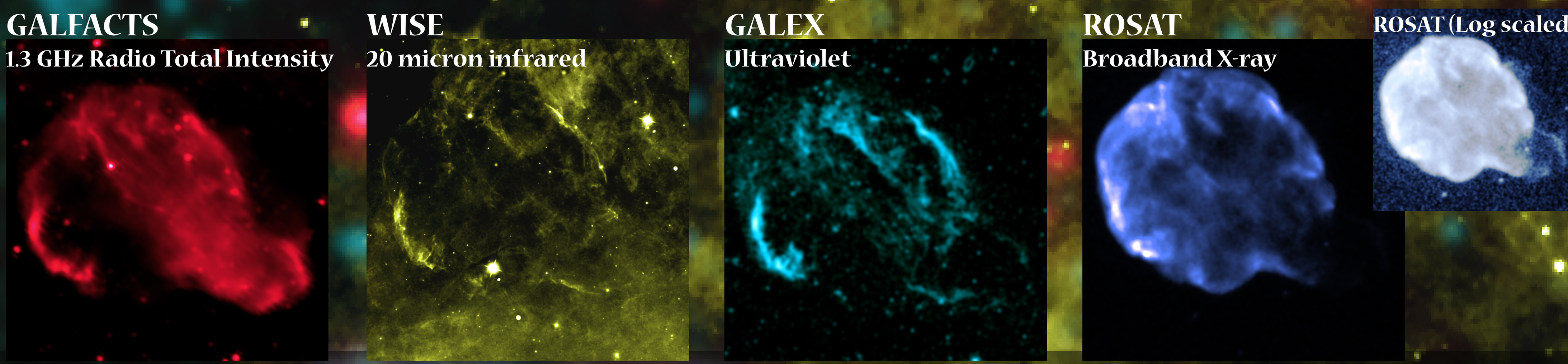

Cygnus Loop: A double bubble?

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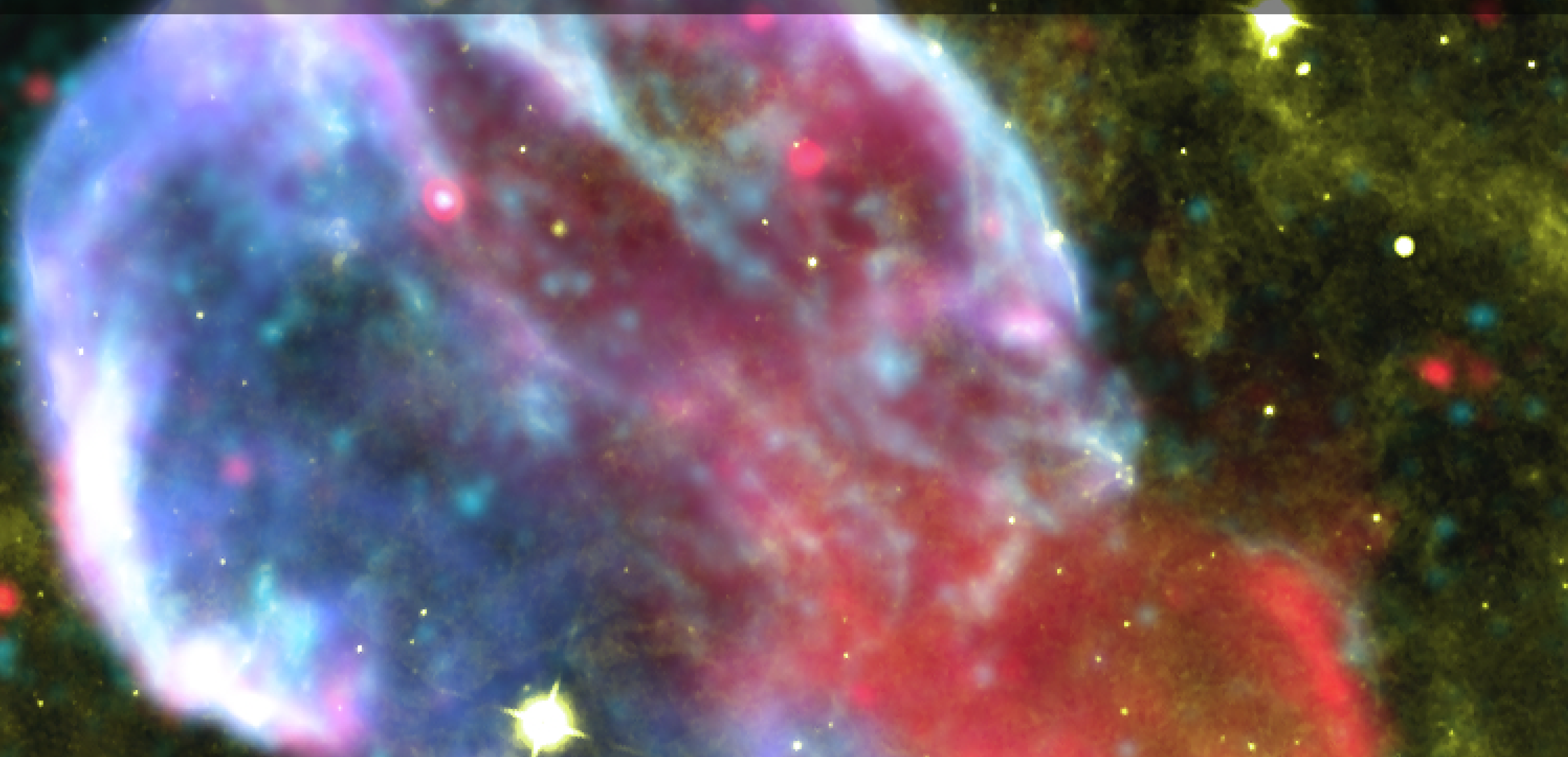


