How self-regulating jets may play a key role during the common-envelope phase

Diego López-Cámara (IA-UNAM)

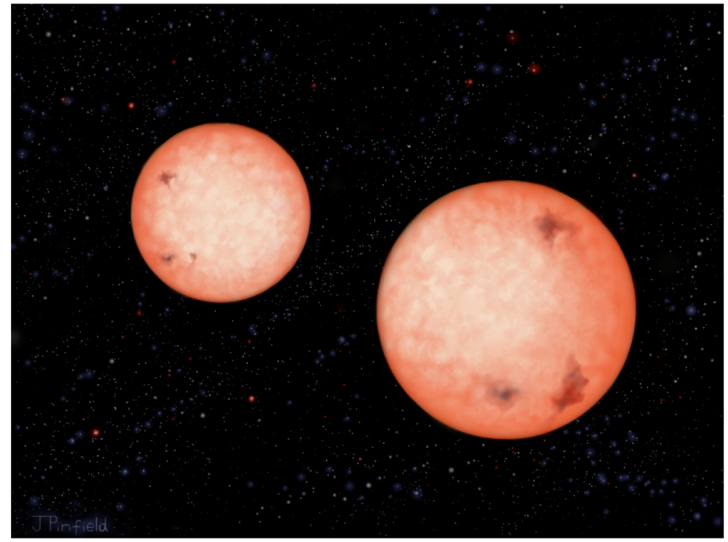
Fabio De Colle (ICN-UNAM)

Enrique Moreno-Méndez (FC-UNAM)

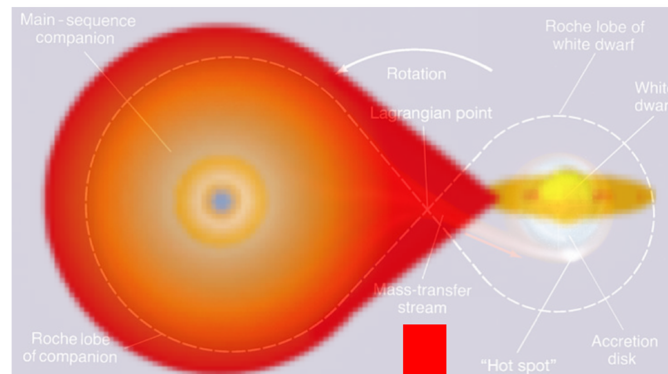
(aka: my other life apart from GRBs)

BSs (intro)

The majority of the stars (~50-71%) are in Binary systems (BSs).
(Sana et al. 2012, 2013)

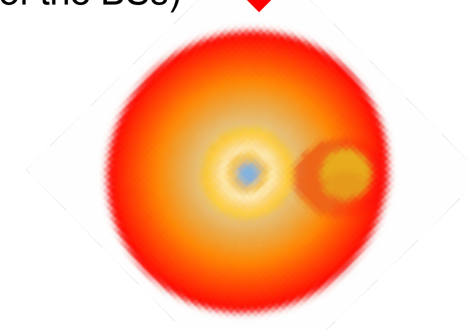


Roche Lobe
(Brown & Weingartner 1994)



(a fraction of the BSs)

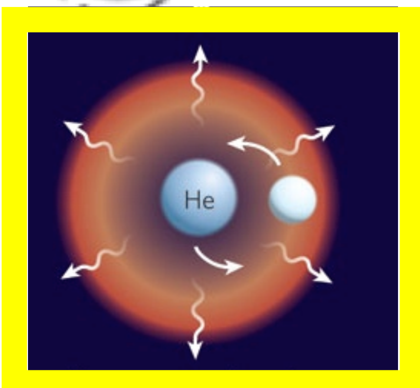
Common envelope (CE) (Paczynski 1976)
$\tau \leq 10^3$ yr (Meyer et al. 1979, Ivanova 2013)

