Modelling the evolution of double white-dwarf systems

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Outline

- Introduction and context
- Observed double white dwarfs
- Common envelope and spiral-in
- Stable first mass transfer
- Conclusions and future work

Astrophysical context

- Possibly progenitors of Supernova type Ia
- Sources of low-frequency gravitational waves

Astrophysical context

- Possibly progenitors of Supernova type Ia
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- Binary evolution theory
- White dwarf cooling theory
- Population synthesis

Observed double white dwarfs

System	P_{orb} (d)	a_{orb} ($R_\odot$)	M_1 ($M_\odot$)	M_2 ($M_\odot$)	$q_2 = M_2/M_1$
WD 0135–052	1.556	5.63	0.52	0.47	0.90 ± 0.04
WD 0136+768	1.407	4.98	0.37	0.47	1.26 ± 0.03
WD 0957–666	0.061	0.58	0.32	0.37	1.13 ± 0.02
WD 1101+364	0.145	0.99	0.33	0.29	0.87 ± 0.03
PG 1115+116	30.09	40.0	0.43	0.52	1.19 ± 0.30
WD 1204+450	1.603	5.72	0.52	0.46	0.87 ± 0.03
WD 1349+144	2.209	6.65	0.44	0.44	1.26 ± 0.05
HE 1414–0848	0.518	2.93	0.55	0.71	1.28 ± 0.03
WD 1704+481a	0.145	1.13	0.56	0.39	0.70 ± 0.03
HE 2209–1444	0.277	1.89	0.58	0.58	1.00 ± 0.12

See refs in: Maxted et al., 2002 and Nelemans & Tout, 2005.

Common envelope

- Average orbital separation: $7\,R_\odot$
- Progenitors: $R_* \gtrsim 50\,R_\odot$

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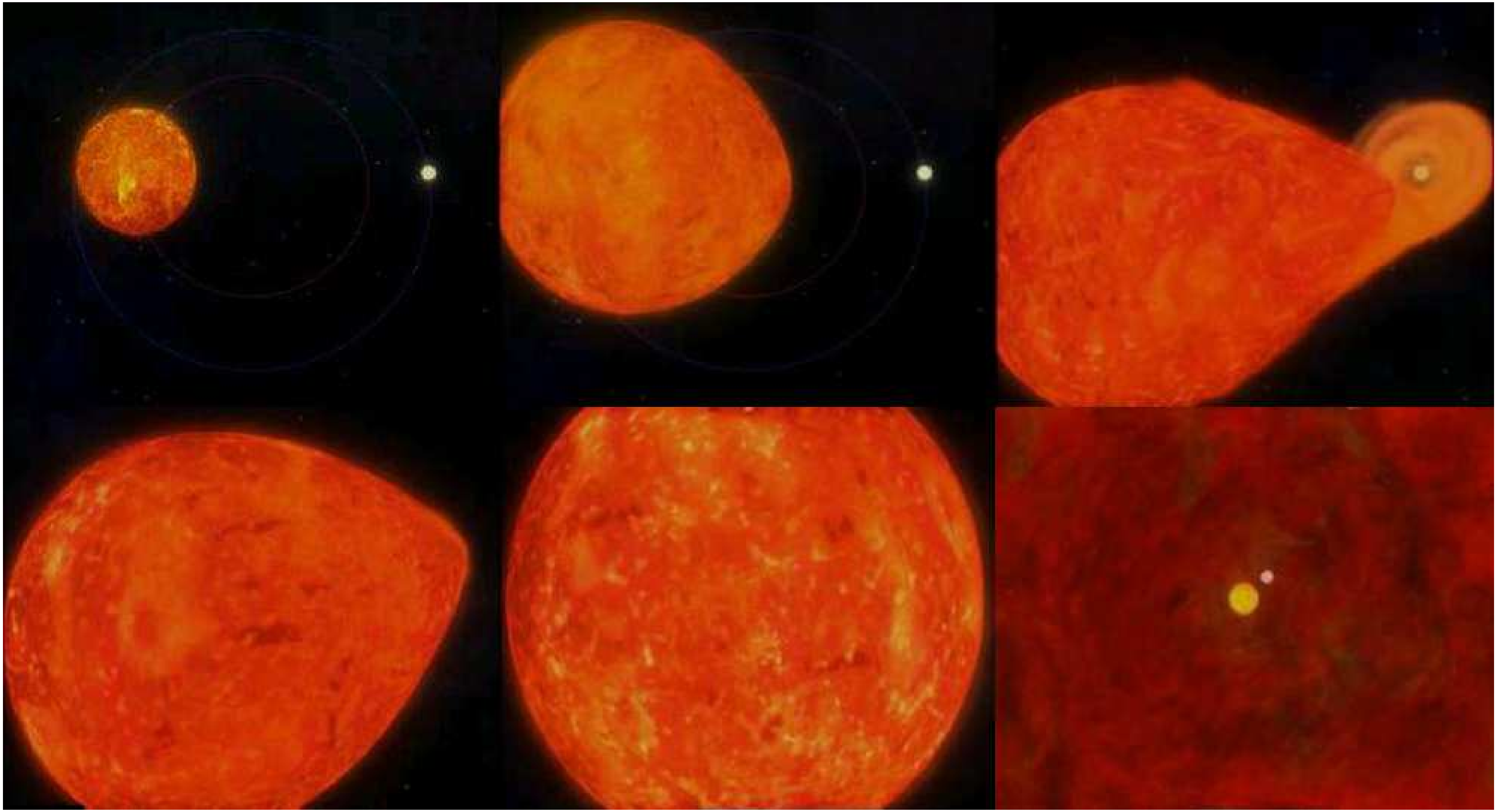
$$\Downarrow$$

- Second mass transfer phase was a spiral-in
- Mechanism: Common envelope

Common envelope



Common envelope

Classical CE:
(Webbink, 1984)

- Friction causes spiral-in of the cores
- Orbital energy is used to expell envelope:

$$U_{\rm bind} = \alpha_{\rm CE} \left[\frac{G M_{\rm wd1} M_{\rm wd2}}{2 a_{\rm f}} - \frac{G M_{\rm wd1} M_{\rm g2}}{2 a_{\rm i}} \right]$$

Common envelope

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- Core mass does not change during CE
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- Radius of the giant gives orbital period
- Envelope binding energy gives α_{CE}

