Fermi-LAT observations of the surprising SNR G150.3+4.5

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Supernova Remnants II
An odyssey in space after stellar death
3-8 June 2019, Chania, Crete, Greece

Abstract: *G150.3+4.5 has been detected as a faint radio supernova remnant with an angular size of 3°, suggesting an old or a nearby SNR. Extended gamma-ray emission spatially coincident with the radio morphology has been reported in the Fermi-LAT Galactic Extended Sources catalog, revealing a hard spectral index from 10 GeV to 2 TeV. A dedicated Fermi-LAT data analysis from 5 GeV to 500 GeV confirmed the hard spectral shape, similar to that observed in young shell-type SNRs such as RX J1713.7–3946 or RCW 86. However, no non-thermal X-ray emission from G150.3+4.5 has been reported, challenging our understanding on the origin of the emission. Using 10 years of Fermi-LAT data, we investigate the morphology and the spectral properties of the SNR G150.3+4.5, from 1 GeV to 1 TeV, to constrain the origin of the emission. This newly discovered SNR may be one of the closest GeV gamma-ray SNRs and one of the best SNR candidates, as a bright TeV object, that could be observed with the next generation of Cherenkov telescopes (CTA, Cherenkov Telescope Array).*

A new radio shell in the sky

The brightest part of the shell (box A in Figure 1) was first detected by [1] with a radio spectral index of $\alpha = -0.38 \pm 0.10$. [2] confirmed the non-thermal emission from the overall remnant. The large angular size of 3° suggests either an evolved or a nearby SNR.

No X-ray studies have been reported so far and no significant emission appears in ROSAT, Integral/IBIS and Swift/BAT archival data.

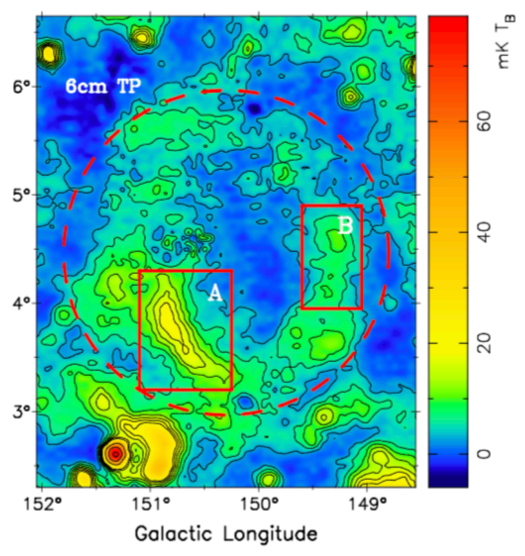

Figure 1*. Urumqi (6 cm) data ([2]). The boxes A and B are the brightest parts of the shell (represented by a red dotted circle).*

Previous gamma-ray studies

Using HI data, the more likely distance for G150.3+4.5 is d = 0.6 kpc ([3]), in agreement with its hard spectrum, similar to that obtained for young TeV SNRs. In this case, G150.3+4.5 would be one of the closest GeV gamma-ray SNRs.

Spectral index:

- $\Gamma = -1.88 \pm 0.06$ from 50 to 500 GeV [3]
- $\Gamma = -1.91 \pm 0.09$ from 10 GeV to 2 TeV [4]

