

LHAASO UHE gamma ray overview

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On behalf of LHAASO Collaboration

2023.10.22

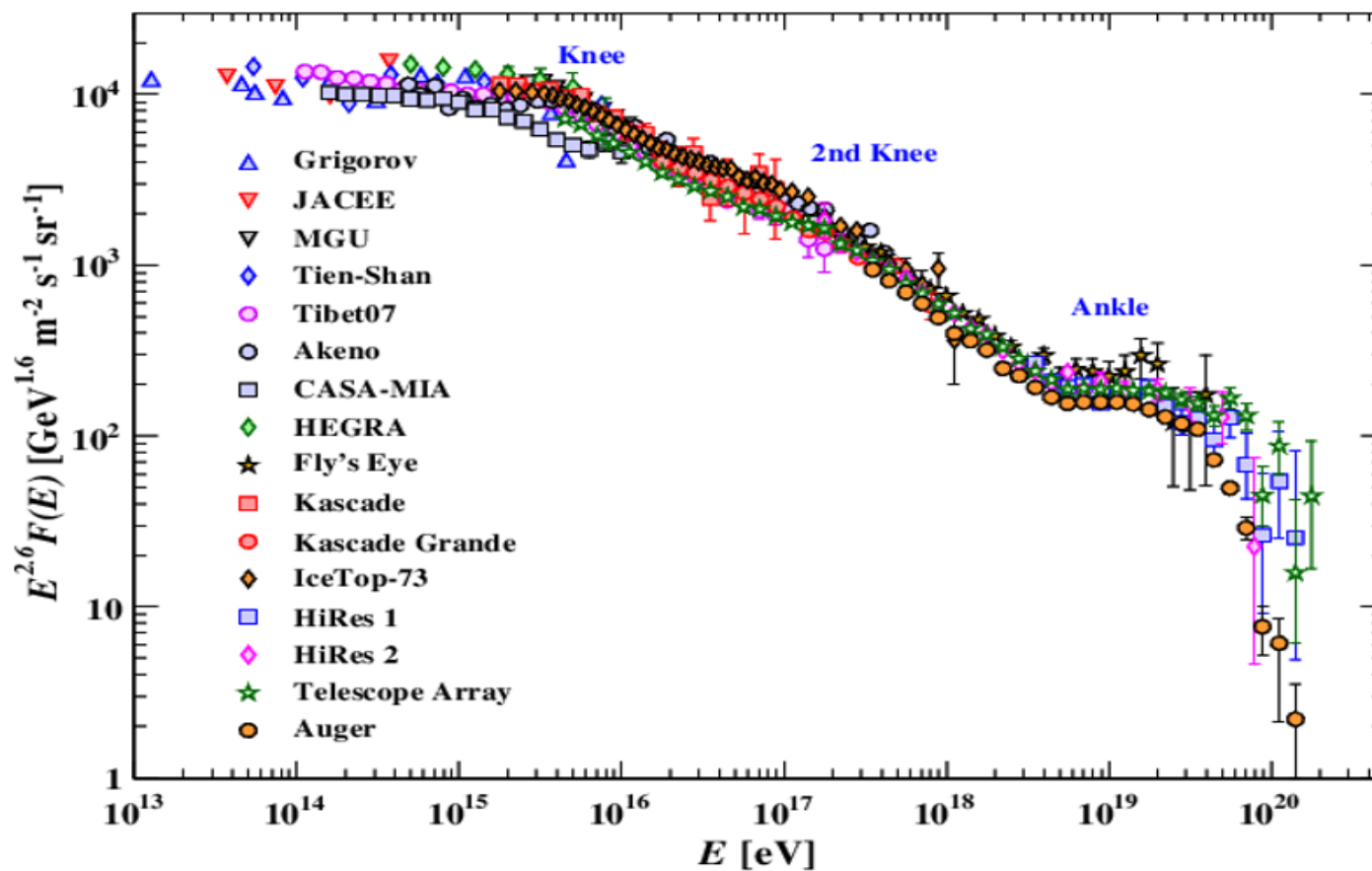
Institute of High Energy Physics(IHEP),CAS

Outline



- Cosmic rays and PeVatrons
- LHAASO detector
- Results from PeVatron candidates
- Conclusion

Where do the highest energy particles come from ?

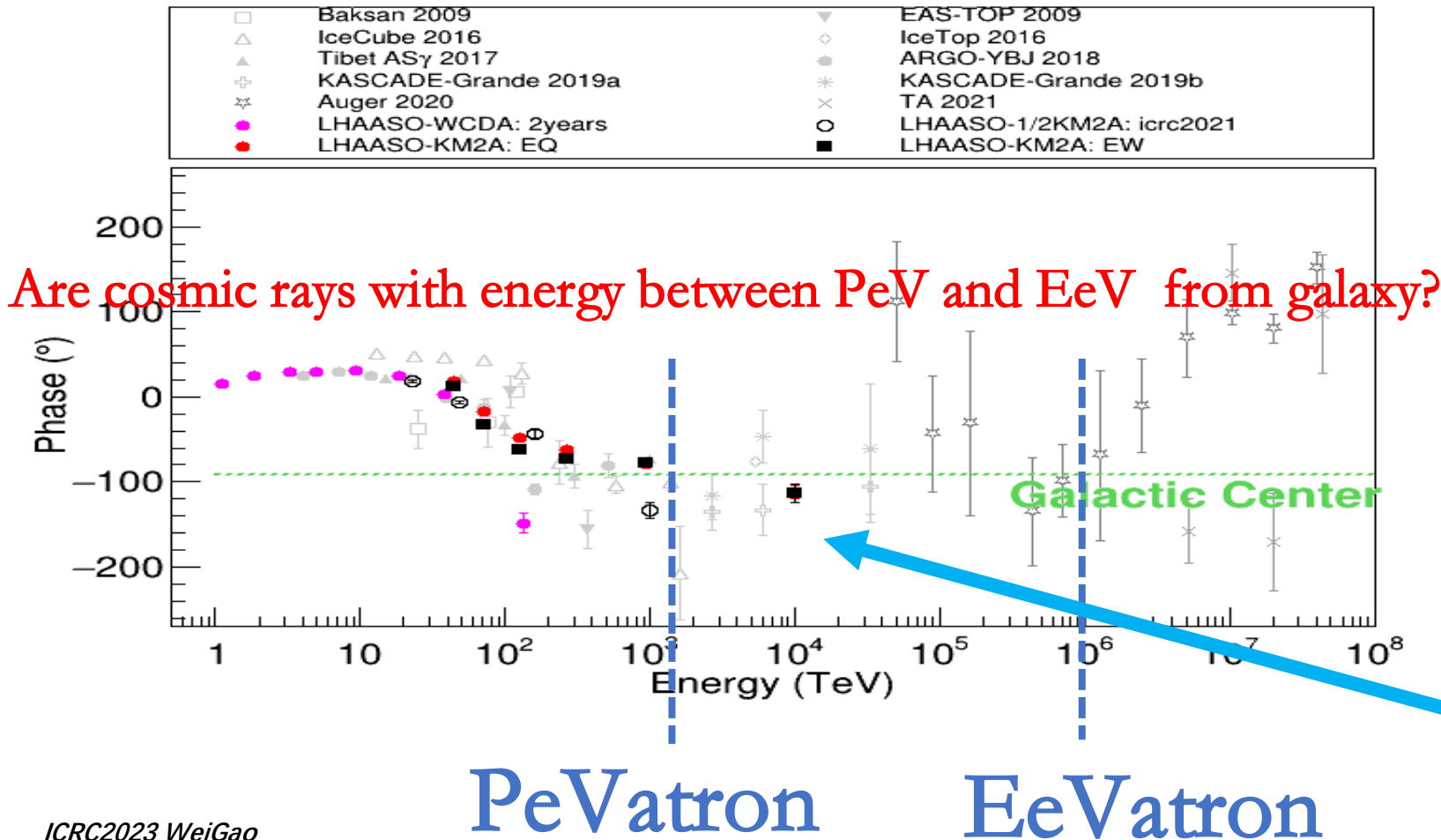


Galactic sources

???

Extragalactic sources

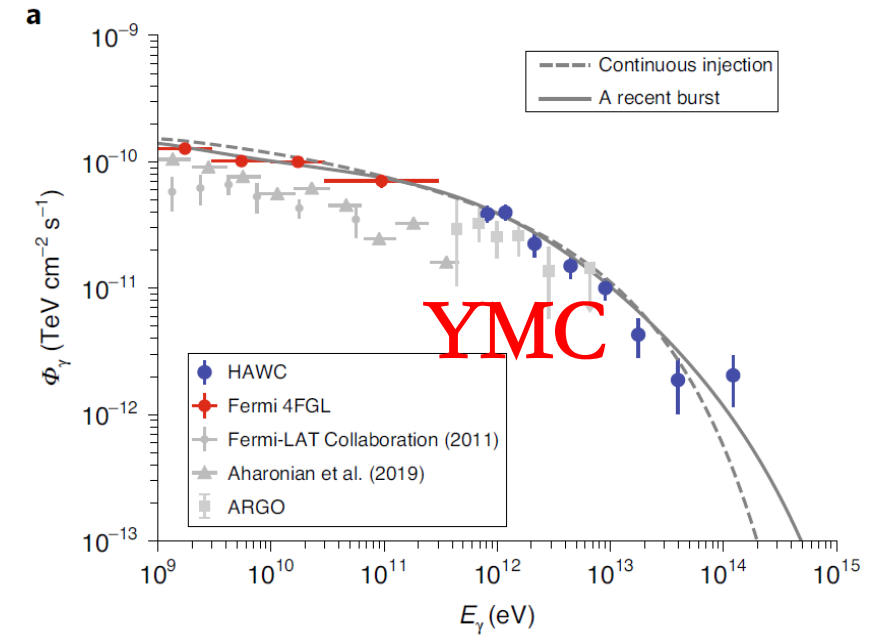
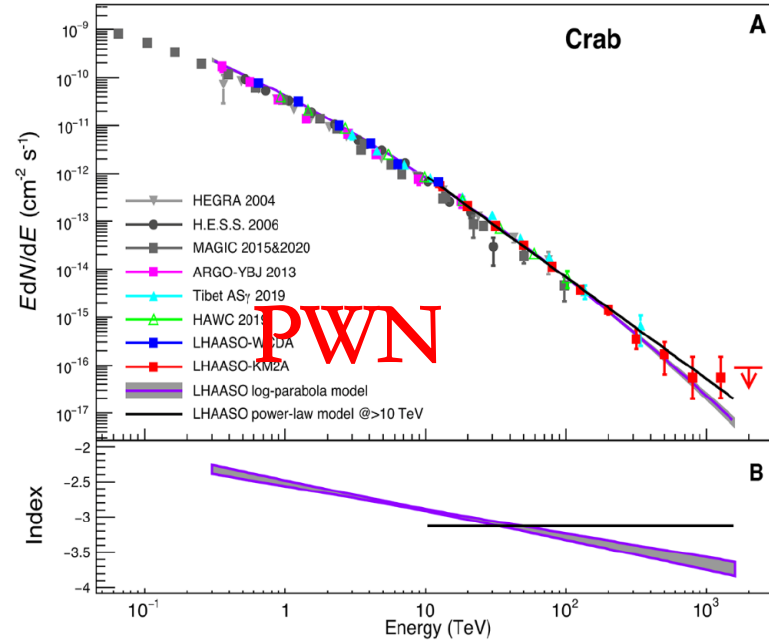
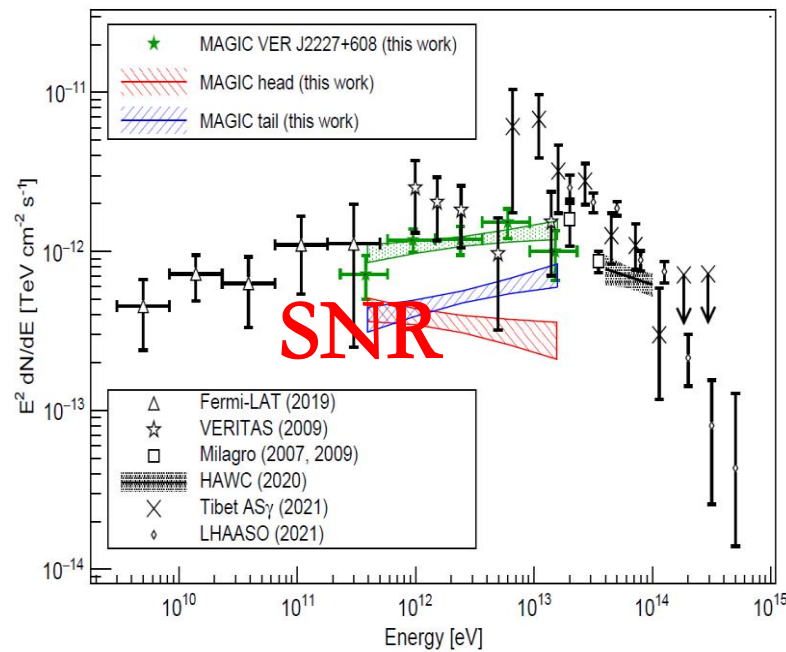
Where do the highest energy particles come from ?



