CSI: Supernova

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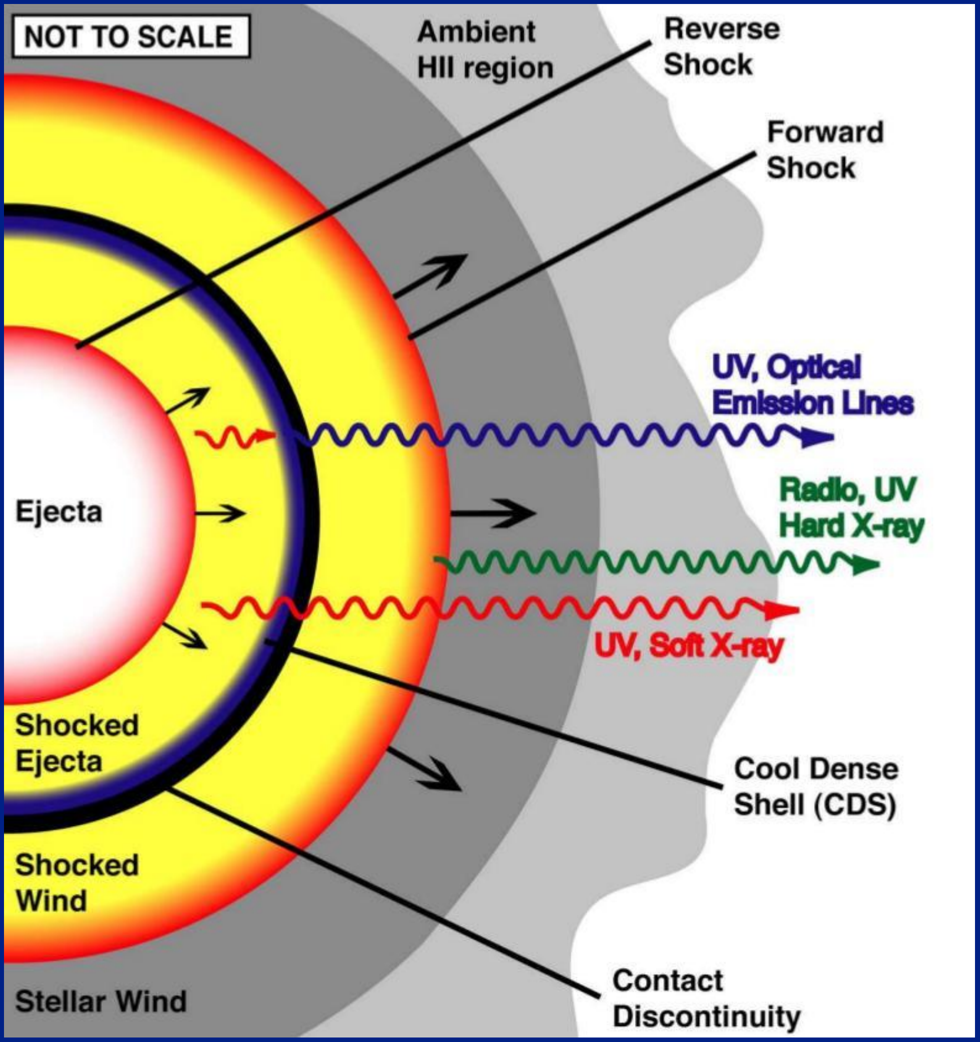
Circum-Stellar Interaction

