Energy-dependent flavor ratios, cascade/track spectrum tension and high-energy neutrinos from magnetospheres of supermassive black holes
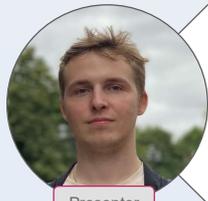
arXiv:2204.09339

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Intro

The origin of high-energy astrophysical neutrinos?

change of the flavor content of astrophysical neutrinos with energy?
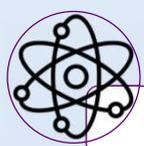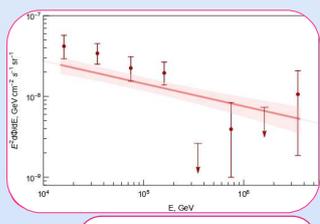
a mild tension between spectra obtained in different analyses
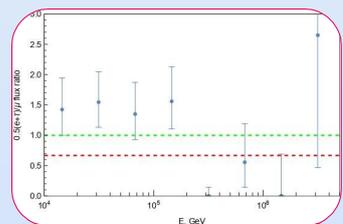
IceCube neutrinos (E>10000 GeV)

Analysis

Observed spectra
- Tau plus electron neutrinos (dots with error bars)
- Mu neutrinos (solid line)

Flavor ratios (at the detector and at the source, taking into account neutrino oscillations)
- The case of flavor equipartition (dashed green line)
- The case of muon damp(dashed red line)

- pp-interactions:
$$p + p \rightarrow p + p + many \times (\pi^+ + \pi^- + \pi^0).$$

- $p\gamma$-interactions:
  1. $p + \gamma \rightarrow \Delta^+$
  2. $\Delta^+ \rightarrow n + \pi^+$ or $\Delta^+ \rightarrow p + \pi^0.$

- Decays following pp- and $p\gamma$-interactions:
  1. $\pi^0 \rightarrow \gamma + \gamma, \ \pi^\pm \rightarrow \mu^\pm + \nu_\mu \, (\overline{\nu_\mu})$
  2. $\mu^\pm \rightarrow e^\pm + \nu_e \, (\overline{\nu_e}) + \overline{\nu_\mu} \, (\nu_\mu).$

Physical conditions at the sources
- In the case of damped muons the neutrinos from the last equation are "missing", changings the flavor ratios
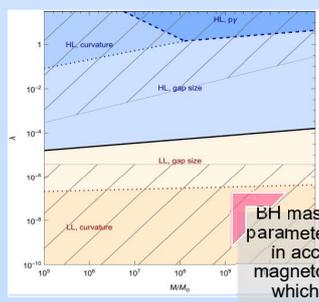- "Muon damp" corresponds to specific magnetic fields
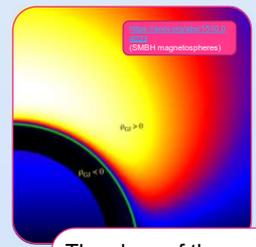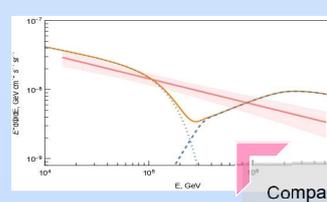

The class of the sources
- Black holes
- ~~Gamma-ray bursts~~

SMBH toy model

BH mass - Eddington ratio parameter space, calculated in accordance with BH magnetosphere toy model, which gets to estimate proton energies and finally provide a prediction of neutrino spectra

Comparison of the muon neutrino spectrum determined by IceCube and predictions of the toy model discussed in the text

Comparison of the e+tau neutrino spectrum determined by IceCube and predictions of the toy model discussed
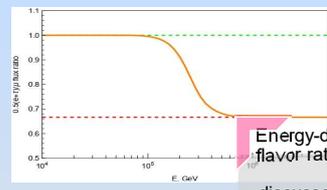
Energy-dependent neutrino flavor ratio predicted by the toy model discussed in the text (solid curve). The dashed green line represents flavor equipartition, while the dashed red line corresponds to 2/3, predicted in the muon damping case

Conclusions

It is presently unclear, whether the tension is caused by systematic uncertainties or by physical reasons.
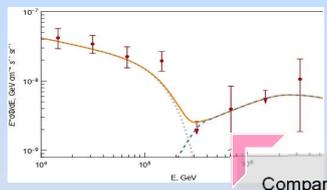
We assumed that the reason for the discrepancy is related to the change of flavor composition

Then we estimated the magnetic field at sources required for this switch

We constructed a quantitative toy model

We found that this model describes well the spectra provided an additional component with standard flavor content is added at low energies

Detailed studies of energy-dependent flavor ratios will become possible only with the next-generation neutrino telescopes

Bibliography
- https://arxiv.org/abs/2111.10299 (mu neutrinos data)
- https://arxiv.org/abs/2001.09520 (e+tau neutrinos data)
- https://arxiv.org/abs/1510.04023 (SMBH magnetospheres)