Search for Neutrino Emission from X-ray Binaries with IceCube

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On behalf of the IceCube Collaboration

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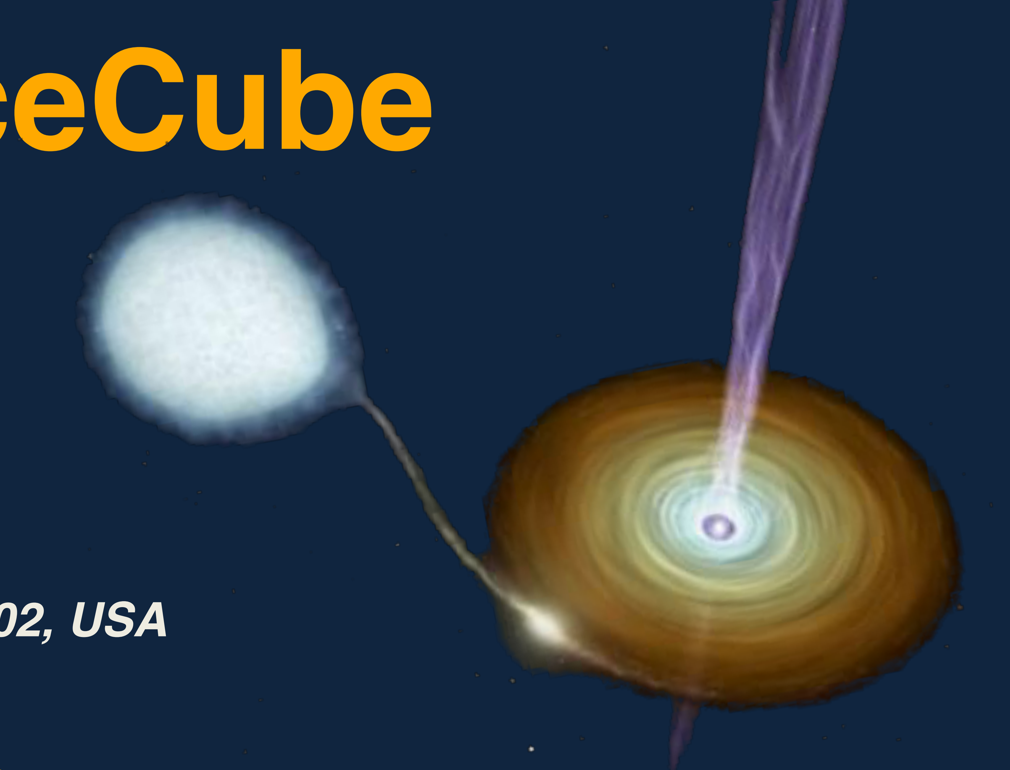
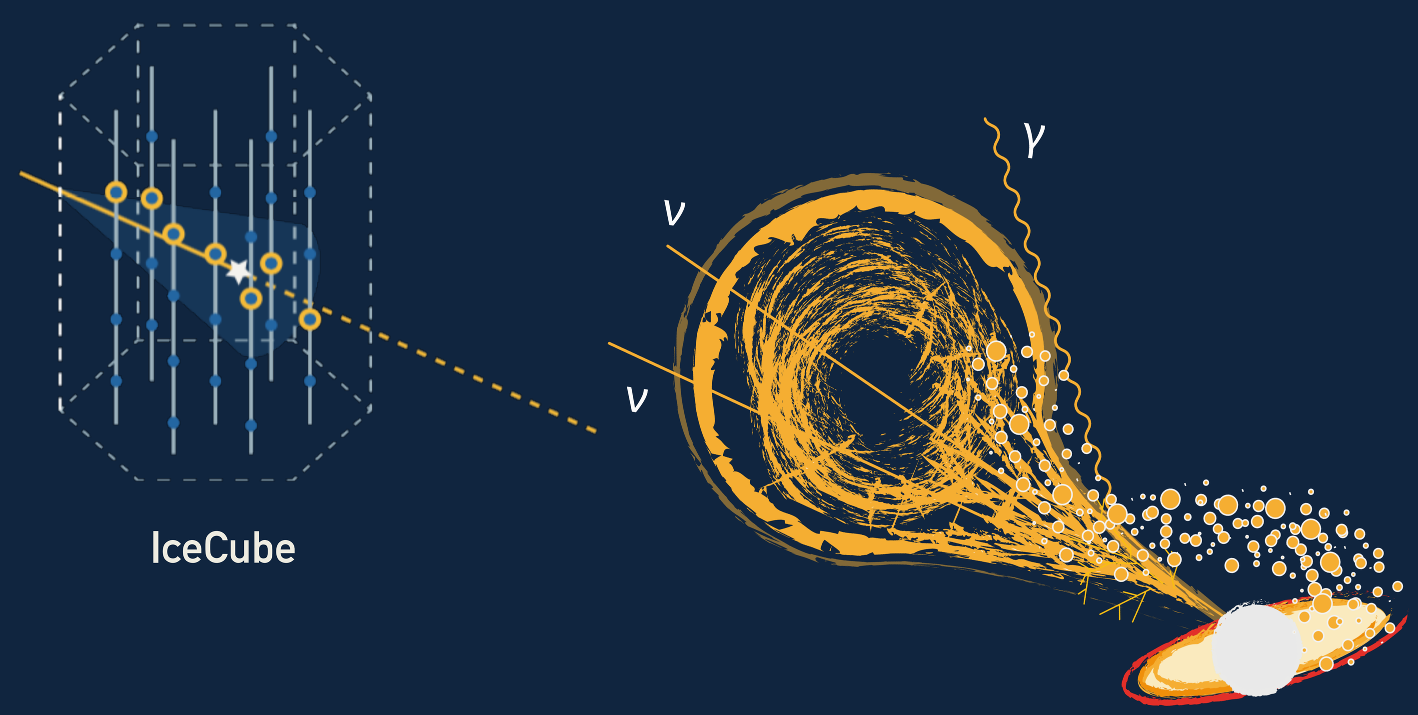


