The Stellar Ancestry of the Youngest Supernovae in the LMC

Work in Progress

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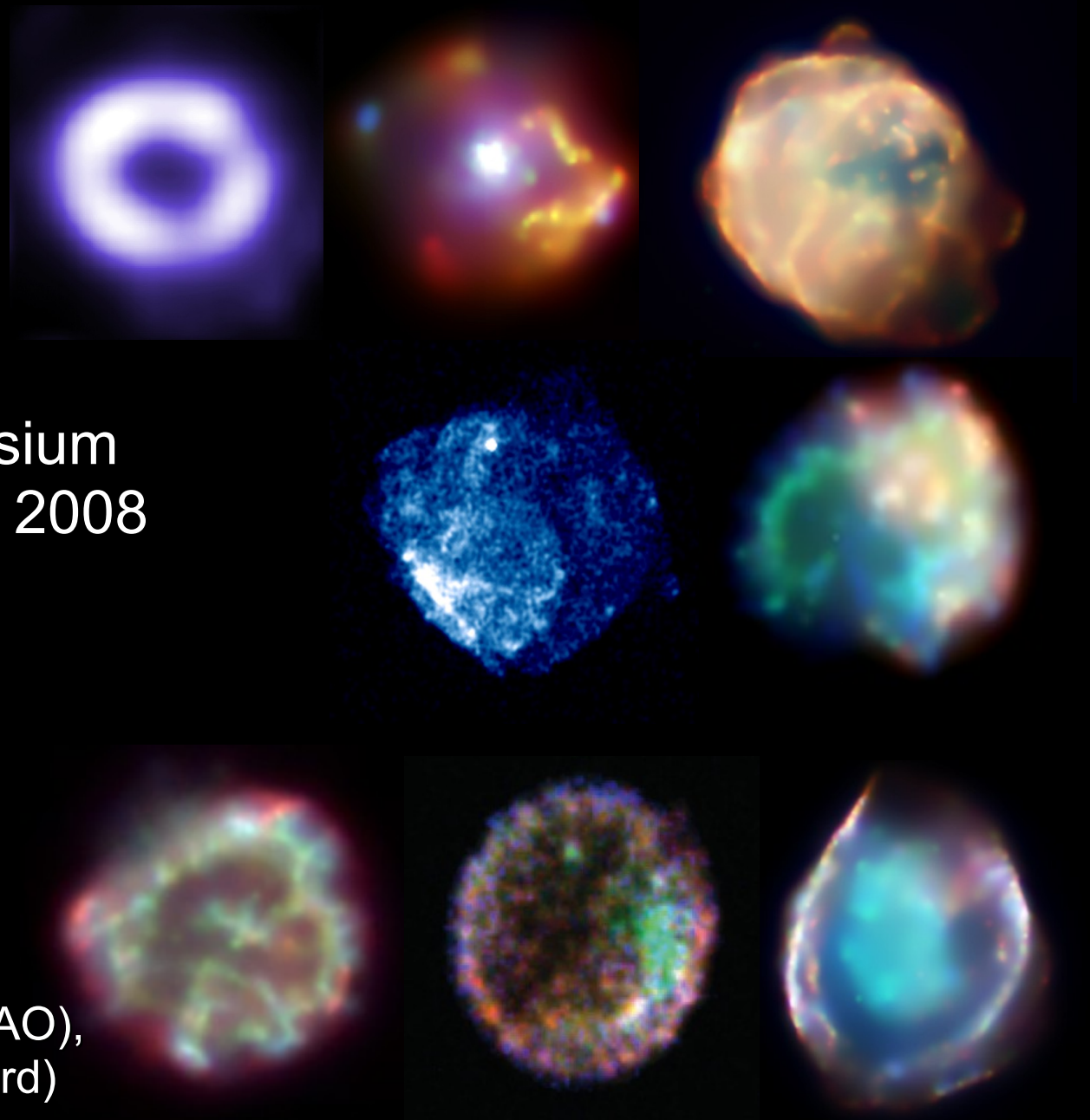
(Princeton University)



Chandra Fellows Symposium
Harvard CfA, October 17 2008

Collaborators:
J.L. Prieto (OSU), J. Harris (NOAO),
D. Zaritsky (UA), A. Rest (Harvard)

Supernova Progenitors

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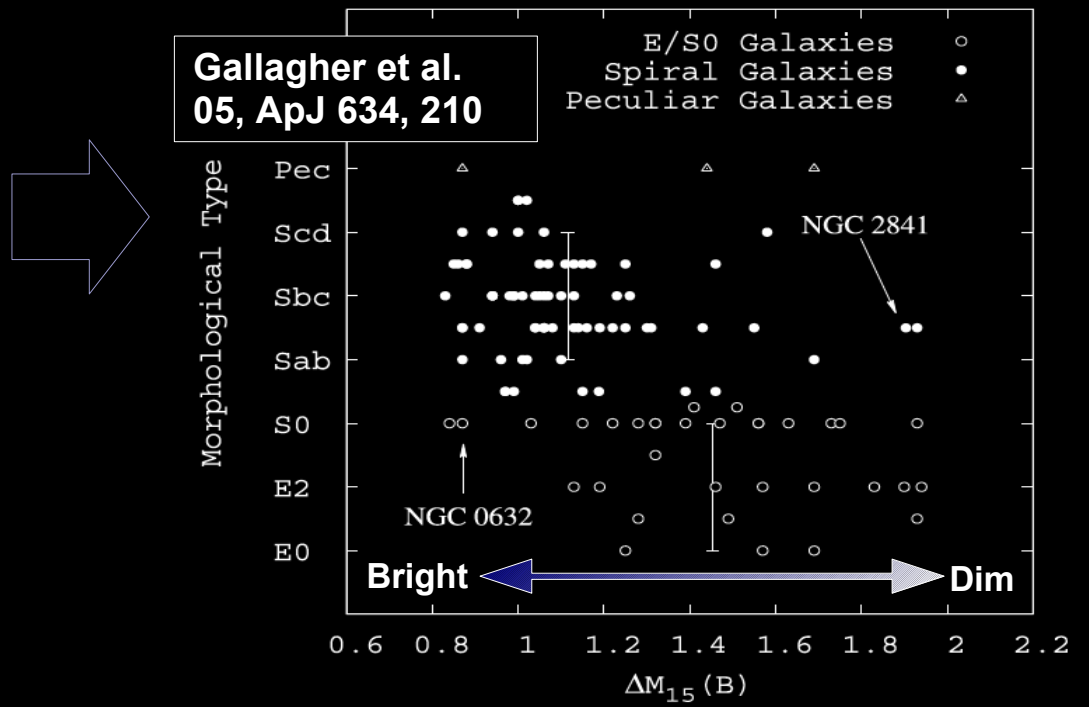
- **Core Collapse SNe (Type II, Ib, Ic)** ⇒ Massive stars ($M>8M_{\odot}$)
  - 9 direct detections (incl. SN 1987A), ~15 upper limits [Smartt et al. 08, arXiv:0809.0403, Kochanek et al. 08, ApJ 684, 1336].
  - Open issues: Mapping stars to SN subtypes (II-P, II-L, IIn, Ib/c), 'silent' SNe, ...
- **Thermonuclear SNe (Type Ia)** ⇒ ?
  - No direct detections; progenitor identity IS an open issue (cosmology).

No direct detections ⇒ study the host galaxies of SNe [Sullivan et al. 06, ApJ 648, 868; Prieto et al. 08, apJ 673, 999; Gallagher et al. 08, ApJ 685, 752]. Issues:

- Usually probe *entire* host [Modjaz et al. 08, AJ 135, 1136].
- Unresolved stellar populations.



