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A MODEL-INDEPENDENT ANALYSIS OF NEUTRINO FLARES DETECTED IN ICECUBE FROM X-RAY SELECTED BLAZARS

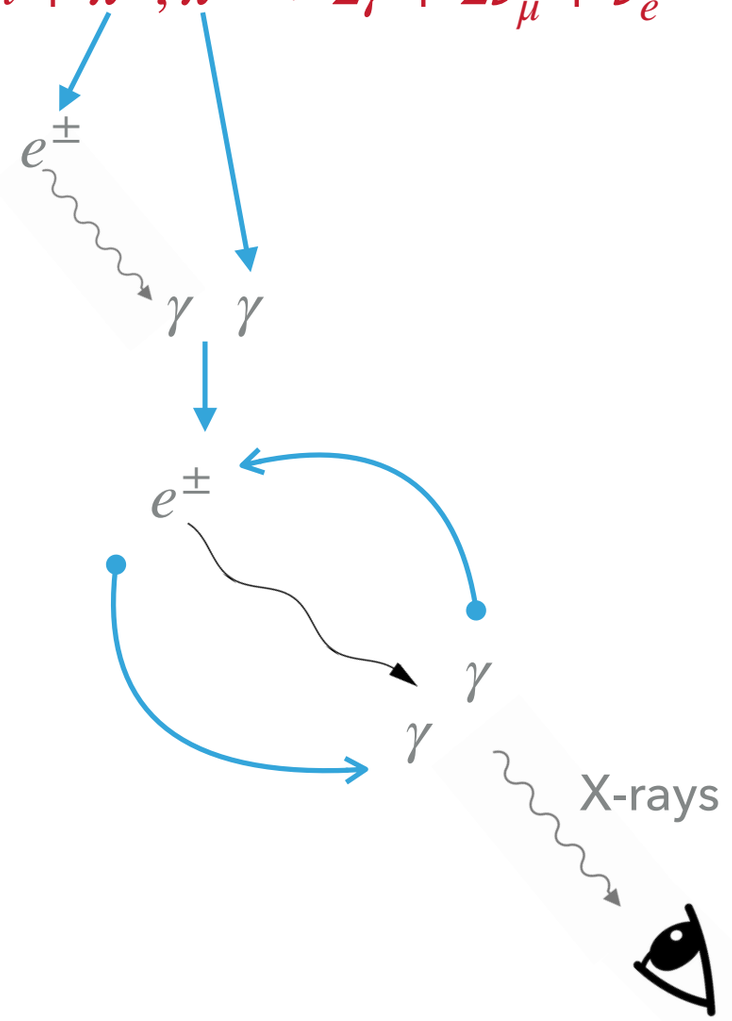
*PRESENTER

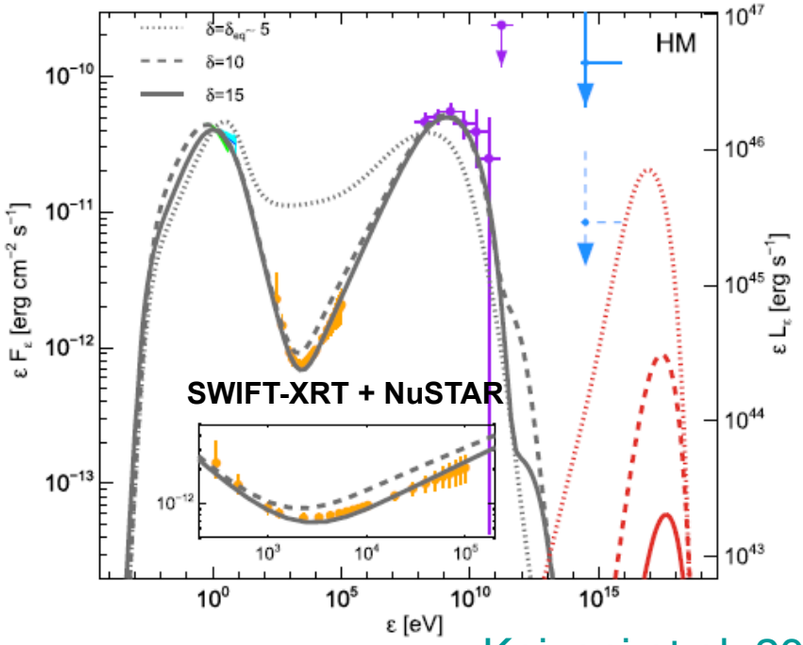
MOTIVATION

Proton Induced Cascades (PIC) :