Motivation

- X-ray binaries are binary systems composed of a compact object and a companion star.
- The compact object (black hole/neutron star) can be a particle accelerator. Acceleration happens in the jet or accretion disk.
- Hadronic processes such as proton-proton, photomeson and photo-disintegration can happen in such binaries systems.
- For microquasars, the site can be the wind/atmosphere of the companion star, in the accretion disk, in the jet…
- In other binary systems, the site can be a wide-angle shocked region, at the interface between the pulsar and stellar winds.
- If those hypotheses are true, correlated neutrinos and photons are expected to be observed.

See references: [1][2][3][4]



Method

Unbinned Maximum Likelihood Method

$$L(n_s) = \prod_i^N \left(\frac{n_s}{N} S_i + \left(1 - \frac{n_s}{N}\right) B_i\right)$$

Signal

$$S_i = S^s(x_s, x_i, \sigma_i) \times S^E(E_i, \gamma_s) \times S^T(t_i, D_t, f_{th})$$

Spatial: 2D Gaussian distribution; Energy: power-law spectrum; Time: extracted from the X-ray light curve

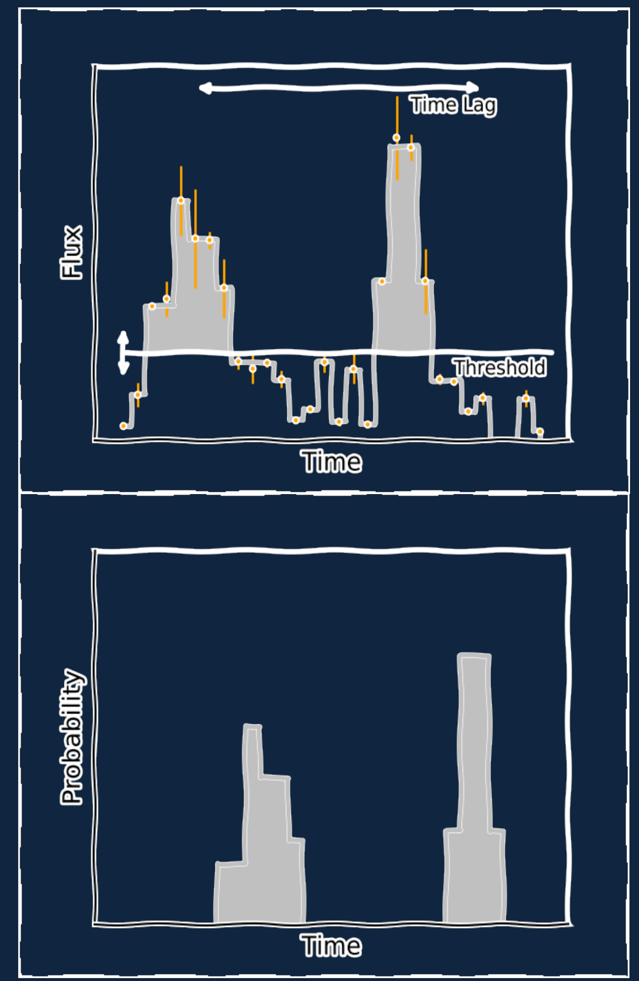
Background

$$B_i(x_i) = \frac{1}{2\pi} B^\delta(\delta_i) \times B^E(E_i) \times B^T$$

Background can be constructed from randomized data.

Time Dependence

- Neutrino emission is assumed to be correlated to X-ray emission.
- The X-ray light curve is used to construct the temporal probability distribution function.
- Bayesian block algorithm [5] is applied to optimize binning of the light curve in order to identify flares.



From X-ray light curve to temporal probability distribution function of neutrino emission.

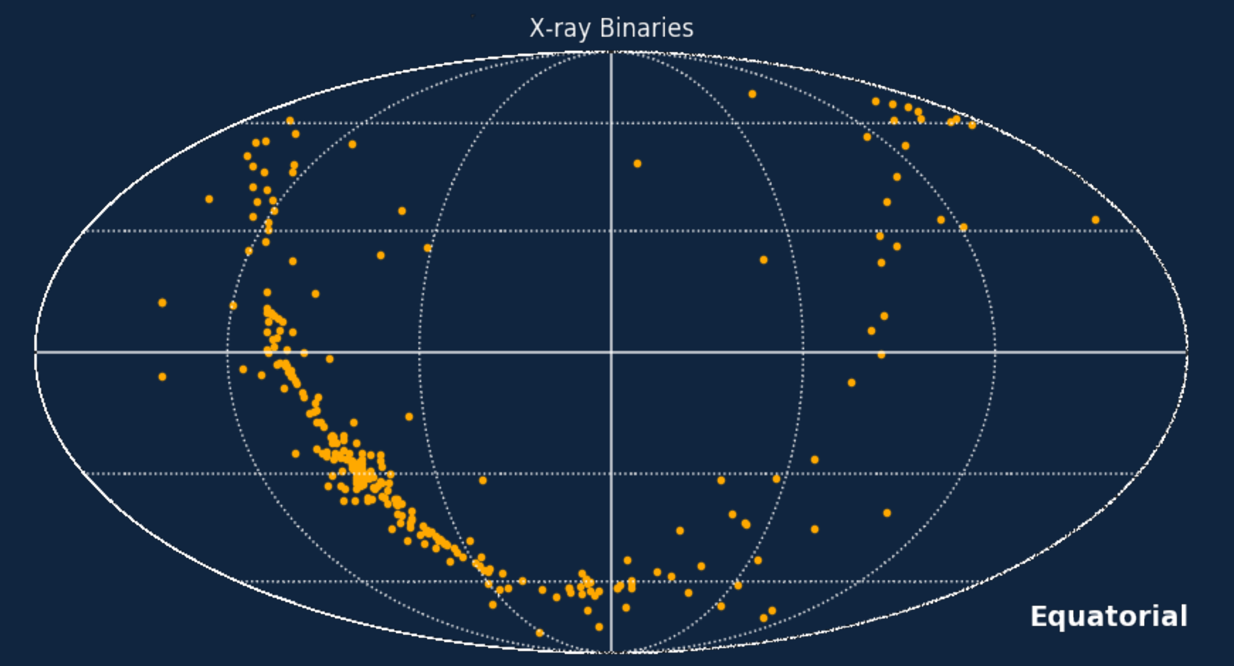
Likelihood Ratio Test

$$TS = -2 \log \frac{L(n_s = 0)}{L(\hat{n}_s, \hat{\gamma}_s, \hat{D}_t, \hat{f}_{th})}$$

