Binary interactions and mergers of core-collapse SN progenitors

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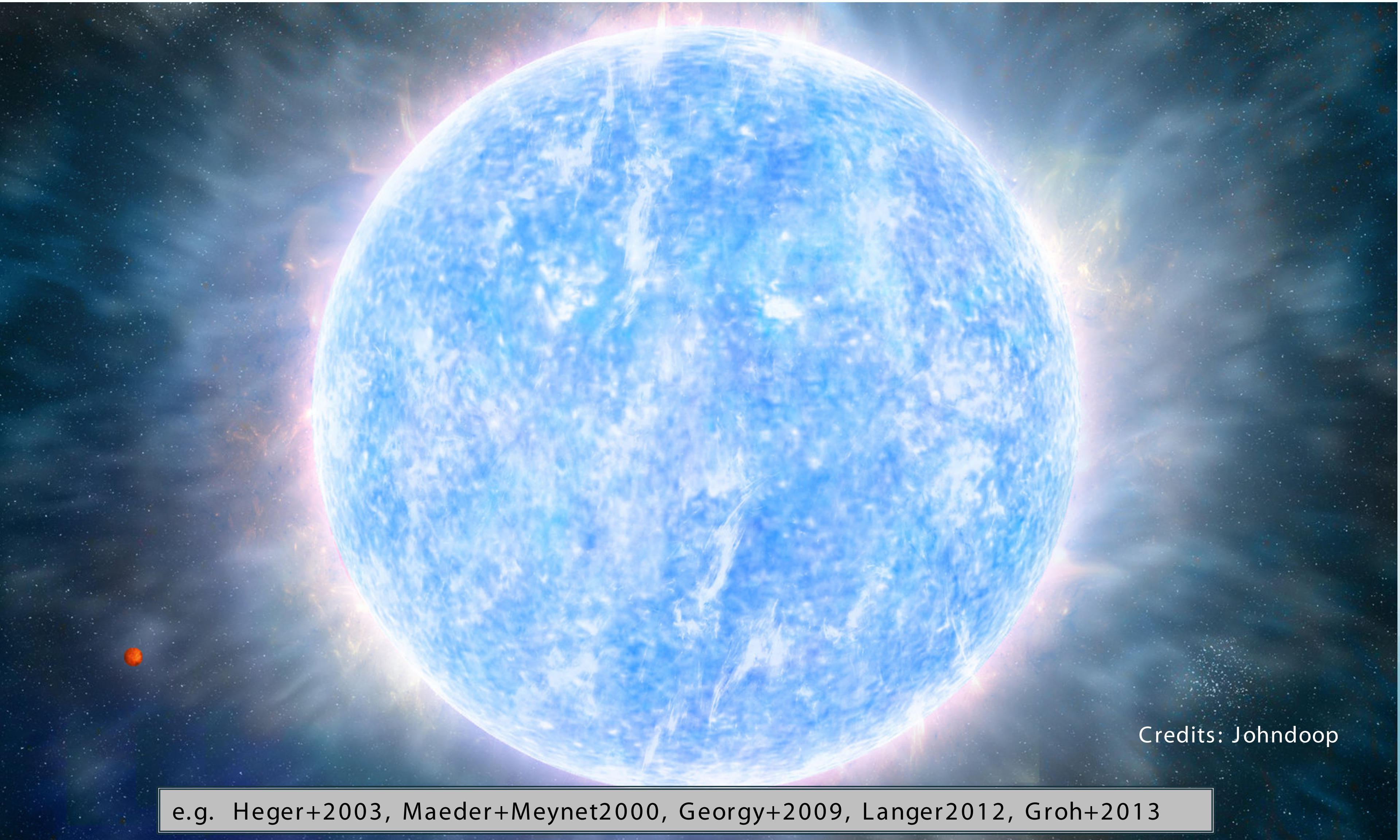
BinCosmos

Image Credits:
ESA/Hubble (Justyn Maund), Deborah Allo

Progenitors of ccSNe:
Massive stars (> 8Mo)



e.g. Heger+2003, Maeder+Meynet2000, Georgy+2009, Langer2012, Groh+2013

Most young massive stars are found in binaries…

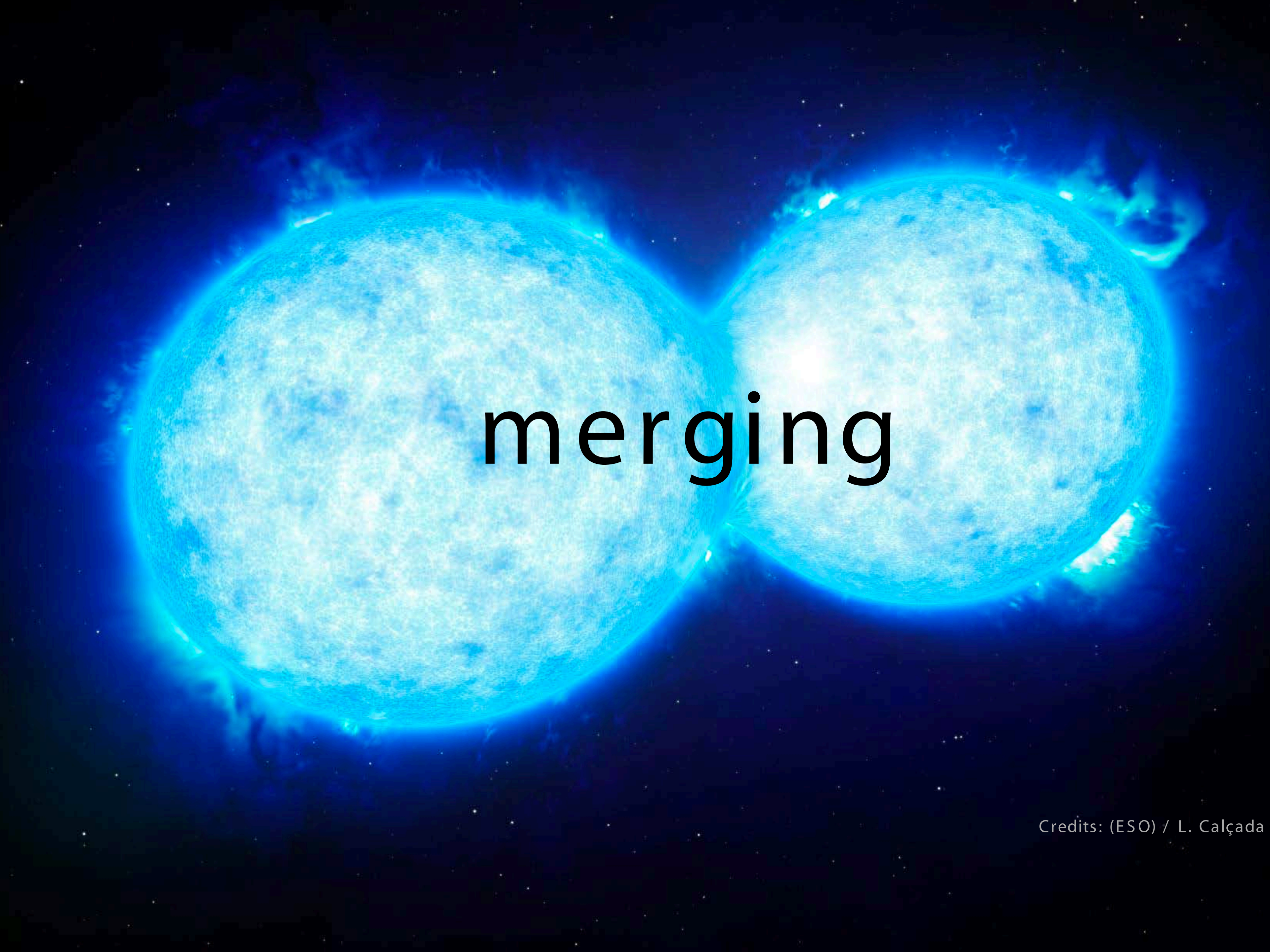
…and will probably interact

(Mason+2009, Sana+Evans2012, Sana+2012, Kiminki+Kobulnicky+2012, Moe+2017)

Credits: (ESO) Calçada, Kornmesser, De Mink


mass
stripping
© ESO

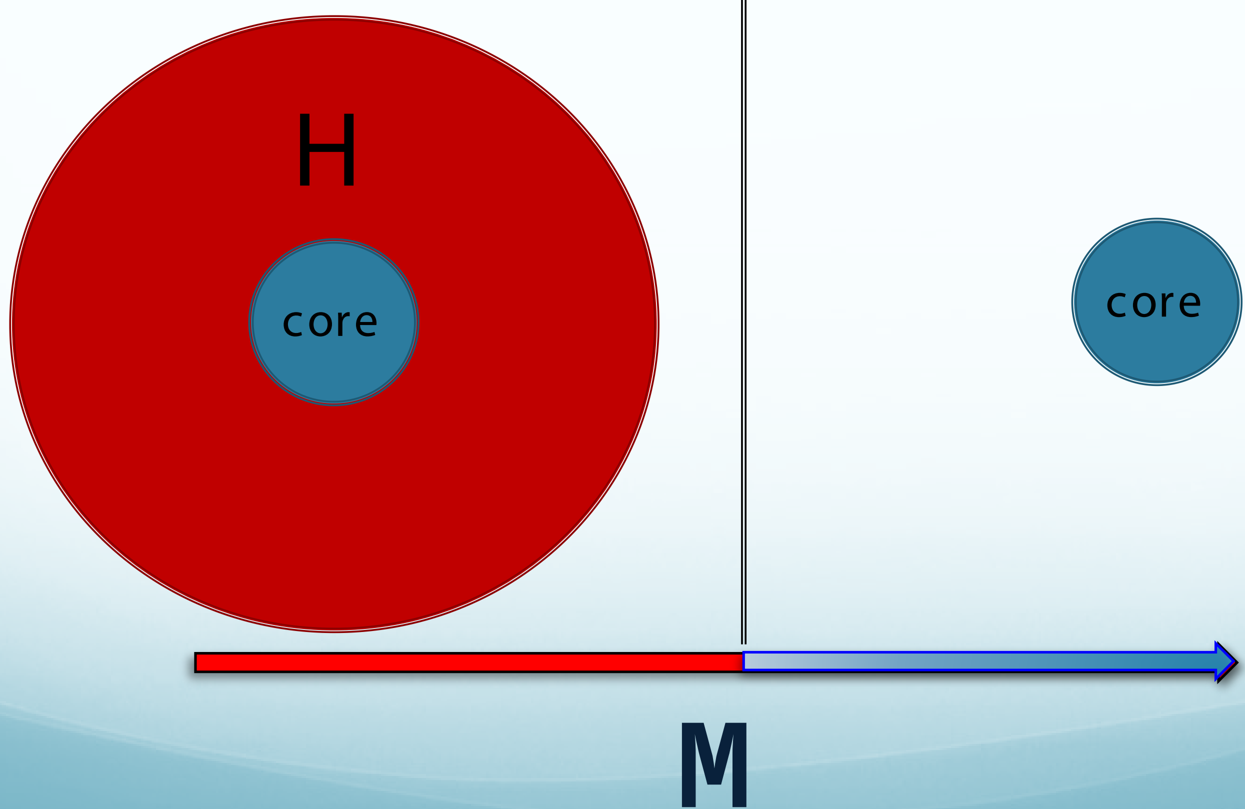

mass
gaining


merging
Credits: (ESO) / L. Calçada

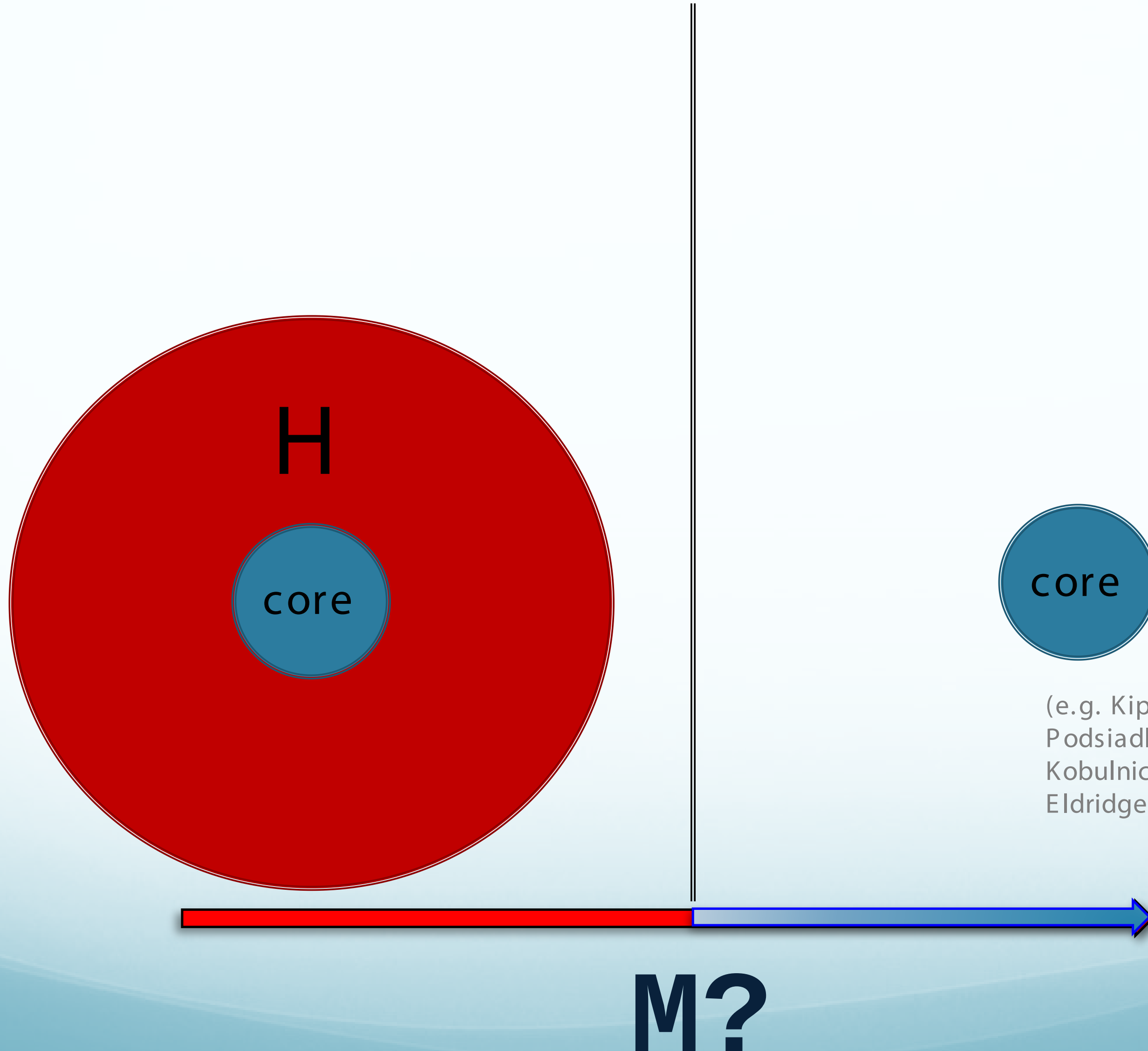
core-collapse SN classes

Type II
(H-rich)

Type Ib, Ic *(and IIb)*
(stripped-envelope)

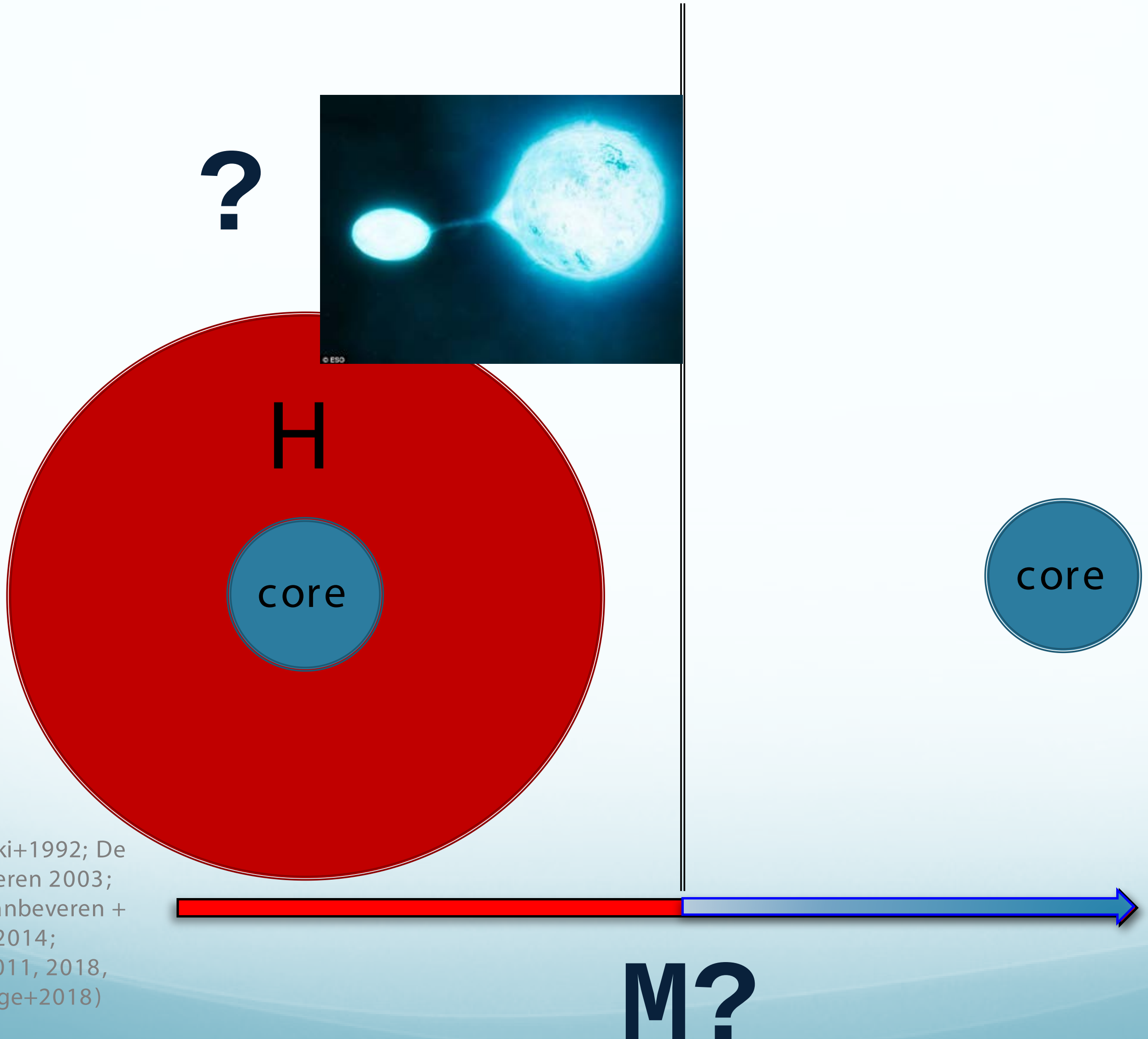


Type IIb, Ib/c: stripping



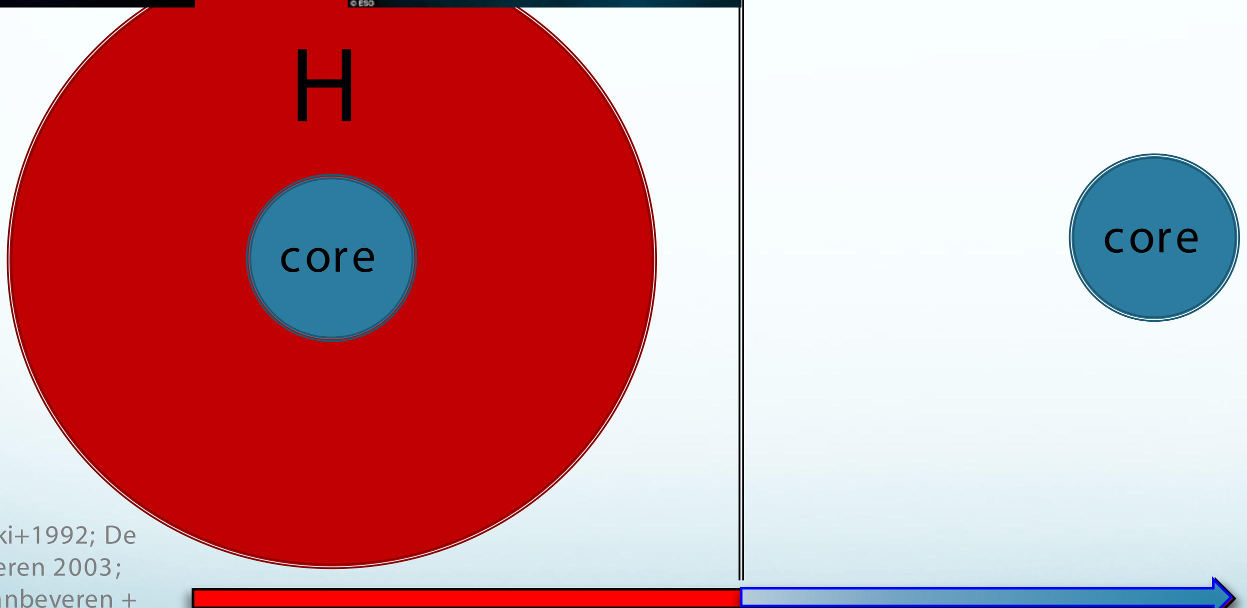
(e.g. Kippenhahn+Weigert 1967; Podsiadlowski+1992; Nomoto+1996; Kobulnicky+Fryer 2007; Smith+2011; Eldridge+2013)

type II



(see Podsiadlowski+1992; De Donder + Vanbeveren 2003; Smartt +2009; Vanbeveren + 2013; Justham + 2014; Eldridge+2008, 2011, 2018, Xiao+2019, Eldridge+2018)

type II: merging or mass gaining



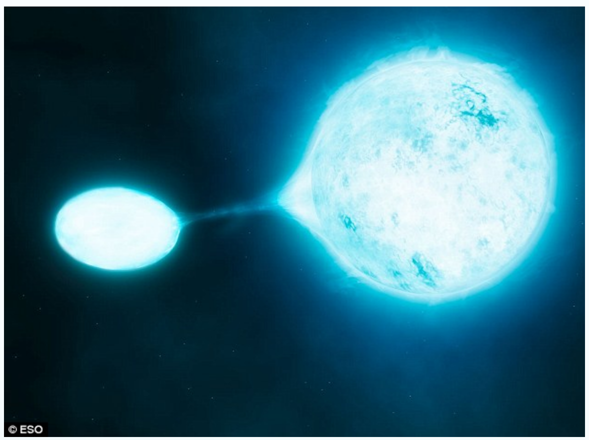
(see Podsiadlowski+1992; De Donder + Vanbeveren 2003; Smartt +2009; Vanbeveren + 2013; Justham + 2014; Eldridge+2008, 2011, 2018, Xiao+2019, Eldridge+2018)

M?

Population synthesis

Binary_c: a rapid binary population synthesis code

(Izzard+'04,'06,'09, Hurley+ '00,'02, de Mink+ '13,Schneider+ '15)



evolution

Mass

Mass ratio

Period

Binary fraction

Metallicity

...

