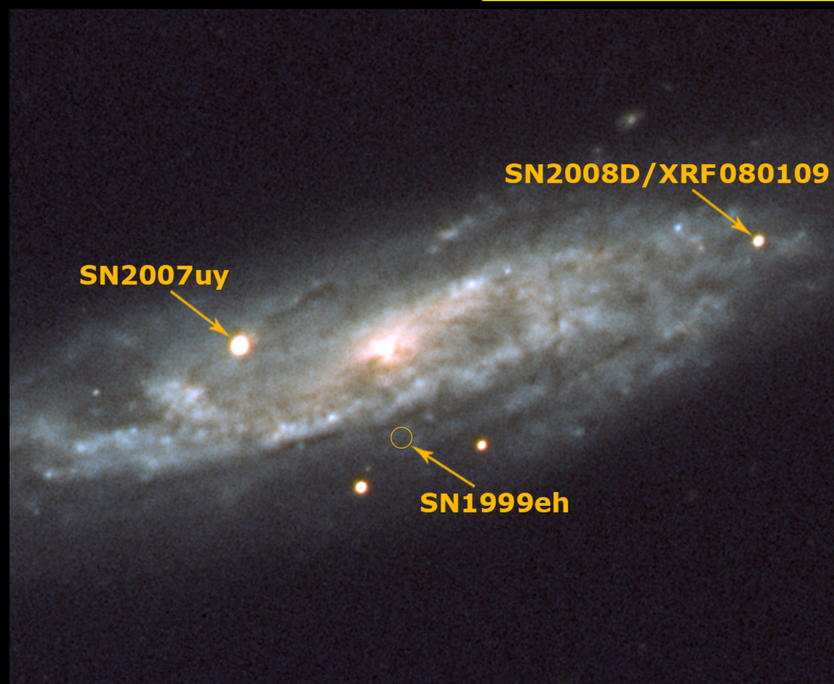
Diagnostics for Stripped SN Progenitors: Directly Measured Metallicities @ SN sites



A. de Ugarte Postigo (ESO) et al., Dark

Maryam Modjaz

Miller Postdoctoral Fellow/UC Berkeley

L. Kewley (IfA), J. S Bloom, A. V. Filippenko, D. Perley, J. M. Silvermann

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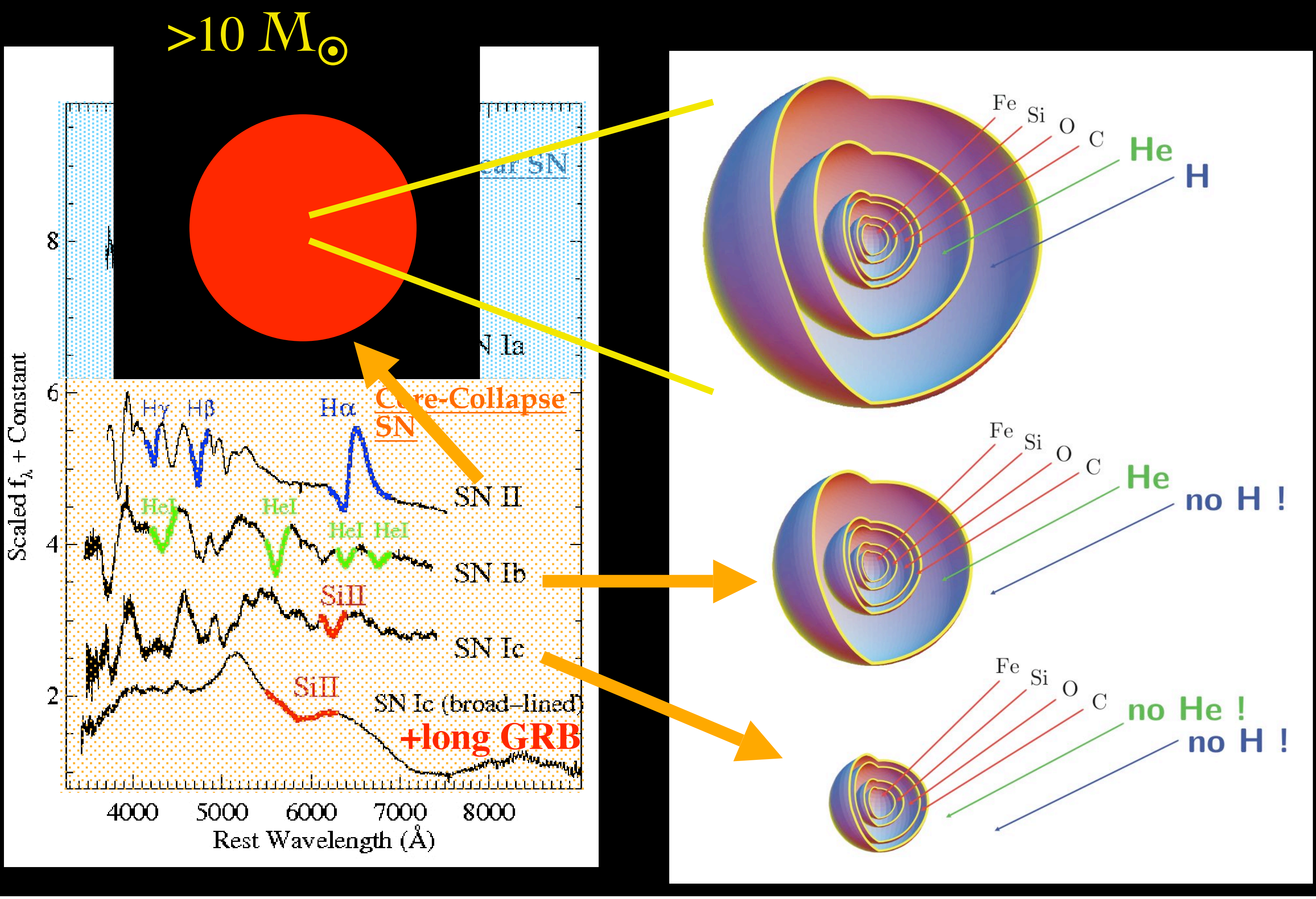
SN ZOO

