Midwest Workshop on SNe and Transients

Evolution and Explosion of Massive Stars

by

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R136 cluster in Large Magellanic Cloud (Hubble Space Telescope, NASA)

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CCAPP

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metallicity [Z⋆]

1

0

low mass solar Z

common solar Z

very massive solar Z

very massive low Z

8   12   30   70   140   250   initial mass [M⋆]

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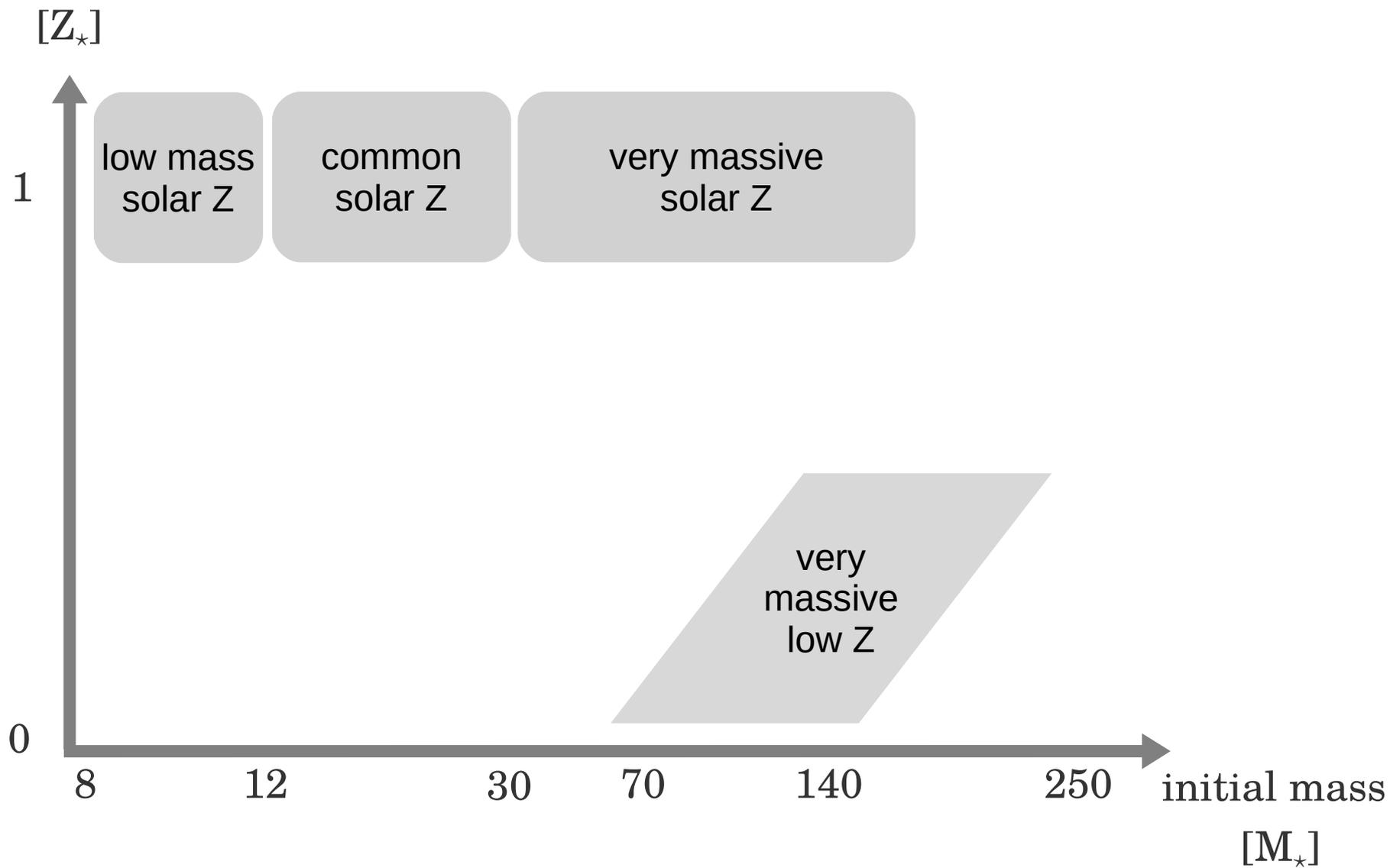
Off-center Ignitions and low L Type-IIP