Stellar structure

Stellar winds

Mass transfer

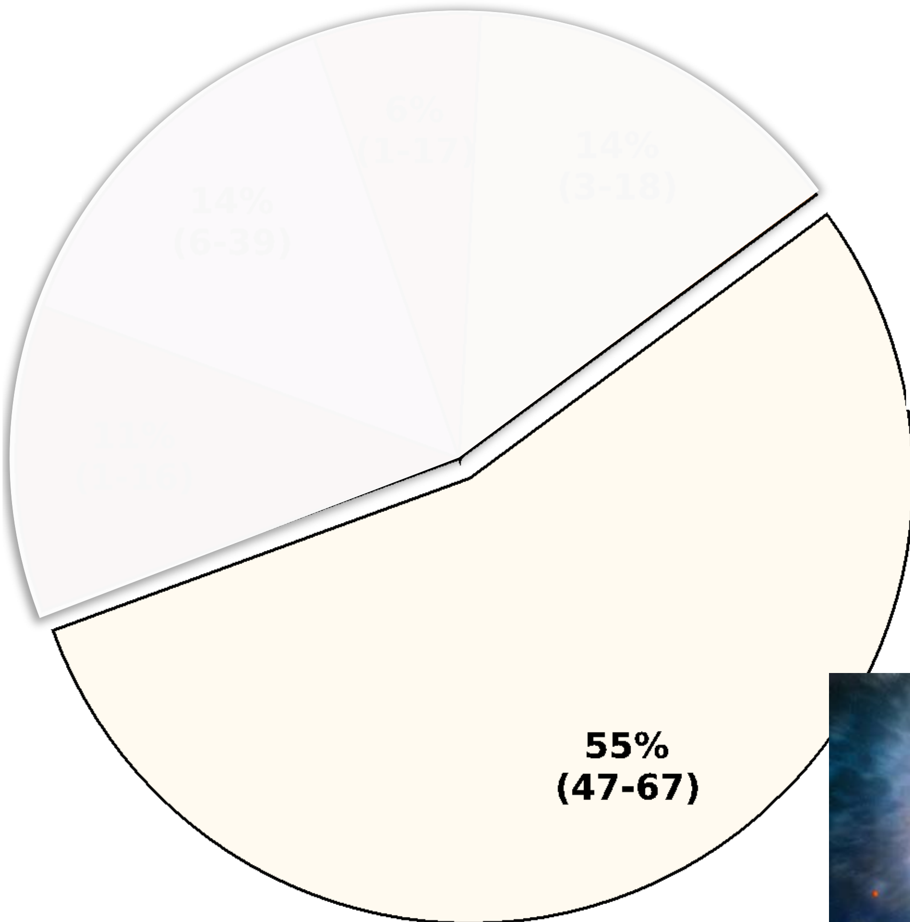
Common envelope

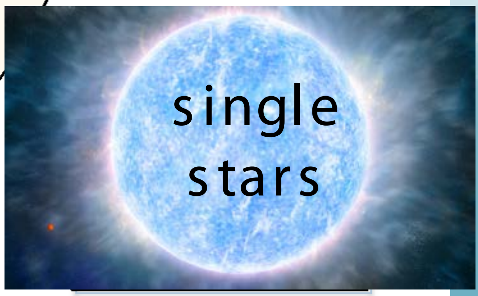
...

Progenitors of type II SNe

Population synthesis for type II SNe

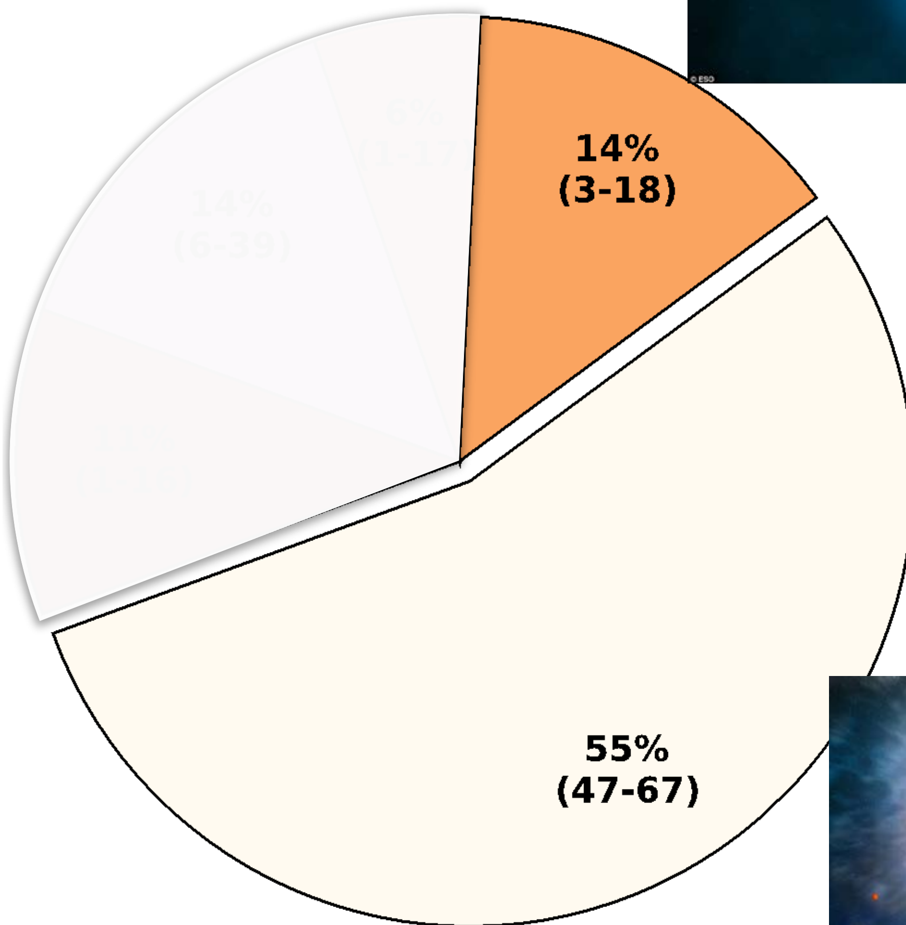
Population synthesis for type II SNe

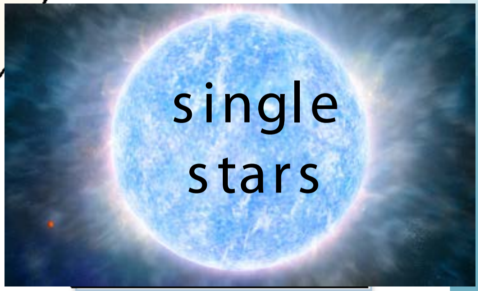




Zapartas+2019

Population synthesis for type II SNe

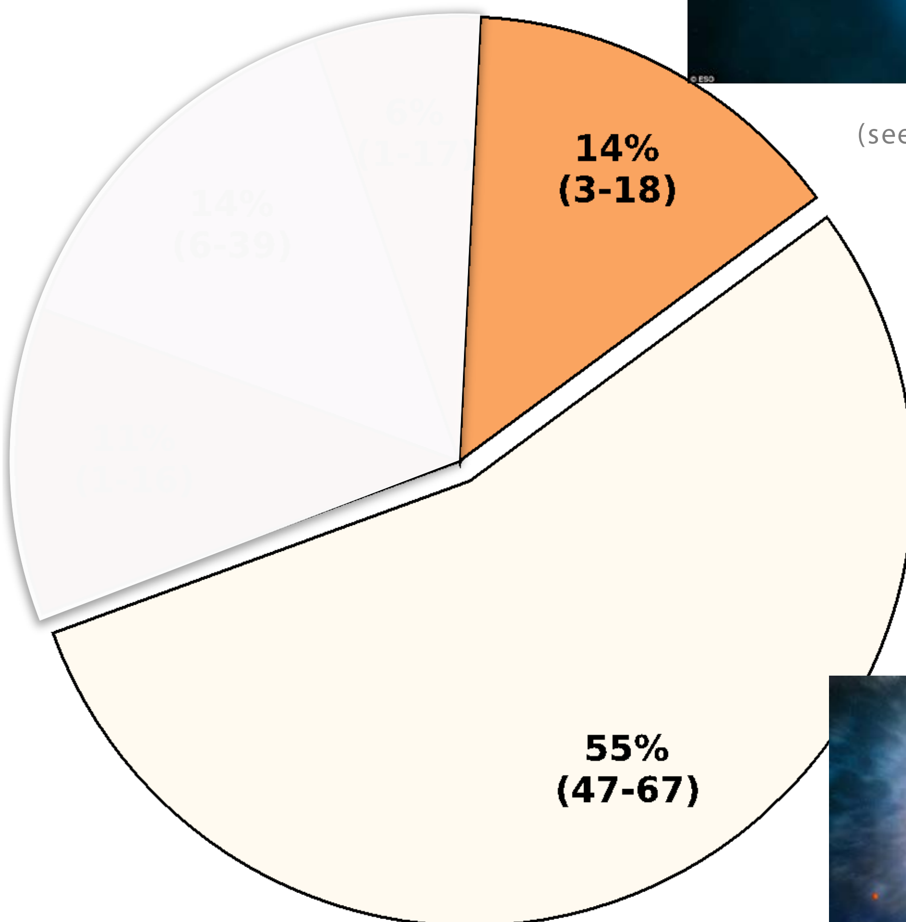




Zapartas+2019

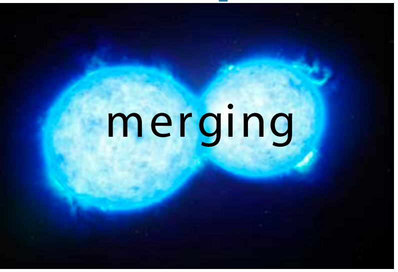
Population synthesis for type II SNe

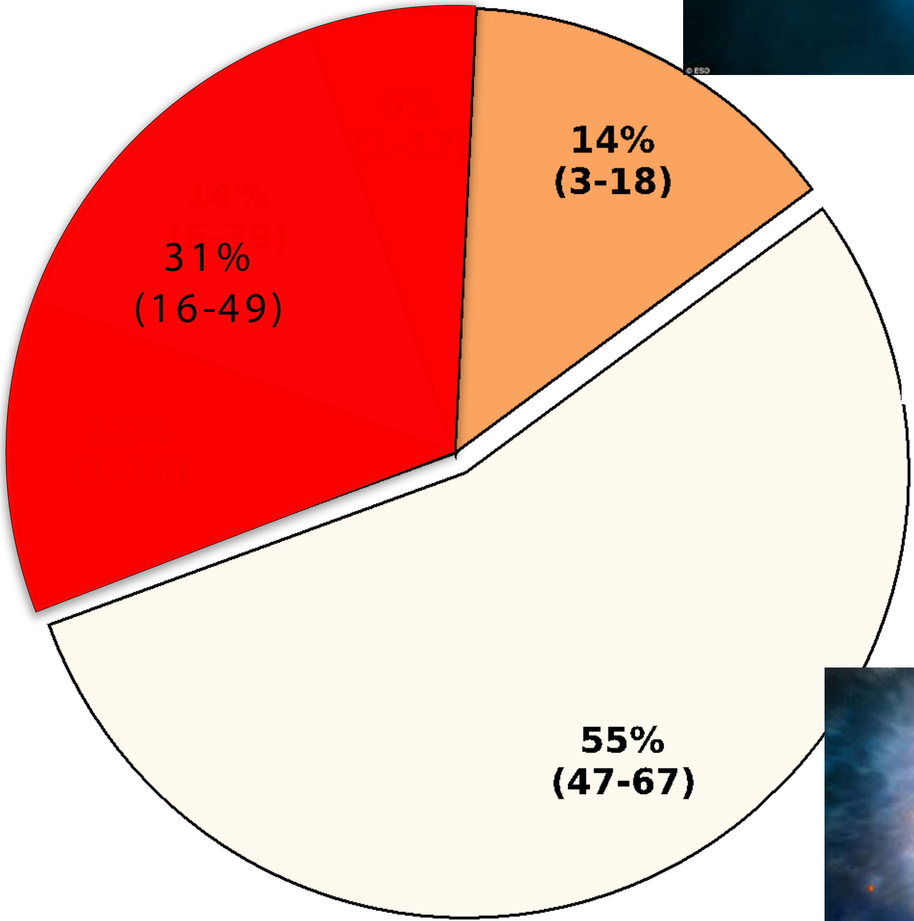
(see e.g. Eldridge+2011, Renzo+2018)