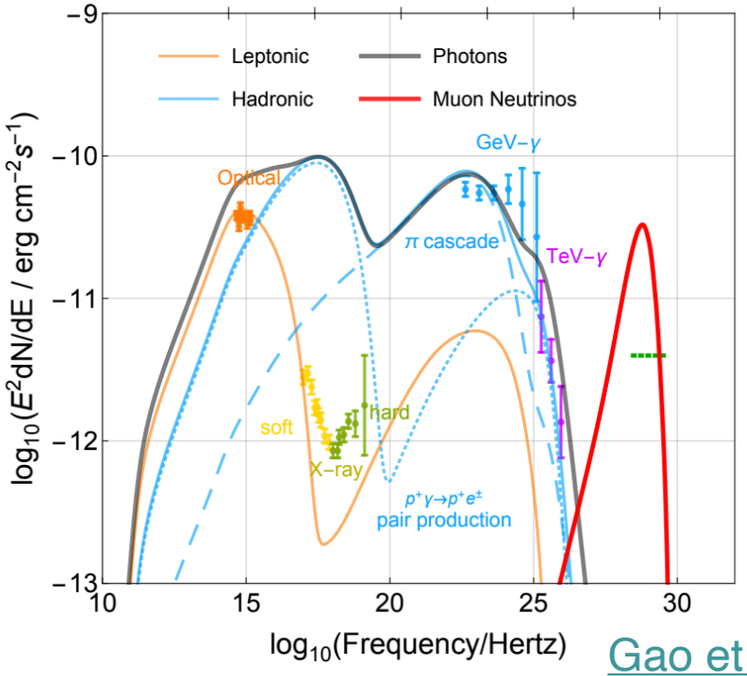
$$p + \gamma \rightarrow p/n + \pi^{\pm}, \pi^{0} \rightarrow 2\gamma + 2\nu_{\mu} + \nu_{e}$$

- Secondary $e^{\pm}$ pairs generated by pion decay produce high energy photons via Synch./Compton processes
- These photons combine to produce new pairs, which radiate a new generation of photons
- The *synchrotron-pair cascades* shift the extreme proton energies down to the X-ray band





Keivani et al. 2018



Gao et al. 2018

X-rays from PIC can be used to constrain the expected neutrino flux from source, if a hadronic contribution is assumed

ANALYSIS FUNDAMENTALS

Objective: Test the hypothesis 'X-ray bright blazars can be sources of high-energy astrophysical neutrinos'….under the assumption that blazars can flare > twice on avg. over the period of observation

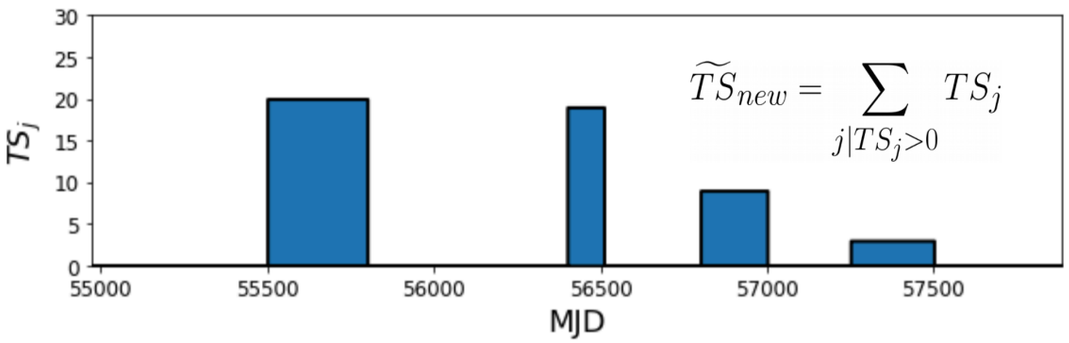
- A **model independent,** time-dependent, untriggered multi-flare search:
  - ➡ search for neutrino flares in 10 years of IceCube data from a catalog of blazars curated by X-ray fluxes, and obtain a local p-value for each source
  - ➡ perform a population test using the binomial test statistic to determine the sub-population with statistically significant emission

