IceCube Neutrinos from the Local Universe using 2MRS

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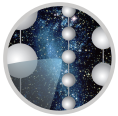
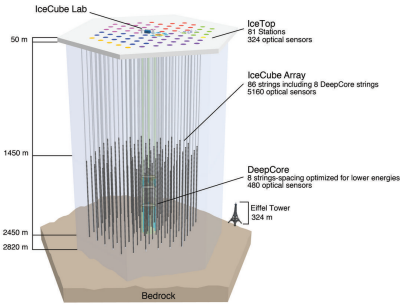


Analysis

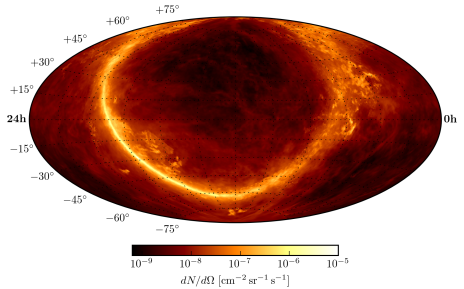
IceCube

- IceCube has identified astrophysical neutrinos; presented evidence for one neutrino source.
- Still searching for sources of most of the astrophysical neutrino flux.
- Can look for neutrinos from stacking cosmic ray accelerators (blazars, SNR, etc.)
- But also can look for neutrinos from secondary Cosmic Ray interactions in interstellar media.



Galactic Plane in IceCube

- Gamma ray sky is dominated by Galactic Plane
- π^0 template follows gas and models some emission from CR interactions with interstellar medium
- IceCube has looked for signatures of these secondary interactions in neutrinos through spatial template analyses, such as Galactic Plane Template
- eg: $\pi^0 \rightarrow 2\gamma, \pi^+ \rightarrow \nu_\mu + e^+ + \nu_e + \bar{\nu_\mu}$

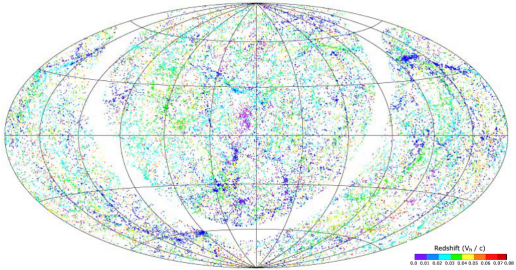


IceCube - arXiv:1808.03531

Galaxy Density Hypothesis

- While galactic plane is a large feature, the same interactions should be happening in other galaxies too.
- Single galaxy contribution is small, but combined effect may be seen in IceCube (stacking).
- Goal: Produce a template of the local matter density, the target for these CR interactions
- Local Universe is anisotropic, can look for overfluctions in neutrinos coincident with overdensities in galaxies
- Correlation with close large scale features – supergalactic plane

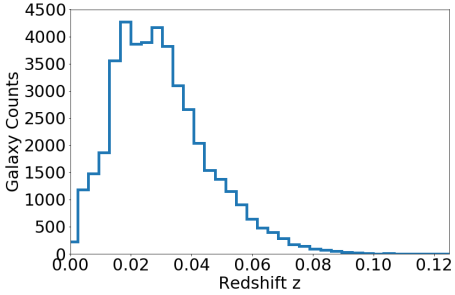
2MRS Survey Background



- 2MRS (2MASS Redshift Survey) maps position, magnitude and redshift for closest 45,000 galaxies
- Use redshift information as a template for local matter density and large scale structure

Huchra et al. (2012), ApJS Vol 199

Templates



- Spatial Templates:
  - Full Catalog; Weighted by Redshift Distance
  - Full Catalog; Equal Weighting
  - Cutoff of Redshift <0.03; Equal Weighting