◆ There should be sources in our galaxy can accelerate particles to PeV or even up to EeV from the measurement of CRs at earth.

Dark region to be explored!

Possible candidates

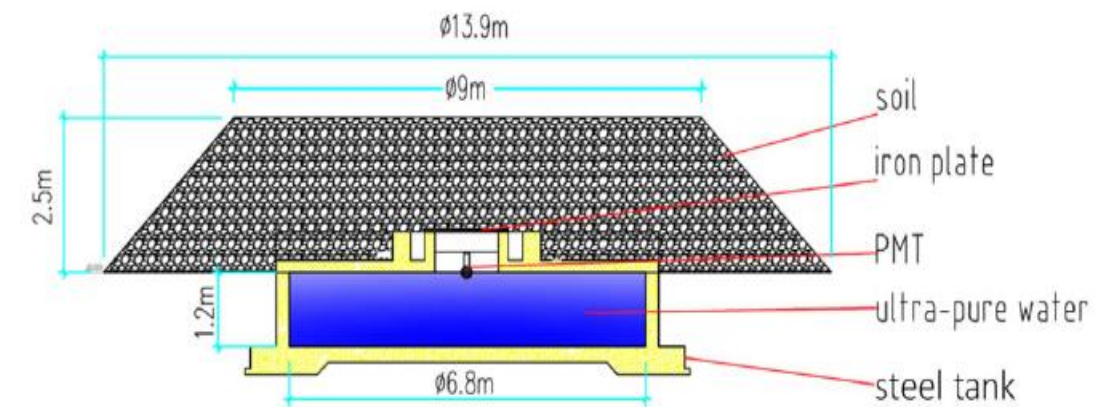


Even though no source is definitely identified as a hadronic PeVatron, it seems several kinds of sources have the potential to accelerate particles to PeV.

Location: $29^{\circ}21'27.6''N$ $100^{\circ}08'19.6''E$

Altitude: $4410m\ a.s.l$





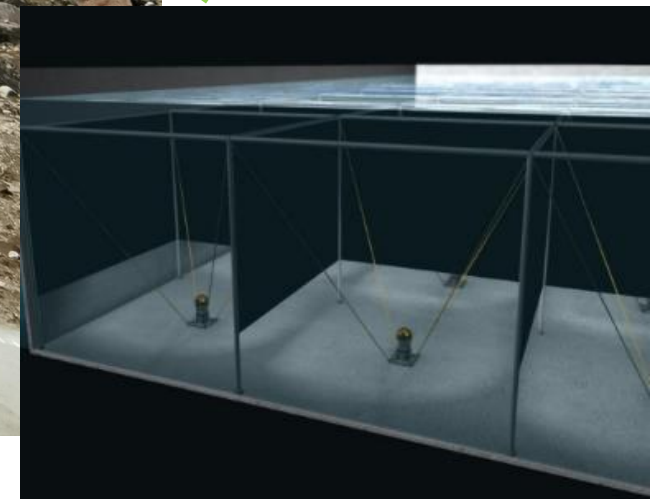
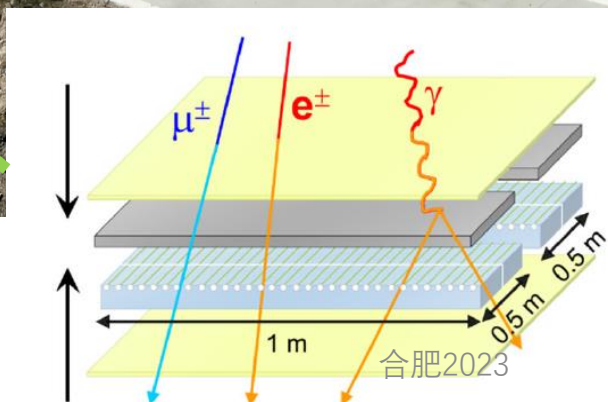
MD
1188x36m²



WFCTA

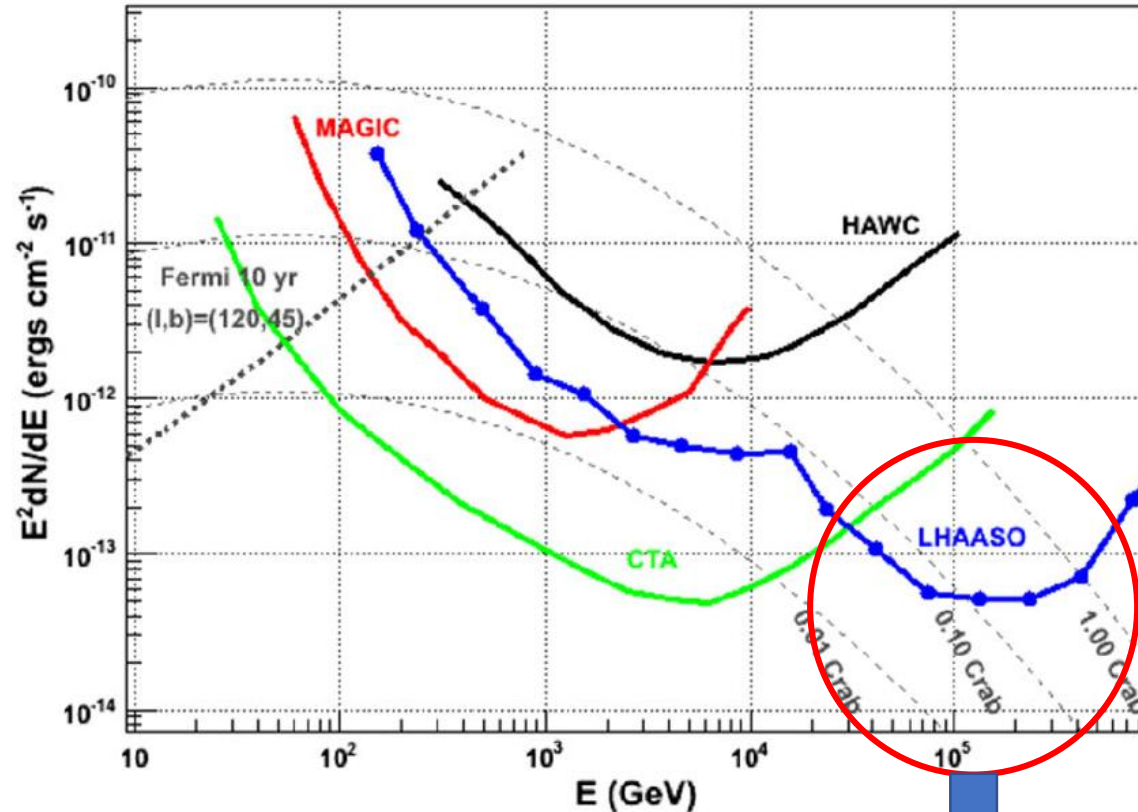


ED
5216x1m²



WCDA
3120x25m²

LHAASO sensitivity



- High sensitivity: $\sim 1\%$ Crab@3TeV@100TeV;
- Wide energy range: sub-TeV to 10 PeV;
- Large FOV: ~ 1.8 sr

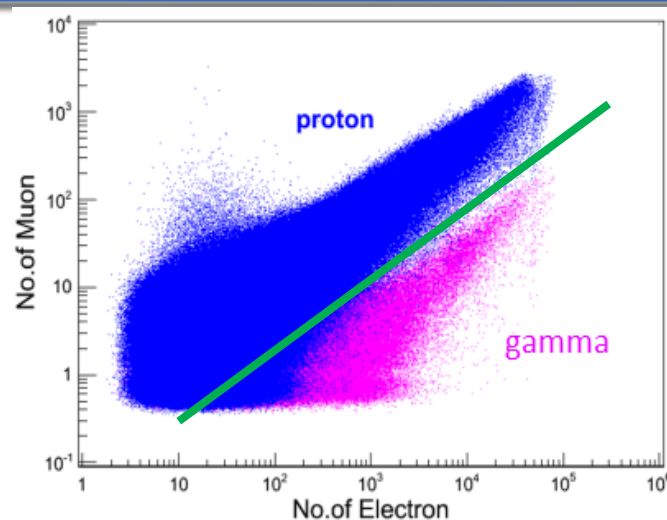
The most sensitive gamma ray detector to explore this highest energy range

Performance

- Rejection power:

