Observational constraint on the mass range of Core Collapse Supernova progenitors from 11 HUGS and LVL data

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Overview: CC SN rate and SFR

$$R_{CC}(t) = \int_{\tau_{min}}^{min(t,\tau_{max})} k(t-\tau) A_{CC}(t-\tau) f_{CC}(\tau) \psi(t-\tau) d\tau$$

$k(t-\tau)$	$A_{CC}(t-\tau)$	$f_{CC}(\tau)$	$\psi(t-\tau)$
number of star per unit mass born at epoch t-τ	fraction of star that end up as CC SNe	distribution function of delay times	SFR

τ_{min} minimum delay time
τ_{max} maximum delay time

- ✓ all stars with mass between $m_u^{cc} - m_l^{cc}$ produce CC SNe
- ✓ negligible delay time ($\tau < 0.05$ Gyr)

$$R_{CC}(t) = \frac{\int_{m_l^{CC}}^{m_u^{CC}} \phi(m) dm}{\int_{m_l}^{m_u} m\phi(m) dm} \psi(t)$$

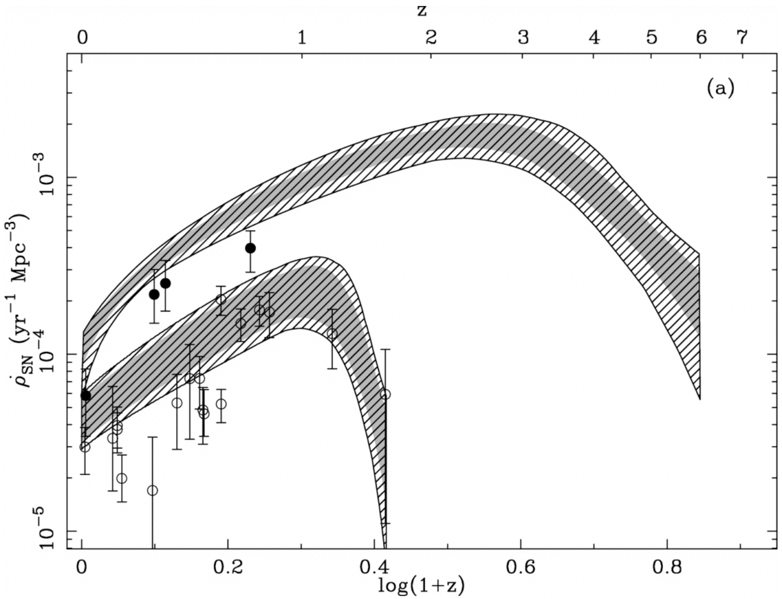
$m_u^{cc} - m_l^{cc}$ mass range CCSN progenitors

$m_u - m_l$ mass range stellar population

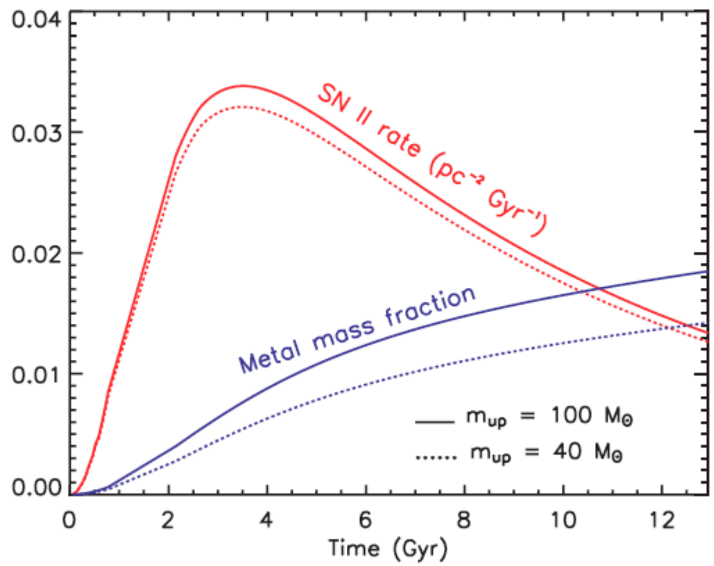
$\phi(m)$ Initial mass function

Motivations

CC SN rate as SFR diagnostic



SFH normalization



Modeling galaxy chemical evolution
SN feedback effects

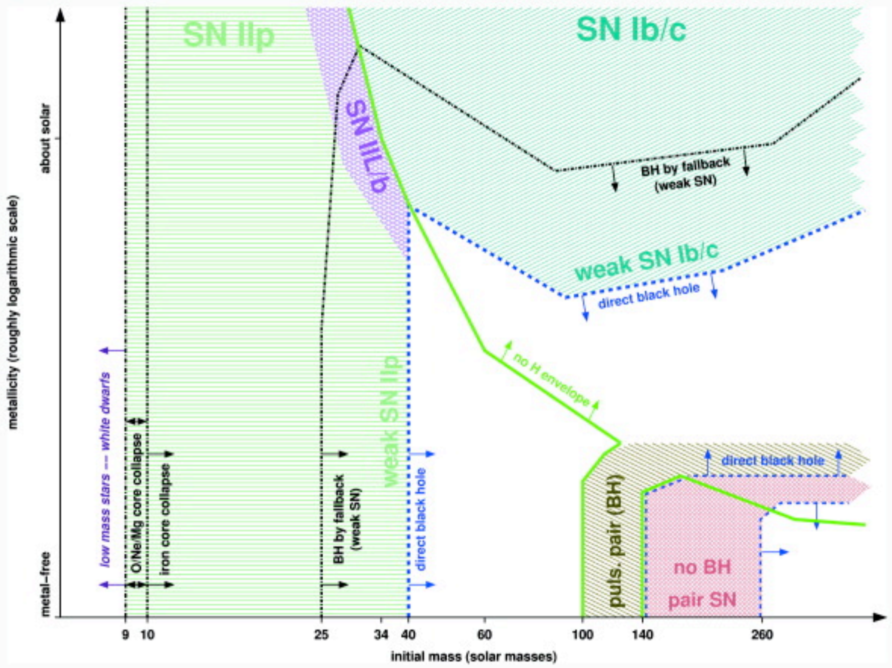
Poor statistics
Systematics

Is the CC SN rate a reliable SFR probe?

