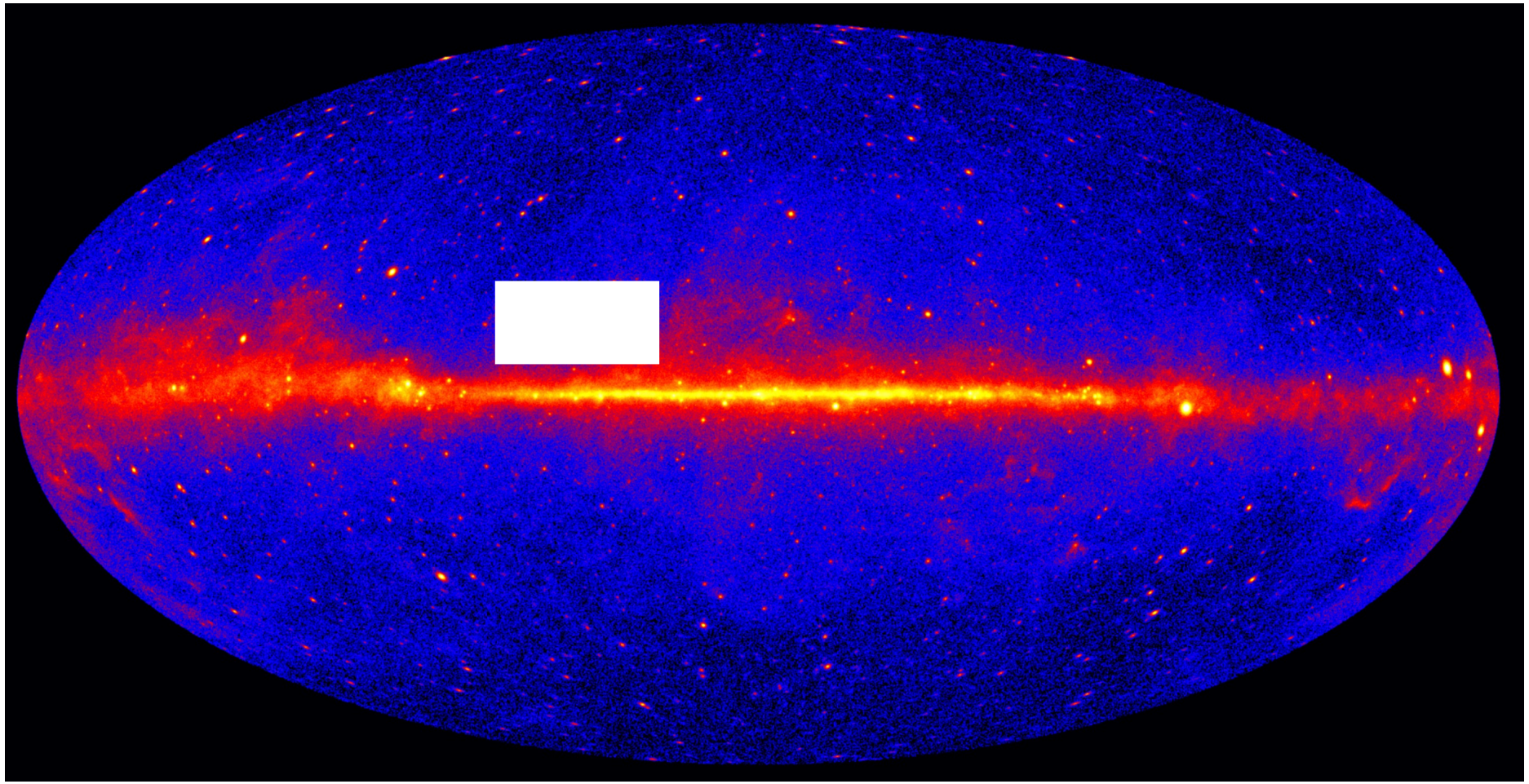
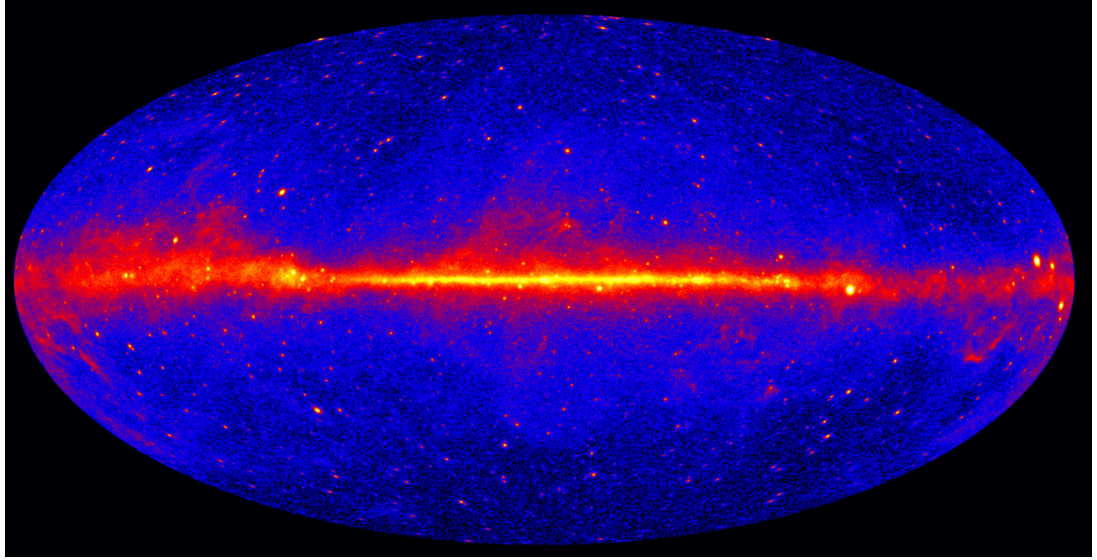
Diffuse gamma-ray emission from local sources

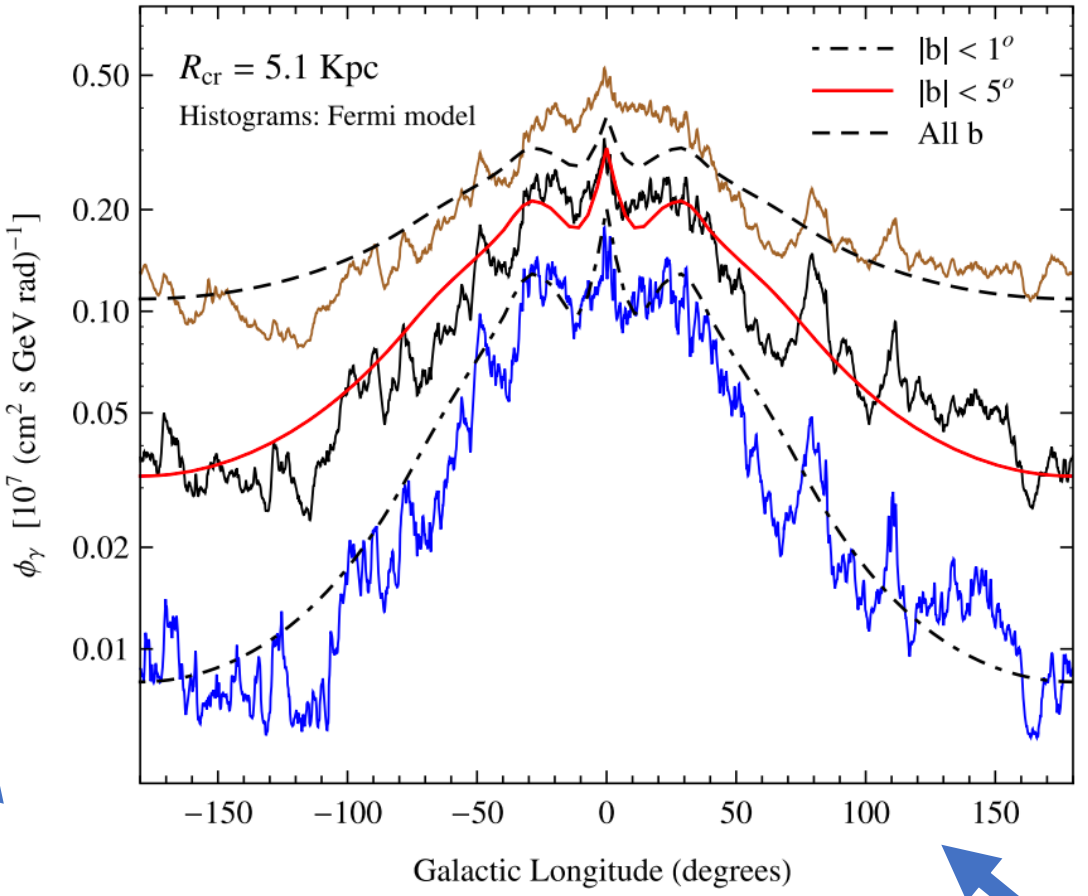
Sergey Koldobskiy (U of Oulu, Finland) et al.



