Disentangling the hadronic from the leptonic emission in the composite SNR G326.3-1.8

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Abstract *Supernova remnants (SNRs), pulsar wind nebulae (PWNe) and pulsars are the usual suspects to accelerate the bulk of cosmic rays in our Galaxy. In those objects the gamma-ray emission allows us to probe the population of high-energy particles and in particular the population of accelerated hadrons radiating through the pion-decay mechanism. In the case of composite SNRs, both the SNR shell and the PWN are bright enough to be observed in the same source. Understanding the nature of the gamma-ray emission in such objects can be challenging for sources of small angular extension. Previous studies of the composite SNR G326.3-1.8 (radius=0.3°) revealed bright and extended gamma-ray emission but its origin remained uncertain. With the recent Fermi-LAT Pass 8 data that provide an increased acceptance and angular resolution, we investigate the detailed morphology of this composite SNR in order to distinguish the SNR from the PWN contribution. In particular, we take advantage of the new possibility to filter events based on their angular reconstruction quality (PSF types).*

Radio and X-ray observations

SNR G326.3-1.8 was first detected in radio and X-ray as a composite SNR. Chandra maps have revealed a compact object in the south west of the SNR and MOST image shows a very bright PWN which has been crushed by the reverse shock. This object is estimated to be 16 500 years old at a distance of 4.1 kpc.

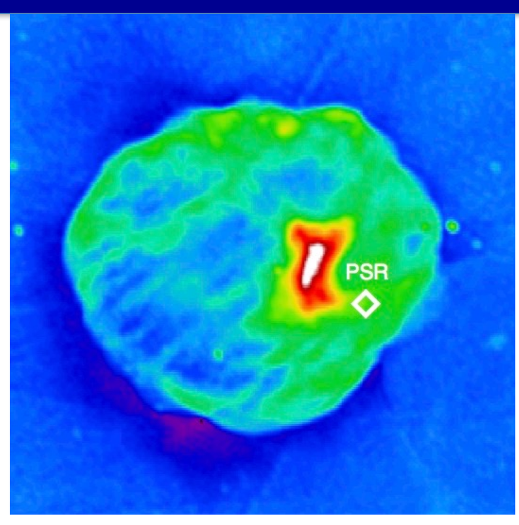


***Figure 1**. MOST radio image of SNR G326.3-1.8[2].*

Fermi-LAT Pass 8 data

The latest data release Pass 8 allows to select events regarding to their quality reconstruction and, as for previous releases, the data set can be still split in *front* and *back* events. The PSF selection divides the data in four parts: from PSF 0 to PSF 3, the latter being the quartile with the best angular resolution (~0.4° at 1 GeV compared to 0.8° with no selection). Since the object remains very significant with 25% of the 6.5 years of data we use here (TS $\approx$600 between 300 MeV and 300 GeV), we take advantage of this new selection to avoid as much as possible the contamination between these two nested objects.

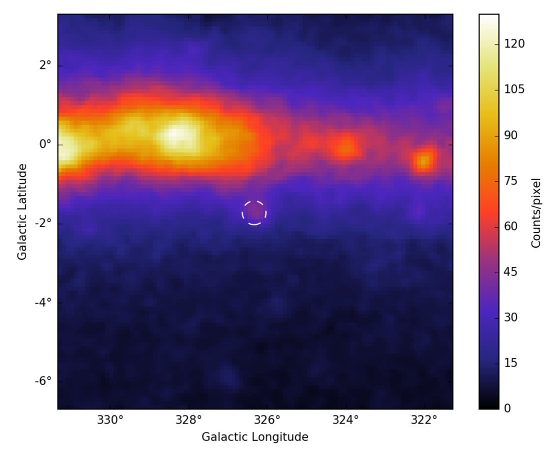


***Figure 2**. Counts map of a 10°x 10° region centered on the position of the SNR and using the PSF3 events.*

Energy-dependent morphology

Using a 2-D symmetrical gaussian morphology in the *pointlike* fitting procedure, the composite SNR appears to be significantly extended in 4 energy bands (from 316 MeV to 32 GeV). The gamma-ray morphology shrinks and shows a clear trend toward the center of the PWN at higher energy.