Meaningful comparison with different SFR diagnostics in the same galaxy sample

Motivations

CC SN rate as a tool to investigate progenitor stars



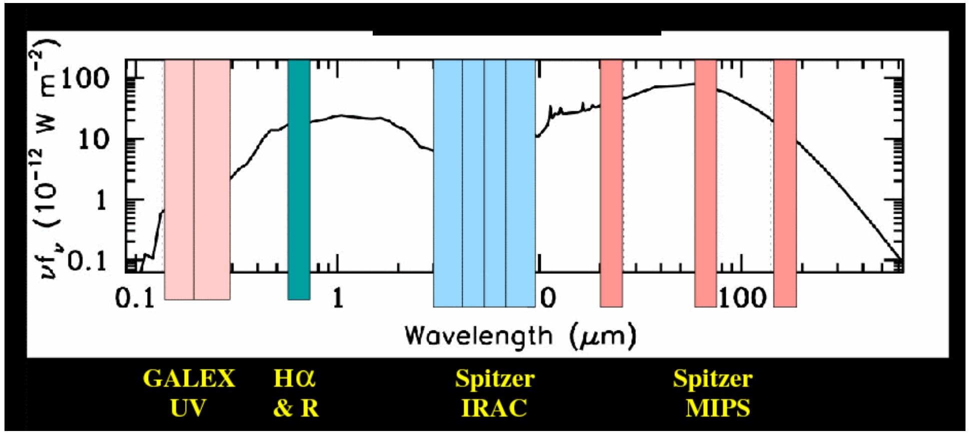
Heger et al 2003

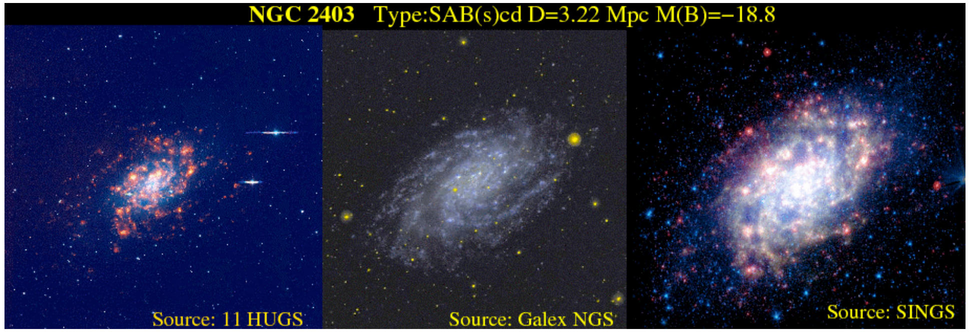
What is the mass range of CC SN progenitors?

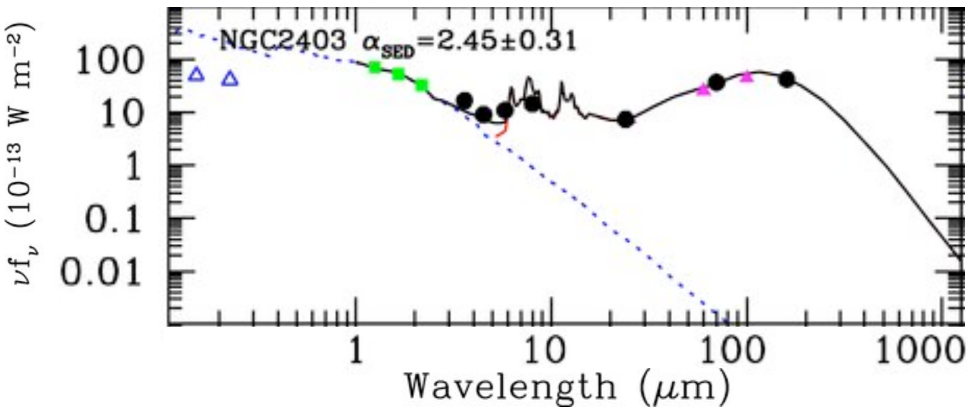
Which massive stars produce which CC SNe ?

Observational constraint on the mass cutoff of CC SN progenitors
by comparing CC SN rate and SFR

The galaxy sample

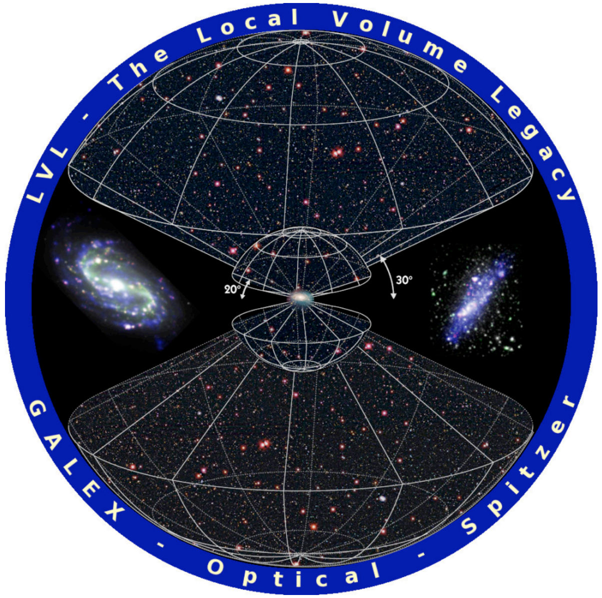






11 Mpc Hα and Ultraviolet galaxy Survey (HUGS)

Local Volume Legacy (LVL)



Kennicutt et al 2008

Lee et al 2009

Dale et al 2009

$D \leq 11$Mpc

Hα data (436 galaxies)

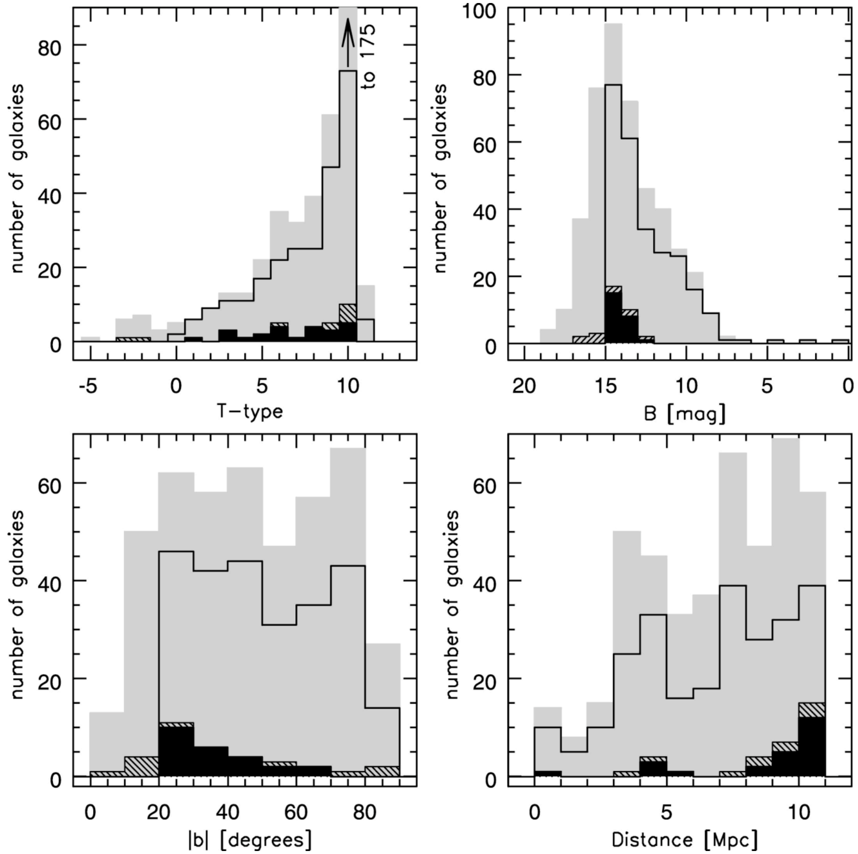
Primary Sample: 261 with $|b| \geq 20^o$, $m_B \leq 15$ mag, $T \geq 0$