- Spectra: Type I (no H) and Type II (with H)



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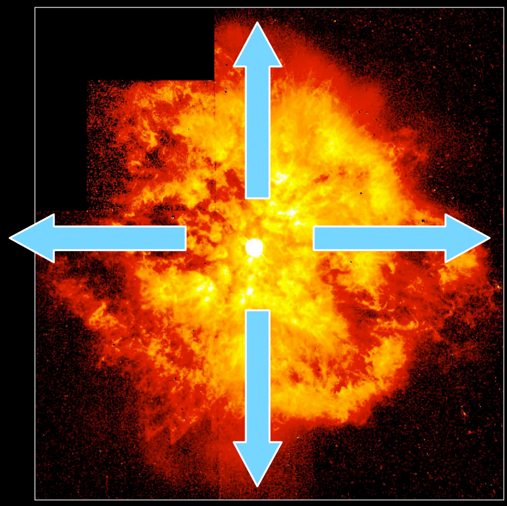
Hunt For SN Ib/c Progenitors

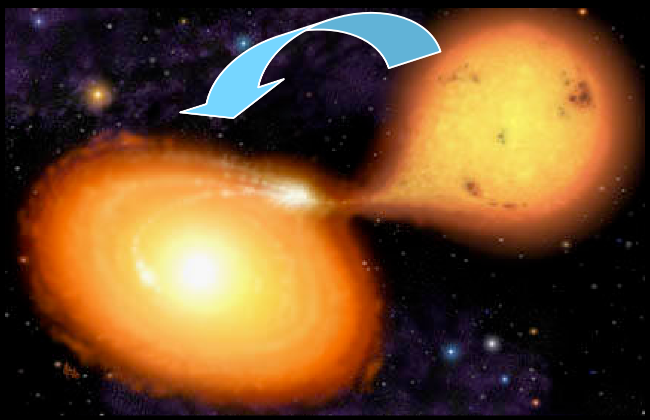
Possible SN Ib/c progenitors:



(Credit: Hubble/NASA)

Single massive (> 30 $M_\odot$) Wolf-Rayet stars with metallicity-dependent winds (e.g., Woosley et al. 1995, Maeder & Conti 2004, but see Smith & Owocki)

or



(Credit: Artist/NASA)

He stars (8-40 $M_\odot$) in binaries (e.g., Podsiadlowski et al. 2004)

?

