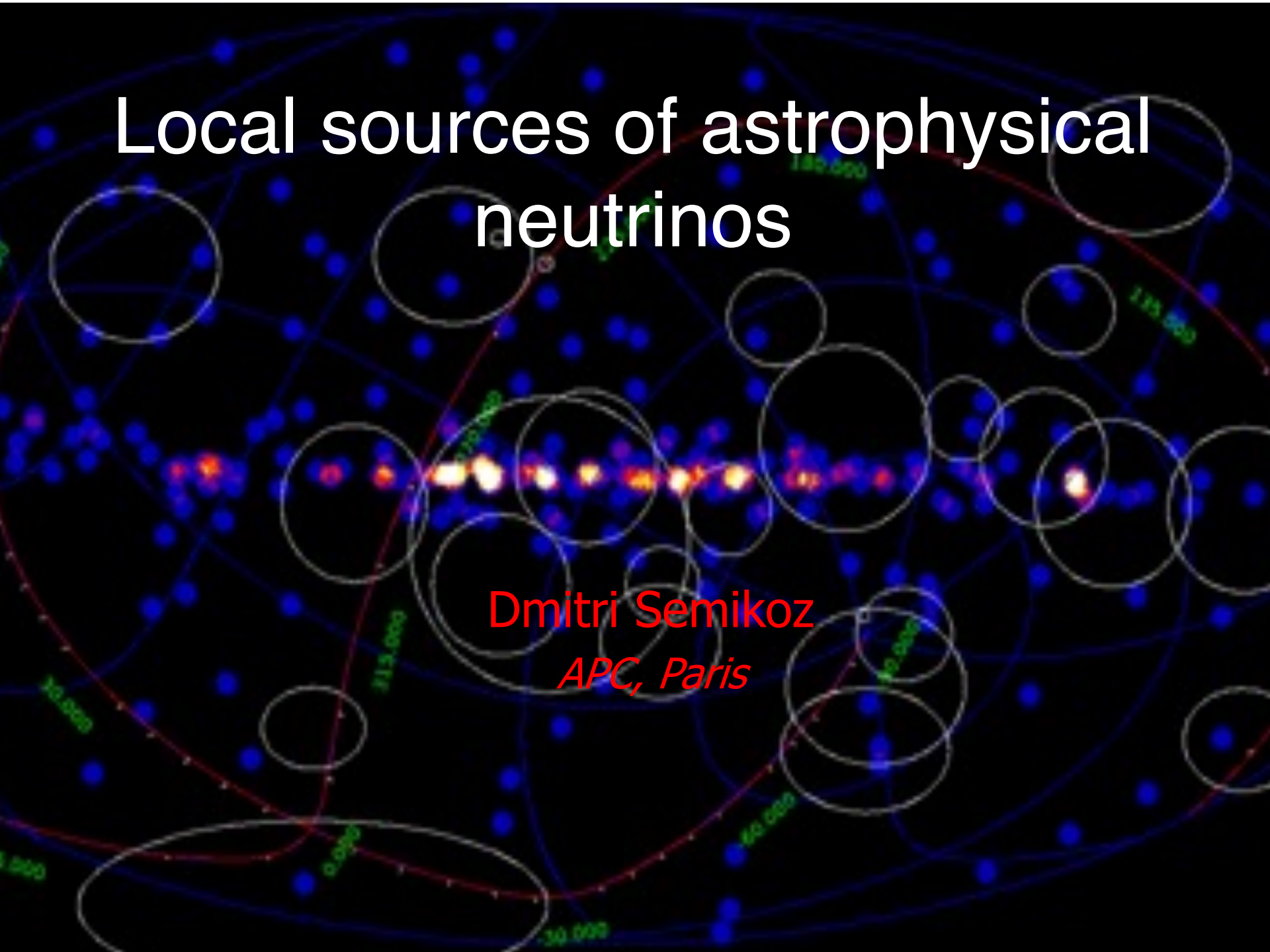
Local sources of astrophysical neutrinos



Dmitri Semikoz

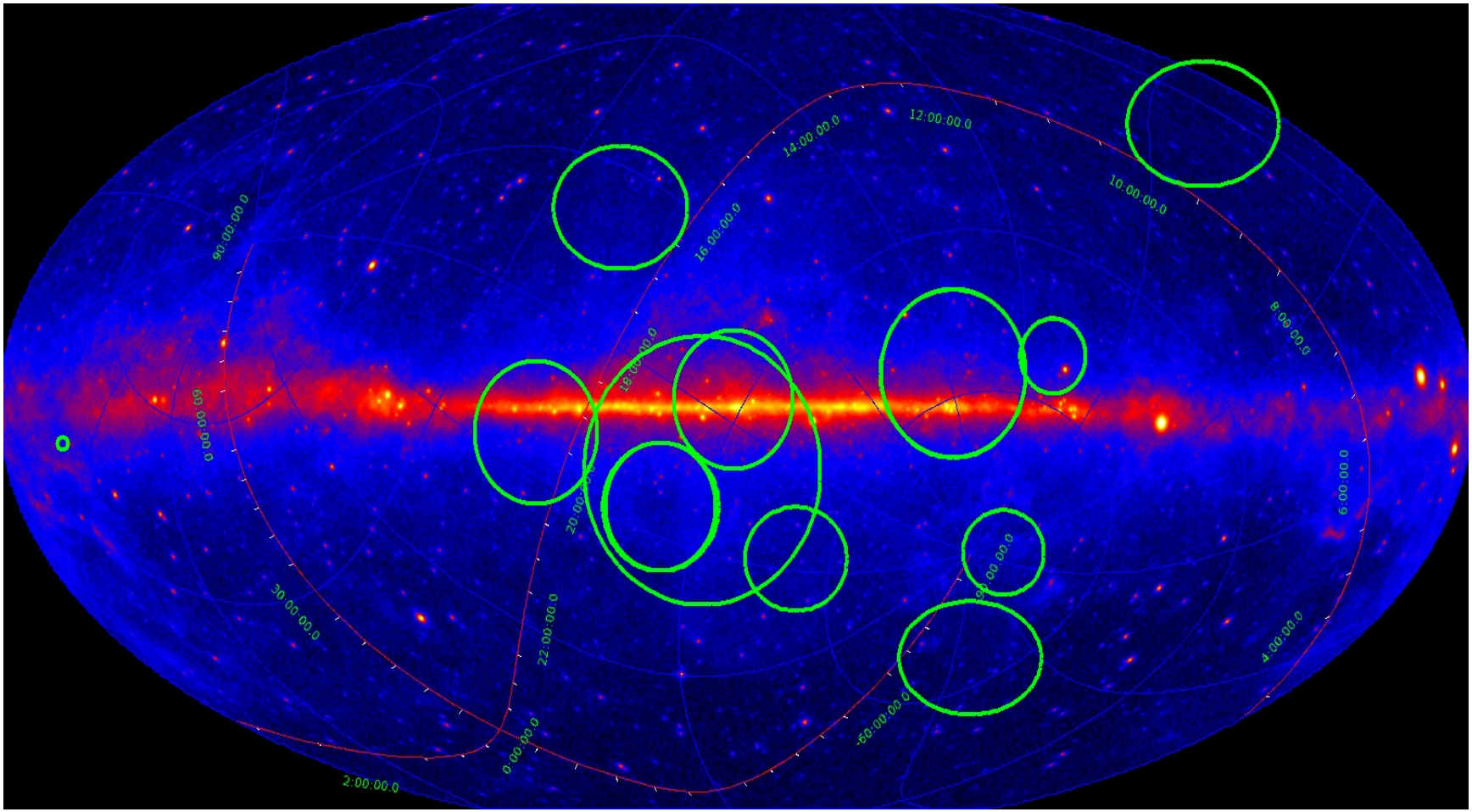
APC, Paris

Plan

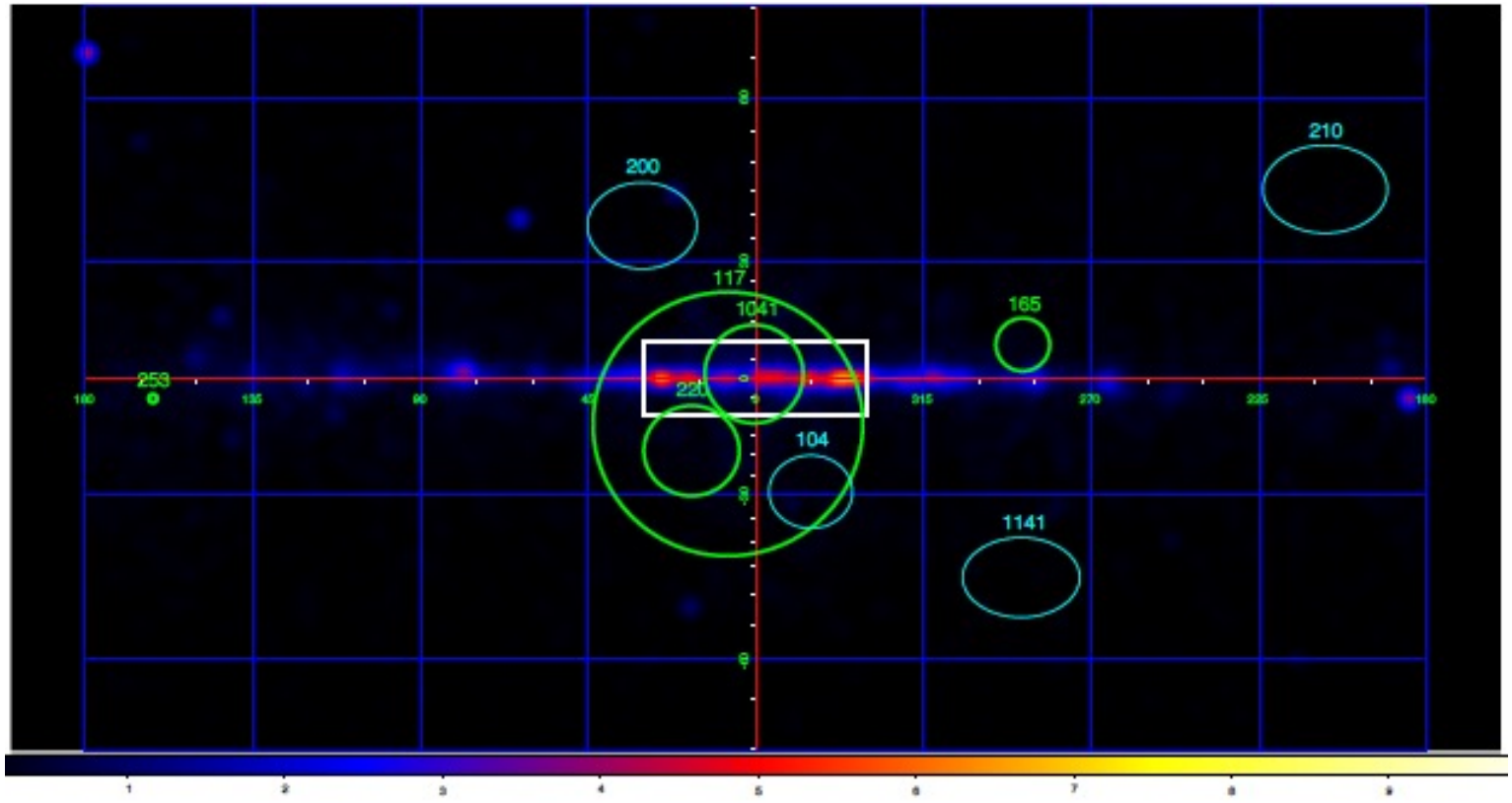
- Neutrino flux in IceCube: galactic and extragalactic contributions
- High energy gamma-rays in Galaxy at 100 TeV
- PeV cosmic ray propagation in Galactic magnetic field: signatures in cosmic rays, gamma-rays and neutrinos
- New type of galactic sources in gamma-ray / IceCube data
- Conclusions

Neutrino flux in IceCube: galactic and extra-galactic

IceCube neutrino sky map
3 years E> 100 TeV

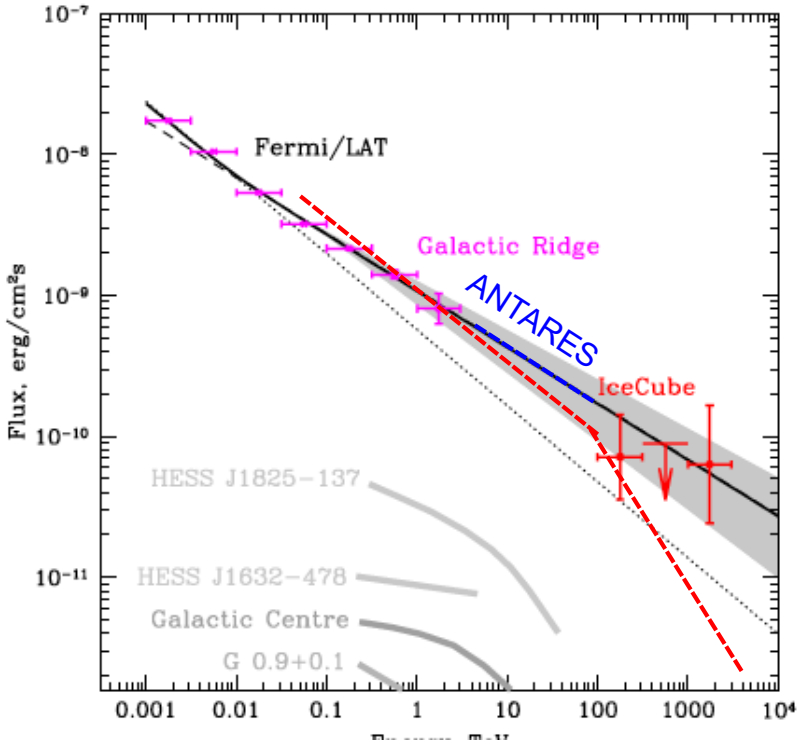


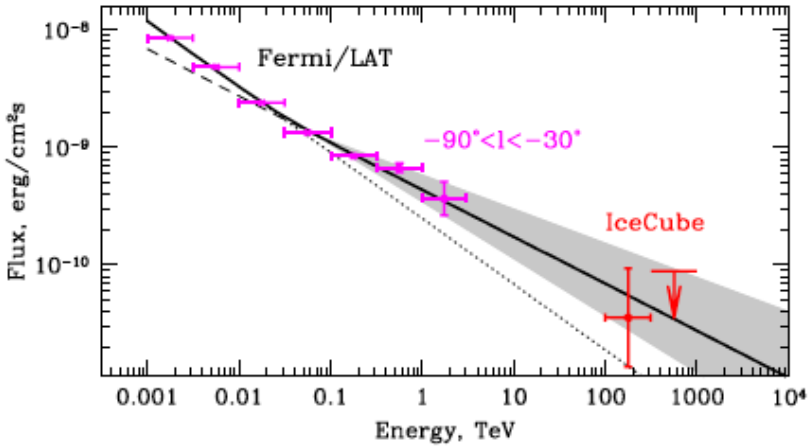
First 3 years: half of ICECUBE events E>100 TeVare in Galactic plane. Are they correlate with gamma-rays?