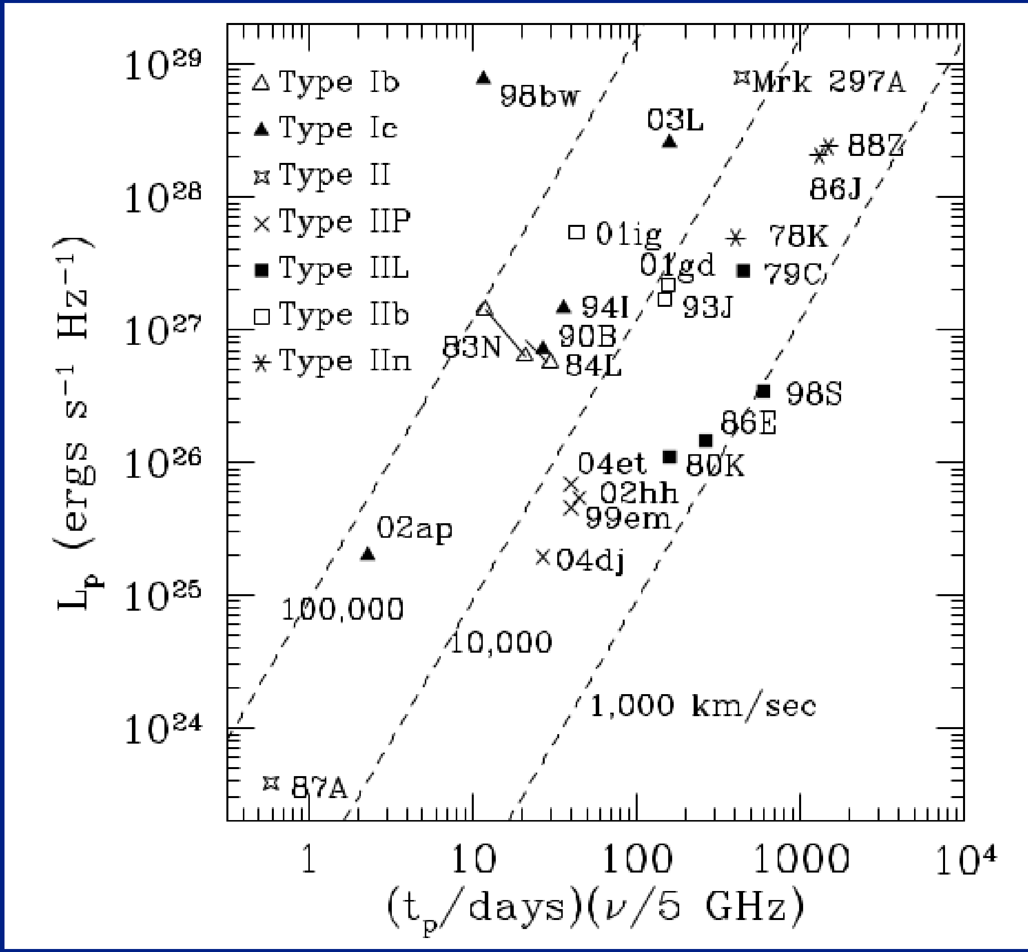


Radio properties of CCSNe

Table 1: Typical radio parameters of core-collapse supernovae

SN Type	f_{CCSN}	α	β	δ	$t_{\mathrm{peak(days)}} \times (\nu/5\ \mathrm{GHz})$	$L_{\nu,\mathrm{peak}}/(10^{26}\mathrm{erg/s/Hz})$
Ib/c	26.0%	-1.1	-1.4	-2.5	2 - 100	0.2 - 200
IIb	10.6%	-1.1	-1.0	-2.0	180	15
IIP	48.2%	-0.7	$-(0.7$ - $1.2)$	-3.0	30 - 500	$\lesssim 2$
IIL	6.4%	-0.7	-0.8	$-(2.7$ - $3.0)$	100 - 800	1 - 30
IIn	8.8%	-0.7	$-(1.3$ - $1.7)$	-3.0	$\gtrsim 800$	100 - 200