Credit: NASA

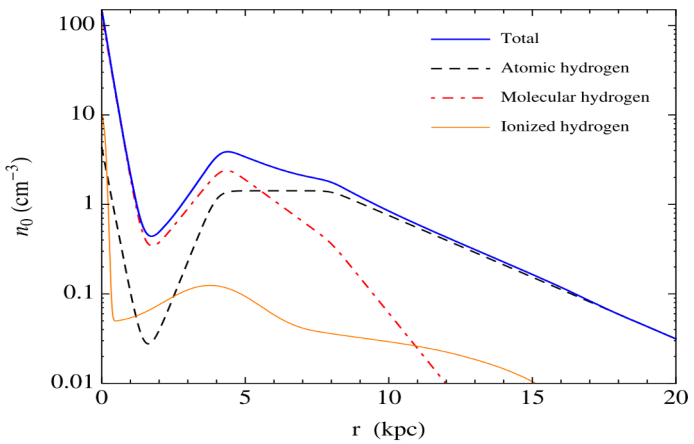


Credit: NASA

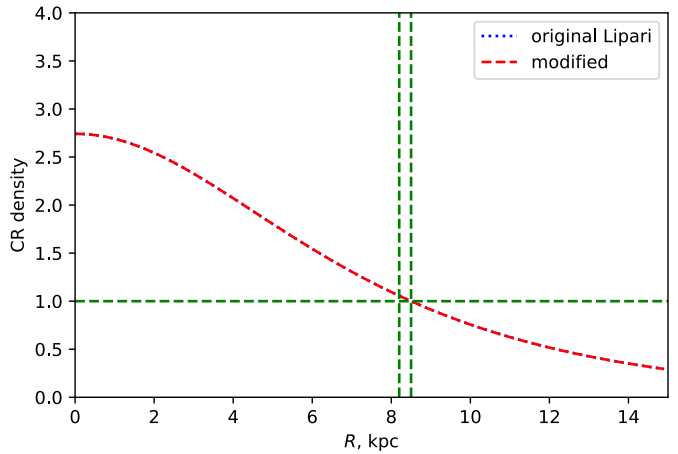


Lipari Vernetto 2018

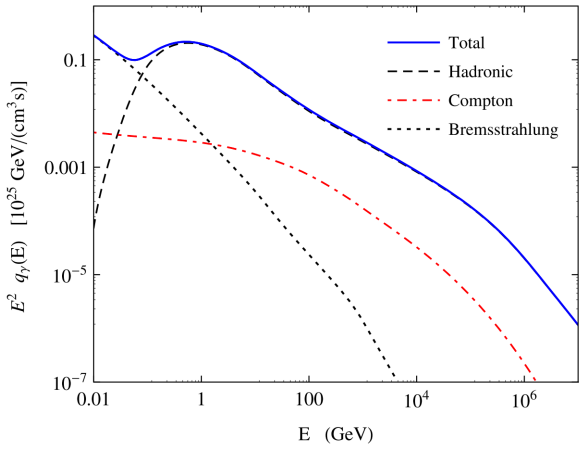
Gas density



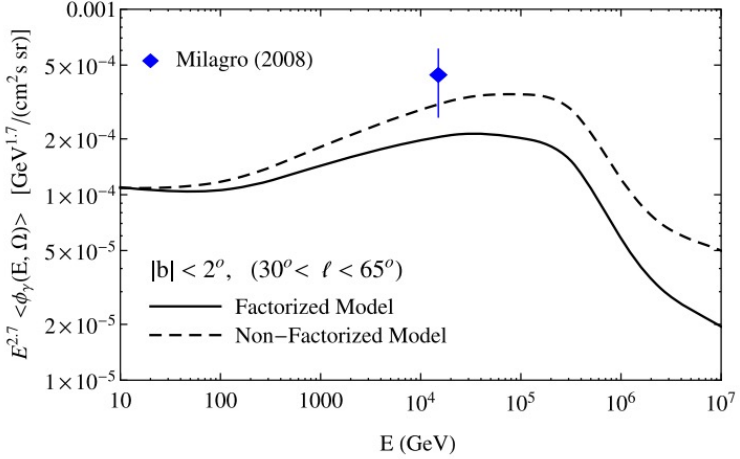
CR density

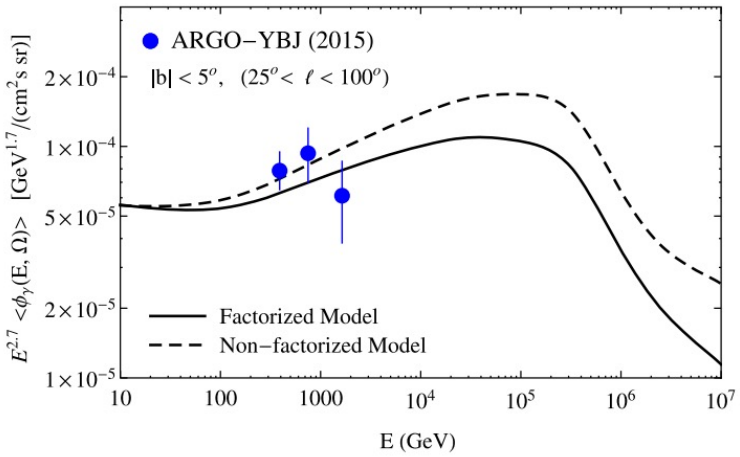


pi0 vs IC vs BS



Lipari Vernetto 2018
high energies





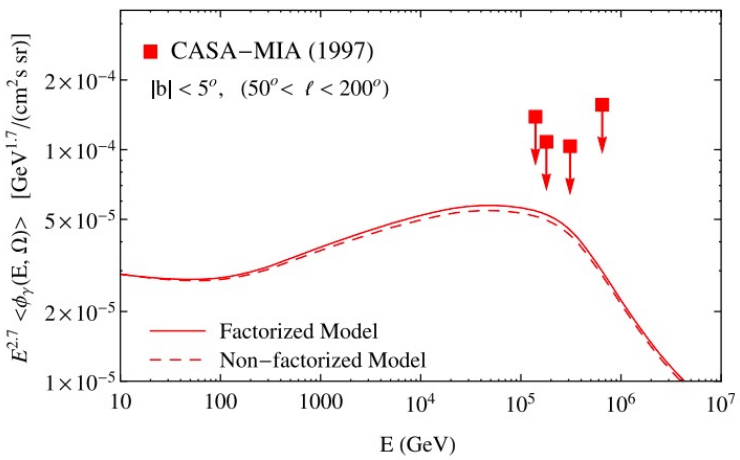
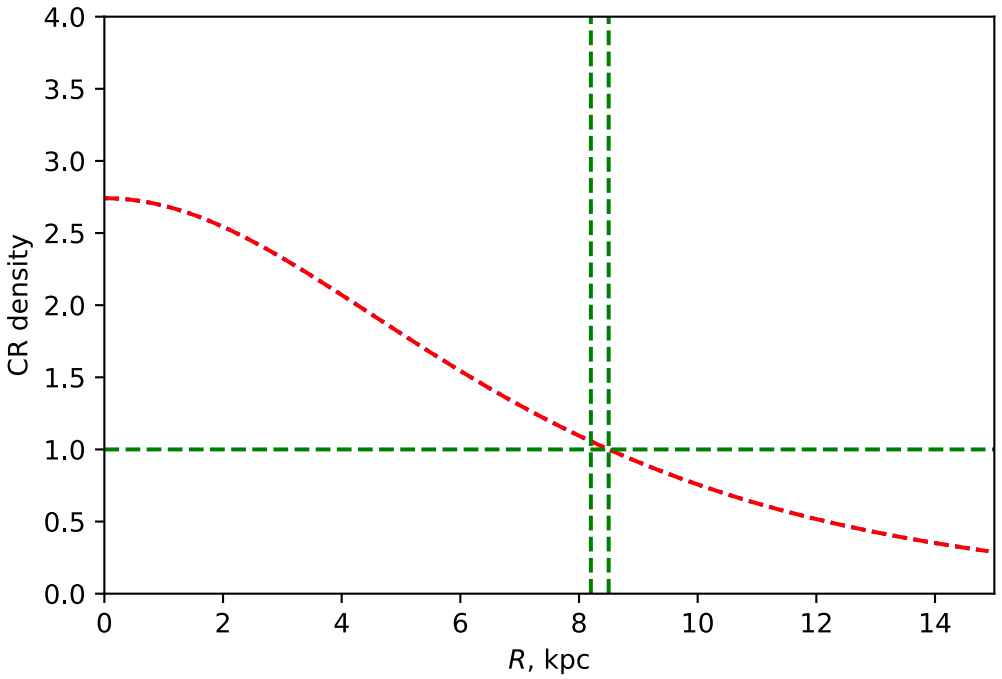
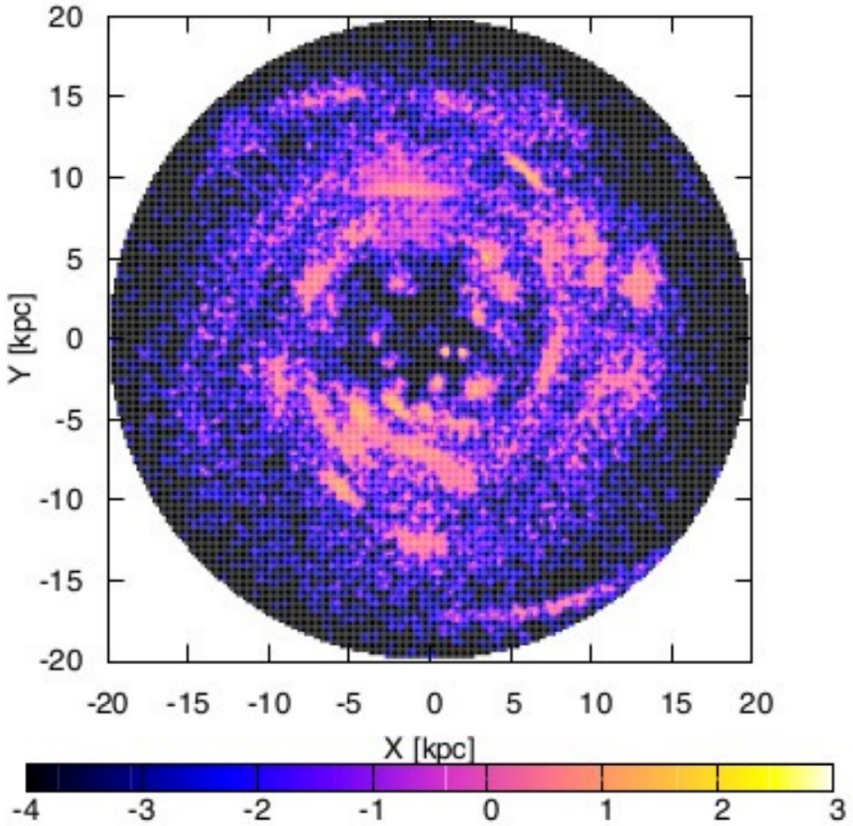
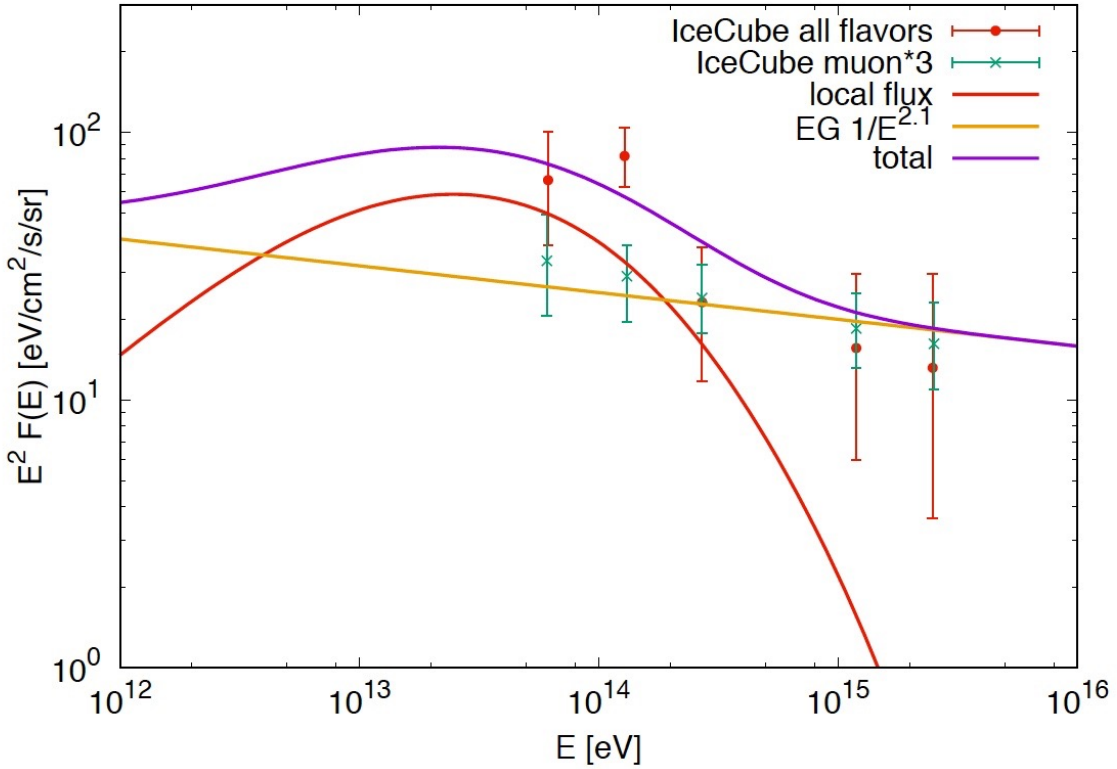


Figure from Gwenael's talk





Local bubble neutrino flux

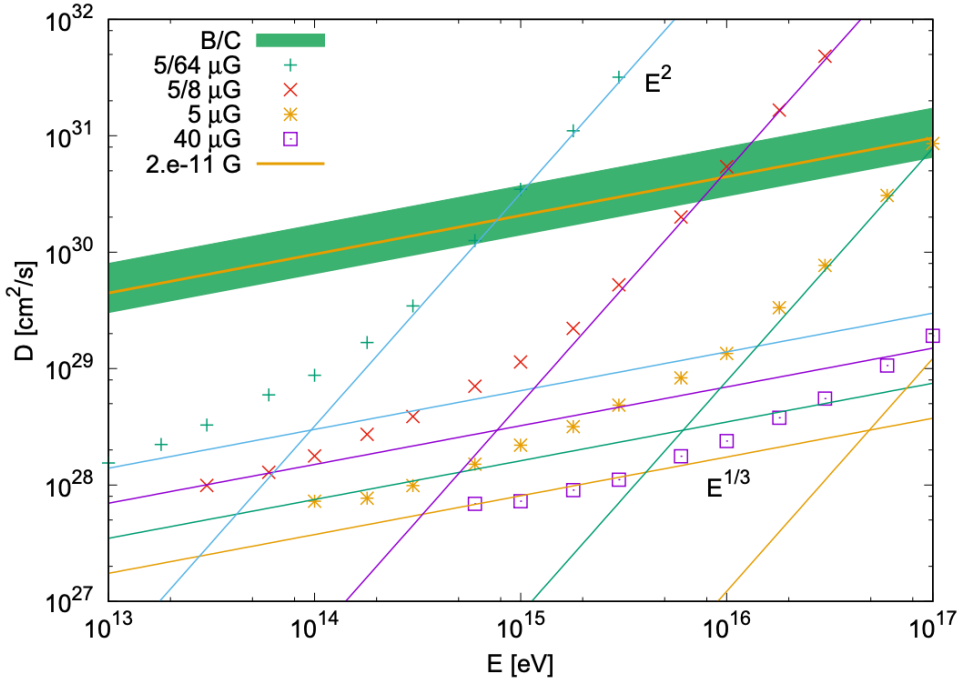


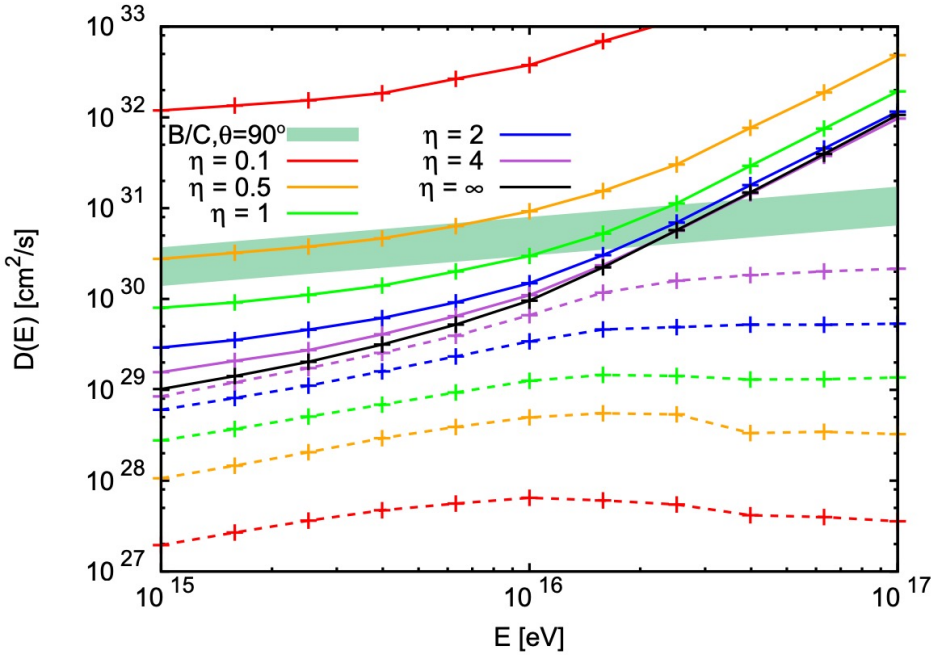
High-energy Neutrinos from Galactic Superbubbles

