Environmental Effects on the LMC SNR Population

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2024 June 10-14, Chania

Outline

0. LMC is great! DeMCELS is coming!
1. Stellar environments
   - C-C isolated B star progenitor
   - C-C isolated O star progenitor
   - C-C 1st O star in OB association
   - C-C Nth O star in OB association
   - C-C B star in OB association
2. Interstellar environment
3. Circumstellar Environment
4. Galactic Environment


50 kpc away; 1” = 0.25pc
→ stars can be resolved
Nearly face-on; small A_V
→ clear, global view
MCELS
R – Hα
G – [S II]
B – [O III]


50 kpc away; 1” = 0.25pc
→ stars can be resolved
Nearly face-on; small A_V
→ clear, global view
LMC is a Land of Milk and Honey for SNR Researchers !!!
MCELS has served us for > 20 yr !
MCELS
R – Hα
G – [S II]
B – [O III]

New!!!

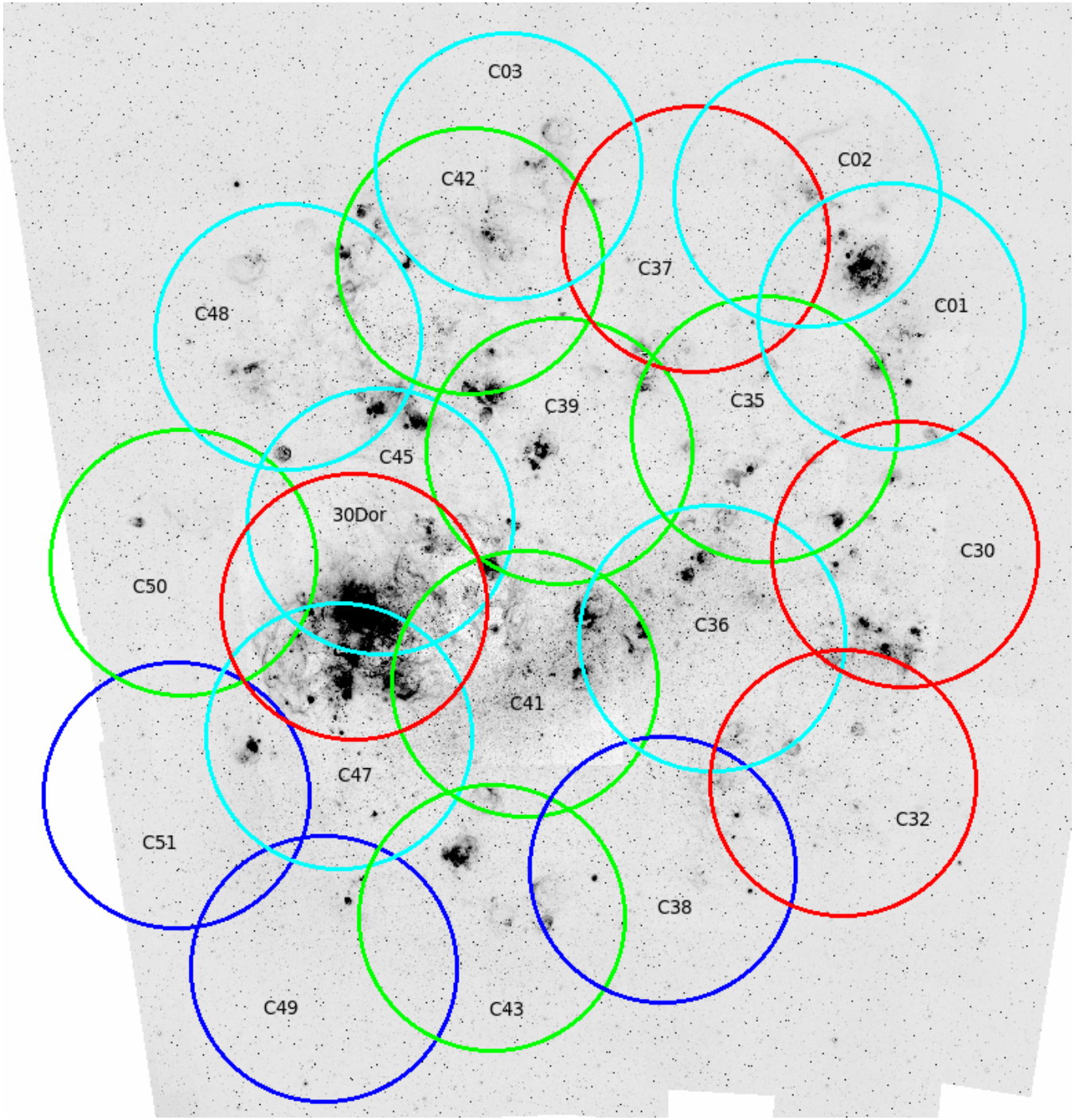
DeMCELS

New!!!

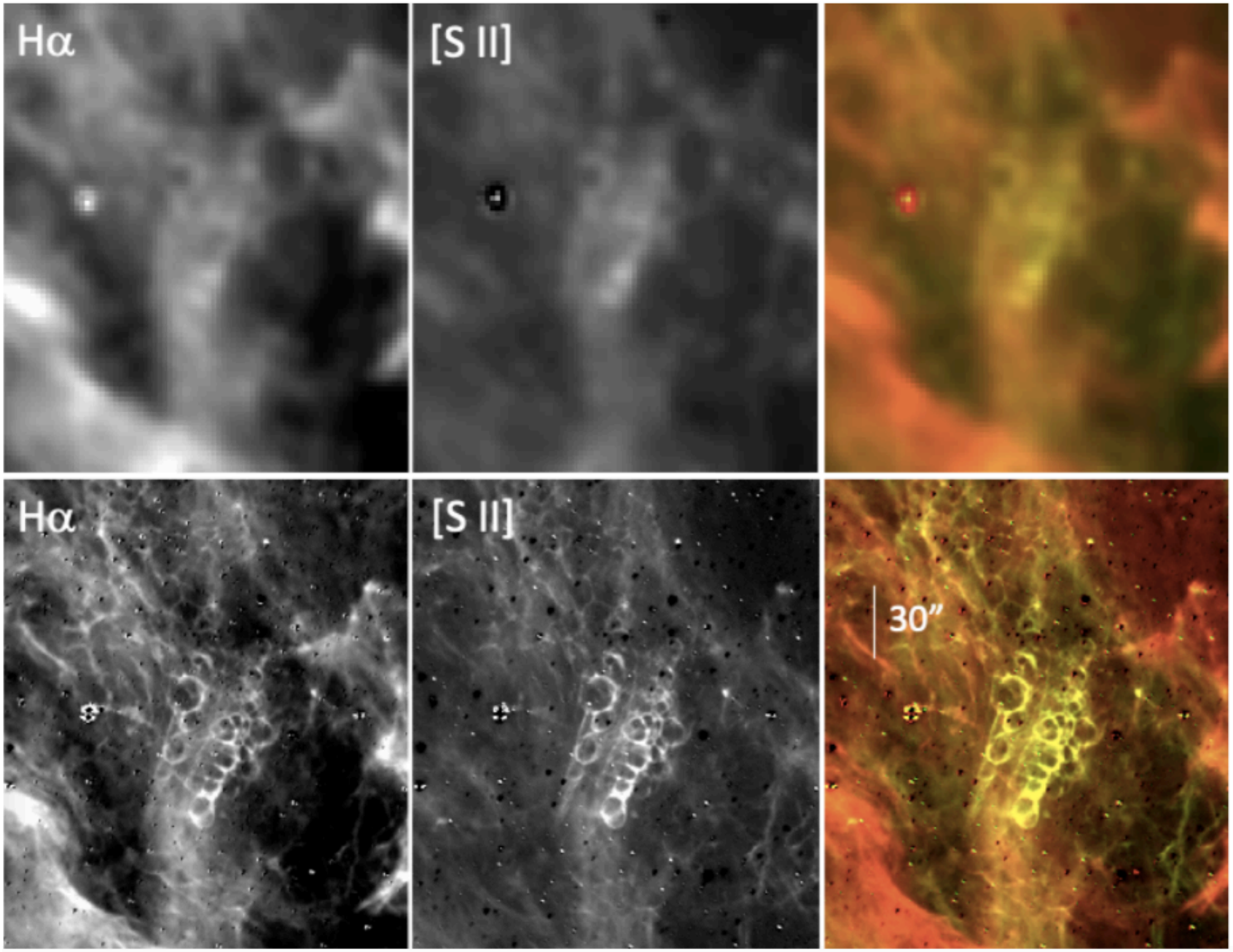
Dark Energy Camera MCs Emission-Line Survey

DeMCELS	MCELS
Blanco 4m	Curtis Schmidt 0.6m
~2 deg	1.4 deg
0.27 “/pix	2.3 “/pix
Hα, [S II], r’	Hα, [O III], [S II], rc, gc
S. Points, T. Puzia	C. Smith

An emission-line survey with SNRs in mind!


C03
C42
C02
C37
C48
C01
C39
C35
C45
30Dor
C30
C50
C36
C41
C47
C32
C51
C38
C49
C43

The Honeycomb SNR



MCELS

DeMCELS

Stellar Environments of C-C SNRs

- Isolated O
- Isolated B
- 1st O star in OB association
- Nth O star in OB association
- B star in OB association

Signatures of Classical SNRs

- Bright diffuse X-ray emission

  $L_x > 10^{35}$ ergs/s

- Nonthermal radio emission

  $S_\nu \propto \nu^{-\alpha}$ $\alpha \sim 0.5 - 0.8$

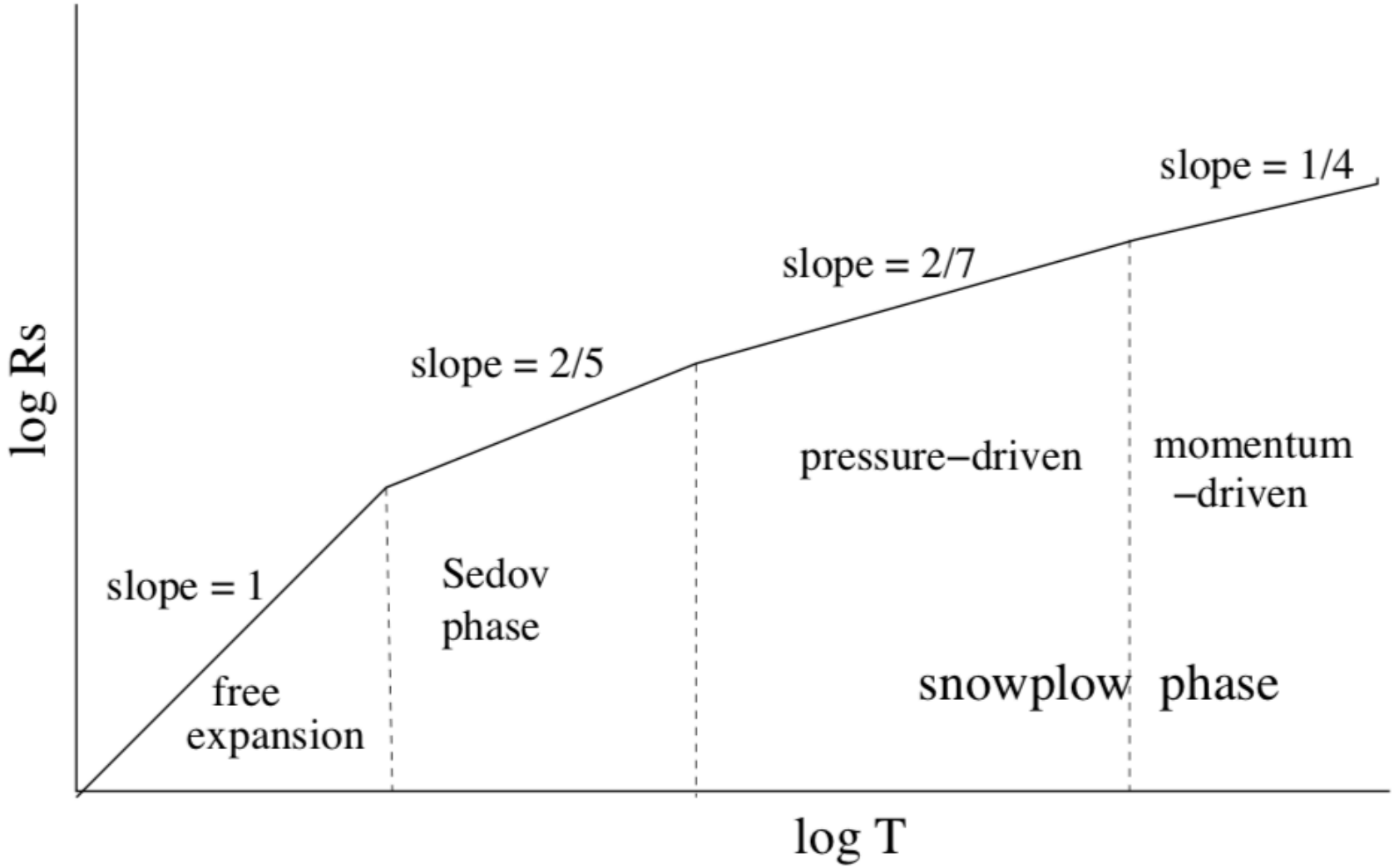
- Enhanced [S II] 6716,6731 emission

  [S II]/Hα > 0.45

- High-velocity gas (Hα line)

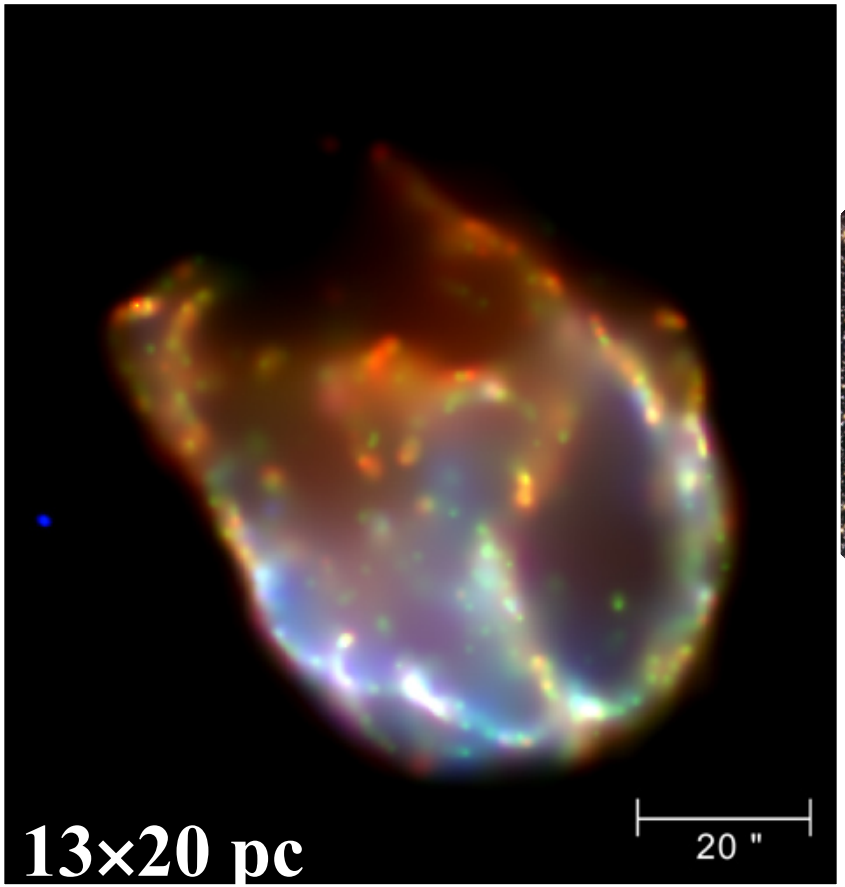
  ionized gas $\Delta V > 100$ km/s

Evolution of SNR in a Uniform Medium



C-C SNR N132D

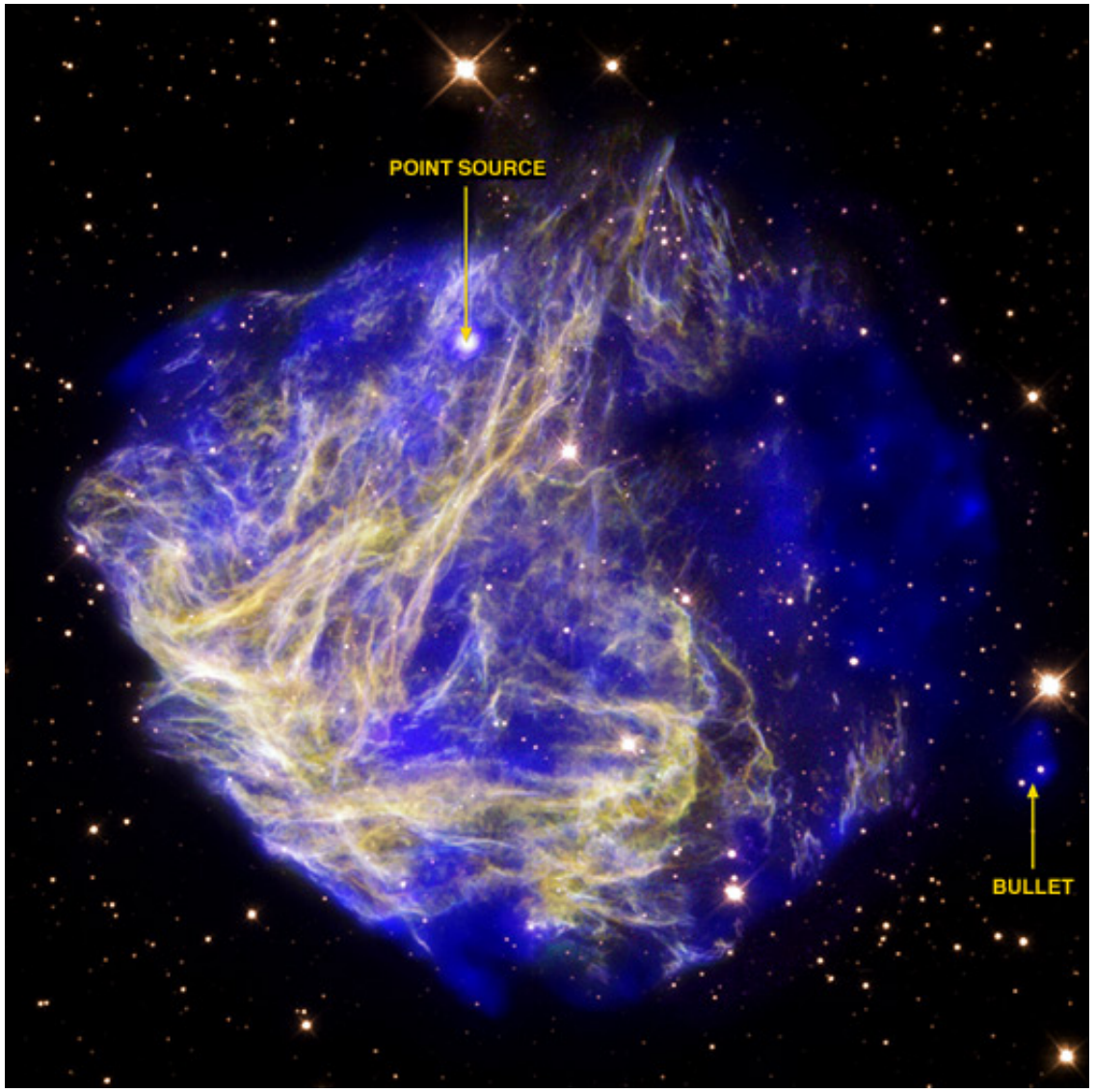
The progenitor O star exploded in its bubble cavity.