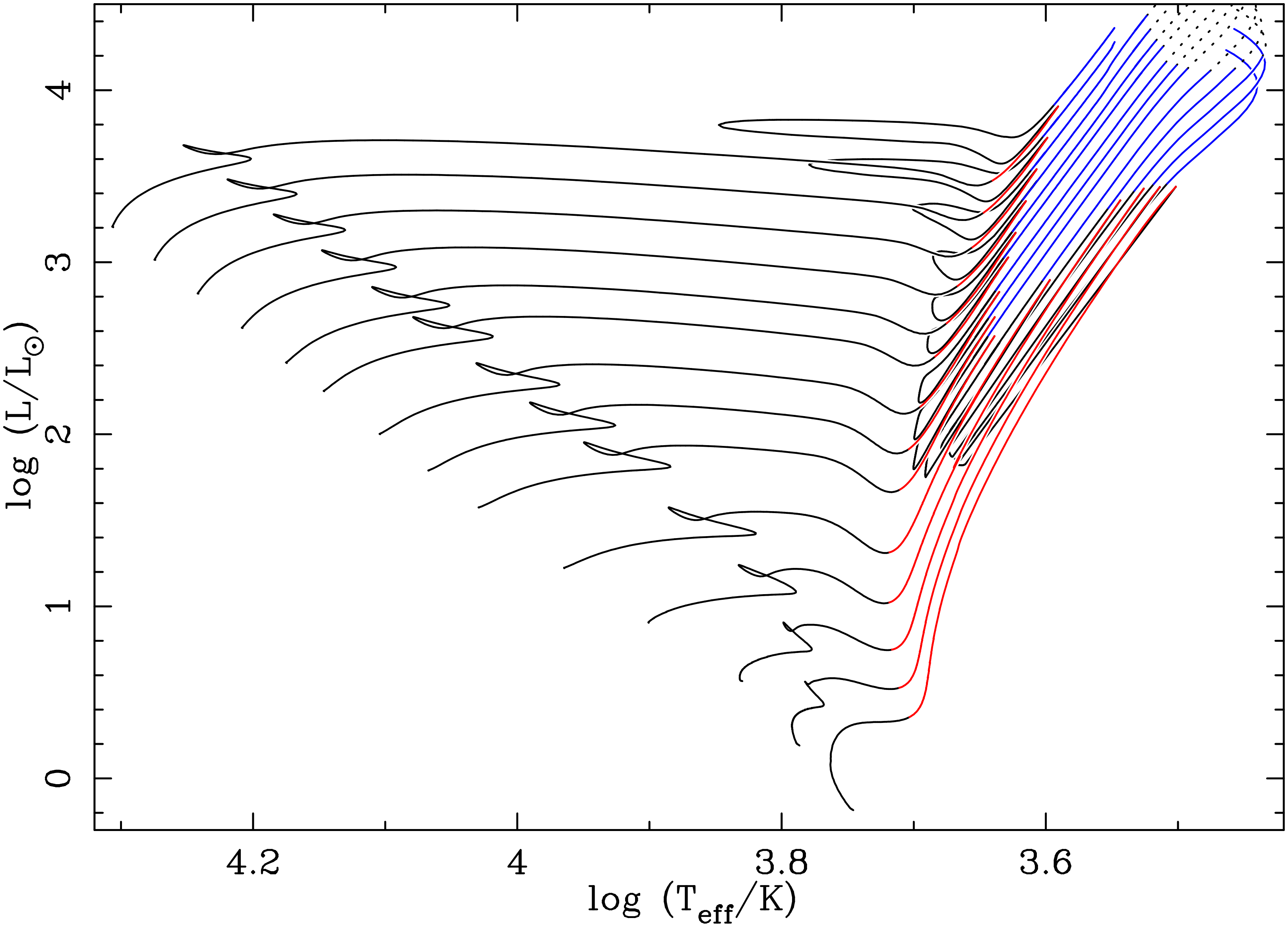
Giant branch models

100 models

0.8-10 $M_{\odot}$

RGB

AGB

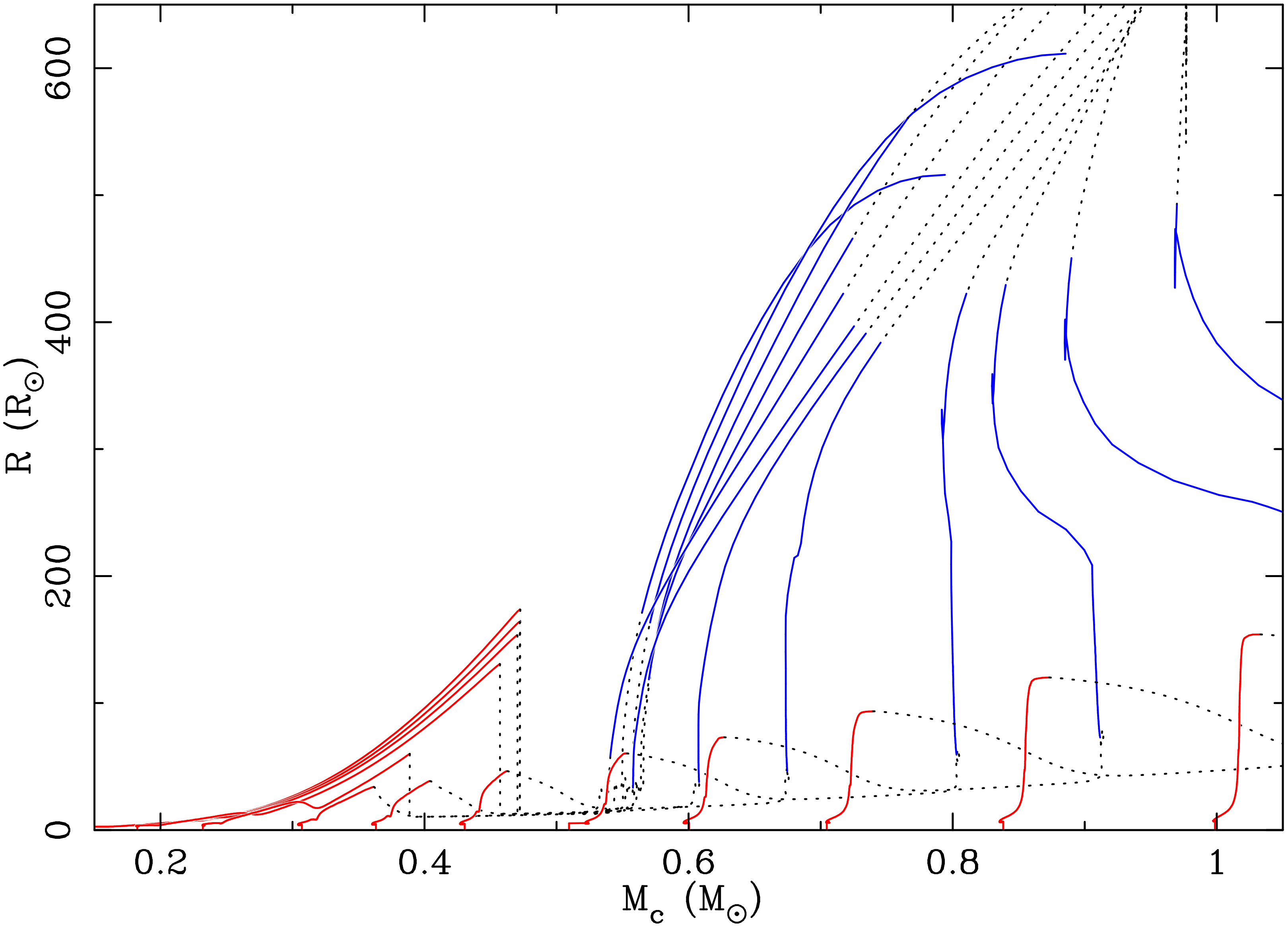


Giant branch models

R_* provides P_{orb} at onset of CE

RGB

AGB

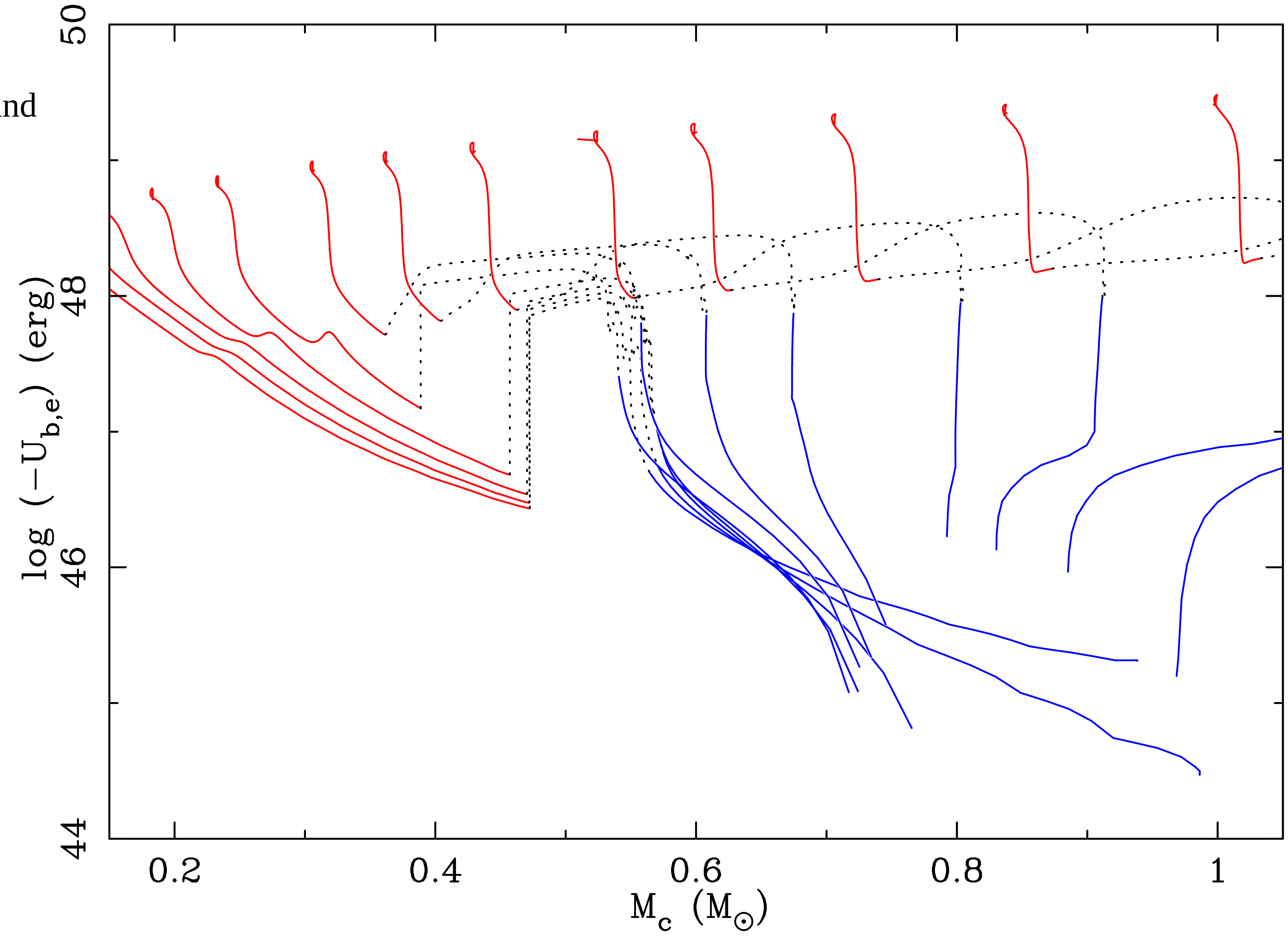


Giant branch models

Envelope U_{bind} provides α_{CE}