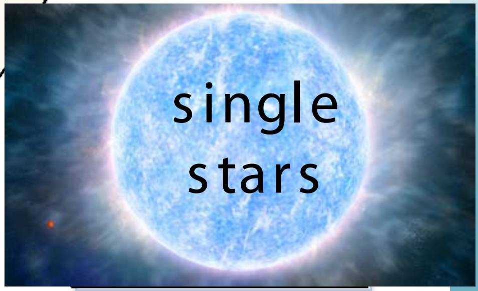


Zapartas+2019

Population synthesis for type II SNe

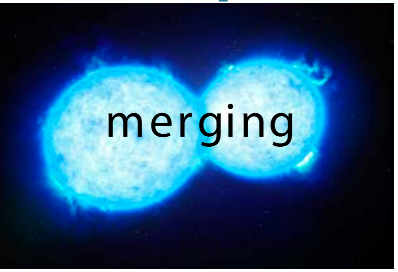


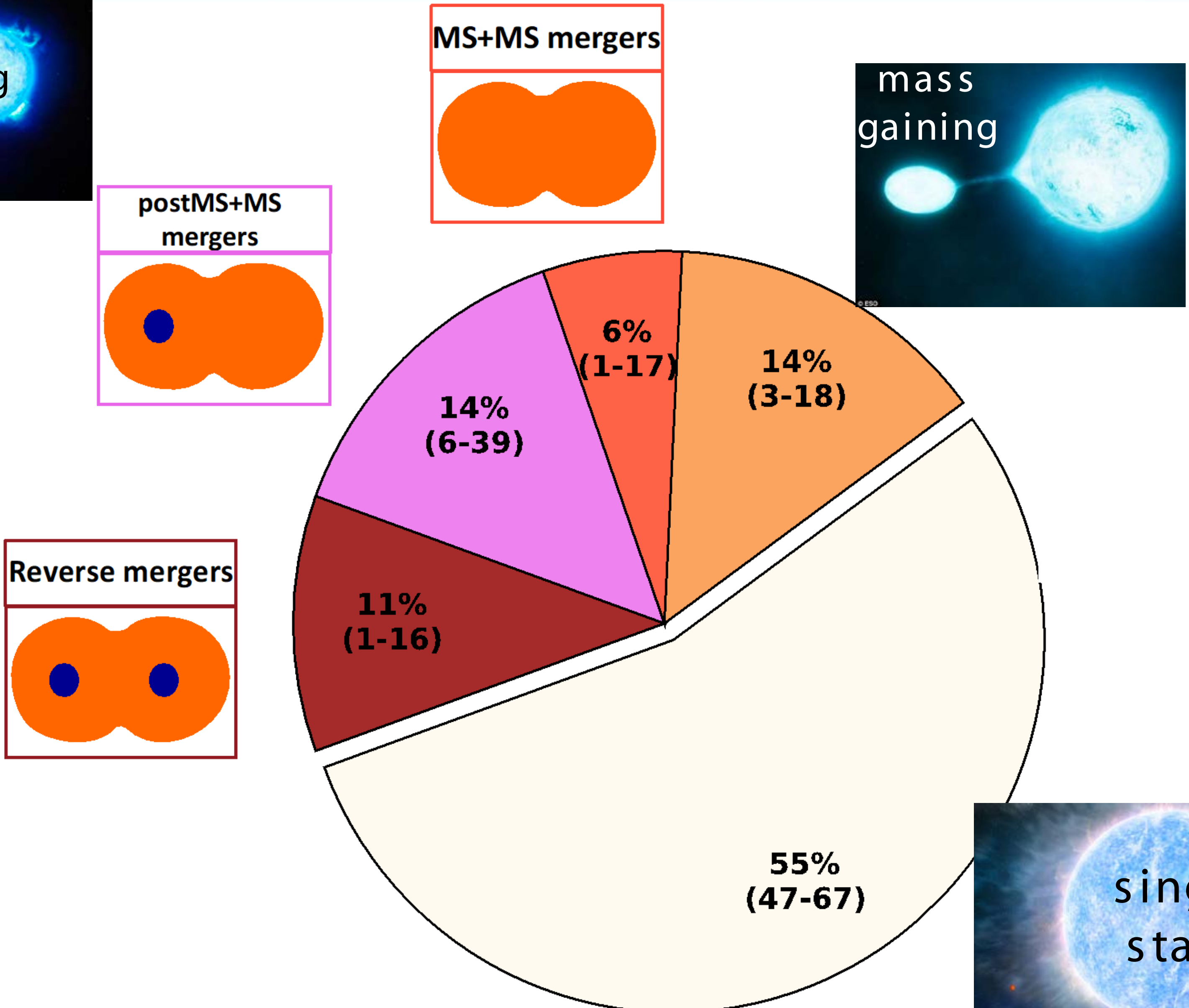


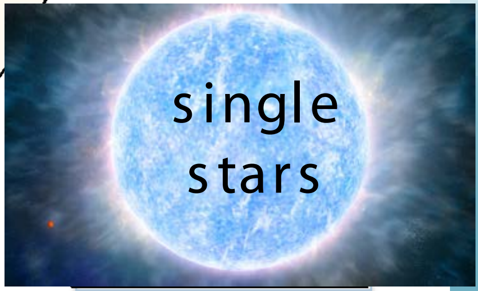


Zapartas+2019

Population synthesis for type II SNe

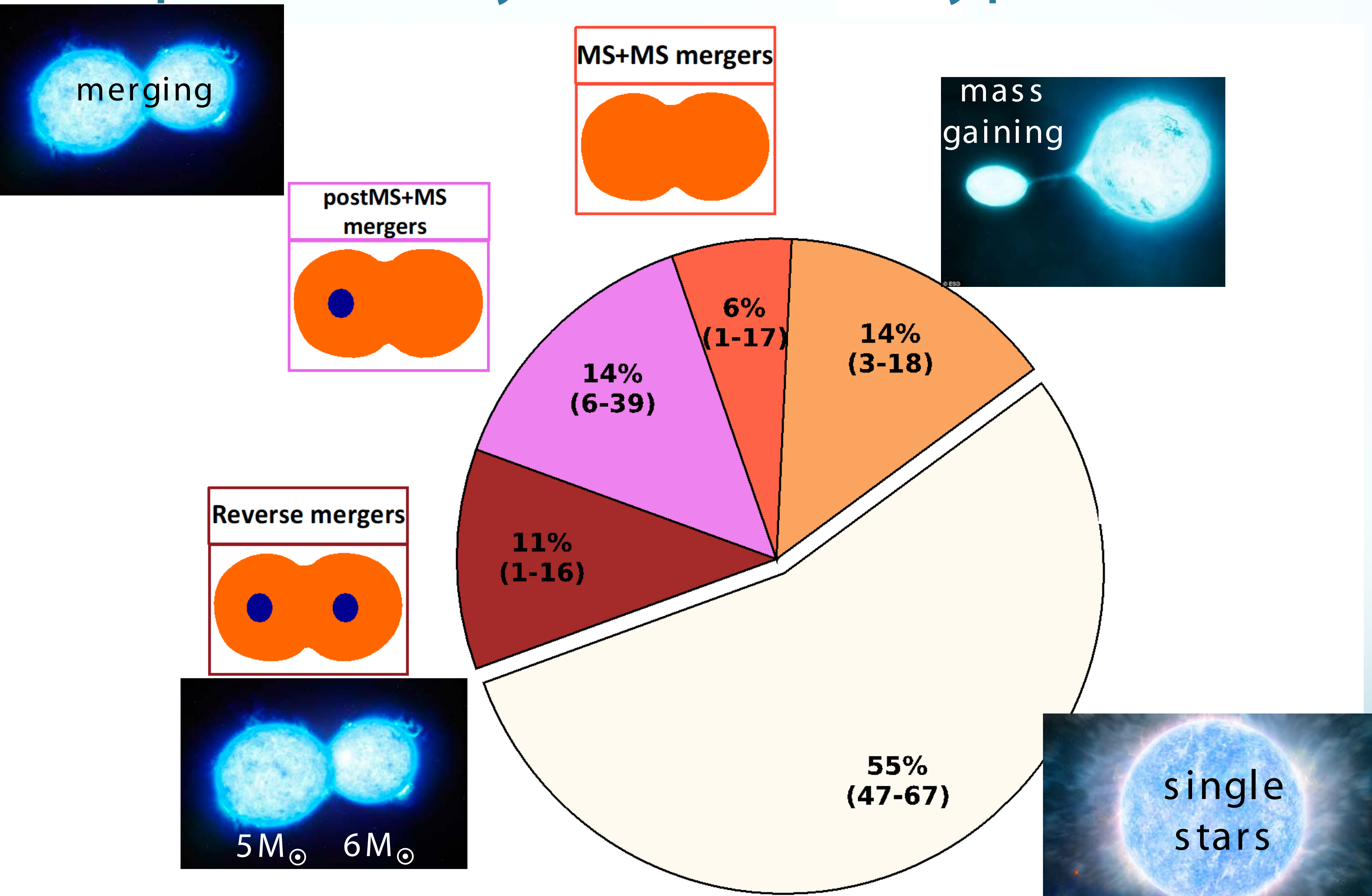






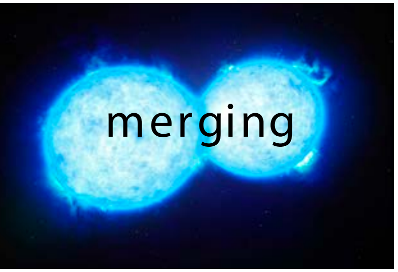
Zapartas+2019

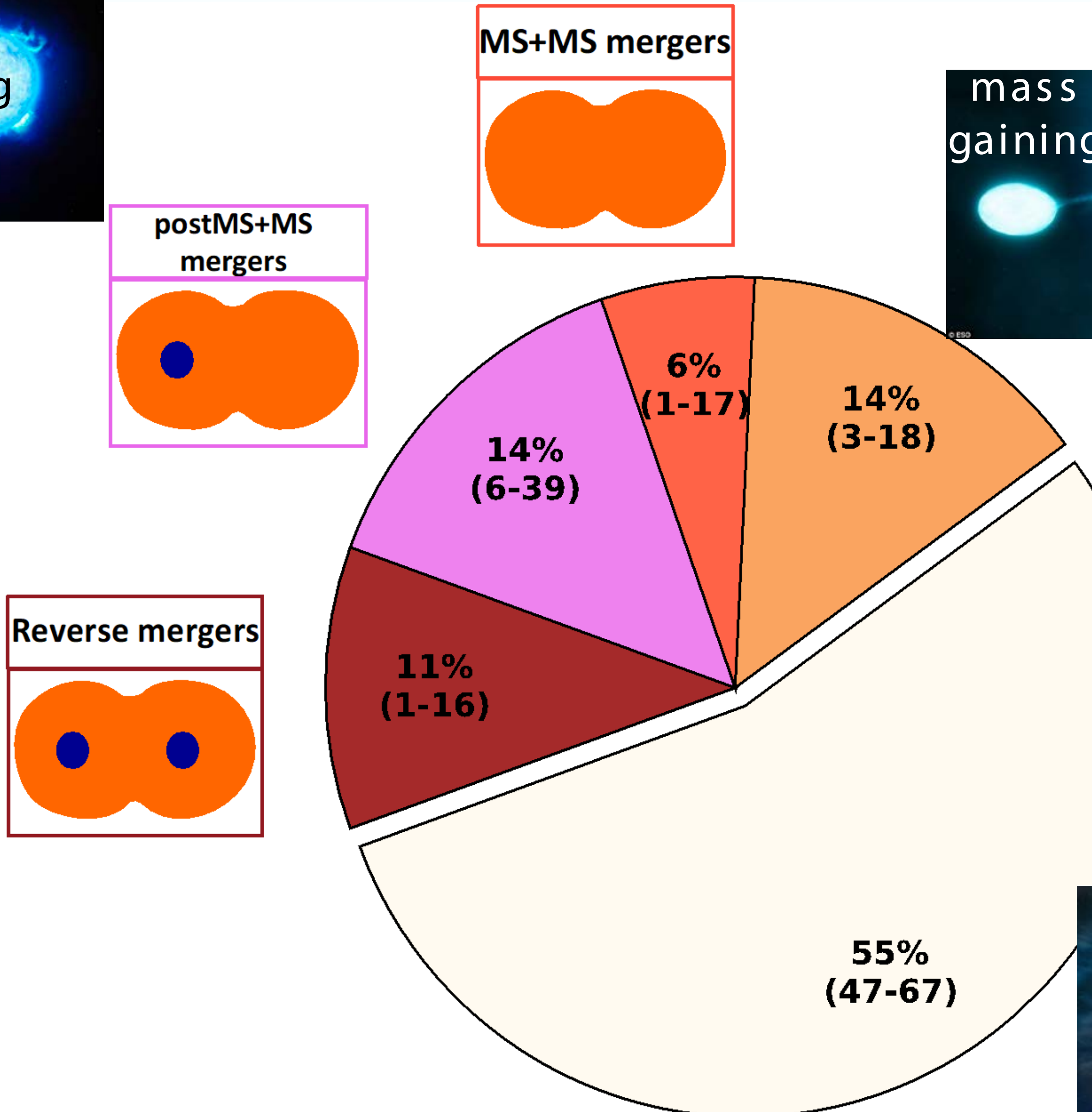
Population synthesis for type II SNe



Zapartas+2017a, see also De-Donder+Vanbeveren2003

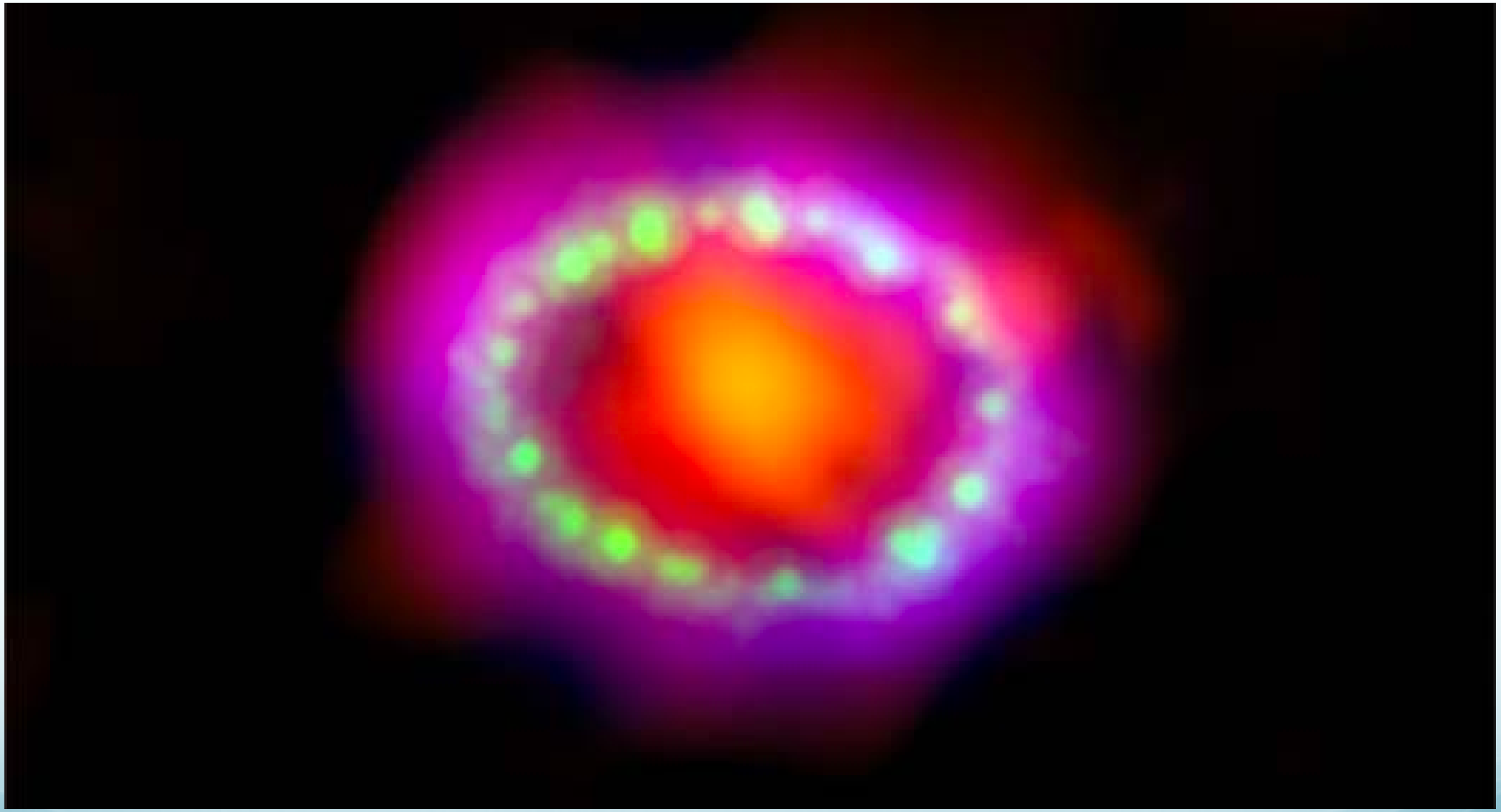
How would they look like?



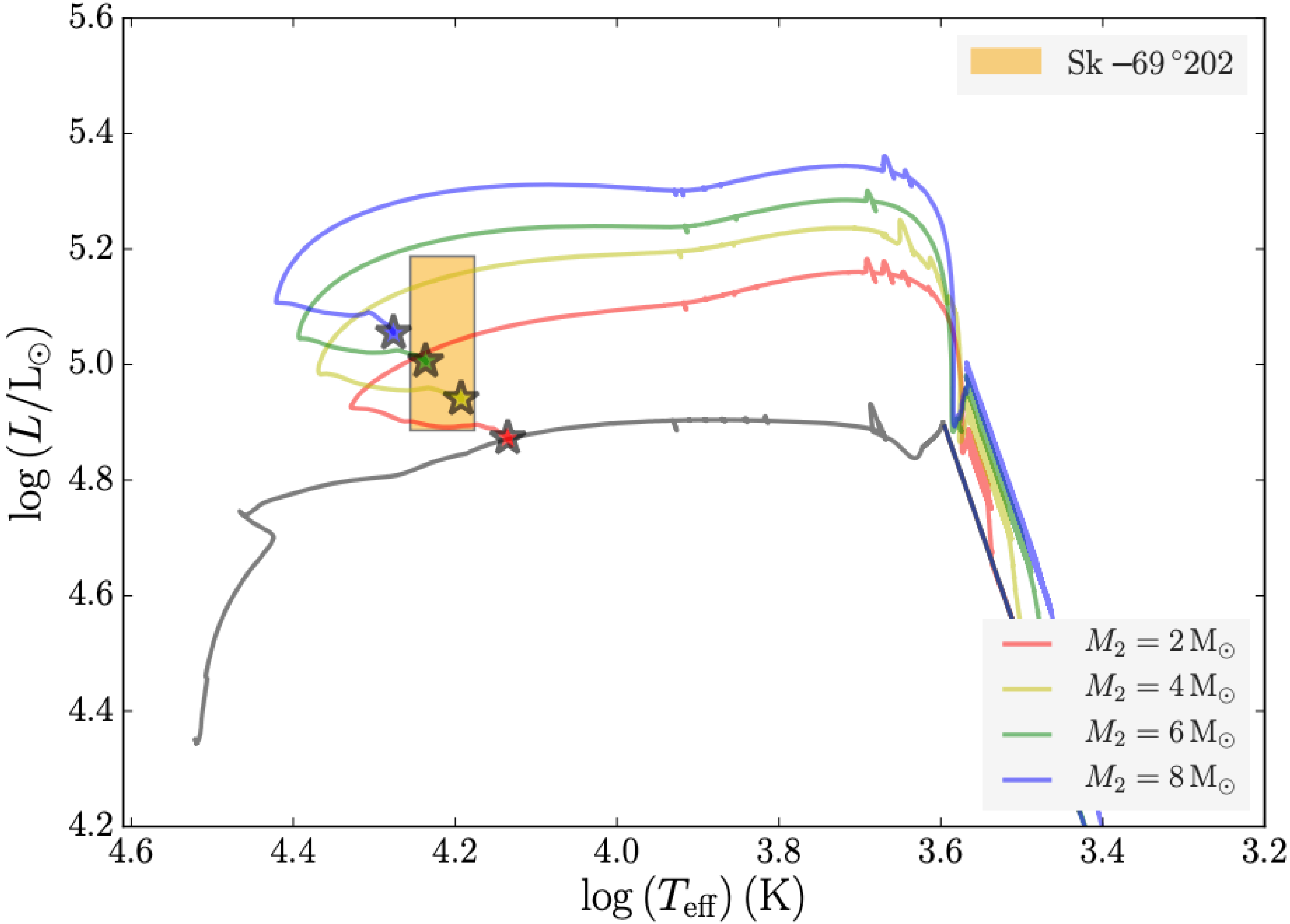


Zapartas+2019

SN 1987A

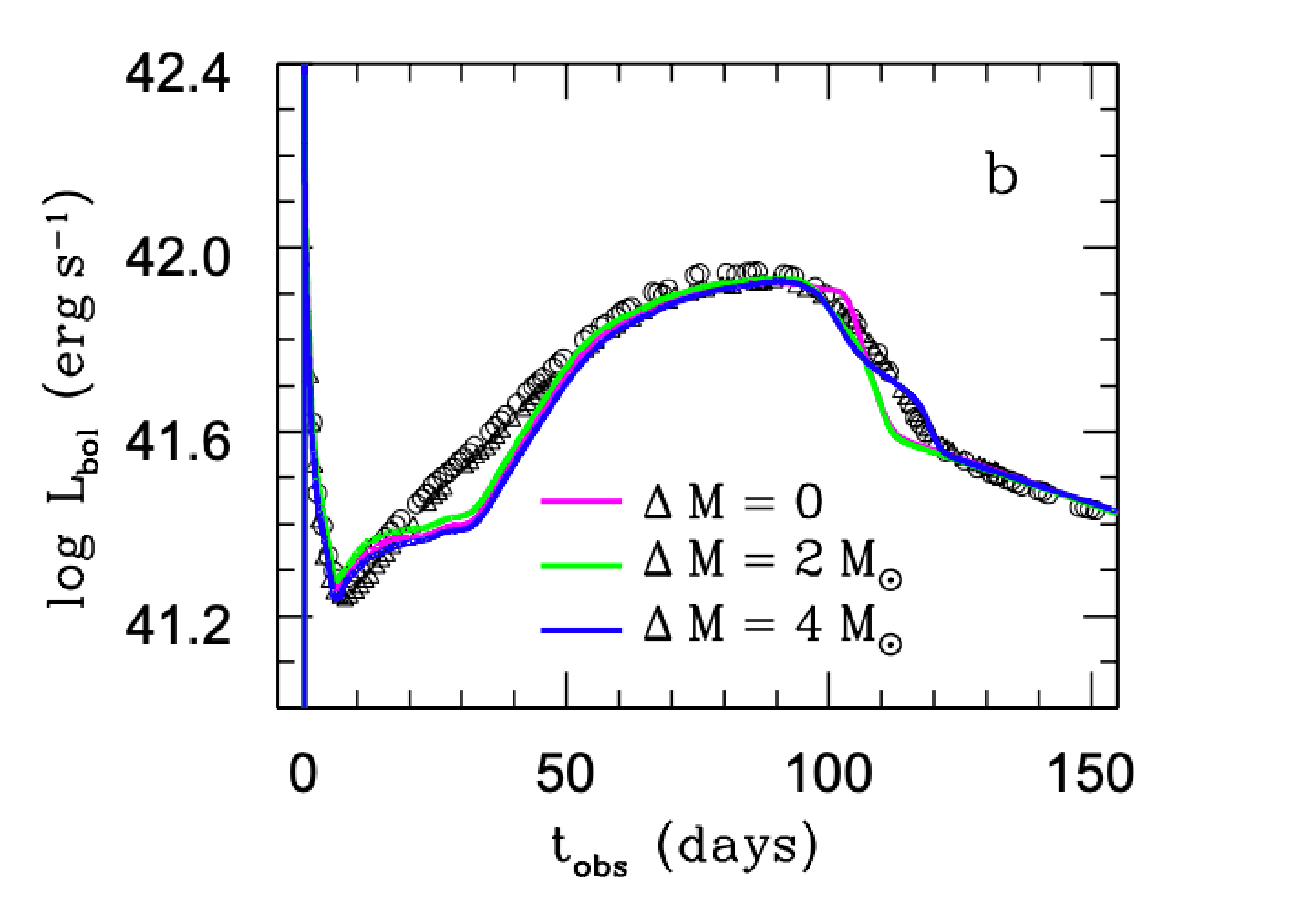


e.g., Podsiadlowski+1990; Podsiadlowski1992; Menon+Heger2017, Urushibata+2018
(although see e.g., Saio+1988, Weiss+1988, Langer+1989)



Sk −69°202
$M_2 = 2\,M_\odot$
$M_2 = 4\,M_\odot$
$M_2 = 6\,M_\odot$
$M_2 = 8\,M_\odot$
$\log(L/L_\odot)$
$\log(T_{eff})$ (K)
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2

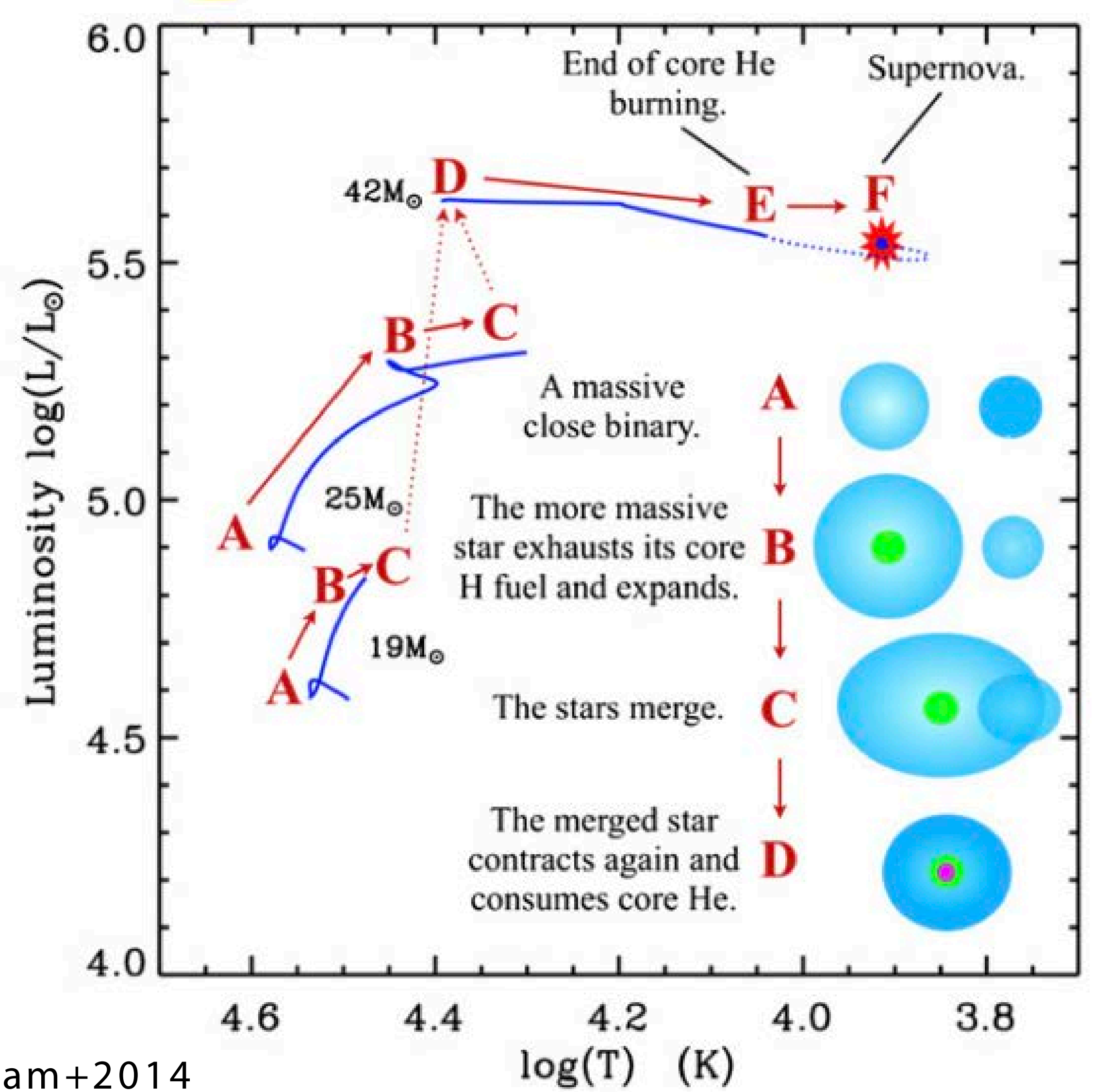
Menon+2017



42.4
42.0
41.6
41.2
log L_bol (erg s^-1)
b
ΔM = 0
ΔM = 2 M_⊙
ΔM = 4 M_⊙
0
50
100
150
t_obs (days)

