Diffuse GeV emissions toward massive star clusters W40 and RSGC 1

Xiaona Sun （孙晓娜）

Guangxi University

In collaboration with Ruizhi Yang Xiangyu Wang et al.

The first LHAASO collaboration conference in 2021

April 25, 2021

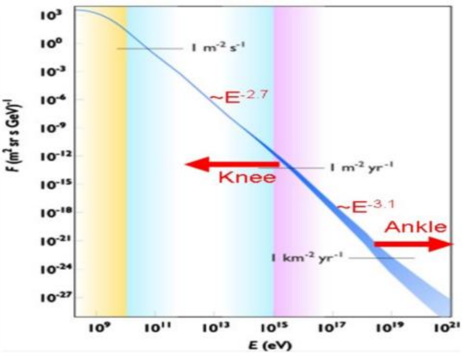
Outline

- Background and introduction
- Diffuse GeV γ-ray emission near the massive star clusters W40, RSGC1 and Mc20 (0.34° from PSR J1913+1011)
- Summary and outlook

Background and introduction

Galactic Cosmic Rays (GCR)

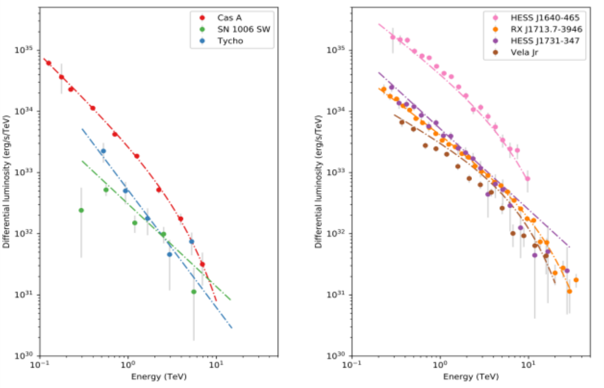
- Single power law spectrum (-2.7 - -3.0) from 10 GeV up to 1 PeV.
- Injection rate of $\sim 10^{40}$erg/s in the Galaxy.
- Supernova remnants (SNR) as one of the best candidates for the PeV CRs.



Background and introduction

Young SNRs as CR source

- All γ-ray spectra show soft or early cutoff at $\sim$10 TeV, correspond to CR energy of 100 TeV.
- Hard to address a single power law spectrum of CRs up to PeV.



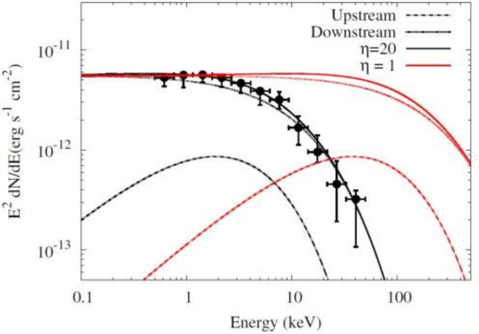
(Aharonian et al., 2019)

Background and introduction

Very young SNRs as CR source - SNR G1.9+0.3

- X-ray observations on G1.9+0.3 (Aharonian et.al 2016).
- t ~ 100 yrs, shock speed $V_{sh} \sim$14000 $\mathrm{km/s}$.
- In the Bohm diffusion limit the synchrotron peak $\sim$ 20 keV but is detected at only 1 keV.

→Not an efficient accelerator.

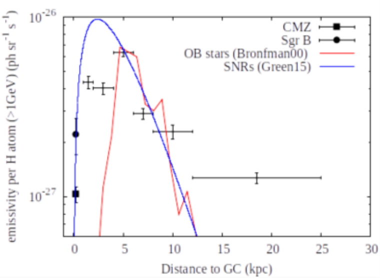


Background and introduction

Massive star clusters: alternative GCR sources?

- CR distribution reveals a similar peak as that for OB stars.

- Isotope ^{60}Fe measurement in CRs favor a superbubble origin. (W.R. Binns et al. (2016)).