See:
Jerkstrand + (2017)
Woosley & Heger (2015)
Jones + (2014)
Takahashi + (2013)

Old:

|			
WD	EC SN	Normal CCSN	initial mass

~8-9

New:

C Flame	Central C Ignition	O Flame and Si Flash	Stable Central Burning	
7	8	9 10.3	>10.4	initial mass
CO WD	ONe WD EC SN	←——— Fe Core Collapse ———→		

Woosley & Heger (2015)

Pastorello + (2009)

SN 1996W
SN 2004et
SN 1999em
SN 2003gd
SN 1999gi
SN 2004dj
SN 1999br
SN 2005cs

SN 1987A

$\log(L_{\mathrm{UBVRI}})$ [erg s^{-1}]

phase [days]
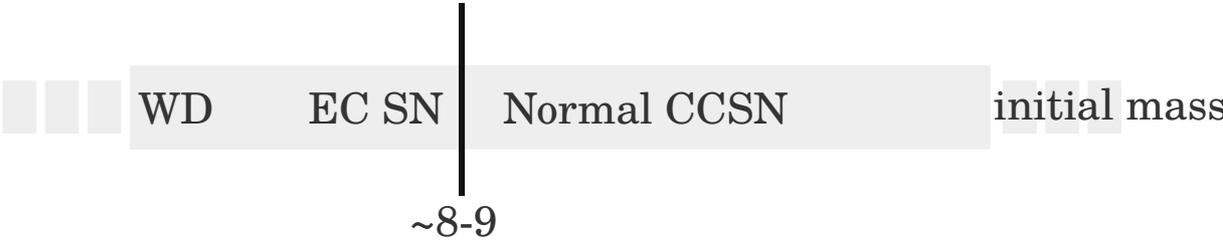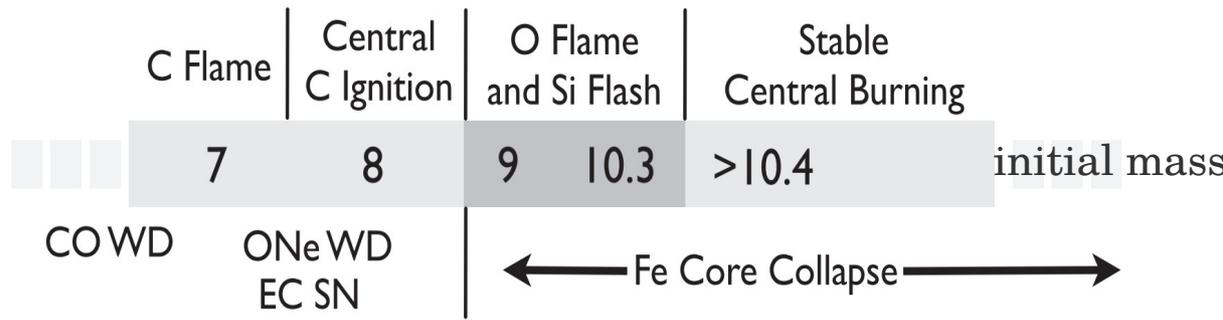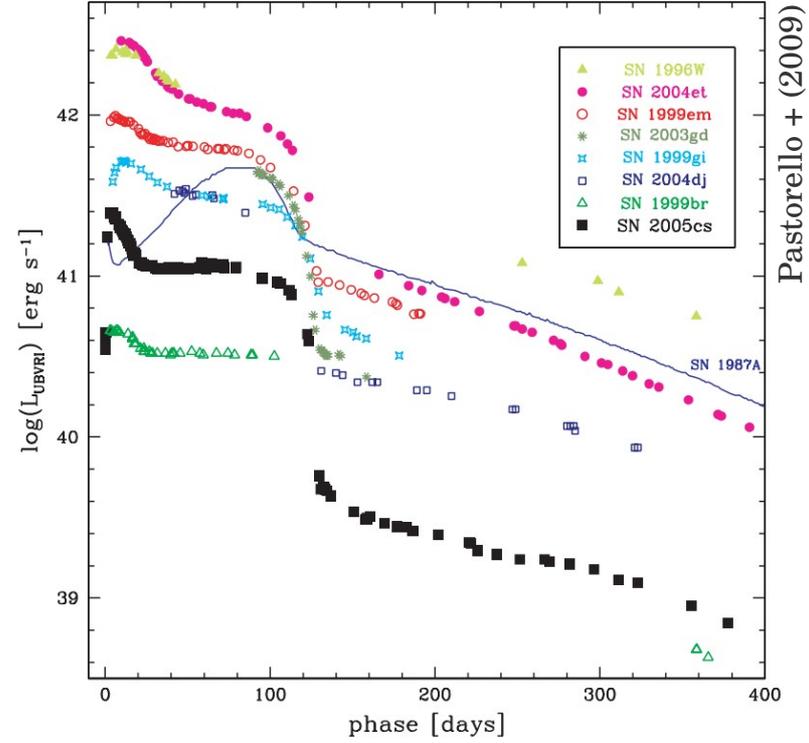
$L_{\mathrm{plateau}} \propto E^{5/6} \, R^{2/3} \, M^{-1/2} \, X_{\mathrm{He}}^{1/3}$

