Observational implications for Common-envelope evolution

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Introduction: what is common-envelope evolution?

- In 1970s
  - Binaries discovered with separation $<$ progenitor giant
  - Angular momentum loss
- Proposal Paczynski (and Ostriker)
  - (dynamical) unstable mass transfer (or tidal instability)
    $\Longrightarrow$ companion ends up in envelope giant:
    "Common-envelope evolution"
- Outcomes
  - Friction slows down companion, orbital energy lost
  - Part of that is used to unbind envelope
    $\Longrightarrow$ envelope lost, close binary emerges

Outcomes

Simple estimates

$$E_{\rm binding} = \alpha_{\rm CE} \Delta E_{\rm orb}$$

i.e.

$$\frac{G M M_{\rm env}}{\lambda R} = \alpha \left[\frac{G M_{\rm c} m}{2 a_f} - \frac{G M m}{2 a_i} \right]$$

Webbink 1984

or

$$\frac{G (M + m) M_{\rm env}}{2 a_0} = \alpha \left[\frac{G M_{\rm c} m}{2 a_f} - \frac{G M_{\rm c} m}{2 a_0} \right]$$

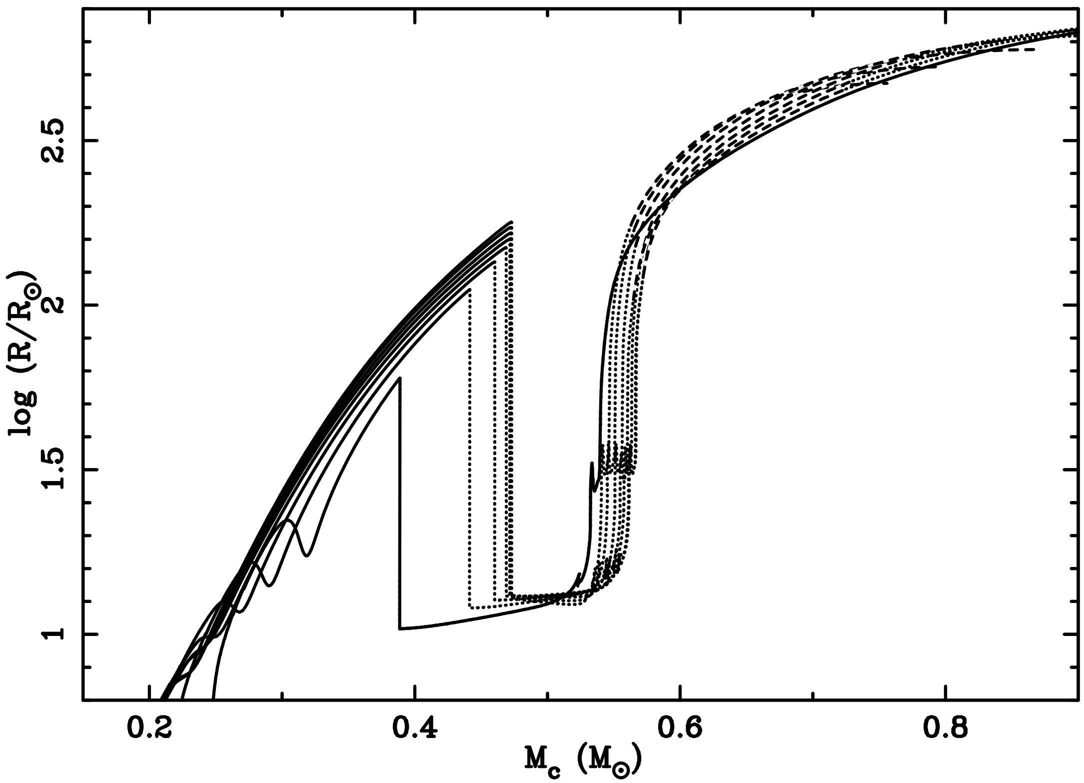
e.g. Tutukov & Yungelson 1979

Why do we bother?

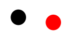
- It is common!
  - ~ 90 per cent of low and intermediate mass close binaries
  - also many massive binaries
- Many close binaries that we observe experienced CE
- Many spectacular phenomena depend on it
  For example SN Ia....