RGB

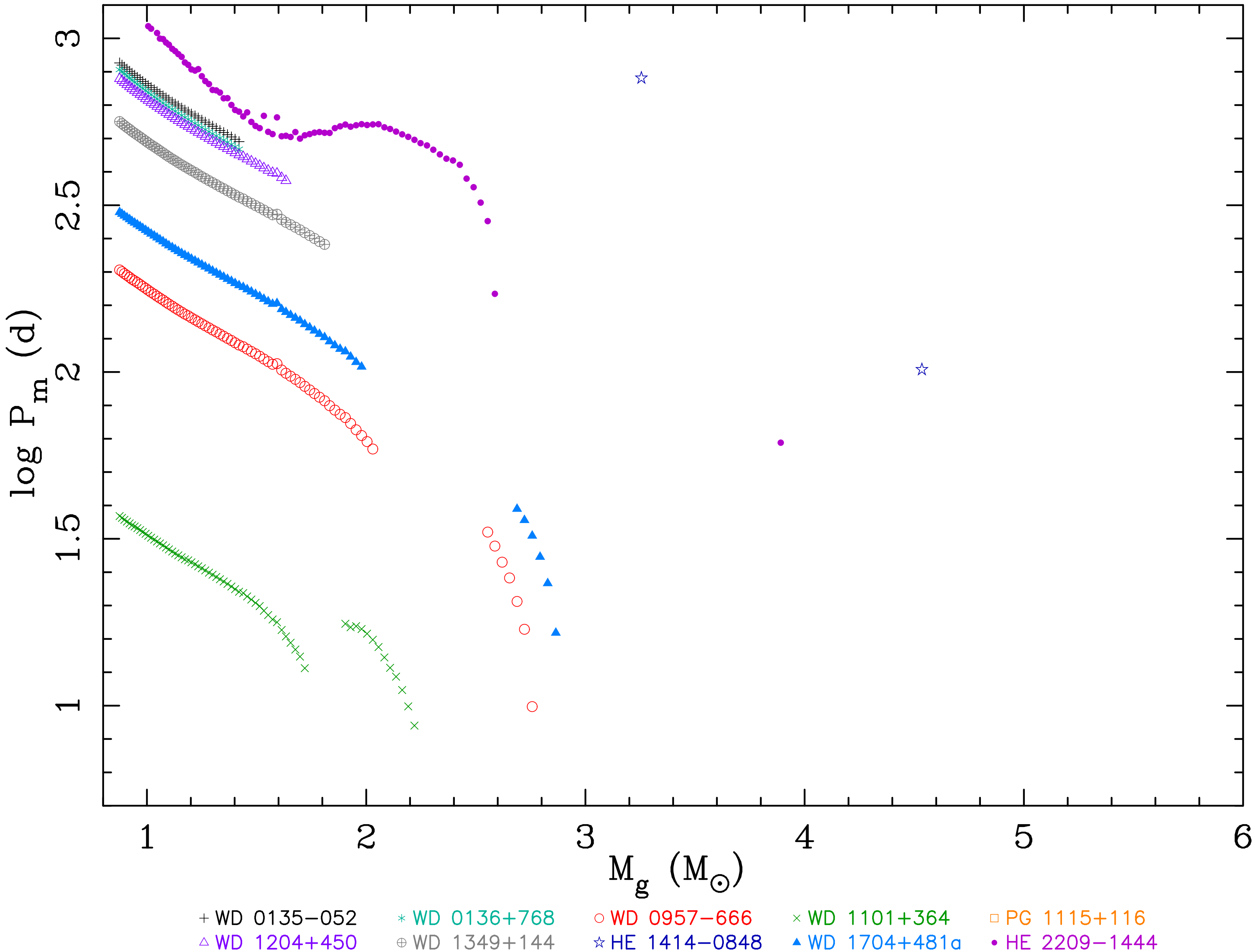
AGB



CE results

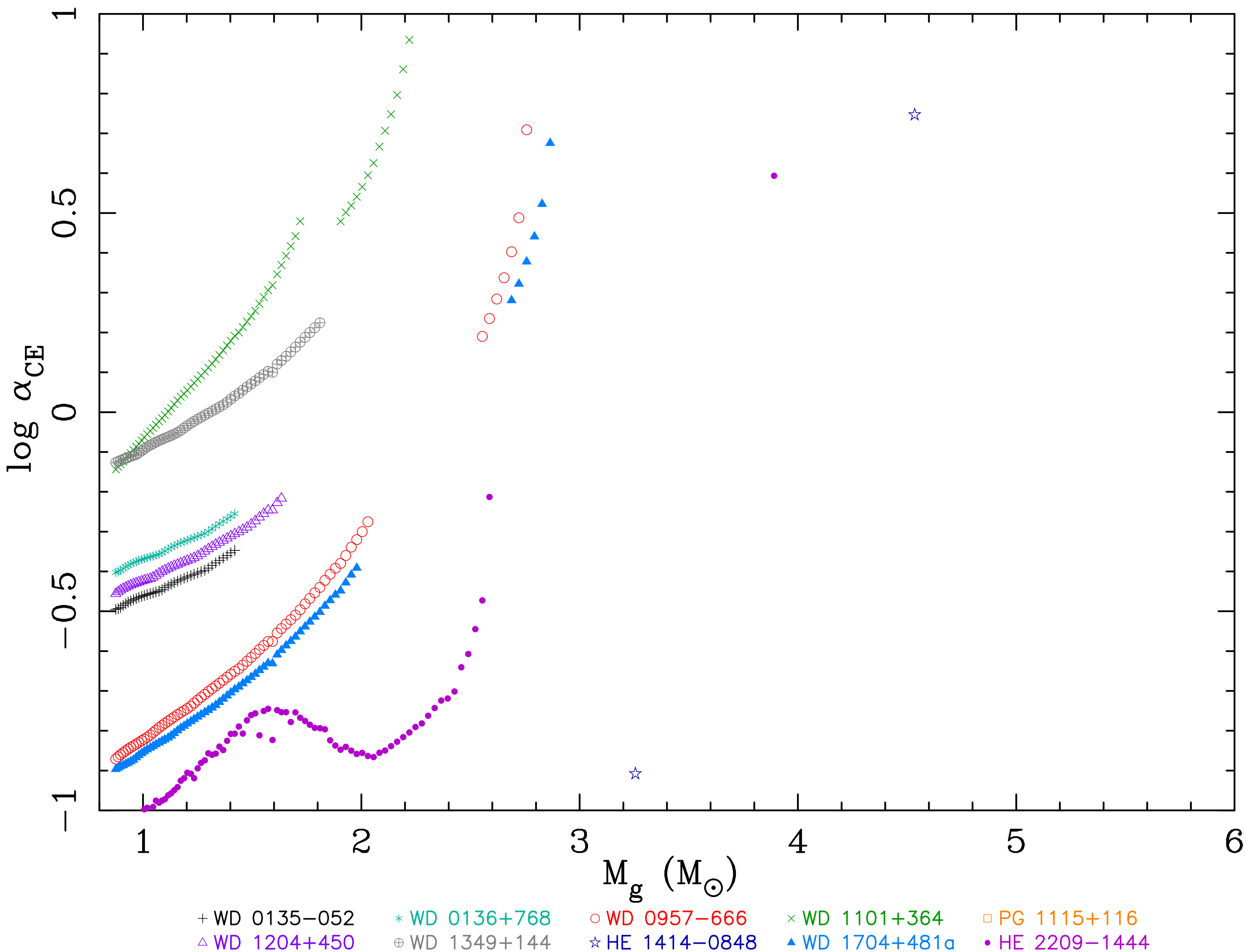
Assumed no errors in observed masses

~ 25% of models give a solution



CE results

Accept solutions with $0.1 < \alpha_{CE} < 10$



CE results

No errors