K.Andersen, M.Kachelriess and D.Semikoz, arXiv:1712.03153 2017

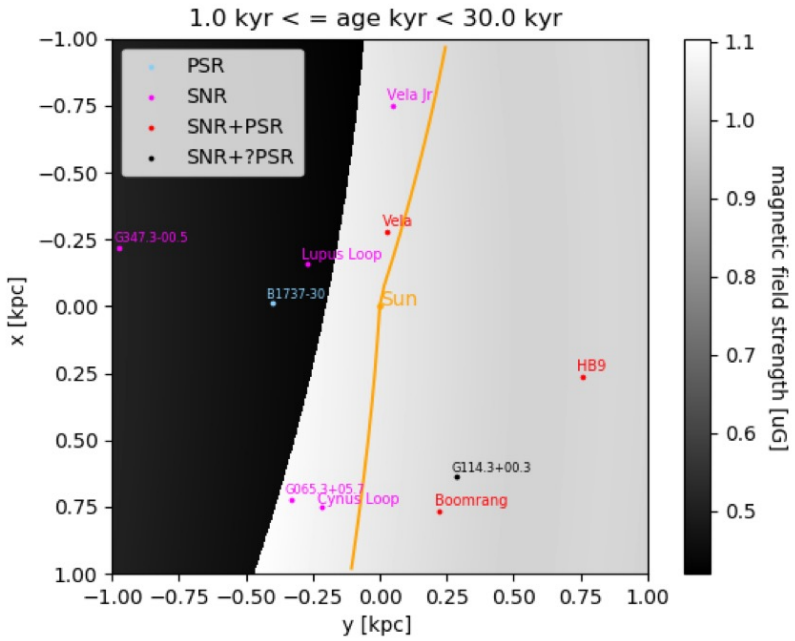
Importance of regular magnetic field

Giacinti et al.1710.08205 2017
Gwenael's talk

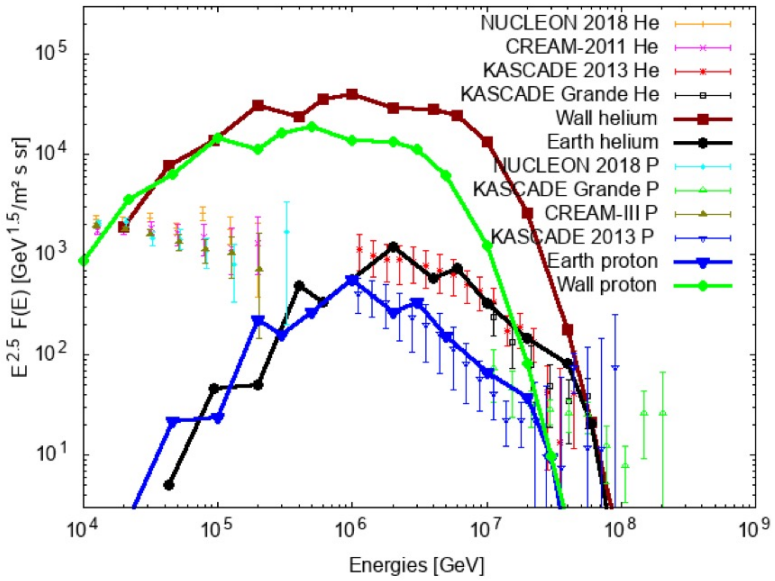




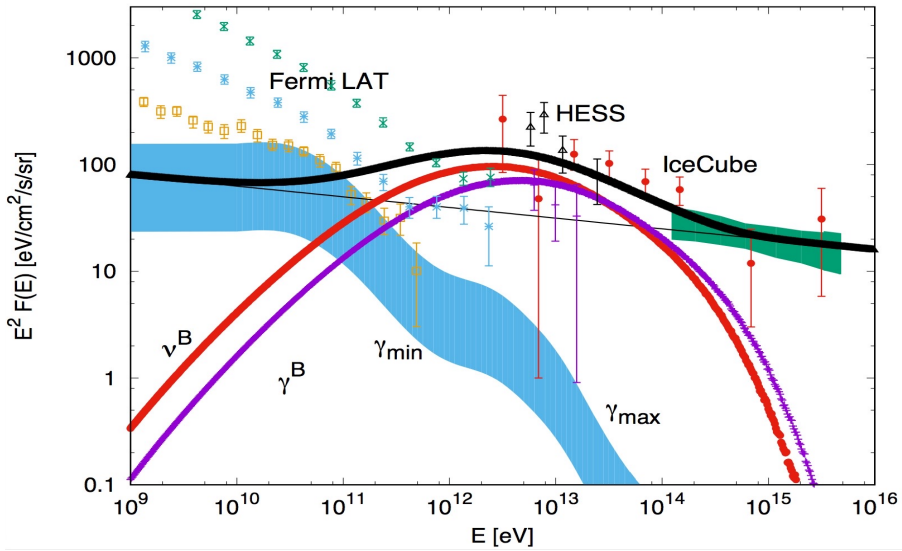
Locations of possible local sources



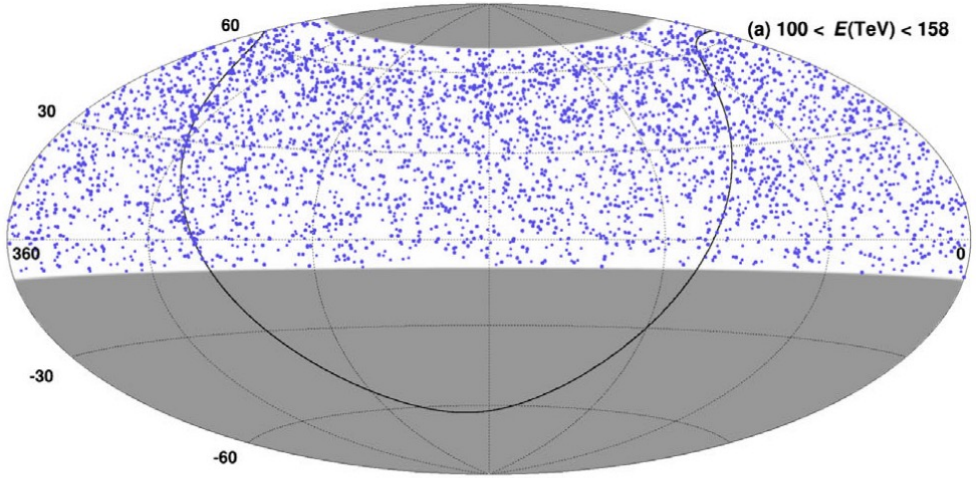
Contribution of Vela to proton and helium spectra

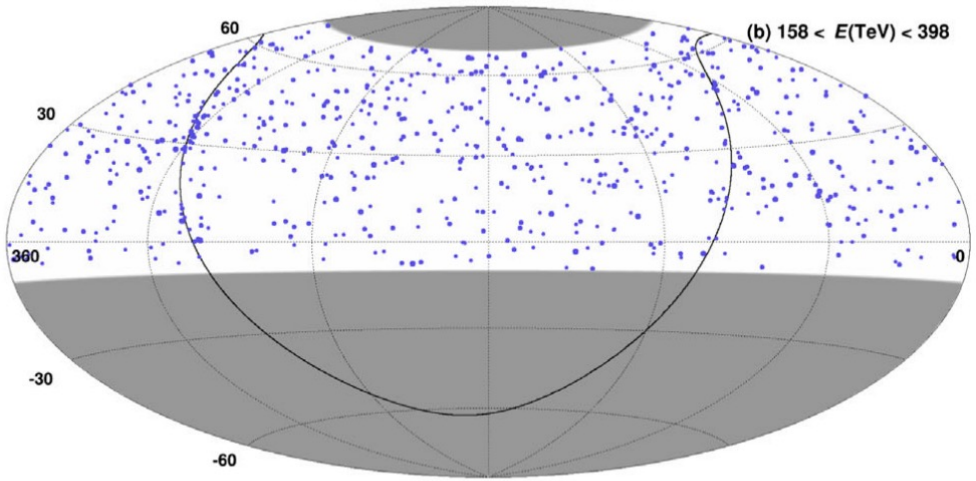


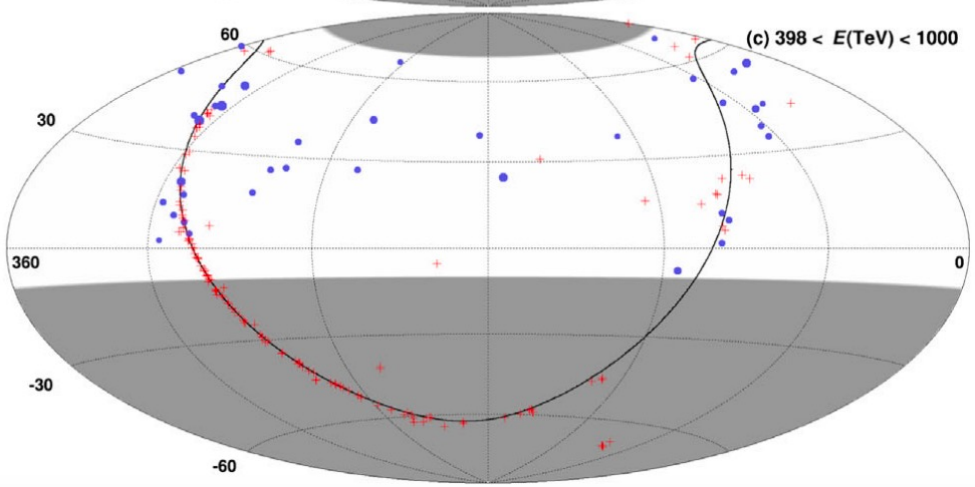
Multi-messenger contribution in neutrinos and gamma-rays of cosmic ray interactions in the walls of Local Bubble compared to Fermi LAT and IceCube measurements.

