Journal Club

Measurement of ultra-high-energy diffuse gamma-ray emission of the Galactic plane from 10 TeV to 1 PeV with LHAASO-KM2A

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The paper

Measurement of ultra-high-energy diffuse gamma-ray emission of the Galactic plane from 10 TeV to 1 PeV with LHAASO-KM2A

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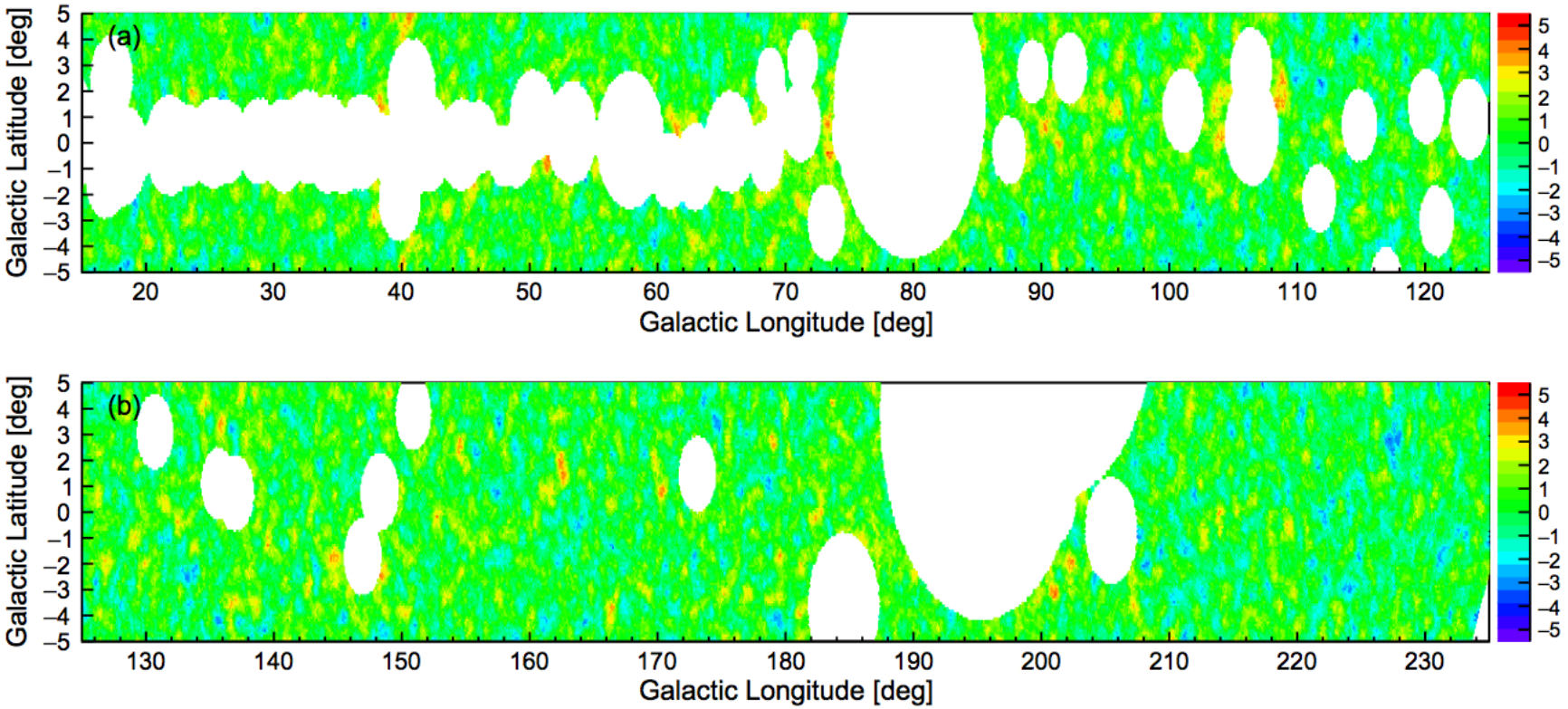
(The LHAASO Collaboration)*