$t_{\mathrm{plateau}} \propto E^{-1/4} \, R^{1/6} \, M^{1/2} \, X_{\mathrm{He}}^{-1/3}$

Popov (1992)
Kasen & Woosley (2009)
Sukhbold + (2016)

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"Islands"

See:
Sukhbold + (2018)
Sukhbold + (2016)
Sukhbold (2016)
Sukhbold & Woosley (2014)

Old:

New:

VS
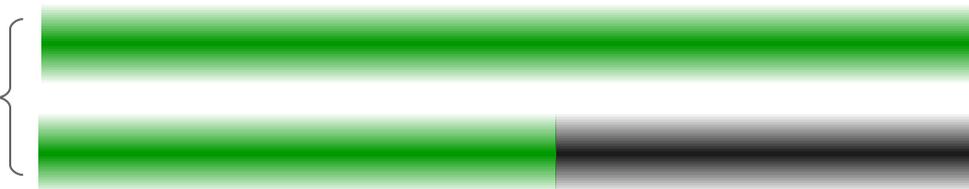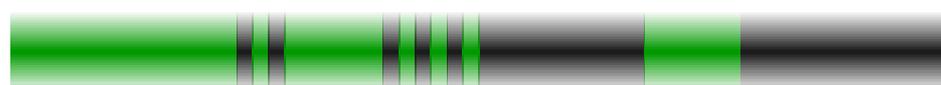
explosion

implosion
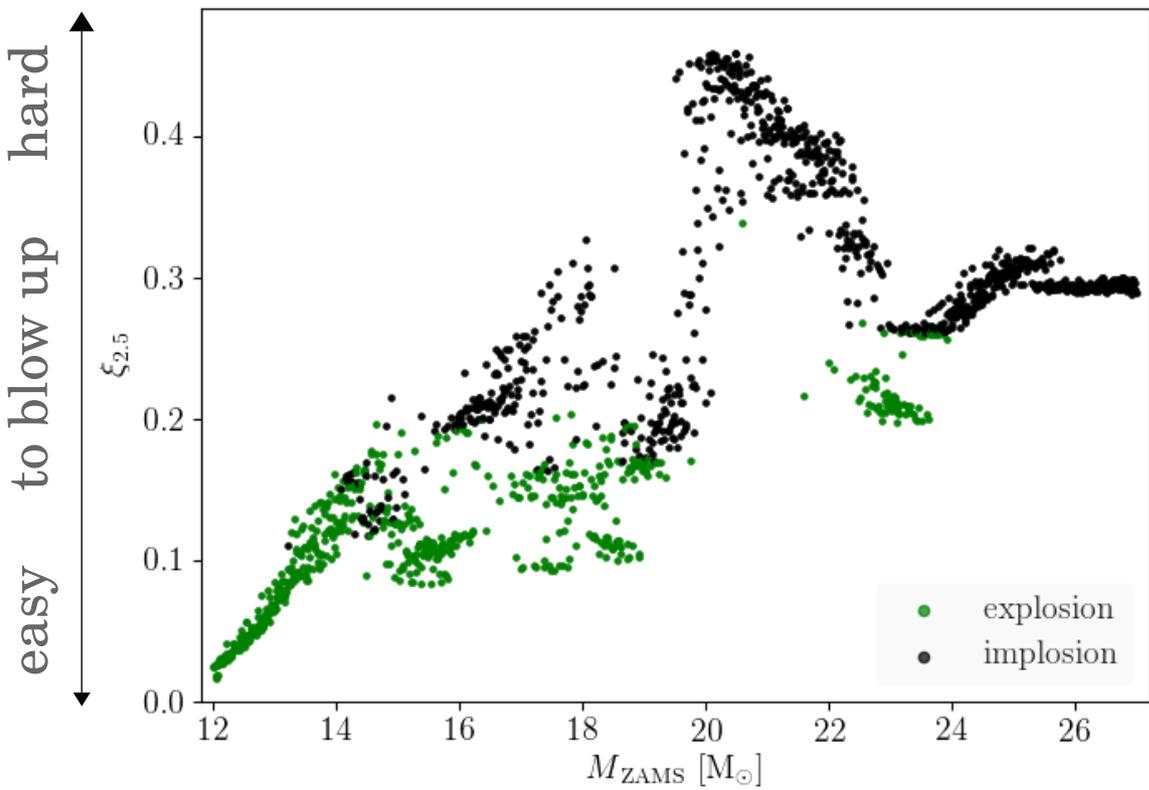
Sukhbold + (2014, 2018)