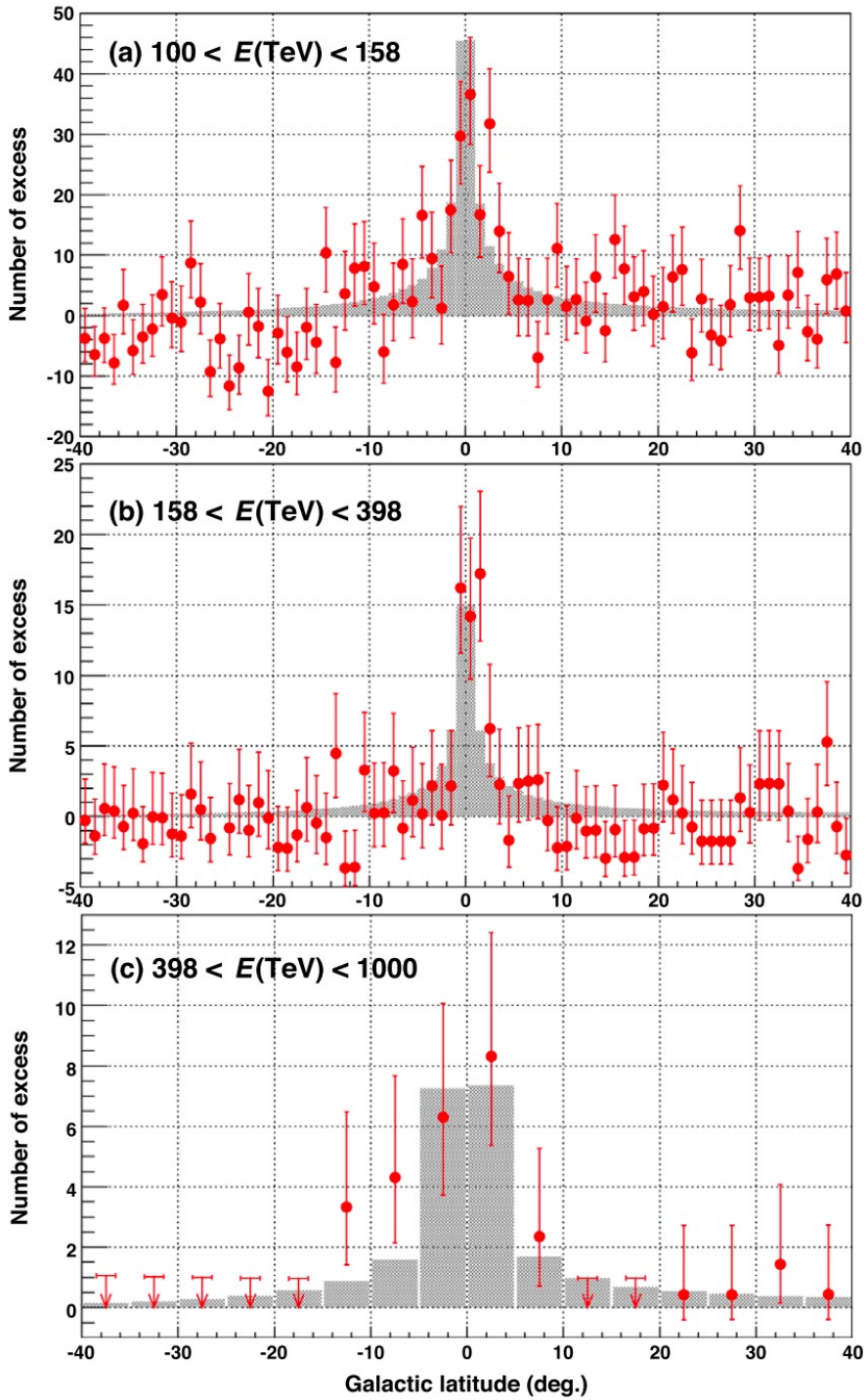


M. Bouyahiaoui, M. Kachelriess, and. D.S. , astro-ph/2001.00768, 2020

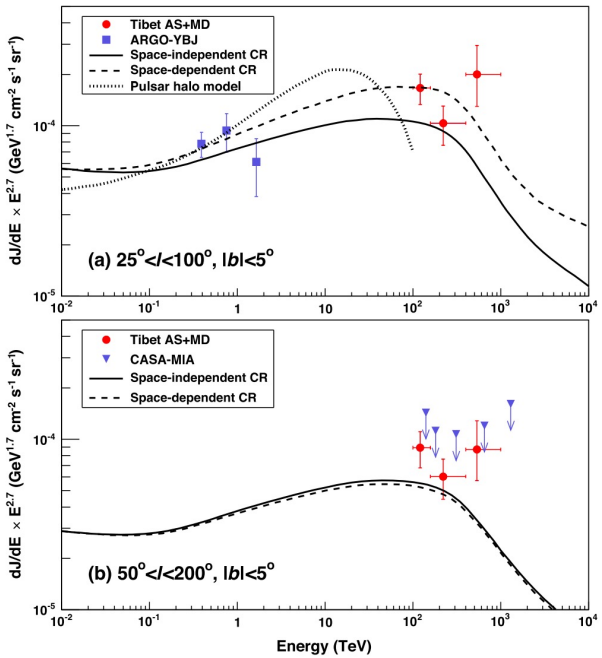




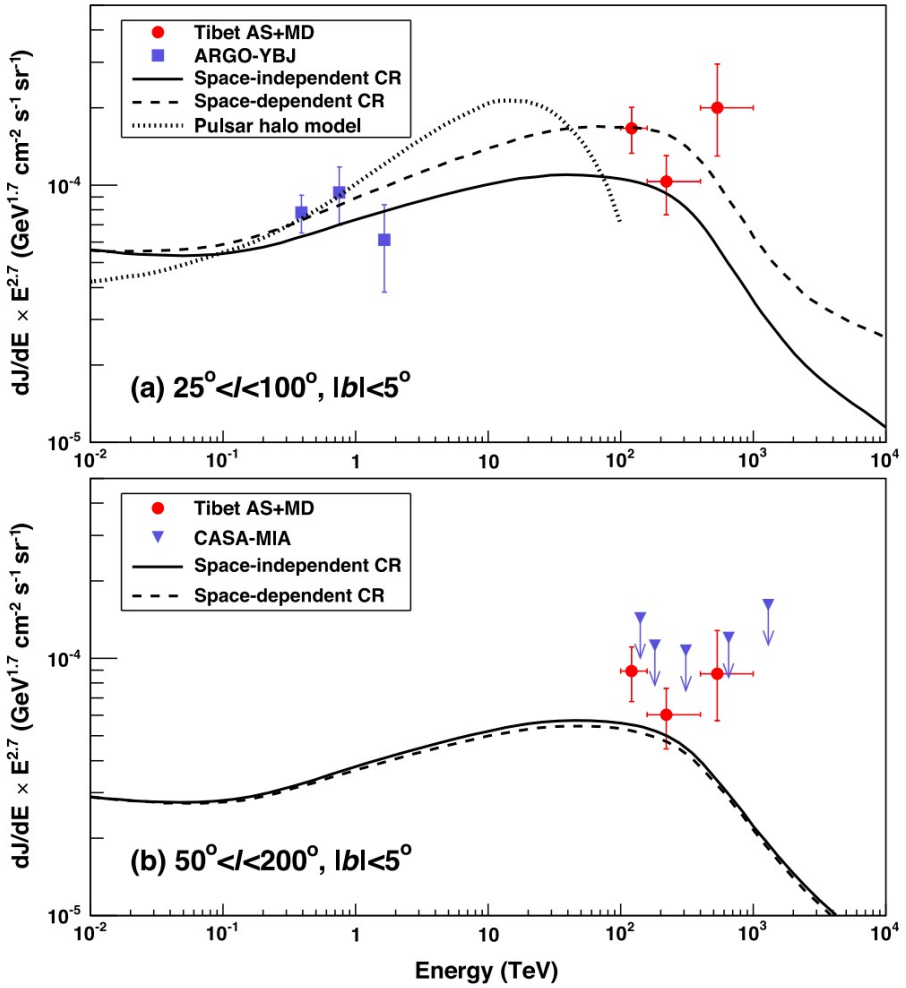




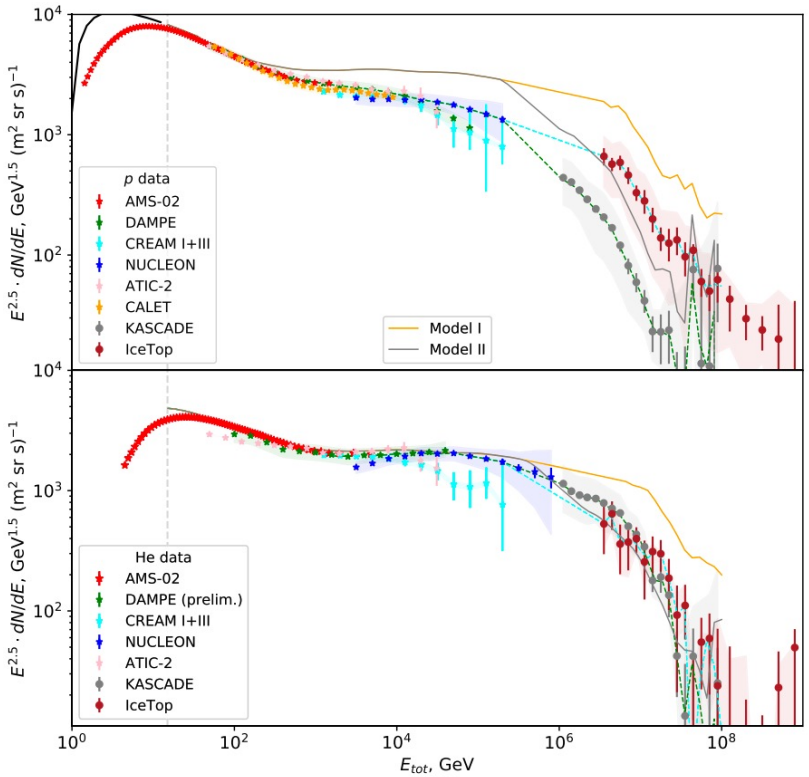
Amenomori et al. 2021

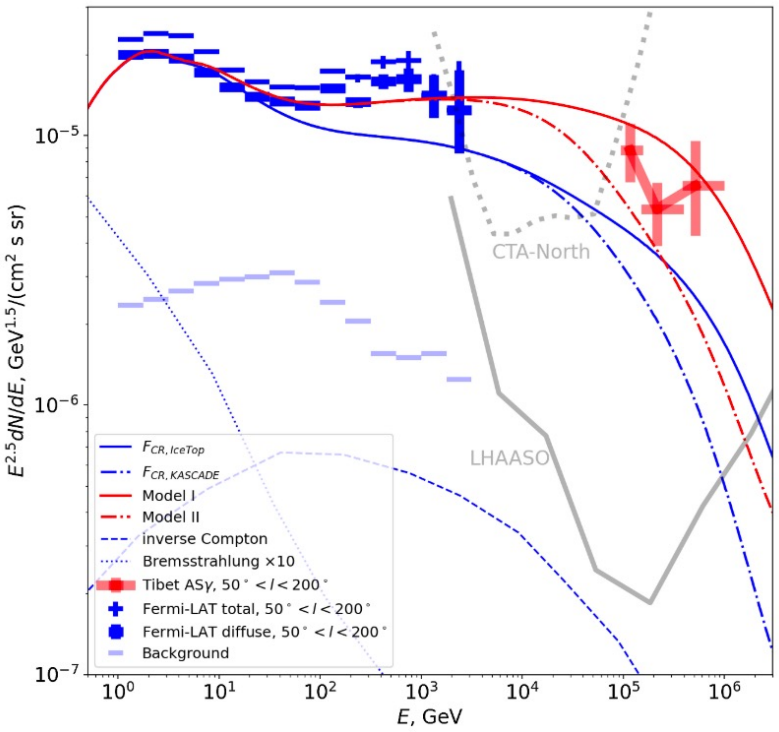


Amenomori et al. 2021



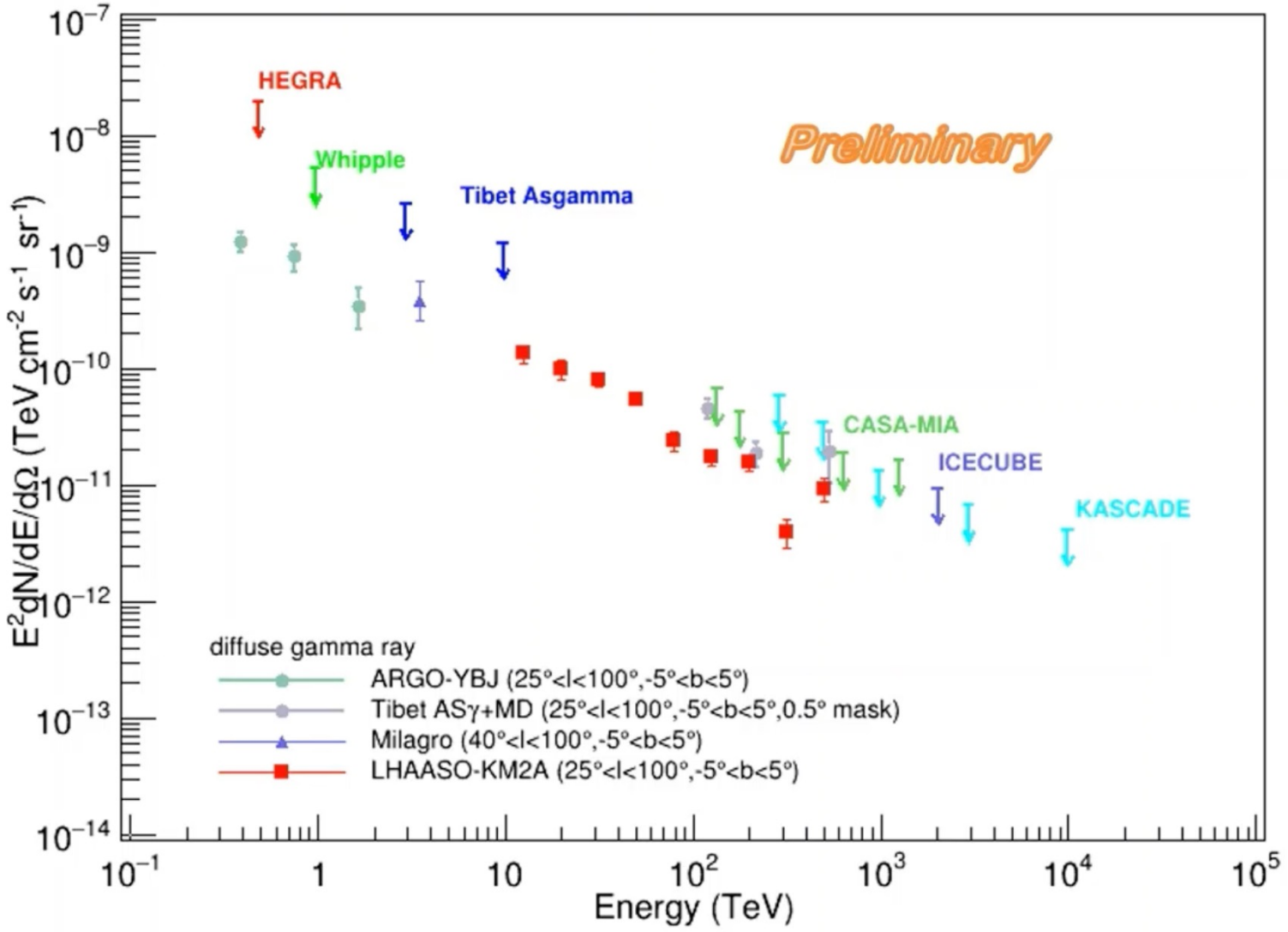
Different explanations were given (mostly playing with the spectral shape of CR spectra), for example: Koldobskiy et al. 2021, local CR flux differs from ”mean galaxy”