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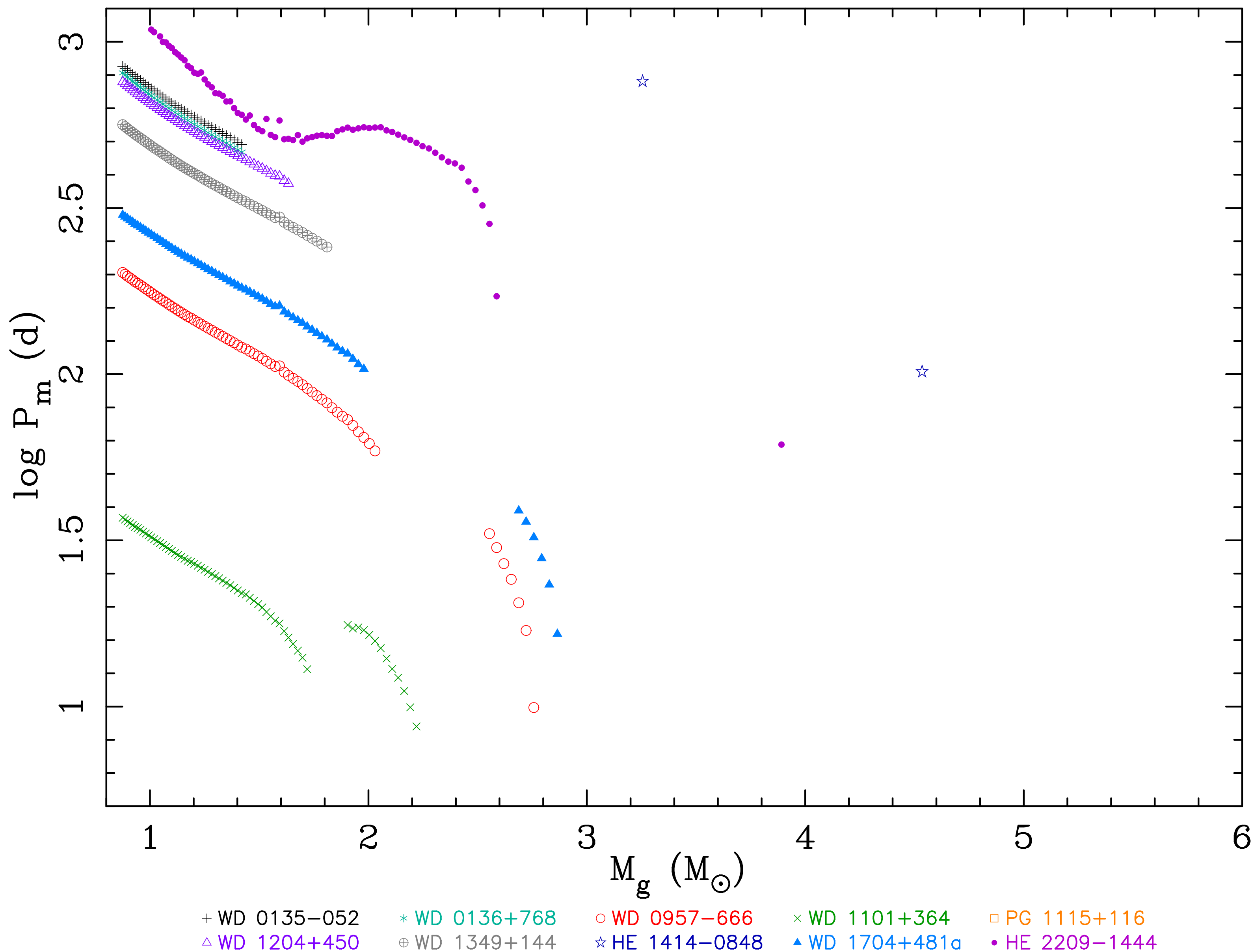
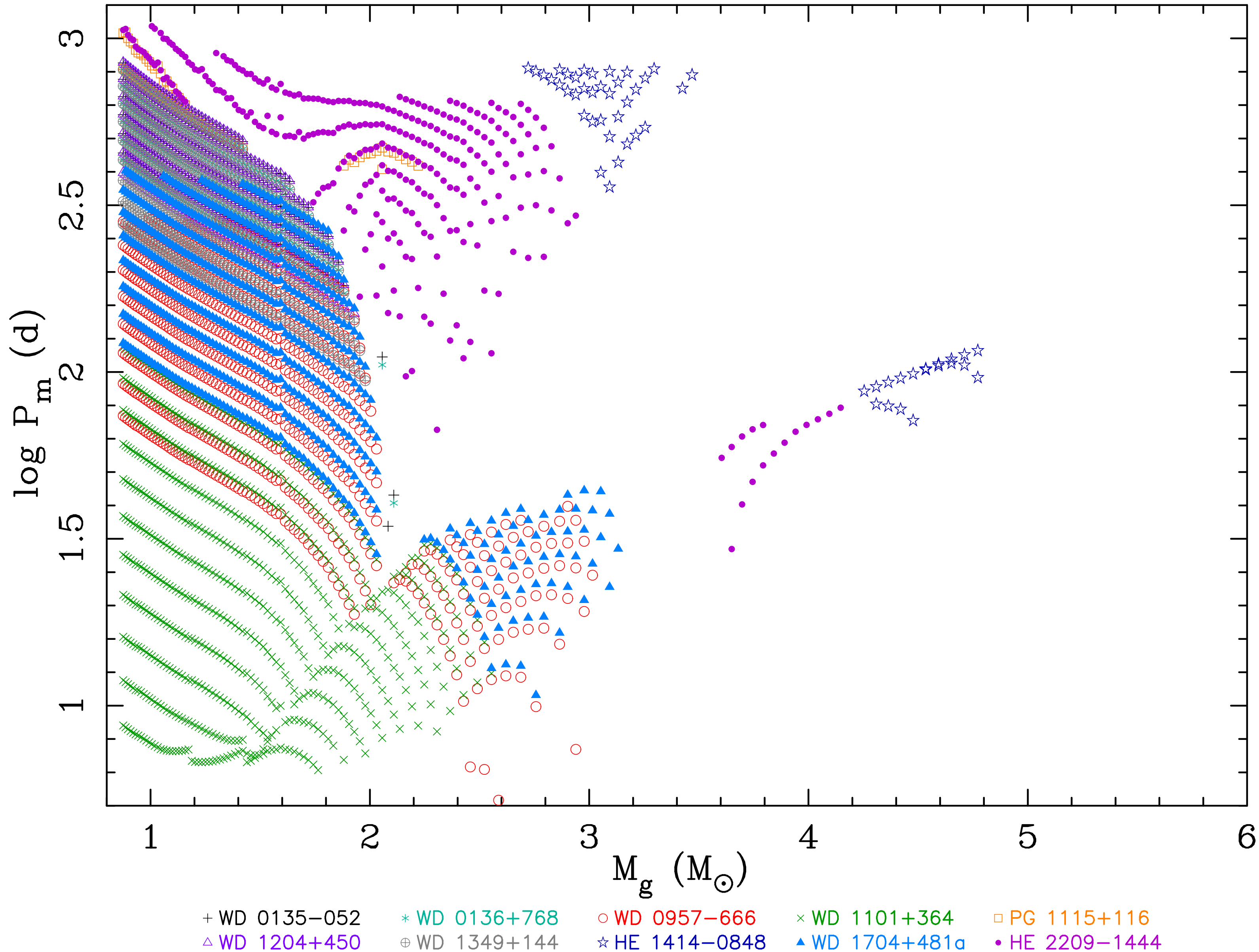


CE results

Introduce errors in observed masses: $\pm 0.05 M_\odot$

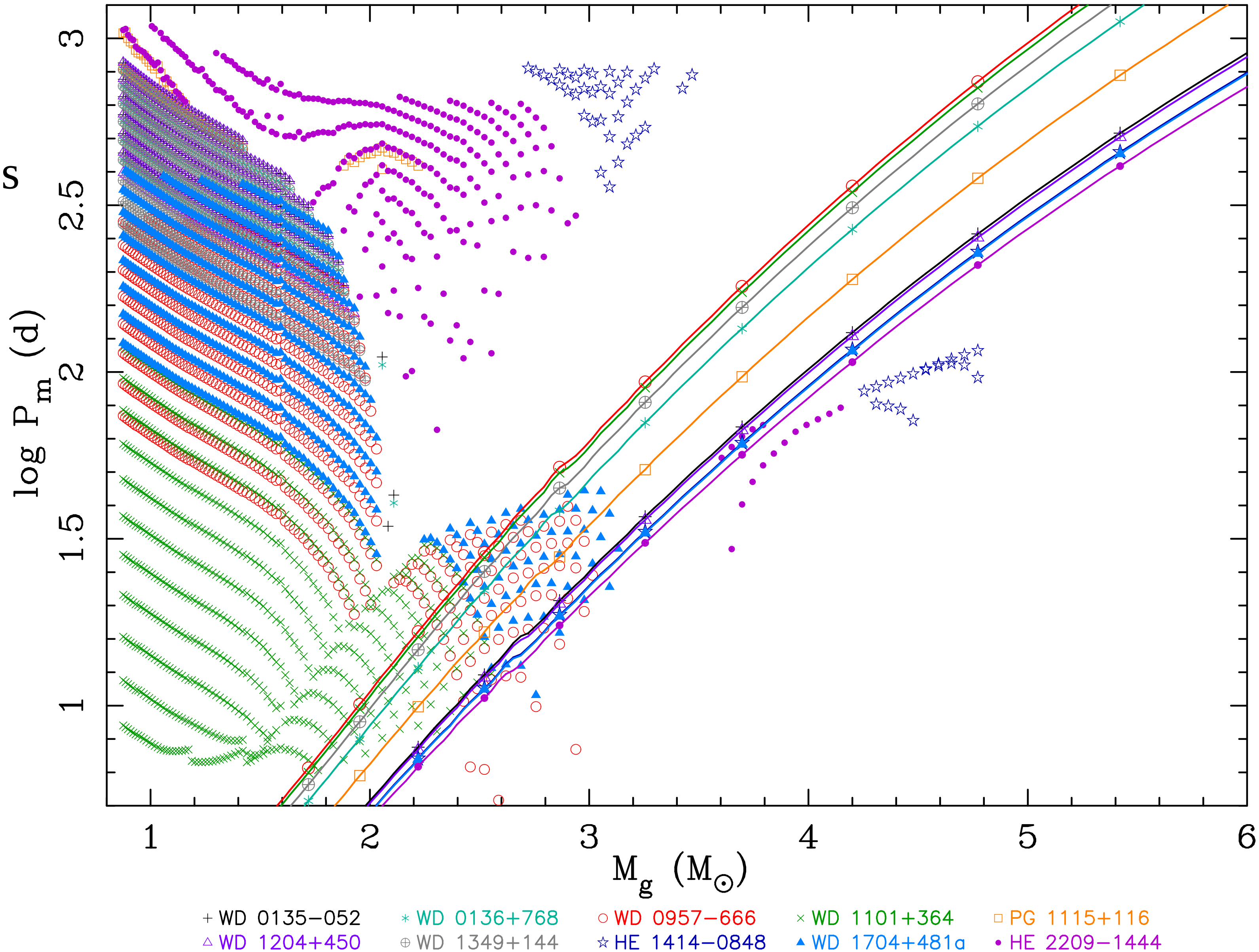


CE results

Maximum P_{orb} after stable mass transfer with $q_i = 0.62$

(Nelemans et al., 2000)