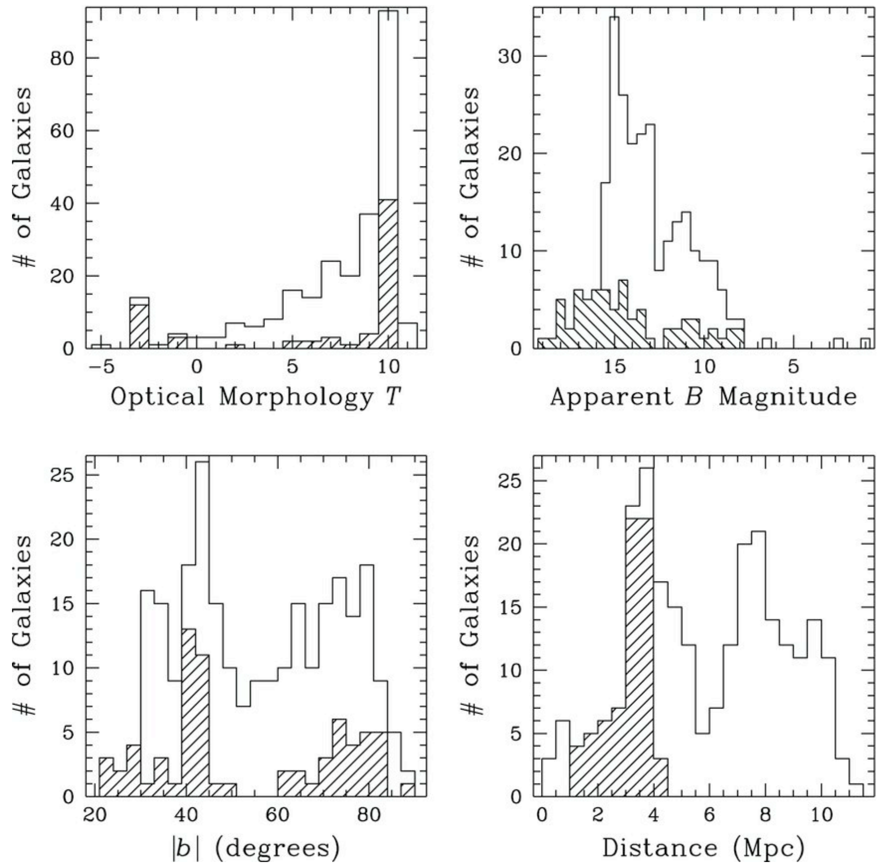
Secondary Sample: 175 with $|b| < 20^o$, $m_B > 15$ mag, $T < 0$

GALEX data (315 galaxies)

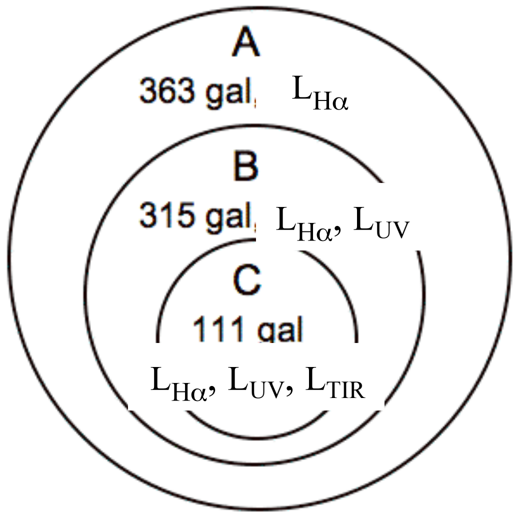
Spitzer data (180 galaxies)

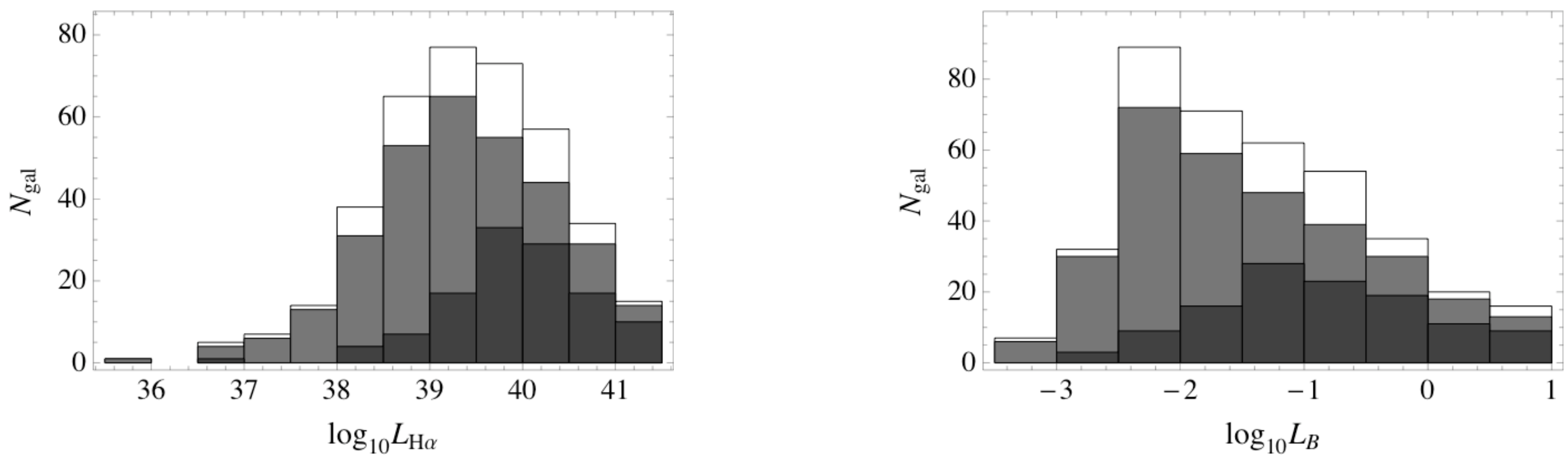
$|b| > 30^o$





The galaxy samples





SFRs

Salpeter IMF (0.1-100 $M_\odot$)

Sample A $SFR(M_\odot\, yr^{-1}) = 7.9 \times 10^{-42} L_{H\alpha}\,(erg\,s^{-1})$ (Kennicutt 1998)

$$A_{H\alpha} = 5.91 log \frac{f_{H\alpha}}{f_{H\beta}} - 2.70$$

$$A_{H\alpha} = 0.10 \quad if\, M_B > -14.5$$

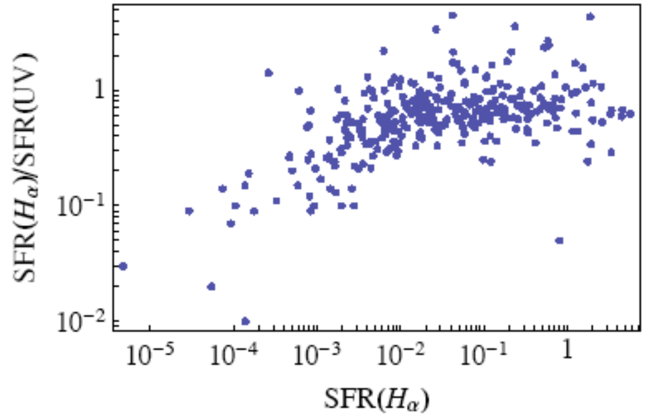
$$A_{H\alpha} = 1.971 + 0.323 M_B + 0.0134 M_B^2 \quad if\, M_B \leq -14.5$$