A.Neronov, D.S. and C.Tchernin, arXiv:1307.2158

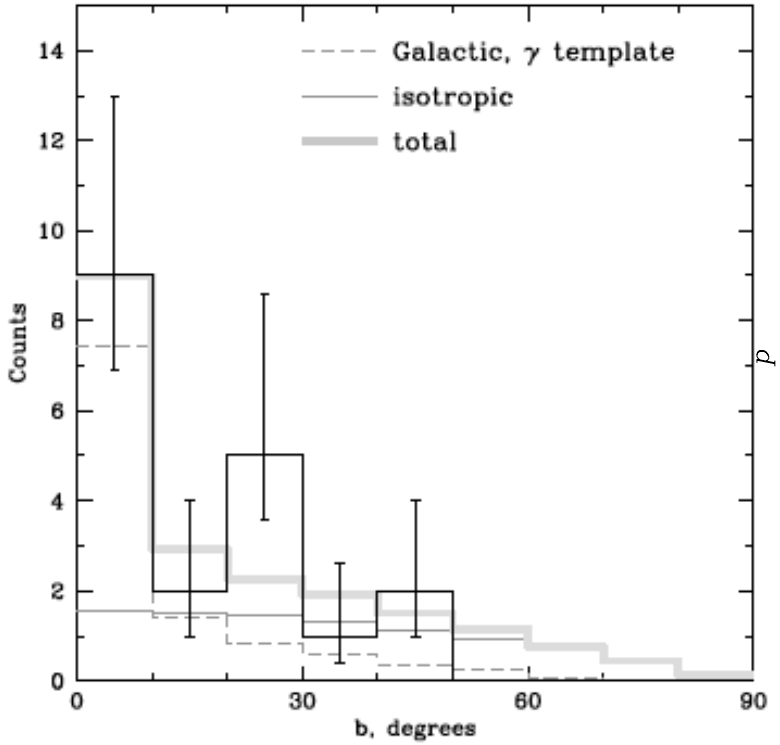
Real multimessenger fluxes, alpha=2.5

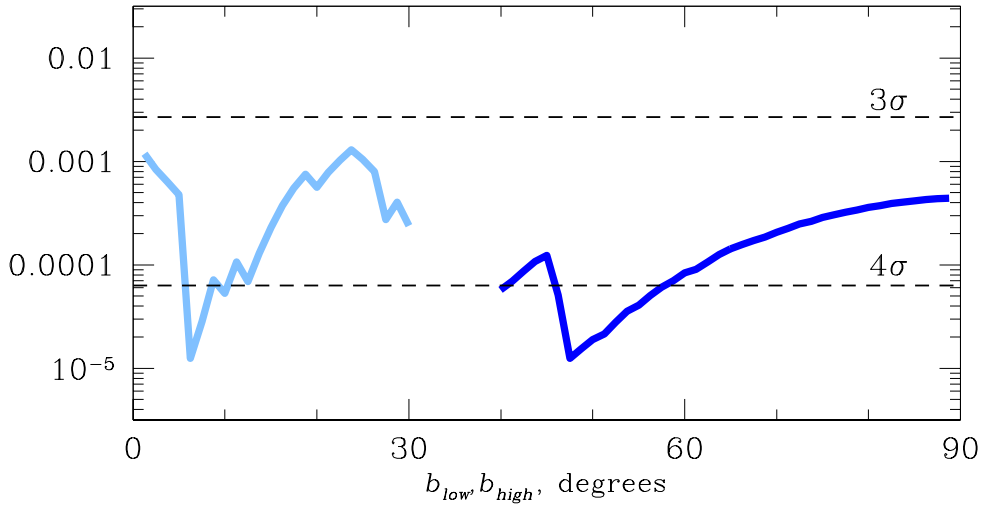




V.Berezinsky & A.Smirnov 1975

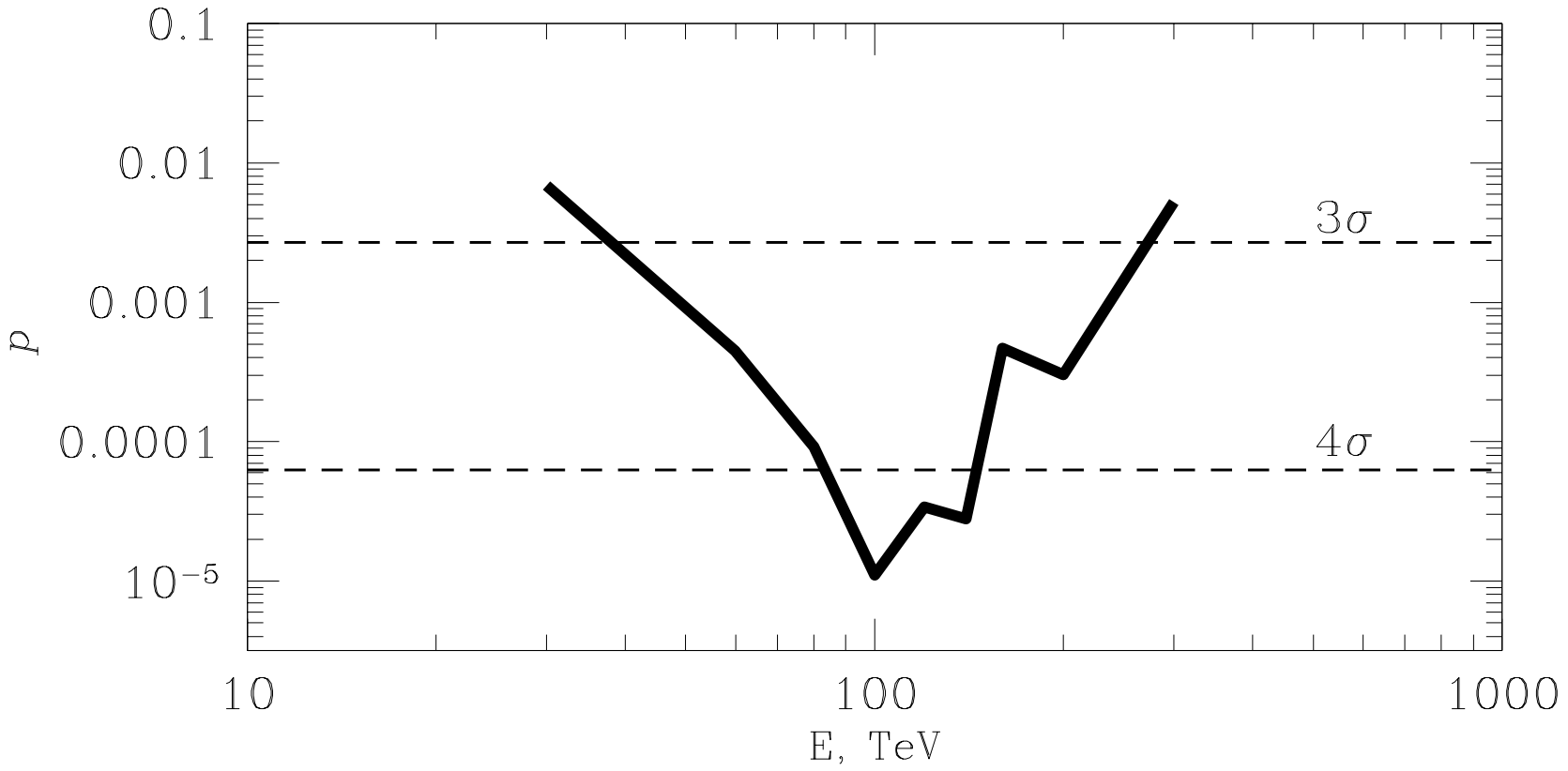
Evidence of Galactic component in 4 year IceCube data E>100 TeV





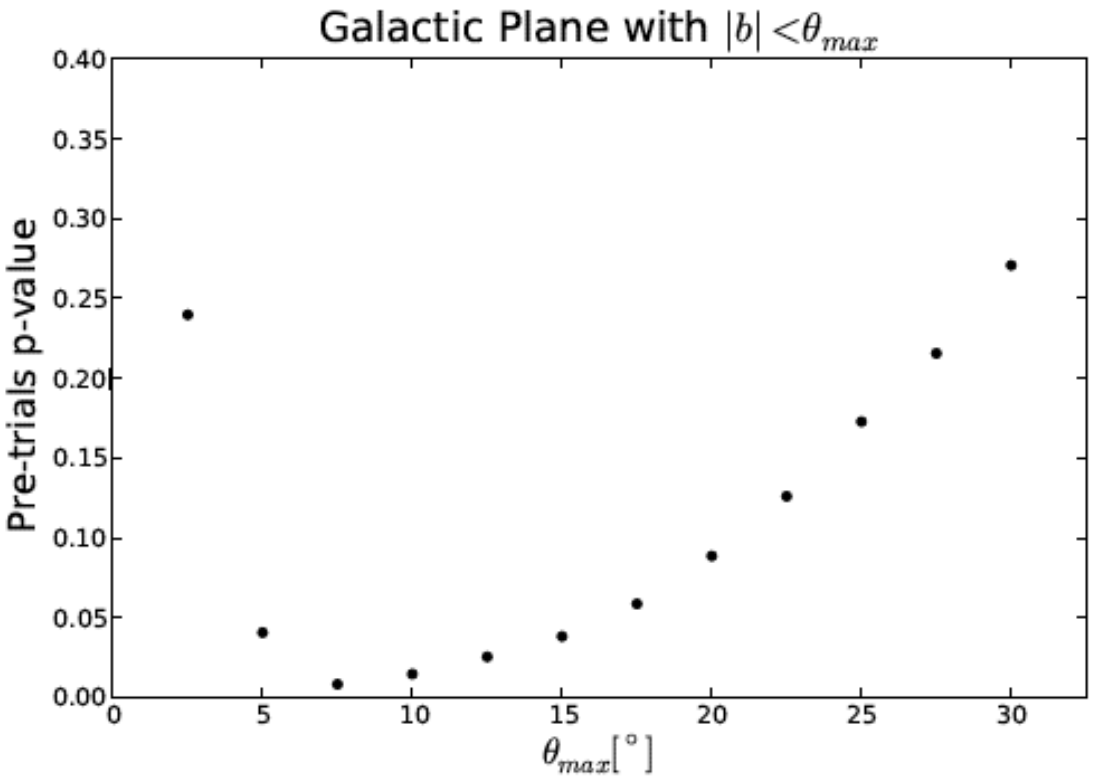
A. Neronov & D.S. arXiv: 1509.03522

Post-trial probability is $1.7*10^{-3}$



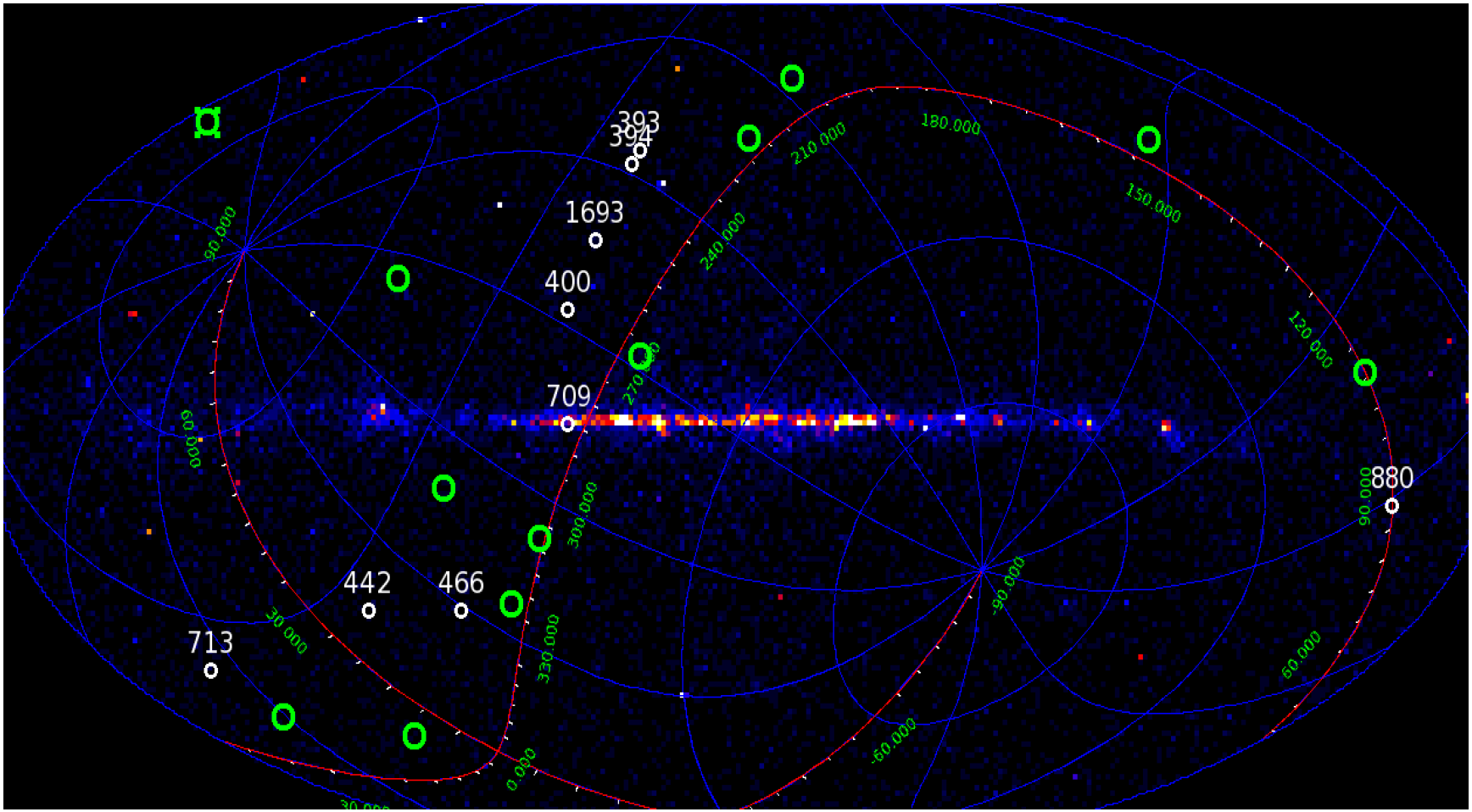
A. Neronov & D.S. arXiv: 1509.03522

IceCube galactic plane 3 years: 2% by chance – small statistics



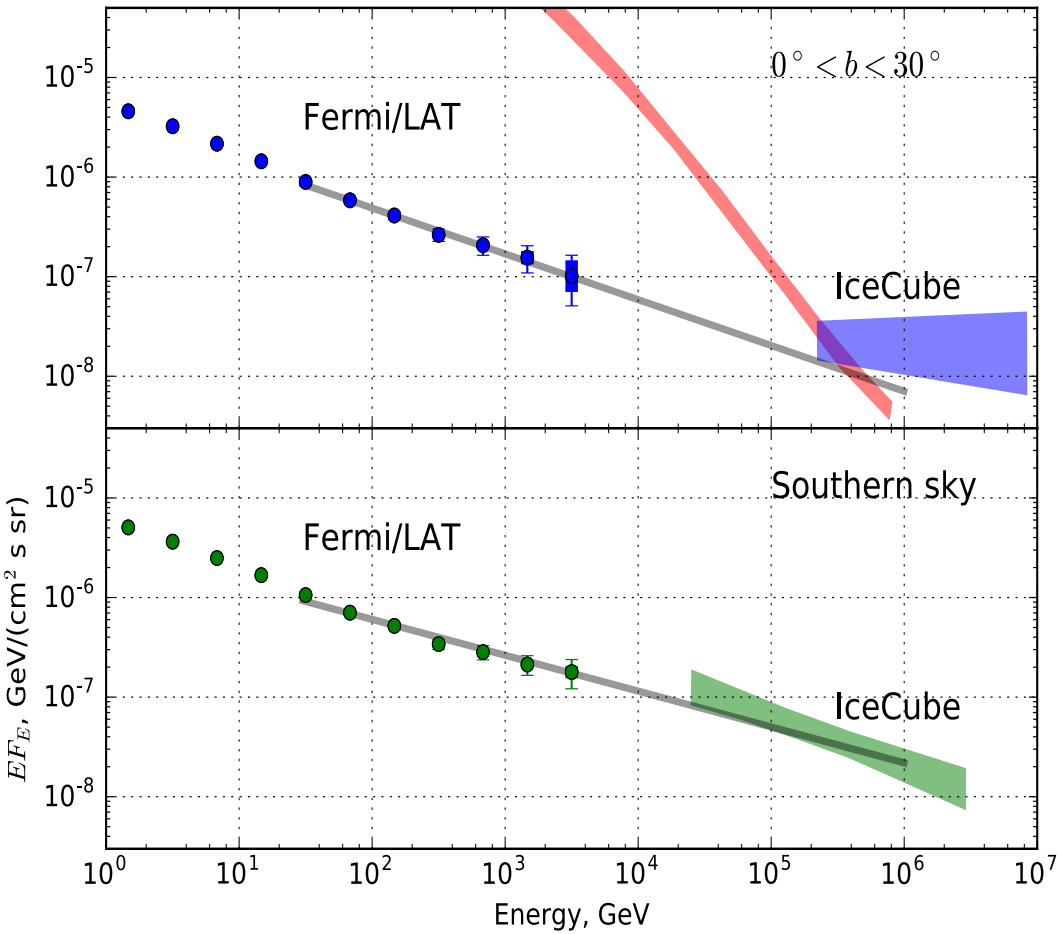
ICECUBE collaboration, arXiv:1405.5303

Muon neutrinos



IceCube, ICRC 2015

North and South sky: IceCube

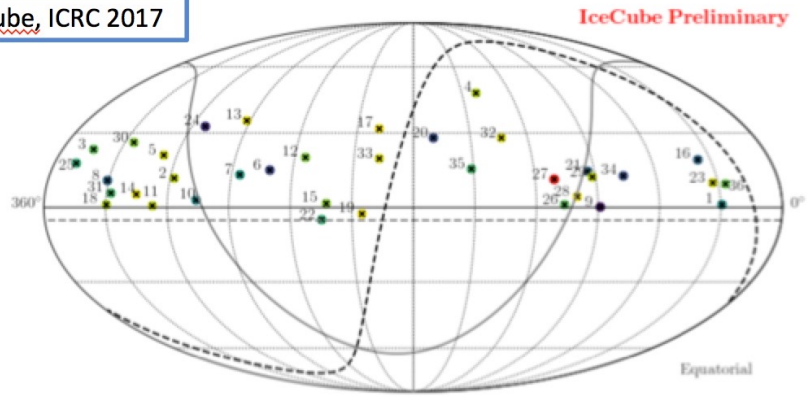


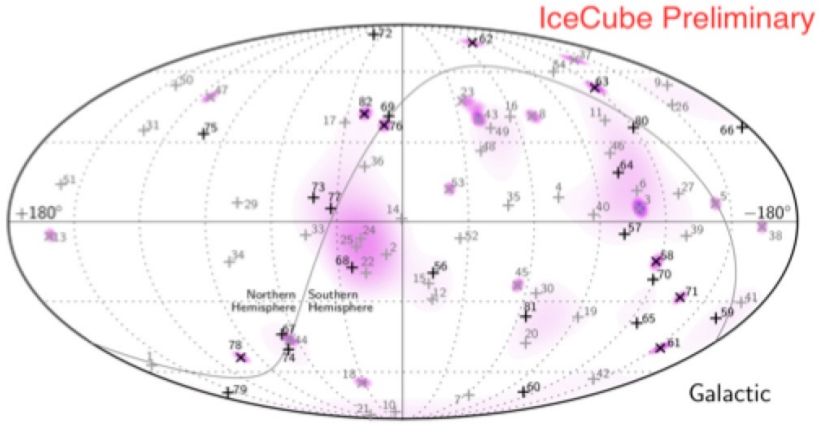
A. Neronov & D.S. arXiv: 1603.06733

IceCube cascade and muon channel

Astrophysical neutrino signal

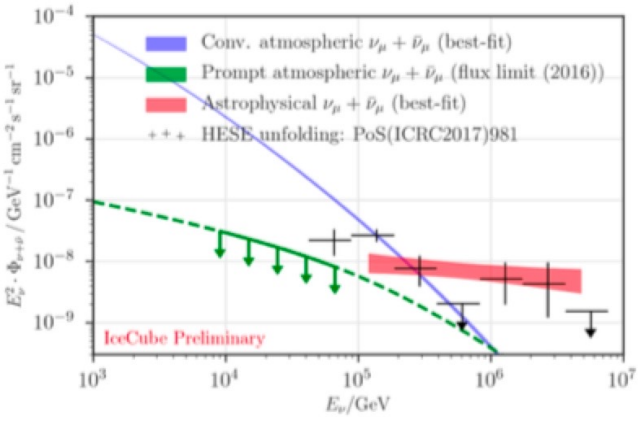
IceCube, ICRC 2017

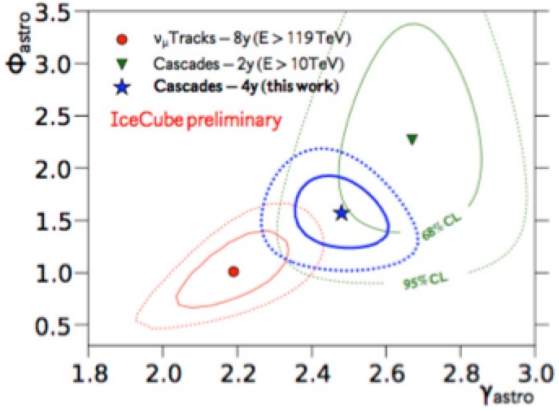


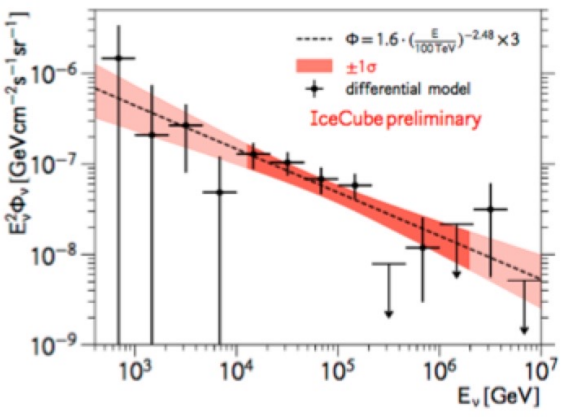


Muon neutrino sample

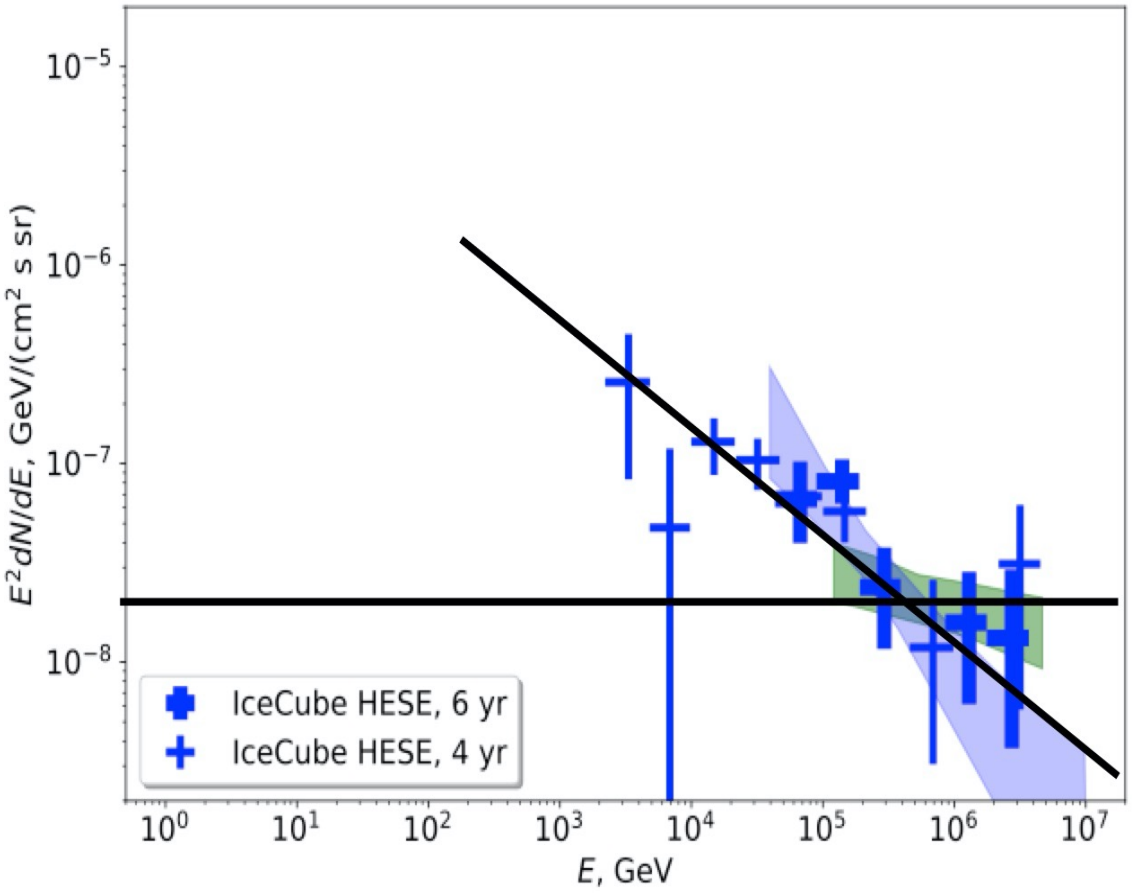
High Energy Starting Event neutrino sample