Only 5 systems have CE solutions with $P_{orb} < P_{max}$

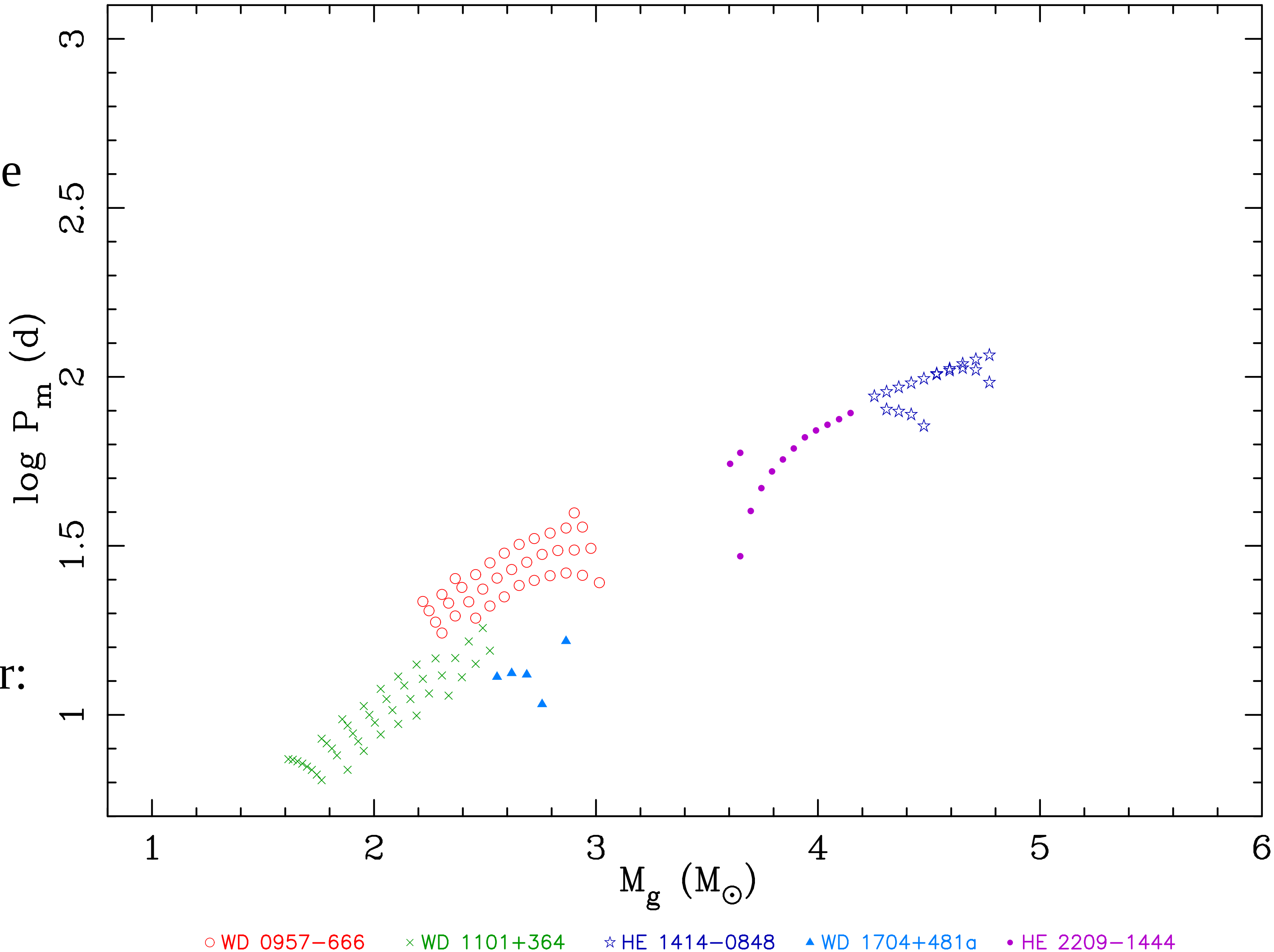


CE results

CE solutions that may be formed by stable mass transfer

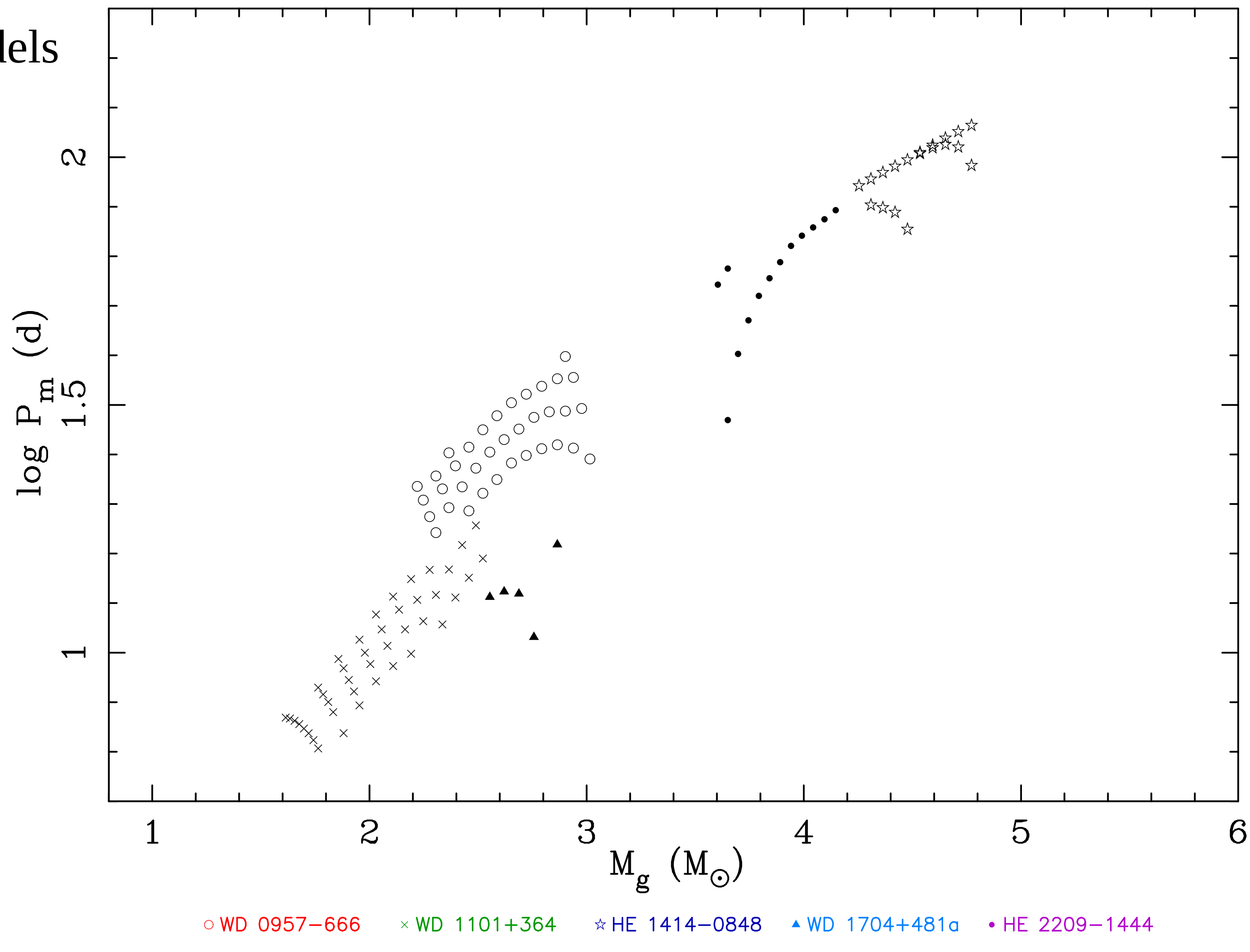
Conservative mass transfer: M_{tot} and J_{orb} fixed