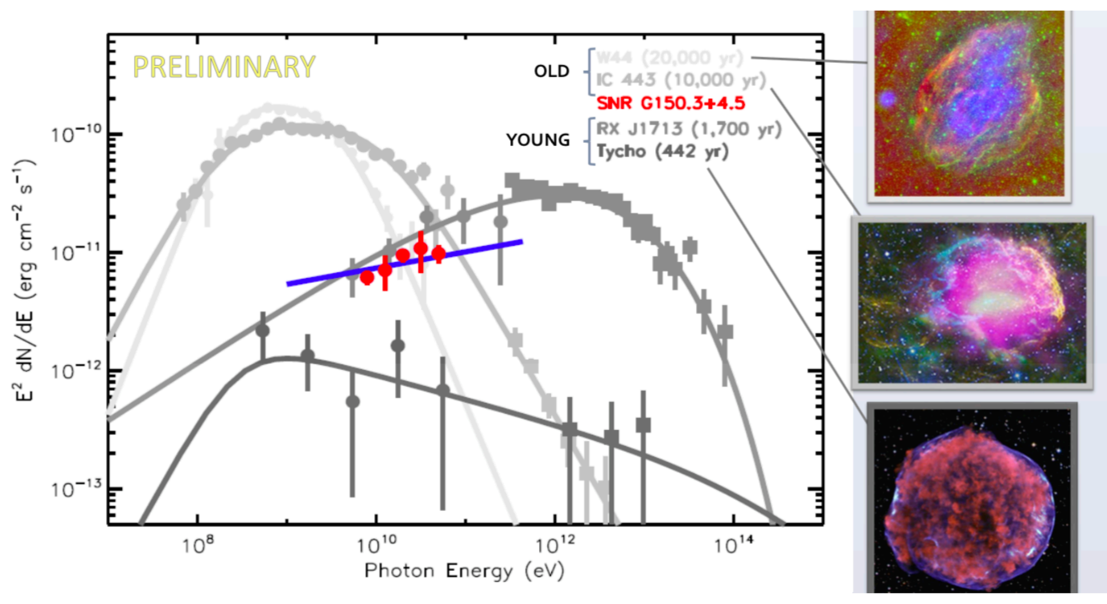

Figure 2*. Comparison of the spectrum of G150.3+4.5 with other spectra from old and young SNRs (taken from [3]), favoring the young SNR scenario for G150.3+4.5.*

Morphological analysis

Analysis with:

- more than 10 years of Fermi-LAT data
- the latest diffuse emission models and source catalog ([5])
- all the events from 1 GeV to 1 TeV
- a region of interest (ROI) of 26° x 26°
- a model including sources up to 20° from the ROI center

Using the Fermipy package, we:

- localize and test the extension of 4FGL J0426.5+5434 (lying in the South of the SNR) using a Gaussian model
- localize and find the extension of G150.3+4.5 (4FGL J0427.2+5533e) using a uniform disk model

Results:

- The source 4FGL J0426.5+5434 is not extended
- For G150.3+4.5: $r = 1.593° \pm 0.022°$ $\quad \mathrm{TS_{ext}} = 598.0$

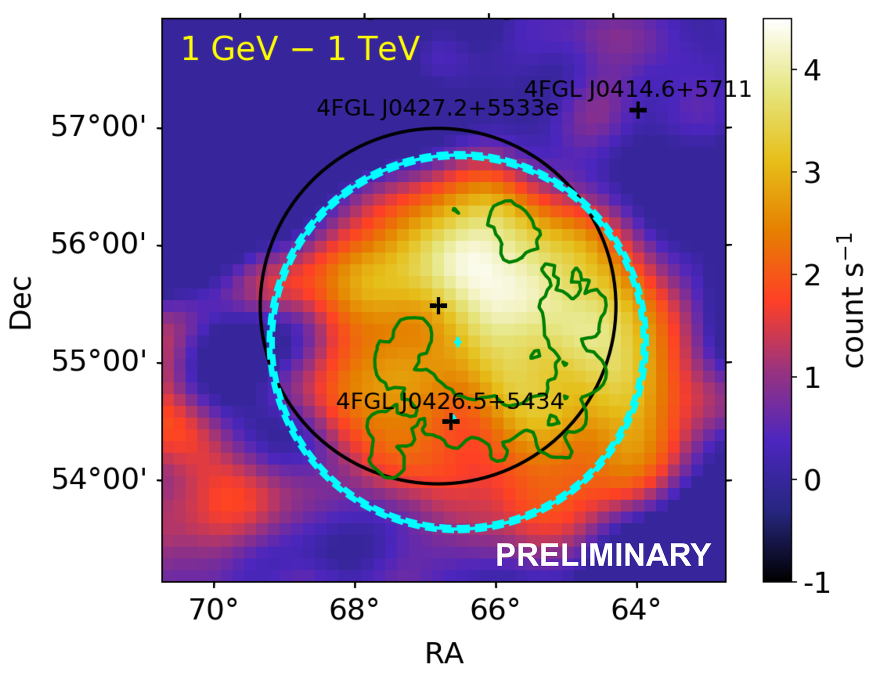

Figure 3*. Residual count map without G150.3+4.5 in the model (black: 4FGL sources, cyan: best-fit disk model). The full circle is the best-fit radius with the associated statistical errors (dashed circles). The green radio contours represent the brightest parts of the shell (from Urumqi 6 cm data, [6]).*