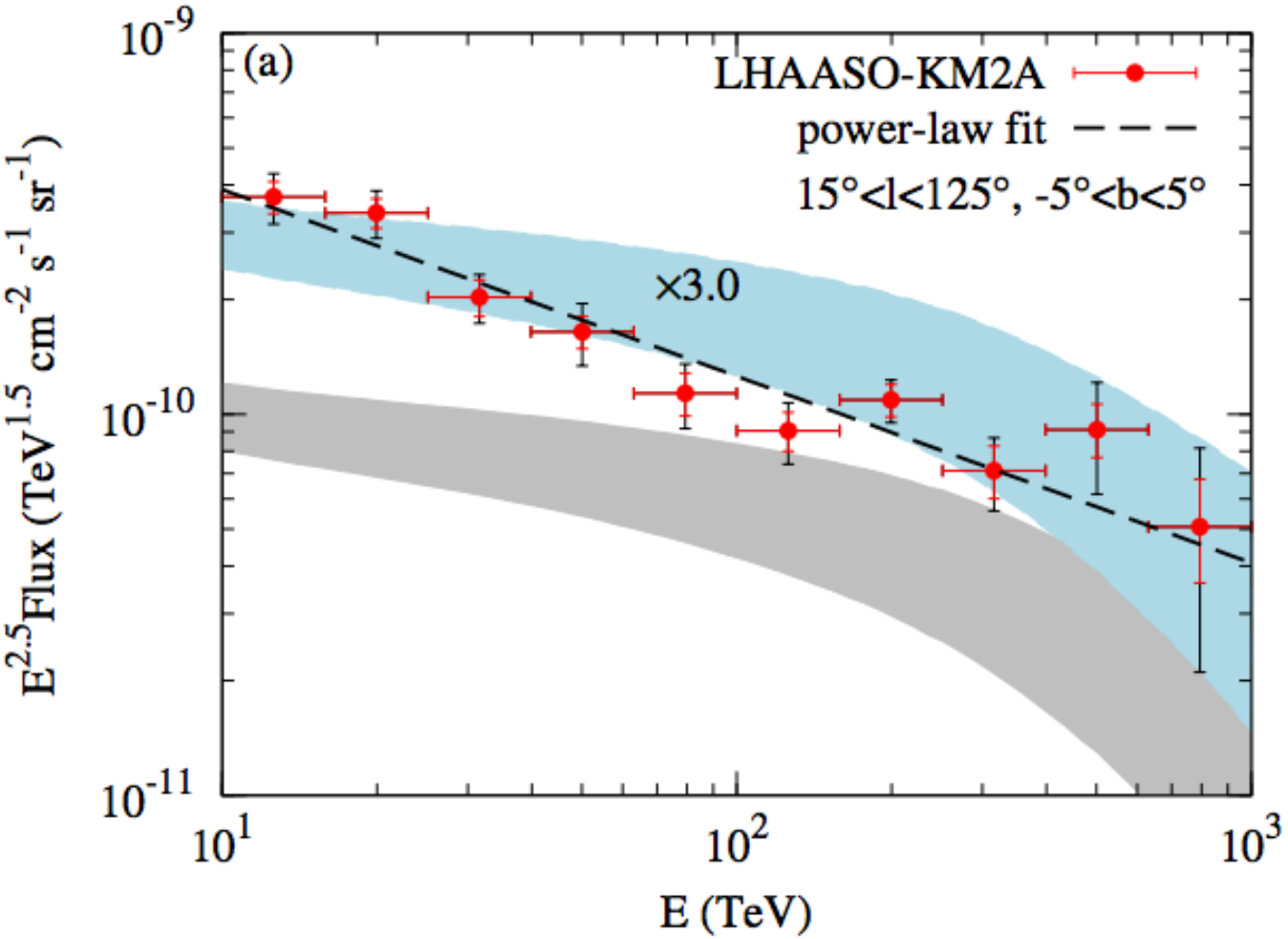
The abstract

The diffuse Galactic γ-ray emission, mainly produced via interactions between cosmic rays and the diffuse interstellar medium, is a very important probe of the distribution, propagation, and interaction of cosmic rays in the Milky Way. In this work we report the measurements of diffuse γ-rays from the Galactic plane between 10 TeV and 1 PeV energies, with the square kilometer array of the Large High Altitude Air Shower Observatory (LHAASO). Diffuse emissions from the inner ($15^\circ < l < 125^\circ$, $|b| < 5^\circ$) and outer ($125^\circ < l < 235^\circ$, $|b| < 5^\circ$) Galactic plane are detected with 29.1σ and 12.7σ significance, respectively. The outer Galactic plane diffuse emission is detected for the first time in the very- to ultra-high-energy domain ($E > 10$ TeV). The energy spectrum in the inner Galaxy regions can be described by a power-law function with an index of -2.99 ± 0.04, which is different from the curved spectrum as expected from hadronic interactions between locally measured cosmic rays and the line-of-sight integrated gas content. Furthermore, the measured flux is higher by a factor of ~ 3 than the prediction. A similar spectrum with an index of -2.99 ± 0.07 is found in the outer Galaxy region, and the absolute flux for $10 \lesssim E \lesssim 60$ TeV is again higher than the prediction for hadronic cosmic ray interactions. The latitude distributions of the diffuse emission are consistent with the gas distribution, while the longitude distributions show slight deviation from the gas distribution. The LHAASO measurements imply that either additional emission sources exist or cosmic ray intensities have spatial variations.