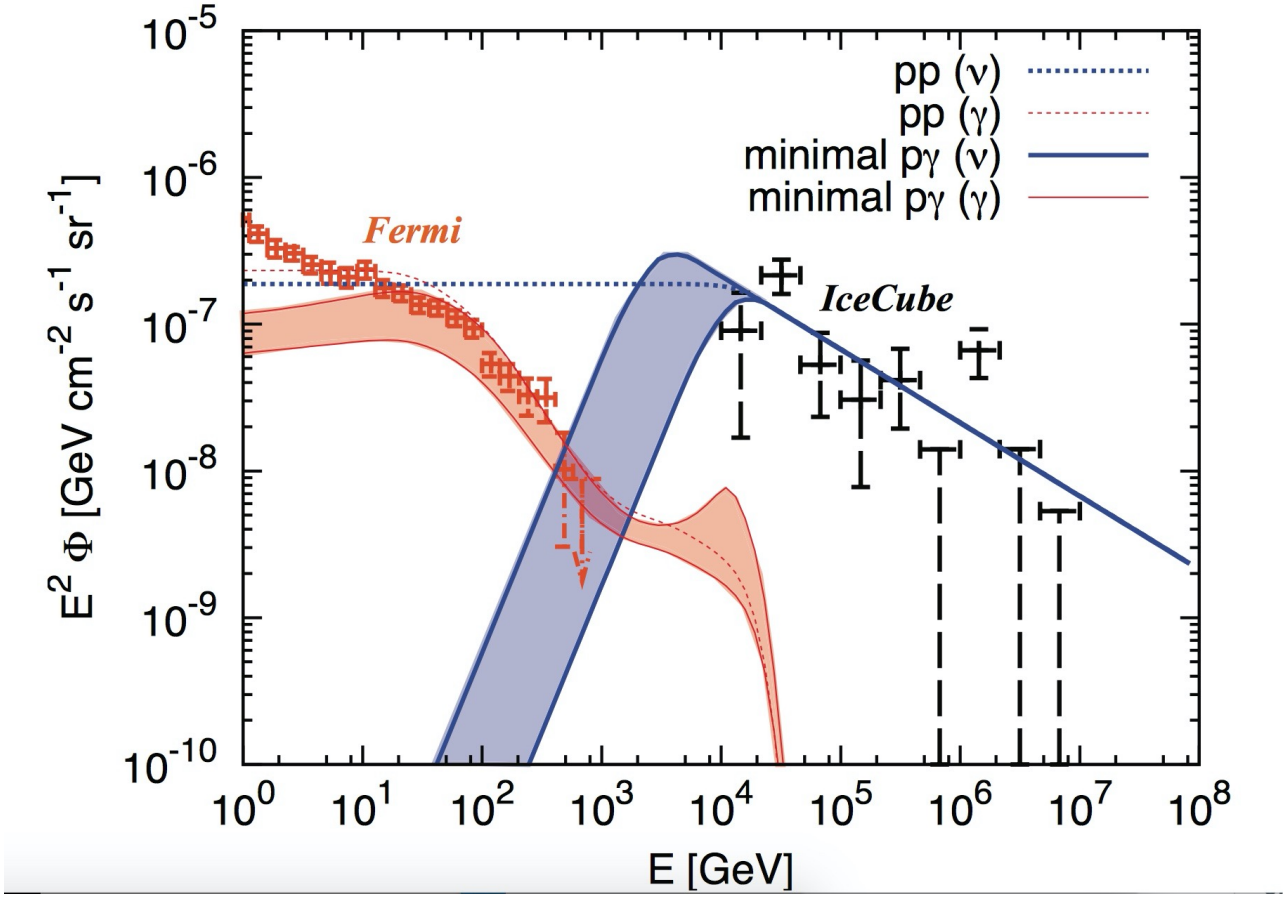




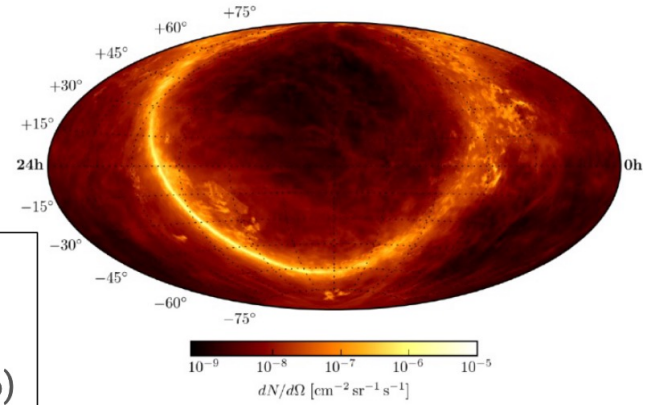
IceCube data



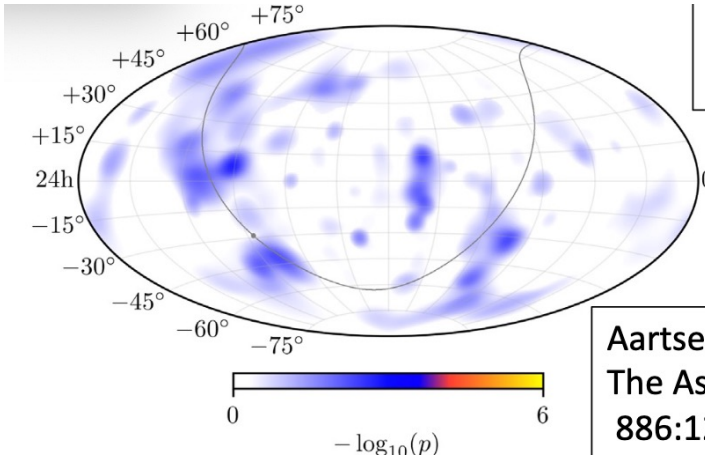
Self-consistent extragalactic sources



IceCube galactic plane



Kheirandish
Astrophysics and Space Science 365(6)

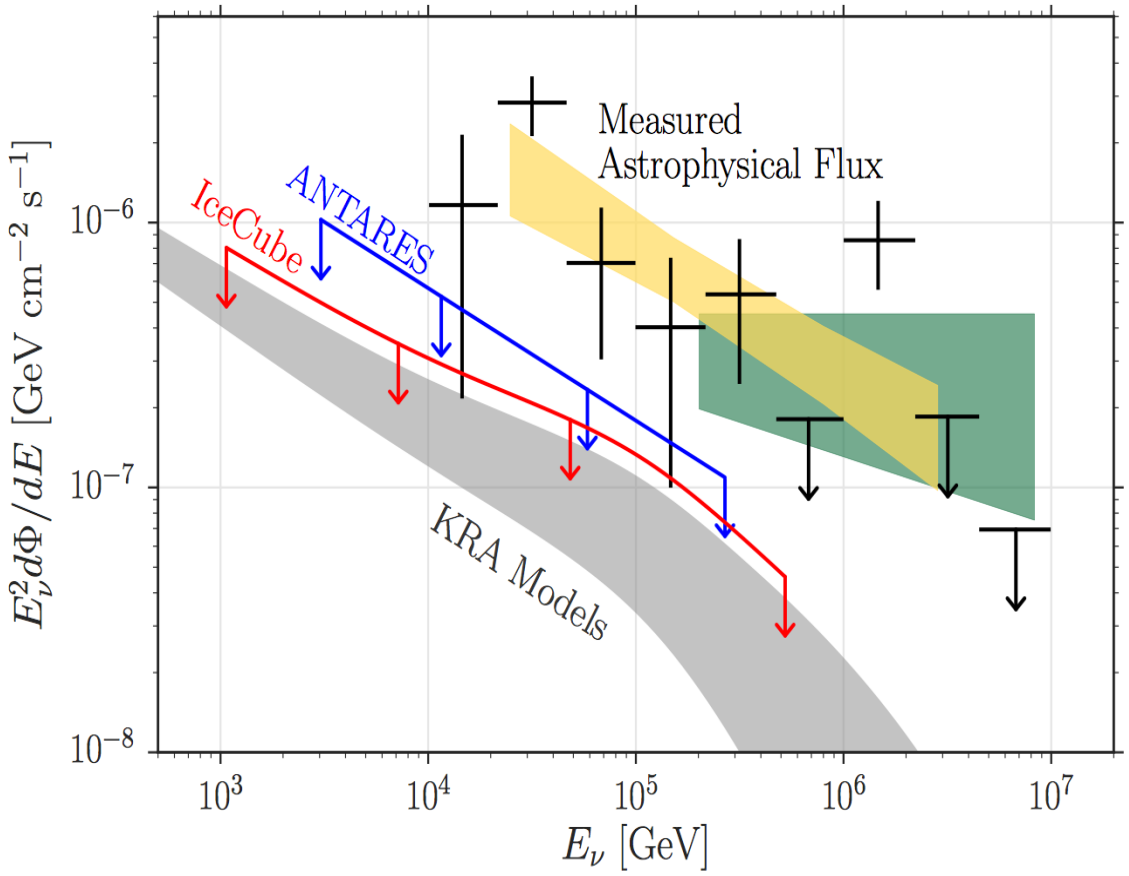


analysi
0.85 *

Aartsen et al.,
The Astrophys
886:12, 2019

From Dorothea's talk yesterday

IceCube and ANTARES galalactic plane limits



ICRC 2017

Gamma-ray sky at 100 TeV with HAWC, Tibet ASg and LHAASO

HAWC 100 TeV sources

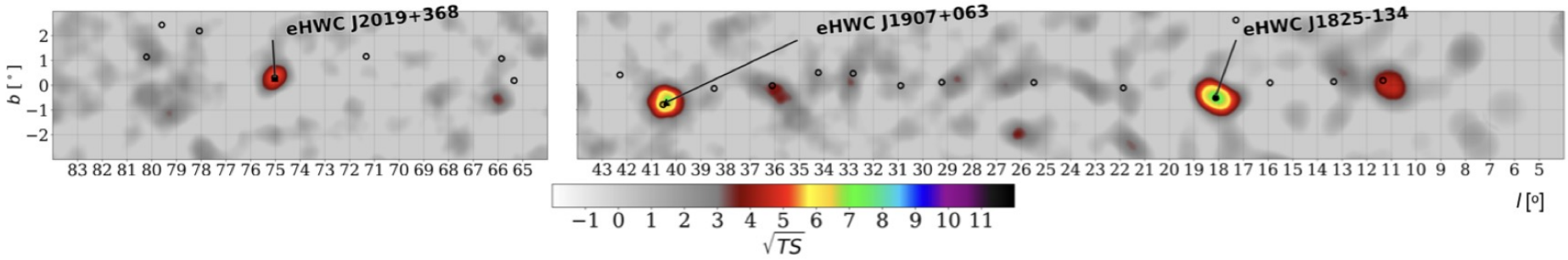
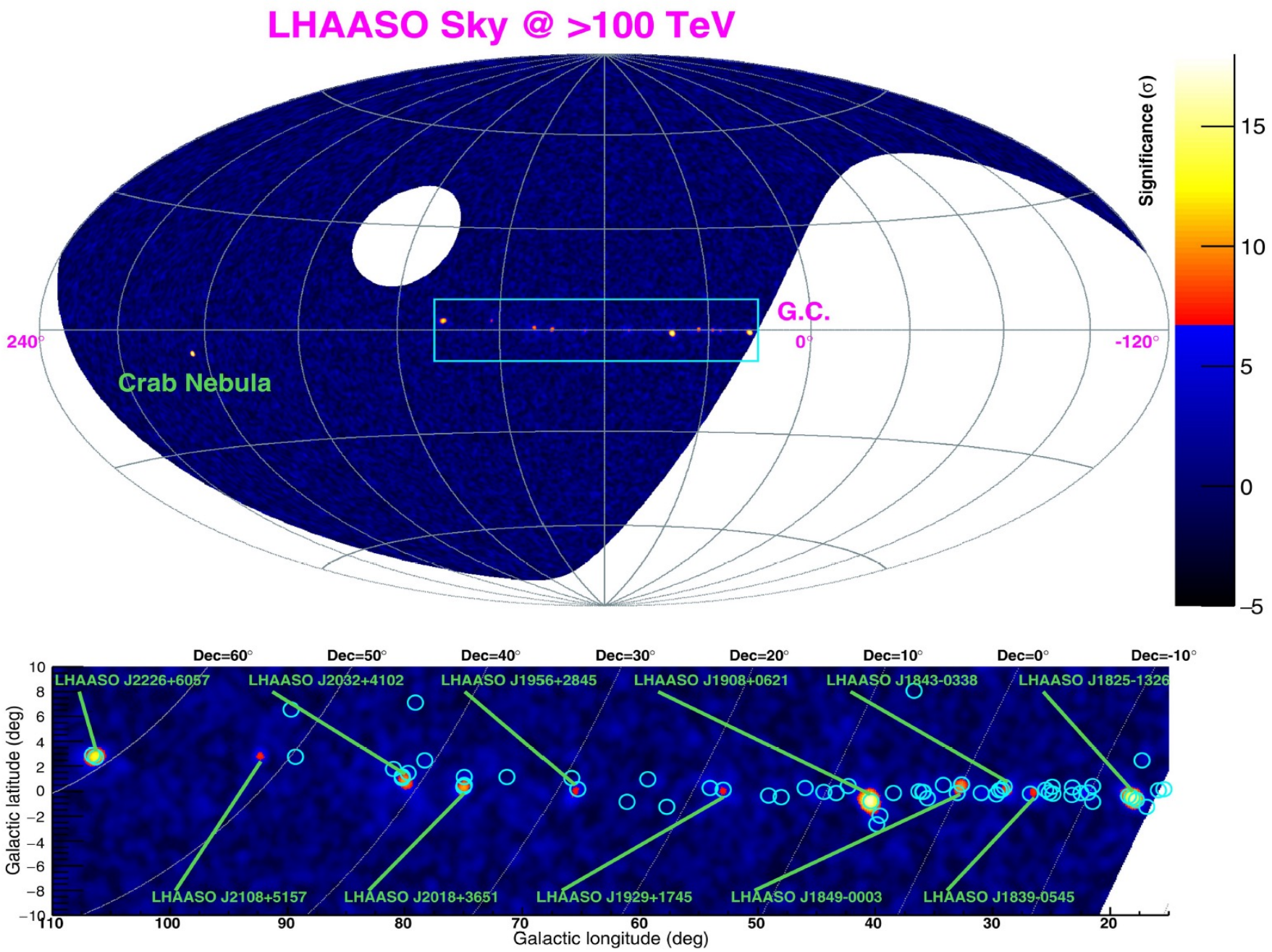


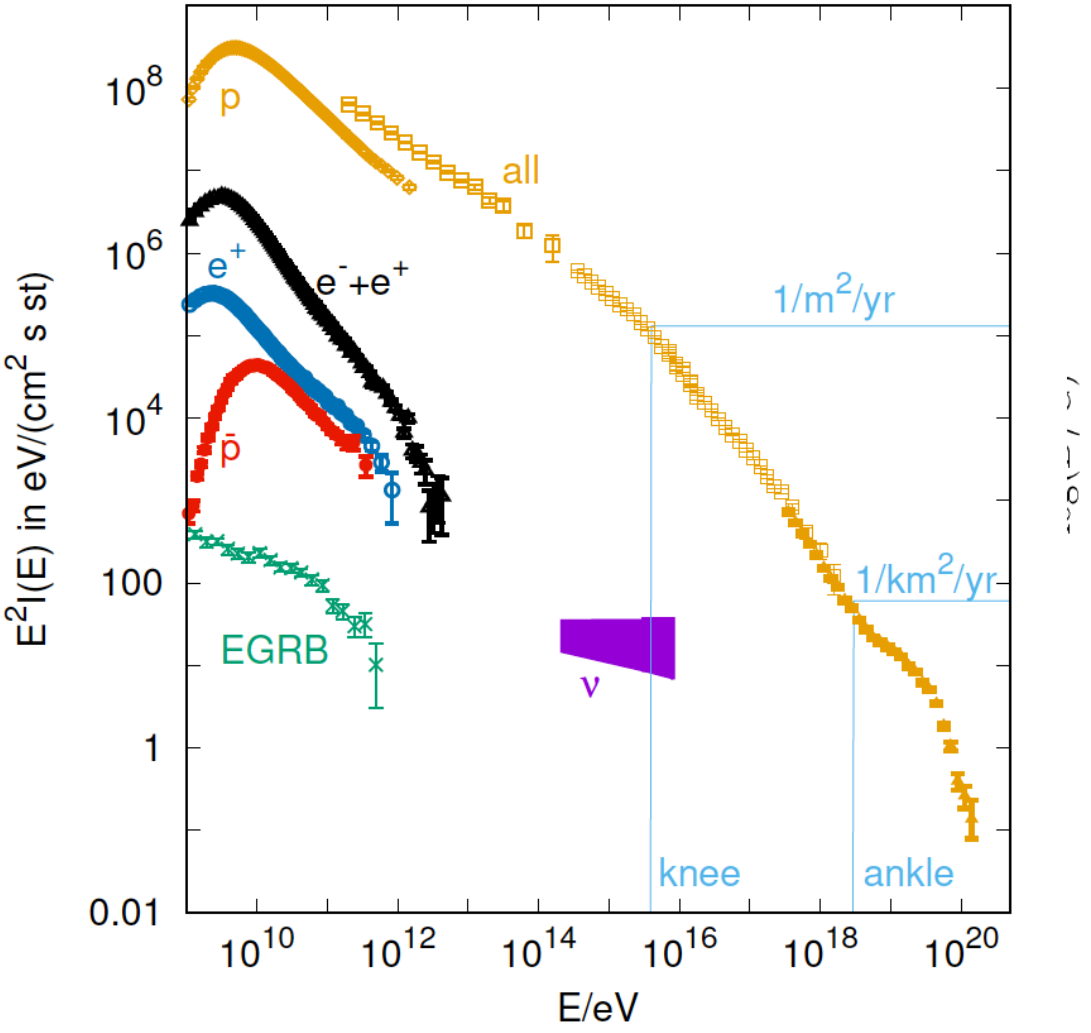
FIG. 2. The same as Figure 1, but for $\hat{E} > 100$ TeV. The symbol convention is identical to Figure 1.