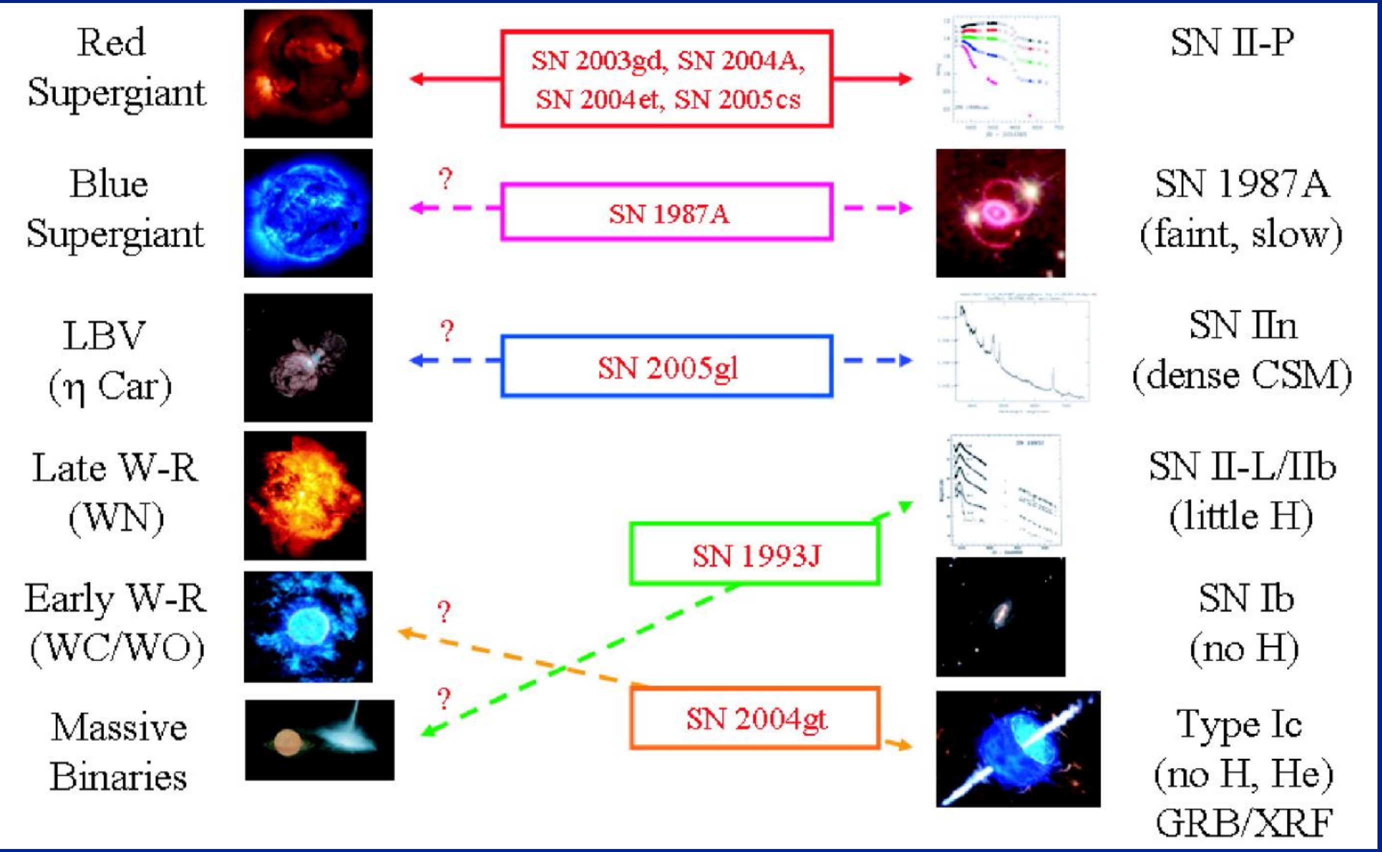
Radio properties of CCSNe



Science Goals

1. What are the progenitors to different (sub-)types of supernova?

Gal-Yam et al. 2007



Mass-loss rates

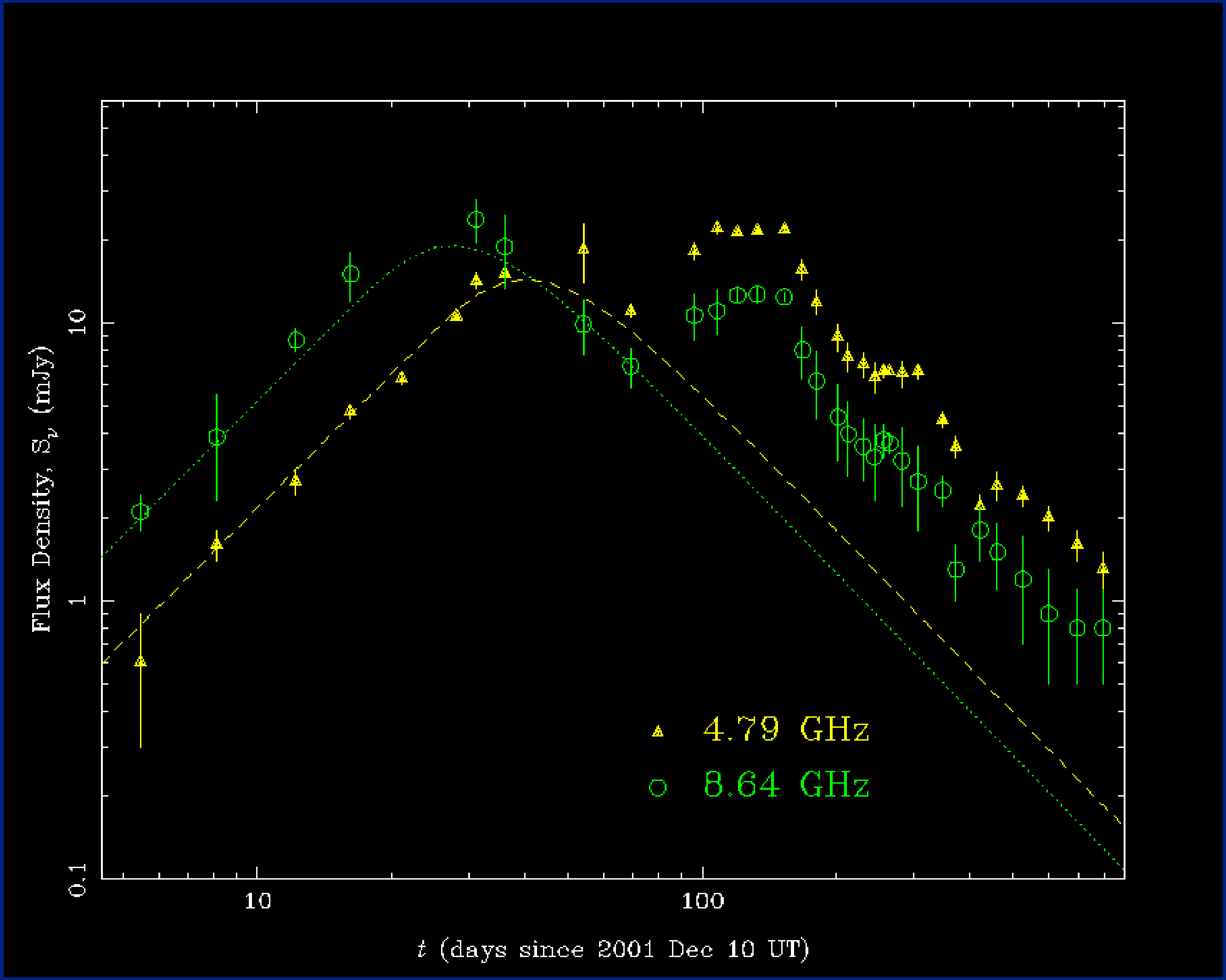
Radio light curve fitting ⇒ $\dot{M}$ ($M_\odot$ yr^{-1}) / v_{wind} (km s^{-1})

Table 1: Mapping of SN types to their likely progenitor star properties

SN	Progenitor Star[a]	M_{ZAMS}	$\dot{M}^b$	V_∞
...	...	($M_\odot$)	($M_\odot$ yr^{-1})	(km s^{-1})
II-P	RSG	8–20	10^{-6}–10^{-5}	10-20
II-L	RSG/YSG	20–30 (?)	10^{-5}–10^{-4}	20-40
II-pec	BSG (b)	15–25	10^{-6}–10^{-4}	100-300
IIb	YSG (b)	10–25	10^{-5}–10^{-4}	20-100
Ib	He star (b)	15–25 (?)	10^{-7}–10^{-4}	100-1000
Ic	He star (b)/WR	25–?	10^{-7}–10^{-4}	1000
Ic-BL	He star (b)/WR	25–?	10^{-6}–10^{-5}	1000
IIn (SL)	LBV	30–?	(1–10)	50-600
IIn	LBV/B[e] (b)	25–?	(0.01-1)	50-600
IIn	RSG/YHG	25–40	10^{-4}–10^{-3}	30-100
IIn-P	super-AGB	8–10	0.01-1	10-600
Ibn	WR/LBV	40–?	10^{-3}–0.1	1000
Ia/IIn	WD (b)	5-8 (?)	0.01-1	50-100