- Differentiate between SN Ib and SN Ic progenitor models via Environments & their Metallicities: different Z_{SNII}, Z_{Ib}, Z_{Ic} expected from different models

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Definition of "metallicity"

- Metallicity = **Oxygen** abundance in gaseous nebula

  $12+\log_{10}(O/H)$

- Why **Oxygen**?
  - **Most abundant** element in gas phase
  - **Weakly depleted** onto grains
  - **Strong** nebular lines in optical
  - **Well-established** diagnostics, e.g., Kewley & Dopita (2002), Pettini & Pagel (2004)

- **From HII regions <u>at SN site</u>** by massive young stars

  = natal metallicity of core-collapse SN progenitor (NOT ejected during explosion)

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Previous SN Ib/c z-measurements

Samples of SN Ib/c hosts:

- SN Ic-bl with and without GRBs **(Modjaz et al. 2008)**
- Central metallicities of large # of SN galaxies in SDSS:
  $Z_{\mathrm{SNIb/c\text{-}Galaxies}} > Z_{\mathrm{SNII\text{-}Galaxies}}$ **(by 0.1 dex)** **(Prieto et al. 2008)**
- **Proxy** for local Z: Host L & L-Z & SN radius **(Boissier & Prantzos 2009)**
- No statistically significant difference b/w measured Z at/near SN position of SN Ib, Ic and II **(Anderson et al 2010 - next talk!)**

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- No statistically significant difference b/w measured Z at/near SN position of SN Ib, Ic and II **(Anderson et al 2010 - next talk!)**
- **But:** - No **local** Z, only nuclear proxy/measurement, but metallicity gradients **(e.g., van Zee et al. 1998)**
  - No distinction b/w SN Ib- or Ic-subtype
  - either historical SN (subtype or offset not well known) or only from targeted surveys

    -> variety of metallicity bias?

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Stripped SN metallicity program

50 Host Galaxy spectra of SN Ib, Ic, Ic-bl with 10m Keck I + LRIS (+Atmospheric Dispersion Corrector, ADC)

- Statistically significant sample
- 35 from **targeted** SN surveys, 15 from **untargeted**: mitigate selection effects **(e.g., Modjaz et al. 2008, Young et al. 2008)**
- Spectra of nucleus and at SN position (ADC!): probe **natal** Z
- Large λ range: **robust & uniform** Z estimate
- Uncertainty budget

Keck

(Credit: T.Mewlon/Cosmotography)

