Correlation between the gamma-ray spectral index and density of the background in SNRs

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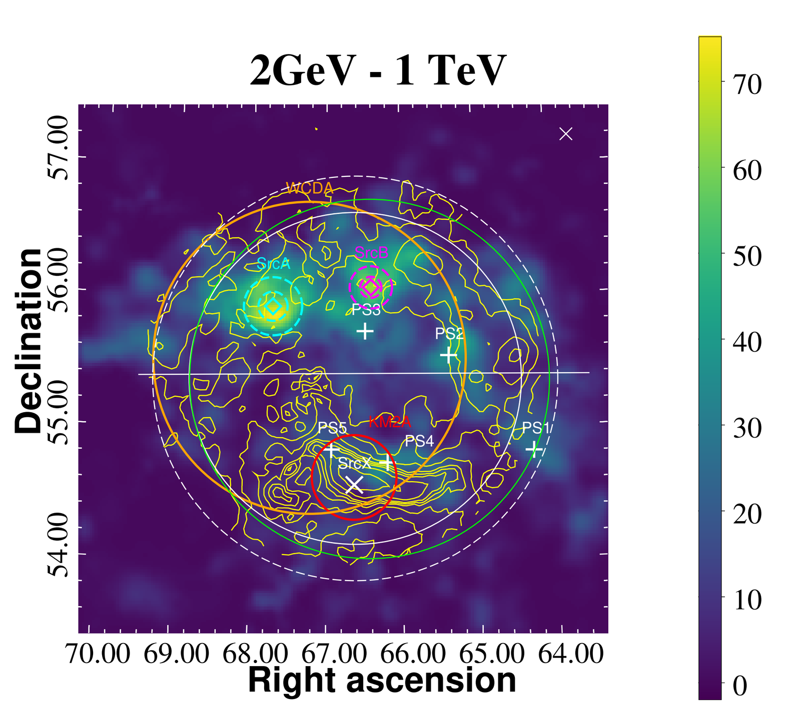
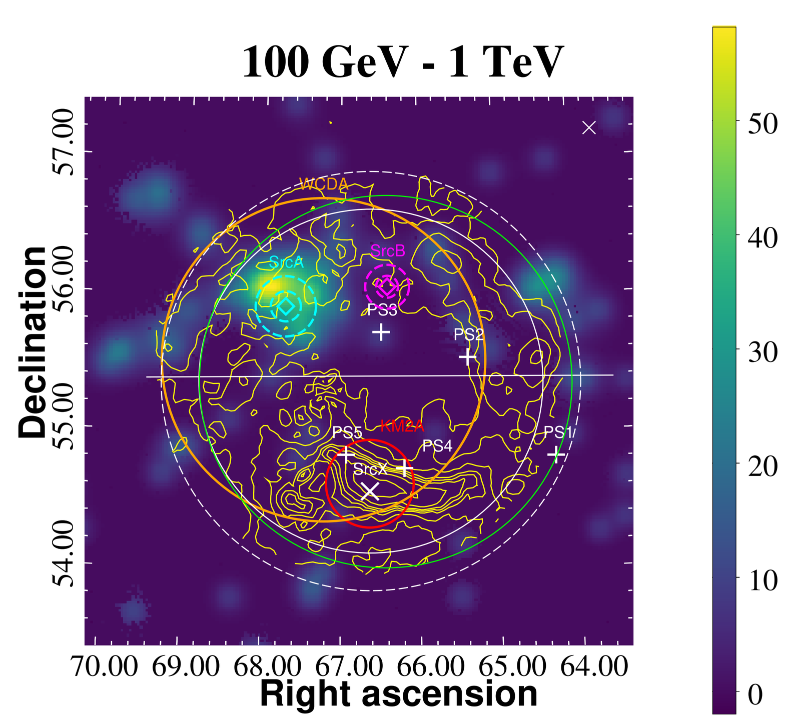
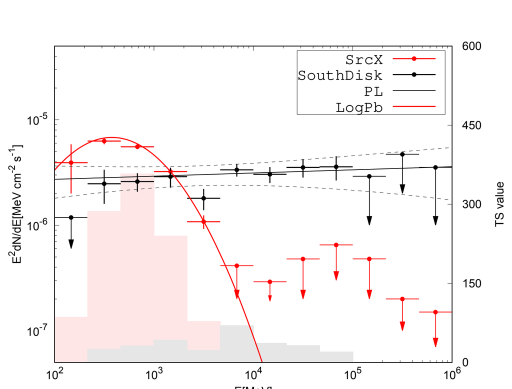
Abstract

