



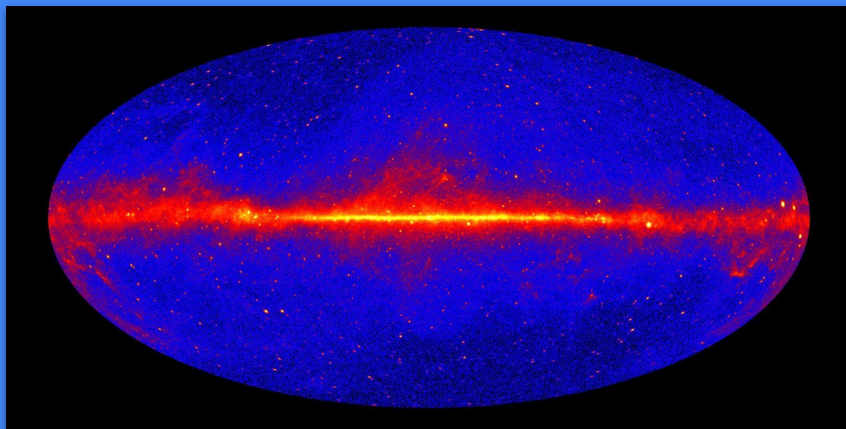
Fermi
Gamma-ray Space Telescope



Search for the GeV Counterpart of PeVatron LHAASO J1912+1014u using Fermi-LAT and FUGIN CO Data

T. Mizuno, N. Nakahara (Hiroshima Univ.), H. Sano, K. Murase (Gifu Univ.), T. Oka (Wuerzburg Univ.), H. Suzuki (Miyazaki Univ.)

2026.03.05 ASJ Meeting (PeVatron Special Session)



LHAASO reported 43 UHE srcs being proton or electron PeVatrons (Cao+24)

Multi- λ data is crucial to examine CR type and spectrum. Particularly, correlation with dense CO clouds is key to identify proton PeVatrons

		Observatory	Energy Range	Angular Resol.	FOV
Complementary	}	LHAASO, Tibet AS-gamma, HAWC	0.01-1 PeV (excellent ✓✓)	~0.5 deg (so-so)	~15% of the sky (good ✓)
		IACTs (e.g., H.E.S.S. MAGIC, VERITAS, CTA)	0.1-100 TeV (good ✓)	~0.08 deg (excellent ✓✓)	a few deg (so-so)
		Fermi-LAT	1-300 GeV (so-so)	0.1 deg in >10GeV (good ✓)	~20% fo the sky, all sky coverage (excellent ✓✓)

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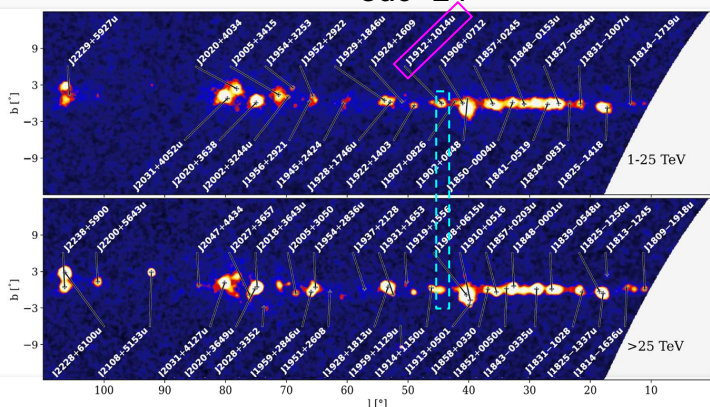
Wide energy coverage allows measuring W_p ; Fermi plays crucial role in studying proton PeVatrons (in collaboration with TeV and CO obs.)

LHAASO J1912+1014u is an extended ($r_{39} \sim 0.5$ deg) UHE source

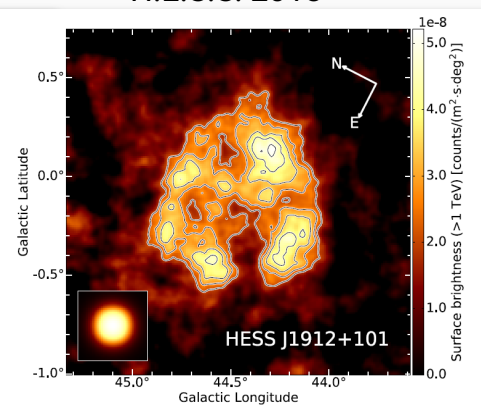
It positionally coincides with H.E.S.S. J1912+101 ($r_{\text{sep}} = 0.1$ deg). Hereafter we assume they are the same object