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"Gold" sample

SN IIb, Ib, Ic, Ic-bl with HII @ SN position

SN Name	SN Type	SN Host Galaxy	SN Redshift z	SN RA Offset[a] ["]	SN Dec Offset[a] ["]	SN Host Galaxy M_B [mag]	SN Discovery[b]
1990U	Ic	NGC 7479	0.00794	22W	54S	−21.7	T
1991ar	Ib	IC 49	0.01521	8.5E	12.5N	−20.1	T
1996aq	Ib	NGC 5584	0.00547	5W	8S	−19.8	T
1996D	Ic	NGC 1614	0.01582	6.6E	0	−21.4	T
1997B	Ic	IC 438	0.01041	42.0E	11.5N	−20.7	T
1999cn	Ic	MCG+02-38-043	0.02231	1.5W	8.3N	−19.9	T
1999di	Ib	NGC 776	0.01641	5.2E	17.0S	−21.2	T
1999dn	Ib	NGC 7714	0.00933	9.9E	9.4S	−20.5	T
2001ig	IIb	NGC 7424	0.00292	139E	109N	−19.6	T
2002bl	Ic-bl	UGC 5499	0.01591	5W	9N	−20.3	T
2004fe	Ic	NGC 132	0.01788	8.7E	12.3S	−21.1	T
2004gt	Ic	NGC 4038	0.00555	34W	10S	−21.4	T
2005eo	Ic	UGC 04132	0.01743	11.0E	26.1N	−22.2	T
2005mf	Ic	UGC 04798	0.01891	5.9W	13.3N	−20.5	T
2006jc	Ib-n	UGC 04904	0.00548	11W	7S	−15.9	T
2007gr	Ic	NGC 1058	0.00173	24.8W	15.8N	−18.6	T
2007cl	Ic	NGC 6479	0.02218	3.2W	8.2N	−20.9	T
2007rw	IIb	UGC 7798	0.00857	4.3E	8.9N	−19.1	T
2007uy	Ib	NGC 2770	0.00700	20.6E	15.5S	−20.7	T
2008D	Ib	NGC 2770	0.00700	38.3W	55.6N	−20.7	T
2008cx	IIb	NGC 309	0.01890	48.E	32.N	−22.1	T
2005kf	Ic	SDSSJ074726.40	0.01508	0.8E	0.6S	−17.0	Non-T
2006fo	Ic	UGC 02019	0.02074	6.0W	0.6N	−20.4	Non-T
2006ip	Ic	2MASXJ23483173	0.03062	1.0W	4.7S	−19.9	Non-T
2006jo	Ib	SDSSJ012314.96	0.07678	3.6W	2.1.S	−21.6	Non-T
2006ld	Ib	UGC 348	0.01394	11.1W	17.1N	−18.5	Non-T
2006lt	Ib	NSFJ021659.89	0.01602	0.	0.	...	Non-T
2007eb	Ic-bl	NSFJ224248.98	0.04262	0.	0.	...	Non-T
2007eq	Ib	NSFJ234805.93	0.02964	0.	0.	...	Non-T
2007gx	Ic-bl	NSFJ171851.49	0.07894	0.	0.	...	Non-T
2007jy	Ib	SDSSJ205121.43	0.18295	0.	0.	−19.6	Non-T
2007qw	Ic	SDSSJ223529.00	0.15064	0.1E	0.1N	...	Non-T
2008cw	IIb	SDSSJ163238.15	0.03193	1.0E	2.4N	−18.3	Non-T
1997ef[c]	Ic-bl	UGC 4107	0.0117	10.E	20.S	−20.2	T
1998ey[c]	Ic-bl	NGC 7080	0.0161	18.W	20.N	−21.8	T
2002ap[c]	Ic-bl	M 74	0.0022	258.W	108.S	−20.6	T
2003jd[c]	Ic-bl	MCG-01-59-21	0.0188	8.E	8.S	−20.3	T
2005nb[c]	Ic-bl	UGC 07230	0.0238	1.5W	5.N	−21.3	Non-T
2005kr[c]	Ic-bl	J030829.66+005320.1	0.1345	0.0E	0.1N	−17.4	Non-T
2005ks[c]	Ic-bl	J213756.52-000157.7	0.0987	0.0E	0.8N	−19.2	Non-T
2006nx[c]	Ic-bl	J033330.43-004038.0	0.1370	0.2E	0.2S	−18.9	Non-T
2006qk[c]	Ic-bl	J222532.38+000914.9	0.0584	0.0E	0.2N	−17.9	Non-T
2007I[c]	Ic-bl	J115913.13-013616.1	0.0216	0.8E	0.8S	−16.9	Non-T
2007Y[e]	Ib	NGC 1187	0.00464	24W	110S	−20.2	T
2007ru[d]	Ic-bl	UGC 12381	0.02218	4.4E	39.8S	−20.3	T

Targeted SN surveys (e.g., LOSS, Amateurs)

Untargeted SN surveys (e.g., SDSS, SN Factory, etc)

From Modjaz+08

Total 46, of which 34 are new

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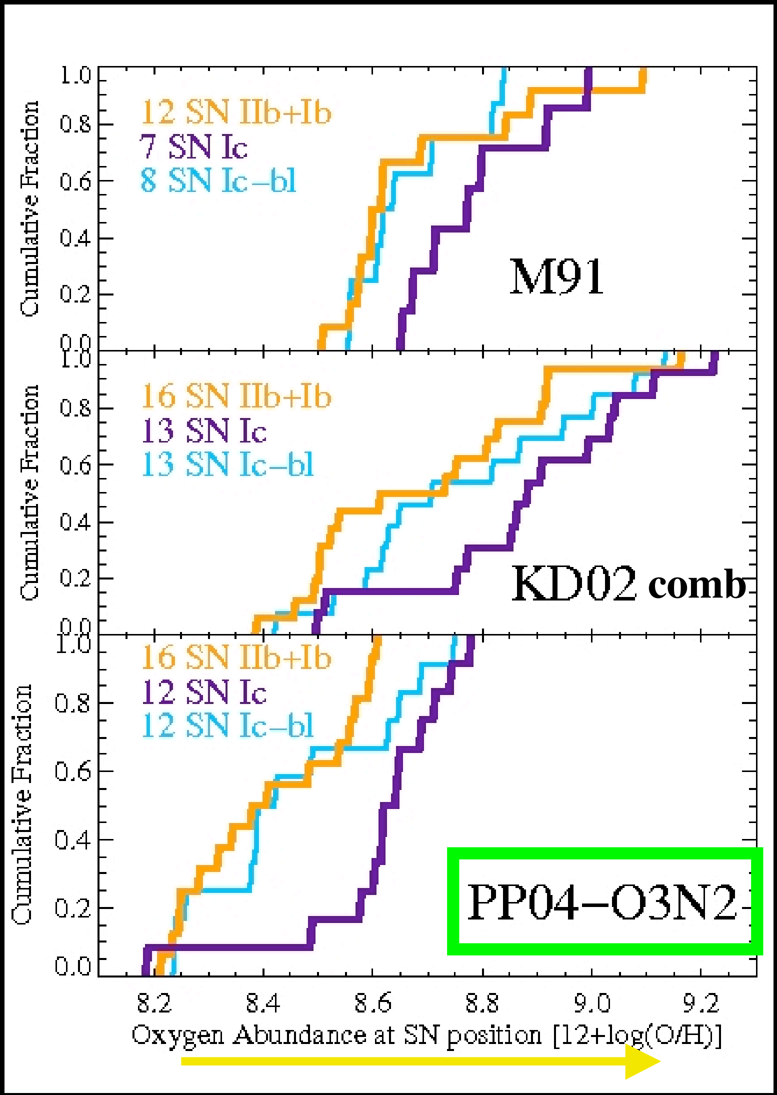
Modjaz et al (2010, ApJL submitted)