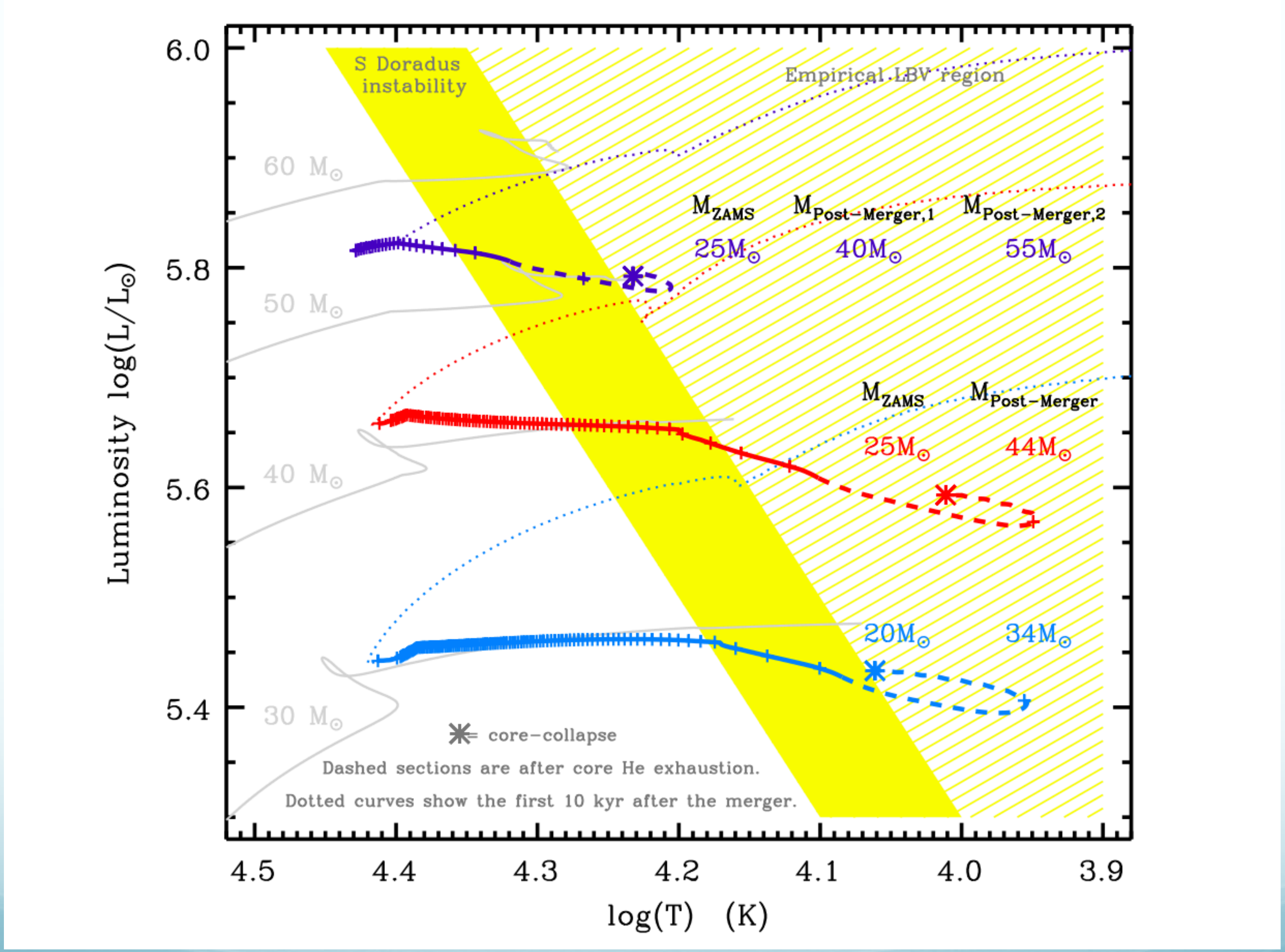
Menon+2019

a fraction of LBVs are possibly mergers



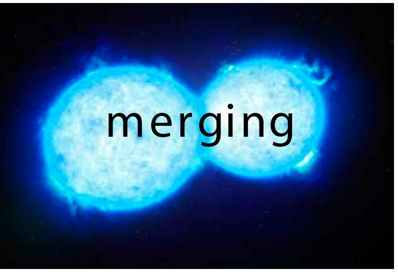
Justham+2014

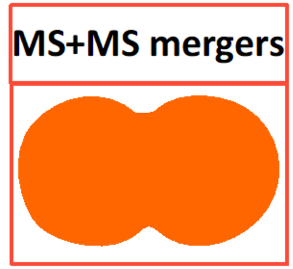
a fraction of LBVs are possibly mergers

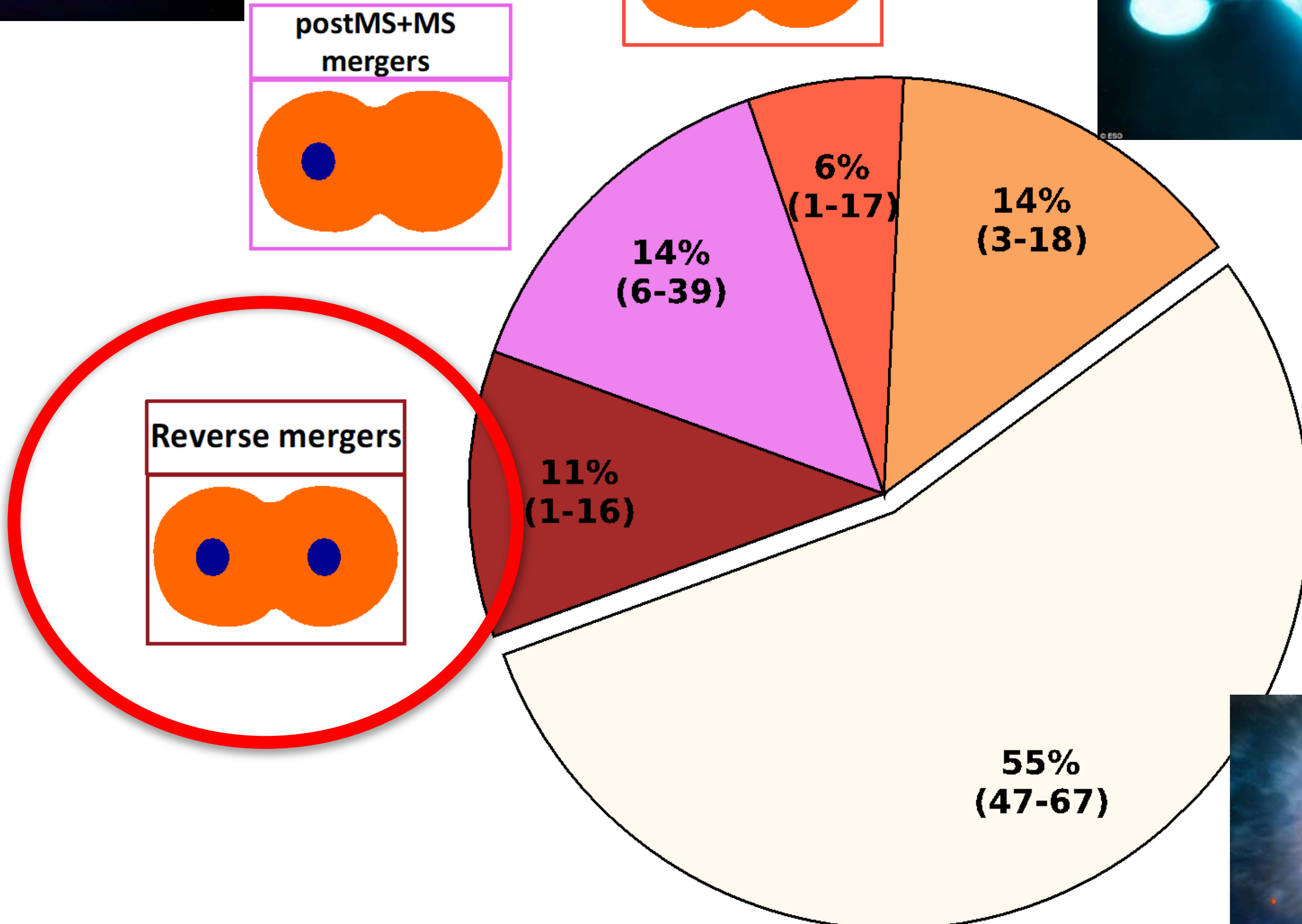


Justham+2014, see also Smith+2015

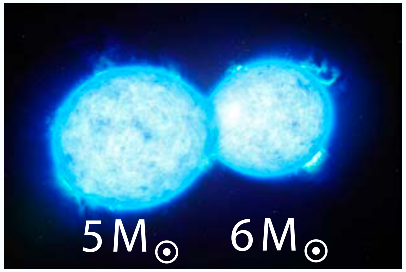
Reverse mergers



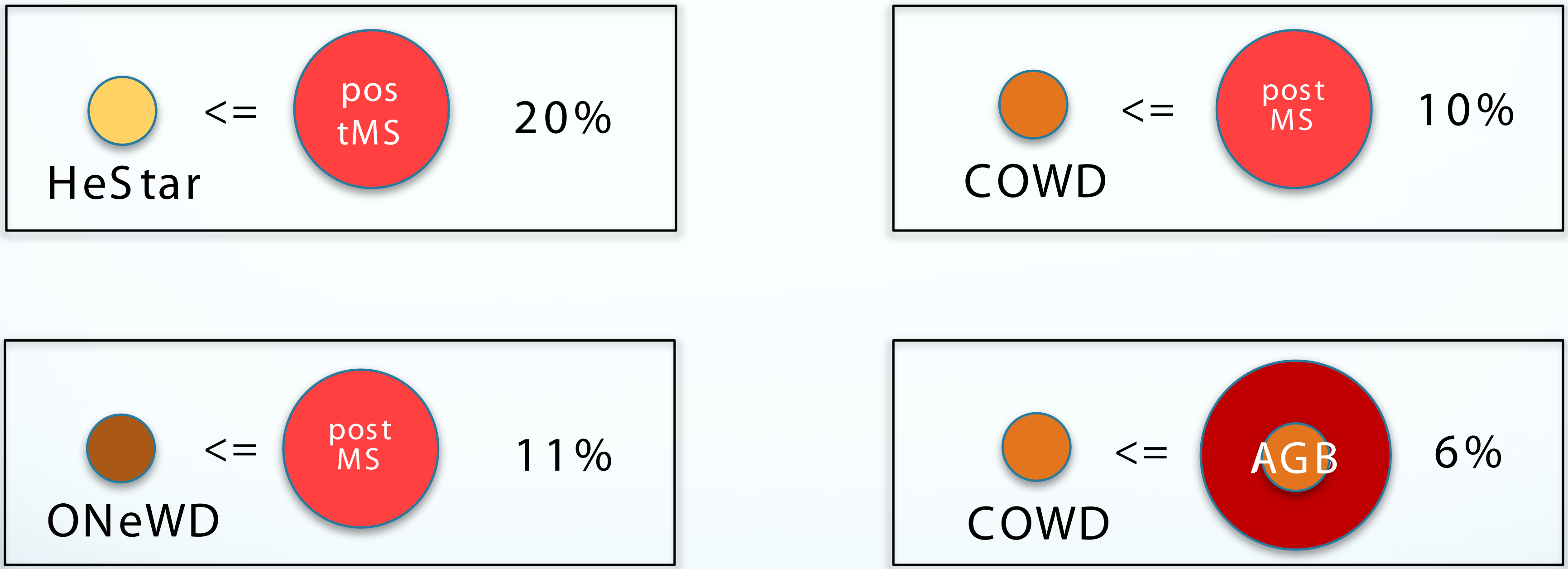




Zapartas+2017a, see also De-Donder+Vanbeveren2003

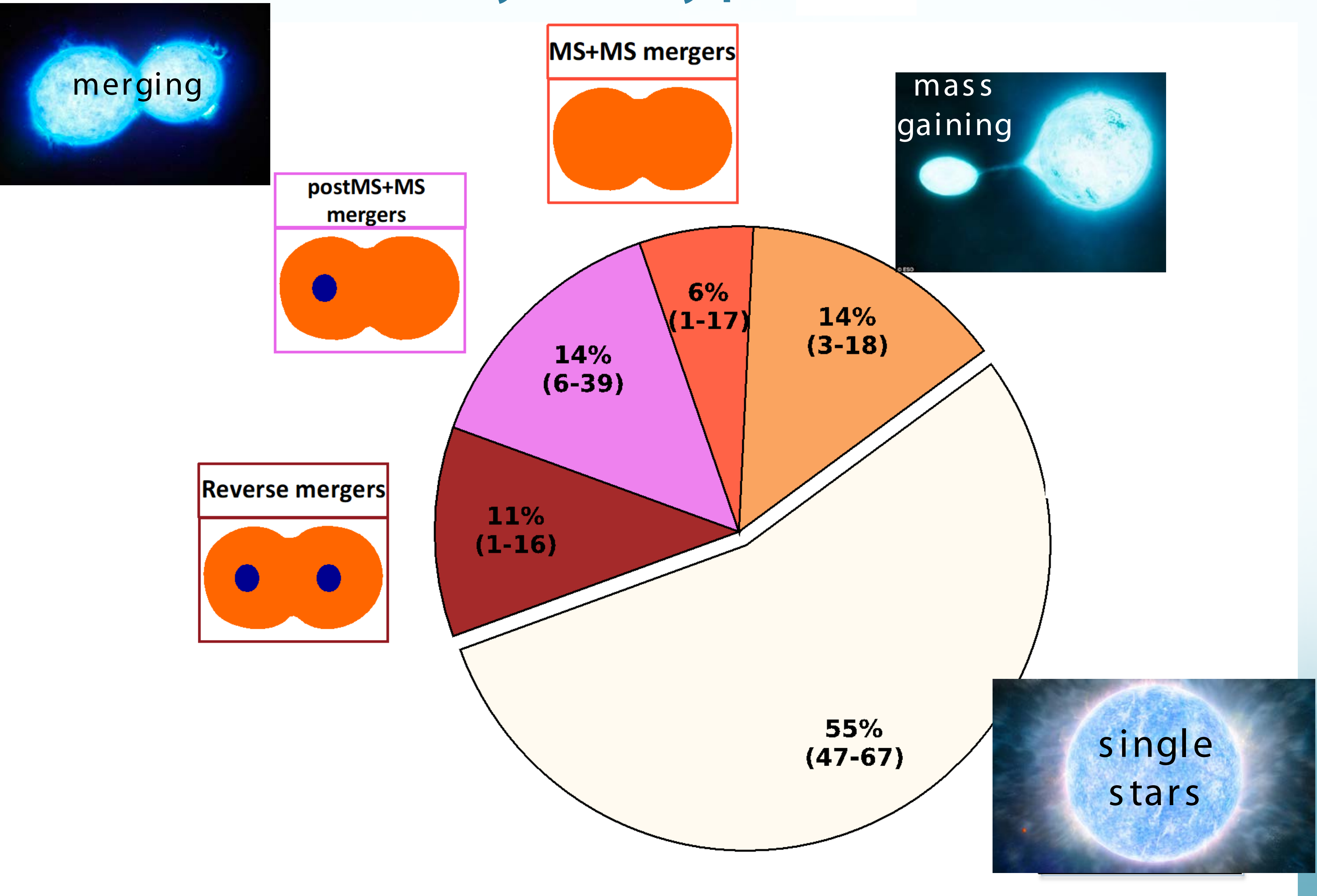


Reverse mergers

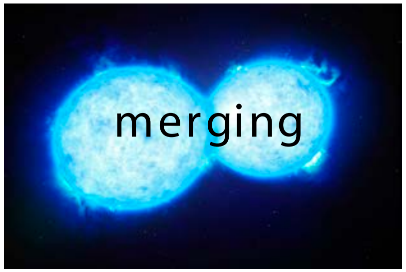


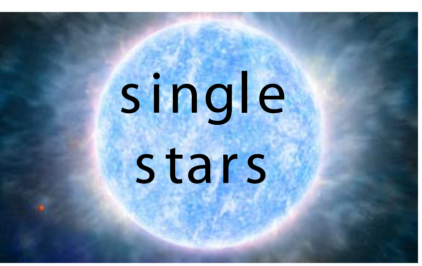
Zapartas+2017a

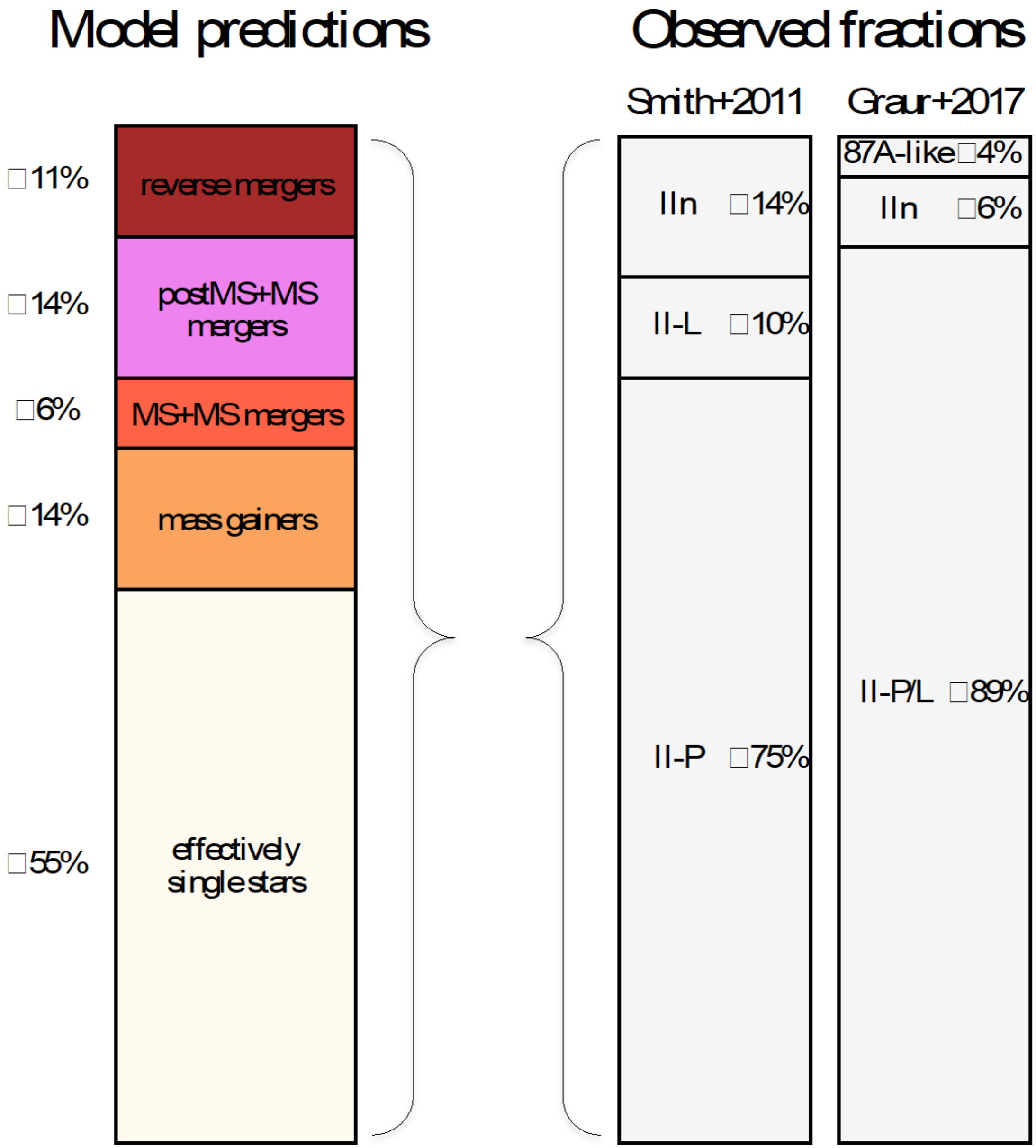
Diversity of type II SNe?



Diversity of type II SNe?



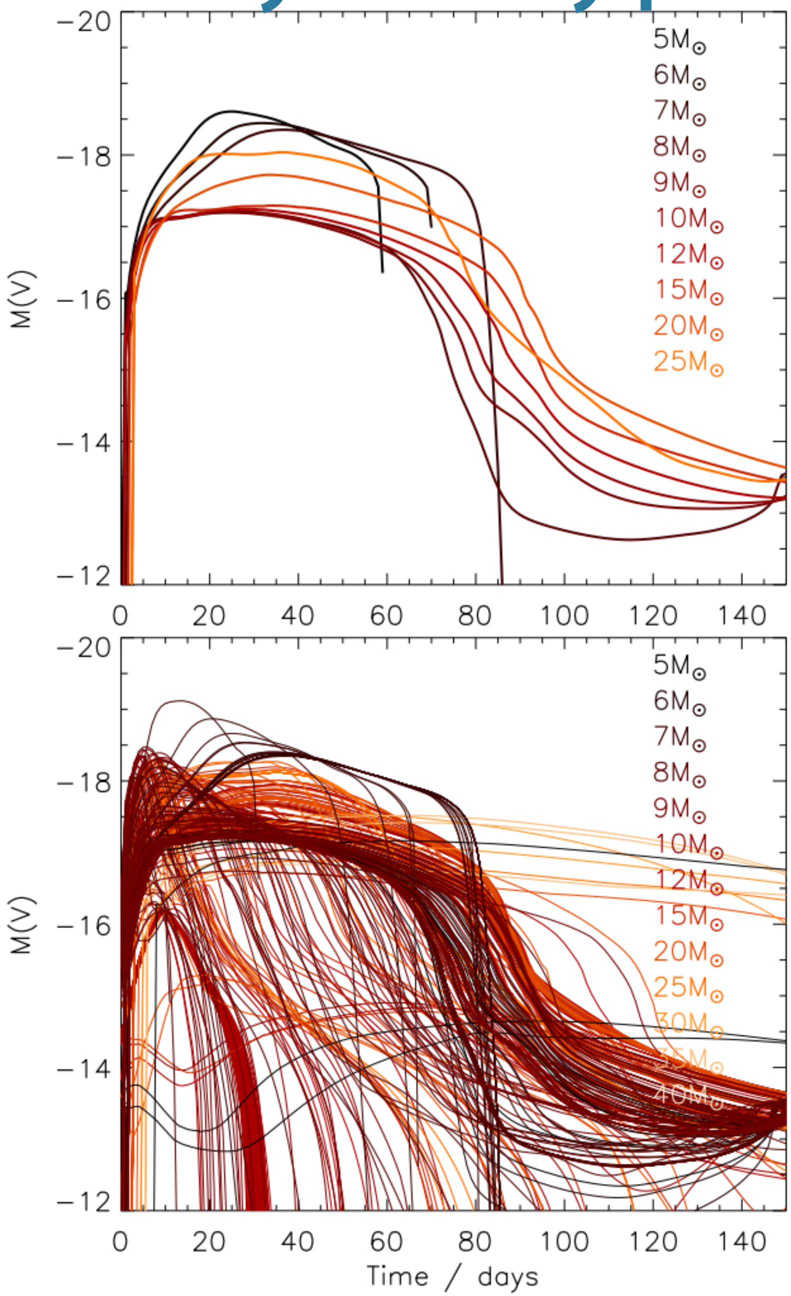




(see also Smartt+2009, Li+2011, Shivvers+2016)

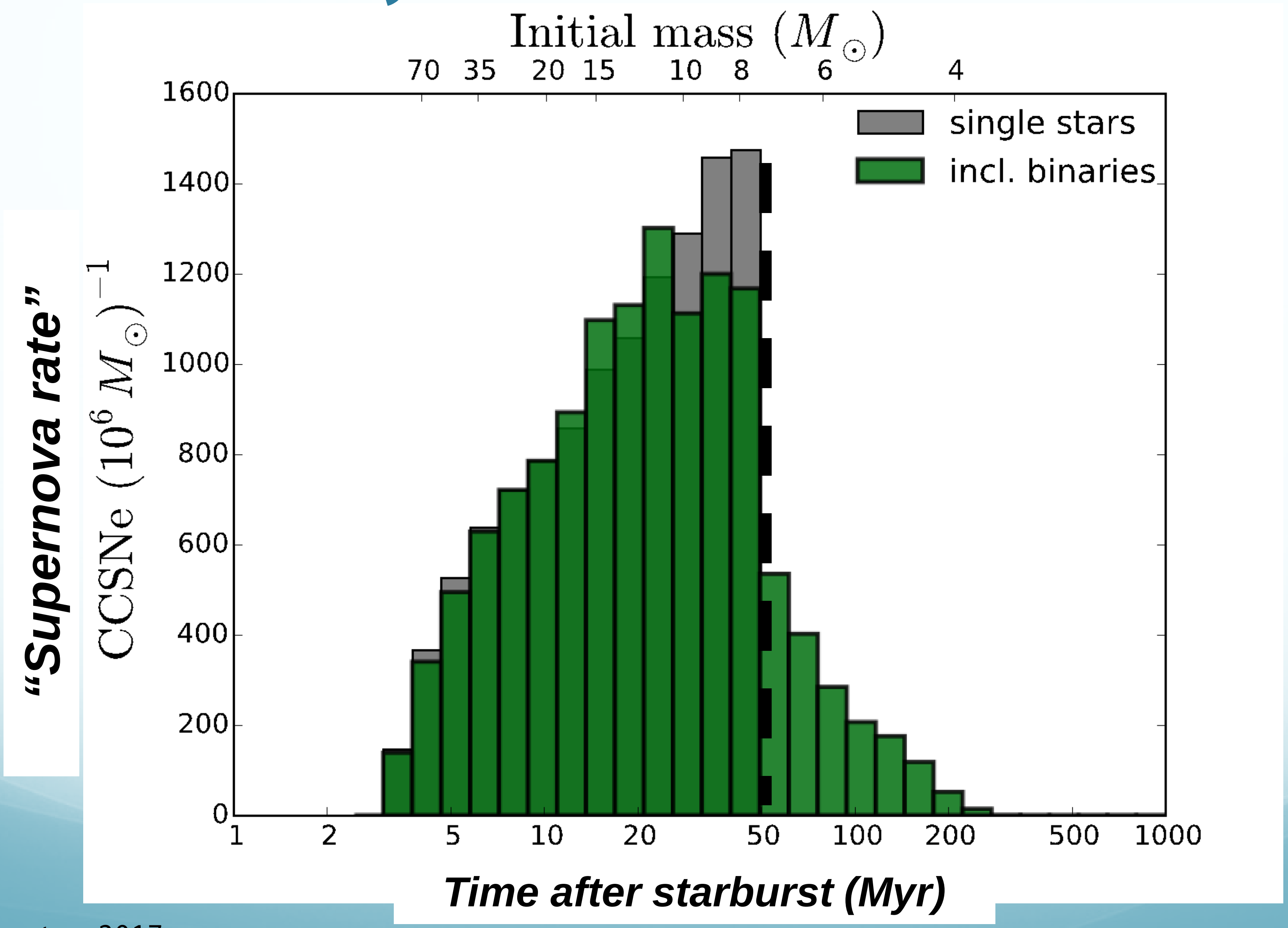
Zapartas+2019

Diversity of type II SNe?



Eldridge+2018

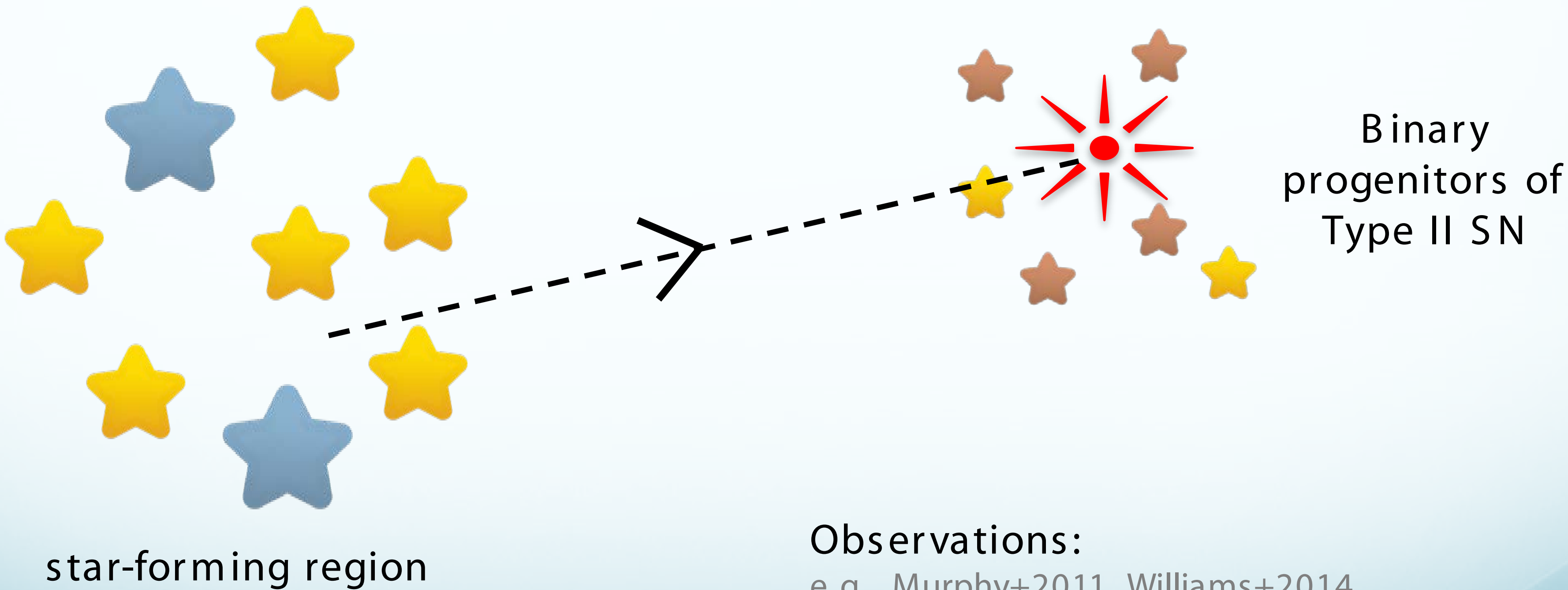
Delay-time distribution



Zapartas+2017a

Older surrounding population

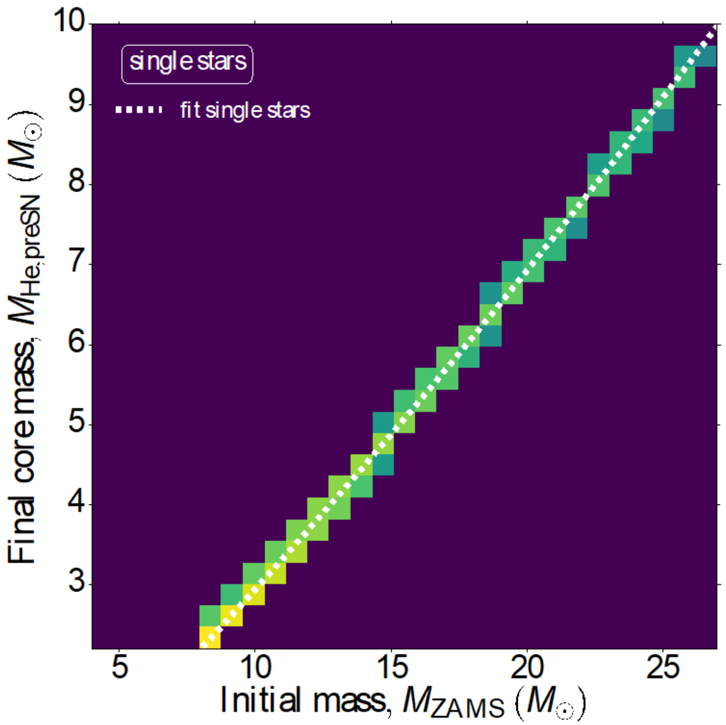
a) Late core-collapse SNe (e.g., De Donder+Vabeveren2003, Zapartas+2017a)
b) Ejected stars (e.g., Eldridge+2011, Renzo+2018)



Observations:
e.g., Murphy+2011, Williams+2014, Jennings+2014, Maund2017, Diaz-Rodriguez+2018, Auchettl+2018

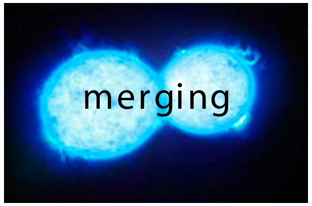
Higher core masses than expected

Single-star progenitors

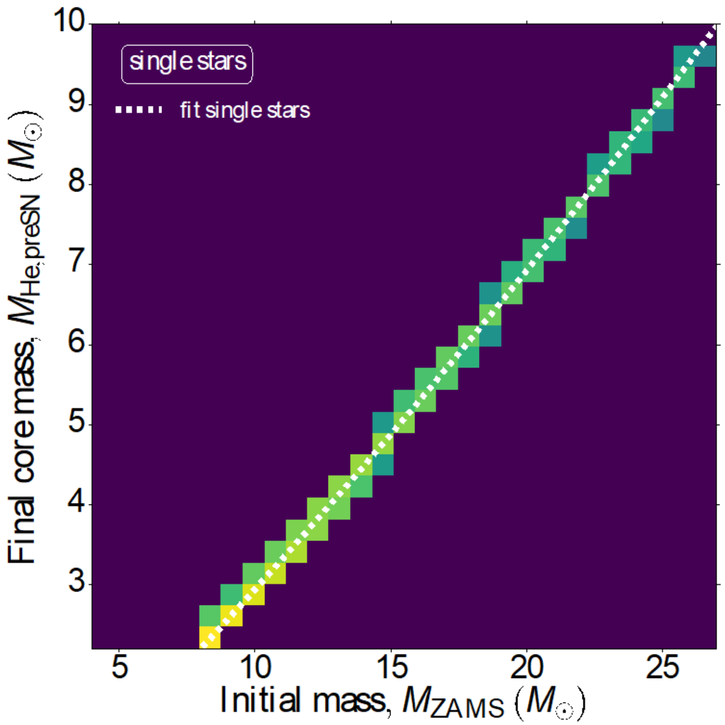


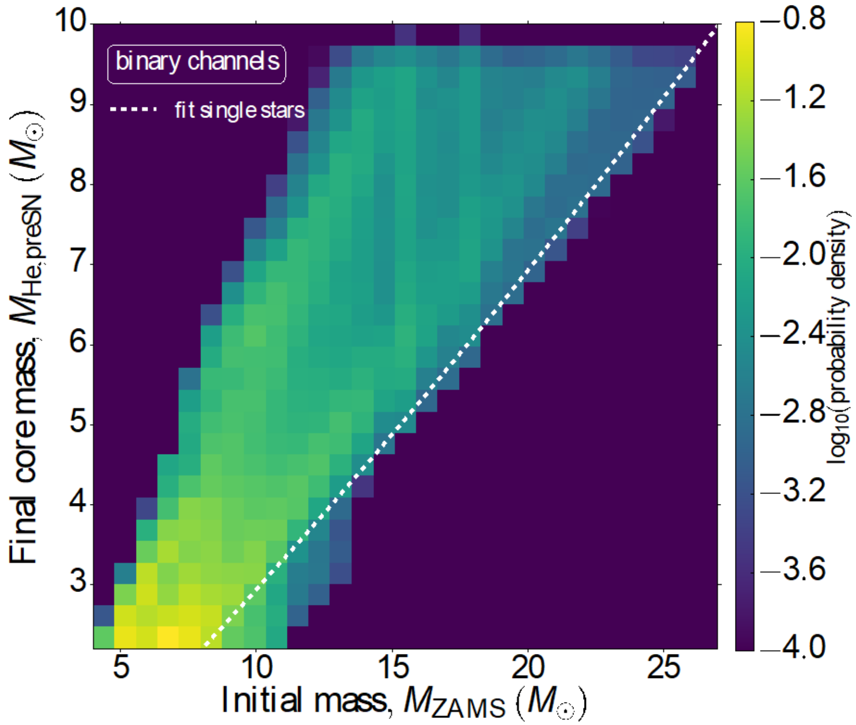
Zapartas+(to be subm.)