We developed a dedicated background model for Fermi-LAT and found hard excess toward the LHAASO/H.E.S.S. source

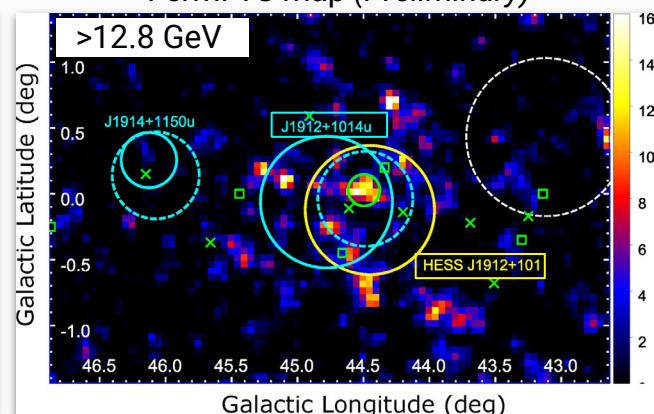
Cao+24



H.E.S.S. 2018

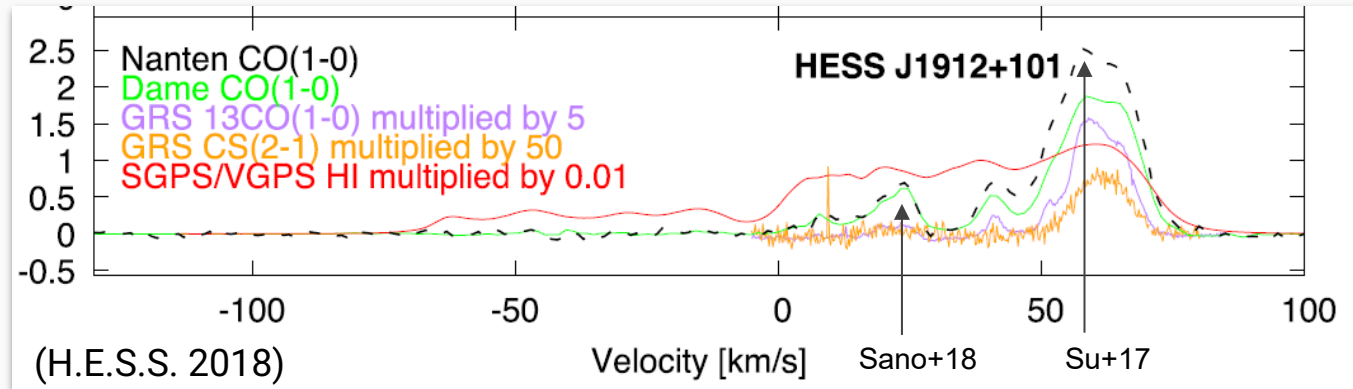


Fermi TS map (Preliminary)



CO data toward HESS J1912+101 exhibit several peaks. Su+17 proposed CO cloud with $v \sim 60$ km/s ($d \sim 4.6$ kpc) corresponds to the source. Sano+18 proposed alternative scenario; CO cloud with $v \sim 25$ km/s ($d \sim 1.7$ kpc) is associated

Here we prepared two ISM-gas templates (+other templates) and tested them against LAT data



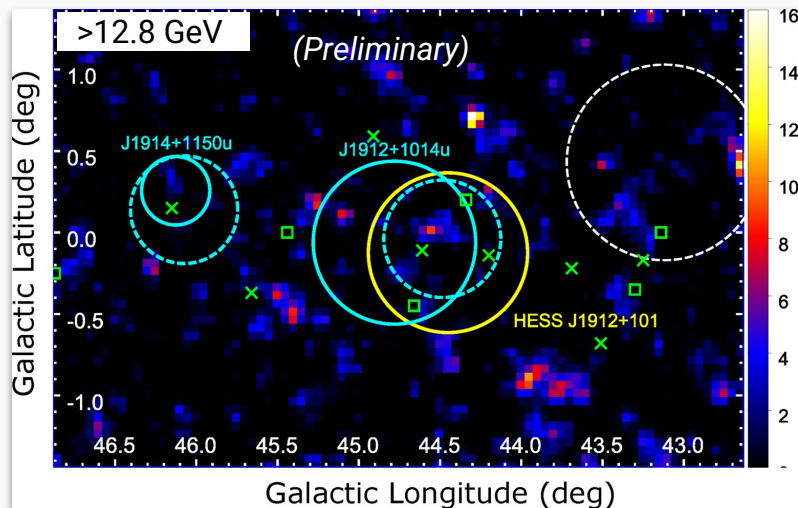
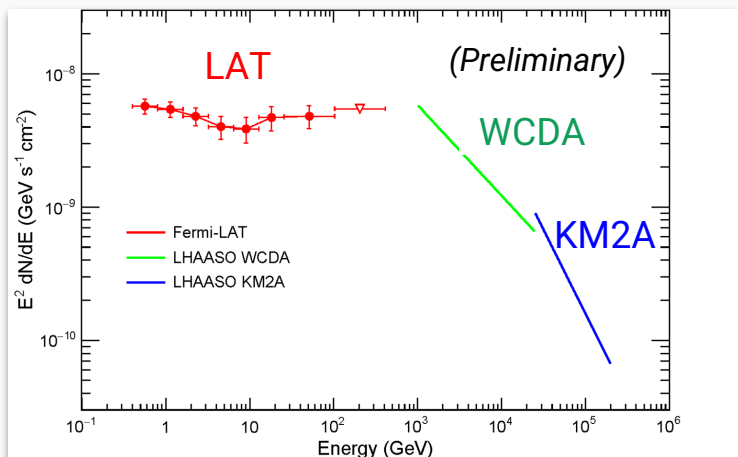
Modeling GeV Counterpart of the Source

