Angular Power Spectrum analysis on current and future neutrino data

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Based on: arXiv:1811.02576, arXiv:1910.12917

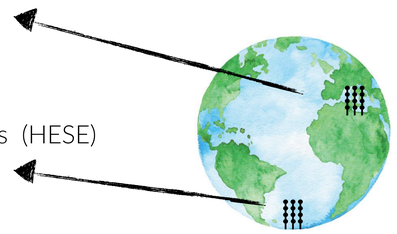
Neutrino Observations

No point-source detected yet
Distribution of neutrino events isotropic

KM3NeT
- View on Galactic Centre with Through-going
- High angular resolution

IceCube, IceCube-Gen2
High-Energy Starting Events (HESE)
- Full sky

Through-Going Events (TG)
- Northern sky



Angular Power Spectrum

Use anisotropic features to constrain source populations

- Bright source classes & decaying/annihilating DM from the galactic centre will show anisotropies on the neutrino sky.
- Monte Carlo method to test model and null (isotropic) hypothesis
- Angular Power Spectrum analysis (assesses anisotropies)

Conclusion

Angular power spectrum is a powerful tool to constrain contributions from source populations:

- Stringent limits on DM cross-section and lifetime using angular information only. With future neutrino observations, the current best-fit DM scenario from HESE observations [3] can be tested. See also poster by Marco Chianese.
- Bright astrophysical source populations like BL Lacs and FSRQs will be significantly constrained if an isotropic distribution will be observed in future. Current 2-yr IceCube data already limits $N_\star < 82$ at 95CL.

References

[1] J. Stettner, IceCube Collaboration, ICRC 2019 [arXiv:1908.09551].
[2] A. Schneider, IceCube Collaboration, ICRC 2019 [arXiv:1907.11266].
[3] M. Chianese, D. F. G. Fiorillo, G. Miele, S. Morisi, and O. Pisanti, JCAP 1911 (2019) [arXiv:1907.11222].
[4] A. U. Abeysekara et al. (HAWC), JCAP 1802, 049 (2018) [arXiv:1710.10288].
[5] T. Cohen, K. Murase, N. L. Rodd, B. R. Safdi, and Y. Soreq, Phys. Rev. Lett. 119, 021102 (2017) [arXiv:1612.05638].

Current and Future Sensitivities

Dark Matter

Tension in observed spectrum between HESE and TG [1,2] suggests 2nd component

$$\frac{d\Phi_\nu}{dE_\nu} = \Phi_0 \left(\frac{E_\nu}{100\text{TeV}}\right)^{-\gamma}$$

$$\gamma^{TG} = 2.28, \quad \gamma^{HESE} = 2.89$$

First-order Fermi acceleration:

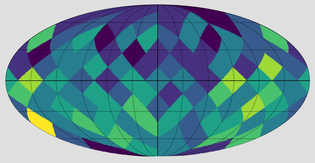
$$2.0 \lesssim \gamma \lesssim 2.2$$

Could second component be explained by DM?

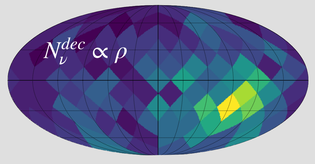
Anisotropic features
- DM from Galactic Centre

Isotropic features
- DM from EG origin
- EG astrophysical sources
- Atmospheric neutrinos

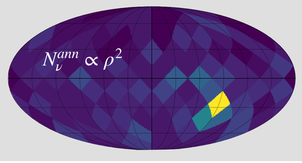
Null hypothesis (Astro)

