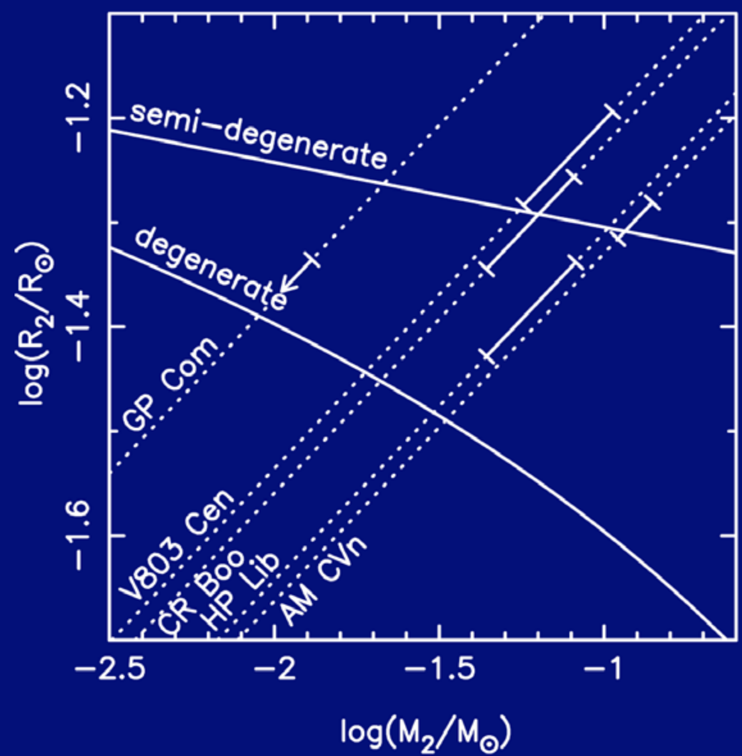
numerical integrations suggest some super-Eddington systems with initial $q > q_{crit}$ may actually survive as turns around

Recent theoretical developments

- Donor stars are (likely) not fully degenerate and their radii do not correspond to cold degenerate objects

  Deloye et al. 2005 , Deloye & Taam 2006

  Imprint of prior evolution, affects orbital period evolution and mass transfer stability

