G150.3+4.5 YEAH!

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ABSTRACT

We report here a dedicated analysis of the γ-ray emission around supernova remnant (SNR) G150.3+4.5, observed with the Large Area Telescope (LAT) on board the *Fermi Gamma-Ray Space Telescope*. The Second Catalog of Hard *Fermi* LAT Sources (2FHL, Ackermann et al. 2015) reported detection of a hard spectrum, spatially extended source from 50 GeV - 2TeV, partially overlapping G150.3+4.5. We extend the energy threshold to 750 MeV for spectral analysis and x GeV for morphological analysis, we significantly detect a large ($\sigma = 1.46° \pm 0.03°$) extended γ-ray source consistent with the entirety of the radio shell, and with a power law spectral index of 1.88. An obtained HI spectrum toward the SNR suggests that the remnant could be one of the closest to us and estimates of its age indicate that G150.3+4.5 may be in the Sedov-Taylor phase. In contrast, the spectrum of the γ-ray source is more akin to that of a young, leptonic dominated SNR, although ROSAT X-ray observations show no signs of nonthermal emission coincident typically observed in young SNRs. We discuss alternate origin scenarios for the γ-ray emission...

Subject headings: Supernova Remnants, γ-rays, Cosmic rays, Radio

1. Introduction

Something about SNRs, cosmic ray accelerators, radio detections, connection between radio-LAT observations, G150 detection, 2FHL blind detection and SNRs at TeV (all young?), this paper extends the energy down to > 5 GeV

We describe the LAT and analysis results in §2, detail multiwavelength observations in §3, and discuss various emission origin scenarios in §4.

2. *Fermi* LAT Observations and Analysis

2.1. Data Set and Reduction

Fermi LAT is a pair conversion telescope sensitive to high energy γ-rays from 20 MeV to greater than 300 GeV (Atwood et al. 2009). We analyzed 7 years of Pass 8 data, from date1 to date2. The Pass 8 event reconstruction provides a greatly improved angular resolution and acceptance (Atwood et al. 2013a,b). Source class events were analyzed within a 10° region of interest (RoI) centered on G150.3+4.5 using the P8R2_SOURCE_V6 instrument response functions, with a pixel size of 0.1°. To reduce contamination from earth limb γ-rays, only events with a zenith angle less than 100° were included.

For spectral and spatial analysis we utilized both the standard *Fermi* Science Tools (version 10-01-01?)[1], and the binned maximum likelihood package `pointlike` (Kerr 2010). `pointlike` provides methods for simultaneously fitting the spectrum, position, and extension of a source, and were extensively validated in Lande et al. (2012). Both packages fit a source model to data, the Galactic diffuse emission, and an isotropic component which accounts for the background of misclassified charged particles and the extragalactic diffuse γ-raybackground[2].

In our source model for the region, we included sources from the third *Fermi* LAT catalog (Acero et al. 2015, 3FGL) within 15° of the center of our RoI . The normalization and spectral index of sources within 5° of the center of the RoI were free to vary, whereas all other source parameters were fixed. Sources with a likelihood test statistic

[1] http://fermi.gsfc.nasa.gov/ssc/

[2] See http://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html for details on LAT Pass8 bakground models

(TS) < 9 were removed from the model. TS is defined as, $\mathrm{TS} = 2(\ln \mathscr{L}_1 - \ln \mathscr{L}_0)$ where $\mathscr{L}_1$ is the likelihood of source plus background and $\mathscr{L}_0$ that of just the background.

2.2. Morphological Analysis

Studying the spatial extension of sources with the LAT is non-trivial due to the energy-dependent point spread function (PSF) and strong diffuse emission present in the Galactic plane. To strike a balance between the best angular resolution and minimal diffuse contamination, we restrict our analysis to energies between 5 GeV - 500 GeV. We divide this energy range into x logarithmically spaced bins for both `pointlike` and `gtlike` binned likelihood analyses.

Three 3FGL sources are located within the extent of G150.3+4.5. 3FGL J0425.8+5600, located approximately 0.6° from the center of the SNR, is the closest of the three sources and is described with a power law spectrum with index $\Gamma = 2.35 \pm 0.17$, and TS = x in the 3FGL catalog. The closest radio source to 3FGL J0425.8+5600 is NVSS J042719+560823, at 0.25 away (Ref?). 3FGL J0426.7+5437 has TS = x in 3FGL and exhibits a pulsar-like spectrum, yet it's located about 0.8°, from the center of the SNR (we discuss in the potential emission scenarios in §4.2). Finally, 3FGL J0423.5+5442, exhibits a power law spectral index, $\Gamma = 2.63 \pm 0.15$, and TS = x, with no clear multiwavelength source association.