Stars in the LMC

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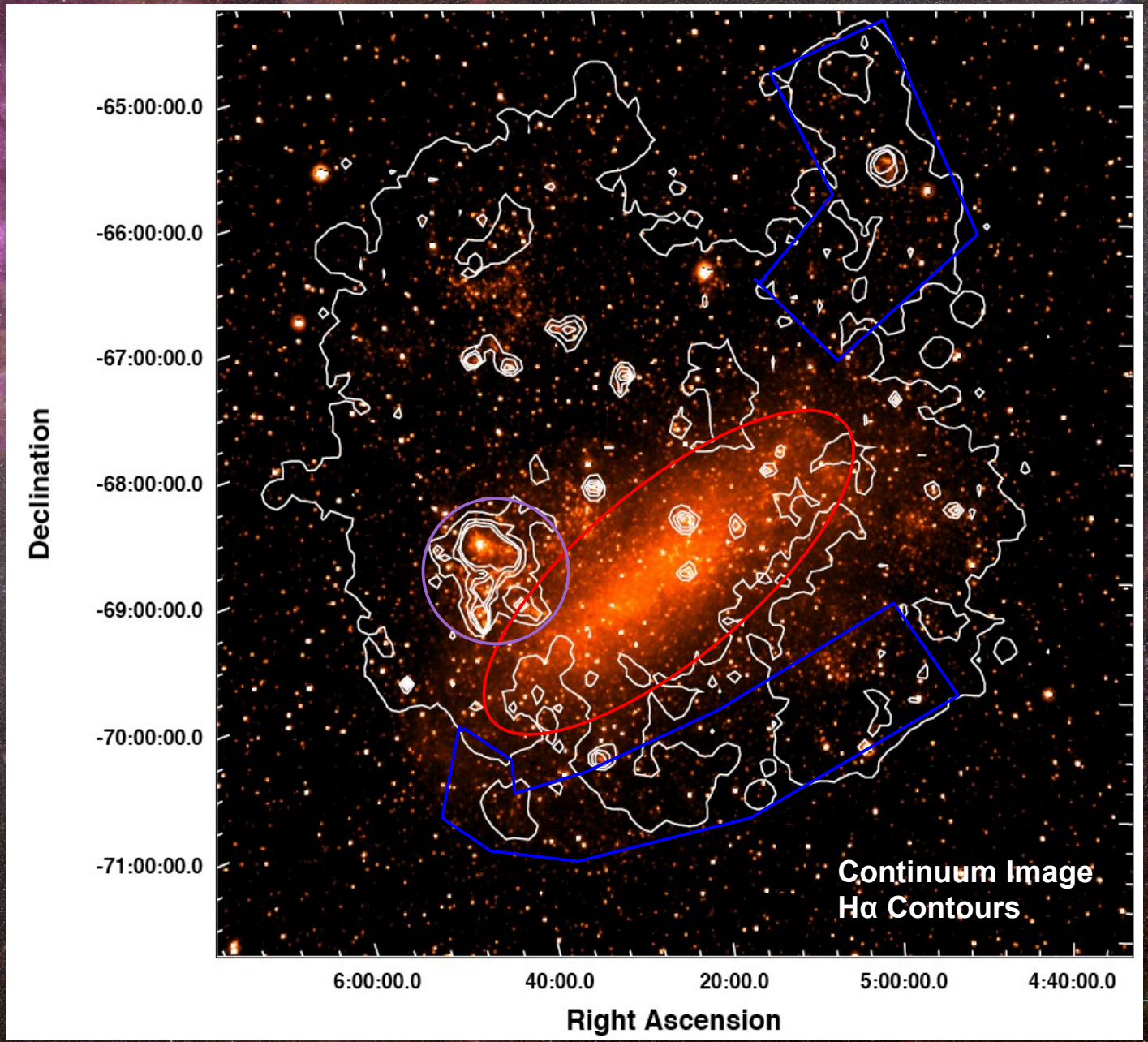
- Quick facts:
  - D=50 kpc
  - Face-on (θ~35º)
  - 11ºx9º on the sky
  - Irr/SB(s)m
  - $M_{stars} \sim 10^{10}\ M_{\odot}$
  - Active SF
- Grand tour of the LMC: Bar, 30 Dor, 'Spiral Arms'.
- The stellar population of the LMC is *resolved.*



LMC image from MCELS (C. Smith et al.)

SFH Map of the LMC

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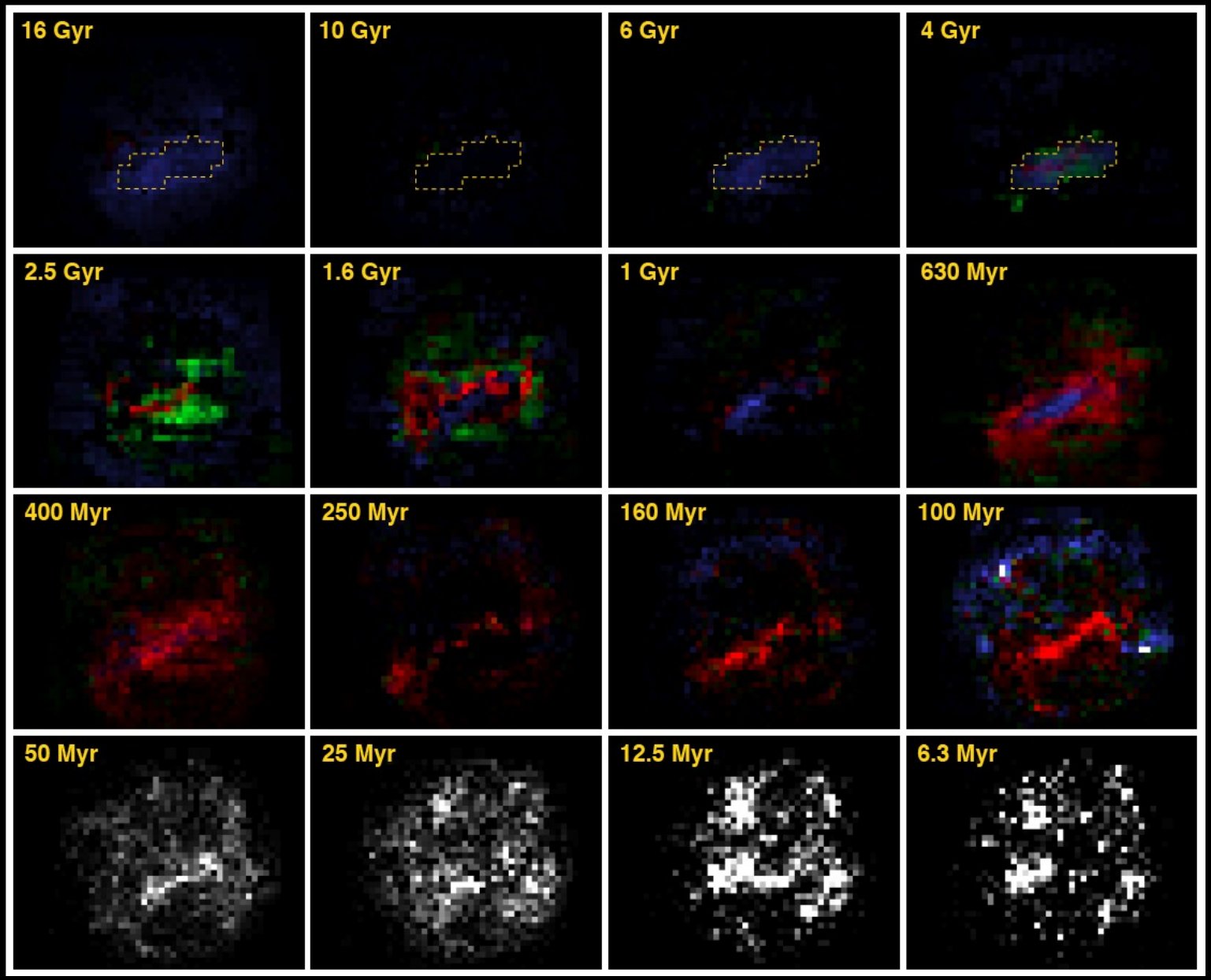
Harris & Zaritsky 08, ApJ submitted [Z=0.008; Z=0.004; Z=0.001]



- SFH (Star Formation History) map of the LMC: ages, metallicities for a 50x40 grid.
- MCPS [Zaritsky et al. 04, AJ 128, 1606] ⇒ 2×10^7 stars.
- StarFISH [Harris & Zaritsky 01, ApJS 136, 25] ⇒ SFH of mixed populations.

