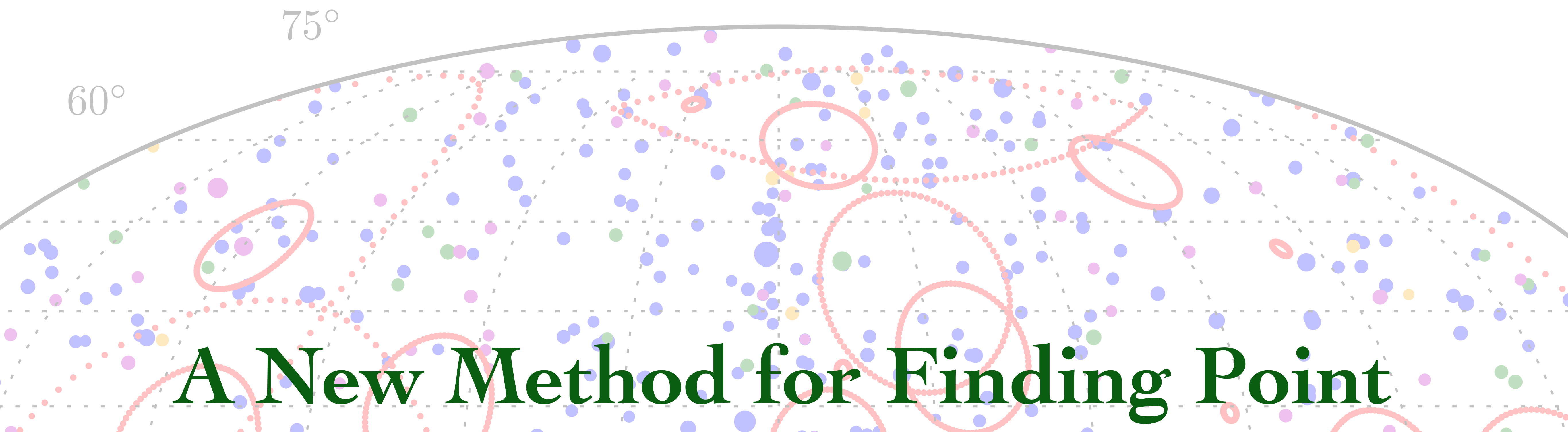

A New Method for Finding Point Sources in High-energy Neutrino Data

Ke Fang

JSI Fellow
University of Maryland

May 9, 2017

Problem Set

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Events

TeV - PeV:

- poor statistics: about 10 high-energy muon neutrino events per year, more at low energies
- poor angular resolution: ~0.4 deg

EeV: undetected, predicted to exist

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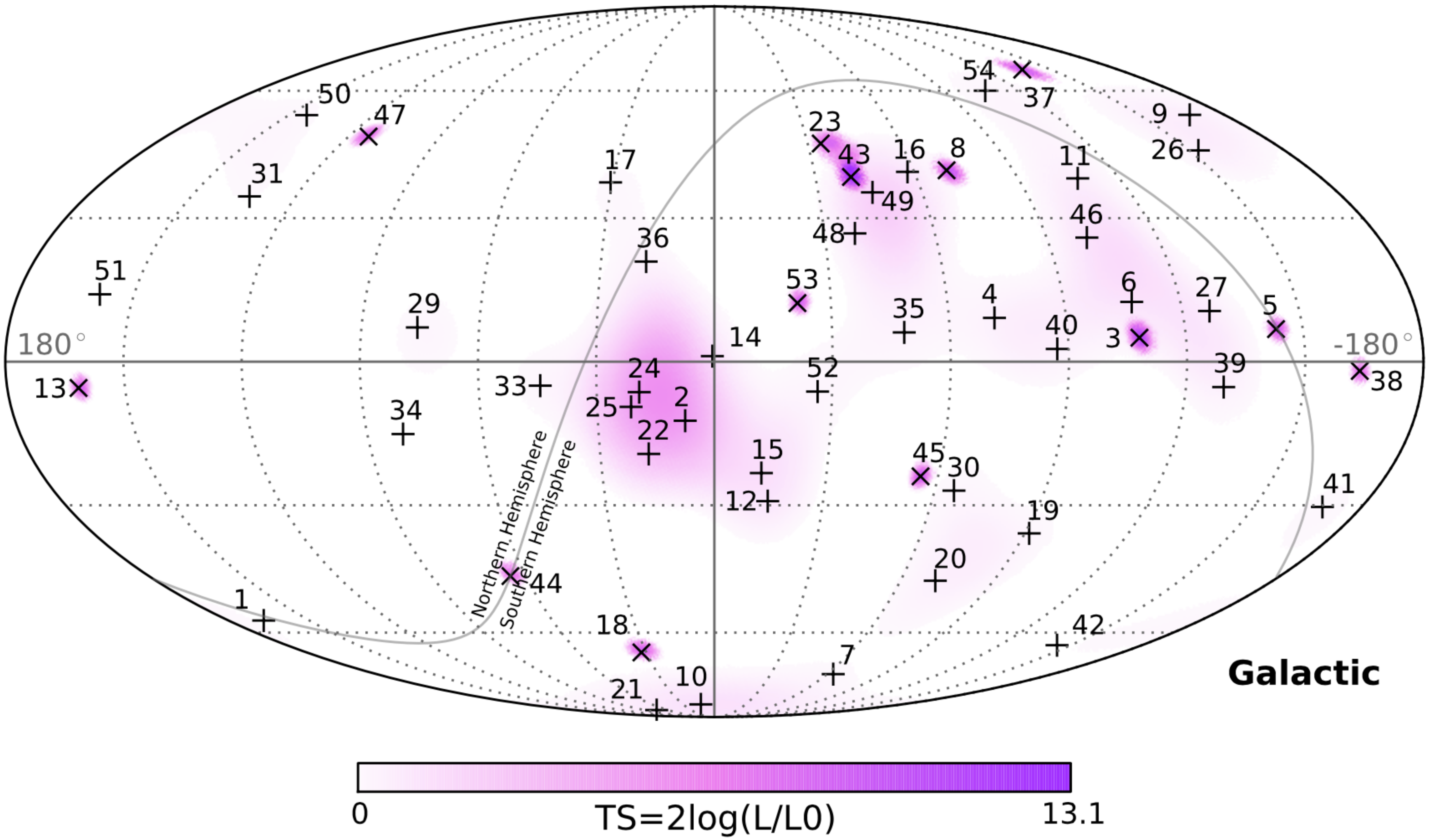
Objective

find the sources!

Standard Point-Source Search Method

Divide the sky!



Braun+ 0801.1604
Braun+ 0912.1572

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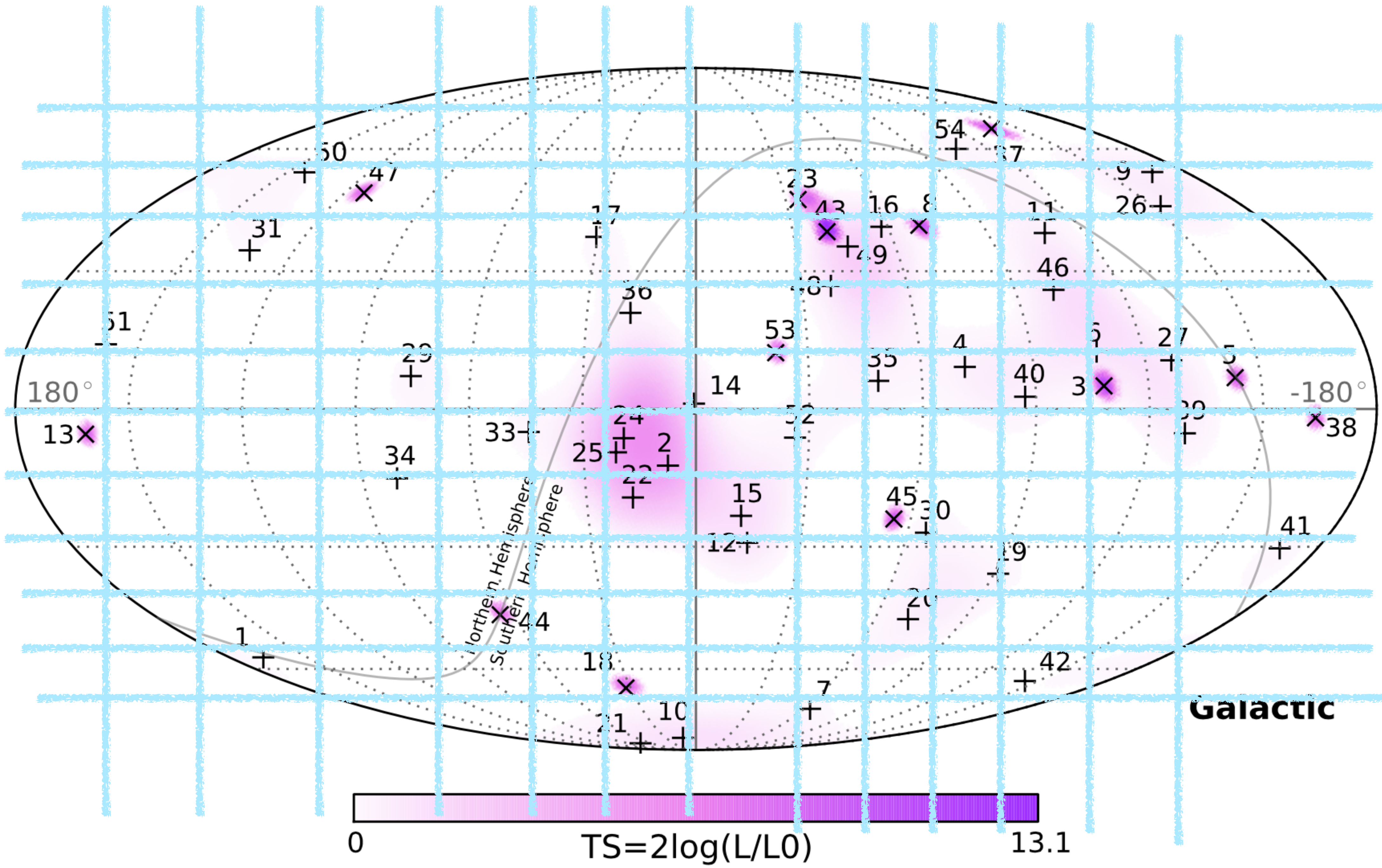

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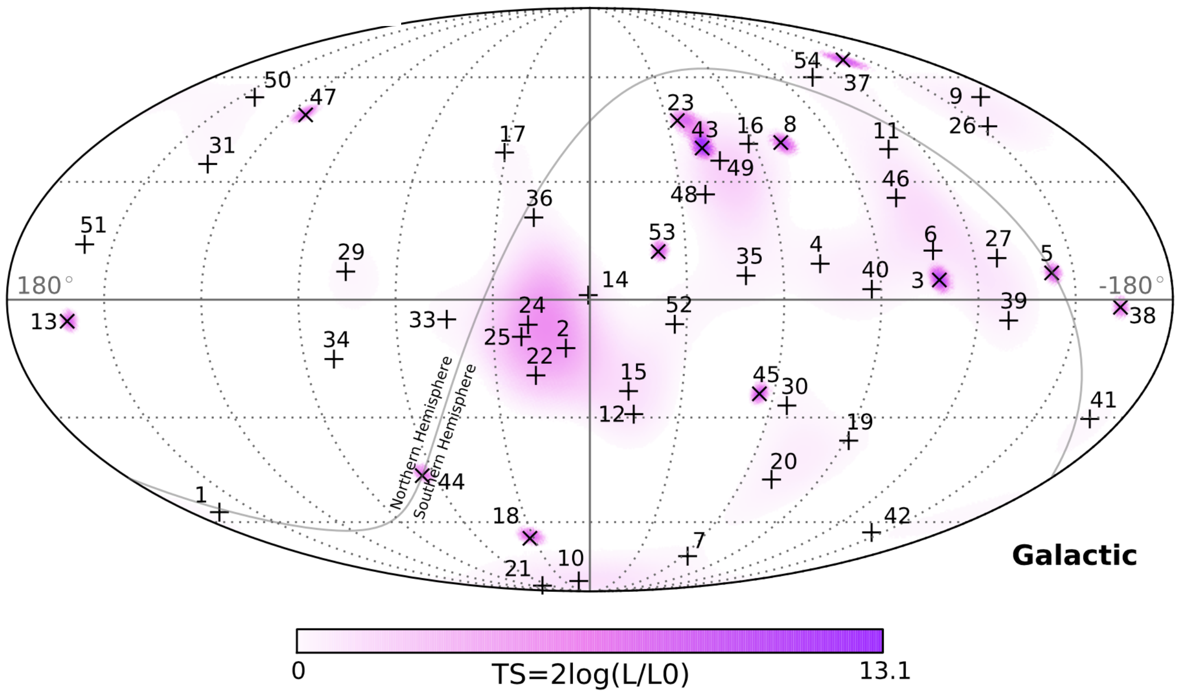

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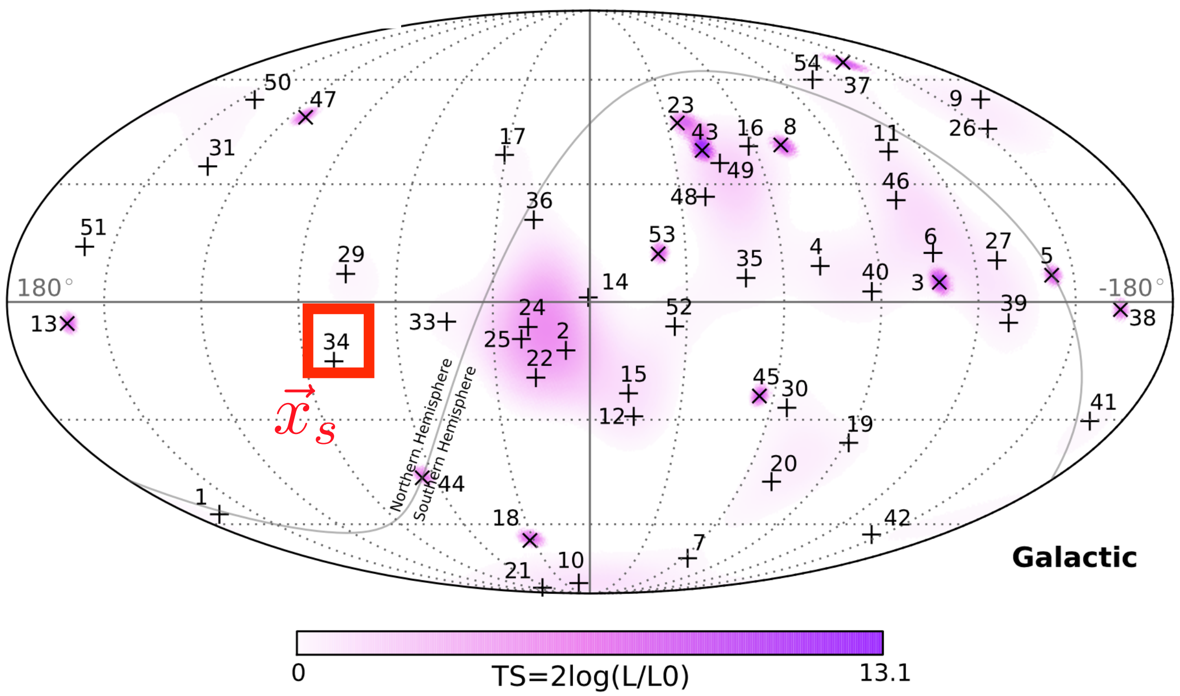

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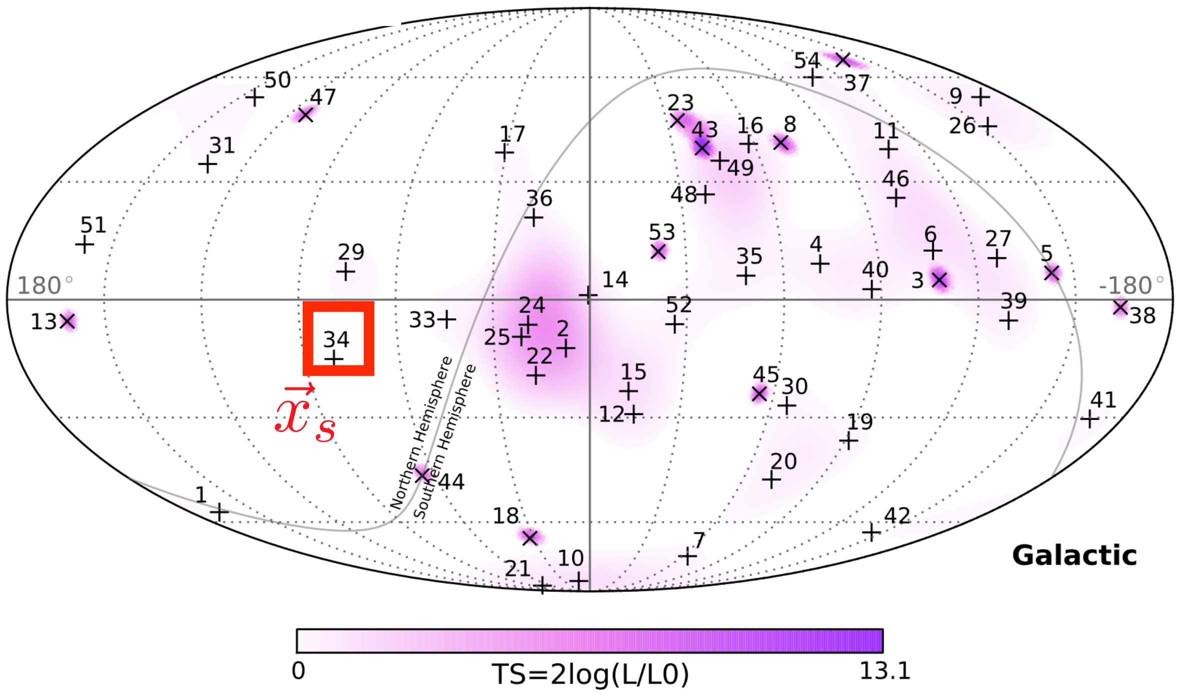