We tested five models against LAT data and found that three are equally good: Su+17 HI+CO (N_p) map, Sano+18 N_p map, and LHAASO KM2A Gaussian

We adopted Sano+18 N_p map and will discuss properties of CRs responsible for GeV/TeV emission (incl. H.E.S.S. and HAWC results)

Model	ΔTS	ΔAIC	index
Radial Disk	98.6	88.6	2.08 ± 0.01
H.E.S.S. int. map	78.6	74.6	2.11 ± 0.01
Su et al. (2017) N_p map	99.6	<u>95.6</u>	2.08 ± 0.01
Sano et al. (2018) N_p map	100.8	<u>94.8</u>	2.06 ± 0.01
WCDA Gaussian	90.4	86.4	2.09 ± 0.01
KM2A Gaussian	98.4	<u>94.4</u>	2.08 ± 0.01

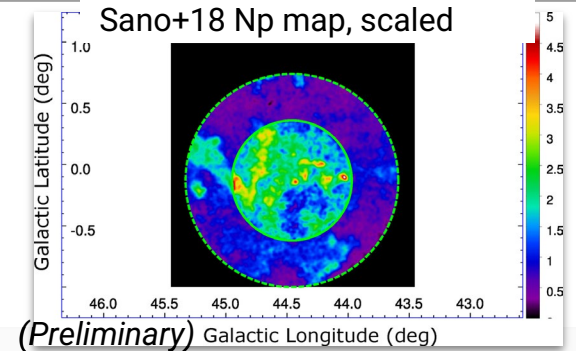
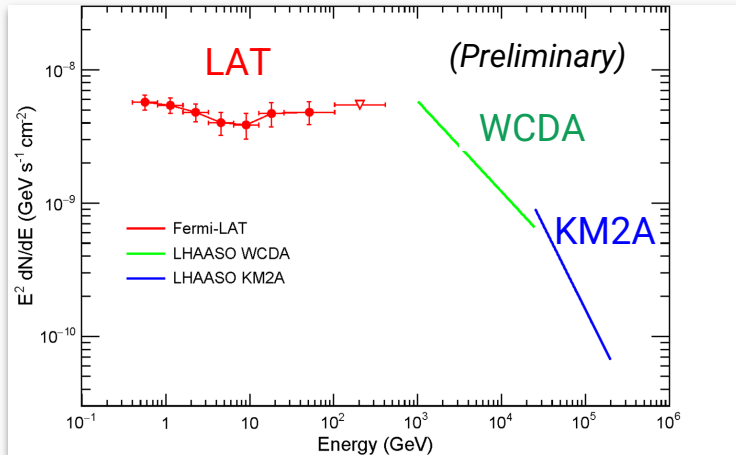
(Preliminary)



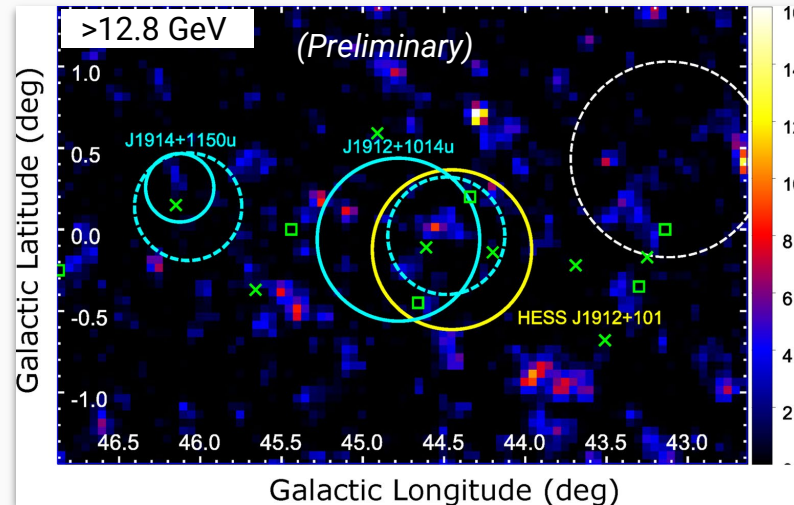
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(Preliminary) Galactic Longitude (deg)