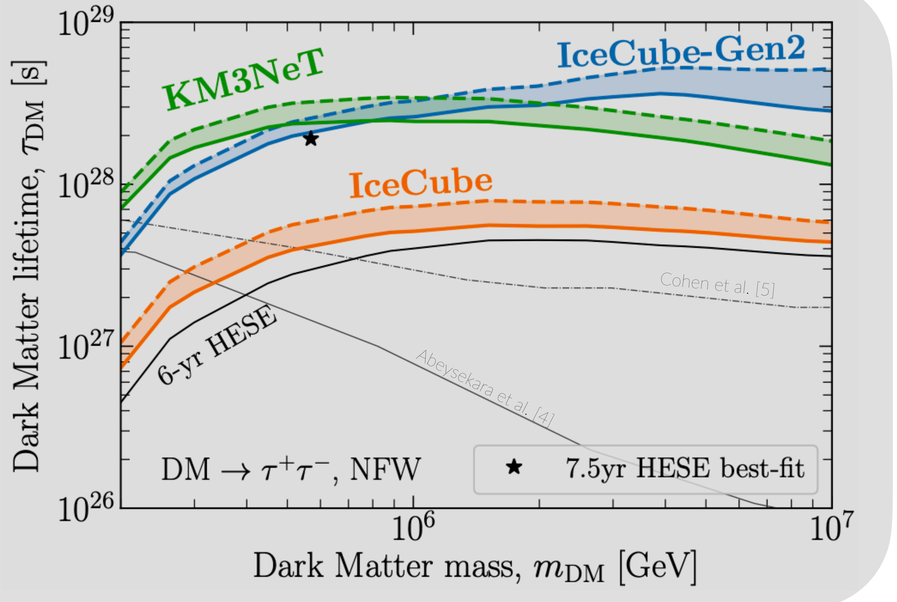


Model (Astro + Decaying DM)

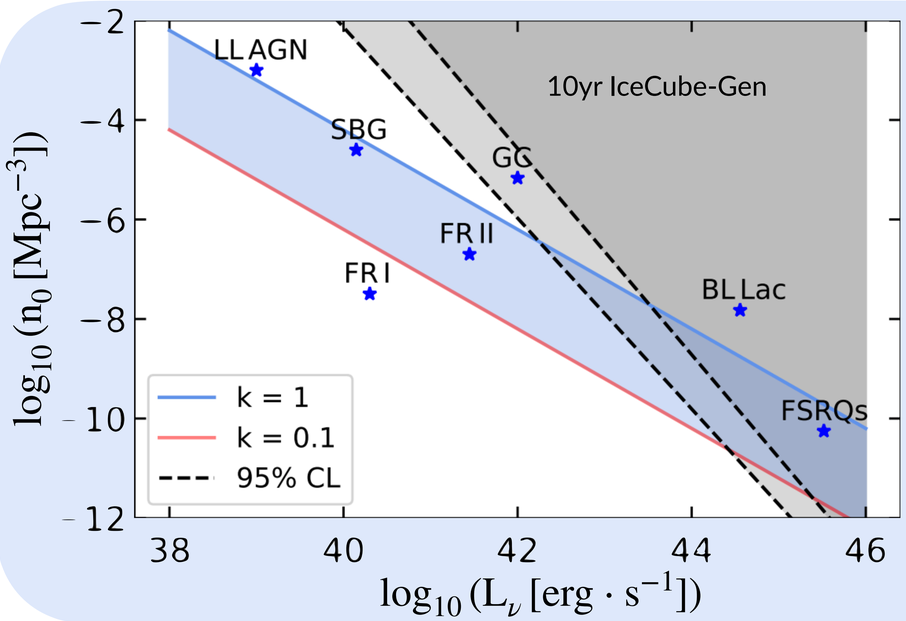


Model (Astro + Annihilating DM)





Astrophysical sources



High-energy neutrinos observed with TG sample mainly from EG astrophysical sources.

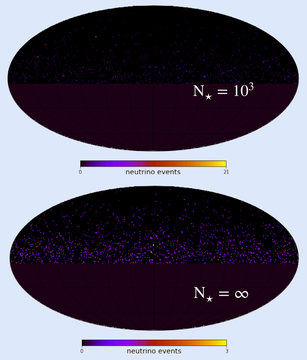
Apply statistical distribution for flux of each source, following broken power-law:

$$\frac{dN_s}{dF} = N_\star \times \begin{cases} \left(\frac{F}{F_\star}\right)^{-2.5} & F_\star < F \\ \left(\frac{F}{F_{-1.5}}\right)^{-2.5} & F_0 < F < F_\star \end{cases}$$

Leave $N_\star \propto \frac{I_\nu}{F_\star}$ as free parameter

Anisotropic features
- Bright, few source populations e.g. blazars ($N_\star = 600$)

Isotropic features
- Faint, numerous source populations e.g. starburst galaxies ($N_\star = 10^7$)
- Atmospheric neutrinos



With current IC data (2-yr, TG) exclude source populations $N_\star < 82$ at 95%CL