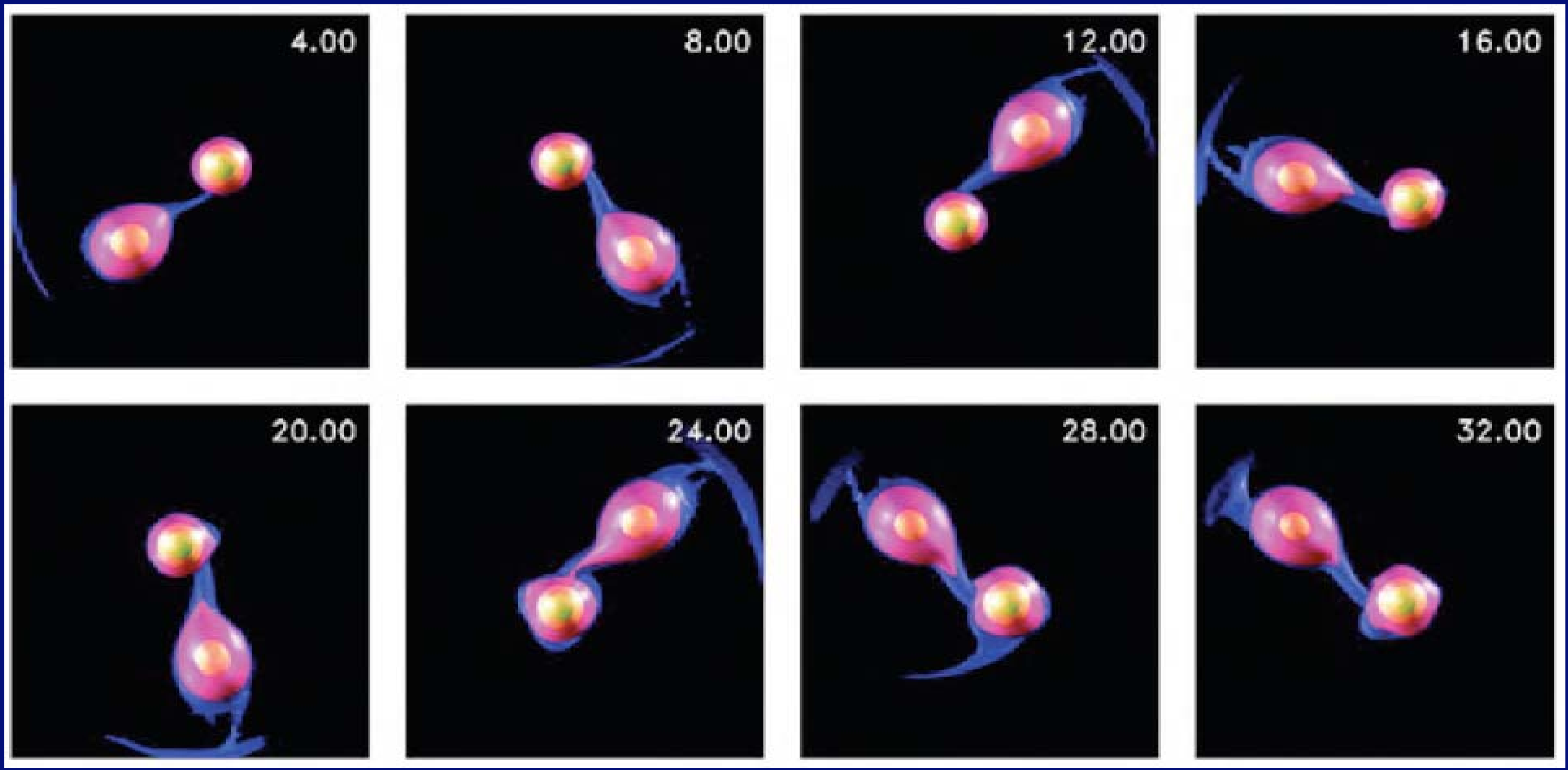


Observations suggest semi-degenerate donors

Roelofs et al. 2007

Recent theoretical developments

- Hydro simulations of initial mass transfer

