Radio-dim, γ-ray-bright Supernova Remnants

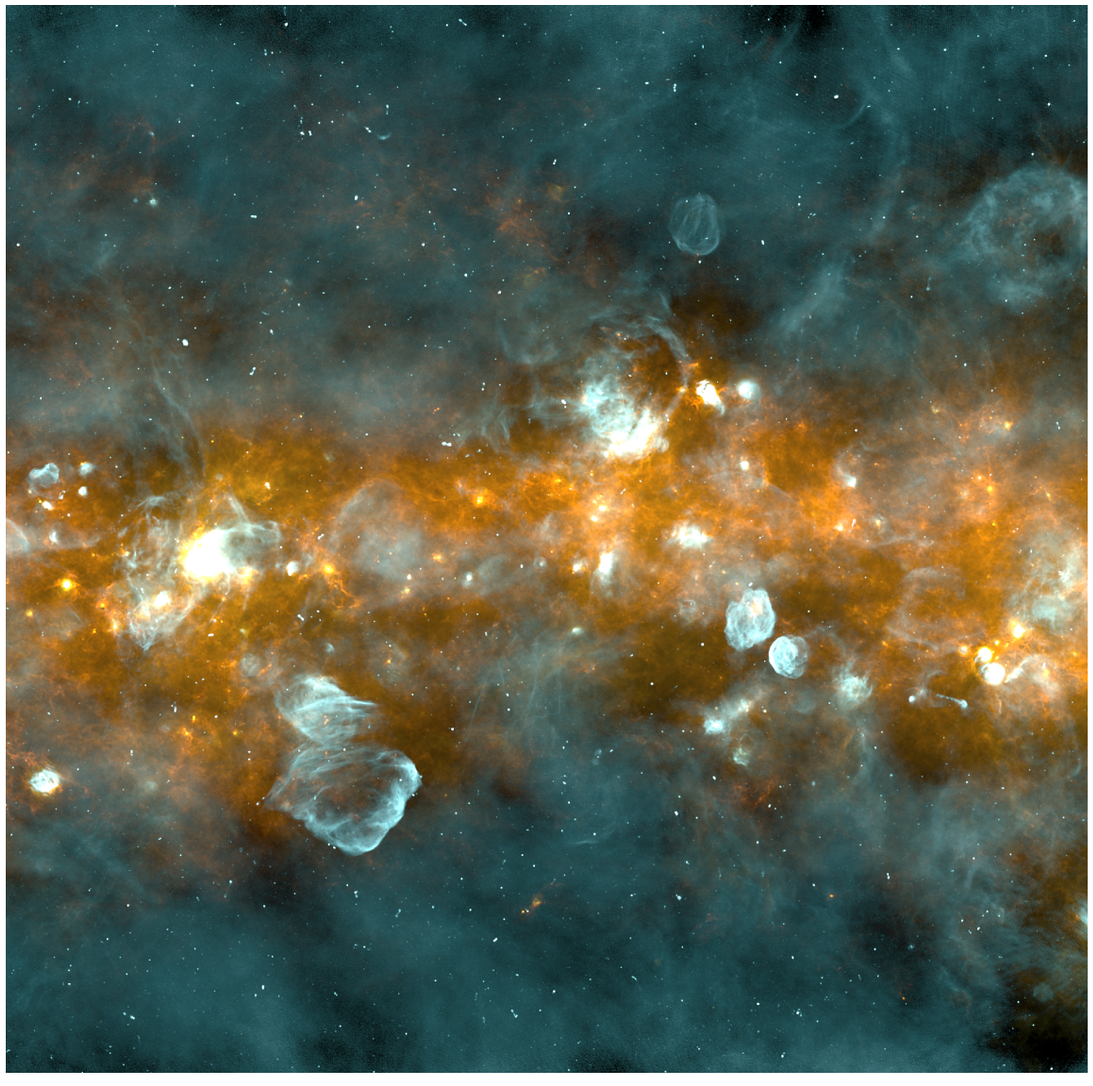
Jack Hewitt (UNF),
Sajan Kumar, Brian Humensky,
on behalf of the *Fermi*-LAT
collaboration

11th Fermi Symposium
September 10, 2024

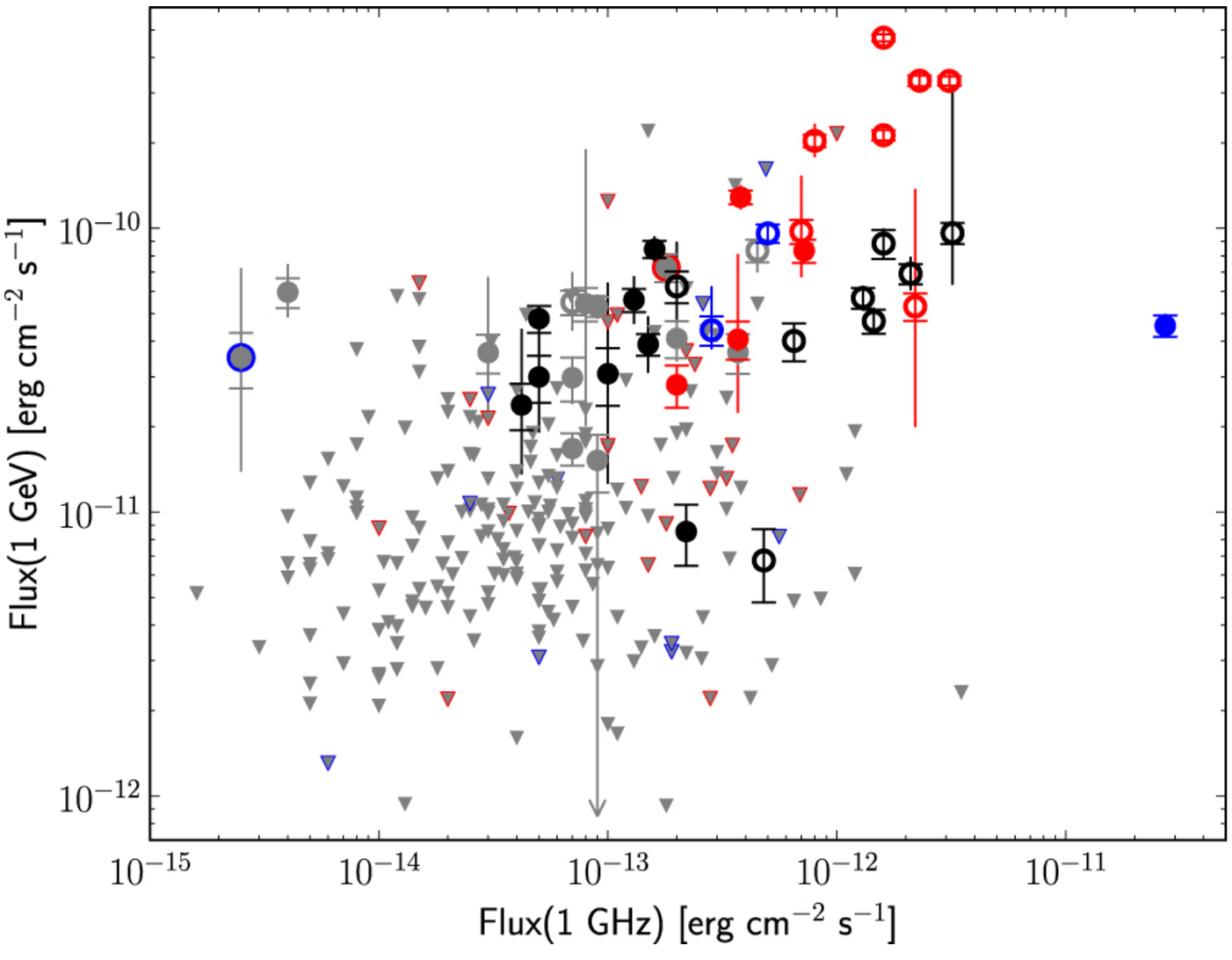
dr.hewitt@unf.edu

Radio and Gamma-ray SNRs

- Missing SNRs Problem: Know of ~300, expect ~1-2,000. Deeper radio surveys?



