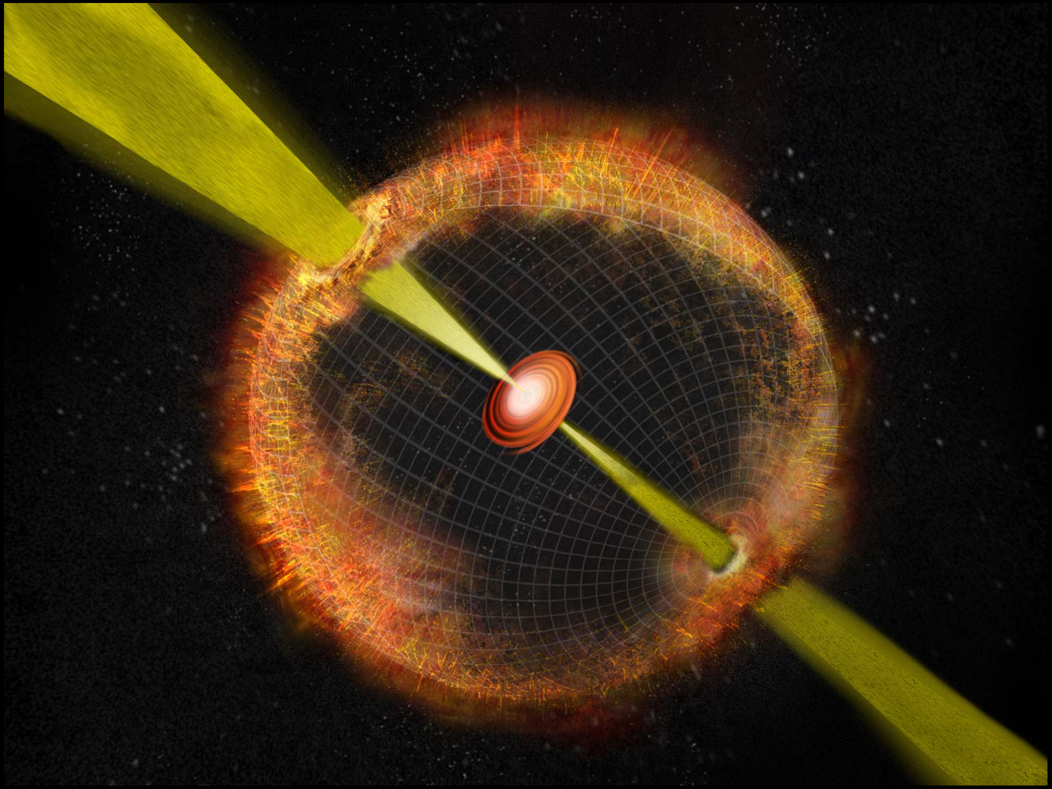
Supernovae shed light on GRBs

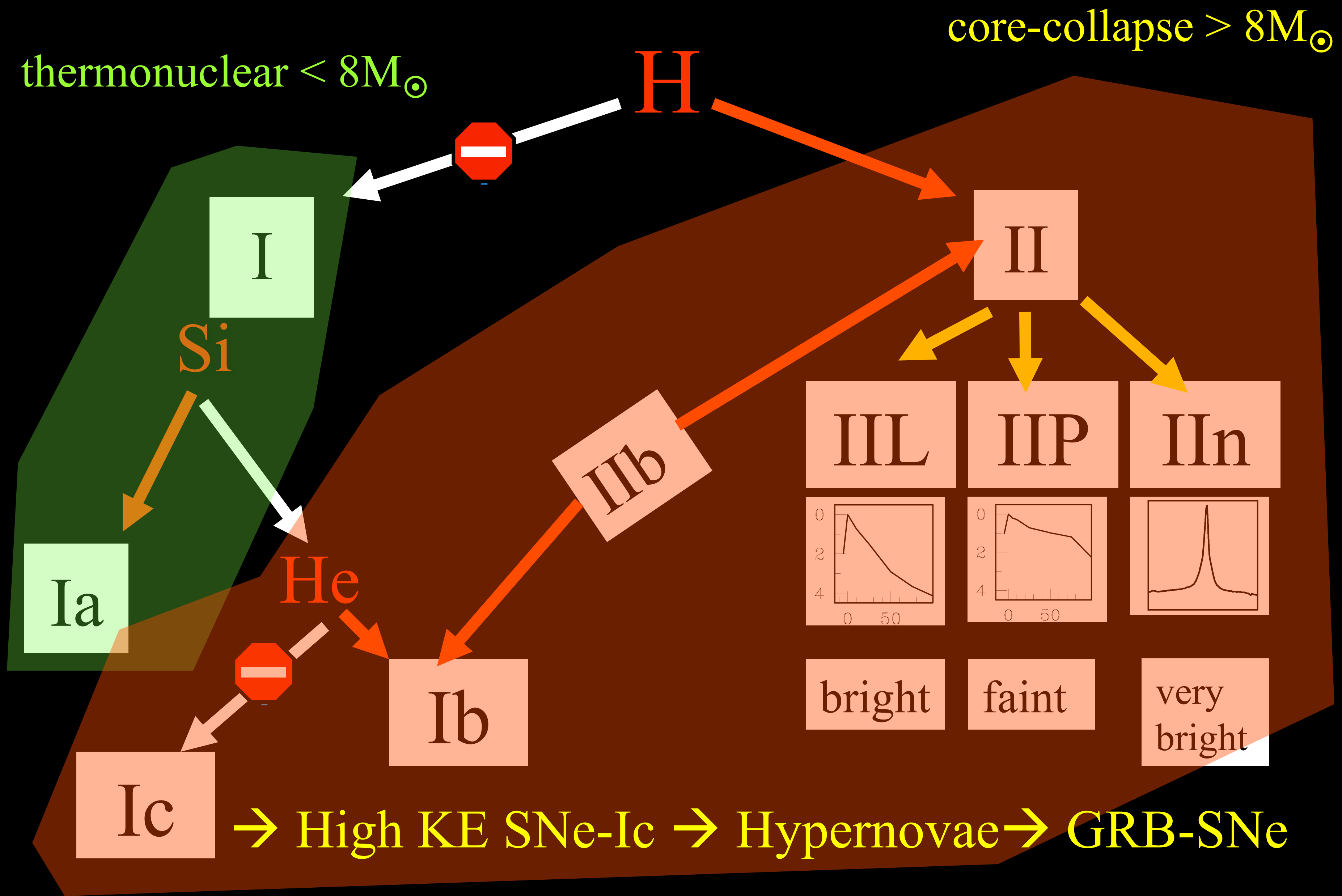


M. Della Valle *(Capodimonte Obs. INAF-Napoli & ICRANet-Pescara)*

Summary

- Supernova Taxonomy
- GRB-SN properties
- GRB and SN rates
- Conclusions

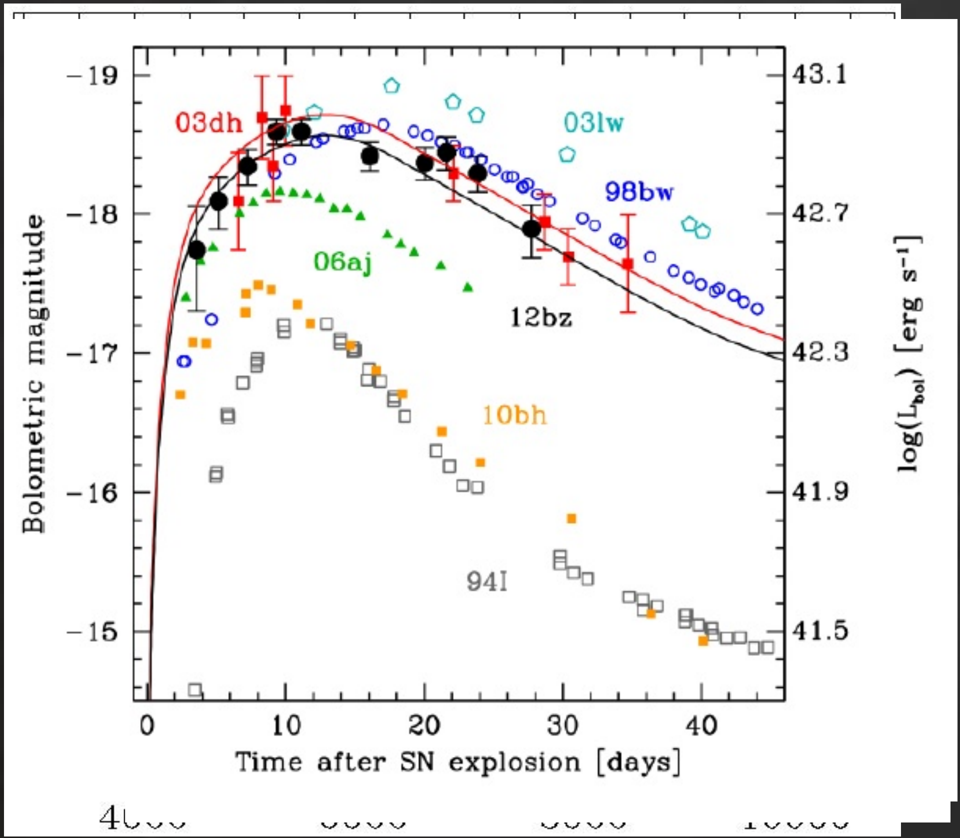
1. Supernova taxonomy



2. SNe & GRBs at z < 0.2

GRB	SN	z	Ref.
GRB 980425	SN 1998bw	0.0085	Galama et al. 1998
GRB 060218	SN 2006aj	0.033	Campana et al. 2006 Pian et al. 2006
GRB 080109	SN 2008D	0.007	Soderberg et al. 2008 Mazzali et al. 2008
GRB 100316D	SN 2010bh	0.06	Bufano et al. 2012 Chornock et al. 2010 Cano et al. 2011 Margutti et al. 2013
GRB 030323	SN 2003dh	0.16	Hjorth et al. 2003 Stanek et al. 2003
GRB 031203	SN 2003lw	0.11	Malesani et al. 2004
GRB 130702A	SN 2013dx	0.15	D'Elia et al. 2014

Properties of GRB-SNe (broad-lined SNe-Ic)



Lack of H and He in the ejecta: SNe-Ic(b)

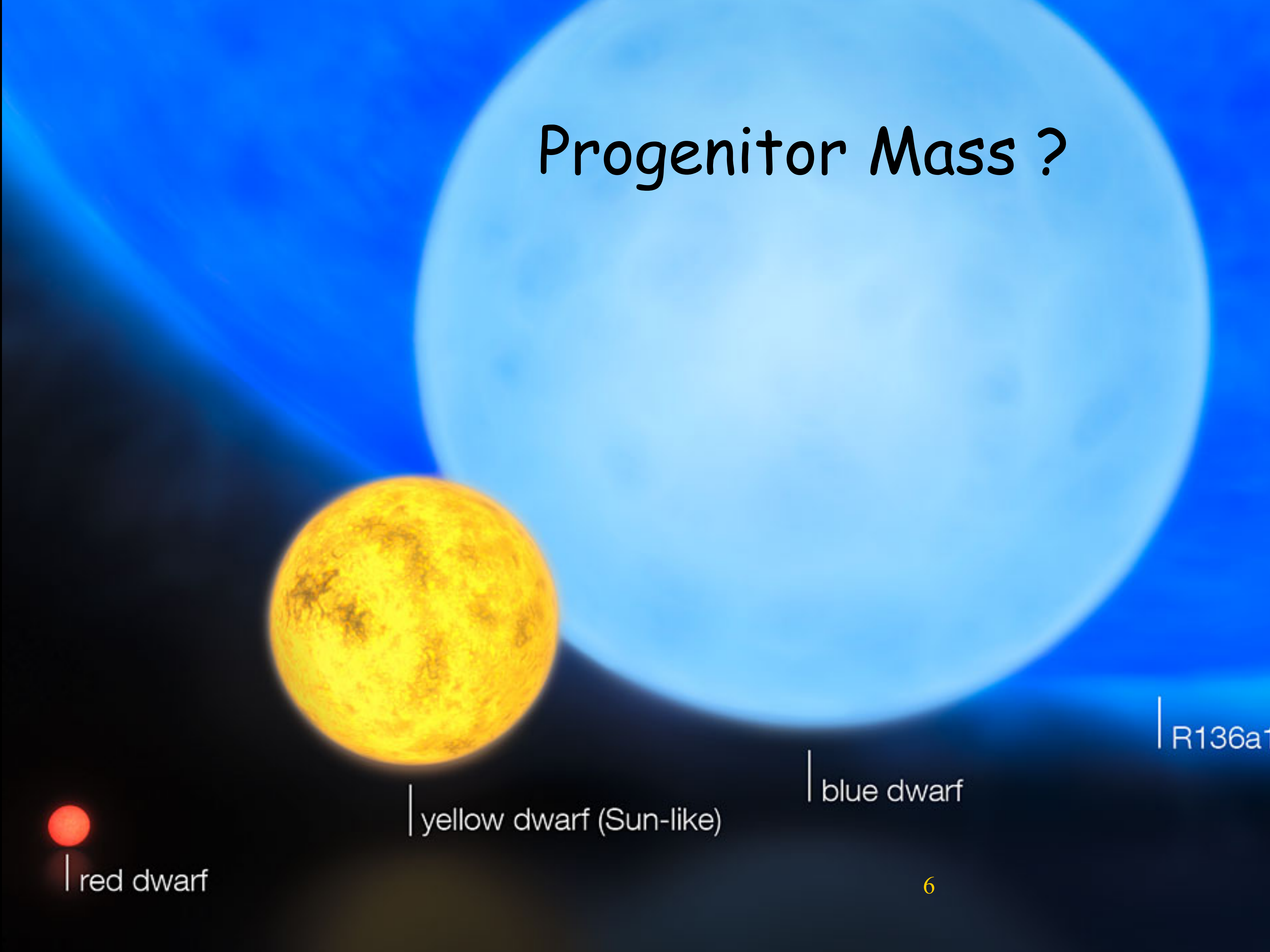
Very broad features: large expansion velocity (0.1c)

Kinetic energy (non-relativistic ejecta) ~ 10^{52} erg ≳ 10 larger than Usual CC-SNe

Range of luminosity: in some case large ^{56}Ni mass (~ 0.5±0.2 $M_{\odot}$)

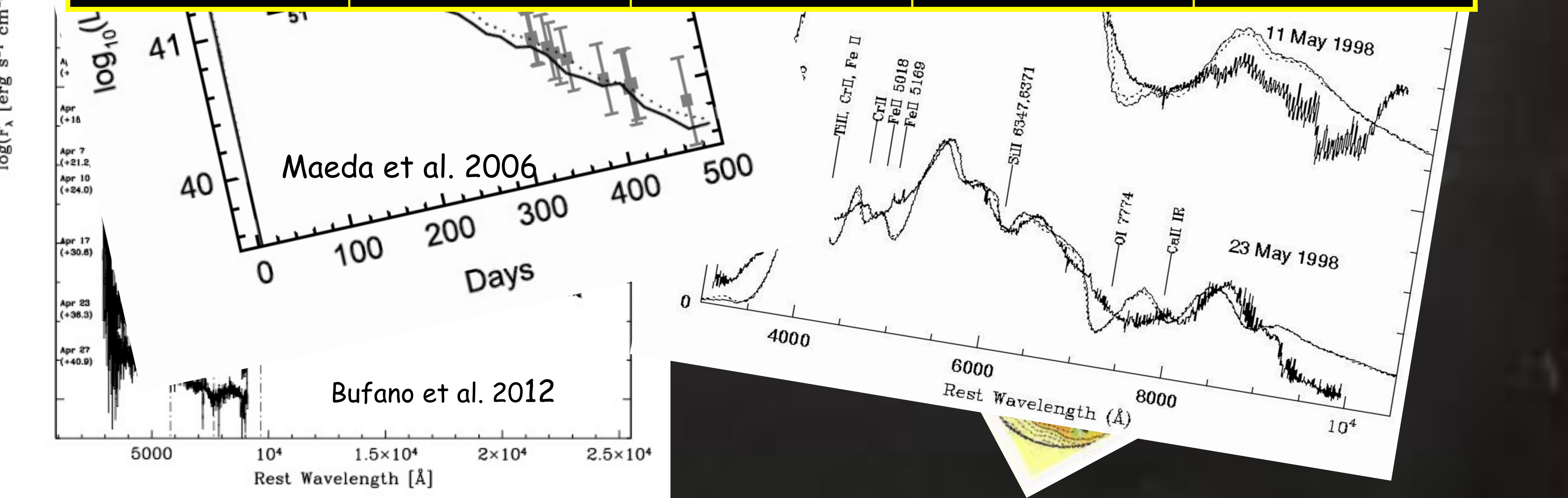
Explosions are aspherical (profiles of nebular lines O vs. Fe and Polarization)

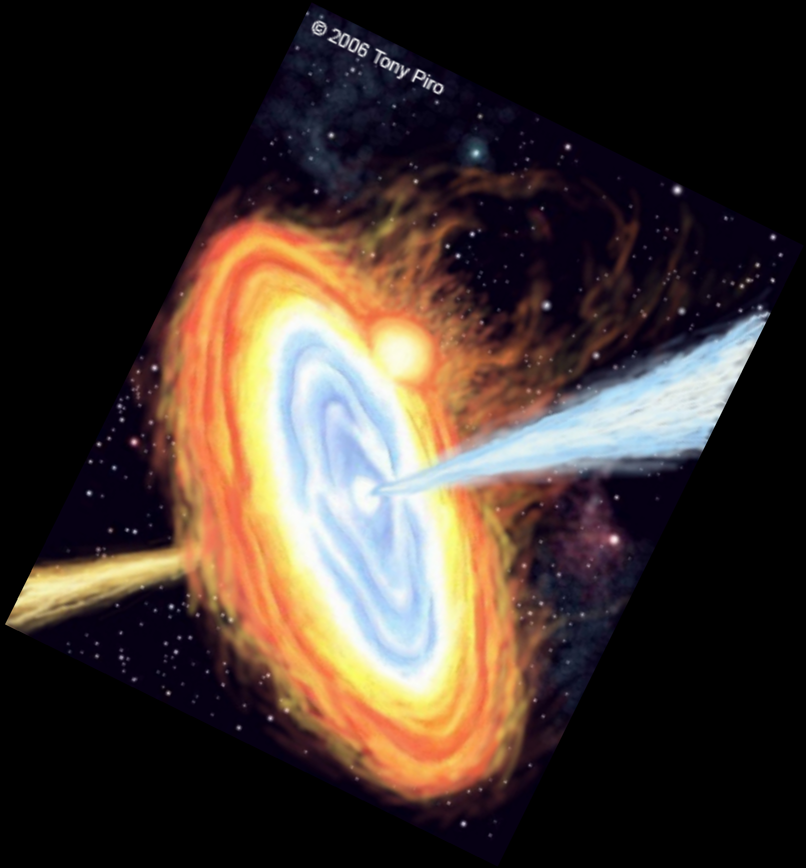
Progenitor Mass ?



Modeling lightcurves and spectra

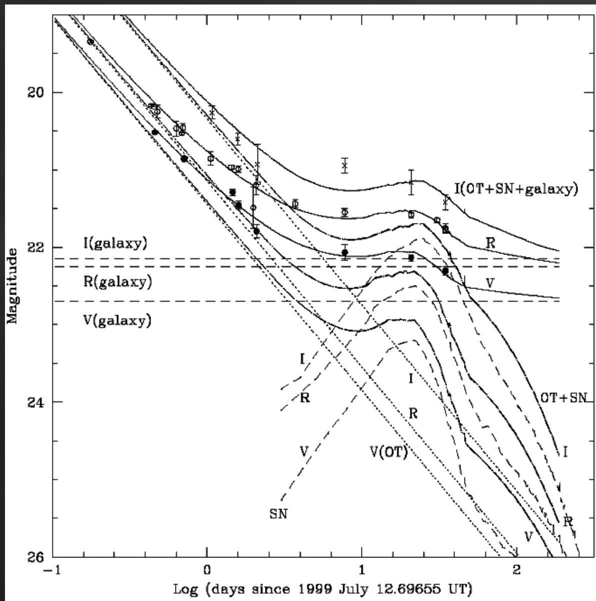
1998bw 40 $M_\odot$	2003dh 35-40 $M_\odot$	2003lw 40-50 $M_\odot$	2006aj 20-25 $M_\odot$	2008D 20-30 $M_\odot$
Maeda et al. 2006	**Mazzali et al. 2003**	**Mazzali et al. 2006**	**Mazzali et al. 2006**	**Tanaka et al. 2008**



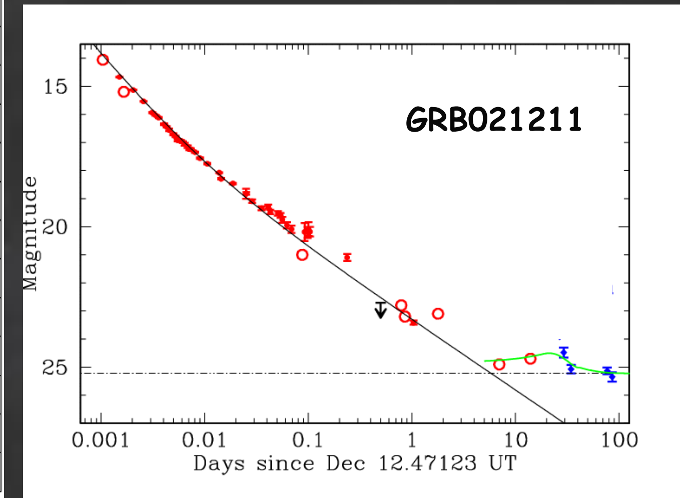


Distant GRB/SNe ?