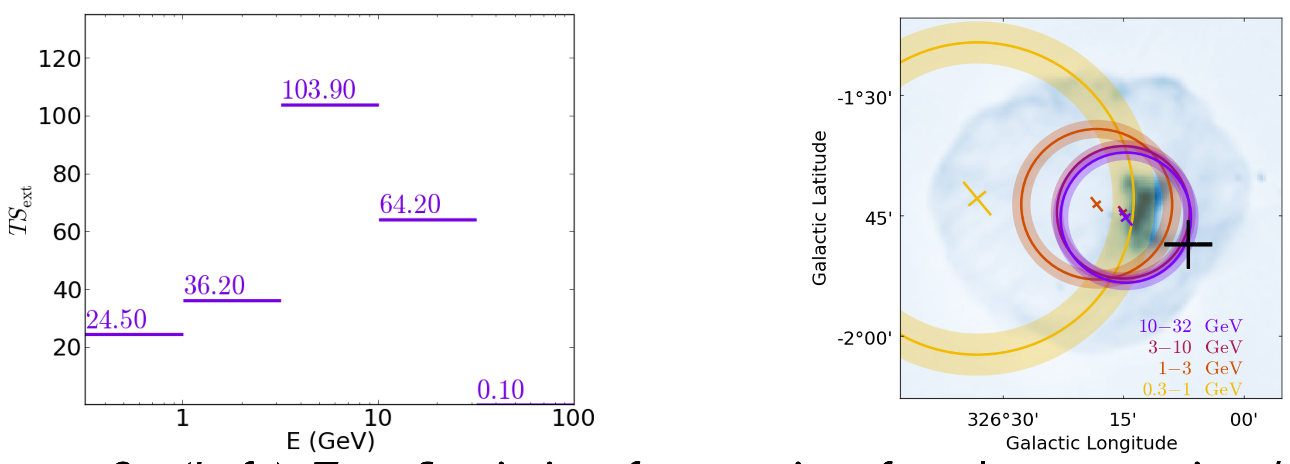
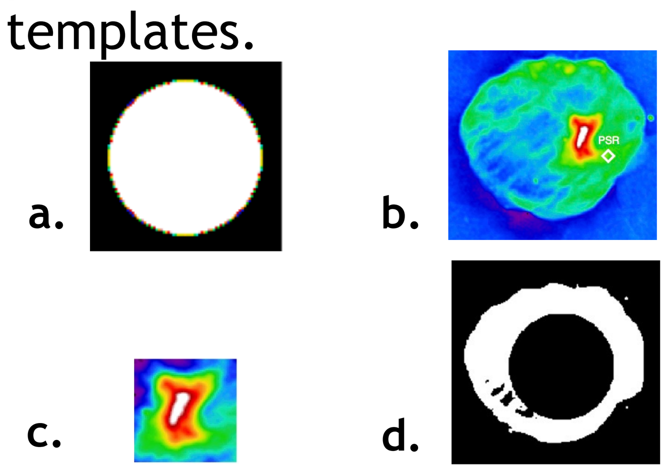


***Figure 3**. (Left) Test Statistic of extension for the respective best-fit extended source in individual energy bands using the front events. (Right) Cross: central localization uncertainties (1σ), circle: σ of the gaussian template with the associated errors (transparent regions).*

Morphological analysis

Using the PSF3 events, we then performed a maximum likelihood fit from 300 MeV to 300 GeV modeling the gamma-ray emission, described by a power law, with different templates.



	TS	N_{dof}
point source	693.0	2
gaussian	836.0	2
disk[a]	837.7	2
radio template[b]	833.3	2
PWN (radio)[c]	742.6	2
PWN (radio)[c] *+ SNR (ring)*[d]	851.3	4
PWN (radio)[c] *+ disk*[a]	851.7	4

***Figure 4**. Results of the likelihood fit using different templates. The Test Statistic (TS) is compared to the model without source and the respective degrees of freedom is given (N_{dof}).*

Spectral Energy Distribution

The spectral fit between 300 MeV and 300 GeV using the radio template of the PWN and the ring highlights different contributions from the components: at low energy the emission is dominated by the SNR while the PWN protrudes at high energy. The Spectral Energy Distribution (SED) also shows distinct spectral signatures that could be consistent with two underlying processes, namely leptonic and hadronic emission for the PWN and the SNR respectively.

	Γ	Φ $(erg.cm^{-2}.s^{-1})$
Disk	2.08 ± 0.04	2.67 ± 0.15
PWN (radio)	1.86 ± 0.09	0.50 ± 0.11
SNR (ring)	2.24 ± 0.07	2.07 ± 0.24

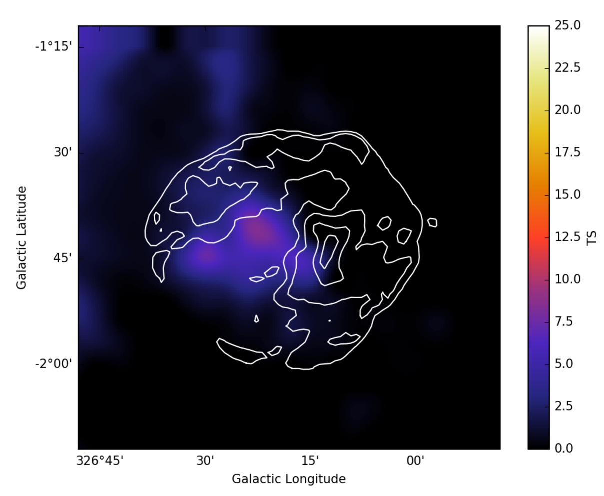


***Figure 5**. (Left) Best fitted parameters for a one-component model (disk) and two-component model (PWN radio + ring) between 300 MeV and 300 GeV. (Right) Residual TS map when the radio template of the PWN and the ring are included to the model.*

