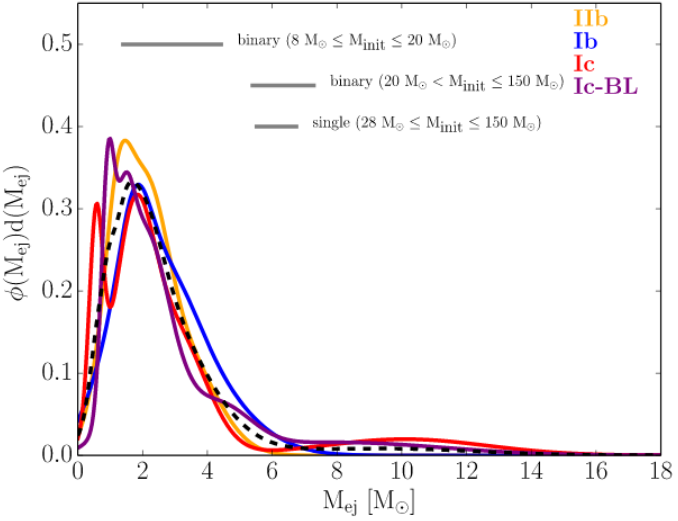
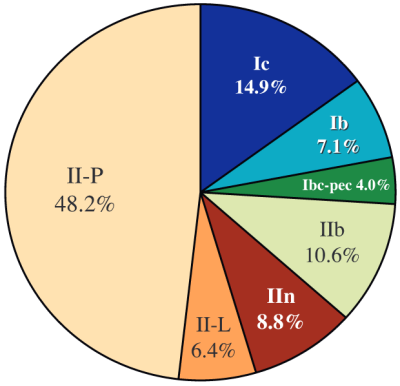
Mass transfer in binary systems

Mathieu Renzo

Mass transfer necessary to explain population of stripped SNe



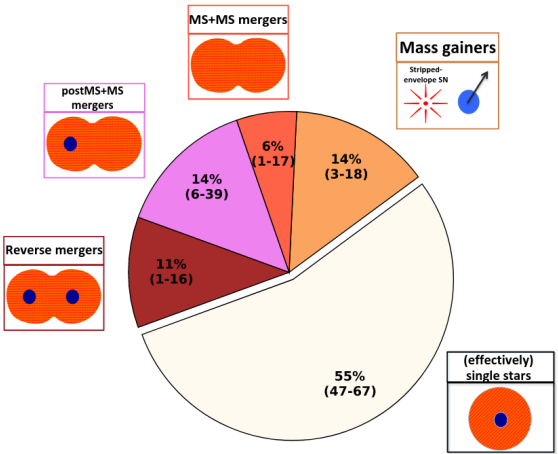


Core-Collapse SN Fractions

Lyman *et al.* 2016, see many others...