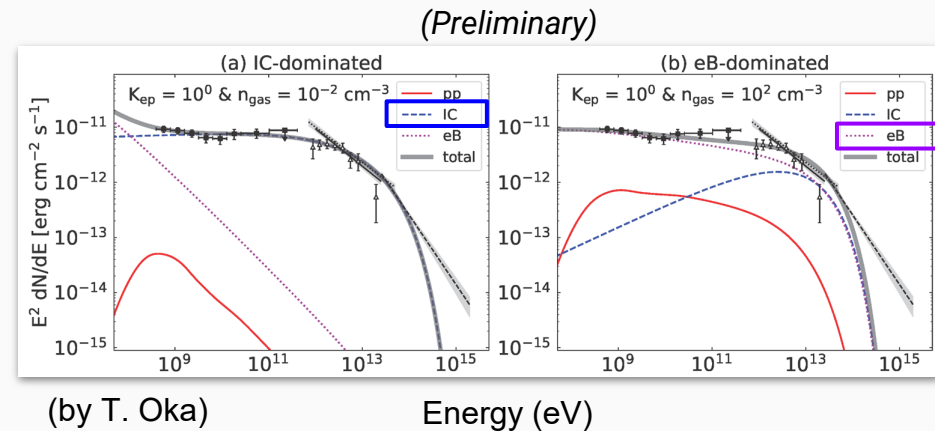


(by Sano, Murase)

We performed a comprehensive fit to GeV and TeV spectrum by scanning wide range of K_{ep} and n_{gas} (let norms, index and E_{cut} vary freely); we consider both $d=1.7$ kpc (Sano+18 N_p map) and 4.6 kpc (Su+17 N_p map)

1. no electron cooling

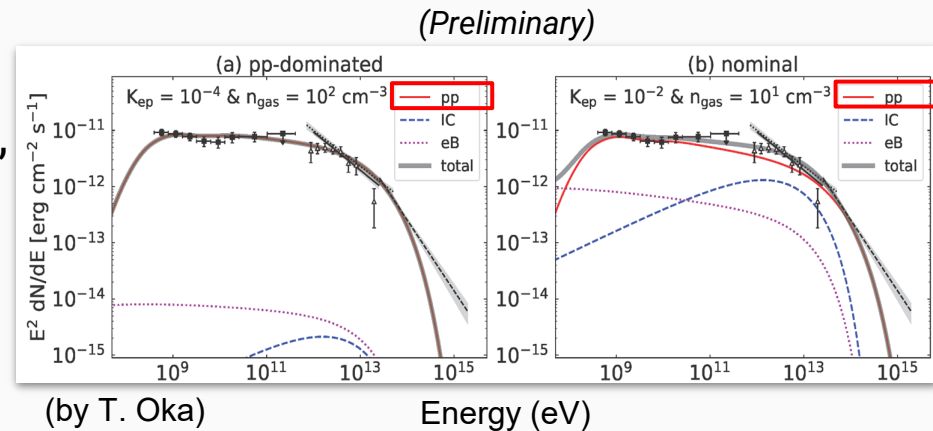
- IC-dominated case (for large K_{ep} and small n_{gas}) can reproduce SED, but is rejected in terms of energetics (even w/ PSR J1913+101)



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2. considering cooling

- Putative SNR's age estimated using size-age relation gives $E_{cut,e} \leq 30$ TeV, making eB-dom. case unlikely
- pp-dom. case (for small K_{ep} & large n_{gas}) and nominal case ($K_{ep}=0.01$ & $n_{gas}=10/cm^3$) are OK with pi0-gamma being dominant from GeV to TeV



