The Next Generation of Binary Evolution Models

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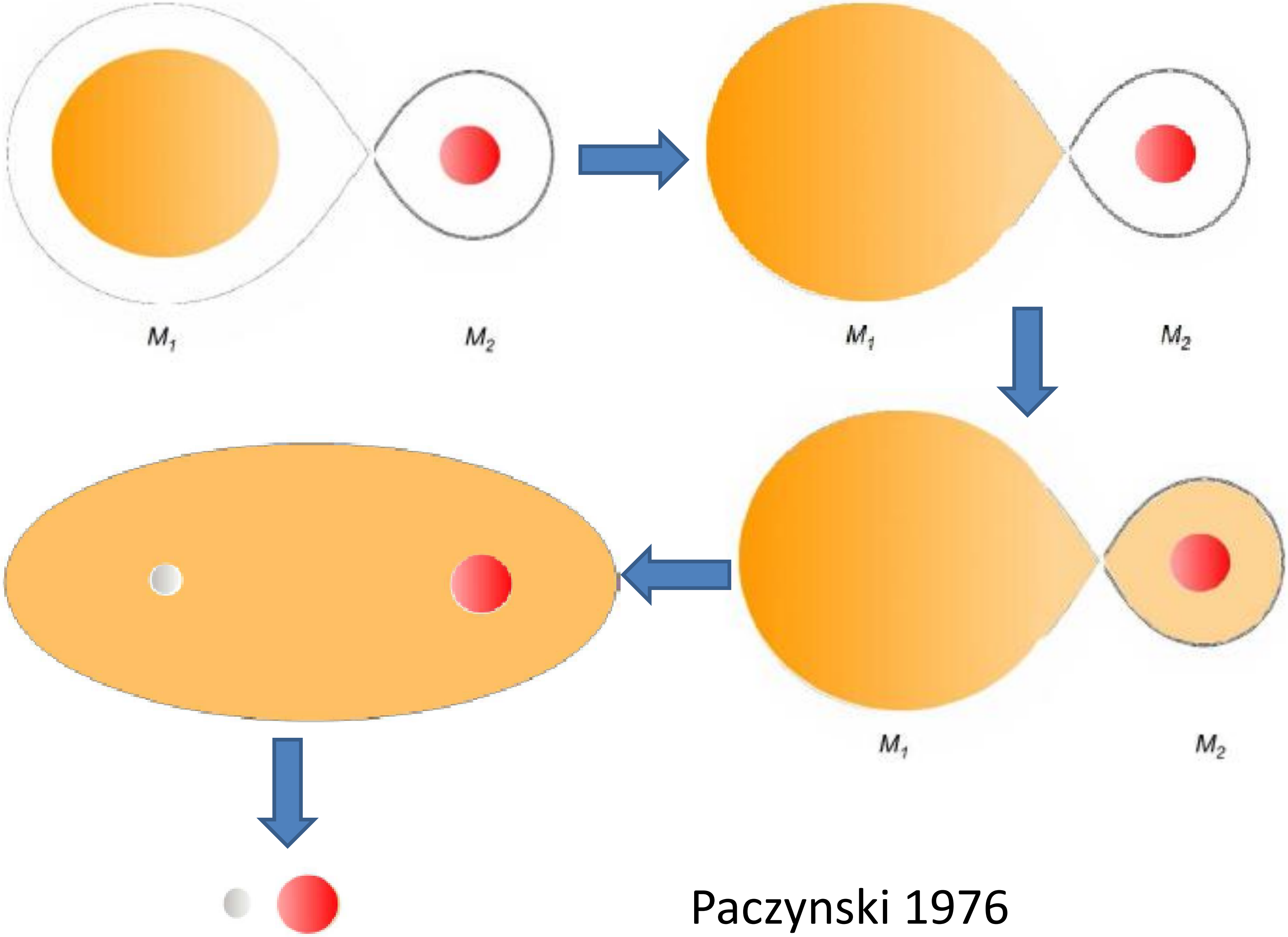
Overview

- Testing the disrupted magnetic braking model

- How well can we model the common envelope (CE) phase?

