Structures of M33 Supernova Remnants Revealed by Broad-Band HST Images

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Supernova Remnants (SNRs) are usually detected in narrow bands centered on emission lines.
We show that **broad-band images can still reveal some SNRs**.

Catalog of 218 SNR candidates in M33
Long et al. (2010); Lee & Lee (2014)

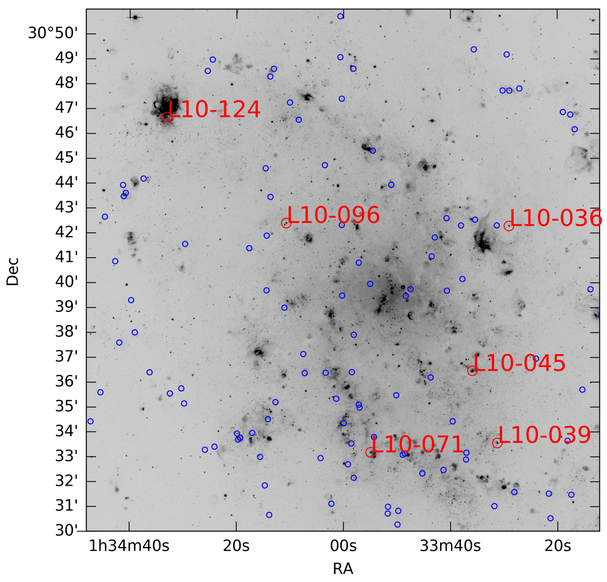
***HST* archival data**
From the Legacy Imaging Survey of M33 (PI: Dalcanton)
Only broad-band images!

80 SNRs imaged
6 SNRs detected in *HST* broad bands

	Surface Brightness (erg/s/cm²/arcsec²) *Long et al. (2010)*	Diameter (pc) *Long et al. (2018)*	Density (cm^{-3})	X-ray Luminosity (erg/s) *Garofali et al. (2017)*
L10-036	5.0×10^{-15}	22	>11	4.1×10^{36}
L10-039	1.5×10^{-14}	16	>22	6.4×10^{36}
L10-045	5.8×10^{-15}	33	>10	1.8×10^{36}
L10-071	5.0×10^{-15}	24	>10	5.4×10^{36}
L10-096	3.7×10^{-15}	22	>9	3.0×10^{36}
L10-124	9.4×10^{-15}	14	>19	1.1×10^{35}

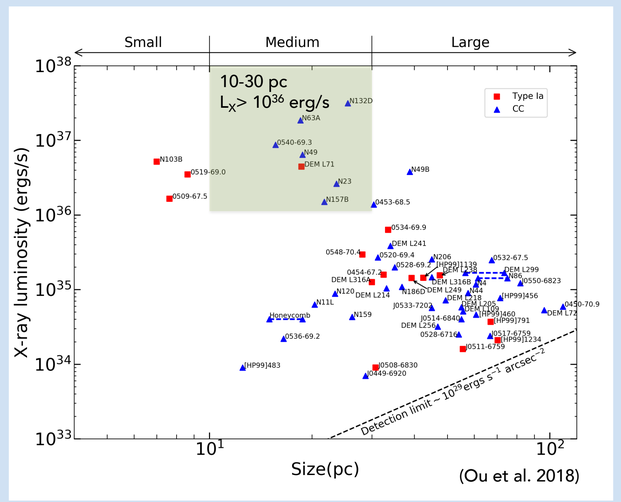
- Density calculated by: SB = 1.9×10^{-18} $\mathbf{n_e^2 L_{pc}}$ erg s^{-1} cm^{-2} $arcsec^{-2}$
  (Emitting path length $\mathbf{L_{pc}}$**= f*diameter of the SNR**, where f<1)
- X-ray luminosity derived from the flux, for a M33 distance of 817 kpc

They are X-ray bright SNRs in dense environments
- The 6 SNRs detected in broad bands are *exactly* the 6 SNRs with highest densities derived from Long et al.'s measurements.
- All but 1 of these SNRs are among the 16 X-ray bright SNRs with $L_X>10^{36}$ erg/s.