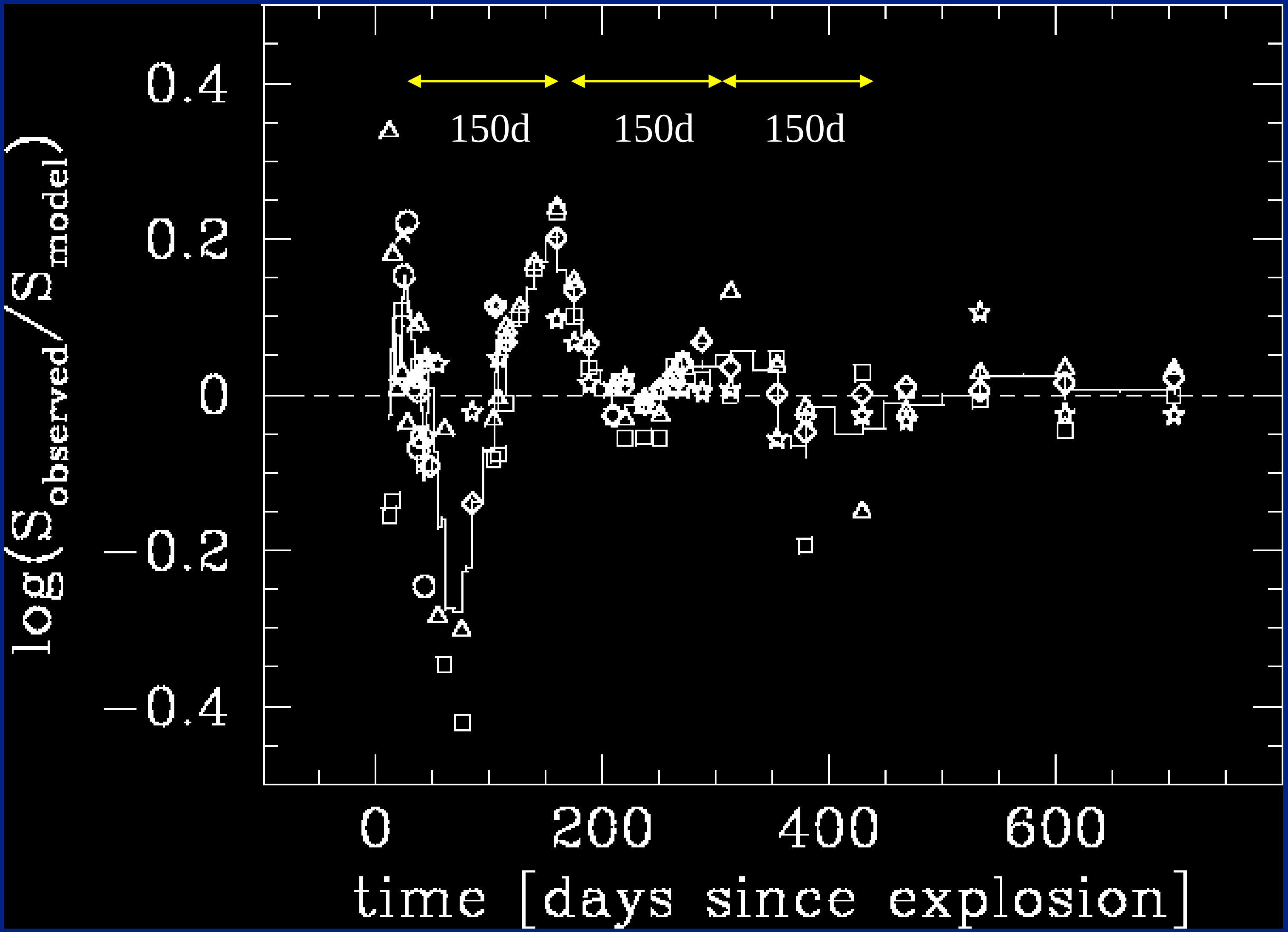
N. Smith 2014

Type IIb SN 2001ig



Ryder et al. 2004

Episodic mass-loss?