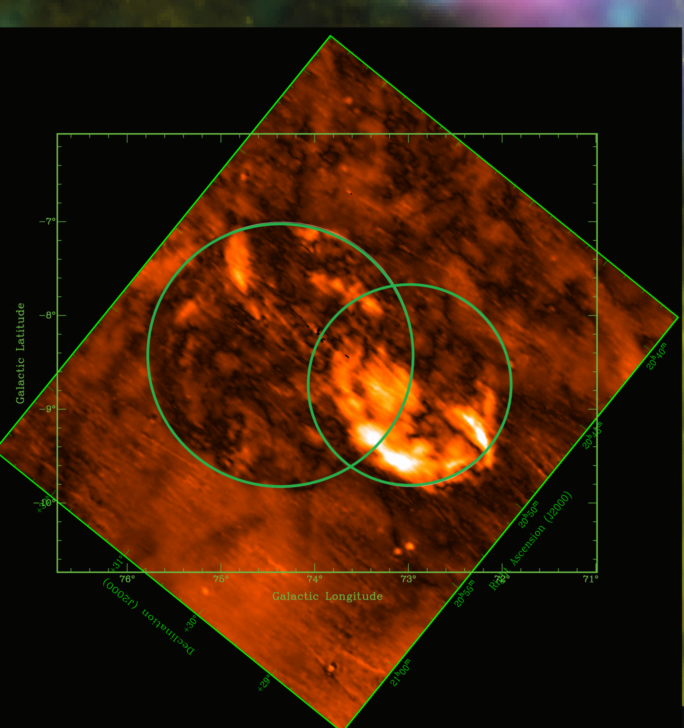


Figure 2: Coordinate grids (both Galactic and Equatorial) and regions from Table 1 shown on GALFACTS polarized intensity data. All images are displayed in Galactic coordinates.

Figure 1: Colour image made by combining GALFACTS, WISE, GALEX, and ROSAT data. Individual images are shown in the insets above. We acknowledge the use of NASA's SkyView for the WISE, GALEX, and ROSAT data.

ABSTRACT

The Cygnus Loop is a well-studied, large, bright and nearby supernova remnant (SNR) that has been observed across the electromagnetic spectrum. It is believed to be an SNR shell with a blow-out region in the south. However, it has also been suggested that this object is in fact two SNRs. We consider this two-SNR scenario by using a multi-wavelength view, focusing on new multi-frequency radio polarization data from the GALFACTS survey, with the addition of microwave (Planck), infrared (WISE), ultraviolet (GALEX), X-ray (ROSAT), and gamma-ray (Fermi-LAT) data. In addition, we present modelling efforts that support the 2-SNR interpretation.