- Nucleosynthesis
- Light Curves:
    Sukhbold + 2016
- Compact Remnants:
    Raithel + 2018
- E_{expl} & M_{Ni}:
    Mueller + 2017
- Consistent with Direct
  Imaging Studies:
    Smartt (2015)

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Branching Solutions

See:
Sukhbold + (2018)

O-depleted core at Si ign.

M_{Si} (at Si ign.) [M$_\odot$]

M_{He} [M$_\odot$]

~14 M_{ZAMS} [M$_\star$]   ~20

Sukhbold + (2018)
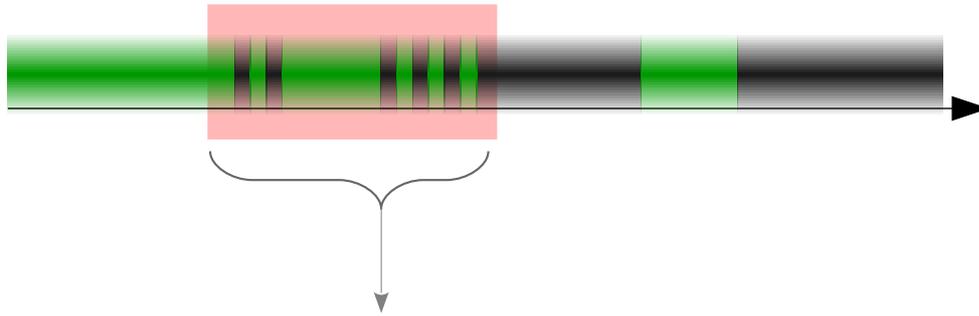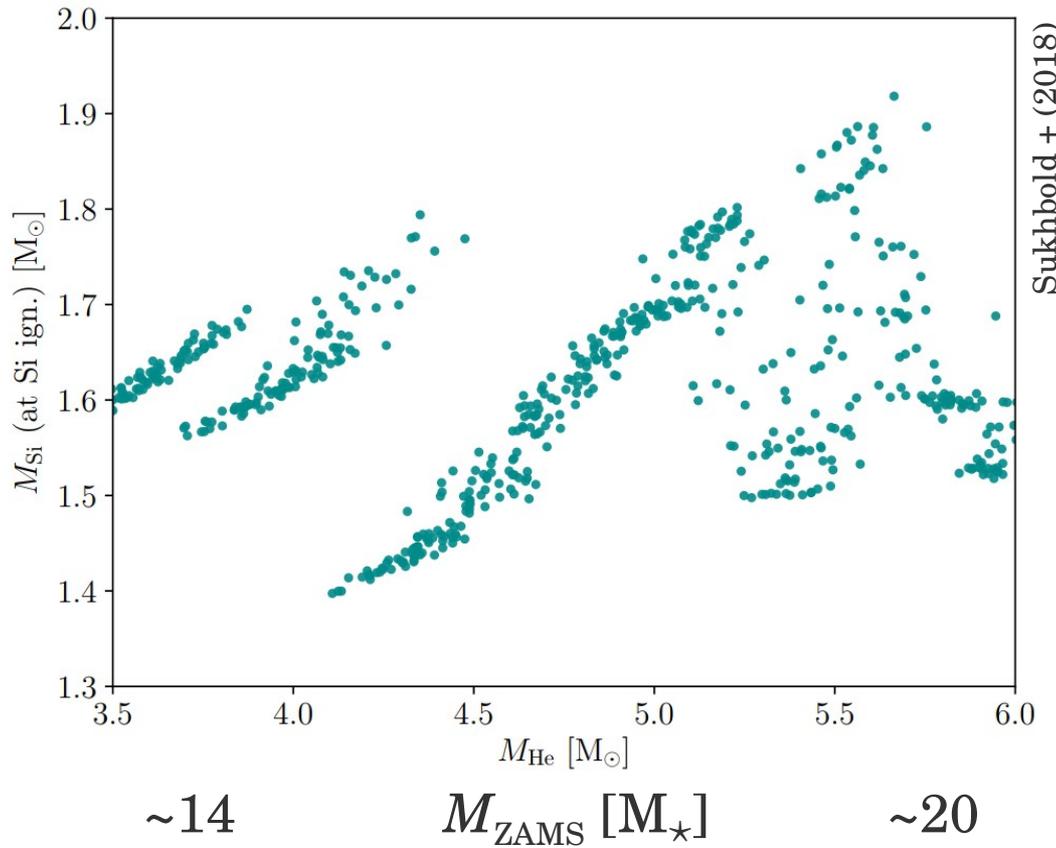
One star may explode, while another with slightly different initial conditions might implode