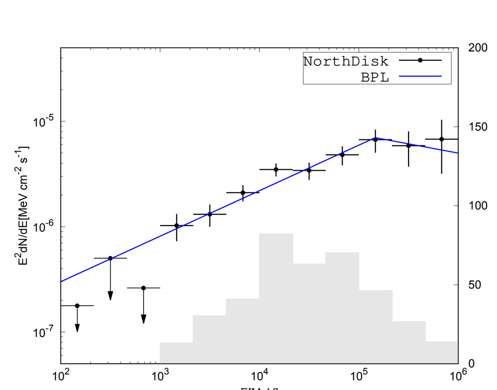
Due to interactions between cosmic rays and the dense magnetized gas in molecular clouds, non-thermal radiation will be amplified if molecular clump is located close to SNR enough . In this work, we re-analyzed the 14 years Fermi-LAT data for several SNRs that may interacting with molecular clouds, such as HESS J1912+101, RX J1713.7-3946 and G150.3+4.5. The SED results show that the spectral index in the regions filled with molecular clouds will be softer, and these sources have significant energy-dependent morphology (The whole area, not just the extended SNR). We suggested that the gamma-ray excess comes from different physical processes in different areas of the same source.

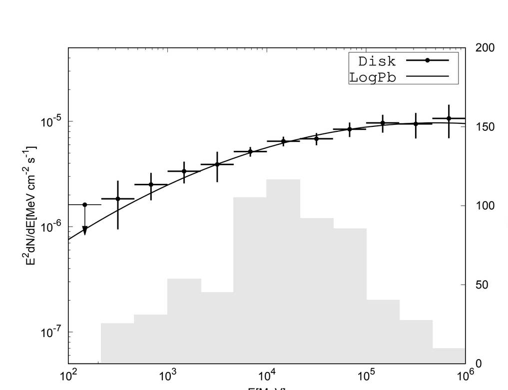
Fermi-LAT Data Reduction











Method

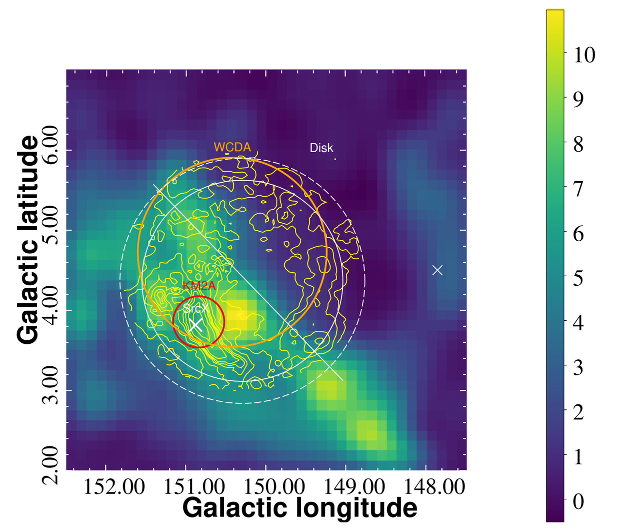
The mass of the molecular complex can be calculated from:

$$M = \mu m_{\rm H} D^2 \Delta\Omega_{\rm px} X_{\rm CO} \sum_{\rm px} W_{\rm CO} \propto N_{\rm H_2}, \tag{1}$$

where μ is equal to 2.8 if a relative helium abundance of 25% is assumed, $m_{\rm H}$ is the mass of the H nucleon, $N_{\rm H} = 2N_{\rm H_2}$ represents the column density of the hydrogen atom in each pixel, and $\Delta\Omega_{\rm px}$ corresponds to the solid angle subtended for each pixel in the map(square binning of 0.125 per side). Assuming that the shock-cloud interaction site is far away from the shock front and CRs is released at the time of the SN explosion, the distribution of the escaped protons follows:

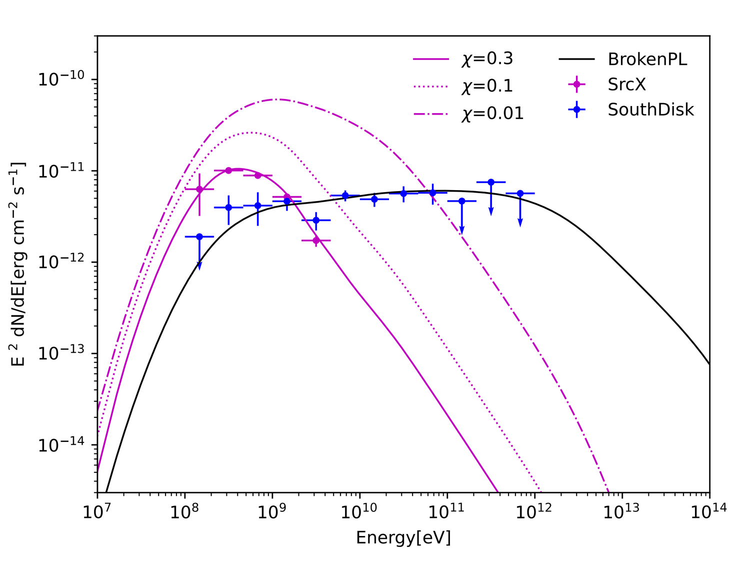
$$N_p(E, r_{\rm s}, T) = \frac{Q(E)}{[4\pi D(E)T]^{\frac{3}{2}}} \exp\left[\frac{-r_{\rm s}^2}{4D(E)T}\right] \tag{2}$$