Density detection threshold
- X-ray: >0.001 cm^{-3} (Ou et al. 2018)
- Hα band: >1 cm^{-3} (Ou et al. 2018)
- HST broad bands: >10 cm^{-3}

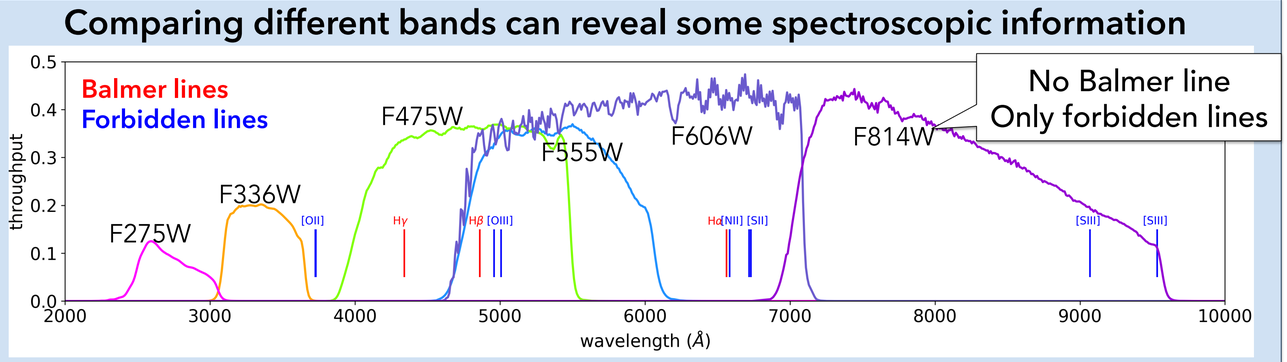
Comparing with the LMC's L_X-size diagram



- The 6 M33 SNRs mostly among the group of medium-sized (10-30 pc), X-ray-bright SNRs
- 3 possible origins:

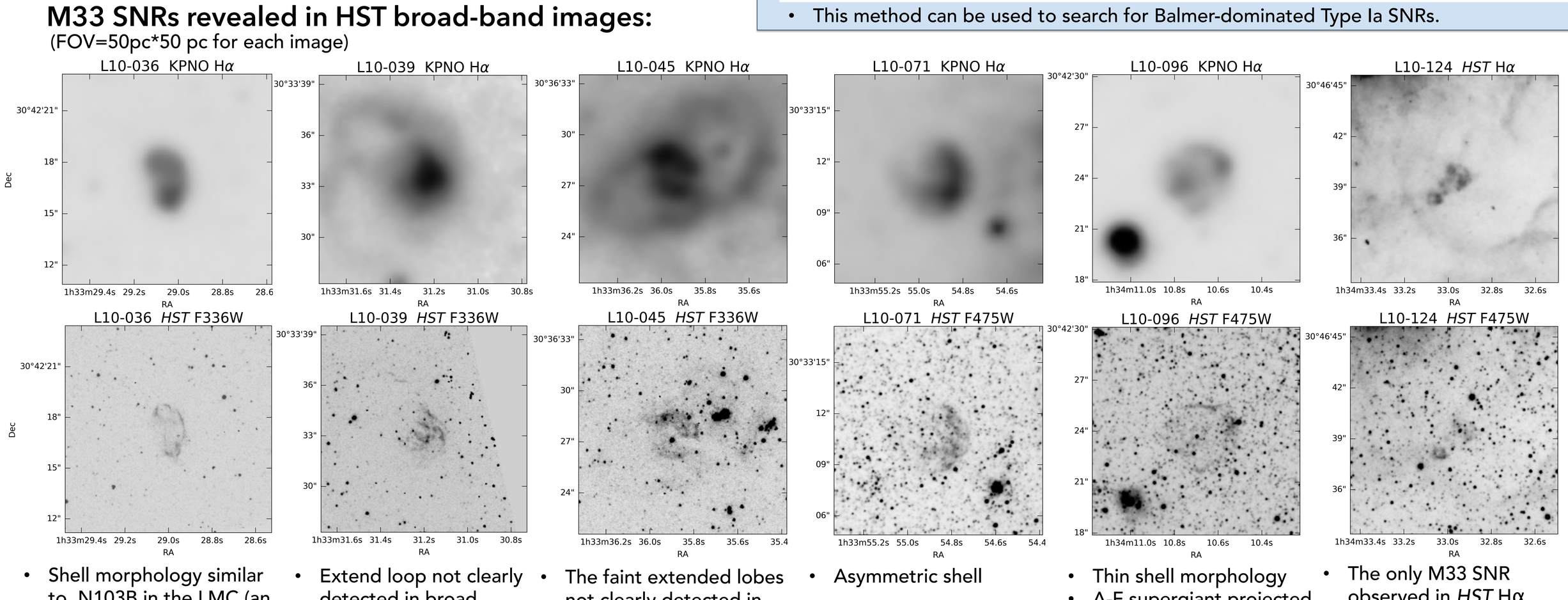
(1) Core-collapse SNRs interacting with dense clouds
(2) Core-collapse SNRs with pulsar-wind nebulae
(3) Type Ia SNRs