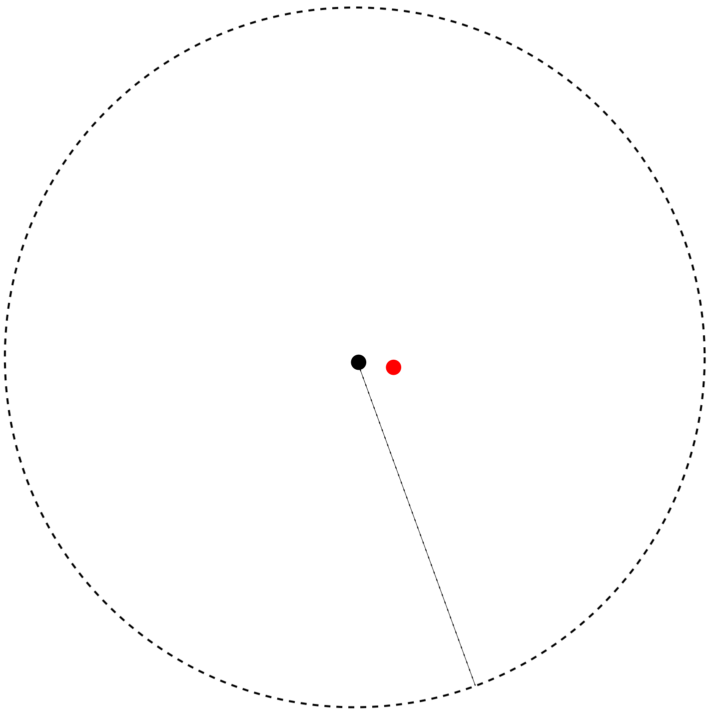
What can we learn from observations?

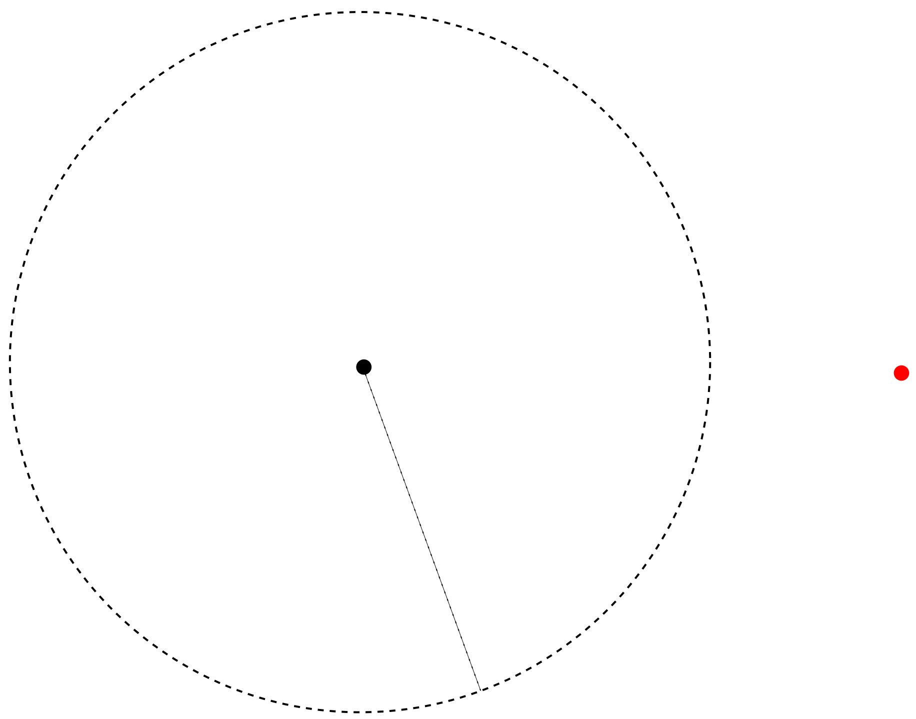
- In white dwarf binaries: reconstruct past evolution
  - White dwarfs were the core of giant
  - Core mass - radius relation gives radius of giant.
  - Radius giant + mass companion $\Longrightarrow$ precursor orbit