Sites of SN Ic are more Metal-rich than those of SN Ib



more metal-rich

- **Robust Conclusions**: seen in all 3 oxygen abundance calibrations

- KS test that Z's of SN Ib & Ic are drawn from same parent distribution:

McGaugh (M91): 2 %

Kewley & Dopita (KD02): 8%

Pettini & Pagel (PP04-O3N2): **0.1 %**

- SN Ic-bl (without GRBs) in between SN Ib and SN Ic

PP04-O3N2: least impacted by reddening and flux scaling uncertainties:

SN Ib & IIb: 8.41 +/- 0.009 (SDOM)

SN Ic: 8.61 +/- 0.013

SN Ic-bl: 8.46 +/- 0.013

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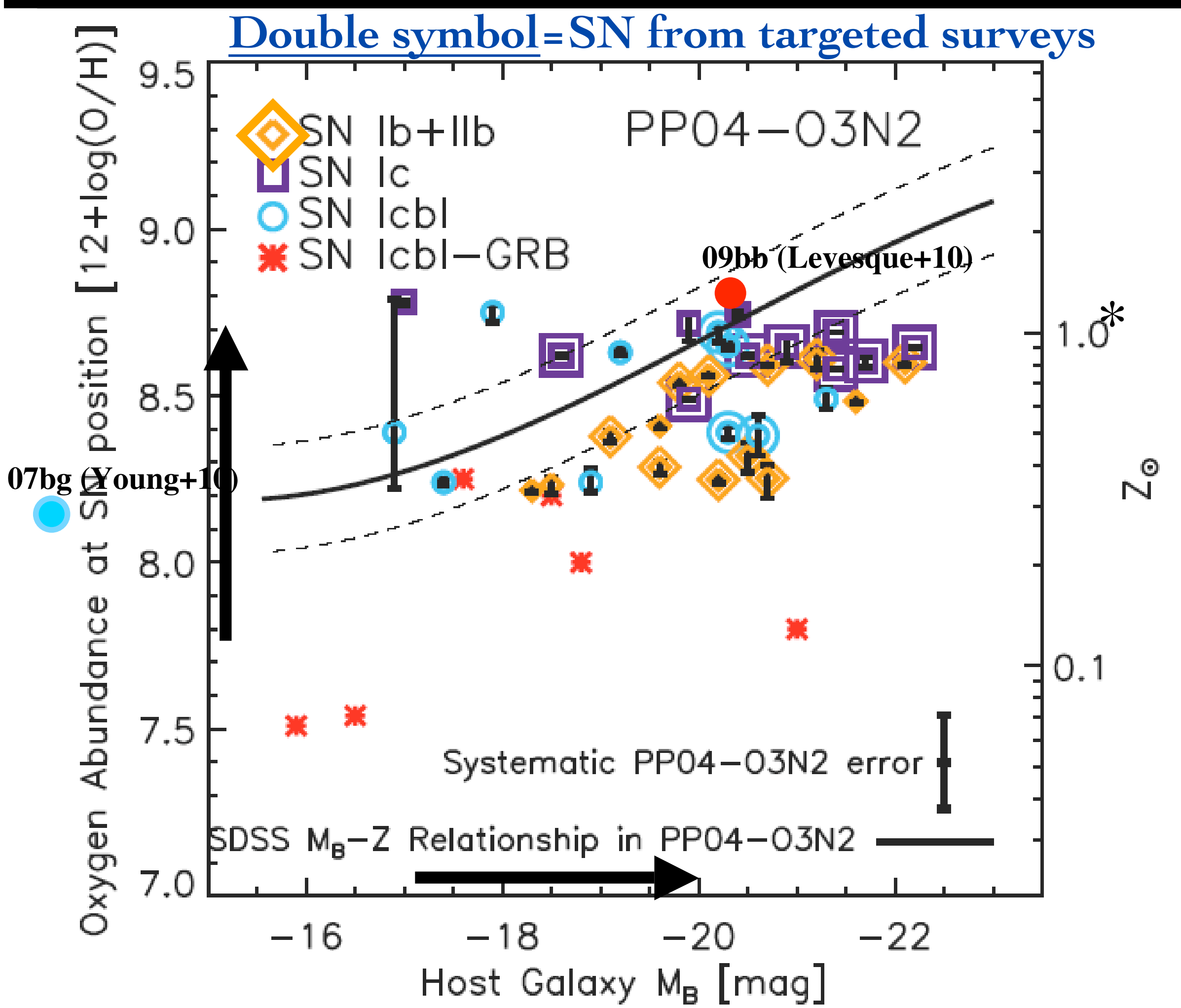
NEED FOR LOCAL Z MEASUREMENTS