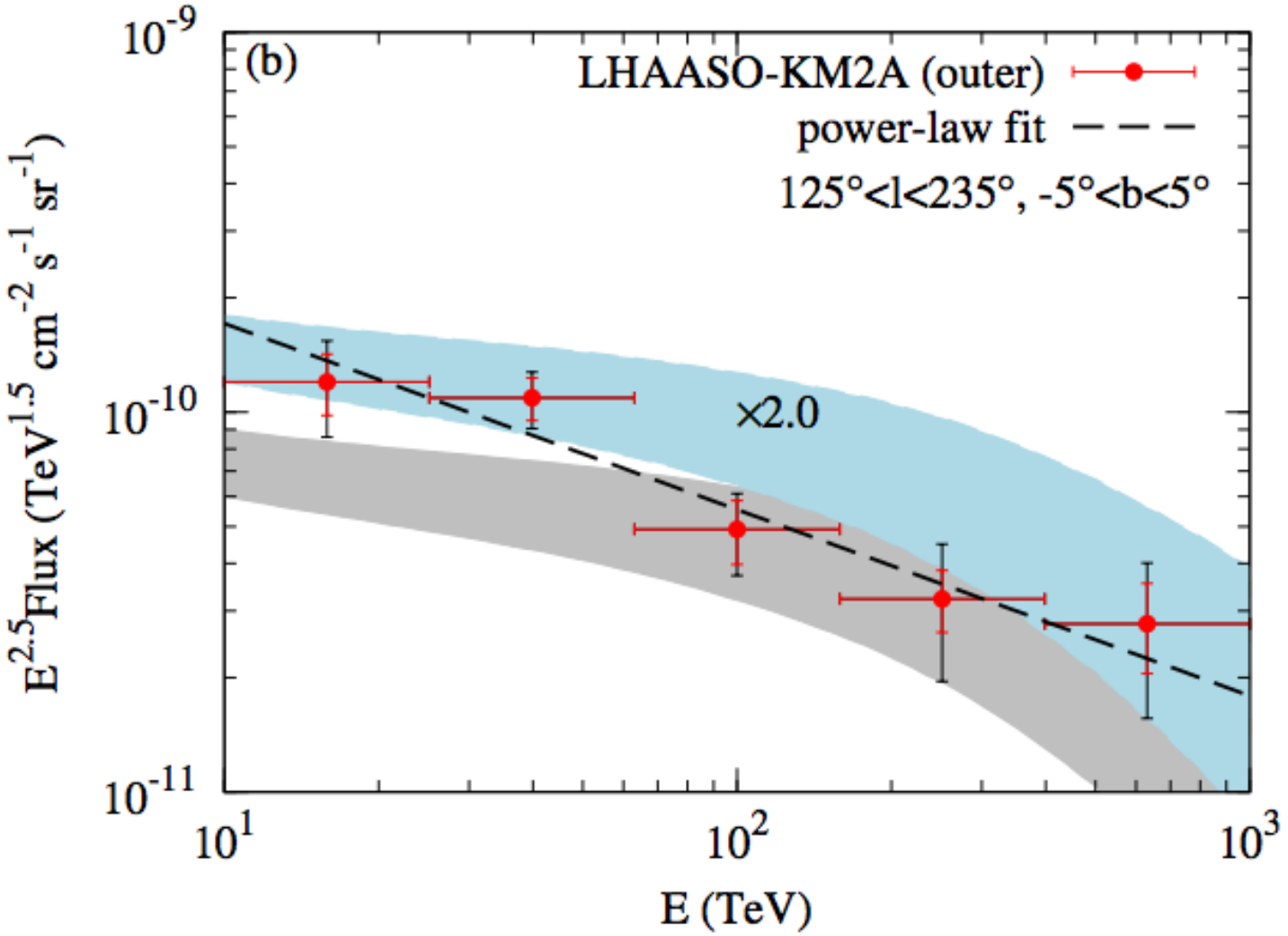
Figures


(a)
Galactic Latitude [deg]
5
4
3
2
1
0
−1
−2
−3
−4
−5
20
30
40
50
60
70
80
90
100
110
120
Galactic Longitude [deg]
(b)
Galactic Latitude [deg]
130
140
150
160
170
180
190
200
210
220
230
Galactic Longitude [deg]