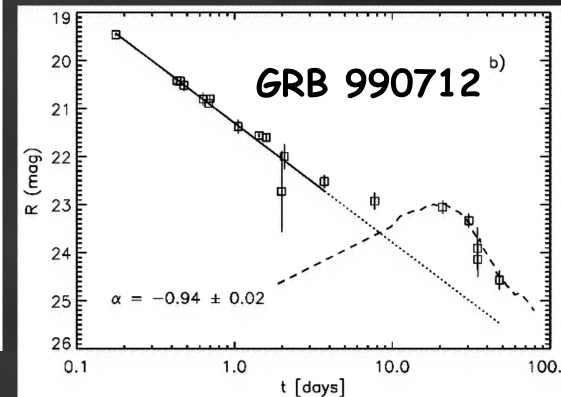
up to z ~ 1



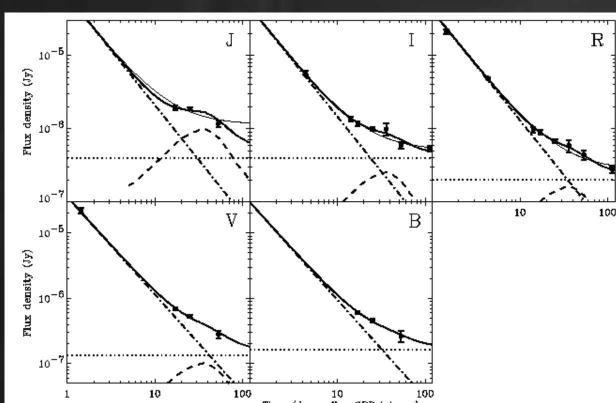
Sahu et al. 2000



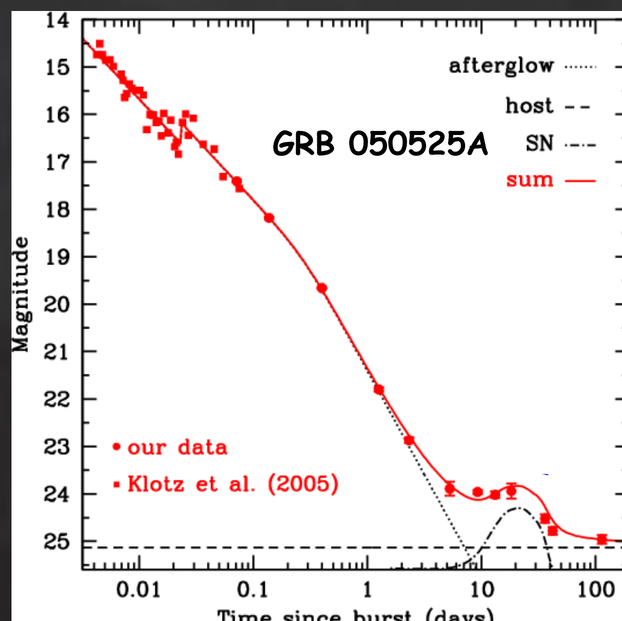
Della Valle et al. 2003



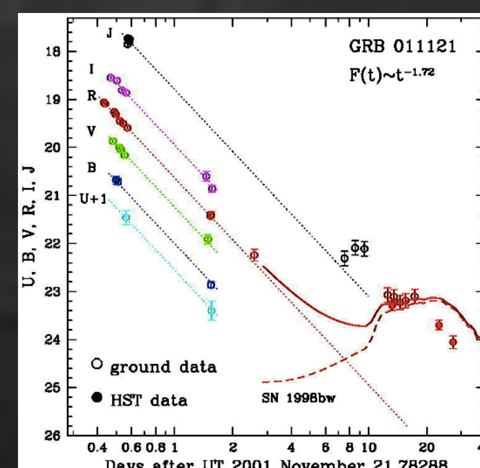
Bjornsson et al. 2001



Lazzati et al. 2005



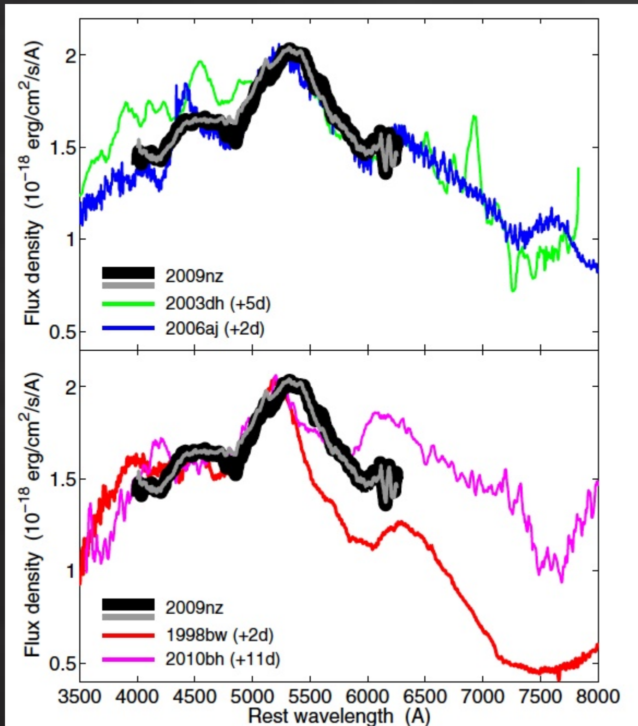
Della Valle et al. 2006



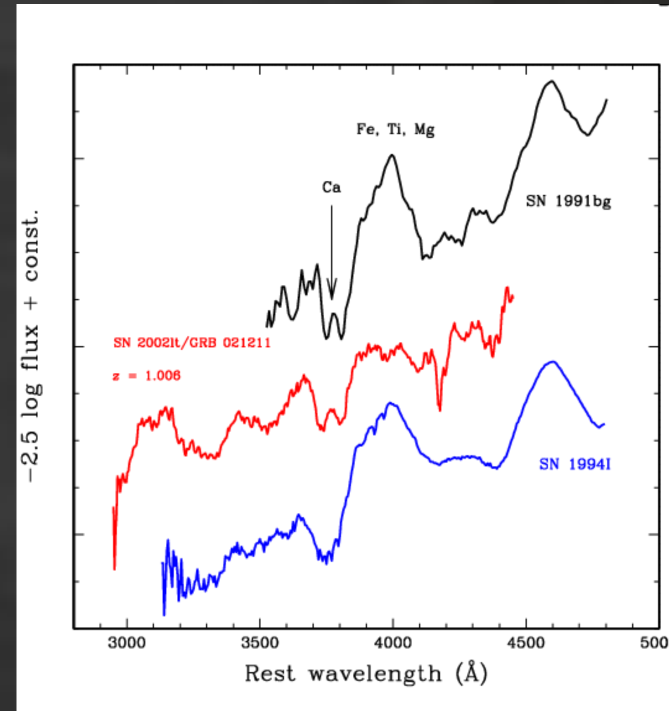
Garnavich et al. 2003

GRB census > 0.2

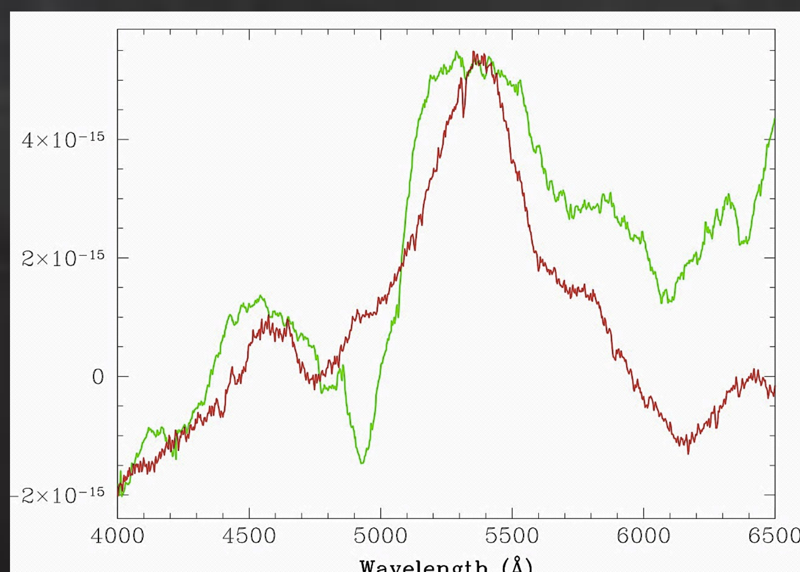
GRB	SN	z	Ref.
GRB 021202	SN 2002lt	1.002	Della Valle et al. 2003
GRB 050525A	SN 2005nc	0.606	Della Valle et al. 2006
GRB 101219B	SN 2010ma	0.55	Sparre et al. 2011
GRB 060729	SN no name	0.54	Cano et al. 2011
GRB 090618	SN no name	0.54	Cano et al. 2011
GRB 081007	SN 2008hw	0.53	Della Valle et al. 2008 Zhi-ping et al. 2008
GRB 091127	SN 2009nz	0.49	Cobb et al. 2010 Berger et al. 2011
GRB120714B	SN 2012eb	0.40	Klose et al. 2012
GRB 130427A	SN 2013cq	0.34	Melandri et al. 2014 Xu et al. 2013
GRB 120422A	SN 2012bz	0.28	Melandri et al. 2012



Berger et al. 2011
SN 2009nz @ z=0.49

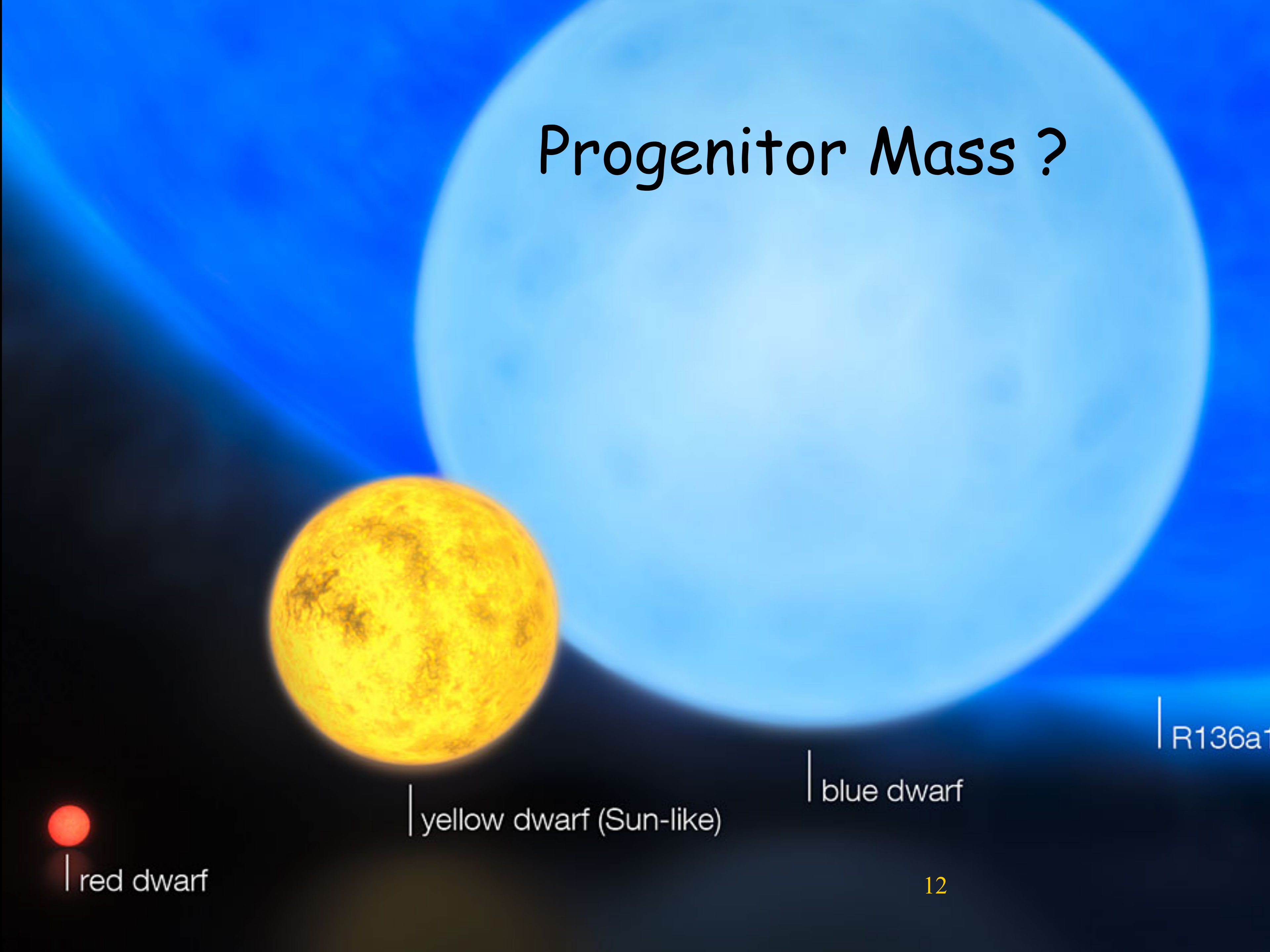


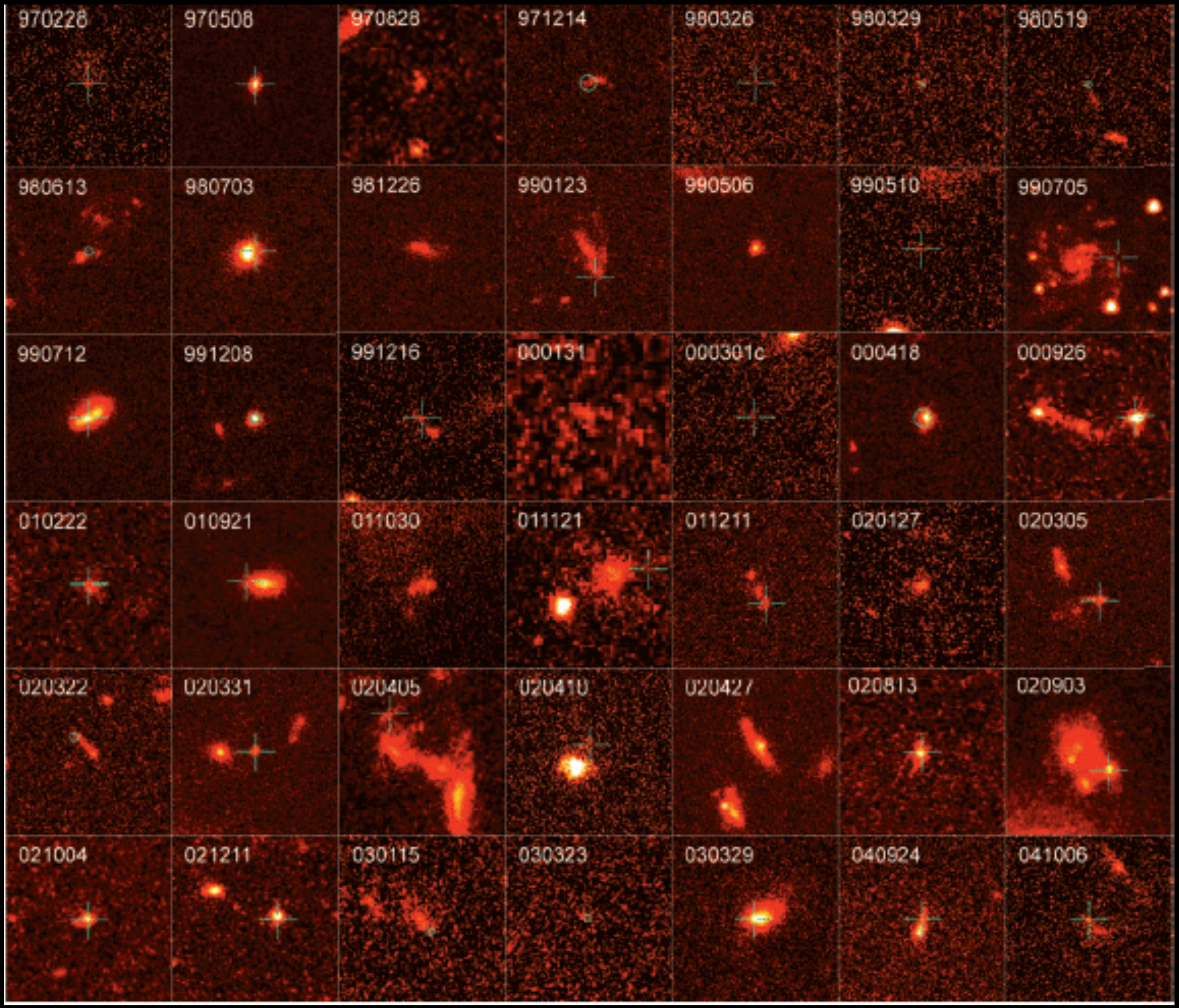
DV et al. 2013
SN 2002lt @ z=1



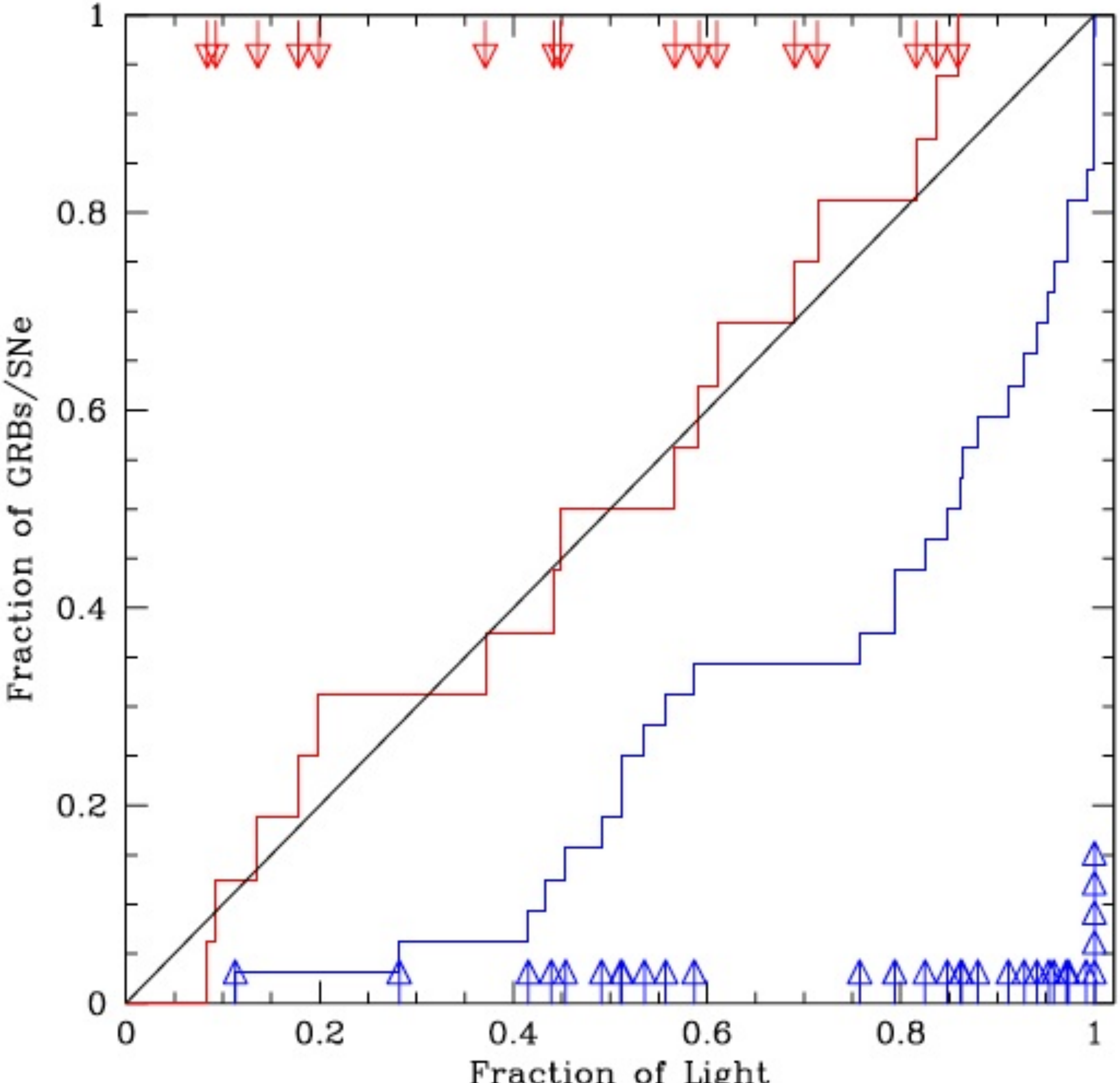
Zhi-Ping et al. 2013
SN 2008hw @ z=0.53

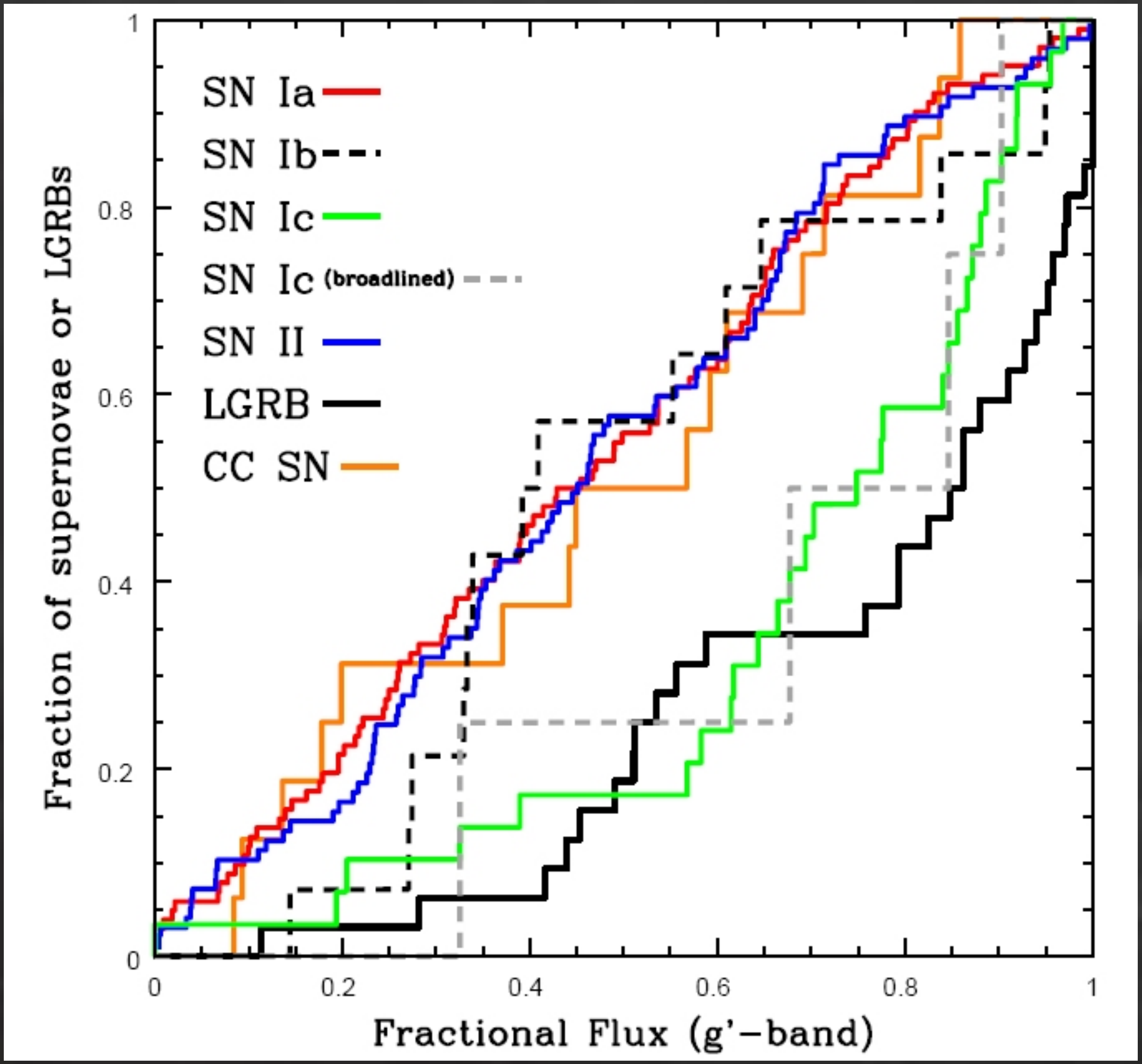
Progenitor Mass ?