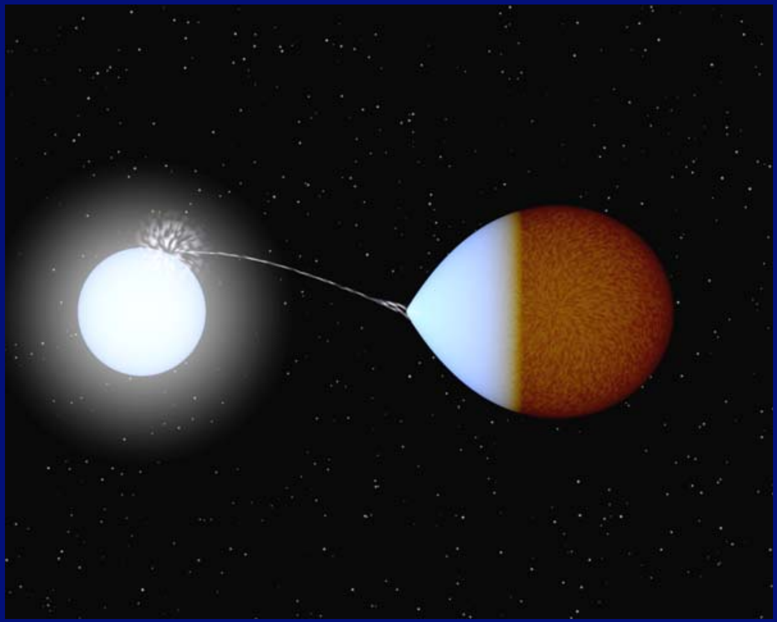


D'Souza et al. 2006

First steps .... At 10^4 M_{Edd} !

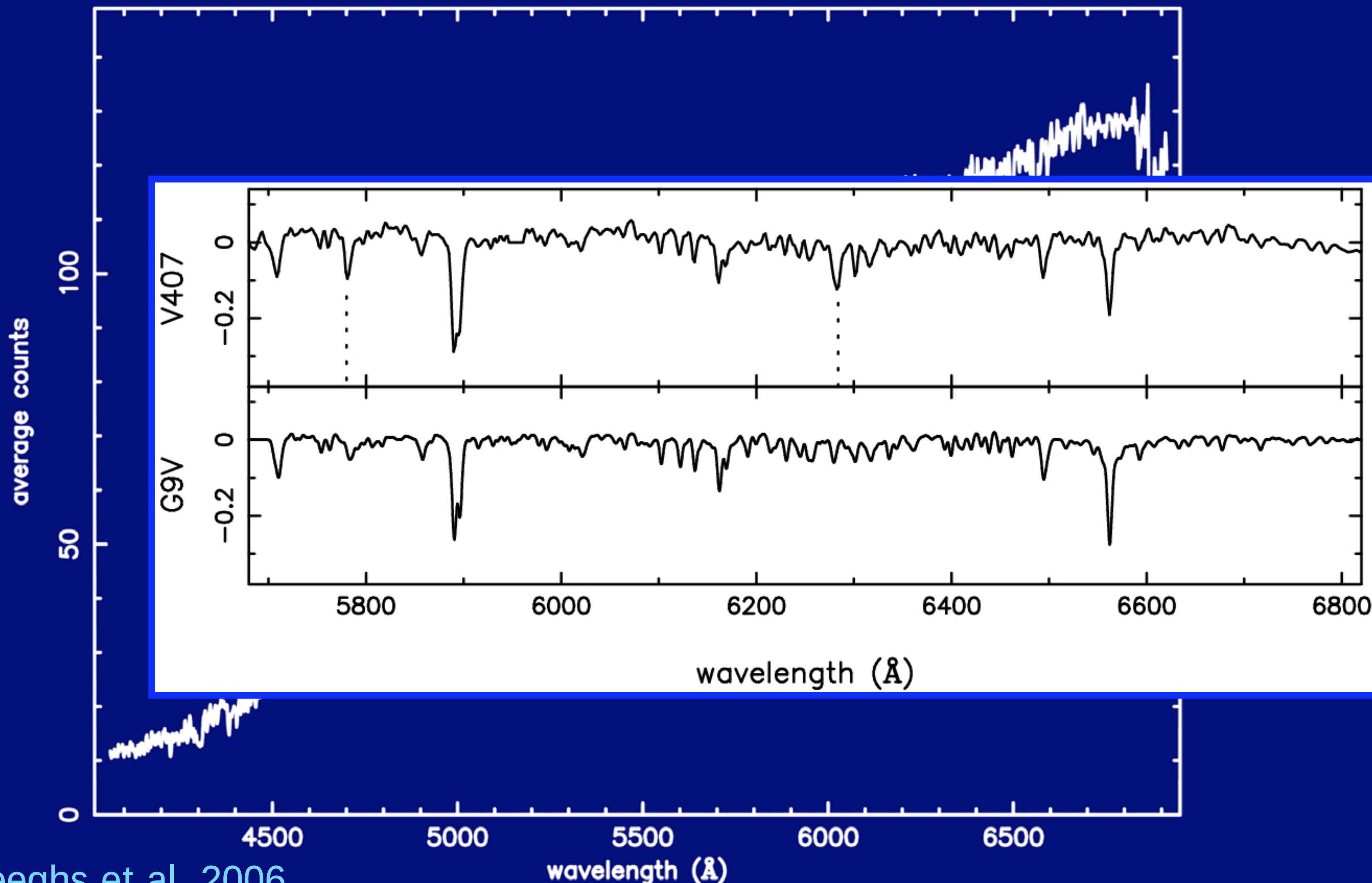
Any systems undergoing direct-impact?