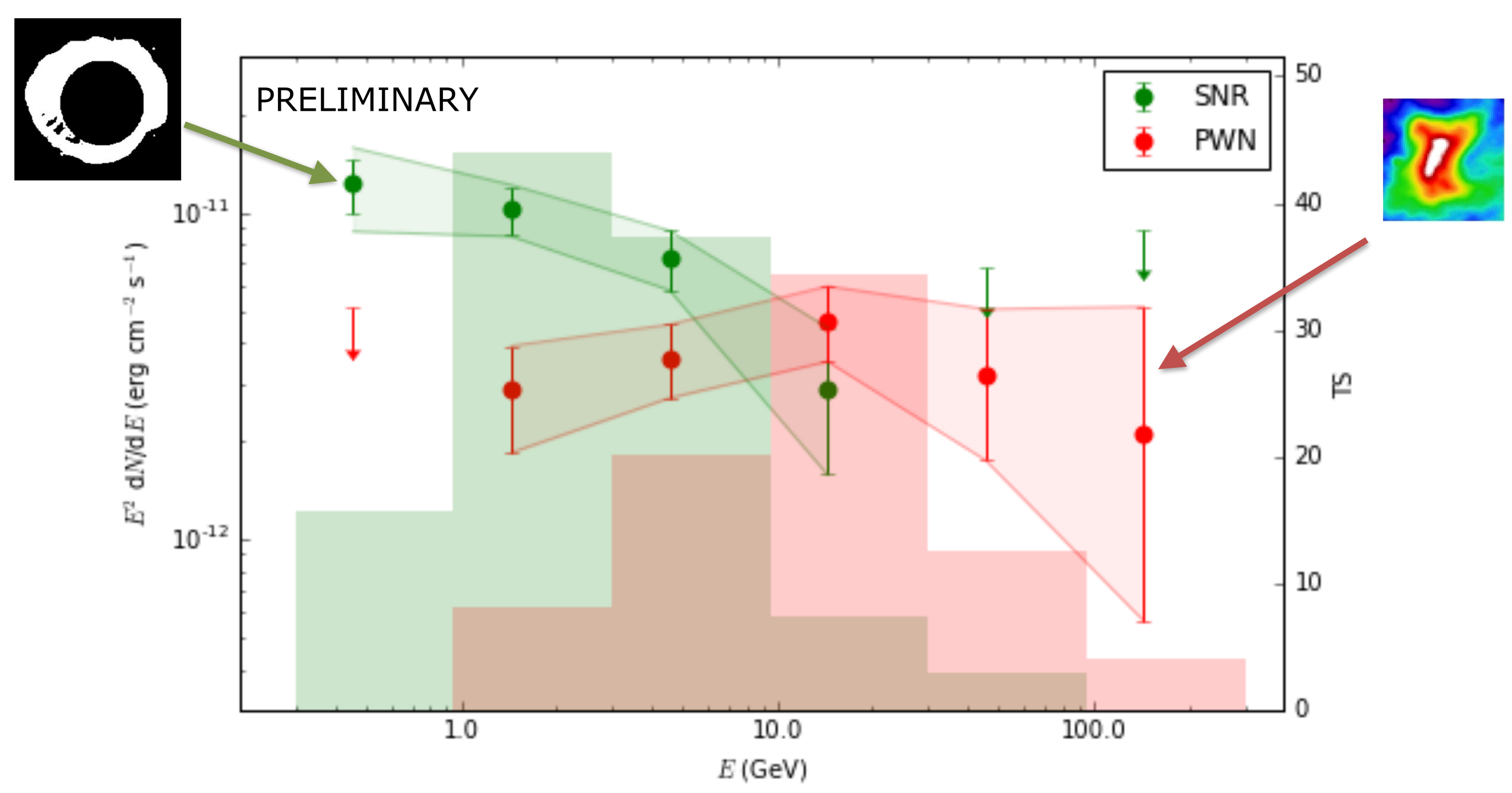


***Figure 6**. Spectral energy distribution (points) and TS values associated to the components in each energy band.The arrows represent the upper limits and the shaded areas take the systematic errors into account.*

Conclusions

The morphological fit of the composite SNR G326.3-1.8 indicates that the gamma-ray emission is clearly extended and seems to come from the PWN at high energy. This morphological evolution may highlight a contribution from two different constituants and adding the radio template of the PWN to the disk has a significance of about 3σ (TS=14 with 2 more degrees of freedom). Using a two-component model, the SED also reveals two distinct spectral indices which might suggest different process origins (hadronic and leptonic).

References

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