(Lee et al 2009)

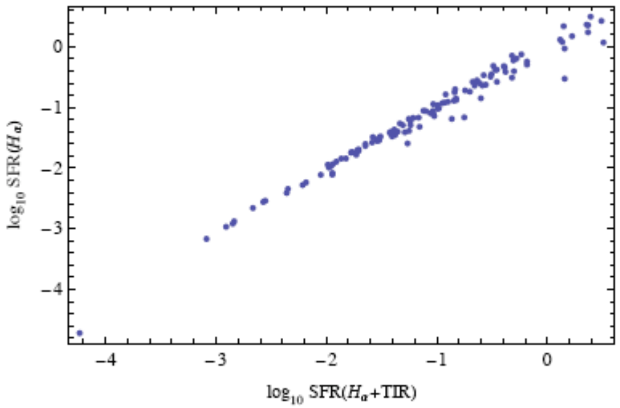
Sample B $SFR(M_\odot\, yr^{-1}) = 1.4 \times 10^{-28} L_{FUV}\,(erg\,s^{-1} Hz^{-1})$

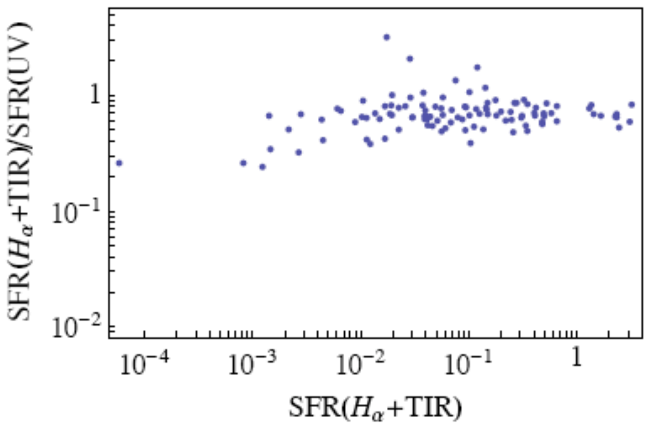
$$A_{FUV} = -0.0333x^3 + 0.3522x^2 + 1.1960x^3 + 0.4967$$

x=log(TIR/FUV) (Buat et al 2005)



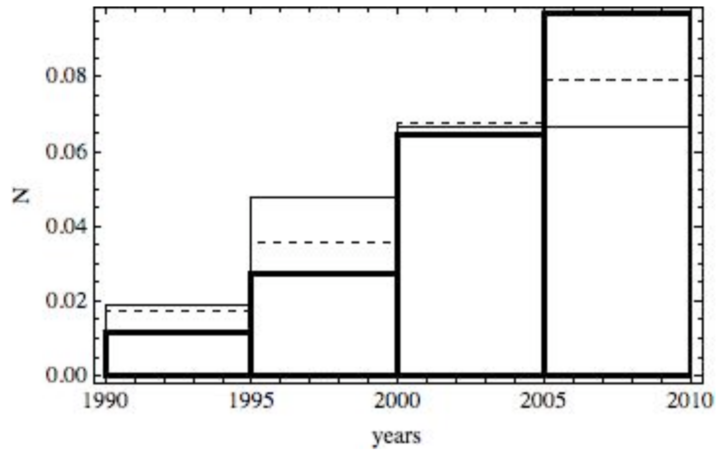
Sample C $SFR(M_\odot\, yr^{-1}) = 7.9 \times 10^{-42} (L_{H\alpha} + 0.0024 L_{TIR})(erg\,s^{-1})$ (Kennicutt et al 2009)

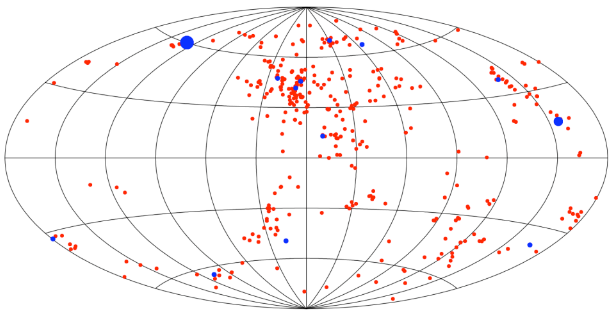




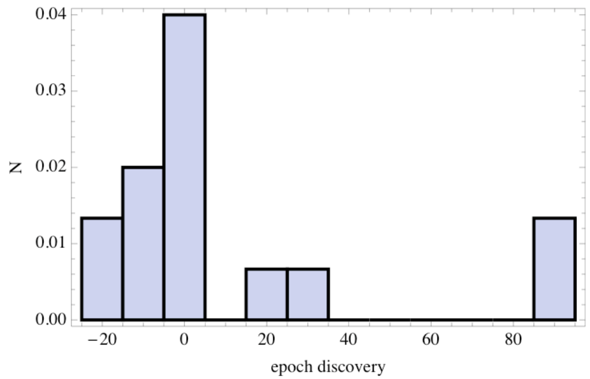
SN sample

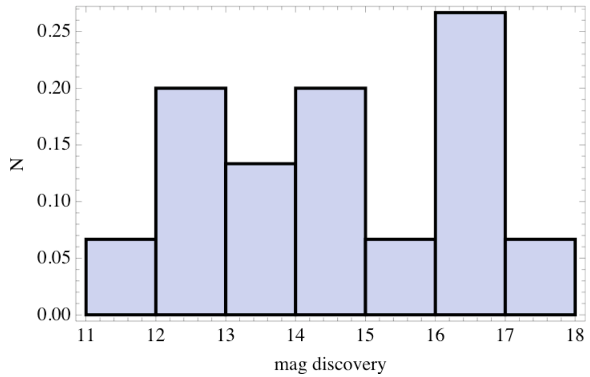
	1885-2009	12 yr (1998-2009)
• CC SNe	38	14
• type Ia SNe	10	1
• faint transients	2	2
• LBVs	6	6
• unclass	10	…

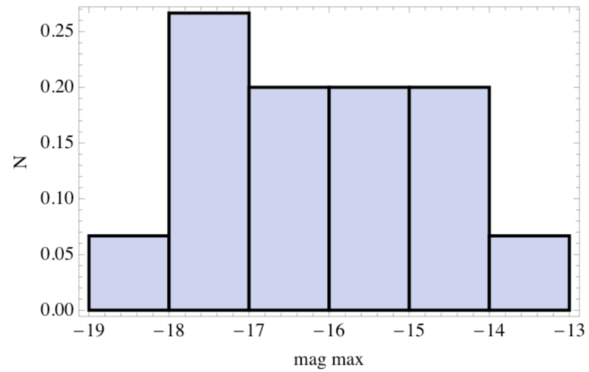




Dec (degree)	N_{gal}	N_{SNe}	F(Gal)	F(L_B)	F(SNe)
$d > 20$	224	9	58%	51%	56%
$-20 < d < 20$	54	3	14%	17%	19%
$d < -20$	108	4	28%	32%	25%