In our analysis, we removed the three 3FGL sources and replaced them with a radially symmetric uniform disk of initial radius $\sigma = 1.5°$

Other analysis to do? Split remnant in half? Motivation: Radio from (Gao & Han 2014) Fig 2 has a void in the center which is an argument for trying a ring template, but there's also radio peak in the SE, so maybe that could be the splot? No good template since radio is so faint? Fig 1 Shows a background subtracted residual counts map, not quite disk-like. Figs below are just for show now

Should try an ellipse since the Radio source is elliptical

2.3. Spectral Analysis

Describe gtlike results, spectral models tested (broken PL? no need to since it looks so power law esque?). No break observed, hard spectra increasing to TeV

how many energy bins

2.4. Systematics

Bracketing IRFs and diffuse systematics study still need to be done

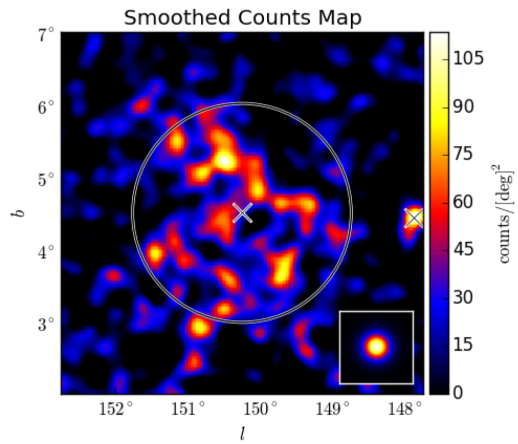

Fig. 1.— Smoothed diffuse and isotropic subtracted counts map, E > 10 GeV.

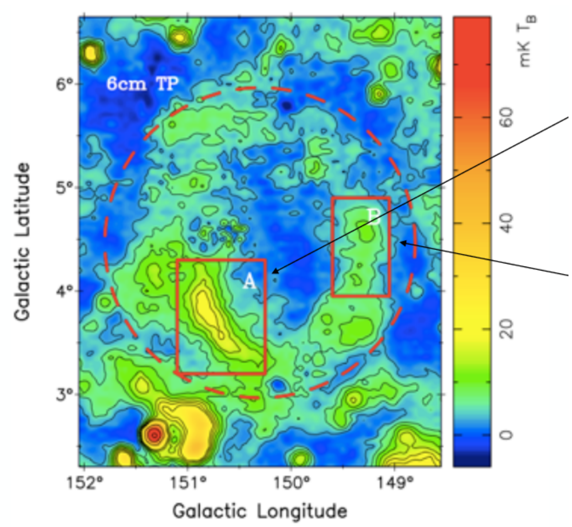

Fig. 2.— Radio image from (Gao & Han 2014)

3. Multiwavelength Observations and Analysis

Not sure yet if I'll need separate sections

3.1. Radio

I don't think we're presenting any new Radio analysis, just rehashing previous results, showing radio maps overlaid on GeV, so maybe this is really discussion. (Gao & Han 2014)

3.2. HI

3.3. CO

Make CO overlay maps for the possible velocities. Only issue is that Dame 2001 only goes up to 5 deg. Other CO data that covers better to use? Planck?

3.4. X-ray

No diffuse nonthermal X-ray emission observed by ROSAT. No point sources near the center? Should a pulsar be near the center? How to quantify this? Can we place a limit on something like density with an upper limit on X-ray emission? What about other x-ray telescopes?

4. Discussion and Results

4.1. What is it?

Size + HI suggest that near distance corresponding to different HI velocities suggest it's aged, spectrum looks more like young SNR (hard + no GeV break). Is it a weird young remnant or weird aged one? Leptonic dominated if young, hadronic dominated if older? Something about nearby dense clouds masking hadronic emission? Maybe this is only true for MeV cosmic rays that are screened out though and it would only mask the pion bump, but not this higher energy emission?

PWN or SNR. Can we rule out PWN? See W41 paper, MSH 11-61A, Fabios recent G326 work (no, he just tries to use the PSF types and testing different model templates to try to disentangle SNR from PWN)?

No PSR candidate near center (should it be near the center? Depends on age) Is there some limit we can place on the PWN based on not seeing the pulsar? Like on Edot? OR something like Mattana et al. 2009 correlation between $\mathrm{flux_x}/\mathrm{flux_g} \propto$ Edot?

Assume it's in Sedov phase based on size + near distance, and calculate age, upper limit on Edot base on lack of x-ray flux? Or maybe if I assume the sources is the PWN and GeV radius is PWN radius, then can I estimate Edot based on size and evolution inside SNR?

If we assume close distance, age is only $\approx$ 5kyr, maybe this is a transitional SNR? What do others like this look like? Puppis A? Gamma Cygni is a similar age too.something

4.2. Distance Considerations

probably doesn't need to be a different section.

4.3. Nonthermal Modeling

I think I could get a working model with naima running pretty quickly, is it worth it?

5. Conclusions

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