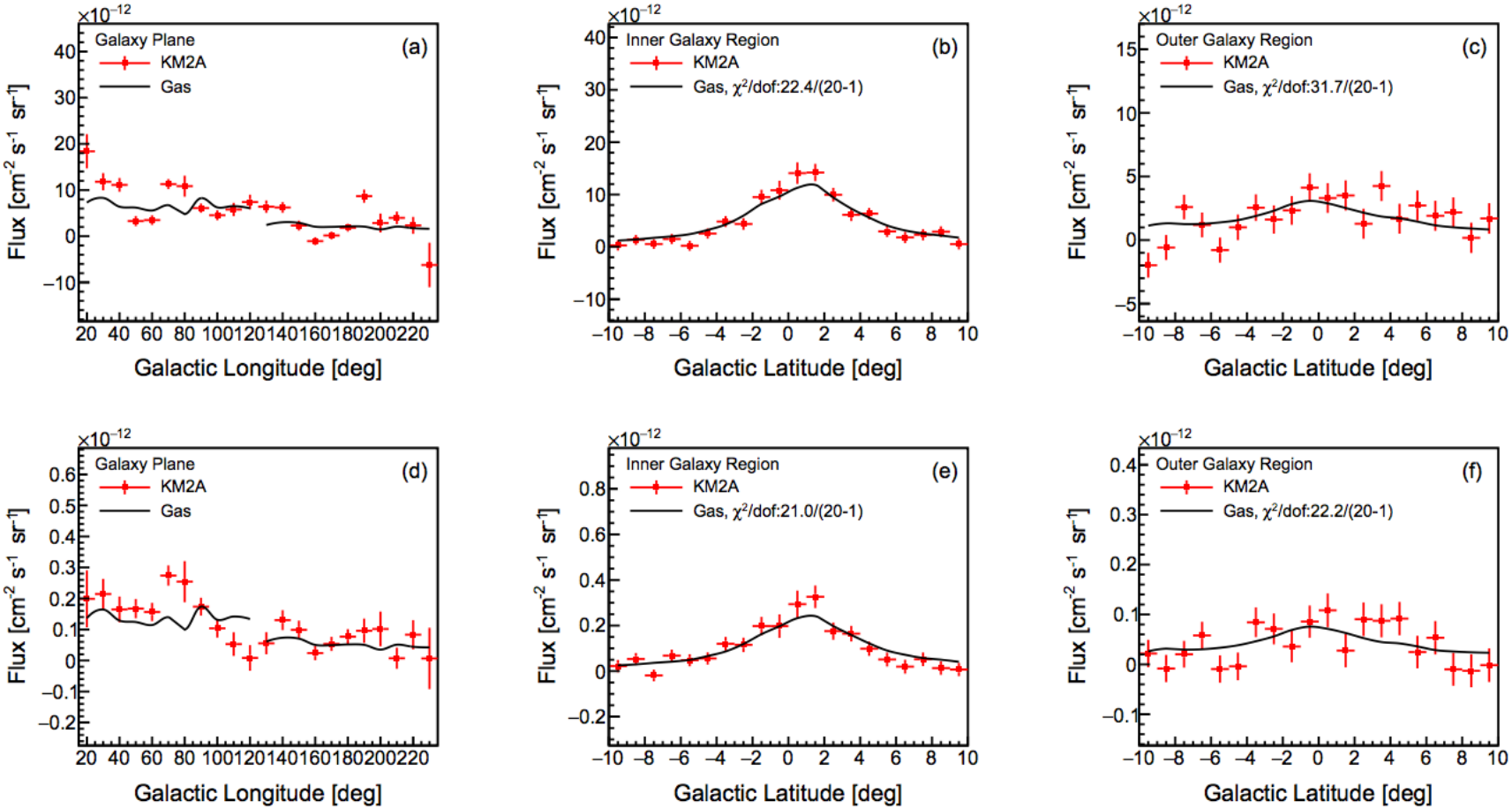
Figures


(a)
LHAASO-KM2A
power-law fit
15°<l<125°, -5°<b<5°
×3.0
10^{-9}
10^{-10}
10^{-11}
10^{1}
10^{2}
10^{3}
$E^{2.5}$Flux (TeV$^{1.5}$ cm^{-2} s^{-1} sr^{-1})
E (TeV)