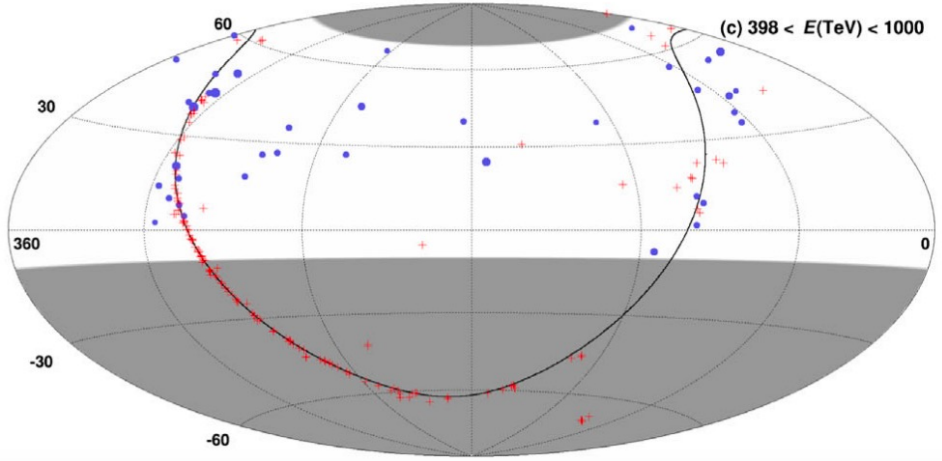


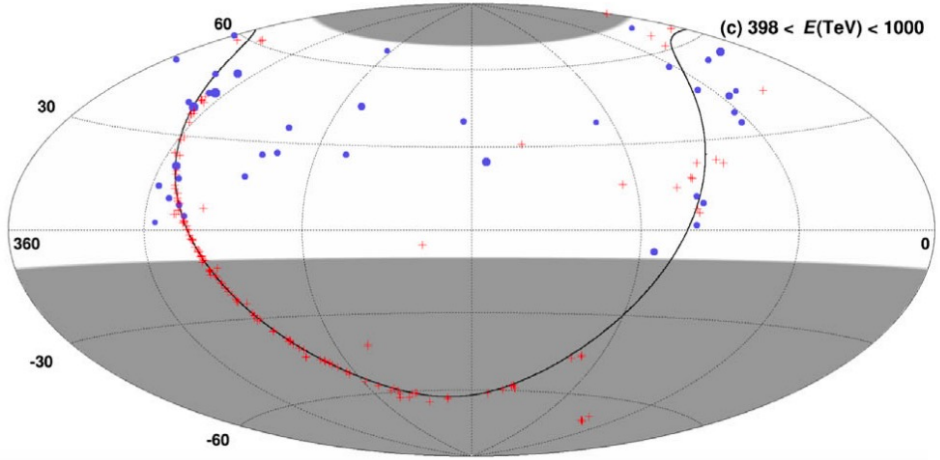


Spectra Energy Distribution
—— 25°<l<100°

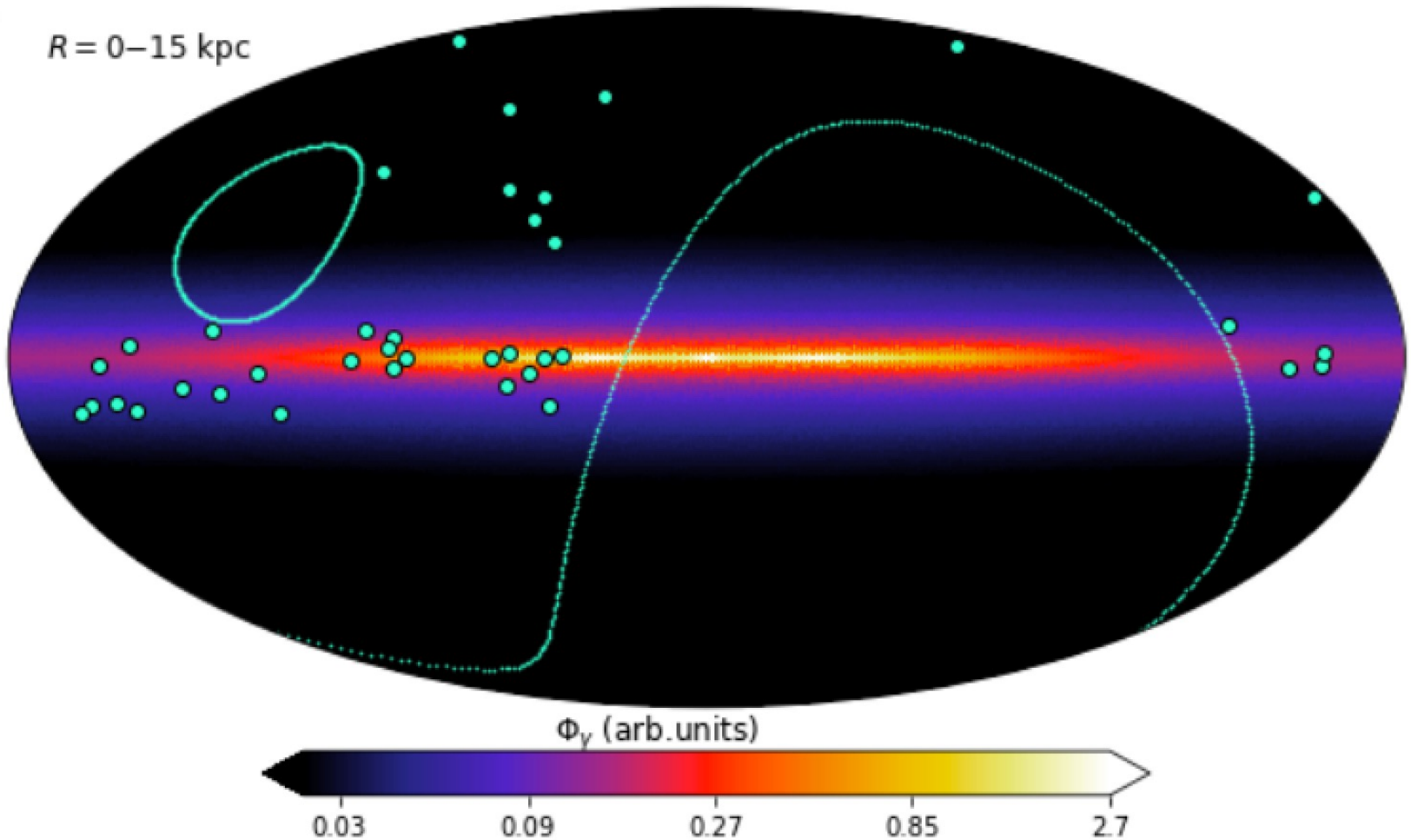
LHASSO ICRC2021 preliminary results



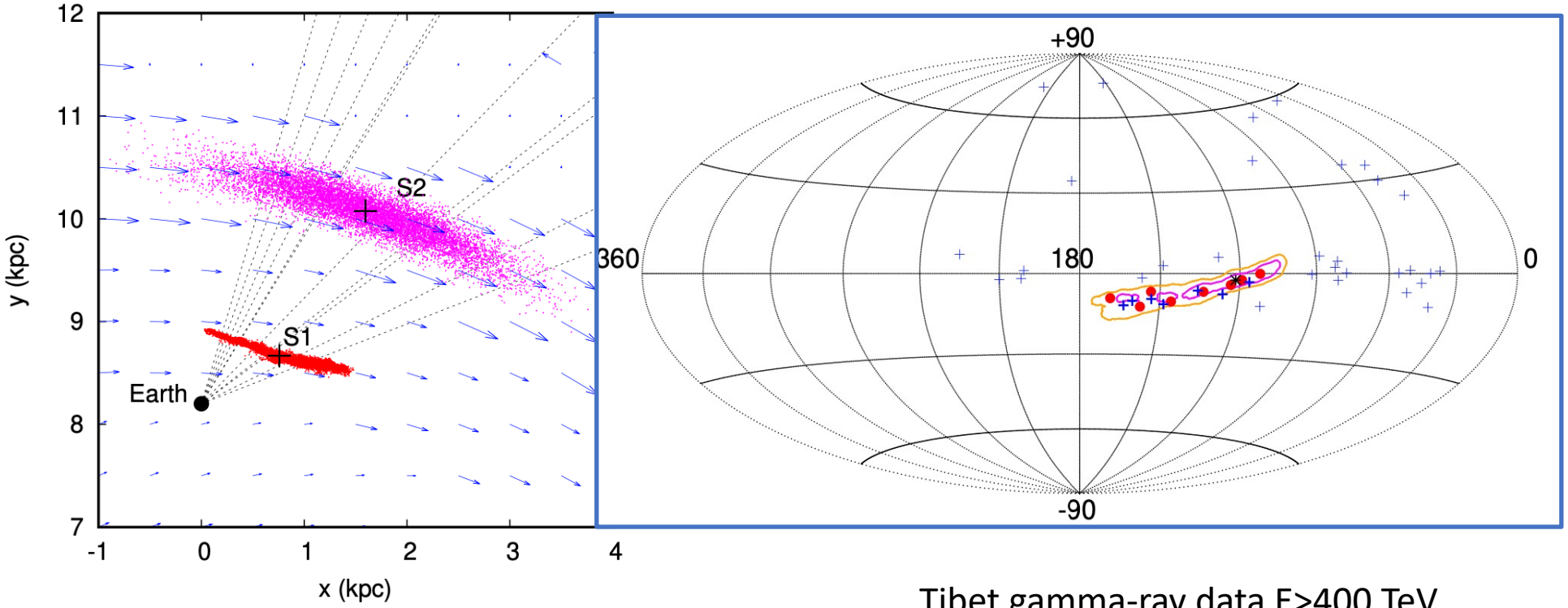

(c) 398 < E(TeV) < 1000
60
30
360
0
-30
-60



Tibet-AS >398 TeV vs Lipari Vernetto 2018 model



Cosmic rays from local sources producing gamma-rays

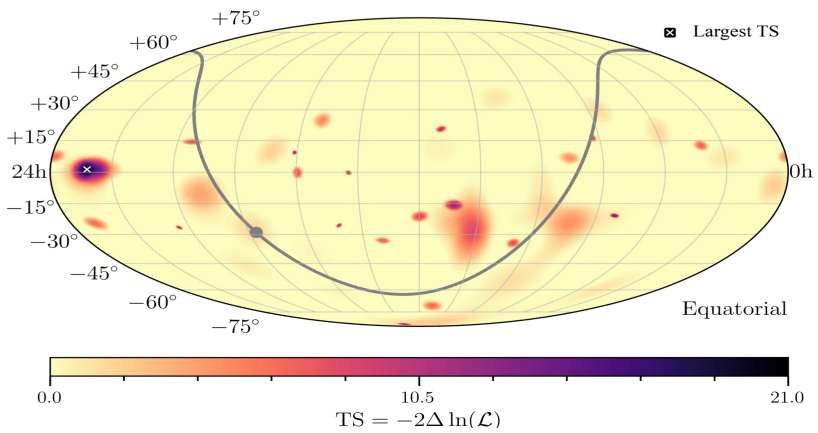


Tibet gamma-ray data E>400 TeV
S=3400 m2 3700 hours 0.5 yr

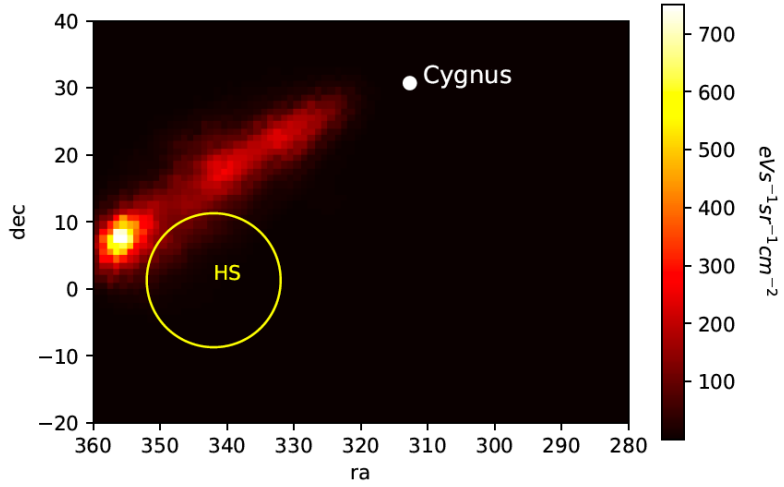
G. Giacinti, T. Abounnasr, A. Neronov and D.S. 2022, astro-ph/2203.11052

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

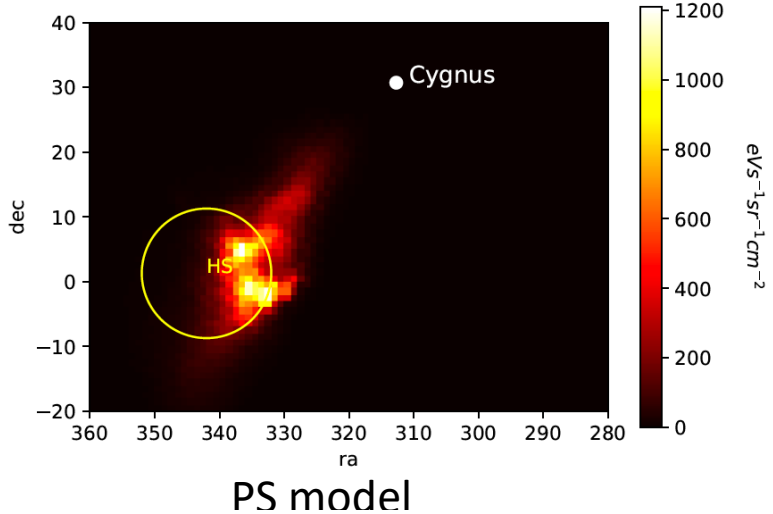
Hot spot on the sky map
HESE 7.5 years



IceCube, astro-ph/2011.03545



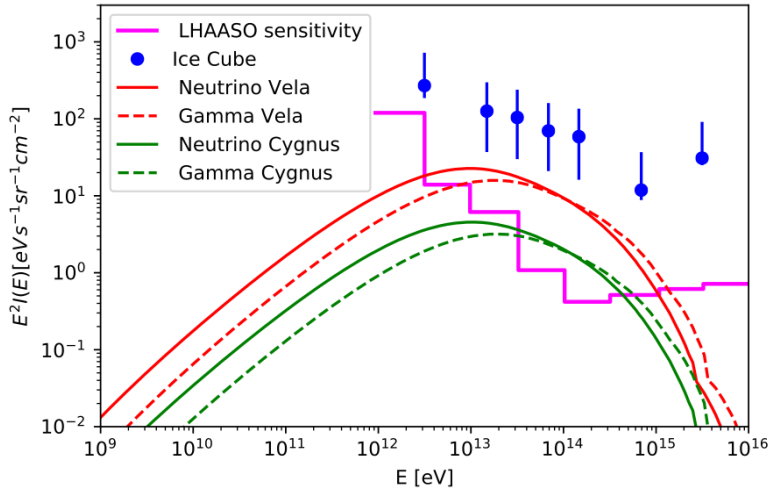
JF12 model



PS model

4 events in hot spot /3 predicted by model
3D Gaia dust maps Lallement et al 2019/2021

Cygnus loop 2-3 events, Vela 9-18 events.

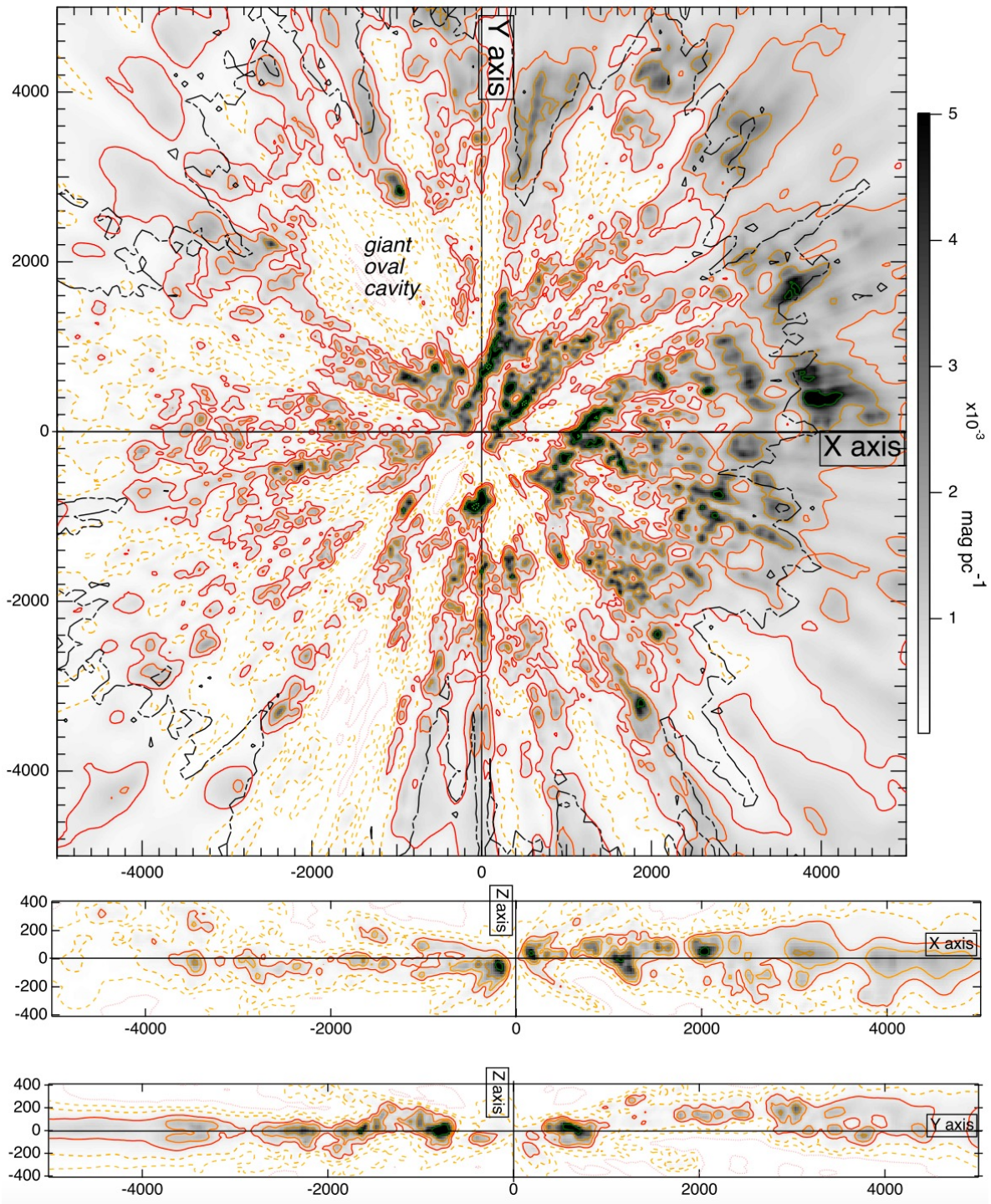


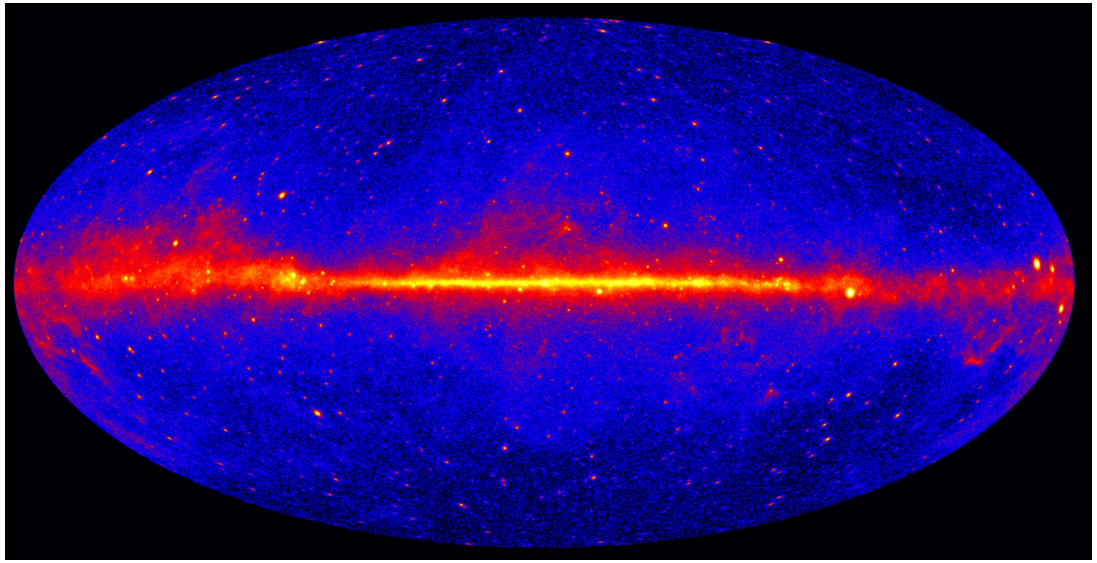
M. Bouyahiaoui, M. Kachelriess, and D.S. , astro-ph/2105.13378, 2021