Comparing different bands can reveal some spectroscopic information



- This method can be used to search for Balmer-dominated Type Ia SNRs.

M33 SNRs revealed in HST broad-band images:
(FOV=50pc*50 pc for each image)



- Shell morphology similar to N103B in the LMC (an Type Ia SNR interacting with CSM)
- A possible candidate for Type Ia SNR

- Extend loop not clearly detected in broad bands
- Filamentary structures

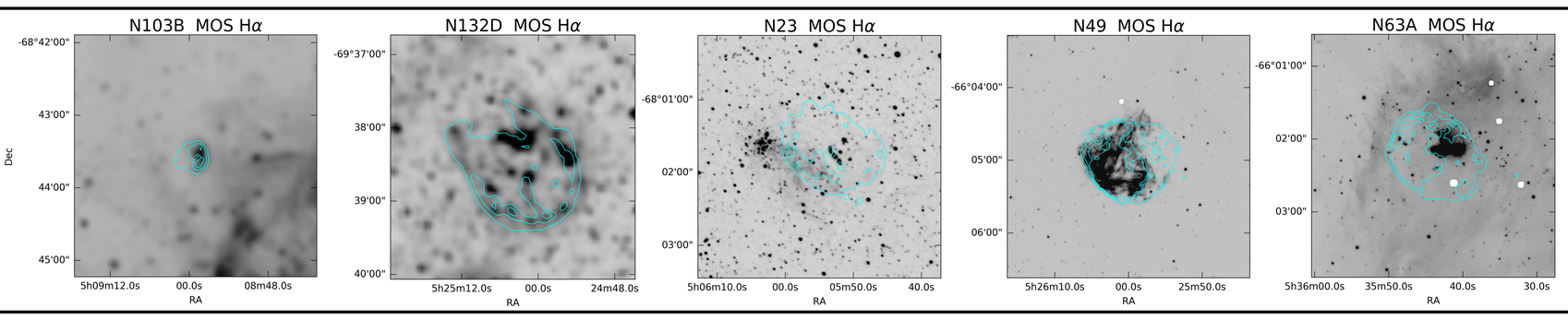
- The faint extended lobes not clearly detected in broad bands
- O supergiant projected within ~10 pc from the shell center
- SNR shell has 2 openings in the NE and SW

- Asymmetric shell

- Thin shell morphology
- A-F supergiant projected within ~10 pc

- The only M33 SNR observed in *HST* Hα
- In the outskirt of giant HII region NGC 604

Comparing with SNRs in the LMC:
- N103B: Type Ia SNR interacting with CSM
- N132D, N23, N49, N63A: X-ray bright CC SNRs interacting with dense clouds



*Blue contours: *Chandra* X-ray

Conclusions
1. SNRs detected in HST broad-band images are also those in the densest medium.
2. Broad-band images can still be used to search for Balmer-dominated Type Ia SNRs. F814W includes forbidden lines but no Balmer lines.