Vogt and Dopita 2011, Ap&Sp Sci

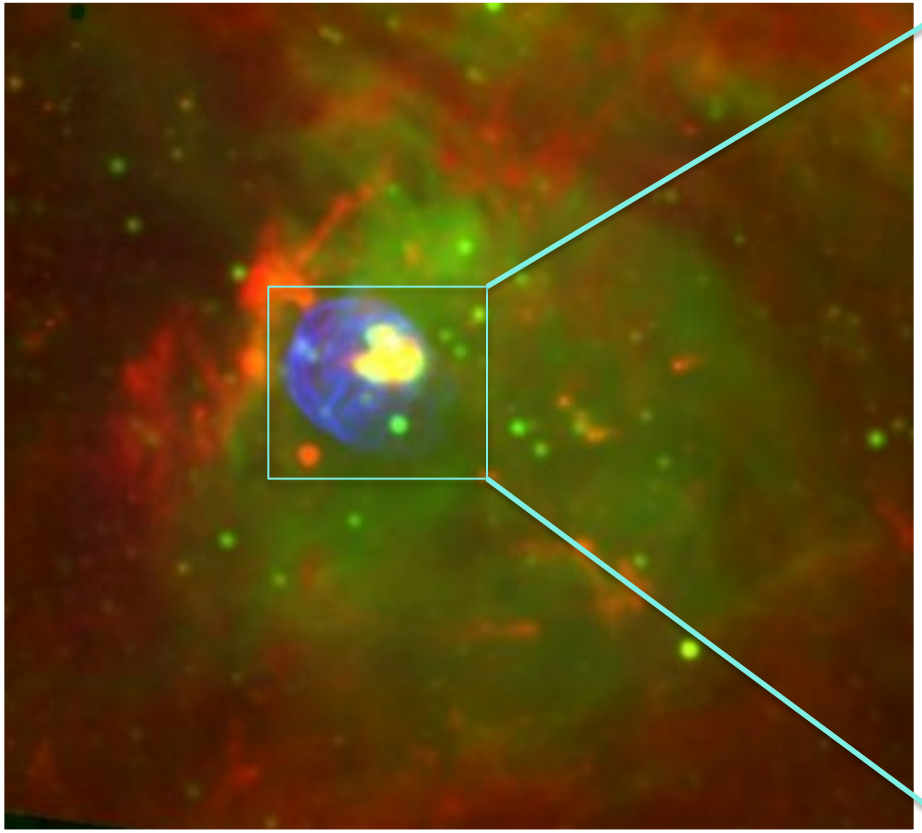
C-C SNR N49

The progenitor was a B star w/o strong stellar wind .



C-C SNR N63A

First O star explosion in the OB Association LH83.

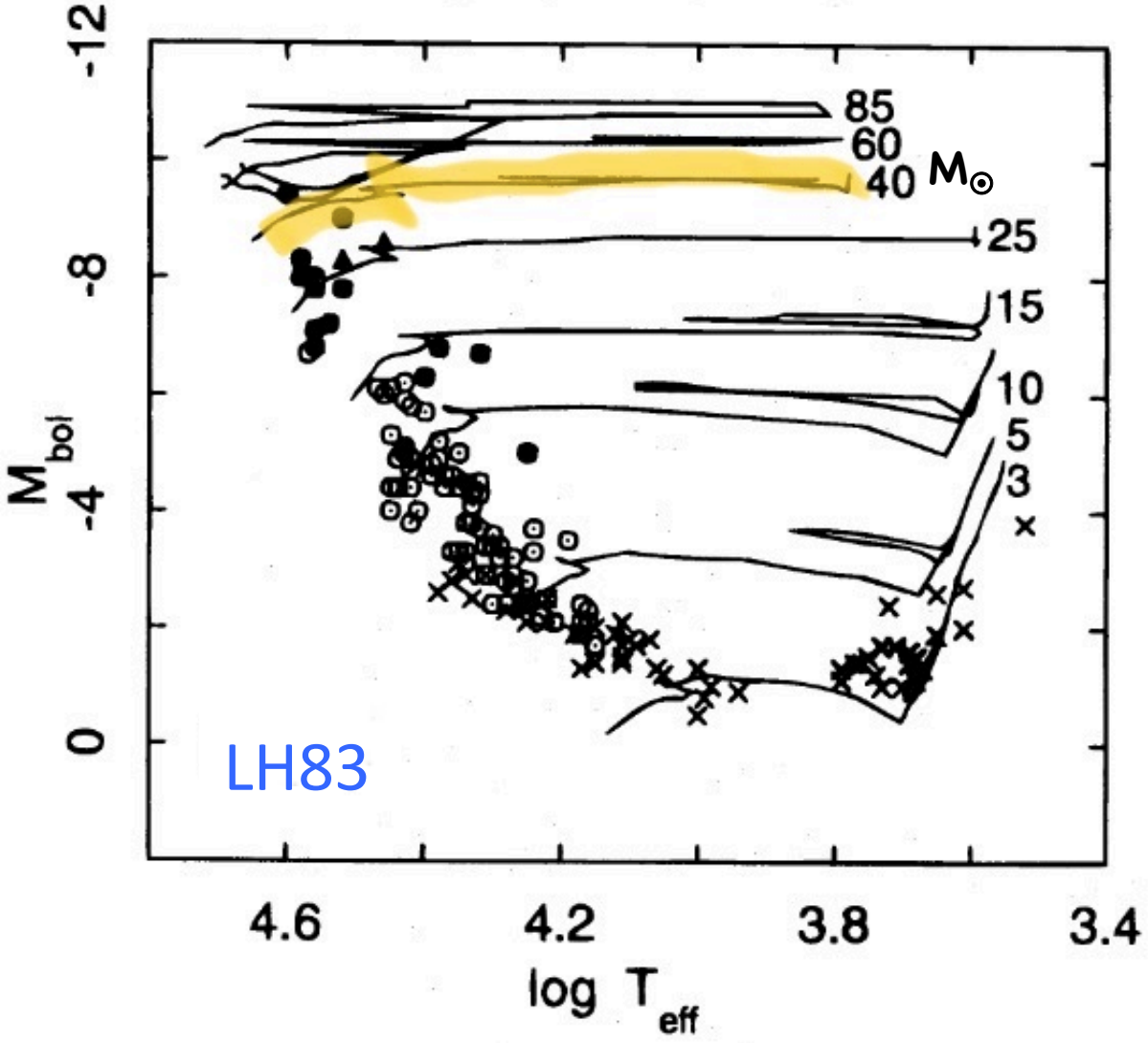


Blue - X-ray Green - Hα Red - 8 μm

HST optical + Chandra X-ray

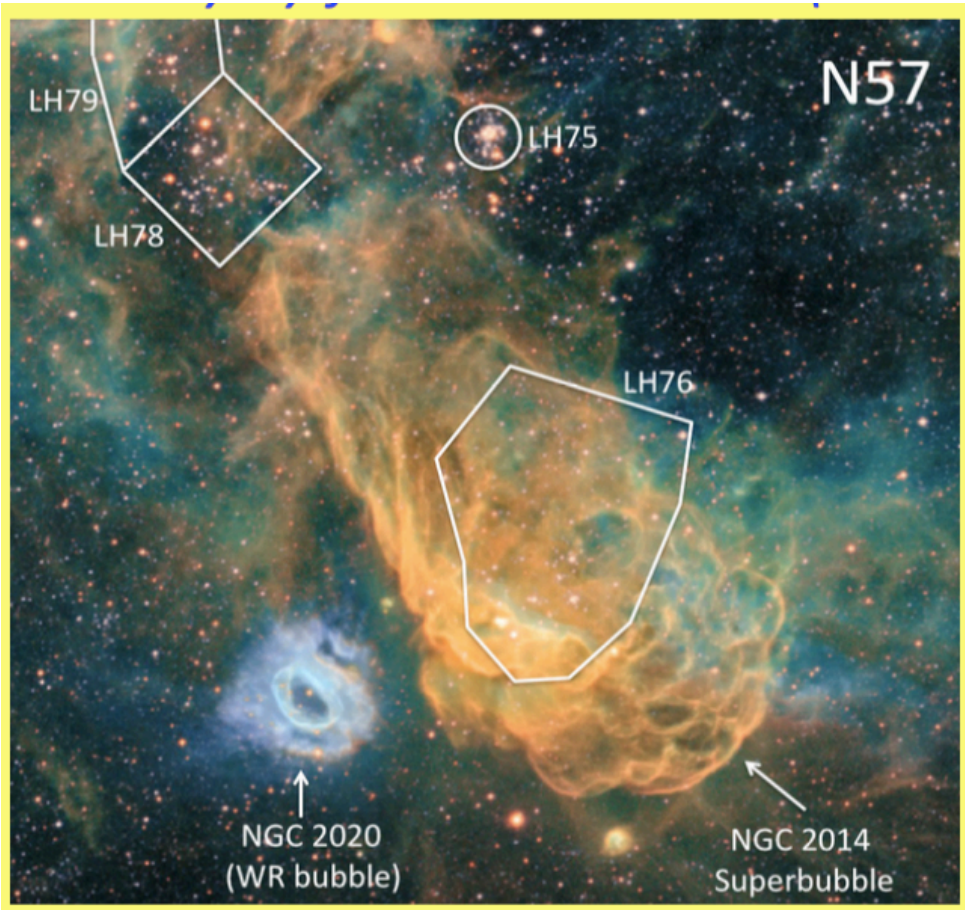
N63A SN progenitor mass ≥ 30 $M_\odot$
(Dufour & van den Bergh 1980)

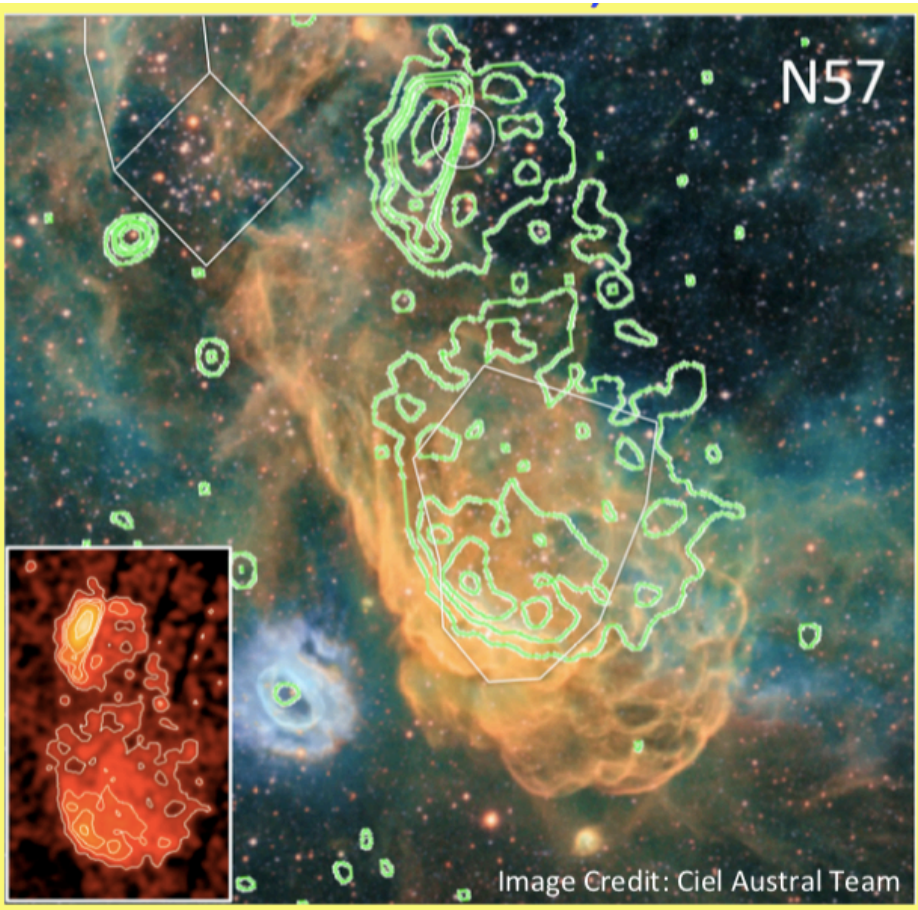
HRD (Oey 1996) ➔ SN progenitor ≥ 45 $M_\odot$



C-C SNR in Superbubble N57

Superbubble N57 around OB Association LH76.

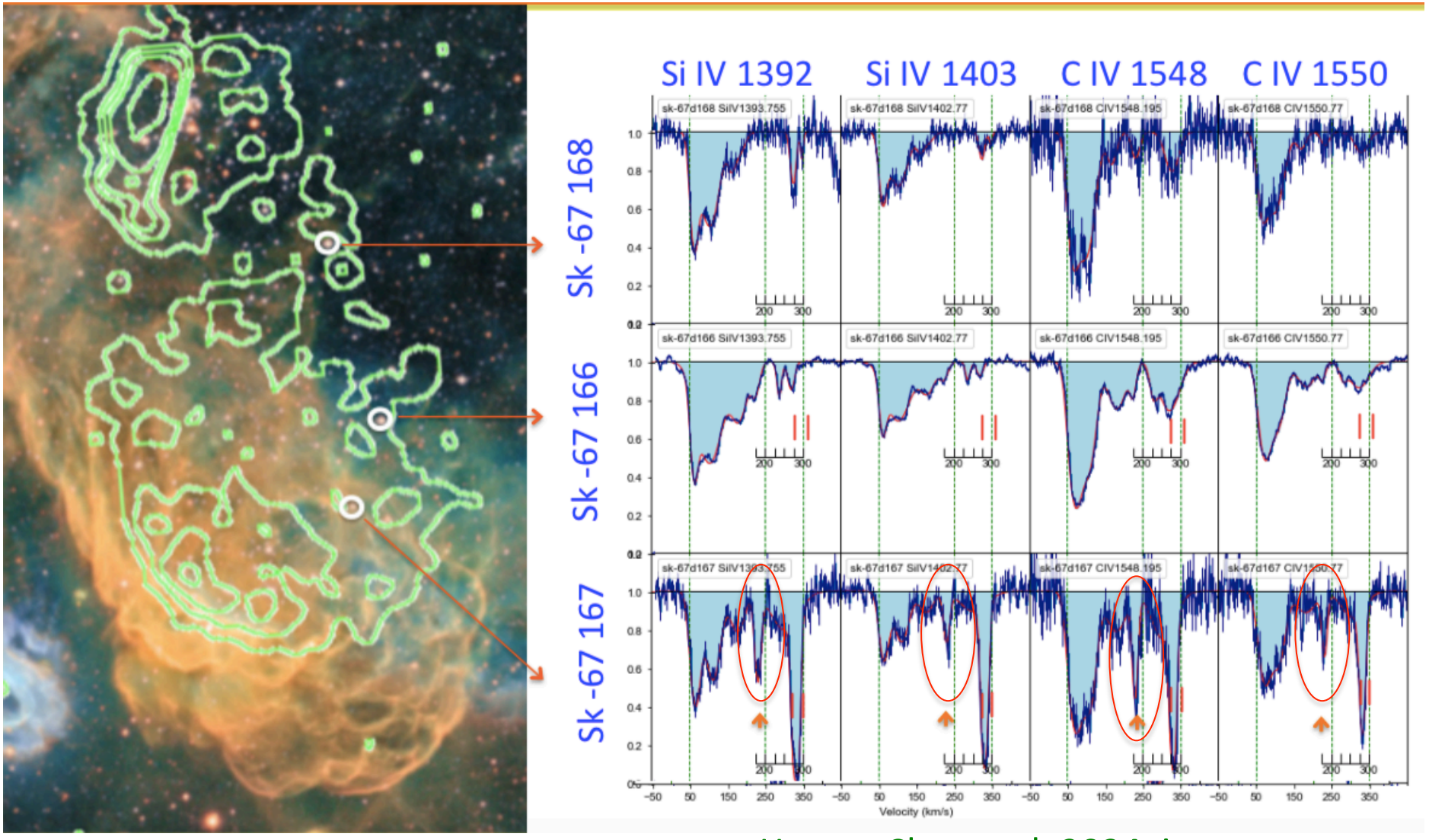




OB associations

XMM detected diffuse X-rays.