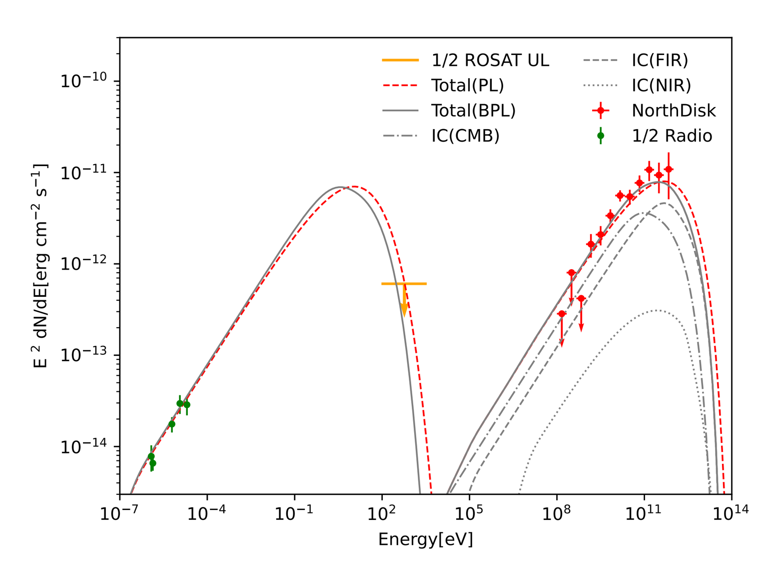
Molecular Cloud Emission Intensity

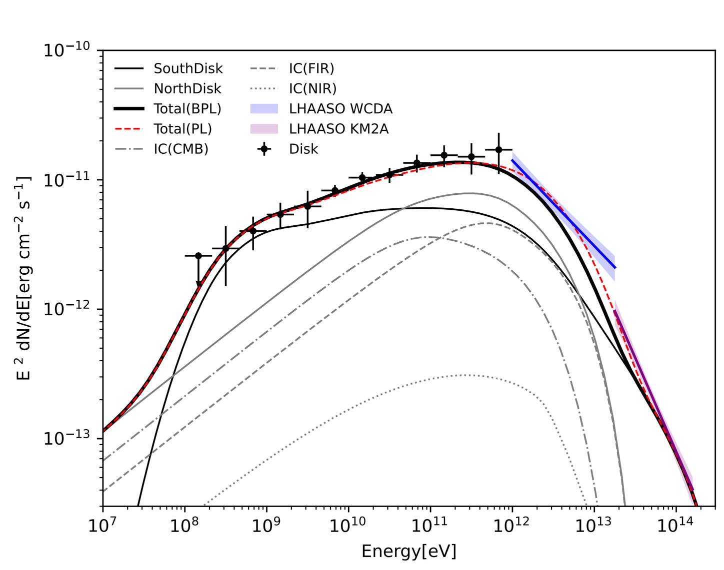


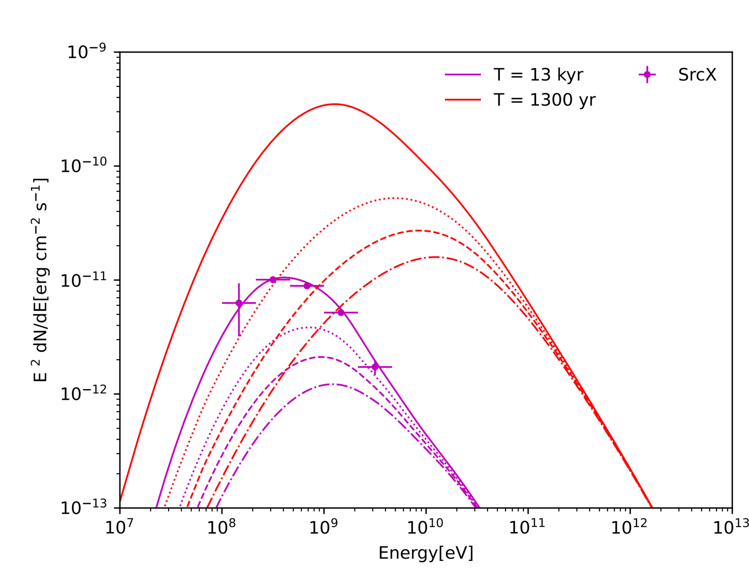
SNR parameters	Symbol		
SN explosion energy	$E_{\rm SN}$	1.0×10^{51} erg	
Convert efficiency	η	0.1	
Age of the SNR	T	13.0 kyr	
Distance to the SNR	d	0.8 kpc	
SNR radius	R	21.4 pc	
Energy break	$E_{p,\rm br}$	10 TeV	
Particle index in the SNR	$BrokenPower-Law$	2.0/3.0	
Particle index after escaping from SNR	$N_p(E, r_{\rm s}, T)$	2.0 + 1.5 δ	
Diffusion parameters	**Symbol**		
Diffusion coefficient at $E = 10$ GeV	D_0	1.0×10^{28} cm^2 s^{-1}	
Index of dependence on E of diffusion	δ	1.0	
Factor of dependence on E of diffusion	χ	0.3/0.1/0.01	
Molecular cloud (MC) parameters	**Symbol**	**SrcX(0.1° sphere)**	**SouthDisk**
Distance to the MC from SNR	$r_{\rm s}$	21.4/35/45/55 pc	–
Average hydrogen number density	$n_{\rm H}$	89cm^{-3}	66cm^{-3}
Mass of the MC	$M_{\rm cl}$	$2.5 \times 10^2\ M_\odot$	$3.1 \times 10^4\ M_\odot$

Theoretical Model building









Conclusion Acknowledgement

We suggest γ-ray emission in the lower TeV energy band detected by WCDA jointly comes from the hadronic and leptonic components. As the energy increase, the leptonic component disappears, and in higher TeV energy band, only hadronic component remains, which leads to the softer spectrum detected by KM2A, that means even the KM2A source is concentrated around SrcX, we expect there should be disperse component detected throughout the whole southern region. We thank Xuyang Gao for the help on the radio continuum data based on the Urumqi and Effelsberg observations. We thank Shaoqiang Xi for the help on the molecular cloud data analysis approach. We also would like to thank Houdun Zeng, Yang Su and P.P.Delia for invaluable discussions. This work is supported by the National Natural Science Foundation of China under the grants No. 12375103, U1931204, 12103040, 12147208, and 12350610239.