- Direct impact accretion first proposed to explain the 9 min variable V407 Vul (Marsh & Steeghs 2002)
  - Short period
  - Luminous x-ray source with emission pulsed at full amplitude
  - No polarisation; non-magnetic
  - Out of phase optical pulsations
  - No emission lines (?)



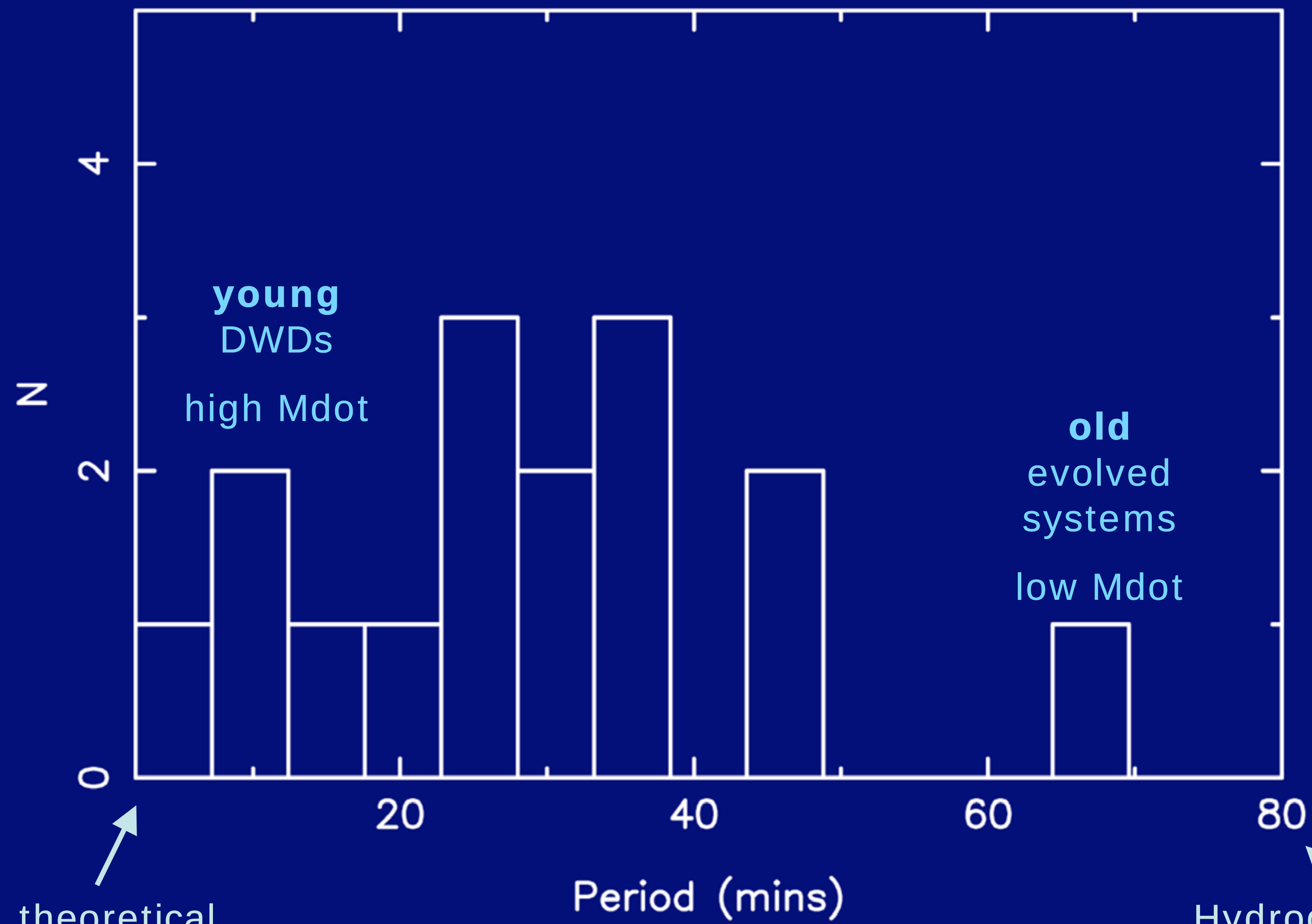
The not-so-cooperative; V407 Vul

- 7 hours (53 orbits) of Gemini GMOS spectroscopy of V407 Vul



Steeghs et al. 2006

Period distribution of current AM CVn systems

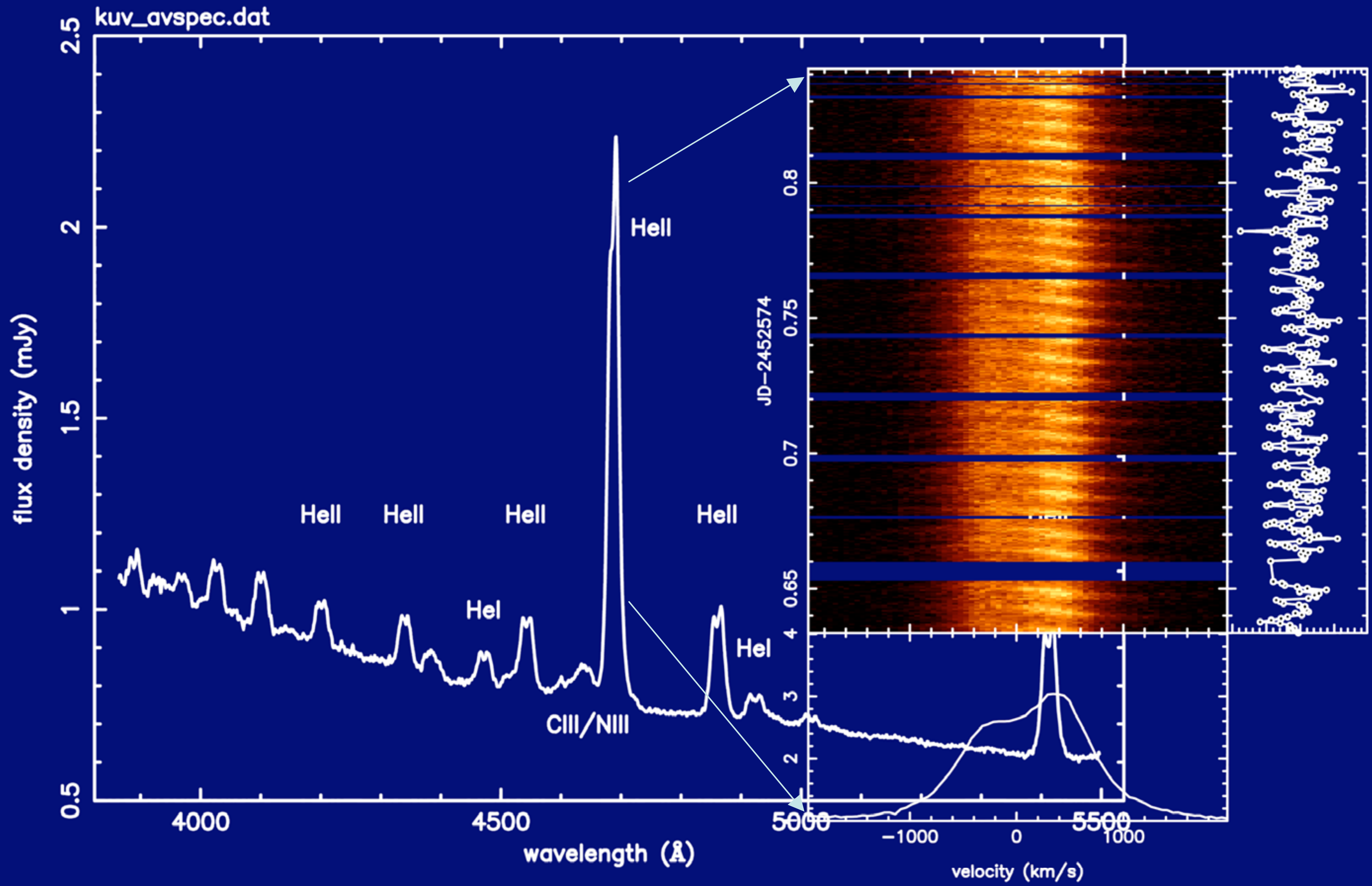


theoretical minimum for 2 WDs (~3m)