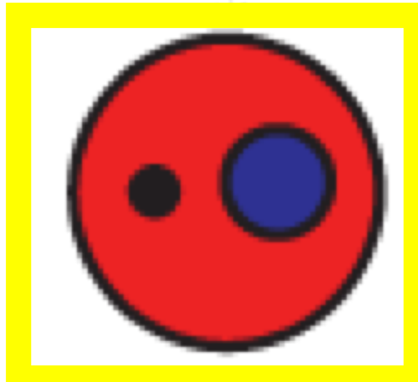


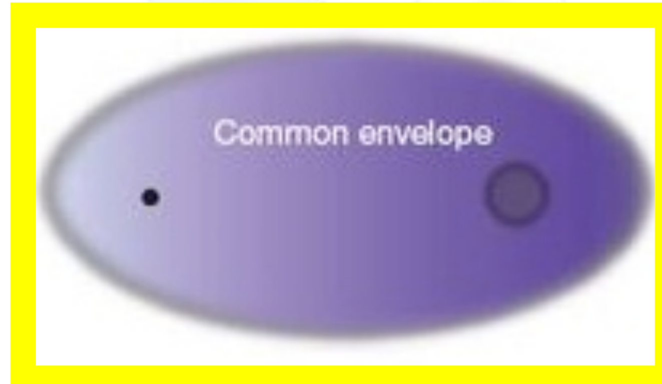
BSs (evolutive channels):

1. removal of CE?

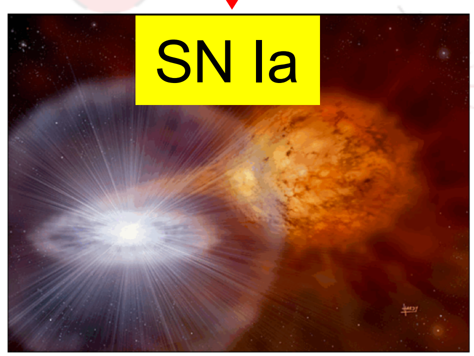
2. CO in CE?