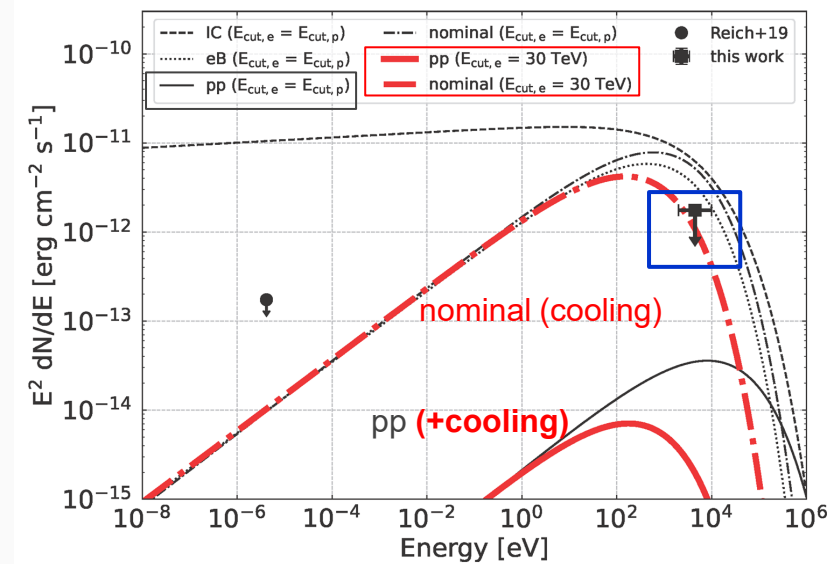
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3. considering X-ray upper limit

- We also **constrained X-ray emission** using Chandra data
- eB-dom. case is rejected, strongly supporting proton PeVatron scenario

case	energetics	cooling	X-ray UL
IC	NG	NG	NG
eB	✓	marginal	NG
pp	✓	✓	✓
nominal	✓	✓	✓

Synchrotron model spectrum (Preliminary)



(by Suzuki, Oka)

We investigated GeV counterpart of LHAASO J1912+1014u (HESS J1912+101) that is a Galactic PeVatron

We developed a dedicated background model and tested several templates against LAT data

- HI+CO templates and KM2A Gaussian are equally good

We performed a comprehensive fit to SED to characterized CRs responsible for GeV/TeV emission

- Fermi-LAT and FUGIN CO data (+ X-ray UL) strongly support proton PeVatron scenario
- $W_p=(1-5)\times 10^{49}$ erg and $\alpha_p=2.1-2.2$ indicated

Thank you for your attention

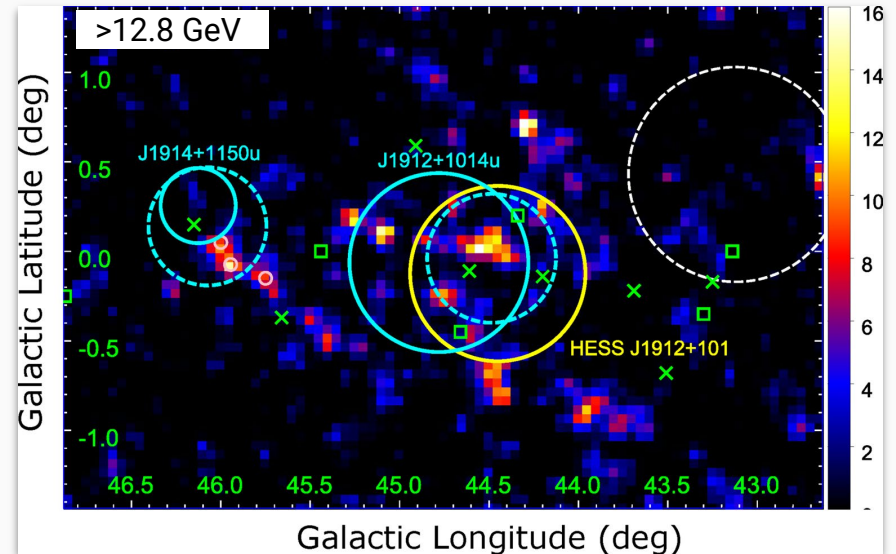
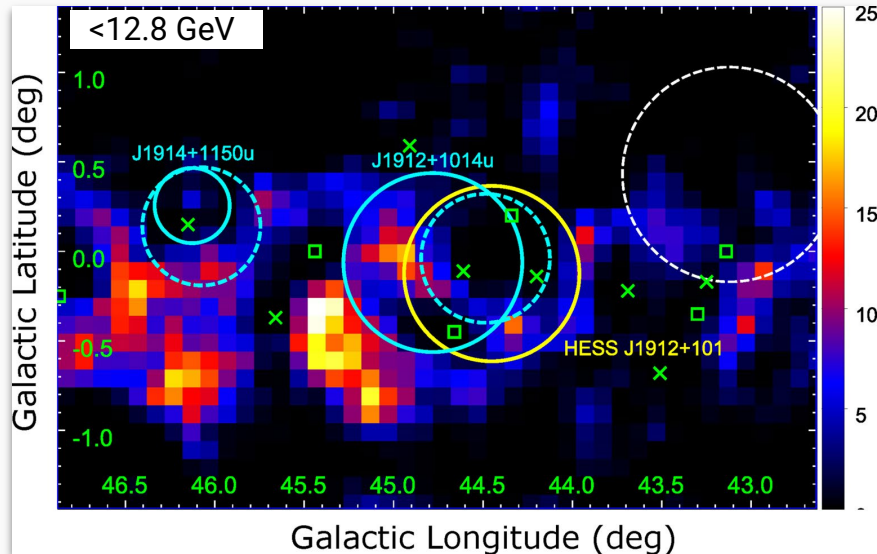
- Abdollahi et al. 2024, ApJS submitted (2FGES; arXiv.2411.07162)
- Aharonian et al. 2008, A&A 484, 435
- Brand&Blitz 1993, A&A 275, 67
- Cao et al. 2024, ApJ 271, 25
- H.E.S.S. Collaboration 2018, A&A 612, 8
- Ranasinghe&Leahy 2023, ApJS 265, 53
- Sano et al. 2018, ASJ meeting (ISM-oriented paper in prep.)
- Smith et al. 2019, ApJ 871, 78 (LAT PSR catalog)
- Su et al. 2017, ApJ 845, 48
- Zeng et al. 2021, ApJ 910 78; Zhang et al. 2020, ApJ 889, 12; Li et al. 2023, ApJ 953, 100 (past studies of LAT data for HESS J1912+101)