1) All SN from low-L hosts are from untargeted SN surveys
(5 SN hosts not shown b/c no measured M_B yet)

2) Big Difference b/w L-Z prediction and measured local Z:

-0.4 dex < Δ Z < 0.5 dex

FUTURE: This kind of local Z study for SN hosts from untargeted, homogenous surveys (PTF, PanSTARRS, Skymappter, etc)

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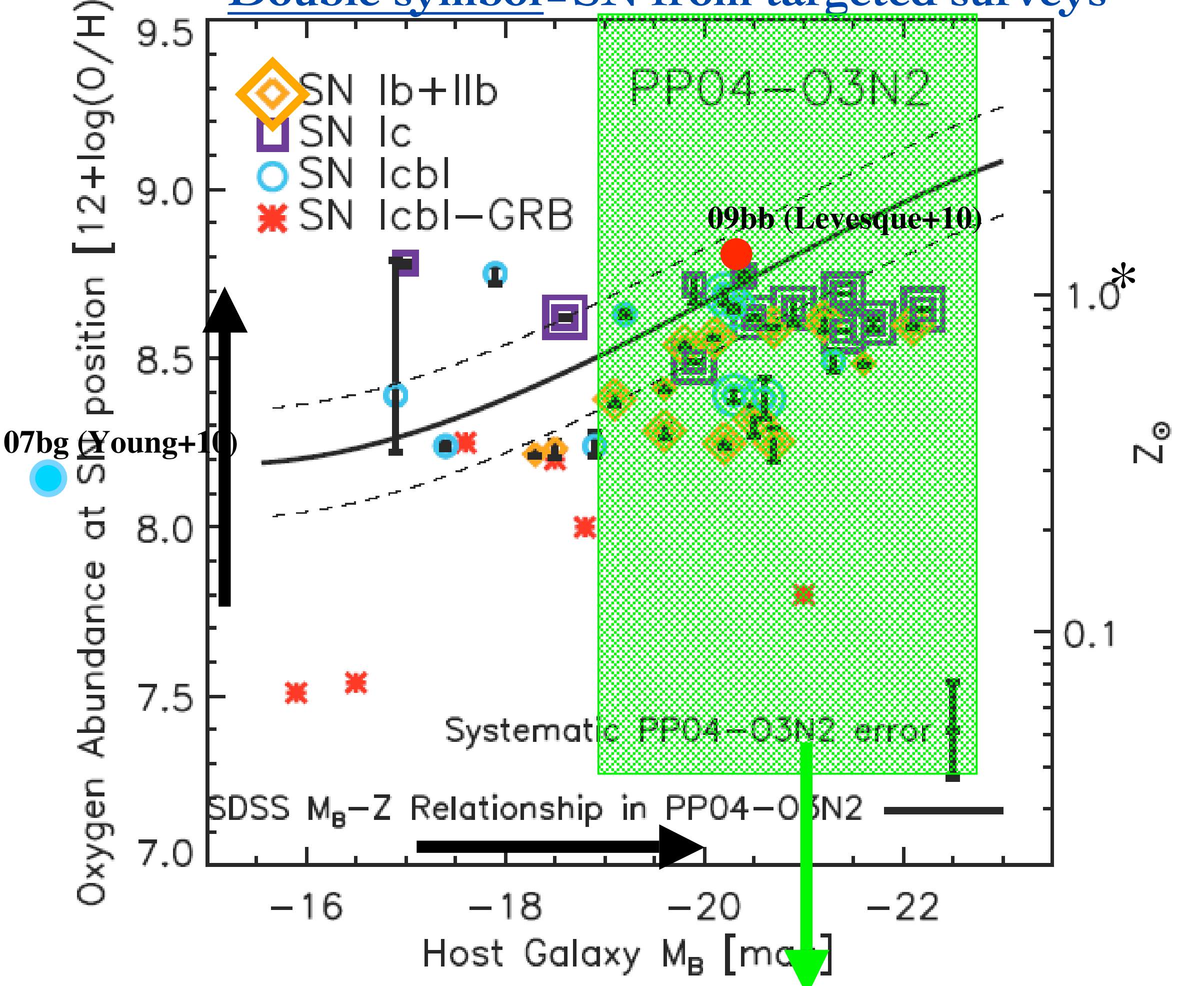
(*): $Z_\odot$ = 12+log(O/H) = 8.69 (Asplund et al. 2009)