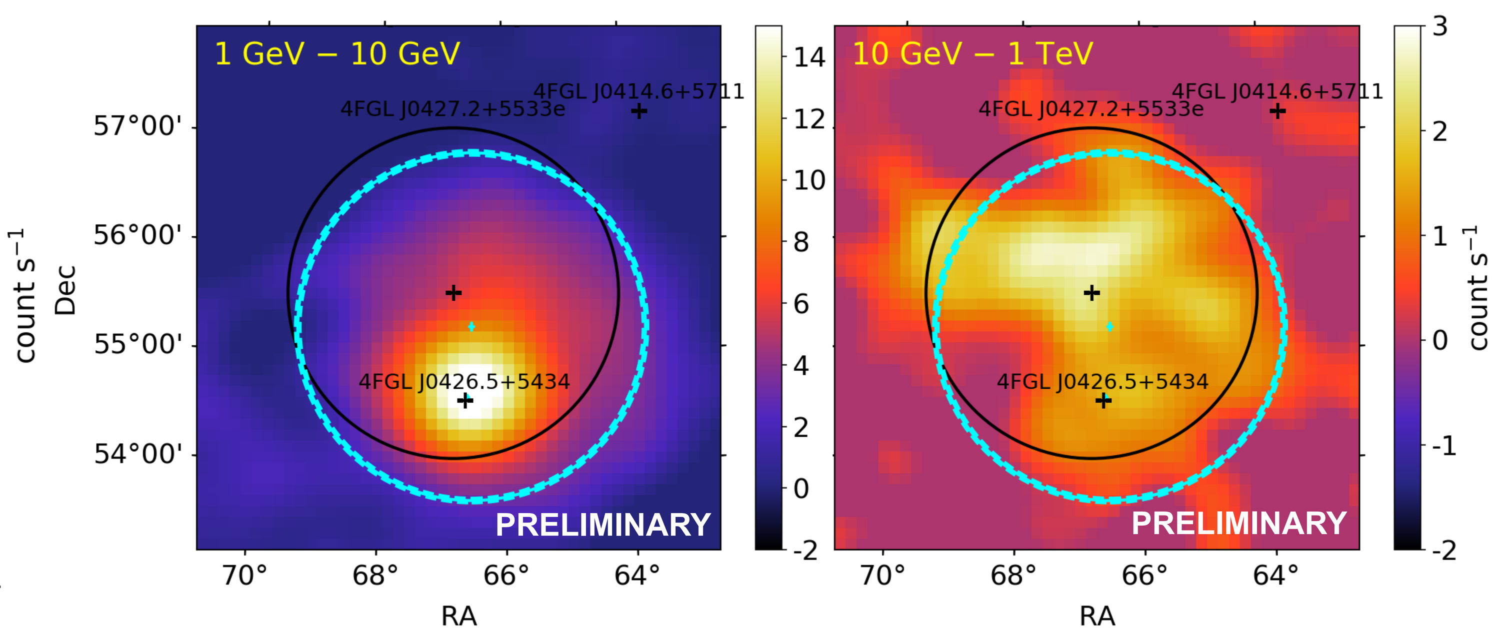

Figure 4*. Residual count maps from 1 GeV to 10 GeV and from 10 GeV to 1 TeV, without G150.3+4.5 and 4FGL J0426.5+5434 in the model. The best-fit disk from 1 GeV to 1 TeV is represented in cyan.*

The source 4FGL J0426.5+5434 dominates the gamma-ray emission up to 10 GeV while the SNR becomes brighter at higher energies.

Spectral analysis

- **4FGL J0426.5+5434**

Power law:

$N_0 = (2.48 \pm 0.36) \times 10^{-11}\ \mathrm{cm^{-2}s^{-1}MeV^{-1}}$

$\Gamma = 3.54 \pm 0.15 \quad E_0 = 0.65\ \mathrm{GeV}$

In the catalog, the source 4FGL J0426.5+5434 has a pulsar-like spectrum (described by a logarithmic parabola with a break energy at 650 MeV). Since the curvature is not seen above 1 GeV, we describe the emission by a power law.

- **G150.3+4.5**

Power law (PL):

$N_0 = (6.53 \pm 0.35) \times 10^{-14}\ \mathrm{cm^{-2}s^{-1}MeV^{-1}}$

$\Gamma = 1.76 \pm 0.03$

$E_0 = 8.97\ \mathrm{GeV}$

Logarithmic parabola (LogP):

$N_0 = (7.06 \pm 0.44) \times 10^{-14}\ \mathrm{cm^{-2}s^{-1}MeV^{-1}}$

$\alpha = 1.69 \pm 0.05 \quad \beta = 0.04 \pm 0.02$

$E_b = 8.97\ \mathrm{GeV}$

$$\Delta \mathrm{TS}_{\mathrm{PL} \rightarrow \mathrm{LogP}} = 4.8$$

The spectrum is not significantly curved and point towards a leptonic origin of the emission. The GeV spectrum is harder than from previous gamma-ray studies and favors the young SNR scenario.