Backup Slides (Appendix)

Developing Baseline Model

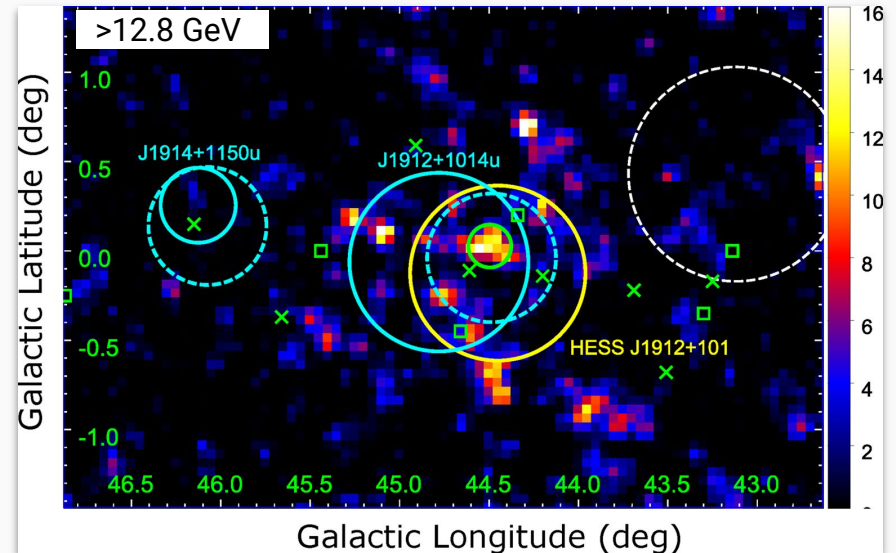
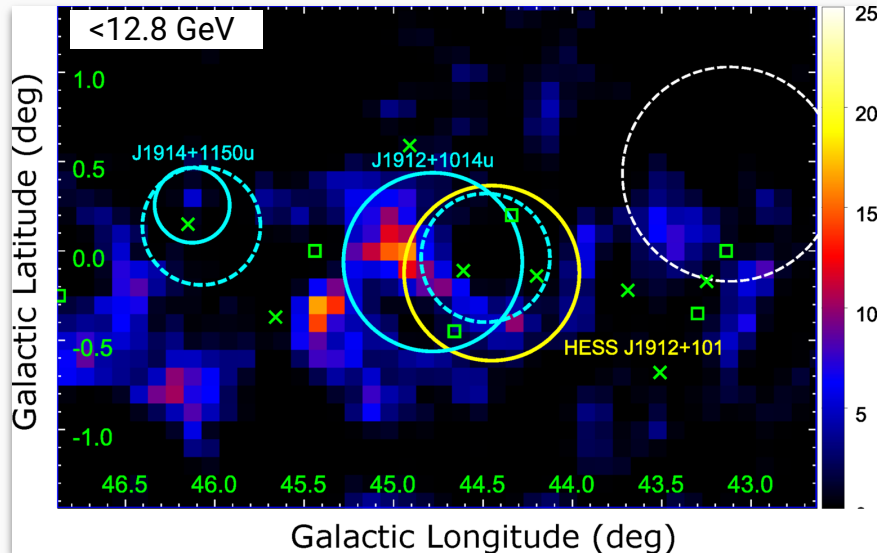
Standard analysis (gll_iem_v07 & 4FGL sources) gives large residuals around the source below and above 10 GeV that affect the past studies