Need for Local Z measurements

Double symbol=SN from targeted surveys



e.g., targeted galaxies in Lick SN Survey (Li et al. 2010)

1) All SN from low-L hosts are from untargeted SN surveys
(5 SN hosts not shown b/c no measured M_B yet)

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Selection Effects?

- Yes, heterogeneous sample, **but** no systematic effect that would affect SN Ib differently than SN Ic:
  - Both SN Ib & Ic to equal parts from **targeted and untargeted** surveys
  - SN Ib & Ic: **similar redshift range**

    <*z*> = 0.015 (SN Ib), <*z*> = 0.016 (SN Ic)
  - No "Shaw" effect **b/c no photographic-plate SN**
  - "Nuclear" SN detection problem, **but all stripped SN types in my sample to ~equal parts either far or nuclear**

- Big selection effect: HII regions @SN pos

  ->Recent burst of star formation activity (~million years)

  (Next step: construct Z gradients and extrapolate to SN position)

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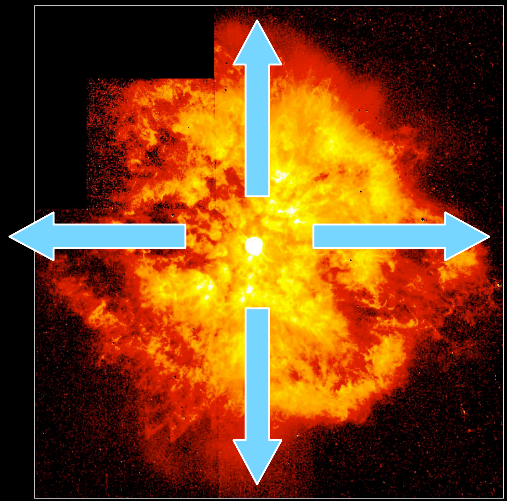
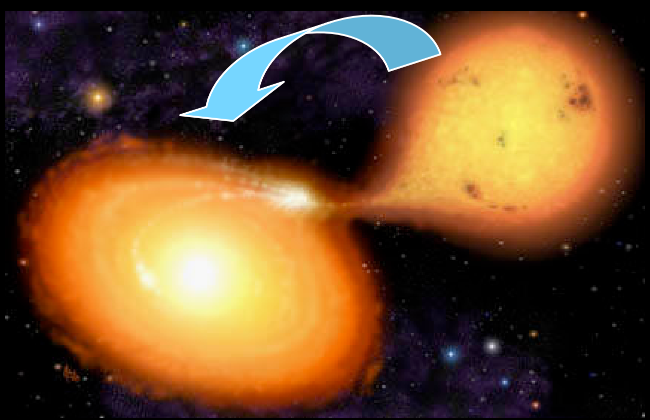
Our Results in Context

- Direct confirmation of independent study of Arcavi et al. (2010)
- Implication for Progenitor Models: with $\dot{M} \propto Z^{0.86}$ (Vink & deKoter 05) is a factor of 3 in Mdot enough for SN Ic single-star progenitors to strip He layer?



(Credit: Hubble/NASA)

or



(Credit: Artist/NASA)

?