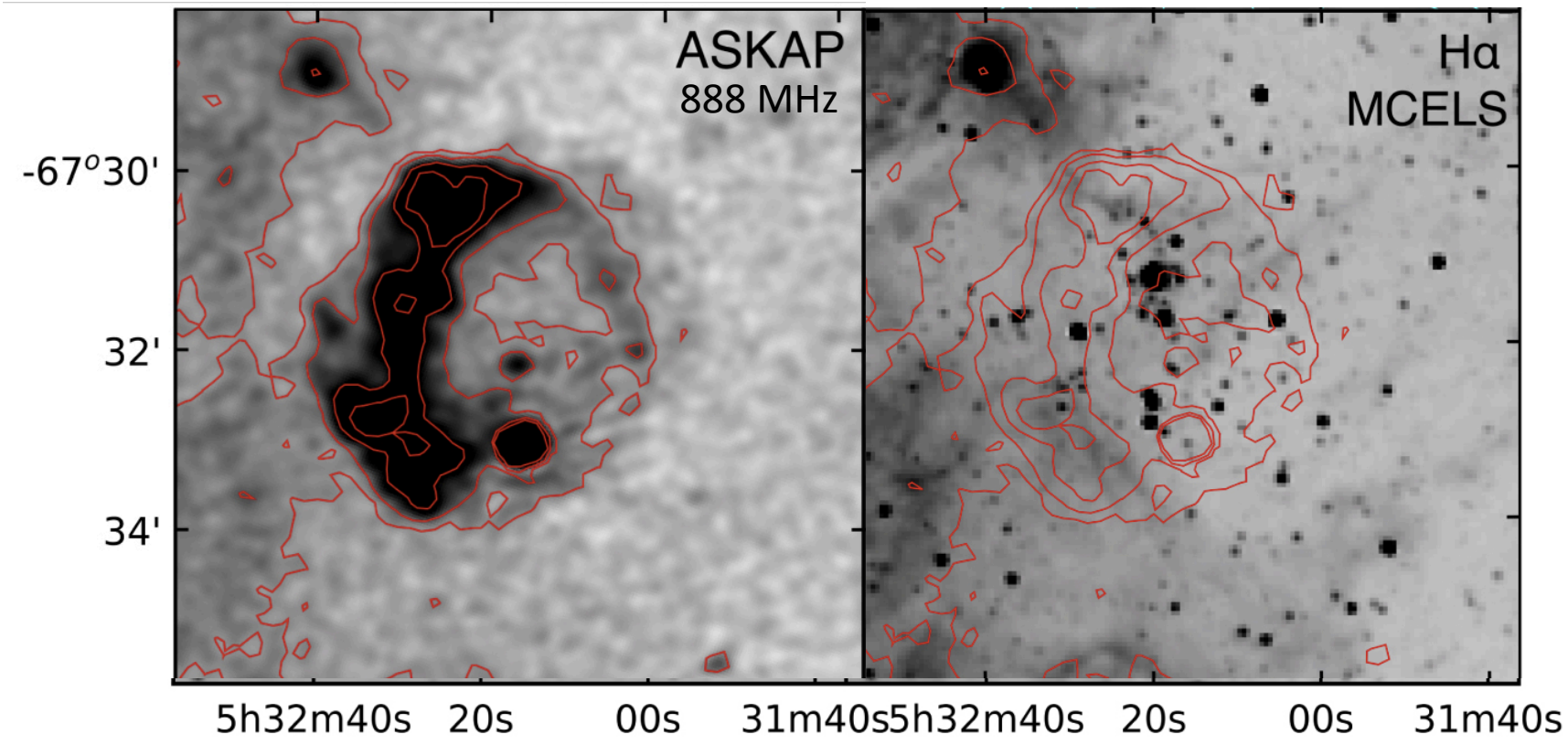
HST STIS observations of SiIV and CIV detected absorption associated with SNR shocks.



Huang, Chu, et al. 2024, in prep

C-C SNR B0532-67.5

Nonthermal radio and X-ray, but no optical.
OB Association LH75.

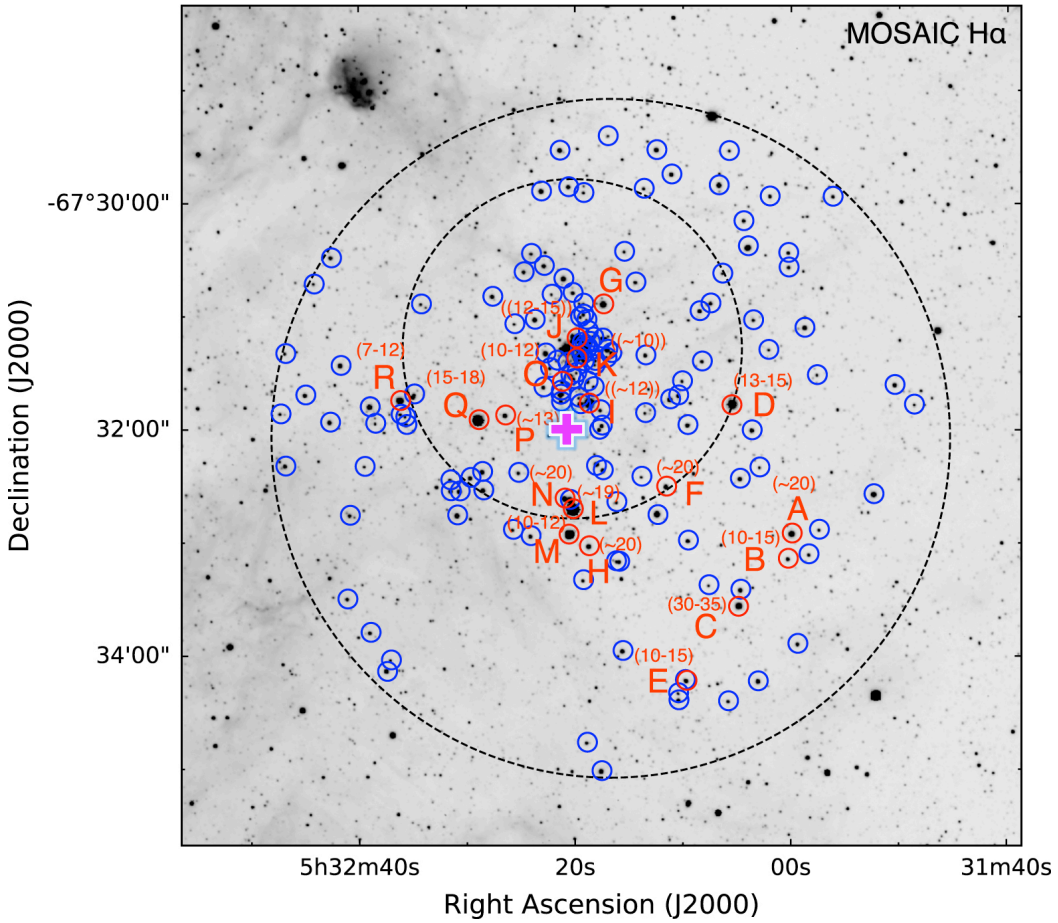


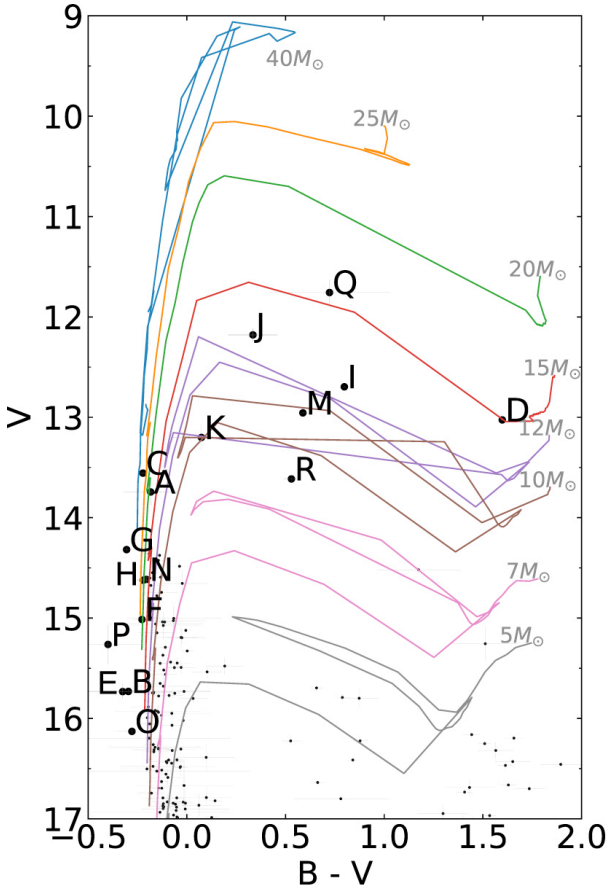
Li, Chu. et al. 2022, AJ

C-C SNR B0532-67.5

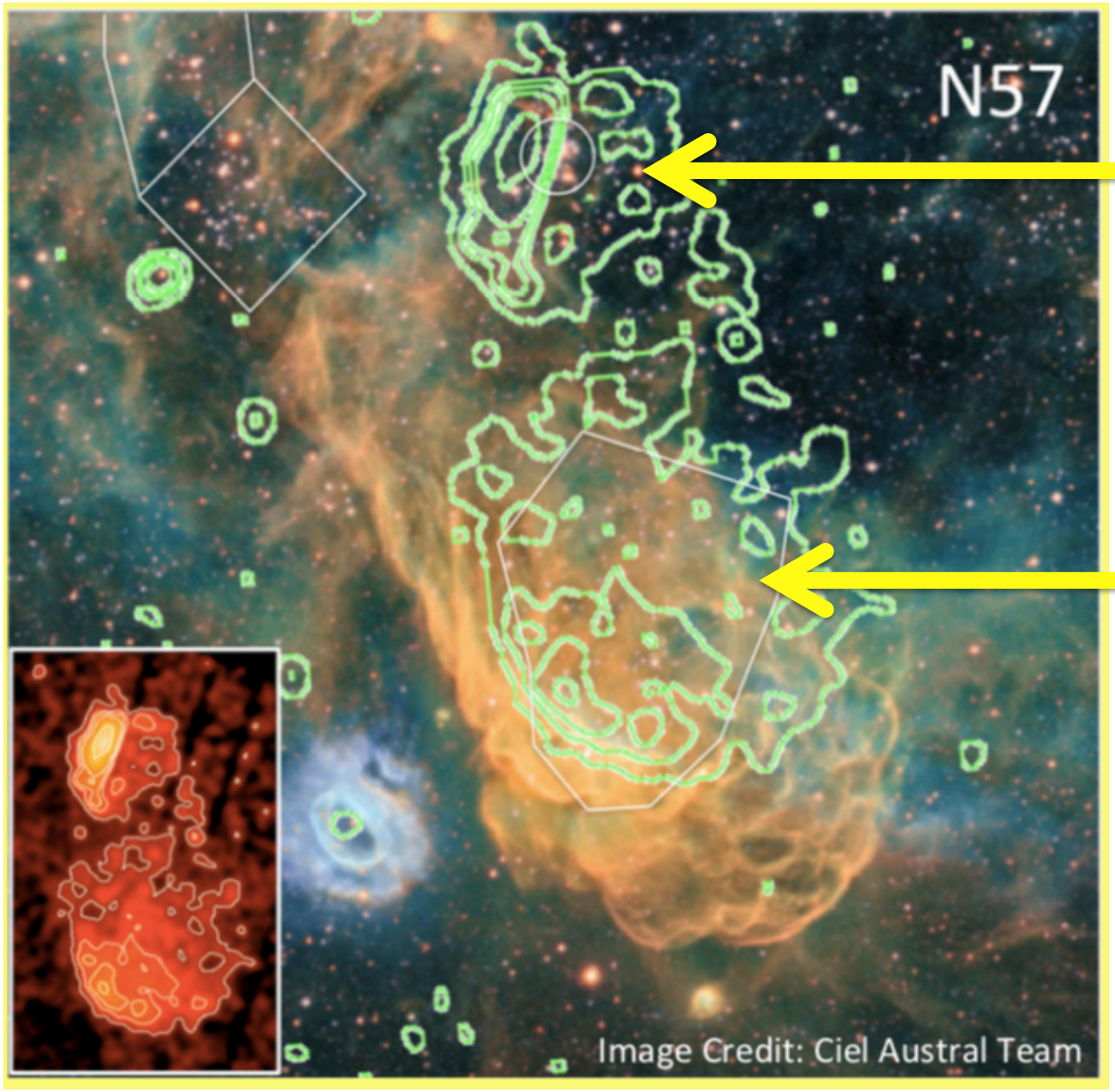
LH75 20-25Myr old, stars < 15 $M_\odot$

SN progenitor mass ≈ 15 $M_\odot$ (B star)





Li, Chu, et al. 2022, AJ, 163, 30


N57
SNR with a
B progenitor
SNR with an
O progenitor
Image Credit: Ciel Austral Team

Still holding onto the SNR doctrine and dismissing nonclassical SNRs ?

Signatures of Classical SNRs

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  $L_X > 10^{35}$ ergs/s
- Nonthermal radio emission
  $S_\nu \propto \nu^{-\alpha}$ $\alpha \sim 0.5 - 0.8$
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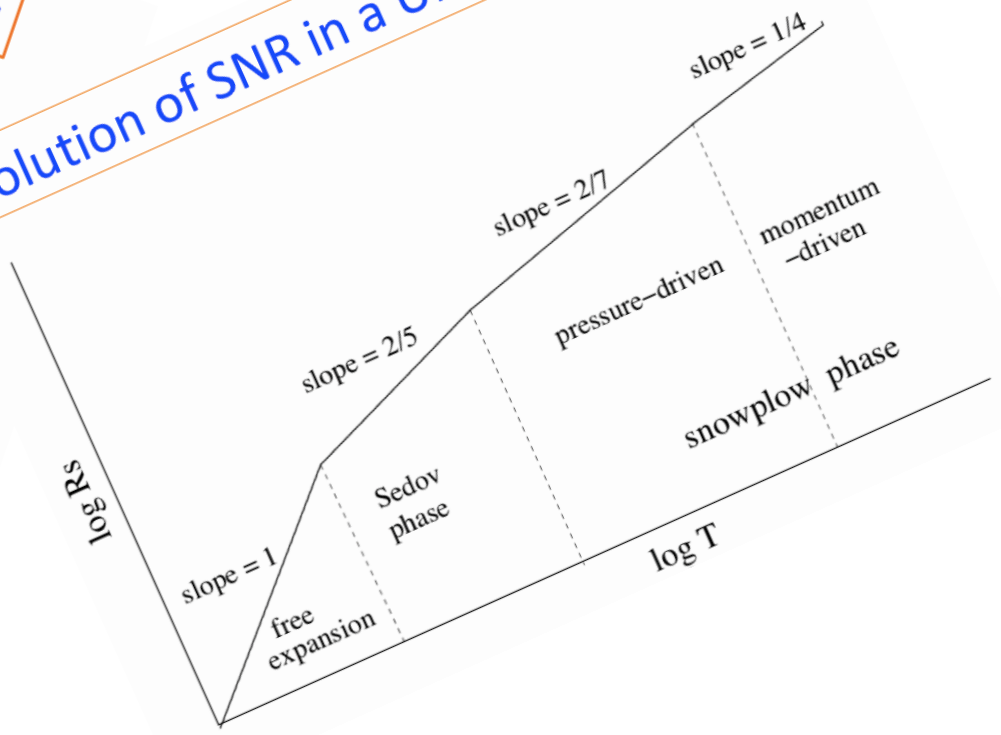
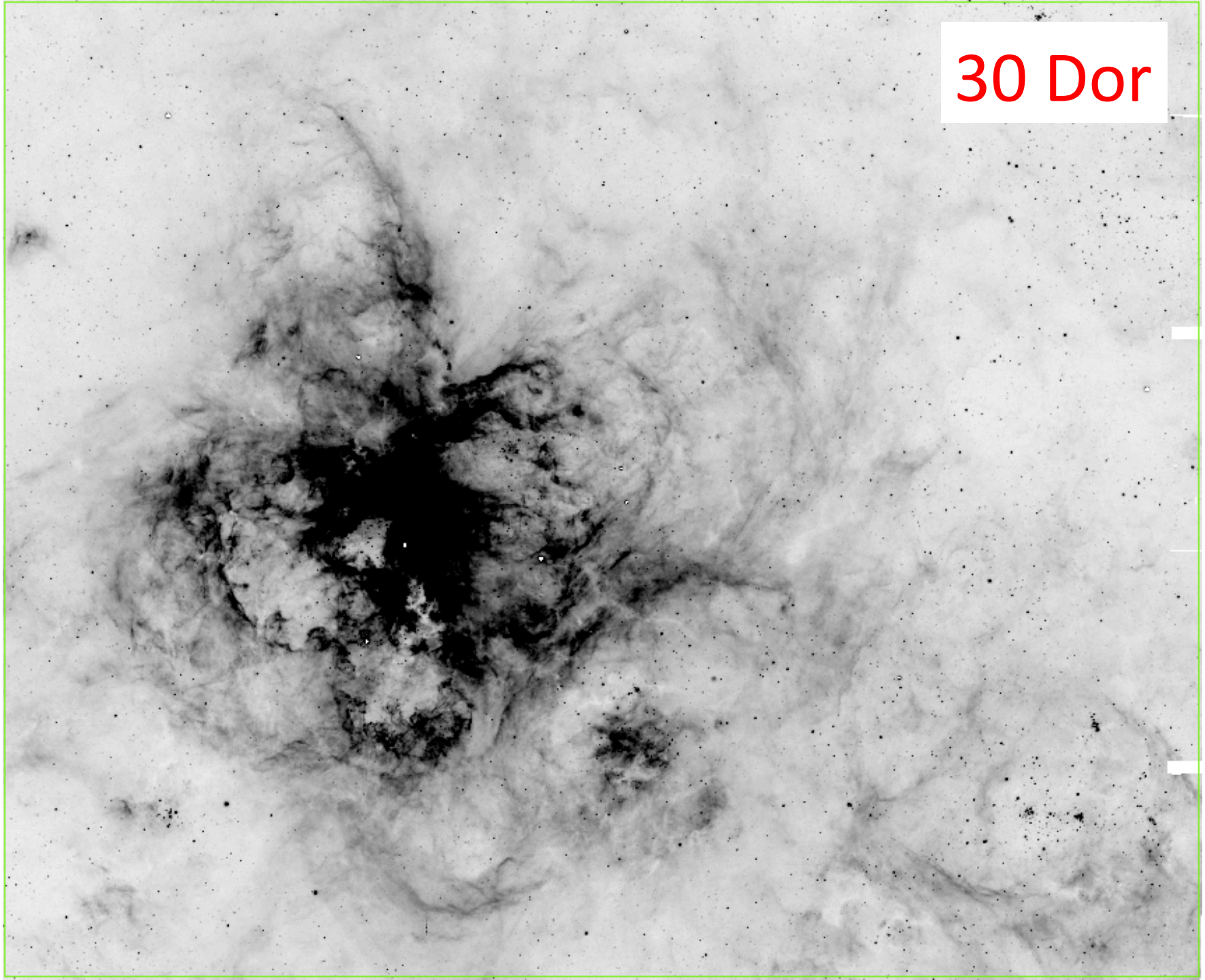
  [S II]/Hα > 0.45
- High-velocity gas (Hα line)
  ionized gas ΔV > 100 km/s