Higher core masses than expected



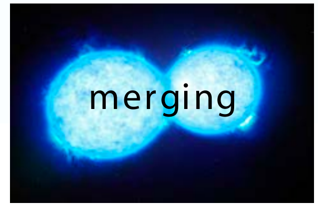
Single-star progenitors



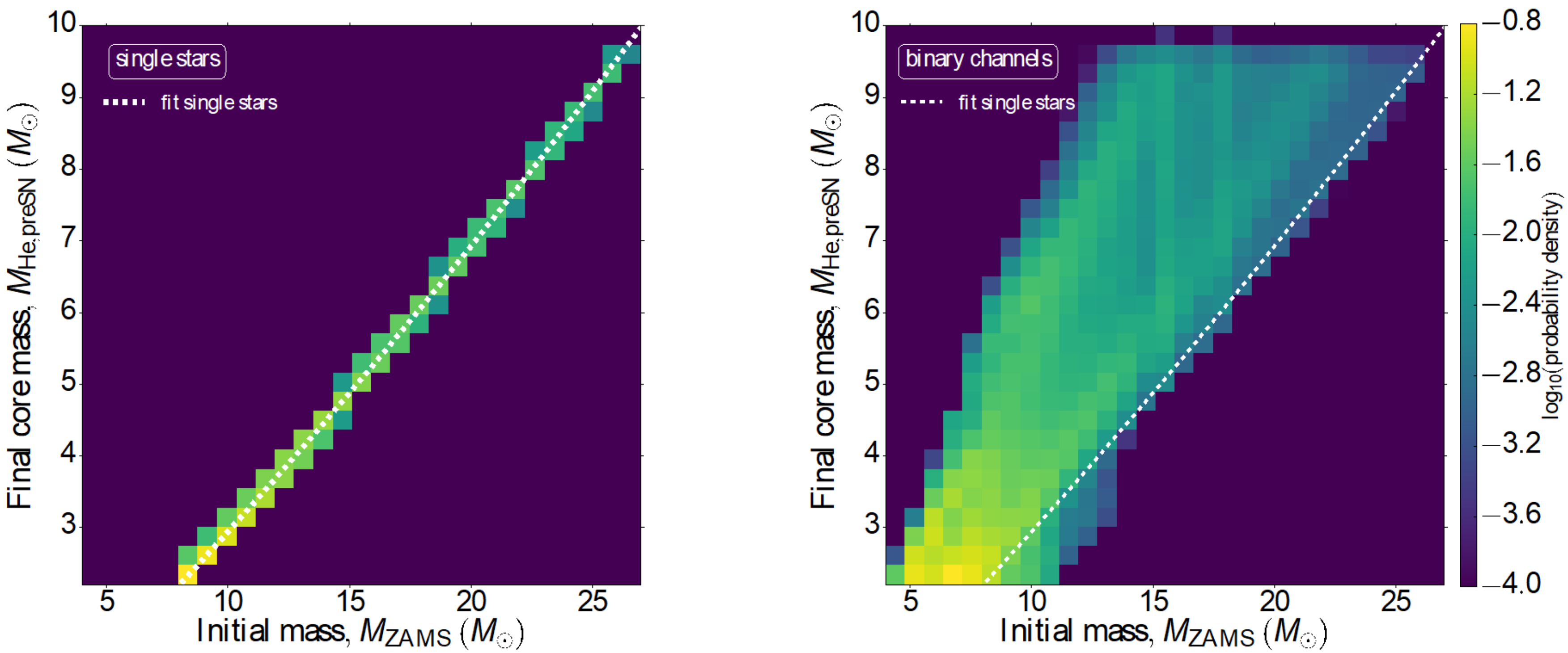


Zapartas+(to be subm.)

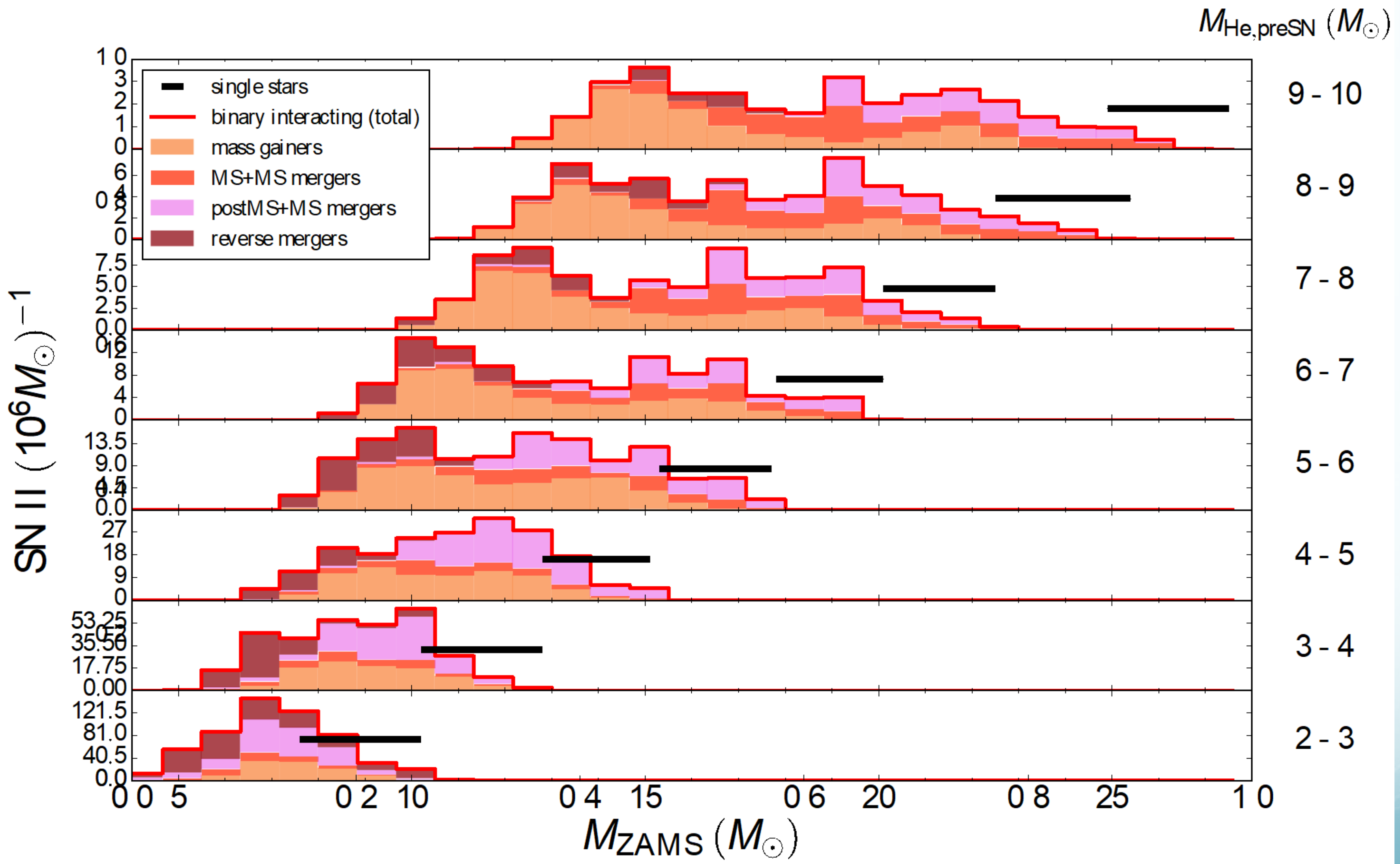
Overestimation of initial mass



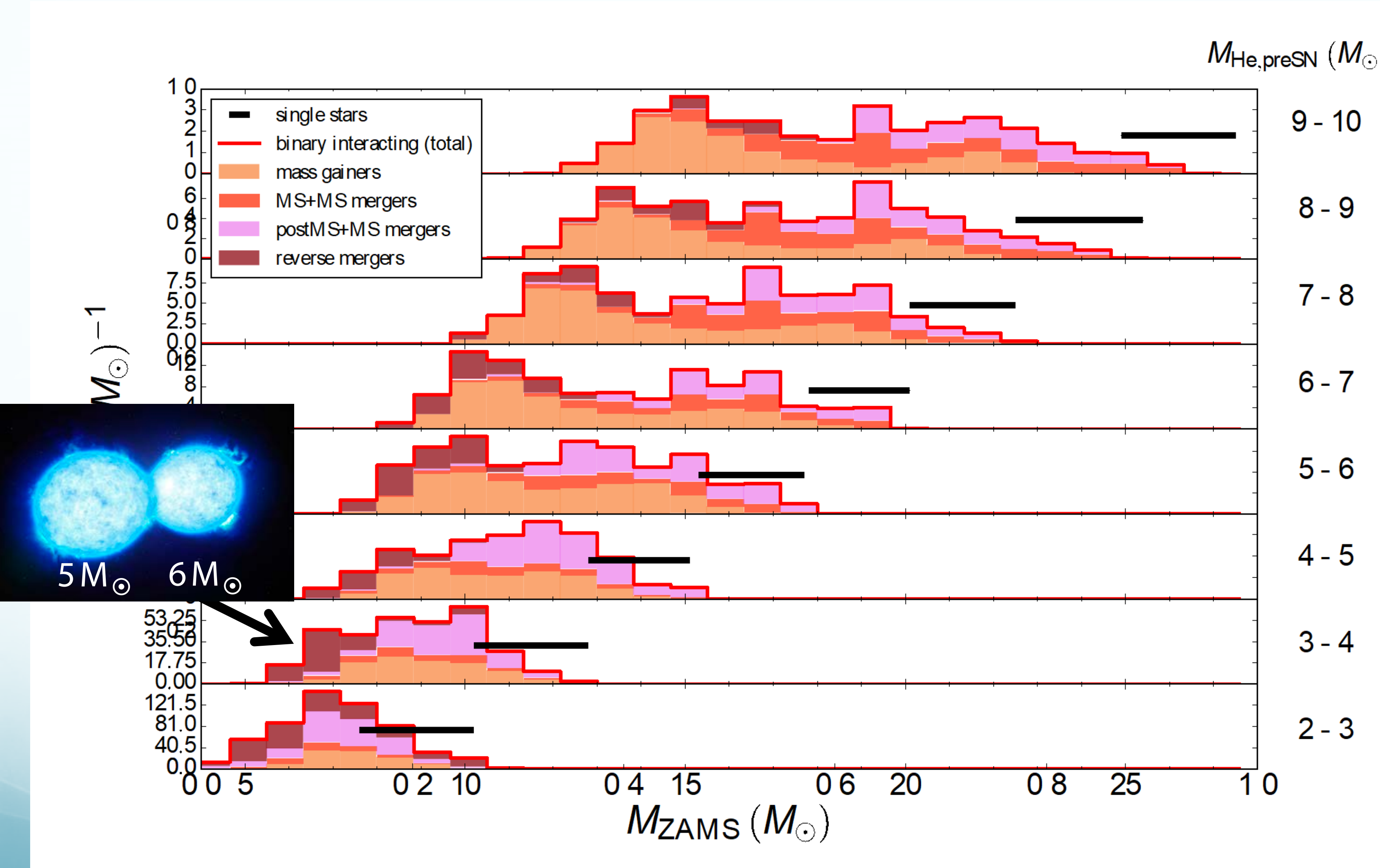
Single-star progenitors



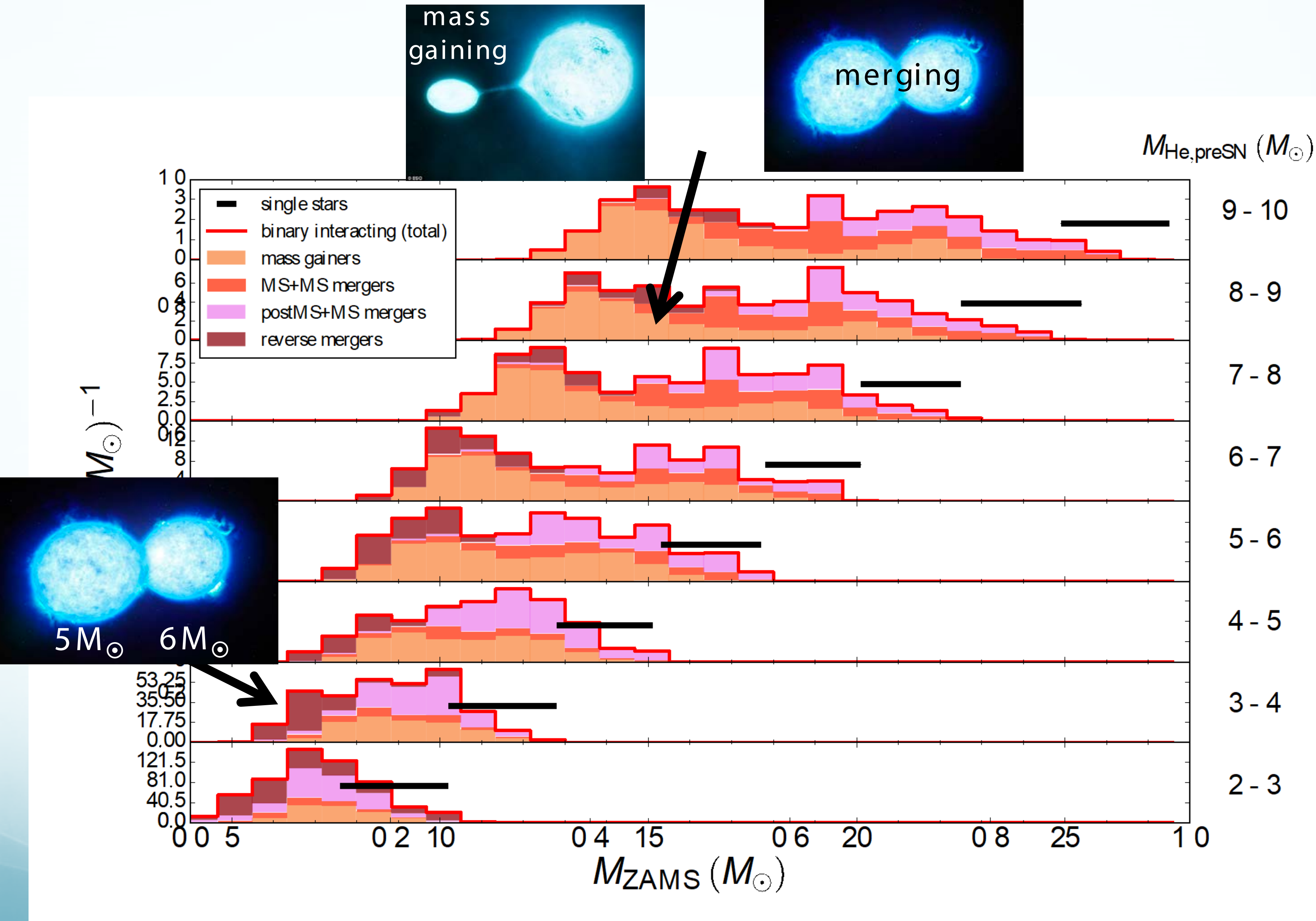
Zapartas+(to be subm.)



Zapartas+(to be subm.)

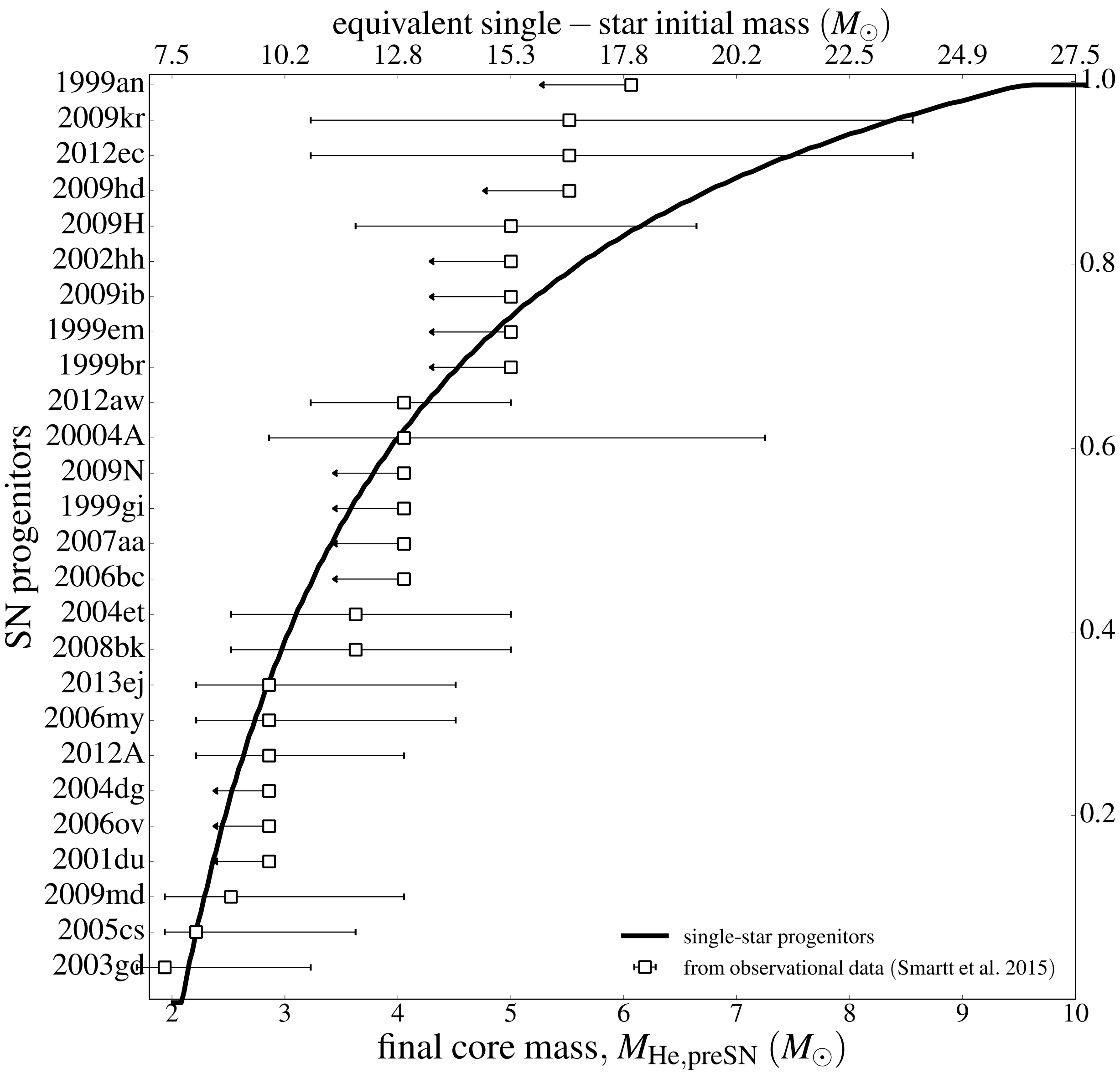


Zapartas+(to be subm.)



Zapartas+(to be subm.)

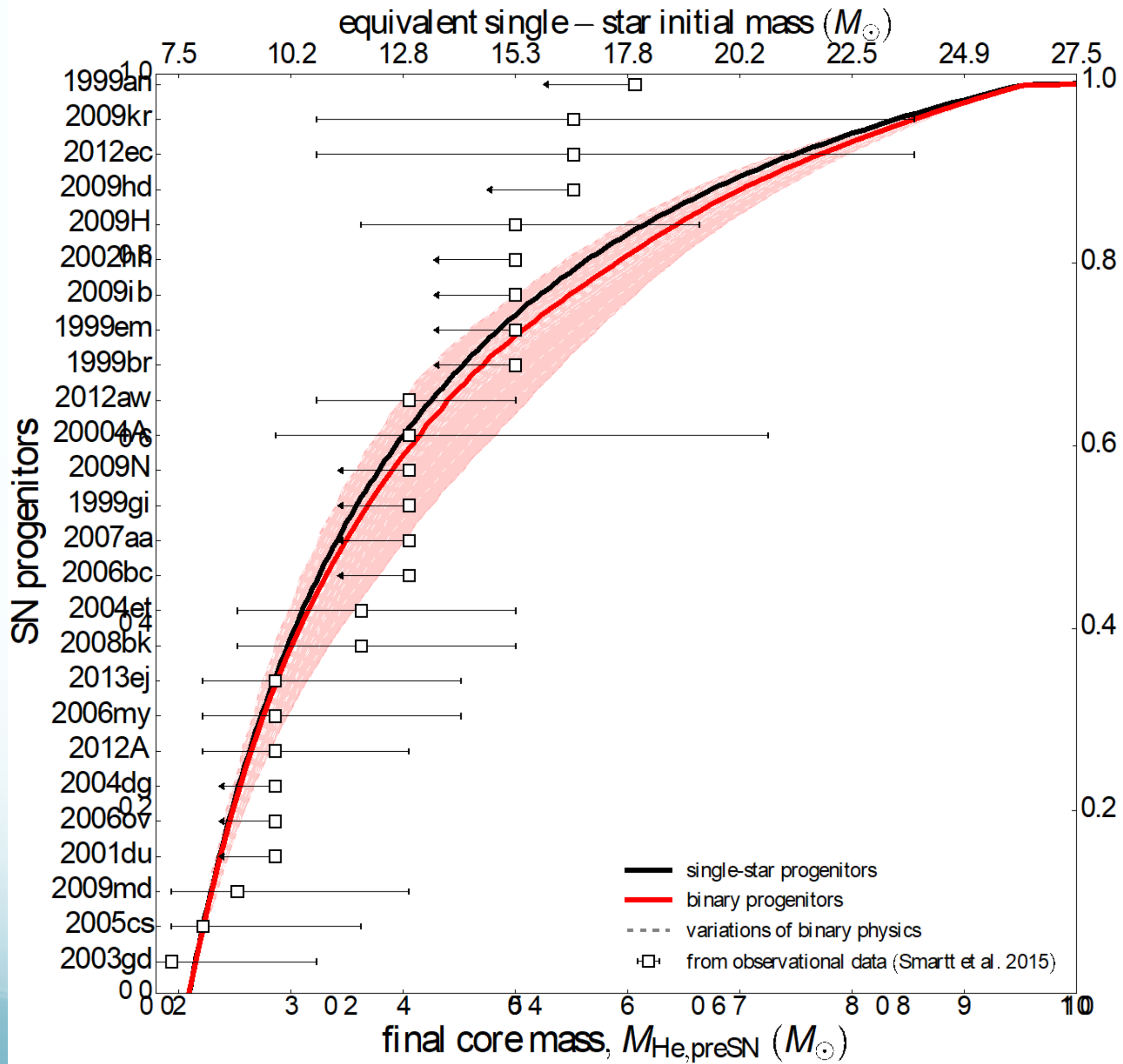
“RSG problem”



Credits: Smartt+2009, Smartt 2015

Zapartas+(to be subm.)