SNRs in the LMC

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- How can one study SN explosions in the LMC? Waiting for an actual SN worked once (in 1987).

- More than 30 Supernova Remnants (SNRs) have been catalogued in the LMC [Williams et al 99, ApJS 123, 467].

- Under the appropriate circumstances, the fundamental properties of the parent SNe (CC vs SN Ia, subtype, energetics, yields) can be extracted from the SNR observations:

  - SN Ia: HD+NEI modeling of the thermal X-ray emission from the shocked SN ejecta [Badenes et al. 03, ApJ 593, 358; Badenes et al. 05, ApJ 624, 198; Badenes et al. 06, ApJ 645, 1373].

  - CC SNe: Combined study of the SNR morphology (presence of H knots, evidence for fast/slow pre-SN winds, etc.) and compact object properties (PWN, spin-down age, proper motion, etc.) [Chevalier 05, ApJ 619, 839].

- The reliability of these techniques can now be verified by the discovery of light echoes from ancient SNe [Rest et al. 05 Nat 438, 1132].

SNe From SNRs: Ia SNe

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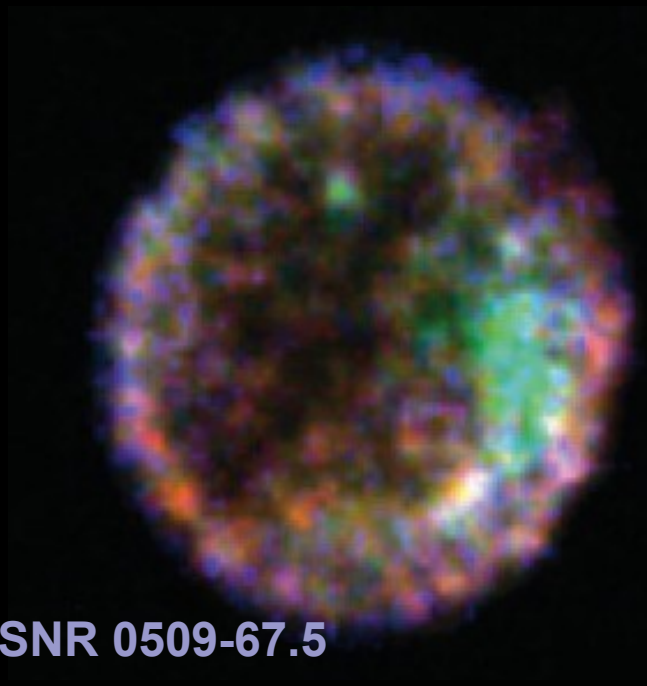
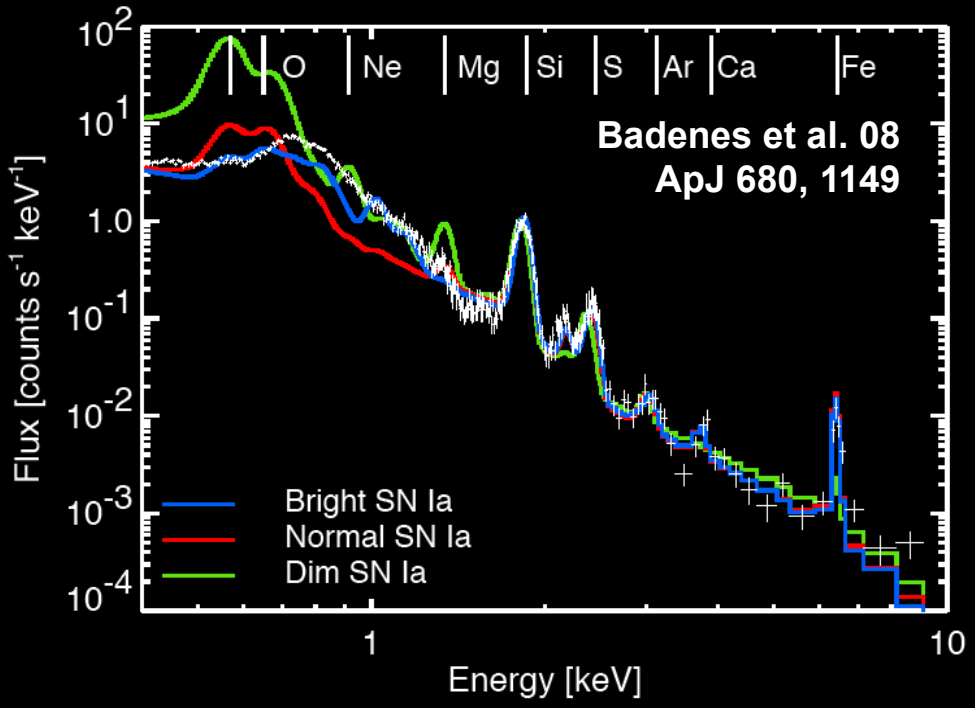
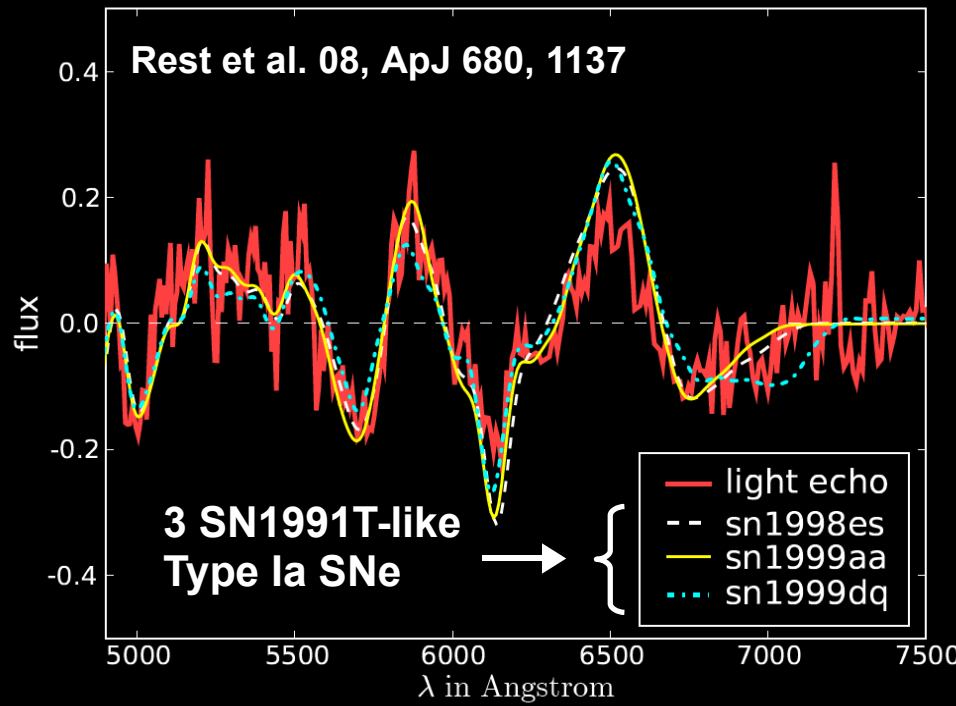


SNR 0509-67.5

- SNR 0509-67.5 was the first object with an ejecta-dominated X-ray SNR and light echo spectroscopy [Badenes et al. 08, ApJ 680, 1149; Rest et al. 08, ApJ 680, 1137].
- Both techniques agree that the SN must have been of Type Ia, exploded 400 yr. ago, and was unusually bright (~1$M_\odot$ ^{56}Ni, SN 1991T-like).