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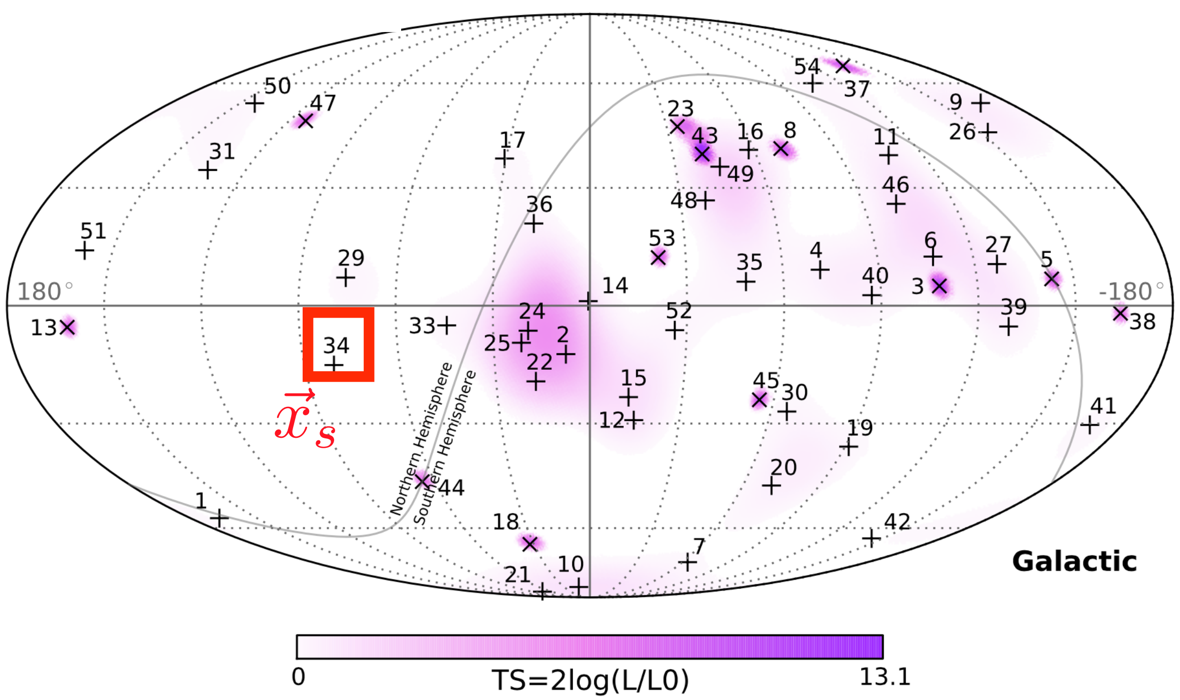

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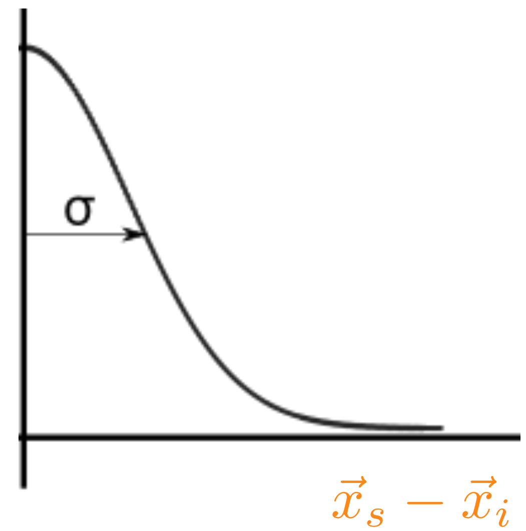

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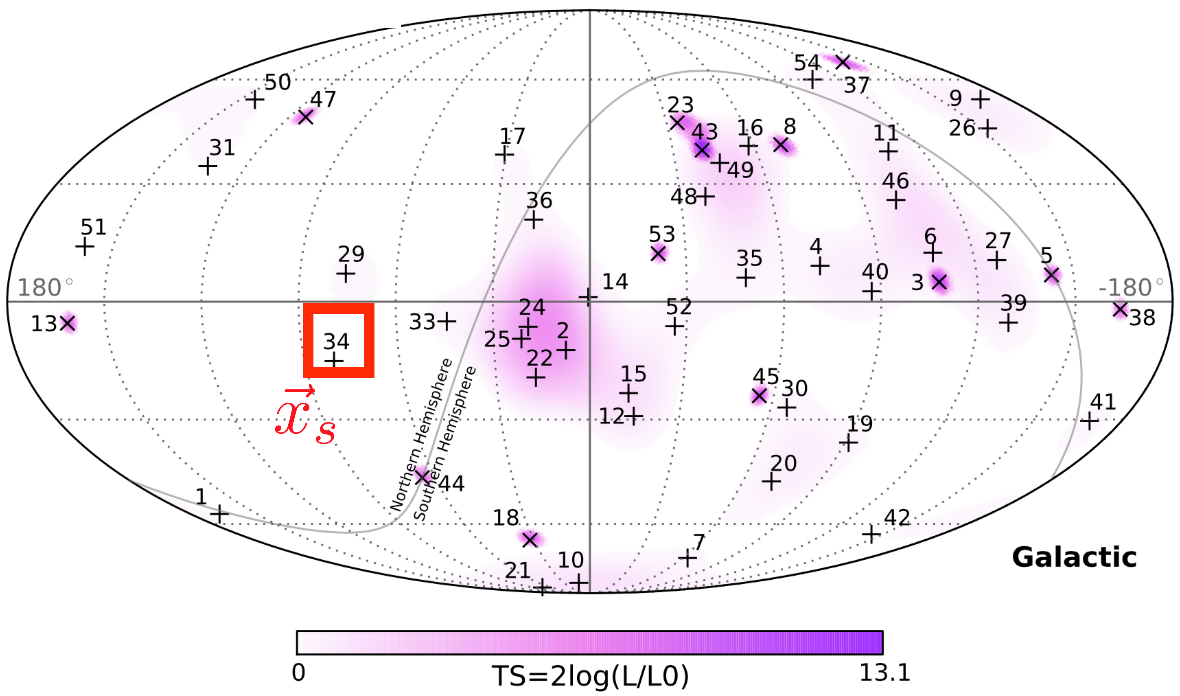

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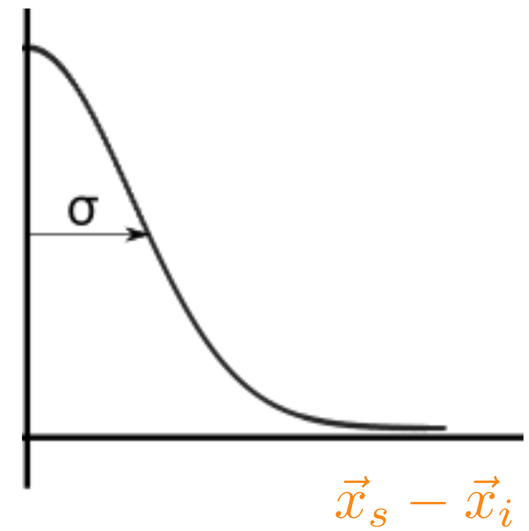

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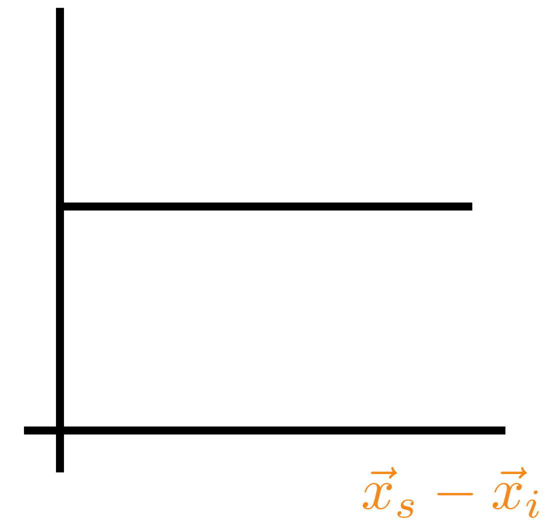

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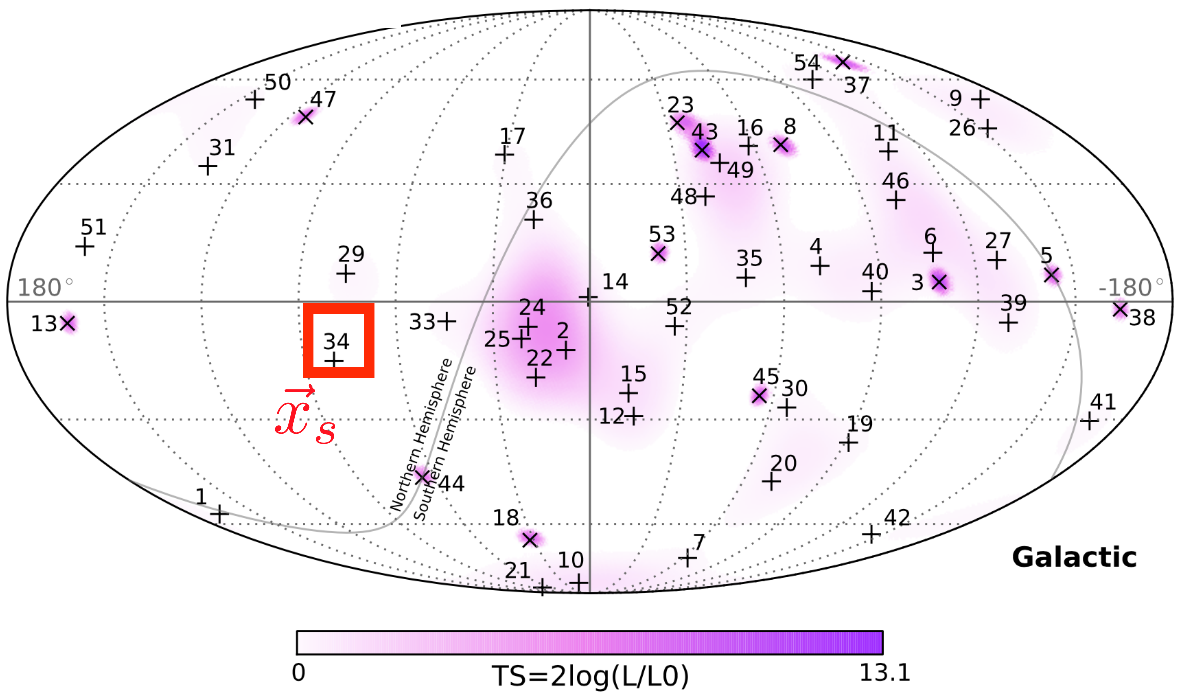

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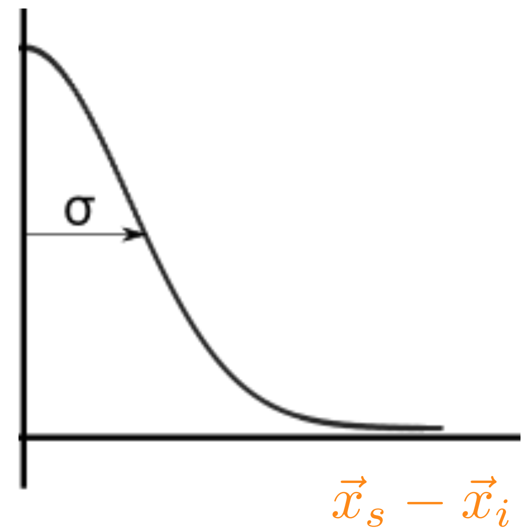

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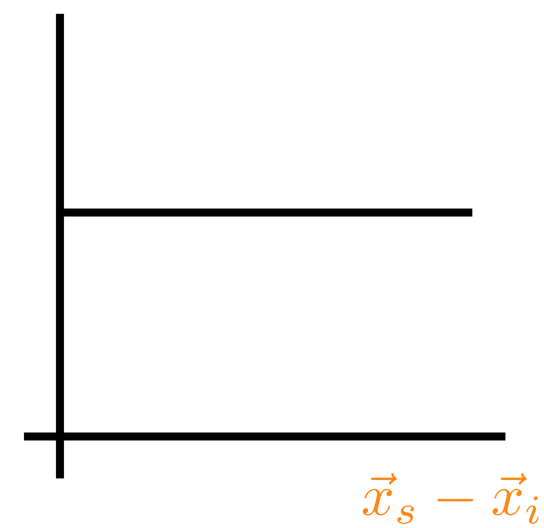

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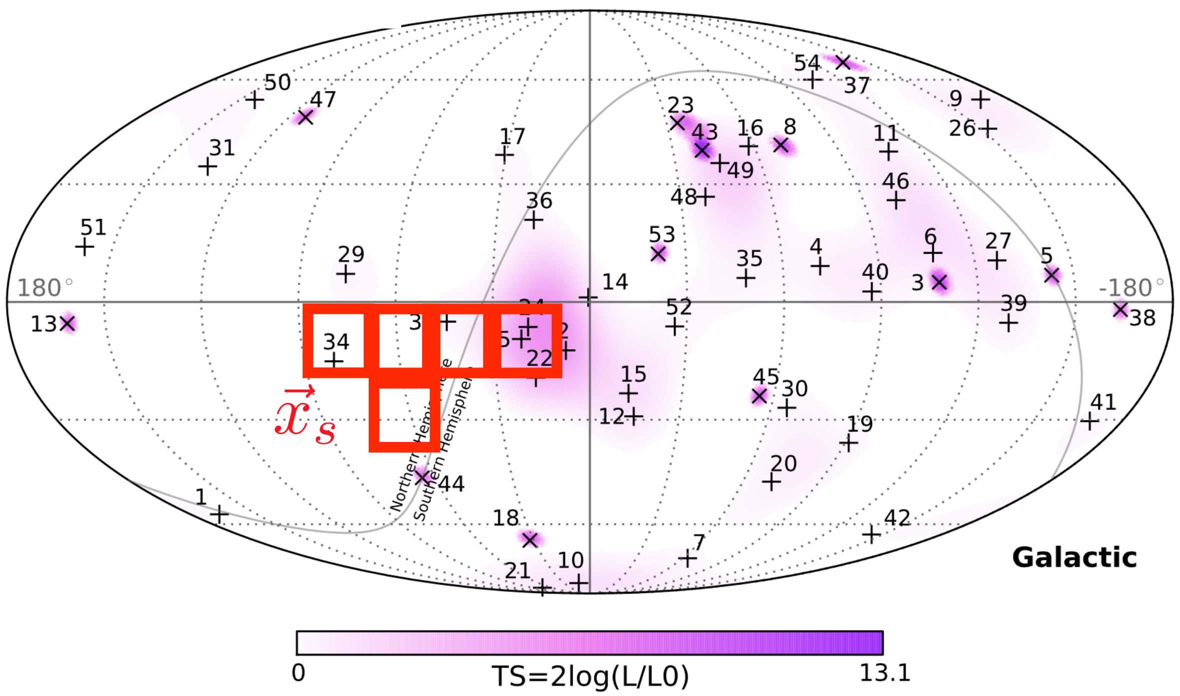

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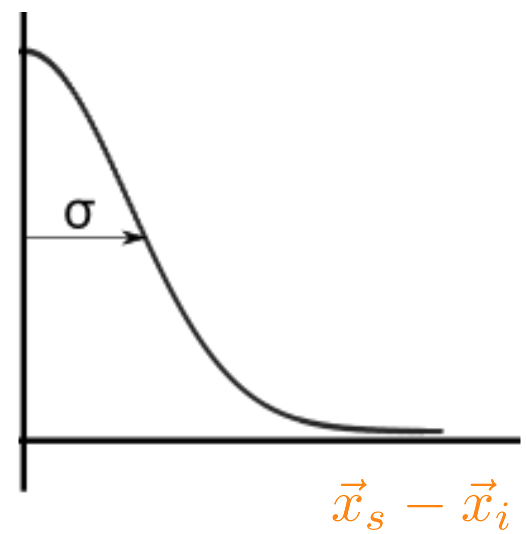