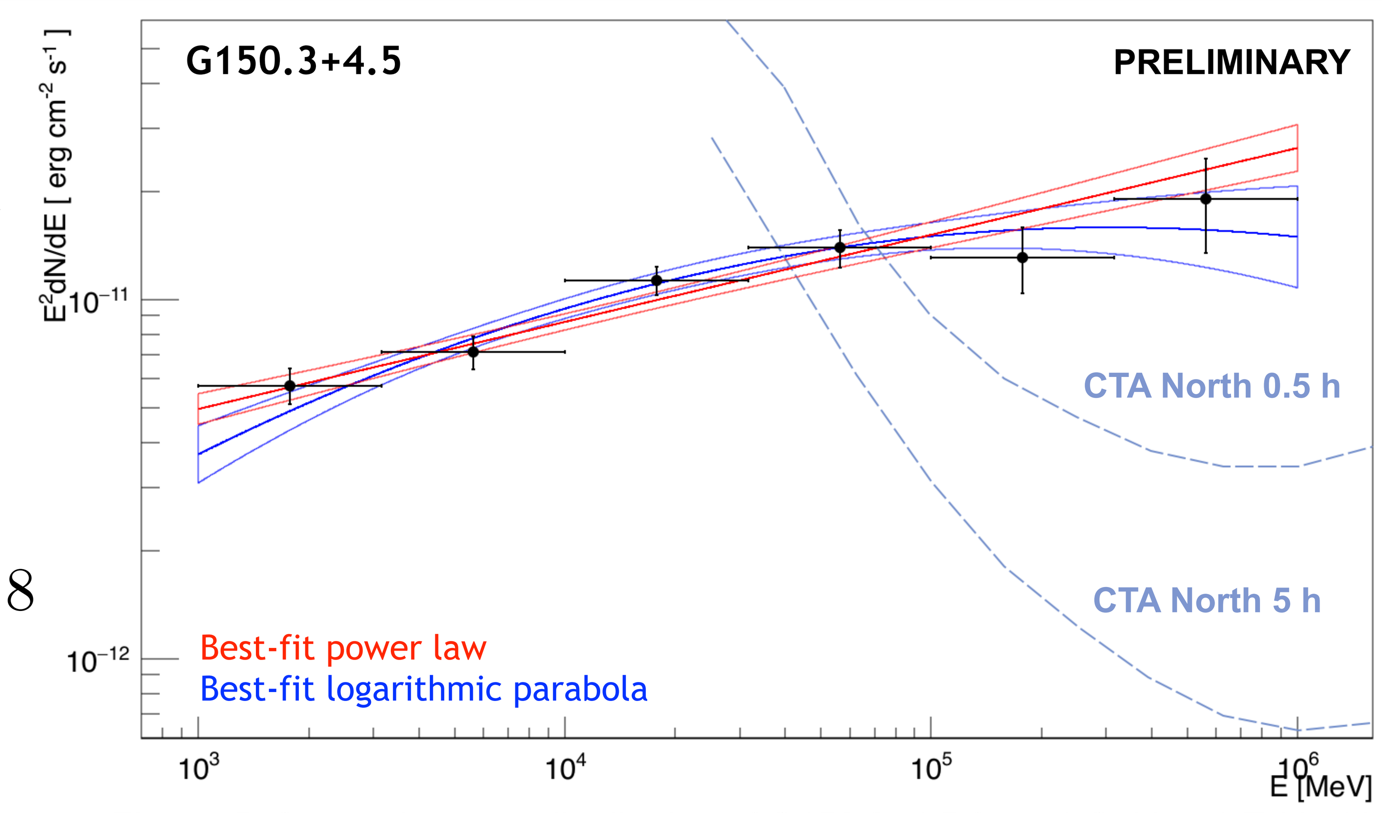

Figure 5*. Spectral energy distribution of G150.3+4.5 from 1 GeV to 1 TeV with the associated statistical errors. The CTA North sensitivities (obtained with 0.5 and 5 hours for point sources) are also represented ([7]).*

Conclusions

The SNR G150.3+4.5 is adequately described by a uniform disk from 1 GeV to 1 TeV. The hard GeV spectrum point towards a leptonic origin of the emission and an acceleration of particles at least up to TeV energies. We are currently investigating the low-energy part of the spectrum to better constrain the origin of the emission from G150.3+4.5 and from 4FGL J0426.5+5434 in order to discuss their possible association. In five hours, CTA will detect significantly G150.3+4.5 and will provide insights concerning the highest particle energy achieved in this likely young SNR.

References

[1] Gerbrandt et al. 2014, A&A, 566
[2] Gao and Han, 2014, A&A, 567
[3] Mysore et al., 2015, poster at the Fermi Symposium
[4] Ackermann et al., 2017, ApJ, 843
[5] 4FGL catalog, Fermi-LAT collaboration, 2019
[6] http://www3.mpifr-bonn.mpg.de/survey.html
[7] https://www.cta-observatory.org

JD, MHG and MLG acknowledge support from Agence Nationale de la Recherche (grant ANR- 17-CE31-0014).

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