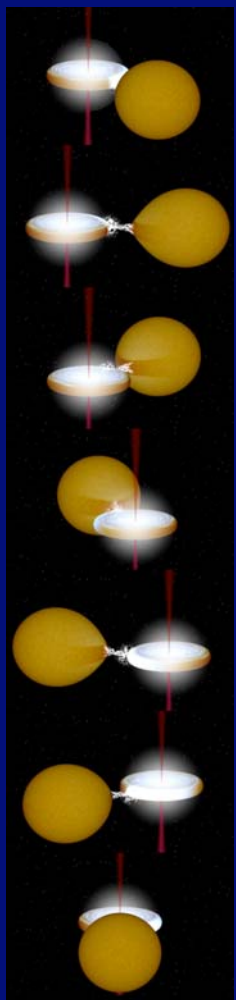
Hydrogen rich period minimum

Danny Steeghs

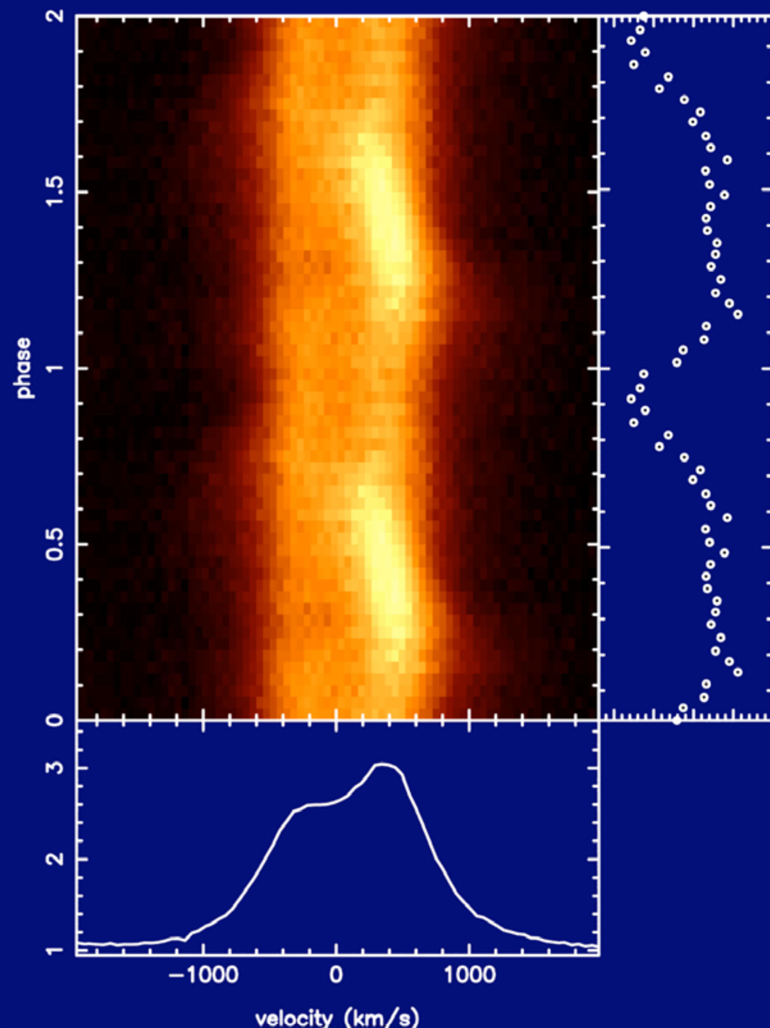
The blue variable ES Ceti with Magellan



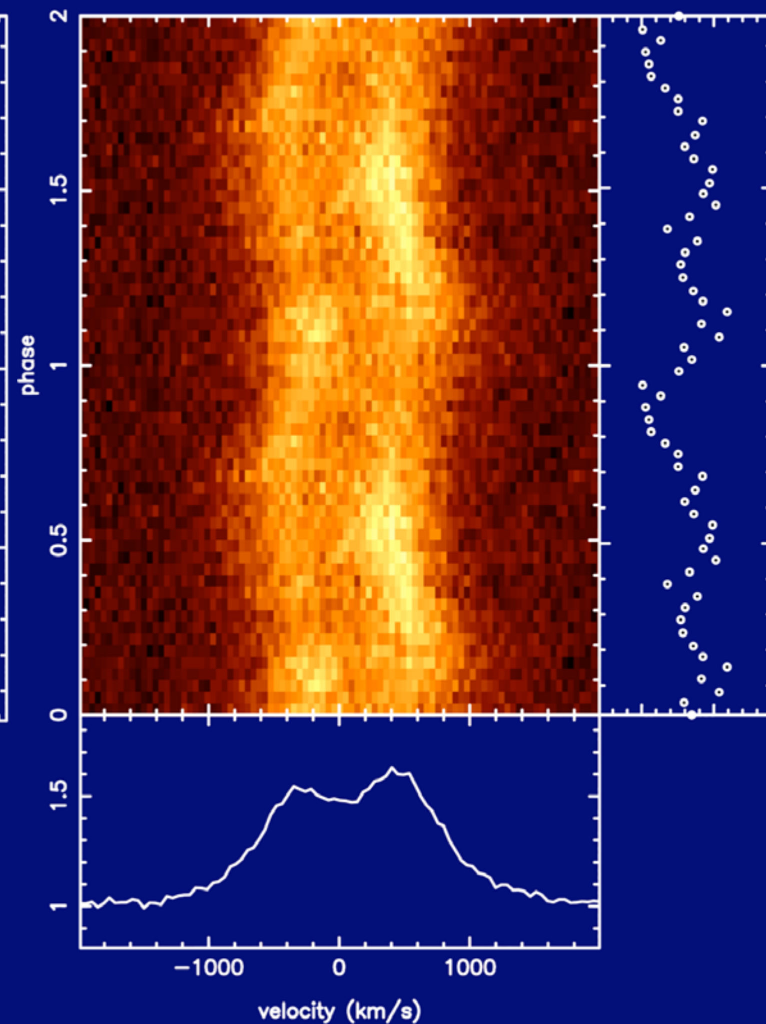
ES Cet : a 10.3 minute binary



HeII 4686



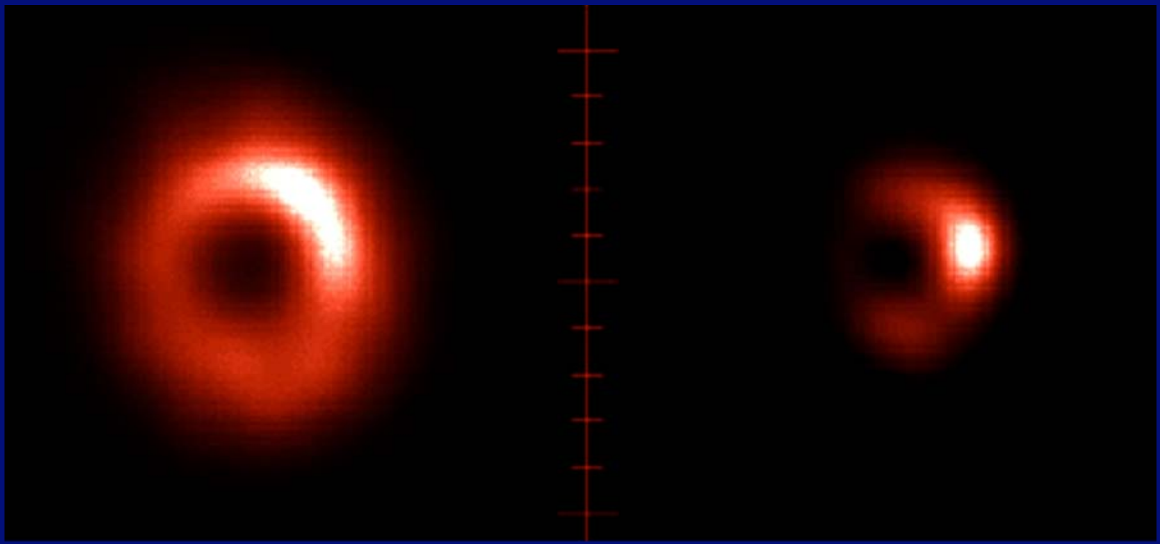
HeII 5411

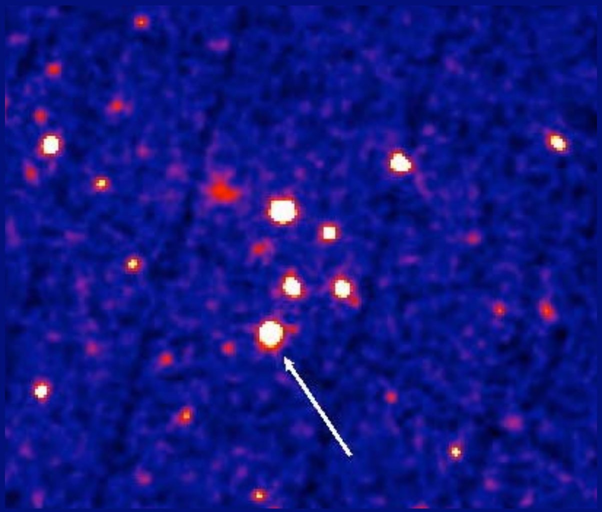


Steeghs, Marsh, Nelemans, Ramsay 2004 ; Steeghs et al. in prep