DATA

Based on Effelsberg 100-m telescope data at 2.7 GHz, Uyaniker et al. (2002) first suggested that the Cygnus Loop may in fact be two SNRs, observed in projection. We present new radio data from the GALFACTS survey —the Galactic Arecibo L-band Feed Array Continuum Transit Survey, a sensitive, high-resolution, spectro-polarimetric survey of the Arecibo Sky — along with other data at many wavelengths that supports this 2-SNR picture. The colour multi-wavelength image (Figure 1) clearly shows a distinct difference between the two regions (defined in Table 1 and Figure 2).

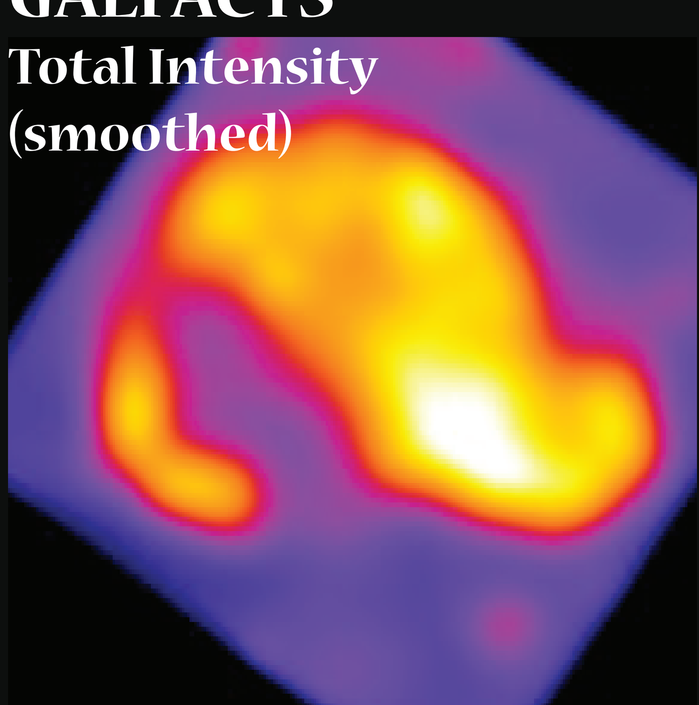
The GALFACTS polarized intensity data (Figure 3) shows very distinct polarization properties between the northern and southern regions. The southern region is much more highly polarized when compared to the northern region, which is nearly completely depolarized.

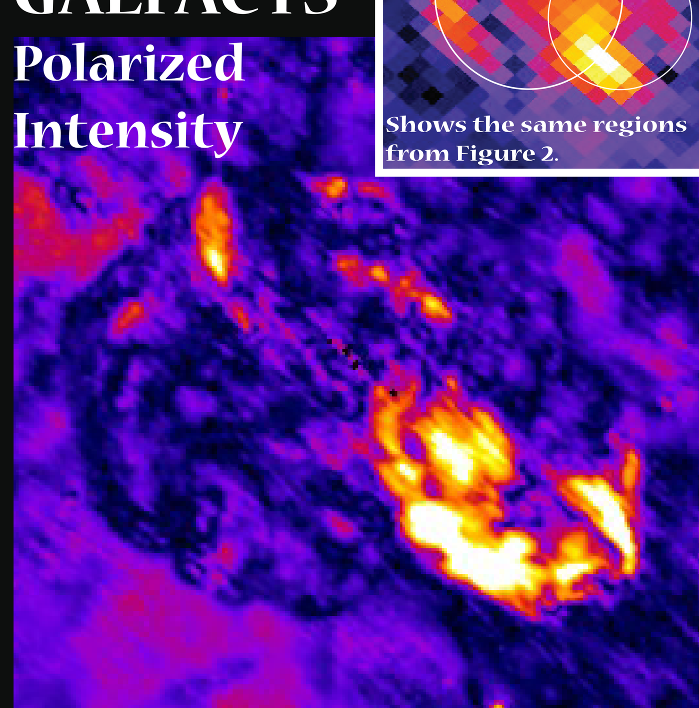
Much higher frequency (30 GHz) polarization data from Planck reveals that both regions are in fact polarized, as would be expected from synchrotron radiation. The depolarization at low frequencies may be due to a Faraday screen existing between the two SNRs (which could depolarize if the northern SNR is behind the screen) and/or a difference in age between the two SNRs, if the northern one is older and more radiative than the southern one.