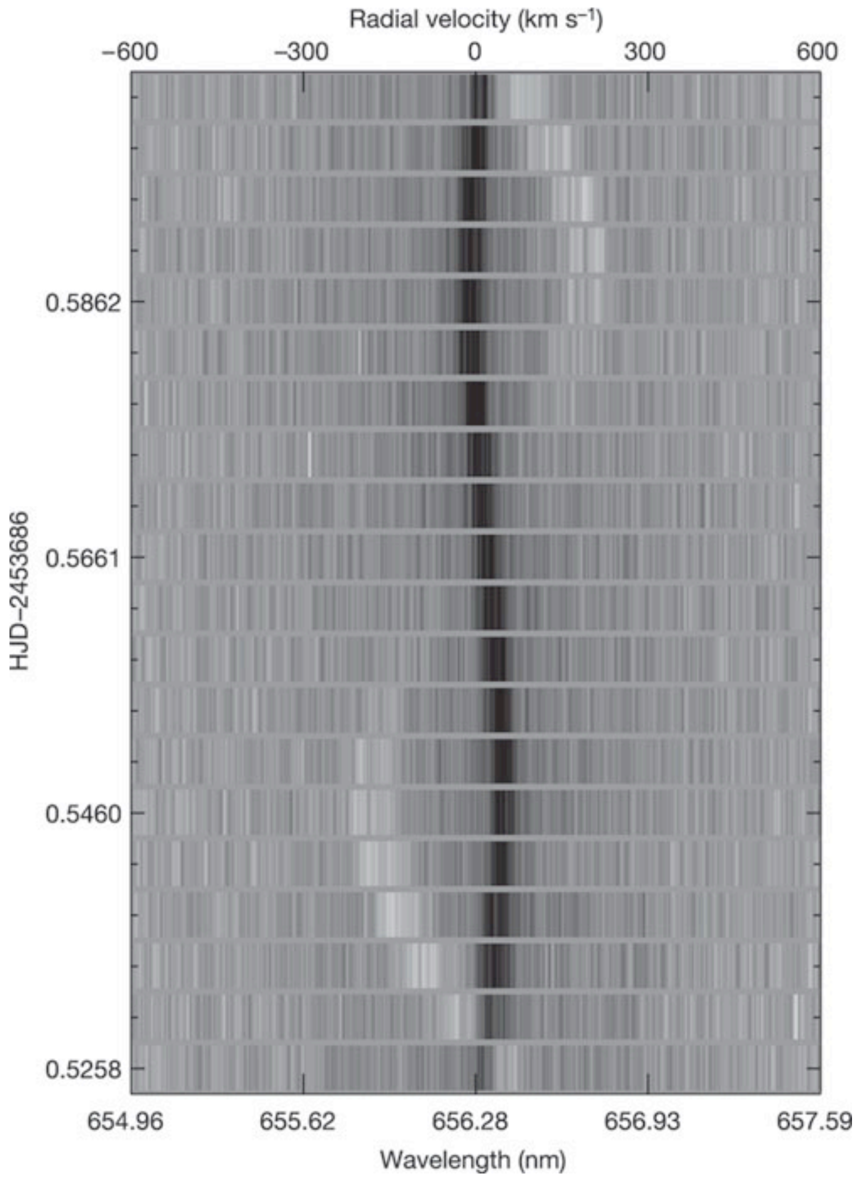
from Van der Sluys et al. 2007







Classes of objects: Pre-CVs (Boris' talk)



WD 0137–349

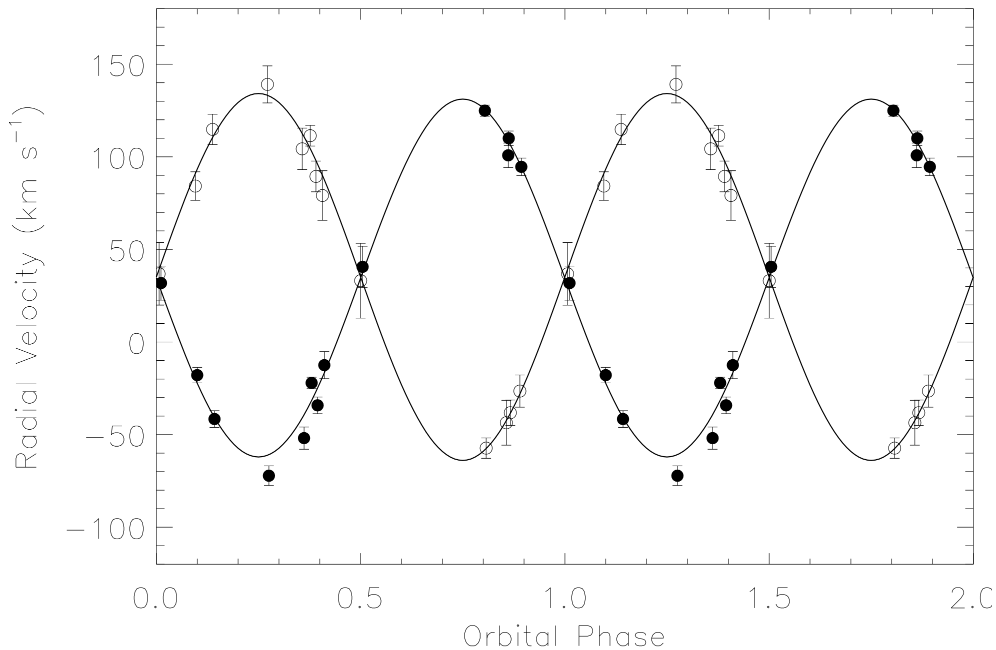
WD + brown dwarf (VLT UVES)

Maxted et al. 2006 Nature 442, 543

Double white dwarfs

- If we observe both white dwarfs
  $\Longrightarrow$ can do trick twice:
  $\Longrightarrow$ reconstruct both mass transfer phases