Extended Data Fig. 4 | LHAASO sky map at energies above 100 TeV. The circles indicate the positions of known very-high-energy γ-ray sources.

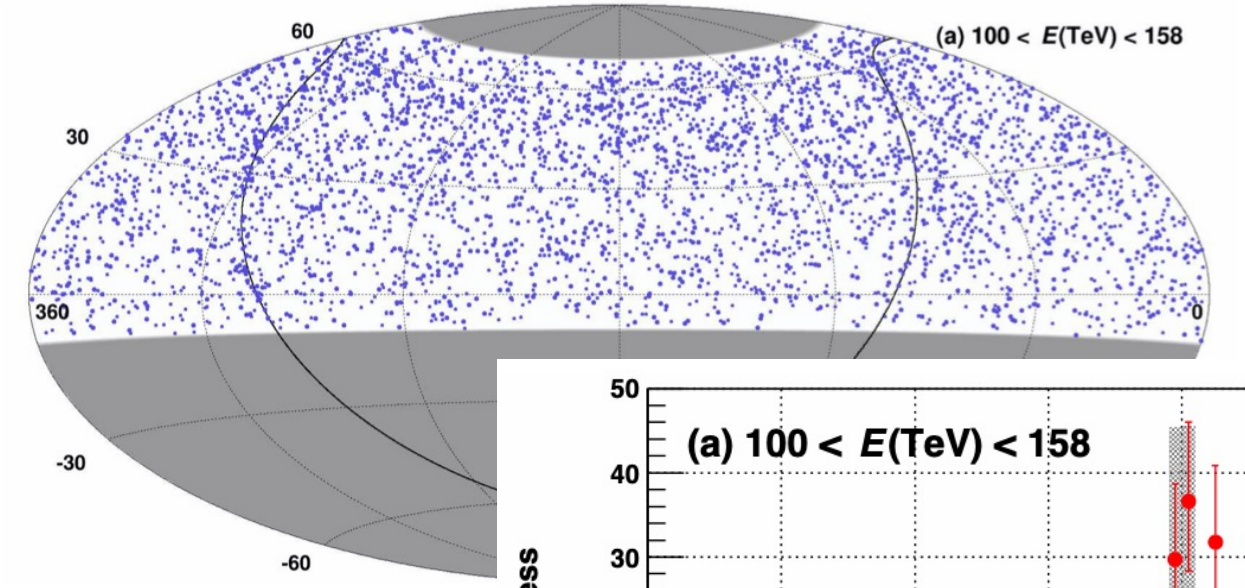
Nature, May 17 2021

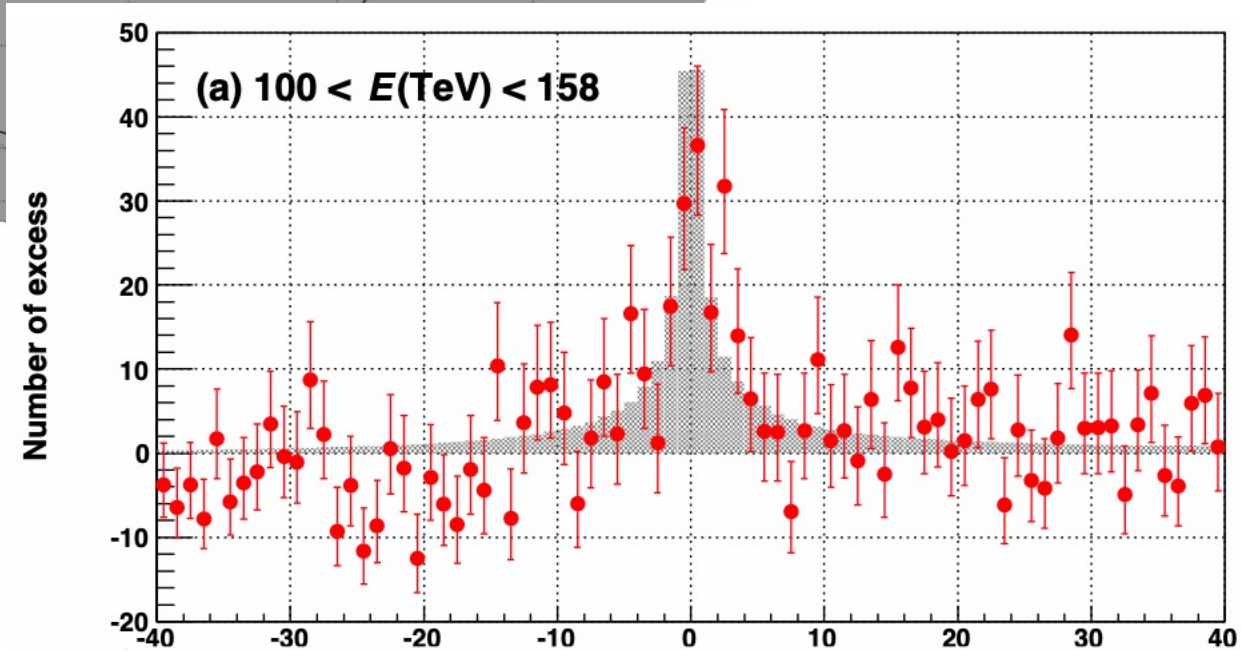
Cosmic rays/ neutrino and gamma



From M.Kachelriess and D.S. Prog. Part. Nucl. Phys. 1904.08160

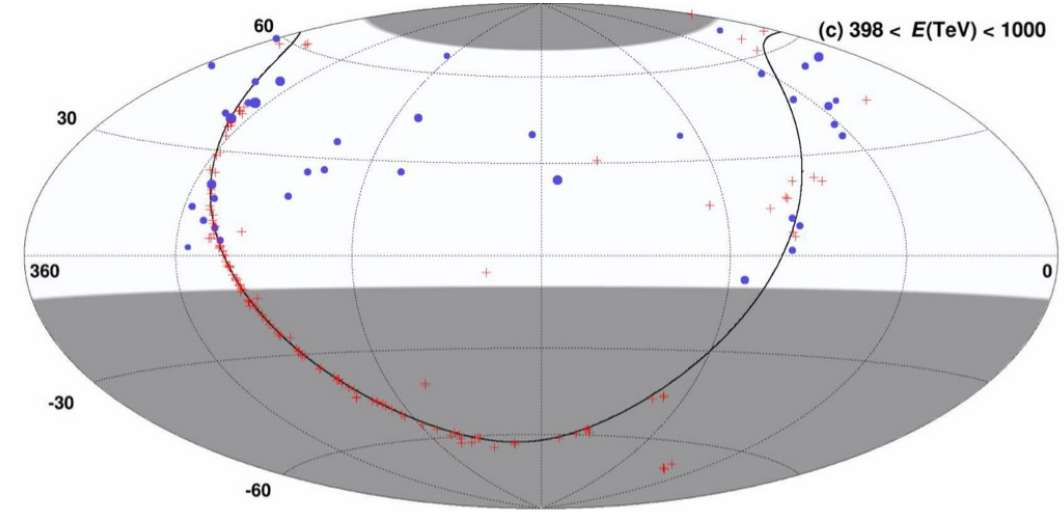
Tibet AS-q gamma-ray sky

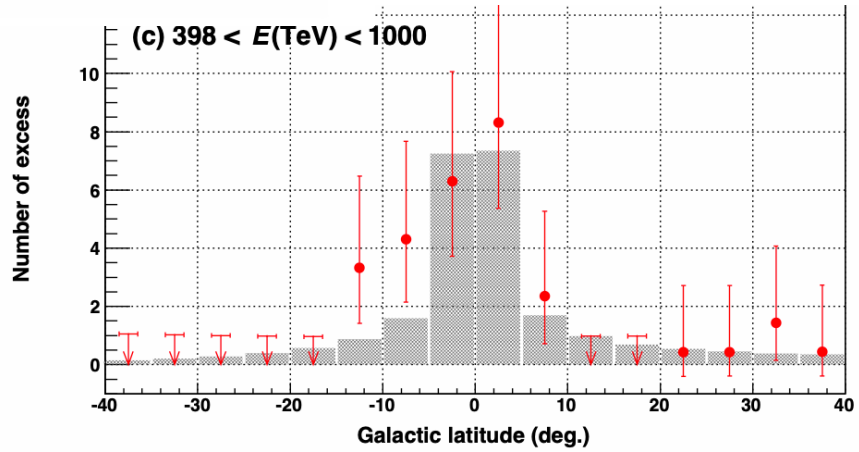




arXiv:2104.05181

Tibet AS-g gamma-ray sky

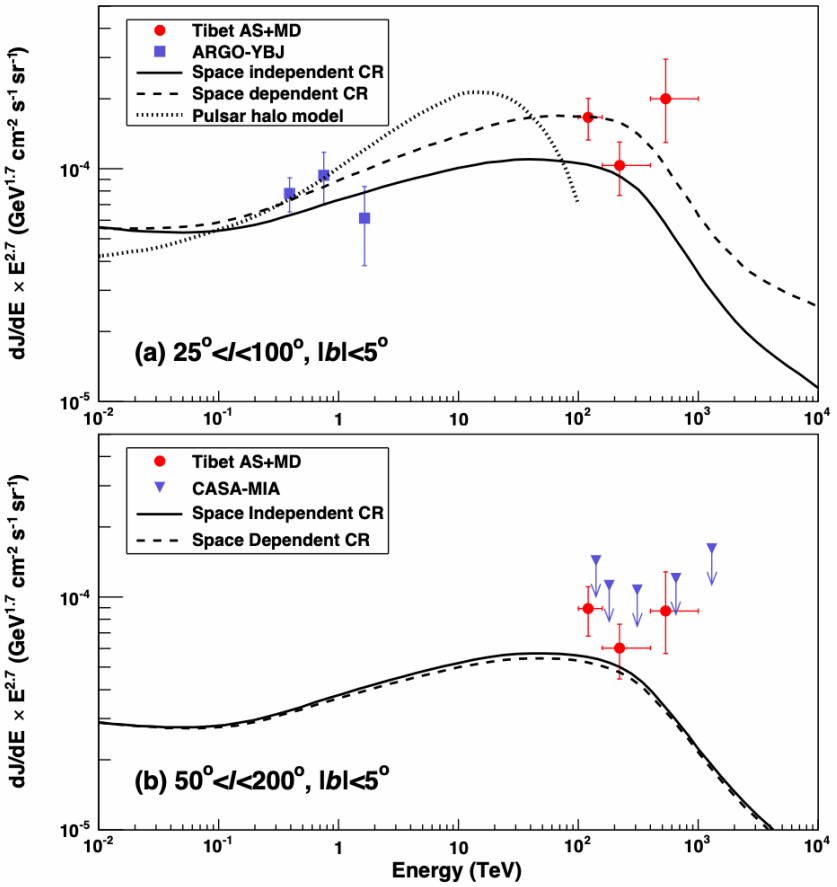




Hadron regection factor 1/10^6

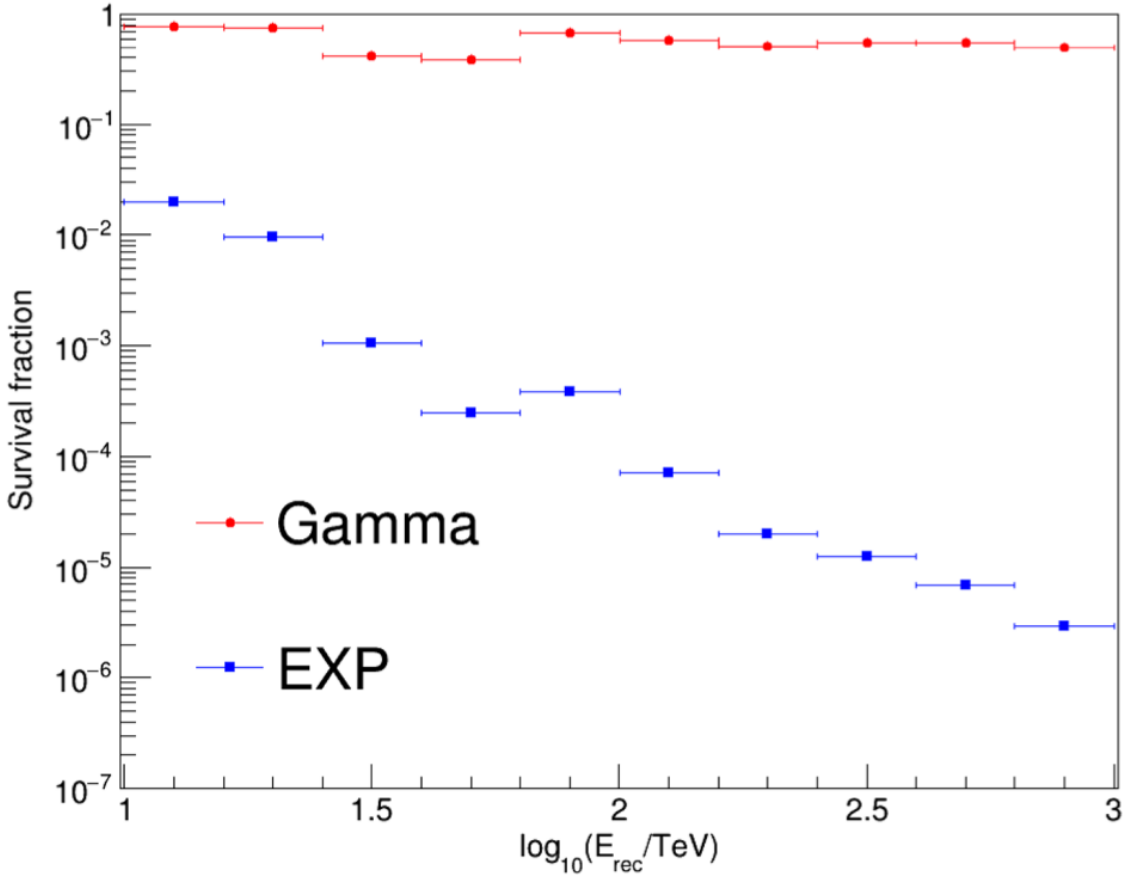
arXiv:2104.05181

Tibet AS-g diffuse gamma-rays



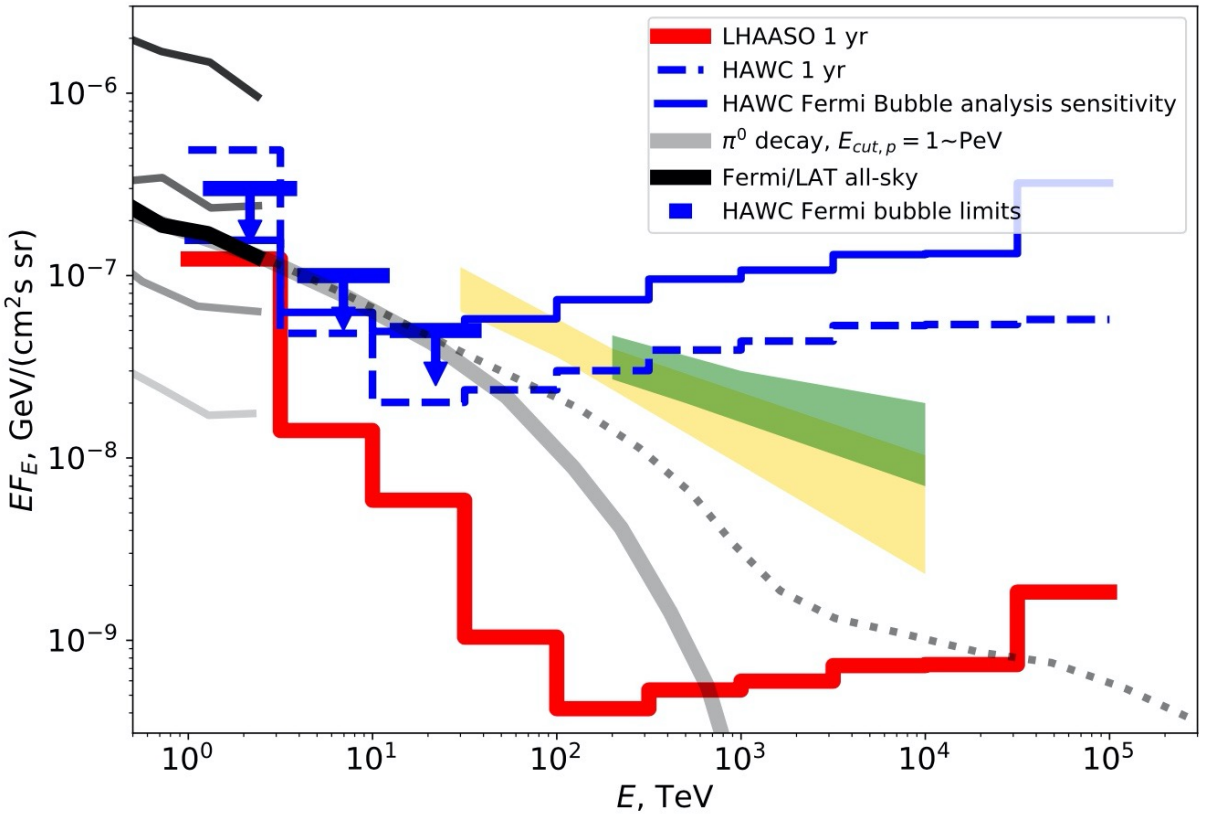
arXiv:2104.05181

LHAASO hadron cut 2021



LHAASO talk ICRC Jul 2021

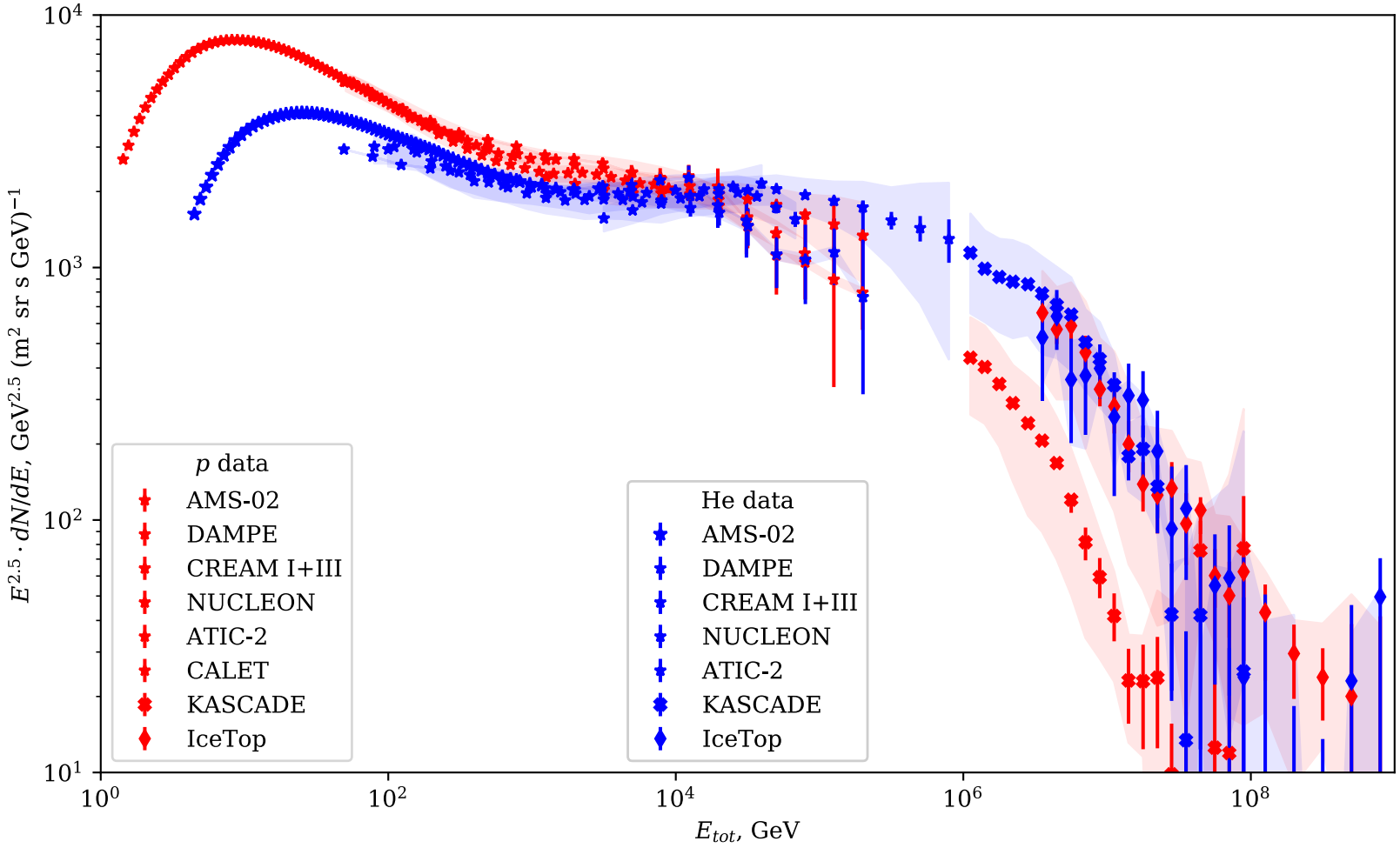
HAWC and LHAASO sensitivity to diffuse gamma



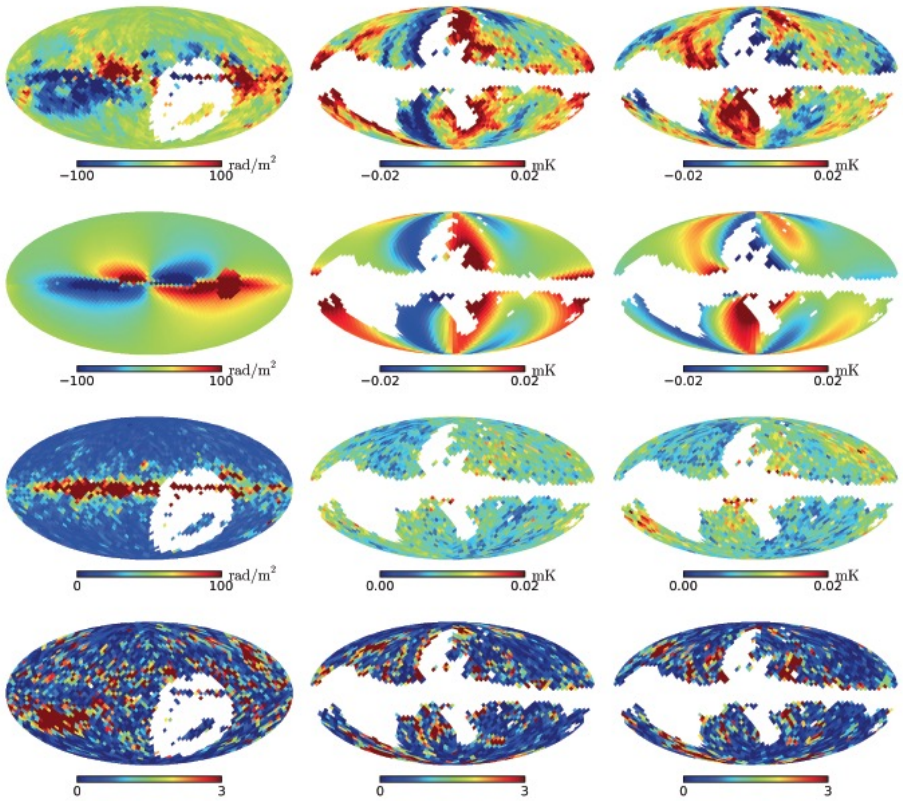
A.Neronov and D.S. , astro-ph/2001.11881

Cosmic rays at knee

Local cosmic ray flux

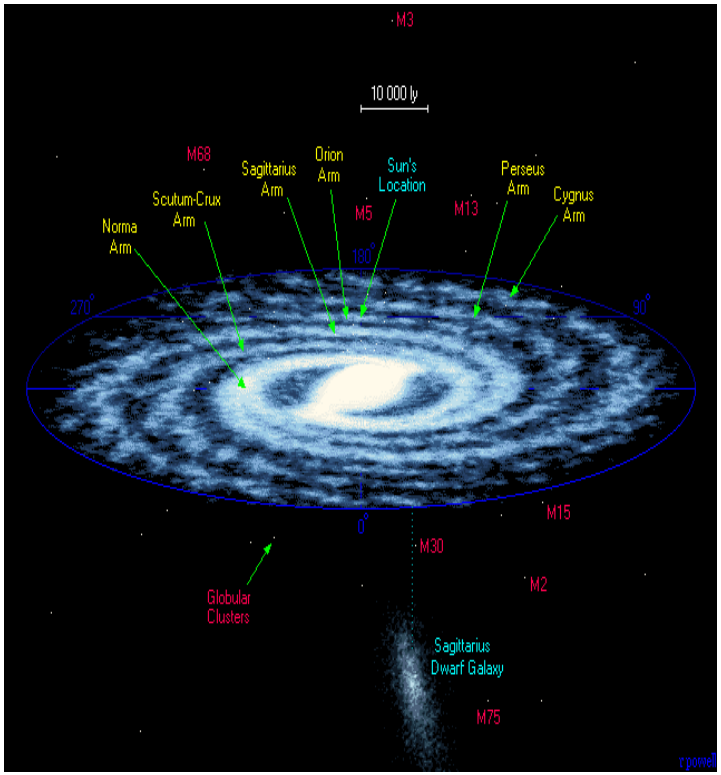


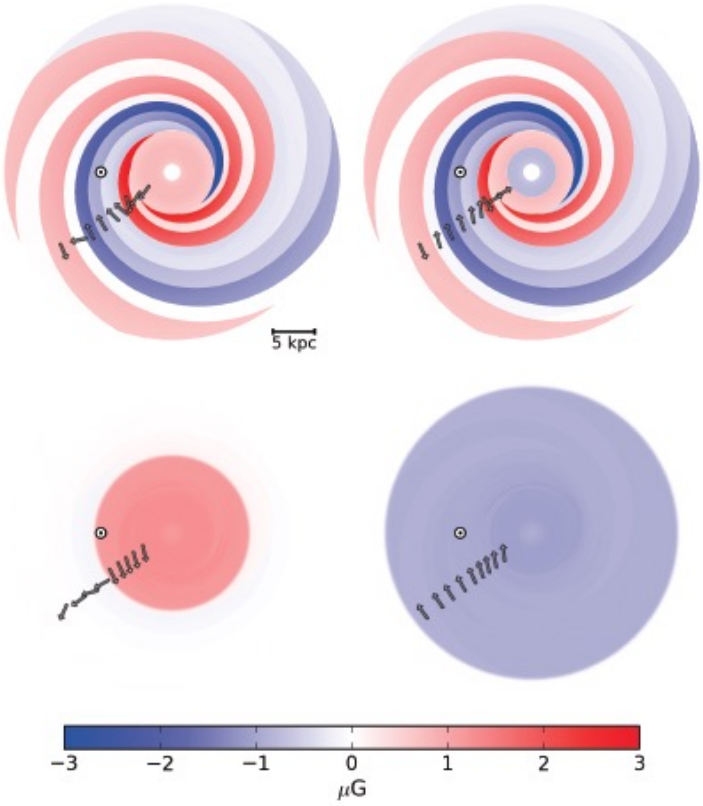
Synchrotron/RM maps



From R.Jansson & G.Farrar, arXiv:1204.3662

