Supernova Remnant Populations in Nearby Star-Forming Galaxies

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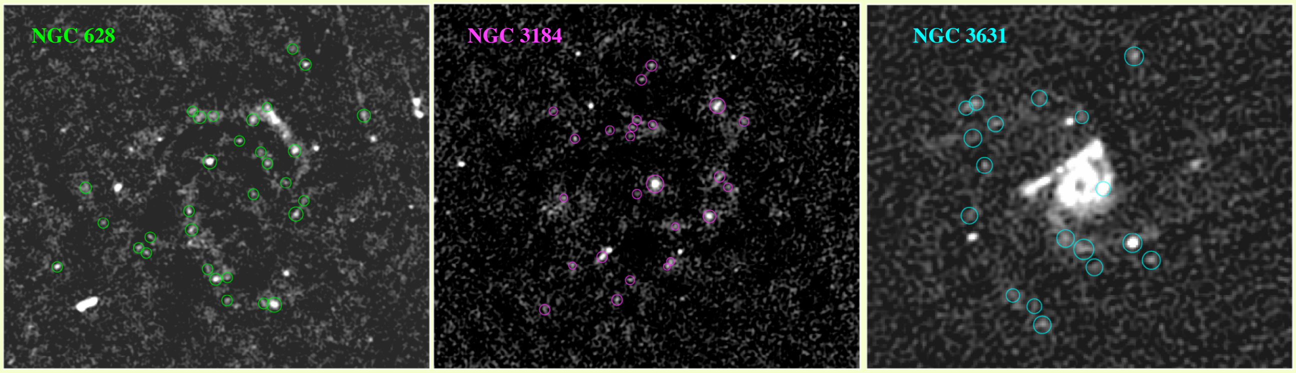


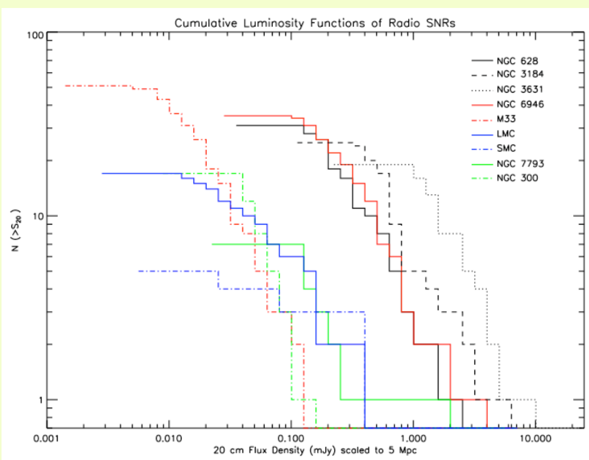
20 cm radio continuum maps obtained at the VLA in its B configuration (~4" resolution). These maps are some of the deepest ever observed (rms noise ~ 0.015 mJy/beam). Maps of similar depth and resolution were also obtained at 6cm. Radio SNRs are marked by circles.

Identifying Radio Supernova Remnants (SNRs)

The SNRs marked in the above maps were chosen to satisfy three criteria:

- Integrated 20 cm flux density greater than 3x the local noise
- Nonthermal spectral index: $\alpha = -\ln (S_{20cm} / S_{6cm}) / \ln (\nu_{20cm} / \nu_{6cm}) > 0.2$
  Needed to separate SNRs from HII regions
- Spatially coincident with Hα emission in a narrow band image
  Needed to separate SNRs from background sources (higher-redshift AGN will have Hα shifted out of the filter)