99.8% @ 6 TeV

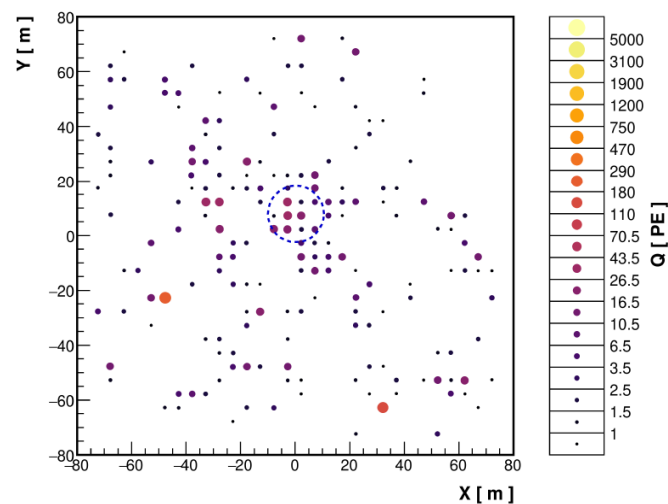
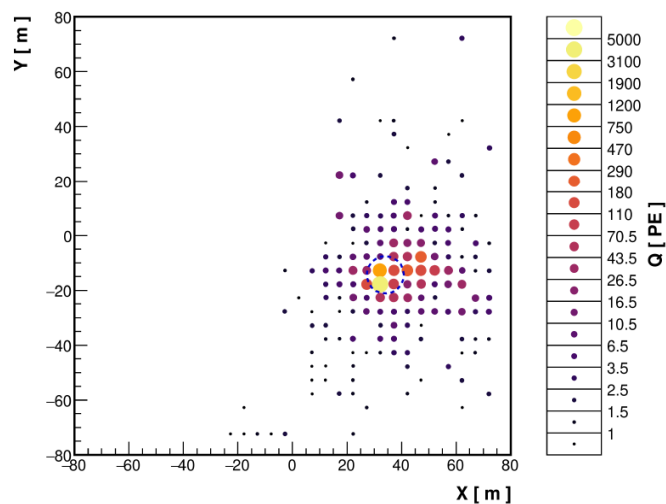
1.e-4 @ 100 TeV



- Angular resolution

0.21° @ 6 TeV

0.25° @ 100 TeV



- Energy resolution:

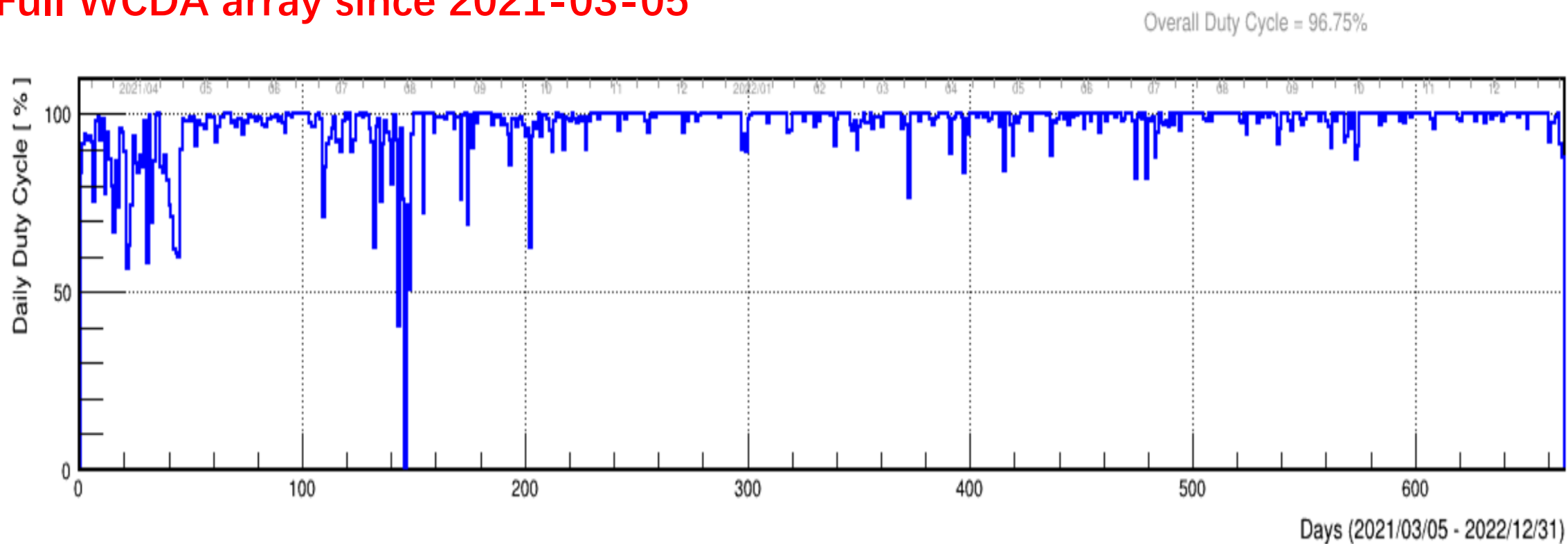
15% @ 100 TeV

Status of WCDA

- The duty cycle is $>95\%$ currently.
- 3×10^9 events/day.



Full WCDA array since 2021-03-05

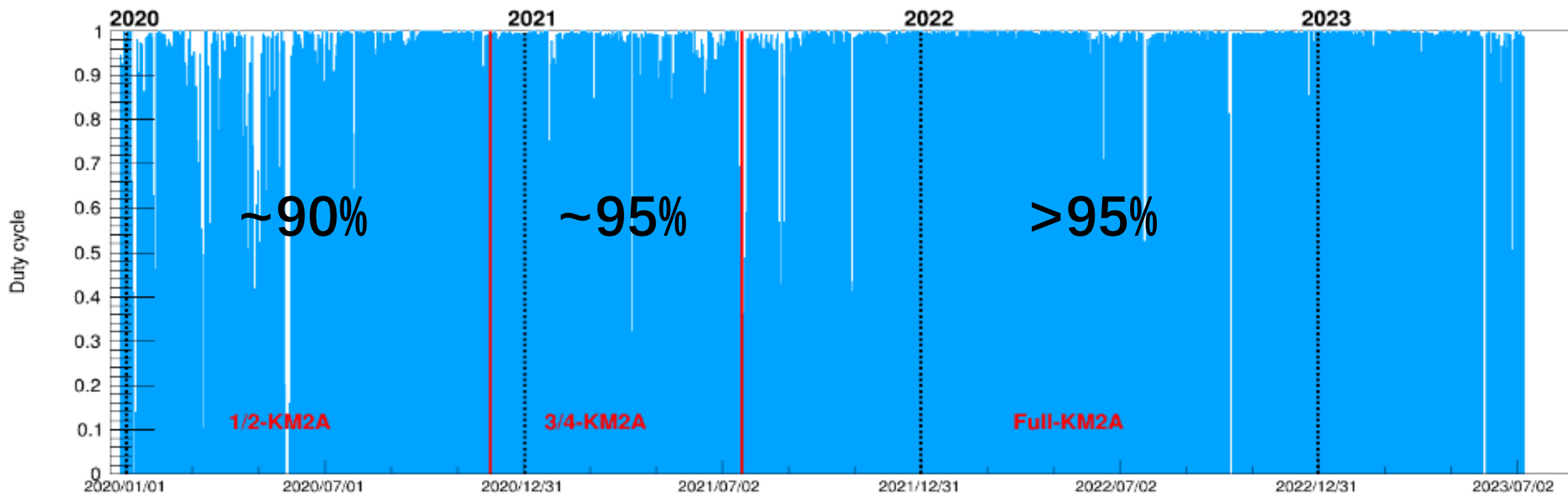


Status of KM2A

- The duty cycle is $>95\%$ for full array.
- 2×10^8 events/day.