Multi-flare method

Reports the combined significance of all flares from a source direction (multi-flare TS) instead of the most significant flare

$$\mathcal{L}(n_s, \gamma, \Delta t_j) = \prod_{i=1}^{N} \frac{n_s}{N} S_i + (1 - \frac{n_s}{N}) B_i$$

$$\mathrm{TS}_j|_{\Delta t_j} = -2 \log \left[\frac{\Delta T_{\mathrm{data}}}{\Delta t_j} \times \frac{\mathcal{L}(\vec{x}_s, n_s = 0)}{\mathcal{L}(\vec{x}_s, \hat{n}_s, \hat{\gamma}_s)} \right]$$

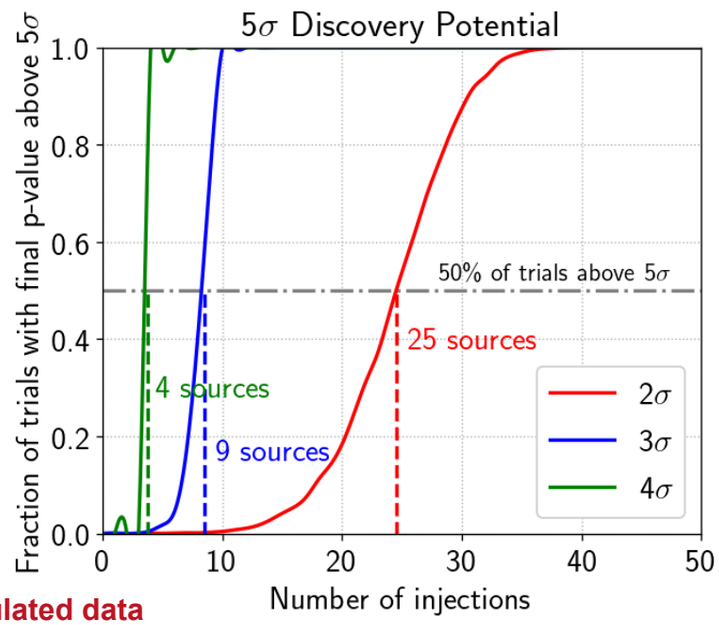


Credit: Will Luszczak

Binomial Test

If a sub-population within the catalog has statistically significant emission, the test can reveal how many and which sources are of interest

