Energy budget, Unbound Mass in Common Envelope Evolution

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Introduction

In a binary stellar system, common envelope evolution occurs when the envelope of a primary star, usually a giant, engulfs a smaller companion. Many astrophysical phenomena are believed to be preceded by one or more common envelope phases. Examples include asymmetric and bipolar planetary nebulae, black hole and neutron star mergers.
In our simulation we have a $M = 2M_{\odot}$ primary with a core $0.37\ M_{\odot}$; the radius of the primary is $49R_{\odot}$. The secondary is placed right outside the primary. We have 3 runs with secondary mass $1M_{\odot}$; $0.5M_{\odot}$; $0.25M_{\odot}$

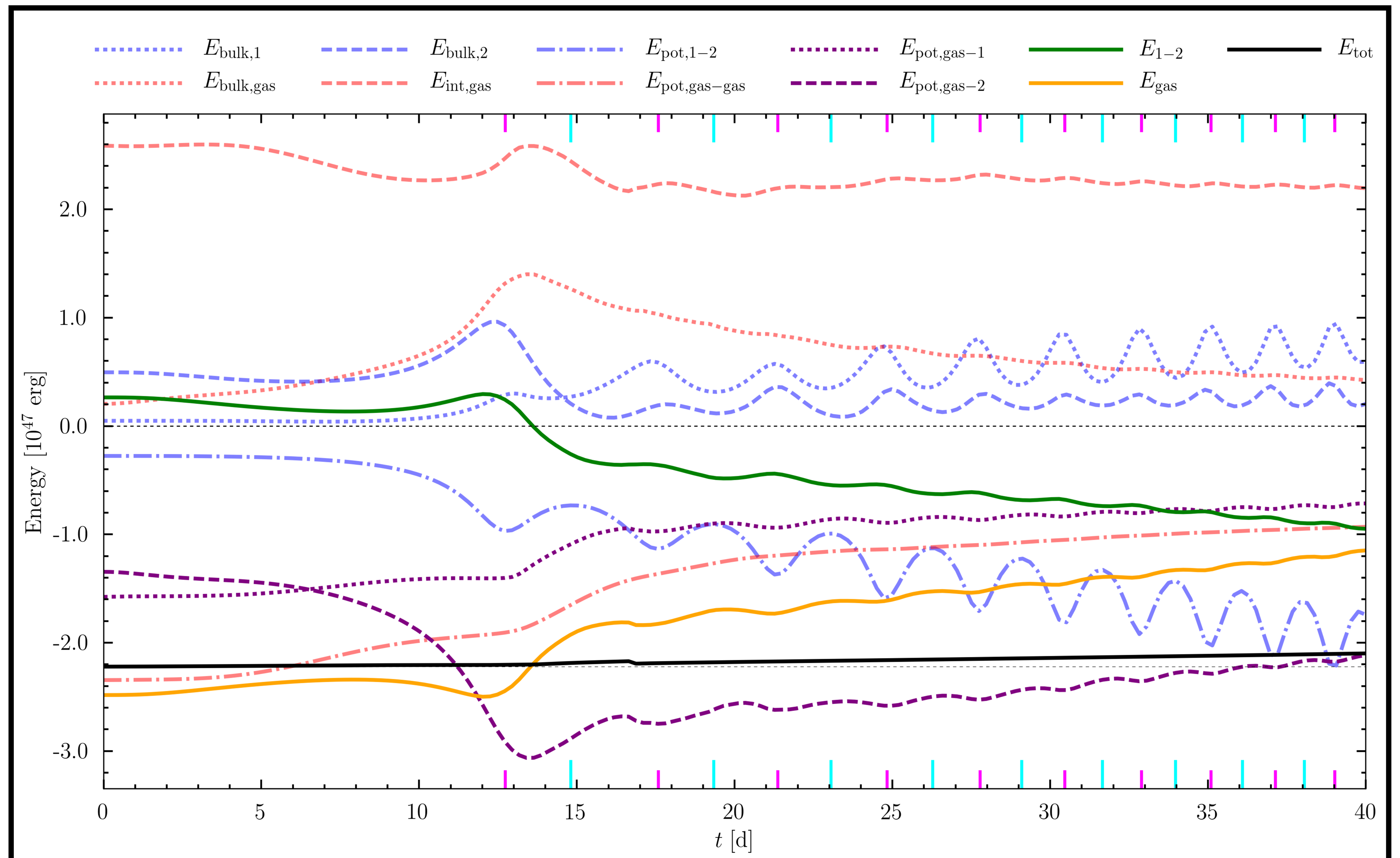
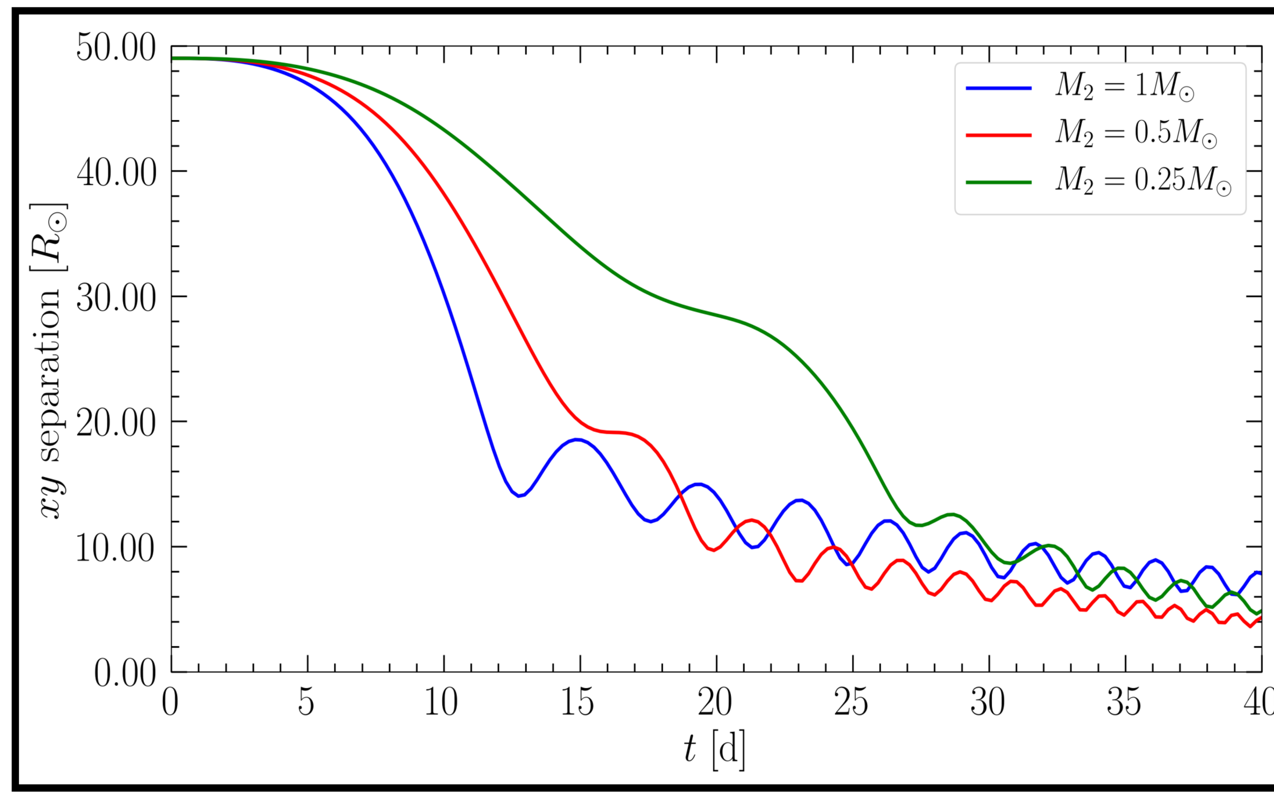