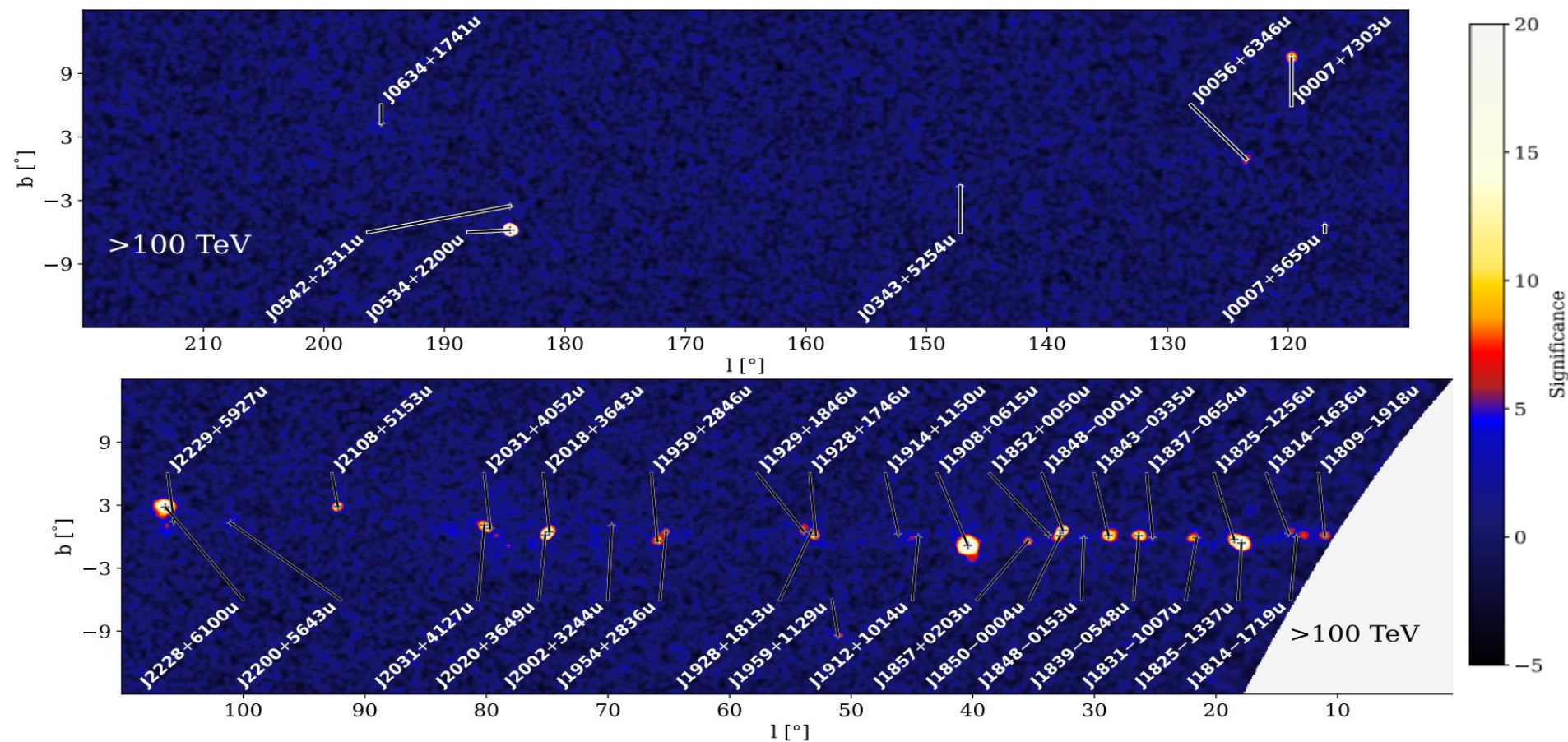


Full KM2A array since 2021-07-19



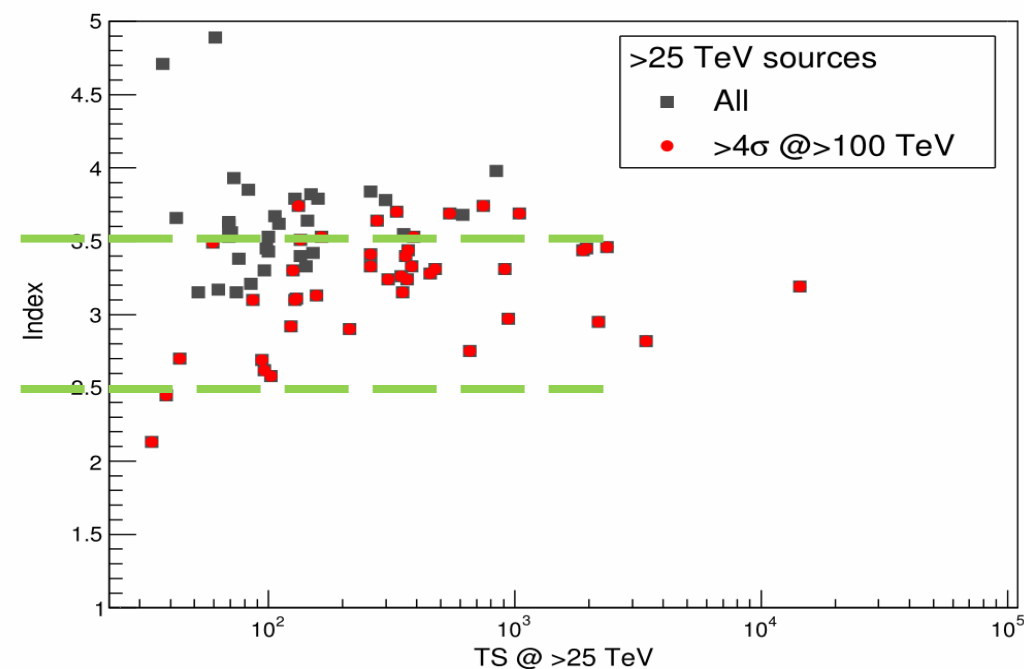
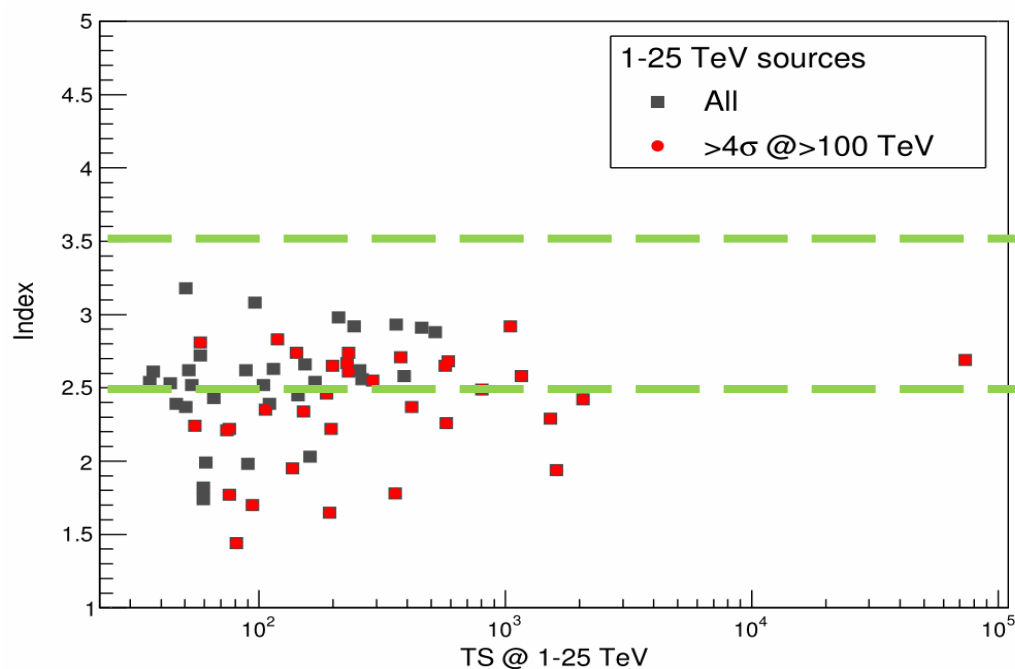
LHAASO UHE sky-map

43 sources were detected with significance $>4\sigma$ above 100TeV



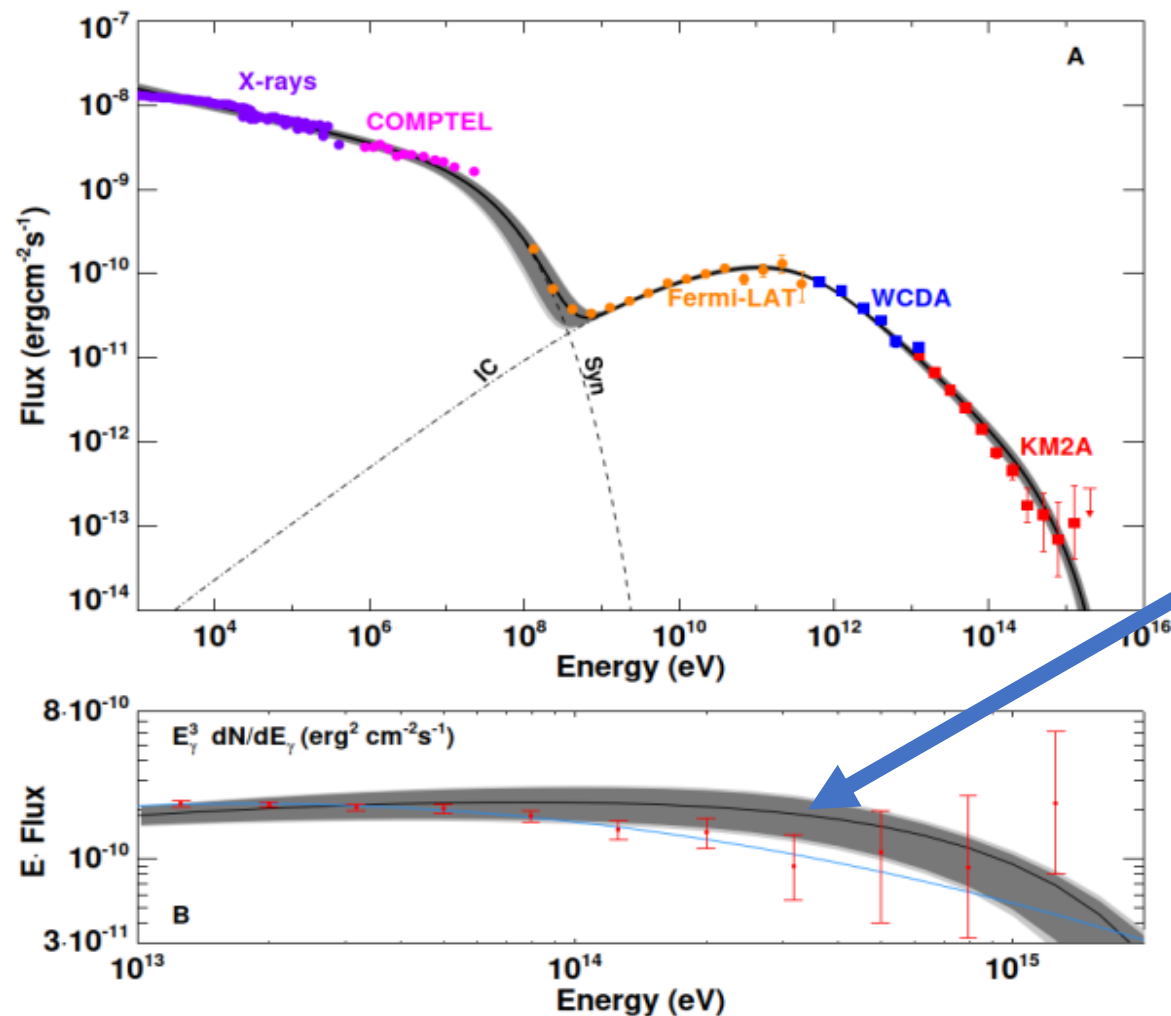
LHAASO UHE sky-map

- **51%** (35/69) 1-25TeV and **57%** (43/75) >25TeV sources are UHE sources.