The accretion geometry

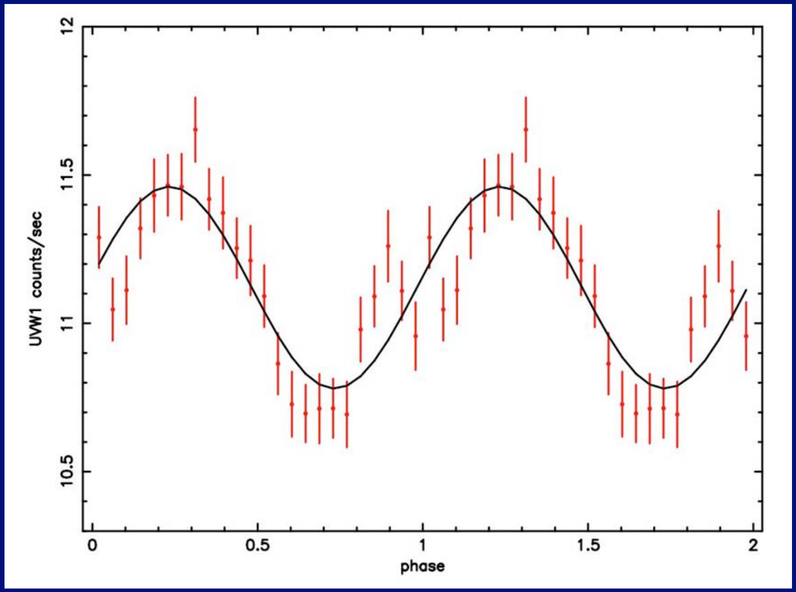
constant variable

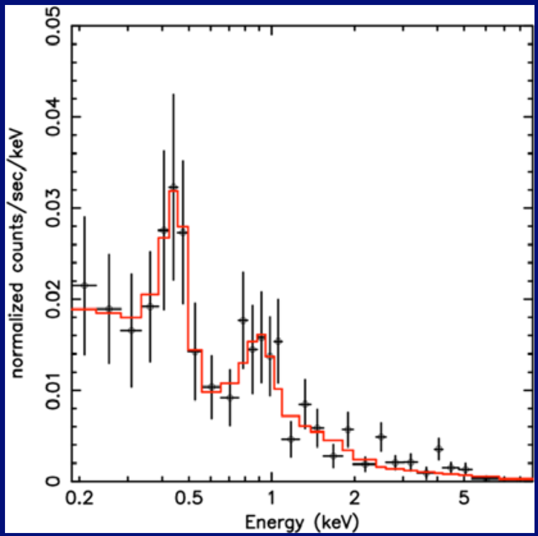




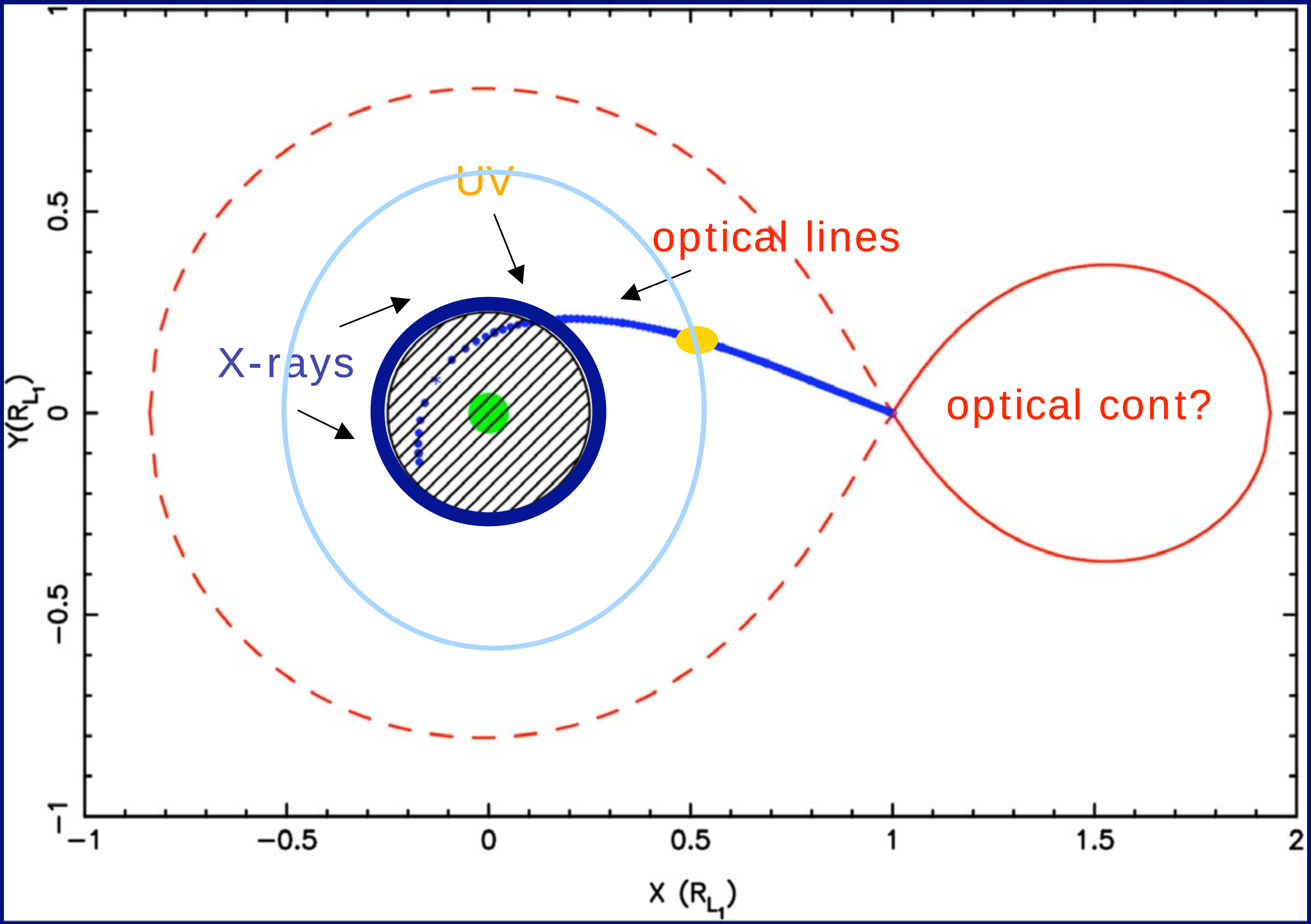
Dynamics: Modulation Doppler imaging

X-ray / UV observations with XMM

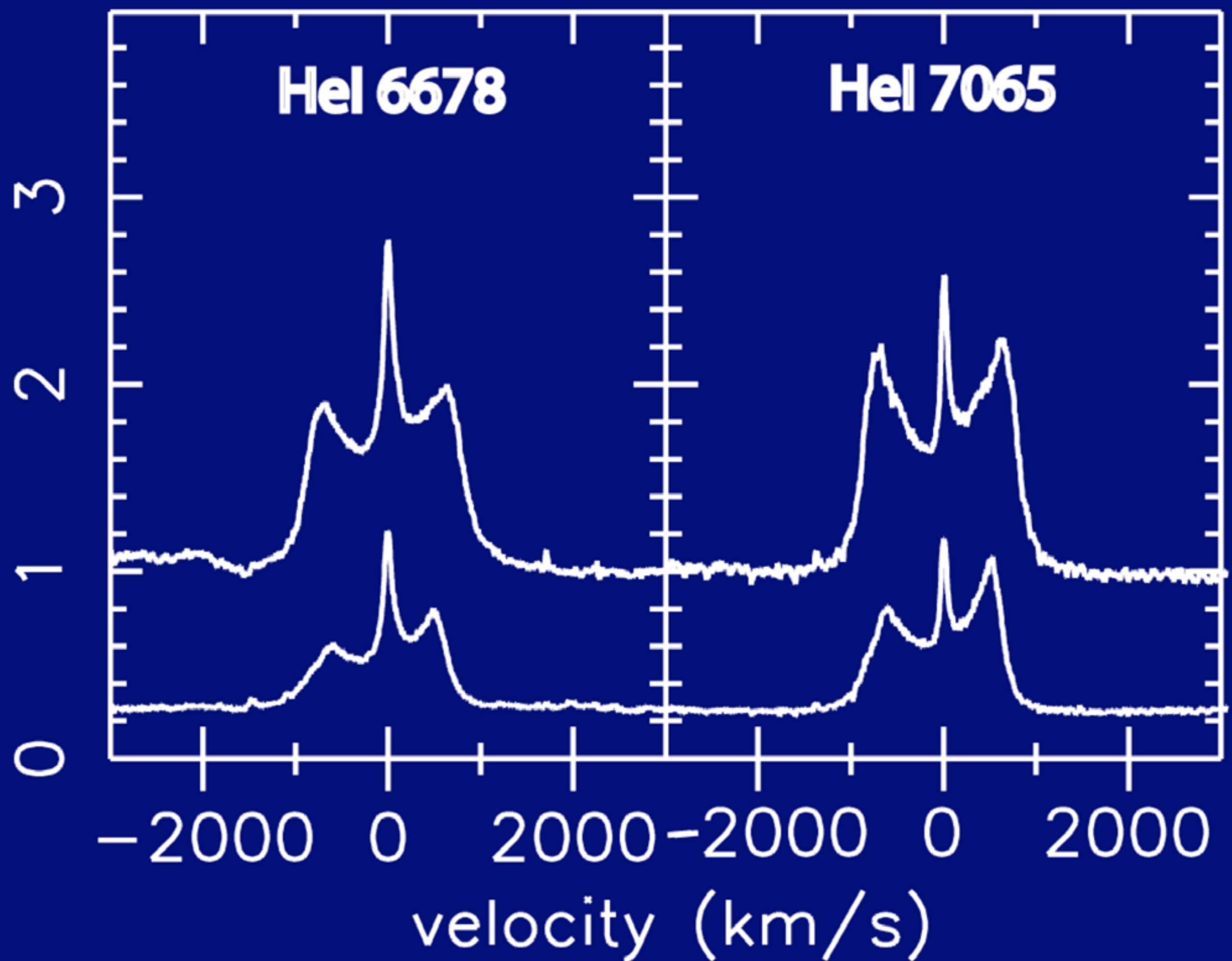




A multi-wavelength picture



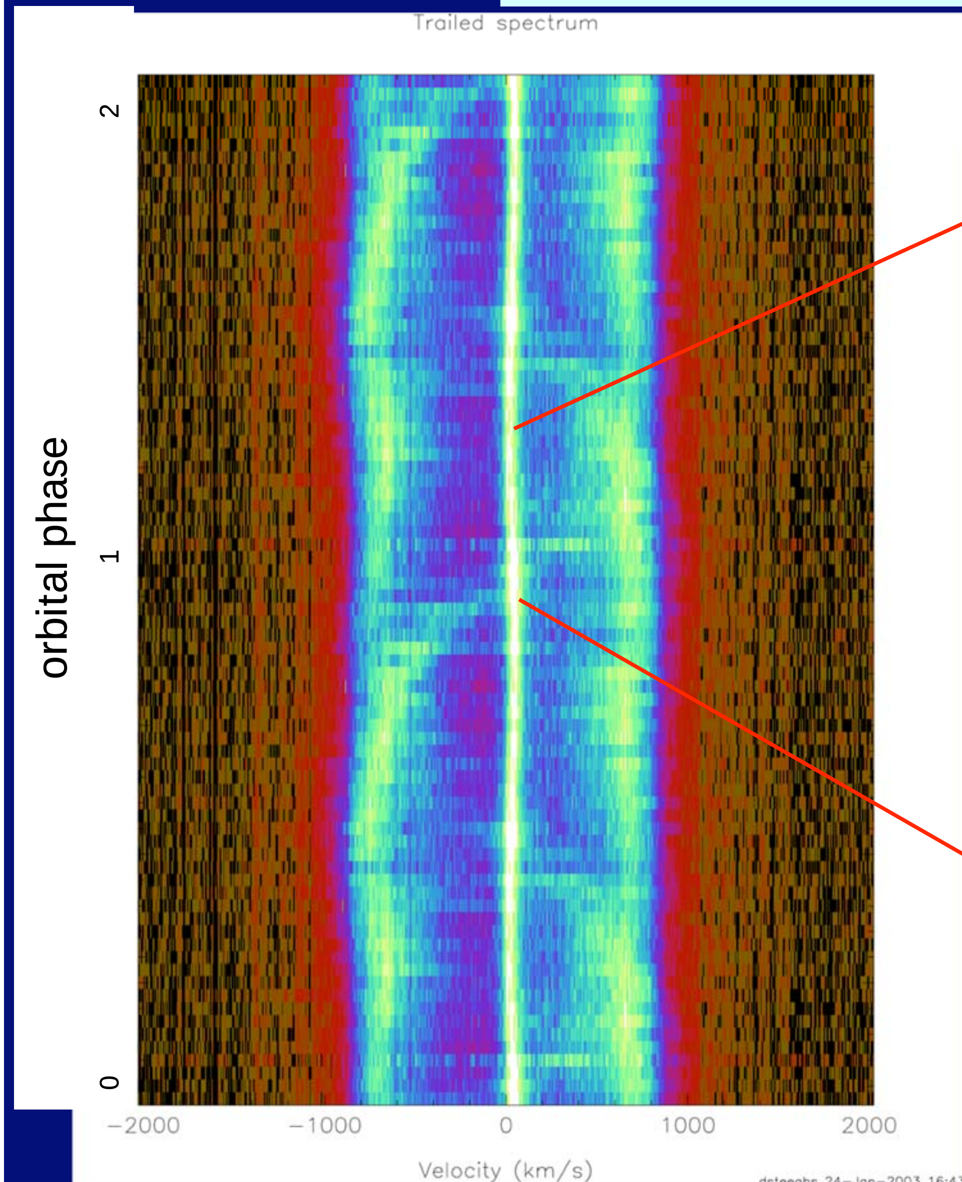
Are the primaries spun-up?