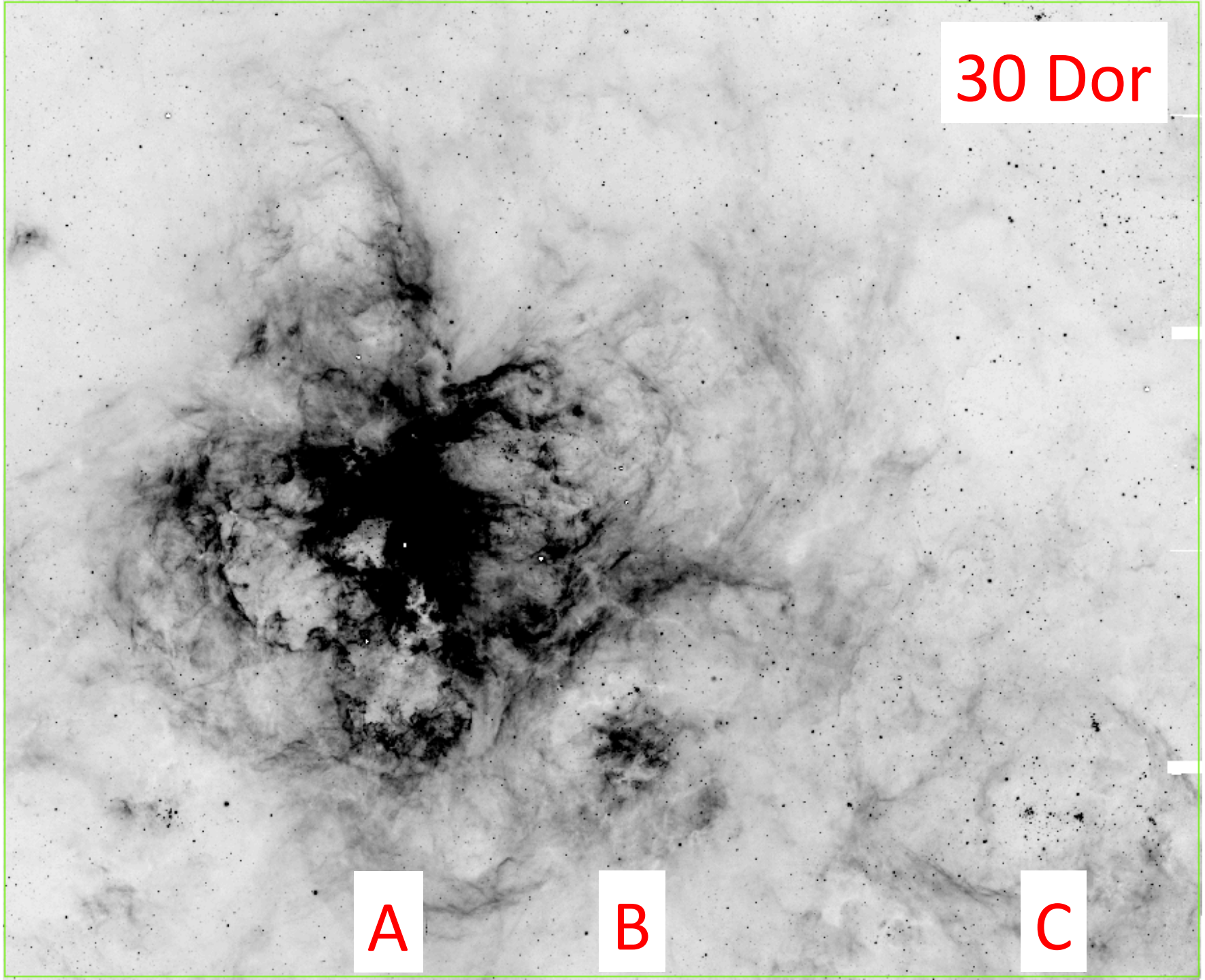
Evolution of SNR in a Uniform Medium

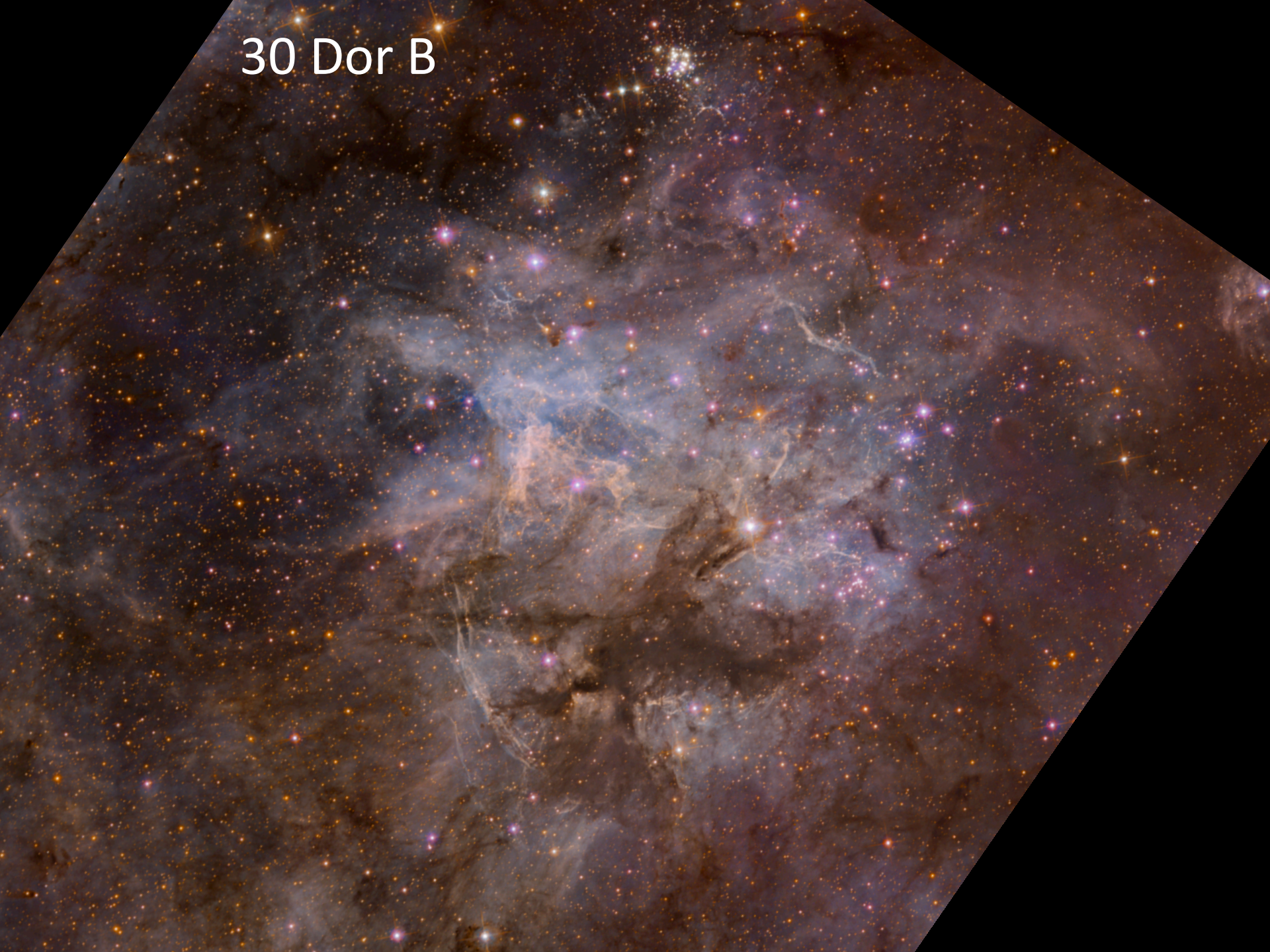


Interstellar Environment

- 30 Dor B SNR (Chen, Li, Chu et al. 2023, AJ)
- SNRs in 30 Dor

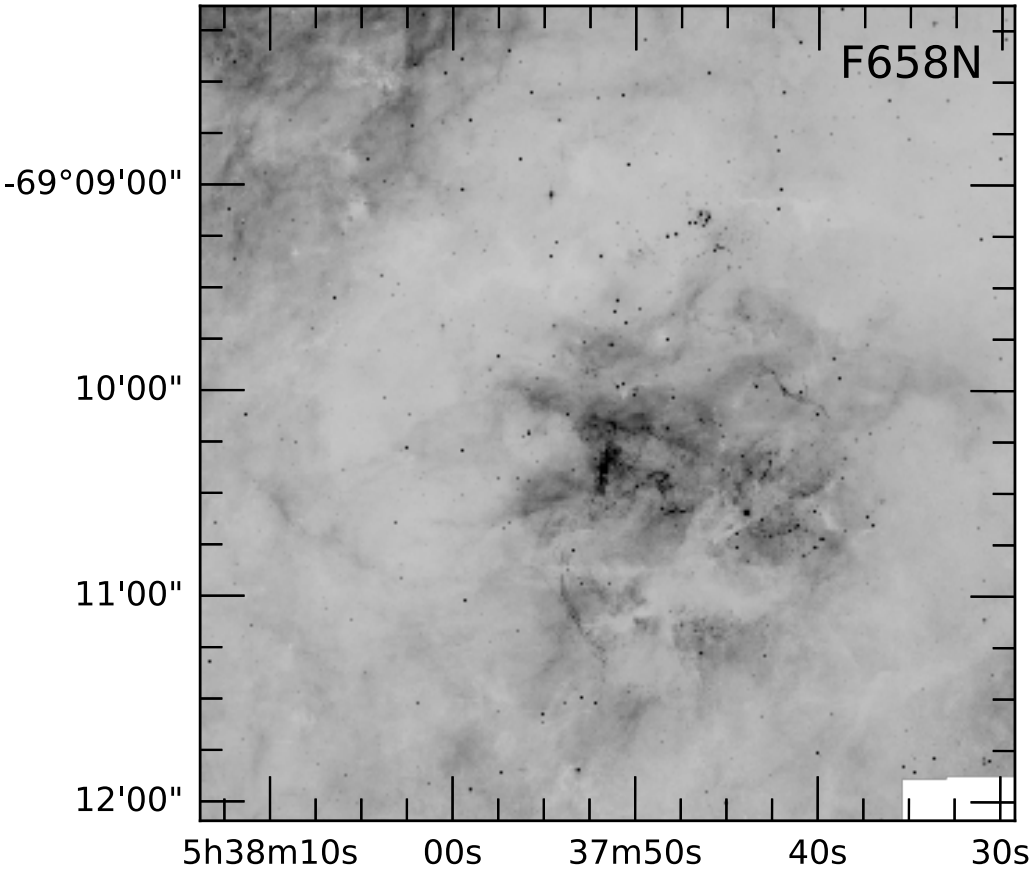

30 Dor


30 Dor
A
B
C


30 Dor B

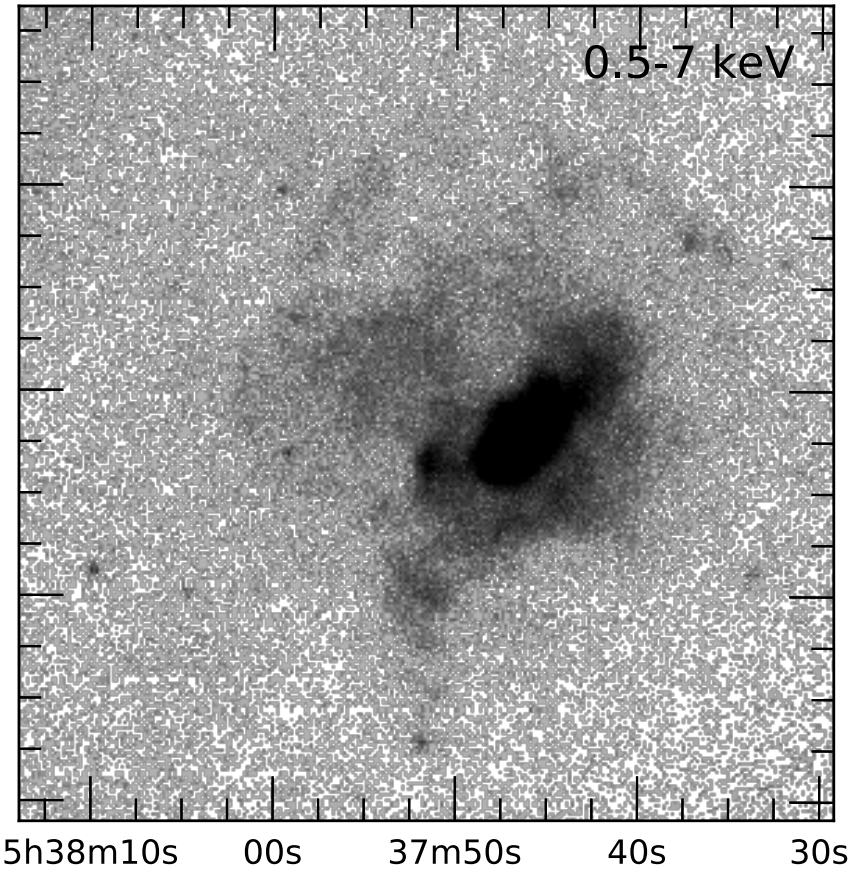
HST and Chandra View of 30 Dor B

HST Hα



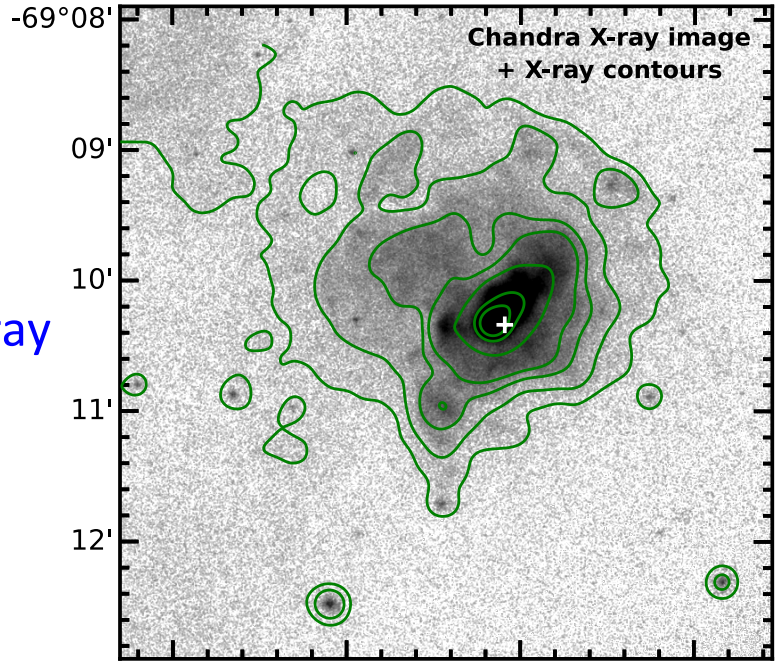
(PI: E. Sabbi)

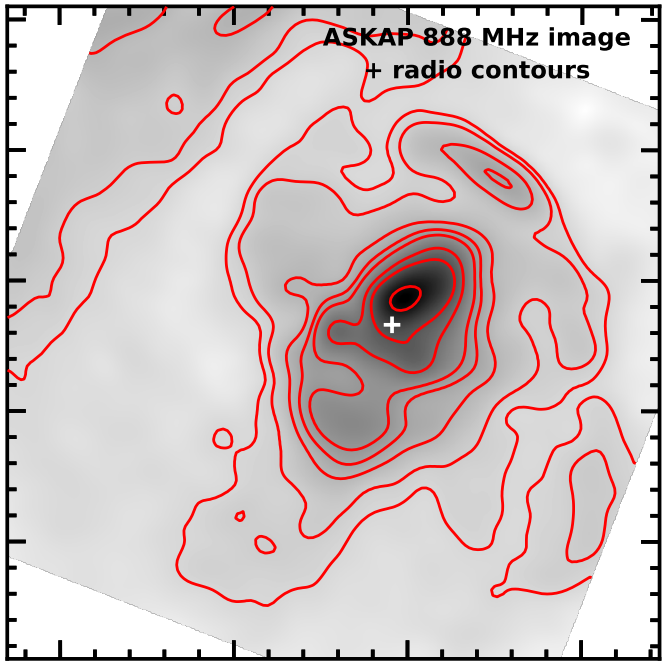
Chandra 0.5-7.0 keV



(PI: L. Townsley)