If both stars explode, they can create very different remnants and explosion properties

Vogt-Russel "theorem" does not apply to presupernova evolution of masive stars

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Implosions to BH and rare Type-Ib/c

See:
Yoon + (2017)
Sukhbold + (2016)
Dessart + (2015)
Dessart + (2012)

M_{ZAMS} [M$_\star$]	M_{final} [M$_\star$]	
30	13	
35	14	
40	15	
45	13	
50	10	lost all envelope
60	8	
80	7	
100	6	
120	6	

Sukhbold + (2016)

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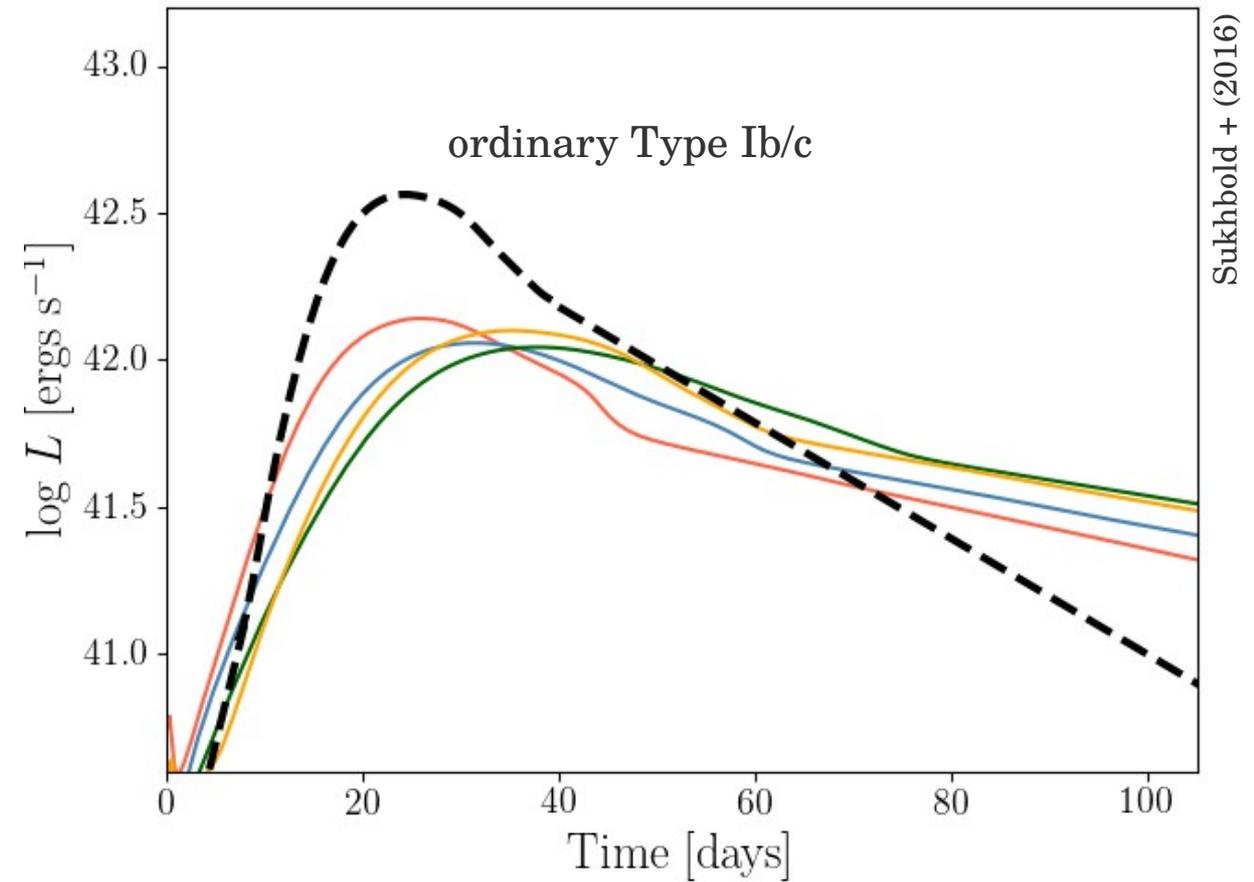
Pulsational Pair-Instability