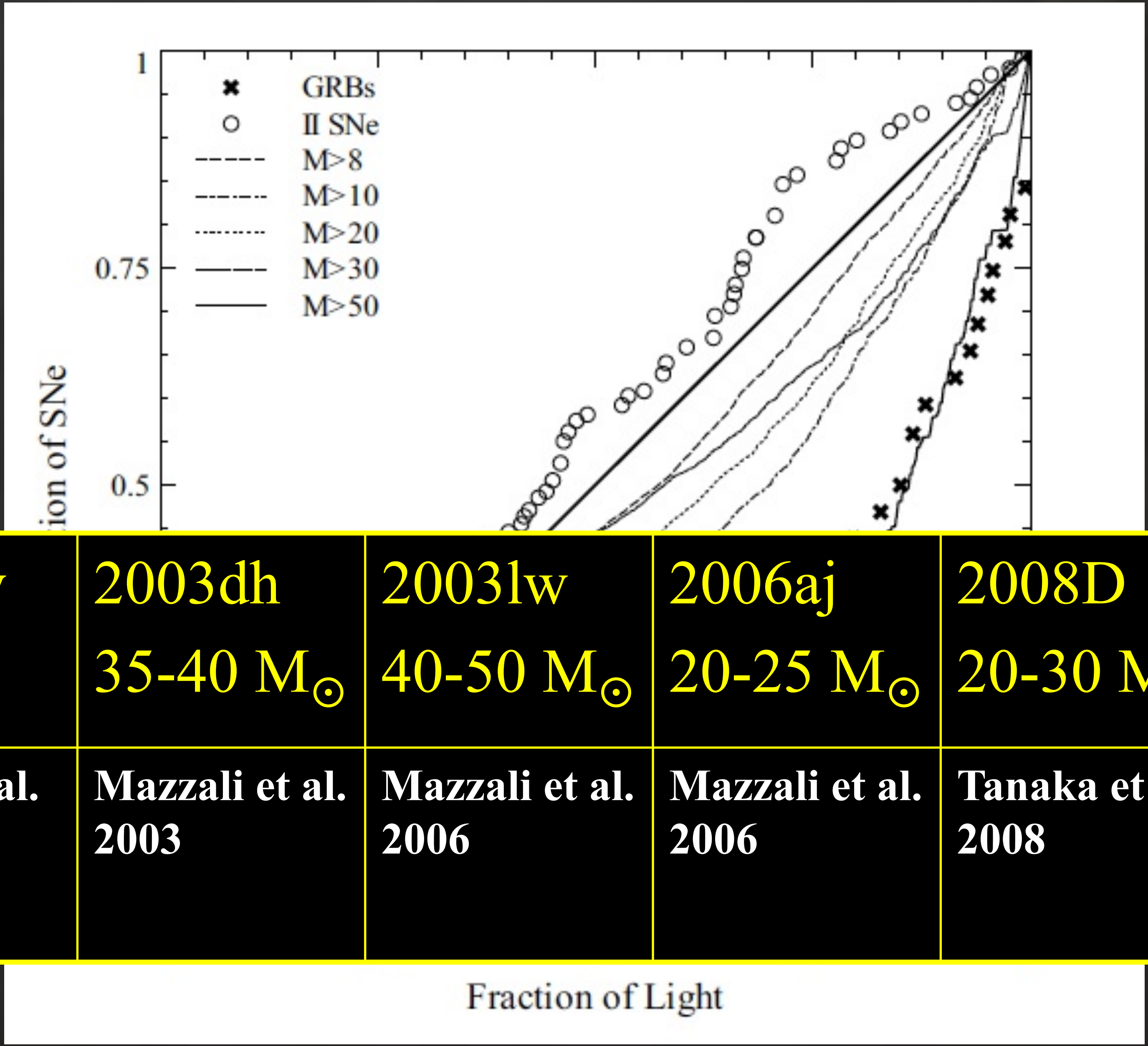


Fruchter et al. 2006


Fraction of GRBs/SNe
Fraction of Light
0
0.2
0.4
0.6
0.8
1



Kelly et al. 2008 find that local SNe-Ic erupt in the brightest regions of their hosts (like GRBs, see Fruchter et al. 2006)



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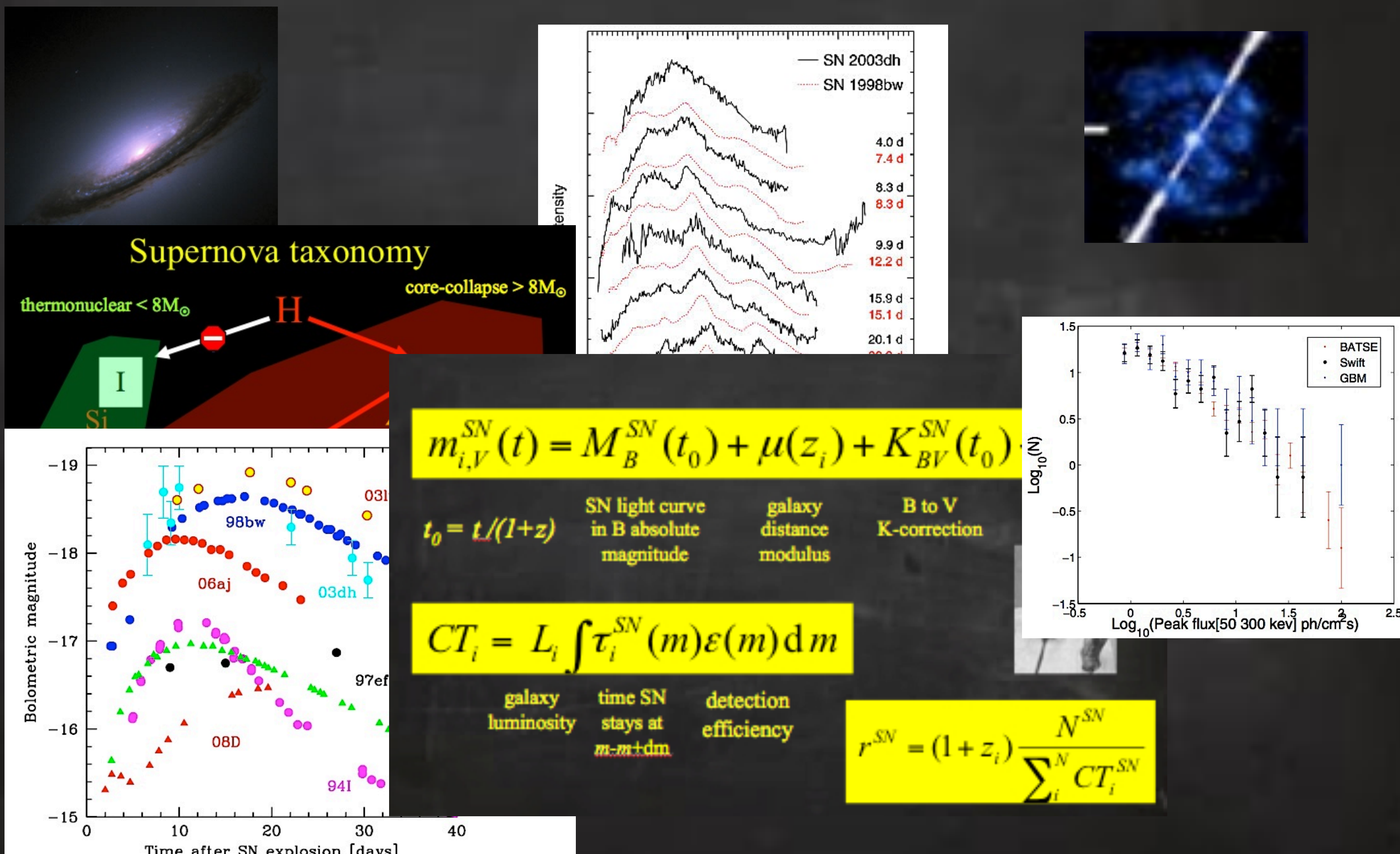
Maeda et al. 2006	**Mazzali et al. 2003**	**Mazzali et al. 2006**	**Mazzali et al. 2006**	**Tanaka et al. 2008**

Long-GRBs have ~ 40 $M_\odot$ Raskin et al. 2008

3. Ingredients for a "healthy" SN and GRB rates



Cooking GRB and SN rates

Main Courses

- Fraction of SNe-Ib/c which produces (long)GRBs

Main Courses

- Fraction of SNe-Ib/c which produces (long)GRBs
- *HL*-GRB vs *LL*-GRB rates

Main Courses

- Fraction of SNe-Ib/c which produces (long)GRBs
- *HL*-GRB vs *LL*-GRB rates
- Fraction of SNe-Ib/c which produces HNe

What is the rate of SNe-Ib/c ?

Asiago Survey (Cappellaro et al. 1999)

galaxy type	N. SNe*			rate [SNu]		
	Ia	Ib/c	II	Ia	Ib/c	II
E-S0	22.0			0.18 ± 0.06	< 0.01	< 0.02
S0a-Sb	18.5	5.5	16.0	0.18 ± 0.07	0.11 ± 0.06	0.42 ± 0.19
Sbc-Sd	22.4	7.1	31.5	0.21 ± 0.08	0.14 ± 0.07	0.86 ± 0.35
Others#	6.8	2.2	5.0	0.40 ± 0.16	0.22 ± 0.16	0.65 ± 0.39
All	69.6	14.9	52.5	0.20 ± 0.06	0.08 ± 0.04	0.40 ± 0.19

Rate for Ib/c: 0.152 ± 0.064 SNu

Guetta & DV 2007

1.8×10^4 SNe-Ibc $Gpc^{-3}\,yr^{-1}$ → **1.1×10^4 up to 2.6×10^4**

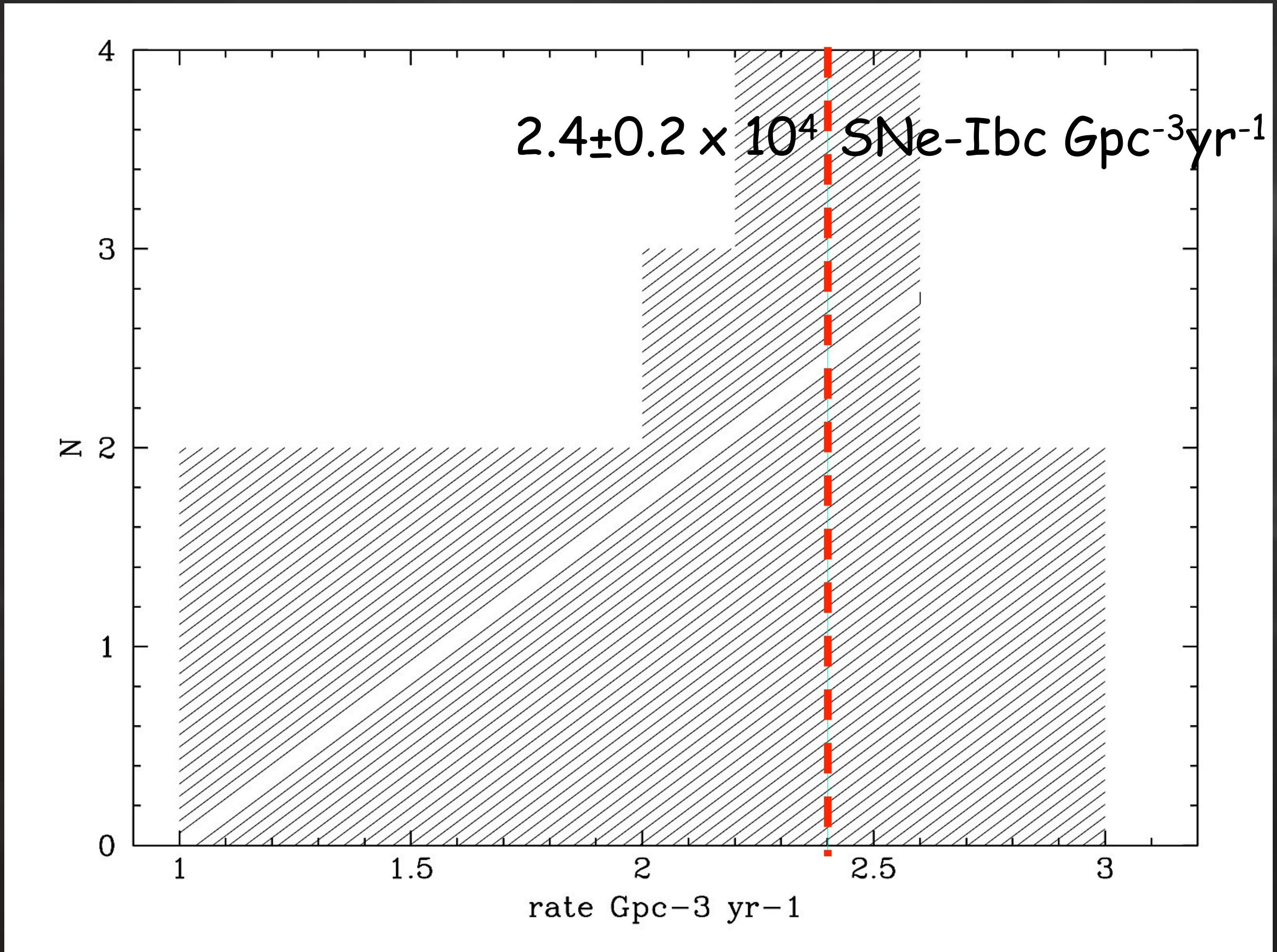
What is the rate of SNe-Ib/c ?

Lick Survey (Li et al. 2011)

Rate	SN Ia	SN Ibc	SN II
Early(fiducial; SNuK)	$0.064^{+0.008}_{-0.007}(^{+0.013}_{-0.013})$	$0.008^{+0.006}_{-0.004}(^{+0.002}_{-0.002})$	$0.004^{+0.003}_{-0.002}(^{+0.001}_{-0.001})$
Late(fiducial; SNuK)	$0.074^{+0.006}_{-0.006}(^{+0.012}_{-0.012})$	$0.096^{+0.010}_{-0.009}(^{+0.018}_{-0.018})$	$0.172^{+0.011}_{-0.011}(^{+0.045}_{-0.036})$
Early(LF-average; SNuK)	$0.048^{+0.006}_{-0.005}(^{+0.010}_{-0.010})$	$0.006^{+0.004}_{-0.003}(^{+0.002}_{-0.002})$	$0.003^{+0.002}_{-0.001}(^{+0.001}_{-0.001})$
Late(LF-average; SNuK)	$0.065^{+0.006}_{-0.005}(^{+0.010}_{-0.010})$	$0.083^{+0.009}_{-0.008}(^{+0.016}_{-0.016})$	$0.149^{+0.010}_{-0.009}(^{+0.039}_{-0.031})$
Vol-rate (10^{-4} SN Mpc^{-3} yr^{-1})	$0.301^{+0.038}_{-0.037}(^{+0.049}_{-0.049})$	$0.258^{+0.044}_{-0.042}(^{+0.058}_{-0.058})$	$0.447^{+0.068}_{-0.068}(^{+0.131}_{-0.111})$

Rate for Ib/c: 2.6×10^4 SNe-Ibc Gpc^{-3} yr^{-1}

2.2×10^4 → 3×10^4 SNe-Ibc Gpc^{-3} yr^{-1}

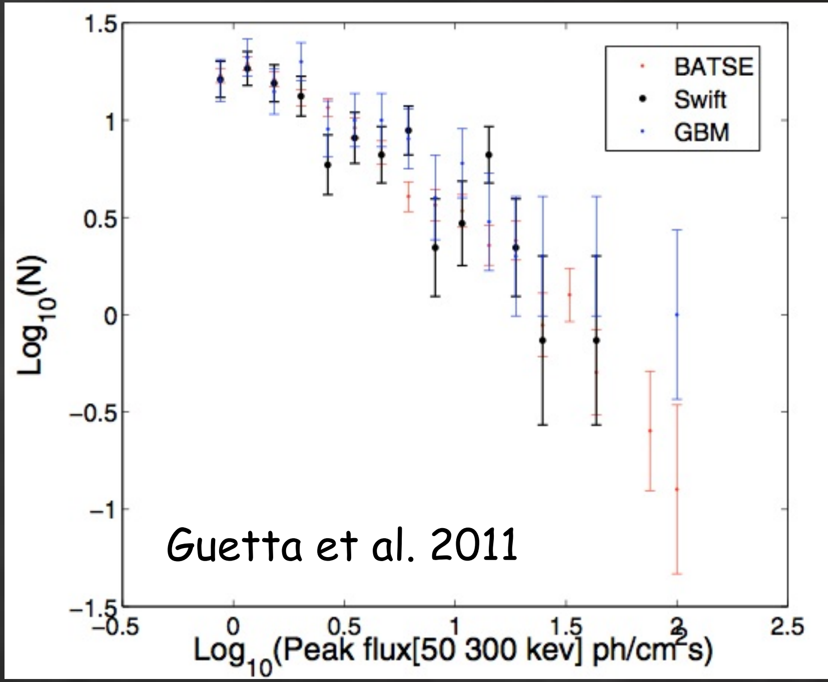


2.4±0.2 x 10^4 SNe-Ibc Gpc^-3yr^-1
N
0
1
2
3
4
1
1.5
2
2.5
3
rate Gpc−3 yr−1

What is the rate of (long) GRBs ?

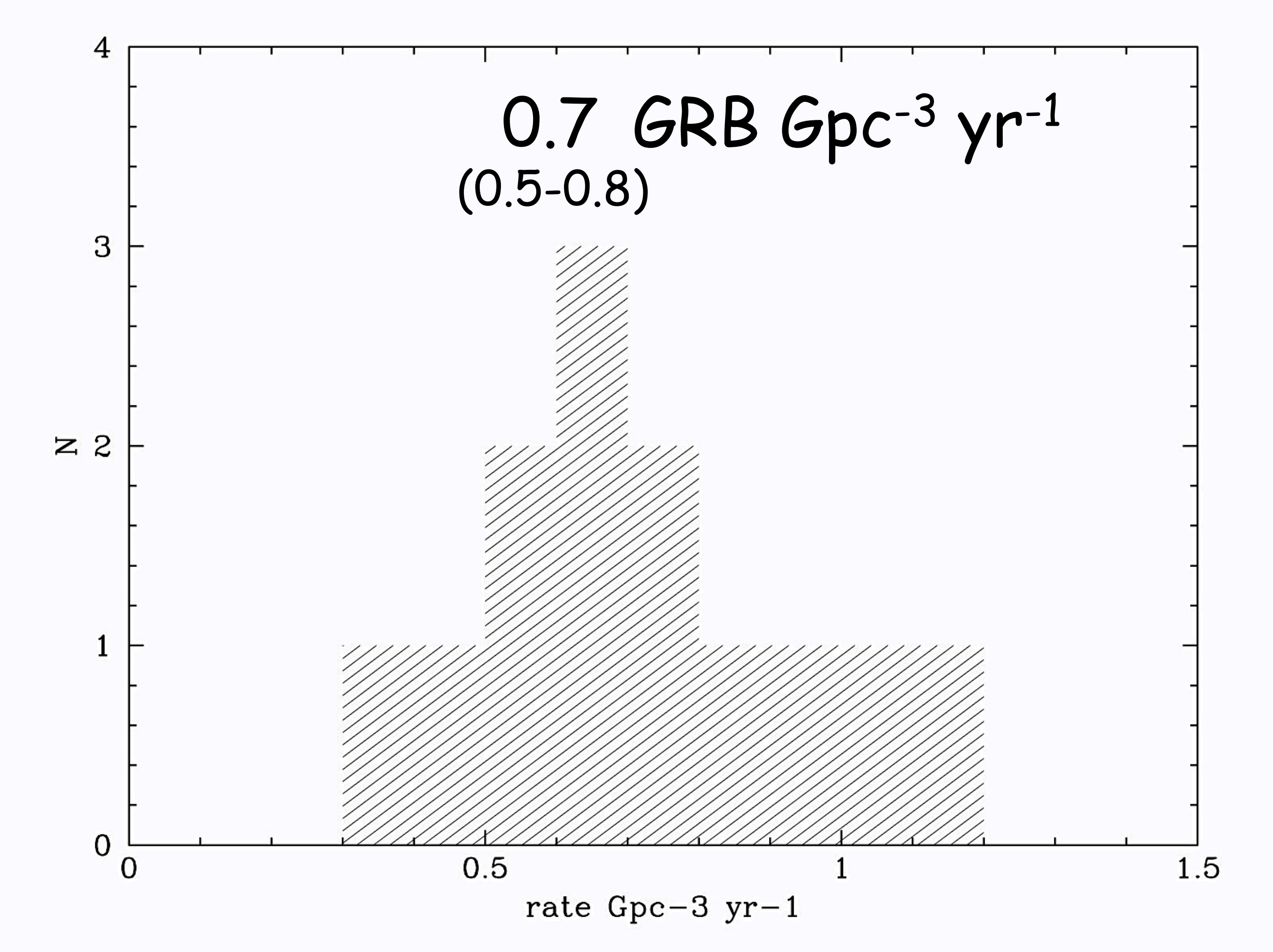
GRB Gpc^{-3} yr^{-1}

1.5	Schmidt 1999
0.15	Schmidt 2001
0.5	Guetta et al. 2005
1.1	Guetta & DV 2007
1.1	Liang et al. 2007
> 0.5	Pelangeon et al. 2008
1.3	Wanderman and Piran



Sample	Rate ($z = 0$)[1] Gpc^{-3} yr^{-1}	L^* [50–300] keV 10^{51} erg/s	a_1	a_2	χ^2/d.o.f.[3]
GBM	$0.5^{+0.3}_{-0.2}$	$5.5^{+1.5}_{-2}$	$0.3^{+0.1}_{-0.5}$	$2.3^{+0.6}_{-0.3}$	1.1
BATSE	$1.0^{+0.2}_{-0.4}$	$4^{+2}_{-1.5}$	$0.1^{+0.3}_{-0.1}$	$2.6^{+0.9}_{-0.5}$	1.1
Swift	$0.6^{+0.3}_{-0.1}$	$3.3^{+2.5}_{-0.5}$	$0.1^{+0.3}_{-0.1}$	$2.7^{+1}_{-0.4}$	0.95

What is the local rate of (long) GRBs ?