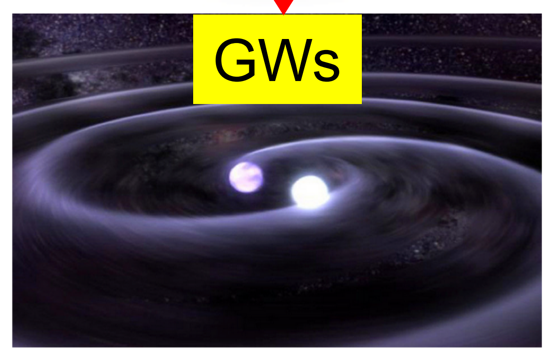




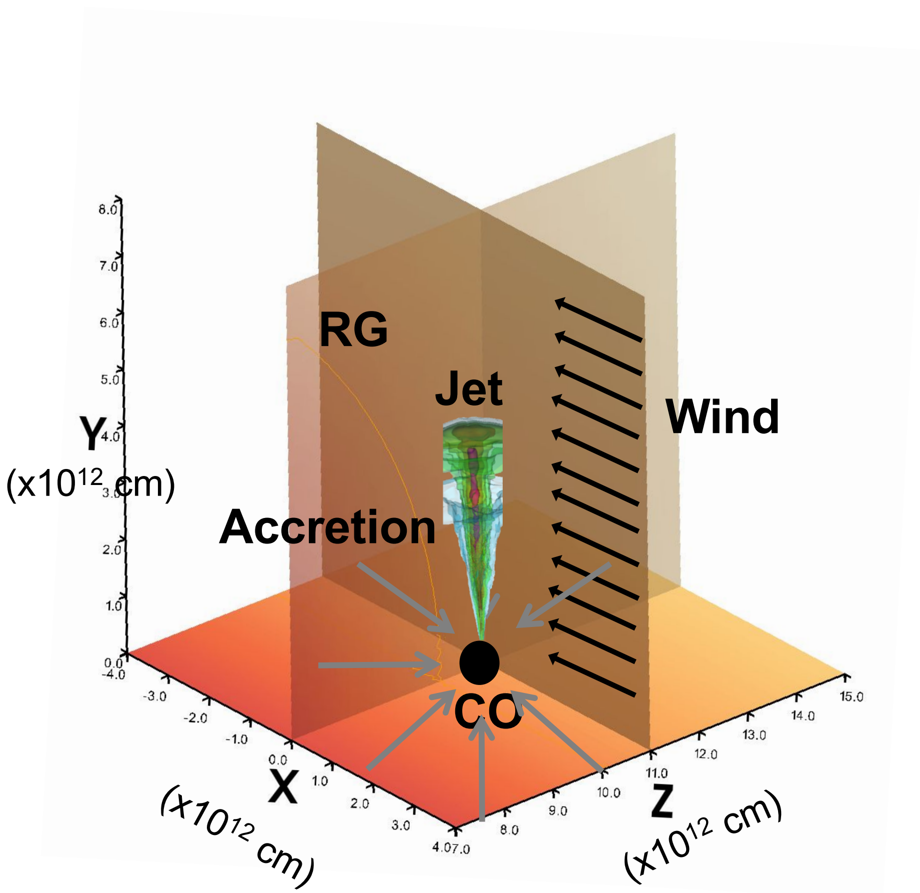


FOE! **FOE!** **FOE!**





CE + CO + jet (model):



RG (16 $M_\odot$, 535 $R_\odot$, Papish & Soker 2015)
(~ 3×10^{13} cm)

CO (1.4 $M_\odot$ or 5 $M_\odot$, a=1.1×10^{13} cm)

Ref system in the CO (wind)
($\Delta x = \Delta y = \Delta z = 8\times10^{12}$ cm)

Accretion ($r_{in} = 1.1\times10^{11}$ cm)

Jet ($L_j = \eta\, L_0$ or $L_j = \eta\, \dot{M}\, c^2$)

($\Delta \sim 10^{10}$ cm , ~ 1024^3 , Δt_{int} ~3-9x10^5 s)
(cpu-h ~ 10^5 h)

CE + CO + jet (analytic vs simulations):

Jet

$$P_j = \rho_j v_j^2 = \rho_\infty v_\infty^2 \left(\frac{GM_*}{r v_\infty^2}\right)^2 \frac{2\epsilon v_j}{\theta_j^2 v_\infty}$$