SNe From SNRs: CC SNe

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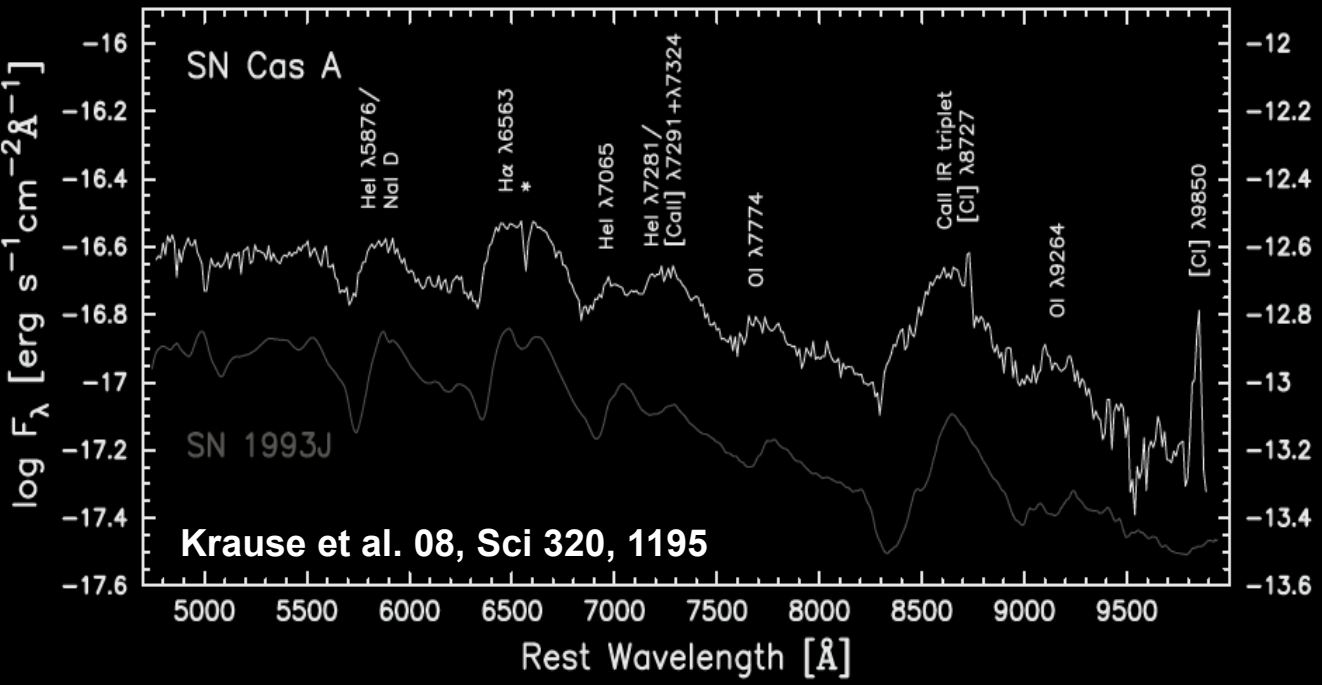
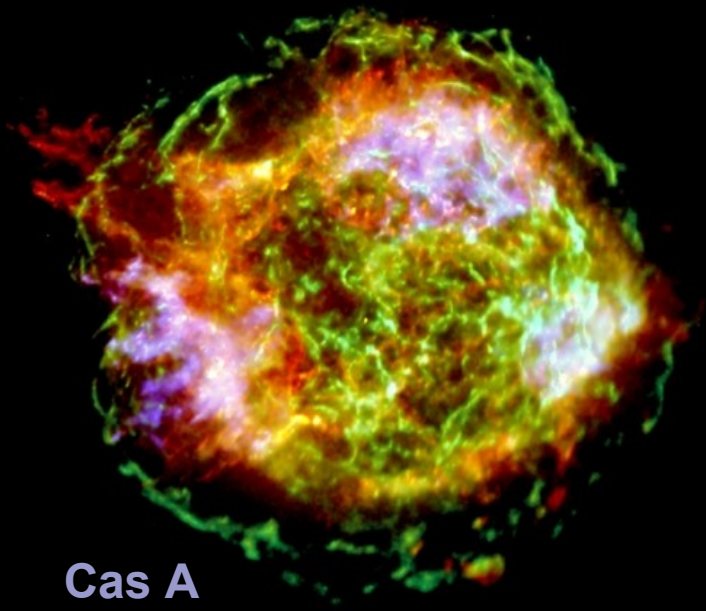
Chevalier 05, ApJ 619, 839

PROPERTIES OF REMNANTS WITHOUT NORMAL PULSARS

Supernova Remnant	Distance (kpc)	Supernova Type	Age (yr)	Radius (pc)
Cas A	3.4	IIL/b	320	2.5
RCW 103	3.8	IIL/b	...	5.0
Pup A	2	IIL/b	3700	16
Kes 73	7	IIL/b	...	4.7
E0102	59	IIL/b	1000–2100	6.3



- From the SNR properties, Cas A was typed as a SN IIL/b event [Chevalier 05, ApJ 619, 839].
- The light echo spectroscopy later confirmed this [Krause et al. 08, Sci 320, 1195] ⇒ SN 1993J analog (IIb).



Cas A

Young SNRs in the LMC

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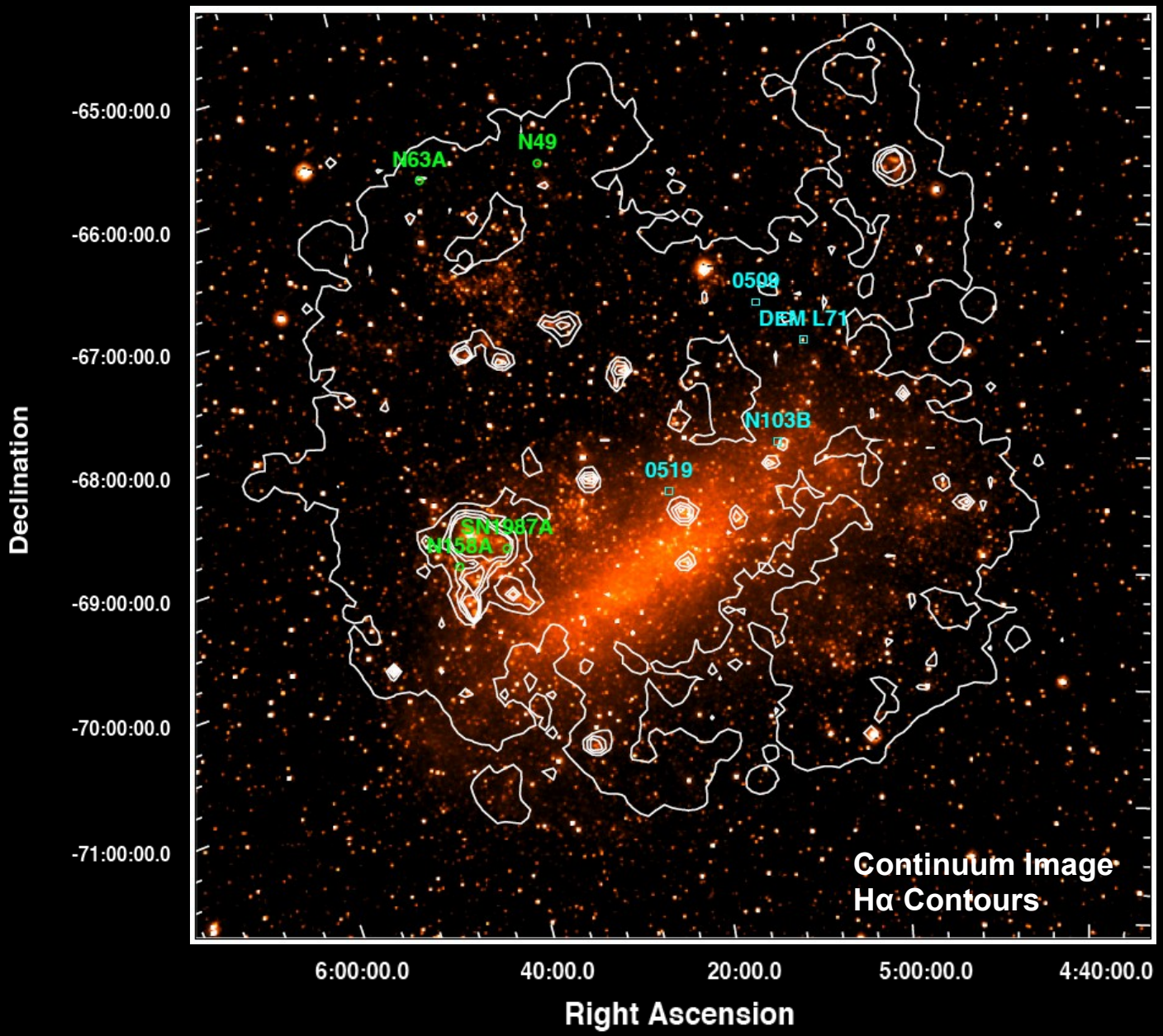

