Search for high-energy neutrino emission from hard X-ray AGN with IceCube

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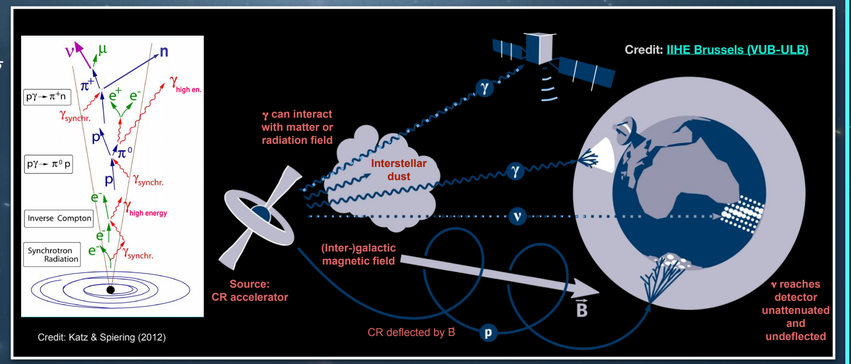
1. Neutrino emission from AGN

Active Galactic Nuclei (AGN) are powerful sources that could accelerate cosmic rays to very high energies. These cosmic rays can interact with the ambient photon or matter field to produce neutrinos and gamma rays, respectively with comparable energies. This makes AGN a promising candidate source of very-high-energy (TeV-PeV) astrophysical neutrinos observed by IceCube [1].

- Evidence for neutrino emission from blazar TXS0506+056 and $\sim 3\sigma$ excess from Seyfert II galaxy NGC 1068 [2, 3].
- Models predict [4] :

TeV-PeV γ rays in AGN
+
Ambient photons in AGN
↓
Cascade down to MeV gamma rays or hard X-rays ($\gtrsim$ 10 keV)



- Hard X-rays are therefore an important probe into hadronic emission of neutrinos.

2. Hard X-ray Sources

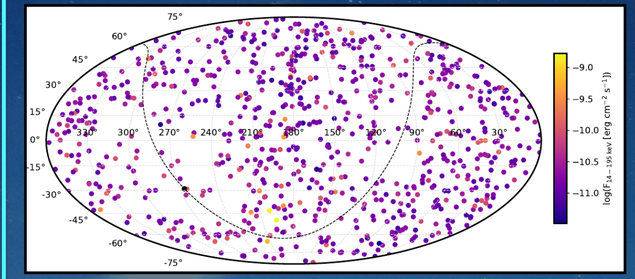


Fig: Skymap showing BASS sources and intrinsic flux in the 14-195 keV band.

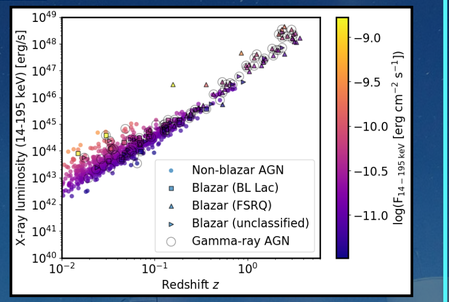


Fig: Hard X-ray luminosity of BASS sources as a function of redshift.