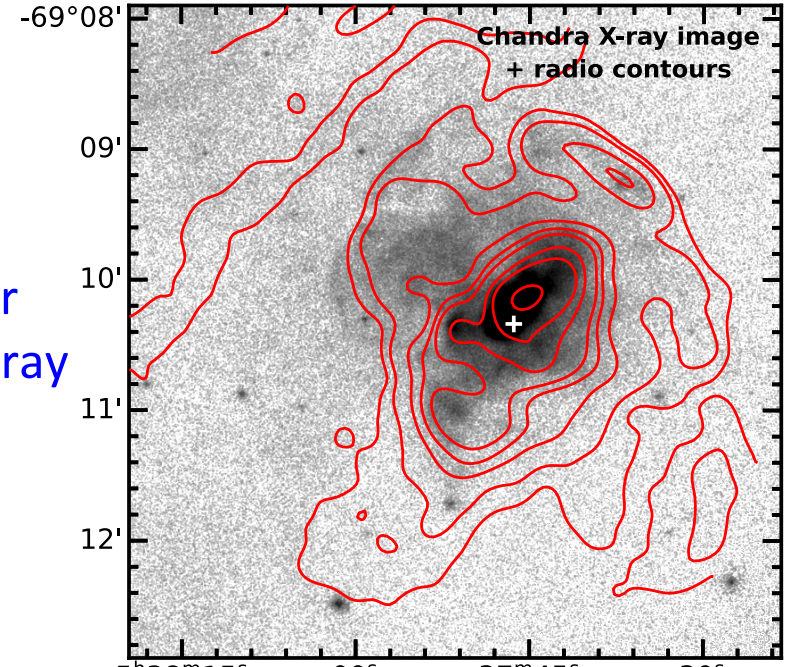
X-ray contour over X-ray image

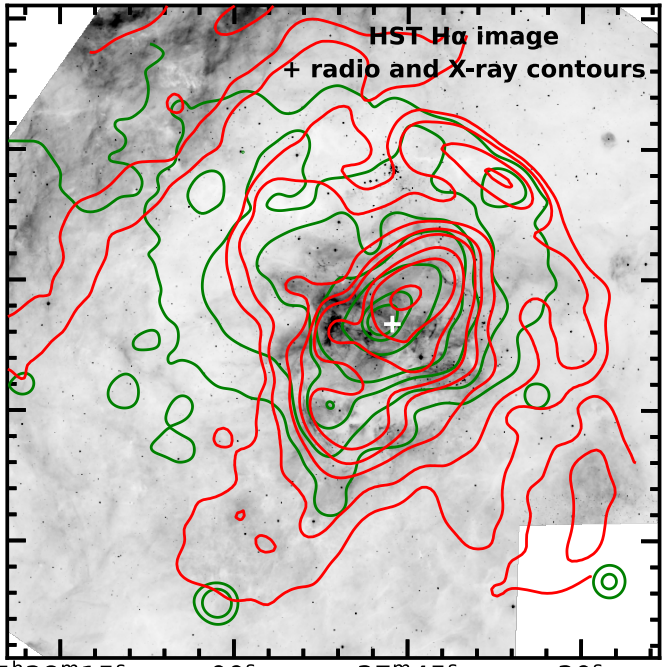


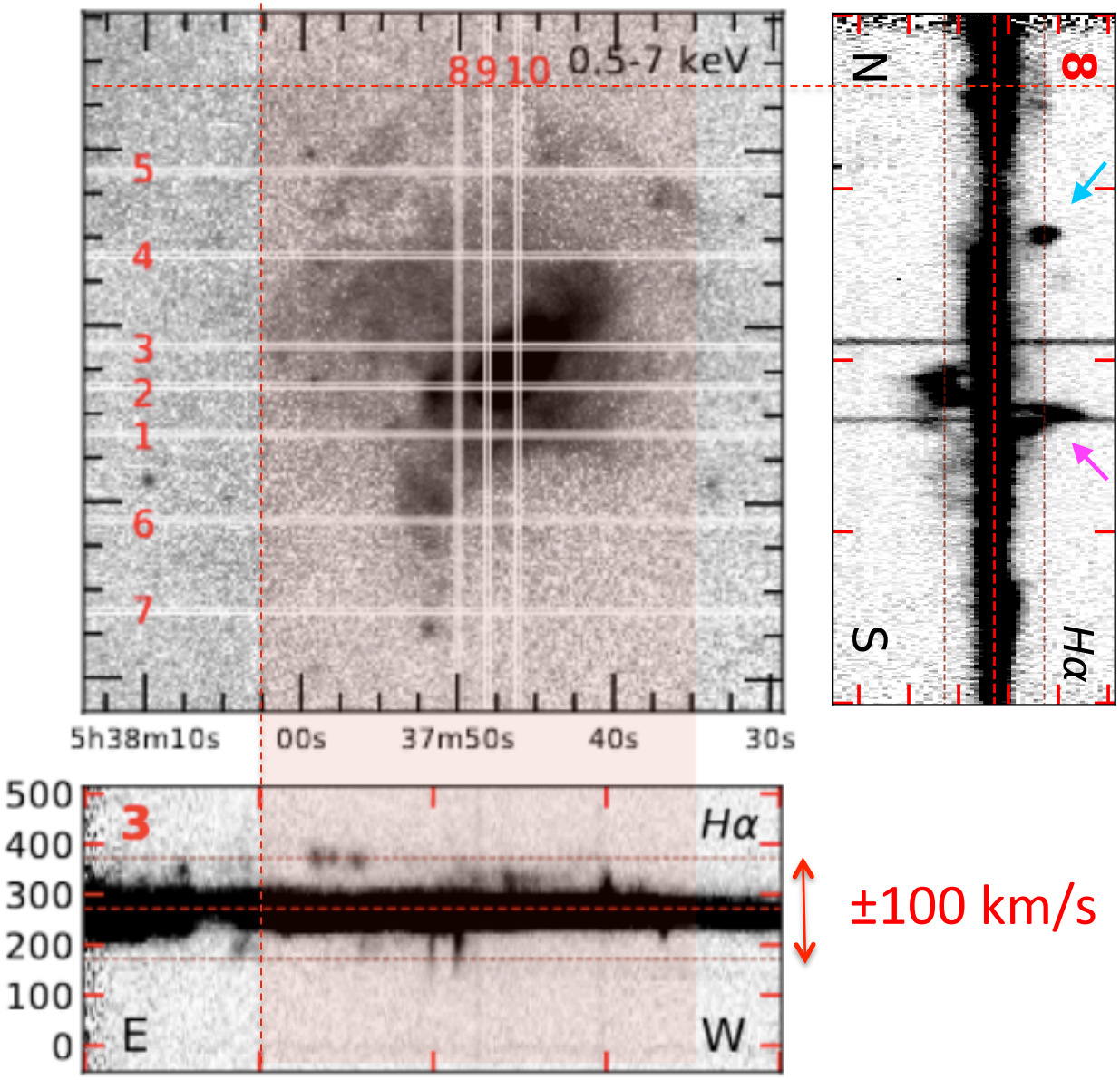


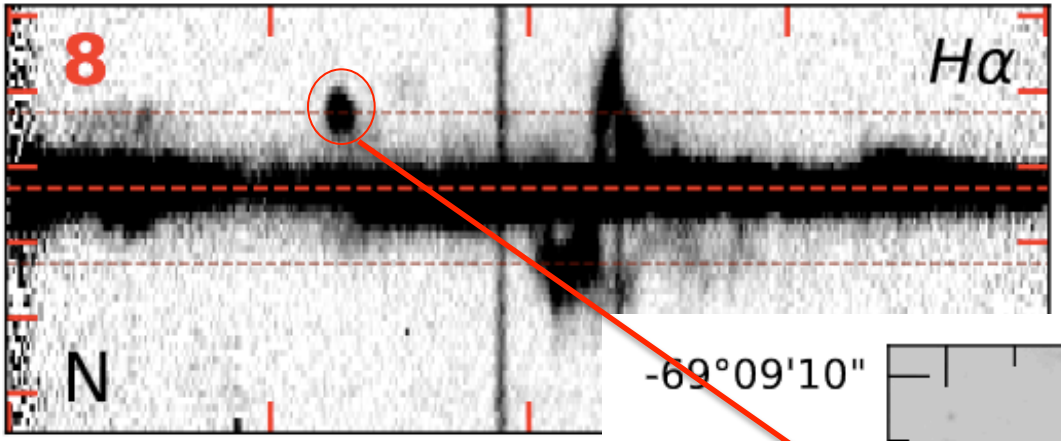
ASKAP 888 MHz contour over image

Radio contour over X-ray image



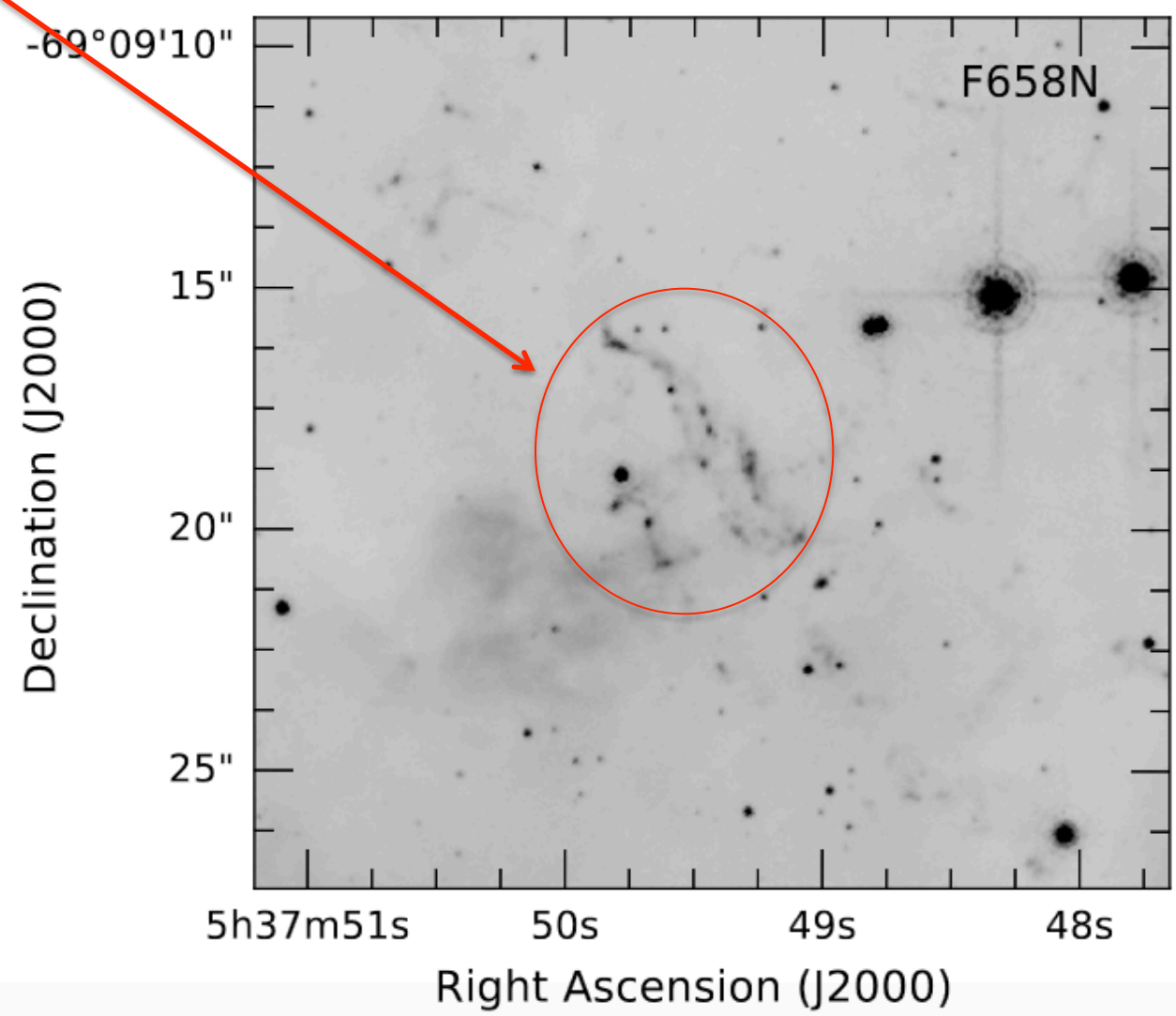


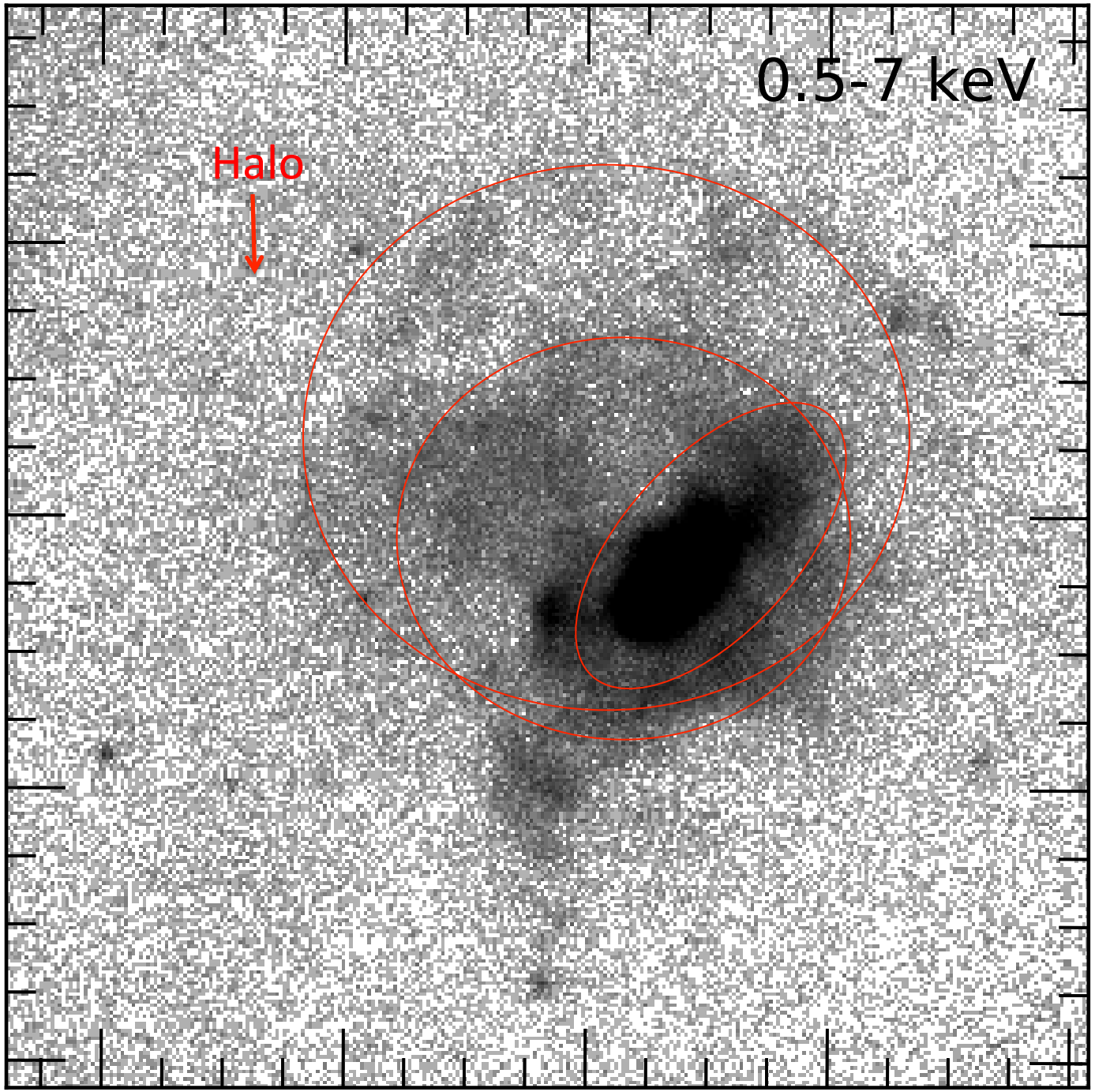

8910 0.5-7 keV
5
4
3
2
1
6
7
5h38m10s
00s
37m50s
40s
30s
N
8
S
Hα
500
400
300
200
100
0
3
Hα
E
W
±100 km/s



HST image resolves
The shredded cloudlet

High-velocity
(shocked)
cloudlet

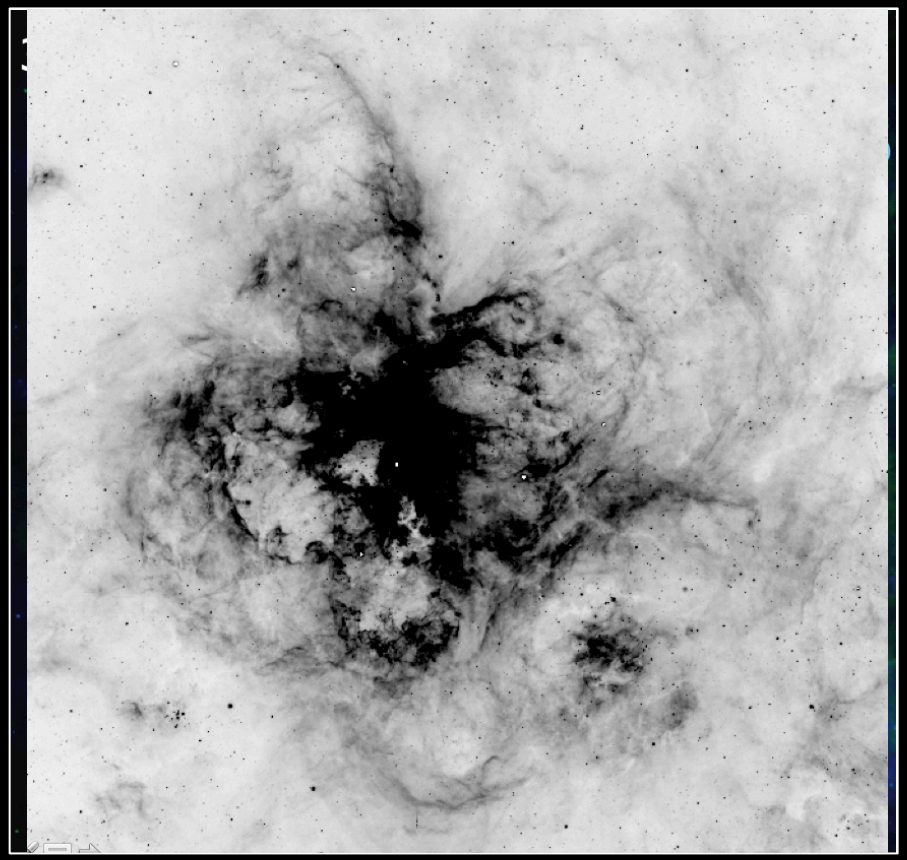


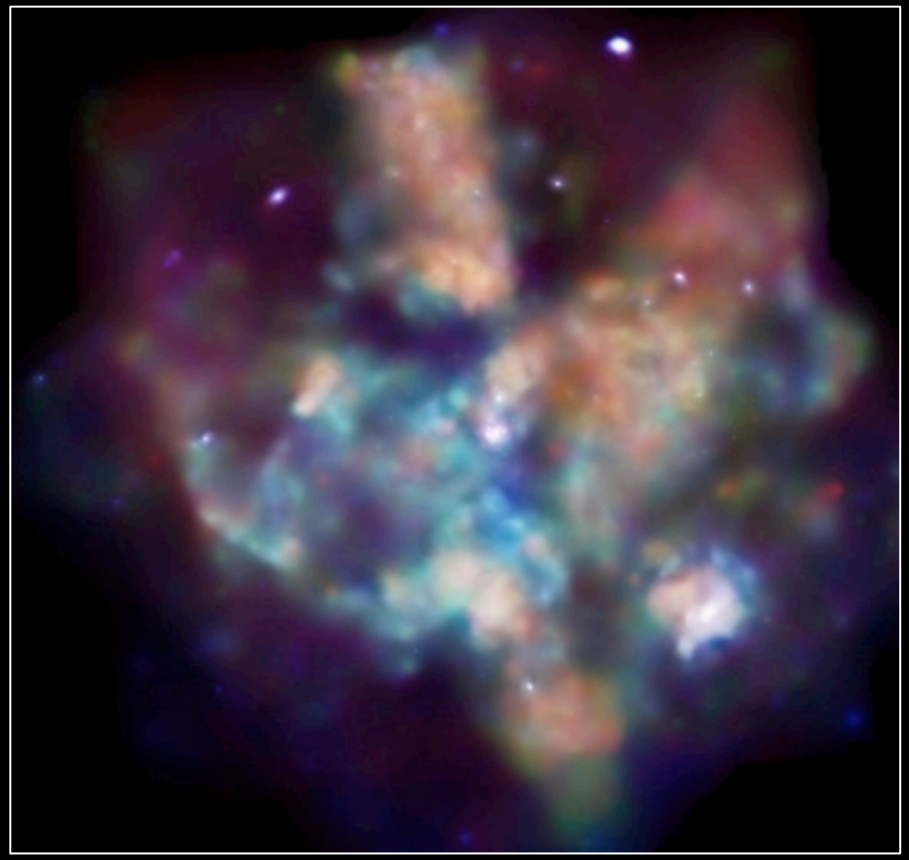

0.5-7 keV
Halo

30 Dor B

- *In a very complex environment*
- *Requires more than 1 SN.*
- *Complex star formation history precludes constraints on SN progenitor mass.*