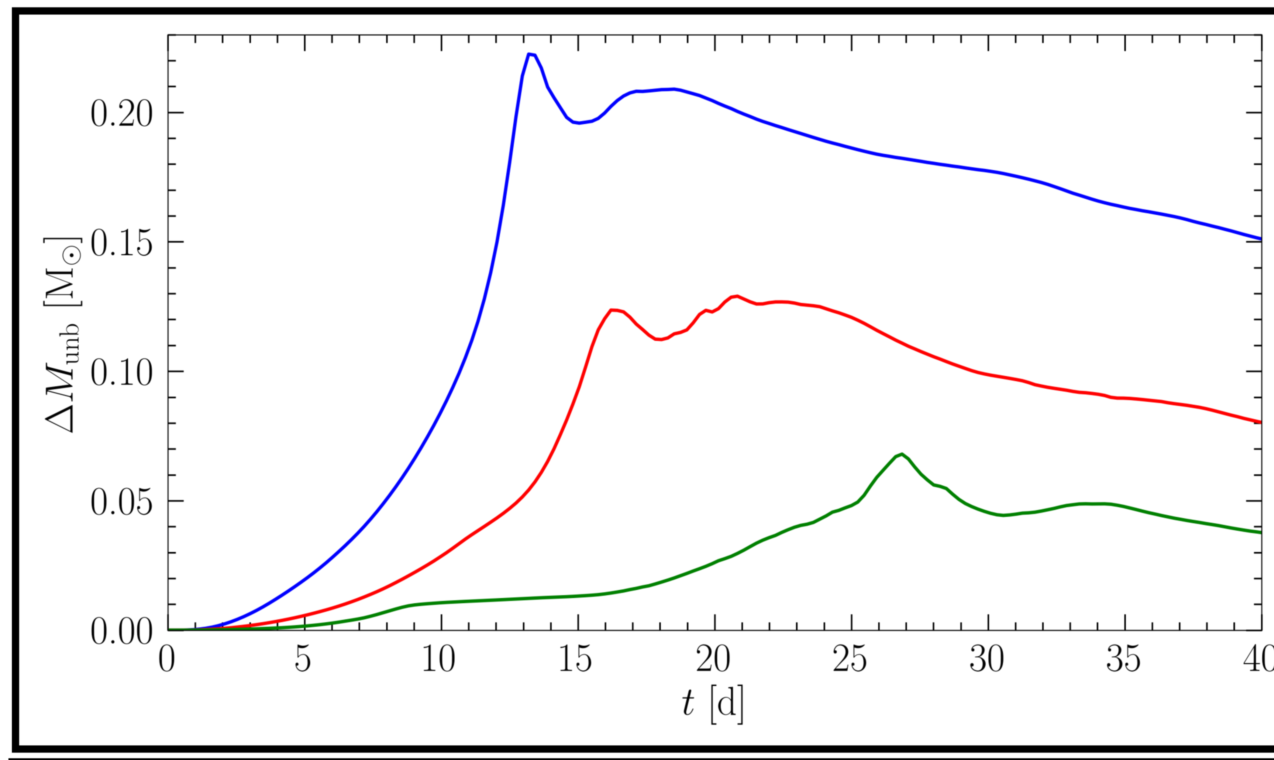
Figure 1 ($M_2 = 1M_{\odot}$)**:** Evolution of the various energy components integrated over the simulation domain. Times of apastron and periastron passage are shown as long cyan and short magenta tick marks, respectively