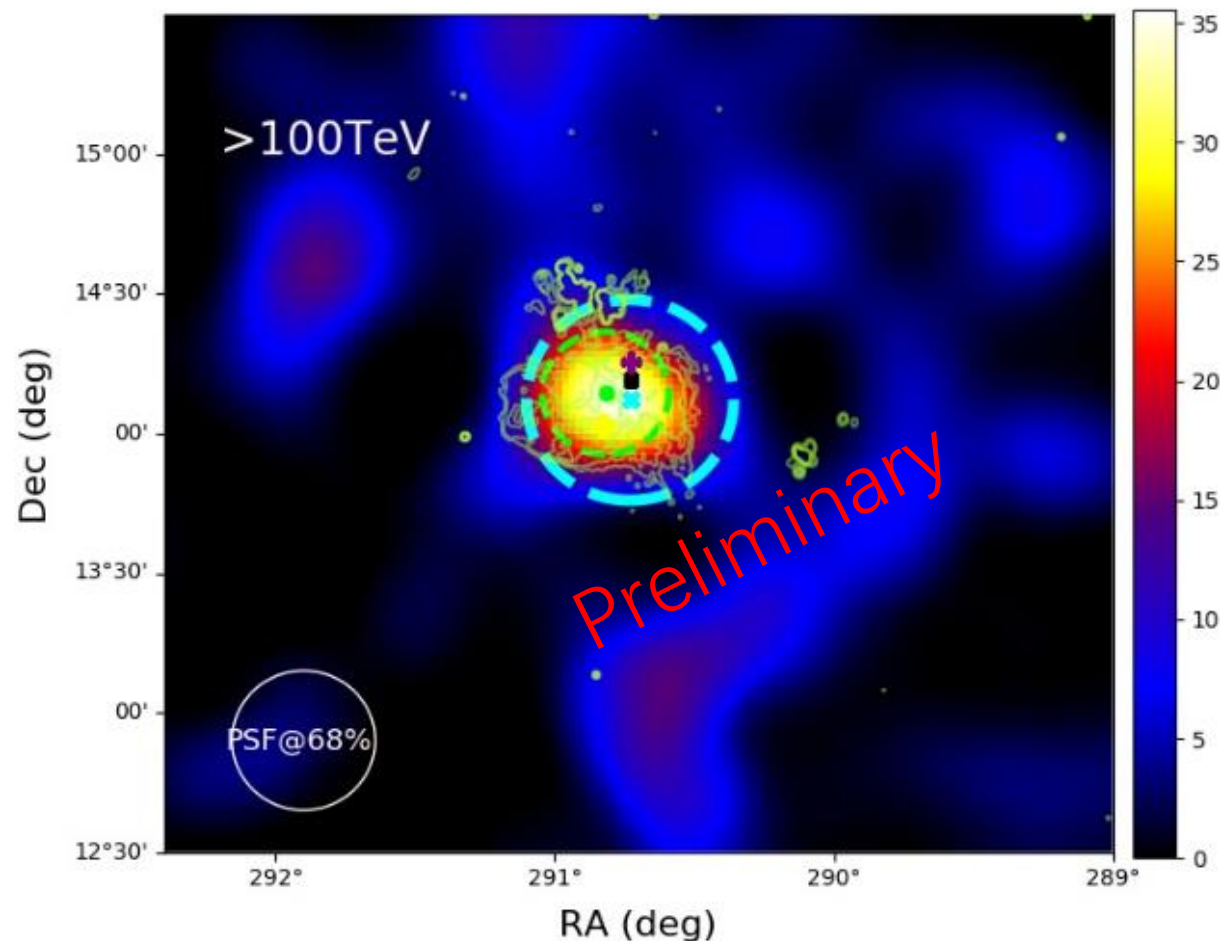
PWN-Crab nebula

Cao et al., Science 373, 425 – 430 (2021)



- The first identified electron-PeVatron.
- Possible deviation from one-zone model(4σ);
- Indication of a second component?

SNR-W51C



□ W51C: shell-type SNR , 30 kyr

□ LHAASO Results:

Position :

$290.73^\circ \pm 0.02^\circ, 14.08^\circ \pm 0.02^\circ$ (*wcda*)

$290.73^\circ \pm 0.02^\circ, 14.11^\circ \pm 0.02^\circ$ (*km2a*)

Extension :

$0.15^\circ \pm 0.027^\circ$ (*wcda*)

$r_{extension,UL} \simeq 0.12^\circ$ (95%C.L.) (*km2a*)

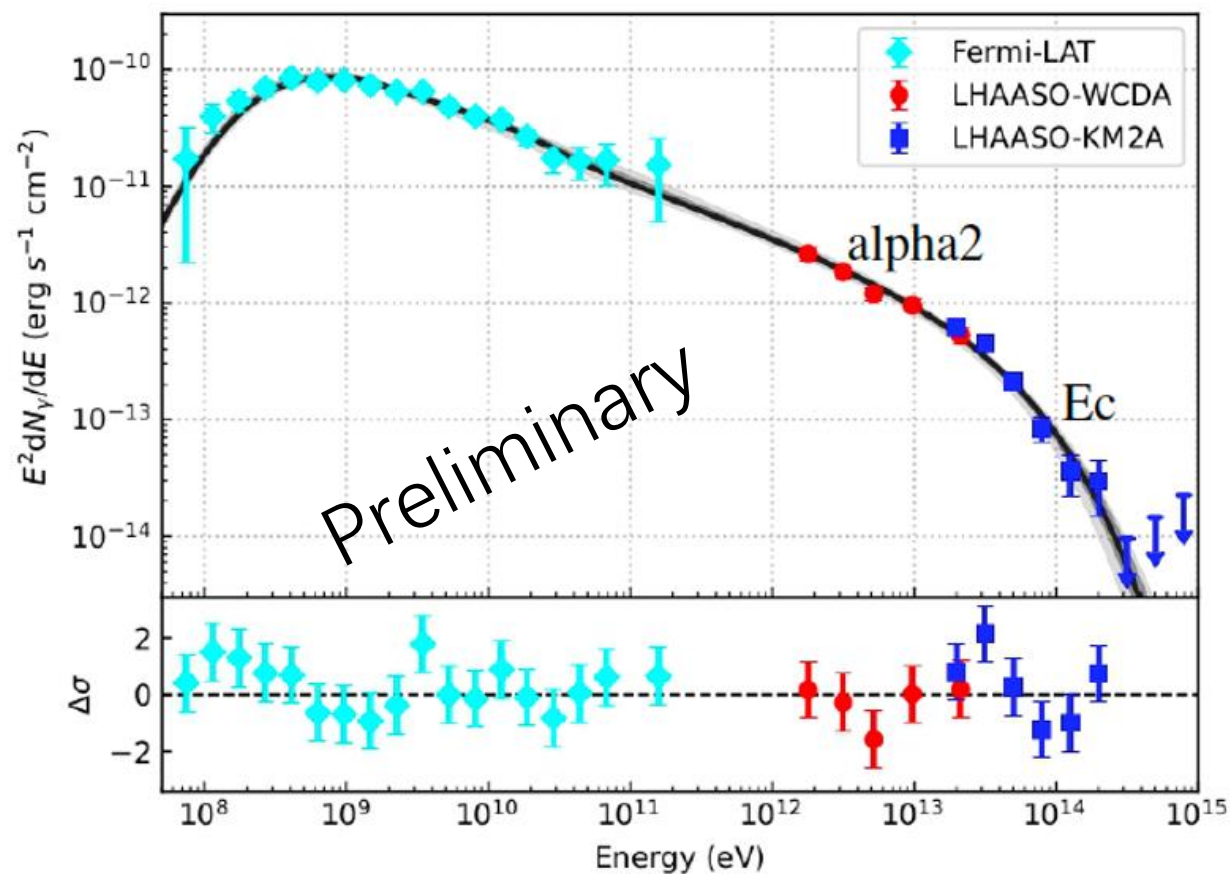
W51C

□ Hadronic scenario:

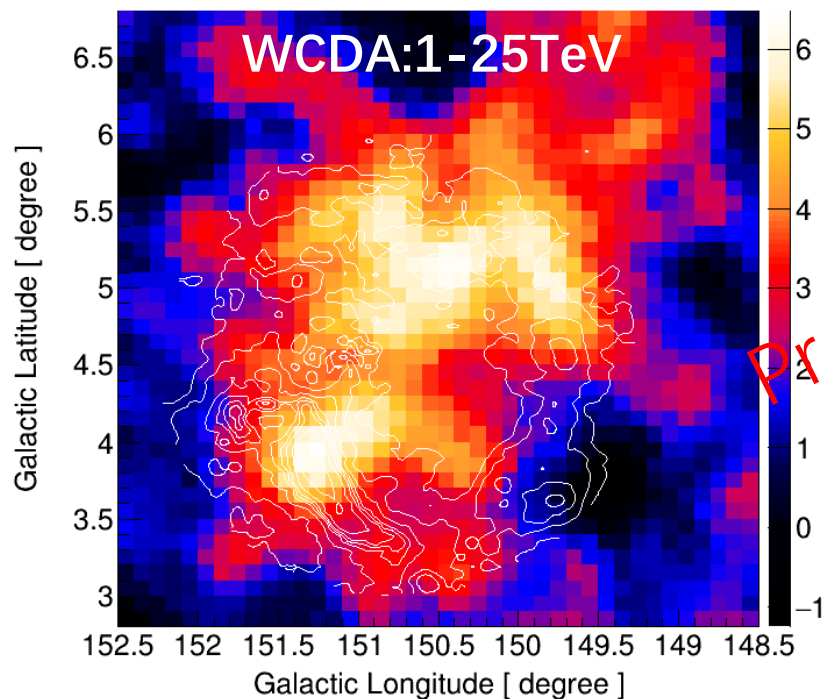
$$\frac{dN_p}{dE} \propto \exp\left(-\frac{E}{E_{\text{cut}}}\right) \cdot \begin{cases} E^{-\alpha_1}, & E < E_{\text{br}} \\ E_{\text{br}}^{\alpha_2 - \alpha_1} E^{-\alpha_2}, & E > E_{\text{br}} \end{cases}$$

$E_{\text{c}} \approx 400 \text{ TeV}$, significantly larger than
 100 TeV (5σ).

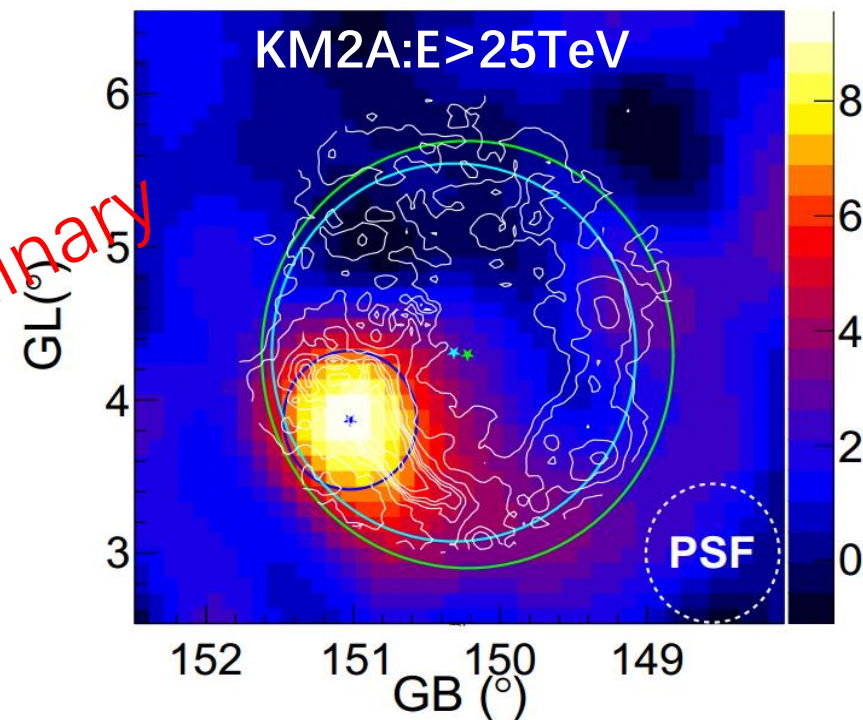
a fresh record for SNRs in terms of CR
acceleration.