Extinction maps from Gaia eDR3 and 2MASS

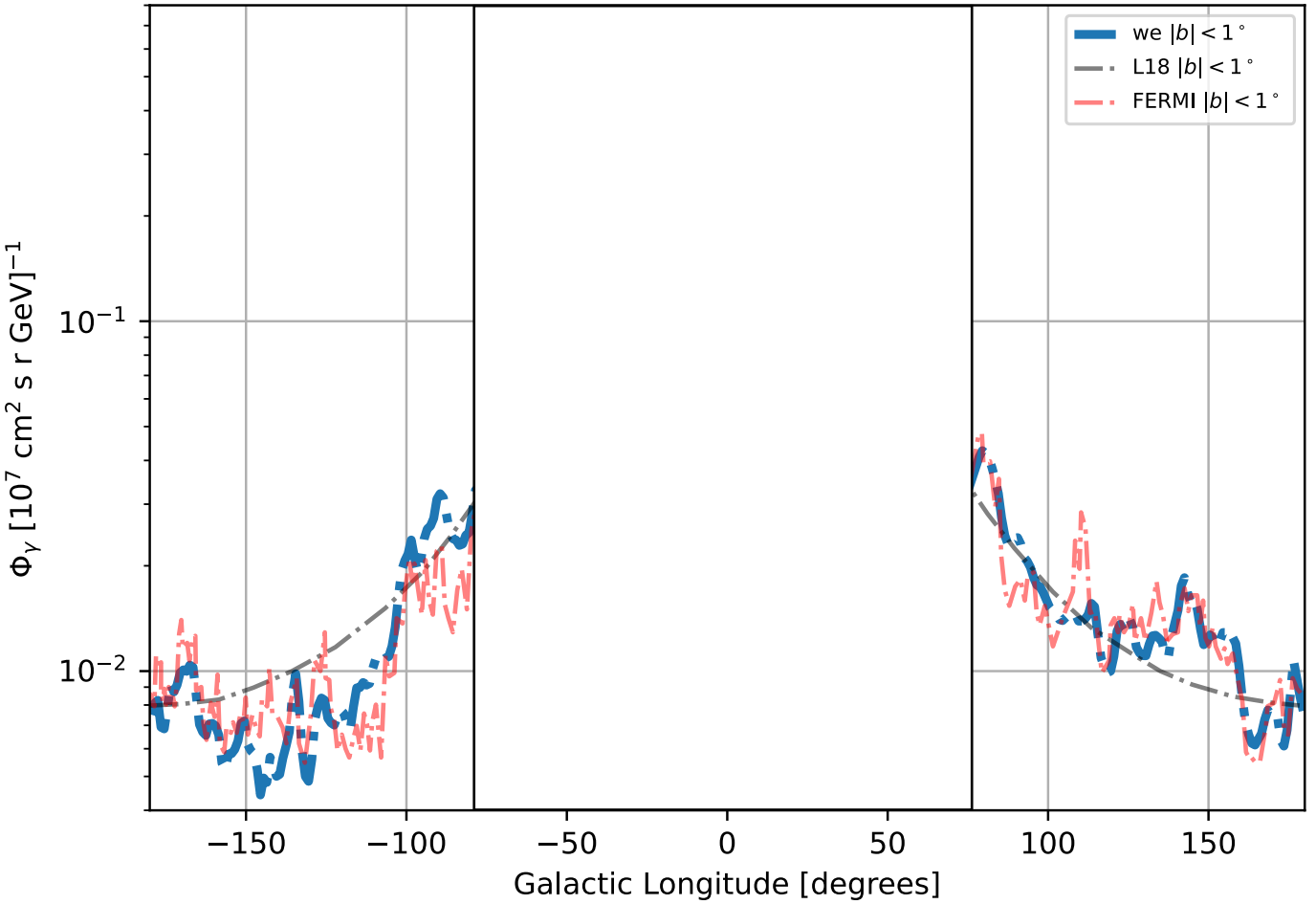
Extinction can be converted to the gas density! -> can be used for gamma and neutrino signal modeling!

Vergely et al. 2022

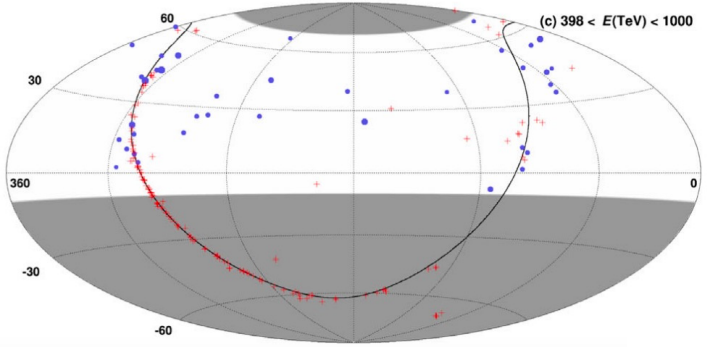




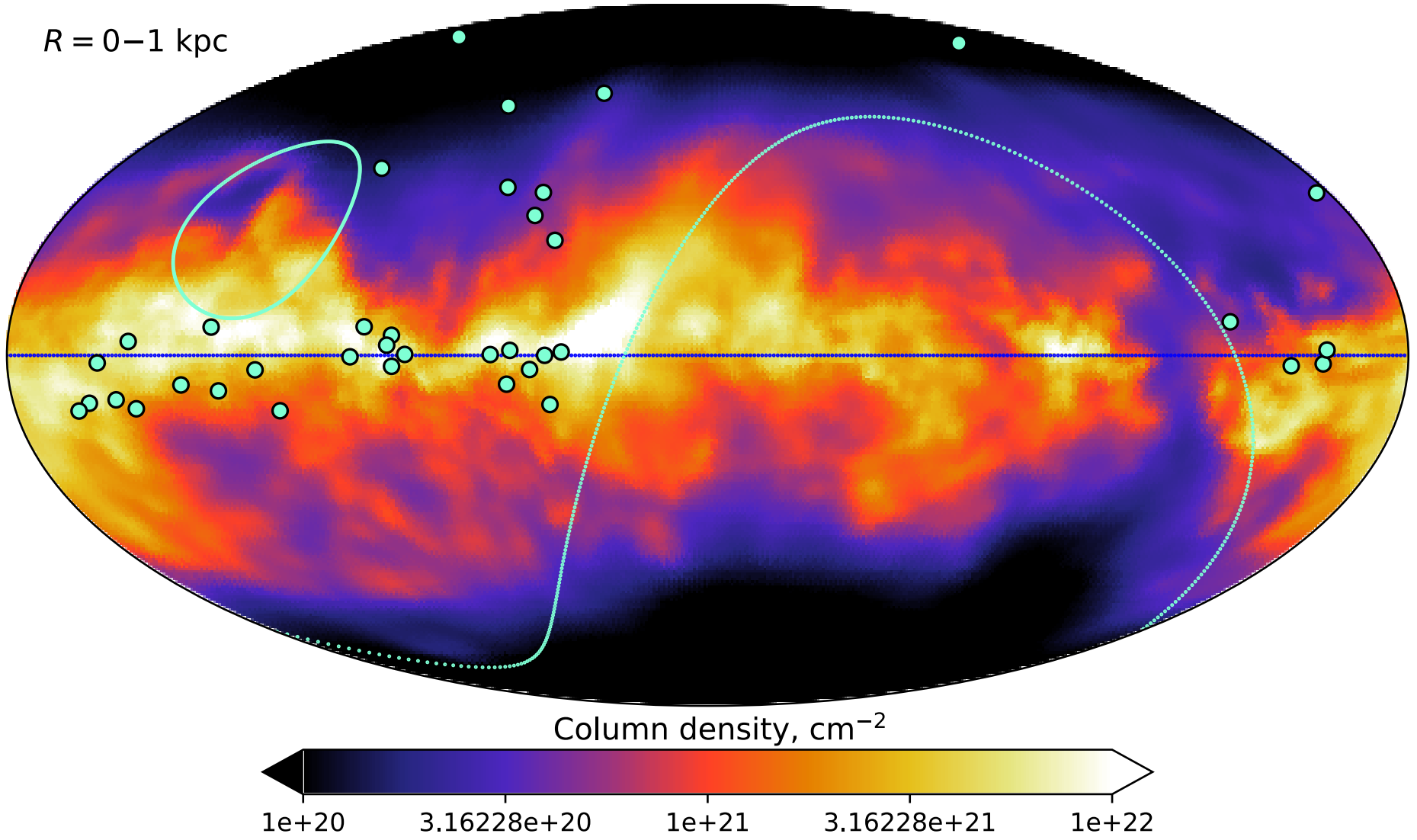
Credit: NASA



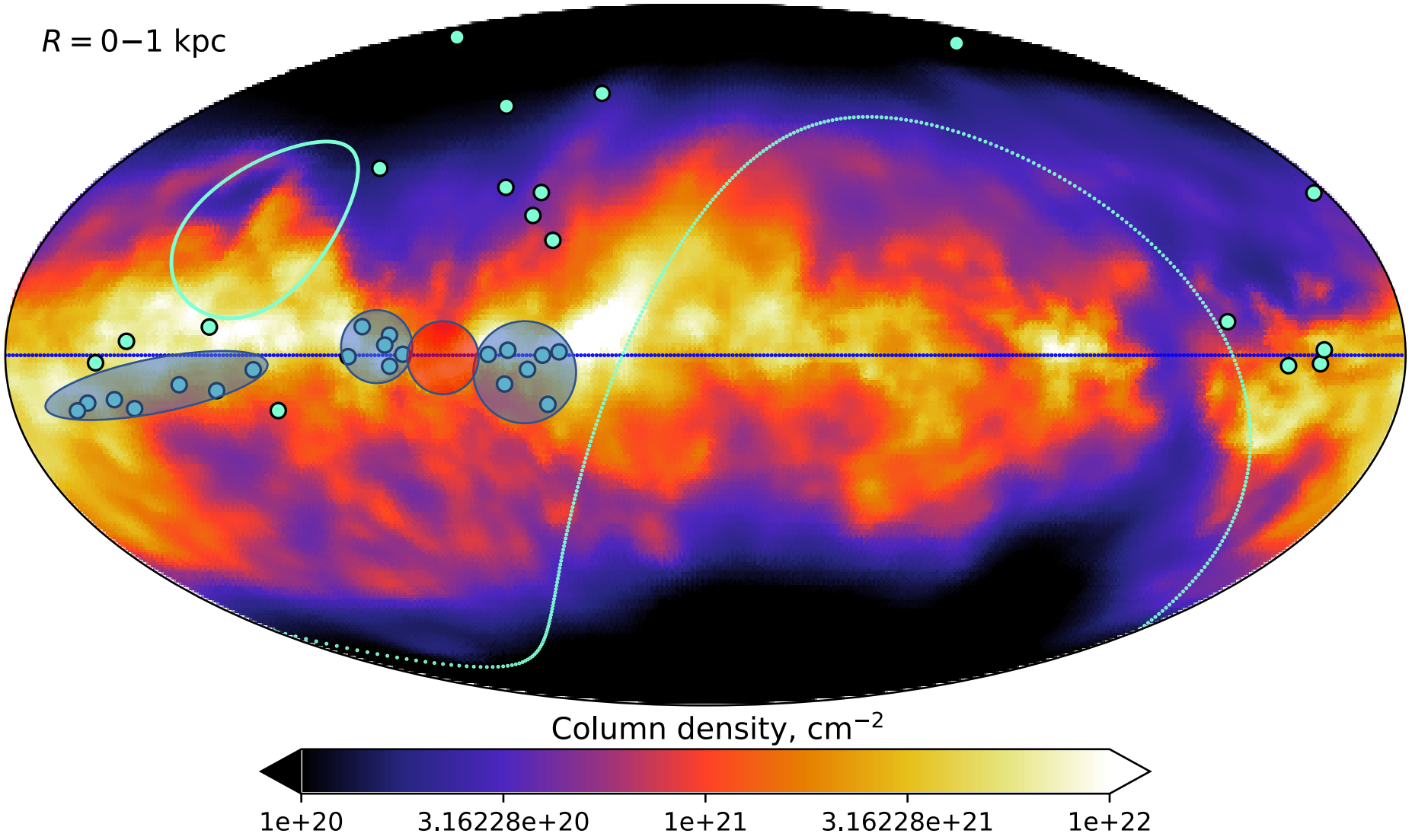
Koldobskiy et al., work in progress



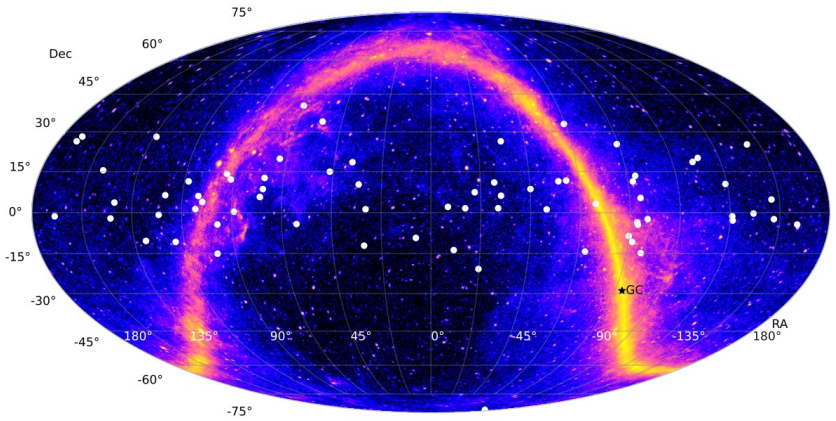
Titbet-AS diffusive gamma skymap vs local column density from Vergely 2022 analysis

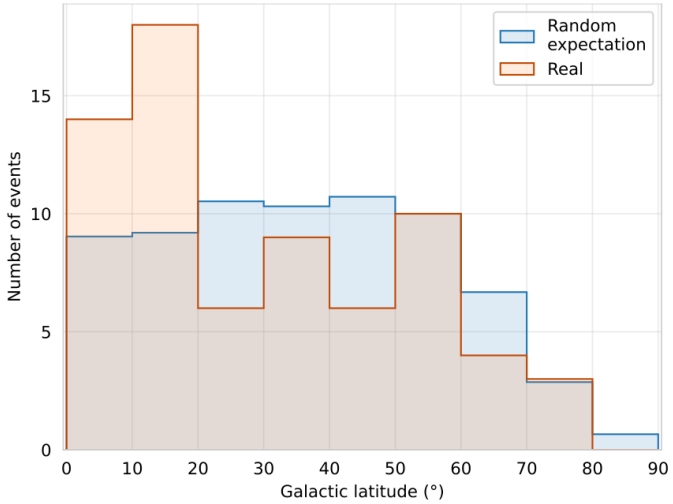


Titbet-AS diffusive gamma skymap vs local column density from Vergely 2022 analysis