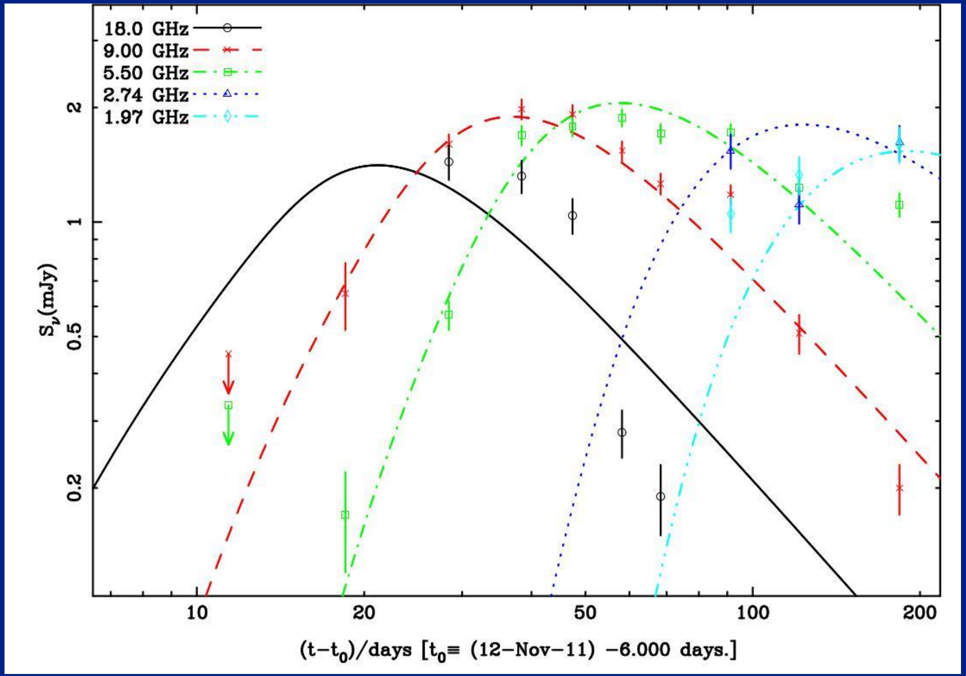
C1473: CCSNe NAPA

Supernova	Type	Host	D (Mpc)	Notes
SN 2010as	Ib/c	NGC 6000	27	~1.5 mJy @ 9.0 & 5.5 GHz
SN 2011cb	IIb	IC 5249	29	~0.5 mJy @ 9.0 & 5.5 GHz
SN 2011hp	Ic	NGC 4219	24	Not detected
SN 2011hs	IIb	IC 5267	26	Bufano et al. (2013)
SN 2011ja	IIP	NGC 4945	4	Chakraborti et al. (2013)
SN 2012hs	II	ESO 213-G2	24	Not detected (ATel 4667)
ASASSN-14ha	II	NGC 1566	10	Not detected (ATel 6480)
PSN J00150875-3912501	?	NGC 55	2	Not detected (ATel 6663). Nova / LBV outburst?
SN 2015J	IIn	???	~20	~0.1 mJy @ 9.0 & 5.5 GHz

Type IIb SN 2011hs

- Faster rise and decline than SN 2001ig, only half as luminous (1.6×10^{27} ergs s^{-1} Hz^{-1}), no companion?
- Mass loss rate (2×10^{-5} $M_{\odot}$ yr^{-1}) almost identical – same (WR) progenitor type?