CC SNRs: N158A, SN1987A, N63A, N49

Type Ia SNRs: 0519-69.0, N103B, DEM L71, 0509-67.5

- Avoid mistyping ⇒ young SNRs (ejecta-dominated or with a compact object).
- One known age (87A), three light echoes (0509-67.5, 0519-69.0, N103B).
- Select SNRs with size<1.5 arcmin ⇒ eight objects
- CC SNRs: N158A, SN 1987A, N63A, N49; Ia SNRs: 0519-69.0, N103B, DEM L71, 0509-67.5.

CC SNRs

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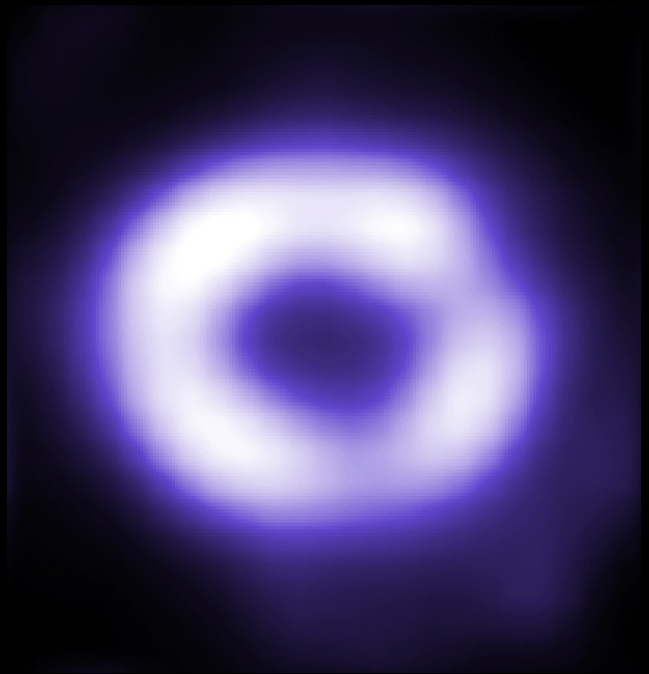
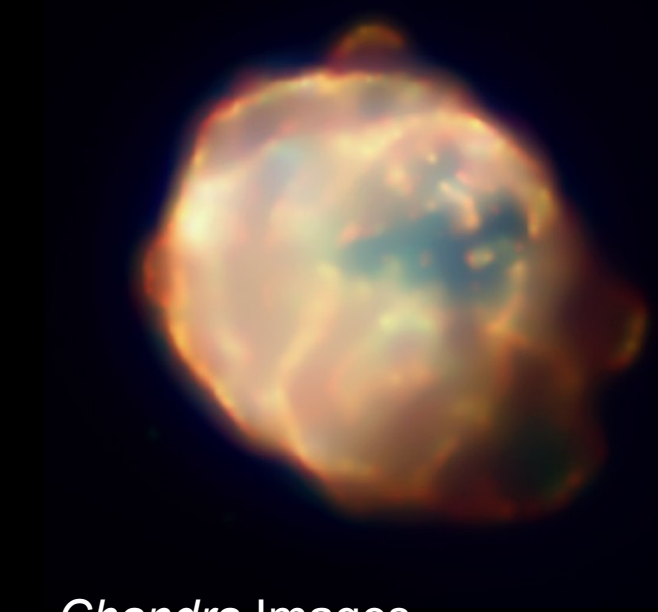
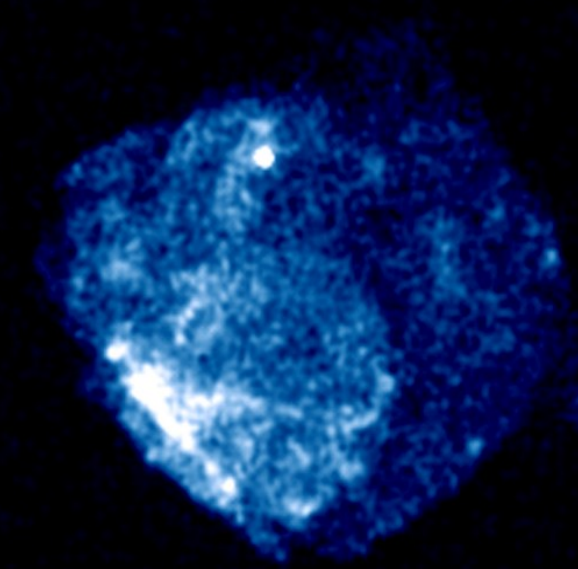
SNR N158A
(0540-69.0)
Type Ib/c
t~800 yr
(Psr, X-ray)



SN 1987A
Type IIpec
t=21 yr
Prog: SK -69 202 (BSG, 20> M>15 $M_{\odot}$)
(SN, X-ray)



SNR N63A
Type unknown
t~3000 yr?
(X-ray)



SNR N49
Type unknown
t~6000 yr?
(CO, X-ray)

Chandra Images

SFHs of the CC SNRs

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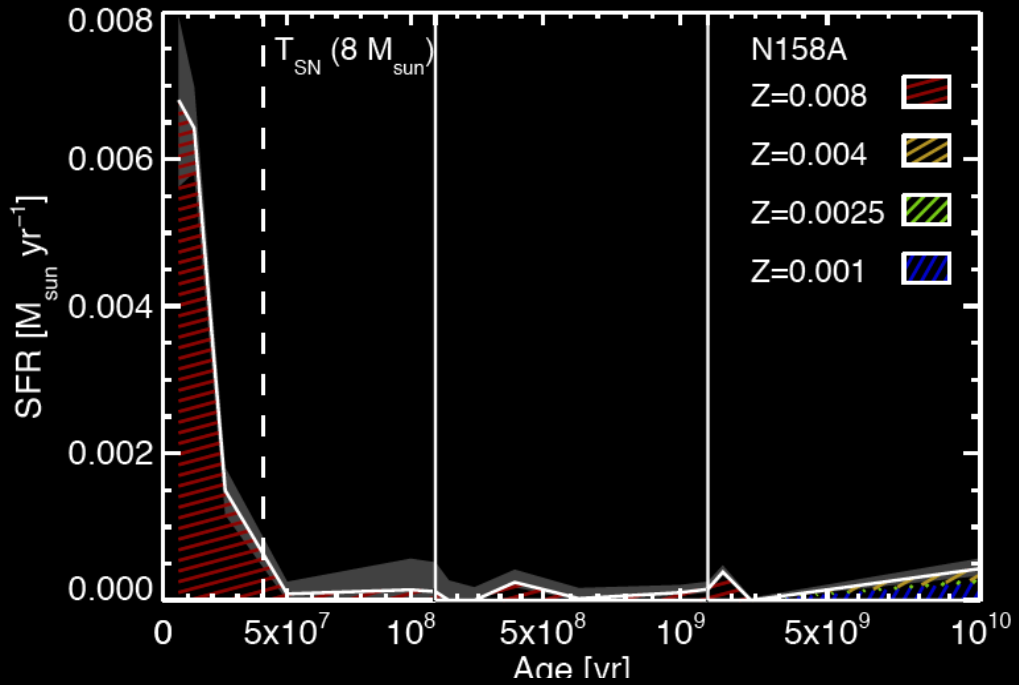