Spatial PDFs

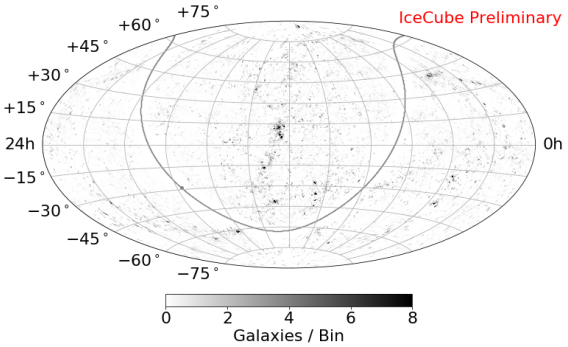


Figure: Galaxy Density weighted by z

Spatial PDFs

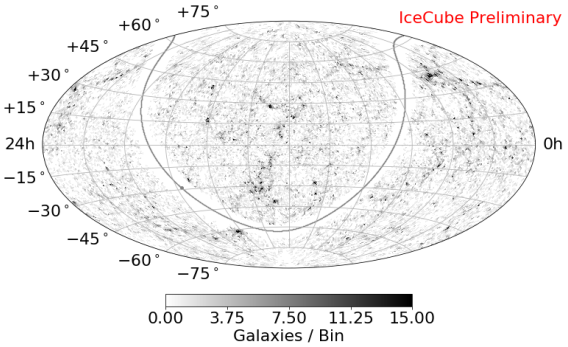


Figure: Galaxy Density for Full Catalog; Equal Weighted

Spatial PDFs

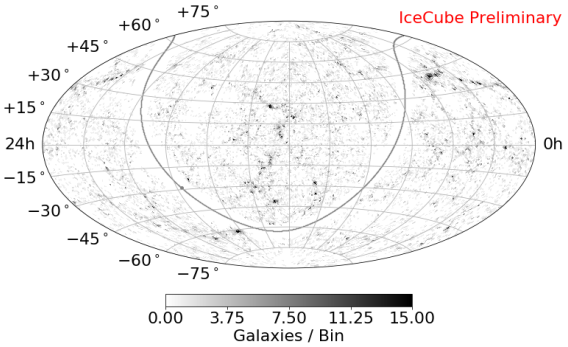


Figure: Galaxy Density for z <0.03

Spatial PDF Construction

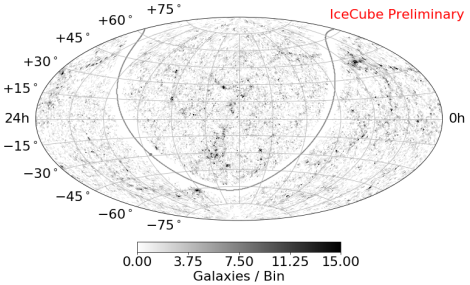


Figure: Binned Galaxy Density

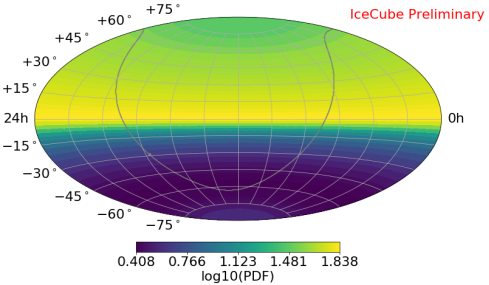


Figure: Convolved with Detector Acceptance E^{-2} ($CC\nu_\mu$ events)

Spatial PDF Construction

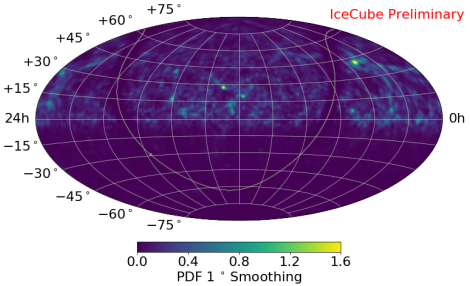


Figure: Gaussian Smoothing (1°)

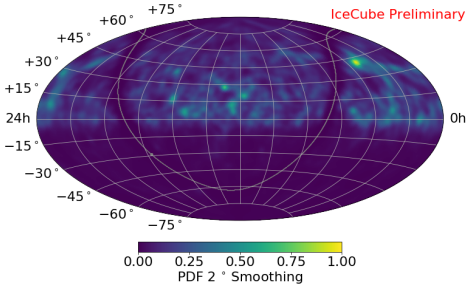


Figure: Gaussian Smoothing (2°)