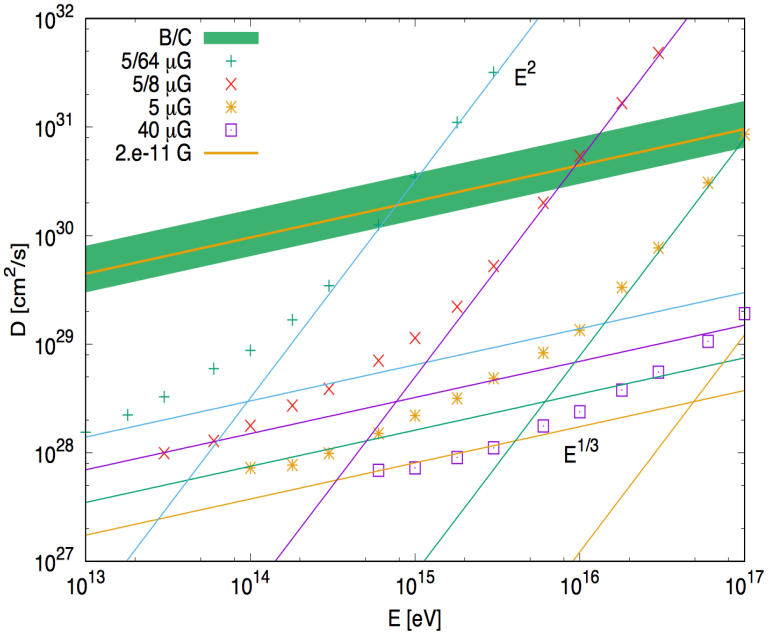
Galactic magnetic field: disk

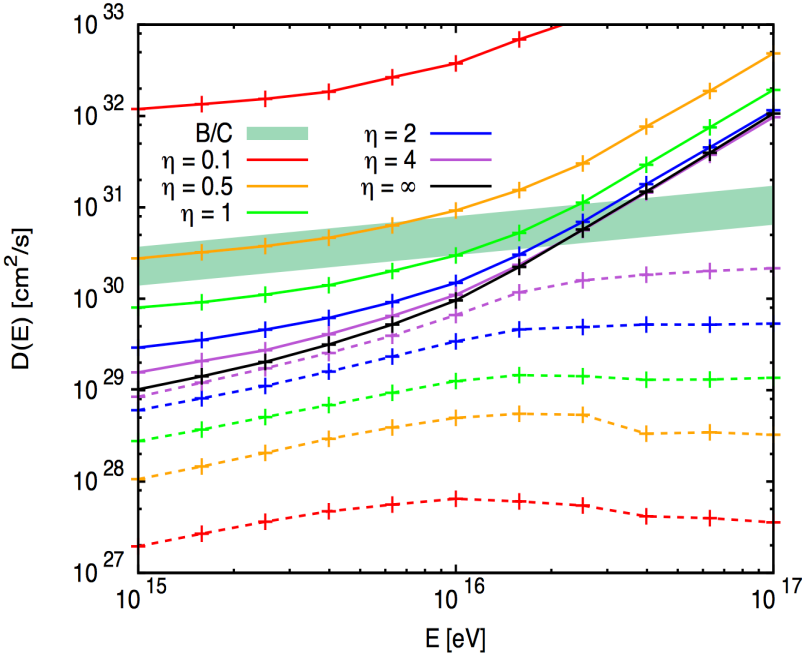




R.Jansson & G.Farrar, arXiv:1204.3662

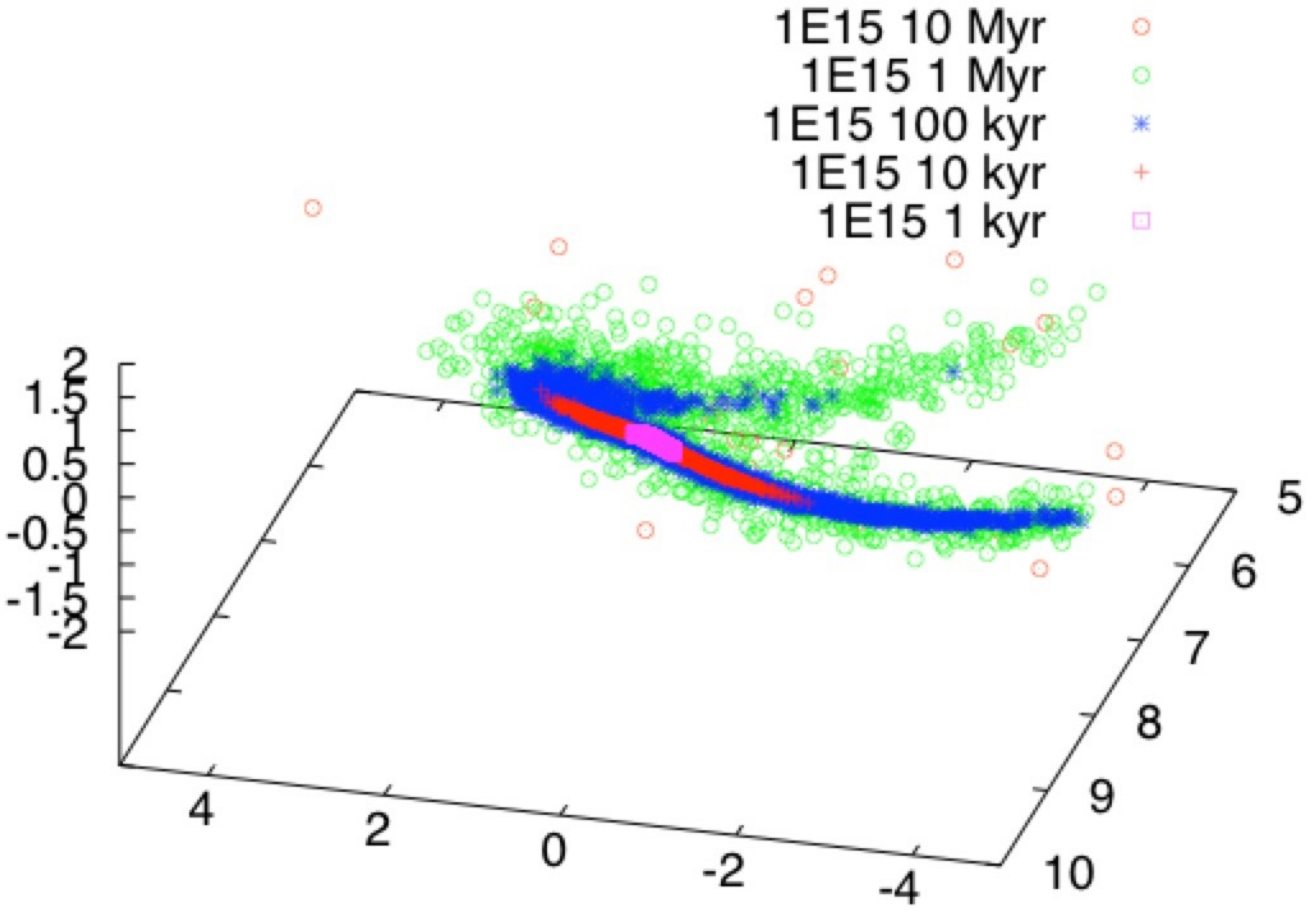
Cosmic ray diffusion in regular and turbulent magnetic field





Giacinti et al, 1710.08205

Proton flux at 1 PeV

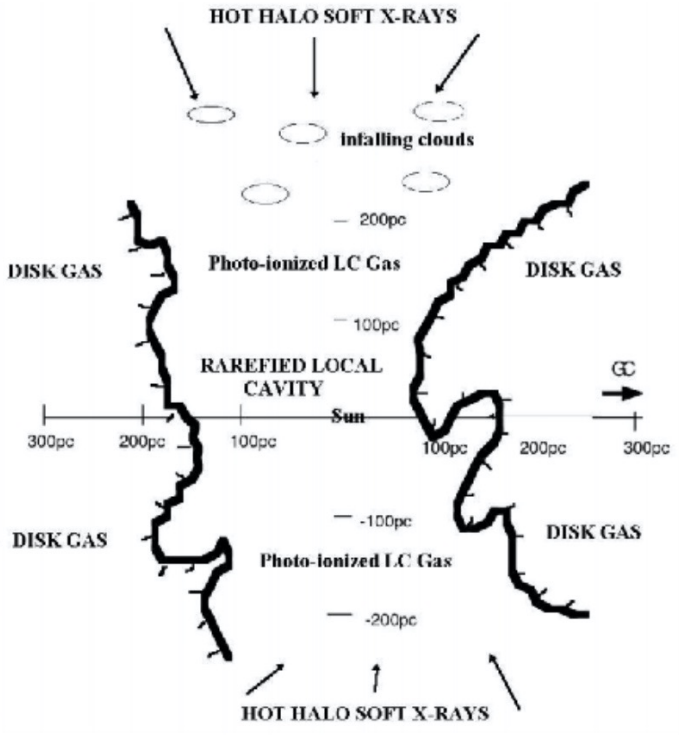


Model of propagation (Motivations for Local MF)

The immediate Galactic vicinity of the Sun is dominated by a low density, ionized structure, commonly referred to as the "Local Bubble". It is bounded by relatively higher density material as traced by Sodium and Calcium absorption line measurements, as well as extinction data (Lallement et al. 2003; Welsh et al. 2010; Lallement et al. 2014). Such measurements show a roughly cylindrical structure with a typical radius of about 100-175 pc, with missing ends towards the north and south Galactic poles. This structure is generally interpreted as being due to strong stellar winds and supernovae evacuating the space, with "blow-outs" in the directions out of the Galactic plane (Lallement et al. 2003).