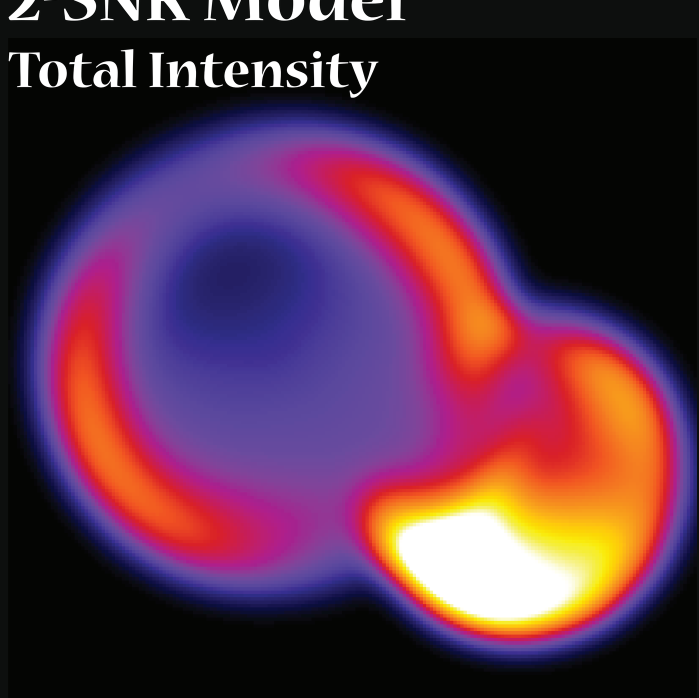
A spectral analysis of Fermi/LAT data (Figure 4) further supports this 2-SNR scenario.

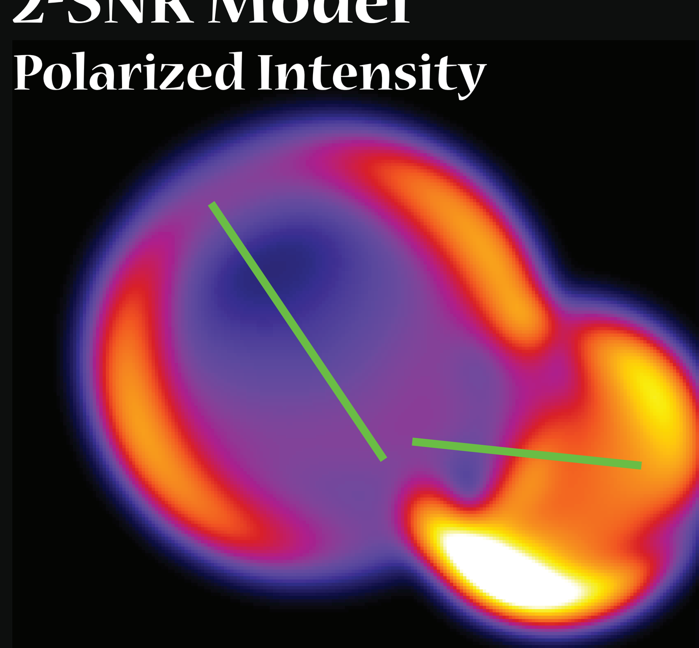
Table 1: Regions used in the analysis and modelling. These are drawn on the image in Figure 2.