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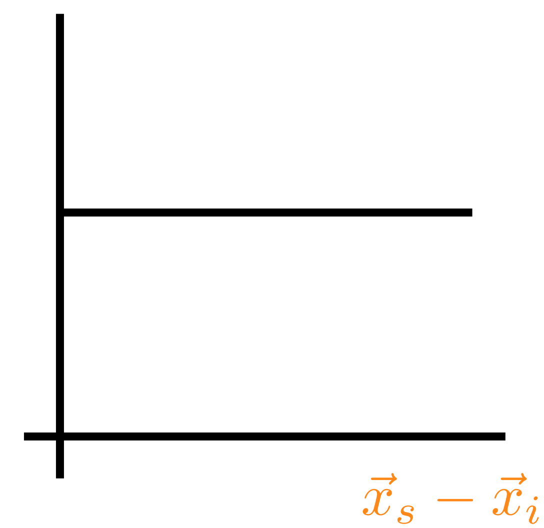

Test Statistic $\mathrm{TS}_{\mathrm{SS}}(\vec{x}_s) = 2 \ln \left[\frac{\mathcal{L}(\hat{f}, \vec{x}_s)}{\mathcal{L}(f=0)} \right]$

Don't know the actual source locations —> Scan the sky for maximum

$$\mathrm{TS} = \max(\mathrm{TS}(\vec{x}_s))$$

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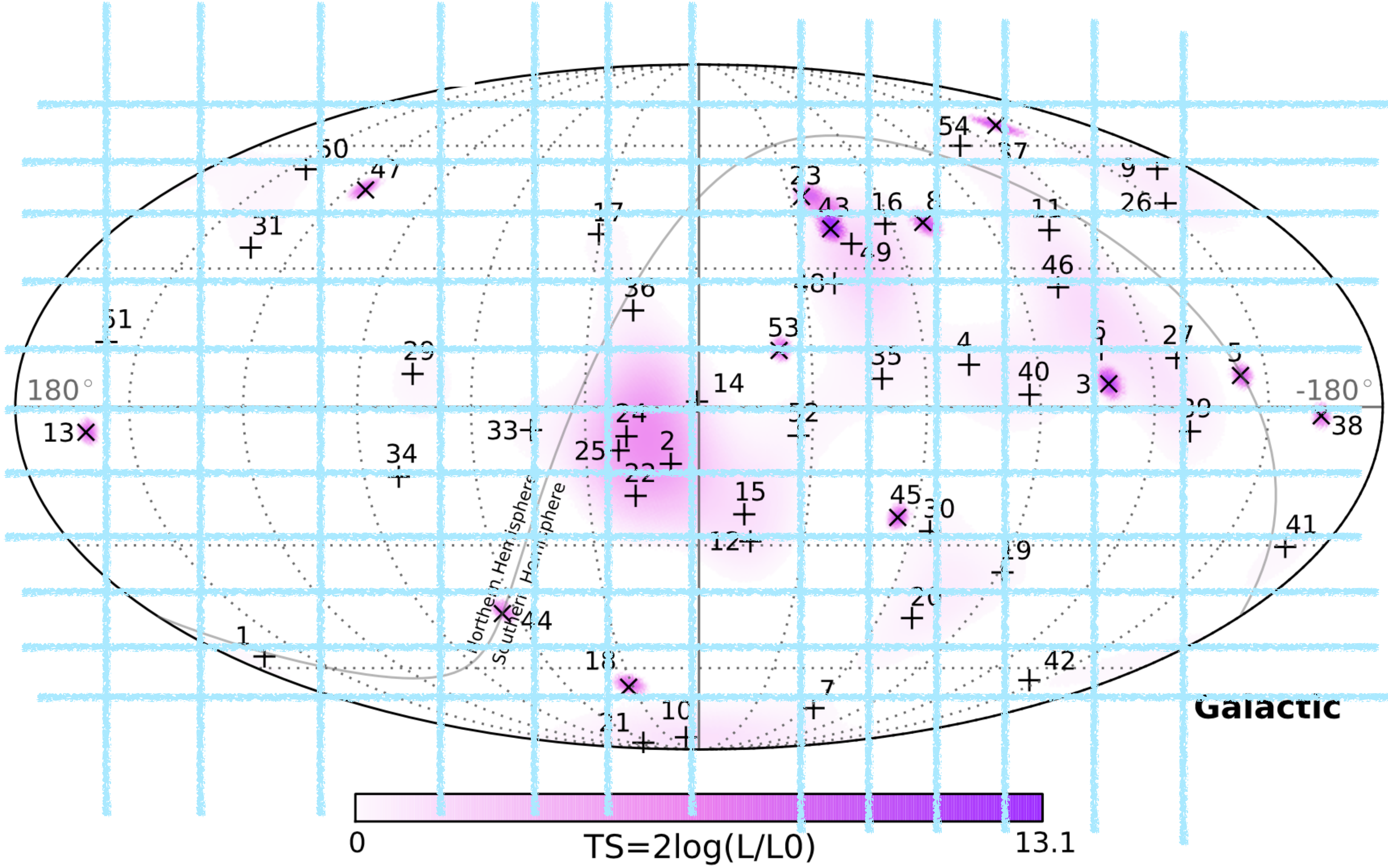
But… Squares = Boundaries + Trials



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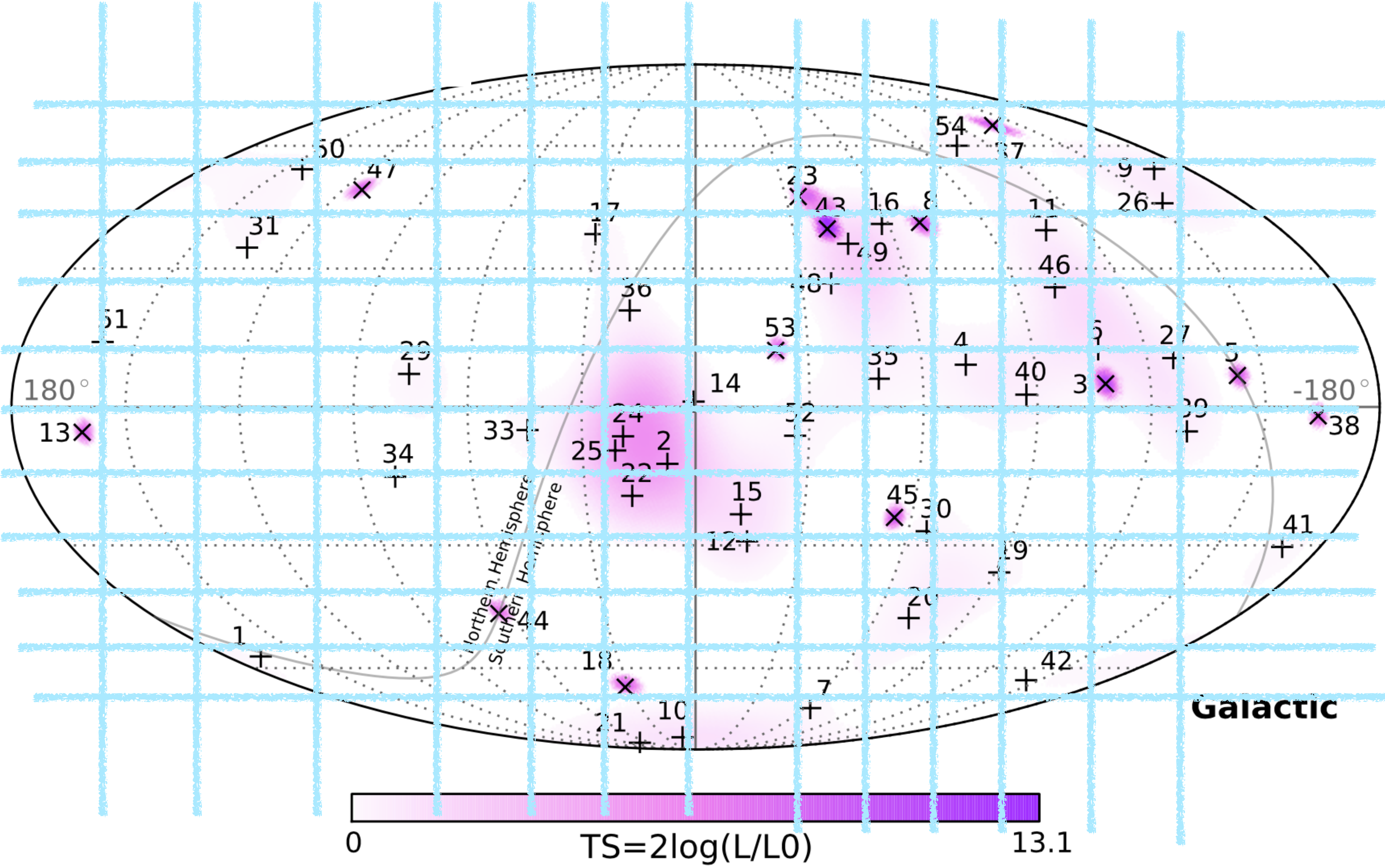
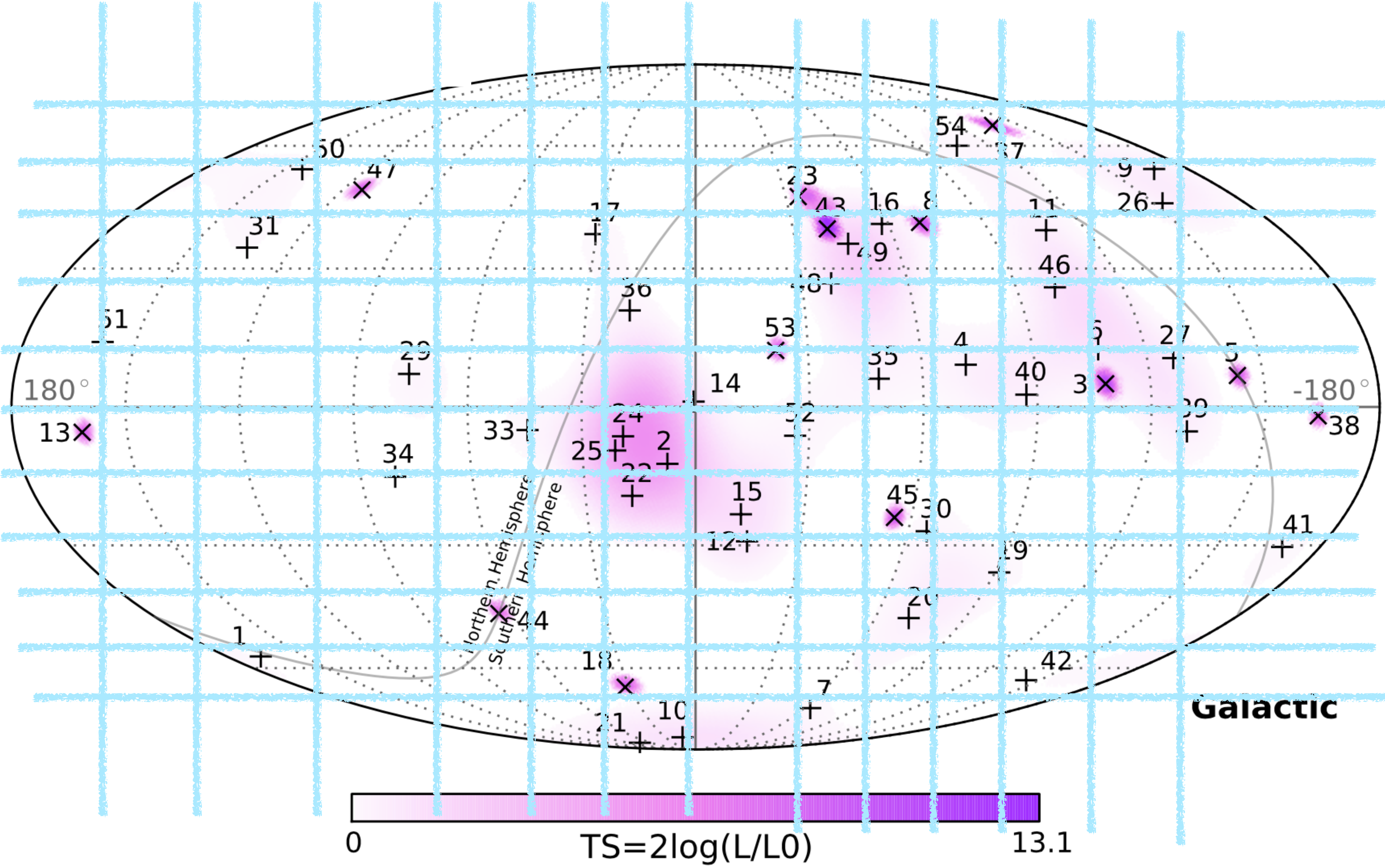


Patch size needs to be much smaller than angular resolution to avoid missing the source

Go without boxes?



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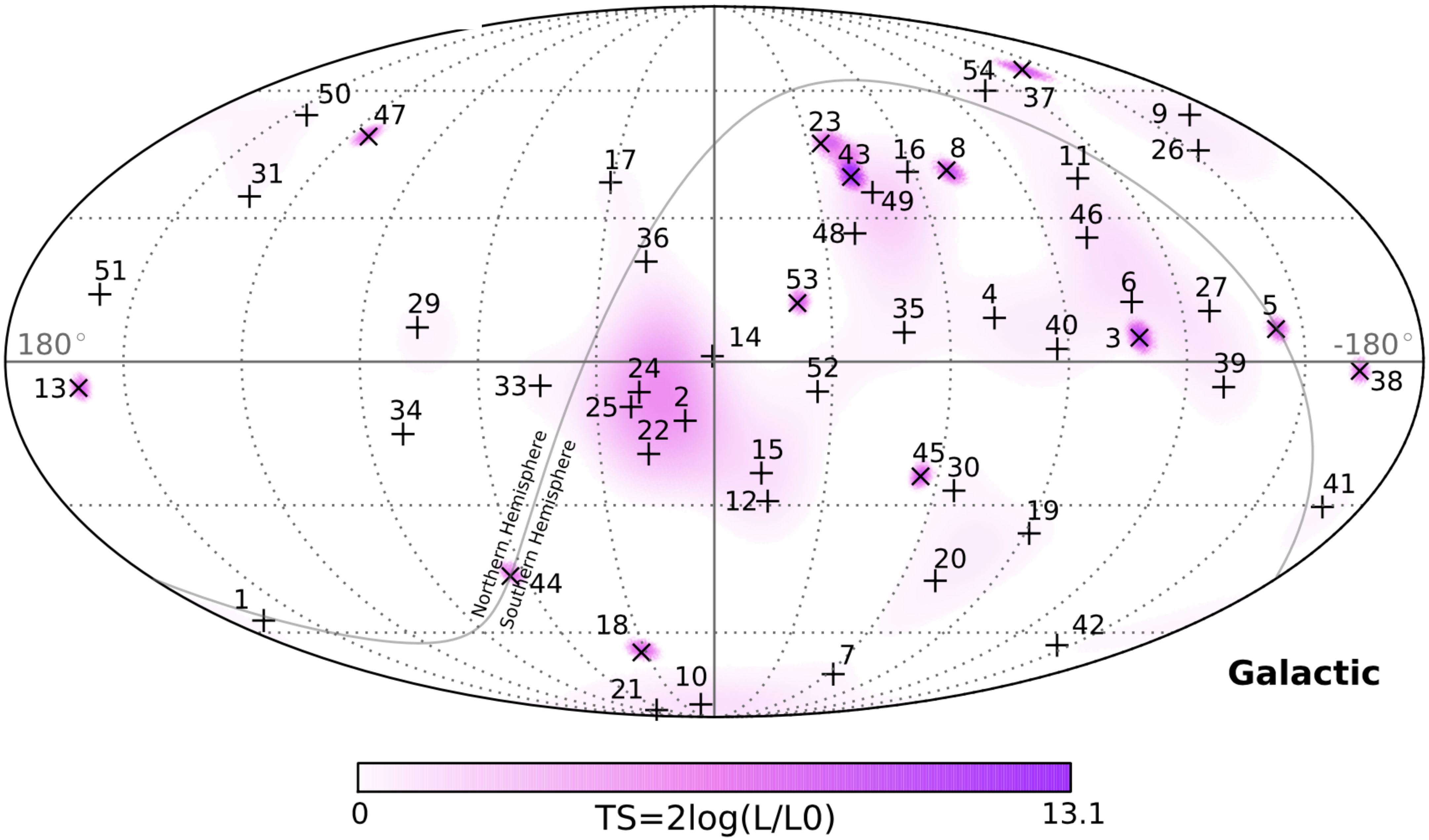