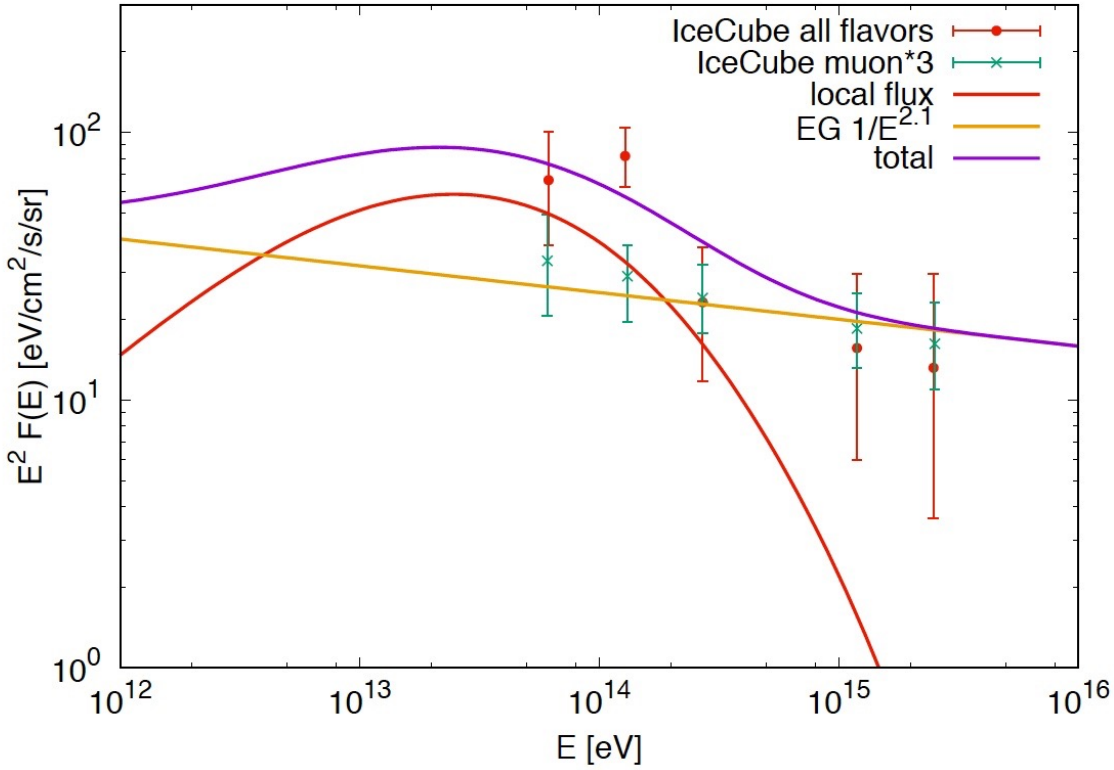
analysis from Lehner et al. (2003) to estimate the gas pressure, density and turbulence, they derived a magnetic field strength of $B_\perp = 8^{+5}_{-3}\mu G$, equivalent to a magnetic pressure of $P_B/k \approx 18,000$ K cm^{-3}, consistent with the results from the X-ray and the EUV observations.

Ilija Medan & Anderson 2019
arXiv 1901.07692



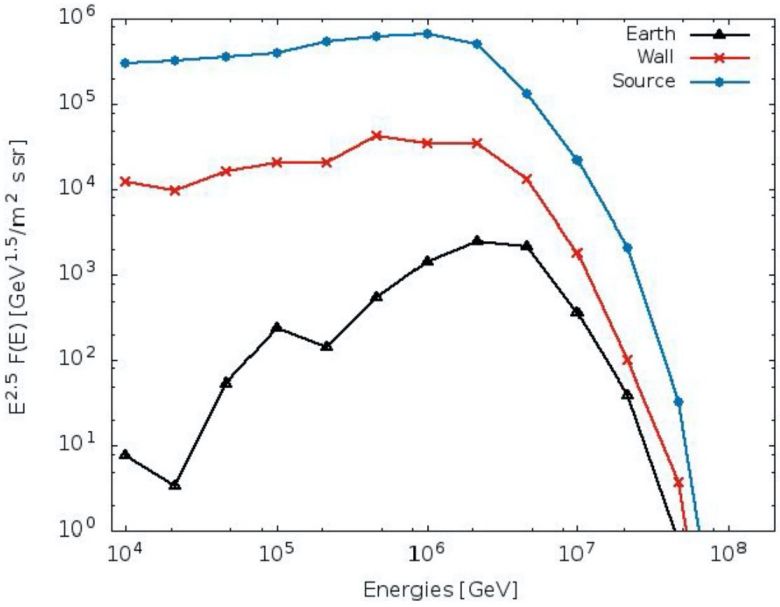
Welsh & Shelton 2009 arXiv
0906.2827

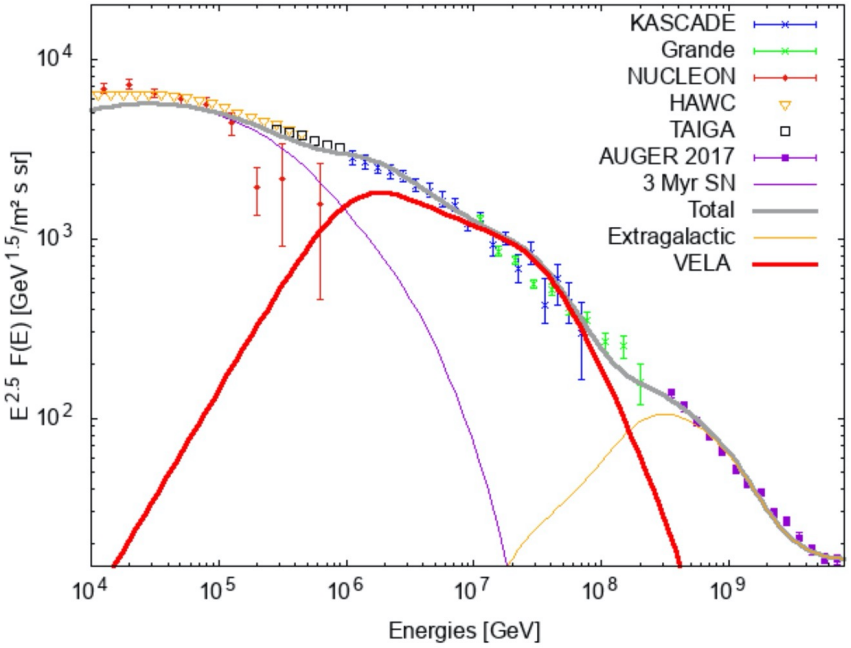
Local bubble neutrino flux



K.Andersen, M.Kachelriess and D.Semikoz, arXiv:1712.03153

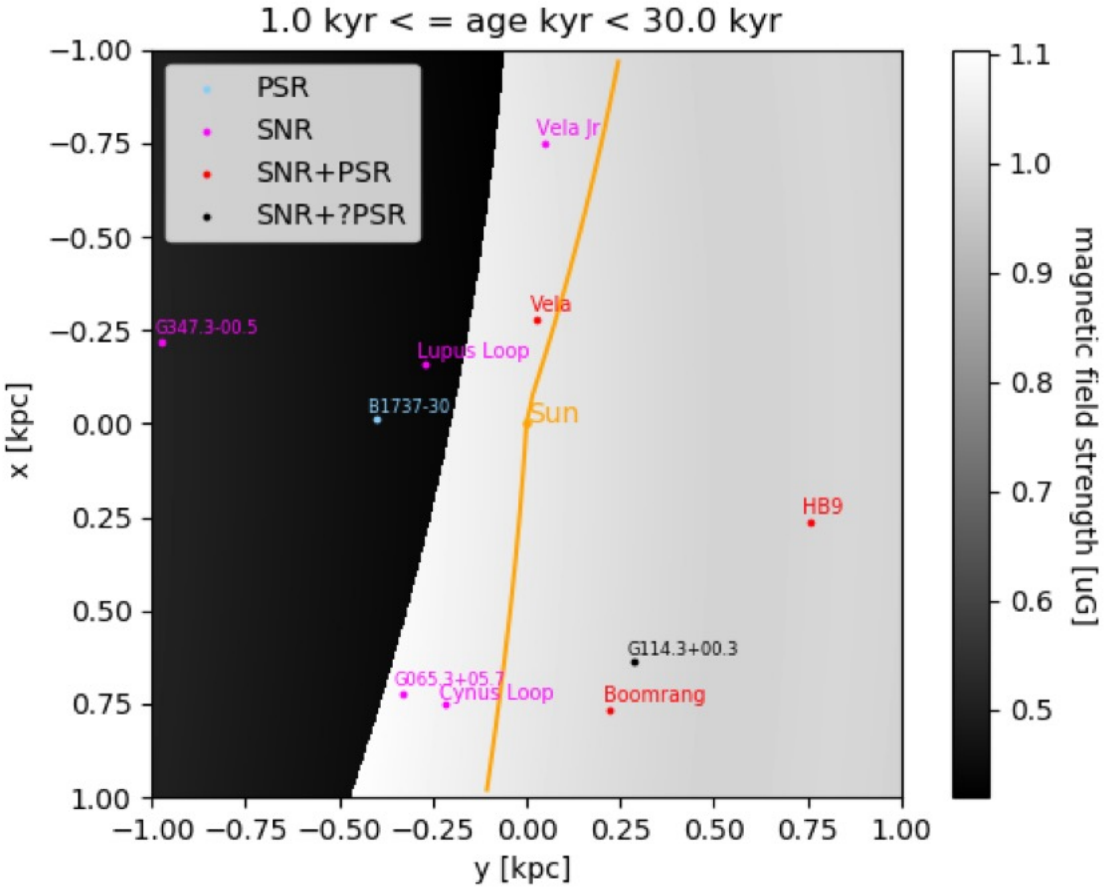
Spectrum in presence of Local bubble





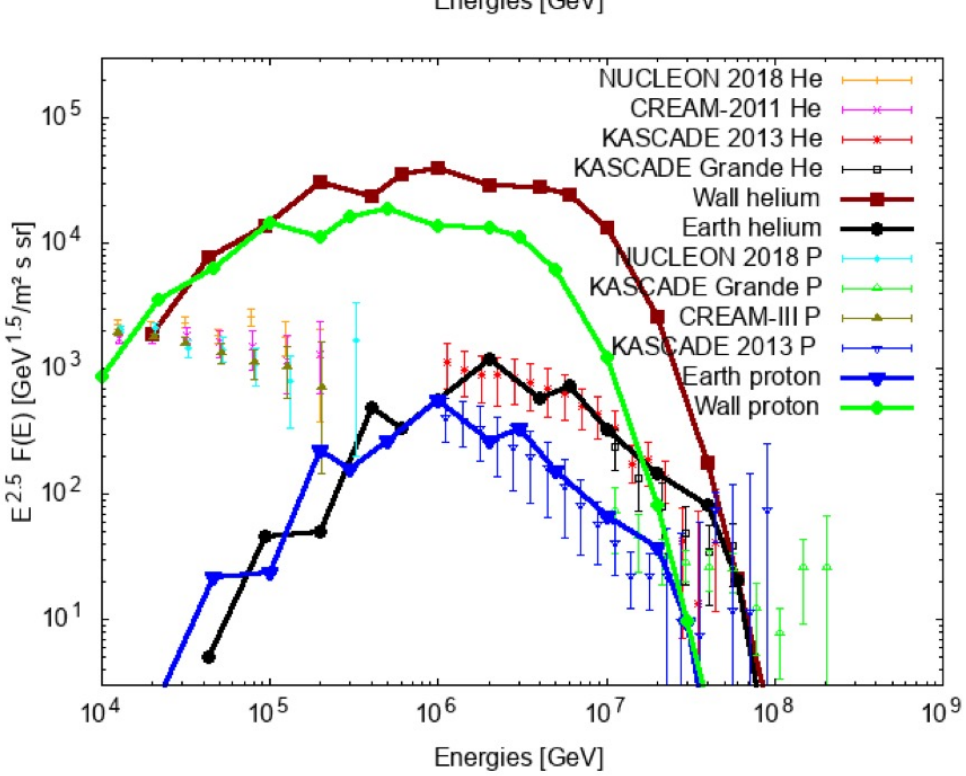
M.Bouyahiaoui, M.Kachelriess and D.S., arXiv:1812.03522

Nearby young SN



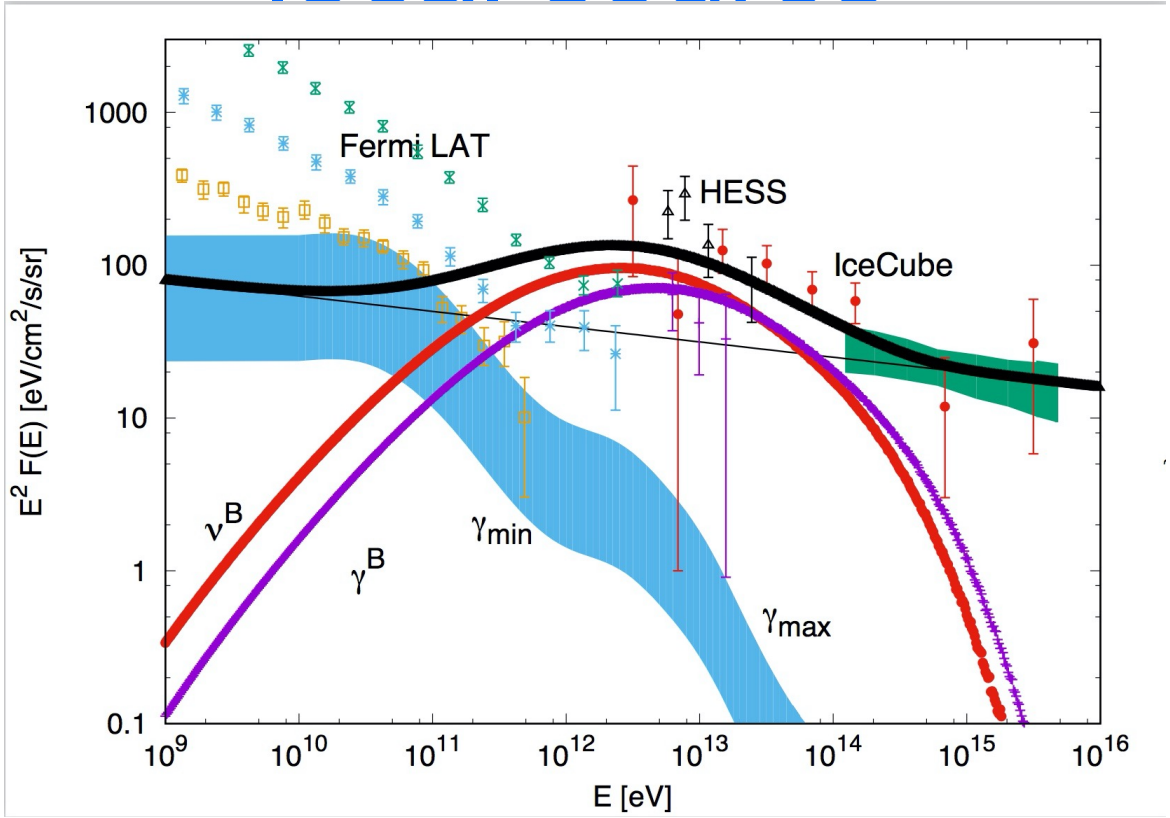
M. Bouyahiaoui, M. Kachelriess, and. D.S. , astro-ph/2001.00768