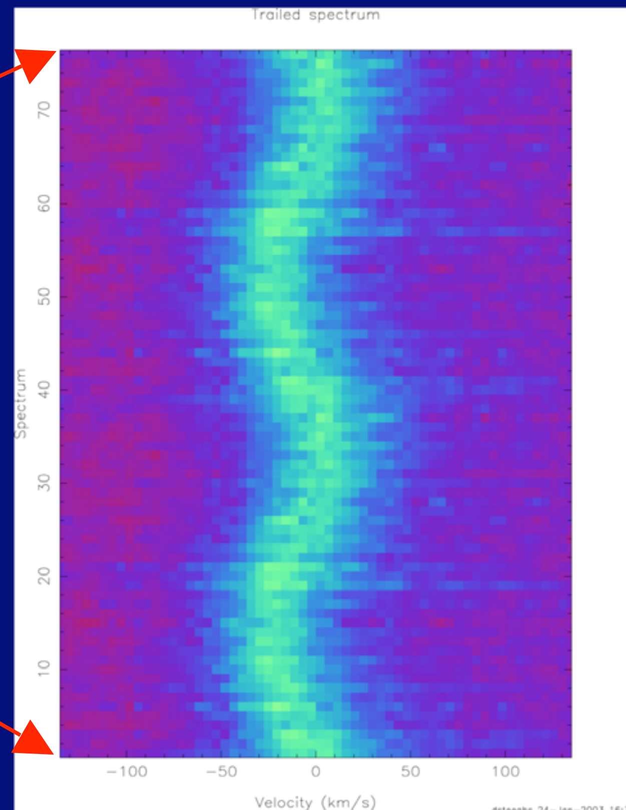
GP Com & V396 Hya

Steeghs et al. 2007

Central spike from the accreting WD



K_1 = 11.7 km/s



Spikes are narrow, imply very slow rotating WD

(if co-rotating)

Summary

- Ultra-compact accreting white dwarfs are an abundant population and provide a crucial anchor for modeling common-envelope evolution and Type Ia DD progenitor route
- Growing sample of stable AM CVn systems, although selection effects are still severe
- Initial phase of mass transfer after contact is dominated by direct-impact geometry
- The survival rate and mass transfer rate evolution depends on the angular momentum exchange (still large uncertainties)
- Fast time-series observations permit accurate orbital periods, accretion geometry and mass (and spin) constraints
- Would like more (short period) systems