Section of Galactic Plane from the SMGPS survey (Goedhart+ 2023). MeerKAT 1.3 GHz radio. Herschel Hi-GAL 70 μm and 250 μm.



GeV to GHz flux comparison of young and interacting **SNRs** (1SC, LAT collab. 2016). Open circles are extended, filled are point-like sources.

Radio and X-ray view of SNR G189.6+3.3

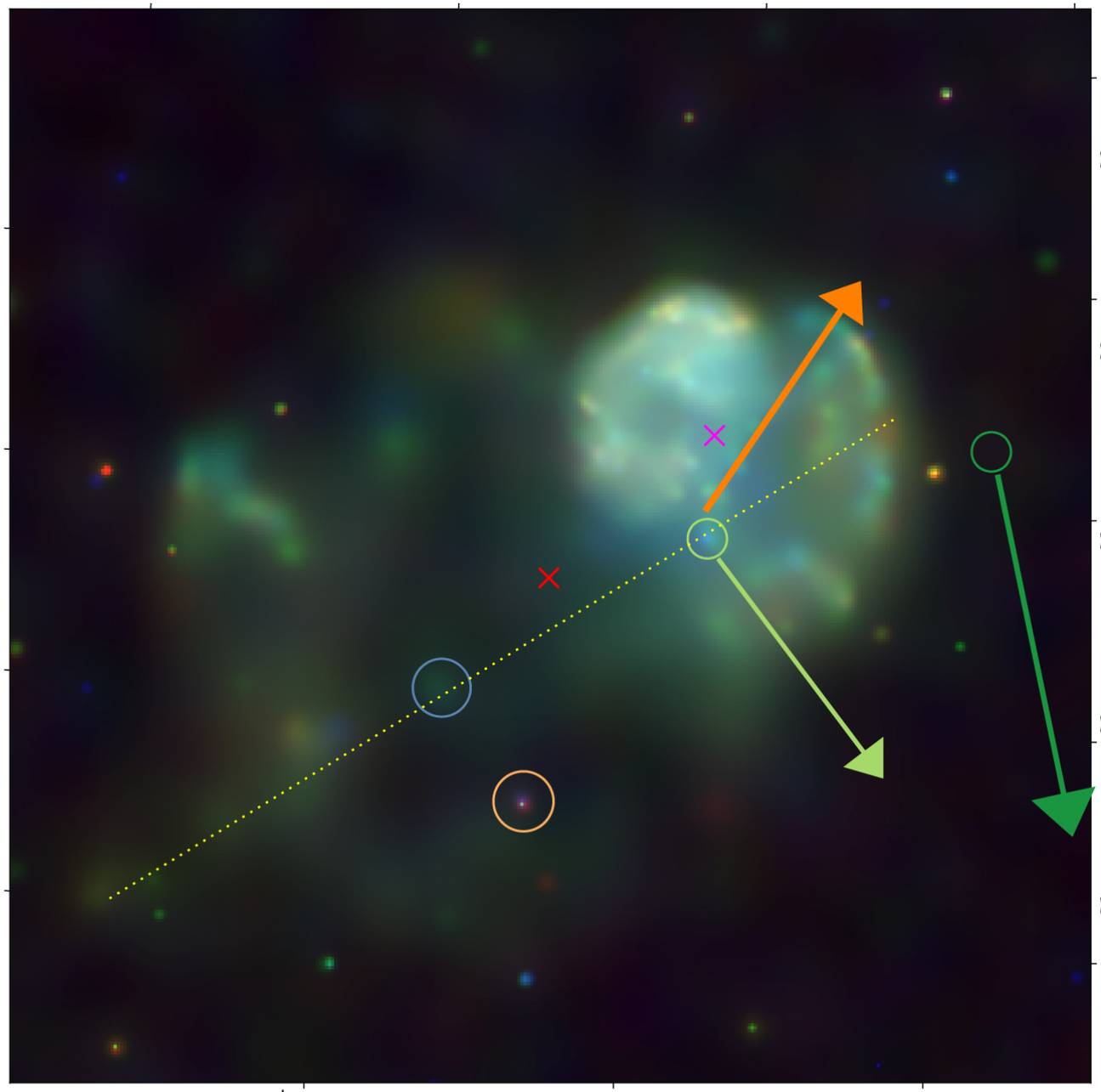
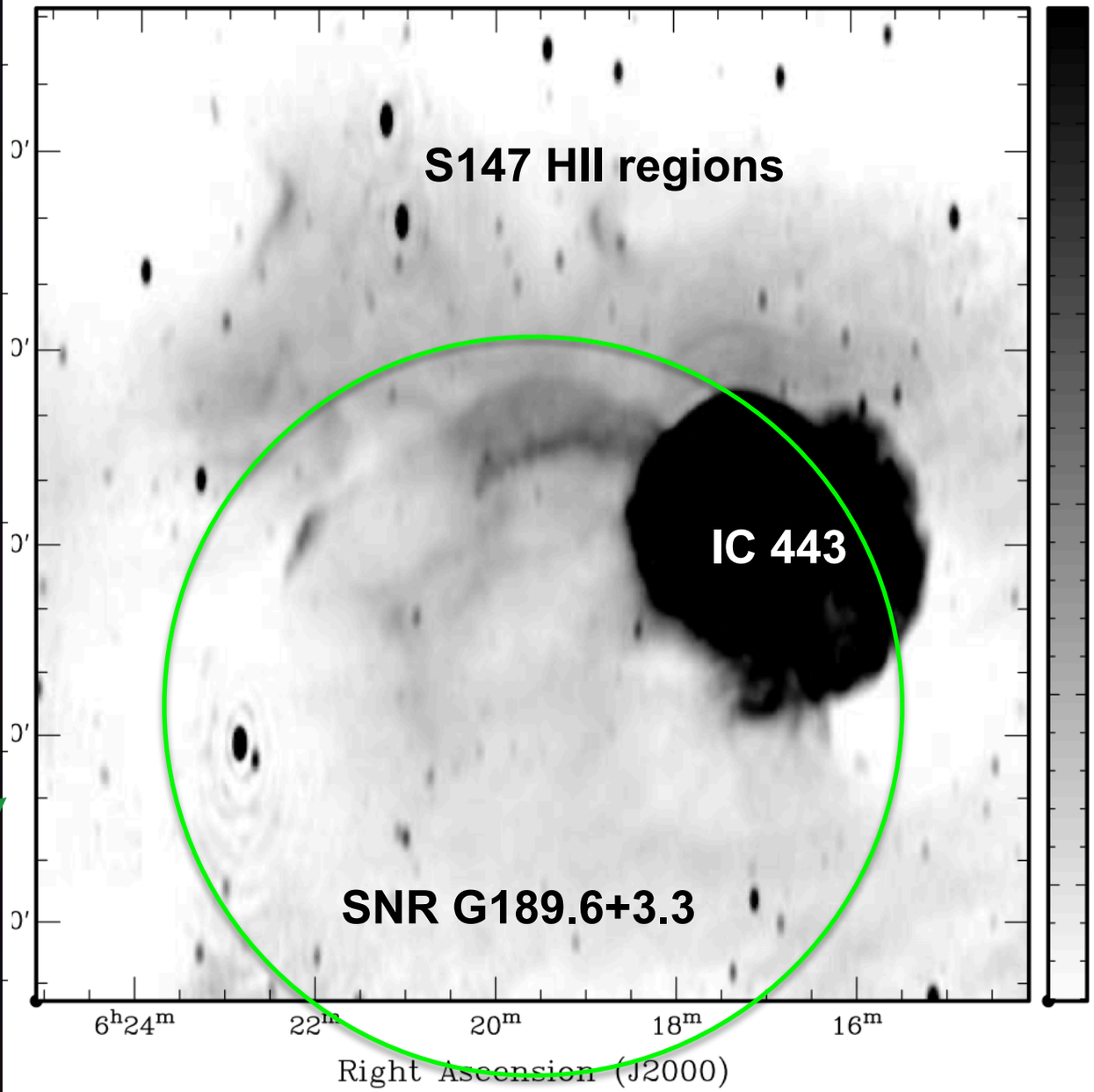