Binaries seem to NOT help at solving the "RSG problem"



Zapartas+(to be subm.)

Take away message

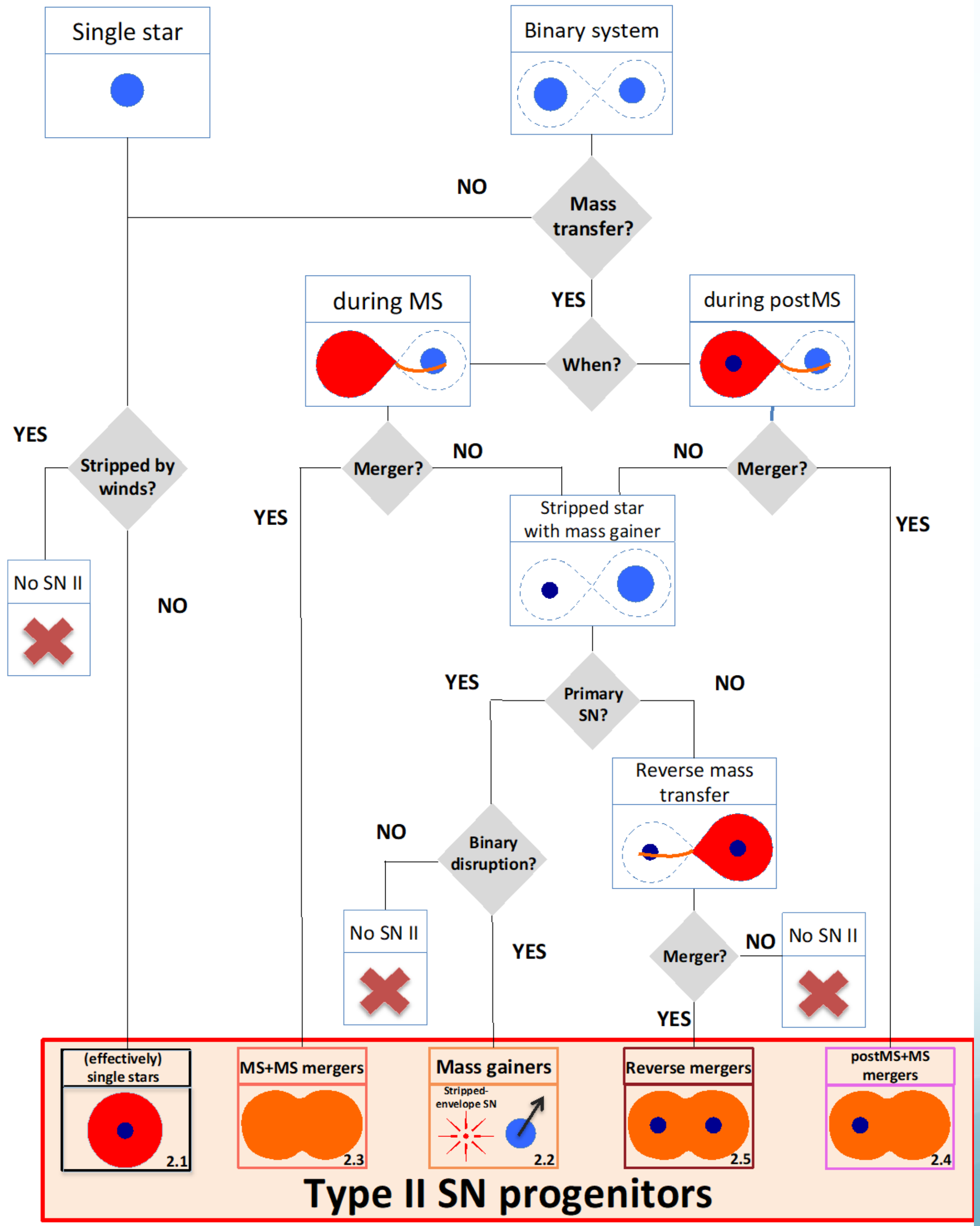
Binary mergers are common as type II SN progenitors

Binary merger channels are diverse

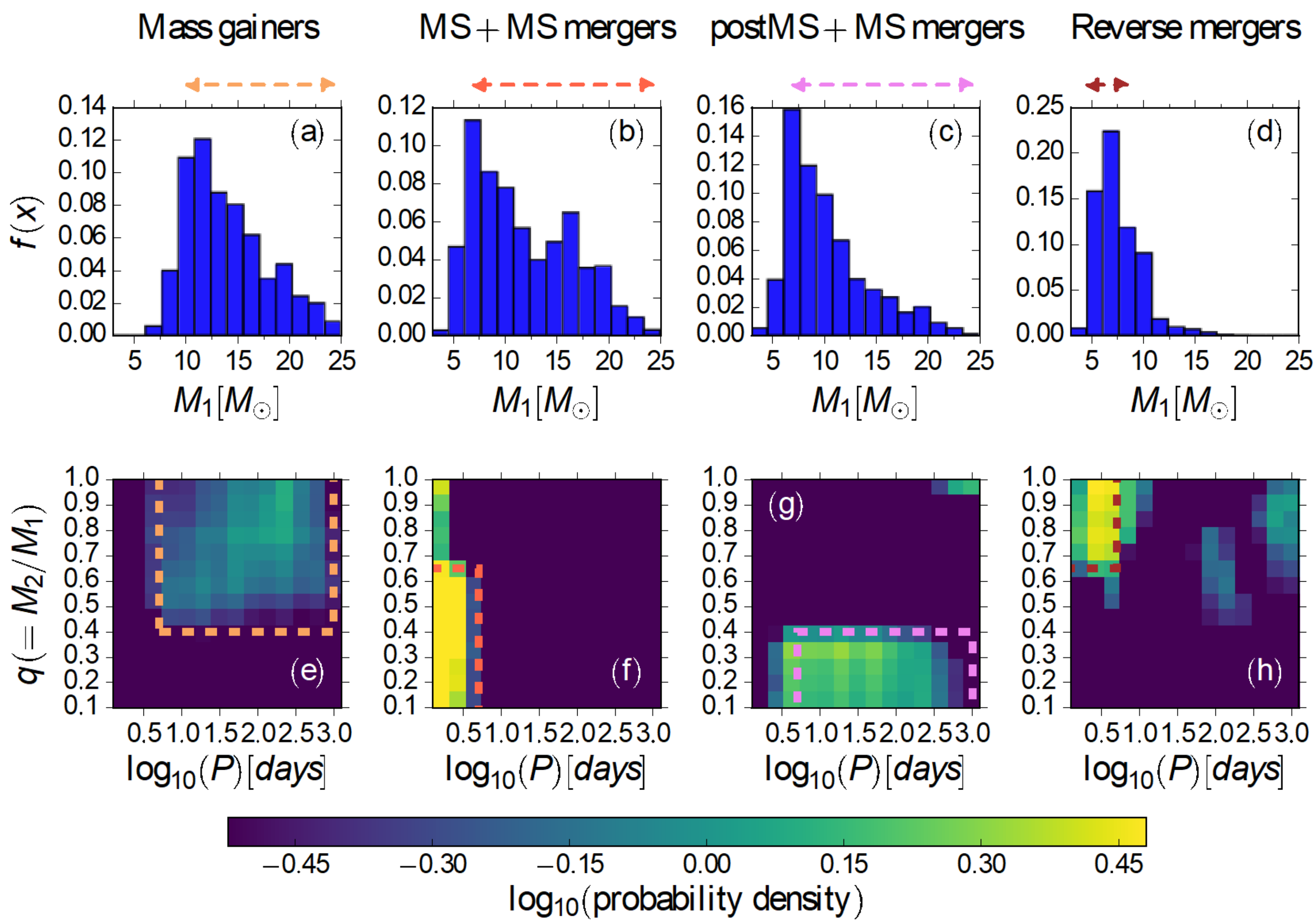
Binary mergers may lead to very interesting events but may also be hidden in "normal" events

We should take them into account as a possibility when inferring the progenitor properties

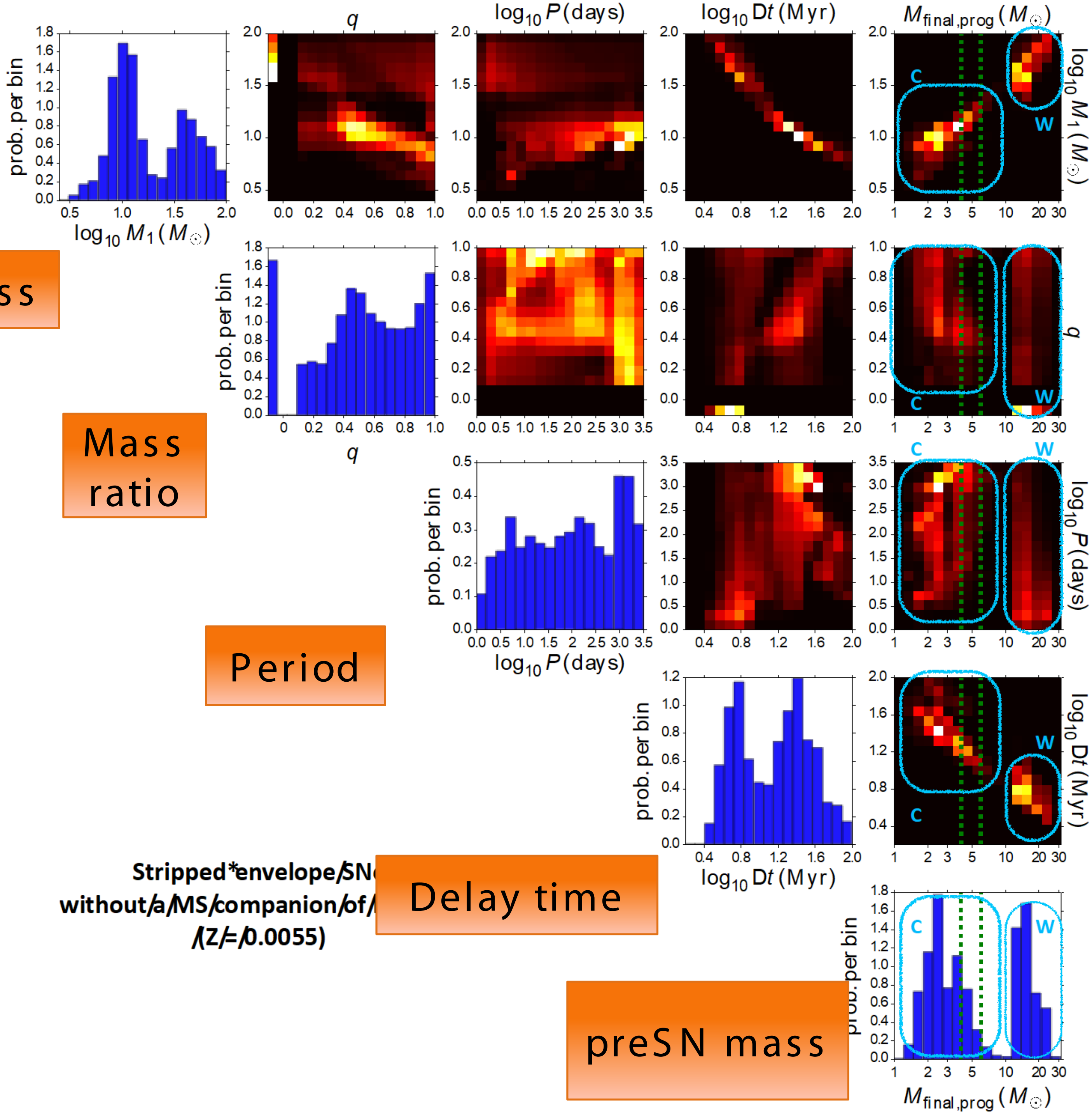
Backup slides



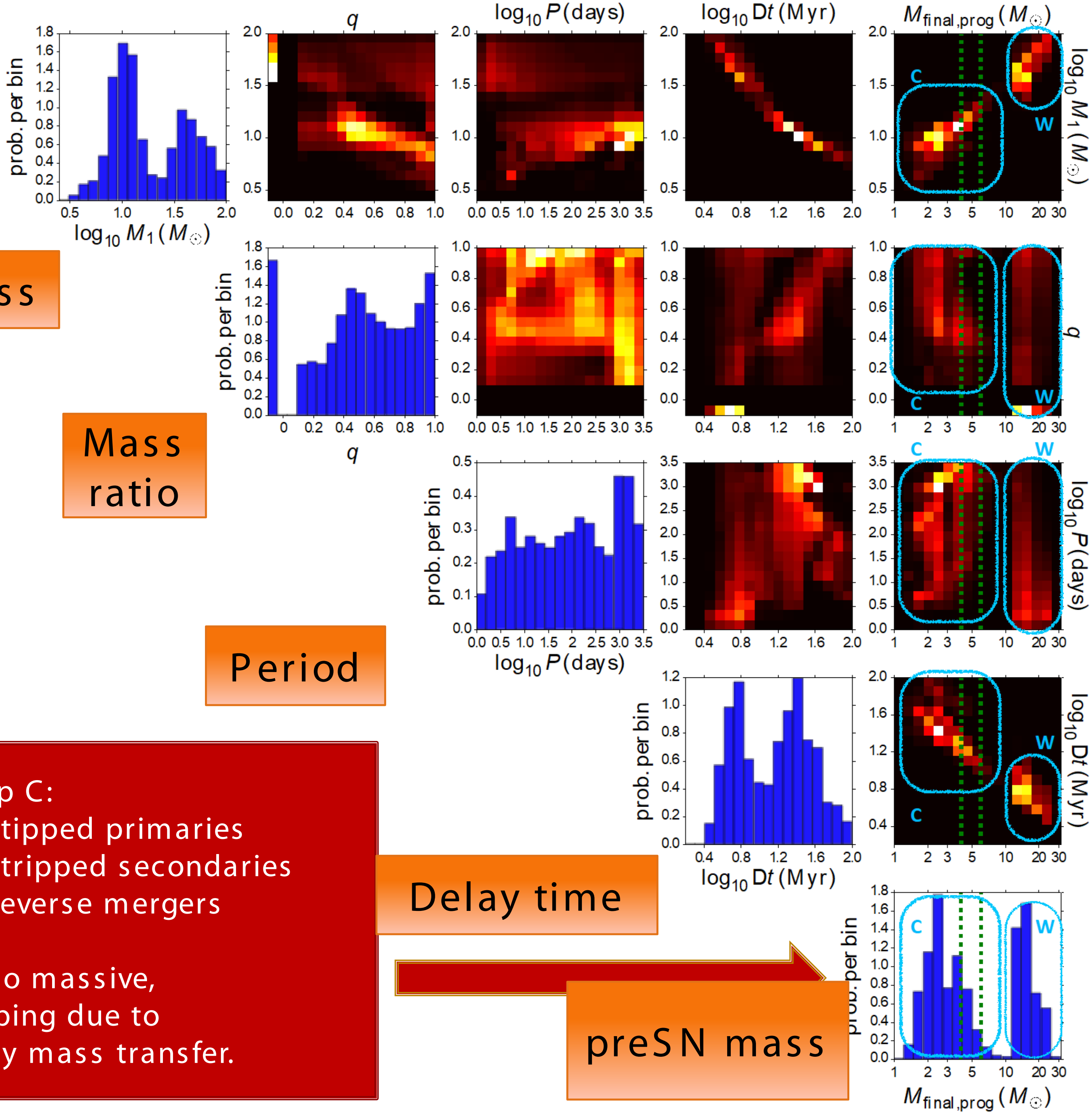
Zapartas et al.
(to be subm.)



Zapartas et al.
(2019)



Zapartas et al. (2017b.)



Group C:
1) Stipped primaries
2) Stripped secondaries
3) Reverse mergers

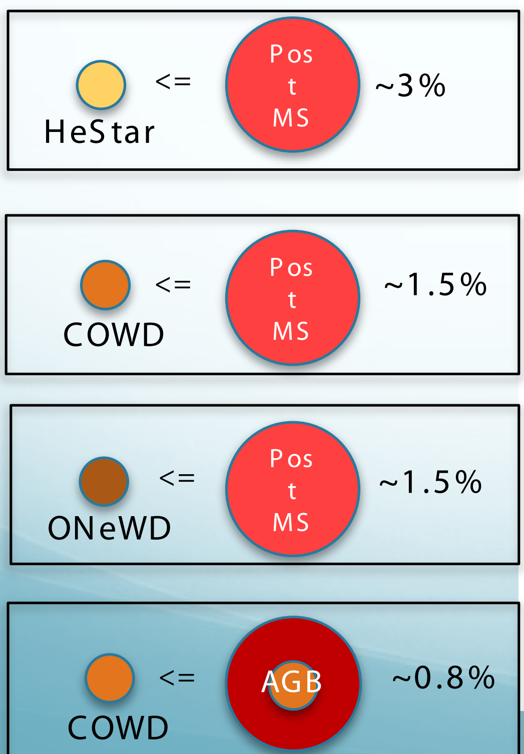
Not so massive, stripping due to binary mass transfer.

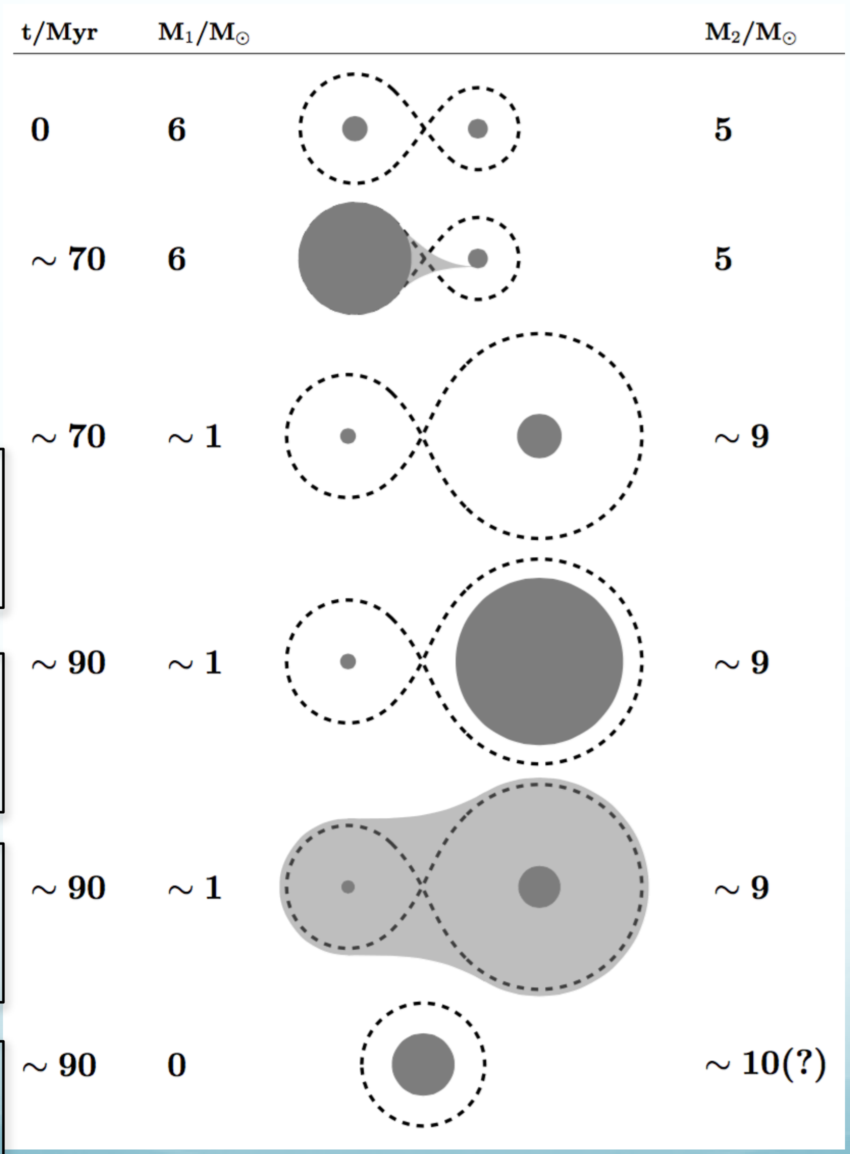
Group W:
1) Single stars
2) Forward mergers
3) Disrupted systems

Massive, winds

Zapartas et al. (2017b.)