$$P(k) = \sum_{m=k}^{N} \binom{N}{m} p_k^m (1 - p_k)^{N-m}$$



*Plot based on simulated data

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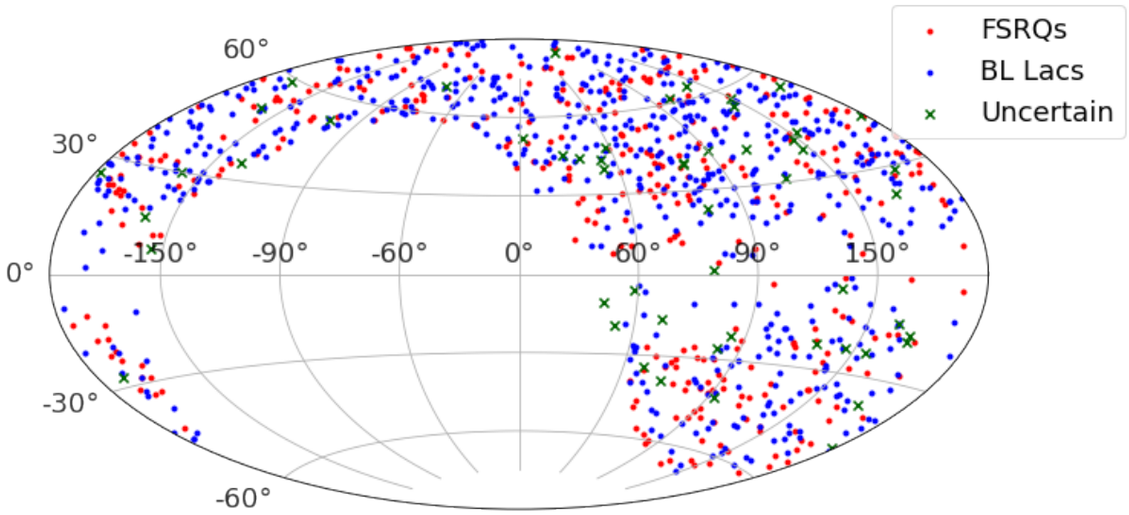
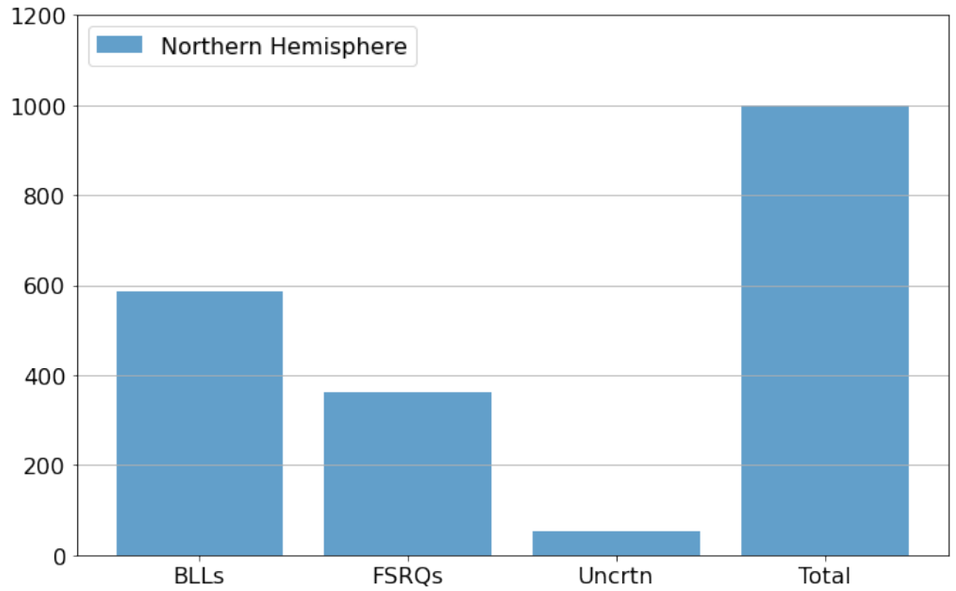
ROMABZCAT 5TH EDITION (2015)

- Multi-frequency blazar catalog; X-ray fluxes (**0.1 - 2.4 keV**) taken from **ROSAT All Sky Survey**