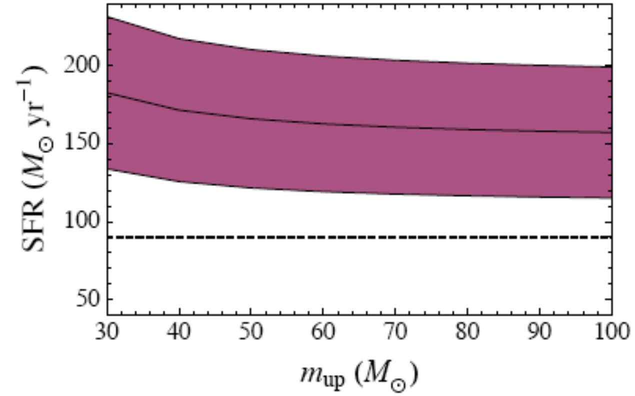
assumptions: CT = 12 years

$m_l = 8\ M_\odot$

Sample A

SFR(Hα)= 90 ± 4 $M_\odot$ yr^{-1}

R_{CC}=1.17 ± 0.27 yr^{-1}

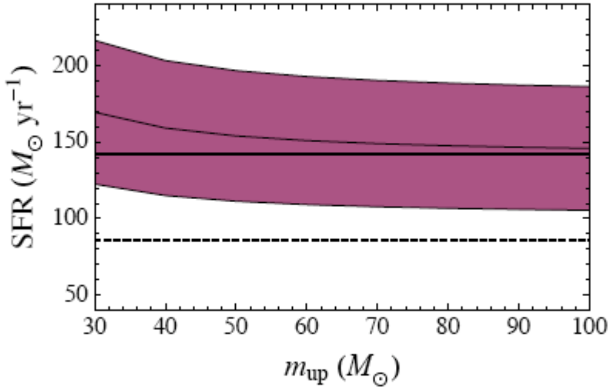


Sample B

SFR(Hα)= 80 ± 4 $M_\odot$ yr^{-1}

SFR(UV)= 142 ± 8 $M_\odot$ yr^{-1}

R_{CC}=1.08 ± 0.27 yr^{-1}



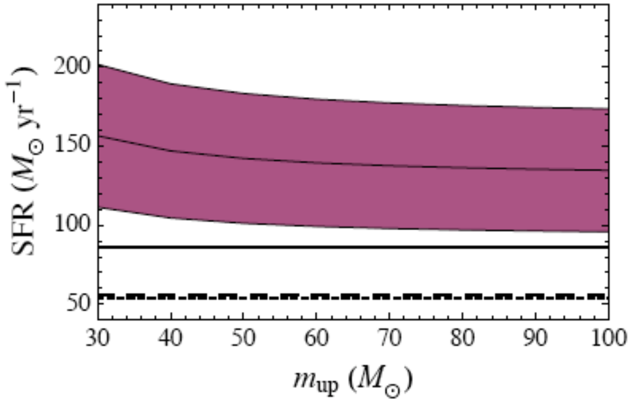
Sample C

SFR(Hα)= 54 ± 4 $M_\odot$ yr^{-1}

SFR(UV)= 86 ± 6 $M_\odot$ yr^{-1}

SFR(Hα+TIR)= 56 ± 4 $M_\odot$ yr^{-1}

R_{CC}=1 ± 0.3 yr^{-1}



CC SN rate in SN unit

Sample A	0.8 ± 0.4	SNu
Sample B	0.85 ± 0.4	SNu
Sample C	1.2 ± 0.5	SNu

SN unit = 1 SN/ 10^{10} $L_{B,\odot}$ / century

Comparison with the SN rates at $z < 0.01$

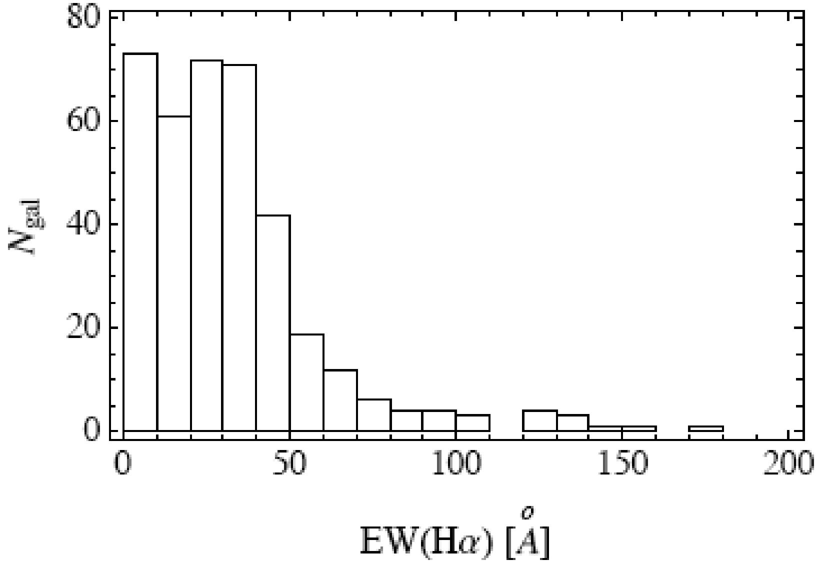
(Cappellaro et al 1999)

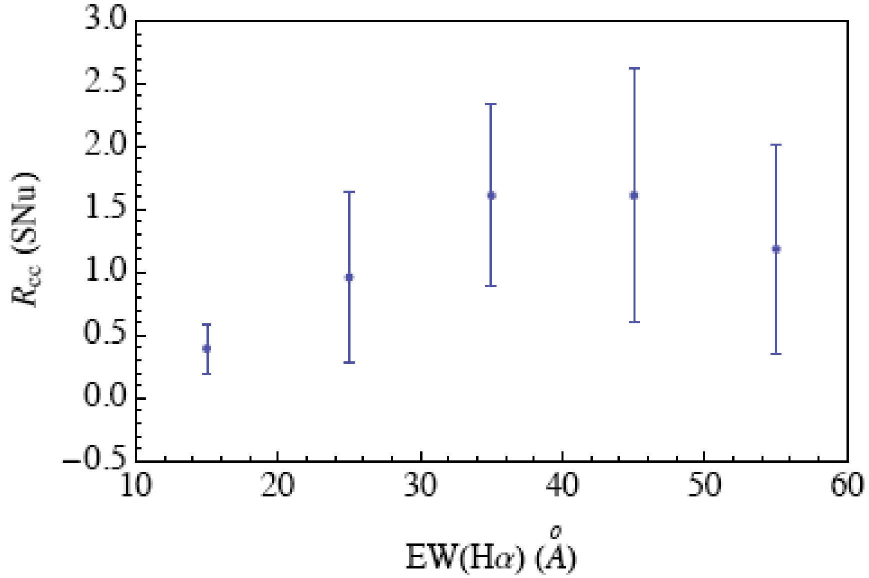
gal. type	N_{Ia}	$N_{Ib/c} + N_{II}$	R_{Ia} (SNu)	$R_{Ib/c} + R_{II}$ (SNu)
E-S0	22.0	0	0.18 ± 0.06	< 0.02
S0a–Sb	18.5	21.5	0.18 ± 0.07	0.53 ± 0.19
Sbc–Sd	22.4	38.6	0.20 ± 0.08	1.0 ± 0.4
Other[1]	6.8	7.2	0.40 ± 0.16	0.87 ± 0.45
All	69.6	67.4	0.20 ± 0.06	0.5 ± 0.2