We constructed baseline model by (1) adding DNM template to reduce LE residual and (2) modeling HE residual close to another sub-PeV source phenomenologically

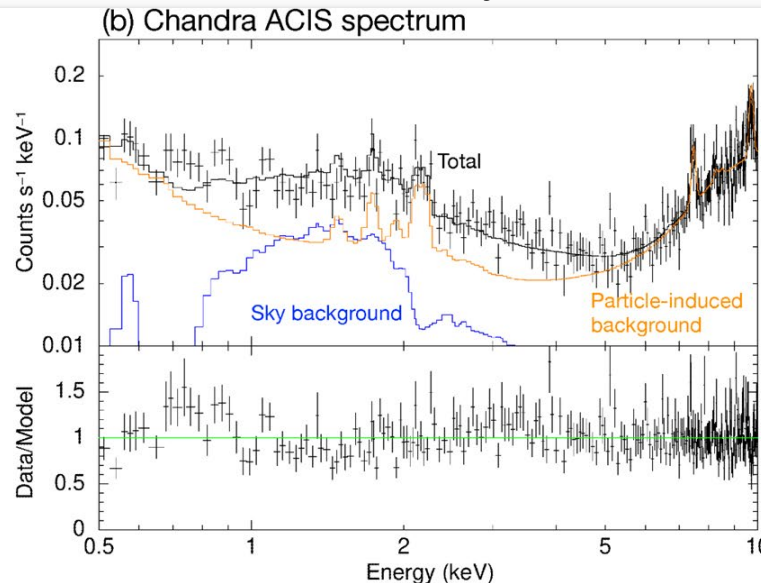
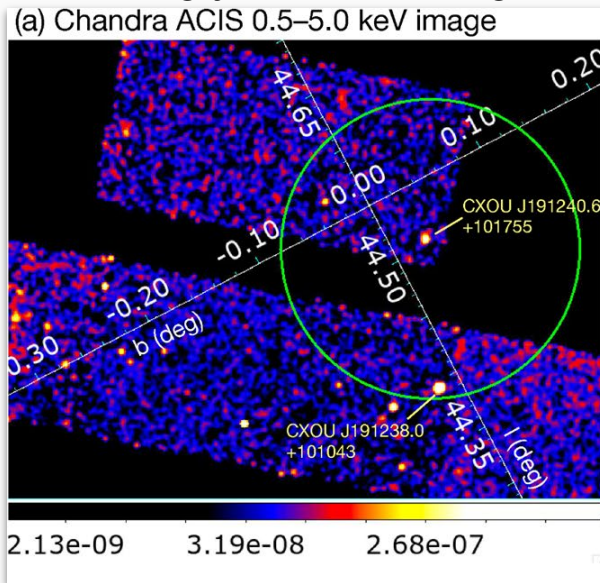


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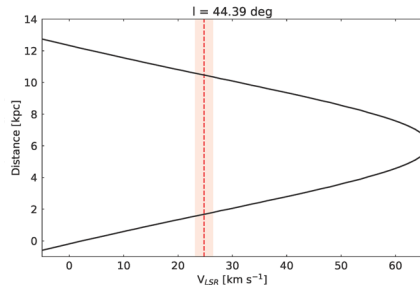
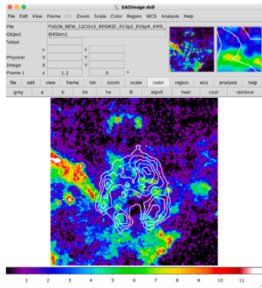
Position of small excess (center of HESS J1912+101) observed by Chandra Diffuse X-ray is well explained by instrumental BG + sky BG + Galactic ridge emission, strongly constraining additional non-thermal X-ray



44.2.0 GeV
 J1912.3+1010
 J1912.3+1011

We refer to rotation curve by Brand&Blitz 1993 and adopt the distances of near side

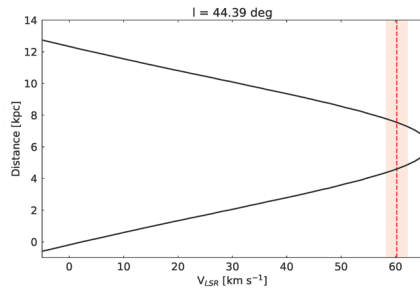
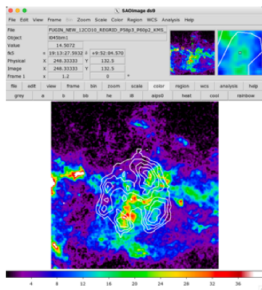
✓ Sano+18 CO model: $V_{\text{LSR}} = +23.2 - 26.4$ [km/s]