1 free parameter: q_i



Conservative mass transfer

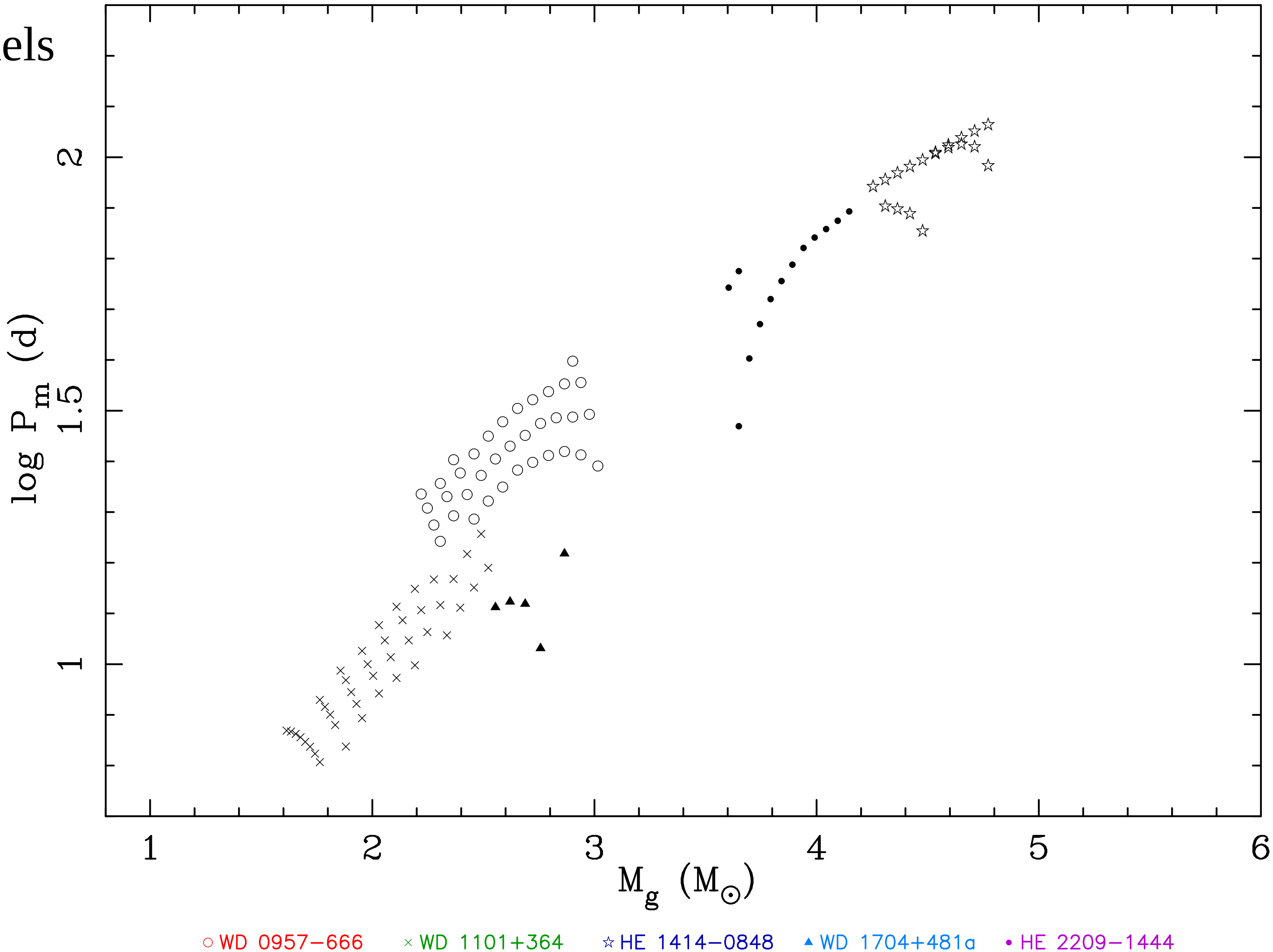
230 binary models calculated:



Conservative mass transfer

230 binary models calculated:

39% dynamical

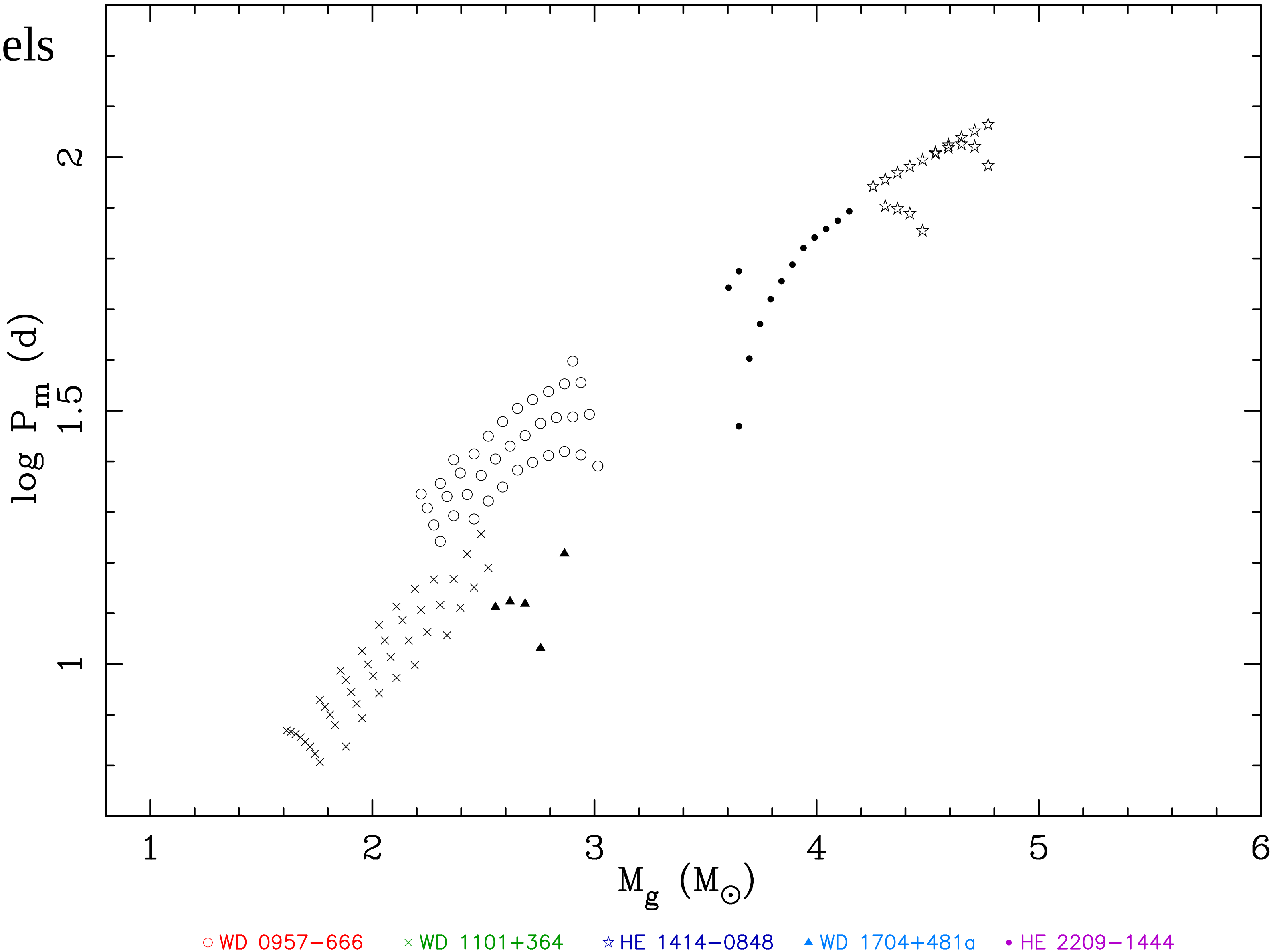


Conservative mass transfer

230 binary models calculated:

39% dynamical

18% contact



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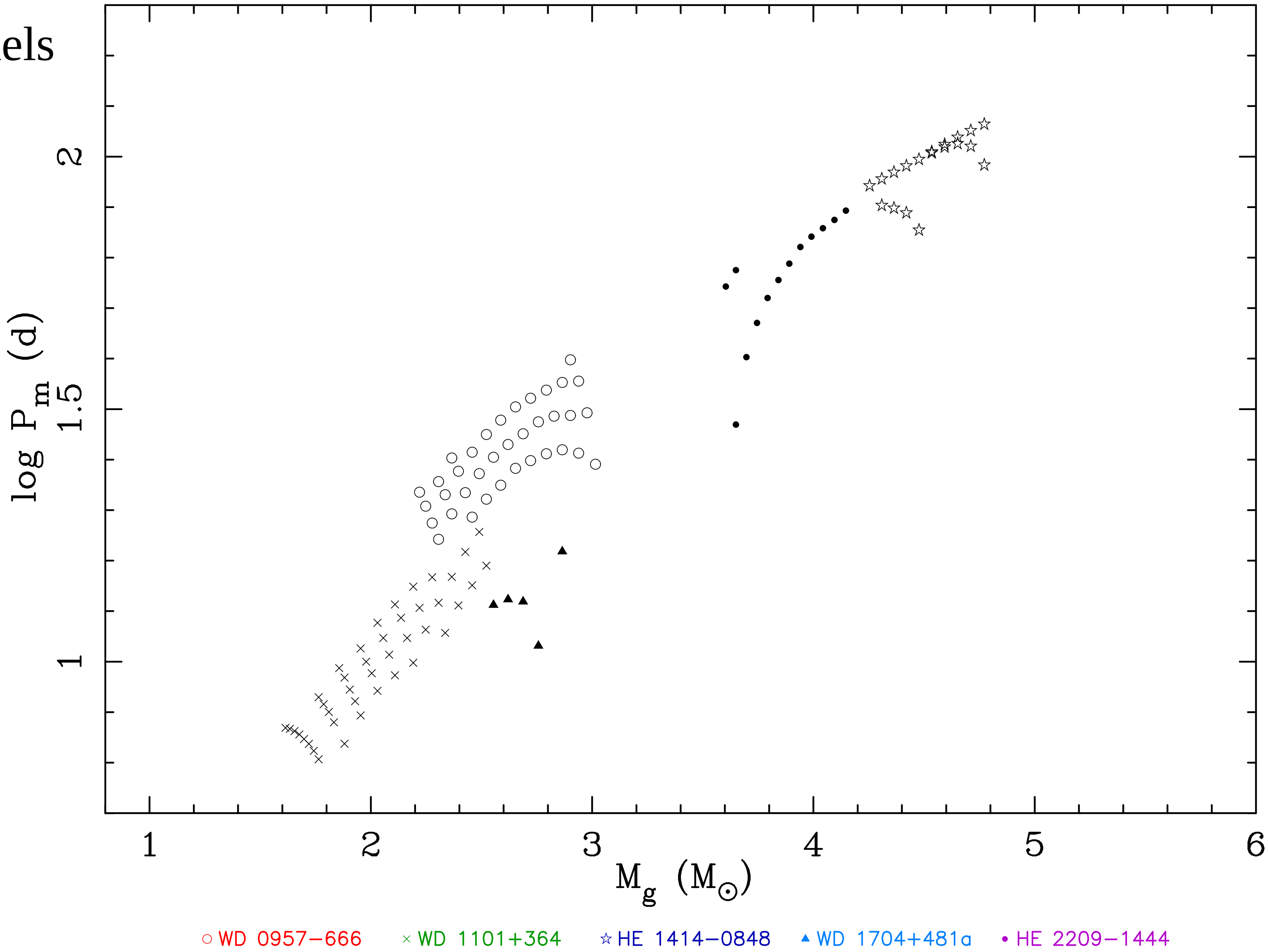
43% DWD



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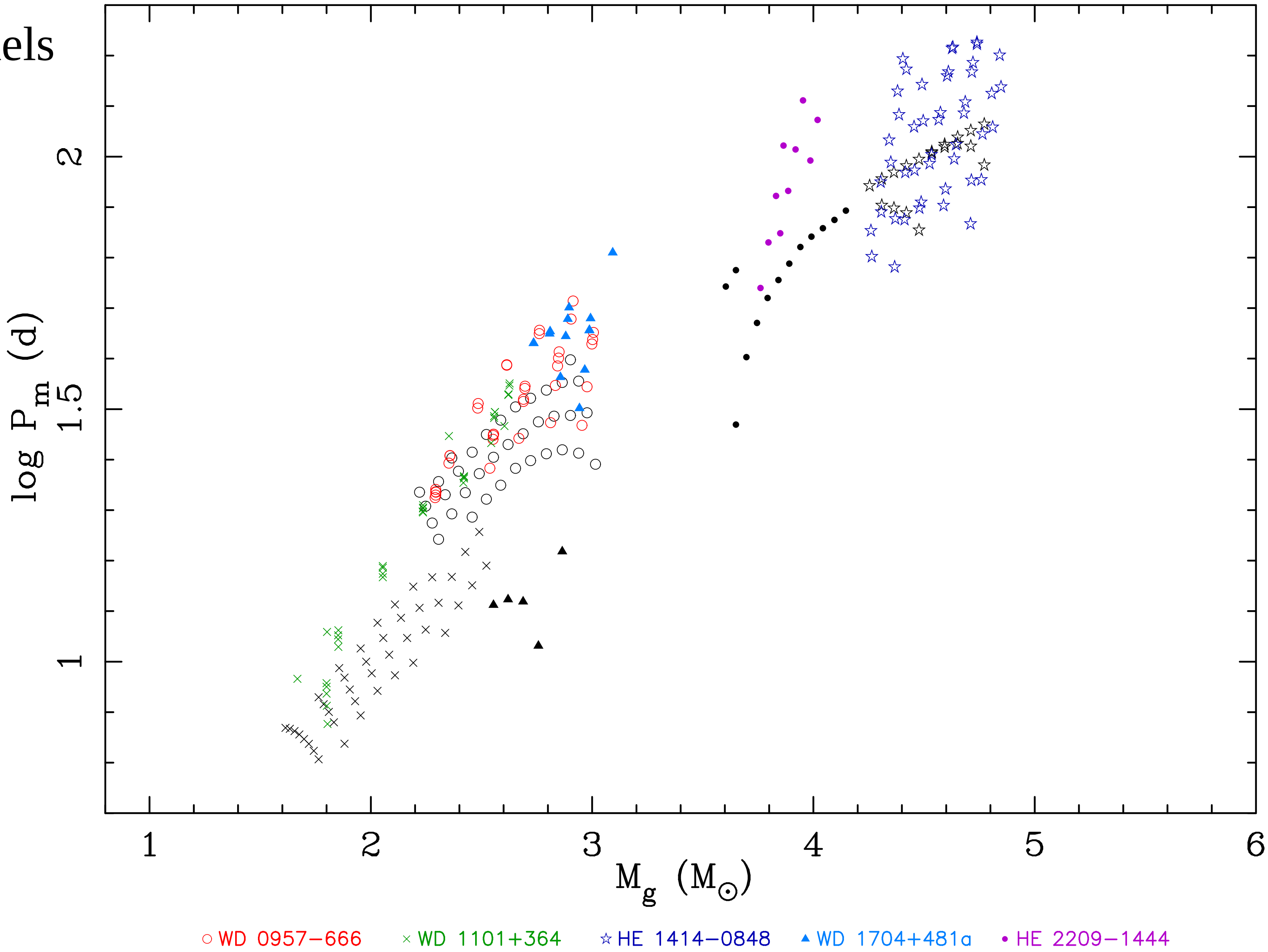
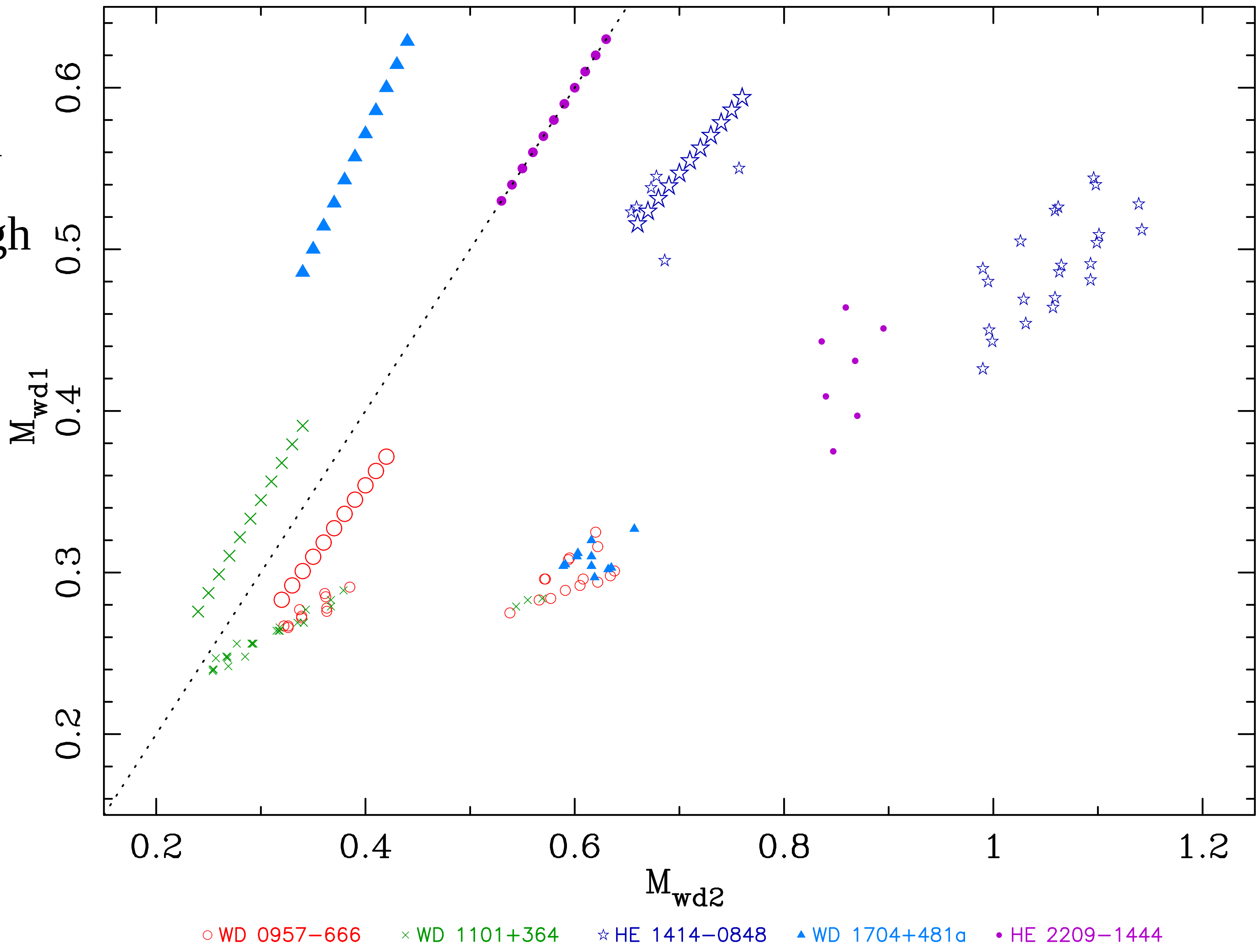