gal. type	N_{gal}	N_{CC}	SFR ($M_\odot$ yr^{-1})	L_B (10^{10} $L_{B,\odot}$)	R_{CC} (SNu)
Sample A					
$T < 0$	12	0	2.6 ± 0.4	9.1 ± 0.9	≤ 1.69
$0 \leq T < 4$	29	1	13.0 ± 1.0	46 ± 5	$0.18^{+0.42}_{-0.15}$
$4 \leq T \leq 7$	88	12	59 ± 4	81 ± 5	$1.23^{+0.47}_{-0.35}$
$T > 7$	257	1	15.6 ± 0.9	13.1 ± 0.6	$0.63^{+1.46}_{-0.52}$
Sample B					
$T < 0$	10	1.33 ± 0.13	8.4 ± 0.9	0	≤ 1.82
$0 \leq T < 4$	25	16.1 ± 0.9	41 ± 5	1	$0.20^{+0.46}_{-0.17}$
$4 \leq T \leq 7$	77	109 ± 8	71 ± 5	11	$1.29^{+0.52}_{-0.38}$
$T > 7$	203	16.1 ± 1.1	10.4 ± 0.5	1	$0.80^{+1.84}_{-0.66}$
Sample C					
$T < 0$	4	0	0.4 ± 0.1	0.4 ± 0.08	≤ 40
$0 \leq T < 4$	15	1	8.4 ± 0.6	27.7 ± 2.6	$0.3^{+0.70}_{-0.25}$
$4 \leq T \leq 7$	41	10	40.5 ± 3.7	49.8 ± 4.4	$1.67^{+0.71}_{-0.52}$
$T > 7$	51	1	5.0 ± 0.4	5.0 ± 0.4	$1.68^{+3.9}_{-1.4}$

CC SN rate and specific SFR

	N_{gal}	N_{CC}	L_B ($10^{10} L_{B,\odot}$)	R_{CC} (SNu)
EW(Hα) ≤20	144	4	83.98	0.39 ± 0.2
20< EW(Hα) ≤ 30	68	2	17.35	0.96 ± 0.68
30< EW(Hα) ≤ 40	72	5	25.83	1.16 ± 0.72
40< EW(Hα) ≤ 50	37	1	8.25	1.01 ± 1
EW(Hα) > 50	65	2	14.06	1.2 ± 0.8

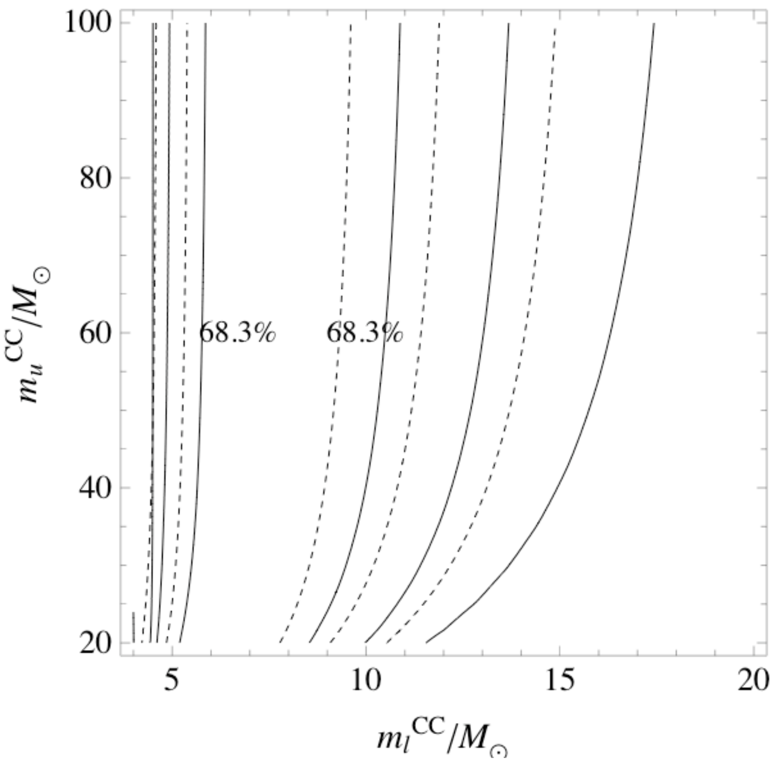


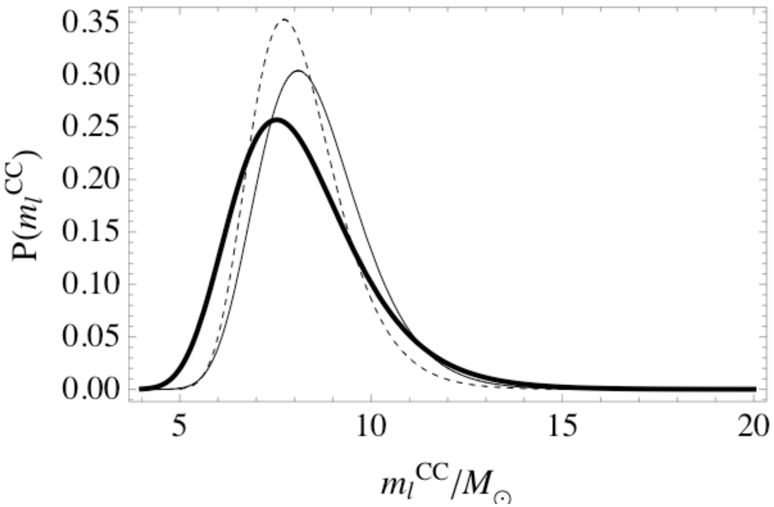


Minimum mass for CC SN progenitors

- SNe discovered in the last 12 years
- + SNe from past searches (1960-1997)
- CC SN rate within z < 0.01 as a prior

SFR ($M_\odot\,yr^{-1}$)	$m^{CC}_{l,12}$ ($M_\odot$)	$m^{CC}_{l,tot}$ ($M_\odot$)	$m^{CC}_{l,prior}$ ($M_\odot$)
Sample A			
90 ± 4	5.7 ± 1.1	5.9 ± 0.9	5.5 ± 0.8
Sample B			
142 ± 8	8.2 ± 1.7	8.5 ± 1.4	8.2 ± 1.2
Sample C			
54 ± 4	5.0 ±0.9	4.4 ± 0.4	5.1±0.7
86 ± 6	6.3 ± 1.4	6.2 ± 1.3	7.0 ± 1.1
56 ± 4	5.1 ±0.9	4.4 ± 0.6	5.2 ±0.8