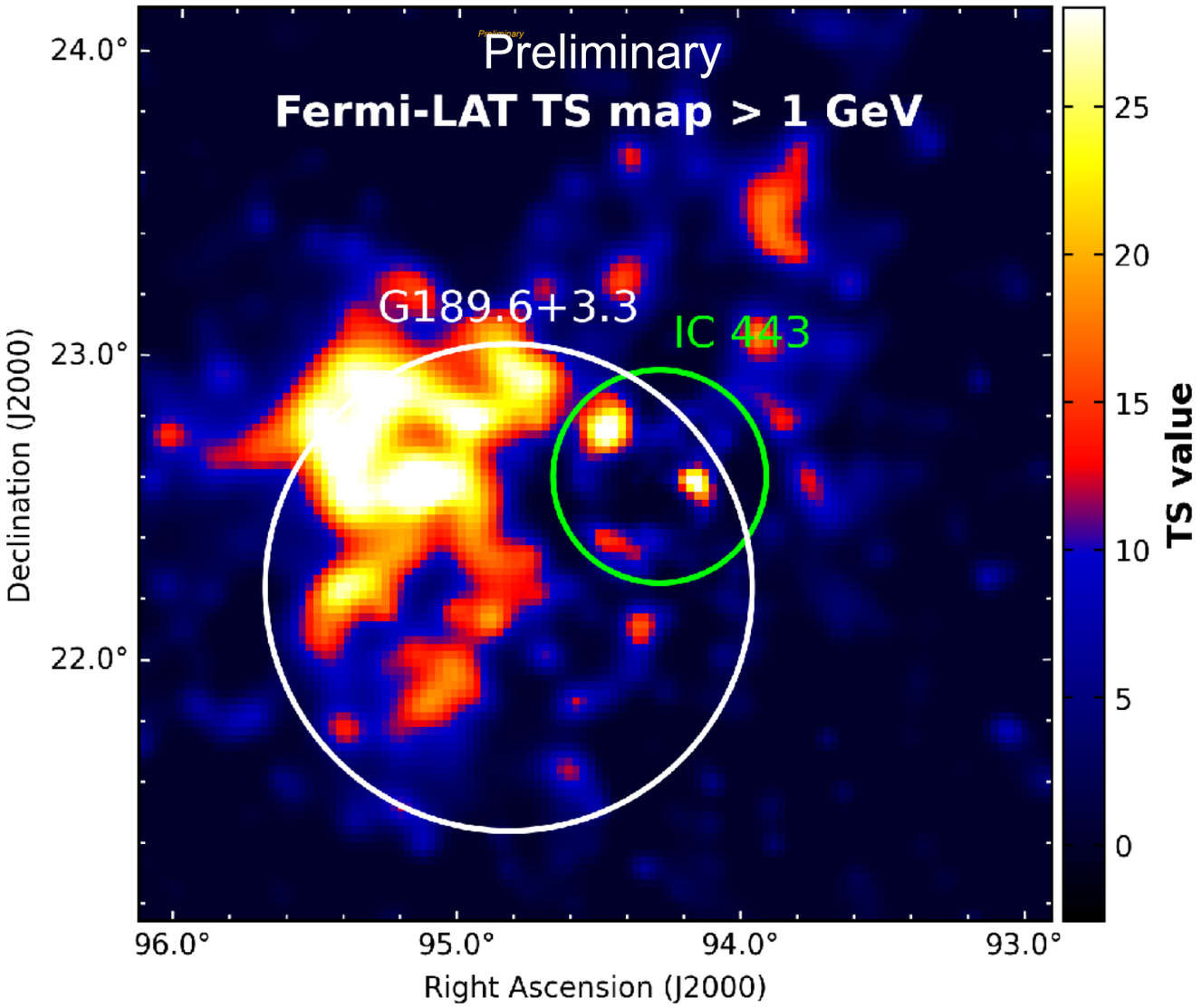
Figure. eROSITA color image (0.2-0.7 keV, 0.7–1.1 keV, 1.1–10 keV) of IC 443 and SNR G189.6+03.3. Image is adaptively smoothed to S/N = 3 to 5 (Camilloni, et al. 2023)

Figure. Radio 1420 MHz image (Leahy 2004)



Suzaku detects X-ray recombining plasma ($T_e < T_i$) indicating past interaction with ISM (Yamauchi, et al. 2020)

LAT detection of SNR G189.6+3.3



- Updated LAT analysis using 15 years, Pass8r2, E ≥ 1 GeV, 4FGL-DR4 model
- Custom template for IC 443 (see next talk by B. Humensky)
- Extended source needed to account for SNR G189.6+3.3
  - PL index = 2.00±0.06
  - RadialDisk with R = 0.92°±0.03° (TS_{ext} = 154)
  - Has negligible effect on spectra of IC 443.

“Nereides” SNR G107.7-5.1

- 2° diameter SNR discovered by imaging narrowband emission line filters in 260 hours of amateur astrophotography (Fesen, et al. 2024)
- No radio counterpart (just outside CGPS survey)
- Extremely faint optical line emission with spatially broad filaments suggests evolved radiative SNR.
- Possible interaction due to morphology of Western filaments