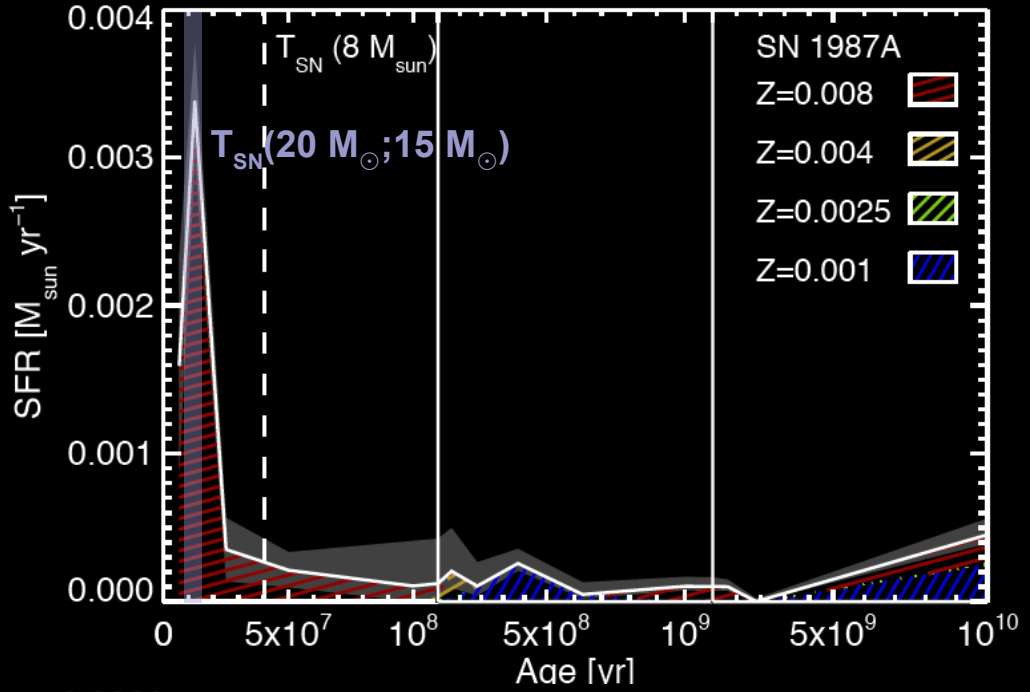

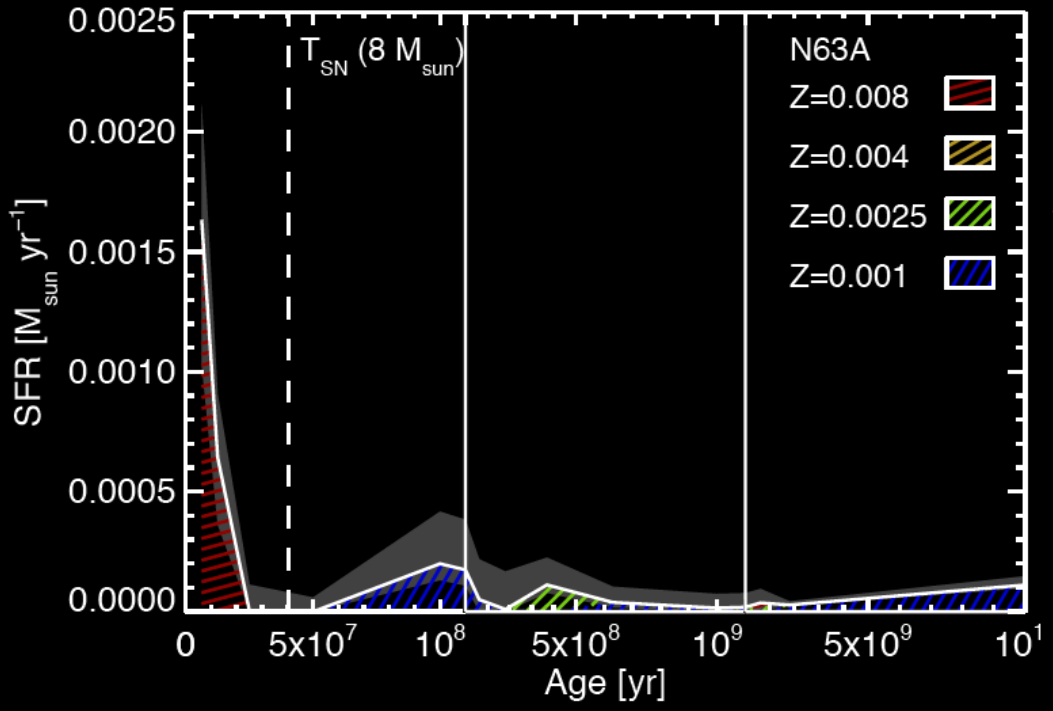

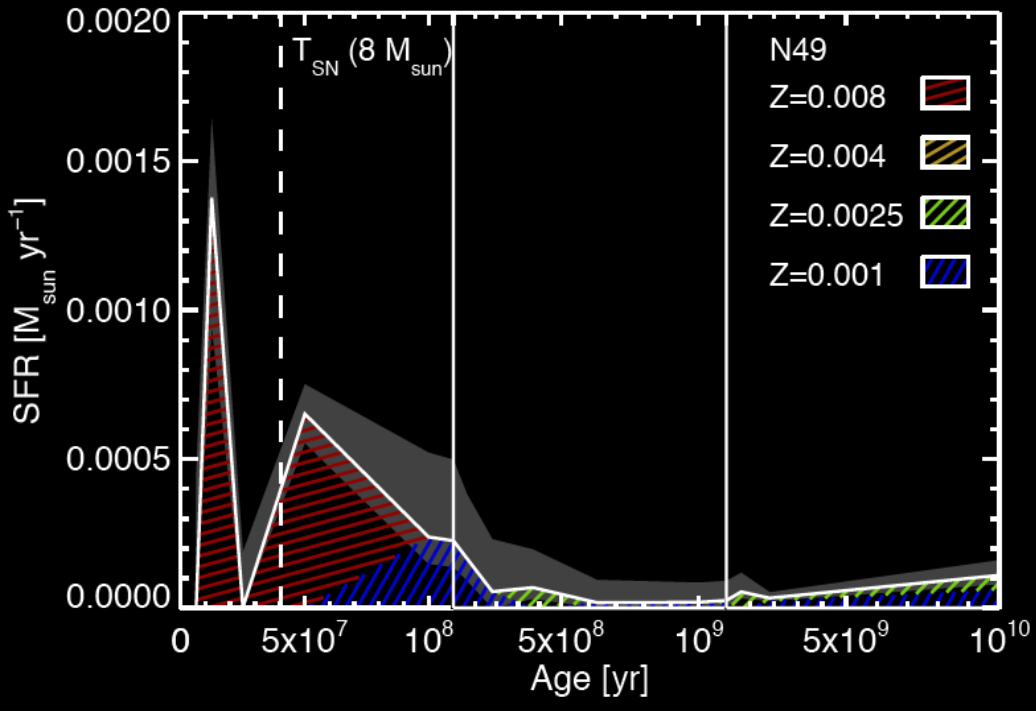

Type Ia SNRs

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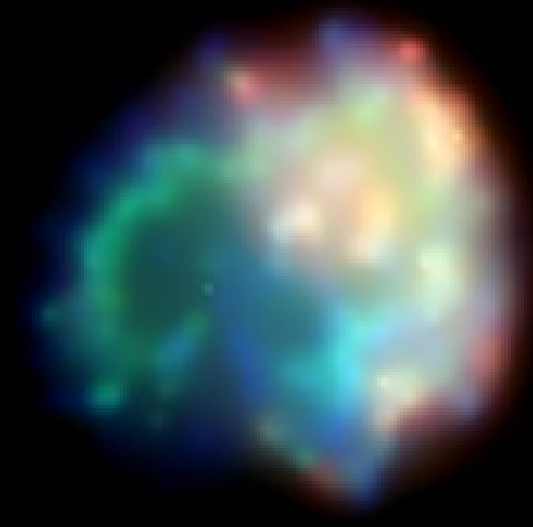
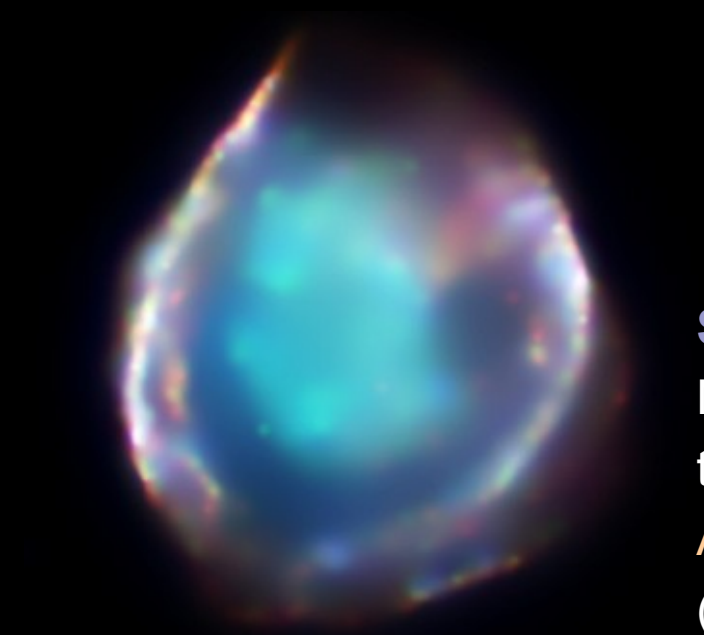
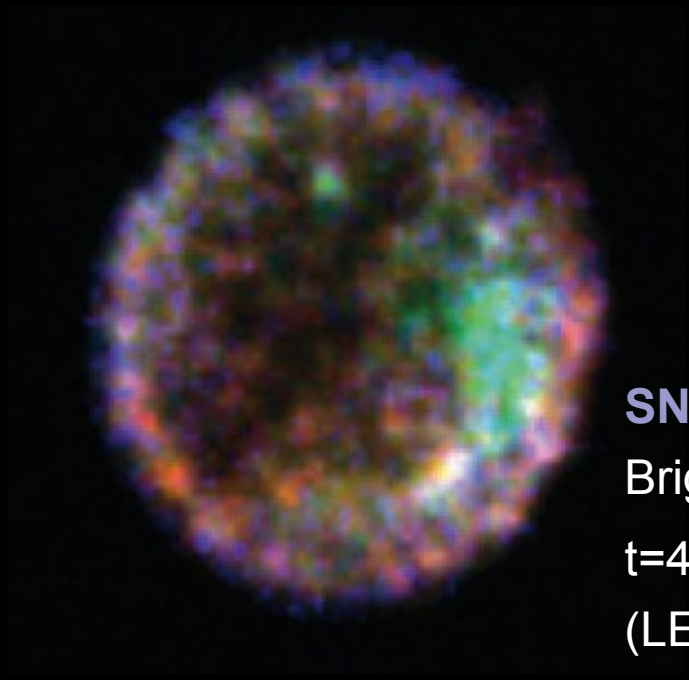
SNR 0519-69.0
Bright; ~0.8$M_\odot$ ^{56}Ni