WD 1204+450



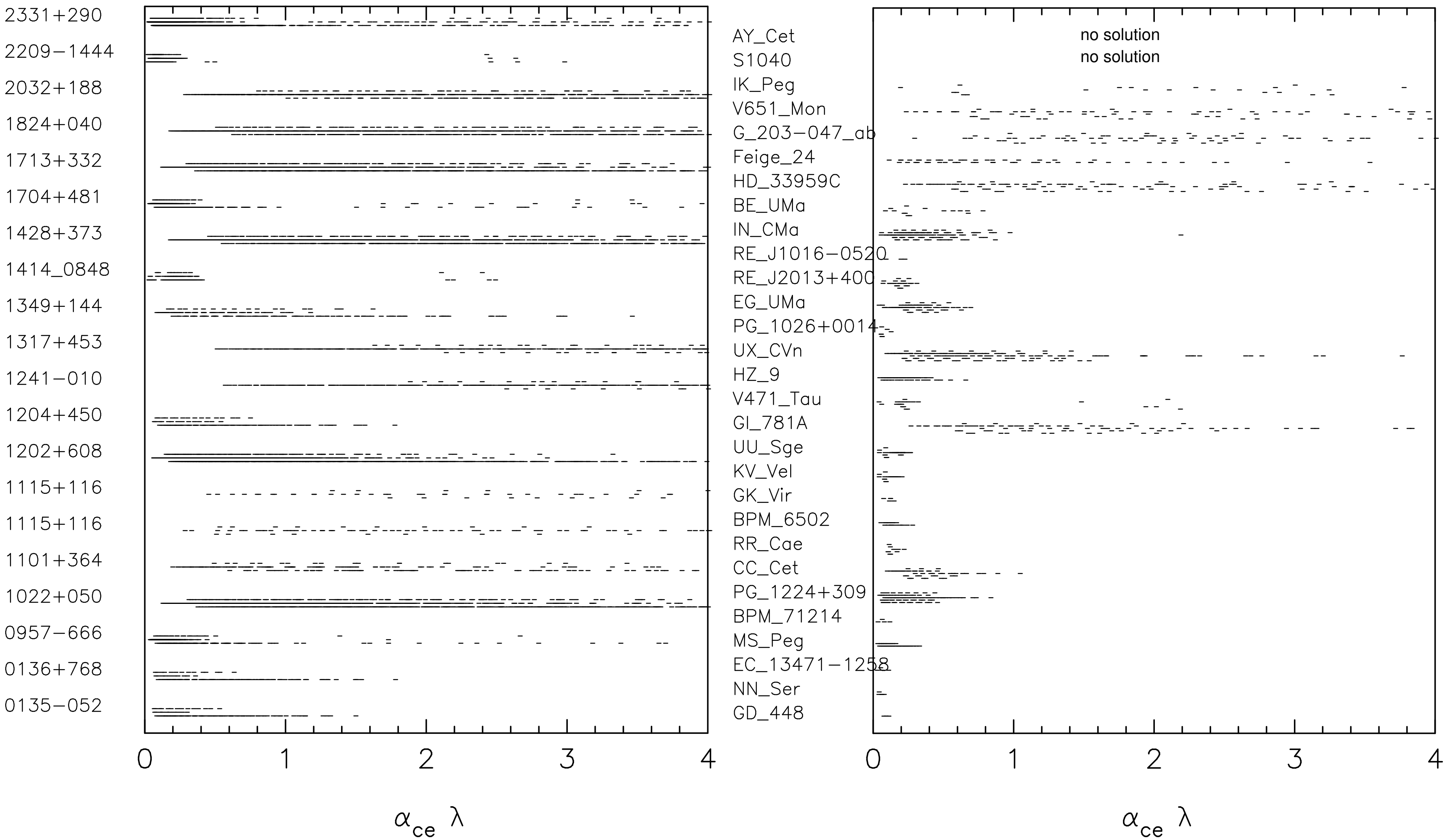
Maxted, Marsh, Moran 2002

Results

- From Nelemans & Tout 2005
  - 19 double white dwarfs (now 25 known)
  - 30 post-CE binaries
- Infer possible values $\alpha\lambda$
  (for different progenitor masses)

$$\frac{GMM_{\rm env}}{R} = \alpha\lambda \left[\frac{GM_{\rm c}m}{2a_f} - \frac{GMm}{2a_i}\right]$$