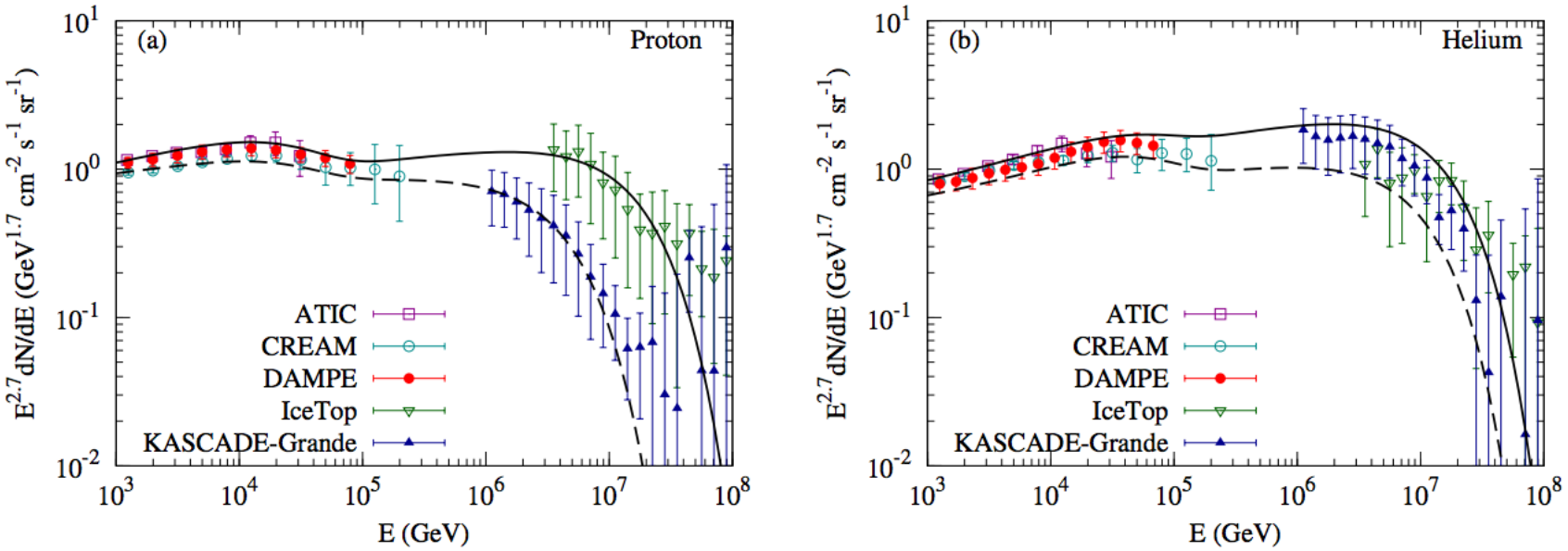
Figures


(b)
LHAASO-KM2A (outer)
power-law fit
125°<l<235°, -5°<b<5°
×2.0
10^{-9}
10^{-10}
10^{-11}
10^{1}
10^{2}
10^{3}
$E^{2.5}$Flux (TeV$^{1.5}$ cm^{-2} s^{-1} sr^{-1})
E (TeV)

Figures


×10⁻¹²
Galaxy Plane
KM2A
Gas
(a)
Flux [cm⁻² s⁻¹ sr⁻¹]
Galactic Longitude [deg]
Inner Galaxy Region
KM2A
Gas, χ²/dof:22.4/(20-1)
(b)
Flux [cm⁻² s⁻¹ sr⁻¹]
Galactic Latitude [deg]
Outer Galaxy Region
KM2A
Gas, χ²/dof:31.7/(20-1)
(c)
Flux [cm⁻² s⁻¹ sr⁻¹]
Galactic Latitude [deg]
×10⁻¹²
Galaxy Plane
KM2A
Gas
(d)
Flux [cm⁻² s⁻¹ sr⁻¹]
Galactic Longitude [deg]
Inner Galaxy Region
KM2A
Gas, χ²/dof:21.0/(20-1)
(e)
Flux [cm⁻² s⁻¹ sr⁻¹]
Galactic Latitude [deg]
Outer Galaxy Region
KM2A
Gas, χ²/dof:22.2/(20-1)
(f)
Flux [cm⁻² s⁻¹ sr⁻¹]
Galactic Latitude [deg]

Figures


(a)
Proton
ATIC
CREAM
DAMPE
IceTop
KASCADE-Grande
E (GeV)
$E^{2.7}$dN/dE ($GeV^{1.7}$ cm^{-2} s^{-1} sr^{-1})
(b)
Helium
ATIC
CREAM
DAMPE
IceTop
KASCADE-Grande
E (GeV)
$E^{2.7}$dN/dE ($GeV^{1.7}$ cm^{-2} s^{-1} sr^{-1})

Conclusions

- We report the measurements of the diffuse γ-ray emission in the VHE to UHE window of 10−1000 TeV from the Galactic plane using the LHAASO-KM2A data.
- In total, 302 days of the half array data, 219 days of the 3/4 array data, and 423 days of the full array data of LHAASO-KM2A are used in this work.
- To reduce the contamination from detected sources, the sky regions around known VHE/UHE sources and those newly detected by the LHAASO-KM2A are masked.
- In the Galactic plane, Two sky regions, the inner Galaxy and the outer Galaxy regions, are analyzed.

Conclusions

- After masking the sources, we find significant diffuse emission above 10 TeV with 29.1σ and 12.7σ significance for the inner and outer Galaxy regions, respectively.
- The outer Galaxy region is, for the first time, to be observed to have VHE-UHE diffuse emission.
- A power-law can well describe the spectra in both the inner and outer regions with similar spectral indices of −2.99.
- Compared with the prediction of CR interactions with the ISM, the LHAASO measured fluxes are higher by a factor of 2 ~ 3 in both regions (for the outer region the excess is evident for E < 60 TeV).
- The latitude distributions of the diffuse emission are consistent with the gas distribution, while moderate deviation is shown in the longitude distribution in the inner Galaxy region.
- The KM2A measurements provide interesting insights in probing the source distribution and interactions of CRs in the Galaxy.
- Further understanding of the nature of the diffuse emission is expected to be achieved with the accumulation of more data by KM2A and the analysis from sub-TeV to ~ 10 TeV energies with the WCDA data.