SNR G150.3+4.5



preliminary



- WCD A Morphology: $1.18^\circ \pm 0.12^\circ$

spatially coincident with the radio observation

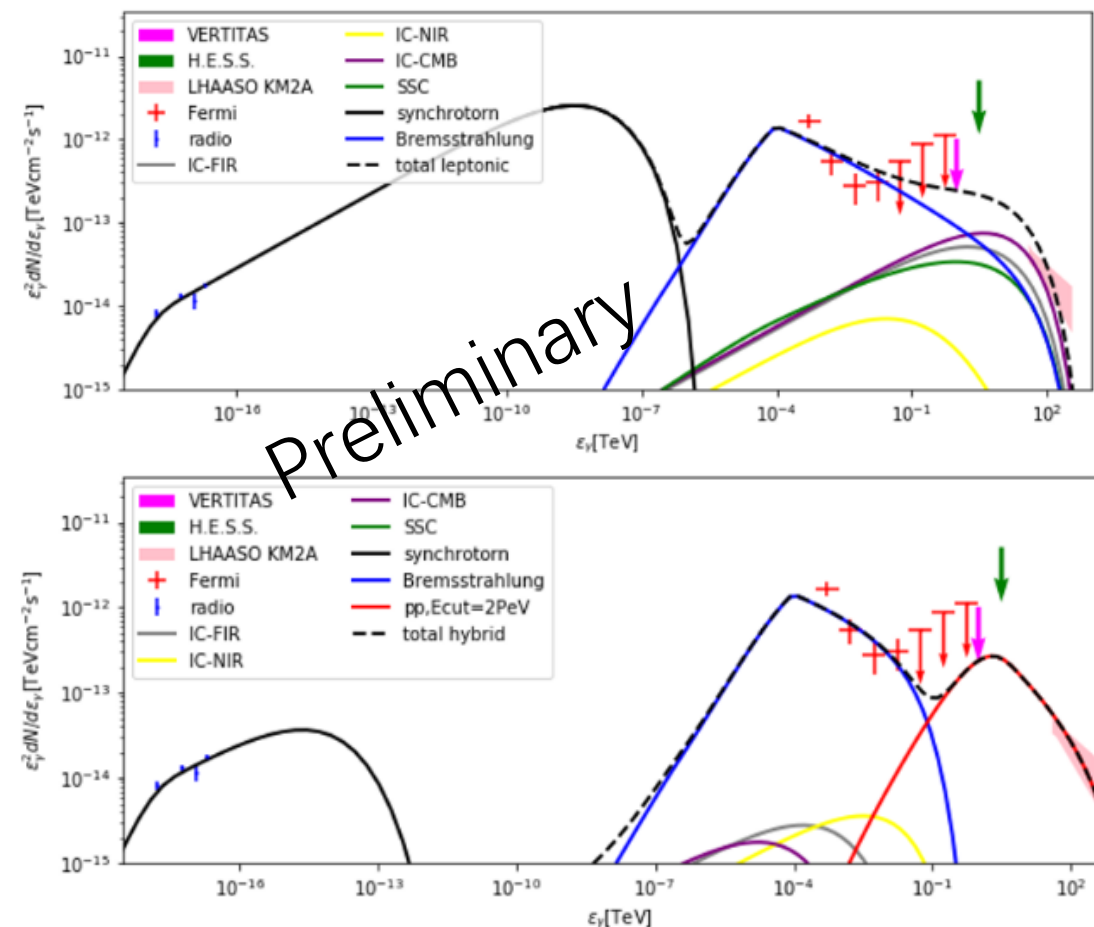
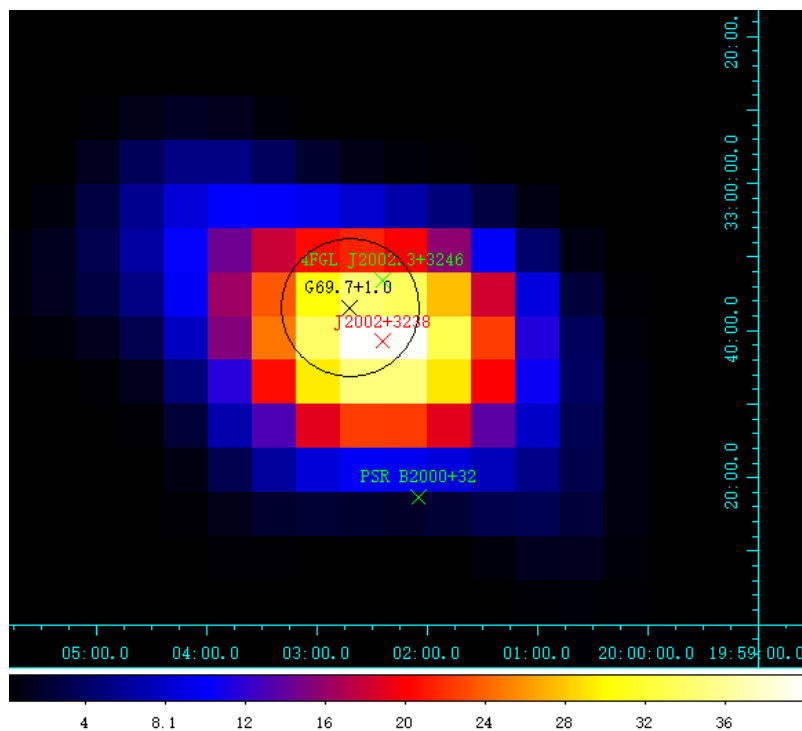
- KM2A Morphology: $0.32^\circ \pm 0.02^\circ$

closed the PSR-like 4FGL J0426.5+5434

SNR G69.7+1.0

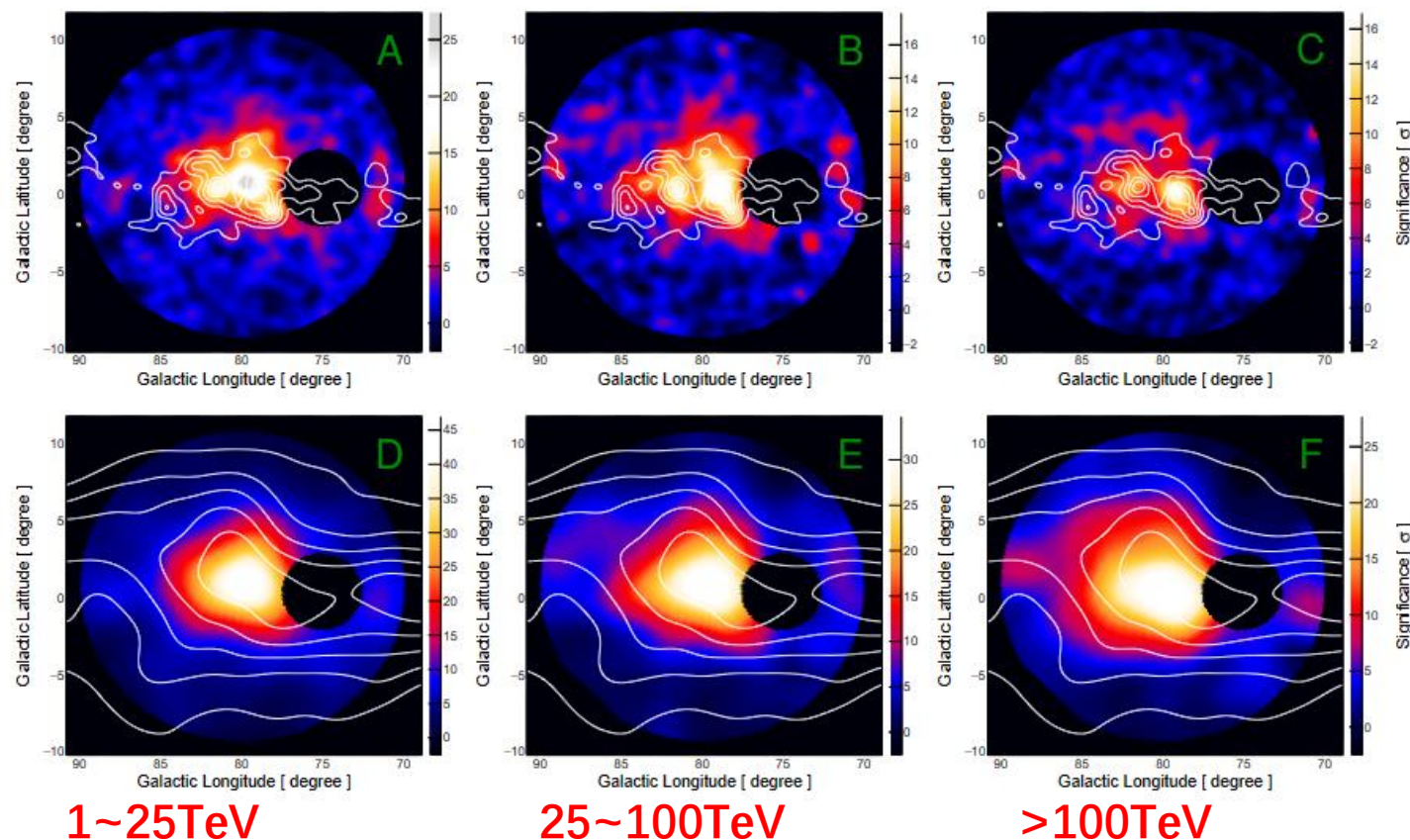
ICRC2023, Inquiry No. 465, Bowen Hou

- SNR G69.7+1.0: 40kyr, 7.8kpc
- The positions are consistent:
SNR radio, Fermi and LHAASO
- The energy spectrum:
very hard(2.7) and no obvious cutoff before 400 TeV.