Accretion

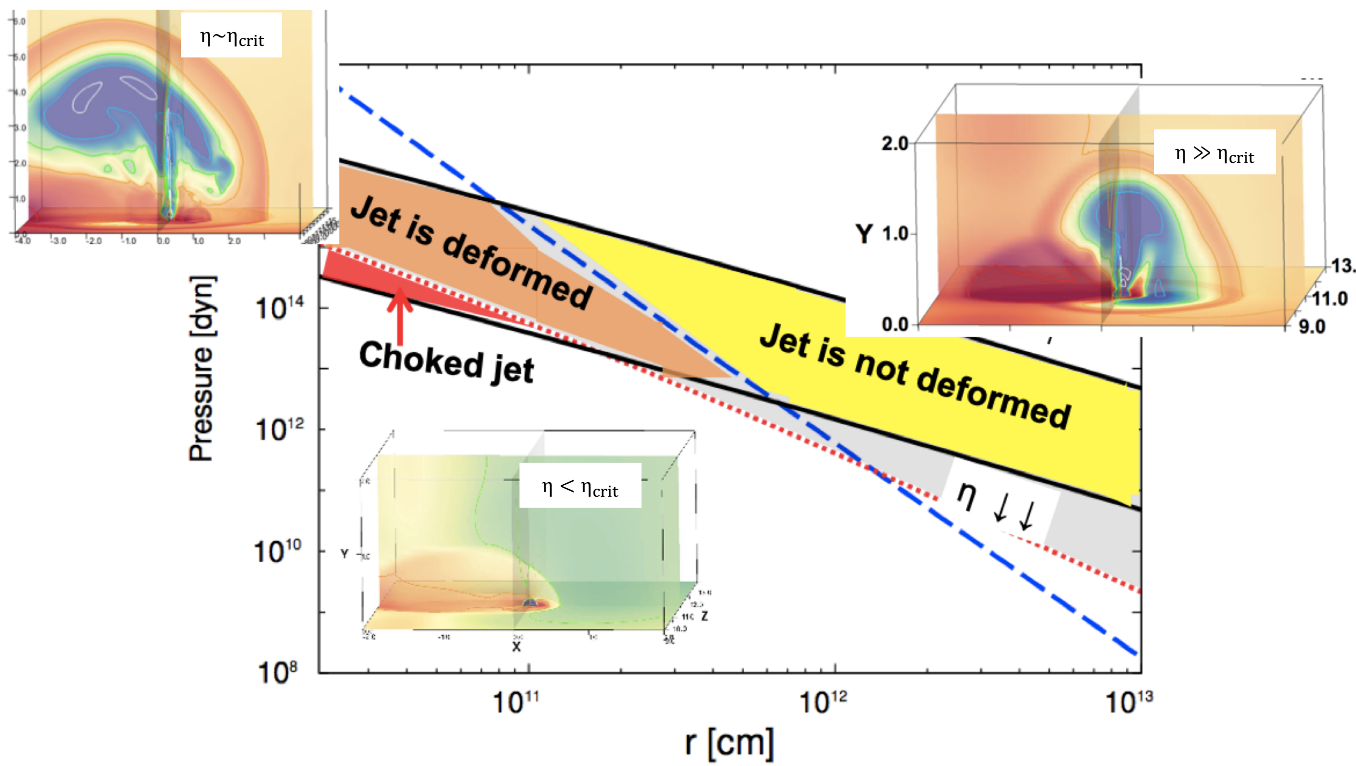
$$P_a = \rho_a v_r^2 = \rho_\infty v_\infty^2 \left(\frac{GM_*}{r v_\infty^2}\right)^2 \frac{1}{\sqrt{1 + \frac{4GM_*}{r v_\infty^2}}}$$

Wind

$$P_w = \rho_\infty v_\infty^2 = \rho_\infty \frac{GM(a)}{a}$$

Analytical model + 3DHD (for the case $L_j = \eta L_0$)

(Moreno-Méndez, LC, De Colle, 2017)



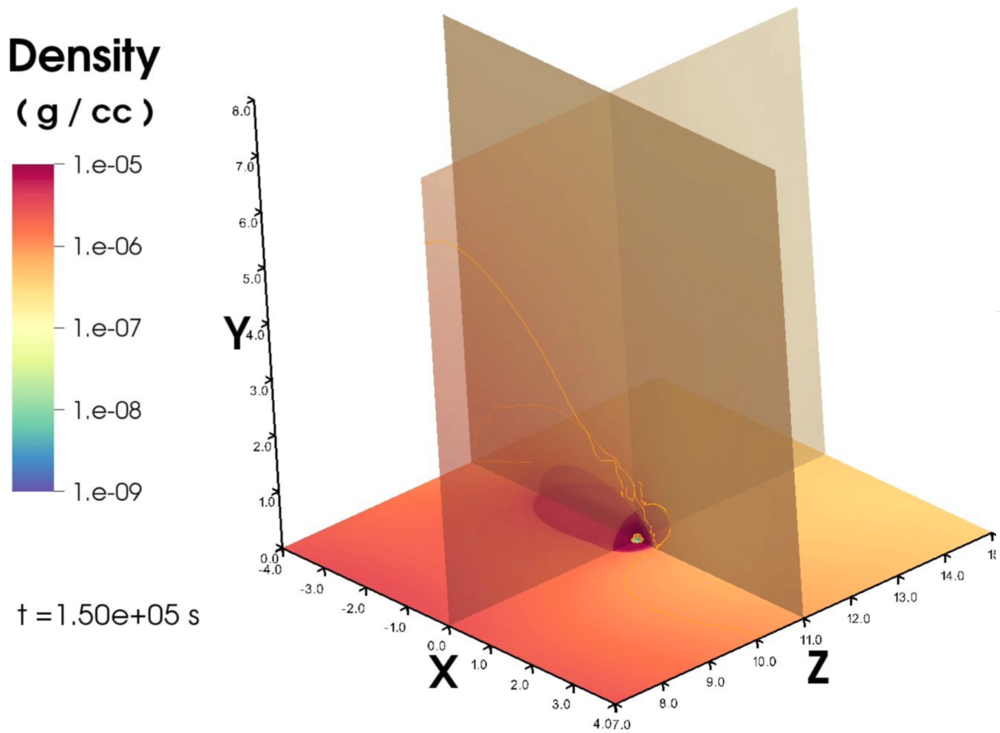
CE + CO + jet (self-regulated jet):