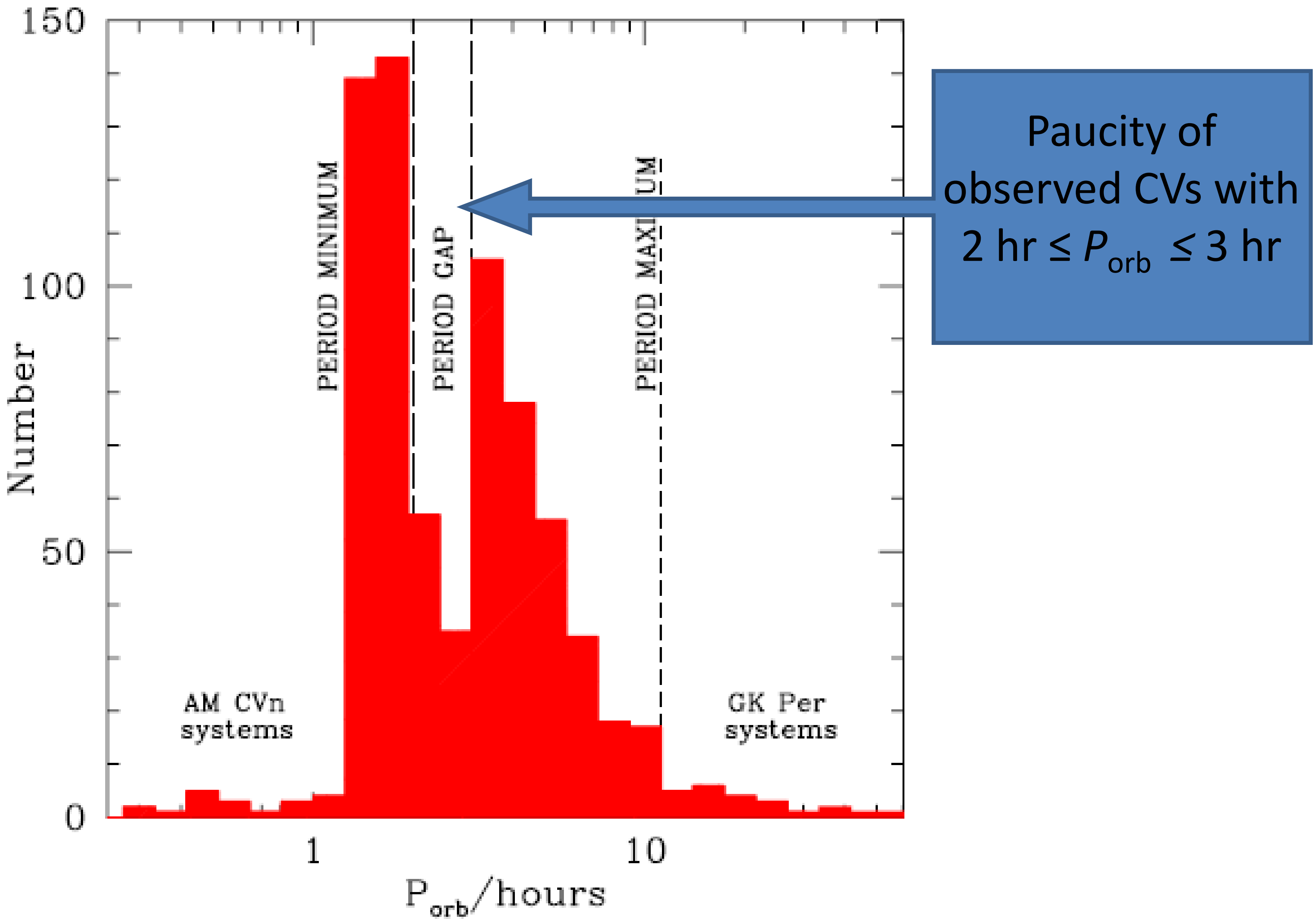
- Calculating the CE ejection efficiency