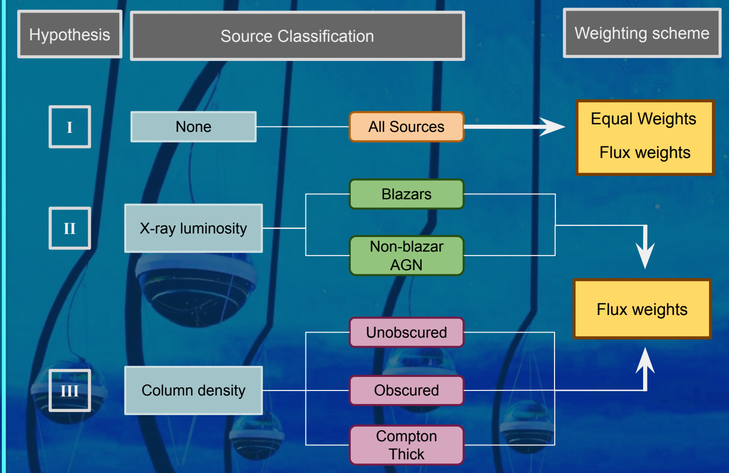
- The 70 Month Swift-BAT All-Sky Hard X-Ray Survey has 1171 hard X-ray sources detected > 10 keV [5].
- The BAT AGN Spectroscopic Survey has 838 AGN sources.
- Most complete all-sky catalog of hard X-ray AGN in the 14-195 keV range.
- Includes soft X-ray (0.3-10 keV) observations.
- Includes multi-wavelength physical properties derived from analysis of X-ray and available optical spectroscopic data [6].
- **836 sources** selected: excluded 2 sources without soft X-ray observation.

3. Neutrino data

The gamma-ray follow-up (GFU) sample [7]

- Sample of tracks with good angular resolution
- All-sky coverage
- 7.5 years of data
- Sample from the complete 86-string IceCube configuration between 2011-2018
- Reprocessed offline for better sensitivity

4. Analysis Outline



- Perform time-integrated un-binned log likelihood analysis by stacking the sources in our catalog.
- Flux weights $\propto$ intrinsic flux in the 14-195 keV range. This is selective towards the sources with a higher flux.
- Equal weights is an unbiased weight.

Column density (N_H) subclass	Log N_H in cm^{-2}
Unobscured	< 22
Obscured	22-24
Compton thick	> 24

5. Sensitivity and Discovery Potential

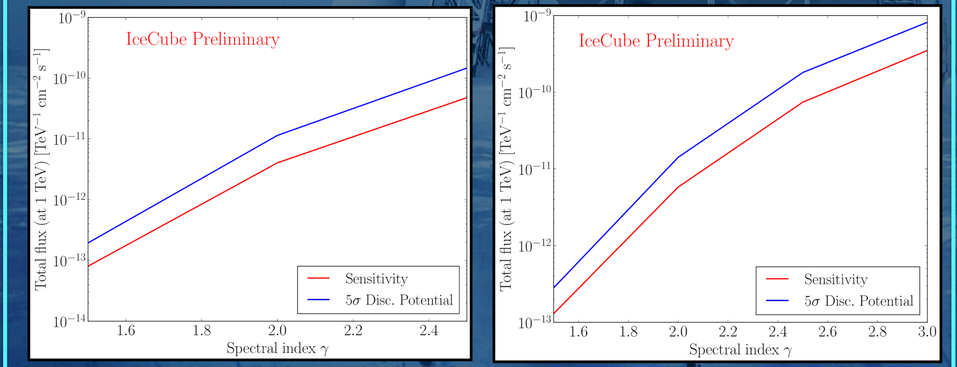


Fig: Stacked flux at normalization energy 1 TeV as a function of spectral index (left) for Flux weights and (right) for Equal weights.

- Hypothesis I : Perform analysis on all the hard X-ray AGN sources in the BASS catalog.
- Sensitivity is the flux required so that 90% of injected signal trials have a value of TS higher than that in 50% of the background-only trials.
- 5σ discovery potential is the flux required so that 50% of the time this flux will produce a result inconsistent with the background-only hypothesis at the discovery level of 5σ.

6. Summary

- We have performed a preliminary blind analysis using all the sources in the catalog as per hypothesis I for both the Flux and the Equal weighting schemes.
- We have evaluated the sensitivities and 5σ discovery potentials and obtained a plot showing their values for various spectral indices.

7. Outlook

- We will perform analysis according to hypothesis II on bazars and non-blazar AGN separately to test correlation between luminosity and neutrino emission .
- We will perform analysis according to hypothesis III on 3 sub-classes of sources based on column density to test correlation between column density and neutrino emission.

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References

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[7] **IceCube** Collaboration, M.G. Aartsen *et al.*, *Astroparticle Physics 92 (Jun, 2017) 30-41*