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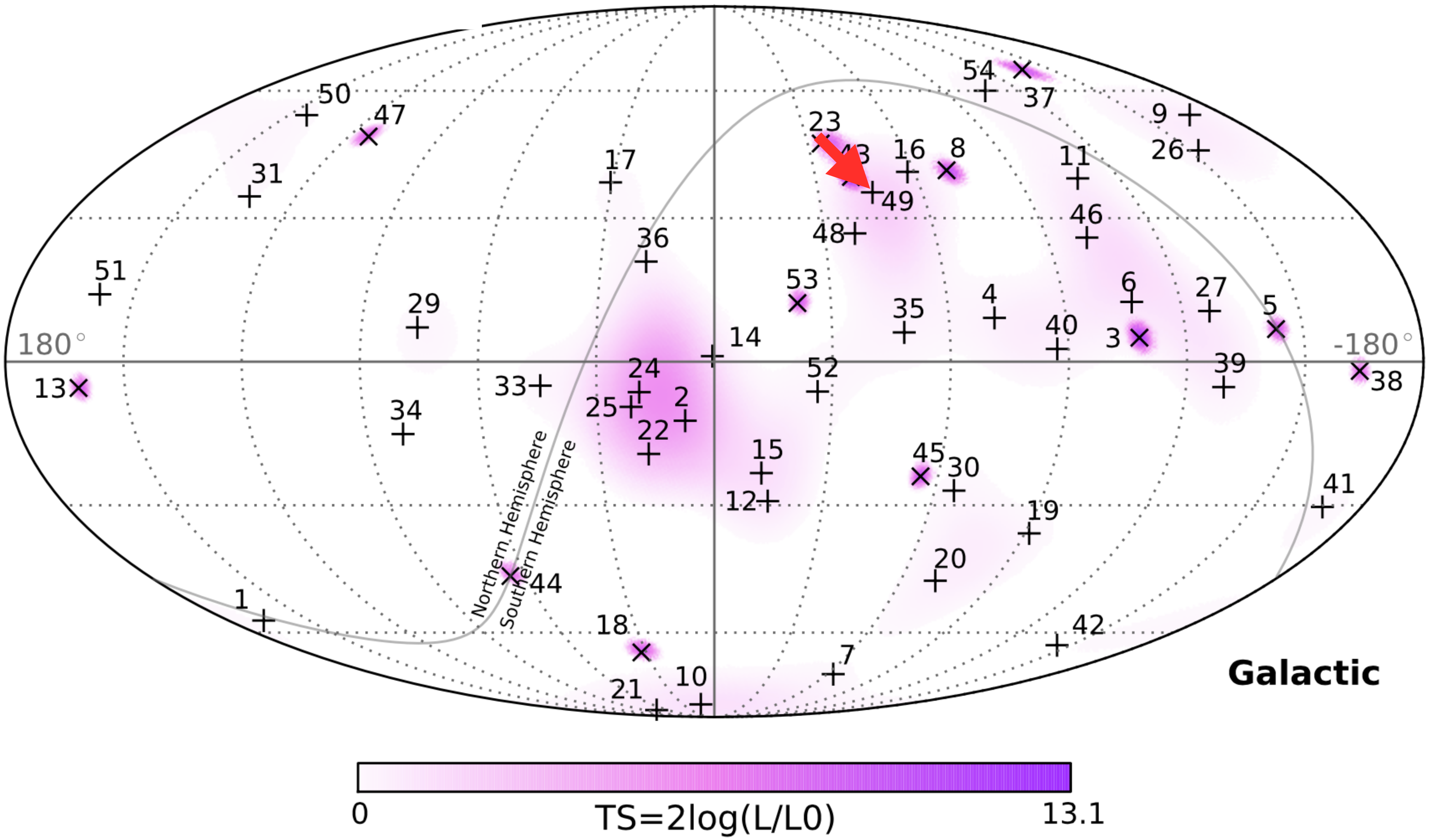

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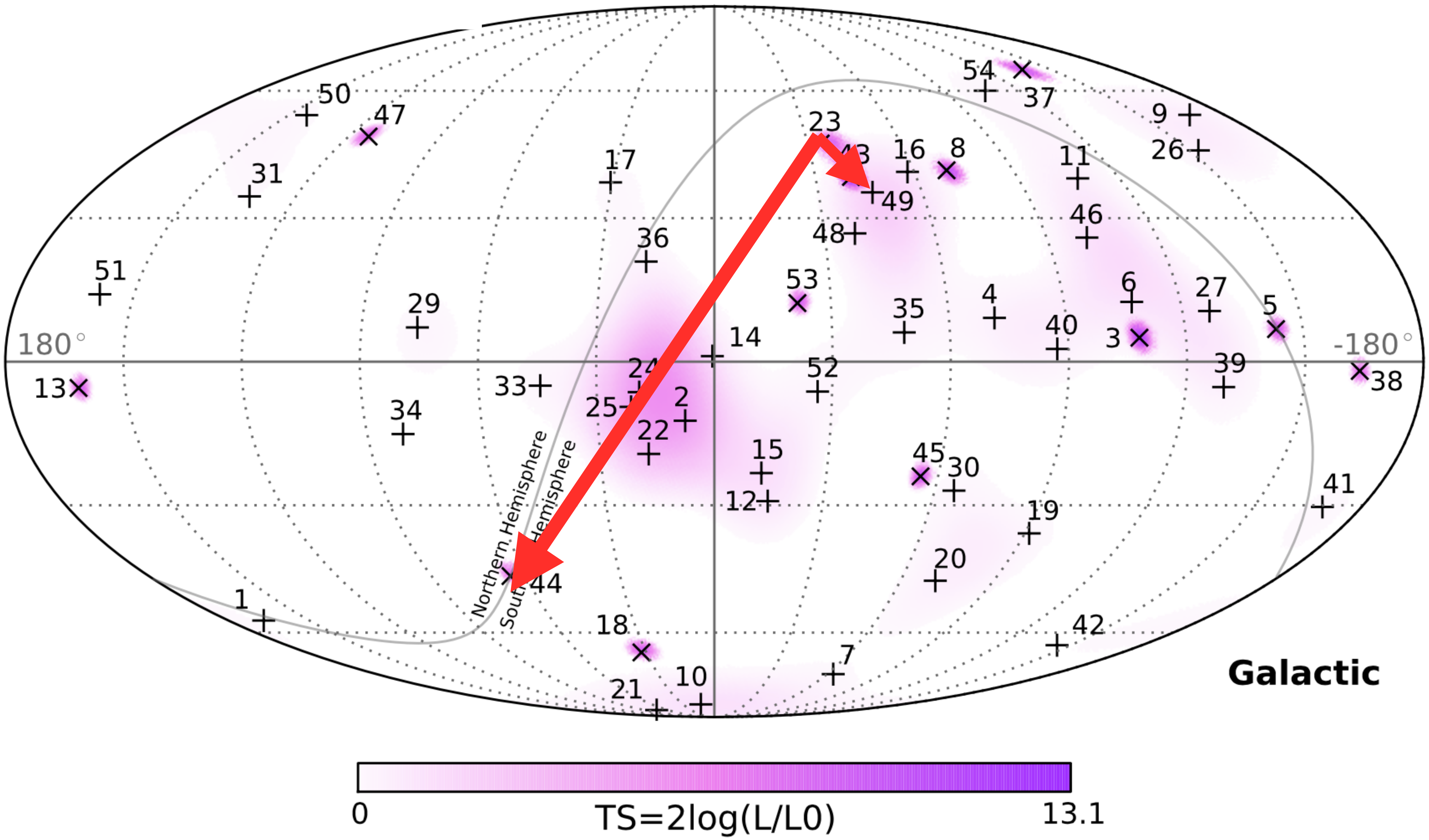
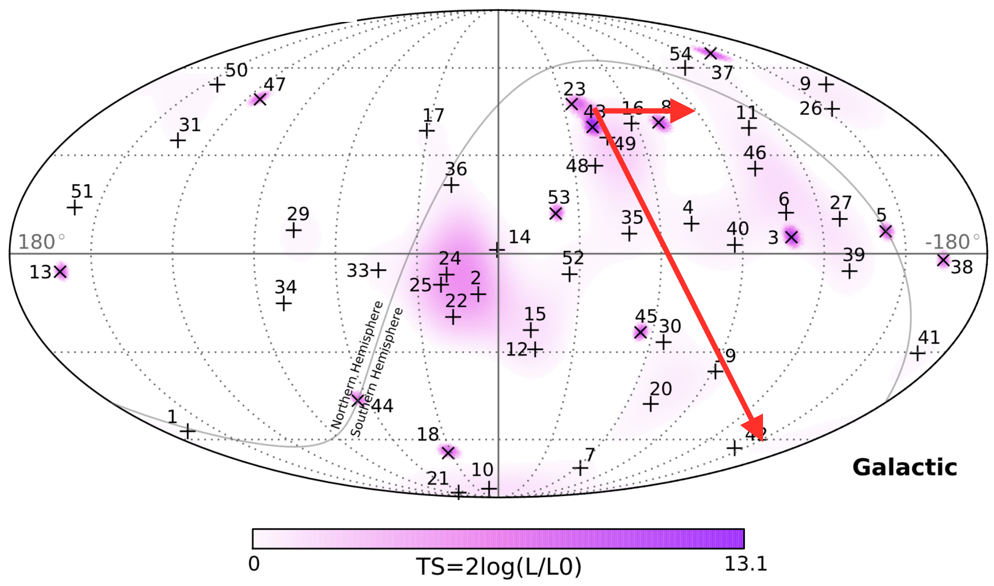


Two-point Autocorrelation Method



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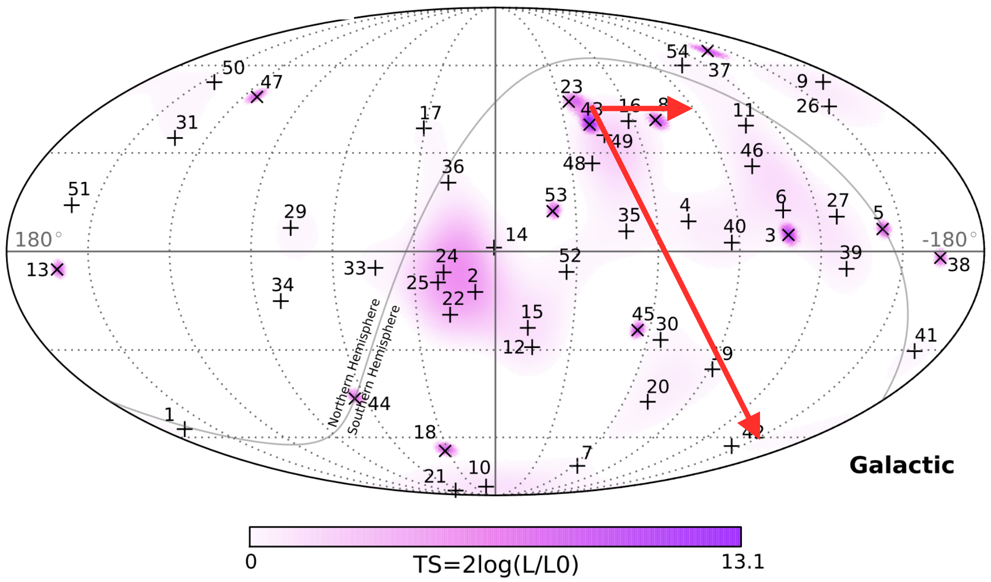
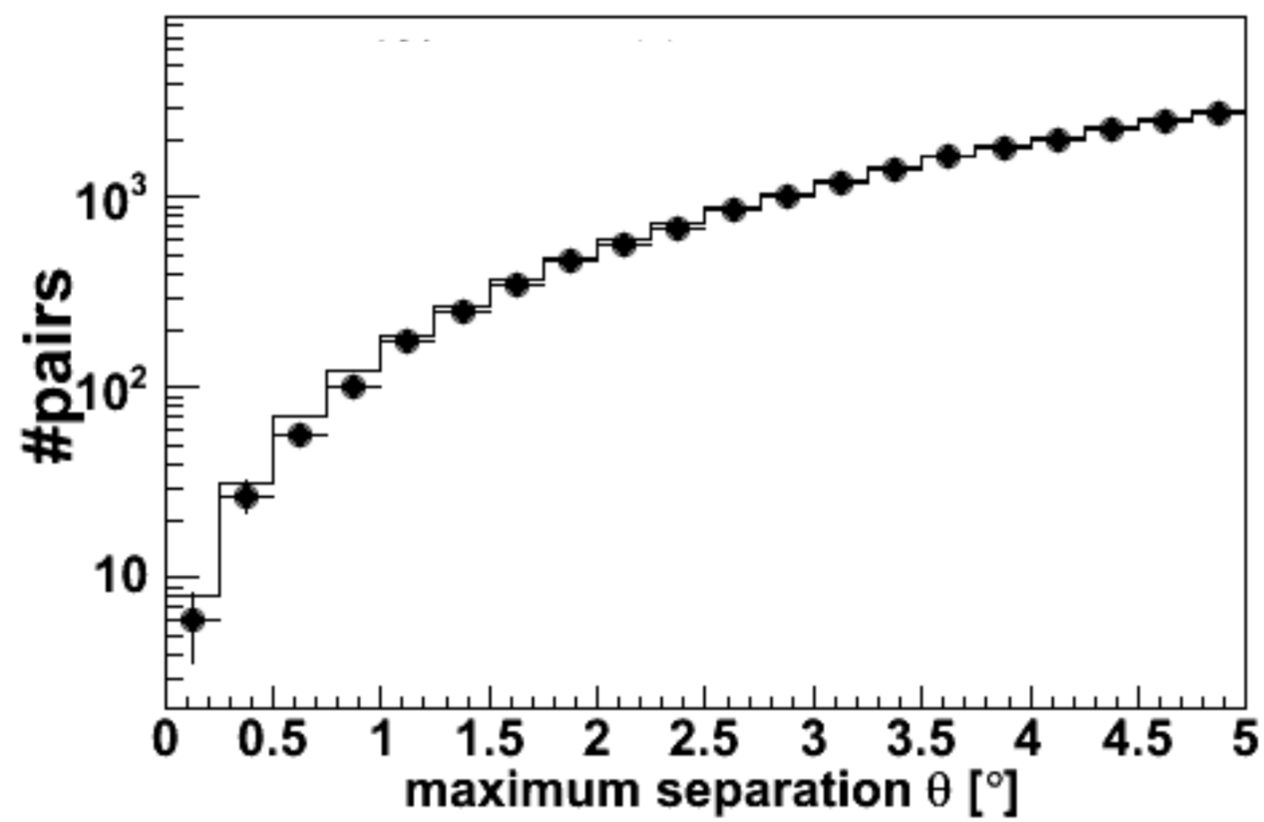
ANTARES Collaboration, JCAP, 1402.2809
IceCube Collaboration, Astroparticle Physics, 1408.0634

Two-point Autocorrelation Method



$$N(\Omega) = \sum_{i,j>i} \mathcal{H}(\Omega - \alpha_{ij})$$



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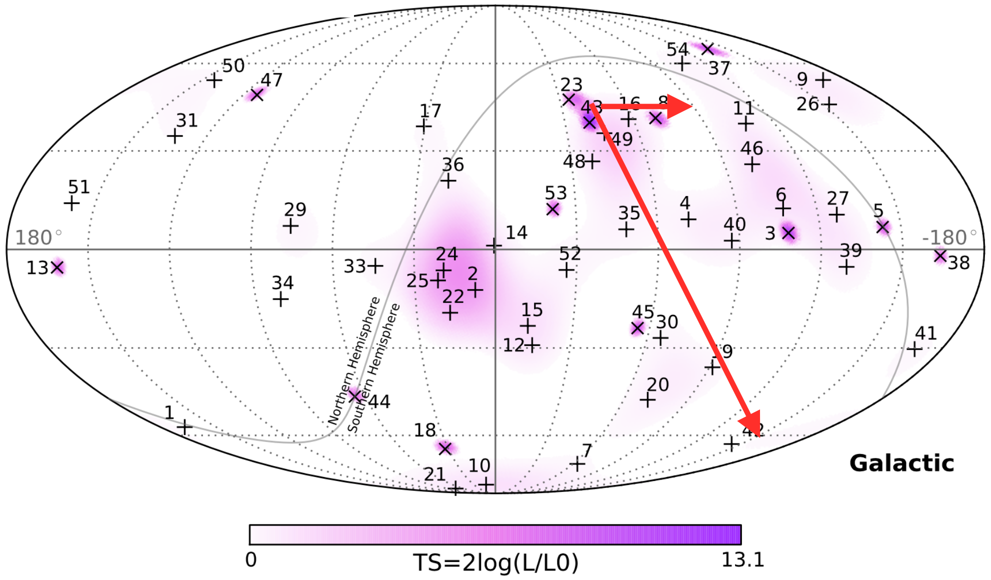