- Introducing BINSTAR: state-of-the-art binary evolution code



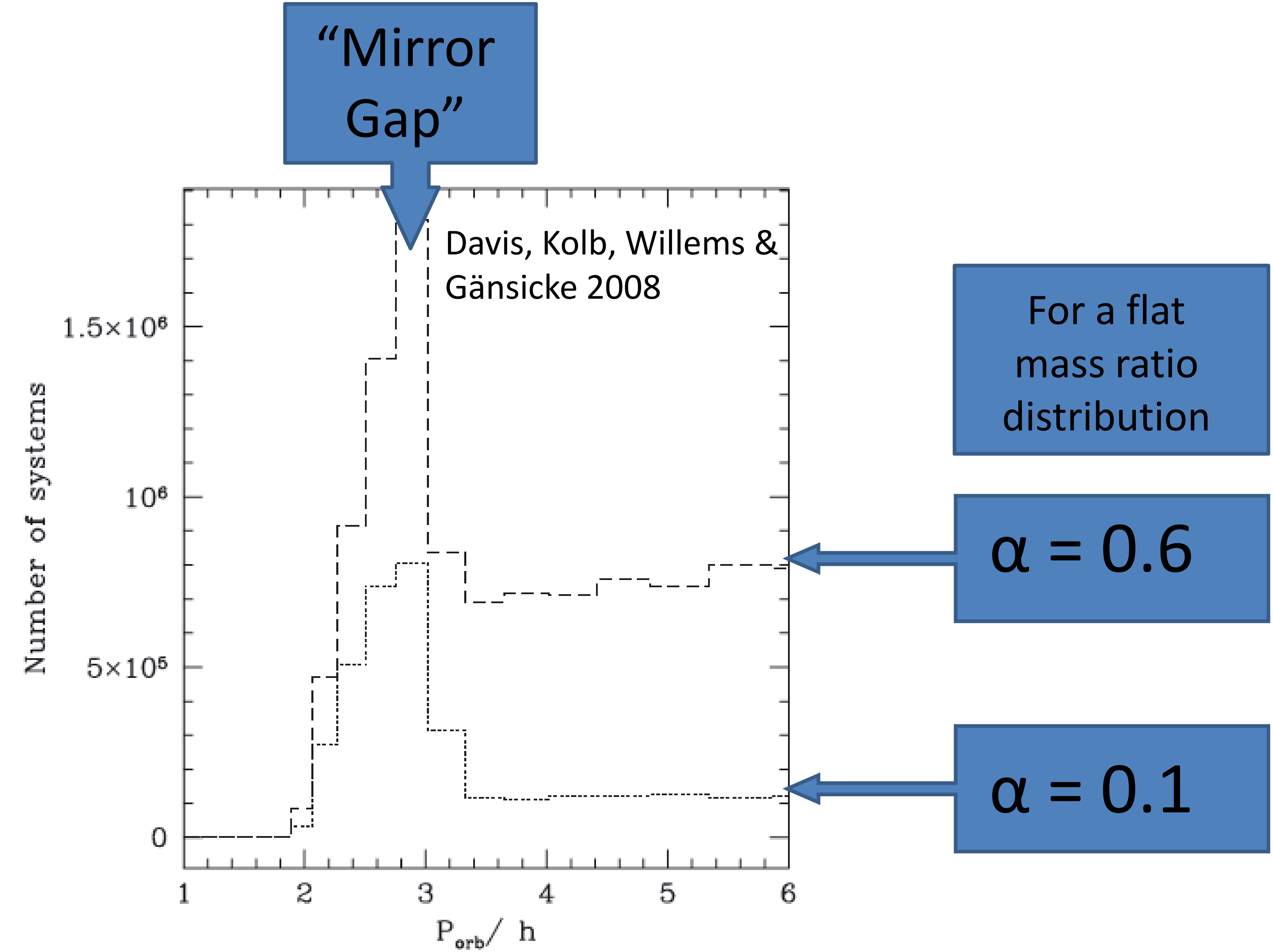
Paczynski 1976

Ritter & Kolb 2003 catalogue, Edition 7.9 (2008)



BiSEPS

- **B**inary **S**ystem **E**volution and **P**opulation **S**ynthesis (Willems & Kolb 2002)
- Single star evolution fit formulae: Hurley, Pols & Tout (2000)
- Based on binary evolution scheme outlined in Hurley, Tout & Pols (2002)
- Incorporated physically consistent treatment of mass transfer and reaction of donor to mass loss (see Davis et al. 2008)