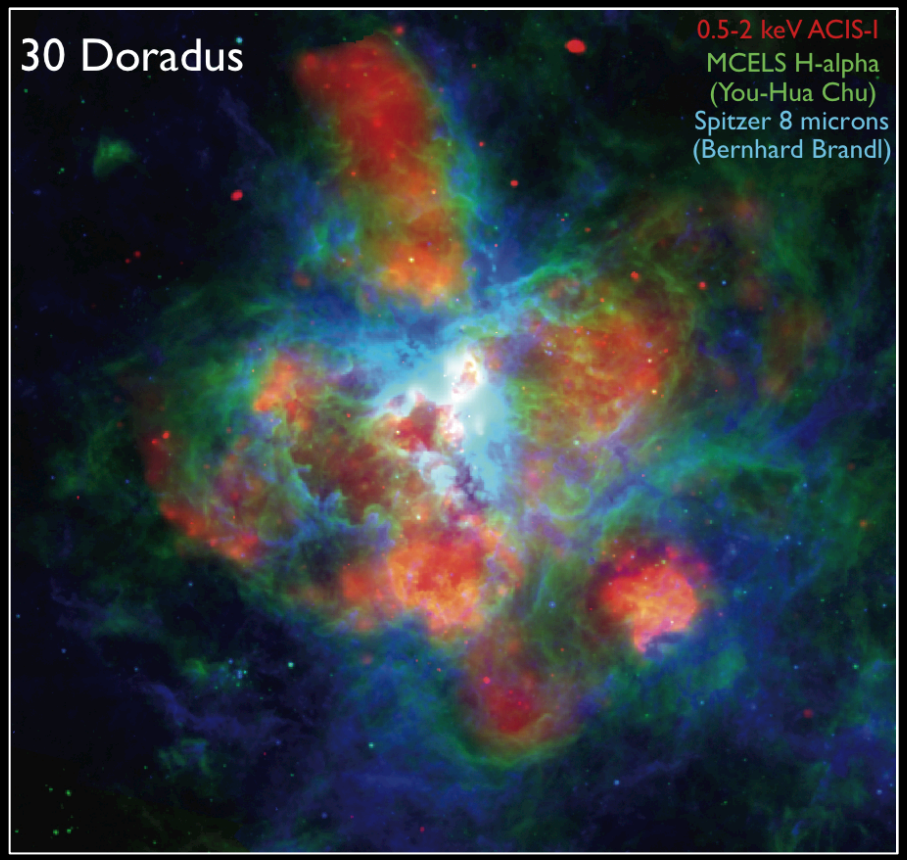
Chandra X-ray Image of Hot Gas in 30 Dor

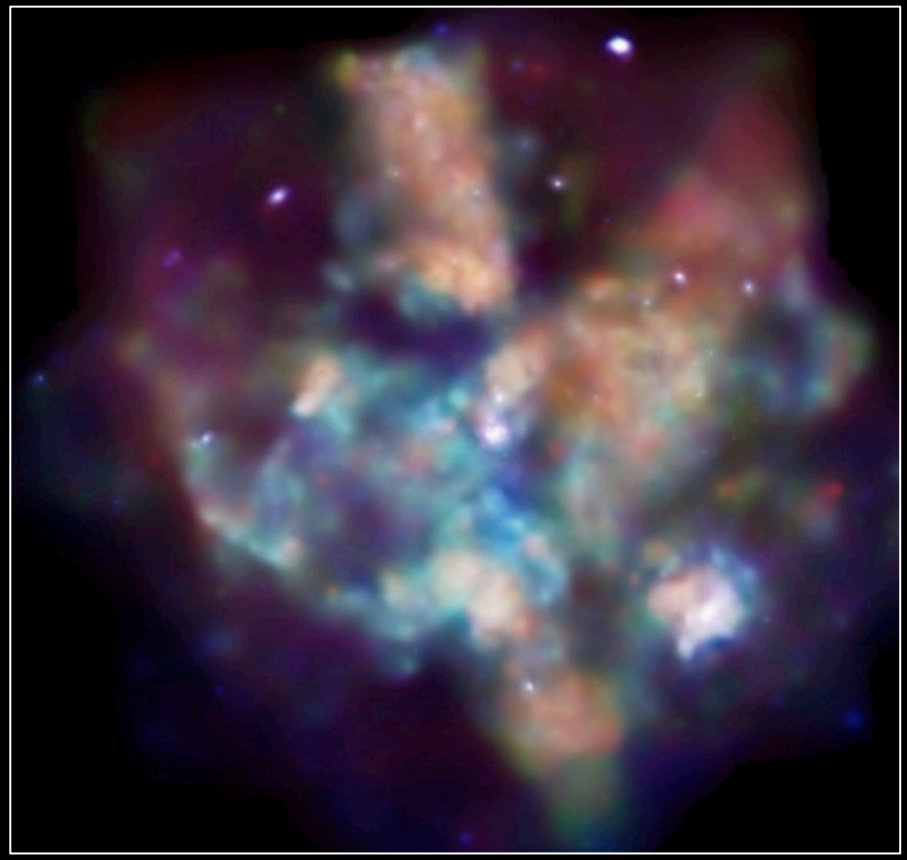




Townsley et al. (2006)

Chandra X-ray Image of Hot Gas in 30 Dor





Townsley et al. (2006)

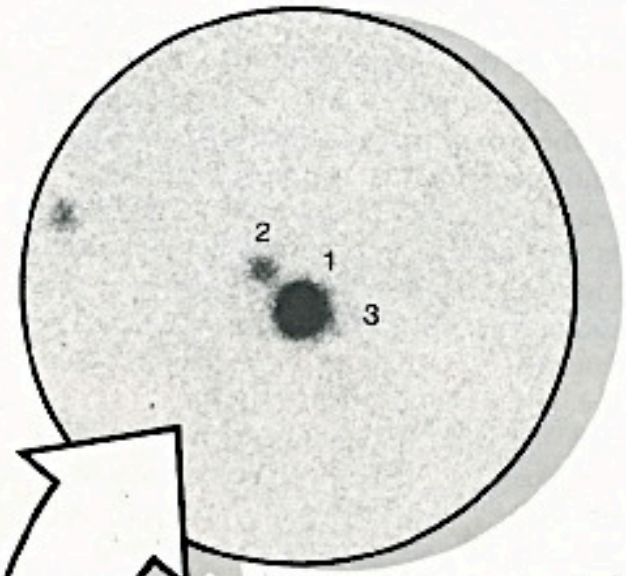
Circumstellar Environment

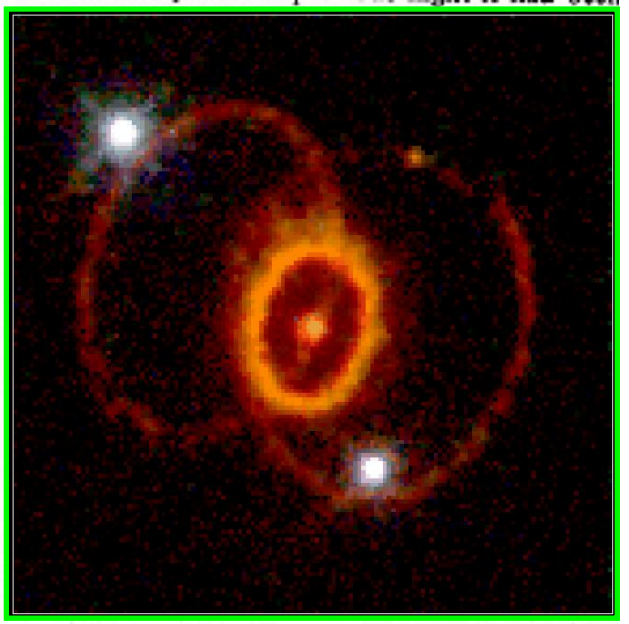
CSM in Type Ia SNRs

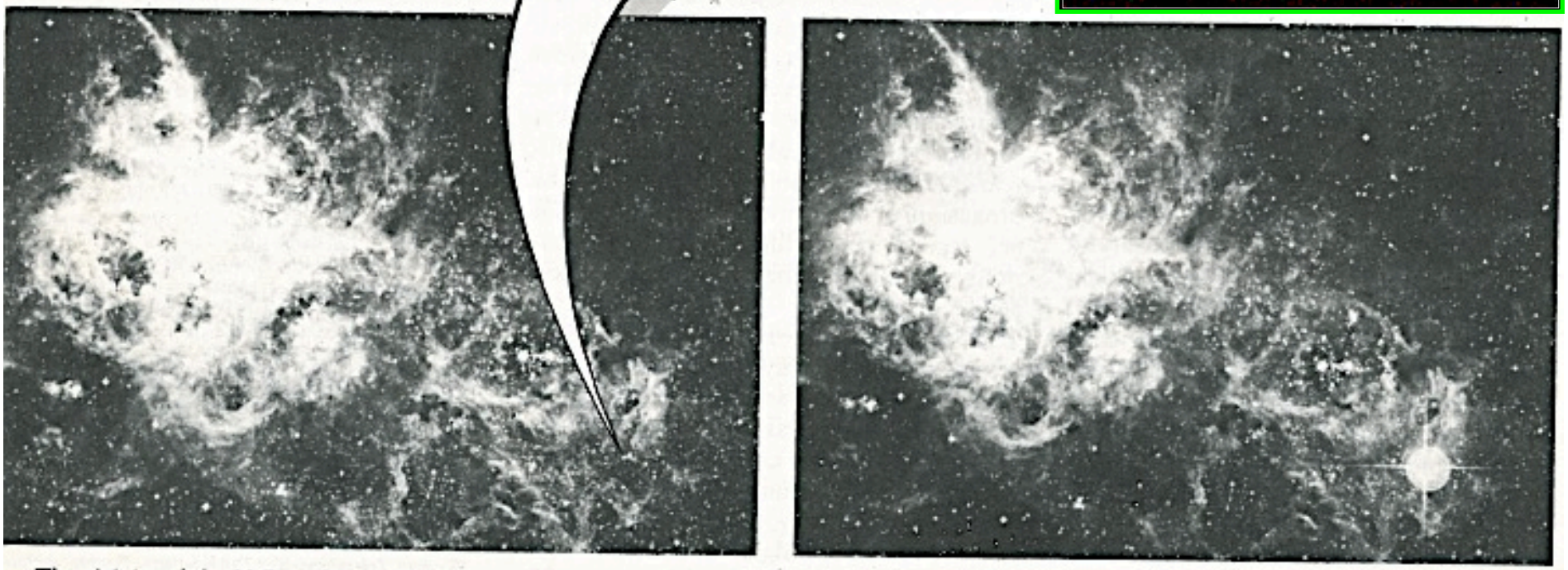
(Li, Chu, Raymond, et al. 2020, ApJ)