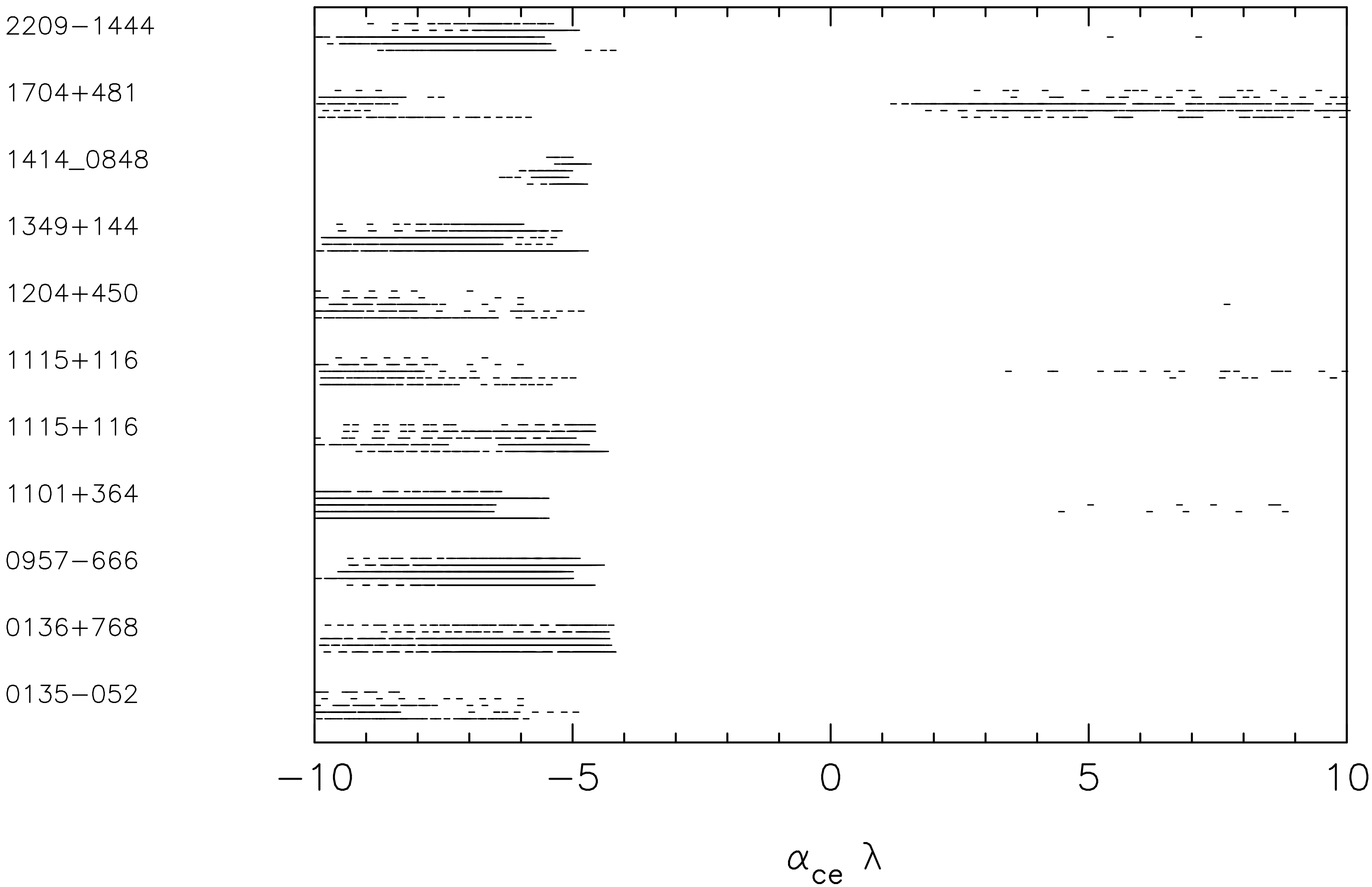
$M_{\rm c}, m, a_f$ observed
M (and thus $M_{\rm env}$), R (and thus a_i) from model