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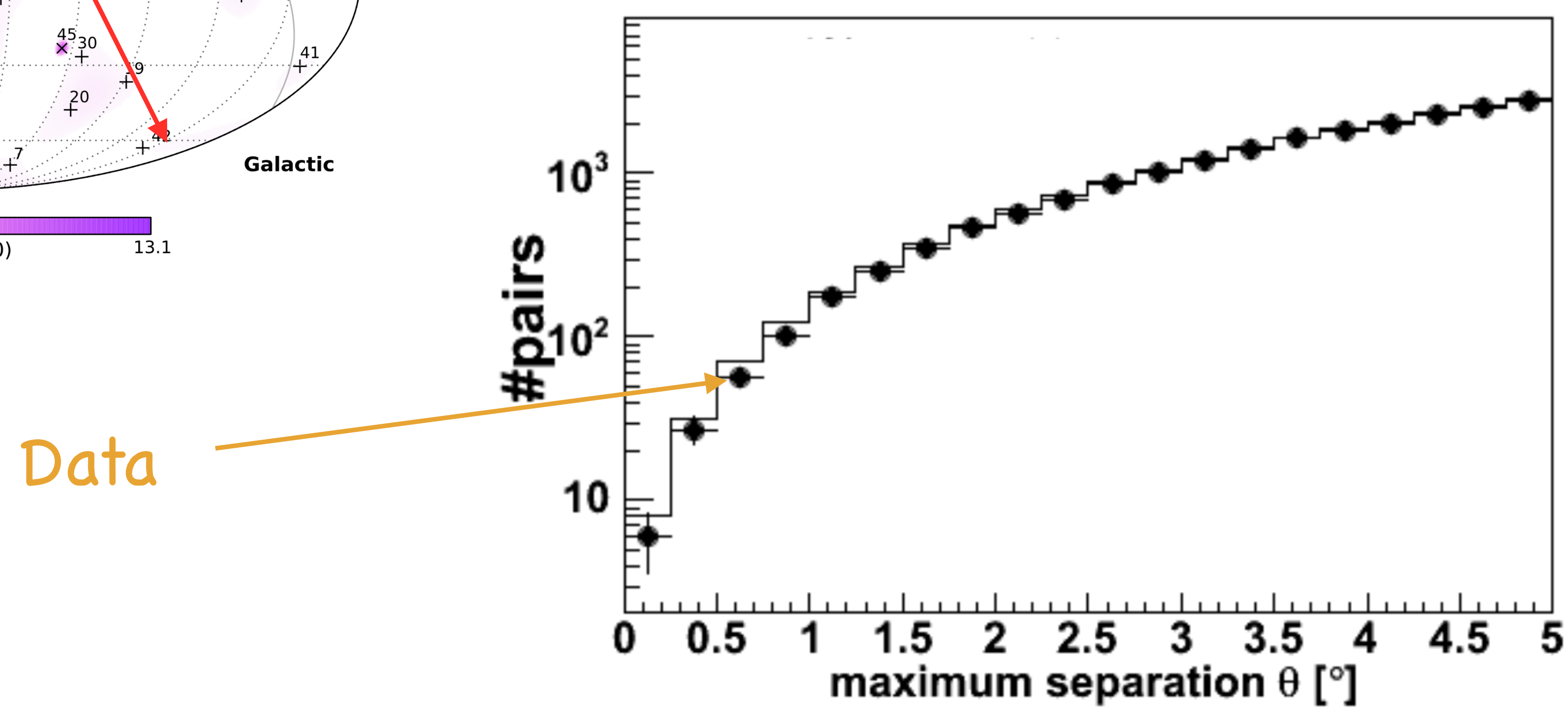

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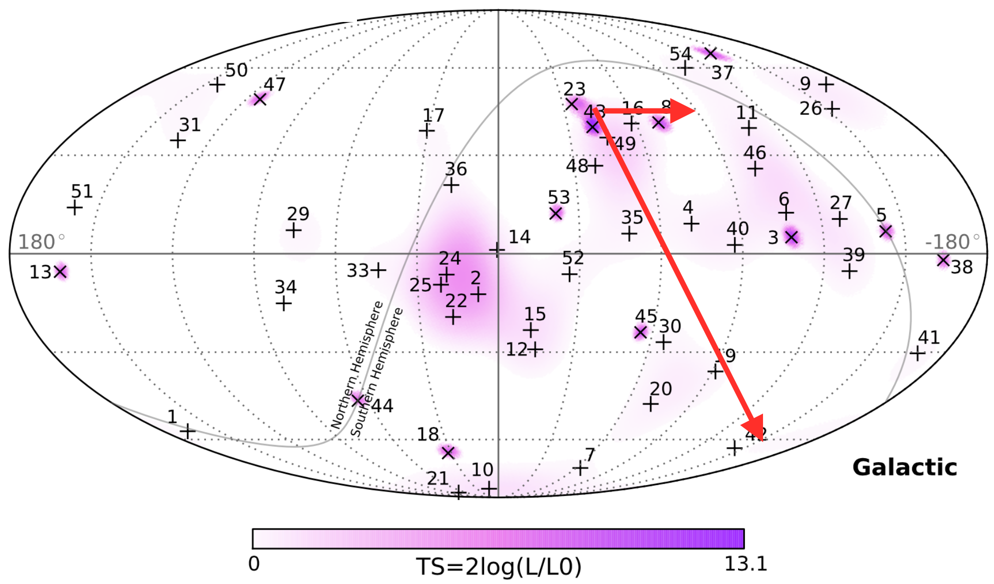

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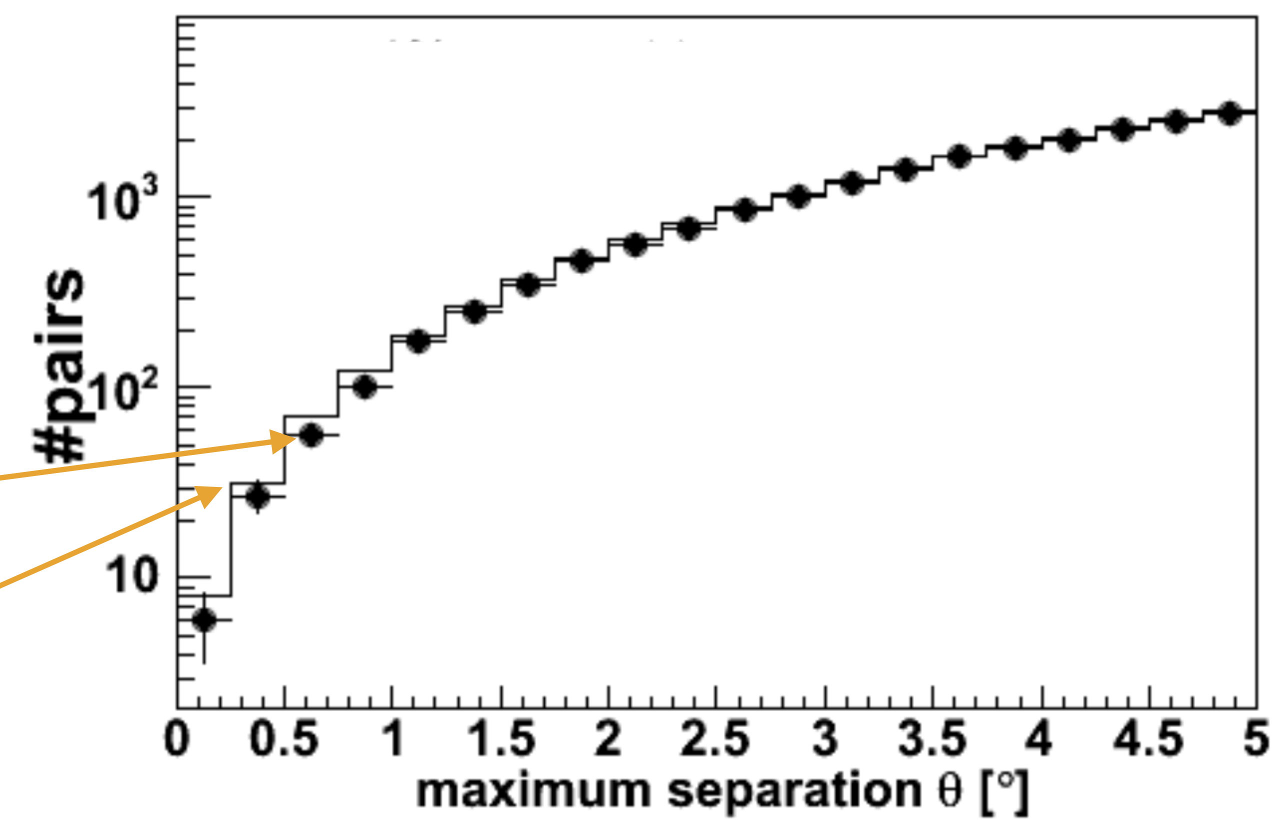

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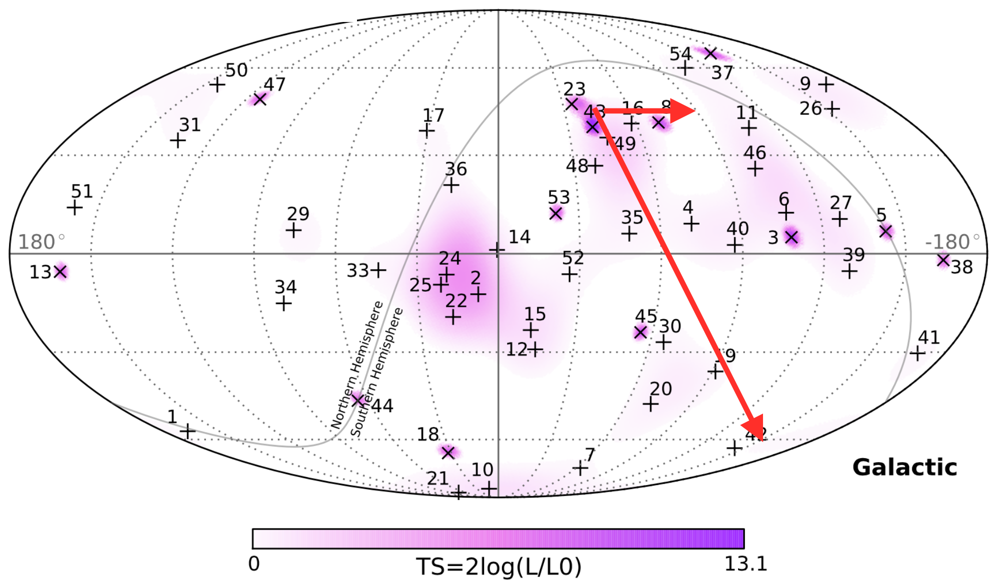

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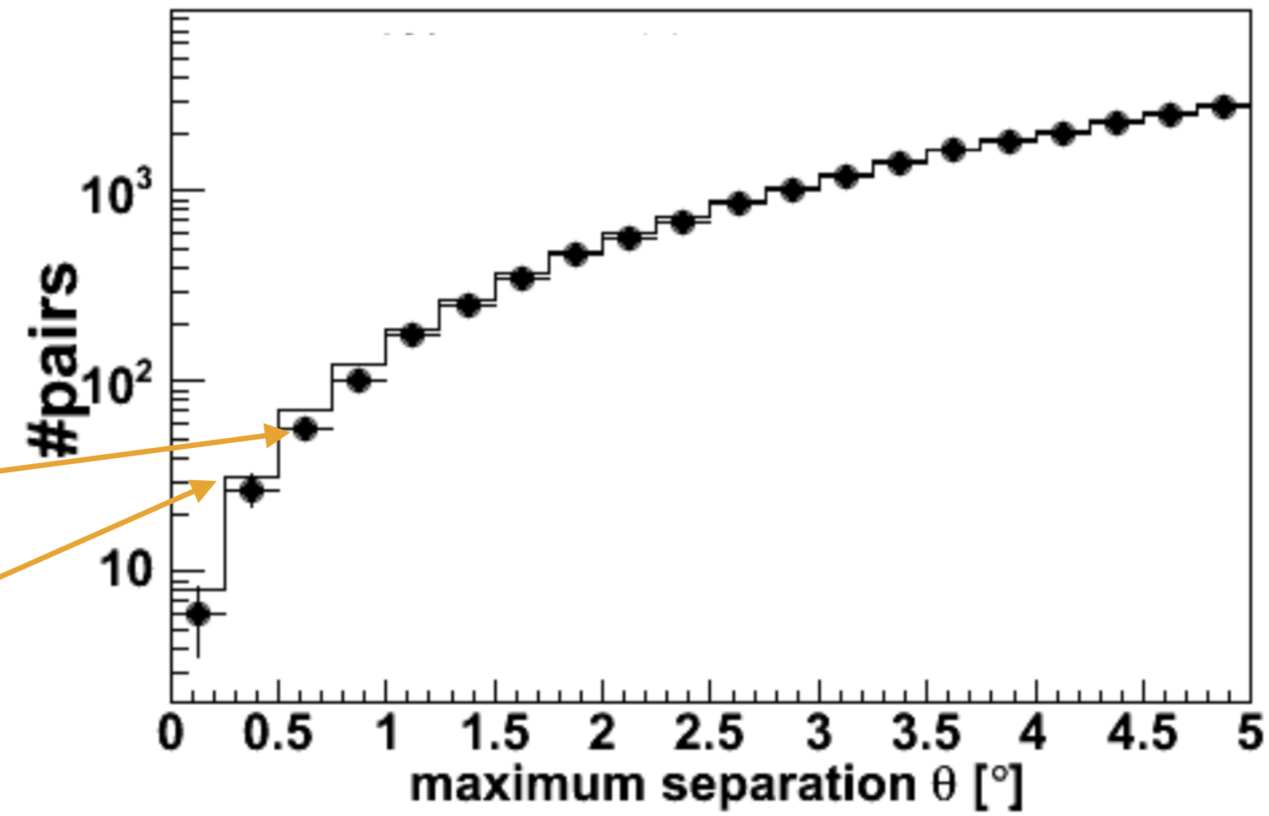

Data

Expectation of background

Prob. of excess or deficit in each angular bin

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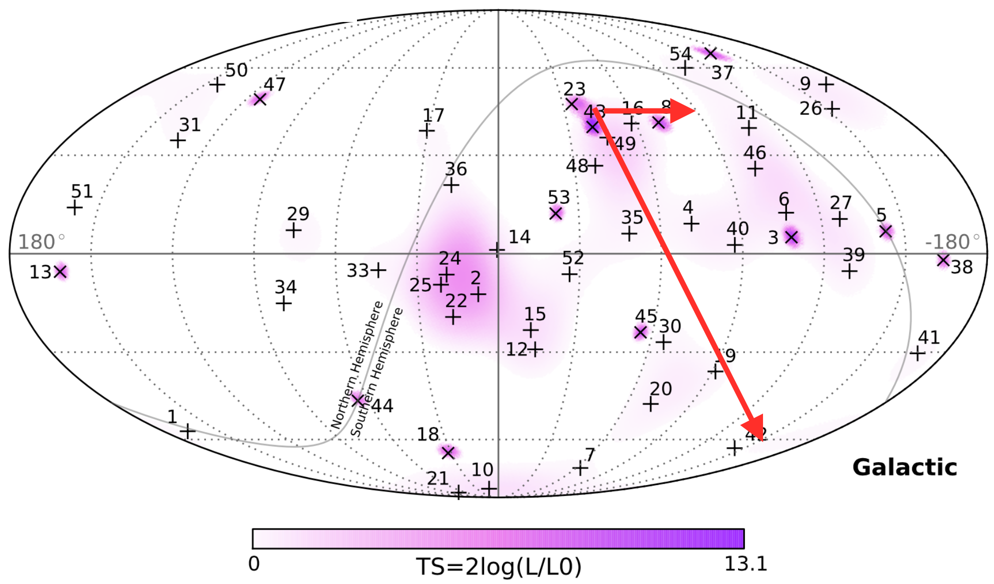

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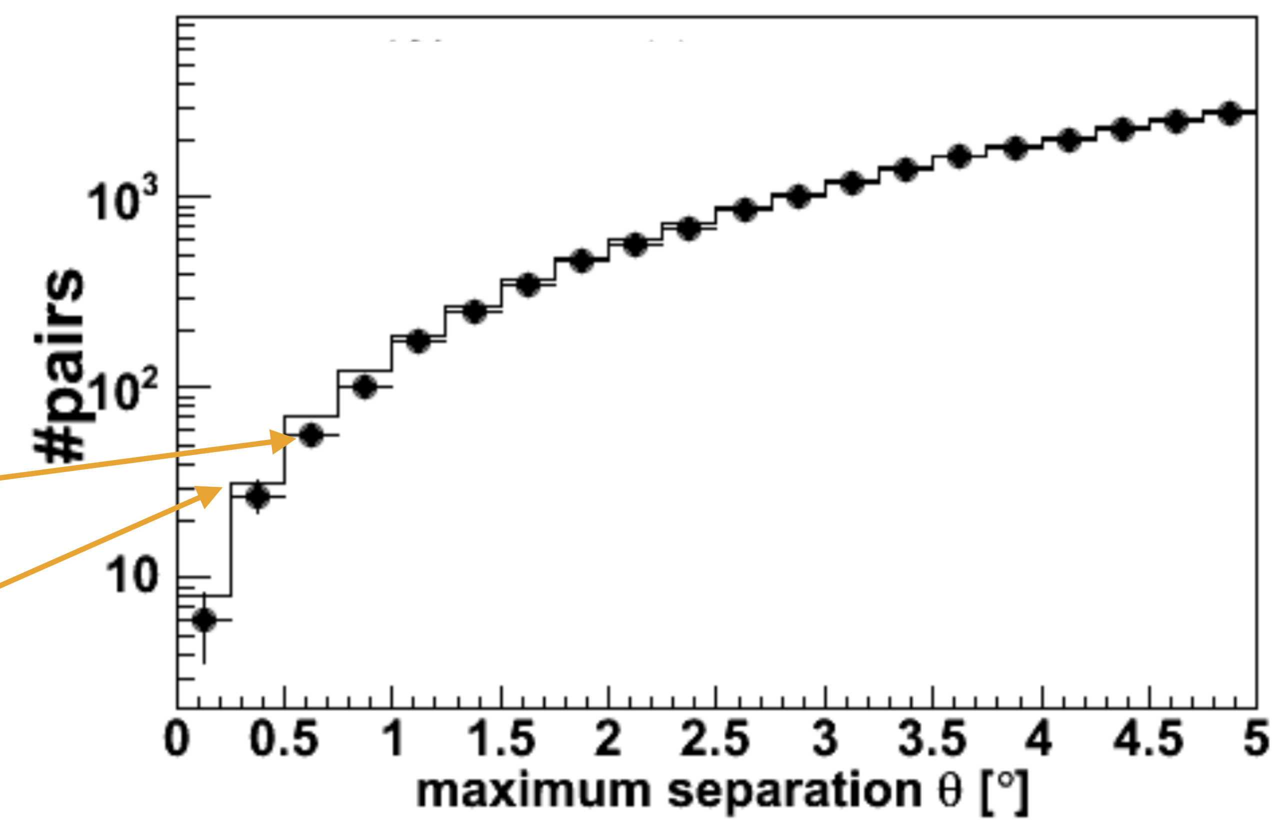