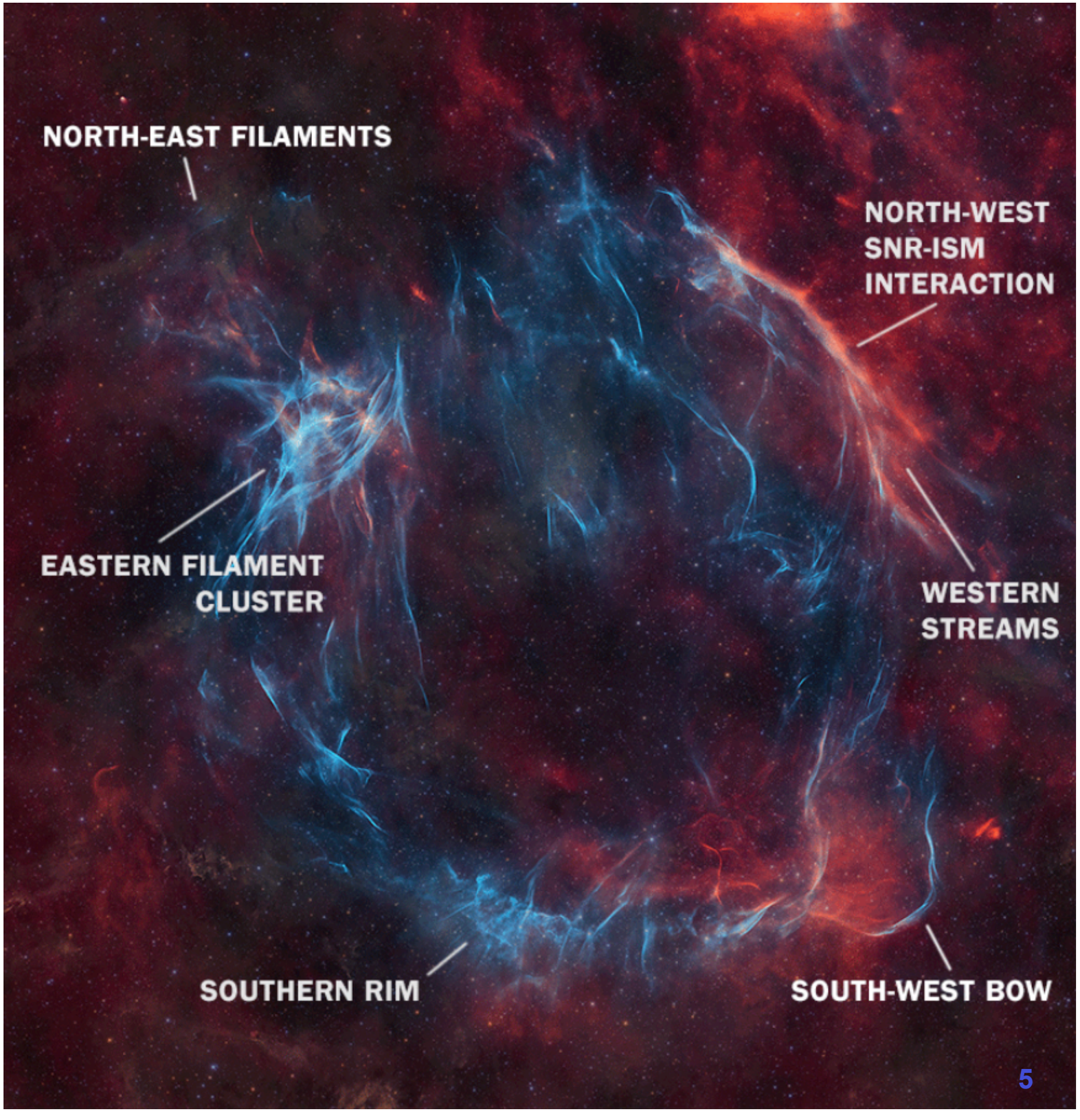
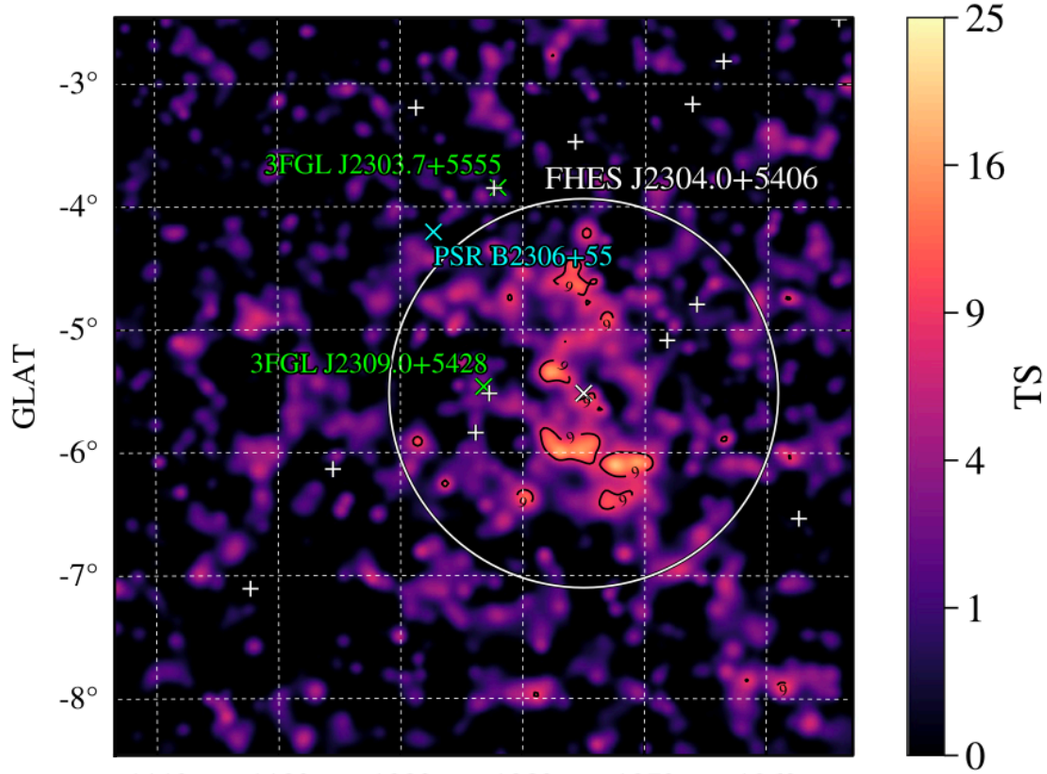


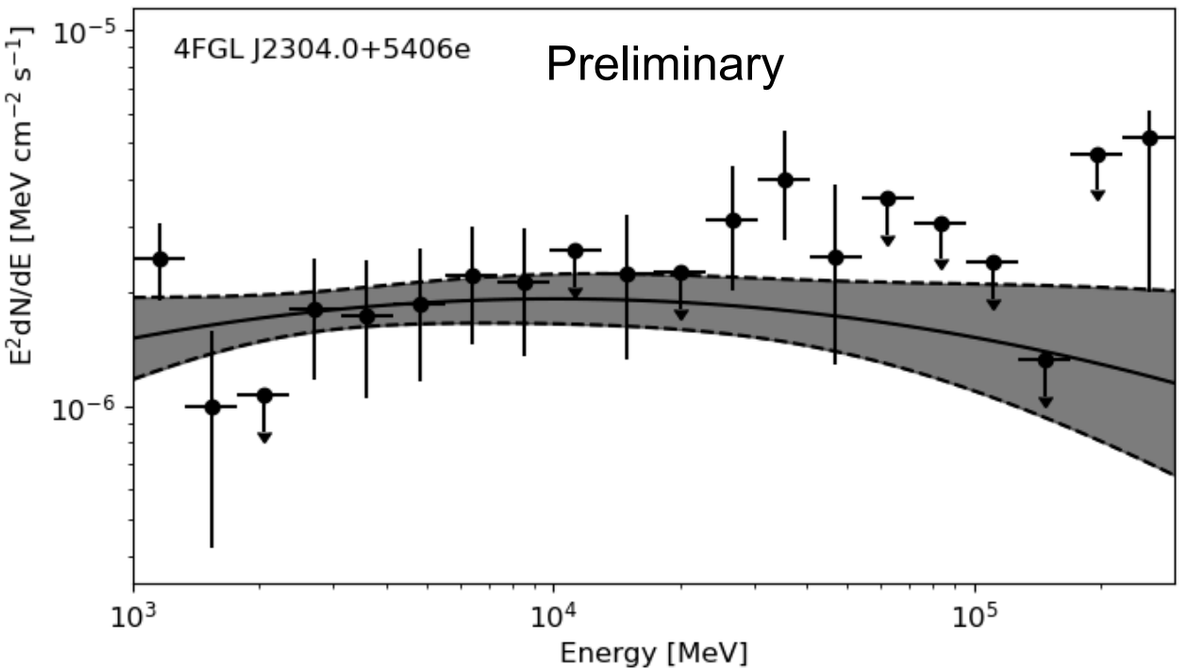
Figure. Optical composite image showing [OIII], Hα, and [SII]. Distinct features across the SNR are labeled. (Fesen+ 2024)