Values $0 < \alpha\lambda < 1$ OK for most

Nelemans & Tout 2005

Complications 1: first phase double WD

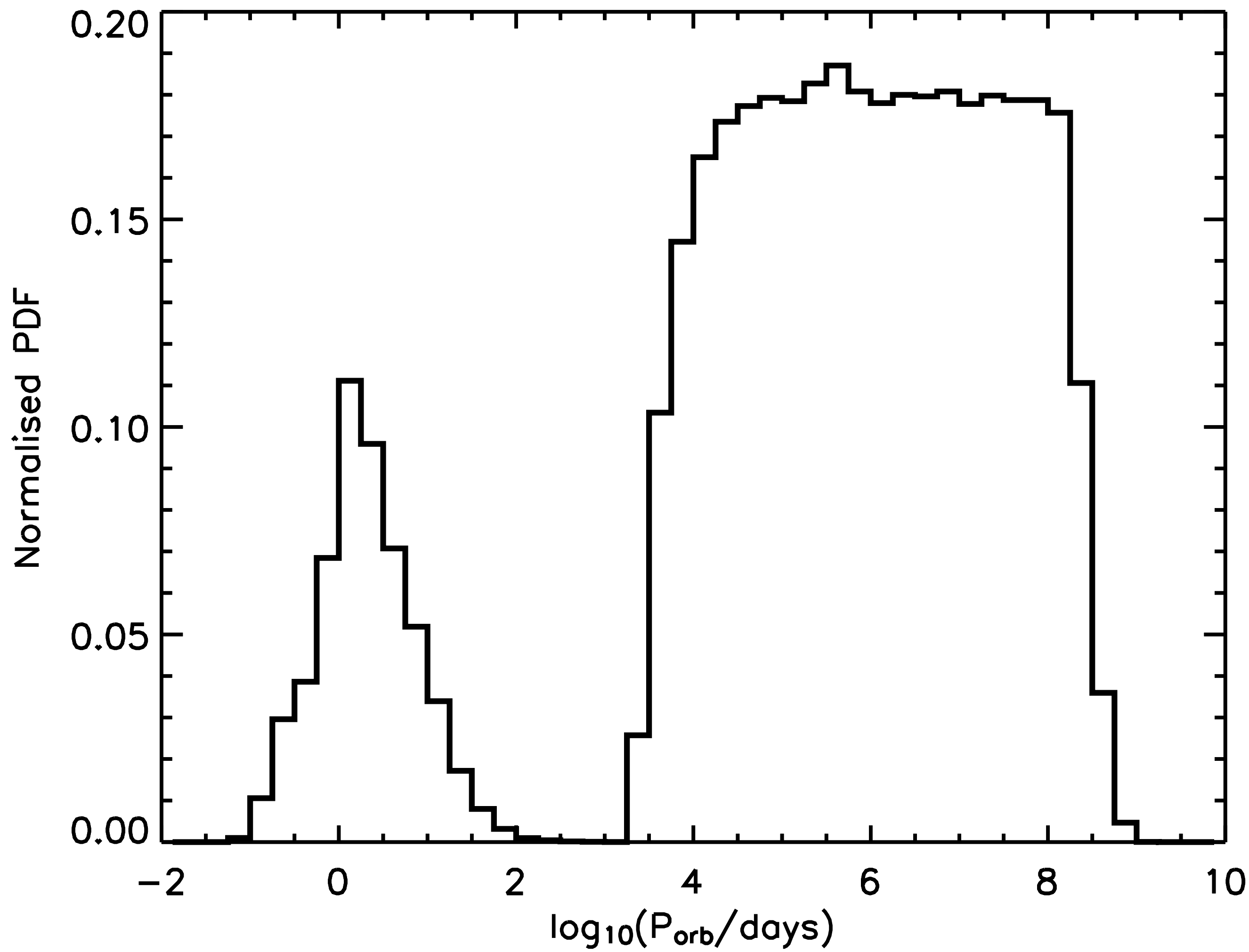


Nelemans & Tout 2005

Complications

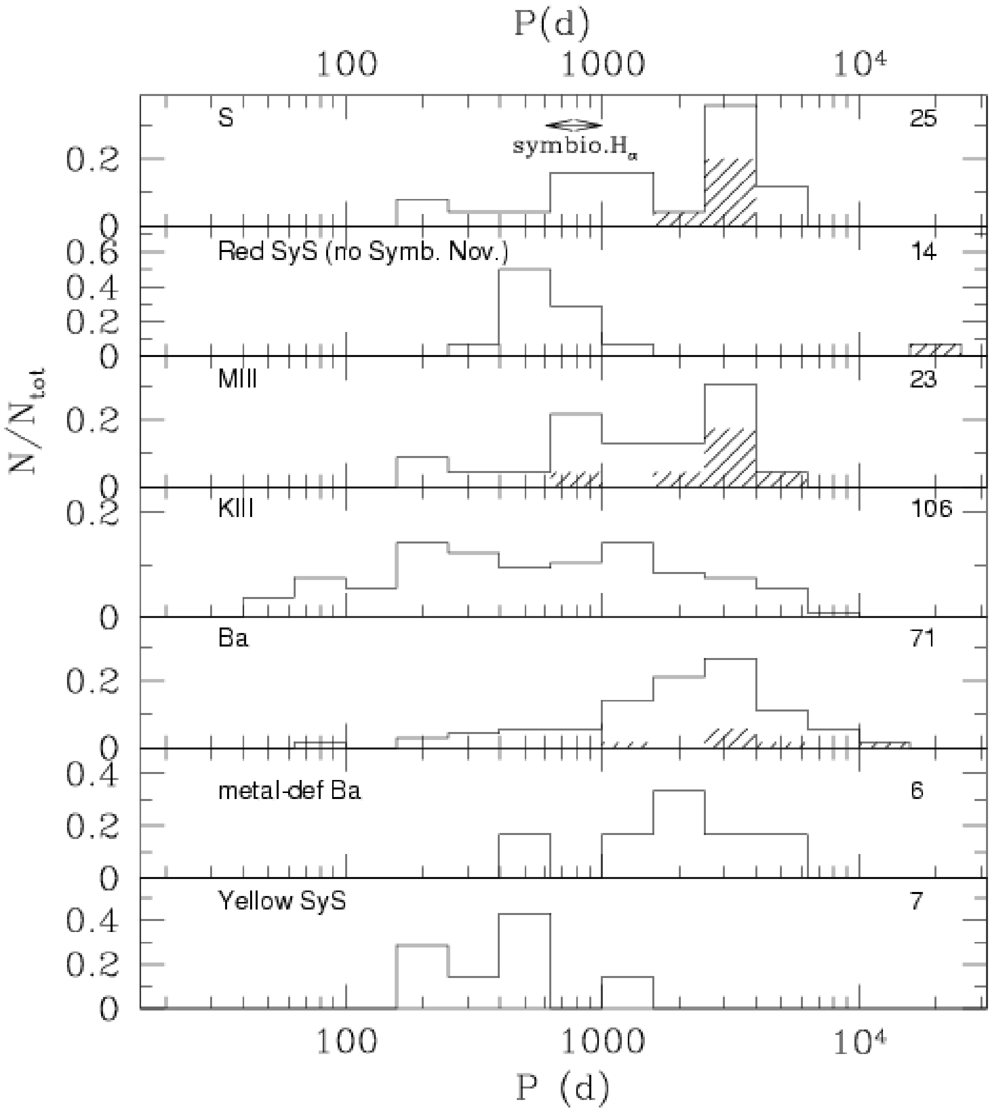
- Are observed systems really post-CE?
- Can have *stable* mass transfer
  - Slow mass transfer
  - Luminosity provides extra energy
- Only possible(?) for donors with radiative envelope (small fraction)
- Do we have all terms in energy balance?