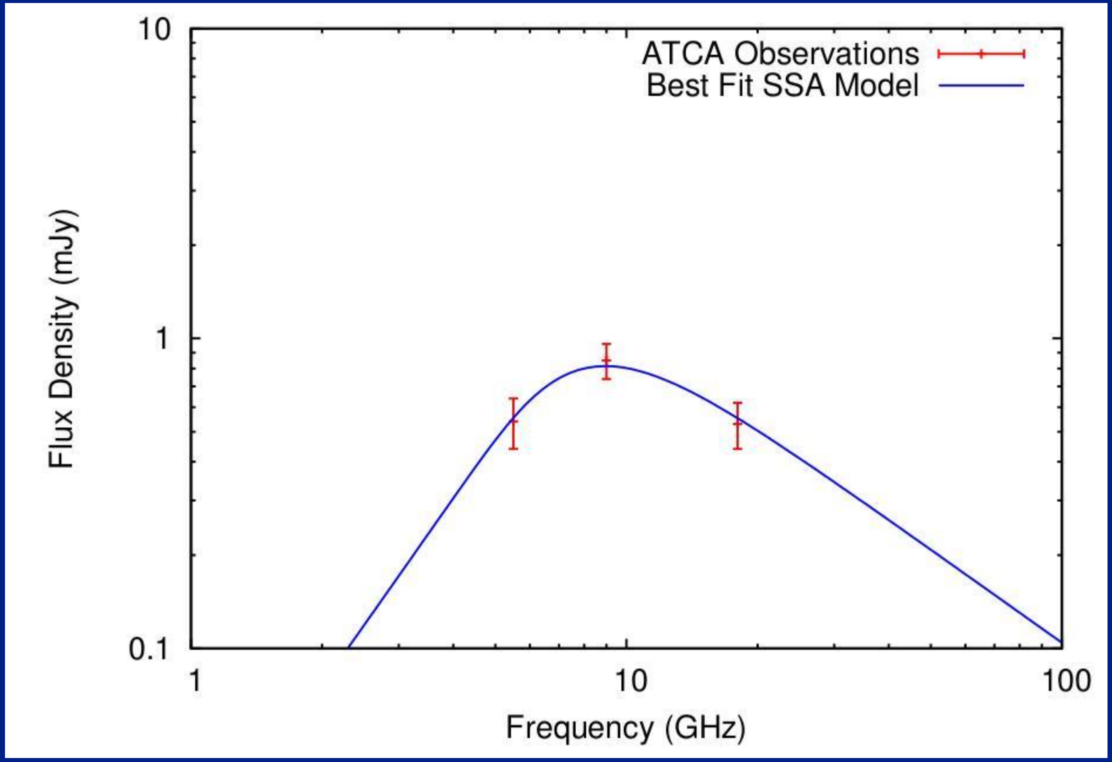
Bufano, Ryder, et al. 2013



Type IIP SN 2011ja

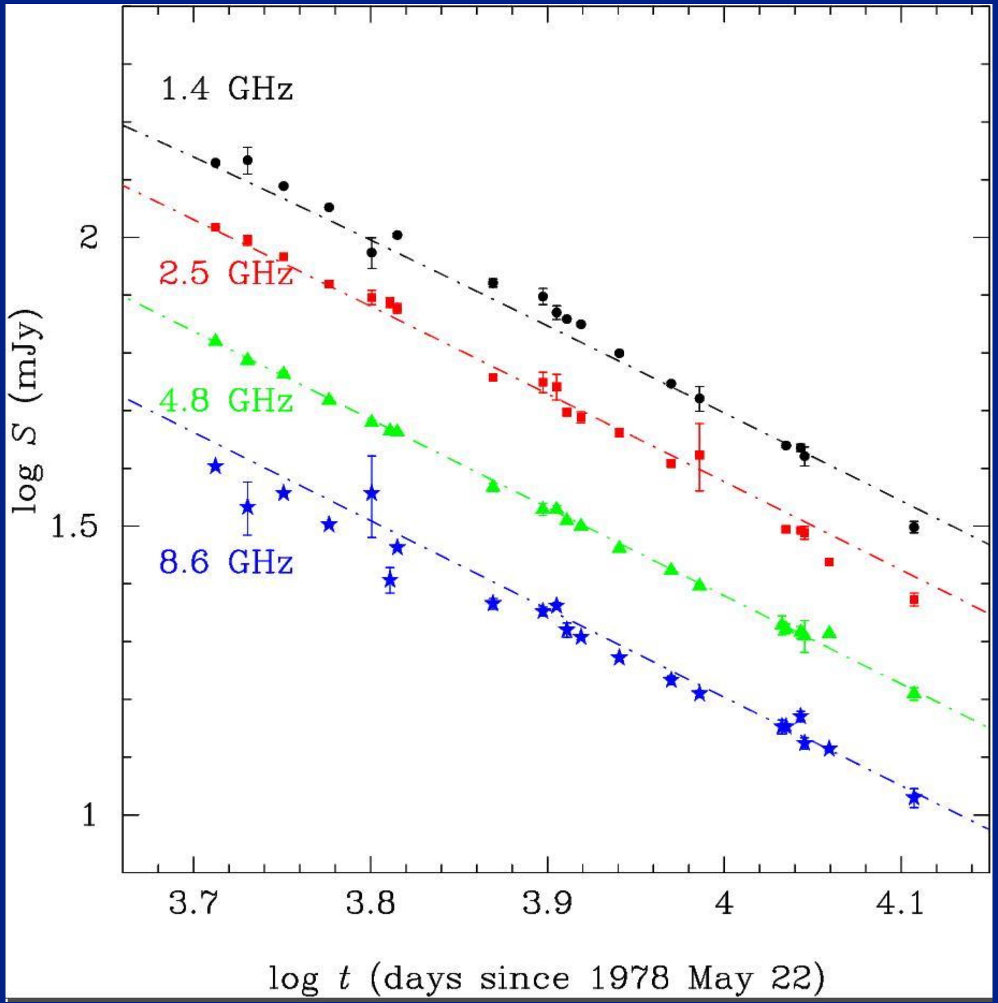
- ATCA detection constrains explosion date.
- Multiple *Chandra* detections indicate low density bubble surrounded by slow-moving wind from >12 $M_\odot$ RSG.