LAT emission from Nereides SNR

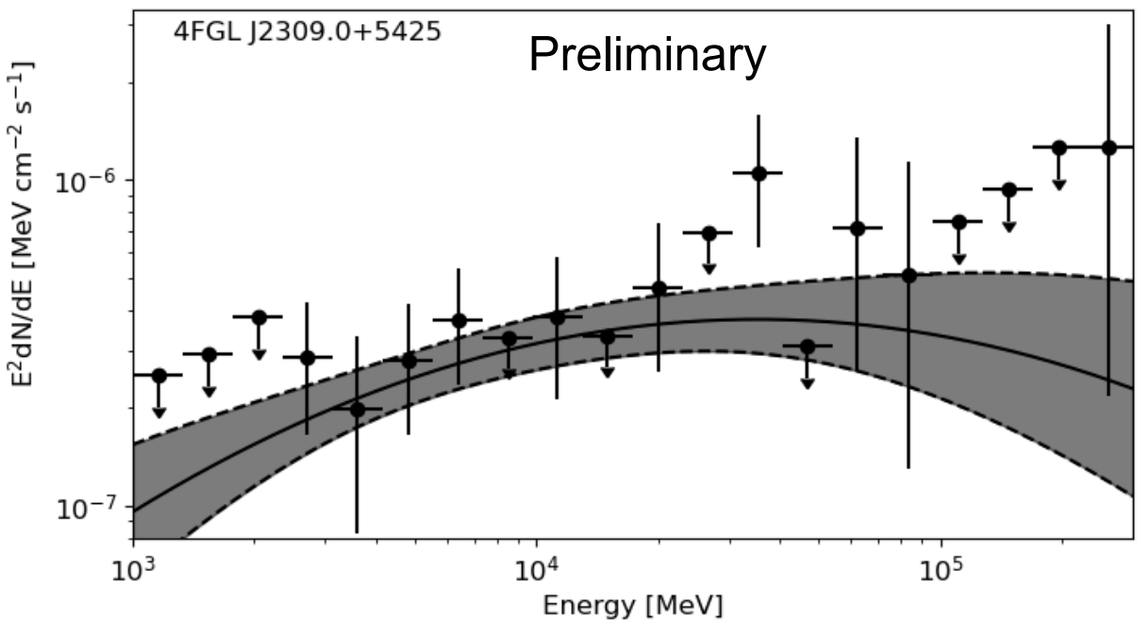
- Coincident with FHES J2304.0+5406 from high-latitude extended source search (FHES, LAT collab., 2018) prior to discovery of optical line emission. TS map from FHES is shown.
- Updated LAT analysis using 15 years, Pass8r2, E ≥ 1 GeV, 4FGL-DR4 model
- SNR has hard spectrum, Γ = 1.8(0.1)
- Overlapping point source 4FGL J2309.0+5425 has similarly hard spectrum, but more curvature. Possible blazar; coincident X-ray point source