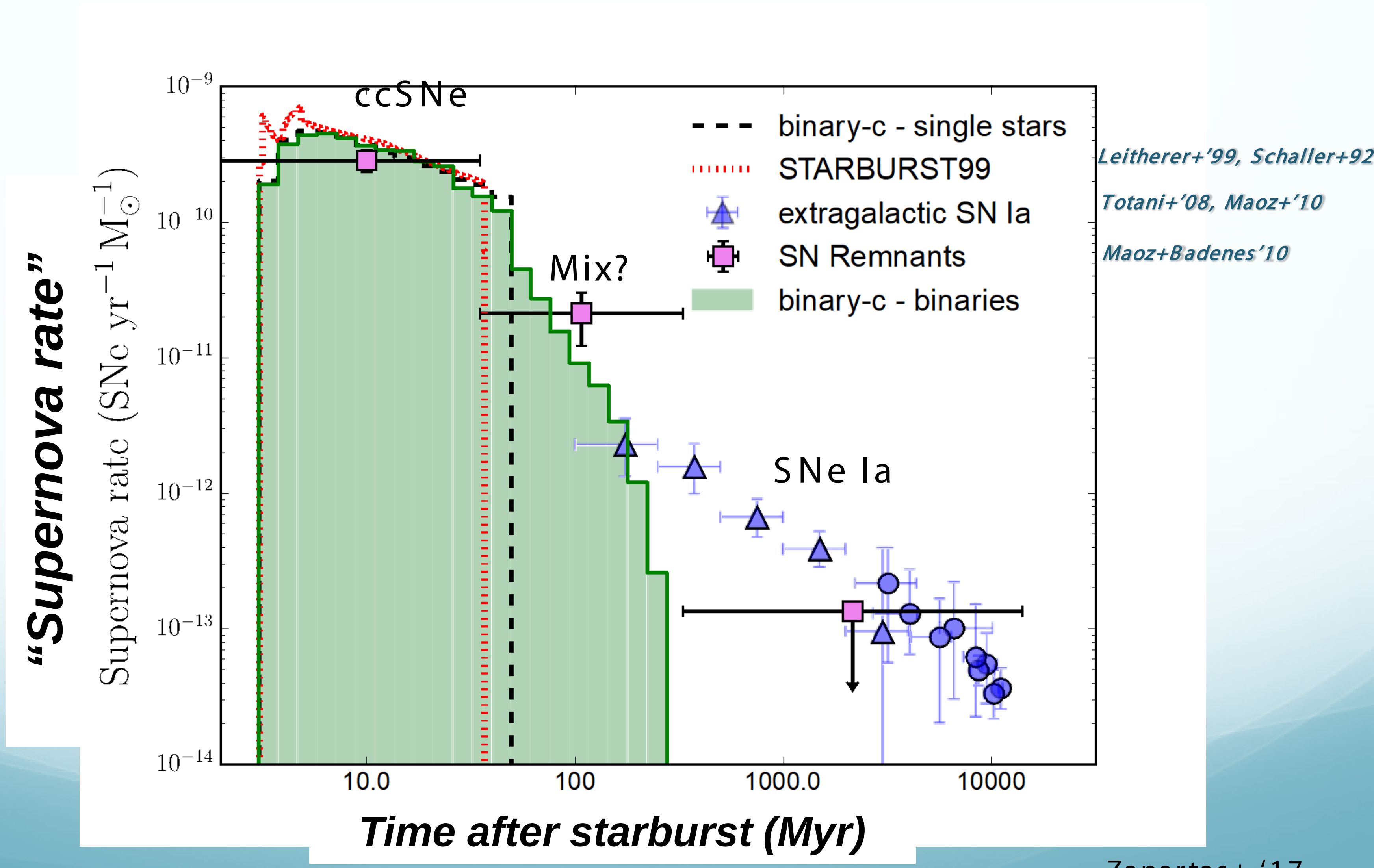
Channels for late ccSNe (15%) from intermediate-mass binaries





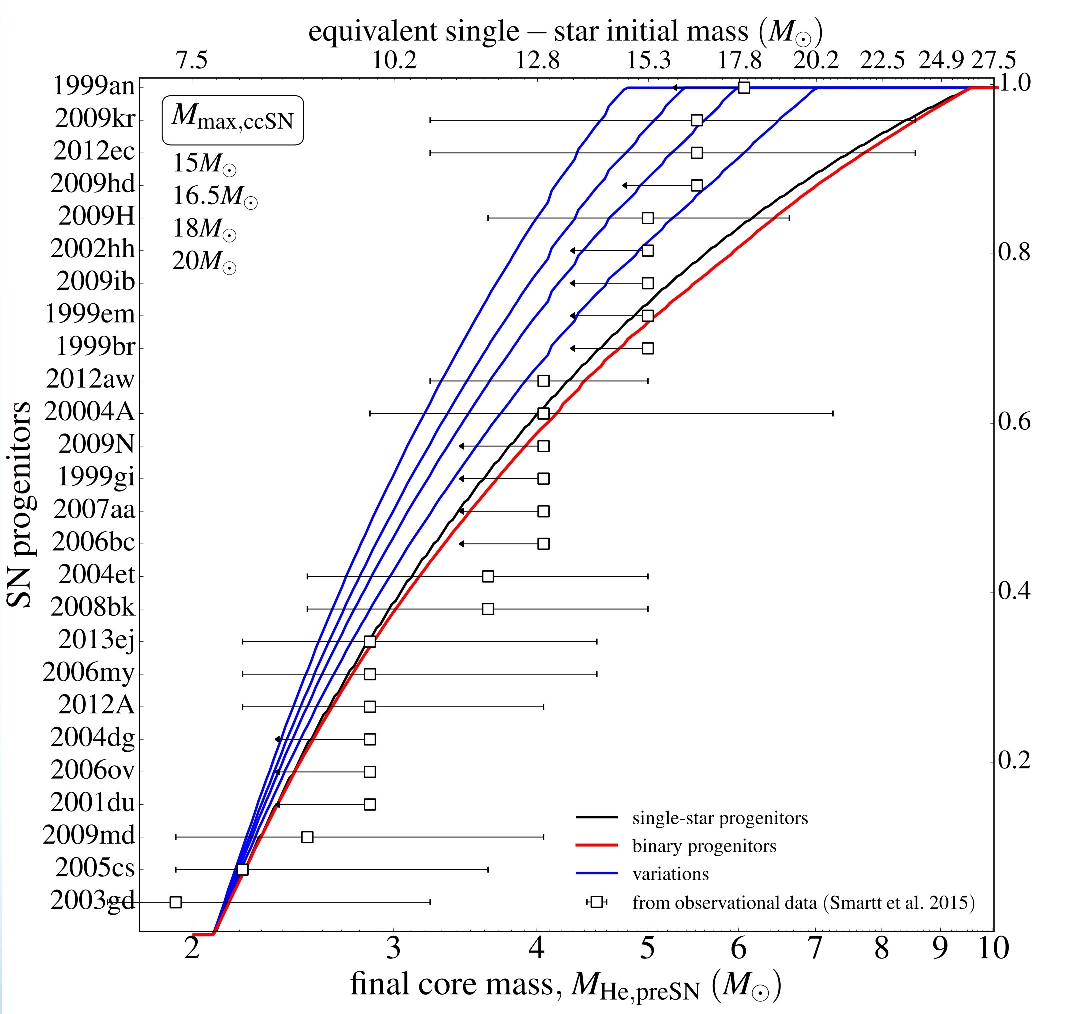
e.g. Sparks+Stecher'74
Sabach+Soker'14

Possible observational signature of late ccSNe



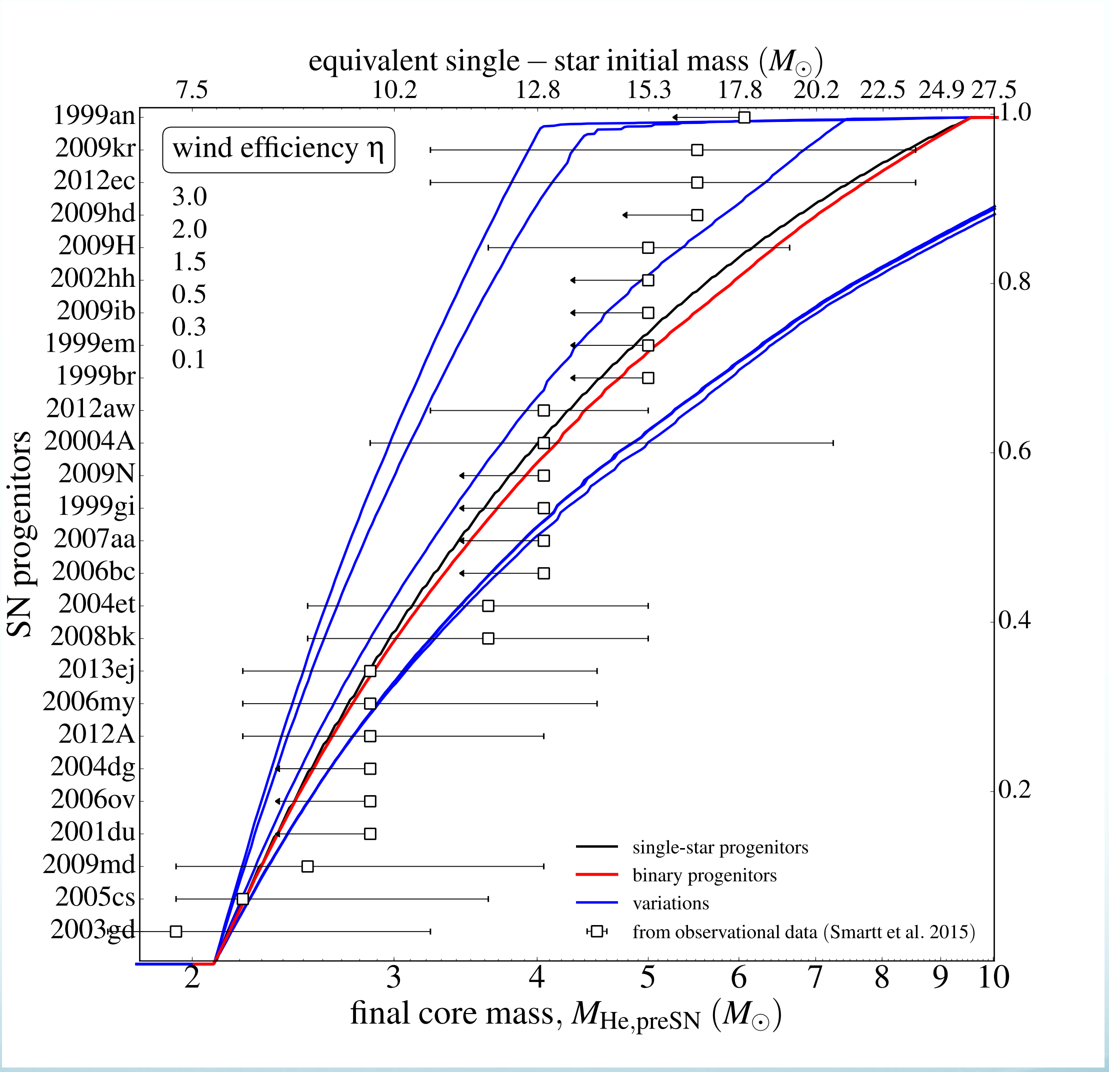
Zapartas+ '17

Failed SNe

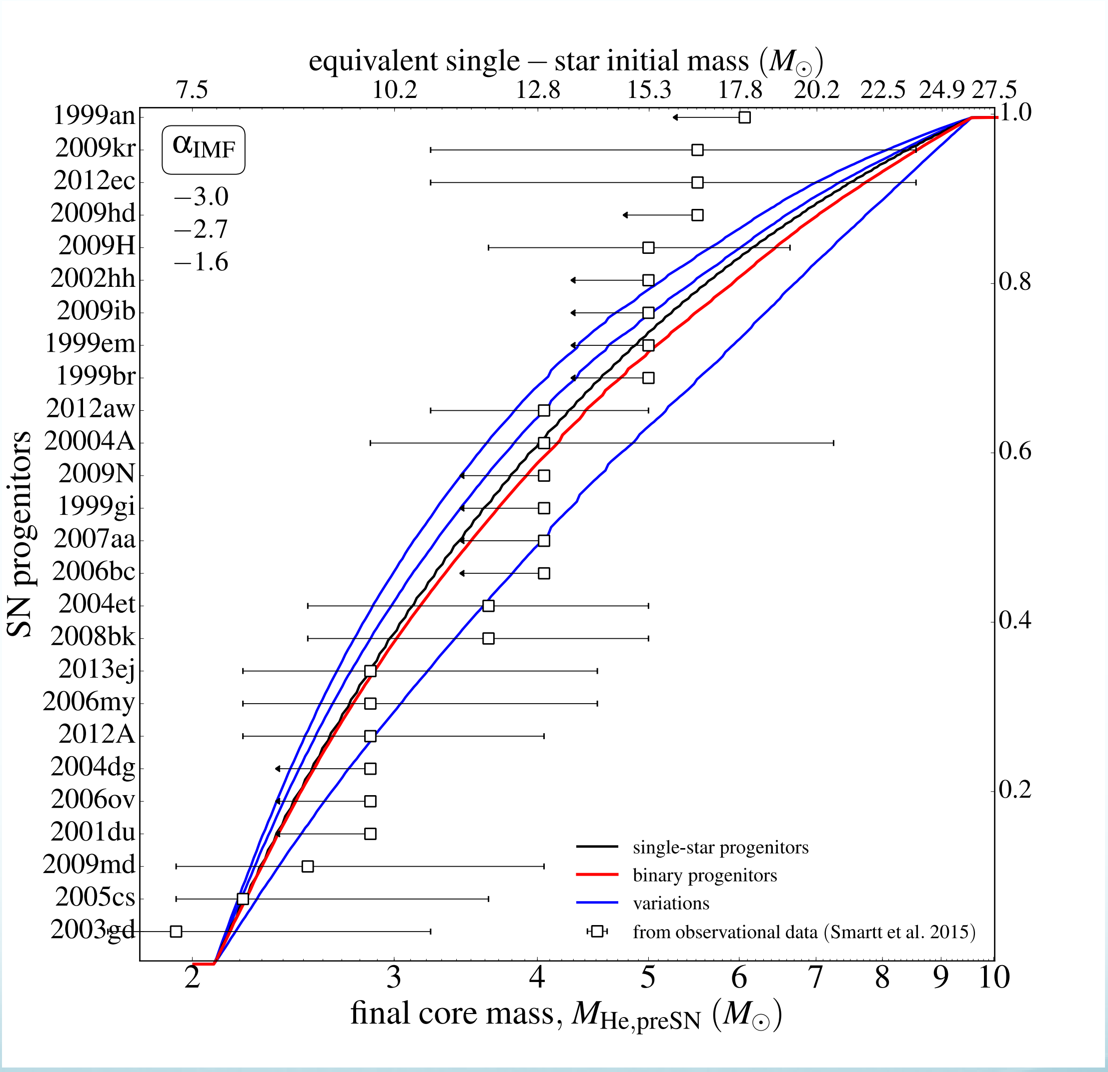


equivalent single – star initial mass ($M_\odot$)
7.5
10.2
12.8
15.3
17.8
20.2
22.5
24.9
27.5
1999an
2009kr
2012ec
2009hd
2009H
2002hh
2009ib
1999em
1999br
2012aw
20004A
2009N
1999gi
2007aa
2006bc
2004et
2008bk
2013ej
2006my
2012A
2004dg
2006ov
2001du
2009md
2005cs
2003gd
SN progenitors
$M_{\rm max,ccSN}$
$15M_\odot$
$16.5M_\odot$
$18M_\odot$
$20M_\odot$
1.0
0.8
0.6
0.4
0.2
single-star progenitors
binary progenitors
variations
from observational data (Smartt et al. 2015)
2
3
4
5
6
7
8
9
10
final core mass, $M_{\rm He,preSN}$ ($M_\odot$)

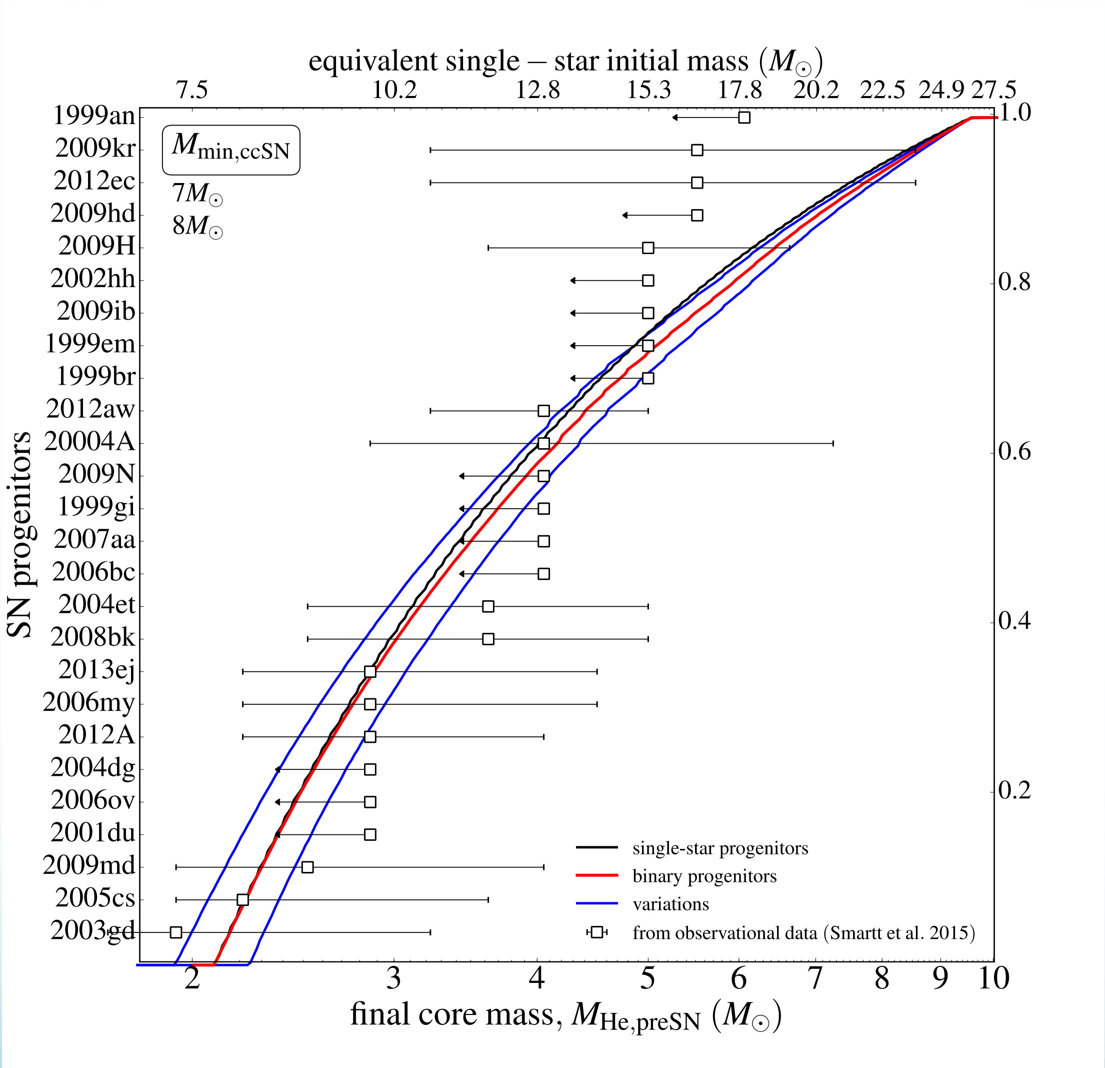
Wind efficiency



IMF efficiency

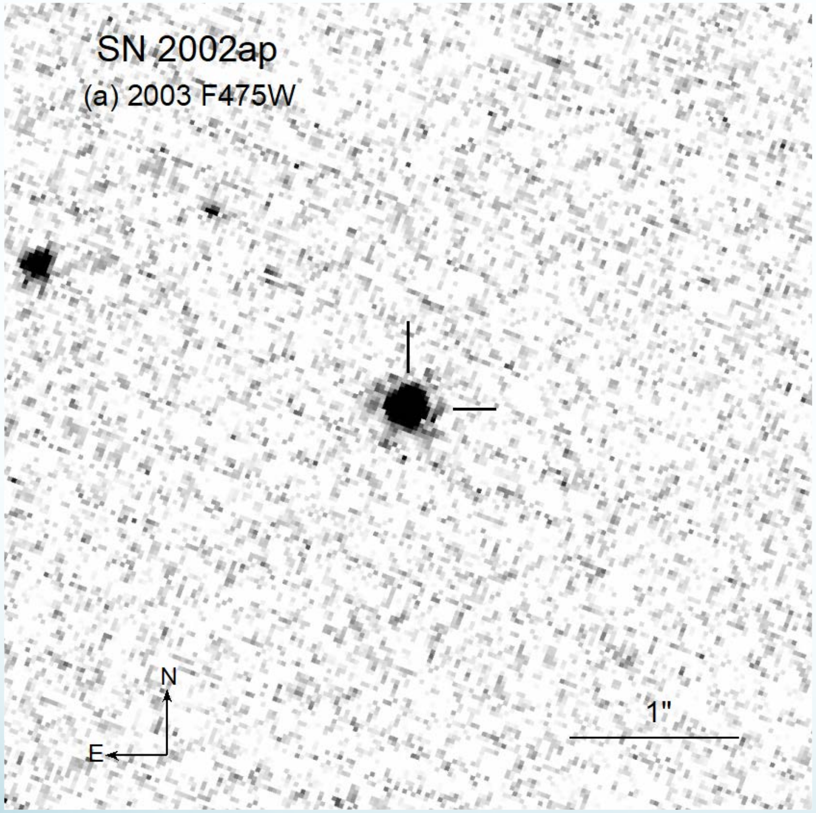


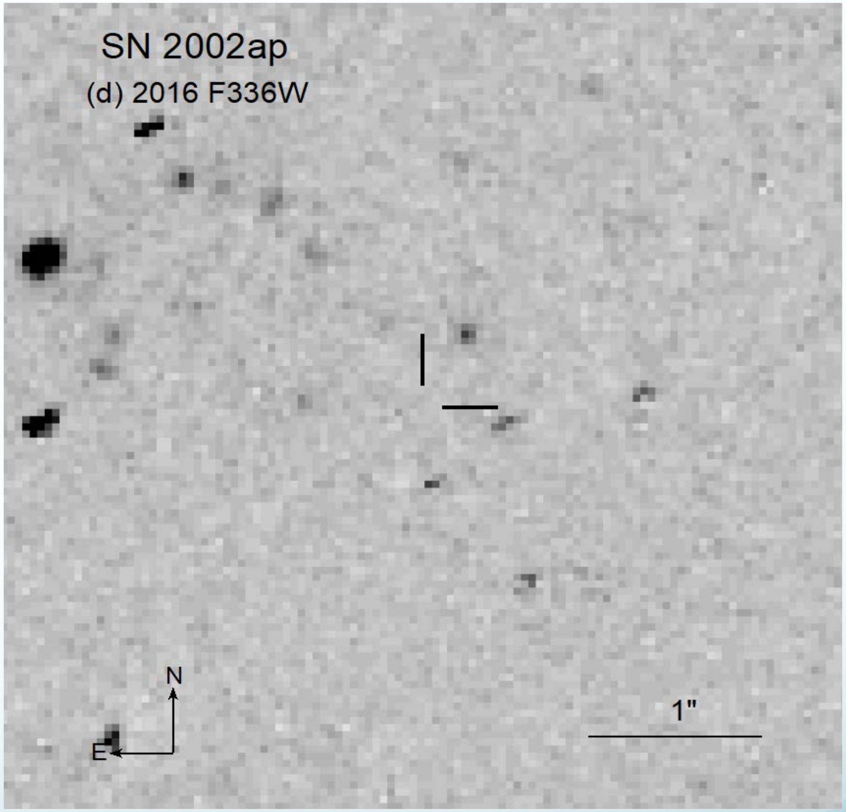
Mmin,ccSN



equivalent single – star initial mass ($M_\odot$)
7.5
10.2
12.8
15.3
17.8
20.2
22.5
24.9
27.5
$M_{\rm min,ccSN}$
$7M_\odot$
$8M_\odot$
1999an
2009kr
2012ec
2009hd
2009H
2002hh
2009ib
1999em
1999br
2012aw
20004A
2009N
1999gi
2007aa
2006bc
2004et
2008bk
2013ej
2006my
2012A
2004dg
2006ov
2001du
2009md
2005cs
2003gd
SN progenitors
1.0
0.8
0.6
0.4
0.2
single-star progenitors
binary progenitors
variations
from observational data (Smartt et al. 2015)
2
3
4
5
6
7
8
9
10
final core mass, $M_{\rm He,preSN}$ ($M_\odot$)

