Post common envelope binaries from SDSS:
Constraining the common envelope efficiency

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Outline

• Introduction:
  - Formation of close compact binaries
  - How to constrain close binary evolution with PCEBs

• The sample

• Our Code: First Results

• Summary
Formation of close compact binaries: Standard Model

Willems & Kolb
2004
Formation of close compact binaries: Standard Model

Scientists try to determine $\alpha_{CE}$ since thirty years
Constraining CE-evolution with PCEBs

- Determine the relation between the separation before and after the CE phase.

- Principal algorithm: **Energy conservation** (Paczynski 1976, standard $\alpha$ formalism)

$$\alpha_{ce} \Delta E_{orb} = E_{gr}$$

...generally approximated by...

$$\frac{GM_g M_e}{\lambda R_g} = \alpha \left( \frac{GM_c m}{2\alpha_f} - \frac{GM_g m}{2\alpha_i} \right)$$

$\lambda \rightarrow$ Structural parameter $\sim 0.5$

$\alpha \rightarrow$ CE efficiency
Constraining CE-evolution with PCEBs

Nelemans & Tout 2005
SSE code (Hurley et al. 2000)

For $M_g$ between 1.0 and $M_{max}$

Assuming

- $R_g = R_L$ when $M_C = M_P$
Constraining CE-evolution with PCEBs

Nelemans & Tout 2005
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For $M_g$ between 1.0 and $M_{\text{max}}$
Assuming
- $R_g = R_L$ when $M_C = M_P$
Angular momentum balance

\( \gamma \)-algorithm

\[
\frac{\Delta J}{J} = \gamma \frac{\Delta M_{\text{total}}}{M_{\text{total}}} = \gamma \frac{M_e}{M_g + m}
\]

\( 1.5 \leq \gamma \leq 1.75 \)
Angular momentum balance

\[ \frac{\Delta J}{J} = \frac{\Delta M_{\text{total}}}{M_{\text{total}}} = \gamma \frac{M_e}{M_g + m} \]

\[ 1.5 \leq \gamma \leq 1.75 \]

Webbink (2007):
- Not all are PCEBs? Quasi-conservative mass transfer?
- The range of \( \gamma \) is expected.

We need a complete and unbiased sample of PCEBs.

Nelemans & Tout (2005)
The Sample

→ 43 PCEBs from SDSS WD/MS

→ 18 Previously known systems (N&T2005, S&G2003)
Our Code:
Finding progenitors for the WD

- INPUTS: $M_{WD}$, $m$, $P_{CE}(a_f)$
- $M_g$ between 0.8 and $M_{max}$

- Assuming $M_C = M_{WD}$
  - $L_g$ using $L-M_c-M$ relations
  - $R_g$ using $R-L-M$ relations

- Assuming $R_g = R_L$
  - $\alpha \lambda$ for every initial mass
Our Code:
Finding progenitors for the WD

- INPUTS: $M_{\text{WD}}$, $m$, $P_{\text{ce}}(a_f)$
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  Hurley et al. (2000)
  - $L_g$ using $L-M_c-M$ relations
  - $R_g$ using $R-L-M$ relations
- Assuming $R_g = R_L$
  - $\alpha \lambda$ for every initial mass
\[ \lambda \text{ and Internal Energy} \]

**Structural parameter:**
\[ \lambda \text{ depends on evolutionary stage (e.g. Dewi & Tauris 2000)} \]

**Internal energy:**
Han et al. (1995) include a fraction \( \alpha_{th} \) of internal energy

\[ \alpha_{CE} \Delta E_{orb} = E_{gr} - \alpha_{th} E_{th} \]

We use BSE code (Hurley et al. 2002) with:
\[ \alpha_{th} = 0 \]
\[ \alpha_{th} = \alpha_{CE} \]
$\lambda$ and Internal Energy

![Graph showing $\lambda$, $\lambda_{\text{ Dest }}$, and $\lambda_{\text{ Dist }} + U_{\text{ Int }}$ vs. $\alpha$]
**α VS γ**

Vertical lines:

$0.2 \leq \alpha \leq 0.3$

$1.5 \leq \gamma \leq 1.75$
$a_i/a_{\dot{i}}$ is extremely sensitive to $\gamma$ (Webbink 2007)
Change in angular momentum per unit mass higher for progenitors in FGB than in AGB
We reconstruct the possible evolutionary histories of a well-defined PCEBs sample including the structural parameter $\lambda$ and internal energy.

Strong new constraints on the CE Efficiency. If $\alpha = \text{constant}$:

$$\alpha \sim 0.2 - 0.3$$

$\alpha$ is better than $\gamma$ to constrain the evolution of close compact binaries.
EXTRAS
Testing for correlations

![Graph 1](image1)

![Graph 2](image2)
Different formulations

- Podsiadlowski et al. (2003)
  \[ E_{\text{orb},i} = \frac{1}{2} \frac{GMm}{a_i} \]
  \[ E_{\text{gr}} = \frac{GMMc}{\lambda R} \]

- Iben & Livio (1993), Yungelson et al. (1994)
  \[ E_{\text{orb},i} = \frac{1}{2} \frac{GM_cm}{a_i} \]
  \[ E_{\text{gr}} = \frac{G(M_g + m)M_c}{2a_i} \]
Structural parameter

\[ E_{\text{env}} = -\frac{GM_{\text{donor}} M_{\text{env}}}{\lambda a_i r_L} = \int_{M_{\text{core}}}^{M_{\text{donor}}} \left( -\frac{GM(r)}{r} + U \right) dm \]