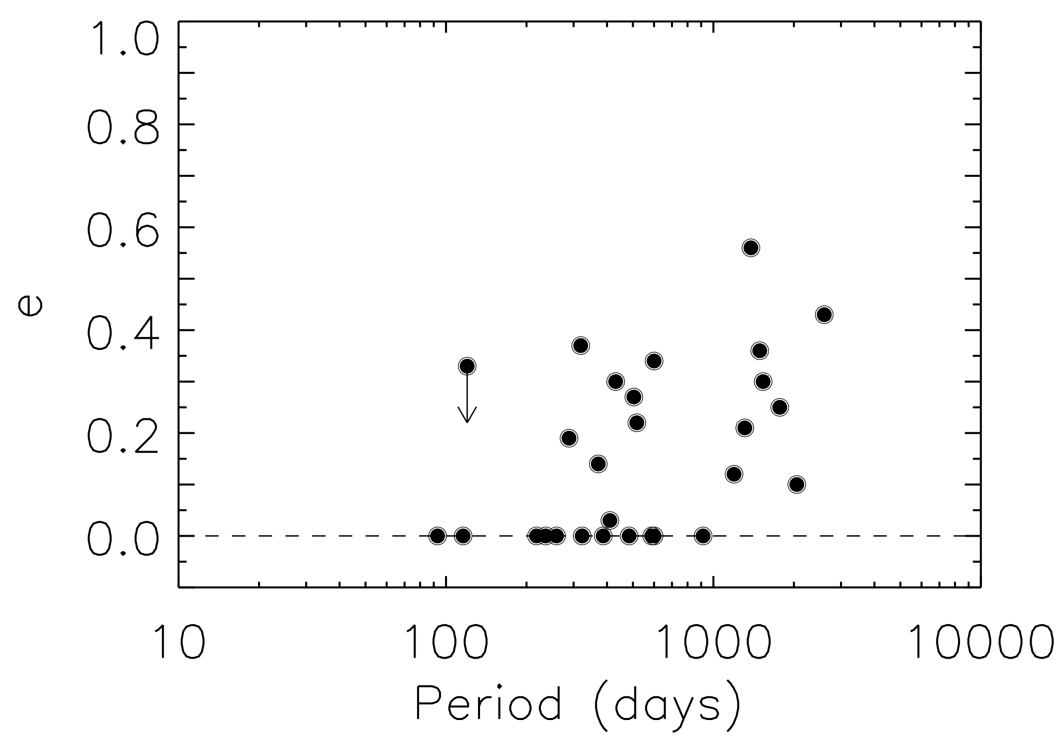
Complications 2: wide WD binaries



Willems & Kolb 2004

Wide (WD) binaries (Jeno's talk)





Jorissen et al., Van Winckel et al.

Interpretations...