YMC-Cygnus region

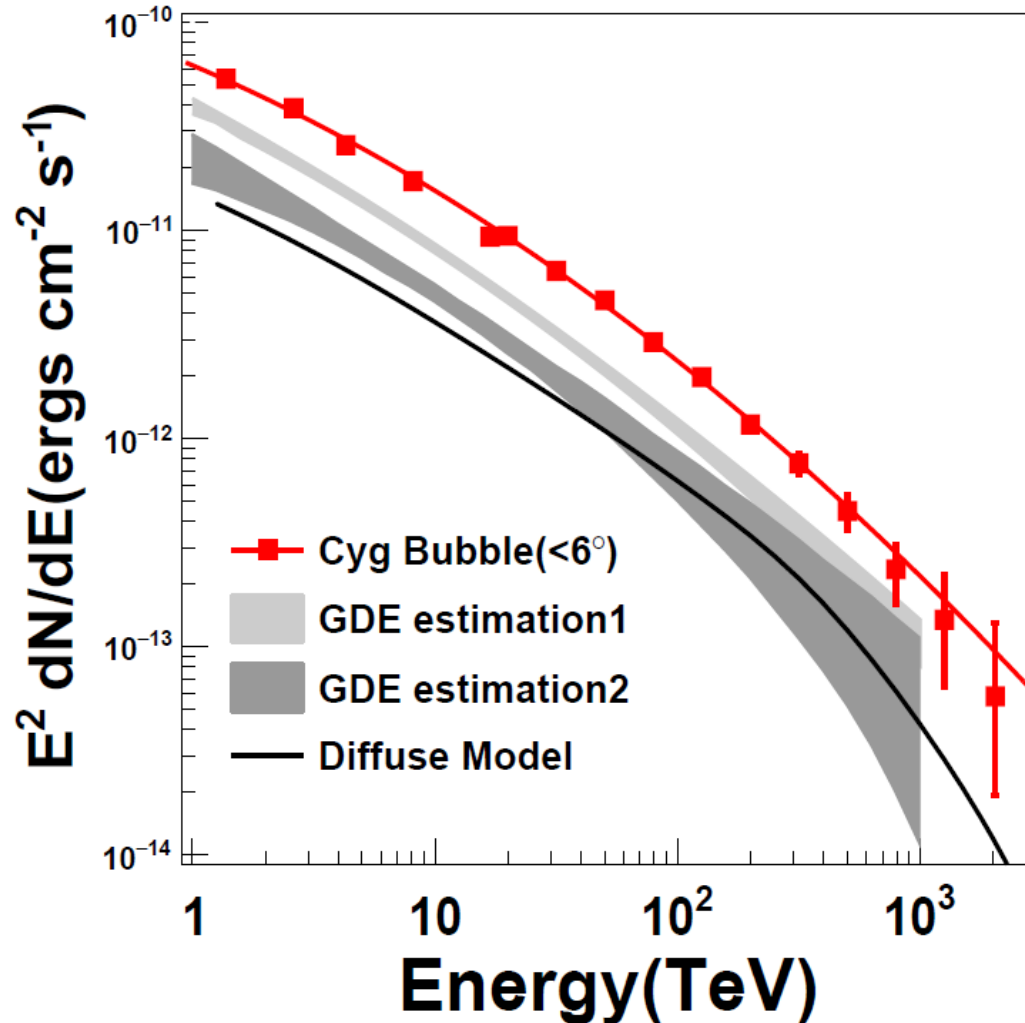
arXiv:2310.10100



- ◆ A ultra-high energy gamma ray bubble with extension up to 10deg.
- ◆ Clear correlation with gas distribution, which indicates a hadronic origin.

- The significance map is smoothed with a Gauss kernel= 0.3^0 (upper) and 1.0^0 (lower);
- The contour is from CfA galactic CO survey (upper) and HI4PI 21-cm line survey(lower) ;

Energy spectrum



Energy Bin	Non	Nb
400TeV-630TeV	42	6.8
630TeV-1PeV	14	1.9
1PeV-1.6PeV	6	0.6
1.6PeV-2.5PeV	2	0.2

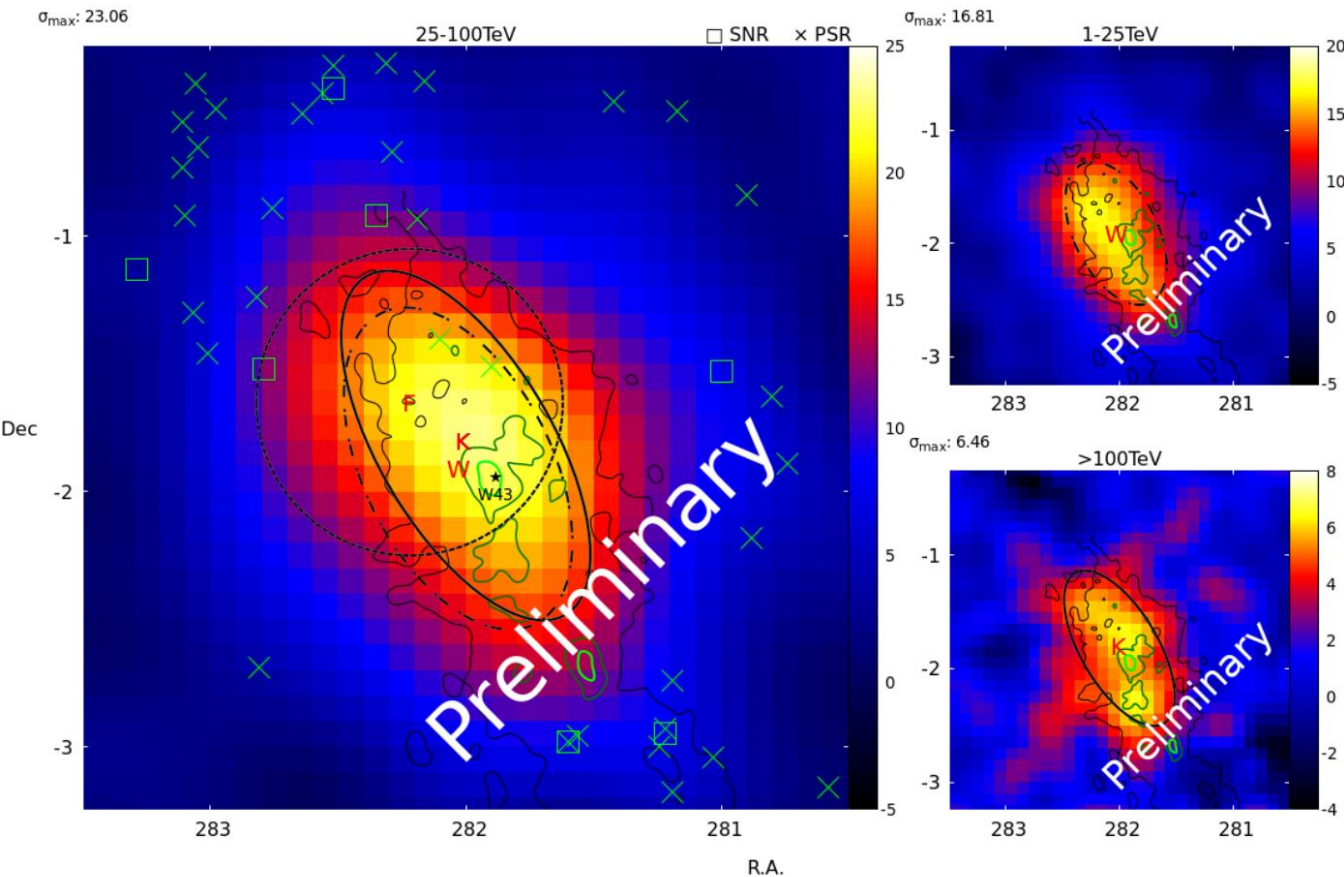


Almost background free

- ◆ The spectrum extends beyond PeV without a cut-off at least up to 2PeV.

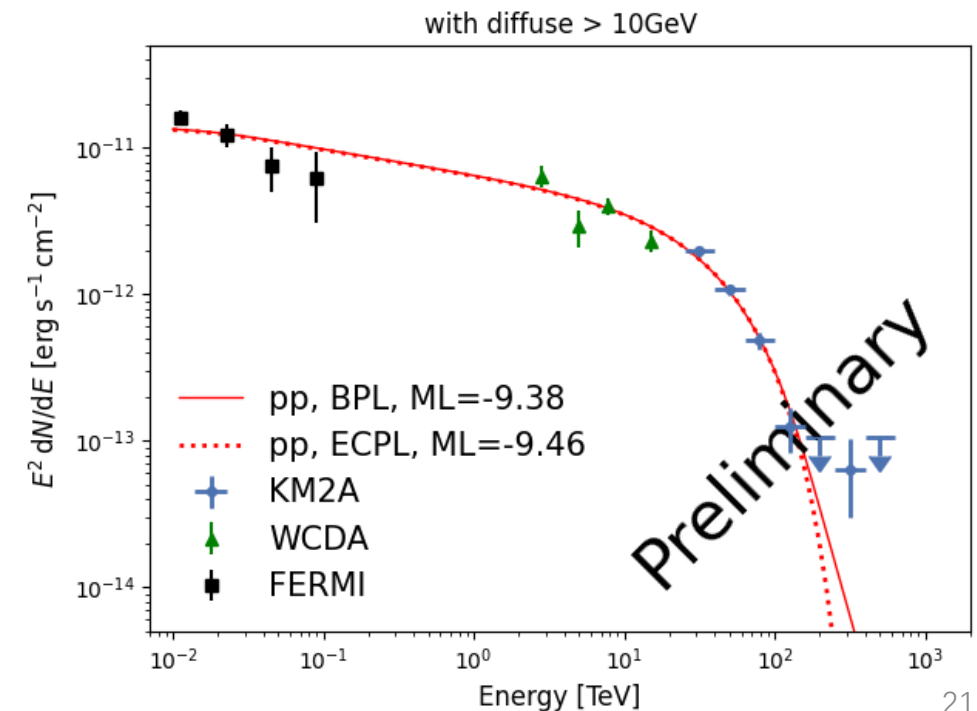
Super-PeVatron!

W43

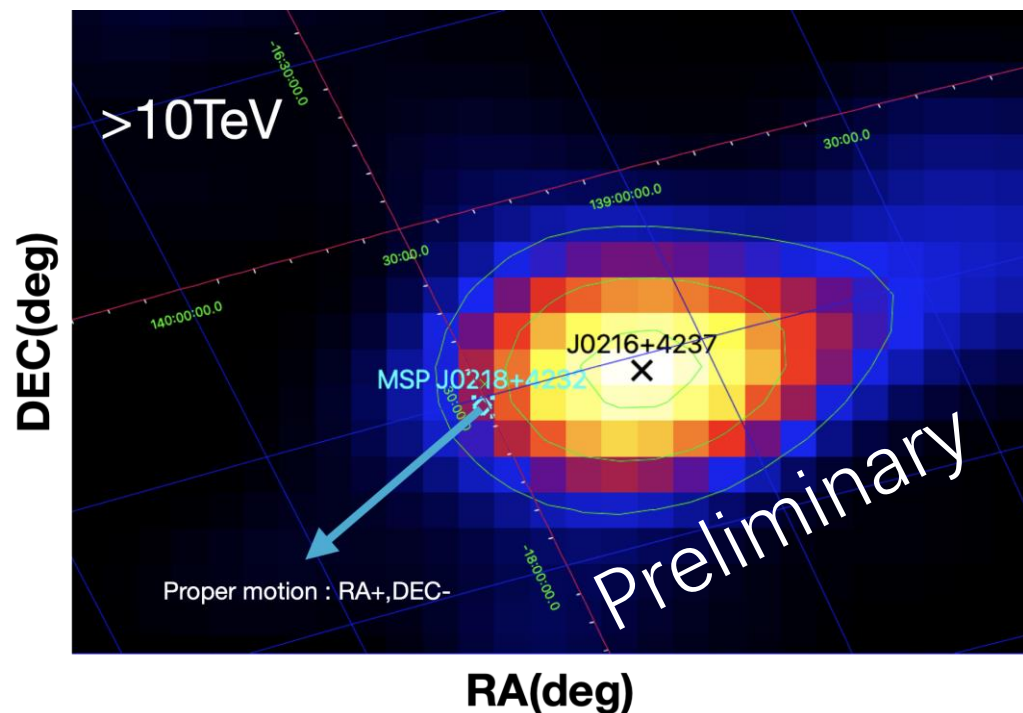


- W43: Galactic mini-starburst region
- Spectrum: extend to 300 TeV

W43 would be the second star-forming region that accelerate CRs to PeV.