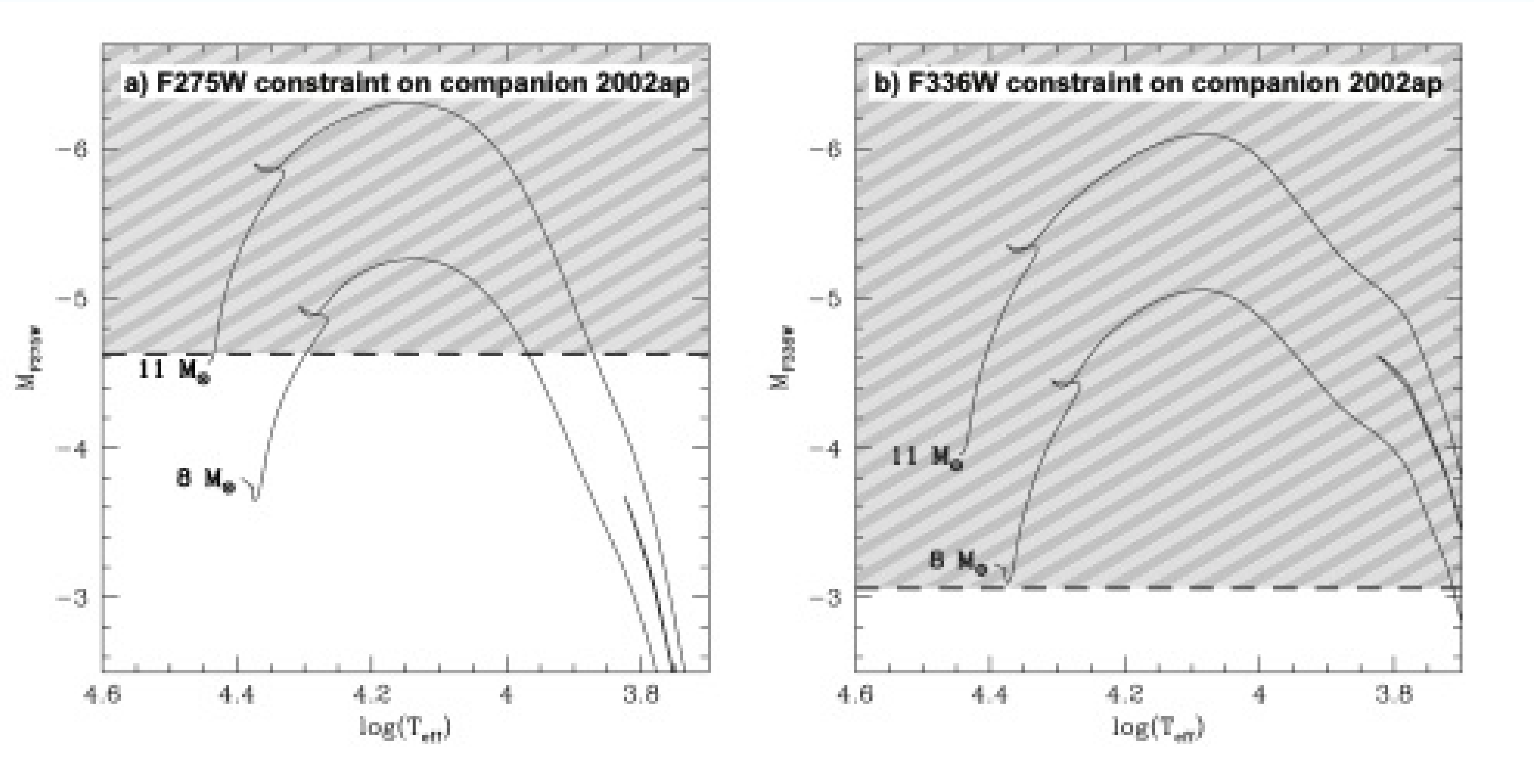
Companion search for SN2002ap



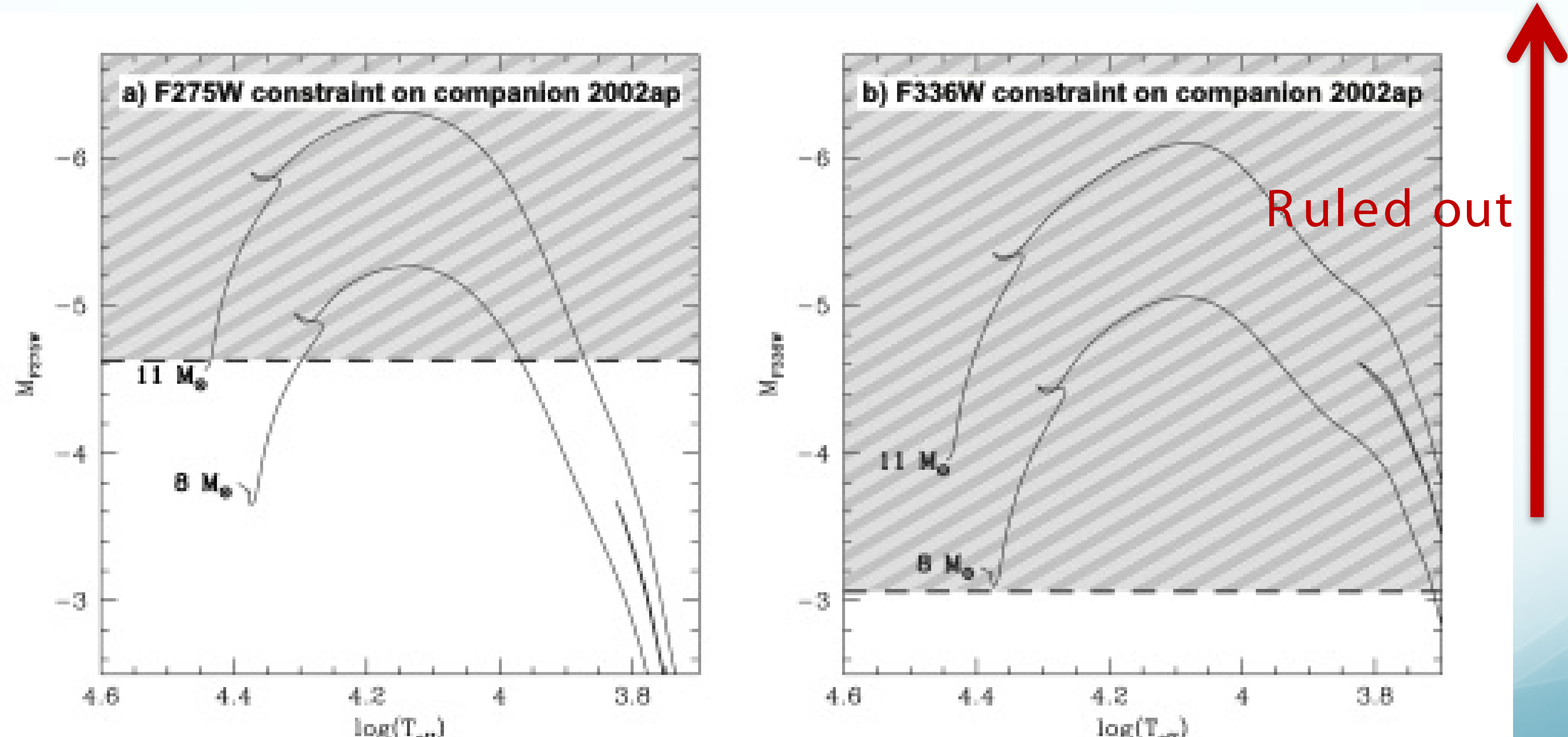


Zapartas et al. (2017b.)

Upper limit on a possible (main-sequence) companion



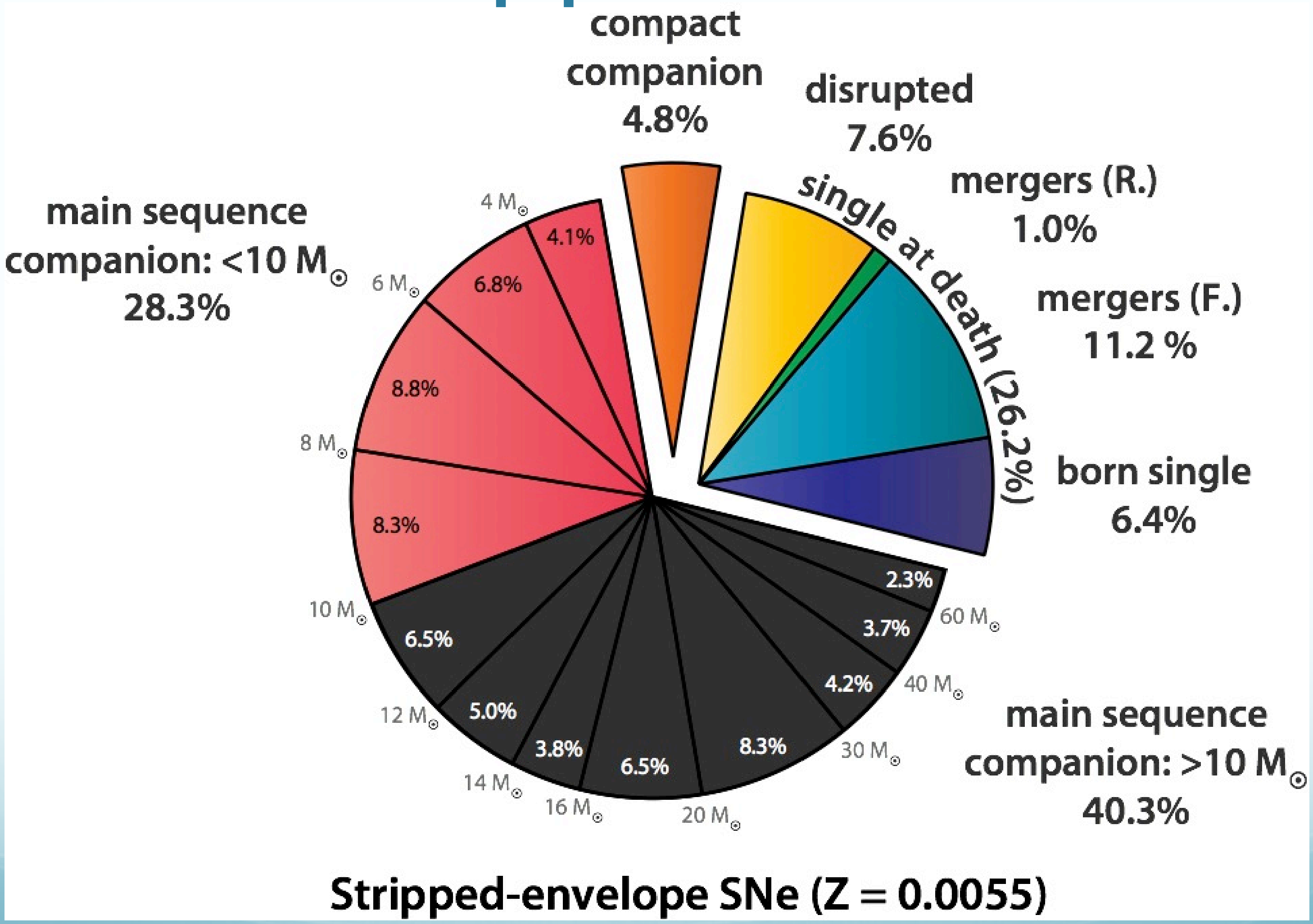
Upper limit on a possible (main-sequence) companion



Possible MS Mcomp < 8-10 Msun

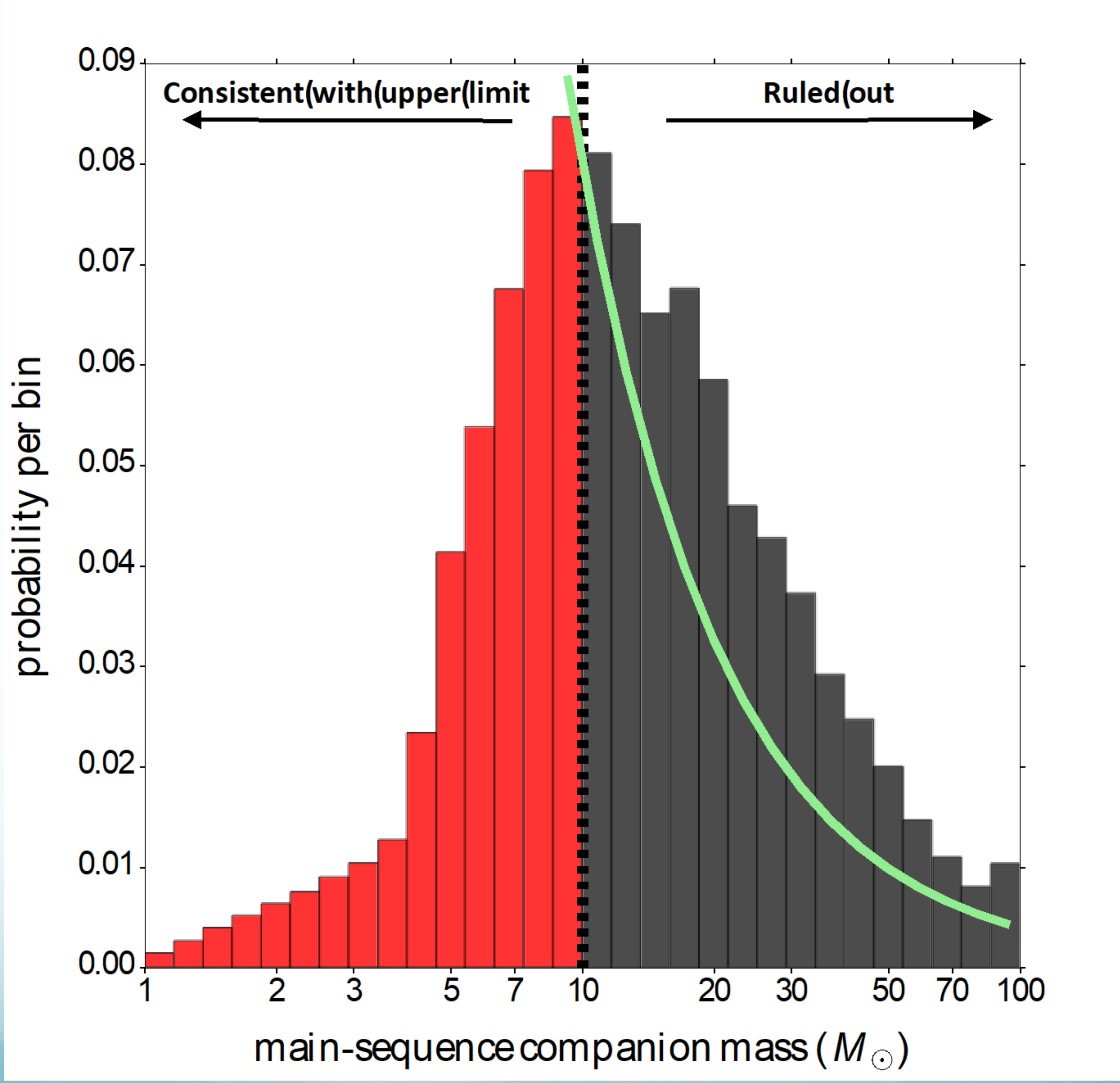
Zapartas et al. (2017b.)

Companions of stripped ccSNe

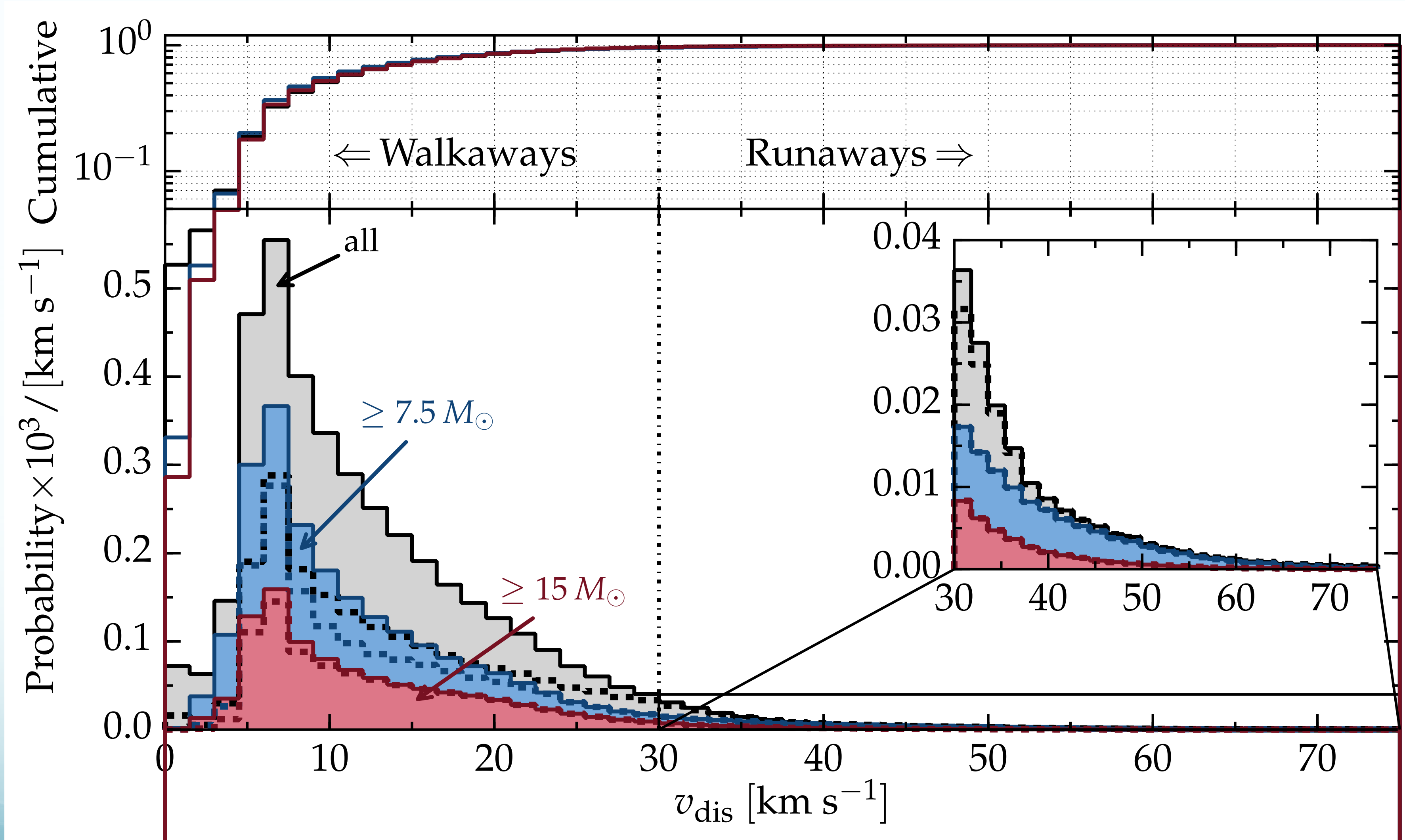


e.g. Maund+ '04,15, Fox+ '14, Follateli+ '14, Ryder+ '06, Van Dyk+ 16, Kochanek+ '17

Zapartas et al. (2017b.)

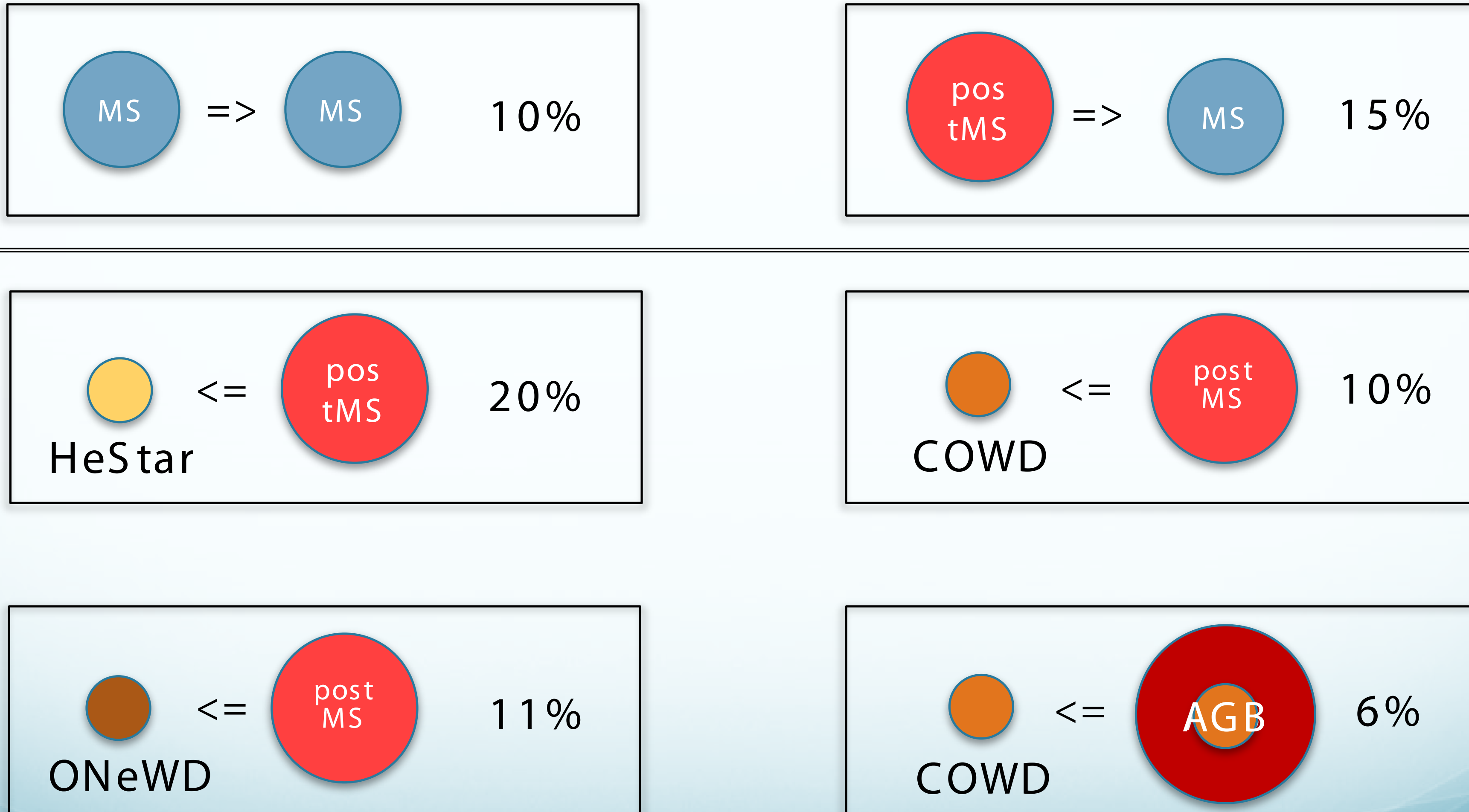


Zapartas et al. (2017b.)



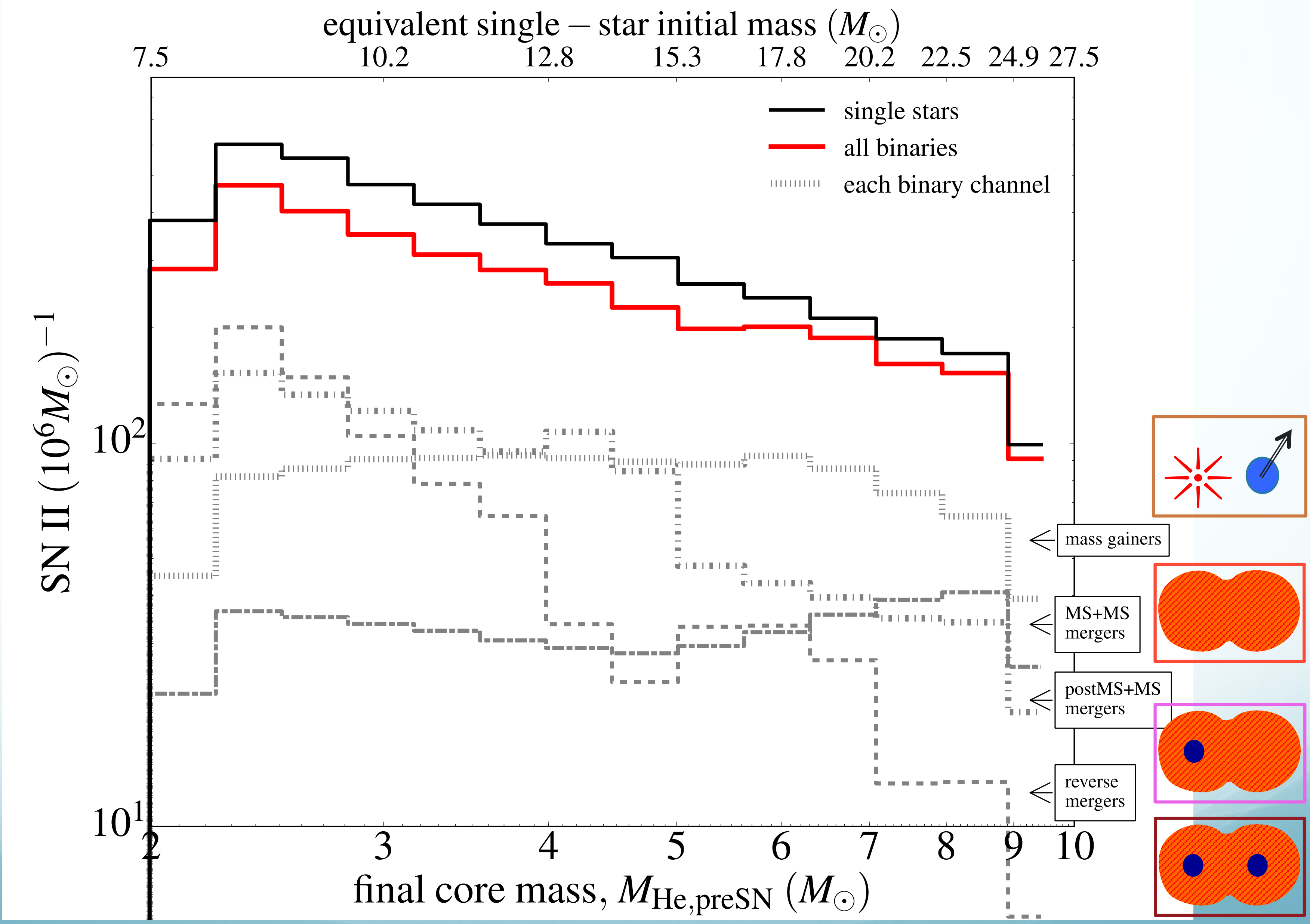
Renzo et al. (2018)

Reverse mergers



Zapartas+2017a

Shallower core mass distribution



Zapartas+(to be subm.)