3DHD with a self-regulated jet

$(L_j = \eta\, \dot{M}_{CO}\, c^2)$

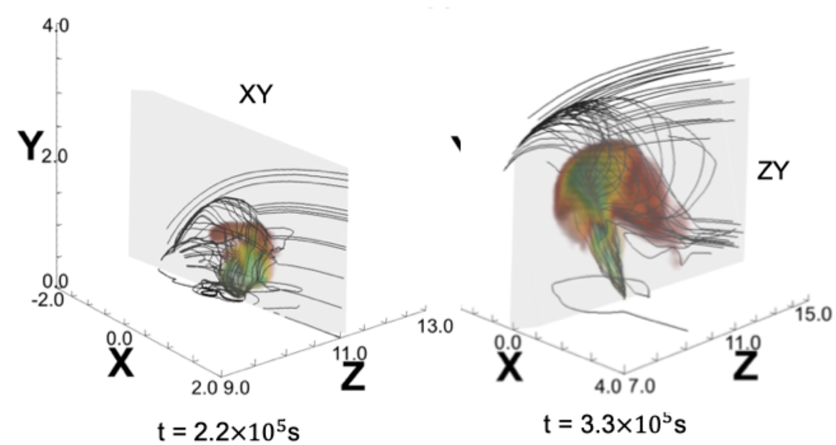
$\eta \leq \eta_{crit} \Rightarrow$ chocked jet

$\eta > \eta_{crit} \Rightarrow$ successful jet



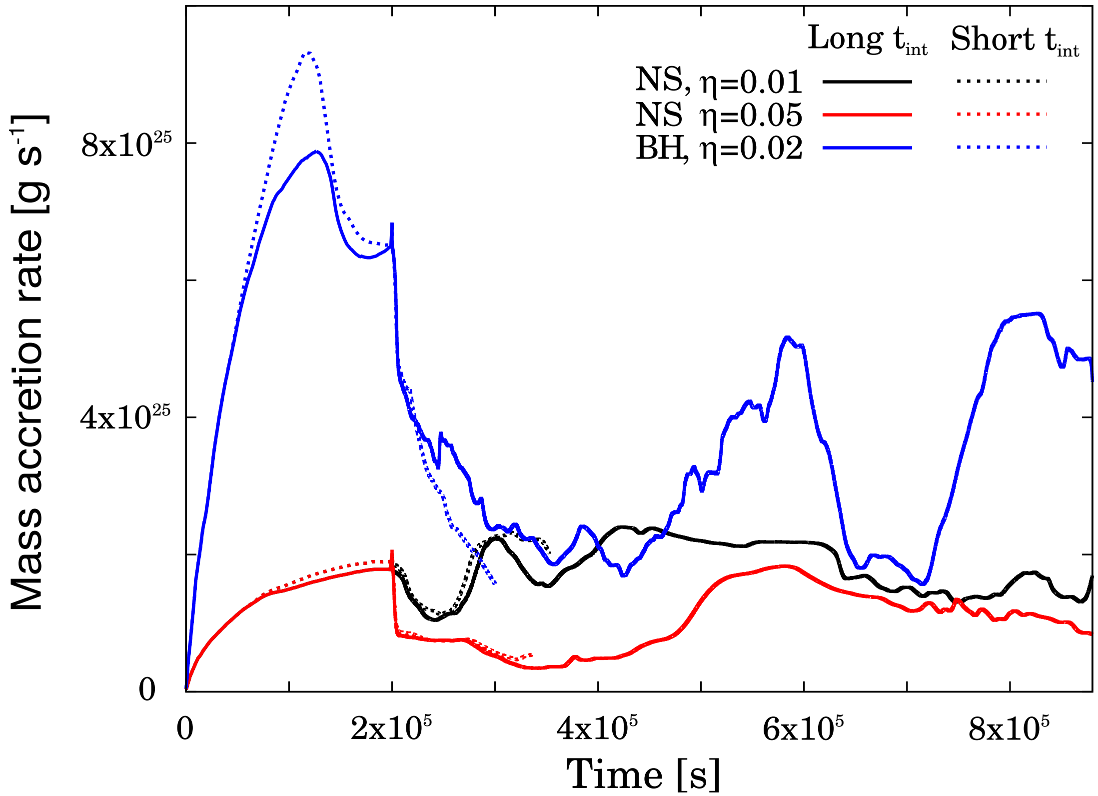
(LC, De Colle, Moreno-Méndez, 2019)