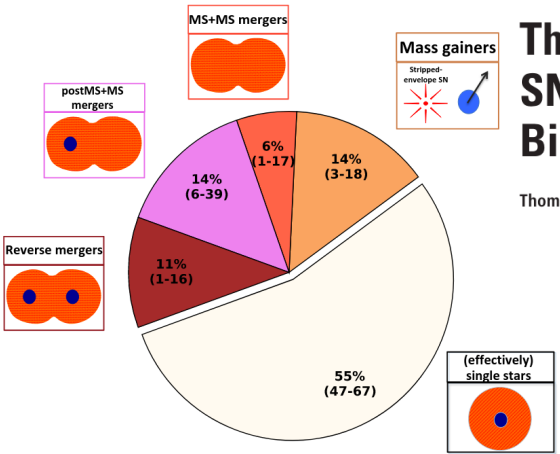
Smith *et al.* 2011

Mass transfer also matters for H-rich SNe



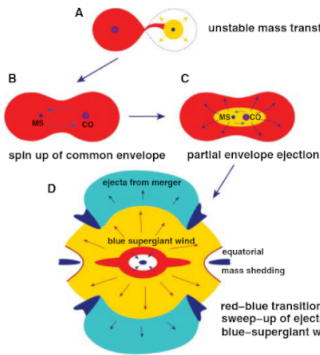
Zapartas *et al.* 2019

Mass transfer also matters for H-rich SNe



The Triple-Ring Nebula Around SN 1987A: Fingerprint of a Binary Merger

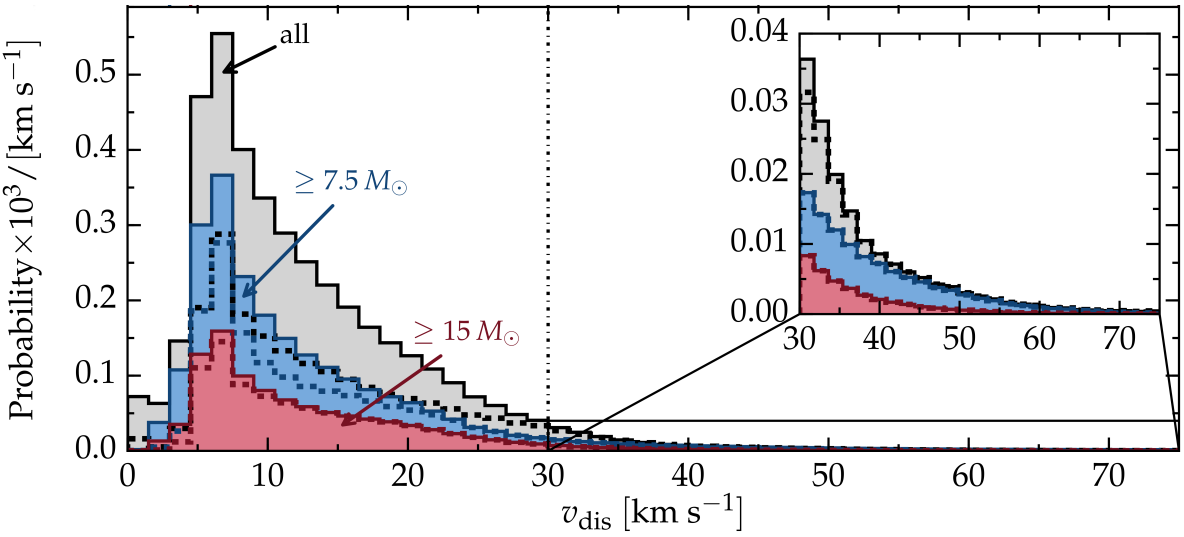
Thomas Morris[1,2] and Philipp Podsiadlowski[1]*



Zapartas *et al.* 2019

Morris & Podsiadlowski 2007, see also Podsiadlowski *et al.* 1990, 1991, 1992 ....

Mass transfer determines the kinematics of ejected companions



Velocity w.r.t. pre-explosion binary center of mass

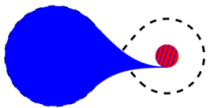
Renzo *et al.* 2019b

Numerical results: http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/624/A66

Mass transfer in binary systems can be

dynamically stable:

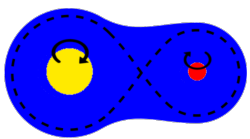
Roche lobe overflow



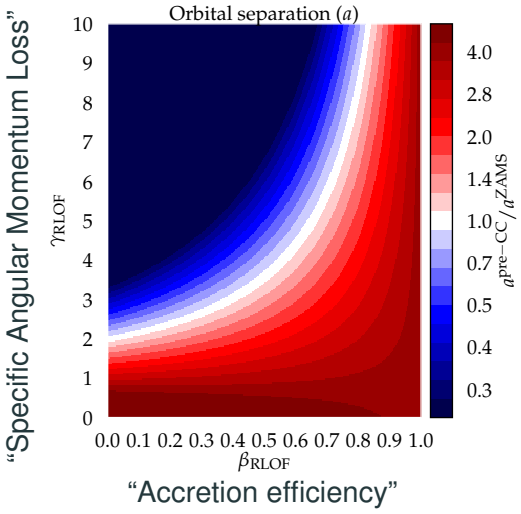
what is/isn't "dynamical" is the response of the orbit

dynamically unstable:

Common envelope



Orbital response to stable RLOF



Stable RLOF tends to widen binaries

except until $M_1 > M_2 \Rightarrow$ channel for GW

van den Heuvel *et al.* 2017, Marchant *et al.* 2021, van Son *et al.* 2021, Gallego-Garcia *et al.* 2021, ...