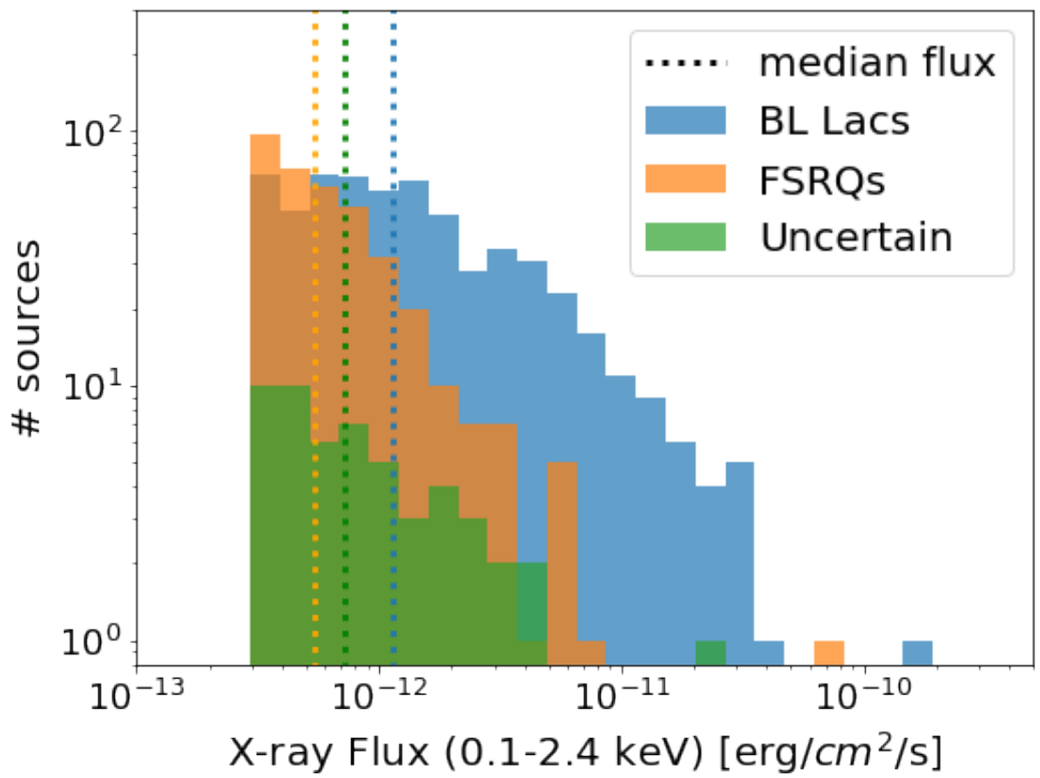
✓ We select 1000 blazars from the Northern hemisphere (-5, +85 deg.) with the highest X-ray fluxes in the catalog