- energy transfer between particle orbital energy (green) and gas total energy (orange) is not significant before the plunge-in (0 to 13 days), Yet the energy in the gas redistributes during this phase.
- After plunge-in (13 days), particle orbital energy gradually transfers to gas energy.
- The potential energy of the secondary (purple dashed) is important even at the beginning of the evolution



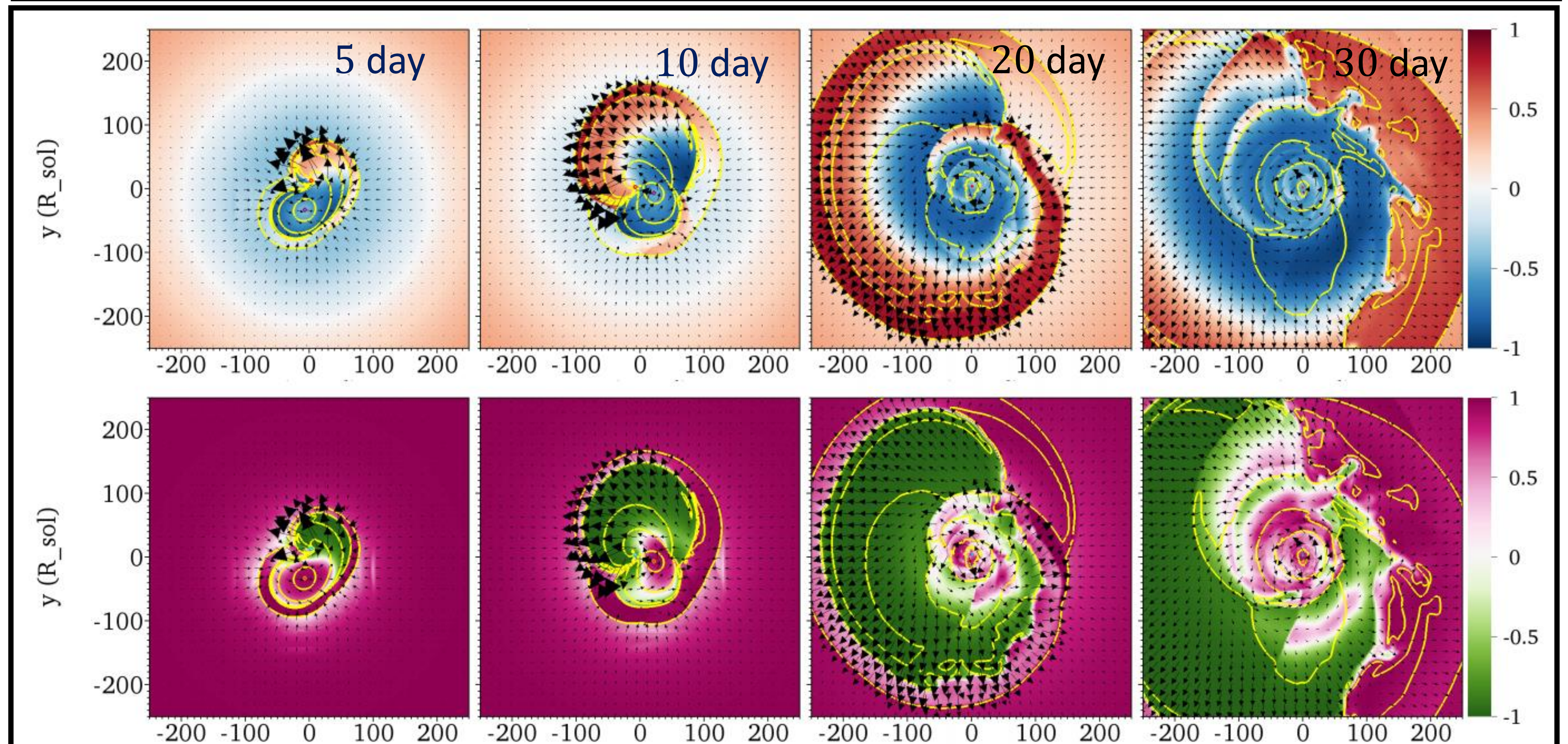
Primary core - secondary separation V.S time plot.

- The end of plunge-in (first periastron) happens earlier as secondary mass becomes larger
- The final separation can be smaller for smaller secondary mass if we run the simulation longer



Unbound mass V.S time plot.

- Almost all unbinding happens during the plunge in (first periastron)
- Then, the amount of unbound mass decreases because of its interaction with the ambient medium



2D slice through the orbital plane. Upper panel: Blue: Bound, Red: Unbound
Lower panel: Green: Kinetic energy dominated, Magenta : Internal energy dominated.

- Most unbound mass are Kinetic energy dominated.
- The spiral-in process forms layer structure of bound/unbound material.

α_{CE} energy formulism

$$\frac{GM_1M_{1,e}}{\lambda R_1} = \alpha_{CE}\frac{GM_2}{2}\left(\frac{M_{1,c}}{a_f} - \frac{M_1}{a_i}\right)$$

a_i [$R_{\odot}$]	LHS [10^{47} erg]	RHS ($a_f = 7R_{\odot}$) [10^{47} erg]
49	1.9	0.2 α_{CE}
109	1.9	0.6 α_{CE}

α_{CE}	0.1	0.25	0.5	1
a_i ($R_{\odot}$)	a_f ($R_{\odot}$)			
49	0.3	0.8	1.5	2.6
109	0.4	0.9	1.7	3.1

A common approach for qualifying envelope unbinding in CEE is the α_{CE} energy formulism. λ denotes the structure of the primary; α_{CE} denotes the efficiency of energy transfer

- Based on the calculation, at the end of the simulation, we don't expect the entire envelope to unbind because α_{CE} must be less then 1 and the separation at the end of our simulation is much greater then required.
- If the energy is transferred from particles to gas at a steady rate equal to that at the end of our simulation, the envelope may be ejected by $10^2 \sim 10^3$ days.

Outlook

- To unbind the envelope, simulations need to run longer
- Additional energy source and a shift in parameter space may also result in envelope ejection

See poster by Luke Chamandy for accretion in CEE and core-envelope motion.

	$M_2 = 1M_{\odot}$	$M_2 = 0.5M_{\odot}$	$M_2 = 0.25M_{\odot}$
Density			
Energy			