What is the fraction of SNe-Ib/c which produces (long)GRBs ?

Rate for Ibc: 2.4×10^4 SNe-Ibc $Gpc^{-3}\ yr^{-1}$

GRB rate: 0.7 GRB $Gpc^{-3}\ yr^{-1}$

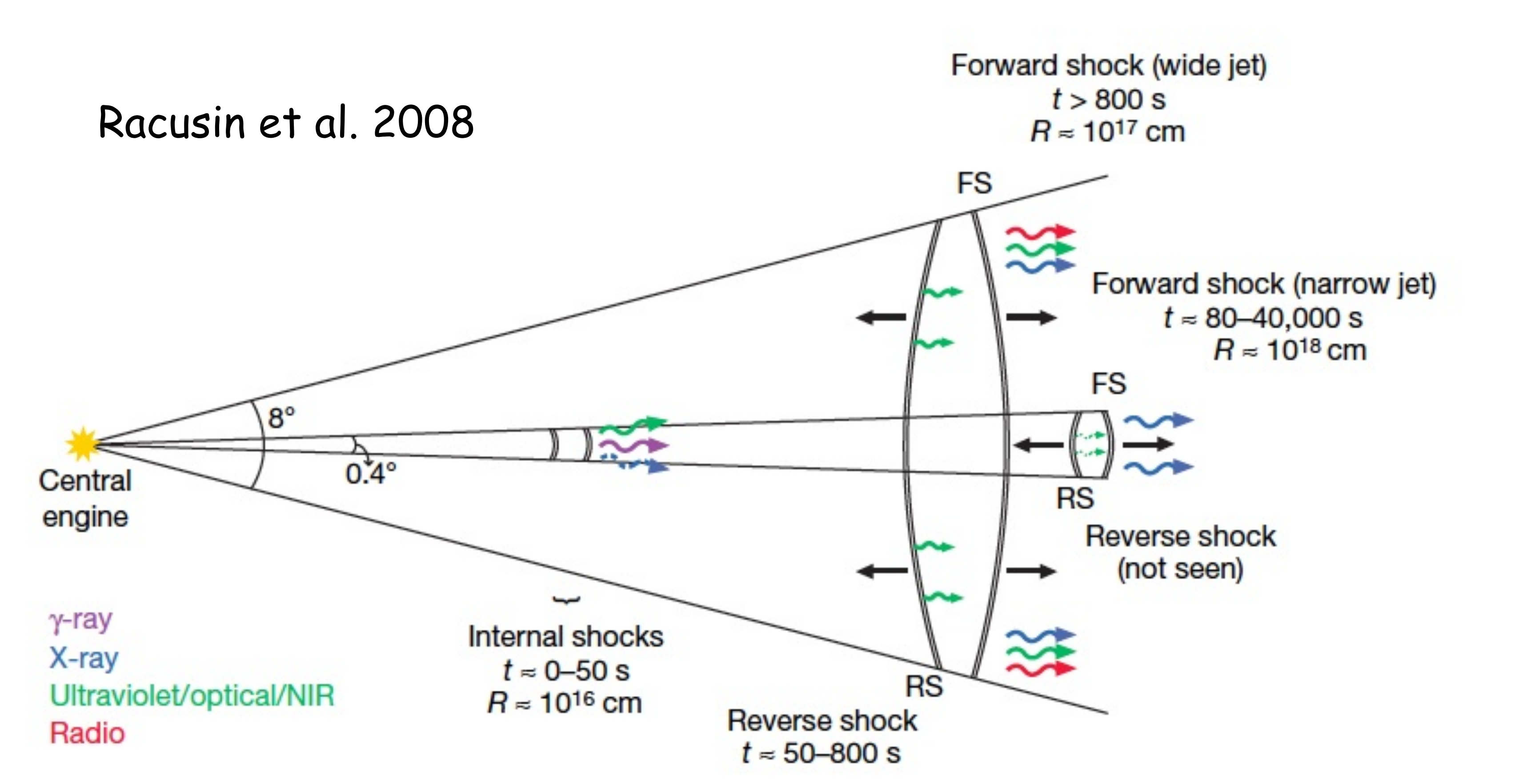
What is the fraction of SNe-Ib/c which produces (long)GRBs ?

Rate for Ibc: 2.4×10^{4} SNe-Ibc $Gpc^{-3}\,yr^{-1}$

GRB rate: 0.7 GRB $Gpc^{-3}\,yr^{-1}$

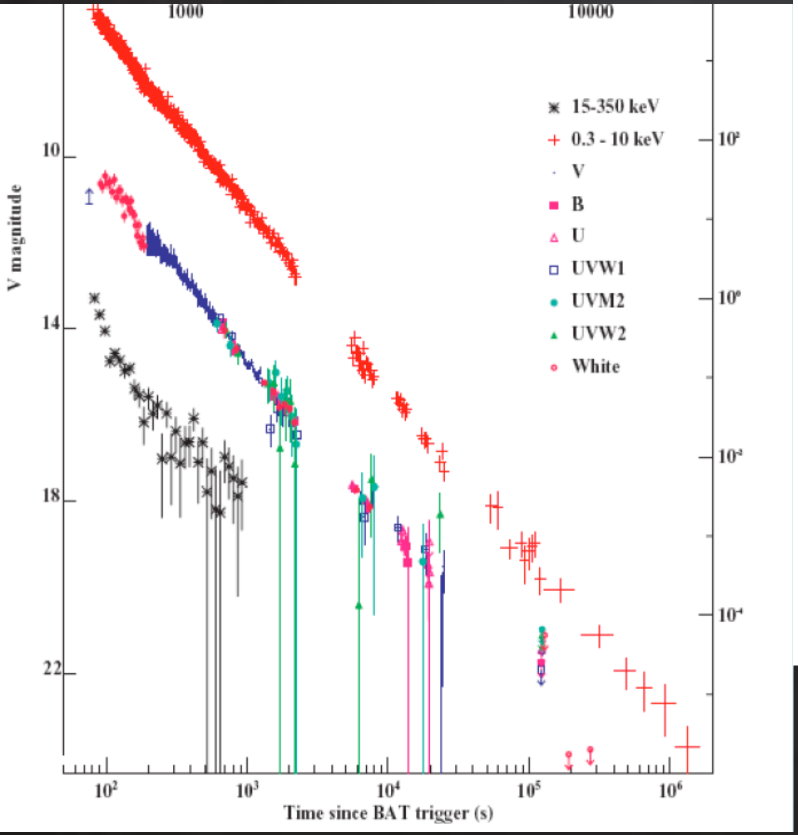
$\langle f_b^{-1} \rangle \sim 500$	(Frail et al. 2001)	($\vartheta \sim 4°$)
$\langle f_b^{-1} \rangle \sim 75$	(Guetta, Piran & Waxman 2004)	($\vartheta \sim 9°$)
$\langle f_b^{-1} \rangle < 10$	(Guetta & DellaValle 2007)	($\vartheta > 25°$) for sub-lum GRBs
$\langle f_b^{-1} \rangle \sim 1$	(Ruffini et al. 2006)	($\vartheta \sim 4\,\pi$)

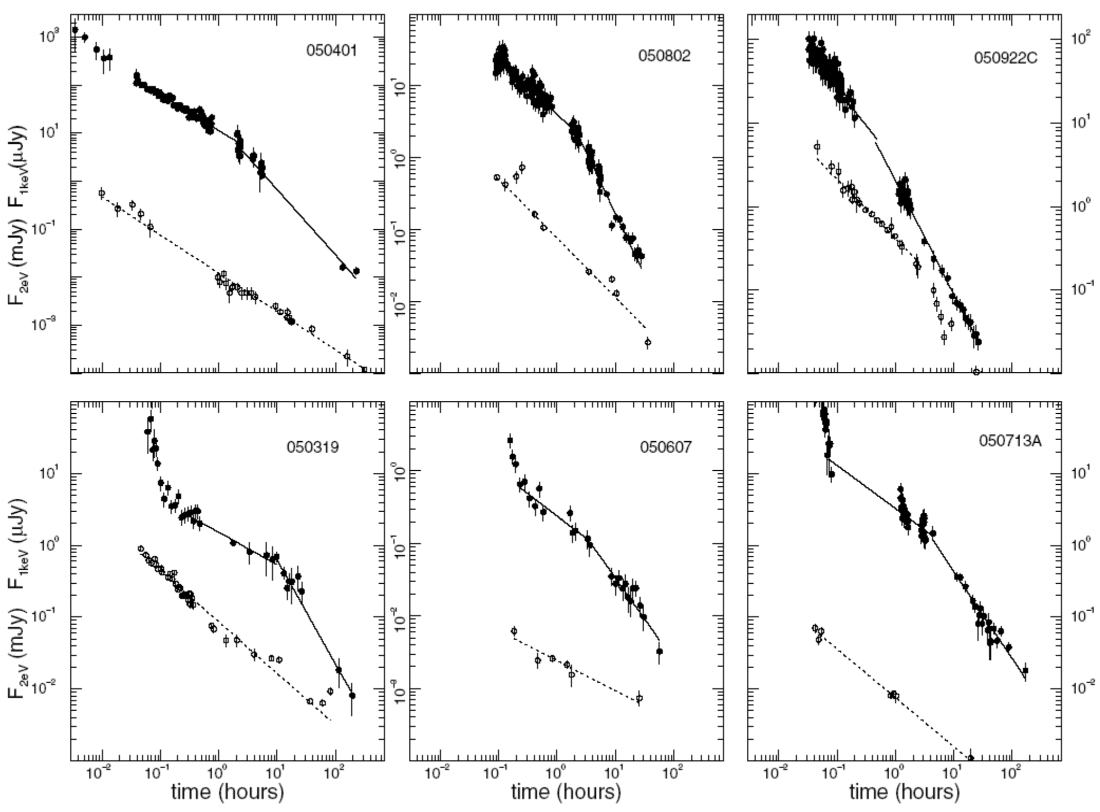
To Beaming, or not to Beaming



GRB 080319B

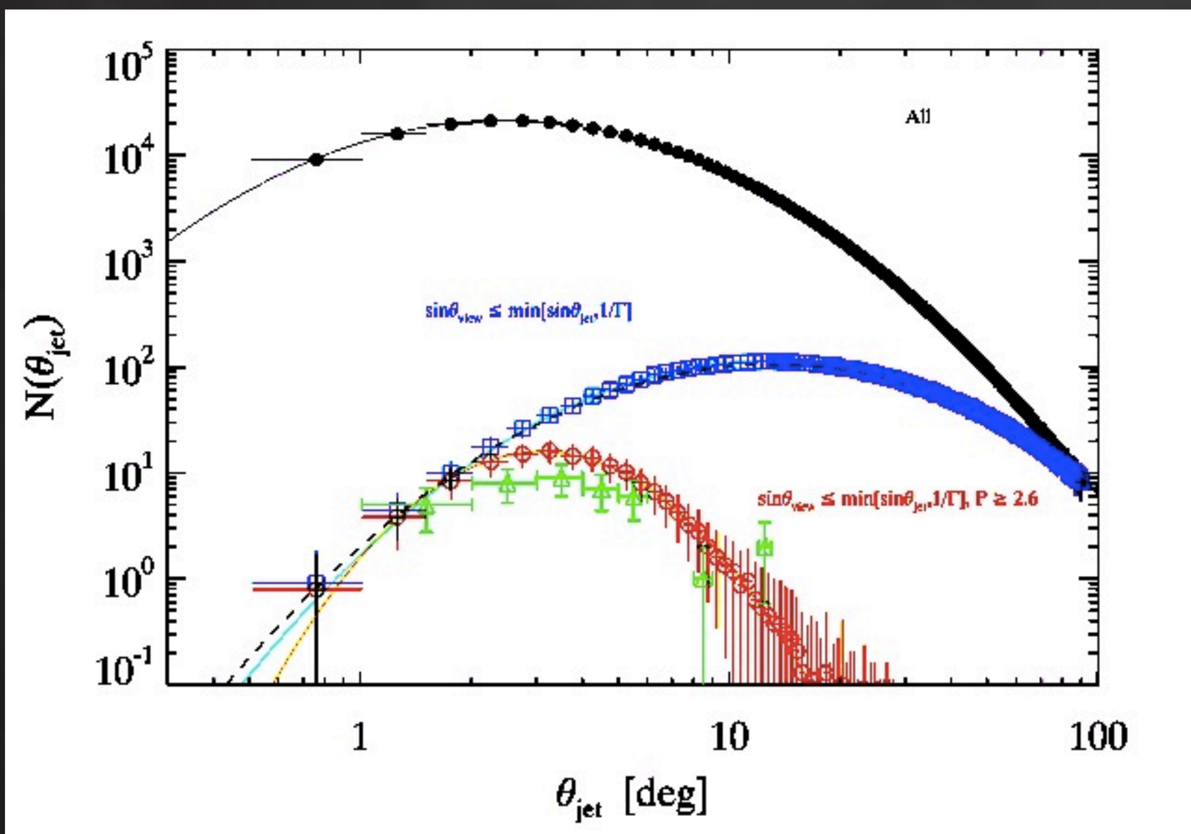
In some cases there is not evidence for beaming, i.e. an achromatic break was not detected (see Campana et al. 2007) .





The faster the narrower: characteristic bulk velocities and jet opening angles of Gamma Ray Bursts

G. Ghirlanda[1*], G. Ghisellini[1], R. Salvaterra[2], L. Nava[3], D. Burlon[4], G. Tagliaferri[1], S. Campana[1], P. D'Avanzo[1], A. Melandri[1] (2013)



$1° < \vartheta < 30°$

$\vartheta_{peak} \sim 4°$

What is the fraction of SNe-Ib/c which produces (long)GRBs ?

Rate for Ibc: 2.4×10^4 SNe-Ibc $Gpc^{-3}\ yr^{-1}$

GRB rate: 0.7 GRB $Gpc^{-3}\ yr^{-1}$

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GRB/SNe-Ibc: 1.5%-0.003%

TABLE 2
LATE-TIME RADIO OBSERVATIONS OF TYPE IBC SUPERNOVAE

SN name	Host Galaxy	Distance[a] (Mpc)	Explosion Date[b] (UT)	IAUC (#)	Date Obs (UT)	Δt^c (days)	Flux density[d] (μJy)
1983N	NGC 5236	7.2	1983 Jun 26	3835	2003 Oct 17	7416	±124
1985F	NGC 4618	7.7	1985 May 14	4042	2003 Oct 17	6730	±37
1987M	NGC 2715	18.9	1987 Aug 31	4451	2003 Oct 17	5891	±34
1990B	NGC 4568	32.0	1989 Dec 23-1990 Jan 20	4949	2003 Oct 17	5032	±24
1990U	NGC 7479	33.7	1990 Jun 28-Jul 27	5063	2003 Oct 17	4845	±44
1991A	IC 2973	45.5	1990 Dec 6-13	5178	2003 Oct 17	4695	±35
1991D	Anon.	173	1991 Jan 16	5153	1992 Oct 11	633	±49
1991N	NGC 3310	14.0	1991 Feb 20-Mar 29	5227	2003 Oct 17	4604	±59
1991ar	IC 49	65.0	1991 Aug 3	5334	2003 Oct 17	4458	±30
1994I	NGC 5194	6.5	1994 Apr 1-2	5961	2003 Oct 17	3486	±42
1994ai	NGC 908	21.3	1994 Dec 8-16	6120	2003 Oct 17	3336	±40
1996D	NGC 1614	68.1	1996 Jan 28	6317	2003 Oct 15	2818	±153
1996N	NGC 1398	19.7	1996 Feb 16-Mar 13	6351	2003 Oct 15	2787	±36
1996aq	NGC 5584	23.2	1996 Jul 30	6465	2003 Oct 17	2635	±32
1997B	IC 438	44.3	1996 Dec 14	6535	2003 Oct 15	2498	±33
1997C	NGC 3160	99.2	1996 Dec 18-1997 Jan 14	6536	2003 Oct 17	2481	±37
1997X	NGC 4691	15.7	1997 Jan 16-Feb 2	6552	2003 Oct 17	2457	±22
1997dc	NGC 7678	49.6	1997 Jul 22	6715	2003 Oct 17	2278	±36
1997dq*	NGC 3810	14.0	1997 Oct 16	6770	2003 Oct 17	2192	±30
1997ef*	UGC 4107	49.8	1997 Nov 16-26	6778	2003 Oct 17	2156	±33
1998T	NGC 3690	44.3	1998 Feb 8-Mar 3	6830	2003 Oct 17	2066	±482
1998ey*	NGC 7080	69.0	1998 Nov 1-Dec 5	6830	2003 Oct 17	1794	±32
1999bc	UGC 4433	90.2	1999 Jan 30	7133	2003 Oct 15	1721	±25
1999di	NGC 776	70.2	1999 Jul 6	7234	2003 Oct 17	1564	±35
1999dn	NGC 7714	39.7	1999 Aug 10-20	7241	2003 Oct 17	1524	±42
1999ec	NGC 2207	38.9	1999 Aug 24	7268	2003 Oct 15	1515	±45
1999eh	NGC 2770	27.6	1999 Jul 26	7282	2003 Oct 17	1544	±19
2000C[†]	NGC 2415	53.8	1999 Dec 30-2000 Jan 4	7348	2003 Oct 17	1385	±35
2000F	IC 302	84.5	1999 Dec 30-2000 Jan 10	7353	2003 Oct 15	1383	±26
2000S	MCG -01-27-2	85.8	1999 Oct 9	7384	2003 Oct 17	1469	±30