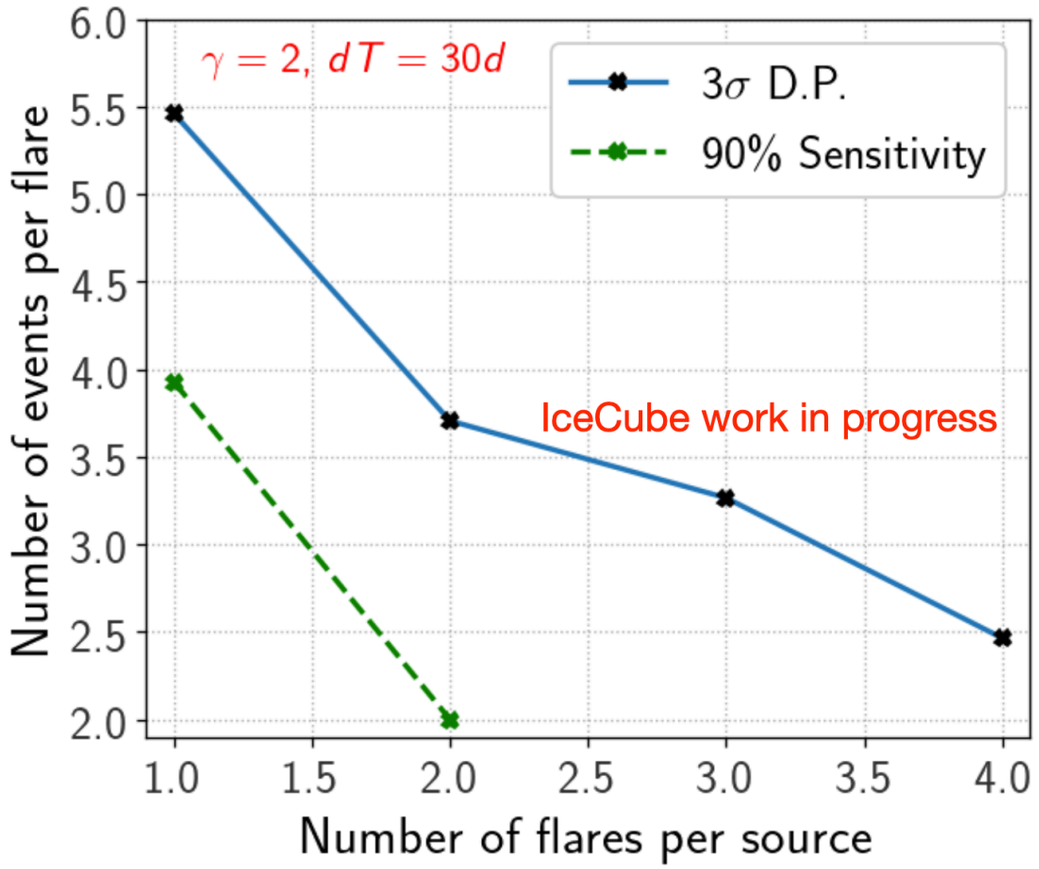


After selection cuts:

- **BL Lacs: 586, FSRQs: 361, Uncertain type: 53**
- **X-ray fluxes b/w 3.1e-13 to 1.8e-10 erg/cm²/s**

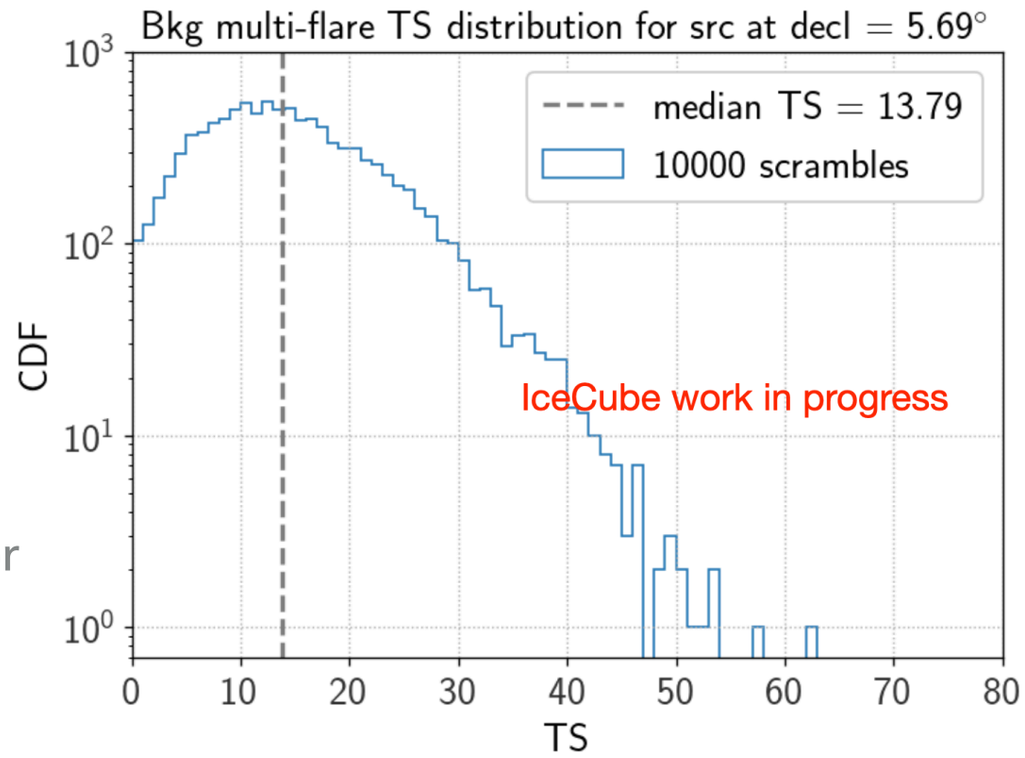


PRELIM RESULTS – PER SOURCE SENSITIVITY



- 10000 trials for a single source location (at the declination of TXS 0506+056) with and w/o signal injection
- Fixed spectral index and flare duration for injected signal (γ = 2, δT = 30 days)
- Box profile flares; S/B = 2000

Strength of individual flares from a single source required to obtain a final discovery potential (D.P.) of 3-sigma and a 90% C.L. sensitivity



Background multi-flare TS distribution for the declination of TXS across 10k trials

Full catalog sensitivity and final p-values for each source will be published soon!!

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