SNR Luminosity Functions



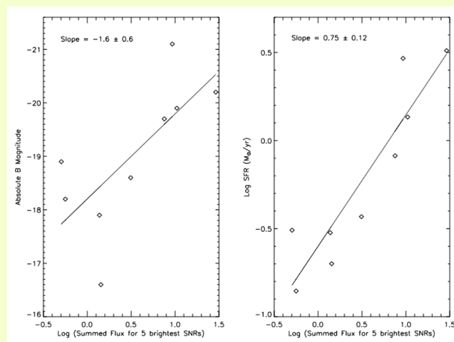
NGC 6946- Lacey & Duric (2001); M33- Gordon et al. (1999); LMC and SMC- Filipovic et al. (1998); NGC 7793- Pannuti et al. (2002); NGC 300- Pannuti et al. (2000)

Name	Distance Mpc	Resolution pc	M_B	Type	SFR $M_\odot yr^{-1}$	$\Sigma_{SFR} \times 10^3$ $M_\odot yr^{-1} kpc^{-2}$	Σ_{HI} $M_\odot pc^{-2}$
LMC	0.05	221	-17.9	Sm	0.3	5.1	7.3
SMC	0.06	241	-16.6	Sm	0.2	14.1	28.4
M33	0.85	29	-18.9	Scd	0.3	2.2	17.5
NGC 300	2.2	43	-18.2	Sd	0.1	1.3	21.0
NGC 7793	3.9	113	-18.6	Sd	0.4	6.2	18.3
NGC 6946	5.9	43	-21.1	Scd	2.9	11.2	26.6
NGC 628	7.3	162	-19.7	Sc	0.8	2.3	16.1
NGC 3184	11.1	231	-19.9	Scd	1.4	3.2	8.6
NGC 3631	16.7	291	-20.2	Sc	3.2	7.3	7.7

The brightest SNRs in luminous spirals emit 10-100 times more light @ 20cm than the brightest SNRs in lower luminosity galaxies!

Why do more luminous galaxies host more luminous SNRs?

- Does the nature of SN feedback vary between galaxies?
  i.e., Do more luminous galaxies transform star formation energy into cosmic ray energy more efficiently?
- Or- is it merely an effect of sampling (more luminous galaxies tend to have higher SF rates (SFRs), and more opportunity to form bright SNRs?)



Luminosities of the brightest SNRs are most tightly correlated with SFR.

In the future…

The cosmic ray energy coming from a SNR scales as $\propto L^{4/7}$ (assuming equipartition), where L = SNR luminosity.

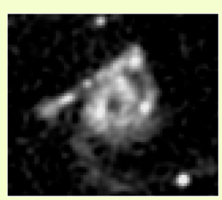
If the cosmic ray energy scales linearly with SFR, then we should observe

$$L_{SNR} \propto SFR^{7/4}$$

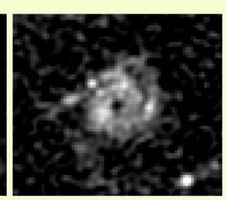
But we need L_{SNR}, an unknown statistic which can robustly characterize the luminosity of a SNR population. We still know very little about the true shape of SNR LFs.

A Mysterious Donut!

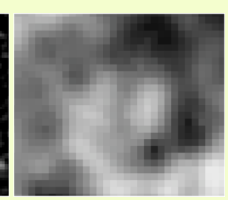
The central ~1.5 kpc of NGC 3631 is vigorously forming stars. Why is synchrotron emission avoiding the inner 300 pc?



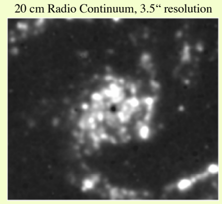
20 cm Radio Continuum, 3.5" resolution



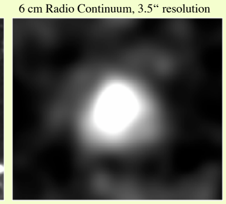
6 cm Radio Continuum, 3.5" resolution



21 cm HI Moment 0, 14.0" resolution



Narrow-band Hα, 1.5" resolution



Diffuse X-ray, 4.0" resolution

Self absorption?

A wind advecting away cosmic rays?

A Superbubble?

Molecular gas so dense that cosmic rays can not diffuse into it?

(We assume the jet structure is a background AGN.)