Fitting for

number of signal	n_s
spectral index	γ_s
time delay	D_t
threshold	f_{th}

Sources

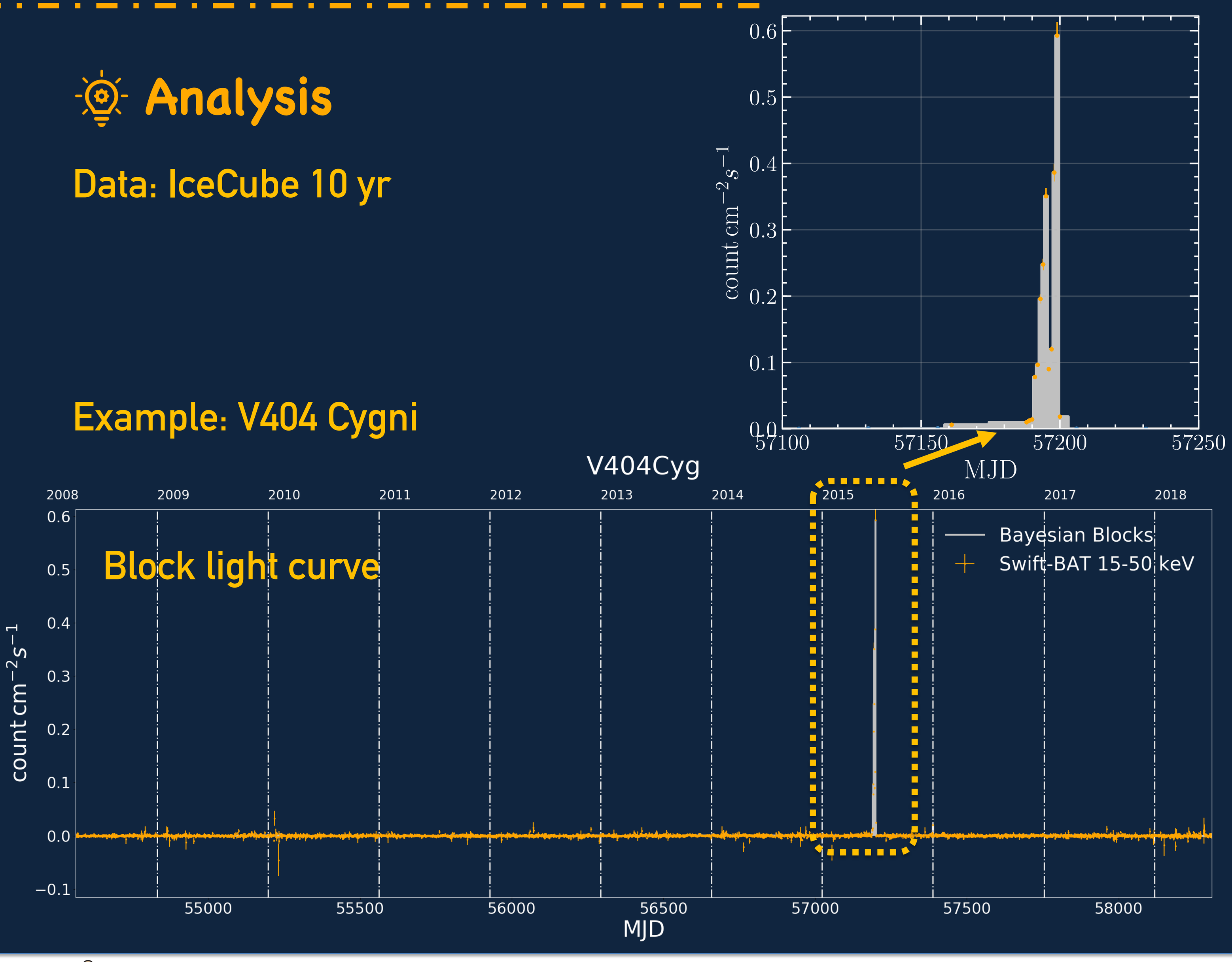


- HMXB and LMXB catalogs [6][7]
- 289 sources after removing overlapping sources.
- Pick *Swift*-BAT (15-50 keV) [9] or MAXI (10-20 keV) [10] light curves.
- Block light curves to construct the time PDF.
- For microquasars without light curves, remove the time PDF and perform a time-integrated analysis.