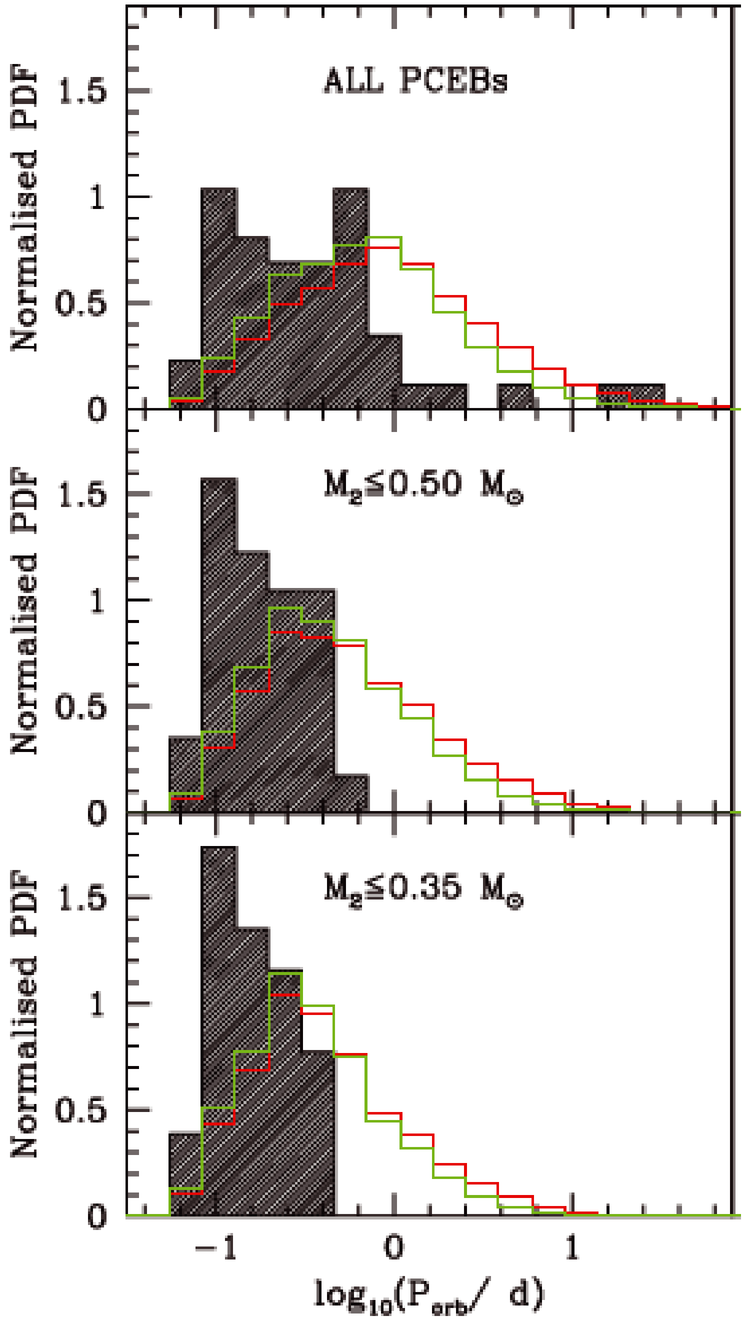

"Mirror Gap"
Davis, Kolb, Willems & Gänsicke 2008
For a flat mass ratio distribution
α = 0.6
α = 0.1
Number of systems
1.5×10⁶
10⁶
5×10⁵
0
1
2
3
4
5
6
Porb/ h

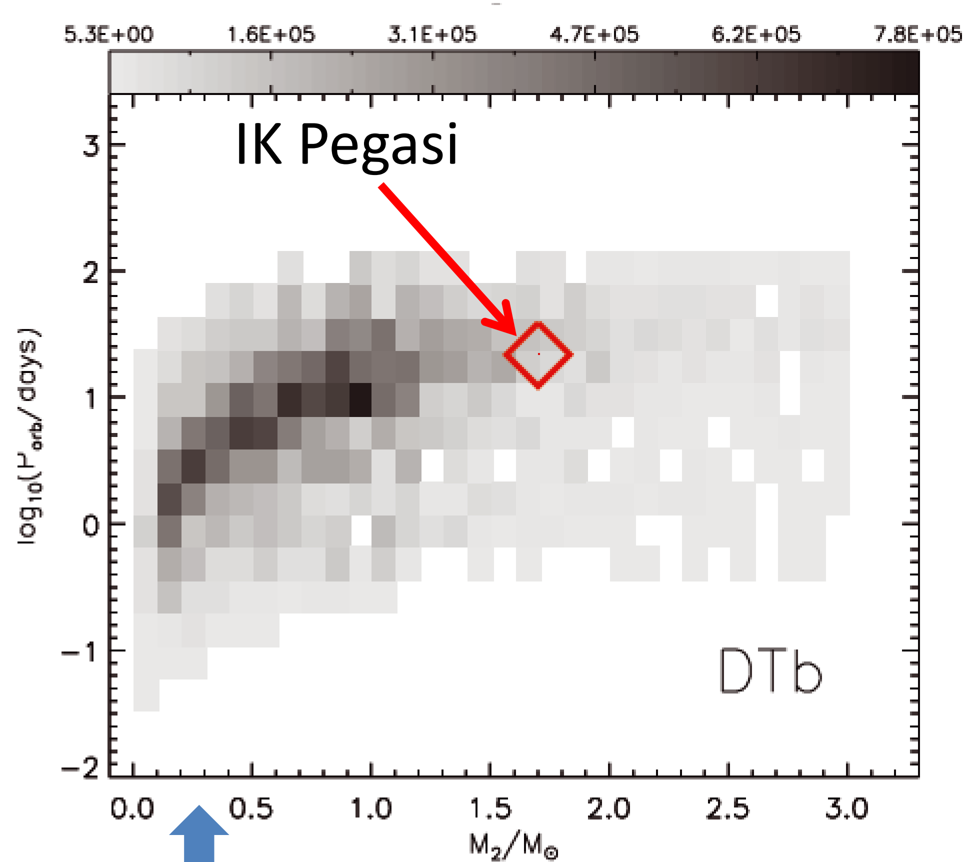
Modelling the CE phase

Energy Budget Webbink 1984	Angular Momentum Budget Nelemans et al. 2000
$\alpha_{CE}\ \Delta E_{orb} = E_{bind}$	$\frac{\Delta J_{bin}}{J_{bin}} = \gamma \frac{\Delta M_{bin}}{M_{bin}}$

So which is it?