Soderberg et al. 2006
62 SNe-Ibc

Bietenholz al. 2011
59 SNe-Ibc

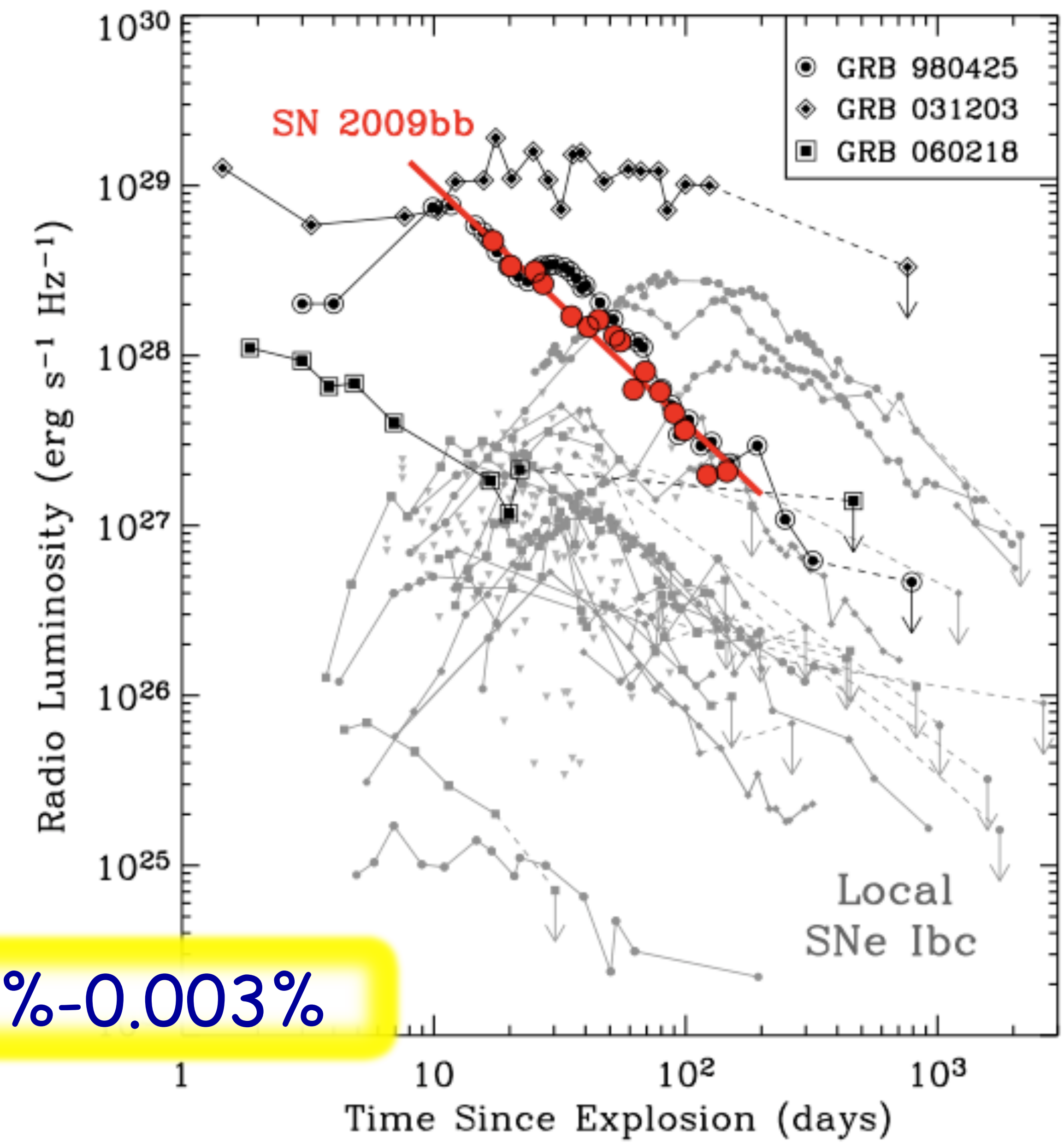
GRB/SNe-Ibc <10%

Discovery of a Relati
Gamma-ray Trigger

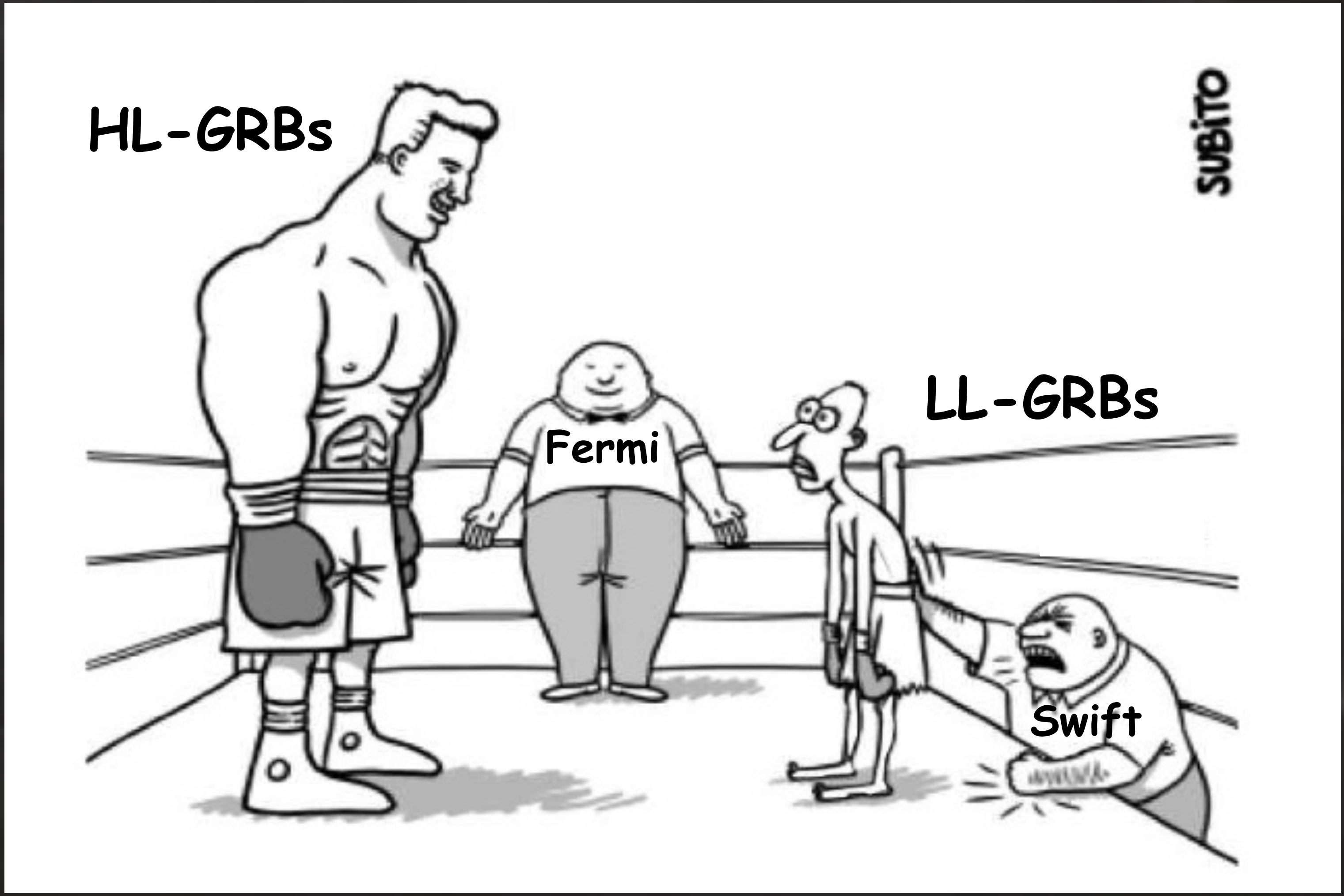
A. M. Soderberg[1], S
R. A. Chevalier[4], P. Chandra[5],
V. Chaplin[7], V. Connaughton[7],
N. Chugai[11], M. D. Stritzinger[12]
E. M. Levesque[1,15], J. E. Grindlay
P. A. Milne[16], M. A. P. Torres[1]

GRB/SNe-Ibc ~ 1/146
GRB/SNe-Ibc ~ 0.7%

< 5% at 99%



GRB/SNe-Ibc: 1.5%-0.003%


HL-GRBs
SUBITO
LL-GRBs
Fermi
Swift

SNe & GRBs at z < 0.1

GRB	SN	z	E_{iso} (erg)
GRB 980425	SN 1998bw	0.0085	$\sim 10^{48}$
GRB 060218	SN 2006aj	0.033	$\sim 10^{50}$
GRB 080109	SN 2008D	0.007	$\sim 10^{46}$
GRB 100316D	SN 2010bh	0.06	$\sim 10^{50}$

LL-GRBs sample a volume 10^6 smaller →
Rate: up to × 10^3 Gpc^{-3} yr^{-1}
(Della Valle 2005, Pian et al. 2006, Cobb et al. 2006, Soderberg et al. 2006, Liang et al. 2006, Guetta & Della Valle 2007, Amati et al. 2007)

SNe & GRBs at z < 0.1

GRB	SN	z	D_{max}	Sky Cov.	Δt (yr)
GRB 980425	SN 1998bw	0.0085	170 Mpc	0.08	7
GRB 060218	SN 2006aj	0.033	160 Mpc	0.17	9
GRB 080109	SN 2008D	0.007	200 Mpc	0.17	9
GRB 100316D	SN 2010bh	0.06	268 Mpc	0.17	9

LL-GRBs Rate

LL-GRBs counts (beppo-Sax) ~ 0.2 – 3.3 (1σ)
SkyCov +V_{max} + Δt → "observed" ~ 90 Gpc^{-3} yr^{-1} (18 up to 300)

LL-GRBs counts (Swift) ~ 1.3 – 6 (1σ) → SkyCov + V_{max} + Δt → "observed" ~ 65 Gpc^{-3} yr^{-1} (48 up to 111)

LL-GRBs "observed" ~ 71 GRBs Gpc^{-3} yr^{-1} (51 up to 104)

LL-GRBs Rate

LL-GRBs counts (beppo-Sax) ~ 0.2 – 3.3 (1σ)
SkyCov +V_{max} + Δt → "observed" ~ 90 Gpc^{-3} yr^{-1} (18 up to 300)

LL-GRBs counts (Swift) ~ 1.3 – 6 (1σ) → SkyCov + V_{max} + Δt→ "observed" ~ 65 Gpc^{-3} yr^{-1} (48 up to 111)

LL-GRBs "observed" ~ 71 GRBs Gpc^{-3} yr^{-1} (51 up to 104)

$\langle fb^{-1} \rangle_{LL\text{-}GRBs}$ ~ 1-2 GRB 060218 θ>80° (Soderberg et al. 2006)
< 7 GRB 031203 θ>30° (Malesani 2006)
< 10 statistic θ>25° (Guetta & Della Valle 2007)

LL vs. HL Rates

LL-GRBs ~ 71 x (1 ÷ 10) ~ 70 ÷ 700 LL-GRBs $Gpc^{-3}\ yr^{-1}$

$\langle fb^{-1} \rangle_{HL\text{-}GRBs}$ ~ 75 ÷ 500

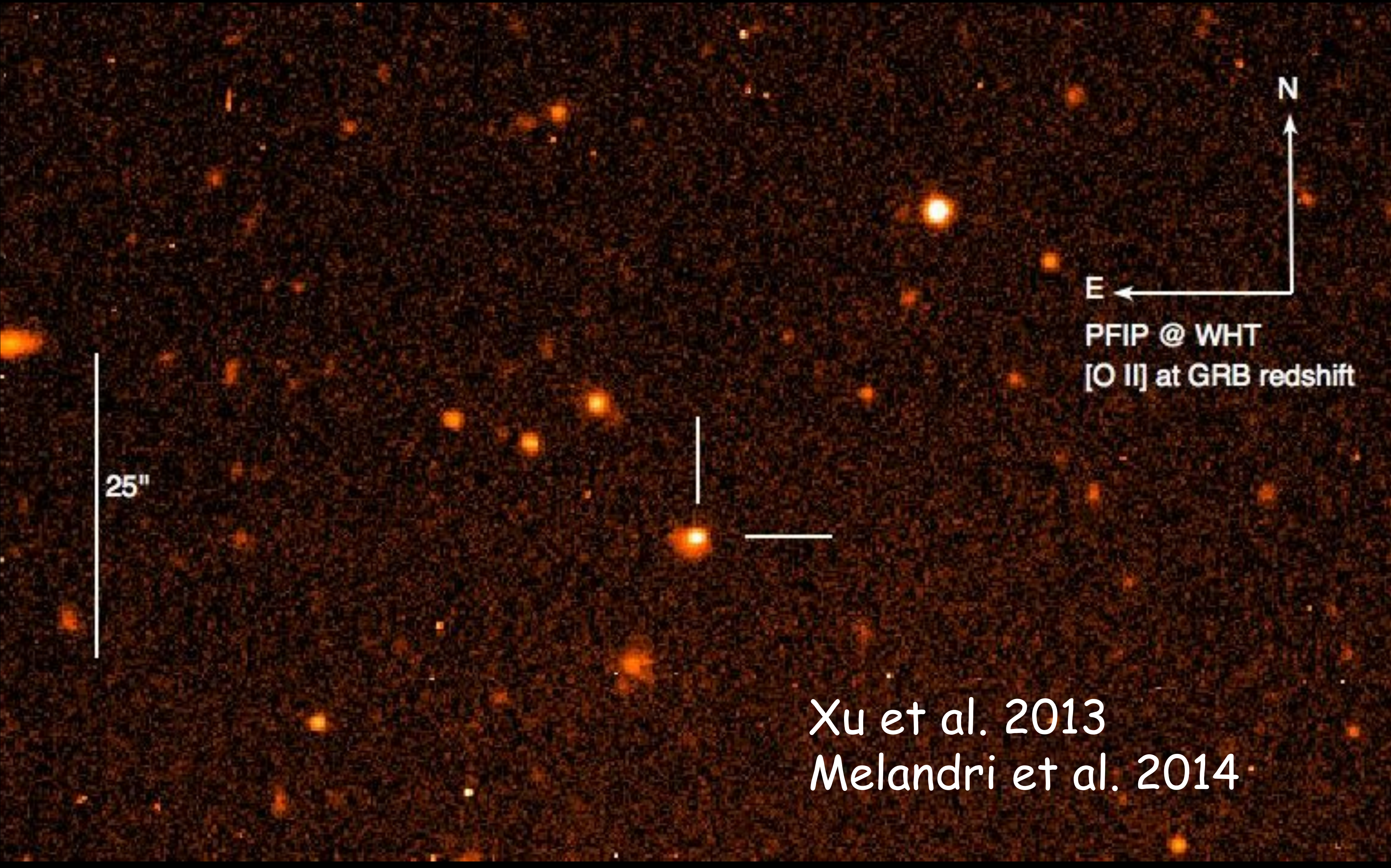
HL-GRBs ~ 0.7 x $\langle fb^{-1} \rangle$ ~ 50 ÷ 350 $Gpc^{-3}\ yr^{-1}$

LL-GRB/*HL*-GRB < 15

On the Subclasses in *Swift* Long Gamma-Ray Bursts: A Clue to Different Central Engines

Ryo TSUTSUI[1], & Toshikazu SHIGEYAMA[1]

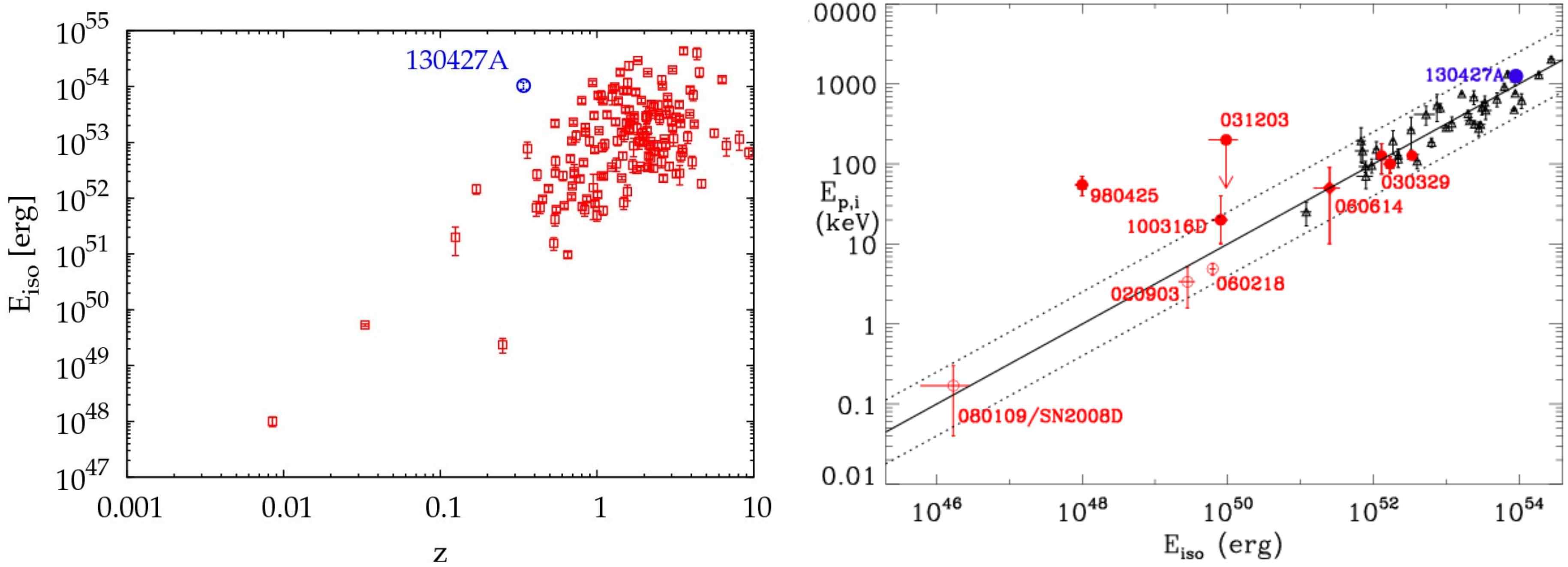
GRB 130427A+SN 2013cq



Xu et al. 2013
Melandri et al. 2014

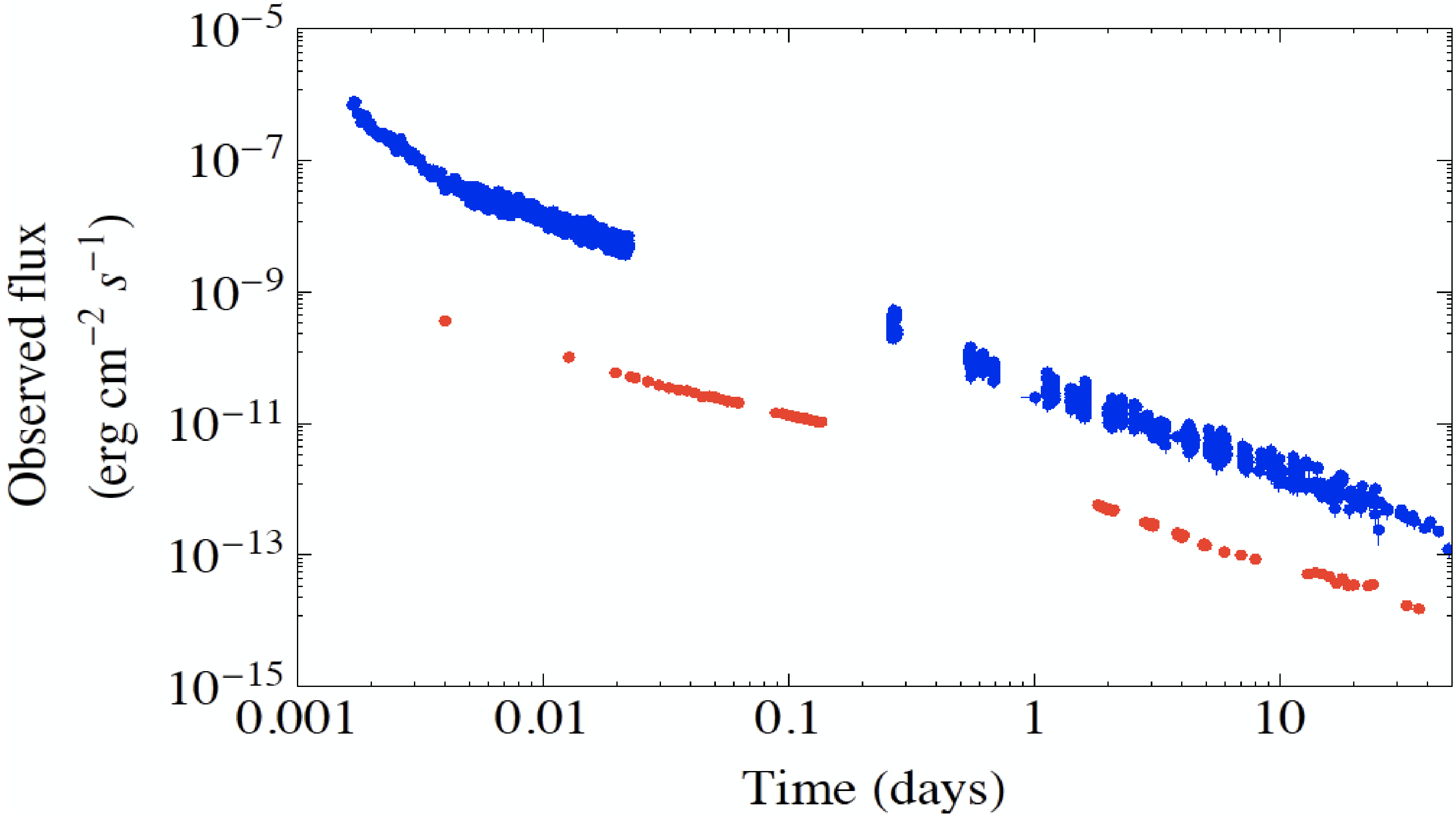
❑ Testing the GRB-SN paradigm with the brightest "close" event; GRB 130427A T90=162s

- Recent detection of the very energetic (Eiso = 10^{54} erg) "neraby" (z = 0.34) GRB030427A
- Unique occasion to test the GRB-SN connection for "cosmological" GRBs



Melandri et al. 2014

GRB 130427A



Swift XRT (0.3-10 keV)

Palomar 60" *r* - band

See also Perley et al. ArXiv 1307.4401

Half-opening angle
In radians !!!