- Formed via stable mass transfer

  e.g. Webbink 2007

- Additional energy in common envelope (recombination)

  e.g. Han et al. 1994, Webbink 2007

- Super-Eddington mass transfer

  Beer et al. 2007

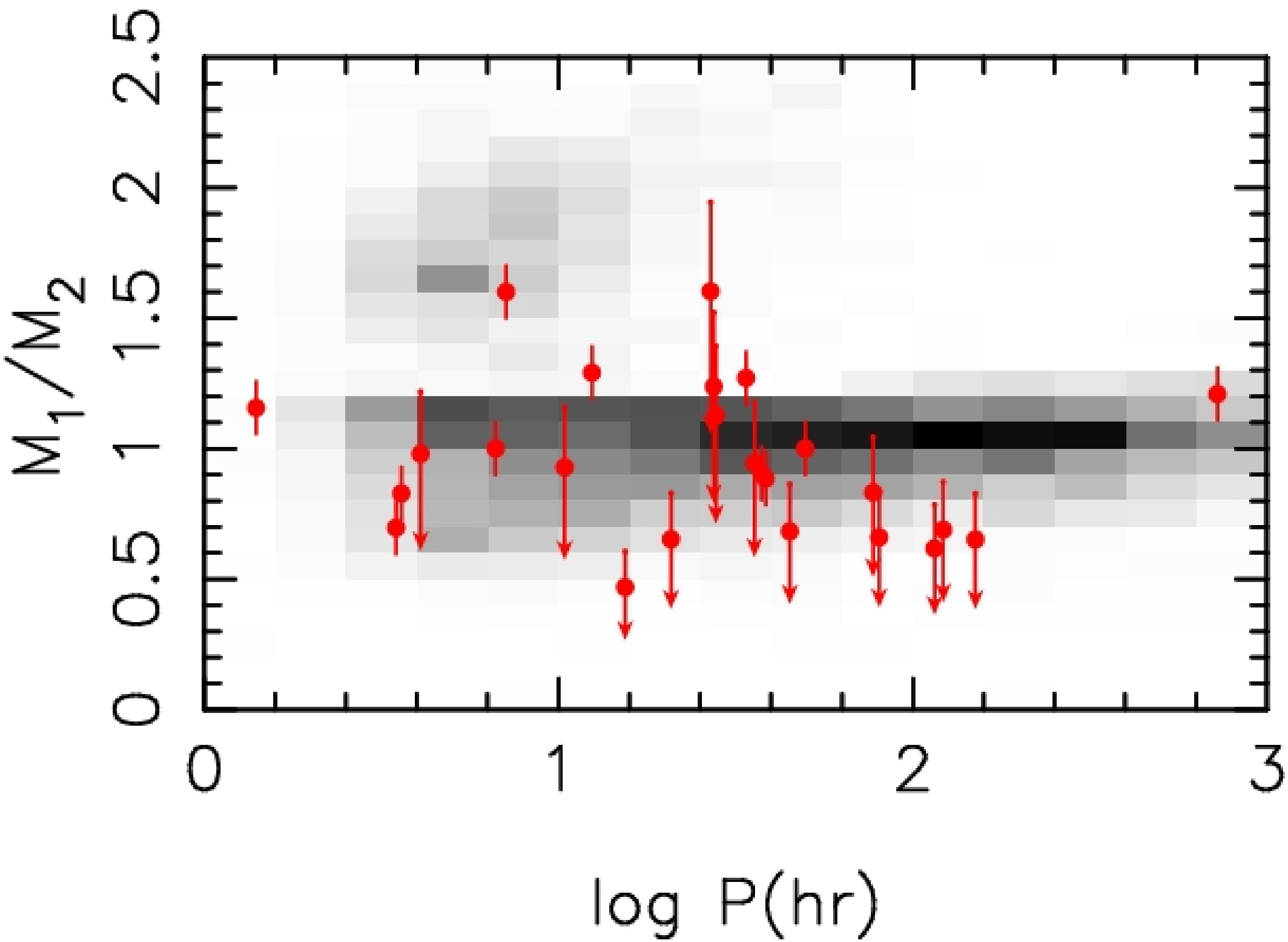
- Angular momentum based formalism

$$\frac{\Delta J}{J} = \gamma \frac{\Delta M}{M}$$

Nelemans et al. 2000; Nelemans & Tout 2005

... and their problems

- Formed via stable mass transfer
  GN: not enough initial parameter space
  (but some do, e.g. WD 2020)
- Additional energy in common envelope (recombination)
  Limited to most evolved giants?
- Super-Eddington mass transfer
  Cannot explain shortest binaries (be careful with γ!)
  Expansion accretor
  Matter “bounces” out of potential well
- Angular momentum based formalism
  What is the physics?



Nelemans et al., 2005

Conclusions

- Observed white dwarf binaries can be used to study CE
- This is good because theoretical problem is (very) hard
- Systems of giant + low-mass companion (WD or M):
  $\Longrightarrow$ short orbit
- First phase in evolution to double WD not
- Important to study post mass transfer
  WD + intermediate mass companions