Davis, Kolb & Willems 2010

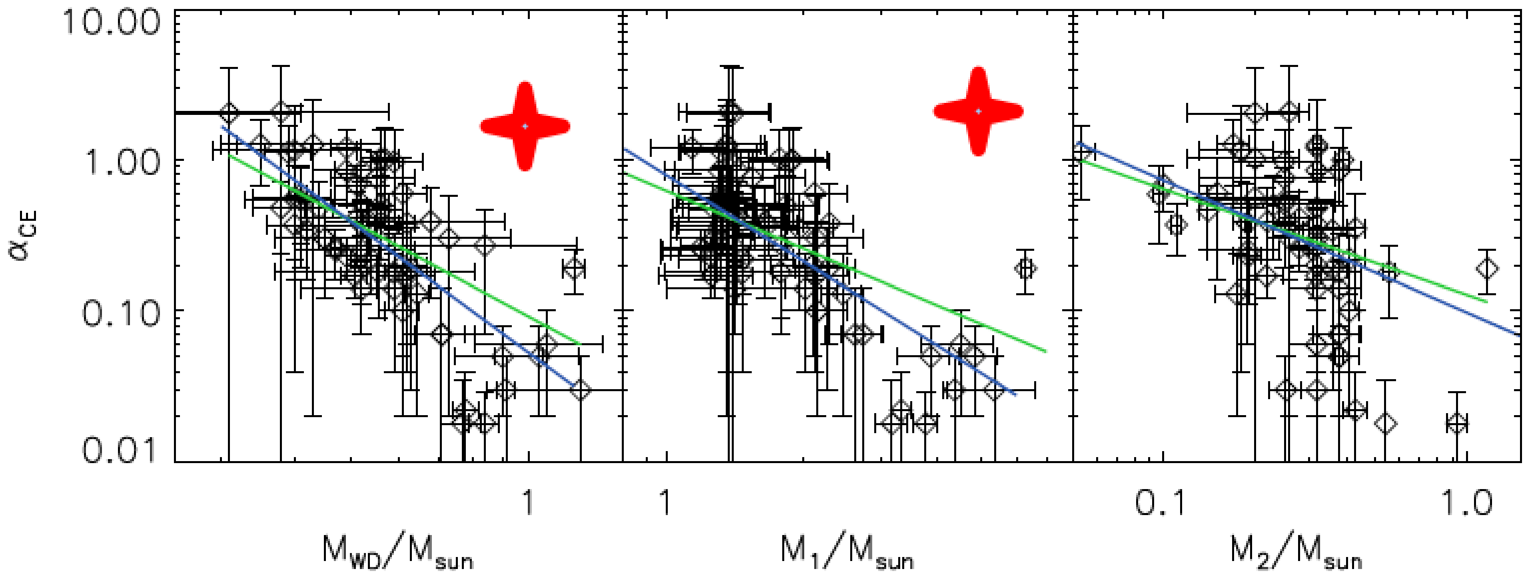




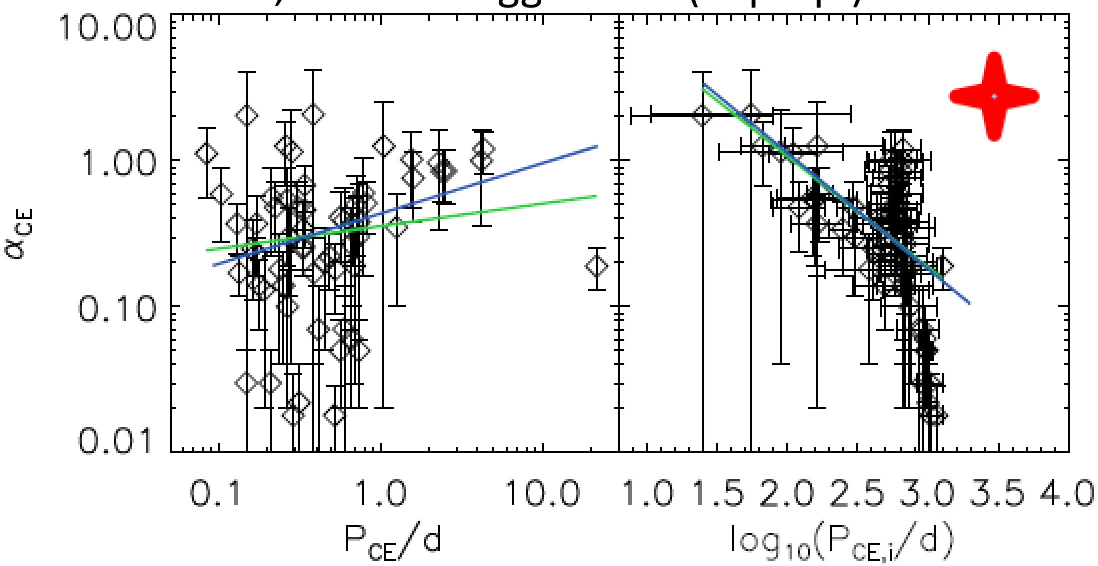
Require $\alpha_{CE} > 1$: "missing" energy source?