t=600±200 yr
(LE, X-ray)



SNR N103B
Bright?
t~860 yr
Asymmetric!
(LE, X-ray)



SNR DEM L71
Normal?
t~2000 yr?
AM Interaction!
(X-ray)



SNR 0509-67.5
Bright; ~1$M_\odot$ ^{56}Ni
t=400 yr
(LE, X-ray)

Chandra Images

SFHs of the Ia SNRs

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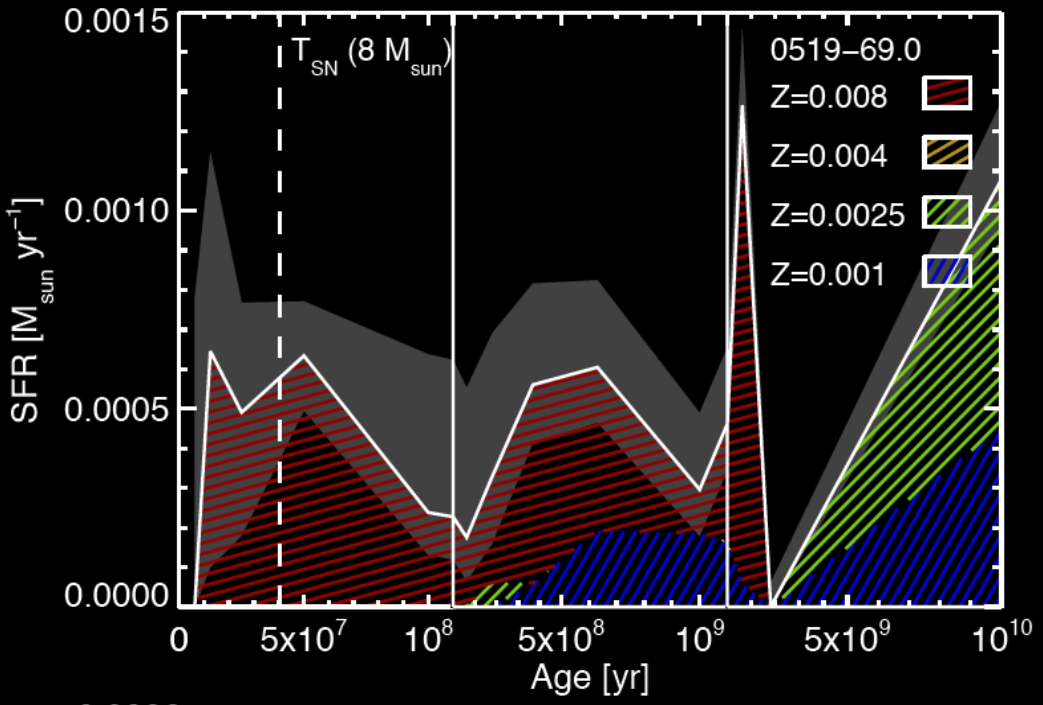