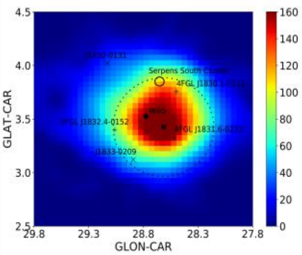


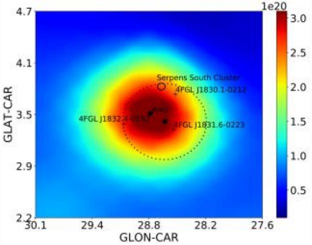
- Most of OB stars exist in associations or clusters, sufficient wind power, stellar wind can accelerate CRs efficiently (Cesarsky & Montmerle 83).

Diffuse γ-ray emission towards W40

Fermi-LAT analysis

- One of the nearest sites of massive star formation (d~400 pc), located 3° above the Galactic plane.
- Young star forming region (< Myr), dominated by four bright OB stars.
- Spatial analysis → 0.46° uniform disk excess→ γ-ray emission region $\sim$ several pc, probably dominated by the cluster itself.
- Use the Planck free-free map to obtain H_{II} column density → spatial consistency suggests that the γ-rays are probably only related to H_{II} gas.

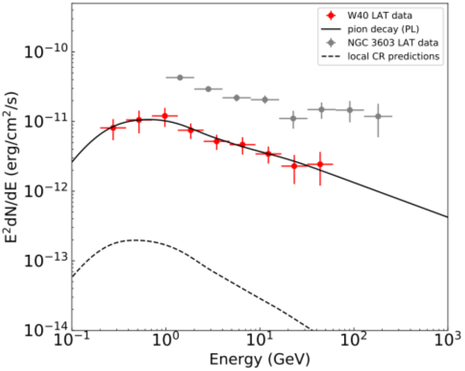




Diffuse γ-ray emission towards W40

γ-ray spectrum and origin - hadronic scenario

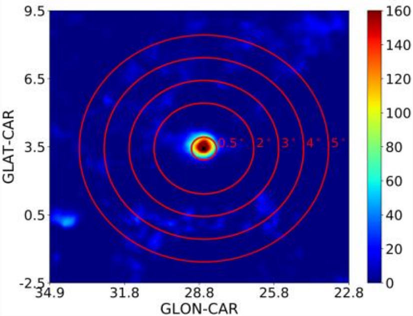
- The observed Fermi-LAT data are higher and harder than the local CR fluxes (10 times).

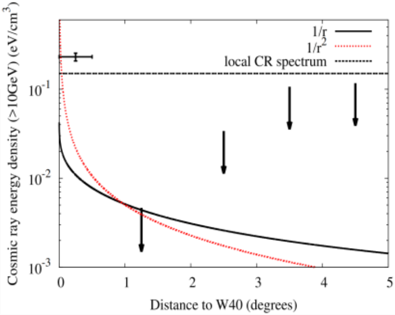


Diffuse γ-ray emission towards W40

CR content

- Derive the CR density upper limits profile (γ-ray upper limits & gas dis., not compatible with 1/r profile.
- W40 is possible not be the beginning of the CR profile, the CRs produced in W40 may be confined inside the source due to the much slower diffusion.

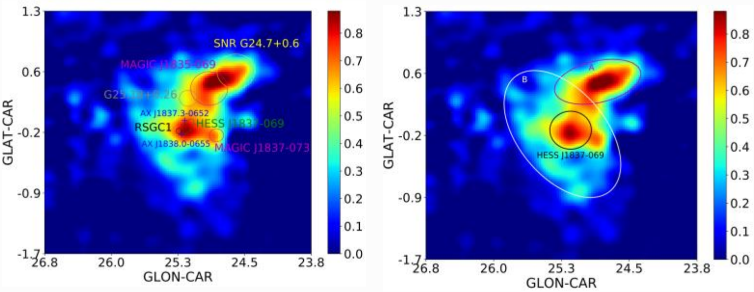




Diffuse γ-ray emission towards RSGC 1

Fermi-LAT analysis

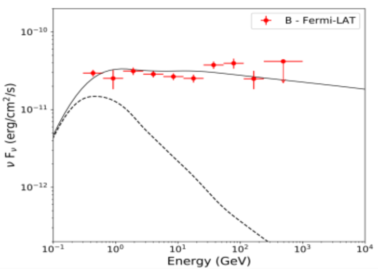
- Massive young star cluster (D~6.6 kpc, $M \sim 3 \times 10^4 M_{\odot}$, t~10 Myr).
  One of the rare clusters in the Galaxy ($>$10 red super-giants).
- A more natural source: >200 main-sequence massive stars provide enough power to accelerate the CRs.
- A(0.25°,0.5°)+B(0.5°,0.9°)+HESSJ1837(0.23°).