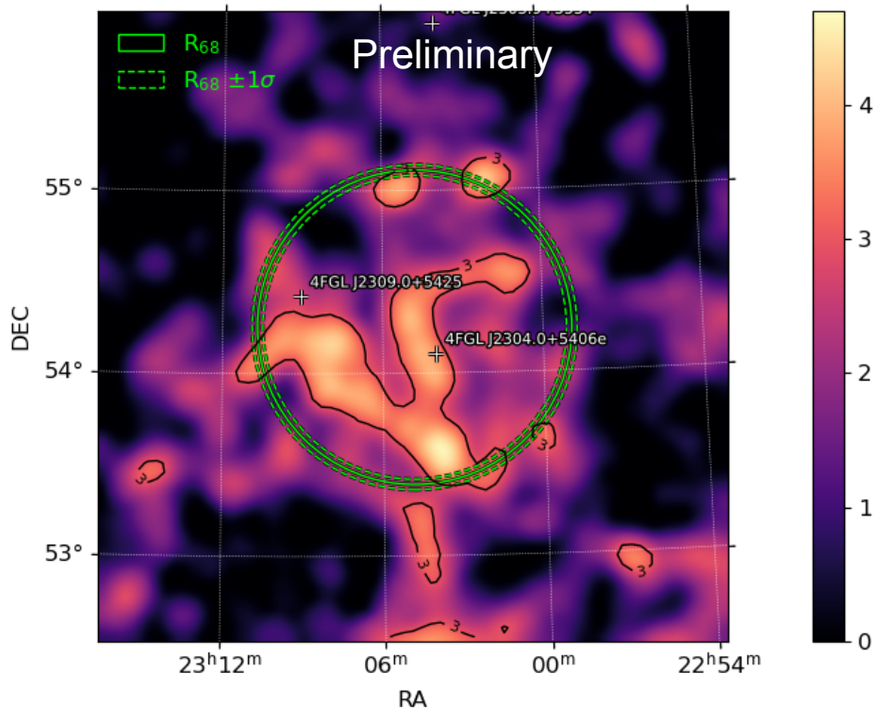
SNR



Point Source

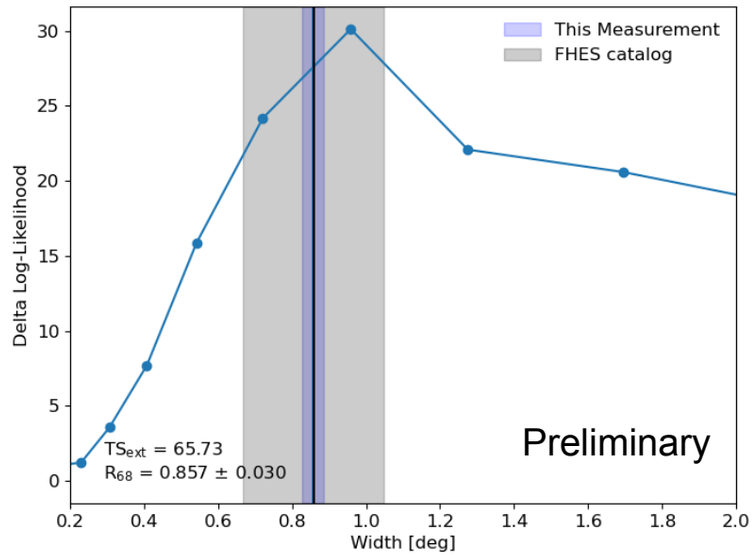


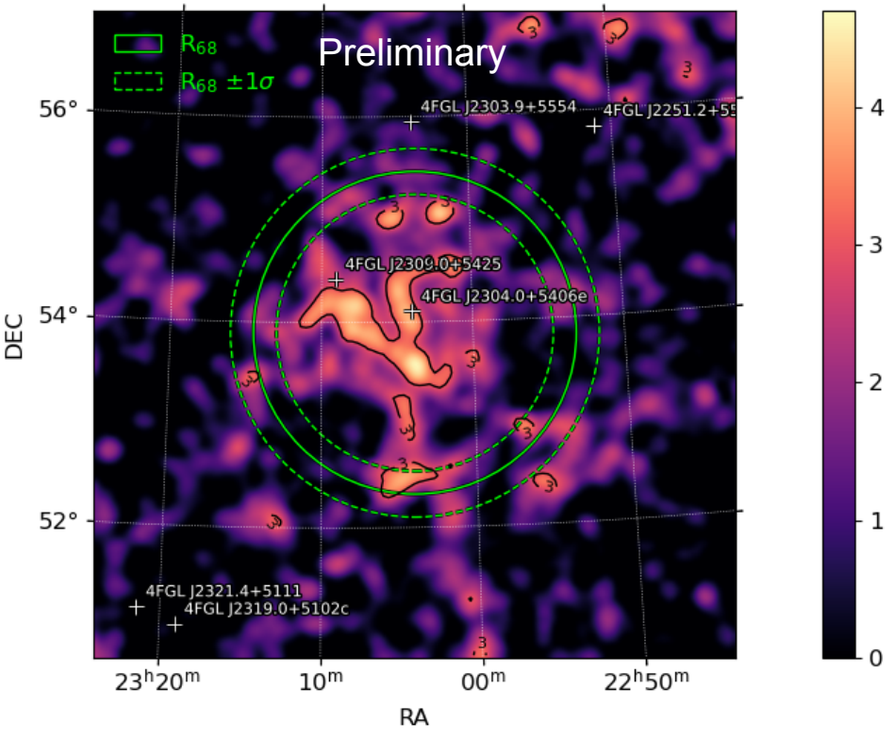
LAT Extension Fit >1 GeV



Radial Disk

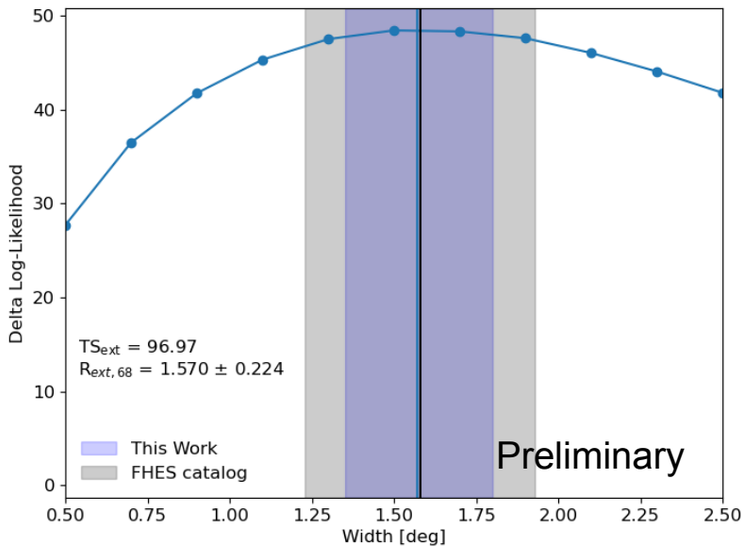
- TS_{ext} = 78
- R_{ext} = 0.88°±0.22°
- LogLike: -206612.9