Cannot reproduce observed sharp decrease in number of PCEBs.

Reconstructing the CE Phase



Davis, Kolb & Knigge 2011 (in prep.)



Internal energy of the progenitor giant envelope considered.

Linear fit statistically better than a constant one

Modelling α_{CE}

- Multi-regression fits

- Does adding additional terms improve the model?

$$\log_{10} \alpha_{CE} = \beta_0 + \sum_{i=1}^{m} \beta_i \log_{10} Q_i \ , \quad Q \in \{P_{CE,i}, M_2, M_{WD}, M_1\}$$

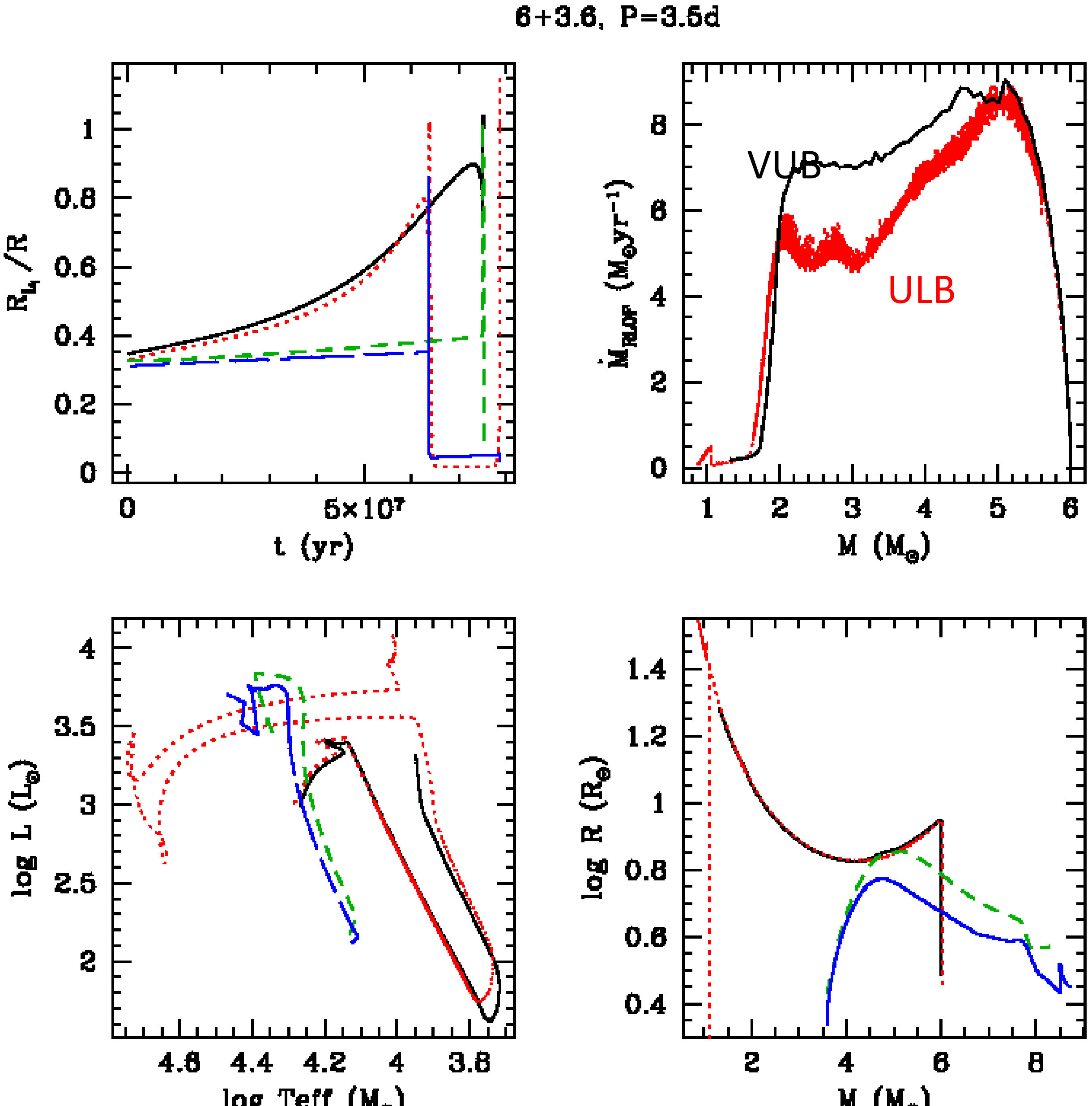
In terms of progenitor parameters

$$\log \alpha_{CE} = -1.04 - (2.10 \pm 0.24) \times \log \left(\frac{M_{WD}}{M_\odot} \right)$$