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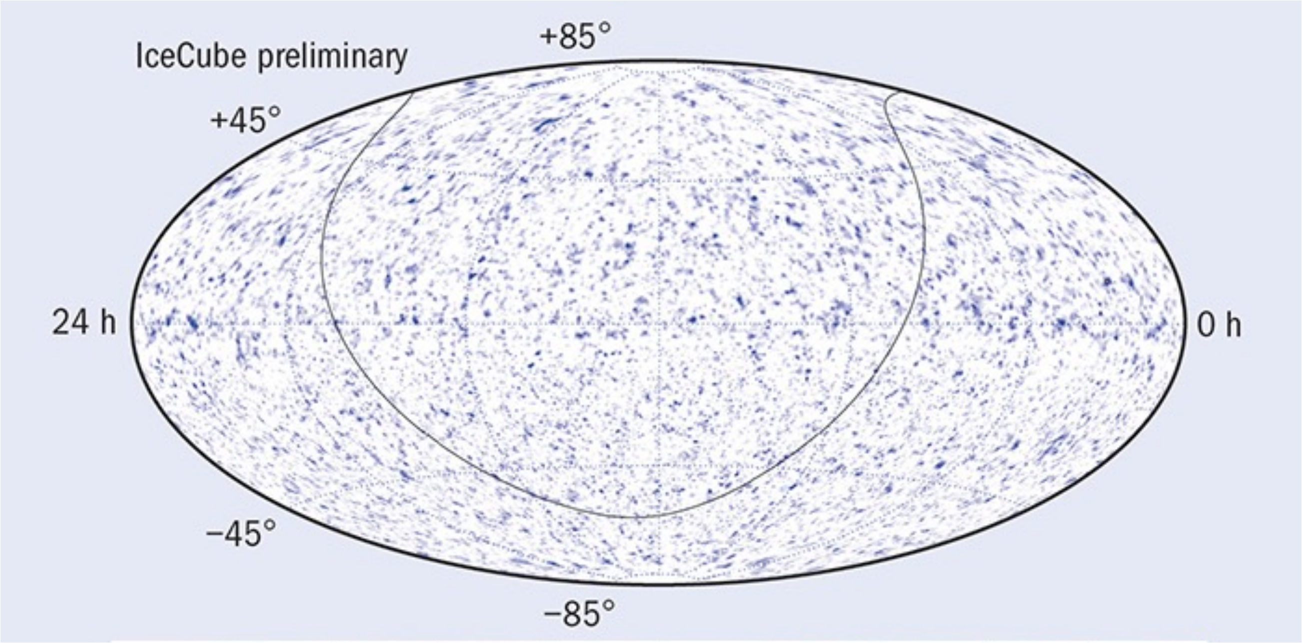

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One angular scale showing the strongest anisotropy $\neq$ Source locations

(The autocorrelation method is not being used to find sources)

So what do we do?

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Pairs

So what do we do?

Pairs + PSF

So what do we do?

Pairs + PSF =

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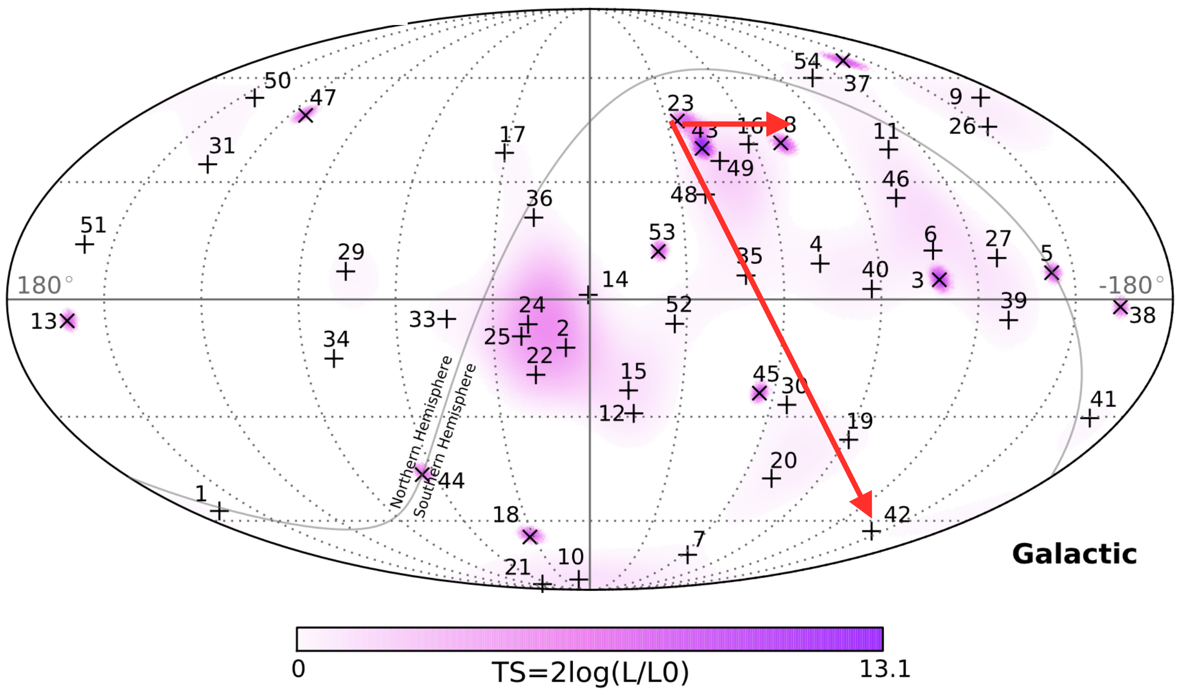
An Unbinned Likelihood Method with Event Pairs



KF & Miller, ApJ, 826 (2016) 102

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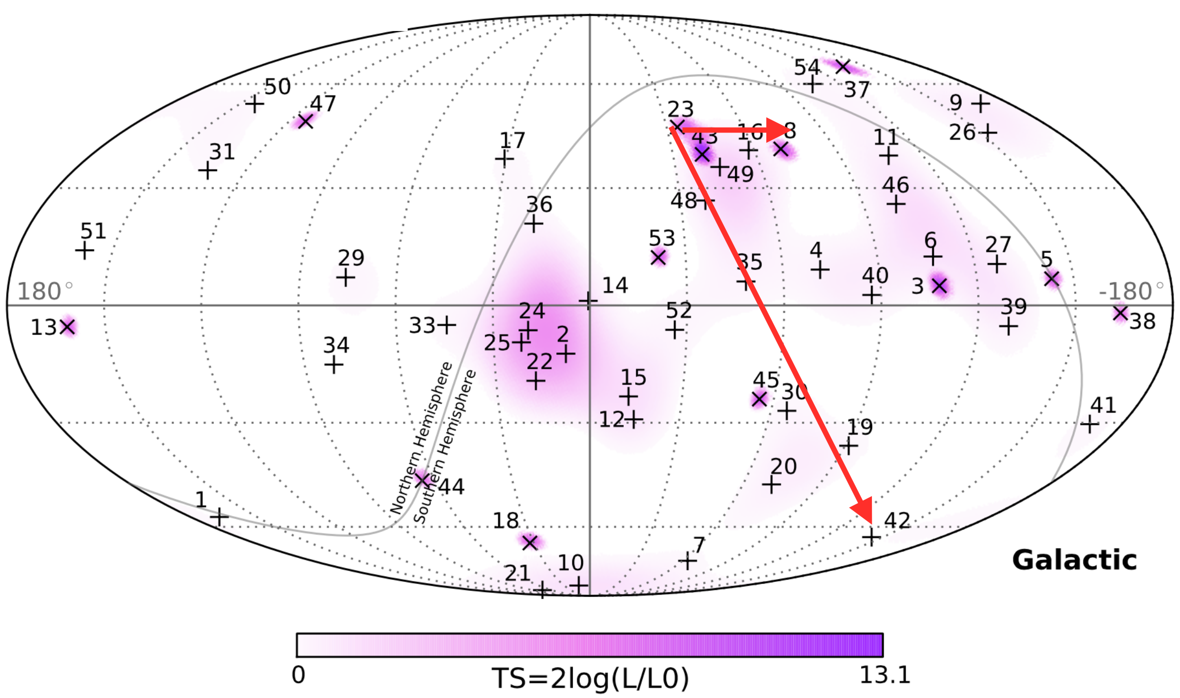

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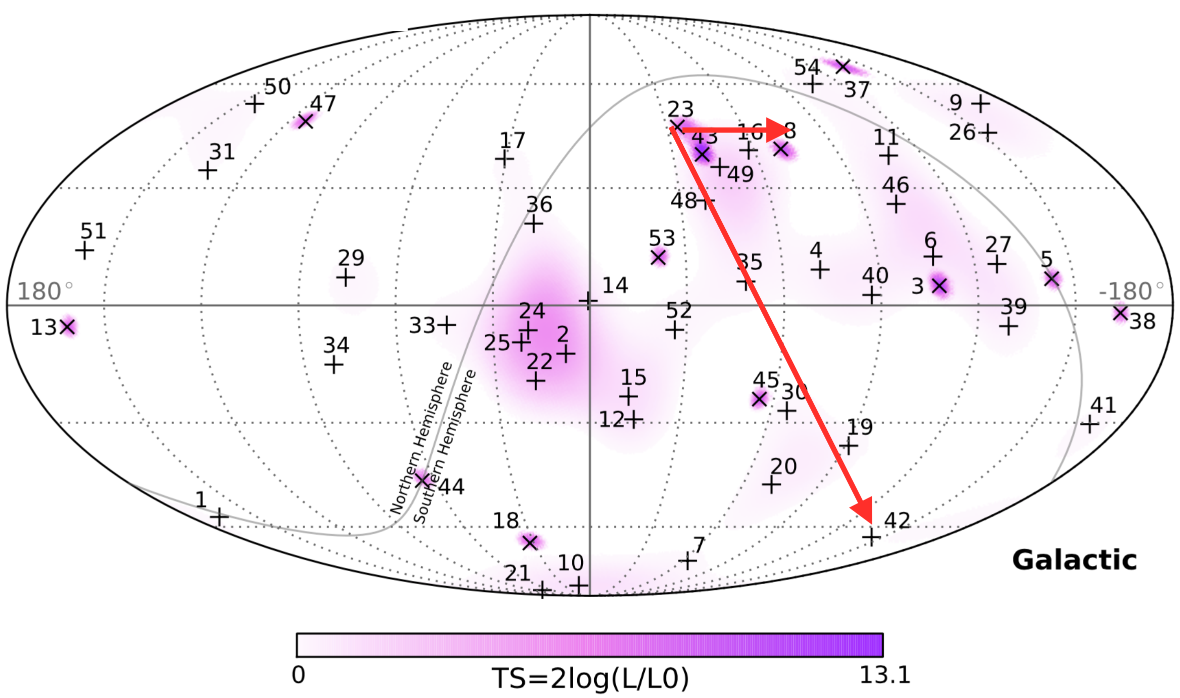

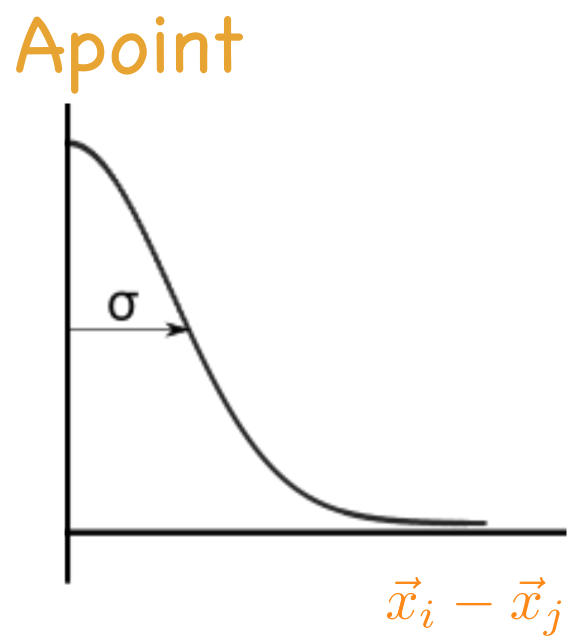

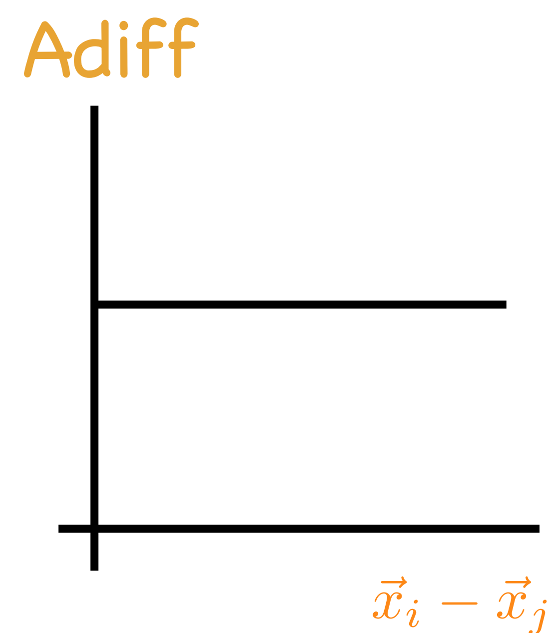

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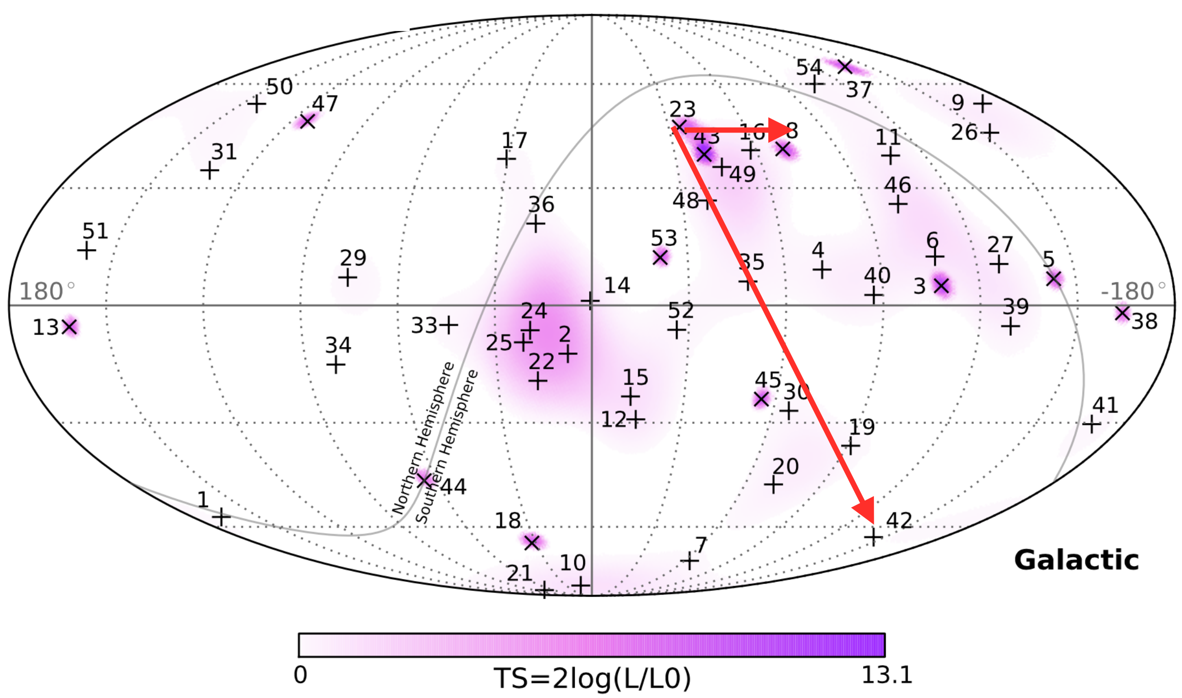