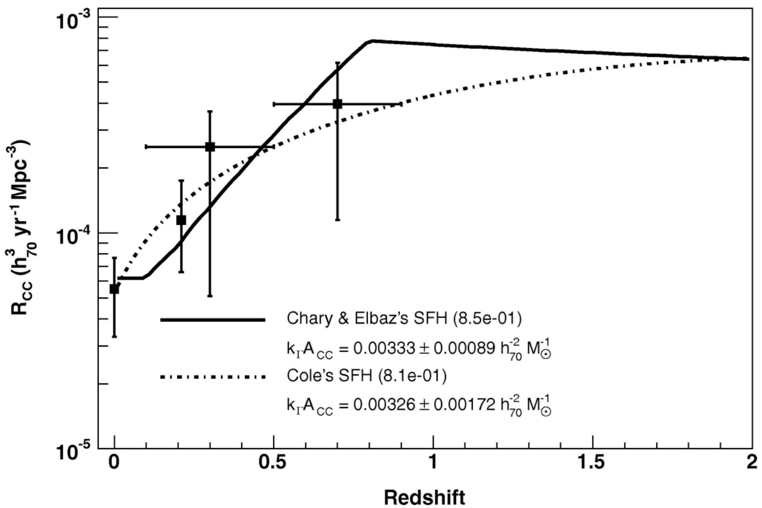


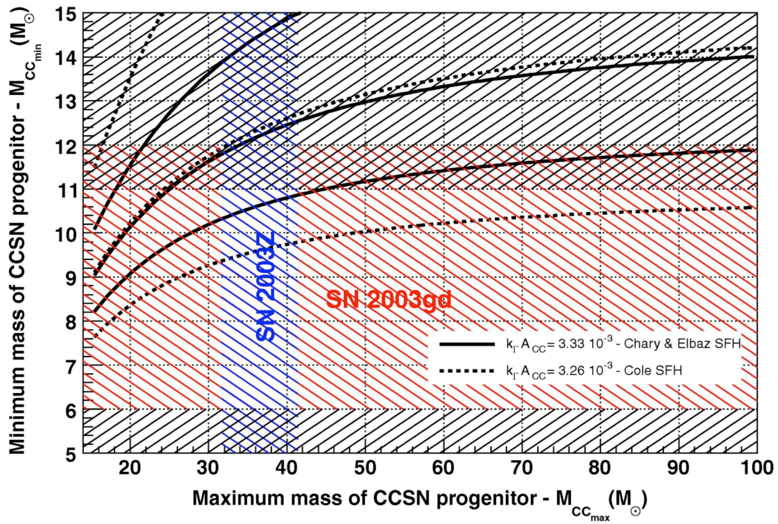
Comparison with other results

$m_l = 5 \pm 0.8\ M_\odot$ Kennicutt 1984
Hα lum for 88 Sc-SBc galaxies
CC SN rate of 1.4 ± 0.2 SNu in Sbc-Sc (Tammann 1982)
Salpeter IMF

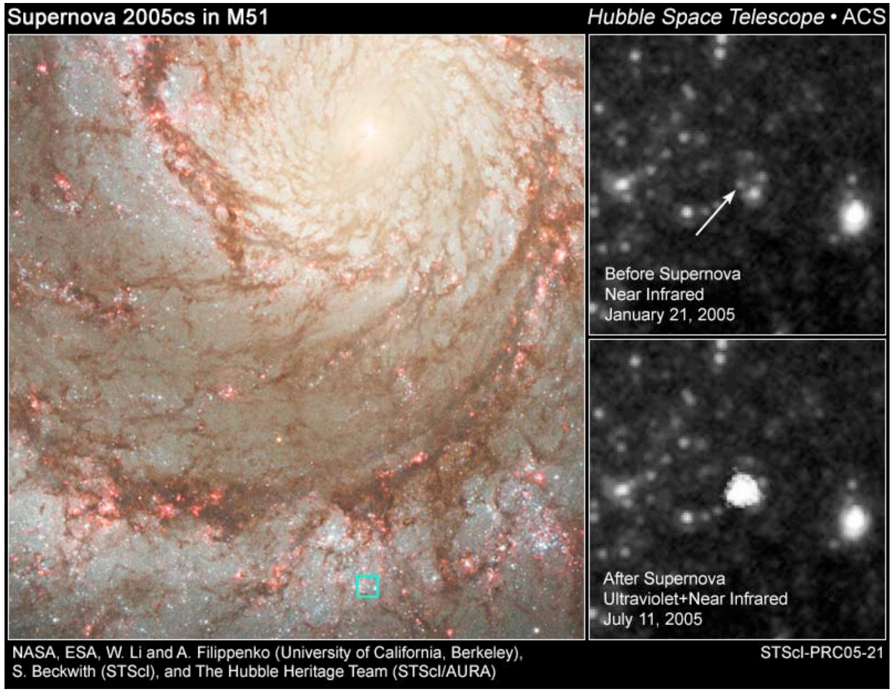
$8 < m_l < 10\ M_\odot$ Maoz et al 2010
LOSS SN+SDSS spectra

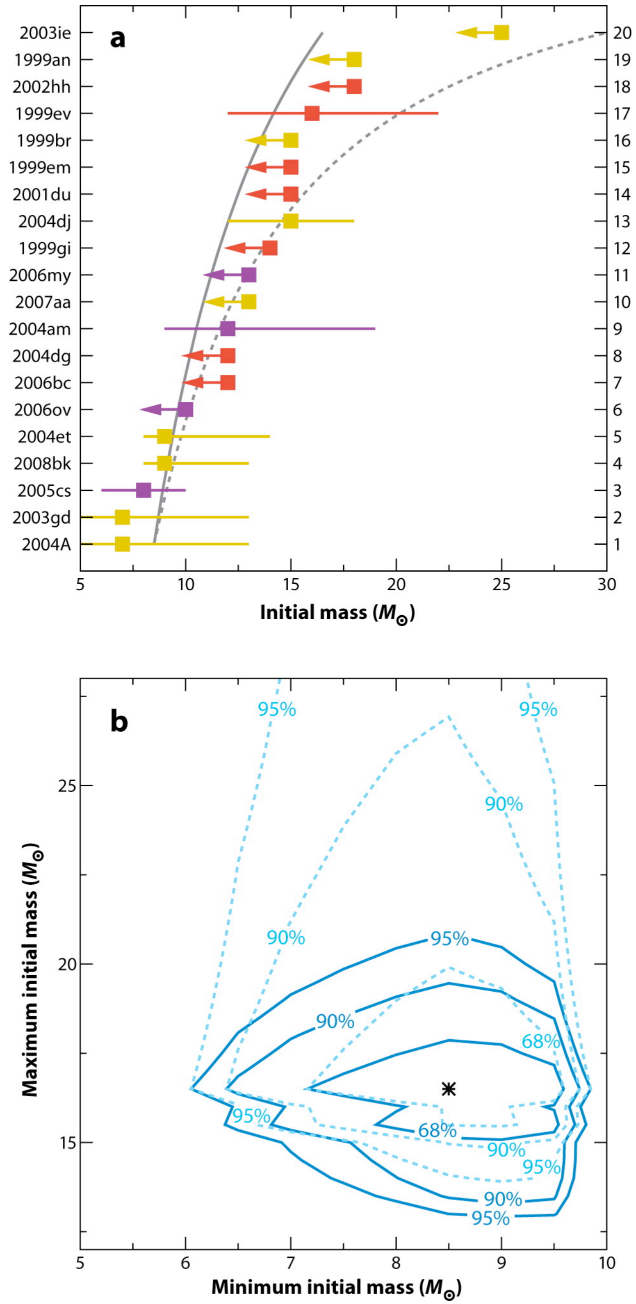
$m_l > 10\ M_\odot$ Blanc & Greggio 2008