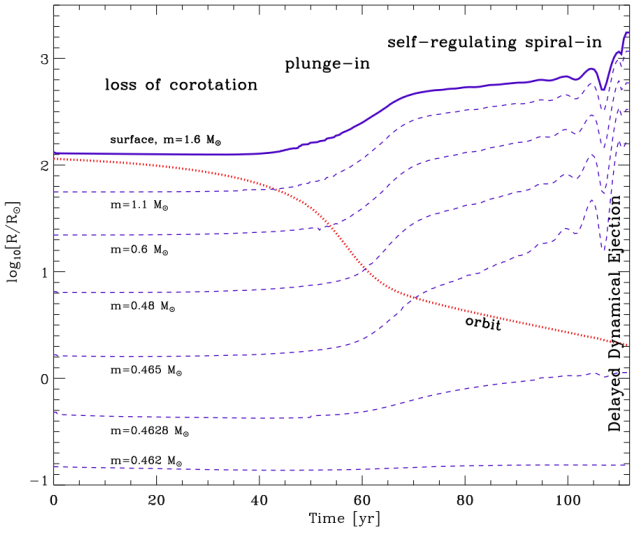
Renzo *et al.* 2019b

Orbital response to Common envelope

Abstract. When a contact binary expands so much that the stellar surface moves beyond the outer Lagrangian point, a common envelope binary is formed. The suggestion is made that while the two dense stellar nuclei spiral towards each other, the envelope expands and is eventually lost. Most of the angular momentum is lost with the envelope, and therefore the final orbital period may be orders of magnitude shorter than the initial period.

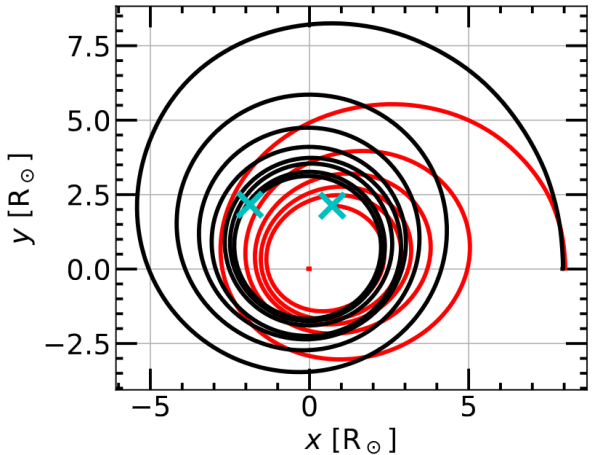
Paczynski 1976, see also Ostriker 1973 Webbink 1975 (PhD thesis)