$D=1.7 \pm 0.1$ kpc

$D=10.5 \pm 0.1$ kpc

✓ Su+17 CO model: $V_{\text{LSR}} = +58.3 - 62.2$ [km/s]



$D=4.6 \pm 0.2$ kpc

$D=7.5 \pm 0.2$ kpc

(by T. Oka)

✓ PSR J1913+1011: $D = 4.6$ kpc

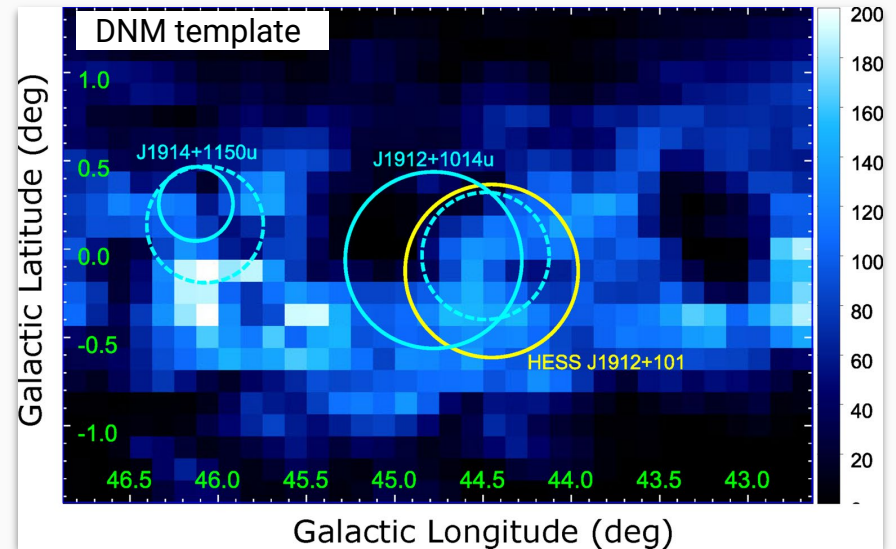
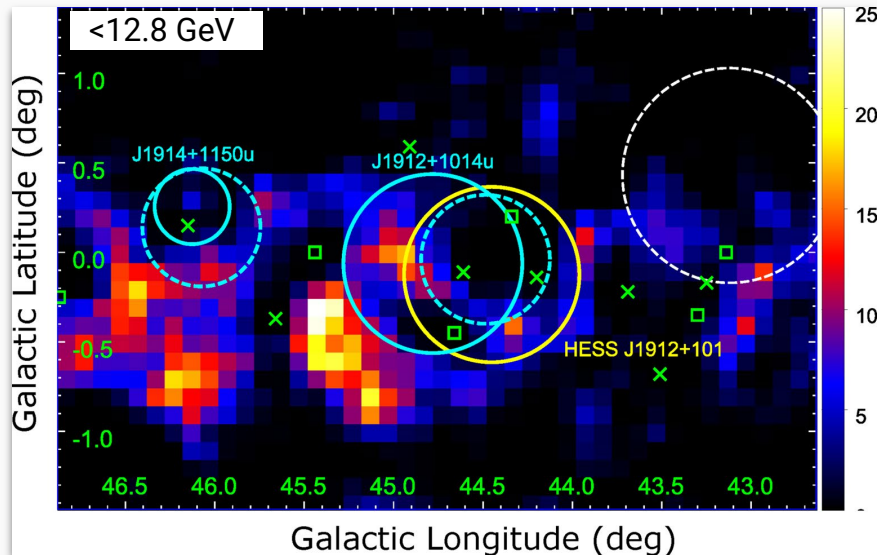
If the LHAASO (and LAT) source is SNR, $D=1$ deg corresponds to

- ~ 30 ps ($t \sim 13$ kyr) for Sano+18
- ~ 80 pc ($t \sim 120$ kyr) for Su+17 ($D=9.5t^{0.44}$ pc; Ranasinghe&Leahy 23)

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Su+17 proposed CO cloud with $v \sim 60$ km/s is associated with HESS J1912+101

Sano+18 proposed alternative scenario (CO cloud with $v \sim 25$ km/s) based on the following:

- expanding gas motion is observed
- good spatial correlation with H.E.S.S. source is observed
- (ISM-oriented paper in prep.)