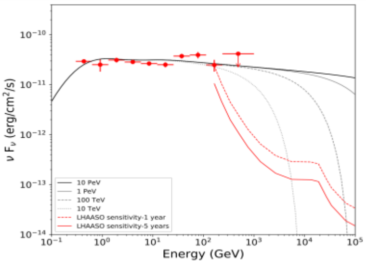


Diffuse γ-ray emission towards RSGC 1

γ-ray spectrum and origin – B

- A very hard spectrum above ~ 300 MeV.
- Hard spectrum without any hint of cutoff, similar to Cygnus Cocoon.
- A significant CR enhancement compared with the predicted emissions assuming the CR local density, CR acceleration site!





GeV emission towards Mc20

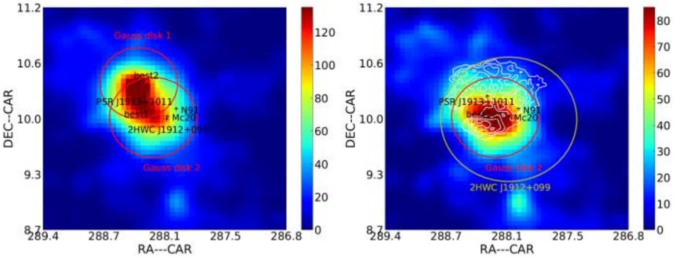
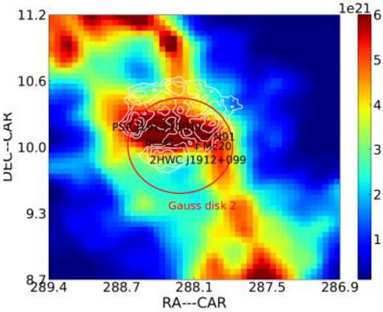
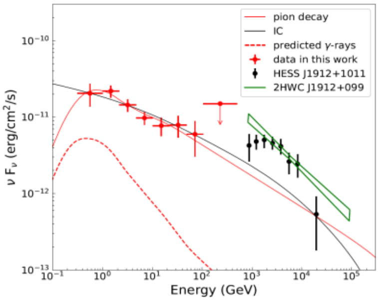


Table 1: Spatial analysis result (> 2 GeV) for different templates.

Model	Components	size (°)[a]	-log(likelihood)	ΔTS_{ext}
Model 0	J1912+J1913 at PSR	no	379834	0
Model 1	J1912+J1913 at best 2	no	379791	86
Model 2	Gauss disk 1+PSR J1913+J1912	0.4	379778	112
Model 3	Gauss disk 2+J1913	0.45	379773	122
Model 4	uniform disk 2+J1913	0.45	379786	96

GeV emission towards Mc20





H_2 column density derived
from the CO data (50 - 70 km/s).

Summary and outlook

- Analyze *Fermi-LAT* data towards W40, γ-ray emission region is ~pc → emission from the cluster itself.
- γ-ray upper limits reveal a slow diffusion region in the vicinity of W40, not compatible with 1/r CR profile caused by strong turbulences and effective CR confinement.
- The γ-ray emission near RSGC 1 has hard spectrum without any hint of cutoff. The spatial and spectral properties make it a clone of Cygnus Cocoon, namely, the γ-rays originate from the interaction of the accelerated protons in RSGC 1 with ambient gas clouds.
- Mc20 analysis is going on…...(Haiming's report: sig~9, need more data)
- LHAASO has the ability to detect this kind of sources at TeV energy band, and set decisive constraint on the cutoff energy→

Combine the observational data of Fermi-LAT and LHAASO, search for the GeV and TeV emissions of the typical young massive star clusters, explore the origin of the CR in the Galaxy.