BINSTAR

STAREVOL Siess 2001-2010	Binary Physics
• Evolution of single stars (0.1 – 80 Msun), $0 < Z < 2Z_o$, up to Ne burning • Angular momentum transport (Zahn 1992) • Extra mixing (thermohaline, semi-conv, overshooting) • particularly suited for PMS, RGB, AGB, SAGB stars	• the two stars and evolution of *a* and *e* solved simultaneously • Self-consistent treatment of tides (Zahn 1989) • Mass transfer via winds and RLOF • Stellar rotation due to mass loss/ accretion + magnetic braking

Code Validation



case A mass transfer : excellent agreement with VUB models from Van Rensbergen & De Greve

Tests also conducted for Case B and C mass transfer

Scientific Objectives

- Mass ratio distribution of Algols

- Algols with P_{orb} < 1 days

- Accreting star not close to break-up and role of magnetic braking

- Mass transfer and tides in eccentric orbits, and implications for e.g. Barium stars.

Summary

- "Mirror gap": an observational test for disrupted magnetic braking

- Energy budget formalism cannot account for sharp decrease in PCEBs with P_{orb}

- Require an additional energy source to gravitational energy?

- Model of α_{CE} in terms of white dwarf mass

- Use BINSTAR to investigate evolution of Algols and chemically peculiar stars e.g. Barium stars