See:
Woosley (2017)
Yoshida + (2016)

not experienced

Pulsational PI

Reversed by E_{nuc}
(PI SN)

Cannot be reversed
(direct implosion)

initial mass

M_{ZAMS} [M$_\star$]	M_{He} [M$_\star$]	#pulse
~70	32	0
	36	33
	40	18
	44	11
	48	8
	50	6
	54	4
	60	3
~140	64	1

Woosley (2017)

Woosley (2017)

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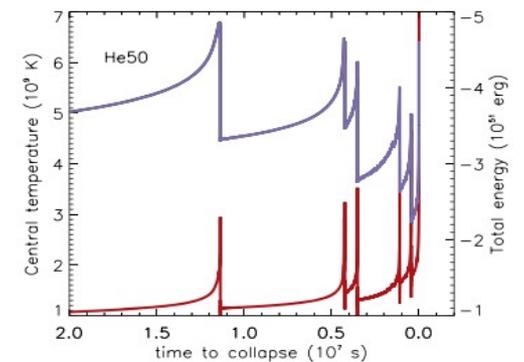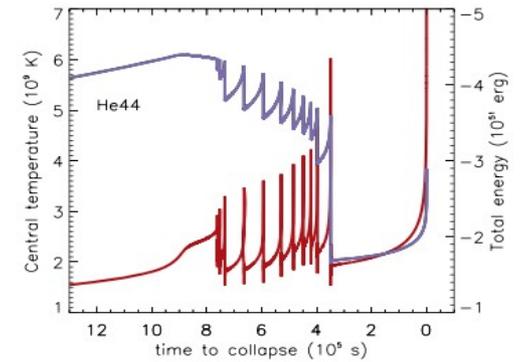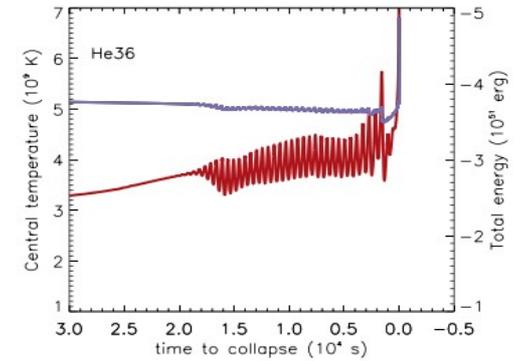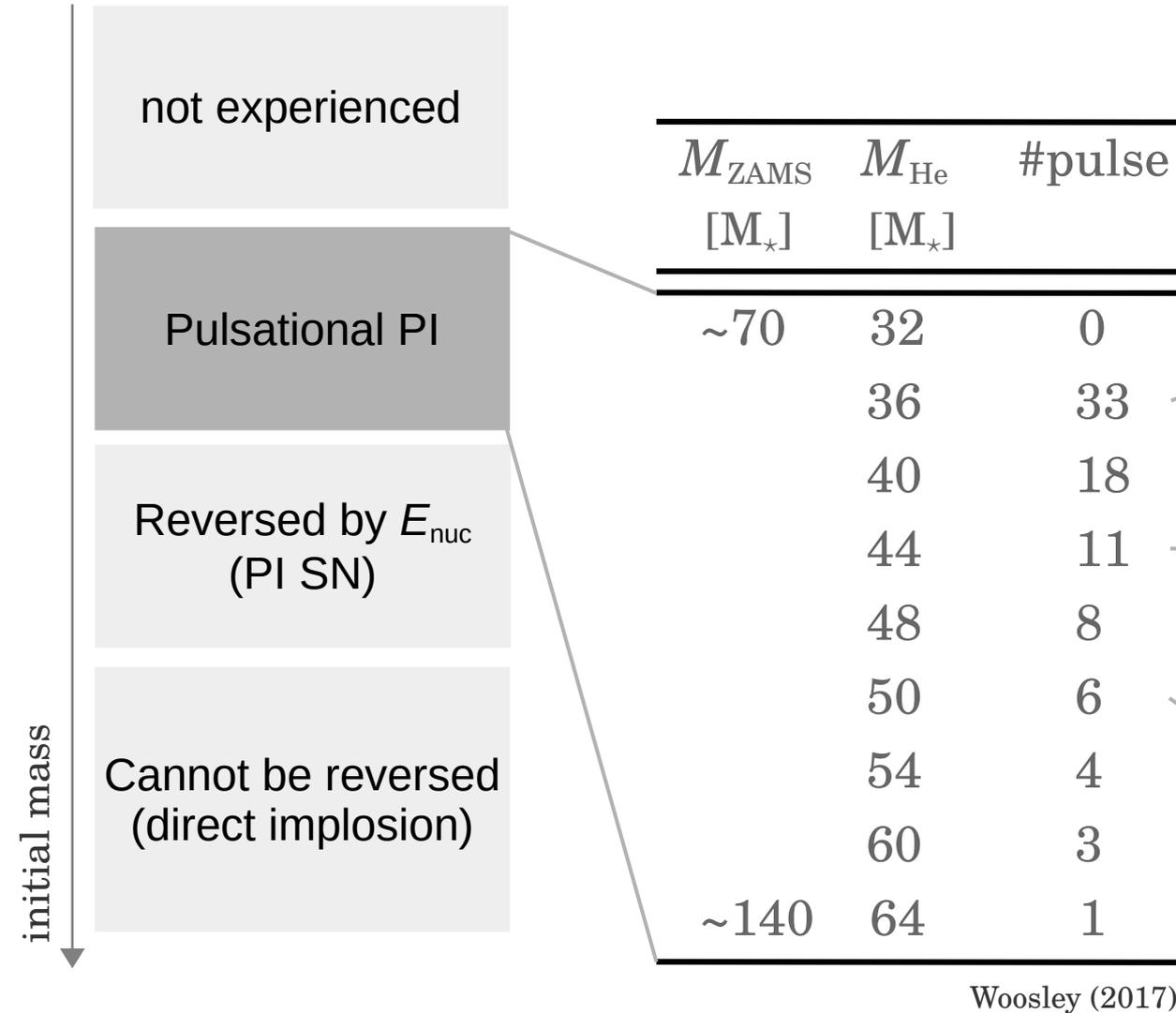
Heger + (2003)

metallicity [Z$_\star$]

SN IIp

SN Ib/c

SN IIL/b

BH by fallback (weak SN)

weak SN Ib/c

direct black hole

no H envelope

weak SN IIp

BH by fallback (weak SN)

direct black hole

direct black hole

puls. pair (BH)

no BH pair SN

low mass stars — white dwarfs

O/Ne/Mg core collapse

iron core collapse

metallicity (roughly logarithmic scale)

about solar

metal-free

9 10   25   34 40   60   100   140   260

initial mass (solar masses)

binarity

low L IIP
IIP
IIn?
Si-Flash

IIP
impl.
IIn?
IIL?
"islands"

rare Ib
rare Ic
impl.

pec. II P/n
pec. I b/c/n
SLSN I, II
PPISN

8   12   30   70   140   initial mass [M$_\star$]

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