Progenitor of SN 1987A

Sk -69 202
B3 I

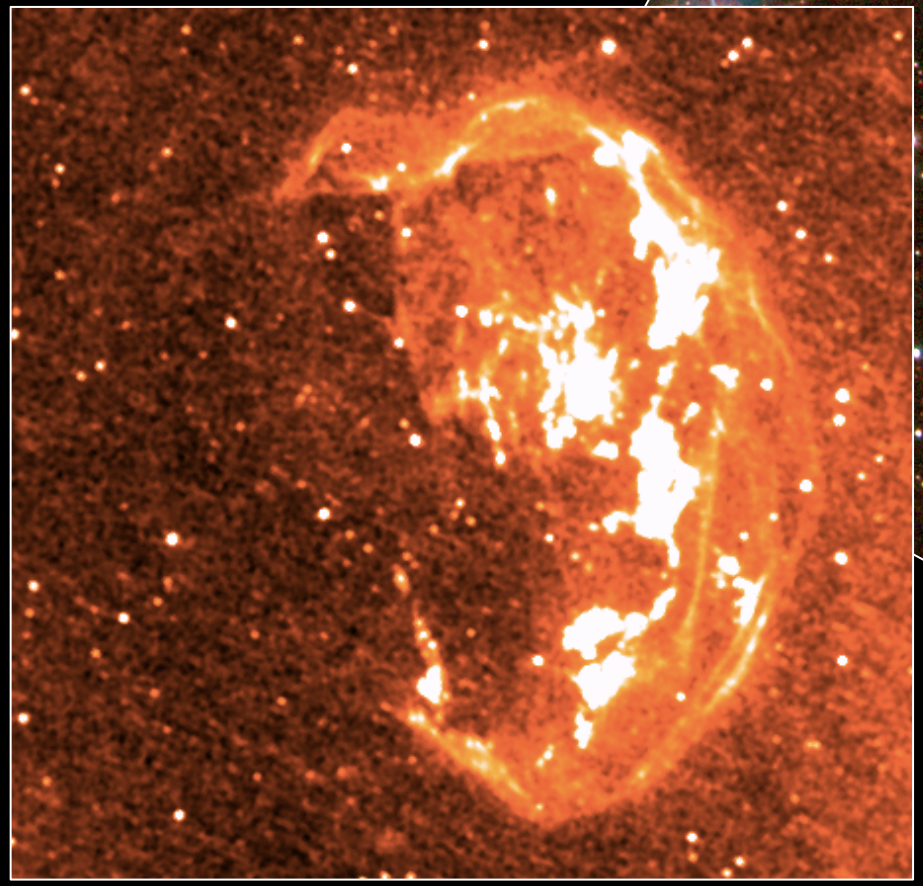


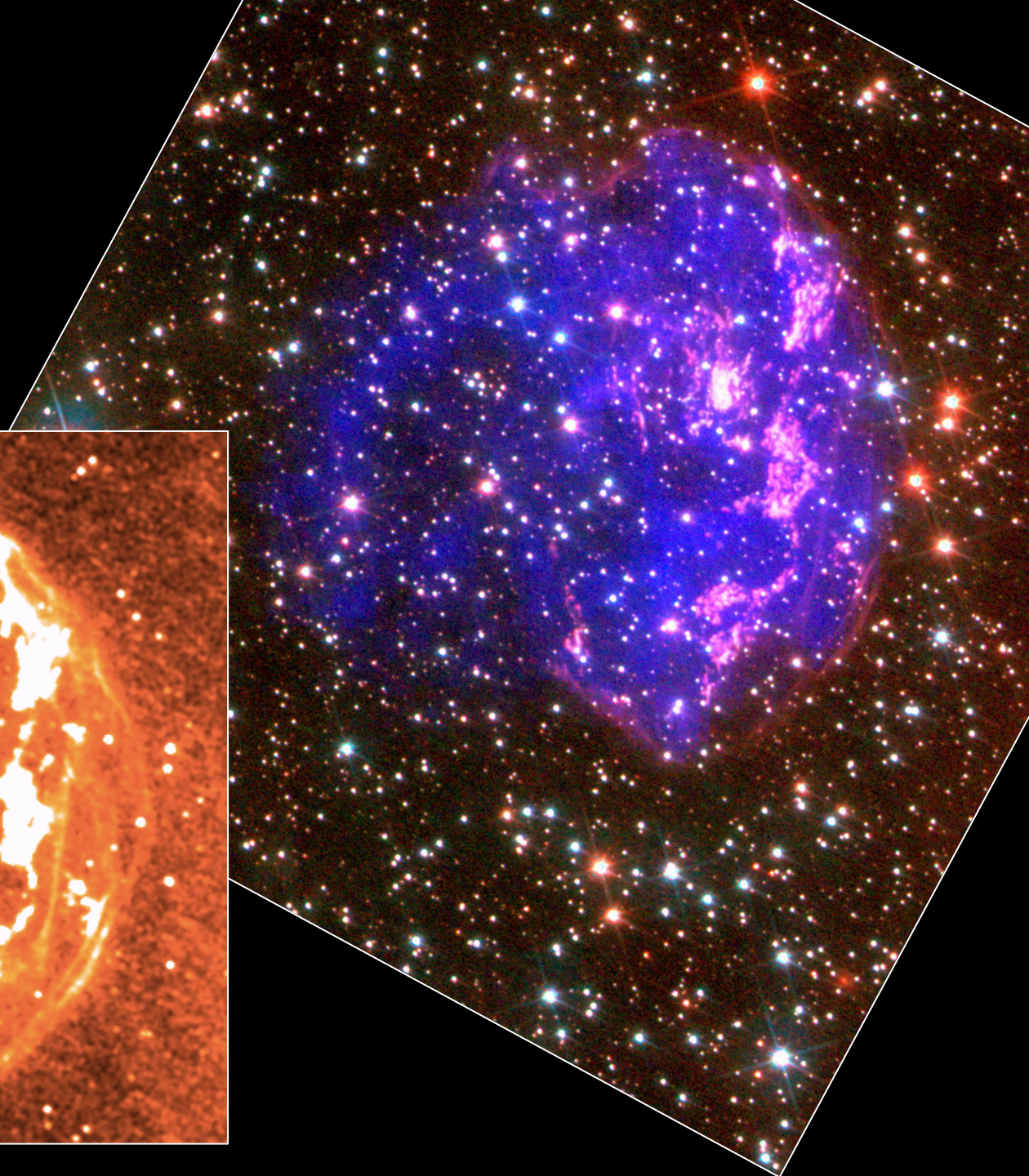




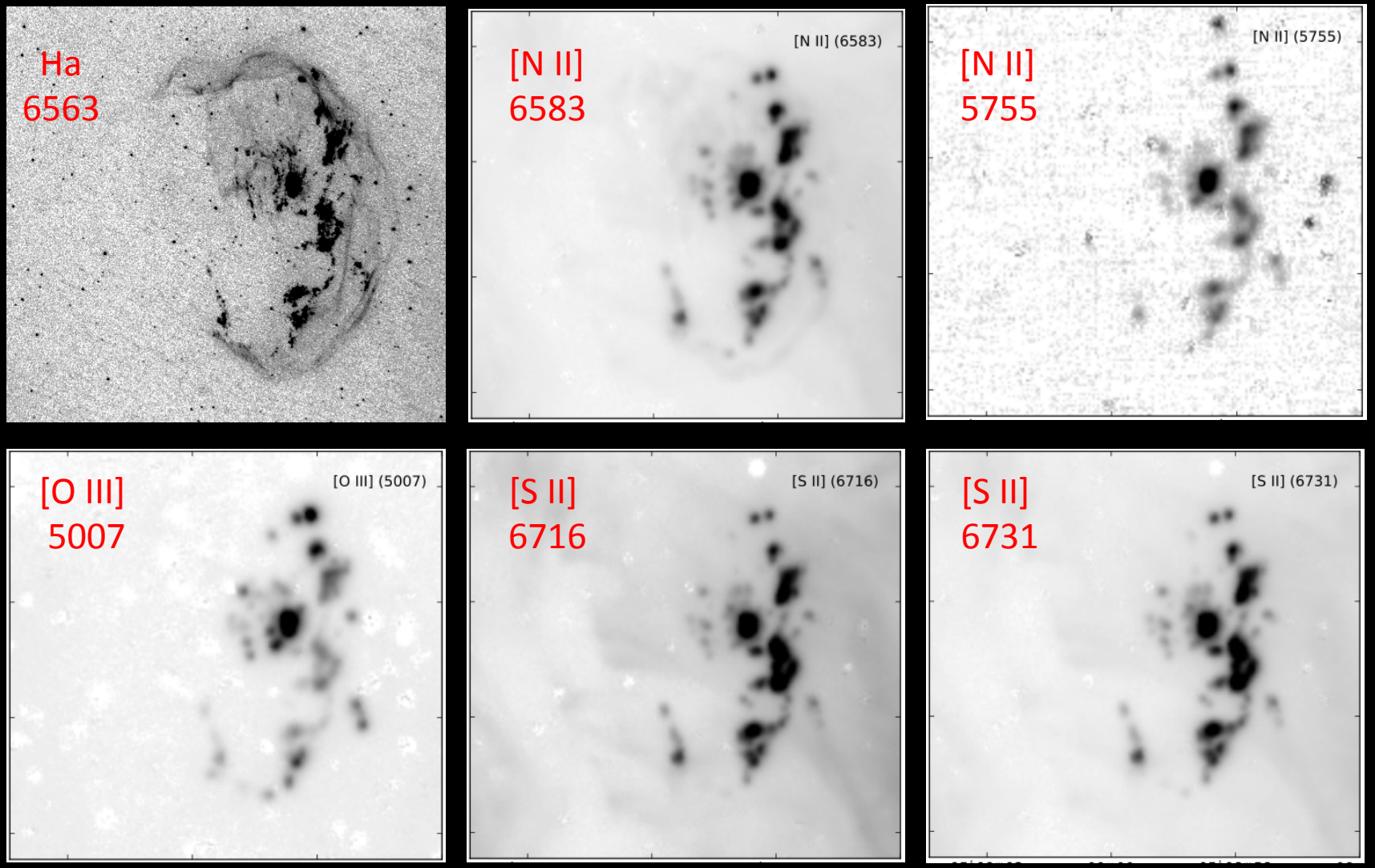
The vicinity of the 30 Doradus nebula before and after Supernova 1987A appeared. The images were made with the UK 1.2-meter Schmidt in Australia. Copyright Royal Observatory, Edinburgh, 1987. The arrow points to a 3-minute exposure of Sanduleak −69° 202, once a presupernova candidate, and its companions. It was taken in 1983 by You-Hua Chu (University of Illinois) with the 4-meter reflector at Cerro Tololo Inter-American Observatory. The image of star 3 forms merely a bump on the image of Sanduleak −69° 202.