Chakraborti, Ryder, et al. 2013



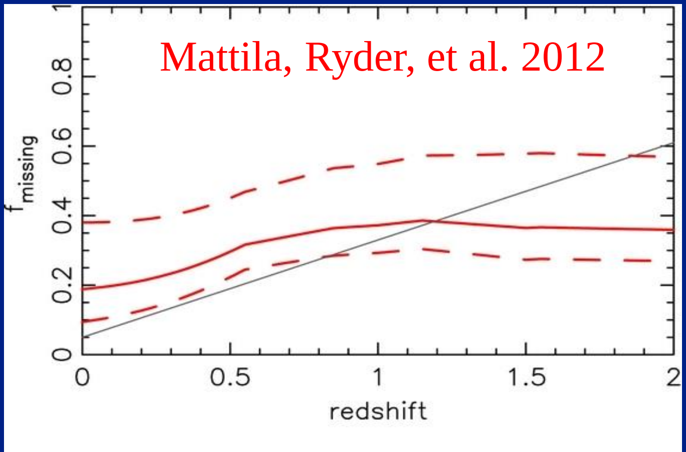
SN 1978K radio light curve

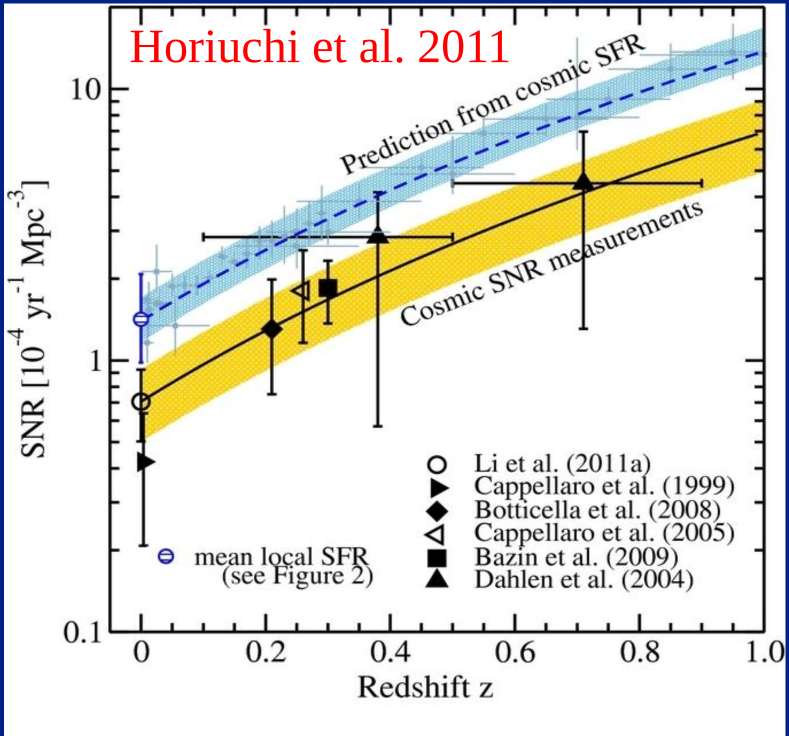
- 24 years of ATCA monitoring (C184).
- Type IIn.
- Progenitor mass-loss rate constant for last 35 (v_{shock} / v_{wind}) yr.
- ATCA detections at 34 and 94 GHz.
- ALMA observations in Cycle 3.



Science Goals

1. What are the progenitors to different (sub-)types of supernova?
2. Towards a complete census of core-collapse supernovae in the local universe.





ASKAP

- Australian Square Kilometre Array Pathfinder.
- 36 × 12m antennas with phased-array feeds ⇒ 30 sq. deg. FoV!
- 0.7–1.8 GHz, 300 MHz bandwidth.
- 10 Survey Science Projects, incl. Variables And Slow Transients (VAST) survey.

SNe in VAST

- Aim to catch SNe on rise at 1.4 GHz in VAST-Wide when flux ~doubles in a week.
- SkyMapper, WiFeS or Gemini ToO for confirmation and sub-type if not previously reported.
- Activate ATCA NAPA to try and catch 5 GHz peak, and *Chandra* ToO.
- Anticipate ~50 core-collapse SNe within 50 Mpc per year, 50% in south, and 50% detection rate
  $\Rightarrow$ 1 SN/month?
- 10" resolution barely adequate to spatially resolve SN from AGN and/or diffuse disk emission, but temporal resolution possible against faint background.

Looking ahead

- What fraction of CCSNe give rise to prompt radio emission?
- What can this reveal about their progenitor populations?
- VAST with ASKAP: first census of CCSNe at radio wavelengths.
- ATCA/JVLA follow-up at higher frequencies will still be vital to derive CSM properties and progenitor mass-loss history.