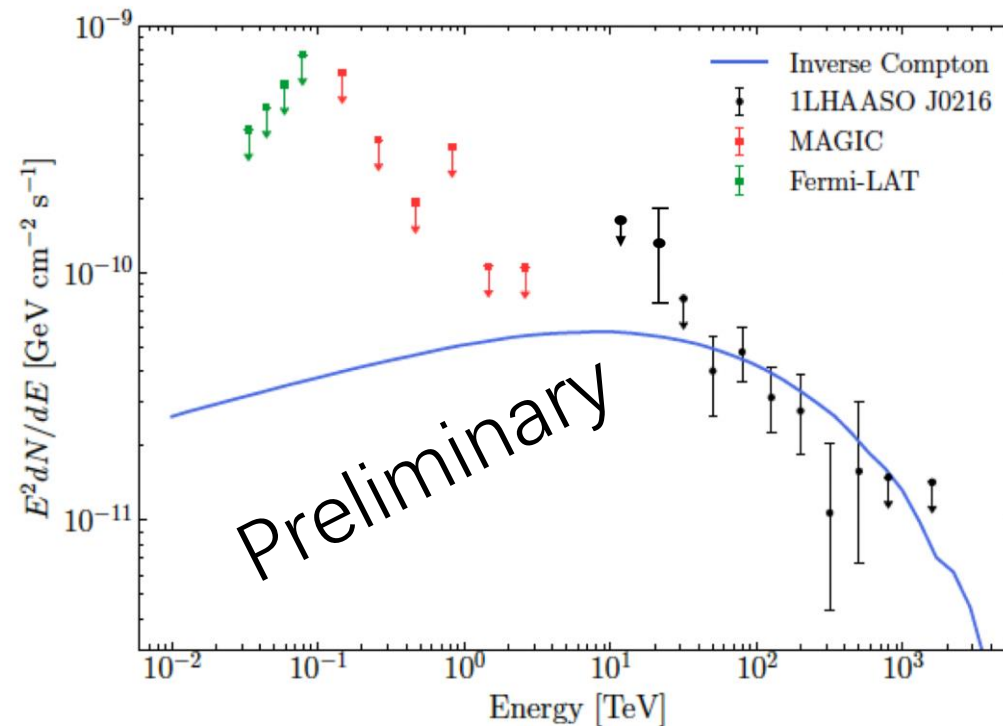


New type Pevatrons?



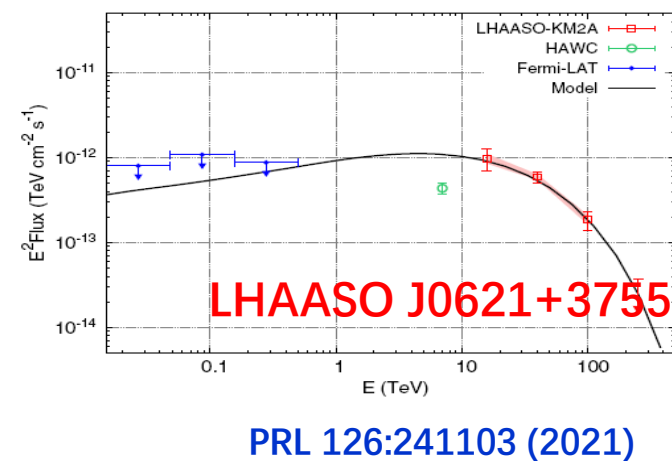
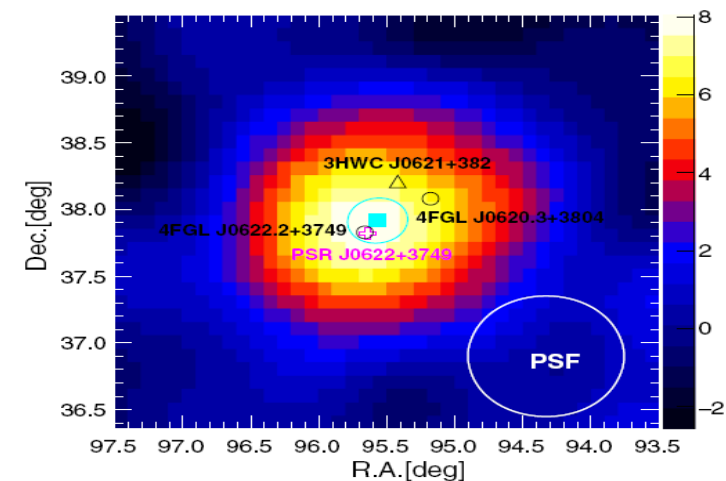
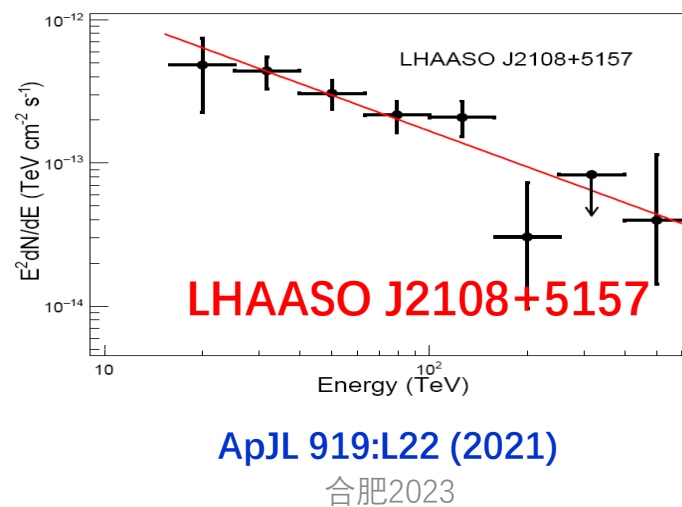
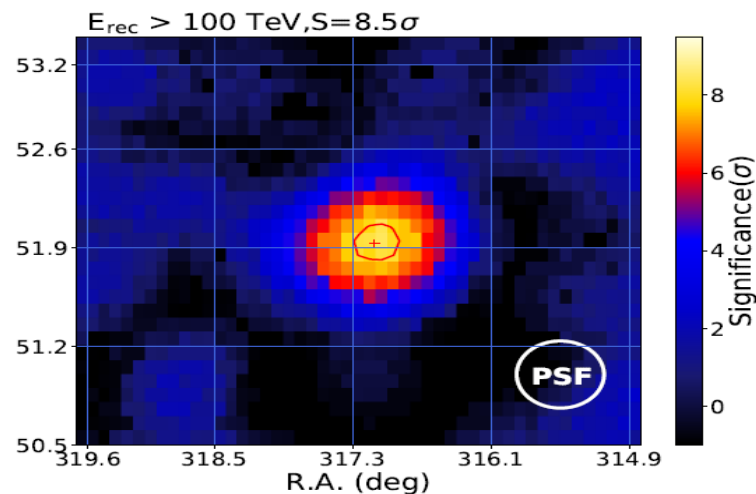
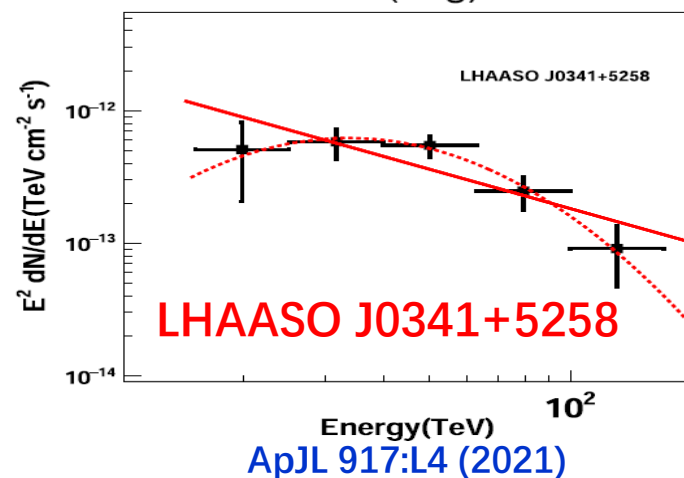
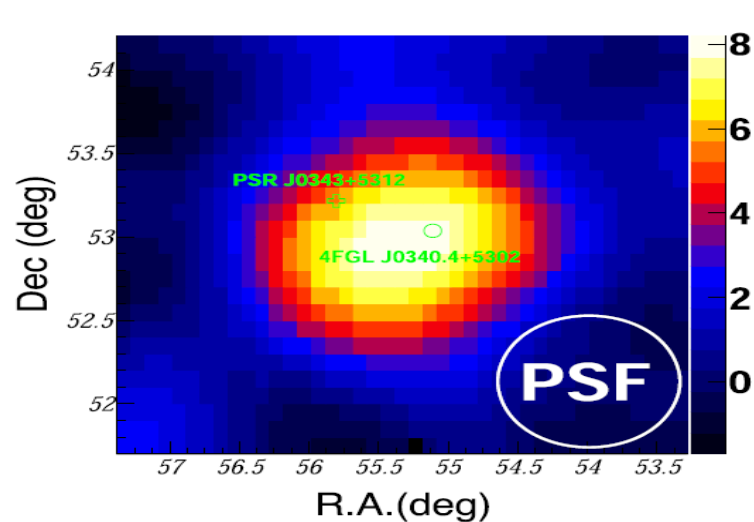
LHAASO J0218+4232

- Position: $34.08^\circ \pm 0.05^\circ$, $42.37^\circ \pm 0.03^\circ$
 $\sim 0.3^\circ$ away from MSP J0218+4232
- Spectrum index: -2.63 ± 0.22



- ◆ The new UHE source might be accelerated by millisecond pulsar.

Discovery of new γ -ray sources



Conclusion



- Our galaxy is full of UHE gamma ray sources;
- PWN, SNR, YMC and other types of sources seem can accelerate particles to at least hundreds of TeV;
- Interesting sign for few special objects accelerating particles beyond PeV.

Thanks very much !

Any question?

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