Type Ia SNR N103B



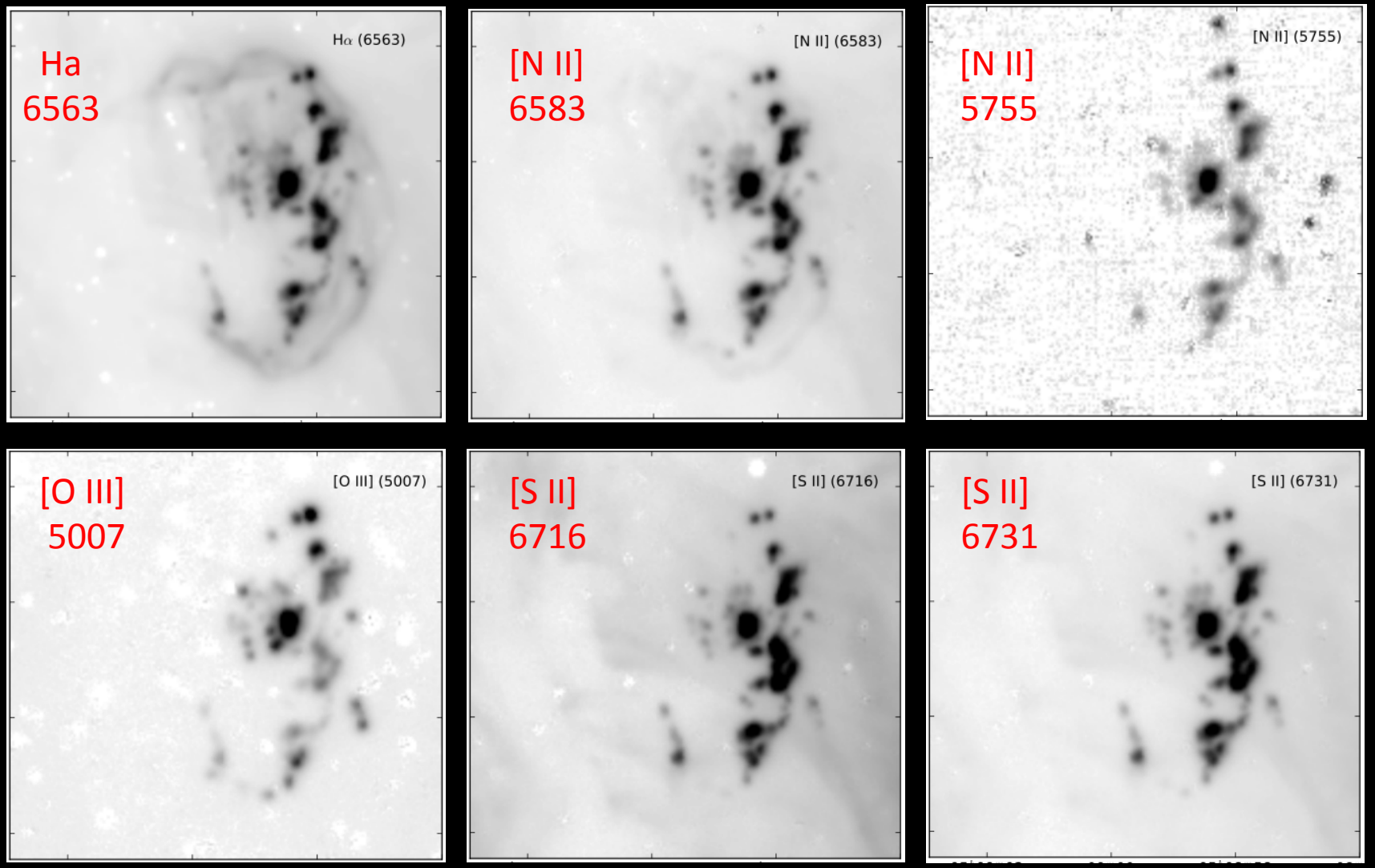


Balmer Shell and CSM Knots of N103B



Li et al. 2017, ApJ

Balmer Shell and CSM Knots of N103B



Li et al. 2017, ApJ

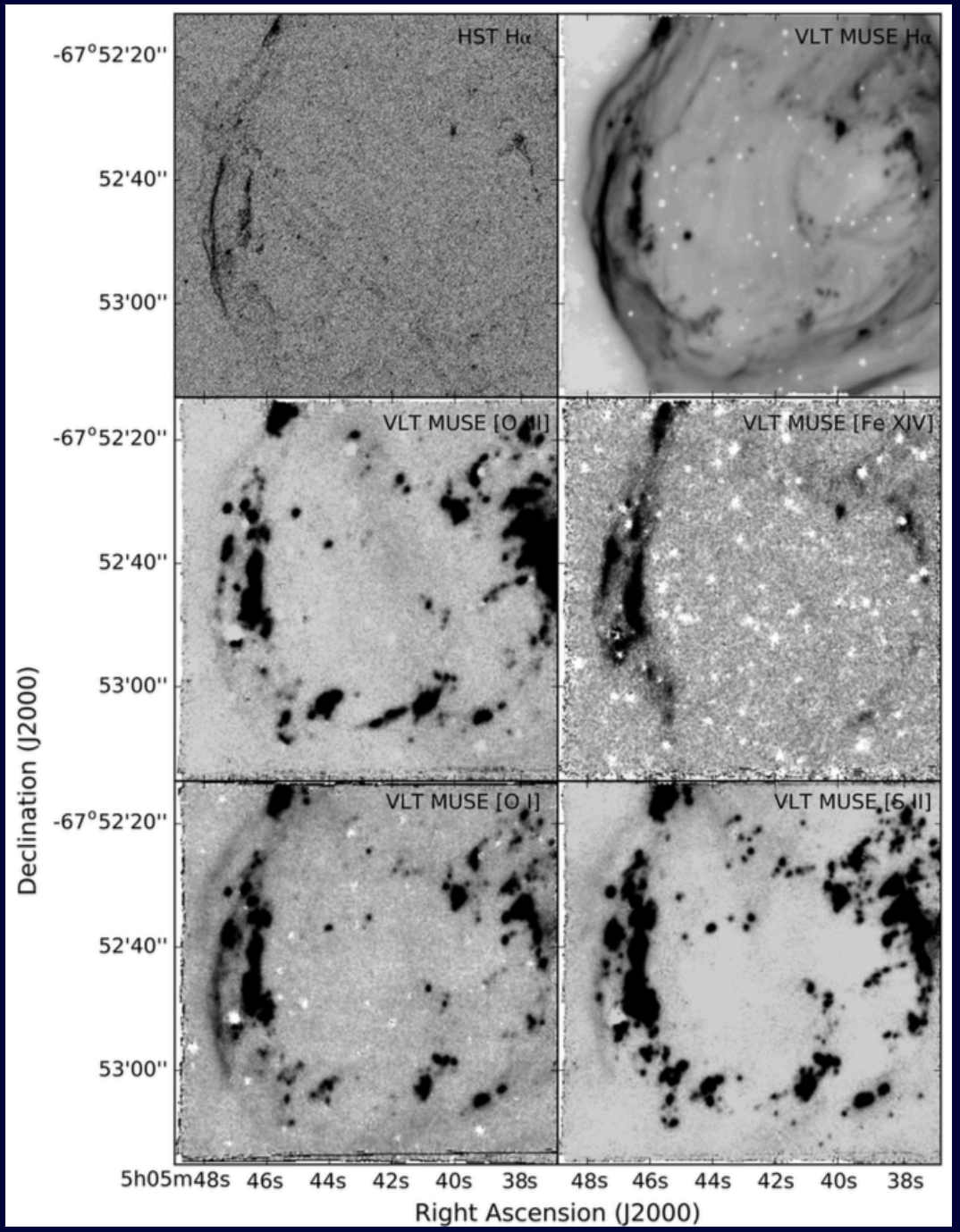
DEM L71

Forbidden Line Emission

⬇

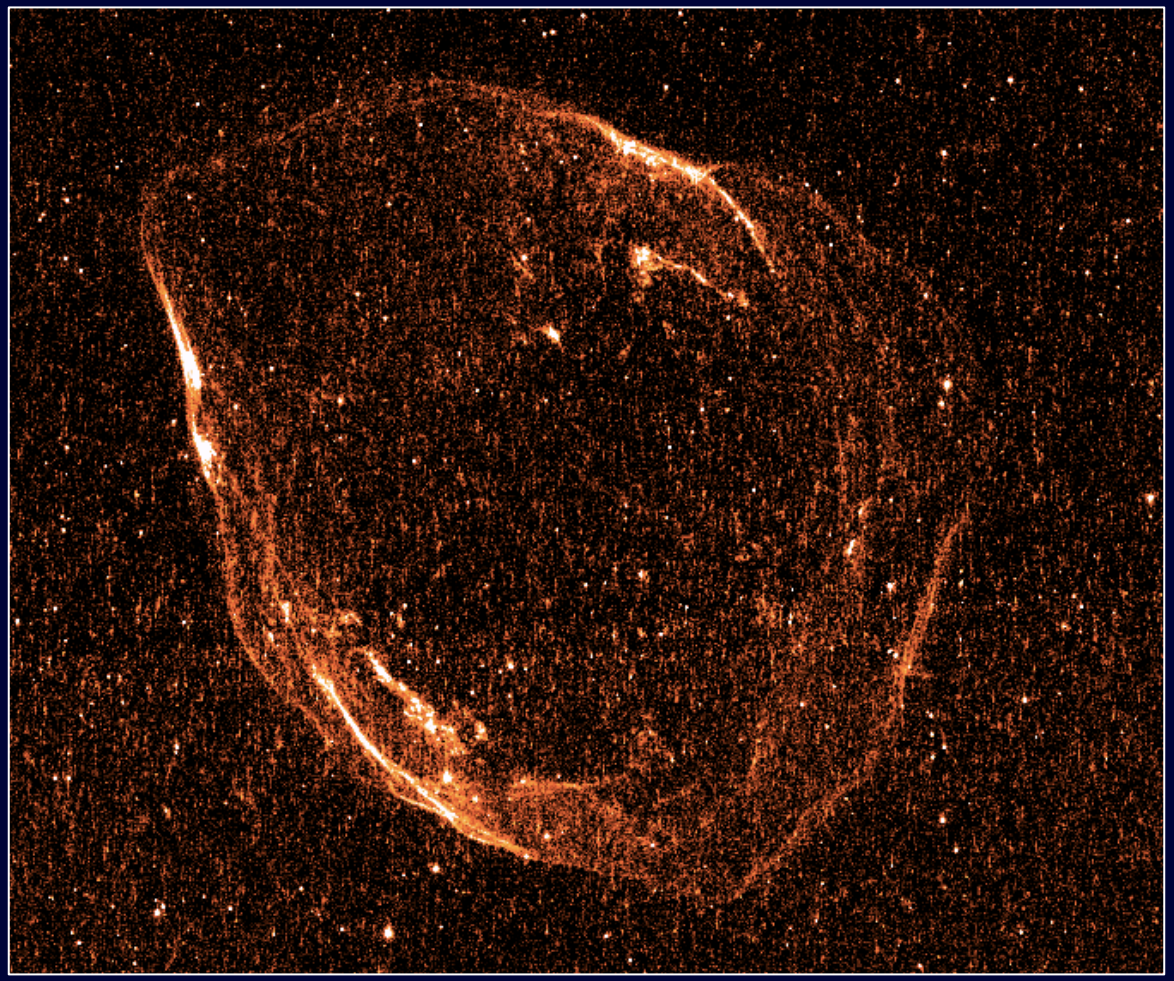
Circumstellar Medium

Li et al. 2021, ApJ



Type Ia SNR DEM L71

Balmer-dominated

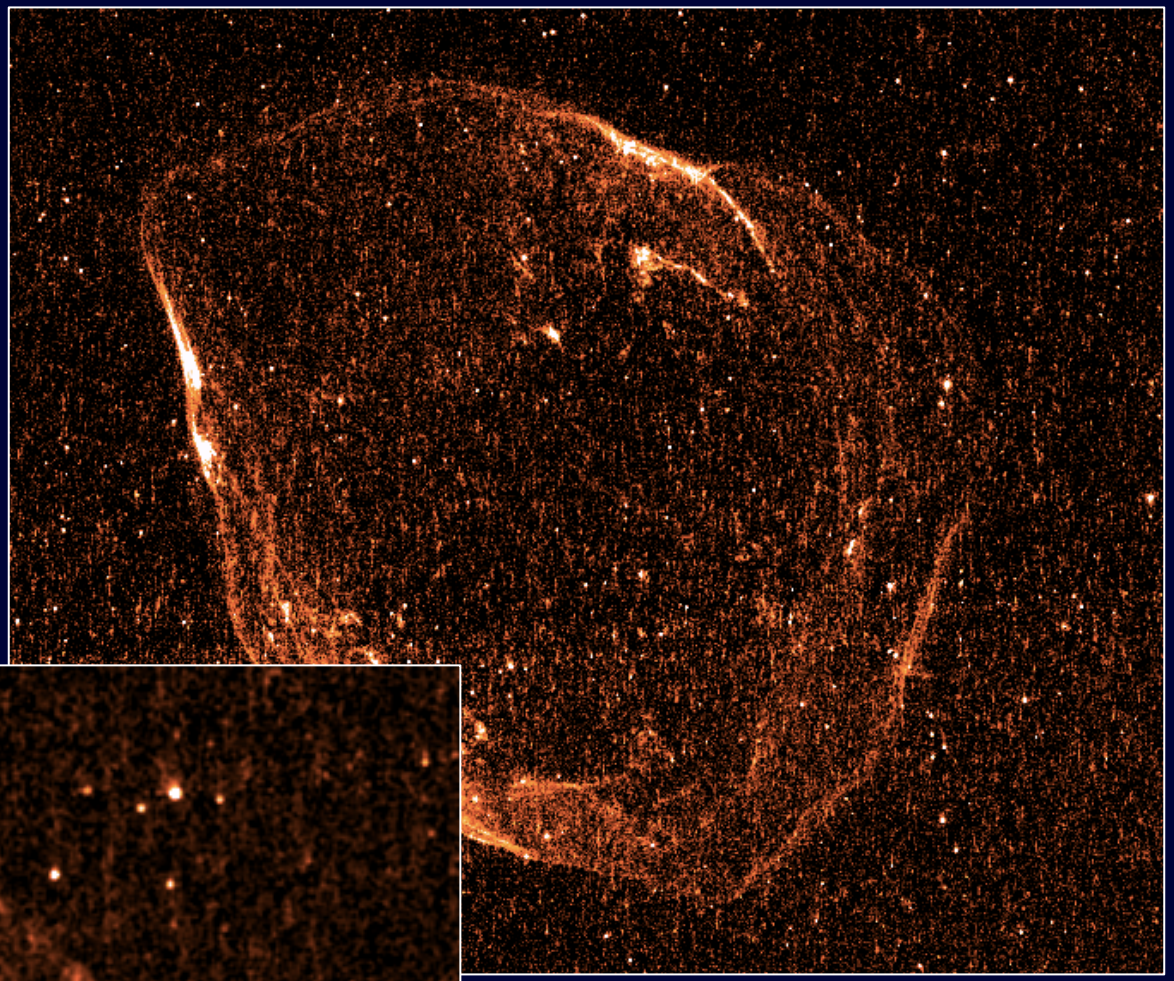


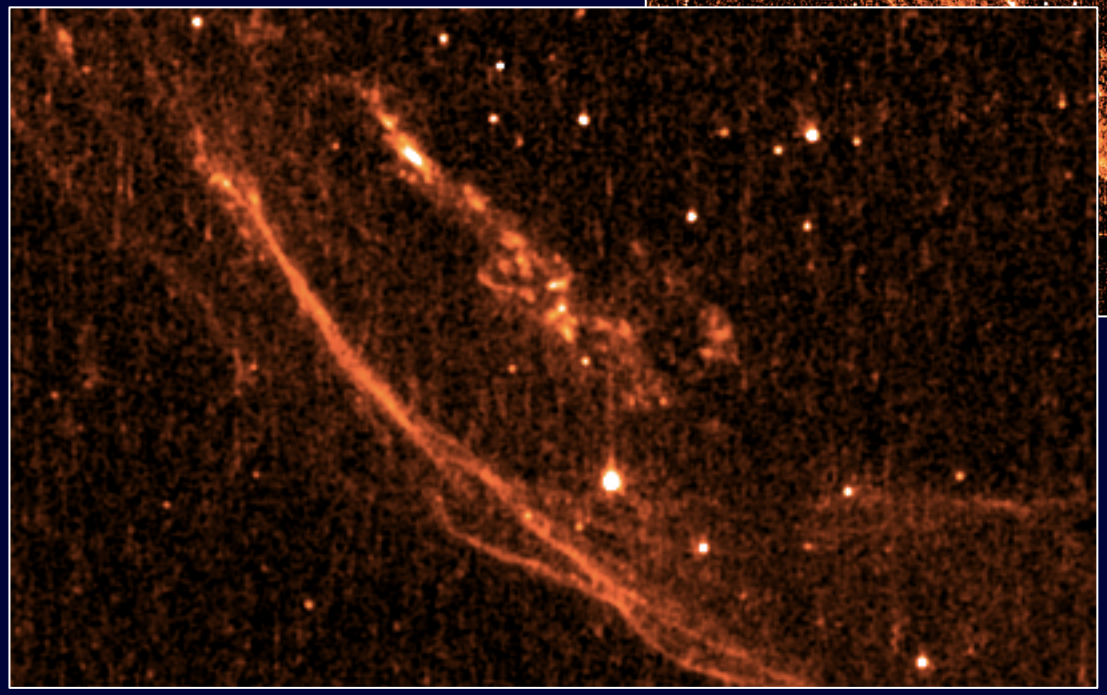
Knots

- forbidden lines
- $n_e \sim 2000\ cm^{-3}$

Type Ia SNR DEM L71

Balmer-dominated

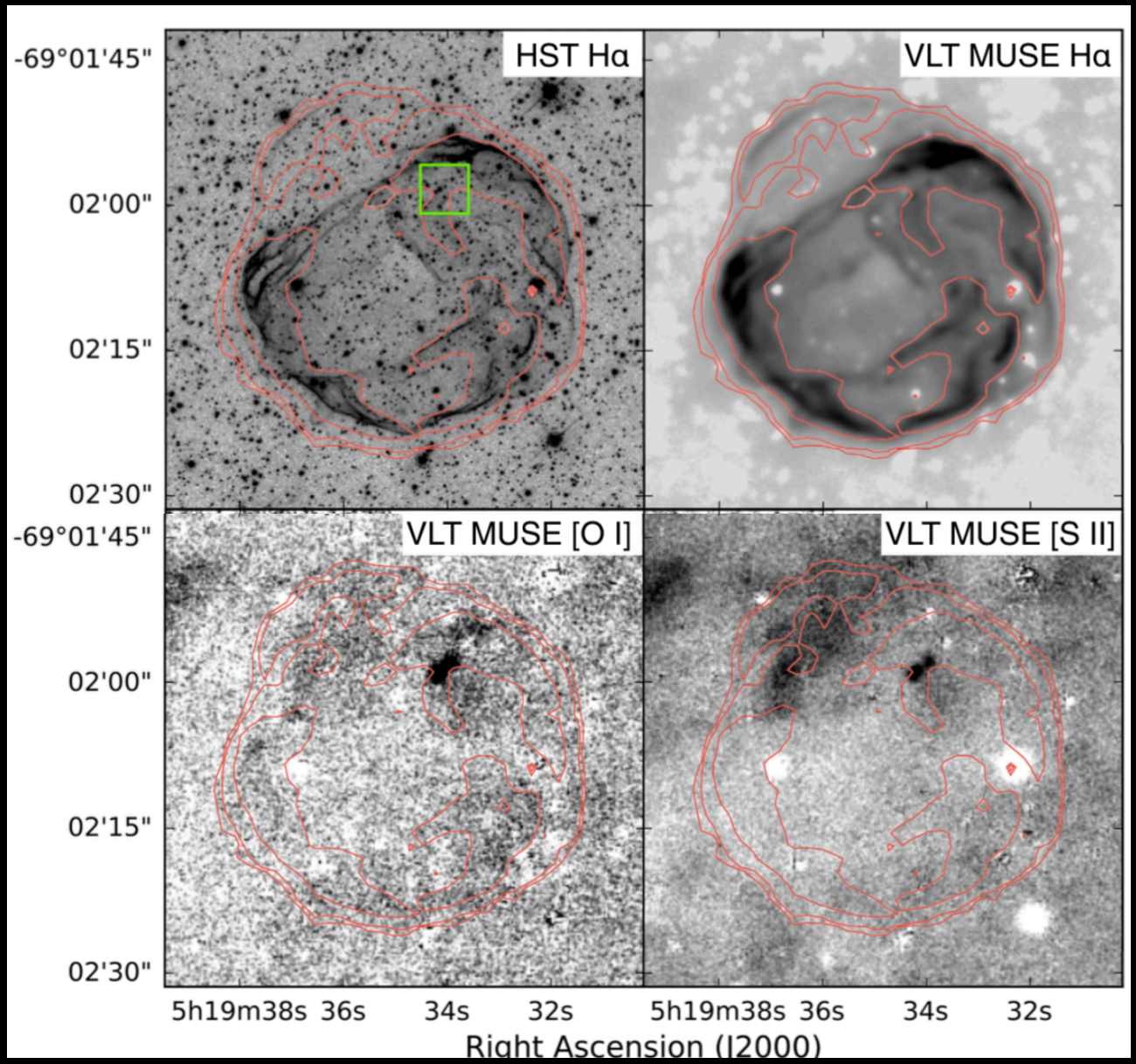




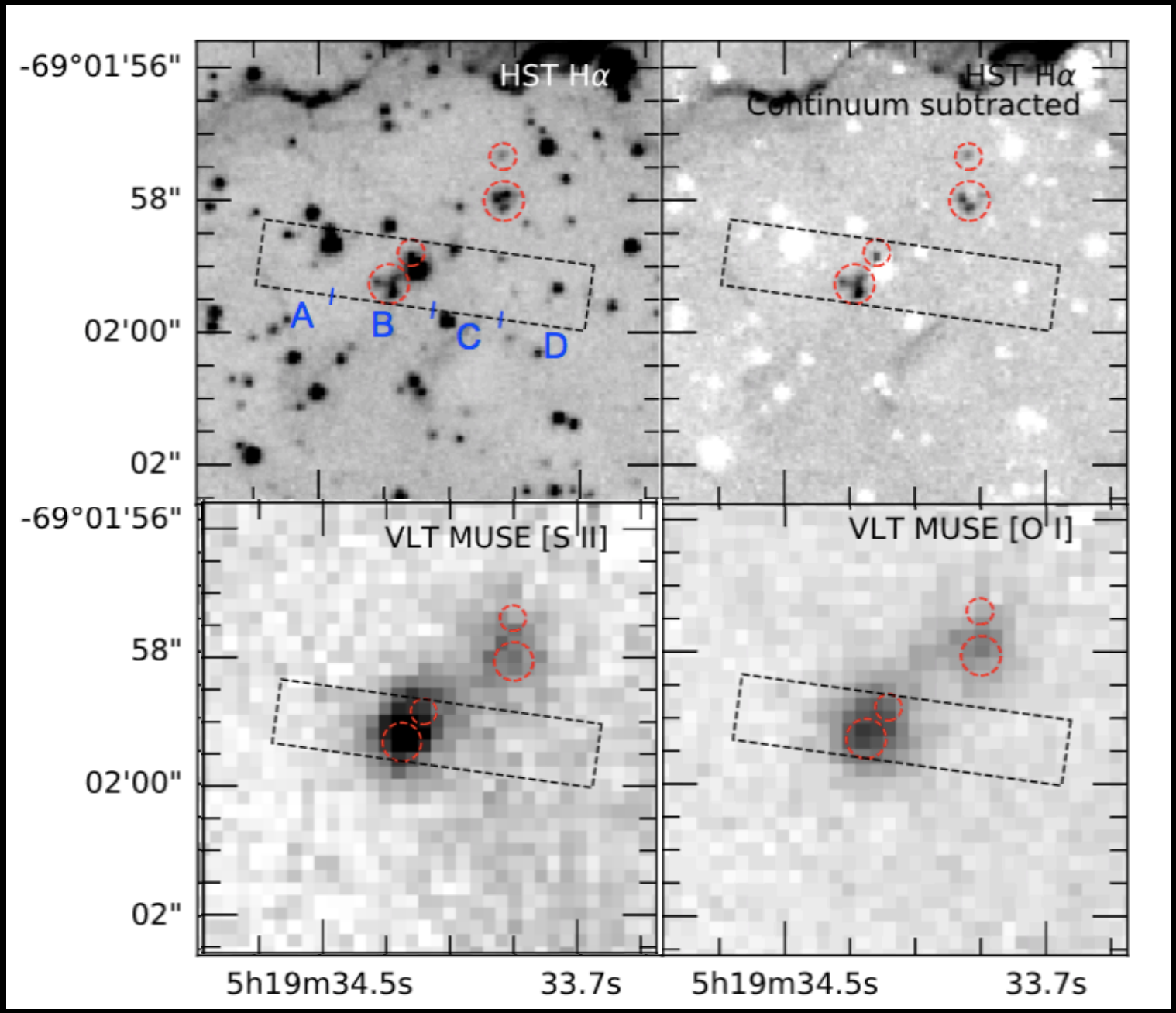
Knots

- forbidden lines
- $n_e \sim 2000\ cm^{-3}$

Balmer Shell and CSM Knots of 0109-69.0



Origin of these nebular knots?



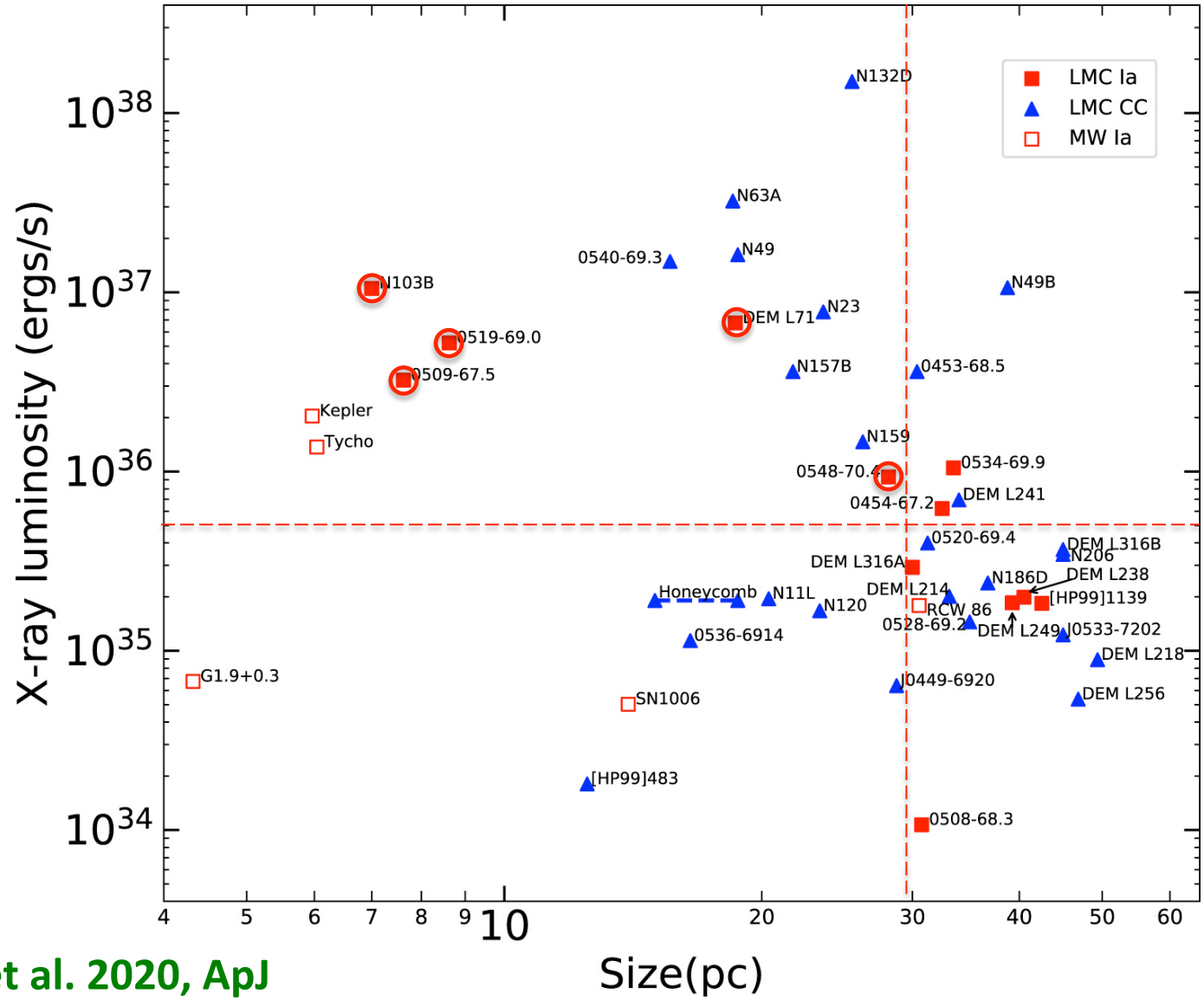
Galactic Environment

Balmer-dominated Type Ia SNRs
LMC vs M33

(Lin, Chu, Ou, Li, 2020, ApJ)

Balmer : up to ~30 pc

X-ray : up to ~45 pc

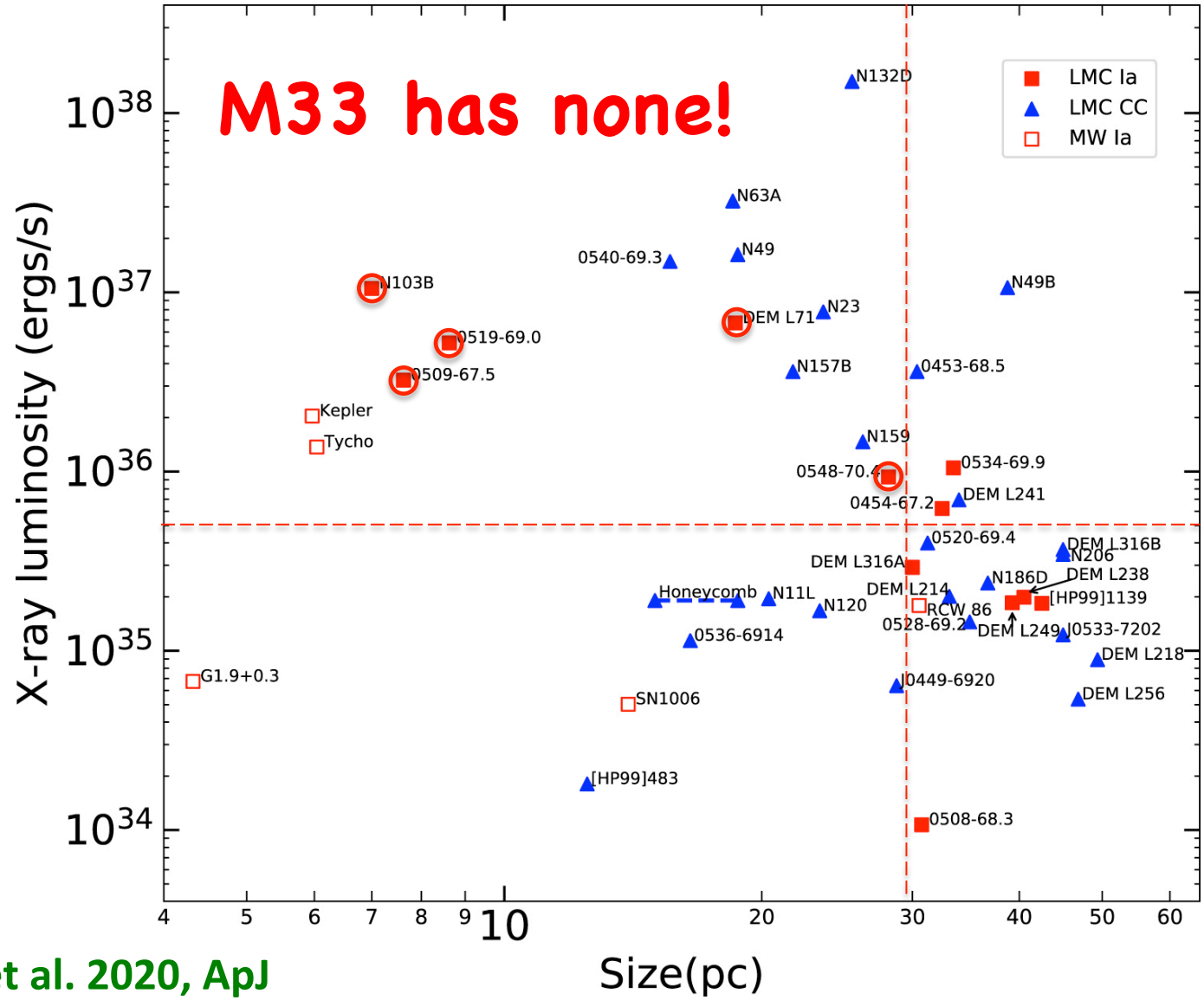


$5x10^{35}$ erg/s

Lin, Chu, et al. 2020, ApJ

Balmer : up to ~30 pc

X-ray : up to ~45 pc



$5x10^{35}$ erg/s

Lin, Chu, et al. 2020, ApJ

	MW	LMC	M33
Bright X-ray (Thermal)	2	5	0
Faint X-ray (Nonthermal)	3	0	?

Small number statistics or real difference?

LMC is wonderful for SNR studies!

DeMCELS will provide superb images of LMC SNRs!