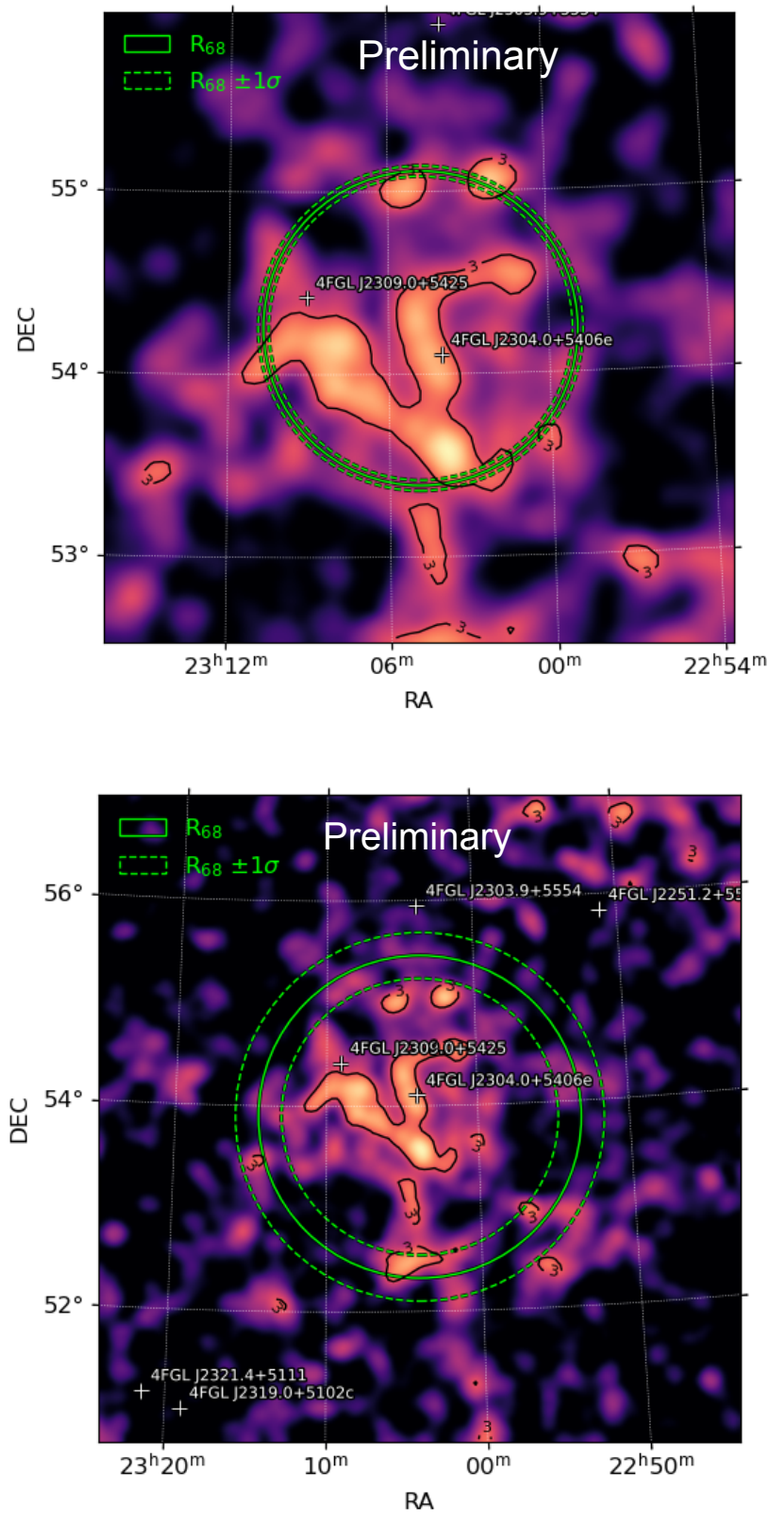
Radial Gaussian

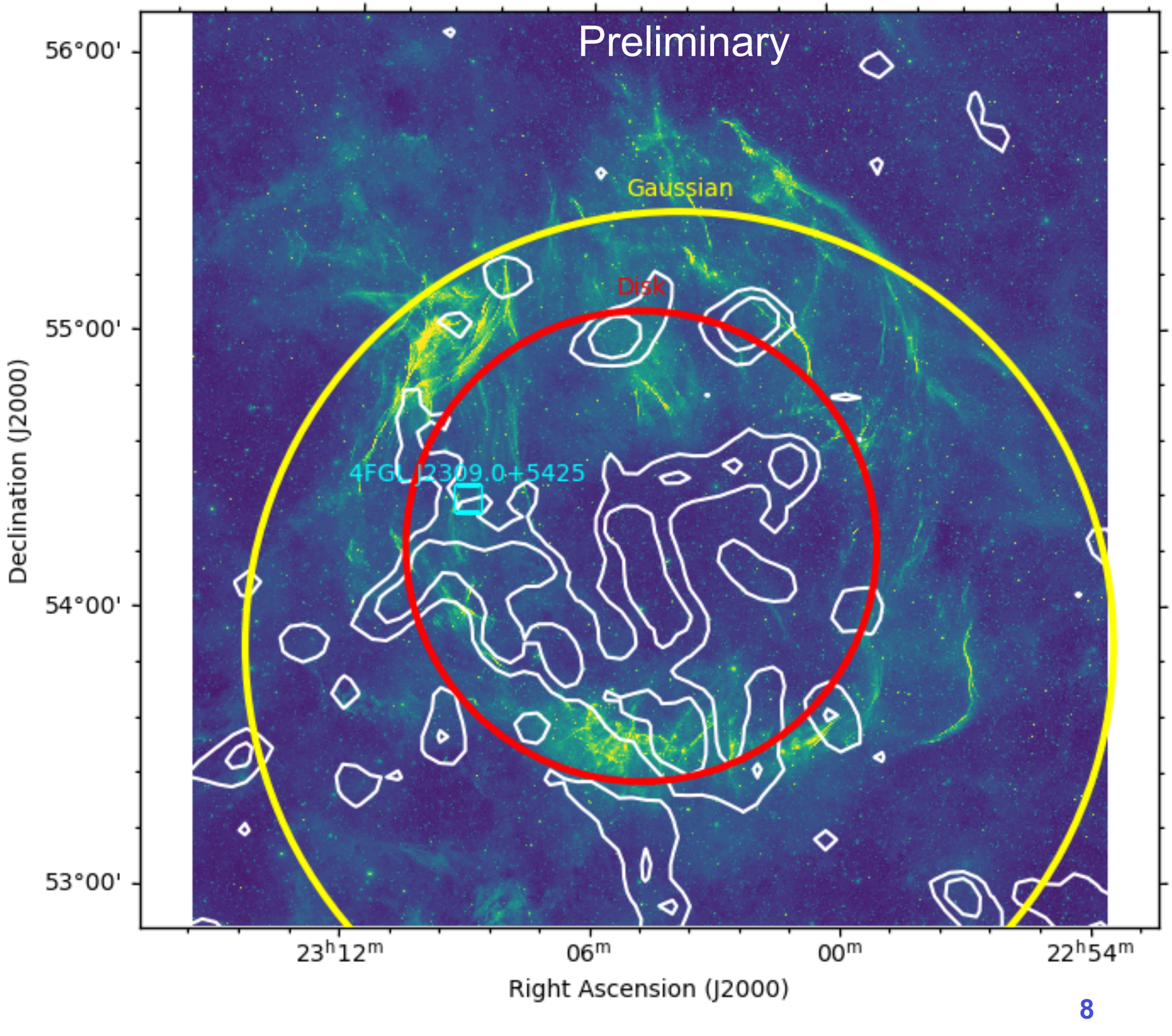
- TS_{ext} = 97
- R_{ext} = 1.57°±0.22°
- LogLike: -206601.7



LAT Extension Fit >1 GeV

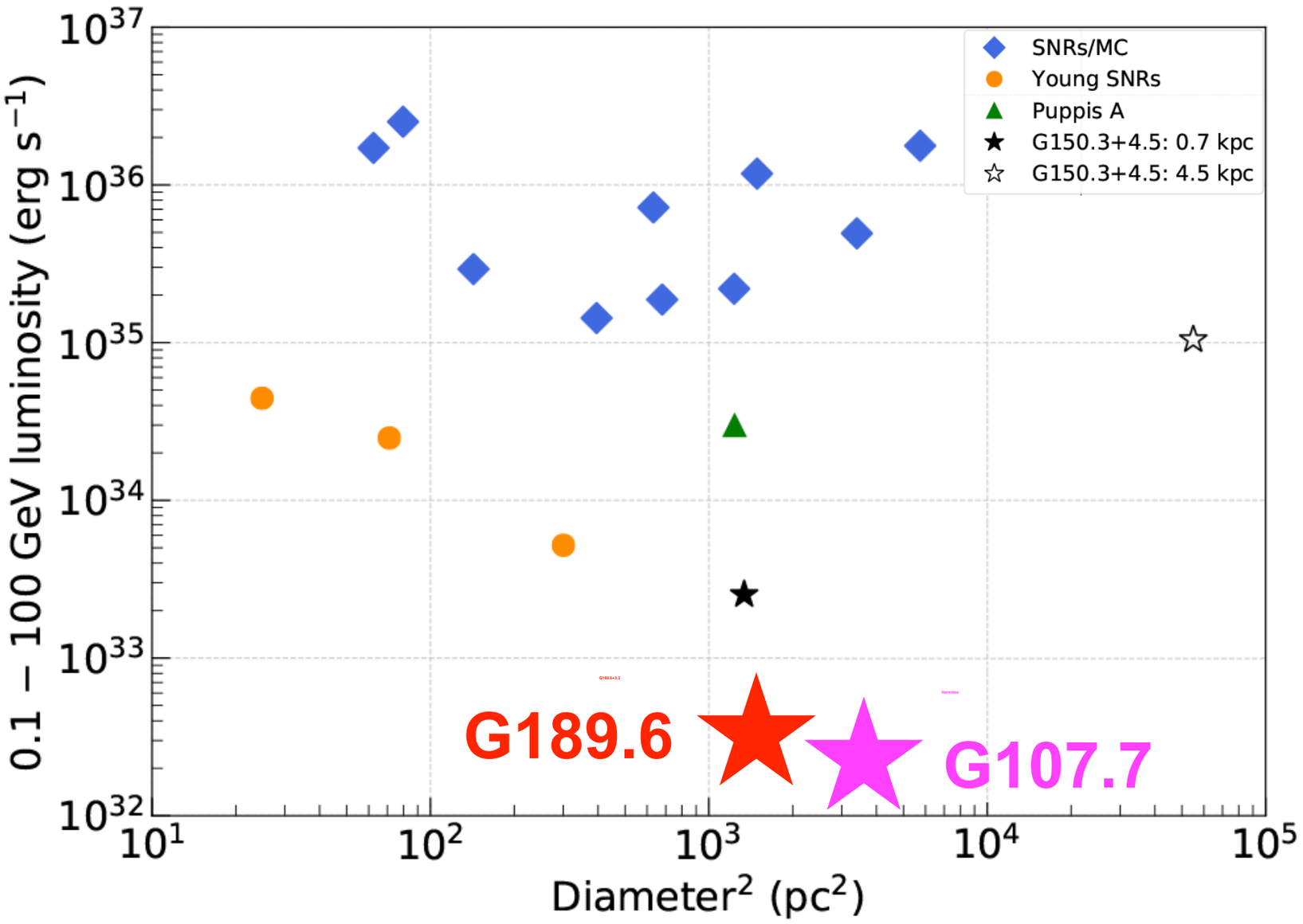
TS contours at 5, 10.