Cosmic ray protons and He from Vela



M.Bouyahiaoui, M.Kachelriess and D.S. , arXiv:2001.00768

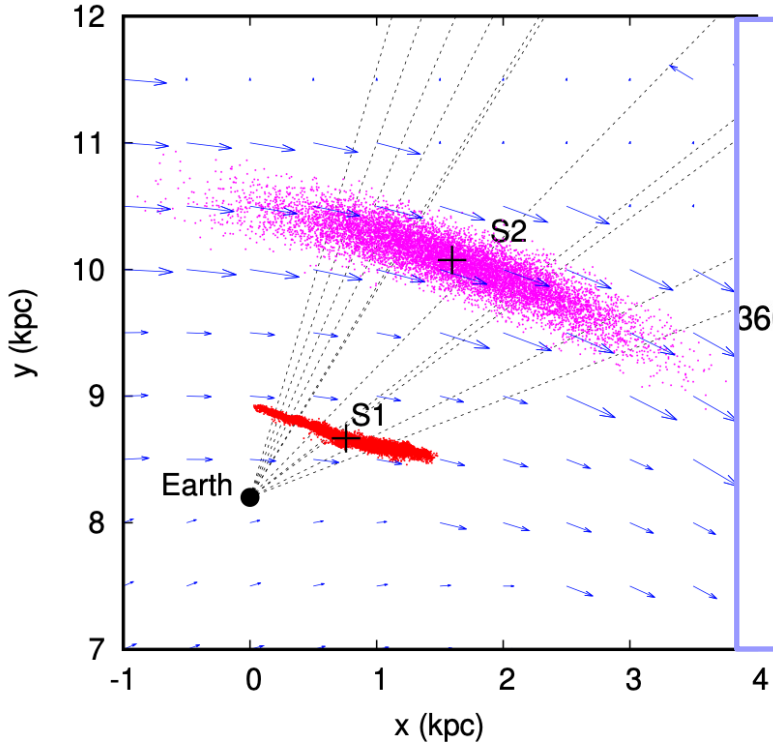
IceCube + Fermi LAT+HESS : local source

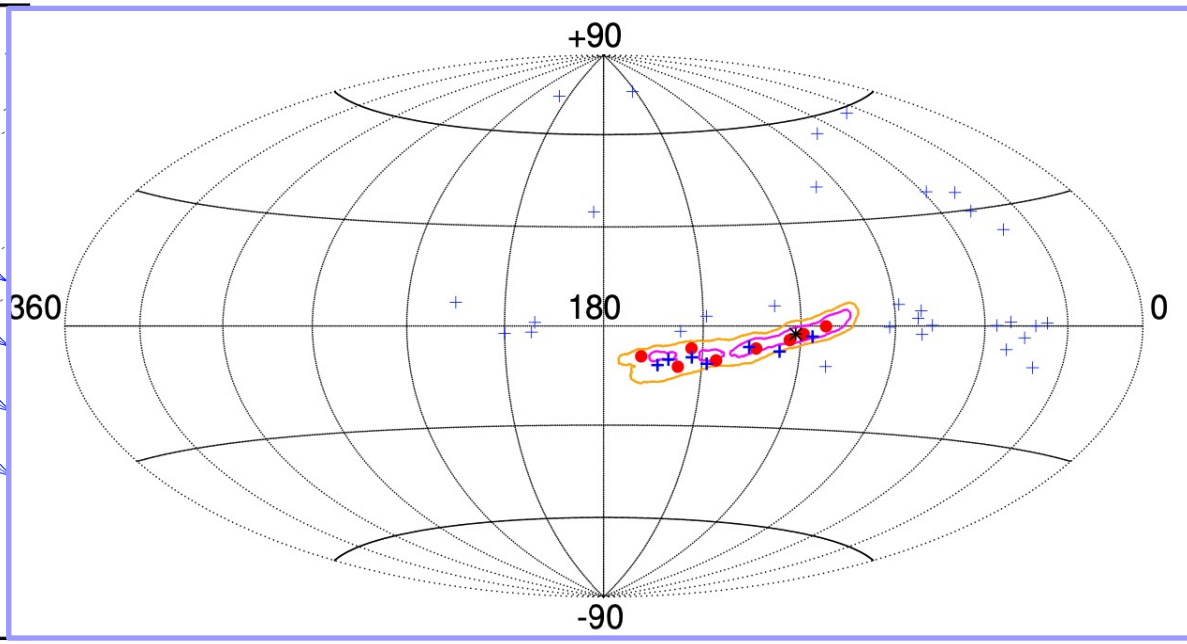


M.Bouyahiaoui, M.Kachelriess and D.S. , arXiv:2001.00768

Cosmic rays from nearby sources seen in gamma-ray and neutrino data

Cosmic rays from local sources producing gamma-rays

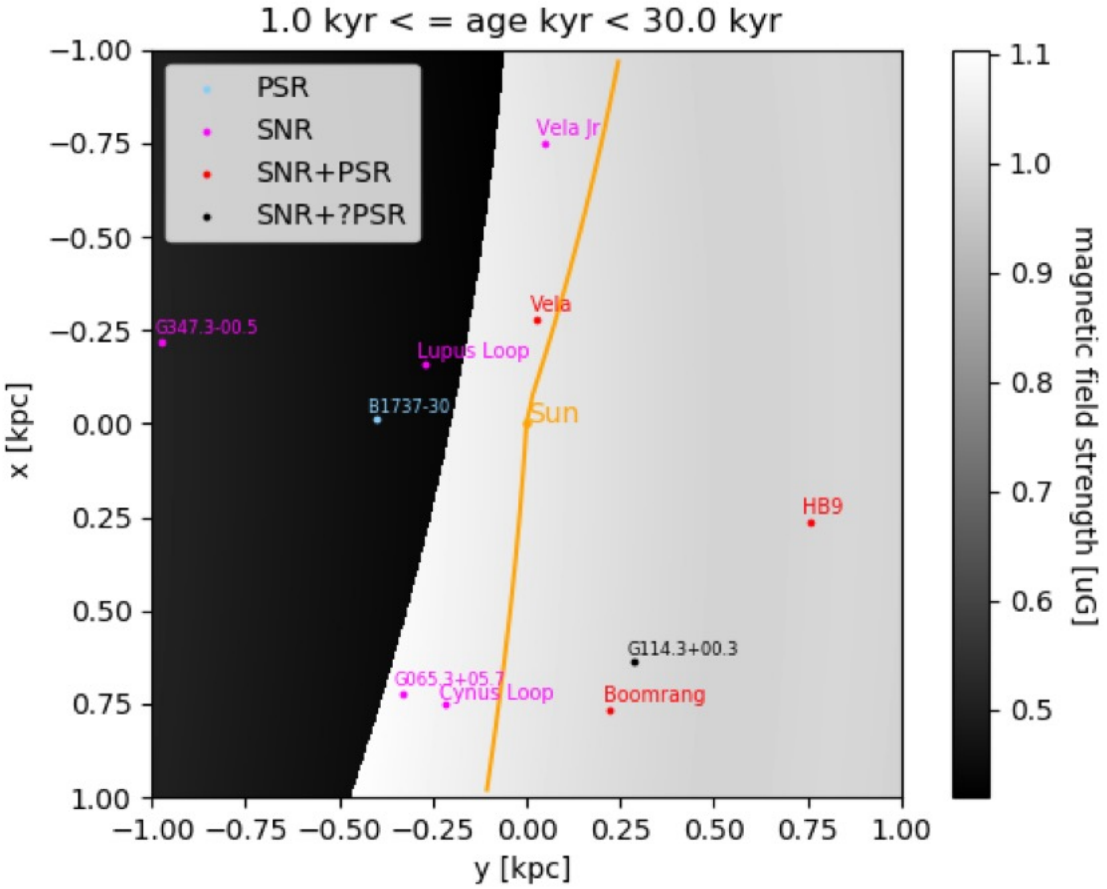




Tibet gamma-ray data E>400 TeV
S=3400 m2 3700 hours 0.5 yr

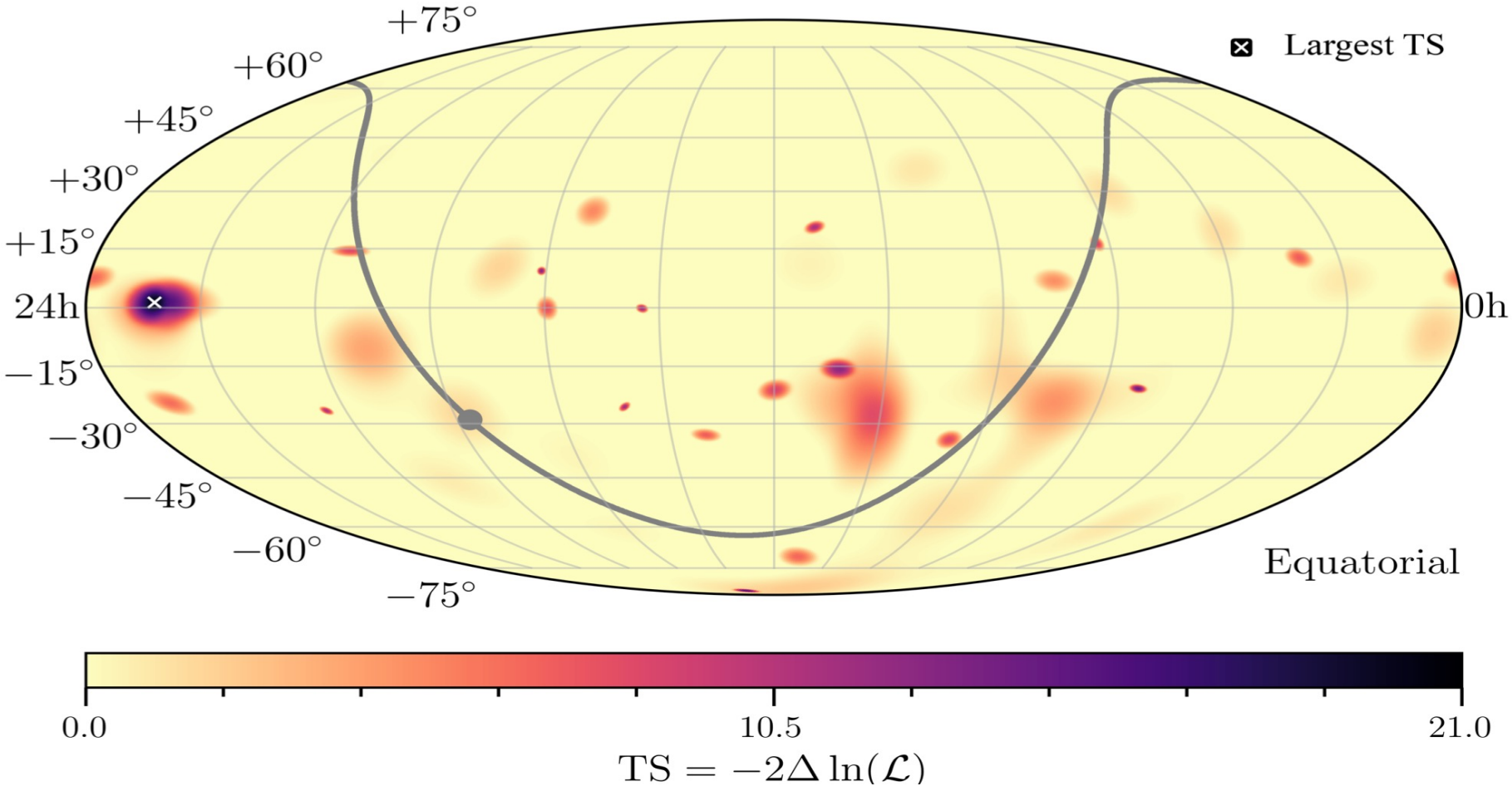
G. Giacinti, T. Abounnasr, A. Neronov and D.S. , astro-ph/2203.11052

Nearby young SN



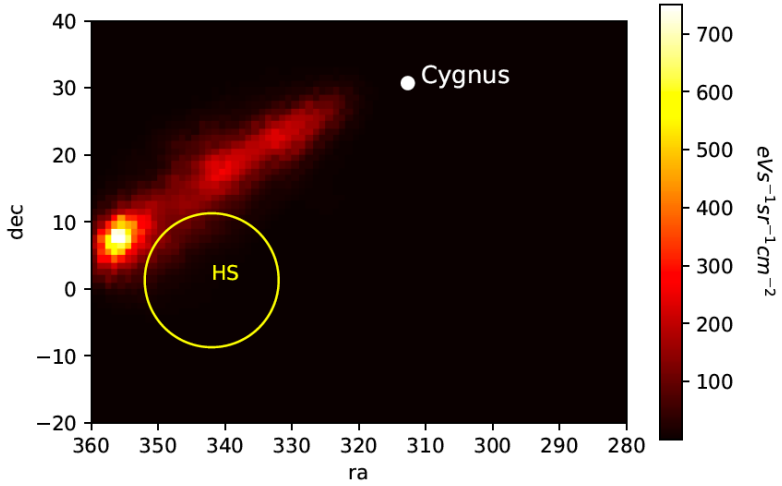
M. Bouyahiaoui, M. Kachelriess, and. D.S. , astro-ph/2001.00768

Sky map HESE 7.5 years

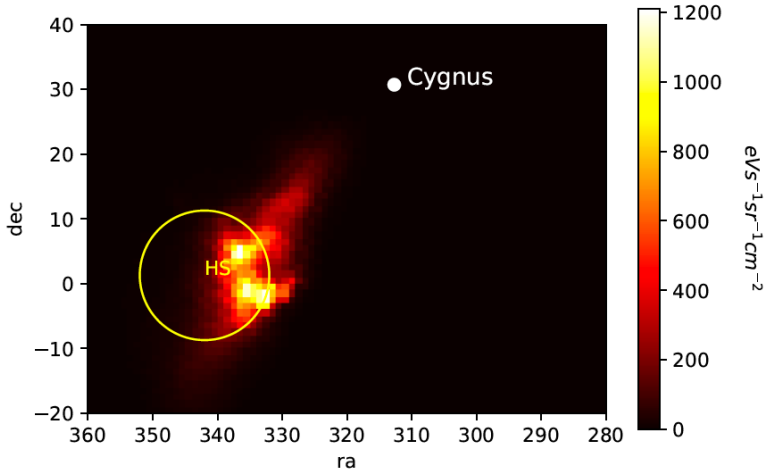


IceCube, astro-ph/2011.03545

Cygnus Loop cosmic rays starting at 720 pc and produce neutrinos on 250 pc from Earth dust cloud 45 degrees outside of Galactic plane!



JF12 model



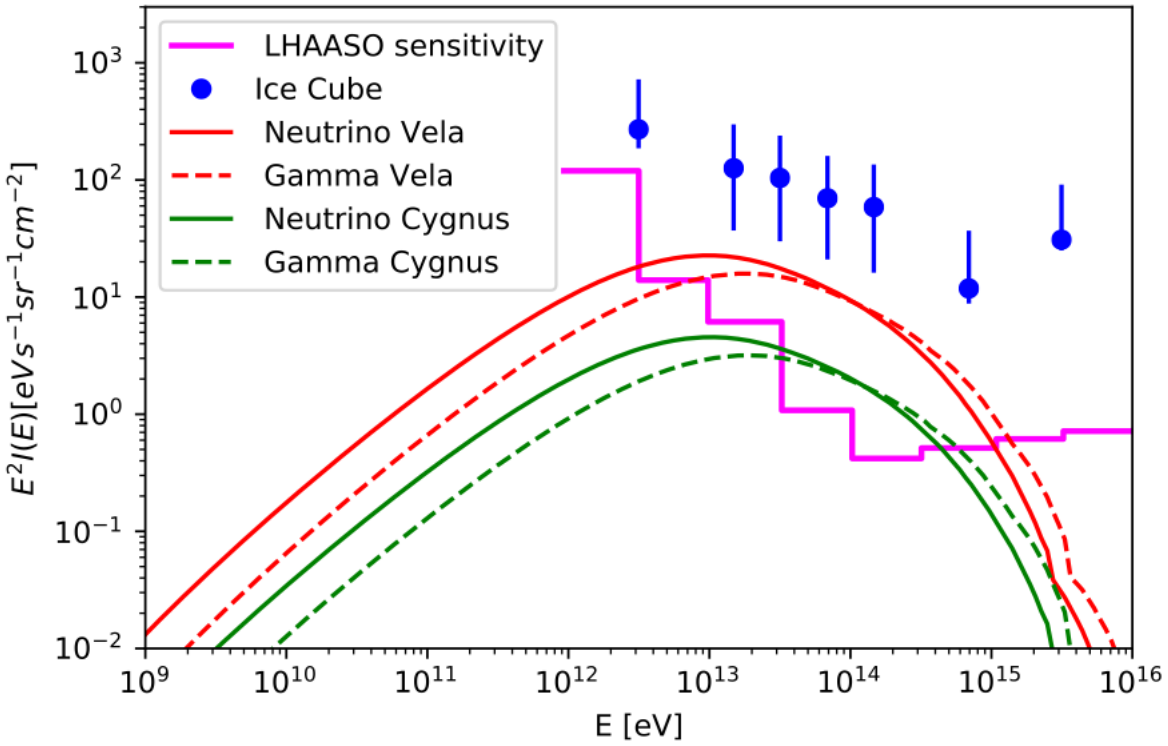
PS model

4 events in hot spot /3 predicted by model

3D Gaia dust maps Lallement et al 2019/2021

M. Bouyahiaoui, M. Kachelriess, and. D.S. , astro-ph/2105.13378

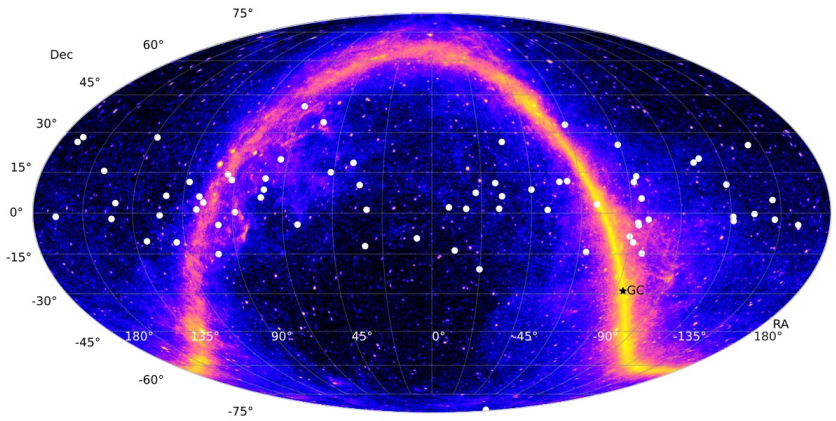
Vela and Cygnus loop neutrinos

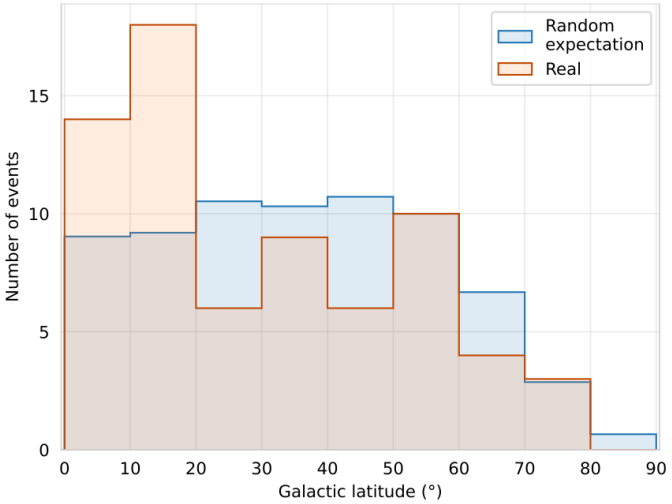


Cygnus loop 2-3 events, Vela 9-18 events. out of 1 kpc sources 1-2 events

M. Bouyahiaoui, M. Kachelriess, and. D.S. , astro-ph/2105.13378

IceCube muon neutrinos from Galaxy at 20 degree scale



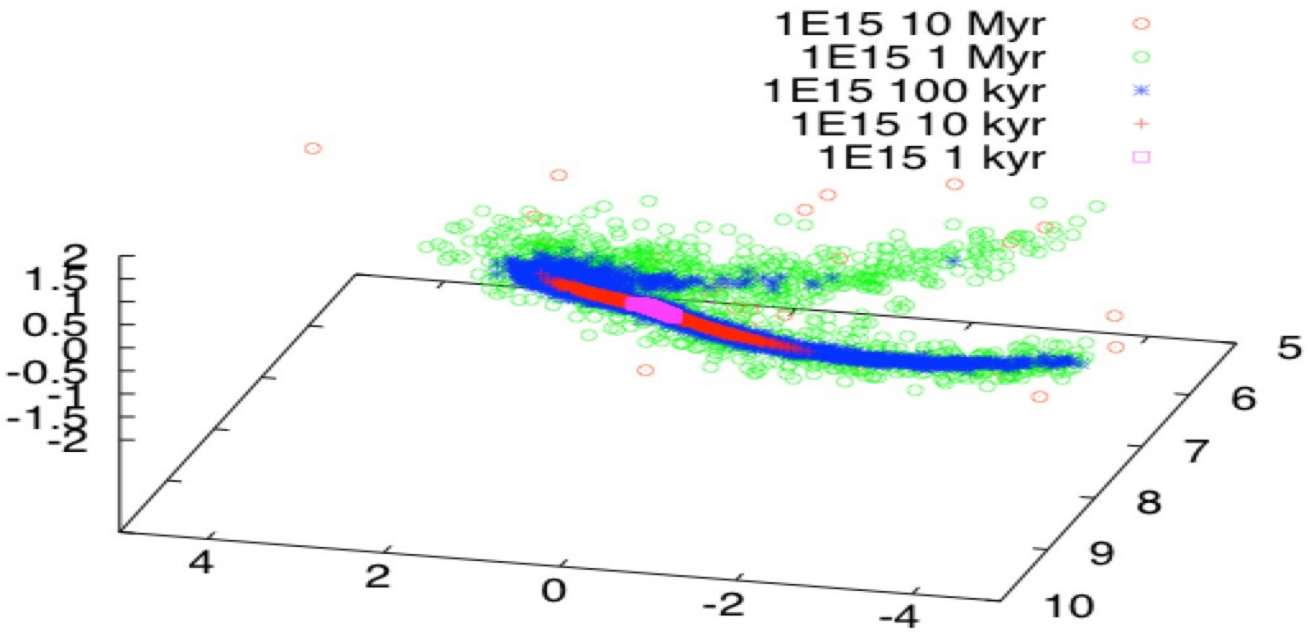


4.3 sigma excess in 20 degrees from galactic plane

70 events: 23 33% atmospheric background
20 28+-9% astro-anisotropic: galactic
27 39% astro-isotorpic: extragalactic