References

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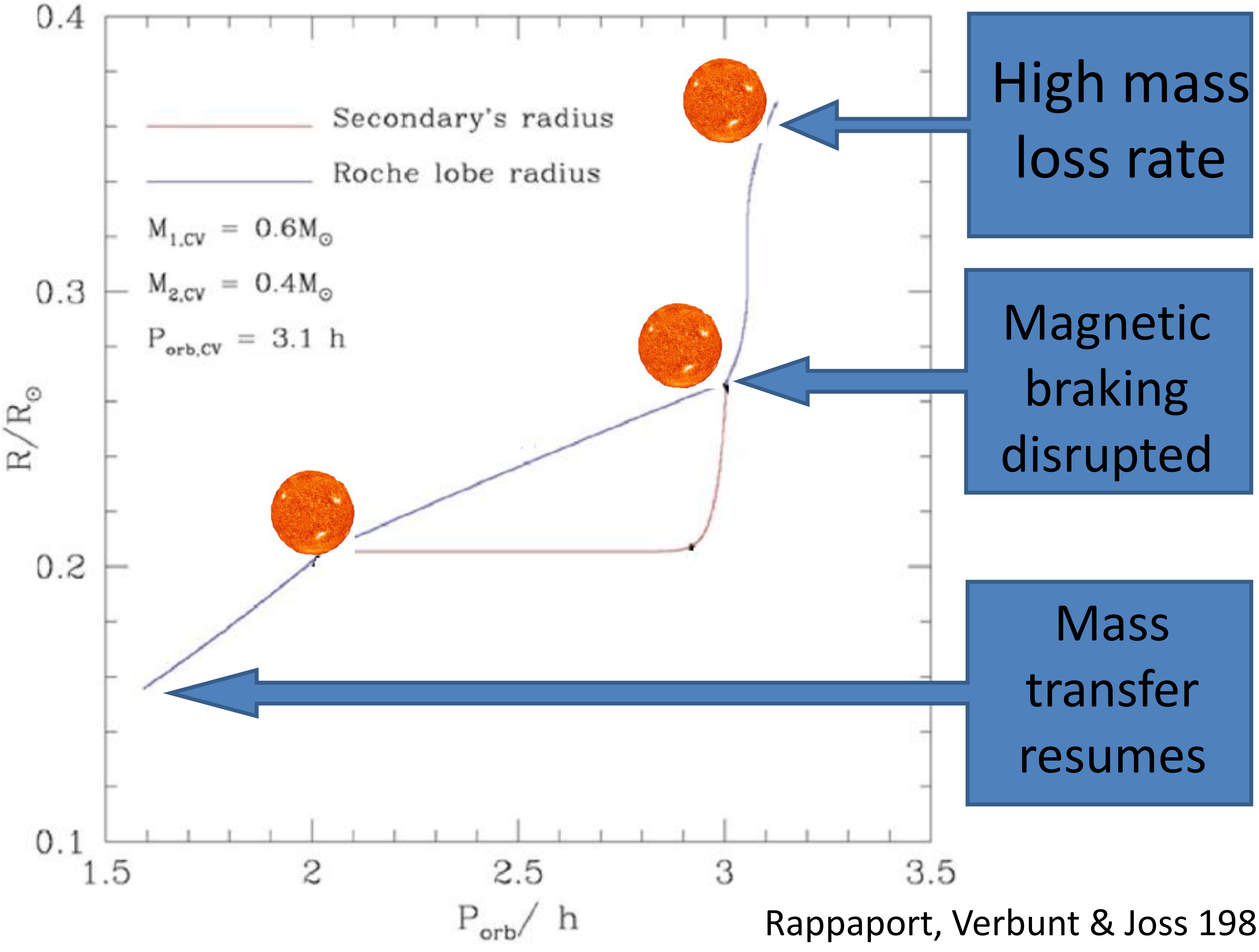
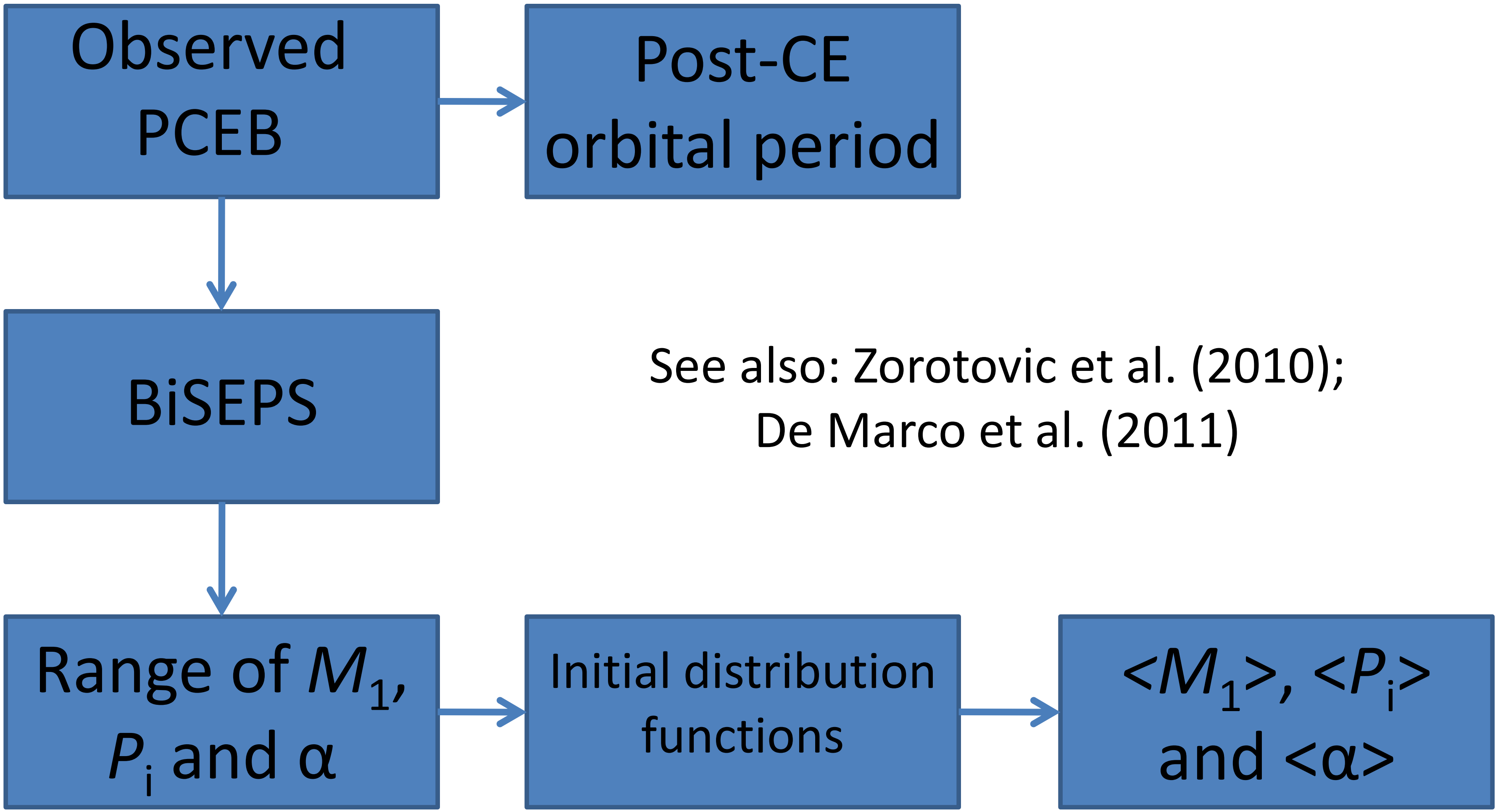
Appendix



Rappaport, Verbunt & Joss 1983
Spruit & Ritter 1983

Reconstructing the CE phase



See also: Zorotovic et al. (2010); De Marco et al. (2011)