Variable jet (size + orientation)



~ behavior for the BH / NS

CE + CO + jet (self-regulated jet):



1. Jet ⇒ cocoon

2. Cocoon ⇒ shields the jet

   NJF ⇒ $\dot{M}_{CO}$ ↓↓

   (Soker et al. 2014)

3. Jet is chocked ⇒ ~~cocoon~~

   ⇒ $\dot{M}_{CO}$ ↑↑

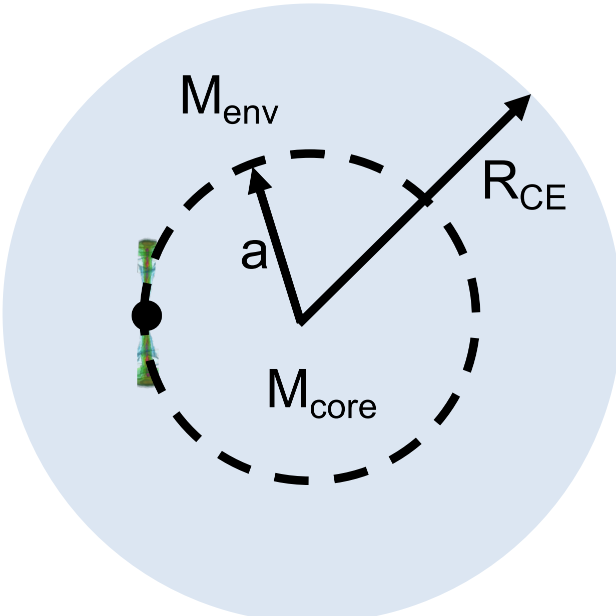
4. Jet ⇒ cocoon

$\dot{M}_{CO} \sim \dot{M}_0 \pm 50\%$ (~1x10^{25} - 3x10^{26} g s^{-1})

(~ 0.1 - 0.5 $M_\odot$ yr^{-1})

removal of CE ?

CE + CO + jet (CE removal):



$$M(a) = M_{core} + M_{env}(a/R_{CE})^{0.3}$$

with: $R_{CE} = 535\ R_\odot$ (Papish et al. 2015)

If a = 10^{13} cm $\Rightarrow M_{core} = 3.5\ M_\odot$, $M_{env} = 16.5\ M_\odot$