Comparison with other results





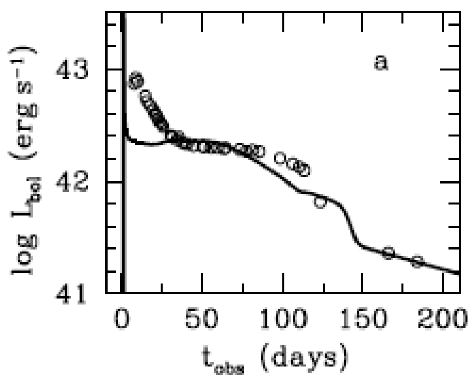
Smartt SJ. 2009.
Annu. Rev. Astron. Astrophys. 47:63–106

20 type IIP SNe and Salpeter IMF

$m_l = 8.5 +1-2\ M_\odot$

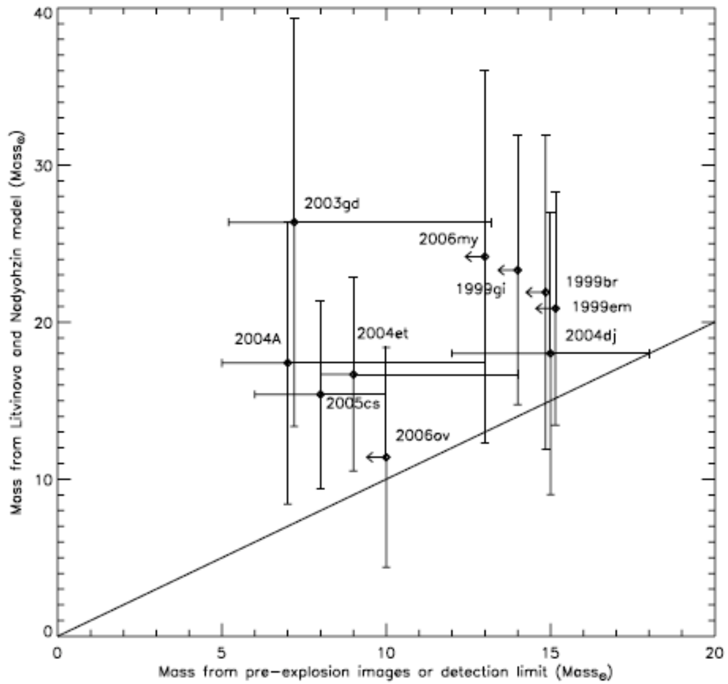
(Smartt et al. 2009)

Hydrodynamic modeling



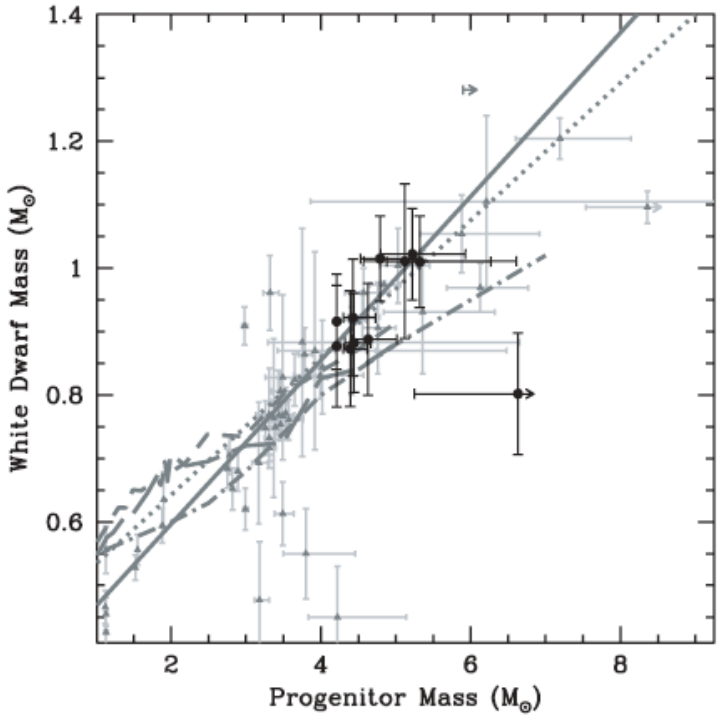
Utrobin & Chugai 2009

15-30 $M_{\odot}$

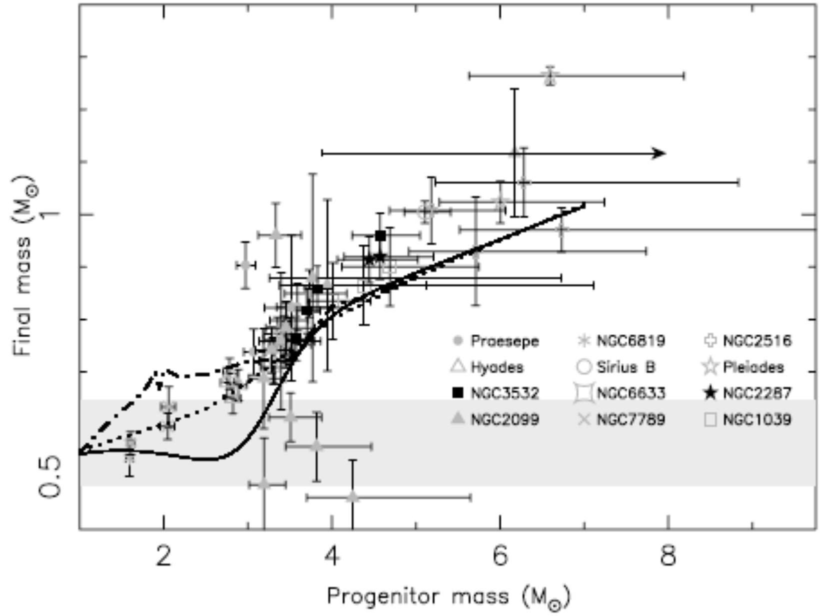


Maguire et al 2010

Maximum mass of WDs



Williams et al 2009



Dobbie et al 2009

WD Sample	Carbon/Oxygen				Oxygen/Neon			
	50% ($M_\odot$)	90% ($M_\odot$)	95% ($M_\odot$)	99% ($M_\odot$)	50% ($M_\odot$)	90% ($M_\odot$)	95% ($M_\odot$)	99% ($M_\odot$)
M35 alone	6.57	5.40	5.19	4.89	6.48	5.34	5.14	4.86
All Clusters	8.86	7.41	7.08	6.51	8.39	6.95	6.70	6.34
All Clusters, "Cleaned"	7.97	6.58	6.25	5.77	7.80	6.54	6.30	5.91

Conclusions

SFR based on L(Hα) can not reproduce the CC SN rate within 11 Mpc

independent of the extinction correction recipe

$m_l = 5.7 \pm 1\ M_{\odot}$ from SFR(Hα)

$m_l = 8.2 \pm 1.2\ M_{\odot}$ from SFR(UV)

in good agreement with estimate from the direct detection of SN progenitors