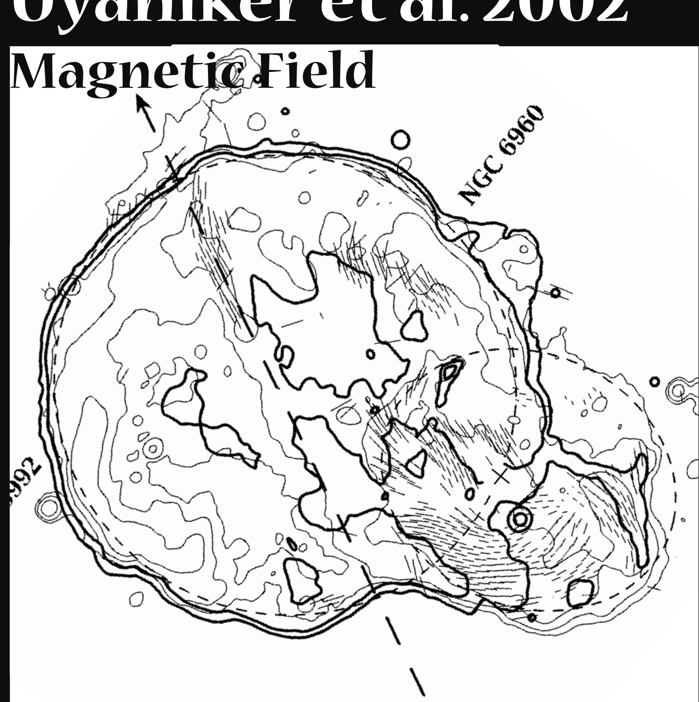
	α	δ	*l*	*b*	size (°)
Northern SNR	20h51.6m	31°3.0'	74.3°	-8.4°	1.40
Southern SNR	20h48.8m	29°47.3'	73.0°	-8.7°	1.07











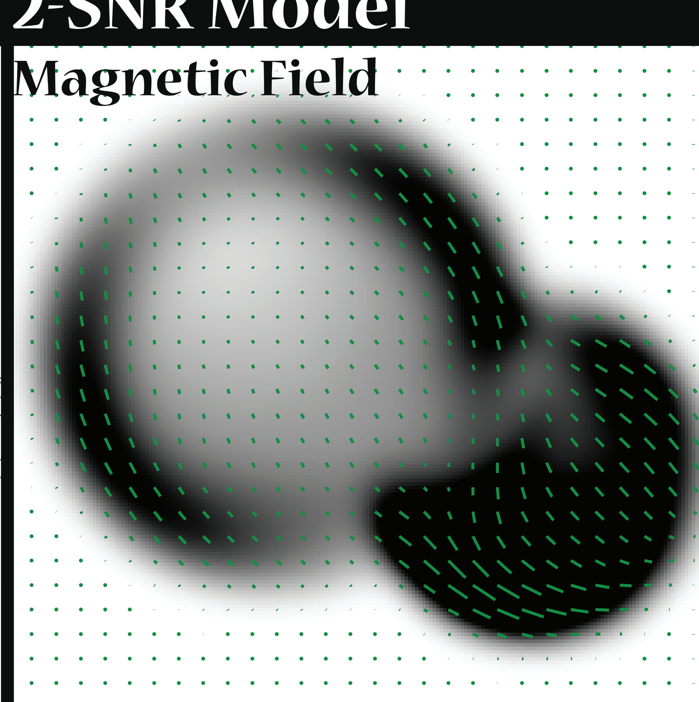


Figure 3: Data shown in comparison to the best fit 2-SNR model. The green lines on the model total intensity image indicate the orientations of the ambient magnetic fields for the background (beyond the transition distance, i.e., 487 pc) and foreground (up to the transition distance of 487 pc).