Test Statistic Methods

LLH:

$$\mathcal{L}(n_s) = \prod_{i=1}^{N} \Big(\frac{n_s}{N} S_i(\mathbf{x}_i, \sigma_i, E_i) + (1 - \frac{n_s}{N}) B_i(sin\delta, E_i) \Big)$$

Data:

$$\tilde{D}_i(\sin\delta_i, E_i) = \frac{n_s}{N} \tilde{S}_i(\sin\delta_i, E_i) + (1 - \frac{n_s}{N}) B_i(\sin\delta_i, E_i)$$

Modified LLH:

$$\mathcal{L}(n_s) = \prod_{i=1}^{N} \Big(\frac{n_s}{N} S_i(\mathbf{x}_i, \sigma_i, E_i) + \tilde{D}_i(\sin\delta_i, E_i) - \frac{n_s}{N} \tilde{S}_i(\sin\delta_i, E_i) \Big)$$

$$TS = -2 \ln \left[\frac{\mathcal{L}(n_s = 0)}{\mathcal{L}(\hat{n}_s)} \right]$$

- Spatial PDF component from template maps, Energy PDF based on 2D Signal and Background histograms

IceCube - arXiv:1707.03416

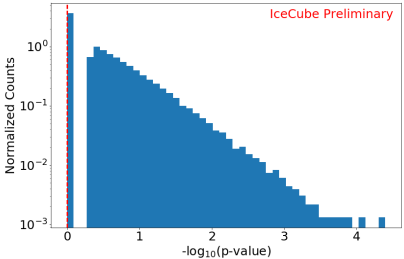
Sensitivity and Discovery Potential

- Inject Signal Monte Carlo to calculate Sensitivity and Discovery Potential
  - Define Sensitivity at point where 90% of trials above median
  - Define Discovery Potential at point where 50% of trials above 5σ TS

Template	Sensitivity Flux (1TeV) ($GeV^{-1}s^{-1}cm^{-2}$)	% of IceCube Astrophysical Flux	Discovery Potential Flux (1TeV) ($GeV^{-1}s^{-1}cm^{-2}$)
Full Catalog	$2.74x10^{-18}$	23%	$12.81x10^{-18}$
z <0.03	$2.26x10^{-18}$	19%	$8.98x10^{-18}$
Weighted by Redshift	$1.90x10^{-18}$	17%	$7.77x10^{-18}$

Results

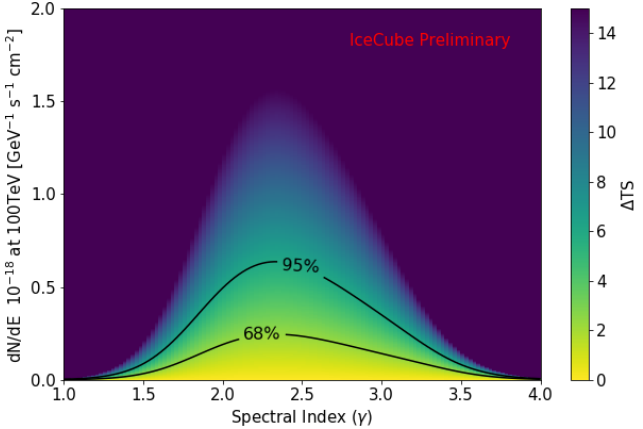
Results



Template	Weighted	z <0.03	Full Catalog
TS	0.0	0.0	0.0
ns	0.0	0.0	0.0
Pre-trials	1.0	1.0	1.0
Post-trials	-	-	-

- Best fit n_s=0 (Under Fluctuation)
- 0.33 of trials results in ns=0 in each

Flux Limits - Redshift Distance weighted



Conclusion

- Can use this model to set limits on models of neutrino production in local galaxies
- Looking at galaxy density as a template allows for general local searches for neutrinos produced through CR interactions.
- Results were consistent with background.
- Paper incoming on this work combined with a colleague also looking at 2MRS / IceCube
- Method can be extended for other deeper or more complete surveys.
- Extra attention must be placed on other surveys with non-homogeneous coverage.