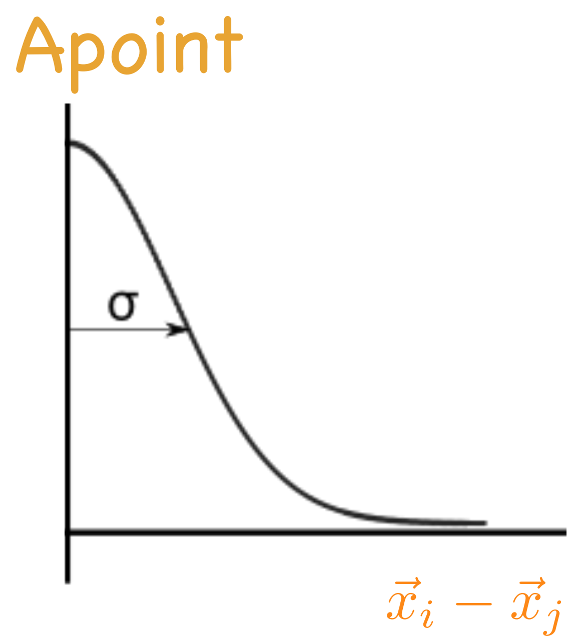

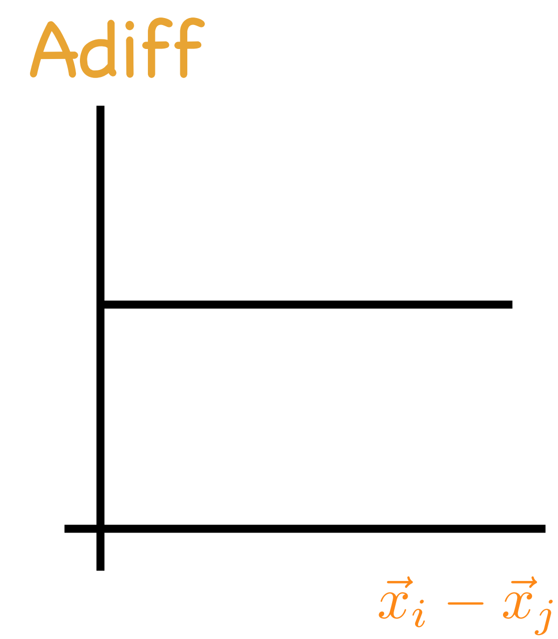

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Difference from the standard method

More than one source can contribute at the same time

Single-Source method

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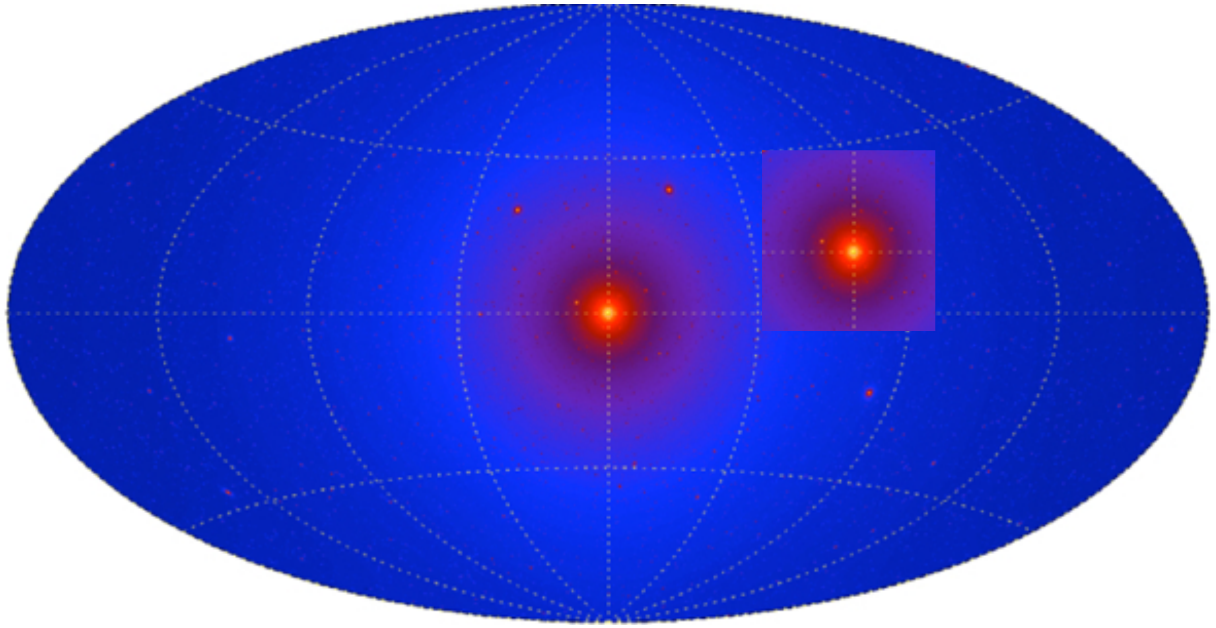

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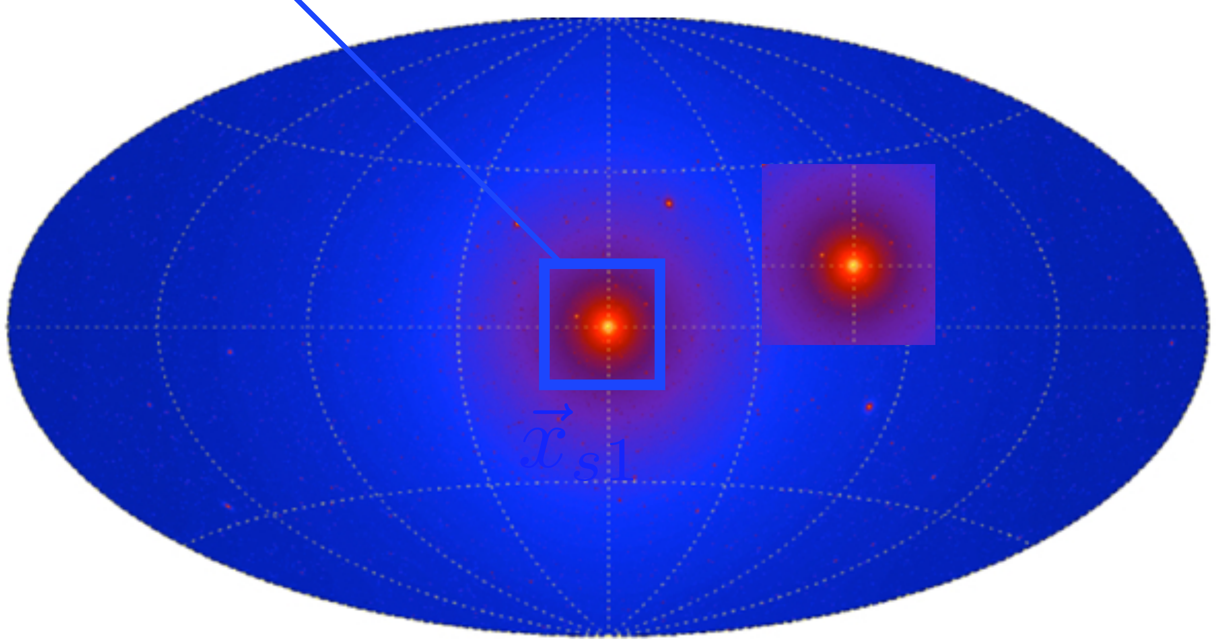

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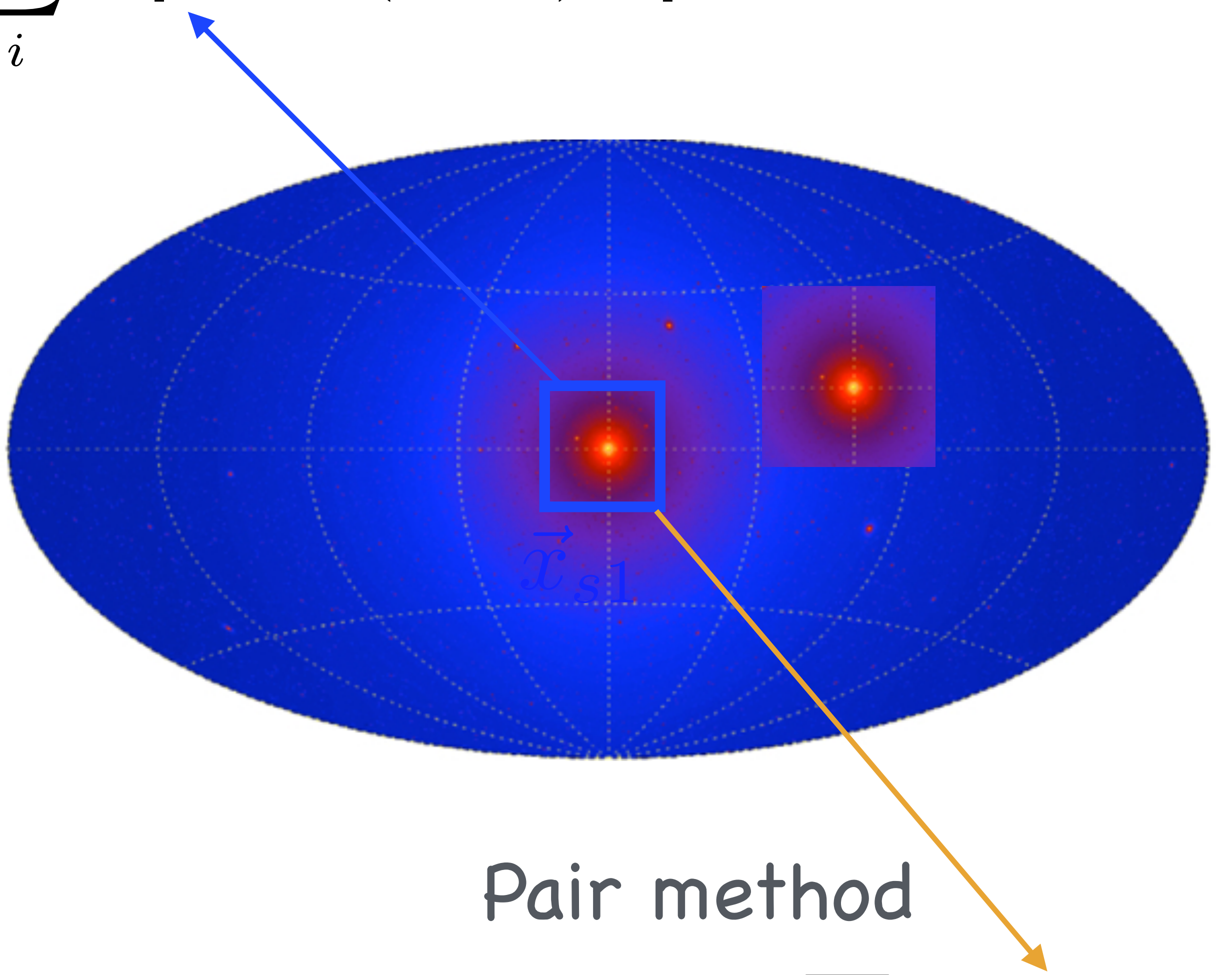

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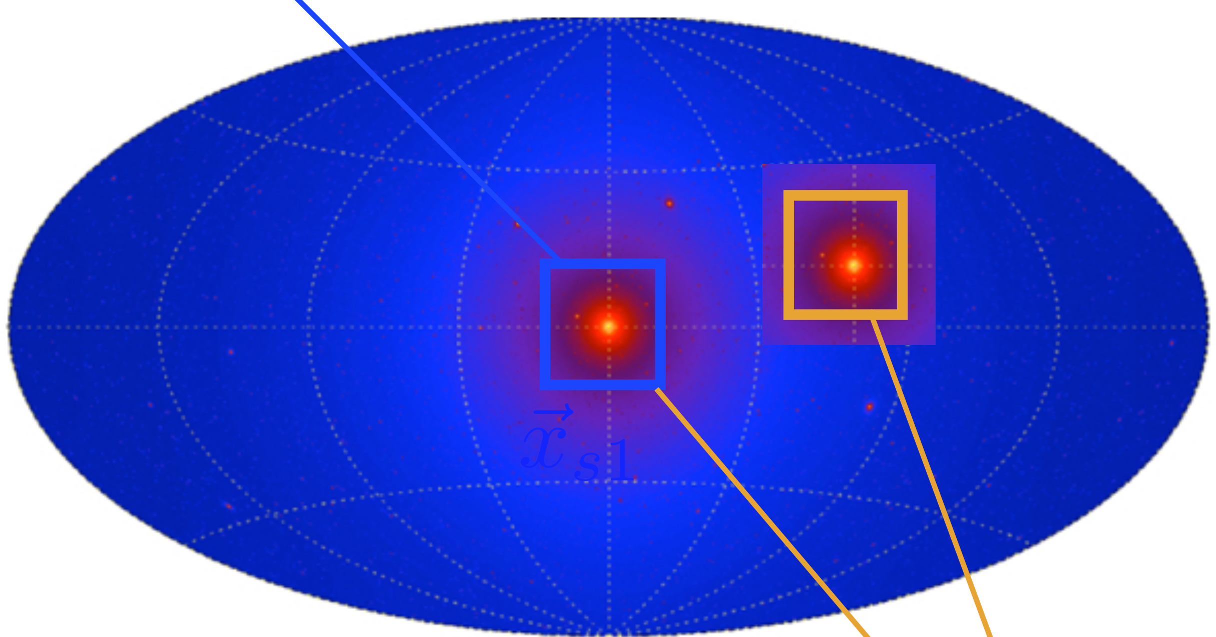