Conservative mass transfer

M_{wd1} too low

$\Rightarrow P_{\mathrm{orb}}$ too high

$\Rightarrow M_{\mathrm{wd2}}$ too high

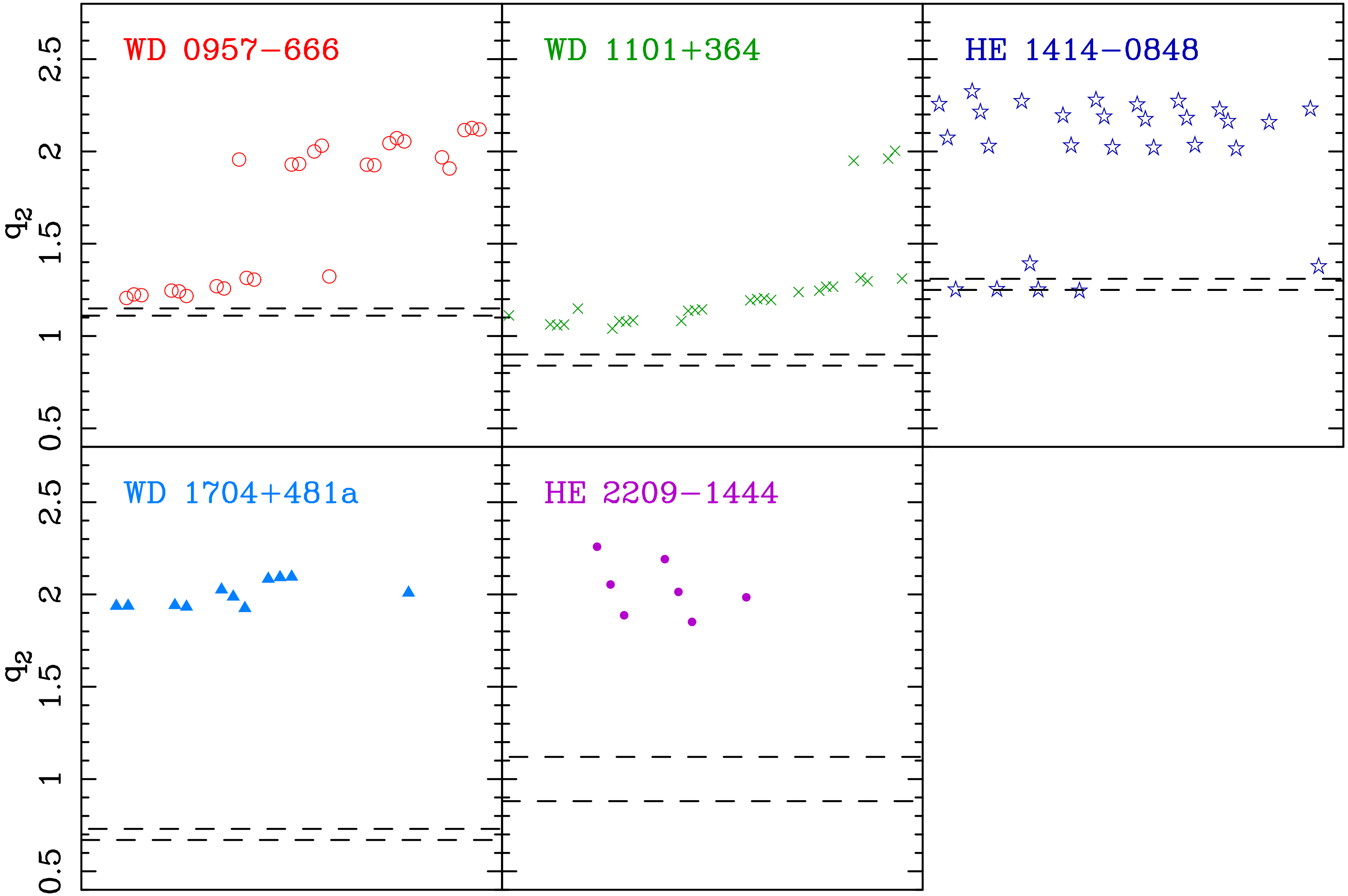


Conservative mass transfer

1414 fits

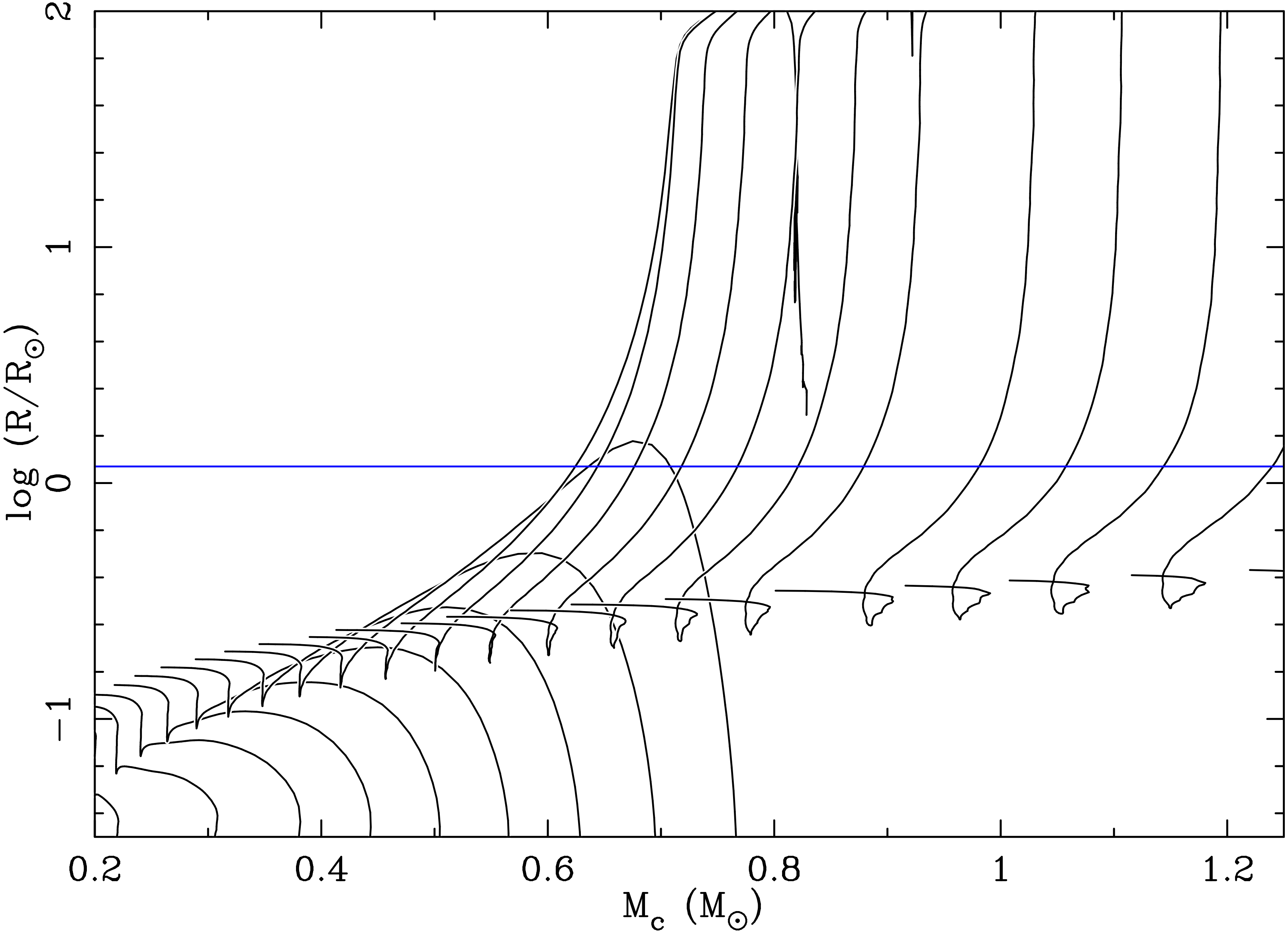
0957 and 1101 almost fit

Out of ten systems, 1 can be explained, 2 are close



HOWEVER...

HE 1414-0848



Conclusions and future work:

- More accurate models change CE only slightly
- Conservative mass transfer cannot produce white-dwarf primaries of sufficiently high mass
- We can explain 0.5 out of 10 systems

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- Conservative mass transfer cannot produce white-dwarf primaries of sufficiently high mass
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- Non-conservative, stable first mass transfer phase
- α-CE and γ-CE as first mass transfer

HE 1414-0848