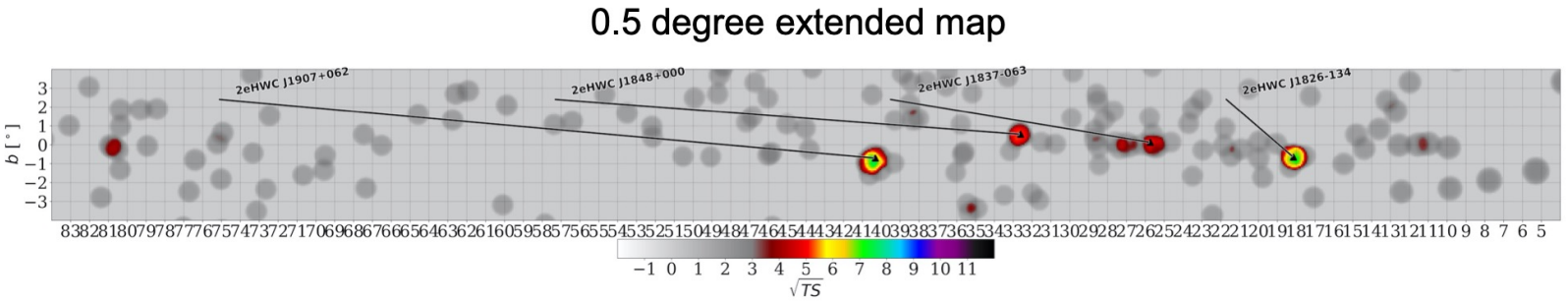
Yu.Kovalev, A.Plavin and S.Troitsky , 2208.08423

Proton flux at 1 PeV



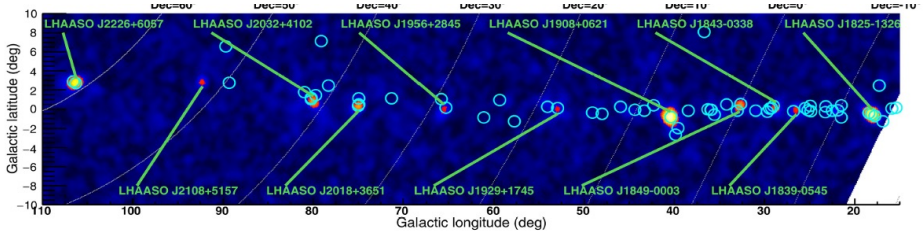
100 kyr in disk / 300 kyr some flux / at 1Myr in halo

Very few sources expected at 1 PeV



More than half unidentified and mostly extended

Talk by Sabrina Casanova



Extended Data Fig. 4 | LHAASO sky map at energies above 100 TeV. The circles indicate the positions of known very-high-energy γ-ray sources.

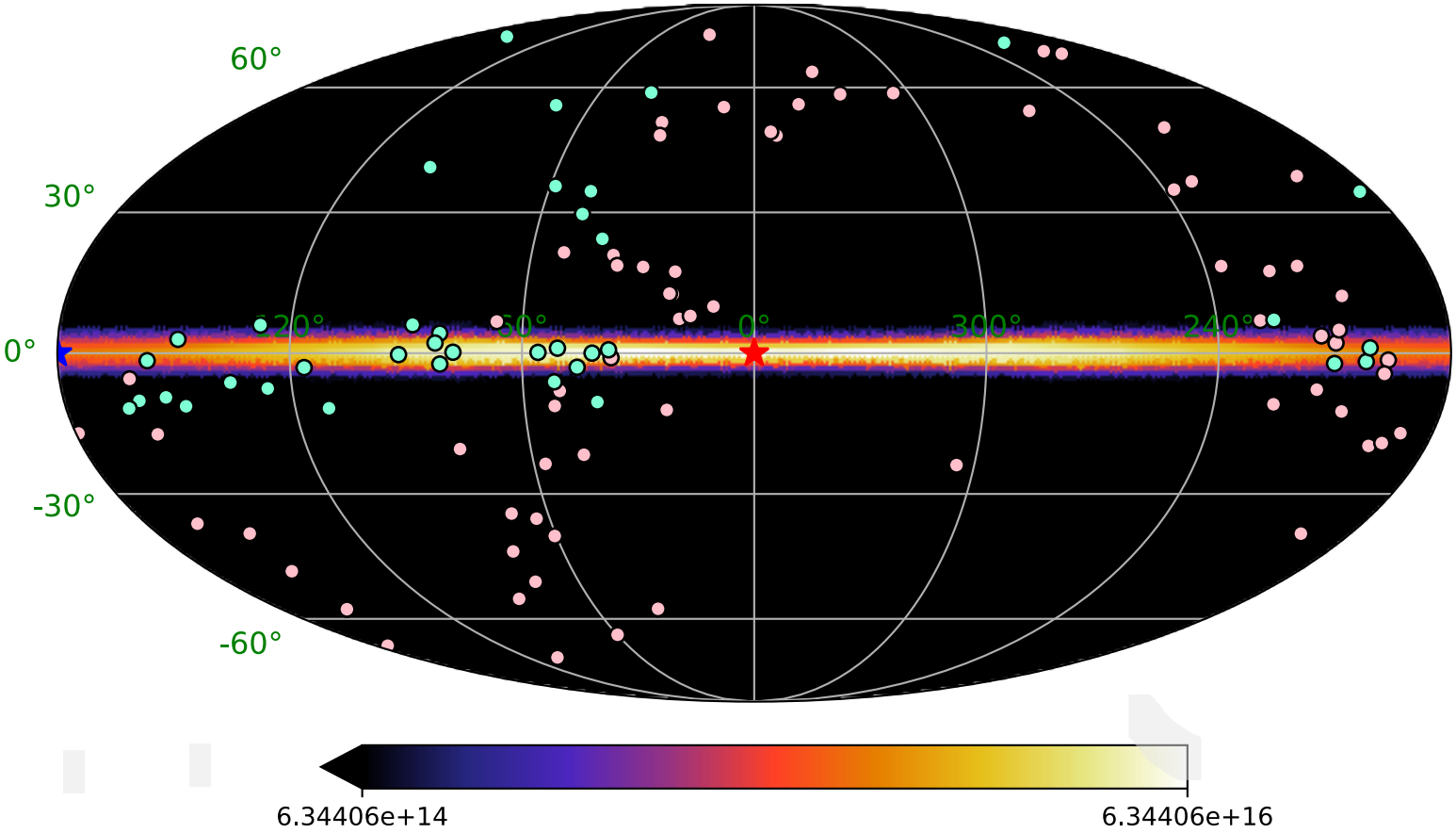
Nature, May 17 2021

LHAASO talk
By Ruo-Yu Liu

100 kyr 3 000 sources 1/10 or 1/30 accelerate to PeV and above 100 sources

300 kyr 1/10 of flux and another 200-300 sources

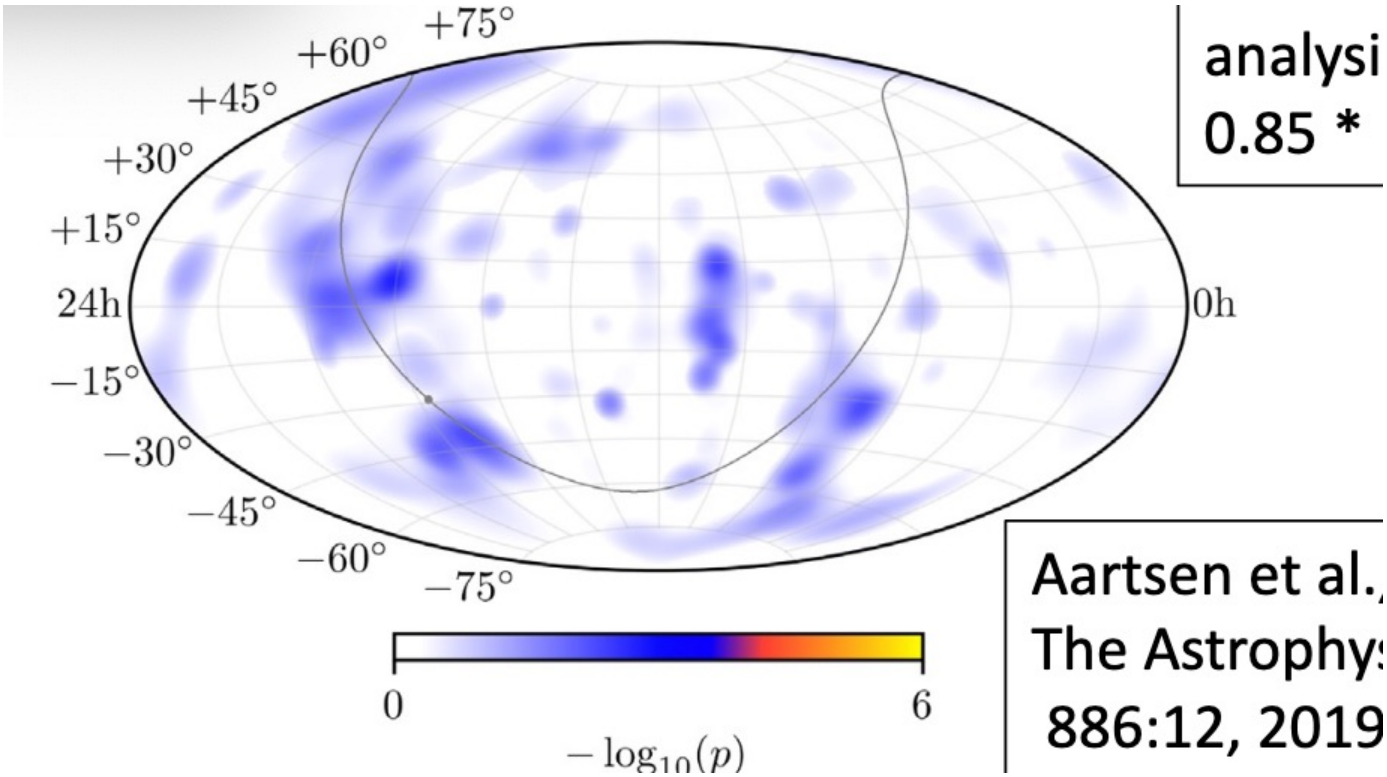
No signal in gamma-rays and neutrinos from galaxy outside of 1 kpc



1-2 events from 70 expected in disk

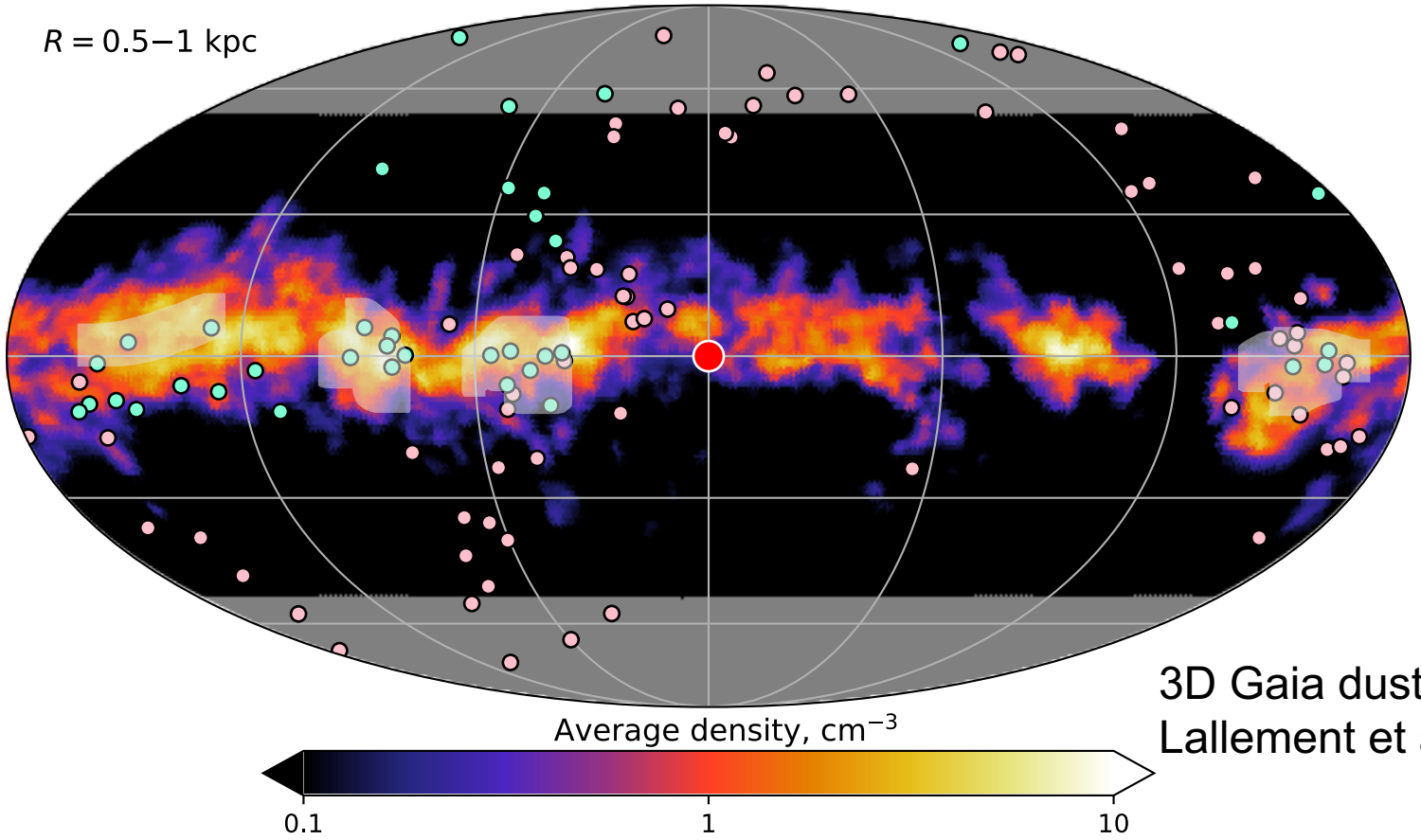
S. Koldobsky, A. Neronov and. D.S. , astro-ph/2209.xxxx

IceCube galactic plane HESE



From Dorothea's talk yesterday

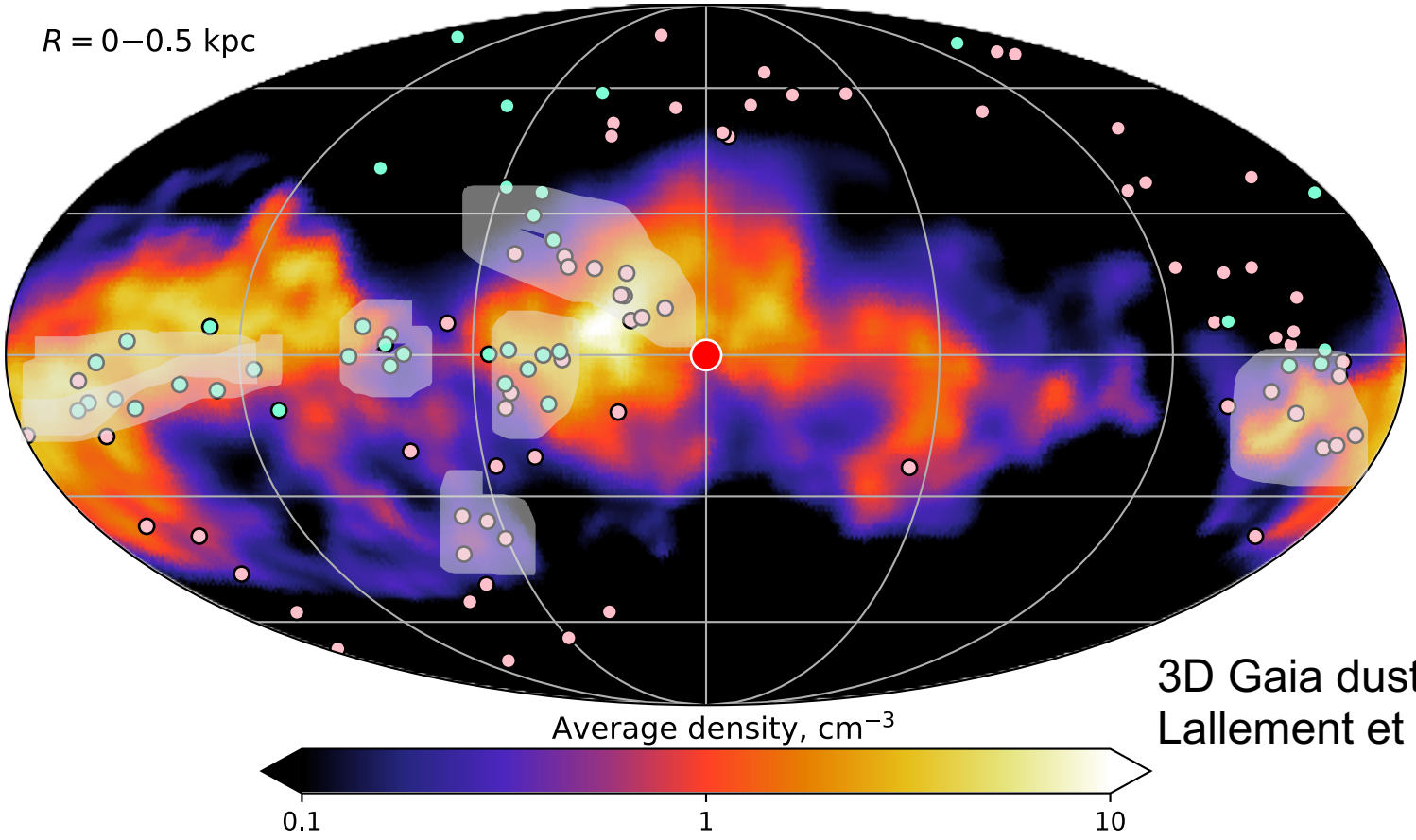
Signal in gamma-rays and neutrinos from galaxy 0.5-1 kpc



3D Gaia dust maps
Lallement et al 2022

S. Koldobsky, A. Neronov and. D.S. , astro-ph/2209.xxxx

Signal in gamma-rays and neutrinos from galaxy inside of 0.5 kpc



3D Gaia dust maps
Lallement et al 2022

S. Koldobsky, A. Neronov and. D.S. , astro-ph/2209.xxxx

Summary

- First detection of diffuse gamma-ray background at E>100 TeV by Tibet AS-gamma is keystone for understanding of cosmic ray physics in outer Galaxy. LHASSO with 10 times better sensitivity can do revolution in 100 TeV gamma-ray astronomy
- New 20 degree anisotropy in IceCube muon data put Galactic contribution at least to 50% of total.
- We start to see first local sources both in neutrinos and in gamma-rays. They are very bright and can be studied by km3 size detector. They should
- and will be studied by LHAASO