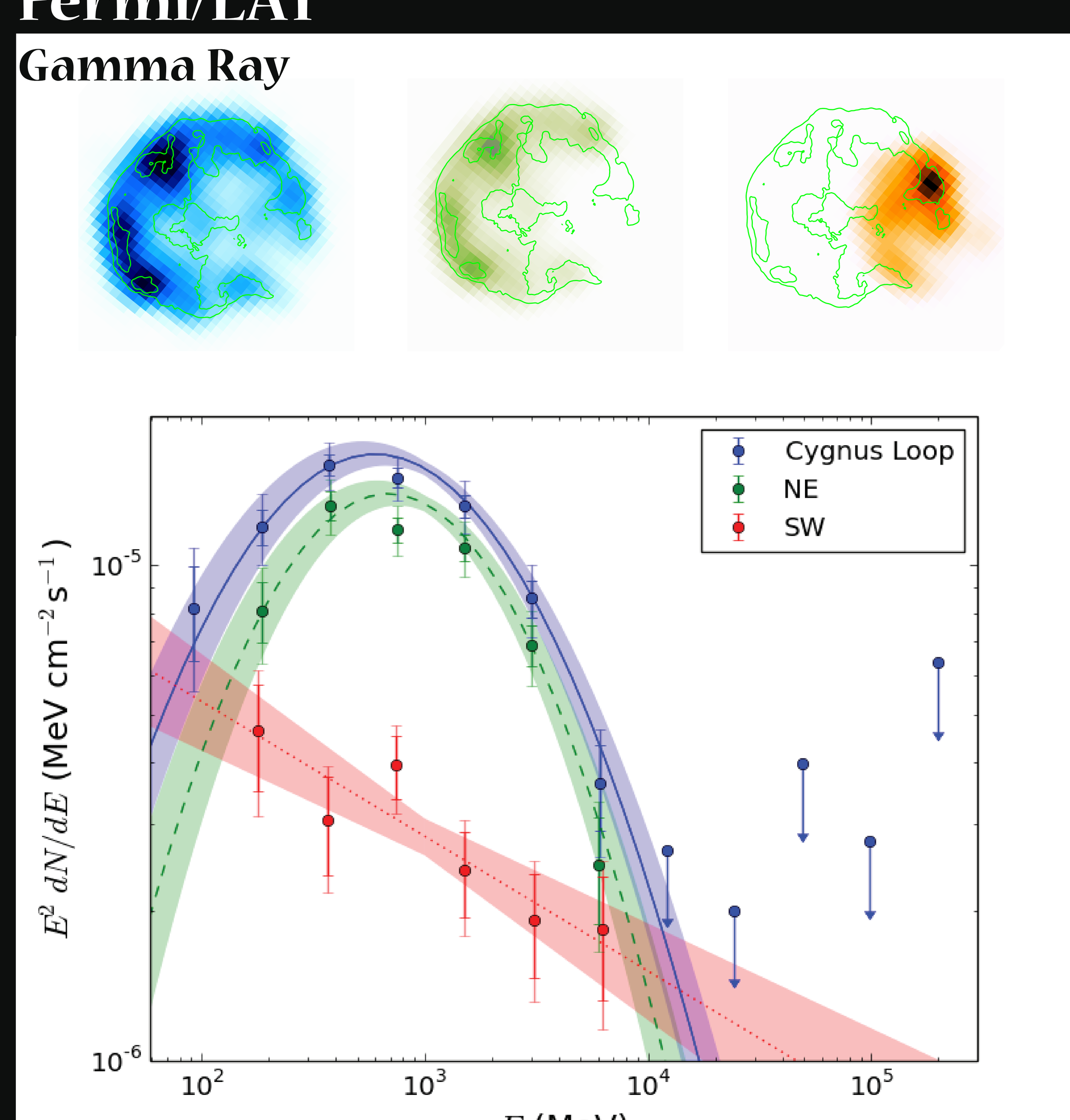


Figure 4: The images above show the image templates used to derive spectra from the Fermi/LAT data. The entire Cygnus Loop is shown (blue); using the regions defined by the GALFACTS data, the northern (NE) SNR is isolated and shown in green and the southern (SW) SNR is isolated and shown in red. The energy spectra from these regions is shown above. The statistical uncertainty range of the best model is shown as a shaded area. Spectral points include statistical uncertainties (solid bars) and systematic uncertainties (shaded bars).

MODEL

We model the 2-SNR scenario by using the coordinate transformation technique applied in West et al. (2016). If we interpret the data as showing two superimposed bilateral SNRs, then we can measure the orientation of the ambient field from the angle of bilateral symmetry. Based on the polarization observations, we assume the northern SNR is at a further distance. We define the ambient magnetic field at this distance to have a different orientation than the one for the southern, foreground SNR (see the green lines in Figure 3).

We assume that the northern SNR is at a fixed distance of 500 pc (radius = 28 pc), and we vary the distances to the southern SNR, as well as the transition distance for the two magnetic field orientations.

CONCLUSIONS

We find a good match between data and model for a distance to the southern SNR of 491 pc (radius = 19 pc) and a transition distance of 487 pc. The published distances to the Cygnus Loop have a range 0.46 - 0.64 kpc (Ferrand & Safi-Harb, 2012, and references therein).

Note that our model does not include a Faraday screen or age differences between the northern and southern SNRs and thus, our model does not show the depolarization found in the GALFACTS data. For these distances, we find that there would be interaction between the two SNRs.

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