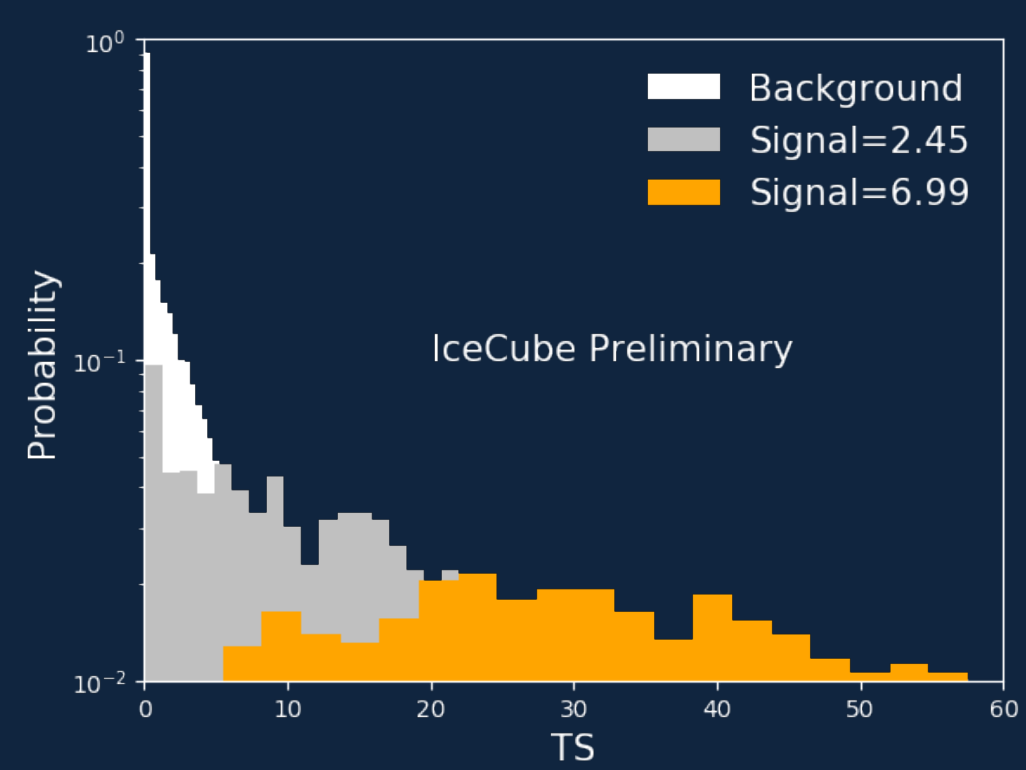
Analysis

Data: IceCube 10 yr

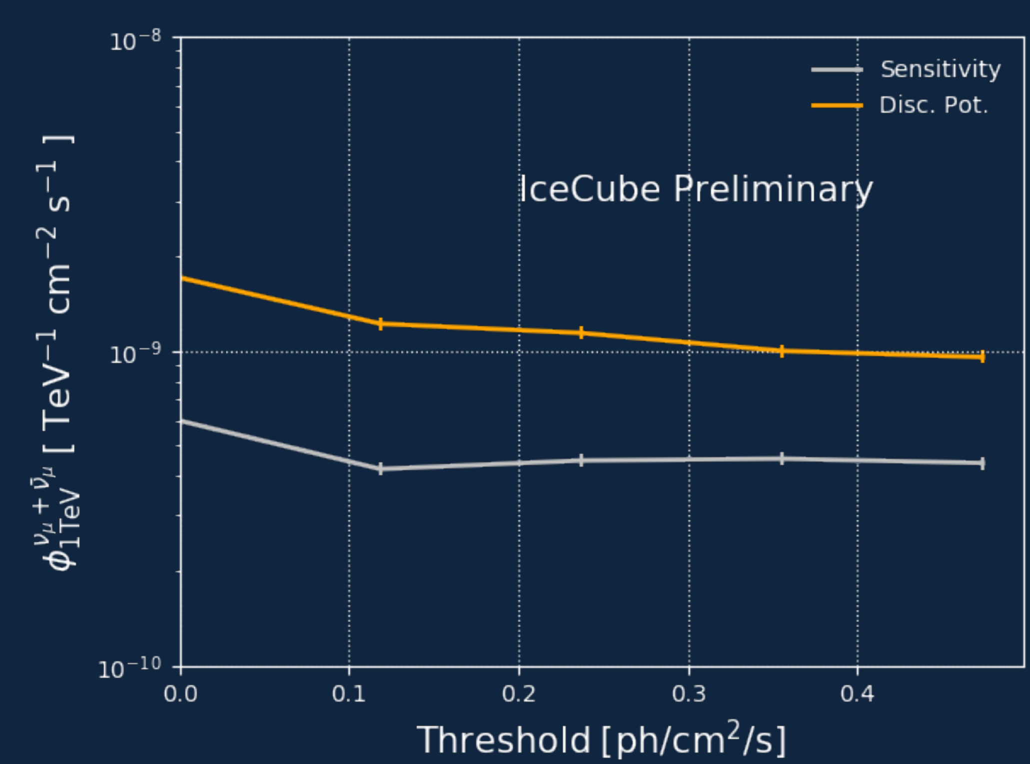
Example: V404 Cygni



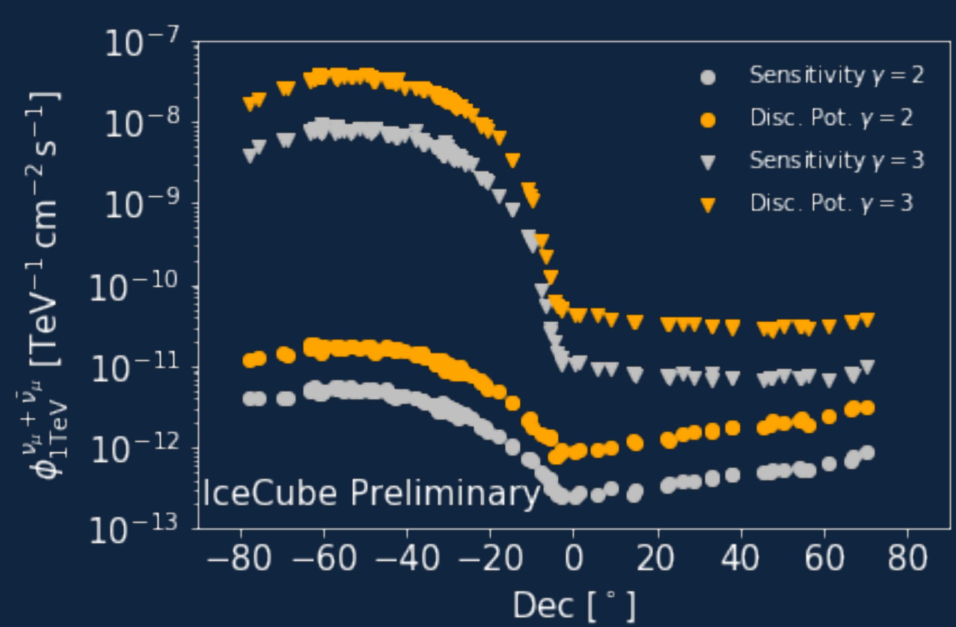
Power-law spectrum E^{-2} is injected.



TS distribution of the background and 90% sensitivity & 5 sigma discovery potential signal numbers. The injection shown here is threshold = 0 and time delay = 0.



90% sensitivity and 5 sigma discovery potential. Time delay is fixed to be 0, vary the threshold.



Time-integrated 90% sensitivity & 5 sigma discovery potential for the rest of sources without hard X-ray light curves from *Swift*-BAT/MAXI.

References

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[5] Scargle, J., et al. *ApJ* 764.2 (2013): 167.
[6] Liu, Q. Z., et al. *Astronomy & Astrophysics* 455.3 (2006): 1165-1168.
[7] Liu, Q. Z., et al *Astronomy & Astrophysics* 469.2 (2007): 807-810.
[8] https://swift.gsfc.nasa.gov/results/transients/index.html
[9] http://www.maxi.jaxa.jp/obs/agn_etc/

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