IceCube muon neutrinos from Galaxy at 20 degree scale

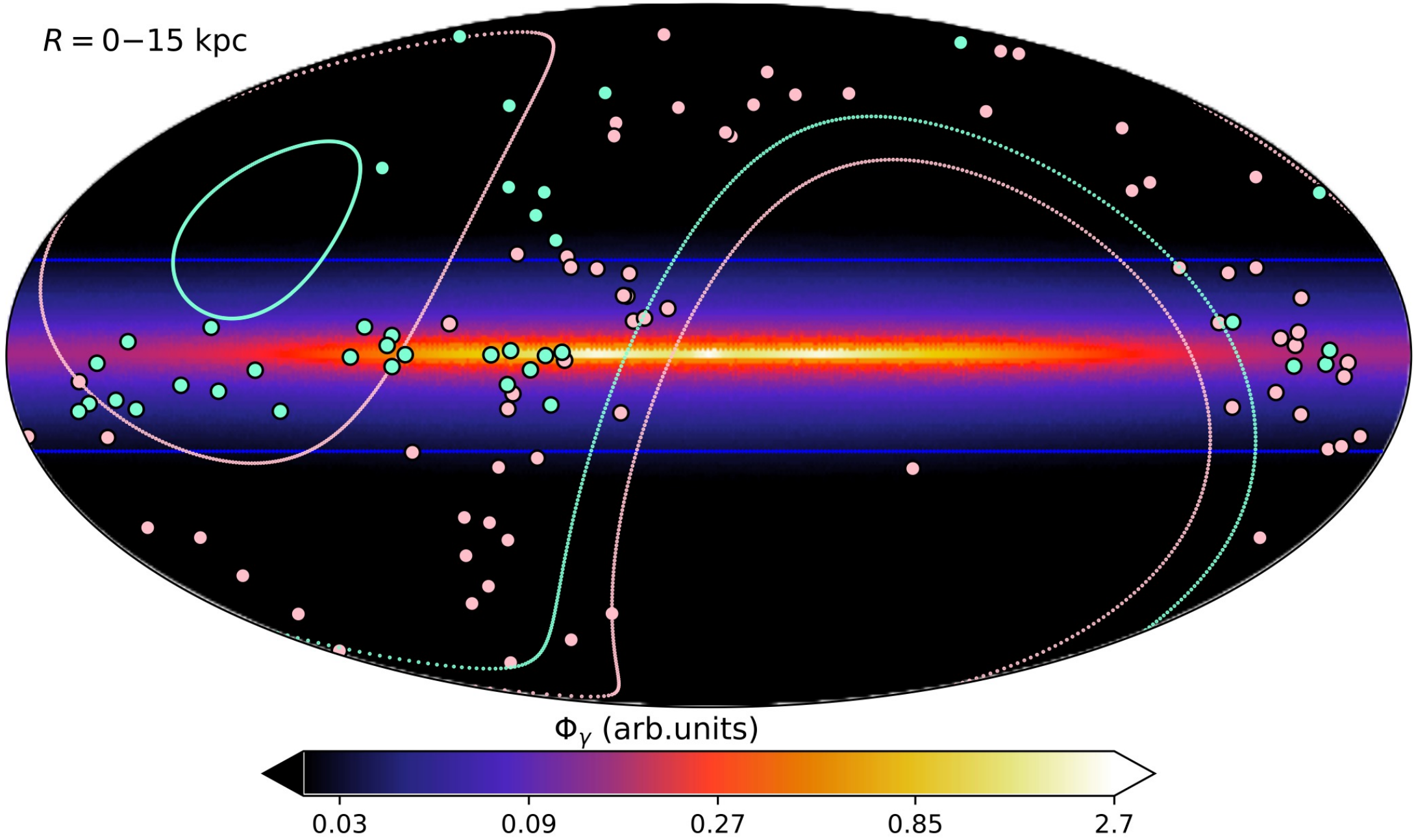


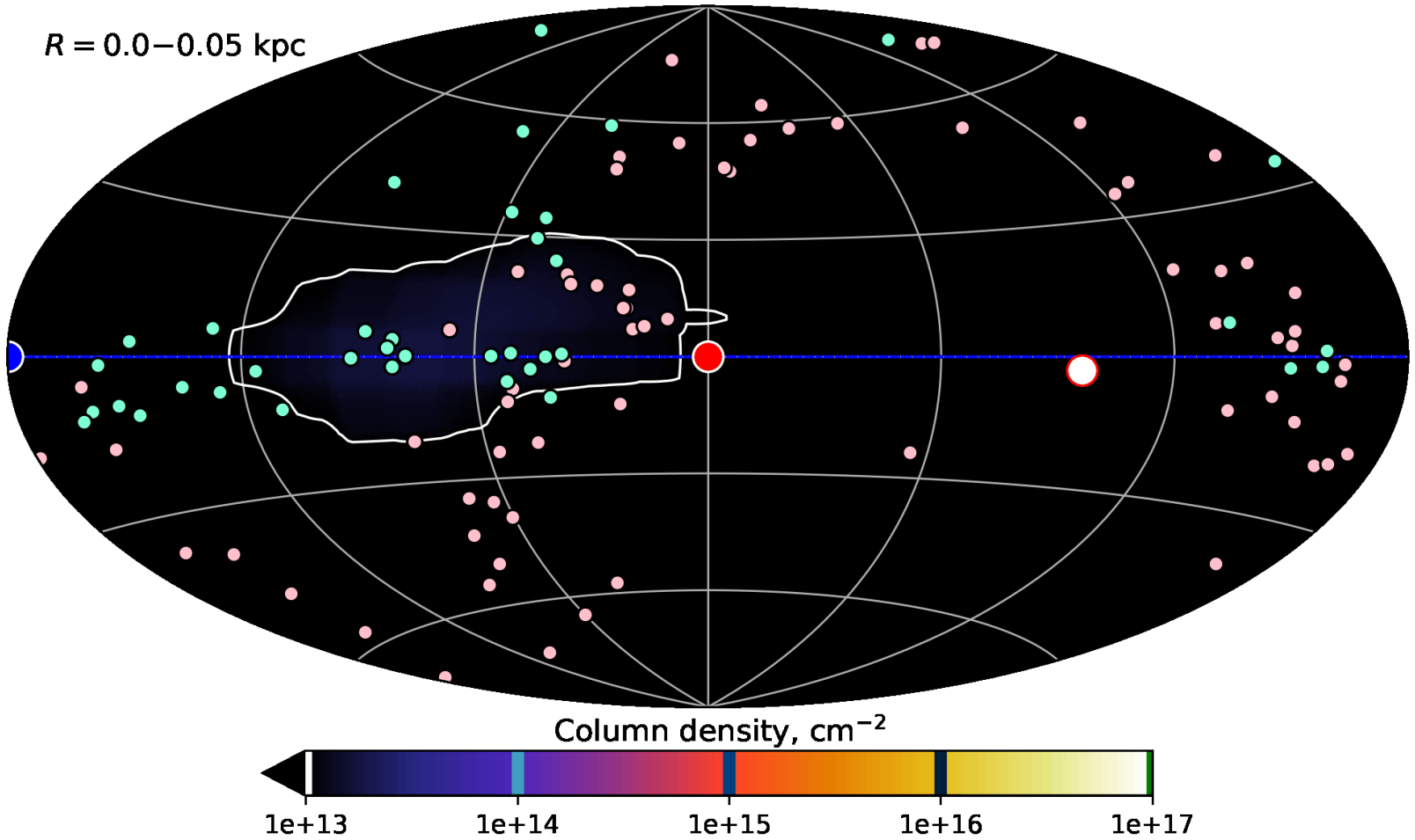


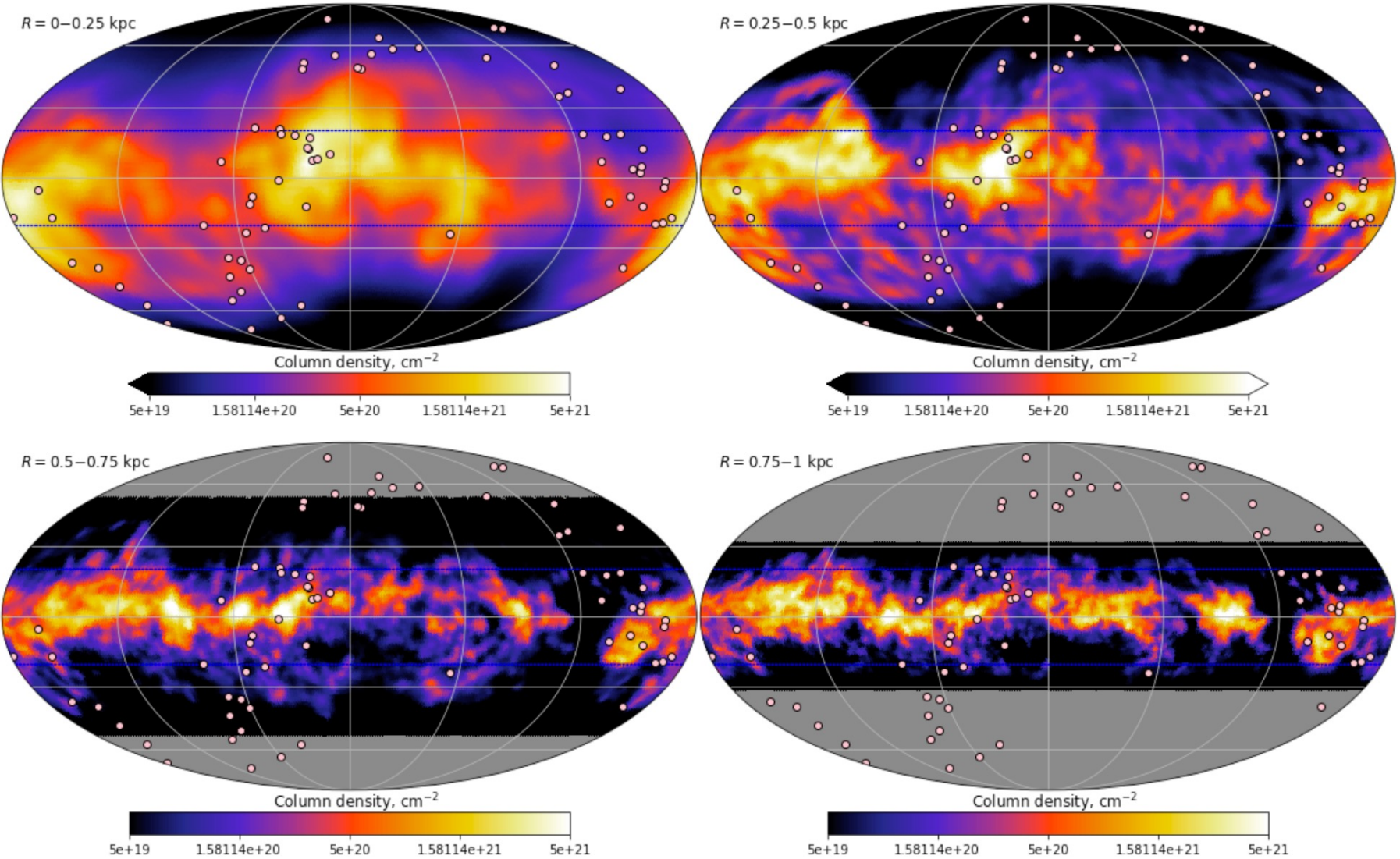
4.3 sigma excess in 20 degrees from galactic plane

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


$R = 0-15$ kpc
Φ_γ (arb.units)
0.03
0.09
0.27
0.85
2.7

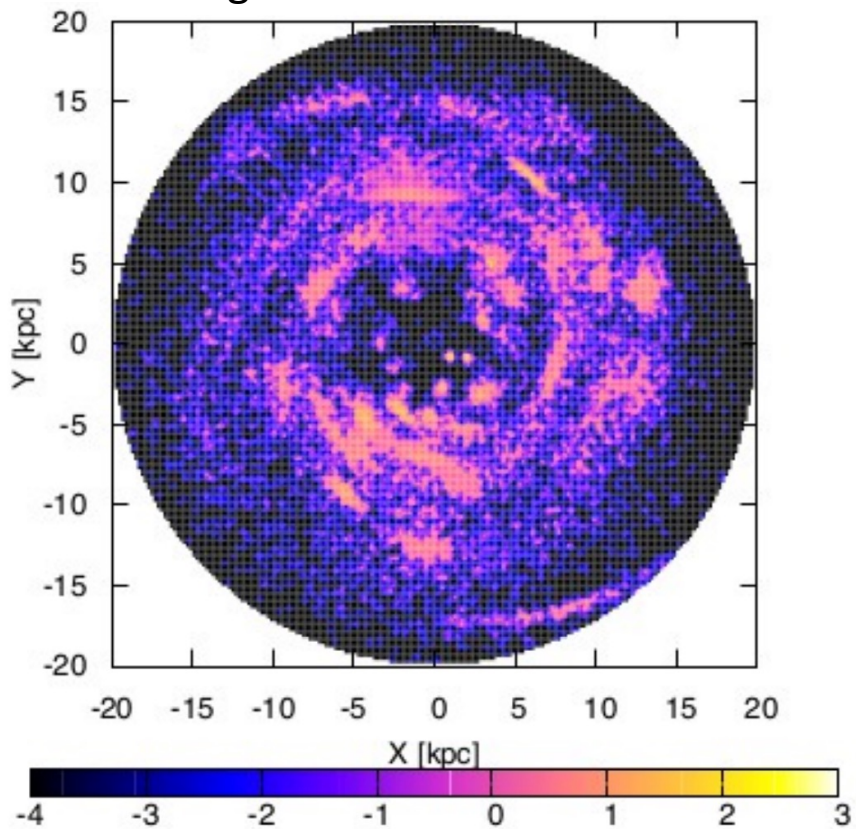

$R = 0.0-0.05$ kpc
Column density, cm^{-2}
1e+13
1e+14
1e+15
1e+16
1e+17



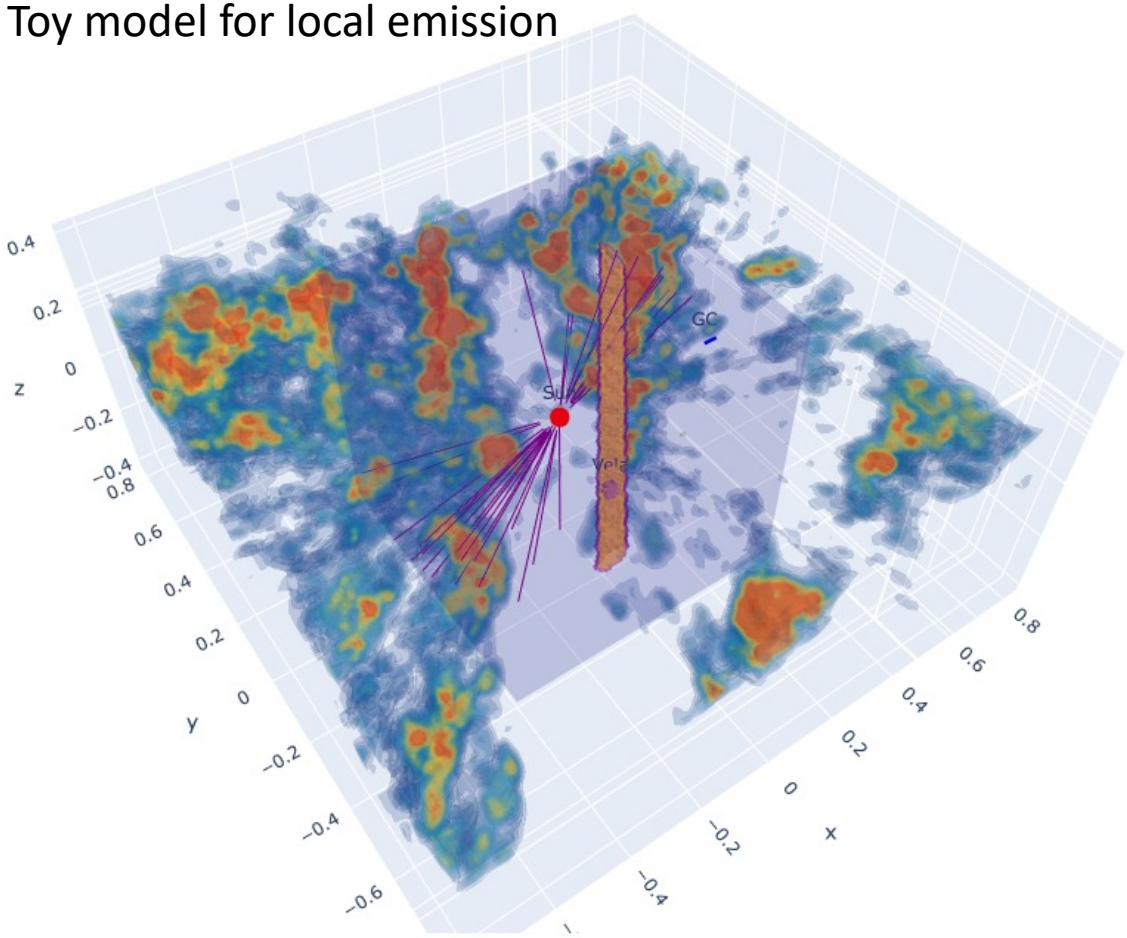
Koldobskiy et al., in prep.