No jet-break → limits on θ

$$\theta_{jet} = 0.161[t_{jet}/(1+z)]^{3/8}(n\ \eta_\gamma / E_{\gamma,iso,52})^{1/8}$$

(Schaefer 2006 formulation)

Assumptions

t_{jet} > 40 days (Perley et al.) 180 days XRT obs up to now

$z = 0.34$

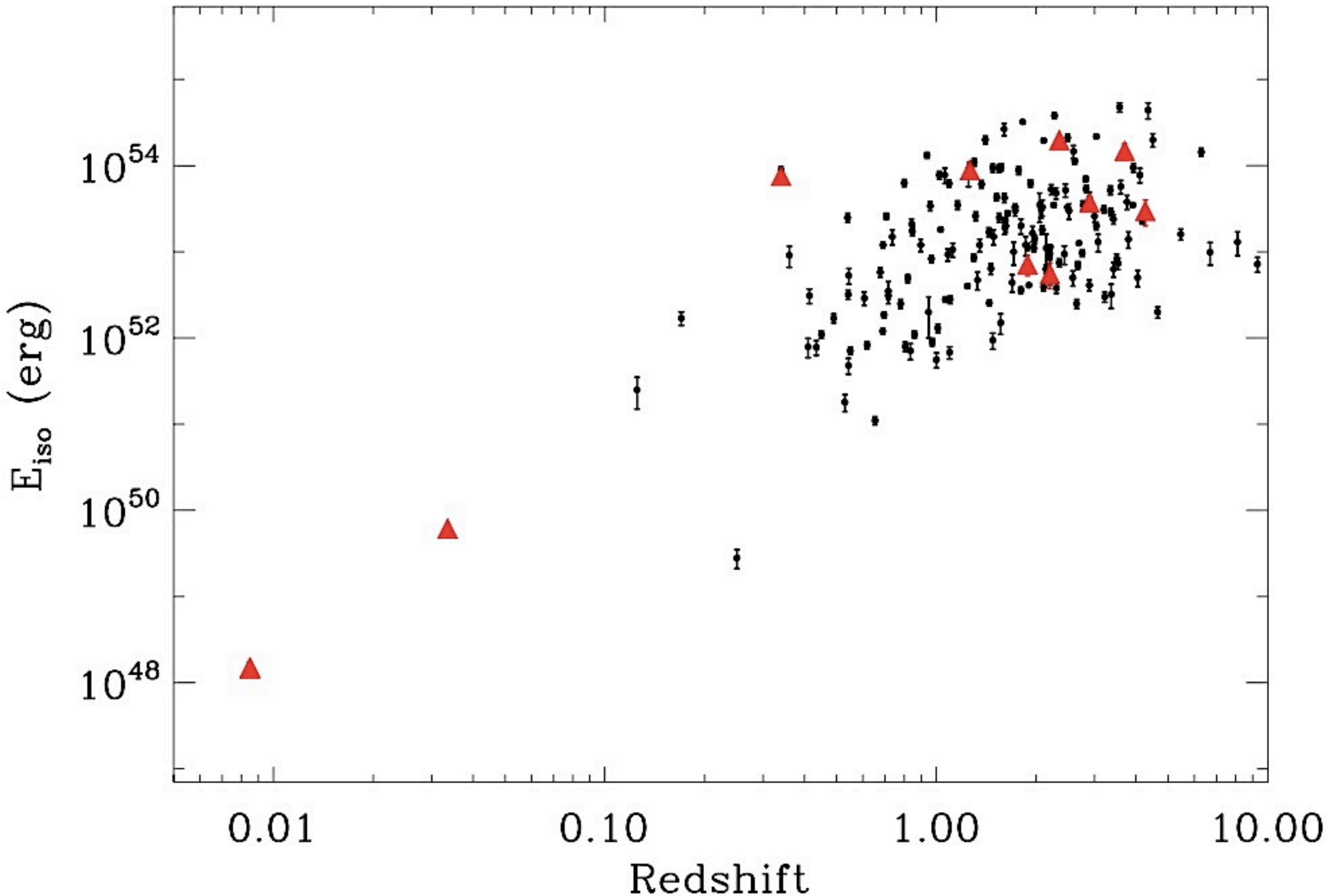
$n = 3\ \#/cm^3$; $\eta = 0.2$

$E_{iso} = 8 \times 10^{53}$ erg → $E_{iso,52} = 80$ erg

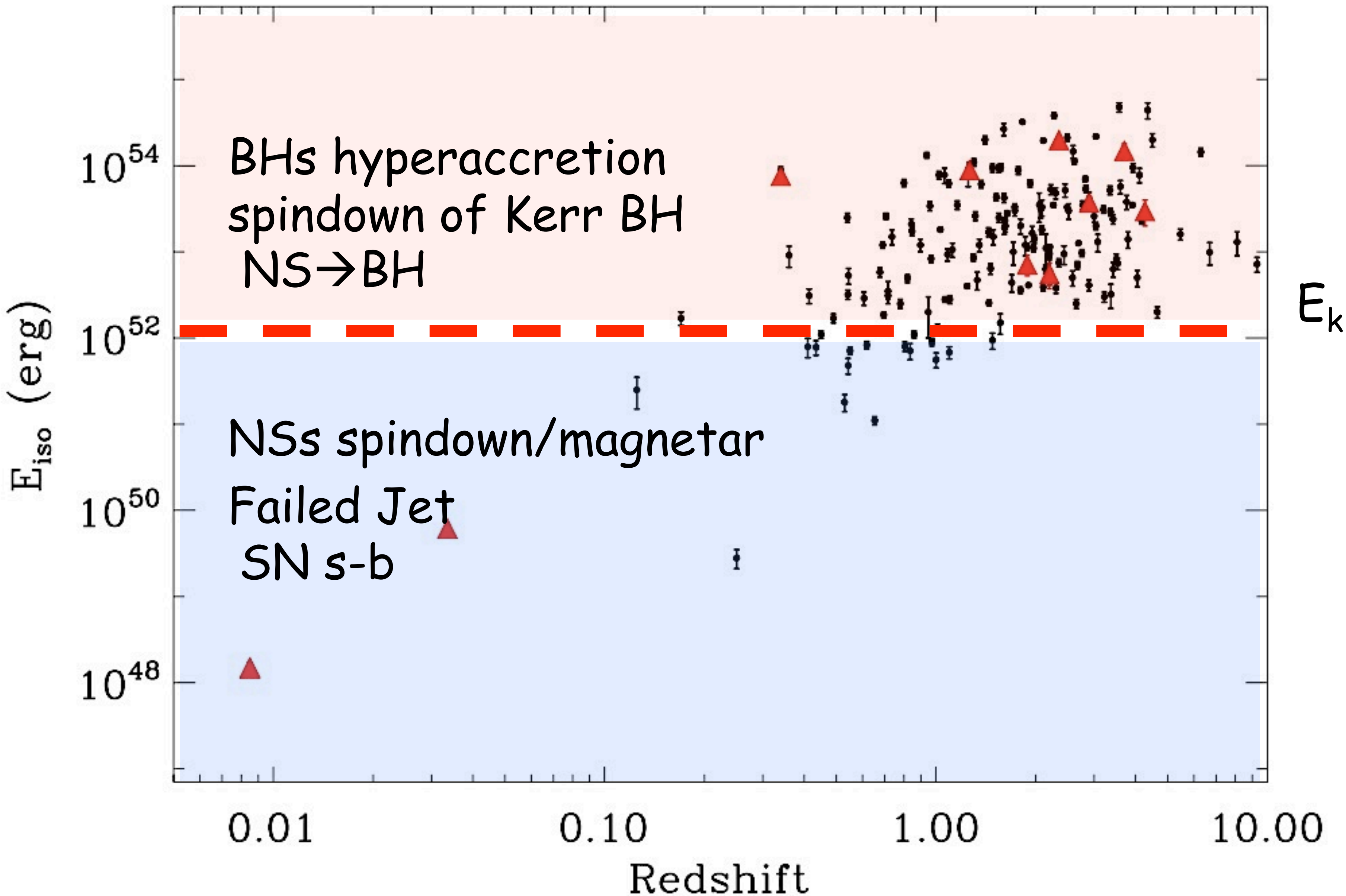
$E_{iso,coll} = E_{iso}\,(1 - \cos\theta)$

$t_{jet} = 40$ days → $\theta = 17.88°$ → $E_{iso,coll} > 3.86 \times 10^{52}$ erg

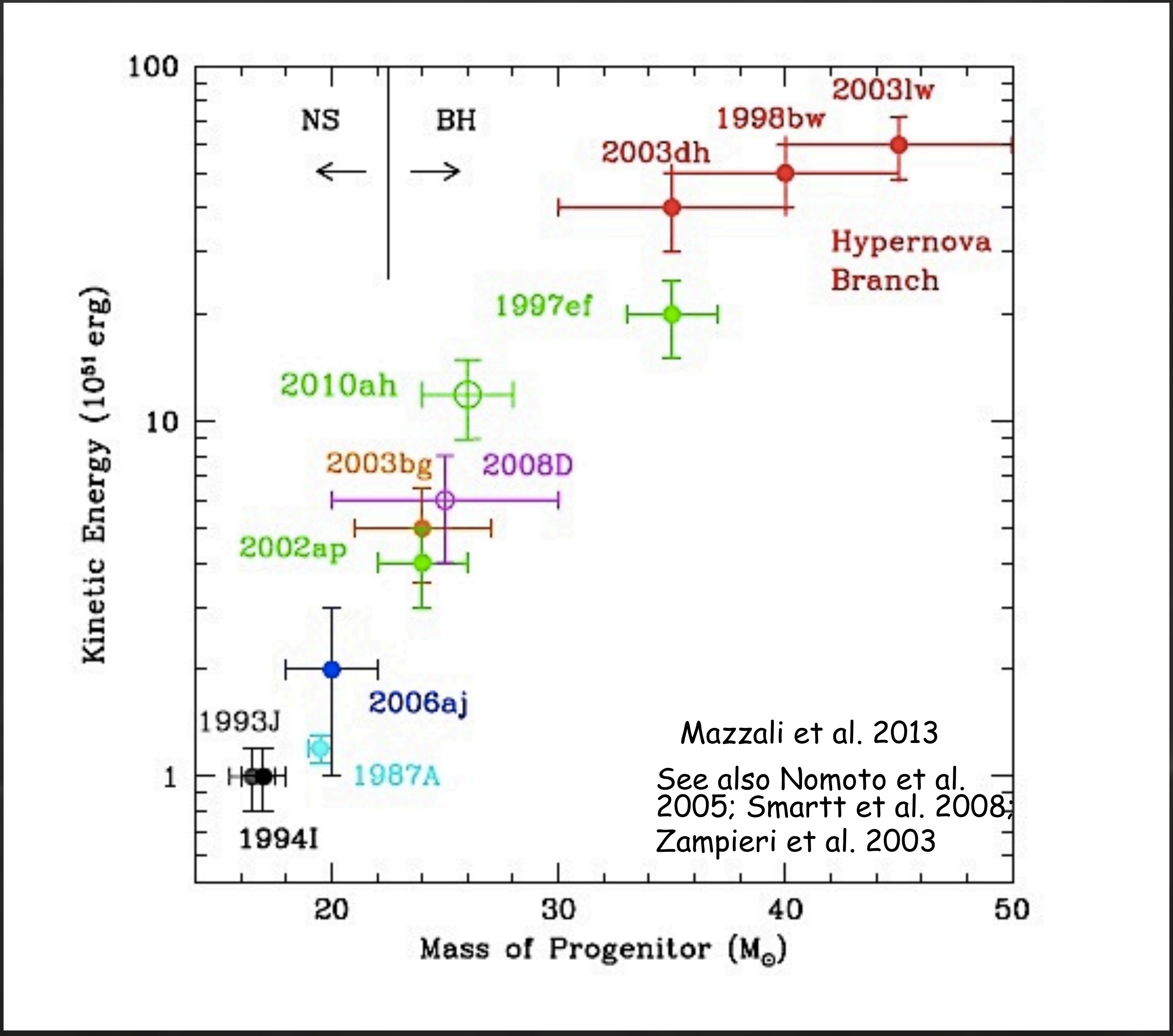
$t_{jet} = 180$ days → $\theta = 31.43°$ → $E_{iso,coll} > 1.17 \times 10^{53}$ erg



10^{54}
10^{52}
10^{50}
10^{48}
E_{iso} (erg)
0.01
0.10
1.00
10.00
Redshift



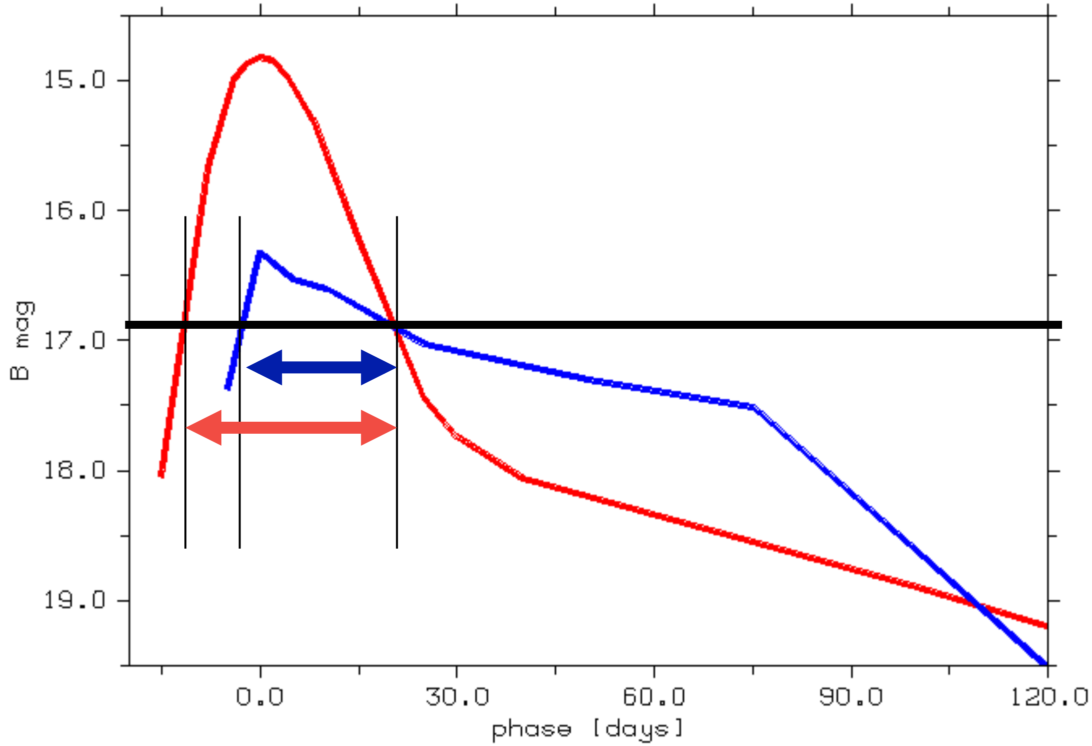
Kopac et al. 2013; ... et al. 2008; ... et al. 2013; Lazzati et al. 2012; Fan et al. 2013 and REFERENCES THEREIN and REFERENCES THEREIN


NS
BH
2003lw
1998bw
2003dh
Hypernova Branch
1997ef
2010ah
2003bg
2008D
2002ap
2006aj
1993J
1987A
1994I
Mazzali et al. 2013
See also Nomoto et al. 2005; Smartt et al. 2008; Zampieri et al. 2003
Kinetic Energy (10^{51} erg)
Mass of Progenitor ($M_\odot$)
100
10
1
20
30
40
50

What is the fraction of SNe-Ib/c which produces HNe?

How to compute rates

1. The observing log: epoch, limiting magnitude
2. Target apparent light curve: SN type, target distance
3. Galaxy sample: distance, type, inclination …….



$$m_{i,V}^{SN}(t) = M_B^{SN}(t_0) + \mu(z_i) + K_{BV}^{SN}(t_0) + A_V^G$$

$t_0 = t/(1+z)$

SN light curve in B absolute magnitude

galaxy distance modulus

B to V K-correction

galactic extinction

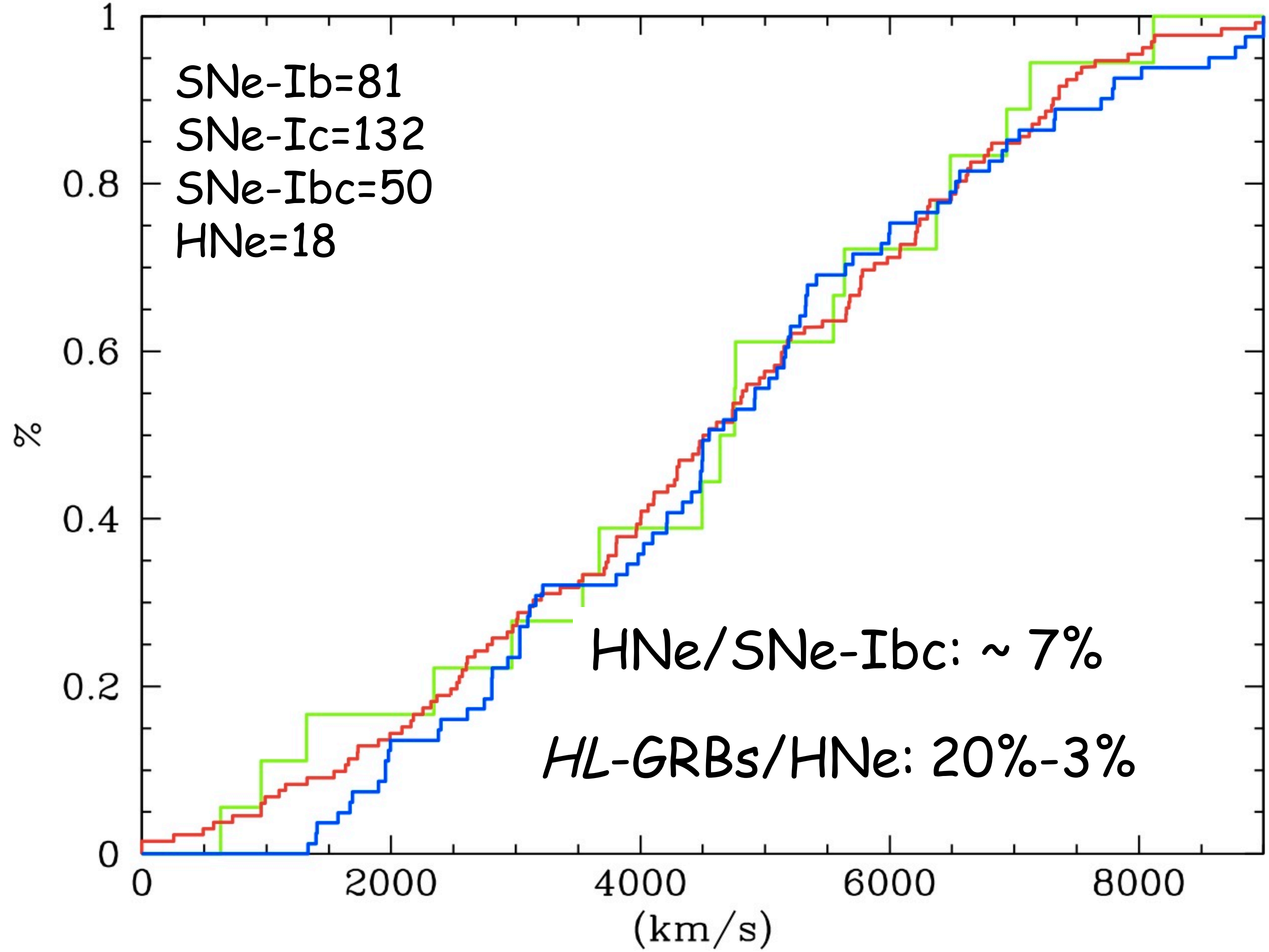
$$CT_i = L_i \int \tau_i^{SN}(m)\,\varepsilon(m)\,\mathrm{d}m$$

galaxy luminosity

time SN stays at *m*-*m*+dm

detection efficiency

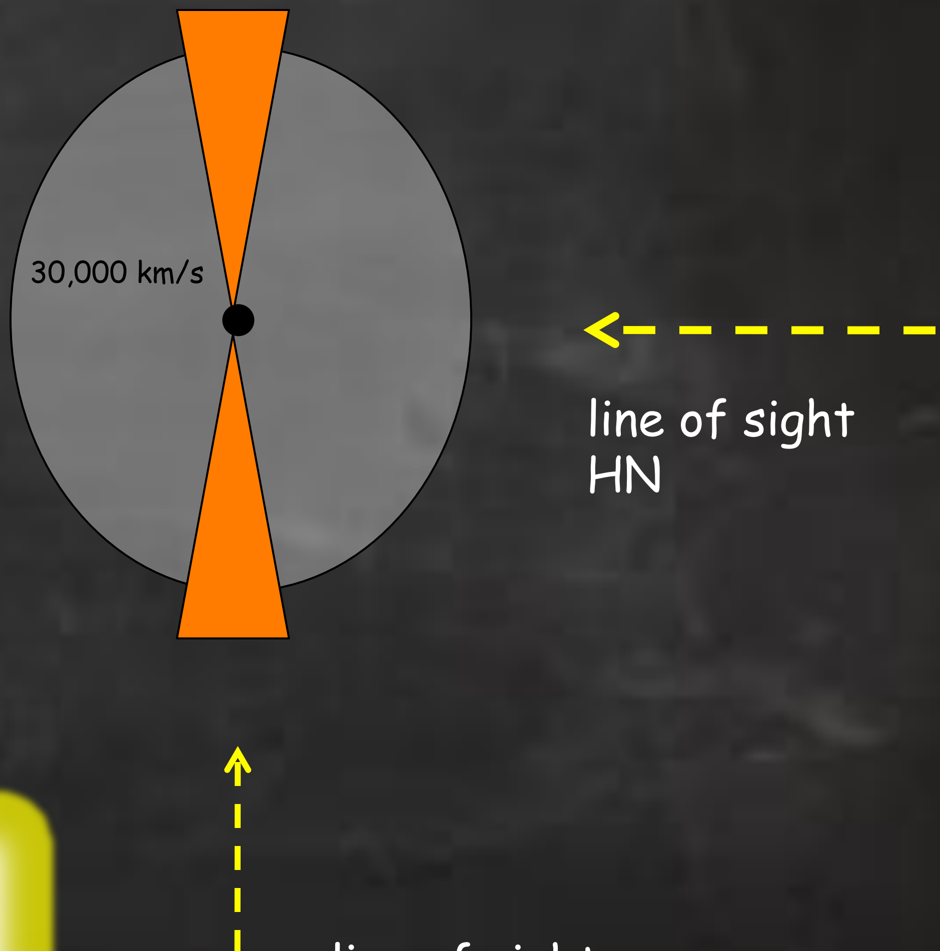
$$r^{SN} = (1+z_i)\frac{N^{SN}}{\sum_i^N CT_i^{SN}}$$


SNe-Ib=81
SNe-Ic=132
SNe-Ibc=50
HNe=18
HNe/SNe-Ibc: ~ 7%
HL-GRBs/HNe: 20%-3%
%
(km/s)
0
0.2
0.4
0.6
0.8
1
0
2000
4000
6000
8000