The time to unbind the outer layer of the CE:

$$E_{\rm bind} = \int_a^{R_{CE}} \frac{GM(r)dM}{r} \approx 10^{49} {\rm erg}$$

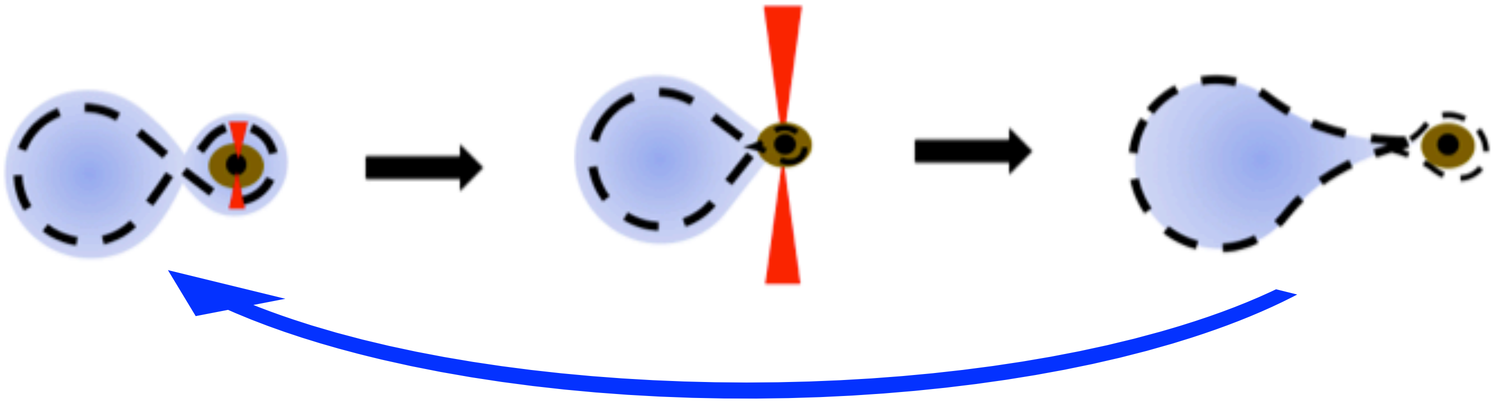
$$E_{\rm jet} = L_{\rm jet} t = (2-4) \times 10^{44} t \ {\rm erg}$$

$$t_{u,e} \sim E_{bind}/L_j \approx (6-14)\ {\rm h}$$

(days if a < 10^{13} cm)

CE + CO + jet (GE phase):

"Grazing envelope" phase



CE is blown in hours - days

$\dot{M}_{CO} \downarrow\downarrow \Rightarrow L_j = 0$ erg s^{-1}

removal of CE ✅

(jet power)

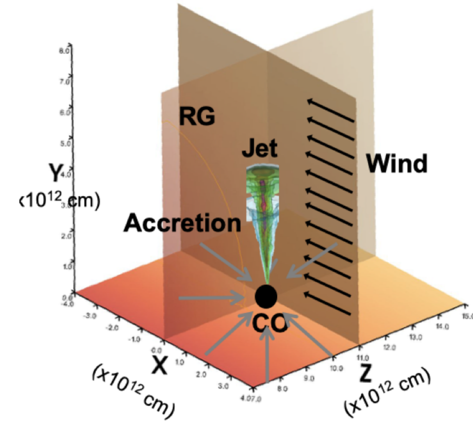
FOE!

CEJSN
(Soker+Papish+Gilkis 2015, 2018ab, 2019ab)

WD-NS fusion

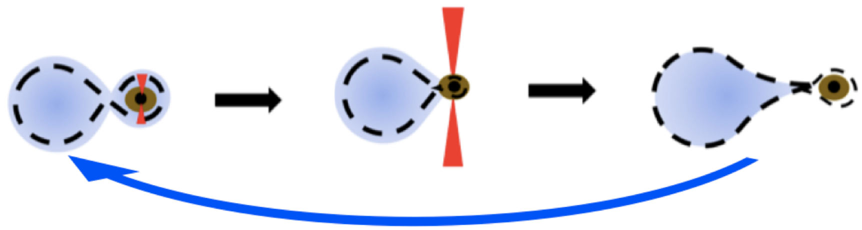
Conclusions:

- 3DHD CE + CO + jet (constant or self-regulated)



- The outer layer of the CE can be unbound in ~ hours - days

- GE configuration may be formed



- CE may be terminated (CEJSN or WD-NS fusion)

FOE!

- More CE studies are needed.