Consistent with suggestion for producing SN Ib vs. SN Ic by Smith et al (2010), where SN Ic come from more metal-rich (and more massive) stars than SN Ib even if in binary:

1) To strip H-layer, need binary or eruptive episode
2) To strip He-layer (for SN Ic), need metallicity-dependent wind

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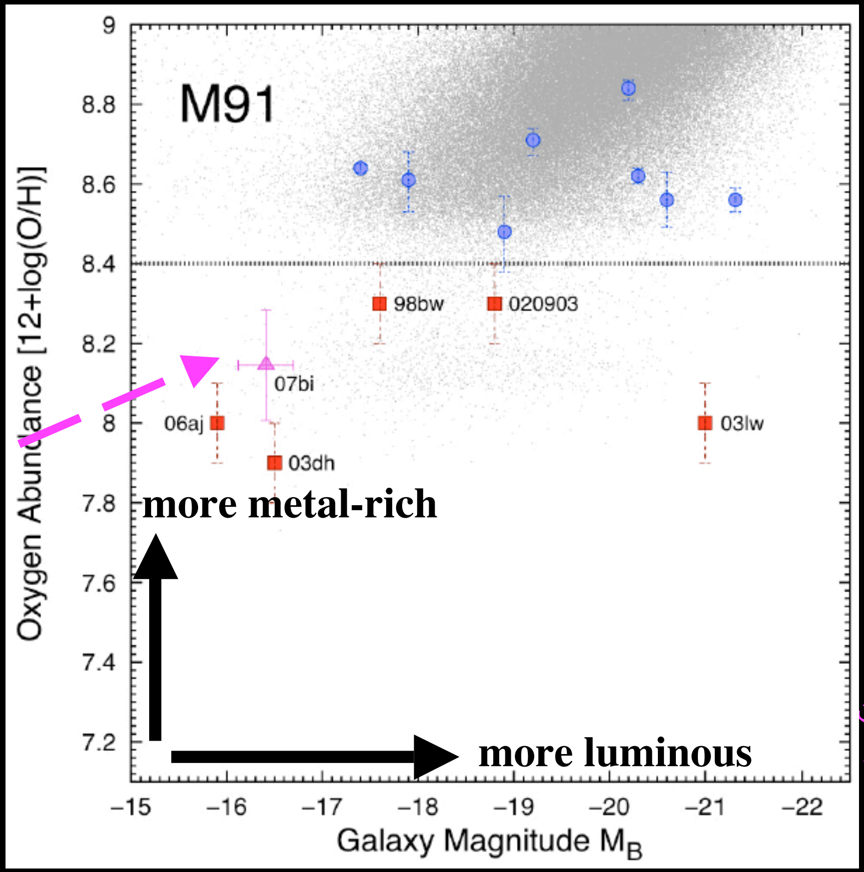
Metallicity Studies: Rapidly developing field

- Individual Objects:
  - Radio-Relativistic SN at high Z (Soderberg et al. 2009, Levesque et al. 2009)
  - 2 "Dark" Bursts (Graham et al. 2009, Levesque et al. 2010)
  - Candidate Off-axis GRB-SN & potential Pair-Instability SN 07bi (Young et al. 2009)
  - High-*z* GRBs (Levesque, Kewley, et al 2010)
  - GRB "Identity Crisis": Short vs. Long GRBs (Gal-Yam et al, Fynbo et al, Della Valle et al, 2006, Levesque & Kewley 2007, Thoene et al. 2007)



Young et al (2009), adapted from Modjaz et al. (2008a)

<u>**See GRB-talks on Wed**</u>

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Conclusions: Locally Measured Z for Stripped SN

- SN progenitor metallicity predicted to be amongst the crucial progenitor parameters …
  yet few direct metallicity studies as of a few years ago
- Results for SN-GRB:
  - Locations of nearby (*z*<0.14) broad-lined SN Ic without GRB have systematically larger Z than SN with GRBs **(Modjaz+ 08, but see 09bb)**
- Large Metallicity Keck Program for SN Ib, Ic, Ic-bl:
  - $\mathbf{Z_{SNIc} > Z_{SNIb}}$: robust & uniform Z measurements
  - $\mathbf{Z_{SNIc\text{-}bl\ (w/o\ observed\ GRB)}}$ in between Z_{SNIb} and Z_{SNIc}
  - Need **local Z** measurements vs. nuclear measurements

  } **(Modjaz+ 10)**
- Stay tuned! SN metallicity measurements constitute a rapidly developing & emerging field!

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