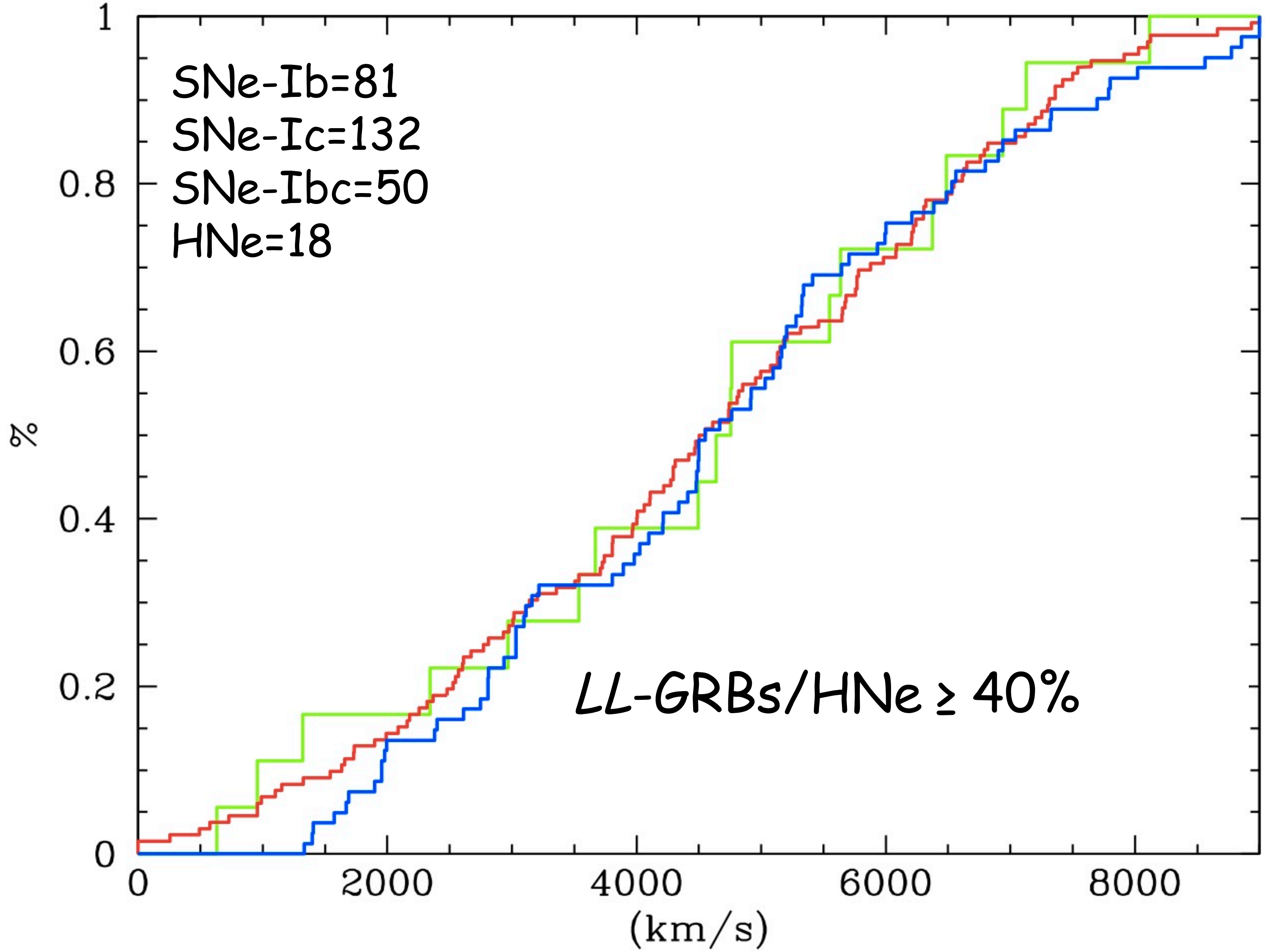
A simplified Scheme for a GRB-SN event

-an almost isotropic component carrying most energy 10^{52} erg and mass ($\sim$5-10$M_\odot$)

-highly collimated component 4°-10° for HL-GRBs containing a tiny fraction of the mass ($10^{-4/-5}$ $M_\odot$) moving at $\Gamma \sim \times 10^{2-3}$



HL-GRBs/HNe: 20%-3%


SNe-Ib=81
SNe-Ic=132
SNe-Ibc=50
HNe=18
LL-GRBs/HNe ≥ 40%
%
(km/s)
0
0.2
0.4
0.6
0.8
1
0
2000
4000
6000
8000

4. Conclusions

GRBs are very rare phenomena (compared to SN explosions)

GRB/SNe-Ibc: 0.003%-1.5%
Ibc/CC ~ 0.30
GRB/CC-SN $\sim 10^{-5} \div 5 \times 10^{-3}$

$$\frac{N(40M_\odot - 120M_\odot)}{N(8M_\odot - 120M_\odot)} \sim 0.1 \text{ (Salpeter IMF)}$$

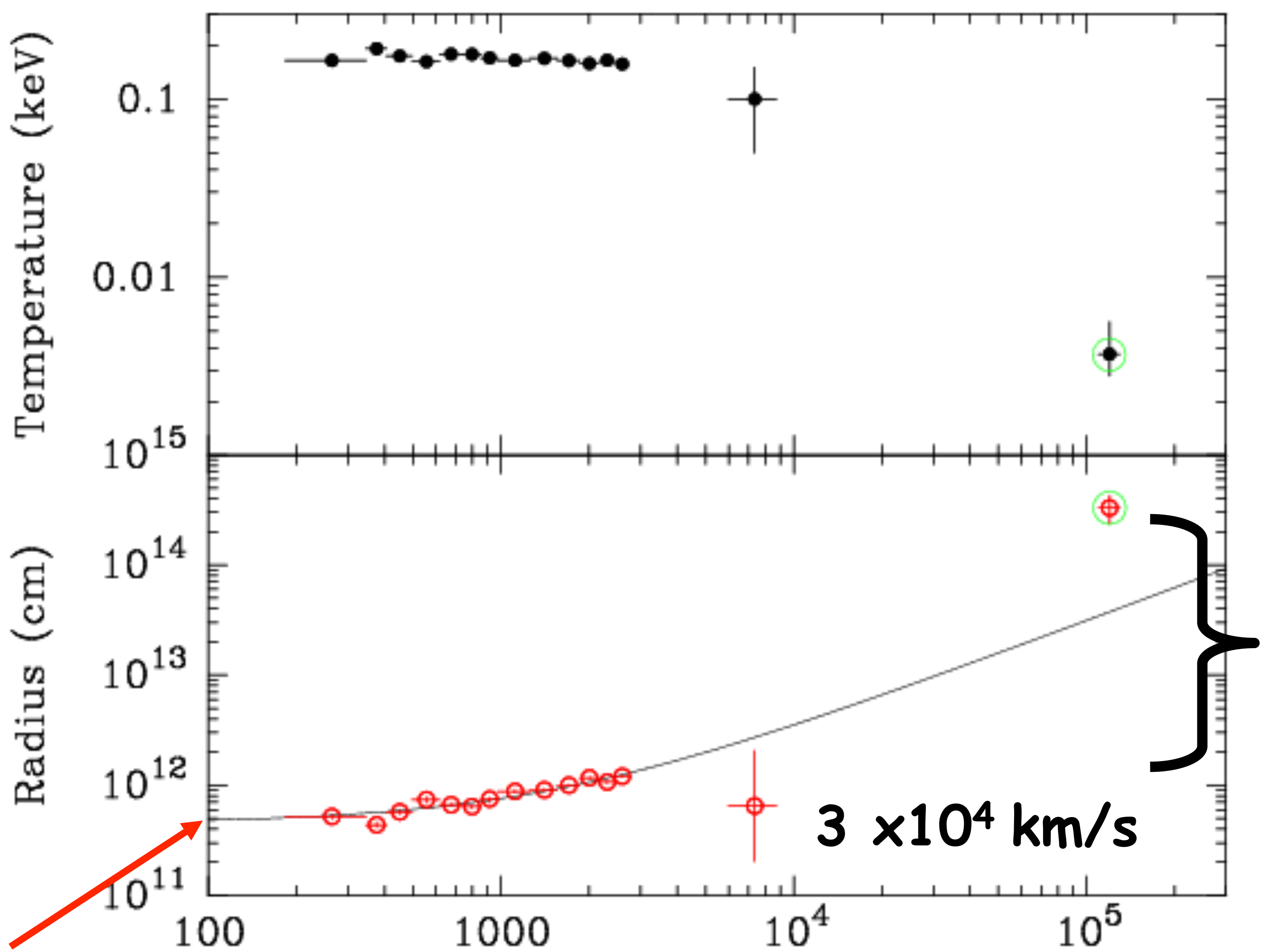
What causes some small fraction of CC-SNe to produce observable GRBs, while the majority do not?

Special conditions are requested to stars to be GRB progenitors:

i) to be massive ~ 30-50 $M_{\odot}$ (Maeda et al. 2006; Raskin et al. 2008; Tanaka et al. 2008)

ii) H/He envelopes to be lost before the collapse of the core, i.e. the GRB progenitor is a WR star (Campana et al. 2006)

GRB 060218/SN 2006aj



Campana et al. 2006

SNe-CC size progenitors

Red Supergiant

R~4x10^{13} cm

Blue Supergiant

R~4x10^{12} cm

The radius of the progenitor of SN 2006aj →

W-R Star

R~4x10^{11} cm

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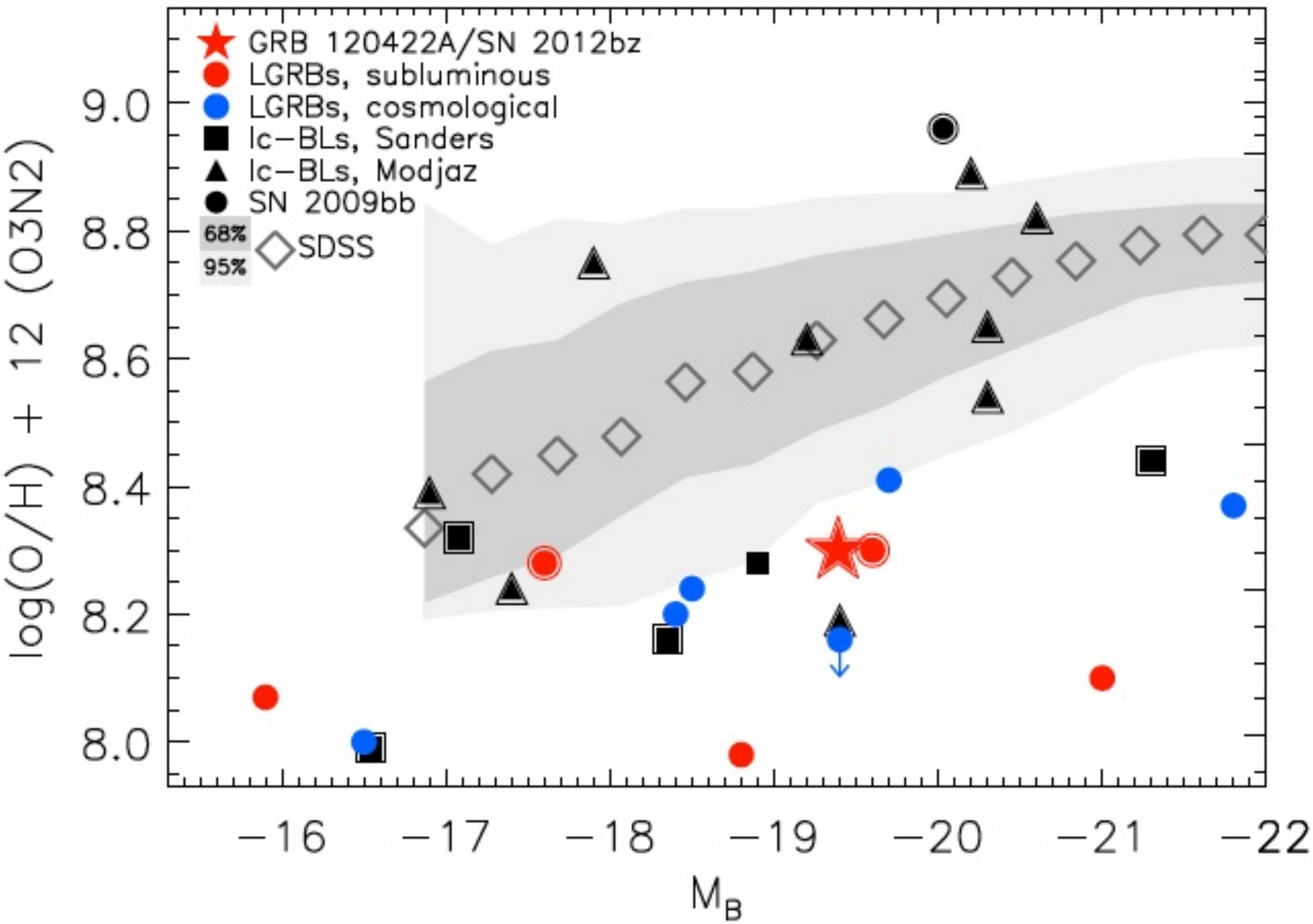
iii) low metallicity and star forming environments (Modjaz et al. 2008, Fruchter et al. 2006)



Levesque et al. 2012
See also Modjaz et al. 2011

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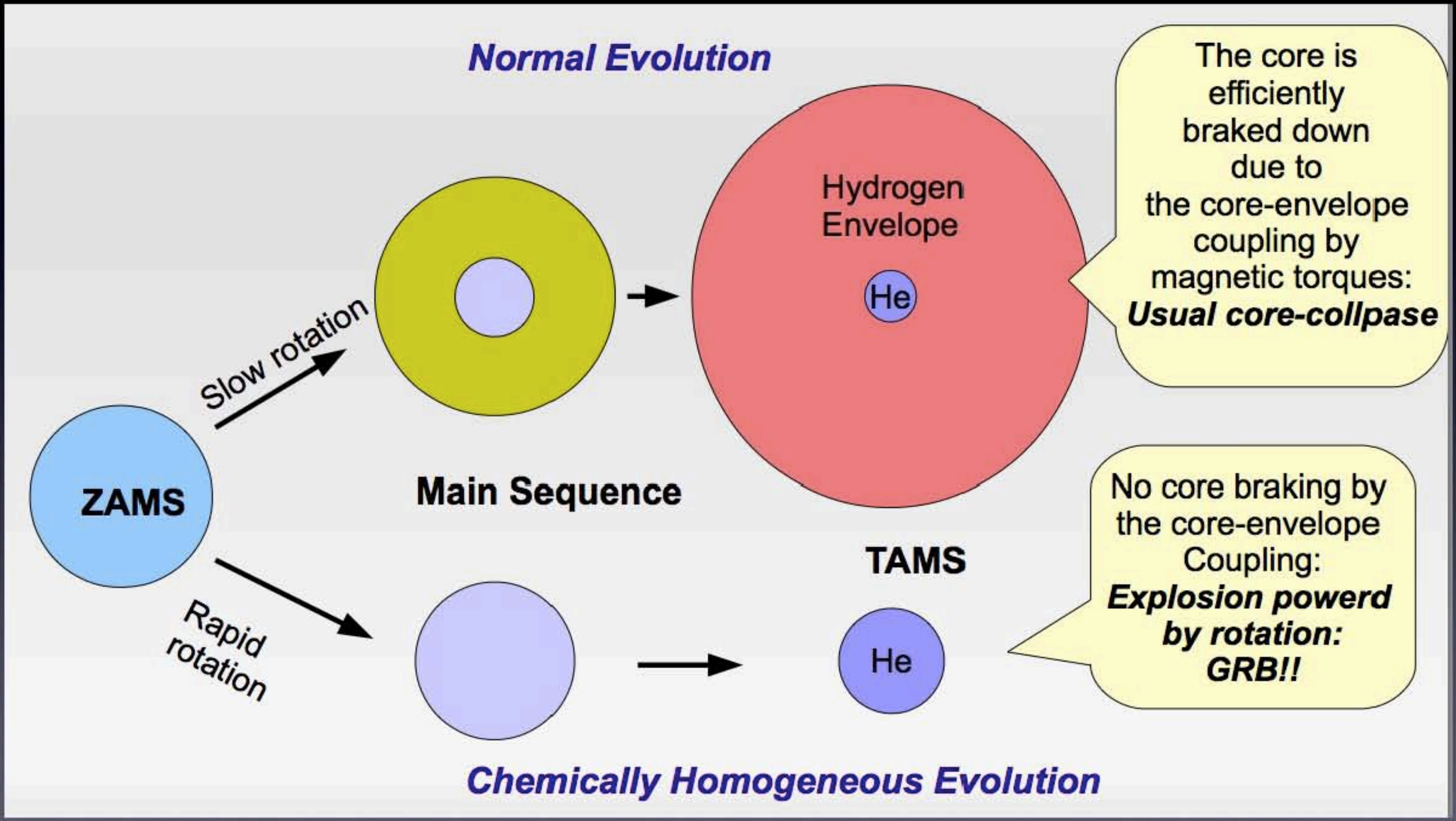
v) high rotation (Yoon et Langer 2005; Campana et al. 2008, Yoon et al. 2012)

Bifurcation of massive star evolution at low-metallicity



Yoon & Langer 05, Yoon et al. 06, Woosley & Heger 06, Yoon et al. 12

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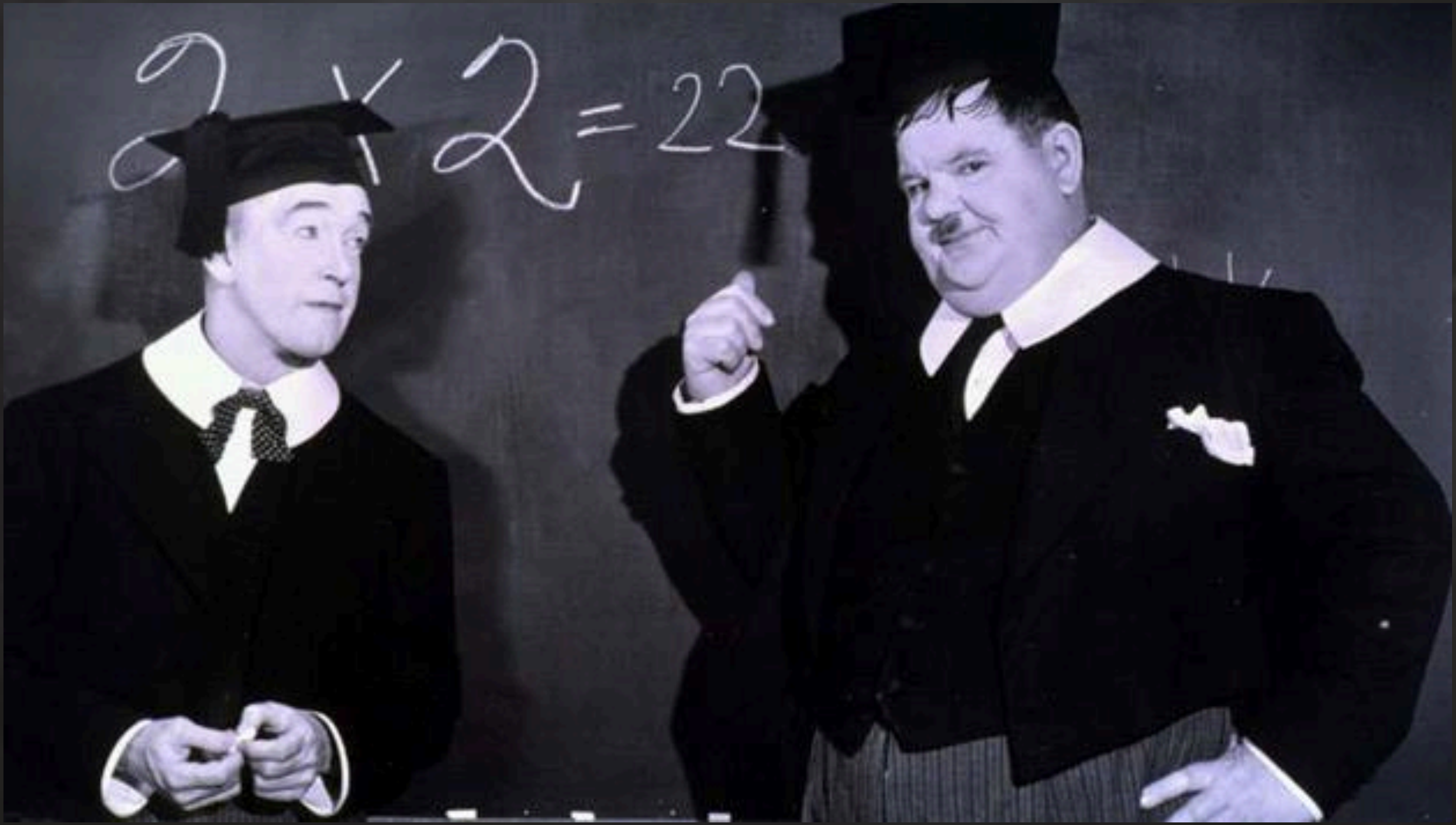
v) high rotation (Yoon et Langer 2005; Campana et al. 2008, Yoon et al. 2012)

vi) asimmetryc explosion (Taubenberger et al. 2009; Maeda et al. 2008)


Within Virgo Circle, in 5 years →
we should observe ~ 5 SNe-Ibc, about half of them
useful for GWs hunting. Only ~ 0.3 HNe
Within 30 Mpc Circle, in 5 years → we should observe
about 1 HN and ~ 15 SNe-Ibc, about half of them
useful for GWs hunting.