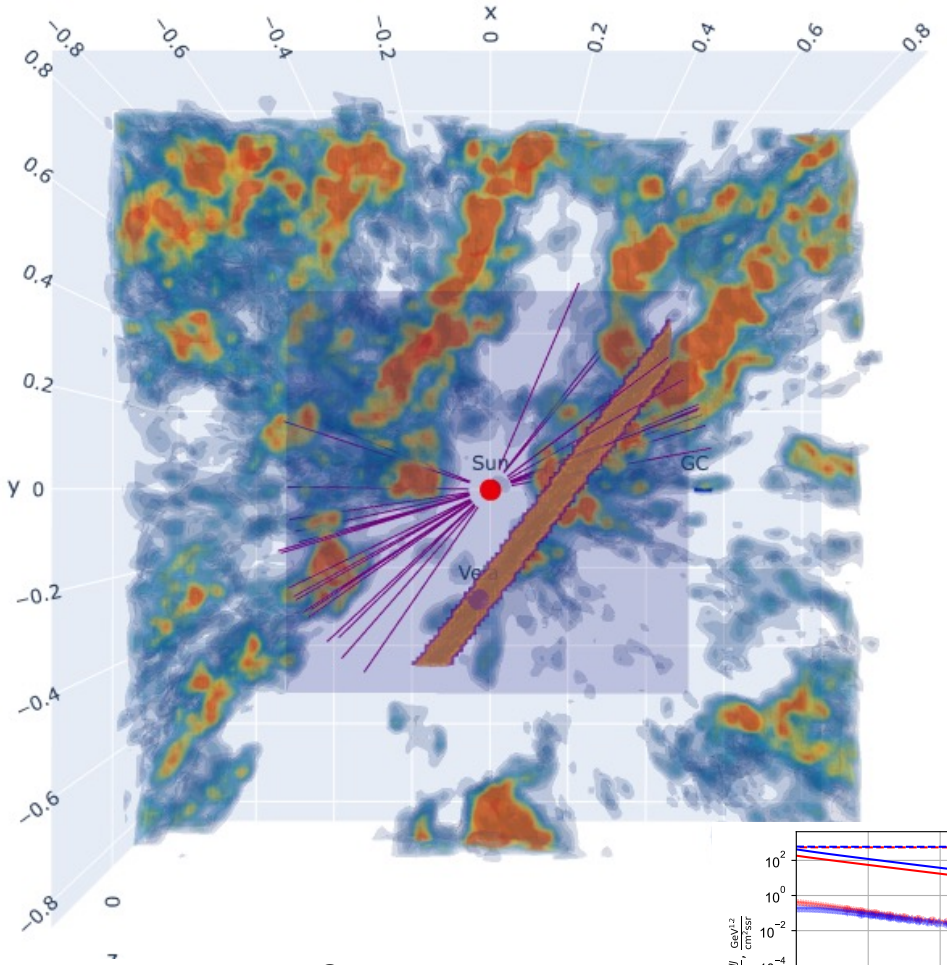
These maps show location of muon neutrino events from recent analysis by Kovalev et al. 2022 (where the excess of the neutrino signal within $|b|<20^\circ$ was reported) versus the line-of-sight local dust column density for four distances.

Figure from Gwenael's talk



Toy model for local emission

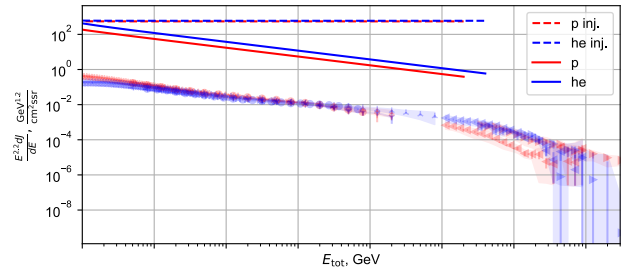




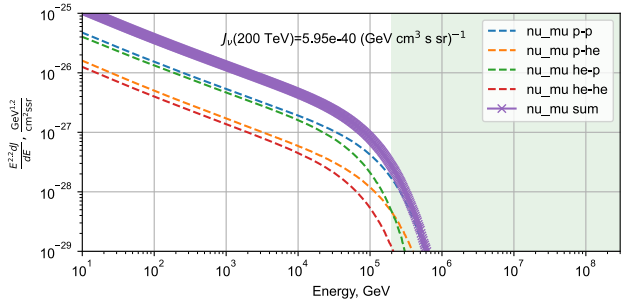
These two maps show the local dust distribution, arrival directions of high-energy (E>200 TeV) muon IceCube events (analysis of Kovalev et al. 2022) within |b|<20°, position of Vela and possible location of Vela-induced CR tube.

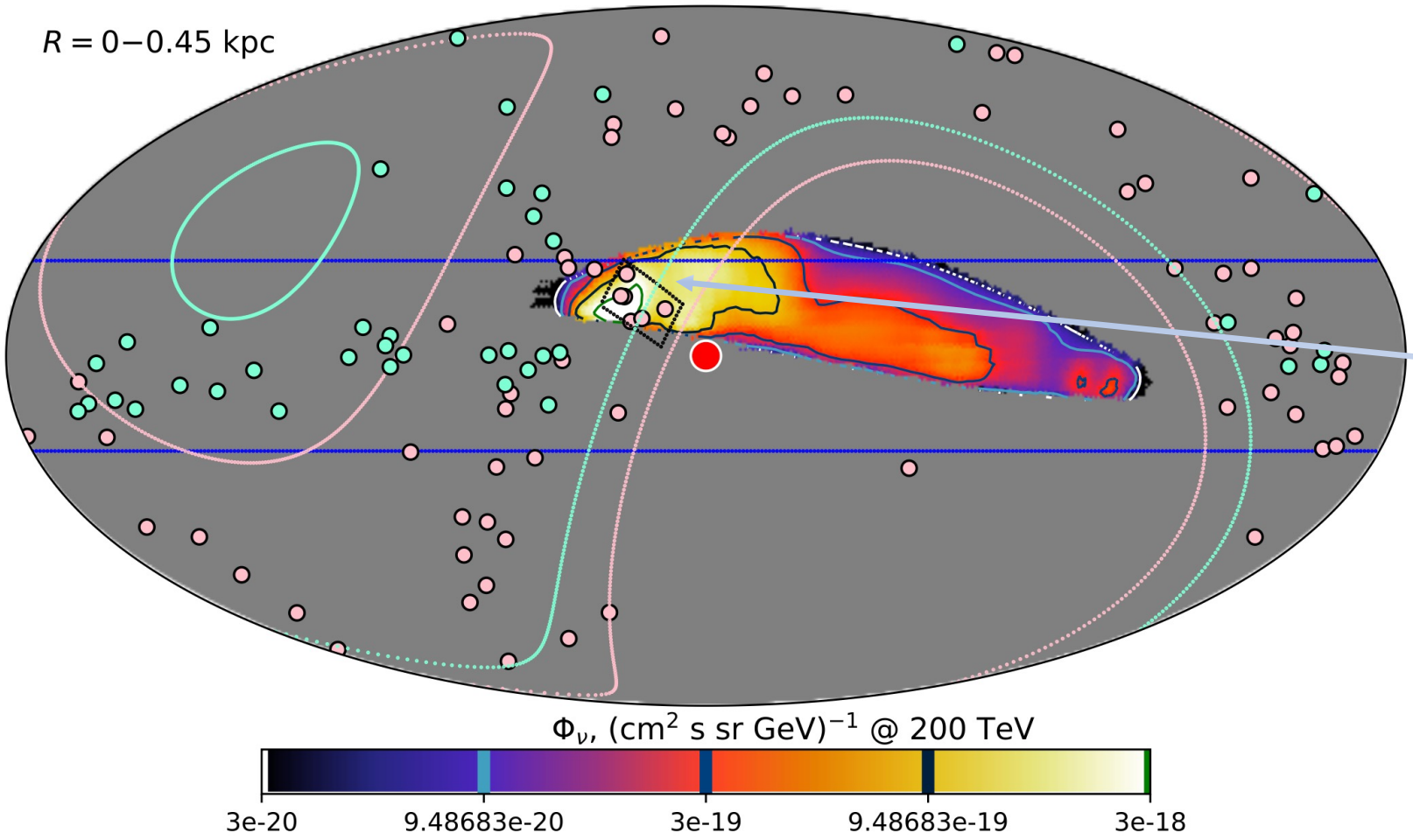
Koldobskiy et al., in prep.

E=1e50 erg
acceleration up to 2 PeV



Neutrino cross sections using AAFrag





Considering Vela as a source of high-energy CRs (up to 10 PeV) with energy budget of 10^{50} erg, we can describe excess in GC direction due to high density of local dust (observed number of neutrinos within the black region is consistent with model). Now we are working to do the same for anticenter.

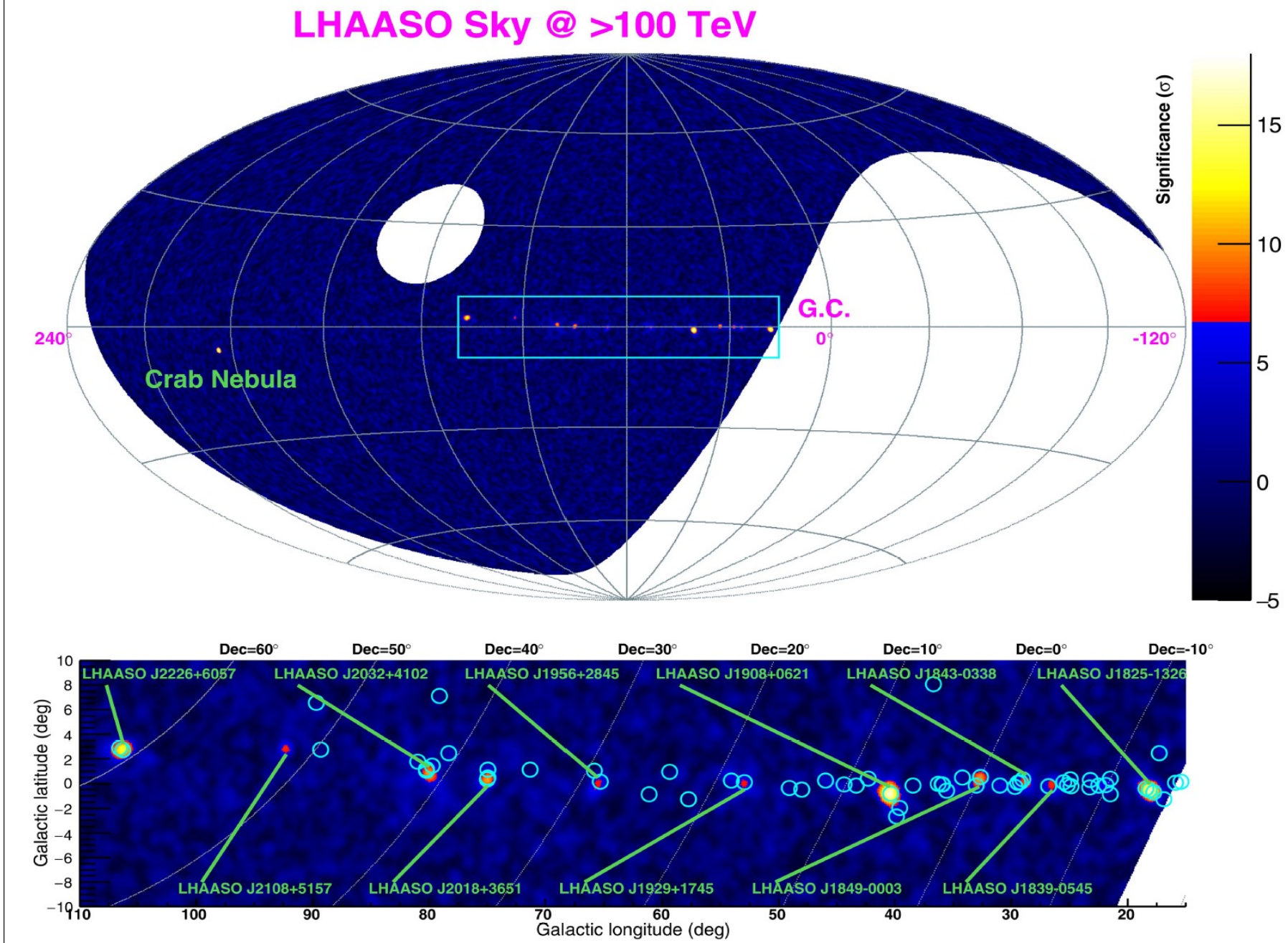
Here, the density of gas is multiplied by normalized CR density, which equal 1 within the magnetic tube otherwise 0.

Interplay between:
- dust density
- distance from the Sun
- CR non-uniformity

Koldobskiy et al., in prep.

Conclusions

- New data reveal patchy spatial distribution of high-energy diffuse gamma flux – in contrary to low energies measured by Fermi;
- The same preliminary results are obtained for neutrino fluxes;
- If we hypothesize that high-energy CR density stops to be quasi-uniform within the Galaxy, we are able to describe these uniformity by interaction between local gas (thanks to Rosaline and her co-workers) and volumes with high CR density (motived by Gwinael et al. studies);
- More gamma and neutrino data are needed to support the hypothesis;



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