Two extremely low-luminosity GeV SNRs

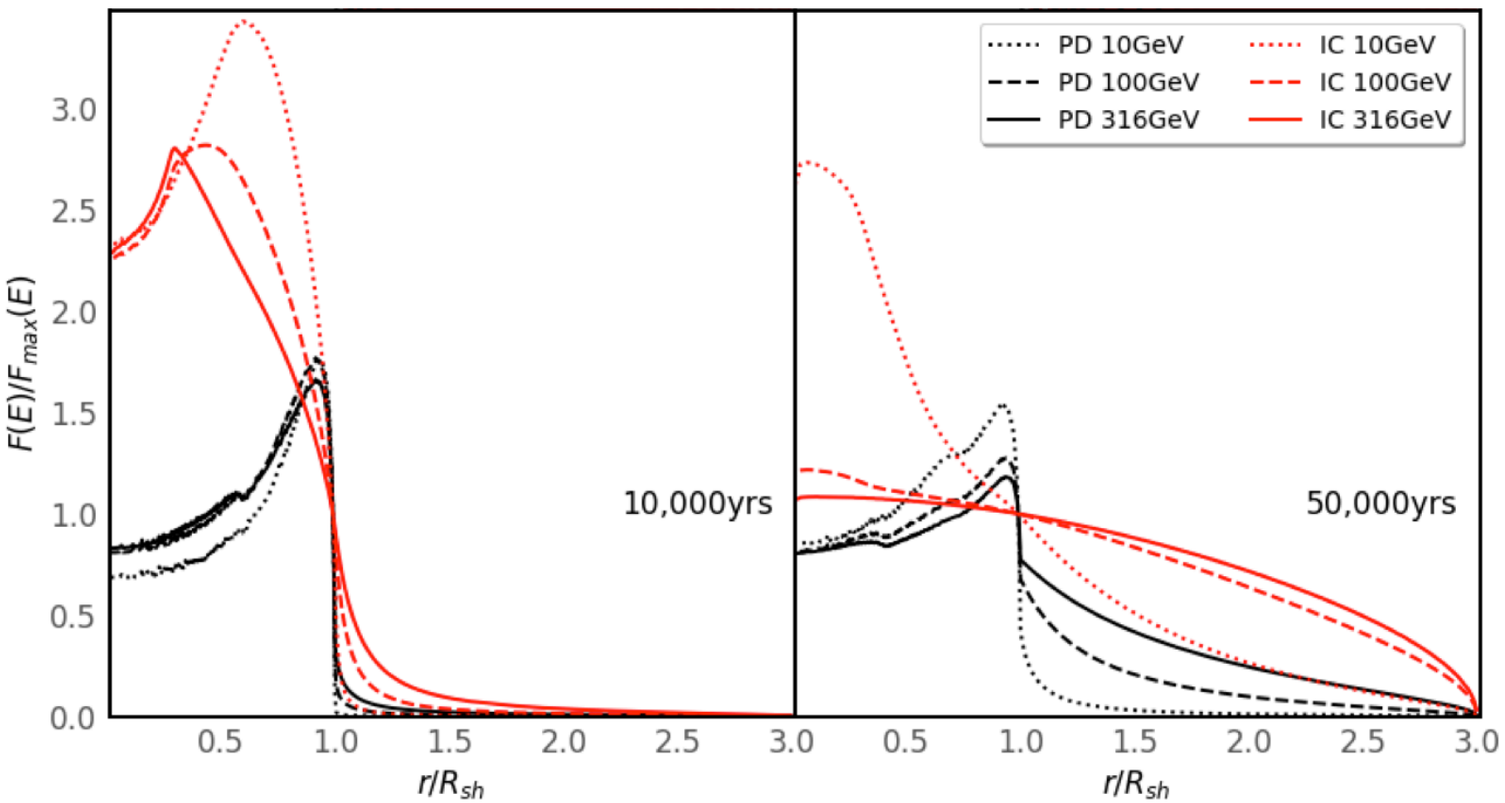
- G189.6+3.3 and G107.7-5.1 are among largest and faintest SNRs detected by LAT so far, probing new luminosity space
- Distance is unknown. Assuming d=1.5 kpc, plot L_{GeV} vs D^2

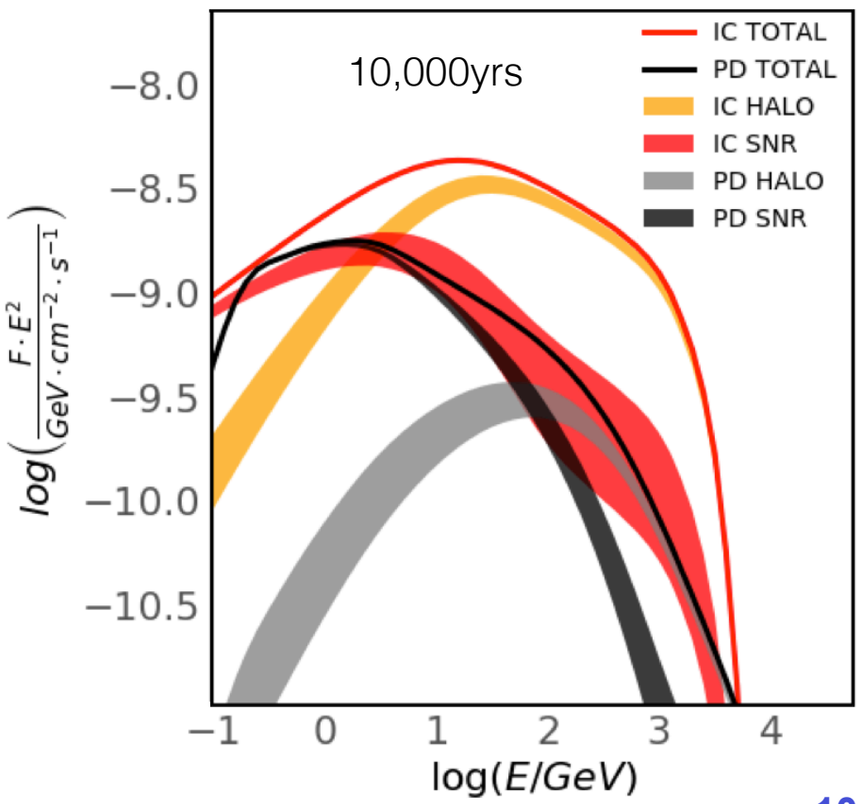


Emerging class of GeV SNRs?

SNR	Diameter (°)	Energy Flux >GeV (MeV cm^{-2} s^{-1})	Photon Index	References
G17.8+16.7	0.73	1.4×10^{-6}	1.8(0.1)	Devin, et al. 2020
G118.4+37.0	0.52	3.1×10^{-6}	1.7(0.1)	Araya 2023
G150.3+4.5	1.5	5.2×10^{-6}	1.6(0.2)	Devin, et al. 2020
G279.0+1.1	2.8	1.9×10^{-5}	1.8(0.1)	Araya 2020
G288.8-6.3	0.92	3.3×10^{-6}	2.3(0.1)	Burger-Scheidlin, et al. 2024
G296.5+10.0	0.7	1.1×10^{-5}	1.8(0.1)	Araya 2013, Ackermann, et al. 2018
G323.7-1.0	0.9×0.6	1.6×10^{-6}	1.1(0.2)	Araya 2017
G107.7-5.1	2	8.3×10^{-6}	1.8(0.1)	This work
G189.6+3.3	1.5	$\times10^{-6}$	2.0(0.1)	This work

Simulations of SNR evolution produce central IC dominated SNRs at late ages (Brose, et al. 2021)





Summary

- In 16+ years, *Fermi* LAT is detecting numerous faint, large diameter SNRs in low-background regions of galaxy.
  - SNR G189.6+3.3 is detected with the LAT overlapping and adjacent to bright IC 443.
  - SNR G107.7-5.1 is detected coincident with optical emission line filaments.
- Two new members of the growing class of low-luminosity GeV SNRs at high Galactic latitudes with large diameters, flat photon indices, and no or very faint radio counterparts.
- Diversity of gamma-ray SNRs may reflect different progenitor types and environments in which they evolve.