Open Issues



"Much ado about nothing": GRB 060614

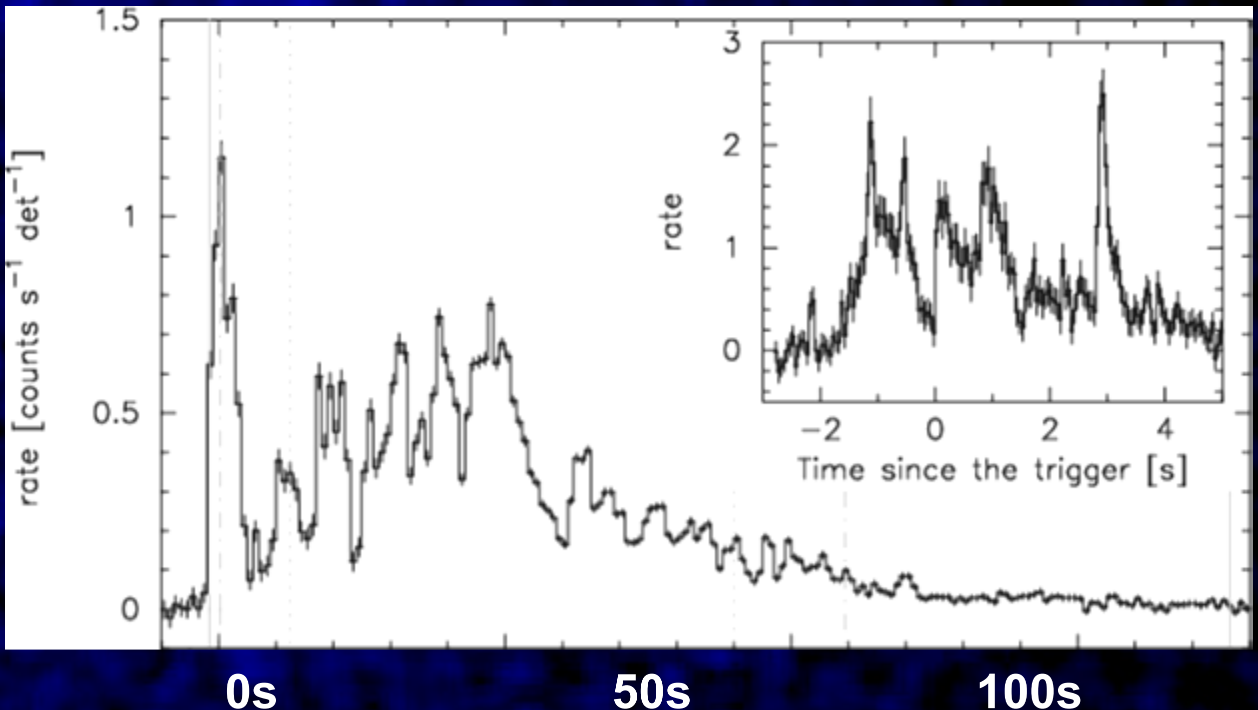
Low redshift:
z = 0.125

SN search?

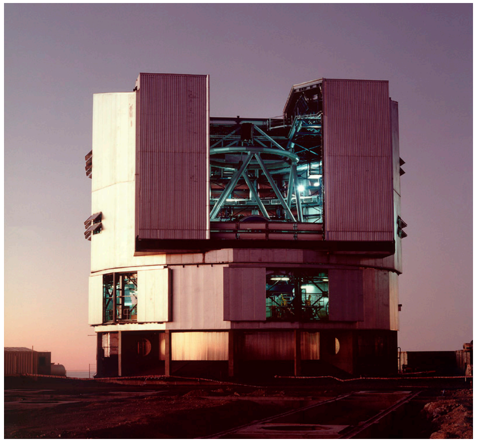
GRB060614

Gehrels et al. 2006

Mangano et al. 2007



What is the rate of GRB 060614-like events ?

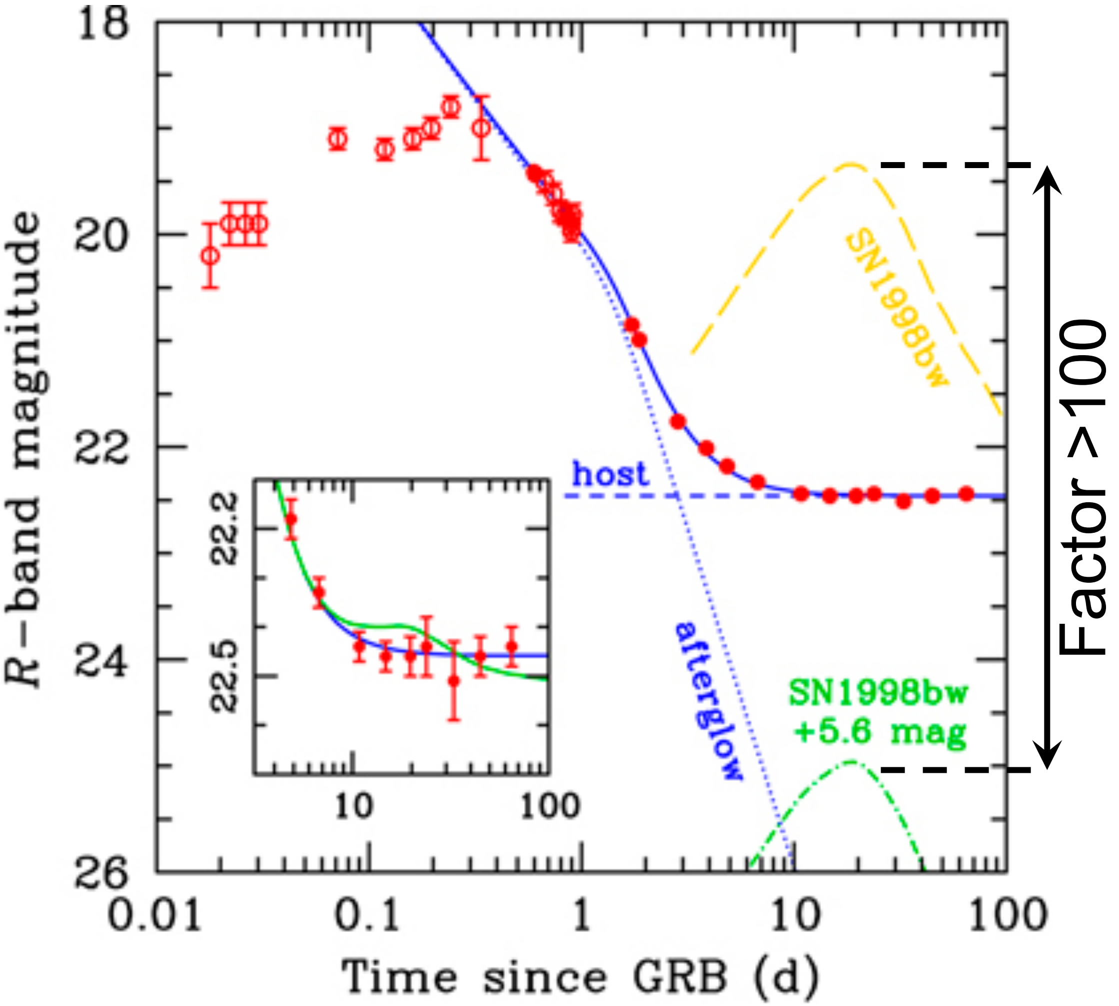


Late time:

host galaxy contribution (no variation)

Upper limit:

M_V > -13.5 (3σ)



Della Valle et al. 2006 (see also **Gal-Yam et al. 2006 – Fynbo et al. 2006**)

Scenarios without Supernova

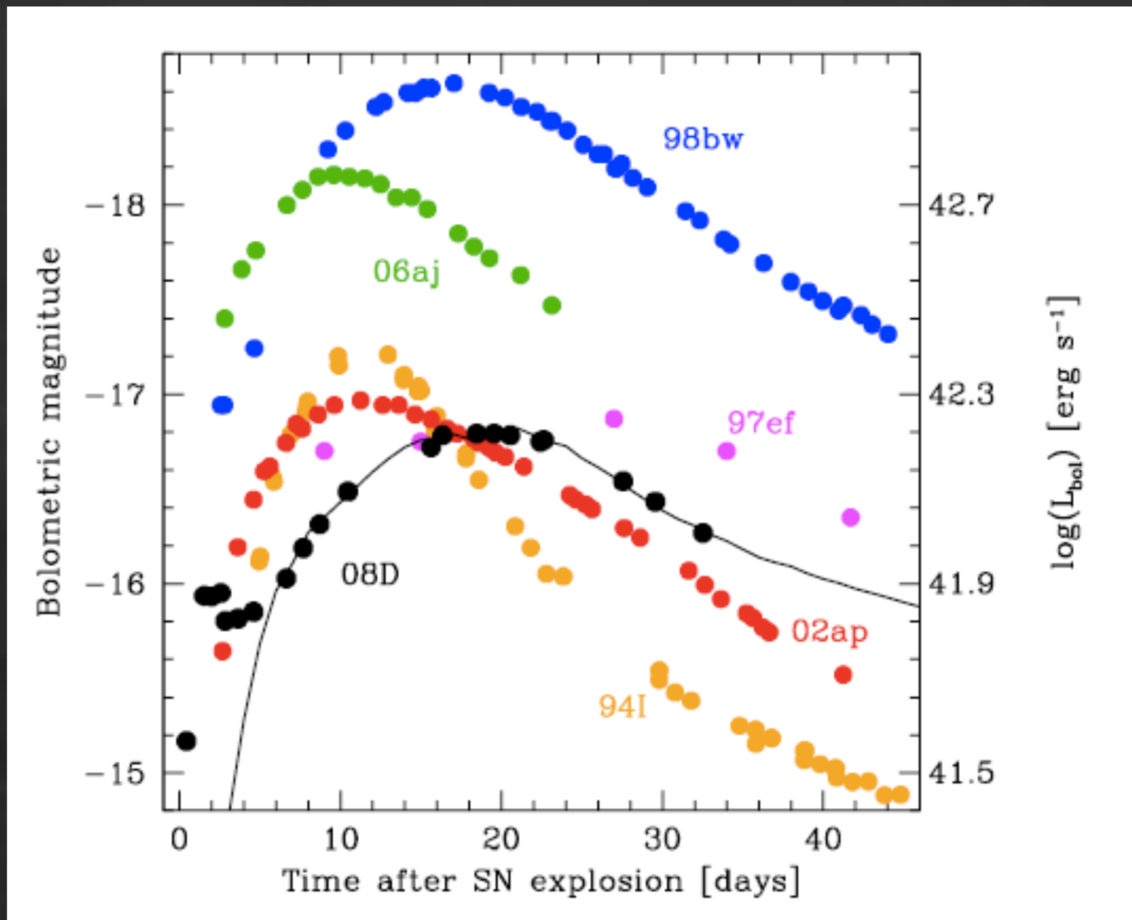
1. Supranova → SN occurs (months, years) before the GRB (Vietri & Stella 1998)

2. NS→ QS (Berezhiani et al. 2003; Drago et al. 2008)

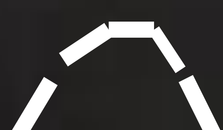
3. Vacuum Polarization around Kerr-BH (Ruffini 1998; Caito et al. 2008)

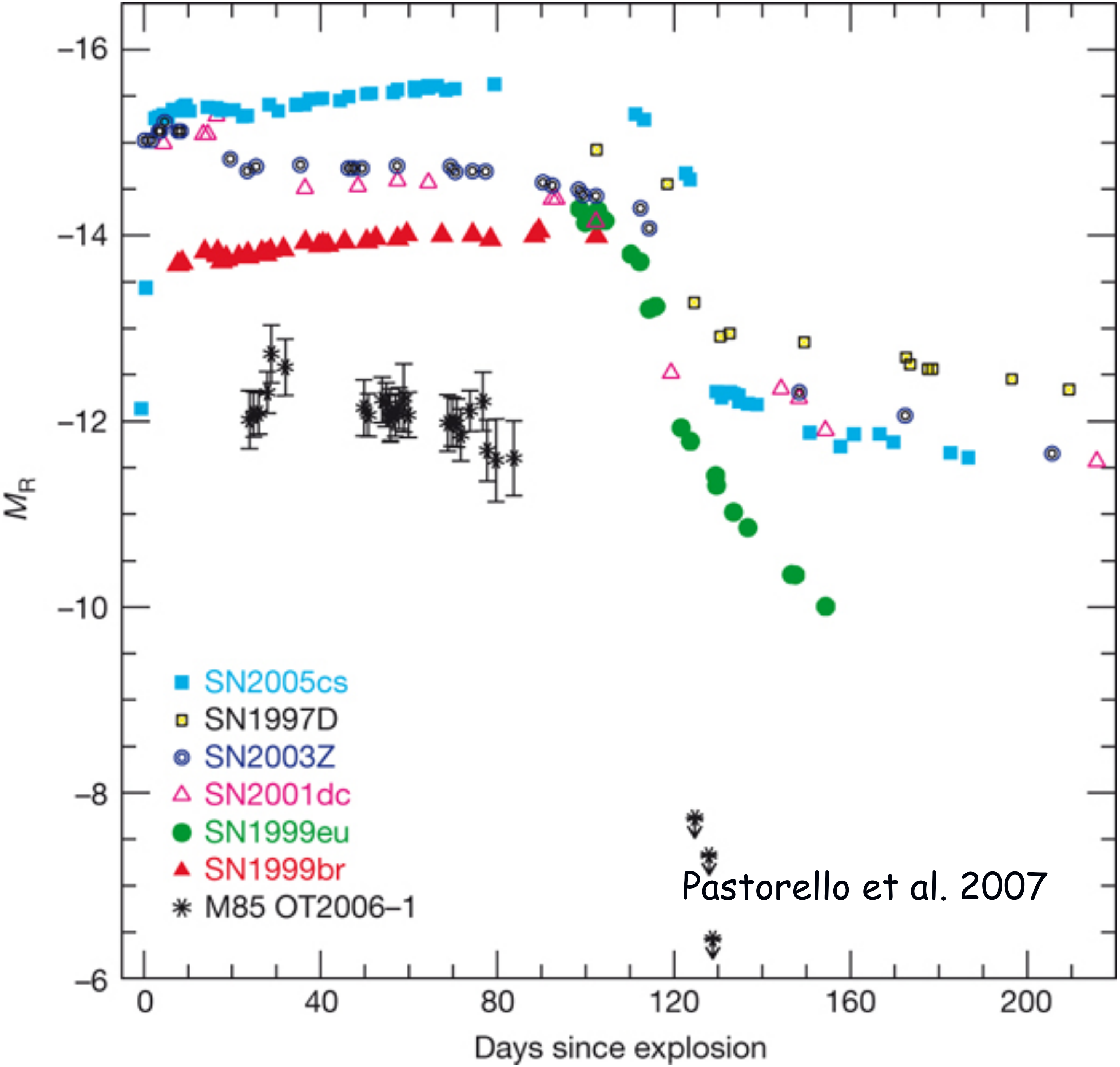
4. Binary merging mechanisms similar to those proposed to power short GRBs (Gehrels et al. 2006)

Scenarios with Supernova



-13.5





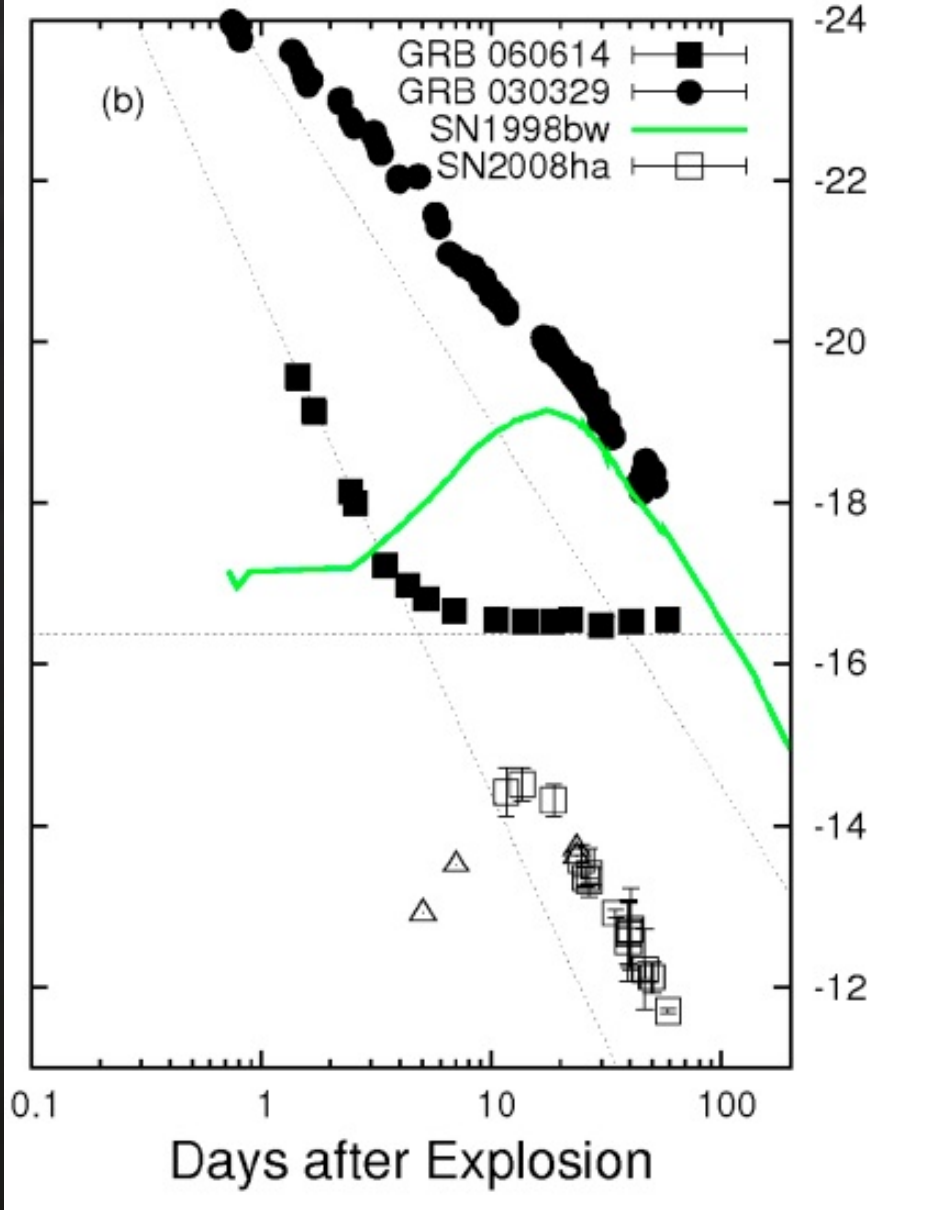
Pastorello et al. 2007

A low energy core-collapse supernova without a

, P.A. Mazzali[2,3], J. Manteca[4], S.

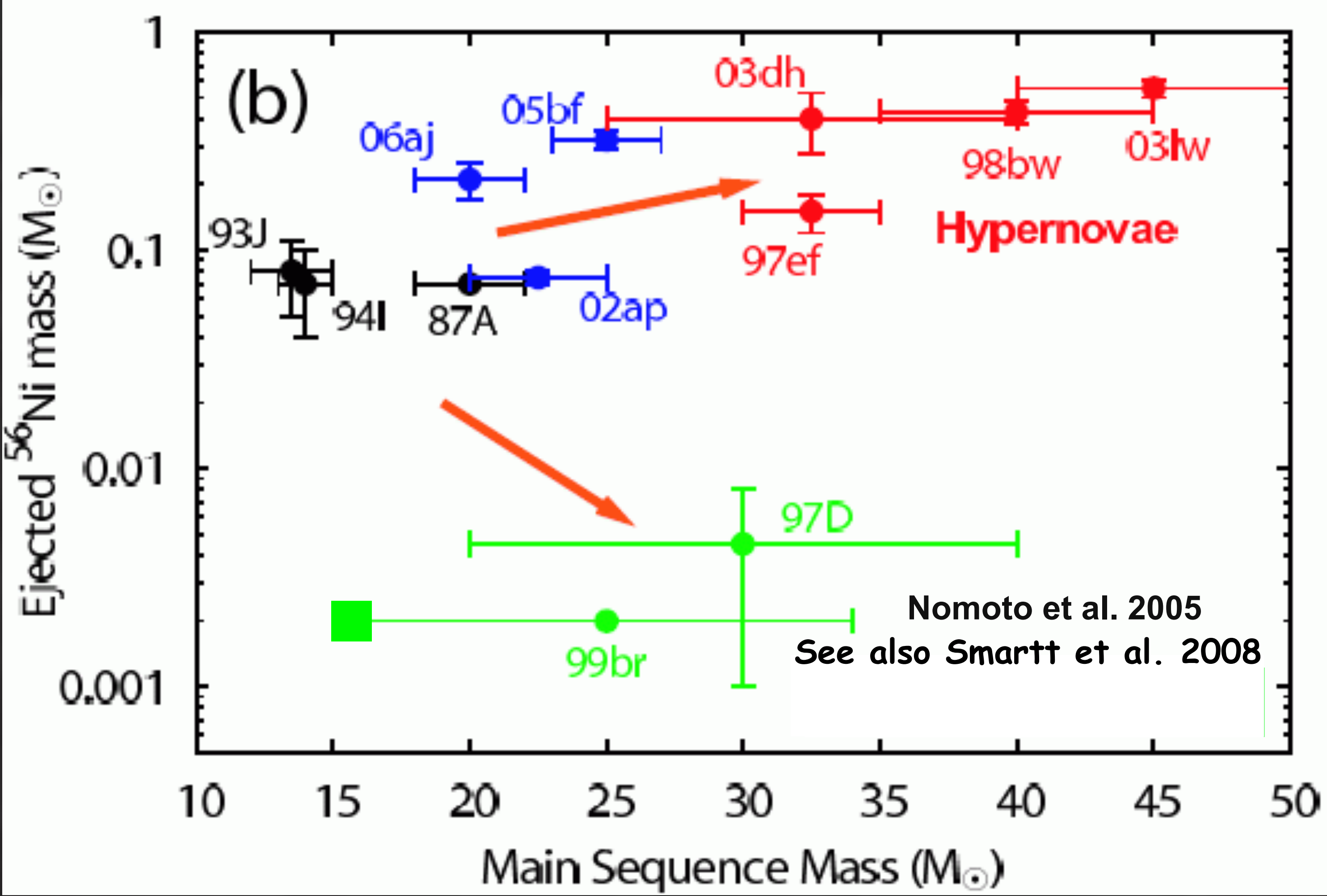
tyunyan[2,7], V. P. Hentunen[8,9], M.

Smartt[1]



SN 2008ha is the first faint, hydrogen deficient, low-energy core-collapse supernovae ever detected.

Potential “dark SN” (GRB progenitor) ?



GRB 060614: SN with small explosion energy → low expansion velocity → most ^{56}Ni falls back into the BH → small ^{56}Ni mass in the ejecta→ < $10^{-4/-5}$ $M_\odot$ ^{56}Ni → "Dark Supernovae" (see DV et al. 2006, Nomoto et al. 2007 and Tominaga et al. 2007)


ADESSO BASTA!!!