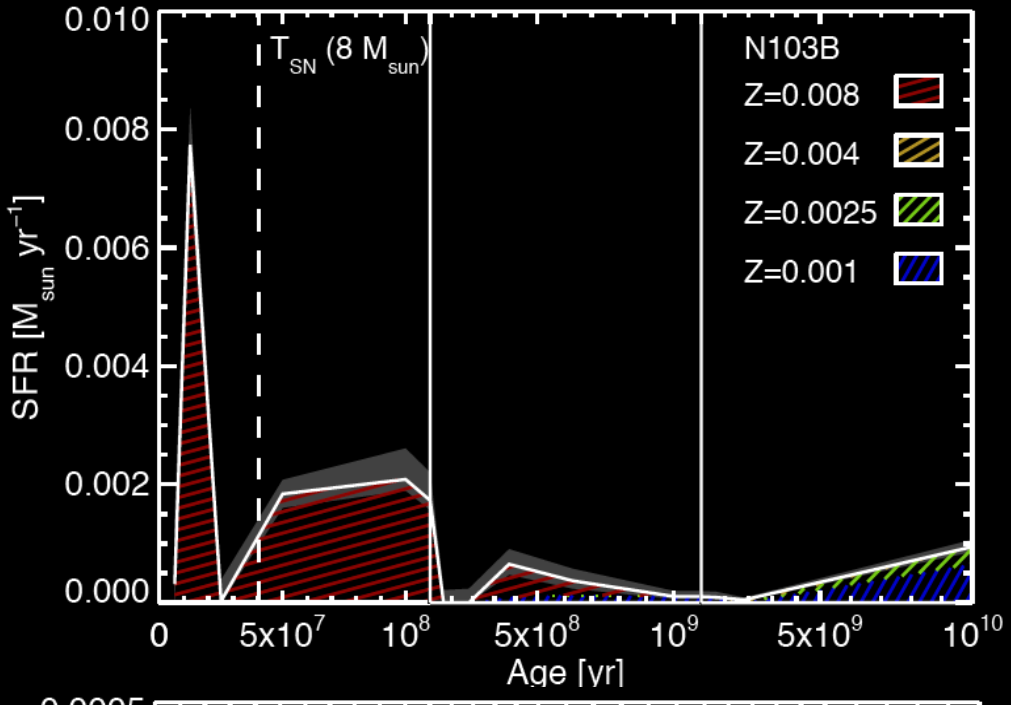

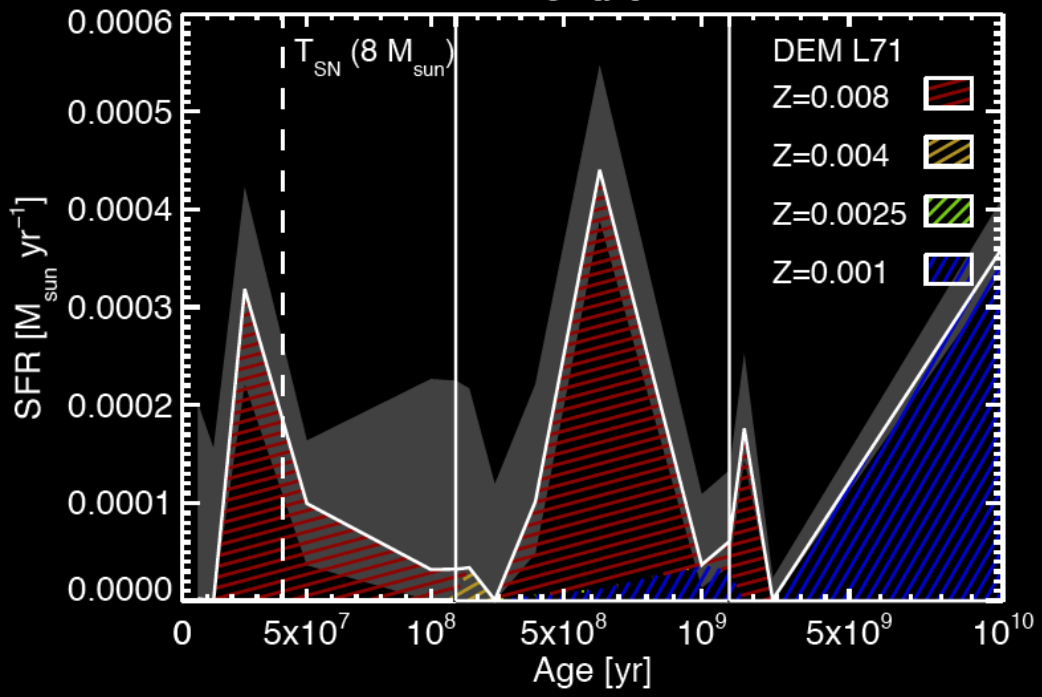

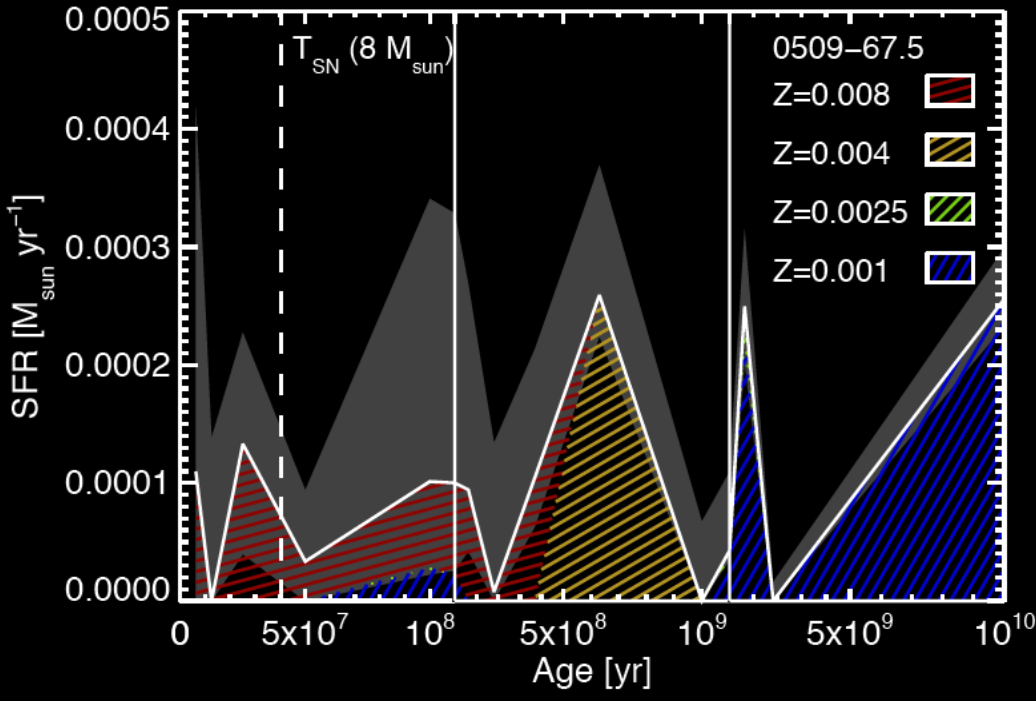

Caveats and Conclusions

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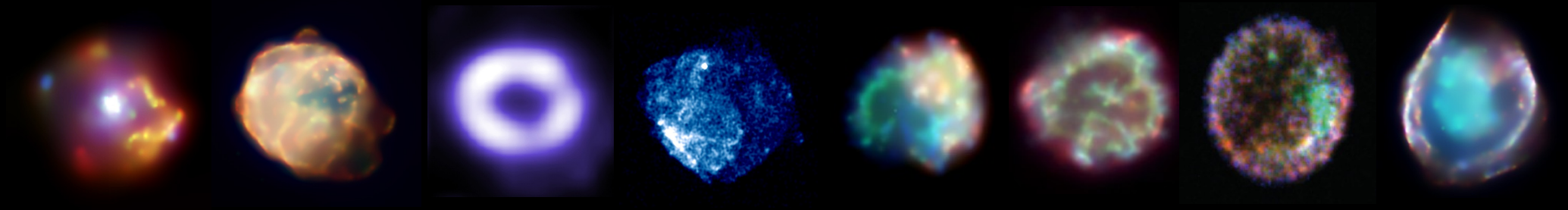

- **Caveats**: This is NOT a statistical study. Galactic dynamics will mix stellar populations (in the LMC, t ~ few hundred Myr).

- **Core Collapse SNe ⇒ associated to recent SF.**
  - SN 1987A: SFH peak at 12.5 Myr (T_{SN} 20>M>15 $M_{\odot}$)
  - SNR N158A: stripped envelope SN (Ib/c), SFH peak at t=6.3 Myr.
- **Type Ia SNe ⇒ explode in a variety of environments.**
  - SNR 0509-67.5: bright (~1$M_{\odot}$ ^{56}Ni) SN Ia associated to an old, metal-poor population (but progenitor might have been massive!).
  - SNR N103B: (bright?) SN Ia associated to recent SF ⇔ 'prompt' progenitors with t<180 Myr? [Aubourg et al. 08, arXiv:0707.1328].