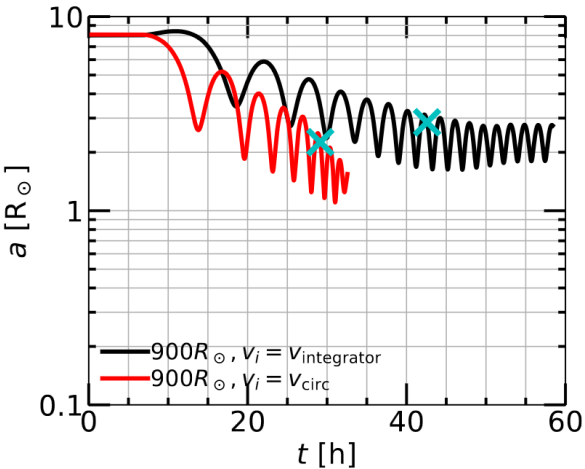
Orbital response to Common envelope



1D simulation from Ivanova *et al.* 2002 as shown in Ivanova *et al.* 2013

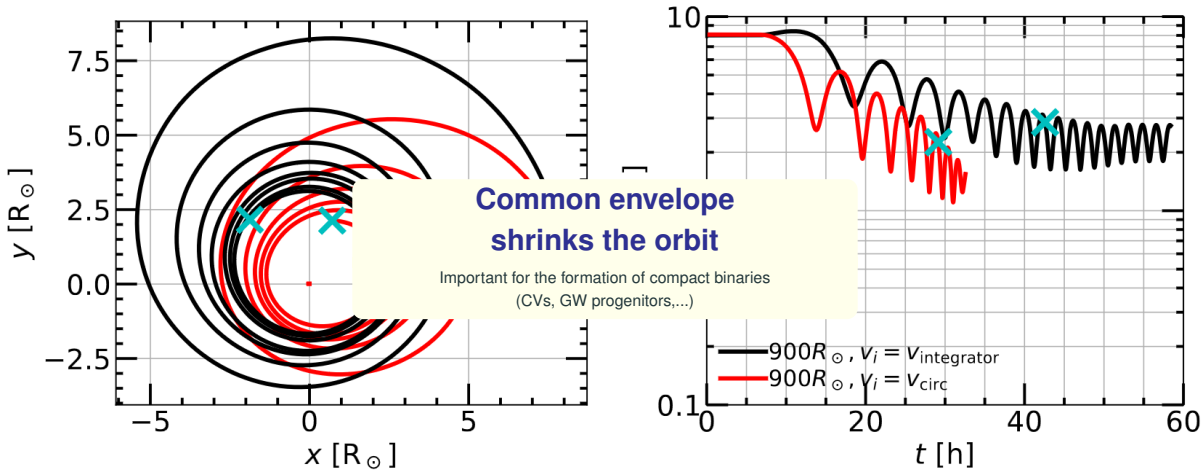
Orbital response to Common envelope





3D simulation from Law-Smith *et al.* 2020 – see many others

Orbital response to Common envelope



Common envelope shrinks the orbit

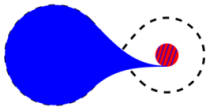
Important for the formation of compact binaries (CVs, GW progenitors,...)

3D simulation from Law-Smith *et al.* 2020 – see many others

Orbital consequences of mass transfer

dynamically stable:

Roche lobe overflow

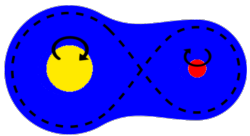


Stable RLOF tends to widen binaries

except until $M_1 > M_2 \Rightarrow$ channel for GW

dynamically unstable:

Common envelope



Common envelope shrinks the orbit

Important for the formation of compact binaries (CVs, GW progenitors,...)

Which binaries remain stable?

Major uncertainty in rate calculations

Stability depends on the reaction of

- donor star envelope to mass **loss**

Ge *et al.* 2010, 2015, 2022, 2023

- accretor star envelope to mass **accretion**

Renzo & Götberg 2021, Lau *et al.* 2024

- orbit and Roche lobes to mass changes

Kippenhahn & Weigert 1977

$\Longrightarrow$

How and when mass is exchanged matters

as well as

where E and J go

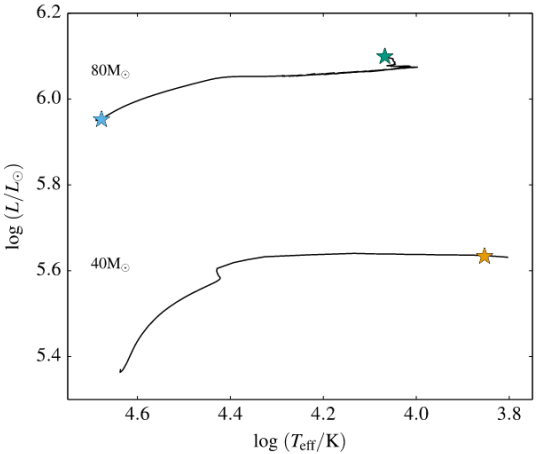
Relevant timescales

- $P_{\rm orb} \simeq$ hours $-$ decades
- $\tau_{\rm dyn} \simeq$ hours $-$ days
- $\tau_{\rm thermal} \lesssim 10^5$ yr

3D radiation-hydro simulations of the onset of RLOF

Donor star from Goldberg *et al.* 2022, credits: Y.-F. Jiang, ATHENA++

Project in need of person-power only!



Already available:

- ATHENA++ working setup
- 3D RHD models of donors
- CPUh on *Pleiadis*

with K. Kratter, Y.-F. Jiang, J. Goldberg

⇓

Objectives:

Full answer for mass-transfer onto BH/NS

3D donor stars from Jiang *et al.* 2018, Goldberg *et al.* 2022, Goldberg *et al.*, in prep., more can be computed if *really* needed