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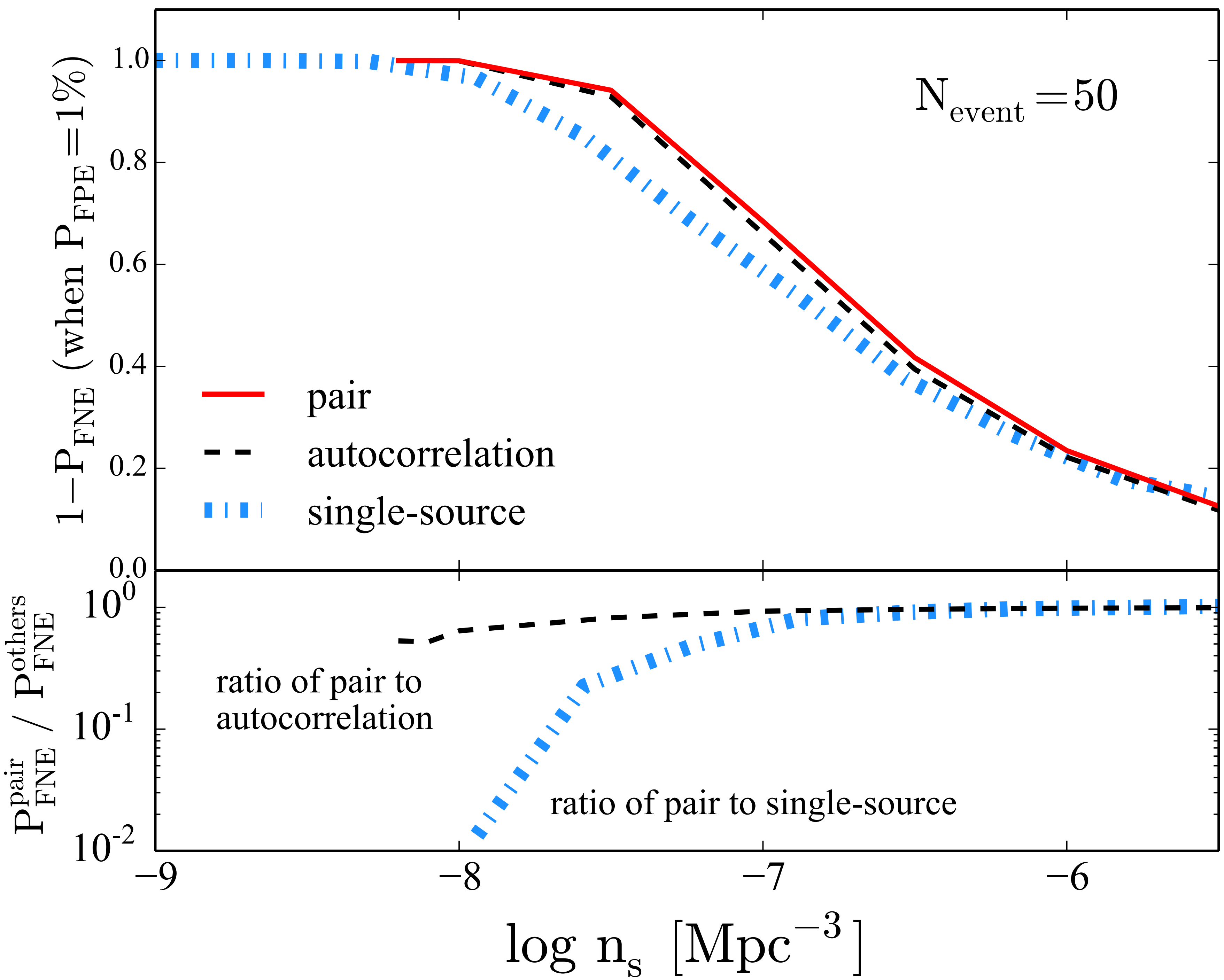
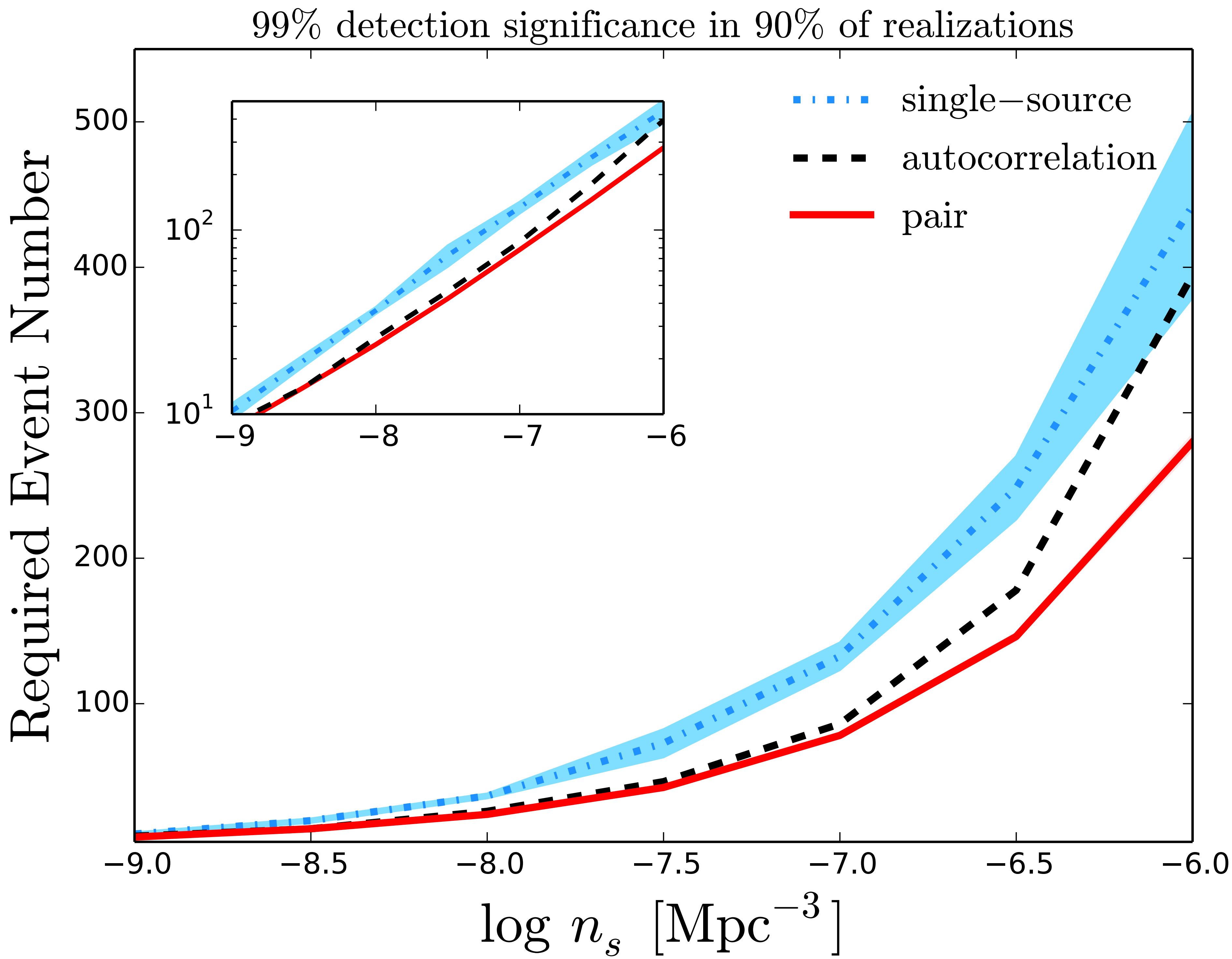
Comparison of Methods in
Rate of False Negative Error (FNE)



KF & Miller, ApJ, 826 (2016) 102

Number of Events Needed for Detection



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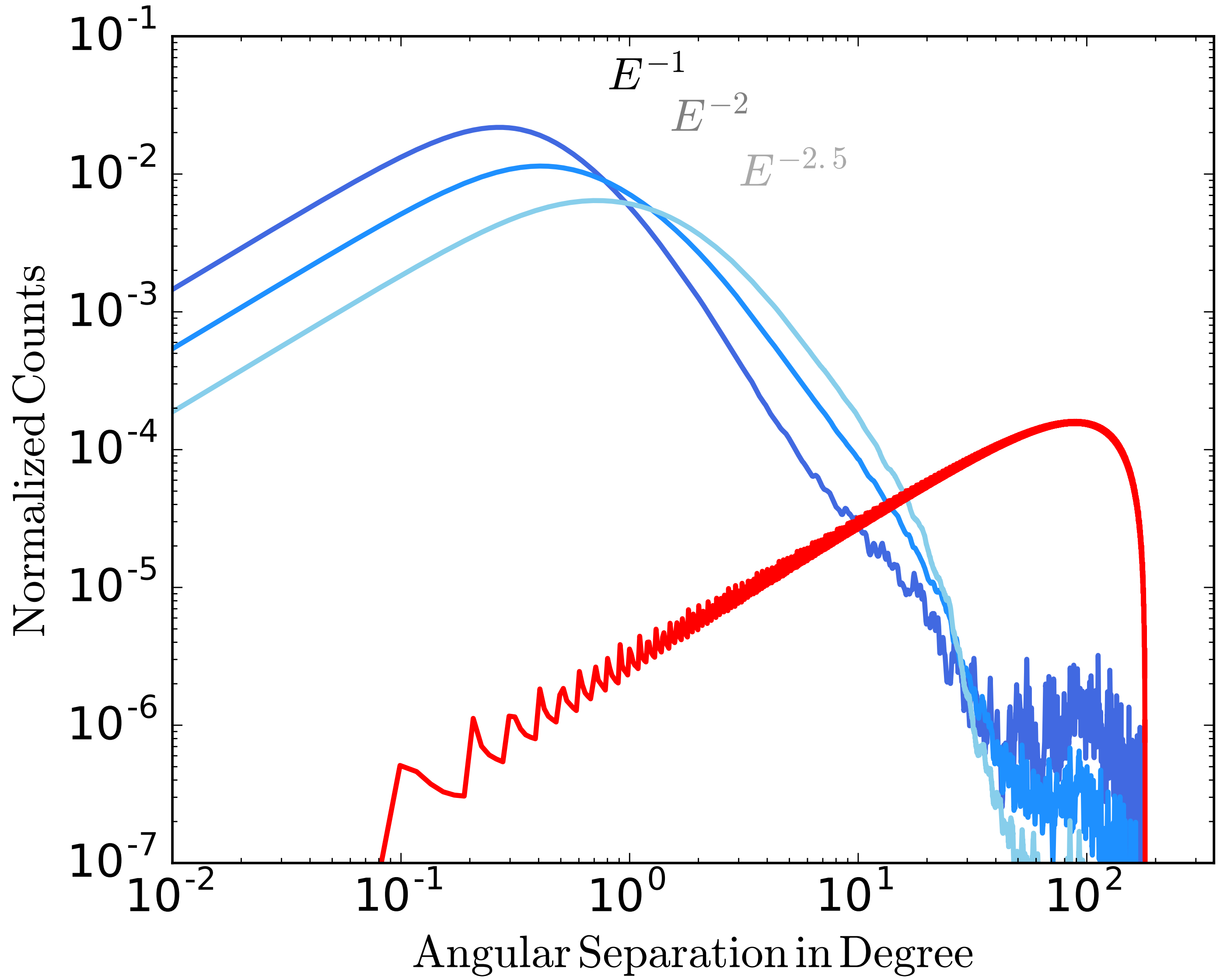
Applying to IceCube Data



PDF of angular separations of pairs from diffuse background and point sources are constructed using IceCube Monte Carlo simulation data and 2011 PS data.

In collaboration with Erik Blaufuss, the Maryland IceCube Group & the Drexel IceCube Group

Next Steps

- Setup and test the method with one-year data
- Implement the energy-dependence of the pair method
- Apply to seven-year PS data
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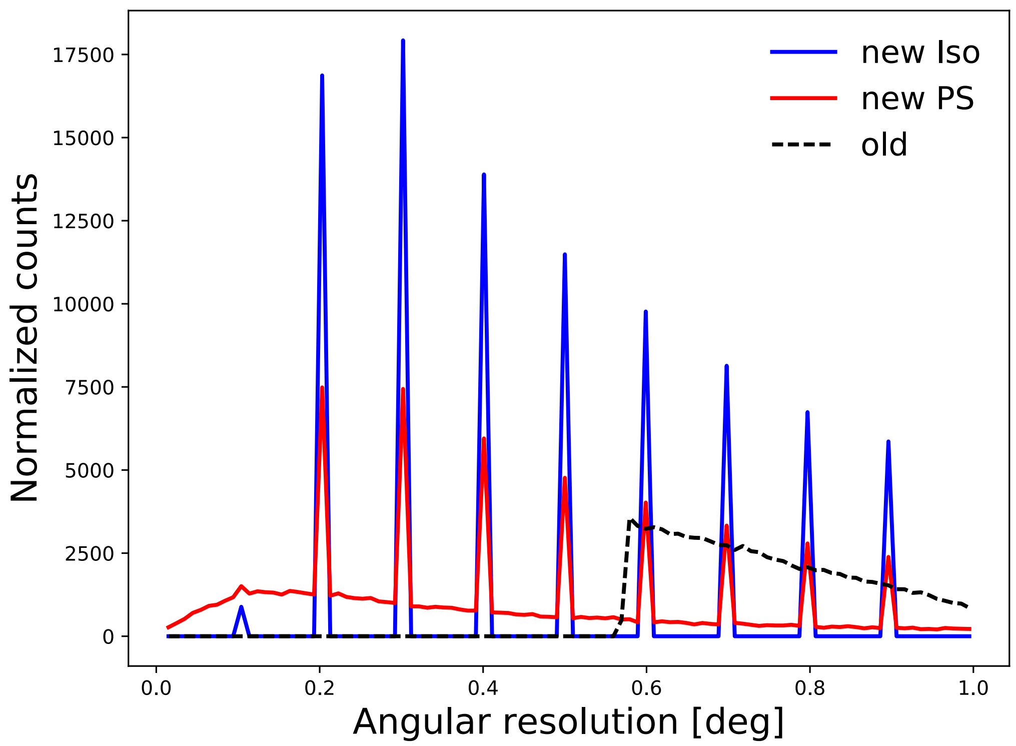
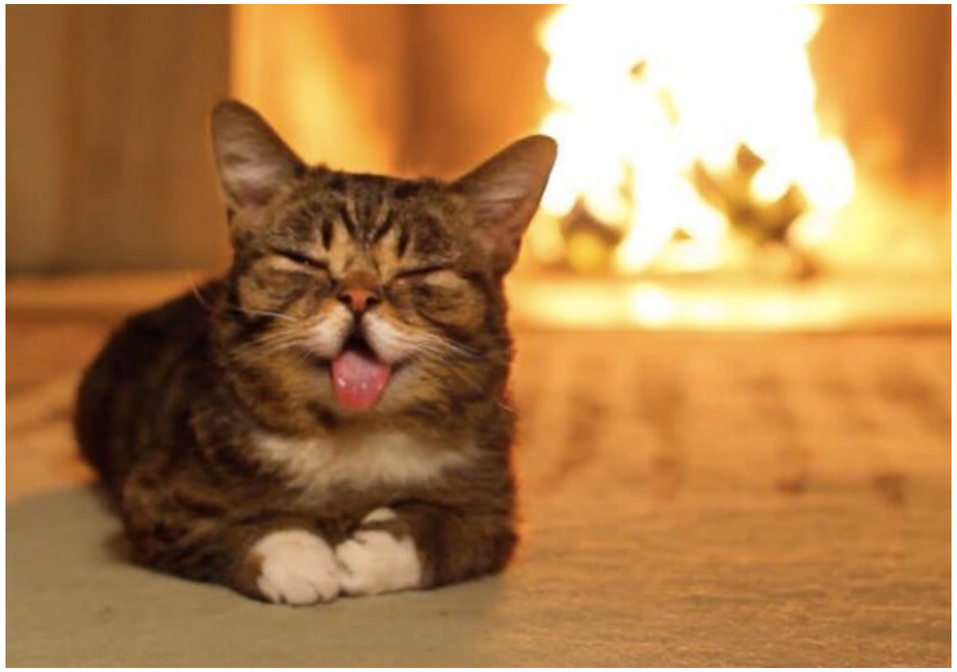
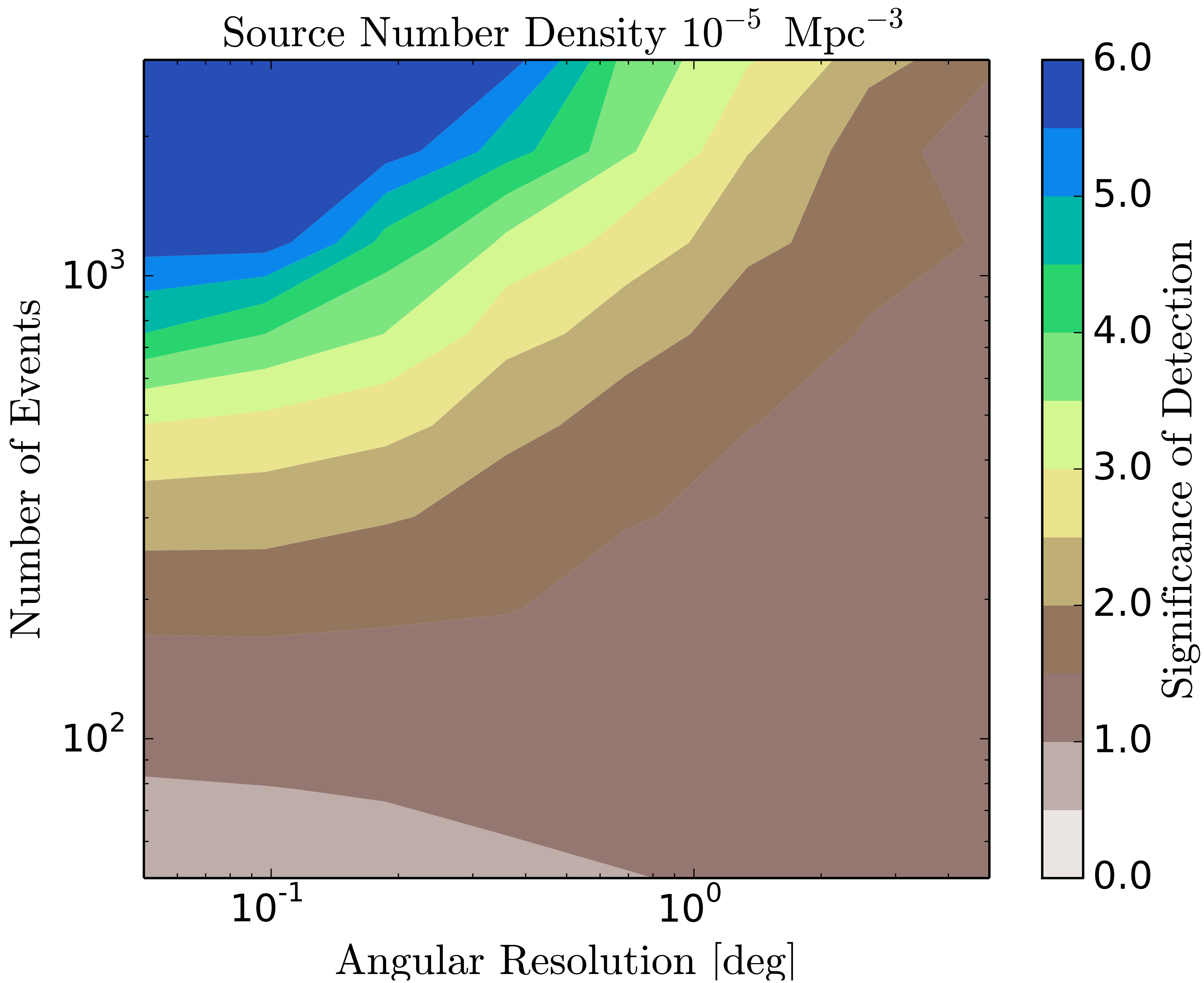
- Apply to seven-year PS data
- Transient search by Andrea Turcati with HESE trigger





Progressing (with small glitches). Stay tuned!

EeV Neutrino Source Detection



KF, Kotera, Miller, Murase, Oikonomou, JCAP, 1609.08027

Difference from the Autocorrelation Method

PSF information embedded in Apoint & Adiff